Online Modules from The University of Chicago

Multiwavelength Astronomy: X-Ray Impact, by Riccardo Giacconni
http://ecuip.lib.uchicago.edu/multiwavelength-astronomy/x-ray/impact/index.html

Subject(s): Astronomy/Physics

Grade(s) Level: 9-12

Duration:

- Two 45-minute class periods OR one 90-minute block;
- Three 45-minute class periods OR 1.5 90-minute block, including homework research and preparation, and extension research activities.

Objectives:

As a result of using this lesson, students will

- Be able to explain the importance of X-ray astronomy and X-ray technology;
- Be able to identify important traits for scientists and understand the reasons these traits are necessary;
- Be able to explain the importance of X-ray astronomy and X-ray technology.

Materials: Internet connection and browser for displaying the lesson; student journal or other mechanism for responding to Reading Guide questions.

Pre-requisites:

- A basic understanding of optical telescopes (lenses and mirrors);
- The understanding that there are different bands of waves in the Electromagnetic Spectrum (i.e., visible, infrared, ultraviolet X-ray, gamma);
- Understanding of astronomical terms (see vocabulary).

Procedures:

Students will read sections of the X-ray Impact lesson and work in small groups to prepare a short summary, answer questions from the Reading Guide, and share any passages, phrases, or words that require clarification (e.g., paraphrasing or defining).

Groups will present their section summaries, answers, and clarifications so that the entire class will have the information from the whole reading. The class will address the discussion questions and other observations and questions that arise from students.

Students complete “Exit Slips” (reflections on what they learned), or short essays on what they found interesting, or specific teacher-directed writing prompts from the discussion.

Extension questions from the Reading Guide are addressed; students present short responses to these based on research conducted outside of class.

Introduction:

- What uses X-rays? (Expected responses: baggage scanners, airline scanners, Homeland Security scanners, X-ray photographs of broken bones, CAT scans, radiation therapy/ cancer treatment, X-men comics.)
- When were they discovered? (In 1895, by William Roentgen, working with cathode ray tubes, discovered an invisible ray that could pass through cardboard.)
- Why is not good to play with X-rays? (Early uses were shoe fitting fluoroscopes, hair removal, taking recreational pictures of bones.)
- In 1949, X-rays from the sun were discovered. Why do you think it took so long to discover? (Because X-rays can't penetrate the atmosphere of Earth so rockets were needed to get instruments above the atmosphere.)
- This reading chronicles some of the landmarks in celestial X-ray research and the impacts that research has had on us today.
- You will read a section of the lesson, become an expert on that section, and report to the class on that section. By paying attention to our experts, you will know all about celestial X-rays.

Adaptations:

Visually impaired students will use text to speech programs to listen to the Web-based reading.

Additional Discussion Questions:

- What do you feel Giacconi would say are important traits for a scientist? Cite specific examples from the reading.
- Do you feel the pursuit of X-ray research has been necessary and justified?
- Is science the solitary pursuit of a single person or a group of people working together? Can you find examples in the reading? Are there examples you know of outside the reading?

Evaluation: Students will be evaluated on their participation within their group in the preparation and execution of the presentation. Groups will be evaluated on the accuracy and completeness of their presentation. Students will be assessed on their responses to the discussion questions.

Extensions: Research on V-2 rockets—their origin, civilian use, and impact on science and technology.

Suggested Readings: The lessons on the history, science, and tools of Gamma Ray Astronomy from the Multiwavelength Astronomy website.

Links: These websites are recommended for providing background and supplemental information:

Tour of the Electromagnetic Spectrum http://missionscience.nasa.gov/ems/
Chandra 101 http://chandra.harvard.edu/edu/chandra101.html
X-ray Images 101 http://chandra.harvard.edu/edu/xray101/xray101.html
Resources for the visually impaired
http://chandra.harvard.edu/resources/misc/visually_impaired.html

Vocabulary: The following terms are used and defined in the lesson. Teachers may want to review these in advance of using the lesson with students.

active galactic nuclei (AGN)
algebraic geometry
American Science and Engineering (AS&E)
angular resolution
aperture
astrophysics
aurora
calibrate
celestial
Chandra X-Ray Observatory
cloud chamber
cosmic background radiation
cosmic rays
cosmological
degree
epoch
external reflection
fascism
fifteenth magnitude
flux
focal plane
Friedman, Herbert
galactic
galaxy
gamma radiation (γ)
Geiger counter
grazing-incidence
guide stars
Gursky, Herbert
High Energy Astronomy Observatory (HEAO)
Indiana University
main sequence star
Occhialini, Giuseppe
payload
photometer
pipeline
plasma
pointing
Princeton University
projective geometry
proportional counter
radio waves
Rossi, Bruno
Scorpius X-1 (Sco X-1)
signal-limited
Space Science Board
star sensor
supermassive black hole
Tananbaum, Harvey
visible light

Standards: This lesson addresses Next Generation Science Standards HS-PS4-5; HS-ESS1-2; HS-ESS1-3; and HS-ESS1-4; and Common Core standards CCSS.ELA-Literacy.RST.9-10.1, 9-10.2, and 9-10.4.

Reading Guide

A Renegade Scientist
What do you think Giacconi means when thought that "astronomers were more like botanists than real physical scientists?"

American Science and Engineering
What did Giacconi work on at AS&E that lead to his working on X-ray Projects?
What is a V-2 Rocket? Where were they made? Why did the U.S. navy have them?
(Extension: What were some of the accomplishments and technologies that came from the V-2?)

Scorpius X-1
Why do the traditional lenses and mirrors for optical telescopes not work for X-rays?
What does work to focus (concentrate) X-rays?
(Extension: How do the reflectors work?)

A Plan for X-ray Astronomy
Why did the experiment to search for X-ray stars and lunar X-rays take an extra two years?
What did the X-ray experiment (June 18, 1962) discover?

Uhuru
What does Uhuru mean, and in what language?
What did Uhuru discover that could not be discovered by previous telescopes?
Why was Uhuru uniquely suited to making this discovery?

From X-ray to Multiwavelength
What are some examples of commercial products that utilize X-rays?
What are the three reasons Giacconi cites to justify his feeling that X-ray astronomy needed to be researched in an academic setting, rather than within a commercial setting?

Einstein (HEAO-2)
Giacconi states the handling of the data on *Einstein (HEAO-2)* was radically different from traditional approaches. What was different? Why was this necessary?

A Methodology for Astronomy
What was Giacconi's method for managing projects?

Hubble Space Telescope
What was necessary to develop before *Hubble's* guidance system could be used?
What is a "software pipeline" and what was its significance for *Hubble*?

Chandra X-ray Observatory
From Proposal to launch, how long did *Chandra* take?
How long is 1 million seconds?

The Impact of X-ray Astronomy
With optical light observations, astronomers could see planets (in our solar system,) stars and galaxies. What did the addition of X-ray observations add to astronomy?
One of the impacts that celestial X-ray research has had is the development of products. What are some of these products?
(Extension: What is a Noble Prize? What is the significance of a Noble Prize? What is the history of the Noble Prize?)