Star Stuff

THE FORD AMATEUR ASTRONOMY CLUB NEWSLETTER

Volume 6, Number 2 February 1997

ENIGMA OF RUNAWAY STARS SOLVED

European Southern Observatory, Press Release 01/97

Supernova Propels Companion Star through Interstellar Space

The following success story is a classical illustration of scientific progress through concerted interplay of observation and theory. It concerns a 35-year old mystery which has now been solved by means of exciting observations of a strange double star. An added touch is the successive involvement of astronomers connected to the European Southern Observatory.

For many years, astronomers have been puzzled by the fact that, among the thousands of very young, hot and heavy stars which have been observed in the Milky Way, there are some that move with exceptionally high velocities. In some cases, motions well above 100 km/sec, or ten times more than normal for such stars, have been measured. How is this possible? Which mechanism is responsible for the large amounts of energy needed to move such heavy bodies at such high speeds?

Could it be that these stars are accelerated during the powerful explosion of a companion star as a supernova? Such a scenario was proposed in 1961 by Adriaan Blaauw [1], but until now, observational proof has been lacking. Now, however, strong supporting evidence for this mechanism has become available from observations obtained at the ESO La Silla observatory.

The mysterious runaway stars

OB-runaway stars [2] are heavy stars that travel through interstellar space with an anomalously high velocity. They have been known for several decades, but it has always been a problem to explain their high velocities. Although most OB-runaway stars are located at distances of several thousands of lightyears, their high velocity results in a measurable change in position on sky photos taken several years apart. The velocity component in the direction of the Earth can be measured very accurately from a spectrogram. From a combination of such observations, it is possible to measure the space velocity of OB-runaways.

Bow shocks reveal runaway stars

It has also been found that some OB-runaways display bow shocks of compressed matter, which look very much like the bow wave around a boat crossing the ocean. They are of the same physical nature as a bow shock created by a jet-fighter in the air. The explanation is similar: when an OB-runaway star plows through the interstellar medium (a very thin mixture of gas and dust particles) with supersonic velocity [3], interstellar matter is swept up in a bow shock.

Stars of low velocity do not create bow shocks. Thus, the detection of a bow shock around a particular OB star indicates that it must have a supersonic velocity, thereby securely identifying it as a runaway star, even if its velocity has not been measured directly.

Runaway stars come from stellar groups

When a star's direction of motion in space is known, it is possible to reconstruct its previous path and, even more interestingly, to find the place where the star originally came from. It turns out that the paths of many OB-runaways can be traced back to so-called OB-associations, that is groups of 10 to 100 OB-type stars which are located in the spiral arms of our galaxy.

About fifty OB-associations are known in the Milky Way. In fact, the majority of all known OB stars are members of an OB-association. Therefore, it is not very surprising that OB-runaway stars should also originate from OB-associations. This is also how they got their name: at some moment, they apparently left the association in which they were formed.

The ejection mechanism

But why were the OB-runaway stars kicked out of the OB-association and how did they achieve such high speeds? One possibility is that some OB stars in an OB-association are ejected due to strong gravitational effects at the time of close encounters between the members of the group. Complicated computer simulations show that this is in principle possible. Nevertheless, since many years, most astronomers think that a more likely scenario is that of violent supernova explosions, first proposed in 1961 by Adriaan Blaauw.

Stellar evolution theory predicts that all OB stars will end their life in a supernova explosion. The heavier the OB star, the shorter its life. For instance, an OB star with a mass of 25 times that of the Sun, will explode after only 10 million years, compared to an expected life-time of about 13,000 million years for the Sun (which is not an OB star and will not become a supernova). Blaauw suggested that when an OB star is bound to another OB star in a binary system (a 'double star'), the supernova explosion of one of the stars (the heaviest of the two would explode first) results in the rapid acceleration (in astronomical terminology, a 'kick') of the other one.

The reason for this is as follows. When two heavy stars orbit each other at high velocity, they are held together by their mutual gravitational attraction. But after the supernova explosion, one of the stars has lost most of its mass and there is no force to hold back the remaining OB star. The OB-star therefore immediately leaves its orbit and continues in a straight line while preserving its high orbital velocity. The effect is the same as cutting a swinging rope with a stone attached to the end. Soon thereafter, this star will escape from the OB-association and start its journey through interstellar space as a new OB-runaway.

Stellar evolution in a binary system

About half of the known OB stars are members of a binary system. Modern evolutionary scenarios for such systems were developed by Edward van den Heuvel [4]. He realized that during the evolution of a close binary system, a phase of intensive mass transfer occurs, whereby matter flows from the heavier star towards its lighter companion. This has important consequences for the further evolution of the system.

The mass transfer happens, after a few million years or even less, when the heaviest and therefore most rapidly evolving star increases in size and becomes a supergiant, many times larger than our Sun. The rate of mass transfer can become so large that this initially heaviest star eventually becomes lighter than its companion. This phase of mass transfer will not change the ultimate fate of the supergiant star and it will still be the first of the two to explode as a supernova.

An important result of the mass transfer process is, however, that the central remnant of the supernova explosion, i.e. a neutron star or a black hole will remain gravitationally bound in an orbit around the companion OB star, also after it has received a high kick velocity.

(continued on page 2)

(continued from page 1)

Compact companions of runaway stars

Thus, from what is known about the evolution of heavy stars in binary systems, an OB-runaway that is expelled from an OB-association by a supernova explosion should be accompanied by a compact star. However, many astronomers have in the past looked carefully for the presence of a neutron star or a black hole around the known OB-runaway stars, but none was ever found. That negative observational result obviously did not lend support to the supernova scenario. This was a long-standing enigma.

Fortunately, it now appears that it has finally been solved. Based on new observations, a group of astronomers [5], headed by Lex Kaper of ESO, has found that a well-known binary system of an OB-star and a compact neutron star possesses all the charateristics of a bona-fide runaway star. Vela X-1 is the brightest X-ray source in the Vela constellation. It consists of a so-called X-ray pulsar [6] which is definitely a neutron star produced by a supernova explosion and an OB star as companion.

Detection of a bow shock around Vela X-1

An image of the surroundings of the comparatively bright OB star HD77581 and its (optically invisible) companion Vela X-1 was obtained with the 1.54-m Danish telescope at La Silla, through a narrow-band H-alpha filter. It clearly shows the presence of a typical bow shock, thus immediately confirming the runaway status of this system. In fact, this is one of the most 'perfect' bow shocks of parabolic form ever observed around an OB-runaway.

Moreover, the orientation of the bow shock indicates that the system is moving towards the north; its origin must therefore lie somewhere south of its present position in the sky. It also turns out that the accordingly deduced path of HD77581 crosses a well-known OB-association with the designation Vel OB1.

At the measured distance of Vel OB1 of about 6000 lightyears, the observed proper motion and radial velocity of HD77581 indicate a space velocity of 90 km/sec. With this velocity, it would have taken HD77581 and its compact companion about 2.5 million years to travel the distance between Vel OB1 and its present position. This corresponds exactly to the expected time that has passed since the supernova explosion of the progenitor star of Vela X-1, as deduced from the observed properties of the binary system.

The puzzle comes together - Now everything fits!

The observation of a bow shock around the OB star HD77581 and its compact companion Vela X-1 supports the scenario originally proposed by Blaauw to create OB-runaway stars by the supernova explosion of the binary companion. Following back the path of the system resulted in the discovery of the place where it was born and from where it escaped after the violent supernova explosion which produced the neutron star that now manifests itself as the strong X-ray source known as Vela X-1.

Notes:

[1] Professor Adriaan Blaauw is a well-known Dutch astronomer. He participated very actively in the build-up of ESO in the 1950's and 60's and he was ESO Director General from 1970 - 1974. He is the author of 'ESO's Early History — The European Southern Observatory from concept to reality' (1991).

[2] The designation OB refers to the classification of their spectra which mostly show absorption lines of hydrogen and helium. Their high surface temperature, in some cases up to 50,000 C, and large masses, from 10 to 50 times that of the Sun, are deduced by analysis of their spectra.

[3] The term supersonic means that the velocity of the moving object is higher than that of the velocity of sound in the surrounding medium. While it is about 330 m/sec in the Earth's lower atmosphere, it is about 10 km/sec in the nearly empty interstellar space.

[4] Professor Edward van den Heuvel works at the University of Amsterdam and is a member of the ESO Council, the highest authority of this Organisation.

[5] The group members are Lex Kaper, Jacco van Loon, Thomas Augusteijn, Paul Goodfrooij, Ferdinando Patat, Albert Zijlstra (ESO) and Rens Waters (Astronomical Institute, Amsterdam, The Netherlands).

[6] In 1971, the current Director General of ESO, Professor Riccardo Giacconi, was one of the first to propose that 'X-ray pulsars' are rapidly rotating neutron stars. ☆

STAR STUFF
Monthly Publication of the Ford Amateur Astronomy Club

Star Stuff Newsletter
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1997 CLUB OFFICERS

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Vice President:	George Korody	810-349-1930
Secretary:	Harry Kindt	313-835-1831
Treasurer:	Ray Fowler	82-92182

GENERAL MEETINGS

The Ford Amateur Astronomy Club holds regular general meetings open to the public on the fourth Thursday of the month at 5:00 PM. Meetings are held at the Ford Motor Credit Company (FMCC) building, Northeast of the World Headquarters build in Dearborn, in conference room 1491, lower floor, East side of the building.

OBSERVING SITE

The Ford Amateur Astronomy Club has an established observing site, by permit, at the Spring Mill Pond area of the Island Lake Recreational Area in Brighton, Michigan located near the intersections of I-96 and US-23. Members are responsible for opening and closing the gate after the parks 10:00pm closing time. The combination for the lock should be available on our hotline number. Always close the gate behind you after 10:00pm whether entering or leaving the park.

OBSERVING HOTLINE NUMBER - (313) 39-05456

On Friday and Saturday nights, or nights before holidays, you can call the hotline number up to 2 hours before sunset to find out if we will be observing that night. Assume that any clear Friday or Saturday night is a candidate observing night unless something else is going on or none of the club officers are able to make it.

WWW PAGE

Computers inside the Ford network or on the Internet can access the F.A.A.C. web page at one of the following addresses:

Ford Intranet:	http://pt0106.pto.ford.com/faac/faac.html
Internet:	http://kode.net/~dougbock/faac/

MEMBERSHIP AND DUES

Membership to the Ford Amateur Astronomy Club is open to both Ford and Non-Ford Motor Company employees. The general public is also welcome to join. The dues structure is as follows:

Annual Individual/Family	$20.00
Lifetime Membership	$100.00

Membership benefits include a subscription to the Star Stuff newsletter, discounts on subscriptions to Astronomy and/or Sky & Telescope magazine(s), after hour use of the observing site at Island Lake, and discounts at selected area astronomical equipment retailers.

NEWSLETTER STAFF

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NEWSLETTER SUBSCRIPTION

A yearly subscription at a rate of $12.00 is available to those who are not members of the Ford Amateur Astronomy Club. Subscriptions are free to other astronomy clubs wishing to participate in a newsletter exchange.

FEBRUARY 1997

SUN	MON	TUE	WED	THU	FRI	SAT
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27 FAAC Meeting	28	

Feb 01 Venus Passes 1 Degree South of Neptune
Feb 03 Comet Russell 4 Perihelion (2.23 AU)
Feb 06 Comet Holt-Olmstead Perihelion (2.15 AU)
Feb 06 Venus Passes 0.3 Degrees South of Jupiter
Feb 07 New Moon (10:07 am)
Feb 07 Mercury Passes 1.4 Degrees South of Neptune
Feb 07 Venus Passes 0.2 Degrees South of Uranus
Feb 10 Comet Shoemaker-Holt 2 Closest Approach to Earth (1.9245 AU)
Feb 12 Mercury Passes 1 Degree South of Jupiter
Feb 13 Mercury Passes 0.9 Degrees South of Uranus
Feb 14 First Quarter Moon (3:58 am)
Feb 16 Jupiter Passes 0.2 Degrees North of Uranus
Feb 22 Full Moon (5:27 am)
Feb 28 Comet Hale-Bopp Crosses the Ecliptic Plane ☆

MEETING ANNOUNCEMENT

The Ford Amateur Astronomy Club (FAAC) holds regular general meetings on the fourth Thursday of each month, except November and December. Our next meeting will be **Thursday, February 27, at 5:00 pm.**

The FAAC meets in the Ford Motor Credit Company (FMCC) building, conference room 1491, located on the lower east side of the building. FMCC is the low building immediately northeast of (but not attached to) Ford World Headquarters in Dearborn. The FMCC building is secured with a card entry system. The easiest way to enter the building for meetings is to park in the northeast lot (Employee Lot 7) and enter through the lower northeast or lower east doors. At 5:00 pm no one seems to have trouble getting in because many people are leaving around that time. At the east door you can dial 0911 on the security phone and say you are here to attend a Ford club meeting, and security will admit you. You may find your way into the building any way you see fit, but direction signs will only be posted at lower northeast and lower east doors. ☆

1/23/97 FAAC MEETING MINUTES

by Harry Kindt (hkindt@voyager.net),FAAC sec'y

The general membership meeting of the Ford Amateur Astronomy Club was called to order at 5:00 PM by our president Bob MacFarland. There were 29 members and guests present. We would like to welcome the newest members to our club; Christopher Hausner, Rod Harris, John Zain and Allan Ipson.

The Treasurer's report was read and accepted. As a reminder, it's that time of the year again, when your annual membership fees are due.

The publication sales committee collected money for the 1997 Wall Calendar and the 1997 Observer's Handbook. An updated club events calendar was passed out to the members. Greg Burnett passed around several astronomy related articles taken from the Science Section of The New York Times.

Doug Bock notified the members of the up-coming DeepSky/Remote Telescope/Photon Acquisition Party at his Northern Cross Observatory on the 8th of February, beginning at 4:00 PM.

George and Pat Korody accepted reservations and collected the money for the First Annual Year-End Dinner Party which is being held at Papa Romono's Headquarters and Restaurant in Plymouth MI. on January 25, 1997

Don Klasser reported on our club's participation in this year's Ice Daze Celebration at the Lake Erie Metro park which was held on Saturday January 18th. Don also repeated his request for volunteers and ideas for several upcoming events these, include:

- The SMAAC on March 1, 1997 in association with EMU.
- The Hale-Bopp Comet Party at Lake Erie Metro Park on the 4th and 5th of April 1997.
- The Astronomy Day Celebration on the 12th of April 1997.
- The Joint (WAS) Astronomy Club Hale-Bopp Comet Party on the 25th and 26th of April at Kensington Metro park.

If you would like to participate in any of these events or need further information, please contact any of the club officers. Bob MacFarland reported on the negotiations with the Lake Erie Metro park officials to set up a Southern observing sight. This sight would be made available for those members living in the South-West area who might find it more convenient than our present Island Lake sight.

Greg Burnett presided over the election of club officers. The results of the election are as follows:

Bob MacFarland was re-elected President by acclimation.
George Korody was elected to the position of Vice-President.
Harry Kindt was re-elected to his present position as Secretary
Ray Fowler was elected to the position of Treasurer.

During our usual pizza and pop break, we held our regular round-table discussion. Members are given a few minutes to introduce themselves and to describe some of their viewing experiences since our last meeting.

Chuck Boren was our main speaker for the evening. Chuck is in the process of building a Lensless Schmidt Camera. Chuck described for us the principle behind the Schmidt Camera and demonstrated the process of grinding the primary lens for the 8" f/3 camera he is in the process of constructing. Thanks Chuck. The meeting was adjourned at 6:45 PM.

On behalf of the executive committee, we would like to thank Pat and George Korody for the fine effort they put forth in organizing our First Annual Year-End Dinner Party. The party turned out to be quite a success with good food, good drink, and good company. We would hope that we can make this dinner a permanent part of our club's activities. Thanks again, Pat and George. ☆

FEBRUARY SPACE HISTORY

The following February events come from the 01/22/97 edition of "Space Calendar." This calendar is compiled and maintained by Ron Baalke (baalke@kelvin.jpl.nasa.gov).

Feb 02 20th Anniversary (1977), Salyut 4 Space Station burnup (USSR)
Feb 05 30th Anniversary (1967), Lunar Orbiter 3 Launch
Feb 07 20th Anniversary (1977), Soyuz 24 Launch (USSR)
Feb 12 50th Anniversary (1947), Sikhote-Alin Meteorite Shower
Feb 14 25th Anniversary (1972), Luna 20 Launch (Soviet Moon Sample)
Feb 20 35th Anniversary (1962), Friendship 7 Launch (John Glenn)
Feb 23 10th Anniversary (1987) of Supernova 1987A Explosion ☆

FEBRUARY 1997 SPACE EVENTS

The following February 1997 events come from the 01/22/97 edition of "Space Calendar." This calendar is compiled and maintained by Ron Baalke (baalke@kelvin.jpl.nasa.gov). Note that launch dates are subject to change.

Feb 04 Mars Pathfinder, Trajectory Correction Maneuver #2 (TCM-2)
Feb 06 Galileo, Orbital Trim Maneuver #19 (OTM-19)
Feb 07 Minisat-01 Pegasus XL Launch
Feb 08 USAF Titan 4B Launch (1st Launch of Titan 4B)
Feb 10 Soyuz TM-25 Launch (Russia)
Feb 11 STS-82 Launch, Discovery, Hubble Telescope Servicing Mission
Feb 14 Lewis LMLV-1 Launch
Feb 15 JCSat-4 Atlas-2AS Launch
Feb 16 Galileo, Orbital Trim Maneuver #20 (OTM-20)
Feb 20 Galileo, 2nd Europa Flyby (Orbit 6)
Feb 22 Thor-2A Delta 2 Launch (Norway/USA)
Feb 23 Galileo, Orbital Trim Maneuver #21 (OTM-21)
Feb 26 Progress M-34 Launch (Russia)
Feb 28 Intelsat 801 Ariane 4 Launch ☆

SUPERNOVA TO LIGHT UP AGAIN

From: Richard McCray, Kazimierz Borkowski, John Blondin, Jim Scott at the University of Colorado at Boulder

Supernova 1987A, which provided astronomers a spectacular show 10 years ago, is brightening once again as a rapidly expanding debris cloud from the original explosion slams into an enormous ring of hydrogen gas encircling the dying star.

Estimated to be roughly one light-year, or about 6 trillion miles, in diameter, the gas ring is believed to have formed from material expelled by the star before it shrank from a red supergiant into a blue supergiant some 20,000 years before exploding. The ring should brighten by a factor of 1,000 in both the visible and invisible portions of the light spectrum during the coming decade, according to astrophysicists Kazimierz Borkowski and John Blondin of North Carolina State University and Richard McCray of the University of Colorado at Boulder.

The brightening already is beginning to appear in x-ray emissions observed by the German-NASA ROSAT telescope and in radio emissions observed by the Australia Telescope array. The blast wave being pushed outward by the explosion apparently is encountering diffuse gas inside the ring, the researchers said.

By simulating these observations with a Cray supercomputer at the North Carolina Supercomputing Center, the researchers predict the blast wave will continue to brighten steadily until about 2007 A.D. Then it will strike the dense ring itself, causing a sudden, spectacular display.

"In a sense, this supernova is digging up its own past," said McCray. "It will light up the material that it spewed out long before the explosion occurred."

The research team presented their results at the winter meeting of the American Astronomical Society held Jan. 12 to Jan. 16 in Toronto.

Supernova 1987A is located in the Large Magellanic Cloud that is visible from the Southern Hemisphere. Light from the stellar explosion, which took some 160,000 years to reach Earth, was first detected by astronomers on Feb. 23, 1987.

Despite the dramatic brightening predicted by researchers, it's doubtful the huge ring will be visible to the naked eye as was the original supernova, McCray said. "But it will be a prime target for astronomers for many years to come."

Astronomers are planning to follow the "renaissance" of 1987A with the Hubble Space Telescope. A new imaging spectrometer built by Ball Aerospace of Boulder, Colo., will be added to the orbiting observatory's scientific arsenal during a February 1997 servicing mission, allowing astronomers to see the blast wave at ultraviolet wavelengths and to track its motion as it approaches the ring.

Astronomers also will be able to observe x-rays from the impact using NASA's AXAF telescope following its 1998 launch, the researchers said.

The glowing ball of supernova debris inside the ring is expanding at a rate of more than 5 million miles per hour, said McCray, and the invisible blast wave is expanding roughly twice that fast. In contrast, the gaseous ring is expanding at the comparatively sluggish rate of about 20,000 miles per hour.

The ring is actually the innermost of three rings now encircling the supernova, McCray said. Two other much larger rings, which he dubbed "wagon wheels," can be seen in astronomical images looping trillions of miles outside the innermost ring.

"The origin of these rings is one of many unsolved mysteries left by the supernova," he said. "It's been fading for 10 years, but now it is becoming rejuvenated. The new light from the impact will give us a better chance to solve these mysteries."

Borkowski and Blondin are professors of physics at North Carolina State University. McCray is a professor of astrophysics and a fellow of JILA at CU-Boulder. JILA is a joint institute of CU-Boulder and the National Institute of Standards and Technology.

The research effort was supported by grants from NASA to North Carolina State University and CU-Boulder.

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DECLINE IN SUNSPOTS PREDICTED

From: YALE News Release (contact: Cynthia L. Atwood)

New Haven, CT — Fewer sunspots will erupt on the sun's surface during the next decade, indicating an unexpected decrease in the activity of magnetic fields that churn the sun's hot gases, Yale University and NASA astronomers predict. The milder "space weather" — marked by a decrease in magnetic storms, cosmic rays and ionspheric disturbances — could bring cooler temperatures on earth, fewer power blackouts and less interference with radio waves.

The optimistic prediction, which contradicts that of many other scientists, will be reported Jan. 14 at a meeting of the American Astronomical Society in Toronto, Canada, by Kenneth Schatten of Goddard Space Flight Center/NASA in Greenbelt, Maryland. He and Sabatino Sofia, chairman of the Yale astronomy department, inferred the magnitude of magnetic fields just below the sun's surface from observations with solar telescopes in Stanford and Big Bear, California.

The researchers noted that the sun's magnetic activity, which waxes and wanes in cycles lasting about eleven years, is as notoriously unpredictable as the weather. "During the last 50 years, the sun has displayed more activity than it has since Galileo first observed sunspots in the early 1600's," said Professor Sofia. "Thus, if the next solar cycle shows a downward trend, it could reverse the general rise in activity which has occurred during the past 400 years."

Variations in solar activity have been linked to long-term climate changes on earth, such as the global phenomenon known as the "Little Ice Age" in the 1600's, which was triggered by a century of little solar activity. The relatively abrupt cooling froze the Thames River and caused glaciers around the world to advance. At the other extreme, increased solar activity during the 11th and 12th centuries may have triggered global warming that enabled the Vikings to inhabit Greenland, which they were forced to abandon when solar activity waned, Dr. Schatten said.

If his prediction for the coming decade proves accurate, the milder space weather could help moderate global warming expected from the greenhouse effect. It also would be good news for NASA, the Air Force and others whose high-tech equipment is often affected by solar storms, Professor Sofia said. For example, the enhanced "drag" caused by a thickening in the earth's upper atmosphere during solar storms can make satellites fall from orbit prematurely. The shortened life of the Skylab satellite in the late 1970's was due to the exceptionally high level of solar activity at that time.

Furthermore, enhanced solar cosmic rays can sometimes cause "glitches" in the sophisticated electronic systems of satellites, while large solar storms have been known to cause widespread power blackouts, especially in northern latitudes, when power surges blow out transformers.

Not everyone agrees with the Schatten and Sofia model for predicting solar activity, which is based on the physics of how magnetic fields are generated within the sun by a "dynamo" process, similar to the way an automobile alternator generates electrical voltages. Their Solar Dynamo Amplitude index — which they call the SODA index because it provides a prediction of the amount of magnetic flux, or "fizz," below the sun's surface — indicates that the next solar cycle will peak in the year 2000.

Many statisticians are predicting a continued increase in solar activity, based on recent patterns of fluctuations, said Dr. Schatten, who explained that solar physicists divide cycles into odd and even pairs. For most cycles — and for all during this century — solar activity during the odd cycle of a pair exceeded that during the previous even numbered cycle. Since the current, even-numbered cycle was the second largest in recorded history, the next cycle would by expected to be larger still.

Yet, the Schatten & Sofia model predicts a significant downturn. "Are solar cycles random, or do they follow rules and behave predictably, in the manner that planets orbit the sun? Put simply, will our prediction technique beat the statistical rules, or will the statisticians win? Stay tuned," said Professor Sofia.

Sabatino Sofia is associate director of Yale's Center for Solar and Space Research. He developed the Solar Disk Sextant, which is a candidate for installation in the year 2002 aboard the U.S. space station. The experiment is designed to provide more accurate measurements of changes in the sun's diameter and shape, and its long-term cyclic changes in energy output.

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FROM STARS TO NEUTRINOS

From: Sally Pobojewski (pobo@umich.edu)

TORONTO, ONT. — University of Michigan astrophysicists Fred Adams and Greg Laughlin have seen the future and it is dark.

Far in the future, they say, after the stars have burned themselves out, the galaxies dispersed and the black holes radiated away, the universe will be nothing but a vast sea of electrons, positrons, neutrinos and radiation immersed in nearly complete and total blackness.

Adams and Laughlin are not reading the universe's future in a crystal ball. "The same fundamental physical laws we study today can be used both to understand how the universe began and to explain how it will end," Adams said. Until now, scientists have been so focused on unlocking the secrets of the universe's past that few have bothered to think much about what will happen in the future.

At a press conference held here today (Jan. 15) during the American Astronomical Society meeting, Adams and Laughlin described their vision of the long-term fate of the universe. A detailed analysis of their research on the future evolution of astrophysical objects, titled "A Dying Universe," also will be published in the April 1997 issue of Reviews of Modern Physics. (Preprints are available on request.)

Understanding the universe's future requires a fundamental shift in our thinking about time, which Adams — a University of Michigan associate professor of physics and winner of this year's AAS Warner Prize — calls the "Copernican Time Principle." "Copernicus taught us that the Earth is not located at the center of the universe," Adams explained. "It is equally true that our current cosmological epoch has no central place in time. We live in an important time in the universe's development, but interesting events will continue to occur as long as the universe exists."

To describe the immense time scales involved in the future evolution of the universe, Adams and Laughlin introduced a convenient new unit of time in their study, which they call a "cosmological decade." Each cosmological decade represents a tenfold increase in the number of years which have elapsed since the beginning of time. For example, the universe is currently only about 10 cosmological decades or 10 billion years old (10 multiplied by itself 10 times). The most distant epochs considered in the University of Michigan study will not occur until the 200th cosmological decade (10 multiplied by itself 200 times).

In their study, the University of Michigan scientists divide future development of the universe into several distinct periods or eras, including:

The Stelliferous or Star-Filled Era — Cosmological Decades 6-14.

We live at the mid-point of the Stelliferous Era, a time in the history of the universe when energy is generated by the birth, life and death of stars. In their study, Adams and Laughlin pay special attention to the longevity of the universe's most ordinary stars — red and white dwarfs.

"Most red dwarfs have considerably less than half the mass of our sun, but they are so numerous that their combined mass is greater than the mass of all the larger stars in the universe," said Laughlin, a University of Michigan post-doctoral fellow. "Red dwarfs are real misers at burning hydrogen. They hoard their energy and some will still be around 10 trillion years from now when the last sun-like star has long since exhausted its fuel supply and collapsed into a white dwarf."

The Degenerate Era - Cosmological Decades 15-37.

When star formation and stellar evolution cease, the universe will move into the Degenerate Era. "The only remaining stellar objects will be degenerate stellar remnants, such as white dwarfs, brown dwarfs, neutron stars and black holes," Laughlin said. During this era, galaxies will begin to relax dynamically with some stellar remnants moving out to the edge of the galaxy and others falling to the center. "An occasional rare burst of energy will be generated when two brown dwarfs collide to create a new low-mass star," Laughlin added. "But on average this will happen only once every quadrillion years in a galaxy the size of the Milky Way."

Capture of dark matter or WIMPs (Weakly Interacting Massive Particles) by white dwarfs will provide another low-level energy source for the dying universe, according to Adams. "WIMPs annihilating through collisions in the centers of white dwarfs will produce small amounts of energy. As they are depleted from the galactic halo, however, the energy level in the universe will continue to decline."

By cosmological decade 30 or so, the supply of dark-matter particles will be exhausted and matter in the universe will be limited to white and brown dwarfs, neutron stars and a few scattered dead planets. Finally, the mass of white dwarfs and neutron stars will begin to dissipate through a process called proton decay.

"A white dwarf fueled by proton decay generates approximately 400 watts — enough to run a few light bulbs," Laughlin said. "An entire galaxy of these stars would have a total luminosity smaller than one hydrogen-burning star."

"As protons decay, a large fraction of the 'ordinary' mass in the universe is eventually converted into radiation," Adams said. "The proton decay epoch thus will initiate the most significant change in the future universe."

The Black Hole Era - Cosmological Decades 38-100.

Although black holes probably will outlive white dwarfs, brown dwarfs and neutron stars, they won't last forever. Fed by material falling to the center of galaxies during the Degenerate Era, black holes will grow larger for a long time. But even their enormous mass will eventually dissipate in thermal radiation, photons and other decay products through a quantum mechanical process first proposed by Stephen Hawking. "Even a black hole with the mass of a large galaxy will evaporate on a time scale of about 98 to 100 cosmological decades," Adams said.

The Dark Era - Cosmological Decades 100 and beyond.

"Once the black holes have radiated away, the universe will consist of a diffuse sea of electrons, positrons, neutrinos and radiation," Adams said. Even though only a few complex particles will exist at this time in the far future of the universe, Adams maintains there is a possibility that interesting things will continue to happen. "The apparent poverty of this distant epoch is most likely due to our difficulties in extrapolating far enough into the future, rather than an actual dearth of physical processes," he said.

The University of Michigan research project was supported by the National Science Foundation, NASA and the university's Department of Physics. Initial work was developed for use in the Winter 1996 University of Michigan undergraduate theme semester, "Death, Extinction and the Future of Humanity," which was sponsored by the university's College of Literature, Science, and the Arts.

☆

OBSERVATIONS

by Greg Burnett

Another cold, rainy night, stuck in rush-hour traffic. Through a wiper-streaked windshield, red tail-lights parade endlessly into bleary darkness. The mind wanders, red lights! Perhaps there are astronomers nearby? The slowly shifting garnet glare sparkles in spattering raindrops and shimmers on glossy black pavement.

All these vehicles are burning fossil fuel, refined hydrocarbons from bio-mass that flourished long ago in the geologic past. Most of our crude oil comes from the Cenozoic Era, which began 65 million years ago. Some is even older, originating as far back as 500 million years.

But no matter the vintage, it's all pretty much the same, liquefied energy, tapped now to power hoards of vehicles for 20-th century civilization; energy that originally accumulated in plants and animals, mostly aquatic, settling to the bottom of some prehistoric ocean, eventually to be buried under layer after layer of sedimentary rock. At last drilled out, percolated through refineries, trucked to local services stations, and pumped covetously into our mechanical chariots, a bit of that energy has found its way to the red tail-lights now glaring in my eyes and blocking my path.

The mind takes flight in such idle moments, finding beauty and wonder in the most common of circumstances. You can almost feel the warmth on your face. What is it? Sunshine, as old as light from the stars!

☆

ORION SHORT-TUBE TELESCOPE

by Jay Reynolds Freeman (freeman@netcom.com) via sci.astro.amateur

I have been hoping to encounter Orion's new, "ShortTube" telescopes in the field, but no luck to date. So I will post a few comments based on long looks at the units in Orion's showrooms in the Bay Area. (Actually, that should read "Telescope & Binocular Center's showrooms", since the organization just changed its name.)

Orion has a pretty good reputation for holding the line on quality at the low-price end of the telescope spectrum. Both the ShortTube 80mm Refractor and the ShortTube 4.5" Equatorial Reflector fall well shy of perfection, yet at $249 each, they are still quite a lot of telescope for the money.

The stubby ShortTube 80 mm f/5 refractor sells as optical tube assembly only. The unit has a nice finder, a 6x30 whose detachable dovetail-footed stalk is long enough so the rest of the telescope doesn't poke through your jaw when you are trying to use it. It comes with two Kellner eyepieces — 10 mm and 25 mm — and a 45-degree erecting diagonal, all in 1.25-inch size. A mounting block allows the unit easily to be attached to a photographer's tripod or to any similar mount. The mechanical parts seemed reasonably made, and worked smoothly. Fit and finish was good.

Unhappily, there were some problems with the optics. The focuser tube was larger than 1.25-inch diameter for most of its length — a bushing at the eye end reduced it to size — but even so, its skyward end vignetted the objective down to an aperture more like 70 mm, even dead on axis. Judicious use of a hack saw on the upper end of the focus tube might allow full aperture without over-restricting focal travel, but I did not want to perform the operation with Orion's clerks looking on, so that speculation remains unverified.

I had no chance to do critical optical evaluation, but in simple, across-the-street views, there was lots of chromatic aberration painfully in evidence, including both longitudinal and lateral color.

You expect longitudinal color from an 80 mm f/5 refractor using conventional glass types, and what's more, the view I had was with the prism-type image erector in place. At f/5, a prism with an in-glass optical path of several cm introduces enough longitudinal color to put the system out of the Rayleigh limit with respect to color, all by itself alone. It introduces spherical aberration, too, in amounts that are just as bad. Manufacturers and vendors keep forgetting this matter, or more likely have never learned it: Unless designed in as part of the system, a prism has no business whatsoever in a fast optical instrument used at much more than very low magnification. I will be quite curious how good the optics in this unit are when tested with either a straight-through view (needs an extension tube) or a mirror diagonal. The lateral color may have had more to do with the Kellner eyepieces than with the objective, but longitudinal color dominated too much to be sure.

Most of what's wrong with the ShortTube 80 mm would be fixed if the f-number were increased by about 3. At f/8, a conventional-glass 80 mm doublet could be reasonably corrected for color, a prism diagonal wouldn't wreak nearly as much havoc with the image, the focuser would not vignette, and the whole system would still be light and compact enough for a photo tripod. Or, Orion could put it on one of their light equatorial mounts and go head-to-head on price and performance with the Celestron FirstScope 80 (the non-Premium one), with a substantial advantage in compactness and rigidity.

Even with the aberrations and vignetting, this instrument might be a quite decent highly portable low-power telescope. Think of it as half a binocular, with the versatility of changing eyepieces, and you will see what I mean. But it will take field testing to tell for sure.

The ShortTube 4.5-inch Equatorial Reflector is a more complete unit; it has the same two Kellner eyepieces, a very cheesy 5x12 plastic finder, and a lightweight equatorial mount and tripod. I'd scrap the finder, and glue a couple of pushpins to the tube, as a simple sight. The mount is on the ragged edge of being too light, and uses rather more pot metal than I like; Orion could probably offer an altazimuth of much better quality for the same price.

The optics are interesting. No, no, I mean, really! The 18-inch long tube holds an f/10 telescope. It's not the Newtonian it appears to be in the catalog — the design has what amounts to a built-in Barlow lens installed in the focuser. Only, I don't think it's a Barlow — I think the overall design is something like a Brixner or a Jones-Bird (look those up in your _Sky_&_Telescope_ master index). That is, I suspect the primary is a sphere, not a paraboloid — who'd make paraboloids if you didn't have to? — and the "Barlow" not only amplifies the focal length, but also cancels out the spherical aberration.

I suspect the telescope is a bear to collimate, has remarkable off-axis aberrations, and shows some color on-axis, as well. So what, a mounted 4.5-inch telescope for $249 ought to be a real winner even with minor problems, right?

Maybe so, but the ShortTube 4.5-inch is not a 4.5-inch telescope. The diagonal is too small! It vignettes the primary to something a lot closer to three inches. I'm tempted to get one, put in a diagonal of a more reasonable size, and see what's what. But even a decently mounted three-inch for $249 would be a welcome addition to today's entry-level telescope market. I would really like to see what one of these instruments performs like in the field; without doing so, I have insufficient information to recommend it.

This review has praised and damned about equally, so I will end it on a positive note. Orion — I mean, Telescope & Binocular Center — ought to be a big enough buyer to have some clout with the overseas firms that manufacture the ShortTube units. I hope they use their influence promptly and wisely, and fix some of the problems I have mentioned here. It would be greatly to their benefit to do so: These inexpensive telescopes are very close to being real winners, in a part of the beginner's telescope market where decent offerings are now very scarce. ☆

PHYSICS NEWS UPDATE

The American Institute of Physics Bulletin of Physics News (physnews@aip.org) by Phillip F. Schewe and Ben Stein

MOUNTAINS ON THE SUN. The SOHO spacecraft, dedicated to observing the sun and doppler-mapping the rise and fall of material and the passage of vibrations across the sun's face, has detected the presence of extended structures a third of a mile high on the solar surface. Jeffrey Kuhn of Michigan State, speaking at this week's American Geophysical Union meeting in San Francisco, said the bumps persisted in the same place on the surface for a month or more. (San Jose Mercury News, 18 December 1996.)

OXYGEN DATING THE MILKY WAY. A new technique uses stardust to formulate an age for our galaxy. By looking at the isotopic composition of meteorites, scientists can tell whether certain grains came from outside the solar system. Such specks of matter would also necessarily predate the solar system and would have originated in other stars, either as part of the stellar wind gusting away from red giant stars or as the debris of ancient supernovas (Science, 15 November). Larry Nittler, now of the Carnegie Institution of Washington (202-686-4370, x4421), has sorted 87,000 oxide grains according to two composition ratios: O-16/O-17 and O-16/O-18. From this huge sample he has isolated 87 grains that seem to be "presolar" in nature. Employing these bits of stardust to represent extrasolar material, and using theories about how the heavier elements are cooked in successive cycles of supernovas, Nittler can estimate an age for the Milky Way galaxy—14.4 (with a statistical uncertainty of 1.3) billion years. (L.R. Nittler and R. Cowsik, upcoming article in Physical Review Letters.)

SPACE WEATHER, like the more familiar lower-atmosphere weather, is a vast agglomeration of fronts and storms that changes by the minute. Filled with radiation and particles arriving from the sun and influenced by a potent terrestrial magnetic field, the near-earth space environment is increasingly important because of the numerous communications and positioning satellites parked there. Components on these craft, as well as astronauts and even passengers in high-flying aircraft, are also potentially endangered when storms on the sun send flurries of particles toward our planet. The National Space Weather Program, an inter-agency system of weather-forecasting instruments and data processing centers, will in coming years provide up-to-the-minute assessments of near-earth conditions. (Session at the American Geophysical Union meeting in San Francisco earlier this month.)

DIGITAL MIRRORS. Texas Instruments has developed a digital micromirror device (DMD), basically a planar array of thousands of tiny, independently-steerable mirrors. Each pixel in the device consists of a mirror (only 16 microns across) mounted on a hinged platform. A signal sent to an electrode makes the mirror tilt forward or backward; a beam of light aimed at the pixel is thereby reflected toward a viewing screen or scattered into oblivion. This compact, fully digital form of optical switch is not yet available in a commercial product, but it may have advantages over liquid crystals in large projection display systems. (Physics World, December 1996.) ☆

STATISTICALLY SPEAKING

Location (Dearborn, MI): 42°19'12" N, 83°10'48" W, 180 meters elevation
Local Time = Universal Time - 5 hours (Eastern Daylight Time)

Abbreviations used in reports:
FM Full Moon FQ First Qtr Moon LQ Last Qtr Moon NM New Moon
MR Moon Rise MS Moon Set SR Sun Rise SS Sun Set

Calendar Report for Febuary 1997

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		Lunar Events: Feb 07 NM: 10:07 Feb 14 FQ: 3:58 Feb 22 FM: 5:27 Feb 07 NM: 10:07				1 SR: 7:46 SS: 17:47 MR: 1:44 MS: 12:19
2 SR: 7:45 SS: 17:48 MR: 2:46 MS: 13:02	3 SR: 7:44 SS: 17:50 MR: 3:48 MS: 13:52	4 SR: 7:43 SS: 17:51 MR: 4:48 MS: 14:51	5 SR: 7:42 SS: 17:52 MR: 5:45 MS: 15:56	6 SR: 7:41 SS: 17:54 MR: 6:37 MS: 17:07	7 SR: 7:39 SS: 17:55 MR: 7:24 MS: 18:22	8 SR: 7:38 SS: 17:56 MR: 8:06 MS: 19:37
9 SR: 7:37 SS: 17:58 MR: 8:44 MS: 20:51	10 SR: 7:36 SS: 17:59 MR: 9:21 MS: 22:03	11 SR: 7:34 SS: 18:00 MR: 9:57 MS: 23:12	12 SR: 7:33 SS: 18:02 MR: 10:33 MS: None	13 SR: 7:32 SS: 18:03 MR: 11:10 MS: 0:19	14 SR: 7:30 SS: 18:04 MR: 11:50 MS: 1:22	15 SR: 7:29 SS: 18:05 MR: 12:34 MS: 2:22
16 SR: 7:28 SS: 18:07 MR: 13:20 MS: 3:17	17 SR: 7:26 SS: 18:08 MR: 14:09 MS: 4:07	18 SR: 7:25 SS: 18:09 MR: 15:02 MS: 4:53	19 SR: 7:23 SS: 18:10 MR: 15:56 MS: 5:33	20 SR: 7:22 SS: 18:12 MR: 16:51 MS: 6:10	21 SR: 7:20 SS: 18:13 MR: 17:48 MS: 6:43	22 SR: 7:19 SS: 18:14 MR: 18:44 MS: 7:14
23 SR: 7:17 SS: 18:15 MR: 19:41 MS: 7:44	24 SR: 7:16 SS: 18:17 MR: 20:39 MS: 8:12	25 SR: 7:14 SS: 18:18 MR: 21:37 MS: 8:41	26 SR: 7:13 SS: 18:19 MR: 22:35 MS: 9:11	27 SR: 7:11 SS: 18:20 MR: 23:35 MS: 9:43	28 SR: 7:09 SS: 18:22 MR: None MS: 10:18	

Planet View Info Report for February 1997

Date	Rise	Set	RA	Dec	Elongation	Ill Fr	DIST(AU)
Mercury							
2/ 5/1997	6:39	15:56	19h44m11s	-21°51'19"	22°10'50"	0.796	1.18574
2/12/1997	6:48	16:18	20h26m46s	-20°33'09"	19°19'48"	0.857	1.26460
2/19/1997	6:55	16:46	21h11m18s	-18°11'40"	15°42'37"	0.906	1.32339
2/26/1997	6:59	17:19	21h57m06s	-14°45'15"	11°20'15"	0.948	1.36155
Venus							
2/ 5/1997	7:06	16:38	20h18m50s	-20°18'10"	13°57'42"	0.973	1.64450
2/12/1997	7:06	16:55	20h55m02s	-18°19'43"	12°18'21"	0.979	1.66145
2/19/1997	7:04	17:12	21h30m17s	-15°55'34"	10°38'31"	0.984	1.67650
2/26/1997	6:59	17:30	22h04m36s	-13°09'43"	8°58'12"	0.989	1.68968
Mars							
2/ 5/1997	21:49	10:03	12h27m10s	0°47'23"	130°13'29"	0.946	0.84917
2/12/1997	21:19	9:35	12h26m35s	1°00'34"	137°29'58"	0.958	0.79777
2/19/1997	20:47	9:06	12h23m40s	1°27'28"	145°22'07"	0.971	0.75268
2/26/1997	20:11	8:36	12h18m23s	2°07'13"	153°48'36"	0.982	0.71516
Jupiter							
2/ 5/1997	7:07	16:40	20h23m15s	-19°45'46"	12°48'55"	1.000	6.07597
2/12/1997	6:44	16:21	20h29m57s	-19°23'24"	18°16'56"	0.999	6.04475
2/19/1997	6:22	16:01	20h36m32s	-19°00'33"	23°45'12"	0.998	6.00360
2/26/1997	5:59	15:42	20h42m56s	-18°37'25"	29°14'04"	0.998	5.95297
Saturn							
2/ 5/1997	9:46	21:46	0h16m52s	-0°37'13"	47°26'20"	0.999	10.11622
2/12/1997	9:20	21:22	0h19m27s	-0°19'29"	41°04'04"	0.999	10.19708
2/19/1997	8:54	20:58	0h22m12s	-0°00'50"	34°45'52"	0.999	10.26817
2/26/1997	8:28	20:35	0h25m04s	0°18'31"	28°31'32"	0.999	10.32881
Uranus							
2/ 5/1997	7:13	16:48	20h31m13s	-19°29'37"	10°56'21"	1.000	20.77030
2/12/1997	6:47	16:23	20h32m52s	-19°23'49"	17°37'21"	1.000	20.74264
2/19/1997	6:20	15:57	20h34m28s	-19°18'08"	24°17'57"	1.000	20.70176
2/26/1997	5:54	15:31	20h36m01s	-19°12'39"	30°58'07"	1.000	20.64831
Neptune							
2/ 5/1997	6:45	16:15	20h00m38s	-20°06'57"	18°04'49"	1.000	31.09039
2/12/1997	6:19	15:49	20h01m41s	-20°03'58"	24°55'06"	1.000	31.04687
2/19/1997	5:52	15:22	20h02m41s	-20°01'05"	31°44'48"	1.000	30.99041
2/26/1997	5:25	14:56	20h03m38s	-19°58'20"	38°33'54"	1.000	30.92191
Pluto							
2/ 5/1997	2:23	13:22	16h22m32s	-8°49'57"	71°23'12"	1.000	30.25543
2/12/1997	1:56	12:55	16h23m00s	-8°48'47"	78°11'13"	1.000	30.14330
2/19/1997	1:28	12:28	16h23m22s	-8°47'15"	85°00'00"	1.000	30.02826
2/26/1997	1:01	12:01	16h23m37s	-8°45'23"	91°49'10"	1.000	29.91200

Planet/Moon Apsides Report for February 1997

2/ 7/1997	Moon @ Perigee	Hour: 16	Distance: 356860 (km)	Diam.: 0.5581°
2/10/1997	Mercury @ Aphelion		Distance: 0.47 (AU)	
2/21/1997	Moon @ Apogee	Hour: 12	Distance: 406401 (km)	Diam.: 0.4901°
2/22/1997	Venus @ Aphelion		Distance: 0.73 (AU)	

Twilight Report for February 1997

	Sun		Astronomical		Nautical		Civil	
Date	Rise	Set	Begin	End	Begin	End	Begin	End
2/ 5/1997	7:42	17:52	6:02	19:33	6:34	19:00	7:07	18:27
2/12/1997	7:33	18:02	5:54	19:41	6:26	19:08	6:59	18:35
2/19/1997	7:23	18:10	5:45	19:49	6:17	19:16	6:50	18:44
2/26/1997	7:13	18:19	5:35	19:57	6:07	19:24	6:40	18:52

☆

SKY & TELESCOPE NEWS BULLETINS

from the editors of Sky & Telescope magazine

SOFIA

NASA has given the Universities Space Research Association the go-ahead to acquire a Boeing 747SP jumbo jet for the Stratospheric Observatory for Infrared Astronomy, or SOFIA. The aircraft will be modified to house a 2.5-meter-wide telescope and should make its first observational flight in the year 2001. The German space agency is providing the telescope for this international project. SOFIA will fly at an altitude of 13 kilometers (42,000 feet), above most of the atmosphere's infrared-opaque water vapor. It replaces the Kuiper Airborne Observatory which flew from 1974 to 1995 with a 0.9-meter telescope.

NEW BLACK-HOLE EVIDENCE

Astronomers from around the world braved the wintry elements to gather in Toronto, Ontario, last week. Among the hundreds of presentations was new evidence that binary star systems emitting X-rays consist of recognizable stars orbiting black holes. V404 Cygni, a binary system 10,000 light-years away, gives off X-rays as matter shed by its visible star heats up while rushing into the black hole's gravitational well. But, according to Ramesh Narayan and his colleagues, only a tiny fraction of the energy expected from this infall seems to find its way out as visible light or X-rays; the rest, they conclude, is being reabsorbed by material which then falls into the black hole. Thus their model may be showing that "event horizons" — the one-way doors from which energy and matter can never escape — really exist.

EUROPA'S ERUPTIONS

At a press conference on January 17th, NASA scientists presented views of the enigmatic ice moon Europa that show features only 35 meters across — roughly the size of a baseball diamond. The jumble of cracks and ridges seen on a global scale continues in ever-finer variation right down to the limit of resolution. More important, some of the views reveal what appear to be eruptions onto the surface from the interior. Based on their thickness, the flows were not liquid water but had the consistency of thick slush. In addition to ice volcanism, investigators can see that the surface is modified by crustal spreading in some places and a strange tectonic collapse in others. More and more evidence suggests that Europa's outer crust is thin, perhaps only a few kilometers thick in places, and that something else — an ocean or rock-ice-water slush — lies just out of sight below. ☆

COMET COMMENTS (1/7/97)

By Don Machholz (DonM353259@aol.com)

Comet Hale-Bopp continues to brighten in the morning sky. It is an easy naked-eye object for early risers. In February and early March the comet is visible in the morning eastern sky. As March progresses the comet is better visible in the evening western sky. On the evening of Sunday March 23 a partial lunar occurs for the US, and Saturday April 12 is Astronomy Day. These nights, and those in-between, are good ones on which to show the comet. Then from after Full Moon (April 22) until the comet moves too far south to be easily visible (the first week of May) you'll have your last opportunities to view Comet Hale-Bopp.

EPHEMERIDES: C/1995 O1 (Hale-Bopp)

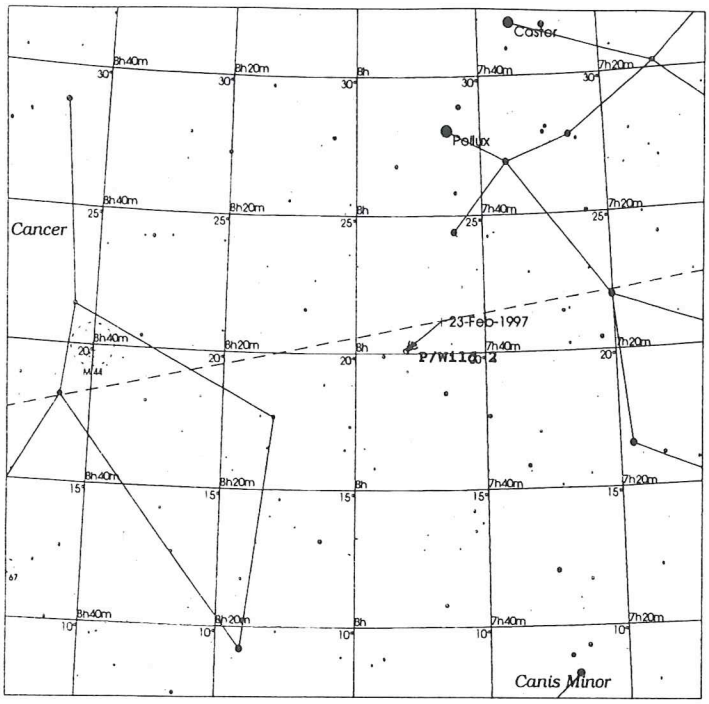
Date(00UT)	R.A. (2000)	Dec	El	Sky	Mag
02-01	19h40.5m	+15°29'	38°	M	1.4
02-06	19h53.4m	+18°01'	40°	M	1.1
02-11	20h07.8m	+20°50'	41°	M	0.7
02-16	20h24.8m	+24°05'	43°	M	0.5
02-21	20h44.1m	+27°31'	44°	M	0.0
02-26	21h06.9m	+31°10'	45°	M	-0.1
03-03	21h34.1m	+34°57'	46°	M	-0.4
03-08	22h06.8m	+38°40'	46°	M	-0.6

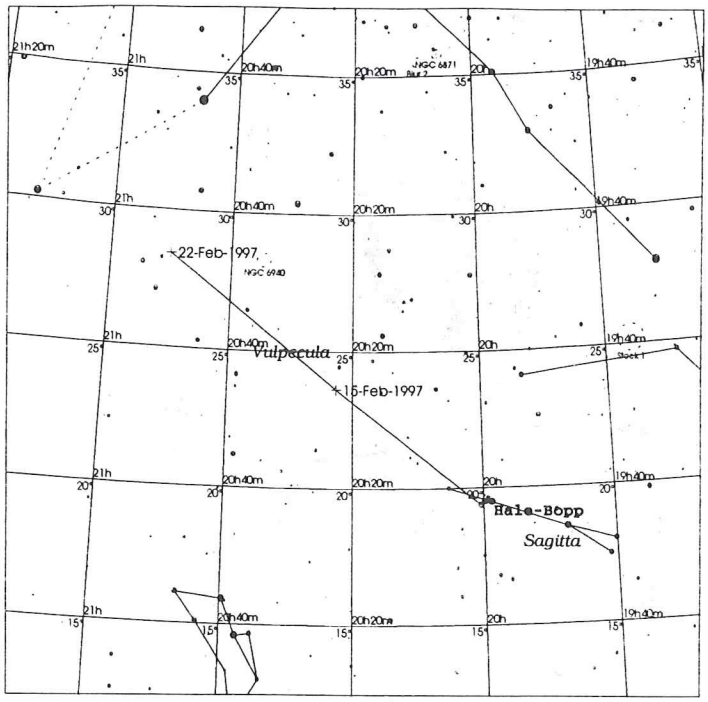
EPHEMERIDES: 81P/Wild 2

Date(00UT)	R.A. (2000)	Dec	El	Sky	Mag
02-01	07h58.2m	+19°22'	166°	E	10.6
02-06	07h54.3m	+19°49'	159°	E	10.5
02-11	07h51.1m	+20°16'	154°	E	10.4
02-16	07h48.5m	+20°40'	148°	E	10.4
02-21	07h47.0m	+21°02'	142°	E	10.3
02-26	07h46.5m	+21°21'	137°	E	10.2
03-03	07h47.1m	+21°37'	132°	E	10.2
03-08	07h49.0m	+21°49'	128°	E	10.2

(Note: M = morning sky, E = evening sky) ☆

FINDING COMET P/WILD 2 AND COMET HALE-BOPP





STARS	SOLAR SYSTEM		NOTES
<0 • 5 1 • 6 2 >7 3 4	☿ Mercury ♅ Uranus ♀ Venus ♆ Neptune ♂ Mars ♇ Pluto ♃ Jupiter ☄ Comet ♄ Saturn ⚬ Asteroid	⬭ Galaxy ⊕ Globular Cluster ∴ Open Cluster ✧ Planetary Nebula ☐ Diffuse Nebula ○ Other Object	

Local Time: 22:00:00 8-Feb-1997 UTC: 03:00:00 9-Feb-1997 Sidereal Time: 06:44:16
Location: 42° 19' 12" N 83° 10' 48" W RA: 8h00m00s Dec: +20° 00' Field: 25.0° Julian Day: 2450488.6250

STARS	SOLAR SYSTEM		NOTES
<0 • 5 1 • 6 2 >7 3 4	☿ Mercury ♅ Uranus ♀ Venus ♆ Neptune ♂ Mars ♇ Pluto ♃ Jupiter ☄ Comet ♄ Saturn ⚬ Asteroid	⬭ Galaxy ⊕ Globular Cluster ∴ Open Cluster ✧ Planetary Nebula ☐ Diffuse Nebula ○ Other Object	

Local Time: 07:00:00 8-Feb-1997 UTC: 12:00:00 8-Feb-1997 Sidereal Time: 15:41:48
Location: 42° 19' 12" N 83° 10' 48" W RA: 20h20m00s Dec: +25° 00' Field: 25.0° Julian Day: 2450488.0000

Ford Amateur Astronomy Club
Star Stuff Newsletter
P.O. Box 7527
Dearborn, MI 48121