# Gravity Using Mobile Atom Interferometer

*Mobile gravimetry is an important technique in metrology, navigation, geodesy and geophysics. [12]*

*The relationship may even unlock the quantum nature of gravity. "It is among our best clues to understand gravity from a quantum perspective," said Witten. [11]*

*Scientists at the University of British Columbia have proposed a radical new theory to explain the exponentially increasing size of the universe. [10]*

*Researchers playing with a cloud of ultracold atoms uncovered behavior that bears a striking resemblance to the universe in microcosm. [9]*

*Gravitational waves may be produced in the heart of the galaxy, says a new study led by Ph.D. student Joseph Fernandez at Liverpool John Moores University. [8]*

*Using data from the first-ever gravitational waves detected last year, along with a theoretical analysis, physicists have shown that gravitational waves may oscillate between two different forms called "g" and "f"-type gravitational waves. [7]*

*Astronomy experiments could soon test an idea developed by Albert Einstein almost exactly a century ago, scientists say. [6]*

*It's estimated that 27% of all the matter in the universe is invisible, while everything from PB&J sandwiches to quasars accounts for just 4.9%. But a new theory of gravity proposed by theoretical physicist Erik Verlinde of the University of Amsterdam found out a way to dispense with the pesky stuff. [5]*

*The proposal by the trio though phrased in a way as to suggest it's a solution to the arrow of time problem, is not likely to be addressed as such by the physics community—it's more likely to be considered as yet another theory that works mathematically, yet still can't answer the basic question of what is time. [4]*

*The Weak Interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and Time reversal symmetry.*

*The Neutrino Oscillation of the Weak Interaction shows that it is a General electric dipole change and it is possible to any other temperature dependent entropy and information changing diffraction pattern of atoms, molecules and even complicated biological living structures.*

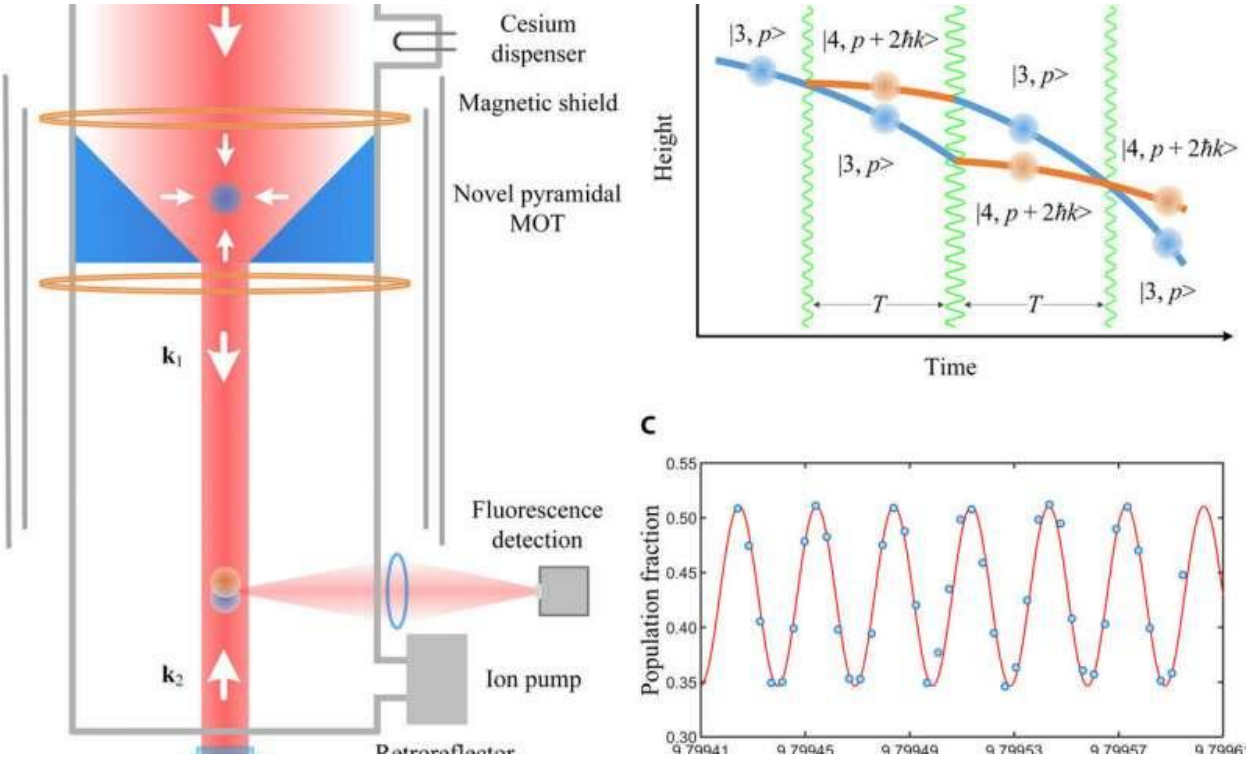
Author: George Rajna

## Gravity surveys using a mobile atom interferometer

Mobile gravimetry is an important technique in metrology, navigation, geodesy and geophysics. Although atomic gravimeters are presently used for accuracy, they are constrained by instrumental fragility and complexity. In a new study, Xuejian Wu and an interdisciplinary research team in the departments of physics, the U.S. Geological Survey, molecular biophysics and integrated bio-imaging, demonstrated a mobile atomic gravimeter. The device measured tidal gravity variations in the lab and surveyed gravity in the field.

They used the equipment to achieve a high sensitivity for tidal gravity measurements with long-term stability to reveal ocean tidal loading effects, as well as several distant earthquakes. The research team surveyed gravity in the Berkeley Hills to determine the density of subsurface rocks from the vertical gravity gradient. The simple and sensitive instrument developed in the study will pave the way to bring atomic gravimeters to field applications. The work is now published on *Science Advances*.

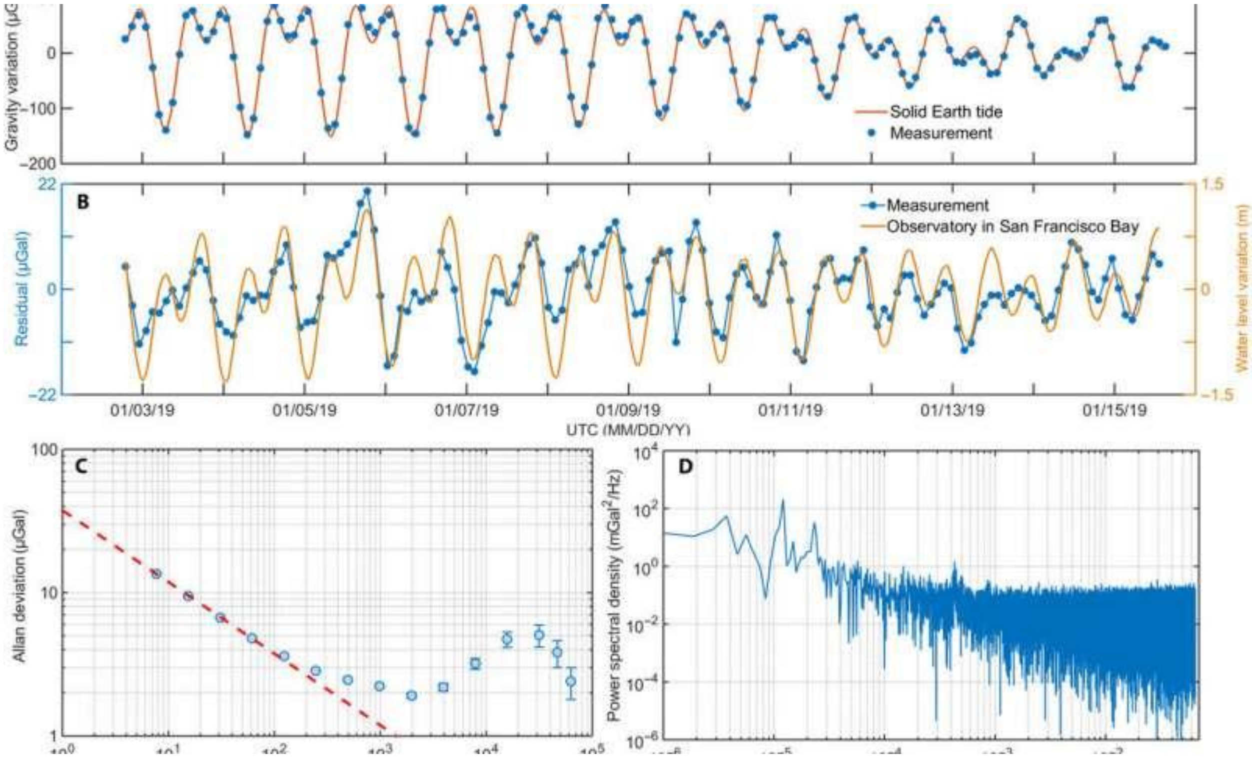
Physicists typically use light-pulse atom interferometers to measure inertial forces alongside studies to understand sub-gravitational forces on atoms. Gravimeters based on atom interferometry are among the most accurate and sensitive tools to precisely measure gravity, in contrast to existing instruments based on springs, superconducting coils, micromechanical devices or falling corner cubes. Atomic gravimeters rely on matter-wave interferometry measurements with a freely falling atomic cloud. In its mechanism of action, scientists can steer matter waves into two interferometer arms using the momentum of photons that are extremely well defined by the integrated laser wavelength.




Atomic gravimeter. (A) Schematic. Cesium clouds are loaded in the novel pyramidal MOT and then freely fall into the region of fluorescence detection. k1 and k2 are the wave vectors of the interferometer beams. A magnetic shield and a solenoid (not shown) around the vacuum chamber create a uniform magnetic bias field. The retroreflector consists of a flat mirror and a quarter-wave plate. The vibration isolation stage includes a passive vibration isolation table, a seismometer, voice coils, and an active feedback loop. (B) Mach-Zehnder interferometer geometry. Three laser pulses (wavy green lines) split, redirect, and combine a matter wave (blue and orange lines). (C) Fringes with T = 120 ms and C = 16%. The blue dots are single-shot experimental data, and the red curve is a sinusoidal fit. Credit: Science Advances, doi: 10.1126/sciadv.aax0800

Researchers are presently engineering transportable atomic gravimeters for applications in metrology, airborne sensing, shipborne surveys and field applications. Such instruments typically reach sensitivities around 5 to 100 µGalileo (µGal) in the lab, while the atomic gravimeter in gravity surveys had only achieved a precision approximating 1 mGal on a marine ship. Precise mobile gravimetry is therefore valuable for gravity measurements with an uncertainty of a few microGalileos in metrology. For instance, to aid inertial marine navigation, gravity reference maps require gravimeters with at least miliGalileo accuracy on board. As a result, atomic gravimeters should be both sensitive and mobile for reliable applications in the field.

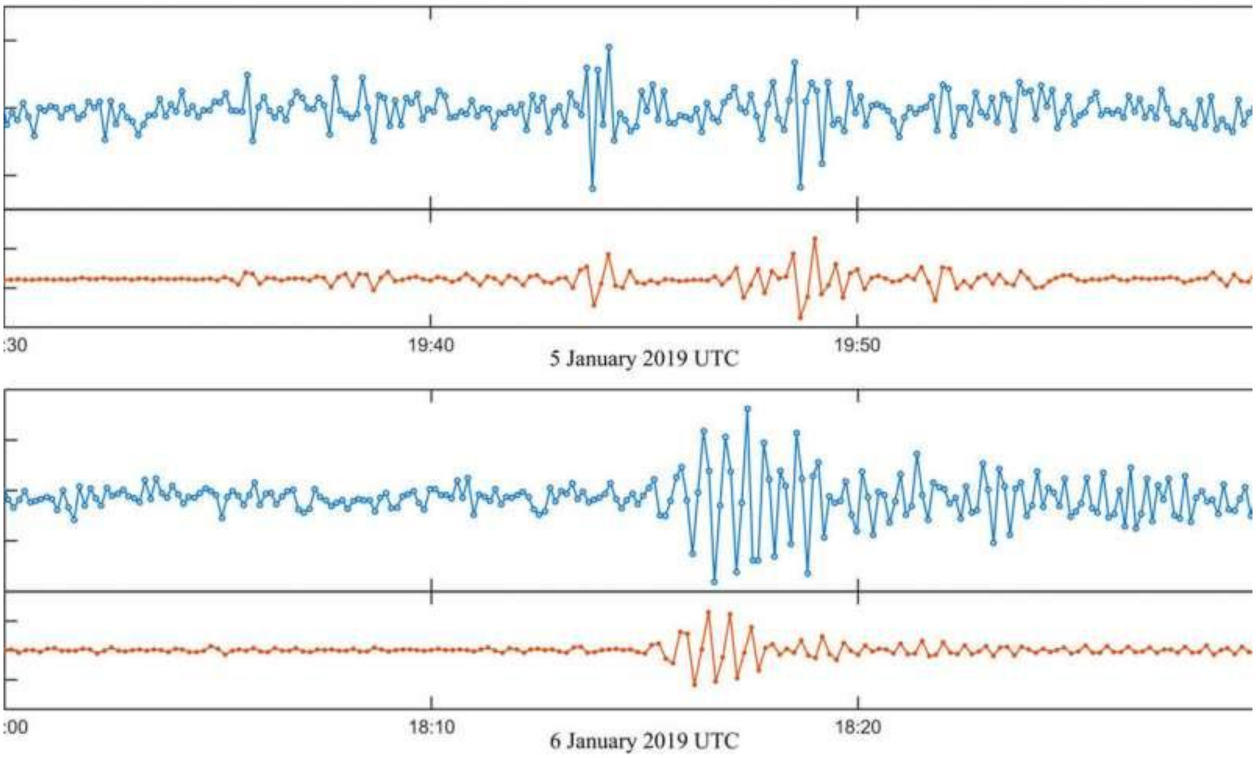
In the present work, Wu et al. demonstrated a mobile atomic gravimeter in the lab and during field operations. The research team compared gravity measured in the experiments with a solid Earth tide model to indicate its atomic sensitivity. Based on the instrumental sensitivity Wu et al. observed ocean tide loading effects and measured seismic waves of distant earthquakes. The research team then implemented gravity surveys in Berkeley Hills using the instrument. The atomic gravimeter can be used for geodetic and geophysical studies to refine the geoid during resource exploration, hydrological studies and hazard monitoring for precise field measurements in the future.




Tidal gravity measurement. (A) Tidal gravity variation as a function of time. Each blue dot is the mean value of the gravity data over 2 hours. (B) Comparison between the gravity residual and the water level variation in the San Francisco Bay. The gravity residual is the difference between the measurements and the solid Earth tide model. The water level variation is measured by the observatory of National Oceanic and Atmospheric Administration in Richmond, CA. (C) Allan deviation of the residual. The dashed line corresponds to a sensitivity of 37 μGal/√ Hz. The broad peak around 3 × 104 s is due to the ocean tidal loading. (D) Power spectral density of the residual. The ocean tidal loading results in the peaks around 1 × 10−5 to 3 × 10−5 Hz. Credit: Science Advances, doi: 10.1126/sciadv.aax0800

Wu et al. engineered the mobile atomic gravimeter on an atom interferometer featuring a magneto-optical trap (MOT) inside a pyramid mirror with a through-hole. This novel geometry offered many advantages; by first forming a differential pumping stage between the MOT and atom interferometry regions, with a vapor pressure ratio of more than 10:1 to accelerate atom-loading speed and decreased background noise for atom detection. The setup allowed the MOT and interferometer laser beams to have different waists to achieve a large MOT volume and high Raman beam intensity with available laser power. As a third feature, the research team enabled the atomic gravimeter to take advantage of retroreflection from a vibration-isolated mirror insensitive to vibrations of the pyramid mirror. The vibration isolation was simpler and effective compared to traditional pyramidal atomic gravimeters. For its fourth feature, Wu et al. used a flat mirror as the retroreflector to eliminate systematic effects from imperfections in the pyramidal setup.

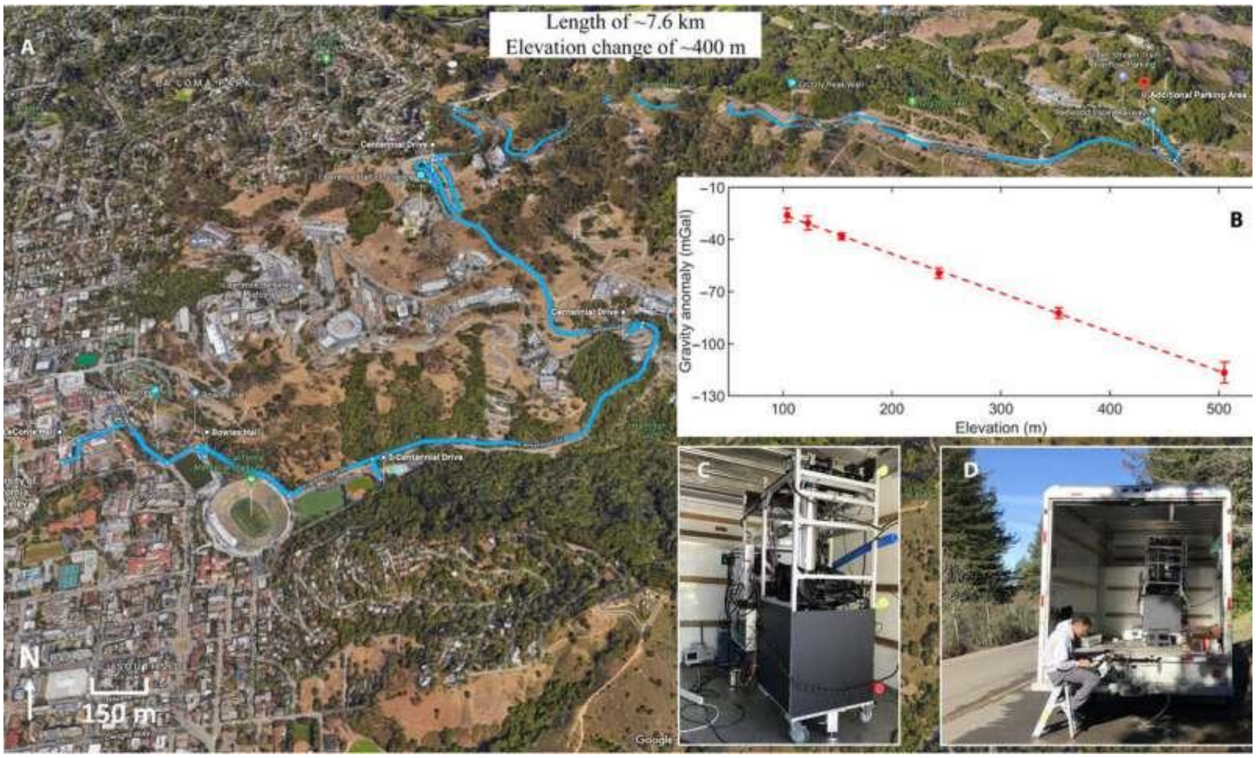
The team performed atom interferometry underneath the pyramid mirror using Doppler-sensitive two-photon Raman transitions driven by two laser beams and a Mach-Zehnder geometry. Since the atoms moved in free fall, the scientists ramped the laser frequency difference between the two beams with a rate of α, which they varied to obtain acceleration in the system. They used a single diode laser with three acousto-optic modulators (AOMs) and one fiber-based electro-optic phase modulator (EOM), to generate all laser beams necessary for the MOT, during interferometry and detection procedures of the study.




Earthquake seismic waves detected in Berkeley. The atomic gravimeter measures the vertical acceleration of the seismic waves with an update rate of 0.13 Hz. The seismic signal is the vertical channel of the seismometer located in Haviland Hall in the University of California (UC) Berkeley campus. It is in arbitrary unit and has an update rate of 0.1 Hz. Credit: Science Advances, doi: 10.1126/sciadv.aax0800.

The scientists measured long-term tidal gravity variation for 12 days using the atomic gravimeter. They then operated the atom interferometer with active vibration isolation and obtained mean values of gravity data every 2 hours, compared with a solid Earth tide model. Since the research lab was located about 4.5 km east of San Francisco Bay area, the ocean tidal loading effect on gravity was notable at the precise location in contrast to previous reports. The researchers corrected for the solid Earth tide and obtained a sensitivity of 37 μGal/√Hz for the atomic gravimeter with stability greater than 2 μGal within half an hour. During tidal gravity measurements, the atomic gravimeter could record seismic wave trains from several distant earthquakes to measure vertical acceleration of the seismic waves. Wu et al. compared the atomic gravimeter with one of the seismometers in the Berkeley Digital Seismic Network. For instance, when a 6.8-magnitude and 570 km deep earthquake occurred in Brazil on January 5, 2019, both the atomic gravimeter and seismometer detected body waves from the earthquake after about 20 mins. The team in Berkeley similarly detected measurements on January 6, 2019, when a 6.6-magnitude and 43-km deep earthquake occurred in Indonesia.

To investigate the accuracy of the atomic gravimeter, the research team estimated systematic effects. They calculated the total systematic error at 0.015 mGal with a measurement bias approximating -0.008 mGal. The researchers verified the repeatability of the experiment in-house after transporting the atomic gravimeter to the Campbell Hall at the University of California Berkeley Campus, to measure gravity on different floors, with gravity on the basement floor as a reference. The values matched those calculated using standard gravity survey techniques. Depending on the vibrational noise, the atomic gravimeter achieved a sensitivity of around 0.2 mGal/√Hz. However, the sensitivity on higher floors decreased due to stronger vibrations. The results indicated the gravitational effect of the mass of the Campbell building.




Gravity survey in Berkeley Hills. (A) Measurement route. The blue curve depicts the route, and the white pin drops are the six measurement locations. (B) Gravity anomaly as a function of the elevation. Elevations are from Google maps. The error bars are 1 − σ statistical and systematic errors. The dashed line indicates a VGG of −0.225(10) mGal/m. (C) The atomic gravimeter apparatus. (D) Field operation of the atomic gravimeter inside a vehicle. [Photo credit for (A): Google Maps; photo credit for (C) and (D): Xuejian Wu, UC Berkeley]. Credit: Science Advances, doi: 10.1126/sciadv.aax0800.

Thereafter, the team used the atomic gravimeter in the field to survey absolute gravity in the Berkeley Hills. They operated the gravimeter inside a vehicle on a route length of 7.6 km and an elevation change of 400 m, while using passive vibration isolation to measure gravity in 6 locations. The team spent approximately 15 mins to setup the gravimeter at each location, which included pairing up the instrument and aligning the interferometer beam to the gravity axis. Due to increased vibrational noise in the field, Wu et al. measured the gravimeter sensitivity at 0.5 mGal//√Hz. In total, the measurements showed approximate gravity changes by 92.6 mGal, from the base to the peak of the Berkeley Hills.

In this way, Xuejian Wu and colleagues developed a mobile atomic gravimeter to perform tidal gravity measurements and gravity surveys. The novel pyramidal MOT instrument took advantage of single-beam atom interferometry to offer simple laser-to-gravity alignment and enhanced vibration isolation. The device is mobile, compact and robust for transportation in the field, while maintaining comparatively higher sensitivity to the existing atomic gravimeters. The features allow geodetic and geophysical applications for precise mobile gravimetry in the lab and on the field. The instrument is presently limited by vibrational noise with room for improvement. Advanced gravimeters will find additional applications as tunnel detectors, sensors for underground water storage and monitor earthquakes and volcanic activity. [12]

## Gravity is mathematically relatable to dynamics of subatomic particles

Albert Einstein's desk can still be found on the second floor of Princeton's physics department. Positioned in front of a floor-to-ceiling blackboard covered with equations, the desk seems to embody the spirit of the frizzy-haired genius as he asks the department's current occupants, "So, have you solved it yet?"

Einstein never achieved his goal of a unified theory to explain the natural world in a single, coherent framework. Over the last century, researchers have pieced together links between three of the four known physical forces in a "standard model," but the fourth force, gravity, has always stood alone.

No longer. Thanks to insights made by Princeton faculty members and others who trained here, gravity is being brought in from the cold—although in a manner not remotely close to how Einstein had imagined it.

Though not yet a "theory of everything," this framework, laid down over 20 years ago and still being filled in, reveals surprising ways in which Einstein's theory of gravity relates to other areas of physics, giving researchers new tools with which to tackle elusive questions.

The key insight is that gravity, the force that brings baseballs back to Earth and governs the growth of black holes, is mathematically relatable to the peculiar antics of the subatomic particles that make up all the matter around us.

This revelation allows scientists to use one branch of physics to understand other seemingly unrelated areas of physics. So far, this concept has been applied to topics ranging from why black holes run a temperature to how a butterfly's beating wings can cause a storm on the other side of the world.

This relatability between gravity and subatomic particles provides a sort of Rosetta stone for physics. Ask a question about gravity, and you'll get an explanation couched in the terms of subatomic particles. And vice versa.

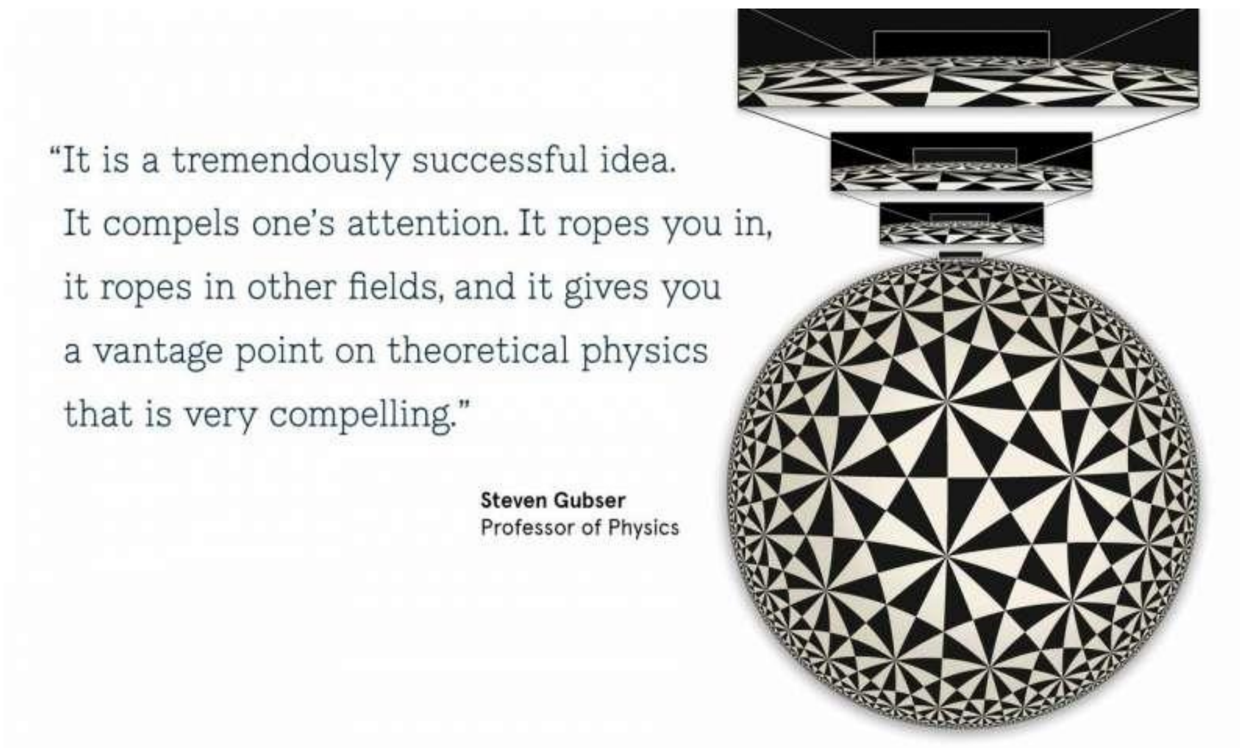
"This has turned out to be an incredibly rich area," said Igor Klebanov, Princeton's Eugene Higgins Professor of Physics, who generated some of the initial inklings in this field in the 1990s. "It lies at the intersection of many fields of physics."

### *From tiny bits of string*

The seeds of this correspondence were sprinkled in the 1970s, when researchers were exploring tiny subatomic particles called quarks. These entities nest like Russian dolls inside protons, which in turn occupy the atoms that make up all matter. At the time, physicists found it odd that no matter how hard you smash two protons together, you cannot release the quarks—they stay confined inside the protons.

One person working on quark confinement was Alexander Polyakov, Princeton's Joseph Henry Professor of Physics. It turns out that quarks are "glued together" by other particles, called gluons. For a while, researchers thought gluons could assemble into strings that tie quarks to each other. Polyakov glimpsed a link between the theory of particles and the theory of strings, but the work was, in Polyakov's words, "hand-wavy" and he didn't have precise examples.

Meanwhile, the idea that fundamental particles are actually tiny bits of vibrating string was taking off, and by the mid-1980s, "string theory" had lassoed the imaginations of many leading physicists. The idea is simple: just as a vibrating violin string gives rise to different notes, each string's vibration foretells a particle's mass and behavior. The mathematical beauty was irresistible and led to a swell of enthusiasm for string theory as a way to explain not only particles but the universe itself.




Credit: J.F. Podevin

One of Polyakov's colleagues was Klebanov, who in 1996 was an associate professor at Princeton, having earned his Ph.D. at Princeton a decade earlier. That year, Klebanov, with graduate student Steven Gubser and postdoctoral research associate Amanda Peet, used string theory to make calculations about gluons, and then compared their findings to a string-theory approach to understanding a black hole. They were surprised to find that both approaches yielded a very similar answer. A year later, Klebanov studied absorption rates by black holes and found that this time they agreed exactly.

That work was limited to the example of gluons and black holes. It took an insight by Juan Maldacena in 1997 to pull the pieces into a more general relationship. At that time, Maldacena, who had earned his Ph.D.

at Princeton one year earlier, was an assistant professor at Harvard. He detected a correspondence between a special form of gravity and the theory that describes particles. Seeing the importance of Maldacena's conjecture, a Princeton team consisting of Gubser, Klebanov and Polyakov followed up with a related paper formulating the idea in more precise terms.

Another physicist who was immediately taken with the idea was Edward Witten of the Institute for Advanced Study (IAS), an independent research center located about a mile from the University campus. He wrote a paper that further formulated the idea, and the combination of the three papers in late 1997 and early 1998 opened the floodgates.

"It was a fundamentally new kind of connection," said Witten, a leader in the field of string theory who had earned his Ph.D. at Princeton in 1976 and is a visiting lecturer with the rank of professor in physics at Princeton. "Twenty years later, we haven't fully come to grips with it."

## *Two sides of the same coin*

This relationship means that gravity and subatomic particle interactions are like two sides of the same coin. On one side is an extended version of gravity derived from Einstein's 1915 theory of general relativity. On the other side is the theory that roughly describes the behavior of subatomic particles and their interactions.

The latter theory includes the catalogue of particles and forces in the "standard model" (see sidebar), a framework to explain matter and its interactions that has survived rigorous testing in numerous experiments, including at the Large Hadron Collider.

In the standard model, quantum behaviors are baked in. Our world, when we get down to the level of particles, is a quantum world.

Notably absent from the standard model is gravity. Yet quantum behavior is at the basis of the other three forces, so why should gravity be immune?

The new framework brings gravity into the discussion. It is not exactly the gravity we know, but a slightly warped version that includes an extra dimension. The universe we know has four dimensions, the three that pinpoint an object in space—the height, width and depth of Einstein's desk, for example—plus the fourth dimension of time. The gravitational description adds a fifth dimension that causes spacetime to curve into a universe that includes copies of familiar four-dimensional flat space rescaled according to where they are found in the fifth dimension. This strange, curved spacetime is called anti-de Sitter (AdS) space after Einstein's collaborator, Dutch astronomer Willem de Sitter.

The breakthrough in the late 1990s was that mathematical calculations of the edge, or boundary, of this anti-de Sitter space can be applied to problems involving quantum behaviors of subatomic particles described by a mathematical relationship called conformal field theory (CFT). This relationship provides the link, which Polyakov had glimpsed earlier, between the theory of particles in four space-time dimensions and string theory in five dimensions. The relationship now goes by several names that relate gravity to particles, but most researchers call it the AdS/CFT (pronounced A-D-S-C-F-T) correspondence.


Credit: J.F. Podevin

## *Tackling the big questions*

This correspondence, it turns out, has many practical uses. Take black holes, for example. The late physicist Stephen Hawking startled the physics community by discovering that black holes have a temperature that arises because each particle that falls into a black hole has an entangled particle that can escape as heat.

Using AdS/CFT, Tadashi Takayanagi and Shinsei Ryu, then at the University of California-Santa Barbara, discovered a new way to study

entanglement in terms of geometry, extending Hawking's insights in a fashion that experts consider quite remarkable.

In another example, researchers are using AdS/CFT to pin down chaos theory, which says that a random and insignificant event such as the flapping of a butterfly's wings could result in massive changes to a large-scale system such as a faraway hurricane. It is difficult to calculate chaos, but black holes—which are some of the most chaotic quantum systems possible—could help. Work by Stephen Shenker and Douglas Stanford at Stanford University, along with Maldacena, demonstrates how, through AdS/CFT, black holes can model quantum chaos.

One open question Maldacena hopes the AdS/CFT correspondence will answer is the question of what it is like inside a black hole, where an infinitely dense region called a singularity resides. So far, the relationship gives us a picture of the black hole as seen from the outside, said Maldacena, who is now the Carl P. Feinberg Professor at IAS.

"We hope to understand the singularity inside the black hole," Maldacena said. "Understanding this would probably lead to interesting lessons for the Big Bang."

The relationship between gravity and strings has also shed new light on quark confinement, initially through work by Polyakov and Witten, and later by Klebanov and Matt Strassler, who was then at IAS.

Those are just a few examples of how the relationship can be used. "It is a tremendously successful idea," said Gubser, who today is a professor of physics at Princeton. "It compels one's attention. It ropes you in, it ropes in other fields, and it gives you a vantage point on theoretical physics that is very compelling."

The relationship may even unlock the quantum nature of gravity. "It is among our best clues to understand gravity from a quantum perspective," said Witten. "Since we don't know what is still missing, I cannot tell you how big a piece of the picture it ultimately will be."

Still, the AdS/CFT correspondence, while powerful, relies on a simplified version of spacetime that is not exactly like the real universe. Researchers are working to find ways to make the theory more broadly applicable to the everyday world, including Gubser's research on modeling the collisions of heavy ions, as well as high-temperature superconductors.

Also on the to-do list is developing a proof of this correspondence that draws on underlying physical principles. It is unlikely that Einstein would be satisfied without a proof, said Herman Verlinde, Princeton's Class of 1909 Professor of Physics, the chair of the Department of Physics and an expert in string theory, who shares office space with Einstein's desk.

"Sometimes I imagine he is still sitting there," Verlinde said, "and I wonder what he would think of our progress." [11]

## New Research May Reconcile General Relativity and Quantum Mechanics

Scientists at the University of British Columbia have proposed a radical new theory to explain the exponentially increasing size of the universe. Ultimately, it seeks to reconcile two different concepts in physics: Quantum Mechanics and Einstein's Theory of General Relativity. the researchers argue that instead of dark energy causing the universe's growth, it could be explained by constant quantum fluctuations of vacuum energy.

In their work, the researchers argue that, instead of dark energy causing the universe's growth, it could be explained by constant quantum fluctuations of vacuum energy. The paper claims — if their findings are true — that "the old cosmological constant problem would be resolved." The press release notes the potentially transformative nature of the work: "Their calculations provide a completely different physical picture of the universe."

Similarly, Bill Unruh, the physics and astronomy professor who supervised P.H.D student Qingdi Wang's work, stated that the research offers an entirely new take on old problems: "This is a new idea in a field where there hasn't been a lot of new ideas that try to address this issue." In the end, their calculations provide a fundamentally different picture of the universe: one in which space-time is "constantly moving," fluctuating between contraction and expansion. It's the small net effect towards expansion, though, that drives the expansion of the universe.

Unruh uses the sea as an analogy to explain why we cannot feel the effects: “It’s similar to the waves we see on the ocean […] They are not affected by the intense dance of the individual atoms that make up the water on which those waves ride.”

## *THE BIG WHY*

Previous belief has held that the universe is expanding steadily due to dark energy pushing other matter further and further away. When we apply quantum theories to vacuum energy, it results in an increasing density which could in turn result in universal explosion — due to the gravitational effect *of* the density.

The discovery that the universe is expanding was made simultaneously by two independent teams in 1998: Supernova Cosmology Project and the High-Z Supernova Search Team. Three members of the two teams have since won Nobel prizes for their work, which measured light using ‘standard candles.’ Since that discovery was made, scientists have tried to work out exactly what this energy is that’s driving the cosmos apart.

Despite the fact that it has been a compelling mystery for decades, there haven’t been that many theories posed. So, while the work of Wang and Unruh may not provide the ultimate answer, they present a new, potential solution to one of the most fundamental problems in cosmology. [10]

## Atoms may hum a tune from grand cosmic symphony

Researchers playing with a cloud of ultracold atoms uncovered behavior that bears a striking resemblance to the universe in microcosm. Their work, which forges new connections between atomic physics and the sudden expansion of the early universe, was published April 19 in *Physical Review X* and featured in *Physics*.

"From the atomic physics perspective, the experiment is beautifully described by existing theory," says Stephen Eckel, an atomic physicist at the National Institute of Standards and Technology (NIST) and the lead author of the new paper. "But even more striking is how that theory connects with cosmology."

In several sets of experiments, Eckel and his colleagues rapidly expanded the size of a doughnut-shaped cloud of atoms, taking snapshots during the process. The growth happens so fast that the cloud is left humming, and a related hum may have appeared on cosmic scales during the rapid expansion of the early universe—an epoch that cosmologists refer to as the period of inflation.

The work brought together experts in atomic physics and gravity, and the authors say it is a testament to the versatility of the Bose-Einstein condensate (BEC)—an ultracold cloud of atoms that can be described as a single quantum object—as a platform for testing ideas from other areas of physics.

"Maybe this will one day inform future models of cosmology," Eckel says. "Or vice versa. Maybe there will be a model of cosmology that's difficult to solve but that you could simulate using a cold atomic gas."

It's not the first time that researchers have connected BECs and cosmology. Prior studies mimicked black holes and searched for analogs of the radiation predicted to pour forth from their shadowy boundaries. The new experiments focus instead on the BEC's response to a rapid expansion, a process that suggests several analogies to what may have happened during the period of inflation.

The first and most direct analogy involves the way that waves travel through an expanding medium. Such a situation doesn't arise often in physics, but it happened during inflation on a grand scale. During that expansion, space itself stretched any waves to much larger sizes and stole energy from them through a process known as Hubble friction.

In one set of experiments, researchers spotted analogous features in their cloud of atoms. They imprinted a sound wave onto their cloud—alternating regions of more atoms and fewer atoms around the ring, like a wave in the early universe—and watched it disperse during expansion. Unsurprisingly, the sound wave stretched out, but its amplitude also decreased. The math revealed that this damping looked just like Hubble friction, and the behavior was captured well by calculations and numerical simulations.

"It's like we're hitting the BEC with a hammer," says Gretchen Campbell, the NIST co-director of the Joint Quantum Institute (JQI) and a coauthor of the paper, "and it's sort of shocking to me that these simulations so nicely replicate what's going on."

In a second set of experiments, the team uncovered another, more speculative analogy. For these tests they left the BEC free of any sound waves but provoked the same expansion, watching the BEC slosh back and forth until it relaxed.

In a way, that relaxation also resembled inflation. Some of the energy that drove the expansion of the universe ultimately ended up creating all of the matter and light around us. And although there are many theories for how this happened, cosmologists aren't exactly sure how that leftover energy got converted into all the stuff we see today.

In the BEC, the energy of the expansion was quickly transferred to things like sound waves traveling around the ring. Some early guesses for why this was happening looked promising, but they fell short of predicting the energy transfer accurately. So the team turned to numerical simulations that could capture a more complete picture of the physics.

What emerged was a complicated account of the energy conversion: After the expansion stopped, atoms at the outer edge of the ring hit their new, expanded boundary and got reflected back toward the center of the cloud. There, they interfered with atoms still traveling outward, creating a zone in the middle where almost no atoms could live. Atoms on either side of this inhospitable area had mismatched quantum properties, like two neighboring clocks that are out of sync.

The situation was highly unstable and eventually collapsed, leading to the creation of vortices throughout the cloud. These vortices, or little quantum whirlpools, would break apart and generate sound waves that ran around the ring, like the particles and radiation left over after inflation. Some vortices even escaped from the edge of the BEC, creating an imbalance that left the cloud rotating.

Unlike the analogy to Hubble friction, the complicated story of how sloshing atoms can create dozens of quantum whirlpools may bear no resemblance to what goes on during and after inflation. But Ted Jacobson, a coauthor of the new paper and a physics professor at the University of Maryland specializing in black holes, says that his interaction with atomic physicists yielded benefits outside these technical results.

"What I learned from them, and from thinking so much about an experiment like that, are new ways to think about the cosmology problem," Jacobson says. "And they learned to think about aspects of the BEC that they would never have thought about before. Whether those are useful or important remains to be seen, but it was certainly stimulating."

Eckel echoes the same thought. "Ted got me to think about the processes in BECs differently," he says, "and any time you approach a problem and you can see it from a different perspective, it gives you a better chance of actually solving that problem."

Future experiments may study the complicated transfer of energy during expansion more closely, or even search for further cosmological analogies. "The nice thing is that from these results, we now know how to design experiments in the future to target the different effects that we hope to see," Campbell says. "And as theorists come up with models, it does give us a testbed where we could actually study those models and see what happens." [9]

## Gravitational waves created by black holes in the centre of most galaxies

Gravitational waves may be produced in the heart of the galaxy, says a new study led by Ph.D. student Joseph Fernandez at Liverpool John Moores University. He sets out the work in a presentation on 3rd April at the European Week of Astronomy and Space Science in Liverpool.

Gravitational waves are small ripples in space-time that spread throughout the universe. When there is a change in air pressure on Earth, this change moves outwards in the form of sound waves. Analogously, when pairs of compact objects like black holes or neutron stars form binaries and rotate around one another, the gravitational field around them changes, producing gravity waves that also move outwards.

This phenomenon was predicted by Albert Einstein in 1915. The amplitude of these ripples was predicted to be so small that Einstein thought they would never be detected. However in 2015, a century after making the prediction, gravity waves were observed directly for the first time

These originated from a pair of stellar mass black holes (around 30 times the mass of the sun each), which fell together, and eventually merged.

Since then, another four confirmed observations of gravity waves have been reported to originate from these systems, and with the LIGO and VIRGO improvements currently underway, we expect to see many more in the near future.

These observations show that black hole mergers are commonplace in the universe. However, researchers are still not sure how these sort of binary systems form. This is because they need to be on very close or very eccentric orbits in order to collapse in such a way that gravity waves are observable.

Fernandez and colleagues, including another Ph.D. student Brown, have shown that the orbits of binaries can be changed by the black hole that lies in the centre of most galaxies, including our own.

A massive black hole results in very intense gravitational fields and extreme physics. If a compact binary were to have a close encounter with one, then in most cases it would be disrupted and its component black holes or stars would be separated.

However, this isn't always the case.

Binaries can emerge from the tidal encounter undisrupted under certain conditions, with their orbits suffering severe modifications. By using Monte Carlo simulations, Fernandez has shown that surviving black hole binary systems can become tight and eccentric, reducing the merger time by over a factor of 100 in 10 percent of cases.

This could be sufficient to force binaries that wouldn't merge within the lifetime of the universe to do so sooner, leading to observable gravitational waves.

This process can also flip the binary system orbital plane, making the black holes orbit in the opposite direction to their initial conditions. This can lead to negative effective spin values, which could be used to distinguish this mechanism from others. [8]

## Gravitational waves may oscillate, just like neutrinos

Using data from the first-ever gravitational waves detected last year, along with a theoretical analysis, physicists have shown that gravitational waves may oscillate between two different forms called "g" and "f"-type gravitational waves. The physicists explain that this phenomenon is analogous to the way that neutrinos oscillate between three distinct flavors—electron, muon, and tau. The oscillating gravitational waves arise in a modified theory of gravity called bimetric gravity, or "bigravity," and the physicists show that the oscillations may be detectable in future experiments.

The researchers, Kevin Max, a PhD student at Scuola Normale Superiore di Pisa and INFN Pisa, Italy; Moritz Platscher, a PhD student at the Max Planck Institute for Nuclear Physics, Germany; and Juri Smirnov, a postdoc at the University of Florence, Italy, have published a paper on their analysis of gravitational wave oscillations in a recent issue of Physical Review Letters.

As the physicists explain, the work may help answer the question of what "the other 95%" of the universe is made of, by suggesting that the answer may lie in modifications to gravity rather than new particles.

"Only 5% of matter is of a type we think to understand properly," Smirnov told Phys.org. "To address the question of what our universe is made of ('dark matter' and 'dark energy'), most authors discuss alternative particle physics models with new particles. However, experiments such as the ones at the LHC [Large Hadron Collider] haven't detected any exotic particles, yet. This raises the question if maybe the gravitational side needs to be modified.

"In our work, we ask what signals we could expect from a modification of gravity, and it turns out that bigravity features a unique such signal and can therefore be discriminated from other theories. The recent detection of gravitational waves by LIGO [Laser Interferometer Gravitational-Wave Observatory] has opened a new window on the dark sectors of the universe for us. Whether Nature has chosen general relativity, bigravity, or any other theory is a different question in the end. We can only study possible signals for experimentalists to look for."

## *Two gravitons instead of one*

Currently, the best theory of gravity is Einstein's theory of general relativity, which uses a single metric to describe spacetime. As a result, gravitational interactions are mediated by a single hypothetical particle called a graviton, which is massless and so travels at the speed of light.

The main difference between general relativity and bigravity is that bigravity uses two metrics, g and f. Whereas g is a physical metric and couples to matter, f is a sterile metric and does not couple to matter. In bigravity, gravitational interactions are mediated by two gravitons, one of which has mass and the other of which is massless. The two gravitons are composed of different combinations (or superpositions) of the g and f metrics, and so they couple to the surrounding matter in different ways. The existence of two metrics (and two gravitons) in the bigravity framework eventually leads to the oscillation phenomenon.

As the physicists explain, the idea that there might exist a graviton with mass has been around since almost as long general relativity itself.

"Einstein's theory of general relativity predicts one mediator (the 'graviton') of the gravitational interactions, which travels at the speed of light, i.e., which is massless," Max said. "Back in the late 1930s, people were already trying to find a theory containing a mediator that has a mass, and thus travels at a speed less than the speed of light. This turned out to be a very difficult task and was only recently accomplished in 2010. Bigravity is a variation of this 2010 framework, which features not one, but two dynamical metrics. Only one of them couples to matter while the other doesn't; and a linear combination of them becomes massive (slower than the speed of light) while the other is massless (speed of light)."

## *Oscillations*

The physicists show that, in the framework of bigravity, as gravitational waves are produced and propagate through space, they oscillate between the g- and f-types—though only the g-type can be detected. Although previous research has suggested that these oscillations might exist, it appeared to lead to unphysical results, such as a violation of energy conservation. The new study shows that the oscillations can theoretically emerge in a realistic physical scenario when considering graviton masses that are large enough to be detected by current astrophysical tests.

In order to understand these oscillations, the scientists explain that in many ways they resemble neutrino oscillations. Although neutrinos come in three flavors (electron, muon, and tau), typically the neutrinos produces in nuclear reactions are electron neutrinos (or electron anti-neutrinos) because the others are too heavy to form stable matter. In a similar way, in bigravity only the g metric couples to matter, so the gravitational waves produced by astrophysical events, such as black hole mergers, are g-type since f-type gravitational waves do not couple to matter.

"The key to understanding the oscillation phenomenon is that electron neutrinos do not have a definite mass: they are a superposition of the three neutrino mass eigenstates," Platscher explained. "More mathematically speaking, the mass matrix is not diagonal in the flavor (electron-muon-tau) basis. Therefore, the wave equation that describes how they move through space will mix them up and therefore they 'oscillate.'

"The same is true in bigravity: g is a mixture of the massive and the massless graviton, and therefore as the gravitational wave travels through the Universe, it will oscillate between g- and f-type gravitational waves. However, we can only measure the former with our detectors (which are made of matter), while the latter would pass through us unseen! This would, if bigravity is a correct description of Nature, leave an important imprint in the gravitational wave signal, as we have shown."

As the physicists note, the similarity between neutrinos and gravitational waves holds even though neutrino oscillation is a quantum mechanical phenomenon that is described by the Schrödinger wave equation, whereas gravitational wave oscillation is not a quantum effect and instead is described by a classical wave equation.

One particular effect that the physicists predict is that gravitational wave oscillations lead to larger strain modulations compared to those predicted by general relativity. These results suggest a path toward experimentally detecting gravitational wave oscillations and finding support for bigravity.

"Since bigravity is a very young theory, there is still a lot to be done, and its potential to address our theories' shortcomings needs to be explored," Smirnov said. "There has been some work along these lines, but certainly a lot is yet to be done and we hope to contribute in the future as well!" [7]

## Quest to settle riddle over Einstein's theory may soon be over

Astronomy experiments could soon test an idea developed by Albert Einstein almost exactly a century ago, scientists say.

Tests using advanced technology could resolve a longstanding puzzle over what is driving the accelerated expansion of the Universe.

Researchers have long sought to determine how the Universe's accelerated expansion is being driven. Calculations in a new study could help to explain whether dark energy- as required by Einstein's theory of general relativity - or a revised theory of gravity are responsible.

Einstein's theory, which describes gravity as distortions of space and time, included a mathematical element known as a Cosmological Constant. Einstein originally introduced it to explain a static universe, but discarded his mathematical factor as a blunder after it was discovered that our Universe is expanding.

Research carried out two decades ago, however, showed that this expansion is accelerating, which suggests that Einstein's Constant may still have a part to play in accounting for dark energy. Without dark energy, the acceleration implies a failure of Einstein's theory of gravity across the largest distances in our Universe.

Scientists from the University of Edinburgh have discovered that the puzzle could be resolved by determining the speed of gravity in the cosmos from a study of gravitational waves -space-time ripples propagating through the universe.

The researchers' calculations show that if gravitational waves are found to travel at the speed of light, this would rule out alternative gravity theories, with no dark energy, in support of Einstein's Cosmological Constant. If however, their speed differs from that of light, then Einstein's theory must be revised.

Such an experiment could be carried out by the Laser Interferometer Gravitational-Wave Observatory (LIGO) in the US, whose twin detectors, 2000 miles apart, directly detected gravitational waves for the first time in 2015.

Experiments at the facilities planned for this year could resolve the question in time for the 100th anniversary of Einstein's Constant.

The study, published in Physics Letters B, was supported by the UK Science Technology Facilities Council, the Swiss National Science Foundation, and the Portuguese Foundation of Science and Technology.

Dr Lucas Lombriser, of the University of Edinburgh's School of Physics and Astronomy, said: "Recent direct gravitational wave detection has opened up a new observational window to our Universe. Our results give an impression of how this will guide us in solving one of the most fundamental problems in physics." [6]

## NEW THEORY OF GRAVITY DOES AWAY WITH NEED FOR DARK MATTER

Let's be honest. Dark matter's a pain in the butt. Astronomers have gone to great lengths to explain why is must exist and exist in huge quantities, yet it remains hidden. Unknown. Emitting no visible energy yet apparently strong enough to keep galaxies in clusters from busting free like wild horses, it's everywhere in vast quantities. What is the stuff – axions, WIMPS, gravitinos, Kaluza Klein particles?

It's estimated that 27% of all the matter in the universe is invisible, while everything from PB&J sandwiches to quasars accounts for just 4.9%. But a new theory of gravity proposed by theoretical physicist Erik Verlinde of the University of Amsterdam found out a way to dispense with the pesky stuff.

Unlike the traditional view of gravity as a fundamental force of nature, Verlinde sees it as an emergent property of space. Emergence is a process where nature builds something large using small, simple pieces such that the final creation exhibits properties that the smaller bits don't. Take a snowflake. The complex symmetry of a snowflake begins when a water droplet freezes onto a tiny dust particle. As the growing flake falls, water vapor freezes onto this original crystal, naturally arranging itself into a hexagonal (six-sided) structure of great beauty. The sensation of temperature is another emergent phenomenon, arising from the motion of molecules and atoms.

So too with gravity, which according to Verlinde, emerges from entropy. We all know about entropy and messy bedrooms, but it's a bit more subtle than that. Entropy is a measure of disorder in a system or put another way, the number of different microscopic states a system can be in. One of the coolest descriptions of entropy I've heard has to do with the heat our bodies radiate. As that energy dissipates in the air, it creates a more disordered state around us while at the same time decreasing our own personal entropy to ensure our survival. If we didn't get rid of body heat, we would eventually become disorganized (overheat!) and die.

The more massive the object, the more it distorts space-time, shown here as the green mesh. Earth orbits the Sun by rolling around the dip created by the Sun's mass in the fabric of space-time. It doesn't fall into the Sun because it also possesses forward momentum. Credit: LIGO/T. Pyle

Emergent or entropic gravity, as the new theory is called, predicts the exact same deviation in the rotation rates of stars in galaxies currently attributed to dark matter. Gravity emerges in Verlinde's view from changes in fundamental bits of information stored in the structure of space-time, that four-dimensional continuum revealed by Einstein's general theory of relativity. In a word, gravity is a consequence of entropy and not a fundamental force.

Space-time, comprised of the three familiar dimensions in addition to time, is flexible. Mass warps the 4-D fabric into hills and valleys that direct the motion of smaller objects nearby. The Sun doesn't so much "pull" on the Earth as envisaged by Isaac Newton but creates a great pucker in space-time that Earth rolls around in.

In a 2010 article, Verlinde showed how Newton's law of gravity, which describes everything from how apples fall from trees to little galaxies orbiting big galaxies, derives from these underlying microscopic building blocks.

His latest paper, titled Emergent Gravity and the Dark Universe, delves into dark energy's contribution to the mix.  The entropy associated with dark energy, a still-unknown form of energy responsible for the accelerating expansion of the universe, turns the geometry of spacetime into an elastic medium.

"We find that the elastic response of this 'dark energy' medium takes the form of an extra 'dark' gravitational force that appears to be due to 'dark matter'," writes Verlinde. "So the observed dark matter phenomena is a remnant, a memory effect, of the emergence of spacetime together with the ordinary matter in it."

Rotation curve of the typical spiral galaxy M 33 (yellow and blue points with errorbars) and the predicted one from distribution of the visible matter (white line). The discrepancy between the two curves is accounted for by adding a dark matter halo surrounding the galaxy. Credit: Public domain / Wikipedia

This diagram shows rotation curves of stars in M33, a typical spiral galaxy. The vertical scale is speed and the horizontal is distance from the galaxy's nucleus. Normally, we expect stars to slow down the farther they are from galactic center (bottom curve), but in fact they revolve much faster (top curve). The discrepancy between the two curves is accounted for by adding a dark matter halo surrounding the galaxy.

I'll be the first one to say how complex Verlinde's concept is, wrapped in arcane entanglement entropy, tensor fields and the holographic principal, but the basic idea, that gravity is not a fundamental force, makes for a fascinating new way to look at an old face.

Physicists have tried for decades to reconcile gravity with quantum physics with little success. And while Verlinde's theory should be rightly be taken with a grain of salt, he may offer a way to combine the two disciplines into a single narrative that describes how everything from falling apples to black holes are connected in one coherent theory. [5]

## Identification of a Gravitational Arrow of Time

The proposal by the trio though phrased in a way as to suggest it's a solution to the arrow of time problem, is not likely to be addressed as such by the physics community—it's more likely to be considered as yet another theory that works mathematically, yet still can't answer the basic question of what is time.

For all the advances made in understanding the world around us, there are still two very basic fundamental concepts that have defied explanation: time and gravity. Though we have progressed greatly in measuring both and using both to understand other concepts, we still today are no closer to understanding either than we were when we first conceptualized them. Such an acknowledgment suggests that we likely have a major flaw in our understanding of the universe. In considering  such a possibility, the three physicists with this new effort suggest we might look at time in a completely new way—by dividing a dynamically closed universe (ala the Newtonian N-body problem) into two halves with shape complexity growing from a single point—each solution to the problem can then be considered as having one past but two distinctly futures. In such a scenario, an observer would of necessity have to exist on one side or the other, and thus would only ever have that perspective. Critical to this idea is that the all of the energy and angular momentum in such a system would have to be zero.

In essence, the team has removed time from mathematical functions that describe the energy of the universe—that's what allows for splitting the equations that have been created to describe the evolution of the universe into two parts, with both having initial low complexity moving to higher complexity (similar in some respects to theories of time based on entropy).

The proposal by the trio though phrased in a way as to suggest it's a solution to the arrow of time problem, is not likely to be addressed as such by the physics community—it's more likely to be considered as yet another theory that works mathematically, yet still can't answer the basic question of what is time. [4]

## Asymmetry in the interference occurrences of oscillators

The asymmetrical configurations are stable objects of the real physical world, because they cannot annihilate. One of the most obvious asymmetry is the proton – electron mass rate $M_p = 1840\ M_e$ while they have equal charge. We explain this fact by the strong interaction of the proton, but how remember it his strong interaction ability for example in the H – atom where are only electromagnetic interactions among proton and electron.

This gives us the idea to origin the mass of proton from the electromagnetic interactions by the way interference occurrences of oscillators. The uncertainty relation of Heisenberg makes sure that the particles are oscillating.

The resultant intensity due to n equally spaced oscillators, all of equal amplitude but different from one another in phase, either because they are driven differently in phase or because we are looking at them an angle such that there is a difference in time delay:

(1) $I = I_0 \sin^2 n\,\varphi/2 \,/\, \sin^2 \varphi/2$

If $\varphi$ is infinitesimal so that $\sin\varphi = \varphi$ than

(2) $\iota = n^2 \iota_0$

This gives us the idea of

(3) $M_p = n^2 M_e$

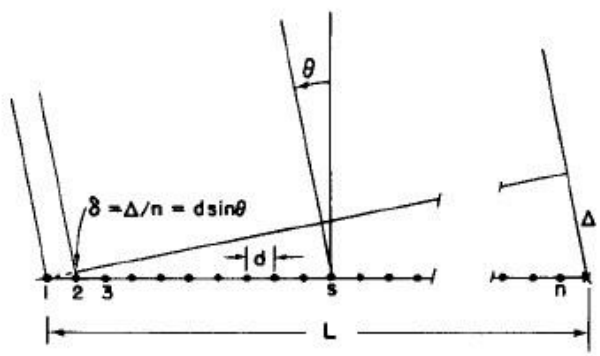



**Fig. 30–3.** A linear array of *n* equal oscillators, driven with phases $\alpha_s = s\alpha$.

Figure 1.) A linear array of n equal oscillators

There is an important feature about formula (1) which is that if the angle $\varphi$ is increased by the multiple of $2\pi$ it makes no difference to the formula.

So

(4) $d \sin \theta = m \lambda$ and we get m-order beam if $\lambda$ less than d. [6]

If d less than $\lambda$ we get only zero-order one centered at $\theta = 0$. Of course, there is also a beam in the opposite direction. The right chooses of d and $\lambda$ we can ensure the conservation of charge.

For example

(5) 2 (m+1) = n

Where 2(m+1) = $N_p$ number of protons and n = $N_e$ number of electrons.

In this way we can see the $H_2$ molecules so that 2n electrons of n radiate to 4(m+1) protons, because $d_e > \lambda_e$ for electrons, while the two protons of one $H_2$ molecule radiate to two electrons of them, because of $d_e < \lambda_e$ for this two protons.

To support this idea we can turn to the Planck distribution law, that is equal with the Bose – Einstein statistics.

## Spontaneously broken symmetry in the Planck distribution law

The Planck distribution law is temperature dependent and it should be true locally and globally. I think that Einstein's energy-matter equivalence means some kind of existence of electromagnetic oscillations enabled by the temperature, creating the different matter formulas, atoms molecules, crystals, dark matter and energy.

Max Planck found for the black body radiation

As a function of wavelength ($\lambda$), Planck's law is written as:

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}.$$

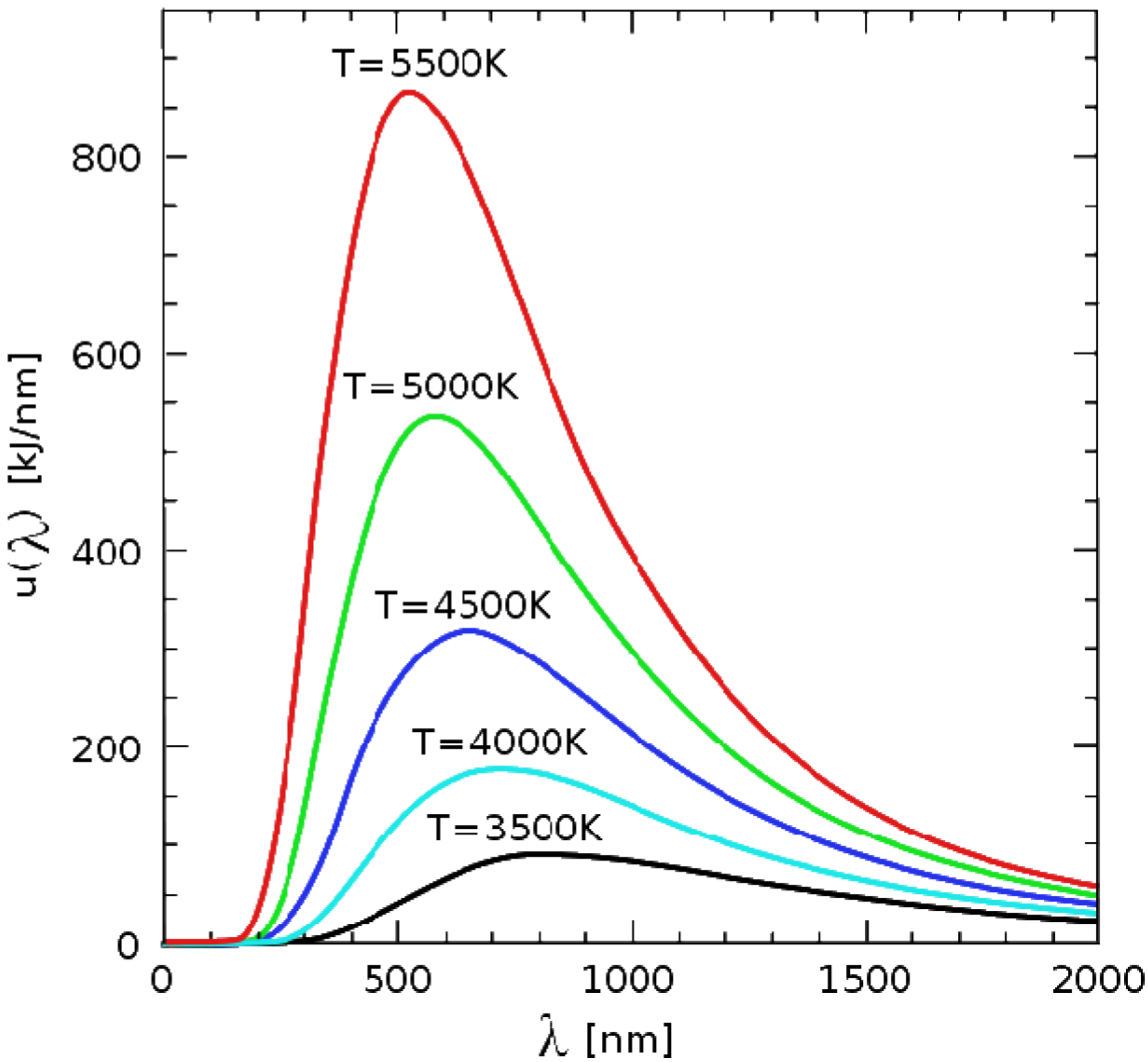



Figure 2. The distribution law for different T temperatures

We see there are two different $\lambda_1$ and $\lambda_2$ for each T and intensity, so we can find between them a d so that $\lambda_1 < d < \lambda_2$.

We have many possibilities for such asymmetrical reflections, so we have many stable oscillator configurations for any T temperature with equal exchange of intensity by radiation. All of these configurations can exist together. At the $\lambda_{max}$ is the annihilation point where the configurations are symmetrical. The $\lambda_{max}$ is changing by the Wien's displacement law in many textbooks.

(7) $$\lambda_{\max} = \frac{b}{T}$$

where $\lambda_{max}$ is the peak wavelength, *T* is the absolute temperature of the black body, and *b* is a constant of proportionality called *Wien's displacement constant*, equal to $2.8977685(51) \times 10^{-3}$ m·K (2002 CODATA recommended value).

By the changing of T the asymmetrical configurations are changing too.

## The structure of the proton

We must move to the higher T temperature if we want look into the nucleus or nucleon arrive to $d<10^{-13}$ cm. If an electron with $\lambda_e < d$ move across the proton then by (5) 2 (m+1) = n with m = 0 we get n = 2 so we need two particles with negative and two particles with positive charges. If the proton can fraction to three parts, two with positive and one with negative charges, then the reflection of oscillators are right. Because this very strange reflection where one part of the proton with the electron together on the same side of the reflection, the all parts of the proton must be quasi lepton so $d > \lambda_q$. One way dividing the proton to three parts is, dividing his oscillation by the three direction of the space. We can order 1/3 e charge to each coordinates and 2/3 e charge to one plane oscillation, because the charge is scalar. In this way the proton has two +2/3 e plane oscillation and one linear oscillation with -1/3 e charge. The colors of quarks are coming from the three directions of coordinates and the proton is colorless. The flavors of quarks are the possible oscillations differently by energy and if they are plane or linear oscillations. We know there is no possible reflecting two oscillations to each other which are completely orthogonal, so the quarks never can be free, however there is an asymptotic freedom while their energy are increasing to turn them to the orthogonally. If they will be completely orthogonal then they lose this reflection and take new partners from the vacuum. Keeping the symmetry of the vacuum the new oscillations are keeping all the conservation laws, like charge, number of baryons and leptons. The all features of gluons are coming from this model. The mathematics of reflecting oscillators show Fermi statistics.

Important to mention that in the Deuteron there are 3 quarks of +2/3 and -1/3 charge, that is three u and d quarks making the complete symmetry and because this its high stability.

The Pauli Exclusion Principle says that the diffraction points are exclusive!

## The Weak Interaction

The weak interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and time reversal symmetry.

Another important issue of the quark model is when one quark changes its flavor such that a linear oscillation transforms into plane oscillation or vice versa, changing the charge value with 1 or -1. This kind of change in the oscillation mode requires not only parity change, but also charge and time changes (CPT symmetry) resulting a right handed anti-neutrino or a left handed neutrino.

The right handed anti-neutrino and the left handed neutrino exist only because changing back the quark flavor could happen only in reverse order, because they are different geometrical constructions, the u is 2 dimensional and positively charged and the d is 1 dimensional and negatively charged. It needs also a time reversal, because anti particle (anti neutrino) is involved.

The neutrino is a 1/2spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with ½ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and
makes possible a different time dilation as of the special relativity.

The limit of the velocity of particles as the speed of light appropriate only for electrical charged particles, since the accelerated charges are self maintaining locally the accelerating electric force. The neutrinos are CP symmetry breaking particles compensated by time in the CPT symmetry, that is the time coordinate not works as in the electromagnetic interactions, consequently the speed of neutrinos is not limited by the speed of light.

The weak interaction T-asymmetry is in conjunction with the T-asymmetry of the second law of thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes the
weak interaction, for example the Hydrogen fusion.

Probably because it is a spin creating movement changing linear oscillation to 2 dimensional oscillation by changing d to u quark and creating anti neutrino going back in time relative to the proton and electron created from the neutron, it seems that the anti neutrino fastest then the velocity of the photons created also in this weak interaction?

A quark flavor changing shows that it is a reflection changes movement and the CP- and T-symmetry breaking. This flavor changing oscillation could prove that it could be also on higher level such as atoms, molecules, probably big biological significant molecules and responsible on the aging of the life.

Important to mention that the weak interaction is always contains particles and antiparticles, where the neutrinos (antineutrinos) present the opposite side. It means by Feynman's interpretation that these particles present the backward time and probably because this they seem to move faster than the speed of light in the reference frame of the other side.

Finally since the weak interaction is an electric dipole change with ½ spin creating; it is limited by the velocity of the electromagnetic wave, so the neutrino's velocity cannot exceed the velocity of light.

## The General Weak Interaction

The Weak Interactions T-asymmetry is in conjunction with the T-asymmetry of the Second Law of Thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes for example the Hydrogen fusion. The arrow of time by the Second Law of Thermodynamics shows the increasing entropy and decreasing information by the Weak Interaction, changing the temperature dependent diffraction patterns. A good example of this is the neutron decay, creating more particles with less known information about them.
The neutrino oscillation of the Weak Interaction shows that it is a general electric dipole change and it is possible to any other temperature dependent entropy and information changing diffraction pattern of atoms, molecules and even complicated biological living structures.

We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too. This gives the limited lifetime for the biological constructions also by the arrow of time. There should be a new research space of the Quantum Information Science the 'general neutrino oscillation' for the greater then subatomic matter structures as an electric dipole change.
There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also.
The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that is the matter formulas are emerging from the chaos. So the Weak Interaction has two directions, samples for one direction is the Neutron decay, and Hydrogen fusion is the opposite direction.

## Fermions and Bosons

The fermions are the diffraction patterns of the bosons such a way that they are both sides of the same thing.

The Higgs boson or Higgs particle is a proposed elementary particle in the Standard Model of particle physics. The Higgs boson's existence would have profound importance in particle physics because it would prove the existence of the hypothetical Higgs field - the simplest of several proposed explanations for the origin of the symmetry-breaking mechanism by which elementary particles gain mass. [3]

## The fermions' spin

The moving charges are accelerating, since only this way can self maintain the electric field causing their acceleration. The electric charge is not point like! This constant acceleration possible if there is a rotating movement changing the direction of the velocity. This way it can accelerate forever without increasing the absolute value of the velocity in the dimension of the time and not reaching the velocity of the light.

The Heisenberg uncertainty relation says that the minimum uncertainty is the value of the spin: 1/2 h = d x d p or 1/2 h = d t d E, that is the value of the basic energy status.

What are the consequences of this in the weak interaction and how possible that the neutrinos' velocity greater than the speed of light?

The neutrino is the one and only particle doesn't participate in the electromagnetic interactions so we cannot expect that the velocity of the electromagnetic wave will give it any kind of limit.

The neutrino is a 1/2spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with ½ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and makes possible a different time dilation as of the special relativity.

## The source of the Maxwell equations

The electrons are accelerating also in a static electric current because of the electric force, caused by the potential difference. The magnetic field is the result of this acceleration, as you can see in [2].

The mysterious property of the matter that the electric potential difference is self maintained by the accelerating electrons in the electric current gives a clear explanation to the basic sentence of the relativity that is the velocity of the light is the maximum velocity of the matter. If the charge could move faster than the electromagnetic field than this self maintaining electromagnetic property of the electric current would be failed.

Also an interesting question, how the changing magnetic field creates a negative electric field? The answer also the accelerating electrons will give. When the magnetic field is increasing in time by increasing the electric current, then the acceleration of the electrons will increase, decreasing the charge density and creating a negative electric force. Decreasing the magnetic field by decreasing the electric current will decrease the acceleration of the electrons in the electric current and increases the charge density, creating an electric force also working against the change. In this way we have explanation to all interactions between the electric and magnetic forces described in the Maxwell equations.

The second mystery of the matter is the mass. We have seen that the acceleration change of the electrons in the flowing current causing a negative electrostatic force. This is the cause of the relativistic effect - built-in in the Maxwell equations - that is the mass of the electron growing with its acceleration and its velocity never can reach the velocity of light, because of this growing negative electrostatic force. The velocity of light is depending only on 2 parameters: the magnetic permeability and the electric permittivity.

There is a possibility of the polarization effect created by electromagnetic forces creates the negative and positive charges. In case of equal mass as in the electron-positron pair it is simply, but on higher energies can be asymmetric as the electron-proton pair of neutron decay by week interaction and can be understood by the Feynman graphs.

Anyway the mass can be electromagnetic energy exceptionally and since the inertial and gravitational mass are equals, the gravitational force is electromagnetic force and since only the magnetic force is attractive between the same charges, is very important for understanding the gravitational force.

The Uncertainty Relations of Heisenberg gives the answer, since only this way can be sure that the particles are oscillating in some way by the electromagnetic field with constant energies in the atom indefinitely. Also not by chance that the uncertainty measure is equal to the fermions spin, which is one of the most important feature of the particles. There are no singularities, because the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on delta x position difference and with a delta p momentum difference such a way that they product is about the half Planck reduced constant. For the proton this delta x much less in the nucleon, than in the orbit of the electron in the atom, the delta p is much higher because of the greatest proton mass.

## The Special Relativity

The mysterious property of the matter that the electric potential difference is self maintained by the accelerating electrons in the electric current gives a clear explanation to the basic sentence of the relativity that is the velocity of the light is the maximum velocity of the matter. If the charge could move faster than the electromagnetic field than this self maintaining electromagnetic property of the electric current would be failed.

## The Heisenberg Uncertainty Principle

Moving faster needs stronger acceleration reducing the dx and raising the dp. It means also mass increasing since the negative effect of the magnetic induction, also a relativistic effect!

The Uncertainty Principle also explains the proton – electron mass rate since the dx is much less requiring bigger dp in the case of the proton, which is partly the result of a bigger mass $m_p$ because of the higher electromagnetic induction of the bigger frequency (impulse).

## The Gravitational force

The changing magnetic field of the changing current causes electromagnetic mass change by the negative electric field caused by the changing acceleration of the electric charge.

The gravitational attractive force is basically a magnetic force.

The same electric charges can attract one another by the magnetic force if they are moving parallel in the same direction. Since the electrically neutral matter is composed of negative and positive charges they need 2 photons to mediate this attractive force, one per charges. The Bing Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together.

You can think about photons as virtual electron – positron pairs, obtaining the necessary virtual mass for gravity.

The mass as seen before a result of the diffraction, for example the proton – electron mass rate $M_p = 1840\ M_e$. In order to move one of these diffraction maximum (electron or proton) we need to intervene into the diffraction pattern with a force appropriate to the intensity of this diffraction maximum, means its intensity or mass. [1]

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

## The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [3]

## What is the Spin?

So we know already that the new particle has spin zero or spin two and we could tell which one if we could detect the polarizations of the photons produced. Unfortunately this is difficult and neither ATLAS nor CMS are able to measure polarizations. The only direct and sure way to confirm that the particle is indeed a scalar is to plot the angular distribution of the photons in the rest frame of the centre of mass. A spin zero particles like the Higgs carries no directional information away from the original collision so the distribution will be even in all directions. This test will be possible when a much larger number of events have been observed. In the mean time we can settle for less certain indirect indicators.

## The Casimir effect

The Casimir effect is related to the Zero-point energy, which is fundamentally related to the Heisenberg uncertainty relation. The Heisenberg uncertainty relation says that the minimum uncertainty is the value of the spin: 1/2 h = dx dp or 1/2 h = dt dE, that is the value of the basic energy status.

The moving charges are accelerating, since only this way can self maintain the electric field causing their acceleration. The electric charge is not point like! This constant acceleration possible if there is a rotating movement changing the direction of the velocity. This way it can accelerate forever without increasing the absolute value of the velocity in the dimension of the time and not reaching the velocity of the light. In the atomic scale the Heisenberg uncertainty relation gives the same result, since the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on delta x position difference and with a delta p momentum difference such a way that they product is about the half Planck reduced constant. For the proton this delta x much less in the nucleon, than in the orbit of the electron in the atom, the delta p is much higher because of the greater proton mass. This means that the electron is not a point like particle, but has a real charge distribution.

Electric charge and electromagnetic waves are two sides of the same thing; the electric charge is the diffraction center of the electromagnetic waves, quantified by the Planck constant h.

## The Fine structure constant

The Planck constant was first described as the proportionality constant between the energy (*E*) of a photon and the frequency (*ν*) of its associated electromagnetic wave. This relation between the energy and frequency is called the **Planck relation** or the **Planck–Einstein equation**:

$$E = h\nu \,.$$

Since the frequency $\nu$, wavelength *λ*, and speed of light *c* are related by *λν* = *c*, the Planck relation can also be expressed as

$$E = \frac{hc}{\lambda}.$$

Since this is the source of Planck constant, the e electric charge countable from the Fine structure constant. This also related to the Heisenberg uncertainty relation, saying that the mass of the proton should be bigger than the electron mass because of the difference between their wavelengths.

The expression of the fine-structure constant becomes the abbreviated

$$\alpha = \frac{e^2}{\hbar c}$$

This is a dimensionless constant expression, 1/137 commonly appearing in physics literature.

This means that the electric charge is a result of the electromagnetic waves diffractions, consequently the proton – electron mass rate is the result of the equal intensity of the corresponding electromagnetic frequencies in the Planck distribution law, described in my diffraction theory.

## Conclusions

In essence, the team has removed time from mathematical functions that describe the energy of the universe—that's what allows for splitting the equations that have been created to describe the evolution of the universe into two parts, with both having initial low complexity moving to higher complexity (similar in some respects to theories of time based on entropy). [4]

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too. This gives the limited lifetime for the biological constructions also by the arrow of time. The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that is the matter formulas are emerging from the chaos. So the Weak Interaction has two directions, samples for one direction is the Neutron decay, and Hydrogen fusion is the opposite direction.

## References


[1] http://www.academia.edu/3834454/3_Dimensional_String_Theory

[2] http://www.academia.edu/3833335/The_Magnetic_field_of_the_Electric_current

[3] http://www.academia.edu/4158863/Higgs_Field_and_Quantum_Gravity

[4] http://phys.org/news/2014-11-physicists-identification-gravitational-arrow.html [5] NEW THEORY OF GRAVITY DOES AWAY WITH NEED FOR DARK MATTER

http://www.universetoday.com/131901/new-theory-of-gravity-does-away-with-need-for-darkmatter/

[6] Quest to settle riddle over Einstein's theory may soon be over

https://phys.org/news/2017-02-quest-riddle-einstein-theory.html

[7] Gravitational waves may oscillate, just like neutrinos

https://phys.org/news/2017-09-gravitational-oscillate-neutrinos.html

[8] Gravitational waves created by black holes in the centre of most galaxies

https://phys.org/news/2018-04-gravitational-black-holes-centre-galaxies.html

[9] Atoms may hum a tune from grand cosmic symphony

https://phys.org/news/2018-04-atoms-tune-grand-cosmic-symphony.html

[10] New Research May Reconcile General Relativity and Quantum Mechanics

https://futurism.com/new-research-may-reconcile-general-relativity-and-quantum-mechanics/

[11] Gravity is mathematically relatable to dynamics of subatomic particles

https://phys.org/news/2018-12-gravity-mathematically-dynamics-subatomic-particles.html

[12] Gravity surveys using a mobile atom interferometer

https://phys.org/news/2019-09-gravity-surveys-mobile-atom-interferometer.html