Black Hole in M83

Topic:
Black holes

Concepts:
multi-wavelength observations,
black hole evolution

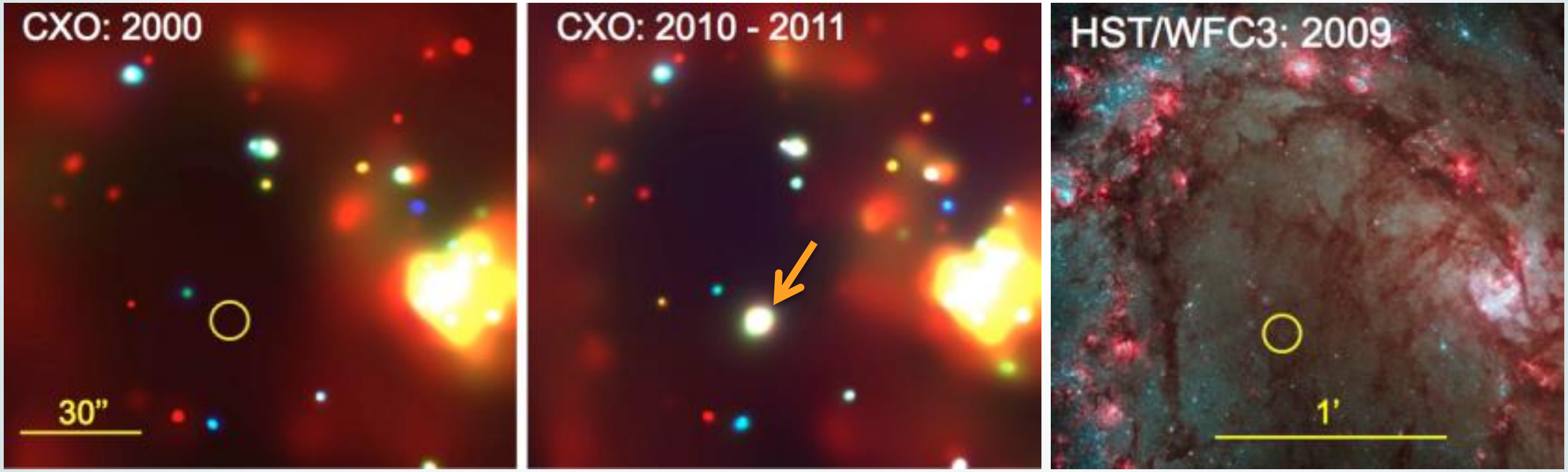
Missions:
Hubble, Chandra, Swift

Coordinated by
the NASA Astrophysics Forum

An Instructor's Guide for using the slide sets is available at the ASP website
https://www.astrosociety.org/education/resources-for-the-higher-education-audience/

A Black Hole Begins a Feeding Frenzy

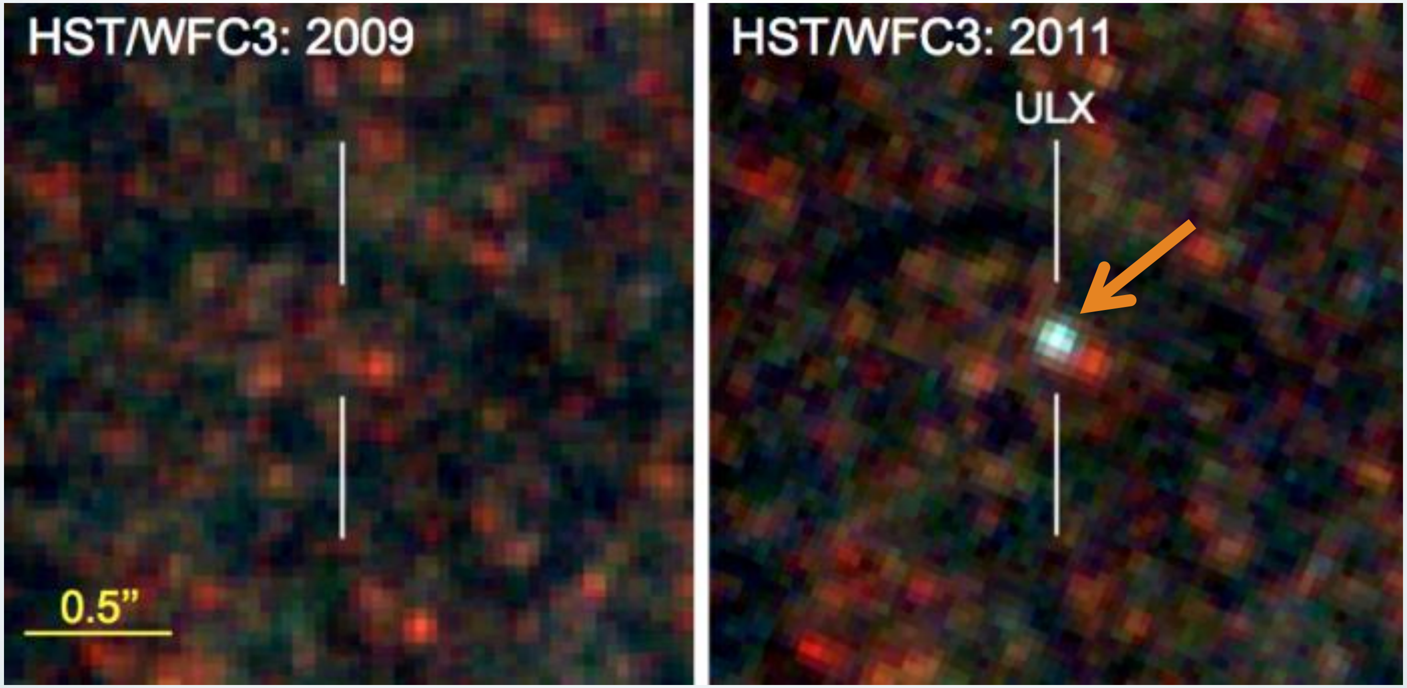
- In December 2010, the *Chandra* X-ray Observatory (CXO) discovered a **very bright x-ray source in the galaxy M83** where none had been seen previously.
- Similar super-bright X-ray sources have been seen in other galaxies, but only in this case are observations available before the source "turned on."
- This **unique discovery** allows insight into the cause of the X-ray emission, and the answer is not what astronomers had expected.



Left and middle: X-ray images of a portion of M83 before and after the new source turned on. Red indicates low energy X-rays and blue indicates higher energy X-rays. Right: Hubble Space Telescope (HST) optical picture of the same region. More details of the galaxy structure are seen in the HST visible-light image including stars, dust lanes and glowing gas clouds.

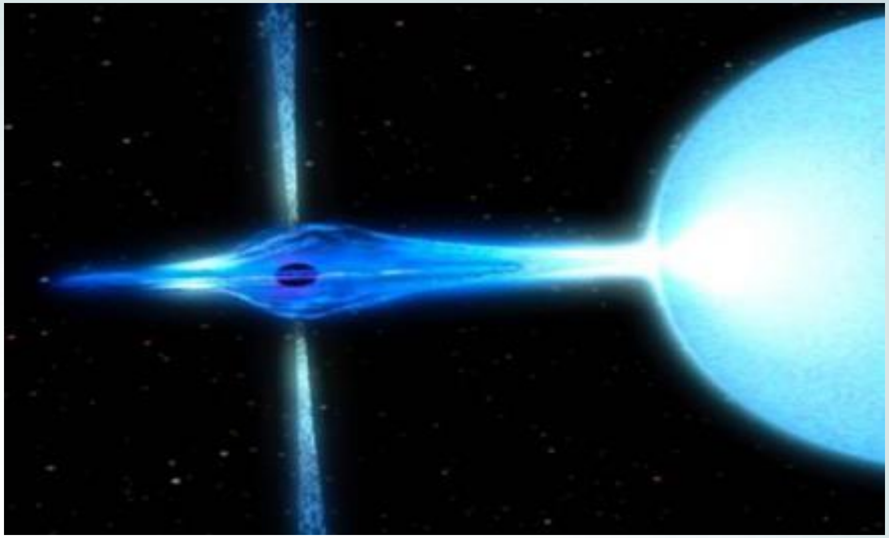
What Was There Before?

- Images taken with the Hubble Space Telescope (HST) a year **before** the X-ray source discovery show only *faint and cool red stars* in that region.
- New HST images taken a few months **after** the X-ray detection, revealed that a very *blue, hot source* had appeared.



HST optical images of a tiny region centered on the new X-ray source position, taken before (left) and after (right) the X-ray source "turned on." *HST*'s high resolving power and sensitivity were needed to see these exceedingly faint stars in M83.

The Big Picture



(Artist's conception: NASA)

A black hole feeds off a blue companion star, creating a hot, blue "accretion" disk of material around the black hole (seen edge-on here) before this material is swallowed up. Prior to the discovery in M83, evidence supported only this model for the formation of such ultra-luminous X-ray sources.

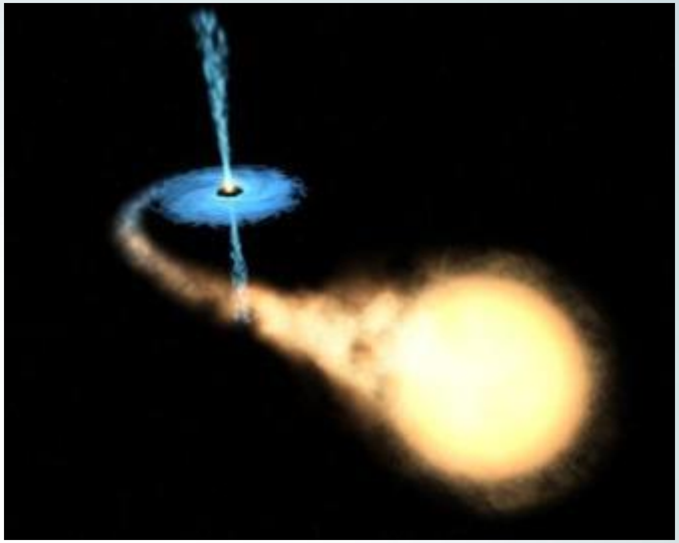
- Similar **ultra-luminous X-ray sources (ULXs),** presumed to be X-ray emitting black holes, found in other galaxies also show blue counterparts in optical images.

- Astronomers usually attribute the blue light to a **young, massive, blue companion star** in orbit around the black hole. Material from the blue companion is gravitationally dragged into the black hole and heated to X-ray temperatures while in the process of being swallowed up.

- In this new case, there was **no blue source present** before the outburst, and so no hot, blue star. So what is the blue source and where did it come from?

How does this discovery change our view?

- **Apparently, an ultra-luminous X-ray source can arise from a black hole in a binary system with a cool, red, lower-mass star.**
  - The blue light comes from a disk of material that is swirling in toward the black hole, not from a blue companion star!
  - *This conclusion could apply also to similar sources in other galaxies that have blue optical counterparts.*



Artist's conception: ESA/NASA/Felix Mirabel

- **Oftentimes, discoveries create new insights for astronomers:**
  - **The X-ray characteristics imply this black hole must be 40-100 times the mass of the sun.**
  - **Evidence suggests that the companion star is a red giant several times the mass of the Sun** that has expanded enough for the black hole to drag material from it to create a bluish accretion disk as it consumes the material.
  - **Astronomers must rethink their ideas about how ULXs are created**—and that there's more than one possible configuration for such objects.

Resources

Press Releases about this result
Chandra Press Release:
http://chandra.harvard.edu/press/12_releases/press_043012.html

Chandra Photo
Release: http://chandra.harvard.edu/photo/2012/m83/

Gemini Release:
http://www.gemini.edu/node/11811

Journal Articles
Soria, R., et al. 2012, ApJ, 750, 152 arXiv:1203.2335

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BONUS CONTENT

Collaboration Leads to Discovery

The discovery benefited from the availability and flexibility of different NASA space observatories:

- *Chandra X-ray Observatory*: **discovered** the new source.
- *Hubble Space Telescope*: had taken (for another science program) optical images of the galaxy M83 **prior** to the onset of the new X-ray source, and could secure **follow-up images** quickly after the discovery.
- *SWIFT*: used on short notice to **monitor the ongoing behavior** of the X-ray emission from the bright X-ray source.

Their combined information at different wavelengths (energies) was vital to unravel the nature of this source:

- X-ray
- Optical

Researchers from institutions around the world contributed:

- Space Telescope Science Institute and Johns Hopkins University, MD, USA
- Middlebury College, VT, USA
- Harvard-Smithsonian Center for Astrophysics, MA, USA
- Curtin University, Australia
- Gemini Observatory, Chile

Collected Instructor's Notes

"A Black Hole Begins a Feeding Frenzy" (page 2 in this PDF)
Chandra and Hubble images look different because of the wavelengths each telescope can observe and spatial resolution. Chandra sees diffuse X-ray emission, while Hubble can observe dust and gas structure in visible wavelengths.

"What Was There Before?" (page 3 in this PDF)
Note the scale bar: these images only show regions about 3 arcsec (3″) across. Without the high spatial resolution provided by Hubble, the details in these images would be completely smeared out.

Note also the serendipity involved here: it was only luck that provided a Hubble image from before the outburst!

"The Big Picture" (page 4 in this PDF)
Ultraluminous X-ray sources, or ULX's, are loosely defined as "compact X-ray sources that are brighter than normally expected for typical X-ray emitting mass-transferring binary stars. So ULXs represent an extreme variety of the X-ray binary star phenomenon.
In physical units, individual sources with luminosities higher than about 10^39 ergs/sec are classified as ULX's.

Compare the illustration on this slide to that on the next to show how astronomers' view of ULXs has now changed.

"How does this discovery change our view" (page 5 in this PDF)
Note: For optical stars, blue-white stars are hotter than red stars, so the color is a temperature indicator.
Because the red stars seen before the outburst are so faint, astronomers can tell they must be low mass stars.
So the star that is now transferring mass to the black hole companion must have been a low-mass cool star.

After the outburst, the blue light is coming not from a hot, blue companion star, but rather from a heated disk of material swirling into the black hole.
The characteristics of the X-ray emission allow the mass of the black hole itself to be estimated.