Join us at the Astronomical Society of the Pacific (ASP)
National Conference on Science Education and Public Outreach
Sunday evening, July 31, through Wednesday afternoon, August 3,
in Baltimore, Maryland

Early Bird Deadline to Register: May 15th, 2011 ~ Don’t miss it.

The “Connecting People to Science” national conference will encourage us to think about and share how we all, individually and collectively, can work to connect our target audiences to science in all of the different settings to which our efforts extend. ASP is partnering this year with the American Geophysical Union and the Space Telescope Science Institute to enhance our work to connect people to science.

The conference begins with a reception at Maryland Science Center and a showing of the dramatic new IMAX film on the repair mission to the Hubble Space Telescope. Conference sessions scheduled include:

• Best selling author Chris Mooney giving the keynote address on “Unscientific America: What’s the Problem? What’s the Solution?”

• America’s favorite public astronomer, Neil DeGrasse Tyson, discussing his experiences with social media and the “Twitterverse” as an avenue to public access

• Additional plenary sessions will address the challenges of climate-change education, the Year of the Solar System and the exciting missions it includes, and techniques for evaluating informal science education projects. A special science night will feature leading Hubble scientists discussing the cutting-edge research the space telescope makes possible.

K–12 teacher workshops and short courses will run in tandem with the conference (pg 32).

For registration and abstract submission guidelines, visit: www.astrosociety.org/2011meeting
Chandrasekhar: The Most Distinguished Astrophysicist of his Time

RICHARD E. WHITE

The career of Subrahmanyan Chandrasekhar, known as “Chandra” in the astronomical community, spanned decades and continents and was highlighted by the 1983 Nobel Prize in physics.

Chandra: The Man Behind the Science

NALINI EASWAR

To the members of the family he evoked the feeling of a forbidding figure, but his gentle and approachable nature came through in every personal interaction.

Extrasolar Planets: The Ongoing Saga

PAUL DEANS

This assemblage of press releases and Web items puts exoplanets in the spotlight, as astronomers draw closer to finding the Holy Grail of extrasolar worlds — an Earth-like planet in a star’s habitable zone.

Astronomy in the News

Ripples in the rings of Jupiter, Voyager 1 nears the limit of the Sun’s solar wind, and a giant ring of black holes — these are some of the discoveries that recently made news in the astronomical community.

NAVIGATION TIPS

• To go directly to an article from here, click on its title.
• Within each article click on the underlined text for additional resources.
• To visit one of our advertisers, click on their website URL.

departments

4 Editorial
Paul Deans
Do You Explore?

5 First Word
James G. Manning
Bueller Speaks

6 Annals of Astronomy
Clifford J. Cunningham
Dual Birthdays: Wright and Fingret at 300

7 Astronomer’s Notebook
Jennifer Birriel
Refining the Extragalactic Distance Scale

8 Planetary Perspectives
Daniel D. Durda
Swapping Comets with Our Stellar Siblings

9 Armchair Astrophysics
Christopher Wanjek
Crunchy Neutron Stars with a Liquid Core

10 Education Matters
David Bruning
Creating the New Age of Education, Pt. II

11 Reaching Out
James Lochner
The Year of the What?

12 Chandrasekhar: The Most Distinguished Astrophysicist of his Time
RICHARD E. WHITE

18 Chandra: The Man Behind the Science
NALINI EASWAR

22 Extrasolar Planets: The Ongoing Saga
PAUL DEANS

27 Astronomy in the News

34 Sky Sights
Paul Deans
Eclipses Galore

37 Reflections
Thierry Legault
The Sun, an Eclipse, and the ISS

32 Society Scope / ASP Supporters
Meet Us in Baltimore

3 Editorial
Paul Deans
Do You Explore?

5 First Word
James G. Manning
Bueller Speaks

6 Annals of Astronomy
Clifford J. Cunningham
Dual Birthdays: Wright and Fingret at 300

7 Astronomer’s Notebook
Jennifer Birriel
Refining the Extragalactic Distance Scale

8 Planetary Perspectives
Daniel D. Durda
Swapping Comets with Our Stellar Siblings

9 Armchair Astrophysics
Christopher Wanjek
Crunchy Neutron Stars with a Liquid Core

10 Education Matters
David Bruning
Creating the New Age of Education, Pt. II

11 Reaching Out
James Lochner
The Year of the What?

34 Sky Sights
Paul Deans
Eclipses Galore

37 Reflections
Thierry Legault
The Sun, an Eclipse, and the ISS

32 Society Scope / ASP Supporters
Meet Us in Baltimore

SPRING 2011  Mercury  3
I first saw Mimas on November 12, 1980. It was floating inside a black and white television monitor in the Von Karman auditorium at the Jet Propulsion Laboratory in Pasadena, California. Voyager 1 had just sped by this tiny Saturnian moon, taking a few quick, slightly soft snapshots as it passed. Due to the moon’s appearance, and with the 1977 movie Star Wars still fresh in memory, this Saturnian satellite was immediately dubbed the “Death Star” moon by the press at JPL.

Fast-forward nearly 24 years to July 1, 2004. The Cassini-Huygens mission entered Saturnian orbit. I recall checking Cassini’s orbital paths and noting its several passes by Mimas. But the photographic results were disappointing and the giant crater — named Herschel, after the 18th-century astronomer William Herschel who discovered Mimas in 1789 — never showed well.

Earlier this year, while working on the Winter issue of Mercury, I stumbled across a recent image of Mimas (above). To use a little British slang, I was gobsmacked. While not a particularly high-resolution shot, it was the type of image I’d been waiting to see for more than 30 years.

Despite my need to finish the issue, I promptly spent a good 45 minutes exploring images and stories on the Cassini website — something I had not done in quite some time. I also looked up more Mimas images on NASA’s planetary Photolnual site. I could have easily spent another 45 minutes or more prowling through the Saturnian system, but duty called.

However, this exercise made me realize how seldom I pause in my daily routine to surf the Web — to boldly go where others have gone before and have posted their results or stories or images for all to see. Don’t get me wrong. I use the Web...a lot. But it’s mostly for work, not fun. And I have to say that after staring at my computer screen all day, the idea of spending an evening staring at that same screen holds little appeal.

As a result, I’ve decided to carve out some occasional time from my work week to go exploring. Perhaps I’ll take a coffee break at an archaeological dig on Santorini, or lunch at the Prado in Madrid, or have a quick snack in the sunshine.

But the best thing about exploring via the Web is that if you follow a link, then another, and another, you never know where you might end up. It’s the electronic equivalent of wandering the physical byways of your neighborhood and stumbling upon something completely unexpected.

So take a moment (after you’ve read this issue, of course!) and use the Web for some non-work exploration. You never know what you might find.

Paul Deans
Editor, Mercury
That happened to me last December, around solstice time. Preparing for Christmas, and for visitors, and dealing with several other simultaneous and unexpected monkey wrenches of the sort life sometimes throws at you, I uncharacteristically misread the timing of the great solstice total eclipse of the Moon. And so the evening of December 20th found me toiling on earthbound matters, believing that the eclipse was still 24 hours in the future.

In mid-evening, on a trip out to the recycling bin, I looked up and spied the Moon shining through a gauze of cloud. I half-noted that it didn't look quite right — a dim fuzziness around part of the rim — but I chalked it up to meteorology. It was only later, when a half-heard prompt on the evening news alerted me that something was up — literally — that things finally clicked. With sudden realization and a bit of dread, I rushed out and looked up again, and there was the high-flung Moon with the gray curved shadow of Earth already halfway across its shining form. It wasn't a day early; I was a day late.

Although this was one of those moments when you go “oops,” I found myself actually reveling in a new sensation. Normally, I have these things nailed to the minute, my schedule and observing spot carefully planned, and observing gear arrayed about me — while tapping my foot as I wait for events to unfold. But for once, I was caught unaware, and in that startling moment, looking up at a Moon suddenly changed, I could instantly empathize with the long-ago farmer or herdsman or hunter who, pausing from their earthly toils, looked up and felt a sudden pang of fear as they saw the constant Moon being inexplicably extinguished.

Well, there was nothing else to be done. I dropped everything, grabbed a chair and my binoculars, and went out to the patio to watch.

And it was glorious — the nearly overhead solstice Moon turning a deep, multi-hued red-orange in a black sky against the stars of Gemini and Taurus. Periodically, vapor clouds from the sea drifted over, masking and then revealing the eclipsed Moon as mist slicked my cheeks. When the clouds thickened, I drove the short distance out to a coastal overlook to clearer sky, opened the aptly-named moon roof of my car and, protected from the chill buffet of the ocean wind, resumed my watch. Presently a patrol car crawled past and stopped, disgorging a patrolman with a flashlight who asked what I was doing (an occupational hazard of middle-of-the-night observing sorties that I've experienced many times before). I pointed up and said: “Eclipse,” and the officer continued on his way. And I continued my vigil, the sea in my ears and the Moon in my eyes.

When the Moon at last slipped slowly out of the dark shadow even as the Earth's turning carried it into the west over the Pacific, I journeyed homeward in the wee hours. All of my previous preoccupations were still waiting for me there, but dealing with them during the ensuing days was lightened by my interlude with the universe and the memory of a red Moon over the singing sea.

And so it happens. I've always held the conviction that the study and enjoyment of astronomy, first and foremost, constitutes an enhancement of life. It opens the mind and soul to beauty and wonder. It creates an understanding that Earthly rhythms are fundamentally cosmic rhythms, and that we can follow along. It connects us to the universe and makes us part of something much bigger than ourselves. And, as my near miss last December reminded me, it's important not to lose track.

Ferris Bueller said it as well as anyone. In John Hughes' classic teen comedy, Ferris Bueller's Day Off, our hooky-playing protagonist, at both the beginning and end of the movie, looks into the camera and says: “Life moves pretty fast. If you don't stop and look around once in a while, you could miss it.”

Wise words indeed. And it's part of the philosophy of your Society, in engaging people in the understanding and appreciation of astronomy, to encourage them to stop and look around once in a while — and to look up. To open their minds and hearts to the larger universe and how science helps us to put it all into perspective. It's important work, and we appreciate your support and companionship as we together strive to make a difference in the lives of others.

And when the world just gets a little too busy, a little too crazy, remember to steal a moment and go outside, and to paraphrase a line from Wordsworth, “Look up in perfect silence at the stars.” You'll find wonders there.

JAMES G. MANNING (jmanning@astrosociety.org) is the Executive Director of the Astronomical Society of the Pacific.
This year we commemorate the 300th birthday of two celebrated men of science. Even though they were born in 1711, their lives on either side of the English Channel followed very different trajectories. Alexandre-Guillaume Pingré (1711-96) was born in Paris and made several voyages to distant locations in the pursuit of astronomy. Thomas Wright (1711-86), was born in County Durham (in northern England). Aside from visits to Scotland, Ireland, and Holland, he spent his entire life in England.

In the 18th century it was not unusual for priests to devote themselves to astronomy. Pingré began as a professor of theology in 1735, but by 1749 had become a professor of astronomy. For 40 years he was based at the Abbey of Sainte-Geneviève, where he built an observatory.

Early in their careers, both Pingré and Wright worked on eclipses. Wright did a calculation of the lunar eclipse of 1732, but it was Pingré’s work on the lunar eclipse of 1749 that was important in launching his career as an astronomer. Nicolas Louis de Lacaille was one of France’s most famous professors of mathematics, so his computation of the eclipse of 1749 was unquestioned by everyone except Pingré, who found an error of four minutes.

The next phase of Pingré’s life was dominated by transits — Mercury in 1753 and the rare transit of Venus in 1761. This most important astronomical event of the age caused Pingré to travel to Rodrigues Island near Madagascar, but he saw only part of the transit due to poor weather.

Controversial disputes with other astronomers were quite typical then (as now). In this regard Pingré was no exception. He combined data, acquired by various observers during the 1761 transit, in an effort to measure the solar parallax. In presenting his findings to the Royal Academy of Sciences in Paris, Pingré said he could not use the data from Dominican Giovanni Audiffredi because the longitude of his observatory was not given. In his defense, Audiffredi, who observed the transit from the observatory at his monastery in Rome felt compelled to publish two Latin tracts about his parallax determination.

Wright, by contrast, does not seem to have provoked such public controversy, though some of his views were fantastic. He believed that the sky was solid and studded with inward-pointing volcanoes down whose shafts we see the stars! However, he was wise enough not to publish this during his lifetime.

As early as 1740 Wright showed a remarkable ability to state bold hypotheses about the heavens. In his book *The Use of Globes*, he wrote the “stars are so many suns, that each of these stars or suns is attended, (as ours is), by a proper number of planets and comets; and that each hath a gravitating power independent of each other... (so that) these several systems cannot interfere with one another.” This very nearly true — though there is very little gravitational effect between distant stars, they are not entirely independent. But the recent discovery of planets around hundreds of nearby stars shows that Wright was anticipating early 21st-century astronomy.

In 1750, at the age of 39, Wright published his famous work *An Original Theory of the New Hypothesis of the Universe*. He explained the appearance of the Milky Way as an optical effect because of the solar system’s position in a layer of stars.

Until just a century ago, it was thought that the Milky Way was the entire universe — the existence of other galaxies being unrecognized even though they could be seen. The intuitive leap required by Wright to explain the appearance of the bright band of stars in the sky is quite astonishing. And he did all this with no observational data of his own! It would be several decades before William Herschel made the observations that moved Wright’s ideas from hypothesis to fact.

Wright moved from the pursuit of astronomy to that of architecture during the 1760s — the same decade that saw Pingré travel to the Baltic to test marine chronometers and to Haiti to successfully see another transit of Venus. Both the adventurous life of Pingré, and the sedate life of Wright, contributed greatly to the advance of astronomy.

Pingré has been immortalized by a crater on the Moon and asteroid 12719 Pingré. Durham University in England is presenting an exhibition to mark Wright’s 300th birthday. It runs from May 14 to July 9, 2011.

In 1979, CLIFFORD CUNNINGHAM had a private dinner with Chandrasekhar during the IAU General Assembly in Montreal.
Recent progress understanding Type Ia supernovae should improve distance estimates.

Knowledge of the “accelerating universe” phenomenon is based on measurements of distances to the most remote galaxies using the brightness of resident Type Ia supernovae (SNe Ia). These galaxies are more distant than would be expected if the Hubble expansion rate had been constant. This leads to the inescapable conclusion that the rate of expansion has been increasing with time. The putative source of this acceleration has been dubbed “dark energy,” a sort of cosmic anti-gravity.

The idea to use SNe Ia as extragalactic distance indicators was first introduced in 1993. Type Ia supernovae are expected to occur when a white dwarf accretes material from an evolved companion star. Since these explosions all occur when the white dwarf’s mass exceeds the Chandrasekhar limit of 1.4 solar masses, the population of SNe Ia is expected to be homogeneous. All SNe Ia are expected to have a peak absolute magnitude of about -19.6 in the blue. Using the inverse square law, a comparison of the apparent peak magnitude with the absolute peak magnitude yields a distance to the SNe Ia and its host galaxy. (In reality, the process of distance determination is a bit more complicated!)

Currently, the very best estimates to individual SNe Ia are good to just under 10%, and so the Hubble scatter is about 10%. When using only visible light curves, distances are accurate to only about 15%. In an attempt to improve distance determinations using optical-only data, several groups have turned to SNe Ia spectra.

In 2009, X. Wang and colleagues studied a group of 158 normal, low-redshift SNe Ia and used the measured blueshift in the Si II feature (Silicone II) to determine the expansion velocity of the supernova ejecta. They found that SNe Ia can be subdivided into two distinct groups: a “normal group” in which ejecta expansions are confined within a narrow range of 10,600 km/s ± 400 kilometers/second, and a “high-velocity” group with expansion velocities in excess of 11,800 km/s.

The high-velocity group exhibits a narrow range of both peak luminosity and rate of decline from peak luminosity, compared to the normal group. In addition, the high-velocity group has a B-V color excess that is 0.1 magnitudes redder. Wang et al suggested that either the high-velocity SNe Ia are intrinsically redder than the normal group objects, or that they’re located in dusty environments. They argued that the extinction ratio (a correction term used to account for interstellar absorption) for the high-velocity group is a best fit with a significantly lower value than the normal group. This dichotomy in absorption-correction values led to improved distances measurements, with uncertainties reduced to 6% to 9%.

More recently, Ryan Foley and Daniel Kasen examined the same SNe Ia sample used by Wang et al. Foley and Kasen argued that extremely reddened objects should be removed from this sample, since such SNe Ia are rarely seen at high redshift. This reduced the data set to 121 spectroscopically normal supernovae. The duo was able to confirm the normal group and high-velocity group dichotomy. However, they also showed that when extremely reddened objects are removed, both groups can be fit with the same extinction ratio! Using the technique, Foley and Kasen find that the Hubble scatter can be successfully reduced to about 10% using optical-only information.

Foley and Kasen still found that the high-velocity group is systematically redder than the normal-group supernovae by 0.07 magnitudes. Thus, there appears to be intrinsic color difference associated with higher ejecta velocities. Foley and Kasen posit that this reddening occurs as a result of the “line-blanketing effect” in which closely spaced absorption lines overlap and reduce the continuum emission. As ejecta velocities in SNe Ia increase, all the absorption lines become broader and overlap. In SNe Ia, the blue region of the spectrum is dominated by absorption lines due to iron-group elements. The longer wavelength regions experience comparatively little of this “line-blanketing” effect, and hence the result is a reddening of high-velocity group objects.

These new findings have important ramifications for cosmological distance determinations. Assuming a single intrinsic color for cosmological supernovae will significantly bias results, especially if there is some evolution of the demographics of high-velocity versus normal-velocity populations over the cosmological time-scale. They suggest that future studies will provide more accurate distances if these employ spectroscopy to determine the ejecta velocity of SNe Ia as a means to determine the intrinsic color of the object first.
Earlier this year the Stardust spacecraft, re-tasked after its very successful flyby and dusty sample return from comet Wild 2, demonstrated that it was not yet done delivering new comet science results. The Stardust-NEXT flyby of comet Tempel 1 provided an opportunity to re-image that dark, dusty ice ball in an attempt to identify and further characterize the crater blasted into its surface by the Deep Impact probe.

The orbital properties of comet Tempel 1, in particular its relatively low inclination of about 10°, suggest that it originated in the Kuiper Belt, the vast disk of ice-rich planetesimals (beyond the orbit of Neptune) left over from the formation of the planets. Some of the comets in this region can, and have, encountered Neptune at some point in their history, scattering them into orbits allowing ultimate passage deeper into the realm of the inner solar system. These short-period, Jupiter-family comets represent some of the most primitive building blocks of the outer planets, so they are valuable witnesses to processes that long ago influenced the evolution and shaped the structure of our planetary system.

But there is another class of comets that suggest a different historical path to inner solar system glory. Many long-period comets fall into our realm of the solar system from the very edges of interstellar space, with orbits that are very highly eccentric and inclinations that seem to show no tie to the plane of the planets. The very large orbital semimajor axes and highly inclined orbits of Halley-type and long-period comets suggested to Dutch astronomer Jan Oort in 1950 that the Sun is surrounded by a vast cloud of comets extending nearly half way to the nearest star.

The usual explanation is that Oort Cloud comets formed in the same disk of icy planetesimals as the Jupiter family comets, accreting among or just beyond the giant planets. As the giant planets formed, some of these planetesimals were scattered outward and most were eventually ejected to interstellar space by the gravitational effects of encounters with the planets. Some of these objects, though, during this scattering process, had their perihelia raised out of the planetary region by interstellar tides and have survived to this day as the Oort Cloud comets.

The key and truly stunning revelation here is that most of the comets in each of the stars’ Oort Clouds were not originally born around the stars they end up orbiting. If this process was indeed the dominant mechanism populating the Oort Cloud, roughly 9 out of 10 long-period comets that occasionally light up our skies were born in the protoplanetary disks of other stars!

So the next time you gaze up at a long-period comet, it’s quite likely you’ll be looking at not just an interplanetary visitor, but ultimately, an interstellar one as well.
Neutron stars aren’t for sissies. They can turn a marshmallow into an atomic bomb, should you somehow manage to drop one on its surface and allow the crushing gravitational force to do its thing. These objects are the collapsed stellar remains of massive stars gone supernova. They pack about a sun’s worth of mass into a sphere some 20 kilometers across. All matter is squeezed together so tightly that most protons and electrons combine to form neutrons.

And while much is known about a neutron star’s gravitational and magnetic fields, and the effects they would have on marshmallows, credit cards and other fanciful objects certain to be with you on your intragalactic journey, precious little is understood about what’s inside a neutron star. Perhaps you’ve seen the illustrations. There’s a sphere, then a meter-high plasma atmosphere above the surface, and then a solid crust a kilometer or two deep. Then there’s a big question mark.

Now, two independent studies based on observations with NASA’s Chandra X-ray Observatory have cracked the surface. Researchers didn’t see a big question mark; instead they found evidence of a core filled with a bizarre form of matter called a superfluid, a conclusion with important implications for understanding nuclear interactions in matter at the highest-known densities.

Researchers turned their attention to Cassiopeia A (Cas A), the remains of a star that exploded (from our perspective) about 330 years ago. Cas A is a favorite among astronomers because it’s close, bright, and contains the youngest-known neutron star in the galaxy.

Dany Page of the National Autonomous University of Mexico, Mexico City, led one team; Peter Shtrninja from the Ioffe Institute, St. Petersburg, Russia, led the other. Yet much of the credit goes to a third team — Craig Heinke from the University of Alberta and Wynn Ho from the University of Southampton, UK.

Last year, Heike and Ho analyzed changes in Cas A’s temperature from 2000 to 2009 and found that it cooled by 4% — surprisingly fast. Shtrninja’s group added a November 2010 temperature reading to the data. Page’s group focused mainly on the Heinke and Ho data.

Independently, the two latter groups concluded that the steep temperature drop was a result of neutrino emission from an internal superfluid. Neutrinos vent heat as they make their way from the stellar core through the dense crust and atmosphere. But Cas A is too far away, and its neutrinos are not plentiful enough to be detected by Earth-bound neutrino catchers. The conclusion is based totally on how a superfluid should behave.

A superfluid is a frictionless state of matter. Without viscosity, fluid would flow uncontrollably — able to form infinite fountains, flow through pores that would otherwise contain the fluid in a non-super state, or seemingly defy gravity by flowing uphill.

Neutron stars cool to some degree through neutrino emission. The steeper cooling decline in Cas A, the researchers said, is from neutrons just now forming Cooper pairs, a transition phase to superfluidity. (Cooper paring can happen to electrons at low temperatures in a laboratory setting to create a superconductor, a flow of electrons without resistance.)

This Cooper pairing emits even more neutrinos, further cooling the neutron star. We have a narrow window of opportunity to observe such a phenomenon, Page said, and we simply might be very lucky in seeing a neutron star at such a young stage just beginning to form its superfluid core.

In referring to all the research teams, Cole Miller, an astrophysicist at the University of Maryland specializing in neutron star and black hole theory, said, “They did a fine job establishing temperature, which is non-trivial for a neutron star. Is this evidence for a superfluid core? Given the standard picture [for a neutron star], this is the best guess.”

There are a few other explanations for abrupt cooling, said Tod Stromayer, an X-ray astronomer at NASA Goddard Space Flight Center, but there is far less evidence for them. Something purely speculative but not implausible, he said, was that Cas A was undergoing “normal” cooling after sudden “heating caused by an episode of accretion onto its surface” from any debris in the region.

“If Cas A stops cooling fast, that would definitely kill our model,” Page said. “But if it keeps cooling fast for another 20 to 30 years, that’s a very good point in our favor. It took more than 40 years of research on pulsars and neutron stars to get possible direct evidence for superfluidity, so waiting another 20 or 30 for final confirmation seems to be something we’ll have to live with.”

“The model is testable to some extent, which is quite nice,” added Stromayer.

CHRISTOPHER WANJEK is a Baltimore-based science writer who attempted to write this piece as frictionless and fictionless as possible.
Creating the New Age of Education or Dismantling the Academy?

Online courses are cheaper to present, but are they better? Part II

In the previous Education Matters column (Mercury, Winter 2011, page 11), I discussed the positive features — accessibility, cost, flexibility, and course availability — of moving higher education instruction to online formats. This column presents a few arguments against online instruction.

Implementation. Many studies report that online learners do as well as face-to-face learners; in fact some studies report that online learners do better (Schulman and Sims, Technological Horizons in Education). But we must be careful about what is being compared. As Timothy Slater and Lauren Jones pointed out in Astronomy Education Review, a properly taught, interactive classroom yields higher learning gains than a well-designed online course. Comparing a novel online course with a poorly taught face-to-face class is not valid, nor is the “equality” of a traditional lecture class with its similarly structured online cousin surprising as neither uses best practices. Beware of comparisons of “skill and drill” courses; this is not a useful assessment of learning, either.

Think-Pair-Share. The work of Prather and others (for example Prather et al., American Journal of Physics) have shown that the most important part of the educational process is the interaction and communication between students as they form concepts. Online discussion environments are typically asynchronous, meaning students contribute at different times. This temporal disconnect makes the conversion of ideas generated by Think-Pair-Share activities into conceptual understanding less likely. (Online synchronous discussions are uncommon as it defeats the idea of online course flexibility.)

Blank stares. Students are reluctant to admit that they have issues with content. I have had students tell me that they are doing “okay” on activities when I can see that their paper is blank. Other students will let me walk past even though if I stop, they will confess that they “don’t have a clue what they are supposed to do.” I can intervene in the classroom because I can see responses and the blank stares — working with students while they process the idea is better than after the fact. Timely intercession is almost impossible online as most students conceal issues until they submit the assignment.

Deeper learning. Raven Wallace of Michigan State University concludes in her review of online learning research that: “...moving student discourse from sharing and explaining to knowledge building is an elusive process in online classes. Students are willing to share ideas but not to challenge each other’s thinking or press for deeper understanding” (Education, Communication and Information). The limited technology of common online testing tools can make it difficult to develop assessments that test for deeper understanding.

Motivation. Time management is paradoxical in today’s classroom. Students have more tools with which to track assignments and yet have more difficulty in submitting work on time. Online courses are often self-paced, and many students fail to complete courses because of poor time and attention management.

Teachable moments. In the classroom, teachable moments come and go. What might be a good moment to interject a topic or a commentary becomes a lost moment just a few minutes later. Online discussions lose many teachable moments because students often read the board once, or comments are seen as “yesterday’s news” and go unread.

To me, this is one of the big pitfalls of online courses. Some of the most memorable moments in my classroom have come because of an unexpected turn in the lesson that took the entire class in a new and totally different direction. Those moments are often the events students recall to me years later, because they were unexpected. Such occasions do not occur in online courses because that moment simply does not occur.

Tool Development. Online classes can build social communities and they can create discussion among students. Getting students to develop a deeper sense of their discipline requires a much tighter control of the online learning environment than simply putting lecture notes on the Internet. Best online practices require the development of user interfaces, different types of assignments, more group or paired projects, tutorials that allow for asynchronous study by student pairs, and “lecture” materials that are more than slide presentations borrowed from a face-to-face class. Yet, most online courses attempt to get by with simply moving lecture materials and exams online without regard to the medium.

I fear that larger numbers of courses will be pushed to the Internet in the future, with the consequence that the learning gains we know students can achieve will be sacrificed for elusive cost savings that are not guaranteed to appear. Courses will be pushed online without the proper development of materials and training of faculty to deal with a dramatically different environment.

While novel methods of engagement can be employed for online courses, evaluation and assessment remains a big issue, with little research to guide us (as yet). Good online courses will be developed by the few and the brave, but current research shows that most of us can better serve our students in traditional classrooms.

DAVID BRUNING is a Distinguished Lecturer at the University of Wisconsin-Parkside.
The Year of the What?

Do you know what’s happening this Year?

Every year seems to be the Year of Something. Some are International Years recognized by the United Nations. For example, 2011 is the International Year of Forests, of Chemistry, and of Youth (which actually started in August 2010 and continues to August 2011). The International Year of Biodiversity took place in 2010. There was also the International Year of Planet Earth (2008, though its activities spanned 2007-09), and the International Helio-physical Year (2007-08).

Then there are years declared by organizations. The Year of the Nurse in 2010 was set up by three international organizations using the centennial of the death of Florence Nightingale to bring attention to the global contributions of nurses. It was also the Year of the Lung, organized by the Forum on International Respiratory Societies.

The purpose of these years is usually to bring attention to some field of study, or to an issue of important significance. These years are accompanied by activities organized by sponsors and those who are followers of the cause.

Sounds familiar, doesn’t it?

We astronomers had our “Year” in 2009. Many of us were involved with the International Year of Astronomy (IYA), the quater-centenary of Galileo pointing a telescope skyward. According to the final report, some 815 million people in 148 countries around the world participated in IYA events. Browsing through the report, I found some of the most fascinating events include the Meteorwatch conducted via Twitter, Indian astronomers participating in the Republic Day Parade in Delhi (with an estimated TV audience of 700 million), the replica of Galileo’s telescope being taken on board the Space Shuttle Atlantis for the Hubble Servicing Mission, and the “From the Earth to the Universe” exhibit showing up in a wide variety of venues (including the Paris Metro). IYA also featured concentrated worldwide events such as the “100 Hours of Astronomy” in early April 2009. (My colleagues within the Astrophysics Science Division at NASA/Goddard held seven events for six distinct audiences during the 100 Hours. We’re still recovering!)

What we hope to get out of these Years is some form of permanence plus some lasting influence. Franco Pacini, who originated the idea for IYA, was hoping for very tangible permanence in terms of new planetaria, science centers, or museum exhibits. There is certainly permanence in other ways. A number of the IYA programs and projects are ongoing, such as the Galileoscope, the 365 Days of Astronomy Podcast, and astronomy development programs in developing countries. In addition, a number of the citizen science programs are ongoing, including the campaign to observe the eclipsing binary Epsilon Aurigae.

There is also the less tangible permanence of the experience. As one of those groups who organized events, we were able to form new partnerships, experiment with new types of events with familiar audiences, and reach out to entirely new audiences. But what we really strive for is for those new audiences to become lasting audiences.

Fortunately, with two new Years, we have the opportunity to sharpen these newfound skills to continue to engage those new audiences and maybe pick up a few more.

The International Year of Chemistry (IYC) celebrates the achievements of chemistry. Since chemistry starts with the periodic table of the elements, and since astronomy has taught us about where those elements come from, we astronomers can have a role in this. In scanning through some of the events (see the Activities section), I found the theme for the third annual “Night of the Stars” show in Mexico on Feb 26, 2011, to be close to both an astronomer’s and chemist’s heart. Its theme was “Chemistry in the Stars” featuring star parties and talks about the chemical composition and evolution of the universe. As a credit to continuation, Night of the Stars was started during IYA and held star parties in 26 archeological and historic sites around Mexico.

And finally, NASA has declared this to be the Year of the Solar System — using a Martian year (Oct 2010 to Aug 2012) to bring attention to a series of NASA spacecraft either launching or arriving at locations around the solar system. The most recent was the orbital insertion of the MESSENGER satellite around Mercury, to commence its yearlong detailed study. There’s a new theme for every month, and lots of ground-based events on our own planet. You can post your planet-related events on their website.

So fire up your Star Parties and Planet Walks and let the Years roll on!

JIM LOCHNER is the E/PO Lead for the Astrophysics Science Division at NASA/GSFC. He can hardly wait for the International Year of the Ice Cream Sundae.
Chandra's career, highlighted by the 1983 Nobel Prize in physics, spanned decades and continents.

by Richard E. White

Brilliant Sirius and Sirius B, its dim white-dwarf companion (to the lower left of brilliant Sirius). It was Chandra (inset) who first determined the maximum mass of a white dwarf star. Sirius image: NASA / ESA / STScI / University of Leicester. Inset: NASA / CXC / University of Chicago.
October 19, 2010, was the centenary of the birth of Subrahmanyan Chandrasekhar, known simply as “Chandra” in the astronomical community. The only person to receive the Nobel Prize in Physics for work primarily in theoretical astrophysics, he is best known for the “Chandrasekhar limit,” the maximum mass of white dwarfs.

I was honored and humbled by an invitation from Chandra’s niece, Nalini Easwar, to return to Smith College and the Five College Astronomy Department to review his science on the very day of the centenary. This article stems from that presentation, which I began with the words of G. Srivinasan, who edited a volume reviewing Chandra’s diverse research: “The range of Chandra’s contributions is so vast that no one person in the physics or astronomy community can undertake the task of commenting on his achievements.”

Here I want to share the inspiration that I felt in reviewing Chandra’s life and work, as well as provide a taste of the aspiration he fostered in my early career.

**Early Life and Education**

Chandra was born in Lahore, British India (now Pakistan), into a south Indian Brahman family that was among the first to seek advancement through the British colonial educational system. His grandfather had been a mathematics professor and, during his early education at home, the mathematically precocious Chandra found a playground in the family library. His uncle, C.V. Raman, provided a model for a research career and became a national hero when he received the 1930 Nobel Prize in Physics for the “Raman effect” in molecular spectra. By then Chandra himself was a physics undergraduate for whom a brief apprenticeship in Raman’s lab confirmed his commitment to theory.

Working independently beyond his university curriculum, he schooled himself in early quantum physics with books at hand. When Arnold Sommerfeld visited India in 1928, Chandra secured an interview, during which he was crestfallen to discover that what he had learned was already obsolete. Undaunted, he studied a draft article in which Sommerfeld applied the new Fermi-Dirac quantum statistics to the electron theory of metals. Within a few months, Chandra had written “The Compton Scattering and the New Statistics” and saw it published in the *Philosophical Transactions of the Royal Society.*

**Cambridge and the Chandrasekhar Limit**

Upon his graduation from Presidency College in Madras (now Chennai) in 1930, Chandra was awarded a fellowship to study in England, which he resolved to do with physicist and astronomer Ralph Fowler in Cambridge. On the three-week voyage from Bombay to Venice, Chandra made the original derivation of the upper limit for the mass of a white dwarf star. These hyperdense configurations, supporting the mass of the Sun in the volume of Earth, had been recognized observationally in the hot, but very faint and compact companions of bright stars such as Sirius.

Fowler had theorized that such dense material could be explained by the phenomenon of “degeneracy,” a result of the Pauli Exclusion Principle in which only two electrons of opposite spins could occupy the same volume with the same energy. At high stellar masses, the most energetic electrons would be travelling near the speed of light. Modifying Fowler’s results to incorporate relativistic
effects, Chandra discovered that owing to instability, white dwarf masses could not exceed a value now calculated as 1.44 solar masses, a value known as the Chandrasekhar limit. This is less than the mass of many stars and much, much less than some.

What could become of stars with masses greater than the Chandrasekhar limit? The answer was unknown in the 1930s before the nuclear reactions that drive stellar evolution were fully understood, though Chandra and others speculated on a connection to supernovae. While neutron stars and what we now call black holes had emerged by the late 1930s as potential astronomical objects, neither had registered widely as solutions to the fate of massive stars.

This puzzle was prominent in the 1930s and led to a traumatic experience for the young Chandra. He had completed his PhD in 1933 and then was elected to a Prize Fellowship at Trinity College, Cambridge. There, Sir Arthur Stanley Eddington — later memorialized by Chandra himself as “the most distinguished astrophysicist of his time” — led the astrophysics group. Eddington’s monograph, The Internal Constitution of the Stars, was (at the time) the definitive study of stellar structure. Chandra finalized work on his mass limit, frequently under Eddington’s inquisitive eye, for presentation to England’s Royal Astronomical Society in 1935. He was stunned when Eddington followed his presentation with an incredulous dismissal: “There should be a law of Nature to prevent a star from behaving in this absurd way!”

The Death of Stars
Uncertainty about the fate of massive stars vanished with the discovery of pulsars in 1967, particularly the Crab Nebula pulsar in the remnant of the historical supernova of 1054, and the recognition by Thomas Gold that they must be rapidly rotating neutron stars. Because neutron stars also have a limiting mass, the idea of even more extreme objects suddenly became credible. Following the coining by John Wheeler of a felicitous name, “black holes” joined the astronomical zoo with the discovery of the first black-hole X-ray binary (Cygnus X-1) in 1971.

Astronomers now understand that stars more massive than about eight solar masses eventually develop degenerate iron cores that exceed the Chandrasekhar limit, leading to core-collapse supernovae. Lower mass stars undergo sufficient mass loss to become white dwarfs, producing often spectacular “planetary nebulae” in the process. Single white dwarfs can then peacefully radiate, cooling slowly over eons to invisibility as “black dwarfs.”

In binary systems, white dwarfs can acquire additional mass as

![A composite image of the Crab Nebula showing X-ray (blue), and optical (red) images superimposed. A three-second movie reveals dynamic rings, wisps, and jets of matter around the Crab pulsar.](image-url)

**14 Mercury SPRING 2011**
their originally less-massive companions evolve. If the process continues long enough, the white dwarf mass grows until it exceeds the Chandrasekhar limit, yielding a supernova after all. This process underlies what are known as Type Ia supernovae. Because the process is virtually universal, these explosions exhibit consistent absolute brightness over cosmic time. As “standard candles” visible even in very distant galaxies, Type Ia supernovae yielded the unexpected result that the expansion of the universe is accelerating.

Chicago and New Fields of Research

A year after the traumatic astronomical meeting, Chandra faced a life-changing choice: return to India to deal with potential political infighting, or accept an appointment in the US, where his theoretical expertise would complement America’s growing dominance in observational astronomy. Otto Struve, with the support of President Hutchins of the University of Chicago, offered a position at the Yerkes observatory. Chandra accepted, then returned to India to visit his family and also to marry Lalitha Doraiswamy, who had been a fellow physics undergraduate.

Faced with Eddington’s prodigious authority and unyielding rejection of his work, Chandra resolved to leave the field of stellar structure. The culmination of this research was the first of his distinctive monographs, laying out in exquisite logical and mathematical detail the synthesis of his understanding.

What followed during the next four decades was an outpouring of work in successive areas of research, usually culminating in a magisterial book likewise synthesizing in great depth the work of Chandra and his students. To paraphrase Chandra’s 1983 Nobel autobiography, there had been seven periods in his professional life (book titles in italics):

- An Introduction to the Study of Stellar Structure, including the theory of white dwarfs (1929-39);
- Principles of Stellar Dynamics, including the theory of Brownian motions (1938-43);
- The theory of Radiative Transfer, the theory of the illumination and the polarization of the sunlit sky, the theories of planetary and stellar atmospheres, and the quantum theory of the negative ion of hydrogen (1943-50);
- Hydrodynamic and Hydromagnetic Stability (1952-61);
- The equilibrium and the stability of Ellipsoidal Figures of Equilibrium (1961-68);
- The general theory of relativity and relativistic astrophysics (1962-71); and

Yerkes Observatory, established in 1897 on Lake Geneva in Williams Bay, Wisconsin.

This image of the galaxy Centaurus A shows a spectacular view of a supermassive black hole’s power. The X-ray jet in the upper left extends about 13,000 light-years away from the black hole.
Professor and Editor

As a lecturer, Chandra earned a reputation for the meticulous clarity of his exposition. Although he coauthored important papers with distinguished colleagues, he chose to collaborate primarily with his more than 50 PhD students. He applied his exacting standards in choosing his students, but enjoyed sharing in their youthful creativity and was supportive in fostering their careers.

His activity as a professor was summarized by one of his famous students, Donald Osterbrock. “To many scientists outside the Yerkes Observatory and the University of Chicago, Chandra seemed a remote, forbidding figure. But to his own graduate students he was highly approachable, even outgoing. A few thought of him as a god; most recognized him as an exceptional human being.”

In 1952, Chandra became editor of The Astrophysical Journal (ApJ). During the 19 years of his tenure, the volume of the journal grew 12-fold, and under his guidance it became the premiere astronomical publication in the world. In spite of the growing volume of manuscripts, he maintained the journal operation with just a single editorial assistant for most of this time. It is said that he read every word that the journal published, yet his own research productivity scarcely changed.

Chandra's editorship and formal mathematical style prompted one of the finest spoofs in the history of astronomy. John Sykes, one of the Yerkes post-doctoral fellows, likely in collaboration with other young researchers, submitted a now legendary parody of Chandra's style titled, “On the Imperturbability of Elevator Operators. LVII” by S. Candlestickmaker. Chandra enjoyed the joke and arranged to reprint the article in ApJ style, bearing the submission date of October 19, 1910, Chandra's own birthday.

Honors

During a career that spanned more than 65 years, Chandra received virtually every major scientific honor. The first, in 1949, was the Henry Norris Russell lectureship of the American Astronomical Society (AAS). At 39 years of age, Chandra was just the third recipient following Henry Norris Russell himself and Walter Adams, George Ellery Hale's distinguished successor as Director of the Mount Wilson Observatory.

Three years later, Chandra received the Bruce Medal of the Astronomical Society of the Pacific. In bestowing the award, his former colleague and then Society President Otto Struve remarked on the hope that receiving the award in mid-career might motivate Chandra to even greater accomplishments — a hope that was abundantly fulfilled.

Crowning Chandra's many laurels was the 1983 Nobel Prize in Physics.

On the Imperturbability of Elevator Operators. LVII*

S. Candlestickmaker
(Institute for Studies in Advancement, Old Cardigan, Wales)
(Communicated by John Sykes; received October 19, 1910)

ABSTRACT

In this paper the theory of elevator operators is completed to the extent that is needed in the elementary theory of Fields. It is shown that the matrix of an elevator operator cannot be inverted, no matter how small the elevation. An explicit solution is obtained for the case when the occupation number is zero.

Physics, “for his theoretical studies of the physical processes of importance to the structure and evolution of the stars.” Interestingly this award, more than those much earlier in his career, seems to have renewed his energy, which had flagged after a heart attack in the mid-1970s. Besides continuing work exploring singularities in general relativity, he undertook to reframe Isaac Newton’s classic, resulting in Newton’s Principia for the Common Reader, which was completed shortly before Chandra’s death on August 21, 1995.

A major posthumous honor was the naming of NASA’s great X-ray observatory Chandra.

Experiences, Character, and Motivation

Chandra’s career spanned decades and continents, from colonial India in the 1920s, where, in Chandra’s words, “It was a part of the patriotism of those times to try and see what Indians could accomplish with respect to the external world,” to the patrician society of England, to America before, during, and after the Civil Rights movement. His appointment in Chicago came through presidential directive over the racist objection of the dean of physical sciences; even so, it came initially at the level of research associate, whereas his European colleagues were hired as regular faculty.

One particular trait was his legendary work ethic, acknowledged by Chandra’s friend and AAS President Martin Schwarzschild in the introduction to the invited lecture Chandra gave at the 1972 summer meeting at Michigan State University. Attending that meeting as a postdoctoral fellow, I have never forgotten the occasion, though at the time I did not fully appreciate it: Chandra had declined every such invitation for the 19 years of his editorship of the ApJ. In his unforgettable clipped German accent, Schwarzschild said, “To know Professor Chandrasekhar is to know the meaning of werk,” a sentiment he reiterated more than once, concluding with, “No one knows the meaning of werk like Mrs. Chandrasekhar.”

Chandra shared aspects of his professional motivation in a volume entitled Truth and Beauty: Aesthetics and Motivation in Science. In one essay, he remarks on the dichotomy in the pattern of creativity between the sciences (where famous work usually comes in youth) and the humanities, where late-career works such as Shakespeare’s tragedies typically are the most accomplished. In his 1972 AAS lecture, the 61-year-old Chandra stated that the pattern of his work had been inspired partly by the hope that changing fields and learning afresh would regenerate his youthful creativity.

Chandra strove mightily to create a body of work that would manifest his aesthetic sensibility and passion for excellence, content to let posterity judge its ultimate merit. In modesty, he concludes another essay:

The pursuit of science has often been compared to the scaling of mountains, high and not so high. But who amongst us can hope, even in imagination, to scale the Everest and reach its summit when the sky is blue and the air is still, and in the stillness of the air survey the entire Himalayan range in its dazzling white of snow stretching to infinity? None of us can hope for a comparable vision of nature and of the universe around us. But there is nothing mean or lowly in standing in the valley below and awaiting the sun to rise over the Kanchenjunga. Neither is there anything mean or lowly in the efforts of the majority of us scientists who have expanded trails in the foothills first blazed by giants such as Subrahmanyan Chandrasekhar.

Richard E. White is Professor Emeritus in the Five College Astronomy Department at Smith College, Northampton, MA, where his teaching included a course on the history of astronomy. His research focused on interstellar absorption lines, in particular, toward the Pleiades star cluster.
CHANDRA: THE MAN BEHIND THE SCIENCE

A brief description of Chandra’s life and family.

by Nalini Easwar

Chandra Vilas in Madras, where Chandra and his nine siblings grew up. The bay room on the second floor is where Chandra used to study. Inset: Chandra as a young boy. Chandra Vilas family collection (x2).
As October 10, 2010 approached, excitement, inspiration, and pride swept over the members of Chandra’s family. It was 100 years since the birth of their beloved Ayya Mama or Periappa (as he was referred to by his 33 nieces and nephews).

A series of events were held in India and at the University of Chicago to mark Chandra’s birth centenary. The family came together to also collect pictures and share essays about their interactions and memories of Chandra. HarperCollins (India) recently published a collection of essays called S. Chandra, Man of Science. To commemorate Chandra’s birth centenary, I invited Dick White, Professor Emeritus at Smith College, to talk on Chandra and his contributions to theoretical astrophysics. This shared experience inspired us to write these paired articles.

Chandra’s Early Years

In 1918 Chandra’s family moved from Lahore, his birthplace, to Madras (now called Chennai). Chandra and his nine siblings grew up in their home, “Chandra Vilas” (“Abode of the Moon”). His grandfather, after whom he was named, was a mathematics teacher with a wide collection of classic math texts. One text that stayed in Chandra’s possession was Maxime Bocher’s Introduction to Higher Algebra. According to his father, the book “put him in the way of the study of higher mathematics and its applications to problems in mathematical physics.” Chandra’s father was himself a musician and an avid reader of literature, and he owned a vast library that lined the walls of Chandra Vilas. This erudite environment fostered Chandra’s love of literature and music in parallel.

Chandra’s mother, Sitalakshmi, played a pivotal role in inspiring Chandra and encouraged him to pursue science. Every evening she read the epic Mahabharata, and stories of great men, to inspire her 10 children and extended family. One such evening, she read about the mathematical genius Srinivasa Ramanujan, and 11-year-old Chandra was inspired. She dreamt that her son, like Ramanujan, would go abroad and achieve fame for his science. She had taught herself English, and her translation of Henrik Ibsen’s A Doll’s House into Tamil was remarkable for that period in India. Chandra was deeply inspired by his mother and her zest for learning.

He studied at Presidency College in Madras, along the famed Marina Beach on the Bay of Bengal. It was a place he loved, and he spent many hours there, lost in thought and reflection. Chandra once confided to his brother that he would often look out into the waters and pray: “Oh, God. Make me like Newton.”

Moving On

Upon finishing his college degree, Chandra received a fellowship to go to Trinity College, Cambridge. He faced a very difficult decision regarding moving to England, since his mother’s health was failing. Besides, his uncle C.V. Raman, who had won the 1930 Nobel Prize in physics for research done exclusively in India, was opposed to leaving India for scientific pursuits. Finally, it was Chandra’s mother who urged him to overlook these difficulties and go to Trinity. She said “He is born for the world, not for me. He must go and pursue his ideals. That is the single gift a mother can give.” Chandra left in 1930, knowing that it might well be the last time he would see his mother.

While at Presidency College, Chandra met Lalitha Doraiswamy, a physics student a year junior to him. A quiet romance developed between them. Lalitha herself came from a family far ahead of the times — she and her three sisters were college educated, and her aunt was a social reformer working to help widowed and destitute women. Lalitha waited for Chandra until his return to India in 1936, when they married. At that point, he had just accepted the offer from University of Chicago, and they both left for the United States.

Lalitha was Chandra’s steady companion and confidant. She attended his talks, shared in his scientific life, and spent her days beside him as he worked 18 hours a day. They shared a love of music and often attended concerts together. Martin Schwartzchild’s comment on Lalitha knowing the true meaning of “werk” captures the essence of her life. If Chandra’s life was one dedicated to science, we can sum up Lalitha’s life as one of selfless dedication to Chandra.

Letters

After his departure from India in 1930, Chandra diligently wrote letters — once a week to his father and regularly to his siblings. These exchanges provide us with a close view into Chandra’s life and his feelings. Chandra shared everything from personal routine to his reflections about science and politics.

The exchange between father and son was warm and open in spite of occasional differences of opinion. His father voiced strong displeasure when Chandra and Lalitha became US citizens in 1953.
In his polite style, Chandra explained that they were neither relinquishing their heritage nor disclaiming loyalty to India.

Of course he wrote about fellow students and professors. In January 1932, he described quantum physicist Paul Dirac.

*His philosophical insight into the general formalism of theoretical physics, his mathematical profundity which allows him to penetrate with ease any region of unexplored mathematical and physical thought, and with all this, what humility! He almost represents to me the perfect man!* 

In 1936 when he was offered the position at the Yerkes Observatory (University of Chicago), he wrote his brother:

> The observatory is situated on the bank of a beautiful lake – Williams Bay – and behind it are woods – a truly inspiring place...So, it does seem that we are to work out our life's purposes in distant countries...Perhaps, I am selfish. But science has the traditions only for itself.

In another letter to his sister in 1951, he says:

> I got this idea on a Sunday about sunspots...On Thursday, when I was in Chicago, I talked to [Enrico] Fermi about it and he was quite excited about it too. When I get an idea like that, I can hardly sleep at nights. On Saturday morning, I told Lalitha that I had 'hit the jackpot'...That day, the morning mail brought the news that I was awarded the Bruce Gold Medal for distinguished service to astronomy.

These letters, spanning the years after he left India, also show the depth of his feelings about the distance between him and his family, his feelings for his country, and a growing sense of loneliness. In a 1935 letter to his brother, he said:

> For the first time in months, I feel homesick...I shall return in less than a year. How I look forward to it! Six years! How long!
Memory recalls what is no more. Whenever I think of home, I think of mother lying in the chair in front of the house…I always recollect her in a red sari…ALL GONE.”

In 1942 he wrote to Balakrishnan, his doctor-writer brother:

All those whom I have loved have lived far away. My feelings have remained strangely unreciprocated, even as your feelings for me must appear unreciprocated. Living apart so long, so far away, memory and imagination alone give me contact with life. What have I done with life?

And in the same year Chandra wrote again to his brother:

I can hardly write coherently…since the war came to India this year, how does it affect your hopes and feeling, your attitude, your life? You see, one pays a terrible price for living in strange foreign lands. You cease to be yourself and you vainly try to be anything else. At home nowhere, a stranger everywhere….

Ayya Mama

To the members of the family, he evoked the same feeling of a forbidding figure that Dick White describes, but his gentle and approachable nature came through in every personal interaction.

When I was in middle school, Chandra and Lalitha visited India and stayed with us in a small apartment in Mumbai. A newspaper reporter asked Chandra why he chose to stay in such a small apartment when he could have had a more luxurious place arranged for him. I was embarrassed, hurt, and hoped that my mother had not heard this. Chandra replied, “Why, this is wonderful. If this is good for my sister, it is good for me too.”

Suddenly, this celebrity uncle became a special person to me. His visits became more and more exciting, and he would engage me in conversation about physics (since I was a physics student). He accepted an invitation to speak at my college and enquired about the texts we used. I mentioned three books that were hard to get, and to my surprise he sent me the books upon his return to the US.

As I grew increasingly aware of his stature, I felt ever more nervous about talking to him regarding my work. However, in every conversation he would put me at ease. For instance, he mentioned having read my paper in the American Journal of Physics. He had read it! At this moment, I truly experienced the meaning of his comment on the scaling of mountains.

“The pursuit of science has often been compared with scaling of mountains, high and not so high. But who amongst us can hope...to scale the Everest and reach its summit?...But there is nothing mean or lowly in standing in the valley below and awaiting the sunrise over the Kanchenjunga.”

NALINI EASWAR is Professor of Physics at Smith College, Northampton, MA. Her research is in the field of complex fluids, in particular, the study of dense granular flows.
EXTRASOLAR PLANETS: THE ONGOING SAGA

An occasional account of our continuing discoveries of planets beyond the solar system.

by Paul Deans

This artist's concept shows the recently discovered planet Gliese 581g. It has a 37-day orbit right in the middle of the star's habitable zone, is only three to four times the mass of Earth, and has a diameter 1.2 to 1.4 times that of Earth. The four planets in the Gliese 581 system orbit a red dwarf star only 20 light-years away from Earth. More details about Gliese 581 can be found in Mercury, Autumn 2010, page 40. Artwork courtesy NASA / Lynette Cook.
Earth-like worlds. Common. Finally, discover how JPL survey suggests that Earth-size planets may be quite prevalent. As a consequence of this data flood, other extrasolar planet discoveries have followed this proliferation of planet discoveries. There's a lot going on! Researchers and facilities are often overlooked, and yet they have determined they are among the smallest confirmed exoplanets, with planets and no planets with life — except for the Sun and Earth. But until the first detection of an extrasolar planet (Gamma Cephei, 1998), this odd argument was the only way to make a case that there should be other planets, and other Earth-like worlds, elsewhere in the cosmos.

No more, thanks to NASA's Kepler mission, whose goal is to: "survey a portion of our region of the Milky Way galaxy to discover dozens of Earth-size planets in or near the habitable zone and determine how many of the billions of stars in our galaxy have such planets."

Two years after Kepler's launch, the discovery rate of extrasolar planets has turned from a trickle into a torrent. As a consequence of this data flood, other extrasolar planet researchers and facilities are often overlooked, and yet they continue to make discoveries or do critical work confirming Kepler's finds. There's a lot going on!

So every now and then I'll take press releases and Web items and assemble an article on exoplanets — probably the hottest topic in astronomy these days. (Of course, exoplanet news items will continue to appear in "Astronomy in the News.") I'll include as many hotlinks as possible so you can keep tabs on the search, as astronomers seek the Holy Grail of extrasolar planets — an Earth-size, Earth-like world in a star's habitable zone.

And where better to start than with the complete press release announcing the detection of a remarkable six-planet system surrounding the star Kepler-11, followed by the discovery of a number of Earth-sized planet candidates in stellar habitable zones. Next, in an October 2010 release (that preceded this proliferation of planet discoveries), a NASA/JPL survey suggests that Earth-size planets may be quite common. Finally, discover how you can join the search for Earth-like worlds.

— P.D.

Kepler Spacecraft Discovers An Extraordinary New Planetary System

Scientists using NASA's Kepler space telescope recently discovered six planets made of a mix of rock and gases orbiting a single Sun-like star, known as Kepler-11, which is located approximately 2,000 light-years from Earth.

"The Kepler-11 planetary system is amazing," said Jack Lissauer, a planetary scientist and a Kepler science team member at NASA's Ames Research Center, Moffett Field, California. "It's amazingly compact, it's amazingly flat, there's an amazingly large number of big planets orbiting close to their star — we didn't know such systems could even exist." In other words, Kepler-11 has the fullest, most compact planetary system yet discovered beyond our own.

"Few stars are known to have more than one transiting planet, and Kepler-11 is the first known star to have more than three," said Lissauer. "So we know that systems like this are not common. There's certainly far fewer than one percent of stars that have systems like Kepler-11. But whether it's one in a thousand, one in ten thousand or one in a million, that we don't know, because we only have observed one of them."

All of the planets orbiting Kepler-11, a yellow dwarf star, are larger than Earth, with the largest ones being comparable in size to Uranus and Neptune. The innermost planet, Kepler-11b, is ten times closer to its star than Earth is to the Sun. Moving outwards, the other planets are Kepler-11c, Kepler-11d, Kepler-11e, Kepler-11f, and the outermost planet, Kepler-11g, which is twice as close to its star as Earth is to the Sun.

"The five inner planets are all closer to their star than any planet is to our Sun and the sixth planet is still fairly close," said Lissauer.

If placed in our solar system, Kepler-11g would orbit between Mercury and Venus, and the other five planets would orbit between Mercury and our Sun. The orbits of the five inner planets in the Kepler-11 planetary system are much closer together than any of the planets in our solar system. The inner five exoplanets have orbital periods between 10 and 47 days around the dwarf star, while Kepler-11g has a period of 118 days.

"By measuring the sizes and masses of the five inner planets, we have determined they are among the smallest confirmed exoplanets, or planets beyond our solar system," said Lissauer. "These planets..."
are mixtures of rock and gases, possibly including water. The rocky material accounts for most of the planets’ mass, while the gas takes up most of their volume."

According to Lissauer, Kepler-11 is a remarkable planetary system whose architecture and dynamics provide clues about its formation. The planets Kepler-11d, Kepler-11e and Kepler-11f have a significant amount of light gas, which Lissauer says indicates that at least these three planets formed early in the history of the planetary system, within a few million years.

A planetary system is born when a molecular cloud core collapses to form a star. At this time, disks of gas and dust in which planets form, called protoplanetary disks, surround the star. Protoplanetary disks can be seen around most stars that are less than a million years old, but few stars more than five million years old have them. This leads scientists to theorize that planets, which contain significant amounts of gas, form relatively quickly in order to obtain gases before the disk disperses.

The Kepler spacecraft will continue to return science data about the new Kepler-11 planetary system for the remainder of its mission. The more transits Kepler sees, the better scientists can estimate the sizes and masses of planets.

“These data will enable us to calculate more precise estimates of the planet sizes and masses, and could allow us to detect more planets orbiting the Kepler-11 star,” said Lissauer. “Perhaps we could find a seventh planet in the system, either because of its transits or from the gravitational tugs it exerts on the six planets that we already see. We’re going to learn a fantastic amount about the diversity of planets out there, around stars within our galaxy.”

NASA Finds Earth-size Planet Candidates in the Habitable Zone

NASA’s Kepler mission has discovered its first Earth-size planet candidates and its first candidates in the habitable zone, a region where liquid water could exist on a planet’s surface. Five of the potential planets are near Earth-size and orbit in the habitable zone of smaller, cooler stars than our Sun. Candidates require follow-up observations to verify they are actual planets.

“In one generation we have gone from extra-terrestrial planets being a mainstay of science fiction, to the present, where Kepler has helped turn science fiction into today’s reality,” said NASA Administrator Charles Bolden.

The discoveries are part of several hundred new planet candidates identified in new Kepler mission science data, released on February 1, 2011. The findings increase the number of planet candidates identified by Kepler to date to 1,235. Of these, 68 are approximately Earth-size; 288 are super-Earth-size; 662 are Neptune-size; 165 are the size of Jupiter and 19 are larger than Jupiter.

Of the 54 new planet candidates found in the habitable zone, five are near Earth-sized. The remaining 49 habitable zone candidates range...
from super-Earth size — up to twice the size of Earth — to larger than Jupiter.

The findings are based on the results of observations conducted May 12 to September 17, 2009, of more than 156,000 stars in Kepler's field of view, which covers approximately 1/400 of the sky.

“The fact that we’ve found so many planet candidates in such a tiny fraction of the sky suggests there are countless planets orbiting Sun-like stars in our galaxy,” said William Borucki of NASA's Ames Research Center in Moffett Field, Calif., the mission's science principal investigator. “We went from zero to 68 Earth-sized planet candidates and zero to 54 candidates in the habitable zone, some of which could have moons with liquid water.”

Among the stars with planetary candidates, 170 show evidence of multiple planetary candidates. Kepler-11, located approximately 2,000 light years from Earth, is the most tightly packed planetary system yet discovered.

Kepler, a space telescope, looks for planet signatures by measuring tiny decreases in the brightness of stars caused by planets crossing in front of them. This is known as a transit. Since transits of planets in the habitable zone of Sun-like stars occur about once a year and require three transits for verification, it is expected to take three years to locate and verify Earth-size planets orbiting Sun-like stars.

**Survey Suggests Earth-size Planets Are Common**

Nearly one in four stars similar to the Sun may host planets as small as Earth, according to a new study funded by NASA and the University of California.

The study is the most extensive and sensitive planetary census of its kind. Astronomers used the W.M. Keck Observatory in Hawaii for five years to search for 166 Sun-like stars near our solar system for planets of various sizes, ranging from three to 1,000 times the mass of Earth. All of the planets in the study orbit close to their stars. The results show more small planets than large ones, indicating small planets are more prevalent in our Milky Way galaxy.

“We studied planets of many masses — like counting boulders, rocks, and pebbles in a canyon — and found more rocks than boulders, and more pebbles than rocks. Our ground-based technology can’t see the grains of sand, the Earth-size planets, but we can estimate their numbers,” said Andrew Howard of the University of California, Berkeley, lead author of the new study. “Earth-size planets in our galaxy are like grains of sand sprinkled on a beach — they are everywhere.”

The research provides a tantalizing clue that potentially habitable planets could also be common. These hypothesized Earth-size worlds would orbit farther away from their stars, where the conditions could be favorable for life. NASA’s Kepler spacecraft is also surveying Sun-like stars for planets and is expected to find the first true Earth-like planets in the next few years.

Howard and his planet-hunting team, which includes principal investigator Geoff Marcy, also of the University of California, Berkeley, looked for planets within 80 light-years of Earth, using the radial velocity, or “wobble,” technique.

They measured the numbers of planets falling into five groups, ranging from 1,000 times the mass of Earth, or about three times the mass of Jupiter, down to three times the mass of Earth. The search was confined to planets orbiting close to their stars — within 0.25 astronomical units, or a quarter of the distance between our Sun and Earth.

A distinct trend jumped out of the data: smaller planets outnumber larger ones. Only 1.6 percent of stars were found to host giant planets orbiting close in. That includes the three highest-mass planet groups in the study, or planets comparable to Saturn and Jupiter. About 6.5 percent of stars were found to have intermediate-mass planets, with 10 to 30 times the mass of Earth — planets the size of Neptune and Uranus. And 11.8 percent had the so-called “super-Earths,” weighing in at only three to 10 times the mass of Earth.

“During planet formation, small bodies similar to asteroids and comets stick together, eventually growing to Earth-size and beyond. Not all of the planets grow large enough to become giant planets like Saturn and Jupiter,” Howard said. “It’s natural for lots of these building blocks, the small planets, to be left over in this process.”

The astronomers extrapolated from these survey data to estimate that 23% of Sun-like stars in our galaxy host even smaller planets, the Earth-sized ones, orbiting in the hot zone close to a star. “This is the statistical fruit of years of planet-hunting work,” said Marcy. “The data tell us that our galaxy, with its roughly 200 billion stars, has at least 46 billion Earth-size planets, and that’s not counting Earth-size planets that orbit farther away from their stars in the habitable zone.”

The findings challenge a key prediction of some theories of planet formation. Models predict a planet “desert” in the hot-zone region close to stars, or a drop in the numbers of planets with masses less

---

Image: Milky Way Galaxy

**Our Sun**, one of more than 200 billion stars in our Milky Way, is located in our galaxy's Orion arm about 26,000 light-years from the galactic center. Kepler is examining more than 100,000 stars, most of which are between 500 and 3,000 light-years from our solar system. As this illustration reveals, the search area and the number of stars studied is exceedingly small compared to the size of the Milky Way.
than 30 times that of Earth. This desert was thought to arise because most planets form in the cool, outer region of solar systems, and only the giant planets were thought to migrate in significant numbers into the hot inner region. The new study finds a surplus of close-in, small planets where theories had predicted a scarcity.

“We are at the cusp of understanding the frequency of Earth-sized planets among celestial bodies in the solar neighborhood,” said Mario R. Perez, Keck program scientist at NASA Headquarters in Washington. “This work is part of a key NASA science program and will stimulate new theories to explain the significance and impact of these findings.”

Citizen Scientists Join Search for Earth-like Planets

Web users around the globe will be able to help professional astronomers in their search for Earth-like planets thanks to a new online citizen science project called Planet Hunters that launched in December 2010.

Planet Hunters, which is the latest in the Zooniverse citizen science project collection, will ask users to help analyze data taken by NASA’s Kepler mission. The space telescope has been searching for planets beyond our own solar system — called exoplanets — since its launch in March 2009.

“The Kepler mission has given us another mountain of data to sort through,” said Kevin Schawinski, a Yale University astronomer and Planet Hunters co-founder. Schawinski also helped create the Galaxy Zoo citizen science project several years ago, which enlisted hundreds of thousands of Web users around the world to help sort through and classify a million images of galaxies taken by a robotic telescope.

The Kepler space telescope is continually monitoring more than 100,000 stars in the constellations Cygnus and Lyra, recording their brightness over time. Astronomers analyze these images, looking for any stars that show a slight dimming of their brightness. This dimming could represent a planet passing in front of its host star, blocking a tiny fraction of its light as seen from Kepler’s vantage point in space. Those stars that periodically dim are the best candidates for hosting relatively small planets that tightly orbit their stars, similar to Earth.

“Each bar represents a different group of planets, divided according to their masses. The chart shows a clear trend — small planets outnumber larger ones. Astronomers extrapolated from these data to estimate the frequency of the Earth-size planets.

The Kepler space telescope is continually monitoring more than 100,000 stars in the constellations Cygnus and Lyra, recording their brightness over time. Astronomers analyze these images, looking for any stars that show a slight dimming of their brightness. This dimming could represent a planet passing in front of its host star, blocking a tiny fraction of its light as seen from Kepler’s vantage point in space. Those stars that periodically dim are the best candidates for hosting relatively small planets that tightly orbit their stars, similar to Earth.

Exoplanets: Hotlinks of Interest

A PDF article by William J. Borucki et al.: “Characteristics of planetary candidates observed by Kepler, II Analysis of the first four months of data.”

The press release announcing the discovery of planets orbiting Gliese 581.

A 3.1 M Earth Planet in the Habitable Zone of the Nearby M3V Star Gliese 581, by Steven Vogt, Paul Butler, et al.

Gliese 581g as a Scaled-up Version of Earth: Atmospheric Circulation Simulations, by Kevin Heng and Steven Vogt.

The Extrasolar Planets Encyclopedia contains an interactive catalog of extrasolar planets, tutorials, and a list of websites relevant to the topic.

Exoplanet Data Explorer: This is an interactive table and plotter for exploring and displaying data from the Exoplanet Orbit Database, a compilation of quality, spectroscopic orbital parameters of exoplanets orbiting normal stars from the peer-reviewed literature. Documentation for the Exoplanet Orbit Database and Explorers is available here and on astro-ph.

NASA’s New World Atlas is an interactive webpage.

Some extrasolar planet artwork is available on NASA’s PlanetQuest website.

And, of course, the Kepler Mission homepage.

“The Kepler mission will likely quadruple the number of planets that have been found in the last 15 years, and it’s terrific that NASA is releasing this amazing data into the public domain,” said Debra Fischer, a Yale astronomer and leading exoplanet hunter. Although Planet Hunters is not tied directly to the Kepler mission, the website will serve as a complement to the work being done by the Kepler team to analyze the data.

Because of the huge amount of data being made available by Kepler, astronomers rely on computers to help them sort through the data and search for possible planet candidates. “But computers are only good at finding what they’ve been taught to look for,” said Meg Schwamb, another Yale astronomer and Planet Hunters co-founder, “whereas the human brain has the uncanny ability to recognize patterns and immediately pick out what is strange or unique, far beyond what we can teach machines to do.”

When users log on to the Planet Hunters website, they’ll be asked to answer a series of simple questions about one of the stars’ light curves — a graph displaying the amount of light emitted by the star over time — to help the Yale astronomers determine whether it displays a repetitive dimming of light, identifying it as an exoplanet candidate.

“The great thing about this project is that it gives the public a front row seat to participate in frontier scientific research,” Schwamb said.

—

As the editor of Mercury, PAUL DEANS receives numerous press releases about extrasolar planets. He finds the idea of life-filled alien worlds utterly fascinating.
Excerpts from recent press releases that describe an assortment of current astronomical discoveries.

Jupiter Scar Likely from Rocky Body
NASA / JPL

A hurtling asteroid about the size of the Titanic caused the scar that appeared in Jupiter’s atmosphere on July 19, 2009, according to two papers published recently in the journal Icarus.

Data from three infrared telescopes enabled scientists to observe the warm atmospheric temperatures and unique chemical conditions associated with the impact debris. By piecing together signatures of the gases and dark debris produced by the impact shockwaves, an international team of scientists was able to deduce that the object was more likely a rocky asteroid than an icy comet.

“Both the fact that the impact itself happened at all and the implication that it may well have been an asteroid rather than a comet shows us that the outer solar system is a complex, violent and dynamic place, and that many surprises may be out there waiting for us,” said Glenn Orton, an astronomer at NASA’s Jet Propulsion Laboratory. “There is still a lot to sort out in the outer solar system.”

The new conclusion is also consistent with evidence from results from NASA’s Hubble Space Telescope indicating the impact debris in 2009 was heavier or denser than debris from comet Shoemaker-Levy 9, the last known object to hurl itself into Jupiter’s atmosphere in 1994.

Forensic Sleuthing Ties Ring Ripples to Impacts
NASA / JPL

Like forensic scientists examining fingerprints at a cosmic crime scene, scientists working with data from NASA’s Cassini, Galileo and New Horizons missions have traced telltale ripples in the rings of Saturn and Jupiter back to collisions with cometary fragments dating back more than 10 years ago.

The ripple-producing culprit, in the case of Jupiter, was Comet Shoemaker-Levy 9, whose debris cloud hurtled through the thin Jupiter ring system during a kamikaze course into the planet in July 1994. Scientists attribute Saturn’s ripples to a similar object — likely another cloud of comet debris — plunging through the inner rings in the second half of 1983. The findings are detailed in a pair of papers published online today in the journal Science.

“What’s cool is we’re finding evidence that a planet’s rings can be affected by specific, traceable events that happened in the last 30 years, rather than a hundred million years ago,” said Matthew Hedman, a Cassini imaging team associate and a research associate at Cornell University, Ithaca, N.Y. “The solar system is a much more dynamic place than we gave it credit for.”

From Galileo’s visit to Jupiter, scientists have known since the late 1990s about patchy patterns in the Jovian ring. But the Galileo images were a little fuzzy, and scientists didn’t understand why such patterns would occur. The trail was cold until Cassini entered orbit around Saturn in 2004 and started sending back thousands of images. A 2007 paper by Hedman and colleagues first noted corrugations in Saturn’s innermost ring, dubbed the D ring.

More information
Frozen Comet Had a Watery Past
*University of Arizona*

For the first time, scientists have found convincing evidence for the presence of liquid water in a comet, shattering the current paradigm that comets never get warm enough to melt the ice that makes up the bulk of their material.

“Current thinking suggests that it is impossible to form liquid water inside of a comet,” said Dante Lauretta, an associate professor of cosmochemistry and planet formation at the UA’s Lunar and Planetary Laboratory.

UA graduate student Eve Berger, who led the study, and her colleagues from Johnson Space Center and the Naval Research Laboratory made the discovery analyzing dust grains brought back to Earth from comet Wild-2 as part of the Stardust mission. Launched in 1999, the Stardust spacecraft scooped up tiny particles released from the comet’s surface in 2004 and brought them back to Earth in a capsule that landed in Utah two years later.

“In our samples, we found minerals that formed in the presence of liquid water,” Berger said. “At some point in its history, the comet must have harbored pockets of water.”

“When the ice melted on Wild-2, the resulting warm water dissolved minerals that were present at the time and precipitated the iron and copper sulfide minerals we observed in our study,” Lauretta said. “The sulfide minerals formed between 50° and 200° Celsius (122° and 392° Fahrenheit), much warmer than the sub-zero temperatures predicted for the interior of a comet.”

More information

How Kleopatra Got its Moons
*UC Berkeley*

The asteroid Kleopatra, like its namesake, the last pharaoh and queen of Egypt, gave birth to twins — two moons probably spawned by the asteroid sometime in the past 100 million years.

A team of French and American astronomers, including Franck Marchis, a research astronomer at the University of California, Berkeley, and Pascal Descamps, an astronomer at the Institut de Mécanique Céleste et de Calculs des Éphémérides (IMCCE) of the Observatoire de Paris, report the discovery and also confirm earlier reports that the asteroid is shaped like a dog bone.

In addition, the team’s detailed study of the asteroid using small telescopes as well as the large Keck II telescope in Hawaii allowed it to determine the precise orbits of the twin moons and calculate the density of Kleopatra, showing that the asteroid is probably a big pile of rock and metal rubble.

“Our observations of the orbits of the two satellites of 216 Kleopatra imply that this large metallic asteroid is a rubble pile, which is a surprise,” said Marchis, who is also a planetary scientist at the SETI Institute in Mountain View, Calif. “Asteroids this big are supposed to be solid, not rubble piles.”

Kleopatra, about 217 kilometers long, is one of several large asteroids recently found to be composed of rocky rubble held together by mutual gravitational attraction. The proportion of large asteroids in the solar system that are rubble piles is unknown, but the fact that, so far, all multiple asteroids are porous collections of gravitationally-bound chunks could have implications for how planets form. “If a large proportion of asteroids in the early solar system were rubble-pile, then the formation of the core of planets would be much faster,” Marchis said.

More information
**Voyager 1 Sees Solar Wind Decline**  
*NASA / JPL*

The 33-year odyssey of NASA's Voyager 1 spacecraft has reached a distant point at the edge of our solar system where there is no outward motion of solar wind.

Now hurtling toward interstellar space some 17.4 billion kilometers (10.8 billion miles) from the Sun, Voyager 1 has crossed into an area where the velocity of the hot ionized gas, or plasma, emanating directly outward from the Sun has slowed to zero. Scientists suspect the solar wind has been turned sideways by the pressure from the interstellar wind in the region between stars.

The event is a major milestone in Voyager 1's passage through the heliosheath, the turbulent outer shell of the sun's sphere of influence, and the spacecraft's upcoming departure from our solar system.

“The solar wind has turned the corner,” said Ed Stone, Voyager project scientist based at the California Institute of Technology in Pasadena, Calif. “Voyager 1 is getting close to interstellar space.”

Voyager 1 crossed the termination shock in December 2004 into the heliosheath. Scientists have used data from Voyager 1’s Low-Energy Charged Particle Instrument to deduce the solar wind’s velocity. When the speed of the charged particles hitting the outward face of Voyager 1 matched the spacecraft’s speed, researchers knew that the net outward speed of the solar wind was zero. This occurred in June 2010, when Voyager 1 was about 17 billion kilometers (10.6 billion miles) from the Sun.

Scientists believe Voyager 1 has not crossed the heliosheath into interstellar space. Researchers currently estimate Voyager 1 will cross that frontier in about four years.

**Planet Formation in Action?**  
*European Southern Observatory*

Planets form from the discs of material around young stars, but the transition from dust disc to planetary system is rapid and few objects are caught during this phase. One such object is T Chamaeleontis (T Cha), a faint star in the small southern constellation of Chamaeleon that is comparable to the Sun, but very near the beginning of its life. T Cha lies about 350 light-years from the Earth and is only about seven million years old. Up to now no forming planets have been found in these transitional discs, although planets in more mature discs have been seen before.

“Earlier studies had shown that T Cha was an excellent target for studying how planetary systems form,” notes Johan Olofsson (Max Planck Institute for Astronomy, Heidelberg, Germany). “But this star is quite distant and the full power of the Very Large Telescope Interferometer (VLTI) was needed to resolve very fine details and see what is going on in the dust disc.”

The astronomers first observed T Cha using the AMBER instrument and the VLTI. They found that some of the disc material formed a narrow dusty ring only about 20 million kilometers from the star. Beyond this inner disc, they found a region devoid of dust with the outer part of the disc stretching out into regions beyond about 1.1 billion kilometers from the star.

Nuria Huélamo (Centro de Astrobiología, ESAC, Spain) takes up the story: “For us the gap in the dust disc around T Cha was a smoking gun...”
**Integrals Spots Matter a Millisecond from Doom**

ESA

ESA's Integral gamma-ray observatory has spotted extremely hot matter just a millisecond before it plunges into the oblivion of a black hole. But is it really doomed? These unique observations suggest that some of the matter may be making a great escape.

No one would want to be so close to a black hole. Just a few hundred kilometers away from its deadly surface, space is a maelstrom of particles and radiation. Vast storms of particles are falling to their doom at close to the speed of light, raising the temperature to millions of degrees.

Ordinarily, it takes just a millisecond for the particles to cross this final distance but hope may be at hand for a small fraction of them. Thanks to the new Integral observations, astronomers now know that this chaotic region is threaded by magnetic fields.

This is the first time that magnetic fields have been identified so close to a black hole. Most importantly, Integral shows they are highly structured magnetic fields that are forming an escape tunnel for some of the doomed particles.

Philippe Laurent, CEA Saclay, France, and colleagues made the discovery by studying the nearby black hole, Cygnus X-1, which is ripping a companion star to pieces and feeding on its gas.

Their evidence points to the magnetic field being strong enough to tear away particles from the black hole's gravitational clutches and funnel them outwards, creating jets of matter that shoot into space.

**More information**

---

**Isolating a Thick Disc in Andromeda**

*Institute of Astronomy at Cambridge, England*

A team of astronomers from the UK, the US and Europe have identified a thick stellar disc in the nearby Andromeda galaxy for the first time. The discovery and properties of the thick disc will constrain the dominant physical processes involved in the formation and evolution of large spiral galaxies like our own Milky Way. The hidden stars are known as red dwarfs for their color and small size. Because red dwarfs are small and dim compared to stars like the Sun, astronomers hadn't been able to detect them in galaxies beyond the Milky Way before now. As such, they didn't know how many stars in the universe were red dwarfs.

By analyzing precise measurements of the velocities of individual bright stars within the Andromeda galaxy using the Keck telescope in Hawaii, the team have managed to separate out stars tracing out a thick disc from those comprising the thin disc, and assess how they differ in height, width and chemistry.

Spiral structure dominates the morphology of large galaxies at the present time, with roughly 70% of all stars contained in a flat stellar disc. The disc structure contains the spiral arms traced by regions of active star formation, and surrounds a central bulge of old stars at the core of the galaxy. "From observations of our own Milky Way and other nearby spirals, we know that these galaxies typically possess two stellar discs, both a 'thin' and a 'thick' disc," explains Michelle Collins, a PhD student at Cambridge's Institute of Astronomy. The thick disc consists of older stars whose orbits take them along a path that extends both above and below the more regular thin disc. "The classical thin stellar discs that we typically see in Hubble imaging result from the accretion of gas towards the end of a galaxy's formation," Collins continues, "whereas thick discs are produced in a much earlier phase of the galaxy's life."

**More information**
Giant Ring of Black Holes

*Chandra X-ray Center*

Arp 147 contains the remnant of a spiral galaxy (right side of the image) that collided with the elliptical galaxy (left of center). This collision has produced an expanding wave of star formation that shows up as a blue ring containing an abundance of massive young stars. These stars race through their evolution in a few million years or less and explode as supernovas, leaving behind neutron stars and black holes.

A fraction of the neutron stars and black holes will have companion stars, and may become bright X-ray sources as they pull in matter from their companions. The nine X-ray sources scattered around the ring in Arp 147 are so bright that they must be black holes, with masses that are likely ten to twenty times that of the Sun.

An X-ray source is also detected in the nucleus of the red galaxy on the left and may be powered by a poorly fed supermassive black hole. This source is not obvious in the composite image but can easily be seen in the X-ray image. Other objects unrelated to Arp 147 are also visible: a foreground star in the lower left of the image and a background quasar as the pink source above and to the left of the red galaxy.

Infrared observations with NASA’s Spitzer Space Telescope and ultraviolet observations with NASA’s Galaxy Evolution Explorer (GALEX) have allowed estimates of the rate of star formation in the ring.

---

**Hubble Rules Out One Alternative to Dark Energy**

*NASA / STScI*

It looks like dark energy may be here to stay. In refining the expansion rate of the universe to unprecedented accuracy, astronomers using NASA’s Hubble Space Telescope have also ruled out an alternative to this mysterious, invisible source of repulsive gravity, which makes the universe appear to expand ever faster.

If dark energy seems like a mind-boggling concept, then the competing model that astronomers have eliminated is equally as fantastic. The alternative hypothesis proposed that an enormous bubble of relatively empty space eight billion light-years across surrounds our galactic neighborhood. If we lived in the center of this void, then observations of galaxies being pushed away from each other at accelerating speeds would be just an illusion.

The simplest form of this hypothesis has now been kicked out because astronomers have placed even tighter constraints on the universe’s present expansion rate. The Hubble observations, conducted by the SHOES (Supernova H0 for the Equation of State) team and led by Adam Riess, helped refine the universe’s current expansion rate to an uncertainty of just 3.3 percent. The new measurement reduces the error margin by 30 percent over the previous best Hubble measurement made in 2009.

Knowing the precise value of the universe’s expansion rate further restricts the range of dark energy’s strength and also helps astronomers tighten up a number of other cosmic properties, including the universe’s shape and its roster of neutrinos, ghostly particles that filled the early universe.

---

Cepheid variables and a Type Ia supernova in this beautiful galaxy (NGC 5584) were used as reliable distance markers to measure the universe’s expansion rate.
Connecting People to Science

The Astronomical Society of the Pacific, in partnership with the American Geophysical Union and the Space Telescope Science Institute, is pleased to announce its 2011 national conference on science education and public outreach, “Connecting People to Science.” We invite you to join us. The conference web site is now accepting registration and abstract submissions.

This national conference is being held in the beautifully refurbished (and very reasonably priced) Tremont Plaza Hotel near the Baltimore Inner Harbor in Maryland from July 31 to Aug. 3, 2011. There will also be a weekend workshop on teaching hands-on astronomy (“In the Footsteps of Galileo”) July 30 and 31, for teachers in grades 3-12 and those who work with them.

Conference registration is now open, and substantial early bird discounts are available until May 15th.

In addition to the weekend workshop, we are pleased to present a series of six hands-on short courses for K-12 teachers concurrent with our EPO conference. Space in these sessions is limited and we urge you to apply for the short courses of your choice as soon as possible (teachers only please.) Each short course requires a separate registration and has a separate registration fee. The courses are as follows (detailed descriptions are on the Workshops & Short Courses for Teachers meeting webpage).

**Active Astronomy:** Classroom Activities for Learning about the Electromagnetic Spectrum (Grades 6-12). Monday morning, August 1, 2011.

**Chasing Shadows:** Bring NASA’s Search for Earth-like Planets Around Other Stars to Your Classroom (Grades 6-12). Monday afternoon, Aug. 1.

**Eye on the Sky:** Exploring the Sun with Activities for the Elementary Classroom (Grades K-5). Tuesday morning, Aug. 2.

**Light and Color:** In the Night Sky, in the City, and in the Classroom (Grades K-8). Tuesday afternoon, Aug. 2.

**Evidence-based Science:** Climate in the Classroom (Grades 6-12). Wednesday morning, Aug. 3.

**Global AND Local:** Activity-based Explorations Connecting Global Climate Change to Change in Students’ Own Communities (Grades 6-12). Wednesday afternoon, Aug. 3.

Registration for these six half-day sessions is limited and will be accepted in the order received, so don’t delay.

**Sky & Telescope Editor Emeritus Leif J. Robinson Passes Away at 71**

Although many Mercury readers also receive Sky & Telescope magazine and so may know of Leif’s passing, we felt it appropriate to mention it in Mercury. Leif was a strong supporter of astronomy outreach in various forms and was elected to the ASP’s Board of Directors in September 2001.

Leif J. Robinson, who served for 20 years as Editor in Chief of Sky & Telescope magazine, passed away February 27, 2011, at the age of 71 at his home in Costa Rica. Robinson worked 38 years on the staff of Sky & Telescope and served as Editor in Chief from 1980 to 2000.

“Leif was a towering figure in the history of Sky & Telescope, and he tirelessly promoted the capabilities and achievements of amateur astronomers,” said current S&T Editor in Chief Robert Naeye.

During his 38-year tenure on the editorial staff, Robinson became a champion of professional-amateur collaborations. Seeing the potential of rapidly evolving digital technology in the 1980s, Robinson lobbied professionals to take amateur observations seriously, an effort that has been amply rewarded with major amateur contributions in many different fields, from discovering asteroids, comets, and supernovae to hunting for and characterizing planets around other stars. “I was one of the few people to walk in both communities with equal facility,” said Robinson. “I could relate CCD cameras to the amateur and I could relate science to the amateur.”

You can download the complete Sky & Telescope press release about Leif, and be sure to read Bob Naeye’s “Spectrum” column in the upcoming June issue of Sky & Telescope.
The Universe at Your Fingertips 2.0
A DVD-ROM of Astronomy Activities and Resources

This greatly expanded and fully updated DVD-ROM version of the ASP’s popular manual for educators at many levels includes:

* 133 classroom-tested, hand-on activities
* 43 background articles on key astronomical topics
* 9 articles on teaching and learning astronomy
* 17 resource guides
* 12 instructional videos
* a grand tour of the universe in images and captions.

Published April 2011. Get your copy hot off the press.

To order, go to: www.astrosociety.org/uayf

A Gift That Gives Back

* PLANNED GIVING
  with

THE ASP HERITAGE SOCIETY

The Astronomical Society of the Pacific is pleased to recognize our members and friends who have included the ASP in their estate plans. This support of our mission is truly appreciated.

Join the Heritage Society by making a planned gift today. Visit us online or contact us to request an informational brochure.

www.astrosociety.org/support.html or
(415) 337-1100 x106

NEW MEMBERS — The ASP welcomes new members who joined between January 1 and March 31, 2011.

**General Membership**
Anna B. Cordes, Squaw Valley, CA
Marcel Erz, Oakland, CA
Suzi P. Fox, Brentwood, CA
Amy C. Fredericks, Rockville, MD
John S. Gianforte, Durham, NH
William K. Istone, Washingtonville, NY
Leonard M. Jensen, Wyndmoor, PA
Marc Kuchner, Greenbelt, MD
Robert Langridge, Berkeley, CA
Maria Lapid, San Diego, CA
Michael L. Sowle, Berkeley, CA
Heather M. Weir, Columbia, MD
Heather Withnell, Chicago, IL

**Technical Membership**
Jill Bechtold, Tucson, AZ

Allan Denton, Sutton Coldfield, United Kingdom
Scott B. Gracie, Melbourne, VIC, Australia
Rasha M. Kamal Aly Moussa, Giza, Egypt
Yolanda Marchante-Ortiz, Albany, CA
Stefan A. Nicholson, Bentley, WA, Australia
Ethan A. Port, Mountain View, CA
John B. VanLeer, Bothell, WA
Ron Williams, Lancaster, CA

**Supporter’s Circle Membership**
Lawrence D. Dickinson, Danville, CA
This year Astronomy Day is set for Saturday May 7th, while Astronomy Week runs from Monday May 2nd to Sunday May 8th inclusive. To quote from the Astronomical League’s Astronomy Day fact sheet:

Astronomy Day is designed to share the joy of astronomy with the general population — “Bringing Astronomy to the People.” On Astronomy Day, thousands of people who have never looked through a telescope will have an opportunity to see first hand what has so many amateur and professional astronomers all excited. Astronomy clubs, science museums, observatories, universities, planetariums, laboratories, libraries, and nature centers host special events and activities to acquaint their population with local astronomical resources and facilities.

The Moon is 4.5 days old on the 7th and will be a popular sight in telescopes of all sizes. The illustration at right shows roughly what will be seen on Astronomy Day. The red line indicates the lunar terminator, the division between day and night. (Exactly where it falls depends on your location and the time of evening that you’re observing.) The terminator is where the shadows are longest and the sights most interesting, because the shadows thrown by mountains, hills, and crater walls give the lunar surface a three-dimensional appearance.

Five mare (lunar seas) are indicated on the chart (though you’ll see only the very eastern edge of Mare Serenitatis). There are simply too many craters to highlight even the largest ones on our small map, but when you’re looking at the Moon through a scope, see if you can spot any ripples or irregularities on the lava floor of Mare Nectaris and Mare Tranquillitatis. In addition to the rugged highlands in the south, check out the rocky region between Mare Nectaris and Mare Tranquillitatis, as well as the craters and hills along the eastern edge of Mare Serenitatis.

If you’ve never seen the Moon though a telescope, Astronomy Day is your chance to do so. But beware — the changing face of the Moon is a fascinating target, and you could easily become hooked on lunar observing!

The morning sky offers an amazing sight at the start of the month — four planets within 10° of each other! It’s too bad the planets sit so low on the horizon. On May 11th, they are all clustered within a span of sky some 6° across. The two brightest — Venus and Jupiter — are within ½° of each other, while dimmer Mars and Mercury are below the bright pair. To see this unusual sight, you will need a clear, low eastern horizon; the chart (lower left) shows the scene roughly 30 minutes before sunrise. This gathering doesn’t end on the 10th — check out the sky each morning as the month progresses to watch Jupiter pull away (higher) from the other three planets. On May 21st, dim Mars is less than 1° to the upper left of brilliant Venus. And on the morning of the 29th, the crescent Moon sits above Jupiter.

Of course this planetary action at dawn means there’s only one planet in the sunset sky, and that’s Saturn. It glows in the south after sunset; the Moon passes beneath the ringed world on the night of the 13th/14th.

The Skies of June

A partial eclipse of the Sun occurs on June 1st — the first of three consecutive Sun/Moon eclipses. The eclipse begins at sunrise in Siberia and northern China. Most of Alaska and northern Canada catch the eclipse, while the southern limit of the shadow sweeps along a curve through northern Quebec, central New Brunswick, and Nova Scotia. Iceland experiences a late-evening partial, while Northern Norway, Sweden, and Finland enjoy a midnight Sun.
The skies of June

The partial solar eclipse. More details are available on NASA's 2011 eclipse webpage.

Two weeks later, on June 15th, most of the world except for North America sees a total eclipse of the Moon. The entire event is visible from the eastern half of Africa, the Middle East, central Asia and western Australia. Observers throughout Europe will miss the early stages of the eclipse because they occur before moonrise, though the rest of the eclipse will be observable. The totally eclipsed Moon lies in southern Ophiuchus, so watch the Milky Way emerge as totality approaches and the brilliant lunar disk is dimmed by Earth's shadow. Mid-eclipse (labeled “Greatest” in the diagram above) occurs at 20:12:37 Universal Time. The labels “U2” and “U4” mark the beginning and end of totality. Totality lasts 52 minutes, while the partial phases (starting at “U1” and ending at “U4”) last for 3 hours 33 minutes. NASA’s 2011 eclipse webpage again provides more details.

After the great gathering of planets in mid-May, most of the “action” continues in the dawn sky. Venus rises less than an hour before the Sun but, despite being bright, is barely visible low in the east just before sunrise. Mars rises before Venus, but it's dim and difficult to spot. Jupiter rises in the east around 4:00 am at month-start, but is up by 2:30 am at month-end.

At the end of June, the Moon parades past these planets — it's to Jupiter's upper left on the 26th, above Mars on the 28th, and about half way between Venus (to its lower left) and Mars (to its upper right) on the 29th.

Meanwhile, Saturn appears high in the southwest as twilight finally falls. On the 10th, Saturn is to the Moon's upper right, while equally bright Spica is to the left of the Moon. If you're observing Saturn with a telescope, note that it lies about ½° south of the tight double star Porrima. Mercury spends the month lost in the Sun's glare, though you might be able to spot it low in the west-northwest as twilight begins to fade at the end of June.

The skies of July

The globular cluster M13 in Hercules

Take your binoculars and scan a line between the two westernmost stars. Careful observation will reveal a fuzzy, out-of-focus star. That's Messier 13 (M13), the great globular cluster in Hercules. It's a lovely sight in telescopes, and the larger the scope, the better the view.

The final eclipse in the sequence of three that started June 1st occurs on July 1st with a partial eclipse of the Sun. However, it's likely that no one will actually see this partial, as it is visible only in a D-shaped region in the Antarctic Ocean south of Africa. Again, NASA's 2011 eclipse webpage has the details (such as they are).

During the first half of the month, can you spot Mercury low in the west-northwest after sunset? Your best chance will be on the 3rd, when this little planet is to the far right of a thin crescent Moon. Several days later (the 7th, to be exact), the nearly first-quarter Moon sits to the lower left of Saturn. Be sure to catch this ringed marvel while you can — it'll be lost in the solar glare by the end of September.

The other three naked-eye planets still appear in the morning sky. Jupiter rises after midnight and by month's end is well up in the southeast at dawn. Mars rises two to three hours after Jupiter, and is low in the east at dawn. The last-quarter Moon is nicely placed above Jupiter on the morning of the 23rd, and the lunar crescent sits to the upper right of Mars on the 27th. Venus is barely above the horizon at sunrise, and it pretty well lost to view by the end of the month. It won't appear again until late October, when it slinks low in the west after sunset.
Thanks to *Sky & Telescope* magazine, *Mercury* readers have direct access to *S&T*’s online Interactive Sky Chart. While anyone can go to it on Sky’s website, registration is required to load and use the charts. Registration is free and has some advantages, but it’s not necessary for ASP members who just want to retrieve the monthly star chart.

*Sky & Telescope*’s Interactive Sky Chart is a Java applet that simulates a naked-eye view of the sky from any location on Earth at any time of night. Charted stars and planets are the ones typically visible without optical aid under clear suburban skies. Some deep-sky objects that can be seen in binoculars are plotted too.

**Using the Chart: The Basics**

When you launch *Sky & Telescope*’s Interactive Sky Chart applet in your Web browser, you should get a rectangular, naked-eye view of the sky on the upper left and a circular all-sky chart on the right. If the chart does not appear, see the “Tech Talk” section at the end of this article.

For instance, when you click on the link for the May Sky Chart, you should see, in a new window, a screen that looks like the image above. Each of the monthly links in Sky Sights will take you to a chart set for 40° north latitude and 100° west longitude (so it’s useful throughout the continental US) at 10:00 pm local time at midmonth in May, June, and July. The chart can be used one hour later at the start of each month and one hour earlier at month-end.

If all you want is a copy of the circular All-Sky Chart to take outside, press the “Create PDF” button, and then print the result. You’ll find the easy-to-use instructions included on the chart.

But Sky’s Interactive Chart offers much more. Click on any area of the circular All-Sky Chart that you’d like to see in more detail. The green frame will jump to where your cursor is pointing, and the scene in the Selected View window will now show this area.

Or click and hold down your mouse button within the green frame on the All-Sky Chart, then drag the frame around the sky. The scene in the Selected View window will change as the location of the green rectangle on the All-Sky Chart changes.

Finally, click and hold down your mouse button in the Selected View window, then drag the cursor to move to another part of the sky. The green frame in the All-Sky Chart will follow your movements.

**Changing the Chart**

Below the Selected View window you’ll find the latitude and longitude the chart is set for, as well as the date and time. These can all be changed.

To alter the *date* and *time*, click on the month, day, year, hour, or minute in the display at lower left, which will become highlighted. 

(You can change only one parameter at a time.) Then use the + or – button to increase or decrease the value you’ve selected. Each time you change a quantity, both the Selected View and All-Sky Chart will be updated instantly.

If you’d rather do a wholesale change, click the large “Change” button in the Date & Time display area. A pop-up window will appear. Here you can choose any date between January 1, 1600, and December 31, 2400, using the day and month pull-down lists and the year text-entry box.

To alter the *location* (and time zone), you’ll need to click the large “Change” button in the Location display area. A pop-up window will appear that will let you select a new location (be sure to enter data in just one of the three sections of this page). A follow-up page will let you select a time zone. But note that unless you register, the system will not remember your new location.

You’ll find more detailed instructions and hints for using the chart on the Help page. To really become familiar with this program, see the article: *Fun with *S&T*’s Interactive Sky Chart*.

**Tech Talk**

The applet should work properly in most Java-enabled Web browsers. For best results on a PC, use Internet Explorer 6 or Netscape 7; on a Mac, use OS X 10.3 (or higher) with Safari.

If you’ve installed a “pop-up stopper” to block advertisements that automatically open in new browser windows, you’ll probably have to turn it off, as the Interactive Sky Chart needs to open in a new browser window.

If you have trouble getting the Sky Chart to open on your computer, please review Sky’s detailed system requirements to check whether you’re using a supported operating system. And don’t forget to also review the Help page.
The Sun, an Eclipse, and the ISS

On January 4, 2011, a partial eclipse of the Sun was visible over Europe, northern Africa, and central Asia. Instead of staying home in France to watch it, renowned astrophotographer Thierry Legault traveled to the Sultanate of Oman to shoot it. Why? Because thanks to orbital calculations made on Calsky, he knew that’s where he needed to be to have a fleetingly brief chance to acquire the photograph on this page.

At 9:09 Universal Time on the 4th, the Sun (147 million kilometers away), the Moon (390,000 km distant), and the International Space Station (350 km away) were perfectly aligned — for less than one second — for Thierry as he stood in the desert near Muscat, the capital of Oman. The result is this stunning, once-in-a-lifetime image. **Left:** A close-up of the ISS and a tiny sunspot group (the image contrast has been boosted for clarity). Credit: Thierry Legault (x2)