The Chandra X-Ray Observatory: Celebrating its 20-th Year of Operation

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### Outline

- Why X-ray Astronomy is so important
- NASA's Great Observatory Program
- A (very) brief history of X-ray astronomy
- The building of the Observatory
  - Began in 1976
  - Launched in 1999
  - Designed for 3 years of operation with a goal of 5
- About to celebrate the 20-th anniversary
- Launch, deployment, first light!
- Some of the wonderful science
- The Nobel for Riccardo Giacconi

### The Importance of X-ray Astronomy



- Most of the matter that we "see" in the universe is via its X-ray emission
- The bulk of this matter is the hot, X-ray-emitting gas in the great galaxy clusters

#### The Atmosphere is a Nuisance-

Altitude (km)



#### The First Extra-Solar X-ray Source (1962)



### The Vision (1963)



#### Riccardo Giacconi



### The Uhuru Satellite – Dec 1970

- First satellite fully devoted to X-ray astronomy
- Mission lasted until 1973
- Comprehensive survey of the X-Ray sky with ~1/2 degree angular resolution (the size of the moon)
- 339 sources detected both galactic and extragalactic
- Discovered the first black hole candidate --- Cygnus X-1



Oh yes, Riccardo Giacconi was the Principal Investigator

### Binaries and Compact Objects -

• Gravity is the key!

### The Einstein Observatory — Nov 1978

- First fully imaging X-ray telescope
  - Few arcsecond angular resolution
- Completed its mission in Mar 1982
- Discovered that every known class of astronomical objects, or a subset thereof, was an X-ray source!
- Forerunner to Chandra



Oh yes, this was a MSFC Project and Riccardo was the PI

#### National Academy of Sciences

### Major New Programs #1: An Advanced X-Ray Astrophysics Facility (AXAF)

### Astronomy and Astrophysics for the 1980's

VOLUME 1: Report of the Astronomy Survey Committee



### The Observatory



**Optics** 



Mirror elements are 0.8 m long and from 0.6 m to 1.2 m diameter

### Optics: Coated, Assembled & Aligned



## The X-ray Calibration Facility at MSFC



#### Include the Upper Stage in the Shuttle





The longest and heaviest payload ever launched by the Shuttle

### Mrs. and Prof. S. Chandrasekhar



### Launch – July 23, 1999

## Beyond the Sky

Words and Music by Judy Collins And we will fly beyond the sky Beyond the stars beyond the heavens Beyond the dawn we'll carry on Until our dreams have all come true To those who fly - we sing to you



# Deployment

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### The Final Orbit



From above, with radiation belts & Moon

#### Closer side view

# Leon X-1



### Official First Light — Cassiopeia A





# Cassiopeia A



a 11

#### The Crab Nebula & it's Pulsar



## Jupiter and its Moons

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#### Europa

### More Planets

Saturn

Mars

Venus

## Two Neutron Stars Collide! (Wow)





#### AUG 19

AUG 22

### Galaxy Clusters – Feedback Fuels Development

- Cavities are 600,000 light years in diameter
- 300 million suns in the last 100 million years

Supermassive Black Hole



### Dark Energy and Dark Matter







### **Colliding Clusters of Galaxies and Dark Matter**

- Blue most of the mass the dark matter
- Pink normal X-ray emitting matter



## Probing Dark Energy

- This study examined 300 galaxy clusters
- Size versus time depends on dark energy
- Confirms the "cosmological constant"



### The 2002 Nobel Prize for Riccardo Giacconi



#### Learn More



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The opportunity for exploration and discovery with Chandra remains as high today as it was at launch