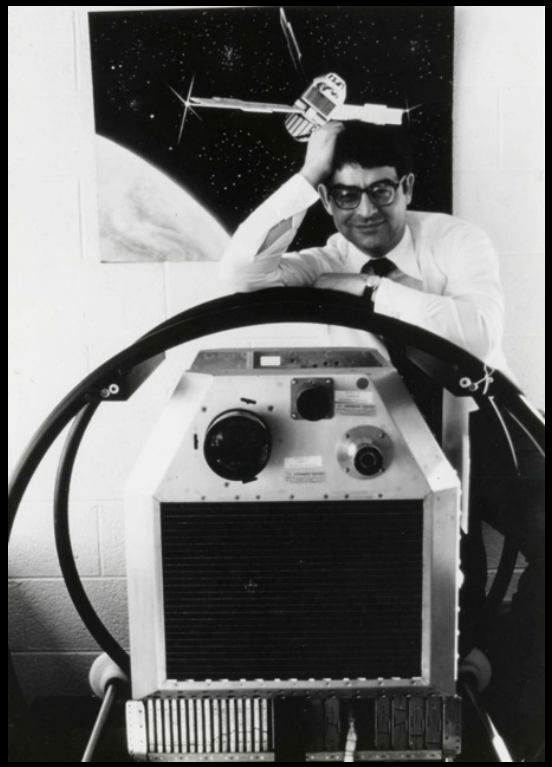
Riccardo Giacconi
Uhuru - the blossoming of X-ray astronomy

"While analyzing Uhuru data, I came to love discovery for its own sake" (SHD p143)



Giacconi's plans for future X-ray astronomy missions

A Proposal for

AN EXPERIMENTAL PROGRAM
OF EXTRA-SOLAR X-RAY
ASTRONOMY

Prepared for

National Aeronautics and Space Administration
Washington 25, D. C.

Prepared by

American Science and Engineering, Inc.
11 Carleton Street
Cambridge 42, Massachusetts

25 September 1963

Approved:

Riccardo Giacconi
Vice President
Space Research and Systems Division

This document consists of 75 pages.
Copy No. 4 of 7 Series A

ASE Log No. 63-104-b

With compliments
Riccardo Giacconi

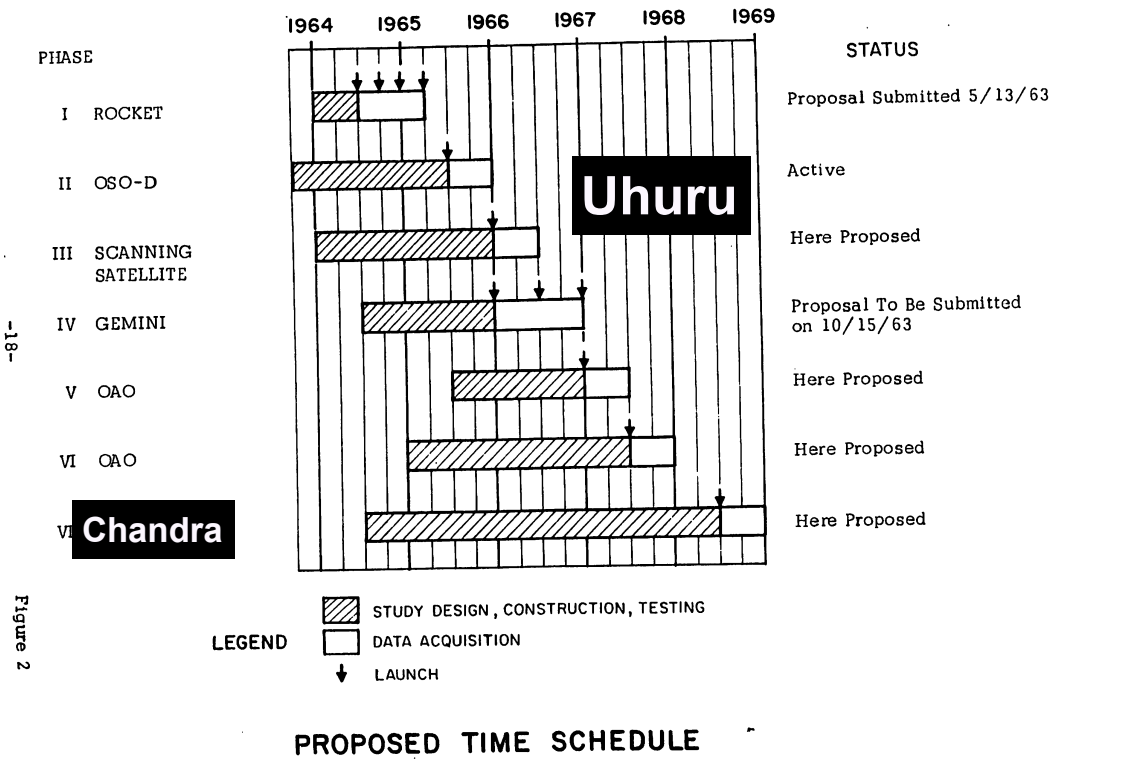
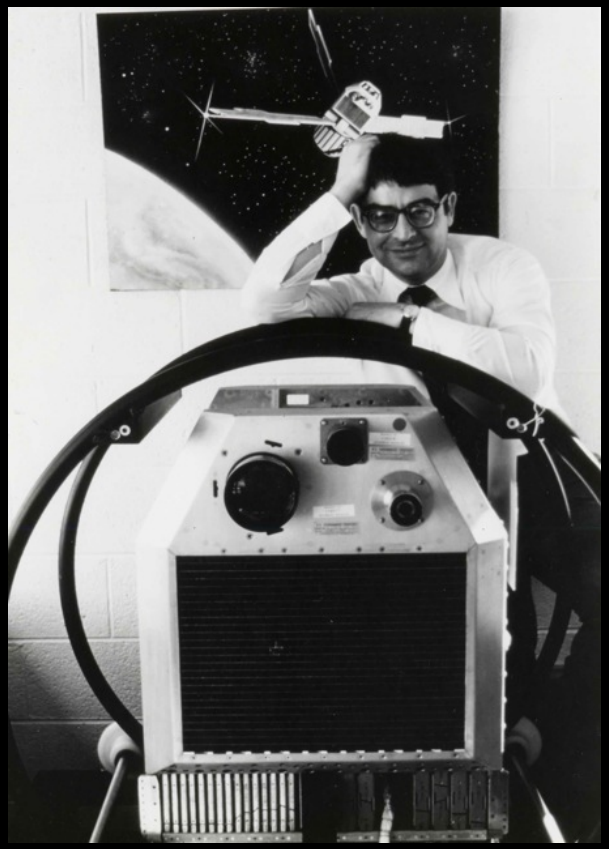
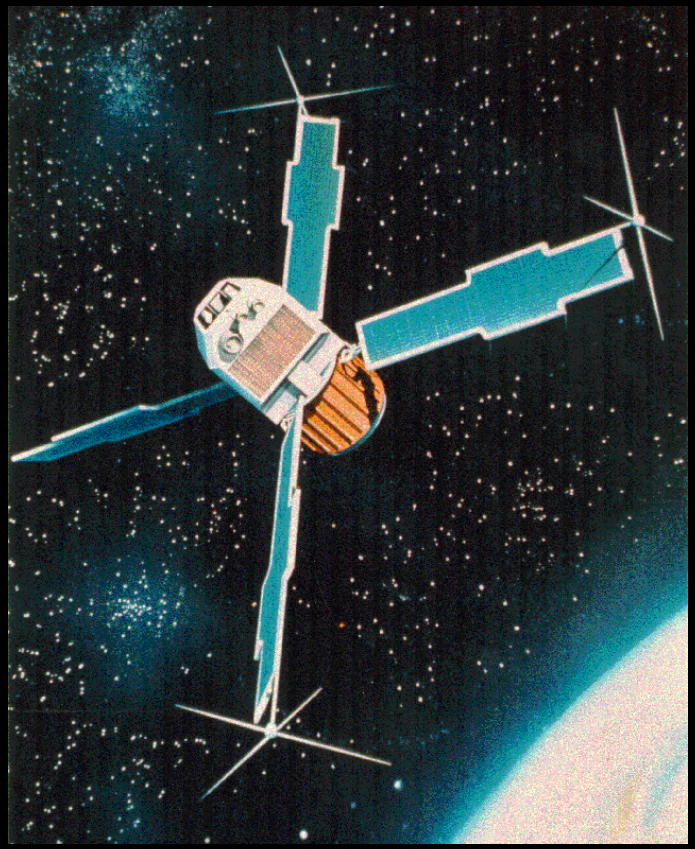


Figure 2

PROPOSED TIME SCHEDULE

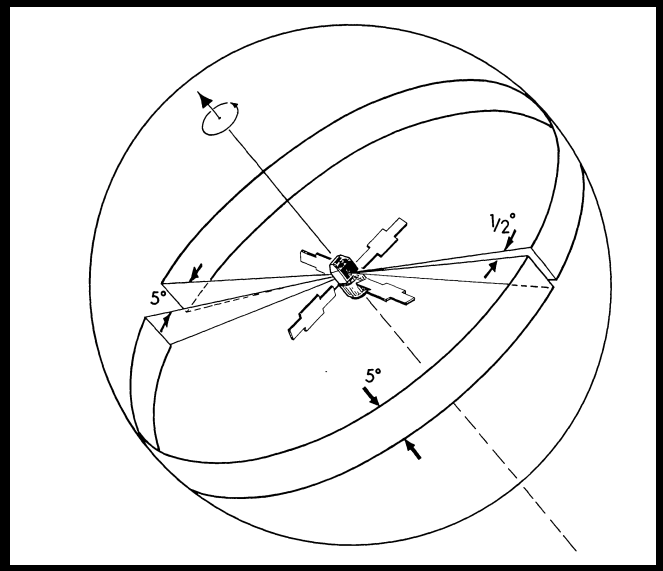
Uhuru - launched December 12, 1970 (Kenyan Independence day)
from an Italian launch platform off the coast of Kenya
Uhuru - freedom in Swahili
Uhuru - built and observations planned and analyzed by scientists at AS&E
(Giacconi, Gursky, Tananbaum, Schreier, Murray, Matilsky)



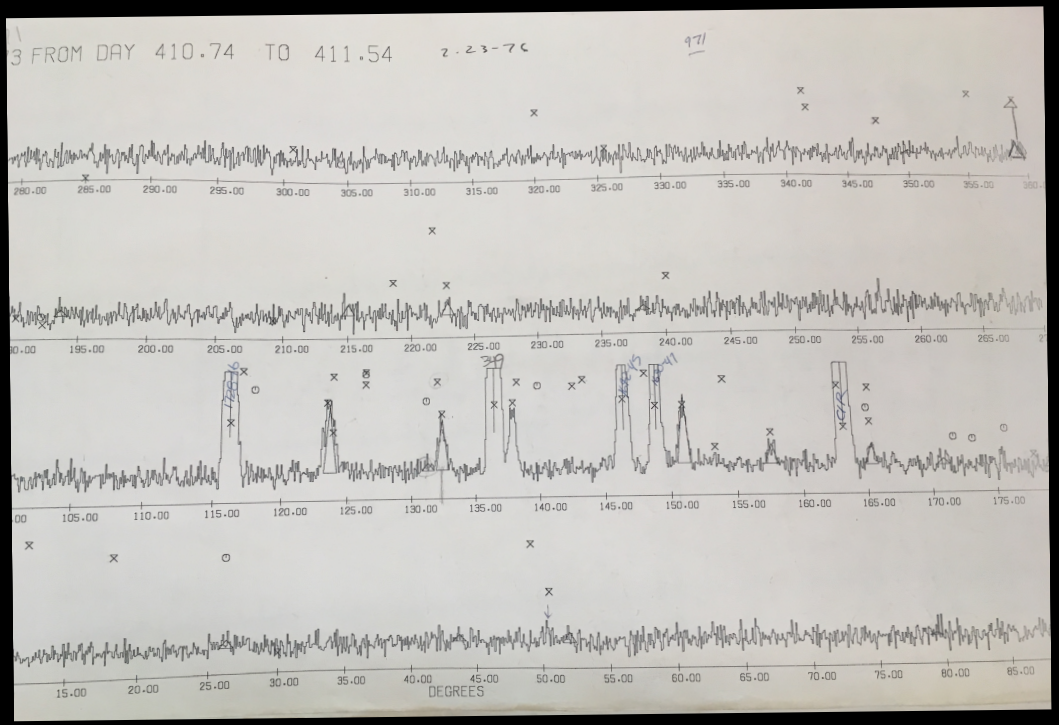


Uhuru scans of the sky

- 20% of daily data received as “quick-look”
- allowed for rapid changes in observing program



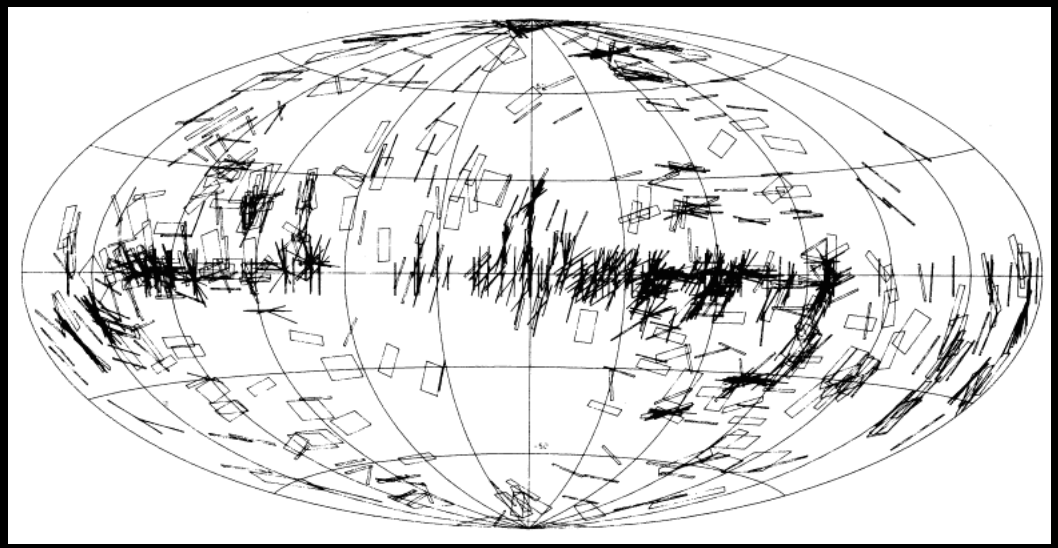
Uhuru scanned the sky with 0.5° x 5° and 5° x 5° collimators Giacconi+1971



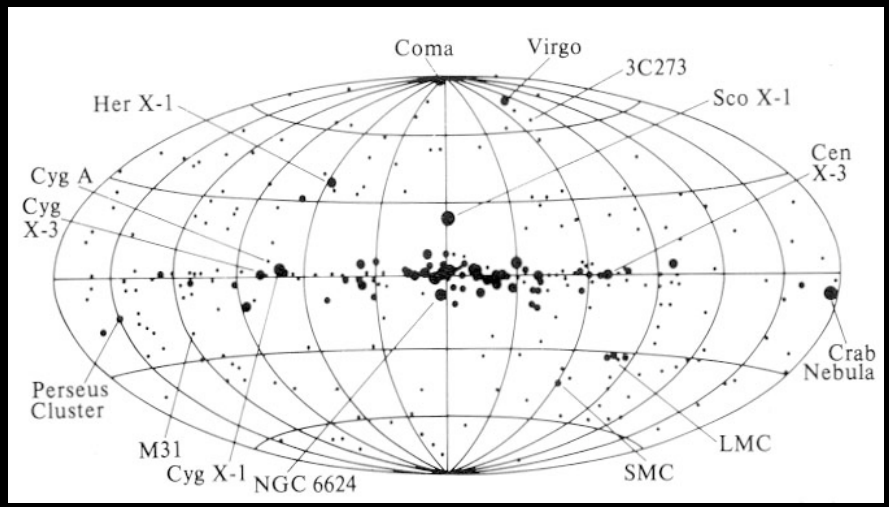
Uhuru observations of the galactic plane

2U UHURU Catalog
Giacconi et al. 1972

- Individual scans superposed
- Each source detection generated a "line of position"
- Intersections defined sources for the Uhuru catalogs



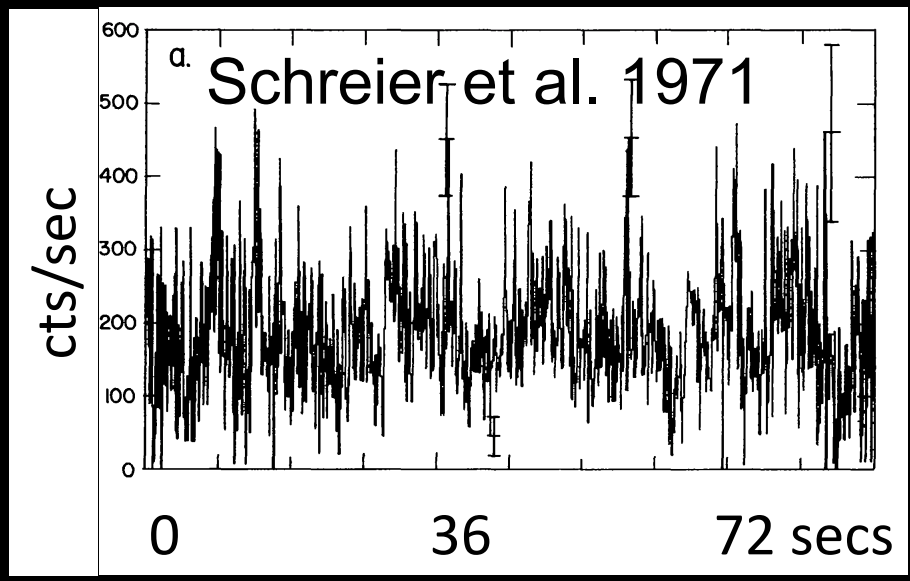
- 70 days of data
- 125 sources
- Bright sources in Galactic Plane — X-ray binaries (Cen X-3, Her X-1) and SNR Tycho and Puppis. Galactic sources often variable
- Extragalactic sources — M31, LMC/SMC, clusters of galaxies (Perseus, Coma and Virgo), and AGN (NGC4151, 3C273, Cen A)

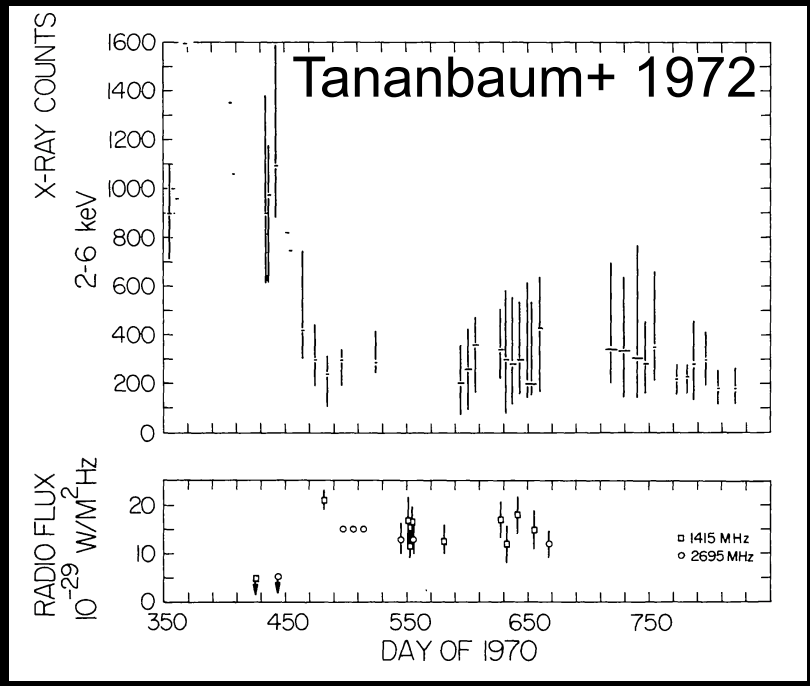


Selected Uhuru highlights
Cygnus X-1
Evidence for a black hole

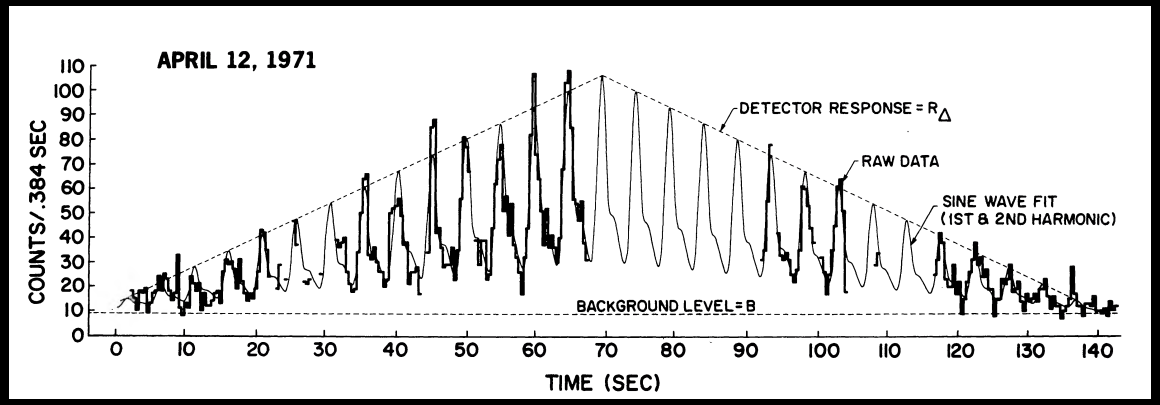
- Short time scale intensity variability (Schreier+71)
- Coordinated radio-x-ray transition (Tananbaum+72)
  - accurate location led to ID with HDE226868 - 9th magnitude OB supergiant
  - first masses from Webster & Murdin (1972); Bolton (1972); Hutchings+(1973)

- More recent, definitive measurements
  - Distance 1.86 kpc (+0.12,-0.11, Reid+2011)
  - **M = 14.81±0.98 M_{sun}** (Orosz, McClintock+2011)
  - Spin > 0.92 (Gou, McClintock+2011)

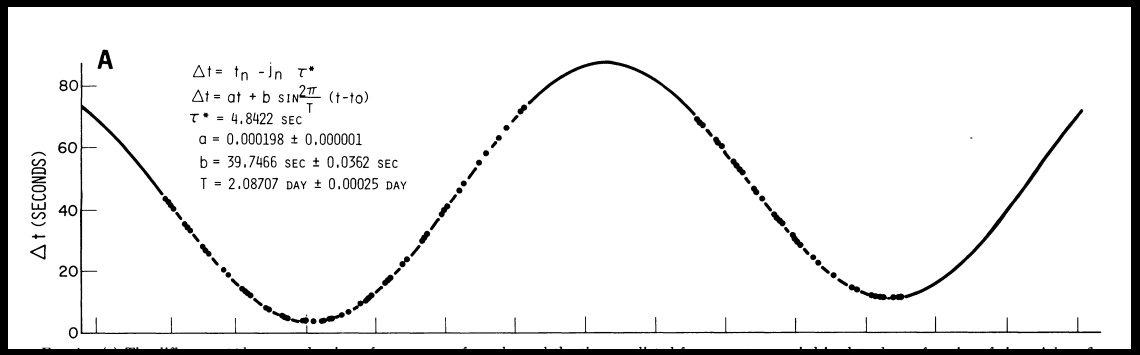


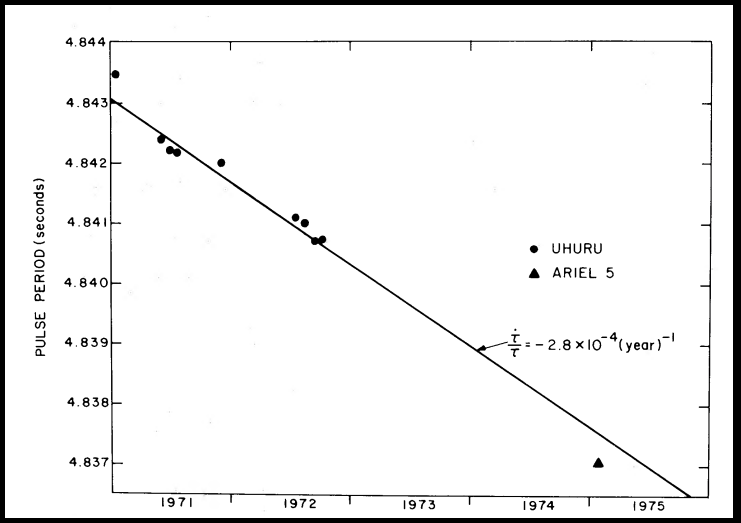


Pulsating X-ray binaries - Centaurus X-3



- 2.0871±0.0003 day binary period
- 4.822 sec pulsations
- spin period decreasing ==>Accretion powered



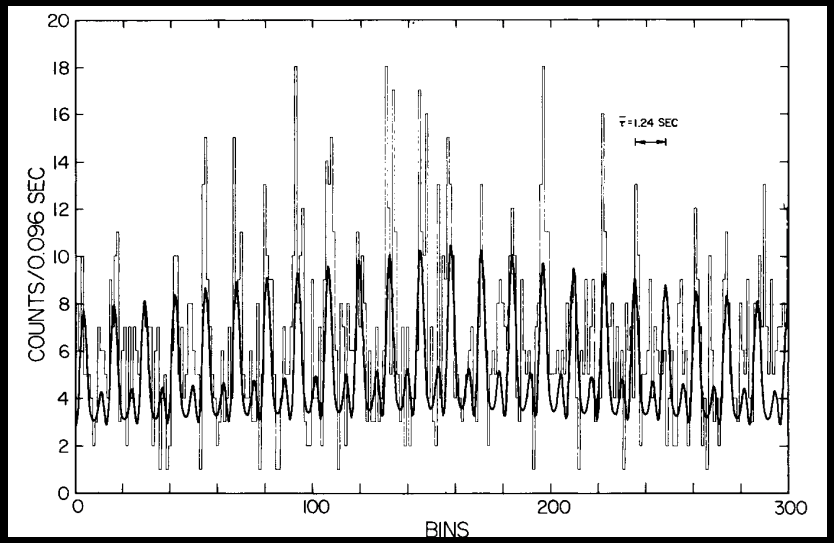


- Phasing from scan to scan enabled by slowing spacecraft spin

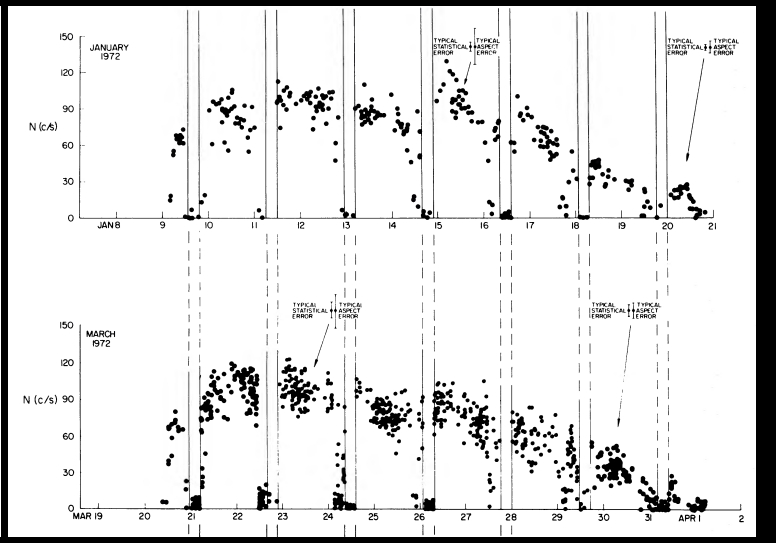
Giacconi + 1971
Schreier + 1972
Fabbiano & Schreier 1977

Hercules X-1

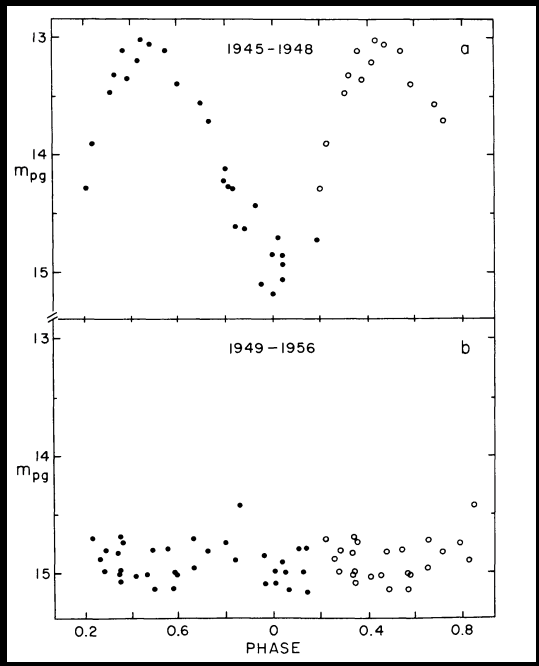
- 1.24 sec X-ray pulsations
- 1.7 day binary
- 35 day on/off cycle -> disk precession
- Long term “off” states from optical



Tananbaum+72



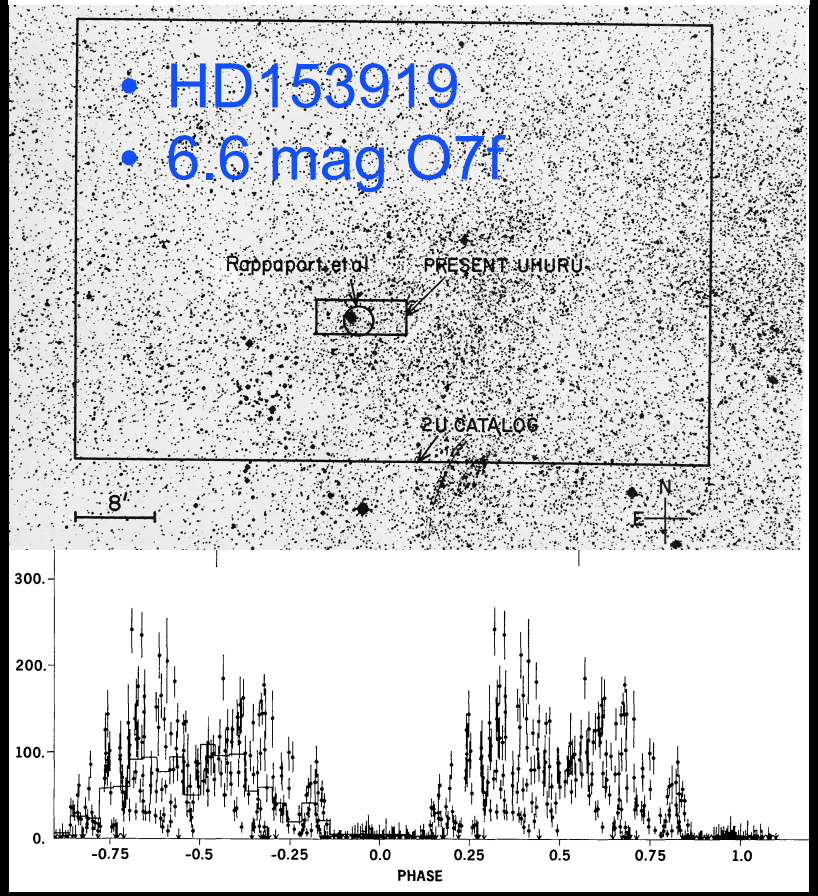
Giacconi+73

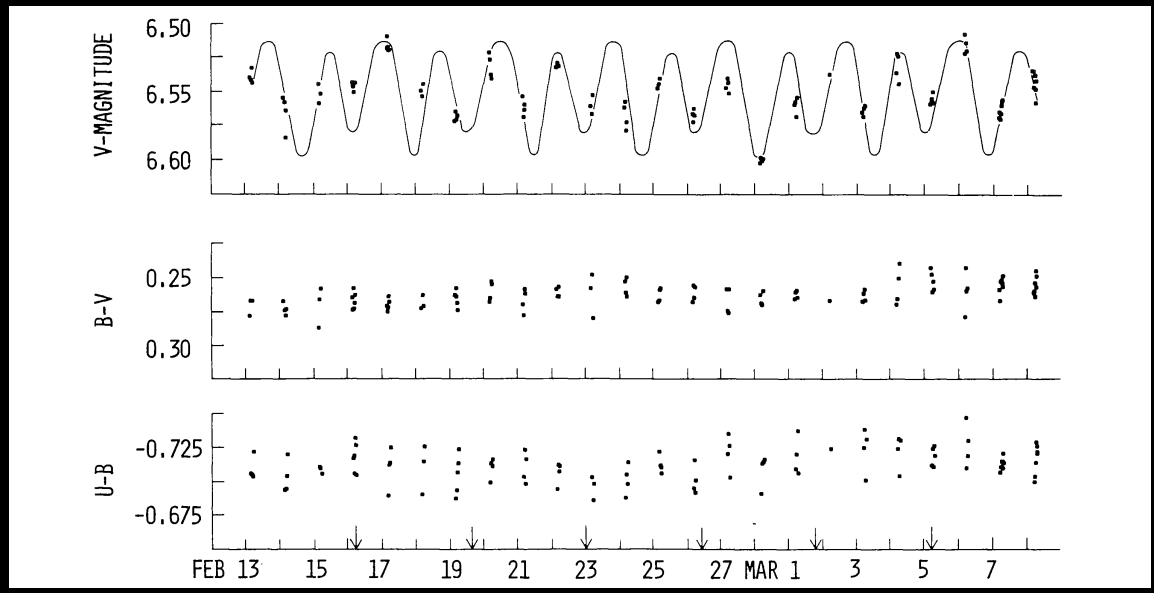


Jones+73

- Uhuru provided accurate positions for optical identifications

4U1700-37; Jones+1973





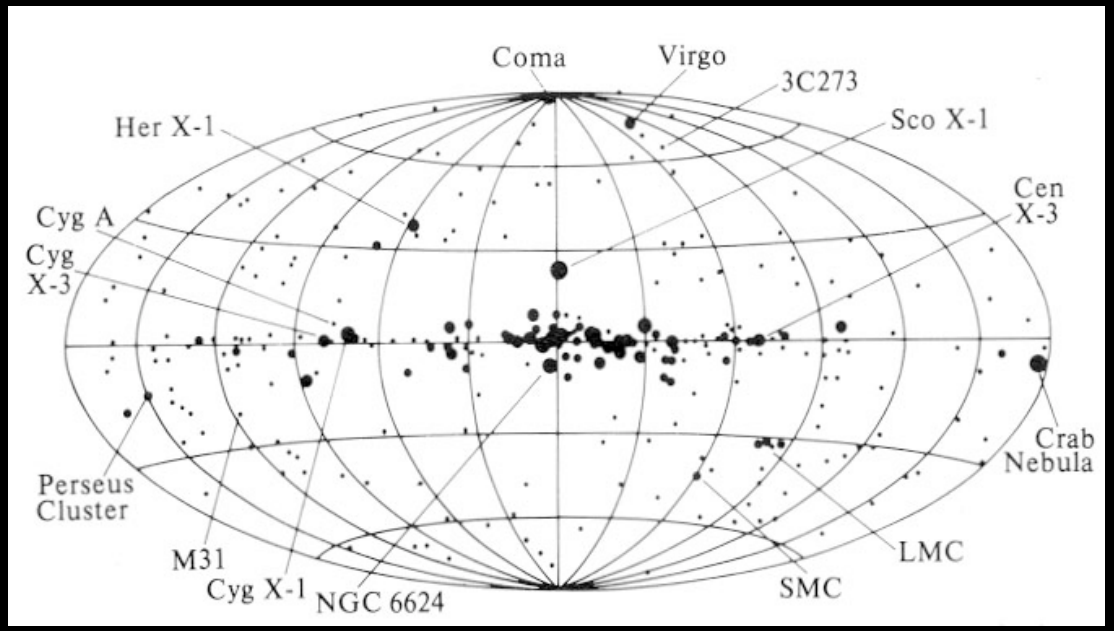
- 3.412±0.002 day period
- 23 days of optical photometry on CTIO 16" telescope (Jones+Liller 1973)

Massive neutron star OR Black Hole (Clark+ 2002)

Mass = 2.44±0.27 M_{sun}

GALACTIC SOURCES

Fourth Uhuru Catalog (Forman + 1978)



339 sources

12 X-ray Binaries

Her X-1, Cen X-3, Cyg X-3, 4U0900-40, 4U1700-37, Cyg X-2, Cir X-1, SMC X-1, LMC X-1, 2, 3, 4

6 X-ray Pulsars

Her X-1, Cen X-3, SMC X-1, Vela, GX304-1, GX17+2

5 Globular Clusters

NGC1851, NGC6440, NGC6441, NGC6624, NGC7078(M15)

9 Transient sources

4U0115+63, 4U1918+15, 4U1543-47, 4U1901+03, 4U1908+00, 4U1730-22, 4U1735-28, 4U1807-10, 4U1630-47

6 X-ray Bursters

4U1608-52, 4U1656-53, 4U1728-33, 4U1820-30, 4U1837+04, 4U1857+01

4 Supernova Remnants

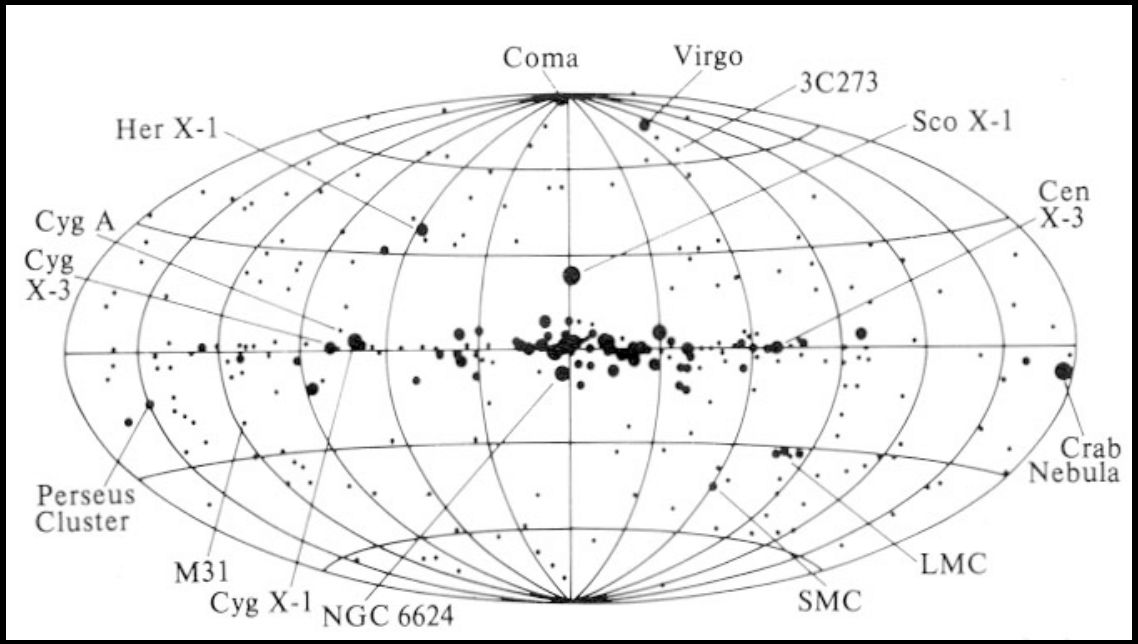
Crab, Tycho, Cas A, Puppis A

X-ray Stars

X Per, Orion, Eta Carina

Extragalactic Sources

Fourth Uhuru Catalog



339 sources

2 Galaxies

Andromeda (M31), M82

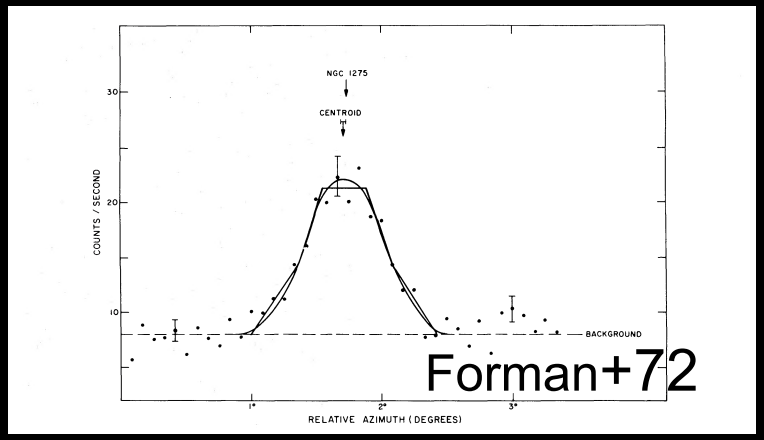
7 Active Galactic Nuclei (AGN)

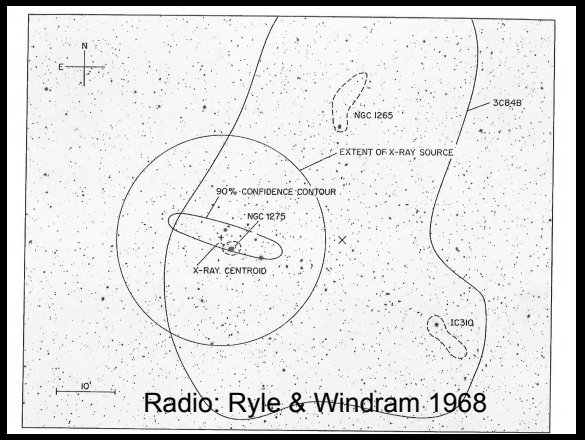
MKN335, 3C120, MCG8-11-11, NGC3783, NGC4151, 3C273, Cen A

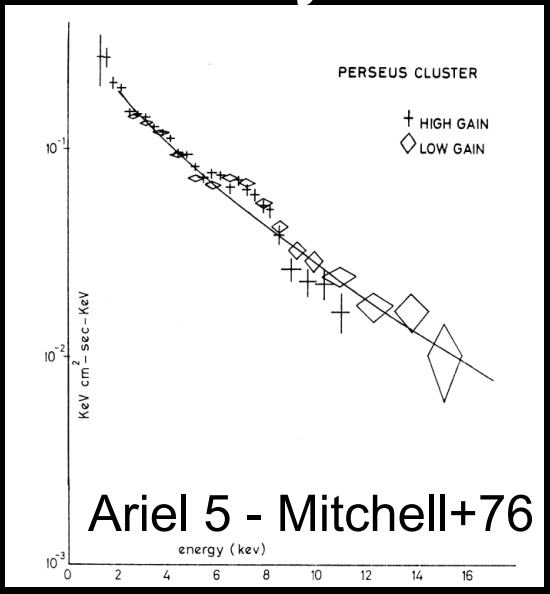
35 Clusters of Galaxies

A85, A133, A262, A358, A401, A426(Perseus), A478, A496, A514, A539, SC0627-54, A576, A754, A1060, A1146, A1367, A1391, Virgo, Centaurus, A1656(Coma), A1795, A1991, A2065, A2142, A2199, A2256, A2318, Cyg A, A2589, A2657, A2666, Klemola 44, SC1329-314, SC1345-301, PKS1252-28

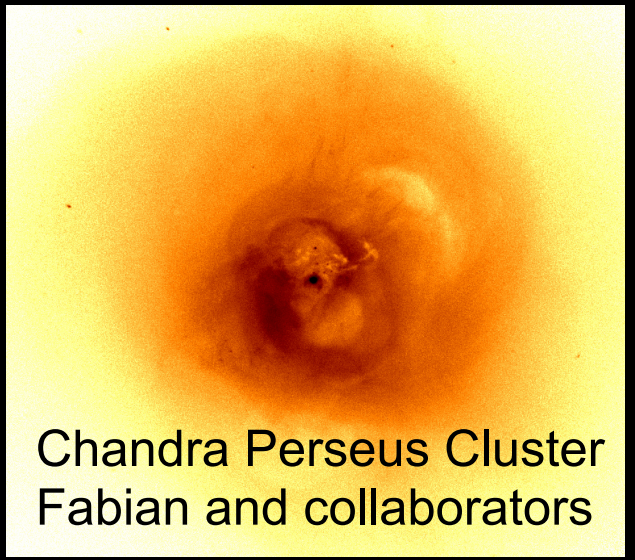
Perseus Cluster - brightest extragalactic X-ray source





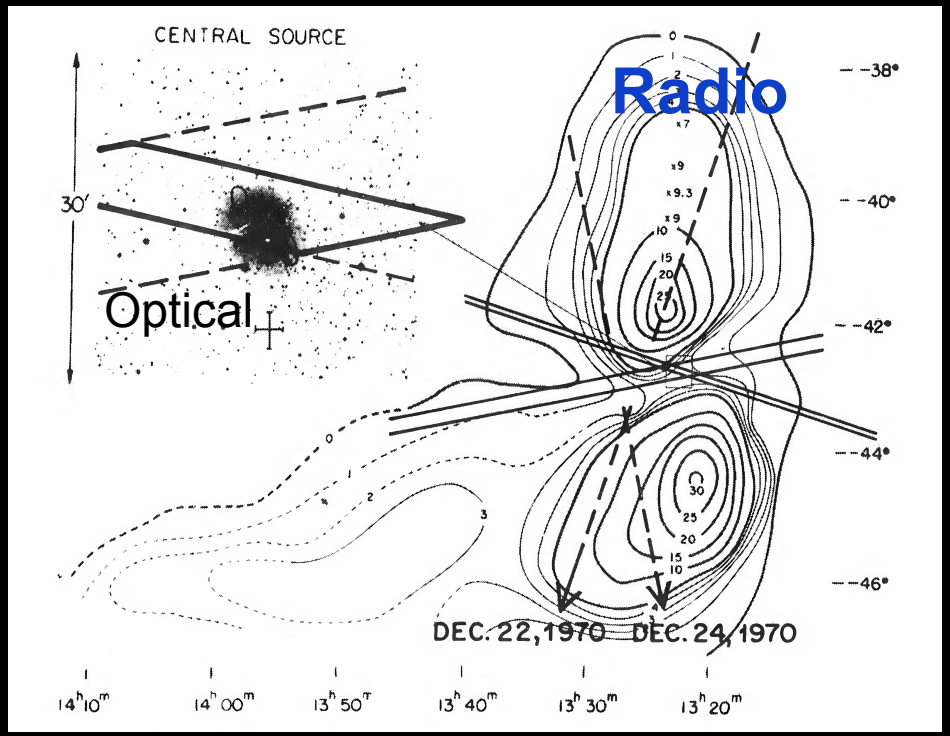


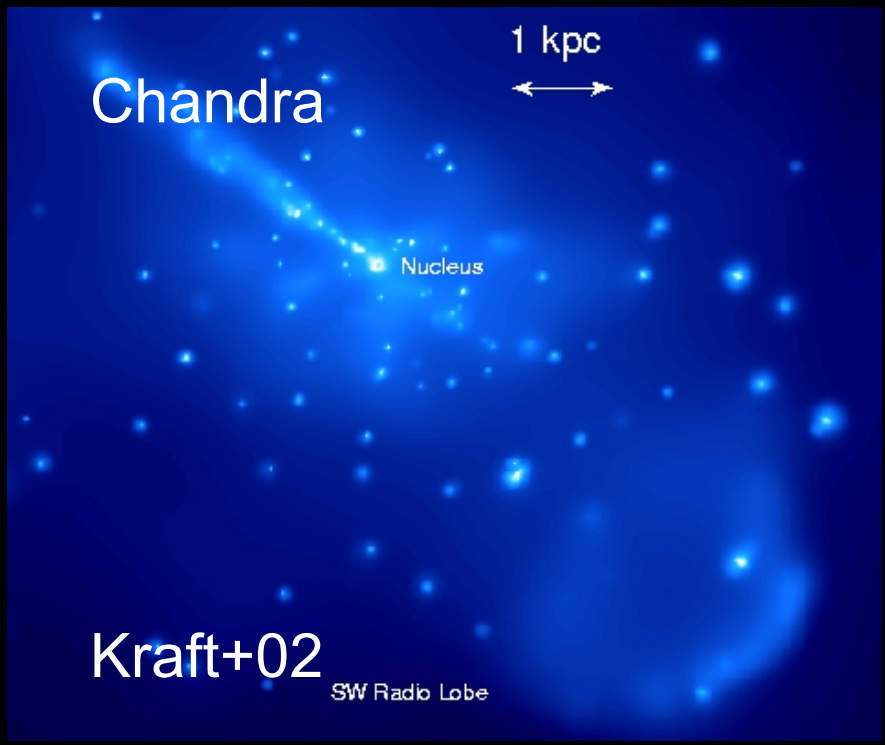
- Perseus extended X-ray source (Forman+72)
- Uncertain if X-ray emission is due to thermal hot gas or IC (since extended radio detected; Ryle & Windham 1986)
- Iron line detected - (Mitchell+76 Serlemitsos+77)
- Cooling flows (Fabian & Nulsen+77)
- Launched feedback from SMBHs— whole new field of investigations



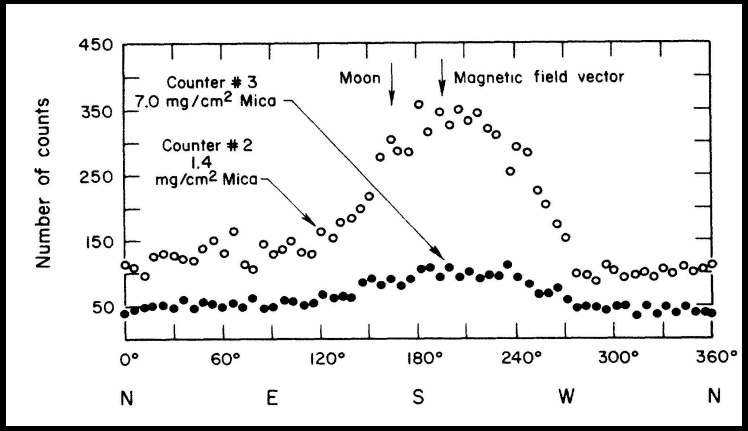
Cen A - active galactic nucleus

- Intersecting Uhuru scans identify X-ray emission from Cen A (Kellogg+71)
- Consistent with a single point source
- No detected emission from lobes (less than 1/3 of the central source)
- 0.07 sq deg. error box (initial detection by Bowyer+70 in 10x larger box)





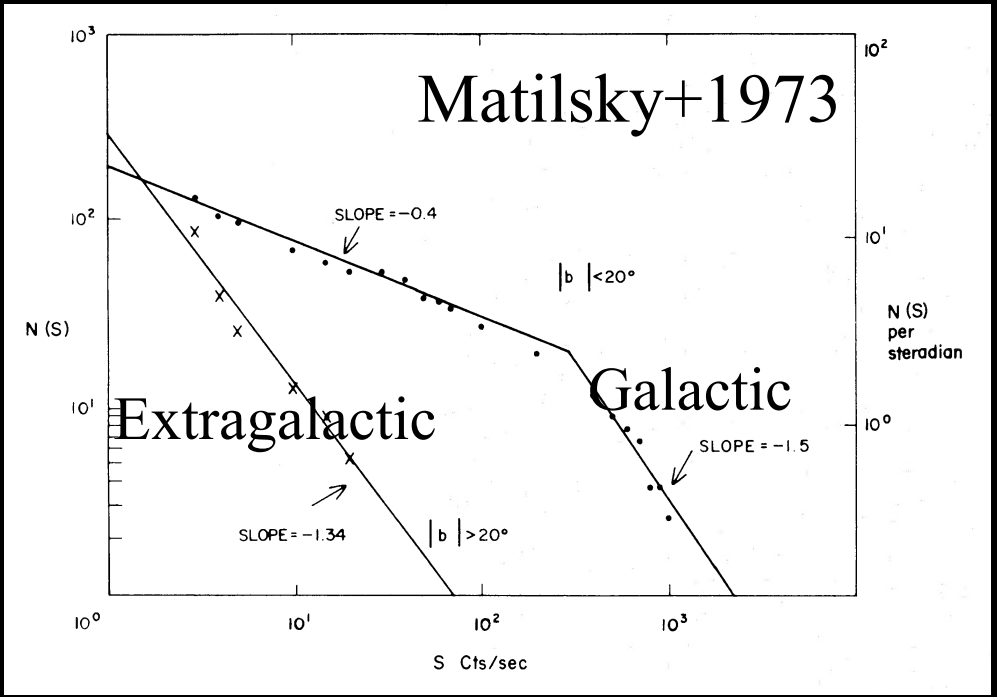
Following the discovery of the XRB in 1962 rocket flight, determining the nature of the XRB became a primary goal.



First steps towards resolving the XRB with Uhuru

Log N-Log S for high & low galactic latitudes

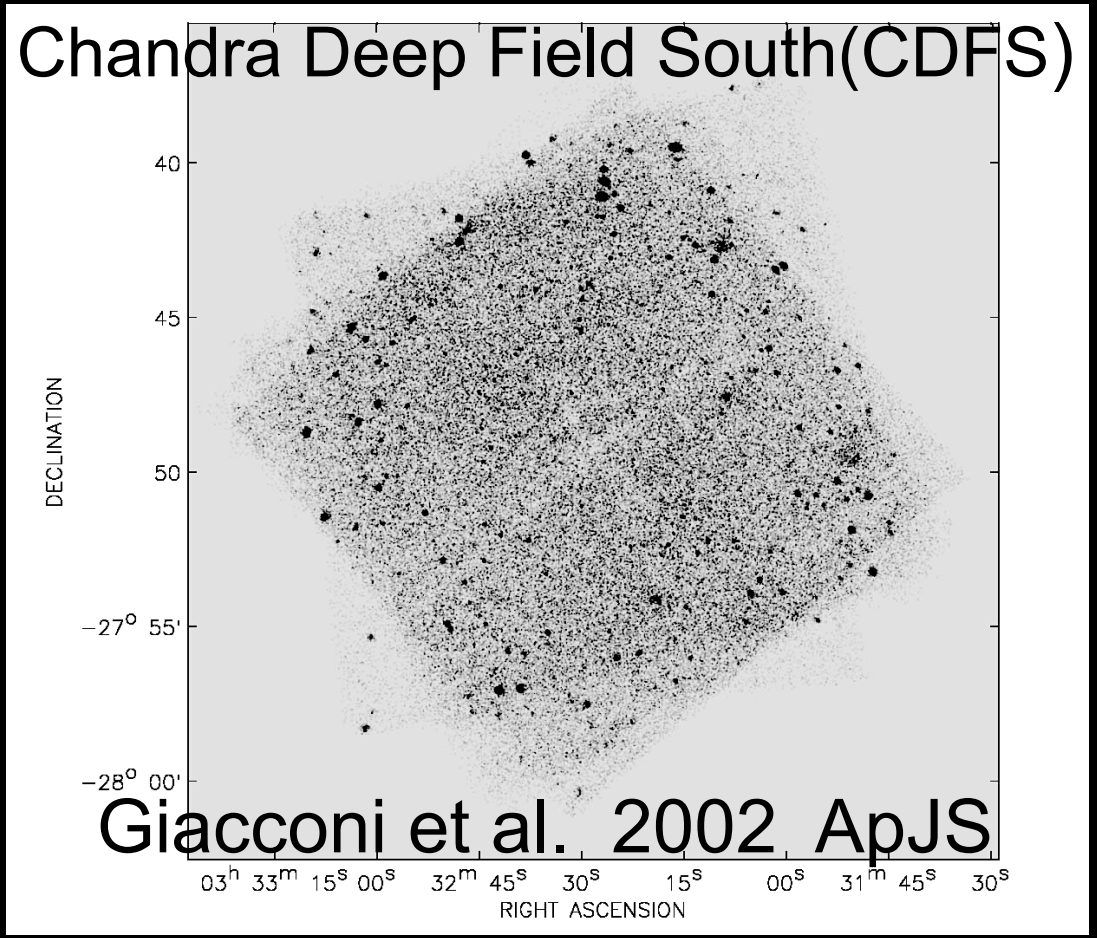
- Low latitude sources show a "break"
  - consistent with "running out of Galaxy"
- High latitude sources
  - α = -1.34±0.20 (consistent with -1.5, expected for an "extragalactic" population)



CDFS 1Ms
Riccardo Giacconi

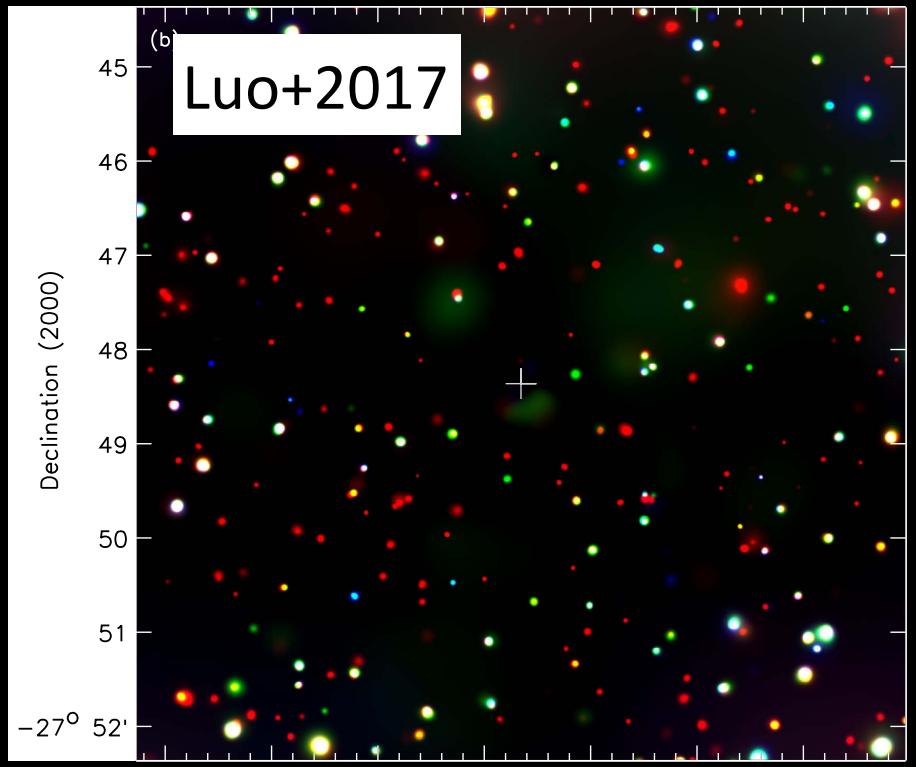
- Chandra Interdisciplinary Scientist
  500ks (+ 500ks DDT)
- 10^{10} increase in sensitivity compared to first detection of Sco X-1 (same sensitiveity increase as naked eye to Hubble)

- Chandra: The Dream Comes True
- RA=3 32 28 Dec=-27 48 30
- Low intervening absorption



"After many years of helping others do their science, it was great to be able to stare at my own data and let them flow through my fingers, as if panning for gold." (Giacconi SHD 2008)

CDFS: From 1Ms (Giacconi+02) to 7Ms (Luo+17)



Resolving the X-ray background

- 50,000 sources per sq. deg
- 6×10^{-18} erg cm^{-2} s^{-1} (0.5-2.0 keV)
- At faint flux, normal galaxies begin to dominate the number counts

Riccardo's Dream: Most of XRB now resolved into sources 81+-4% (0.5-2.0) keV 93+-13% (2-7 keV)

"During my university years in Milan, not one of my senior colleagues had ever invited me over to his home (except for Beppo Occhialini)."

"Secrets of the Hoary Deep" (2008)
Riccardo Giacconi

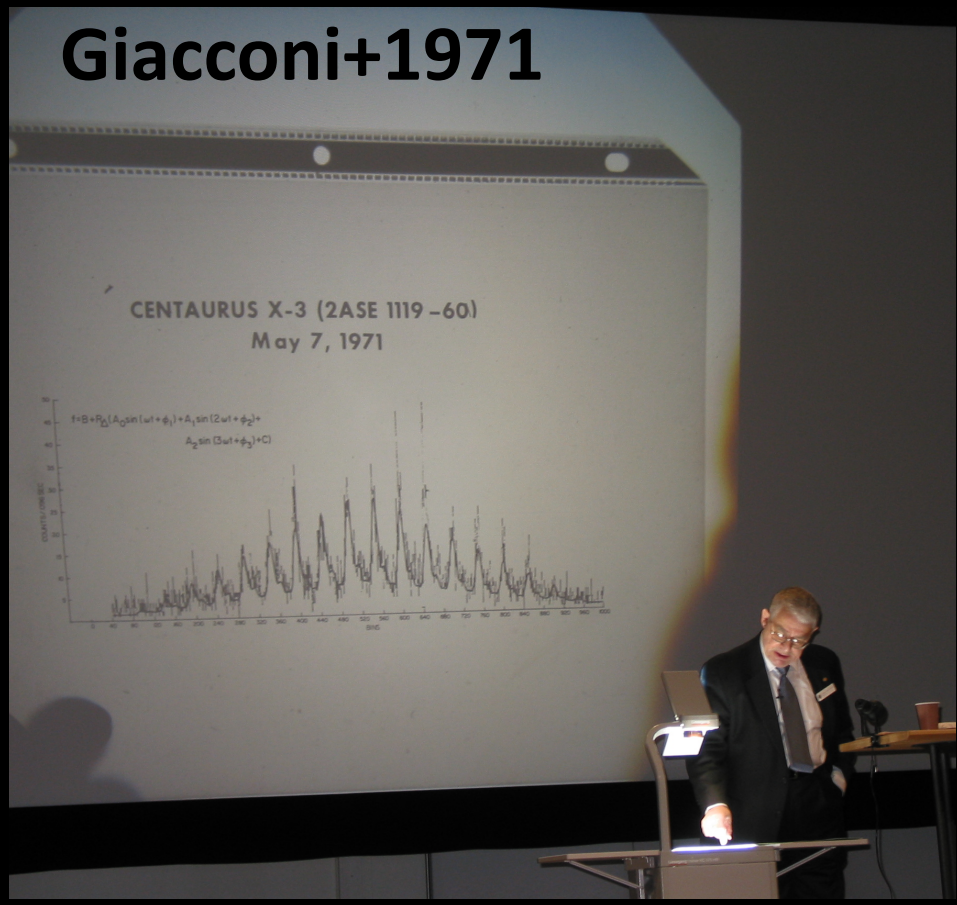
Riccardo moved from AS&E to join the astronomy faculty at Harvard in 1973. Harvey Tananbaum, Leon van Speybroeck, Ethan Schreier, Herb Gursky, Ed Kellogg, and Bill Forman also joined the newly formed High Energy Astrophysics Division at the CfA.

Riccardo and Mirella often invited students and colleagues to their home for wonderful dinners or larger social gatherings.

They lived just a short walk from the CfA.

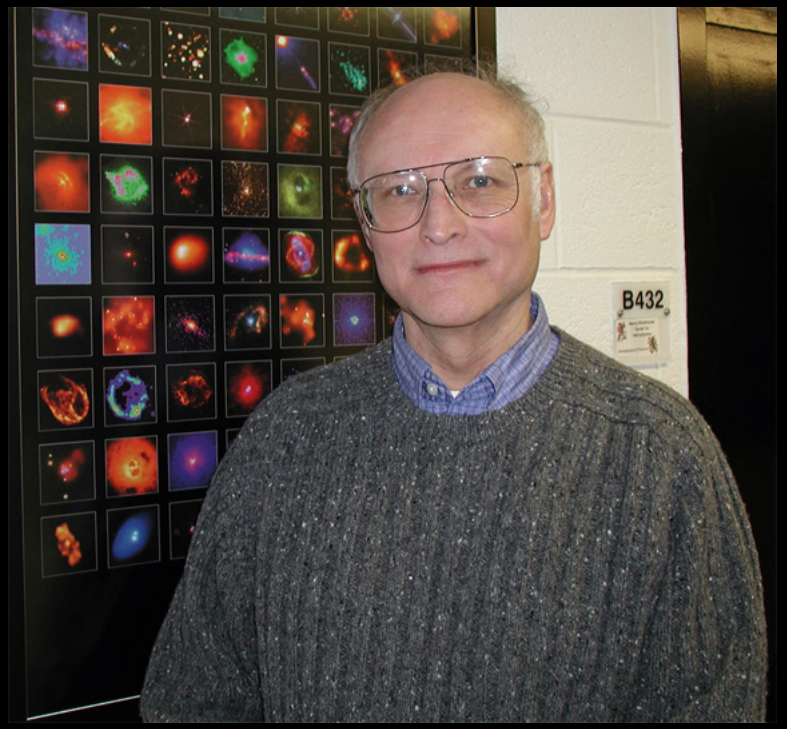
Nobel Prize Lecture 2002

Schreier, Gursky, Giacconi, Tananbaum



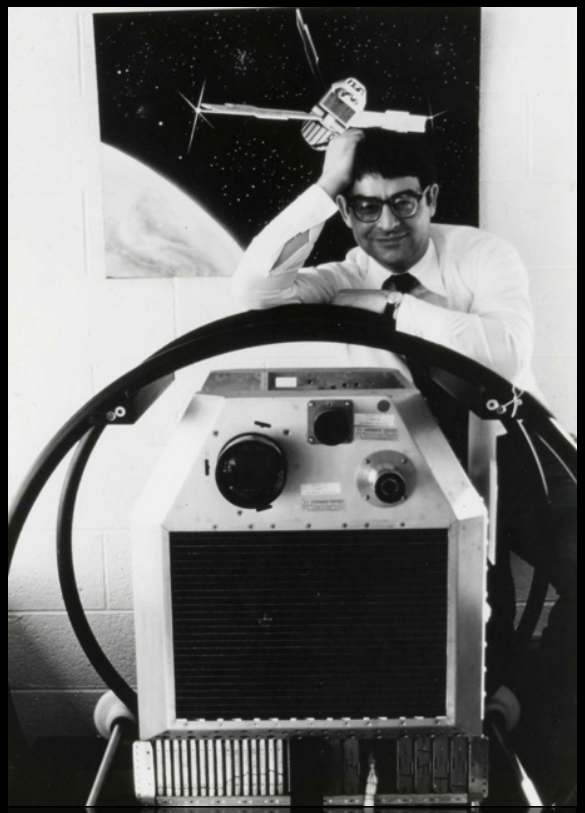
Return to UHURU
with VU graphs!!

Not with us today,
but very much pioneered what was to come



Leon van Speybroeck
Mirror Scientist - Einstein/Chandra

Steve Murray
High Resolution Imager PI- Einstein/Chandra



"Had I but known it, those were the happiest years of my life." Riccardo Giacconi 2008, "Secrets of the Hoary Deep, p 91"

Waiting for Uhuru Launch

Bologna X-ray astronomy 2009