Star Dust

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Open House at Hopewell Observatory

NCA members, families, and guests are invited to view the spring sky at Hopewell Observatory on Saturday evening, April 17. Sunset will be at 7:49 PM; astronomical twilight ends at 9:25. Mars will be near opposition, and surface detail should be visible. If you wish, come any time after 6:00 PM and bring your picnic dinner. Coffee, tea and cocoa will be provided by the Hopewell Corporation.

Directions:
(1) From the Beltway (I-495) go west on I-66 25 miles to Exit 40 at Haymarket onto U.S. 15. (2) Turn left on U.S. 15 at the end of the exit ramp. (3) Go 0.3 mile to traffic light, turn right onto Va. 55. (4) Go 0.8 mile to Antioch Road (Rt. 681) and turn right. (5) Go 3.2 miles to the end of Antioch Rd. and turn left onto Waterfall Road (601). (6) Go one mile and bear right onto Bull Run Mountain Rd. (Rt. 629). (7) Go 0.9 mile on 629 to narrow paved road at right with an orange pipe gate (Directly across from an entrance gate with stone facing). (8) Turn right through pipe gates, go 0.3 mile to top of ridge and around the microwave station. (9) Continue on dirt road through the white gate and woods a few hundred feet to the observatory. Park along the road short of the buildings. There will be another open house on May 15. For further information call (703) 960-9126. O

What We Now Know about How Galaxies Evolve

A Talk by Daniel Kelson

Submitted by Nancy Byrd

At the Saturday, April 3, 1999 meeting of National Capital Astronomers (NCA) in the Lippsett Auditorium at NIH, Dr. Daniel Kelson, a fellow of the Department of Terrestrial Magnetism, Carnegie Institute of Washington, will survey for us what the highest and largest optical telescopes have told us about how galaxies form and evolve.

Dr. Kelson obtained his undergraduate degree in physics and astronomy at the University of Michigan and his PhD from the University of California at Santa Cruz. He submits the following abstract of his talk:

The first ten years of the Hubble Space Telescope (HST) mission have given us new tools and new views on how galaxies evolve from the early Universe to the present. When combined with the first five years of the new era of 8-10m class ground-based optical telescopes, such as those at the W. M. Keck Observatory on Mauna Kea, we see new details about the nature of galaxy formation and evolution. In this presentation, the progression of HST data on the evolution of galaxies will be discussed along with results from surveys taken with the Keck 10m telescopes. Together, these give some insight into the future with Keck, the Magellan 6.5m telescopes, European Southern Observatory's 8m telescopes, the new generation of detectors on the HST, and even the Next Generation Space Telescope. O

Shocking News about Supernova 1987A

Presented by George Sonneborn

Reviewed by Wayne H. Warren, Jr.

At their monthly meeting of March 6, 1999, NCA members and guests were treated to a lecture by Dr. George Sonneborn of Goddard Space Flight Center's Laboratory for Astronomy and Solar Physics. Dr. Sonneborn has been involved with observations of the now famous Large Magellanic Cloud (LMC) SN 1987A since the early days of its discovery, using NASA's International Ultraviolet Explorer (IUE) space observatory to study the explosion in the ultraviolet (uv) region of the spectrum.

Dr. Sonneborn began by reminding us that SN 1987A was only the first of many supernovae that occurred in 1987 and that there are currently a hundred or more of these stellar explosions being discovered every year. The difference between SN 1987A and all of the others was that the former occurred in a satellite

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Calendar of Monthly Events

The Public is Welcome!

NCA Home Page: http://myhouse.com/NCA/home.htm

Saturday, April 3, 5:30 PM - Dinner with the speaker, and NCA members at Bangkok Garden, 4906 St. Elmo Ave., Bethesda, MD. *See* map and directions on back page.

Saturday, April 3, 7:30 PM - NCA meeting, at Lipsett Auditorium in Building 10 at NIH, will feature Dan Kelson, speaking on "What We Now Know about How Galaxies Evolve" *See* map and directions on back page.

Mondays, April 5, 12, 19, and 26, 7:30 PM - Public nights at U.S. Naval Observatory (USNO), in Northwest Washington, D.C. (off Massachusetts Avenue). Includes orientation on USNO's mission, viewing of operating atomic clocks, and glimpses through the finest optical telescopes in the Washington-Baltimore region. Held regardless of cloud cover. Information: USNO Public Affairs Office, 202/762-1438. Home page: http://www.usno.navy.mil.

Fridays, April 9, 16, and 23, 8:30 PM - Open nights with NCA's Celestron C–14 telescope at Ridgeview Observatory; near Alexandria, Virginia; 6007 Ridgeview Drive (off Franconia Road between Telegraph Road and Rose Hill Drive). Information: Bob Bolster, 703/960-9126. Call before 6:00 PM.

Fridays, April 9, 16, 23, and 30, 7:30 PM - Telescope making classes at American University, McKinley Hall Basement. Information: Jerry Schnall, 202/362-8872.

Saturday, April 17, Beginning at 6:00 PM - Open House at Hopewell Observatory. *See* article on page 1.

Saturday, April 17, 8:30 PM - Exploring the Sky at Rock Creek Park in the field south of the intersection of Military and Glover Roads near the Nature Center. Information: 202/426-6829.

Tuesdays, Closed - Telescope making classes at Chevy Chase Community Center, Connecticut Avenue and McKinley Street, NW. Classes from November 10th through April will be cancelled due to construction and will resume in May. Information: Jerry Schnall, 202/362-8872.

See page 8 for more Washington area astronomical events. Other events too numerous to list in *Star Dust* are listed in the publications, *Sky & Telescope*, the *Astronomical Calendar 1999*, the *Observer's Handbook 1999*. NCA members can purchase all these (and much more) at a discount. Information can also be found in numerous software packages, and links available on the NCA Home Page (*see* above for address). To join NCA, use the membership application on page 9.

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galaxy of the Milky Way, while all of the others took place in distant galaxies and were correspondingly faint. In fact, even though the distance to SN 1987A has been determined as 52,000 pc (170,000 ly), the early brightness was visual magnitude 4.0. Since the distance modulus (the difference between the unreddened visual magnitude and the magnitude at a standard distance of 10 pc, known as the absolute visual magnitude, M_V) of the LMC is 18.6, this means that at this brightness, SN 1987A had an M_V of -14.5. Placed at a distance of 10 pc from the Sun, the supernova would have shone as a point source 316 times as bright as the full Moon. An absolute visual magnitude of -14.5 is actually rather faint for a Type II supernova, many of which reach absolute brightnesses that rival those of entire spiral galaxies. (Approximately 80-90 days after the explosion, the star actually brightened even more to a maximum of 2.9, corresponding to an M_V of -15.7, or 5,000 times the brightness of the full Moon at 10 pc. The long slow rise was expected and is ascribed to energy from radioactive decay, as will be discussed later.)

SN 1987A was discovered very soon after the light from the event reached Earth on February 24, 1987. The discovery was made nearly simultaneously by Ian Shelton and Oscar Duhalde at the Carnegie Institution of Washington's Las Campanas Observatory in Chile. While Shelton, of the University of Toronto, discovered the image on a photographic plate, Duhalde, a night assistant on the Yale 40-inch reflector, found it visually a short time later during his coffee break. It is a testament to the enormity of the Universe that the actual explosion took place in the Illinoian glacial stage of the upper middle Pleistocene near the end of the reign of Homo Erectus, 170,000 years ago. (See Levin, Harold L., *The Earth Through Time*, Saunders College Publishing, 1994 or 1998 editions; this is my favorite general geology text.) Even more astounding is the fact that this was the closest supernova (that we know about - one or more could have occurred on the other side of our Galaxy) since the galactic one that Kepler observed in 1604. Dr. Sonneborn

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showed photographs of the region near 30 Doradus in the LMC where the star later identified as CPD-69 404 (from the *Cape Photographic Durchmusterung* catalog) and Sk-69 202 (from a catalog assembled by the late Dr. Nicholas Sanduleak of Case Western Reserve University) went supernova.

The real significance of SN 1987A was, not only that it was the first naked eye supernova since the invention of the telescope, but that it occurred in the LMC, our satellite galaxy that we know the distance of with reasonable accuracy. Knowledge of the distance allows us to determine absolute quantities such as luminosity, expansion velocity, physical size of the expanding shell, etc., rather than just relative quantities as we would if the distance were unknown. It was also important because it generated a great amount of interest in the field; as a result, many astronomers have studied SN 1987A and other supernovae, thus significantly increasing our knowledge of these immensely important events. There are many reasons why supernovae are among the most important astronomical events. First of all, they are among the most spectacular events in the Universe; thus, their observational history goes back further than any other astronomical phenomenon, at least several thousand years. This allows us to identify and study supernova remnants resulting from events that occurred in the historical record. Second, we know that stars can make elements only up through iron (element 26); all significant quantities of heavier elements are synthesized in supernova explosions. This tells us that much of the material of which the Earth and we are composed was made by nuclear synthesis in supernovae - significant indeed! Third, as seen earlier, supernovae are very luminous, rivaling the absolute brightnesses of the brightest galaxies. Therefore, they can be seen over vast distances and can be used as standard candles to calibrate the distance scale of the Universe. Fourth, it is reasonably certain that the shock waves sent out by supernovae explosions compress gas in the interstellar medium and trigger the formation of new stars. Thus, the deaths of older stars are directly responsible for the birth of new ones, which condense from remnant material to form the next generation of stars enriched in heavy elements.

We mentioned above that SN 1987A was a Type II supernova, which is defined as one having hydrogen (H) in its spectrum. A Type I supernova is one having no H lines, only Helium (He) and heavier elements. These definitions were at one time purely observational, but we have since come to understand the difference in terms of physical significance. The Type II supernova contains H because it results from the explosion of a star of 10 solar masses or greater that has exhausted its supply of nuclear fuel. When that happens, the core of the star, which is perhaps 100 km in diameter, can no longer support the weight of the overlying layers, and collapses catastrophically in approximately a tenth of a second, generating a maelstrom of $\sim 10^{51}$ neutrinos and the release of approximately 3×10^{53} ergs of energy. The rebound from the collapse blows the outer layers of the star away. In the case of SN 1987A, the energy released corresponds to what one would expect from the collapse of a 1.6 solar mass iron core to a neutron star, with the release of 10-15% of its mass as energy. The detection of simultaneous neutrino events by the Kamiokande II detector in Japan (11 events over a 13-second interval) and the Irvine-Michigan-Brookhaven (IMB) detector under Lake Erie, beautifully confirmed the theory of supernova neutrino generation. Another confirming event was the detection 6-12 months later of γ radiation resulting from the decay of ^{56}Co and other radioactive elements synthesized in the explosion. In fact, these γ-ray detections provided the first direct observational confirmation of the theories of nucleosynthesis that had been around for a long time.

Of course, there was a concentrated observational effort both from the ground and from Earth orbit. Since the Hubble Space Telescope and the Compton Gamma Ray Observatory were not yet in orbit, γ-ray data were collected by the Solar Maximum Mission and uv observations were made with the International Ultraviolet Explorer (IUE). IUE spectra in the wavelength range 1200-2000Å show numerous emission lines of highly ionized C, O, N, He, etc. The emission lines strengthened with time, reaching maximum strength about 400 days after the explosion. These emission lines were produced in the region surrounding the supernova when material was heated to approximately 10^5 kelvins by the shock waves from the event. Analysis of the spectra has revealed some surprising things about the circumstellar material surrounding the supernova. Contrary to the spherical geometry that one would expect, the material is distributed in a thin ring. It was also found that the elemental abundances are very different from solar, with N/C up by a factor of about 23 and N/O by 13. This is also significantly different from interstellar abundances, indicating that the material came from inside the star and was expelled very late in its life. The composition also tells us something about the age of the progenitor star because stellar evolutionary theory predicts how composition changes with age. Thus, we have direct evidence that the star was "old" (for a 20 solar mass object is expected to live $\sim 10^7$ years) and could have been expected to end its life soon.

So the inner ring can be explained by some kind of ejection phenomenon that occurred not too long before the explosion, perhaps as part of a complex series of pre-supernova events. Why the ejection would be in the form of a ring instead of a sphere is a mystery. The ring is currently about 0.2 pc (0.65 ly) in radius and inclined 45° to our line of sight if it is circular. The multiple outer rings present an enigma - no one understands their origin at the present time.

The exciting thing now is the collision of high-velocity supernova ejecta with this ring. Unlike most astronomical events, which occur over time scales so long as to make them unobservable

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for us, we have been able to watch SN 1987A evolve and we knew that this collision would take place soon. At this point, Dr. Sonneborn briefly summarized the chronology of events relating to the circumstellar gas:

- First detected in 1987 with the IUE Observatory
- Physical size deduced about a year later when the emission lines reached maximum brightness, but was thought to be a spherical shell, even though the shape of the light curve couldn't be explained by spherical geometry
- Ring shape first seen in 1991 when the first images were taken with the HST (even before the optical corrections)
- Following Costar (the spherical aberration corrective optics), new images showed the two outer rings
- Radio and x-ray observations in 1995 showed evidence of shocked gas from the supernova, but the spatial resolution wasn't high enough to pinpoint the location
- Images taken in 1997 with the Space Telescope Imaging Spectrograph (STIS), one of the second generation HST instruments, allowed measurement of the spectroscopic signature of the collision between the debris and the circumstellar gas, and showed the origin of the emission to be at the inner edge of the ring
- Observations in 1998 showed evidence of a "hot spot" located at the interface of the neutral debris moving at about 15,000 km/s and the inside edge of the inner ring

Radio and x-ray observations (from ROSAT, the ROntgen SATellite) show characteristic signatures of a collision of rapidly moving gas with material that is moving much more slowly. Continued radio observations show an evolving double-lobe structure reminiscent of highly shocked gas emitting synchrotron radiation.

The angular size of the ring at 1200 days (0.6") requires the gas from the explosion to be moving at about 35,000 km/s. Other evidence indicated that the outer layers of the star were moving at roughly 40,000 km/s soon after the explosion, so a consistent picture seems to be developing. Following the interaction of the high-velocity debris with the circumstellar material, the expansion slowed to 2400 km/s and has been increasing only slowly since.

The overall picture shows the visible gas ring at the outer edge, behind which is slow-moving gas from mass loss during the star's red supergiant phase. Interior to that is an H II region-like ring of gas ionized by radiation from the blue supergiant phase before the explosion, with the high-velocity gas barreling through the ring.

Dr. Sonneborn next discussed his observations of the rings, made with Bruce Woodgate and J. Pun, with the STIS, which was designed to provide both spectral and spatial resolution simultaneously. This capability allowed the motions on opposite sides of the expanding ring to be measured. The northern edge was found to be moving toward us at 15,000 km/s, while the southern edge is moving away at about the same velocity. Combining the spatial information from HST observations with spectral data allows improved modeling of the physical conditions and evolution of the material surrounding the supernova.

A comparison of HST images taken in 1994 and 1997 clearly shows the development of the "hot spot" mentioned earlier as being present in a 1998 image. In fact, the spot doubled in brightness between 1997 July and 1998 February, with more recent observations showing a continuing brightening. The STIS spectrum of the spot shows that it is moving with a velocity in the range 300 to 400 km/s, a value considerably different from all other velocities observed in the region, thus indicating that something new is happening in this small area. An STIS image at H_α was then taken in 1998 March using a slit only 0.2" wide to isolate the hot spot. Although some material is red shifted, most is blue shifted (moving toward us) to the tune of 500 km/s.

The interpretation of all these observations was shown in a schematic centered on the H II region mentioned earlier. The SN debris moving outward at about 15,000 km/s has heated the gas in the H II region to 10^7 kelvins. At the interface where the neutral debris is slamming into the gas in the H II region, we see Lyman α emission from the shock front. It appears that the hot spot is another shock front that has formed at the inner edge of the inner ring as a result of the debris shock front.

Dr. Sonneborn summarized his presentation by briefly reviewing what we have learned about the interaction of SN 1987A with its surroundings. For the first time, we have been able to measure temperatures, velocities, and physical locations of shock fronts, etc., thus showing us in great detail how a supernova recycles material back to where it came from, only with vastly different composition. Over the next decade or so, the localized brightening at the inner edge of the ring is expected to increase in intensity as additional material from the supernova reaches the area. The expected increase of 100 to 1000 in brightness will make possible different kinds of observations, so we should be able to increase our knowledge of the supernova phenomenon even further.

Dr. Sonneborn noted that the brightening events expected may be related to comments in historical records about "guest" stars revisiting 10-20 years after their initial sightings. It would appear, not surprisingly, that the interactions of supernovae with their own material ejected through mass loss from a progenitor over tens or hundreds of thousands of years before an explosion, is the standard mechanism of the supernova phenomenon. By studying these interactions, we can learn much about the part of a star's life that we knew almost nothing about before, and about how these phenomena contribute to the evolution of the Universe itself.

NCA thanks Dr. Sonneborn for an inspiring and enlightening talk. We hope that he will be able to return at future times to report on further developments in the evolution of the SN 1987A remnant and on science with the Far-Ultraviolet Spectroscopic Explorer (FUSE) mission, for which he is the Project Scientist, and which is expected to yield many new and exciting results in the study of hot stars and high-energy phenomena.

I am indebted to George for reviewing this "review" prior to publication. ❍

Views From Galileo

Presented by Dr. Gordon Bjoraker
Reviewed by Gladys Fuller

Editor's Note: Due to a faulty e-mail transmission, this article was originally published in incomplete form. We here republish it, in its entirety with apologies to all concerned.

This was primarily a talk about beautiful images from the Galileo orbiter. This mission was planned from 1977 to 1978 to be launched in 1982. Space shuttle delays caused it to be rescheduled to 1986, but the Challenger disaster caused another delay. Finally the over two-ton orbiter was launched in October 1989 and took the scenic route to Jupiter in order to conserve energy. When it arrived on December 7, 1995, the orbiter dropped a probe into Jupiter's atmosphere and went into an elliptical orbit around the planet. After fulfilling its design goals, the two-year mission was given an additional 2 years as the Galileo Europa mission.

The probe went into an area of thin clouds, about 6° N latitude, entering at about 47 km/s, decelerating rapidly (about 230 g's). It drifted down through the atmosphere sending back data to the orbiter for about one hour, until it last recorded a pressure of 22 bars at a temperature of 150° C. The atmosphere did attenuate the radio signal, but the probe's demise was due to melting. The probe found that the winds got stronger as it went deeper. Thus Jupiter is not like the Earth where sunlight drives our winds. Jupiter has it's own source of energy which drives its winds. In fact, Jupiter gives off more energy than it receives from the Sun. It was expected that the probe would experience thin, NH_3 ice crystal clouds; then a cloud layer of NH_4SH, and finally a thick cloud of H_2O. What it found was a then wispy NH_3 layer, a thicker intermediate layer, but no water layer. This layering is probably only representative of relatively cloud-free hot spots. On board was also a neutral mass spectrometer that could measure the presence of elements from He to Xe, for comparison with solar abundances. In the Sun these exist as storms, but on Jupiter, they are tied up in H-molecules such as methane, CH_4; ammonia, NH_3; and water. It seems that Jupiter has 3 times as much C as the Sun and very much less water (which is not currently understood). An N reading is not possible since NH_3 gets stuck in the plumbing. This increased C implies that Jupiter did not accrete out of solar-type gases, but from small planetesimals until it grew to about 10 Earth masses. It then started trapping H and He every rapidly. The probe also found evidence of S and that the H_2S abundances increased with depth. (Sulphur had also been observed when Shoemaker-Levy hit Jupiter.)

Images of the Great Red Spot were taken from the orbiter with different filters to give some indication of altitudes. These show that the upper cloud layer of the center is layered like a wedding cake, with a thick upper level, next a thin layer, and then a lower level. One image appeared to reveal a small water cloud or storm at a deeper level. The evidence was not convincing until spots were traced to Jupiter's dark side and lightning bolts were observed; this requires water clouds. The Great Red Spot was also imaged using the Near Infrared Mapping Spectrometer using wavelengths from 1 to 5 microns. This covers the reflected sunlight regime, going through strong CH_4 bands, to longer wavelengths to get the thermal emission. This yields vertical structure nicely. NH_3 ice reflections and the top of the clouds in the center of the Great Red Spot appeared to be about 20 km higher than the rest of the spot. Thermal radiation cannot get out through the thick clouds but can in the region around it. Fabulous auroras are observed on Jupiter looking in the ultraviolet with the Space Telescope Imaging Spectrograph. The N and S auroras show up as caps on the poles, but additional thin rings appear just south of the north pole and just north of the south pole. These additional rings are due to the Io Flux Tube. This current of about one MA causes a glow where it hits Jupiter's upper atmosphere. The ring of Jupiter, which was first observed by Voyager, is maintained by collisions of debris into the smaller moons. If the moons were not there, the rings would soon disappear into Jupiter.

There have been many flybys by the orbiter to observe the Galilean satellites. The most exotic, Io, looks something like a rotten orange with its bright regions of SO_2 frost and dark, hot calderas, and its surface which is always changing. These volcanoes are more like geysers, spewing material about 100 km high. The hot SO_2 gases shoot out of the volcano, fall further away and cool. In one image, the plume of a crater near the terminator cast a visible shadow. The largest eruption seen, called Pele after the Hawaiian goddess, was about the size of Arizona! To get some idea of the types of volcanoes on Io, the radiation was observed in several different wavelengths to see if they were all sulphur volcanoes (at only about a few 100° C) or if they were silicate volcanoes (like Hawaiian ones with very high temperatures). It was found there were only a few sulphur volcanoes while most are small silicate ones. The orbiter also looked at Io when it was in Jupiter's shadow and saw not only volcanoes, but also auroras and some bright spots, which are thought to indicate where the one MA flux is hitting gases.

Ganymede is the largest moon in the solar system, just a little larger than Saturn's Titan. Its surface seems to be mostly dirty water-ice with some bright areas which are interpreted as fresh impacts causing clean watery ice. The ice is not static but subject to stretching forces.

The image of Callisto showed a long line of craters, which is thought to be possibly from impacts of a broken-up comet, much like Shoemaker-Levy.

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Occultations in the Mid-Atlantic States Region

by David Dunham
dunham@erols.com

Total Lunar Occultations

DATE	Day	EDT	Star	Mag	%	alt o	CA	Notes
Apr 10	Sat	06:22	R omicronCap	5.9	37-	26	66S	Sun-4; 2nd mag. 6.6, 22", PA 239 deg.
Apr 12	Mon	05:45	R 42 Aquarii	5.3	18-	11	53S	Sun alt. -10 deg.
Apr 18	Sun	20:21	D 75 Tauri	5.0	11+	27	56S	Sun -7; 2nd mag. 7.9, sep. 0.02"
Apr 19	Mon	20:45	D DV Tau	7.8	-8.3	20+	35	72S Sun -11 deg.
Apr 19	Mon	21:15	D 119 Tau	4.3	20+	29	80S	need 12x camcorder
Apr 19	Mon	21:51	D 120 Tau	5.7	21+	23	68S	35x camcorder?
Apr 19	Mon	22:47	D SAO 094678	7.6	21+	13	63N	Possible close double
Apr 20	Tue	20:58	D SAO 095790	7.9	30+	44	10N	Graze, Columbia, MD
Apr 20	Tue	21:49	D ZC 1006	7.1	31+	35	82N	Possible close double
Apr 20	Tue	22:39	D SAO 095890	7.9	31+	25	39N	
Apr 20	Tue	23:01	D SAO 095902	7.6	31+	21	53S	
Apr 21	Wed	23:34	D ZC 1151	6.9	42+	25	35N	
Apr 23	Fri	22:13	D SAO 098571	7.8	64+	56	80S	
Apr 23	Fri	22:41	D ZC 1396	6.8	64+	52	40S	
Apr 24	Sat	15:38	D Regulus	1.3	71+	14	65S	Azimuth 86 deg.; Sun alt. 47 deg.
Apr 24	Sat	16:32	R Regulus	1.3	72+	24	-49S	Sun alt. 38 deg.
May 22	Mon	00:19	D Regulus	1.3	49+	19	87N	Preview of Naked-eye event!

"D" following the time denotes a disappearance, while "R" indicates that the event is a reappearance. The times are for Greenbelt, MD, and will be good to within +/-1 min. for other locations in the Washington-Baltimore metropolitan areas unless the cusp angle (CA) is less than 30 deg., in which case, it might be as much as 5 minutes different for other locations across the region. "Mag" is the star's magnitude. "%" is the percentage of the Moon's visible disk that is sunlit, followed by a plus (+) indicating that the Moon is waxing and a minus (-) showing that it is waning. "CA" is Cusp Angle, measured around the Moon's disk from the North or South cusp.

Planned Grazing Occultation Expeditions

DATE	Day	EDT	Star	Mag	%	alt	CA	Location
Apr 19	Mon	20:25	ZC 823	6.6	20+	38	2S	Laurel & Comus, MD; Sun alt. -8 deg.
Apr 20	Tue	21:03	SAO 095790	7.9	30+	43	1N	Columbia, MD; Sun alt. -14 deg.

Asteroidal Appulses

DATE	Day	EDT	Star	Mag	Asteroid	dmag	dur. s	ap. in.	Location
Apr 4	Sun	20:50	SAO 061123	9.1	Aeternitas	5.3	7	3	CT, Long Is.
Apr 9	Fri	03:14	ACT67520355	10.5	Nausikaa	1.5	10	7	MD, n.VA, s. PA
Apr 10	Sat	23:05	ACT18780551	10.7	Ophelia	3.2	5	7	PA, n.e. MD, DE
Apr 13	Tue	00:45	SAO 139322	7.0	Lutetia	3.8	8	1	n. NB, PEI, n. NS
Apr 18	Sun	23:44	TAC+14 2312	11.0	Elektra	2.2	9	8	Quebec
Apr 24	Sat	04:21	PPM 734008	10.4	Emita	3.6	29	7	Tenn., Alabama
Apr 26	Mon	05:31	SAO 189027	9.8	Ausonia	1.9	7	6	GA, S. Carolina
May 1	Sat	21:52	SAO 059397	6.9	Panopaea	7.3	4	1	Greenland

see the March Stardust for EST appulses on April 2 and 3.

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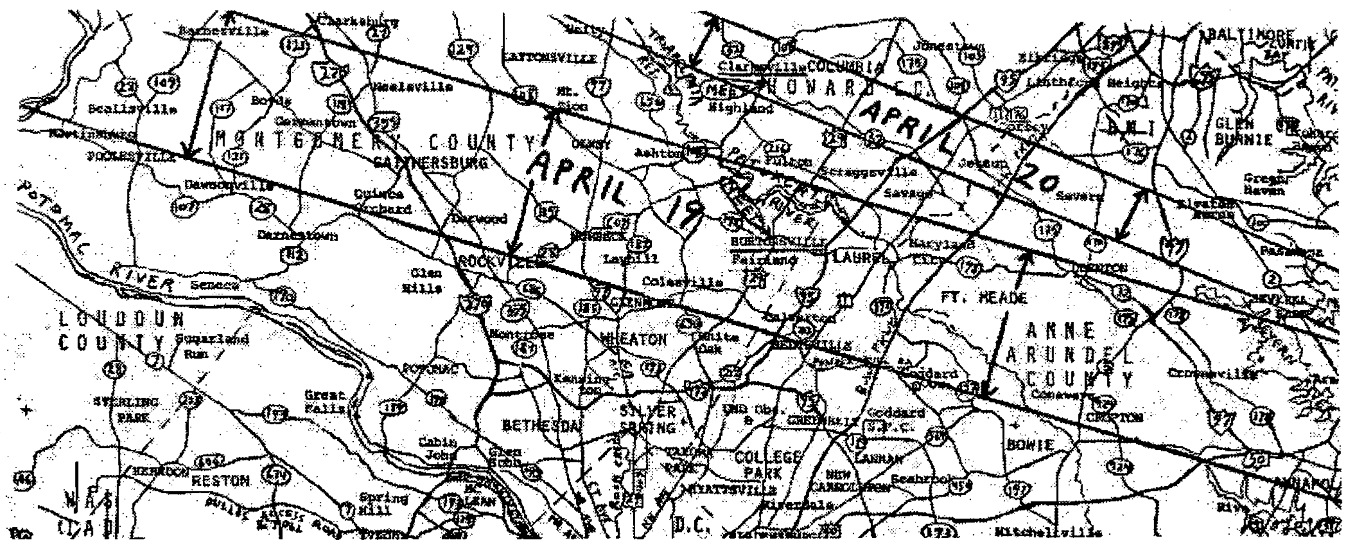
The three or four craters in a row, also seen, could be explained by a process of secondary craters, caused by the ejecta from the original crater.

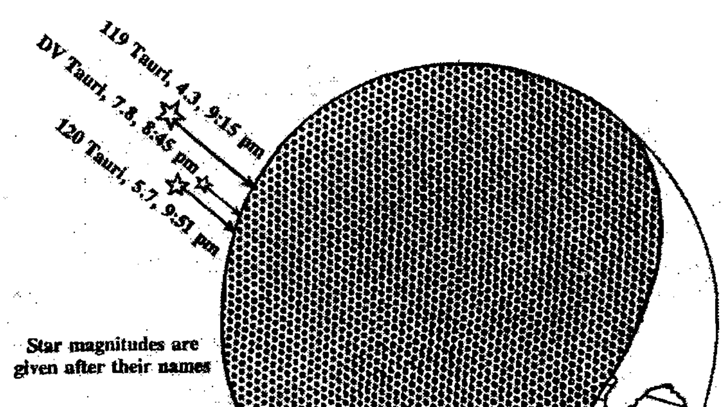
The water-ice surface of Europa is very cracked and has interesting craters as well. Impacts would melt some ice and disturb the terrain, but it also has a very strange arrangement of grooves. Close inspection of the Ice Raft region, which looks like a jigsaw puzzle, provides some clues. It is believed that Europa once had a liquid water surface. Icebergs formed, floated around, came together, separated, came together, etc. It is thought the surface is an ice shell, possibly over an ocean, but they don't know how thick the shell is. If it is only 10 km thick, it might pay to explore to find out how far down the water is. If 100 km thick, it wouldn't be feasible to explore for an ocean. The grooves have not yet been explained.

The original December '95 mission to explore Jupiter was extended two years to explore the Galilean moons. There have been rather extensive studies of Europa, Ganymede, and Callisto, but not so much about Io since the environment, with the one MA flux near it, is quite deadly to the instruments. The orbiter has already been damaged by the radiation near Europa, and Mission Control wants the orbiter to survive at least long enough to transmit its data. There are two chances to observe Io in October and November of '99. Mission Control will take a gamble to get 6m resolution images and hope it will survive and still be alive when Cassini flies by in December 2000 on its way to Saturn in July 2004. ❍

An Invitation to an Occultation Expedition



Path of Southern-Limit Grazing Occultation of 6.7-mag., ZC 823, Monday Evening, April 19, 1999, 8:22 - 8:29 PM EDT.



Occultations, Monday Evening, April 19, 1999, Washington, DC Area.

The April 19th ZC 823 graze in Gaithersburg, Burtonsville, Laurel, and Annapolis is the best in the DC-Baltimore area during 1999, visible with any small telescope. To participate in the expedition, meet at 7:00 PM in the Burtonsville Shopping Center parking lot at the northwest corner of US 29 and MD 198. Meet there at 6:30 PM if you need to borrow any equipment.

On the next night, April 20, there is another less favorable chance, with the northern-limit graze of 7.9-mag. SAO 95790 in Clarksville, Columbia, Severn and Pasadena. Observe it with at least a 4-inch telescope from 9:00-9:05 PM EDT. Weather permitting, an expedition will meet at 7:30 PM at the gas station at the southeast corner of MD routes 32 & 108 in Clarksville. Its path is shown north of the one for the April 19th graze.

National Capital Area Astronomical Events

Free Lectures at the Einstein Planetarium and Other Daily Events
National Air & Space Museum

202/357-1550, 202/357-1686, or 202/357-1505 (TTY)
Home page: http://www.nasm.edu

Other Area Astronomical Events

Arlington Planetarium — "Worlds in Motion," April 9-May 23, Fri., Sat., Sun., 7:30 PM, Admission: Adult $2.50, Children & Seniors $1.50. Information 703/228-6070.

Maryland Space Grant Observatory — Open House every Friday evening (weather permitting), Bloomberg Center of Physics and Astronomy, Johns Hopkins University, Baltimore, MD. Information: 401/516-6525 or check their web site at www.pha.jhu.edu/facilities/observatory/telescope.html.

Montgomery College's Planetarium, Takoma Park — "Black Holes, Gravity to the Max," April 17, 7:00 PM.

NASA Goddard Scientific Colloquia — All Colloquia will take place in Bldg. 3 Auditorium, with coffee and cookies at 3:30.

"Distance Supernovae and the Accelerating Universe", Speaker Saul Perlmutter, April 2.

"What's the Matter with the Universe: Photinos, Neutrinos, Wimpzellas, Omega, Lamda, et al.", Speaker, Edward Kolb, April 9.

U.S. Naval Observatory — All Colloquia will take place in Bldg. 52 Auditorium, with coffee and cookies at 10:30.

"Long Term Comparison between GPD Carrier Phase and TWTTS", Speaker Dr. Kristine Larson, April 9.

University of Maryland, Dept. of Astronomy — "AstroCappella-A Musical Exploration of the Universe", Speaker, The Chromatics, April 5, 9:00 PM.

"Marylands, BIMA Array Telescope," Speaker, Dr. Stuart Vogel, April 20, 9:00 PM.

Meteor Showers

Major Activity

Radiant	Duration	Maximum
Lyrids	April 16-25	April 22 16:00 (UT)

Minor Activity

Radiant	Duration	Maximum
Tau Draconids	March 13-April 17	March 31-April 2
Librids	March 11-May 5	April 17/18
Delta Pavonids	March 21-April 8	April 5/6
Pi Puppids	April 18-25	April 23/24
April Ursids	March 18-May 9	April 19/20
Alpha Vigninds	March 10-May 6	April 7-18
April Virginids	April 1-16	April 7/8
Gamma Virginids	April 5-21	April 14/15

Daylight Activity

Radiant	Duration	Maximum
April Piscids	April 8-29	April 20/21

European Symposium of Occultation Projects

The Carl-Zeiss-Planetarium, Sstuttgart and the Schwabian Observatory, Stuttgart invite you in the name of the International Occultation Timing Association — European Section (IOTA-ES) to the 18th European Symposium of Occultation Projects (XVIII ESOP) from 5th to 11th August, 1999, on the occultation of the total solar eclipse of 11th August 1999 in Stuttgart, Germany. Please consider this date in your plannings.

This meeting is divided into two sections.

August 5-8: Symposium with lectures and papers

August 8-11: Inspections, excursions and eclipse observation program.

The symposium can be attended by all amateur and professional astronomers, interested in the occultations and eclipses of solar system bodies.

For more information *see* http://www.sternwarte.de/esop-99/

Otto Farago
Swabian Observatory
Stuttgard, Germany

Upcoming Event

Universe 99—Tononto, Ontario, July 1-7. IOTA presentations are sought. RASC, AAVSO, and the Astronomical Society of the Pacific will also meet. For more information, see http://www.aspsky.org.

Don't throw this newsletter away. If you're finished with it, pass it on to someone else to read or recycle it. It's right for astronomy and the environment.

National Capital Astronomers, Inc.

SERVING SCIENCE & SOCIETY SINCE 1937

NCA is a non-profit, membership supported, volunteer run, public-service corporation dedicated to advancing space technology, astronomy, and related sciences through information, participation, and inspiration, via research, lectures, presentations, publications, expeditions, tours, public interpretation, and education. NCA is the astronomy affiliate of the Washington Academy of Sciences. All are welcome to join NCA.

SERVICES & ACTIVITIES:

Monthly Meetings feature presentations of current work by researchers at the horizons of their fields. All are welcome; there is no charge. *See* monthly *Star Dust* for time and location.

NCA Volunteers serve as skilled observers frequently deploying to many parts of the National Capital region, and beyond, on campaigns and expeditions collecting vital scientific data for astronomy and related sciences. They also serve locally by assisting with scientific conferences, judging science fairs, and interpreting astronomy and related subjects during public programs.

Discussion Groups exchange information, ideas, and questions on preselected topics, moderated by an NCA member or guest expert.

Publications received by members include the monthly newsletter of NCA, *Star Dust*, and an optional discount subscription to *Sky & Telescope* magazine.

NCA Information Service answers a wide variety of inquiries about space technology, astronomy, and related subjects from the public, the media, and other organizations.

Consumer Clinics on selection, use, and care of binoculars and telescopes, provide myth-breaking information, guidance, and demonstrations for those contemplating acquiring their first astronomical instrument.

Dark-Sky Protection Efforts educate society at large about the serious environmental threat of light pollution, plus seek ways and means of light pollution avoidance and abatement. NCA is an organizational member of the International Dark-Sky Association (IDA), and the National Capital region's IDA representative.

Classes teach about subjects ranging from basic astronomy to hand-making a fine astronomical telescope. NCA's instructors also train educators in how to better teach astronomy and related subjects.

Tours travel to dark-sky sites, observatories, laboratories, museums, and other points of interest around the National Capital region, the Nation, and the World.

Discounts are available to members on many publications, products, and services, including *Sky & Telescope* magazine.

Public Sky Viewing Programs are offered jointly with the National Park Service, the Smithsonian Institution, the U.S. Naval Observatory, and others.

NCA Juniors Program fosters children's and young adults' interest in space technology, astronomy, and related sciences through discounted memberships, mentorship from dedicated members, and NCA's annual Science Fair Awards.

Fine Quality Telescopes up to 36-cm (14-inch) aperture are available free for member's use. NCA also has access to several relatively dark-sky sites in Maryland, Virginia, and West Virginia.

YES! I'D LIKE TO JOIN THE NATIONAL CAPITAL ASTRONOMERS

Enclosed is my payment for the following membership category:

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If family membership, list names of additional participating immediate family members in same household, with birthdates of all those under 18 years old: ________________________________

Note: If you already subscribe to ***Sky & Telescope***, please attach a recent mailing label. You may renew this subscription through NCA for $27 when it expires.

Make check payable to: **National Capital Astronomers, Inc.**, and send with this form to:

NCA c/o Jeffrey B. Norman, 5410 Connecticut Avenue, NW, Apt. #717, Washington, D.C. 20015-2837.

The following information is optional. Please indicate briefly any special interests, skills, education, experience, or other resources which you might contribute to NCA. **Thank you, and welcome to NCA!**

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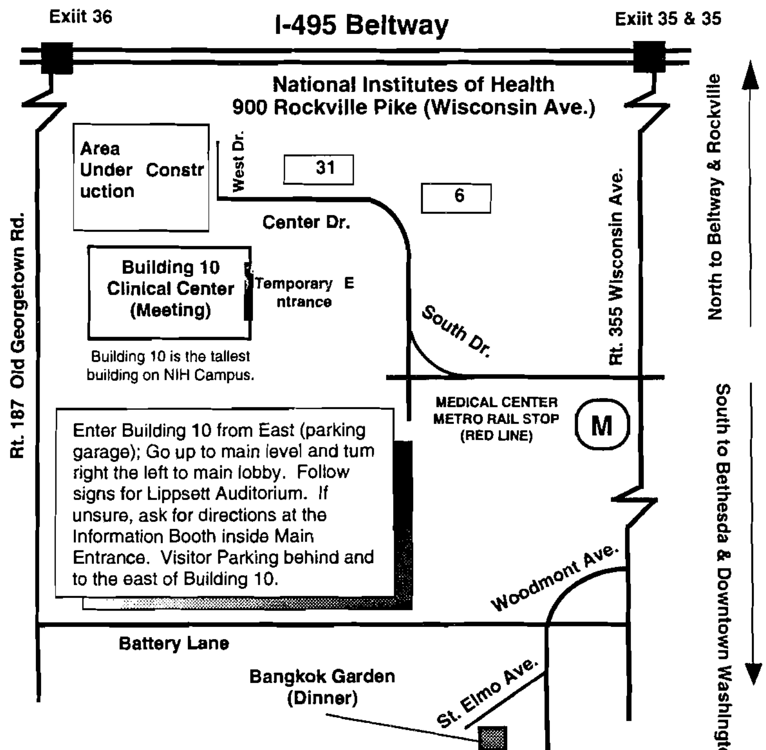
Getting to the NCA Monthly Meeting

Metrorail Riders - From Medical Center Metro Station: Walk down the hill, pass the bus stops and turn right at the anchor onto Center Drive. Continue uphill to Building 10, the tallest building on campus (walking time about 10 minutes). Also, the J2 bus line connects the Bethesda (7:16 PM) and NIH (7:23 PM) Metro stops with Building 10 (7:25 PM).

To Bangkok Garden - From the beltway, take Wisconsin Avenue toward Bethesda and turn right onto Woodmont. Follow Woodmont and take a right onto St. Elmo. The address is 4906 St. Elmo Avenue (301/951-0670). There are parking garages nearby. Seats are not guaranteed after 5:30 PM.



Map is not to scale.

A more current map for parking at NIH may be found at: www.cc.nih.gov/ccc/waytogo/update1.html

***Star Dust* is published ten times yearly (September through June) by the National Capital Astronomers, Inc. (NCA), a nonprofit, astronomical organization serving the entire National Capital region, and beyond. NCA is the astronomy affiliate of the Washington Academy of Sciences and the National Capital region's representative of the International Dark-Sky Association. President: Andrew Seacord, 301/805-9741. Deadline for *Star Dust* is the 15th of the preceding month. Editors: Alisa & Gary Joaquin, 4910 Schuyler Dr., Annandale, VA 22003, 703/750-1636, E-mail: ajglj@erols.com. Editoral Advisor: Nancy Byrd**

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