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
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

Harvard-Smithsonian Center for Astrophysics
Christine Jones
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)
  - \( M = 14.81 \pm 0.98 \, M_{\odot} \) (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

- HD153919
- 6.6 mag O7f

• 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)

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

339 sources
Extragalactic Sources

Fourth Uhuru Catalog

2 Galaxies
Andromeda (M31), M82

7 Active Galactic Nuclei (AGN)
MKN335, 3C120, MCG8-11-11, NGC3783, NGC4151, 3C273, Cen A

35 Clusters of Galaxies

339 sources
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

Chandra Perseus Cluster
Fabian and collaborators
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
  - $\alpha = -1.34 \pm 0.20$ (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 sensitivity 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
- $6 \times 10^{-18}$ 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).”

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.
Giacconi+1971

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.”

Waiting for Uhuru Launch
Bologna X-ray astronomy 2009