O R I O N

Newsletter of the
Friends of Astronomy
Cornell University

Dear Friends,

It was a great pleasure for all of us to see so many of you at the October Symposium organized by Yervant and Patricia. We heard first-hand about the continuing discoveries being made in our solar system by Cornell astronomers and students, and even a little bit about what we are learning about planets around other stars. We also heard about our Department's next major project–plans for the construction of a world-class 25 meter (that big!) telescope at a high altitude site in Chile. This telescope, operating at long infrared and short microwave wavelengths will give us unprecedented insight into the early Universe and into the distant reaches of our own Solar System. With our partners, Caltech and the Jet Propulsion Laboratory, we are just completing the first phase of the project. Everything looks good so far, but we and our partners face the daunting task of raising the $100M that is needed to make the telescope a reality by 2012.

With the end of the year approaching, I want to express our sincere thanks for all the interest and support provided by you, our Friends of Astronomy, in 2005. Astronomy at Cornell is doing great, and you, our Friends, continue to play a significant role in our success.

Thank you and the very best of happy holidays to each and all,

Joe Veverka

The Mountains of Creation as seen by Spitzer.
Harvard-Smithsonian CfA, JPL-Caltech, NASA.

Greetings

Dear Friends of Astronomy:

Another year is coming to a close, and looking back we are happy to see that our October Symposium for the Friends on *Adventures in the Solar System* was a great success with about 50 Friends attending. The next opportunity to get together is June 2-3, 2006 to attend the Hans Bethe Centennial Symposium on Astrophysics. This meeting is hosted by the Departments of Physics and Astronomy to celebrate Bethe's extraordinary career. Four main sessions have been scheduled on (a) Supernova observations and theory, (b) Neutrino astrophysics, (c) Compact objects, and (d) The future of high energy astrophysics. On Friday, June 2, a reception and banquet are being organized. All speakers have been confirmed and include Kip Thorne from Caltech, Bob Kirshner from Harvard, Roger Blandford from Stanford, Rashid Sunyaev from the Max Planck Institute in Germany, and Mike Turner from Chicago. This is an exiting

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Winter 2005

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Meet the Friends!

It's always fun to be around Mark and Joyce Cascella—you're either laughing or enjoying a great conversation, or both!

Q: How did you become interested in Astronomy and Space Sciences? How did you become involved with the FoA?

A: Joyce and I attended several three-day programs by Cornell Adult University. One featured Yervant's infectious enthusiasm on all subjects cosmological, and very understandable presentations by Cornell professors and guest speakers from NASA, JPL, and elsewhere, regarding their latest scientific work. Excellent! What a pleasure to finally see and hear a substantive and literate explanation of why the topics were important, how the research was performed, what were the findings, and the importance of the new discoveries, with the opportunity thereafter to ask questions. What a pleasure to see animations and scores of detailed photographs from Cornell's Hubble, Mars, and Deep Space projects, rather than the one or two poor resolution images shown on television or in newspapers, with explanations too simplistic and too brief. We saw the latest high-resolution results long before the media deflated them. Better yet, we understood them. Best of all, we heard from the actual explorers themselves. It is like being a member of the geographical society in earlier centuries, sharing first-hand accounts of expeditions to never-before-seen reaches of mountaintops, deserts, jungles, and the high seas.

Q: What have been your most memorable experiences with the FoA?

A: We heard and saw symposia held at Cornell and elsewhere, like the Kitt Peak National Observatory in Arizona, where we also saw some of the latest telescopes up-close. There are always great side trips, expertly guided by Cornell professors, both fun and educational, like the world's largest telescope mirror factory (no quiz afterwards) and the desert, flora, and fauna around our dude ranch accommodations near Kitt Peak. Loved the star- and satellite-gazing. Despite the spectacular science, the best experiences have been meeting and becoming friends with many fellow FoA. What interesting people they are! Dinner party conversations cover all topics and viewpoints with animated conversations.

Q: What do you value most in the FoA?

A: New friends and new thinking.

Q: What activities or programs would you like the FoA to organize?

A: (1) Don't know if you can arrange a trip to clear-skies to coincide with the Perseids, Leonids meteor showers, or a similar event. We cannot see anything from New Jersey or Ithaca, or most of the light-polluted east coast. I grew up in Newark, thinking the only three stars one could see were those in Orion's belt. No surprise when the starship Enterprise visited planets with red skies; Newark had that yellow-orange HPS glow overhead all night!

(2) How about an optional half-day presentation for the truly whacked, while the others get a nice tour or a three-hour shopping event at the Cornell Store. Truly whacked topics include:

Discussion of Brian Green's new book, *Origin of the Cosmos*, with emphasis on later chapters, like String versus M Theory versus Branes versus High Gravitation. Rutherford said atoms were like plum pudding, a sufficient simile for his time. Is string theory just a simile for our time, or is it real?

Quantum Physics 101, 201, and 301, abridged. Black holes evaporate, says Quantum Physics. Why? String theory works, due to Quantum Physics. Why? Uncertainty Principle works because of Quantum Physics. Why? Bohr Theory of the atom is unstable; yep, Quantum Physics. Why? Electrons aren't here and they aren't there, and what became of them? Quantum Physics. Why?

Congratulations!

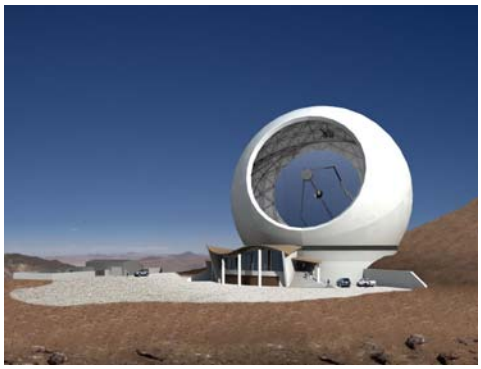
In recognition of more than 50 years of service to Cornell, Friends of Astronomy Chuck and Carol Mund received the Frank Rhodes Exemplary Alumni Service Awards on Friday, October 14. Congratulations!

Martian Anniversary

On Friday, November 18, we celebrated Mars Exploration Rover Spirit's first Martian Anniversary. That's right, it was 687 Earth days since Spirit began exploring the surface of Mars! Thanks to dust devils that cleaned off their solar panels, Spirit and its twin, Opportunity, have continued to provide scientists with a wealth of clues about Martian geography, geology and climate for much longer than expected. In its first Martian year, Spirit has found evidence of Mars' wet past in the Martian soil and rocks. It also photographed Mars' moons Phobos and Deimos, looked for evidence of nighttime clouds or haze and provided information helpful to understand large dust storms and how Mars became a dust-covered red planet.

The Atacama Telescope

An old, good friend of mine refers to me as "Don Q.", for my proclivity to engage in uphill battles of the kind an imaginary Spanish gentleman was reported to fight against windmills. My current battle is that of bringing a beautiful project to fruition: to build the best, highest, most sensitive instrument to investigate cosmic origins by the year 2012. I fortunately am not alone in fighting this battle, for all my colleagues in the Astronomy Department have endorsed it as the "numero uno" priority for our near future, and many contribute to the effort in a variety of ways: Yervant started the ball rolling with a hefty contribution from the departmental funds, when he was Chairman; Joe with strong, untiring support in dealing with the University and our colleagues at large; Terry and Gordon in being driving forces towards the development of the science case and instrumental needs for the initiative; and many others, in many ways large and small. Yet we wouldn't have moved as far as we have, without the enthusiasm and generous suport of the Friends of Astronomy, particularly Fred Young's.



A computer generated rendition of the Cornell-Caltech Atacama Telescope.

We call the project CCAT, Cornell-Caltech Atacama Telescope, because the plan, started by us at Cornell, is now an equal partnership between the two institutions. Last year we hired a talented and energetic Project Manager, Tom Sebring, and just as talented a Deputy Project Manager, Simon Radford. They have given the project an injection of "traction", which has delivered most satisfying results: we are now confidently looking forward to a succesful review of the Feasibility Phase of the project by a blue-ribbon panel. That review will be held in mid-January 2006.

The summit of Licancabur (19,600 ft.) seen from the Valle de la Luna (Valley of the Moon).

CCAT will be a telescope sensitive to light with wavelengths longer than 200 microns, or 1/100 of an inch. These wavelengths (called far-infrared or sub-millimeter) are too long to be perceived by the human eye, but are much shorter than the waves that transmit radio and television signals. The telescope will have a diameter of 25 meters, about 82 feet, and it will be enclosed within a dome. It will be located at a very high site (about 18,000 feet above sea level) in the high Atacama Desert of Chile. The driving reason for that choice is that we seek as dry an atmosphere as possible, and water vapor content diminishes quickly with increasing elevation. If mountains rise above a desert, we have the ideal combination.

The CCAT is designed to optimize our ability to study the genesis of structure in the Universe. It will allow us to explore the process of formation of galaxies, which saw its heyday about a billion years after the Big Bang, some 13 billion years ago; to peek into the interior of the dusty molecular clouds within which stars and planets form; to survey the pristine chunks of material left intact for billions of years in the outskirts of our Solar System. In doing so, CCAT will take advantage of the "coming of age" of new, far infrared detector technology. While leading-edge far infrared cameras currently have a few hundred pixels, the technology is evolving so fast that, by the time CCAT starts operation, we will be able to build far infrared cameras with tens of thousands of pixels, dramatically increasing the mapping potential of the telescope.

By a fortunate circumstance, the best home for CCAT happens to be in one of the most wildly beautiful regions of Earth, and in a country that has made a strong commitment to the development of international astronomical science. The future telescope site is within the boundary of the protected "National Science Preserve," which was instituted by a decree of President Eduardo Frei Ruiz Tagle in the course of a ceremony attended by Martha Haynes, as representative of Associated Universities, Inc. (I was also invited as representative of Cornell, but could not attend and missed my chance to be kissed by a President; Martha was).

Martha Haynes with President Frei and E. Hardy during the ceremony at which Frei created a "National Science Preserve" in the Chajnantor region.

The ground you step on in Atacama is "Earth in the making", barely 10 million years old or so. So barren and yet so varied in color and topography, so raggedly beautiful that it has beed dubbed as "a playground for curious adults." Near the border at which Chile, Argentina and Bolivia meet, Atacama has been a crossroads of civilizations throughout its history. The nearest inhabited center to the telescope site is the village of San Pedro de Atacama. Through it, the early settlers of

Continued p. 4

Cosmic Gamma Ray Bursts

In August, 1963 President Kennedy and Premier Krushchev signed the Limited Test Ban Treaty banning nuclear weapons tests "in the atmosphere, in outer space and under water." The treaty went into effect in mid-October, 1963—but contained no provisions for monitoring compliance.

The United States undertook the Vela satellite program for this purpose. (In Spanish, the verb *velar* means to watch.) The Vela satellites were launched in pairs, into orbits at opposite sides of Earth in high altitudes, about 100,000 km. The first pair was launched about a week after LTBT took effect. They carried 12 X-ray detectors and 18 internal neutron and gamma ray detectors. The Vela satellites were designed to detect nuclear explosions on Earth or in space as far away as Venus or Mars. In time, several pairs of Vela satellites were launched. None ever saw an explosion on Earth.

With the launch of Vela 3 in 1965, Ray Klebesadel of Los Alamos began to record events that triggered the on-board X-ray and gamma ray detectors but were demonstrably not nuclear weapons detonations. (It is relatively easy to recognize these from the spectra of X-rays and gamma rays they emit.) The Vela 5 and 6 satellites were able to record the times of detections of gamma rays accurately, and this enabled determination of the positions of their source on the sky using time delay across their orbits and "triangulation." In this way, Klebesadel, Ray Olsen and Ian Strong were able to announce the discovery of cosmic Gamma Ray Bursts in 1972, in a paper that detailed the properties of about 16 such events discovered from about 1969 (launch date of Vela 5).

These cosmic bursts are remarkable because the bulk of their energy is emitted in gamma rays. For reference, the visual electromagnetic spectrum corresponds to photons—light particles—whose individual energies are about one electron volt; the electromagnetic spectrum of the Sun peaks at about 1.5 electron volts, and even the hottest ordinary stars are only slightly stronger. The energy of a photon that can ionize hydrogen, the most abundant chemical element, is 13.6 electron volts. In contrast, the spectra of cosmic Gamma Ray Bursts (GRBs) peak at around one million electron volts—1 mega electron volt or 1 MeV!

The most intense phase of emission by cosmic GRBs is incredibly short-lived. There turn out to be two different classes. Short GRBs only last a fraction of a second, and may be as short as a few milliseconds in duration. Long GRBs last a few seconds to a minute or so. Something goes BANG, and a lot of gamma rays are emitted very quickly.

From their discovery, it was evident that the GRBs were distributed evenly on the sky. In 1973, when I was a MIT senior, I heard the recently deceased Phil Morrison—famous as the voracious book reviewer at *Scientific American*, MIT Institute Professor of Physics, and before that, a renowned astrophysicist at Cornell—conclude this from the first 16 bursts reported. This observation means that either the bursts came from very nearby, or from cosmological distances, since for any distance in between we ought

Continued p. 8

The Atacama Telescope

(cont.)

The church of San Pedro de Atacama, built in 1774 over the ruins of a sixteeenth century church.

the southern cone of America transited more than 10,000 years ago. The Incas invaded 600 years ago, seeking mineral wealth. The Spaniards did the same 100 years later. The house built in the 1540s for the first Spanish conquistador, don Pedro de Valdivia, still stands in the square of San Pedro. A wealth of archeological remains dot the region, well preserved by the dry climate. I cannot imagine a better place for having one of the next Friends of Astronomy meetings. I hope to see you there soon.

-Riccardo Giovanelli

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Barbara Asks!

Q. How did Hubble conclude that the Universe is expanding?

A. You might say that the time was right for Edwin Hubble to deduce that the Universe was expanding. In 1908, studying periodic variable stars in the Magellanic Clouds, Henrietta Swan Leveatt of Harvard found a relationship between their apparent brightness and period. (Periodic variable stars vary in brightness in a regular fashion and the period is the time for the star to brighten, dim, and brighten again.) Within a decade (1916), Harlow Shapley, also of Harvard, had calibrated this relationship to determine the absolute brightnesses (magnitudes) of several variable stars. Using the 100-inch telescope on Mount Wilson, Hubble found the same variable stars in the then so-called spiral nebulae, M31 (Andromeda galaxy) and M33 (Triangulum Galaxy). He was able to deduce their distance from the period-luminosity relationship and announced in 1925 that they were separate entities from the Milky Way, that is, they were galaxies in their own right. This, in itself, was a breakthrough of truly astronomical proportions and changed forever our perception of the Universe and our place in it. Suddenly we realized that the Universe was enormously larger than we had thought.

Meanwhile, other research on spiral nebulae had been proceeding along a different line.

Vesto Slipher of Lowell Observatory in Flagstaff, Arizona, was noted as a pioneer in spectroscopy and had determined the rotation periods of Venus, Mars, Jupiter, Saturn, and Neptune using the well known physics Doppler effect. In addition, he had also made measurements of spiral nebulae. By 1914, Slipher's results were showing that most of these nebulae were moving away from us with large velocities. This was investigated further by German astronomer C. W. Wirtz, who concluded in 1922 that these spiral nebulae were receding from the Sun. Based on the theoretical work of Willem De Sitter of the Leiden Observatory that suggested a systematic displacement of spectral lines for distant nebulae, Wirtz investigated the possibility that the recessional velocity of spiral nebulae might be a function of distance (the larger the distance, the smaller the angular sizes of the nebulae should look). However, when he tried to correlate velocity with angular diameter, he found no correlation. Attempts to do this by others again met with failure because there were no reliable distances to these spiral nebulae.

Finding distances to spiral nebulae is what Edwin Hubble did! By 1929, using a combination of variable stars, the brightest stars in galaxies, and the brightest galaxies in clusters of galaxies, Hubble had measured distances to a number of galaxies with velocities. He found not only that galaxies are moving away from us, but that their recessional velocity increases with increasing distance. We now call this linear relationship between distance and velocity Hubble's law, and the constant of proportionality is designated by the letter *H* in honor of Edwin Hubble. Hubble's law is one of the fundamental underpinnings of modern cosmology forcing us to realize that the Universe is not static and forever unchanging.

Hubble was a very skilled and careful in his work. Although some of the pieces were available to others, it was Hubble who had the insight to look for variable stars in spiral nebulae, conclude that these were indeed galaxies, and determine that they were moving away from us.

-Barbara Burger (for the question)
-Terry Herter (for the answer)

Hubble's original plot relating distance and velocity for galaxies and a modern version of it (Edwin Hubble, "A Relation between Distance and Radial Velocity among Extra-Galactic Nebulae," 1929, *Proceeding of the National Academy of Sciences*, vol. 15, pp 168-173, and Jerome Kristian et al., "The Extension of the Hubble Diagram. II. New Redshifts and Photometry of Very Distant Galaxy Clusters" 1978, *The Astrophysical Journal*, 221, p. 389).

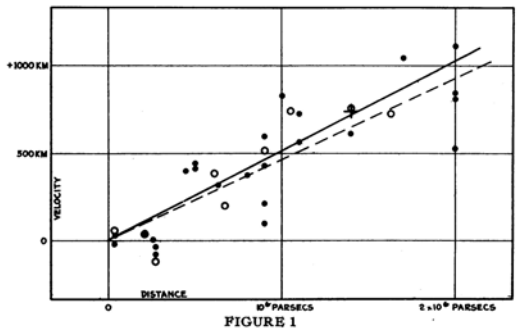
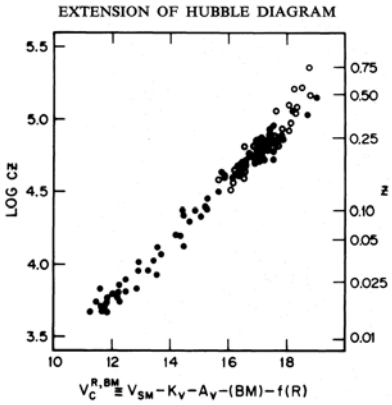


FIGURE 1
Velocity-Distance Relation among Extra-Galactic Nebulae.



The Friends Symposium on Adventures in the Solar System

It was busy in the Space Sciences Building last October 7, 8 and 9. The weather was rainy, but that didn't stop the Friends of Astronomy from arriving to attend a weekend of fascinating scientific talks preceded and followed by opportunities to mingle with good friends and meet new ones. The event began Friday with a reception and dinner that was capped by a presentation on extra-solar planets by Jamie Lloyd, who recently joined the faculty of the Department of Astronomy. The next day we listened to exciting talks on a variety of topics concerning our Solar System including, among others, our projects on Mars, Saturn, its rings and satellites, and the composition of comets. We also had a stimulating discussion about the possibility of life in other planets. The day ended with Friends and faculty gathering for another reception and dinner at the Statler. Jean-Luc Margot, also a recent faculty member, brought our thought-provoking day to a close with a talk about the Kuiper Belt objects, which orbit our Sun beyond Neptune's orbit.

On Sunday, a number of us met at the Ornithology Lab, where John Fitzpatrick, the director, gave us a wonderful tour, complete with an opportunity to see and hold specimens collected by Louis Agassiz Fuertes in the 1890s and an ivory-billed woodpecker collected in Cuba in the 1920s.

It was a delighful weekend and until next time, we can only say, Come back soon!

-Yervant Terzian and Patricia Fernández de Castro

Dan Wilcox

Next page, clockwise, from top left:
Nancy Bellamy, Vanne Cowie, Bob Horn, Joan Horn, Carolyn Sampson
Fred Young, Bob Cowie, Bill Bellamy
John Timmerman, Paul Jones
Jean-Luc Margot, Sandy Bricker, Jeff Bricker
Carolyn Sampson, Yervant Terzian
Lee Corbin, Nancy Corbin, Chuck Burger, Barbara Burger
Bryan Patten, Richard Levao
Jeff Bricker, Bob Cowie, Albina Janus
Jim Myerberg, Yervant Terzian, Ellen Myerberg
Photography,
Phil Handler
(except picture of the Corbins and the Burgers, Yervant Terzian).

For pictures of the Friends, visit

<http://www.astro.cornell.edu/people/friends/photos.php>

To update your e-mail

Send a note to
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The New Frontier

Oh Yeah it's pretty clear Space is now our new frontier
Oh Yeah it's really so There's so much we still don't know

astronomy keeps dazzling us ever since Copernicus
who said the earth went round the sun shocking nearly everyone
the earth was not a special place just a pale blue dot in space
then Galileo caused a stir finding moons of Jupiter
rings on Saturn? What would be the next celestial heresy?
Oh Yeah just goes to show There's so much we still don't know

Newton watched an apple fall and changed the laws once and for all
his physics would be so far-ranging heaven's laws, once thought unchanging
now were just the same as *ours* we're related to the stars
Oh Yeah just goes to show There's so much we still don't know

when Kepler came, to much dismay, the circle, too, became passé
a former theory in eclipse planets moving in ellipse
Hubble made it even worse looking at the universe
altering our understanding nothing's static – all's expanding
Maxwell too astonished us with his field hypothesis
Einstein's relativity added to the mystery - and our curiosity
Oh Yeah, just goes to show There's so much we still don't know

through advanced technology we've enlarged what we can see
we got the Spirit and then we got the Opportunity.
Some observers think we oughta find the planet once had water -
if water's what the Rovers find can Martian life be far behind?
Oh Yeah, just goes to show There's so much we still don't know

astronomers have now just seen a novel object they
call Xena
(that's its nickname – formally it's called UB 3-1-3)
and they'll discover other things like just why Saturn has its rings
and they landed Huygens *right 'n* Saturn's largest moon called Titan
Deep Impact showed to you – me? – us a comet's icy nucleus
who knows what's next, a black hole's *rim? it* surely seems the sky's the limit!
First the Moon, then was Mars, several visits, soon the stars
other planets, other places, someday, maybe other faces

Oh yeah, just goes to show Tho *there's* so much we *still* don't know
It's becoming pretty clear Space is now our new frontier

Barbara Burger

to see some preference for one direction or another. For example, if they were distributed like stars, we ought to be able to detect the disk of our Galaxy in their distribution on the sky, or if they were in the halo of our Galaxy, we ought to be able to discern that they were centered on the Galactic center.

The Compton Gamma Ray Observatory—one of NASA's great space observatories—was expected to decide where the bursts were coming from by seeing a preferred direction. Before its launch, most astrophysicists thought the bursts were going off in our Milky Way Galaxy, and that Compton GRO would show that definitively. There was one lonely exception to this consensus—the late Bohdan Paczynski of Princeton, who proposed that bursts were at extragalactic distances, and hence would exhibit no preferred direction in space. Compton GRO, which detected about a burst per day for a total of a few thousand bursts, showed that Paczynski was right. GRBs are at least overwhelmingly extragalactic.

This conclusion was reinforced by the Beppo-SAX satellite, which was principally an X-ray satellite but had on-board gamma ray detection capabilities. Beppo-SAX found X-ray counterparts to GRBs beginning in 1997. This discovery was critical because X-ray imaging is far more accurate than is possible in gamma rays, so the positions of the bursts could be nailed down. In this way, it became possible to identify not only the X-ray emission of a burst, but also its optical, infrared and radio emission, which was found to last for months after the original burst. Redshifts could be measured for some bursts, and they turned out to be high (one or above), indicating a cosmological origin. GRBs were ocurring far away from our Galaxy.

The energies associated with GRBs are therefore gargantuan. At the Hubble distance (ten billion light years away), a typical GRB emits about 10^{51} ergs (one followed by 51 zeroes) in gamma rays, in a time span of at most a minute or so, and often much shorter. There is also strong evidence that this energy is not emitted equally in all directions by a burst, but is shot out in relatively narrow beams. Beamed or not, this represents prodigious emission: our Sun will emit about the same amount of energy over its entire projected lifetime of about 10 billion years! Not only that, but these gigantic energies make GRBs the most energetic phenomena in the Universe, only rivalled by supernovae, which release about the same amount of energy.

Most astrophysicists now believe that the two classes of bursts, long and short, originate in different explosive events. The long bursts are thought to be triggered by a gravitational collapse to a black hole, an event that can be accompanied by a particular type of supernova explosion, and, more importantly, by the formation of a short-lived disk around the newly minted black hole. Jets of electromagnetic radiation, fields and particles can be shot up out of the disk and produce the gamma ray emission. (Cornell's Richard Lovelace and Marina Romanova are world experts in these kinds of magnetohydrodynamic phenomena, as is Roger Blandford, the 2005-6 Thomas Gold Lecturer.) Short bursts are thought to be triggered by the collision of a pair of neutron stars in a binary star system that has shrunk down to an orbital radius of only 20 or 30 km. Binary star systems with pairs of neutron stars are known to exist, and the shrinking of their orbits has been measured, although for the observed neutron star binaries, the shrinkage is still very slow. (The first such system was discovered at the Arecibo Observatory by Russell Hulse and Joseph Taylor in 1974, and eventually earned them the Nobel Prize in Physics.) The rate of shrinking accelerates as the orbit gets smaller, and since neutron stars have radii of about 10 km apiece, this must ultimately lead to a spectacular collision whose most active phase ought to last no more than a few tens of milliseconds. (Cornell astrophysicists Eanna Flanagan and Saul Teukolsky are, by the way, world leaders in the study of different aspects of neutron star binary collisions.)

Given that we detect about one GRB per day, we can deduce that they occur at a rate of about one per million years or so in a typical galaxy such as our own. In other words, over a time of about 10 billion years, the lifetime of our Sun, about 10,000 GRBs ought to explode in our own Galaxy. If these are distributed at random over the disk of our Galaxy (a reasonable but not definitely correct supposition) then over the lifetime of the Sun, the closest burst would be a few hundred parsecs away (i.e., maybe a thousand light years away). Even at such a great distance, the results would be catastrophic for Earth: the incident gamma rays would destroy the ozone layer. Clearly, no such event has occured this close during the much shorter time during which human beings have populated our planet—and fortunately we know of no nearby astronomical objects that are likely to produce cosmic GRBs any time soon! However, the less energetic cousins of GRBs, the so-called soft gamma repeaters, do pop off repeatedly in our Galaxy (or in the Magellanic Clouds), and. As recently as December 2004 an unusually energetic soft gamma repeater did alter the ionosphere of Earth considerably, but, fortunately, temporarily. Nevertheless, such events—no matter how harmless in the long run—remind us that we live in a larger cosmos that is often violent and dangerous.

-Ira Wasserman

meeting, open to all, which you are very welcome to attend. To register, please visit the web site <http://astro.cornell.edu/~dong/bethe.htm>. Under 'Affiliation,' enter 'Friends of Astronomy.

We wish you Happy Holidays and a Great Year ahead!

Cordially,

Yervant

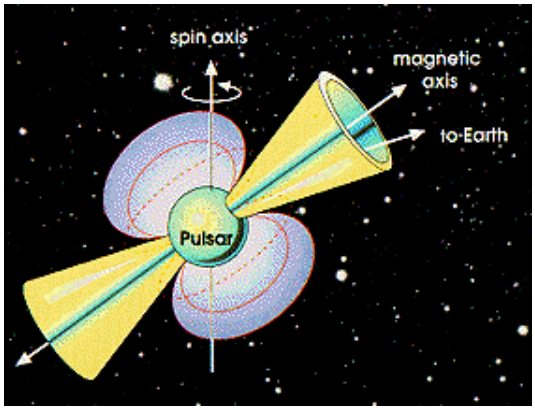
Listening for Stellar Heartbeats

Born in Russe, Bulgaria, Julia Deneva has never grown out of her dream of being an astronaut, and in her ever-shrinking spare time writes poetry.

"Happy hunting!" says my roommate as I am about to fly out to Puerto Rico for an observing run at the Arecibo telescope. My game is fascinating but elusive: as part of my astronomy studies, I hunt for pulsars. I am a member of the Pulsar-ALFA consortium, a group of astronomers from around the world who collaborate on finding and studying pulsars with the new ALFA receiver, which was installed in 2004 on the Arecibo telescope. Currently the P-ALFA survey is combing the region of the Galaxy visible from Arecibo and has already found 20 new pulsars. Hundreds remain to be discovered.

Pulsars are the "life after death" stage of stars more massive than our Sun but not massive enough to produce a black hole. Massive stars live in the fast lane: just like the Sun, they produce energy by hydrogen fusion in their cores, but because their strong gravity compresses material in the core and makes it hotter, the hydrogen burns out more quickly. For hefty stars, the hydrogen-burning period is followed by burning of other elements, and the final outcome is a spectacular supernova explosion that can outshine a galaxy and expels most of the star's matter into space. What survives is the core: small, dense, hot, and in trouble.

While nuclear fusion goes on, the thermal pressure of the hot material pushing outwards balances gravity's pull inwards and the star is stable: it neither expands nor contracts. Once nuclear reactions cease, there is nothing to counteract gravity, and the leftover core starts contracting. As it contracts, its rotation speeds up, like a pirouetting ice skater who speeds up by pulling her outstretched arms inwards. Its surface magnetic field also grows stronger because the field lines are compressed into a smaller volume. And the compression of matter into an ever smaller volume increases the density and pressure to such extreme values that matter breaks down into its constituent electrons and protons, some of which are forced together to make neutrons. Eventually, quantum mechanical forces come into play and stop the collapse: the object has achieved new stability as a very compact (~10km in diameter), highly magnetic and fast-spinning neutron star with about 1.4 times the mass of the Sun and a density such that makes a cupful of material weigh millions of tons. Particles accelerated to speeds close to the speed of light by the magnetic field are flung along the magnetic field lines out of the magnetic poles of the neutron star and emit radiation, including radio waves which Arecibo can detect. Since the magnetic field axis may not coincide with the rotation axis and the neutron star spins very fast, an observer would see periodic pulses of radiation like from a lighthouse—the reason why radio-loud neutron stars are called pulsars.



An artist's depiction of a rotating magnetized neutron star or (pulsar). GSFC.

We look for pulsars exactly because of their extreme and exotic nature. It may be hundreds of years before technology is able to replicate in a lab the physical conditions which exist in a pulsar. But we don't have to wait that long to study the properties and behavior of this form of matter because pulsars are natural "laboratories." The proof of the existence of gravitational waves—ripples of space itself—came about from observations of a pulsar in a binary system with another neutron star. As the two stars orbit around each other, they slowly spiral inwards, which indicates that the system is losing energy. This loss can only be accounted for by gravitational wave emission—predicted by Einstein, and proven by Hulse and Taylor in the 1980s with observations made at Arecibo for which they received the Nobel prize in Physics. The opportunity for studying gravitation wave emission, among other relativistic phenomena, is what makes pulsars in tight binaries very valuable. But they are also rare: out of more than 1700 known pulsars, only about 100 are in binary systems, and in most of those the two companions are too far from each other for gravitational wave emission to be a significant effect. Binary pulsars have another quirk: they spin faster than isolated pulsars. The reason is that the pulsar is likely to accrete material from its companion, causing it to spin up. The fastest known pulsar has a period of about 1.5 milliseconds, while most known pulsars have periods of 0.2-1.2 seconds. If we could hear pulsars, a slow one would sound a bit like heartbeat, and a fast one like a buzzing bee <http://www.jb.man.ac.uk/~pulsar/Education/Sounds/sounds.html>.

Observing pulsar emission gives us clues about the physical processes that take place near the surface of or even within the

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Books in Science and the Universe

Divine Wind: The History and Science of Hurricanes by Kerry Emanuel, Professor of Earth and Atmospheric and Planetary Sciences (MIT), Oxford University Press, 2005.

Imagine standing at the center of a huge stadium 20 miles across with walls 10 miles into the sky, with cascades of ice crystals falling rapidly along its white vertical surface. That is how it is in the eye of a hurricane. Kerry Emanuel is a world authority on hurricanes. In his book Divine Wind he gives an engaging historical account on how hurricanes and typhoons have changed human history. He also offers an account of the physics and discusses how a tropical atmosphere gives rise to the most powerful storms.

Emanuel relates very interesting tales about the most important hurricanes in history, including the 17th century one that may have inspired *The Tempest* by William Shakespeare. The book contains some 100 illustrations, from modern photos of hurricanes taken from earth-orbiting artificial satellites to classic paintings by Winslow Homer.

-Yervant Terzian

Yervant's Critical Thinking Corner

–Do you believe in free will? We have to, we have no choice!

–Chance has its reasons.

–I had amnesia once –or twice?

–I used to be indecisive, now I am not sure.

–While informing the telephone company that the phone was out of order, the telephone clerk responded 'We'll call you when we are ready to come to fix it'.

–Someone won a one million dollar lottery that was paying one dollar per year for a million years!

–Someone talking to a nurse said 'I have never had knee surgery at any other part of my body'.

–All those who believe in psychokinesis, raise my hand.

–During a solar eclipse someone asked, 'And where is the Moon?'.

–If the sun is a star, why can't we see it at night?

–I am nobody, nobody is perfect, therefore I am perfect!

–What is a 'free gift'? Aren't all gifts free?

Bound for Pluto

The next issue of *Orion* will feature Ann Harch's work in NASA's New Horizons mission, which is due to launch in January of 2006 and will fly by Pluto and possibly two Kuiper belt objects in 2015.

Listening for Stellar Heartbeats

(cont.)

neutron star. Statistical studies of the pulsar population in the Galaxy estimate stellar formation rates. And finding pulsars with extreme characteristics—very short periods or very high masses—lets us probe the limits of the state of neutron star matter. The current pulsar mysteries to be solved include: how massive can a neutron star get, how fast can it spin without centrifugal forces breaking it up, how exactly is pulsar radio emission generated, and do elementary particles break down into their constituent quarks in the high-density interior of neutron stars?

After a week of pulsar hunting at Arecibo, the catch is good: one candidate that will hopefully be confirmed during the next observing run, and one new pulsar whose relatively short period means it may be part of a binary system. In-between observing sessions, I work on software to process the accumulated data in more detail and eventually make it and the results publicly accessible on the web. But the most tantalizing aspect of the work is the search and discovery. To me there is nothing else like the excitement of seeing for the first time the pulse signature of a previously unknown pulsar and determining whether it may not provide answers to some of the questions we have been asking for a long time.

-Julia Deneva