Star Dust

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Jim Zimbelman to Describe Volcanism throughout the Solar System

By Wayne H. Warren Jr.
(including a summary by James R. Zimbelman)

The next meeting of the National Capital Astronomers will be held on March 5, 1994 at 7:30 PM in the Bunim Room of the Clinical Center (Building 10, floor 9) at the National Institutes of Health. At this meeting, we look forward to a talk by Dr. James R. Zimbelman of the National Air and Space Museum, who will tell us about his recent work concerning volcanism in the Earth and other bodies of the Solar System.

Volcanism is one of the most important geologic processes observed on planetary objects. All of the terrestrial planets, as well as many of the moons throughout the Solar System, have surface features indicative of volcanic processes. The lecture will start with a short review of volcanic features here on Earth, as a reference for comparison to the planetary examples. Volcanic landforms have been imaged or photographed on Earth's Moon, Mercury, Venus, Mars, Io, Enceladus, and Triton. As spacecraft moved farther from the Sun, the volcanic process remained active as the magma material changed, ranging from basalts on the terrestrial planets to water, methane, and even nitrogen ice/gas interactions. All of the these features are expressions of the basic force in nature that is removing heat from the interior of a planet or moon by expulsion of some molten material. Volcanism in non-Earthlike environments provides an excellent test of our theories of volcanic processes, making each planet or moon a separate test case that the theories need to incorporate.

The lecture will be based primarily on photographs and images of various volcanic features throughout the Solar System. Selected examples of ongoing research on volcanic processes will be included to illustrate how this new information is being incorporated into theories of volcanism.

Come and join Dr. Zimbelman and other NCA members to learn about the processes of volcanism and how it has manifested itself throughout our home planetary system. As we prepare to send new probes to Mars and the outer planets over the next decade, the study of volcanism will no doubt receive further attention and planetary geologists like Dr. Zimbelman will have no shortage of new observations and data to keep them busy over succeeding years. Even in the wake of the tragic loss of our Mars Observer, new missions are being planned and launched, as evidenced by the recent successful sendoff of the Clementine mission, which will map the lunar poles and go on to fly by the asteroid Geographos. Thus, Dr. Zimbelman's topic will be of increasing relevance in the near future of America's space program.

March Calendar

The Public is Welcome!

Tuesdays, March 1, 8, 15, and 22, 7:30 PM - Telescope making classes at Chevy Chase Community Center, Connecticut Avenue and McKinley Street, NW. Information: Jerry Schnall, 202/362-8872.

Fridays, March 4, 11, 18, and 25, at 7:30 PM - Telescope making classes at American University, McKinley Hall Basement. Information: Jerry Schnall, 202/362-8872.

Fridays, March 4, 11, and 18, 8:30 PM - Open nights with NCA's Celestron-14 telescope with Bob Bolster, 6007 Ridgeview Drive, south of Alexandria off Franconia Road between Telegraph Road and Rose Hill Drive. Call Bob for details 703/960-9126.

Saturday, March 5, 1994, 5:30 PM - Dinner with the speaker at The Rio Grande Cafe (4919 Fairmont Avenue, Bethesda) before the monthly meeting. Reservations are for 5:30PM sharp.

Saturday, March 5, 1994, 7:30PM - Dr. James R. Zimbelman will speak on "Volcanism Throughout the Solar System." Meeting will be held in the Bunim Room at the National Institutes of Health. For directions, refer to map and description on back page.

Smithsonian Sky Watchers' Report

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The Merging of Galaxies and Interpretation of the Hubble Sequence of Galaxy Types

by Wayne H. Warren Jr.

At the February 5, 1994 meeting of the National Capital Astronomers, members and guests were treated to a superb talk by Dr. Francois Schweizer of the Department of Terrestrial Magnetism, Carnegie Institution of Washington. Dr. Schweizer's presentation traced the history of scientific thought concerning galactic merger events, recent observational and theoretical work in this area, and the implications of such mergers to the interpretation of the well-known Hubble sequence.

Dr. Schweizer first told us that he felt quite at home with the NCA because his first real connection with astronomy was with the "NCA" of Switzerland, the Bernische Astronomische Gesellschaft of his home city of Bern, the capital of that beautiful alpine country (my words). He then began his scientific presentation by reminding us that the great astronomer Edwin Hubble made at least three fundamental discoveries, two of which brought him instant fame and the third of which turned into a major puzzle that has only begun to be resolved over the last 20 years. The first two discoveries were: (1) he showed that even the external galaxies nearest to us are still very far away and that the Milky Way is just one of millions of these "island universes", as they were then called; and (2) that the universe is expanding and that all galaxies are moving away from each other at velocities that increase in direct proportion to their distances. His third important discovery was made only after many years of studying thousands of galaxy images and that was the realization that the various galaxy types could apparently be arranged in what appeared at the time to be a logical sequence possibly in some way attributable to evolutionary characteristics.

Hubble's sequence is well represented schematically in the form of a wishbone (or tuning fork) with the single point facing left. At the extreme left are the relatively featureless elliptical galaxies, starting at E0 (nearly round) and proceeding to E7 (quite elongated), then to S0 located at the center of the wishbone, which breaks to the lower (barred spirals) and upper (normal spirals) branches, where we go from the tightly wound (Sa, SBa) to the open (loosely wound) spirals (Sc, SBc) like M 33,M 81 and our own Milky Way Galaxy. In between the extremes are galaxies that have some disk characteristics and spiral structure with small elliptical centers that Hubble called bulges. The problem to emerge was the question of why nature should make two entirely different structures in galaxies.

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Dr. Schweizer then showed some examples of modern photographs of galaxies, first NGC 2997, a galaxy thought to be very similar in structure to the Milky Way. Such a galaxy typically contains about 100-200 billion (10**9) stars revolving around the center in orderly fashion, and has a diameter of about 30,000 parsecs (pc) (100,000 light years). In the Milky Way, the Sun is located about two-thirds (8-10 kpc) out from the center and quite close (estimated distance 7 pc) from the plane. It is also known that approximately 10-15 percent of the luminous mass in such a galaxy is not in the form of stars, but in gas. As the gas passes through the spiral arms during the course of galactic rotation, it is compressed and forms new stars, which in turn give such galaxies their typical appearance of blue spiral arms. When we see such a galaxy nearly edge-on, we notice that the disk is quite thin, with a vertical dimension typically less than 10 percent of its diameter. This is very different from an elliptical galaxy such as M87 in the Virgo cluster, which is nearly spherical, or other ellipticals that have shapes more akin to a football (two different sized axes) and sometimes even three unequal axes, but never display thin disks like the spirals. In addition, these ellipticals seem to be virtually free of cold gas, meaning that they have no fuel to form new stars and are composed of older (and redder) stars that give them their ruddy appearance. So we return to the question of why there is this dichotomy in the shapes of galaxies.

In the early 1960s, astronomers thought that they had found the answer to this puzzling question. They argued that all galaxies formed very early in the history of the universe from huge protogalactic collapsing gas clouds. When these gas clouds had time to collapse under the influence of their own gravity, they would form flatter pancake-like structures; as stars formed in these pancakes, they would become spiral galaxies, which make up 80-85 percent of all known galaxies. If, on the other hand, stars began forming during the collapse of a cloud and before the gas had time to settle into a pancake, then they would be on infalling random orbits and a galaxy would never have a chance to flatten out and an elliptical galaxy would form. The one major problem with this theory was that no one could come up with a reason why stars in certain galaxies should form while the gas was still collapsing.

Then about 20 years ago, as more and more images of fainter galaxies were examined, it was noticed that many galaxies seemed to be colliding. One very clear example was that of the ring galaxies, of which about a dozen were known and were included in Arp's "Atlas of Peculiar Galaxies." It was also noticed that whenever a ring galaxy occurs, there seems to be another small nearby galaxy along the minor axis of the ring. Theoretical models of the time indicated that if a central collision between two galaxies took place, such a ring would form, much like wavelets in a pond when a stone drops into it. However, these galaxies were rare because central collisions were presumably very uncommon. Another class of interesting galaxies found in the late 1970s and early 1980s are what became known as S0 galaxies with polar rings. The objects themselves are disk galaxies of the S0 type, meaning that they have barely discernible spiral structure, yet some of them have faint rings of material going right over the poles of the inner disk and rotating perpendicular to it. Since it seemed impossible for a single collapsing gas cloud to form such a structure, it began to be suspected that collisions might be more frequent than previously believed. However, by far the most frequent of these apparently interacting galaxies were cases of pairs of disk galaxies from which jets (or tails) of various sizes emerged from each galaxy, as had been pointed out by Arp in the 1960s and even by the well-known Swiss astronomer

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NCA Welcomes These New Members!

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Fritz Zwicky in the 1950s. An example is NGC 4676, nicknamed "The Mice" for obvious reasons apparent in the image shown by Dr. Schweizer. Even more obvious are the galaxies that display large antenna-like structures of luminous material. In the early 1970s, astronomers began to realize that these "antennae" might be produced by tidal forces in a way similar to tides on the Earth are produced by the gravitational attraction of our Moon. What is very important here is the dependence of the tidal effect on the distance of the object causing the tides. For example, if the Moon were located at one-half of its present distance, then the tides would be eight times as strong as they now are because the dependence is to the third power. Thus, these strong tidal effects might account for the varying shapes and lengths of the luminous jets emerging from galaxy pairs of different distances apart. Convincing evidence was to be found in early models of interacting galaxies, particularly those of Alar Toomre and his brother Juri, who published a review article summarizing their work in Scientific American (1973). These models showed that tidal interactions of galaxies on elliptical orbits produced tails very similar to those observed and that one long tail and one short bridge were produced per galaxy. Thus, two long tails indicated that two galaxies had collided. The brilliant and daring extrapolation of the Toomres consisted of the following: the formation of the tails requires energy, which must be produced during the interaction. This "friction" causes a loss of orbital energy and a decay of the orbits, resulting eventually in a galactic merger. The Toomres then used various known interacting galaxies as examples of objects in various stages of merging. Dr. Schweizer then showed images of pairs of galaxies, including NGC 3256, where the disks are already nearly merged, but can still be seen as distinct, to NGC 3921, where only a single object can be seen with two long tails sticking out. The Toomres then asked where the remnants of such mergers are and estimated that from the dozen or so mergers seen in the NGC catalog, plus the 0.5-1.0-billion-year duration of such mergers, there must be about 400 such remnants in that same catalog. It turned out that there are just about 400 elliptical galaxies in the NGC. Thus, it could very well be that these mergers are what eventually produce the elliptical galaxies. Now this was a radical departure from conventional theory and, as is so often the case in science, was virtually ignored for some 5-10 years.

In 1977, during a meeting at Yale University, the astronomer Ivan R. King asked a very penetrating question, namely: if galaxy mergers are a relatively common occurrence, then where are the intermediate products? That is, we should see galaxies in various states of merging, some about to merge, others just touching, etc. Since computers were not then powerful enough for large-scale simulations, the task of looking for these intermediate products fell to the observers. Dr. Schweizer then showed an image of one of the best known "antennae" galaxies, NGC 7252, and pointed out that the northwest tail extends for a distance of 120 kpc, about four times the diameter of the Milky Way. The measured velocities of this tail indicate that it was formed over a period of about 1 billion (give or take a factor of two) years. So, it appears that a merger of two disk galaxies may have occurred some 10**9 years ago, even though at the present time only one object can be seen. Even more surprisingly, the measured light distribution as one goes out from the center does not resemble that of a disk galaxy, but rather compares more closely with that of an elliptical galaxy. However, a lot of structure is seen on images of varying exposures and at the center of the system is a bright disk of ionized gas in which there seems to be a lot of star formation occurring. Yet, when the rotation curve of the object is examined, one sees not one direction of motion, but opposite directions inside and outside the disk. Thus, NGC 7252 provides strong evidence that we are seeing the remnants of a merger in which the motions still display some characteristics of the individual motions of the galaxies before the merger event. To clarify this concept, Dr. Schweizer used an example of a hypothetical solar system in which the motions of the inner planets, Mercury, Venus, Earth, and Mars, were, say prograde, and those of the Jovian planets were retrograde; from such motion, one would conclude that the system had not formed from a single gas cloud, but from two preformed systems that had merged with each other. Dr. Schweizer then showed a spectrum of NGC 7252 taken at Las Campanas Observatory in Chile. Unlike most galaxies, which display composite spectra of a mixture of young and old stars, the NGC 7252 spectrum contains clear and strong lines of the whole hydrogen series and closely resembles that of a predominantly young stellar population. The presence of such young stars once again strongly indicates that the merger event produced a tremendous burst of star formation and that the ages of these stars, less than 10**9 years, are in agreement with the inferred age of the tails.

As a result of the NGC 7252 work, people were generally willing to believe that this particular galaxy was the result of a merger, but very few were convinced that this was a mechanism by which all or most elliptical galaxies are produced.

Then in 1983, NASA launched the Infrared Astronomical Satellite (IRAS), which was designed to scan the sky to detect objects that radiate primarily in the infrared (IR) between 12.5 and 100 micrometers. Although this satellite discovered many cool stars and radiating gas in our Galaxy, it also found bright IR sources that could be identified with small and distant galaxies. When images of these galaxies were taken with large telescopes, they almost invariably turned out to be objects that were perturbed in some way; i.e., they showed tails or there were two objects snuggling together, etc., and it soon became clear that most of these IRAS-bright galaxies were merging systems.

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From many additional studies that have now been done over the last decade, it appears that when collisions occur, the gas in these galaxies is highly compressed and forms new stars much in the same way that young stars are born in the spiral arms of the Milky Way, as discussed earlier. Moreover, these young stars are surrounded by massive amounts of dust, which prevents us from seeing the stars themselves, but the dust is heated by the stellar radiation and reradiates the energy in the IR. In fact, in extreme cases, almost all (99 percent) of the radiation is emitted in the IR. There are now so many of these galaxies known that there is no shortage of objects that can turn into ellipticals; rather, it is the opposite way and some mergers may even result in the formation of other structures such as S0 galaxies.

In the meantime, the computational resources have caught up and there are now much more sophisticated models of encounters between two galaxies. Dr. Schweizer showed a sequence of illustrations computed by Joshua Barnes of the University of Hawaii that depicts the interaction of two galaxies containing 64,000 independent particles each; i.e., each particle interacts with all other particles. This model showed very clearly the merging of the two objects after a few interactions and the subsequent formation of long tails similar in appearance to those observed in NGC 7252, thus providing theoretical evidence that these structures can form as a result of merger events. Although one might expect that a collision of two large galaxies like the Milky Way and M 31 would produce many stellar collisions, such is not the case because of the immense distances between the stars relative to their sizes. Dr. Schweizer used the analogy of shrinking the stars to the size of a cherry and noting that even in a relatively dense region of the Galaxy, the distances would correspond to placing a cherry in the capital of each state in the U.S. When two such objects pass through one another, the probability of a stellar collision is not very large.

Now that we have convinced ourselves that mergers of disk galaxies can form ellipticals, that does not mean that ellipticals are actually formed this way. To prove this, we need to find evidence of past mergers in the elliptical galaxies themselves. If such "signatures" can be found, then we can actually identify specific ellipticals that have formed as a result of merger events. This possibility became quite real when, in 1980, David Malin of the Anglo-Australian Observatory discovered around an otherwise normal elliptical galaxy some rather sharply-defined features that he called shells. Since galaxies that had always been ellipticals would be expected to show no sharp-edged features, it is now believed that these features are the remnants of disks of spiral or dwarf galaxies that have merged to form an elliptical galaxy. Such ordered motions in an elliptical galaxy can thus be thought of as displaying a memory of its previous life. Dr. Schweizer then showed additional models of Barnes and Hernquist that depict a rotating disk galaxy dropping right through the middle of an existing elliptical. It could be seen clearly in a time series of illustrations that the disk galaxy is disrupted by tidal forces and that sharp edges of stars are formed as the remnants of the disk galaxy move back and forth inside the elliptical.

Dr. Schweizer then described a survey of more than a hundred elliptical galaxies that he had done with collaborator Pat Seitzer to look for the signatures just described. Of the 70 galaxies that have been fully analyzed, more than half show structure indicative of the types of tidal interactions depicted by the models. These structures could be seen on images of NGC 474 (Arp 227), NGC 5018, and Arp 230, which shows some spiral structure and ripples that Arp referred to as shells. If we include other signatures, such as plumes and tails, more than two-thirds of all ellipticals show such structures, implying that most ellipticals display signs of past merger events. It is also found that galaxies containing more structure are, on average, a bit bluer when B-V colors are compared. The same correlation is found in spectral signatures; i.e., hydrogen-line absorption is stronger in galaxies with more structure, implying that more young stars are present in highly structured galaxies. When the ages of elliptical galaxies are estimated from their colors, as modeled by mergers of disk galaxies, it is found, contrary to the old assumption that all ellipticals are old, that no such galaxies seem to be older than about 10 billion years, whereas the universe is estimated to be some 15 billion years old. Moreover, the ellipticals examined seem to have ages from 10

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Wayne Warren Receives 1994 Van Biesbrock Award

By John Graham

As I announced at the November meeting, our Vice President, Wayne Warren is the recipient of the 1994 Van Biesbrock Award. This is a national award given annually to people who have made considerable unselfish contributions to astronomy, sometimes sacrificing their personal research or career advancement to serve the broader needs of the astronomical community. Wayne's particular contribution has centered on his untiring efforts in compiling and distributing astronomical data to the community in easily accessible format. Many of us who have been helped by him over the years are delighted that he has received this recognition of his work. The award was presented in Tucson last month. All of us in National Capital Astronomers join in congratulating Wayne for this well-deserved honor.

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billion years right up to the present, again implying that ellipticals have formed from merger events over the entire history of the universe starting at about 10 billion years ago.

Following the publication of a number of these studies, many of the old objections gradually disappeared. However, it was still noted that, while disk galaxies all contain a lot of cold gas, ellipticals contain very little, so where has all the gas gone? But cold gas cannot be detected in the visual or IR, and radio observations are necessary to see it. Recent VLA observations of NGC 7252 do show that there is a lot of cold gas in the tails, while a small disk of about 10 billion solar masses of molecular hydrogen that is rotating in the opposite direction from the rest of the galaxy is observed. It turns out that about a quarter of all ellipticals appear to contain rotating cores of stars, many of which rotate the opposite way. It also appears that in merger remnants, similar disks of gas are turning into stars, thus producing the blue component. Observations with the ROSAT observatory show a small x-ray flux from these cores of very hot gas, which could be produced from collisional processes or from the explosions of supernovae.

Another significant finding is that elliptical galaxies have five times as many globular clusters as do typical spiral systems, whereas one would only expect twice as many if a pair of spirals merged to form an elliptical. Now it is quite well known that all Milky Way globular clusters are quite old, but blue (young) globulars are very apparent in our satellite galaxies the Magellanic Clouds. So, why can't merger events, which are known to produce young stars, be producing young globular clusters as well? Observations over the last few years have shown that some elliptical galaxies do contain blue globular clusters, a prime example being NGC 1275. A new study of NGC 7252 with the Hubble Space Telescope, carried out by Dr. Schweizer and Brad Whitmore (ST ScI) shows numerous blue globular clusters in this galaxy. Spectra of a few of these objects taken with the 5-meter Hale telescope show strong Balmer-line absorption that indicates ages of 10**8 to 10**9 years, similar to those indicated from their colors. The velocities of these "globular" clusters show that they are at the same distance as the assumed parent galaxy, NGC 7252. The brightest of these globular clusters is about 600 times the brightness of the brightest known Milky Way globular cluster, which is omega Centauri.

There is now increasing evidence for mergers, not only in elliptical galaxies, but in disk galaxies as well, although this evidence is a bit weak at the present time. However, up until 2 years ago, leading theoreticians still discounted this, stating that disk structures are much too fragile to remain intact following a merger. In a paper of 1992, it was stated that if even the Large Magellanic Cloud, which has only four percent of the mass of the Milky Way, fell into the latter's disk, the disk would be destroyed, or at least would become much fatter than it is now. Subsequent to this, however, Vera Rubin and John Graham took spectra of the edge-on Virgo-cluster spiral galaxy, NGC 4550, and found two cospatial disks of stars rotating in opposite directions from each other. It appears that this disk galaxy survived some kind of merger event. Dr. Rubin has very recently (1994, Astronomical Journal, 107, 173) studied motions in another spiral galaxy (NGC 4826, type Sab) that displays retrograde rotation of ionized gas outward from its prominent dust lane that exhibits, along with its stellar component, prograde rotation, again indicating that this galaxy has experienced the acquisition of external gas or a merger event.

Another interesting area of recent study is large clusters of galaxies. In the relatively nearby Virgo cluster, one sees many ellipticals with a smattering of spirals. However, as we observe more distant clusters and look farther back in time, we notice more interacting disk galaxies and fewer ellipticals. It seems, then, that as we look back to a younger universe, we can observe directly in the big clusters how the proportion of interacting disk galaxies diminishes and the proportion of ellipticals increases as the clusters age.

Finally, there is now evidence that even quasars may be affected by mergers. High-quality images of the QSO 3CR249.1, taken at Mauna Kea Observatory, appear to show a pair of small disks and even two tails sticking out. Alan Stockton (University of Hawaii) has measured velocities for these apparent tails, which consist of hydrogen (as in NGC 7252), but in ionized state (the NGC 7252 gas is neutral), which could be due to the effects of the intense radiation field from the quasar.

Now we can go back and look at the Hubble sequence once again because we think that its puzzle is beginning to be understood in terms of galactic mergers. Dr. Schweizer summarized his talk while showing another illustration of the sequence, but with the wishbone (tuning fork) reversed from left to right. He stated that we think we now understand that the pure disk (with no bulges) galaxies formed in a natural way from collapsing gas clouds without any influence from mergers. At the other end are the wreckages of disk galaxies that have merged to become ellipticals, while in between are the Sb (like M 31) and Sa (like the Sombrero; M 104 = NGC 4594) galaxies that have disks and also increasingly larger bulges that have been produced by gas capture or merger events. So, it does appear today that the Hubble sequence ranks galaxies by increasingly violent and/or the number of merger events that they have undergone during their lifetimes. Since the reversed Hubble sequence is really now thought to be more physically meaningful, Dr. Schweizer ended by speculating that maybe the great Edwin Hubble, like Leonardo da Vinci before him, put his most secret thoughts into mirror writing.

Like all graduate students of 20 years ago, my schooling had thoroughly entrenched the idea that the elliptical galaxies are the oldest and somehow gave way to the come-lately spirals. After hearing several lectures by Dr. Schweizer, including this one, and reading many of his published papers, a famous one of the many sayings of the well-known and brilliant Swiss astronomer, Fritz Zwicky, who, like Francois Schweizer after him, was way ahead of his time in many areas, came to mind. In fact, this saying recently appeared in a review of 1993 astronomy and astrophysics by Virginia Trimble and Peter Leonard of the University of Maryland (see Publ. Astronomical Society of the Pacific, 106, 1, 1994 January) and might be appropriate for many of us who held out for years until the evidence accumulated. We can now hear Dr. Schweizer quietly snickering and quoting his predecessor Zwicky, who said in his characteristic accent: "Zey come out of ze trenches viss ze hands up." In no way do I mean this to imply that I am ready to believe that quasars are not at cosmological distances, that redshifts are caused by some as yet undetermined mechanism, or that the universe did not start with a Big Bang.

The NCA expresses its appreciation to Dr. Schweizer for volunteering his valuable time to prepare and present this fascinating talk. We were also delighted that his wife, Linda, and their four lovely daughters were able to attend our meeting. Thanks to my wife, Martha, for proofreading a draft of this review, and to Francois Schweizer and John Graham for refereeing it.

National Capital Astronomers, Inc.

is a non-profit, public-service corporation for advancement of the astronomical sciences and is the astronomy affiliate of the Washington Academy of Sciences. For information, call NCA: (301) 320-3621.

SERVICES AND ACTIVITIES:

A Forum for dissemination of the status and results of current work by scientists at the horizons of their fields is provided through the monthly NCA Meeting. (See monthly *Stardust* for time and location.) All interested persons are welcome; there is no charge.

Expeditions frequently go to many parts of the world to acquire observational data from occultations and eclipses which contribute significantly to refinement of orbital parameters, the coordinate system, navigation tables and timekeeping. Other results of this work under continuing study include the discovery of apparent satellites of some asteroids, discovery of apparent small variations in the solar radius, and profiles of asteroids.

Discussion Groups provide opportunities for participants to exchange information, ideas, and questions on preselected topics, moderated by a 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.

The NCA Public Information Service answers many astronomy-related questions, provides predictions of the paths and times of eclipses and occultations, schedules of expeditions and resulting data, assistance in developing programs, and locating references.

Astronomical Telescope & Binocular - Public Seminar, for Selection, Use, and Care, held annually in November, offers the public guidance for those contemplating the acquisition of a first telescope, and dispels the many common misconceptions which often leads to disappointment.

Working Groups support areas such as computer science and software, photographic materials and techniques, instrumentation, and others.

Telescope-Making Classes teach the student to grind and polish, by hand, the precise optical surface that becomes the heart of a fine astronomical telescope.

NCA Travel offers occasional tours, local and world-wide, to observatories, laboratories, and other points of interest. NCA sponsored tours for comet Halley to many parts of the southern hemisphere.

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The following information is optional. Please indicate briefly any special interests, skills, vocation, education, experience, or other qualifications which you might contribute to NCA.

Thank you, and welcome!

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Getting to the NCA Monthly Meeting

•Subway Riders - From Medical Center Metro Stop: Walk down the hill, pass the bus stops and turn right at the anchor (onto Center Drive). Continue uphill to building 10, the largest building on campus. 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 Rio Grande Cafe: Take Wisconsin Avenue toward Bethesda and bear right onto Woodmont (or take the next right onto Battery Lane). Follow Woodmont to Fairmont (4 blocks south of Battery) and make a right. Proceed across Norfolk on Fairmont for about half a block. Rio Grande is on the right (4919 Fairmont Avenue). There should be adequate parking on the street outside the restaurant, or in a nearby parking garage (no charge on weekends). Seats are not guaranteed after 5:30.

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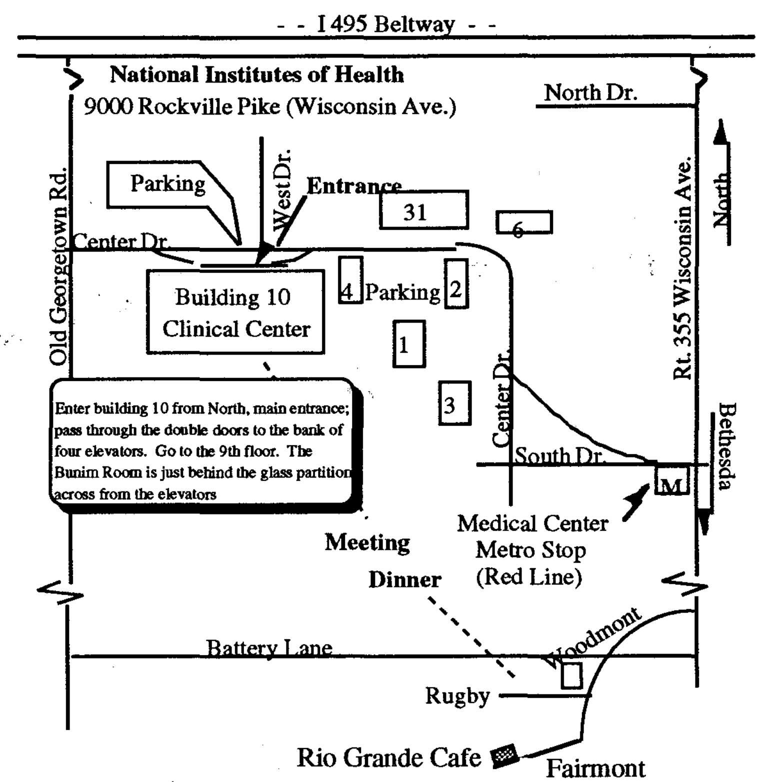

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