

O R I O N



Newsletter of the Friends of Astronomy Cornell University

Greetings

Dear Friends,

Another school year has come to an end. Patricia and Yervant have put together another fascinating issue of **Orion**. Exciting things continue to happen in the Department.

Right now the excitement focuses on three missions of exploration, two of which, the Mars Exploration Rovers (MER A and B) will soon be headed for Mars, while the third, the Space Infrared Telescope Facility (SIRTF) is expected to reveal new secrets of the distant universe.

The SIRTF launch on April 28 was postponed due to problems with the solid rocket boosters on the Delta II and rescheduled for August 27. So the Cornell team, led by Professor James Houck, will have to endure another four-month delay before its instrument, the InfraRed Spectrometer (IRS) begins studying remote stars and galaxies. Check out <<http://sirtf.caltech.edu/>> for more information.

Continued p.2



Galaxy N6946

Happy Summer!

Dear Friends,

Last year NASA used a satellite called Wilkinson Microwave Anisotropy Probe to map the remnant radiation from the Big Bang fireball that is still weakly glowing everywhere in the universe. The photons in this background radiation have been expanding undisturbed with the universe. Since their last interactions, about 300,000 years after the Big Bang, they have preserved the tiny temperature fluctuations of that early time. The image of those fluctuations from place to place indicates the seeds of the formation of galaxies in the baby universe.

The data obtained with with the WMAP has allowed us to determine with unprecedented accuracy the age of the universe as 13.7 Billion years with an uncertainty of only 1%. On page 3 of this **Orion** you can see a sky map of the WMAP results and read Ira Wasserman's response to Barbara Burger's question about them.

I have been very impressed with the undisputed accuracy of

Continued p.8



Spring 2003

Contents

- Greetings1
- Happy Summer!1
- Studying the OH/IR Stars at Arecibo.....2
- Barbara Asks!3
- Meet the Friends.....4
- Magnetars: The Strongest Magnets in the Universe.....5
- Upcoming Events.....5
- The Instruments Aboard the Mars Rovers.....6
- Department News.....6
- Thanks to the Friends!.....7
- Congratulations!.....7
- 2003 and 2004 CAUs.....7
- New Director at NAIC.....8
- Books in Science and the Universe.....8
- Yervant's Critical Thinking Corner.....8



Studying OH/IR Stars at Arecibo

The first two things that a Chicagoan notices upon arriving at Arecibo are that the land isn't boringly flat and the stars aren't smeared out from nearby city lights. In fact, the terrain of inland Puerto Rico varies rapidly, with wild hills jutting up and down like some out-of-control sine wave. The stars are amazingly bright and well-complimented by the ubiquitous *coqui* (ko-kee), a little frog that will keep most visitors awake for their first few nights. On clear nights, one can walk to the top of one of the observatory's many hills and make out the faint strip of light that is the galactic equator of the Milky Way.



As an undergraduate at Cornell, I had the good fortune to spend two summers and a winter break at the observatory working with Professor Yervant Terzian and Dr. Murray Lewis. We are studying OH/IR stars—lightweight stars undergoing mass-loss at the end of their life. When a star similar in mass to our sun depletes its hydrogen fuel, it begins burning helium and expands into a red giant. After this phase, the star begins shedding mass in the form of a circumstellar shell that will eventually expand into a planetary nebula¹ as the central star collapses on its way to becoming a white dwarf. In between the red giant stage and the planetary nebula stage, coherent maser² emission can develop that emanates from the ejected shell of mass that surrounds the central star. This maser emission is studied at Arecibo and other radio telescopes around the world. OH/IR stars also emit unique radiation in the infrared range that is observed by infrared satellite telescopes and 2-micron near-infrared radiation that is observed by ground based telescopes, such as the 2MASS (2-micron all-sky survey) telescopes run by the University of Massachusetts in Arizona and Chile. Getting a good idea of the physics of how OH/IR stars evolve requires studying data from all these different sources and synthesizing it into one coherent picture.

Arecibo is unique not only because of the world-class science that it allows researchers to perform, but also because it teaches people, particularly undergraduates, about the culture of science. When my mother and sister came to visit, we went up on the platform of the telescope and after walking to the edge of the azimuth arm, Mom exclaimed, "This whole thing is here for science? Awesome!" When so many of the most grandiose and technologically advanced machines and facilities that we see today exist solely for military or commercial purposes, it is rewarding and inspirational to work at a place that is totally devoted to studying the beauty of nature. The undergraduate research program at Arecibo gives students from across the country the chance to be involved with cutting-edge research. But more importantly, it shows them the power and vigor of science by allowing them to interact with people who have devoted their lives to scientific inquiry. Hundreds of visiting researchers converge on Arecibo every year, making the observatory cafeteria a meeting of minds where people from around the world are drawn together through their love of astronomy. Now, more than any time in my memory, this meeting of minds across cultures is the most important thing that a scientific institution can provide to its students in an increasingly chaotic world.

-Derek Kopon '02, '03

¹The exploding outer mantle of dying stars.

²Microwave stimulated emission of radiation—lasers but at radio waves.



WOULD YOU LIKE TO UPDATE
YOUR E-MAIL?



Send a note to
Patricia Fernández de Castro
pf46@cornell.edu

Greetings

(cont.)

Meanwhile, Professor Steve Squyres and his team are getting ready for the launch of MER A early in June. This event will be followed by the launch of MER B at 12:30 am on June 25. Arrangements have been made to make it possible for the Friends of Astronomy to witness what promises to be another spectacular night launch. Both rovers will arrive at Mars in January 2004. For more information, go to <http://www.athena.cornell.edu>, and don't forget to go out and have a look at the red planet this summer. According to *Sky and Telescope* magazine, Mars will be closer to Earth in August than it has been at any time in recorded history!

Have a great summer!

-Joe Veverka

Barbara Asks!

Analyses of the new WMAP all-sky image indicate that the universe is composed of 73 percent dark energy, 23 percent cold dark matter and only 4 percent atoms

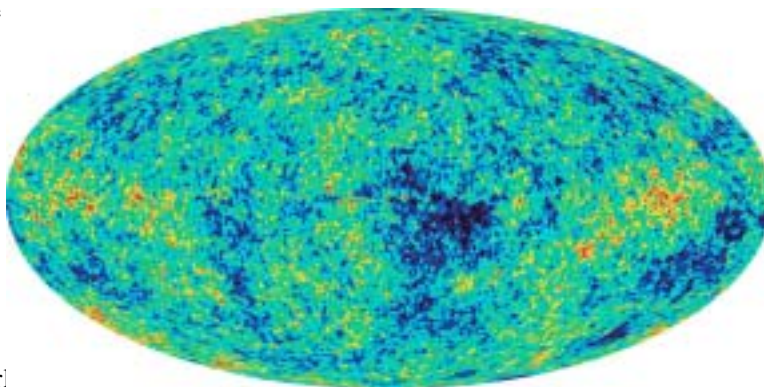
Q. How is it possible to formulate a valid theory of cosmology when 96% of the matter and energy of the universe is unknown?

A. Cosmological observations now show that ordinary matter made of protons, neutrons and electrons makes up only about 4% of the mass density of the Universe today. Radiation, mainly in the form of the cosmic microwave background radiation, only adds about four parts in one hundred thousand to the total. We are sure that three types of neutrinos exist, but their contribution to the total mass density is now limited to less than one percent. What is the rest of the Universe made of, and how can we even figure out how the Universe works when we do not know what it is made of?

The answers to both questions are connected. Astrophysicists talk about different classes of matter. One such class is “cold dark matter.” This is a type of matter that is “dark” in that it does not emit electromagnetic radiation. It is “cold” because the particles that constitute it have only very slow random motions (hence very low temperatures). We now believe that about 23% of the mass density of the Universe is in this form. We do not know precisely what the dark matter is, but it is far likelier to be some as-yet-undiscovered elementary particle rather than black holes. Elementary particle physicists do not believe that they have found all of the fundamental particles in the Universe, and they are probably right. There are many theories, particularly supersymmetric theories, that predict the existence of particles that would behave like cold dark

matter. There are, in fact, ongoing experimental searches for dark matter particles in the halo of our Galaxy—their flux is big but their interactions are very weak, making such experiments quite challenging.

Why do we believe that cold dark matter must exist in the Universe? The answer is that without it, large scale structure and its descendants—such as galaxies, stars, planets and us—could not have formed from the small density fluctuations that existed in the early Universe. The amplitude of these perturbations is revealed to us in the fluctuations of the Cosmic Microwave Background temperature on the sky observed by experiments like the Cosmic Background



*Wilkinson Microwave Anisotropy Probe All-Sky Map
WMAP Science Team, NASA*

Explorer, and the Wilkinson Microwave Anisotropy Probe. If the Universe were made exclusively out of ordinary matter, there simply would not have been enough mass in the Universe to grow the kinds of structures we see.

Dark energy is a more nebulous concept. One form of it is the cosmological constant invented by Einstein in what he famously called his greatest blunder. I wish I would

make a mistake that bad in my own research. The data we have now can be explained if the dark energy is indeed Einstein’s cosmological constant, and makes up about 73% of the mass density of the Universe. Some blunder!

Crudely speaking, the dark energy is a kind of ubiquitous “field” which, like many fields encountered in physics, can have both a kinetic energy, related to how fast the value of the field is changing, and a potential energy. You can think of the potential energy like a hill, and the field as the position of a ball on the hill. The ball will roll down the hill, if it starts out at the top. There may be a bottom a short distance away, in which the ball could become trapped eventually—resulting in a cosmological constant. Or else it may never be trapped, and just roll down forever, resulting in a time variable dark energy density.

Given a model for the dark energy field, one can compute the evolution of the Universe from the equations of general relativity, and compare with observations. The problem is that there are large classes of models for the dark energy that fit all of the available data more or less equally well. For example, measurements of fluctuations on the sky of the Cosmic Microwave Background temperature tell us the total mass density of the Universe, and the relative contributions of ordinary matter, dark matter and dark energy to an accuracy of a few percent. But, these observations, the most precise ever made, do not constrain the nature of the dark energy very much at all; numerous models will do just as well. Until we understand how to narrow the possibilities somehow, it will not be easy to make progress.

Continued p. 4

Meet the Friends

Phil and Maddy Handler are Charter Members of the Friends of Astronomy at Cornell University. They have been very close to the Department now for many years. We appreciate their numerous contributions and Phil's talents in documenting many of the activities of the Friends

Q. How did you become interested in Astronomy? Was it before the Friends group was organized?

Maddy: My interest in Astronomy was peaked by necessity several years before the Friends' group was organized. I trained in the biological sciences at Cornell, but in the 80s I found myself teaching high school earth and space sciences. I was looking for an exciting way to update my knowledge in these fields and bring students current information, so I decided to interview scientists at work. That's how it started. During the school vacations we went on trips around the country primarily. Phil, who is a Cornell AAP grad and architect, served as my videographer. In the fall of 1990, we came to visit Cornell's Astronomy Department, where we interviewed the dynamic Chairman, Yervant Terzian, and that's how we became involved with the Friends!

Q. Do you keep up with new discoveries and research in Astronomy? How?

Maddy and Phil: These days, with Maddy retired from teaching, and therefore Phil having been relieved of his duties as videographer for those scientific trips, and with our extensive use of the internet, we find that our scientific reading is done mainly online, whether it be the *NYT* for general matters, the *Cornell Chronicle* and *Sun* for Department coverage, and the *Orion* of course.

Q. What Astronomy topics do you find most exciting?

Phil and Maddy: Of course, any project that involves Department members! Over the years there have been so many.

Maddy: While I was teaching, I favored following the planetary missions, such as Galileo to Jupiter, and Magellan to Venus, or the rendezvous missions with the various asteroids. I've always found cosmological discoveries very exciting,

especially those being made over the past few years by the various space telescopes.

Phil: I found the various kinds of ground-based telescope technology the most exciting—I learned so much about this topic while videotaping our many visits to giant telescopes around the country.

Q. How did you become involved with the Friends?

Maddy and Phil: We were among the first Friends Yervant recruited in the summer of 1991, while Maddy was taking his CAU course, *The Nature of the Universe*. It was an unforgettable experience. She learned about TOE, the Theory of Everything, relativity with no equations, why existence?—why something rather than nothing?, and the difficult subject of



quantum mechanics. We also heard other 'Yervant-isms,' and met other "friends," his colleagues Joe Veverka, Martha Haynes, Jim Cordes, and Paul Goldsmith, who helped out with the lectures in those days.

Q. What do you value most in belonging to the Friends?

Phil and Maddy: There are so many things—getting to learn first-hand about the Department's projects; being given the opportunity to be 'cheerleaders' for the

Continued p. 5



Barbara Asks!

(cont.)

Let me close with a couple of cautionary remarks about the dark energy. Remember that all of our cosmological observations probe the Universe's past. We are constitutionally unable to probe the future. Even if we can figure out exactly how the dark energy behaved before now, we cannot predict its future behavior in any kind of model-independent way. Thus, we are no longer able to predict whether or not the Universe will expand forever based on observations alone—any such predictions must invoke a basic theory of the dark energy. For now, dark energy, like Einstein's cosmological constant, is somewhat *ad hoc*, invoked just for the purposes of explaining cosmological observations. As far as we know, it only interacts with matter gravitationally; in fact, there are very stringent limits on its nongravitational interactions. It may have something to do with the deepest theories of physics, like string theory, or the brane world, in which we only live in three dimensions out of ten. However, the energy density of the dark energy, as determined by observations, is many orders of magnitude smaller than "typical" energy densities associated with string theory or the brane world. Why this is so may very well be the most profound and important issue confronting theoretical physics and cosmology today.

-Barbara Burger (for the questions)
-Ira Wasserman (for the answers)

Magnetars: The Strongest Magnets in the Universe



Neutron stars are the densest material objects in the universe, with slightly more than the sun's mass packed inside a ball just 20 kilometers across. They are formed when the core of a massive star exhausts its nuclear fuel and collapses under its own weight, thereby triggering a supernova explosion. Astronomers have long thought that the most common products of supernova explosions are radio pulsars, magnetized neutron stars emitting beams of radio waves which sweep through space as the stars rotate. Over the last few years, astronomical observations have revealed an even more exotic type of young neutron stars, whose magnetic fields are more than 100 times stronger than radio pulsars. Such super-magnetized neutron stars are called magnetars. Unlike radio pulsars, which are powered by rotational energy, the energy source of a magnetar lies in its superstrong magnetic field.

The most dramatic manifestation of magnetars is the so-called Soft Gamma-Ray Repeaters (SGRs). SGRs were discovered in 1979, but their "magnetar" nature was not realized until recently. During a "burst", which typically lasts several seconds, an SGR puts out gamma rays and X-rays, which can be millions of times as bright as any other outburst known. Indeed, an SGR burst can radiate away as much energy in a single second as the Sun does in a whole year! One such SGR burst was so powerful it caused detectable changes in the Earth's ionosphere, even though the star is thousands of light years away from the earth. SGRs are different from classical gamma-ray bursts in that their emission shows up at lower energies and the burst events repeat. Astronomers now believe that the SGR bursts are triggered by "starquakes" (similar to earthquakes) induced by the neutron star's superstrong magnetic field.

The magnetic field strengths of magnetars are believed to be 100,000,000,000,000 Gauss (G) or even higher. Recall that the magnetic field of the earth, which drives a compass, is about 1 G. A typical toy magnet on a refrigerator door has a strength of about 100 G, and the strongest sustained magnetic fields produced in laboratories are around one million G. A lot of peculiar things can

Continued p. 7

Meet the Friends

(cont.)

Department by supporting various activities and projects, and also for the Friends' by sharing the photos Phil takes and which now are posted on the Department's website on the Friends' page. There is also Maddy's periodic group email to the Friends wherein she shares and spreads the word about the Department and the Friends' activities. But, probably what stands out as the most valuable of all is the personal interaction and access afforded to us with such a talented group of Cornell faculty. As Yervant has been known to say, "The Department is a happy, happy place."

Q. What Friends activities have you enjoyed the most?

We've enjoyed many of the Friends' activities, but some of the most enjoyable have been the series of Symposia in Honor of 60th Birthdays. The first one was for Carl Sagan in 1994, then for Yervant in 1999,

for Joe Veverka in 2001, and the latest for Don Campbell last September 2002. All the birthday celebrations were terrifically enjoyable because of the diversity of activities combining the personal and academic sides of each faculty member. Carl's untimely death lent our memory of his a certain bittersweet quality. For us it was very special because Phil had the unique opportunity to capture the event in still photographs and videotape Carl at the party the evening before the more formal and public events at the Johnson Museum. We were particularly happy *Planetary Report* used Phil's photo of Sagan posing with former students to illustrate its lead story in their 1997 tribute issue.

-Patricia Fernández de Castro



Upcoming Events

On Wednesday June 25 at 12:30 am, the Mars Exploration Rover will be launched from Cape Canaveral, Fla.

Special activities for alumni and Friends include a buffet dinner and show at the Astronaut Memorial Planetarium and Observatory, a mission briefing, a launch day banquet at the Kennedy Space Center Saturn V Center, with feature speakers Steven Squyres and Gentry Lee, and a launch night party at Jetty Park.

For updates and information, go to www.athena.cornell.edu
See you in Florida!

The Instruments Aboard the Mars Rovers

The Mars Rovers are equipped with the Athena Payload, seven scientific instruments that will be used to search for signs of water and life and to explore the geologic and climatic history of Mars. The landing sites, Meridiani Planum and Gusev Crater, were chosen because conditions there may once have been favorable to life.

- The Pancam will take panoramic photos of the Martian surface that scientists will use to survey the landscape and identify rocks and soils.
- The Microscopic Imager (MI), composed of both a microscope and a camera, will capture enlarged views of tiny objects other cameras cannot detect, such as small quantities of minerals, that may contain tiny fossilized organisms.
- The Rock Abrasion Tool (RAT) is a powerful drill that will allow scientists to study the inside of rocks in search of evidence about their formation.
- The Mini-TES (Thermal Emission Spectrometer) sees infrared radiation emitted by objects. It can penetrate the dust coatings common to the Martian surface to recognize, from afar, carbonates, silicates, organic molecules and minerals formed in water.
- Using alpha particles and x-rays to determine the abundance of all rock-forming elements except hydrogen, the Alpha Particle X-Ray Spectrometer (APXS) will provide scientists with information about the formation of the planet's crust, weathering processes and water activity.



*The Pancam
Photo: NASA*



*The sundial
Photo: NASA/JPL/Cornell*

- The Mössbauer Spectrometer will determine the composition and abundance of iron bearing minerals that are difficult to detect and that will yield information about early Martian environmental conditions. It can also examine the magnetic properties of surface materials and identify minerals formed in hot, watery conditions that could preserve fossil evidence of life.
- Finally, the Rovers will carry the first-ever interplanetary sundials. Scientists will use them to calibrate the color and brightness of the images captured by the Pancam. The sundials are also works of art designed from ideas submitted by students from across the U.S. The rings around the center post symbolize the orbits of the Earth and Mars. The word Mars is written in 17 different languages, and each side of the sundial has an inscription that tells why we made the journey there.

Department News

Last April 29, Professor Saul Teukolsky, the Hans A. Bethe Professor of Physics and Astrophysics and director of the Center for Radiophysics and Space Research was elected to the U.S. National Academy of Sciences.

Graduate student Lynne Carter received the Eleanor Norton York Prize in Astronomy.

Kristine Spekkens and Jonathan Darvill received the Shelley Award for, respectively, Graduate and Undergraduate Research in Astronomy (see [Thanks to the Friends!](#) on page 7).

Of the Ph.D. recipients, Shami Chatterjee was awarded the Jansky Fellowship and will go to the National Radio Astronomy Observatory at Socorro, NM. Wynn Ho received a Hubble Fellowship and will join the Kavli Institute for Particle Astrophysics and Cosmology at the Stanford University and Stanford Linear Accelerator in Palo Alto, Ca., and Dae-Sik Moon accepted a Robert A. Millikan fellowship in experimental astrophysics from Caltech, in Pasadena, Ca.



*The class of '03. From left to right, Shami Chatterjee, Wynn Ho, Shannon Patel, Alex Hayes, Dara Zeelandelaar and Andrea Schneider
Photo: Yervant Terzian*



Orion
Department of Astronomy
Cornell University

Editor
Patricia Fernández de
Castro
pf46@cornell.edu

Magnetars

happen in magnetars' superstrong magnetic fields. For example, such fields distort atoms, compressing atomic electron clouds into cigar shapes, with the long axis aligned with the field, thus rendering the chemistry of life impossible. Together with Cornell undergraduate students Carolyn Sealfon ('00), Brian Cameron ('03) and Marcus Woo ('03), I have been exploring the properties of various forms of matter (atoms, molecules and solid) in superstrong magnetic fields for the past several years. They are important in order to interpret new observations of radiation from neutron stars.

Many new physical effects can also arise in the magnetar field regime. The ultra-magnetized vacuum—which, according to quantum mechanics, seethes with virtual electron-positron pairs and other particles—becomes birefringent, like a calcite crystal, capable of distorting and magnifying images. X-ray photons traveling through such strong fields readily split into two, or merge together. Together with graduate students Wynn Ho (who will graduate this May and take on a Hubble fellowship to a postdoctoral position at Stanford) and Matt van Adelsberg, I have also been studying these exotic radiative processes in the highly magnetized atmospheres of magnetars. Our goal is to use magnetars as an astrophysical laboratory to test physics under extreme conditions and use new observations to learn more about these fascinating objects.

-Dong Lai



Contributors

Barbara Burger

Founding Member, Friends of Astronomy

Patricia Fernández de Castro

Editor, *Orion*

Derek Kopon

B. A. '02, M. Eng. '03

Dong Lai

Associate Professor, Department of Astronomy

Yervant Terzian

The David C. Duncan Professor in Physical Sciences

Joseph Veverka

Chair, Department of Astronomy

Ira Wasserman

Professor of Astronomy and Physics

Congratulations!

.... to Bob and Vanne Cowie, who were honored with the 2003 Frank H. T. Rhodes Alumni Service Awards.



CAU 2003 and 2004

Yervant will be leading two CAU trips that may be of interest to the Friends:

- The Devil and Dr. Einstein: The Western Tradition and Its Foes. A Weekend Seminar at the Sanderling Resort (Duck, North Carolina) November 2-6, 2003
Barry Adams, Ross Brann and Yervant Terzian
- Probing the Cosmos: A Seminar at the Cornell Radio/Radar Telescope of the National Astronomy and Ionosphere Center at Arecibo, Puerto Rico March 2-6, 2004

More information is available on the CAU website <www.cau.cornell.edu>.

(cont.)

Thanks to the Friends!

Generous contributions from Friends of Astronomy have funded three annual colloquia, two of which took place during the spring semester. Dr. Jeff Hester of the Arizona State University was the guest for the Charles and Barbara Burger Special Colloquium. On Thursday February 27, 2003, he made a presentation on *The Crab Nebula: the Gift that Keeps on Giving*.



The Crab Nebula

On Thursday April 3, 2003 Professor Imke De Pater, of Berkeley University, discussed *Studies at Near and Mid-infrared Wavelengths with the Keck Telescope of 1) Volcanism on Io and 2) Titan's Atmosphere and Surface* in the Maryanne Shelley Jessup MacConochie Colloquium, established by Bob and Vanne Cowie in memory of Vanne's sister.

Jonathan Darvill and Kristine Spekkens were the recipients of the Cranson W. and Edna B. Shelley Awards for Excellence in Undergraduate and Graduate Research in Astronomy, Jonathan for his outstanding work in the upgrading of the Hartung-Boothroyd Observatory, and Kristine for the high quality of her work in the investigation of the structure of spiral galaxy disks and of the neutral hydrogen mass function in the local Universe.

In 2002 and 2003 the Terzian Fellowships, which are supported by an endowment from the Friends, went to Kate Dellenbusch '02, Malia Jackson '02, David Choi '03, Jason Neuswanger '03 and David Dror '03 (both years). They are all Astronomy majors!

Books in Science and the Universe

Here are two excellent books by Peter Ward and Donald Brownlee from the University of Washington in Seattle. Peter is a geologist and Donald is an astronomer. The first book is called *Rare Earth, Why Complex Life Is Uncommon in the Universe*. The authors discuss the conditions for life to develop on other planets and describe the habitable zones around stars. They also describe how life may have developed on earth and the many geologic and other events that have made life on earth possible like mass extinctions, plate tectonics and the effects of the Moon and Jupiter. They conclude that it is not easy to evolve complex systems like you and me, and that intelligent technological life may be very rare in the universe. Perhaps we are the only ones in the Milky Way Galaxy. Some may not agree with this conclusion. You have to read the book and make up your mind.

Their second book, which has just appeared, is called *The Life and Death of Planet Earth, How the New Science of Astrobiology Charts the Ultimate Fate of Our World*. This is a very engaging description of the 4.5 billion year history of our planet. It includes discussions on the changes in the earth's atmosphere, changes in the earth's climate, the different glacial periods, the various mass extinctions and the present brief state of the planet. The authors continue and describe the future of our planet, the return of the glaciers, the end of plant and animal life, the loss of the oceans, and the effects of the hot red sun as it begins its death. It all sounds provocative and scary. But will the human intellect find a way out of this and continue to survive?

-Yervant Terzian

New Director at NAIC



Robert L. Brown has been appointed to head the National Astronomy and Ionosphere Center (NAIC) and the Arecibo Observatory. Dr. Brown is a well-known astrophysicist and observatory administrator. Most recently he was deputy director of the National Radio Astronomy Observatory (NRAO), in Charlottesville, Va. Welcome Bob!



Happy Summer! (cont.)

these data and want to share this knowledge with you.

I hope you enjoy this issue of Orion that Patricia has put together for you, and please send your comments, suggestions and letters to her at pf46@cornell.edu.

I wish you a warm and happy summer.

-Yervant Terzian



Yervant's Critical Thinking Corner

Below are a few intriguing questions. Answers are posted on <http://www.astro.cornell.edu/people/friends> (or send e-mail to yt28@cornell.edu!)

- How many times can you subtract 6 from 30?
- Find the highest number that can be written with three digits.
- What time is it when the clock strikes 13 times?
- A criminal is sentenced to death. Before his execution, he is allowed to make a statement. If his statement is false, he will be hanged, and if it is true, he will be drowned. What should he say to confuse the jury and save his life?
- A doctor has a brother who is an attorney in Alabama, but the attorney in Alabama does not have a brother who is a doctor. How can this be?

