NASA
National Aeronautics and Space Administration
Goddard Space Flight Center

Goddard News

Greenbelt, Maryland / Wallops Island, Virginia

November 1993 Vol. 40 No. 11

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Hubble deep-sky survey finds interacting galaxies in a cluster

While preparations are being made on the ground for the early December Hubble Space Telescope (HST) First Servicing Mission, the HST on-orbit continues to deliver first-class scientific information.

In one of the deepest celestial surveys yet made by the Goddard-managed Hubble Space Telescope, astronomers have discovered a small group of previously unknown interacting galaxies estimated to be 3 billion light-years away.

Because Hubble caught the galaxies in an early stage of evolution, they offer new clues to developing a much clearer understanding of how galaxies have changed over time.

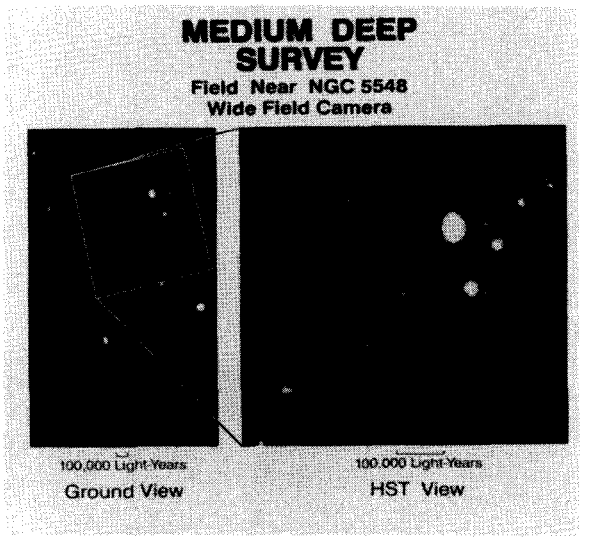
Nearly half of the galaxies appear to be merging with one another in the Hubble image. This suggests a very rapid evolution of galaxies and clusters of galaxies over very short time spans, according to astronomers. These results might help improve theories which predict that galaxies evolved faster than earlier thought, perhaps due to the influence of dark matter — invisible or undetected mass pervading the Universe.

A galaxy is a city of stars held together by their mutual gravitation. Galaxies are considered the basic building blocks of the Universe. HST's high resolution image reveals that many early galaxy "building blocks" are in pairs.

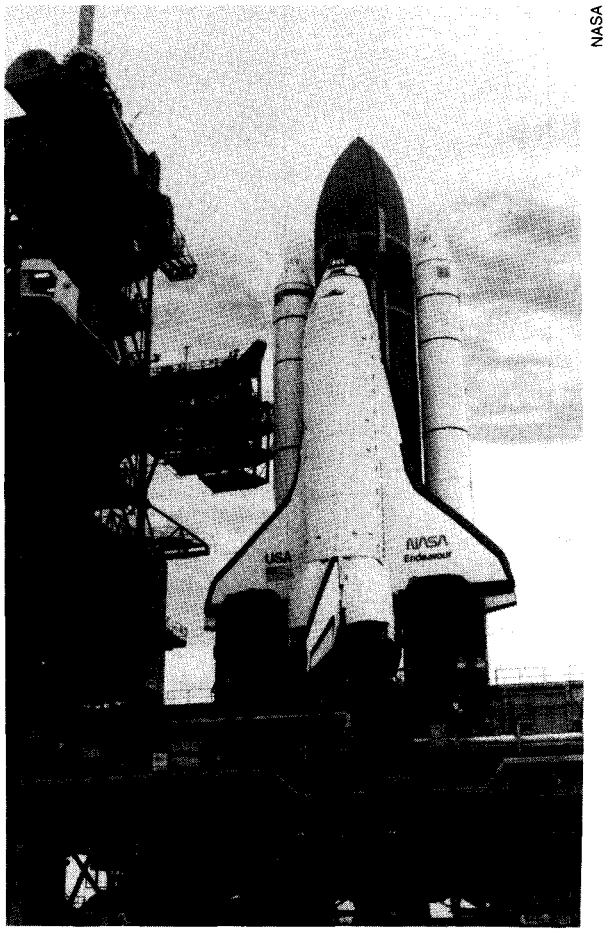
"In many of the pairs, at least one galaxy is blue, which indicates that star formation is underway at a high rate, possibly triggered by interaction with the neighbor galaxy," says Dr. Richard Griffiths, The Johns Hopkins University, Baltimore. "Such mergers and interactions may be the rule within galaxy clusters rather than the exception."

"Though the largest galaxy in the image is about the size of our own Milky Way galaxy, most of the galaxies detected are much smaller than our own. They might eventually merge to form the many large galaxies that

Continued on page 2

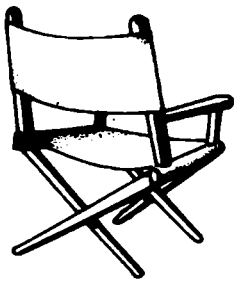


Endeavour ready for STS-61



NASA

The Space Shuttle Endeavour arrives at Launch Pad 39B. Endeavour is being readied for the STS-61 mission, targeted for liftoff in early December. During the 11 day flight, the seven-member crew will carry out the first servicing mission of the Hubble Space Telescope using tools developed at Goddard.



Directors' Dialogue

Q: How does an employee become eligible for being a recipient of the Leave Donor Program?

A: To become a leave recipient, an employee or a family member of an employee must have a medical emergency that is likely to or will require an employee's unpaid absence from duty for at least 10 workdays, and therefore, result in a substantial loss of income.

Q: How long does a person remain a Leave Donor Recipient after he/she returns to work?

A: After leave recipients return to work, they remain in the Leave Transfer Program until they have received either the amount of leave needed to cover the medical emergency or 1 year after the medical emergency ends, whichever occurs first. Any questions regarding the Leave Transfer Program may directed to Clita Graham at the Employment and Employee Services Branch on Ext. 6-8930.

Roger L. Jenkin,
director, Office of Human Resources, Code 110

Questions for Directors Dialogue may be sent in to Directors' Dialogue, Code 130, with or without identification. Due to space limitations, not all questions can be answered. Questions are sent to the appropriate directorate office as written but may be edited for space and clarity before being printed. Some questions may be answered outside of this forum.

Goddard scientist receives award for achievement

by Allen Kenitzer

Dr. Compton J. Tucker, Code 923, a research scientist in the Laboratory for Terrestrial Physics at Goddard has been awarded the 1993 National Air and Space Museum Trophy for current achievement. This award is bestowed annually on a single individual or team for extraordinary service in air and space science and technology. Dr. Tucker accepted the award at the National Air and Space Museum-Smithsonian Institution in Washington, D.C., on Oct. 22, 1993.

Tucker began his career at Goddard in 1975 as a National Research Council postdoctoral fellow and subsequently joined NASA in 1977. He has specialized in using satellite observations to study the Earth's vegetation, including questions about the carbon cycle, tropical deforestation and desertification. Some areas of recent and continuing work include quantifying expansion and contraction of the major deserts of Africa and Asia and determining tropical deforestation and habitat fragmentation in the Amazon Forest of South America.

Tucker received the NASA Exceptional Scientific Achievement Medal in 1986 for his work using satellite data to study Earth's vegetation. In 1988, he was appointed as a NASA/Goddard Senior Fellow. In 1992, Tucker was awarded the Henry Shaw medal from the Missouri Botanical Gardens for his contribution to the plant sciences using satellite data. He is the author of more than 80 scientific and technical publications and is a member of the American Association for the Advancement of Science.

In addition to his duties in the Laboratory for Terrestrial Physics, Tucker is an adjunct professor at the University of Maryland in College Park, Md.

(A story about Tucker's work appears on page 4.)

Smithsonian Institute

Goddard's Compton Tucker with trophy.

Deep-sky survey

Continued from page 1

we see in the Universe at the present day," he says.

Over the past 2 years, Griffiths and colleagues at The Johns Hopkins University, with a team of astronomers in the United States and Britain, have used the Hubble Space Telescope to carry out a serendipitous survey of small areas of sky. This is done with the HST Wide Field Camera, which is used to take a picture of a piece of sky close to a main target, such as a quasar or galaxy, that is being observed by a different Hubble instrument.

The survey is one of several key projects using Hubble. In previous images, the deep survey has uncovered remote and unusual galaxies never before resolved by an optical telescope. HST's new level of detail reveals a bizarre variety of shapes and structures in these distant galaxies, which previously only appeared as fuzzy blobs from ground-based telescopes.

The Hubble Space Telescope is a program of international cooperation between NASA and the European Space Agency.

The distance to the largest galaxy in the image has been measured by Prof. Rogier Windhorst and his group at Arizona State University, using the Multi-Mirror Telescope in Arizona, operated by the University of Arizona and the Smithsonian Institution.

1993 Antarctic ozone hole reaches record lows

by Allen Kenitzer

Antarctic ozone levels have reached record lows, according to data obtained by scientists at Goddard and the National Oceanic and Atmospheric Administration (NOAA), Climate Monitoring and Diagnostic Lab, Boulder, Colo. These record low levels were recorded at the South Pole Station, Antarctica, at the end of September and early October 1993 and confirmed by satellite measurements.

Preliminary data from NASA's Total Ozone Mapping Spectrometer (TOMS) onboard the Russian Meteor-3 satellite showed values less than 100 Dobson Units (DU) in a region near the South Pole. On October 6, a balloon-borne ozone sensor flown by the NOAA measured only 90 DU down from 275 DU in mid-August. The balloon measurement has an uncertainty of 5 DU more or less than the measured level.

A Dobson Unit is the physical thickness of the ozone layer if it were brought to the Earth surface (300 Dobson Units equals 1/10th of an inch or three millimeters).

These low measurements were confirmed by a surface based Dobson spectrophotometer, which measured 88 DU on October 6, 1993. These are the lowest values of total column ozone ever measured, anywhere in the world.

Previous research by NASA, NOAA and scientists around the world have linked the annual cycle of severe Antarctic ozone depletion to the release of certain chlorine compounds and other chemicals through human activities. Recent international agreements to phase out the use of these chemicals should allow ozone levels to recover over the next century.

"Deep ozone holes will continue to form annually, into the next century," said Dr. Jay R. Herman, Code 916, a research scientist with Goddard's Laboratory for Atmospheres. "This situation will persist until stratospheric chlorine levels decrease."

Ozone, a molecule made up of three atoms of oxygen, comprises a thin layer of the atmosphere which absorbs harmful ultraviolet radiation from the Sun. The term "ozone hole" is used to describe a large area of intense ozone depletion that occurs over Antarctica during late-August through early-October and typically breaks up in late-November.

The balloon-borne ozone altitude profile indicated that ozone was totally destroyed between the altitudes of 8.4 and 11.8 miles (13.5 and 19 kilometers) creating an ozone void 3.4 miles (5.4 kilometers) thick.

The surface area covered by the 1993 ozone hole was nearly as large as the record 1992 ozone hole. The ozone hole reached a maximum extent of 9 million square-miles (23.4 million square-kilometers) on September 21, 1993, based on the preliminary TOMS data.

Since the discovery of the ozone hole in 1985, TOMS has been the key instrument for monitoring ozone levels throughout the southern hemisphere. Since the mid-1980s, the Antarctic region covered by low total ozone began to grow in early August. This region reaches its maximum extent in late September and its greatest depth in early October.

A third TOMS instrument is scheduled for launch onboard a U.S. Earth Probe satellite in 1994 and a fourth aboard the Japanese Advanced Earth Observing Satellite in 1996.

The TOMS instruments are managed by Goddard for NASA's Office of Mission to Planet Earth, Washington, D.C.

What's UP? November 1993

Compton Gamma-Ray Observatory
Days in orbit: 890
The second phase of the spacecraft reboost is expected to began in late November. The second phase will lift the observatory's perigee to 280 miles (450 kilometers) and circularize the orbit. The first phase, successfully completed Oct. 17, lifted the apogee to the same elevation. As of Oct. 25, the perigee was 345.9 kilometers and the apogee 450.1.

Cosmic Background Explorer
Days in orbit: 1,441
The COBE project plans to terminate all instrument operations in late December and will perform end-of-life engineering tests in January. After those tests are completed in mid- to -late-January, the spacecraft will be transferred to Wallops Flight Facility in Virginia for use as a test satellite.

Hubble Space Telescope
Days in orbit: 1,192
The HST First Servicing Mission remains on schedule for launch in early December. date of Dec. 1. The mission originally was scheduled to launch from pad 39A at Kennedy Space Center, Fla. That has been changed to pad 39B due to contamination of pad A from sandblasting of the pad last summer. Some of the sandy material was found on the protective bags covering the hardware. The hardware was transferred back to the Payload Hazardous Servicing Facility, where the bags were to be removed and the hardware inspected for possible contamination, then rebagged with new material. The crew of STS-61 will carry more than 200 tools with them for the servicing mission; many of the tools were developed by Goddard.

NASA helps provide famine early warning for Africa

by Allen Kenitzer

NASA satellite data, processed to study the expansion and contraction of the deserts and semi-arid lands of Africa, are being used to provide early warning of developing famine and control of desert locust swarms in Africa.

Goddard and the U.S. Agency for International Development (AID) are cooperating on this project to provide data to AID's Famine Early Warning System (FEWS). Scientists at Goddard and the U.S. AID's FEWS have been working together since 1987. The effort is directed at understanding the natural variations of climate, as they relate to desert boundaries and adjacent semi-arid areas, and to determine any changes in the 1980-2000 time period.

"The Agency for International Development of our State Department came to us, after seeing some of our publications on remote sensing of the Sahel of Africa, and indicated it was interested in studying the famine stricken regions in Africa," said Dr. Compton J. Tucker, Code 923, a research scientist in the Laboratory for Terrestrial Physics at Goddard. *(See story on Tucker on page 2.)* "Because we use satellites to look at vegetation in these regions, we can obtain data on countries that have been affected historically by famine and do so very close to real time."

Vegetation Measurements

Through the use of daily data from the Earth-observing National Oceanic and Atmospheric Administration (NOAA) -7, -9 and -11 polar-orbiting meteorological satellites, scientists are able to measure the density of green vegetation in a specific region every 10 days. As a consequence of several years of comparing satellite data to ground data in Africa, dating back to 1981, Tucker and his co-worker, Brent Holben, and contractor co-workers, Dr. Christopher Justice, of the University of Maryland, and Wayne Newcomb, of Science Systems Applications Inc., have a good understanding of vegetation and hence, rainfall patterns throughout Africa. Comparing satellite data between or among years for any geographical area is an easy task Tucker said. Data are processed and available for distribution within two to four days after each 10-day period.

"Since 1981, we have compiled a time series of plant growth histories for the entire continent of Africa and use it to assess current and future vegetation growth," Tucker said. "This information is used by AID's FEWS to determine where droughts are occurring, the severity of the drought, and how widespread the drought is."

The AID's FEWS uses the satellite data provided by the GSFC scientists, augments these with meteorological information and socioeconomic information, where available, to determine the location and severity of drought in Africa, Tucker said. When drought conditions are detected, an AID's FEWS team springs into action by coordinating relief efforts, if required The NASA-provided satellite data are invaluable for identifying areas in greatest need of food aid, Tucker explained.

AID is interested in the famine potential of African countries because maximizing the efficiency of supplying food aid to needy countries, saving lives and reducing waste are important. Because there are often so many requests for assistance, the satellite information also saves the U.S. taxpayers money by helping to prioritize allocation of relief efforts, Tucker said. AID also publishes the "Famine Early Warning Newsletter," which is distributed to African countries, AID missions in Africa and donor countries every ten days.

Locust Control

In addition to making possible climatic studies and famine early warning determinations, the same satellite data gathered by the GSFC scientists also are being used to identify areas where desert locust swarms are developing in Africa.

"This is a straight-forward task because we simply look for areas within the desert zone of Africa and adjacent areas of Arabia where anomalous green vegetation development is detected," said Tucker. "The rainfall that enabled growth of green vegetation also provided the soil moisture to hatch desert locust eggs, which often can remain dormant for 10-30 years in the soil, the newly-hatched desert locusts then feed on the green vegetation present."

Developing desert locust swarms often go unreported for several weeks or even months because there are few people within the desert zone. By that time, desert locust populations may have exploded to many millions of insects—the types of desert locust swarms mentioned in antiquity and the Old Testament.

The desert locust can go through a complete life cycle every three to five weeks, depending upon temperature. During the first five growth stages, or "instars," the desert locust is not capable of flight, but in the last two growth stages desert locust swarms have been documented traveling hundreds and even thousands of miles, moving with the prevailing winds. Desert locust swarms devour all green vegetation in their path, as each locust eats its body weight in green vegetation every day.

Satellite Data

The key to effective desert locust swarm control is the use of satellite data to identify areas of probable populations early in the development cycle, Tucker explained.

The satellite data are used to direct more detailed ground or aircraft survey within the 7,000,000 square-mile (18,129,989 square-kilometer) recession-area of the desert locust. The use of NASA-supplied satellite data make possible early control of desert locust swarms, thus preventing subsequent human suffering. Concurrently, the use of powerful insecticides is reduced because they are restricted to localized areas before the swarms become mobile and disperse.

A severe locust outbreak was reported in South Yemen in August 1992. In February 1993, outbreaks also were reported along the Red Sea coast in Ethiopia and in Sudan. Since then, numerous outbreaks have been reported in other parts of Africa, notably Somalia. The use of satellite data is invaluable in Somalia because of the difficulty in obtaining current information from many parts of that country because of the chaotic conditions there. Desert locust swarms, which develop in Somalia for example, will usually fly out of that country into other parts of Africa or Arabia.

For a NASA/Goddard research effort, which has published over 40 articles in scientific journals, also to be the principal data source for a famine early warning and desert locust swarm control in Africa is unusual, Tucker said. Nonetheless, this research project is continuing to obtain excellent and continuing scientific results, while providing information collected from satellites which saves hundreds of thousands of lives and reduces human suffering throughout Africa.

Goddard engineer designs new joystick

by Brian O. Granville

To eliminate major problems with many current commercially available hand-operated controls known as joysticks, Goddard design engineer, James Kerley, Code 754.1, has invented a joystick that proves to be superior in all aspects to those on the market.

Kerley's invention produces a nonlinear response by implementing cable for increasing control and reducing fatigue of the operator. A feedback loop to the operator's hand is an option that makes the joystick more "user-friendly."

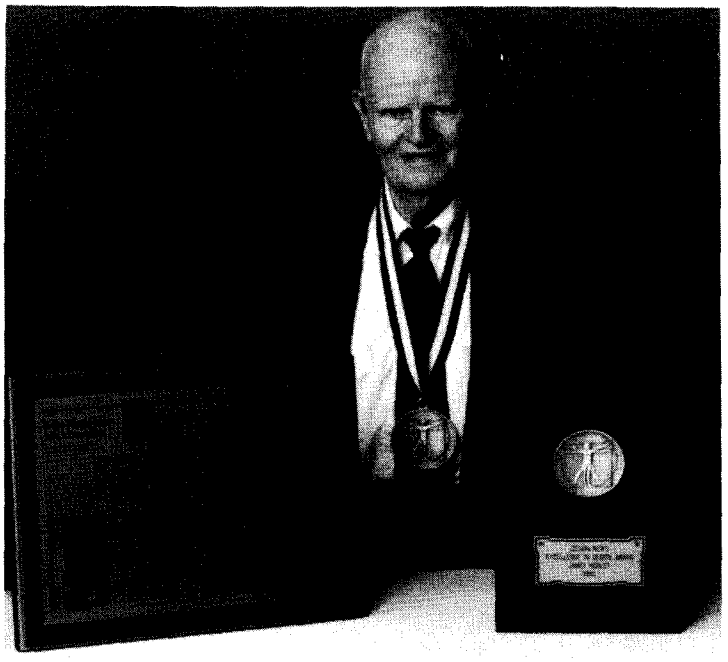
"One of its first uses was in isolation activities for the military by mounting electronics systems to be flown through reentry," Kerley said. Joysticks have many applications in the electrical control of moving bodies such as cranes, small vehicles, remote handling apparatus, robots, and aircraft.

By hand manipulation of the joystick, the operator selectively causes a specific operational control. A major setback with currently available joysticks on the market is that "they tend to move either too little or too much in response to operator input," said Kerley.

The operator also has no sensory feedback from the commercial joystick that would indicate how hard or fast the machine is moving. Because of this, commercial joysticks do not work well with the natural action of the hand, brain, and body's feedback characteristics.

The handle deflection on Kerley's joystick is not proportional to the amount of force input. The mechanism gets stiffer with increasing force. This provides superior control and feedback to the operator, since it reflects the natural action of the operator's hand, brain, and feedback nature of man. Thus, increasing control and cutting down on his fatigue.

As the operator moves Kerley's joystick handle, the cable compliant initially provides a low reaction force, but as the handle is moved farther in any direction, the reaction force becomes nonlinearly greater. The cables are virtually indestructible and may be bent in angles over 90 degrees.



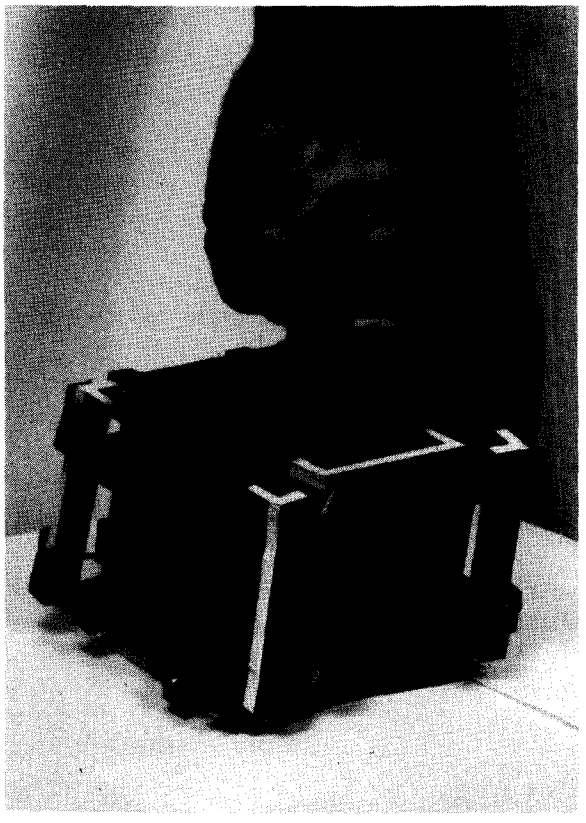
Inventor James Kerley.

Kerley's invention has received great interest from the private sector. According to Dennis Marchant, Code 204, Goddard's Chief Patent Counsel, "an exclusive royalty barring license (number DE-159) was granted to Itac Systems out of Garland, Texas on July 1, 1993."

Kerley has proved an exceptional contributor to cable compliance technology. During his 50 years as an engineer, Kerley has been responsible for more than fifty inventions. His inventions include the climbing/crawling robot, walker and electronic bolt analyzer. Kerley is also a recipient of various honors and top engineering awards for his inventions.

His experience ranges from product design to leadership positions as president of various engineering companies. For the last 29 years, Kerley has been a NASA employee. An author as well as a design engineer, Kerley has written books on mathematics, science and engineering.

Kerly's latest invention: the joystick.



Hubble vision: senior scientist hopes to keep space telescope dream alive

by Michael Finneran

Every now and then as senior scientist for the Hubble Space Telescope, Goddard's Dr. David Leckrone, Code 600, requires an extra dose of inspiration. That's when he flicks on the TV in his Columbia, Md., home and pops in a laser-disk copy of "The Dream is Alive."

David Leckrone

The 50-year-old astronomer plans on watching the IMAX space shuttle documentary at least a couple more times before the December mission to service Hubble in orbit.

"It's incredibly moving," says Leckrone, of Code 600. "I sit down and look at it before every servicing mission simulation. And it just makes me feel like I am a part of something that goes way beyond myself and my own life — something that is of historical importance, of importance to our country, of importance to mankind and of importance to our future and our children."

If Leckrone sounds like a true believer, he is, having spent the last 17 years of his life working on what has been one of NASA's grandest — and most controversial — projects. It has been a roller-coaster ride, from the crest reached with its launch on the Space Shuttle Discovery in April 1990 to the valley three months later, when it became apparent that the primary mirror was flawed.

Leckrone sees Hubble as much more than an assemblage of parts whirling about the Earth. It is, he asserts, nothing less than the first of a new species in astronomy — the space-based equivalent of a Mount Palomar. And keeping it up there and working properly is something of a high calling, a service to future generations, for Leckrone.

Despite its problems, he says, Hubble still represents the best we have, and he doesnít see any reason the space telescope should not exceed its design life of 15 years.

"What many people don't appreciate is there's a difference between a mission or an experiment and an observatory," Leckrone says. "Astronomers are accustomed to working with observatories where you develop a facility with a telescope, and you expect it to last basically forever. And you keep upgrading it as the technology comes along. And there's no particular reason why one should shut down an observatory after a specific set of scientific objectives has been gone through.

"It's like the equipment a doctor uses in an operating room of a hospital. He expects it to last a long time, and of course new technology comes along and the equipment gets upgraded and improved. But basically the operating theater stays open, and that's the place the doctor finds the basic tools of his trade. Similarly, an observatory is where an astronomer can find the basic tools he or she needs to answer the new questions that keep being asked."

Leckrone came to Goddard after graduating from the University of California with doctoral and master's degrees in astronomy and a bachelor's in physics from Purdue University in Indiana. For 5 years, he worked on design concepts for the attached payloads of Spacelab.

In 1976, Leckrone joined the Hubble project as instruments scientist. He became deputy to the senior scientist in 1989 and took over the position in 1992.

Leckrone says Hubble is the best astronomical telescope on the ground or above it and that the effort to service the telescope is worth it.

"I don't know of any other missions that were designed consciously to last this long in orbit," he added. "Generally, satellites are designed not to last much longer than a few years, and so the only way to get beyond that obstacle of failure in orbit is this concept of on-orbit servicing."

Planning for the servicing mission began immediately after the mirror flaw was discovered. And with the servicing launch coming up fast, Leckrone and everyone connected with the project have been working furiously to meet the deadline.

Leckrone says all of the work has left him with a "tiny bit" of spare time to spend with his family and his interests, which include music, movies, hiking and adding to his wine cellar. He and his wife, Carolyn, a reading specialist at West Friendship Elementary School in Howard County, have two grown children. Rick, 24, is a graduate of the Rochester Institute of Technology who manages a stock photography company in Irvine, Calif., and works as a professional photographer. Lynn, 22, is majoring in sociology at the University of Maryland-Baltimore County.

Goddard minority contractor of the year named

CTA, Incorporated, Rockville, Md., recently was honored in a ceremony in the office of Center Director Dr. John Klineberg as the Goddard minority contractor of the year. According to Walter Truszkowski, Code 522.3, "Over the past 4 years CTA has demonstrated both technical and management excellence in their performance under their contract with Goddard."

CTA, is a full service aerospace company that maintains capabilities to perform all aspects of analysis, design, and development of complex aerospace information systems. The CTA contract is managed by the Data Systems Technology Division, Code 520. The contract requires CTA to provide comprehensive research and development services in systems and software engineering related to space vehicle ground and onboard systems for the Mission Operations and Data Systems Directorate. CTA has served in this role as Code 500's advanced systems engineering contractor for over 10 years.

David E. Provost, Code 733, also was cited at the ceremony for significant achievement in fostering contracting with Small Disadvantaged Businesses.

Bloodmobile

On October 6, 1993, the Bloodmobile was held in the Building 8 auditorium and 187prospective donors volunteered to donate blood. The following is a list of Goddard employees who were cited by the American Red Cross with gallon pins at the Bloodmobile.

# of Gallons	Name	Code
4	Roberto Aleman	740.4
3	Oren Sheinman	722.3
3	Jeffrey Bolognese	721.1
3	Michael Conner	740
11	Barry Kirkham	441
2	Linda Pattison	251
6	Paul Trahan	750.5
2	Ryan Simmons	721.3
20	John Unger	503
5	Theodore Gull	680
3	Nancy Rivers	SRC

The next Bloodmobile is scheduled for December 1 n the Building 26, room 205. Watch *Dateline Goddard* for more details.

RETIREES

Congratulations to the following employees who recently retired!

Name	Code	Years
Patrick L. Hinkson	292.3	38
William W. West	822	35
Walter J. Hensel	542.3	33
James B. Farrall	254	33
Frank M. Boykin	841.3	33
Emory Kopf	531.4	33
Barbra L. Moton	254	31
William C. Bryant	415	31
G. W. Martin	823.1	31
Frank V. Moore	200 Wallops	31
Thomas C. Underwood, Jr.	530.4	30
Betty H. Fitchett	205.2	30
Helen A. Mitchell	262	30
Loren R. Linstrom	704	29
Patricia A. Parkes	535.3	29
Andy Gray	470	28
Virginia G. Estes	51.5	28
Patrick W. Humphrey	723.2	28
James L. Faris	691	27
Barbara A. Walton	506	27
Richard J. Palace	743.1	27
Carolyn J. Chandler	750	27
Kenneth M. Huffman	743.1	26
Maurice J. Robertson, Jr.	311	26
William A. Carr	743.2	25
Eugene M. Sober	205	25
Nancyann Wilkerson	703	20

Goddard Colloquia Fall Schedule

This is the December schedule for the Scientific and Engineering Colloquium Series. The colloquiums are held in the Building 3 auditorium and begin at 3:30 p.m.

Scientific Colloquium:

December 3: George Philander of Princeton University presents "El Nino: A Predictable Climate Fluctuation."

December 10: David Gillette, State of Utah, presents "Seismosaurus, Wooly Mammoths, and Other Extinct Beasts."

Engineering Colloquium:

December 6: Dr. David Kaplan, Johnson Space Center discusses "Exploration of the Moon and Mars."

December 13: Dr. Richard Stallmann, M.I.T., leads a discussion on "Software Patents."

December 20: This is the final colloquium of 1993. Dr. H.B. Siegel, Wavefront Technologies, presents "Scientific Visualization—Truth or Consequences."

ROSAT solves mystery of Seyfert galaxy

by Michael Finneran

A galaxy has lost its distinction as most rapidly flickering galaxy of its kind in the Universe and the only one showing a periodic, predictable change of brightness.

Instead, this periodic flickering is caused by a pair of stars that lies near to the line of sight of the Seyfert galaxy but are about 100,000 times closer to Earth, according to researchers at Goddard and several other institutions. The scientists published their findings in the Oct. 14 issue of the science journal "Nature."

"This binary system just happens to be close to the light of sight of NGC 6814, but previous satellite observations were unable to separate the pair from the Seyfert galaxy," said Dr. Greg M. Madejski, Code 666, of the Universities Space Research Association at Goddard.

Seyfert galaxies are distant celestial objects with very bright and highly active central regions, or nuclei. In visible light, these nuclei can outshine the billion stars in the galaxy itself, while also producing large amounts of ultraviolet and X-ray radiation.

The Seyfert galaxy known as NGC 6814 was thought to be unique because the variations of its brightness not only were very fast, but extremely regular, going up and down in a pattern or "periodicity" that repeated itself every 3.4 hours.

Now, however, the international Roentgen Satellite (ROSAT) has shown that the 3.4-hour periodicity of NGC 6814 is an optical illusion of sorts, caused by a binary system of two stars orbiting each other. The binary system does not even lie within the Seyfert galaxy, according to the "Nature" paper.

"Meanwhile," said Madejski, the paper's lead author, "the interaction of these two stars produced what appeared to be this unique periodicity in NGC 6814. In fact, though, these two stars have absolutely nothing whatever to do with NGC 6814."

The pair of stars are what is known as a binary system, in which the two stars orbit each other. In this case, say Madejski and his colleagues, one of the two, probably a small, very dense star called a white dwarf, is pulling material from its companion. In turn, the impact of this material on the white dwarf is producing X-rays that previous observations had associated with NGC 6814, according to the "Nature" paper.

What appeared to be the unique characteristics of NGC 6814 first were detected by the European X-ray Satellite (EXOSAT) in the mid 1980s and confirmed by the Japanese orbiting observatory GINGA several years later.

"Given the limited spatial resolution of the previous X-ray observatories, however, it simply was not possible to disentangle the two sources — namely NGC 6814 and this binary system," Madejski said. "It required the precise imaging capability of ROSAT, coupled with its large field of view."

Following the observations of GINGA and EXOSAT, scientists speculated that the cause of the Seyfert galaxy's periodicity was related to a black hole at the center of the galaxy. A black hole is believed to be a collapsed star with a gravitational field so strong that not even light can escape it.

One leading theory said the periodicity was caused by a captured star orbiting a super-massive black hole at the galaxy's center. Another theory held that the periodicity was caused by "gravitational lensing," or distortion, by a central black hole of X-ray emitting hot spots on a disk of matter falling into the black hole.

Madejski said that despite ROSAT's findings about NGC 6814, other lines of evidence still favor a presence of black holes in Seyfert galaxies.

Collaborating with Madejski on the "Nature" paper were T. Jane Turner, Code 666; Richard F. Mushotzky, Code 666; and Peter Serlemitsos, Code 666; Chris Done of the Leicester University in Great Britain; Fabrizio Fiore of the Center for Astrophysics in Cambridge, Mass.; Marek Sikora of the Copernicus Astronomical Center in Warsaw, Poland and JILA/University of Colorado in Boulder, Colo.; and Mitchell C. Begelman of JILA/University of Colorado.

ROSAT, launched by NASA in 1990, is a collaboration between the United States, Germany and the United Kingdom. NASA's role is managed by Goddard for the Office of Space Sciences at NASA Headquarters in Washington, D.C., and involves sharing observing time with scientists from Germany and the United Kingdom.

Goddard also managed the development and delivery of one of the instruments on the spacecraft, handled launch vehicle preparation, provided initial satellite tracking and orbit determination and developed a ROSAT Science Data Center.

Goddard

The GODDARD NEWS is published monthly by the Office of Public Affairs, Goddard Space Flight Center, Greenbelt MD 20771.

Deadline for submitted material is the fifteenth of each month. For additional information contact Fred Brown (301) 286-7277, TDD (301) 286-8955.

The GODDARD NEWS Staff is:
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