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Inside this issue:

A quantum leap for the next generation of superconductors

Quantum materials – materials designed at the sub-atomic level – can be finely-tuned to achieve extremely useful properties that are often not found in nature. These include superconductivity, the ability to conduct electricity without resistance below a certain temperature.

An ambitious six-year EU-funded project, Q-MAC (Frontiers in Quantum Materials Control) was only launched in 2013, but has already achieved a number of potentially significant breakthroughs in this field. These findings could significantly advance European understanding of superconductivity and help to pioneer new industrial applications ranging from supercomputers to hover trains.

Superconductors at higher temperatures

For example, the team has shown that shining lasers at superconductors can make them work at higher temperatures. This is significant because superconductors currently only work at very low temperatures, which requires expensive liquid nitrogen or helium.

Superconductors are used in numerous high tech instruments such as medical scanners, super-fast electronic computer circuits and trains that use superconducting magnets to hover above the tracks, thus eliminating friction. The development of superconductors that work at higher temperatures – or even at room temperature – could help to cut costs by eliminating the need for cooling and lead to new applications.

Having focused on material made from potassium atoms and carbon atoms arranged in ball-like structures, the Q-MAC project ...Read More...

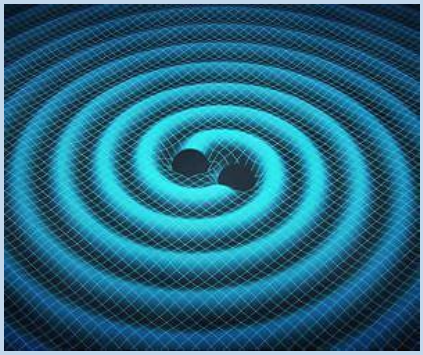
LIGO's twin black holes might have been born inside a single star

On September 14, 2015, the Laser Interferometer Gravitational-wave Observatory (LIGO) detected gravitational waves from the merger of two black holes 29 and 36 times the mass of the Sun. Such an event is expected to be dark, but the Fermi Space Telescope detected a gamma-ray burst just a fraction of a second after LIGO's signal. New research suggests that the two black holes might have resided inside a single, massive star whose death generated the gamma-ray burst.

"It's the cosmic equivalent of a pregnant woman carrying twins inside her belly," says Harvard astrophysicist Avi Loeb of the Harvard-Smithsonian Center for Astrophysics (CfA).

Normally, when a massive star reaches the end of its life, its core collapses into a single black hole. But if the star was spinning very rapidly, its core might stretch into a dumbbell shape and fragment into two clumps, each forming its own black hole.

A very massive star as needed here often forms out of the merger of two smaller ...Read More...



On Sept. 14, 2015, LIGO detected gravitational waves from two merging black holes, shown here in this artist's conception. The Fermi space telescope detected a burst of gamma rays 0.4 seconds later. New research suggests that the burst occurred because the two black holes lived and died inside a single, massive star. Image courtesy Swinburne Astronomy Productions.

Quantum phase transition underpins superconductivity in copper oxides

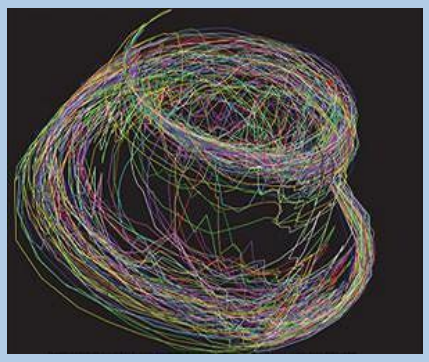
Physicists have zoomed in on the transition that could explain why copper-oxides have such impressive superconducting powers.

Settling a 20-year debate in the field, they found that a mysterious quantum phase transition associated with the termination of a regime called the "pseudogap" causes a sharp drop in the number of conducting electrons available to pair up for superconductivity. The team hypothesizes that whatever is happening at this point is probably the reason that cuprates support superconductivity at much higher temperatures than other materials - about half way to room temperature.

"It's very likely that the reason superconductivity grows in the first place, and the reason it grows so strongly, is because of that critical point," CIFAR Senior Fellow Louis Taillefer (Universite de Sherbrooke) says. The new findings are published in Nature.

Taillefer, the director of CIFAR's program in Quantum Materials, collaborated with his team and CIFAR Cyril Proust (Laboratoire National des Champs Magnetiques Intenses), Doug Bonn, Walter Hardy and Ruixing Liang (all three University of British Columbia). The study combined the University of British Columbia's expertise in making copper-oxide materials known as cuprates, the Universite de Sherbrooke's expertise at probing them, and the powerful magnetic fields produced at the Toulouse lab.

Their work is part of a global effort to harness superconductivity - the transmission of electricity with zero resistance in certain ...Read More...



File Image.

Researchers demonstrate 'quantum surrealism'

New research demonstrates that particles at the quantum level can in fact be seen as behaving something like billiard balls rolling along a table, and not merely as the probabilistic smears that the standard interpretation of quantum mechanics suggests. But there's a catch - the tracks the particles follow do not always behave as one would expect from "realistic" trajectories, but often in a fashion that has been termed "surrealistic."

In a new version of an old experiment, CIFAR Senior Fellow Aephraim Steinberg (University of Toronto) and colleagues tracked the trajectories of photons as the particles traced a path through one of two slits and onto a screen. But the researchers went further, and observed the "nonlocal" influence of another photon that the first photon had been entangled with.

The results counter a long-standing criticism of an interpretation of quantum mechanics called the De Broglie-Bohm theory. Detractors of this interpretation had faulted it for failing to explain the behaviour of entangled photons realistically. For Steinberg, the results are important because they give us a way of visualizing quantum mechanics that's just as valid as the standard interpretation, and perhaps more intuitive.

"I'm less interested in focusing on the philosophical question of what's 'really' out there. I think the fruitful question is more down to earth. Rather than thinking about different metaphysical interpretations, I would phrase it in ...Read More...

File Image.

A mathematical advance in describing waves

One of the great joys in mathematics is the ability to use it to describe phenomena seen in the physical world, says University at Buffalo mathematician Gino Biondini.

With UB postdoctoral researcher Dionyssios Mantzavinos, Biondini has published a new paper that advances the art—or shall we say, the math—of describing a wave. The findings, published Jan. 27 in Physical Review Letters, are thought to apply to wave forms ranging from light waves in optical fibers to water waves in the sea.

The study explores what happens when a regular wave pattern has small irregularities, a question that scientists have been trying to answer for the last 50 years.

Researchers have long known that in many cases such minor imperfections grow and eventually completely distort the original wave as it travels over long distances, a phenomenon known as "modulational instability." But the UB team has added to this story by showing, mathematically, that many different kinds of disturbances evolve to produce wave forms belonging to a single class, denoted by their identical asymptotic state.

"Ever since Isaac Newton used math to describe gravity, applied mathematicians have been inventing new mathematics or using ...Read More...

New development builds on centuries of research devoted to using math to describe the physical world

Imaging Technique May Help Discover Earth-Like Planets Around Other Stars

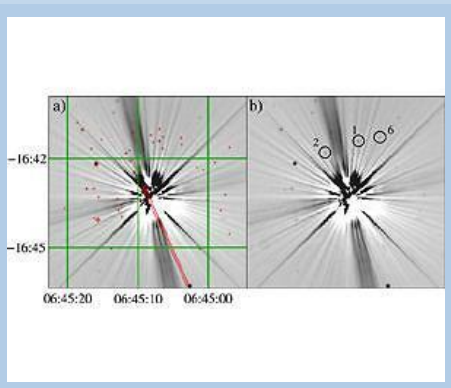
One of the biggest quests in astrophysics is to find Earth-like planets around other stars - places where life may exist. Regular telescopes are not good at directly imaging such small objects because a host star's light generally drowns out the relatively dimmer light of a potential planet. But a new development in space imaging may solve that vexing problem.

A study led by Florida Institute of Technology astrophysicist Daniel Batcheldor has demonstrated that a charge injection device, or CID, has the ability to capture light from objects tens of millions of times fainter than another object in the same picture.

An exoplanet next to bright star is one such example. This ability is a result of how the CID is used as a type of camera: each individual pixel works independently and uses a special indexing system. Very bright pixels get addressed very quickly, while the faint pixels are allowed to carry on gathering the fainter light.

"If this technology can be added to future space missions, it may help us make some profound discoveries regarding our place in the universe," Batcheldor said. The study's findings were reported in the Jan. 18, 2016, edition of the Publications of the Astronomical Society of the Pacific.

To study exoplanets in detail, scientists are forced to make observations of these very faint objects next to bright stars. The situation is often described as the ...Read More...



The CID device has the ability to detect dim objects even behind Sirius, the brightest star in our galaxy. The "a" image shows the Sirius field and the sky coordinates in green. Red dots represent already cataloged objects. The red line is the motion of Sirius. The "b" image shows faint objects detected near Sirius.

ATLASGAL survey of Milky Way completed

APEX, the Atacama Pathfinder EXperiment telescope, is located at 5100 metres above sea level on the Chajnantor Plateau in Chile's Atacama region. The ATLASGAL survey took advantage of the unique characteristics of the telescope to provide a detailed view of the distribution of cold dense gas along the plane of the Milky Way galaxy [1]. The new image includes most of the regions of star formation in the southern Milky Way [2].

The new ATLASGAL maps cover an area of sky 140 degrees long and 3 degrees wide, more than four times larger than the first ATLASGAL release [3]. The new maps are also of higher quality, as some areas were re-observed to obtain a more uniform data quality over the whole survey area.

The ATLASGAL survey is the single most successful APEX large programme with nearly 70 associated science papers already published, and its legacy will expand much further with all the reduced data products now available to the full astronomical community [4]. At the heart of APEX are its sensitive instruments. One of these, LABOCA (the LArge ...Read More...

This part image of the Milky Way has been released to mark the completion of the APEX Telescope Large Area Survey of the Galaxy (ATLASGAL). The APEX telescope in Chile has mapped the full area of the Galactic Plane visible from the southern hemisphere for the first time at submillimeter wavelengths -- between infrared light and radio waves -- and in finer detail than recent space-based surveys.

Discovered for the first time the "birthplace" of a fast radio burst

An international team of astronomers, including Marta Burgay, Delphine Perrodin and Andrea Possenti from the Italian National Institute for Astrophysics (INAF), identified for the first time the place of origin of a Fast Radio Burst (FRB), enigmatic radio signals lasting just a few milliseconds, which appear without warning in the sky. The discovery was made thanks to observations done with optical telescopes and radio telescopes and allowed to confirm the current cosmological model describing the distribution of matter in the universe.

It all starts on April 18th, 2015, when the typical signal of a FRB is detected by the Commonwealth Scientific and Industrial Research Organisation (CSIRO)'s 64-m Parkes radio telescope in Australia.

"In a matter of hours - says Evan Keane, Project Scientist at the Square Kilometre Array Organisation, first author of the paper describing the discovery, published in the latest issue of the journal Nature - it has been issued an international alert and various telescopes around the world were involved in the search for the 'result' of that signal".

The INAF's Sardinia Radio Telescope (SRT) was among them. "In April 2015, SRT was not in operation at 100% as it is today. Thanks to the great work of the INAF team for scientific validation of the radio telescope, SRT has, however, been able to attend promptly to the international campaign" explains Marta Burgay.

"The SRT observations, combined with those of other radio telescopes single disc ...Read More...

The INAF's Sardinia Radio Telescope (SRT). Image courtesy Gianni Alvito.

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Moons might hold key to finding E.T. life

When I was young, the only planets we knew about were the ones in our own solar system.

Astronomers presumed that many of the other stars in the night sky had planets too, but this was sheer speculation. We could never know for sure, the thinking went, because such planets were ridiculously small and faint. To ever see or study them seemed a complete impossibility. "Extrasolar planets," or "exoplanets," were a staple of science fiction, but not of professional astrophysics.

It's hard to believe that there was once such a simple time. The first definitive detection of an exoplanet was in 1991, identified by the tiny wobbles experienced by the parent star as its exoplanet swung around it. Since then, the field has exploded. There are now around 1,600 confirmed exoplanets, with almost 4,000 other known candidates. There are exoplanets smaller than Mercury, and others many times bigger than Jupiter. Their orbits around their parent stars range from a few hours to hundreds of years. And the ones we know about are just a tiny fraction of the approximately 100 billion exoplanets we now believe are spread throughout our Milky Way galaxy...Read More...

If you're looking for life, you'd do well to look for some moons. Image credit: Maxwell Hamilton/Flickr

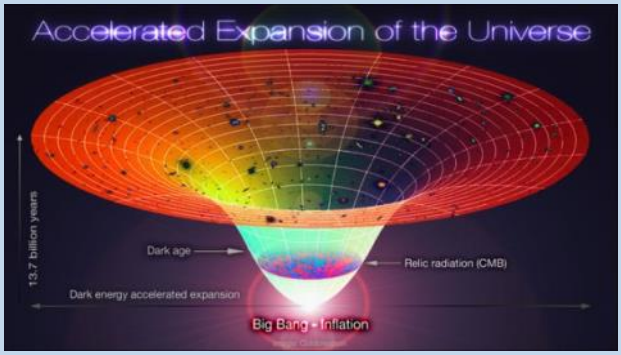
What is time? … And why does it move forward?

Imagine time running backwards. People would grow younger instead of older and, after a long life of gradual rejuvenation – unlearning everything they know – they would end as a twinkle in their parents' eyes. That's time as represented in a novel by science fiction writer Philip K Dick but, surprisingly, time's direction is also an issue that cosmologists are grappling with.

While we take for granted that time has a given direction, physicists don't: most natural laws are "time reversible" which means they would work just as well if time was defined as running backwards. So why does time always move forward? And will it always do so?

Does time have a beginning?

Any universal concept of time must ultimately be based on the evolution of the cosmos itself. When you look up at the ...Read More...



The universe's timeline. Image: Alex Mittelmann/wikimedia

Chemically storing solar power

Nature shows us how it is done: Plants can absorb sunlight and store its energy chemically. Imitating this on large industrial scale, however, is difficult. Photovoltaics convert sunlight to electricity, but at high temperatures, the efficiency of solar cells decreases. Electrical energy can be used to produce hydrogen, which can then be stored - but the energy efficiency of this process is limited.

Scientists at TU Wien (Vienna) have now developed a new concept: By combining highly specialised new materials, they have managed to combine high temperature photovoltaics with an electrochemical cell. Ultraviolet light can be directly used to pump oxygen ions through a solid oxide electrolyte. The energy of the UV light is stored chemically. In the future, this method could also be used to split water into hydrogen and oxygen.

Special Materials for High Temperatures

As a student at TU Wien, Georg Brunauer started pondering possible combinations of photovoltaics and electrochemical storage. The feasibility of such a system depends crucially on whether it is able to work at high temperatures. ...Read More...

This is a picture of a heated reactor (TU Wien). Image courtesy TU Wien.