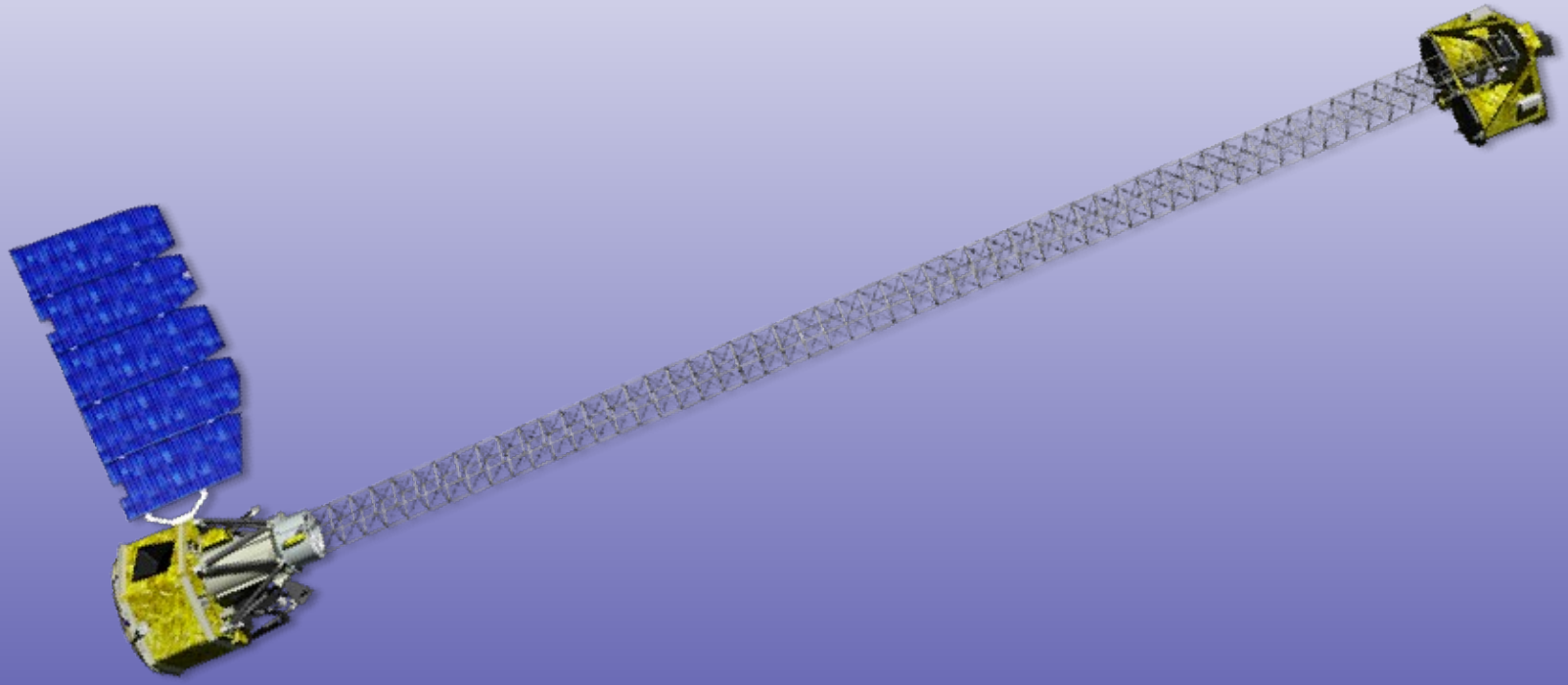
NuSTAR's Sharper View of the Universe



Prof. Lynn Cominsky
SSU Education and Public Outreach
Sonoma State University

My Mom and the Stars

- I first learned about the stars from my Mom
- She taught me the constellations on camping trips with our girl scout troop
- And so I started looking up at the night sky in wonder…

Home, Sweet Home?

- Growing up in Buffalo, we didn't see the sky too often – too much snow!

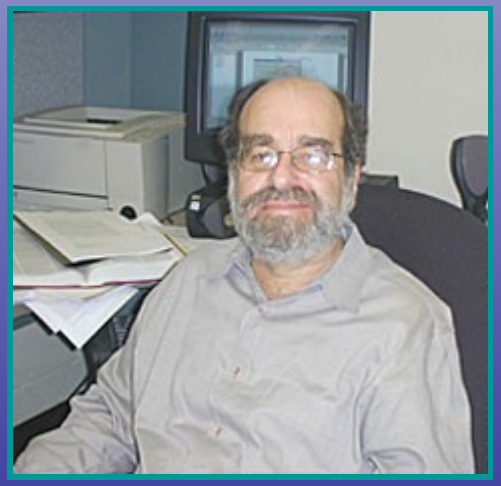
A young skywatcher…

Sweet Home High School

My childhood

College at Brandeis U. (1971-1975)

- I was a physical chemist, with a double major in physics
- I studied the Belusov-Zhabotinsky oscillating reaction



Prof. Irv Epstein

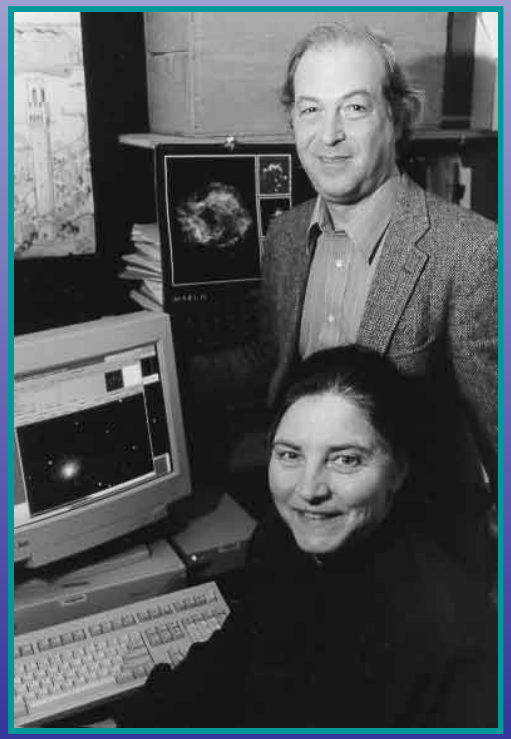
Non-linear chemical dyamics

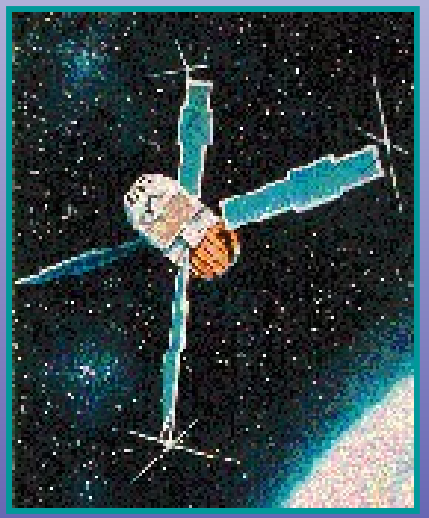
Harvard -Smithsonian Center for Astrophysics (1975-1977)

- Analyzed data from Uhuru – first x-ray satellite

Drs. Bill Forman and Christine Jones

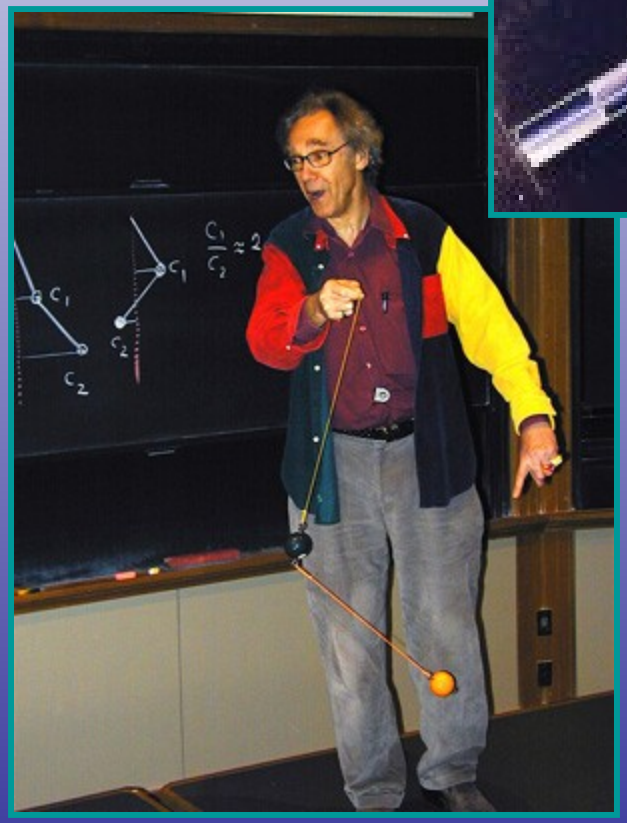
60 Garden Street
Cambridge, MA





Grad School at MIT (1977-1981)

Prof. Walter Lewin



SAS-3 satellite

Re-entered in 1979

Got married to Dr. J. Garrett Jernigan, Jr. on 6/1/1980

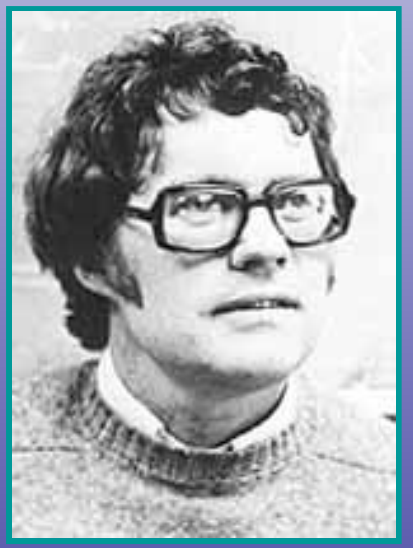
UCB Space Sciences Lab (1981 – 1986)

- Worked on Extreme Ultraviolet Explorer satellite project

Prof. C. Stuart Bowyer

UCB SSL

EUVE



Sonoma State University (1986 – present)

- Worked on Very Small Array radio telescope on roof of Darwin Hall
- Taught electronics, various physics & astronomy courses
- Many NASA research

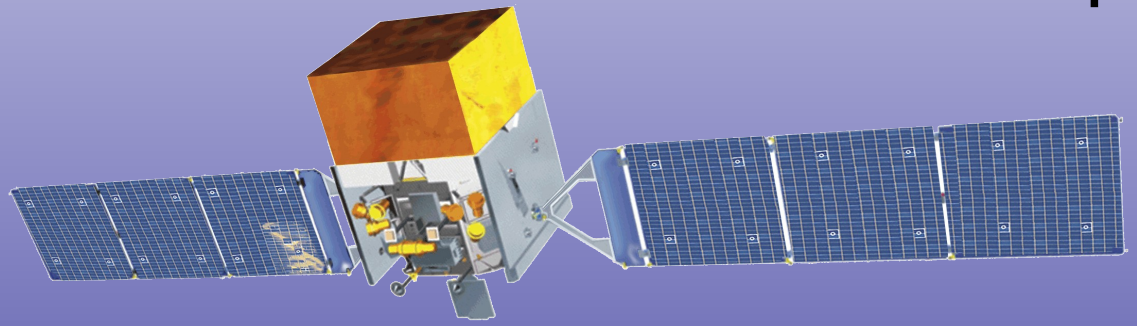
grants with undergrads

- Tenure in 1990
- Full professor in 1991

One VSA dish

The Education and Public Outreach Program at SSU (1999 – present)

We are a group of scientists and educators working on high-energy astrophysics space science missions and other projects.



Fermi

On-line course for college students

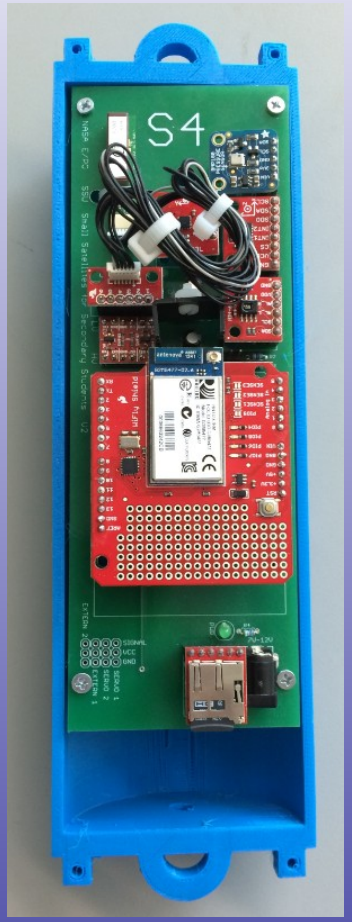
XMM-Newton

Swift

http://s4.sonoma.edu

Small Satellites Project

Balloon payload launched on tether



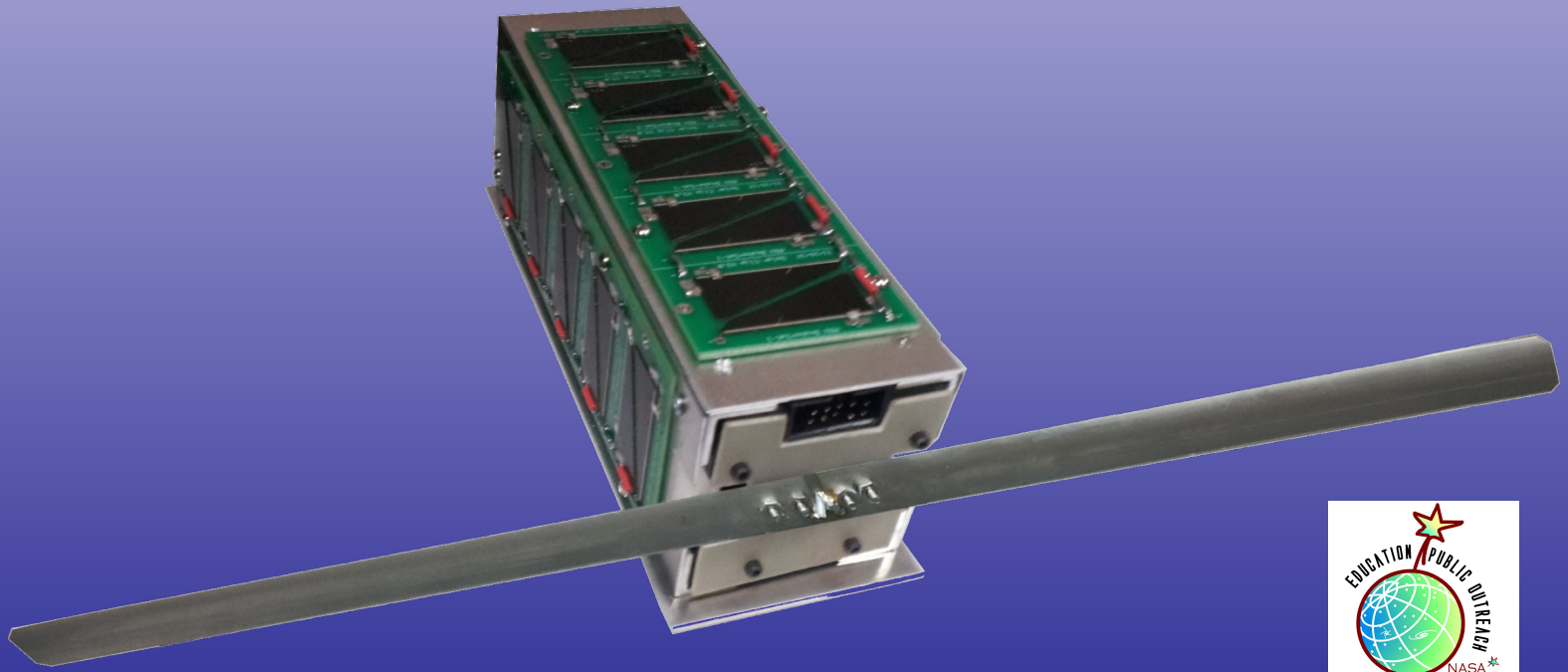
S4 payload designed by Kevin Zack

Bottom view

Zack's L2 rocket at Black Rock

T-LogoQube – SSU's first satellite

- About 5 cm x 5 cm x 15 cm and 1 pound
- Polar orbit at 634 km
- Launched 11/20/13 – worked for 2 months!

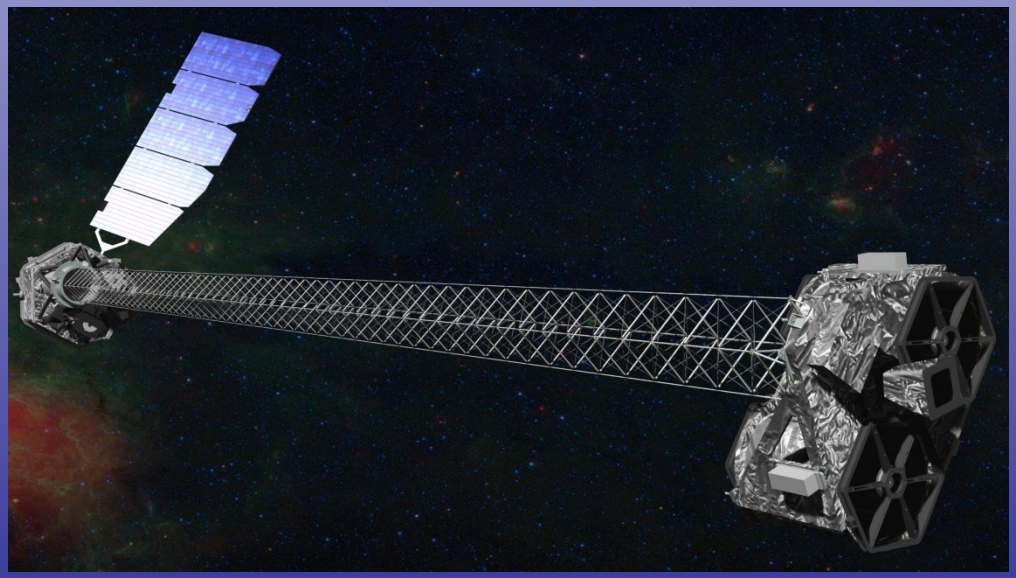


E/PO Group Satellite Missions

- *XMM-Newton* – launched 12/10/1999
  - Focusing soft x-ray telescope
- *Swift* – launched 11/20/2004
  - Gamma-ray burst explorer
- *Fermi* (aka *GLAST)* – launched 6/11/2008
  - High energy gamma-ray sky survey +GRBs
- *NuSTAR* – launched 6/13/2012
  - Focusing hard x-ray telescope

NuSTAR

- **Nu**clear **S**pectroscopic **T**elescope **AR**ray
- NASA's newest "Eyes on the Skies"
- Focuses X-rays creating images at higher energies than ever before



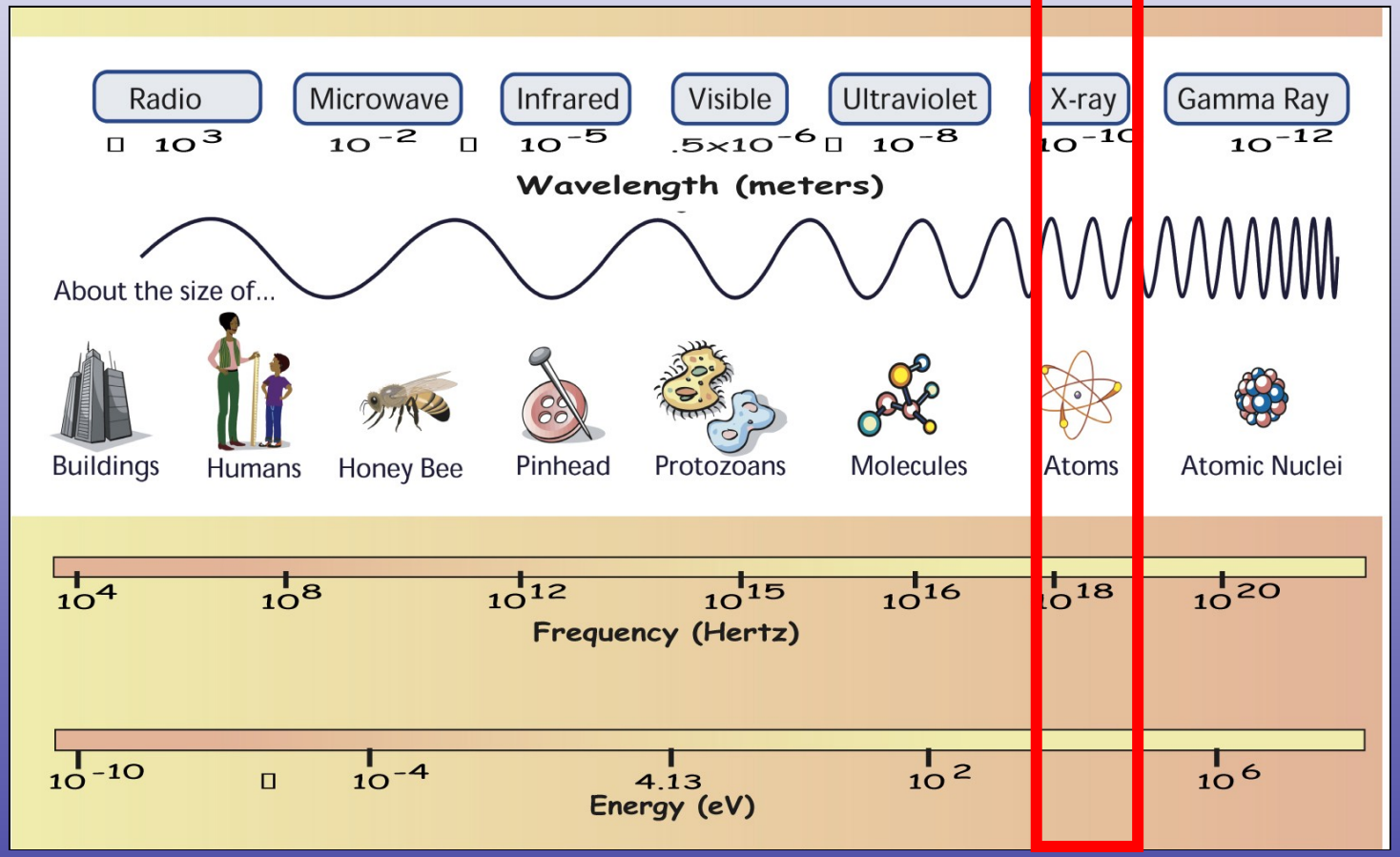
http://www.nustar.caltech.edu

P.I. Prof. Fiona Harrison, Caltech

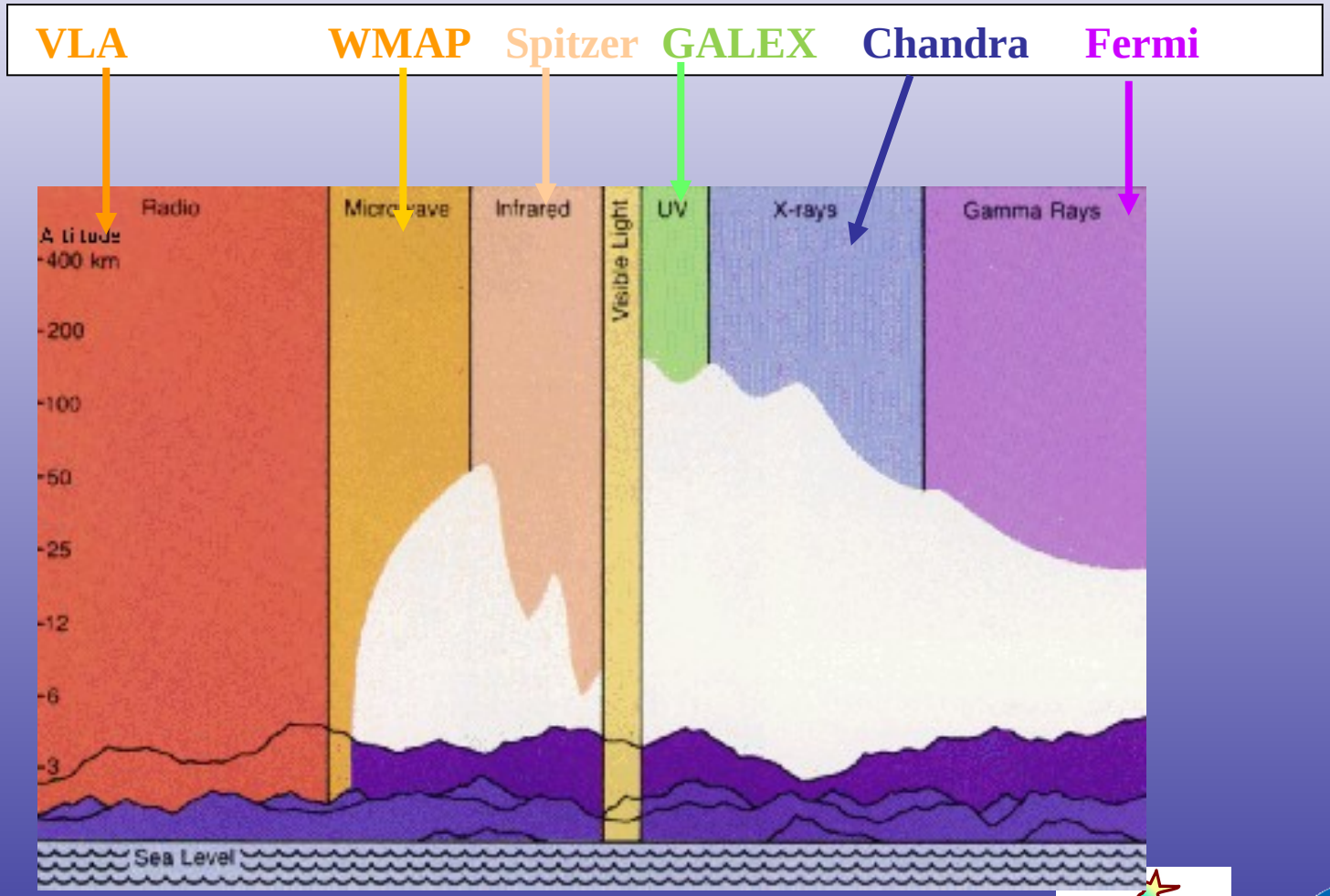
JPL, Columbia U., UC Berkeley, and Cambridge & Durham, UK

NuSTAR observes "hard" X-rays

3 -79 keV



What you can see from Earth



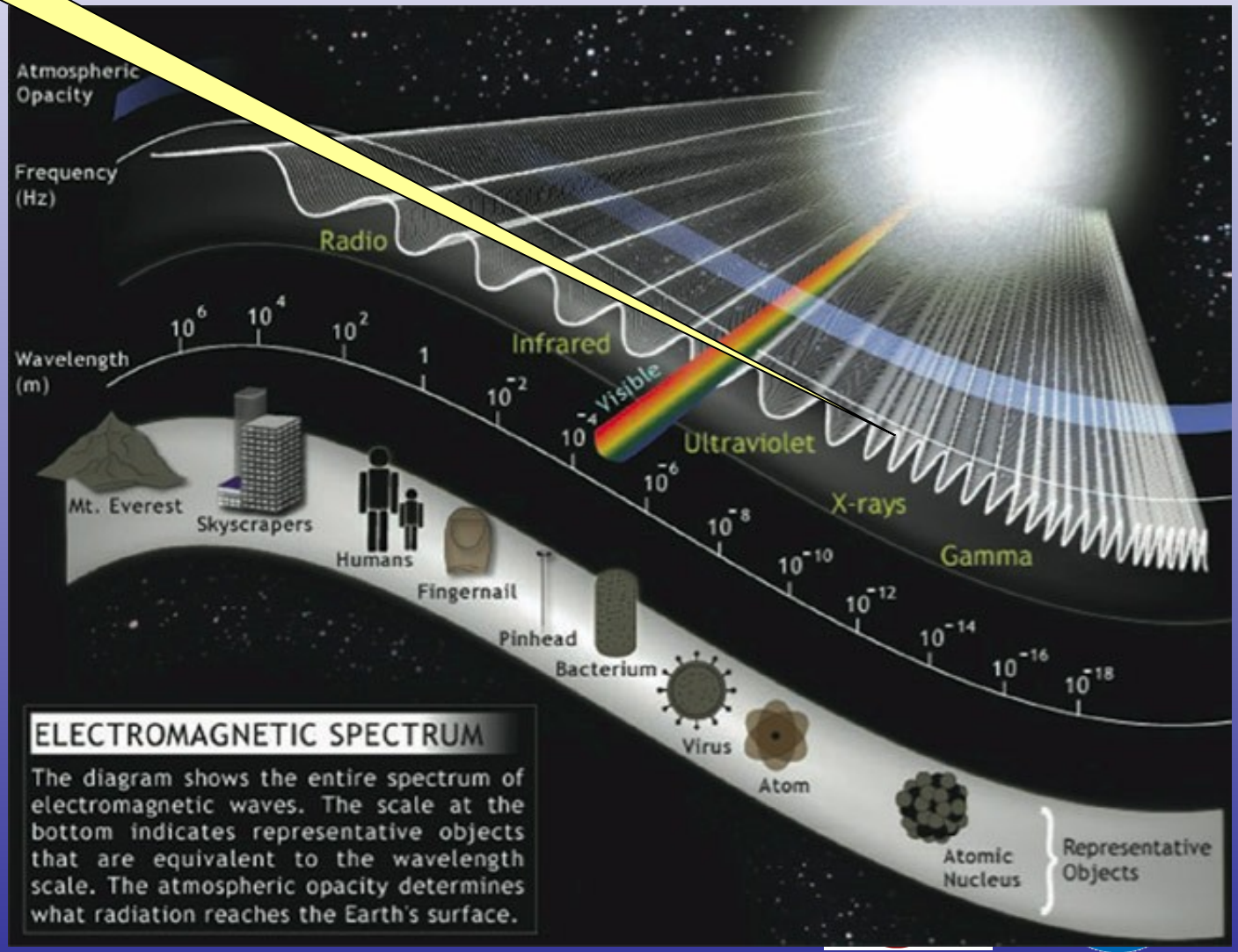
Exploring the Space Environment with X Rays

The second most energetic band of the EM spectrum

Wavelengths about the size of atoms

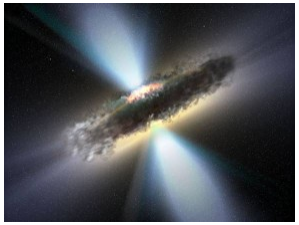
Photon Energies range from around 1000 to 100,000 times that of visible light

Emitted by objects at temperatures of millions of degrees. Including supernova remnants and disks of gas orbiting black holes

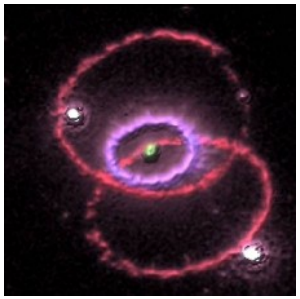


EDUCATION PUBLIC OUTREACH SSU

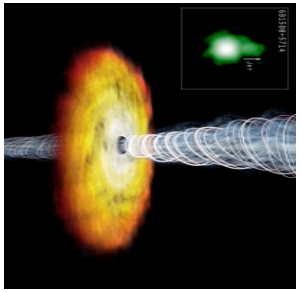
Why Hard X-rays?



Hard X-rays are the peak in emission from active black holes in the centers of galaxies; shining with a luminosity that rivals that of starlight



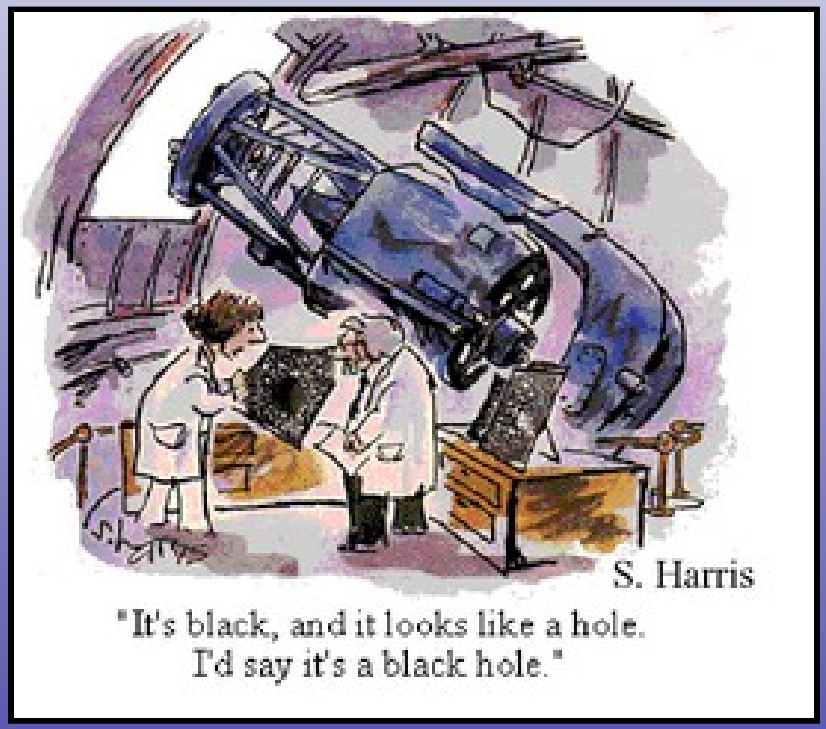
Hard X-rays escape from the deepest layers of exploding stars, revealing newborn chemical elements



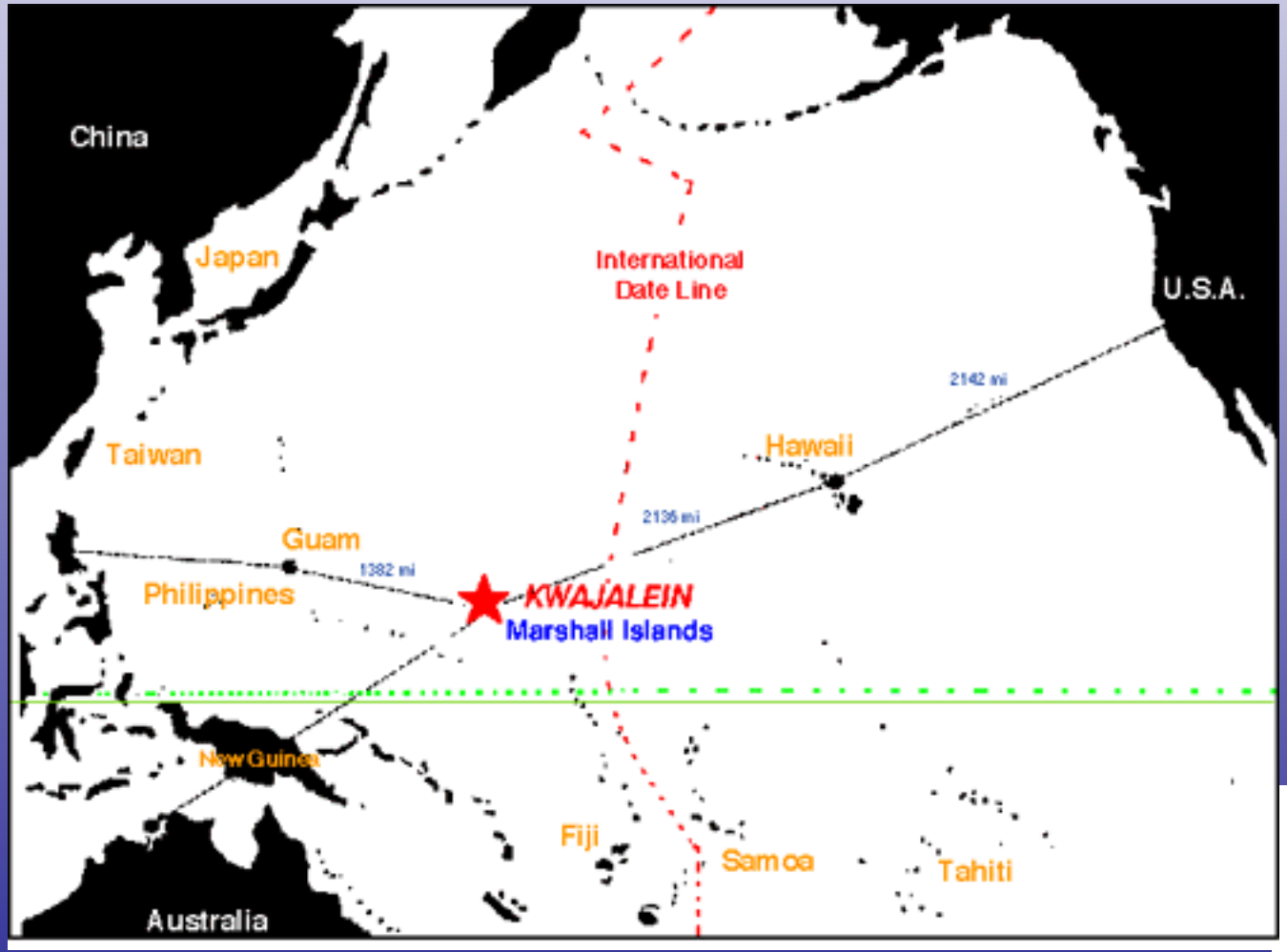
Hard X-rays are copiously emitted by the most extreme particle accelerators found anywhere in the universe

Black Holes and Exploding Stars

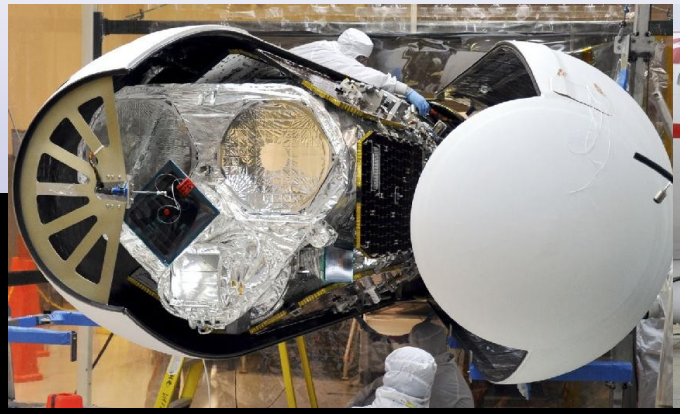
- What do you know about black holes?
- Where do the chemical elements come from?



Launch Location



NuSTAR arrives

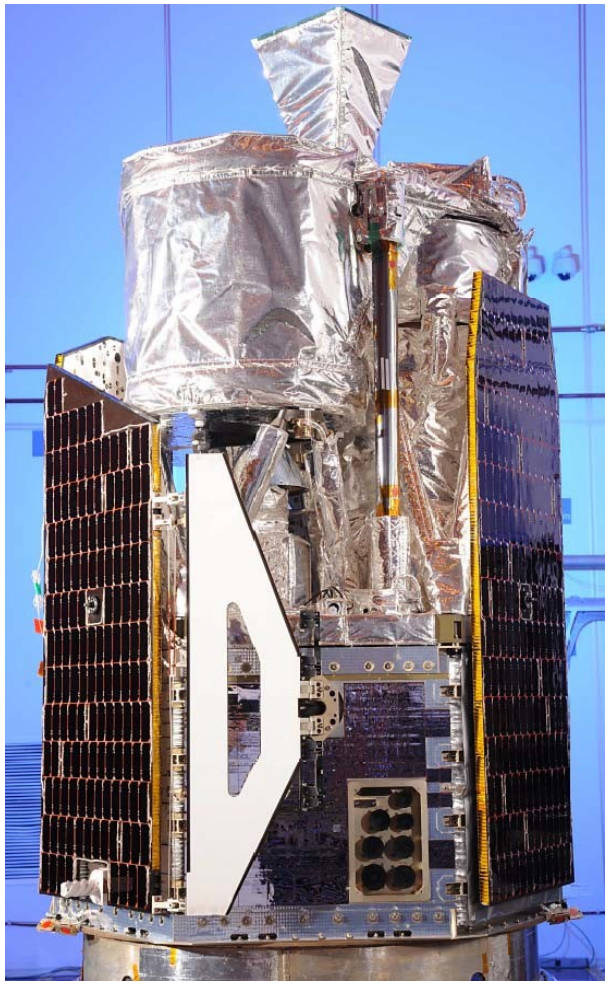


Launch June 13, 2012

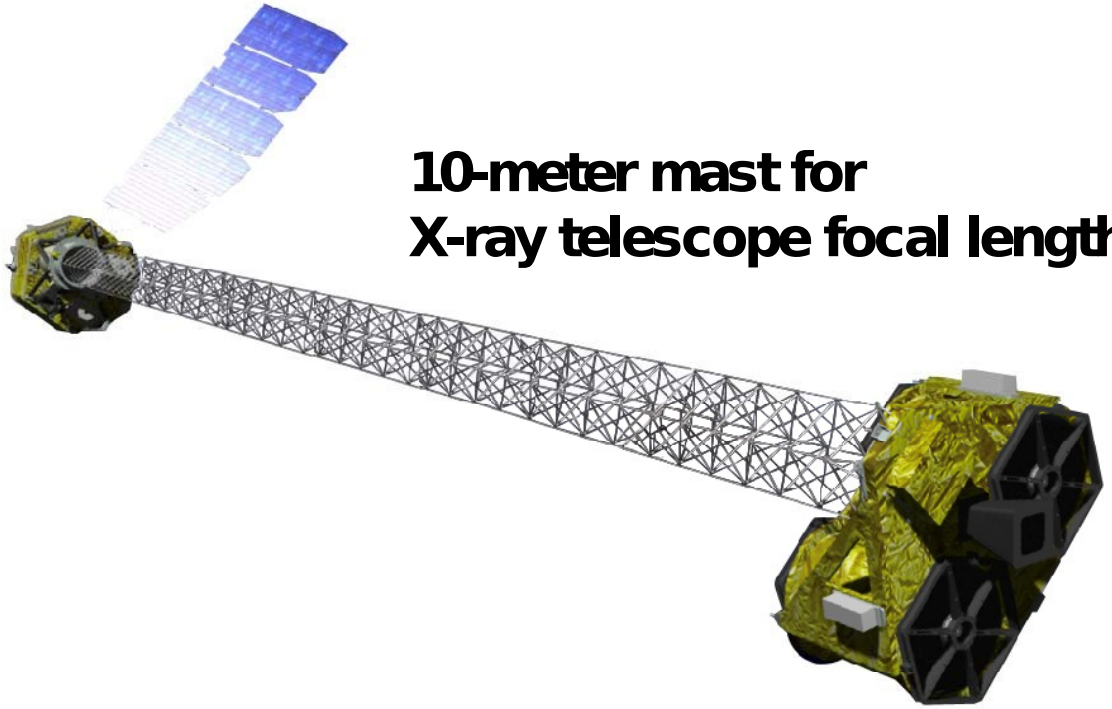
Reagan Test Site, Kwajalein Atoll


MISSION OPERATIONS CENTER
UNIVERSITY OF CALIFORNIA, BERKELEY

Before and after launch



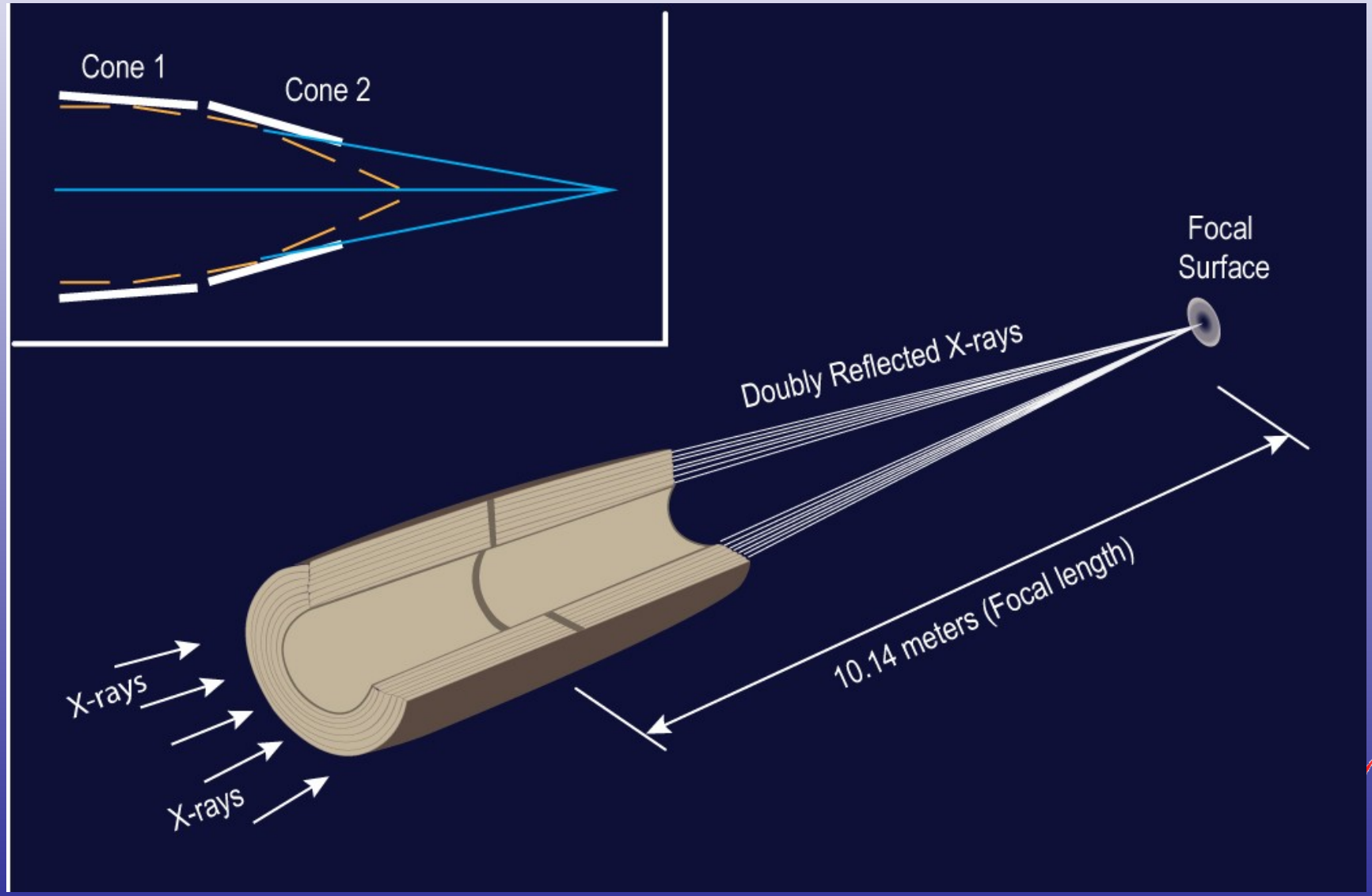
Stowed observatory



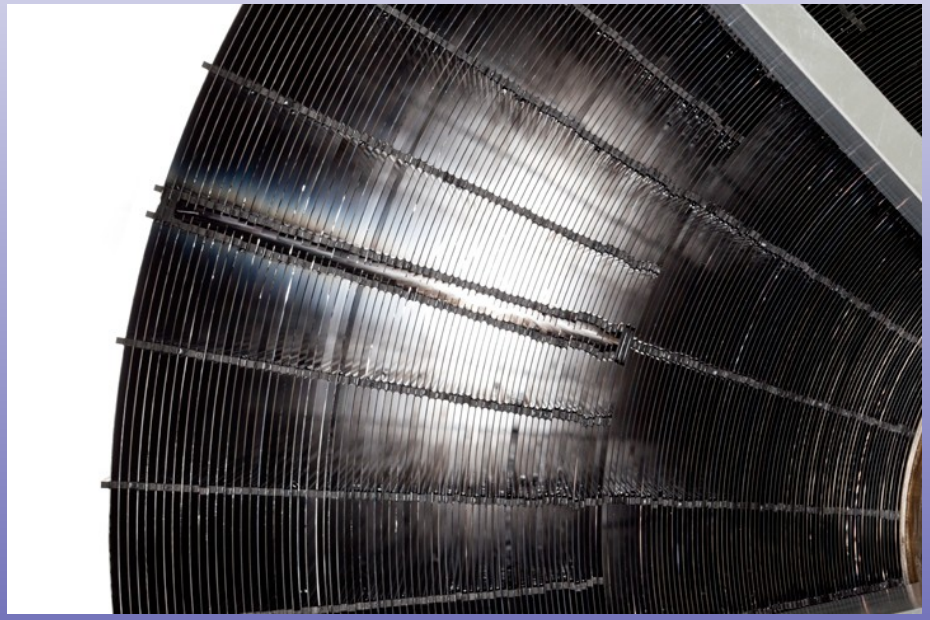
Deployed observatory

NuSTAR's "24 min of terror"

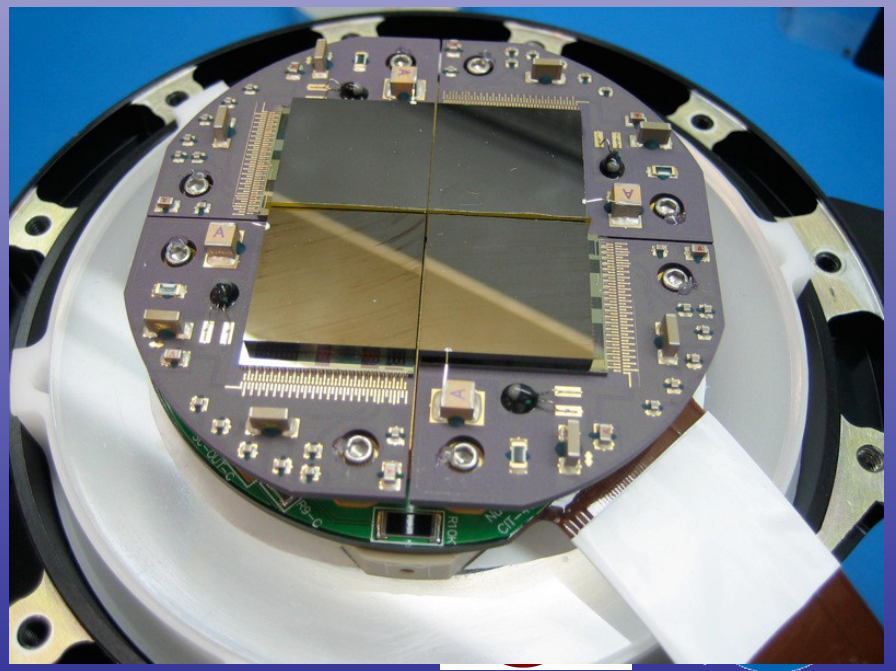
How to focus X-rays



NuSTAR's mirrors and detectors

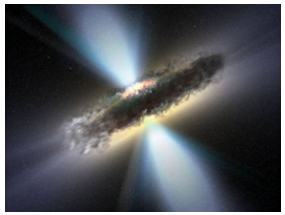


133 nested mirrors made of multilayers that reflect higher-energy X-rays



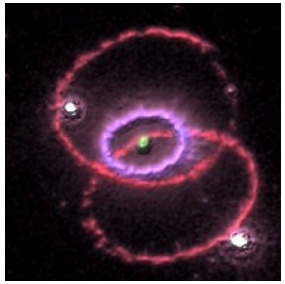
A 2 x 2 array of Cd-Zn-Te detectors and electronics

NuSTAR Science Objectives



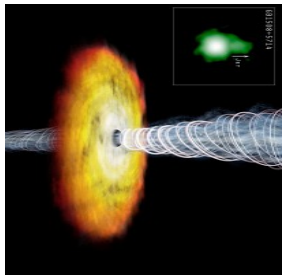
Goal #1: How are black holes distributed through the cosmos, and how do they affect the formation of galaxies like our own?

- *15 months surveying regions of the sky*



Goal #2: How do stars explode and forge the elements that compose the Earth?

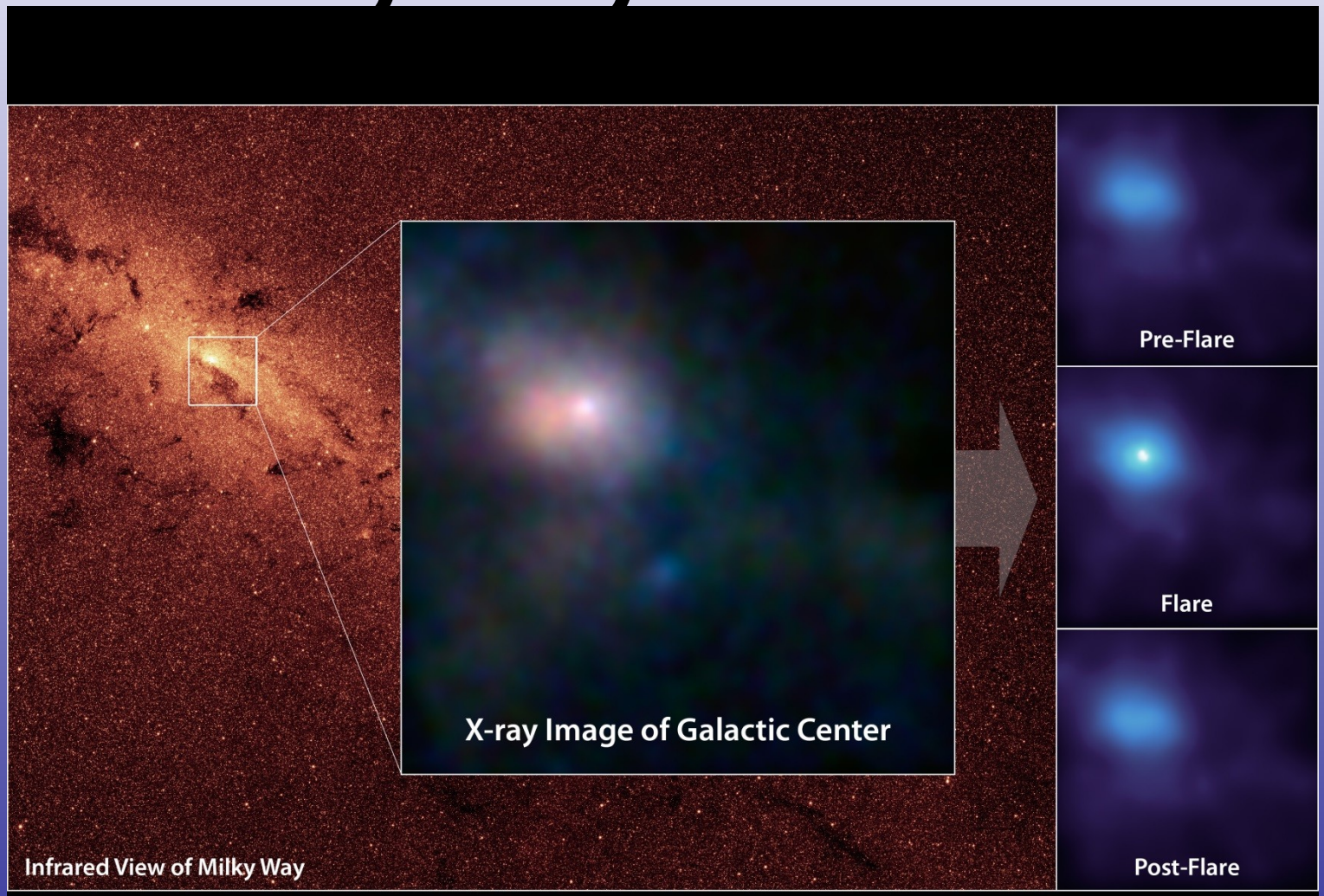
- *6 months mapping young supernova remnants*



Goal #3: What powers the most extreme active galactic nuclei?

- *3 months monitoring extreme black holes.*

NuSTAR sees Flare from Milky Way's Black Hole



NuSTAR images two BHs in distant galaxy

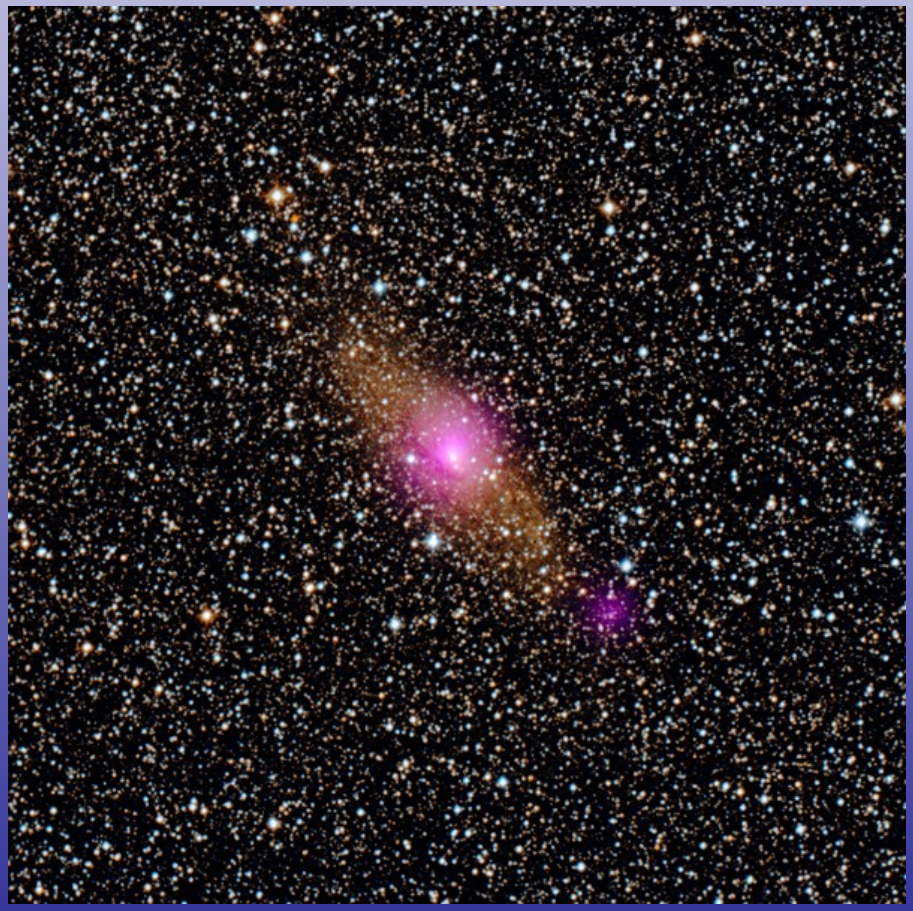
Since BHs are not in center, they are probably “intermediate mass” BHs

IC 342/Caldwell 5

More Medium-sized BH

NGC 1313 (70 and 30 solar)

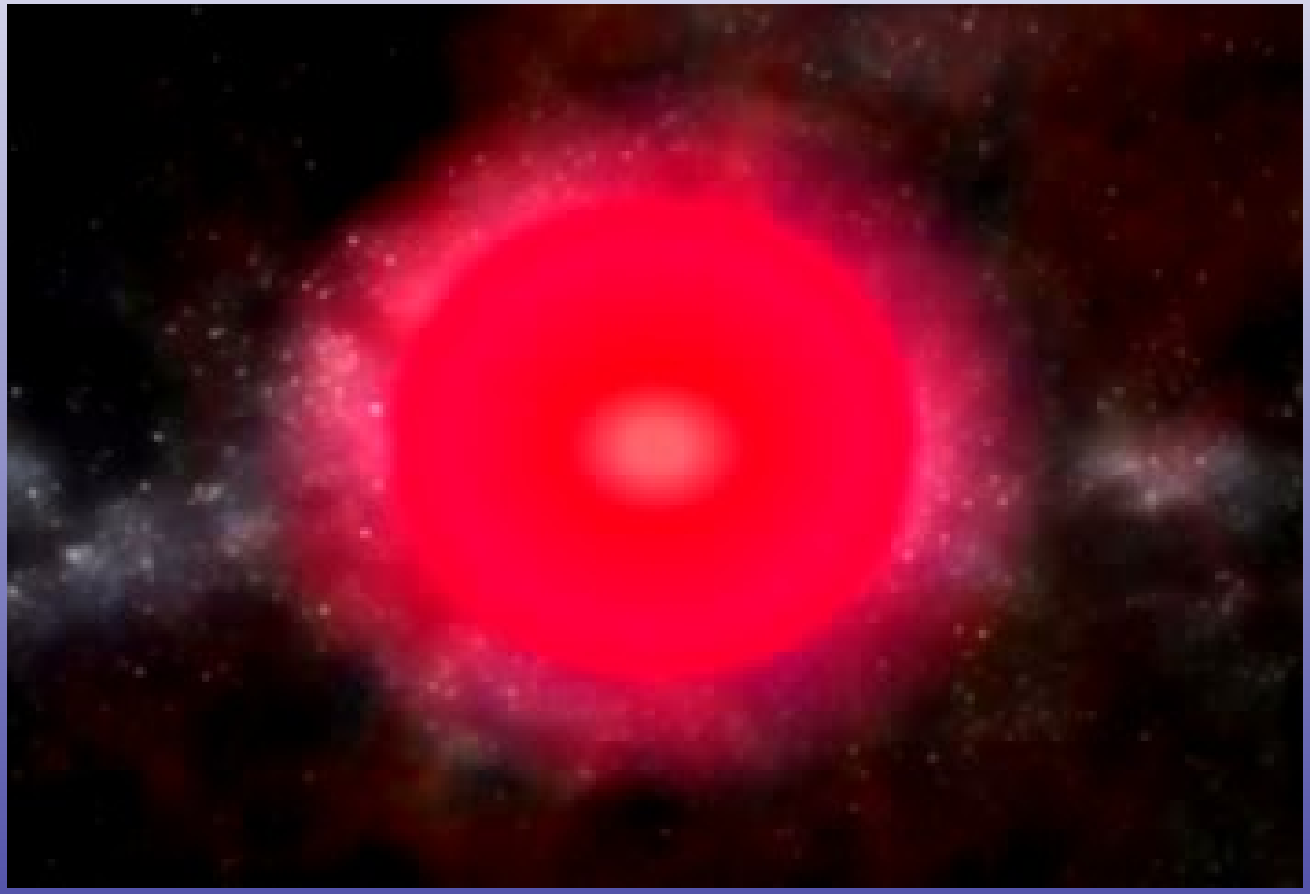
Circinus galaxy – SMBH + IMBH



Find the Supernova

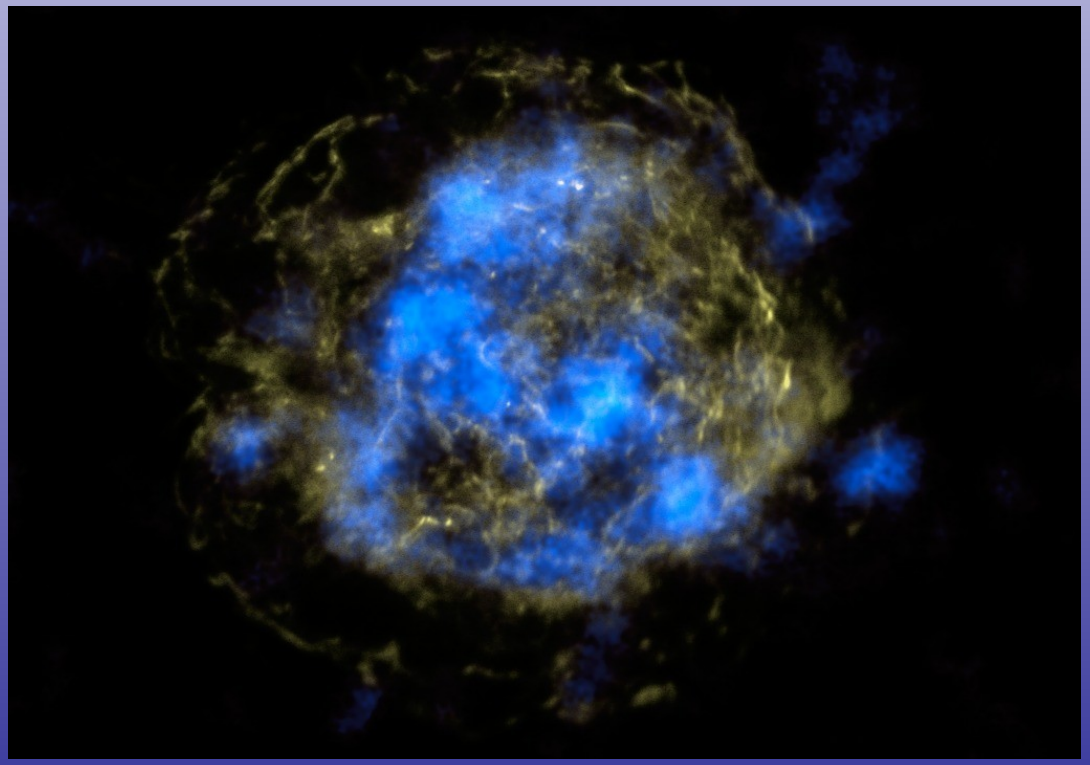
Credit: R. Jay GeBany

Supernova!



Radioactive “guts” in Cas A

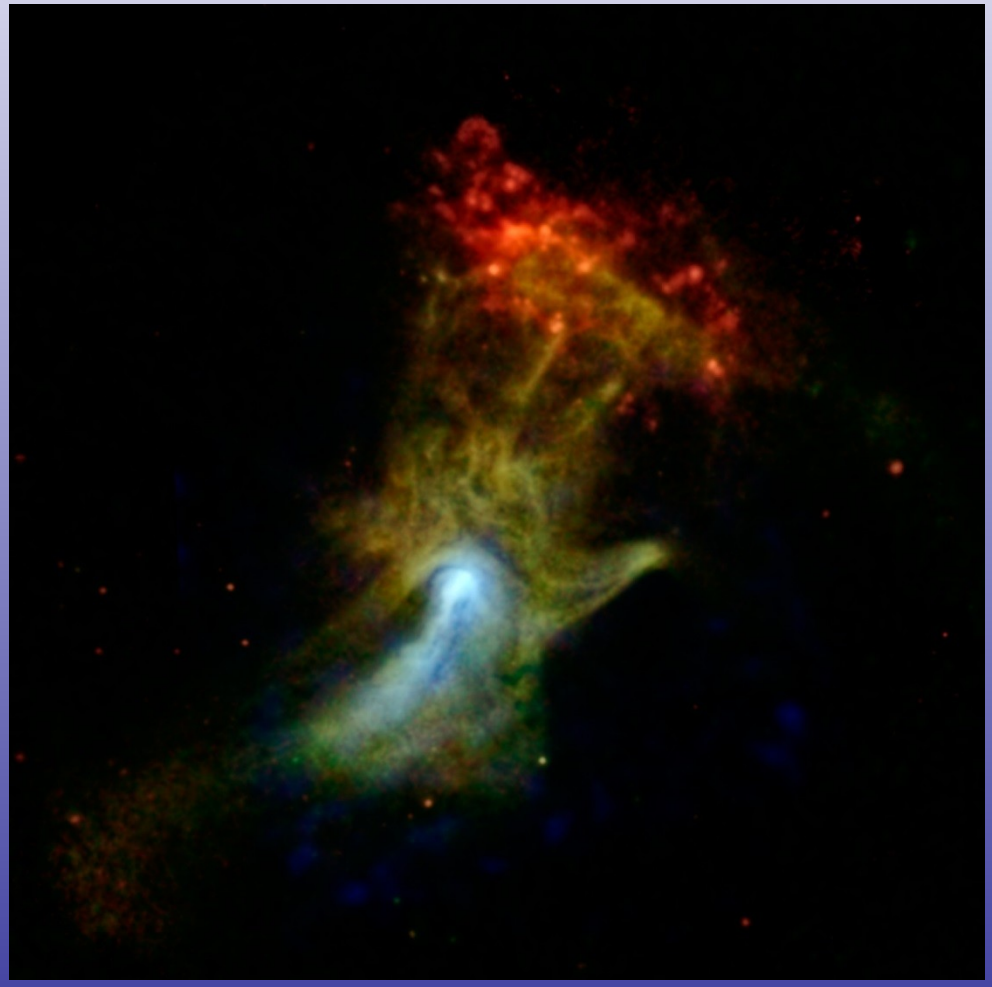
- NuSTAR data are blue, and show high-energy X-rays from radioactive Titanium. Yellow is non-radioactive material emitting low-energy X-rays (from Chandra).



Clumps of Titanium give clues to how stars explode

Inner material must slosh around so shock wave reaches outer layers

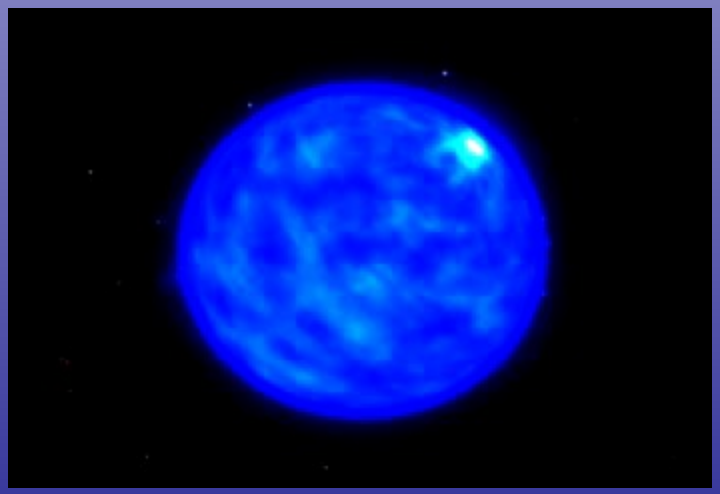
The “Hand of God”



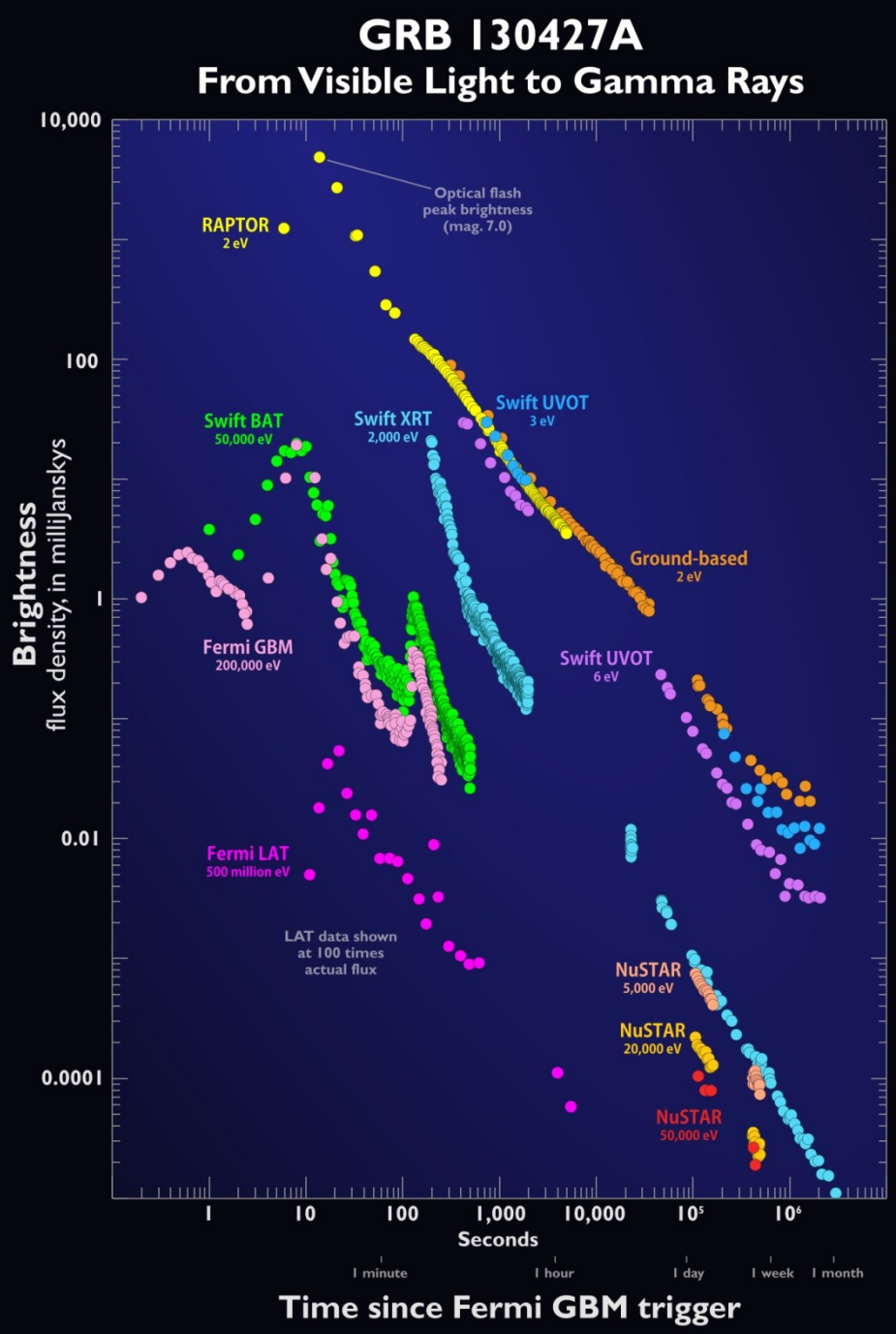
- Glowing gas blown out from a pulsar formed in a supernova explosion
- High-energy X-rays seen by NuSTAR are in blue (lower-energy in green and red from Chandra)

More super than a supernova?

- A gamma-ray burst!
- Long bursts (>2 seconds) may be from a hypernova: a super-supernova
- Short bursts (<2 s) may be from merging neutron stars
- GRBs are birth cries of black holes
- Each GRB emits as much energy as our Sun in its entire lifetime!



GRB 130427A


GRB 130427A
From Visible Light to Gamma Rays
Brightness
flux density, in millijanskys
10,000
100
1
0.01
0.0001
Optical flash
peak brightness
(mag. 7.0)
RAPTOR
2 eV
Swift BAT
50,000 eV
Swift XRT
2,000 eV
Swift UVOT
3 eV
Ground-based
2 eV
Fermi GBM
200,000 eV
Swift UVOT
6 eV
Fermi LAT
500 million eV
LAT data shown
at 100 times
actual flux
NuSTAR
5,000 eV
NuSTAR
20,000 eV
NuSTAR
50,000 eV
1
10
100
1,000
10,000
10⁵
10⁶
Seconds
1 minute
1 hour
1 day
1 week
1 month
Time since Fermi GBM trigger

Why the GRB was so bright

Conclusions

- NuSTAR is bringing the high energy universe into focus
- We are getting sharper views and looking through the dust and gas into the centers of galaxies at huge black holes and at the elements created by exploding stars
- Stay tuned for more – we are just getting started!

Resources

- **http://epo.sonoma.edu** – our group's main page
- http://www.nustar.caltech.edu for latest discoveries from NuSTAR

- http://www.nasa.gov/nustar