O R I O N

Newsletter of the Friends of Astronomy Cornell University

Summer 2006

Dear Friends,

Summer is a special time for us in many ways. Perhaps the most important is that in summer we open our doors to eager undergraduates from Cornell and other institutions, eager young folk who join our faculty and staff for six or eight weeks of very intensive immersion in research. For some it is the first opportunity to find out what it is like to be an astronomer or a planetary scientist by actually doing what astronomers and planetary scientists do. For our faculty and staff it is a chance to meet and work with some of the brightest students who will be the leading scientists of the future.

Hands-on experience with how astronomy is done is also an important aspect of how we teach our introductory astronomy courses—courses such as Astronomy 101, 102, 107 and 195. These courses include actual telescope observing as well as related laboratory exercises. A key to teaching such courses successfully is to have up to date computer hardware and software. Accordingly, every few years it is time for major computer upgrades and this happens to be one of those years. By the time classes start in the Fall all the refurbishing will have been completed and we will be up to date once again (for two or three years!).

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There may be an ocean of liquid water beneath the icy surface of Europa, one of Jupiter's moons. The dark reddish spots, or freckles, are thought to be blobs of warmer ice that have gradually risen from below through the colder surface layers. U. Colorado, Galileo Project, JPL, NASA

Greetings

A few weeks ago we celebrated Hans Bethe's Centennial with a Symposium on High Energy Astrophysics. Various distinguished speakers around the country presented up-to-date research on topics from the Physics of Supernovae, Neutron Stars and Black Holes, Neutrinos in Astrophysics, and Cosmology. It was a meeting of the minds of leading scientists exchanging notes on fundamental physics and astrophysics. Ten Friends of Astronomy were brave to attend the technical talks, some of which are available at the following web site <http://astro.cornell.edu/~dong/bethe/program.html>.

Last April several Friends joined the Cornell Adult University group that visited Hawaii with me. Among other telescopes and adventures, we saw the giant Keck optical telescopes on Mauna Kea mountain, which are 10 meters in diameter. The most important telescope now operating is the aging Hubble Space Telescope. NASA plans to launch Hubble's successor,

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Meet the Friends!

Earlier in the year we had the opportunity to spend an afternoon with Jim and Ellen Myerberg.

Q. How did you get interested in Astronomy?

Jim - As far as I can remember, I've always been interested in what's out there, but it's been within the last ten years that I've really taken the time to get into it more deeply. I took the introductory Astronomy course at the University of Maryland and a course about life in the universe—the search for life on other planets. The professor taught it as much as a science as a literature course. We did the science part, but we also discussed how people on earth think about life on other planets, both as science fiction and what we think might be out there. Also, we've gone on a couple of Yervant's programs. I'm enjoying learning more!

Ellen - We did a CAU trip in the Poconos Mountains. All we could talk about on the trip back home was the intellectual stimulation of what we had heard. We had a sense that our universe has been enlarged by participating in the course. We still talk about the Tanque Verde trip. And Flagstaff! It was amazing, being at the Lowell Observatory in Arizona, we had read about it and *now we were there*.

Jim - The combination of the Lowell Observatory and the Grand Canyon, all in three or four days was really an incredible experience.

Ellen - I think if I had half an hour, I could sketch out almost every day of the Tanque Verde trip.

One thing Jim has not said, he is very interested in life, life on other planets and he will get very excited about some things and I tend to be …

Jim - You don't have as much faith.

Ellen - That would be a good way to put it (laughs).

Jim and Ellen Myerberg with Patricia Fernández de Castro (center).

Jim - Billions and billions of stars, there's got to be life somewhere!

Ellen - He's the statistician. I share his passion, but in a different way. I took a few astronomy courses that were offered by the Smithsonian when our son was young. I volunteered at the planetarium in his elementary school, so each season I took one of the Smithsonian courses. Many of the instructors were from the University of Maryland program, and they were wonderful and shared their enthusiasm for the subject. There would usually be a lecture and then, depending on the weather, we would get to go outside to look at the sky or through one of the telescopes at the Naval Observatory. That was when we received a notice about a course in Tanque Verde. Someone named Yervant Terzian was teaching this course and I said to Jim, "We love the Southwest, and this looks like an interesting experience." It was probably one of the most awesome trips we've taken. We met lovely people and we just had a really wonderful time. Yervant made something extremely complicated comprehensible to someone like myself who is not a scientist. We've been involved from that time on and whenever there is a seminar, if we can possibly arrange our schedule we try to be there.

Q. What area of Astronomy do you find more fascinating?

Jim - I'm more interested in what's closer to home, in the solar system. Learning about the planets, the solar system, or the rovers on Mars—to me that's the exciting part! In a way that may be because it's easier to understand than the physics of the Big Bang or the multi-verses. But there are things about the larger universe I'd like to understand like, what happened before the Big Bang?

Ellen - I'm more interested in the process, in what is involved when someone has an idea, how to make it happen, how does everyone work together, or how do you overcome areas where people don't work together. I'm also in awe of the people that are making the presentations at the Friends' programs. Many of them are young, this is their life and to think about what they will see and discover! In our lifetime, man walked on the moon. That was really amazing, and now, the discoveries are advancing at a geometric pace. Intellecutally the Friends' meetings are very interesting and challenging, and it is always an incredible opportunity to be with Yervant and the Friends.

Jim - Once we attended an alumni meeting about the Shoemaker-Levy comet, which was going to hit Jupiter. I had been fascinated about what was going to happen for several months, and hearing people like Carl Sagan talk about it was fantastic.

Ellen - I was just blown away by Carl Sagan, by his ability to take this very complicated topic and reduce it to something that we could understand. When we come up to Cornell and walk by where his office was, it's meaningful to me in a very personal way. He was not there when I was a student at Cornell, but it makes me think about the brilliance of this one department. It's exciting that there are all these incredible things happening. That's why I'd take another trip to the Southwest anytime, I really do enjoy going back and experiencing the campus.

Q. Which Friends programs have you enjoyed best?

Jim - I guess it was the one three or four years ago when Steve Squyres talked about the—at the time—planned mission to Mars.

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Listening to the Cosmos

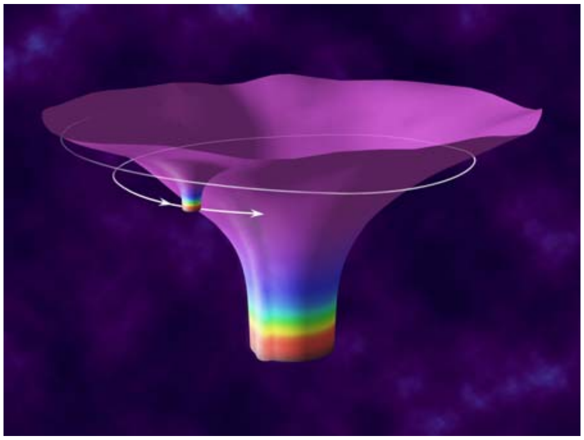
Eanna Flanagan has received the Xanthopoulos International Award for Research in Gravitational Physics.

Normally the air that surrounds us is a passive backdrop for events which we do not notice. However, we know that it can make its presence felt in the form of winds and hurricanes, and also that it is the medium through which sound waves travel and bring us information. Similarly, we are used to thinking of space and time as forming a passive backdrop for the events which take place within it. In fact, Einstein taught us that this is not so: there can be "hurricanes" in the fabric of spacetime itself in the form of rotating black holes. Moreover, violent events in distant galaxies will produce tiny vibrations in the fabric of spacetime, warps we call gravitational waves. If these vibrations are ever detected, they will allow us to hear the rumbles and crashes of distant events and open up a new branch of astronomy.

In 1974 astronomers using the Cornell-administered Arecibo radio telescope in Puerto Rico discovered a binary star system of two neutron stars at a distance of about 3,000 light years. The two stars—each about the size of Ithaca, yet as massive as our Sun—orbit each other roughly once every eight hours. General relativity predicted that the two stars should give off gravitational waves, and consequently should very gradually spiral in towards one another. In 1993, the Nobel prize in physics was awarded to Joseph Taylor and Russell Hulse of Princeton University, for their precise measurement of the gradual inspiral that agreed with general relativity's prediction. Thanks to this work today we are confident that gravitational waves exist.

Since then, physicists and astronomers around the world have worked to open this new window on the Universe. The most promising technology is to monitor the relative displacement of suspended masses in a vacuum using laser interferometry. Passing gravitational wave bursts will cause the masses to oscillate back and forth, a motion we can detect using an extraordinarily sensitive interferometer. In November 1999, such an instrument, the Laser Interferometer Gravitational Wave Observatory (LIGO) was inaugurated; it consists of two separate laser interferometers in two sites in Washington and Louisiana, each 4 kilometers long. LIGO has enabled us to begin searching for gravitational waves. Similar instruments are being constructed in Europe and Japan, and there are plans to build a joint NASA-European Space Agency space-based detector sometime around 2015.

In parallel with this experimental effort, theoretical physicists and astrophysicists are preparing for gravitational wave astronomy. A gravitational wave detector is something like the sonar on a submarine that is used to track other submarines. Sonar operators need to be skilled at distinguishing between screw noises and sounds from fish, whales and other natural noises. Similarly, gravitational wave astronomers will have to be skilled at separating out the signals we seek from the background cacophony due to detector noise. The role of gravitational theorists like myself is to predict the characteristics of signals from various types of sources, which will be vital to aid in the detection process, as well as to interpret the signals we detect.



An illustration of a small black hole spiralling into a large black hole. Courtesy of the LISA Project.

So what cosmic signals do we expect to hear? Primarily cataclysmic events involving black holes and neutron stars, which have very strong gravitational fields. Neutron stars can spin at speeds of up to 60,000 rpm, as fast as a laboratory ultracentrifuge. We hope to hear the high pitched whine coming from several spinning neutron stars in our Galaxy. The physicist Freeman Dyson pointed out back in the 1960's that a binary system of two inspiralling neutron stars (or black holes) will give off a very strong and distinctive gravitational wave signal in the last few minutes of its inspiral, before the two stars merge. This may well be the first type of signal that we detect.

My colleagues Professors Ira Wasserman and Saul Teukolsky and I, together with our former students Katrin Schenk and Phil Arras, have recently been exploring the details of yet another process involving neutron stars that produces gravitational waves. Neutron stars are born in supernovae explosions, when the core of a massive star that has exhausted its nuclear fuel is crushed by its own gravitational field. Several years ago, theorists realized that a type of fluid oscillation occurring in newly born neutron stars should create a sort of drag in space-time and slow down the star's rotation. These motions ("r-modes") look much like the ocean eddies that move currents in circular motions on Earth. The drag effect, caused by the gravitational waves leaving the star, in turn causes the r-modes to grow when they would normally die away due to the internal friction. The nature of the resulting gravitational wave signal depends critically on how large the fluid sloshing motions get. Are they like tiny

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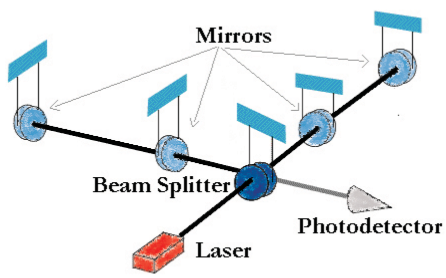
ripples on the surface of a pond or the huge breakers generated by hurricanes? This was the question we set out to answer. We found that the sloshing motions get about as large as the heaviest of ocean swells, a few tens of meters. Within a few years we may be able to hear these sloshing motions with LIGO and other detectors.

Over the last few years, astronomers have discovered that a majority of galaxies contain enormous black holes at their centers. Every so often, neutron stars (or small black holes) in the central regions of galaxies will get knocked towards the large black hole, will gradually spiral around it, and eventually fall inside. During the last year of inspiral, the neutron star might orbit the black hole a few hundred thousand times, moving at speeds close to the speed of light. The gravitational waves produced will carry encoded within them a detailed map of the warpage of space and time near the large black hole, something that has never been observed before. Reconstructing this map is one of the holy grails of gravitational wave astronomy.

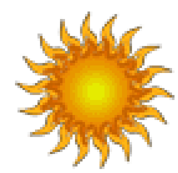


Each arm of a laser interferometer is formed by two mirrors hanging very far apart, and each arm is perpendicular to the other. Laser light enters the arms through a beam splitter located at the corner of the "L." Scientists allow the light to bounce many times before it returns to the beam splitter. If the two arms are of identical length, the interference of the light beams returning to the beam splitter will direct all the light toward the laser. If there is any difference between the lengths, which would happen if a gravitational wave had rippled space, some light will travel to where it can be recorded by a photodetector. (Image and text adapted from LIGO).

To reconstruct this map, we need to be able to predict the complicated motions of the neutron star near the black hole. Although in principle this motion is dictated by the theory of general relativity, in practice theorists are unable, as yet, to predict the motion except in special cases due to various complexities. Over the last few years, I and a number of other gravitational theorists from around the world have been working on developing the required mathematical and computational tools. We meet every year to discuss our progress and make plans for the coming year. After several years, our goal is now almost in hand; we hope within a year or two to have detailed predictions of the gravitational wave signals.

It is now almost four hundred years since Galileo first raised a telescope to the sky and discovered the moons of Jupiter. Today, several hundred physicists and astronomers around the world are attempting to open a completely new window onto the Universe using gravitational waves. My students and I find it tremendously exciting to be part of this effort. No doubt, the gravitational wave signals, when they are finally detected, will bring lots of surprises.

-Eanna Flanagan



Thanks to the Friends!

Amelie Saintonge received the 2006 Graduate Shelley Prize for outstanding accomplishment in research. As a fourth year graduate student—who also happens to have a 16 month old—Amelie has been extraordinarily productive, pursuing concurrently observations at several wavelengths, developing a code for the ALFALFA (Arecibo Legacy Fast Alfa Survey) project which is in use at the Department and elsewhere, and coordinating work by several senior external collaborators.

David Rothstein was awarded The 2006 Graduate York Prize for service to the community and academic achievement. Dave's outstanding work on microquasars has resulted in two papers in The Astrophysical Journal and two more in progress, as well as invitations to talks in China and Mexico. In addition, this past year he held a special fellowship awarded by Cornell (with NSF funds) for educational outreach to local high schools. In previous years, he was a regular contributor to the "Ask an Astronomer" web site and taught a Mini Course titled "Einstein for Everyone" at the Ithaca High School.

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Music of the Spheres: An Onlooker's Impressions of a Total Solar Eclipse

On March 29th, 2006, a beautiful variation of the "music of the spheres" was enacted in a rare and highly choreographed partnership between the sun and the moon: a total solar eclipse. Beginning at 12:38 p.m. and concluding at 3:14, the two celestial bodies interacted in such a way as to produce an astonishing and improbable visual effect. This effect is seen on earth only at a specific place and time. The moon is in alignment with the earth and sun at the exact distance necessary to conceal the sun. As the moon proceeds in its orbit, its shadow slowly traverses the earth. Then at totality, mere minutes in duration, the tiny moon obscures the sun's huge mass so that only its corona is visible.

A total solar eclipse is a rare spectacle but one that is completely predictable. And so on a terrace in Antalya, Turkey, an audience assembled to watch. The solar system is the theater for a performance of unerring precision. Against this celestial setting, the moon and the sun engage in their intricate choreography. They need no practice to be perfect.

I am one of the onlookers. I am filled with awe and wonder not only at nature's incredible repertory, but also at how human curiosity and science combine in striving to understand this. And my own reaction varies between an attempt (inaccurate no doubt) to comprehend what a total solar eclipse is—and my absorption in the sheer beauty and magic of it all.

-Barbara Burger

The Total Solar Eclipse of March 29, 2006

On March 29, Barbara and I were fortunate enough to see a spectacular total eclipse of the sun in Side, a small resort town in Antalya on the coast of the Turkish Mediterranean whose name, ironically, is pronounced "see-day."

We don't consider ourselves to be veteran eclipse chasers, but we've tried it twice and it worked both times. Having said this, we have emerged with a very clear understanding that you need a gambler's mentality to arrange a vacation around seeing an eclipse. It is like going to see a play at great expense with the knowledge that the show will go on but the curtain—the local weather conditions—may not be raised.

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Music of the Spheres

This lesson was brought home to us on August 11, 1999, the day of our first eclipse. On that occasion we had joined a tour to Romania sponsored by Yale and Cal Tech. In Bucharest, we were supposed to be able to view the eclipse to maximum advantage. However, as the event approached, the weather, which was predicted to be bad, created major anxieties. Reports reached us that all of the parts of Western Europe that lay in the path of the eclipse had no visibility at all. Our own chances of seeing anything seemed tenuous. In our group, which included astronomers from both universities, sager heads than ours had debated until early in the morning of the day of the eclipse whether we should board a bus and head in a direction that promised clear skies. We ultimately stayed put, not because anyone believed we would have an unobstructed view, but because no one could suggest a surefire alternative. In the event, the skies cleared and we were treated to a glorious view of the eclipse. Totality was unforgettable, all 2 minutes and 23 seconds of it.

We took away from Bucharest two valuable things in addition to our memories of the eclipse. First, a number of friendships with several Cal Tech faculty members (dazed though they were by Barbara's steady stream of questions) and, second, a very deep conviction of how lucky we had been and how chancy it was to make the viewing of an eclipse the capstone of a vacation trip.

I had over the years nagged one of the Cal Tech astronomers we had befriended to organize an eclipse trip himself. Finally, with the lure of an eclipse over Turkey that was to feature a totality much longer than the one in Bucharest (3 minutes and 45 seconds), he agreed to take on the task. He enlisted a local Pasadena travel agent to handle the travel arrangements and recruited a small group of his colleagues (and Barbara and myself) for an almost three-week expedition to Turkey and Egypt, with the eclipse scheduled to occur on the sixth day.

This seemed ideal. First, we had a knowledgeable person picking a climatically safe location for viewing the eclipse (we thought). Second, we had a group of astronomically sophisticated people with similar (or at least overlapping) interests to travel and spend time with (and answer Barbara's questions). Third, we had lots of engaging things to do on the trip (Greek ruins in Phaselis, Ephesus and Pergamon, and tombs, pyramids and the Sphinx in Egypt), which could serve as consolations if the eclipse didn't pan out.

A total solar eclipse is not that rare (there is one somewhere on Earth every 18 months). However, finding one that passes over a suitable place for viewing is another story. A "suitable place" is one that provides a high probability of clear skies at the relevant time, hospitable climate and terrain, an absence of unfriendly inhabitants *and* falls within the moon's shadow ("umbra"). Only within the umbra does one see a total eclipse and the umbra traverses a narrow band of the Earth's surface approximately 100 miles wide and 10,000 miles long (the "path of totality"). For some distance on either side of the path of totality (in the "penumbra") one can see a partial eclipse, but will not experience any of the astonishing visual effects to be seen in the umbra.

Previous page: The solar eclipse of March 29 photographed from Side, Turkey by Chuck Burger with an 8.2 megapixel camera and a 12X optical zoom.

There is also the issue of duration. The maximum theoretical duration of totality (I have read) is 7 minutes and 31 seconds. An eclipse over seven minutes long is very rare. Three occurred during the 20th Century and none will take place in the 21st. For this reason we were happy with our 3 minutes and 45 seconds of totality in Side.

(cont.)

This may all serve to explain why Barbara and I were pleased with our arrangements: the prospect of clear skies, balmy climate, friendly natives, comforts and amenities (we were located on the broad terrace of a seaside hotel which served food and drink throughout and which we shared with enthusiastic groups of young people from all over the world) and a reasonably long totality. And everything worked as planned. What else could we have asked for? We both agreed that the eclipse was not only longer but more beautiful than our first. I will only add one subjective observation to Barbara's account, which accompanies this piece. I was on both occasions struck by how small and distant the eclipsed sun seemed in the darkened daytime sky, even with the glorious halo of its corona made visible, as compared with the sun we are all used to. Yet it was impossible to look away for the duration of totality; the eclipsed sun dominated the black sky in a way it never does otherwise.

It rained all the next day.

-Chuck Burger

Upcoming Events

Please join us to celebrate two of our distinguished faculty! On July 28-29 we will hold a symposium, *From Dust to Planets*, to honor Joe Burns on his 65th birthday. Stan Dermott, Brett Gladman, Jeff Cuzzi, Doug Hamilton, Dale Cruikshank, Bill Bottke, Terry Alfriend, Phillip Holmes and Bob Kolvoord will review Joe's remarkable and wide-ranging contributions to understanding how our solar system works. Among other topics, they will discuss interplanetary dust, planetary rings, the dynamics of asteroids, outer planet satellites, and the mysteries of Saturn's two-faced satellite Iapetus. For more information and to register, please visit <http://www.astro.cornell.edu/~karla/Burns/index.htm>.

Then on October 13-14 we will celebrate Riccardo Giovanelli's 60th birthday. Our guests on this occasion will be Neal Evans, Jim Gunn, Jill Knapp, Jeremy Darling, Guido Chincarini, Eduardo Hardy, Loris Magnani, John Salzer, Kristine Spekkens, Paul Vanden Bout and Jonas Zmuidzinas. They will examine issues related to the formation of galaxies and stars and how surveys—underway in Arecibo and planned in Atacama—will help us understand them. Information about this event is available at <http://egg.astro.cornell.edu/rg60>.

Spreading the Word about Astronomy and Science

Dave Rothstein is researching how material that is spiraling into black holes changes with time. When he is not doing Astronomy, he enjoys Ultimate frisbee and classical karate.

I'm standing in a hallway on a cold day in March, looking at a cluster of galaxies. These galaxies are a bit different from normal ones, though. Rather than stars and dust lanes, they're more likely to be sporting jeans and sneakers.

"OK, everyone should be in groups of three, two galaxies and one light beam in each group. When I say 'Go,' the universe starts expanding. Everyone knows what they're supposed to do, right? Ready, set, go!"

My "galaxies" today are teenagers, a slightly skeptical yet inquisitive group of students from a tiny high school in the rural town of Rushville. Their teacher is Peter Saracino, a member of the Friends of Astronomy, but otherwise, we're a long way from Cornell, both literally and figuratively. I drove 65 miles this morning to get here, and I'll drive 65 back in the afternoon. I'm a little tired—I left Ithaca at an hour when most graduate students (including myself) would be happy to still be in bed—but I'm here because I want my students to see that acting out the universe can be an exciting thing to do.

I'm in my sixth year in the Cornell astronomy department, about to complete my Ph.D. thesis. My research focuses on the behavior of material that is spiraling into black holes. But this year, I'm not being paid to do research. Instead, my funding comes from a program called Cornell Science Inquiry Partnerships (CSIP), a six-year-old effort that takes about ten graduate students per year, from a variety of scientific fields all across the Cornell campus, and matches them with middle- and high-school classrooms for an average of 15 hours per week <http://csip.cornell.edu>.

The name of the game in CSIP is *inquiry*. We try to teach students that science is not a list of facts; rather, it is a process of asking questions and doing the experiments necessary to rule out some of the possible answers. Without this understanding, the students risk growing up into adults who hear about scientific results in the news and dismiss them as mere opinions, conclusions about a particular topic that are no more valid than anyone else's. I believe that scientists have a professional responsibility to teach the public about the real power (and the real limitations) of our work, and that is why I've made public outreach a major part of my graduate career.

Astronomers in particular have an important role in this effort.

Eleventh and twelveth grade students at he Marcus Whitman High School in Rushville, N.Y. learned about th e physics of wind power.

The public is inherently fascinated by astronomy, and we can harness this interest for the good of science as a whole. Indeed, members of the Cornell Astronomy Department participate in many public outreach activities with this as their goal. I have worked with some of these efforts in the past—the Ask an Astronomer website <http://curious.astro.cornell.edu>, which answers questions emailed in by the public, and the Focus For Teens Astronomy Workshop, a summer program for high school students, to name two—but CSIP is my focus this year.

Each day I visit a classroom is something new. In Rushville I wanted to teach students about different scenarios for the expansion of the universe by having them assume the role of galaxies and act it out, but I have also worked with physics students on calculating orbits of stars around a black hole, and I've traveled to Rochester to help eighth-graders study a polluted lot near their school and work with city officials to learn how to clean it up. I've even driven my aging Buick up to the top of a hill in the backwoods of Steuben County (hoping upon all hope that it would make it through the "road" without getting stuck in the mud) to take photos of sites where a local company wants to build wind turbines, so that my students who are learning the physics of wind power can decide if the project is a good idea or not.

The idea behind CSIP is that when graduate students and schoolteachers work together, each group benefits from the other. The teachers and their classes get the experience of doing real scientific inquiry. As for the graduate students,—I have learned more lessons from teachers than I can count: how to manage a classroom, how to motivate students, and the challenges that schools face in trying to create a scientifically literate citizenry. The graduate students educate each other too; by getting together and sharing our experiences in a weekly seminar, we are helping to build relationships between scientists in different departments (from microbiology to developmental sociology to everything in between) who otherwise would never have had the chance to meet.

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Spreading the Word

(cont.)

Even though public outreach invariably takes time away from my graduate studies, it isn't at all a zero-sum game. Working with students has helped me learn how to better communicate the results of my research, not only to the public, but also to other astronomers. And helping to build the Ask an Astronomer website has made me fluent in computer database programming, which I plan to use next year when I start a postdoctoral fellowship at Cornell and construct a database of black hole observations to be put on the Internet for myself and other researchers.

What is the future of these outreach activities? We're hoping to continue the CSIP program next year. For its first six years, it has been funded by the National Science Foundation, but with this funding coming to an end, Cornell is working to try to sustain CSIP through funding from other sources, including alumni donations. As for my future, all I can say is that my experience doing public outreach as a member of the Astronomy Department has been amazing, and my time as a graduate student has convinced me that I want to continue with this type of experience throughout my life and my career.

-David Rothstein

Dear Friends

Why am I telling you all this? Because without your help such necessary improvements would not be possible. The College provided half of the necessary funds. The other half came from individual gifts from you, our Friends of Astronomy. This is only one example of how your support continues to help us maintain the high quality of education for which our Department is known. You play an important role in what we do and we appreciate your participation and multi-faceted support.

A pleasant and happy summer to all!

-Joe Veverka

Greetings

(cont.)

the James Webb Space Telescope, which will have 7 times the light collecting area of the Hubble to detect much fainter objects, including the formation of the first galaxies after the Big Bang. Launch of the JWST is scheduled for 2013.

We wish you a relaxing summer and remind you to watch the Perseid Meteor Shower the evening of August 12. Hope for clear skies!

Cordially,

-Yervant Terzian

Meet the Friends!

(cont.)

Ellen - For me, it was the opportunity to see the Contour and the Rover blastoffs. I particularly enjoyed the opportunity to spend time with some of the wonderful people that were involved in those missions.

Jim - To see a blastoff! We've been wanting to see a blastoff for nearly 40 years.

Q. What programs would you like to see the Friends do?

Jim - If it were possible, to get into some of the science of life on other planets. And the trips to the blastoffs! We couldn't hang around when there was a delay with the rover mission, but next time we'll know, if we're going down, we'll just schedule to be there a couple of weeks (laughs).

Ellen – There could be worse places to be than Florida!

I hope that sometime the Friends will do a program here in Washington. Because we live here, we're aware of some of the really exciting possibilities. We could go to the Naval Observatory, Goddard and the new Udvar-Hazy Center.

Q. What do you appreciate most of the Friends?

Ellen – The people we meet. We just enjoy being with each other, the intellectual stimulation, the presentations, the sense of community. Through the Friends I have become very passionate about the Astronomy Department and the work they are doing. It brings another dimension of the University into focus.

Q. What has belonging to the Friends brought to your lives?

Jim - Going to the Friends' meetings has given us the opportunity to learn about cutting-edge research in Astronomy presented by the people that are doing it. We're not just reading about it in a magazine. Plus, we get to ask these experts questions in an informal setting.

Ellen – That's one of the best parts. The experts are right there and available. If you didn't get to ask the question during the presentation, you can talk to the person during cocktails or dinner. Meeting the other Friends has also been a great experience. They are extremely interesting people in their own right and we share this experience with them.

-Patricia Fernández de Castro

You can find old issues of **Orion** at <http://www.astro.cornell.edu/people/friends/orionnews.php>

Hunting for Extra-Solar Planets

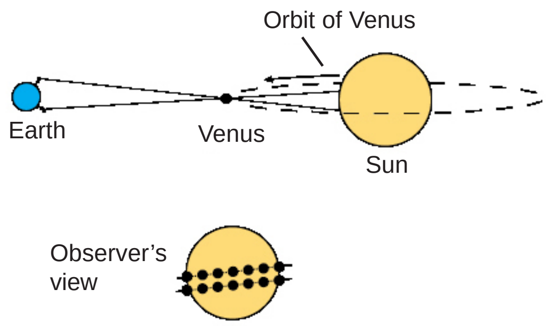
Jamie Lloyd spent two years in the South Pole exploring the southern sky at infrared wavelengths.

In the last decade, the field of extrasolar planet research has dramatically progressed from the realm of speculation and theory to a flourishing field, with now over 150 known planets around other stars. There has been a long list of unexpected discoveries, ranging from the 'Hot Jupiters' (Jupiter-mass planets that orbit their host star in only a few days and roast to temperatures of 1,000° K, or about 1,340° F) to systems of planets of completely unexpected varieties. Despite such progress no planetary system has yet been found that is qualitatively like our own.

Nearly all of the recent progress in extrasolar planet research has been focused on sun-like stars, partly for anthropocentric reasons, but mostly for technical reasons. Such stars are the most suitable for searching for planets by the radial velocity method, which observes the line of sight motion of the star through the Doppler shift of light. The current frontier is the detection of planets around stars that are less massive than the sun, and therefore are smaller and cooler. Although fainter and smaller, these low-mass stars are the most populous stars in the Galaxy, outnumbering sun-like stars by at least 10 to 1. Since these stars are intrinsically very faint at optical wavelengths, finding the ones that have planets requires a spectrograph that is sensitive at the infrared wavelengths at which they are most luminous.

Based on these considerations, Terry Herter and myself are leading an effort to develop new instruments to explore this new frontier. Recently we were awarded a grant to build a prototype infrared radial velocity spectrometer for the historic Palomar 200" telescope that will be operational early in 2007. In addition, our proposal for an infrared precision radial velocity spectrometer for one of the Gemini Observatory's 8-meter telescopes was selected as one of two competing design studies that will ultimately lead to the construction of a $6M instrument. This spectrometer will begin operation in approximately 2010. These two instruments will enable the detection of planets for the first time around the most numerous, but small and faint stars in the solar neighborhood.

Unfortunately, using the radial velocity method to detect planets produces only indirect inferences, not direct observations. The gravitational tug of the planet on the star produces a wobble that is detected by the Doppler effect. This indirect technique yields only the parameters of the orbit of the planet, but no information about its composition, size or surface. For a small subset of planets, there is the possibility of a fortuitous alignment of the orbital plane with our viewing direction. In these cases, the planet will transit the surface of the star. Even within our own solar system, such transits are rare (the transit of Venus occurs only 4 times every 243 years), but transits of planets are of great historical and fundamental significance in astronomy. The determination of the distance from the Earth to the Sun, for example, is a difficult measurement without modern techniques such as radar. Ancient astronomers did not solve the problem until in 1680 Edmond Halley suggested that the transit of Venus could be used to measure the size of the solar system. The first such measurement was finally accomplished by observations of the transit of Venus in 1769.



By observing the transit of Venus from two different positions on the Earth, it's possible to measure the distance to the sun. The two observers see Venus traverse different paths across the sun. By measuring carefully the apparent path of the transit of Venus across the sun, the observers can directly measure the ratio of the distance of the Earth to the Sun to the distance of Venus to the Sun. Combined with Kepler's laws, this yields a measurement of the distance to the Sun. This experiment was one of the motivations for Captain Cook's voyage around the world in 1769.

Transits of extrasolar planets promise to be similarly key in unraveling the physics of the planets that inhabit our immediate universe. The first transiting planet was discovered by surveying stars for the characteristic dip in brightness of the dark planet passing across the surface of the star. A Jupiter-sized planet passing in front of a sun-like star occults about 1% of the surface of the star, resulting in a detectable 1% dip in the brightness of the star. The first such planet, known by the catalog number of its host star, HD 209458b, has proven to be a gold mine of information. By comparing the spectrum of the star in and out of transit, is has been possible to detect absorption of Sodium in the atmosphere of the planet. This is the first time any knowledge of the composition of an extrasolar planet has been available. By observing the "secondary transit", when the planet passes behind the star, it is possible to compare the flux emitted by the star to the flux emitted by the planet and star combined, yielding an observation of the light directly emitted by the planet. Observations of HD 209458b by the Spitzer Space Telescope have confirmed that the planet is indeed heated to over 1,000° K and is therefore unlike any

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Books in Science and the Universe

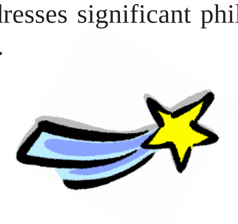
A World Without Time: The Forgotten Legacy of Gödel and Einstein by Palle Yourgrau (Basic Books, 2005).

Palle Yourgrau is a professor of philosophy at Brandeis University who has written before about Gödel and Einstein. In his recent book, *A World Without Time*, Yourgrau relates the great friendship that existed between the 20th century's greatest physicist, Albert Einstein, and its greatest logician, Kurt Gödel, while they both worked at the famous Institute for Advanced Study at Princeton. The book, which is more about Gödel than about Einstein, relates Gödel's attempts to understand the nature of time through the theory of relativity. In 1949 he published a paper where he showed that certain solutions of the relativity equations allow a universe where time does not exist!

Gödel, of course, was already famous, since he had published in 1931 one of the greatest philosophical papers on the "Incompleteness Theorem", where he proved that in any axiomatic formal system, like geometry and mathematics, one can never prove that the system is complete and consistent in itself.

Yourgrau focuses on Gödel's life and his eccentric style, and includes numerous stories about his relation with Einstein. He also addresses significant philosophical discussions on the nature of mathematics and the nature of truth.

-Yervant Terzian



Yervant's Critical Thinking Corner

The Question of Identity:

The Greek philosopher Heraclitus asserted that when one steps in a river twice, one steps into different bodies of water. However, the river stays the same even though its parts change.

In this context, I would like to share the following paradox with you. The ancient ship of the Greek hero Thesseus was preserved by the Athenians. When, with time, some old planks began to break, they were replaced by new and stronger timbers. Piece by piece, all the old wood was replaced. However, the old planks had been put aside and were re-assembled into a ship. At that point, which was the ship of Thesseus?

Hunting for Extra-Solar Planets

(cont.)

object either known in our solar system or yet found in isolation in free space.

Detecting the transit of an earth-like planet around a sun-like star requires a photometric precision of better than one part in ten thousand, which has only ever been achieved from space on a very small number of observations. However, due to the scaling of the size of the star, an earth-like planet around a faint, low-mass star would yield a transit depth of 1%, *the same depth as the transits already detected* in the case of Jupiter-like planets around sun-like stars. Similarly, the precision required to detect directly the light from the planet by observing the secondary transit is one part in one thousand, *the same precision that has already been achieved* in the case of HD 209458b.

This is a path to find and characterize potentially habitable terrestrial planets that does not require expensive or difficult space missions, but instead follows the development of techniques that have succeeded in the study of planets around sun-like stars and applies them to the numerous low-mass stars in the Galaxy. The radial velocity component of this path is already under development and will ultimately yield the discovery of a transiting rocky planet around a nearby star. Once a transiting planet has been found, astronomers will be able to bring to bear the full capability of current and future observatories such as the Spitzer and James Webb Space Telescopes on the detailed characterization of its properties. These planets will yield the first opportunity to study directly the atmosphere and possible biological activity that so dramatically effects the atmospheric composition of terrestrial planets. The first detection of an earth-like planet will have a profound and lasting impact on our perception of our place in the universe, our view of our own Earth, and the future history of mankind.

-James Lloyd

Thanks to the Friends!

(cont.)

Last but not least, Mark Keremedjiev received the Cranson W. and Edna B. Shelley Award for Undergraduate Research in Astronomy. As a sophomore, Mark worked with the Infrared Spectrograph Team to design and reduce data from a lengthy set of Spitzer Space Telescope observations to improve the pointing accuracy of the telescope. He has also been working with Lei Hao, a recent Princeton PhD in the Department's plasma astrophysics group, on the spectral properties of active galactic nuclei and quasi stellar objects.