INTERNATIONAL YEAR OF LIGHT 2015

100 Million Stars in the Andromeda galaxy.

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Weekly news from around the world compiled by Dr. Ilias Fernini

Inside this issue:

Solving the gravitational N-body problem in general relativity

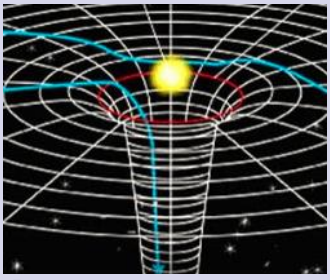
Recent experiments have successfully tested Einstein's general theory of relativity in a variety of ways and to remarkable precision. These experiments included spacecraft Doppler tracking, planetary radar ranging, lunar and satellite laser ranging, as well as a number of dedicated gravitational experiments in space and many ground based efforts. How can computational models keep up with the ever improving accuracy of these missions?

Finding a solution to the Einstein's gravitational field equations in the case of an unperturbed one-body problem is quite a simple task. A generalization of the resulting post-Newtonian solution to a system of N extended arbitrary bodies is not so straightforward.

The coupling of the intrinsic multipole moments or the angular momentum of an extended or spinning body to the gravitational field affects the body's equations of motion. The transformation of these quantities from one coordinate frame to another must take into account the nonlinearity of the the gravitational interaction.

Although the theory of relativity is independent of any coordinate representation, picking the right coordinate chart can greatly expedite calculations.

In our approach, we break down the N-body problem using a global inertial ...***Read More***...



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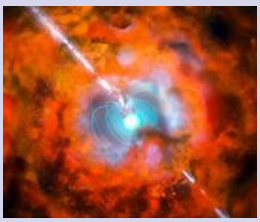
Biggest explosions in the universe powered by strongest magnets

Gamma-ray bursts are one of the outcomes associated with the biggest explosions to have taken place since the Big Bang. They are detected by orbiting telescopes that are sensitive to this type of high-energy radiation, which cannot penetrate the Earth's atmosphere, and then observed at longer wavelengths by other telescopes both in space and on the ground.

GRBs usually only last a few seconds, but in very rare cases the gamma rays continue for hours. One such ultra-long duration GRB was picked up by the [Swift satellite] - on 9 December 2011 and named GRB 111209A. It was both one of the longest and brightest GRBs ever observed.

As the afterglow from this burst faded it was studied using both the GROND instrument on the MPG/ESO 2.2-metre telescope at La Silla and also with the X-shooter instrument on the [Very Large Telescope] - (VLT) at Paranal. The clear signature of a supernova, later named SN 2011kl, was found. This is the first time that a supernova has been found to be associated with an ultra-long GRB.

The lead author of the new paper, Jochen Greiner from the Max-Planck-Institut fur extra-terrestrische Physik , Garching, Germany explains: "Since a long-duration gamma-ray burst is produced only once every 10 000-100 000 supernovae, the star that exploded must be somehow special….***Read More***...



This artist's impression shows a supernova and associated gamma-ray burst driven by a rapidly spinning neutron star with a very strong magnetic field - an exotic object known as a magnetar. ESO

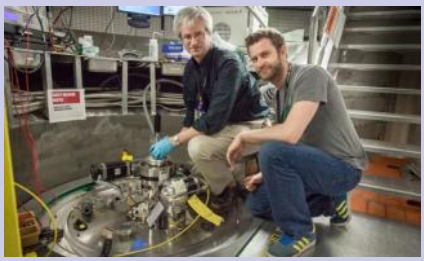
Neutrons find 'missing' magnetism of plutonium

Groundbreaking work at two Department of Energy national laboratories has confirmed plutonium's magnetism, which scientists have long theorized but have never been able to experimentally observe. The advances that enabled the discovery hold great promise for materials, energy and computing applications.

Plutonium was first produced in 1940 and its unstable nucleus allows it to undergo fission, making it useful for nuclear fuels as well as for nuclear weapons. Much less known, however, is that the electronic cloud surrounding the plutonium nucleus is equally unstable and makes plutonium the most electronically complex element in the periodic table, with intriguingly intricate properties for a simple elemental metal.

While conventional theories have successfully explained plutonium's complex structural properties, they also predict that plutonium should order magnetically. This is in stark contrast with experiments, which had found no evidence for magnetic order in plutonium.

Finally, after seven decades, this scientific mystery on plutonium's "missing" magnetism has been resolved. Using neutron scattering, researchers from the Department of Energy's Los Alamos and Oak Ridge (ORNL) national laboratories have made the first direct measurements of a unique characteristic of plutonium's fluctuating magnetism. In a recent paper in the journal Science Advances, Marc Janoschek from Los Alamos, the paper's lead scientist, explains that plutonium is not devoid of ...***Read More***...



Doug Abernathy, left, ARCS instrument scientist at Oak Ridge National Laboratory, and Marc Janoschek, Los Alamos National Laboratory, prepare their sample for experiments at the Spallation Neutron Source. Credit: Genevieve Martin/ORNL

Quantum physics provides startling insights into biological processes

Can something be for instance in two different places at the same time? According to quantum physics, it can. More precisely, in line with the principle of 'superposition', a particle can be described as being in two different states simultaneously.

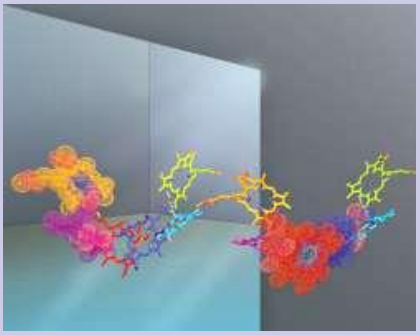
While it may sound like voodoo to the non-expert, superposition is based on solid science. Researchers in the PAPETS project are exploring this and other phenomena on the frontier between biology and quantum physics. Their goal is to determine the role of vibrational dynamics in photosynthesis and olfaction.

Quantum 'superposition' makes photosynthesis more efficient.

Quantum effects in a biological system, namely in a photosynthetic complex, were first observed by Greg Engel and collaborators in 2007, in the USA. These effects were reproduced in different laboratories at a temperature of around -193 degrees Celsius and subsequently at ambient temperature.

'What's surprising and exciting is that these quantum effects have been observed in biological complexes, which are large, wet and noisy systems,' says PAPETS project coordinator, Dr. Yasser Omar, researcher at Instituto de Telecomunicações and professor at Universidade de Lisboa. 'Superposition is fragile and we would expect it to be destroyed by the environment.'

Superposition contributes to more efficient energy transport. An exciton, a quantum ...***Read More***..



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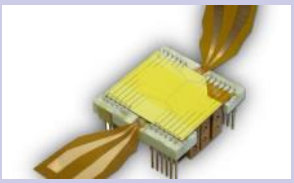
Good quantum states and bad quantum states

It is impossible to obtain all information about a large quantum system consisting of hundreds or thousands of particles. A new technique allows to describe such systems in terms of 'continuous matrix product states.' With this approximation, the relevant information about a quantum system can be obtained by only a few measurements.

For a long time, quantum experiments were only carried out with a small number of particles. Even the behaviour of single atoms or molecules can be very hard to describe.

Today, it has become possible to control several thousand atoms in an experiment, but for theoretical calculations this entails serious problems. The quantum state of such a large system is so complicated that all matter on earth would not be enough to store it in a classical way. In the journal Nature Communications, scientists from the TU Wien (Vienna) and the Free University of Berlin now present a quantum tomography method, which makes it possible to measure and describe the state of a large quantum system very precisely with just a few measurements. The basic idea behind this new technique is simple: even though the system can be in one of unimaginably many quantum states, it is a very good approximation to ignore most of them.

Many Particles, Many States
The result of a coin toss is either heads or tails. The behaviour of quantum particles, however, is much more complicated. When a quantum system can be in two different states, any mixture of these states is also a physically ...***Read More***...



The atom chip used to control the atoms. Credit: TU Wien

A black hole under the gravitational lens

Turbulent processes take place close to supermassive black holes, which lurk in the centres of nearly all galaxies. They swallow up matter flowing in from the outside while at the same time producing so-called gas jets which shoot out into space in two opposite directions.

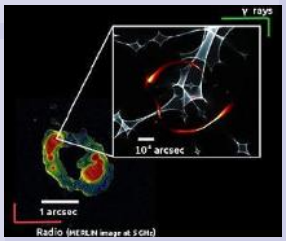
Researchers at the Max Planck Institute for Physics in Munich and the University of Geneva have now succeeded in localizing the origin of the high-energy gamma radiation in such a jet: it apparently originates very close to the black hole. This discovery was made possible by a micro-gravitational lens effect that occurs by chance and selectively amplifies the light from different regions close to the black hole like a magnifying glass.

Astronomers are aware of many active galaxies which emanate such jets from their centre. These gas jets can be seen in the radio region, and occasionally in visible light and in the X-ray and gamma radiation regions as well.

There is still a great deal of uncertainty about the mechanism of their formation. What is clear is that hot gas in the form of a disk orbits the central black hole. It is probable that strong magnetic fields, which accelerate the particles at right angles to the disk and into the jets, occur here as well.

This central machinery cannot, however, be observed directly from Earth due to the large distances involved. A stroke of luck helped Ievgen Vovk from the Max Planck Institute of Physics and his colleagues in Geneva here. The researchers looked at an active galaxy known as PKS 1830-211. This is a blazar - a rare case in which one of the two jets happens to be directed towards Earth so that the astronomers look directly into the jet along the longitudinal axis.

It so happens that there is a galaxy roughly half way between Earth and the blazar, which is billions of light years away. Its strong gravitation causes the space around it to ...***Read More***..



Looking at a distant galaxy: the radio chart (left) shows the image of the blazar PKS 1830-211 distorted by the gravitational lens effect. The detail on the right is a simulation of the micro-gravitational lens effect in the gamma ray region; direct observation of the orange ring - it also represents images of the blazar - is not possible due to its small size. Image courtesy Patnaik et al. 1994, Liege Conference on Gravitational Lenses and the Universe and Vovk.

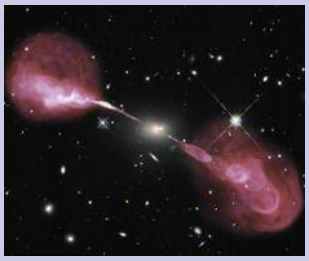
The dark side of galactic radio jets

Cosmic microwave radiation points to invisible 'dark matter', marking the spot where jets of material travel at near light speed, according to an international team of astronomers. Lead author Rupert Allison of Oxford University presented their results yesterday (6 July) at the National Astronomy Meeting in Venue Cymru, Llandudno, Wales.

Currently, no one knows for sure what dark matter is made of, but it accounts for about 26% of the energy content of the Universe, with massive galaxies forming in dense regions of dark matter. Although invisible, dark matter shows up through its gravitational effect - a big blob of dark matter pulls in normal matter (like electrons, protons and neutrons) through its own gravity, eventually packing together to create stars and entire galaxies.

Many of the largest of these are 'active' galaxies with supermassive black holes in their cores. Some of the gas falling towards the black holes is ejected out as jets of particles and radiation. Observations made with radio telescopes show that these jets often stretch for millions of light years from their host galaxy - far larger in extent than the galaxy itself.

Scientists therefore expected that the jets ...***Read More***...



Active galaxy, Hercules A, showing extensive radio jets. Image courtesy NRAO.

Astronomers teach a machine how to 'see'

A team of astronomers and computer scientists at the University of Hertfordshire have taught a machine to 'see' astronomical images. The technique, which uses a form of artificial intelligence called unsupervised machine learning, allows galaxies to be automatically classified at high speed, something previously done by thousands of human volunteers in projects like Galaxy Zoo.

Masters student Alex Hocking led the new work and presented it for the first time in a paper published July 8 at the National Astronomy Meeting at Venue Cymru, Llandudno, Wales.

The team have demonstrated their algorithm using data from the Hubble Space Telescope 'Frontier Fields': exquisite images of distant clusters of galaxies that contain several different types of galaxy.

Mr Hocking, who led the new work, commented: "The important thing about our algorithm is that we have not told the machine what to look for in the images, but instead taught it how to 'see'."

His supervisor and fellow team member Dr James Geach added: "A human looking at these images can intuitively pick out and instinctively classify different types of object without being given any additional information. We have taught a machine to do the same thing."

'Our aim is to deploy this tool on the next generation of giant imaging surveys where no human, or even group of humans, could closely inspect every piece of data. But this algorithm has a huge number of applications far beyond astronomy, and investigating these applications will be our next step," concludes Geach...***Read More***...

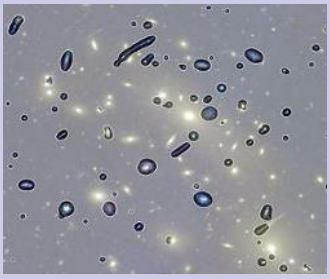


Image showing the MACS0416.1-2403 cluster, highlighting parts of the image that the algorithm has identified as 'star-forming' galaxies. Image courtesy NASA, ESA, J. Geach and A. Hocking.

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World record: Most powerful high-energy particle beam for a neutrino experiment ever generated

A key element in a particle-accelerator-based neutrino experiment is the power of the beam that gives birth to neutrinos: The more particles you can pack into that beam, the better your chance to see neutrinos interact in your detector. Today scientists announced that Fermilab has set a world record for the most powerful high-energy particle beam for neutrino experiments.

Scientists, engineers and technicians at the U.S. Department of Energy's Fermi National Accelerator Laboratory have achieved for high-energy neutrino experiments a world record: a sustained 521-kilowatt beam generated by the Main Injector particle accelerator. More than 1,000 physicists from around the world will use this high-intensity beam to more closely study neutrinos and fleeting particles called muons, both fundamental building blocks of our universe.

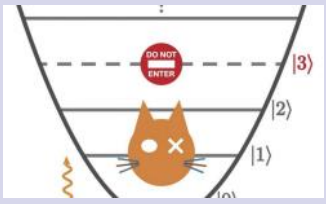
The record beam power surpasses that of the 400-plus-kilowatt beam sent to neutrino experiments from particle accelerators at CERN. Setting this world record is an initial step for the Fermilab accelerator complex as it will gradually increase beam power over the coming years. The next goal for the laboratory's two-mile-around Main Injector accelerator—the final and most powerful in ...***Read More***...

Fermilab's Main Injector accelerator, one of the most powerful particle accelerators in the world, has just achieved a world record for high-energy beams for neutrino experiments. Credit: Fermilab

Training Schrodinger's cat: Controlling the quantum properties of light

Constructing quantum computers and other quantum devices requires the ability to leverage quantum properties such as superposition and entanglement – but these effects are fragile and therefore hard to maintain. Recently, scientists at Ecole Normale Supérieure in Paris demonstrated a novel method for controlling the quantum properties of light by probing a superconducting circuit in a cavity with microwave photons to control the energy levels that photon quanta can occupy.

Specifically, the scientists prevented access to a single energy level corresponding to a number of photons N, and thereby confined the dynamics of the field to levels 0 to N -1. In so doing, the intracavity field changed from a classical wave to a Schrödinger cat of light – a superposition between two waves of opposite phases instead of a single one. As a result, this new technique could apply to the development of quantum computers by protecting qubits from decoherence as well as enhancing quantum error correction and quantum systems measurement….***Read More***...

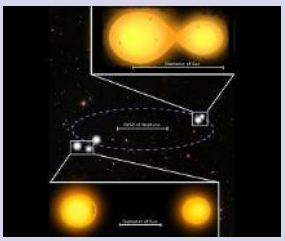


Zeno cat. A Zeno cat refers to non-classical states of light created by shining a cavity on resonance while it is forbidden to access a given energy level. The name originates from the Zeno effect, which can similarly prevent an energy level from being occupied by the sole fact of measuring its occupation frequently. The cat comes from the similarity of such a state with ...

A five star, doubly-eclipsing star system

Astronomers at the Open University have discovered the first quintuple star system containing two eclipsing binary stars. Details of the five star system, the first of its kind to be found, will be presented by Marcus Lohr of the Open University in a talk on Wednesday 8 July at the National Astronomy Meeting at Venue Cymru, Llandudno, Wales. Scientists think that about a third of stars are found in pairs or multiple systems. To find five stars connected to each other though is very rare.

The unusual star system was originally detected in archived data from the SuperWASP (Wide Angle Search for Planets) project, which uses relatively small and low-cost cameras in the Canary Islands and South Africa to image almost the whole sky every few minutes. Over many years, its measurements of the brightness of individual stars have been assembled into light curves - plots of brightness against time - for some 30 million sources in the Milky Way.…***Read More***...



An artist's impression of the five star system 1SWASP J093010.78+ 533859.5. The smaller orbits are not shown to scale relative to the larger orbit, as the binary components would be too close together to distinguish. The inset images are to scale, along with an image of the Sun for comparison. The blue dotted line marks the orbital path of the two pairs of stars. The fifth star, whose position is uncertain, is to the right of the left pair. Image courtesy Marcus Lohr.