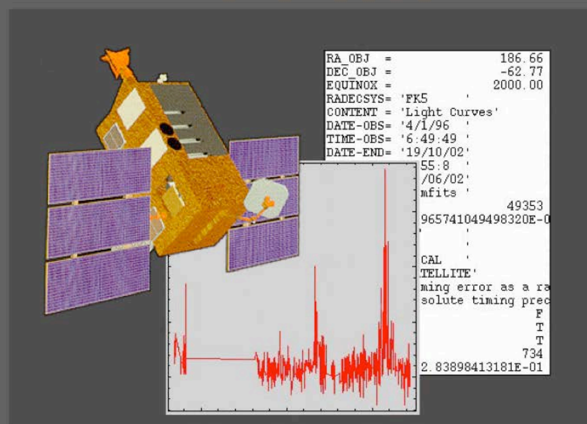
NASA Data, Activities, and Analysis in Your Classroom



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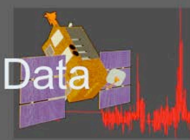
This presentation is a summary of Student Hera, featuring each of the tutorials.

This presentation is for NSTA Philadelphia, March 2010

Astronomy in the Classroom

- ★ What if you could explore pulsars, binary stars, and black holes in your classroom?
- ★ What if your students could work with the same astronomical data and software that scientists at NASA use?

Connect to classroom using NASA Data

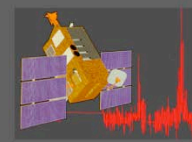


Astronomy data analysis offers students:

- ★ applications in science and math concepts
- ★ opportunities to improve inquiry and research skills
- ★ engagement in real-world problem solving
- ★ an understanding of relationship between data and theory
- ★ learning of concepts within an exciting context
- ★ a connection with NASA and other institutions
- ★ experience with what “real scientists” do

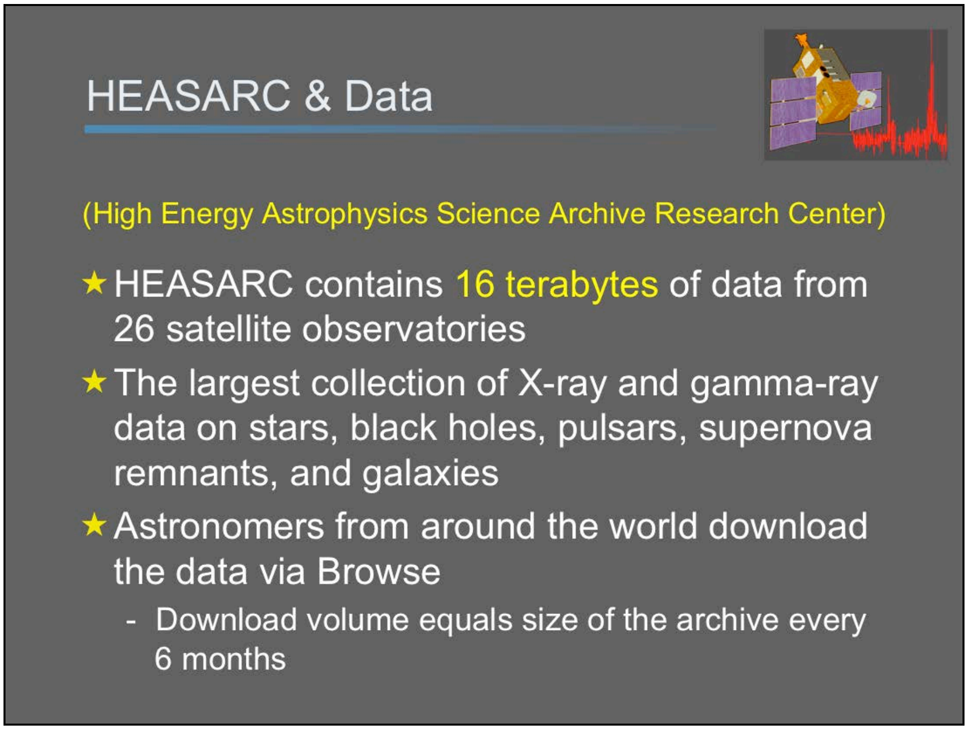
Using data in the classroom shows that anyone can do “real science” – it’s not scary!

NASA & Data



- ★ NASA has petabytes of data from its satellites, manned exploration, and research programs
- ★ 1 petabyte of information = approximately 50 times the size of the entire print collection of the U.S. Library of Congress
- ★ Data is ever-growing with new missions – and with newer technology, data gets bigger
- ★ Specialized data management has been created for NASA's unique storage needs

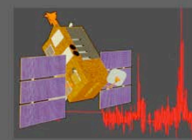
A petabyte is a billion megabytes. (or a million gigabytes)



The HEASARC data holdings are from a variety of satellite missions, going back to the 1970's.

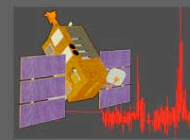
Browse is a tool used developed by the HEASARC to access its data archives.

Welcome to Student Hera!

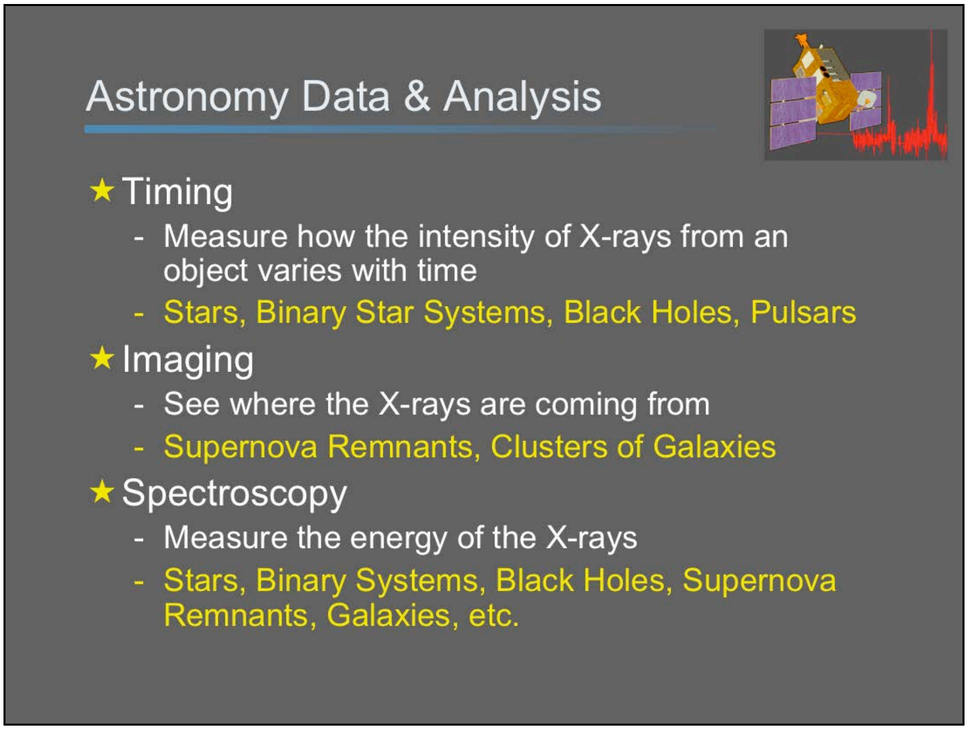


- ★ Student Hera brings real astronomy into the classroom!
- ★ Students use the same software and methods as scientists to study objects in space such as black holes, pulsars, and binary stars.
- ★ One small download brings the universe to your fingertips.

What are Hera and Student Hera?



- ★ Hera provides an interface to satellite data and analysis tools which are used by scientists.
  - Neither tools or data need to be downloaded to user's local computer.
- ★ Hera is used by scientists around the world.
- ★ Student Hera is a scaled-down interface which provides selected data sets and tools for teachers and students.
  - Web pages provide tutorials of the analysis for students.

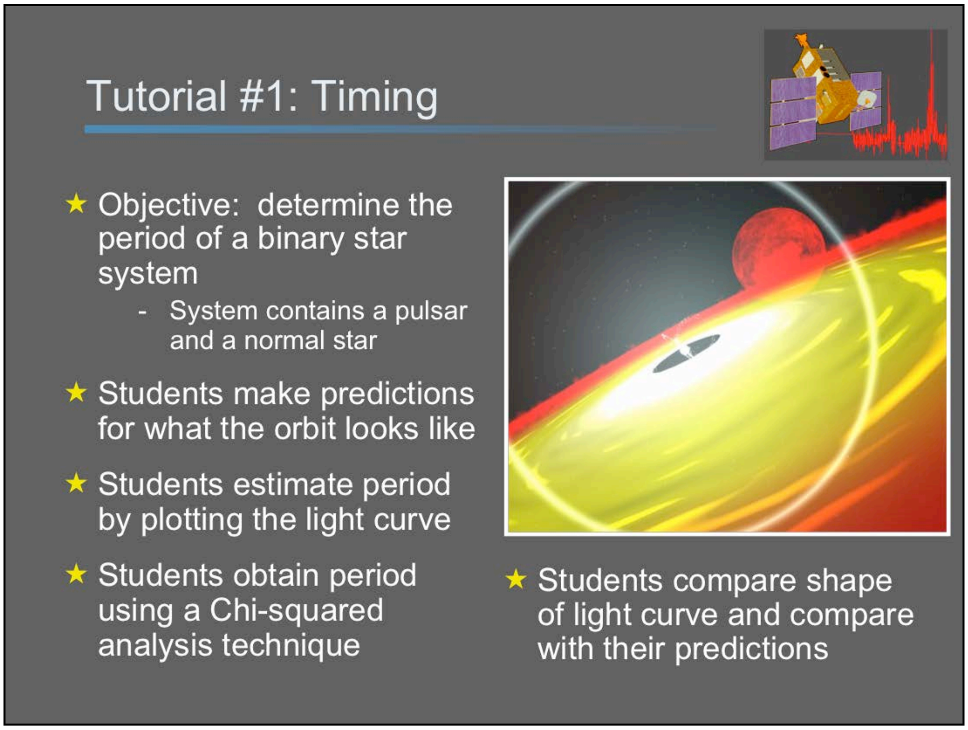


Astronomy data and analysis falls in these three broad categories. Student Hera provides three tutorials covering these.

"Timing" data measures how the object's intensity varies with time.

"Imaging" data allows us to see what the object looks like. With "false color" techniques, we can view objects in wave bands other than optical

"Spectroscopy" data measures the energy of the X-rays, allowing us to determine the physical mechanisms which give rise to the radiation.



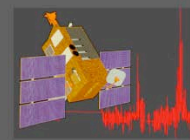
Each tutorial provides science background and exercises that walk the student through the concepts and using the analysis tools.

The Timing tutorial is a good place to start.

A pulsar is a type of neutron star. This object shines in X-rays when matter from its nearby binary companion flows toward the pulsar. As the matter circles around the pulsar, the pressure and density rise, causing the temperature to rise. As the temperature rises, the matter emits X-rays.

The closer the two stars are to each other, the more X-rays we see. So if the X-ray intensity varies as the two stars orbit each other, what type of orbit might they be in? (Answer: elliptical).

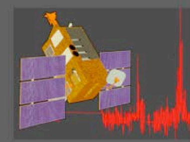
Studying pulsars with HERA



- Looking at objects with an X-ray telescope can teach us about their structure, features, and behavior.
- Pulsars are neutron stars (very small, dense stars) that "pulse" with radiation through the rotation of intense magnetic fields.
- Observing these pulses can teach us about the rotation, period, and other features of the pulsar!

A neutron star is the end point of stellar evolution for stars that have between about 8 to 20 times the mass of our Sun. When that star ends it's life, it will explode in a supernova, and the core will collapse, leaving behind a neutron star that is about 1.4 to 5 times the mass of our Sun and has a diameter of about 20 km.

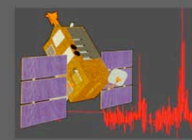
GX301-2

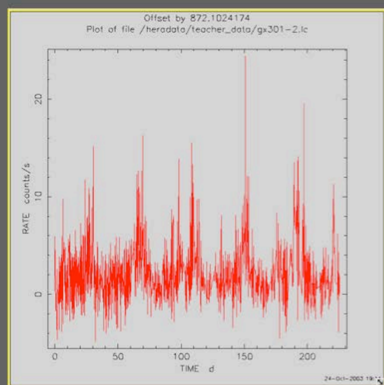


- ★ GX301-2 is an X-ray binary system -- a pulsar in orbit with a supergiant star. Mass is transferred from the supergiant to the pulsar.
- ★ The more mass dumped onto the pulsar, the more X-rays it will emit.

- ★ From the data, we can calculate the orbital period and determine the type of orbit.

Light Curves and Periods

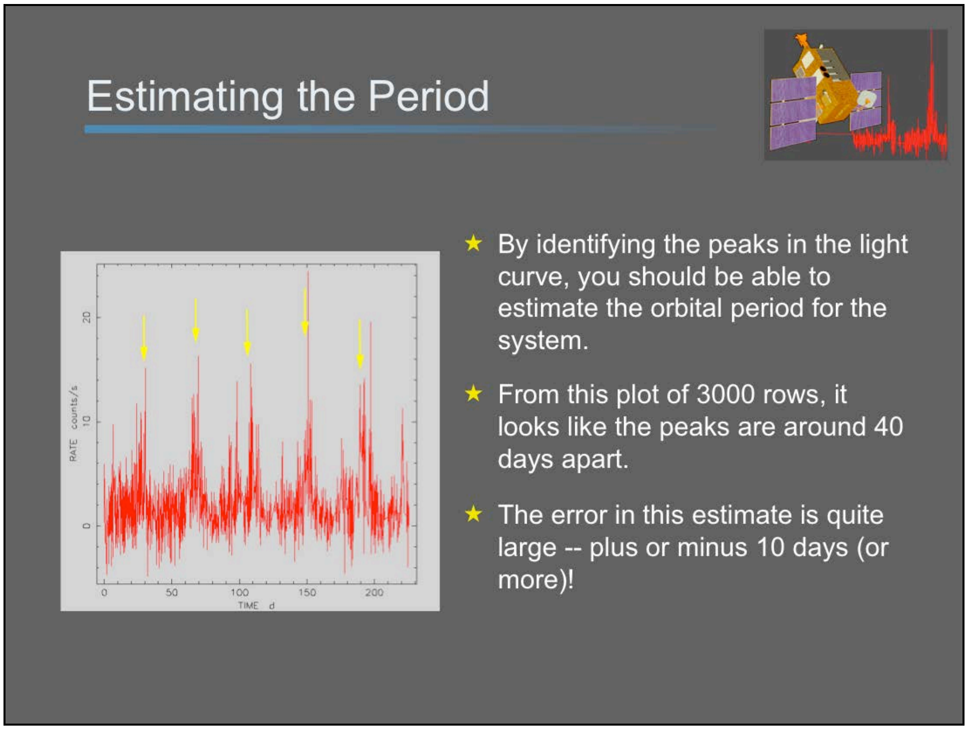




- ★ A light curve is a graph which shows the brightness of an object over a period of time.
- ★ In the study of objects which change their brightness over time, the light curve can help us determine the rotational period of an object, or the orbital period of two objects in a binary system!

In the timing tutorial, students plot the light curve, adjusting the amount of data to plot. Students identify a pattern in the light curve and visually estimate a period. For middle school students, this is a natural stopping point in the lesson.

This is the RXTE data from GX301-2. Have participants estimate the period (by eye)



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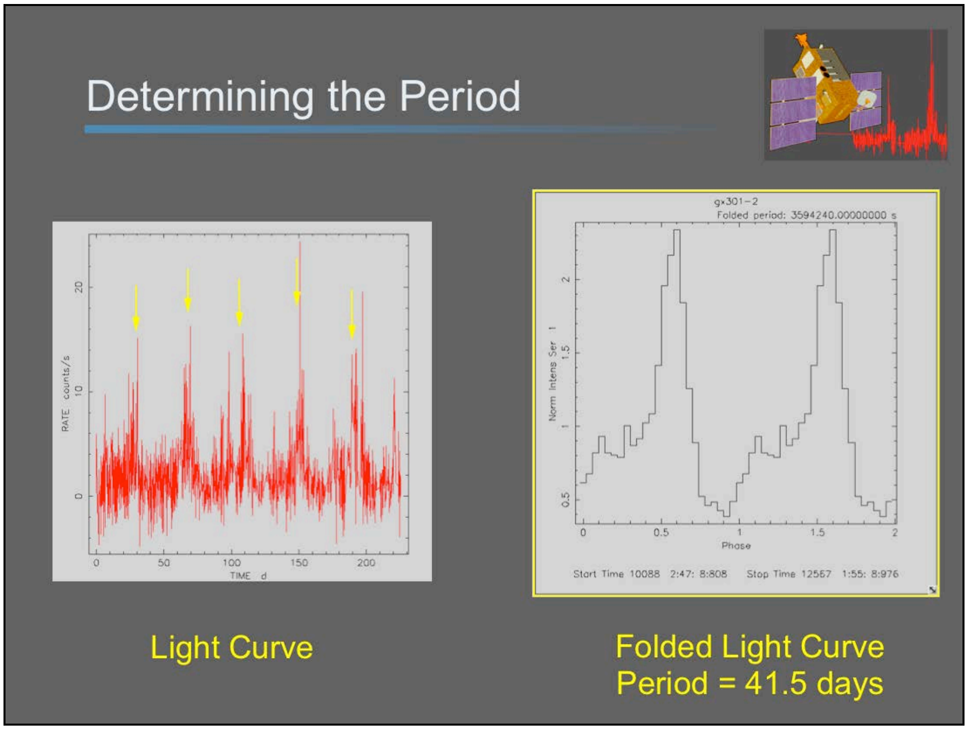
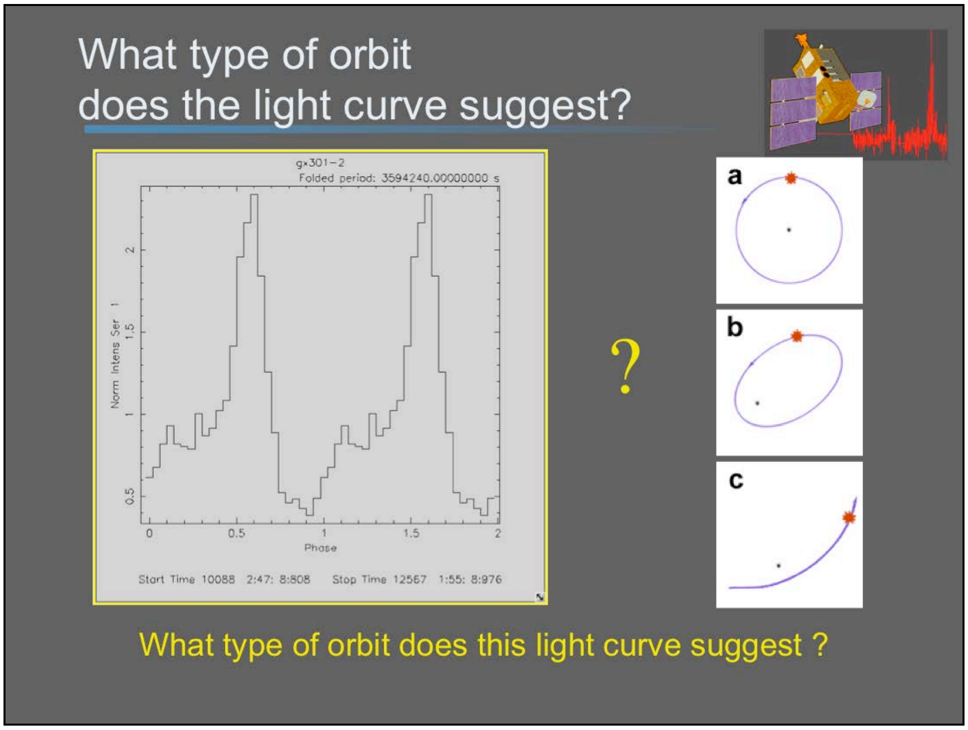


Using their estimated period, high school students use techniques to better determine the period. They end with a plot of the “Folded Light Curve” [Right Figure], which depicts the light curve averaged over the period.

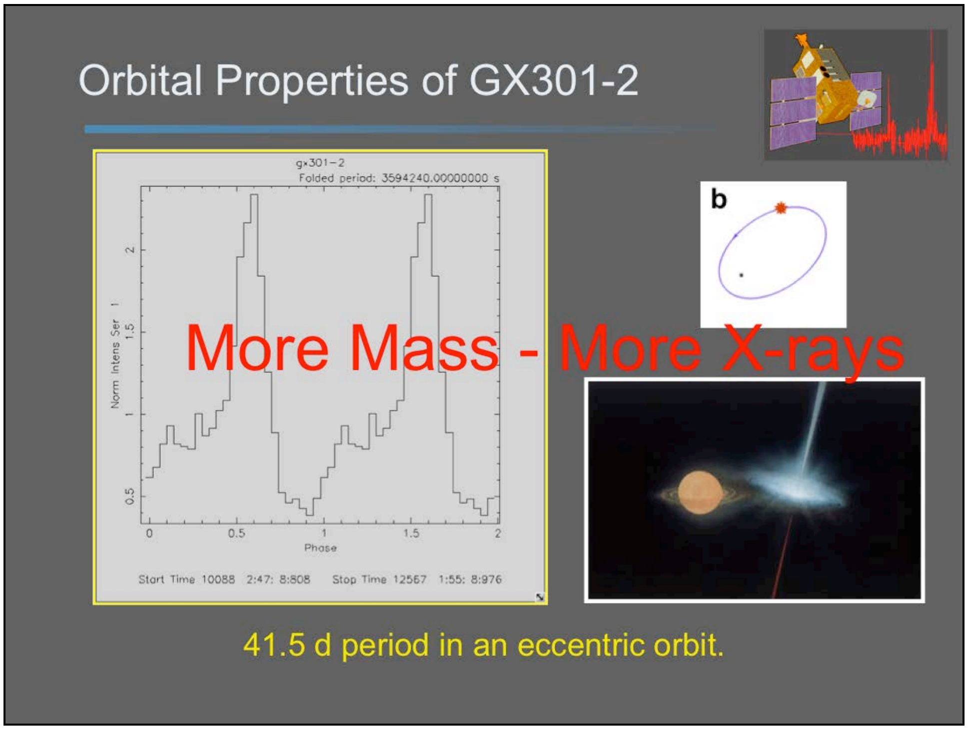
In “folding a light curve” you identify individual periods, and average them together. The folding algorithm tests a series of trial periods, and uses a chi-squared statistic to determine the best period.

Students then compare this with their predictions for the nature of the orbit.



From the folded light curve, have participants predict the type of orbit.

Recall that “more X-rays results from more mass transfer”



Watson, Warkwick & Corbet, 1982 MNRAS, Vol 199, p. 915 is discovery paper for the period. They note the sharp peak is a flare just before periastron passage (about 5 days). They also note that the light curve cannot be explained simply by accretion via the stellar wind. There's an additional interaction of the x-rays from the pulsar with the stellar wind. The interaction may produce shocks, which result in absorption regions trailing the pulsar. They awaited spectroscopic results for confirmation.

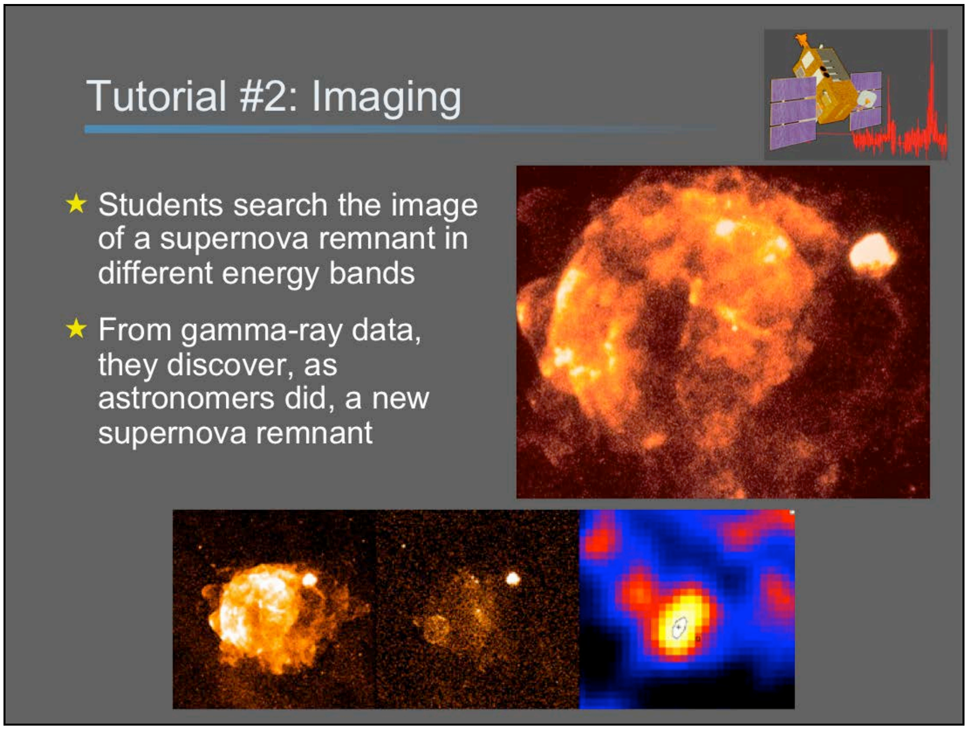


Image in upper right is the Vela Supernova Remnant (SNR)

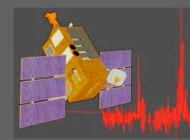
In the bottom row of three images:

Left - The Vela SNR (filling most of the image) and the smaller Puppis A SNR (near the 2 o'clock position at the edge of Vela) in ROSAT Image at X-ray energies 0.1-2.4 KeV;

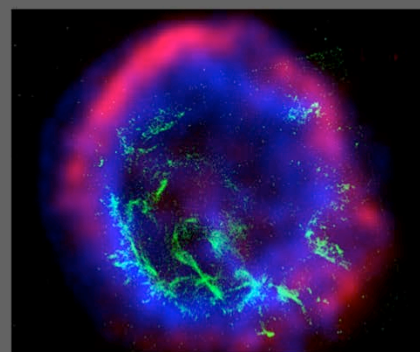
Center - ROSAT Image for X-ray energies 1.3-2.4 KeV;

Right - COMPTEL Image (from the Compton Gamma Ray Observatory) of newly discovered Supernova Remnant

Tutorial #3: Spectroscopy



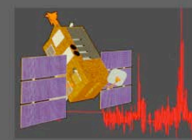
- Examine a supernova remnant
  - An exploded star and element “factory”
- Determine the elemental composition
- Students model the spectrum with continuous x-ray emission and spectral lines



Here’s the APOD description of the image of E0102-72

Not all stars form a big Q after they explode. The shape of supernova remnant E0102-72, however, is giving astronomers a clue about how tremendous explosions disperse elements and interact with surrounded gas. The above image is a composite of three different photographs in three different types of light. Radio waves, shown in red, trace high-energy electrons spiraling around magnetic field lines in the shock wave expanding out from the detonated star. Optical light, shown in green, traces clumps of relatively cool gas that includes oxygen. X-rays, shown in blue, show relatively hot gas that has been heated to millions of degrees. This gas has been heated by an inward moving shock wave that has rebounded from a collision with existing or slower moving gas. This big Q currently measures 40 light-years across and was found in our neighboring SMC galaxy. Perhaps we would know even more if we could buy a vowel.

Supernova !



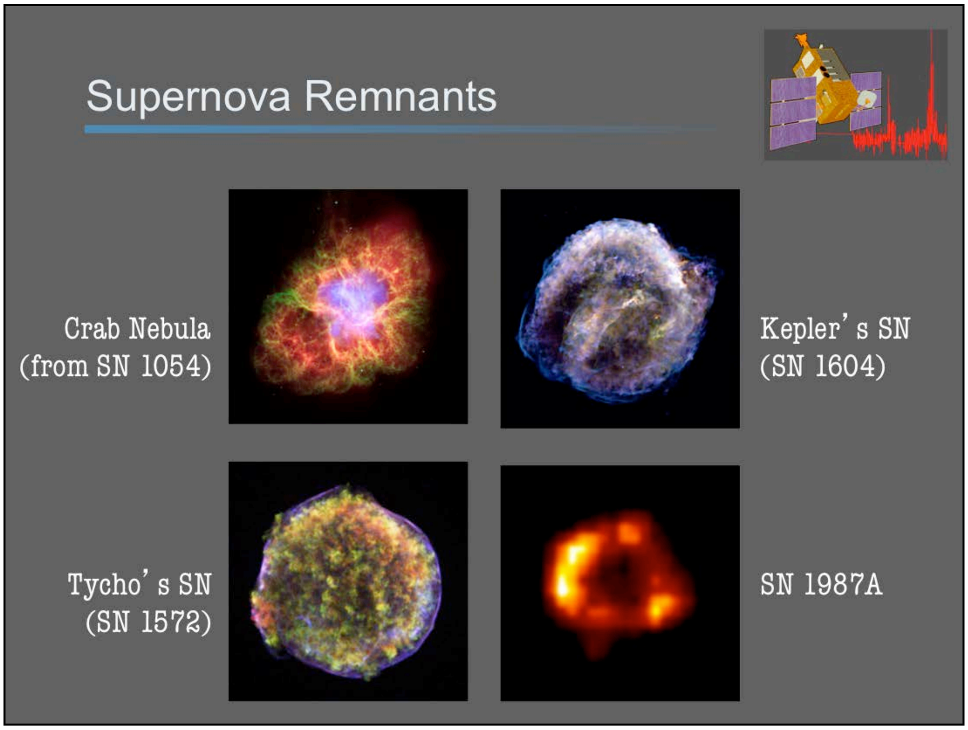
The End of the Road for Massive Stars

SN1987A before and after image from Anglo-Australian Observatory. It's in the LMC, 160,000 light-years distant.

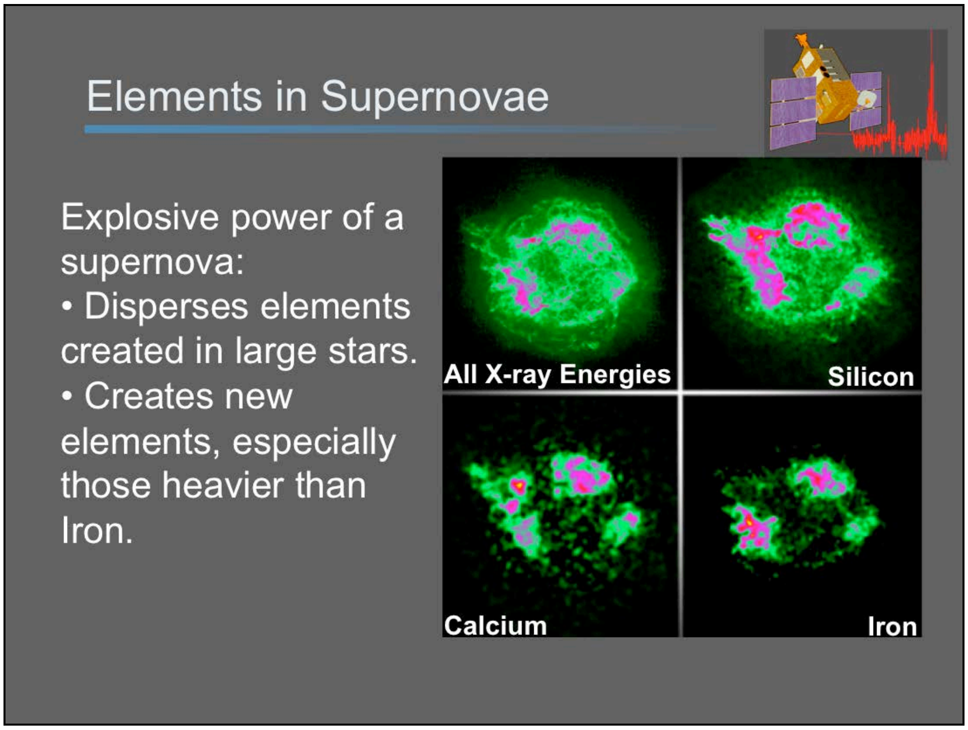
A supernova is the end of the road for massive stars. It occurs once the core of the star is filled with enough iron that sufficient fusion no longer is possible

When fusion process no longer produces energy to support the star, the core of the star collapses. With nothing to stop it, the atoms are crushed together, and the infalling material bounces off the superdense core, causing the explosion.

A supernova produces 10^{40} erg/s (a million times more than the sun). The supernova disperses the elements it has created. In addition, the energy of the explosion creates elements heavier than iron.



These are examples of recent supernovae. These leave remnants of gas.



Supernovae are able to do two very important things:

(1) Create new, heavier elements.

(2) Disperse the elements that were created in the star that exploded.

These images are from Chandra, showing the Cassiopeia A supernova remnant in different x-ray energies. These images show the distribution of elements ejected in the explosion. They are part of a gas that's about 50 million degrees.

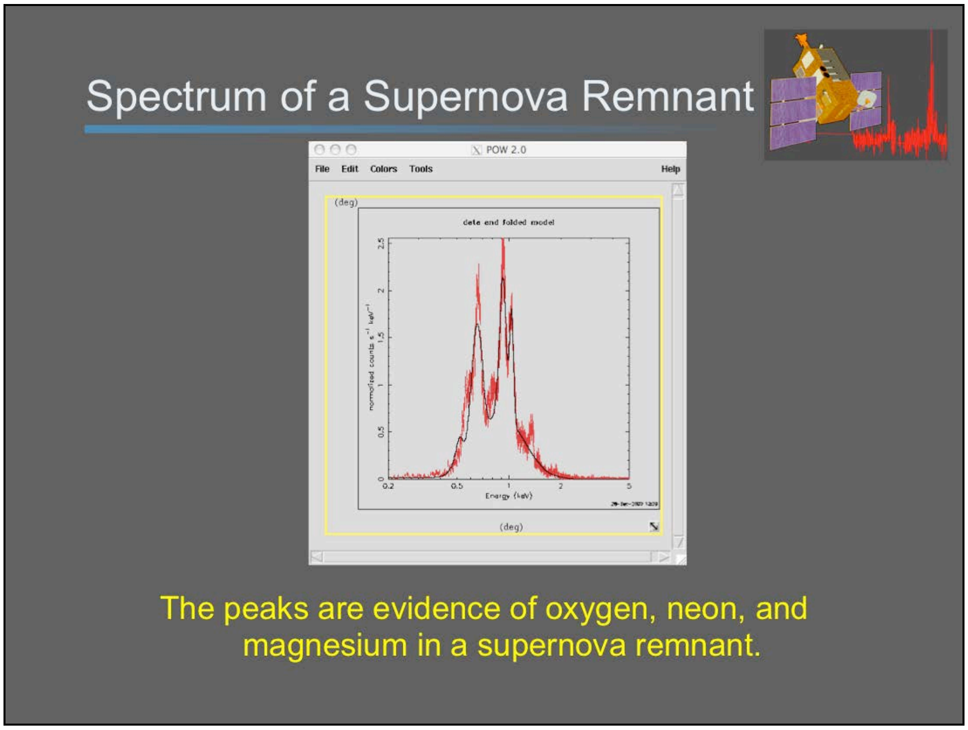
In these images, yellow regions show the most intense concentration, followed by red, purple, and green.

The upper left image is from all X-ray energies, and the others are centered on the lines of particular elements (Silicon, Calcium, and Iron).

Note the asymmetry, especially in silicon, possibly due to an asymmetry in the explosion. The iron image suggests that the layers of the star were overturned either before or during the explosion.

Click on the poster icon in lower right to return to slide #6

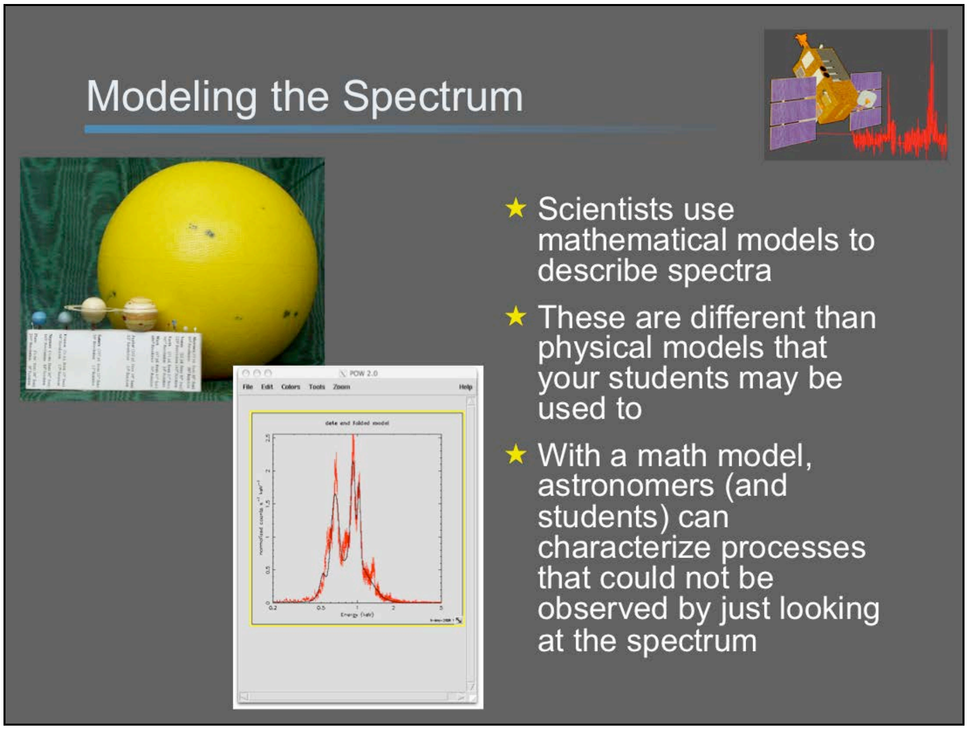
[All images are 8.5 arc minutes on a side (28.2 light years for a distance to Cas



In analyzing a spectrum, students match the data with models which describe types of emission mechanisms.

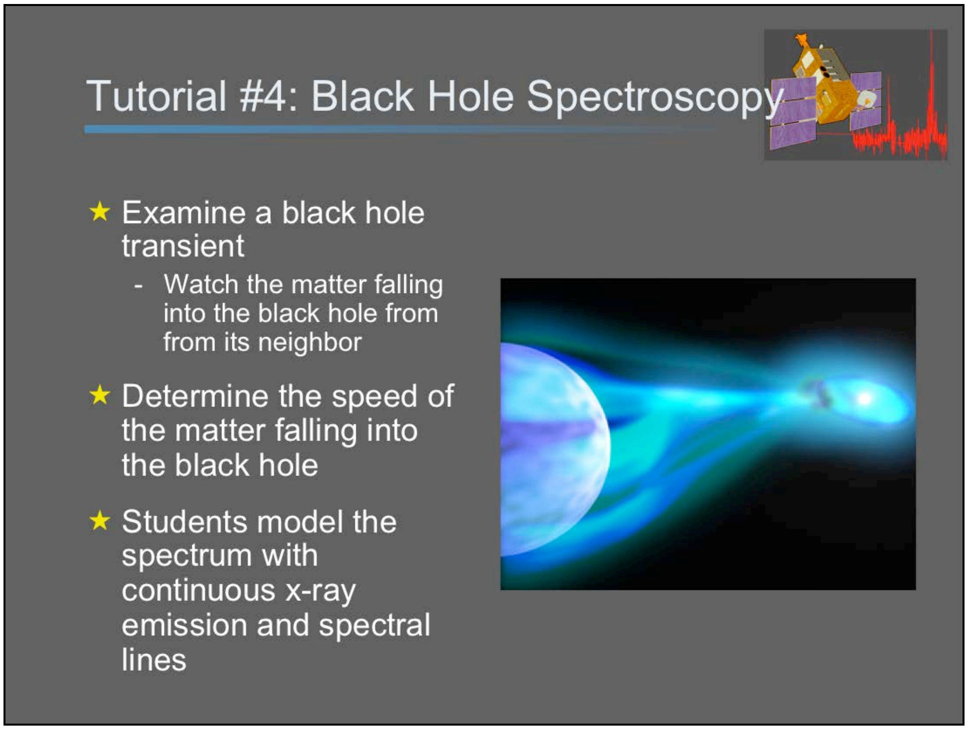
In the spectroscopy module, students first choose a model for the overall continuum. They then insert lines to model the distinct emission lines seen in the data. They then match the energies of those lines with known energies of emission lines from common elements. They find the supernova remnant contains oxygen, neon, and magnesium.

Students (and teachers) are probably more familiar with spectral lines in the optical, where you look at a light through a grating and lines of colors appear, the specific lines being unique to a specific element. This plot is essentially the same thing, but instead of lines of color, we have spikes in the intensity – each of the three spikes is similar to the bands of color in the more familiar spectral experiments. In the case of the X-ray, we generally need only one line of color to identify an element (or in this case, ion of an element) – again, students are used to needing several lines, like a fingerprint, to ID elements. Each of these spikes corresponds to a transition unique to a specific ion of an element (in this case, oxygen, neon and magnesium).



Students are generally familiar with physical models – such as a model of the relative sizes of the planets in the solar system. They might pick a pilates ball as the sun, then determine other appropriately sized objects to represent each planet.

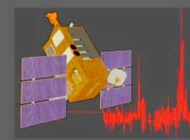
However, with spectroscopy, astronomer need to use mathematical models, with equations describing the different processes that could be causing the observed spectrum. A computer then optimizes the “free parameters” of the model (the aspects of the model that the astronomer allows to change, such as a temperature of the emitting body or the energy/wavelength at which a spectral line appears).



The data is from black hole transient named 4U 1630-472, a low-mass x-ray binary. A low-mass X-ray binary is a system that started with two stars; one of which has ended it's life as a black hole or neutron star (in this case, a black hole). We see X-rays from the system because the black hole's companion is donating material to the black hole. As that material approaches the black hole, it spirals around it, forming a disk of matter. The matter in the disk (called an accretion disk) heats up due to friction/viscosity. When the matter in the accretion disk gets close enough to the black hole, it dives directly in, accelerating and emitting X-rays.

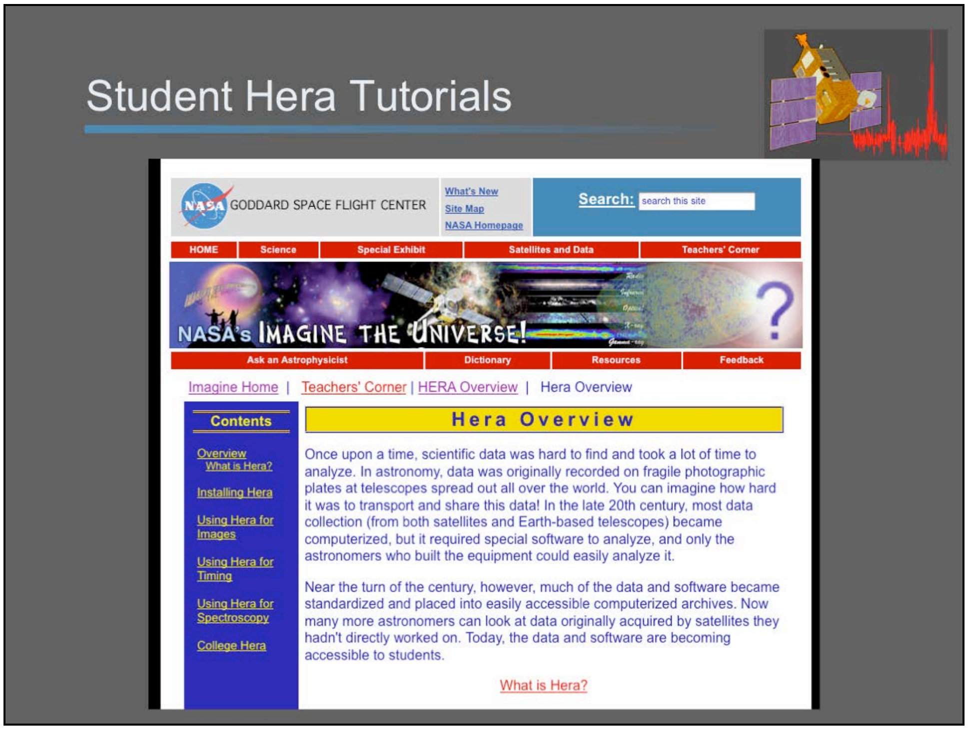
This system has had a sudden outburst, which was captured by Suzaku. Students get to examine the resulting spectra and see what caused the outburst.

Using Student Hera

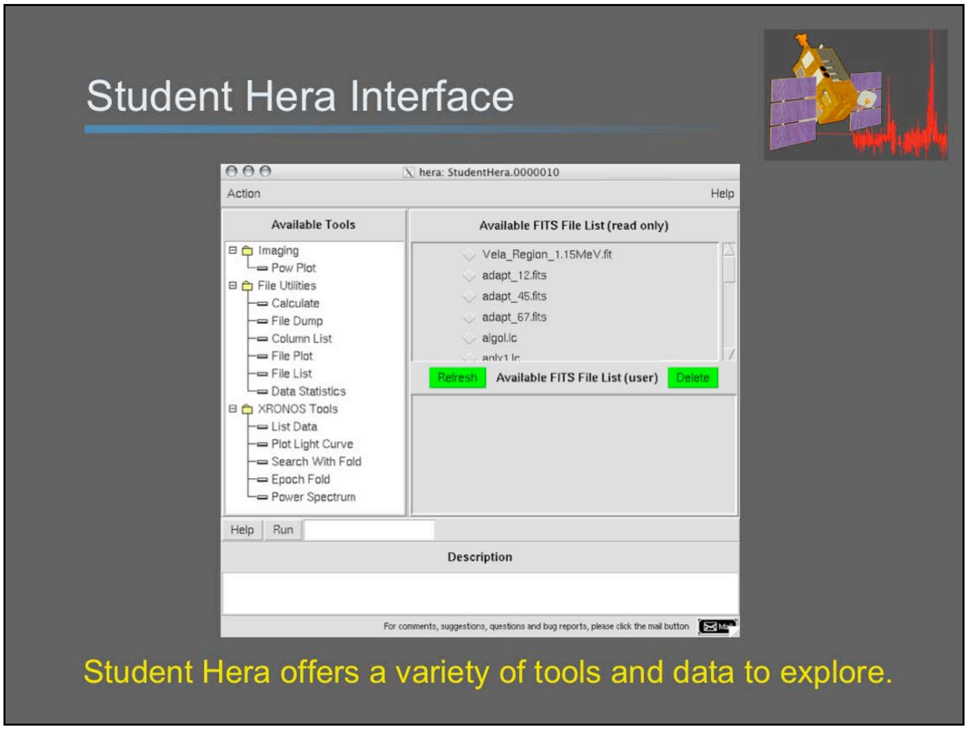


- It's easy to get started with Student Hera in the classroom. The website leads you through installation and getting started.
- Student Hera requires one 10MB download from the website and an active internet connection. An installation wizard to guide you through set-up. Just click on the Student Hera icon on your desktop, and you're ready to go!

The one drawback is that there is a download and installation of software required at this time – we are currently working to make this available through a web-interface, especially keeping in mind those schools that have a stringent process for getting new software on their classroom computers.



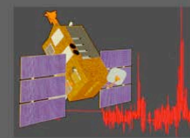
The Student Hera tutorials are available on the Student Hera web pages on the imagine site (full URL is given later).



Using Student Hera is easy!

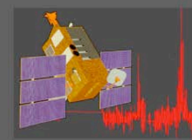
Just select a Tool (in the left hand menu), a data set (upper right hand menu), and click “Run”. A dialogue box will appear. The tutorial guides students in choosing parameter inputs.

From Tutorials to Research



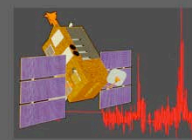
- Once students have mastered the analysis techniques, they can expand analysis to other objects
  - Group or individual research projects
  - Science fair projects
- Tutorials parallel historical research done by scientists – results can be researched and verified in scientific literature

Classroom uses for Student Hera

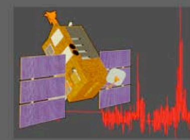


- ★ Use software and exercises within lessons on related concepts, such as light curves, X-ray astronomy, or binary stars. Plotting tools can create useful visual aids!
- ★ Assign students individual or group projects using Student Hera. Projects can be based on the guided activities on the website -- many variations are possible.
- ★ Integrate into lessons on mission design and technology. Student Hera offers a look at the real data that comes back from satellites, as well as the specialized analysis and manipulation that scientists perform.
- ★ Use with related lessons and activities from online learning resources such as Imagine the Universe! and mission-related sites like the RXTE Learning Center.

College Hera Lab

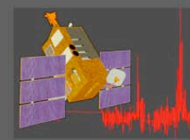


- Timing Tutorial is also available as a 2-hour lab experience for 1st year college astronomy courses.
  - Guided web course tracks student progress and tests concept understanding
  - http://imagine.gsfc.nasa.gov/docs/teachers/hera_college/
  - Developed by Dr. Beth Hufnagel, Anne Arundel Community College, Maryland



New Ideas?

How would you use Student Hera in your classroom?



Check us out online!

http://imagine.gsfc.nasa.gov/docs/teachers/hera/