



O R I O N

Newsletter of the Friends of Astronomy Cornell University

Greetings

Dear Friends,

Spring has brought us a cornucopia of good news. Two new faculty members are joining us to strengthen and rejuvenate our staff. Dr. James Lloyd, a graduate of Berkeley, will be joining us as an Assistant Professor following a postdoctoral appointment at Caltech. James is an expert in techniques being developed to image “exoplanets,” or planets around other stars.

Also joining the faculty is Dr. Jean-Luc Margot, a Cornell graduate who has worked as a post-doc at Arecibo and most recently at Caltech. Jean-Luc, a leading radar astronomer, is also an expert in several other areas of planetary science including the study of distant comets in the faraway Kuiper Belt beyond Neptune.

The Department continues to bask in the glory associated with the outstanding successes of Spitzer (the last of NASA’s four Great Observatories) and the Mars Rovers. We are very proud that our faculty and staff are playing major roles in these endeavors.

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*V838 Monocerotis: an exploding star
NASA and Hubble Heritage Team (AURA/
STScI)*

Dear Friends,

On June 30, 2004, Elizabeth M. Bilson will retire from her position as Administrative Director for the Department of Astronomy and the Center for Radiophysics and Space Research. For 21 years Elizabeth has been an outstanding administrator, performing her work with supreme intelligence, deep responsibility and care, and also with long hours. We will all miss Elizabeth very much, but wish her all the best for a happy retirement!

Born Elizabeth Marie Jarmay in 1937 in Budapest, her mother was a pianist, her father, Dr. Gyula Jarmay, was a prominent lawyer and a congressman in the few post Second World War, pre-communist years which ended by the creation of the iron curtain. Elizabeth grew up during the most intense communist years witnessing the persecution of her father for his views. Early on she decided to be a chemist and began her university studies at the Polytechnical University in Budapest in 1955. She left

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Summer 2004



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Editor

Patricia Fernández de Castro

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Dear Friends

(cont.)

Hungary after the unsuccessful 1956 revolution and became a refugee student in Paris at the Sorbonne. Near the end of her undergraduate years in Paris she met her future husband, pianist Malcolm Bilson. She married him in 1961 and embarked on graduate studies in chemistry at the University of Illinois. In 1968 the couple moved to Ithaca where Malcolm joined the Department of Music at Cornell. Elizabeth obtained her Ph.D. from the University of Illinois in 1969 and started working as an assistant to Tommy Gold at the CRSR that same year. At that time the first lunar samples were returned to Earth by the Apollo11 astronauts and Gold soon started receiving them for analysis in the Lunar Laboratory.



Thank you Elizabeth for all your excellent work. We will miss you.

In the early 1970's, Elizabeth became the director of the Lunar Lab and for some seven years did analytical work on the physical and chemical properties of lunar materials. Along with Tommy Gold and Richard Baron, she published some 25 papers on the subject culminating in a seminal paper in the *Journal of Geophysical Research* entitled "Why the Moon is Dark". In the late seventies, she joined Gold in his research on the origin of natural gas

and petroleum on Earth. In 1983 Elizabeth became the Administrative Director of the Department of Astronomy and the CRSR. Research with Tommy Gold was interesting and rewarding but so were the 21 years in administration during which both the Department and the Center grew considerably, especially in research funding and involvement in large scale space missions.

Much as she loved her professional career, family life has always been most important. Malcolm and Elizabeth raised two daughters: Andrea and Monica, and are now the proud grandparents of two little girls and a boy.

As Elizabeth begins a new phase of her life, we are happy to welcome Mary Mulvanerton, who will be the new Director of Administration. Mary has been with us as a Research Support Specialist with the Mars Exploration Rovers Mission since February 2002, a challenging position with a major project that allowed her to get to know the Department well. Mary holds a JD degree from New York Law School. We wish her all the very best in her new role!



Welcome Mary! We look forward to working with you.

-Yervant Terzian

Greetings

(cont.)



Eanna Flanagan

As I am writing this letter, I have just learned that Eanna Flanagan, Associate Professor in Physics and Astronomy, has won the Xanthopoulos International Award in General Relativity and Cosmology. The prize is given to a scientist, below age 40, who has made outstanding theoretical contributions to gravitational physics. Eanna is being honored for a broad range of contributions ranging from data analysis for gravitational wave detectors to studies of quantum gravity and cosmology.

I am particularly happy to be able to tell you that our Department has received an A+ rating from a Visiting Committee appointed by Peter Lepage, the Dean of the College of Arts and Sciences. In the words of the committee, the "department continues its rich tradition of seminal contributions, singular individuals and emphasis on the highest quality education for undergraduate and graduate students." We are especially pleased that the Committee enthusiastically endorsed the Atacama Project and concluded with the recommendation "We urge the College to move rapidly on" it.

The Atacama Project has made giant strides in the past few

months. We have established a partnership with Caltech and our two institutions are currently engaged in a 2-year study phase. Cornell's participation in this study phase was made possible by the vision and generosity of one of the Friends of Astronomy. After it is completed in late 2005 or early 2006, we expect to see the actual start of implementation and construction—an immense undertaking of vast importance to the future of our Department, and one which we know can be completed successfully with the continued strong encouragement and support from our Friends of Astronomy.

In closing, I am happy to report that the Special Symposium on



The Friends of Astronomy Special Symposium on the New Cosmology

Cosmology on the 4th and 5th of June was a complete success. We were delighted to have a group of over seventy of our Friends. Yervant organized a great program with Patricia to elucidate as never before the infinite mysteries of dark matter and dark energy. As a special bonus, Jim Bell and Jim Houck updated us on the fantastic discoveries currently being made by the two Rovers on Mars and by Spitzer in space.

I wish you a happy and productive summer!

-Joe Veverka

The Spitzer Space Telescope Is in Space!

James R. Houck, the Kenneth A. Wallace Professor of Astronomy, is the principal investigator of the Infrared Spectrograph on Spitzer. Vassilis Charmandaris is a senior staff scientist for this fascinating project.

In the early morning hours of August 25, 2003, many of us had the unique opportunity to witness the Spitzer Space Telescope, mounted atop a Delta II rocket, being successfully launched into space from Cape Canaveral. This brought closure for many astronomers and engineers here in Ithaca who had been working hard on the project for more than two decades. However, it was also a new beginning. For the past few months, along with colleagues around the world, we have been experiencing the excitement and joy of new discoveries made by this superb new telescope. The mission, formerly known as the Space Infrared Telescope Facility (SIRTF) was recently renamed after Lyman Spitzer, who as a young man in 1945, long before the launch of the first artificial satellite, wrote a short but prophetic paper correctly identifying all of the major advantages of space borne telescopes: freedom from atmospheric absorption, emission and image blurring. Spitzer discussed the benefits to a wide scope of observations, from x-rays to the far infrared.



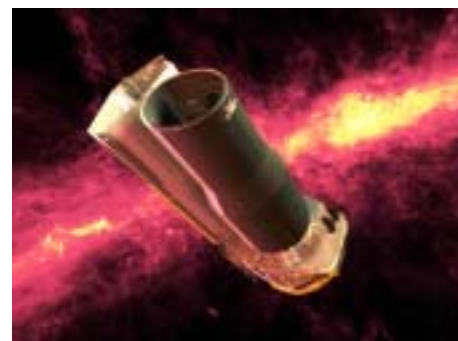
Spitzer, which is the largest scientific infrared telescope ever placed into space, follows Hubble, Compton, and Chandra as the last of NASA's "Great Observatories." The idea of a telescope like this one goes back to 1983, when NASA's Infrared Astronomical Satellite (IRAS), another space mission in which Cornell astronomers were involved, revealed for the first time the importance of the infrared emission to understanding the physics of most regions in the Universe. Due to the presence of dust, the majority of extragalactic sources, as well as many sources in the Milky Way, emit a large fraction of their energy in the mid- and far-infrared. Up until the IRAS mission, astronomers had not fully appreciated that even though dust grains constitute less than one hundredth of the mass of the interstellar medium, they play a role in heating the gas and selectively absorbing the emission of stellar light. Moreover, the most exciting regions in the Universe, such as planets forming in disks around young stars, or supermassive black holes in distant luminous galaxies, are actually enshrouded in gas and dust. This makes it impossible to examine their properties using the optical light. After several years of planning and many redesigns due to budget constraints, the current design of Spitzer was finalized in 1996. Cornell, with its longstanding tradition in leading the nation in



An infrared image of a protostar called HH46/47 obtained by Spitzer shows how matter ejected by the young star as it forms heats the surrounding gas and dust. Noriega-Crespo, SSC/Caltech.

infrared and space astronomy, was one of the three institutions selected to deliver an instrument for Spitzer. We designed and built the infrared spectrograph (IRS), an instrument that enables us to obtain spectra at wavelengths between 5 and 40 microns, as well as images at 16 and 22 microns. (A five micron wavelength is ten times longer than the wavelength of green light.) The other two instruments are cameras that take images at several wavelengths between 3 and 160 microns.

The most important advantage of IRS and Spitzer, when compared to previous infrared instruments, is their superb sensitivity, nearly 10,000 times better than that of Infrared Astronomical Satellite (IRAS) twenty years ago. Observing from space is essential in the infrared since the sky brightness is nearly a million times lower than that of any ground-based observatory. Since the telescope and its instruments are cooled to ~5 Kelvin (-450°F) by evaporating liquid helium, the lifetime of the mission is determined by the helium supply. The telescope boils away about one ounce



An artist's conception of Spitzer against the backdrop of the Milky Way, as seen in the far infrared. The main telescope is encased in the cylindrical cell.

of liquid helium every day, so in about 6 years its supply will be exhausted. Unlike most other satellites, including all of the other Great Observatories, Spitzer is in heliocentric orbit, trailing behind the Earth as it is revolves around the Sun. Since Spitzer is slightly further away from the Sun than the Earth is, it is gradually drifting further and further behind the Earth. In about 60 years, long after the end of the mission, the Earth will "catch up" again with Spitzer.

Spitzer has been performing superbly, and for the past several months IRS has enabled us to probe, in an unprecedented way, the chemical composition of objects ranging from moons in the solar system to distant galaxies formed when the Universe was just 1/10th of its current age. Twenty scientific papers chronicling the early discoveries of the IRS were submitted in early April for publication in late

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An Opportunity for Cornell Graduate Students

Jascha Sohl-Dieckstein



We waited patiently for Opportunity to launch. Fortunately Cocoa Beach is an excellent place to be stranded. The days dragged on, though, and the problems with cork insulation and batteries continued. Despite the relaxing sun and surf, we began to feel apprehensive. Assurances by launch veterans did little to calm our fears born of inexperience. Finally, on July

7, 2003, after two weeks of delays and one traumatic hold at T-minus 7 seconds, Opportunity launched flawlessly.

Seven months later, after countless run-throughs, we were gathered together on the opposite side of the country at Caltech's Jet Propulsion Laboratory in Pasadena, with nothing left to do but wait and listen. In staccato succession, signals were sent back: each reporting the success of another crucial step in descent; each met by applause and cheers, each followed by more tense silence. Finally, the words for which we had been waiting were heard: "Roll stop!" Opportunity had come to rest on the surface of another planet.

A few hours later, we assembled again in the main science room to see the first images sent back from Meridiani Planum. First teased by thumbnail images, we squinted at the screens mouthing questions like "What is that?!" and "Where are we?!" The full-resolution images were greeted with gasps. We were staring at bright rocks jutting from dark sand, not scattered about randomly but ordered: we'd found bedrock! That evening during the press conference, Professor Steve Squyres, the mission's Principal Investigator exclaimed, "This is exactly what I thought it looked like in my wildest dreams!" For the students, one thought floated through each of our minds that night, "I have a thesis!"

"Opportunity made an interplanetary 'hole in one'" read one headline. She had landed in a small impact crater - Mother Nature's time machine - where deeper, older bedrock was exposed and could easily be studied. Our rover was sent to work grinding with the Rock Abrasion Tool (RAT) and analyzing this outcrop, a window into the Martian past. The Alpha Particle X-ray Spectrometer (APXS) discovered high concentrations of sulfur suggesting magnesium and iron sulfates. The Mössbauer Spectrometer identified jarosite, a hydrated iron sulfate that forms in acidic water. The Microscopic Imager (MI) showed spherules, dubbed 'blueberries,' believed to be hematite-rich concretions that formed as minerals transported by water were deposited in the rocks. As if this were not enough, the MI confirmed that this bedrock exhibited crossbedding. Each of these alone would have been only a tantalizing clue. Taken together they gave us exactly what we'd sent these rovers to find: conclusive evidence of a past body of water. *A shallow sea once flooded this region of Mars!* At this point we began to wonder, "Could it get any better?"

The answer was a resounding **YES!!** We found Bounce Rock, the only rock beyond Eagle Crater that the Panoramic Camera (Pancam) could see. Unlike anything seen before on Mars, Bounce Rock turned out to be a dead ringer for one of the SNC meteorites found on



Outcrop. Pancam false color image. NASA/JPL/Cornell.



Berries in outcrop. Pancam false color image. NASA/JPL/Cornell.

Thanks to the Friends

On June 5, during the Friends' Symposium we inaugurated the Josephine Hopkins Teaching Radio Telescope, which is located on the top of the Space Sciences Building. This was made possible in part by Friends Lee and Nancy Corbin. Thanks!



Nancy and Lee Corbin with Dean Peter LePage. Photo: Nicola Kountoupes/Cornell University.



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Barbara Asks!

On the Physics of Black Holes

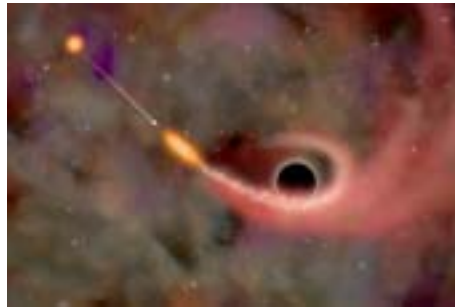
Q. What is the physics inside a black hole? How do we know that there are singularities in their cores?

A. Most of the remarkable objects in the Universe have a sort of romantic appeal, because either we can see their physical beauty—such as in photographs of gaseous nebulae by the Hubble Space Telescope—or we fantasize about what life might be like if we could only visit them—such as the austere seductive vistas of Mars revealed by the Mars Rovers. Black holes are probably the most unromantic objects in the Universe. They are ultra-compact aggregates of mass so dense that not even light can escape from them, so we only sense their presence indirectly, by their gravitational effects on nearby matter. Thus, we have discovered some black holes by observing hot gas falling toward them in tight binary star systems, and others by mapping the orbits of stars and gas in the inner regions of galaxies.

The modern version of the black hole first emerged right after Einstein published his theory of gravitation, general relativity. Karl Schwarzschild, a world-renowned astrophysicist then fatally ill from injuries sustained as a German soldier during World War I, solved Einstein's brand new equations exactly to find the gravitational field of a mass concentrated at a point. Later, the mathematician George Birkhoff proved that Schwarzschild's solution applies outside any spherical distribution of mass, just as the gravitational field outside a spherical mass in Newtonian gravity is the same as it would be if all the mass were concentrated at a point. However, in Schwarzschild's solution it appeared that there was a special radius—called the Schwarzschild radius—where the characteristics of the space changes character. It soon became clear that light could not escape outwards if emitted at or inside this surface.

Many physicists and astronomers recoiled from the idea of a black hole at first. Some, like Sir Arthur Eddington, refused to believe they could ever exist in Nature. However, in 1939, Robert Oppenheimer and Hartland Snyder, his student, showed that a uniform gas cloud collapsing under its own self gravity would contract inside its Schwarzschild radius and then collapse to infinite density. We now know that even nonuniform, spherical clouds will, if sufficiently massive, collapse in much the same way. In local patches of collapsing matter, the laws of physics hold just as they would in a laboratory (although under extreme conditions involving large density and, perhaps, temperature impossible to achieve terrestrially).

One way to understand physics “inside” a black hole is to ask what you might detect if you were inside a small vessel falling freely into one. Now in free fall, you do not, to



Giant black holes in just the right mass range would pull on the front of a closely passing star much more strongly than on the back. Such a strong tidal force would stretch out a star and likely cause some of the star's gasses to fall into the black hole. Above, an artist's depiction of the sequence of destruction (assuming that image-distorting gravitational-lens effects of the black hole are somehow turned off). Most of the stellar remains would be flung out into the galaxy. Such events are rare, occurring perhaps only one in 10,000 years for typical black holes at the center of typical galaxies. M. Weiss, CXC, NASA/ <http://antwrp.gsfc.nasa.gov/apod/ap040224.html>

lowest order, feel any effects of gravitation. We are all familiar with that from watching astronauts in space, where they are, even in orbiting space stations, in free fall. They toss around cameras, food, shoes, and float around without any gravitational effect. The same is true inside your rocket ship falling freely into a black hole.

More accurately, you do feel the effects of gravity, because the gravitational acceleration towards a mass concentration is stronger when you are closer to it. So inside any freely falling vessel that is outside a mass there are “tidal forces” that pull objects at the near and far ends away from one another. This effect is small—proportional to the size of the spacecraft divided by the cube of the distance to the mass concentration—(explain the formula?) as long as you are at a large enough distance. It is the only gravitational effect detectable by anyone inside a rocket in free fall.

So imagine you fall into a super-massive black hole, such as the one in the center of our galaxy. At first, you simply pass through the Schwarzschild radius uneventfully. After about another half hour life becomes uncomfortable because the tidal forces begin to become strong enough to distort your body substantially. As you fall to the center, these tidal forces grow without bound, according to general relativity, and eventually you will die because they will rip you apart.

General relativity states that wherever tidal forces are infinite there is a singularity. Strictly speaking, the singularity is at a point inside a black hole. The point is hidden from outside observers, who can never know about its existence because no signal can ever be sent out from within the Schwarzschild radius. Physics breaks down at this point, but all physicists also expect that general relativity needs to be modified on very small distance scales, where quantum effects can become important.

-Barbara Burger (for the question)
-Ira Wasserman (for the answer)

The Friends' Symposium on The New Cosmology

June 4th and 5th was a busy and delightful weekend. The Friends started to arrive Friday afternoon. After picking up their Symposium folder and name tag, many of them visited with the faculty. In the evening, we met for a reception and dinner at the Music Department's beautiful Lincoln Hall, after which Jim Bell virtually transported us to Mars. His video let us see all that the Rovers



The Friends in session ...

have seen and go everywhere they have gone. It was absolutely breathtaking!

The next day we covered a wide range of important cosmology topics through a series of lectures that explored the issues in depth but in good, plain English and were complemented with instructive and often beautiful illustrations. We are thrilled to say quite a number of Friends called or wrote to Yervant to let him know how much they enjoyed the talks! The faculty were also very happy. Professor Henry Tye, who delivered the lecture on



... and in recess

THE NEW COSMOLOGY

FRIENDS OF ASTRONOMY SYMPOSIUM

CORNELL UNIVERSITY

Friday, June 4, 2004

Space Sciences Building

02:00 [Open House](#)

06:30 [Reception \(Lincoln Hall B20\)](#)

07:00 [Dinner](#)

08:30 The Rovers on Mars (J. Bell)

Saturday, June 5, 2004

Space Sciences Building 105

08:30 am [Coffee and Pastries](#)

09:00 Welcome (J. Veverka and P. Lepage)

09:15 Introduction to Cosmology (E. Salpeter)

09:45 The Big Bang Theory (I. Wasserman)

10:30 [Coffee Break](#)

10:45 Black Holes and the Big Bang (S. Teukolsky)

11:15 Cosmology and String Theory (H. Tye)

11:45 [Lunch \(Red Barn\)](#)

01:30 pm Cosmology & the Anthropic Principle (Y. Terzian)

02:00 Cosmology Questions

02:45 [Coffee Break](#)

03:00 The State of the Department (J. Veverka)

03:15 The Space Infrared Telescope (J. Houck)

03:45 The Atacama Project (T. Herter)

04:10 The Square Kilometer Array (J. Cordes)

05:00 Rare Science Book Collection (D. Corson)

06:30 [Reception \(Lincoln Hall B20\)](#)

07:00 [Banquet](#)

08:30 Meet the Astronomy Graduate Students

Sunday, June 6, 2004

10:30 am [Hike in the Plantations](#)

string theory, wrote, "You have a spectacularly successful Friends of Astronomy program. I am very impressed that so many non-scientists will spend the time to hear about Mars, cosmology and astronomy."

Saturday afternoon David Corson treated the Friends to a special exhibit of rare science books that included works by Ptolemy, Copernicus, Brahe, Kepler, Galileo, Huygens, Newton, Halley, Herschel, Laplace, Foucault, Lowell and Wallace. Later, after a relaxing reception and dinner, we met four of the Department's students, who shared with us how they got to where they are and where they plan to go from there. To paraphrase Barbara Burger, we were only sad that it couldn't last longer.

-Patricia Fernández de Castro

An Opportunity for Cornell Graduate Students

(cont.)

Earth and long believed to have come from Mars. Bounce Rock sealed the case on the origin of these meteorites.

In fact, things will likely continue to get better. We're driving towards Endurance Crater, a crater substantially larger than Eagle Crater, which may have even older layers of bedrock exposed. By the time you read this we will have arrived and found . . . who knows what? So far this experience has taught us that when you're a student working on MER and Mars is your classroom, it only gets better!

Zoe Asta Learner and Jason Soderblom

See you again soon!



Mark and Joyce Cascella.



Carolyn Sampson, Bill and Nancy Bellamy.



Jim Byrnes.



Ryan and Fred Young.



From left to right, kneeling, Gabriele and Helen Villa; first row, Bryan and Kathy Patten, Bob Cowie, Carolyn Sampson, Barbara Kelly, Albina Janus, Betty and Paul Klaas, Nancy Klein; in between rows, Nancy Bellamy; second row, Chuck and Carol Mund, Richard Kelly, Chuck Mund jr., Bill Bellamy, Vanne Cowie, Jerry Klein; back row, Lorne Trotter.



Phil Handler and Ed Hewitt.



Jeff and Sandy Brickner.



Albina, Peter and Nancy Janus.



Joan and Bob Horn.

Books in Science and the Universe

The Great Book of Optical Illusions by Al Seckel. Published by Firefly Books, 2002.

This book is the most comprehensive, educational and entertaining book on illusions that I have seen. Some 300 pages of illusions, mostly in color, will shake your confidence in the ability of your senses to accurately perceive reality. You will be surprised with every page you turn. The book provides many lessons on vision and perception. How do we sort out the various images we see? The process of perception happens in our brain in ways that we have only begun to understand. Your visual/brain system can indeed interpret scenes in more than one way!

This book is really fun. After examining its illusions you will realize how easily you can be fooled, tricked and misled, but this will bring great joy, to old and young alike.

-Yervant Terzian



Yervant's Critical Thinking Corner

A paradox:

The host of a game show presents you with two closed envelopes containing money. One contains twice as much as the other. After you choose one envelope, the host asks you if you wish to exchange it for the other one. Should you change? You can take a look to know what your envelope contains.

Say that your envelope contains \$20. The other should have either \$10 or \$40. Since each alternative is equally probable, the expected value of switching is $(1/2 \times \$10) + (1/2 \times \$40)$ which equals \$25. Since this is more than your envelope contains, this suggests you should switch. This reasoning works for whatever amount you find in your envelope. Therefore it does not matter whether you look in your envelope or not: you should change.

But if someone else was playing the game and had chosen the second envelope, the same arguments would suggest that person should switch to your envelope to have a better expected value. What is wrong with this argument?

For a discussion of this paradox, see the Friends' website at www.astro.cornell.edu.

-Yervant Terzian

Professor Thomas Gold 1920-2004



As we were closing this issue of Orion, the Department received the sad news of Professor Thomas Gold's passing. Tommy, as we knew him, passed away peacefully early on the morning of June 22, 2004.

He became the first Director of Cornell's Center for Radiophysics and Space Research in 1959. He founded Cornell's modern Department of Astronomy and introduced radio-astronomy at the Arecibo Observatory early in the '60s.

We will miss him greatly.

Among Tommy Gold's many and important contributions was his explanation in 1968 of pulsars as rapidly rotating neutron stars. To the right, the Crab pulsar (inside the Crab Nebula), a city-sized neutron star that spins thirty times per second. (Image, J. Hester (ASU) et al., CXC, HST, NASA).

N.B. There will be a memorial service on October 13, 2004 in Barnes Hall at Cornell. Orion will carry a more extensive article in the winter.



New Faculty



Jim Lloyd is developing instrumentation and experimental techniques for the study of extrasolar planets.



Jean-Luc Margot is interested in the rotational response of planets to different forces as a way to understand their internal structure and rheology as well as their dynamic and thermal evolution.

Spitzer Space Telescope (cont.)

summer. If this is a guide to what lies ahead, we expect that the scientific output of Spitzer will keep astronomers busy for decades to come.

-James R. Houck
and

-Vassilis Charmandaris

Both Cornell and NASA maintain websites where you can see the latest results from Spitzer. Visit

<http://www.news.cornell.edu/releases/SIRTF> or

<http://www.spitzer.caltech.edu>