O R I O N

Newsletter of the Friends of Astronomy Cornell University

Winter 2009

Dear Friends,

I want to send best wishes to everyone for the holidays. It was great to see you at the Friends of Astronomy Symposium. I am particularly happy that we had an opportunity to honor Yervant, who is not only a great member of the Cornell faculty but a good friend to all of us.

Next year should mark some milestones in the department. Our important new telescope projects, SKA and CCAT, are moving forward through rigorous reviews as part of the influential Astro2010 decadal survey. CCAT continues to benefit immensely from the terrific generosity and energetic support of Fred Young. And in 2010 we will inaugurate the Yervant Terzian Lectures in Astronomy, which were so generously endowed by Charles Mund, jr.

Happy Holidays!

–Ira

The Butterfly Nebula is about 4,000 light-years away in the constellation of Scorpius. Although the star at the center is very hot (~250,000° C at the surface), the ring of dust that gives the nebula its hourglass shape hides it and constricts the star's outflow. This image, one of the first taken with Hubble's new Wide Field Camera 3, was proposed by Yervant's former student Bruce Balick (U of W) and K. Noll and H. Bond (STScI).
Photo: NASA, ESA and Hubble SM4 ERO Team.

Greetings

First, we wish you all a Happy Holiday Season full of Joy and Peace. Second of course, we want to thank you for attending the October Friends Symposium to celebrate my birthday with me! It was grand to see all of you here at Cornell. Thank you for all your good wishes and special thanks to Maddy and Phil Handler for preparing the video that they titled 'Celebrating Yervant,' copies of which will be mailed to all Symposium participants soon.

This is the sixteenth issue of this *Orion* newsletter, which is dedicated to the Friends of Astronomy at Cornell. The major effort of this success is due to Dr. Patricia Fernández de Castro who has not missed a deadline yet! In this issue, among other news, you will read Ira Wasserman's answer to Barbara Burger's question about the Andromeda Galaxy colliding with the Milky Way, and an article by Joe Veverka about what comets are made of.

Cordially,

–Yervant

Contents

P. Fernández de Castro, Editor
pf46@cornell.edu

Thanks to the Friends!

Chuck Mund jr. and Yervant celebrate the announcement of the Yervant Terzian Lectures in Astronomy.

The Department has much to be grateful for this season. As many of you know, during the Friends' Symposium Chuck Mund jr. announced a very generous gift of 100,000 dollars to endow the Yervant Terzian Lectures in Astronomy. Thanks, Chuck, for this exciting gift!

Also on the occasion of the Symposium, Phil and Maddy Handler presented Yervant with the gift of a birthday video celebrating his life at Cornell into which they very generously put, in addition to production costs, much time and effort. Carol and Chuck Mund sr. underwrote the costs of reproducing it for all the Friends, for which we are grateful. Look for it in your mail! Thanks once more to Bob and Vanne Cowie, who sponsored the reception on October 10th and hosted us for brunch on the 11th, to Cornell's Department of Music, which donated copies of the Anillos dvd for participants, and to the Arecibo Observatory, which donated the Symposium folders.

The Department is strongly indebted to Fred Young for his great generosity and longstanding support of CCAT, and to Ed Hewitt, who in addition to his very generous and continued support of the Hewlett Lab, again funded a field trip for Jim Bell's Astro 6577 - Planetary Surface Processes class. Many thanks to both of them!

We are also grateful to Don and Mibs Follett and to Jim and Ellen Myerberg for their gifts towards the production of *Orion* and to the Department, and to the Josephine Hopkins Foundation, which funded a summer fellowship that was awarded to Cornell Astronomy major Katherine Hamren '11. Our thanks to Nancy and Lee Corbin for this.

Beyond all these wonderful gifts, we were happy and humbled by the outpouring of love and enthusiasm for Yervant, the Department and Astronomy not only during the birthday tributes at dinner on the 11th, but in the course of the Symposium and in the days and weeks preceding and following it.

Colleges and universities around the country are facing cuts. The Department is all the more grateful to the Friends for your committed support. Thanks!

The Friends' Symposium

The Special Symposium went off with a bang! One hundred and twenty-eight Friends and colleagues came from as far as Greece and all corners of the U.S. to celebrate Astronomy and Yervant's 70th birthday from October 9 to 11. It was stupendous fun. Exciting talks during the day on Saturday gave us insights into the awe-inspiring understanding of the Universe astronomers are gaining, while the evening events on both days gave us a chance to enjoy old friends, make new ones and celebrate a very special one.

Jim Bell's a fascinating talk about the future of lunar exploration on Friday evening gave us a taste of things to come. Saturday, after Ira's welcome, Rachel Bean and Éanna Flanagan tackled two of the most difficult topics in astrophysics, the Big Bang and the physics of black holes with engaging elegance and clarity. Then Ed Salpeter's former student George Helou, the executive director of Caltech's Infrared Processing and Analysis Center, recalled Cornell's groundbreaking contributions to infrared astronomy, while Bruce Balick, now at the University of Washington and one of Yervant's first students, discussed dying stars. The morning closed with Jamie Lloyd's talk about his search for planets around other stars.

After lunch at the Red Barn, Jay Pasachoff of Williams College and one of the world's experts on the sun, discussed one of his favorite topics, solar eclipses. He was followed by Steve Squyres, who gave us a superb lecture on the future of planetary exploration. Jim Cordes and Ira Wasserman then gave us brief but enlightening updates on the Department's Josephine Hopkins Teaching Radio Telescope and, more

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Group picture next page:

First row, Linda Feldstein, Yervant Terzian, Patricia Fernández de Castro, Pat Edelstein, Steve Ginsberg, Tom Krecji, Ed Churchwell, Bob Cowie, Becky Koopman, Betsey Adams, Tom Balonek, Charles Liu

Second row, Bill Newman, Bonnie Buratti, a visitor, Adadot Hayes, George Helou, Richard Edelstein, Lee and Nancy Corbin.

Last row, Vern Pankonin, Chuck Mund jr., George Feldstein, Mike Davis, Ira Wasserman, Bhante Wimala, Patrick McLaughlin, Nikos Spyrou, Shri Kulkarni and Martha Haynes.

Photos on this and pages 3-6: Cornell University Photography, Patricia Fernández de Castro and Dan Wilcox.

The Friends' Symposium

Right, Shirley Norton, Bonnie Buratti, Carol and Chuck Mund sr. Below, Nikos Spyrou, Linda Feldstein, George Helou, Bob Cowie, and James Bruno.

Left, Ed Churchwell, Hal Craft, Linda Kennett and Dayton Jones. Below, Vern Pankonin, Naomi and Jay Pasachoff, Bruce Balick and Kevin Covey.

Right, Martha Haynes, Yervant and Nikos Spyrou.

Left, Richard Lovelace Barbara Burger, Marina Romanova, Elizabeth Bilson and Chuck Burger.

Right, Yervant with Bill and Jenny Newman. Far right, Tracey and Mike Clements with Sandy and Jeff Bricker.

Above, Bob Horn, Phil and Maddy Handler and Joan Horn. Right, Jean Rowley and Vern Pankonin.

Above, Nancy Bellamy, Bob Cowie, Ed Hewitt, Bill Bellamy and Vanne Cowie. Right, Bill Gratz and Betty Rowley. Far right, Ira Wasserman and James Bruno.

Right, Adadot Hayes and Riccardo Giovanelli.Far above, Bob Cowie and Yervant.

The Reception

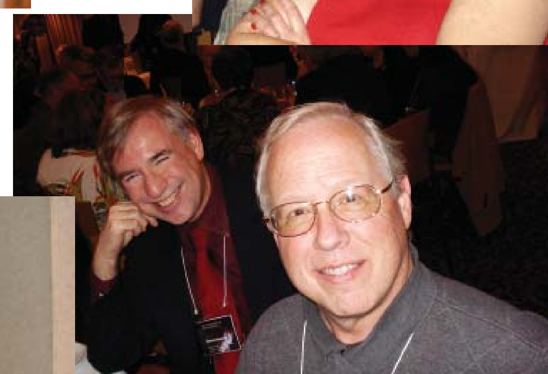
Left, Marina Romanova and Tom Balonek.
Below left, Phil Handler and Chuck Burger.

Left, Nancy Corbin and Tom Krecji.
Below, Yervant with Ed Churchwell and Jim Moran.

Left, Jay and Naomi Pasachoff with Richard Edelstein.
Below left, Barbara Burger and George Feldstein.
Far left, Sevan Terzian with Nikos Spyrou and Riccardo Giovanelli.

Left, Mibs and Don Follett with Martha Haynes.
Far left, Becky Koopman with Jim and Ellen Myerberg.

Friends' Symposium: The Birthday Dinner



Clockwise from top left:
Betsey Adams;
Yervant and Patrick McLaughlin; Mark and Shelley Schimelman;
Rich Isaacman and Dayton Jones;
Phil and Maddy Handler, Yervant and Patricia, Sharon Falk and Chuck Mund jr., Chuck sr. and Carol Mund;
Bill Newman and Bonnie Buratti;
Sevan and Yervant Terzian.

Are We Made of Comet Stuff?

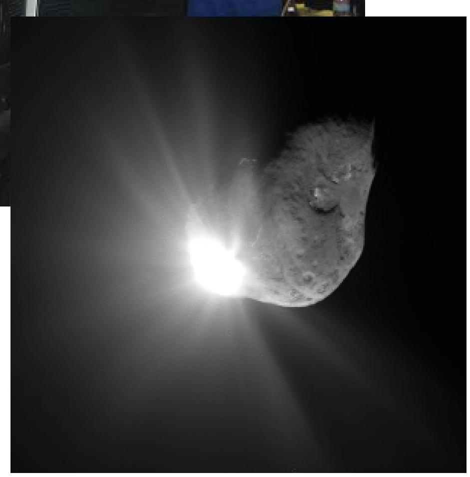
A leader in the exploration of comets, Joe Veverka is the Principal Investigator on NASA's Stardust-NExT mission to Comet Tempel 1 and a Co-Investigator on the EPOXI mission to Hartley 2.

For almost a century and a half we have known that comets contain organic molecules—molecules that could provide clues to the origin of life on Earth. Therefore the question: Did life on Earth originate from organic matter brought to early Earth by comets—or, in Carl Sagan's words, "Are we made of comet stuff?"

The answer has been surprisingly hard to obtain. In 1986 the European spacecraft Giotto flew close to Comet Halley collecting dust it ejected. Rudimentary analyses of this dust by Giotto's instruments showed that a significant fraction of the dust particles did not contain the usual rock forming elements such as silicon, iron and magnesium. Instead, these particles were composed entirely of the light elements: carbon (C), hydrogen (H), oxygen (O), and nitrogen (N). It is likely that these "CHON particles" are fragments of organic matter within the comet. Unfortunately, Giotto's instruments were not sufficiently sophisticated to determine the exact makeup of this matter.

More recently, in January 2004, NASA's Stardust spacecraft flew close to Comet Wild 2 and picked up dust from the comet's coma (or atmosphere) and returned it in a capsule to Earth for detailed laboratory studies. A few of these particles contained traces of glycine, an important amino acid—a tantalizing clue that comets may indeed be reservoirs of biologically important materials.

A smashing success.



Why is this organic mystery so hard to solve? The problem is that the accessible part of a comet—the surface of the nucleus from which comes the dust ejected into the coma (analyzed by Giotto and returned to Earth by Stardust) has been severely modified by radiation: x-rays and ultraviolet light from the Sun, solar wind protons and electrons, as well as cosmic rays, all energetic agents which are dramatically efficient at breaking apart organic molecules. To capture pristine organic materials in a comet, we must dig below the surface, preferably deep below the surface!

So far the only attempt to "dig" below the surface of a comet occurred in 2005 during the Deep Impact mission to Comet Tempel 1, a mission in which Cornell scientists played a major role. The Deep Impact spacecraft consisted of two parts—an impactor that hit the nucleus at high speed with an energy of some 5,000 tons of high explosive, and a mother spacecraft instrumented to observe the event. It was expected that the collision would dig a hole some 300 feet across and perhaps 50 feet deep. The actual size of the crater would tell us how hard is the surface of a comet. High time resolution observations with camera and spectrometer would tell us what sorts of materials were dug up and thrown out from different depths. As the magazine *Sky and Telescope* reported, the experiment was a "smashing success". The spectrometer confirmed that as you dig deeper and deeper below the surface, more and more organic material is ejected. (We believe that, by bulk, a typical comet is about one third ice (mostly H_2O), one third rocky minerals, and one third organics.)

Unfortunately the spectro-meter on Deep Impact was not capable enough to tell us exactly what organics are present: it saw evidence of carbon-hydrogen bonds in a diversity of complex molecules, but could not determine their precise composition. So much material was ejected by the impact that the cameras on the mother spacecraft could not see to the surface to determine the size of the crater made by the impactor! But more on that later.

What's next? ESA—the European Space Agency—launched the Rosetta spacecraft in 2004 to orbit Comet Churyumov-Gerasimenko in 2014 and deploy a lander to the surface. The lander will be able to "scratch" the surface and deliver

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Are We Made of Comet Stuff?

(cont.)

material from a depth of a few inches to a mass spectrometer that will perform the most thorough chemical analysis of cometary material to date. But will this answer the question? Rosetta's analytical capabilities are limited, and digging to only a few inches may not yield the unmodified "pristine" comet material that we seek. The full answer will only come one day in the future when a spacecraft will sample the subsurface of a comet, say to a depth of three feet or so, and return the samples, altered as little as possible, for detailed chemical analysis in a laboratory on Earth. NASA is considering such a mission, in which Cornell scientists are expected to play key roles, for the end of the coming decade.

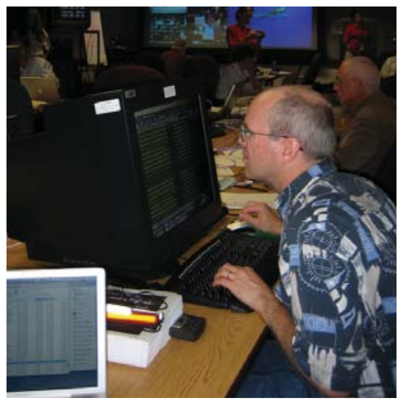
What can we expect in the meantime? To land on a comet and sample its subsurface we need to know more about the mechanical properties of the surface. Here we come back to Deep Impact. If we knew the size and depth of the crater made by the impactor in 2005, we could calculate many of the mechanical properties we need to know. A NASA mission led by scientists at Cornell called Stardust-NExT is on its way to provide the answer.

With the help of colleagues in Maryland and California, we figured out a few years ago that we could retarget the old Stardust spacecraft—the one that delivered the dust-containing capsule to Earth but remained in orbit round the Sun—to get to Comet Tempel 1 the next time the comet gets close to the Sun, which will be in early 2011. Using the Earth's gravity during a close flyby in January 2009, the Stardust spacecraft was deflected onto a path that will take it to within 120 miles of the nucleus of Tempel 1 on February 14, 2011 (Valentine's Day!). We expect to see the crater made by Deep Impact and from its size and depth infer how strong the surface and sub-surface are—information essential to a future sample return mission. Because we will have accumulated so much detailed information about Tempel 1, this comet will be a prime target for the future sample return mission.

So while Carl Sagan's question will remain for a few years yet, we are getting closer and closer to an answer.

–Joe Veverka

Comet Hale-Bopp's intrinsic brightness exceeded any comet since 1811. Since it peaked on the other side of the Earth's orbit, however, it appeared only brighter than comets seen in the previous two decades. Its blue tail was composed of ionized gas. The light colored dust tail was made of bits of grit from the comet's nucleus. Photo: John Gleason (Celestial Images).



Comet missions require dedication and hard work. Two Cornellians work during the Deep Impact encounter.

The Friends Symposium

(cont.)

generally, the Department's activities. To close the day's lectures, a panel formed by Jim, Ira and Martha Haynes and led by a good friend of the Department, Shri Kulkarni, the director of Caltech's Optical Observatories, discussed dark matter and dark energy.

We met again for a reception at the Statler that was followed by the presentation of Phil and Maddy Handler's birthday gift, a video titled *Yervant Terzian's Cornell Story*, and then by a delicious dinner at the Terrace. As we were ending, Shri Kulkarni gave a lively talk on "How Astronomy is Changing."

Friends, former students and colleagues then came up to share their stories of Yervant as a student, a colleague and, foremost, a teacher and a mentor. Chuck Mund jr. opened these tributes with an awesome surprise: a donation of 100,000 dollars to endow the Yervant Terzian Lectures in Astronomy!

With Sunday came the time for farewells, but not before meeting once more for a brunch offered by Bob and Vanne Cowie—a delightful end to a wonderful weekend.

Barbara Asks!

Q. When might our Milky Way Galaxy fuse with the Andromeda Galaxy? What causes galaxies to collide, and is the collision usually a violent one that alters both galaxies unrecognizably or may it be a more moderate one in which some stars and solar systems survive?

A. Overall, the Universe is smooth and expanding, but local matter density fluctuations lead to the formation of dense systems that "freeze out" of the global Hubble flow. This is fortunate, for without these fluctuations we would not exist.

The Milky Way galaxy itself is one of these frozen-out fluctuations, and it is part of a larger aggregate, the Local Group of galaxies. The other prominent member of the Local Group is the Andromeda galaxy, which is similar in size, mass and shape to our galaxy.

And we are falling toward one another.

The Milky Way and Andromeda are about 2 million light years apart. The speed with which we are approaching one another is about 120 km/s, or about $^{1}/_{2,500}$ times the speed of light. Thus, the two galaxies will hit one another in 2,500 times 2 million years, or about 5 billion years. While this is a rough estimate, it is pretty close to the result one finds "rigorously."

Galaxy collisions are violent events, but the likelihood that any two stars in them hit one another is negligible. The nearest star to the Sun is about 4.5 light years away; this is a pretty typical value for the distance between stars in both the Milky Way and its very similar partner, Andromeda. By contrast, the size of the Sun is about 2 light seconds, which is about 70,000,000 times smaller. Even giant stars are only a few light minutes in size—still far smaller than the distance between the stars. There are regions where the density of stars is larger than it is near the Sun, such as the center of our Galaxy, but even in these regions the spacing between stars is far greater than the size of a star. As a result of the disparity between the sizes of stars and the distances between them, the probability that any two stars will collide when the Milky Way and Andromeda do is tiny. Of course, about 100 billion stars will be involved in the collision, and perhaps one pair of stars out of this multitude might actually hit one another, an unfortunate and spectacular event, but an exceedingly rare one.

Our Milky Way will collide with Andromeda Galaxy much like this. Galaxies NGC 5426 and NGC 5427, also known as Arp 271, about 90 million light-years away toward the constellation of Virgo, together span about 130,000 light years. As they advance over the next tens of millions of years, their component stars are unlikely to collide, although new stars will form in the bunching of gas caused by gravitational tides. Notice in the image a bridge of material momentarily connecting the two giants.
Photo: Gemini Observatory, GMOS-South, NSF.

The Antennae Galaxies in Collision. When galaxies collide, the stars that compose them usually do not. This is because galaxies are mostly empty space; stars take up only a small amount of that space. During the slow, hundred million year collision, however, one galaxy will rip the other apart, and dust and gas common to both galaxies will collide. In the image, dark dust pillars mark massive molecular clouds being compressed during the galactic encounter, causing the rapid birth of millions of stars.
Photo: NASA, ESA, Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration / B. Whitmore (Space Telescope Science Institute) et al.

The collision of the Milky Way and Andromeda will distort them enormously. Ultimately, the two galaxies will coalesce into a single galaxy that is fatter than either one. Before things settle down, there will be tidal streams of stars and gas ejected from the collisions. Spectacular examples have been observed by telescopes on the ground and in space.

In addition to stars, the Milky Way and Andromeda have "interstellar mediums" made up of gas and dust. When the two galaxies hit, the gas and dust will bang into one another at supersonic speeds, causing shocks to form. Star formation can occur furiously in the shocked interstellar medium. Distant observers recording the collision will see many young, bright blue stars born in the cataclysm.

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

Memories of Apollo 11

Elizabeth Bilson, Ph.D. (Chemistry, University of Illinois) was a research associate at the CRSR, where she worked for Tommy Gold, mostly on lunar matters. In 1983 she became the Administrative Director of the Center, a position from which she retired in 2004.

The world and Cornell have changed considerably since the first Apollo Moon Landing. Forty years ago most Cornell faculty members had been born and raised in the pre-2nd world war era; a number of them had joined Cornell from abroad fleeing the Nazis. This was the case for two of the most prominent members of the Physics Department: Hans Bethe, who had just received the Nobel prize in 1967, and his disciple Edwin Salpeter. Also displaced by the war was Austrian physicist and astronomer Thomas Gold, who had been invited to Cornell in 1959 to form a modern department of astronomy. He had accomplished this with great success: by 1969 Cornell already had a very distinguished Department of Astronomy and Space Research Center, a brand new Space Sciences building, and was operating the world-famous Arecibo radio-radar observatory. Gold, who died five years ago, was involved in many branches of astronomy, but one of his main interests at that time was the Moon. That was how he came to be an advisor to NASA's Apollo program.

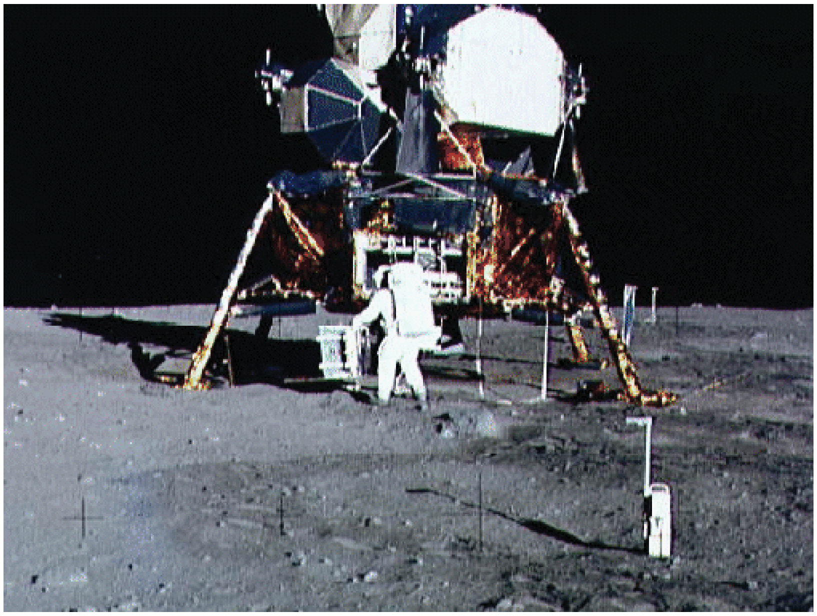
In July 1969 I and my family watched the Apollo 11 landing on television, an enormously exciting and memorable event. It was the culmination of a decade of extraordinary effort, an almost unbelievable technological triumph, and a celebration of a huge national accomplishment. It seemed fantastic to sit in our living room and be able to watch a man step out of a spaceship to the lunar soil! After all the drama and horror of the sixties this was finally a truly positive, happy event for the nation to share.

Soon after the landing, in the fall of 1969, I started working for Tommy Gold. Cornell scientists had been selected by NASA for two different studies on the lunar samples brought back by the Apollo11 mission; in addition Gold was the principal investigator of the lunar stereo camera project. His research group was to receive several dust and rock samples to determine some of their physical properties. George Morrison, of the Chemistry department, was to work on a second set to determine their elemental composition.

There was so much excitement at Space Sciences when the first lunar samples arrived and a few insiders could hold them in their hand, look at them and examine them under the microscope! Their presence was an important subject of conversation on campus—but so was their security. NASA required that the samples be guarded in a safe in a room equipped with an alarm system that was connected to the Cornell Police. To access them, authorized researchers had to disarm the alarm by a special key. More than once an eager researcher forgot the alarm system, and the police arrived with drawn guns, causing quite a commotion in the building.

Another unusual circumstance was the frequent presence of the press equipped with cameras, light and lots of equipment wanting to interview mostly Tommy Gold on the latest findings and the overall assessments of the Apollo program. Gold was very proud of having predicted that the astronauts would find a thick layer of dust covering the lunar surface, perhaps deep enough to actually sink into it. Although this was not a problem, there was nevertheless a soft coherent layer of dust on the Moon, as shown by the footprints of the astronauts. Such a surface cover had not been at all the prevailing wisdom before the landing. Gold had predicted it partially on account of the radio properties of the lunar surface determined by earth-based observations. He had actually prepared a small vial of fake moondust before the landing, and loved to show it off to the press and visitors, comparing it to a vial of actual moondust—it was really difficult to distinguish the two by casual observation.

After the first excitement started to die down, serious work began in the Lunar Lab at Space Sciences



Astronaut Neal Armstrong unloading equipment from the Lunar Lander. In the foreground, Tommy Gold and Edwin Land's Stereoscopic Camera. Photo: NASA.

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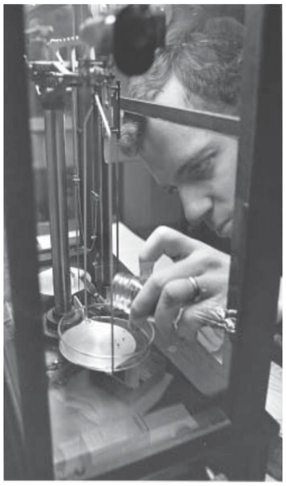
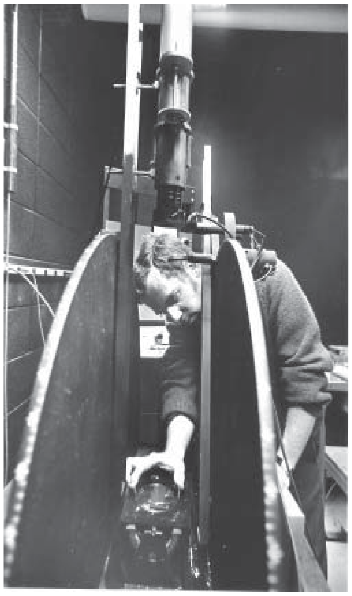

Above, Cornell astromer Brian O'Leary preparing a lunar sample for analysis. Right, placing another one in the goniometer, an instrument used to determine the reflectivity of a sample as a function of the angle of the incident light. Photos: Cornell University.

and in George Morrison's analytical lab in Chemistry. Each group received a few grams of dust sample and tiny rock chips. Although Apollo 11 had brought back a remarkable quantity of samples (some 22 kg., including 50 rocks, some soil and a core sample from 13 cm below the surface), there were 150 laboratories involved in analyzing this material, and NASA was determined to save most of it in pristine condition for future investigations. Thus, not more than 20% of the moon dust and rocks were distributed for scientific analysis at that time.

There was a sense of urgency. Results of the laboratory observations were due to NASA within a few months, to be ready for the First Lunar Science Conference in early 1970. I was not a geologist, but as Tommy's assistant, I was fortunate to be part of the small group that first looked at the samples. I was in awe by the sheer fact that I was staring at material from the Moon. Our group was to determine the particle size distribution in the dust, the optical reflectivity and some of the electrical properties of the dust and rock samples. The particle size distribution of the dust sample indicated how fine the dust was at the Apollo 11 landing site. When compared to the ones obtained later using dust at other locations on the Moon, it turned out that no great variation in the particle size distribution of dust at various locations on the Moon was observed. The electrical properties of the dust and rock samples are important for the interpretation of earth-based radar observations. We found that the optical reflectivity of the dust matched rather well the ground-based measurements of the reflectivity of the lunar maria, which argued for a ubiquitous dust coating of the lunar surface. The Morrison group, for its part, determined the abundance of 67 elements in the soil sample and in seven rock samples, finding an apparent uniformity in the composition of these as well as an overall similarity to terrestrial basaltic rocks. Yet these samples were depleted in volatile elements and somewhat enriched in rare earth elements.

In the meantime, Tommy Gold studied 17 stereo photographs of small (a few square inches) areas of the surface the astronauts had taken with the help of a special camera designed by himself and Edwin Land of the Polaroid Corporation. Gold noticed in several a shiny, glassy-looking coating on small, fragile clumps of soil. Of a number of possible explanations for these glassy coatings, Gold speculated that an intense source of radiation heating could best account for them. He put forth the possibility of a giant Solar flare in the geologically recent past in a daring and imaginative paper in Science magazine only weeks after the Apollo 11 landing. A debate so lively ensued that Apollo 12 and 15 collected glazed samples for scientists to elucidate the question.

I continued to do research involving samples from all six successful Apollo landings for seven years. It was a fascinating period of my life that yielded some two dozen scientific papers. My work focused on explaning the optical properties of the samples in terms of the chemical composition of the surface of the soil grains, as well as the explanation of those processes on the Moon which may change the surface of the soil grains, rendering them much darker than expected based on their bulk chemical composition. We concluded that the low reflectivity (relative darkness) of the Moon could be explained by a process in which the solar wind (solar protons and helium ions) sputters iron and other heavy metal atoms on the surface of soil grains. This metal coating changes the reflectivity of the dust grains, making them darker. We demonstrated the existence of the metal coating by a then novel technique: Auger electron spectroscopy measurements of the chemical composition of outermost few atomic layers of the soil grains. When compared to the surface chemical composition of freshly sawn lunar rock samples never exposed to the solar wind, these measurements clearly showed the dark coatings (enriched in iron and other heavy metals) only existed on dust grains exposed to the solar wind.

The author in her office.

–Elizabeth Bilson

Books in Science and the Universe

Carl Sagan: A Biography, by Ray Spangenburg and Kit Moser (Prometheus Books, 2009).

Carl Sagan was the premier science popularizer in the world in the second half of the 20th Century. His monumental PBS *Cosmos* series was seen around the world by millions of people. He motivated countless of young students to follow the sciences; many important scientists today credit Sagan for inspiring them to make their careers in scientific fields such as astronomy, geology, and biology. Unfortunately, he died young and the world lost his gift and pathos to explain the universe the way it is and not the way we wish it to be.

Carl Sagan: A Biography is a concise, well written, easy to read and uncomplicated treatise of his life that correctly emphasizes the two most important questions Sagan posed, "Is there life on other planets?" and "What is the rest of the solar system made of?"

Sagan's research took him from biology to physics and astronomy. His leadership in many of NASA's early space missions contributed greatly in the quest of planetary exploration. His academic affiliations included the University of Chicago, where he received his Ph.D., Berkeley, Harvard and, since 1968, Cornell. Here he did most of his productive work in exobiology and planetary exploration and authored several popular astronomy and space sciences books. This writer was Chair of the Department of Astronomy and Space Sciences at Cornell for most of Sagan's tenure until his untimely death in 1996. We were close friends and colleagues, and I applauded his efforts in science education.

His TV appearances made him a celebrated public figure, but a trusted one. Sagan was sympathetic to the claims of UFOs and tried to find any evidence that would prove their existence. However, he never did and he remained a skeptic. He enthusiastically participated in attempts to send messages to extraterrestrials, some attached to spacecraft such as Pioneer 1 and 2, which by now have traveled beyond the solar system. He was the first to recognize that the greenhouse effect keeps the surface of Venus about 800° F, too hot to sustain life. When the Mariner Mission showed Mars is a vast reddish desert, Sagan, who had hoped to see the photos of Martians dancing in front of the spacecraft's cameras, at once provided exciting scientific commentary on TV to the public.

The book details the many discussions that Sagan had with other SETI (Search for Extra Terrestrial Intelligence) enthusiasts and describes how one can estimate the number of intelligent communicative civilizations in our galaxy. As Sagan liked to say, our galaxy alone has 200 billion, or 'billions and billions of stars.' Probability argues we are not alone, especially now that we talk of 'billions and billions' of galaxies!

Later in life, he and other colleagues described 'nuclear winter,' the devastation that could result from a global nuclear war, bringing the end of our civilization by spreading ashes on the earth's upper atmosphere, blocking sunlight for a long time, cooling the surface of the earth and thus precluding food production. He advocated an end to nuclear weapons.

Books *(cont.)*

In 1977 he published *The Dragons of Eden: Speculations on the Evolution of Human Intelligence*, in which he explored the brain and how it evolved, a subject clearly connected to intelligent life on other planets. He received the Pulitzer Prize for this work. Later he wrote *Contact*, a fiction about contact with an extraterrestrial civilization that became a successful movie.

Although it gives scant attention to the 13 episodes of the PBS-produced *Cosmos*, the spectacular series that was Sagan's most important contribution to society, this book is an excellent account of his life and personality.

–Yervant Terzian

Yervant's Critical Thinking Corner

A professor is teaching a class every day of the week. One day he says to the class, "Next week I will give you a surprise exam."

The students worry because they have no idea which day of the week the professor will give the exam. One student, however, was not worried. He says, "I am not sure there will be an exam next week."

He then argues as follows: "If the professor does not give us the exam by Thursday, then he cannot do so on Friday because that would not be a surprise. So the exam cannot be on Friday. So Friday is out of consideration. Again, if he does not give us the exam by Wednesday, it cannot be on Thursday since that would not be a surprise either. Hence Thursday is out too. Similarly, all the previous days are out too. Therefore there cannot be an unexpected exam and since the Professor speaks the truth, then there will be no exam."

But on Wednesday the professor comes to class and gives an exam! Was this unexpected?

Contributors
Elizabeth Bilson
Former Administrative Director, CRSR, Department of Astronomy
Barbara Burger
Founding member, Friends of Astronomy
Patricia Fernández de C.
Editor
Yervant Terzian
The David C. Duncan Professor in the Physical Sciences
Joe Veverka
The James A. Weeks Professor of Astronomy
Ira Wasserman
Chair, Department of Astronomy