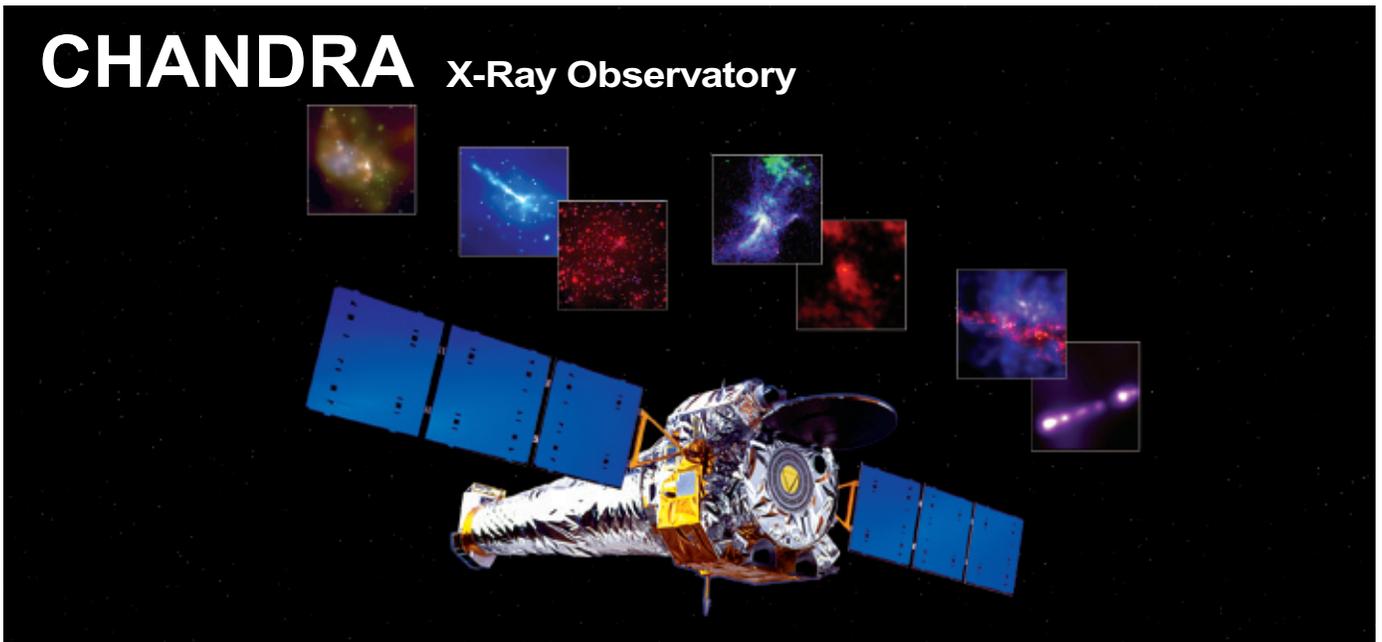


# CHANDRA X-Ray Observatory



## *Chandra's Mission*

NASA's Chandra X-ray Observatory, which was launched and deployed by Space Shuttle Columbia in July of 1999, is one of the world's most sophisticated X-ray observatory. X-ray telescopes are the only way to observe extremely hot, turbulent regions of space where matter has temperatures of millions of degrees Celsius. Chandra's unique power and precision provide astronomers with detailed information about the remnants of exploded stars, active young stars in star clusters, neutron star powerhouses, matter swirling toward black holes, supermassive black holes at the centers of galaxies, and vast clouds of hot gas in clusters of galaxies.

The data from Chandra observations are enabling scientists to make significant advances toward solving problems of fundamental importance, including:

- ♦The life cycles of stars, from the birth of stars like our sun to the fiery destruction of massive stars in supernovae that disperse carbon, nitrogen, oxygen and other elements necessary for life.
- ♦The generation of winds and jets of high energy particles into interstellar and intergalactic space by rapidly rotating, highly magnetized neutron stars and accretion disks around black holes.
- ♦The flow pattern of matter near black holes and the nature of gravitationally warped space near black hole event horizons.
- ♦The formation of supermassive black holes in the centers of galaxies and their role in the formation of galaxies.
- ♦The formation of galaxy clusters, the largest gravitationally bound objects in the universe, and the nature of the mysterious dark matter that comprises most of the mass of the universe.



## *Education & Public Outreach Program*

The goals of the Chandra EPO program are to:

- ♦Share new discoveries about the universe with broad segments of the public
- ♦Engage the imaginations of students, teachers and general public
- ♦Increase learning opportunities

We offer many resources for the education community:

- ♦A PUBLIC WEB SITE at <http://chandra.harvard.edu>  
The site includes all publicly released images in multiple, downloadable formats, extensive background materials, a section of informal education activities, both interactive and downloadable, and a section of formal, classroom ready materials.

### **Informal Education**

- ♦Posters, postcards, bookmarks, lithos, other printed materials and other resources are available to educators and amateur organizations by written request from the Chandra X-Ray Center or through the public web site. For a complete list see <http://chandra.harvard.edu/edu/print.html>
- ♦A CD-ROM of Chandra images is available by request through the Chandra public web site (<http://chandra.harvard.edu/edu/cd/request.html>)

### **Formal Education**

- ♦Classroom-ready activities aligned with national science standards are downloadable at <http://chandra.harvard.edu/edu/formal/index.html>
- ♦Teacher workshops are held each summer in collaboration with the Wright Center for Innovative Science Education. [http://www.tufts.edu/as/wright\\_center/](http://www.tufts.edu/as/wright_center/)

*Visit our public web site for the latest updates, and new downloadable products.*

**<http://chandra.harvard.edu>**

## Why an X-ray Telescope?

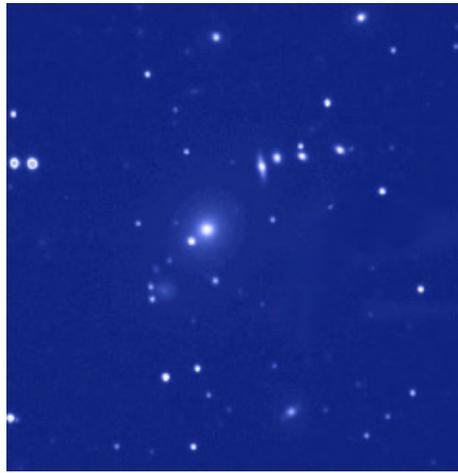
On the right are two images of the central part of the galaxy cluster called Hydra A. The cluster is approximately 840 million light years from Earth. The images are to the same scale but show very different things.

The optical image shows the many individual galaxies that make up the cluster. The stars in the galaxies have temperatures of several thousands of degrees Celsius and radiate light in the visible wavelength.

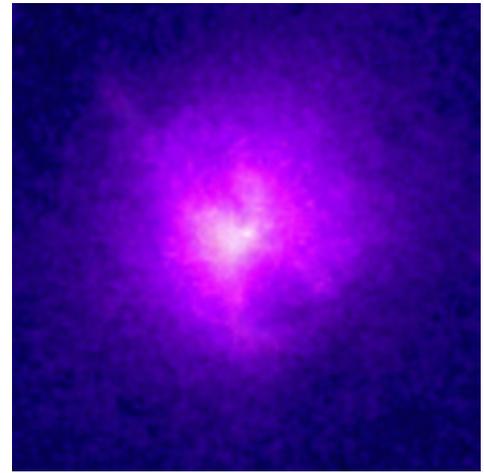
In the Chandra image, we can see the large cloud of multimillion degree gas that fills the space between the galaxies and radiates in the X-ray wavelength. The false colors applied to the image represent the brightness of the X-ray radiation, with white being the brightest.

The Chandra image shows the complex structure of the cloud of 35 million degree Celsius gas. Long strands are seen extending away from the center of the cluster, possibly deflected by intense magnetic fields produced by explosions from the supermassive black hole at the core of the central galaxy. Neither the hot gas nor its complex structures would be visible without an X-ray telescope like Chandra.

Why are scientists interested in studying the gas clouds in clusters? Galaxy clusters are the largest gravitationally bound objects in the universe. There is more mass in the hot gas between the galaxies than in all the stars in the galaxies that make up the clusters. Studying the composition and evolution of these gas clouds gives scientists information about the amount of matter, and the mysterious dark matter, in the universe. Those studies will help scientists understand the origin and ultimate fate of our universe.



Hydra A (Optical: La Palma/B. McNamara)



Hydra A (X-ray: NASA/CXC/SAO)

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### MEASURING THE CLUSTER ACTIVITY

#### Teacher's Note:

Before starting this activity, teachers and students may wish to read some of the background materials on the Chandra public web site at <http://chandra.harvard.edu>. Of particular relevance would be the section Chandra 101, and the Field Guide sections on galaxy clusters. Students should be familiar with the concepts of mass and density, and know the formula for computing the volume of a sphere.

How would an astronomer go about measuring the mass of this galaxy cluster? We can't visit it to take samples of the materials that compose it. What do we do?

If we can calculate the volume of the cluster in this image, then we can use a value for the mass density (which we get from other kinds of X-ray observations) to approximate the mass density of the part of the cluster that we see. To make it interesting, we are going to approximate the mass of this cluster in terms of the number of Earths and the number of Suns that could be made from the gas in this cloud.

1. For purposes of this calculation, the cloud of multimillion degree gas in the Chandra image is treated as a sphere. The sphere has a diameter of 500,000 light years. Using the formula for the volume of a sphere, calculate the volume of this gas cloud in cubic light years.
2. From other studies we know that the average mass density for the gas in a cluster is much, much smaller than the average mass density of the Earth, or even of the air we breathe. A cube measuring one light-year on a side would have only twice as much mass as the Earth. (Think about that: one light year = distance light travels in a year = 6 trillion miles, so a cube of gas with only about twice as much mass as the Earth would be really really huge!) Calculate how many Earth's could be made with the total mass from the gas cloud in the Chandra image.
3. The mass of the Earth is about 0.0003 percent of the mass of the Sun. How many Suns could be made from the cloud of hot gas in galaxy cluster Hydra A?

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Aligned with NSES grades 9-12 content standards A (Science as Inquiry), B (Physical Science-Interactions of energy and matter) and C Earth and Space (Origin and Evolution of the Universe).

Answers:  
1. Volume = 65,000 trillion cubic light years  
2. 130,000 trillion Earths  
3. 390 billion Suns