Chandra X-ray Observatory: On a mission to explore the hot universe

By Wallace Tucker and Karen Tucker
Smithsonian Astrophysical Observatory

Liftoff. We have liftoff of Columbia. Reaching new heights for women and X-ray astronomy! Those words from Kennedy Space Center commentator Lisa Malone on the evening of July 23, 1999, were music to the ears of hundreds of Smithsonian scientists and staff. Many of them had been waiting for a week—to make that 23 years in the case of Harvey Tananbaum—for the space shuttle to deliver the National Aeronautics and Space Administration's Chandra X-ray Observatory into space.

Eight hours later, under the direction of Col. Eileen Collins, the first female commander of a space shuttle mission, Chandra was gently pushed away from the shuttle. Over the next two weeks, two separate rocket systems would fire a total of seven times and boost Chandra to its operating Earth orbit, an ellipse that ranges from approximately 6000 miles at its low point to about 86,500 miles at its high point.

The Chandra X-ray Observatory, named in honor of one of the foremost astrophysicists of the 20th century, the late Nobel Laureate Subrahmanyan Chandrasekhar, joins the Hubble Space Telescope and the Compton Gamma-Ray Observatory as the third in NASA's fleet of four great observatories. They are designed to observe the cosmos from infrared through gamma-ray wavelengths. The fourth observatory, the Space Infrared Telescope Facility, or SIRTF, is slated for launch in 2001.

In its first months of operation, Chandra gave astronomers an unprecedented look at the extreme universe of black holes, exploding stars and galaxy clusters. "Chandra is everything we ever hoped for and more," says Tananbaum, who, along with Riccardo Giacconi, wrote the first proposal in 1976 to fund the Chandra X-ray Center, which controls operations of the observatory under contract to NASA. The center is located at the Smithsonian Astrophysical Observatory in Cambridge, Mass. The Chandra project is managed by NASA's Marshall Space Flight Center in Huntsville, Ala., and TRW, an automotive, space defense and information technology company headquartered in Cleveland, Ohio. (See the article on Page 2 for details on the Chandra X-ray Center.)

Studying X-rays

The high energies of X-rays, which are invisible forms of light, have two important consequences for astronomers. First, they are absorbed by the atmosphere, so telescopes must be placed on spacecraft that travel above the atmosphere in order to detect them. Second, X-ray telescopes must be constructed differently than optical telescopes. X-rays will reflect off mirrors, but only if they strike at grazing angles, like a stone skipping across a pond. For this reason, X-ray mirrors have to be specially shaped, then aligned nearly parallel to incoming X-rays. These barrel-shaped mirrors are nested one inside the other to increase the collection area and thereby the sensitivity of the telescope.

Chandra's telescope consists of four pairs of such mirrors. These mirrors are the smoothest mirrors ever constructed. The largest of the mirrors is almost four feet in diameter and three feet long. These unique mirrors enable Chandra to make images 25 times sharper than any previous or planned X-ray telescope.

Two sensitive, electronic X-ray cameras are used to collect the X-rays focused by the mirrors. Scientists specify which cameras will be at the focus for their observations. The High Resolution Camera—conceived, designed and constructed at SAO—uses an array of 69 million tiny glass tubes and a grid of electrically charged wires to determine the position and arrival time of each individual X-ray. In addition, the camera reconstructs a high-resolution image of the celestial source of the X-rays.

The other camera, a product of the Massachusetts Institute of Technology and Pennsylvania State University, is the Advanced Charge-Coupled Device Imaging Spectrometer, or ACIS, which works much like a camcorder or digital camera. It contains 18 X-ray-sensitive charged-coupled devices, or CCD chips, each with more than a million pixels, or "detection elements," to record the position and energy of X-rays.

Even more details about the energy of the incoming X-rays can be obtained by inserting two special instruments, called transmission gratings, into the path of the X-rays. The gratings, built by MIT and the Space Research Organization of the Netherlands, disperse the X-rays into a high-energy rainbow, containing thousands of distinct X-ray colors.

As the following sample of recent observations shows, Chandra has already begun to transform astronomy.

Star birth

One of Chandra's early targets was the brilliant Orion star cluster, a cosmic birthing ground for stars. Stars in the Orion cluster were formed during the last few million years, so they are infants compared with our 4.5-billion-year-old sun.

"Chandra," continued on Page 6

Special Issue: The Smithsonian Astrophysical Observatory’s Work on the Chandra X-ray Observatory
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Research Vistas

A tradition of research • Some readers of this special issue devoted to the Chandra X-ray Observatory may be surprised to discover the central role of the Smithsonian Astrophysical Observatory in Cambridge, Mass., in the development of this spacecraft and in the history of X-ray astronomy.

Other readers may be just as surprised to discover that the Institution even has an “observatory,” especially one making observations across the entire electromagnetic spectrum, using a variety of Earth- and space-based instruments. In addition to X-ray astronomy, researchers at SAO conduct experiments in laboratory astrophysics, studies in geophysics and earth sciences, and research in science education.

In fact, the Smithsonian has had an observatory since 1890, when the Institution’s third secretary, Samuel Pierpont Langley, founded SAO to study what he called “the new astronomy.” He was referring to what we now know as astrophysics, a then-revolutionary notion that one might study the physical nature of astronomical bodies, as well as their positions and motions.

The first half of SAO’s scientific life was devoted primarily to solar research, until the dawn of the Space Age, when the observatory moved to Cambridge, Mass. From there, SAO embarked on a multifaceted research program, eventually encompassing almost every major field in modern astronomy and astrophysics—from the study of large-scale structures in the universe to the composition of comets in our solar system. Today, SAO is part of the Harvard-Smithsonian Center for Astrophysics.

But SAO is not alone among Smithsonian research centers in its pursuit of knowledge or in its prominence in the international scientific community. The Smithsonian Tropical Research Institute in Panama is a world leader in tropical biology, geology and anthropology. Field biologists come each year to STRI’s natural “laboratory” on Barro Colorado Island to study the complex and delicate ecosystems of the rain forest, while marine scientists pursue research at stations on Panama’s Atlantic and Pacific coasts.

Similarly, the Smithsonian Environmental Research Center is in its 35th year of studying the relationships between land and estuarine environments, the interactions of fresh and salt water, and the impact of human activity on coastal ecosystems. From its main laboratories and field stations on the shore of the Chesapeake Bay, SERC research radiates to sites around the world.

In addition to SAO, STRI and SERC, there are more than a half-dozen other centers of research at the Smithsonian—ranging from the Archives of American Art to the Center for Latino Initiatives, where scholars come to use the Institution’s matchless collections of artifacts, specimens, books and papers. Moreover, every Smithsonian museum has its own research staff and facilities. For example, the Center for Earth and Planetary Studies is part of the National Air and Space Museum, and the Smithsonian Marine Station at Fort Pierce, Fla., is part of the National Museum of Natural History.

Much of the research at these extraordinary centers is never seen or appreciated by the general public. For most Americans, the Smithsonian is identified with the great museums on the National Mall in Washington, D.C. Nevertheless, the Institution has conducted visionary basic research since its beginnings. Occasionally, the Smithsonian’s long-term, behind-the-scenes basic research bursts into public consciousness with discoveries of both scientific significance and stunning beauty. Such is the case with the Chandra images of the cosmos.

—Dennis O’Connor, Under Secretary for Science, Smithsonian Institution

Chandra X-ray Observatory opens up a ‘whole new world’ of astronomy

By Wallace Tucker and Karen Tucker

Smithsonian Astrophysical Observatory

As a precedent-setting example of the National Aeronautics and Space Administration’s initiative to streamline the operations of its space science missions, the Chandra X-ray Observatory is operated by the Smithsonian Astrophysical Observatory in Cambridge, Mass. Chandra, the largest space observatory ever operated outside of a NASA facility, is now receiving data at an all-purpose facility in Cambridge called the Chandra X-ray Center.

The center, which is operated under a contract with NASA’s Marshall Space Flight Center, is a collaboration of personnel from SAO and the Massachusetts Institute of Technology. TRW, an automotive, space defense and information technology company, is the prime contractor for Chandra. The center is directed by Harvey Tananbaum and managed by Roger Brissenden, both of SAO.

Chandra was activated during a three-week period after launch last July. The Chandra X-ray Center’s routine is to serve as the space science equivalent of a one-stop shopping supermarket. From the time that a scientist types out a proposal and sends it to the center until the happy days when data are received and findings published, the center is involved.

Behind-the-scenes support

The User Support group organizes peer review of proposals from aspiring observers. For the first year of observation, about 800 proposals were submitted from around the world, and about 200 were accepted. Successful proposals are passed along to the Mission Planning group, which uses input from the Calibration group and the Science Operations team to schedule the observations. The Science Operations team and the Flight Operations team then work together to “run the show” by sending a series of commands up from the Operations Control Center to Chandra via NASA’s Deep Space Network, which has stations in California, Spain and Australia.

When the observation—which may take anywhere from an hour to three days—ends, the users get a call back and are allowed to download the data. Chandra’s orbit takes it 11.5 days to go around the Earth. The onboard computer processes the data and sends it to the Earth via the DSN. The data are then transferred from SAO and the Massachusetts Institute of Technology to the Chandra X-ray Center, where the computer scientists and engineers work to process the data and provide information to the scientists.

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In pursuit of a target of opportunity, Chandra rises to the occasion

By Wellness Tucker and Karen Tucker
Smithsonian Astrophysical Observatory

The first Chandra rapid-response observation of an exploding star began one Friday afternoon in October 1999. Alex Filippenko, an astronomer at the University of California at Berkeley, notified Robert Kirshner, associate director of optical and infrared astronomy at the Harvard-Smithsonian Center for Astrophysics, that his supernova search project had a good candidate in a relatively nearby spiral galaxy, NGC 1637. In this case, “nearby” meant about 25 million light-years from Earth!

Weidong Li, a visiting astronomer from the Beijing Astronomical Observatory who was working with Filippenko’s group, called his colleagues in Beijing, who made confirming observations of the supernova, which was given the official name SN1999em.

Kirshner’s group at the Smithsonian’s Whipple Observatory in Arizona took a spectrum of the object on Saturday. The spectrum showed that the object was a Type II supernova, an explosion produced by the collapse of the core of a star 10 or more times as massive as the sun. Such supernovae are of great interest to cosmologists such as Kirshner, for these supernovae can serve as heavenly milestones helping to mark cosmic distances.

Interrupting a late dinner, Kirshner sent an e-mail message to Harvey Tananbaum, director of the Chandra X-ray Center, around 11 pm. “There’s a bright supernova in NGC 1637,” he wrote. After giving some of the details, Kirshner signed off, “Explosively yours, Bob.”

A brewing dilemma

The discovery presented a dilemma for the Chandra team. On the one hand, a supernova this close to Earth goes off only once every five or 10 years, and it would be the first supernova observed with X-rays and telescopes since Chandra’s sensitivity had looked at a new supernova. It definitely qualified as a target of opportunity, or TOO, which is an exceptional and fleeting astronomical event for which Chandra’s normal—and prescheduled—observing program could be interrupted.

On the other hand, implementation of an accepted, coordinated, “quick-response” TOO Program was not planned to begin until the Chandra X-ray Center had more experience running the space observatory, learning about its quirks and testing the software used to command it.

Making a decision

Tananbaum decided to go for it, pending a review by various experts on the risks and rewards of such an undertaking. Shortly after 9 a.m. on Sunday, Tananbaum sent an e-mail message to key team members, asking for their advice and counsel.

Pat Slane, a principal investigator on the Smithsonian Astrophysical Observatory’s Chandra Science Mission Planning team, was the first to respond, and he passed the word along to William Forman, an SAO astronomer and head of the group. Soon, e-mail messages and phone calls were zipping back and forth across Cambridge and the country—as the pros and cons of the observation were discussed.

In the meantime, the scientists needed to juggle their professional and personal responsibilities, including their children’s Halloween parties. (Slane managed to attend his child’s party and stay in touch with the center. He went as a vampire with a cell phone.)

The countdown

At 9:59 a.m. on Sunday, SAO’s Roger Brissenden, manager of the Chandra X-ray Center, weighed in with practical considerations. Brissenden emphasized the need to carefully review the procedures to maintain spacecraft safety. Anil Dossaj, an SAO mission planner in the Science Mission Planning group, volunteered to come in and prepare the official Observation Request file to observe the supernova. At 3:42 p.m., Dossaj notified Tananbaum that the “load” could be replaced by 2 a.m. Monday morning.

For the next five hours, the team worked feverishly, with Lewin and Derek Fox, an MIT graduate student, consulting with Plucinsky and Royce Buehler of MIT’s ACIS team to plan the details of the observation. When they were finished, Brissenden called the team together for a final review at 9 p.m.

Team members present were Jeff Shirk of TRW’s Flight Operations team, Buehler, Slane, Forman, and Marsh. Additional SAO members with responsibilities for other aspects of the mission included Rob Cameron, Jon Chapell and Gerry Austin.

The results

“The review is complete and there are no issues,” Brissenden reported to Tananbaum. “Overall, a good effort from the team…. All that remained was the wait for the timer to go off (late Monday afternoon) to uptick to Chandra and for the spacecraft to slew over to and point on the source, which would take about half an hour. The observation began at 6:37 p.m. Monday and continued for several hours. It would then take a week or so to analyze the data.”

“I was impressed by how rapid the Chandra response was,” Kirshner says. “It typically takes a week for the Hubble Space Telescope to be reprogrammed for such an opportunity.”

In its first TOO operation, Chandra observed an X-ray glow from SN1999em with the total power of 50,000 suns. Ten days later, it observed the supernova for another nine hours and found that the X-rays had faded to half their previous intensity. The optical luminosity, which had the brightness of 200 million suns, had somewhat faded. No radio emission was detected at any time.

With this information, the MIT group and their colleagues began piecing together a picture of the catastrophic explosion. The intense heat generated in the collapse of the original star produced a cataclysmic rebound that sent high-speed debris flying outward at speeds in excess of 20 million miles per hour. The debris crashed into matter shed by the former star before the explosion. This awesome collision generated shock waves that heated the expanding debris to millions of degrees.

The X-ray glow from this hot gas detected by Chandra provides astrophysicists with a better understanding of the dynamics of the explosion, as well as the behavior of the doomed star in the years before its explosion.

The combination of X-ray detection and radio nondetection is unusual, but may have less to do with the supernova and more to do with the great sensitivity of Chandra,” says Roger Chevalier, a professor at the University of Virginia, Charlottesville, and a supernova expert.

Chevalier explained that the combined observations indicate that SN1999em shed a relatively small amount of matter before it exploded, compared with other supernovae observed in X-rays. The Chandra observation is important because it may represent a more common type of supernova.

A little more than two months after outburst, radio emission was detected, probably signaling the arrival of the shock wave at the outer shell. Another Chandra observation of SN1999em is scheduled for the near future and is eagerly awaited by supernova specialists around the world.

Outreach and Education

The Education and Outreach program at the Chandra X-ray Center covers a full range of activities, which include producing and distributing electronic and print materials to lay and professional audiences and developing educational materials to acquire students and teachers with astrophysical research and discovery.

The Chandra X-ray Center’s Web site at chandra.harvard.edu has received more than 27 million hits and 28 awards for design and content. It contains a wealth of information about the satellite. Visitors can get information on the construction of the satellite, technology (involved in making the mirror and general background information on the types of astronomical objects and questions that Chandra is designed to investigate. In addition, there are educational games and puzzles for children and a “photo album” of images taken from Chandra.

An array of other materials, including classroom modules, teacher guides, public activities for young children and new science materials are in development. A documentary film is in production and expected to be released this year.
Getting Chandra into orbit was the work of a team back on Earth

By Wallace Tucker and Karen Tucker
Smithsonian Astrophysical Observatory

ike all major space science pro-
jects, the success of the Chandra X-ray Observatory is due to the con-
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dreds of individuals—at the Smithsonian Astrophysical Observatory; the National Aeronautics and Space Administration; the Massachusetts Institute of Technology; Pennsylvania State University; NASA; and dozens of other academic, industrial and commercial partners.

At the Smithsonian Astrophysical Observatory, some of the people who made a difference were Harvey Tananbaum, director of the Center, and Roger Brissenden, director of the Chandra X-ray Center. And in 1997, Tananbaum and Riccardo Giacconi, along with SAO astrophysicists Paul Greisenstein, Rick Haardun, Pat Henry, Ed Kellogg, Stephen Murray, Herb Schopper and Leon Van Speybroeck, submitted a proposal to NASA for the “Study of the 1.2-Meter X-ray Telescope National Space Observatory.”

The next year, preliminary work began at NASA Marshall Space Flight Center in Huntsville, Ala., and at SAO on the Advanced X-ray Astrophysics Facility (later renamed Chandra).

In 1981, Tananbaum became the SAO project scientist for the Mission Support group in the Chandra X-ray Center. The group is responsible for monitoring the focal plane instruments and the aspect camera, especially in the pre-launch, launch, activation and checkout operation phases of Chandra’s life.

For the last four years, Schwartz has served as the Science Operations team coordinator, working with the Flight Operations team to carry out the overall mission.

When Schwartz is not working on the Chandra project, he enjoys playing soccer and visiting historical and natural sites throughout the country.

Martin Elvis

Martin Elvis has been with the Chandra X-ray Center since its beginning in the 1980s. But even before Chandra, he worked on SAO’s Einstein Observatory project in a succession of roles.

In addition, he worked with Einstein data to produce the first X-ray spectra of quasars, which, when combined with data from other spacecraft, mapped out the powerful quasar light sources across the whole spectrum.

For Chandra, Elvis is leading the team that has developed new software tools that enable astronomers to analyze and interpret the observatory’s detailed three- and four-dimensional images and spectra.

With his wife, Giuseppina Fabbiano, Elvis is a partner in one of the two husband-and-wife astronomer teams working on Chandra. The other couple is Christine Jones and William Homan.

Giuseppina Fabbiano

An SAO astrophysicist who has been involved in X-ray astronomy since 1973, Giuseppina “Pepi” Fabbiano has made groundbreaking contributions to the study of the X-ray properties of galaxies. She also is working to develop large-area, high-resolution X-ray telescopes that can further these studies in the future.

She has a long-standing interest and involvement in issues of scientific data pro-
cessing and archiving. Thus, as head of the Chandra X-ray Center’s Data Systems Division, she leads those scientists and computer specialists responsible for the development of Chandra data-processing and analysis software. She also oversees the processing and archiving of Chandra data and the distribution of data and software to the scientific community.

Claude Canizares

Claude Canizares is the Bruno Rossi Pro-
fessor of Experimental Physics at MIT and director of its Center for Space Research. He is a principal investigator for the Chandra X-ray Center, leading the development

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Like all major space science projects, the success of the Chandra X-ray Observatory is due to the contributions of literally hundreds of individuals—at the Smithsonian Astrophysical Observatory; the National Aeronautics and Space Administration; the Massachusetts Institute of Technology; Pennsylvania State University; TRW, an automotive, space defense and information technology company; and dozens of other academic, industrial and commercial partners.

Among those who made a difference were Harvey Tananbaum, director of the Center, and Roger Brissenden, director of the Chandra X-ray Center. In 1976, Tananbaum and Riccardo Giacconi, along with SAO astrophysicists Paul Greisenstein, Rick Haardun, Pat Henry, Ed Kellogg, Stephen Murray, Herb Schopper and Leon Van Speybroeck, submitted a proposal to NASA for the “Study of the 1.2-Meter X-ray Telescope National Space Observatory.”

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'Chandra team,' continued on Page 5
Stephen Murray

In 1990, as a member of the team that proposed SAO as a site for the Chandra X-ray Center, he coordinated production of the proposal's technical book that outlined the data system and the implementation plan. Today, with Chandra in orbit, Murray is carrying out a broad program of science, using all of the Chandra instruments.

"My major projects include monitoring the Andromeda galaxy (M31) and overseeing studies of star-forming regions and clusters of galaxies, as well as research on distant quasars and violent galaxies," he says.

Lester Cohen

As chief engineer for the Structural Analysis and Design group, Lester Cohen represents the scores of technical experts in SAO's Central Engineering Department who contributed to Chander's success. His specific tasks included overseeing the optics fabrication, working with SAO project scientists, NASA technicians and other team members to verify that manufacturing and assembling of the Chandra optics met the program requirements.

This meant he "would spend about three months a year in Chandra's project office," Cohen says. "What had been expected from pre-launch ground testing and "what previous observations of cosmic sources have shown." After receiving undergraduate and graduate degrees from Harvard University, Jones joined SAO and worked on the Chandra team since 1988, when he commented, "I was still in high school at the time playing Scrabble. In fact, he is a tournament-level Scrabble player and ranked, as he puts it, "about 100th in the country, or at the bottom of the experts." Christine Jones is head of the Chandra Calibration team. The team's job is to compare the performance of Chandra's telescope and instruments in space with what was expected from pre-launch ground testing and what previous observations of cosmic sources have shown. After receiving undergraduate and graduate degrees from Harvard University, Jones joined SAO and worked on the Chandra team since 1988, when he concentrated on laboratory measurements of X-ray reflectivity, work that resulted in the selection of iridium as the coating material for the Chandra optics. He also participated in testing the Chandra mirrors before flight and now serves on Chandra's Mission Planning team. Slane's own research includes the study of supernova remnants. As principal investigator on three approved research programs, he will use Chandra to observe supernova remnants and neutron stars.

Christine Jones and William Forman

Uhuru X-ray satellite and Einstein projects prior to Chandra. She still finds time to supervise the SAO Summer Science Intern Program for undergraduates and to participate in many public outreach activities. Her husband, William Forman, is head of Chandra's Mission Planning team. Like his wife, he has worked at SAO on the Uhuru, Einstein and Chandra projects since receiving his doctorate from Harvard. Together, they have made major contributions to our understanding of X-ray emission from galaxy clusters—research for which they were jointly awarded the American Astronomical Society's prestigious Bruno Rossi Prize.

Pat Slane

Pat Slane has been a member of SAO's Chandra team since 1988, when he was one of the High-Resolution Transmission Grating Spectrometer.

In addition, he is associate director of the Chandra X-ray Center. Cañizares, the author and co-author of some 135 scientific papers, received undergraduate and graduate degrees in physics from Harvard University. He came to MIT as a postdoctoral fellow in 1971 and joined the faculty in 1974.

Cañizares' main research interests are high-resolution spectroscopy and X-ray studies of supernova remnants, galaxies and clusters, dark matter, quasars and active galactic nuclei, as well as gravitational lenses. His nonastronomical interests include tennis, hiking, skiing and dancing to a Latin beat.

Robert Kirshner

Robert Kirshner is associate director for optical and infrared astronomy at the Harvard-Smithsonian Center for Astrophysics. After graduating from Harvard College, he went on to receive a doctorate in astronomy from the California Institute of Technology.

Kirshner has authored 200 research papers on supernovae, the large-scale distribution of galaxies, and the size and shape of the universe. His work on the suspected "acceleration" of the universe was dubbed the "Science Breakthrough of the Year for 1998" by Science magazine. A member of the National Academy of Sciences, Kirshner is a popular lecturer among Harvard undergraduates and a frequent public speaker on astronomy.

Stephen Murray

Stephen Murray is principal investigator for the High-Resolution Camera, the imaging instrument conceived and constructed by SAO. A member of the original group of young X-ray astronomers who joined SAO in the mid-1970s, Murray has been actively involved in what was called the Advanced X-ray Astrophysics Facility program (later renamed Chandra) since the initial proposals for an orbiting telescope were sent to NASA more than two decades ago.
The Crab Nebula, a supernova remnant in the Constellation Taurus, was seen and recorded by Chinese and other early observers. In its central core, the Crab Nebula may harbor a black hole that is the remnant of a massive star. The Crab Nebula is one of the most important objects in the sky because of its brilliance and the wealth of information that can be obtained from it. The Crab Nebula is a favorite target of X-ray astronomers because it is one of the brightest X-ray sources known. The Crab Nebula is also a favorite target of radio astronomers because it is one of the brightest radio sources known.

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and Museum Studies
feature an individual who has made excep-
tions to wider cultural anxieties. (Photo courtesy of Universitets
Viking art. (Photo courtesy of Universitets
The collection, "with
objects dating from the 17th to the 20th
Inventing Jerry Lewis, Frank Krutnik (Smithsonian Institution Press, 2000, $44.95). Drawing on films, rare TV shows, recordings, trade reviews, magazine arti-
cles, biographies and documentaries, the
author looks at Lewis' physical comedy and
influenced not only the ideals but also the
cultural tensions of the times.
Fair America: World's Fairs in the
United States, by Robert W. Rydell, and Kimberly D. Relle
(Smithsonian Institution Press, 2000, $29.95 cloth; $13.95 paper). The
authors show how the fairs reflected and influenced not only the ideals but also the
cultural tensions of the times.
Prides: The Lions of Moremi, by Chris
Harvey and Peter Kat (Smithsonian Insti-
tion Press, 2000, $34.95). This striking
volume of 200 color photographs reveals the
worlds of four neighboring prides that roam the diverse habitats of Botswana's
Okavango Delta.
Four omen beastlike animal head carvings, such as this one, were found on posts in
the elaborate 14th-century ship burial of a pagan high-status female. The "grinning beast" carving is typical of early pagan
Viking art. (Photo courtesy of Universitets
Drawing upon several decades of fieldwork
in Africa, as well as research on a range of
societies worldwide, Goody, a noted
anthropologist, demonstrates that writing
don't only has empowered formerly subordi-
nate groups but also has allowed ancient
empires and modern nations to dominate
their noble-tier counterparts.

### Books & Recordings

**Vikings: The North Atlantic Saga**, edited by William W. Fitzhugh and Elisabeth J. Ward (Smithsonian Institution Press, 2000, $60 cloth; $34.95 paper). Replete with color photographs, drawings and maps of Viking sites, artifacts and land-
scapes, the book explores and celebrates the Vikings' expansion from their Scandi-
navian homelands across the Atlantic to North America 1000 years ago.

**Home on the Road: The Motor Home in America**, by Roger B. White (Smithsonian Institution Press, 2000, $24.95). Chronic-
ing more than 50 years of individual and industrial tinkering, the author describes how the technological innovations and
cultural ideals of each era influenced motor home design and popular use.

### Series Publications

The following publications on research in various fields were issued during the period
Nov. 1, 1999, through Jan. 31, 2000, by Smithsonian Institution Press in the
regular Smithsonian series. Diane Tyler is managing editor. Requests for series
publications should be addressed to
Smithsonian Institution Press, Series Divi-

**Inventing Jerry Lewis**, Frank Krutnik (Smithsonian Institution Press, 2000, $44.95). Drawing on films, rare TV shows, recordings, trade reviews, magazine arti-
cles, biographies and documentaries, the
author looks at Lewis' physical comedy and
multifaceted star personas as mediated
responses to wider cultural anxieties.

**The Power of the Written Tradition**, by Jack Goody (Smithsonian Institution Press, 2000, $45 cloth; $18.95 paper).
Forces of Change: A New View of Nature
(Published by the National Museum of Natural History in association with National Geographic, 2000, $40)

Forces of Change offers a sweeping vision of our Earth and illuminates the forces that define and continue to profoundly transform our planet and all of its inhabitants. It provides a forum for exploring a broad range of scientific and social questions relating to change, both natural and human-influenced.

"The growing public awareness of potential climate shifts, diminishing biodiversity, and other environmental and social issues is enough to make change a timely and provocative theme," Alan Cutler writes in the book's introduction. He adds, "But the complexity of the issues that confront us and of the underlying forces of change leads inevitably to more basic questions—questions regarding our relationship with nature and our complicated, often ambivalent attitudes toward change."

In the book, almost two dozen of the world's most innovative and visionary scientists, scholars and writers, including George Horse Capture, deputy assistant secretary for Natural History at the Smithsonian's National Museum of Natural History, discuss the forces that have shaped our planet and how they will affect people and environments on a global scale. They explore different facets of Earth's interdependent systems and the unpredictable future may hold. Beautifully illustrated with some 200 color photographs, the book is divided into four parts—"Forces of Nature," "Time and Complexity," "Adapting to Change" and "Changing Views."

In Part 3, "Adapting to Change," Horse Capture presents a chapter titled "Leave it to the School Children." In his moving personal account of how a mining company forever changed the Fort Belknap Reservation in Montana where he grew up, Horse Capture focuses on the economic factors, mainly gold, that brought the miners to the reservation. In addition, he writes about the impact of these "intruders" on the land and its native people. "No laws existed to protect our sacred ground from desecration," Horse Capture says. "Economics eventually sent the miners away again, but not before they reduced once proud mountains to rubble."

Mining in the mountains had been going on since the late 1800s, Horse Capture says, but it was taking place primarily in tunnels and shafts with little irreparable damage to the surface. "In other words," he explains, "the damage was out of view of the people."

But when open-pit mining began, he continues, the mountains were destroyed. "Massive destruction in our American Indian world is inconceivable. These mountains, which were sacred to us, were destroyed for gold, and we never directly benefited from any of it." In addition, Horse Capture says, mining left the rivers, from which water was used for drinking and swimming, full of pollutants. "We were helpers," he adds. When the price of gold dropped, the mining companies shut down. Even though they have long been gone, he continues, it is only a matter of time before they return again. When the price of gold escalates, the spirit of the sacred grounds will once again be "awakened" to the sounds of bulldozers and dynamite.

"Should we cut down the forest tonight so that we can build a big fire and cook supper?" Horse Capture asks. "What about tomorrow? What about the children?"

"As we enter the new millennium," he adds, "it would be an ideal time to reconsider some of the values and standards of the past, because what was good for one time may not be good for another. We must think of tomorrow."

Other segments of the book focus on forces of change such as climate, biodiversity, mass extinctions, migration, technology and the Information Age.

—Jo Ann Webb

Editor's Note: This spring, Contributing Members will receive Forces of Change as a benefit of membership.

Big Bill Broonzy: Trouble in Mind (Smithsonian Folkways Recordings, 2000, $14 CD). This compact disc of children's songs, recorded live at a music workshop, features intricate guitar playing, soaring vocals and commentary and demonstrate Broonzy's amazing skill as a solo performer.

Ella Jenkins: Seasons for Singing (Smithsonian Folkways Recordings, 2000, $14 CD). This compact disc features Jenkins' traditional songs from around the world.

Memphis Slim: The Folkways Years, 1959-1973 (Smithsonian Folkways Recordings, 2000, $14 CD). This compact disc features Jenkins' traditional songs from around the world.

Pete Seeger: American Folk, Game and Activity Songs for Children (Smithsonian Folkways Recordings, 2000, $14 CD). This collection presents many classic songs for children of all ages.

Books published by Smithsonian Institution Press can be ordered from PO. Box 960, Herndon, Va. 20172-0960. To order by phone or for more information, call 1 (800) 782-4612. There is a $3.50 postage and handling fee for the first book ordered and $1 for each additional book. Smithsonian Folkways Recordings can be ordered by writing to Smithsonian Folkways Mail Order, 955 L'Enfant Plaza, Suite 7300, Washington, D.C., 20560-0953. To order by phone or for more information, call (202) 287-7297 or 1 (800) 410-9815. There is a $4 fee for shipping and handling of the first three recordings ordered; call for other shipping prices.

Forces of Change is a new 200-page, full-color book produced by the Smithsonian's National Museum of Natural History in association with National Geographic.