The Red Pill..

It's the question that drives us⋯

Menu

The Puzzles

Puzzles

First Puzzle: Just a Probability?

Is special relativity and quantum mechanics really as weird as advertised, and is our underlying reality just a probability? Or is there a common sense explanation that contains no magical elements?

Puzzle Piece 1: Optical Black Holes and Particles of Sound
Puzzle Piece 2: What's the Matter with Matter?
Puzzle Piece 3: What's special about Special Relativity?
Puzzle Piece 4: The (other) Heisenberg
Puzzle Piece 5: The Doppler Challenge
Puzzle Piece 6: Disentangling the Entanglement

Second Puzzle: Big Bang or Big Problem?

How well do the observations really match the (inflationary) Big Bang model? Are there some unanswered questions, and what about alternative models?

Big Bang Puzzle Piece I: Seeing Red
Big Bang Puzzle Piece 2: Older than Legally Allowed
Big Bang Puzzle Piece 3: Static Universe?

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Entries RSS
Comments RSS
WordPress.org

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Menu

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Puzzles

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Puzzle Piece 3: What's special about Special Relativity?
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Puzzle Piece 5: The Doppler Challenge
Puzzle Piece 6: Disentangling the Entanglement

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Comments RSS
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Menu

The Puzzles

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Puzzle Piece 1: Optical Black Holes and Particles of Sound
Puzzle Piece 2: What's the Matter with Matter?
Puzzle Piece 3: What's special about Special Relativity?
Puzzle Piece 4: The (other) Heisenberg
Puzzle Piece 5: The Doppler Challenge
Puzzle Piece 6: Disentangling the Entanglement

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Big Bang Puzzle Piece 3: Static Universe?

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ARCHIVES

CATEGORIES

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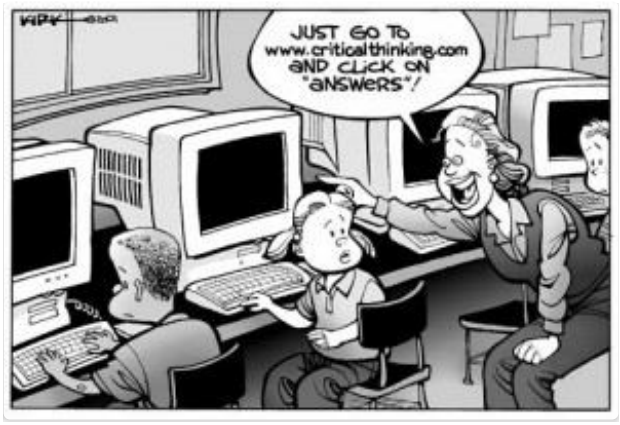
It's the question that drives us⋯

Menu

The Quest



I am not easily satisfied with answers to questions, and I am very skeptical. It doesn't matter who makes a claim, who wrote that paper, how long something has been established as a "fact", or what it is about. I won't believe it unless I completely understand it, and even then, I never stop to doubt - I doubt myself as well, because I know I am fallible and I make mistakes. I will be happy to change my mind if you can convince me that my current opinion is wrong :-).

I believe that in some respects we are not much better than in the middle ages: then as now there are certain "beliefs" we consider to be true (say, the Big Bang theory), which centuries from now may turn out to be completely wrong – and people will laugh at us for "believing" such crazy things (such as the idea of earth being flat, or the idea of Epicycles).

That is why I am open minded and will at least listen (skeptically) to ideas that others may not consider (or have forgotten about), because history tells us that once in a while people like Galileo come along with supposedly crazy ideas that bring science forward.

The question of course is: which of all of the scientific theories that we believe in now are wrong, and which ones turn out to be correct? To identify problems in current theories, and in order to make scientific discoveries, it does not help to simply nod and accept all mainstream ideas, but instead we should be asking critical questions.

Because of this, I have read countless books and papers about topics ranging from relativity to quantum mechanics all the way to economics, and I've had interesting discussions and debates with various people. So at some point, I thought it might be more efficient to collect and summarize these questions and discussions in a blog instead of repeating the same in yet another email :-).

This blog is an attempt to illustrate some of these questions and the line of thinking this has let me to, and to bring some of seemingly complicated ideas closer to the "normal" person, who may not have

a PhD both in physics *and* mathematics :-). My hope is that, at the very least, this will lead to interesting debates and discussions down the road. And maybe, some of you might be willing to swallow the red pill and live with the consequences :-).

I will start this blog around the topics of relativity and quantum mechanics, but may also discuss other questions in completely different areas.

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First Puzzle: Just a Probability?

Introduction

What if I told you that special relativity is not so complicated to understand and that even quantum mechanics may no be as weird as you think? In the pursuit of many (skeptical) questions, I found an intuitive yet completely equivalent way that explains these concepts. This model is not new, and it is not my idea, but unfortunately it has not gotten as much attention as the mainstream ideas.

With this first puzzle I have three goals:

1. to use this equivalent model to explain (potentially) difficult concepts such as (aspects of) general relativity, special relativity and quantum mechanics in a way such that a "normal" person can understand it (one who may not necessarily have a PhD in mathematics *and* physics :-)
2. to attempt to put these individual "puzzle pieces together" into one coherent picture that makes sense
3. to dare to ask the question whether this alternative model is not just for fun and nice pictures, but whether it may in fact represent reality – as it was suggested by such famous people as Schrödinger, Lorentz and even Einstein (see page on speeches).

Let me know what you think – and feel free to debate this topic!

[Puzzle Piece 6: Disentangling the Entanglement]

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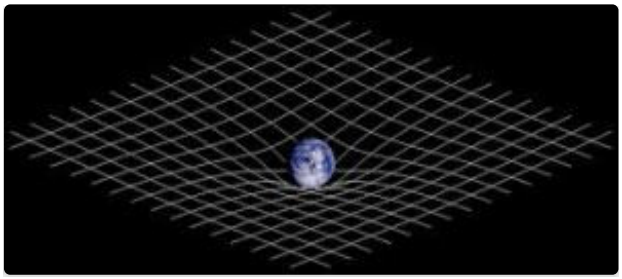
Puzzle Piece 1: Optical Black Holes and Particles of Sound

Space-time versus space-density

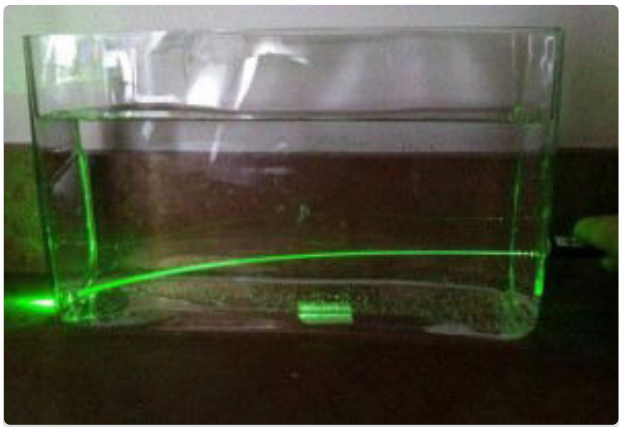
As you probably know, special relativity (SR) and general relativity (GR) are usually described using space-time, which is an interwoven continuum of 3 spacial and one time dimension. In this model, gravity is caused by the space-time curvature.



Typical image that shows a 2D version of the space-time curvature (from Wikipedia)

However, what many of you probably *don't* know is that there is a different but completely *equivalent* way to describe all this (the GR metric tensor), that does not use space-time, but ***space-density*** (Hagen Kleinerts World Crystal). This is an optical-mechanical analogy to GR, where gravity is not the result of "space-time curvature", but the result of refraction! (If you are wearing glasses, you know what refraction is: refraction causes a change in the angle of a wave due to the change in the medium, such as air -> glasses). You are probably thinking, what?! I know, this sounds odd, so just stick with me a bit and you will see that this not as weird as you may think – with an experiment you can do in the kitchen:

You also get refraction with a density gradient, such as in a Jell-O pudding with varying Jell-O concentration, or sugar water with a sugar gradient. The image below shows a rectangular container with water and sugar. There is more sugar at the bottom than on top. When you shine a laser pointer through it, the laser beam will bend because of the sugar gradient, which causes refraction. You can actually try this yourself :-).

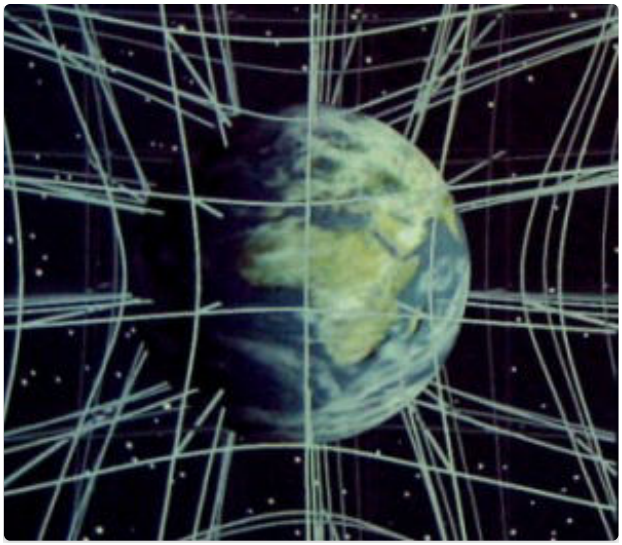


Bending of light in a sugar gradient

You are probably wondering, how this applies in any way to general relativity? In this model, instead of using space-time, we are working with space-density. What this means is that the space/vacuum in that model is not "empty", but is in fact like a huge⋯ crystal – or more generally: an elastic solid.

Ok, I can already hear the "but⋯?": the most important point first: this space/elastic solid, is **not** made of ordinary matter. Think of it more like "the fabric of space" or similar – an immaterial structure of some sort. And the question of "how in the world would we move through this solid" is not even the right question as you will see⋯ but one thing at time (I will try to address all of these "but⋯?" questions :-).

This elastic solid (just think of it as "space") is compressed in certain places – in places where there is more matter. Just like Einstein said: matter bends space, and this bent space "tells" matter how to move. Except we are not considering space-time, but space-density as our metric. For instance, space would be denser where the sun or a planet is compared to somewhere in outer space.



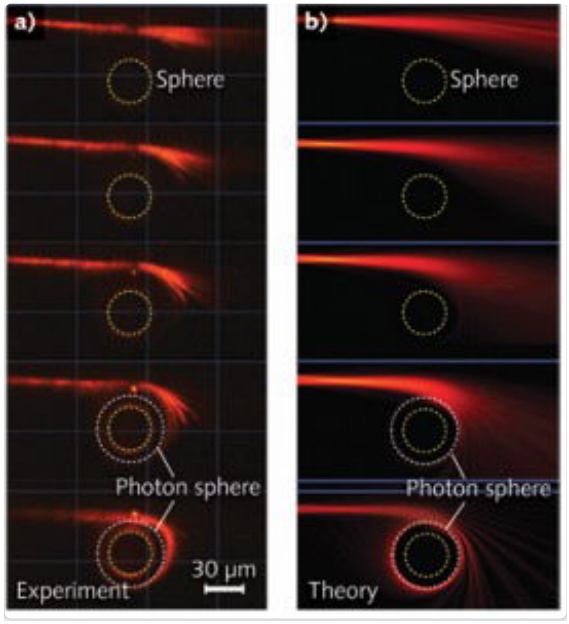
Curvature of space in a lattice model

Changes in density, as you can see with the Jell-O (or sugar gradient) causes changes in the refractive index, which means, light will always bend towards the areas of higher density. Hence, if space is denser where the sun is, light would (slightly) bend towards the sun. (This is similar to what people sometimes refer to as "the bending of space-time", except, that we are now using an elastic solid – like a Jell-O). This is not my crazy idea, I swear, there are many papers on this (see below), and as we explore this idea further, I hope you can see that it is not as silly as it may seem now!

***Note**: if you are thinking of the word "aehter" or "ether", forget it again, quickly, because there are just too many (wrong) interpretations of this word. This **not** like the "ether" that people were talking about (except Einstein, see his remarks in the speeches section!). First of all, that "ether" was sometimes considered to be a gas or a fluid. It has been shown in several experiments that this cannot be correct. Also, at that time, people did not know about quantum mechanics yet, and thought that matter would have to move "through" this "ether". As you will see later, this is a misleading question. The famous Michelsen-Morley experiment however did **not** disproof the model of "space as an elastic solid" model. The elastic solid model is completely equivalent to the "Minkowski space-time" model (see links below).*

Optical Black Holes

What if space gets so dense that the refractive index is so large that light can no longer escape? Then you get a black hole. The optical analogy does not just stop there – it is actually possible to create a real *optical* black hole, by using a material with a smoothly increasing refracting index. In this case, the refraction is such that the the light will always bend towards the center no matter from which direction the light originates:

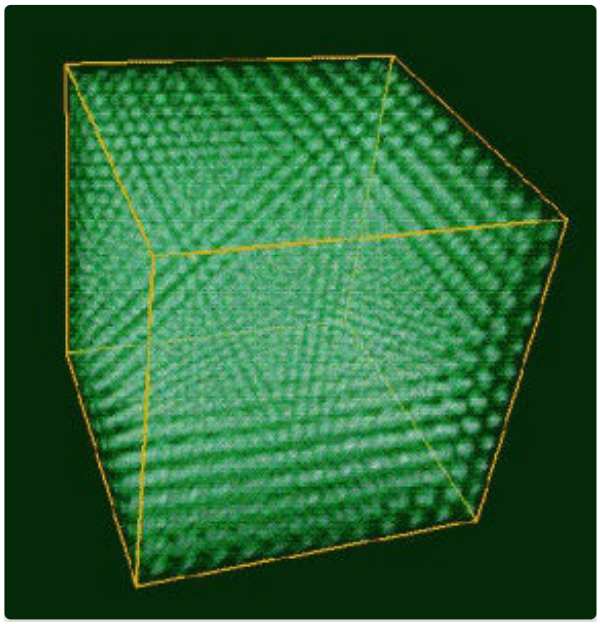


Of course this is nothing scary, and it is very real – people do this in the lab. It is simply a play with refraction. People are actually using this model now in the laboratory to study actual black holes (since the real ones are kind of difficult to create in the lab :-). Some people are even considering to build super solar cells that contain such optical black holes.

You may wonder, well this is all fine for light, since we know refraction works. The suggestion above was that this is actually equivalent to general relativity, so, this would also have to include *matter*, and surely, matter is totally different from light and there is no way there could be any kind of optical analogy, right? But before we dive into this, we will do an excursion into solid state physics.

Crystals and Elastic Solids

In solid state physics, people are often dealing with crystals and elastic solids. Now as it happens, crystal with defects and elastic solids with deformations can be described with the same non-Euclidean geometry as space with curvature and torsion (and the same way as the optical-mechanical analogy shown above). So a solid space with compression (and torsion) can be described the same way as actual, real crystals or elastic solids!

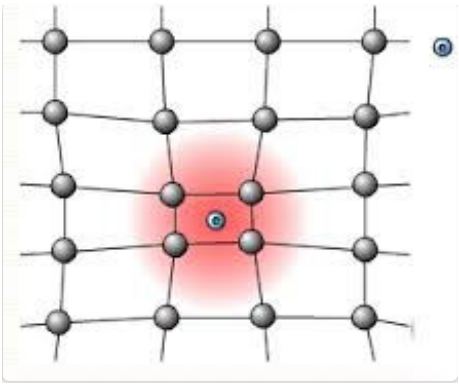


With the recent advances in solid state physics, there are more and more papers about this topic (see below), people are now using general relativity and apply it to crystals, and the other way around, they use crystals to learn more about general relativity. So this is no joke!

What do you think happens when you hit such a crystal (without breaking it :-)? We end up (among other things) with phonons, which are *quantized vibrations*, also called "particles of sound" or even "particles of heat"! Yep, no kidding!

Phonons: "Particles" of Sound

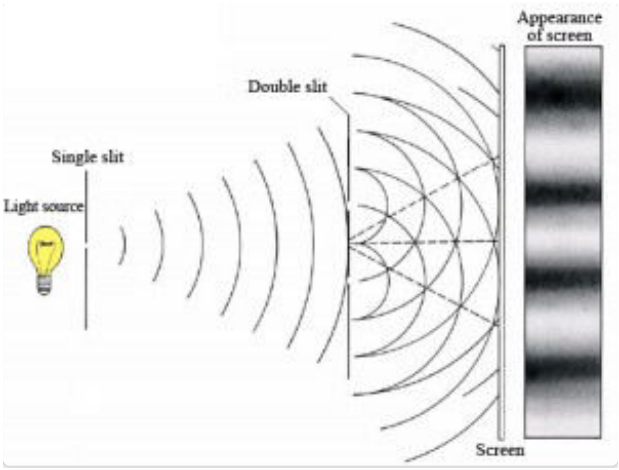
Why in the world would we use the word *particle* here? Clearly, a vibrating crystal (or a jiggling Jell-O) can be described with just vibrations (waves), and definitively not with "particles". Interestingly though, these vibrations actually exhibit a *particle-wave duality*, because their energy levels are quantized, just like photons! They are actually described using quantum mechanics, and even more, they are considered to be bosons, just like photons are.



Phonons – "Particles" of Sound

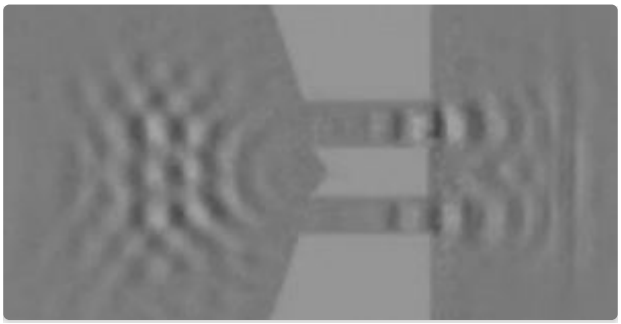
Like photons, the energy of a pho**n**on is E= $\hbar\omega$. So if they are described like photons and act like photons, would it be possible to create a phonon *laser*? A laser of sound, in a way? The answer is⋯ yes :-). In several recent articles researchers were able demonstrate "coherent phonons", which is the first step in constructing a "phonon laser" (more links at the bottom)

And would it actually be possible to do a *double slit experiment* with phonons, like we can do with photons?



The image above shows a typical double slit experiment. When light passes through two slits that are close to each other, then you see an interference pattern on the screen. This is one of the typical experiments to show the wave nature of light.

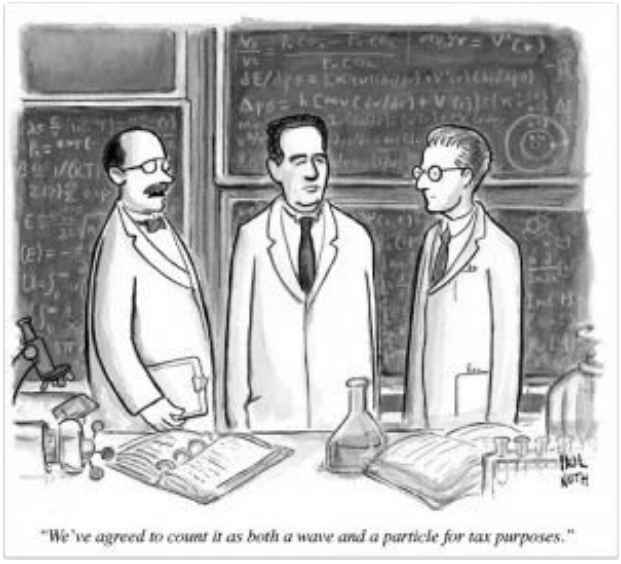
We can do just such a double slit experiment with **phonons** (in this case: polaritons). Below is an image from a video from MIT about just such an experiment (video link). I think that's quite amazing! Why? Because of all the mystery surrounding that "magical and weird" double slit experiment, where nobody seems to be able to give a clear answer of what exactly happens (is it "consciousness" collapsing the wave function? Is it parallel universes?)



Yet here we are, with the same kind of experiment, with quasi-particles that exhibit the same wave-particle duality as photons, yet, where is the magic? Where is the weirdness? These phonons are clearly waves, and exhibit the same behavior as photons and produce the typical interference pattern in a double slit experiment. Here it is clear that all that happens is that actual waves/vibrations are moving in a crystal, and interfere with each other. The waves are spatially spread out, and so can influence parts of the wave on the other side of the slit. We don't need consciousness to do anything here, we don't need parallel universes either.

Let's get back to the "Crystal Universe" idea by Hagen Kleinert: in this model, the universe (you can use the word space or vacuum), is basically just like such a crystal (or at least, an elastic solid – like a firm Jell-O – but not made of ordinary matter!). In this model (whether real or not), photons would in fact be exactly like phonons. They would indeed be *true waves*, vibrations in that "solid space". This "crystal" may be discrete or not. If it is, then the lattice size must be around the Planck length (since this is the smallest known length). But, as an approximation, as long as the frequency of the phonon or photon is large compared to the lattice size, the calculation is the same as for a *continuous* medium (see chapter 6.5 in "Materials Science"). (Personally, my guess would be that it is discrete – in a later post I will add more speculative thoughts on this and possible experiments on how to distinguish the two models)

Most (mainstream) physicists (except for instance Schrödinger!) will tell you that in he case of photons, we are dealing with a "probability density function" and not *real* waves. They will tell you that the result of the double slit experiment can only be explained by one of several ("weird") explanations, including: parallel worlds, the Copenhagen interpretations (that somehow looking at something decides the outcome), the many minds interpretation and several other models. All except basically that photons are simply… (quantized) waves :-).



Yet at the same time, in the case of phonons in a crystal (and any other quasi particles!), which are described just like photons, there is nothing magical or weird at all, and none of the same physicists above would claim otherwise. We definitively don't need parallel universes to explain the interference

pattern of phonons. And we don't need any "conscious observer" to cause a "wave function collapse" in a phonon – there is a paper on this:

> *"The quantum mechanical properties of phonons in a one-dimensional lattice are studied, with the conclusion that the phonon behaves in all essential respects as a normal quantum particle. "Wavefunction collapse" of the phonon state is shown to occur in an automatic way when an observation is made. This gives possible insight concerning the nature of wavefunction collapse in the general particle case"*

It is simply a matter (no pun intended) of waves that are interacting with each other, cancelling each other out at some places, and when being "measured", transforming into another wave (or interacting with another wave). Doesn't that make you wonder if we really do need all that weirdness in the case of photons? Of course, you might consider the idea of "solid universe" weird (I first did). But maybe if all the other "weirdness" vanishes, maybe it is not so weird at all.

You are probably thinking, well photons is one thing, but matter has got to be completely different though, after all we are dealing with actual "particles" there such as protons and electrons, right? Clearly, the analogy ends here, or does it? I mean, how would particles move through a solid space? (That's actually a misleading question, as you will see in a later post)

Puzzle Piece 2: What's the Matter with Matter?

Summary

At the end of each post, I will update this table that shows the differences between the two models that we have seen so far – the mainstream "space-time" versus the "space-density" model:

	Space-density Universe (RED pill)	**Space-Time Universe (BLUE pill)**
Tags	elastic solid, crystal universe, optical-mechanical analogue, space exists	Minkowski, space-time, absolute space does not exist
GR Metric Tensor	space-density (space with compression)	space-time
Cause of Gravity	refraction (density gradient, optical)	curvature of space-time

Photon	quantized wave, similar to phonon quasiparticles in crystal (vibrational mode), there are no photon "particles"	probability density wave function, no "real" wave, probability of finding photon
Double Slit Experiment	real waves interfering (like phonons)	parallel universes, no real wave, "consciousness" ,probabilistic…

Links

Optical analogues of General Relativity:

1. Hagen Kleinerts World Crystal: http://users.physik.fu-berlin.de/~kleinert/papers/planckklcZN.pdf
2. Defects and Diffusion in the Planck-Kleinert Crystal: http://ceram.agh.edu.pl/~icmmagh/artykuly/237%20PLANCK%20CRYSTAL%20DSL%20final.pdf
3. Emerging Gravity from Defects in World Crystal: http://www.sbfisica.org.br/bjp/files/v35_359.pdf
4. De Felice, F. On the gravitational field acting as an optical medium. Gen. Relativ. Gravit. 2,347–357 (1971).
5. On the optical-mechanical analogy in general relativity: http://arxiv.org/abs/0905.4479 , http://www2.ups.edu/physics/faculty/evans/Optical%20Mechanical%20GRG.pdf
6. The Classical Wave Theory of Matter by Robert Close: http://www.verumversa.com/
7. Analogue Special and General Relativity: http://arxiv.org/abs/1302.6729, http://www.tandfonline.com/doi/abs/10.1080/09500340.2013.769638#.Uw5Gnfl5M1I
8. Mimicking general relativity with Newtonian Dynamics: http://www.hindawi.com/journals/isrn.mathematical.physics/2012/260951/
9. A Table-Top Test for General Relativity? http://www.universetoday.com/35384/a-table-top-test-of-general-relativity/
10. A condensed Matter Interpretation of SM Fermions and Gauge Fields (Ilja Schmelzer): http://link.springer.com/article/10.1007%2Fs10701-008-9262-9, http://arxiv.org/abs/arXiv:0908.0591
11. The Cell lattice model (Ilja Schmelzer): http://ilja-schmelzer.de/clm/
12. Analogue Gravity: http://relativity.livingreviews.org/open?pubNo=lrr-2011-3&page=articlesu17.html
13. General Relativity in Electrical Engineering: http://www.int.kit.edu/downloads/RG_Pernice/Paper21.pdf
14. Lorentz Contraction of Space and the Gravitational Field: http://vixra.org/pdf/1008.0023v2.pdf
15. Surprising Connections Between General Relativity and Condensed Matter: http://arxiv.org/abs/1010.2784

Optical Black Holes:

1. First black hole for light created on Earth: http://www.newscientist.com/article/dn17980-first-black-hole-for-light-created-on-earth.html#.UwiBW_l5M1I
2. Physicists Make Artificial Black Hole Using Optical Fiber: http://spectrum.ieee.org/aerospace/astrophysics/physicists-make-artificial-black-hole-using-optical-fiber
3. Analytical Theory of Optical Black Hole Analogues: http://arxiv.org/abs/1209.5148
4. Trapping light by mimicking gravitational lensing: http://www.nature.com/nphoton/journal/v7/n11/full/nphoton.2013.247.html
5. Creating Optical Black Holes to Produced Super Solar Cells: http://www.dailygalaxy.com/my_weblog/2009/10/-creating-micro-black-holes-to-produce-super-solar-cells.html
6. 'Black hole' made from light: http://www.nature.com/news/2008/080306/full/news.2008.651.html

Phonons: Particles of Sound

1. Definitions of Phonons: http://physics.about.com/od/physicsmtop/g/phonon.htm, http://en.wikipedia.org/wiki/Phonon
2. Double slit experiments with phonons: http://nelson.mit.edu/node/178
3. Fantastic Phonons: http://www.sciencedaily.com/releases/2013/11/131113143215.htm
4. Black body analogue for phonon: http://en.wikipedia.org/wiki/Debye_model
5. Polaritons: http://en.wikipedia.org/wiki/Polariton
6. Photoelectric Effect: http://en.wikipedia.org/wiki/Photoelectric_effect
7. Chapter 6.5 in Material Science
8. The Phonon as a Model for Elementary Particles: http://www.nature.com/nchem/journal/v3/n4/full/nchem.1008.html

Phonon Lasers:

1. Phonon Lasers gain a Sound Foundation: http://physics.aps.org/articles/v3/16
2. Phonon Lasers Make a More Practical Sound: http://spectrum.ieee.org/semiconductors/optoelectronics/phonon-lasers-make-a-more-practical-sound
3. Researches Build Fully Mechanical Phonon Laser: http://phys.org/news/2013-03-fully-mechanical-phonon-laser.html

Wave Function Collapse:

1. Quantum Field Theory solves the problem of collapse of the wave function:

http://arxiv.org/ftp/arxiv/papers/1311/1311.0205.pdf

2. The phonon as a model for elementary particles: http://www.sciencedirect.com/science/article/pii/0375960193910273

FAQ

Q1: Wasn't there some proof that photons are particles, such as the photoelectric effect and the blackbody spectrum?

A1: What the photoelectric effect shows is that the wave has to be quantized (just like a phonon is quantized), and that this cannot be explained with an **un**quantized wave. Phonons are also quantized, yet that does not indicate that they are particles (and nobody would disagree with that). There are many other cases of "quasi particles" (which are quantized waves) like the phonons that can act like particles, but are also clearly just waves have nothing to do at all with particles.

Another argument that photons are supposed to be particles is the black body spectrum. The black body spectrum can however also be computed using phonons vibrating in a solid body instead of a "photon gas" in a box: http://en.wikipedia.org/wiki/Debye_model

See also: "No Evidence for Particles"

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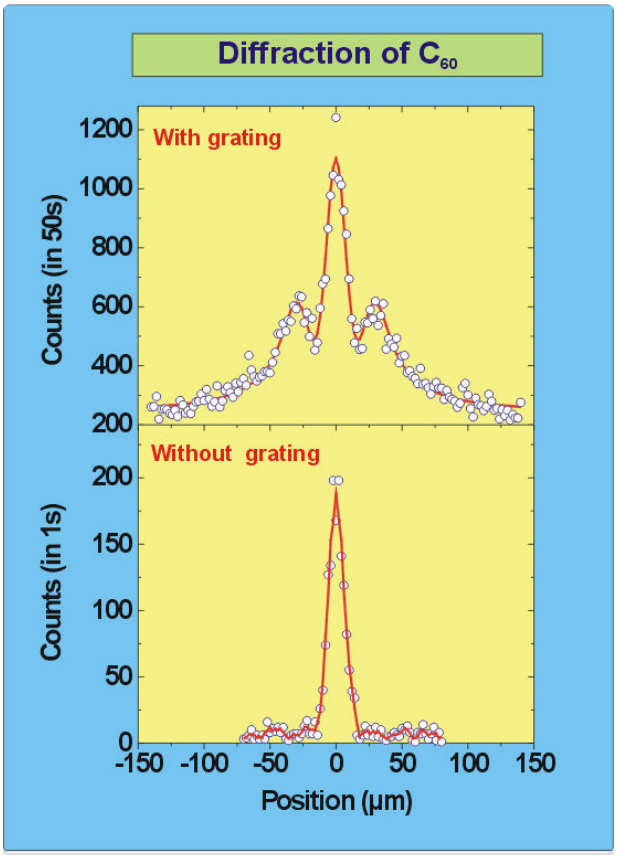
Puzzle Piece 2: What's the Matter with Matter?

The last post ended with phonons – quantized waves that have particle like behavior. So⋯ how does this even remotely relate to matter?

As you probably know, matter also exhibits wave like properties, which was originally proposed by de Broglie. Based on that theory, matter has a frequency that is directly proportional to the total energy (which includes it's mass). Schrödinger then published the famous wave equations of matter, which describe how those matter waves evolve over time (the equivalent of Maxwell's equations). For instance, did you know that the Energy of a "particle" is also $E = \hbar\omega$? Just like in the case of photons and phonons?

It is not only possible to do the double slit experiment with electrons and neutrons, but even with atoms (such as He) and complex molecules even as large as C60 molecules (soccer ball shaped carbon cages):

Again you get the familiar interference pattern – even with such large molecules:



That means that even complex molecules as large as C60 behave as if they were in fact waves and not particles.

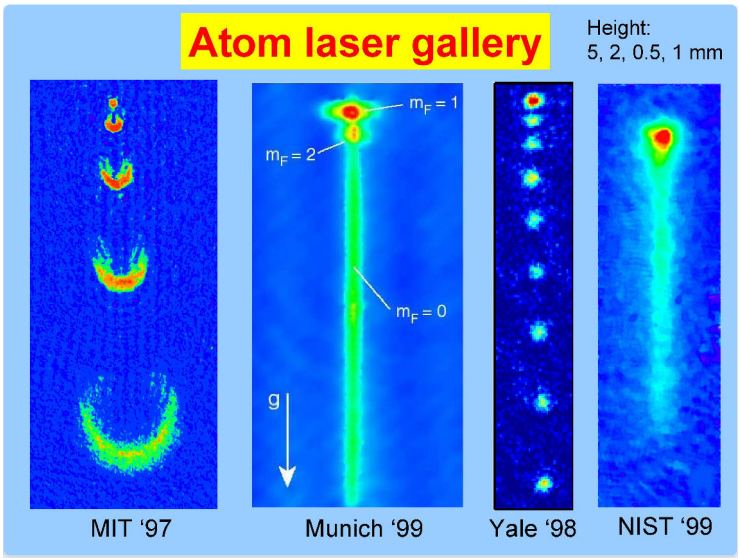
If you ask physicists (or check Wikipedia), they will give you one of several explanations for this wave like behavior of matter:

- the Many World interpretation: that basically each possibility actually happens for real in one of the infinite universes (and we live in just one of them).
- The Pilot Wave model, which proposes that there is a “guiding wave” that guide the actual real “particles”
- The Copenhagen interpretation, where the observer basically causes the wave function to collapse. The world is basically probabilistic, and the wave function does not describe a real wave, just a probability (and there is no real world out there if you don’t look)
- Wikipedia does mention that there is one scientist (Carver Mead) who thinks matter are real waves

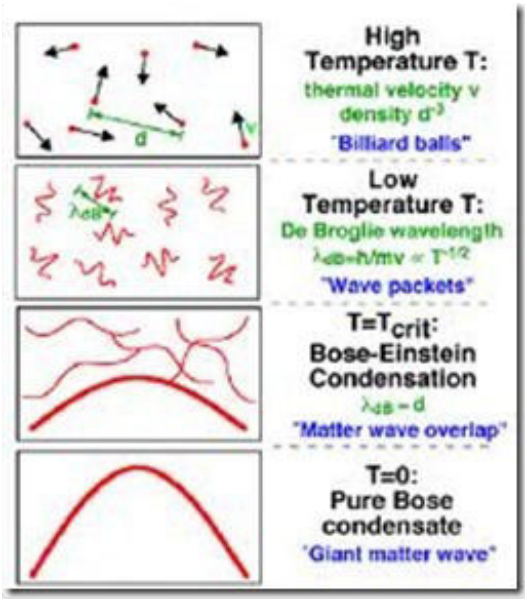
So do we really need “parallel universes” and similarly weird explanations? Is there any more evidence?

Atom Lasers, Atom Interferometry and Atom Optics

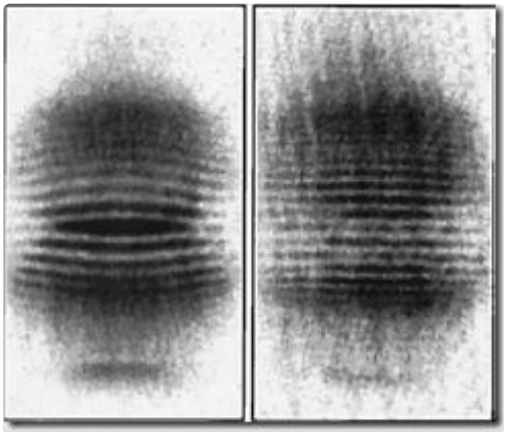
There is an entire branch in physics called atom optics, which includes atom lasers, which are coherent beams of matter waves. Even here of course you could say well, these are not “real” waves, but just “probability density functions” as in the case for photons.



Such coherent matter waves are made using Bose Einstein Condensates. Wolfgang Ketterle won the Nobel prize for his work in this area – here is a link to his Nobel lecture on "When Atoms Behave as Waves".



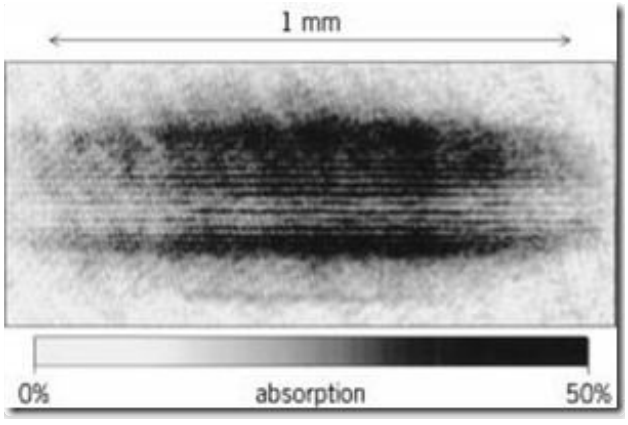
Basically as certain atoms (such as He4) are cooled down, the matter waves of the individual atoms start to overlap, until they form one gigantic matter wave. The wave is so large, that is is around 1mm in size (!). Not micrometer, millimeter. The distance between the fringes is about 15μm, that's huge! In fact, it is even possible to take a picture of such a matter wave! Here, in the picture below, we see two such matter waves interfering with each other. Notice the light and dark lines? These is the same kind of interference pattern we are used to seeing with other interacting waves.



This is quite dramatic. Basically this means that atom + atom can = vacuum in some places. Parts of the matter waves cancel each other out!

Here is an excerpt from:
http://cua.mit.edu/ketterle_group/Projects_1997/Interference/Interference_BEC.htm

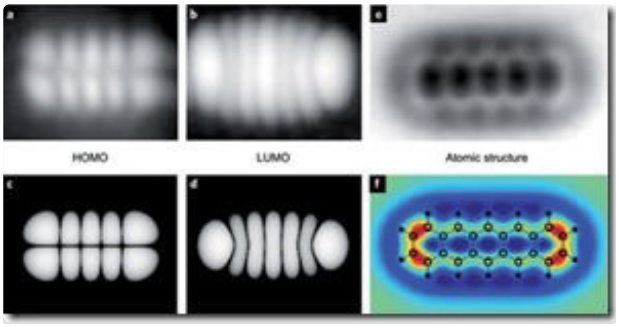
> *Perhaps the most striking feature of quantum mechanical theory is the fact that it predicts that matter can behave like waves. This means that coherent matter waves can form interference patterns, just like the ones you would get if you combined two laser beams in an interferometer. The demonstration of interfering pathways in a neutron interferometer was perhaps the strongest affirmation of quantum theory and the wavelike nature of matter. Atom interferometer experiments followed which extended this demonstration to the size of an entire atom. But these experiments were limited to showing that a single particle could interfere with itself. Now, Bose-Einstein condensation has allowed us to make another advance, making it possible to interfere two completely independent clouds of atoms with each other.*



In a recent experiment (2012), scientists say they have shown that matter waves are indeed real physical entities, where they conclude:

> *"In conclusion, we have presented a no-go theorem,*
> *which shows that models* ***in which the quantum state is interpreted as mere information about an objective physical state of a system cannot reproduce the predictions of quantum theory.****"*

In another quite recent experiment, researchers were able to take pictures of a single molecule, where one can see the electron orbitals (on the top is the actual picture, the bottom shows the computer simulation):



And here there are several online simulations that let you play with waves (including the double slit experiment): Simulation of Quantum Wave Interference

The mainstream interpretation is that this is not really a wave, but just a probability of finding a particle at a given spot. However, one does have to wonder if this is really the case, after all, the fact that one can take a real picture of this – without causing a "wave function collapse" – is quite some evidence that we are dealing with a real wave, and not just some probabilities.

Getting back to the "Crystal Universe" idea by Hagen Kleinert – and much more detailed work based on this idea by Robert Close in "Classical Wave Theory of Matter": in these models, we are in fact dealing with true waves, where the Dirac equation is interpreted as a "classical second-order wave equation for rotational waves in an elastic medium" (page 126) of space (or crystal, if you prefer that picture). So now, given the images and experiments on BEC above, maybe the idea that matter could indeed be true waves does not seem so totally strange anymore. Actually, did you know that Schrödinger had originally proposed that waves are real waves (until Max Born later introduced the interpretation of the probability density)? In fact, this is what Schrödinger had to say about the probability interpretation later on:

> *What we observe as material bodies and forces are nothing but shapes and variations in the structure of space…..Let me say at the outset, that in this discourse, I am opposing not a few special statements of quantum physics held today (1950s), I am opposing as it were the whole of it, I am opposing its basic views that have been shaped 25 years ago, when* ***Max Born*** *put*

> *forward his **probability interpretation**, which was accepted by almost everybody. I don't like it, and I'm sorry I ever had anything to do with it. (**Erwin Schrödinger** , The Interpretation of Quantum Physics.)*

Why is this idea not discussed more? After all, this model is equivalent to the "space time" model. One reason is that at the time when people did consider similar models (mostly related to an "aether"), they didn't know yet that matter also exhibits wave properties. So at that time, even though they considered that light could be waves hat moves through a medium, they still treated matter as particles – which created problems. The question was, how do those particles move "through" such an "aether". Now we know that the question is in fact misleading! In the crystal universe model, matter does *not* "move" through that (solid) space. It is only the vibrations that appear to "move", just like heat or phonons appear to "move" through a crystal (when it is just the vibrations that change location, or just as sound waves appear to move (even thought the air itself is mostly stationary – if there is no wind).

Another reason for not discussing the idea more is probably the resistance to the idea that there could be a preferred frame – for some reason, many physicists really seem to hate that idea, even though (as you will see), this does not contradict special relativity in any way. We will discuss this more in the next post, when we talk about special relativity, and how SR looks like in the "crystal universe" model.

Next puzzle: Puzzle Piece 3: What's special about Special Relativity?

Summary Table

	Space-density Universe (RED pill)	Space-Time Universe (BLUE pill)
Tags	elastic solid, crystal universe, optical-mechanical analogue, space exists	Minkowski, space-time, absolute space does not exist
GR Metric Tensor	space-density (space with compression)	space-time
Cause of Gravity	refraction (density gradient, optical)	curvature of space-time
Photon	quantized wave, similar to phonon quasiparticles in crystal (vibrational mode), there are no photon "particles"	probability density wave function, no "real" wave, probability of finding photon
Double Slit Experiment	real waves interfering (like phonons)	parallel universes, no real wave, "consciousness" ,probabilistic…

Schrödinger Wave Equation	describes real waves, rotational waves in an elastic solid. There are no particles	probability of finding a particle, there are no real waves
What is space?	An elastic solid (not made of matter). Matter and light moves though space as waves move through a crystal	There is no absolute space

Links

Matter waves

- http://en.wikipedia.org/wiki/Matter_wave^
- Quantum Interference Experiments with Large Molecules: http://130.58.92.210/Students/phys%205_2010/zeilinger%20ajp%202003.pdf
- Double slit with single electrons: http://physicsworld.com/cws/article/news/2013/mar/14/feynmans-double-slit-experiment-gets-a-makeover
- Wave-particle duality of C60 molecules: http://www.nature.com/nature/journal/v401/n6754/abs/401680a0.html
- Diffraction fo C60 at a SiN grating: http://www.univie.ac.at/qfp/research/matterwave/c60/
- Atom Laser: http://cua.mit.edu/ketterle_group/Popular_papers/Atom%20laser%20Enc.pdf
- Atom Laser: http://cua.mit.edu/ketterle_group/Projects_1997/atomlaser_97/atomlaser_comm.html
- W. Ketterle: When Atoms Behave as Waves: http://www.nobelprize.org/nobel_prizes/physics/laureates/2001/ketterle-lecture.pdf
- Interference of two BEC: http://cua.mit.edu/ketterle_group/Projects_1997/Interference/Interference_BEC.htm
- Properties of a Bose Einstein Condensate: http://www.uni-muenster.de/Physik.AP/Demokritov/en/Forschen/Forschungsschwerpunkte/mBECwatpoabec.html
- Bose Einstein Condensation: http://www.theory.caltech.edu/~preskill/ph12c/ketterle-physicsworld.pdf
- Exact Description of Rotational waves in an Elastic Solid (by Robert Close): http://www.classicalmatter.org/RotationWaves.pdf
- Torsion Wave in Three Dimensions: Quantum Mechanics with a Twist (by Robert Close): http://www.ingentaconnect.com/content/klu/fopl/2002/00000015/00000001/00371047
- Classical Wave Theory of Matter (by Robert Close): http://www.verumversa.com/ClassicalWaveTheoryOfMatter.pdf
- Quantum Theorem Shakes Foundations (The wave function is a real physical object after all, say researchers): http://www.nature.com/news/quantum-theorem-shakes-foundations-1.9392
- On the Reality of the Quantum State: http://xxx.lanl.gov/abs/1111.3328

- No Evidence for Particles: http://arxiv.org/ftp/arxiv/papers/0807/0807.3930.pdf
- Recent Advances in Submolecular Resolution with Scanning Probe Microscopy: http://www.nature.com/nchem/journal/v3/n4/full/nchem.1008.html

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Puzzle Piece 3: What's Special about Special Relativity?

Previous puzzle: Puzzle Piece 2: What's the Matter with Matter?

1. Time Dilation

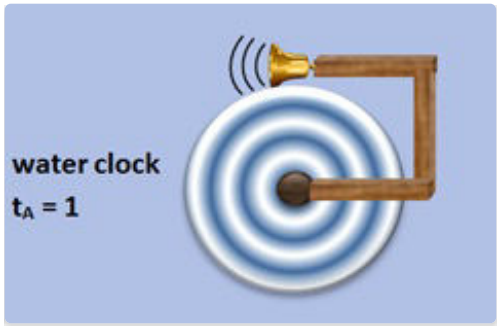
You probably think that special relativity is hard to understand and explain (I mean, so that your grandmother would understand it), and that his surely has nothing to do with any of that "Crystal Universe" idea or "The Classical Wave Theory of Matter".

So let me give it a shot: all you need to know is 2 things:

1. the Pythagorean formula $a^2 + b^2 = c^2$.
2. that waves in a medium have a particular speed **c**
   (such as sound in air (w/o wind), sonar in water, earthquake waves, phonons in a crystal, water waves etc)

First, the easiest example – one that you can actually try yourself in real life:

Take a regular boat, put it on a still lake. At the end, we build a "water wave clock": we add a wooden frame with a stick at the end. We "start" the clock by making waves with a stick. The clock "ticks"(rings) when the wave front reaches the bell:



Note that the wave extends in all directions. For simplicity, we will use arrows – even though of course the waves don't go just in one direction. But it shows the direction from the start of where the wave originated to the end, where the "bell" rings. When the boat is stationary, this is what it looks like:

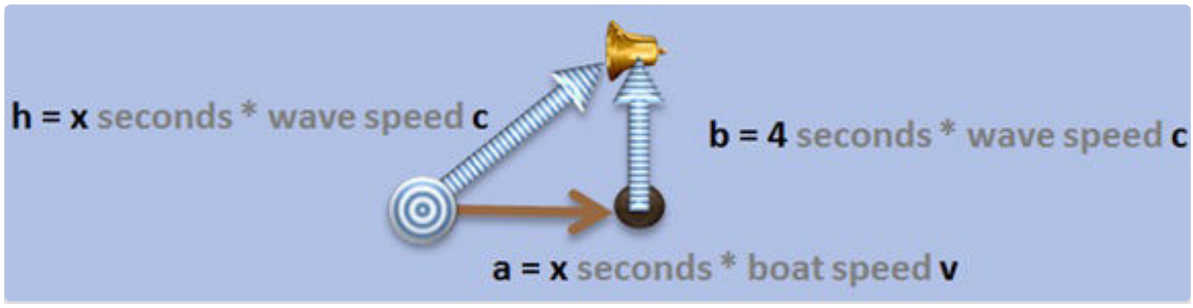
(I know I am going kind of slow here, but I really want my grandmother also to understand this :-).

What does it look like when the boat is moving?

You can see that the distance the water wave has to travel is now longer, because the boat is moving away. Say it took 4 seconds when the boat was still for the ring to bell. How long do you think it takes now? It clearly takes longer now – but how long depends on how fast the boat is moving. How can we compute that?

(Note: in water, the speed of the wave is depending on the wave length… to make this work with water, we have to use the same wave length, such as 10cm from water crest to water crest)

All we need to know is that **distance = time * speed**, and the Pythagorean formula:



The distance **h** (the hypothenuse) is the number of seconds **x** we want to compute * the speed **c** of the water wave. We know that when the boat was still, it took 4 seconds for the wave to reach the bell. The distance **b** = 4 seconds * wave speed **c** (I know, of course we could simply measure it, but the point is that we want to get a **formula** to compute these things ;-). The distance a is how far the boat went, so **a** = the speed **v** of the boat, times the number of (unknown) seconds **x** we want to compute.

All we do now is apply the Pythagorean formula, and solve for x! One small change: instead of putting 4 for the 4 seconds, let's use **t.**

$$(x*v)^2 + (t*c)^2 = (x*c)^2$$

$$x^2 * c^2 - x^2 * c^2 = t^2 * c^2$$

$$x^2 (c^2 - v^2) = t^2 * c^2$$

$$x^2 = t^2 * c^2 / (c^2 - v^2)$$

$$x = t \frac{c}{\sqrt{(c^2 - v^2)}}$$

Example with real numbers: say in the stationary case it took **t = 4** seconds. Let's pick a speed v for the boat, such as 3/4 as fast as the wave speed c (for a wave with 10cm wave length in clean water, it travels about 30cm/second): **v = c*3/4.**
We replace **v** with **c*3/4** in the formula and get:

$$x = t \frac{c}{\sqrt{(c^2 - c^2 * 9/16)}} = t \frac{1}{\sqrt{(1 - 9/16)}},$$

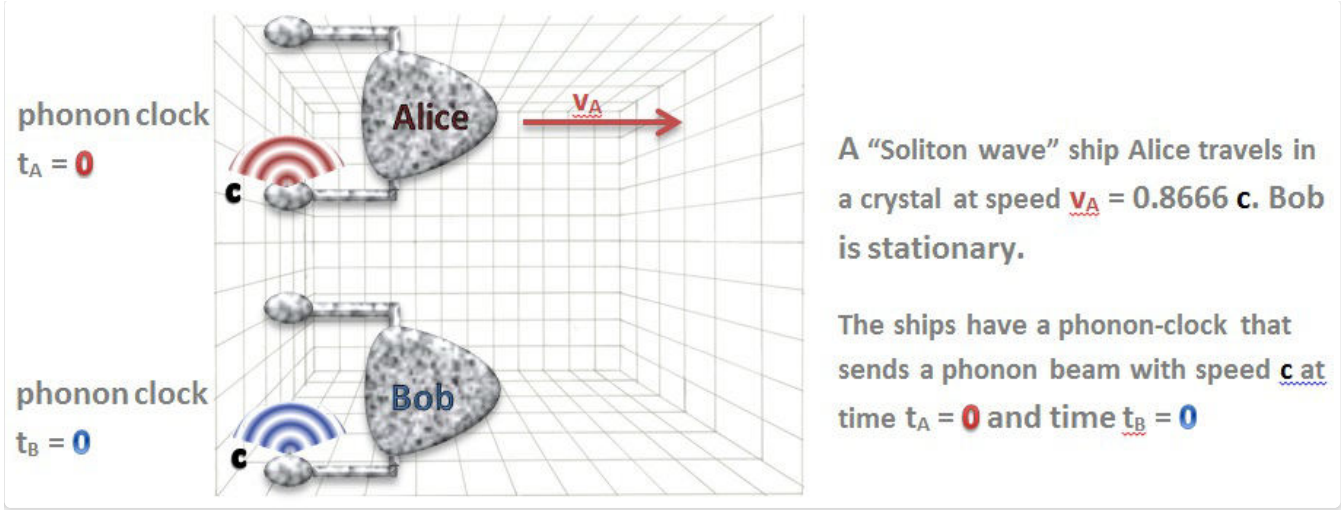
x = 1.5 * t = 1.5 * 4 seconds = **6 seconds**

What happens if the boat is going as fast as the wave speed c? Then the clock never ticks! Because the wave front can never reach the bell…

This is where this particular analogy ends of course, and as we said, for surface water waves, the wave speed depends on the frequency, and also because the boat is not a wave…

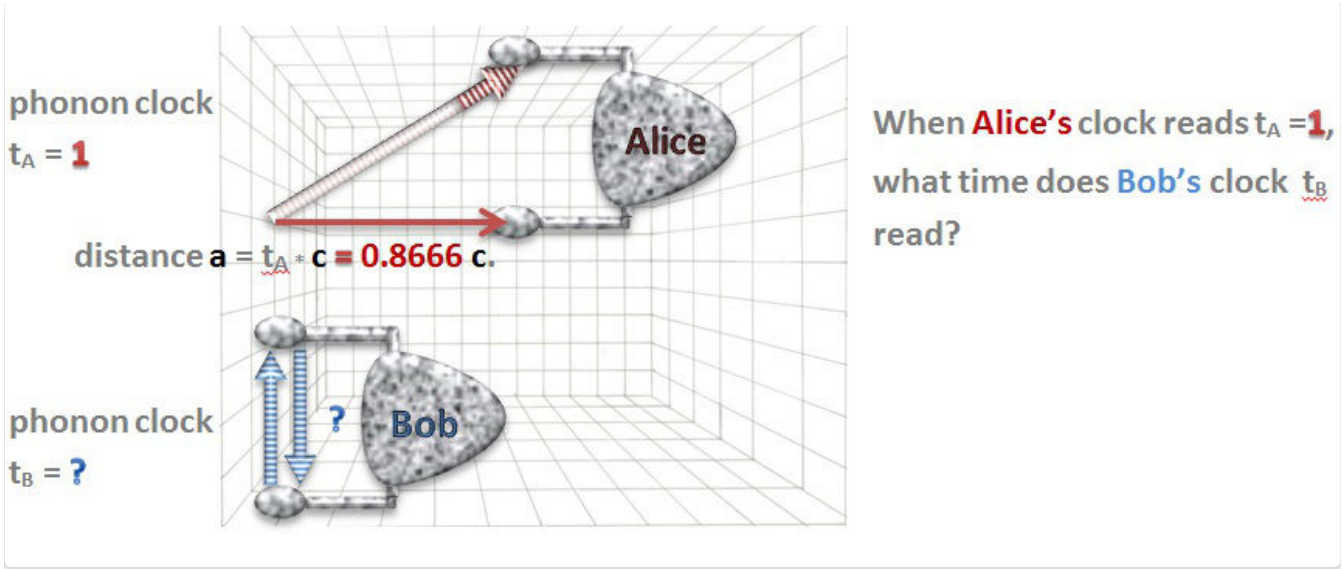
Following is a more analogous example of the "crystal universe" – it is really exactly the same, except that we replace the water with the crystal (or elastic solid like Jell-O), and that we replace the water

clock with a “phonon” clock (sound), and that we replace the boat with a “matter wave” boat:

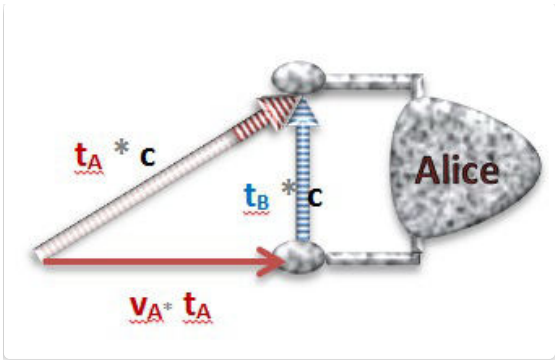


The two ships have a ***phonon clock*** attached. Each “tick” in the clock is when the phonon beam from the bottom part of the clock reaches the detector on the top. **c** is the speed of the waves (phonon waves) in that crystal.

Alice boat is moving at speed **v = (0.866 * c)** (to get an even result :-).



We do the same thing as we did with the regular boat. All we have to do is use the Pythagorean formula to solve for the unknown t_B:



Simple Pythagoras:

$$(v_A * t_A)^2 + (t_B * c)^2 = (t_A * c)^2$$

Solve for t_B:

$$(t_B * c)^2 = (t_A * c)^2 - (v_A * t_A)^2$$

$$t_B^2 * c^2 = t_A^2 * c^2 - v_A^2 * t_A^2$$

$$t_B = t_A \frac{c}{\sqrt{c^2 - v_A^2}}$$

Using value for v_A = 0.866 c.

$$t_B = t_A \frac{c}{\sqrt{c^2 - 0.75c^2}} = t_A \frac{c}{\sqrt{0.25c^2}} = 2 * t_A$$

The answer for this example is: Bob's "clock" runs twice as fast as Alice's clock. In this example, because the ships themselves are composed of (soliton) waves, they can never go faster than c either!

For an animated version of this, please check out Robert Close underwater relativity!

How does this translate to "our" world? If photons are actual (quantized) waves like phonons, and if matter waves are also true waves (and not just probabilities for particles), waves in a "solid space", then we get ***exactly the same result***. In that model it is completely logical, that photons always travel at the wave speed c, and that no wave, so no matter wave either, can ever go faster than c.

The entire "time dilation" then in this model is simply a wave phenomenon. There is absolutely nothing magical about it! You get the same result for ***any*** wave system.

If you think about it, what are clocks? All our clocks are at end made of either light or matter. And if matter are waves, then of course, any moving clock would tick slower. So in this "crystal" model, it is not the case the that (abstract) time is really moving slower. It is simply the actual clocks that tick slower (because the paths of moving clocks are longer!). We could even argue, is there an abstract concept of time.

In the "mainstream" (space-time) version, this is a bit different. In that model, there is no absolute time, and there is no absolute space either. Clocks are not ticking slower, it is actual time that is slower for that particular "frame" (that particular object). And the speed of light in that model is not constant in an absolute sense, since in that model, there is no absolute space either. In the space-time interpretation, the speed of light is constant ***for each observer***. This might seem like a detail, but it means you can no longer use "common sense" to explain it. And also, in that model, special relativity has nothing to do with waves.

You might say: but, it has been shown that light is in fact the same for any (moving) frame. Yes, that is true! And I will show next how indeed, for any moving or non-moving observer, the speed c always *__appears__* the same, even though it is actually constant in the absolute sense:

So let's measure the wave speed c in two situations, when then boat is stationary, or when the boat is moving:

a) Stationary Situation

The distance **b** between the source of the wave clock and target bell is **time * wave speed c**. We want to know how kind of c that the person in the boat measures, with his clock. Hence we use his time t_A. The distance b is known of course, the person in the boat can just measure the frame width. Therefore **c = b/t_A**.. The time t_A is **1**, since this is how our clock works: when the ring bells, the time ticks once. Hence **c = b**

b) Moving Situation

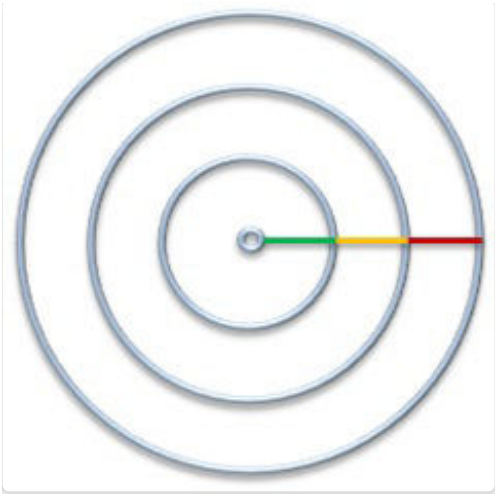
When the boat is moving, viewed from a stationary observer, the wave has to travel further, and the clock of the moving boat is running slower.

What wave speed does the person in the moving boat measure? Well, for him, one tick is still – per definition – the time it takes for the wave to hit the bell. For the moving observer, the time t_A is still **1** tick. The distance **b** has not changed (the width of the frame). And again, c is the same: **c = b**

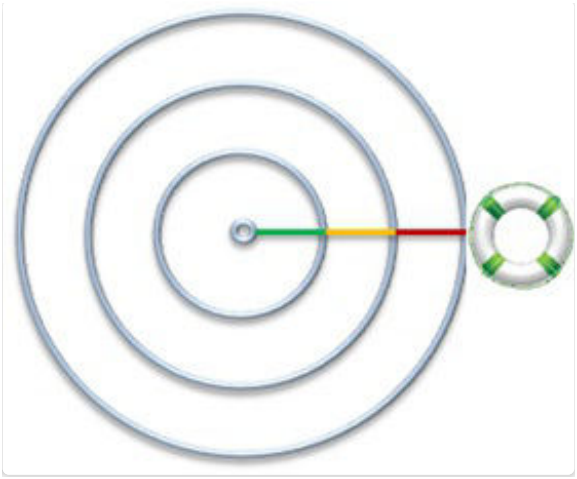
We will look at a more complicated situation in the length contraction section, but basically every observer will always measure the same speed of c, no matter whether the observer is stationary or moving.

2. Length Contraction and Doppler Effect (part 1)

We'll do a simplified example first. Imagine we are on a still lake, and dipping a stick into the water at regular intervals from a boat. You get this familiar wave pattern below:

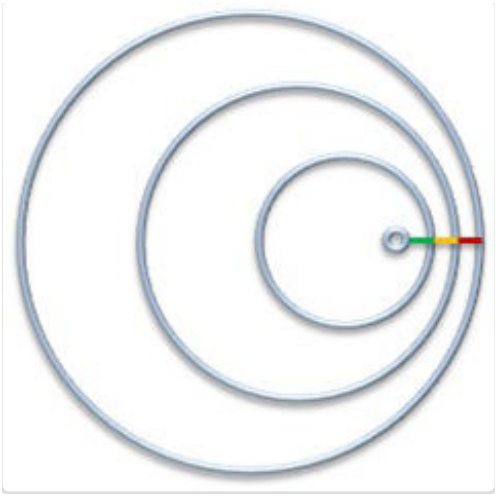


Notice how the distance between the wave crests is constant, and the same on both sides. Let's use the number of wave crests as our measuring stick. We use it to measure the distance to say a life buoy:



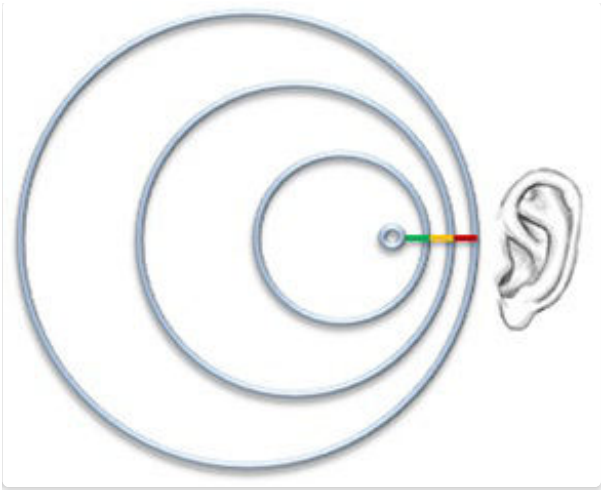
The distance is 3 weave crests.

If we do the same thing in a uniformly moving boat, say at 2/3 of the speed of the wave in a horizontal direction, then it looks like this:

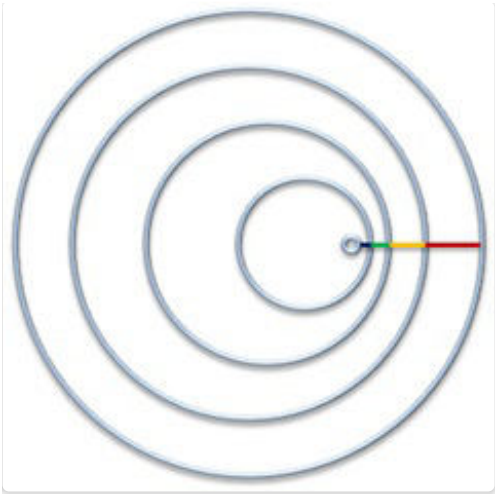


The distance between the weave crests is now 1/3 as it was before on the right (but still equidistant). So our measuring "stick" has shrunk to a third . Of course we notice that, because we are (in this examples) outside observers and can see that. If we were composed of the same kind of waves as in this example however, we would also have shrunk to 1/3 in the horizontal direction, and would not notice (a more detailed example on that later make this point clear).

This also illustrates the Doppler effect: The wave length has shrunk, and so if someone were listening (in a sound example) as the object approaches, then the frequency would be higher as in the stationary case:



If the boat is uniformly accelerating to the right, then the wave crests are no longer equidistant, they get shorter as we measure them towards the center:



So to a listener, the frequency would get higher and higher, and our measuring "stick" would get shorter and shorter⋯

For a much more detailed example, please take at the (animated) unterwater relativty by Robert Close:
http://www.classicalmatter.org/UnderwaterRelativity/ParallelLength.swf

And for a more "correct" version of this, with boats that are also made out of waves, see this animated example:
http://www.classicalmatter.org/UnderwaterRelativity/MatterWaves.swf

Next puzzle: Puzzle Piece 4: The (other) Heisenberg

Summary Table

	Space-density Universe (RED pill)	**Space-Time Universe (BLUE pill)**
Tags	elastic solid, crystal universe, optical-mechanical analogue, space exists	Minkowski, space-time, absolute space does not exist
GR Metric Tensor	space-density (space with compression)	space-time
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Double Slit Experiment	real waves interfering (like phonons)	parallel universes, no real wave, “consciousness” ,probabilistic⋯
Schrödinger Wave Equation	describes real waves, rotational waves in an elastic solid. There are no particles	probability of finding a particle, there are no real waves
What is space?	An elastic solid (not made of matter). Matter and light moves though space as waves move through a crystal	There is no absolute space
Special Relativity	Time dilation and length contraction are consequence of *any* wave system. Any wave has a maximum speed in any given medium.	There is no intuitive explanation. It follows from the constancy of the speed of light for each *observer*
Speed of light	c, constant in absolute space. Also c for each observer, due to time dilation	c is constant for each observer. There is no absolute space
Twin Paradox	No paradox. Whoever moved slower relative to absolute space ages faster.	If A is considered to be at rest, B ages more slowly, and vice versa. There is no clear answer as to who ages faster.

Links

Special Relativity:

- The Other Meaning of Special Relativity (Robert Close): http://www.classicalmatter.org/ClassicalTheory/OtherRelativity.pdf
- Classical Wave Theory of Matter (by Robert Close), chapter 2: http://www.verumversa.com/ClassicalWaveTheoryOfMatter.pdf
- Underwater Relativity: http://www.classicalmatter.org/UnderwaterRelativity.htm

Other:

- Hagen Kleinerts World Crystal: http://users.physik.fu-berlin.de/~kleinert/papers/planckklcZN.pdf

Puzzle Piece 4: The (other) Heisenberg

Previous puzzle: Puzzle Piece 3: What's special about Special Relativity?

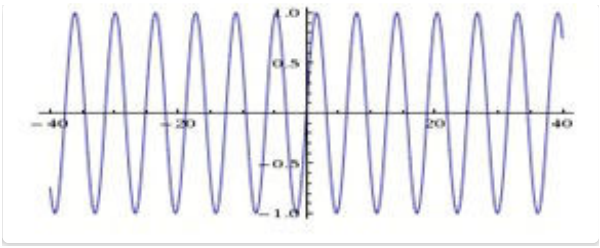
Let's talk about Heisenberg – not Walter White, the real Heisenberg, who came up with the uncertainty principle. The fact that for any particle, one cannot measure location and momentum exactly at the same time.

If we look at this in the context of waves, as in sound waves, then maybe it does not sound so strange. Basically, the principle says that the error in the position (dx) times error in momentum (dp) is larger or equal to $\hbar/2$:

$$\sigma_x \sigma_p \geq \frac{\hbar}{2},$$

where $\hbar$ is the reduced Planck constant.

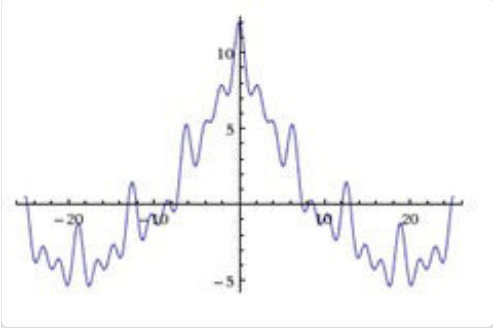
So what does that mean in the context of sound? A pure sine tone (say 440 Hz) has an exact frequency, but has no clearly defined starting and ending position:



Imagine you play this tone on an instrument, say a violin. Then you hear just that one frequency, and there is no beginning or end of that tone (except when the player begins and ends of course). So that sine wave extends in space for as long as the player plays that tone. It is not localized – it makes no sense to talk about location, as it is the same for the entire duration of the sound.

Now what does an exploding balloon sound like? It's the opposite of a pure sine wave: a popping balloon has quite a specific location, but the frequency of that sound is not one pure tone, but a mixture of many frequencies. How can this be represented? Basically by adding a bunch of sine waves (Fourier) together, to get the shape of the explosion sound: below I added a bunch of cos

curves – the more you add, the more localized the sound gets, but the more frequencies are mixed in, so the harder it gets to determine a frequency.



You can either measure the frequency, but then you can't tell quite exactly where the sound begins or ends, or else, you measure the location, but then you can't quite tell what frequency the tone had. In fact, the perfect impulse has an infinite number of frequencies, and it doesn't even make sense to talk about measuring the frequency in that case, because there is no clearly defined frequency. In the other case, it makes no sense to say where exactly the tone is, because it has no clear beginning or end.

This is true for any kind of wave, whether we talk about sound waves, water waves, light waves or matter waves. If matter is composed of true waves, then maybe the idea that for a "particle" you can either determine it's location or it's momentum, but not both at the same time, does not seem so strange anymore – it is simply a natural consequence of any wave.

Next puzzle: Puzzle Piece 5: The Doppler Challenge

Summary Table

	Space-density Universe (RED pill)	**Space-Time Universe (BLUE pill)**
Tags	elastic solid, crystal universe, optical-mechanical analogue, space exists	Minkowski, space-time, absolute space does not exist
GR Metric Tensor	space-density (space with compression)	space-time
Cause of Gravity	refraction (density gradient, optical)	curvature of space-time
Photon	quantized wave, similar to phonon quasiparticles in crystal (vibrational mode), there are no photon "particles"	probability density wave function, no "real" wave, probability of finding photon

Double Slit Experiment	real waves interfering (like phonons)	parallel universes, no real wave, "consciousness",probabilistic⋯
Schrödinger Wave Equation	describes real waves, rotational waves in an elastic solid. There are no particles	probability of finding a particle, there are no real waves
What is space?	An elastic solid (not made of matter). Matter and light moves though space as waves move through a crystal	There is no absolute space
Special Relativity	Time dilation and length contraction are consequence of *any* wave system. Any wave has a maximum speed in any given medium.	There is no intuitive explanation. It follows from the constancy of the speed of light for each *observer*
Speed of light	c, constant in absolute space. Also c for each observer, due to time dilation	c is constant for each observer. There is no absolute space
Twin Paradox	No paradox. Whoever moved slower relative to absolute space ages faster.	If A is considered to be at rest, B ages more slowly, and vice versa. There is no clear answer as to who ages faster (if cleverly engineered – see post on that)
Uncertainty Principle	Natural consequence of any wave system	Due to wave property of matter and light (but only probabilistic)

Links

Uncertainty Principle

- Wikipedia: http://en.wikipedia.org/wiki/Uncertainty_principle
- The Uncertainty Principle: http://www.mtnmath.com/whatrh/node72.html
- The Open University: http://www.met.reading.ac.uk/pplato2/h-flap/phys10_2.html (chapter 4)

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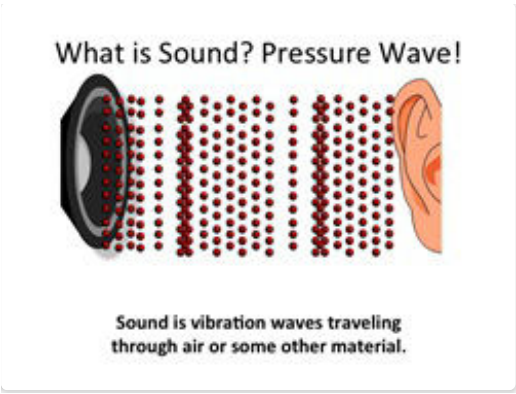
Puzzle Piece 5: The Doppler Challenge

Previous puzzle: Puzzle Piece 4: The (other) Heisenberg

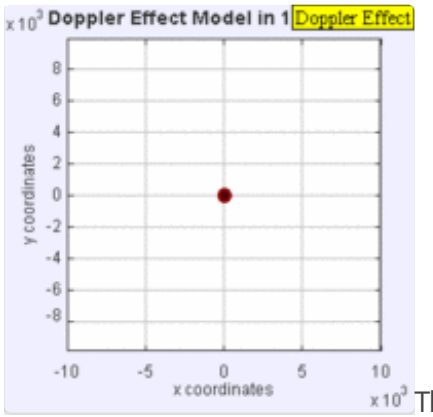
The Doppler effect for sound is very simple of course, and you surely know how it works. And I am sure you also think it is easy for light, but unfortunately, due to the way that "mainstream physics" interprets relativity, the whole thing gets very strange for light. However, if we consider the "elastic solid" interpretation of relativity, than the entire mystery vanishes, and what is left is the same explanation as for sound. To see what the issue is, let's first take a detailed look at the Doppler effect for sound:

Doppler Effect for Sound:

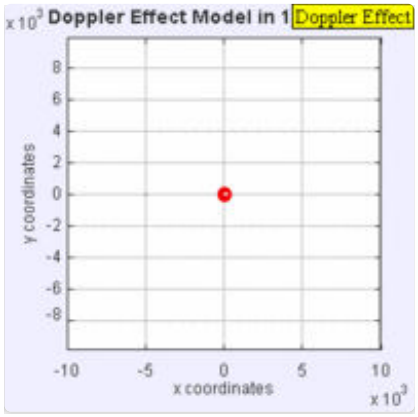


Let's first consider what sound is: it is a pressure wave that moves through a medium such as air. When a sound is emitted, the sound wave travels at a fixed speed (assuming no wind) through the medium. Once the sound is emitted, it exists whether the speaker disappears afterwards or if there is no listener (you will see why I write such a weird thing later).

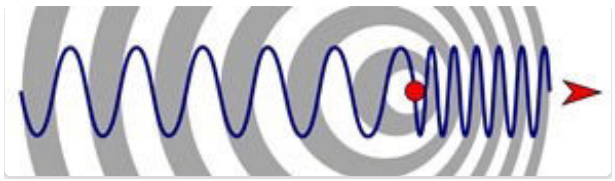
Let's take a look at the stationary case: imagine a speaker in a room that emits sound of a particular frequency (such as 440hz) (from Wikipedia)



The sound spreads in all directions, at the speed of sound.



Now imagine the speaker is moving to the right. The speed of sound never changes, so the waves always spread at the same speed. But now, because the speaker is moving, the pressure waves are **closer together** in the moving direction, because the speaker is moving relative to the **medium**. If we plot the frequency on top of the waves, then you can see clearly that the frequency is higher in the moving direction, and lower behind the speaker.



The exact same effect happens if there is a microphone (an observer) that is moving towards the waves**, relative to the medium.** Note I said towards the waves, not towards the speaker. We can destroy the speaker or move it after it emitted the sound, but the sound waves are still in the air and moving no matter what the speaker does afterwards. What matters is how the microphone moves relative to the medium, and what pressure waves it records. If the microphone moves towards the waves, it will observe more pressure waves than if it is moving away.

The total shift depends on the speed of the speaker and also on the speed of the observer (relative to the medium!). The general formula is:

$$f = \left(\frac{c + v_r}{c + v_s}\right) f_0$$

If vr and vs are small relative to the speed of the wave c, then this can be simplified to:

$$f = \left(1 + \frac{\Delta v}{c}\right) f_0$$

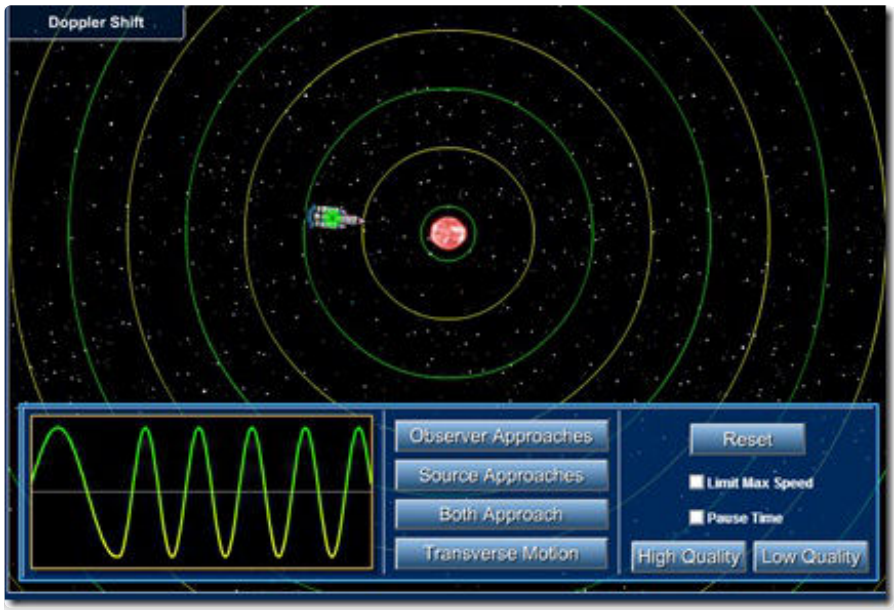
Where $\Delta v = v_r - v_s$

Doppler Effect for Light:

The formula for light is exactly the same (for non-relativistic speed):

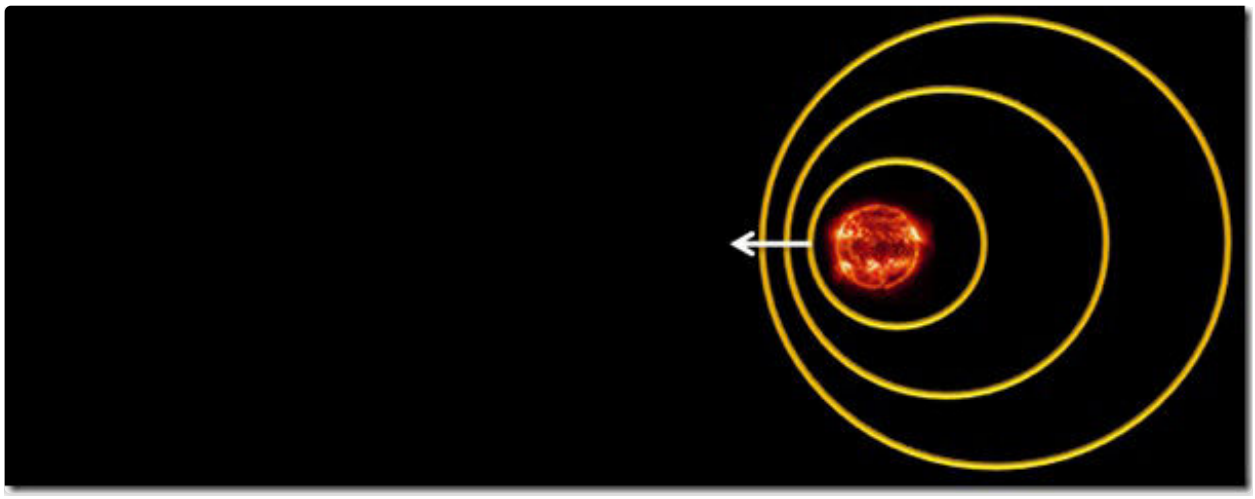
$$f = \left(1 + \frac{\Delta v}{c}\right) f_0$$

Below is an interactive animation (click on it) where you can play with the Doppler effect for light. It really shows how the effect actually works in reality. However, as you will see shortly, this contradicts the “mainstream” interpretation.

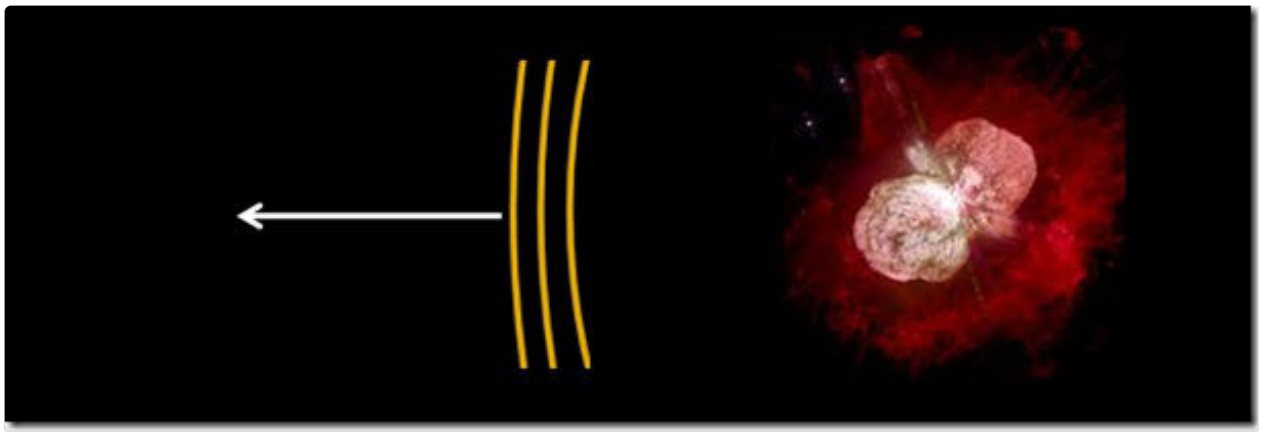


Clearly, since light is also a wave, and since the formula is also the same, it is logical that the mechanism for light is also the same. So what is the issue here? If you have read the other posts, then you know that there are two interpretations of relativity. The space-time interpretation, which is the mainstream one, and the elastic solid interpretation of space (Hagen Kleinerts World Crystal).

The animation above actually corresponds more to the elastic solid interpretation than the mainstream interpretation: in this model, just as with sound, the light waves are nothing more than oscillations in an absolute space. Once the star has emitted light, the light continues to exist and travel no matter what the star does: in the image below, a star that is moving to the left is emitting light. At that time, earth does not exist yet (say the star is 6 billion light years away from (future) earth).



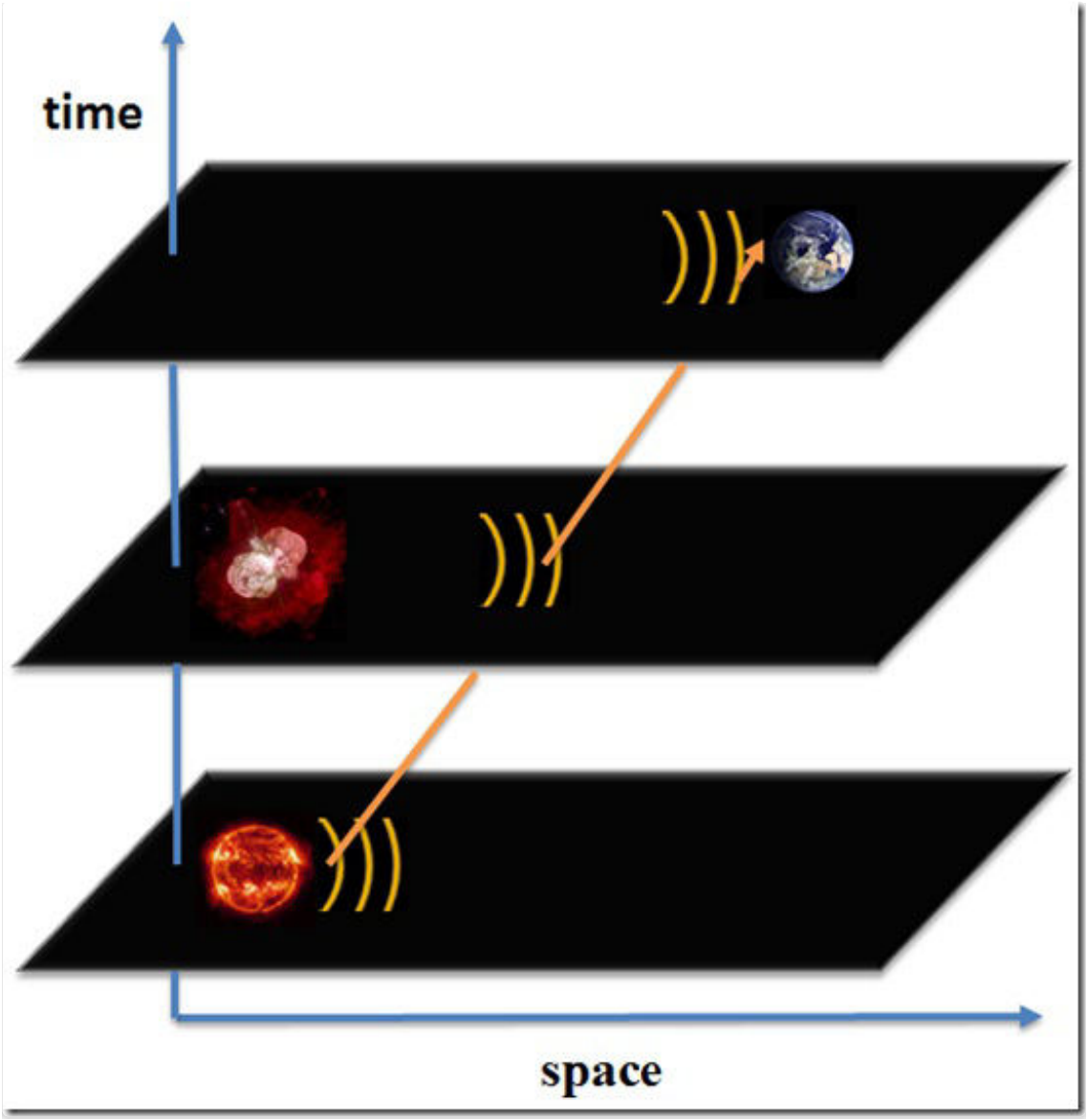
If the star explodes as a super nova, it doesn't matter. The light that was emitted before still continues to travel through space, no matter if it will ever be "observed" or not. Just think of all the supernovas that have been observed already millions of light years a away. By the time the light reaches earth, the super nova is long gone! The source is no longer there:



Similar in other cases: if the start has emitted light and was moving, then by the time the light reaches earth, it might be on the other side of the galaxy… The light we observe from stars is independent of the existence of the star. I know it sounds like I am beating a dead horse, but there are people who seriously claim otherwise.

The frequency that the light has in space depends on the velocity that the star had at the time the light was emitted – just like with the speaker example above. And when the light is observed, say on earth, the frequency may be shifted a second time, depending on how earth is moving relative to **space** (and **not** relative to the star – which may be been gone by now!),**:**

The problem is that based on the “space time” interpretation, there is no absolute space, so there is **no medium** at all through which light can propagate. The question then is, *how would a Doppler effect in that case even be possible*? If there really is no “space” (no medium), then at the time light is emitted by a moving star, and if there is no observer yet (no earth), then *there should be no frequency shift at all*, since the star is not really moving at all if there is no absolute space. So what frequency will the light have? There is no explanation as how it could possibly be red or blue shifted if there were no space, as there is no mechanism, no medium where this change of frequency could occur. If you ask a mainstream physicist, most likely you will get a space-time diagram, that shows the source and observer in the same image:



This may look nice, but it doesn't change the fact that the first frequency shift happens *at the time that the light waves are emitted from the star*, and that at each point in space (and time), the light wave *exists*, and has a well defined frequency – which can only be true if some kind of "space" exists. Just because we can draw a line from the past to the present does not somehow change this problem. At the time the light waves were emitted, the star did not "'know" that one day earth will come into existence and will measure its rays… so it cannot depend on the (future) observer…. So based on this model, there can never be any frequency shift at the time the light is emitted. The line from the past to the present, and using the relative speed between source and observer is just a mathematical trick, and says nothing about the underlying reality.

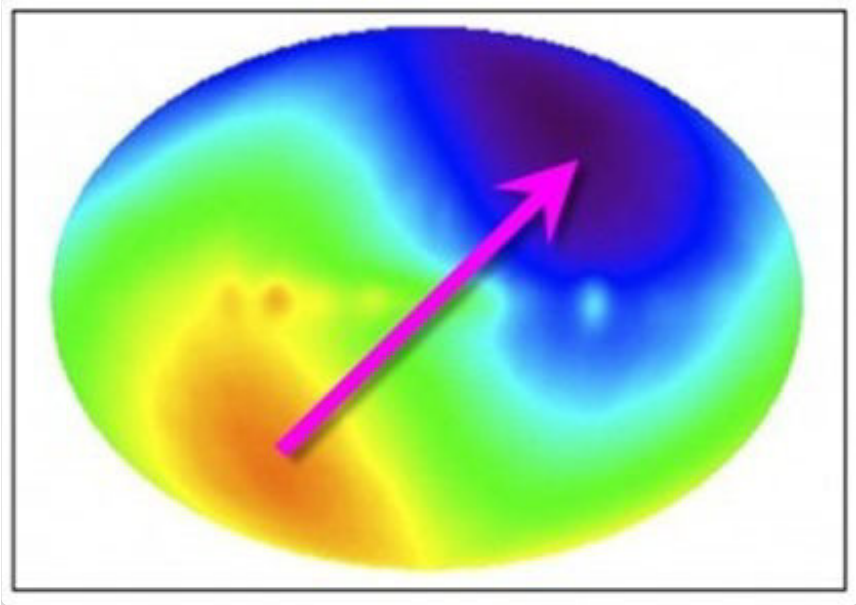
So you have two choices:

a) believe that space exists in an absolute sense (the **red** pill). Then the Doppler effect of light is explained exactly the same way as it is for sound – no magic involved, it's totally simple.

b) believe that no space exists in an absolute sense (the **blue** pill). Then the Doppler effect can only be explained by some magic between the source and (future) observer… where the light wave does

not really exist until measured, and one cannot even talk about a frequency of the light wave on its own. There is no physical explanation of all of this, just a mathematical formula (and a nice space-time diagram that looks complicated).

Interestingly tough, most of them will admit that we are in fact moving **relative to the cosmic microwave background** (CMB), as it clearly shows a Doppler effect (an anisotropy):



It is even possible to compute the speed of earth **relative to the universe** that way, and it is on the order of 600km/s (which includes the movement of earth around the sun, the sun around the galaxy, and the movement of the milky way itself relative to the cosmos).

So I wonder, if maybe the idea of an absolute space is not so absurd after all?

Next puzzle: [Puzzle Piece 6: Disentangling the Entanglement]

Summary Table

	Space-density Universe (RED pill)	**Space-Time Universe (BLUE pill)**
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Uncertainty Principle	Natural consequence of any wave system	Due to wave property of matter and light (but only probabilistic)
Doppler Effect	Same as sound. Shift depends of speed of source and observer relative to an absolute space	Not same as sound as there is no medium. Strictly depends on relative velocity between observer and source. No physical explanation.

Links

Doppler Effect:

- Wikipedia: http://en.wikipedia.org/wiki/Doppler_effect
- Wikibooks: http://en.wikibooks.org/wiki/A-level_Physics_(Advancing_Physics)/Doppler_Effect
- Animation for light: http://www.acs.psu.edu/drussell/Demos/doppler/doppler.html
- Interactive Demo: http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::800::600::/sites/dl/free/0072482621/78778/Doppler_Nav.swf::Doppler%20Shift%20Inte

ractive

- Mathpages: http://mathpages.com/rr/s2-04/2-04.htm
- Cosmic Microwave Background Dipole Anisotropy: http://www.astro.ucla.edu/~wright/CMB-dipole-history.html

Optical analogues of General Relativity:

- Hagen Kleinerts World Crystal: http://users.physik.fu-berlin.de/~kleinert/papers/planckklcZN.pdf
- Defects and Diffusion in the Planck-Kleinert Crystal: http://ceram.agh.edu.pl/~icmmagh/artykuly/237%20PLANCK%20CRYSTAL%20DSL%20final.pdf
- Emerging Gravity from Defects in World Crystal: http://www.sbfisica.org.br/bjp/files/v35_359.pdf
- De Felice, F. On the gravitational field acting as an optical medium. Gen. Relativ. Gravit. 2,347–357 (1971).
- On the optical-mechanical analogy in general relativity: http://arxiv.org/abs/0905.4479 , http://www2.ups.edu/physics/faculty/evans/Optical%20Mechanical%20GRG.pdf
- The Classical Wave Theory of Matter by Robert Close: http://www.verumversa.com/

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Puzzle Piece 6: Disentangling the entanglement

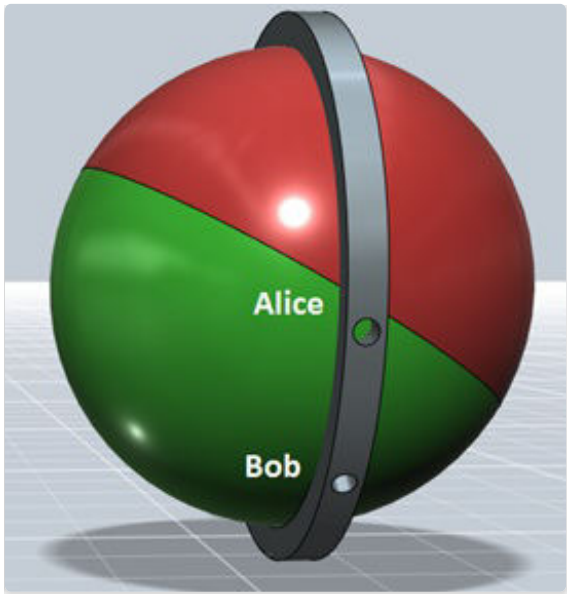
Previous puzzle: Puzzle Piece 5: The Doppler Challenge

The only potentially *really* weird thing in quantum mechanics in my opinion is the concept of "**entanglement**". After reading and re-rereading lots of papers on it, at some point I decided that the best way to really understand the problem is to write a computer simulation.

But first, let me try to explain the problem in simple terms – using a similar model as Caroline Thompson's chaotic ball. Imagine a colored ball, one side red and one side green. A ring with holes is attached. We can rotate the ball in any direction, and when it stops, two players Alice and Bob each peek through a hole and check what color they see. Then they write down two things:

- how far apart he holes were (in degrees, such as 45 degrees),
- whether they agreed on the color or not
  (if both saw red or both saw green, then they agreed)

In the first example, they both see green – so they **agree**. The angle is say 45 degrees between the holes.

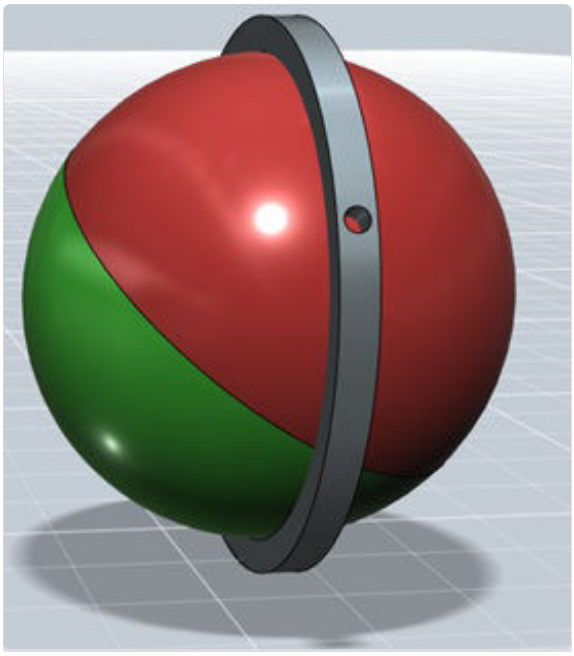


Now we repeat this game many times, for different random orientations of the ball. You can see that

if the red/green border falls between the holes, they won't agree, and otherwise they will agree. After say 1000 such experiments, we change the angle between the holes to one of:

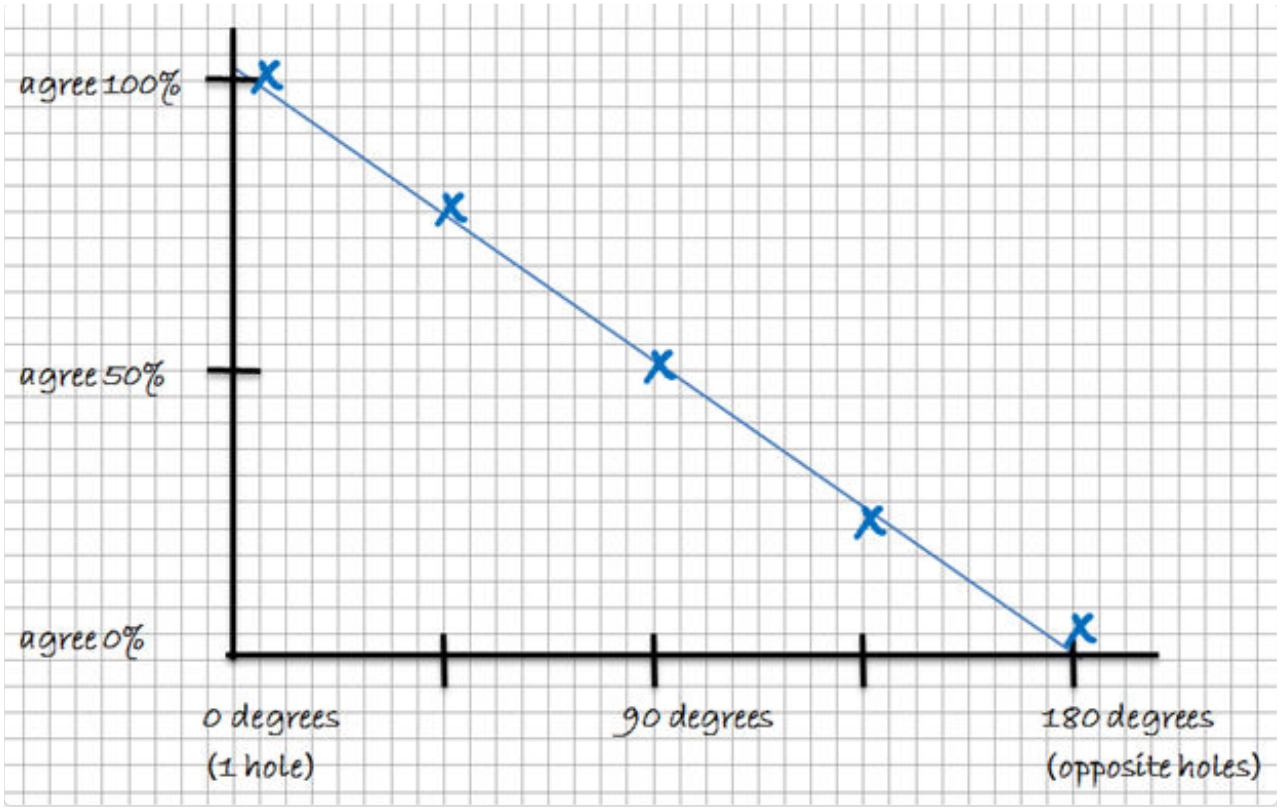
- 0 degrees (just one hole – both use the same 🙂
- 45 degrees
- 90 degrees
- 180 degrees

Obviously, for 0 degrees, Alice and Bob always agree on the color, since they both look into the same hole :-):

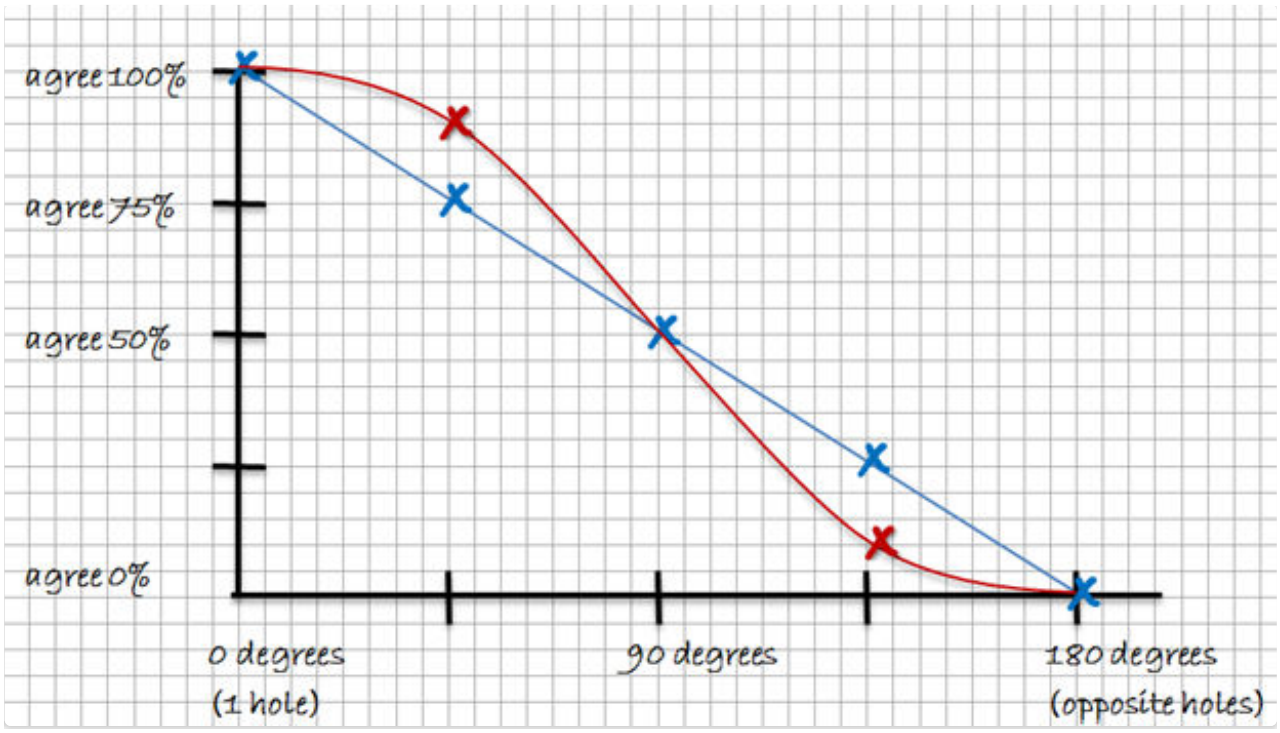


For 180 degrees, they never agree (since the holes are completely opposite).

Finally, we plot the result: for each angle between the holes (such as 0 degrees), we count the percentage of **how often we agreed** (nr of agreements / total observations). This will result in the typical shape like this – a straight line down:



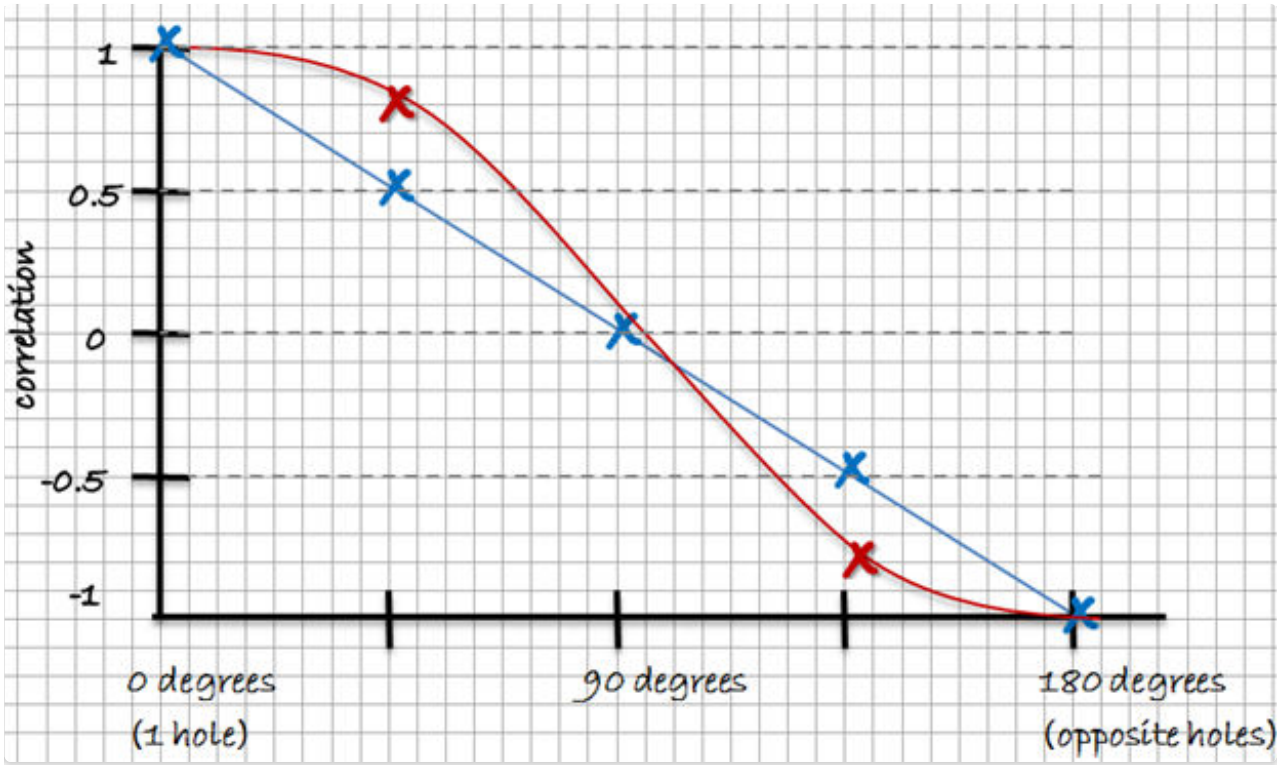
So··· what is special about that? So far, absolutely **nothing** :-). The thing is, if you do this with **photons** (two photon beams that have the same or opposite polarization, for instance), then you get the red curve – a cosine shape:



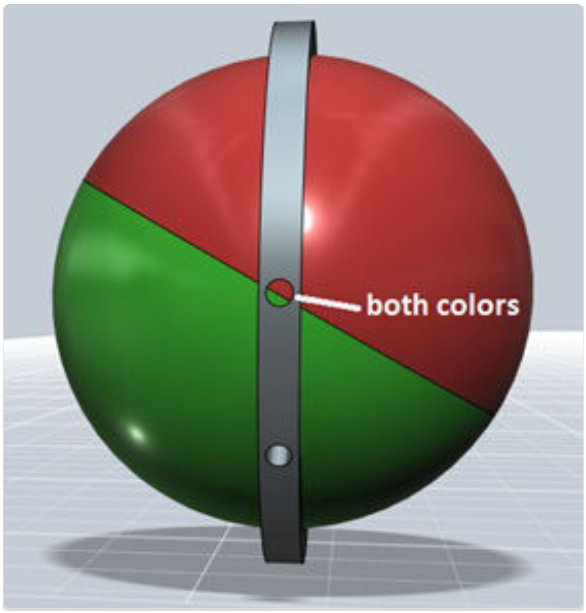
Before we jump to conclusions and exclaim that this is proof of entanglement, let's see if we can reproduce this result with our red/green ball. *And yes, we can actually quite easily do it!*

First, just to be a bit more accurate, we don't express the "agree" in percent, but in correlation. 0% agree means a correlation of –1, 50% agree means 0 correlation, and 100% agree means a

correlation of 1:



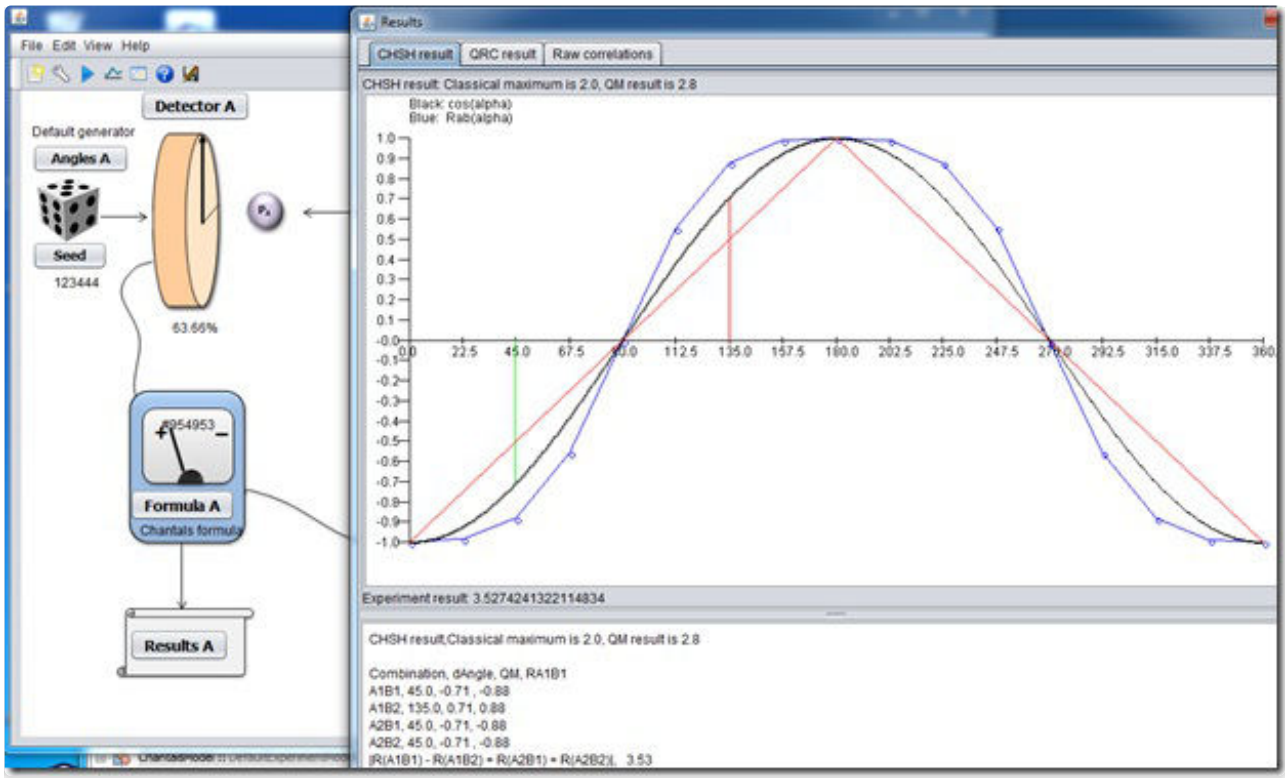
Now we change the rules of the game just a tiny bit: whenever we look into the hole and see **both colors** (red and green), like in the image below, then we have the right to say "**I don't know**!"



In that case, we **don't record a value** (or just a question mark). To make this even more like the quantum mechanics result, we say "**I don't know**" more often when we see both colors about the same amount, like in this image:

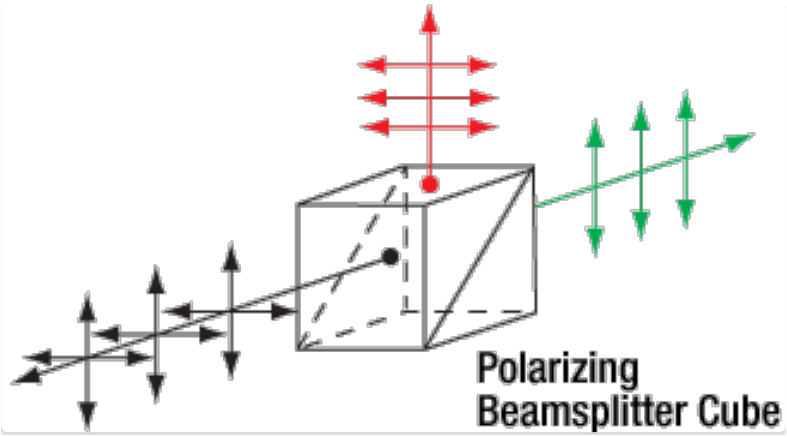
And we decide to call the color more often if one color clearly dominates (even though both colors are visible):

What does this change? Below is the result of a computer simulation that I wrote that you can download from GitHub: https://github.com/chenopodium/tango, which simulates such a game (in this example we can get even a "better" result than in QM). This game is called the "**detection loophole**" if you read papers on this (but there are other interpretations as well).

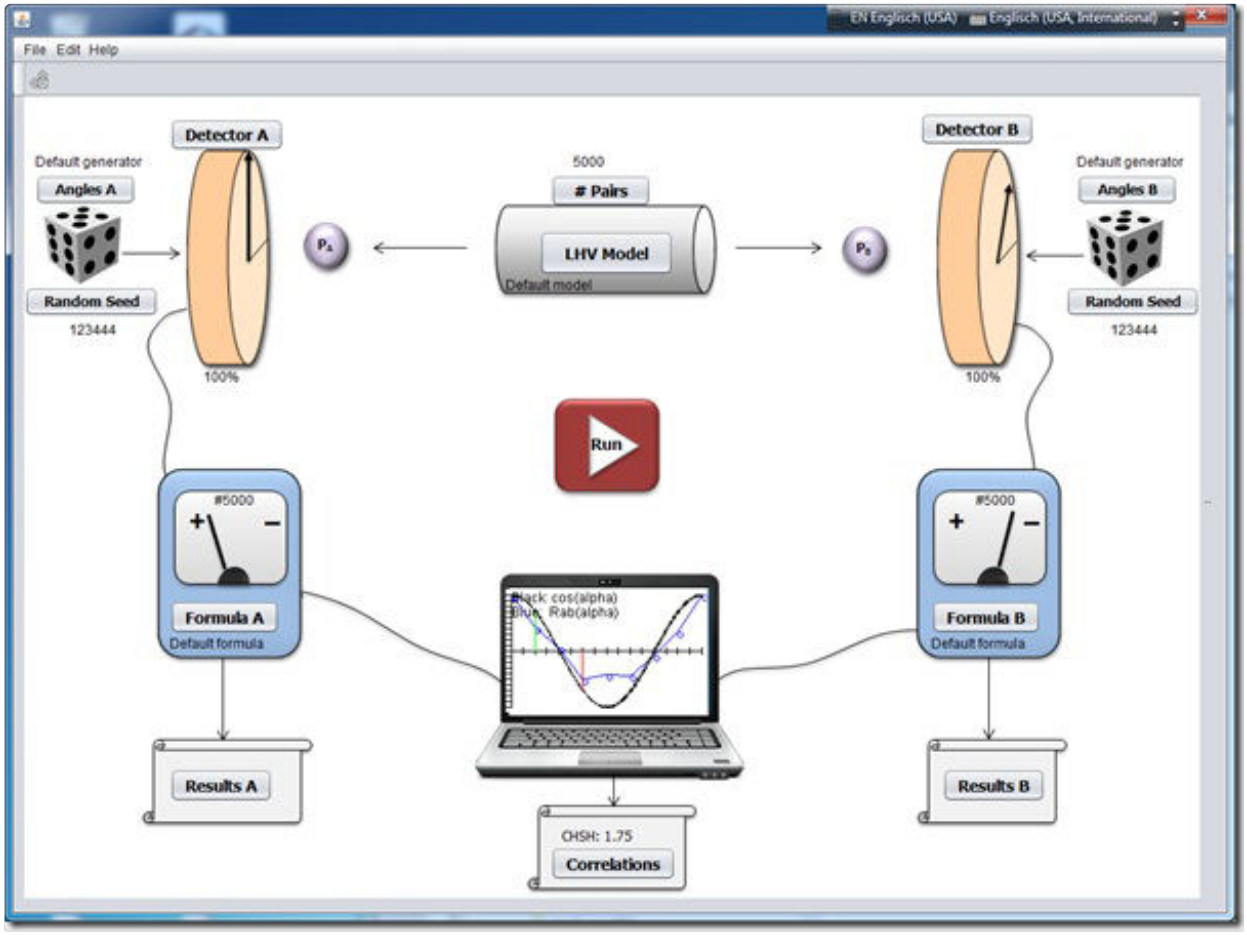


Instead of a red/green ball, we have two **photon beams** (P_A and P_B), which are created in a way that one beam is polarized **up/down**, and the other one is polarized **left/right**. This can be done with a beam splitter – similar to a prism. So we know that if one of the photon beams is up/down polarized, then the other side is left right polarized, and vice versa (of course we can make it so that there is a random angle to the whole thing, like in the example with the ball). These two beams are now **called**

“entangled”. The reason is that the system can be described with *one mathematical formula* (since the polarization is correlated).



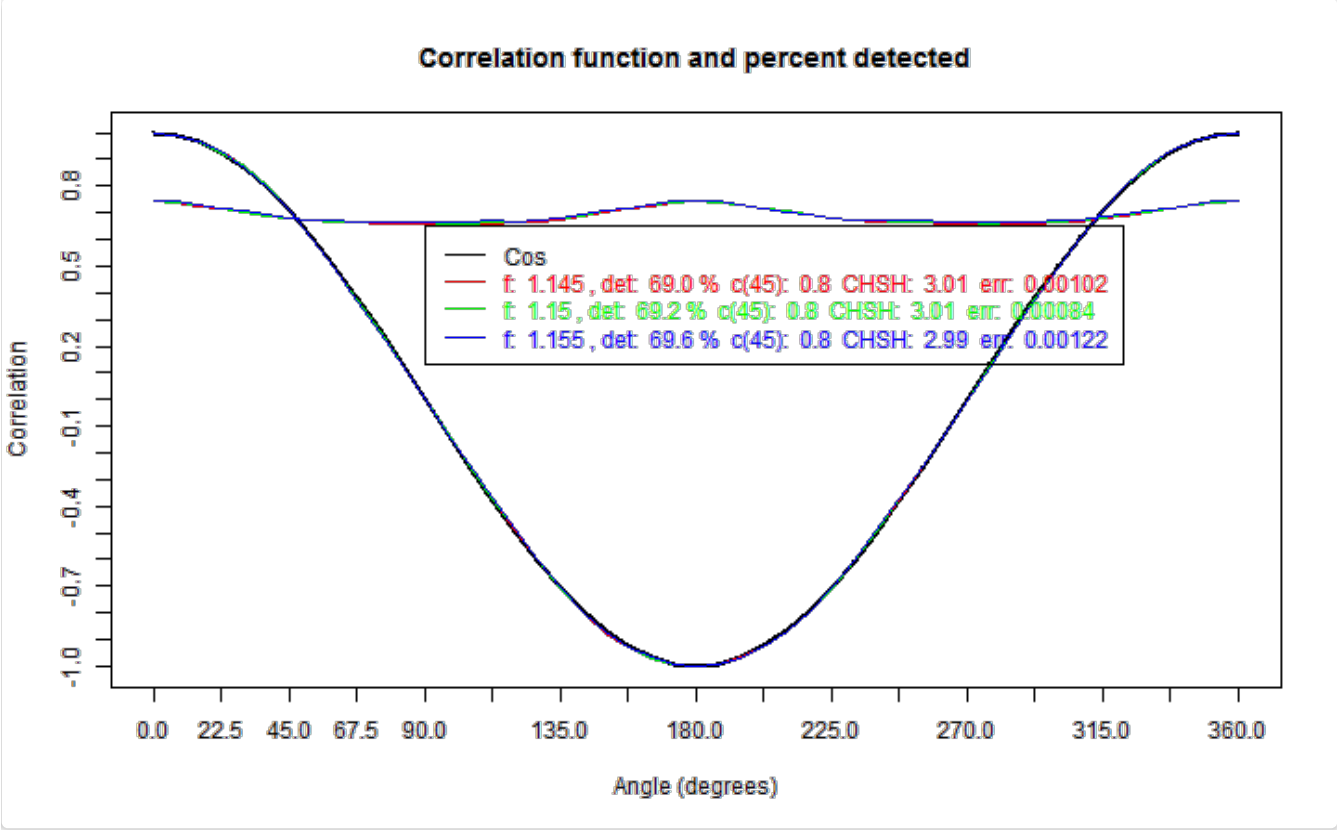
The **detector** is like our **holes**, where we decide if we measure the same polarization or not (up or down instead of red or green). Also, our detector can say “I don’t know” in this model.



You can click on the various images and change the rules of the game a bit, and see what the resulting correlation curve looks like. One rule you can change for instance is how large the “holes” are – basically how likely we are to say “I don’t know”. We know from experiments that we do detect at least 70-80% of the pairs (approximately), so we know approximately how often we can say “I don’t know” and still get results that match the actual QM experiments with photons.

For those who prefer the programming language **R** over Java, there is also an **R** simulation of the same type of "game": http://rpubs.com/chenopodium/detection1. (Thanks Richard Gill for the help!)

The additional wavy line on top shows how often we did make the call (and how often we said "I don't know"). In the chart below, we more had "no detection" around 90 degrees than at 0 degrees – and this is the reason why we get the cosine shape.



Where's the Magic?

You are probably wondering··· **so where exactly is the magic**, and what is all the fuss about entanglement? Well, **if** it turns out – and that is actually **not** known yet! – that we indeed are not measuring all pairs at all angles the same number of times, then there is in fact *no magic*. Then the only "entanglement" is in the mathematical formula, and in the fact that we know that the beams angle is correlated at the *source* – and nothing else (or at least, not in those kinds of experiments). Of course we can debate possible reasons why we don't measure all photons.

This is just one tiny part of this huge discussion, for more information, please check out the links below, in particular this blog:

http://challengingbell.blogspot.ch/

If someone can proof that we do indeed measure **all** photons **equally** at **all angles** (and also produce an equal number of photons for each angle!), then yes, there is something weird going on.

And then we need to seriously think about what this means (you can pick one of the weird models: faster then speed of light communication, some kind of connection in another dimension, parallel universes etc⋯)

However, until that day, I am not getting too excited about it :-).

First puzzle: Puzzle Piece 1: Optical Black Holes and Particles of Sound

Links

Papers and Information Links

- http://philoscience.unibe.ch/documents/TexteHS10/bell1964epr.pdf
- http://www.drchinese.com/David/Aspect.pdf
- http://cms.unige.ch/gap/optics/wiki/_media/publications:bib:annphys_9_831.pdf
- http://www.drchinese.com/David/EPR_Bell_Aspect.htm
- http://en.wikipedia.org/wiki/Loopholes_in_Bell_test_experiments

Links to web pages (alternative models, blogs etc):

- Chaotic Ball: http://arxiv.org/abs/quant-ph/9611037
- http://freespace.virgin.net/ch.thompson1/intro.htm
- Challenging Bell Blog: http://challengingbell.blogspot.ch/
  http://challengingbell.blogspot.ch/2014/02/new-models-by-richard-gill-and-chantal.html
- Joy Christian: http://arxiv.org/abs/1211.0784
- http://freespace.virgin.net/ch.thompson1/
- http://quantummechanics.mchmultimedia.com/

Simulations that I wrote or participated in:

- Java: Tango, an EPR playground to try multiple models): https://github.com/chenopodium/tango
- Java: older NetBeans implementation: https://github.com/chenopodium/EPR
- R: detection loophole: http://rpubs.com/chenopodium/detection1 (with help from Richard Gill)
- R: model for Joy Christian: http://rpubs.com/chenopodium/joychristian
- R: Gisin experiment: http://rpubs.com/chenopodium/gisin1
- R: another version of Joy Christians model: http://rpubs.com/chenopodium/joychristian
- Java, Joy Christians model: http://challengingbell.blogspot.ch/2013/09/a-parallelized-3-sphere-based-simulation.html
  https://github.com/chenopodium/JCS
- Java, another version of Joy's model: https://github.com/chenopodium/JCS2
- Java, for Bryan Sanctuary: http://challengingbell.blogspot.ch/2013/05/a-local-realistic-simulation-

of-epr.html

ther simulations:

- in Java Script: http://libertesphilosophica.info/eprsim/EPR_3-sphere_simulation_test5m.html
- Python: https://github.com/minkwe/epr-simple/
- c# simulation: http://sourceforge.net/projects/epr-bohm/

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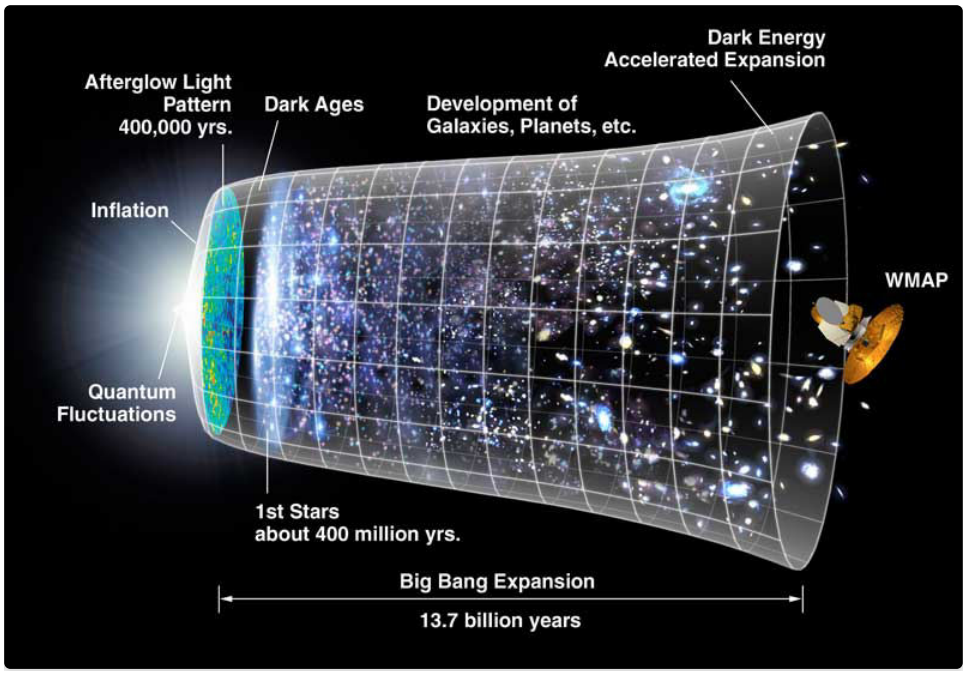
Second Puzzle: Big Bang or Big Problem?

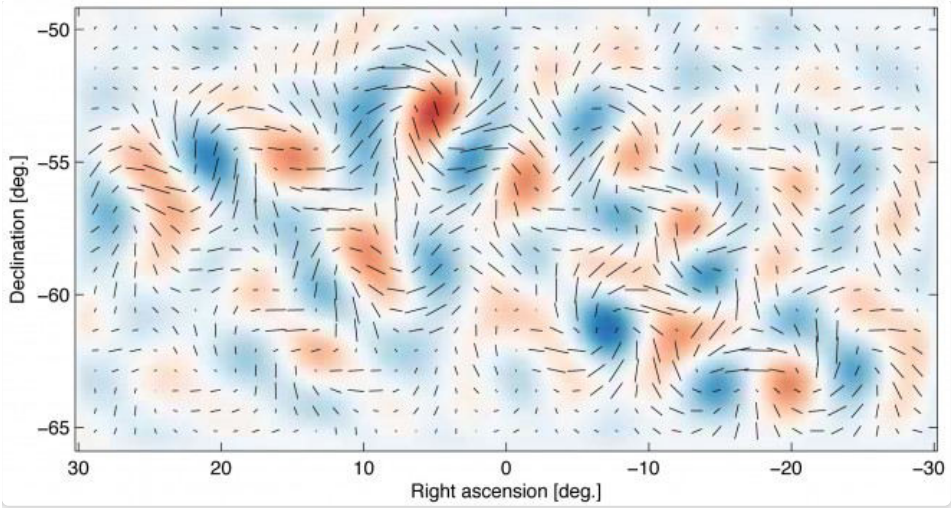
It's was all over the news: proof that the inflationary model is true. This revelation is based on the observation of (B-mode) polarized light patterns in the cosmic microwave background.



This polarization pattern is supposedly caused by gravitational waves – and not just any gravitational waves: waves from the Big Bang event itself. And not only that, based on the pattern of the polarization, scientists say that this is proof of an inflationary model, that at approximately

> *"0.00000000000000000000000000000000001 seconds after the Big Bang, it suddenly went through an accelerated expansion that drove it to become one thousand quadrillion quadrillion quadrillion quadrillion quadrillion times bigger than it previously was" (wired)*

This is much faster than the speed of light, by the way. Yes, we all know, nothing can go faster than the speed of light, neither light nor matter, nor even information, except of course, the universe itself. For some reason, this does not count⋯



I guess I don't sound very convinced – what I am not convinced of is that there is really no other reasonable explanation for the polarized CMB pattern. Does it really, explicitly proof both gravity waves and also inflation? What exactly is the logic that leads one from to this conclusion? Based on Wayne Hu, an expert in the field, it sounds like there are many possible foreground causes for this polarization, including scattering on dust, radio point sources, Bremsstrahlung and galactic synchrotron emissions – all of which have to be excluded. And of course, there is gravitational lensing, which is also a cause for B-modes. And is this really a complete list? Do we truly know all possible causes?

(Add-on: in the meantime, there is more and more doubt about this result, see for instance: Backlash to Big Bang Discovery Gathers Steam, http://www.scientificamerican.com/article/backlash-to-big-bang-discovery-gathers-steam/)

I have actually been one of those fierce defenders of the Big Bang Theory most of my life, and was convinced that scientists new it all down to a fraction of a second, and even wondered that some people wouldn't "believe" this – after all this is science, and not religion, right?

Well, that was before the addition of dark matter, dark energy, and super luminal expansion. It just got too much to take at some point, and I started to ask questions, which led to more questions, which never got properly answered. In this "Puzzle" I discuss some of those questions.

Big Bang Puzzle Piece I: Seeing Red
Big Bang Puzzle Piece 2: Older than Legally Allowed
Big Bang Puzzle Piece 3: Static Universe?

Links on CMB polarization

- http://www.scientificamerican.com/article/gravity-waves-cmb-b-mode-polarization/
- http://www.wired.com/wiredscience/2014/03/gravitational-waves-b-mode-inflation/
- Circular Polarization: http://en.wikipedia.org/wiki/Circular_polarization
- Foreground causes for CMB polarization:

http://background.uchicago.edu/~whu/polar/webversion/node21.html

- http://phenomena.nationalgeographic.com/2014/03/21/how-will-science-confirm-those-cosmic-signals-from-the-infant-universe/
- Backlash to Big Bang Discovery Gathers Steam http://www.scientificamerican.com/article/backlash-to-big-bang-discovery-gathers-steam/

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Big Bang Puzzle Piece I: Attachment issues

Hubble discovered that the further stars and galaxies are, the more red shifted the light is. ***One*** possible cause of red shift is the Doppler effect that we discussed in Puzzle Piece 5: The Doppler Challenge. This effect is the one that is usually mentioned in discussions about the Big Bang – even though it is not the one that is actually assumed to be the cause anymore.

This seems like a very reasonable assumption, and that's how the idea of the expanding universe came about.

As you may know, the problem with this is that the red shift happens to be symmetrical around earth. So if it was really the standard Doppler effect, then it would mean that earth is at the center of the universe, which is of course not very realistic.

The energy of a photon is E=hv, where v is the frequency. When photons get red shifted, it means they lose energy. Hence ***any*** process, by which photons lose energy, results in a red shift. There several dozen possible explanations of how photons can lose energy and thus be red shifted (See Marmet's paper on this) . Some include absorption by dust or electrons (Thompson scattering), another is one is due to gravity, yet another one is an intrinsic red shift of objects, interaction with the plasma of space etc, and yes, ***one*** of them is the idea of the expansion of "space time".

The last one seemed to fit nicely with the (mainstream) interpretation of general relativity (the space-

time interpretation), and so this is the one and **only** cause that is simply *assumed* to be true.

What did Hubble have to say about "his" discovery and the idea that space is supposed to be expanding?

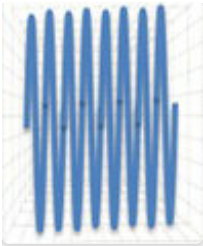
> *"Astronomer Edwin P. Hubble says that after a six-year study, evidence does not support what we now call the Big Bang theory, according to the Associated Press. "The universe probably is* ***not*** *exploding but is a quiet, peaceful place and possibly just about infinite in size.""*
>
> *http://www.science20.com/eternal_blogs/blog/hubble_eventually_did_not_believe_big_bang_associated_press-85962*

Halton Arp has observed several highly red shifted quasars that appear in **front** of close by galaxies… so then it seems that the red shift of at least some quasars does not necessarily indicate distance (or space expansion)… (and if that is the case, not only are quasars not very distant, enormously large and bright objects, but this raises the question about the red shift interpretation in general).

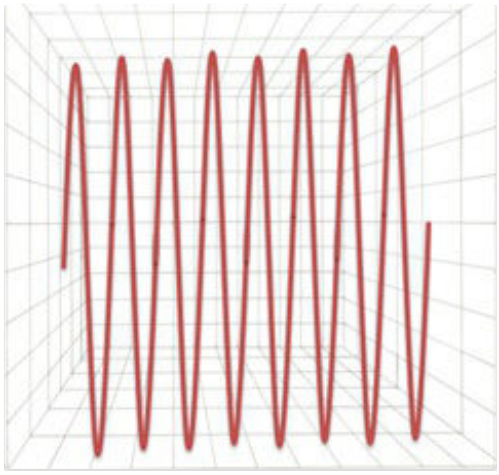
Even if space expansion is real, then an obvious question is: how much of the observed red shift is due to space expansion, how much is due to galaxies/stars actually literally moving (Doppler), and how much is due to other causes? The fact that light travels billions of years through space makes me think that the idea that light just *might* be losing a bit of energy during such a long trip does not sound entirely unreasonable, and should be seriously investigated. After all, the entire Big Bang idea rests mainly on the red shift interpretation…

Ok, let's be positive about this, and assume that indeed, the red shift is due to space expansion, at least part of it. Then how would that work, **exactly**?

Let's picture a part of space, indicated with a grid, and a light wave traveling through it.

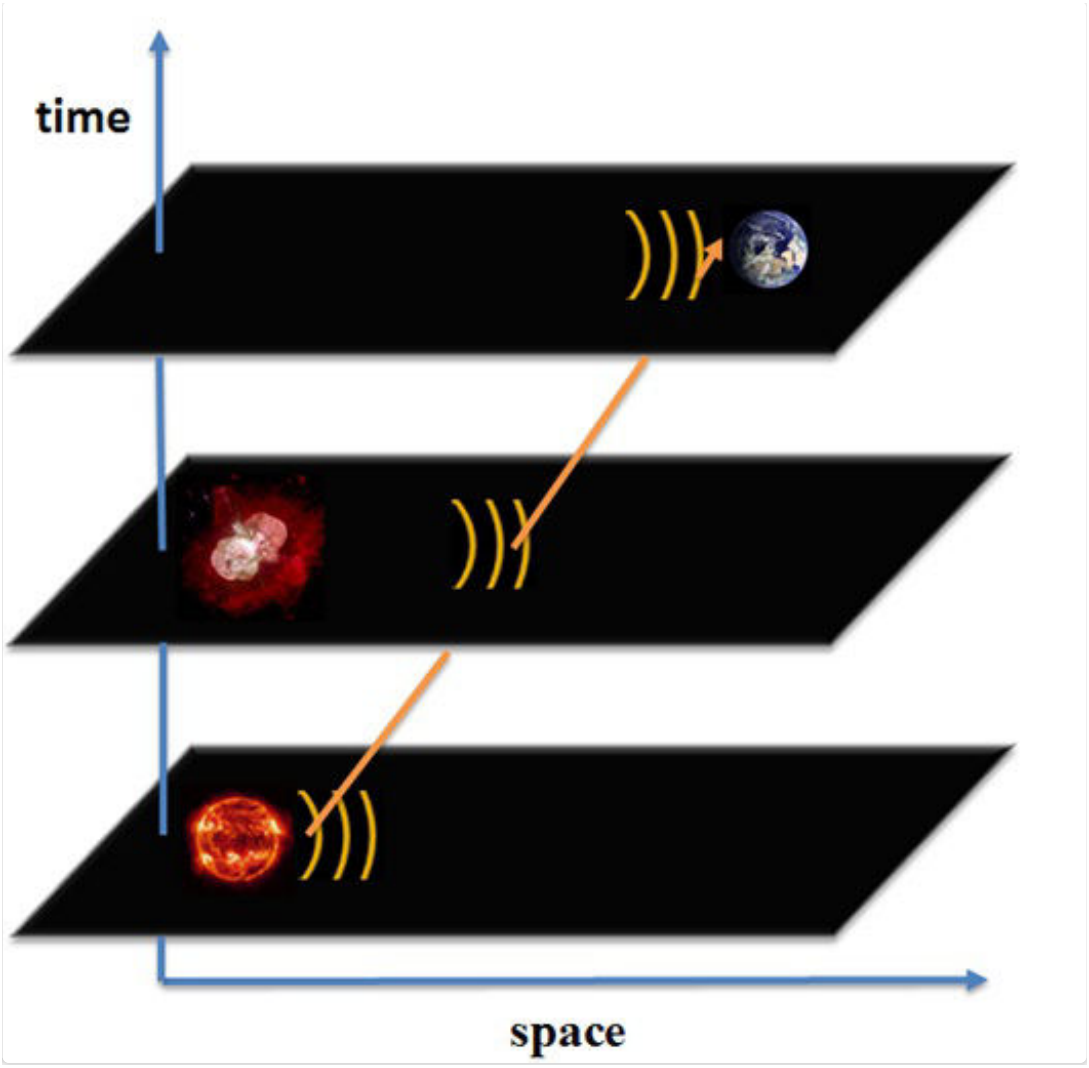


If we expand this piece of space, and if light is "attached" to that piece of space, then yes, the light wave will be red shifted (at least in this picture – relative to an **outside** observer…):

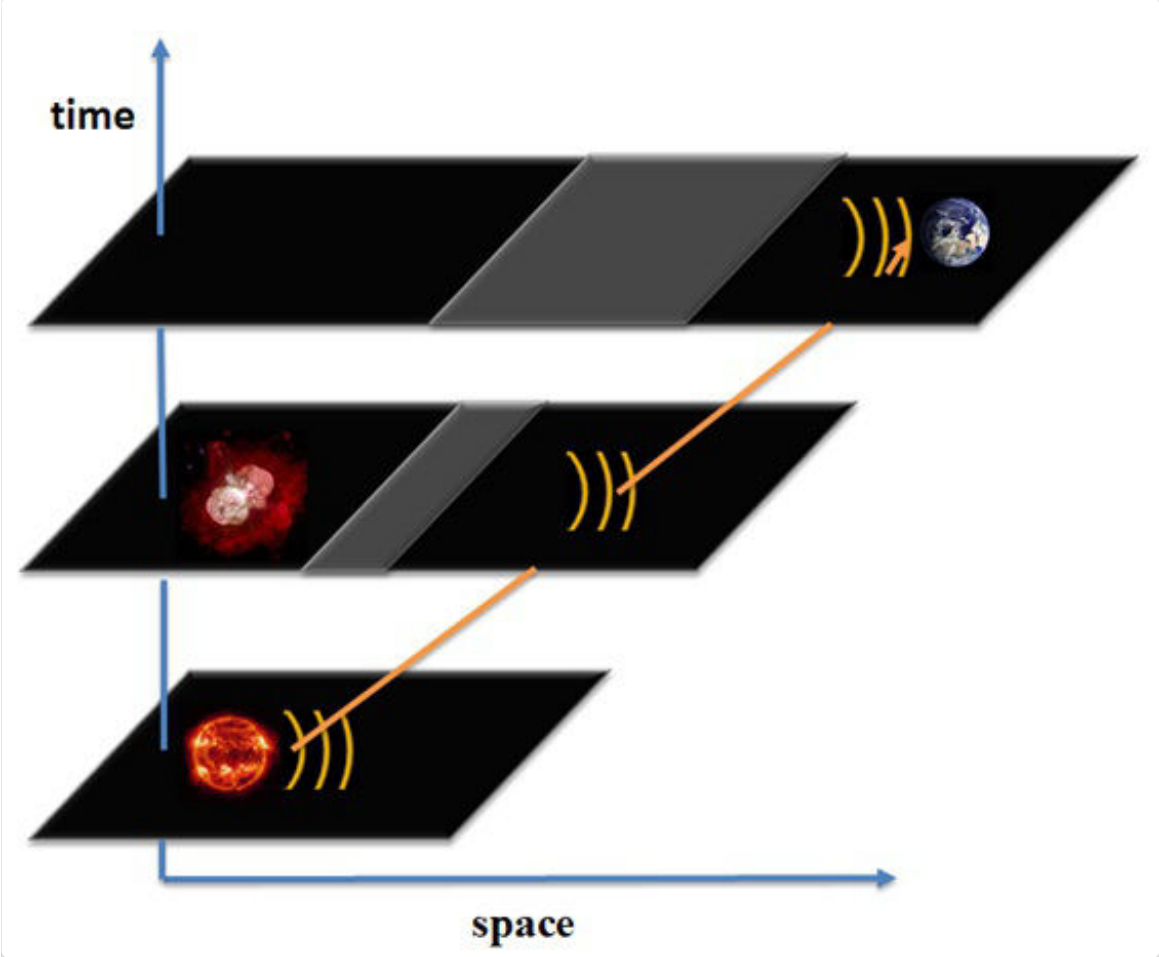


But wait a minute: if the light wave is literally stretched because it is somehow “attached” to space, just like a drawing on a balloon is stretched as it expands, then not only would the light wave expand, then it seems to me matter would also have to expand the same way.

If we use the usual assumption that there is no absolute space, then light in that model of course cannot be “attached” or connected to this (non-existent) absolute space, then why would the expansion of that space affect light in any way at all? Simply increasing the **distance** that light has to travel does not affects its wave length. Let’s consider a typical space-time diagram. For this example, let’s assume neither earth nor that star is moving (note, earth does not exist yet when the star emits the light).



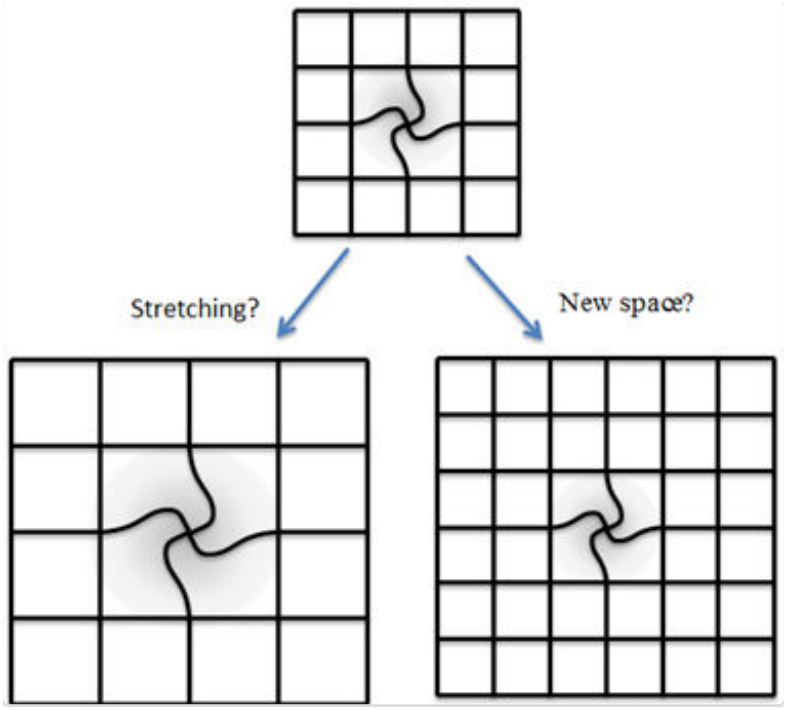
There is no red shift. Now, let's add some space, and assume that neither light nor matter is *attached* to space. So the only thing that changes is the distance. The gray area indicates the amount of space added:



Since the sun was not moving when the light was emittd, and the planet is not moving when the light arrives⋯ there is no Doppler effect and no red shift.

So it seems that this *only* works if light and matter is in fact somehow “attached” to space and thus stretched by the space expansion. In the space-density model, this is obvious, as light and matter are oscillations **of** space, so there clearly, any stretching of space would indeed affect light - and matter:

Let’s consider a small “particle”, indicated by a wave in the “medium space”.



Does expansion mean that space is stretched (left)? Well in that case, if light is stretched by this, then matter would **also** have to be stretched, and all atoms, and molecules would get larger over time. That of course essentially means we would not be able to notice anything different at all. If the entire universe, including matter in it, would increase in size proportionally, then all distances would never change relative to each other, and we would not observe a red shift either.

If expansion means that space is somehow "added" – even in the case where matter is in fact attached to space, neither light nor matter would be stretched. If light is just moving through **more** space, then all it means it takes light longer to travel.

Even if this were the case, then where exactly is that new space added? Is it added just between atoms? Then it would mean that the distance between atoms, including within a molecule, a star, within a galaxy etc. would be increasing. (And where would this new space be coming *from)*?

So the only way that light could be affected by the expansion of space is:

- if space is stretched (no new space)
- if light is somehow attached to space (like in the elastic solid model)
- => but then matter would also be affected the exact same way, resulting in no relative net effect

This is just one of many question – many more are discussed in numerous places elsewhere (see links below). To me, these were some of the question that started my doubt, because nobody was ever able to answer it⋯
Next Puzzle: Big Bang Puzzle Piece 2: Older than Legally Allowed

Links

Red Shift:

- http://www.marmet.org/cosmology/redshift/mechanisms.pdf
- http://en.wikipedia.org/wiki/Hubble's_law
- Hubble and red shift: http://www.science20.com/eternal_blogs/blog/hubble_eventually_did_not_believe_big_bang_associated_press-85962
- Is the Universe Really Expanding: http://arxiv.org/PS_cache/arxiv/pdf/1107/1107.2485v2.pdf
- Causes of red shift: http://www.plasma-universe.com/Redshift
- Other causes of red shift: http://qedradiation.scienceblog.com/11/redshift-by-cosmic-dust-trumps-hubble-and-tired-light-theories/
- Tired Light: http://www.lyndonashmore.com/
- http://www.setterfield.org/redshift.htm
- http://www.academia.edu/3189949/Dispersive_Extinction_Theory_of_Cosmic_Red_Shift_–_An_Alternative_to_the_Big_Bang_Theory
- http://charles_w.tripod.com/red.html
- http://electric-cosmos.org/arp.htm

Big Bang Problems:

- http://csep10.phys.utk.edu/astr162/lect/cosmology/bbproblems.html
- http://science.howstuffworks.com/dictionary/astronomy-terms/big-bang-theory7.htm
- http://www.spaceandmotion.com/Cosmology-Big-Bang-Theory.htm
- http://metaresearch.org/cosmology/BB-top-30.asp
- http://www.marmet.org/cosmology/fallofbigbang/index.html
- http://www.dailygalaxy.com/my_weblog/2013/11/the-largest-discovered-structure-in-the-universe-contradicts-big-bang-theory-cosmology-weekend-featu.html
- http://www.rense.com/general63/bbang.htm
- http://voices.yahoo.com/old-galaxies-young-universe-contradict-big-8744047.html
- http://cosmologyscience.com/cosblog/observation-of-two-early-mature-galaxies-rare-objects-or-is-big-bang-model-inaccurate/
- http://cosmologyscience.com/cosblog/spiral-galaxy-bx442-supports-hubbles-belief-redshift-does-not-mean-expansion/
- http://rense.com/general53/bbng.htm
- http://www.spaceandmotion.com/cosmology/halton-arp-seeing-red-errors-big-bang.htm
- http://www.haltonarp.com/articles/is_physics_changing
- http://electric-cosmos.org/arp.htm

Alternative models:

- http://www.nature.com/news/cosmologist-claims-universe-may-not-be-expanding-1.13379
- http://bigbangneverhappened.org/

- http://arxiv.org/abs/astro-ph/0401420v3
- http://www.haltonarp.com/articles/is_physics_changing

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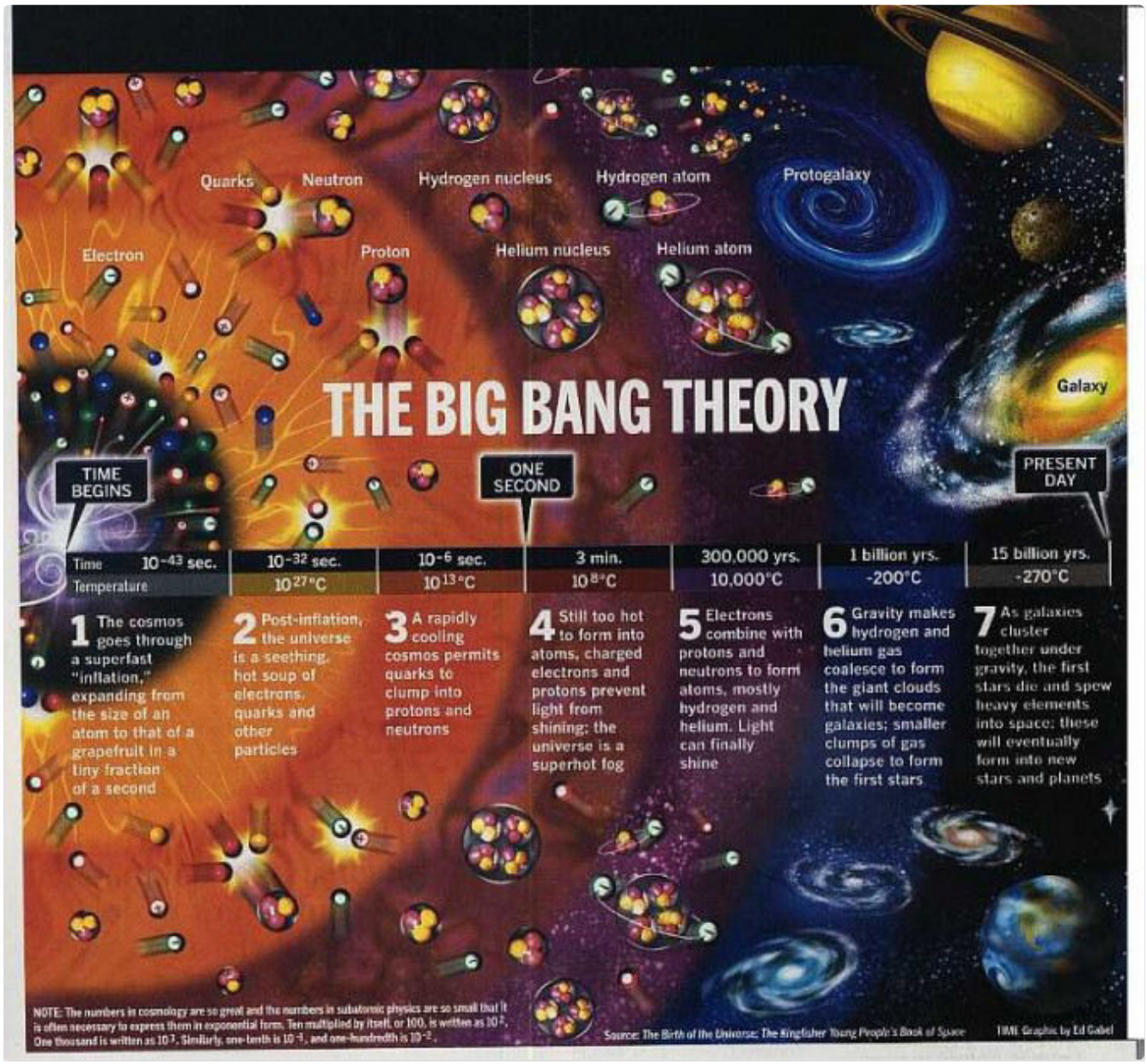
Big Bang Puzzle Piece 2: Older than legally allowed

Previous Puzzle: Big Bang Puzzle Piece I: Seeing Red

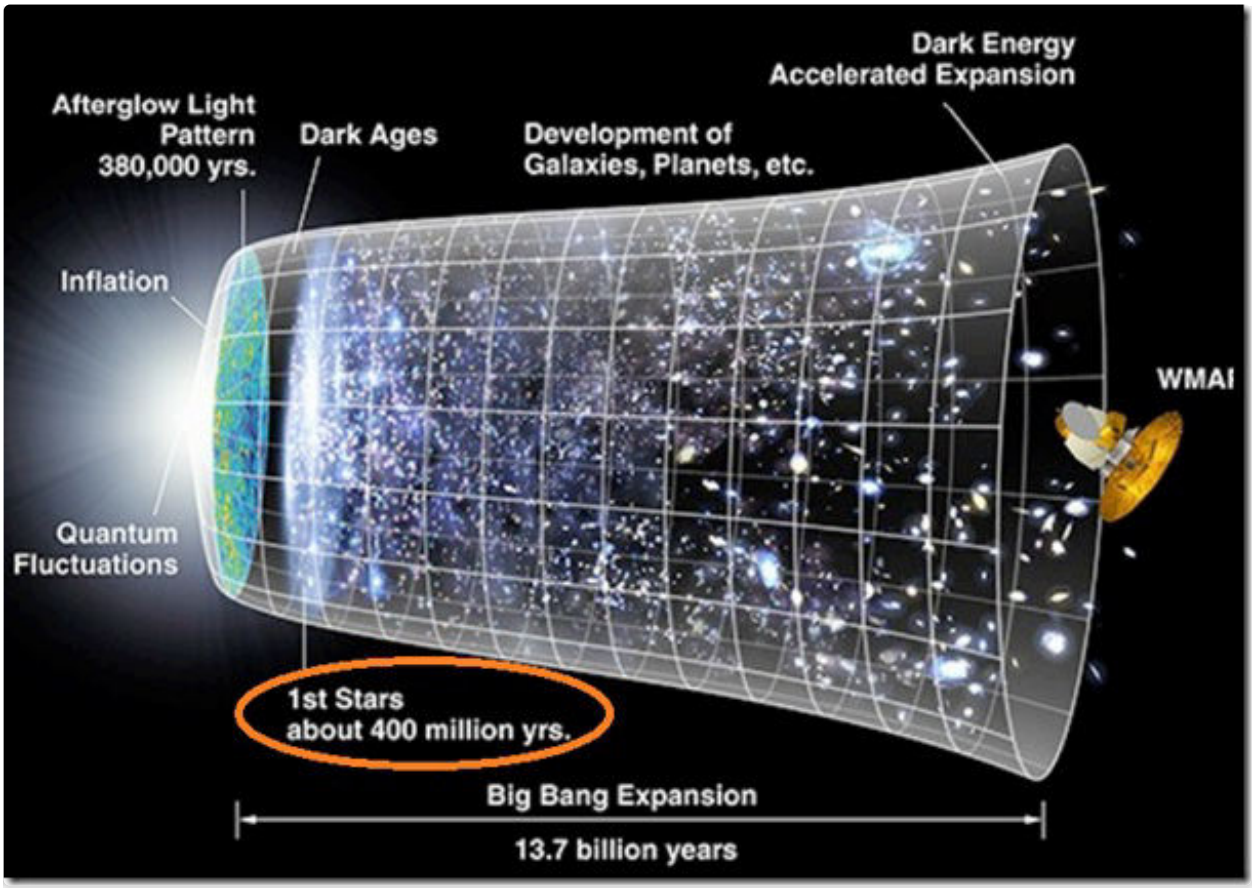
Oldest Galaxies and Stars

Based on a poster of the Big Bang, the first stars should have formed about **1 billion years** after the big bang:

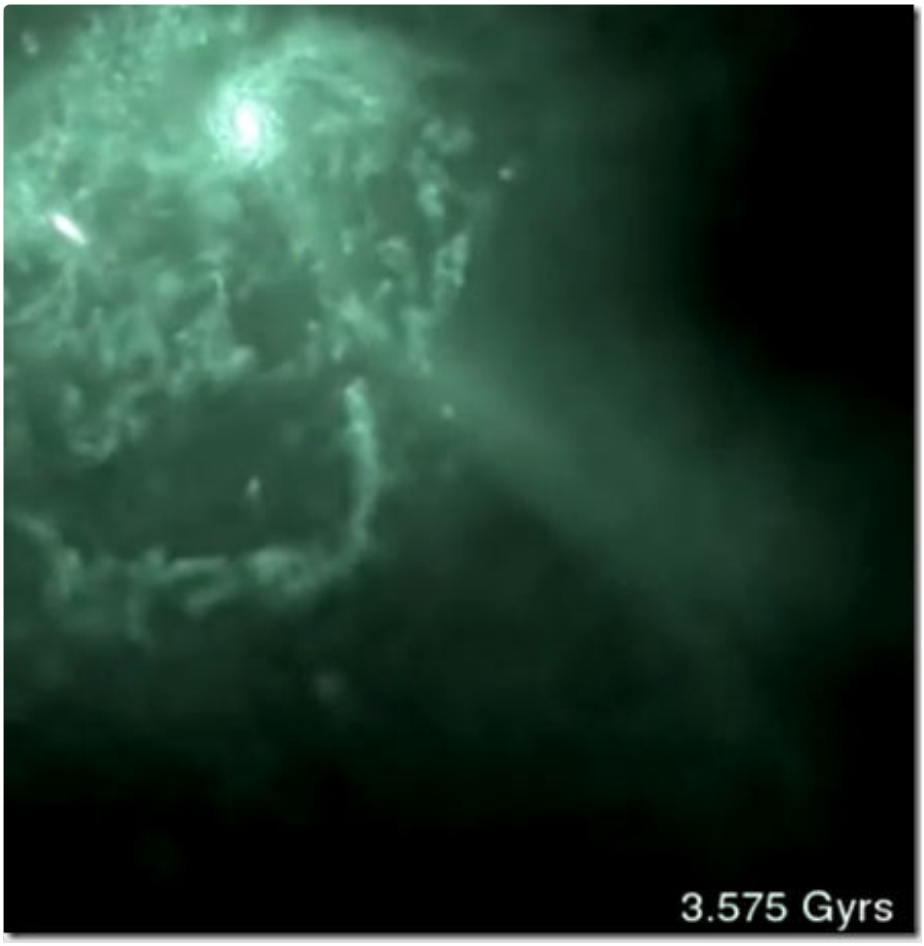


Yet, recently we keep finding more and more completely formed **galaxies**, that are **older** than that: for instance 7 from a period around 380 million years after the big bang. So that is much earlier than predicted. Also, this means that the galaxies only had a very short time to form. It takes over 200 million years just for one rotation of the milky way galaxy, for instance. Yet galaxy formation requires many rotations. There is even one galaxy that was found a mere 200 million years after the Big Bang. That means it didn't even have time for *one* complete rotation… ?

Even in later posters, where they move the star formation to an earlier time, the **first stars** are supposed to have formed **400 million years** after the Big Bang, and galaxies much later than that:



Based on computer simulations, it takes **more than 1 billion** years for a complete spiral galaxy to form: http://apod.nasa.gov/apod/ap120717.html (in this one, *several billion* years). Other simulations also indicate that it takes at least 1-2 billion years for a galaxy to form: http://www.theguardian.com/science/video/2013/may/28/galaxy-formation-universe-video



The **obvious** question is: ***is the universe older than we think*** ? But instead of asking this question, scientists are changing the models of galaxy formation. They don't even *mention* the possibility, that just *maybe*, the universe is older. They simply assume that we know that the Big Bang is true, so everything else has to be changed to fit this model. To me, this sounds more like a religious dogma that true science…

Next Puzzle: Big Bang Puzzle Piece 3: Static Universe?

Links

Oldest galaxies and stars:

- 200 million years after big bang:
  http://www.extremetech.com/extreme/176497-weve-found-the-oldest-star-in-the-known-universe-and-its-right-on-our-galactic-doorstep
  http://news.softpedia.com/news/First-Galaxies-Formed-200-Million-Years-After-Big-Bang-195083.shtml
- 380 million years after big bang:
  http://news.nationalgeographic.com/news/2012/121214-hubble-oldest-galaxy-discovered-space-science/
  http://www.scientificamerican.com/article/early-universe-galaxy-hst/
- 420 million years after big bang:

http://rt.com/news/oldest-galaxy-discovered-universe-922/

- 500 million years after big bang: http://news.nationalgeographic.com/news/2014/01/140107-hubble-oldest-frontier-science-space-astronomy/
- 650 million years after big bang: http://www.upi.com/Science_News/2014/02/20/New-Hubble-Space-Telescope-images-showcase-universes-oldest-galaxy/4671392934751/
- 700 million years after big bang: http://www.theguardian.com/science/2013/oct/23/most-distant-galaxy-star-factory http://arstechnica.com/science/2013/10/oldest-galaxy-yet-seen-forming-stars-100-times-faster-than-milky-way/

Galaxy Formation/Simulations:

- http://www.universetoday.com/23870/the-milky-ways-rotation/
- http://arxiv.org/abs/1103.6030
- http://apod.nasa.gov/apod/ap120717.html
- http://www.theguardian.com/science/video/2013/may/28/galaxy-formation-universe-video
- http://www.plasma-universe.com/Galaxy_formation

Big Bang Problems:

- http://csep10.phys.utk.edu/astr162/lect/cosmology/bbproblems.html
- http://science.howstuffworks.com/dictionary/astronomy-terms/big-bang-theory7.htm
- http://www.spaceandmotion.com/Cosmology-Big-Bang-Theory.htm
- http://metaresearch.org/cosmology/BB-top-30.asp
- http://www.marmet.org/cosmology/fallofbigbang/index.html
- http://www.dailygalaxy.com/my_weblog/2013/11/the-largest-discovered-structure-in-the-universe-contradicts-big-bang-theory-cosmology-weekend-featu.html
- http://www.rense.com/general63/bbang.htm
- http://voices.yahoo.com/old-galaxies-young-universe-contradict-big-8744047.html
- http://cosmologyscience.com/cosblog/observation-of-two-early-mature-galaxies-rare-objects-or-is-big-bang-model-inaccurate/
- http://cosmologyscience.com/cosblog/spiral-galaxy-bx442-supports-hubbles-belief-redshift-does-not-mean-expansion/
- http://rense.com/general53/bbng.htm
- http://www.spaceandmotion.com/cosmology/halton-arp-seeing-red-errors-big-bang.htm
- http://www.haltonarp.com/articles/is_physics_changing
- http://electric-cosmos.org/arp.htm
- http://www.astronomynotes.com/cosmolgy/s12.htm

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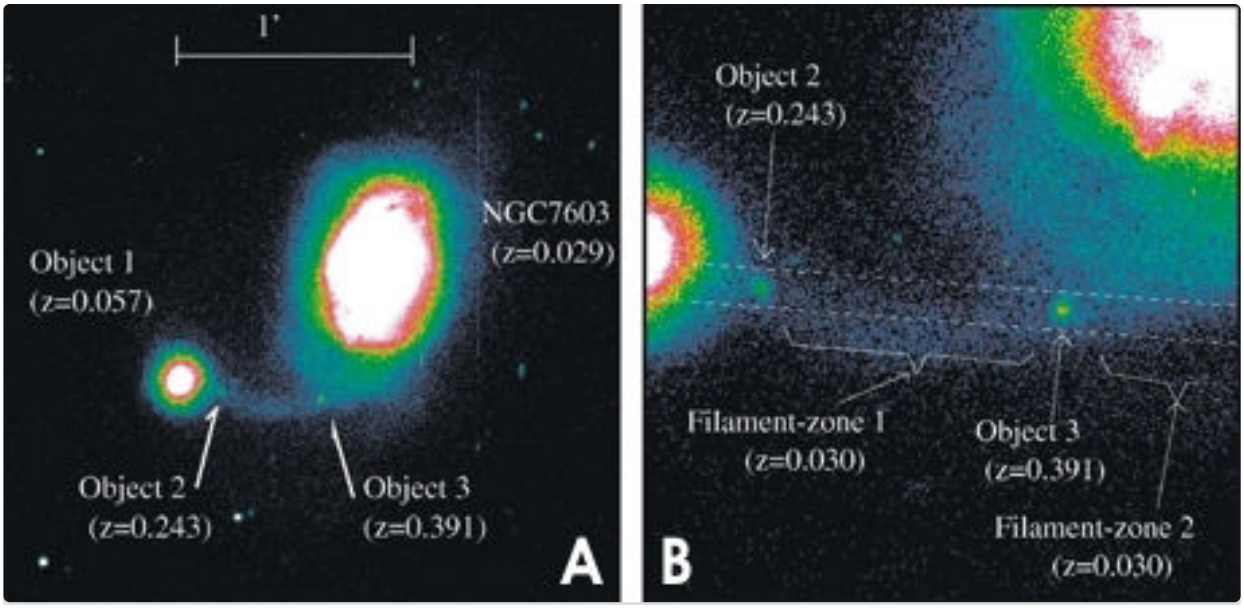
Big Bang Puzzle Piece 3: Static Universe?

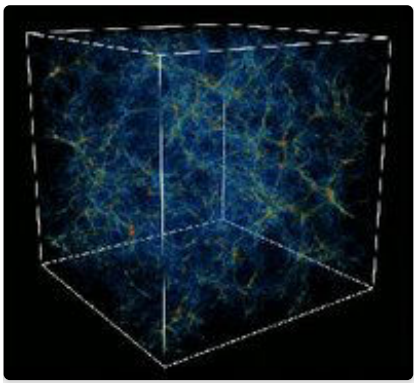
Previous puzzle: Big Bang Puzzle Piece 2: Older than Legally Allowed

The Big Bang theory is facing some serious issues, including:

- highly red shifted quasars that appear next and even in front of nearby galaxies (so they are not really that far away, not as huge as suggested, and this also means that there is at least one other cause for the red shift)



- galaxies that formed too soon after the big bang and do not look primitive
- super clusters (Tully) that are over hundred million light years across and are older than the universe
- large scale voids that would take 70 billion years to form
- the fact that space is supposed to exist in an absolute sense in order to expand, yet in other areas of physics it is strictly assumed that space does not exist
- the "expansion" as sole reason for the red shift, which is ***not*** a Doppler effect, and how this red shift is really supposed to happen so that the light wave expands, but not matter.
- The suns center to limb variation in red shift – which is clearly



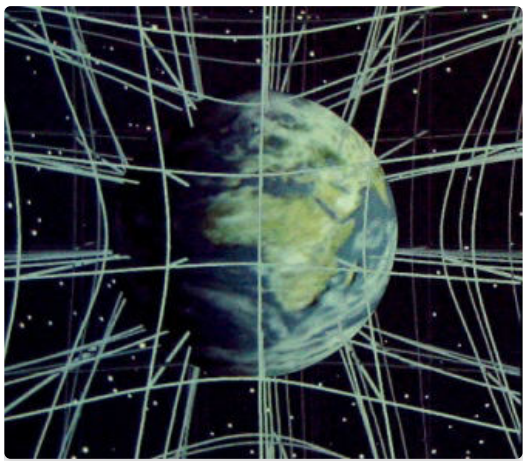
has another cause than expansion (so if it is the case for the sun, this would also apply to other stars)
- very old stars that already contain carbon, which should not be there
- the fact that the distant universe does not look any denser than the universe today
- the energy conservation problem: how can the entire universe have arisen out of nothing?
- the black hole problem: given that all matter in the universe used to be much closer than now, and so much denser, it means the entire universe was well within its own Schwarzschild radius, meaning it was a black hole. If nothing can get out of a black hole, then how come the universe itself can?
- the whole idea of inflation, dark matter, dark energy – all ad hoc additions to the theory because observations do not fit
- the supposedly observed "time dilation" of supernovas, but lack of such time dilation in gamma ray bursts

(These are just some of the main issues – for more information, please check the links below.)

Static, Infinite Universe

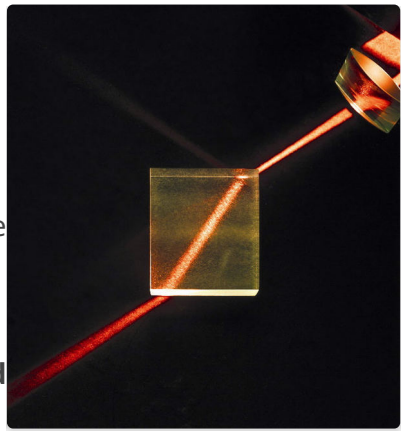
One possible solution to those issues is a simple static, infinite universe. That is, one that always existed, will always exist, where space neither expands nor contracts.

In another puzzle on the interpretation of general relativity, we discussed the idea that there is a completely equivalent model, the "crystal universe" model, where the space curvature is described with space-density, and not space-time, and where gravity is a purely optical phenomenon. In that model, both matter and light are purely made of (real) waves, oscillations in that elastic solid medium "space".



What kinds of observations and predictions could we make based on this simple model? If this medium even has the tiniest bit of imperfection, then we would expect several observations:

- **Red shift**:



For *nearby moving* objects, the dominant effect is probably a simple Doppler effect, that causes light to be red or blue shifted, depending on the velocity relative to earth (even Big Bang proponents agree on that). For more distant objects, there are many possible mechanisms (see Marmet's paper for an extensive list). One explanation not in Marmet's paper is the IsoRedShift by Santilli: the observation that as light travels through a transparent physical medium it loses some of its energy which results in a **red shift** (*without* any relative motion between source and observer)

- **CMB**: when light travels a long distance through any (real) medium, the intensity decreases (*attenuation*). At the same time, this energy is not lost, but causes the medium to **warm up** slightly. This would not only explain *Olber's* Paradox (that the sky is not bright), but also explain one possible reason that the universe has a temperature (**CMB)**
- No need for dark energy and no dark matter

Following are several predictions that could confirm such a model:

- The speed of light might be ***frequency dependent***: at least for regular media, such as for sound waves in a crystal, waves with very short wave length (comparable to the crystal grid size) would travel slower than waves of longer wave length. If we consider that the universe has a grid size of around the Planck length ***h***, then this would only affect ultra short gamma rays. This would mean that gamma rays with short wave length from far away events would arrive a bit later than longer wave lengths.
- As we look deeper into space, we would expect completely formed galaxies no matter how far away they are, and stars that contain carbon (and other heavier elements)
- The universe does not get any denser the further away we look
- Any size of void or cluster is possible
- The entropy of the entire universe does ***not*** increase, but is ***constant***.
- There must be a process by which particles form out of the background energy/oscillations of space (such as the "spontaneous" particle/anti particle formation in vacuum)

Links

Static Universe Models:

- Static Universe: http://en.wikipedia.org/wiki/Static_universe
- Static Universe (Lerner): http://www.learner.org/courses/physics/unit/text.html?unit=11&secNum=2
- Static Universe (Ratcliffe): http://www.hiltonratcliffe.com/Static.htm

RedShift:

- http://www.santilli-foundation.org/docs/IRS-confirmations-212.pdf
- http://www.workshops-hadronic-mechanics.org/isoshifts.php
- http://www.benthamscience.com/open/toaaj/articles/V003/126TOAAJ.pdf
- http://www.redorbit.com/news/science/1113036944/santillis-invariant-derivation-of-hubbles-law-without-expansion-of-the/
- http://qedradiation.scienceblog.com/11/redshift-by-cosmic-dust-trumps-hubble-and-tired-light-theories/
- http://www.newtonphysics.on.ca/universe/
- German: http://www.newtonphysics.on.ca/hubble/rotverschiebung.pdf

Optical analogues of General Relativity:

- Hagen Kleinerts World Crystal: http://users.physik.fu-berlin.de/~kleinert/papers/planckklcZN.pdf
- Defects and Diffusion in the Planck-Kleinert Crystal: http://ceram.agh.edu.pl/~icmmagh/artykuly/237%20PLANCK%20CRYSTAL%20DSL%20final.pdf

Big Bang Problems:

- http://metaresearch.org/cosmology/BB-top-30.asp
- http://www.spaceandmotion.com/Cosmology-Big-Bang-Theory.htm
- http://csep10.phys.utk.edu/astr162/lect/cosmology/bbproblems.html
- http://science.howstuffworks.com/dictionary/astronomy-terms/big-bang-theory7.htm
- http://www.marmet.org/cosmology/fallofbigbang/index.html
- http://www.dailygalaxy.com/my_weblog/2013/11/the-largest-discovered-structure-in-the-universe-contradicts-big-bang-theory-cosmology-weekend-featu.html
- http://www.rense.com/general63/bbang.htm
- http://voices.yahoo.com/old-galaxies-young-universe-contradict-big-8744047.html
- http://cosmologyscience.com/cosblog/observation-of-two-early-mature-galaxies-rare-objects-or-is-big-bang-model-inaccurate/
- http://cosmologyscience.com/cosblog/spiral-galaxy-bx442-supports-hubbles-belief-redshift-does-not-mean-expansion/
- http://rense.com/general53/bbng.htm
- http://www.spaceandmotion.com/cosmology/halton-arp-seeing-red-errors-big-bang.htm
- http://www.haltonarp.com/articles/is_physics_changing
- http://electric-cosmos.org/arp.htm
- http://www.libertysteve.com/commonsense/big-bang-baloney-real-science-is-suppressed/
- German: http://www.mahag.com/allg/urknall.php http://www.mahag.com/allg/urknall2.php

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Speeches

Following are links (and quotes) from speeches of Einstein and Schrödinger – in particular those that may not be so familiar, and in the context of the alternative interpretation of space and matter (as real waves):

1. Ether and the Theory of Relativity (Albert Einstein)

> *"More careful reflection teaches us however, that **the special theory of relativity does not compel us to deny ether**. We may assume the existence of an ether; only we must give up ascribing a definite state of motion to it"*
>
> *"Recapitulating, we may say that **according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an ether**. According to the general theory of relativity **space without ether is unthinkable**; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense"*

2. Äther und Relativtäts-Theorie (Albert Einstein, German)

> *"…die Ätherhypothese an sich widerstreitet der speziellen Relativitätetheorie nicht"*
>
> *"**Nach der allgemeinen Relativitätstheorie ist der Raum mit physikalischen Qualitäten ausgestattet; es existiert also in diesem Sinne ein Äther**. Gemäß der allgemeinen Relativitätstheorie ist **ein Raum ohne Äther undenkbar**; denn in einem solchen gäbe es nicht nur keine Lichtfortpflanzung, sondern auch keine Existenzmöglichkeit von Maßstäben und Uhren, also auch keine räumlich-zeitlichen Entfernungen im Sinne der Physik."*

3. Concerning the Aether (Albert Einstein)

> *"But even if these possibilities do mature into an actual theory,* ***we will not be able to do without the aether in theoretical physics****, that is, a* ***continuum endowed with physical properties****; for general relativity, to whose fundamental viewpoints physicists will always hold fast, rules out direct action at a distance. But* ***every theory of local action assumes continuous fields, and thus also the existence of an 'aether'****."*

3. Über den Aether (Albert Einstein, German)

> *Aber selbst wenn diese Möglichkeiten zu wirklichen Theorien heranreifen,* ***werden wir des Äthers, d. h. des mit physikalischen Eigenschaften ausgestatteten Kontinuums, in der theoretischen Physik nicht entbehren können****; denn die allgemeine Relativitätstheorie, an deren grundsätzlichen Gesichtspunkten die Physiker wohl stets festhalten werden, schliesst eine unvermittelte Fernwirkung aus;* ***jede Nahewirkungs-Theorie aber setzt kontinuierliche Felder voraus, also auch die Existenz eines „Äthers"****.*

4. The Meaning of Wave Mechanics (Schrödinger)

> *"Let me say at the outset, that in this discourse, I am opposing not a few special statements of quantum physics held today (1950s), I am opposing as it were the whole of it, I am opposing its basic views that have been shaped 25 years ago, when Max Born put forward his* ***probability interpretation****, which was accepted by almost everybody."*

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Äther und Relativitäts-Theorie (Einstein)

ÄTHER
UND
RELATIVITÄTS-THEORIE

REDE

GEHALTEN AM 5. MAI 1920
AN DER REICHS-UNIVERSITÄT ZU LEIDEN

VON
ALBERT EINSTEIN

BERLIN
VERLAG VON JULIUS SPRINGER
1920

Meine Herren Kuratoren, Professoren, Doktoren und Studenten dieser Universität!

Sie alle ferner, meine Damen und Herren, welche diese Feier durch Ihre Anwesenheit ehren!

"Wie kommen die Physiker dazu, neben der der Abstraktion des Alltagslebens entstammenden Idee, der ponderabeln Materie, die Idee von der Existenz einer anderen Materie, des Äthers, zu setzen? Der Grund dafür liegt wohl in denjenigen Erscheinungen, welche zur Theorie der Fernkräfte Veranlassung gegeben haben, und

in den Eigenschaften des Lichtes, welche zur Undulationstheorie geführt haben. Wir wollen diesen beiden Gegenständen eine kurze Betrachtung widmen.

Das nichtphysikalische Denken weiß nichts von Fernkräften. Bei dem Versuch einer kausalen Durchdringung der Erfahrungen, welche wir an den Körpern machen, scheint es zunächst keine anderen Wechselwirkungen zu geben als solche durch unmittelbare Berührung, z.B. Bewegungs-Übertragung durch Stoß, Druck und Zug, Erwärmung oder Einleitung einer Verbrennung durch eine Flamme usw. Allerdings spielt bereits in der Alltagserfahrung die Schwere, also eine Fernkraft, eine Hauptrolle.

Da uns aber in der alltäglichen Erfahrung die Schwere der Körper als etwas Konstantes, an keine räumlich oder zeitlich*veränderliche* Ursache Gebundenes entgegentritt, so denken wir uns im Alltagsleben zu der Schwere überhaupt keine Ursache und werden uns deshalb ihres Charakters als Fernkraft nicht bewußt. Erst durch Newtons Gravitations-Theorie wurde eine Ursache für die Schwere gesetzt, indem letztere als Fernkraft gedeutet wurde, die von Massen herrührt. Newtons Theorie bedeutet wohl den größten Schritt, den das Streben nach kausaler Verkettung der Naturerscheinungen je gemacht hat. Und doch erzeugte diese Theorie bei Newtons Zeitgenossen lebhaftes Unbehagen, weil sie mit dem aus der sonstigen Erfahrung fließenden Prinzip in Widerspruch zu treten schien, daß es nur Wechselwirkung durch Berührung, nicht aber durch unvermittelte Fernwirkung gebe.

Der menschliche Erkenntnistrieb erträgt einen solchen Dualismus nur mit Widerstreben. Wie konnte man die Einheitlichkeit der Auffassung von den Naturkräften retten? Entweder man konnte versuchen, die Kräfte, welche uns als Berührungskräfte entgegentreten, ebenfalls als Fernkräfte aufzufassen, welche sich allerdings nur bei sehr geringer Entfernung bemerkbar machen; dies war der Weg, welcher von Newtons Nachfolgern, die ganz unter dem Banne seiner Lehre standen, zumeist bevorzugt wurde. Oder aber man konnte annehmen, daß die Newtonschen Fernkräfte nur *scheinbar* unvermittelte Fernkräfte seien, daß sie aber in Wahrheit durch ein den Raum durchdringendes Medium übertragen würden, sei es durch Bewegungen, sei es durch elastische Deformation dieses Mediums. So führt das Streben nach Vereinheitlichung unserer Auffassung von der Natur der Kräfte zur Ätherhypothese. Allerdings brachte letztere der Gravitationstheorie und der Physik überhaupt zunächst keinen Fortschritt, so daß man sich daran gewöhnte, Newtons Kraftgesetz als nicht mehr weiter zu reduzierendes Axiom zu behandeln.

Die Ätherhypothese mußte aber stets im Denken der Physiker eine Rolle spielen, wenn auch zunächst meist nur eine latente Rolle.

Als in der ersten Hälfte des 19. Jahrhunderts die weitgehende Ähnlichkeit offenbar wurde, welche zwischen den Eigenschaften des Lichtes und denen der elastischen Wellen in ponderabeln Körpern besteht, gewann die Ätherhypothese eine neue Stütze. Es schien unzweifelhaft, daß das Licht als Schwingungsvorgang eines den Weltraum erfüllenden, elastischen, trägen Mediums gedeutet werden müsse. Auch schien aus der Polarisierbarkeit des Lichtes mit Notwendigkeit hervorzugehen, daß dieses Medium – der Äther – von der Art eines festen Körpers sein müsse, weil nur in einem solchen, nicht aber in einer Flüssigkeit Transversalwellen möglich sind. Man mußte so zu der Theorie des "quasi-starren" Lichtäthers kommen, dessen Teile relativ zueinander keine anderen Bewegungen auszuführen vermögen als die kleinen Deformationsbewegungen, welche den Lichtwellen entsprechen.

Diese Theorie – auch Theorie des ruhenden Lichtäthers genannt – fand ferner eine gewichtige Stütze in dem auch für die spezielle Relativitätstheorie fundamentalen Experimente von Fizeau, aus welchem man schließen mußte, daß der Lichtäther an den Bewegungen der Körper nicht teilnehme. Auch die Erscheinung der Aberration sprach für die Theorie des quasistarren Äthers.

Die Entwicklung der Elektrizitätstheorie auf dem von Maxwell und Lorentz gewiesenen Wege brachte eine ganz eigenartige und unerwartete Wendung in die Entwicklung unserer den Äther betreffenden Vorstellungen. Für Maxwell selbst war zwar der Äther noch ein Gebilde mit rein mechanischen Eigenschaften, wenn auch mit mechanischen Eigenschaften viel komplizierterer Art als die der greifbaren festen Körper. Aber weder Maxwell noch seinen Nachfolgern gelang es, ein mechanisches Modell für den Äther auszudenken, das eine befriedigende mechanische Interpretation der Maxwellschen Gesetze des elektromagnetischen Feldes geliefert hätte. Die Gesetze waren klar und einfach, die mechanischen Deutungen schwerfällig und widerspruchsvoll. Beinahe unvermerkt paßten sich die theoretischen Physiker dieser vom Standpunkte ihres mechanischen Programms recht betrübenden Sachlage an, insbesondere unter dem Einfluß der elektrodynamischen Untersuchungen von Heinrich Hertz. Während sie nämlich vordem von einer endgültigen Theorie gefordert hatten, daß sie mit Grundbegriffen auskomme, die ausschließlich der Mechanik angehören (z.B. Massendichten, Geschwindigkeiten, Deformationen, Druckkräfte), gewöhnten sie sich allmählich daran, elektrische

und magnetische Feldstärken als Grundbegriffe neben den mechanischen Grundbegriffen zuzulassen, ohne für sie eine mechanische Interpretation zu fordern. So wurde allmählich die rein mechanische Naturauffassung verlassen. Diese Wandlung führte aber zu einem auf die Dauer unerträglichen Dualismus in den Grundlagen. Um ihm zu entgehen, suchte man umgekehrt die mechanischen Grundbegriffe auf die elektrischen zu reduzieren, zumal die Versuche an ß-Strahlen und raschen Kathodenstrahlen das Vertrauen in die strenge Gültigkeit der mechanischen Gleichungen Newtons erschütterten.

Bei H.Hertz ist der angedeutete Dualismus noch ungemildert. Bei ihm tritt die Materie nicht nur als Trägerin von Geschwindigkeiten, kinetischer Energie und mechanischen Druckkräften, sondern auch als Trägerin von elektromagnetischen Feldern auf. Da solche Felder auch im Vakuum – d.h. im freien Äther – auftreten, so erscheint auch der Äther als Träger von elektromagnetischen Feldern. Er erscheint der ponderabeln Materie als durchaus gleichartig und nebengeordnet. Er nimmt in der Materie an den Bewegungen dieser teil und hat im leeren Raum überall eine Geschwindigkeit, derart, daß die Äthergeschwindigkeit im ganzen Raume stetig verteilt ist, Der Hertzsche Äther unterscheidet sich grundsätzlich in nichts von der (zum Teil in Äther bestehenden) ponderabeln Materie.

Die Hertzsche Theorie litt nicht nur an dem Mangel, daß sie der Materie und dem Äther einerseite mechanische, anderseits elektrische Zustande zuschrieb, die in keinem gedanklichen Zusammenhange miteinander stehen; sie widersprach auch dem Ergebnis des wichtigen Fizeauschen Versuches über die Ausbreitungsgeschwindigkeit des Lichtes in bewegten Flüssigkeiten und anderen gesicherten Erfahrungsergebnissen.

So standen die Dinge, als H.A. Lorentz eingriff. Er brachte die Theorie in Einklang mit der Erfahrung und erreichte dies durch eine wunderbare Vereinfachung der theoretischen Grundlagen. Er erzielte diesen wichtigsten Fortschritt der Elektrizitätstheorie seit Maxwell, indem er dem Äther seine mechanischen, der Materie ihre elektromagnetischen Qualitäten wegnahm. Wie im leeren Raume, so auch im Innern der materiellen Körper war ausschließlich der Äther, nicht aber die atomistisch gedachte Materie, Sitz der elektromagnetischen Felder. Die Elementarteilchen der Materie sind nach Lorentz *allein* fähig, Bewegungen auszuführen; ihre elektromagnetische Wirksamkeit liegt einzig darin, daß sie elektrische Ladungen tragen. So gelang es Lorentz, alles elektromagnetische Geschehen auf die Maxwellschen Vakuum-Feldgleichungen zu

reduzieren.

Was die mechanische Natur des Lorentzschen Äthers anlangt, so kann man etwas scherzhaft von ihm sagen, daß Unbeweglichkeit die einzige mechanische Eigenschaft sei, die ihm H.A. Lorentz noch gelassen hat. Man kann hinzufügen, daß die ganze Änderung der Ätherauffassung, welche die spezielle Relativitätstheorie brachte, darin bestand, daß sie dem Äther seine letzte mechanische Qualität, nämlich die Unbeweglichkeit, wegnahm. Wie dies zu verstehen ist, soll gleich dargelegt werden.

Der Raum-Zeittheorie und Kinematik der speziellen Relativitätstheorie hat die Maxwell-Lorentzsche Theorie des elektromagnetischen Feldes als Modell gedient. Diese Theorie genügt daher den Bedingungen der speziellen Relativitätstheorie; sie erhält aber, von letzterer aus betrachtet, ein neuartiges Aussehen. Sei nämlich K ein Koordinatensystem, relativ zu welchem der Lorentzsche Äther in Ruhe ist, so gelten die Maxwell-Lorentzschen Gleichungen zunächst in bezug auf K. Nach der speziellen Relativitätstheorie gelten aber dieselben Gleichungen in ganz umgeändertem Sinne auch in bezug auf jedes neue Koordinatensystem K1, welches in bezug auf K in gleichförmiger Translationsbewegung ist. Es entsteht nun die bange Frage: Warum soll ich das System K, welchem die Systeme K1 physikalisch vollkommen gleichwertig sind, in der Theorie vor letzterem durch die Annahme auszeichnen, daß der Äther relativ zu ihm ruhe? Eine solche Asymmetrie des theoretischen Gebäudes, dem keine Asymmetrie des Systems der Erfahrungen entspricht, ist für den Theoretiker unerträglich. Es scheint mir die physikalische Gleichwertigkeit von K und K1 mit der Annahme, daß der Äther relativ zu K ruhe, relativ zu K1 aber bewegt sei, zwar nicht vom logischen Standpunkte geradezu unrichtig, aber doch unannehmbar.

Der nächstliegende Standpunkt, den man dieser Sachlage gegenüber einnehmen konnte schien der folgende zu sein. Der Äther existiert überhaupt nicht. Die elektromagnetischen Felder sind nicht Zustände eines Mediums, sondern selbständige, Realitäten, die auf nichts anderes zurückzuführen sind und die an keinen Träger gebunden sind, genau wie die Atome der ponderabeln Materie. Diese Auffassung liegt um so näher, weil gemäß der Lorentzschen Theorie die elektromagnetische Strahlung Impuls und Energie mit sich führt wie die ponderable Materie, und weil Materie und Strahlung nach der speziellen Relativitätstheorie beide nur besondere Formen verteilter Energie sind, indem ponderable Masse ihre Sonderstellung verliert und nur als besondere Form der

Energie erscheint.

Indessen lehrt ein genaueres Nachdenken, daß diese Leugnung des Äthers nicht notwendig durch das spezielle Relativitätsprinzip gefordert wird. Man kann die Existenz eines Äthers annehmen; nur muß man darauf verzichten, ihm einen bestimmten Bewegungszustand zuzuschreiben, d.h. man muß ihm durch Abstraktion das letzte mechanische Merkmal nehmen, welches ihm Lorentz noch gelassen hatte. Später werden wir sehen, daß diese Auffassungsweise, deren gedankliche Möglichkeit ich sogleich durch einen etwas hinkenden Vergleich deutlicher zu machen suche, durch die Ergebnisse der allgemeinen Relativitätstheorie gerechtfertigt wird.

Man denke sich Wellen auf einer Wasseroberfläche. Man kann an diesem Vorgang zwei ganz verschiedene Dinge beschreiben. Man kann erstens verfolgen, wie sich die wellenförmige Grenzfläche zwischen Wasser und Luft im Laufe. der Zeit ändert. Man kann aber auch – etwa mit Hilfe von kleinen schwimmenden Körpern – verfolgen, wie sich die Lage der einzelnen Wasserteilchen im Laufe der Zeit ändert. Würde es derartige schwimmende Körperchen zum Verfolgen der Bewegung der Flüssigkeitsteilchen prinzipiell nicht geben, ja würde überhaupt an dem ganzen Vorgang nichts anderes als die zeitlich veränderliche Lage des von Wasser eingenommenen Raumes sich bemerkbar machen, so hätten wir keinen Anlaß zu der Annahme, daß das Wasser aus beweglichen Teilchen bestehe. Aber wir könnten es gleichwohl als Medium bezeichnen.

Etwas Ähnliches liegt bei dem elektromagnetischen Felde vor. Man kann sich nämlich das Feld als in Kraftlinien bestehend vorstellen. Will man diese Kraftlinien sich als etwas Materielles im gewohnten Sinne deuten, so ist man versucht, die dynamischen Vorgänge als Bewegungsvorgänge dieser Kraftlinien zu deuten, derart, daß jede einzelne Kraftlinie durch die Zeit hindurch verfolgt wird. Es ist indessen wohl bekannt, daß eine solche Betrachtungsweise zu Widersprüchen führt.

Verallgemeinernd müssen wir sagen. Es lassen sich ausgedehnte physikalische Gegenstände denken, auf welche der Bewegungsbegriff keine Anwendung finden kann. Sie dürfen nicht als aus Teilchen bestehend gedacht werden, die sich einzeln durch die Zeit hindurch verfolgen lassen. In der Sprache Minkowskis drückt sich dies so aus: nicht jedes in der vierdimensionalen Welt ausgedehnte Gebilde läßt sich als aus Weltfäden zusammengesetzt auffassen. Das spezielle

Relativitätsprinzip verbietet uns, den Äther als aus zeitlich verfolgbaren Teilchen bestehend anzunehmen, aber die Ätherhypothese an sich widerstreitet der speziellen Relativitätetheorie nicht. Nur muß man sich davor hüten, dem Äther einen Bewegungszustand zuzusprechen.

Allerdings erscheint die Ätherhypothese vom Standpunkte der speziellen Relativitätstheorie zunächst als eine leere Hypothese. In den elektromagnetischen Feldgleichungen treten außer den elektrischen Ladungsdichten *nur* die Feldstärken auf. Der Ablauf der elektromagnetischen Vorgänge im Vakuum scheint durch jenes innere Gesetz völlig bestimmt zu sein, unbeeinflußt durch andere physikalische Größen. Die elektromagnetischen Felder erscheinen als letzte, nicht weiter zurückführbare Realitäten, und es erscheint zunächst überflüssig, ein homogenes, intropes Äthermedium zu postulieren, als dessen Zustände jene Felder aufzufassen wären.

Anderseits läßt sich aber zugunsten der Ätherhypothese ein wichtiges Argument anführen. Den Äther leugnen bedeutet letzten Endes annehmen, daß dem leeren Raume keinerlei physikalische Eigenschaften zukommen. Mit dieser Auffassung stehen die fundamentalen Tatsachen der Mechanik nicht im Einklang. Das mechanische Verhalten eines im leeren Raume frei schwebenden körperlichen Systems hängt nämlich außer von den relativen Lagen (Abständen) und relativen Geschwindigkeiten noch von seinem Drehungszustande ab, der physikalisch nicht als ein dem System an sich zukommendes Merkmal aufgefaßt werden kann. Um die Drehung des Systems wenigstens formal als etwas Reales ansehen zu können, objektiviert Newton den Raum. Dadurch, daß er seinen absoluten Raum zu den realen Dingen rechnet, ist für ihn auch die Drehung relativ zu einem absoluten Raum etwas Reales. Newton hätte seinen absoluten Raum ebensogut "Äther" nennen können; wesentlich ist ja nur, daß neben den beobachtbaren Objekten noch ein anderes, nicht wahrnehmbares Ding als real angesehen werden muß, um die Beschleunigung bzw. die Rotation als etwas Reales ansehen zu können.

Mach suchte zwar der Notwendigkeit, etwas nicht beobachtbares Reales anzunehmen, dadurch zu entgehen, daß er in die Mechanik statt der Beschleunigung gegen den absoluten Raum eine mittlere Beschleunigung gegen die Gesamtheit der Massen der Welt zu setzen strebte. Aber ein Trägheitswiderstand gegenüber relativer Beschleunigung ferner Massen setzt unvermittelte Fernwirkung voraus. Da der moderne Physiker eine solche nicht annehmen zu dürfen glaubt, so landet er auch bei dieser Auffassung wieder beim Äther, der die Trägheitswirkungen zu

vermitteln hat. Dieser Ätherbegriff, auf den die Machsche Betrachtungsweise führt, unterscheidet sich aber wesentlich vom Ätherbegriff Newtons, Fresnels und H.A. Lorentz. Dieser Machsche Äther *bedingt* nicht nur das Verhalten der trägen Massen, sondern *wird* in seinem Zustand *auch bedingt* durch die trägen Massen.

Der Machsche Gedanke findet seine volle Entfaltung in dem Äther der allgemeinen Relativitätstheorie. Nach dieser Theorie sind die metrischen Eigenschaften des Raum-Zeit-Kontinuums in der Umgebung der einzelnen Raum-Zeitpunkte verschieden und mitbedingt durch die außerhalb des betrachteten Gebietes vorhandene Materie. Diese raum-zeitliche Veränderlichkeit der Beziehungen von Maßstäben und Uhren zueinander, bzw. die Erkenntnis, daß der "leere Raum" in physikalischer Beziehung weder homogen noch isotrop sei, welche uns dazu zwingt, seinen Zustand durch zehn Funktionen, die Gravitationspotentiale g_{mn} zu beschreiben, hat die Auffassung, daß der Raum physikalisch leer sei, wohl endgültig beseitigt. Damit ist aber auch der Ätherbegriff wieder zu einem deutlichen Inhalt gekommen, freilich zu einem Inhalt, der von dem des Äthers der mechanischen Undulationstheorie des Lichtes weit verschieden ist. Der Äther der allgemeinen Relativitätstheorie ist ein Medium, welches selbst aller mechanischen und kinematischen Eigenschaften bar ist, aber das mechanische (und elektromagnetische) Geschehen mitbestimmt.

Das prinzipiell Neuartige des Äthers der allgemeinen Relativitätstheorie gegenüber dem Lorentzschen Äther besteht darin, daß der Zustand des ersteren an jeder Stelle bestimmt ist durch gesetzliche Zusammenhänge mit der Materie und mit dem Ätherzustände in benachbarten Stellen in Gestalt von Differentialgleichungen, während der Zustand des Lorentzschen Äthers bei Abwesenheit von elektromagnetischen Feldern durch nichts außer ihm bedingt und überall der gleiche ist. Der Äther der allgemeinen Relativitätstheorie geht gedanklich dadurch in den Lorentzschen über, daß man die ihn beschreibenden Raumfunktionen durch Konstante ersetzt, indem man absieht von den seinen Zustand bedingenden Ursachen. Man kann also wohl auch sagen, daß der Äther der allgemeinen Relativitätstheorie durch Relativierung aus dem Lorentzschen Äther hervorgegangen ist.

Über die Rolle, welche der neue Äther im physikalischen Weltbilde der Zukunft zu spielen berufen ist, sind wir noch nicht im klaren. Wir wissen, daß er die metrischen Beziehungen im raum-zeitlichen Kontinuum, z.B. die Konfigurationsmöglichkeiten fester Körper sowie die Gravitationsfelder bestimmt;

aber wir wissen nicht, ob er am Aufbau der die Materie konstituierenden elektrischen Elementarteilchen einen wesentlichen Anteil hat. Wir wissen auch nicht, ob seine Struktur nur in der Nähe ponderabler Massen von der Struktur des Lorentzschen wesentlich abweicht, ob die Geometrie von Räumen kosmischer Ausdehnung eine nahezu euklidische ist. Wir können aber auf Grund der relativistischen Gravitationsgleichungen behaupten, daß eine Abweichung vom euklidischen Verhalten bei Räumen von kosmischer Größenordnung dann vorhanden sein muß, wenn eine auch noch so kleine positive mittlere Dichte der Materie in der Welt existiert. In diesem Falle muß die Welt notwendig räumlich geschlossen und von endlicher Größe sein, wobei ihre Größe durch den Wert jener mittleren Dichte bestimmt wird.

Betrachten wir das Gravitationsfeld und das elektromagnetische Feld vom Standpunkt der Ätherhypothese, so besteht zwischen beiden ein bemerkenswerter prinzipieller Unterschied. Kein Raum und auch kein Teil des Raumes ohne Gravitationspotentiale; denn diese verleihen ihm seine metrischen Eigenschaften, ohne welche er überhaupt nicht gedacht werden kann. Die Existenz des Gravitationsfeldes ist an die Existenz des Raumes unmittelbar gebunden. Dagegen kann ein Raumteil sehr wohl ohne elektromagnetisches Feld gedacht werden; das elektromagnetische Feld scheint also im Gegensatz zum Gravitationsfeld gewissermaßen nur sekundär an den Äther gebunden zu sein, indem die formale Natur des elektromagnetischen Feldes durch die des Gravitationsäthers noch gar nicht bestimmt ist. Es sieht nach dem heutigen Zustande der Theorie so aus, als beruhe das elektromagnetische Feld dem Gravitationsfeld gegenüber auf einem völlig neuen formalen Motiv, als hatte die Natur den Gravitationsäther statt mit Feldern vom Typus der elektromagnetischen, ebensogut mit Feldern eines ganz anderen Typus, z.B. mit Feldern eines skalaren Potentials, ausstatten können.

Da nach unseren heutigen Auffassungen auch die Elementarteilchen der Materie ihrem Wesen nach nichts anderes sind als Verdichtungen des elektromagnetischen Feldes, so kennt unser heutiges Weltbild zwei begrifflich vollkommen voneinander getrennte, wenn auch kausal aneinander gebundene Realitäten nämlich Gravitationsäther und elektromagnetisches Feld oder – wie man sie auch nennen könnte – Raum und Materie.

Natürlich wäre es ein großer Fortschritt, wenn es gelingen würde, das Gravitationsfeld und elektromagnetische Feld zusammen als ein einheitliches Gebilde aufzufassen. Dann erst würde die von Faraday und Maxwell begründete

Epoche der theoretischen Physik zu einem befriedigenderen Abschluß kommen. Es würde dann der Gegensatz Äther – Materie verblassen und die ganze Physik zu einem ähnlich geschlossenen Gedankensystem werden wie Geometrie, Kinematik und Gravitationstheorie durch die allgemeine Relativitätstheorie. Ein überaus geistvoller Versuch in dieser Richtung ist von dem Mathematiker H.Weyl gemacht worden; doch glaube ich nicht, daß seine Theorie der Wirklichkeit gegenüber standhalten wird. Wir dürfen ferner beim Denken an die nächste, Zukunft der theoretischen Physik die Möglichkeit nicht unbedingt abweisen, daß die in der Quantentheorie zusammengefaßten Tatsachen der Feldtheorie unübersteigbare Grenzen setzen könnten.

Zusammenfassend können wir sagen: Nach der allgemeinen Relativitätstheorie ist der Raum mit physikalischen Qualitäten ausgestattet; es existiert also in diesem Sinne ein Äther. Gemäß der allgemeinen Relativitätstheorie ist ein Raum ohne Äther undenkbar; denn in einem solchen gäbe es nicht nur keine Lichtfortpflanzung, sondern auch keine Existenzmöglichkeit von Maßstäben und Uhren, also auch keine räumlich-zeitlichen Entfernungen im Sinne der Physik. Dieser Äther darf aber nicht mit der für ponderable Medien charakteristischen Eigenschaft ausgestattet gedacht werden, aus durch die Zeit verfolgbaren Teilen zu bestehen; der Bewegungsbegriff darf auf ihn nicht angewendet werden."

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Concerning the Aether (Einstein)

Concerning the Aether

by

Albert Einstein

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> *When we speak here of aether, we are, of course, not referring to the corporeal aether of mechanical wave-theory that underlies Newtonian mechanics, whose individual points each have a velocity assigned to them. This theoretical construct has, in my opinion, been superseded by the special theory of relativity. Rather the discussion concerns, much more generally, those things thought of as physically real which, besides ponderable matter consisting of electrical elementary particles, play a role in the causal nexus of physics. Instead of 'aether', one could equally well speak of 'the physical qualities of space'. Now, it might be claimed that this concept covers all objects of physics, for according to consistent field theory, even ponderable matter, or its constituent elementary particles, are to be understood as fields of some kind or particular 'states of space'. But it must be admitted that such a view would be premature, since, thus far, all efforts directed toward this goal have foundered. So we are effectively forced by the current state of things to distinguish between matter and aether, even though we may hope that future*

generations will transcend this dualistic conception and replace it with a unified theory, as the field theoreticians of our day have tried in vain to accomplish.

It is usually believed that aether is foreign to Newtonian physics and that it was only the wave theory of light which introduced the notion of an omnipresent medium influencing, and affected by, physical phenomena. But this is not the case. Newtonian mechanics had its 'aether' in the sense indicated, albeit under the name 'absolute space'. To get a clear understanding of this and, at the same time, to explore more fully the concept of aether, we must take a step back.

We will consider first a branch of physics which makes do without any notion of aether, namely the geometry of Euclid, understood as the study of the possible ways of bringing essentially rigid bodies into contact with each other. (For now, we will set to one side light rays, which may also contribute to the development of geometrical concepts and theorems.) The laws concerning the placement of rigid bodies, excluding relative motion, temperature and the influence of deformations, as laid down in an idealised way in Euclid's geometry, derive from the concept of a rigid body. Any environmental influence which could be thought of as existing independently of those bodies and as acting on them and influencing the laws governing their placement is unknown to Euclidean geometry. The same holds for the non-Euclidean geometries of constant curvature if these are understood as conceivable laws of nature. It would be different if we were to find ourselves forced to adopt a geometry of variable curvature. This would mean that the laws governing the ways essentially rigid bodies can be brought into contact would be different in different cases, depending on environmental influences. Here we would have to say that, in the sense we are considering, such a theory would require an aether hypothesis. Its aether would be something every bit as physically real as matter. If the laws of placement were impervious to the influence of physical factors, such as the accumulation and state of motion of bodies in the environment, but irrevocably given, then we would call this aether 'absolute', i.e. by its nature independent of any influence.

The kinematics, or phoronomy, of classical physics had as little need of an aether as (physically interpreted) Euclidean geometry has. For its laws have a clear physical meaning only if we assume that the special-relativistic influences of motion on rulers and clocks do not exist. Not so in the dynamics of Galileo and Newton. The law of motion 'force equals mass times acceleration', does not consist only of a statement about material systems, not even if, according to Newton's fundamental law of astronomy, the force is expressed at a distance, i.e. by quantities whose 'real definition' [definitio realis, a definition in terms of the object's distinguishing properties] can be based on measurements involving rigid bodies. For the 'real definition' of acceleration cannot be completely reduced to observations of rigid bodies and clocks. It cannot be reduced to the measurable distances between the points that make up the mechanical system. Its definition requires also a coordinate system or reference body having some suitable state of motion. If a different coordinate system is chosen, the Newtonian equations do not hold with respect to this new coordinate system. With those equations, the milieu in which the bodies move appears as an implicit, real factor in the laws of motion,

alongside the real bodies themselves and the distances that massive bodies define. In contrast to geometry and kinematics, the 'space' of Newton's theory of motion possesses physical reality. We will call this physical reality which enters the Newtonian law of motion alongside the observable, ponderable real bodies, the aether of mechanics. The occurrence of centrifugal effects with a (rotating) body, whose material points do not change their distances from one another, shows that this aether is not to be understood as a mere hallucination of the Newtonian theory, but rather that it corresponds to something real that exists in nature.

We see that, for Newton, 'space' was something physically real, in spite of the curiously indirect way this real thing reaches our awareness. Ernst Mach, the first after Newton to subject the foundations of mechanics to a deep analysis, perceived this clearly. He sought to escape this hypothesis of the 'mechanical aether' by reducing inertia to immediate interaction between the perceived mass and all other masses of the universe. This view was certainly a logical possibility but, as a theory involving action at a distance, cannot be taken seriously today. The mechanical aether–which Newton called 'absolute space'–must remain for us a physical reality. Of course, one must not be tempted by the expression aether into thinking that, like the physicists of the 19th century, we have in mind something analogous to ponderable matter.

When Newton referred to the space of physics as 'absolute', he was thinking of yet another property of what we call here aether. Every physical thing influences others and is, it its turn, generally influenced by other things. This does not however apply to the aether of Newtonian mechanics. For the inertia-giving property of this aether is, according to classical mechanics, not susceptible to any influence, neither from the configuration of matter nor anything else. Hence the term 'absolute'.

Only in recent years has it become clear to physicists that the preferred nature of initial systems, as opposed to non-inertial systems, requires a real cause. Viewed historically, the aether hypothesis has emerged in its present form by a process of sublimation from the mechanical aether hypothesis of optics. After long and fruitless efforts, physicists became convinced that light was not to be understood as the motion of an inertial, elastic medium, that the electromagnetic fields of Maxwell's theory could not be construed as mechanical. So under the pressure of this failure, the electromagnetic fields had gradually come to be regarded as the final, irreducible physical reality, as states of the aether, impervious to further explanation. What remained of the mechanical theory was its definite state of motion; it somehow embodied a state of absolute rest. While at least in Newtonian mechanics all inertial systems were equivalent, it seemed that, in the Maxwell-Lorentz theory, the state of motion of the preferred coordinate system (at rest with respect to the aether) was completely determined. It was accepted implicitly that this preferred coordinate system was also an inertial system, i.e. that the principle of inertia [Newton's first law] applied relative to the electromagnetic aether.

There was another way too in which the Maxwell-Lorentz theory set back physicists' basic understanding. Since electromagnetic fields were seen as fundamental, irreducible entities, they

seemed destined to rob ponderable masses, possessing inertia, of their primary meaning. It was shown by Maxwell's equations that a moving, electrically charged body is surrounded by a magnetic field whose energy is, to first approximation, a quadratic function of speed. It seemed only natural to conceive of all kinetic energy as electromagnetic energy. Thus one could hope to reduce mechanics to electromagnetism, since efforts to reduce electromagnetic phenomena to mechanics had failed. Indeed this looked all the more promising as it became apparent that all ponderable matter was composed of electromagnetic elementary particles. But there were two difficulties that could not be overcome. Firstly the Maxwell-Loretz equations could not explain how the electric charge constituting an electrical elementary particle can exist in equilibrium in spite of the forces of electrostatic repulsion. Secondly electromagnetic theory could not give a reasonably natural and satisfactory explanation of gravitation. Nevertheless the results that electromagnetic theory achieved for physics were so significant they came to be regarded as a completely secured possession, indeed as its most firmly established success.

The Maxwell-Lorentz theory eventually influenced our view of the theoretical basis to the extent that it led to the creation of the special theory of relativity. It was recognised that the equations of electromagnetism did not, in fact, single out one particular state of motion, but rather that, in accordance with these equations, just as with those of classical mechanics, there exists an infinite multitude of coordinate systems in mutually equivalent states of motion, providing the appropriate transformation formulas are used for the spatial and temporal coordinates. It is well known that this realisation entailed a profound modification, not only in our ideas about space and time, but also to kinematics and dynamics. No longer was a special state of motion to be ascribed to the electromagnetic aether. Now, like the aether of classical mechanics, it resulted not in the favoring of a particular state of motion, only the favoring of a particular state of acceleration. Because it was no longer possible to speak, in any absolute sense, of simultaneous states at different locations in the aether, the aether became, as it were, four dimensional, since there was no objective way of ordering its states by time alone. According to special relativity too, the aether was absolute, since its influence on inertia and the propogation of light was thought of as being itself independent of physical influence. While classical physics took it for granted that the geometry of bodies was independent of their state of motion, the special theory of relativity stated that the laws of Euclidean geometry only apply to the positioning of bodies at rest with respect to one another when these bodies are at rest with respect to an inertial coordinate system.[1] This can be easily concluded from the so-called Lorentz contraction. Thus geometry, like dynamics, came to depend on the aether.

The general theory of relativity rectified a mischief of classical dynamics. According to the latter, inertia and gravity appear as quite different, mutually independent phenomena, even though they both depend on the same quantity, mass. The theory of relativity resolved this problem by establishing the behaviour of the electrically neutral point-mass by the law of the geodetic line, according to which inertial and gravitational effects are no longer considered as separate. In doing so, it attached characteristics to the aether which vary from point to point, determining the metric and the dynamic behaviour of material points, and determined, in their turn, by

physical factors, namely the distribution of mass/energy.

Thus the aether of general relativity differs from those of classical mechanics and special relativity in that it is not 'absolute' but determined, in its locally variable characteristics, by ponderable matter. This determination is a complete one if the universe is finite and closed. That there are, in general relativity, no preferred spacetime coordinates uniquely associated with the metric is more characteristic of its mathematical form than its physical framework.

Even using mathematical apparatus of general relativity it has not been possible to reduce all of the inertia of mass to electromagnetic fields, or to fields in general. Neither are we yet, in my view, at the point of formally incorporating the electromagnetic forces into the scheme of general relativity. On the one hand, the metric tensor, which codetermines the phenomena of gravitation and inertia and, on the other, the tensor of the electromagnetic field appear still as different expressions of the state of the aether, whose logical independence one is inclined to attribute rather to the incompleteness of our theoretical ediface than to a complex structure of reality.

It is true that Weyl and Eddington have, by a generalisation of Riemannian geometry, found a mathematical system, in which both kinds of field appear to be unified under a single perspective. But the simplest field laws which that theory provides seem to me not to advance physical insight. On the whole, we seem to be much further now from an understanding of the fundamental laws of electromagnetism than we did at the beginning of this century. As justification for this opinion, I should here like to briefly refer to the problem of the magnetic fields of the earth and the sun, and also to the problem of light quanta, which problems have some bearing on the gross and fine structure of the electromagnetic field.

The earth and sun possess magnetic fields whose orientation and sense are closely related to the spin axes of these bodies. According to Maxwell's theory, these fields may be due to electric currents which flow in the opposite direction to the rotation of the earth and sun about their axes. Even sunspots, which there are good grounds to think of as vortices, posses analogous, and very powerful, magnetic fields. But it is hardly conceivable that, in all these cases, circuits or convection currents of sufficient strength are actually present. Rather it looks as if cyclic motion of neutral masses generated magnetic fields. Neither Maxwell's theory as originally conceived nor as extended in general relativity predict field generation of that sort. Here nature seems to point us toward some fundamental connection, not yet understood.[2]

If the case we have just discussed is one that field theory, in its current form, seems not yet able to address, the facts and ideas subsumed under quantum theory threaten to the blow the edifice of field theory to bits. Specifically, we find increasing arguments suggesting that the quanta of light are to be understood as physical reality, and that the electromagnetic field cannot be seen as the final reality to which all other physical objects can be reduced. As Planck's formula had already shown that the transmission of energy and momentum by radiation

happens as if the latter consisted of particles moving at the speed of light, , with energy so Compton demonstrated, by his research into the scattering of X-rays by matter that scattering events occur in which quanta of light collide with electrons and transmit to them a portion of their energy, as a result of which the quanta of light undergo a change of energy and direction. It is at least a fact that X-rays experience such changes in frequency on scattering (in agreement with the predictions of Debye and Compton) as quantum theory demands.

Recently there has appeared work by the Indian physicist Bose on the derivation of Planck's formula which is of particular significance to our theoretical understanding for the following reasons: hitherto all complete derivations of Planck's formula made some use of the hypothesis of the wave structure of radiation. So, for example, in the well-known Ehrenfest-Debye derivation, the factor in this formula was deduced by counting the eigenvibrations of the cavity belonging to the frequency range . Bose replaces this derivation based on the ideas of wave theory with a gas-theoretical calculation which he applies to a quantum of light conceived of like some sort of molecule present in the cavity. This raises the question of whether it might perhaps also be possible to link the phenomena of diffraction and interference to quantum theory in such a way that the field-like concepts of the theory are presented only as expressions of the interaction between quanta, so that independent physical reality would no longer be ascribed to the fields.

The important fact that the radiation emitted is not, according to Bohr's frequency theory, determined by electrically charged masses which periodically cycle through occurrences of the same frequency can only strengthen this doubt of ours as to the independent reality of the wave field.

But even if these possibilities do mature into an actual theory, we will not be able to do without the aether in theoretical physics, that is, a continuum endowed with physical properties; for general relativity, to whose fundamental viewpoints physicists will always hold fast, rules out direct action at a distance. But every theory of local action assumes continuous fields, and thus also the existence of an 'aether'.

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Ether and the Theory of Relativity (Einstein)

Even Einstein thought that space must be "real" and be "rigid" – he called it Ether, but he clearly refers to it as the "solid elastic" kind of ether mentioned in the blog posts. Examples (from below)

> *"More careful reflection teaches us however, that* ***the special theory of relativity does not compel us to deny ether****. We may assume the existence of an ether; only we must give up ascribing a definite state of motion to it"*

> *"Recapitulating, we may say that* ***according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an ether****. According to the general theory of relativity* ***space without ether is unthinkable****; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense"*

Ether and the Theory of Relativity

by
Albert Einstein

How does it come about that alongside of the idea of ponderable matter, which is derived by abstraction from everyday life, the physicists set the idea of the existence of another kind of matter, the ether? The explanation is probably to be sought in those phenomena which have given rise to the theory of action at a distance, and in the properties of light which have led to the undulatory theory. Let us devote a little while to the consideration of these two subjects.

Outside of physics we know nothing of action at a distance. When we try to connect cause and effect in the experiences which natural objects afford us, it seems at first as if there were no other mutual actions than those of immediate contact, e.g. the communication of motion by impact, push and pull, heating or inducing combustion by means of a flame, etc. It is true that even in everyday experience

weight, which is in a sense action at a distance, plays a very important part. But since in daily experience the weight of bodies meets us as something constant, something not linked to any cause which is variable in time or place, we do not in everyday life speculate as to the cause of gravity, and therefore do not become conscious of its character as action at a distance. It was Newton's theory of gravitation that first assigned a cause for gravity by interpreting it as action at a distance, proceeding from masses. Newton's theory is probably the greatest stride ever made in the effort towards the causal nexus of natural phenomena. And yet this theory evoked a lively sense of discomfort among Newton's contemporaries, because it seemed to be in conflict with the principle springing from the rest of experience, that there can be reciprocal action only through contact, and not through immediate action at a distance.

It is only with reluctance that man's desire for knowledge endures a dualism of this kind. How was unity to be preserved in his comprehension of the forces of nature? Either by trying to look upon contact forces as being themselves distant forces which admittedly are observable only at a very small distance and this was the road which Newton's followers, who were entirely under the spell of his doctrine, mostly preferred to take; or by assuming that the Newtonian action at a distance is only apparently immediate action at a distance, but in truth is conveyed by a medium permeating space, whether by movements or by elastic deformation of this medium. Thus the endeavour toward a unified view of the nature of forces leads to the hypothesis of an ether. This hypothesis, to be sure, did not at first bring with it any advance in the theory of gravitation or in physics generally, so that it became customary to treat Newton's law of force as an axiom not further reducible. But the ether hypothesis was bound always to play some part in physical science, even if at first only a latent part.

When in the first half of the nineteenth century the far-reaching similarity was revealed which subsists between the properties of light and those of elastic waves in ponderable bodies, the ether hypothesis found fresh support. It appeared beyond question that light must be interpreted as a vibratory process in an elastic, inert medium filling up universal space. It also seemed to be a necessary consequence of the fact that light is capable of polarisation that this medium, the ether, must be of the nature of a solid body, because transverse waves are not possible in a fluid, but only in a solid. Thus the physicists were bound to arrive at the theory of the "quasi-rigid" luminiferous ether, the parts of which can carry out no movements relatively to one another except the small movements of deformation which correspond to light-waves.

This theory – also called the theory of the stationary luminiferous ether – moreover found a strong support in an experiment which is also of fundamental importance in the special theory of relativity, the experiment of Fizeau, from which one was obliged to infer that the luminiferous ether does not take part in the movements of bodies. The phenomenon of aberration also favoured the theory of the quasi-rigid ether.

The development of the theory of electricity along the path opened up by Maxwell and Lorentz gave the development of our ideas concerning the ether quite a peculiar and unexpected turn. For Maxwell himself the ether indeed still had properties which were purely mechanical, although of a much more

complicated kind than the mechanical properties of tangible solid bodies. But neither Maxwell nor his followers succeeded in elaborating a mechanical model for the ether which might furnish a satisfactory mechanical interpretation of Maxwell's laws of the electro-magnetic field. The laws were clear and simple, the mechanical interpretations clumsy and contradictory. Almost imperceptibly the theoretical physicists adapted themselves to a situation which, from the standpoint of their mechanical programme, was very depressing. They were particularly influenced by the electro-dynamical investigations of Heinrich Hertz. For whereas they previously had required of a conclusive theory that it should content itself with the fundamental concepts which belong exclusively to mechanics (e.g. densities, velocities, deformations, stresses) they gradually accustomed themselves to admitting electric and magnetic force as fundamental concepts side by side with those of mechanics, without requiring a mechanical interpretation for them. Thus the purely mechanical view of nature was gradually abandoned. But this change led to a fundamental dualism which in the long-run was insupportable. A way of escape was now sought in the reverse direction, by reducing the principles of mechanics to those of electricity, and this especially as confidence in the strict validity of the equations of Newton's mechanics was shaken by the experiments with b-rays and rapid cathode rays.

This dualism still confronts us in unextenuated form in the theory of Hertz, where matter appears not only as the bearer of velocities, kinetic energy, and mechanical pressures, but also as the bearer of electromagnetic fields. Since such fields also occur in vacuo – i.e. in free ether-the ether also appears as bearer of electromagnetic fields. The ether appears indistinguishable in its functions from ordinary matter. Within matter it takes part in the motion of matter and in empty space it has everywhere a velocity; so that the ether has a definitely assigned velocity throughout the whole of space. There is no fundamental difference between Hertz's ether and ponderable matter (which in part subsists in the ether).

The Hertz theory suffered not only from the defect of ascribing to matter and ether, on the one hand mechanical states, and on the other hand electrical states, which do not stand in any conceivable relation to each other; it was also at variance with the result of Fizeau's important experiment on the velocity of the propagation of light in moving fluids, and with other established experimental results.

Such was the state of things when H A Lorentz entered upon the scene. He brought theory into harmony with experience by means of a wonderful simplification of theoretical principles. He achieved this, the most important advance in the theory of electricity since Maxwell, by taking from ether its mechanical, and from matter its electromagnetic qualities. As in empty space, so too in the interior of material bodies, the ether, and not matter viewed atomistically, was exclusively the seat of electromagnetic fields. According to Lorentz the elementary particles of matter alone are capable of carrying out movements; their electromagnetic activity is entirely confined to the carrying of electric charges. Thus Lorentz succeeded in reducing all electromagnetic happenings to Maxwell's equations for free space.

As to the mechanical nature of the Lorentzian ether, it may be said of it, in a somewhat playful spirit,

that immobility is the only mechanical property of which it has not been deprived by H A Lorentz. It may be added that the whole change in the conception of the ether which the special theory of relativity brought about, consisted in taking away from the ether its last mechanical quality, namely, its immobility. How this is to be understood will forthwith be expounded.

The space-time theory and the kinematics of the special theory of relativity were modelled on the Maxwell-Lorentz theory of the electromagnetic field. This theory therefore satisfies the conditions of the special theory of relativity, but when viewed from the latter it acquires a novel aspect. For if *K* be a system of coordinates relatively to which the Lorentzian ether is at rest, the Maxwell-Lorentz equations are valid primarily with reference to *K*. But by the special theory of relativity the same equations without any change of meaning also hold in relation to any new system of co-ordinates *K*' which is moving in uniform translation relatively to *K*. Now comes the anxious question:- Why must I in the theory distinguish the *K* system above all *K*' systems, which are physically equivalent to it in all respects, by assuming that the ether is at rest relatively to the *K* system? For the theoretician such an asymmetry in the theoretical structure, with no corresponding asymmetry in the system of experience, is intolerable. If we assume the ether to be at rest relatively to *K*, but in motion relatively to *K*', the physical equivalence of *K* and *K*' seems to me from the logical standpoint, not indeed downright incorrect, but nevertheless unacceptable.

The next position which it was possible to take up in face of this state of things appeared to be the following. The ether does not exist at all. The electromagnetic fields are not states of a medium, and are not bound down to any bearer, but they are independent realities which are not reducible to anything else, exactly like the atoms of ponderable matter. This conception suggests itself the more readily as, according to Lorentz's theory, electromagnetic radiation, like ponderable matter, brings impulse and energy with it, and as, according to the special theory of relativity, both matter and radiation are but special forms of distributed energy, ponderable mass losing its isolation and appearing as a special form of energy.

More careful reflection teaches us however, that the special theory of relativity does not compel us to deny ether. We may assume the existence of an ether; only we must give up ascribing a definite state of motion to it, i.e. we must by abstraction take from it the last mechanical characteristic which Lorentz had still left it. We shall see later that this point of view, the conceivability of which I shall at once endeavour to make more intelligible by a somewhat halting comparison, is justified by the results of the general theory of relativity.

Think of waves on the surface of water. Here we can describe two entirely different things. Either we may observe how the undulatory surface forming the boundary between water and air alters in the course of time; or else-with the help of small floats, for instance – we can observe how the position of the separate particles of water alters in the course of time. If the existence of such floats for tracking the motion of the particles of a fluid were a fundamental impossibility in physics – if, in fact nothing else whatever were observable than the shape of the space occupied by the water as it varies in time, we should have no ground for the assumption that water consists of movable

particles. But all the same we could characterise it as a medium.

We have something like this in the electromagnetic field. For we may picture the field to ourselves as consisting of lines of force. If we wish to interpret these lines of force to ourselves as something material in the ordinary sense, we are tempted to interpret the dynamic processes as motions of these lines of force, such that each separate line of force is tracked through the course of time. It is well known, however, that this way of regarding the electromagnetic field leads to contradictions.

Generalising we must say this:- There may be supposed to be extended physical objects to which the idea of motion cannot be applied. They may not be thought of as consisting of particles which allow themselves to be separately tracked through time. In Minkowski's idiom this is expressed as follows:- Not every extended conformation in the four-dimensional world can be regarded as composed of world-threads. The special theory of relativity forbids us to assume the ether to consist of particles observable through time, but the hypothesis of ether in itself is not in conflict with the special theory of relativity. Only we must be on our guard against ascribing a state of motion to the ether.

Certainly, from the standpoint of the special theory of relativity, the ether hypothesis appears at first to be an empty hypothesis. In the equations of the electromagnetic field there occur, in addition to the densities of the electric charge, only the intensities of the field. The career of electromagnetic processes in vacuo appears to be completely determined by these equations, uninfluenced by other physical quantities. The electromagnetic fields appear as ultimate, irreducible realities, and at first it seems superfluous to postulate a homogeneous, isotropic ether-medium, and to envisage electromagnetic fields as states of this medium.

But on the other hand there is a weighty argument to be adduced in favour of the ether hypothesis. To deny the ether is ultimately to assume that empty space has no physical qualities whatever. The fundamental facts of mechanics do not harmonize with this view. For the mechanical behaviour of a corporeal system hovering freely in empty space depends not only on relative positions (distances) and relative velocities, but also on its state of rotation, which physically may be taken as a characteristic not appertaining to the system in itself. In order to be able to look upon the rotation of the system, at least formally, as something real, Newton objectivises space. Since he classes his absolute space together with real things, for him rotation relative to an absolute space is also something real. Newton might no less well have called his absolute space "Ether"; what is essential is merely that besides observable objects, another thing, which is not perceptible, must be looked upon as real, to enable acceleration or rotation to be looked upon as something real.

It is true that Mach tried to avoid having to accept as real something which is not observable by endeavouring to substitute in mechanics a mean acceleration with reference to the totality of the masses in the universe in place of an acceleration with reference to absolute space. But inertial resistance opposed to relative acceleration of distant masses presupposes action at a distance; and as the modern physicist does not believe that he may accept this action at a distance, he comes back once more, if he follows Mach, to the ether, which has to serve as medium for the effects of

inertia. But this conception of the ether to which we are led by Mach's way of thinking differs essentially from the ether as conceived by Newton, by Fresnel, and by Lorentz. Mach's ether not only conditions the behaviour of inert masses, but is also conditioned in its state by them.

Mach's idea finds its full development in the ether of the general theory of relativity. According to this theory the metrical qualities of the continuum of space-time differ in the environment of different points of space-time, and are partly conditioned by the matter existing outside of the territory under consideration. This space-time variability of the reciprocal relations of the standards of space and time, or, perhaps, the recognition of the fact that "empty space" in its physical relation is neither homogeneous nor isotropic, compelling us to describe its state by ten functions (the gravitation potentials g_{mn}), has, I think, finally disposed of the view that space is physically empty. But therewith the conception of the ether has again acquired an intelligible content although this content differs widely from that of the ether of the mechanical undulatory theory of light. The ether of the general theory of relativity is a medium which is itself devoid of all mechanical and kinematical qualities, but helps to determine mechanical (and electromagnetic) events.

What is fundamentally new in the ether of the general theory of relativity as opposed to the ether of Lorentz consists in this, that the state of the former is at every place determined by connections with the matter and the state of the ether in neighbouring places, which are amenable to law in the form of differential equations; whereas the state of the Lorentzian ether in the absence of electromagnetic fields is conditioned by nothing outside itself, and is everywhere the same. The ether of the general theory of relativity is transmuted conceptually into the ether of Lorentz if we substitute constants for the functions of space which describe the former, disregarding the causes which condition its state. Thus we may also say, I think, that the ether of the general theory of relativity is the outcome of the Lorentzian ether, through relativation.

As to the part which the new ether is to play in the physics of the future we are not yet clear. We know that it determines the metrical relations in the space-time continuum, e.g. the configurative possibilities of solid bodies as well as the gravitational fields; but we do not know whether it has an essential share in the structure of the electrical elementary particles constituting matter. Nor do we know whether it is only in the proximity of ponderable masses that its structure differs essentially from that of the Lorentzian ether; whether the geometry of spaces of cosmic extent is approximately Euclidean. But we can assert by reason of the relativistic equations of gravitation that there must be a departure from Euclidean relations, with spaces of cosmic order of magnitude, if there exists a positive mean density, no matter how small, of the matter in the universe.

In this case the universe must of necessity be spatially unbounded and of finite magnitude, its magnitude being determined by the value of that mean density.

If we consider the gravitational field and the electromagnetic field from the standpoint of the ether hypothesis, we find a remarkable difference between the two. There can be no space nor any part of space without gravitational potentials; for these confer upon space its metrical qualities, without

which it cannot be imagined at all. The existence of the gravitational field is inseparably bound up with the existence of space. On the other hand a part of space may very well be imagined without an electromagnetic field; thus in contrast with the gravitational field, the electromagnetic field seems to be only secondarily linked to the ether, the formal nature of the electromagnetic field being as yet in no way determined by that of gravitational ether. From the present state of theory it looks as if the electromagnetic field, as opposed to the gravitational field, rests upon an entirely new formal motif, as though nature might just as well have endowed the gravitational ether with fields of quite another type, for example, with fields of a scalar potential, instead of fields of the electromagnetic type.

Since according to our present conceptions the elementary particles of matter are also, in their essence, nothing else than condensations of the electromagnetic field, our present view of the universe presents two realities which are completely separated from each other conceptually, although connected causally, namely, gravitational ether and electromagnetic field, or – as they might also be called – space and matter.

Of course it would be a great advance if we could succeed in comprehending the gravitational field and the electromagnetic field together as one unified conformation. Then for the first time the epoch of theoretical physics founded by Faraday and Maxwell would reach a satisfactory conclusion. The contrast between ether and matter would fade away, and, through the general theory of relativity, the whole of physics would become a complete system of thought, like geometry, kinematics, and the theory of gravitation. An exceedingly ingenious attempt in this direction has been made by the mathematician H Weyl; but I do not believe that his theory will hold its ground in relation to reality. Further, in contemplating the immediate future of theoretical physics we ought not unconditionally to reject the possibility that the facts comprised in the quantum theory may set bounds to the field theory beyond which it cannot pass.

Recapitulating, we may say that according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an ether. According to the general theory of relativity space without ether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense. But this ether may not be thought of as endowed with the quality characteristic of ponderable media, as consisting of parts which may be tracked through time. The idea of motion may not be applied to it.

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The Meaning of Wave Mechanics (Schrödinger)

Schrödinger did not like the "probability" interpretation of the wave function – he always considered the wave to be a real wave. He mentions this in several places, for instance"

> *"Let me say at the outset, that in this discourse, I am opposing not a few special statements of quantum physics held today (1950s), I am opposing as it were the whole of it, I am opposing its basic views that have been shaped 25 years ago, when Max Born put forward his* ***probability interpretation****, which was accepted by almost everybody."*
> *(Schrödinger E, The Interpretation of Quantum Physics. Ox Bow Press, Woodbridge, CN, 1995).*

Below is a longer speech he gave in 1952:

THE MEANING OF WAVE MECHANICS
by Erwin Schrödinger
(For the July Colloquium, Dublin 1952)

Louis de Broglie's great theoretical discovery of the wave phenomenon associated with the electron was followed within a few years, on the one hand by incontrovertible experimental evidence (based on interference patterns) of the reality of the de Broglie waves (Davisson and Germer, G. P. Thomson), and on the other hand by a vast generalization of his original ideas, which embraces the entire domain of physics and chemistry, and may be said to hold the field today along the whole line, albeit not precisely in the way de Broglie and his early followers had intended.

For it must have given to de Broglie the same shock and disappointment as it gave to me, when we learnt that a sort of transcendental, almost psychical interpretation of the wave phenomenon had been put forward, which was very soon hailed by the majority of leading theorists as the only one reconcilable with experiments, and which has now become the orthodox creed, accepted by almost everybody, with a few notable exceptions. Our disappointment consisted in the following. We had believed that the eigenfrequencies of the wave phenomenon, which were in exact numerical agreement with the, until then so called, energy levels, gave a rational understanding of the latter. We had confidence that the mysterious "fit and jerk theory" about the jump-like transition from one

energy level to another was now ousted. Our wave equations could be expected to describe any changes of this kind as slow and actually *describable* processes. This hope was not informed by personal predilection for continuous description, but if anything, by the wish for any kind of description at all of these changes. It was a dire necessity. To produce a coherent train of light, waves-of 100 cm length and more, as is observed in fine spectral lines, takes a time comparable with the average interval between transitions. The transition must be coupled with the production of the wave train. Hence if one does not understand the transition, but only understands the "stationary states", one understands nothing. For the emitting system is busy all the time in producing the trains of light waves, it has no time left to tarry in the cherished "stationary states", except perhaps in the ground state.

Another disconcerting feature of the probability interpretation was and is that the *wave function* is deemed to change in two entirely distinct fashions; it is thought to be governed by the wave equation as long as no observer interferes with the system, but whenever an observer makes a measurement, it is deemed to change into an eigenfunction of *that* eigenvalue of the associated operator that he has measured. I know only of one timid attempt (J. von Neumann in his well known book) to put this "change by measurement" to the door of a perturbing operator introduced by the measurement, and thus to have it also controlled solely by the wave equation. But the idea was not pursued, partly because it seemed unnecessary to those who were prepared to swallow the orthodox tenet, partly because it could hardly be reconciled with it. For in many cases the alleged change involves an *actio in distans*, which would contradict a firmly established principle, if the change referred to a physical entity. The non-physical character of the wave function (which is sometimes said to embody merely our knowledge) is even more strongly emphasized by the fact that according to the orthodox view its change by measurement is dependent on the observer's taking cognizance of the result. Moreover the change holds only for the observer who does. If *you* are present, but are not informed of the result, then *for you* even if you have the minutest knowledge both of the wave function before the measurement and of the appliances that were used, the changed wave function is irrelevant, not existing, as it were; *for you* there is, at best, a wave function referring to the measuring appliances plus the system under consideration, a wave function in which the one adopted by the knowing observer plays no distinguished role.

M. de Broglie, so I believe, disliked the probability interpretation of wave mechanics as much as I did. But very soon and for a long period one had to give up opposing it, and to accept it as an expedient interim solution. I shall point out some of the reasons why the originally contemplated alter-native seemed deceptive and, after all, too naive. The points shall be numbered for later reference; the illustrating examples are representative of wide classes.

- i) As long as a particle, an electron or proton etc., was still believed to be a permanent, individually identifiable entity, it could not adequately be pictured in our mind as a wave parcel. For as a rule, apart from artificially constructed and therefore irrelevant exceptions, no wave parcel can be indicated which does not eventually disperse into an ever increasing volume of space.

- ii) The original wave-mechanical model of the hydrogen atom is not self-consistent. The electronic cloud effectively shields the nuclear charge towards outside, making up a neutral whole, but is inefficient inside; in computing its structure its own field that it will produce must not be taken into account, only the field of the nucleus.
- iii) It seemed impossible to account for e.g. Planck's radiation formula without assuming that a radiation oscillator (proper mode of the hohlraum) can only have energies $nh\nu$, with n an integer (or perhaps a half odd integer). Since this holds in all cases of thermodynamic equilibrium that do not follow the classical law of equipartition we are thrown back to the discrete energy states with abrupt transitions between them, and thus to the probability interpretation.
- iv) Many non-equilibrium processes suggest even more strongly the "transfer of whole quanta"; the typical, often quoted example is the photoelectric effect, one of the pillars of Einstein's hypothesis of light quanta in 1905.

All this was known 25 years ago, and abated the hopes of "naive" wave-mechanista. The now orthodox view about the wave function as "probability amplitude" was put forward and was worked out into a scheme of admirable logical consistency. Let us first review the situation after the state of knowledge we had then. The view suggested by (iii) and (iv), that radiation oscillators, electrons and similar constituents of observable systems always find themselves at one of their respective energy levels except when they change abruptly to another one handing the balance over to, or receiving it from, some other system, this view, so I maintain, is in glaring contradiction with the above mentioned scheme in spite of the admirable logical self-consistency of the latter. For one of the golden rules of this scheme is, that any observable is always *found* at one of its eigenvalues, when you measure it, but that you must not say that it *has* any value, if you do not measure it. To attribute sharp energy values to all those constituents, whose energies we could not even dream of measuring (except in a horrible nightmare), is not only gratuitous but strictly forbidden by this rule.

Now let us review the situation as it is today. Two new aspects have since arisen which I consider very relevant for reconsidering the interpretation. They are intimately connected. They have not turned up suddenly. Their roots lie far back, but their bearing was only very gradually recognized.

I mean first the recognition that the thing which has always been called a particle and, on the strength of habit, is still called by some such name is, whatever it may be, certainly *not* an individually identifiable entity. I have dwelt on this point at length elsewhere ["Endeavour", Vol.IX, Number 35, July 1950; reprinted in the Smithsonian Institution Report for 1950, pp. 183, - 196; in German "Die Pyramide", Jan. and Feb. 1951 (Austria)]. The second point is the paramount importance of what is sometimes called "second quantization".

To begin with, if a particle is not a permanent entity, then of the four difficulties labelled above, (i) is removed. As regards (ii), the quantization of de Broglie's waves around a nucleus welds into one comprehensive scheme all the 3n-dimensional reprasentations that I had. proposed for the n-body problems. It is not an easy scheme, but it is logically clear and it can be so framed that only

the *mutual* Coulomb energies enter.

As regards (iii) – keeping to the example of black body radiation – the situation is this. If the radiation is quantized each radiation oscillator (proper mode) obtains the frequencies or levels *nhv*. This is sufficient to produce Planck's formula for the radiation in a cavity surrounded by a huge heat bath. I mean to say, the level scheme suffices: it is not necessary to assume that each oscillator *is* at one of its levels, which is absurd from any point of view. The same holds for all thermodynamical equilibria. I have actually given a general proof of this in the last of my "Collected Papers" (English version: Blackie and Son, Glasgow 1928). A better presentation is added as an appendix to the forthcoming 2nd impression of "Statistical Thermodynamics" (Cambridge University Press).

Under (iv) we alluded to a vast range of phenomena purported to be conclusive evidence for the transfer of whole quanta. But I do not think they are, provided only that one holds on to the wave aspect throughout the whole process. One must, of course, give up thinking of e.g. an electron as of a tiny speck of something moving within the wave train along a mysterious unknowable *path*. One must regard the "observation of an electron" as an*event* that occurs within a train of de Broglie waves when a contraption is interposed in it which by its very nature cannot but answer by discrete responses: a photographic emulsion, a luminescent screen, a Geiger counter. And one must, to repeat this, hold on to the wave aspect throughout. This includes, that the equations between frequencies and frequency differences, expressing the resonance condition that governs wave mechanics throughout, must *not* be multiplied by Planck's constant *h* and then interpreted as tiny energy balances of microscopic processes between tiny specks of something that have, to say the least, no permanent existence.

This situation calls for a revision of the current interpretation, which involves computing transition probabilities from level to level, and disregards the fact that the wave equation, with few exceptions if any, indicates nothing of the sort, but leads each of the reacting systems into a state composed of a wide spread of energy eigenstates. To assume that the system actually leaps into just one of them which is selected by "playing dice", as it were, is not only gratuitous, but as was pointed out above, contradicts in most cases even the current interpretation. These inconsistencies will be avoided by returning to a wave theory that is not continually abrogated by dice-miracles; not of course to the naive wave theory of yore, but to a more sophisticated one, based on second quantization and the non-individuality of "particles". Originating from contraptions that by their very nature cannot but give a discrete, discontinuous response, the probability aspect has unduly entered the fundamental concepts and has domineeringly dictated the basic structure of the present theory.

In giving it up we must no longer be afraid of losing time-honoured atomism. It has its counterpart in the level-scheme (of second quantization) and nowhere else. It may be trusted to give atomism its due, without being aided by dice-playing.

To point here to the general failure of the present theory to obtain finite transition probabilities and finite values of the apparent mass and charge, might seem a cheap argument and a dangerous one

at that. The obvious retort would be: Can you do better, sir? Let me frankly avow that I cannot. Still I beg to plead that I am at the moment groping for my way almost single-handed, as against a host of clever people doing their best along the recognized lines of thought.

But let me still draw attention to a point that is seldom spoken of. I called the probability interpretation a scheme of admirable logical consistency. Indeed it gives us a set of minute prescriptions, not liable ever to be involved in contradiction, for computing the probability of a particular outcome of any intended measurement, given the wave function and the hermitian operator associated with that particular measuring device. But, of course, an abstract mathematical theory cannot possibly indicate the rules for this *association* between operators and measuring devices. To describe one of the latter is a long and circumstantial task for the experimentalist. Whether the device which he recommends really corresponds to the operator set up by the theorist, is not easy to decide. Yet this is of paramount importance. For a measuring appliance means now much more than it did before the advent of quantum mechanics and of its interpretation which I am opposing here. It has a physical influence on the object; it is deemed to press it infallibly into one of the eigenstates of the associated operator. If it fails to put it in an eigenstate belonging to the value resulting from the measurement, the latter is quantum-mechanically not repeatable. I cannot help feeling that the precariousness of the said association makes that beautiful, logically consistent theoretical scheme rather void. At any rate its contact with actual laboratory work is very different from what one would expect from its fundamental enunciations.

A further discussion of the points raised in this paper can be found in a forthcoming longer (but equally non-mathematical) essay in the British Journal for the Philosophy of Science.

(Dublin. Institute for Advanced Studies)

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Über den Äther (Einstein)

Über den Äther

Von

Prof. Dr. Albert Einstein (Berlin)
Wenn hier vom Äther die Rede ist, so soll es sich natürlich nicht um den körperlichen Äther der mechanischen Undulationstheorie handeln, welcher den Gesetzen der Newtonschen Mechanik unterliegt, und dessen einzelnen Punkten eine Geschwindigkeit zugeteilt wird. Dies theoretische Gebilde hat nach meiner Überzeugung seit der Aufstellung der speziellen Relativitätstheorie seine Rolle endgültig zu Ende gespielt. Es handelt sich vielmehr allgemeiner um diejenigen als physikalisch-real gedachten Dinge, welche neben der aus elektrischen Elementarteilchen bestehenden ponderabeln Materie im Kausal-Nexus der Physik eine Rolle spielen. Man könnte statt von „Äther" also ebensogut von „physikalischen Qualitäten des Raumes" sprechen. Nun könnte allerdings die Meinung vertreten werden, dass unter diesen Begriff *alle* Gegenstände der Physik fallen, weil nach der konsequenten Feldtheorie auch die ponderable Materie, bzw. die sie konstituierenden Elementarteilchen als „Felder" besonderer Art, bzw. als besondere „Raum-Zustände" aufzufassen seien. Indessen wird man zugeben müssen, dass beim heutigen Stande der Physik eine solche Auffassung verfrüht wäre, denn bisher sind alle auf dies Ziel gerichteten Bemühungen der theoretischen Physiker gescheitert. So sind wir beim heutigen Stand der Dinge faktisch gezwungen, zwischen „Materie" und „Feldern" zu unterscheiden, wenn wir auch hoffen dürfen, dass spätere Generationen diese dualistische Auffassung überwinden und durch eine einheitliche ersetzen werden, wie es die Feldtheorie in unseren Tagen vergeblich versucht hat.

Man glaubt gewöhnlich, dass die Physik Newtons keinen Äther gekannt habe, sondern dass erst die Undulationstheorie des Lichtes [86] ein allgegenwärtiges, die physikalischen Phänomene mitbedingendes Medium eingeführt habe. Dies ist jedoch nicht der Fall. Die Newtonsche Mechanik hat ihren „Äther" in dem angedeuteten Sinne, der allerdings als „absoluter Raum" bezeichnet wird. Um dies klar zu erkennen und gleichzeitig den Äther-Begriff etwas schärfer herauszuarbeiten, müssen wir ein wenig ausholen.

Wir betrachten zuerst einen Zweig der Physik, der ohne Äther auskommt, nämlich die

Geometrie Euklids, aufgefasst als die Lehre von den möglichen Arten, praktisch starre Körper miteinander in Berührung zu bringen. (Von den Lichtstrahlen, die ebenfalls bei der Entstehung der Begriffe und Gesetze der Geometrie beteiligt sein mögen, sehen wir hier ab.) Die Lagerungs-Gesetze fester Körper bei Ausschluss von relativen Bewegungen, Temperaturen und Deformationseinflüssen, wie sie idealisiert in der Geometrie Euklids niedergelegt sind, kommen mit dem Begriff des starren Körpers aus; irgend welche Milieu-Einflüsse, die als unabhängig von den Körpern vorhanden und als auf die Körper wirkend und ihre Lagerungs-Gesetze beeinflussend gedacht würden, kennt die euklidische Geometrie nicht. Dasselbe gilt von den nicht-euklidischen Geometrien konstanter Krümmung, wenn diese als (denkbare) Naturgesetze der Körper-Lagerung aufgefasst werden. Anders wäre es, wenn man eine Geometrie variabler Krümmung anzunehmen sich genötigt sähe; dies würde bedeuten, dass die möglichen Berührungslagerungen von praktisch starren Körpern in verschiedenen Fällen verschieden, von Milieu-Einflüssen bedingt wäre. Hier müsste man im Sinne unserer Betrachtung sagen, eine solche Theorie bediene sich einer Äther-Hypothese. Ihr Äther wäre etwas physikalisch Reales, so gut wie die Materie. Wären die Lagerungsgesetze durch physikalische Faktoren, wie Anhäufung und Bewegungszustand von Körpern in der Umgebung usw., nicht beeinflussbar, sondern unverrückbar gegeben, so würde man diesen Äther als „absolut“ (d. h. unabhängig von Einflüssen irgend welcher anderer Gegenstände) bezeichnen.

Ebensowenig wie die euklidische (physikalisch interpretierte) Geometrie einen Äther braucht, ebensowenig bedarf die Kinematik oder Phoronomie der klassischen Mechanik eines solchen; ihre Sätze haben einen klaren physikalischen Sinn, wenn nur angenommen wird, dass die in der speziellen Relativitätstheorie angenommenen Einflüsse der Bewegung auf Maßstäbe und Uhren nicht existieren. [87]

Anders in der Dynamik Galileis und Newtons. Das Bewegungsgesetz „Masse × Beschleunigung = Kraft“ enthält nicht nur eine Aussage über materielle Systeme, auch dann nicht, wenn, wie bei Newtons astronomischem Fundamentalgesetz die Kraft durch Abstände, also durch Grössen ausgedrückt ist, deren Realdefinition auf Messungen mit starren Messkörpern gegründet werden kann. Denn die Realdefinition der Beschleunigung kann nicht restlos auf Beobachtungen an starren Körpern und Uhren gegründet werden. Sie kann nicht zurückgeführt werden auf die messbaren Abstände zwischen den das mechanische System konstituierenden Punkten. Man bedarf zu ihrer Definition noch eines Koordinationssystems, bzw. Bezugskörpers von geeignetem Bewegungszustand. Wird der Bewegungszustand des Koordinatensystems anders gewählt, so gelten inbezug auf dasselbe die Newtonschen Gleichungen nicht. In jenen Gleichungen tritt gleichsam das Milieu, in welchem die Körper bewegt sind, implicite als realer Faktor im Bewegungsgesetze auf neben den realen Körpern und ihren durch Messkörper definieraren Abständen. InNewtons Bewegungslehre besitzt der „Raum“ physikalische Realität — im Gegensatz zu Geometrie und Kinematik. Wir wollen dies physikalisch Reale, welches neben den beobachtbaren ponderabeln Körpern in das Newtonsche Bewegungsgesetz eingeht, als „Äther der Mechanik” bezeichnen. Das Auftreten von Zentrifugalwirkungen bei einem (rotierenden) Körper, dessen materielle Punkte ihre Abstände gegeneinander nicht ändern, zeigt, dass dieser Äther nicht nur als ein Phantasiegebilde der Newtonschen Theorie aufzufassen ist, sondern dass ihm etwas Reales in der Natur entspricht.

Wir sehen, dass für Newton der „Raum“ etwas physikalisch Reales war, trotz der merkwürdig indirekten Art, in welcher dieses Reale zu unserer Kenntnis gelangt. Ernst Mach, der als Erster nach Newton das Fundament der Mechanik einer tiefen Analyse unterzog, hat dies klar erkannt. Er suchte der Hypothese des „Äthers der Mechanik“ dadurch zu entgehen, dass er die Trägheit auf unvermittelte Wechselwirkung zwischen der ins Auge gefassten Masse und allen übrigen Massen der Welt zurückzuführen suchte. Diese Auffassung ist zwar logisch möglich, kommt aber als Fernwirkungstheorie für uns heute nicht mehr ernsthaft in Betracht. Der mechanische Äther, von Newton als „absoluter Raum“ bezeichnet, muss uns also als physikalische Realität gelten. Natürlich darf aber [88] der Ausdruck „Äther“ nicht dazu verleiten, dass man sich wie die Physik des 19. Jahrhunderts etwas der ponderabeln Materie Analoges darunter denke.

Wenn Newton den Raum der Physik als „absolut“ bezeichnet, so denkt er noch an eine andere Eigenschaft dessen, was wir hier „Äther“ nennen. Jedes physikalische Ding beeinflusst andere und wird umgekehrt im allgemeinen von anderen beeinflusst. Letzteres trifft aber für den Äther der Newtonschen Mechanik nicht zu. Die trägheitspendende Eigenschaft des letztern ist nämlich gemäss der klassischen Mechanik durch nichts beeinflussbar, weder durch die Konfiguration der Materie, noch durch sonst etwas; insofern kann man ihn als „absolut“ bezeichnen.

Dass für die Bevorzugung der Inertialsysteme gegenüber den Nicht-Inertialsystemen ein reales Ding als Ursache vorausgesetzt werden müsse, wurde den Physikern erst in den letzten Jahren deutlich. Historisch ist die Äther-Hypothese in ihrer heutigen Gestalt aus der mechanischen Äther-Hypothese der Optik durch Sublimierung hervorgegangen. Nach langen, unfruchtbaren Bemühungen kam man zu der Überzeugung, dass das Licht nicht als Bewegung eines trägen, elastischen Mediums aufzufassen sei, dass die elektromagnetischen Felder der Maxwellschen Theorie überhaupt nicht mechanisch gedeutet werden könnten. Die elektromagnetischen Felder wurden so unter dem Druck dieser Misserfolge allmählich als letzte, irreduzible, physikalische Realitäten, als nicht mehr weiter erklärbare Zustände des Äthers betrachtet. Was dem Äther von der mechanischen Theorie zunächst noch blieb, das war sein bestimmter Bewegungszustand; er verkörperte gewissermassen eine „absolute Ruhe“. Waren in der Newtonschen Mechanik wenigstens alle Inertialsysteme gleichberechtigt, so schien der Maxwell-Lorentzschen Theorie der Bewegungszustand des berechtigten Koordinatensystems (Ruhe gegen den Äther) völlig determiniert zu sein. Man nahm stillschweigend an, dass dies bevorzugte System gleichzeitig ein Inertialsystem sei, d. h. dass relativ zum elektromagnetischen Äther das Trägheitsprinzip gelte.

Noch in einer zweiten Weise verschob sich unter dem Einfluss der Maxwell-Lorentzschen Theorie die grundsätzliche Auffassung der Physiker. Nachdem die elektromagnetischen Felder als fundamentale, irreduzible Wesenheiten aufgefasst worden waren, [89] schienen sie berufen zu sein, der ponderabeln trägen Masse auch in der Mechanik ihre grundlegende Bedeutung zu rauben. Es wurde aus den Maxwellschen Gleichungen geschlossen, dass ein bewegter elektrisch geladener Körper von einem Magnetfelde umgeben sei, dessen Energie in erster Näherung quadratisch von der Geschwindigkeit abhängig ist. Was lag näher, als *alle* kinetische Energie als elektromagnetische Energie aufzufassen? Man konnte so hoffen, die Mechanik auf die Elektromagnetik zurückzuführen, nachdem

zuvor die Zurückführung der elektromagnetischen Vorgänge auf die mechanischen misslungen war. Dies schien umso hoffnungsvoller, als es immer wahrscheinlicher wurde, dass alle ponderable Materie aus elektrischen Elementarteilchen aufgebaut sei. Indessen konnte man zweier Schwierigkeiten nicht Herr werden. Erstens nämlich konnten dieMaxwell-Lorentzschen Gleichungen nicht verständlich machen, wieso die ein elektrisches Elementarteilchen konstituierende elektrische Ladung trotz der elektrostatischen Abstossungskräfte im Gleichgewicht existieren kann. Zweitens vermochte die elektromagnetische Theorie die Gravitation nicht einigermassen natürlich und befriedigend zu erklären. Trotzdem waren die Erfolge, welche die elektromagnetische Theorie der Physik brachte, so bedeutende, dass sie als vollkommen gesicherter Besitz der Physik, ja als deren am besten fundierte Errungenschaft betrachtet wurde.

Die Maxwell-Lorentzsche Theorie beeinflusste endlich dadurch unsere Einstellung zu den Fragen des theoretischen Fundamentes, dass sie zu der Aufstellung der speziellen Relativitätstheorie führte. Man erkannte, dass die elektromagnetischen Gleichungen in Wahrheit gar keinen bestimmten Bewegungszustand auszeichnen, sondern dass nach diesen Gleichungen ebenso wie nach der klassischen Mechanik eine unendliche Mannigfaltigkeit von gegeneinander gleichförmig bewegten Koordinatensystemen gleich berechtigt seien, wenn man nur passende Transformationsformeln für die räumlichen Koordinaten-und die Zeit anwendet. Es ist wohlbekannt, dass diese Erkenntnis eine tiefe Modifikation der Kinematik und Dynamik im Gefolge hatte. Dem Äther der Elektrodynamik war nun kein bestimmter Bewegungszustand mehr zuzuschreiben. Er bewirkte nun — wie der Äther der klassischen Mechanik — nicht die Bevorzugung eines bestimmten *Bewegungs*-Zustandes, sondern nur die Bevorzugung eines bestimmten *Beschleunigungs*-Zustandes. Dadurch, [90] dass in einem absoluten Sinne nicht mehr von gleichzeitigen Zuständen an verschiedenen Stellen des Äthers gesprochen werden konnte, wurde der Äther gewissermassen vierdimensional, denn es gab keine objektive Ordnung seiner Zustände nach der Zeit allein. Auch nach der speziellen Relativitätstheorie war der Äther absolut, denn sein Einfluss auf Trägheit und Lichtausbreitung war als unabhängig gedacht von physikalischen Einflüssen jeder Art. Während in der klassischen Physik die Körper-Geometrie als unabhängig vom Bewegungszustande vorausgesetzt wird, sind gemäss der speziellen Relativitätstheorie die Gesetze der euklidischen Geometrie für die Lagerung von relativ zu einander ruhenden Körpern nur dann massgebend, wenn diese Körper relativ zu einem Inertialsystem in Ruhe sind;[1] dies kann leicht aus der sogenannten Lorentz-Kontraktion geschlossen werden. Also wird die Körpergeometrie wie die Dynamik vom Äther mitbedingt.

Die allgemeine Relativitätstheorie beseitigt einen Übelstand der klassischen Dynamik: nach letzterer erscheinen Trägheit und Schwere als ganz verschiedene, voneinander unabhängige Erscheinungen, trotzdem sie beide durch dieselbe Körperkonstante, die Masse, bedingt werden. Die Relativitätstheorie überwindet diesen Mangel, indem sie das dynamische Verhalten des elektrisch neutralen Massenpunktes durch das Gesetz der geodätischen Linie festlegt, in welchem die Trägheits- und Schwerewirkungen nicht mehr auseinandergehalten sind. Dabei legt sie dem Äther von Punkt zu Punkt variable, die Metrik und das dynamische Verhalten materieller Punkte bestimmende Eigenschaften bei, welche ihrerseits durch physikalische Faktoren, nämlich durch die Verteilung von Masse bezw. Energie bestimmt sind. Der Äther der allgemeinen Relativitätstheorie unterscheidet sich

also von demjenigen der klassischen Mechanik bezw. der speziellen Relativitätstheorie dadurch, dass er nicht „absolut", sondern in seinen örtlich variablen Eigenschaften durch die ponderable Materie bestimmt ist. Diese Bestimmung ist dann eine vollständige, wenn die Welt räumlich endlich und in sich geschlossen ist. Dass es in der allgemeinen Relativitätstheorie keine bevorzugten, mit der Metrik eindeutig verknüpften raumzeitlichen Koordinaten gibt, ist mehr für die [91] mathematische Form dieser Theorie als für ihren physikalischen Gehalt charakteristisch.

Auch mit der Anwendung des formalen Apparates der allgemeinen Relativitätstheorie gelang es nicht, alle Massenträgheit auf elektromagnetische Felder, überhaupt auf Felder, zurückzuführen. Auch sind wir bis jetzt nach meiner Ansicht über eine äusserliche Einordnung der elektromagnetischen Kräfte in das Schema der allgemeinen Relativitätstheorie nicht hinausgekommen. Der die Gravitations- und Trägheitserscheinungen mitbestimmende metrische Tensor einerseits und der Tensor des elektromagnetischen Feldes anderseits, erscheinen nach wie vor als wesensverschiedene Ausdrücke des Ätherzustandes, deren logische Unabhängigkeit man wohl weit eher auf das Konto der Unvollkommenheit unseres theoretischen Gebäudes als auf dasjenige einer komplexen Struktur der Wirklichkeit zu setzen geneigt sein wird.

Zwar haben Weyl und Eddington durch Verallgemeinerung der Riemannschen Geometrie ein mathematisches System gefunden, welches beide Feldarten als unter einem einheitlichen Gesichtspunkte vereinigt erscheinen lässt. Aber die einfachsten Feldgesetze, welche jene Theorie liefert, scheinen mir nicht zu Forschritten der physikalischen Erkenntnis zu führen. Überhaupt scheint es heute, dass wir von einer Kenntnis der elektromagnetischen Elementargesetze viel weiter entfernt sind, als es am Anfange dieses Jahrhunderts der Fall zu sein schien. Zur Begründung dieser Meinung möchte ich hier noch kurz auf das *Problem des magnetischen Erd- und Sonnenfeldes* sowie auf das *Problem der Lichtquanten* hinweisen, welche Probleme gewissermassen die Grobstruktur und die Feinstruktur des elektromagnetischen Feldes betreffen.

Erde und Sonne besitzen Magnetfelder, deren Orientierung und Sinn mit der Drehaxe dieser Himmelskörper in annäherndem Zusammenhang stehen. Nach der Maxwellschen Theorie könnten jene Felder von elektrischen Strömen herrühren, welche entgegengesetzt der Drehbewegung um die Drehachse der Himmelskörper herum fliessen. Auch die Sonnenflecken, welche mit guten Gründen als Wirbel aufgefasst werden, besitzen analoge, sehr kräftige Magnetfelder. Es ist aber kaum denkbar, dass in allen diesen Fällen elektrische Leitungs-, bzw. Konvektionsströme von hinreichender Stärke wirklich vorhanden seien. Es sieht vielmehr so aus, wie wenn zyklische Bewegungen neutraler Massen Magnetfelder erzeugten. Weder die [92] Maxwellsche Theorie in ihrer ursprünglichen Fassung noch die im Sinne der allgemeinen Relativitätstheorie erweiterte Maxwellsche Theorie lassen eine derartige Feldererzeugung voraus sehen. Hier scheint uns die Natur auf einen fundamentalen, bis jetzt theoretisch noch nicht erfassten Zusammenhang hinzuweisen.[2]

Handelte es sich soeben um einen Fall, welchem die Feldtheorie in ihrer gegenwärtigen Gestalt nicht gewachsen zu sein scheint, so drohen die in der *Quantentheorie* zusammengefassten Tatsachen und Gedanken das Gebäude der Feldtheorie überhaupt zu sprengen. Es mehren sich nämlich die

Argumente dafür, dass die Lichtquanten als physikalische Realitäten aufzufassen seien, dass das elektromagnetische Feld nicht als letzte Realität angesehen werden könne, auf welche die anderen physikalischen Dinge zurückgeführt werden könnten. Nachdem die Theorie der Planckschen Formel schon gezeigt hatte, dass die Übertragung von Energie und Impuls durch die Strahlung so erfolgt, wie wenn letztere aus mit der Lichtgeschwindigkeit *c* bewegten Atomen von der Energie *hν* und von dem Impuls $\frac{h\nu}{c}$ bestünde, hat Compton durch Versuche über die Zerstreuung von Röntgenstrahlen an Materie nachgewiesen, dass Zerstreuungs-Akte auftreten, bei welchen Lichtquanten auf Elektronen stossen und diesen einen Teil ihrer Energie übertragen, wobei die Lichtquanten ihre Energie und Richtung ändern. Tatsache ist wenigstens, dass die Röntgenstrahlen solche (von Debye und Compton vorhergesehene) Frequenzänderungen bei ihrer Zerstreuung erfahren, wie es die Quantenhypothese erfordert.

Vor kurzem ist ferner eine Arbeit des Inders Bose über die Ableitung der Planckschen Formel erschienen, die aus folgendem [93] Grunde für unsere theoretische Auffassung von besonderer Bedeutung ist: Bisher wurde bei allen vollständigen Ableitungen der Planckschen Formel irgendwie von der Hypothese der Undulations-Struktur der Strahlung Gebrauch gemacht. So wurde z. B. der Faktor $\frac{8\pi h\nu^3}{c^3}$ dieser Formel bei der bekannten Ehrenfest-Debyechen Ableitung dadurch gewonnen, dass die Zahl der Eigenschwingungen des Hohlraumes gezählt wurden, welche zum Frequenzbereiche *dν* gehören. Bose ersetzt diese auf die Vorstellungen der Undulationstheorie gegründete Abzählung durch eine gastheoretische Rechnung, die er auf ein in dem Hohlraum befindliches, nach Art eines Moleküls gedachtes Lichtquant bezieht. Da drängt sich die Frage auf, ob nicht doch einmal die Beugungs- und Interferenz-Erscheinungen derart an die Quantentheorie angeschlossen werden könnten, dass die feldartigen Begriffe der Theorie nur Ausdrücke der Wechselwirkungen zwischen Quanten darstellen, wobei dem Felde keine selbständige physikalische Realität mehr zugeschrieben würde.

Die wichtige Tatsache, dass nach der Bohrschen Theorie die Frequenz der emittierten Strahlung nicht bestimmt wird durch elektrische Massen, die periodische Vorgänge von *derselben* Frequenz durchlaufen, kann uns nur bestärken in diesem Zweifel an der selbständigen Realität des Undulationsfeldes.

Aber selbst wenn diese Möglichkeiten zu wirklichen Theorien heranreifen, werden wir des Äthers, d. h. des mit physikalischen Eigenschaften ausgestatteten Kontinuums, in der theoretischen Physik nicht entbehren können; denn die allgemeine Relativitätstheorie, an deren grundsätzlichen Gesichtspunkten die Physiker wohl stets festhalten werden, schliesst eine unvermittelte Fernwirkung aus; jede Nahewirkungs-Theorie aber setzt kontinuierliche Felder voraus, also auch die Existenz eines „Äthers“.

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The Red Pill..

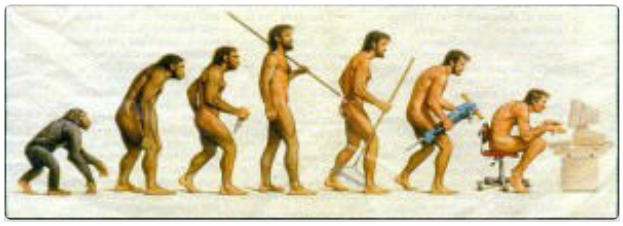
It's the question that drives us⋯

Menu

About Me

What defines me are both my curiosity and passion to learn more about how our world works. I always prefer the red over the blue pill – no matter how painful the truth is, even if it changes my world view. I even got my genome sequenced recently, which is pretty crazy given that you never know what might lurk in those genes (luckily, I do not have the "Angelina Jolie" gene, but I now have definitive confirmation that I am in fact a fast caffeine metabolizer :-).

I got my PhD in scientific computing at the ETH Zürich – after I did a Masters in Biochemistry – which is even more evidence that I am a crazy person (at least at that time, the professors thought I was :-). But at least I know I am crazy, so that probably makes me less dangerous.



After my PhD I spent 8 years in San Diego, California, where I worked in the biotech industry as a software engineer (all the way from robotics to biofuels), and currently I am developing software for IonTorrent (PGM – the personal genome machine) for Thermo Fisher Scientific, in the context of personalized medicine.

My hobbies include even more software engineering, physics, Karate and playing the violin.

Contact: **croth** and then the **at** symbol **nobilitas** the dot **com**

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3. Emerging Gravity from Defects in World Crystal: http://www.sbfisica.org.br/bjp/files/v35_359.pdf
4. De Felice, F. On the gravitational field acting as an optical medium. Gen. Relativ. Gravit. 2,347–357 (1971).
5. On the optical-mechanical analogy in general relativity: http://arxiv.org/abs/0905.4479 , http://www2.ups.edu/physics/faculty/evans/Optical%20Mechanical%20GRG.pdf
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8. Mimicking general relativity with Newtonian Dynamics: http://www.hindawi.com/journals/isrn.mathematical.physics/2012/260951/
9. A Table-Top Test for General Relativity? http://www.universetoday.com/35384/a-table-top-test-of-general-relativity/
10. A condensed Matter Interpretation of SM Fermions and Gauge Fields (Ilja Schmelzer): http://link.springer.com/article/10.1007%2Fs10701-008-9262-9, http://arxiv.org/abs/arXiv:0908.0591
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13. General Relativity in Electrical Engineering: http://www.int.kit.edu/downloads/RG_Pernice/Paper21.pdf
14. Lorentz Contraction of Space and the Gravitational Field: http://vixra.org/pdf/1008.0023v2.pdf
15. Surprising Connections Between General Relativity and Condensed Matter:

http://arxiv.org/abs/1010.2784

Optical Black Holes:

1. First black hole for light created on Earth: http://www.newscientist.com/article/dn17980-first-black-hole-for-light-created-on-earth.html#.UwiBW_l5M1I
2. Physicists Make Artificial Black Hole Using Optical Fiber: http://spectrum.ieee.org/aerospace/astrophysics/physicists-make-artificial-black-hole-using-optical-fiber
3. Analytical Theory of Optical Black Hole Analogues: http://arxiv.org/abs/1209.5148
4. Trapping light by mimicking gravitational lensing: http://www.nature.com/nphoton/journal/v7/n11/full/nphoton.2013.247.html
5. Creating Optical Black Holes to Produced Super Solar Cells: http://www.dailygalaxy.com/my_weblog/2009/10/-creating-micro-black-holes-to-produce-super-solar-cells.html
6. 'Black hole' made from light: http://www.nature.com/news/2008/080306/full/news.2008.651.html

Phonons: Particles of Sound

1. Definitions of Phonons: http://physics.about.com/od/physicsmtop/g/phonon.htm, http://en.wikipedia.org/wiki/Phonon
2. Double slit experiments with phonons: http://nelson.mit.edu/node/178
3. Fantastic Phonons: http://www.sciencedaily.com/releases/2013/11/131113143215.htm
4. Black body analogue for phonon: http://en.wikipedia.org/wiki/Debye_model
5. Polaritons: http://en.wikipedia.org/wiki/Polariton
6. Photoelectric Effect: http://en.wikipedia.org/wiki/Photoelectric_effect
7. Chapter 6.5 in Material Science

Matter waves

- http://en.wikipedia.org/wiki/Matter_wave^
- Quantum Interference Experiments with Large Molecules: http://130.58.92.210/Students/phys%205_2010/zeilinger%20ajp%202003.pdf
- Double slit with single electrons: http://physicsworld.com/cws/article/news/2013/mar/14/feynmans-double-slit-experiment-gets-a-makeover
- Wave-particle duality of C60 molecules: http://www.nature.com/nature/journal/v401/n6754/abs/401680a0.html

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- Classical Wave Theory of Matter (by Robert Close): http://www.verumversa.com/ClassicalWaveTheoryOfMatter.pdf

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First Puzzle: Just a Probability?

Introduction

What if I told you that special relativity is not so complicated to understand and that even quantum mechanics may no be as weird as you think? In the pursuit of many (skeptical) questions, I found an intuitive yet completely equivalent way that explains these concepts. This model is not new, and it is not my idea, but unfortunately it has not gotten as much attention as the mainstream ideas.

With this first puzzle I have three goals:

1. to use this equivalent model to explain (potentially) difficult concepts such as (aspects of) general relativity, special relativity and quantum mechanics in a way such that a "normal" person can understand it (one who may not necessarily have a PhD in mathematics *and* physics :-)
2. to attempt to put these individual "puzzle pieces together" into one coherent picture that makes sense
3. to dare to ask the question whether this alternative model is not just for fun and nice pictures, but whether it may in fact represent reality – as it was suggested by such famous people as Schrödinger, Lorentz and even Einstein (see page on speeches).

Let me know what you think – and feel free to debate this topic!

[Puzzle Piece 6: Disentangling the Entanglement]

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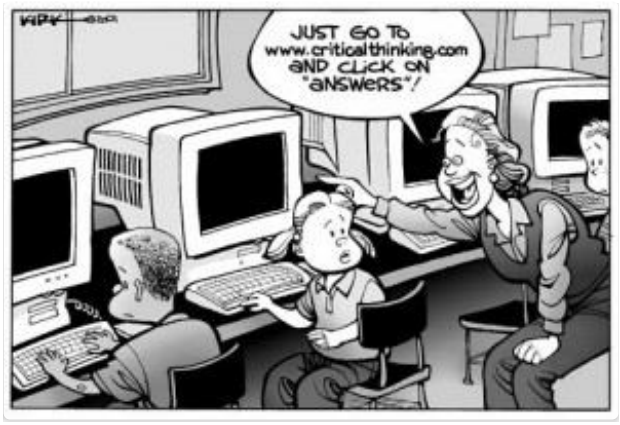
Menu

The Quest



I am not easily satisfied with answers to questions, and I am very skeptical. It doesn't matter who makes a claim, who wrote that paper, how long something has been established as a "fact", or what it is about. I won't believe it unless I completely understand it, and even then, I never stop to doubt - I doubt myself as well, because I know I am fallible and I make mistakes. I will be happy to change my mind if you can convince me that my current opinion is wrong :-).

I believe that in some respects we are not much better than in the middle ages: then as now there are certain "beliefs" we consider to be true (say, the Big Bang theory), which centuries from now may turn out to be completely wrong – and people will laugh at us for "believing" such crazy things (such as the idea of earth being flat, or the idea of Epicycles).

That is why I am open minded and will at least listen (skeptically) to ideas that others may not consider (or have forgotten about), because history tells us that once in a while people like Galileo come along with supposedly crazy ideas that bring science forward.

The question of course is: which of all of the scientific theories that we believe in now are wrong, and which ones turn out to be correct? To identify problems in current theories, and in order to make scientific discoveries, it does not help to simply nod and accept all mainstream ideas, but instead we should be asking critical questions.

Because of this, I have read countless books and papers about topics ranging from relativity to quantum mechanics all the way to economics, and I've had interesting discussions and debates with various people. So at some point, I thought it might be more efficient to collect and summarize these questions and discussions in a blog instead of repeating the same in yet another email :-).

This blog is an attempt to illustrate some of these questions and the line of thinking this has let me to, and to bring some of seemingly complicated ideas closer to the "normal" person, who may not have

a PhD both in physics *and* mathematics :-). My hope is that, at the very least, this will lead to interesting debates and discussions down the road. And maybe, some of you might be willing to swallow the red pill and live with the consequences :-).

I will start this blog around the topics of relativity and quantum mechanics, but may also discuss other questions in completely different areas.

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  http://www.scientificamerican.com/article/superfluid-spacetime-relativity-quantum-physics/

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Menu

Puzzles

Puzzles

First Puzzle: Just a Probability?

Is special relativity and quantum mechanics really as weird as advertised, and is our underlying reality just a probability? Or is there a common sense explanation that contains no magical elements?

Second Puzzle: Big Bang Questions

How well do the observations really the (inflationary) Big Bang model? Are there some unanswered questions, and what about alternative models?

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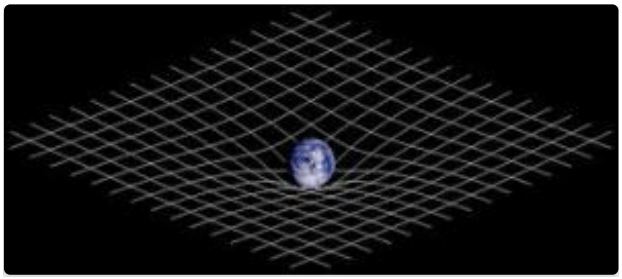
Puzzle Piece 1: Optical Black Holes and Particles of Sound

Space-time versus space-density

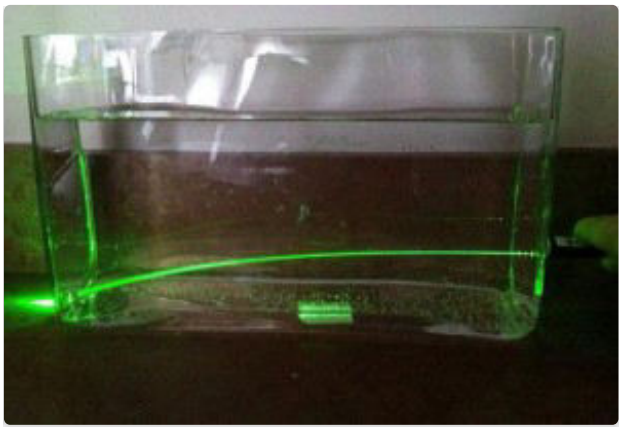
As you probably know, special relativity (SR) and general relativity (GR) are usually described using space-time, which is an interwoven continuum of 3 spacial and one time dimension. In this model, gravity is caused by the space-time curvature.



Typical image that shows a 2D version of the space-time curvature (from Wikipedia)

However, what many of you probably *don't* know is that there is a different but completely *equivalent* way to describe all this (the GR metric tensor), that does not use space-time, but ***space-density*** (Hagen Kleinerts World Crystal). This is an optical-mechanical analogy to GR, where gravity is not the result of "space-time curvature", but the result of refraction! (If you are wearing glasses, you know what refraction is: refraction causes a change in the angle of a wave due to the change in the medium, such as air -> glasses). You are probably thinking, what?! I know, this sounds odd, so just stick with me a bit and you will see that this not as weird as you may think – with an experiment you can do in the kitchen:

You also get refraction with a density gradient, such as in a Jell-O pudding with varying Jell-O concentration, or sugar water with a sugar gradient. The image below shows a rectangular container with water and sugar. There is more sugar at the bottom than on top. When you shine a laser pointer through it, the laser beam will bend because of the sugar gradient, which causes refraction. You can actually try this yourself :-).

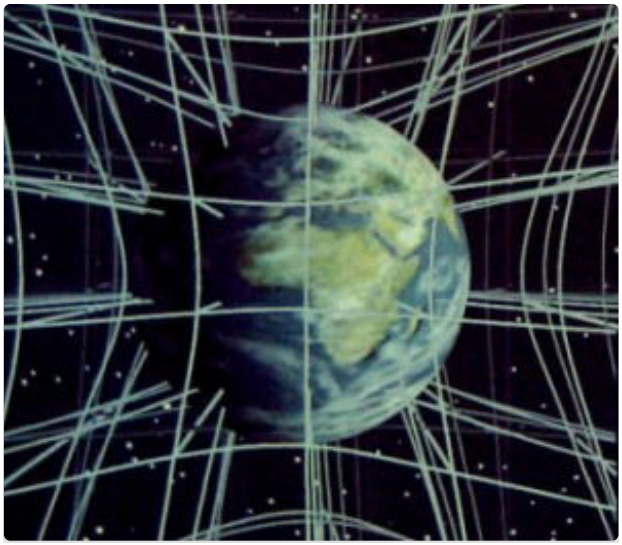


Bending of light in a sugar gradient

You are probably wondering, how this applies in any way to general relativity? In this model, instead of using space-time, we are working with space-density. What this means is that the space/vacuum in that model is not "empty", but is in fact like a huge⋯ crystal – or more generally: an elastic solid.

Ok, I can already hear the "but⋯?": the most important point first: this space/elastic solid, is **not** made of ordinary matter. Think of it more like "the fabric of space" or similar – an immaterial structure of some sort. And the question of "how in the world would we move through this solid" is not even the right question as you will see⋯ but one thing at time (I will try to address all of these "but⋯?" questions :-).

This elastic solid (just think of it as "space") is compressed in certain places – in places where there is more matter. Just like Einstein said: matter bends space, and this bent space "tells" matter how to move. Except we are not considering space-time, but space-density as our metric. For instance, space would be denser where the sun or a planet is compared to somewhere in outer space.



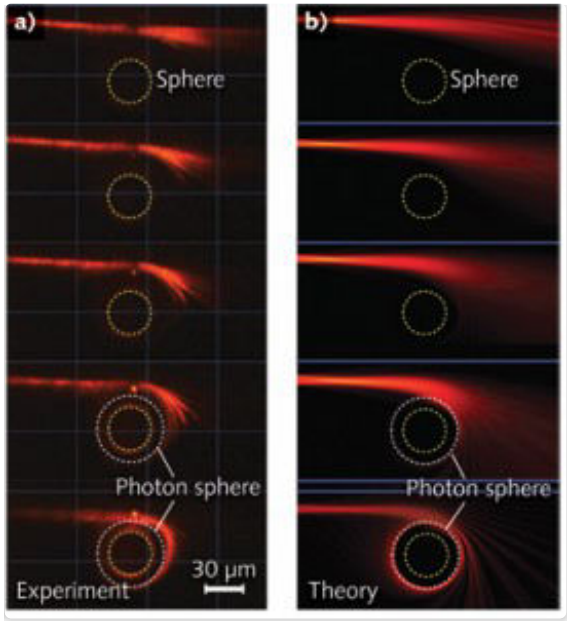
Curvature of space in a lattice model

Changes in density, as you can see with the Jell-O (or sugar gradient) causes changes in the refractive index, which means, light will always bend towards the areas of higher density. Hence, if space is denser where the sun is, light would (slightly) bend towards the sun. (This is similar to what people sometimes refer to as "the bending of space-time", except, that we are now using an elastic solid – like a Jell-O). This is not my crazy idea, I swear, there are many papers on this (see below), and as we explore this idea further, I hope you can see that it is not as silly as it may seem now!

***Note**: if you are thinking of the word "aehter" or "ether", forget it again, quickly, because there are just too many (wrong) interpretations of this word. This **not** like the "ether" that people were talking about (except Einstein, see his remarks in the speeches section!). First of all, that "ether" was sometimes considered to be a gas or a fluid. It has been shown in several experiments that this cannot be correct. Also, at that time, people did not know about quantum mechanics yet, and thought that matter would have to move "through" this "ether". As you will see later, this is a misleading question. The famous Michelsen-Morley experiment however did **not** disproof the model of "space as an elastic solid" model. The elastic solid model is completely equivalent to the "Minkowski space-time" model (see links below).*

Optical Black Holes

What if space gets so dense that the refractive index is so large that light can no longer escape? Then you get a black hole. The optical analogy does not just stop there – it is actually possible to create a real *optical* black hole, by using a material with a smoothly increasing refracting index. In this case, the refraction is such that the the light will always bend towards the center no matter from which direction the light originates:

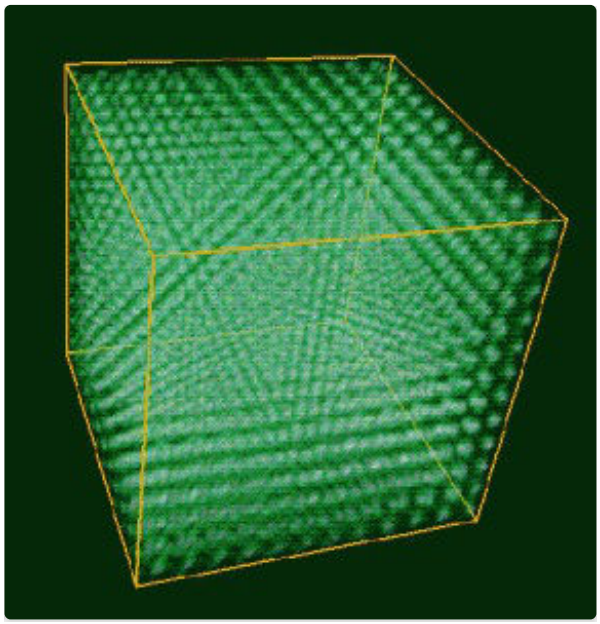


Of course this is nothing scary, and it is very real – people do this in the lab. It is simply a play with refraction. People are actually using this model now in the laboratory to study actual black holes (since the real ones are kind of difficult to create in the lab :-). Some people are even considering to build super solar cells that contain such optical black holes.

You may wonder, well this is all fine for light, since we know refraction works. The suggestion above was that this is actually equivalent to general relativity, so, this would also have to include *matter*, and surely, matter is totally different from light and there is no way there could be any kind of optical analogy, right? But before we dive into this, we will do an excursion into solid state physics.

Crystals and Elastic Solids

In solid state physics, people are often dealing with crystals and elastic solids. Now as it happens, crystal with defects and elastic solids with deformations can be described with the same non-Euclidean geometry as space with curvature and torsion (and the same way as the optical-mechanical analogy shown above). So a solid space with compression (and torsion) can be described the same way as actual, real crystals or elastic solids!

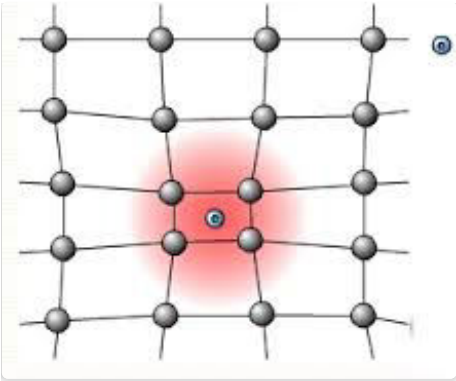


With the recent advances in solid state physics, there are more and more papers about this topic (see below), people are now using general relativity and apply it to crystals, and the other way around, they use crystals to learn more about general relativity. So this is no joke!

What do you think happens when you hit such a crystal (without breaking it :-)? We end up (among other things) with phonons, which are *quantized vibrations*, also called "particles of sound" or even "particles of heat"! Yep, no kidding!

Phonons: "Particles" of Sound

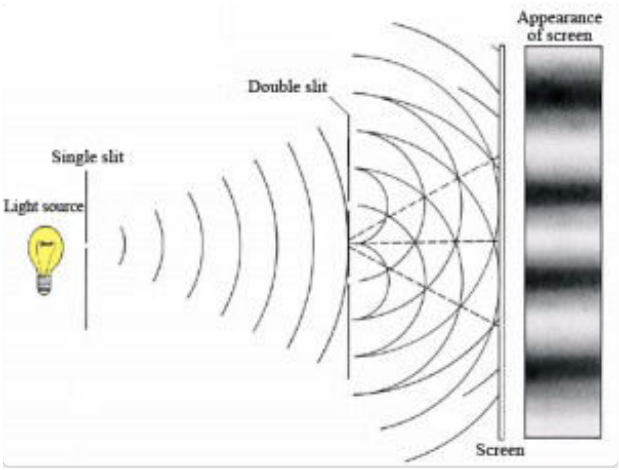
Why in the world would we use the word *particle* here? Clearly, a vibrating crystal (or a jiggling Jell-O) can be described with just vibrations (waves), and definitively not with "particles". Interestingly though, these vibrations actually exhibit a *particle-wave duality*, because their energy levels are quantized, just like photons! They are actually described using quantum mechanics, and even more, they are considered to be bosons, just like photons are.



honons – "Particles" of Sound

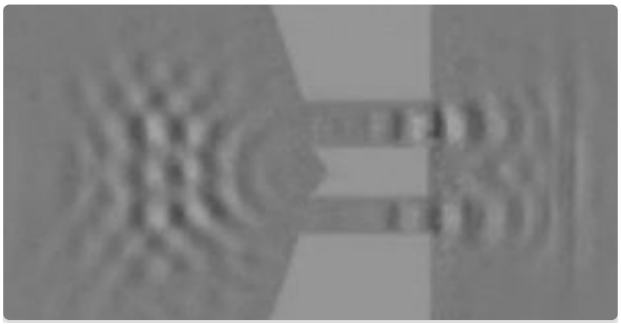
Like photons, the energy of a pho**n**on is E= $\hbar\omega$. So if they are described like photons and act like photons, would it be possible to create a phonon *laser*? A laser of sound, in a way? The answer is⋯ yes :-). In several recent articles researchers were able demonstrate "coherent phonons", which is the first step in constructing a "phonon laser" (more links at the bottom)

And would it actually be possible to do a *double slit experiment* with phonons, like we can do with photons?



The image above shows a typical double slit experiment. When light passes through two slits that are close to each other, then you see an interference pattern on the screen. This is one of the typical experiments to show the wave nature of light.

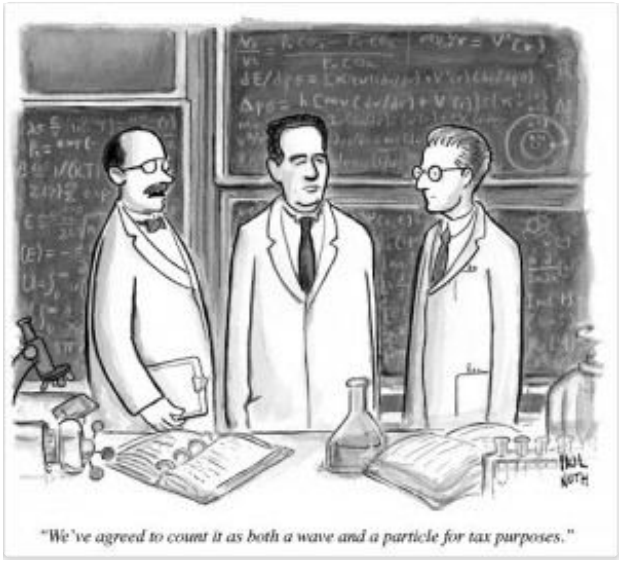
We can do just such a double slit experiment with **phonons** (in this case: polaritons). Below is an image from a video from MIT about just such an experiment (video link). I think that's quite amazing! Why? Because of all the mystery surrounding that "magical and weird" double slit experiment, where nobody seems to be able to give a clear answer of what exactly happens (is it "consciousness" collapsing the wave function? Is it parallel universes?)



Yet here we are, with the same kind of experiment, with quasi-particles that exhibit the same wave-particle duality as photons, yet, where is the magic? Where is the weirdness? These phonons are clearly waves, and exhibit the same behavior as photons and produce the typical interference pattern in a double slit experiment. Here it is clear that all that happens is that actual waves/vibrations are moving in a crystal, and interfere with each other. The waves are spatially spread out, and so can influence parts of the wave on the other side of the slit. We don't need consciousness to do anything here, we don't need parallel universes either.

Let's get back to the "Crystal Universe" idea by Hagen Kleinert: in this model, the universe (you can use the word space or vacuum), is basically just like such a crystal (or at least, an elastic solid – like a firm Jell-O – but not made of ordinary matter!). In this model (whether real or not), photons would in fact be exactly like phonons. They would indeed be *true waves*, vibrations in that "solid space". This "crystal" may be discrete or not. If it is, then the lattice size must be around the Planck length (since this is the smallest known length). But, as an approximation, as long as the frequency of the phonon or photon is large compared to the lattice size, the calculation is the same as for a *continuous* medium (see chapter 6.5 in "Materials Science"). (Personally, my guess would be that it is discrete – in a later post I will add more speculative thoughts on this and possible experiments on how to distinguish the two models)

Most (mainstream) physicists (except for instance Schrödinger!) will tell you that in he case of photons, we are dealing with a "probability density function" and not *real* waves. They will tell you that the result of the double slit experiment can only be explained by one of several ("weird") explanations, including: parallel worlds, the Copenhagen interpretations (that somehow looking at something decides the outcome), the many minds interpretation and several other models. All except basically that photons are simply… (quantized) waves :-).



Yet at the same time, in the case of phonons in a crystal (and any other quasi particles!), which are described just like photons, there is nothing magical or weird at all, and none of the same physicists above would claim otherwise. We definitively don't need parallel universes to explain the interference

pattern of phonons. And we don't need any "conscious observer" to cause a "wave function collapse" in a phonon – there is a paper on this:

> *"The quantum mechanical properties of phonons in a one-dimensional lattice are studied, with the conclusion that the phonon behaves in all essential respects as a normal quantum particle. "Wavefunction collapse" of the phonon state is shown to occur in an automatic way when an observation is made. This gives possible insight concerning the nature of wavefunction collapse in the general particle case"*

It is simply a matter (no pun intended) of waves that are interacting with each other, cancelling each other out at some places, and when being "measured", transforming into another wave (or interacting with another wave). Doesn't that make you wonder if we really do need all that weirdness in the case of photons? Of course, you might consider the idea of "solid universe" weird (I first did). But maybe if all the other "weirdness" vanishes, maybe it is not so weird at all.

You are probably thinking, well photons is one thing, but matter has got to be completely different though, after all we are dealing with actual "particles" there such as protons and electrons, right? Clearly, the analogy ends here, or does it? I mean, how would particles move through a solid space? (That's actually a misleading question, as you will see in a later post)

Puzzle Piece 2: What's the Matter with Matter?

Summary

At the end of each post, I will update this table that shows the differences between the two models that we have seen so far – the mainstream "space-time" versus the "space-density" model:

	Space-density Universe (RED pill)	**Space-Time Universe (BLUE pill)**
Tags	elastic solid, crystal universe, optical-mechanical analogue, space exists	Minkowski, space-time, absolute space does not exist
GR Metric Tensor	space-density (space with compression)	space-time
Cause of Gravity	refraction (density gradient, optical)	curvature of space-time

Photon	quantized wave, similar to phonon quasiparticles in crystal (vibrational mode), there are no photon "particles"	probability density wave function, no "real" wave, probability of finding photon
Double Slit Experiment	real waves interfering (like phonons)	parallel universes, no real wave, "consciousness" ,probabilistic…

Links

Optical analogues of General Relativity:

1. Hagen Kleinerts World Crystal: http://users.physik.fu-berlin.de/~kleinert/papers/planckklcZN.pdf
2. Defects and Diffusion in the Planck-Kleinert Crystal: http://ceram.agh.edu.pl/~icmmagh/artykuly/237%20PLANCK%20CRYSTAL%20DSL%20final.pdf
3. Emerging Gravity from Defects in World Crystal: http://www.sbfisica.org.br/bjp/files/v35_359.pdf
4. De Felice, F. On the gravitational field acting as an optical medium. Gen. Relativ. Gravit. 2,347–357 (1971).
5. On the optical-mechanical analogy in general relativity: http://arxiv.org/abs/0905.4479 , http://www2.ups.edu/physics/faculty/evans/Optical%20Mechanical%20GRG.pdf
6. The Classical Wave Theory of Matter by Robert Close: http://www.verumversa.com/
7. Analogue Special and General Relativity: http://arxiv.org/abs/1302.6729, http://www.tandfonline.com/doi/abs/10.1080/09500340.2013.769638#.Uw5Gnfl5M1I
8. Mimicking general relativity with Newtonian Dynamics: http://www.hindawi.com/journals/isrn.mathematical.physics/2012/260951/
9. A Table-Top Test for General Relativity? http://www.universetoday.com/35384/a-table-top-test-of-general-relativity/
10. A condensed Matter Interpretation of SM Fermions and Gauge Fields (Ilja Schmelzer): http://link.springer.com/article/10.1007%2Fs10701-008-9262-9, http://arxiv.org/abs/arXiv:0908.0591
11. The Cell lattice model (Ilja Schmelzer): http://ilja-schmelzer.de/clm/
12. Analogue Gravity: http://relativity.livingreviews.org/open?pubNo=lrr-2011-3&page=articlesu17.html
13. General Relativity in Electrical Engineering: http://www.int.kit.edu/downloads/RG_Pernice/Paper21.pdf
14. Lorentz Contraction of Space and the Gravitational Field: http://vixra.org/pdf/1008.0023v2.pdf
15. Surprising Connections Between General Relativity and Condensed Matter: http://arxiv.org/abs/1010.2784

Optical Black Holes:

1. First black hole for light created on Earth: http://www.newscientist.com/article/dn17980-first-black-hole-for-light-created-on-earth.html#.UwiBW_l5M1I
2. Physicists Make Artificial Black Hole Using Optical Fiber: http://spectrum.ieee.org/aerospace/astrophysics/physicists-make-artificial-black-hole-using-optical-fiber
3. Analytical Theory of Optical Black Hole Analogues: http://arxiv.org/abs/1209.5148
4. Trapping light by mimicking gravitational lensing: http://www.nature.com/nphoton/journal/v7/n11/full/nphoton.2013.247.html
5. Creating Optical Black Holes to Produced Super Solar Cells: http://www.dailygalaxy.com/my_weblog/2009/10/-creating-micro-black-holes-to-produce-super-solar-cells.html
6. 'Black hole' made from light: http://www.nature.com/news/2008/080306/full/news.2008.651.html

Phonons: Particles of Sound

1. Definitions of Phonons: http://physics.about.com/od/physicsmtop/g/phonon.htm, http://en.wikipedia.org/wiki/Phonon
2. Double slit experiments with phonons: http://nelson.mit.edu/node/178
3. Fantastic Phonons: http://www.sciencedaily.com/releases/2013/11/131113143215.htm
4. Black body analogue for phonon: http://en.wikipedia.org/wiki/Debye_model
5. Polaritons: http://en.wikipedia.org/wiki/Polariton
6. Photoelectric Effect: http://en.wikipedia.org/wiki/Photoelectric_effect
7. Chapter 6.5 in Material Science
8. The Phonon as a Model for Elementary Particles: http://www.nature.com/nchem/journal/v3/n4/full/nchem.1008.html

Phonon Lasers:

1. Phonon Lasers gain a Sound Foundation: http://physics.aps.org/articles/v3/16
2. Phonon Lasers Make a More Practical Sound: http://spectrum.ieee.org/semiconductors/optoelectronics/phonon-lasers-make-a-more-practical-sound
3. Researches Build Fully Mechanical Phonon Laser: http://phys.org/news/2013-03-fully-mechanical-phonon-laser.html

Wave Function Collapse:

1. Quantum Field Theory solves the problem of collapse of the wave function:

http://arxiv.org/ftp/arxiv/papers/1311/1311.0205.pdf

2. The phonon as a model for elementary particles: http://www.sciencedirect.com/science/article/pii/0375960193910273

□ □ □

□ □ *Wasn't there some proof that photons are particles, such as the photoelectric effect and the blackbody spectrum?*

A1: What the photoelectric effect shows is that the wave has to be quantized (just like a phonon is quantized), and that this cannot be explained with an **un**quantized wave. Phonons are also quantized, yet that does not indicate that they are particles (and nobody would disagree with that). There are many other cases of "quasi particles" (which are quantized waves) like the phonons that can act like particles, but are also clearly just waves have nothing to do at all with particles.

Another argument that photons are supposed to be particles is the black body spectrum. The black body spectrum can however also be computed using phonons vibrating in a solid body instead of a "photon gas" in a box: http://en.wikipedia.org/wiki/Debye_model

See also: "No Evidence for Particles"

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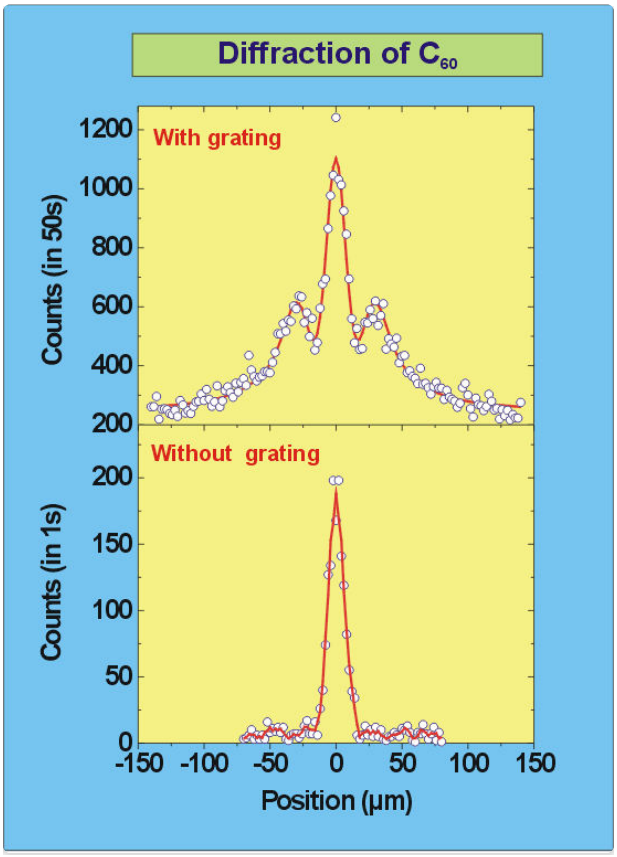
Puzzle Piece 2: What's the Matter with Matter?

The last post ended with phonons – quantized waves that have particle like behavior. So⋯ how does this even remotely relate to matter?

As you probably know, matter also exhibits wave like properties, which was originally proposed by de Broglie. Based on that theory, matter has a frequency that is directly proportional to the total energy (which includes it's mass). Schrödinger then published the famous wave equations of matter, which describe how those matter waves evolve over time (the equivalent of Maxwell's equations). For instance, did you know that the Energy of a "particle" is also $E = \hbar\omega$? Just like in the case of photons and phonons?

It is not only possible to do the double slit experiment with electrons and neutrons, but even with atoms (such as He) and complex molecules even as large as C60 molecules (soccer ball shaped carbon cages):

Again you get the familiar interference pattern – even with such large molecules:



That means that even complex molecules as large as C60 behave as if they were in fact waves and not particles.

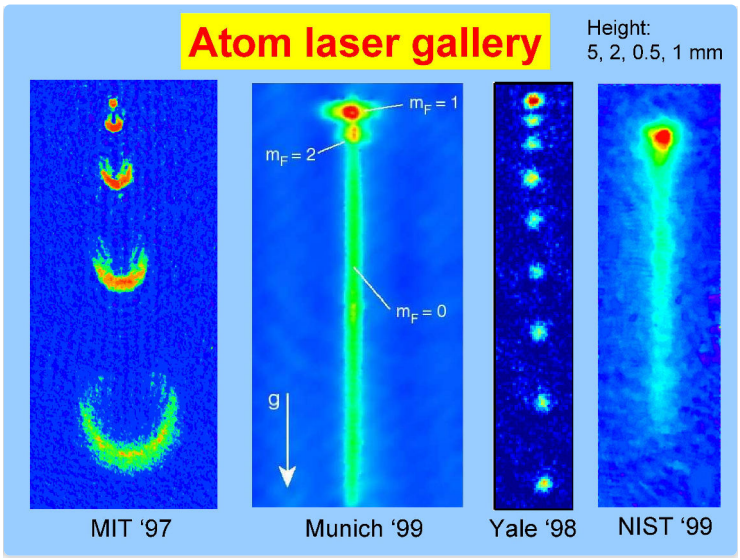
If you ask physicists (or check Wikipedia), they will give you one of several explanations for this wave like behavior of matter:

- the Many World interpretation: that basically each possibility actually happens for real in one of the infinite universes (and we live in just one of them).
- The Pilot Wave model, which proposes that there is a “guiding wave” that guide the actual real “particles”
- The Copenhagen interpretation, where the observer basically causes the wave function to collapse. The world is basically probabilistic, and the wave function does not describe a real wave, just a probability (and there is no real world out there if you don’t look)
- Wikipedia does mention that there is one scientist (Carver Mead) who thinks matter are real waves

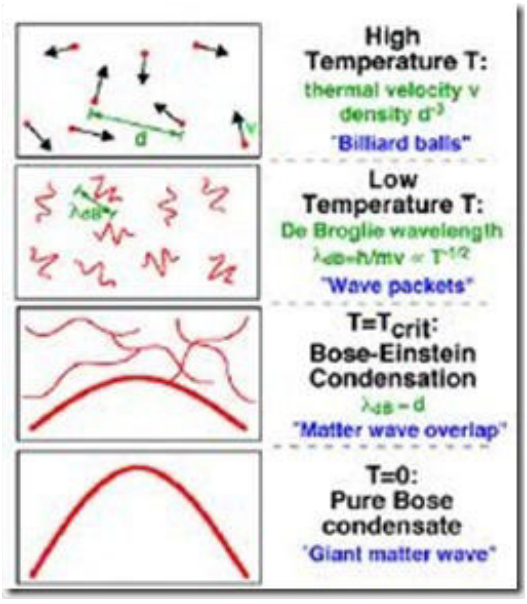
So do we really need “parallel universes” and similarly weird explanations? Is there any more evidence?

Atom Lasers, Atom Interferometry and Atom Optics

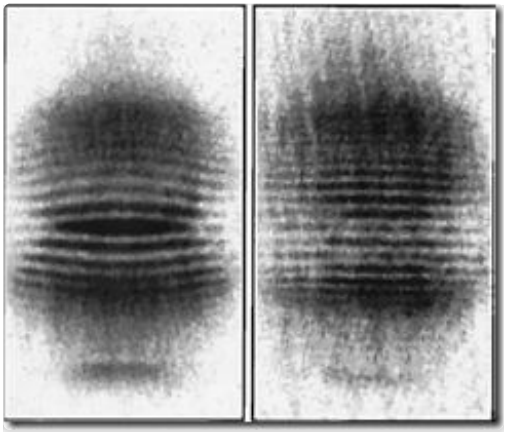
There is an entire branch in physics called atom optics, which includes atom lasers, which are coherent beams of matter waves. Even here of course you could say well, these are not “real” waves, but just “probability density functions” as in the case for photons.



Such coherent matter waves are made using Bose Einstein Condensates. Wolfgang Ketterle won the Nobel prize for his work in this area – here is a link to his Nobel lecture on "When Atoms Behave as Waves".



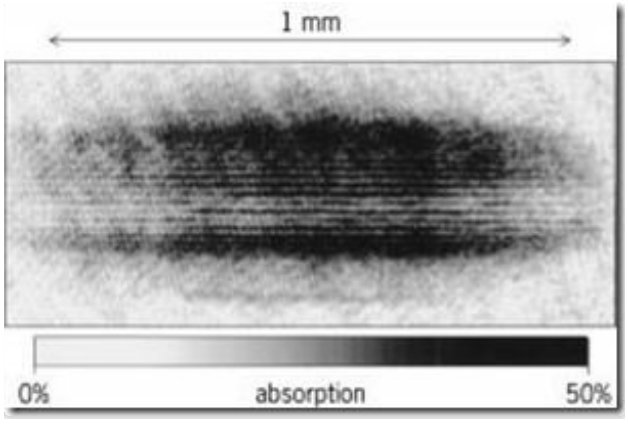
Basically as certain atoms (such as He4) are cooled down, the matter waves of the individual atoms start to overlap, until they form one gigantic matter wave. The wave is so large, that is is around 1mm in size (!). Not micrometer, millimeter. The distance between the fringes is about 15μm, that's huge! In fact, it is even possible to take a picture of such a matter wave! Here, in the picture below, we see two such matter waves interfering with each other. Notice the light and dark lines? These is the same kind of interference pattern we are used to seeing with other interacting waves.



This is quite dramatic. Basically this means that atom + atom can = vacuum in some places. Parts of the matter waves cancel each other out!

Here is an excerpt from:
http://cua.mit.edu/ketterle_group/Projects_1997/Interference/Interference_BEC.htm

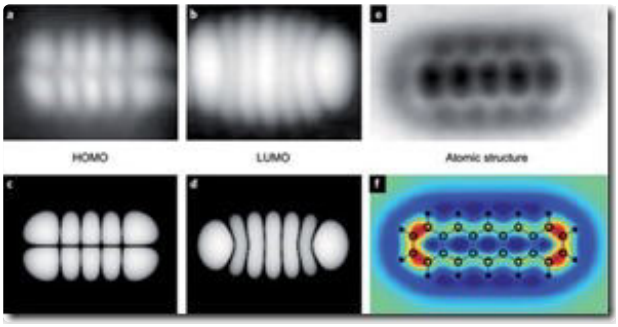
> *Perhaps the most striking feature of quantum mechanical theory is the fact that it predicts that matter can behave like waves. This means that coherent matter waves can form interference patterns, just like the ones you would get if you combined two laser beams in an interferometer. The demonstration of interfering pathways in a neutron interferometer was perhaps the strongest affirmation of quantum theory and the wavelike nature of matter. Atom interferometer experiments followed which extended this demonstration to the size of an entire atom. But these experiments were limited to showing that a single particle could interfere with itself. Now, Bose-Einstein condensation has allowed us to make another advance, making it possible to interfere two completely independent clouds of atoms with each other.*



In a recent experiment (2012), scientists say they have shown that matter waves are indeed real physical entities, where they conclude:

> *"In conclusion, we have presented a no-go theorem,*
> *which shows that models* ***in which the quantum state is interpreted as mere information about an objective physical state of a system cannot reproduce the predictions of quantum theory.****"*

In another quite recent experiment, researchers were able to take pictures of a single molecule, where one can see the electron orbitals (on the top is the actual picture, the bottom shows the computer simulation):



And here there are several online simulations that let you play with waves (including the double slit experiment): Simulation of Quantum Wave Interference

The mainstream interpretation is that this is not really a wave, but just a probability of finding a particle at a given spot. However, one does have to wonder if this is really the case, after all, the fact that one can take a real picture of this – without causing a "wave function collapse" – is quite some evidence that we are dealing with a real wave, and not just some probabilities.

Getting back to the "Crystal Universe" idea by Hagen Kleinert – and much more detailed work based on this idea by Robert Close in "Classical Wave Theory of Matter": in these models, we are in fact dealing with true waves, where the Dirac equation is interpreted as a "classical second-order wave equation for rotational waves in an elastic medium" (page 126) of space (or crystal, if you prefer that picture). So now, given the images and experiments on BEC above, maybe the idea that matter could indeed be true waves does not seem so totally strange anymore. Actually, did you know that Schrödinger had originally proposed that waves are real waves (until Max Born later introduced the interpretation of the probability density)? In fact, this is what Schrödinger had to say about the probability interpretation later on:

> *What we observe as material bodies and forces are nothing but shapes and variations in the structure of space…..Let me say at the outset, that in this discourse, I am opposing not a few special statements of quantum physics held today (1950s), I am opposing as it were the whole of it, I am opposing its basic views that have been shaped 25 years ago, when* ***Max Born*** *put*

> *forward his **probability interpretation**, which was accepted by almost everybody. I don't like it, and I'm sorry I ever had anything to do with it. (**Erwin Schrödinger** , The Interpretation of Quantum Physics.)*

Why is this idea not discussed more? After all, this model is equivalent to the "space time" model. One reason is that at the time when people did consider similar models (mostly related to an "aether"), they didn't know yet that matter also exhibits wave properties. So at that time, even though they considered that light could be waves hat moves through a medium, they still treated matter as particles – which created problems. The question was, how do those particles move "through" such an "aether". Now we know that the question is in fact misleading! In the crystal universe model, matter does *not* "move" through that (solid) space. It is only the vibrations that appear to "move", just like heat or phonons appear to "move" through a crystal (when it is just the vibrations that change location, or just as sound waves appear to move (even thought the air itself is mostly stationary – if there is no wind).

Another reason for not discussing the idea more is probably the resistance to the idea that there could be a preferred frame – for some reason, many physicists really seem to hate that idea, even though (as you will see), this does not contradict special relativity in any way. We will discuss this more in the next post, when we talk about special relativity, and how SR looks like in the "crystal universe" model.

Next puzzle: Puzzle Piece 3: What's special about Special Relativity?

Summary Table

	Space-density Universe (RED pill)	Space-Time Universe (BLUE pill)
Tags	elastic solid, crystal universe, optical-mechanical analogue, space exists	Minkowski, space-time, absolute space does not exist
GR Metric Tensor	space-density (space with compression)	space-time
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Photon	quantized wave, similar to phonon quasiparticles in crystal (vibrational mode), there are no photon "particles"	probability density wave function, no "real" wave, probability of finding photon
Double Slit Experiment	real waves interfering (like phonons)	parallel universes, no real wave, "consciousness" ,probabilistic…

Schrödinger Wave Equation	describes real waves, rotational waves in an elastic solid. There are no particles	probability of finding a particle, there are no real waves
What is space?	An elastic solid (not made of matter). Matter and light moves though space as waves move through a crystal	There is no absolute space

Links

Matter waves

- http://en.wikipedia.org/wiki/Matter_wave^
- Quantum Interference Experiments with Large Molecules: http://130.58.92.210/Students/phys%205_2010/zeilinger%20ajp%202003.pdf
- Double slit with single electrons: http://physicsworld.com/cws/article/news/2013/mar/14/feynmans-double-slit-experiment-gets-a-makeover
- Wave-particle duality of C60 molecules: http://www.nature.com/nature/journal/v401/n6754/abs/401680a0.html
- Diffraction fo C60 at a SiN grating: http://www.univie.ac.at/qfp/research/matterwave/c60/
- Atom Laser: http://cua.mit.edu/ketterle_group/Popular_papers/Atom%20laser%20Enc.pdf
- Atom Laser: http://cua.mit.edu/ketterle_group/Projects_1997/atomlaser_97/atomlaser_comm.html
- W. Ketterle: When Atoms Behave as Waves: http://www.nobelprize.org/nobel_prizes/physics/laureates/2001/ketterle-lecture.pdf
- Interference of two BEC: http://cua.mit.edu/ketterle_group/Projects_1997/Interference/Interference_BEC.htm
- Properties of a Bose Einstein Condensate: http://www.uni-muenster.de/Physik.AP/Demokritov/en/Forschen/Forschungsschwerpunkte/mBECwatpoabec.html
- Bose Einstein Condensation: http://www.theory.caltech.edu/~preskill/ph12c/ketterle-physicsworld.pdf
- Exact Description of Rotational waves in an Elastic Solid (by Robert Close): http://www.classicalmatter.org/RotationWaves.pdf
- Torsion Wave in Three Dimensions: Quantum Mechanics with a Twist (by Robert Close): http://www.ingentaconnect.com/content/klu/fopl/2002/00000015/00000001/00371047
- Classical Wave Theory of Matter (by Robert Close): http://www.verumversa.com/ClassicalWaveTheoryOfMatter.pdf
- Quantum Theorem Shakes Foundations (The wave function is a real physical object after all, say researchers): http://www.nature.com/news/quantum-theorem-shakes-foundations-1.9392
- On the Reality of the Quantum State: http://xxx.lanl.gov/abs/1111.3328

- No Evidence for Particles: http://arxiv.org/ftp/arxiv/papers/0807/0807.3930.pdf
- Recent Advances in Submolecular Resolution with Scanning Probe Microscopy: http://www.nature.com/nchem/journal/v3/n4/full/nchem.1008.html

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Puzzle Piece 3: What's Special about Special Relativity?

Previous puzzle: Puzzle Piece 2: What's the Matter with Matter?

1. Time Dilation

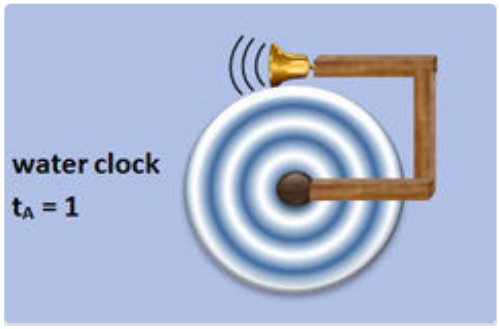
You probably think that special relativity is hard to understand and explain (I mean, so that your grandmother would understand it), and that his surely has nothing to do with any of that "Crystal Universe" idea or "The Classical Wave Theory of Matter".

So let me give it a shot: all you need to know is 2 things:

1. the Pythagorean formula $a^2 + b^2 = c^2$.
2. that waves in a medium have a particular speed **c**
   (such as sound in air (w/o wind), sonar in water, earthquake waves, phonons in a crystal, water waves etc)

First, the easiest example – one that you can actually try yourself in real life:

Take a regular boat, put it on a still lake. At the end, we build a "water wave clock": we add a wooden frame with a stick at the end. We "start" the clock by making waves with a stick. The clock "ticks"(rings) when the wave front reaches the bell:



Note that the wave extends in all directions. For simplicity, we will use arrows – even though of course the waves don't go just in one direction. But it shows the direction from the start of where the wave originated to the end, where the "bell" rings. When the boat is stationary, this is what it looks like:

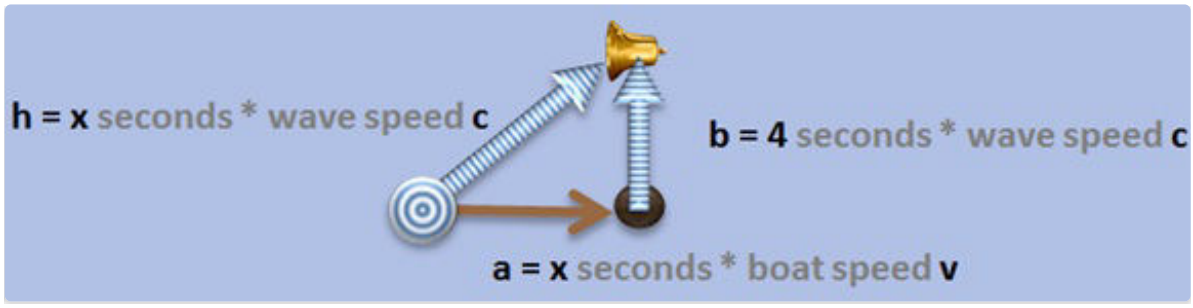
(I know I am going kind of slow here, but I really want my grandmother also to understand this :-).

What does it look like when the boat is moving?

You can see that the distance the water wave has to travel is now longer, because the boat is moving away. Say it took 4 seconds when the boat was still for the ring to bell. How long do you think it takes now? It clearly takes longer now – but how long depends on how fast the boat is moving. How can we compute that?

(Note: in water, the speed of the wave is depending on the wave length… to make this work with water, we have to use the same wave length, such as 10cm from water crest to water crest)

All we need to know is that **distance = time * speed**, and the Pythagorean formula:



 he distance **h** (the hypothenuse) is the number of seconds **x** we want to compute * the speed **c** of the water wave. We know that when the boat was still, it took 4 seconds for the wave to reach the bell. The distance **b** = 4 seconds * wave speed **c** (I know, of course we could simply measure it, but the point is that we want to get a **formula** to compute these things ;-). The distance a is how far the boat went, so **a** = the speed **v** of the boat, times the number of (unknown) seconds **x** we want to compute.

All we do now is apply the Pythagorean formula, and solve for x! One small change: instead of putting 4 for the 4 seconds, let's use **t.**

$$(x*v)^2 + (t*c)^2 = (x*c)^2$$

$$x^2 * c^2 - x^2 * c^2 = t^2 * c^2$$

$$x^2 (c^2 - v^2) = t^2 * c^2$$

$$x^2 = t^2 * c^2 / (c^2 - v^2)$$

$$x = t \frac{c}{\sqrt{(c^2 - v^2)}}$$

Example with real numbers: say in the stationary case it took **t = 4** seconds. Let's pick a speed v for the boat, such as 3/4 as fast as the wave speed c (for a wave with 10cm wave length in clean water, it travels about 30cm/second): **v = c*3/4.**
We replace **v** with **c*3/4** in the formula and get:

$$x = t \frac{c}{\sqrt{(c^2 - c^2 * 9/16)}} = t \frac{1}{\sqrt{(1 - 9/16)}}$$

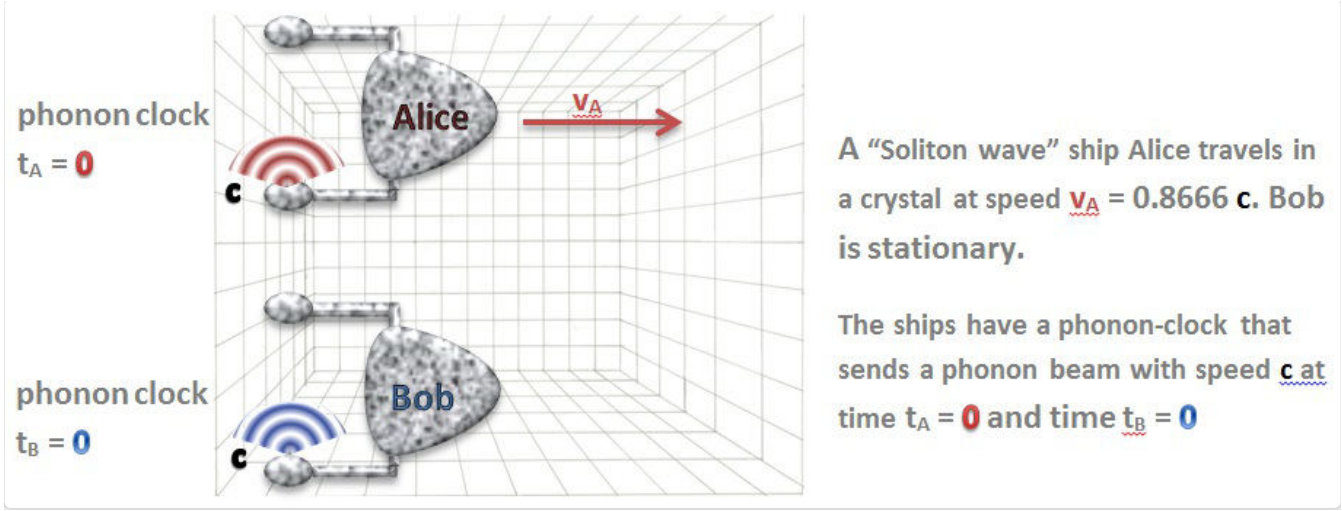
x = 1.5 * t = 1.5 * 4 seconds = **6 seconds**

What happens if the boat is going as fast as the wave speed c? Then the clock never ticks! Because the wave front can never reach the bell…

This is where this particular analogy ends of course, and as we said, for surface water waves, the wave speed depends on the frequency, and also because the boat is not a wave…

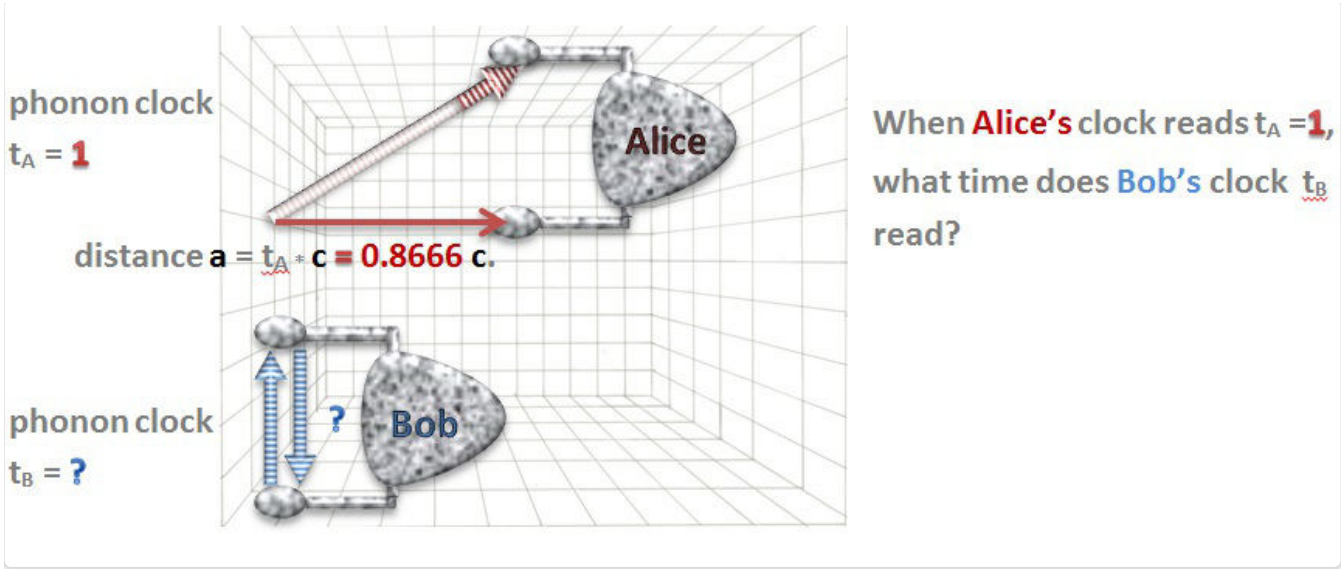
Following is a more analogous example of the "crystal universe" – it is really exactly the same, except that we replace the water with the crystal (or elastic solid like Jell-O), and that we replace the water

clock with a “phonon” clock (sound), and that we replace the boat with a “matter wave” boat:

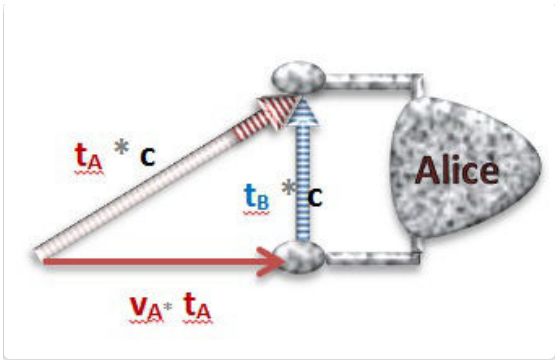


The two ships have a ***phonon clock*** attached. Each “tick” in the clock is when the phonon beam from the bottom part of the clock reaches the detector on the top. **c** is the speed of the waves (phonon waves) in that crystal.

Alice boat is moving at speed **v = (0.866 * c)** (to get an even result :-).



We do the same thing as we did with the regular boat. All we have to do is use the Pythagorean formula to solve for the unknown t_B:



Simple Pythagoras:

$$(v_A * t_A)^2 + (t_B * c)^2 = (t_A * c)^2$$

Solve for t_B:

$$(t_B * c)^2 = (t_A * c)^2 - (v_A * t_A)^2$$

$$t_B^2 * c^2 = t_A^2 * c^2 - v_A^2 * t_A^2$$

$$t_B = t_A \frac{c}{\sqrt{c^2 - v_A^2}}$$

Using value for v_A = 0.866 c.

$$t_B = t_A \frac{c}{\sqrt{c^2 - 0.75c^2}} = t_A \frac{c}{\sqrt{0.25c^2}} = 2 * t_A$$

 he answer for this example is: Bob's "clock" runs twice as fast as Alice's clock. In this example, because the ships themselves are composed of (soliton) waves, they can never go faster than c either!

For an animated version of this, please check out Robert Close underwater relativity!

How does this translate to "our" world? If photons are actual (quantized) waves like phonons, and if matter waves are also true waves (and not just probabilities for particles), waves in a "solid space", then we get ***exactly the same result***. In that model it is completely logical, that photons always travel at the wave speed c, and that no wave, so no matter wave either, can ever go faster than c.

The entire "time dilation" then in this model is simply a wave phenomenon. There is absolutely nothing magical about it! You get the same result for ***any*** wave system.

If you think about it, what are clocks? All our clocks are at end made of either light or matter. And if matter are waves, then of course, any moving clock would tick slower. So in this "crystal" model, it is not the case the that (abstract) time is really moving slower. It is simply the actual clocks that tick slower (because the paths of moving clocks are longer!). We could even argue, is there an abstract concept of time.

In the "mainstream" (space-time) version, this is a bit different. In that model, there is no absolute time, and there is no absolute space either. Clocks are not ticking slower, it is actual time that is slower for that particular "frame" (that particular object). And the speed of light in that model is not constant in an absolute sense, since in that model, there is no absolute space either. In the space-time interpretation, the speed of light is constant ***for each observer***. This might seem like a detail, but it means you can no longer use "common sense" to explain it. And also, in that model, special relativity has nothing to do with waves.

You might say: but, it has been shown that light is in fact the same for any (moving) frame. Yes, that is true! And I will show next how indeed, for any moving or non-moving observer, the speed c always *__appears__* the same, even though it is actually constant in the absolute sense:

So let's measure the wave speed c in two situations, when then boat is stationary, or when the boat is moving:

a) Stationary Situation

The distance **b** between the source of the wave clock and target bell is **time * wave speed c**. We want to know how kind of c that the person in the boat measures, with his clock. Hence we use his time t_A. The distance b is known of course, the person in the boat can just measure the frame width. Therefore **c = b/t_A**.. The time t_A is **1**, since this is how our clock works: when the ring bells, the time ticks once. Hence **c = b**

b) Moving Situation

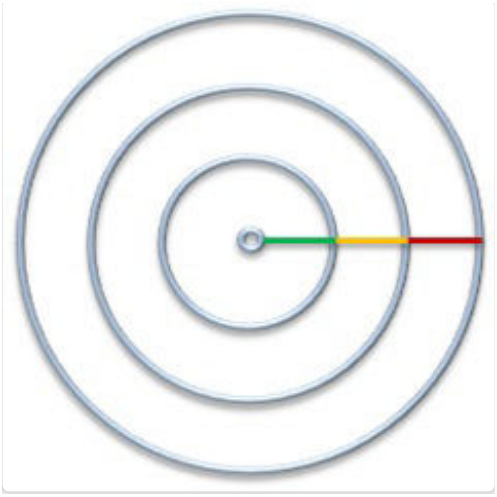
When the boat is moving, viewed from a stationary observer, the wave has to travel further, and the clock of the moving boat is running slower.

What wave speed does the person in the moving boat measure? Well, for him, one tick is still – per definition – the time it takes for the wave to hit the bell. For the moving observer, the time t_A is still **1** tick. The distance **b** has not changed (the width of the frame). And again, c is the same: **c = b**

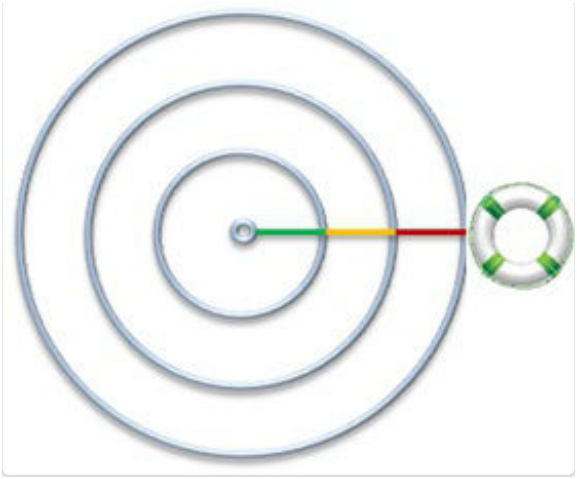
We will look at a more complicated situation in the length contraction section, but basically every observer will always measure the same speed of c, no matter whether the observer is stationary or moving.

Length Contraction and Doppler Effect (part 1)

We'll do a simplified example first. Imagine we are on a still lake, and dipping a stick into the water at regular intervals from a boat. You get this familiar wave pattern below:

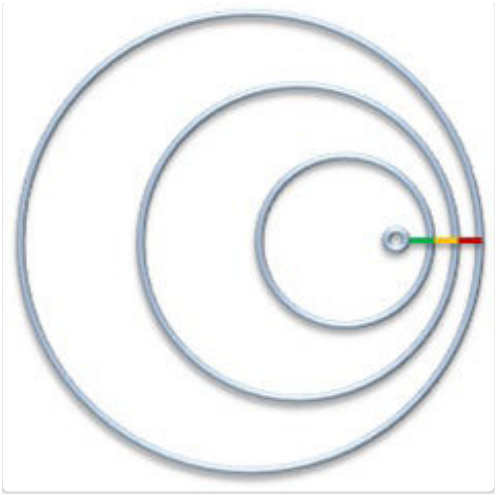


Notice how the distance between the wave crests is constant, and the same on both sides. Let's use the number of wave crests as our measuring stick. We use it to measure the distance to say a life buoy:



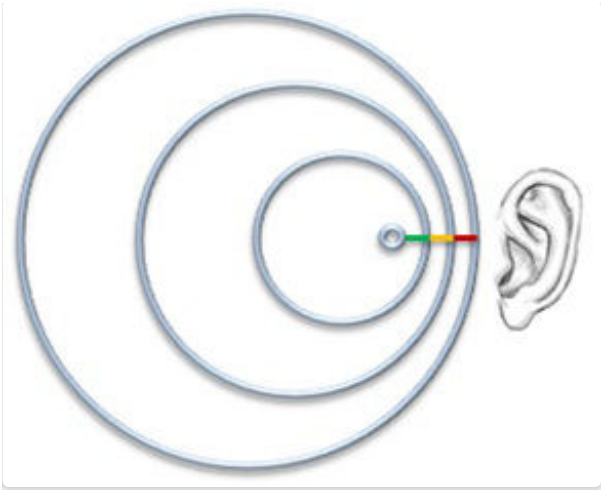
The distance is 3 weave crests.

If we do the same thing in a uniformly moving boat, say at 2/3 of the speed of the wave in a horizontal direction, then it looks like this:

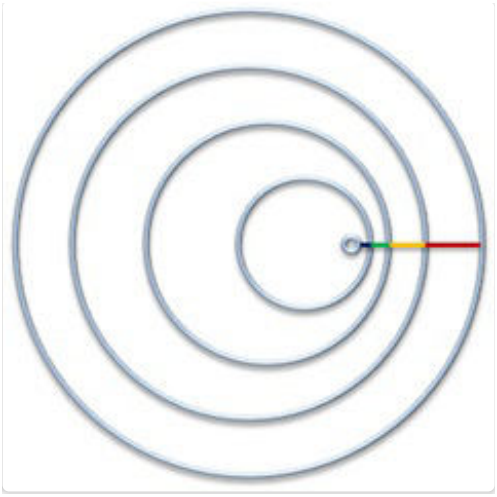


 he distance between the weave crests is now 1/3 as it was before on the right (but still equidistant). So our measuring "stick" has shrunk to a third . Of course we notice that, because we are (in this examples) outside observers and can see that. If we were composed of the same kind of waves as in this example however, we would also have shrunk to 1/3 in the horizontal direction, and would not notice (a more detailed example on that later make this point clear).

This also illustrates the Doppler effect: The wave length has shrunk, and so if someone were listening (in a sound example) as the object approaches, then the frequency would be higher as in the stationary case:



If the boat is uniformly accelerating to the right, then the wave crests are no longer equidistant, they get shorter as we measure them towards the center:



So to a listener, the frequency would get higher and higher, and our measuring "stick" would get shorter and shorter…

For a much more detailed example, please take at the (animated) unterwater relativty by Robert Close:
http://www.classicalmatter.org/UnderwaterRelativity/ParallelLength.swf

And for a more "correct" version of this, with boats that are also made out of waves, see this animated example:
http://www.classicalmatter.org/UnderwaterRelativity/MatterWaves.swf

Next puzzle: Puzzle Piece 4: The (other) Heisenberg

Summary Table

	Space-density Universe (RED pill)	Space-Time Universe (BLUE pill)
Tags	elastic solid, crystal universe, optical-mechanical analogue, space exists	Minkowski, space-time, absolute space does not exist
GR Metric Tensor	space-density (space with compression)	space-time
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What is space?	An elastic solid (not made of matter). Matter and light moves though space as waves move through a crystal	There is no absolute space
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Speed of light	c, constant in absolute space. Also c for each observer, due to time dilation	c is constant for each observer. There is no absolute space
Twin Paradox	No paradox. Whoever moved slower relative to absolute space ages faster.	If A is considered to be at rest, B ages more slowly, and vice versa. There is no clear answer as to who ages faster.

Links

Special Relativity:

- The Other Meaning of Special Relativity (Robert Close): http://www.classicalmatter.org/ClassicalTheory/OtherRelativity.pdf
- Classical Wave Theory of Matter (by Robert Close), chapter 2: http://www.verumversa.com/ClassicalWaveTheoryOfMatter.pdf
- Underwater Relativity: http://www.classicalmatter.org/UnderwaterRelativity.htm

Other:

- Hagen Kleinerts World Crystal: http://users.physik.fu-berlin.de/~kleinert/papers/planckklcZN.pdf

Puzzle Piece 4: The (other) Heisenberg

Previous puzzle: Puzzle Piece 3: What's special about Special Relativity?

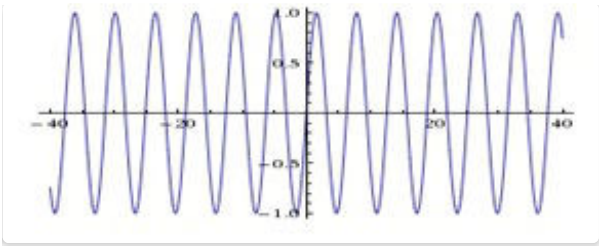
Let's talk about Heisenberg – not Walter White, the real Heisenberg, who came up with the uncertainty principle. The fact that for any particle, one cannot measure location and momentum exactly at the same time.

If we look at this in the context of waves, as in sound waves, then maybe it does not sound so strange. Basically, the principle says that the error in the position (dx) times error in momentum (dp) is larger or equal to $\hbar/2$:

$$\sigma_x \sigma_p \geq \frac{\hbar}{2},$$

where $\hbar$ is the reduced Planck constant.

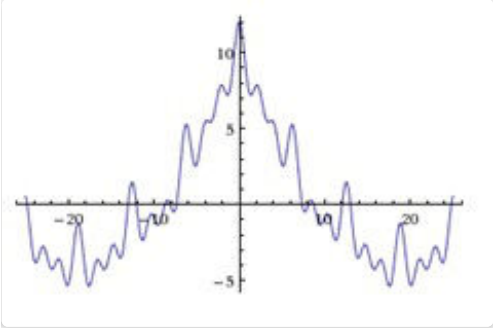
So what does that mean in the context of sound? A pure sine tone (say 440 Hz) has an exact frequency, but has no clearly defined starting and ending position:



Imagine you play this tone on an instrument, say a violin. Then you hear just that one frequency, and there is no beginning or end of that tone (except when the player begins and ends of course). So that sine wave extends in space for as long as the player plays that tone. It is not localized – it makes no sense to talk about location, as it is the same for the entire duration of the sound.

Now what does an exploding balloon sound like? It's the opposite of a pure sine wave: a popping balloon has quite a specific location, but the frequency of that sound is not one pure tone, but a mixture of many frequencies. How can this be represented? Basically by adding a bunch of sine waves (Fourier) together, to get the shape of the explosion sound: below I added a bunch of cos

curves – the more you add, the more localized the sound gets, but the more frequencies are mixed in, so the harder it gets to determine a frequency.



You can either measure the frequency, but then you can't tell quite exactly where the sound begins or ends, or else, you measure the location, but then you can't quite tell what frequency the tone had. In fact, the perfect impulse has an infinite number of frequencies, and it doesn't even make sense to talk about measuring the frequency in that case, because there is no clearly defined frequency. In the other case, it makes no sense to say where exactly the tone is, because it has no clear beginning or end.

This is true for any kind of wave, whether we talk about sound waves, water waves, light waves or matter waves. If matter is composed of true waves, then maybe the idea that for a "particle" you can either determine it's location or it's momentum, but not both at the same time, does not seem so strange anymore – it is simply a natural consequence of any wave.

Next puzzle: Puzzle Piece 5: The Doppler Challenge

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Twin Paradox	No paradox. Whoever moved slower relative to absolute space ages faster.	If A is considered to be at rest, B ages more slowly, and vice versa. There is no clear answer as to who ages faster (if cleverly engineered – see post on that)
Uncertainty Principle	Natural consequence of any wave system	Due to wave property of matter and light (but only probabilistic)

Links

Uncertainty Principle

- Wikipedia: http://en.wikipedia.org/wiki/Uncertainty_principle
- The Uncertainty Principle: http://www.mtnmath.com/whatrh/node72.html
- The Open University: http://www.met.reading.ac.uk/pplato2/h-flap/phys10_2.html (chapter 4)

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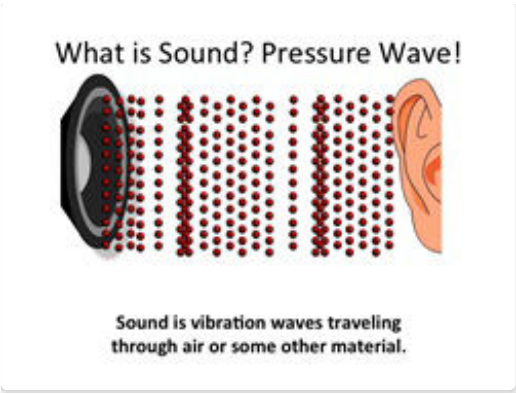
Puzzle Piece 5: The Doppler Challenge

Previous puzzle: Puzzle Piece 4: The (other) Heisenberg

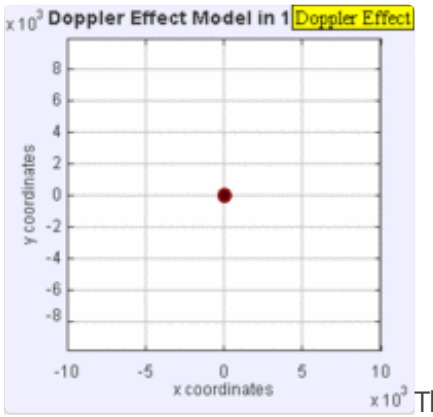
The Doppler effect for sound is very simple of course, and you surely know how it works. And I am sure you also think it is easy for light, but unfortunately, due to the way that "mainstream physics" interprets relativity, the whole thing gets very strange for light. However, if we consider the "elastic solid" interpretation of relativity, than the entire mystery vanishes, and what is left is the same explanation as for sound. To see what the issue is, let's first take a detailed look at the Doppler effect for sound:

Doppler Effect for Sound:

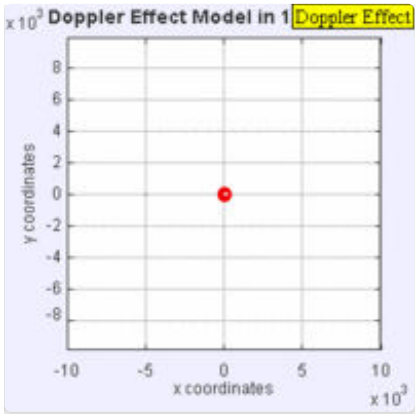


Let's first consider what sound is: it is a pressure wave that moves through a medium such as air. When a sound is emitted, the sound wave travels at a fixed speed (assuming no wind) through the medium. Once the sound is emitted, it exists whether the speaker disappears afterwards or if there is no listener (you will see why I write such a weird thing later).

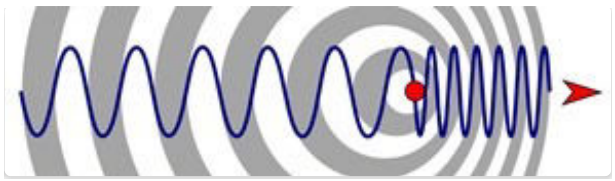
Let's take a look at the stationary case: imagine a speaker in a room that emits sound of a particular frequency (such as 440hz) (from Wikipedia)



The sound spreads in all directions, at the speed of sound.



Now imagine the speaker is moving to the right. The speed of sound never changes, so the waves always spread at the same speed. But now, because the speaker is moving, the pressure waves are **closer together** in the moving direction, because the speaker is moving relative to the **medium**. If we plot the frequency on top of the waves, then you can see clearly that the frequency is higher in the moving direction, and lower behind the speaker.



The exact same effect happens if there is a microphone (an observer) that is moving towards the waves**, relative to the medium.** Note I said towards the waves, not towards the speaker. We can destroy the speaker or move it after it emitted the sound, but the sound waves are still in the air and moving no matter what the speaker does afterwards. What matters is how the microphone moves relative to the medium, and what pressure waves it records. If the microphone moves towards the waves, it will observe more pressure waves than if it is moving away.

The total shift depends on the speed of the speaker and also on the speed of the observer (relative to the medium!). The general formula is:

$$f = \left(\frac{c + v_r}{c + v_s}\right) f_0$$

If vr and vs are small relative to the speed of the wave c, then this can be simplified to:

$$f = \left(1 + \frac{\Delta v}{c}\right) f_0$$

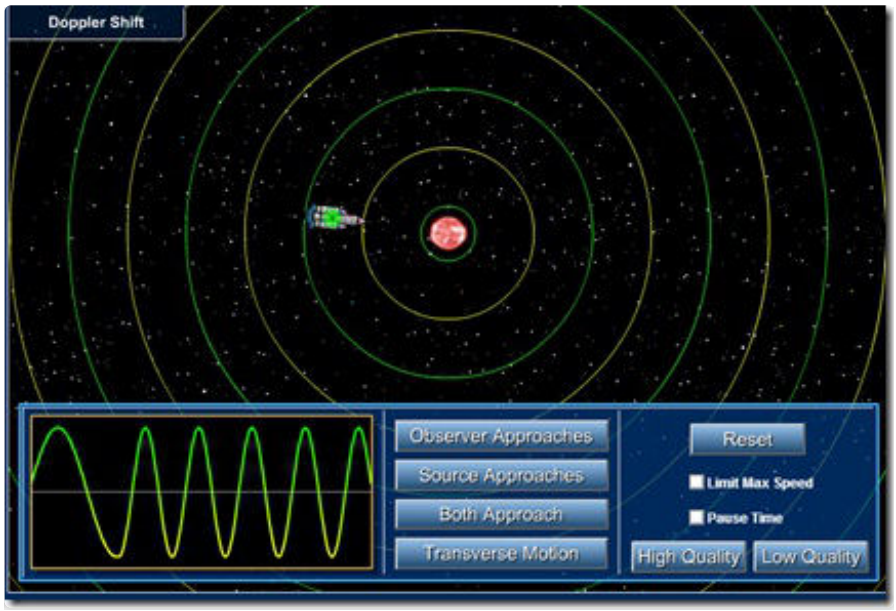
Where $\Delta v = v_r - v_s$

Doppler Effect for Light:

The formula for light is exactly the same (for non-relativistic speed):

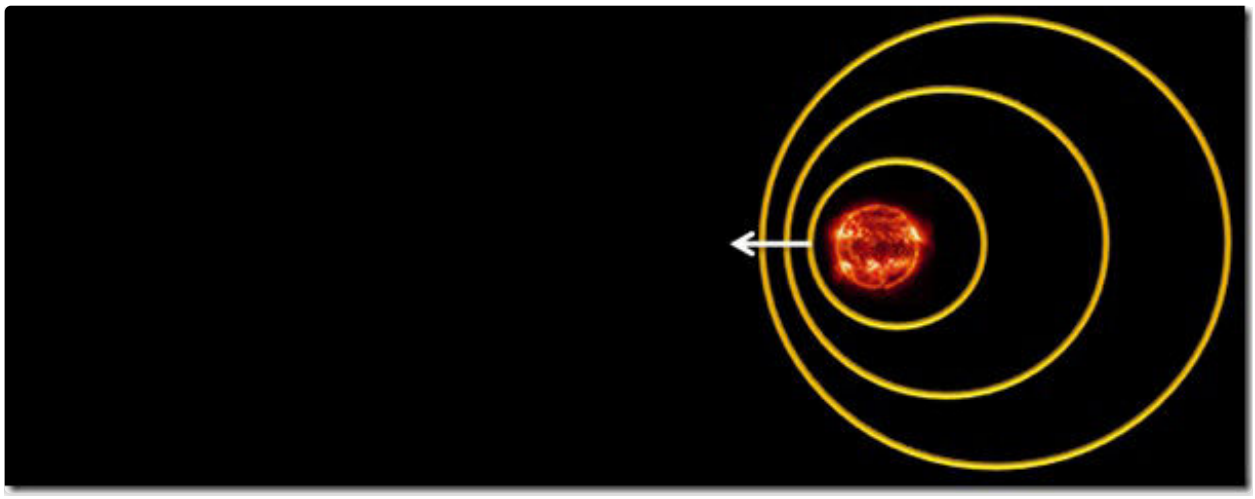
$$f = \left(1 + \frac{\Delta v}{c}\right) f_0$$

Below is an interactive animation (click on it) where you can play with the Doppler effect for light. It really shows how the effect actually works in reality. However, as you will see shortly, this contradicts the “mainstream” interpretation.

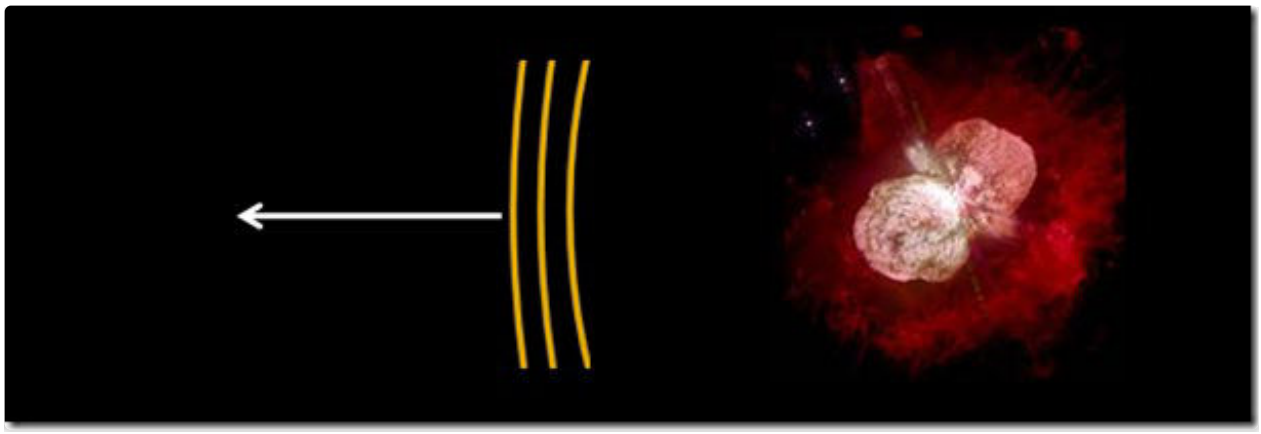


Clearly, since light is also a wave, and since the formula is also the same, it is logical that the mechanism for light is also the same. So what is the issue here? If you have read the other posts, then you know that there are two interpretations of relativity. The space-time interpretation, which is the mainstream one, and the elastic solid interpretation of space (Hagen Kleinerts World Crystal).

The animation above actually corresponds more to the elastic solid interpretation than the mainstream interpretation: in this model, just as with sound, the light waves are nothing more than oscillations in an absolute space. Once the star has emitted light, the light continues to exist and travel no matter what the star does: in the image below, a star that is moving to the left is emitting light. At that time, earth does not exist yet (say the star is 6 billion light years away from (future) earth).



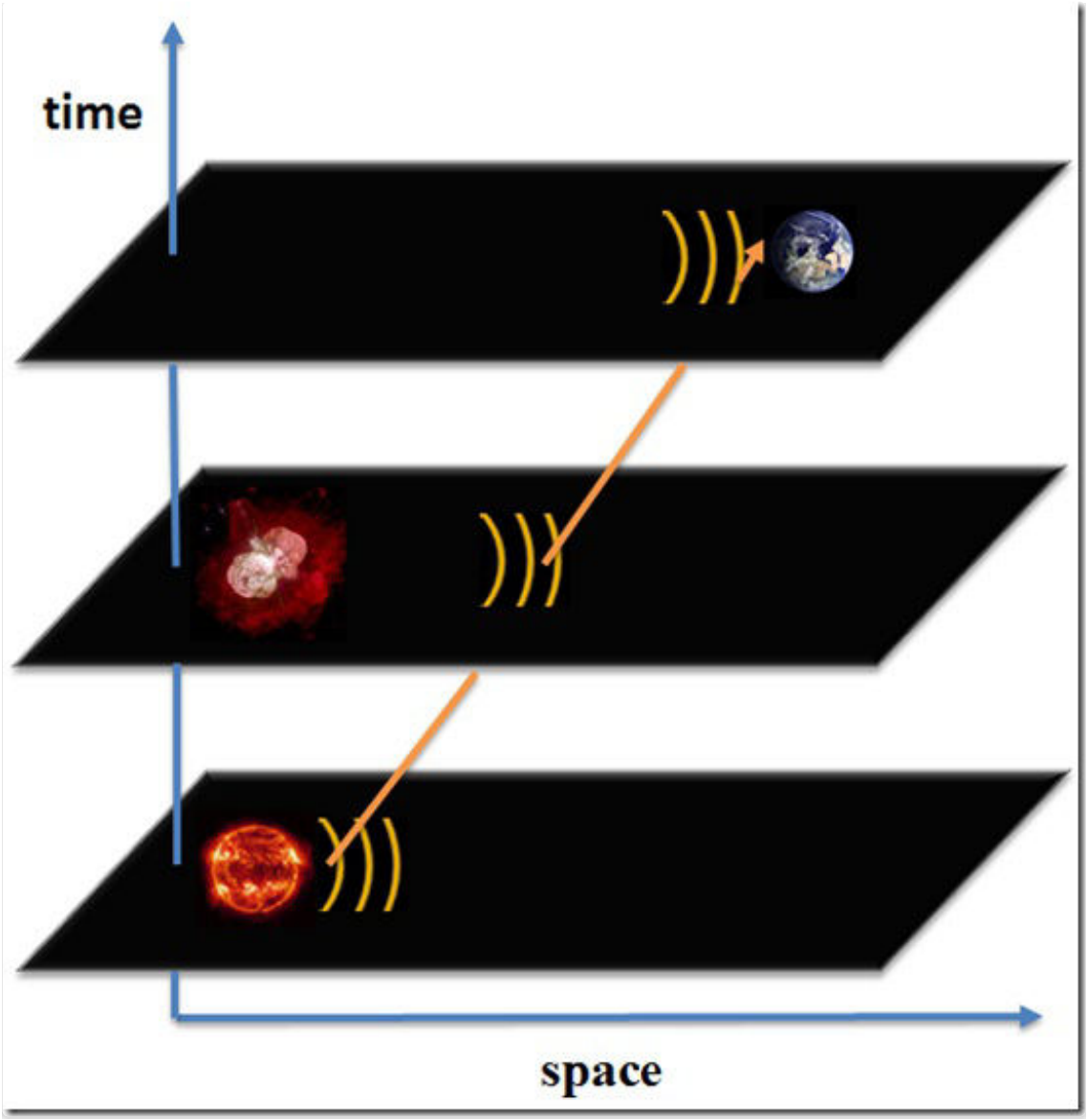
If the star explodes as a super nova, it doesn't matter. The light that was emitted before still continues to travel through space, no matter if it will ever be "observed" or not. Just think of all the supernovas that have been observed already millions of light years a away. By the time the light reaches earth, the super nova is long gone! The source is no longer there:



Similar in other cases: if the start has emitted light and was moving, then by the time the light reaches earth, it might be on the other side of the galaxy… The light we observe from stars is independent of the existence of the star. I know it sounds like I am beating a dead horse, but there are people who seriously claim otherwise.

The frequency that the light has in space depends on the velocity that the star had at the time the light was emitted – just like with the speaker example above. And when the light is observed, say on earth, the frequency may be shifted a second time, depending on how earth is moving relative to **space** (and **not** relative to the star – which may be been gone by now!),**:**

The problem is that based on the “space time” interpretation, there is no absolute space, so there is **no medium** at all through which light can propagate. The question then is, *how would a Doppler effect in that case even be possible*? If there really is no “space” (no medium), then at the time light is emitted by a moving star, and if there is no observer yet (no earth), then *there should be no frequency shift at all*, since the star is not really moving at all if there is no absolute space. So what frequency will the light have? There is no explanation as how it could possibly be red or blue shifted if there were no space, as there is no mechanism, no medium where this change of frequency could occur. If you ask a mainstream physicist, most likely you will get a space-time diagram, that shows the source and observer in the same image:



This may look nice, but it doesn't change the fact that the first frequency shift happens *at the time that the light waves are emitted from the star*, and that at each point in space (and time), the light wave *exists*, and has a well defined frequency – which can only be true if some kind of "space" exists. Just because we can draw a line from the past to the present does not somehow change this problem. At the time the light waves were emitted, the star did not "'know" that one day earth will come into existence and will measure its rays… so it cannot depend on the (future) observer…. So based on this model, there can never be any frequency shift at the time the light is emitted. The line from the past to the present, and using the relative speed between source and observer is just a mathematical trick, and says nothing about the underlying reality.

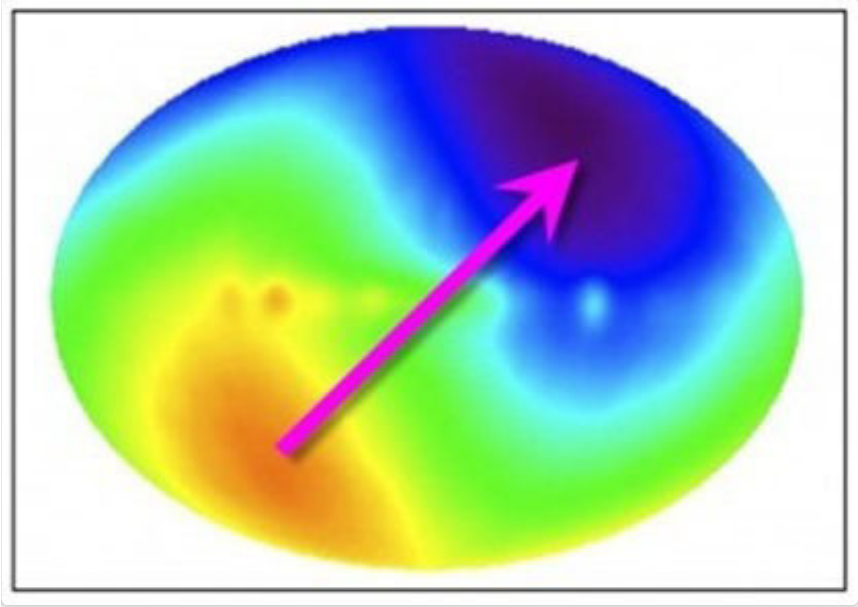
So you have two choices:

a) believe that space exists in an absolute sense (the **red** pill). Then the Doppler effect of light is explained exactly the same way as it is for sound – no magic involved, it's totally simple.

b) believe that no space exists in an absolute sense (the **blue** pill). Then the Doppler effect can only be explained by some magic between the source and (future) observer… where the light wave does

not really exist until measured, and one cannot even talk about a frequency of the light wave on its own. There is no physical explanation of all of this, just a mathematical formula (and a nice space-time diagram that looks complicated).

Interestingly tough, most of them will admit that we are in fact moving **relative to the cosmic microwave background** (CMB), as it clearly shows a Doppler effect (an anisotropy):



It is even possible to compute the speed of earth **relative to the universe** that way, and it is on the order of 600km/s (which includes the movement of earth around the sun, the sun around the galaxy, and the movement of the milky way itself relative to the cosmos).

So I wonder, if maybe the idea of an absolute space is not so absurd after all?

Next puzzle: [Puzzle Piece 6: Disentangling the Entanglement]

Summary Table

	Space-density Universe (RED pill)	**Space-Time Universe (BLUE pill)**
Tags	elastic solid, crystal universe, optical-mechanical analogue, space exists	Minkowski, space-time, absolute space does not exist
GR Metric Tensor	space-density (space with compression)	space-time
Cause of Gravity	refraction (density gradient, optical)	curvature of space-time

Photon	quantized wave, similar to phonon quasiparticles in crystal (vibrational mode), there are no photon "particles"	probability density wave function, no "real" wave, probability of finding photon
Double Slit Experiment	real waves interfering (like phonons)	parallel universes, no real wave, "consciousness" ,probabilistic…
Schrödinger Wave Equation	describes real waves, rotational waves in an elastic solid. There are no particles	probability of finding a particle, there are no real waves
What is space?	An elastic solid (not made of matter). Matter and light moves though space as waves move through a crystal	There is no absolute space
Special Relativity	Time dilation and length contraction are consequence of *any* wave system. Any wave has a maximum speed in any given medium.	There is no intuitive explanation. It follows from the constancy of the speed of light for each *observer*
Speed of light	c, constant in absolute space. Also c for each observer, due to time dilation	c is constant for each observer. There is no absolute space
Twin Paradox	No paradox. Whoever moved slower relative to absolute space ages faster.	If A is considered to be at rest, B ages more slowly, and vice versa. There is no clear answer as to who ages faster (if cleverly engineered – see post on that)
Uncertainty Principle	Natural consequence of any wave system	Due to wave property of matter and light (but only probabilistic)
Doppler Effect	Same as sound. Shift depends of speed of source and observer relative to an absolute space	Not same as sound as there is no medium. Strictly depends on relative velocity between observer and source. No physical explanation.

Links

Doppler Effect:

- Wikipedia: http://en.wikipedia.org/wiki/Doppler_effect
- Wikibooks: http://en.wikibooks.org/wiki/A-level_Physics_(Advancing_Physics)/Doppler_Effect
- Animation for light: http://www.acs.psu.edu/drussell/Demos/doppler/doppler.html
- Interactive Demo: http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::800::600::/sites/dl/free/0072482621/78778/Doppler_Nav.swf::Doppler%20Shift%20Inte

ractive

- Mathpages: http://mathpages.com/rr/s2-04/2-04.htm
- Cosmic Microwave Background Dipole Anisotropy: http://www.astro.ucla.edu/~wright/CMB-dipole-history.html

Optical analogues of General Relativity:

- Hagen Kleinerts World Crystal: http://users.physik.fu-berlin.de/~kleinert/papers/planckklcZN.pdf
- Defects and Diffusion in the Planck-Kleinert Crystal: http://ceram.agh.edu.pl/~icmmagh/artykuly/237%20PLANCK%20CRYSTAL%20DSL%20final.pdf
- Emerging Gravity from Defects in World Crystal: http://www.sbfisica.org.br/bjp/files/v35_359.pdf
- De Felice, F. On the gravitational field acting as an optical medium. Gen. Relativ. Gravit. 2,347–357 (1971).
- On the optical-mechanical analogy in general relativity: http://arxiv.org/abs/0905.4479 , http://www2.ups.edu/physics/faculty/evans/Optical%20Mechanical%20GRG.pdf
- The Classical Wave Theory of Matter by Robert Close: http://www.verumversa.com/

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Puzzle Piece 6: Disentangling the entanglement

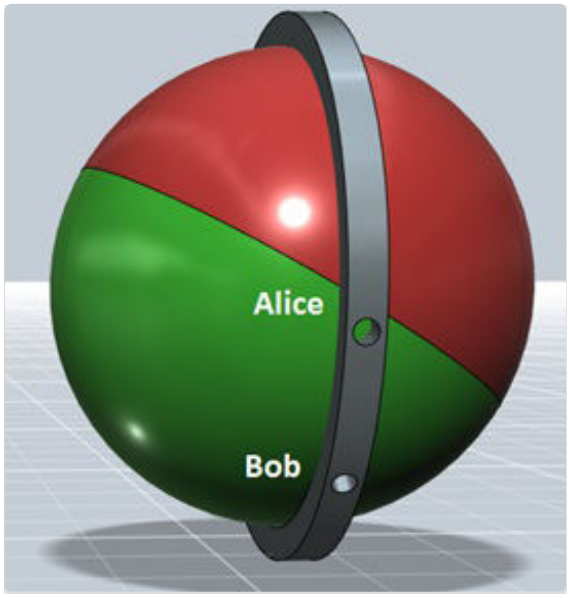
Previous puzzle: Puzzle Piece 5: The Doppler Challenge

The only potentially *really* weird thing in quantum mechanics in my opinion is the concept of "**entanglement**". After reading and re-rereading lots of papers on it, at some point I decided that the best way to really understand the problem is to write a computer simulation.

But first, let me try to explain the problem in simple terms – using a similar model as Caroline Thompson's chaotic ball. Imagine a colored ball, one side red and one side green. A ring with holes is attached. We can rotate the ball in any direction, and when it stops, two players Alice and Bob each peek through a hole and check what color they see. Then they write down two things:

- how far apart he holes were (in degrees, such as 45 degrees),
- whether they agreed on the color or not
  (if both saw red or both saw green, then they agreed)

In the first example, they both see green – so they **agree**. The angle is say 45 degrees between the holes.

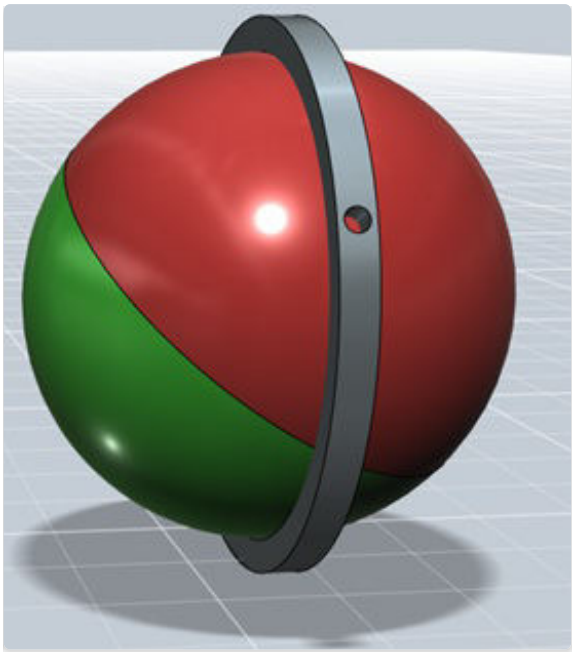


Now we repeat this game many times, for different random orientations of the ball. You can see that

if the red/green border falls between the holes, they won't agree, and otherwise they will agree. After say 1000 such experiments, we change the angle between the holes to one of:

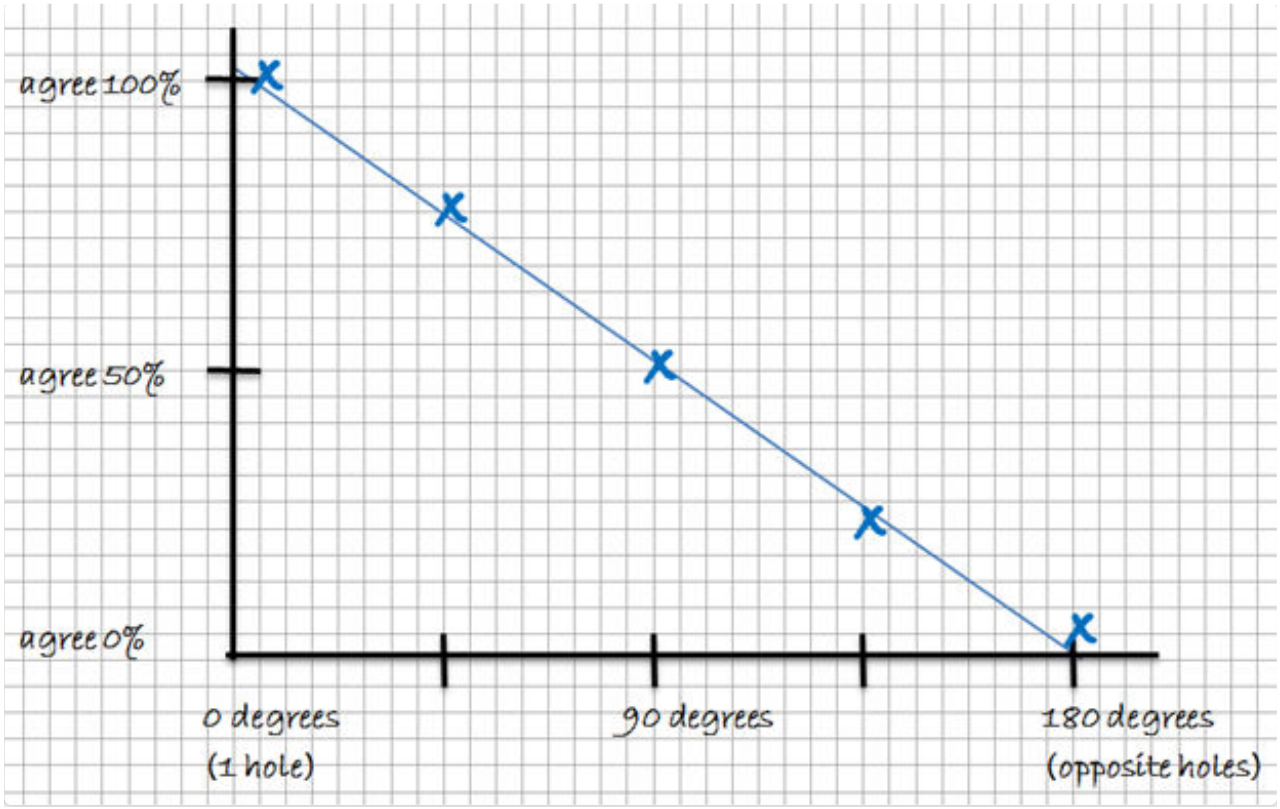
- 0 degrees (just one hole – both use the same 🙂
- 45 degrees
- 90 degrees
- 180 degrees

Obviously, for 0 degrees, Alice and Bob always agree on the color, since they both look into the same hole :-):

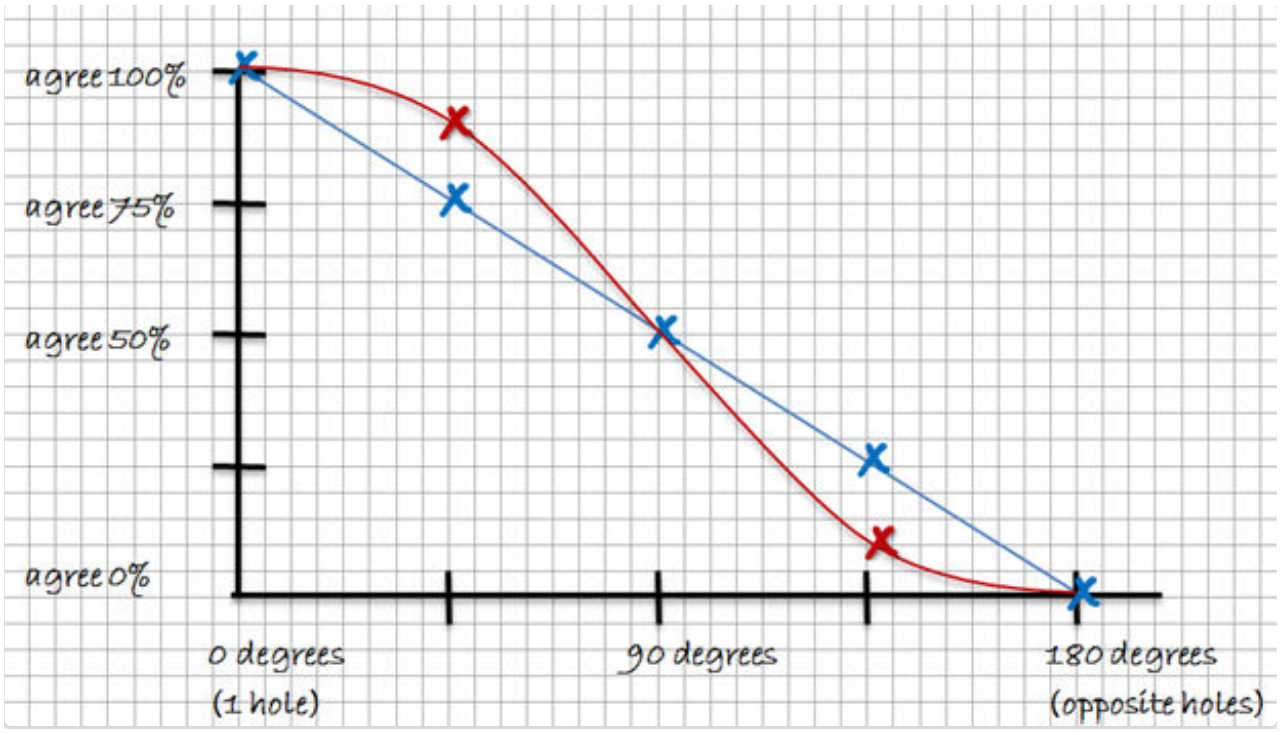


For 180 degrees, they never agree (since the holes are completely opposite).

Finally, we plot the result: for each angle between the holes (such as 0 degrees), we count the percentage of **how often we agreed** (nr of agreements / total observations). This will result in the typical shape like this – a straight line down:



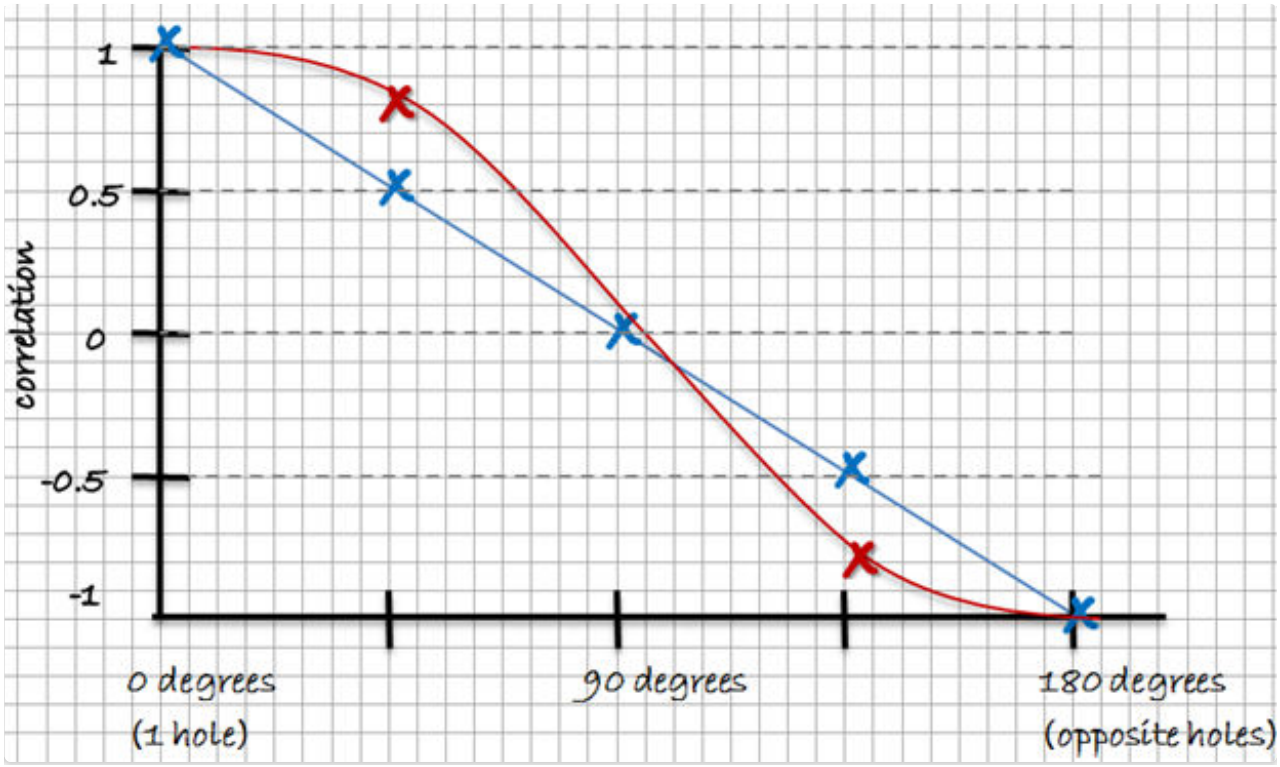
So··· what is special about that? So far, absolutely **nothing** :-). The thing is, if you do this with **photons** (two photon beams that have the same or opposite polarization, for instance), then you get the red curve – a cosine shape:



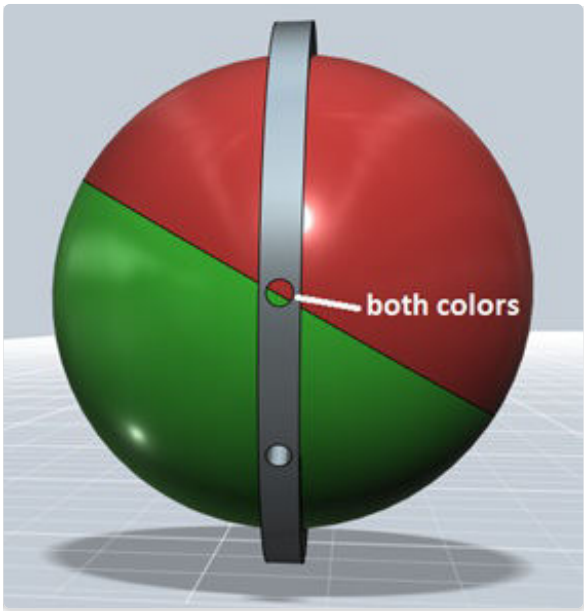
Before we jump to conclusions and exclaim that this is proof of entanglement, let's see if we can reproduce this result with our red/green ball. *And yes, we can actually quite easily do it!*

First, just to be a bit more accurate, we don't express the "agree" in percent, but in correlation. 0% agree means a correlation of –1, 50% agree means 0 correlation, and 100% agree means a

correlation of 1:



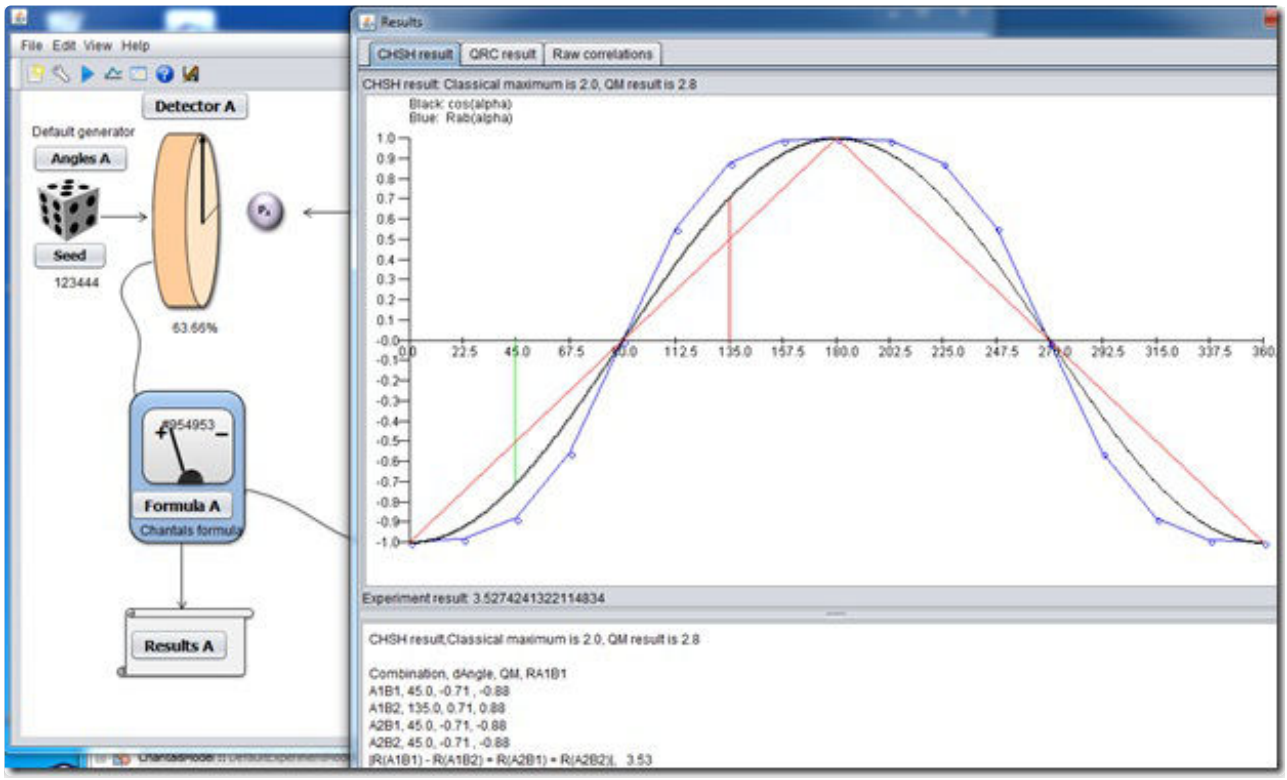
Now we change the rules of the game just a tiny bit: whenever we look into the hole and see **both colors** (red and green), like in the image below, then we have the right to say "**I don't know**!"



In that case, we **don't record a value** (or just a question mark). To make this even more like the quantum mechanics result, we say "**I don't know**" more often when we see both colors about the same amount, like in this image:

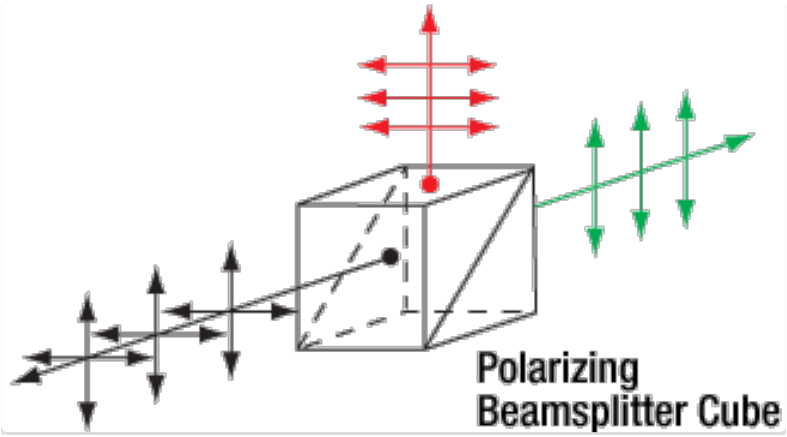
And we decide to call the color more often if one color clearly dominates (even though both colors are visible):

What does this change? Below is the result of a computer simulation that I wrote that you can download from GitHub: https://github.com/chenopodium/tango, which simulates such a game (in this example we can get even a "better" result than in QM). This game is called the "**detection loophole**" if you read papers on this (but there are other interpretations as well).

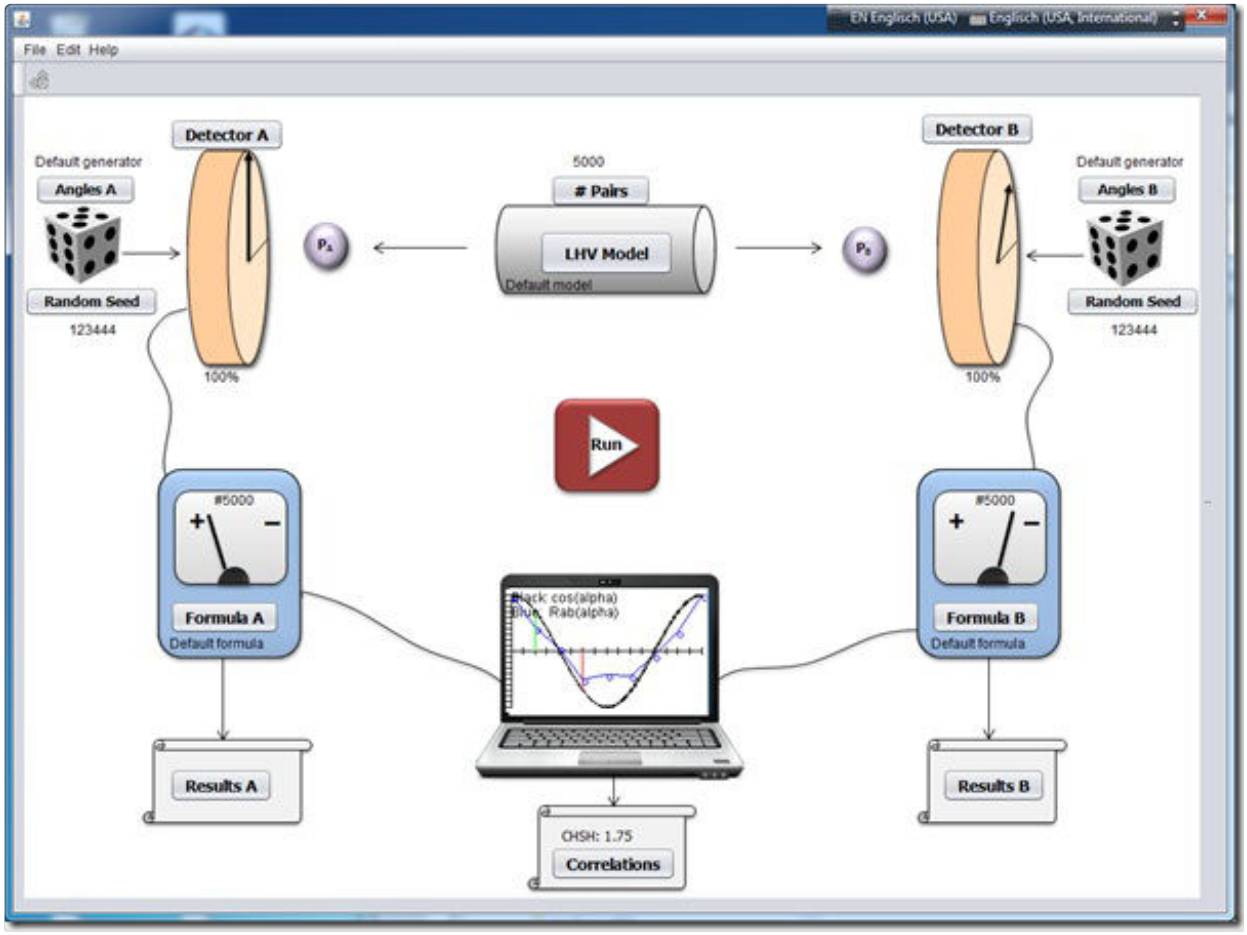


Instead of a red/green ball, we have two **photon beams** (P_A and P_B), which are created in a way that one beam is polarized **up/down**, and the other one is polarized **left/right**. This can be done with a beam splitter – similar to a prism. So we know that if one of the photon beams is up/down polarized, then the other side is left right polarized, and vice versa (of course we can make it so that there is a random angle to the whole thing, like in the example with the ball). These two beams are now **called**

 ntangled”. The reason is that the system can be described with *one mathematical formula* (since the polarization is correlated).



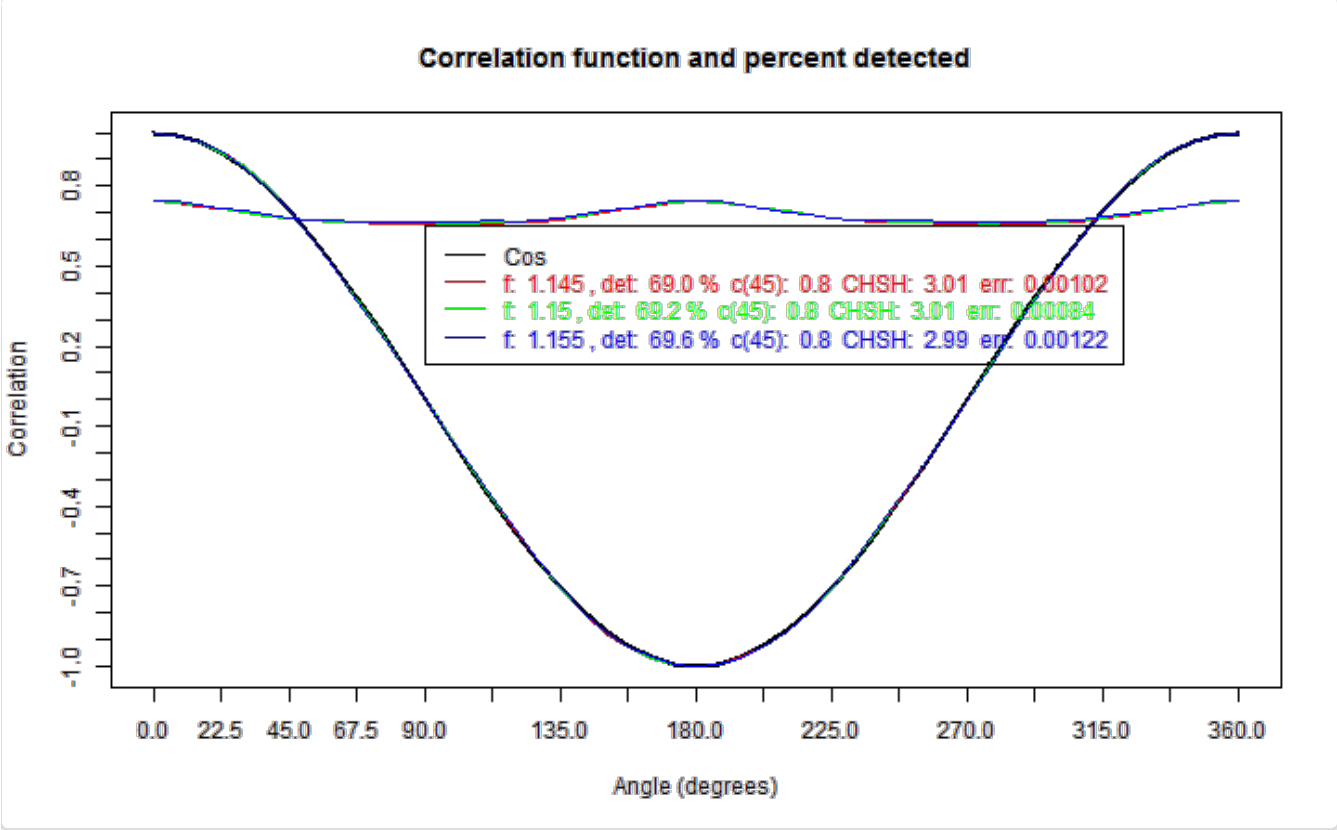
The **detector** is like our **holes**, where we decide if we measure the same polarization or not (up or down instead of red or green). Also, our detector can say “I don’t know” in this model.



You can click on the various images and change the rules of the game a bit, and see what the resulting correlation curve looks like. One rule you can change for instance is how large the “holes” are – basically how likely we are to say “I don’t know”. We know from experiments that we do detect at least 70-80% of the pairs (approximately), so we know approximately how often we can say “I don’t know” and still get results that match the actual QM experiments with photons.

For those who prefer the programming language **R** over Java, there is also an **R** simulation of the same type of "game": http://rpubs.com/chenopodium/detection1. (Thanks Richard Gill for the help!)

The additional wavy line on top shows how often we did make the call (and how often we said "I don't know"). In the chart below, we more had "no detection" around 90 degrees than at 0 degrees – and this is the reason why we get the cosine shape.



hɐe's the Magic?

You are probably wondering··· **so where exactly is the magic**, and what is all the fuss about entanglement? Well, **if** it turns out – and that is actually **not** known yet! – that we indeed are not measuring all pairs at all angles the same number of times, then there is in fact *no magic*. Then the only "entanglement" is in the mathematical formula, and in the fact that we know that the beams angle is correlated at the *source* – and nothing else (or at least, not in those kinds of experiments). Of course we can debate possible reasons why we don't measure all photons.

This is just one tiny part of this huge discussion, for more information, please check out the links below, in particular this blog:

http://challengingbell.blogspot.ch/

If someone can proof that we do indeed measure **all** photons **equally** at **all angles** (and also produce an equal number of photons for each angle!), then yes, there is something weird going on.

And then we need to seriously think about what this means (you can pick one of the weird models: faster then speed of light communication, some kind of connection in another dimension, parallel universes etc⋯)

However, until that day, I am not getting too excited about it :-).

First puzzle: Puzzle Piece 1: Optical Black Holes and Particles of Sound

riks

Papers and Information Links

- http://philoscience.unibe.ch/documents/TexteHS10/bell1964epr.pdf
- http://www.drchinese.com/David/Aspect.pdf
- http://cms.unige.ch/gap/optics/wiki/_media/publications:bib:annphys_9_831.pdf
- http://www.drchinese.com/David/EPR_Bell_Aspect.htm
- http://en.wikipedia.org/wiki/Loopholes_in_Bell_test_experiments

Links to web pages (alternative models, blogs etc):

- Chaotic Ball: http://arxiv.org/abs/quant-ph/9611037
- http://freespace.virgin.net/ch.thompson1/intro.htm
- Challenging Bell Blog: http://challengingbell.blogspot.ch/
  http://challengingbell.blogspot.ch/2014/02/new-models-by-richard-gill-and-chantal.html
- Joy Christian: http://arxiv.org/abs/1211.0784
- http://freespace.virgin.net/ch.thompson1/
- http://quantummechanics.mchmultimedia.com/

Simulations that I wrote or participated in:

- Java: Tango, an EPR playground to try multiple models): https://github.com/chenopodium/tango
- Java: older NetBeans implementation: https://github.com/chenopodium/EPR
- R: detection loophole: http://rpubs.com/chenopodium/detection1 (with help from Richard Gill)
- R: model for Joy Christian: http://rpubs.com/chenopodium/joychristian
- R: Gisin experiment: http://rpubs.com/chenopodium/gisin1
- R: another version of Joy Christians model: http://rpubs.com/chenopodium/joychristian
- Java, Joy Christians model: http://challengingbell.blogspot.ch/2013/09/a-parallelized-3-sphere-based-simulation.html
  https://github.com/chenopodium/JCS
- Java, another version of Joy's model: https://github.com/chenopodium/JCS2
- Java, for Bryan Sanctuary: http://challengingbell.blogspot.ch/2013/05/a-local-realistic-simulation-

of-epr.html

ther simulations:

- in Java Script: http://libertesphilosophica.info/eprsim/EPR_3-sphere_simulation_test5m.html
- Python: https://github.com/minkwe/epr-simple/
- c# simulation: http://sourceforge.net/projects/epr-bohm/

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The Red Pill..

It's the question that drives us⋯

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Apologies, but no results were found. Perhaps searching will help find a related post.

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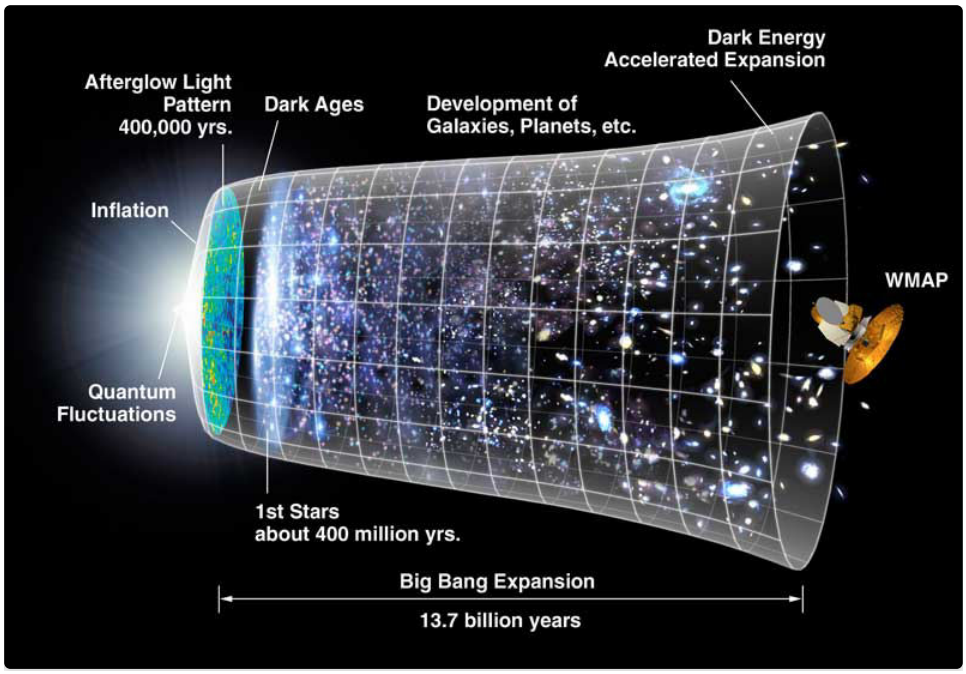
Second Puzzle: Big Bang or Big Problem?

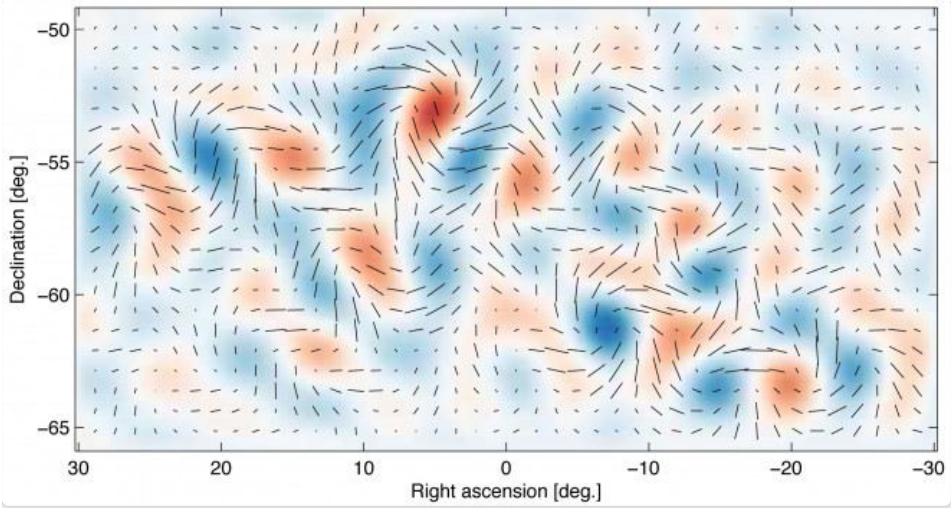
It's was all over the news: proof that the inflationary model is true. This revelation is based on the observation of (B-mode) polarized light patterns in the cosmic microwave background.



This polarization pattern is supposedly caused by gravitational waves – and not just any gravitational waves: waves from the Big Bang event itself. And not only that, based on the pattern of the polarization, scientists say that this is proof of an inflationary model, that at approximately

> *"0.00000000000000000000000000000000001 seconds after the Big Bang, it suddenly went through an accelerated expansion that drove it to become one thousand quadrillion quadrillion quadrillion quadrillion quadrillion times bigger than it previously was" (wired)*

This is much faster than the speed of light, by the way. Yes, we all know, nothing can go faster than the speed of light, neither light nor matter, nor even information, except of course, the universe itself. For some reason, this does not count⋯



I guess I don't sound very convinced – what I am not convinced of is that there is really no other reasonable explanation for the polarized CMB pattern. Does it really, explicitly proof both gravity waves and also inflation? What exactly is the logic that leads one from to this conclusion? Based on Wayne Hu, an expert in the field, it sounds like there are many possible foreground causes for this polarization, including scattering on dust, radio point sources, Bremsstrahlung and galactic synchrotron emissions – all of which have to be excluded. And of course, there is gravitational lensing, which is also a cause for B-modes. And is this really a complete list? Do we truly know all possible causes?

(Add-on: in the meantime, there is more and more doubt about this result, see for instance: Backlash to Big Bang Discovery Gathers Steam, http://www.scientificamerican.com/article/backlash-to-big-bang-discovery-gathers-steam/)

I have actually been one of those fierce defenders of the Big Bang Theory most of my life, and was convinced that scientists new it all down to a fraction of a second, and even wondered that some people wouldn't "believe" this – after all this is science, and not religion, right?

Well, that was before the addition of dark matter, dark energy, and super luminal expansion. It just got too much to take at some point, and I started to ask questions, which led to more questions, which never got properly answered. In this "Puzzle" I discuss some of those questions.

Big Bang Puzzle Piece I: Seeing Red
Big Bang Puzzle Piece 2: Older than Legally Allowed
Big Bang Puzzle Piece 3: Static Universe?

Links on CMB polarization

- http://www.scientificamerican.com/article/gravity-waves-cmb-b-mode-polarization/
- http://www.wired.com/wiredscience/2014/03/gravitational-waves-b-mode-inflation/
- Circular Polarization: http://en.wikipedia.org/wiki/Circular_polarization
- Foreground causes for CMB polarization:

http://background.uchicago.edu/~whu/polar/webversion/node21.html

- http://phenomena.nationalgeographic.com/2014/03/21/how-will-science-confirm-those-cosmic-signals-from-the-infant-universe/
- Backlash to Big Bang Discovery Gathers Steam http://www.scientificamerican.com/article/backlash-to-big-bang-discovery-gathers-steam/

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Big Bang Puzzle Piece I: Attachment issues

Hubble discovered that the further stars and galaxies are, the more red shifted the light is. ***One*** possible cause of red shift is the Doppler effect that we discussed in Puzzle Piece 5: The Doppler Challenge. This effect is the one that is usually mentioned in discussions about the Big Bang – even though it is not the one that is actually assumed to be the cause anymore.

This seems like a very reasonable assumption, and that's how the idea of the expanding universe came about.

As you may know, the problem with this is that the red shift happens to be symmetrical around earth. So if it was really the standard Doppler effect, then it would mean that earth is at the center of the universe, which is of course not very realistic.

The energy of a photon is E=hv, where v is the frequency. When photons get red shifted, it means they lose energy. Hence ***any*** process, by which photons lose energy, results in a red shift. There several dozen possible explanations of how photons can lose energy and thus be red shifted (See Marmet's paper on this) . Some include absorption by dust or electrons (Thompson scattering), another is one is due to gravity, yet another one is an intrinsic red shift of objects, interaction with the plasma of space etc, and yes, ***one*** of them is the idea of the expansion of "space time".

The last one seemed to fit nicely with the (mainstream) interpretation of general relativity (the space-

time interpretation), and so this is the one and **only** cause that is simply *assumed* to be true.

What did Hubble have to say about "his" discovery and the idea that space is supposed to be expanding?

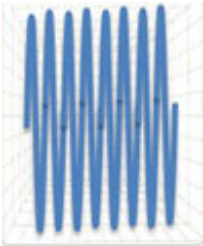
> *"Astronomer Edwin P. Hubble says that after a six-year study, evidence does not support what we now call the Big Bang theory, according to the Associated Press. "The universe probably is* ***not*** *exploding but is a quiet, peaceful place and possibly just about infinite in size.""*
>
> *http://www.science20.com/eternal_blogs/blog/hubble_eventually_did_not_believe_big_bang_associated_press-85962*

Halton Arp has observed several highly red shifted quasars that appear in **front** of close by galaxies… so then it seems that the red shift of at least some quasars does not necessarily indicate distance (or space expansion)… (and if that is the case, not only are quasars not very distant, enormously large and bright objects, but this raises the question about the red shift interpretation in general).

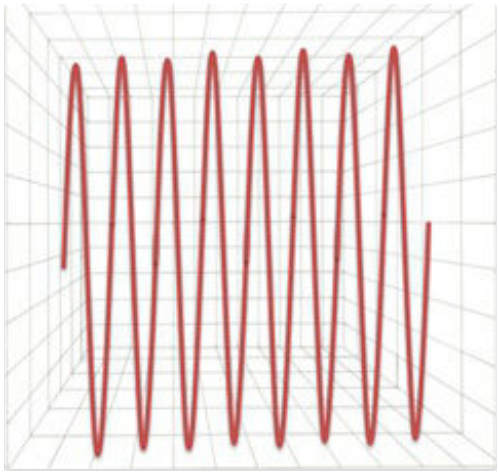
Even if space expansion is real, then an obvious question is: how much of the observed red shift is due to space expansion, how much is due to galaxies/stars actually literally moving (Doppler), and how much is due to other causes? The fact that light travels billions of years through space makes me think that the idea that light just *might* be losing a bit of energy during such a long trip does not sound entirely unreasonable, and should be seriously investigated. After all, the entire Big Bang idea rests mainly on the red shift interpretation…

Ok, let's be positive about this, and assume that indeed, the red shift is due to space expansion, at least part of it. Then how would that work, **exactly**?

Let's picture a part of space, indicated with a grid, and a light wave traveling through it.

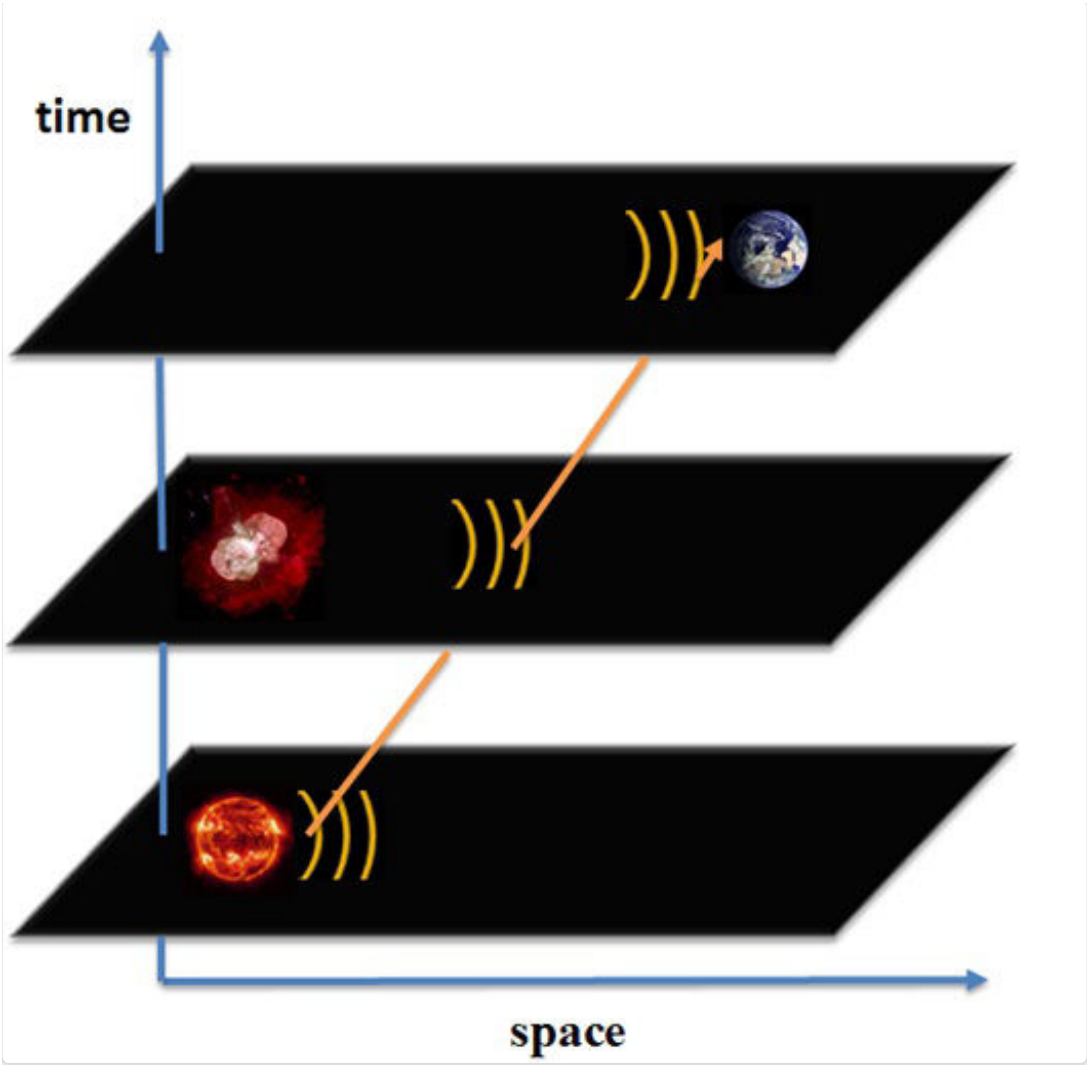


If we expand this piece of space, and if light is "attached" to that piece of space, then yes, the light wave will be red shifted (at least in this picture – relative to an **outside** observer…):

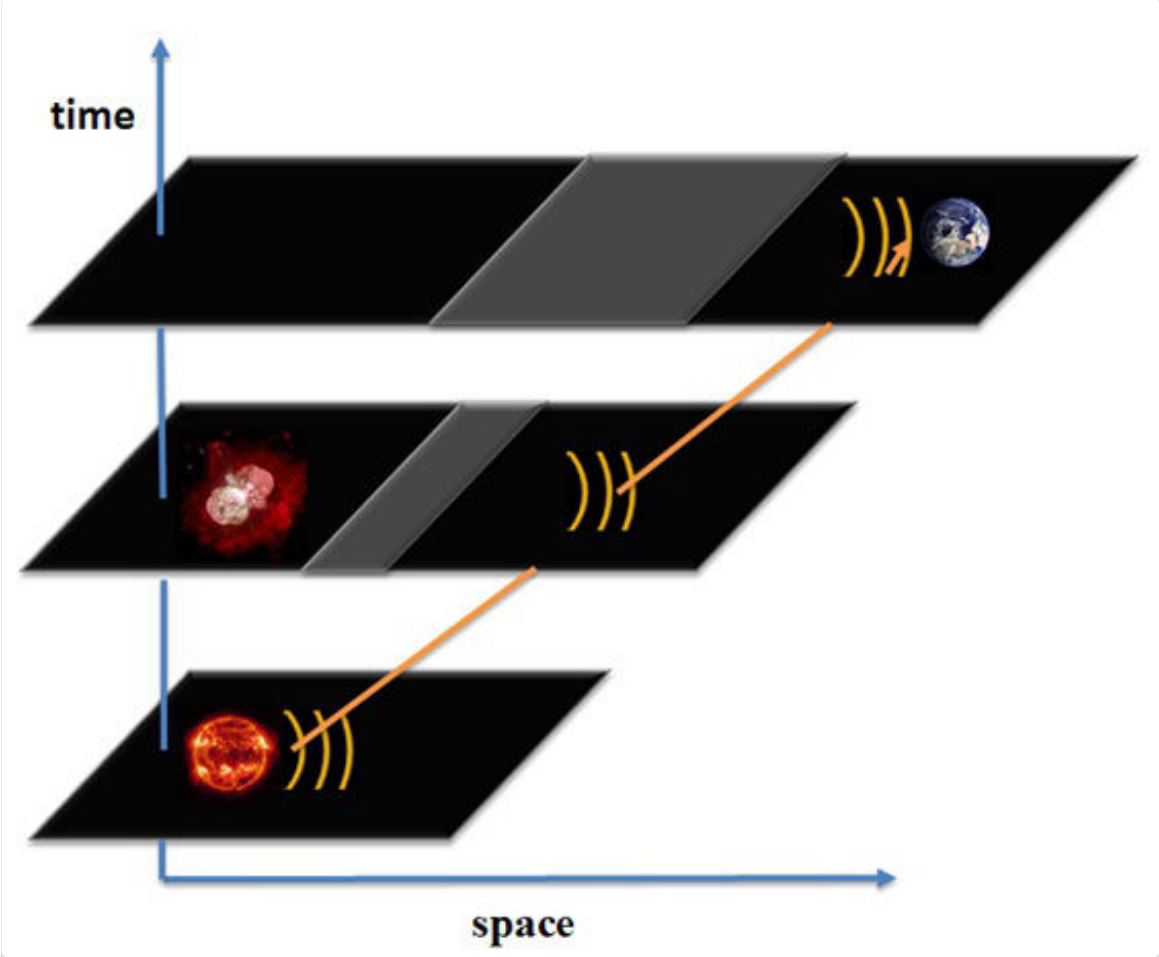


But wait a minute: if the light wave is literally stretched because it is somehow “attached” to space, just like a drawing on a balloon is stretched as it expands, then not only would the light wave expand, then it seems to me matter would also have to expand the same way.

If we use the usual assumption that there is no absolute space, then light in that model of course cannot be “attached” or connected to this (non-existent) absolute space, then why would the expansion of that space affect light in any way at all? Simply increasing the **distance** that light has to travel does not affects its wave length. Let’s consider a typical space-time diagram. For this example, let’s assume neither earth nor that star is moving (note, earth does not exist yet when the star emits the light).



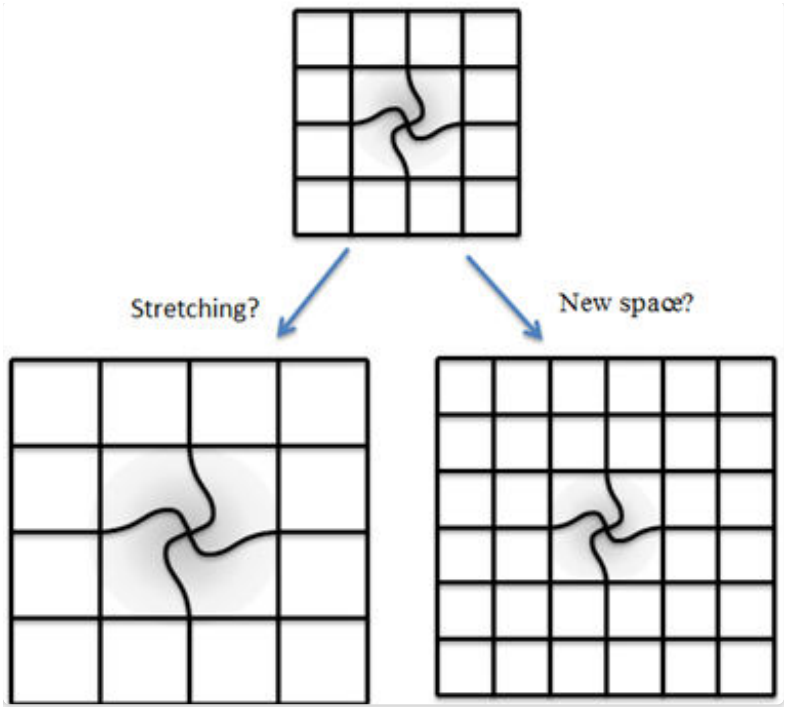
There is no red shift. Now, let's add some space, and assume that neither light nor matter is *attached* to space. So the only thing that changes is the distance. The gray area indicates the amount of space added:



Since the sun was not moving when the light was emittd, and the planet is not moving when the light arrives⋯ there is no Doppler effect and no red shift.

So it seems that this *only* works if light and matter is in fact somehow “attached” to space and thus stretched by the space expansion. In the space-density model, this is obvious, as light and matter are oscillations **of** space, so there clearly, any stretching of space would indeed affect light - and matter:

Let’s consider a small “particle”, indicated by a wave in the “medium space”.



Does expansion mean that space is stretched (left)? Well in that case, if light is stretched by this, then matter would **also** have to be stretched, and all atoms, and molecules would get larger over time. That of course essentially means we would not be able to notice anything different at all. If the entire universe, including matter in it, would increase in size proportionally, then all distances would never change relative to each other, and we would not observe a red shift either.

If expansion means that space is somehow "added" – even in the case where matter is in fact attached to space, neither light nor matter would be stretched. If light is just moving through **more** space, then all it means it takes light longer to travel.

Even if this were the case, then where exactly is that new space added? Is it added just between atoms? Then it would mean that the distance between atoms, including within a molecule, a star, within a galaxy etc. would be increasing. (And where would this new space be coming *from)*?

So the only way that light could be affected by the expansion of space is:

- if space is stretched (no new space)
- if light is somehow attached to space (like in the elastic solid model)
- => but then matter would also be affected the exact same way, resulting in no relative net effect

This is just one of many question – many more are discussed in numerous places elsewhere (see links below). To me, these were some of the question that started my doubt, because nobody was ever able to answer it⋯
Next Puzzle: Big Bang Puzzle Piece 2: Older than Legally Allowed

Links

Red Shift:

- http://www.marmet.org/cosmology/redshift/mechanisms.pdf
- http://en.wikipedia.org/wiki/Hubble's_law
- Hubble and red shift: http://www.science20.com/eternal_blogs/blog/hubble_eventually_did_not_believe_big_bang_associated_press-85962
- Is the Universe Really Expanding: http://arxiv.org/PS_cache/arxiv/pdf/1107/1107.2485v2.pdf
- Causes of red shift: http://www.plasma-universe.com/Redshift
- Other causes of red shift: http://qedradiation.scienceblog.com/11/redshift-by-cosmic-dust-trumps-hubble-and-tired-light-theories/
- Tired Light: http://www.lyndonashmore.com/
- http://www.setterfield.org/redshift.htm
- http://www.academia.edu/3189949/Dispersive_Extinction_Theory_of_Cosmic_Red_Shift_–_An_Alternative_to_the_Big_Bang_Theory
- http://charles_w.tripod.com/red.html
- http://electric-cosmos.org/arp.htm

Big Bang Problems:

- http://csep10.phys.utk.edu/astr162/lect/cosmology/bbproblems.html
- http://science.howstuffworks.com/dictionary/astronomy-terms/big-bang-theory7.htm
- http://www.spaceandmotion.com/Cosmology-Big-Bang-Theory.htm
- http://metaresearch.org/cosmology/BB-top-30.asp
- http://www.marmet.org/cosmology/fallofbigbang/index.html
- http://www.dailygalaxy.com/my_weblog/2013/11/the-largest-discovered-structure-in-the-universe-contradicts-big-bang-theory-cosmology-weekend-featu.html
- http://www.rense.com/general63/bbang.htm
- http://voices.yahoo.com/old-galaxies-young-universe-contradict-big-8744047.html
- http://cosmologyscience.com/cosblog/observation-of-two-early-mature-galaxies-rare-objects-or-is-big-bang-model-inaccurate/
- http://cosmologyscience.com/cosblog/spiral-galaxy-bx442-supports-hubbles-belief-redshift-does-not-mean-expansion/
- http://rense.com/general53/bbng.htm
- http://www.spaceandmotion.com/cosmology/halton-arp-seeing-red-errors-big-bang.htm
- http://www.haltonarp.com/articles/is_physics_changing
- http://electric-cosmos.org/arp.htm

Alternative models:

- http://www.nature.com/news/cosmologist-claims-universe-may-not-be-expanding-1.13379
- http://bigbangneverhappened.org/

- http://arxiv.org/abs/astro-ph/0401420v3
- http://www.haltonarp.com/articles/is_physics_changing

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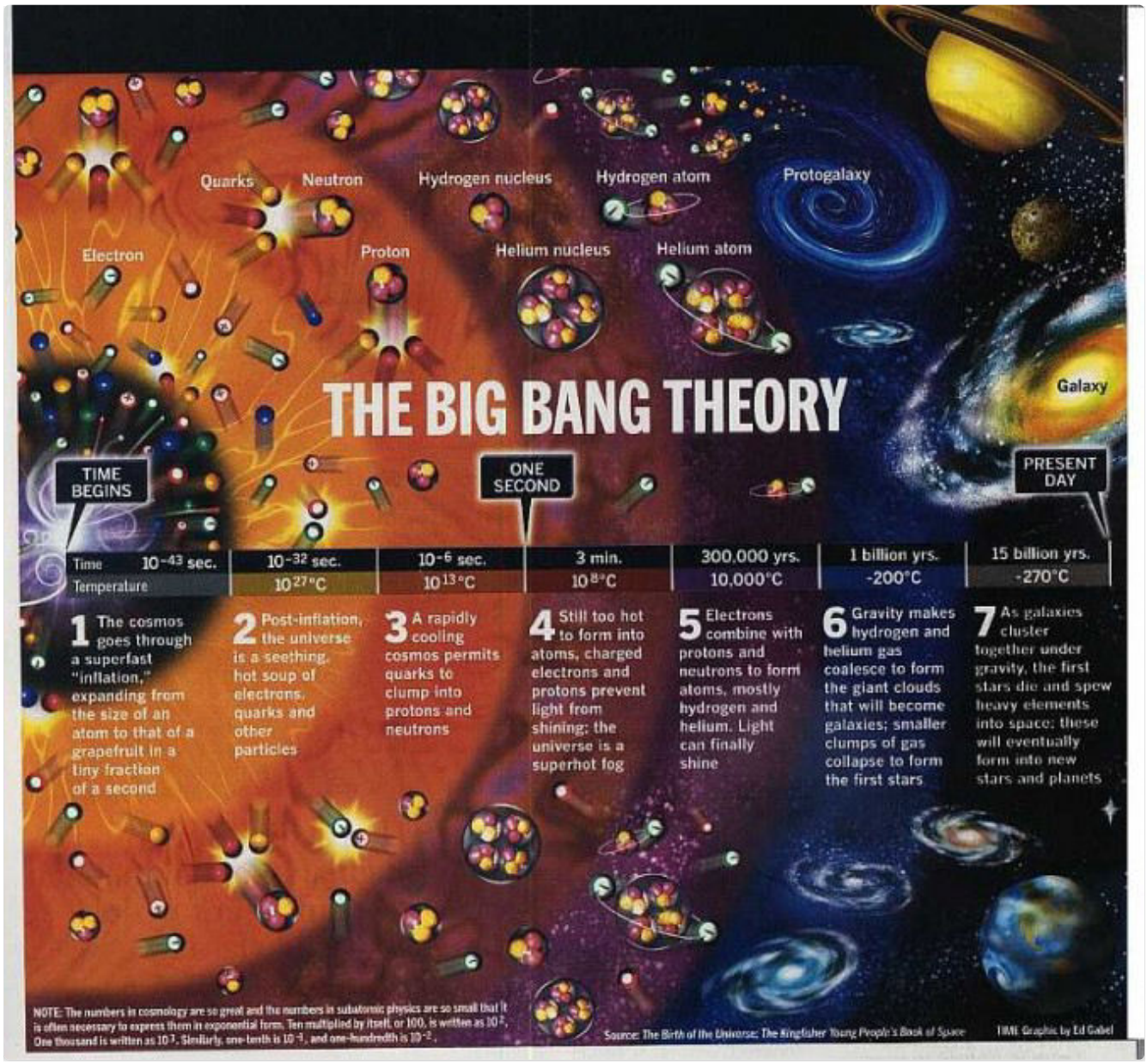
Big Bang Puzzle Piece 2: Older than legally allowed

Previous Puzzle: Big Bang Puzzle Piece I: Seeing Red

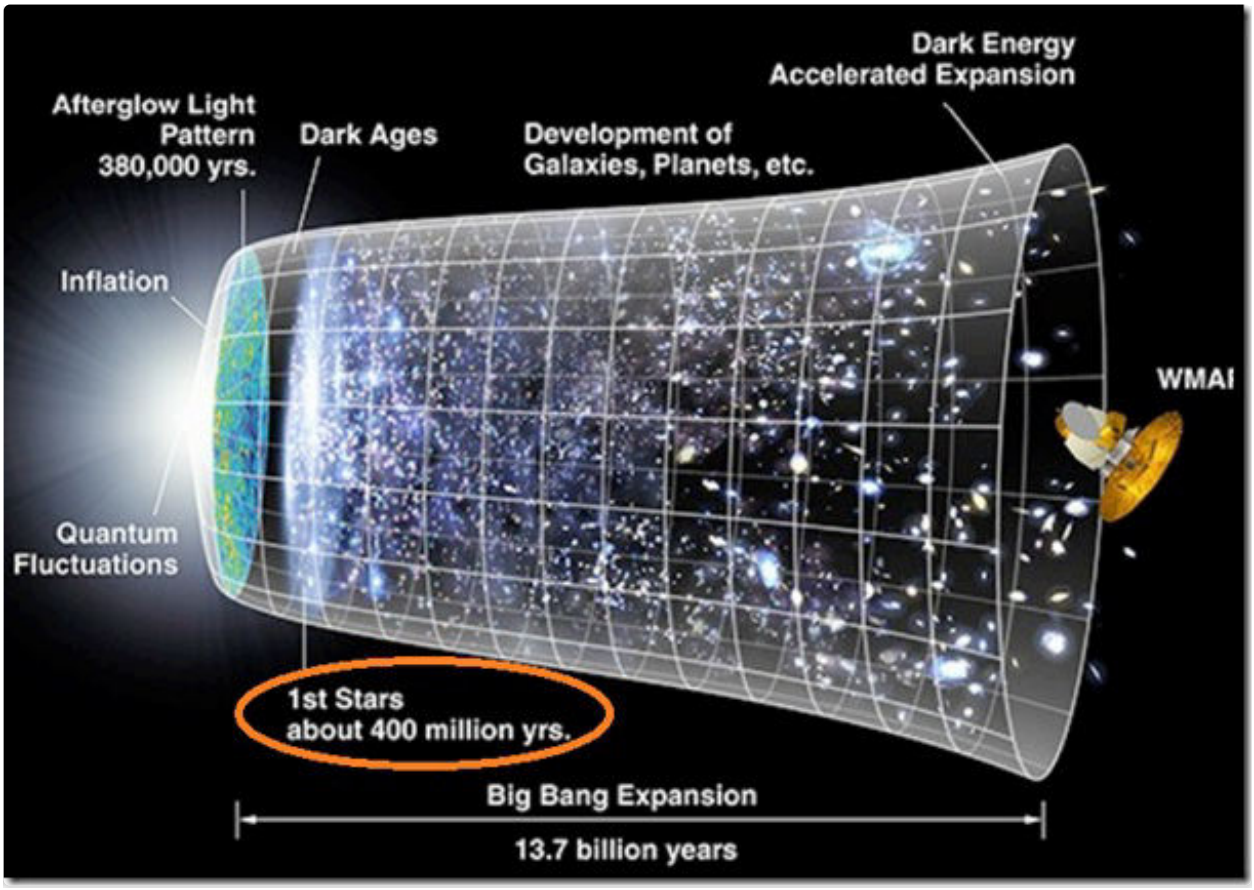
Oldest Galaxies and Stars

Based on a poster of the Big Bang, the first stars should have formed about **1 billion years** after the big bang:

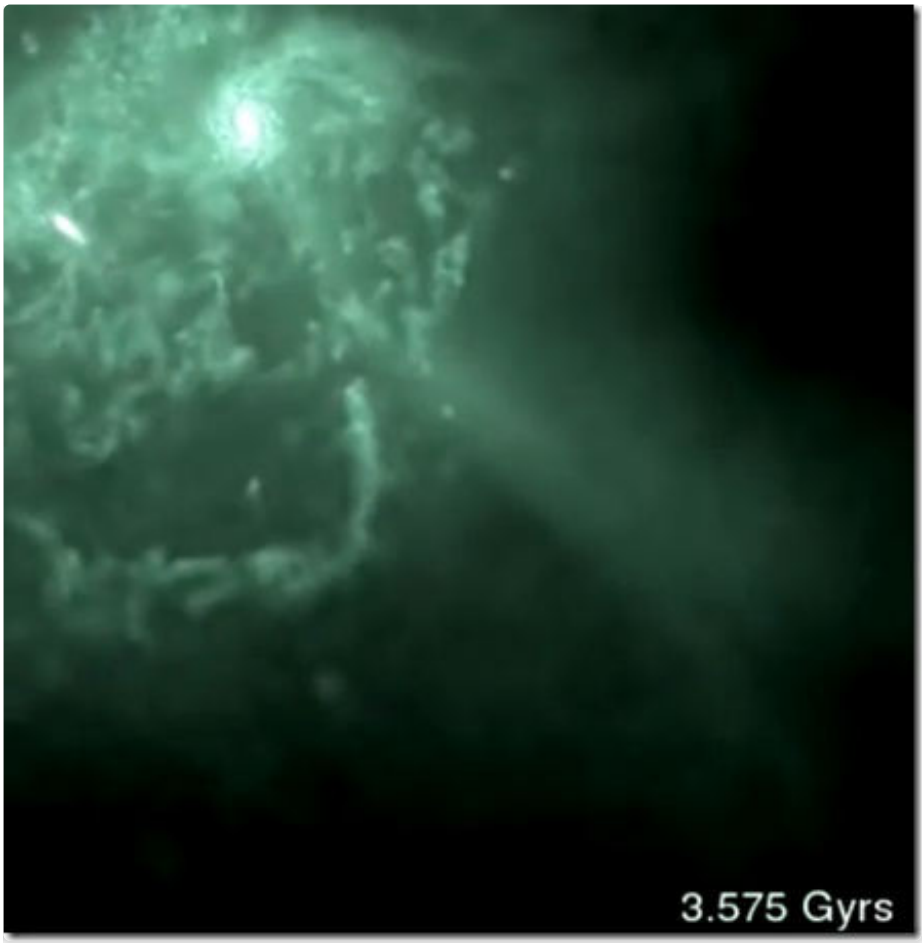


Yet, recently we keep finding more and more completely formed **galaxies**, that are **older** than that: for instance 7 from a period around 380 million years after the big bang. So that is much earlier than predicted. Also, this means that the galaxies only had a very short time to form. It takes over 200 million years just for one rotation of the milky way galaxy, for instance. Yet galaxy formation requires many rotations. There is even one galaxy that was found a mere 200 million years after the Big Bang. That means it didn't even have time for *one* complete rotation… ?

Even in later posters, where they move the star formation to an earlier time, the **first stars** are supposed to have formed **400 million years** after the Big Bang, and galaxies much later than that:



Based on computer simulations, it takes **more than 1 billion** years for a complete spiral galaxy to form: http://apod.nasa.gov/apod/ap120717.html (in this one, *several billion* years). Other simulations also indicate that it takes at least 1-2 billion years for a galaxy to form: http://www.theguardian.com/science/video/2013/may/28/galaxy-formation-universe-video



 he**obvious** question is: ***is the universe older than we think*** But instead of asking this question, scientists are changing the models of galaxy formation. They don't even *mention* the possibility, that just *maybe*, the universe is older. They simply assume that we know that the Big Bang is true, so everything else has to be changed to fit this model. To me, this sounds more like a religious dogma that true science…

Next Puzzle: Big Bang Puzzle Piece 3: Static Universe?

Links

Oldest galaxies and stars:

- 200 million years after big bang:
  http://www.extremetech.com/extreme/176497-weve-found-the-oldest-star-in-the-known-universe-and-its-right-on-our-galactic-doorstep
  http://news.softpedia.com/news/First-Galaxies-Formed-200-Million-Years-After-Big-Bang-195083.shtml
- 380 million years after big bang:
  http://news.nationalgeographic.com/news/2012/121214-hubble-oldest-galaxy-discovered-space-science/
  http://www.scientificamerican.com/article/early-universe-galaxy-hst/
- 420 million years after big bang:

http://rt.com/news/oldest-galaxy-discovered-universe-922/

- 500 million years after big bang: http://news.nationalgeographic.com/news/2014/01/140107-hubble-oldest-frontier-science-space-astronomy/
- 650 million years after big bang: http://www.upi.com/Science_News/2014/02/20/New-Hubble-Space-Telescope-images-showcase-universes-oldest-galaxy/4671392934751/
- 700 million years after big bang: http://www.theguardian.com/science/2013/oct/23/most-distant-galaxy-star-factory http://arstechnica.com/science/2013/10/oldest-galaxy-yet-seen-forming-stars-100-times-faster-than-milky-way/

Galaxy Formation/Simulations:

- http://www.universetoday.com/23870/the-milky-ways-rotation/
- http://arxiv.org/abs/1103.6030
- http://apod.nasa.gov/apod/ap120717.html
- http://www.theguardian.com/science/video/2013/may/28/galaxy-formation-universe-video
- http://www.plasma-universe.com/Galaxy_formation

Big Bang Problems:

- http://csep10.phys.utk.edu/astr162/lect/cosmology/bbproblems.html
- http://science.howstuffworks.com/dictionary/astronomy-terms/big-bang-theory7.htm
- http://www.spaceandmotion.com/Cosmology-Big-Bang-Theory.htm
- http://metaresearch.org/cosmology/BB-top-30.asp
- http://www.marmet.org/cosmology/fallofbigbang/index.html
- http://www.dailygalaxy.com/my_weblog/2013/11/the-largest-discovered-structure-in-the-universe-contradicts-big-bang-theory-cosmology-weekend-featu.html
- http://www.rense.com/general63/bbang.htm
- http://voices.yahoo.com/old-galaxies-young-universe-contradict-big-8744047.html
- http://cosmologyscience.com/cosblog/observation-of-two-early-mature-galaxies-rare-objects-or-is-big-bang-model-inaccurate/
- http://cosmologyscience.com/cosblog/spiral-galaxy-bx442-supports-hubbles-belief-redshift-does-not-mean-expansion/
- http://rense.com/general53/bbng.htm
- http://www.spaceandmotion.com/cosmology/halton-arp-seeing-red-errors-big-bang.htm
- http://www.haltonarp.com/articles/is_physics_changing
- http://electric-cosmos.org/arp.htm
- http://www.astronomynotes.com/cosmolgy/s12.htm

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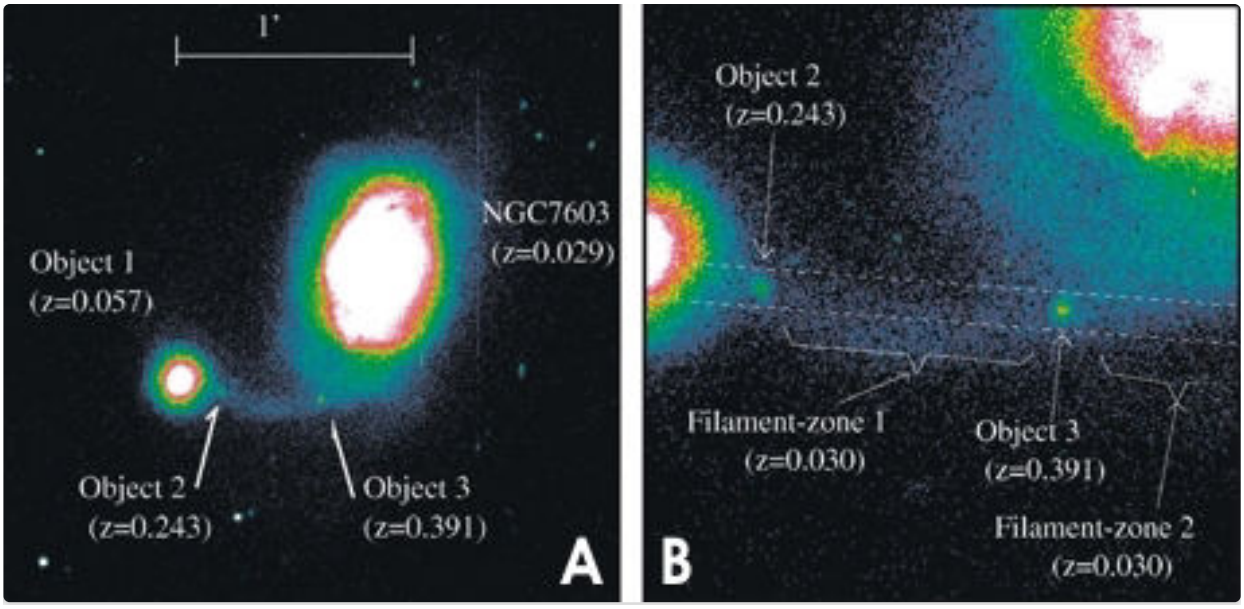
Big Bang Puzzle Piece 3: Static Universe?

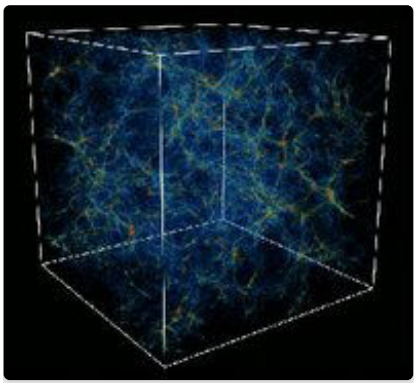
Previous puzzle: Big Bang Puzzle Piece 2: Older than Legally Allowed

The Big Bang theory is facing some serious issues, including:

- highly red shifted quasars that appear next and even in front of nearby galaxies (so they are not really that far away, not as huge as suggested, and this also means that there is at least one other cause for the red shift)



- galaxies that formed too soon after the big bang and do not look primitive
- super clusters (Tully) that are over hundred million light years across and are older than the universe
- large scale voids that would take 70 billion years to form
- the fact that space is supposed to exist in an absolute sense in order to expand, yet in other areas of physics it is strictly assumed that space does not exist
- the "expansion" as sole reason for the red shift, which is ***not*** a Doppler effect, and how this red shift is really supposed to happen so that the light wave expands, but not matter.
- The suns center to limb variation in red shift – which is clearly



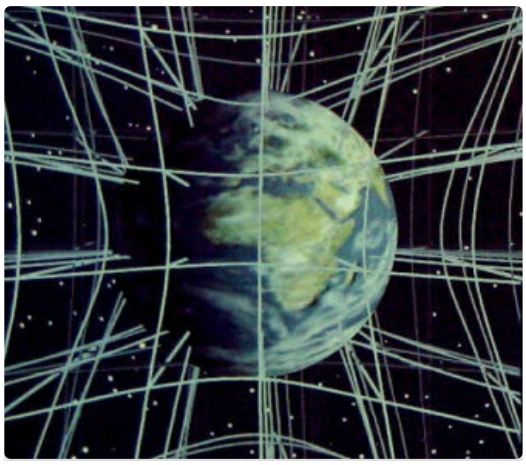
has another cause than expansion (so if it is the case for the sun, this would also apply to other stars)
- very old stars that already contain carbon, which should not be there
- the fact that the distant universe does not look any denser than the universe today
- the energy conservation problem: how can the entire universe have arisen out of nothing?
- the black hole problem: given that all matter in the universe used to be much closer than now, and so much denser, it means the entire universe was well within its own Schwarzschild radius, meaning it was a black hole. If nothing can get out of a black hole, then how come the universe itself can?
- the whole idea of inflation, dark matter, dark energy – all ad hoc additions to the theory because observations do not fit
- the supposedly observed "time dilation" of supernovas, but lack of such time dilation in gamma ray bursts

(These are just some of the main issues – for more information, please check the links below.)

Static, Infinite Universe

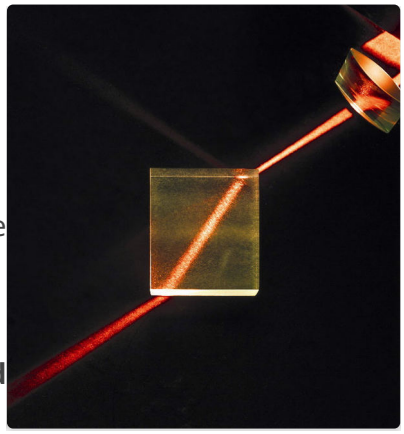
One possible solution to those issues is a simple static, infinite universe. That is, one that always existed, will always exist, where space neither expands nor contracts.

In another puzzle on the interpretation of general relativity, we discussed the idea that there is a completely equivalent model, the "crystal universe" model, where the space curvature is described with space-density, and not space-time, and where gravity is a purely optical phenomenon. In that model, both matter and light are purely made of (real) waves, oscillations in that elastic solid medium "space".



What kinds of observations and predictions could we make based on this simple model? If this medium even has the tiniest bit of imperfection, then we would expect several observations:

- **Red shift**:



For *nearby moving* objects, the dominant effect is probably a simple Doppler effect, that causes light to be red or blue shifted, depending on the velocity relative to earth (even Big Bang proponents agree on that). For more distant objects, there are many possible mechanisms (see Marmet's paper for an extensive list). One explanation not in Marmet's paper is the IsoRedShift by Santilli: the observation that as light travels through a transparent physical medium it loses some of its energy which results in a **red shift** (*without* any relative motion between source and observer)

- **CMB**: when light travels a long distance through any (real) medium, the intensity decreases (*attenuation*). At the same time, this energy is not lost, but causes the medium to **warm up** slightly. This would not only explain *Olber's* Paradox (that the sky is not bright), but also explain one possible reason that the universe has a temperature (**CMB)**
- No need for dark energy and no dark matter

Following are several predictions that could confirm such a model:

- The speed of light might be ***frequency dependent***: at least for regular media, such as for sound waves in a crystal, waves with very short wave length (comparable to the crystal grid size) would travel slower than waves of longer wave length. If we consider that the universe has a grid size of around the Planck length ***h***, then this would only affect ultra short gamma rays. This would mean that gamma rays with short wave length from far away events would arrive a bit later than longer wave lengths.
- As we look deeper into space, we would expect completely formed galaxies no matter how far away they are, and stars that contain carbon (and other heavier elements)
- The universe does not get any denser the further away we look
- Any size of void or cluster is possible
- The entropy of the entire universe does ***not*** increase, but is ***constant***.
- There must be a process by which particles form out of the background energy/oscillations of space (such as the "spontaneous" particle/anti particle formation in vacuum)

Links

Static Universe Models:

- Static Universe: http://en.wikipedia.org/wiki/Static_universe
- Static Universe (Lerner): http://www.learner.org/courses/physics/unit/text.html?unit=11&secNum=2
- Static Universe (Ratcliffe): http://www.hiltonratcliffe.com/Static.htm

RedShift:

- http://www.santilli-foundation.org/docs/IRS-confirmations-212.pdf
- http://www.workshops-hadronic-mechanics.org/isoshifts.php
- http://www.benthamscience.com/open/toaaj/articles/V003/126TOAAJ.pdf
- http://www.redorbit.com/news/science/1113036944/santillis-invariant-derivation-of-hubbles-law-without-expansion-of-the/
- http://qedradiation.scienceblog.com/11/redshift-by-cosmic-dust-trumps-hubble-and-tired-light-theories/
- http://www.newtonphysics.on.ca/universe/
- German: http://www.newtonphysics.on.ca/hubble/rotverschiebung.pdf

O□tical anal□ □ s□ □f General Relativity:

- Hagen Kleinerts World Crystal: http://users.physik.fu-berlin.de/~kleinert/papers/planckklcZN.pdf
- Defects and Diffusion in the Planck-Kleinert Crystal: http://ceram.agh.edu.pl/~icmmagh/artykuly/237%20PLANCK%20CRYSTAL%20DSL%20final.pdf

Big Bang Problems:

- http://metaresearch.org/cosmology/BB-top-30.asp
- http://www.spaceandmotion.com/Cosmology-Big-Bang-Theory.htm
- http://csep10.phys.utk.edu/astr162/lect/cosmology/bbproblems.html
- http://science.howstuffworks.com/dictionary/astronomy-terms/big-bang-theory7.htm
- http://www.marmet.org/cosmology/fallofbigbang/index.html
- http://www.dailygalaxy.com/my_weblog/2013/11/the-largest-discovered-structure-in-the-universe-contradicts-big-bang-theory-cosmology-weekend-featu.html
- http://www.rense.com/general63/bbang.htm
- http://voices.yahoo.com/old-galaxies-young-universe-contradict-big-8744047.html
- http://cosmologyscience.com/cosblog/observation-of-two-early-mature-galaxies-rare-objects-or-is-big-bang-model-inaccurate/
- http://cosmologyscience.com/cosblog/spiral-galaxy-bx442-supports-hubbles-belief-redshift-does-not-mean-expansion/
- http://rense.com/general53/bbng.htm
- http://www.spaceandmotion.com/cosmology/halton-arp-seeing-red-errors-big-bang.htm
- http://www.haltonarp.com/articles/is_physics_changing
- http://electric-cosmos.org/arp.htm
- http://www.libertysteve.com/commonsense/big-bang-baloney-real-science-is-suppressed/
- German: http://www.mahag.com/allg/urknall.php http://www.mahag.com/allg/urknall2.php

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Speeches

Following are links (and quotes) from speeches of Einstein and Schrödinger – in particular those that may not be so familiar, and in the context of the alternative interpretation of space and matter (as real waves):

1. Ether and the Theory of Relativity (Albert Einstein)

> *"More careful reflection teaches us however, that **the special theory of relativity does not compel us to deny ether**. We may assume the existence of an ether; only we must give up ascribing a definite state of motion to it"*
>
> *"Recapitulating, we may say that **according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an ether**. According to the general theory of relativity **space without ether is unthinkable**; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense"*

2. Äther und Relativtäts-Theorie (Albert Einstein, German)

> *"…die Ätherhypothese an sich widerstreitet der speziellen Relativitätetheorie nicht"*
>
> *"**Nach der allgemeinen Relativitätstheorie ist der Raum mit physikalischen Qualitäten ausgestattet; es existiert also in diesem Sinne ein Äther**. Gemäß der allgemeinen Relativitätstheorie ist **ein Raum ohne Äther undenkbar**; denn in einem solchen gäbe es nicht nur keine Lichtfortpflanzung, sondern auch keine Existenzmöglichkeit von Maßstäben und Uhren, also auch keine räumlich-zeitlichen Entfernungen im Sinne der Physik."*

3. Concerning the Aether (Albert Einstein)

> *"But even if these possibilities do mature into an actual theory,* ***we will not be able to do without the aether in theoretical physics****, that is, a* ***continuum endowed with physical properties****; for general relativity, to whose fundamental viewpoints physicists will always hold fast, rules out direct action at a distance. But* ***every theory of local action assumes continuous fields, and thus also the existence of an 'aether'****."*

3. Über den Aether (Albert Einstein, German)

> *Aber selbst wenn diese Möglichkeiten zu wirklichen Theorien heranreifen,* ***werden wir des Äthers, d. h. des mit physikalischen Eigenschaften ausgestatteten Kontinuums, in der theoretischen Physik nicht entbehren können****; denn die allgemeine Relativitätstheorie, an deren grundsätzlichen Gesichtspunkten die Physiker wohl stets festhalten werden, schliesst eine unvermittelte Fernwirkung aus;* ***jede Nahewirkungs-Theorie aber setzt kontinuierliche Felder voraus, also auch die Existenz eines „Äthers"****.*

4. The Meaning of Wave Mechanics (Schrödinger)

> *"Let me say at the outset, that in this discourse, I am opposing not a few special statements of quantum physics held today (1950s), I am opposing as it were the whole of it, I am opposing its basic views that have been shaped 25 years ago, when Max Born put forward his* ***probability interpretation****, which was accepted by almost everybody."*

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Äther und Relativitäts-Theorie (Einstein)

ÄTHER
UND
RELATIVITÄTS-THEORIE

REDE

GEHALTEN AM 5. MAI 1920
AN DER REICHS-UNIVERSITÄT ZU LEIDEN

VON
ALBERT EINSTEIN

BERLIN
VERLAG VON JULIUS SPRINGER
1920

Meine Herren Kuratoren, Professoren, Doktoren und Studenten dieser Universität!

Sie alle ferner, meine Damen und Herren, welche diese Feier durch Ihre Anwesenheit ehren!

"Wie kommen die Physiker dazu, neben der der Abstraktion des Alltagslebens entstammenden Idee, der ponderabeln Materie, die Idee von der Existenz einer anderen Materie, des Äthers, zu setzen? Der Grund dafür liegt wohl in denjenigen Erscheinungen, welche zur Theorie der Fernkräfte Veranlassung gegeben haben, und

in den Eigenschaften des Lichtes, welche zur Undulationstheorie geführt haben. Wir wollen diesen beiden Gegenständen eine kurze Betrachtung widmen.

Das nichtphysikalische Denken weiß nichts von Fernkräften. Bei dem Versuch einer kausalen Durchdringung der Erfahrungen, welche wir an den Körpern machen, scheint es zunächst keine anderen Wechselwirkungen zu geben als solche durch unmittelbare Berührung, z.B. Bewegungs-Übertragung durch Stoß, Druck und Zug, Erwärmung oder Einleitung einer Verbrennung durch eine Flamme usw. Allerdings spielt bereits in der Alltagserfahrung die Schwere, also eine Fernkraft, eine Hauptrolle.

Da uns aber in der alltäglichen Erfahrung die Schwere der Körper als etwas Konstantes, an keine räumlich oder zeitlich*veränderliche* Ursache Gebundenes entgegentritt, so denken wir uns im Alltagsleben zu der Schwere überhaupt keine Ursache und werden uns deshalb ihres Charakters als Fernkraft nicht bewußt. Erst durch Newtons Gravitations-Theorie wurde eine Ursache für die Schwere gesetzt, indem letztere als Fernkraft gedeutet wurde, die von Massen herrührt. Newtons Theorie bedeutet wohl den größten Schritt, den das Streben nach kausaler Verkettung der Naturerscheinungen je gemacht hat. Und doch erzeugte diese Theorie bei Newtons Zeitgenossen lebhaftes Unbehagen, weil sie mit dem aus der sonstigen Erfahrung fließenden Prinzip in Widerspruch zu treten schien, daß es nur Wechselwirkung durch Berührung, nicht aber durch unvermittelte Fernwirkung gebe.

Der menschliche Erkenntnistrieb erträgt einen solchen Dualismus nur mit Widerstreben. Wie konnte man die Einheitlichkeit der Auffassung von den Naturkräften retten? Entweder man konnte versuchen, die Kräfte, welche uns als Berührungskräfte entgegentreten, ebenfalls als Fernkräfte aufzufassen, welche sich allerdings nur bei sehr geringer Entfernung bemerkbar machen; dies war der Weg, welcher von Newtons Nachfolgern, die ganz unter dem Banne seiner Lehre standen, zumeist bevorzugt wurde. Oder aber man konnte annehmen, daß die Newtonschen Fernkräfte nur *scheinbar* unvermittelte Fernkräfte seien, daß sie aber in Wahrheit durch ein den Raum durchdringendes Medium übertragen würden, sei es durch Bewegungen, sei es durch elastische Deformation dieses Mediums. So führt das Streben nach Vereinheitlichung unserer Auffassung von der Natur der Kräfte zur Ätherhypothese. Allerdings brachte letztere der Gravitationstheorie und der Physik überhaupt zunächst keinen Fortschritt, so daß man sich daran gewöhnte, Newtons Kraftgesetz als nicht mehr weiter zu reduzierendes Axiom zu behandeln.

Die Ätherhypothese mußte aber stets im Denken der Physiker eine Rolle spielen, wenn auch zunächst meist nur eine latente Rolle.

Als in der ersten Hälfte des 19. Jahrhunderts die weitgehende Ähnlichkeit offenbar wurde, welche zwischen den Eigenschaften des Lichtes und denen der elastischen Wellen in ponderabeln Körpern besteht, gewann die Ätherhypothese eine neue Stütze. Es schien unzweifelhaft, daß das Licht als Schwingungsvorgang eines den Weltraum erfüllenden, elastischen, trägen Mediums gedeutet werden müsse. Auch schien aus der Polarisierbarkeit des Lichtes mit Notwendigkeit hervorzugehen, daß dieses Medium – der Äther – von der Art eines festen Körpers sein müsse, weil nur in einem solchen, nicht aber in einer Flüssigkeit Transversalwellen möglich sind. Man mußte so zu der Theorie des "quasi-starren" Lichtäthers kommen, dessen Teile relativ zueinander keine anderen Bewegungen auszuführen vermögen als die kleinen Deformationsbewegungen, welche den Lichtwellen entsprechen.

Diese Theorie – auch Theorie des ruhenden Lichtäthers genannt – fand ferner eine gewichtige Stütze in dem auch für die spezielle Relativitätstheorie fundamentalen Experimente von Fizeau, aus welchem man schließen mußte, daß der Lichtäther an den Bewegungen der Körper nicht teilnehme. Auch die Erscheinung der Aberration sprach für die Theorie des quasistarren Äthers.

Die Entwicklung der Elektrizitätstheorie auf dem von Maxwell und Lorentz gewiesenen Wege brachte eine ganz eigenartige und unerwartete Wendung in die Entwicklung unserer den Äther betreffenden Vorstellungen. Für Maxwell selbst war zwar der Äther noch ein Gebilde mit rein mechanischen Eigenschaften, wenn auch mit mechanischen Eigenschaften viel komplizierterer Art als die der greifbaren festen Körper. Aber weder Maxwell noch seinen Nachfolgern gelang es, ein mechanisches Modell für den Äther auszudenken, das eine befriedigende mechanische Interpretation der Maxwellschen Gesetze des elektromagnetischen Feldes geliefert hätte. Die Gesetze waren klar und einfach, die mechanischen Deutungen schwerfällig und widerspruchsvoll. Beinahe unvermerkt paßten sich die theoretischen Physiker dieser vom Standpunkte ihres mechanischen Programms recht betrübenden Sachlage an, insbesondere unter dem Einfluß der elektrodynamischen Untersuchungen von Heinrich Hertz. Während sie nämlich vordem von einer endgültigen Theorie gefordert hatten, daß sie mit Grundbegriffen auskomme, die ausschließlich der Mechanik angehören (z.B. Massendichten, Geschwindigkeiten, Deformationen, Druckkräfte), gewöhnten sie sich allmählich daran, elektrische

und magnetische Feldstärken als Grundbegriffe neben den mechanischen Grundbegriffen zuzulassen, ohne für sie eine mechanische Interpretation zu fordern. So wurde allmählich die rein mechanische Naturauffassung verlassen. Diese Wandlung führte aber zu einem auf die Dauer unerträglichen Dualismus in den Grundlagen. Um ihm zu entgehen, suchte man umgekehrt die mechanischen Grundbegriffe auf die elektrischen zu reduzieren, zumal die Versuche an ß-Strahlen und raschen Kathodenstrahlen das Vertrauen in die strenge Gültigkeit der mechanischen Gleichungen Newtons erschütterten.

Bei H.Hertz ist der angedeutete Dualismus noch ungemildert. Bei ihm tritt die Materie nicht nur als Trägerin von Geschwindigkeiten, kinetischer Energie und mechanischen Druckkräften, sondern auch als Trägerin von elektromagnetischen Feldern auf. Da solche Felder auch im Vakuum – d.h. im freien Äther – auftreten, so erscheint auch der Äther als Träger von elektromagnetischen Feldern. Er erscheint der ponderabeln Materie als durchaus gleichartig und nebengeordnet. Er nimmt in der Materie an den Bewegungen dieser teil und hat im leeren Raum überall eine Geschwindigkeit, derart, daß die Äthergeschwindigkeit im ganzen Raume stetig verteilt ist, Der Hertzsche Äther unterscheidet sich grundsätzlich in nichts von der (zum Teil in Äther bestehenden) ponderabeln Materie.

Die Hertzsche Theorie litt nicht nur an dem Mangel, daß sie der Materie und dem Äther einerseite mechanische, anderseits elektrische Zustande zuschrieb, die in keinem gedanklichen Zusammenhange miteinander stehen; sie widersprach auch dem Ergebnis des wichtigen Fizeauschen Versuches über die Ausbreitungsgeschwindigkeit des Lichtes in bewegten Flüssigkeiten und anderen gesicherten Erfahrungsergebnissen.

So standen die Dinge, als H.A. Lorentz eingriff. Er brachte die Theorie in Einklang mit der Erfahrung und erreichte dies durch eine wunderbare Vereinfachung der theoretischen Grundlagen. Er erzielte diesen wichtigsten Fortschritt der Elektrizitätstheorie seit Maxwell, indem er dem Äther seine mechanischen, der Materie ihre elektromagnetischen Qualitäten wegnahm. Wie im leeren Raume, so auch im Innern der materiellen Körper war ausschließlich der Äther, nicht aber die atomistisch gedachte Materie, Sitz der elektromagnetischen Felder. Die Elementarteilchen der Materie sind nach Lorentz *allein* fähig, Bewegungen auszuführen; ihre elektromagnetische Wirksamkeit liegt einzig darin, daß sie elektrische Ladungen tragen. So gelang es Lorentz, alles elektromagnetische Geschehen auf die Maxwellschen Vakuum-Feldgleichungen zu

reduzieren.

Was die mechanische Natur des Lorentzschen Äthers anlangt, so kann man etwas scherzhaft von ihm sagen, daß Unbeweglichkeit die einzige mechanische Eigenschaft sei, die ihm H.A. Lorentz noch gelassen hat. Man kann hinzufügen, daß die ganze Änderung der Ätherauffassung, welche die spezielle Relativitätstheorie brachte, darin bestand, daß sie dem Äther seine letzte mechanische Qualität, nämlich die Unbeweglichkeit, wegnahm. Wie dies zu verstehen ist, soll gleich dargelegt werden.

Der Raum-Zeittheorie und Kinematik der speziellen Relativitätstheorie hat die Maxwell-Lorentzsche Theorie des elektromagnetischen Feldes als Modell gedient. Diese Theorie genügt daher den Bedingungen der speziellen Relativitätstheorie; sie erhält aber, von letzterer aus betrachtet, ein neuartiges Aussehen. Sei nämlich K ein Koordinatensystem, relativ zu welchem der Lorentzsche Äther in Ruhe ist, so gelten die Maxwell-Lorentzschen Gleichungen zunächst in bezug auf K. Nach der speziellen Relativitätstheorie gelten aber dieselben Gleichungen in ganz umgeändertem Sinne auch in bezug auf jedes neue Koordinatensystem K1, welches in bezug auf K in gleichförmiger Translationsbewegung ist. Es entsteht nun die bange Frage: Warum soll ich das System K, welchem die Systeme K1 physikalisch vollkommen gleichwertig sind, in der Theorie vor letzterem durch die Annahme auszeichnen, daß der Äther relativ zu ihm ruhe? Eine solche Asymmetrie des theoretischen Gebäudes, dem keine Asymmetrie des Systems der Erfahrungen entspricht, ist für den Theoretiker unerträglich. Es scheint mir die physikalische Gleichwertigkeit von K und K1 mit der Annahme, daß der Äther relativ zu K ruhe, relativ zu K1 aber bewegt sei, zwar nicht vom logischen Standpunkte geradezu unrichtig, aber doch unannehmbar.

Der nächstliegende Standpunkt, den man dieser Sachlage gegenüber einnehmen konnte schien der folgende zu sein. Der Äther existiert überhaupt nicht. Die elektromagnetischen Felder sind nicht Zustände eines Mediums, sondern selbständige, Realitäten, die auf nichts anderes zurückzuführen sind und die an keinen Träger gebunden sind, genau wie die Atome der ponderabeln Materie. Diese Auffassung liegt um so näher, weil gemäß der Lorentzschen Theorie die elektromagnetische Strahlung Impuls und Energie mit sich führt wie die ponderable Materie, und weil Materie und Strahlung nach der speziellen Relativitätstheorie beide nur besondere Formen verteilter Energie sind, indem ponderable Masse ihre Sonderstellung verliert und nur als besondere Form der

Energie erscheint.

Indessen lehrt ein genaueres Nachdenken, daß diese Leugnung des Äthers nicht notwendig durch das spezielle Relativitätsprinzip gefordert wird. Man kann die Existenz eines Äthers annehmen; nur muß man darauf verzichten, ihm einen bestimmten Bewegungszustand zuzuschreiben, d.h. man muß ihm durch Abstraktion das letzte mechanische Merkmal nehmen, welches ihm Lorentz noch gelassen hatte. Später werden wir sehen, daß diese Auffassungsweise, deren gedankliche Möglichkeit ich sogleich durch einen etwas hinkenden Vergleich deutlicher zu machen suche, durch die Ergebnisse der allgemeinen Relativitätstheorie gerechtfertigt wird.

Man denke sich Wellen auf einer Wasseroberfläche. Man kann an diesem Vorgang zwei ganz verschiedene Dinge beschreiben. Man kann erstens verfolgen, wie sich die wellenförmige Grenzfläche zwischen Wasser und Luft im Laufe. der Zeit ändert. Man kann aber auch – etwa mit Hilfe von kleinen schwimmenden Körpern – verfolgen, wie sich die Lage der einzelnen Wasserteilchen im Laufe der Zeit ändert. Würde es derartige schwimmende Körperchen zum Verfolgen der Bewegung der Flüssigkeitsteilchen prinzipiell nicht geben, ja würde überhaupt an dem ganzen Vorgang nichts anderes als die zeitlich veränderliche Lage des von Wasser eingenommenen Raumes sich bemerkbar machen, so hätten wir keinen Anlaß zu der Annahme, daß das Wasser aus beweglichen Teilchen bestehe. Aber wir könnten es gleichwohl als Medium bezeichnen.

Etwas Ähnliches liegt bei dem elektromagnetischen Felde vor. Man kann sich nämlich das Feld als in Kraftlinien bestehend vorstellen. Will man diese Kraftlinien sich als etwas Materielles im gewohnten Sinne deuten, so ist man versucht, die dynamischen Vorgänge als Bewegungsvorgänge dieser Kraftlinien zu deuten, derart, daß jede einzelne Kraftlinie durch die Zeit hindurch verfolgt wird. Es ist indessen wohl bekannt, daß eine solche Betrachtungsweise zu Widersprüchen führt.

Verallgemeinernd müssen wir sagen. Es lassen sich ausgedehnte physikalische Gegenstände denken, auf welche der Bewegungsbegriff keine Anwendung finden kann. Sie dürfen nicht als aus Teilchen bestehend gedacht werden, die sich einzeln durch die Zeit hindurch verfolgen lassen. In der Sprache Minkowskis drückt sich dies so aus: nicht jedes in der vierdimensionalen Welt ausgedehnte Gebilde läßt sich als aus Weltfäden zusammengesetzt auffassen. Das spezielle

Relativitätsprinzip verbietet uns, den Äther als aus zeitlich verfolgbaren Teilchen bestehend anzunehmen, aber die Ätherhypothese an sich widerstreitet der speziellen Relativitätetheorie nicht. Nur muß man sich davor hüten, dem Äther einen Bewegungszustand zuzusprechen.

Allerdings erscheint die Ätherhypothese vom Standpunkte der speziellen Relativitätstheorie zunächst als eine leere Hypothese. In den elektromagnetischen Feldgleichungen treten außer den elektrischen Ladungsdichten *nur* die Feldstärken auf. Der Ablauf der elektromagnetischen Vorgänge im Vakuum scheint durch jenes innere Gesetz völlig bestimmt zu sein, unbeeinflußt durch andere physikalische Größen. Die elektromagnetischen Felder erscheinen als letzte, nicht weiter zurückführbare Realitäten, und es erscheint zunächst überflüssig, ein homogenes, intropes Äthermedium zu postulieren, als dessen Zustände jene Felder aufzufassen wären.

Anderseits läßt sich aber zugunsten der Ätherhypothese ein wichtiges Argument anführen. Den Äther leugnen bedeutet letzten Endes annehmen, daß dem leeren Raume keinerlei physikalische Eigenschaften zukommen. Mit dieser Auffassung stehen die fundamentalen Tatsachen der Mechanik nicht im Einklang. Das mechanische Verhalten eines im leeren Raume frei schwebenden körperlichen Systems hängt nämlich außer von den relativen Lagen (Abständen) und relativen Geschwindigkeiten noch von seinem Drehungszustande ab, der physikalisch nicht als ein dem System an sich zukommendes Merkmal aufgefaßt werden kann. Um die Drehung des Systems wenigstens formal als etwas Reales ansehen zu können, objektiviert Newton den Raum. Dadurch, daß er seinen absoluten Raum zu den realen Dingen rechnet, ist für ihn auch die Drehung relativ zu einem absoluten Raum etwas Reales. Newton hätte seinen absoluten Raum ebensogut "Äther" nennen können; wesentlich ist ja nur, daß neben den beobachtbaren Objekten noch ein anderes, nicht wahrnehmbares Ding als real angesehen werden muß, um die Beschleunigung bzw. die Rotation als etwas Reales ansehen zu können.

Mach suchte zwar der Notwendigkeit, etwas nicht beobachtbares Reales anzunehmen, dadurch zu entgehen, daß er in die Mechanik statt der Beschleunigung gegen den absoluten Raum eine mittlere Beschleunigung gegen die Gesamtheit der Massen der Welt zu setzen strebte. Aber ein Trägheitswiderstand gegenüber relativer Beschleunigung ferner Massen setzt unvermittelte Fernwirkung voraus. Da der moderne Physiker eine solche nicht annehmen zu dürfen glaubt, so landet er auch bei dieser Auffassung wieder beim Äther, der die Trägheitswirkungen zu

vermitteln hat. Dieser Ätherbegriff, auf den die Machsche Betrachtungsweise führt, unterscheidet sich aber wesentlich vom Ätherbegriff Newtons, Fresnels und H.A. Lorentz. Dieser Machsche Äther *bedingt* nicht nur das Verhalten der trägen Massen, sondern *wird* in seinem Zustand *auch bedingt* durch die trägen Massen.

Der Machsche Gedanke findet seine volle Entfaltung in dem Äther der allgemeinen Relativitätstheorie. Nach dieser Theorie sind die metrischen Eigenschaften des Raum-Zeit-Kontinuums in der Umgebung der einzelnen Raum-Zeitpunkte verschieden und mitbedingt durch die außerhalb des betrachteten Gebietes vorhandene Materie. Diese raum-zeitliche Veränderlichkeit der Beziehungen von Maßstäben und Uhren zueinander, bzw. die Erkenntnis, daß der "leere Raum" in physikalischer Beziehung weder homogen noch isotrop sei, welche uns dazu zwingt, seinen Zustand durch zehn Funktionen, die Gravitationspotentiale g_{mn} zu beschreiben, hat die Auffassung, daß der Raum physikalisch leer sei, wohl endgültig beseitigt. Damit ist aber auch der Ätherbegriff wieder zu einem deutlichen Inhalt gekommen, freilich zu einem Inhalt, der von dem des Äthers der mechanischen Undulationstheorie des Lichtes weit verschieden ist. Der Äther der allgemeinen Relativitätstheorie ist ein Medium, welches selbst aller mechanischen und kinematischen Eigenschaften bar ist, aber das mechanische (und elektromagnetische) Geschehen mitbestimmt.

Das prinzipiell Neuartige des Äthers der allgemeinen Relativitätstheorie gegenüber dem Lorentzschen Äther besteht darin, daß der Zustand des ersteren an jeder Stelle bestimmt ist durch gesetzliche Zusammenhänge mit der Materie und mit dem Ätherzustände in benachbarten Stellen in Gestalt von Differentialgleichungen, während der Zustand des Lorentzschen Äthers bei Abwesenheit von elektromagnetischen Feldern durch nichts außer ihm bedingt und überall der gleiche ist. Der Äther der allgemeinen Relativitätstheorie geht gedanklich dadurch in den Lorentzschen über, daß man die ihn beschreibenden Raumfunktionen durch Konstante ersetzt, indem man absieht von den seinen Zustand bedingenden Ursachen. Man kann also wohl auch sagen, daß der Äther der allgemeinen Relativitätstheorie durch Relativierung aus dem Lorentzschen Äther hervorgegangen ist.

Über die Rolle, welche der neue Äther im physikalischen Weltbilde der Zukunft zu spielen berufen ist, sind wir noch nicht im klaren. Wir wissen, daß er die metrischen Beziehungen im raum-zeitlichen Kontinuum, z.B. die Konfigurationsmöglichkeiten fester Körper sowie die Gravitationsfelder bestimmt;

aber wir wissen nicht, ob er am Aufbau der die Materie konstituierenden elektrischen Elementarteilchen einen wesentlichen Anteil hat. Wir wissen auch nicht, ob seine Struktur nur in der Nähe ponderabler Massen von der Struktur des Lorentzschen wesentlich abweicht, ob die Geometrie von Räumen kosmischer Ausdehnung eine nahezu euklidische ist. Wir können aber auf Grund der relativistischen Gravitationsgleichungen behaupten, daß eine Abweichung vom euklidischen Verhalten bei Räumen von kosmischer Größenordnung dann vorhanden sein muß, wenn eine auch noch so kleine positive mittlere Dichte der Materie in der Welt existiert. In diesem Falle muß die Welt notwendig räumlich geschlossen und von endlicher Größe sein, wobei ihre Größe durch den Wert jener mittleren Dichte bestimmt wird.

Betrachten wir das Gravitationsfeld und das elektromagnetische Feld vom Standpunkt der Ätherhypothese, so besteht zwischen beiden ein bemerkenswerter prinzipieller Unterschied. Kein Raum und auch kein Teil des Raumes ohne Gravitationspotentiale; denn diese verleihen ihm seine metrischen Eigenschaften, ohne welche er überhaupt nicht gedacht werden kann. Die Existenz des Gravitationsfeldes ist an die Existenz des Raumes unmittelbar gebunden. Dagegen kann ein Raumteil sehr wohl ohne elektromagnetisches Feld gedacht werden; das elektromagnetische Feld scheint also im Gegensatz zum Gravitationsfeld gewissermaßen nur sekundär an den Äther gebunden zu sein, indem die formale Natur des elektromagnetischen Feldes durch die des Gravitationsäthers noch gar nicht bestimmt ist. Es sieht nach dem heutigen Zustande der Theorie so aus, als beruhe das elektromagnetische Feld dem Gravitationsfeld gegenüber auf einem völlig neuen formalen Motiv, als hatte die Natur den Gravitationsäther statt mit Feldern vom Typus der elektromagnetischen, ebensogut mit Feldern eines ganz anderen Typus, z.B. mit Feldern eines skalaren Potentials, ausstatten können.

Da nach unseren heutigen Auffassungen auch die Elementarteilchen der Materie ihrem Wesen nach nichts anderes sind als Verdichtungen des elektromagnetischen Feldes, so kennt unser heutiges Weltbild zwei begrifflich vollkommen voneinander getrennte, wenn auch kausal aneinander gebundene Realitäten nämlich Gravitationsäther und elektromagnetisches Feld oder – wie man sie auch nennen könnte – Raum und Materie.

Natürlich wäre es ein großer Fortschritt, wenn es gelingen würde, das Gravitationsfeld und elektromagnetische Feld zusammen als ein einheitliches Gebilde aufzufassen. Dann erst würde die von Faraday und Maxwell begründete

Epoche der theoretischen Physik zu einem befriedigenderen Abschluß kommen. Es würde dann der Gegensatz Äther – Materie verblassen und die ganze Physik zu einem ähnlich geschlossenen Gedankensystem werden wie Geometrie, Kinematik und Gravitationstheorie durch die allgemeine Relativitätstheorie. Ein überaus geistvoller Versuch in dieser Richtung ist von dem Mathematiker H.Weyl gemacht worden; doch glaube ich nicht, daß seine Theorie der Wirklichkeit gegenüber standhalten wird. Wir dürfen ferner beim Denken an die nächste, Zukunft der theoretischen Physik die Möglichkeit nicht unbedingt abweisen, daß die in der Quantentheorie zusammengefaßten Tatsachen der Feldtheorie unübersteigbare Grenzen setzen könnten.

Zusammenfassend können wir sagen: Nach der allgemeinen Relativitätstheorie ist der Raum mit physikalischen Qualitäten ausgestattet; es existiert also in diesem Sinne ein Äther. Gemäß der allgemeinen Relativitätstheorie ist ein Raum ohne Äther undenkbar; denn in einem solchen gäbe es nicht nur keine Lichtfortpflanzung, sondern auch keine Existenzmöglichkeit von Maßstäben und Uhren, also auch keine räumlich-zeitlichen Entfernungen im Sinne der Physik. Dieser Äther darf aber nicht mit der für ponderable Medien charakteristischen Eigenschaft ausgestattet gedacht werden, aus durch die Zeit verfolgbaren Teilen zu bestehen; der Bewegungsbegriff darf auf ihn nicht angewendet werden."

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Concerning the Aether (Einstein)

Concerning the Aether

by

Albert Einstein

Einstein, Albert (1924) 'Über den Äther',

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> *When we speak here of aether, we are, of course, not referring to the corporeal aether of mechanical wave-theory that underlies Newtonian mechanics, whose individual points each have a velocity assigned to them. This theoretical construct has, in my opinion, been superseded by the special theory of relativity. Rather the discussion concerns, much more generally, those things thought of as physically real which, besides ponderable matter consisting of electrical elementary particles, play a role in the causal nexus of physics. Instead of 'aether', one could equally well speak of 'the physical qualities of space'. Now, it might be claimed that this concept covers all objects of physics, for according to consistent field theory, even ponderable matter, or its constituent elementary particles, are to be understood as fields of some kind or particular 'states of space'. But it must be admitted that such a view would be premature, since, thus far, all efforts directed toward this goal have foundered. So we are effectively forced by the current state of things to distinguish between matter and aether, even though we may hope that future*

generations will transcend this dualistic conception and replace it with a unified theory, as the field theoreticians of our day have tried in vain to accomplish.

It is usually believed that aether is foreign to Newtonian physics and that it was only the wave theory of light which introduced the notion of an omnipresent medium influencing, and affected by, physical phenomena. But this is not the case. Newtonian mechanics had its 'aether' in the sense indicated, albeit under the name 'absolute space'. To get a clear understanding of this and, at the same time, to explore more fully the concept of aether, we must take a step back.

We will consider first a branch of physics which makes do without any notion of aether, namely the geometry of Euclid, understood as the study of the possible ways of bringing essentially rigid bodies into contact with each other. (For now, we will set to one side light rays, which may also contribute to the development of geometrical concepts and theorems.) The laws concerning the placement of rigid bodies, excluding relative motion, temperature and the influence of deformations, as laid down in an idealised way in Euclid's geometry, derive from the concept of a rigid body. Any environmental influence which could be thought of as existing independently of those bodies and as acting on them and influencing the laws governing their placement is unknown to Euclidean geometry. The same holds for the non-Euclidean geometries of constant curvature if these are understood as conceivable laws of nature. It would be different if we were to find ourselves forced to adopt a geometry of variable curvature. This would mean that the laws governing the ways essentially rigid bodies can be brought into contact would be different in different cases, depending on environmental influences. Here we would have to say that, in the sense we are considering, such a theory would require an aether hypothesis. Its aether would be something every bit as physically real as matter. If the laws of placement were impervious to the influence of physical factors, such as the accumulation and state of motion of bodies in the environment, but irrevocably given, then we would call this aether 'absolute', i.e. by its nature independent of any influence.

The kinematics, or phoronomy, of classical physics had as little need of an aether as (physically interpreted) Euclidean geometry has. For its laws have a clear physical meaning only if we assume that the special-relativistic influences of motion on rulers and clocks do not exist. Not so in the dynamics of Galileo and Newton. The law of motion 'force equals mass times acceleration', does not consist only of a statement about material systems, not even if, according to Newton's fundamental law of astronomy, the force is expressed at a distance, i.e. by quantities whose 'real definition' [definitio realis, a definition in terms of the object's distinguishing properties] can be based on measurements involving rigid bodies. For the 'real definition' of acceleration cannot be completely reduced to observations of rigid bodies and clocks. It cannot be reduced to the measurable distances between the points that make up the mechanical system. Its definition requires also a coordinate system or reference body having some suitable state of motion. If a different coordinate system is chosen, the Newtonian equations do not hold with respect to this new coordinate system. With those equations, the milieu in which the bodies move appears as an implicit, real factor in the laws of motion,

alongside the real bodies themselves and the distances that massive bodies define. In contrast to geometry and kinematics, the 'space' of Newton's theory of motion possesses physical reality. We will call this physical reality which enters the Newtonian law of motion alongside the observable, ponderable real bodies, the aether of mechanics. The occurrence of centrifugal effects with a (rotating) body, whose material points do not change their distances from one another, shows that this aether is not to be understood as a mere hallucination of the Newtonian theory, but rather that it corresponds to something real that exists in nature.

We see that, for Newton, 'space' was something physically real, in spite of the curiously indirect way this real thing reaches our awareness. Ernst Mach, the first after Newton to subject the foundations of mechanics to a deep analysis, perceived this clearly. He sought to escape this hypothesis of the 'mechanical aether' by reducing inertia to immediate interaction between the perceived mass and all other masses of the universe. This view was certainly a logical possibility but, as a theory involving action at a distance, cannot be taken seriously today. The mechanical aether–which Newton called 'absolute space'–must remain for us a physical reality. Of course, one must not be tempted by the expression aether into thinking that, like the physicists of the 19th century, we have in mind something analogous to ponderable matter.

When Newton referred to the space of physics as 'absolute', he was thinking of yet another property of what we call here aether. Every physical thing influences others and is, it its turn, generally influenced by other things. This does not however apply to the aether of Newtonian mechanics. For the inertia-giving property of this aether is, according to classical mechanics, not susceptible to any influence, neither from the configuration of matter nor anything else. Hence the term 'absolute'.

Only in recent years has it become clear to physicists that the preferred nature of initial systems, as opposed to non-inertial systems, requires a real cause. Viewed historically, the aether hypothesis has emerged in its present form by a process of sublimation from the mechanical aether hypothesis of optics. After long and fruitless efforts, physicists became convinced that light was not to be understood as the motion of an inertial, elastic medium, that the electromagnetic fields of Maxwell's theory could not be construed as mechanical. So under the pressure of this failure, the electromagnetic fields had gradually come to be regarded as the final, irreducible physical reality, as states of the aether, impervious to further explanation. What remained of the mechanical theory was its definite state of motion; it somehow embodied a state of absolute rest. While at least in Newtonian mechanics all inertial systems were equivalent, it seemed that, in the Maxwell-Lorentz theory, the state of motion of the preferred coordinate system (at rest with respect to the aether) was completely determined. It was accepted implicitly that this preferred coordinate system was also an inertial system, i.e. that the principle of inertia [Newton's first law] applied relative to the electromagnetic aether.

There was another way too in which the Maxwell-Lorentz theory set back physicists' basic understanding. Since electromagnetic fields were seen as fundamental, irreducible entities, they

seemed destined to rob ponderable masses, possessing inertia, of their primary meaning. It was shown by Maxwell's equations that a moving, electrically charged body is surrounded by a magnetic field whose energy is, to first approximation, a quadratic function of speed. It seemed only natural to conceive of all kinetic energy as electromagnetic energy. Thus one could hope to reduce mechanics to electromagnetism, since efforts to reduce electromagnetic phenomena to mechanics had failed. Indeed this looked all the more promising as it became apparent that all ponderable matter was composed of electromagnetic elementary particles. But there were two difficulties that could not be overcome. Firstly the Maxwell-Loretz equations could not explain how the electric charge constituting an electrical elementary particle can exist in equilibrium in spite of the forces of electrostatic repulsion. Secondly electromagnetic theory could not give a reasonably natural and satisfactory explanation of gravitation. Nevertheless the results that electromagnetic theory achieved for physics were so significant they came to be regarded as a completely secured possession, indeed as its most firmly established success.

The Maxwell-Lorentz theory eventually influenced our view of the theoretical basis to the extent that it led to the creation of the special theory of relativity. It was recognised that the equations of electromagnetism did not, in fact, single out one particular state of motion, but rather that, in accordance with these equations, just as with those of classical mechanics, there exists an infinite multitude of coordinate systems in mutually equivalent states of motion, providing the appropriate transformation formulas are used for the spatial and temporal coordinates. It is well known that this realisation entailed a profound modification, not only in our ideas about space and time, but also to kinematics and dynamics. No longer was a special state of motion to be ascribed to the electromagnetic aether. Now, like the aether of classical mechanics, it resulted not in the favoring of a particular state of motion, only the favoring of a particular state of acceleration. Because it was no longer possible to speak, in any absolute sense, of simultaneous states at different locations in the aether, the aether became, as it were, four dimensional, since there was no objective way of ordering its states by time alone. According to special relativity too, the aether was absolute, since its influence on inertia and the propogation of light was thought of as being itself independent of physical influence. While classical physics took it for granted that the geometry of bodies was independent of their state of motion, the special theory of relativity stated that the laws of Euclidean geometry only apply to the positioning of bodies at rest with respect to one another when these bodies are at rest with respect to an inertial coordinate system.[1] This can be easily concluded from the so-called Lorentz contraction. Thus geometry, like dynamics, came to depend on the aether.

The general theory of relativity rectified a mischief of classical dynamics. According to the latter, inertia and gravity appear as quite different, mutually independent phenomena, even though they both depend on the same quantity, mass. The theory of relativity resolved this problem by establishing the behaviour of the electrically neutral point-mass by the law of the geodetic line, according to which inertial and gravitational effects are no longer considered as separate. In doing so, it attached characteristics to the aether which vary from point to point, determining the metric and the dynamic behaviour of material points, and determined, in their turn, by

physical factors, namely the distribution of mass/energy.

Thus the aether of general relativity differs from those of classical mechanics and special relativity in that it is not 'absolute' but determined, in its locally variable characteristics, by ponderable matter. This determination is a complete one if the universe is finite and closed. That there are, in general relativity, no preferred spacetime coordinates uniquely associated with the metric is more characteristic of its mathematical form than its physical framework.

Even using mathematical apparatus of general relativity it has not been possible to reduce all of the inertia of mass to electromagnetic fields, or to fields in general. Neither are we yet, in my view, at the point of formally incorporating the electromagnetic forces into the scheme of general relativity. On the one hand, the metric tensor, which codetermines the phenomena of gravitation and inertia and, on the other, the tensor of the electromagnetic field appear still as different expressions of the state of the aether, whose logical independence one is inclined to attribute rather to the incompleteness of our theoretical ediface than to a complex structure of reality.

It is true that Weyl and Eddington have, by a generalisation of Riemannian geometry, found a mathematical system, in which both kinds of field appear to be unified under a single perspective. But the simplest field laws which that theory provides seem to me not to advance physical insight. On the whole, we seem to be much further now from an understanding of the fundamental laws of electromagnetism than we did at the beginning of this century. As justification for this opinion, I should here like to briefly refer to the problem of the magnetic fields of the earth and the sun, and also to the problem of light quanta, which problems have some bearing on the gross and fine structure of the electromagnetic field.

The earth and sun possess magnetic fields whose orientation and sense are closely related to the spin axes of these bodies. According to Maxwell's theory, these fields may be due to electric currents which flow in the opposite direction to the rotation of the earth and sun about their axes. Even sunspots, which there are good grounds to think of as vortices, posses analogous, and very powerful, magnetic fields. But it is hardly conceivable that, in all these cases, circuits or convection currents of sufficient strength are actually present. Rather it looks as if cyclic motion of neutral masses generated magnetic fields. Neither Maxwell's theory as originally conceived nor as extended in general relativity predict field generation of that sort. Here nature seems to point us toward some fundamental connection, not yet understood.[2]

If the case we have just discussed is one that field theory, in its current form, seems not yet able to address, the facts and ideas subsumed under quantum theory threaten to the blow the edifice of field theory to bits. Specifically, we find increasing arguments suggesting that the quanta of light are to be understood as physical reality, and that the electromagnetic field cannot be seen as the final reality to which all other physical objects can be reduced. As Planck's formula had already shown that the transmission of energy and momentum by radiation

happens as if the latter consisted of particles moving at the speed of light, , with energy so Compton demonstrated, by his research into the scattering of X-rays by matter that scattering events occur in which quanta of light collide with electrons and transmit to them a portion of their energy, as a result of which the quanta of light undergo a change of energy and direction. It is at least a fact that X-rays experience such changes in frequency on scattering (in agreement with the predictions of Debye and Compton) as quantum theory demands.

Recently there has appeared work by the Indian physicist Bose on the derivation of Planck's formula which is of particular significance to our theoretical understanding for the following reasons: hitherto all complete derivations of Planck's formula made some use of the hypothesis of the wave structure of radiation. So, for example, in the well-known Ehrenfest-Debye derivation, the factor in this formula was deduced by counting the eigenvibrations of the cavity belonging to the frequency range . Bose replaces this derivation based on the ideas of wave theory with a gas-theoretical calculation which he applies to a quantum of light conceived of like some sort of molecule present in the cavity. This raises the question of whether it might perhaps also be possible to link the phenomena of diffraction and interference to quantum theory in such a way that the field-like concepts of the theory are presented only as expressions of the interaction between quanta, so that independent physical reality would no longer be ascribed to the fields.

The important fact that the radiation emitted is not, according to Bohr's frequency theory, determined by electrically charged masses which periodically cycle through occurrences of the same frequency can only strengthen this doubt of ours as to the independent reality of the wave field.

But even if these possibilities do mature into an actual theory, we will not be able to do without the aether in theoretical physics, that is, a continuum endowed with physical properties; for general relativity, to whose fundamental viewpoints physicists will always hold fast, rules out direct action at a distance. But every theory of local action assumes continuous fields, and thus also the existence of an 'aether'.

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Ether and the Theory of Relativity (Einstein)

Even Einstein thought that space must be "real" and be "rigid" – he called it Ether, but he clearly refers to it as the "solid elastic" kind of ether mentioned in the blog posts. Examples (from below)

> *"More careful reflection teaches us however, that* ***the special theory of relativity does not compel us to deny ether****. We may assume the existence of an ether; only we must give up ascribing a definite state of motion to it"*

> *"Recapitulating, we may say that* ***according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an ether****. According to the general theory of relativity* ***space without ether is unthinkable****; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense"*

Ether and the Theory of Relativity

by
Albert Einstein

How does it come about that alongside of the idea of ponderable matter, which is derived by abstraction from everyday life, the physicists set the idea of the existence of another kind of matter, the ether? The explanation is probably to be sought in those phenomena which have given rise to the theory of action at a distance, and in the properties of light which have led to the undulatory theory. Let us devote a little while to the consideration of these two subjects.

Outside of physics we know nothing of action at a distance. When we try to connect cause and effect in the experiences which natural objects afford us, it seems at first as if there were no other mutual actions than those of immediate contact, e.g. the communication of motion by impact, push and pull, heating or inducing combustion by means of a flame, etc. It is true that even in everyday experience

weight, which is in a sense action at a distance, plays a very important part. But since in daily experience the weight of bodies meets us as something constant, something not linked to any cause which is variable in time or place, we do not in everyday life speculate as to the cause of gravity, and therefore do not become conscious of its character as action at a distance. It was Newton's theory of gravitation that first assigned a cause for gravity by interpreting it as action at a distance, proceeding from masses. Newton's theory is probably the greatest stride ever made in the effort towards the causal nexus of natural phenomena. And yet this theory evoked a lively sense of discomfort among Newton's contemporaries, because it seemed to be in conflict with the principle springing from the rest of experience, that there can be reciprocal action only through contact, and not through immediate action at a distance.

It is only with reluctance that man's desire for knowledge endures a dualism of this kind. How was unity to be preserved in his comprehension of the forces of nature? Either by trying to look upon contact forces as being themselves distant forces which admittedly are observable only at a very small distance and this was the road which Newton's followers, who were entirely under the spell of his doctrine, mostly preferred to take; or by assuming that the Newtonian action at a distance is only apparently immediate action at a distance, but in truth is conveyed by a medium permeating space, whether by movements or by elastic deformation of this medium. Thus the endeavour toward a unified view of the nature of forces leads to the hypothesis of an ether. This hypothesis, to be sure, did not at first bring with it any advance in the theory of gravitation or in physics generally, so that it became customary to treat Newton's law of force as an axiom not further reducible. But the ether hypothesis was bound always to play some part in physical science, even if at first only a latent part.

When in the first half of the nineteenth century the far-reaching similarity was revealed which subsists between the properties of light and those of elastic waves in ponderable bodies, the ether hypothesis found fresh support. It appeared beyond question that light must be interpreted as a vibratory process in an elastic, inert medium filling up universal space. It also seemed to be a necessary consequence of the fact that light is capable of polarisation that this medium, the ether, must be of the nature of a solid body, because transverse waves are not possible in a fluid, but only in a solid. Thus the physicists were bound to arrive at the theory of the "quasi-rigid" luminiferous ether, the parts of which can carry out no movements relatively to one another except the small movements of deformation which correspond to light-waves.

This theory – also called the theory of the stationary luminiferous ether – moreover found a strong support in an experiment which is also of fundamental importance in the special theory of relativity, the experiment of Fizeau, from which one was obliged to infer that the luminiferous ether does not take part in the movements of bodies. The phenomenon of aberration also favoured the theory of the quasi-rigid ether.

The development of the theory of electricity along the path opened up by Maxwell and Lorentz gave the development of our ideas concerning the ether quite a peculiar and unexpected turn. For Maxwell himself the ether indeed still had properties which were purely mechanical, although of a much more

complicated kind than the mechanical properties of tangible solid bodies. But neither Maxwell nor his followers succeeded in elaborating a mechanical model for the ether which might furnish a satisfactory mechanical interpretation of Maxwell's laws of the electro-magnetic field. The laws were clear and simple, the mechanical interpretations clumsy and contradictory. Almost imperceptibly the theoretical physicists adapted themselves to a situation which, from the standpoint of their mechanical programme, was very depressing. They were particularly influenced by the electro-dynamical investigations of Heinrich Hertz. For whereas they previously had required of a conclusive theory that it should content itself with the fundamental concepts which belong exclusively to mechanics (e.g. densities, velocities, deformations, stresses) they gradually accustomed themselves to admitting electric and magnetic force as fundamental concepts side by side with those of mechanics, without requiring a mechanical interpretation for them. Thus the purely mechanical view of nature was gradually abandoned. But this change led to a fundamental dualism which in the long-run was insupportable. A way of escape was now sought in the reverse direction, by reducing the principles of mechanics to those of electricity, and this especially as confidence in the strict validity of the equations of Newton's mechanics was shaken by the experiments with b-rays and rapid cathode rays.

This dualism still confronts us in unextenuated form in the theory of Hertz, where matter appears not only as the bearer of velocities, kinetic energy, and mechanical pressures, but also as the bearer of electromagnetic fields. Since such fields also occur in vacuo – i.e. in free ether-the ether also appears as bearer of electromagnetic fields. The ether appears indistinguishable in its functions from ordinary matter. Within matter it takes part in the motion of matter and in empty space it has everywhere a velocity; so that the ether has a definitely assigned velocity throughout the whole of space. There is no fundamental difference between Hertz's ether and ponderable matter (which in part subsists in the ether).

The Hertz theory suffered not only from the defect of ascribing to matter and ether, on the one hand mechanical states, and on the other hand electrical states, which do not stand in any conceivable relation to each other; it was also at variance with the result of Fizeau's important experiment on the velocity of the propagation of light in moving fluids, and with other established experimental results.

Such was the state of things when H A Lorentz entered upon the scene. He brought theory into harmony with experience by means of a wonderful simplification of theoretical principles. He achieved this, the most important advance in the theory of electricity since Maxwell, by taking from ether its mechanical, and from matter its electromagnetic qualities. As in empty space, so too in the interior of material bodies, the ether, and not matter viewed atomistically, was exclusively the seat of electromagnetic fields. According to Lorentz the elementary particles of matter alone are capable of carrying out movements; their electromagnetic activity is entirely confined to the carrying of electric charges. Thus Lorentz succeeded in reducing all electromagnetic happenings to Maxwell's equations for free space.

As to the mechanical nature of the Lorentzian ether, it may be said of it, in a somewhat playful spirit,

that immobility is the only mechanical property of which it has not been deprived by H A Lorentz. It may be added that the whole change in the conception of the ether which the special theory of relativity brought about, consisted in taking away from the ether its last mechanical quality, namely, its immobility. How this is to be understood will forthwith be expounded.

The space-time theory and the kinematics of the special theory of relativity were modelled on the Maxwell-Lorentz theory of the electromagnetic field. This theory therefore satisfies the conditions of the special theory of relativity, but when viewed from the latter it acquires a novel aspect. For if *K* be a system of coordinates relatively to which the Lorentzian ether is at rest, the Maxwell-Lorentz equations are valid primarily with reference to *K*. But by the special theory of relativity the same equations without any change of meaning also hold in relation to any new system of co-ordinates *K*' which is moving in uniform translation relatively to *K*. Now comes the anxious question:- Why must I in the theory distinguish the *K* system above all *K*' systems, which are physically equivalent to it in all respects, by assuming that the ether is at rest relatively to the *K* system? For the theoretician such an asymmetry in the theoretical structure, with no corresponding asymmetry in the system of experience, is intolerable. If we assume the ether to be at rest relatively to *K*, but in motion relatively to *K*', the physical equivalence of *K* and *K*' seems to me from the logical standpoint, not indeed downright incorrect, but nevertheless unacceptable.

The next position which it was possible to take up in face of this state of things appeared to be the following. The ether does not exist at all. The electromagnetic fields are not states of a medium, and are not bound down to any bearer, but they are independent realities which are not reducible to anything else, exactly like the atoms of ponderable matter. This conception suggests itself the more readily as, according to Lorentz's theory, electromagnetic radiation, like ponderable matter, brings impulse and energy with it, and as, according to the special theory of relativity, both matter and radiation are but special forms of distributed energy, ponderable mass losing its isolation and appearing as a special form of energy.

More careful reflection teaches us however, that the special theory of relativity does not compel us to deny ether. We may assume the existence of an ether; only we must give up ascribing a definite state of motion to it, i.e. we must by abstraction take from it the last mechanical characteristic which Lorentz had still left it. We shall see later that this point of view, the conceivability of which I shall at once endeavour to make more intelligible by a somewhat halting comparison, is justified by the results of the general theory of relativity.

Think of waves on the surface of water. Here we can describe two entirely different things. Either we may observe how the undulatory surface forming the boundary between water and air alters in the course of time; or else-with the help of small floats, for instance – we can observe how the position of the separate particles of water alters in the course of time. If the existence of such floats for tracking the motion of the particles of a fluid were a fundamental impossibility in physics – if, in fact nothing else whatever were observable than the shape of the space occupied by the water as it varies in time, we should have no ground for the assumption that water consists of movable

particles. But all the same we could characterise it as a medium.

We have something like this in the electromagnetic field. For we may picture the field to ourselves as consisting of lines of force. If we wish to interpret these lines of force to ourselves as something material in the ordinary sense, we are tempted to interpret the dynamic processes as motions of these lines of force, such that each separate line of force is tracked through the course of time. It is well known, however, that this way of regarding the electromagnetic field leads to contradictions.

Generalising we must say this:- There may be supposed to be extended physical objects to which the idea of motion cannot be applied. They may not be thought of as consisting of particles which allow themselves to be separately tracked through time. In Minkowski's idiom this is expressed as follows:- Not every extended conformation in the four-dimensional world can be regarded as composed of world-threads. The special theory of relativity forbids us to assume the ether to consist of particles observable through time, but the hypothesis of ether in itself is not in conflict with the special theory of relativity. Only we must be on our guard against ascribing a state of motion to the ether.

Certainly, from the standpoint of the special theory of relativity, the ether hypothesis appears at first to be an empty hypothesis. In the equations of the electromagnetic field there occur, in addition to the densities of the electric charge, only the intensities of the field. The career of electromagnetic processes in vacuo appears to be completely determined by these equations, uninfluenced by other physical quantities. The electromagnetic fields appear as ultimate, irreducible realities, and at first it seems superfluous to postulate a homogeneous, isotropic ether-medium, and to envisage electromagnetic fields as states of this medium.

But on the other hand there is a weighty argument to be adduced in favour of the ether hypothesis. To deny the ether is ultimately to assume that empty space has no physical qualities whatever. The fundamental facts of mechanics do not harmonize with this view. For the mechanical behaviour of a corporeal system hovering freely in empty space depends not only on relative positions (distances) and relative velocities, but also on its state of rotation, which physically may be taken as a characteristic not appertaining to the system in itself. In order to be able to look upon the rotation of the system, at least formally, as something real, Newton objectivises space. Since he classes his absolute space together with real things, for him rotation relative to an absolute space is also something real. Newton might no less well have called his absolute space "Ether"; what is essential is merely that besides observable objects, another thing, which is not perceptible, must be looked upon as real, to enable acceleration or rotation to be looked upon as something real.

It is true that Mach tried to avoid having to accept as real something which is not observable by endeavouring to substitute in mechanics a mean acceleration with reference to the totality of the masses in the universe in place of an acceleration with reference to absolute space. But inertial resistance opposed to relative acceleration of distant masses presupposes action at a distance; and as the modern physicist does not believe that he may accept this action at a distance, he comes back once more, if he follows Mach, to the ether, which has to serve as medium for the effects of

inertia. But this conception of the ether to which we are led by Mach's way of thinking differs essentially from the ether as conceived by Newton, by Fresnel, and by Lorentz. Mach's ether not only conditions the behaviour of inert masses, but is also conditioned in its state by them.

Mach's idea finds its full development in the ether of the general theory of relativity. According to this theory the metrical qualities of the continuum of space-time differ in the environment of different points of space-time, and are partly conditioned by the matter existing outside of the territory under consideration. This space-time variability of the reciprocal relations of the standards of space and time, or, perhaps, the recognition of the fact that "empty space" in its physical relation is neither homogeneous nor isotropic, compelling us to describe its state by ten functions (the gravitation potentials g_{mn}), has, I think, finally disposed of the view that space is physically empty. But therewith the conception of the ether has again acquired an intelligible content although this content differs widely from that of the ether of the mechanical undulatory theory of light. The ether of the general theory of relativity is a medium which is itself devoid of all mechanical and kinematical qualities, but helps to determine mechanical (and electromagnetic) events.

What is fundamentally new in the ether of the general theory of relativity as opposed to the ether of Lorentz consists in this, that the state of the former is at every place determined by connections with the matter and the state of the ether in neighbouring places, which are amenable to law in the form of differential equations; whereas the state of the Lorentzian ether in the absence of electromagnetic fields is conditioned by nothing outside itself, and is everywhere the same. The ether of the general theory of relativity is transmuted conceptually into the ether of Lorentz if we substitute constants for the functions of space which describe the former, disregarding the causes which condition its state. Thus we may also say, I think, that the ether of the general theory of relativity is the outcome of the Lorentzian ether, through relativation.

As to the part which the new ether is to play in the physics of the future we are not yet clear. We know that it determines the metrical relations in the space-time continuum, e.g. the configurative possibilities of solid bodies as well as the gravitational fields; but we do not know whether it has an essential share in the structure of the electrical elementary particles constituting matter. Nor do we know whether it is only in the proximity of ponderable masses that its structure differs essentially from that of the Lorentzian ether; whether the geometry of spaces of cosmic extent is approximately Euclidean. But we can assert by reason of the relativistic equations of gravitation that there must be a departure from Euclidean relations, with spaces of cosmic order of magnitude, if there exists a positive mean density, no matter how small, of the matter in the universe.

In this case the universe must of necessity be spatially unbounded and of finite magnitude, its magnitude being determined by the value of that mean density.

If we consider the gravitational field and the electromagnetic field from the standpoint of the ether hypothesis, we find a remarkable difference between the two. There can be no space nor any part of space without gravitational potentials; for these confer upon space its metrical qualities, without

which it cannot be imagined at all. The existence of the gravitational field is inseparably bound up with the existence of space. On the other hand a part of space may very well be imagined without an electromagnetic field; thus in contrast with the gravitational field, the electromagnetic field seems to be only secondarily linked to the ether, the formal nature of the electromagnetic field being as yet in no way determined by that of gravitational ether. From the present state of theory it looks as if the electromagnetic field, as opposed to the gravitational field, rests upon an entirely new formal motif, as though nature might just as well have endowed the gravitational ether with fields of quite another type, for example, with fields of a scalar potential, instead of fields of the electromagnetic type.

Since according to our present conceptions the elementary particles of matter are also, in their essence, nothing else than condensations of the electromagnetic field, our present view of the universe presents two realities which are completely separated from each other conceptually, although connected causally, namely, gravitational ether and electromagnetic field, or – as they might also be called – space and matter.

Of course it would be a great advance if we could succeed in comprehending the gravitational field and the electromagnetic field together as one unified conformation. Then for the first time the epoch of theoretical physics founded by Faraday and Maxwell would reach a satisfactory conclusion. The contrast between ether and matter would fade away, and, through the general theory of relativity, the whole of physics would become a complete system of thought, like geometry, kinematics, and the theory of gravitation. An exceedingly ingenious attempt in this direction has been made by the mathematician H Weyl; but I do not believe that his theory will hold its ground in relation to reality. Further, in contemplating the immediate future of theoretical physics we ought not unconditionally to reject the possibility that the facts comprised in the quantum theory may set bounds to the field theory beyond which it cannot pass.

Recapitulating, we may say that according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an ether. According to the general theory of relativity space without ether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense. But this ether may not be thought of as endowed with the quality characteristic of ponderable media, as consisting of parts which may be tracked through time. The idea of motion may not be applied to it.

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The Meaning of Wave Mechanics (Schrödinger)

Schrödinger did not like the "probability" interpretation of the wave function – he always considered the wave to be a real wave. He mentions this in several places, for instance"

> *"Let me say at the outset, that in this discourse, I am opposing not a few special statements of quantum physics held today (1950s), I am opposing as it were the whole of it, I am opposing its basic views that have been shaped 25 years ago, when Max Born put forward his* ***probability interpretation****, which was accepted by almost everybody."*
> *(Schrödinger E, The Interpretation of Quantum Physics. Ox Bow Press, Woodbridge, CN, 1995).*

Below is a longer speech he gave in 1952:

THE MEANING OF WAVE MECHANICS
by Erwin Schrödinger
(For the July Colloquium, Dublin 1952)

Louis de Broglie's great theoretical discovery of the wave phenomenon associated with the electron was followed within a few years, on the one hand by incontrovertible experimental evidence (based on interference patterns) of the reality of the de Broglie waves (Davisson and Germer, G. P. Thomson), and on the other hand by a vast generalization of his original ideas, which embraces the entire domain of physics and chemistry, and may be said to hold the field today along the whole line, albeit not precisely in the way de Broglie and his early followers had intended.

For it must have given to de Broglie the same shock and disappointment as it gave to me, when we learnt that a sort of transcendental, almost psychical interpretation of the wave phenomenon had been put forward, which was very soon hailed by the majority of leading theorists as the only one reconcilable with experiments, and which has now become the orthodox creed, accepted by almost everybody, with a few notable exceptions. Our disappointment consisted in the following. We had believed that the eigenfrequencies of the wave phenomenon, which were in exact numerical agreement with the, until then so called, energy levels, gave a rational understanding of the latter. We had confidence that the mysterious "fit and jerk theory" about the jump-like transition from one

energy level to another was now ousted. Our wave equations could be expected to describe any changes of this kind as slow and actually *describable* processes. This hope was not informed by personal predilection for continuous description, but if anything, by the wish for any kind of description at all of these changes. It was a dire necessity. To produce a coherent train of light, waves-of 100 cm length and more, as is observed in fine spectral lines, takes a time comparable with the average interval between transitions. The transition must be coupled with the production of the wave train. Hence if one does not understand the transition, but only understands the "stationary states", one understands nothing. For the emitting system is busy all the time in producing the trains of light waves, it has no time left to tarry in the cherished "stationary states", except perhaps in the ground state.

Another disconcerting feature of the probability interpretation was and is that the *wave function* is deemed to change in two entirely distinct fashions; it is thought to be governed by the wave equation as long as no observer interferes with the system, but whenever an observer makes a measurement, it is deemed to change into an eigenfunction of *that* eigenvalue of the associated operator that he has measured. I know only of one timid attempt (J. von Neumann in his well known book) to put this "change by measurement" to the door of a perturbing operator introduced by the measurement, and thus to have it also controlled solely by the wave equation. But the idea was not pursued, partly because it seemed unnecessary to those who were prepared to swallow the orthodox tenet, partly because it could hardly be reconciled with it. For in many cases the alleged change involves an *actio in distans*, which would contradict a firmly established principle, if the change referred to a physical entity. The non-physical character of the wave function (which is sometimes said to embody merely our knowledge) is even more strongly emphasized by the fact that according to the orthodox view its change by measurement is dependent on the observer's taking cognizance of the result. Moreover the change holds only for the observer who does. If *you* are present, but are not informed of the result, then *for you* even if you have the minutest knowledge both of the wave function before the measurement and of the appliances that were used, the changed wave function is irrelevant, not existing, as it were; *for you* there is, at best, a wave function referring to the measuring appliances plus the system under consideration, a wave function in which the one adopted by the knowing observer plays no distinguished role.

M. de Broglie, so I believe, disliked the probability interpretation of wave mechanics as much as I did. But very soon and for a long period one had to give up opposing it, and to accept it as an expedient interim solution. I shall point out some of the reasons why the originally contemplated alter-native seemed deceptive and, after all, too naive. The points shall be numbered for later reference; the illustrating examples are representative of wide classes.

- i) As long as a particle, an electron or proton etc., was still believed to be a permanent, individually identifiable entity, it could not adequately be pictured in our mind as a wave parcel. For as a rule, apart from artificially constructed and therefore irrelevant exceptions, no wave parcel can be indicated which does not eventually disperse into an ever increasing volume of space.

- ii) The original wave-mechanical model of the hydrogen atom is not self-consistent. The electronic cloud effectively shields the nuclear charge towards outside, making up a neutral whole, but is inefficient inside; in computing its structure its own field that it will produce must not be taken into account, only the field of the nucleus.
- iii) It seemed impossible to account for e.g. Planck's radiation formula without assuming that a radiation oscillator (proper mode of the hohlraum) can only have energies $nh\nu$, with n an integer (or perhaps a half odd integer). Since this holds in all cases of thermodynamic equilibrium that do not follow the classical law of equipartition we are thrown back to the discrete energy states with abrupt transitions between them, and thus to the probability interpretation.
- iv) Many non-equilibrium processes suggest even more strongly the "transfer of whole quanta"; the typical, often quoted example is the photoelectric effect, one of the pillars of Einstein's hypothesis of light quanta in 1905.

All this was known 25 years ago, and abated the hopes of "naive" wave-mechanista. The now orthodox view about the wave function as "probability amplitude" was put forward and was worked out into a scheme of admirable logical consistency. Let us first review the situation after the state of knowledge we had then. The view suggested by (iii) and (iv), that radiation oscillators, electrons and similar constituents of observable systems always find themselves at one of their respective energy levels except when they change abruptly to another one handing the balance over to, or receiving it from, some other system, this view, so I maintain, is in glaring contradiction with the above mentioned scheme in spite of the admirable logical self-consistency of the latter. For one of the golden rules of this scheme is, that any observable is always *found* at one of its eigenvalues, when you measure it, but that you must not say that it *has* any value, if you do not measure it. To attribute sharp energy values to all those constituents, whose energies we could not even dream of measuring (except in a horrible nightmare), is not only gratuitous but strictly forbidden by this rule.

Now let us review the situation as it is today. Two new aspects have since arisen which I consider very relevant for reconsidering the interpretation. They are intimately connected. They have not turned up suddenly. Their roots lie far back, but their bearing was only very gradually recognized.

I mean first the recognition that the thing which has always been called a particle and, on the strength of habit, is still called by some such name is, whatever it may be, certainly *not* an individually identifiable entity. I have dwelt on this point at length elsewhere ["Endeavour", Vol.IX, Number 35, July 1950; reprinted in the Smithsonian Institution Report for 1950, pp. 183, - 196; in German "Die Pyramide", Jan. and Feb. 1951 (Austria)]. The second point is the paramount importance of what is sometimes called "second quantization".

To begin with, if a particle is not a permanent entity, then of the four difficulties labelled above, (i) is removed. As regards (ii), the quantization of de Broglie's waves around a nucleus welds into one comprehensive scheme all the 3n-dimensional reprasentations that I had. proposed for the n-body problems. It is not an easy scheme, but it is logically clear and it can be so framed that only

the *mutual* Coulomb energies enter.

As regards (iii) – keeping to the example of black body radiation – the situation is this. If the radiation is quantized each radiation oscillator (proper mode) obtains the frequencies or levels *nhv*. This is sufficient to produce Planck's formula for the radiation in a cavity surrounded by a huge heat bath. I mean to say, the level scheme suffices: it is not necessary to assume that each oscillator *is* at one of its levels, which is absurd from any point of view. The same holds for all thermodynamical equilibria. I have actually given a general proof of this in the last of my "Collected Papers" (English version: Blackie and Son, Glasgow 1928). A better presentation is added as an appendix to the forthcoming 2nd impression of "Statistical Thermodynamics" (Cambridge University Press).

Under (iv) we alluded to a vast range of phenomena purported to be conclusive evidence for the transfer of whole quanta. But I do not think they are, provided only that one holds on to the wave aspect throughout the whole process. One must, of course, give up thinking of e.g. an electron as of a tiny speck of something moving within the wave train along a mysterious unknowable *path*. One must regard the "observation of an electron" as an*event* that occurs within a train of de Broglie waves when a contraption is interposed in it which by its very nature cannot but answer by discrete responses: a photographic emulsion, a luminescent screen, a Geiger counter. And one must, to repeat this, hold on to the wave aspect throughout. This includes, that the equations between frequencies and frequency differences, expressing the resonance condition that governs wave mechanics throughout, must *not* be multiplied by Planck's constant *h* and then interpreted as tiny energy balances of microscopic processes between tiny specks of something that have, to say the least, no permanent existence.

This situation calls for a revision of the current interpretation, which involves computing transition probabilities from level to level, and disregards the fact that the wave equation, with few exceptions if any, indicates nothing of the sort, but leads each of the reacting systems into a state composed of a wide spread of energy eigenstates. To assume that the system actually leaps into just one of them which is selected by "playing dice", as it were, is not only gratuitous, but as was pointed out above, contradicts in most cases even the current interpretation. These inconsistencies will be avoided by returning to a wave theory that is not continually abrogated by dice-miracles; not of course to the naive wave theory of yore, but to a more sophisticated one, based on second quantization and the non-individuality of "particles". Originating from contraptions that by their very nature cannot but give a discrete, discontinuous response, the probability aspect has unduly entered the fundamental concepts and has domineeringly dictated the basic structure of the present theory.

In giving it up we must no longer be afraid of losing time-honoured atomism. It has its counterpart in the level-scheme (of second quantization) and nowhere else. It may be trusted to give atomism its due, without being aided by dice-playing.

To point here to the general failure of the present theory to obtain finite transition probabilities and finite values of the apparent mass and charge, might seem a cheap argument and a dangerous one

at that. The obvious retort would be: Can you do better, sir? Let me frankly avow that I cannot. Still I beg to plead that I am at the moment groping for my way almost single-handed, as against a host of clever people doing their best along the recognized lines of thought.

But let me still draw attention to a point that is seldom spoken of. I called the probability interpretation a scheme of admirable logical consistency. Indeed it gives us a set of minute prescriptions, not liable ever to be involved in contradiction, for computing the probability of a particular outcome of any intended measurement, given the wave function and the hermitian operator associated with that particular measuring device. But, of course, an abstract mathematical theory cannot possibly indicate the rules for this *association* between operators and measuring devices. To describe one of the latter is a long and circumstantial task for the experimentalist. Whether the device which he recommends really corresponds to the operator set up by the theorist, is not easy to decide. Yet this is of paramount importance. For a measuring appliance means now much more than it did before the advent of quantum mechanics and of its interpretation which I am opposing here. It has a physical influence on the object; it is deemed to press it infallibly into one of the eigenstates of the associated operator. If it fails to put it in an eigenstate belonging to the value resulting from the measurement, the latter is quantum-mechanically not repeatable. I cannot help feeling that the precariousness of the said association makes that beautiful, logically consistent theoretical scheme rather void. At any rate its contact with actual laboratory work is very different from what one would expect from its fundamental enunciations.

A further discussion of the points raised in this paper can be found in a forthcoming longer (but equally non-mathematical) essay in the British Journal for the Philosophy of Science.

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Über den Äther (Einstein)

Über den Äther

Von

Prof. Dr. Albert Einstein (Berlin)
Wenn hier vom Äther die Rede ist, so soll es sich natürlich nicht um den körperlichen Äther der mechanischen Undulationstheorie handeln, welcher den Gesetzen der Newtonschen Mechanik unterliegt, und dessen einzelnen Punkten eine Geschwindigkeit zugeteilt wird. Dies theoretische Gebilde hat nach meiner Überzeugung seit der Aufstellung der speziellen Relativitätstheorie seine Rolle endgültig zu Ende gespielt. Es handelt sich vielmehr allgemeiner um diejenigen als physikalisch-real gedachten Dinge, welche neben der aus elektrischen Elementarteilchen bestehenden ponderabeln Materie im Kausal-Nexus der Physik eine Rolle spielen. Man könnte statt von „Äther" also ebensogut von „physikalischen Qualitäten des Raumes" sprechen. Nun könnte allerdings die Meinung vertreten werden, dass unter diesen Begriff *alle* Gegenstände der Physik fallen, weil nach der konsequenten Feldtheorie auch die ponderable Materie, bzw. die sie konstituierenden Elementarteilchen als „Felder" besonderer Art, bzw. als besondere „Raum-Zustände" aufzufassen seien. Indessen wird man zugeben müssen, dass beim heutigen Stande der Physik eine solche Auffassung verfrüht wäre, denn bisher sind alle auf dies Ziel gerichteten Bemühungen der theoretischen Physiker gescheitert. So sind wir beim heutigen Stand der Dinge faktisch gezwungen, zwischen „Materie" und „Feldern" zu unterscheiden, wenn wir auch hoffen dürfen, dass spätere Generationen diese dualistische Auffassung überwinden und durch eine einheitliche ersetzen werden, wie es die Feldtheorie in unseren Tagen vergeblich versucht hat.

Man glaubt gewöhnlich, dass die Physik Newtons keinen Äther gekannt habe, sondern dass erst die Undulationstheorie des Lichtes [86] ein allgegenwärtiges, die physikalischen Phänomene mitbedingendes Medium eingeführt habe. Dies ist jedoch nicht der Fall. Die Newtonsche Mechanik hat ihren „Äther" in dem angedeuteten Sinne, der allerdings als „absoluter Raum" bezeichnet wird. Um dies klar zu erkennen und gleichzeitig den Äther-Begriff etwas schärfer herauszuarbeiten, müssen wir ein wenig ausholen.

Wir betrachten zuerst einen Zweig der Physik, der ohne Äther auskommt, nämlich die

Geometrie Euklids, aufgefasst als die Lehre von den möglichen Arten, praktisch starre Körper miteinander in Berührung zu bringen. (Von den Lichtstrahlen, die ebenfalls bei der Entstehung der Begriffe und Gesetze der Geometrie beteiligt sein mögen, sehen wir hier ab.) Die Lagerungs-Gesetze fester Körper bei Ausschluss von relativen Bewegungen, Temperaturen und Deformationseinflüssen, wie sie idealisiert in der Geometrie Euklids niedergelegt sind, kommen mit dem Begriff des starren Körpers aus; irgend welche Milieu-Einflüsse, die als unabhängig von den Körpern vorhanden und als auf die Körper wirkend und ihre Lagerungs-Gesetze beeinflussend gedacht würden, kennt die euklidische Geometrie nicht. Dasselbe gilt von den nicht-euklidischen Geometrien konstanter Krümmung, wenn diese als (denkbare) Naturgesetze der Körper-Lagerung aufgefasst werden. Anders wäre es, wenn man eine Geometrie variabler Krümmung anzunehmen sich genötigt sähe; dies würde bedeuten, dass die möglichen Berührungslagerungen von praktisch starren Körpern in verschiedenen Fällen verschieden, von Milieu-Einflüssen bedingt wäre. Hier müsste man im Sinne unserer Betrachtung sagen, eine solche Theorie bediene sich einer Äther-Hypothese. Ihr Äther wäre etwas physikalisch Reales, so gut wie die Materie. Wären die Lagerungsgesetze durch physikalische Faktoren, wie Anhäufung und Bewegungszustand von Körpern in der Umgebung usw., nicht beeinflussbar, sondern unverrückbar gegeben, so würde man diesen Äther als „absolut“ (d. h. unabhängig von Einflüssen irgend welcher anderer Gegenstände) bezeichnen.

Ebensowenig wie die euklidische (physikalisch interpretierte) Geometrie einen Äther braucht, ebensowenig bedarf die Kinematik oder Phoronomie der klassischen Mechanik eines solchen; ihre Sätze haben einen klaren physikalischen Sinn, wenn nur angenommen wird, dass die in der speziellen Relativitätstheorie angenommenen Einflüsse der Bewegung auf Maßstäbe und Uhren nicht existieren. [87]

Anders in der Dynamik Galileis und Newtons. Das Bewegungsgesetz „Masse × Beschleunigung = Kraft“ enthält nicht nur eine Aussage über materielle Systeme, auch dann nicht, wenn, wie bei Newtons astronomischem Fundamentalgesetz die Kraft durch Abstände, also durch Grössen ausgedrückt ist, deren Realdefinition auf Messungen mit starren Messkörpern gegründet werden kann. Denn die Realdefinition der Beschleunigung kann nicht restlos auf Beobachtungen an starren Körpern und Uhren gegründet werden. Sie kann nicht zurückgeführt werden auf die messbaren Abstände zwischen den das mechanische System konstituierenden Punkten. Man bedarf zu ihrer Definition noch eines Koordinationssystems, bzw. Bezugskörpers von geeignetem Bewegungszustand. Wird der Bewegungszustand des Koordinatensystems anders gewählt, so gelten inbezug auf dasselbe die Newtonschen Gleichungen nicht. In jenen Gleichungen tritt gleichsam das Milieu, in welchem die Körper bewegt sind, implicite als realer Faktor im Bewegungsgesetze auf neben den realen Körpern und ihren durch Messkörper definieraren Abständen. InNewtons Bewegungslehre besitzt der „Raum“ physikalische Realität — im Gegensatz zu Geometrie und Kinematik. Wir wollen dies physikalisch Reale, welches neben den beobachtbaren ponderabeln Körpern in das Newtonsche Bewegungsgesetz eingeht, als „Äther der Mechanik” bezeichnen. Das Auftreten von Zentrifugalwirkungen bei einem (rotierenden) Körper, dessen materielle Punkte ihre Abstände gegeneinander nicht ändern, zeigt, dass dieser Äther nicht nur als ein Phantasiegebilde der Newtonschen Theorie aufzufassen ist, sondern dass ihm etwas Reales in der Natur entspricht.

Wir sehen, dass für Newton der „Raum“ etwas physikalisch Reales war, trotz der merkwürdig indirekten Art, in welcher dieses Reale zu unserer Kenntnis gelangt. Ernst Mach, der als Erster nach Newton das Fundament der Mechanik einer tiefen Analyse unterzog, hat dies klar erkannt. Er suchte der Hypothese des „Äthers der Mechanik“ dadurch zu entgehen, dass er die Trägheit auf unvermittelte Wechselwirkung zwischen der ins Auge gefassten Masse und allen übrigen Massen der Welt zurückzuführen suchte. Diese Auffassung ist zwar logisch möglich, kommt aber als Fernwirkungstheorie für uns heute nicht mehr ernsthaft in Betracht. Der mechanische Äther, von Newton als „absoluter Raum“ bezeichnet, muss uns also als physikalische Realität gelten. Natürlich darf aber [88] der Ausdruck „Äther“ nicht dazu verleiten, dass man sich wie die Physik des 19. Jahrhunderts etwas der ponderabeln Materie Analoges darunter denke.

Wenn Newton den Raum der Physik als „absolut“ bezeichnet, so denkt er noch an eine andere Eigenschaft dessen, was wir hier „Äther“ nennen. Jedes physikalische Ding beeinflusst andere und wird umgekehrt im allgemeinen von anderen beeinflusst. Letzteres trifft aber für den Äther der Newtonschen Mechanik nicht zu. Die trägheitspendende Eigenschaft des letztern ist nämlich gemäss der klassischen Mechanik durch nichts beeinflussbar, weder durch die Konfiguration der Materie, noch durch sonst etwas; insofern kann man ihn als „absolut“ bezeichnen.

Dass für die Bevorzugung der Inertialsysteme gegenüber den Nicht-Inertialsystemen ein reales Ding als Ursache vorausgesetzt werden müsse, wurde den Physikern erst in den letzten Jahren deutlich. Historisch ist die Äther-Hypothese in ihrer heutigen Gestalt aus der mechanischen Äther-Hypothese der Optik durch Sublimierung hervorgegangen. Nach langen, unfruchtbaren Bemühungen kam man zu der Überzeugung, dass das Licht nicht als Bewegung eines trägen, elastischen Mediums aufzufassen sei, dass die elektromagnetischen Felder der Maxwellschen Theorie überhaupt nicht mechanisch gedeutet werden könnten. Die elektromagnetischen Felder wurden so unter dem Druck dieser Misserfolge allmählich als letzte, irreduzible, physikalische Realitäten, als nicht mehr weiter erklärbare Zustände des Äthers betrachtet. Was dem Äther von der mechanischen Theorie zunächst noch blieb, das war sein bestimmter Bewegungszustand; er verkörperte gewissermassen eine „absolute Ruhe“. Waren in der Newtonschen Mechanik wenigstens alle Inertialsysteme gleichberechtigt, so schien der Maxwell-Lorentzschen Theorie der Bewegungszustand des berechtigten Koordinatensystems (Ruhe gegen den Äther) völlig determiniert zu sein. Man nahm stillschweigend an, dass dies bevorzugte System gleichzeitig ein Inertialsystem sei, d. h. dass relativ zum elektromagnetischen Äther das Trägheitsprinzip gelte.

Noch in einer zweiten Weise verschob sich unter dem Einfluss der Maxwell-Lorentzschen Theorie die grundsätzliche Auffassung der Physiker. Nachdem die elektromagnetischen Felder als fundamentale, irreduzible Wesenheiten aufgefasst worden waren, [89] schienen sie berufen zu sein, der ponderabeln trägen Masse auch in der Mechanik ihre grundlegende Bedeutung zu rauben. Es wurde aus den Maxwellschen Gleichungen geschlossen, dass ein bewegter elektrisch geladener Körper von einem Magnetfelde umgeben sei, dessen Energie in erster Näherung quadratisch von der Geschwindigkeit abhängig ist. Was lag näher, als *alle* kinetische Energie als elektromagnetische Energie aufzufassen? Man konnte so hoffen, die Mechanik auf die Elektromagnetik zurückzuführen, nachdem

zuvor die Zurückführung der elektromagnetischen Vorgänge auf die mechanischen misslungen war. Dies schien umso hoffnungsvoller, als es immer wahrscheinlicher wurde, dass alle ponderable Materie aus elektrischen Elementarteilchen aufgebaut sei. Indessen konnte man zweier Schwierigkeiten nicht Herr werden. Erstens nämlich konnten dieMaxwell-Lorentzschen Gleichungen nicht verständlich machen, wieso die ein elektrisches Elementarteilchen konstituierende elektrische Ladung trotz der elektrostatischen Abstossungskräfte im Gleichgewicht existieren kann. Zweitens vermochte die elektromagnetische Theorie die Gravitation nicht einigermassen natürlich und befriedigend zu erklären. Trotzdem waren die Erfolge, welche die elektromagnetische Theorie der Physik brachte, so bedeutende, dass sie als vollkommen gesicherter Besitz der Physik, ja als deren am besten fundierte Errungenschaft betrachtet wurde.

Die Maxwell-Lorentzsche Theorie beeinflusste endlich dadurch unsere Einstellung zu den Fragen des theoretischen Fundamentes, dass sie zu der Aufstellung der speziellen Relativitätstheorie führte. Man erkannte, dass die elektromagnetischen Gleichungen in Wahrheit gar keinen bestimmten Bewegungszustand auszeichnen, sondern dass nach diesen Gleichungen ebenso wie nach der klassischen Mechanik eine unendliche Mannigfaltigkeit von gegeneinander gleichförmig bewegten Koordinatensystemen gleich berechtigt seien, wenn man nur passende Transformationsformeln für die räumlichen Koordinaten-und die Zeit anwendet. Es ist wohlbekannt, dass diese Erkenntnis eine tiefe Modifikation der Kinematik und Dynamik im Gefolge hatte. Dem Äther der Elektrodynamik war nun kein bestimmter Bewegungszustand mehr zuzuschreiben. Er bewirkte nun — wie der Äther der klassischen Mechanik — nicht die Bevorzugung eines bestimmten *Bewegungs*-Zustandes, sondern nur die Bevorzugung eines bestimmten *Beschleunigungs*-Zustandes. Dadurch, [90] dass in einem absoluten Sinne nicht mehr von gleichzeitigen Zuständen an verschiedenen Stellen des Äthers gesprochen werden konnte, wurde der Äther gewissermassen vierdimensional, denn es gab keine objektive Ordnung seiner Zustände nach der Zeit allein. Auch nach der speziellen Relativitätstheorie war der Äther absolut, denn sein Einfluss auf Trägheit und Lichtausbreitung war als unabhängig gedacht von physikalischen Einflüssen jeder Art. Während in der klassischen Physik die Körper-Geometrie als unabhängig vom Bewegungszustande vorausgesetzt wird, sind gemäss der speziellen Relativitätstheorie die Gesetze der euklidischen Geometrie für die Lagerung von relativ zu einander ruhenden Körpern nur dann massgebend, wenn diese Körper relativ zu einem Inertialsystem in Ruhe sind;[1] dies kann leicht aus der sogenannten Lorentz-Kontraktion geschlossen werden. Also wird die Körpergeometrie wie die Dynamik vom Äther mitbedingt.

Die allgemeine Relativitätstheorie beseitigt einen Übelstand der klassischen Dynamik: nach letzterer erscheinen Trägheit und Schwere als ganz verschiedene, voneinander unabhängige Erscheinungen, trotzdem sie beide durch dieselbe Körperkonstante, die Masse, bedingt werden. Die Relativitätstheorie überwindet diesen Mangel, indem sie das dynamische Verhalten des elektrisch neutralen Massenpunktes durch das Gesetz der geodätischen Linie festlegt, in welchem die Trägheits- und Schwerewirkungen nicht mehr auseinandergehalten sind. Dabei legt sie dem Äther von Punkt zu Punkt variable, die Metrik und das dynamische Verhalten materieller Punkte bestimmende Eigenschaften bei, welche ihrerseits durch physikalische Faktoren, nämlich durch die Verteilung von Masse bezw. Energie bestimmt sind. Der Äther der allgemeinen Relativitätstheorie unterscheidet sich

also von demjenigen der klassischen Mechanik bezw. der speziellen Relativitätstheorie dadurch, dass er nicht „absolut", sondern in seinen örtlich variablen Eigenschaften durch die ponderable Materie bestimmt ist. Diese Bestimmung ist dann eine vollständige, wenn die Welt räumlich endlich und in sich geschlossen ist. Dass es in der allgemeinen Relativitätstheorie keine bevorzugten, mit der Metrik eindeutig verknüpften raumzeitlichen Koordinaten gibt, ist mehr für die [91] mathematische Form dieser Theorie als für ihren physikalischen Gehalt charakteristisch.

Auch mit der Anwendung des formalen Apparates der allgemeinen Relativitätstheorie gelang es nicht, alle Massenträgheit auf elektromagnetische Felder, überhaupt auf Felder, zurückzuführen. Auch sind wir bis jetzt nach meiner Ansicht über eine äusserliche Einordnung der elektromagnetischen Kräfte in das Schema der allgemeinen Relativitätstheorie nicht hinausgekommen. Der die Gravitations- und Trägheitserscheinungen mitbestimmende metrische Tensor einerseits und der Tensor des elektromagnetischen Feldes anderseits, erscheinen nach wie vor als wesensverschiedene Ausdrücke des Ätherzustandes, deren logische Unabhängigkeit man wohl weit eher auf das Konto der Unvollkommenheit unseres theoretischen Gebäudes als auf dasjenige einer komplexen Struktur der Wirklichkeit zu setzen geneigt sein wird.

Zwar haben Weyl und Eddington durch Verallgemeinerung der Riemannschen Geometrie ein mathematisches System gefunden, welches beide Feldarten als unter einem einheitlichen Gesichtspunkte vereinigt erscheinen lässt. Aber die einfachsten Feldgesetze, welche jene Theorie liefert, scheinen mir nicht zu Forschritten der physikalischen Erkenntnis zu führen. Überhaupt scheint es heute, dass wir von einer Kenntnis der elektromagnetischen Elementargesetze viel weiter entfernt sind, als es am Anfange dieses Jahrhunderts der Fall zu sein schien. Zur Begründung dieser Meinung möchte ich hier noch kurz auf das *Problem des magnetischen Erd- und Sonnenfeldes* sowie auf das *Problem der Lichtquanten* hinweisen, welche Probleme gewissermassen die Grobstruktur und die Feinstruktur des elektromagnetischen Feldes betreffen.

Erde und Sonne besitzen Magnetfelder, deren Orientierung und Sinn mit der Drehaxe dieser Himmelskörper in annäherndem Zusammenhang stehen. Nach der Maxwellschen Theorie könnten jene Felder von elektrischen Strömen herrühren, welche entgegengesetzt der Drehbewegung um die Drehachse der Himmelskörper herum fliessen. Auch die Sonnenflecken, welche mit guten Gründen als Wirbel aufgefasst werden, besitzen analoge, sehr kräftige Magnetfelder. Es ist aber kaum denkbar, dass in allen diesen Fällen elektrische Leitungs-, bzw. Konvektionsströme von hinreichender Stärke wirklich vorhanden seien. Es sieht vielmehr so aus, wie wenn zyklische Bewegungen neutraler Massen Magnetfelder erzeugten. Weder die [92] Maxwellsche Theorie in ihrer ursprünglichen Fassung noch die im Sinne der allgemeinen Relativitätstheorie erweiterte Maxwellsche Theorie lassen eine derartige Feldererzeugung voraus sehen. Hier scheint uns die Natur auf einen fundamentalen, bis jetzt theoretisch noch nicht erfassten Zusammenhang hinzuweisen.[2]

Handelte es sich soeben um einen Fall, welchem die Feldtheorie in ihrer gegenwärtigen Gestalt nicht gewachsen zu sein scheint, so drohen die in der *Quantentheorie* zusammengefassten Tatsachen und Gedanken das Gebäude der Feldtheorie überhaupt zu sprengen. Es mehren sich nämlich die

Argumente dafür, dass die Lichtquanten als physikalische Realitäten aufzufassen seien, dass das elektromagnetische Feld nicht als letzte Realität angesehen werden könne, auf welche die anderen physikalischen Dinge zurückgeführt werden könnten. Nachdem die Theorie der Planckschen Formel schon gezeigt hatte, dass die Übertragung von Energie und Impuls durch die Strahlung so erfolgt, wie wenn letztere aus mit der Lichtgeschwindigkeit *c* bewegten Atomen von der Energie *hν* und von dem Impuls $\frac{h\nu}{c}$ bestünde, hat Compton durch Versuche über die Zerstreuung von Röntgenstrahlen an Materie nachgewiesen, dass Zerstreuungs-Akte auftreten, bei welchen Lichtquanten auf Elektronen stossen und diesen einen Teil ihrer Energie übertragen, wobei die Lichtquanten ihre Energie und Richtung ändern. Tatsache ist wenigstens, dass die Röntgenstrahlen solche (von Debye und Compton vorhergesehene) Frequenzänderungen bei ihrer Zerstreuung erfahren, wie es die Quantenhypothese erfordert.

Vor kurzem ist ferner eine Arbeit des Inders Bose über die Ableitung der Planckschen Formel erschienen, die aus folgendem [93] Grunde für unsere theoretische Auffassung von besonderer Bedeutung ist: Bisher wurde bei allen vollständigen Ableitungen der Planckschen Formel irgendwie von der Hypothese der Undulations-Struktur der Strahlung Gebrauch gemacht. So wurde z. B. der Faktor $\frac{8\pi h\nu^3}{c^3}$ dieser Formel bei der bekannten Ehrenfest-Debyechen Ableitung dadurch gewonnen, dass die Zahl der Eigenschwingungen des Hohlraumes gezählt wurden, welche zum Frequenzbereiche *dν* gehören. Bose ersetzt diese auf die Vorstellungen der Undulationstheorie gegründete Abzählung durch eine gastheoretische Rechnung, die er auf ein in dem Hohlraum befindliches, nach Art eines Moleküls gedachtes Lichtquant bezieht. Da drängt sich die Frage auf, ob nicht doch einmal die Beugungs- und Interferenz-Erscheinungen derart an die Quantentheorie angeschlossen werden könnten, dass die feldartigen Begriffe der Theorie nur Ausdrücke der Wechselwirkungen zwischen Quanten darstellen, wobei dem Felde keine selbständige physikalische Realität mehr zugeschrieben würde.

Die wichtige Tatsache, dass nach der Bohrschen Theorie die Frequenz der emittierten Strahlung nicht bestimmt wird durch elektrische Massen, die periodische Vorgänge von *derselben* Frequenz durchlaufen, kann uns nur bestärken in diesem Zweifel an der selbständigen Realität des Undulationsfeldes.

Aber selbst wenn diese Möglichkeiten zu wirklichen Theorien heranreifen, werden wir des Äthers, d. h. des mit physikalischen Eigenschaften ausgestatteten Kontinuums, in der theoretischen Physik nicht entbehren können; denn die allgemeine Relativitätstheorie, an deren grundsätzlichen Gesichtspunkten die Physiker wohl stets festhalten werden, schliesst eine unvermittelte Fernwirkung aus; jede Nahewirkungs-Theorie aber setzt kontinuierliche Felder voraus, also auch die Existenz eines „Äthers“.

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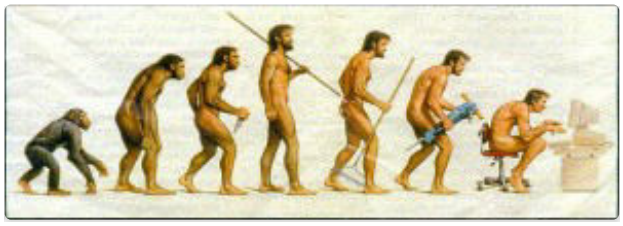
About Me

What defines me are both my curiosity and passion to learn more about how our world works. I always prefer the red over the blue pill – no matter how painful the truth is, even if it changes my world view. I even got my genome sequenced recently, which is pretty crazy given that you never know what might lurk in those genes (luckily, I do not have the "Angelina Jolie" gene, but I now have definitive confirmation that I am in fact a fast caffeine metabolizer :-).

I got my PhD in scientific computing at the ETH Zürich – after I did a Masters in Biochemistry – which is even more evidence that I am a crazy person (at least at that time, the professors thought I was :-). But at least I know I am crazy, so that probably makes me less dangerous.



After my PhD I spent 8 years in San Diego, California, where I worked in the biotech industry as a software engineer (all the way from robotics to biofuels), and currently I am developing software for IonTorrent (PGM – the personal genome machine) for Thermo Fisher Scientific, in the context of personalized medicine.

My hobbies include even more software engineering, physics, Karate and playing the violin.

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