PROCEEDINGS OF THE 47TH CONVENTION OF THE ASSOCIATION OF LUNAR AND PLANETARY OBSERVERS

TUCSON, ARIZONA, OCTOBER 19-21, 1996

Edited by John E. Westfall, A.L.P.O. Editor

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Monday, October 21

Tour of Space Imagery Center, Lunar and Planetary Laboratory

THE OCTOBER, 1996 MEETING OF THE ASSOCIATION OF LUNAR AND PLANETARY OBSERVERS IN TUCSON, ARIZONA

By: Richard Hill

This gathering began very informally with a number of the attendees getting together around the registration table in the lobby of the Plaza Hotel from 10 am to 1 pm Saturday, October 19. Among those on hand were John Westfall, Cecil Post, Terri Lappin, Gary Rosenbaum, Jeffery Sandel, Dan Joyce, Robert Gent, and Rik Hill. The conversation was lively and was a portent of things to come.

[Several of the above were local A.L.P.O. members, and had been of invaluable help in planning the meeting and insuring that it ran smoothly. Special thanks go to Terri Lappin, Rik Hill, David Levy, and Gary Rosenbaum. John Westfall]

After lunch at the hotel restaurant, Dean Ketelsen, an optician with the Steward Observatory Mirror Laboratory, took everyone to that facility. There we saw several impressive works in progress. The 6.5-meter mirror that will replace the six mirrors of the Multiple Mirror Telescope dominated the floor of the fabrication section of the lab. The mirror was in its cell and skidded about the lab on a film of pressurized air in a huge air-cart. As we were looking at this mirror with it's 13" sagitta, we could see the figure on a computer nearby as it was under test the whole time. Next was the pouring and molding section of the lab. There attendees saw the 8.4-meter chamber being readied for a melt in January. The size of it dwarfed even the enormous 6.5-meter! We then headed down to the floor and were escorted into a tent that held another 6.5-meter blank that was standing on edge awaiting grinding after the first one was moved out of the way. So here, in one big room would be created more light-gathering power than even existed on the earth before WWII!

Those of us attending the evening CCD Workshop left Tucson about 3:30 PM (Sat. Oct. 19) and had magnificent views on the drive to Mt. Bigelow, getting there about 5 PM. After dinner in the "Monastery," we toured the 16-3/4-inch Schmidt dome and then went to the 61-inch Cassegrain. It was already beginning to cloud over, but we trained the 61-inch on Jupiter during breaks and then went downstairs to focus the CCD on the monitor. Due to the increasing clouds, all we saw were some faint fuzzy Jupiters on the screen, and one relatively clear view with a satellite. Then it clouded over completely.

The evening was far from lost, however; for a couple hours, Mike Newberry demonstrated CCD image processing, using previously-acquired Jupiter, Saturn, Comet, and deep-sky images. This session was very instructive.

We also took a break for a short trip even higher to Mt. Lemmon, where we toured the telescopes. (Up there, we were actually in the clouds.)

Thus, although we acquired no usable images that night, we had a most interesting tour and a very instructive image-processing workshop, thanks largely to Mike Newberry's efforts. Nobody in our group of ten expressed disappointment in the trip; the workshop and telescope tour more than compensated for the clouds.

All credit for this delightful outing should be given to Gary Rosenbaum, who masterminded the workshop, to Terri Lappin, who handled the logistics (bus and box dinner), and to Ed Vega and Mike Newberry.

On Sunday morning people began gathering in the Steward Observatory building about 9 am. The talks began at 9:35 with keynote speaker, Dr. William Hubbard of Lunar and Planetary Lab. who addressed the group on "Planetary Occultations and the Amateur Astronomer's Contributions." He described the circumstances of typical occultation events, how best to observe them, and why.

He was followed by David Levy, who brought us up to date on the impact sites from comet S/L-9 and their appearance with his talk, “Comet Shoemaker-Levy 9 and Jupiter: A Retrospective.” After a coffee break, Rik Hill talked on “Observing the Lunar Atmosphere with a 7-inch Coronagraph,” showing how sodium and potassium had been measured to a height of 1000 km from the surface of the moon. This was followed by Dan Fischer and “Lessons from Comet Hyakutake, With the Next Bright Comet in Mind (Be it Hale-Bopp or not...).” He described techniques used in the photography of Hyakutake, how they worked, and how some did not, along with the plans stemming from these for the photographing of Hale-Bopp.

The catered Mexican-food lunch was from a bit after noon to 1:30 pm. The topics around the tables were fascinating and perhaps the best part of any meeting! The next session started around 1:35 pm with Strolling Astronomer Editor, Dr. John Westfall speaking on, “The Amateur and Unpopular Science.” This light-hearted talk was a great way to rehone the satiated audience. He highlighted his talk with slides of many newspaper and tabloid covers from the last several decades. After John the team of Carl Hergenroether and Tim Spahr talked about their work in asteroid and comet patrolling with the Schmidt telescope on Mt. Bigelow that netted them their own comet along with a lot of the near earth flying rocks! This was followed by a coffee break and stretch for a few minutes and then the Amateur-Professional Panel convened to discuss, “Amateur-Professional Cooperation—Projects, Training, Equipment,Communications.” This was an exhilarating roundtable discussion that touched on many excellent points; particularly how the website could be better utilized to get amateur observations out to the world.

Later in the afternoon, after 4 pm, Gary Rosenbaum and Mike Newberry held another workshop on CCD Image Analysis/Processing. Mike showed the members how MIRA, an image-processing program he developed, works and some of its capabilities with images taken by some of the members.

Other Sunday-afternoon activities included a group photograph [shown on the front cover] and a fascinating tour of the Steward Observatory CCD fabrication and test facility. This tour was given by Teresa Lappin, who works there and is an expert on the subject.

In the evening there was an informal Banquet at the China Rose Restaurant. Here David Levy gave the second portion of his presentation on comets and amateur astronomy.

Those of the members who stayed to Monday morning enjoyed a very informative tour of the Space Imagery Center of the Lunar and Planetary Laboratory. All who attended our Tucson meeting were looking forward to the 50th Anniversary meeting in Las Cruces.

(The above is a slightly edited version of the meeting description that appeared on the A.L.P.O. web-page: http://www.lpl.arizona.edu./alpo/)

Lessons from Comet Hyakutake

with the next bright comet in mind (be it Hale-Bopp or not...)

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There are those who use the utmost of equipment for their astrophotographical endeavours - and those who prefer to enjoy the visual pleasure and employ photography only as an additional means of capturing the unusual sights astronomy can offer. The author tends strongly towards the latter group, and yet there is science even in some of the „data“ taken with little effort. This paper grew out of the author's unusual experience of having *overexposed* many of his photographs of comet Hyakutake (which led to experiment #2) - and of having missed the opportunity to try out certain experiments (number 1 and 3) himself. When the next bright comet in the zero magnitude class comes along, he will be ready, and so should you...

Experiment #1: *Defocus your camera!*

Even half a year after the apparition there is still a controversy about the magnitude Hyakutake's head reached in the days around its March 25, 1996, perigee: Was it -0.8 mag as claimed by some, or +0.5 mag as seen by others? Perhaps we will never know, and I will never be able to prove that the 'best guess' is 0.0±0.3 mag - this is the seemlingly unsolvable property of visual magnitude estimates of comets. With large-field CCD cameras still scarce and methods for the photometry of very extended sources not yet widely known (or even developed), the visual estimate has remained the only accepted technique for obtaining the overall brightness of cometary comae, even in the 1990's. There have been many efforts to determine the physical 'meaning' of comet brightnesses and their change with solar distance (including several by the author [1,2]) - but isn't it about time to get the brightness determination itself on a firmer footing? And not with an exotic technique accessible to just a few but a method that almost everyone could use? The large Halley observing campaign in particular had made it clear that many factors, largely uncontrollable, are affecting visual magnitude estimates [3,4,5], and the ensuing controversies on the 'right' way to treat these abundant but flawed data have never been solved.

Why then can't one just take a photograph of a comet's coma and analyze it with photoelectric of photovisual means which are well established in the photographic photometry *of stars?* The reason is simple: Photographic film records information in a - sometimes highly - nonlinear way. And the processes that produce the image of star and that of a comet's coma on a piece of film are quite different. A star is a point source, which, though convolved by the optics (namely their non-infinite aperture and various aberrations), basically reaches the film as a point, as long as the focal length stays short. (Otherwise strange things can happen - witness the 'Saturn-Like Object' seemingly in pursuit of comet Hale-Bopp in November, 1996, that one gullible astrophotographer captured with high magnification - and which turned out to be nothing but the deformed image of a bright star [6]...) While the film is exposed, the stellar point source produces a growing dark spot on the negative, the photochemistry behind that growth being beyond the scope of this paper. If you only compare stars to each other, the size of the spot can be calibrated with stars of known brightness, and the unknown magnitudes of other stars can be deduced, by visual inspection or with special machines one still finds in old observatories.

A comet however, unless almost starlike, is anything but a point source: If is a - in the film plane - a two-dimensional brightness distribution, often with a condensed peak, but always with fainter wings. And it is this pattern, often with the central part burned out by overexposure (really: overexposing comets of Hyakutake's class takes is easy), that the film records. There is *no* way that one can compare the comet and star images on film and arrive at a reasonable magnitude value for the comet. But what would happen if one defocuses the image? Just like one does for a visual brightness estimate? Such a technique was proposed in passing by S. Edberg at a post-Halley amateur meeting in Heppenheim, Germany, in 1986, but it apparently never caught on - and I sadly recalled it only after Hyakutake was already gone. This would probably have been the only comet since Halley's bright enough to experiment with this technique even with unguided astrophotography. The basic idea behind the photo-defocusing technique is that it spreads out both the star and the comet light *before* it reaches the film plane, and the hope is that the light pattern recorded would be at least as useful to deduce the comet magnitude than the pure visual method. Another advantage would be that even stars far away from the comet could be used now for objective comparision (a very difficult and unreliable method visually), by taking equally exposed images of different parts of the sky. Even zero-magnitude Hyakutake required 'collecting' comparision stars all across the sky (which only worked really well after midnight, when the Summer Triangle was up).

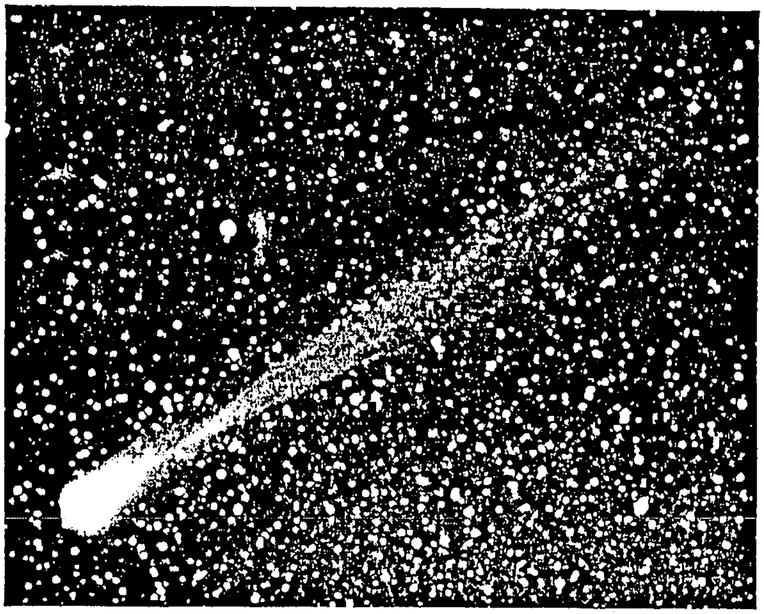
This paper is an invitation to try out the photographic defocusing trick on the next bright comet coming along - and please forward your results to me under the address given above! Here's what everyone should do:

- Use mostly black-and-white negative film instead of color slide film which has a much smaller exposure latitude and gets burned in fast. Negative film, on the other hand, records a vast range of brightness levels, and even though it is next to impossible to see this in prints, the information will be in the film, waiting to be extracted.
- Try out different exposure times: Even if you think - from previous experience - you know how long to expose for a 'decent' comet image, the rules will change once you get out of focus. Different f stops might be tried out as well.
- Try out different degrees of defocusing! This is the most important experiment: How far out of focus do we have to go for the best result? Going too far would dim out the light too much and it would both get lost in the background (which can be high if one does the experiment close to a city) and will be confused with neighboring sources.
- Record all the parameters of the experiment carefully: Only then can we learn from it and waste less film on the next comet. Date, time, film type, lens, exposure time and development details are essential.
- Do the visual magnitude estimation anyway: The larger the data bank of traditionally obtained magnitudes, the better the photographic method can be calibrated afterwards. Don't forget to determine a potentially important parameter: the visual limiting magnitude in the vicinity of the comet!

Experiment #2: *Enhance your photographs!*

The non-linearity of photographic film can actually be used to the advantage of the lazy astrophotographer: With the help of this effect you can record amazingly faint features in the sky without having to expose for hours *or* the hazzle of moving to a dark site. If there are only a few photons around, your film will just record nothing (or rather not anything the subsequent developing will bring out): Only from a certain light level onwards does the darkness of the image on a negative (or its brightness on a slide) increase about proportionally to the light received. Thus, if you work under dark skies that make every visual observer happy, you have to expose for some time before an image of faint structures, be they galactic nebulae or comet tails, starts to form. But light pollution comes to the rescue! The stray photons from street lights all around you join up with the 'real' photons from the sky and push the sum over the threshold where the film starts to record retrievable information. This effect is well known among photographers who sometimes use 'diffusely pre-expose' or 'pre-flash' film to make it more sensitive - but it doesn't matter if the diffuse excess additional light reaches the film before or during the exposure. Let's *use* the dreaded light pollution as a 'natural' image enhancer!

The result can be amazing, especially when the skies are moderately light-polluted (let's say the visual limiting magnitude is around 5.5) and very transparent at the same time. (Low temperature further enhances the film sensitivity, for yet other physical reasons). With a mere *unguided* 30 second exposure, a 50 mm f/1.4 lens at full aperture and a ISO 400 film one can, with the aid of moderate light pollution, *easily* catch big galactic H II regions like the California nebula or even Barnard's Loop in Orion - or tens of degrees of Hyakutake's tail! This works best with color slide film which tends to enhance subtle color differences: The following discussion applies only to color slide photography. Now there is one problem: The *contrast* is not nearly as high as one would get with a (much) longer exposure under dark skies, where the celestial photons do all the work. My own Hyakutake pictures suffered from that problem: They showed a bright blue tail in front of an almost as bright green sky (the sky color is a function of the kind of street lamps dominating the light pollution, the brand of film and differential reciprocity failure of its color layers). Slides like these have only one advantage: They show up better than good ones when projected in rooms that aren't properly darkened. But to show them around or publish them in print, their contrast should be increased. And there are two ways to do it.



One approach is to *take a picture of the picture:* Most photographic slide films increase the contrast, i.e. the gradient of the slide is larger than the brightness variation in the real object. This effect, while guaranteeing nice images on the screen, is normally unwanted when one duplicates slides - but since we want to increase the contrast, they work just perfectly. Take a slide duplicator, ordinary slide film with small grain (ISO 100 or less) and a strong light source: I always work with a slide projector (with its lens taken out), shining its glaring light directly onto the diffusor of the slide duplicator. Since the projector's lamp is very hot, the light is bluer than ordinary incandescent light: Only a weak blue filter is needed to turn it into the daylight white the film wants. Now try a few different exposures, bracketing what the TTL exposure meter recommends: Typically one or two of them will be right - and the contrast between the comet's tail and the sky background will be up. Now do that trick again, but this time to the 1st generation copy: The 2nd generation copy will be even better contrastwise. And you can repeat that process again and again, until you like the contrast - as I write this I have just seen the 3rd generation copies of my Hyakutake slides, and the tail contrast is vastly better now than in the original. I have no idea how far one can go (but I intend to find out)!

Some slide duplicators also allow you to zoom in on a part of the original slide, which can be helpful if the comet was significantly smaller than the field of view. This, of course, will enhance not only the contrast but also the grain (which gets stronger with 1:1 copies, too): There will thus be a tradeoff between contrast and graininess - but then again, there's always some time for experiments before the next bright comet comes (like the 10 years between Halley and Hyakutake...). There is, however, another flaw in many pictures taken with the simple technique described above: Because you work with the full aperture when taking the original slide, the image will be heavily vignetted, i.e. much darker at the edges of the field than at its center. If the comet it small, you just place it in the center and ignore the vignetting - but if the tail spans 10's of degrees like Hyakutake's did, you cannot escape the vignetting effect - which will grow horrendously with each step of duplicating. Regions of the sky will get brighter, others will turn to black - without sophisticated darkroom tricks this effect probably can't be removed. With the 2nd method, however, one might be able to get rid of it mathematically (and save a lot of film in the process): Do the contrast enhancement in a computer!

The main problem now turns to getting your chemical pictures into the machine and get them out again after image processing, but for simple experiments a photographic hardcopy of the slide plus a flatbed scanner will do. Cranking up the contrast then works ususally with one or two mouse clicks, and you can even enhance the *color contrast.* As I described, in my Hyakutake slides the sky was greenish (as space isn't) and the tail blueish (as it really is). Killing most of the blue channel with a commercial popular image processing program, in combination with simple contrast enhancement, led to a dark green sky with a brilliant blue tail. Switching off the color information *now* led to the best overall contrast (and the image reproduced here), while working with a b/w version of the same slide from the start led to less convincing results. Again the rule is: Experiment! The options are countless, and why not copy methods from the professionals like leading comet coma enhancer S. Larson? His rotational shift-differencing [7] works wonders on long focal-length pictures of jets - and in general most of the methods that improve pictures of the solar corona [8] work on comets, too. From an image-processing point of view, most fuzzy things in the sky are the same...

Experiment #3: *Spectroscopy for everyone!*

Why should we leave the most important of all astrophysical observing techniques to the professionals? Only by spectroscopy can we learn what things in the sky are made of, and apart from the sun bright comets are perhaps the easiest objects to study. Only the part of their light that is dust-reflected sunlight is a continuum: Much of the brightness of a comet head and tail is due to emission lines (or bands, rather) instead, and while the most itense ones aren't recorded by the human eye or photographic film, there are still intense lines in the visual spectrum. With really bright comets it should suffice to put a dispersive element like a diffration grating or a prism in front of a camera lens - and this has worked indeed with Hyakutake [9]. While no new physical insights are likely to emerge from these experiments they still have a great didactical value. How else would one demonstrate to oneself (or perhaps a class) that the green color of a comet's head or the blue color of its tail are gas physics in action? The challenge here is to find out, how small and simple (and cheap) a home-made „spectroscope“ can be that still shows convincingly that comets are not mere reflectors of sunlight but amazing physics labs? Let the next bright one come!

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OBSERVING THE LUNAR ATMOSPHERE WITH A 7-INCH CORONAGRAPH

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Abstract: The Planetary Atmospheres Group, run by Regents' Professor Dr. Donald M. Hunten, makes measurements of the lunar atmosphere using a 7-inch coronagraph atop Mt. Lemmon, just north of Tucson, Arizona. The operation and configuration of this instrument is described.

With a telescope of only seven inches aperture the Planetary Atmospheres Group (run by Regents' Professor Dr. Donald M. Hunten) has been making observations of the sodium lunar atmosphere. This instrument is designed along the lines of a solar coronagraph with several innovations specific to lunar atmosphere observing.

The instrument consists of a 7-inch diameter lens of the highest quality glass, free of bubbles or striae. This lens is held in front of the main body of the coronagraph by a surrier-type truss. The lens comes to focus on a polished metal knife edge at a 45° angle. The light of the moon's surface is reflected into a TV camera for guiding while the light of the region above the surface of the moon goes on through the instrument and next into a field lens. There are several more lenses and a dove prism, for rotating the image, and then the spectrograph itself. This spectrograph is a simple type consisting of a 5-slit carrier, 5-filter carrier a doublet collimating lens, a plane grating and an identical doublet camera lens. The camera is a cryogenic (liquid nitrogen) 1024x1024-pixel CCD camera made by a local Tucson company.

Observations are a tricky operation requiring the coordination of a number of elements. The moon's limb to be observed must be brought tangent to the knife edge. Then the image must be rotated until the knife edge is perpendicular to the slit. The best slit must be chosen and the image carefully focussed. Next the guider is set up for two points on the limb and one intensity reference point in the brighter part of the visible disk. Once all this is done and the observer is certain that there are no clouds threatening and the dome is in a good position, all in the dome must take a seat and stay there until the exposure, usually 1800 seconds or half an hour, is finished as the telescope is attached to the floor of the dome. This situation was unavoidable due to restricted funds for the project.

Back in the lab the data are subject to intense scrutiny. Processes in reduction not only include the usual dark subtraction and flat division of any CCD images, but transformation of the data to straighten curved spectral lines and assign a wavelength scale to the pixels. Then all extraneous scattered light needs to be accounted for (from the moon's surface and any instrumental leaks) and subtracted. This step has always proven to be the greatest challenge, even with a coronagraph.

If all has gone well, when we are done we are left with an image that only contains the two sodium D-lines in emission. This is the lunar atmosphere. In one direction an image will have wavelength, another altitude above the surface, and the third will be intensity. These lines are then measured and the data numbers of the CCD camera are converted to energy (Rayleighs) and plotted as a function of true height in kilometers.

Thus far we have been able to measure atmosphere out to a lunar radius. This atmosphere is extremely tenuous, less than 100 atoms per cubic centimeter in the middle of the column. This is far better than any man-made vacuum on earth. Yet it is there.

It is important for us to complete this work and to do so rapidly. Since the announcement of the discovery of ice on the moon many are talking of returning to the moon very soon. If all the atmosphere we observe were brought to sea level on the Earth, it would weight a total of only two or three kilograms!

Should astronauts return to the moon, as soon as they open the hatch of their spacecraft they will significantly increase the atmosphere of the moon in sodium and other elements. Mining or other similar activities will make matters even worse. Once this is started it will likely be a permanent condition and the further study of the indigenous atmosphere of the moon will be impossible.

COMET SHOEMAKER-LEVY 9 AND JUPITER: A RETROSPECTIVE

By: David H. Levy , Association of Lunar and Planetary Observers

The 18-inch telescope at Palomar is accompanied by a room the size of a small kitchen. On May 22, 1993, Gene Shoemaker, his wife Carolyn, and I were in that room. Carolyn was sitting at her stereomicroscope, an instrument designed to present two images of identical fields of sky at the same time. Carolyn has used the stereomicroscope to search for asteroids and comets since 1982, when she joined her husband Gene's survey of these small solar system objects. Gene was about to enter the darkroom to prepare the films for our night's observing. Peering at his computer, I was checking my e-mail to see if there were any new comets or asteroids that needed to be added to the coming night's observing schedule. There were none; however, within a few hours we would be reporting our latest discovery, Comet Shoemaker-Levy 1993h. But the news that afternoon concerned the previous comet we had discovered, the multi-part beauty called Comet Shoemaker-Levy 9. The news: S-L 9 would collide with Jupiter in July of 1994. We were stunned. Hastily covering the film, Gene opened the darkroom door and rushed out to read for himself. "Good God!" he exulted. "We're going to see an impact."

JULY 16, 1994: IMPACTS BEGIN

Fourteen months later, the first word was electrifying: Nucleus A had left a large plume. Calar Alto Observatory in Spain had recorded the infrared signature of a large plume shooting some 3000 kilometers above the clouds of Jupiter. For astronomers awaiting the downloading of the first data from the Hubble, tension was high. The HST data were in different filters from the big scope in Spain: what would the nightly space telescope record? The entire HST comet team huddled around a single monitor as the first images came down. The first, and then the second, did not show anything obvious. But the third showed a spot as bright as one of Jupiter's moons. The fourth showed it rising and brightening over Jupiter. "The room erupted in celebration," notes Harold Weaver of HST's comet team, "as we realized that we had something truly spectacular on our hands. The feeling of elation was indescribable, and I doubt that I will ever experience anything like this again."

Nucleus A left a large spot that consisted of three parts: a central core surrounded by an expanding ring, and a semicircular area towards the southwest. In infrared and methane light, these spots very white because they were hot. In optical wavelengths, however, they were dark. Interpreting these unique and complex features, never before seen on any planet, was a challenge. The central part of the spot was the residue left from the initial impact, and the semicircular region was apparently the residue left from the infalling material from the plume. The spots were composed probably of hydrocarbons, of which soot is a familiar form. The circular ring would remain a mystery.

Several hours later, Fragment B struck Jupiter with different effects. Even though it was brighter than A, the plume that rose from its impact was so much smaller that only the largest telescope in the world, the Keck 10-meter, recorded it easily. It is likely that this fragment split off from C some time after the initial breakup in July of 1992. Fragment B may have consisted of a large group of small house-sized sub-nuclei. One can speculate that an observer on Jupiter saw a fabulous storm of meteors as the pieces of B crashed into Jupiter, but little of that was seen from Earth.

A BATTERED PLANET

On July 18, Nucleus G crashed with such tremendous force that its erupting plume, in IR and methane wavelengths, was brighter than the entire planet. The drama associated with this impact was almost as great on this planet as it was on Jupiter. All the telescopes on Mauna Kea were shut down because of fog and drizzle, but only a minute before the impact of G, the clouds miraculously parted just where Jupiter was. Domes raced to open, and the fireworks were recorded before more fog and rain closed them again ten minutes later. Fragment G left the same kind of spot structure as the earlier major impacts of A, C, and E, but the residue was much more intense and as large as the entire Earth. The circular ring was much darker. The Hubble had now imaged the ring in the impacts from A, E, and G, and it was expanding at the same rate of 450 meters per second.

Interpreting these expanding rings was the complex task of Caltech's Andrew Ingersoll, who used data from several impact—A, E, G, and later Q1 and R. First becoming visible from one to 2 hours after the impacts, each ring expanded at the rate of 450 meters per second. Soon after impact week, Ingersoll realized that the waves were not moving out fast enough to be acoustic waves. Since the speed of sound in that part of Jupiter's atmosphere was 775 meters per second, these waves were propagating much too slowly to be a sound wave "boom from a plume," as Ingersoll originally thought. The waves' speed was constant in all five impacts, and their temperature was measured as being between 253 and 335 Kelvins. Ingersoll next assumed that on Jupiter the abundance of water—or the ratio of hydrogen to oxygen—was about 10 times that of the Sun. If this supposition was correct, then the observed wave seemed to be propagating vertically while trapped in a stable moist layer. It would be similar to the kind of wave that would result from hitting a waterbed. However, data from the Galileo probe, which explored Jupiter on December 7, 1995, did not confirm that Jupiter had that much water. Did the probe simply enter an unusually dry region? Did the spacecraft encounter "the mother of all updrafts" and hit an abnormally dry region? Stay tuned: the riddle may be difficult to solve.

Using Hubble's faint object spectrograph, University of Arizona's Roger Yelle and his colleagues detected sulfur. the graphic trace of the spectrum showed ripples. The fact that the ripples were spaced regularly, indicated a simple molecule. The ripples were also close together, the signature of a heavy one. "At 3:00 this morning," Yelle announced at one of NASA's press conferences, "we zeroed in on sulfur," he concluded. If the sulfur came from Jupiter, then this would be the first indication of the agent responsible for Jupiter's rich colors, both the blues lower down in the atmosphere and the reds, like those in the Great Red Spot. Also, sulfur, in the form of hydrogen sulfide, exists deep in the atmosphere. There was still some question as to whether the sulfur came from the comet or from Jupiter (sulfur was detected in Comet IRAS-Araki-Alcock in 1983).

Fragment K delivered two major surprises as it impacted. The first was the most intense display of the northern lights ever detected on Jupiter. This impact also produced features on the Northern polar region, opposite to where Jupiter was being pounded. They were interpreted as unusually intense auroral activity, actually a northern light display caused by charged particles following lines of magnetic force, a sort of invisible magnetic highway in space that stretches from Jupiter's southern to northern polar regions. The other shock was that the impact did not produce the reflection off the moon Europa that was expected. At the moment K struck Jupiter, Jupiter was positioned between Europa and the Sun; an eclipse of the Sun was taking place there. As K entered Jupiter's atmosphere it produced a meteor that should have been bright enough to reflect off the darkened moon, whose icy surface is highly reflective. Observers were watching to see if the eruptive plume that followed also reflected off Europa's surface. The surprising result—no obvious detections—implies that at visible wavelengths, the meteor and fireball were not as bright as predicted. In fact, the brightnesses and heights of the meteors and plumes were puzzling. The Galileo spacecraft observed most of them, and did not find them excessively bright. However, the faintest nucleus Galileo observed, N, impacted as a meteor fully half as bright as K, the brightest one the spacecraft reported. The Hubble Space Telescope recorded something similar—all the plumes, from relatively faint nucleus A to the much brighter G, rose to the same height of 3000 kilometers. But the spots left by the various impacts were clearly not identical; the G fragment was much larger and more intense than the A fragment. Interpreting this anomalous data will be difficult. One suggestion: All the fragments were in fact the same size, but some were denser than others. As impact week continued, nucleus L left the largest impact cloud, once again complete with central core, expanding ring, and semicircular cloud of infalling debris. By this time the dark spots on Jupiter were so large and dense that they could be seen with the smallest telescope. Q1 and Q2 fell within an hour or each other—Q2 left the smallest detectable spot from any major fall. R impacted close enough to Jupiter's sunrise limb that several ground-based telescopes detected the initial flash of its meteor as it fell high above Jupiter's cloud tops.

Finally, the Galileo craft's solid state imaging system took an engaging series of "snapshots" of W, the final fragment, as it tore into Jupiter. The Hubble's image sequence of the same fall ended with a view of the plume collapsing directly on top of the spot from K.

ANSWERS AND QUESTIONS

Despite the mass of observations of this dramatic episode, many of the pre-impact questions still remain unanswered. How large were the nuclei? How much energy did they release? To what layer of Jupiter's atmosphere did they penetrate? If these questions are not soon answered, we should not be surprised, for that is the nature of scientific inquiry. The case of Shoemaker-Levy 9 is extreme, for the sheer mass of observations—more than for any other event in the history of science—precludes a simple analysis. Just as meetings before the impact emphasized a coordination of observations, post-impact sessions concentrate on comparing data to see which of the models fit best. The energy released from each of the larger impacts was probably between 1027 to 1029 ergs (20,000 to 2,000,000 megatons of TNT). Mordecai-Mark Mac Low (University of Chicago) postulated that most of the impact energy was deposited at high altitudes, and that nucleus sizes of less than half a kilometer best fill the observed effects. On the other hand, a group led by David Crawford of Sandia National Labs saw nuclei of 3 kilometers diameter that started to release their energy as they hit the planet's upper atmosphere. However, in this model the nuclei kept on releasing energy as they dug their way into a tunnel: One estimate was that the tunnel went more than 300 kilometers below Jupiter's cloud tops.

What was the comet's history? For a number of reasons, most scientists consider that Shoemaker-Levy 9 had a cometary past rather than an asteroidal one. According to Brian Marsden, by far the majority of objects found near Jupiter have orbital histories not of asteroids but of short-period comets with revolution periods around the Sun of fewer than 15 years. Further, HST images of Shoemaker-Levy 9 always showed a thickening amount of coma near the centers of the fragments. This observation convinced most astronomers that dust was being produced all the time, and by definition, comets do produce dust, while asteroids do not. A likely scenario is that the comet began its wanderings in the outer solar system, and that its capture by Jupiter came at the end of a long journey, and in two stages. The first was a gradual process of repeated encounters with Jupiter that gradually changed its orbit from a long-period one, with a period of revolution about the Sun of several thousand, to later, several hundred years. In about 1920, the latest orbital calculations indicate, the comet had what we call a low-velocity encounter with Jupiter that allowed the planet to capture the comet as a moon; instead of orbiting the Sun, the comet was now orbiting Jupiter. This orbit was unstable. Each revolution differed from its predecessor, and in 1992 the comet passed so close to Jupiter that it was tidally disrupted. What did the comet get torn into? The nuclei might have been rubble piles of loose, unconsolidated gravel. Fluffy snow, with a mixture of frozen gases and dust, was a second possibility. Less likely is the possibility that they might have been coherent, solid asteroid-like masses.

THE MEUDON MEETING

At a three-day symposium about the collision held at the Paris Observatory at Meudon—it was at least the fifth international conference devoted specifically to Comet Shoemaker-Levy 9/Jupiter—near Paris, in early July, 1996. A. Marten, of the Paris Observatory, reported continued presence of both Hydrogen Cyanide (HCN) and Carbon Sulfide (CS). In May of 1995, spectra recorded at the 30-meter IRAM telescope in Granada, Spain, and at the JCMT in Hawaii showed that the HCN and CS showed strong signatures. According to Julianne I. Moses of the Lunar and Planetary Institute, both HCN and CS possibly have increased with time, spreading even to the northern hemisphere. A plethora of new molecular species were detected either for the first time or in greater quantity after the impacts, including S2, CS2, OCS, NH3, HCN, H20, and CO. S2, OCS, H2S, and NH3 apparently did not survive more than a few months. NH3 was still visible 8 months after the impacts, and although CS2 and CO weakened, they were still detected in the Jovian stratosphere as late as May 1996. Compared to these, the CS and HCN remained prominent. An unsolved question: how long will these new species last? Years? Decades? Besides these chemicals, an upper atmosphere haze was still visible as late as June 1995. By that time it had spread from latitude 70°S as far as 20°S.

Other reports from Meudon: The object S-L 9 was most likely a comet, not an asteroid as some thought around the time of impacts. It spent almost all its life in the the Kuiper Belt beyond Neptune. According to Paul Chodas at JPL, it is possible that as recently as several thousand years ago the comet began its journey into the solar system. It was captured as a satellite of Jupiter around 1929, broke up near Jupiter in 1992, and collided with the planet in 1994—a complicity of events described as extremely rare. Although most scientists now agree that the comet was less than 2 km in diameter before it broke apart in 1992, the verdict on size is still not unanimous, some still favoring a larger nucleus.

Another unresolved question: Was the comet a pile of rubble loosely bound together by gravity, or was it a more traditional icy conglomerate? Although more observations were made of this astronomical event than of any other in the history of astronomy, much of the data still remain to be reduced and analyzed. Hopefully more answers will be forthcoming as the data set continues to take shape, and the modelers continue to work with it.

THE AMATEUR AND UNPOPULAR SCIENCE

By: John E. Westfall

INTRODUCTION

This paper is an unusual plea that amateur observers consider occasionally conducting observing projects involving topics that are unpopular in the professional astronomical community. This plea is easy to misunderstand. First, I fully recognize that the most scientifically valuable work being done by amateurs today is in active cooperation with professionals; this work must continue and, indeed, be expanded. Second, I also recognize that many possible observing projects are ignored by professionals for very good reasons, which I divide among three categories:

- "Crank" Science (Seeking to prove or disprove questions that have already been answered; examples: Vortex Theory, Martian canals, lunar dust)
- Premature Science (Needs observations beyond present and near-future capabilities; example: Composition of, or life on, extrasolar planets)
- Inappropriate Science (Good topic but inappropriate methodology or instruments; examples: Visual photometry used to detect Io's post-eclipse brightening; statistical analysis with too small or biased datasets)

The above illustrate valid reasons for topics/projects to be "Unpopular." However, the following are not intellectually valid reasons for projects to be avoided, although they might be more suitable for amateurs than professionals.

- Requires large amounts, or long sessions, of telescope time. (Example: Any patrol/monitoring project to detect rare events)
- Requires observing at short notice, at locations other than permanent observatories, or both. (Example: Stellar occultations by Moon [grazes] or asteroids)
- Can't get funding (or telescope time) because proposal is incorrectly judged unpromising or "unscientific" by others. (I hope instances of this are rare, but they are likely to occasionally occur.)

The list above gives clues for identifying topics that might be worthy subjects for amateurs to study. Which particular topics would be suitable for amateurs, even though they are ignored by professionals, depends on exploiting the advantages that amateurs sometimes have as well as frankly recognizing that sometimes amateurs are at a disadvantage. The following table (p. 15) lists some of the advantages and disadvantages that amateurs have in respect to professionals.

What the table below suggests is that amateurs might do well with projects that require lengthy observing periods on relatively small instruments. Another consideration is that most amateurs would be confined to work requiring visual or photographic methods, or such electronics as video, small CCD arrays, or photoelectric photometry, limited to visual and near-UV and -IR wavelengths. In terms of "administration," projects requiring fairly simple guidelines, and maximizing the freedom of the observer to observe when he or she is able, are to be preferred. The next section lists several projects that appear to meet the above criteria.

SOME AMATEUR–PROFESSIONAL DISTINCTIONS (WITHOUT VALUE JUDGMENTS)

The Amateur	The Professional
Lots of Time on Small Telescopes (Larger than 0.4 meter unusual for equatorially mounted instrument)	**A Little Time on Large Telescopes**
Somewhat Obsolescent Equipment (But improving; e.g., video, photoelectric photometers, small but growing CCD chips)	**"Cutting-Edge" Equipment** (e.g., large CCD arrays, thermal IR imaging, spectroscopy)
Self Taught in Field (No higher degree in astronomy/planetary science; may have some relevant training)	**Formal Education in Field** (Higher degree, probably Doctorate, in astronomy/planetary science; still needs to keep current in field)
Less Access to Specialized Libraries (May not live near a campus or other research facility; problem being relieved by Internet, CD-ROMs)	**Access to Specialized Libraries**
Less Contact With Colleagues (Travel self-funded; may attend amateur meetings [and sometimes professional ones]; electronic communication rapidly growing)	**Frequent Contact With Colleagues** (But face-to-face contact with other than local colleagues requires travel funds; electronic communications is a partial partial substitute)
Self-Funded (Usually not much funding, but utter freedom to pursue one's own topic!)	**Needs Funding** (May have more funding than the amateur, but some need to conform to opinions of others)
"Amateur" Publications (Unrefereed or informally refereed; volunteer editorial staff)	**Prestige Publications** (Refereed Journals; paid editorial staff)

MODEST SUGGESTIONS FOR WORTHY BUT "UNPOPULAR" PROJECTS

Video Monitoring of Earthlit Moon for LTP/Lunar Meteors.—These are rare events and few if any professional have the personal or telescope time to monitor the Moon for lengthy enough periods. Amateur searches, on the other hand, have had difficulties in the past. Their chief problems have been that most reports have been visual and unconfirmed. Now many amateurs have suitable equipment—all that is needed for prolonged monitoring is a fairly sensitive camcorder. Still, even electronic recording is subject to "False signals" (e.g., cosmic ray hits, point meteors, glints from artificial satellites), so carefully-timed simultaneous recording by at least two observers is needed. Some aspects of such a lunar monitoring project would be:

- Modest equipment needs (short focal-length fast optics, sensitive video camera).
- Need at least two stations, some tens of km apart (but in same time zone), for continuous simultaneous monitoring.
- Might be extended to sunlit lunar hemisphere (for LTP).
- Requires clear-sky site, large time investment (including tape viewing!) for any payoff
- Meteor Search tried visually for several years; official A.L.P.O. project 1955-1965; lots

of reports but no positive confirmations (needed more frequent simultaneous monitoring by independent observers).

Search for/Monitoring of Lunar Libration Clouds.—What amateur work that was done in the past appeared to be visual. Now CCD cameras could provide more objective results, particularly with their capability for flat-fielding and dark subtraction. Also, it is not widely known that they can be used with conventional camera lenses so that even small arrays can cover fields of several degrees (the clouds were reported 2°-5° across, varying in position by 5°-6°). Some points to be considered are:

- A possibly-forgotten topic; to the writer's knowledge existence (let alone characteristics) never settled pro or con.
- Very suitable for amateur patrol; needs dark-sky site, short-focus lens, small-format CCD.
- Someone needs to provide an ephemeris of the location of the Lagrangian Points (L4 and L5) where the clouds are suspected, with times when they can be observed in a dark sky yet not superimposed on the gegenschein.
- An official A.L.P.O. project 1967-1970; visual, little interest from observers.

Lunar Eclipses.—Every lunar eclipse is a unique event, and changes in the brightness, color, and size of the Earth's umbra and penumbra give information about the Earth's atmosphere. Partial or total lunar eclipses are also good times to search for lunar meteors and LTP.

- Admittedly an occasional project!
- Amateurs can easily time umbral ingress/egress of craters; those more advanced can conduct whole-disk or spot photometry; both efforts provide knowledge about umbral density and extent, thus about Earth's upper atmosphere.
- The smallness of amateurs' telescopes is an advantage; they can easily observe the entire disk of the Moon.
- Very little professional activity (a literature search for 1990-96 showed two involved!).

Lunar Mapping.—Not many people was working on maps of the Moon, and existing maps exploit only a tiny part of the photography from the Apollo Era, let alone the Clementine Mission. However, commonly-available relatively inexpensive computers, scanners, printers, and software let the amateur convert publicly-available images to finished maps.

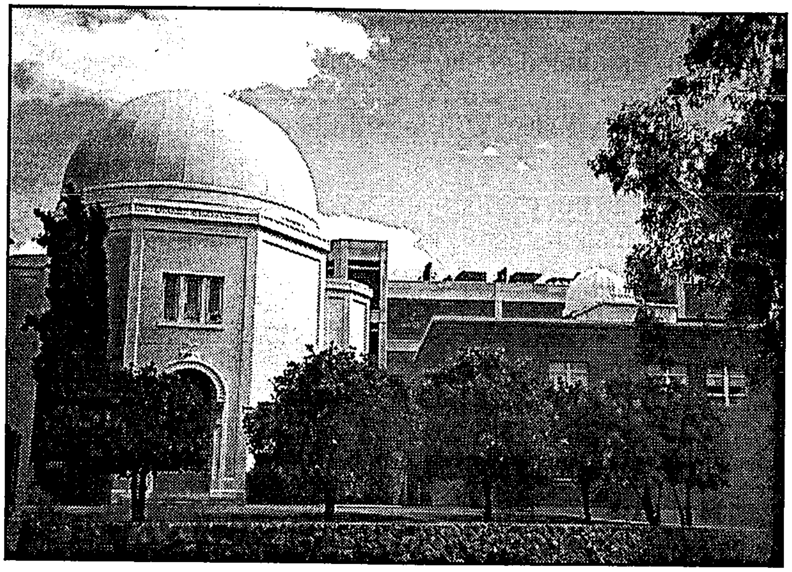
- Never a central theme for modern astronomers/planetary scientists; left to professional cartographers; geological maps done by professional geologists; now funding is less.
- Largest-scale post-Apollo whole-Moon coverage only 1:5,000,000 (80 mi/in); only 2 of the 44 1:1,000,000-scale charts updated with space-mission photography.
- Amateurs can do "indoors" research; Orbiter, Apollo, and Clementine coverage are available; scanners and software for desktop computers are adequate to convert photography/imagery into map form.

Solar Transits of Mercury and Venus: Optical Phenomena.—Because these phenomena are visible over entire hemispheres of the Earth, some might think that professional observatories cover them well. Actually, most professional instruments, except for solar telescope of course, cannot be used for the Sun. Add to this that solar observers are interested in the Sun and not in transits, and there is almost no professional interest. Naturally, many of the purposes for transit observations in the 18th and 19th centuries, such as determining the distance from the Earth to the Sun, are no longer valid. On the other hand, visual observers of past transits noted optical phenomena that have not been objectively recorded nor always totally explained. The Transits of Venus in 2004 and 2012 represent mankind's first opportunity to continuously record the transits and any optical phenomena that may accompany them. Some points to consider are:

- A historical questions to be investigated is: What are the causes of the optical phenomena ("black drop," haloes, light spots, etc.) reported by past visual observers?
- Topic neglected by professionals; to the writer's knowledge there was no professional interest at all in the 1993 Mercury Transit. The Venus Transits of 2004/2012 are apoproaching, along with a rare "graze" transit of Mercury in 1999. Will recording and measuring these rare events be relegated to amateurs?
- Present-day amateur visual observers provide an analogy with historic observers and their work can help us interpret them. Modern amateurs can also employ video and CCDs, quantitatively recording any optical phenomena.

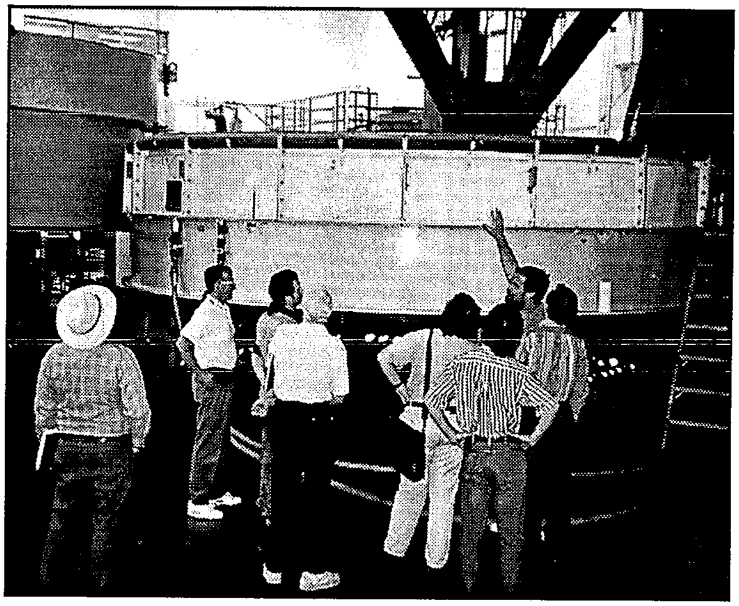
So here are five solar-system observing projects in which professional planetary scientists currently show little or no interest. Yet all appear to have some scientific merit; some possible payoff for admittedly lengthy period of observation or analysis. All appear to be suitable for amateurs and their instruments. Certainly, we need to continue to provide observational support for professionals conducting their own research programs. However, it looks as if some potentially awarding topics have been neglected and that amateurs can give them new life.

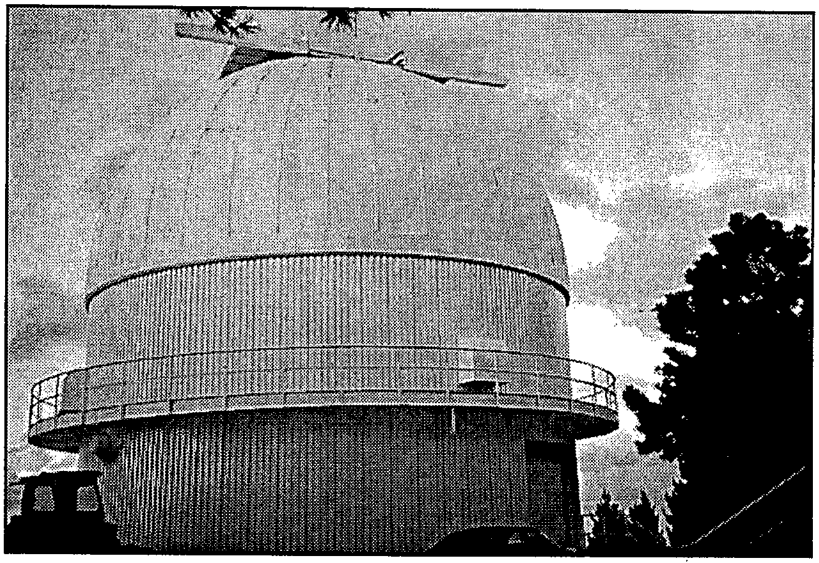
A.L.P.O.-Tucson, October 19-21, 1996, Photo Gallery



Steward Observatory, on the University of Arizona Campus, hosted the paper sessions and workshops in its auditorium (behind trees to right of large dome).

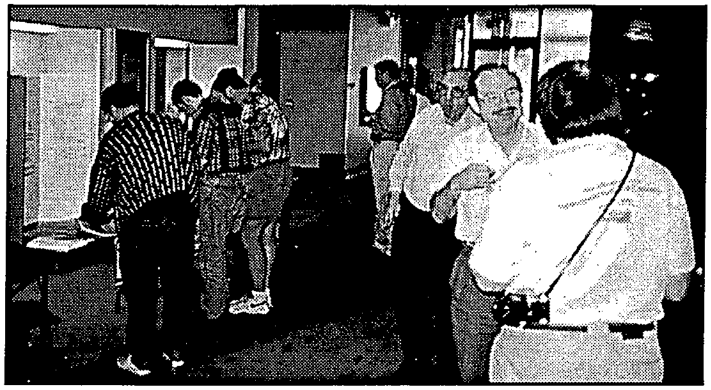
On Saturday afternoon, the 19th, the group inspects the 6.5-meter mirror, in its cell in the Mirror Casting Facility, that will be the new primary for the Multiple-Mirror Telescope on Mount Hopkins.



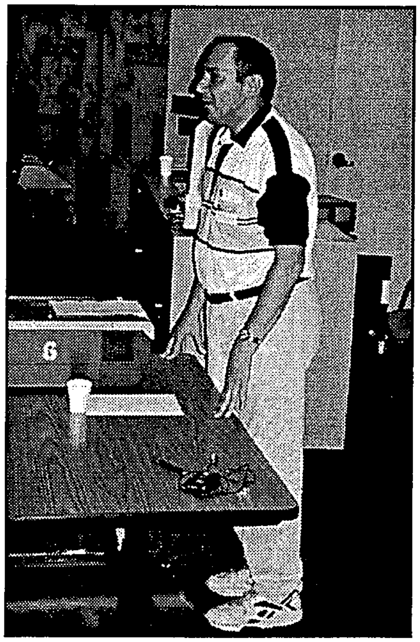


Destination of the CCD Workshop group on Saturday evening; the dome of the 61-in Cassegrain of the Catalina Station of Steward Observatory, 8235 feet above sea level on Mount Bigelow. Photograph taken shortly after sunset.

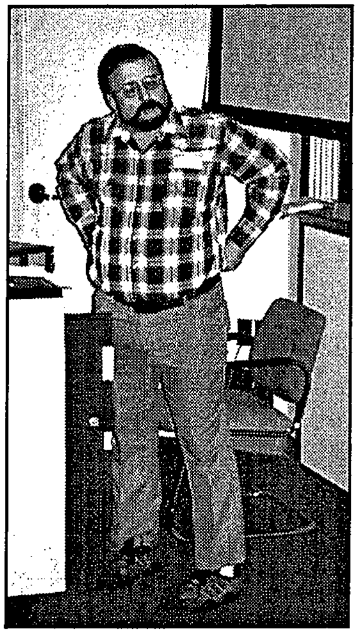
The 61-inch Catalina reflector on Saturday evening, prior to training it on Jupiter. Unfortunately the sky then clouded over, but the group continued with a CCD Workshop, making use of previously-stored images.



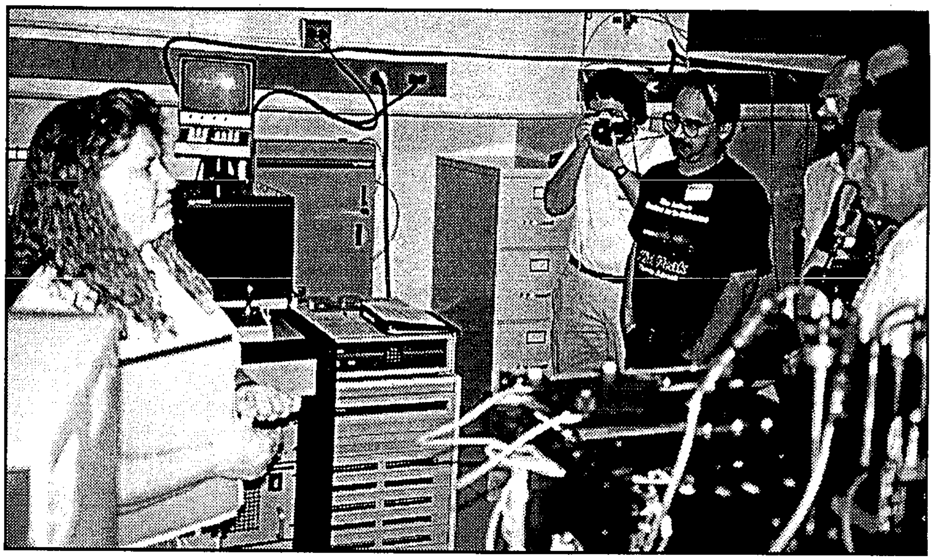
The meeting Registration Desk in the Steward Observatory lobby on Sunday Morning, October 20th, prior to the start of the sessions.



David Levy, co-discoverer of Comet Shoemaker-Levy 9, delivering the first portion of his talk, "Comet Shoemaker-Levy 9 and Jupiter: A Retrospective," during the first Saturday morning session.

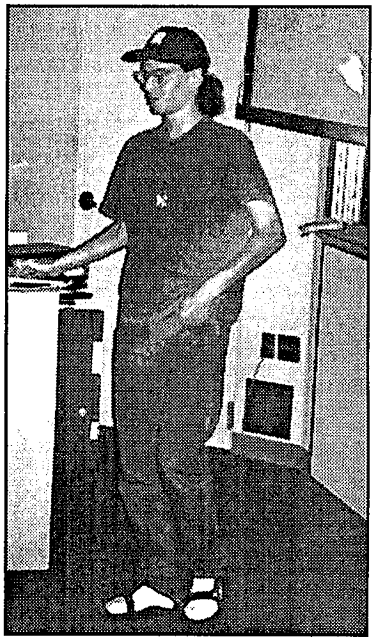


Rik Hill, A.L.P.O. Associate Solar Coordinator, speaking during the second Saturday morning paper session on "Observing the Lunar Atmosphere with a 7-inch Coronagraph."

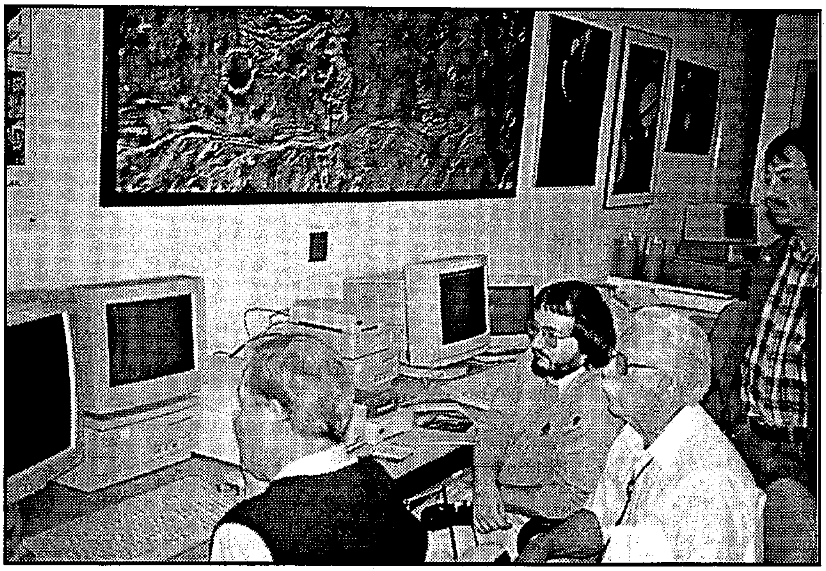


Teresa Lappin of Steward Observatory, and the conference's local coordinator, taking the participants on a tour of the Observatory's CCD Laboratory.

Four of the Conference's members: (left to right) Eugene Cross of La Mirada, California; Daniel Fischer of Koenigswinter, Germany; David Levy of Vail, Arizona; and John Westfall of San Francisco, California.



During the Saturday afternoon session, Carl Hergenroether delivered his and Tim Spahr's paper, "The Present State of Near-Earth Asteroid Surveying."



The Monday morning (Oct. 21) tour of the Space Imagery Center of the Lunar and Planetary Laboratory. The "audience" here consists of (left to right) Daniel Fischer, Cecil Post, and Jeffery Sandel.