O R I O N

Newsletter of the Friends of Astronomy Cornell University

Dear Friends,

The Spring Semester is over and summer has come to Ithaca. Good things continue to happen for Astronomy at Cornell. We expect fascinating results from the Deep Impact encounter with Comet Tempel 1 on July 4, 2005, an exciting mission in which members of the Department are playing major roles.

The Mars Exploration Rovers continue to uncover clues about what Mars was like in the distant past. SPITZER continues to provide new insights into the evolution of stars and galaxies. Jim Houck, the Wallace Professor of Astronomy, has been awarded the NASA Scientific Achievement Medal for his development of one of the key instruments on SPITZER, the Infrared Spectrometer (IRS).

Recently, Steve Squyres has been appointed Goldwin Smith Professor of Astronomy and Planetary Science and has been elected to the Academy of Arts and Sciences, a prestigious organization dating back to the days of Benjamin Franklin and Thomas Jefferson.

The Department is welcoming a new outstanding Assistant Professor, Rachel Bean, an expert in cosmology, particularly the

Continued p. 2

An artist's rendition of the initial encounter between the Deep Impact spacecraft and Comet Tempel 1. Pat Rawlings/U. Md./ JPL/NASA.

Greetings

Dear Friends of Astronomy,

Many faculty and students in our Department have long been involved in exciting research to study details of our solar system, our home in the universe. At present, among other space missions, Cornell astronomers and students are involved in the exploration of Mars with robots, in examining the nature of comets with 'close encounters,' in studying Saturn, its rings and satellites with the Cassini spacecraft, and in assessing the possibilities of any form of life in the solar system away from earth. To present all these fascinating research missions to you, we are announcing a Friends of Astronomy Symposium on 'Adventures in the Solar System' that will take place on the Cornell campus starting Friday evening, October 7 and ending Sunday noon, October 9, 2005. Attached find a detailed program. Patricia Fernández de Castro is in charge of the Symposium arrangements and you will hear from her about the registration details.

Summer 2005

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Contents

Editor
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Dear Friends *(cont.)*

enigmas of dark matter and dark energy. Dr. Bean, a graduate of Imperial College in the UK, is joining us following a post-doctoral appointment at Princeton.

As many of you know, one of our most successful undergraduate teaching enterprises has been the Hewitt Laboratory. Thanks to the generosity of Friend of Astronomy Mr. Ed Hewitt (and with some help from the College of Arts and Sciences), we are replacing the computers in the Hewitt Laboratory with newer machines, which will enable us to keep the capabilities of the Laboratory up to date.

The Study Phase of the Atacama Project (a joint Cornell-Caltech endeavor) is proceeding well, with a major status review scheduled for mid-July. We are very grateful for the major support for the study that is being provided by another Friend of Astronomy, Mr. Fred Young.

As I already noted, there is growing excitement about Deep Impact, the first ever mission that will study the make-up and composition of the sub-surface of a comet. No one knows what we will find, but it is certain that there will be surprises. We hope that by the time many of you join us for the special Friends of Astronomy Symposium that Yervant has organized for October, we will have the results from Deep Impact figured out and will be able to tell you many new fascinating things about comets.

Have a pleasant and relaxing summer and think good thoughts about comets on the morning of July 4!

-Joe Veverka

ADVENTURES IN THE SOLAR SYSTEM

FRIENDS OF ASTRONOMY SYMPOSIUM

CORNELL UNIVERSITY

Friday, October 7, 2005
Space Sciences Building

02:00 to 4:30 pm	Open House
06:30	Reception and Dinner
	Planets Around Other Stars (J. Lloyd)

Saturday, October 8, 2005
Space Sciences Building 105

08:15 am	Coffee and Pastries
08:55	Welcome Back to Cornell (P. Lepage)
09:00	Planetary Exploration and our Department: Past and Future Projects (J. Veverka)
09:15	Our Star the Sun (Y. Terzian)
09:45	The New Mars (J. Bell)
10:15	Mars and Our Rovers (S. Squyres)
10:45	Coffee Break
11:00	Cassini and Rings Around Planets (J. Burns)
11:30	Titan Around Saturn (D. Campbell)
12:00	Lunch (Red Barn)
02:00 pm	Comets and Deep Impact (J. Veverka)
02:30	Life on Other Planets (J. Cordes)
03:00	Coffee Break
03:30	Questions and Answers
04:00	Meeting of the Friends of Astronomy
04:30	Adjourn
06:30	Reception and Dinner
	Asteroids and Kuiper Belt Objects (J.L. Margot)

Sunday, October 9, 2005

10:30 am	Ornithology Lab: Visit and Hike

WOULD YOU LIKE TO UPDATE YOUR E-MAIL?

Send a note to
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Greetings *(cont.)*

Fall in Ithaca is full of colors calling you back to campus. I hope you will be able to attend. Guests and other friends of yours are, as always, most cordially invited.

Hope to see you in October!

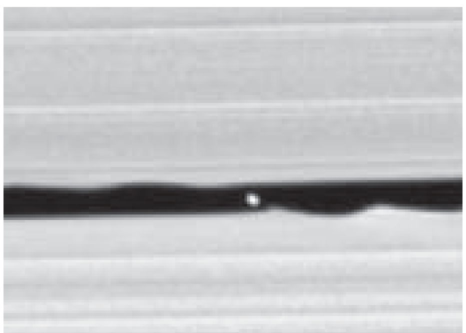
Best wishes,

-Yervant Terzian

Cassini-Huygens: Mission to Saturn

Phil Nicholson is a professor of Astronomy and Planetary Sciences.
He is the editor of the international planetary sciences journal Icarus.

On June 30, 2004, shortly after 7:30 pm, a crowd of several hundred scientists, engineers and family memebers sat anxiously in the Pasadena City College Auditorium, their eyes glued to a large screen relaying live video from the Mission Operations Center at the Jet Propulstion Laboratory, seven miles away. They were waiting for a thin, red horizontal line that was making its way across the screen to turn downwards, signaling that the main engine on the Cassini spacecraft had ignited and begun the process of decelerating the 3,000 kg vehicle. Right on cue, the line twitched, wavered, and settled on its new, downward course, and the room erupted in cheers.



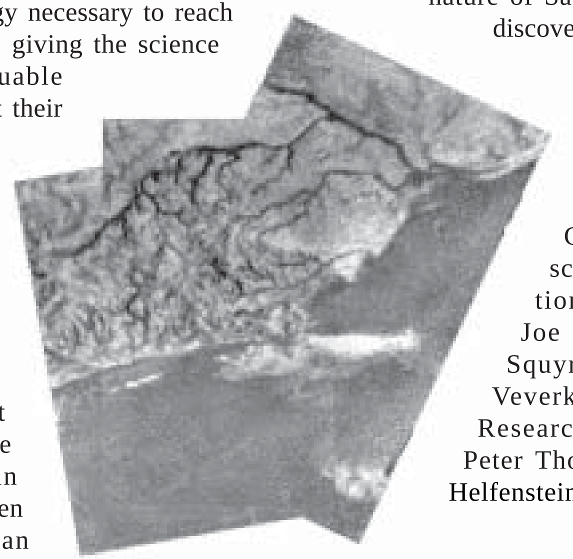
Among the many breathtaking images of Saturn's rings returned so far, one of the most beautiful and scientifically valuable shows a newly discovered moonlet orbiting within 40 km wide Keeler Gap in the outer, or A, ring. Gravitational tugs by the moonlet as it passes by result in the wavelike patters seen on both edges of the gap. NASA/JPL/ Space Science Institute.

Ninety-six minutes later, when the engine shut down, Cassini became the first man-made object to enter orbit around Saturn, the second largest planet in the solar system. Following an exquisitely scripted sequence of commands from its onboard computer, the spacecraft pointed its battery of five cameras and spectrometers at the planet's ring system. For an hour, Cassini skimmed across them at a velocity of 20 km/second and an altitude of as little as 10,000 km, and then plunged through the ring plane in a gap between the F and G rings. The most dangerous phase of its mission safely accomplished, the spacecraft turned its 4 m main antena towards Earth to report and download its harvest of new data, including the most spectacular series of ring images ever taken.

Saturn Orbit Insertion (SOI) marked the end of Cassini's seven year interplanetary cruise, a rather indirect voyage on which the craft was launched atop a Titan IV/ Centaur rocket on October 15, 1997. Not even the mighty Titan IV, the largest launch vehicle in the current US inventory, could send a payload the size of Cassini directly to Saturn. Instead, the craft was dispatched on a trajectory twice around the inner solar system, where a series of two Venus flybys and an Earth flyby provided a gravitational "slingshot" that boosted it towards the outer planets. A relatively distant flyby of Jupiter on December 30, 2000 finally provided the energy necessary to reach Saturn, while also giving the science teams an invaluable opportunity to test their instruments and develop integrated observing sequences.

For most of the Cassini-Huygens scientists, work began well before launch. The project originated in the early 1980s, in discussions between US and European planetary scientists on the desirability of landing an unmanned probe on the surface of Titan, Saturn's planet-sized satellite, which Voyager I had found to be enshrouded by a thick layer of organic smog. Models of Titan's atmospheric photochemistry suggested the exciting possibility that lakes—or even oceans—of liquid hydrocarbons might have accumulated on the moon's surface over the eons. Subsequently, the project evolved into a more ambitious Saturn orbiter and Titan probe mission, christened Cassini-Huygens after the Italo-French discoverer of four of Saturn's satellites and the Dutch astron-omer who first fathomed the nature of Saturn's ring and discovered Titan.

Cornell's Astronomy Department is heavily involved in Cassini's scientific operations. Professors Joe Burns, Steve Squyres and Joe Veverka, along with Research Associates Peter Thomas and Paul Helfenstein, are members



The camera aboard the Huygens probe took this mosaic of three images of Titan's surface during its descent to the surface. The image shows a portion of the boundary (or "shoreline") between a dark, almost featureless, surface to the south, and a brighter, more irregular region which contains what appear to be several branching channels. ESA/ NASA/JPL/UAZ.

Continued p. 6

Confinement of Supernova Explosions in a Collapsing Cloud of Dust and Gas

Mansi Kasliwal graduated summa cum laude this May.
In addition to receiving the Cuykendall award to the most outstanding Engineering Physics senior, she received the Dorothy and Fred Chau award for excellence in undergraduate research for the paper on which this article is based.

Last spring, professors Jim Houck, Richard Lovelace and I came across an intriguing puzzle. Massive supernova (a dying exploding star) blast waves appeared to be confined within only tens of parsecs in blue compact dwarf galaxies (BCDs). Typically, supernova remnants expand to much larger distances, of the order of hundreds of parsecs.[1] New evidence, from observation of non-thermal radio emission from the BCDs, SBS 0335 and Henize 2-10, showed otherwise. This was important because the blast waves from the explosion of hot, massive stars might destroy these small galaxies, which are similar to ones thought to have played a key role in the early history of the universe. Curious about what could possibly confine the blast waves, we attempted to explain this puzzle by looking at the interplay between the inertia of the interstellar clouds in which the explosions occurred and the pressure of the gases released by supernovae.

Imagine being at the heart of a region of intense star formation—a place where an interstellar cloud of dust and gas is collapsing under its own gravity to give birth to new stars. As described by professor Ed Salpeter's Initial Mass Function, you would witness the formation of a few high-mass stars and many low-mass stars. The most massive stars, 24 to 30 solar masses, have the shortest lifetimes, of 2 to 3.5 million years. These stars die and explode as supernovae while, at the same time, the cloud is still in the process of collapsing. Under the direction of Houck and Lovelace, I decided to explore whether the collapsing cloud shells could exert sufficient force on the shock front of the expanding supernovae blast waves to limit their expansion to the "small" distances we were observing.

A shock front is analogous to the bow wave of a boat moving through water. The waves do not move fast enough to get out of the way of the boat and "stack up." In astrophysics, this is a shock front. Three forces operate on it. First, the outward pressure of the blast wave. Second, the inward force of gravity. Third, the inward ram pressure, which describes the effect of the cloud collapsing onto the shock-front.

Ram pressure (the pressure caused by the drag force on a body traveling through a fluid) measures changes in the momentum of a system. For example, consider a sticky piston that accretes matter as it expands into a stationary medium. The accumulation of mass to the sticky piston will slow it down but not change the net momentum of the system since the accreted mass has no momentum of its own. However, if the ambient medium is moving, the velocity of the accreted mass will play a role in changing the net momentum of the system. This meant I needed to work out the velocity of the cloud as it hits the blast wave in order to understand how this inward force affects the expansion of the shock front.

This picture of the expansion of the remnants of a supernova in the constellation of Cygnus shows a shock front analogous to the ones Mansi Kasliwal studies, but in our own galaxy, not in a BCD. ASU/NASA.

We found that not only does cloud collapse slow down the shock front, it eventually forces it to stop and even begin to collapse. This means there is a definitive upper limit to the expansion of supernova remnants as they explode in a collapsing cloud! This simple result, with a few embellishments, resulted in my first publication in the *Astrophysical Journal*.[2]

Our solution was simple and only needed to be scaled to be applied to a region of a different density or different energy of the supernova. Typical values of density and energy of the supernova, give us a number that is of the order of tens of parsecs. I found the simplicity quite elegant and satisfying. This confinement is important because it allows a BCD galaxy to survive its first generation of star formation without being obliterated by its own blast waves.

Astrophysics is a field full of fundamental but as yet unexplored mysteries waiting to be unveiled. It challenges the frontiers of our knowledge and allows our curiosity to

Continued p. 6

New Faculty

Rachel Bean's research centers on cosmology, combining theoretical work on the early universe and dark energy, the mysterious phenomenon causing the universe's expansion to accelerate, with new observations including those of the cosmic microwave background.

Contributors

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The David C. Duncan Professor in Physical Sciences
Joseph Veverka
Chair, Department of Astronomy

Special thanks to professors James Houck and Eanna Flanagan

Barbara Asks!

Q. How large is our galaxy?

A. In shape and size, our Milky Way is a typical galaxy. It has a diameter of about 100,000 light years (the distance light travels, at its speed of 300,000 km/sec, in 100,000 years). Like many other galaxies, it is shaped like a very flat pancake with a central bulge. The thickness of the 'pancake', the plane of our galaxy, is only somewhat less than 1,000 light years. Imagine a flat spiral a meter across with a thickness of one millimeter!

The galaxy contains some 200 billion stars, many like our star the Sun, mostly distributed in a few spiral arms and in the central bulge. The Sun is located in one of the arms, two thirds of the distance out from the center of the galaxy.

The average distance between stars in the galaxy is about 3 light years. This means that the galaxy is mostly empty. To illustrate this point, imagine the sun as a basketball located in Ithaca. At that scale, the edge of the solar system would be about 2 km away and the nearest star would be in Hawaii!

Galaxy NGC 4414 is a typical galaxy, similar in many ways to the Milky Way. Carnegie Obs./STScI/ Hubble Heritage Team.

Observations indicate that at the very center of the central bulge of the Milky Way there is a massive black hole containing the equivalent of two million suns. (To put this in perspective, one million earths would fit inside the sun, a typical small star). All objects in our galaxy, including our solar system, revolve around this central nucleus at a speed of about 200 km/sec.

All these numbers are based on measurements of the distances of individual stars, for which there are several good methods, and on the physics of the Doppler effect, which allows us to measure velocities of objects in the line of sight from observations of their spectral features (spectral lines due to the chemical elements).

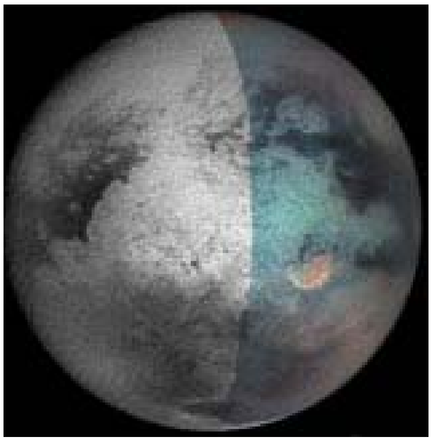
The Milky Way galaxy is just one of billions of other similar galaxies we observe in the universe. It is not likely that we are alone in the universe.

-Barbara Burger (for the question)
-Yervant Terzian (for the answer)

To view pictures of the Friends of Astronomy (and old issues of Orion), visit <www.astro.cornell.edu/people/friends/>

of the Imaging team, while Peter Gierasch and myself are members of the Mid- and Near-Infrared Spectrometer teams. Personnel in our Space Sciences Building, including several post-docs and graduate and undergraduate students, play a major role in generating the sequences of observations which are eventually executed by the spacecraft, although actual spacecraft operations are managed at JPL. As the archive of scientific data returned by the mission grows, we can expect many classes and Ph. D. dissertations will be based on results from Cassini.

Following SOI, the top priority of the mission was to deliver the Huygens probe safely to the surface of Titan. This probe, which was built in Germany for ESA, is equipped with a sophisticated suite of cameras, atmospheric sensors and even a mass spetrometer for chemical analyses. In December, 2004, as the Cassini Orbiter began its third orbit around Saturn, it released the probe. First an aeroshell and then a series of parachutes slowed its three-hour descent through Titan's atmosphere. Since it was unknown whether it would survive the landing (or spashdown …), all science data were transmitted in real time via the Orbiter. In the event, Huygens landed safely and continued to transmit until its batteries died four hours later, its signal recorded by radioastronomers in West Virginia and Australia. Although most of these data are still being analyzed, ESA has released a series of fascinating but rather enigmatic images of Titan's surface taken during its descent. These images appear to show eroded mountains, a series of branching channels reminiscent of terrestrial rivers, and what may be some sort of shoreline. The surface where the probe landed was soft, with a consistency not unlike that of crème brûlée!



This is a composite of Cassinitwo images, one taken in April of this year by its near-infrared camera and the other a visual wavelength image of December, 2004. It shows a prominent, reddish, bright feature about 300 km in diameter. Although its nature is presently unknown, possibilities include an unusual surface coloration, a mountain, low-lying clouds, or a hotspot due to some form of volcanic activity. The larger bright area within which it is located is Xanadu Regio. NASA/JPL/UAZ/Space Science Institute.

Since then, Cassini has been busy with remote sensing studies of Saturn, its satellites, including Titan, and the spectacular ring system. During the last year there have been close flybys of Phoebe, Iapetus and Enceladus. Phoebe, 200 km in diameter, and perhaps a captured interplanetary body, is the largest of the planet's outer or "irregular" satellites. Iapetus is a distant, mid-sized satellite, 1,400 km in diameter, with a striking dichotomy in reflectivity between its leading and trailing sides. Infrared spectra of Phoebe and Iapetus have revealed the presence not only of water ice, as expected from Earth-based studies, but also of organic (i.e., carbon-bearing) compounds and small amounts of liquid or gaseous carbon dioxide, possibly trapped as bubbles in the ice. Enceladus is a smallish icy 'inner' moon, 500 km in diameter, with a rather smooth, lightly cratered surface. After Titan, it is the Saturnian satellite most likely to show signs of recent, or even current, geological activity on its surface. Images returned in February and March of this year show a heavily fractured surface, while Cassini's magnetometer detected what may be indirect evidence of a thin atmosphere on Enceladus.

The Orbiter has also been peering at Titan using both infrared-sensitive cameras and a side-looking radar system. Gradually, we are filling in our map of its surface, but its exact nature remains elusive. Large, dark areas resemble terrestrial oceans, but are more likely to be low lying hydrocarbon "swamps." The largest bright area, christened Xanadu Regio, is suspected to be an exposed area of water ice, which at Titan's surface temperature of 95°K (-177°C) will have the consistency of solid rock on Earth.

This exciting research has just begun. Stay tuned!

-Philip Nicholson

For further details, go to <http://saturn.jpl.nasa.gov>.

Confinement of Supernova Explosions (cont.)

know no bounds. Thinking in terms of time scales many orders of magnitude longer than our own lifetimes and distance scales much greater than what we can traverse is humbling. This feeling of awe, inspiration and excitement is a source of inspiration for me now that I will begin pursuit of a PhD in astrophysics at Caltech.

-Mansi M. Kasliwal

[1] A unit of astronomical length, 1 parsec = 3.258 light-years, 200,000 times the distance from the Earth to the Sun, or 1.918 $\times 10^{13}$ miles.

[2] The paper can be found at <http://xxx.lanl.gov/PS_cache/astro-ph/pdf/0505/0505298.pdf>

Methanol Masers: Signposts of High-Mass Star Formation

Jagadheep Pandian is a fifth- year student in the Ph. D. program. He hopes to graduate in the summer of 2006.

High-mass stars are interesting beasts. A star much more massive than the Sun burns the nuclear fuel in its core at a furious rate, forging the elements that make up Earth and our bodies, and ends its life in a spectacular supernova explosion that can be seen across billions of light years in the Universe. However, the question of how these stars form is poorly understood. Stars form from cold dense interstellar clouds of gas and dust. There are two mechanisms proposed for the formation of high-mass stars. The first is that they form by accreting material from a proto-stellar disk similar to ones that have been observed in low-mass stars. However, high-mass protostars are so luminous that any material that tries to accrete onto the star is likely to be blown away by radiation pressure. The second mechanism is that high-mass stars form through mergers of low-mass stars in dense stellar clusters.

The Orion nebula, one of the best known nebulae in the sky, is the nearest high-mass star forming region.. The image, taken by2MASS, shows the cluster of stars in the center of the nebula.Caltech/ University of Massachusetts.

However, this requires a very high density of stars in the cluster, and no cluster has been observed to date with such high densities. Thus the question of how high-mass stars form is a conundrum that is yet to be answered.

One of the reasons why this problem is poorly understood is that high-mass star forming regions are less common and thus typically more distant compared to their low-mass counterparts. Moreover, these regions are heavily obscured by interstellar dust, making them invisible at optical and even near-infrared wavelengths. Fortunately, there are some tracers that can be used for this search, one of them being 6.7 GHz methanol masers. A maser is very similar to a laser; the primary difference between the two is that the output radiation is at microwave rather than optical wavelengths. Methanol masers at 6.7 GHz have been found to be excellent tracers of the very early (and poorly understood) stages of high-mass star formation. They are extremely bright and do not suffer extinction from interstellar dust, making them ideal tools with which to search and identify high-mass star forming regions.

Curiously, up to a year back, there were no instruments in any major radio telescope in U.S. to study this spectral line, in spite of its importance. As a graduate student in the Molecular Cloud and Star Formation Group, I built a broadband receiver for the giant Arecibo radio telescope to enable these studies. The high sensitivity of this receiver coupled with the large collecting area of Arecibo makes it the most sensitive instrument in the world for studying methanol masers. I am currently using this instrument to carry out a survey for methanol masers in the plane of our Milky Way galaxy, and thereby identify regions undergoing high-mass star formation. This has to date already resulted in the detection of 23 methanol masers, of which 15 are new detections. The survey, when completed in the Fall of 2005, is expected

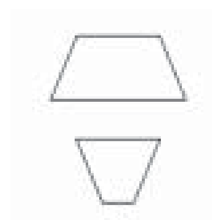
Jagadheep Pandian at Arecibo next to the 6.7 GHz receiver he designed.

to significantly increase the number of known methanol masers. Since high-mass stars occur preferentially along spiral arms of our Galaxy, this data should give information about the spiral arm structure of our Galaxy.

Ultimately, when we get a better understanding of what is responsible for exciting these masers, one can use high-resolution images of methanol masers to probe the dynamics of high-mass star formation. Future instruments like the Atacama Large Millimeter Array (ALMA) and the Square Kilometer Array (SKA) should help us better our understanding of how high-mass stars, which play an important role in the Universe and our lives, are born.

-Jagadheep Pandian

Optical Illusion



Despite their appearance, the top horizontal lines of these trapezoids are of exactly the same length!

Books in Science and the Universe

A Devil's Chaplain: Reflections on Hope, Lies, Science and Love by Richard Dawkins (2003).

Richard Dawkins, of Oxford University, is a renowned evolutionary biologist who has written with clarity and passion such books as *The Selfish Gene* and *The Blind Watchmaker*. In this volume he brings together a set of provocative short essays on topics that range from biology and evolution to philosophy of science, ethics and religion. Some of the notable chapters include 'What is True?', 'Postmodernism Disrobed', 'The Great Convergence' (about science and religion), 'Unfinished Correspondence with a Darwinian Heavyweight' (his letters with the late Harvard evolutionist, Stephen Jay Gould), 'Son of Moore's Law' (the increase of the DNA sequencing power being exponential, by 2050 we shall be able to sequence a complete individual human genome for about $160!), and 'Good and Bad Reasons for Believing' (a letter addressed to his young daughter about what to believe in life).

Dawkins defends scientific truth and reason strongly and impressively. He is inspirational and writes with clarity and courage.

-Yervant Terzian

Thanks to the Friends

Elise Furlan and John Dermondy were, respectively, the recipients of the Cranson W. & Edna B. Shelley Award for Graduate and Undergraduate Research in Astronomy, Elise for her research on circumstellar disks around T-Tauri stars—using Spitzer and ground based data—and for her leadership role with the IRS disks team; and John for his significant contribution to the field of astronomical spectroscopy, especially for developing state of the art algorithms and computer code that provide much improved signal extraction and promises to be widely used in research. Jagadheep Pandian won the Eleanor York Prize in Astronomy for his many contributions to the Department's activities in research and education, and in particular for his design of the 6.7 GHz receiver at Arecibo and his public outreach activities at Fuertes Observatory.

Generous contributions from the Friends funded three special colloquia in March and April. The guests of the the Charles and Barbara Burger Special Colloquium Series, the Josephine Lawrence Hopkins Foundation Colloquium and Maryanne Shelley Jessup MacConochie Colloquium were Sarah Church (Stanford), Deane Peterson (SUNY Stony Brook) and Martin Duncan (Queen's University, Kingston, Ontario), respectively.

This year three Terzian Fellows graduated: Elizabeth Bass (Astronomy), Sibren Isaacman (Physics) and Magdalena Preciado López (Engineering Physics). Their fellowships are supported by an endowment established by the Friends in honor of Yervant.

Finally, many thanks to all the Friends who have contributed towards the publication of Orion!

Yervant's Critical Thinking Corner

Logical and arithmetic errors:

- The sun and the nearest star, Alpha Centauri, are separated by empty space.
  Empty space is nothing.
  Therefore nothing separates Alpha Centauri from the sun.
  If nothing separates two things, they are next to one another.
  Hence, Alpha Centauri and the sun are next to each other.
- If a bottle and a cork together cost $1.10, and the bottle costs $1.00 more than the cork, then what does the cork cost?
- There are 365 days in a year. People work 8 hours per day. So people work the equivalent of one third of 365 days, which is about 122 days.
  But people work usually only weekdays. This means two days off per week; for 52 weeks in a year, this makes 104 days off per year. Subtracting this from 122 days, we are left with only 18 days of work per year.
  But with a ten day vacation per year, and eight days of regular holidays, we are left with zero time for work!