JILA: LIGHT & MATTER
Fall 2006

An artist's conception of a magnetized neutron star
Credit: NASA

Universal Attractions

What do fermions in atomic nuclei, neutron stars, and ultracold trapped gases have in common? They have the same fundamental behavior. The exciting news is that there's now hard evidence that this is true, thanks to graduate students Jayson Stewart and John Gaebler, Cindy Regal who received her Ph.D. in physics in November, and Fellow Debbie Jin.

Jin says that many of us might expect the behavior of an ultracold trapped gas of fermions to depend on the interactions between the fermions (or how they "feel" each other). But, ironically, if these interactions are extremely strong, then they no longer matter; under such conditions, the behavior of the gas depends only on temperature and density.

In a recent experiment, the Jin group measured the potential energy of an ultracold trapped gas of 40 K atoms in the crossover region between Bose-Einstein condensation and superconductivity/superfluidity. The researchers used a magnetic Feshbach resonance to maximize the intensity of the interatomic interactions and found that an attraction between the atoms caused them to become more tightly packed.

They then studied the effect of temperature on the ratio of the potential energy of their strongly interacting gas to that of a noninteracting gas. By extrapolating the ratio to a temperature of 0 K, they were able to extract a universal (many-body) parameter β and determine its value. Their experimental value of -0.54 was consistent with previous measurements of ^{6}Li atoms, recent crossover theory developed at JILA, and Monte Carlo calculations. (Monte Carlo calculations use many calculations starting with random numbers to produce solutions to problems that are otherwise too difficult to solve.)

This work proved that the universal parameter β is not specific to ^{6}Li atoms; rather it is characteristic of any Fermi gas, neutron star, or atomic nucleus. From now on, researchers in the Jin group are confident that the results of their experiments on ^{40}K atoms reflect general properties of fermions, not just those of a particular atom.

Reference:
J. T. Stewart, J. P. Gaebler, C. A. Regal, and D. S. Jin, *Physical Review Letters*, submitted.

Exploring the frontiers of quantum mechanics

The South Broadway Shootout

In the race to develop the world's best optical atomic clock, accuracy and precision are what count. Accuracy is the degree to which a measurement of time conforms to time's true value. Precision is a gauge of the exactness, or reproducibility, of the measurements. By definition, a high-precision clock must be extremely stable. JILA may well be home to one of the world's most precise (and stable) optical atomic clocks, thanks to the efforts of graduate students Marty Boyd, Andrew Ludlow, Seth Foreman, and Sebastian Blatt; postdoc Tanya Zelevinsky; former postdoc Tetsuya Ido; and Fellow Jun Ye.

There are two key reasons why the Ye group's lattice-based strontium clock is so precise: (1) Its ultrastable clock laser has a short-term laser linewidth of ~0.2 Hz (NIST's experimental mercury ion clock's laser is the only laser in the world that's more stable), and (2) Its optical lattice holds the strontium atoms in place for a relatively long time but doesn't perturb the critical optical atomic clock transitions. Taken together, the ultrastable laser and perturbation-free atomic sample produce the world's highest quality resonance profile, a measure of the clock's precision (Q ~2.5 x 10^{14}).

Aided by unprecedented spectral resolution, the group's clock can achieve the highest precision ever measured with coherent spectroscopy. Its precision is much greater than the NIST-F1 cesium fountain atomic clock, the nation's primary time and frequency standard. Boyd says that the precision of his group's clock is potentially superior to the mercury ion clock under development by Jim Bergquist's group at NIST. But Boyd and his colleagues must still prove this claim in a direct comparison of the two optical atomic clocks. The mercury ion clock has already proven itself to be at least five times more precise than the NIST-F1.

Then there's the question of accuracy. The current NIST-F1 clock neither gains nor loses a second in about 70 million years. For the mercury ion clock, which is the most accurate clock in the world, the figure is 400 million years. Ye and his group recently showed that the current version of their Sr clock has an accuracy similar to that of the NIST-F1 cesium fountain clock.

The new optical atomic clocks at JILA and NIST perform so well that it's becoming increasingly difficult to assess their precision and accuracy in comparison to the current cesium fountain technology. To test their performance against a much better clock, the clocks must go head-to-head with each other.

The shootout began in November of 2006 when NIST and JILA began transmitting their optical clock signals across the fiber optic link between the two organizations. The clock designers will use NIST researcher Scott Diddams' optical frequency comb as an intermediate clock gear to facilitate the comparison of the mercury ion and lattice-based Sr clocks. When the dust settles, both groups will have the data they need to go back to the lab and improve their clock designs. The measurements will also help them determine the best optical atomic clock to use in the future.

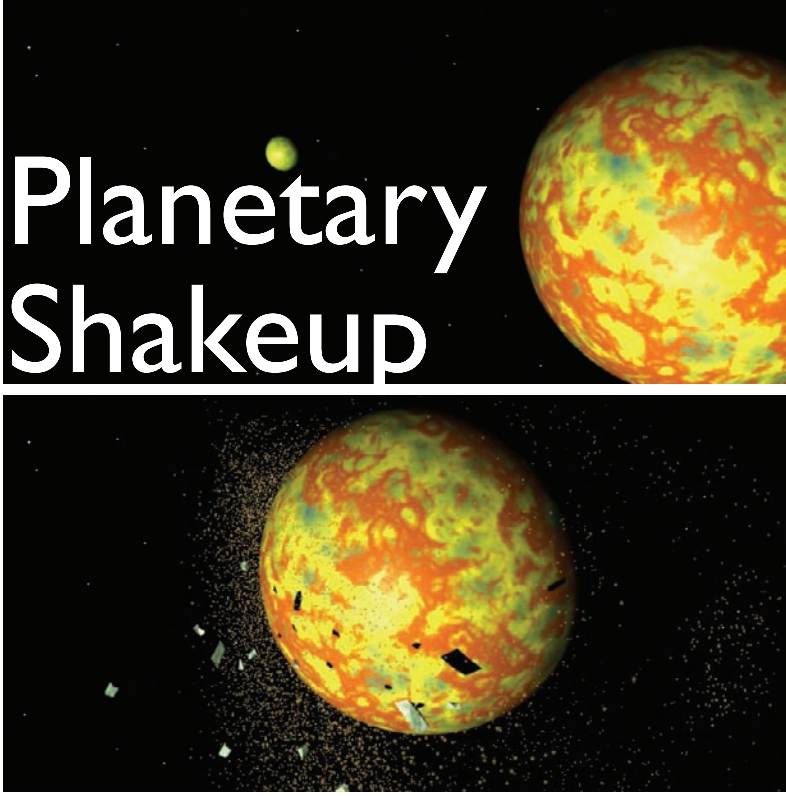
References:

Martin M. Boyd, Tanya Zelevinsky, Andrew D. Ludlow, Seth M. Foreman, Sebastian Blatt, Tetsuya Ido, and Jun Ye, *Science*, **314**, 1430 (2006).

Andrew D. Ludlow, X. Huang, Mark Notcutt, Thomas Zanon, Seth M. Foreman, Martin M. Boyd, Sebastian Blatt, and Jun Ye, *Optics Letters*, submitted.

Martin M. Boyd, Andrew D. Ludlow, Sebastian Blatt, Seth M. Foreman, Tetsuya Ido, Tanya Zelevinsky, and Jun Ye, *Physical Review Letters*, submitted.

Planetary Shakeup



For astrophysicists working to discover the origins of stars and planets, a small clue can go a long way. They can't get a close look at distant stars and planets, so they only know the barest details about other planetary systems. One such detail is that some extra-solar planets revolve around their stars in elliptical orbits rather than the nearly circular orbits that are the norm in our solar system. According to JILA Fellow Phil Armitage and graduate student Dimitri Veras, this small difference indicates a very different history – one that could have spelled doom for a planet like Earth.

Armitage and Veras believe that when a planetary system includes planets with eccentric orbits, it is a sign that the now-stable system has been through a tumultuous past. They think that such planets started out with circular orbits, but were pushed and pulled out of step, upsetting the equilibrium of the whole system. Eventually, the planets settled into their new elliptical orbits, but only after a period of instability while the system regained its balance. Using computer simulations, Armitage and Veras have investigated how this process of upset and stabilization might occur and how it might occur differently for systems with different configurations.

The chaos begins when the planets are too close together. They tug on each other with their gravity fields, pushing one another out of orbit. From here, they gain momentum, and soon they are careening toward other planets, getting them into the act. This time is a dangerous one for planets. Those close to the star have a chance of diving right in and being disintegrated. Planets far away from the star will sometimes be thrown so far that their orbit becomes "hyperbolic," which means they fly away, never to return. Occasionally planets will even smash into each other.

According to Armitage, our solar system never went through a period like this. Aside from the circular nature of our orbits, the existence of small, terrestrial planets is an argument against it. Imagine Jupiter or Saturn flying across the asteroid belt and through the neighborhood of Earth and Mars. Even without making direct contact, the gravity of a gas giant would likely destroy a smaller planet, either by sucking it in or sending it on a fatal trajectory. For this reason, Armitage and Veras think that where we find eccentric orbits, we probably won't find many Earth-like planets. Certainly, as the scientists are able to look more and more closely at neighboring stars, they will find out if their hypothesis is correct.

Reference:
Dimitri Veras and Philip J. Armitage, *The Astrophysical Journal*, **645**, 1509 (2006).

JILA Welcomes Associate Fellow James Thompson

JILA has appointed James K. Thompson as a new NIST associate fellow and adjoint professor of Physics at CU. Thompson arrived in Colorado in mid-September. He received his Ph.D. in physics in 2004 from the Massachusetts Institute of Technology (MIT), where he worked with Dave Pritchard, who was also Eric Cornell's thesis advisor. In his thesis work, he made the world's most precise mass comparisons by learning how to detect and precisely control the relative motion of two single ions confined for weeks to months in a Penning trap consisting of magnetic and electric fields. His work led to the most precise direct test to date of Einstein's relationship $E=mc^2$ and a novel method for non-destructively monitoring the quantum state of a single molecular ion. He received the 2004 American Physical Society's DAMOP thesis award for this research.

Thompson did his postdoctoral research (with Vladan Vuletic) in the MIT-Harvard Center for Ultracold Atoms. There he focused on the interface between ultracold atoms and quantum optics, a topic he plans to pursue at JILA. His goal is to apply his understanding of the interface between light and matter to the field of precision measurement. When his lab is up and running in January of 2007, he will begin by devising strategies to reduce the effect of the fundamental quantum noise that arises from Heisenberg's uncertainty relationship as applied to atomic spins. He plans to non-destructively measure and cancel out the quantum fluctuations in the collective spin state of an ensemble of atoms. By learning how to minimize the effect of quantum noise, Thompson hopes to advance the precise measurements required for atomic clocks and in searches for permanent electric dipole moments in atoms and molecules.

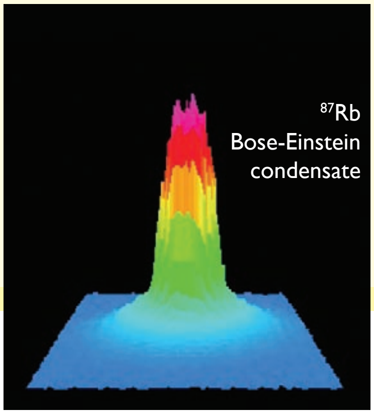
Thompson is married to Deborah Whitehead, who will join the faculty of CU's Department of Religious Studies in January of 2007. The couple has two children, Grace, aged 2, and Lily, aged 5 months.

Molecule Magic

Under ordinary circumstances, making new molecules can be simple and straightforward — just a matter of mixing together some highly reactive chemicals and letting nature take its course. However, when the reactants are a few millionths of a degree above absolute zero, the creation of new molecules requires the sophisticated tools of modern experimental physics. Using those tools, graduate student Scott Papp and Fellow Carl Wieman recently created the world's first ultracold diatomic molecules made from two different atoms.

The atomic constituents of the new molecules are different isotopes of rubidium, ^{85}Rb and ^{87}Rb. Both are bosons and contain the same number of protons in their nuclei, making them the same chemical element. However, ^{87}Rb has two additional neutrons in its nucleus. The creation of ^{85}Rb–^{87}Rb molecules is a key first step toward the efficient production of a variety of heteronuclear ultracold molecules, many of which are expected to exhibit permanent dipole moments in their ground states. Such dipolar ultracold molecules are expected to play a role in quantum computing and the search for the electron electric dipole moment.

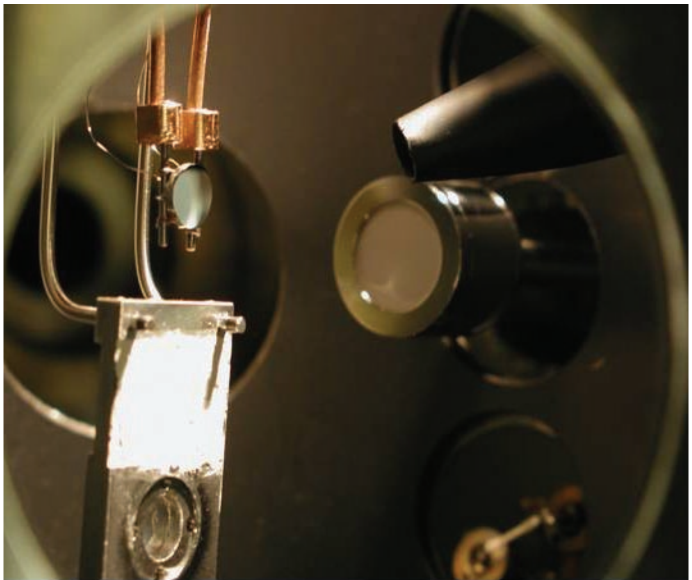
To create their ultracold molecules, the researchers cooled a mixture of the two atoms to below 10 μK, where the ^{87}Rb formed a Bose-Einstein condensate and the



Team Photon

When illuminated by X-ray and infrared light beams in tandem, electrons can tap dance off a platinum surface because they've actually grabbed a photon from both beams simultaneously. As you might have guessed, there is more going on here than the ordinary photoelectric effect, which Albert Einstein explained more than a century ago. In the photoelectric effect, electrons escape from a solid after absorbing a single photon or bundle of light energy. What happens when two laser beams simultaneously hit a surface is called the "laser-assisted photoelectric effect."

The laser-assisted photoelectric effect was recently observed for the first time in a solid by research associate Guido Saathoff, graduate student Luis Miaja-Avila, Fellows Margaret Murnane and Henry Kapteyn, former post-doc Chi-Fong Lei, and former Visiting Fellows Martin Aeschlimann (Technische Universität Kaiserlautern) and John Gland (University of Michigan). Their apparatus is shown below. A platinum sample (the disk at the left of center) is simultaneously illuminated by X-ray and infrared (IR) laser beams. In addition to absorbing the X-ray photon energy necessary for escaping from the surface, the electrons escaping from the surface can simultaneously either grab, or hurl away, an infrared photon. This complex interaction changes the characteristic energies of the newly freed electrons.



The laser-assisted photoelectric effect works the same way on a surface as it does in a cloud of atoms: energetic X-rays eject electrons from a surface (or a cloud of atoms). The liberated electrons would normally have a fixed energy, given by the absorbed photon energy minus the energy needed to escape the surface barrier. This is simply Einstein's photoelectric effect. However, when an intense IR pulse hits the surface at the same time as an X-ray pulse, the liberated electrons are either sped up or slowed down as they escape the surface barrier. Which way it goes depends on the exact moment in the IR light wave when it encounters a particular free electron.

What's interesting is that the Murnane-Kapteyn group didn't set out to discover the laser-assisted photoelectric effect on a surface. In fact, until the group discovered it, physicists did not realize that it could be observed in solids. Rather, the researchers had intended to probe molecular vibrations on a surface that had well-defined energy states. However, when they simultaneously illuminated their surface with IR and X-ray beams, the well-defined photoemission energy structure, which is usually observed from a platinum surface, completely disappeared. In looking for an explanation for this unexpected result, they deduced that the laser-assisted photoelectric effect was the only process that could explain their observations.

References:

L. Miaja-Avila, C. Lei, M. Aeschlimann, J. L. Gland, M. M. Murnane, H. C. Kapteyn, and G. Saathoff, *Physical Review Letters*, **97**, 113604 (2006).

Physical Review Focus, "Photons Team Up," 26 September (2006).

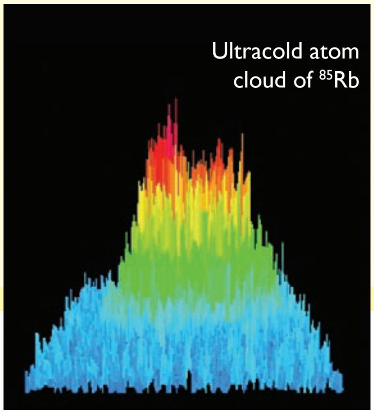
G. Saathoff, L. Miaja-Avila, C. Lei, M. Aeschlimann, J. Gland, M. Murnane, and H. Kapteyn, *Optics and Photonics News*, December (2006).

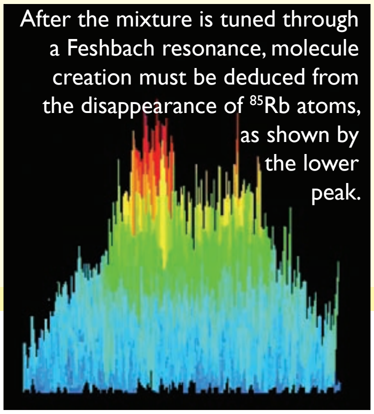
^{85}Rb remained a gas. They then tuned a magnetic field from low to high through a Feshbach resonance, a particular magnetic field that precisely controls the collision speed of the atoms and allows their quantum states (wave functions) to overlap. They also tried applying a small oscillating magnetic field to the ultracold atom mixture.

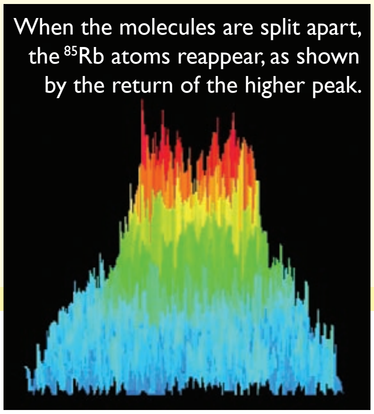
Both processes created exotic, large molecules in their highest possible vibrational states. The new molecules were bound together by only a tiny amount of energy. In fact, they were about 10 orders of magnitude more weakly bound than if they were in their ground state! Not surprisingly, the ^{85}Rb–^{87}Rb molecules didn't last very long — only about a millisecond — before they fell apart spontaneously or got knocked apart in a collision.

Now the researchers want to develop methods to put the ^{85}Rb–^{87}Rb molecules into their lowest vibrational state. Once the molecules are in their ground state, they will last longer and be much more stable. The ability to create stable, long-lasting ultracold heteronuclear molecules will lead to many new and exciting research projects for years to come.

Reference:
S. B. Papp and C. E. Wieman, *Physical Review Letters*, in press.


Ultracold atom cloud of ^{85}Rb


After the mixture is tuned through a Feshbach resonance, molecule creation must be deduced from the disappearance of ^{85}Rb atoms, as shown by the lower peak.


When the molecules are split apart, the ^{85}Rb atoms reappear, as shown by the return of the higher peak.

Running Backwards

Does the electron have an electric dipole moment (eEDM)? If it does, the standard model of elementary particle physics says this dipole moment is many orders of magnitude below what can be measured experimentally. As Fellow John Bohn quips, "It's a darn small one."

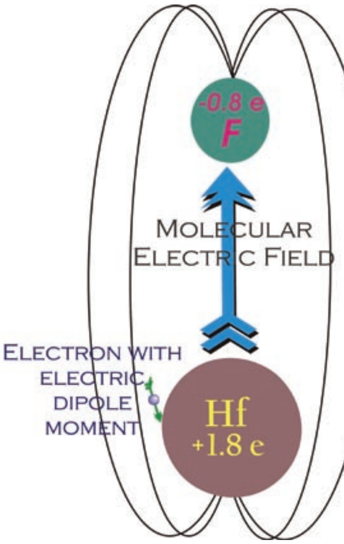
On the other hand, various extensions of the standard model predict a much larger eEDM that might be just within reach of a cleverly designed experiment. That tantalizing idea has induced Fellow Eric Cornell to collaborate with Bohn on a multiyear project to try to measure the eEDM in ultracold trapped molecular ions. If the researchers succeed in detecting an eEDM, they will show that running time forward or backward at the quantum level makes a difference in the behavior of individual particles.

Recently, Bohn, a theorist, and graduate students Ed Meyer and Mike Deskevich decided to try and figure out good candidates for the proposed experiment, which will use high-precision spectroscopy to search for an eEDM signal in ultracold trapped molecular ions. Before they started their analysis, the theorists knew they needed to find ions consisting of two atoms capable of creating a huge effective electric field on the ions' valence electrons — a much bigger field than would be possible to apply in the lab. This criterion meant that one atom in a candidate ion had to be large and heavy.

The researchers also knew the experimentalists would need to be able to use a small applied electric field to precisely align the internal electric fields of their trapped ions. This requirement meant that the unpaired, or valence, electron in a candidate ion had to have a high angular momentum around the molecular axis. However, such a high angular momentum would naturally keep that electron far away from the nucleus. But, a valence electron has to be fairly close to the nucleus to experience the big electric field between the ion's atomic constituents. At this point, the theorists muttered, "So now what?"

Undaunted, they decided to look for molecular ions with two unpaired electrons, one with no angular momentum and the other with lots of it. In the process, they figured out that the candidate ions would need to exhibit these characteristics in the ground state (or a long-lived metastable state) so they would last long enough to be probed. The good news is that they found two good candidates, hafnium hydride (HfH^+) and platinum hydride (PtH^+).

Artist's conception of a valence electron interacting with a HfF^+ ion's internal electric field.



Before they could even publish their results, the Cornell group asked them to evaluate the hafnium fluoride (HfF^+) ion because the experimentalists thought it might be easier to make and observe in the lab. HfF^+ whizzed through the theoretical evaluation with flying colors — in time to make it into print with the two hydrides. So now the experimentalists have the ball, and they're off and running. Stay tuned.

References:
R. Stutz and E. A. Cornell, *Bulletin of the American Physical Society*, **89**, 76 (2004).

Edmund R. Meyer, John L. Bohn, and Michael Deskevich, *Physical Review A*, **73**, 062108 (2006).

Seeds of Creation

There is an enormous black hole at the center of every galaxy, gobbling up matter over eons of time — some for as long as 13 billion years. One of the great questions of modern astronomy is: Where did the seeds for all these black holes come from? Not, as you might think, from the fiery collapse of massive hot stars formed in the early Universe, says Fellow Mitch Begelman. That may well be how new, much smaller black holes are formed, even now. However, despite long-standing theories to the contrary, Begelman believes that ancient supernovae cannot account for the genesis of the black holes as massive as a million suns at the center of galaxies.

Rather, he says, the seeds for these supermassive black holes were created during the formation of the galaxies themselves. The black holes formed at the centers of huge, but dense, reservoirs of mostly dark matter coupled to ordinary matter, mostly hydrogen gas. The formation of galaxies with massive black holes at their centers occurred millions of years after the Universe spawned its first stars.

The formation of galaxies began when the gas cooled down enough to decouple from the dark matter and fall towards the center under its own gravity. Rotation hindered its collapse at first, but eventually the rotating gas became unstable and formed a bar, similar to the one shown below. Bar formation rapidly transferred the angular momentum of the disk further away from the core. As the gas lost angular momentum, it moved inward and became even more unstable. New bars formed within old bars in discrete steps, like a set of Russian dolls nested inside one another.

Barred Spiral Galaxy NGC 1300

Credit: Hubble Heritage Team, ESA, NASA

The “bar within bars” process was proposed by Isaac Shlosman, then a JILA postdoc, JILA Visiting Fellow Juhan Frank, and Begelman in 1989 and refined in 2001–2002 when Shlosman was a Visiting Fellow. The researchers now posit that this process led to the creation of a dense, self-gravitating core supported by gas pressure. The core eventually got so compressed that radiation was literally squeezed out of it, causing its outer envelope to begin to shine and signaling the creation of a quasi-star. Quasi-stars were very hot and even more luminous than the Pop III stars, the earliest stars that formed in the Universe.

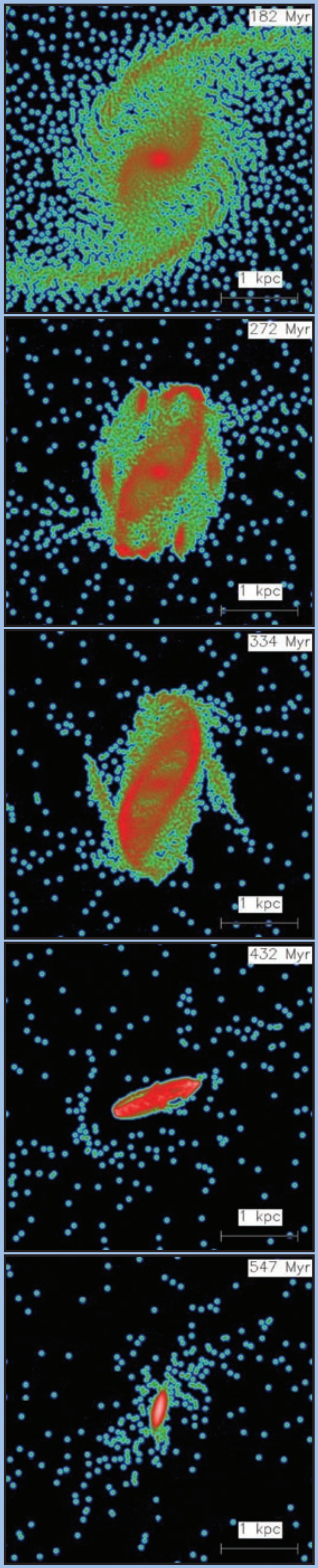
However, a quasi-star’s dazzling brilliance lasted only a few thousand years. Even the inefficient nuclear reactions that started within the typical quasi-star weren’t strong enough to counter the intense gravity it experienced and inflate its core. Instead, as the core got more compressed, it continued to get denser and hotter. Soon, the core got hot enough to radiate neutrinos, which caused it to lose its internal pressure. The core then collapsed into a black hole with a mass equal to 10–20 Suns.

The newly formed black hole was surrounded by most of the mass of the quasi-star — equivalent to at least 1000 Suns. The black hole started swallowing this material at an incredible rate. However, some of the matter falling toward the black hole grew hot and energetic enough to escape the black hole’s gravitational pull. This escaping matter puffed up the quasi-star, expanding it at least a hundredfold (from its original diameter the size of Earth’s orbit) in a period of only 10–20 thousand years.

As the quasi-star expanded, it became cooler, forming a yellow giant star composed entirely of hydrogen and helium. Eventually, the nearby black hole overwhelmed its ability to radiate away energy, and the quasi-star began to evaporate. Just before it evaporated, the quasi-star would have had not only a predictable spectrum, but also a well-defined temperature somewhat

Bars within Bars

Stills from a simulation of the “bars within bars” process.



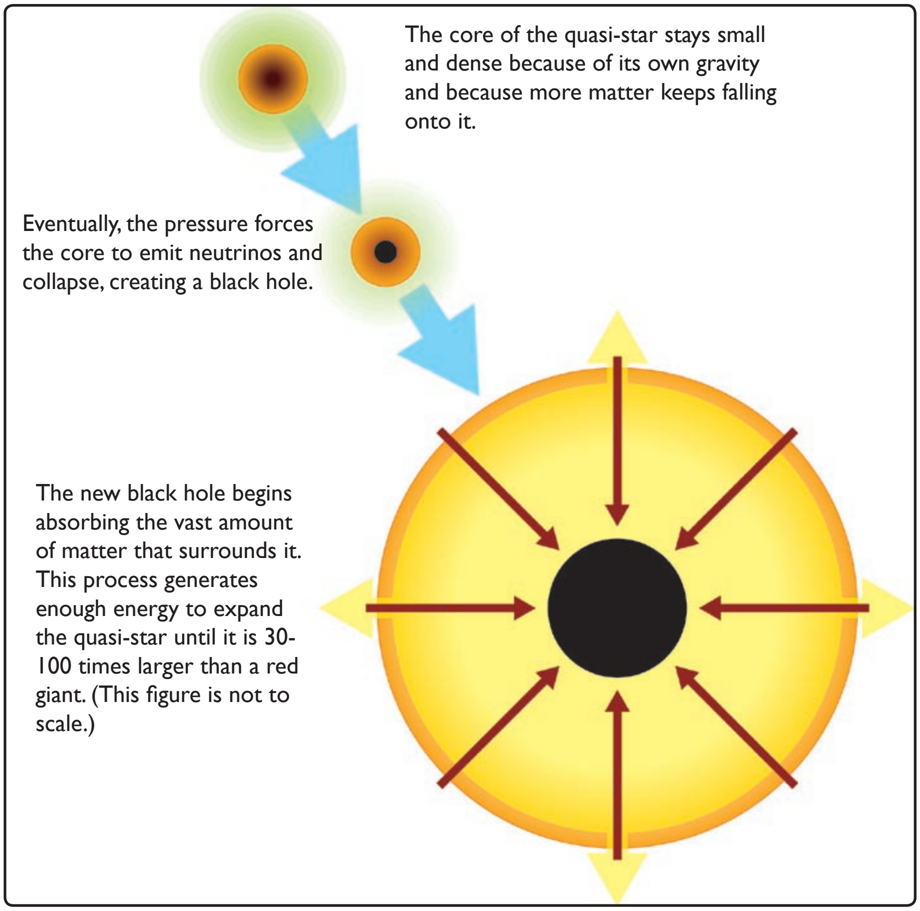
Credit: Peter Englmaier & Isaac Shlosman below that of the Sun's surface. The evaporation of the quasi-star slowed the growth of the black hole, which by then had a mass between 10,000 and 100,000 Suns — a very large seed indeed at the center of every galaxy in the Universe.

Thus, according to Begelman's theory, were sowed the seeds for the creation of supermassive black holes. The good news is that the new theory predicts that the James Webb Space Telescope, scheduled for launch in 2013, should be able to detect and identify the remnants of the ancient yellow giant quasi-stars in nearly every field of view of its infrared telescope. At high redshift, the giant yellow stars will look like pure radiating black bodies, says Begelman.

References:

Isaac Shlosman, Juhan Frank, and Mitchell C. Begelman, *Nature*, **338**, 45 (1989).

Mitchell C. Begelman, Marta Volonteri, and Martin J. Rees, *Monthly Notices of the Royal Astronomical Society*, **370**, 289 (2006).



The core of the quasi-star stays small and dense because of its own gravity and because more matter keeps falling onto it.

Eventually, the pressure forces the core to emit neutrinos and collapse, creating a black hole.

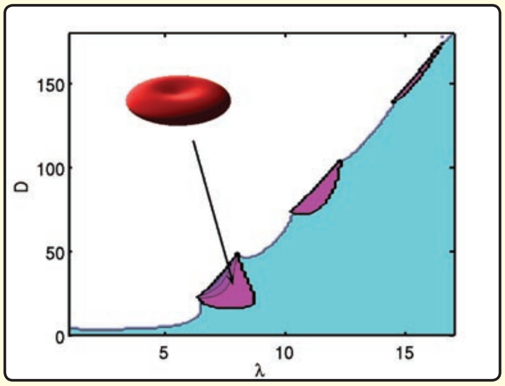
The new black hole begins absorbing the vast amount of matter that surrounds it. This process generates enough energy to expand the quasi-star until it is 30-100 times larger than a red giant. (This figure is not to scale.)

BEC Pancakes

Pancakes of Bose-Einstein condensates (BECs) of polar molecules are repulsive and potentially unstable. However, the physics of these dipolar condensates is delicious, according to research associate Shai Ronen, graduate student Daniele Bortolotti, and Fellow John Bohn. The JILA theorists recently studied BECs with purely dipolar interactions in oblate (pancake) traps.

The researchers discovered that if you keep adding more and more atoms to dipolar condensates of ^{52}Cr, the condensates will eventually become unstable and collapse into a blob of metal after ejecting high-energy atoms. However, the flatter the pancakes (traps), the more atoms they can hold before the condensate collapses. This relationship is evident in the figure at right. As the trap becomes flatter (moving to the right along the horizontal axis), the number of atoms present in a stable condensate increases (vertical axis). In the figure, the blue area is the region where stable condensates form, while the white area is the zone of instability, where collapse is inevitable.

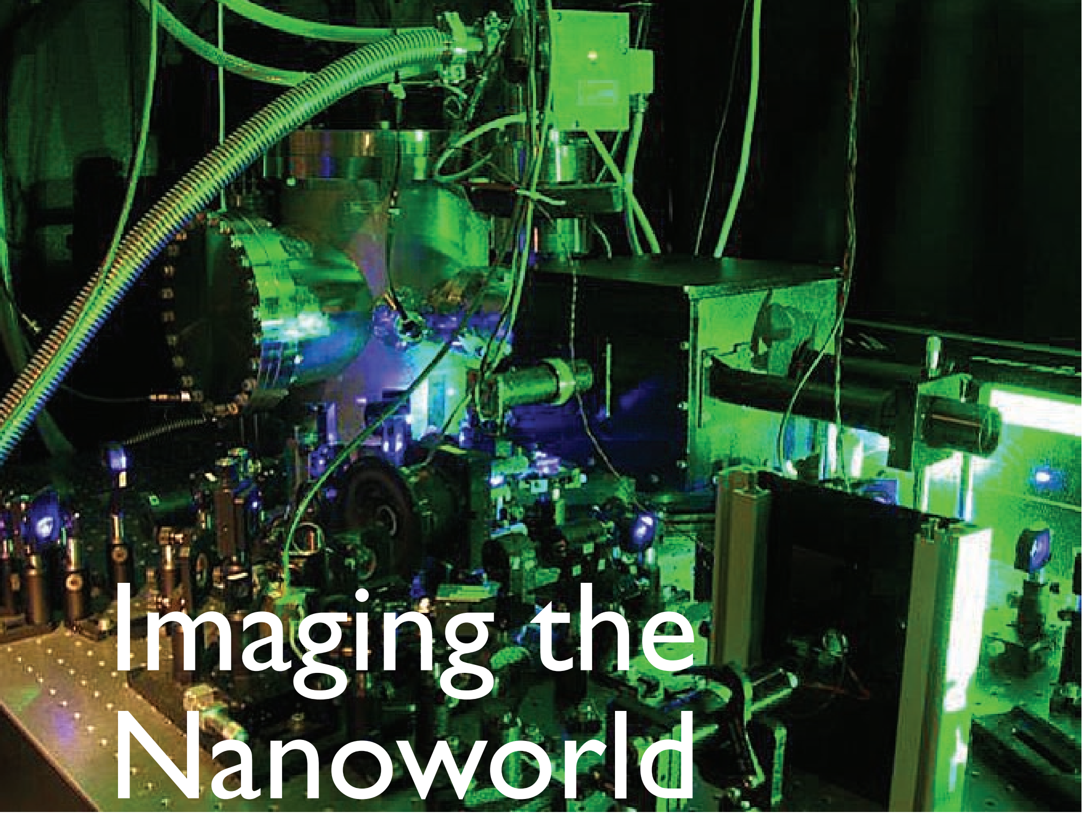
The theorists were surprised to find that, under certain circumstances, the wave function of a dipolar condensate starts looking a whole lot like a red blood cell, with a region of lower density in the center of the gas. This phenomenon repeats itself in a distinct pattern as the trap becomes increasingly oblate, as shown in the figure. The researchers believe this behavior is caused by repulsive long-range interactions of the atoms in the condensate. What they don't yet understand is why most of the time, the dipolar condensate has a single maximum in the center, but sometimes it morphs into the red-blood-cell shape, with its maximum density along a ring.



Interestingly, the two different condensate shapes collapse in different ways. When a "normal" condensate begins to collapse, density fluctuations move out symmetrically from the center like waves. In contrast, a red-blood-cell-shaped condensate begins to exhibit azimuthal density fluctuations around its perimeter, breaking the cylindrical symmetry and causing the ring to buckle. Explaining these and other exotic behaviors of dipolar condensates should keep theorists busy for some time. At the moment, they're predicting that sometime soon, experimentalists will observe dipolar condensates shaped like red blood cells.

Reference:

Shai Ronen, Daniele C. E. Bortolotti, and John L. Bohn, *Physical Review Letters*, submitted.



Imaging the Nanoworld

If you want to “see” physical objects whose dimensions are measured in nanometers and simultaneously probe the electronic structure of the atoms, molecules, and surfaces populating this nanoworld, you just might have to invent a new microscope. In fact, that’s exactly what Fellow David Nesbitt’s group recently accomplished. Oliver Monti, a former JILA postdoc currently at the University of Arizona, graduate student Tom Baker, and Nesbitt have invented a microscope capable of analyzing the make-up and properties of nanoscale electronics and nanoparticles.

The group’s new scanning photoionization microscope (SPIM) is shown above. It includes an optical microscope in a vacuum chamber and an ultrafast laser, which appears blue in the foreground. It combines the high spatial resolution of optical microscopy with the ability to detect low-energy electrons emitted by a material illuminated with laser pulses.

The ability to monitor photoelectron emission should make it possible for the microscope to detect electronic patterns in devices such as nano-scale transistors or electrode sensors and to identify their chemical constituents. At the same time, the new microscope can make a physical picture of the tiny structures.

“You make images by virtue of how readily electrons are photoejected from a material,” Nesbitt explains. “The method is in its infancy, but nevertheless it really does have the power to provide a new set of eyes for looking at nanostructured metals and semiconductors.”

The Nesbitt group recently confirmed the accuracy of its new technique in comparisons of SPIM images of nanostructured gold films with scans made using atomic force microscopy. They also determined that SPIM images can detect spikes in electron energy, or current, with sufficient resolution to detect variations in material thickness and estimate the depth of electrons escaping from a metal sample. The group is currently working on enhancing SPIM to make chemically specific images.

Reference:

Oliver L. A. Monti, Thomas A. Baker, and David J. Nesbitt, *The Journal of Chemical Physics*, **125**, 154709 (2006).

Kudos to...

Julia Bachinski for receiving the 2006 NIST Bronze Medal for excellence in administrative support of science at JILA.

Jim Faller for receiving a 2006 Presidential Rank Award in the Meritorious category. The award recognizes exceptional long-term accomplishments in public service by career senior government executives.

Jun Ye for receiving NIST’s Samuel W. Stratton Award in recognition of his work on femtosecond comb technology, which merges time- and frequency-domain spectroscopic techniques. The new technology has laid the foundation for a new generation of optical atomic clocks.

Jun Ye for receiving the American Physical Society’s 2007 I. I. Rabi Prize “for advances in precision measurement, including techniques for stabilizing and measuring optical frequencies, controlling the phase of femtosecond laser pulses, and measuring molecular transitions.”

Debbie Jin for being selected as a 2006 Fellow of the American Association for the Advancement of Science (AAAS). She will be recognized for her contributions to science and technology at the annual meeting in San Francisco in February and awarded a blue and gold rosette as symbol of her distinguished accomplishments.

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