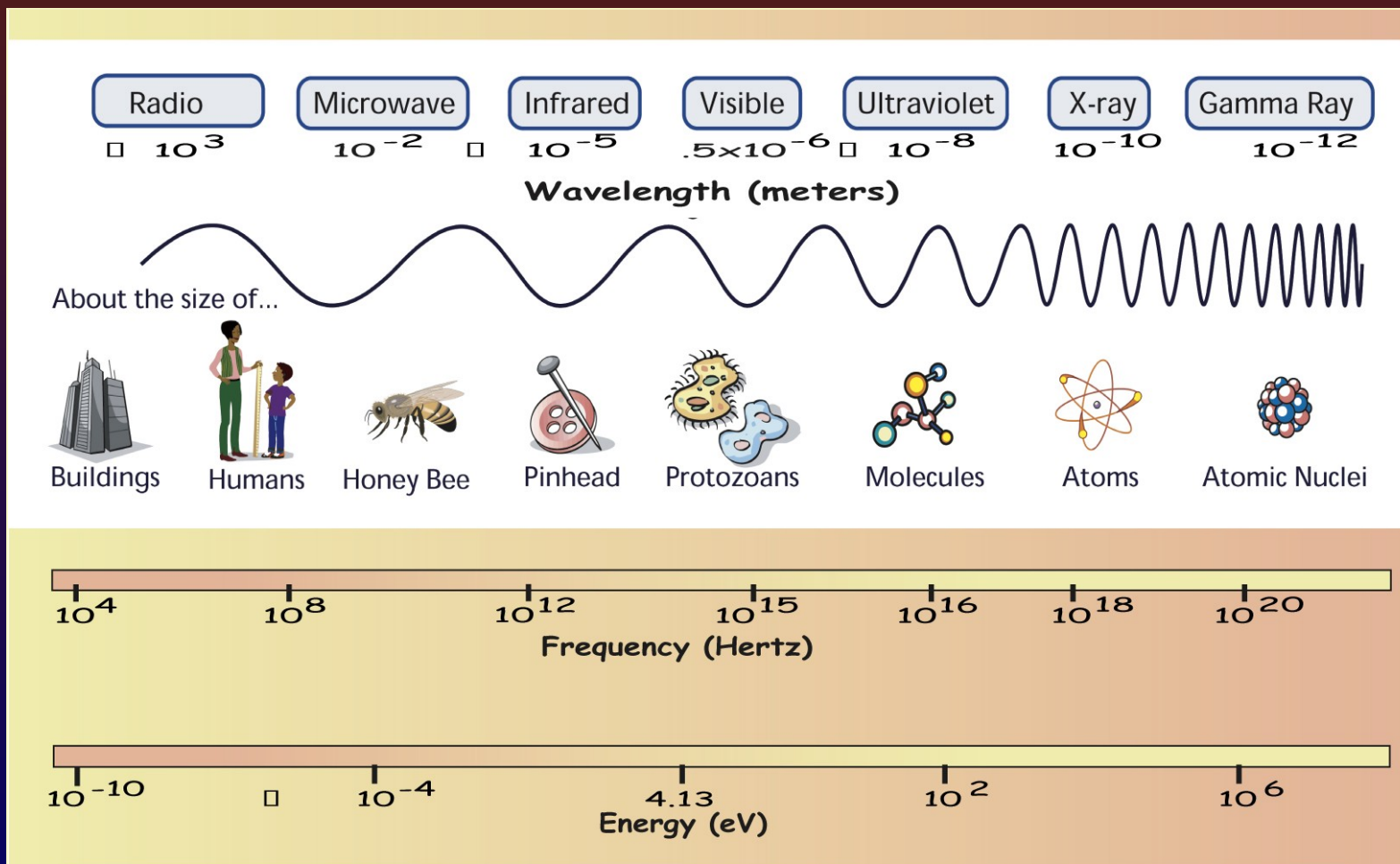
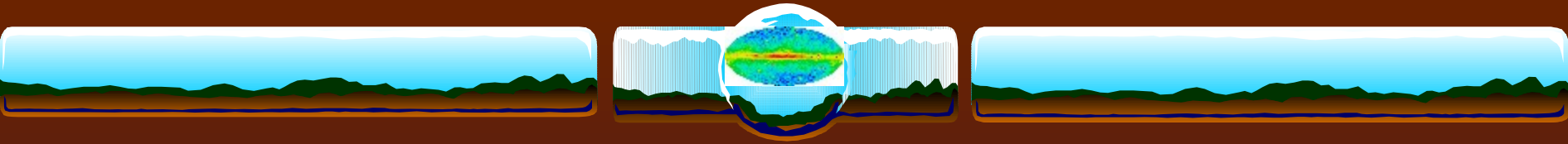


# Extreme Astronomy and Supernovae

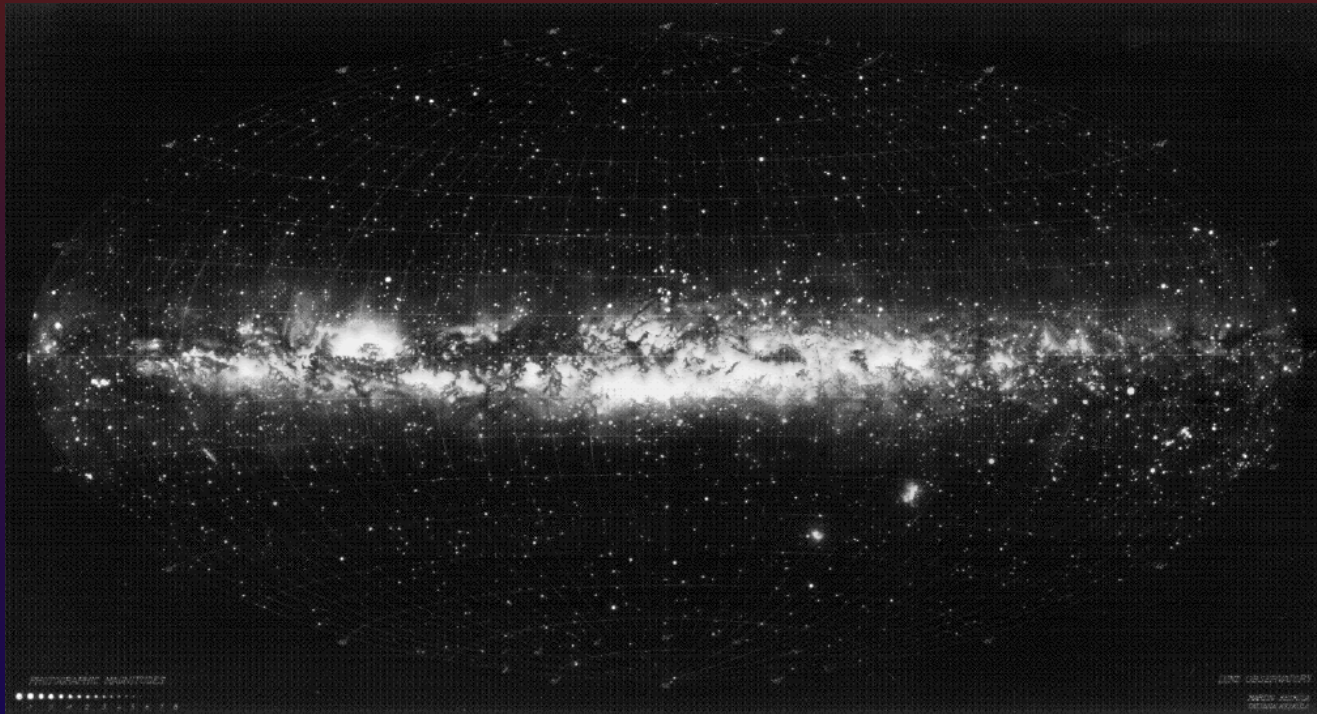
Professor Lynn Cominsky  
Department of Physics and  
Astronomy  
Sonoma State University

# What are X- & Gamma rays?





# Why study X- & gamma rays?



- ❖ Universe as seen by eye is peaceful



# How to study X- & Gamma rays?

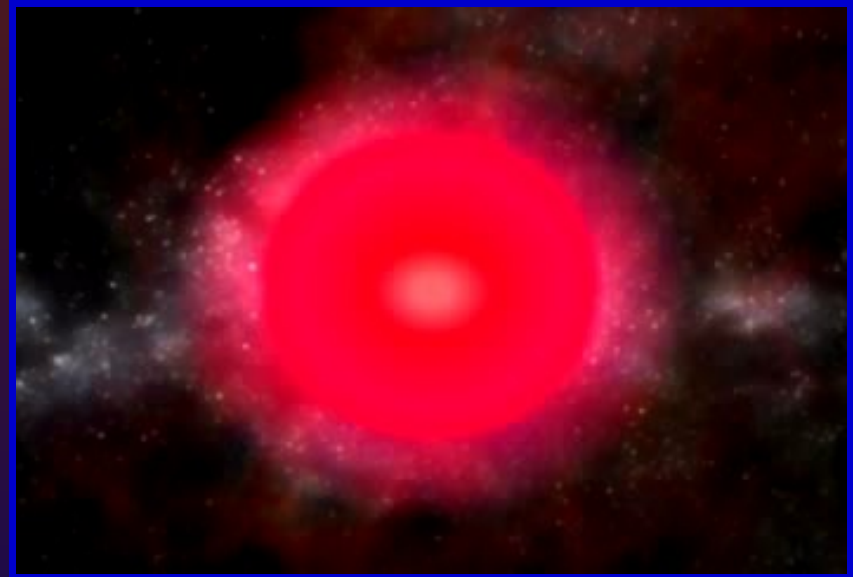
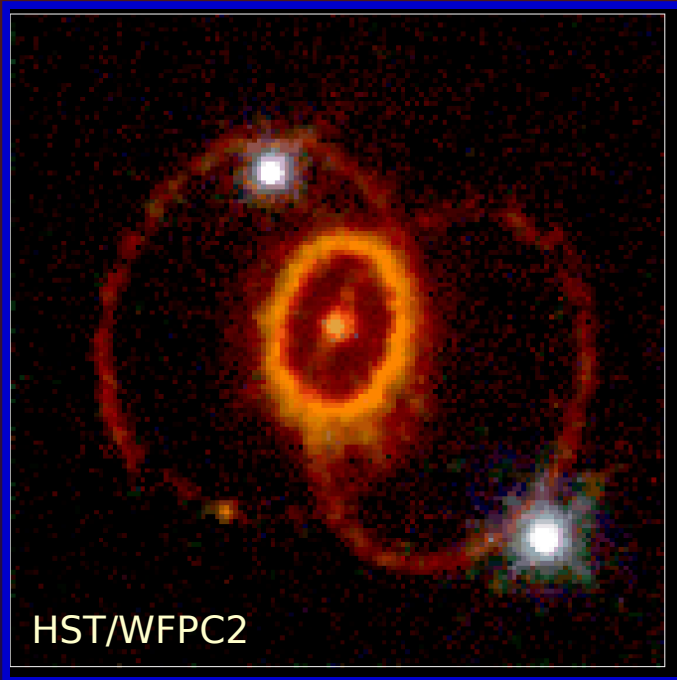
- ❖ Absorbed by the Earth's atmosphere
- ❖ Use rockets, balloons or satellites
- ❖ X-rays can be focused using special telescope designs
- ❖ Can't image or focus gamma rays
- ❖ Special detectors: CCDs, crystals, silicon-strips



Balloon  
experiment



# Exploding Stars

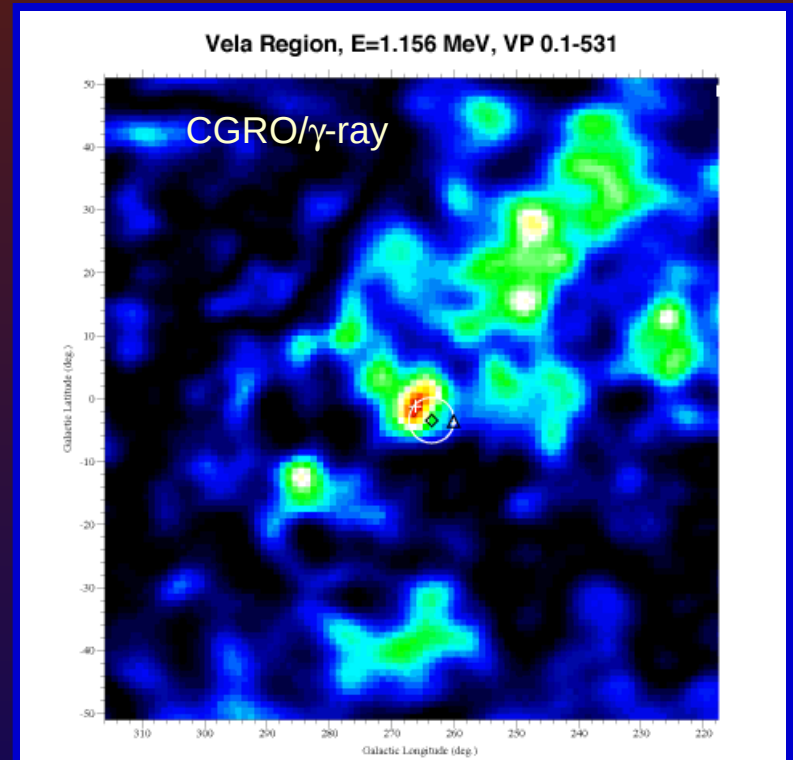
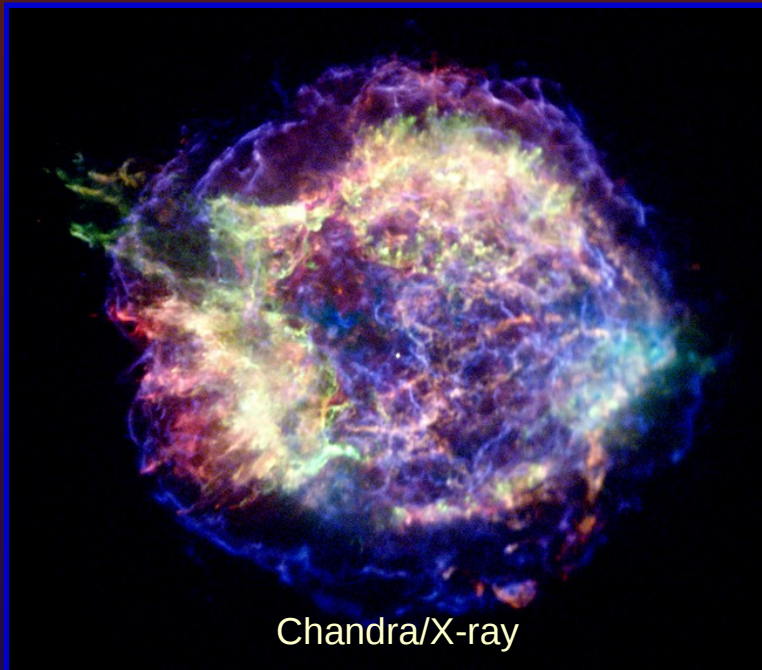


Credit: Dana Berry

- ❖ At the end of a star's life, if it is large enough, it will end with a bang (and not a whimper!)



# Supernova Remnants



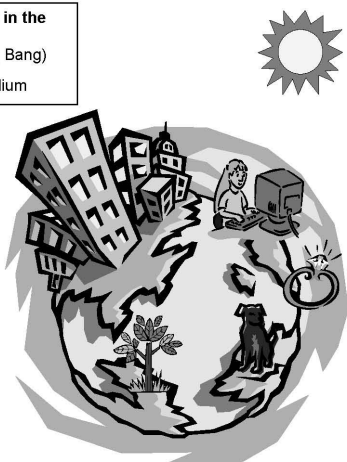
- ❖ Radioactive decay of chemical elements created by the supernova explosion

# Cosmic Connection to the Elements

- ❖ Only H and He are primordial
- ❖ Lighter elements made in stellar cores
- ❖ Heavier elements made in explosion itself
- ❖ *“We are all star-stuff” – C. Sagan*

**A Universe without Supernovae**

If supernovae never occurred in our universe to disperse the elements made in stars, what would be left in the universe?



**Basic Elements in the Universe**  
(originated in Big Bang)  
Hydrogen, Helium

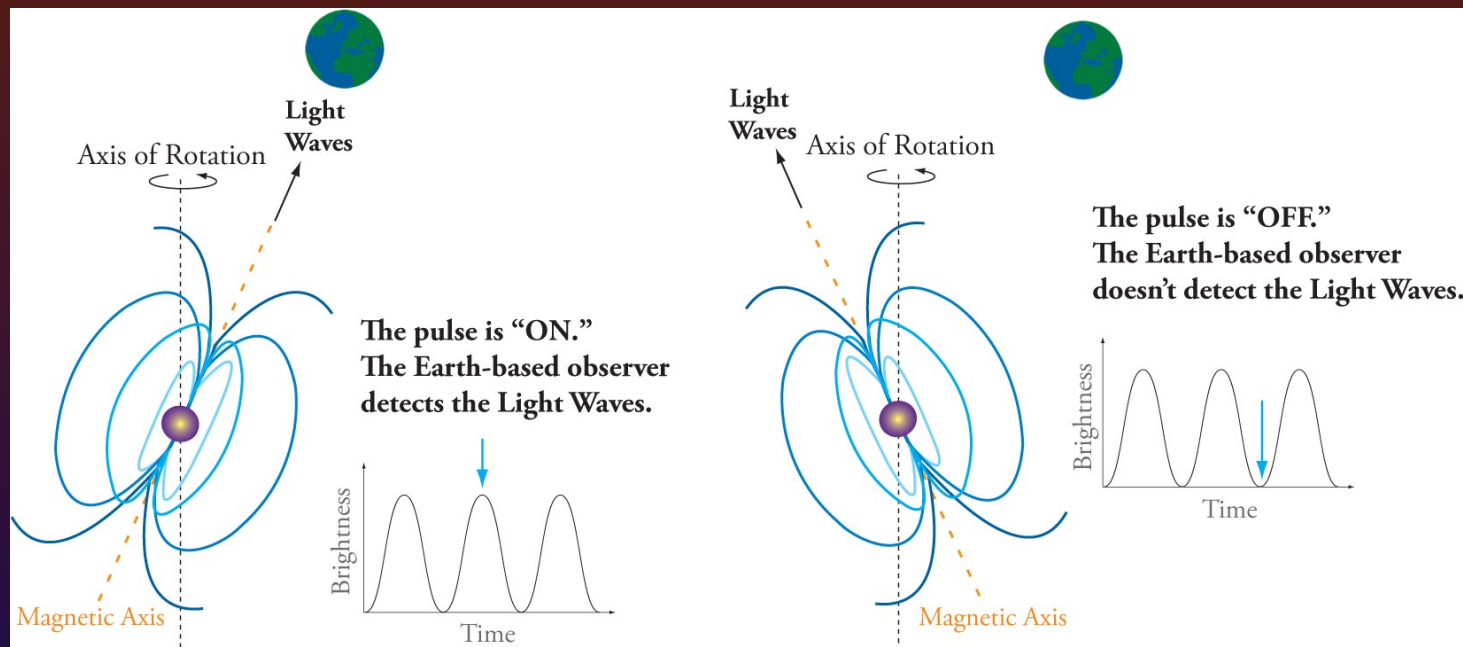
**Common Elements originating from small stars**  
Nitrogen  
Carbon  
Lithium

**Common Elements whose primary source is from stars that go supernova**  
Aluminum  
Calcium  
Carbon  
Chlorine  
Copper  
Gold  
Iron  
Magnesium  
Mercury  
Nickel  
Oxygen  
Phosphorus  
Platinum  
Potassium  
Silicon  
Silver  
Sodium  
Sulfur  
Titanium  
Uranium  
Zinc

**Some of the elements found in:**  
**Diamond rings:** Carbon, Gold  
**Computers & Cell Phones:** Silicon (computer chips), Carbon, Hydrogen, Oxygen, Sulfur (plastics)  
**Buildings:** Iron (in steel), Calcium, Silicon, Oxygen (in concrete)  
**Plants, Animals, and People:** Carbon, Hydrogen, Nitrogen, Oxygen, Sodium, Magnesium, Phosphorus, Sulfur, Potassium, Calcium, Iron, Zinc  
**Atmosphere:** Nitrogen, Oxygen  
**Earth:** Iron, Oxygen, Silicon, Aluminum, Calcium  
**Sun:** Hydrogen, Helium

[www.nasa.gov](http://www.nasa.gov)

# Pulsars

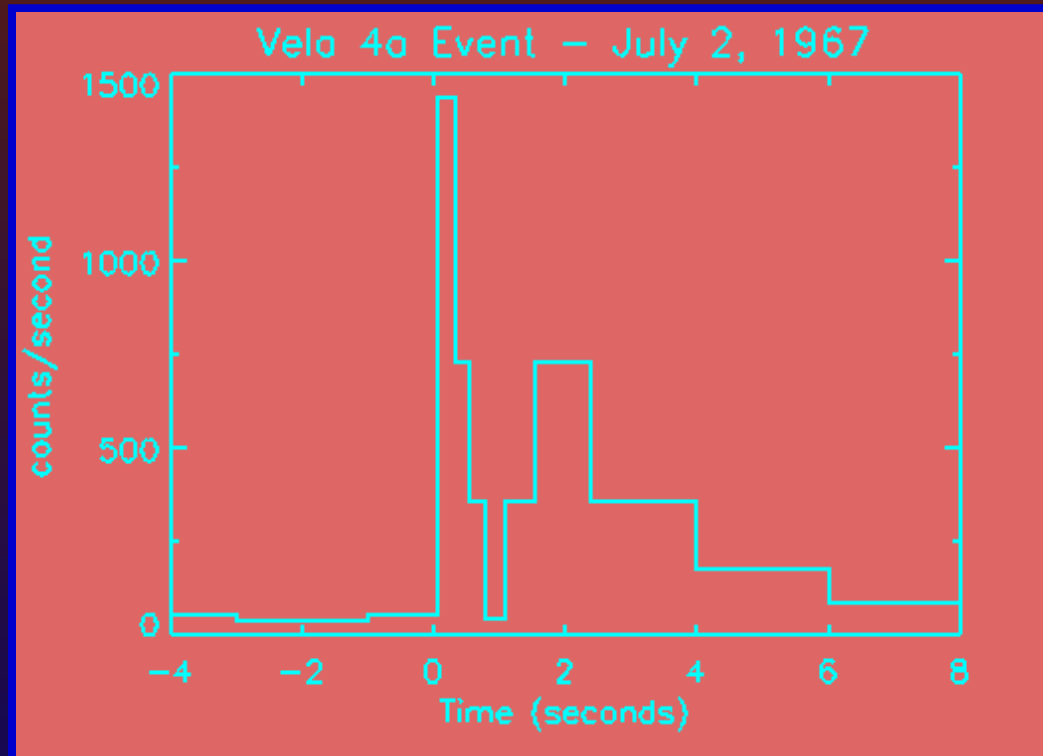


- ❖ Stellar corpses - size of a city, mass of the Sun, spinning up to 1000 times per second
- ❖ Exist in isolation and also in binary systems



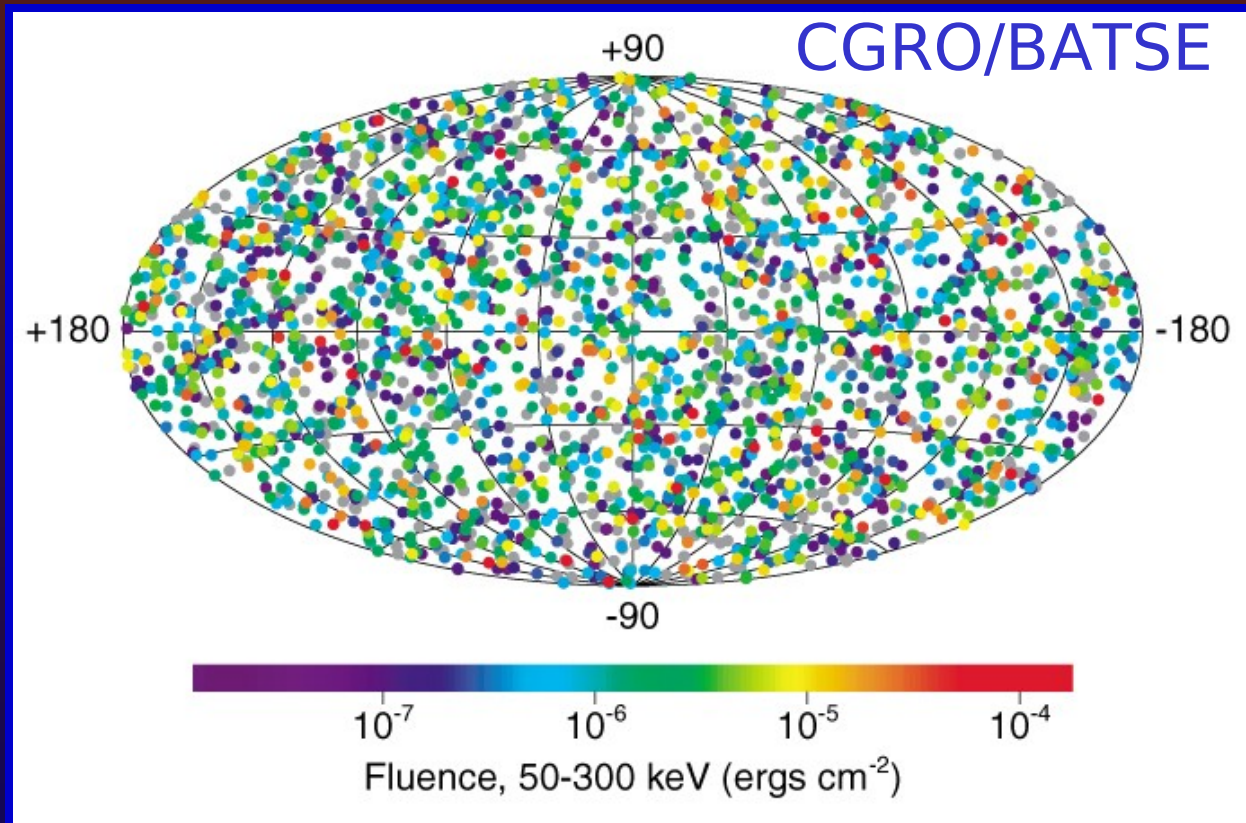


# Gamma-ray Bursts



- ❖ Discovered in 1967 while looking for nuclear test explosions

# Gamma-ray Burst Sky



❖ Once a day, somewhere in the Universe



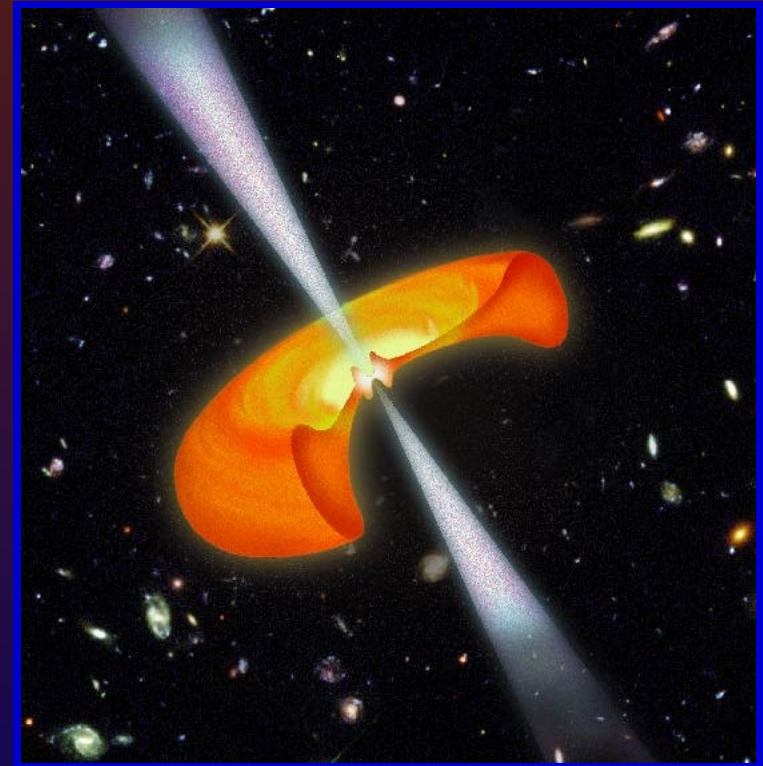
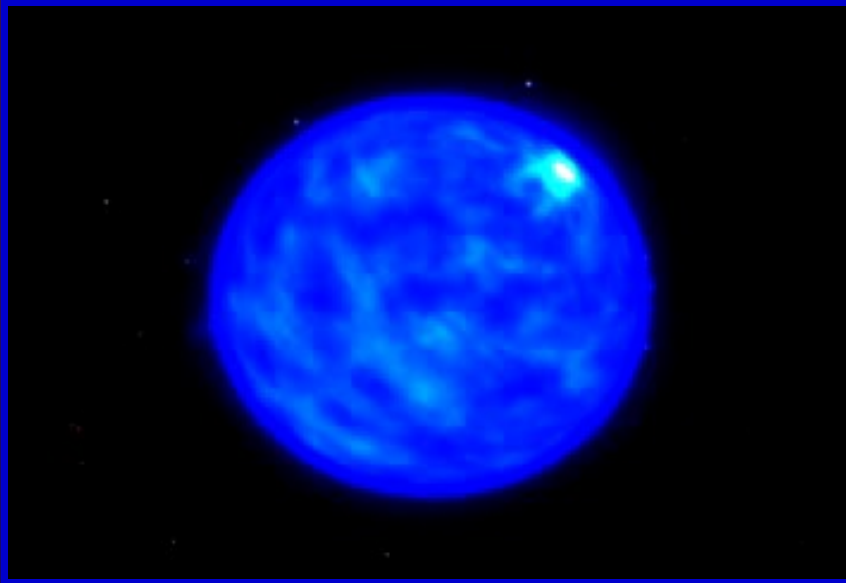
# Gamma-ray Bursts



- ❖ Signal the birth of a black hole?
- ❖ Seen to occur in two types: long and short
- ❖ Connection between the long GRBs and supernovae



# Hypernova

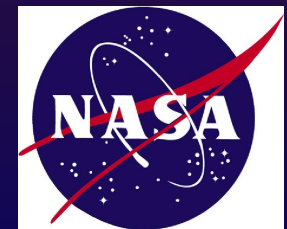
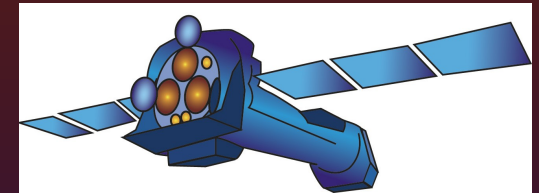


❖ A billion trillion times the power from the Sun



# XMM-Newton

- ❖ Launched in December, 1999
- ❖ European Space Agency mission with NASA instruments and Guest Observers
- ❖ Large X-ray focusing mirror assembly
- ❖ High throughput X-ray spectroscopy





# Swift Gamma-ray Burst Mission

- ❖ Burst Alert Telescope (BAT)
- ❖ Ultraviolet/Optical Telescope (UVOT)
- ❖ X-ray Telescope (XRT)
- ❖ Launched 11/20/04





# Gamma-ray Large Area Space Telescope (GLAST)

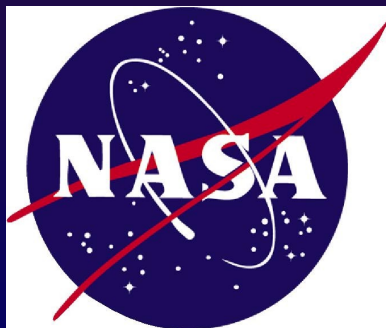


- ❖ GLAST Burst Monitor (GBM)
- ❖ Large Area Telescope (LAT)

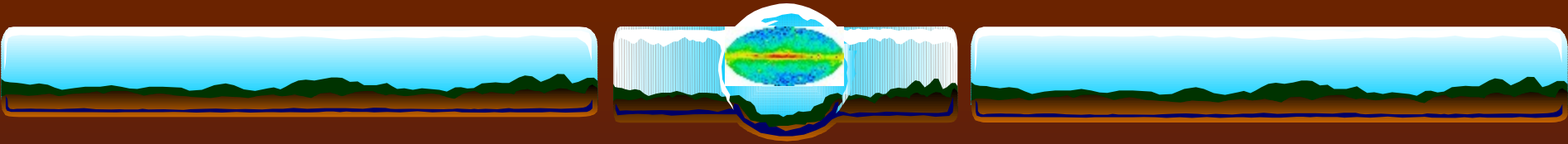


# GLAST Mission

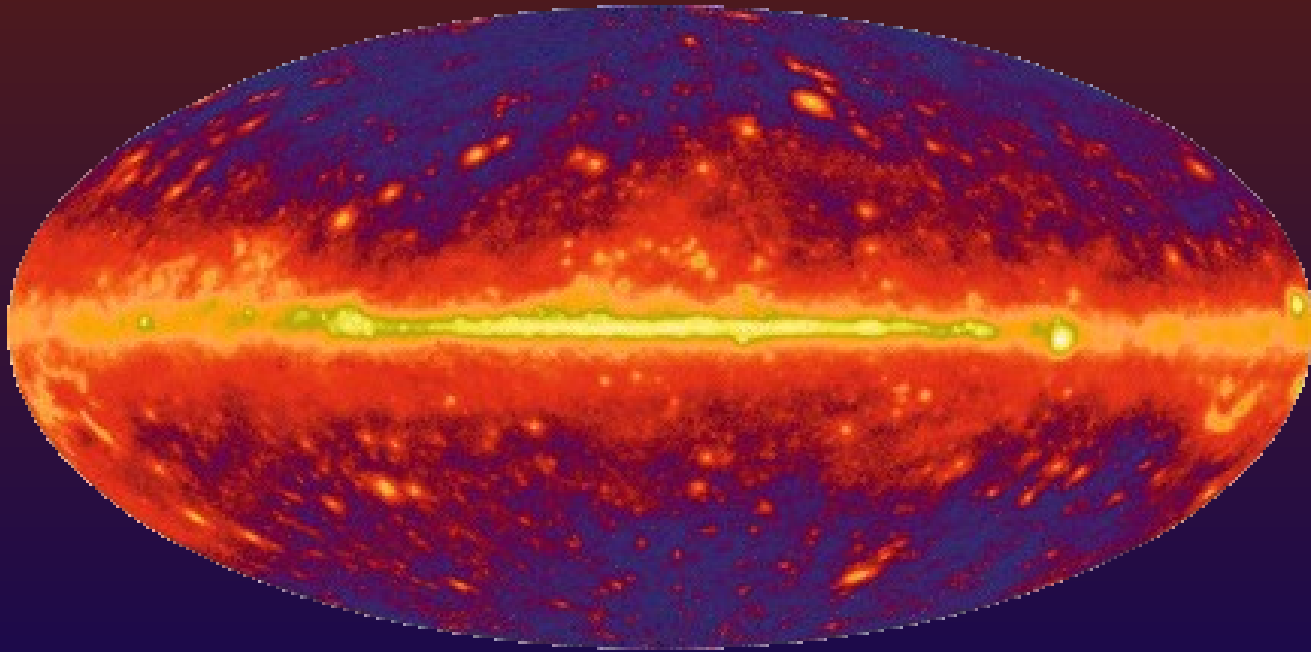
- ❖ First space-based collaboration between astrophysics and particle physics communities
- ❖ Launch expected in 2008 (June?)
- ❖ Expected duration 5-10 years
- ❖ Over 3000 gamma-ray sources will be seen







# GLAST view of the Universe



- ❖ Studies blazars, supernovae, gamma-ray bursts, pulsars and more!



# Global Telescope Network

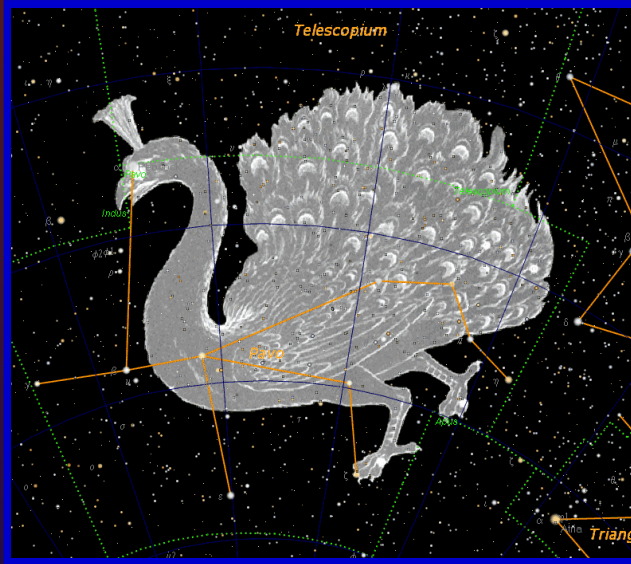
- ❖ Ground-based observations of GRBs and flaring galaxies
- ❖ Coordinated with Swift and GLAST satellite data
- ❖ <http://gtn.sonoma.edu>



GORT



# Fly the Extreme Skies



- ❖ Follow GRBs on the GRB Skymap site
- ❖ Join the Global Telescope Network
- ❖ XMM-Newton skymaps are on Google Earth/Sky

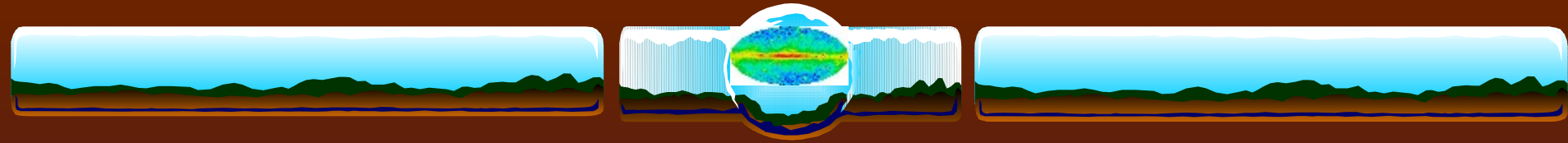


# For more information:

- ❖ <http://glast.sonoma.edu>
- ❖ <http://swift.sonoma.edu>
- ❖ <http://grb.sonoma.edu>
- ❖ <http://gtn.sonoma.edu>
- ❖ <http://xmm.sonoma.edu>
- ❖ <http://epo.sonoma.edu>



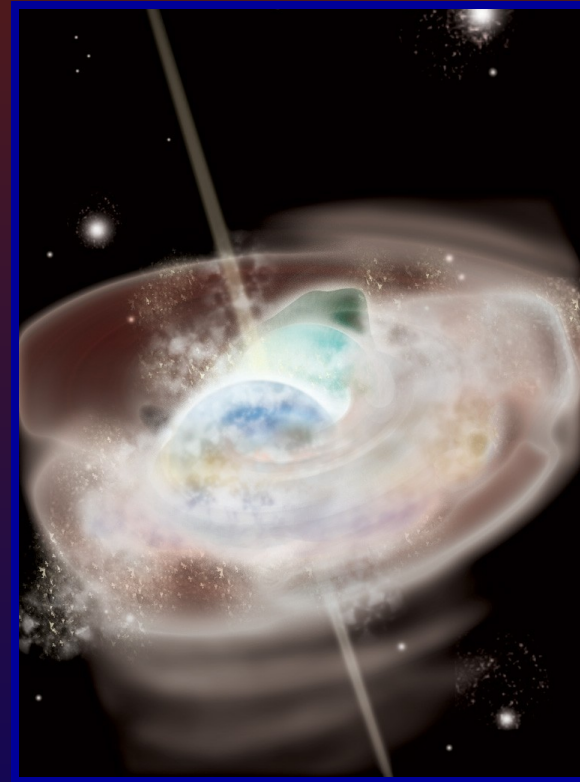
Photo Credit: Linnea Mullins



Backups Follow

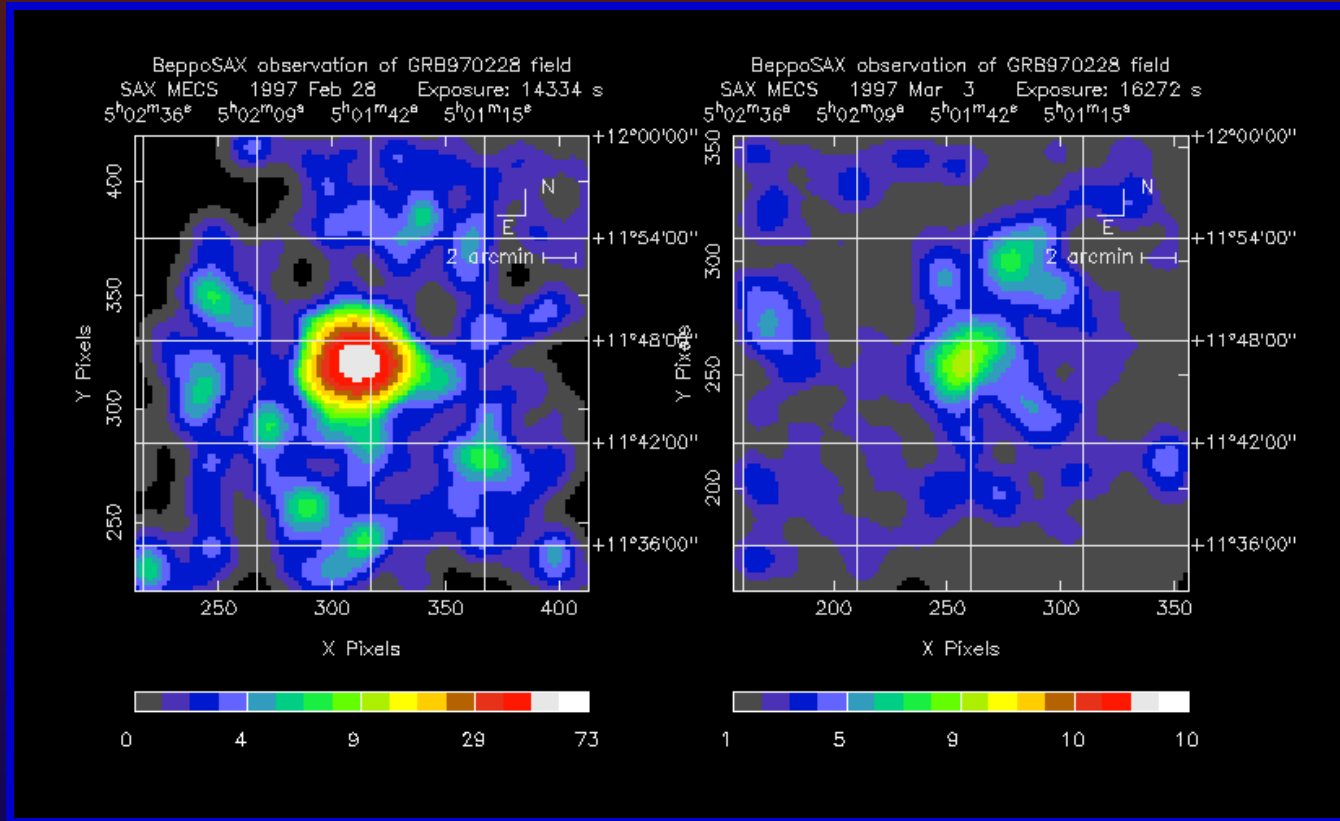


# Catastrophic Mergers



- ❖ Death spiral of 2 neutron stars or black holes

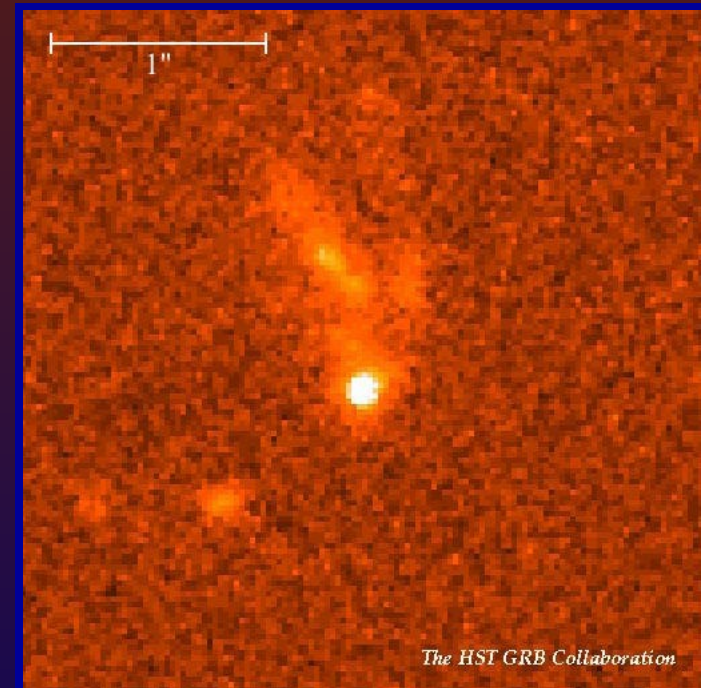
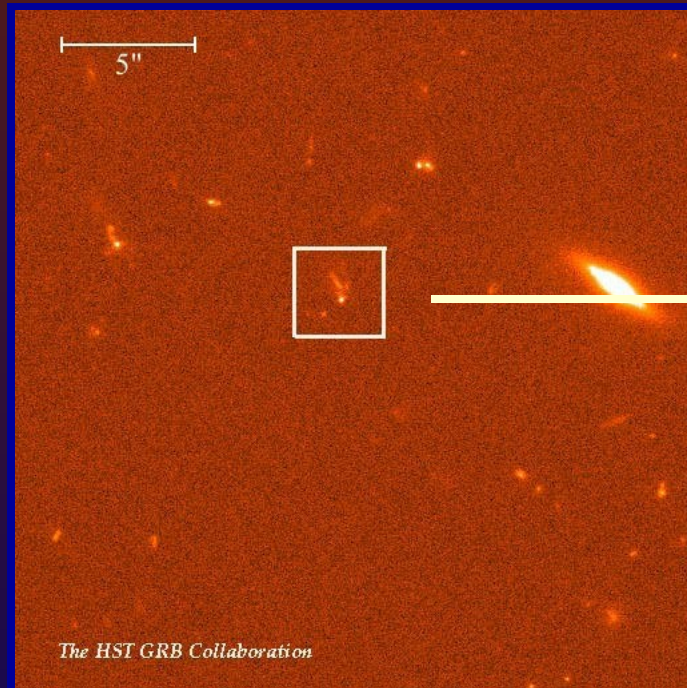
# Afterglow



❖ Discovered in 1997 by BeppoSAX satellite



# Afterglow



❖ Cooling ashes in distant galaxies

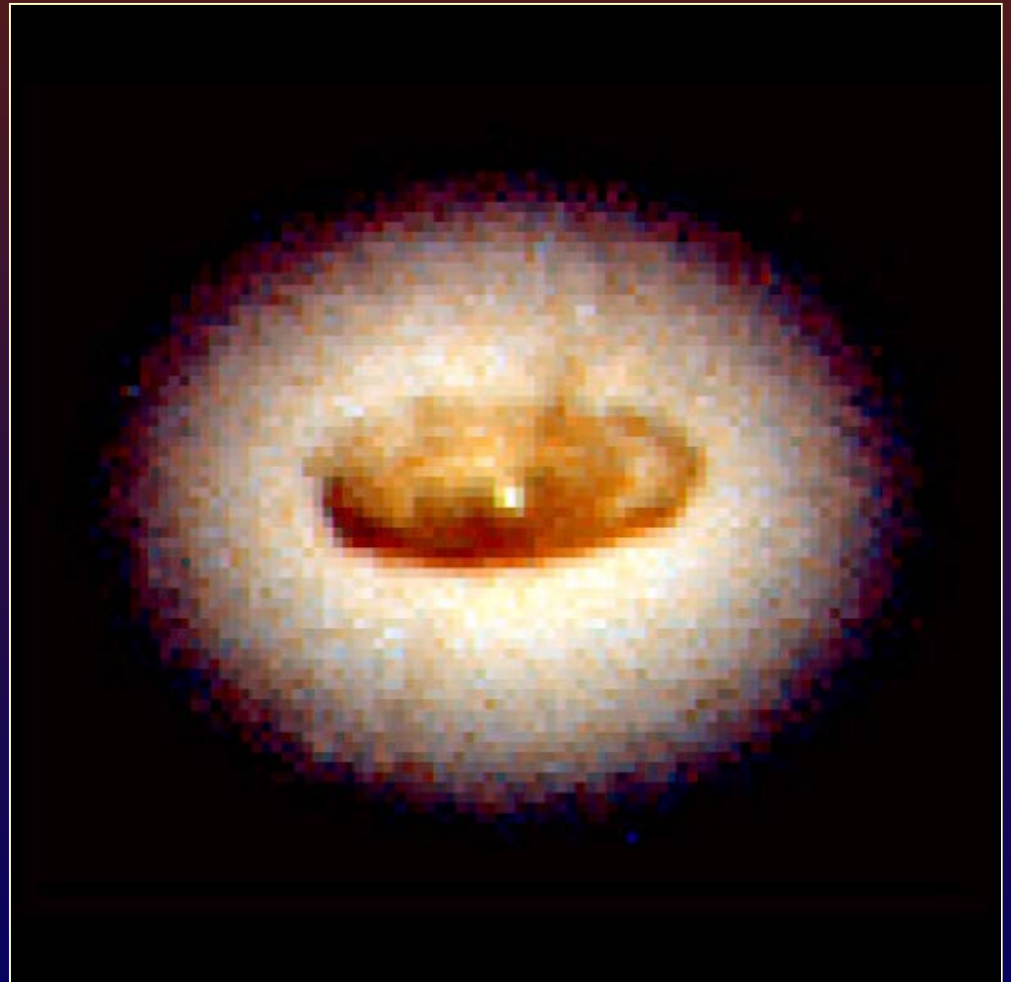




# Monstrous black holes

- ❖ At the heart of every galaxy lies a black hole, millions to billions times the mass of our Sun

HST/NGC  
4261





# Blazing Galaxies



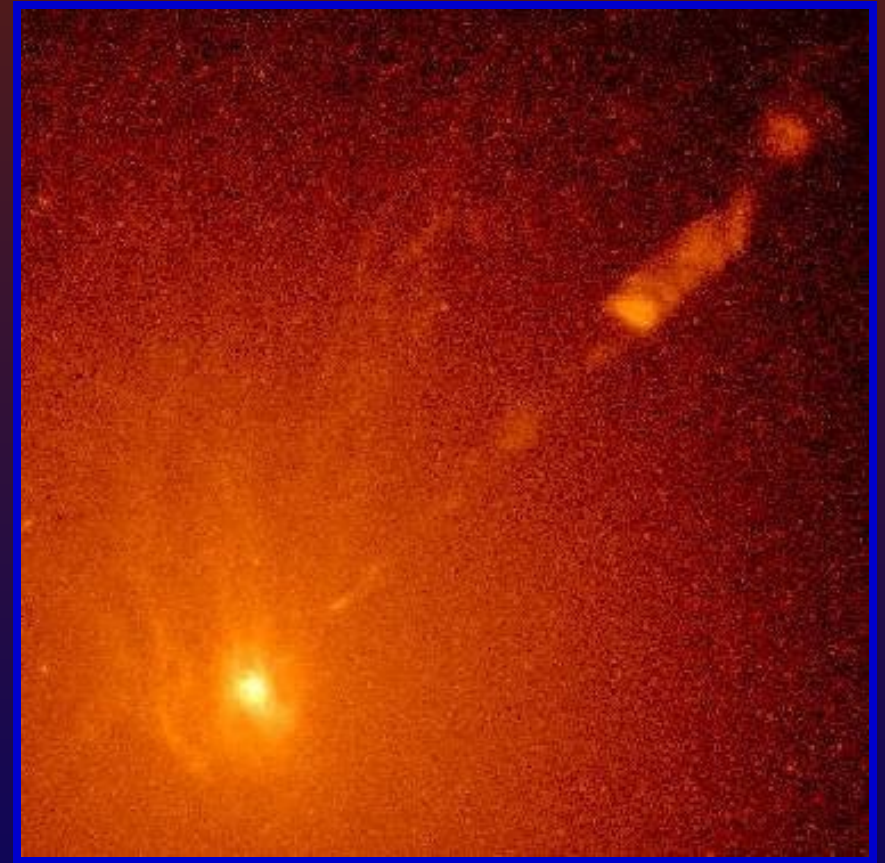
Credit: Dana  
Berry

- ❖ Gravity is so strong inside its “event horizon” that not even light can escape

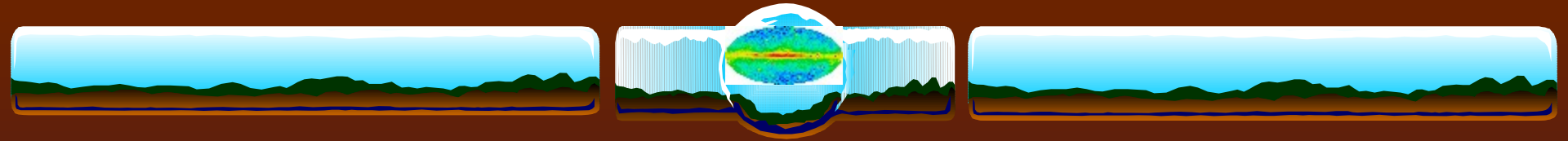


# Jet Mysteries

- ❖ So, how do black holes emit jets of particles and light?
- ❖ And, how do the particles in the jets accelerate to near light speed?

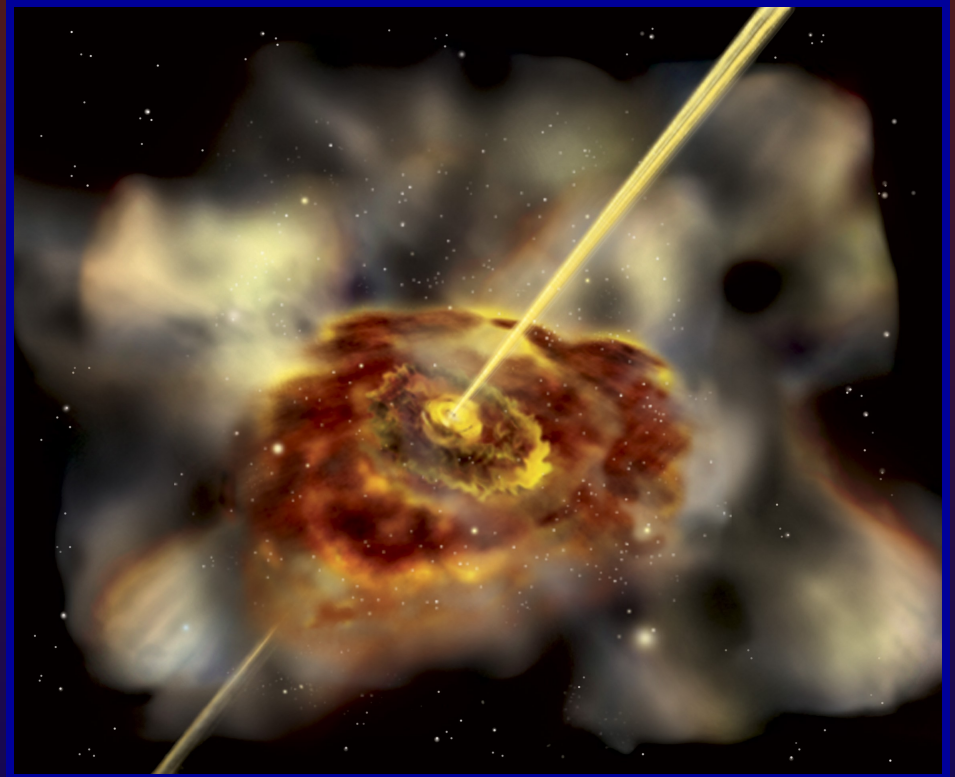


HST/ M87



# Gamma-ray Jets

- ❖ Jets flare dramatically in gamma rays
- ❖ Galaxies that point their jets at us are called “blazars”
- ❖ GLAST should detect thousands



Credit: Aurore Simonnet

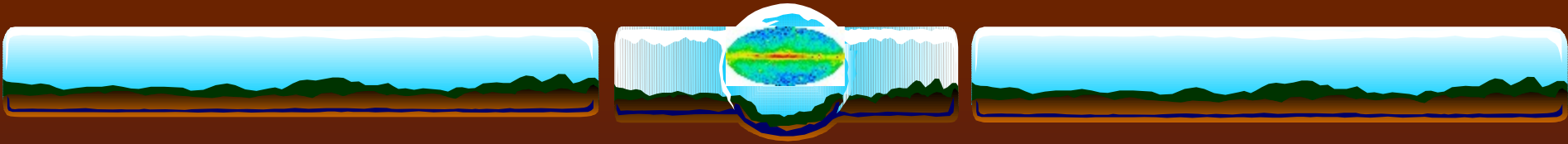


# Dark Matter



- ❖ Dark Matter makes up over 90% of the matter in the Universe
- ❖ You can't see it, but you can feel it!

HST/CL0024+1654



# Shining light on dark matter

- ❖ Dark Matter can be traced by studying X-rays from hot gas in clusters of galaxies

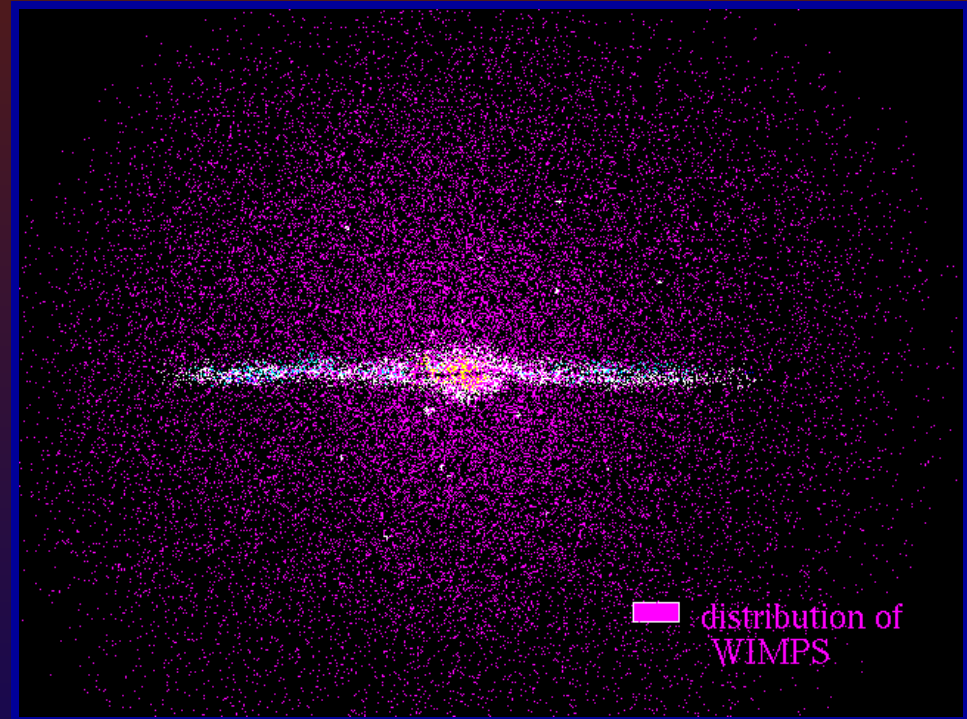


ROSAT X-ray over visible light image



# WIMPs

- ❖ Dark matter may be Weakly Interacting Massive Particles
- ❖ Annihilating WIMPs may produce gamma rays



A calculation of WIMPs around our galaxy



# GLAST and WIMPs

- ❖ If WIMPs are the dark matter and...
- ❖ If WIMPs self-annihilate producing GeV gamma rays....
- ❖ Then GLAST should be able to see gamma rays from WIMPs within 3 years of observations

■ *“The most incomprehensible thing about the Universe is that it is comprehensible” - A. Einstein*