



Multiwavelength Astronomy: The Tools of X-ray Astronomy, by Harvey Moseley (Goddard Space Flight Center)

<http://ecuip.lib.uchicago.edu/multiwavelength-astronomy/x-ray/tools/index.html>

Subject(s): Astronomy/Space Science

Grade(s) Level: 9-12

Duration: Two Class Periods

Objectives: After reading The Tools of X-ray Astronomy, students will be able to

- Summarize Harvey Moseley’s personal journey as a scientist and his contributions to developing detector technologies;
- Specify ways in which the nature of scientific inquiry is collaborative and challenging;
- Identify examples of technology developments at the leading edge of astrophysical research and explain how they work;
- Discuss the role of problem-solving, creativity, and serendipity in science.

Materials: Internet connection and browser for displaying the lesson; student journal.

Pre-requisites: Students should be familiar with the Electromagnetic Spectrum and understand that light behaves differently according to its wavelength. Students should have basic understanding of how a telescope works. Students should also understand that some light does not reach Earth, so it is necessary to place telescopes and detection instruments in space.

Procedures: Students will read through the X-Ray Tools lesson and answer questions using the Reading Guide below.

Introduction:

X-ray light has much more energy than optical light. If you try to capture X-ray light with a reflecting telescope, as you do for optical light (which is also called visible light), the X-rays will go right through the telescope’s mirror. It took someone with a very creative outlook to develop a detector that could catch X-rays. Harvey Moseley is that person. As you read through Harvey’s story think about the questions listed below.



Reading Guide

A Farm Education

Harvey grew up on a farm in an area of the country that his family had been since before the founding of the United States. He had the opportunity to fix farm equipment with his father by taking it apart and putting it back together again. “A surprisingly good education” is what Harvey called it. What kind of experiences have you had that gave you “a surprisingly good education” outside of the classroom?

Leaving Home – Coming to Chicago

Harvey’s move to boarding school gave him exposure to better curriculum and helped him become a better student, but it came at a price. Do you think it was worth it?

A Mathematical Answer

The microcalorimeter spectrometer (called XRS) Dan and Harvey developed was used for the first time in the Astro-E Astronomy mission. This was a joint project between Japan and the United States. Unfortunately, the rocket it was on failed 42 seconds after launch and it crashed back into the ocean. It was five more years before a second one was launched and that one had problems also. Another calorimeter will be going up during 2013-14 and hopefully will be the first working one. What would you have done, how would you have felt if it had been your work crashing into the ocean? Would you have been able to keep working on another one?

Detecting X-rays – Serendipity in Science

Can you imagine pulling out a piece of paper from a drawer with a calculation you had done a year before and using it to launch a new type of detector for a telescope? That is what Harvey did when the X-ray group came knocking on his door and a micro calorimeter that has high resolution was evidently developed. He calls this one of those “serendipitous moments in science.” Think about today’s climate of instantaneous results and impatience for long term research. The public and Congress often do not want to fund scientific research that doesn’t have a quick payoff. How does this attitude affect what Harvey says we have to keep doing, in regards to keeping people thinking and inventing?

The James Webb Space Telescope

Harvey showed creativity in his work with X-ray detectors and he did it again with the new James Webb Telescope. His work with microshutters is ground breaking. The microshutters are arranged in several arrays, each array containing over 62,000 shutters. Each shutter is about the width of a human hair.

Advice to Young Scientists – The Nature of Scientific Inquiry

Harvey made several points in his advice to young scientists. Some are listed below. Which do you think is the most important? Explain why.

The trick is, you have to be so enthusiastic about tackling the work that you’re willing to put the time in to do it. It’s an emotional investment.



The technical stuff you can learn to do, but to answer interesting questions you have to figure out how to improve upon something to solve your problem.

Find the best thing in the world, and then duplicate it. Once you can do that, then you can try some innovation.

Inquiry involves connecting things that are from very different phases of your experience and exploring and discussing them with a team of people with different ideas and experiences of their own.

Adaptations: Have students work in small groups to read sections of the X-ray tools lesson and prepare a short summary of each section to present to the class as a whole. As a group address discussion questions and reflections on the material.

For Additional Discussion: At The University of Chicago Harvey had the opportunity to work in infrared astronomy with the Kuiper Airborne Observatory. This telescope allowed astronomers to look at wavelengths of infrared light that do not reach the surface of the Earth. What effect do you think this experience had on Harvey in light of his later work with X-ray light and gamma ray light detectors?

Evaluation: Formative assessment of student understanding based on answers to questions in the Reading guide. Follow up with extensions and/or suggested readings.

Extensions:

Harvey's work with CoBE brought him into contact with John Mather and George Smoot. These two men won the Nobel Prize in 2006 for their work and discoveries using this COBE telescope. This telescope, which Harvey helped build, looked at light from the Big Bang that is still shining down on us. Spend some time to understand the importance of this telescope and its discoveries by choosing one of these links below to explore. Then describe what you think is the reason they got the Nobel Prize and if it is a worthy reason.

- Listen to [John Mather's Nobel Lecture](#) explaining these discoveries.
- Listen to the short version – [John Mather's 4-minute talk](#) at the Nobel banquet.
- Listen to [John Mather's interview](#) on the Nobel Prize website.
- Read [John Mather's biography](#) at the Nobel Prize website.
- Listen to [George Smoot's Nobel Lecture](#) explaining the importance of the COBE work.
- Listen to [George Smoot's interview](#) on the Nobel Prize website.
- Read [George Smoot's biography](#) on the Nobel Prize website.



Find out more about microshutters by browsing the links below. Describe what you find most interesting about the shutters.

- [ESA To Set Tiny Hair-Like Webb Telescope Microshutters](#)
- [James Webb Space Telescope – Microshutters](#)
- [NASA Engineers Rehearse Placement of Webb Telescope’s NIRSpec and Microshutters](#)

Suggested Readings: The lessons on the history, science, and impact of X-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/>
 The newest airborne observatory is [SOFIA](#) – the Stratospheric Observatory for Infrared Astronomy. It just started test flights in 2012.

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.

Cosmic Background Explorer (CoBE)	James Webb Space Telescope (JWST)	microcalorimeter
cosmic background radiation	Kuiper Airborne Observatory	National Bureau of Standards
dark matter	laser	serendipitously
galaxy	Learjet	Sputnik 1
Goddard Space Flight Center (GSFC)	Mather, John C.	University of Chicago
Harper, Doyal	McCammon, Dan	University of Wisconsin-Madison
indium		X-ray spectroscopy
infrared astronomy		Yerkes Observatory

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.