Plumbing the Electron's Depths

Careful observation of a single electron in an atom trap over a period of several months has resulted in the best measurement yet of the electron's magnetic moment and an improved value for alpha, the fine structure constant, the parameter which sets the overall strength of the electromagnetic force.

The theory of quantum electrodynamics (QED) predicts that an electron is perpetually grappling with virtual particles emerging briefly from the surrounding vacuum. In the absence of these interactions, the magnetic moment of the electron (referred to by the letter $g$), which relates the size of the electron's magnetism to its intrinsic spin, would have a value of 2. But direct measurements of $g$ show that it is slightly different from 2. The finer these measurements become, the better one can probe the quantum nature of electrons and QED itself. Furthermore, if the electron had structure this too would show up in measurements of $g$.

To gain the greatest possible control over the electron and its environment, Gerald Gabrielse and his students Brian Odom and David Hanneke at Harvard University create a macroscopic artificial atom consisting of a single electron executing an endless looping trajectory with virtual particles emerging briefly from the surrounding vacuum.

It is this masterful control over the electron's motions and the ability to measure the energy levels of the electron's artificial quantum environment that allows the Harvard group to improve the measurement of $g$ by a factor of 6 over previous work. The new uncertainty in the value, set forth in an article in Physical Review Letters, is now at the level of 0.7 parts per trillion.

No less important than $g$ is alpha. By inserting the new value of $g$ into QED equations, and thanks to improved QED calculations of very high accuracy, the experimenters and theorists together determined a new value for alpha, one with an accuracy ten times better than available from any other method. This is the first time a more precise value of alpha has been reported since 1987. The new alpha, published in a companion article in Physical Review Letters, has an uncertainty of 0.7 parts per billion.

The measured value of $g$ can also be used to address the issue of hypothetical electron constituents. Such subcomponents, the new $g$ measurement shows, could be no lighter than 130 gigaelectronvols.


Dark Energy at Redshift Z=1

Dark energy, the unidentified force that's pushing the universe to expand at ever faster rates, was already at work as early as nine billion years ago, scientists reported in November. New Hubble Space Telescope sightings of distant supernova explosions support the explanation of dark energy as energy of the vacuum whose density has stayed constant throughout the universe's history, the scientists said.

Using the Hubble, a team led by Adam Riess, an astrophysicist at the Space Telescope Science Institute and at Johns Hopkins University has now observed 23 new supernovae dating back to 8 to 10 billion years ago. Until now, astronomers had only seen seven supernovae from that period, Riess said, too few to measure the properties of dark energy. The data show that the repulsive action of dark energy was already active at that time, and are consistent with a constant energy density—in other words, with an energy of the vacuum that does not dilute itself as the universe expands, eventually fueling an exponential growth of the universe.

More complicated models with non-constant energy density—including a class known as quintessence models—aren't completely ruled out, Riess said during the press conference: the new data still allows for variations of up to 45 percent from constant density. For more recent ages, dark energy is known to have been constant up to a 10 percent variation.

The new data also confirm the reliability of supernovae as signposts of the universe's expansion, Riess said.

First Direct Evidence of Turbulence in Space

Turbulence can be studied on Earth easily by mapping such things as the density or velocity of fluids in a tank. In space, however, where we expect turbulence to occur in such settings as solar wind, interstellar space, and the accretion disks around black holes, it's not so easy to measure fluids in time and space. Now, a suite of four plasma-watching satellites, referred to as Cluster, has provided the first definitive study of turbulence in space.

The fluid in question is the wind of particles streaming toward Earth from the sun, while the location in question is the region just upstream of Earth's bow shock, the place where the solar wind gets disturbed and passes by Earth's magnetosphere. The waves in the shock-upstream plasma, pushed around by complex magnetic fields, are observed to behave a lot like fluid turbulence on Earth.

One of the Cluster researchers, Yasuhiro Narita of the Institute of Geophysics and Extraterrestrial Physics in Braunschweig, Germany, says that the data is primarily in accord with the leading theory of solar wind turbulence, the so-called Kolmogorov's model. (Narita et al. Phys. Rev. Lett. 97, 191101, 2006)

A New Triumph for Inflation

The inflationary big bang model has passed a crucial test as scientists working on the Wilkinson Microwave Anisotropy Probe released a long-awaited second set of data at a press conference held March 17.

The earlier release of WMAP data 3 years ago nudged several grand features of the universe that had previously been known only very roughly, including: the time of recombination (380,000 years after the big bang, when the first atoms were formed); the age of the universe (13.7 billion years, plus or minus 200 million years); and the makeup of the universe (with dark energy accounting for 73 percent of all energy).

Since that 2003 announcement, WMAP researchers have painstakingly worked to reduce the uncertainties in their results. The new result in the March 17 announcement, based on three years of data, was the release of a map of the sky containing information about the microwaves' polarization.

The microwaves are partly polarized from the time of their origin (emerging from the so-called sphere of last scattering) and partly polarized by scattering, on their journey to Earth, from the pervasive plasma of mostly ionized hydrogen created when ultraviolet radiation from the first generation of stars struck surrounding interstellar gas.

WMAP now estimates that this recombination, effectively denoting the era of the first stars, occurred 400 million years after the big bang, instead of 200 million years as had been previously thought. The main step forward is that smaller error bars, courtesy of the polarization map and the much better temperature map across the sky—with an uncertainty of only 200 billionths of a Kelvin—provide a new estimate for the inhomogeneities in the CMB's temperature.

The simplest model, called Harrison-Zeldovich, posits that the spectrum of inhomogeneities should be flat; that is, the inhomogeneities should have the same variation at all scales. Inflation, on the other hand, predicts a slight deviation from this flatness.

The new WMAP data for the first time measures the spectrum with enough precision to show a preference for inflation rather than the Harrison-Zeldovich spectrum—a test that was long-awaited as inflation's smoking gun. (Papers available on the NASA website: http://map.gsfc.nasa.gov/m_mm/pub_papers/threeyear.html)

Two-Dimensional Light

Two-dimensional light, or plasmons, can be triggered when light strikes a patterned metallic surface. Plasmons may well serve as a proxy for bridging the divide between photonics (high throughput of data but also at the relatively large circuit dimensions of one micron) and electronics (relatively low throughput but tiny dimensions of tens of nanometers, or milliionths of a millimeter).
One might be able to establish a hybrid discipline, plasmonics, in which light is first converted into plasmons, which then propagate in a metallic surface but with a wavelength smaller than the original light; the plasmons could then be processed with their own two-dimensional optical components (mirrors, waveguides, lenses, etc.), and later plasmons could be turned back into light or into electric signals.

To show how this field is shaping up, here are a few plasmon results from the APS March Meeting.

1. Plasmons in biosensors and cancer therapy: Naomi Halas described how plasmons exist in the surface of tiny gold-coated, rice-grain-shaped particles can act as powerful, localized sources of light for doing spectroscopy on nearby bio-molecules. The plasmons' electric fields at the surface of the rice are much more intense than those of the laser light used to excite the plasmons, and this greatly improves the speed and accuracy of the spectroscopy. Tuned a different way, plasmons on nanoparticlules can be used not just for identifying but for the eradication of cancer cells in rats.

2. Plasmon microscope: Igor Smolyaninov reported that he and his colleagues were able to image tiny objects lying in a plane with spatial resolution much better than diffraction would normally allow; furthermore, this far-field microscopy—the light source doesn't have to be so close to the light—lets them send light waves of the opposite hand through mirrors and lenses to help in the imaging and then conduct plasmons away by a waveguide.

3. Photon-polariton superlensing and giant transmission: Gennady Shvets reported on his use of surface phonons excited by light to achieve super-lensing (lensing with flat-panel materials) microscope resolutions as good as one-twentieth of a wavelength in the mid-infrared range of light. He and his colleagues could image subsurface features in a sample, and they observed what they call "giant transmission," in which light falls on a surface covered with holes much smaller than the wavelength of the light. Even though the total area of the holes is only 6 percent of the total surface area, 30 percent of the light got through, courtesy of surface phonons excited by light to achieve super-lens (lensing with flat-panel materials) but also for the eradication of cancer cells in rats.

The QHE studies also revealed that when an electron completes a full circular trajectory in the imposed magnetic field, its wavefunction is shifted by 180 degrees. This modification, called "Berry's phase," acts to reduce the propensity for electrons to scatter in the backwards direction, thus in turn helps reduce electron energy loss. Geim reported the first evidence to support this story. Studying QHE in graphene bilayers he observed a new twist to this story. Studying QHE in graphene bilayers he observed that strange quarks could account for as much as 10 percent of the proton's magnetic moment, and that owing to experimental uncertainties both of these measured values might be consistent with zero. In other words, the proton is a lot less strange than thought.

A New Kind of Acoustic Laser

Sound amplification by stimulated emission of radiation, or SASER, is the acoustic anal og of a laser. Instead of a feedback-built poten wave of electromagnetic radiation, a saser would deliver a potent ultrasound wave.

The concept has been around for ages, and several labs have implemented models with differing features. In a new version, undertaken by scientists from the University of Nottingham in the U.K. and the Lashkarev Institute of Semiconductor Physics in Ukraine, the acoustic version of the model amplification takes place—consists of stacks (or a superlattice) of thin layers of semiconductors which together form "quantum wells." In these wells, really just carefully confined planar regions, electrons can be excited by parcels of ultrasound, which typically possess millielectronvolts of energy, equivalent to a frequency of 0.1-1 terahertz. Just as coherent light can build up in a laser by the concerted, stimulated emission of light from a lot of atoms, so in a saser coherent sound can build up by the concerted emission of phonons from a lot of quantum wells in the superlattice.

In lasers the light buildup is maintained by a reflective optical cavity. In the U.K.-Ukraine saser, the acoustic build-up is maintained by an artful spacing of the lattice thickness, as well as the periodicity of the traveling magnetic field in the device. Eventually the sound waves emerge from the device at a narrow angular range, as do laser pulses. The monoelectric nature of the acoustic emission, however, has not yet been fully probed. The researchers believe their saser is the first to reach the terahertz frequency range while using also modest electrical power input. Terahertz acoustical devices might be used in modulating light waves in optoelectronic devices.

A Hint of Negative Electrical Resistance

A hint of negative electrical resistance emerges from a new experiment in which microwaves of two different frequencies are directed at a 2-dimensional electron gas. The electrons, moving at the interface between two semiconductor crystals, are subjected to an electric field in the forward (longitudinal) direction and a faint magnetic field in the direction perpendicular to the plane. In such conditions the electrons execute closed-loop trajectories which will, in addition, drift forward depending on the strength of the applied voltage.

A few years ago, two experimental groups observed that when, furthermore, the electrons were exposed to microwaves, the overall longitudinal resistance could vary widely—for example, increasing by an order of magnitude or extending down to zero, forming a zero-resistance state, depending on the relation between microwave frequency and the strength of the applied magnetic field.

Some theorists proposed that in such zero-resistance states, the resistance would actually have been less than zero: the swirling electrons would have drifted backwards against the applied electric field. But this rearwards motion would be difficult to observe because of an instability in the current flow. A Utah/Minnesota/Rice/Bell Labs group has now tested this hypothesis in a clever bichromatic experiment using microwaves at the two frequencies. Michael Zudov and Rahul Dutta sent microwaves of two different frequencies at the electrons, observing for nonzero-resistance states the resultant resistance was the average of the values corre sponding to the two frequencies separately. On the other hand, when the measurements included frequencies that had yielded a zero resistance, the researchers observed a dramatic rise in the measured resistance.

Judging from the average resistance observed for non-zero measurements, they deduced that whenever zero resistance was detected, the true microscopic resistance had actually been zero. (Zudov et al., Phys. Rev. Lett. 96, 215504, 2006)
The electrons stimulate the atoms into giving up their surplus energy through collisions. The electrons’ energy is amplified in a coherent way. Although millions of collisions are involved for each electron, no heat is generated. The transferred energy goes into an enhanced electron motion. One could say that here was a laser which produced no laser light, only a laser-like transfer of energy resulting in electron acceleration. It should be said that the electrons began with an energy of 45 million electron volts (MeV) and absorbed only a modest energy of about 200 thousand electron volts (keV).

Hypersound
Hypersound, acoustic pulsation at 200 gigahertz frequencies, has been produced in the same kind of research semiconductor cavity as in laser physics. Physicists at the Instituto de Nanosciences de Paris (France) and the Centro Atómico Bariloche and Instituto Balseiro (Argentina) generate the high frequency sound pulses in a solid material made of thin gallium arsenide and aluminum arsenide layers. One can picture the sound, excited by a femtosecond laser, as being a short pulse of waves or equivalently as particle-like phonons, excitations pulsing through the stack of layers. These phonons are reflected at either end of the device, called a nanocavity, by further layers with a much different acoustic impedance acting as mirrors. Acoustic impedance is the acoustic analog of the refractive index for light.

Bernard Jussens says that he and his colleagues hope to reach the terahertz acoustic range. The wavelength for such sound is only nanometers in length. They believe that a new field, nanoflan, has been inaugurated, and that the acoustical properties of semiconductor nanodevices will become more prominent. THz phonons, and more specifically the reported nanocavities could, for example, be used to modulate the flow of charges or light at high frequency and in small spaces. THz sound might also participate in the development of novel techniques for the in vivo diagnosis or for novel forms of tomography for imaging the interior of opaque solids.

New Baryons Discovered
The periodic table of baryons has now been supplemented with several heavyweight members. The new members of the baryonic periodic table are unstable and ephemeral, but their observed existence serves to expand our understanding of matter in the universe. The new baryons, the heaviest yet with mass around 5.8 billion electronvolts, were sifted from trillions of proton-antiproton collisions conducted at an energy of 18 GeV at the Fermilab at Batavia. Up to now there was only one well established bottom-quark-bearing baryon, the so-called Lambda.

The first Antimatter Chemistry
The Athena collaboration, an experimental group working at the CERN laboratory in Geneva, has measured chemical reactions involving antiprotonic hydrogen, a bound object consisting of an antiproton paired with a proton. This composite object, which can also be called protonium, eventually annihilates, emitting an even number of telltale charged pions. Normally the annihilation comes about in a trilionth, of a second, but in the Athena apparatus the duration is a whopping millionth of a second.

The protonium comes about in the following way. First, antiprotons are created in CERN’s superconducting semiconducotor cavity as a beam of antiprotons. Several more of the PASER, provides new opportunities since the accelerated electrons may prove to be significantly “cooler” (they are more collimated in velocity) than in some other prospective acceleration schemes, enabling in turn the secondary cooling of electrons.

Hypersound, the first Antimatter Chemistry

Have Particle Masses Changed since the Early Universe?
Indications of a change in the proton-to-electron mass ratio have shown up in comparisons of the spectra of hydrogen gas as recorded in a lab with spectra of light coming from hydrogen clouds at the distance of quasars. This is another of those tests of so-called physics that has a very absolute constant.

The proton-to-electron mass ratio (denoted by the letter mu) figures in setting the scale of the strong nuclear force. There is at present no explanation why the proton's mass should be 1,836 times that of the electron. The new search for a varying mu was carried out by Weim Ubachs of the Vrije Universiteit Amsterdam. He and his colleagues studied hydrogen gas in the lab, performing ultra-high-resolution spectroscopy in the difficult-to-access extreme-ultraviolet range. This data is compared to accurate observations of absorption spectra of distant hydrogen clouds from space, leading to the surprising result that it has been moving in one direction.

A Baby Picture That’s Worth a Nobel Prize
The 2006 Nobel Prize for Physics was awarded to John Mather of NASA/Goddard Space Flight Center, University of Maryland and Michael Turner of the University of Chicago, Berkeley and Lawrence Berkeley National Laboratory. They are cited for the study of the early universe. They were instrumental in developing the Cosmic Background Explorer (COBE) experiment. This orbiting satellite was launched to detect faint temperature variations in the cosmic microwave background (CMB), the bath of radiation representing the first light that could move freely through the universe after the big bang. COBE's map of these temperature variations across the whole sky has been called the earliest "baby picture" we have of the universe.

CMB was first observed in the 1960s by Arno Penzias and Robert Wilson at Bell Labs, in New Jersey, for which they would later receive the Nobel Prize. It was thought at the time that the CMB would be least somewhat inhomogeneous since the subsequent galaxies we now see would have to form from slight imbalances of matter in the pervasive hot plasma that constituted the universe (as far as we know) just before the first...
Atoms in a Trap Measure Gravity at the Micron Level

Nowadays many of the most sensitive measurements in science depend on some quantum phenomenon which very subtly can often be exploited to gain maximum precision. In an experiment conducted at the Università di Firenze (University of Florence), the quantum phenomenon in question is called Bloch oscillation. This weird effect occurs when subjects particle to a periodic potential—such as electrons feeling the regular gridlike electric force of a crystalline lattice—of atoms are exposed to an additional static force, say, an electric force in a single direction, which happens is that the electrons do not all move in the direction of the force, but instead oscillate back and forth in place.

In a new experiment conducted by Guglielmo Tino and his Florentine colleagues, the particles studied were strontium atoms that were intentionally held in a vertically oriented optical trap formed by crossing laser beams, while the static force itself was an in situ force of gravity pulling down on the atoms.

Although Bloch oscillations have been observed before, they have never been seen as precisely as in this case. Close observation of the Bloch oscillations allows you to measure the strength of the static force, with high precision—in this case to measure gravity with an uncertainty of a part in a million.

With planned improvements to the apparatus, the researchers will be able to bring the atoms to within a few microns of a test mass and will measure g with an uncertainty of 0.1 parts per million. With these conditions, one can probe theories which say that gravity should depart from Newtonian newton, perhaps signaling the emergence of a new phase of spacetime.

According to Tino, unlike gravity-measuring experiments which use torsional balances or cacticlines, the Florence approach measures gravity directly and over shorter distances. The atom-trap setup should also prove useful for future inertial guidance systems and optical clocks.

Nanopores and Single-Molecule Biophysics

Some proteins naturally form nanometer-scale pores that serve as channels for useful biochemical ions. Through this ionic communication, nanoparticles enable many functions in cells, such as moving proteins and lipids to and from the cell membrane.

Nanopores can be destructive, too. When the proteins of bacteria and viruses attach to a cell, their nanopores can facilitate infection, for example by shooting viral DNA through them into the cell.

By monitoring animal blood samples for changes in current, Kasaian and his colleagues at the National Cancer Research Institute and the University of Florence have shown that certain proteins can be used to detect and characterize individual molecules of RNA and DNA. He also demonstrated constructive uses for protein-related nanopores in diagnosing anthrax infections and testing for drugs.

Anthrax bacteria secrete a protein called “protective antigen” that attaches to an organic membrane such as a cell wall. The protein forms a nanopore that penetrates the membrane. When another anthrax protein, called “lethal factor,” attaches to the protective antigen nanopore, it prevents ionic current from flowing through the pore and out of the organic membrane.

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ies. Discussing his group’s latest work with artificial, silicon-based nanopores, Cees Dekker of the Delft University of Technology in Delft, Holland showed how lasers and other manipula-
tions with the artificial pores are enabling new single-molecule biophysics studies on the prop-
critics of DNA, RNA, and proteins by studying how they pass through the pores.

Dune Tunes

For centuries, world travelers have known of sand dunes that issue sound waves, sometimes of great quality. Now, a team headed by Holger Holtz and colleagues believes that the sounds come from vibrations of the dune as a whole and proven, through field studies and through controlled experiments in a lab, that the sounds come from the synchronized motions of the grains in avalanches of a certain size. Small avalanches don’t produce any detectable sound, while large avalanches produce sound at lots of frequencies (leading to cacophonous noise). But sand slides of just the right size and velocity result in sounds of a pure frequency, with just enough overtones to give the sound “color,” as Holtz put it. They found that the sound is not the same however, the tuning isn’t produced by any other influence and but by critically self-organizing tendencies of the dune itself. The researchers thus rule out various “musical” explanations.

For example, the dune sound does not come from the stick-slip motion of blocks of sand across each other, study of only the dune (much as violin sounds are made by the friction between a string and a bow) or one who is rotated through some angle or traveling at a constant speed relative to the observ-

fication-violating effects involving electrons.

The Hawking/Hertog paper is meant to address this concern. It looks at the universe as a quantum system in the framework of string theory. In Richard Feynman’s formulation of quan-
tum theory, the probability that a photon ends up at a particular spot is calculated by summing up all possible trajectories for the photon. Hawking and Hertog argue that the universe itself must also have different trajectories at once, evolving through many simultaneous, parallel histories, or “branches.”

But applying quantum theory to the entire universe is tricky. Here you have no control over the initial conditions, nor can you repeat the experiment again and again for statistical signif-
lation. Instead, the Hawking-Hertog approach starts with the present and uses what we know about our branch of the universe to trace its history backwards. Again, there will be multiple possible branches in our past, but most can be ignored in the Feynman summation because they are just too different from the universe we know.

For example, Hertog says, knowledge that our universe is very close to being flat could allow one to concentrate on a very small portion of the string theory landscape whose values for the cosmological constant are compatible with that flatness. That could in turn lead to predictions that are not so far away from the universe we know.

An even more fragile “atom” is the tripartite object consisting of two electrons and one positron. P- states, it is known, is less suitable for QED studies than Ps, but has the great virtue of being the simplest three-body system in physics. Again, it is simpler than H-, H2

A new model, proposed by physicists at Los Alamos National Laboratory of America’s Hottest Lab

A temperature of 2 to 3 billion degrees Kelvin—hotter than the interior of any known star—has been achieved in a lab in New Mexico.

The temperature record was set recently in a test shot at the Z Pinch device at Sandia National Laboratory, where an immense amount of electrical charge is stored in a device called a Marx generator. Many capacitors in parallel are charged up and then suddenly switched into a series configuration, generating a voltage of 8 million volts.

This colossal electrical discharge could cut a hole of 20 million amps passing through a cylindrical array of wires, which implodes. The imploding material reaches the record high temperature and also emits a large amount of X-ray ener-

Why the implosion process should be so hot, and why it generates X-rays so efficiently (10 to15 percent of all electric-

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A new model, proposed by physicists at Los Alamos

Theorists have speculated about this possibility (often called the Strange Quark Matter Hypothesis) since the early 1980’s. A star made in this way, a quark

The strange (s) quarks in neutrons or protons is typically unstable. In the high-density environment of quark stars, however, matter containing up, down and strange quarks might be stable. This process really comes into play in collapsed stars, where strange quarks could rough-

the wave moving in pulsilke fashion. But in this case, owing to the curved length of the wire, a standing wave pattern is what results as the temperature is low-

the wave is a quantum thing; hence certain wavelengths are allowed. In other words, the charge density wave is frozen in place, allowing the STM probe to measure the wave–the electron densi-
ty at many points along the wire. Surprisingly, two or more density waves could co-exist along the wire. The charge density turbulence can also be considered as a particle-

hexagon of atoms. The conclusion: any such quasi-magnetic field would have to be weaker than

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The Sharpest Object Yet

The sharpest object yet made is a tungsten needle tapering down to thickness of a single atom. The needle, made by the group of Robert Wolok at the University of Alberta and the National Institute for Nanotechnology, starts out much broader. Exposed to a pure nitrogen atmosphere, however, a rapid slimming begins. To start with the tungsten is chemically very reactive and the nitrogen toughens the tungsten surface. But at the tip, where the electric field created by applying a voltage to the tungsten is at its maximum, N₂ molecules are driven away. This process reaches an equilibrium condition in which the point is very sharp.

Furthermore, N₂ in the present setup helps to stabilize the tungsten against further chemical degradation. Indeed, the resultant needle is stable at temperatures of 900 degrees Celsius even after 24 hours of exposure to air.

Wolok says that although a narrower tip will be useful in the construction of STM arrays (you can pack more tips into a small area), and a wide array might prove useful in devices of atomic precision, the present solution won't improve thereby. The real benefit of the sharp tungsten tips, he believes, will be as superb electron emitters. Being so slender, they would emit electrons in a bright, narrow, stable stream. (Rezazadeh, P., and Wolok, J. Chem. Phys. 124, 205716, 2006)

Chemical Transistor

A new device, the chemical equivalent of a transistor, might make possible ultrasonic bio-based single-atom electronics. The things we associate with transistors, the closing or opening of a switch or the amplification of a signal, are normally carried out by injecting a tiny electric signal into a gate electrode to then change the conductivity of a channel region. This allows a current to be shut off or to be amplified. In an experiment carried out by physicists at the University of California at Irvine, the same things are done through chemical reactions.

Philip Collins and his colleagues cleverly engineered a small cavity into the central working substance of their device. The nanoparticles, small on the surface of the stars. Such a surface, says Los Alamos scientist Andrew Steiner, can be thought of as ‘liquid’ in the manner we understand the surface of the sea. On Earth, liquid surfaces are generally flat. Because of surface tension, the surface of a liquid droplet is a sphere. The radius of the sphere can be expressed as R = 2(π/3)(V/SA)^1/2, where V is the volume of the droplet and SA is the surface area. Vapor pressure, the pressure of the vapor on which the droplet floats, of course, is an important factor in determining the surface tension. The research team came up with a simple method for measuring liquid surface tension. The researchers measured the radius of a droplet attached to the nanotube. In previous detectors, chemical activation has required the presence of tens of antigens; here, a single antigen might be enough to change the state of the nanotube. (Mannik et al., Phys. Rev. Lett. 97, 016601, 2006)

Liquid Flowing Uphill; Might Be Used to Cool Chips

In a phenomenon known as the “Leidenfrost effect,” water droplets can perform a dance in which they glide in random directions on a cushion of vapor that forms between the droplets and the surface. Such a cushion might be generated, for example, by an object that is heated to a temperature above the boiling point of water. In such cases, the surface tension of the water droplet is not enough to hold it to the surface. Here, heat is conducted through the droplet and by capillary action the droplet is dragged up the heated surface. The Irvine researchers showed that this process can be per- formed the order of magnitudes faster than the periods of time, as fast as 30 minutes.

This striking method for pumping a liquid occurs for many different liquids (including nitro- gen, acetone, methanol, ethanol, and water) over a wide temperature range (from -196 to +151 degrees Celsius). A practical application of this phenomenon might be to cool off hot computer chips. A water droplet that is moved across the surface of the chip would be used to cool off the chip. In a concept the researchers plan to test, waste heat in a computer would activate a pump moving a stream of liquid past the processor to cool it off. Such a pump for coolants might need additional power, have no moving parts, and would spring into action only when needed, when the processor gets warm. (Linke et al., Phys. Rev. Lett. 99, 154502, 2006)

Stock Market Criticality

In the months before and after a major stock market crash, price fluctuations follow patterns similar to those seen in phenomena such as heartbeats and earthquakes, physicists write in the 17 February Physical Review Letters.

A University of Tokyo team studied the Standard & Poor’s S&P 500 index, focusing on small deviations of the long-term average of daily changes. The distributions of these deviations were found to resemble a “Gaussian,” at least when measured over sufficiently long time scales–for example, for more than one day. That means that fluctuations are likely to be small, while larger fluctuations are less likely, their probability following a bell curve.

But when the team looked at 2-month periods surrounding major crashes such as the Black Monday event of October 19, 1987, they saw a different story: Fluctuations of all magnitudes were equally probable. As a consequence, the graph of index fluctuations looked statistically in the way that a normal distribution was overlaid over different time scales. This pattern of behavior is called “critical” and would be expected in situations that are in a critical state: when a system is on the brink of a phase transition, and when its structure or dynamics change abruptly. The pattern is also expected in situations that are far from equilibrium, and when the system is in the middle of a dynamic process. In such cases, the system is said to be in a critical state. The critical state is a state of high sensitivity and high probability, and in such states the system is more likely to change its behavior in a dramatic way. The critical state is also a state of high complexity, and in such states the system is more likely to exhibit complex behavior.

Such behavior is called critical in analogy with a ferromagnetic metal at the “critical temperature,” when regions of the metal are, for example, on the brink of melting or freezing. In such cases, the system is said to be in a critical state. The critical state is a state of high sensitivity and high probability, and in such states the system is more likely to change its behavior in a dramatic way. The critical state is also a state of high complexity, and in such states the system is more likely to exhibit complex behavior.

It is unclear what individual trading decisions lead to criticality in the stock market, co-author Zhengzhou Shuksz says, although he and the team at the University of Tokyo are working on finding explanations. Also unclear is whether the findings could one day lead to an early-warning system to predict crashes, and if such a system would precipitate a crash– or create one artificially by inducing panic. (Kiyono et al., Phys. Rev. Lett. 96, 204801, 2006)