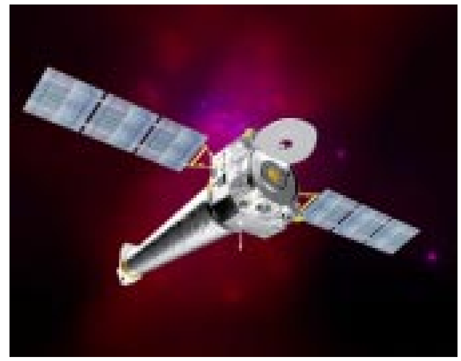
# M82 Black Hole Press Kit

## CHANDRA X-RAY OBSERVATORY



The Chandra X-ray Observatory is the third in NASA's family of Great Observatories that includes the Hubble Space Telescope and the Compton Gamma Ray Observatory. NASA's Marshall Space Flight Center manages the Chandra program. TRW is the prime contractor for the spacecraft. Key subcontractors include Ball Aerospace & Technologies, Inc., Eastman Kodak Company, and Raytheon Optical Systems, Inc. The scientific instruments were built by teams from MIT, Pennsylvania State University, the Smithsonian Astrophysical Observatory, the Laboratory for Space Research in the Netherlands, and the Max Planck Institute in Germany. The Smithsonian's Chandra X-ray Center controls science and flight operations from Cambridge, MA

**M82 Black Hole Press Kit Contents:**

## M82 BLACK HOLE SCIENCE CONTACTS

Dr. Philip Kaaret
Harvard-Smithsonian Center for Astrophysics
Phone: 617.495.7313
pkaaret@cfa.harvard.edu

Dr. Donald Kniffen
NASA Headquarters
Phone: 202.358.0351
dkniffen@hq.nasa.gov

Dr. Hironori Matsumoto
MIT Center for Space Research
77 Mass. Ave., Cambridge, MA 02139-4307
Phone: 617.253.8008
matumoto@space.mit.edu

Dr. Andrea Prestwich
Harvard-Smithsonian Center for Astrophysics
Phone: 617.496.7576
aprestwich@cfa.harvard.edu

Dr. Douglas Richstone
Univ. of Michigan
Dept. of Astronomy, Dennison Bldg., Ann Arbor, MI 48109-1090
Phone: 734.764.3466
dor@elektra.astro.lsa.umich.edu

Dr. Martin Ward
Department of Physics & Astronomy
University of Leicester, Leicester LEI 7RH -UK
Phone: 44.0.116.252.3540
mjw@star.le.ac.uk

## CHANDRA PRESS CONTACTS

Dr. Wallace Tucker, Chandra Science Spokesperson.
Smithsonian Astrophysical Observatory, Cambridge, MA
Phone: 617.496.7998 Fax: 617.495.7356
wtucker@cfa.harvard.edu

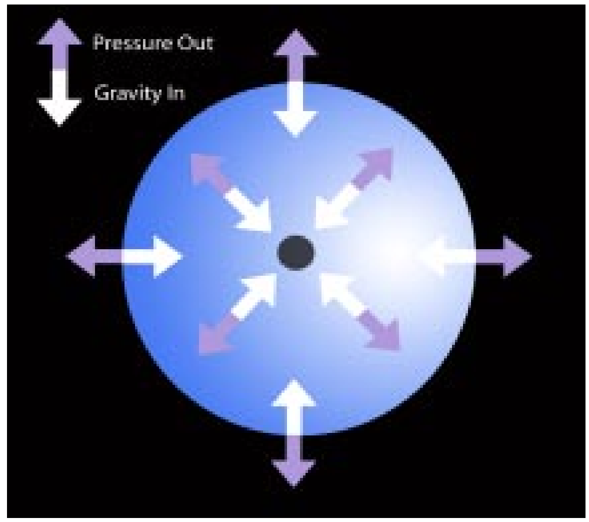
### NASA Contacts

Dolores Beasley, Public Affairs Officer
NASA Headquarters, Washington D.C.
Phone: 202.358.1753
dolores.beasley@hq.nasa.gov

Steve Roy, Media Relations Office
Marshall Space Flight Center, Huntsville, AL
Phone: 256.544.6535
steve.roy@msfc.nasa.gov

## MORE ABOUT BLACK HOLES

When a star runs out of nuclear fuel, it will collapse. If the core, or central region of the star, has a mass that is greater than three suns, no known nuclear forces can prevent the core from forming a black hole. Anything that comes within a certain distance of the black hole, called the event horizon, cannot escape, not even light. The radius of the event horizon (proportional to the mass) is very small, only 30 kilometers for a non-spinning black hole with the mass of ten suns.




Since a black hole cannot be directly observed, astronomers must use circumstantial evidence to prove its existence. The bottom line is that the observations must imply that a sufficiently large amount of matter is compressed into a sufficiently small region of space so that no other explanation is possible.

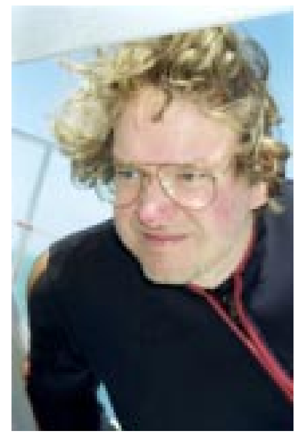
How can black holes be located? X-ray observations are extremely useful for finding black holes. The extreme gravity around black holes will produce X-rays when infalling gas is heated to millions of degrees. The best places to look for black holes are regions where large supplies of gas are available, such as double star systems, star forming regions, or the centers of galaxies.

Have different types of black holes been discovered? There is strong evidence for two types of black holes: stellar black holes with masses of a dozen or so suns, and supermassive black holes with masses of many millions of suns. Stellar black holes are formed as a natural consequence of the evolution of massive stars (see 1st paragraph). The origin of supermassive black holes is a mystery. They are found only in the centers of galaxies. It is not known whether they formed in the initial collapse of the gas cloud that formed the galaxy, or from the gradual growth of a stellar mass black hole, or from the merger of a centrally located cluster of black holes, or by some other mechanism.

How do astronomers determine the mass of black holes? The mass of a stellar black hole can be deduced by observing the orbital acceleration of a star as it orbits its unseen companion. Likewise, the mass of a supermassive black hole can be determined by using the orbital acceleration of gas clouds swirling around the central black hole. When orbital acceleration cannot be used to establish the mass of a black hole, astronomers can place a lower limit on its mass by measuring the X-ray luminosity due to matter falling into a black hole. The radiation pressure of the X-rays must be less than the pull of the black hole's gravity. In the case of the black hole discovered in M82, this limits its mass to greater than 500 suns. The M82 black hole is much larger than known stellar black holes, and much smaller than supermassive black holes, thus it is called a "mid-mass" black hole.

What is the significance of a third type of black hole? Astrophysicists had come to believe that galactic centers were the only places where conditions were right for the formation and growth of large or very large black holes. The discovery of a large, mid-mass black hole away from the galaxy's center shows that somehow -- and it is not an easy task theoretically – black holes much more massive than ordinary stellar black holes can form in dense star clusters. Current possible explanations for the formation of mid-mass black holes includes such exotica as black hole mergers or the collapse of a hyperstar. An intriguing implication is that mid-mass black holes could prove to be a common feature in star forming regions of galaxies.

## Dr. Philip Kaaret
## Astrophysicist, Smithsonian Astrophysical Observatory



Philip Kaaret is an Astrophysicist at the Smithsonian Astrophysical Observatory and a member of the Harvard-Smithsonian Center for Astrophysics. Kaaret received a B.S. in Physics in 1984 from the Massachusetts Institute of Technology, and a Ph.D. in experimental particle physics from Princeton University in 1989. He was subsequently on the faculty of the Physics Department at Columbia University in New York City before coming to SAO in 1998.

Kaaret's main interest is understanding the intense gravitational fields surrounding black holes and neutron stars via X-ray observations of luminous matter captured by these collapsed stars. He studies the timing of oscillations in the X-ray emission and the spectrum of X-ray emission as means to determine the fundamental parameters (mass and spin) of the compact objects and to probe the behavior of matter in the strong gravitational fields near the compact objects. Kaaret also works in gamma-ray astronomy, primarily on the unidentified Galactic gamma-ray sources and the diffuse gamma-ray background.

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## Dr. Donald A. Kniffen
## Deputy Program Scientist, Chandra X-ray Observatory at NASA Headquarters

Dr. Donald A. Kniffen, formerly an astrophysicist at NASA's Goddard Space Flight Center, is currently Deputy Program Scientist for the Chandra X-ray Observatory at NASA Headquarters. He is a Visiting Senior Staff Scientist at NASA Headquarters on leave from his current position as William W. Elliott Professor of Physics and Astronomy at Hampden-Sydney College in Virginia.

## Dr. Hironori Matsumoto
## Postdoctoral Researcher, Massachusetts Institute of Technology

Dr. Hironori Matsumoto received a B.S, M.S., and Ph. D. in physics from Kyoto University, Japan, in 1993, 1995, and 1998. After receiving the Ph. D., he moved to RIKEN (The Institute of Physical & Chemical Research), Japan, in 1998, and then joined the Center for Space Research at MIT as a postdoctoral fellow of the Japan Society for the Promotion of Science (JSPS) in 1999.

His main research interest is X-ray emission from elliptical galaxies, starburst galaxies, and clusters of galaxies. He is also interested in X-ray CCD cameras, especially the radiation damage effects of the X-ray CCD.

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## Dr. Andrea Prestwich
## Staff Scientist, Smithsonian Astrophysical Observatory

Andrea Prestwich was born in Bristol, England in 1962 and has been interested in astronomy since she was about 5 years old. In 1984 she graduated from Queen Mary College, London, with a degree in physics. She completed her PhD in Astrophysics at Imperial College London in 1989, then accepted a post-doctoral position as a NRC Resident Research Associate at NASA-Marshall Space Flight Center. In 1991 she moved to the Smithsonian Astrophysical Observatory and has been a staff scientist at the Chandra X-ray Center for 5 years.

Her research interests focus on extragalactic astronomy, especially starburst galaxies and star formation in colliding galaxies. Her current position at the Chandra X-ray Center involves managing the science web site and organizing the science help desk.

## Professor Douglas Richstone
## Professor and Chair of Astronomy, University of Michigan

Douglas Richstone is Professor and Chair of Astronomy at the University of Michigan, where he has worked since 1980. He has held brief concurrent appointments at the National Observatory of Japan, the Institute for Advanced Study and the Institute for Theoretical Physics at UC Santa Barbara, and as a Guggenheim Fellow.

His service activities over the last decade include the State of Ohio Physics and Astronomy Review of Ph.D. Programs, member and chair of the Space Telescope Institute Council, the Gemini Project Oversight Committee, American Astronomical Society and Dynamical Division Prize Committees and the DDA council, the AURA (Association of Universities for Research in Astronomy) Board of DIrectors and the NASA Space Science Advisory Committee.

Richstone received a B.S. with honors in Astronomy from Caltech and a Ph.D. in Astrophysics from Princeton University in 1975. His most active current research activities include dynamics of galaxy centers and the demographics, formation and evolution of massive black holes. He is the leader of the "Nukers", an international collaboration of 15 scientists studying the nuclei of galaxies, and a member of the LISA (Large Interferometry Space Antenna) Mission Definition Team. He maintains interests in the estimation of cosmological parameters and formation and evolution of clusters of galaxies.

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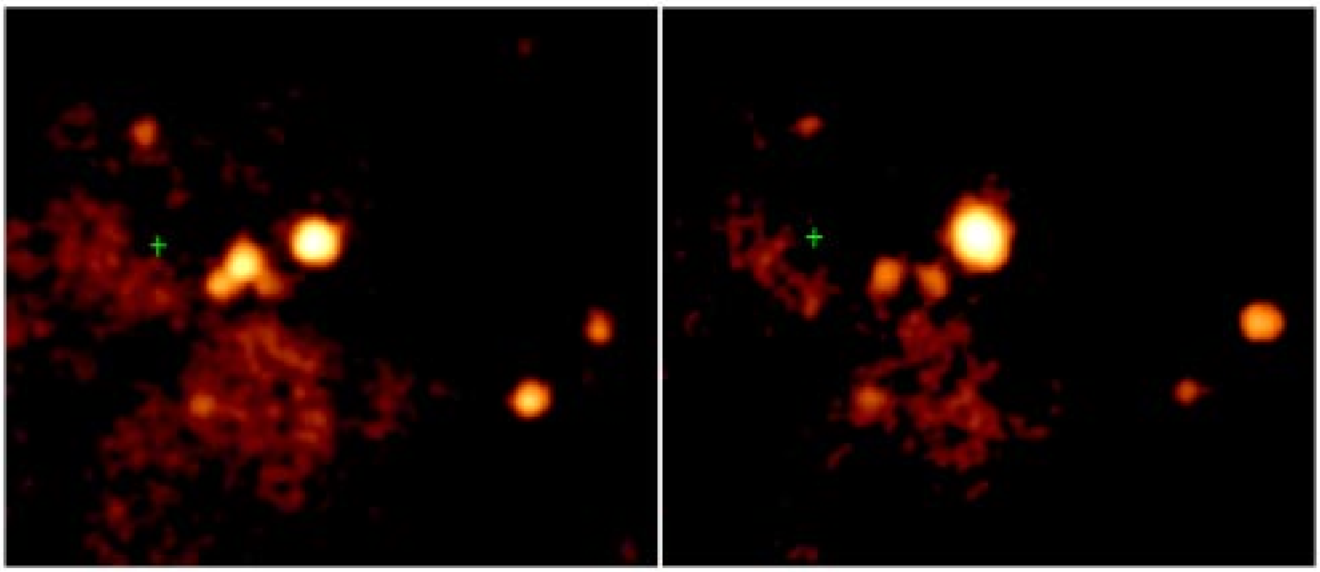
## Professor Martin Ward
## Professor of Astronomy, and Director of the X-ray Astronomy Group at the University of Leicester, UK

Martin Ward is currently Professor of Astronomy, and Director of the X-ray Astronomy Group at the University of Leicester, UK. He is Chairman of the European Space Agency's Astronomy Working Group and on the Editorial Board of the Monthly Notices of the Royal Astronomical Society.

His research interests include studies of active galactic nuclei, quasars and star-forming galaxies, with emphasis on multi-wavelength investigations to determine the primary energy source in luminous galaxies.

## M82



**M82:** A starburst galaxy, central region.

**Credit:** NASA/SAO/CXC

Using Chandra's superior resolution, astronomers have discovered a new type of black hole. The bright source near the center of the image is associated with the black hole. It is located 600 light years away from the dynamical center (small green +) of M82 and has a mass of more than 500 suns. This mid-mass black hole may represent the missing link between smaller stellar black holes and the supermassive variety found at the centers of most galaxies.

The source was seen to increase dramatically in intensity over a period of three months (compare left and right panels). Short-term flickering of the intensity with a period of ten minutes was also observed. This fast flickering and the peak intensity of the source are strong evidence that the X-rays are produced by matter falling into a large black hole.

**Scale:** The image is 30 arcsec on a side.

*Chandra X-ray Observatory HRC Images*