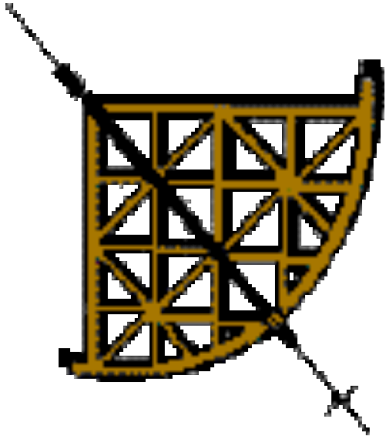
Birth and Growth of High Energy Astrophysics

Urbino July 28, 2008



Giorgio G.C. Palumbo

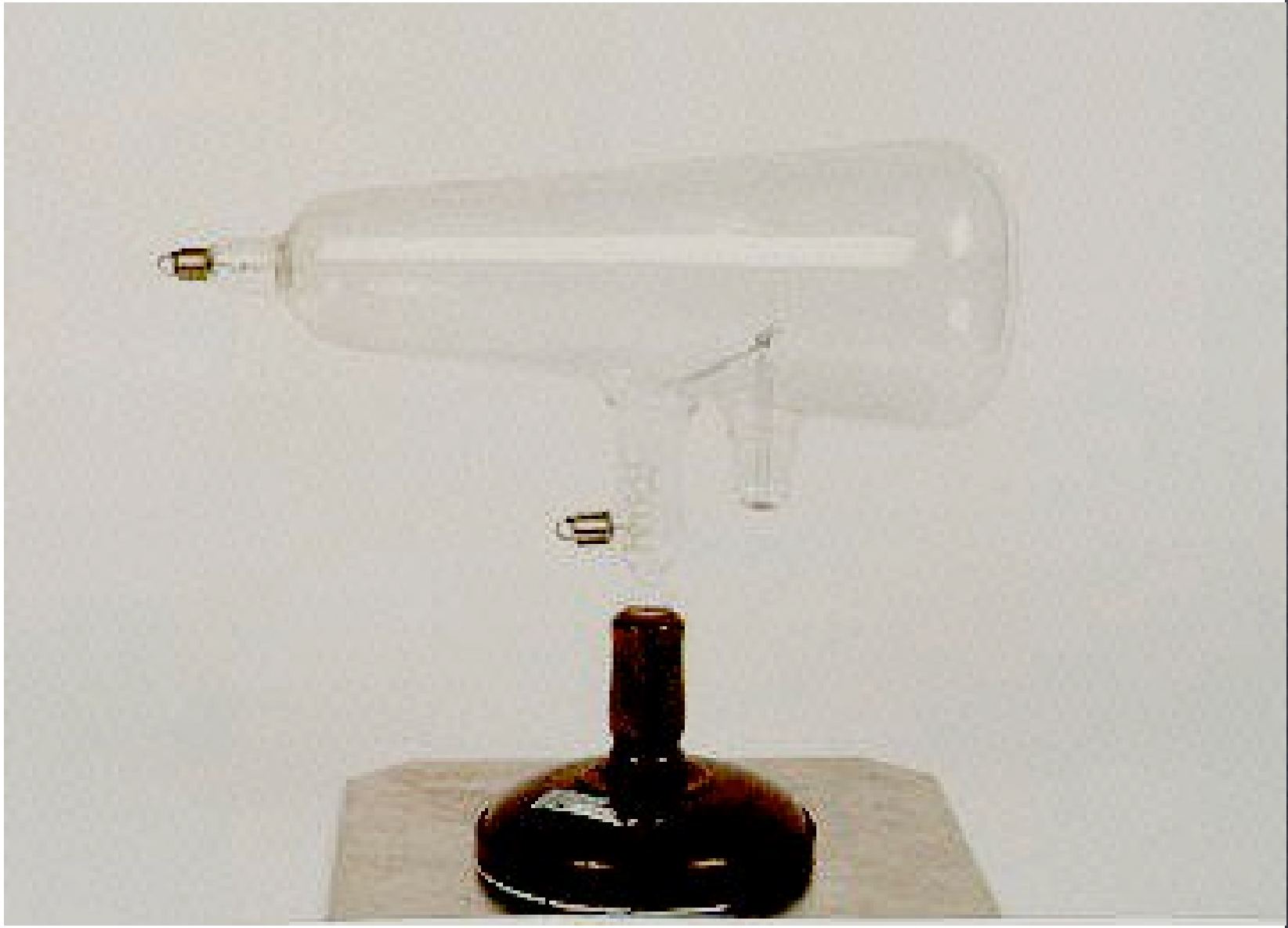
Università degli Studi di Bologna

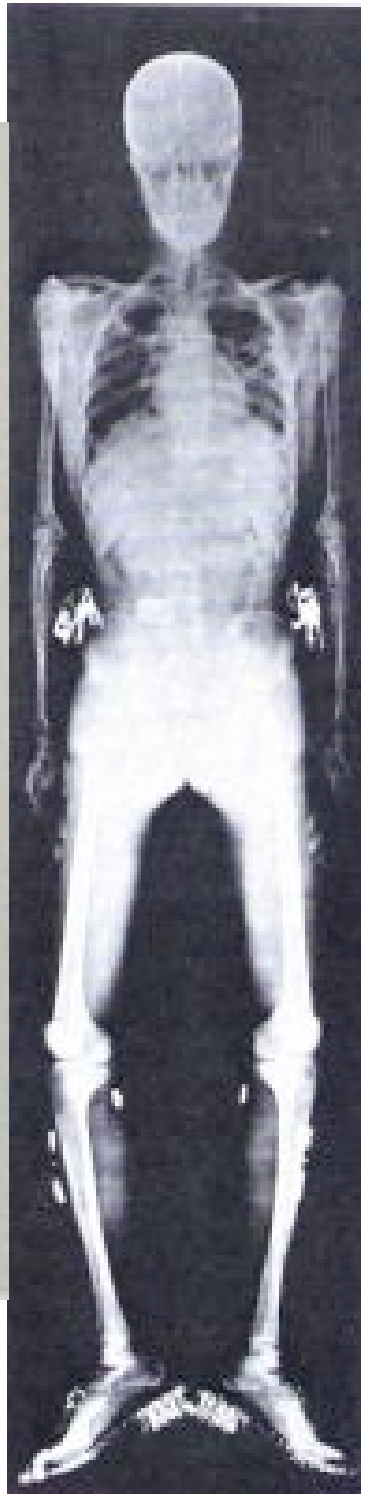
Dipartimento di Astronomia

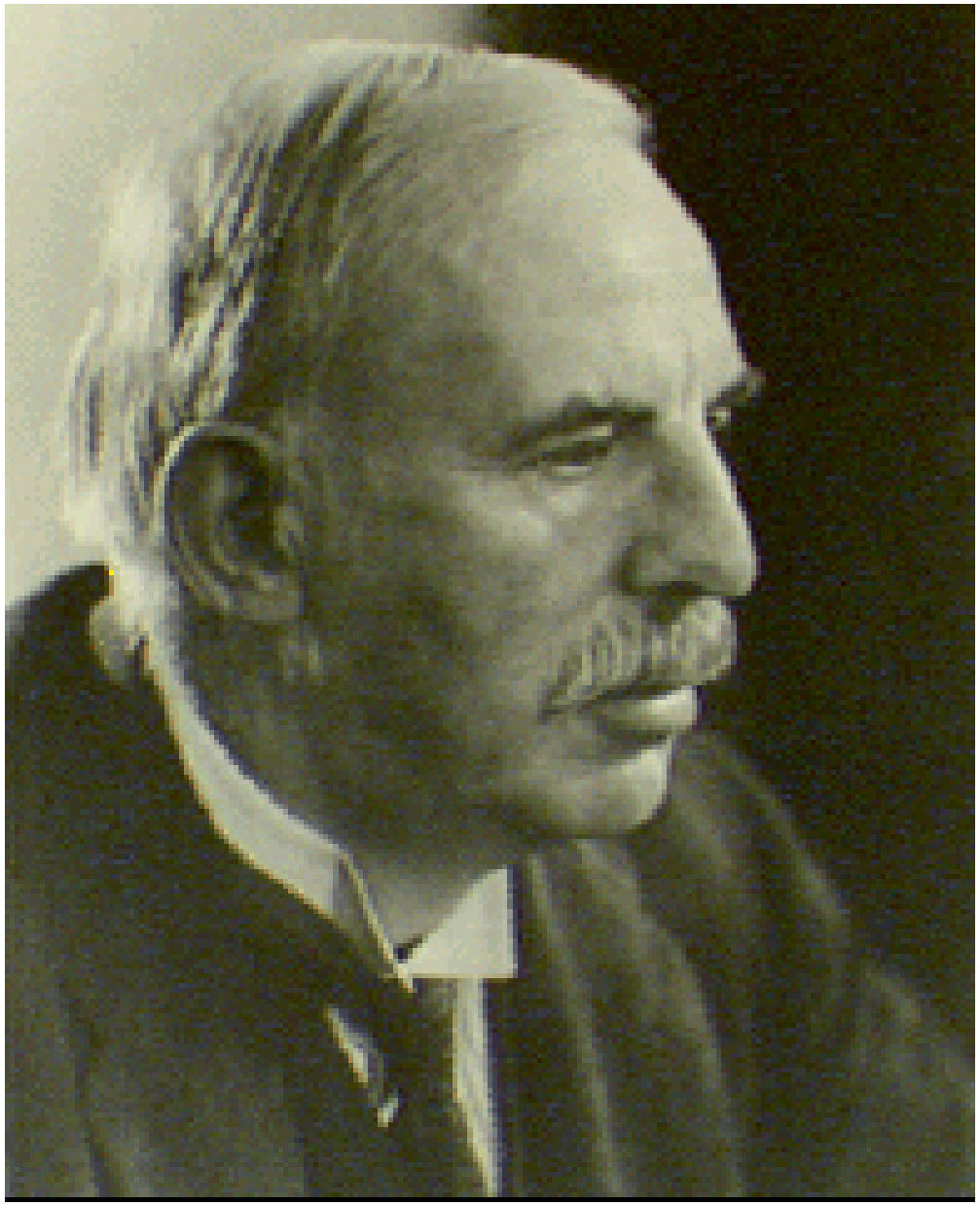
Wilhelm Konrad

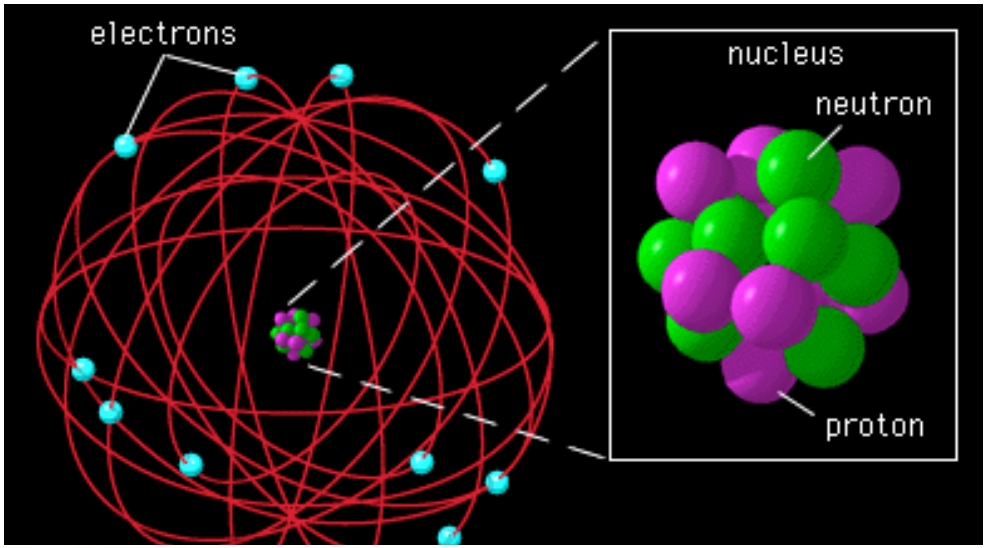
Roentgen 1845-1923

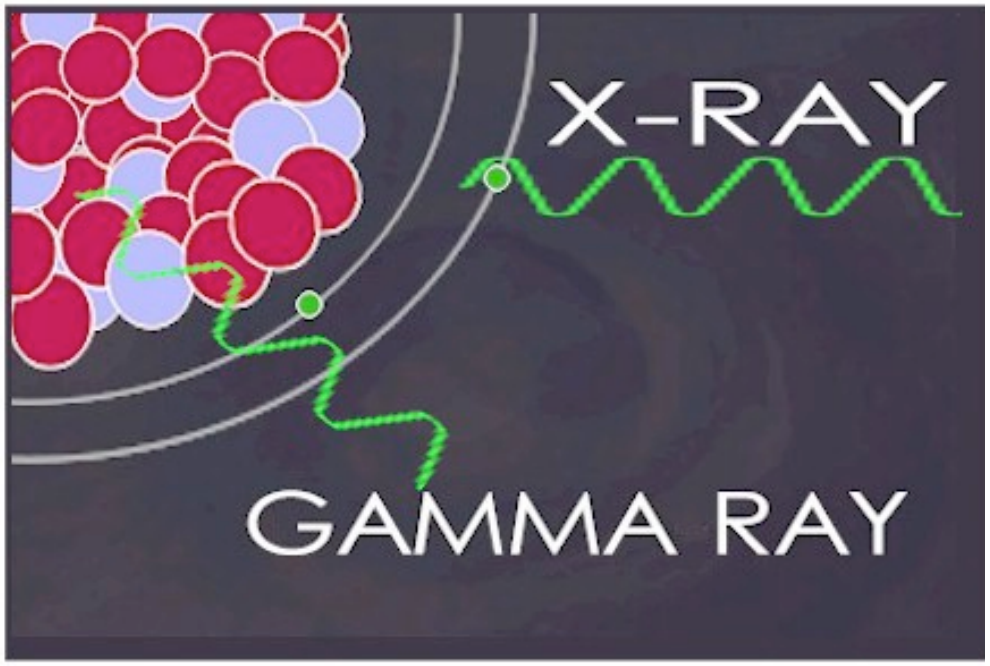
Physics Nobel Price (1901) for the discovery of X-Rays



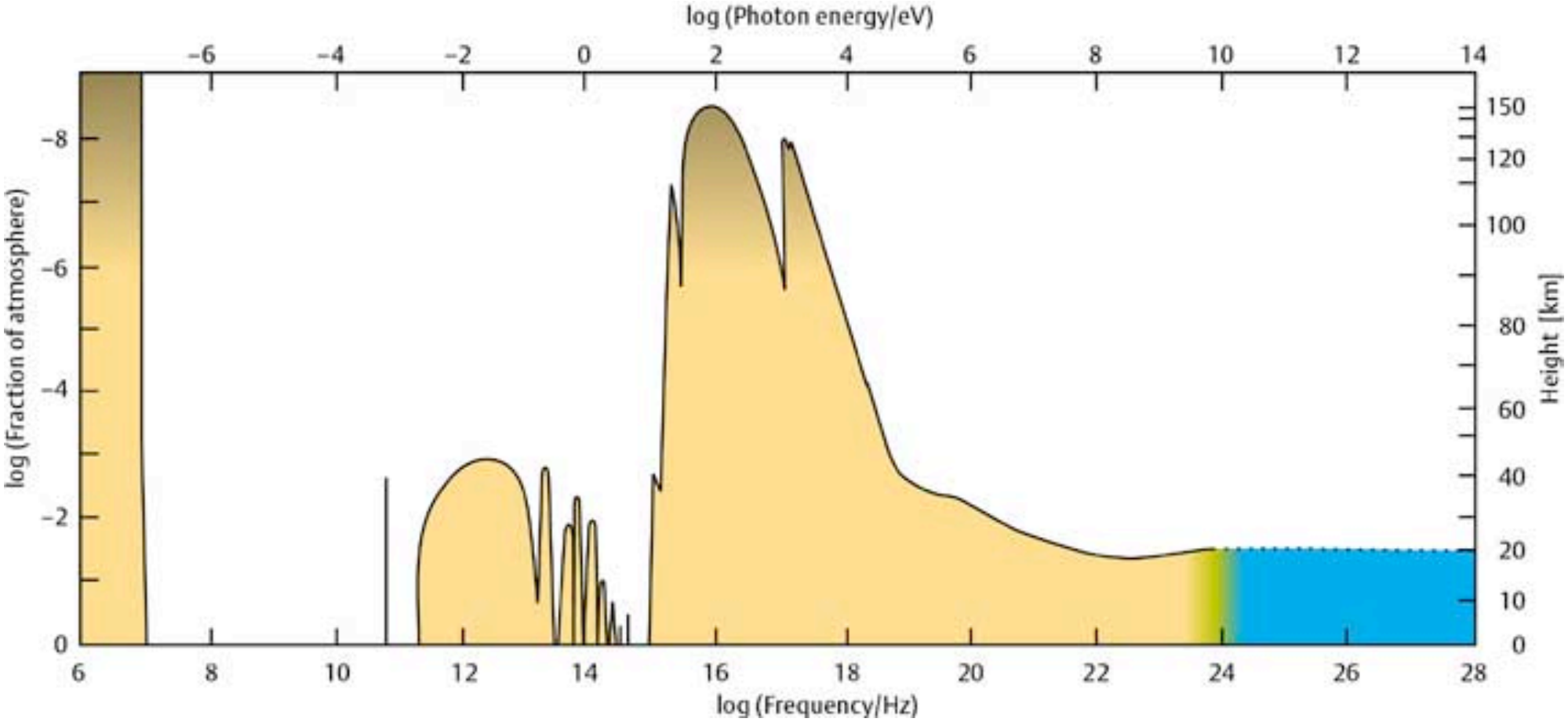




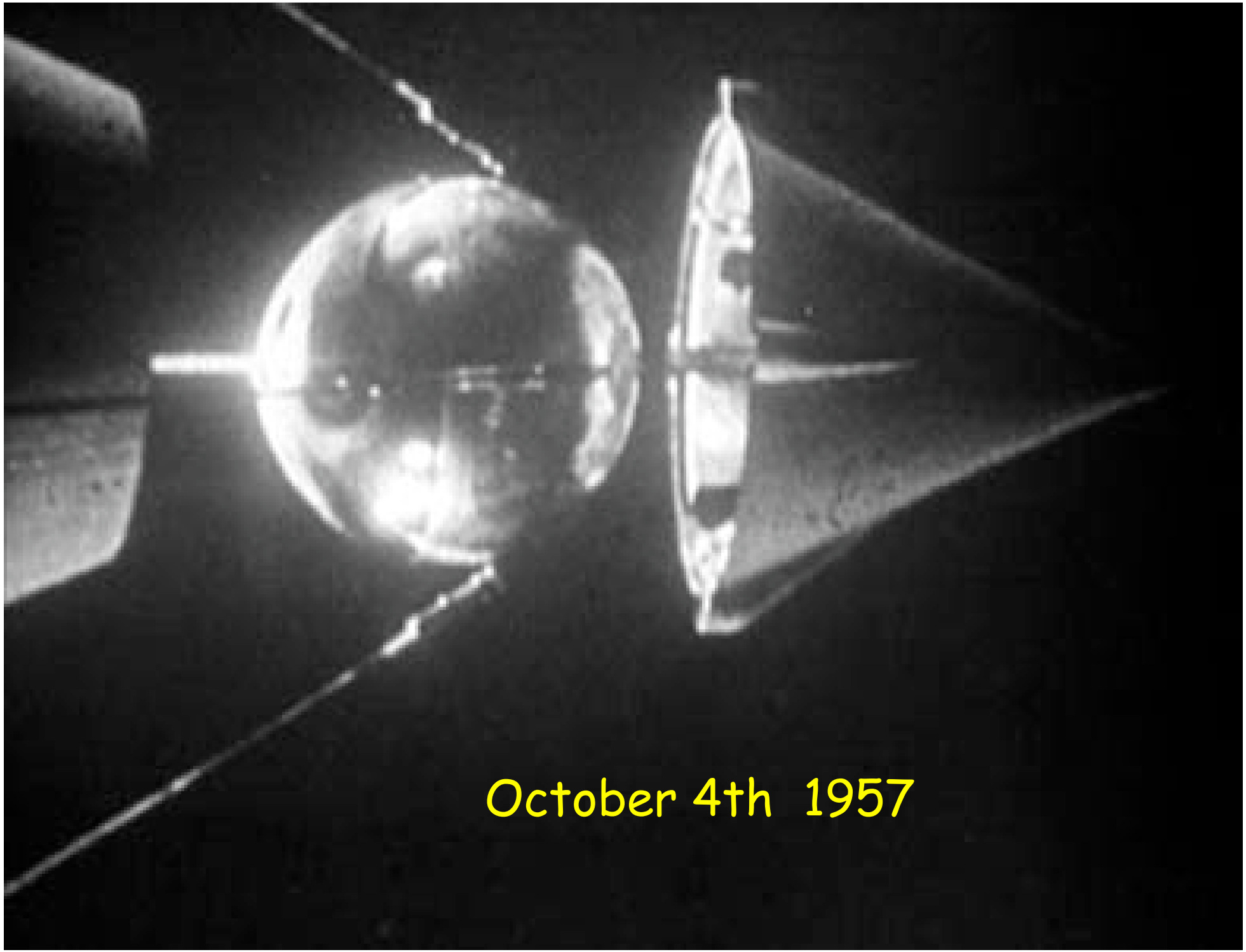




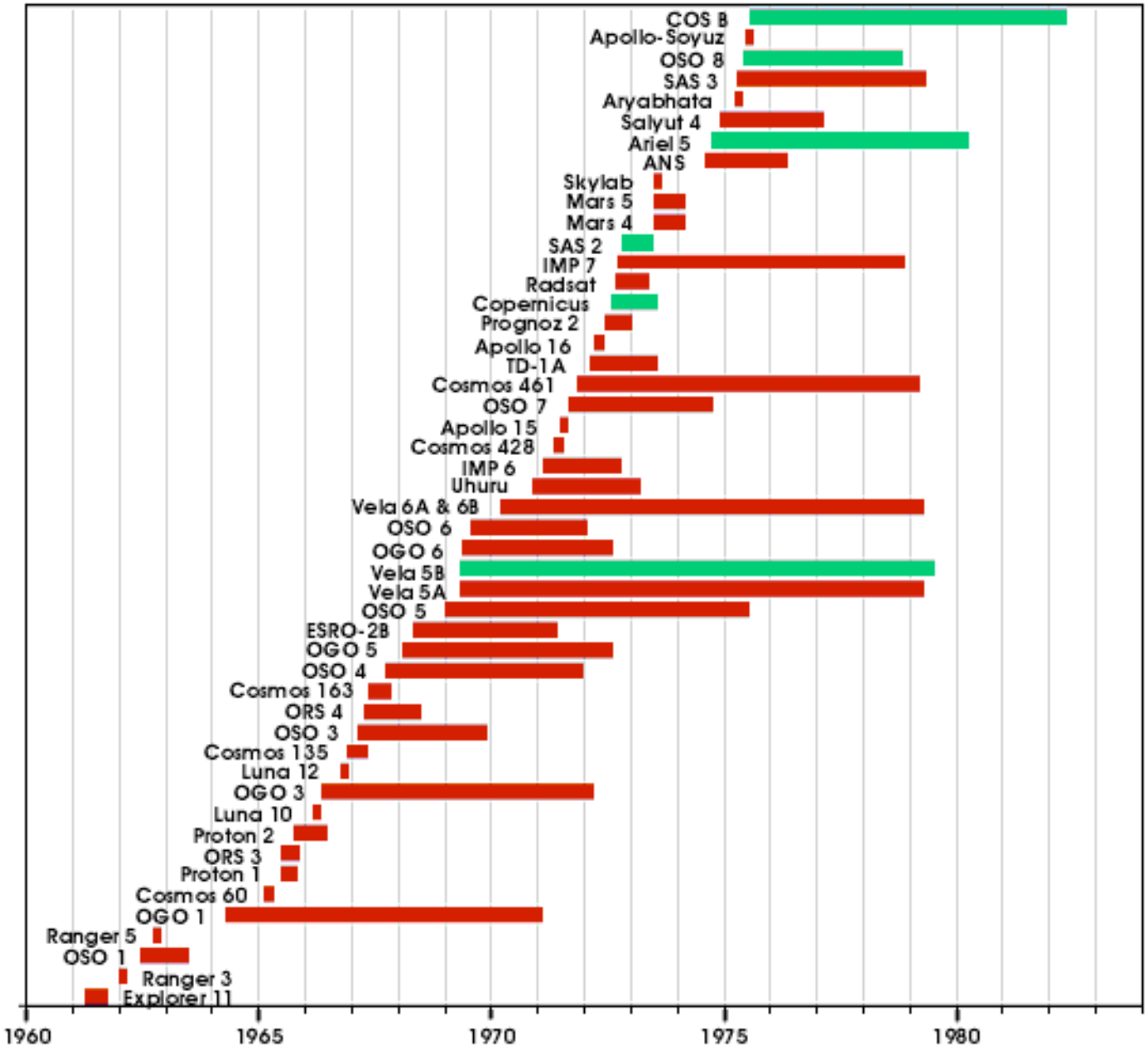
Lord Rutherford 1911, discovery of Gamma Rays



Athmospheric transparency to electromagnetic radiation

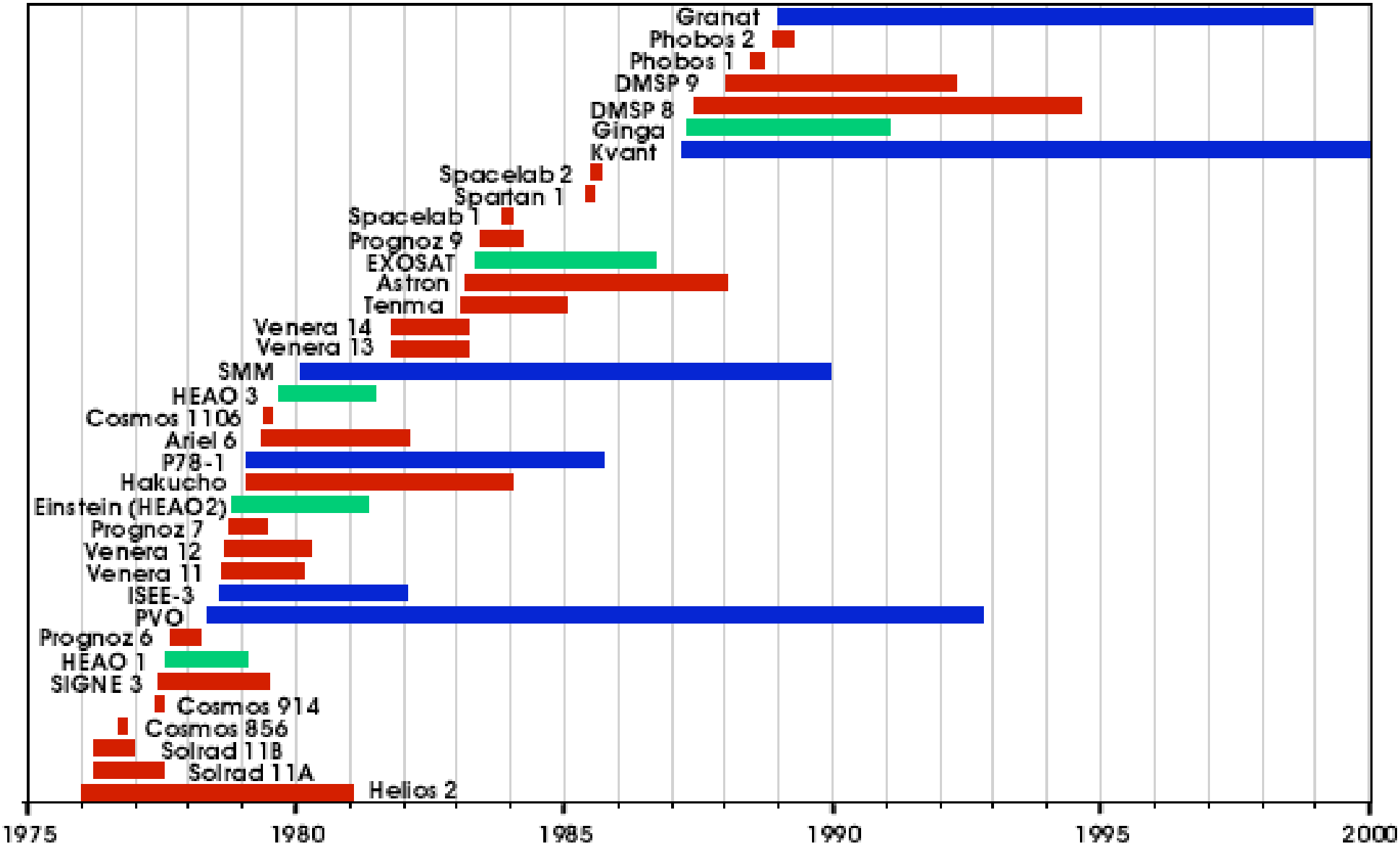

October 4th 1957

High Energy Astrophysics: the early days



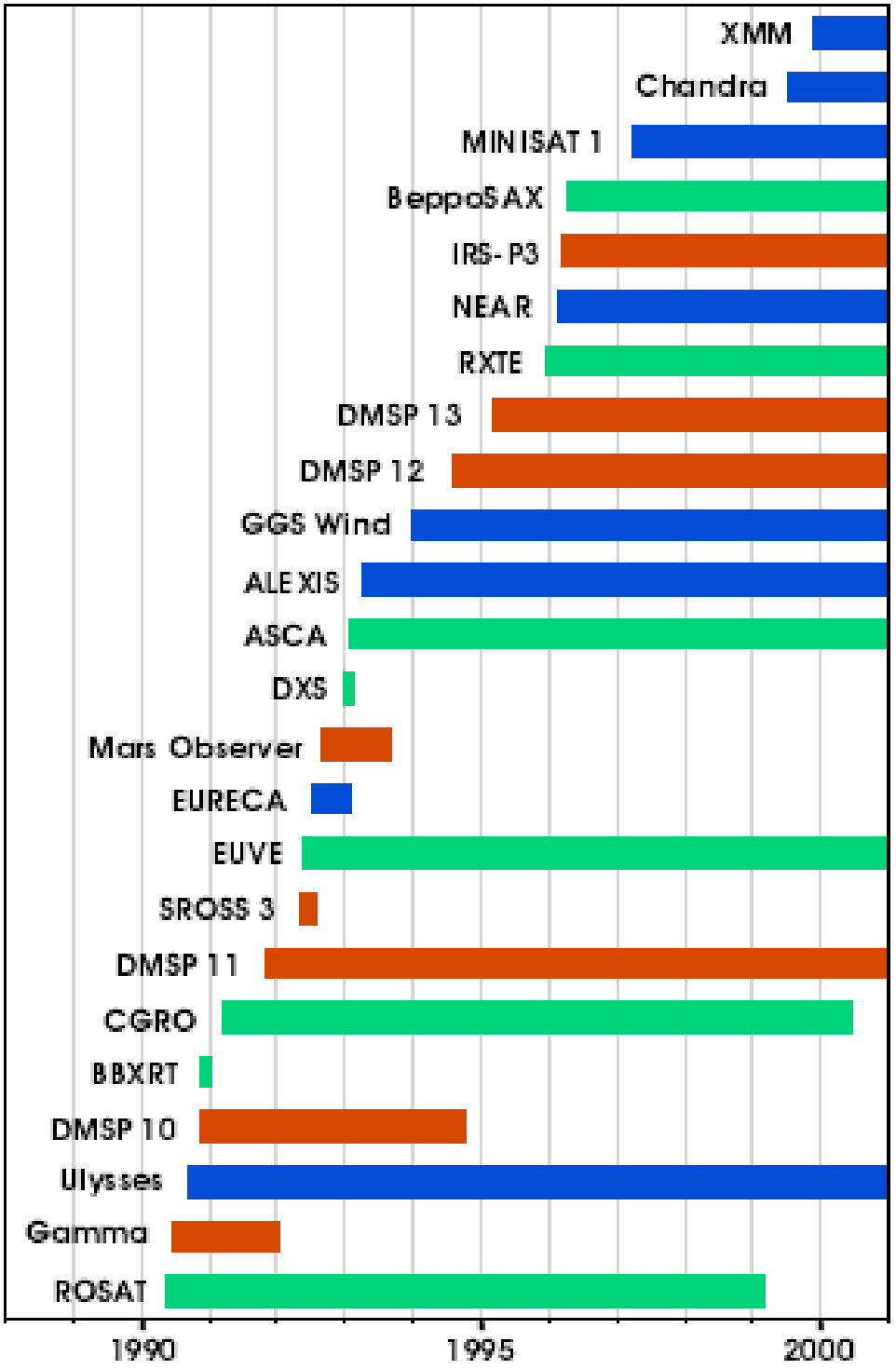
High Energy Astrophysics:

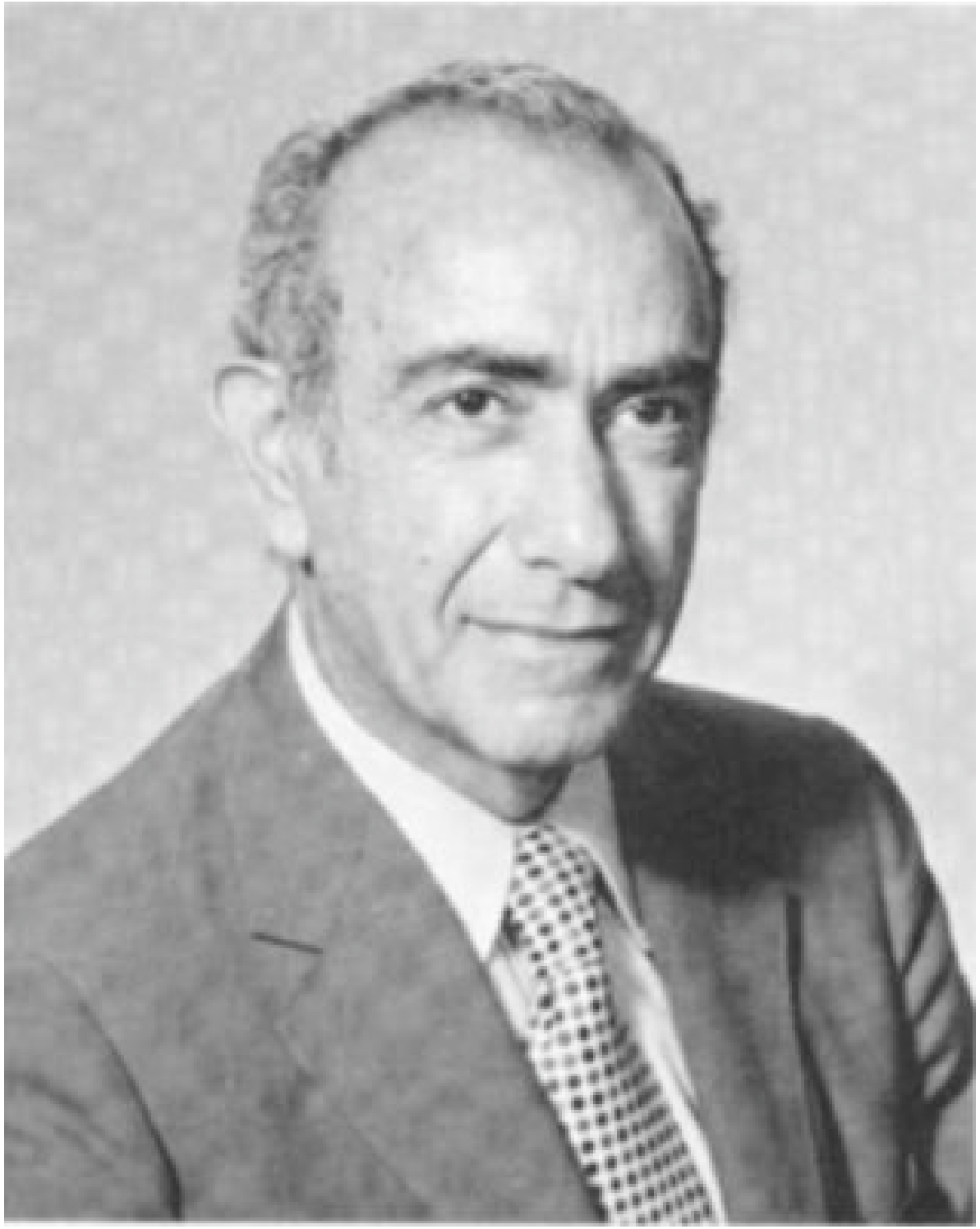
the days of maturity



High Energy Astrophysics:

the golden days

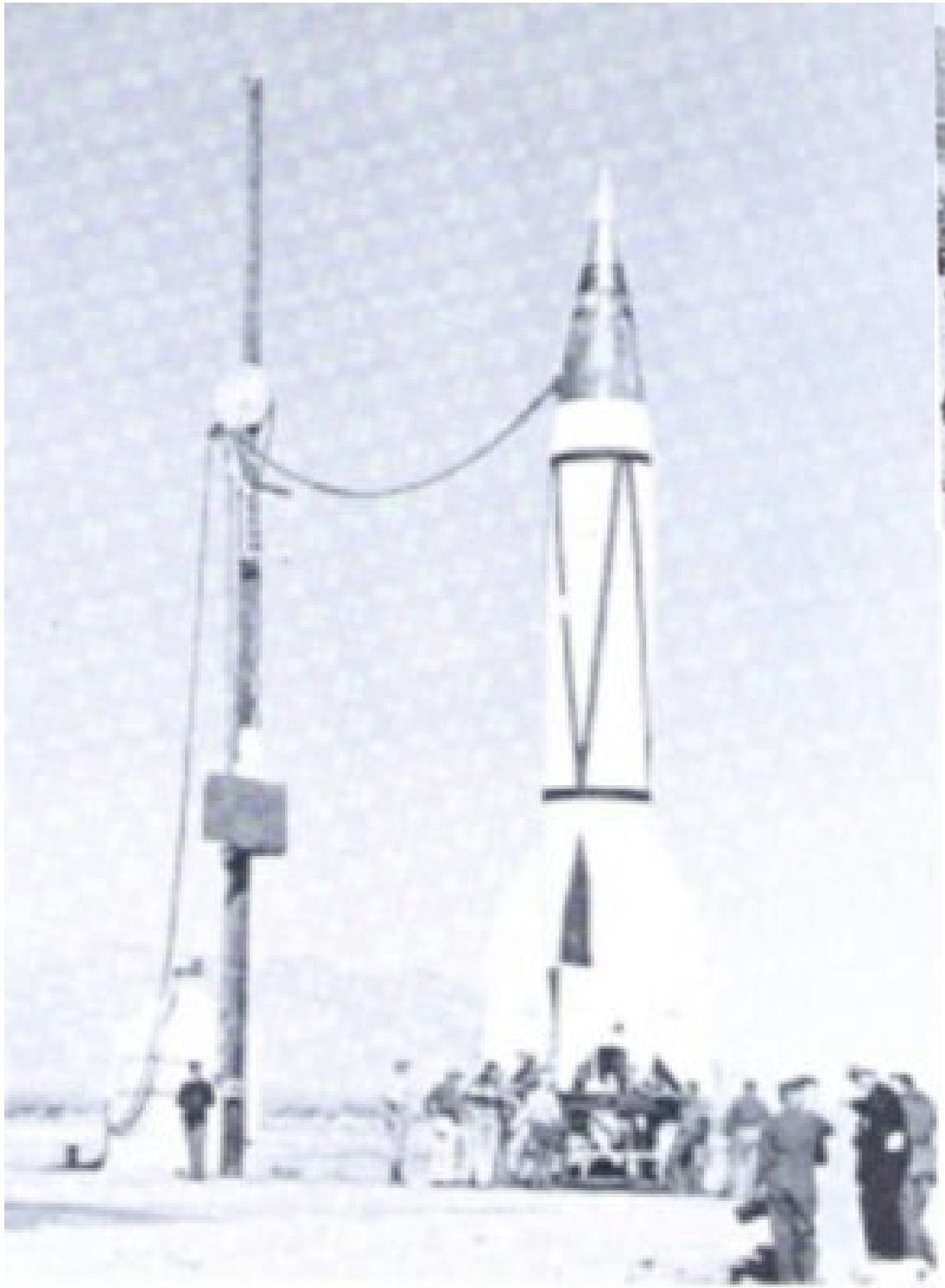




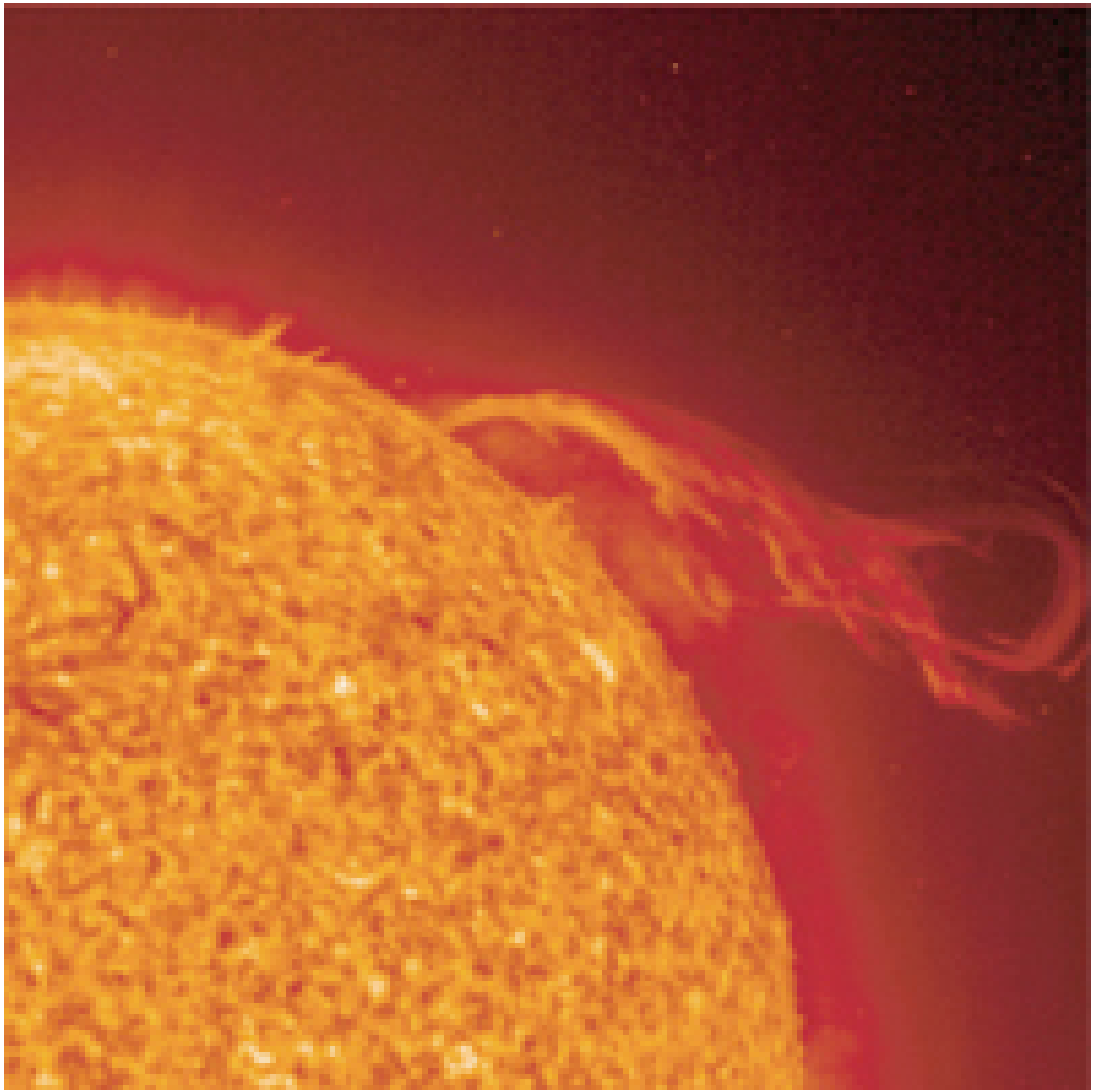
Herbert Friedman

(1916-2000)

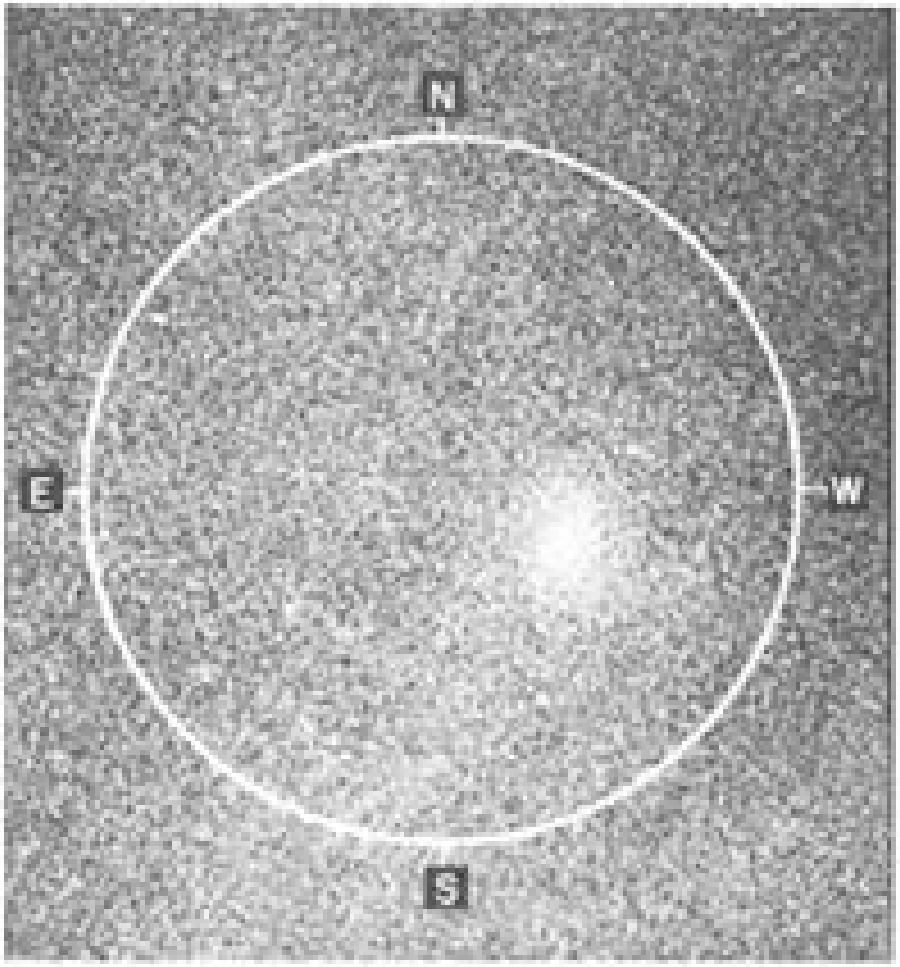
NRL



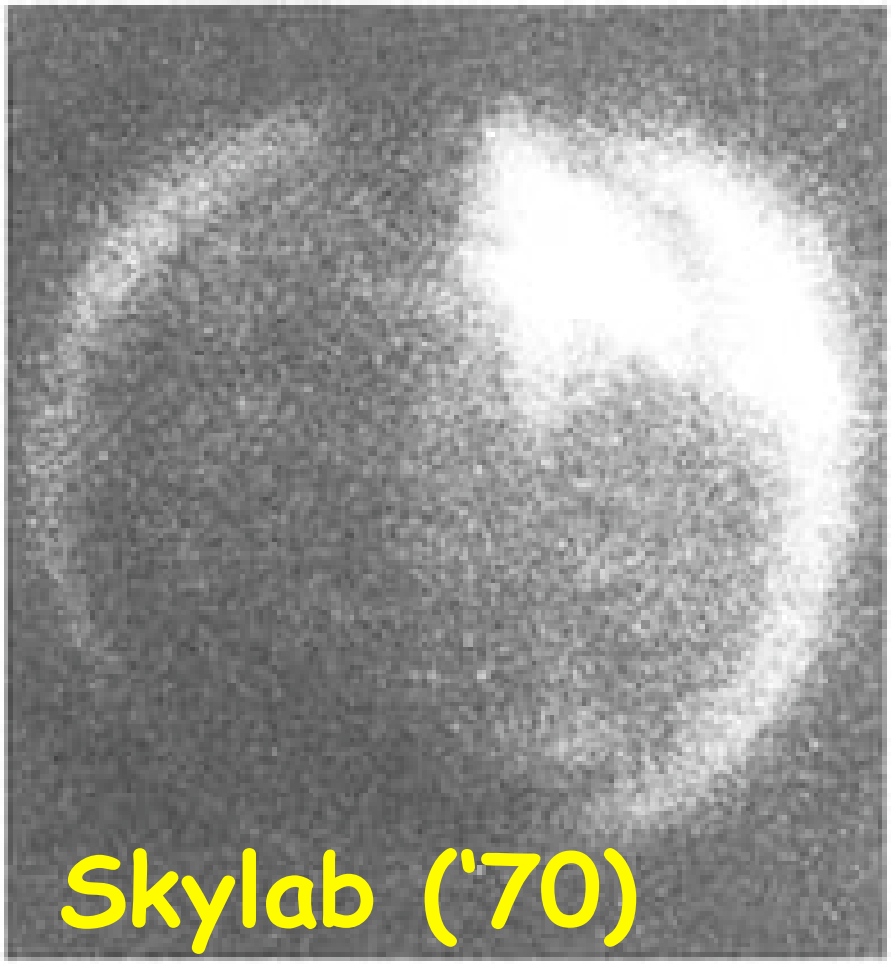
V2 (1947)



SOLAR X-RAY PHOTOGRAPH
NRL, APRIL 19, 1960



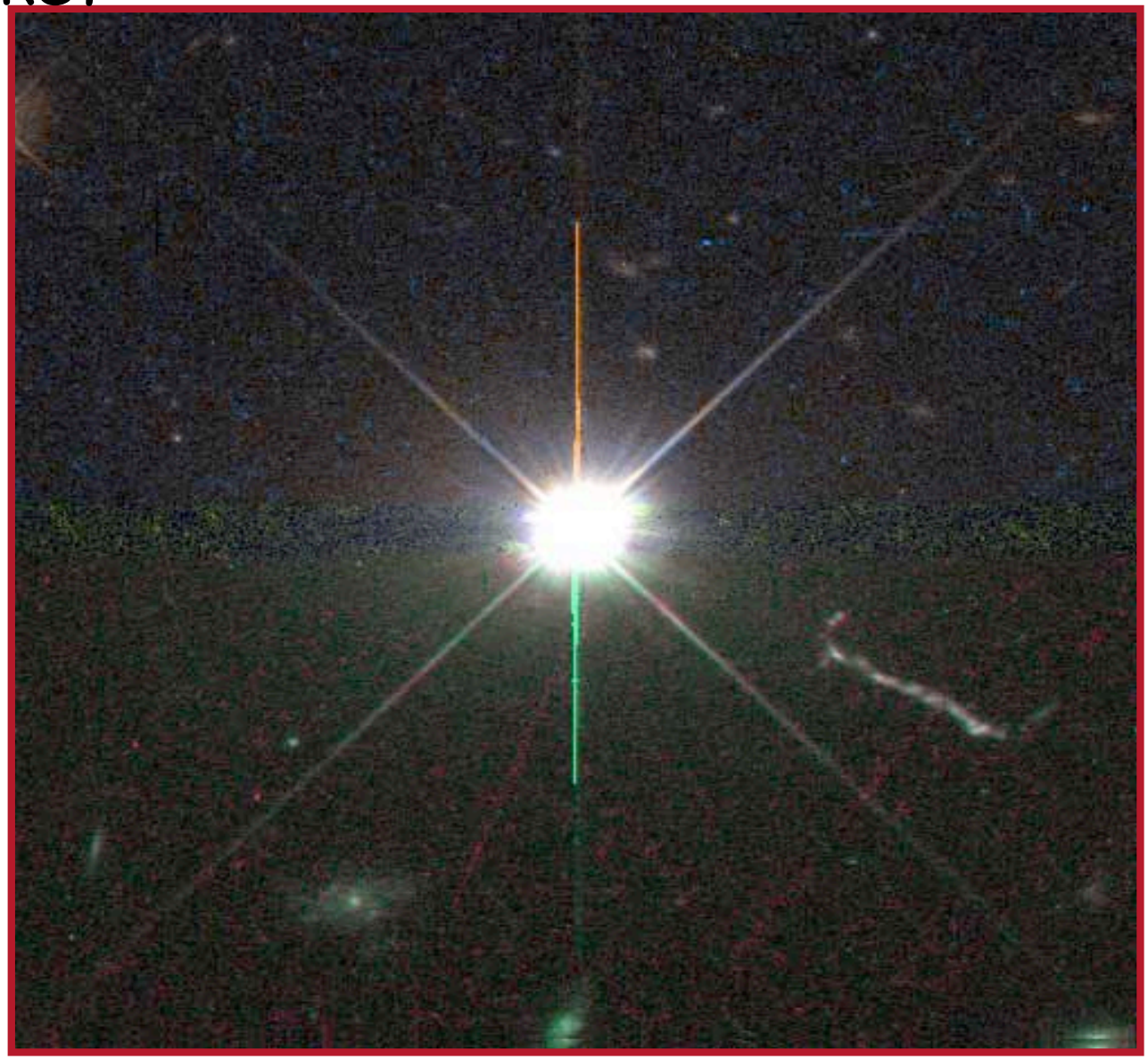
3



4

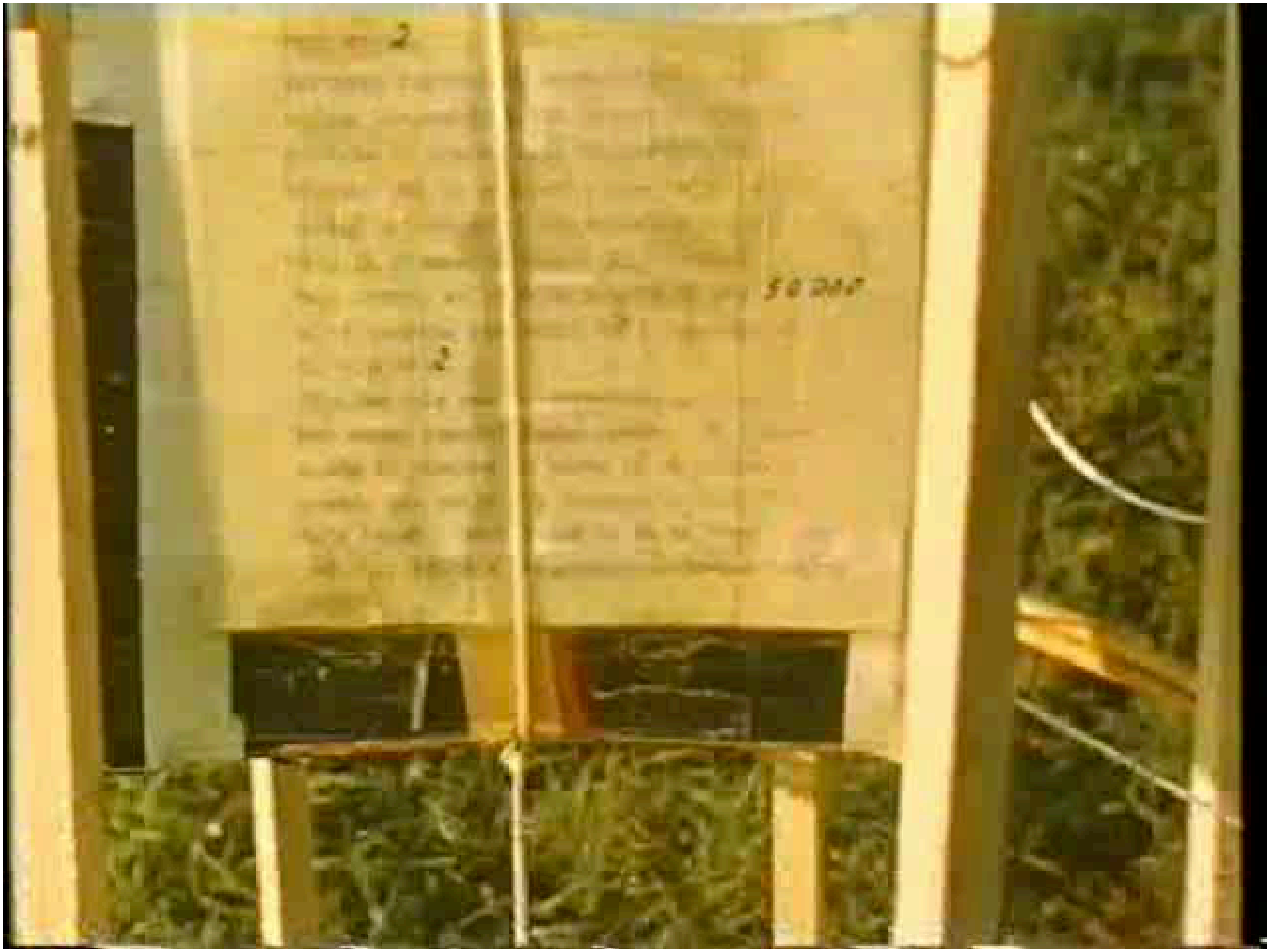
Pacific Ocean (1950)
Aerobee rockets ready
for launch

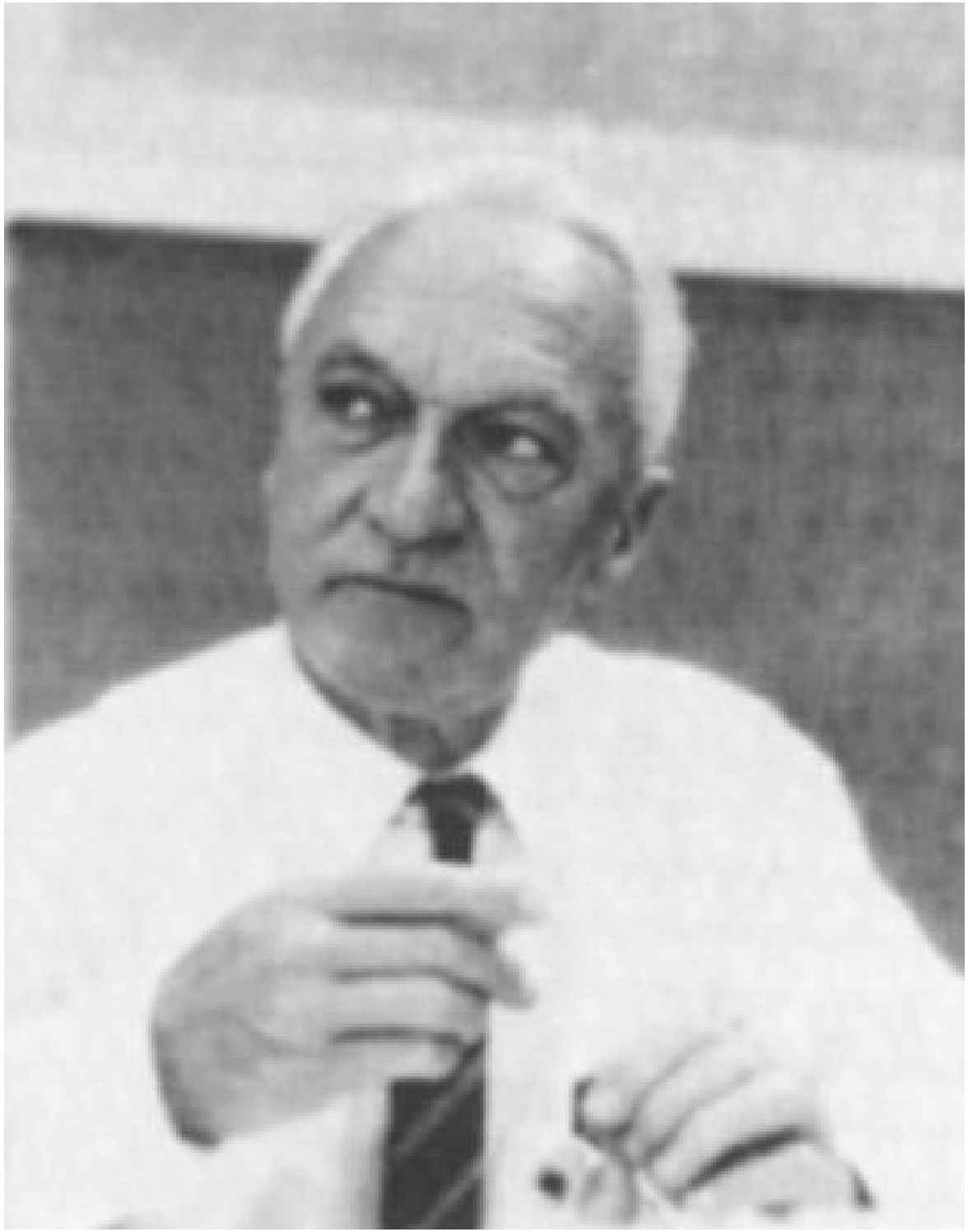
NRL scientists detect, for the first time, X-Rays from 3C273 with a detector on board an Aerobee rocket



May 17 1967

From early '50s to late '70 experiments on balloons. From local to across the Ocean flights





Bruno Rossi

Born in Venice

(1905-1993)

Ph.D. in Bologna

Leaves for U.S.A. because of racial laws

Manhattan Projet

prof. at MIT

Riccardo Giacconi

(Genova 1931)

Ph.D. in Milano (1954) supervisor

Giuseppe (Beppo) Occhialini

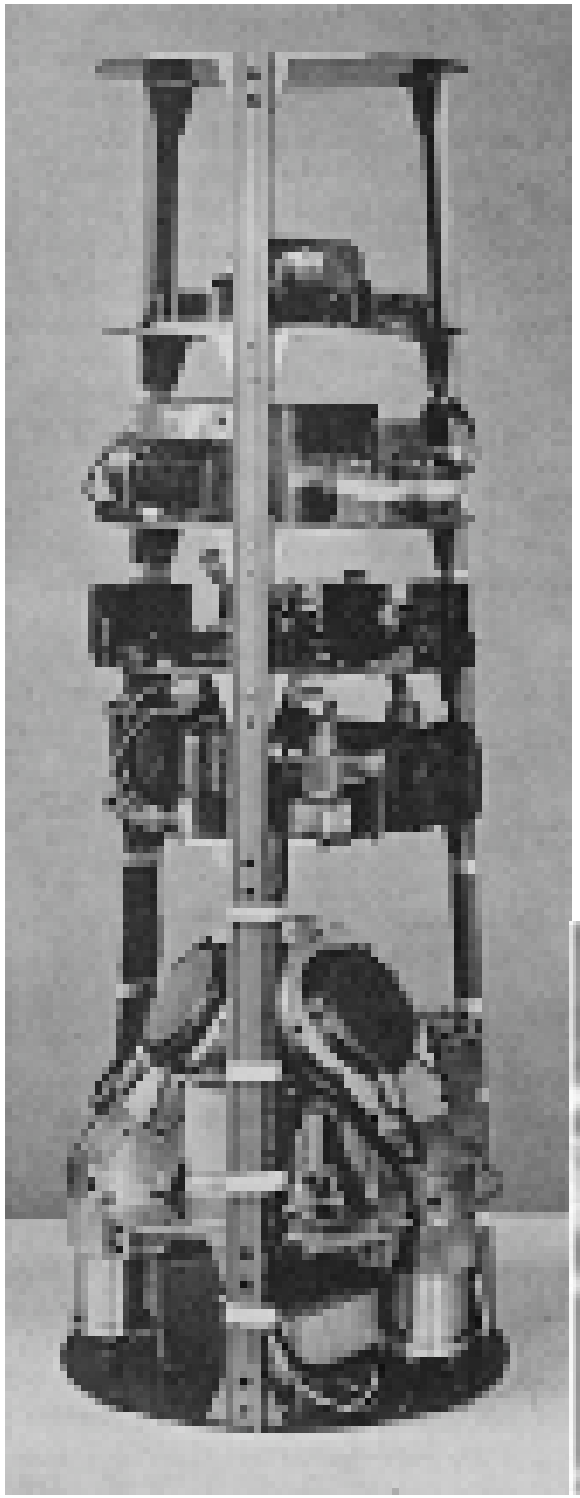
Riccardo Giacconi & Herb Gursky in Princeton

Experiment motivations

Sun	10^{6} cm^{-2} s^{-1}
Sun at 8 l.y.	$2{,}5\ 10^{-4}$ cm^{-2} s^{-1}
Sirius assuming $L_X = L_{opt}$	0,25 cm^{-2} s^{-1}
Flare stars, Peculiar A stars, Crab Nebula	?
Fluorescence from Moon	0,4 cm^{-2} s^{-1}
Solar wind reflected by the Moon	(0 - 1,6) 10^{3} cm^{-2} s^{-1}

==========

Sco X-1	28 +/- 1.2 cm^{-2} s^{-1}

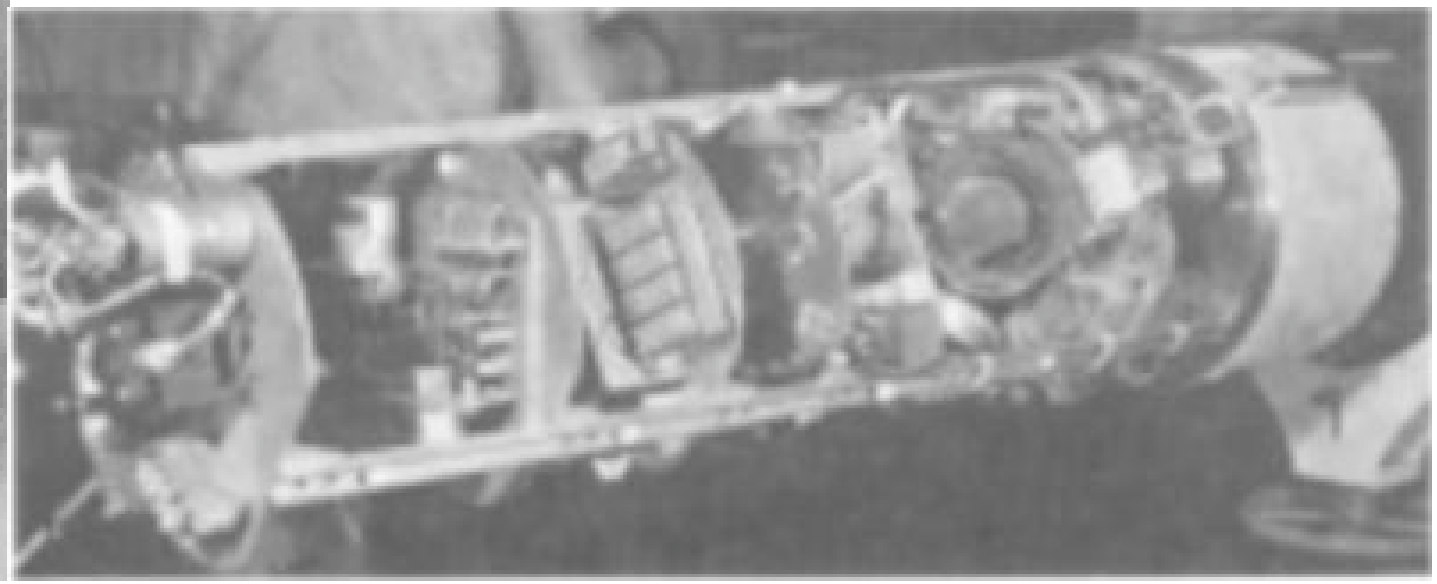


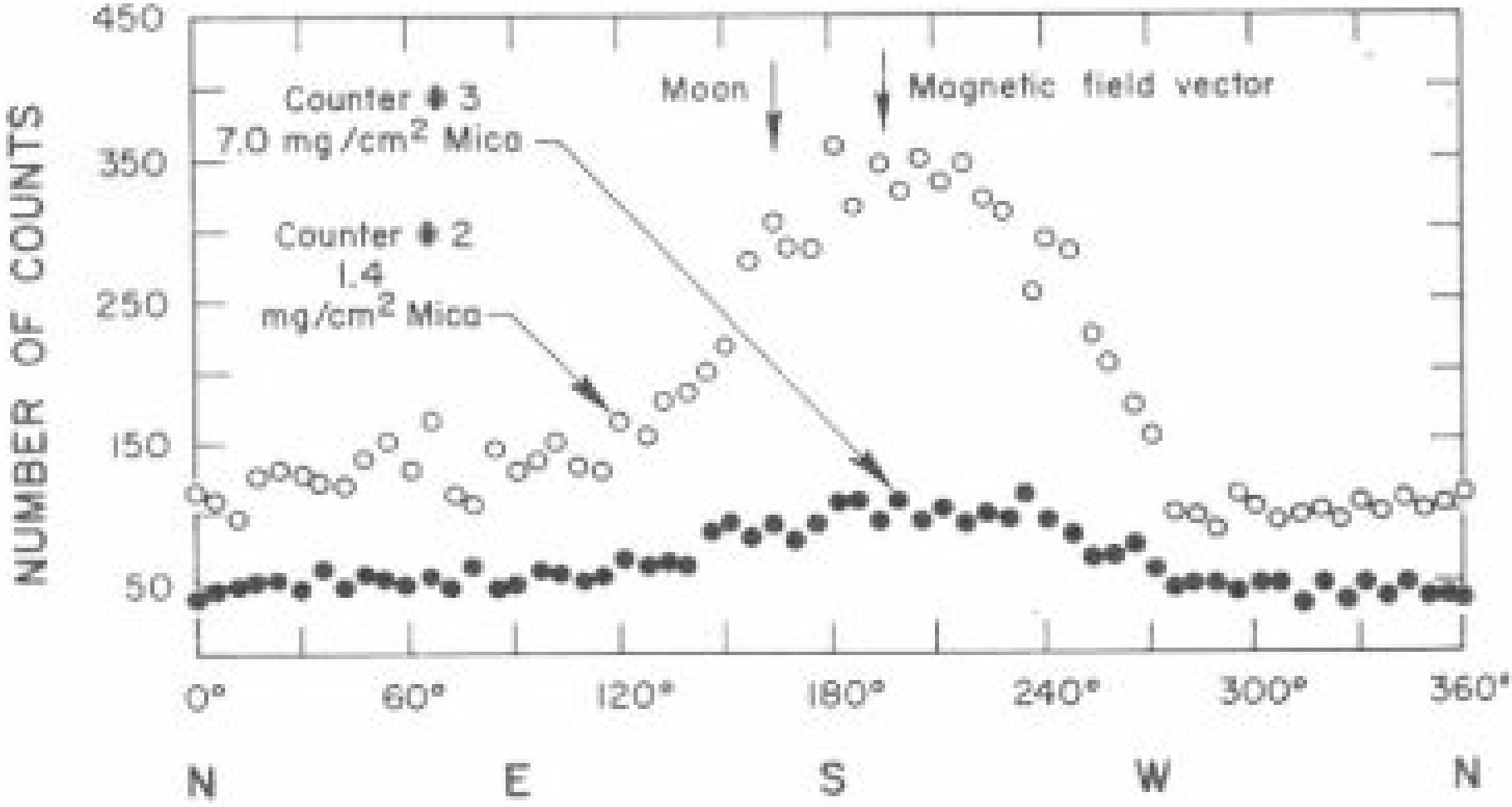
Geiger Counters

1962 Launch

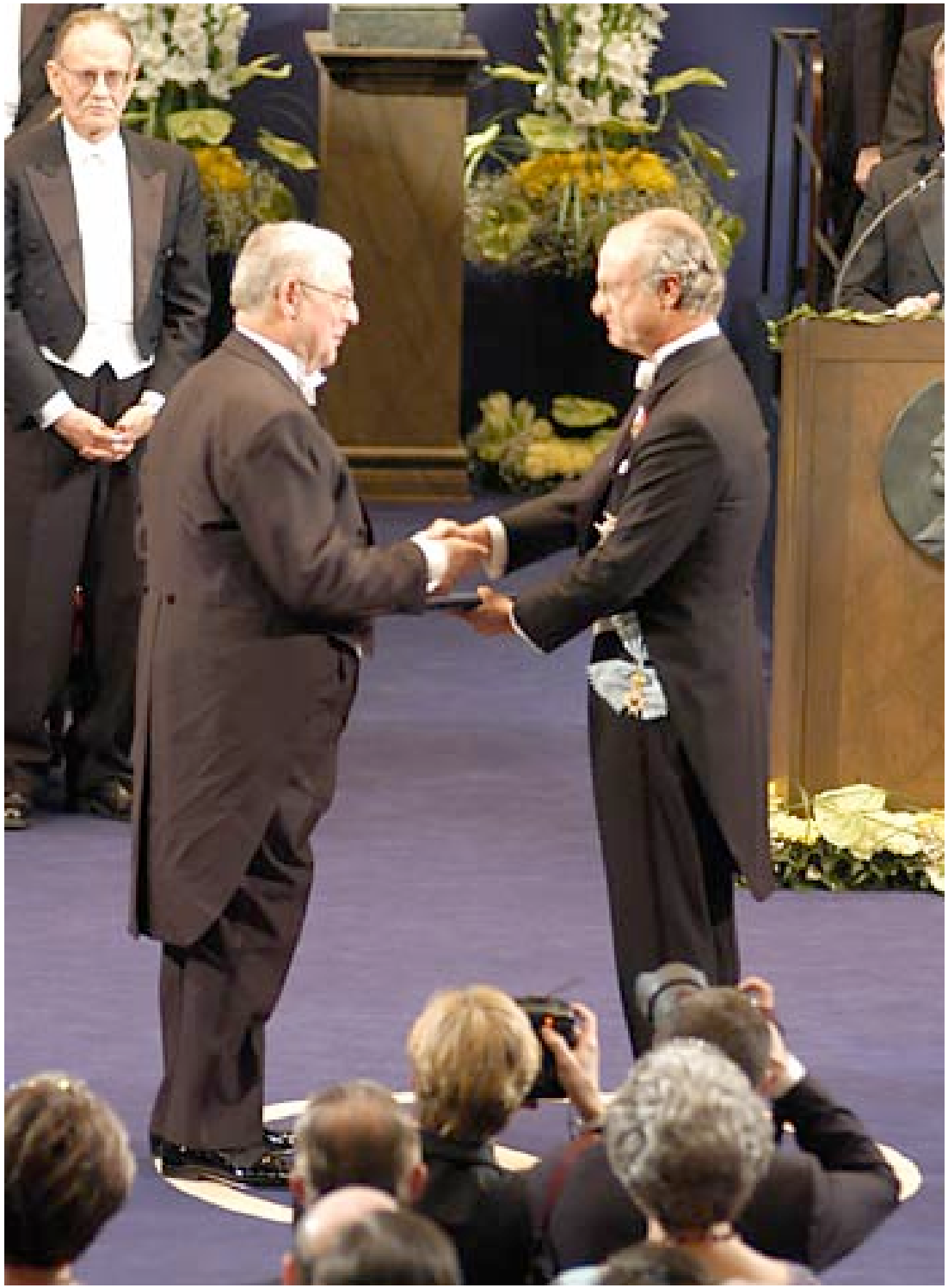
Giacconi, Gursky, Paolini

& Rossi (MIT)





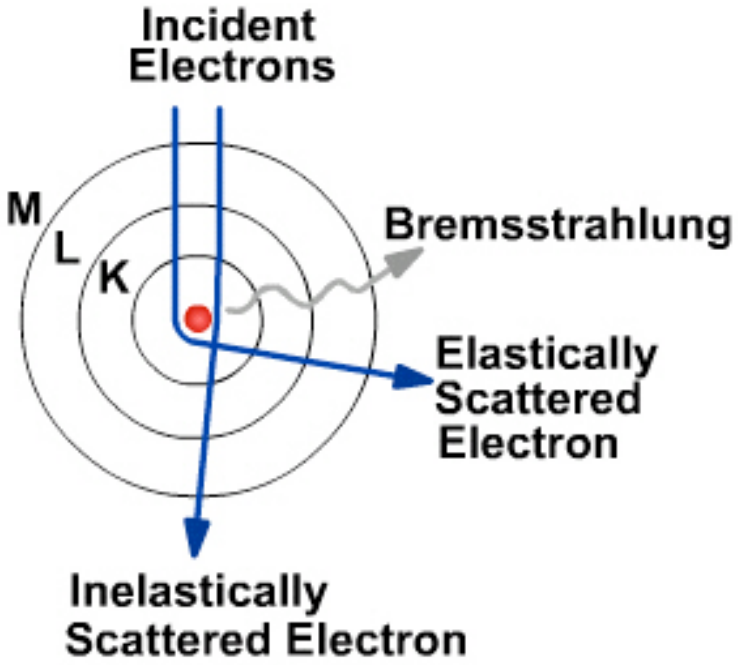
Azimuthal distributions of recorded counts from Geiger counters flown during June, 1962. (R. Giacconi et al., *Physical Review Letters* 9 (1962), 439)

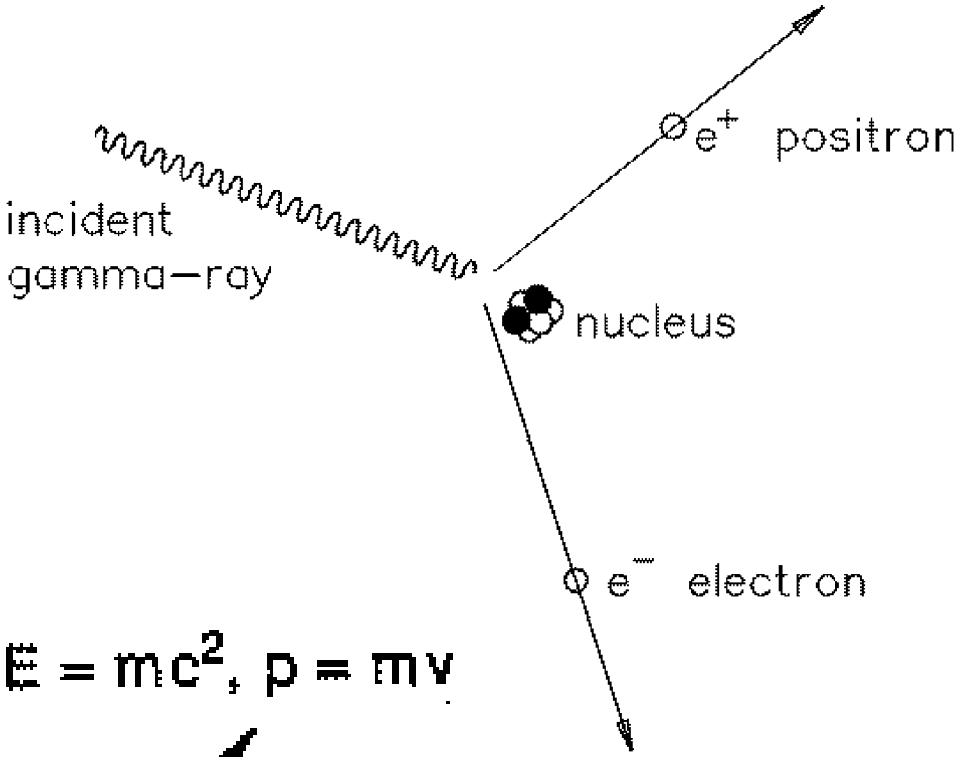


Nobel Price to
Riccardo Giacconi

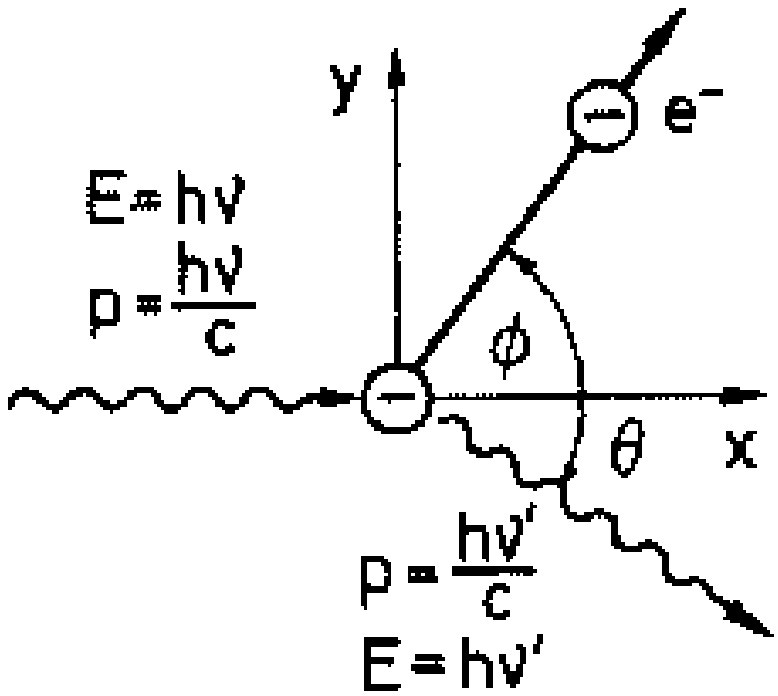
2002

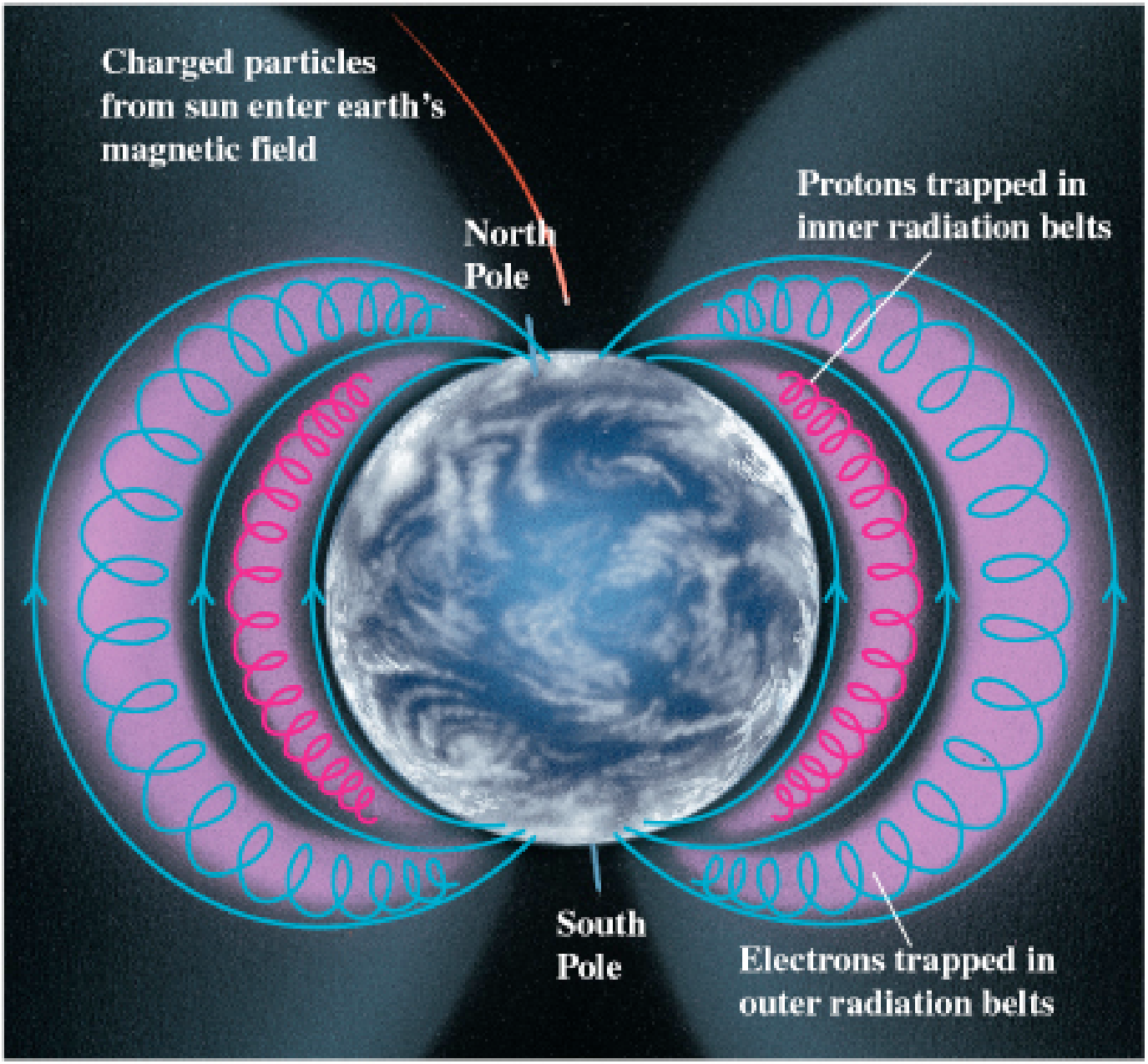
Early '60s Rockets from White Sands desert New Mexico


Incident
Electrons
M
L
K
Bremsstrahlung
Elastically
Scattered
Electron
Inelastically
Scattered Electron

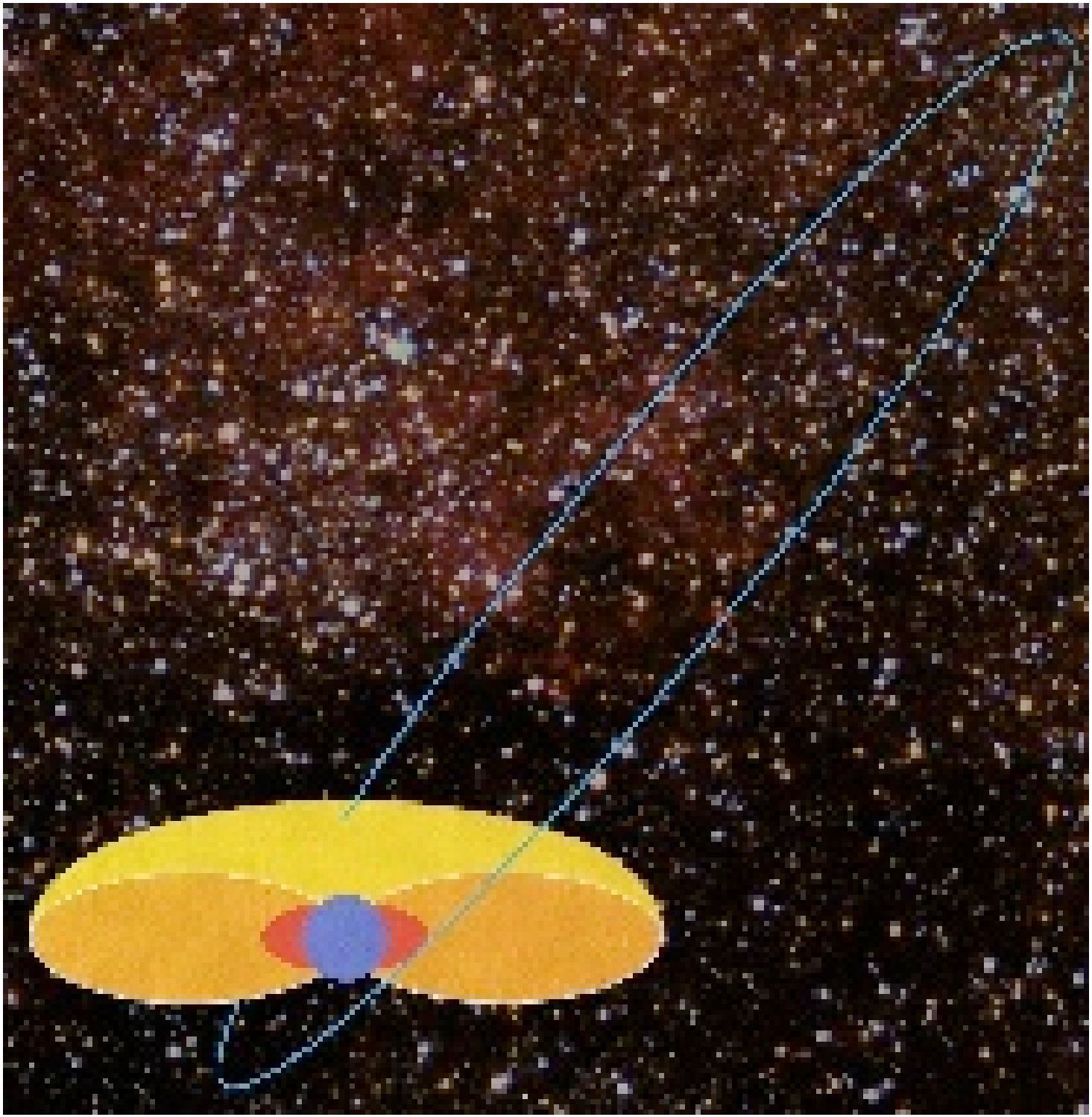

incident
gamma–ray
e+ positron
nucleus
e− electron

$E = mc^2,\ p = mv$


y
e⁻
E = hν
p = hν/c
φ
θ
x
p = hν'/c
E = hν'

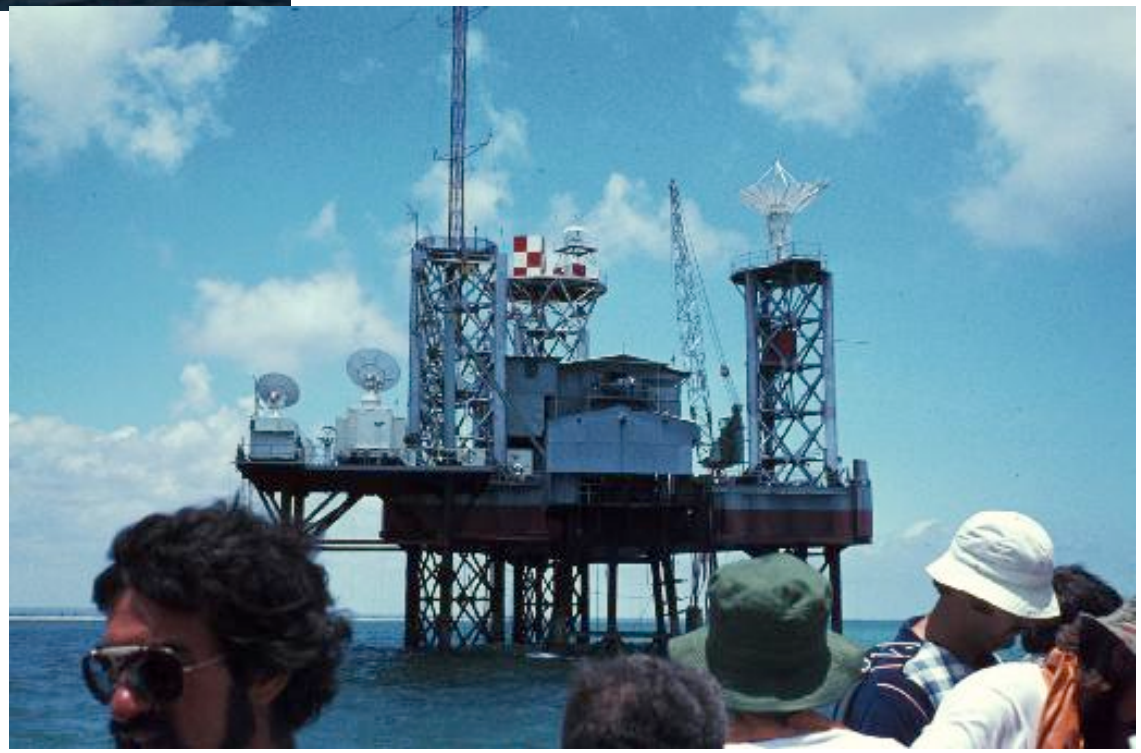


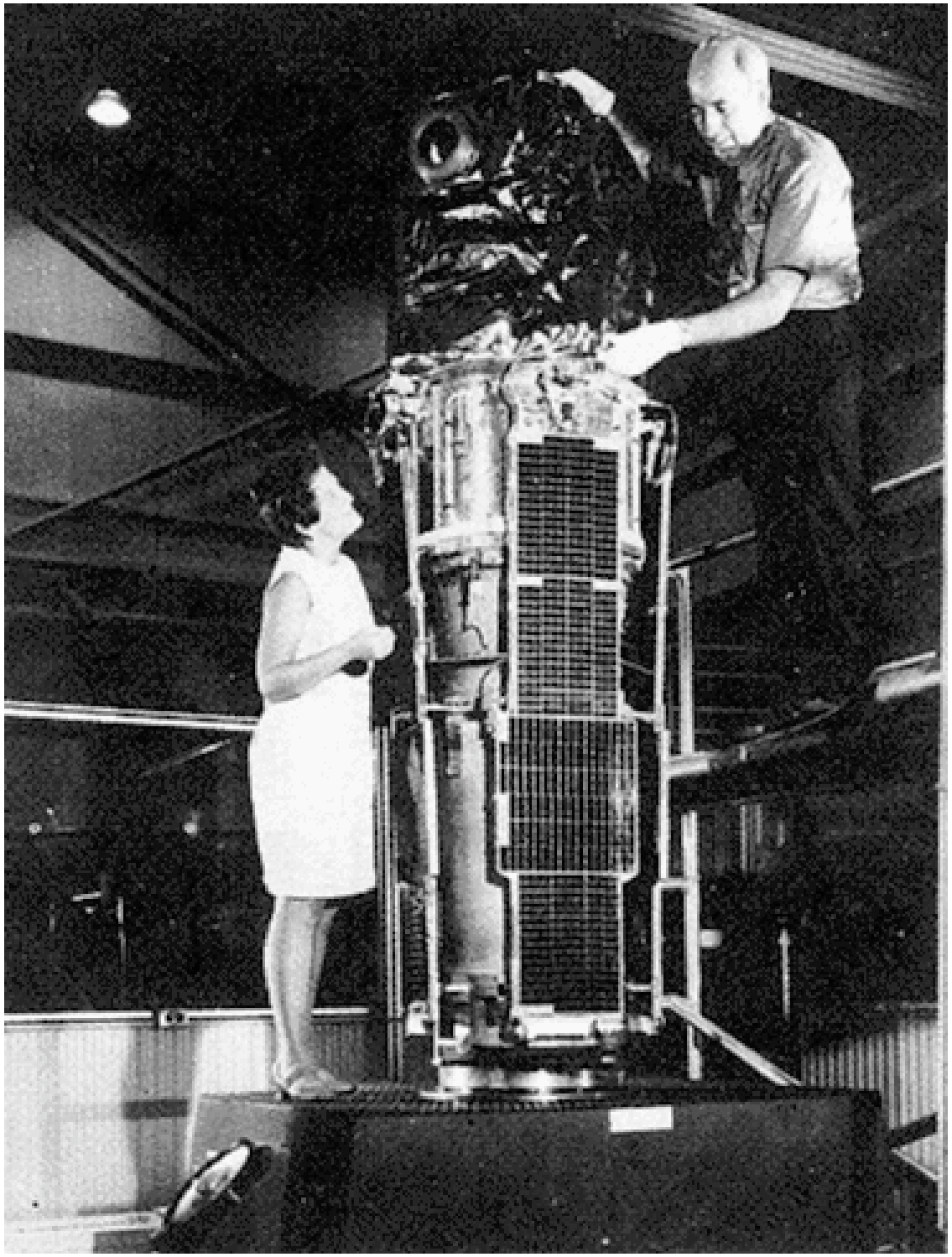
(a)



The Italian platform
San Marco in Kenya

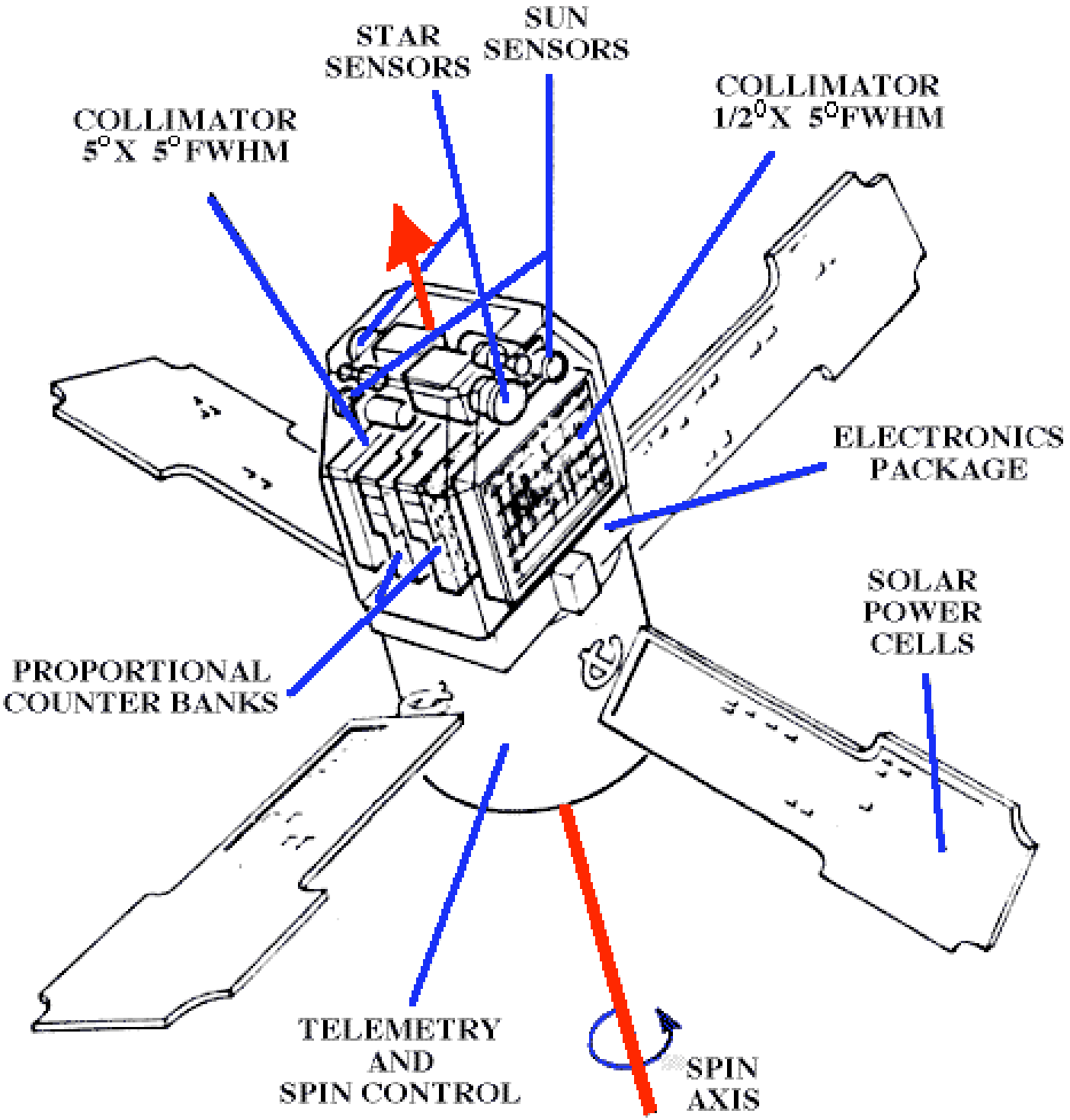
The Santa Rita
platform





Professor Bruno Rossi with assistant working on the OSO-1 UHURU payload [2 – 20 keV]

0.084 m^2 10^{-3} Crab


STAR SENSORS
SUN SENSORS
COLLIMATOR 5° X 5° FWHM
COLLIMATOR 1/2° X 5° FWHM
ELECTRONICS PACKAGE
SOLAR POWER CELLS
PROPORTIONAL COUNTER BANKS
TELEMETRY AND SPIN CONTROL
SPIN AXIS

Small Astronomical Satellite 1 (SAS-1)

UHURU

Lifetime : 12 Dec 1970 - March 1973

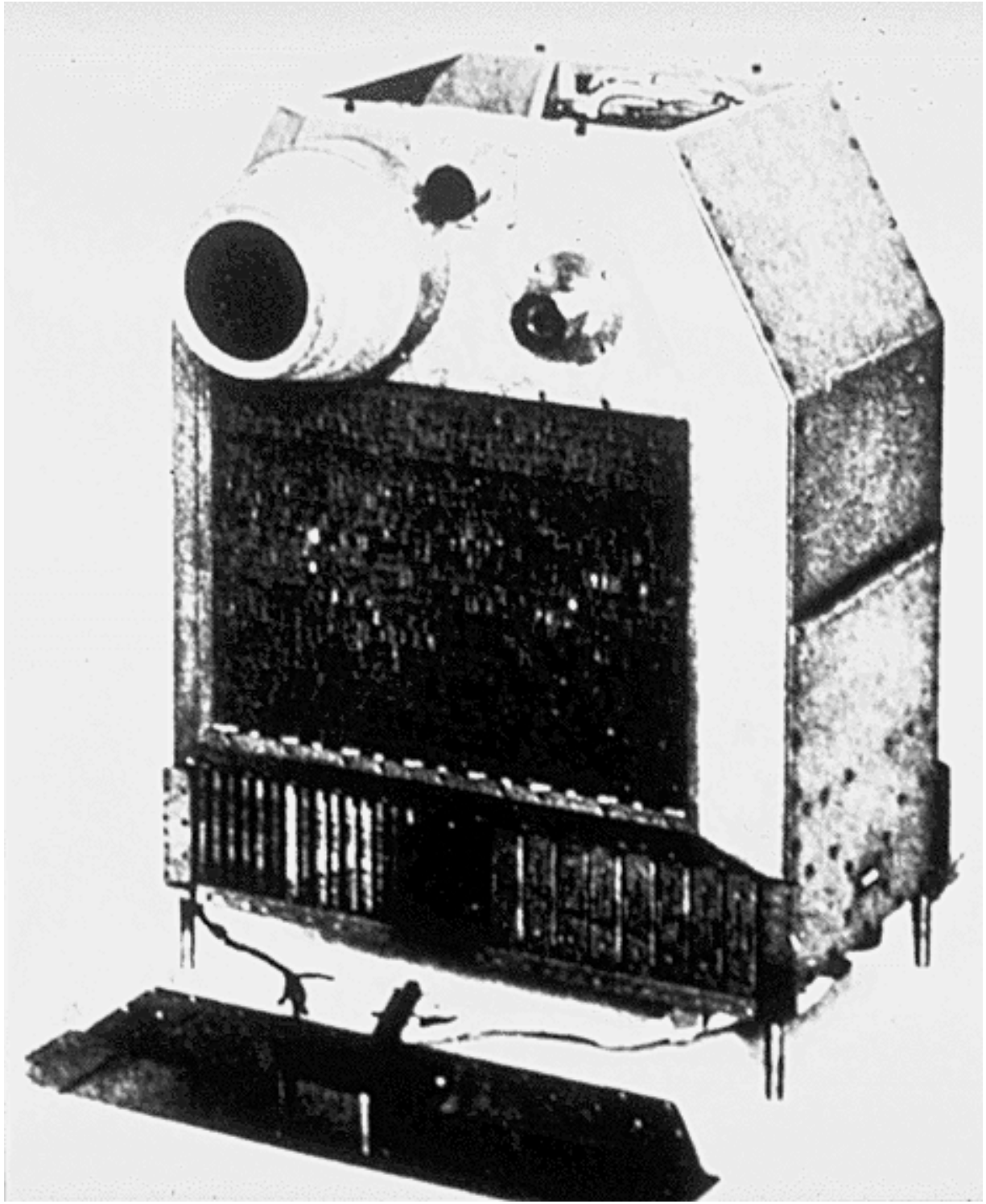
Energy Range : 2-20 keV

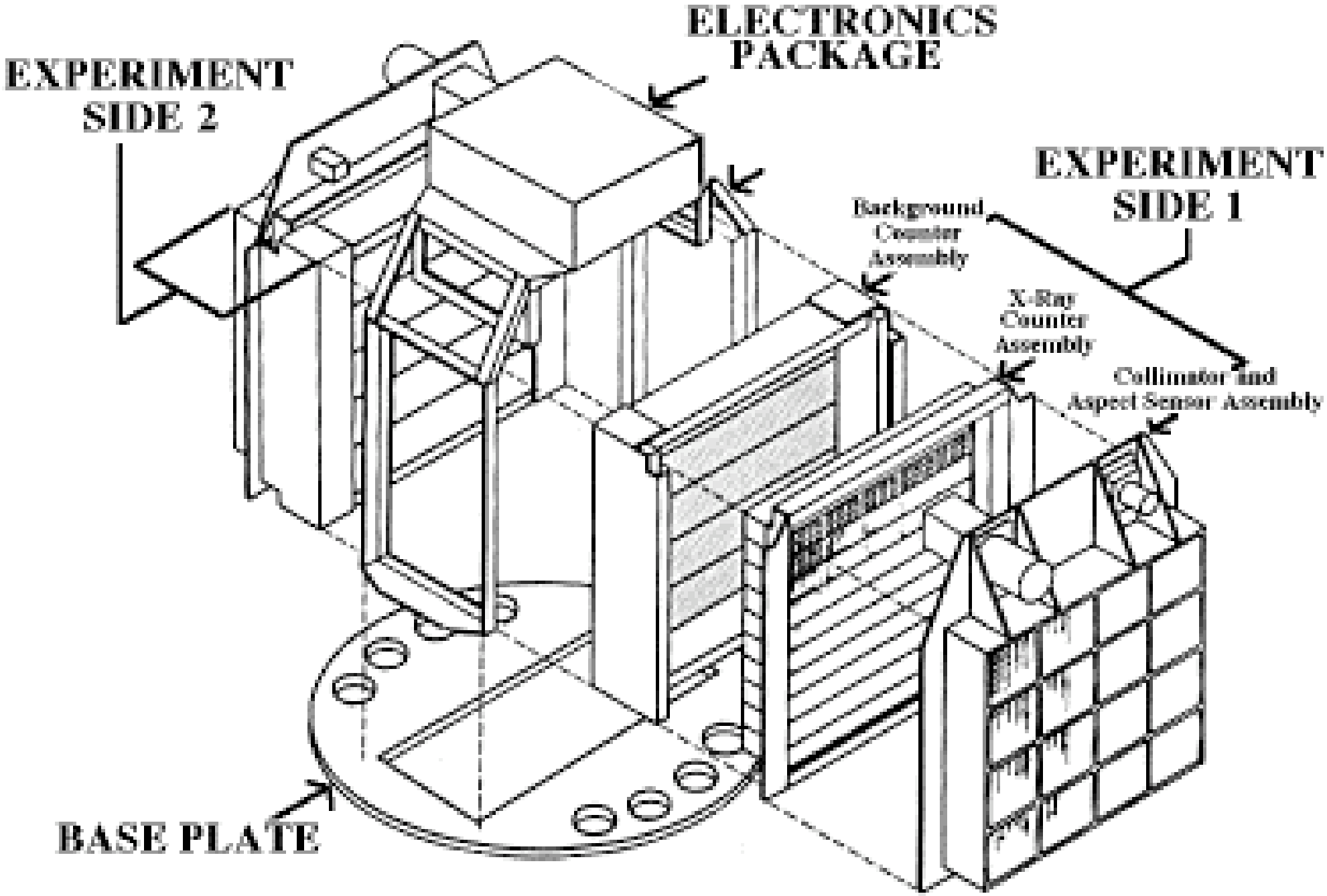
Payload : Two sets of proportional counters

First comprehensive and uniform all sky survey.

The 339 X-ray sources detected are binaries, supernova remnants, Seyfert galaxies and cluster of galaxies

Discovery of the diffuse X-ray emission from clusters of galaxies




ELECTRONICS PACKAGE
EXPERIMENT SIDE 2
EXPERIMENT SIDE 1
Background Counter Assembly
X-Ray Counter Assembly
Collimator and Aspect Sensor Assembly
BASE PLATE

Riccardo Giacconi and Luigi Broglio just before UHURU launch. Italian base in Malindi, Kenya, 1969

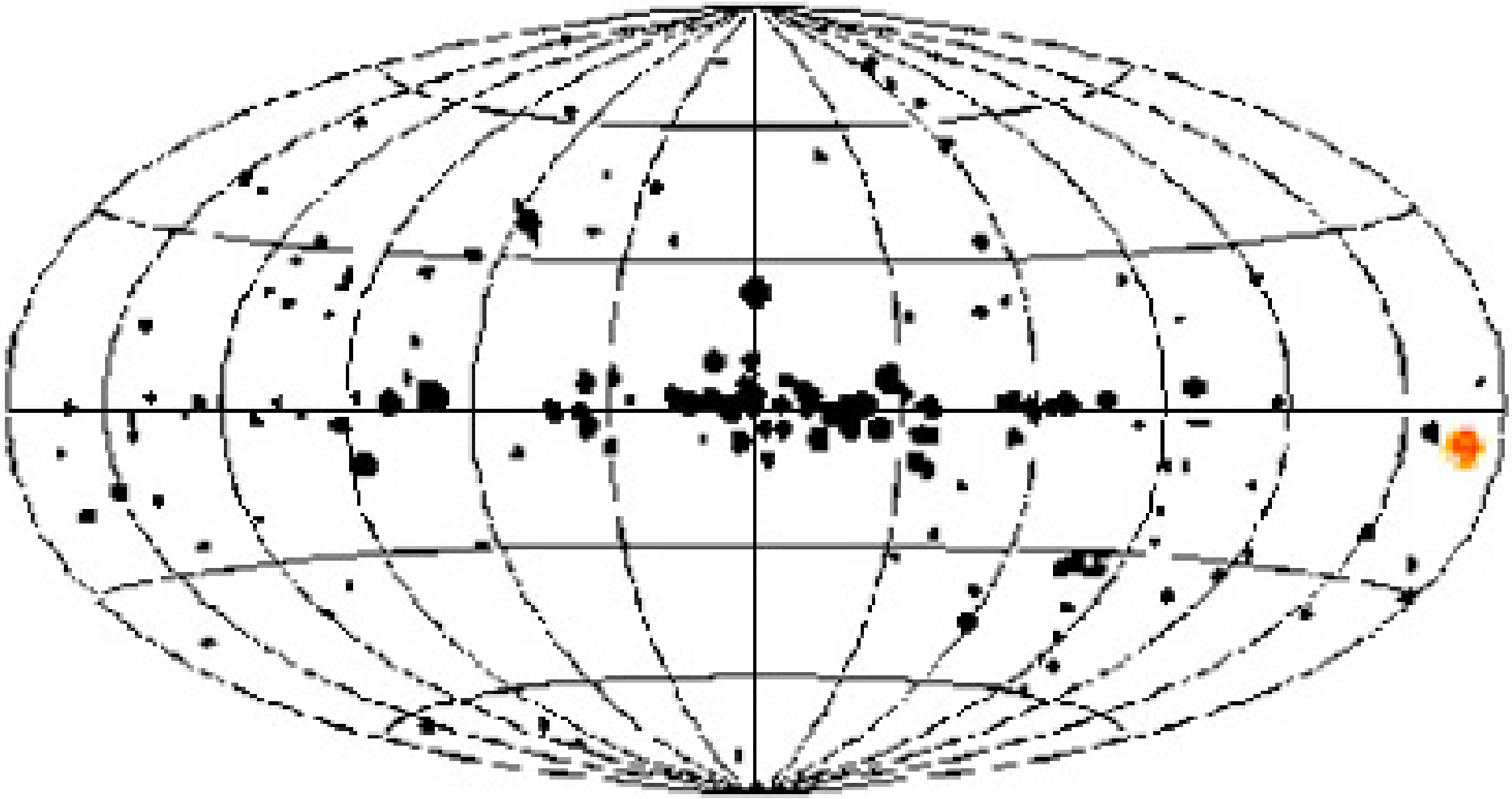
Agreement with NASA launch from San Marco of the first 3 SAS satellites

SAS-1 X

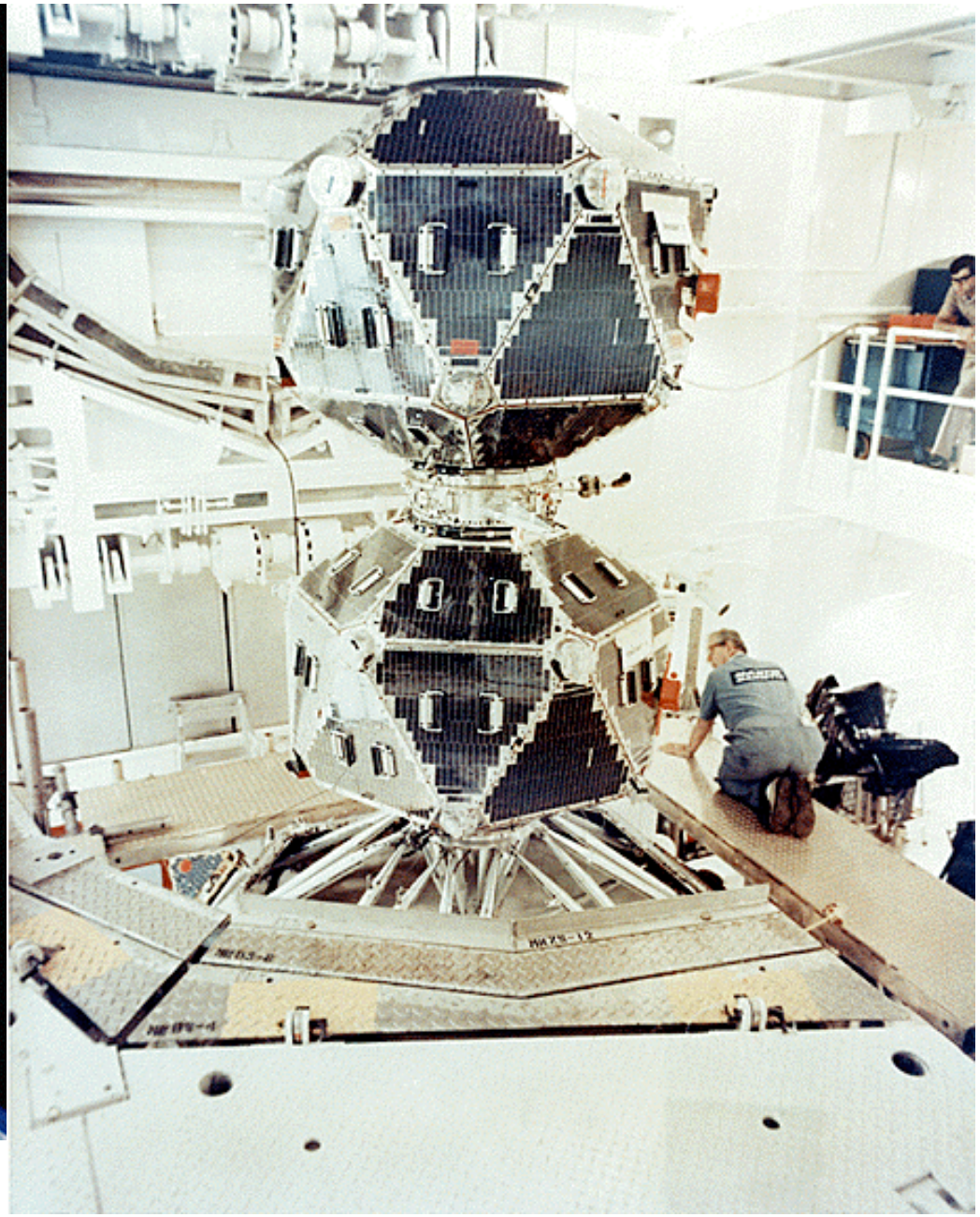
SAS-2 Gamma

SAS-3 X

+ ARIEL V



Fourth UHURU Catalog:
339 X-ray sources detected: binaries,
SNR, Seyfert galaxies and cluster of galaxies



Vela 5B

The Vela-5B Satellite

was part of a classified series of US Vela satellites

The Vela-5A and 5B satellites were launched in 1969 and Vela-6A and 6B in 1970 and they operated in spinning mode. Each operated for about a year except Vela-5B which provided data until mid 1979.

Energy Range : 3-750 keV

Payload : A Scintillation X-ray detector (All-Sky Monitor; ASM) 3-12 keV ~26 cm^2, ~6.1° x 6.1 ° FOV (FWHM)

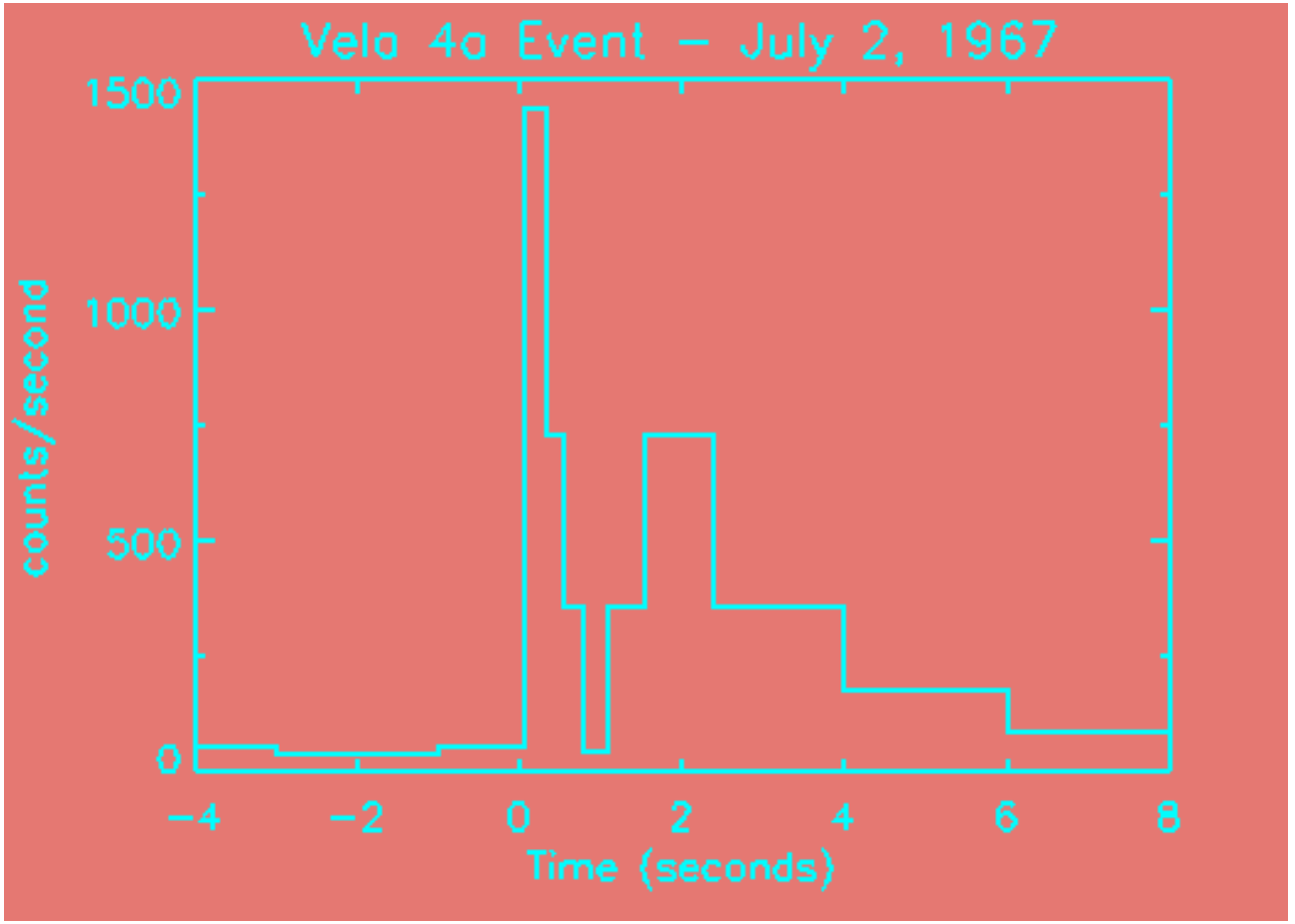
6 Gamma Ray detectors 150-750 keV

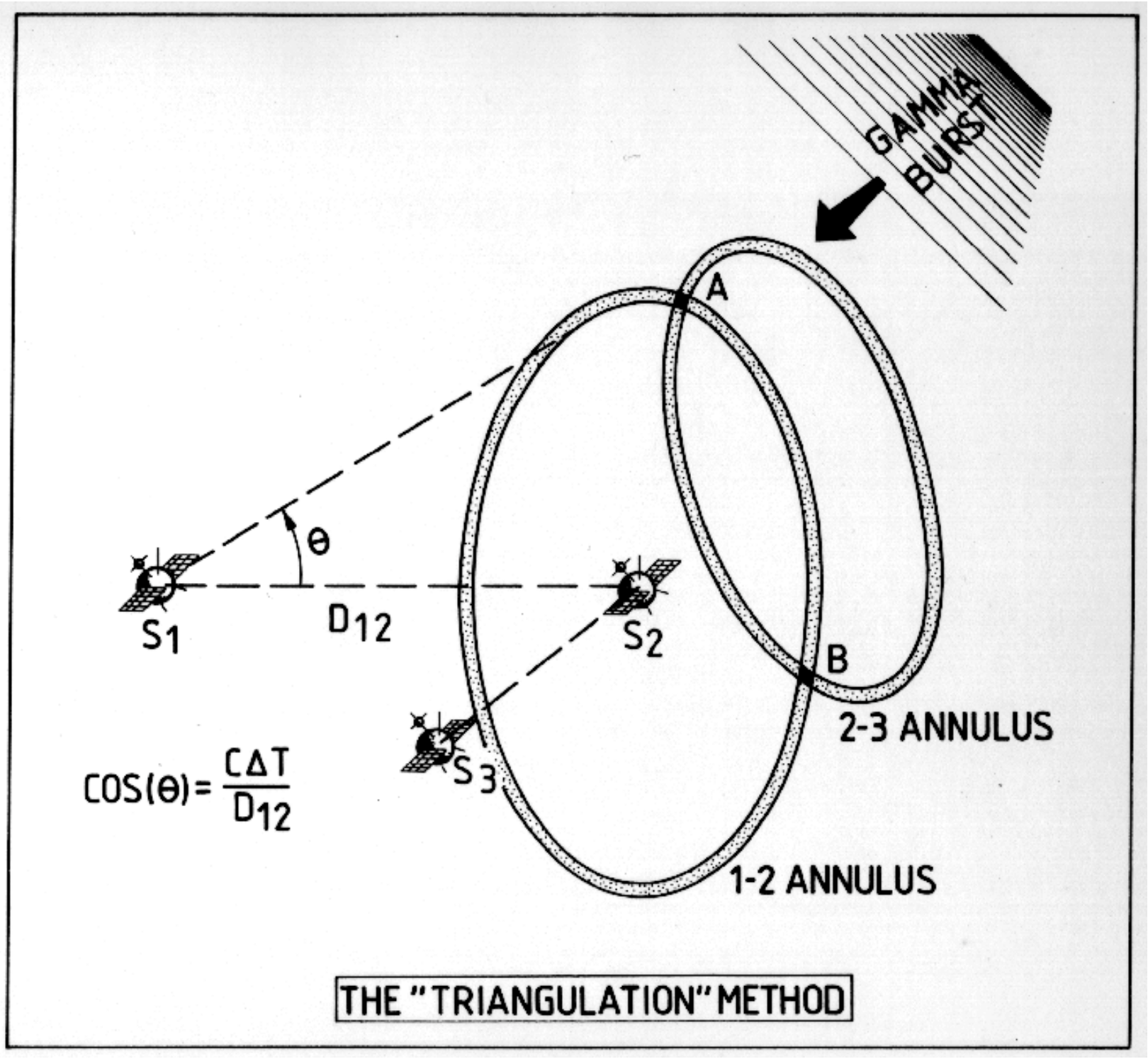
Total volume ~60 cm^3 of CsI

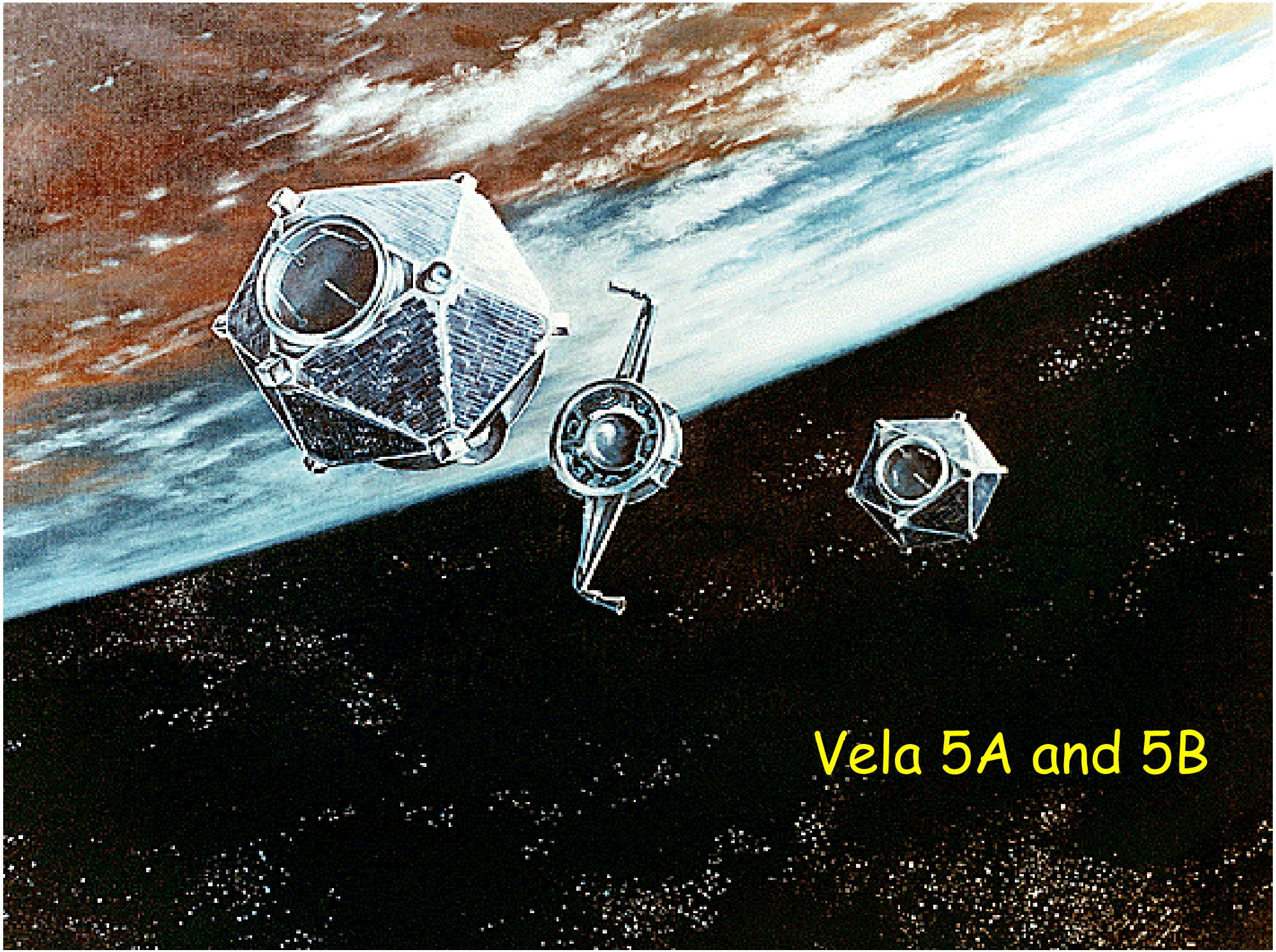
Long lifetime allowed for study of long-term variability of X-ray binaries and X-ray transients

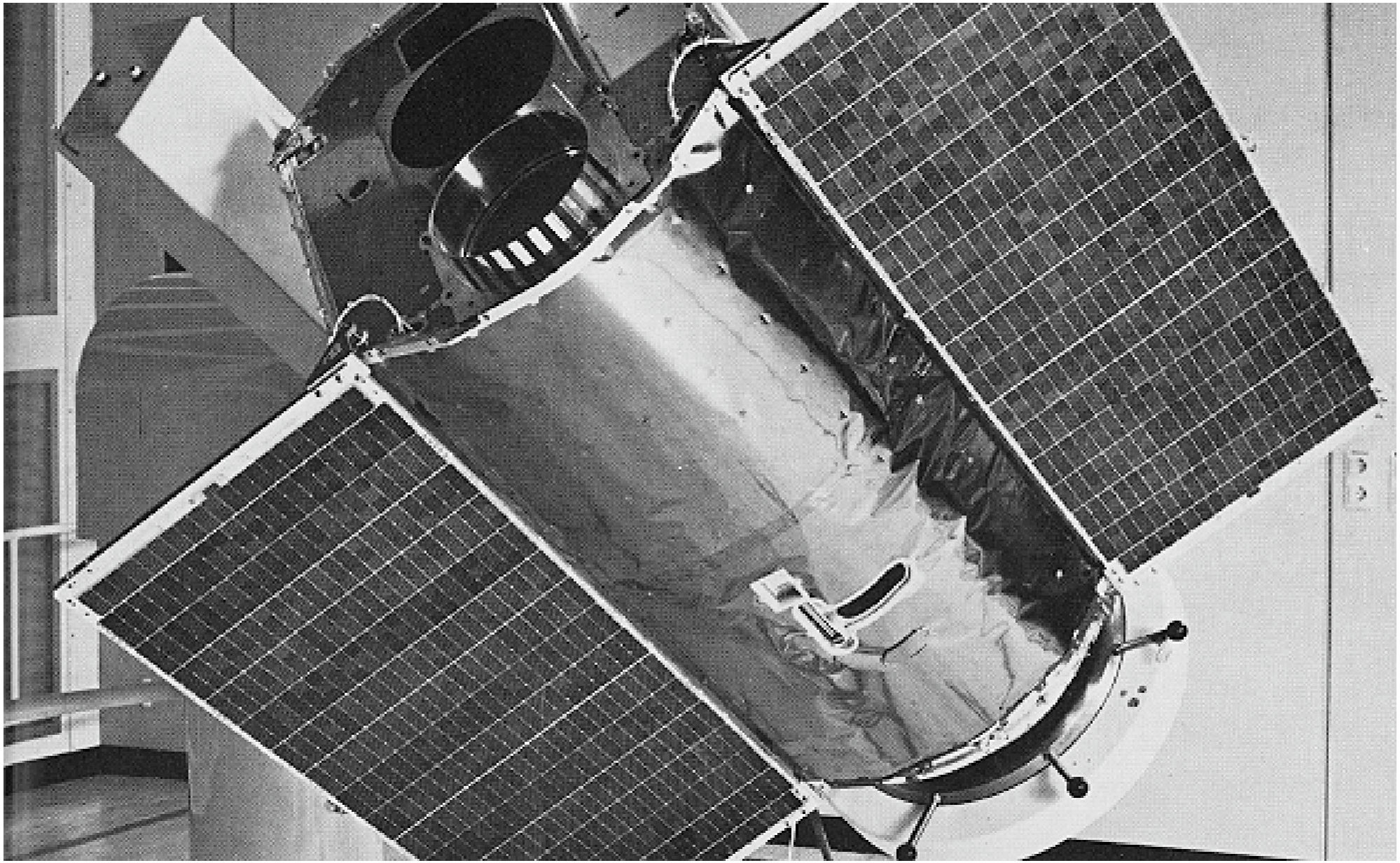
Co-discovered (with ANS) X-ray bursts.

One of the first satellites to detect gamma-ray bursts




GAMMA BURST
A
B
θ
S1
D12
S2
S3
2-3 ANNULUS
1-2 ANNULUS
COS(θ) = CΔT / D12
THE "TRIANGULATION" METHOD


Vela 5A and 5B



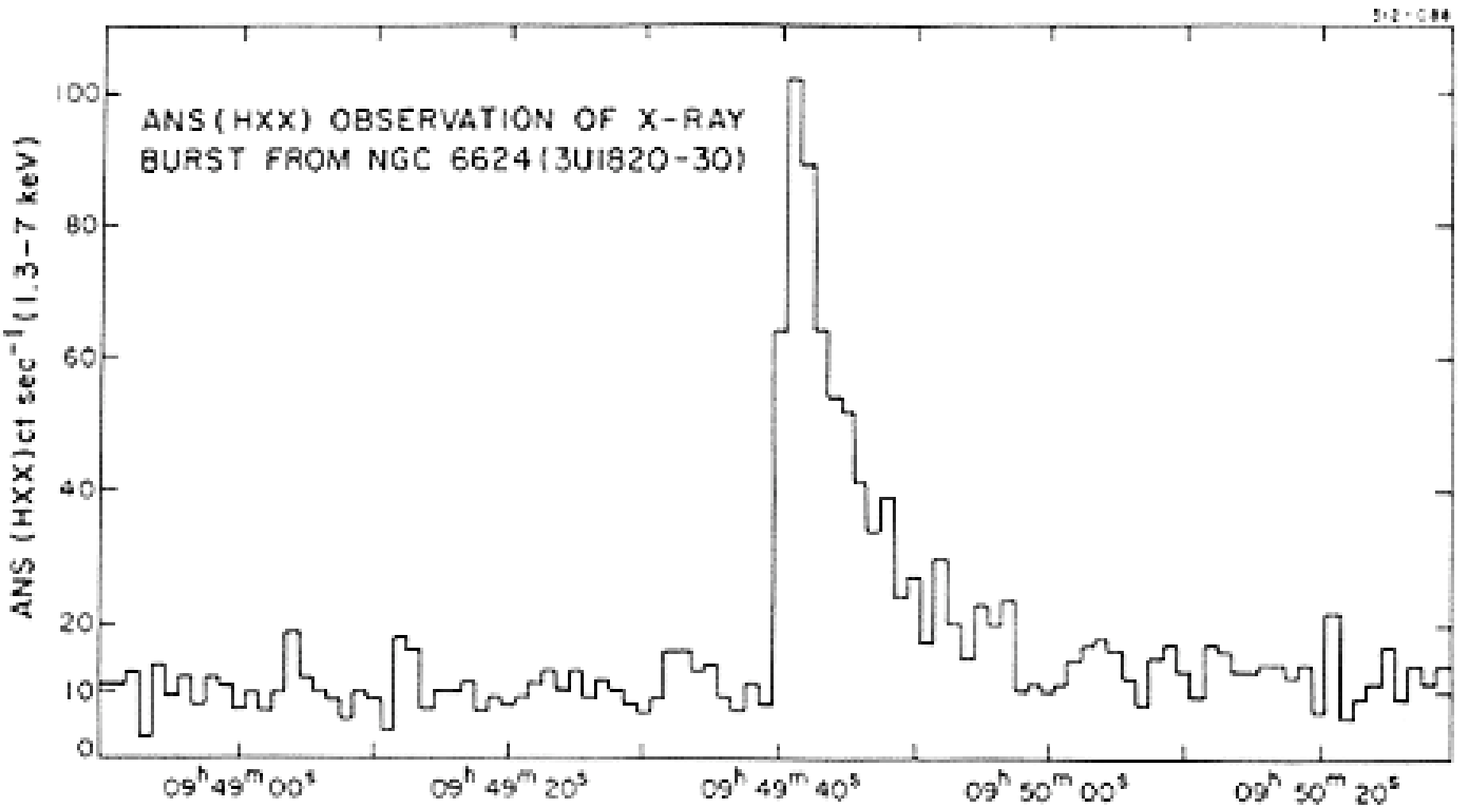
Astronomische Nederlandse Satelliet (ANS)

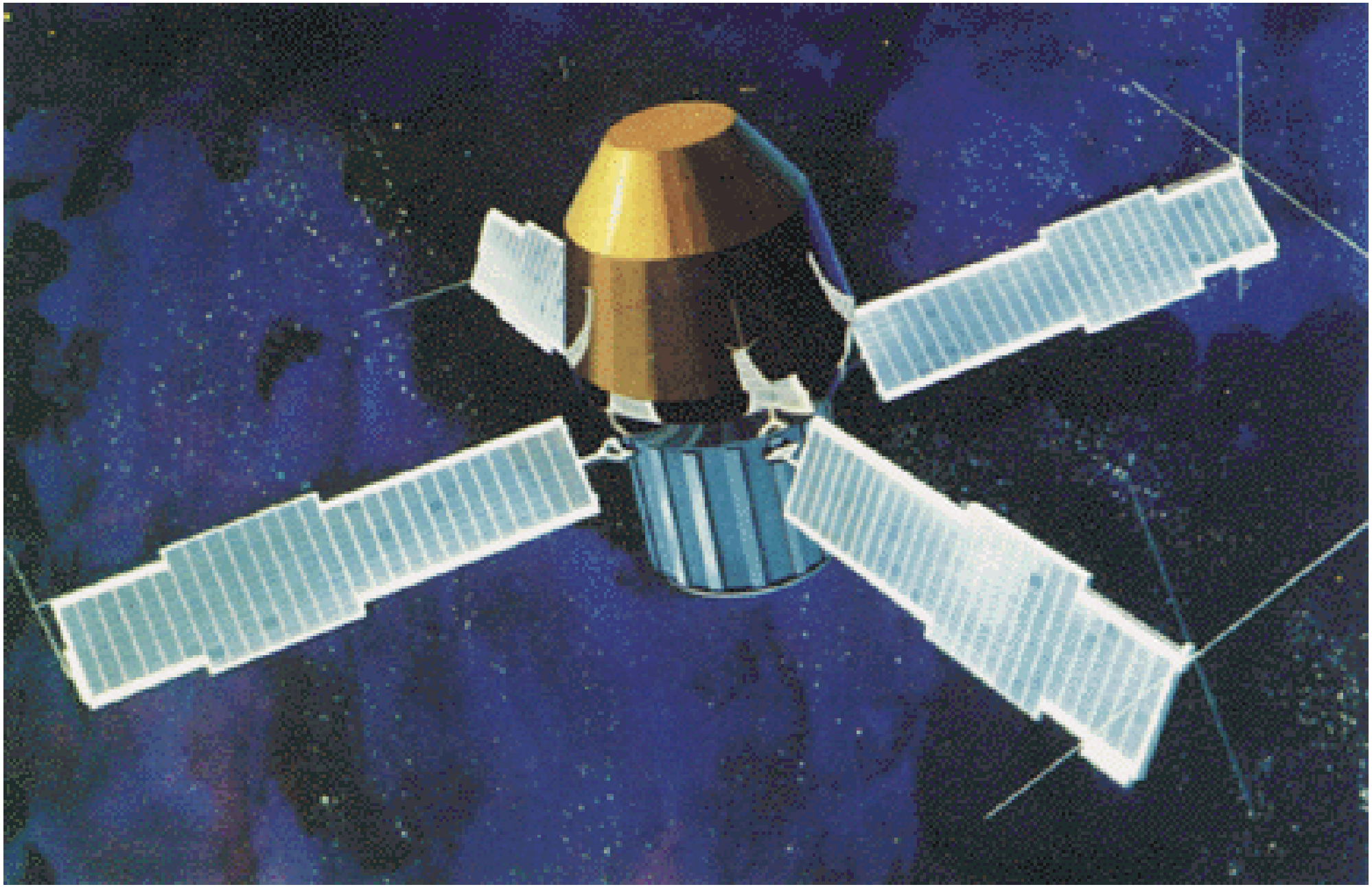
ANS

Discovery of the X-ray bursts

Detection of X-ray from Stellar Coronae (Capella)

First detection of X-ray flares from UV Ceti and YZ CMi


ANS (HXX) OBSERVATION OF X-RAY
BURST FROM NGC 6624 (3U1820-30)
ANS (HXX) ct sec⁻¹ (1.3–7 keV)
100
80
60
40
20
10
0
09h 49m 00s
09h 49m 20s
09h 49m 40s
09h 50m 00s
09h 50m 20s

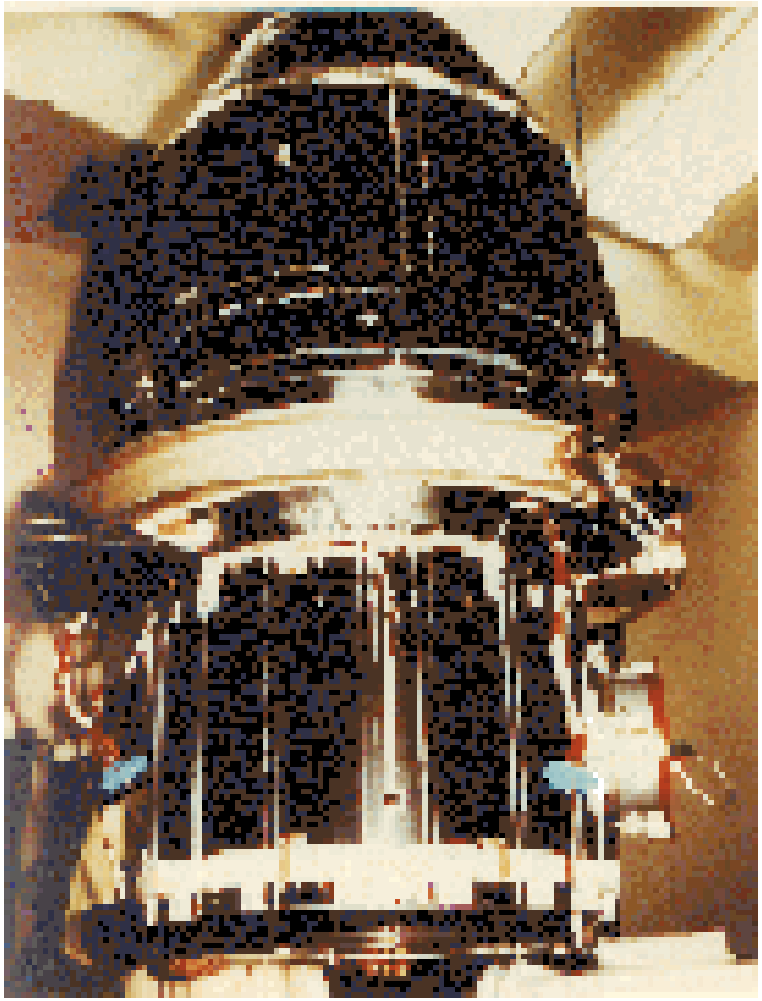


SAS - 2

Lifetime : 19 November 1972 - 8 June 1973

Energy Range : 20 MeV - 1 GeV

Payload : 32-level wire spark-chamber aligned with satellite spin axis (20 MeV-1 GeV), eff. area 540 cm^2



The Small Astronomy Satellite 2 (SAS-2)

The first detailed look at the gamma-ray sky.

Established the high energy component of diffuse celestial radiation.

Correlated the gamma-ray background with galactic structural features.

Ariel V

Launch October 15 1974

from S. Marco in Kenya.

USA UK collaboration.

End of Operation March 14 1980

0.3-40 keV

Payload :

Experiments aligned with the spin axis.

- Rotation Modulation Collimator (RMC) (0.3-30 keV).
- High resolution proportional counter spectrometer.
- Polarimeter/spectrometer.
- Scintillation telescope.

All-Sky Monitor (ASM) a small (~1 cm^2) pinhole camera (3-6 keV).

Sky Survey Instrument (SSI) composite of two proportional counters with 290 cm^2 effective area each (1.5-20 keV).

Ariel V

Long-term monitoring of numerous X-ray sources.

Discovery of several long period (minutes) X-ray pulsars.

Discovery of several bright X-ray transients probably containing a Black Hole (*e.g.* A0620-00=Nova Mon 1975).

Establishing that Seyfert I galaxies (AGN) are a class of X-ray emitters.

Discovery of iron line emission in extragalactic sources.

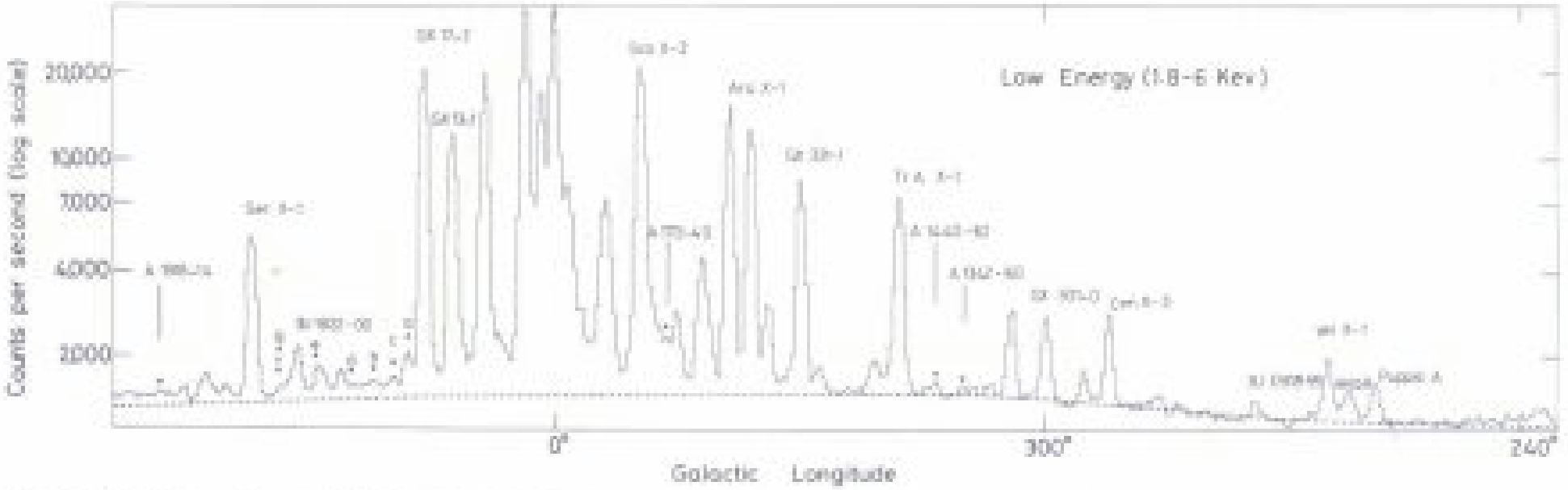
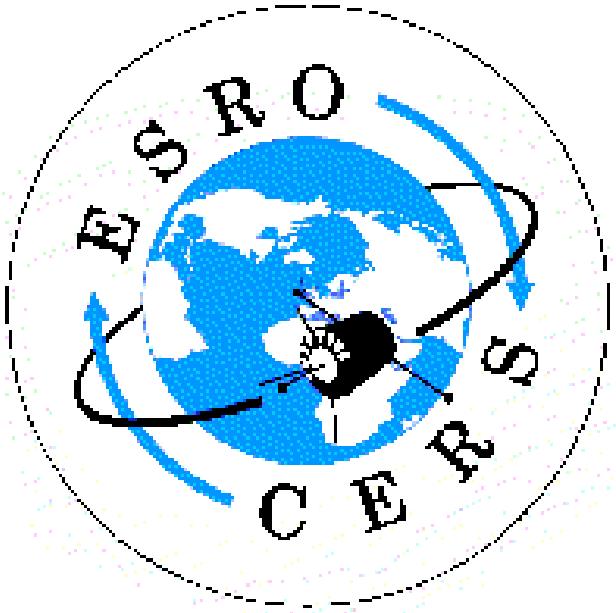


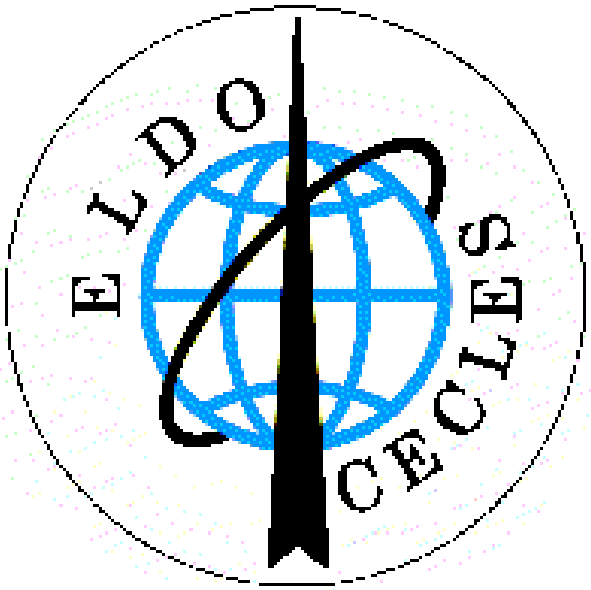
Fig. 1.3 An Ariel V scan of the central half of the galactic plane. Two detectors scanned the sky, each with 0.7° x 10° field of view. The two collimators were inclined at different angles to and in opposite directions to the galactic plane, so that sources do not appear at identical longitudes in this figure. Note the improvement in the ability to detect weak sources. (Courtesy of K. Pounds, University of Leicester.)

Ariel V data: X-Ray emission from AGN and Fe emission line

March 1973

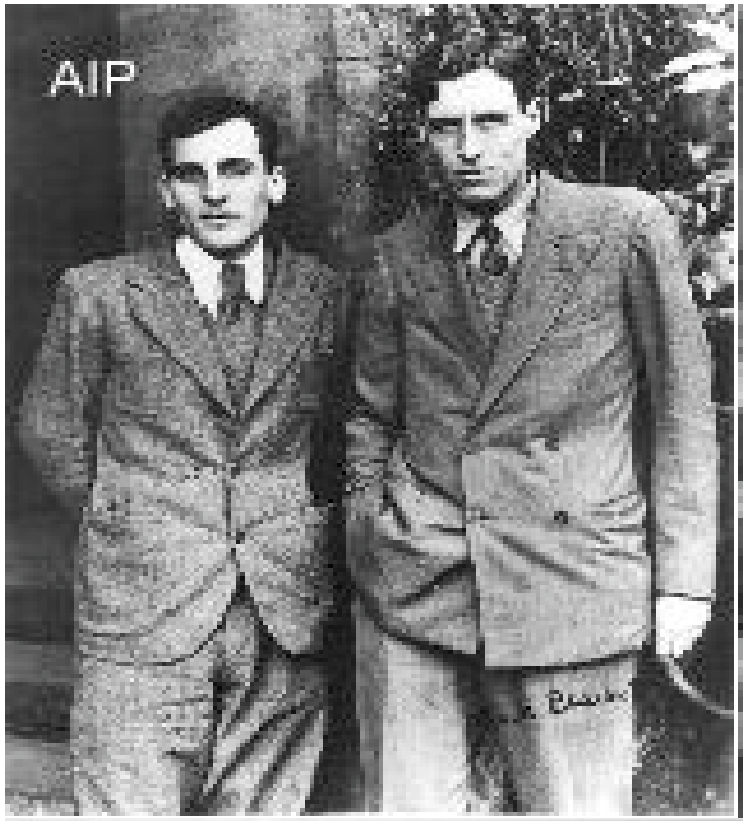


+

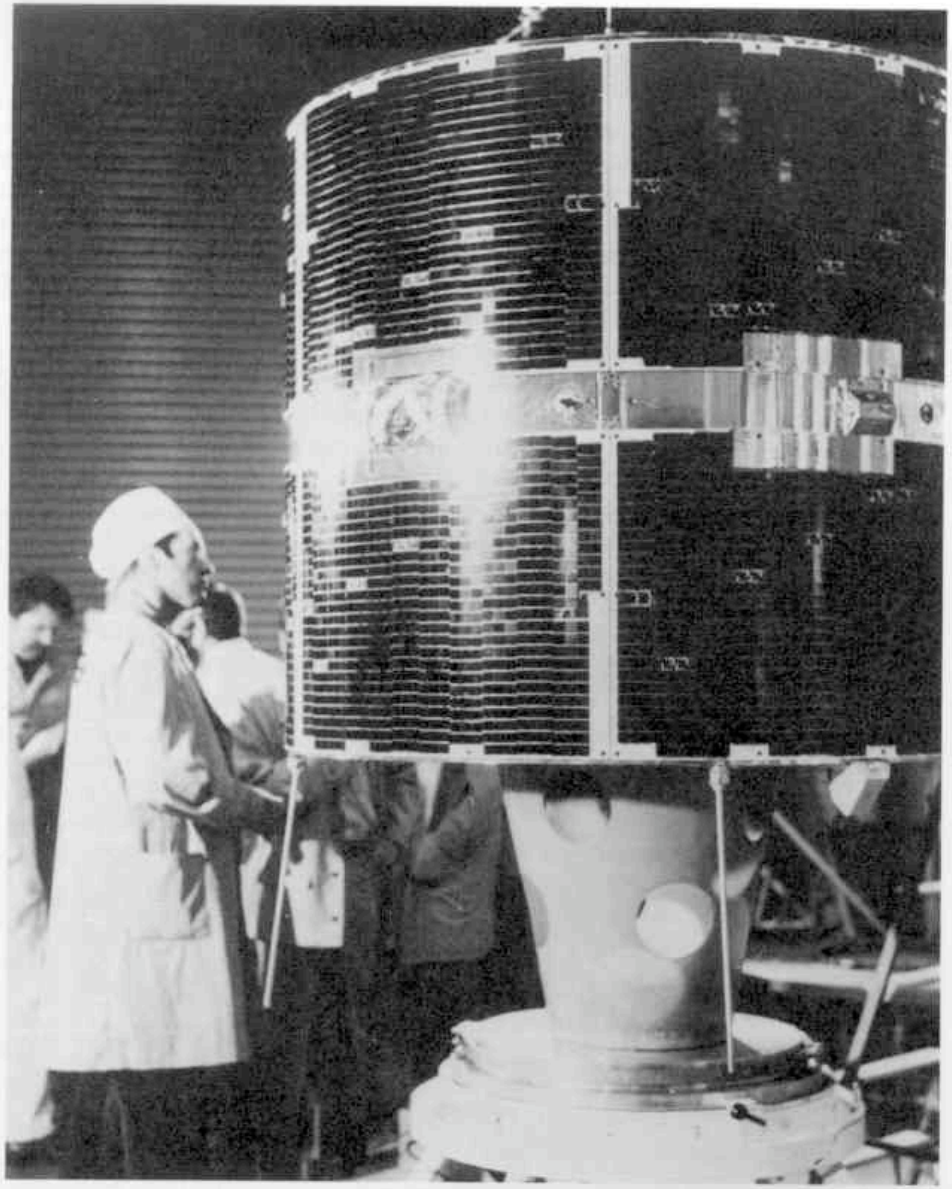


esa


EUROPA
A VELE SPIEGATE



COS-B



COS-B — Europe's first observatory satellite. (NASA photo)

COS-B

Lifetime : August 1975 - April 1982

Energy Range : 20 MeV - 1 GeV

Payload:32-level wire spark-chamber aligned with satellite spin axis (20 MeV-1 GeV), eff. area 540 cm^2

Observations of gamma-ray pulsars, binary systems.

Gamma-ray map of the Galaxy.

Detailed observations of the GEMINGA gamma-ray pulsar.

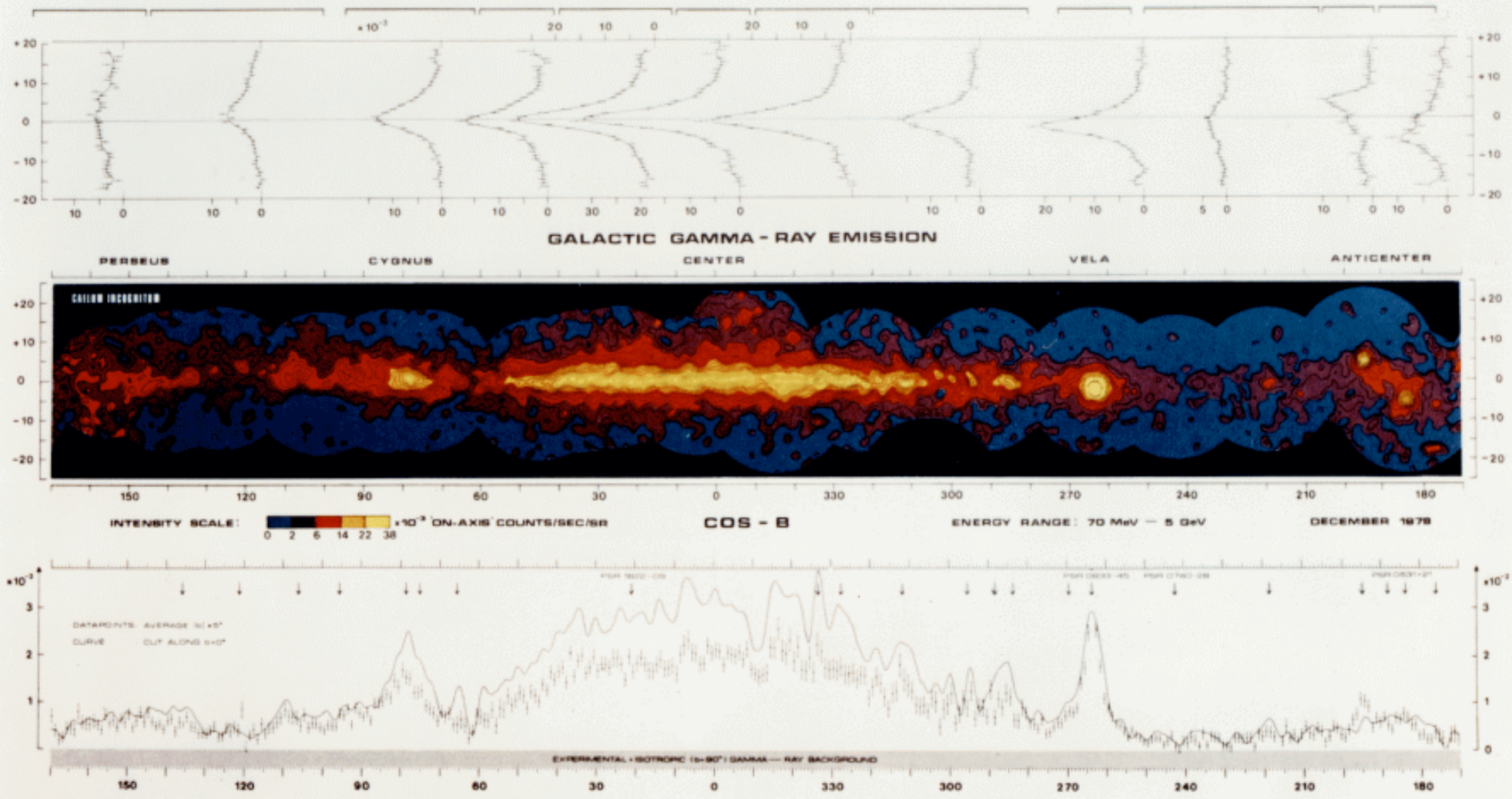
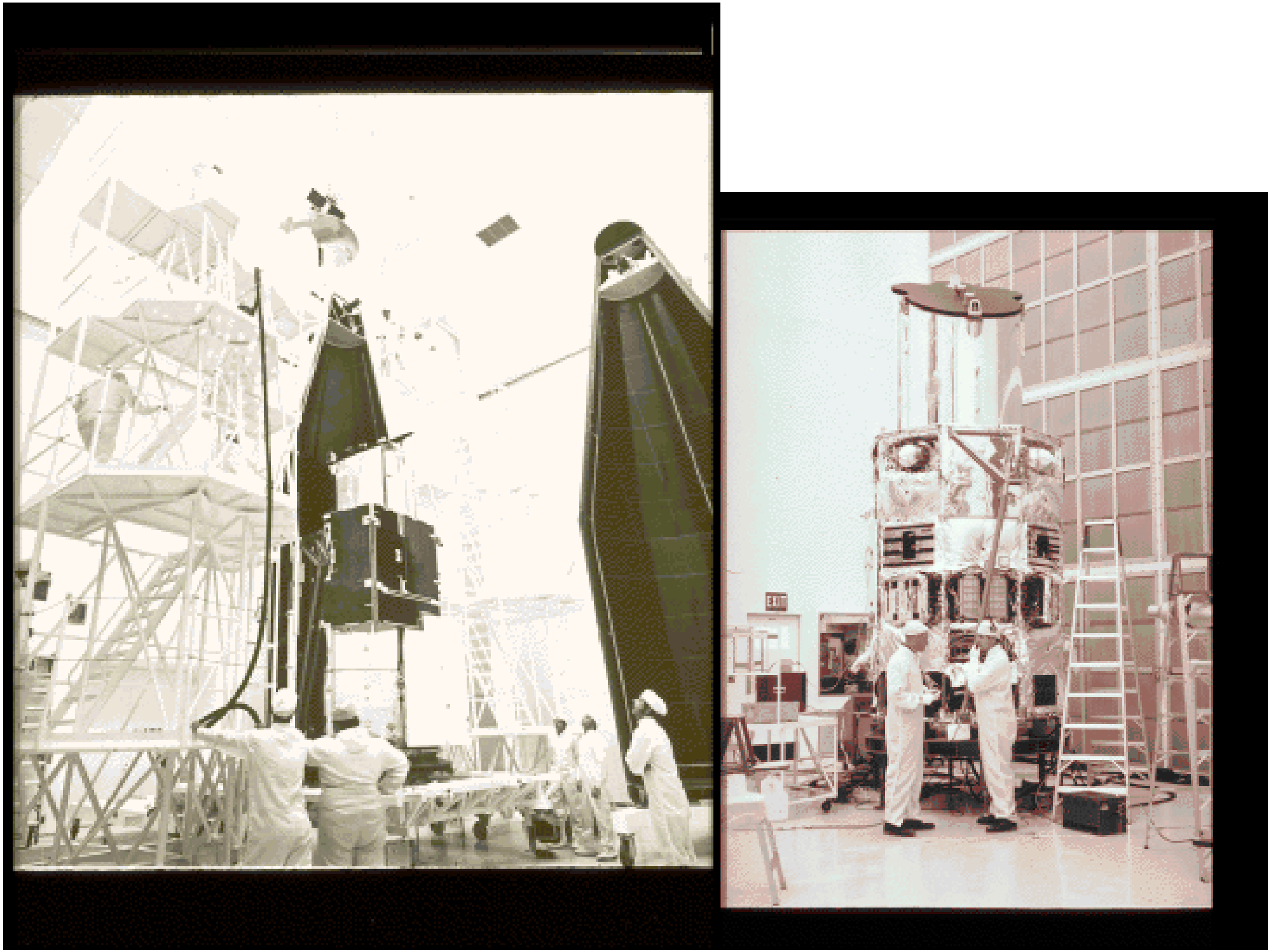


Abb. 63: Isointensitätskontourenkarte der Gammaemission der Milchstraße. Profile entlang galaktischer Länge bzw. Breite.


EXIT

The Copernicus Satellite (OAO-3)

Discovery of several long period pulsars (e.g. X Per).

Discovery of absorpton dips in Cyg X-1.

Long-term monitoring of pulsars and other bright X-ray binaries.

Observed rapid intensity variability from Cen A.

Lifetime : 21 August 1972 - February 1981

Energy Range : 0.5 - 10 keV
(X-ray experiment only)

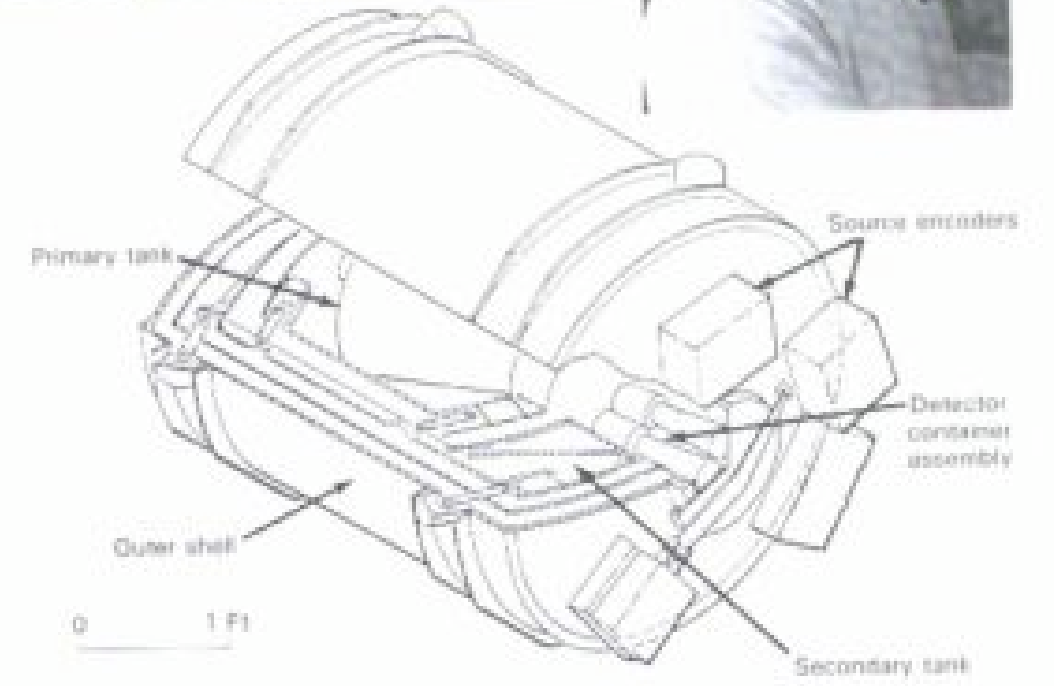
Payload :

The University College London X-ray Experiment (UCLXE) consisted of 4 co-aligned X-ray detectors 3 Wolter type 0 grazing incidence telescopes with 2 proportional counters (3-9 Å and 6-18 Å) and a channel photomultiplier at the foci. (variable FOV from 1 to 12 arcmin)

1 proportional counter (1-3 Å) with a simple collimation tube. (2.5° X 3.5° FOV)

NASA High Energy Astronomical Observatories (HEAO) Scientists

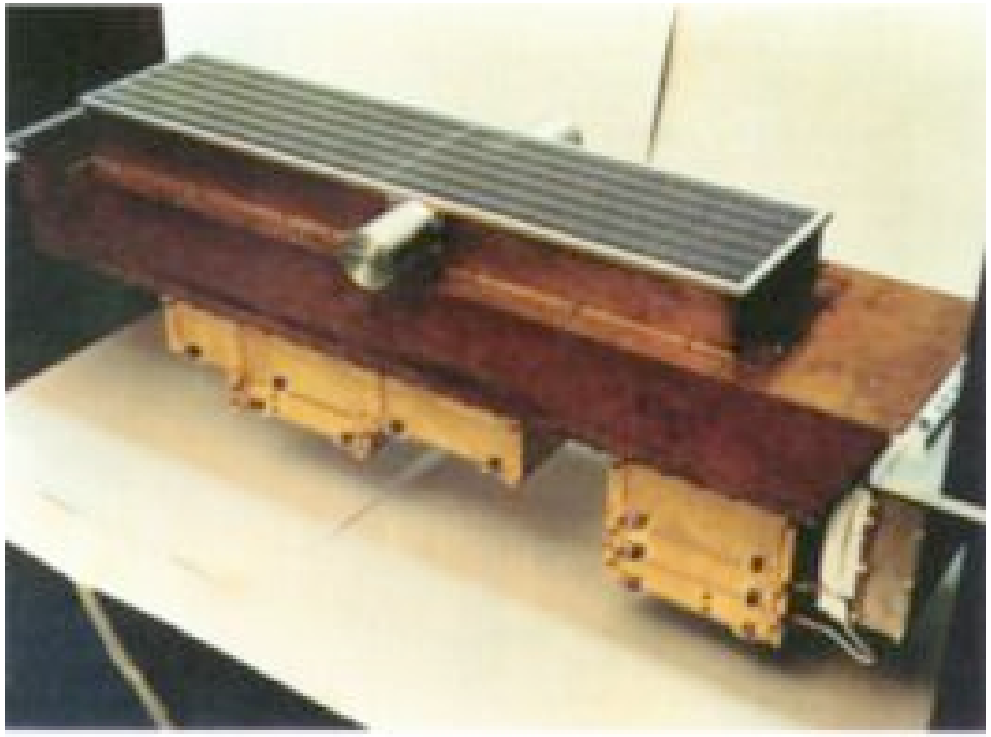
HEAO-1 satellite solar panels which provided the 400 W power necessary to operate the Observatory

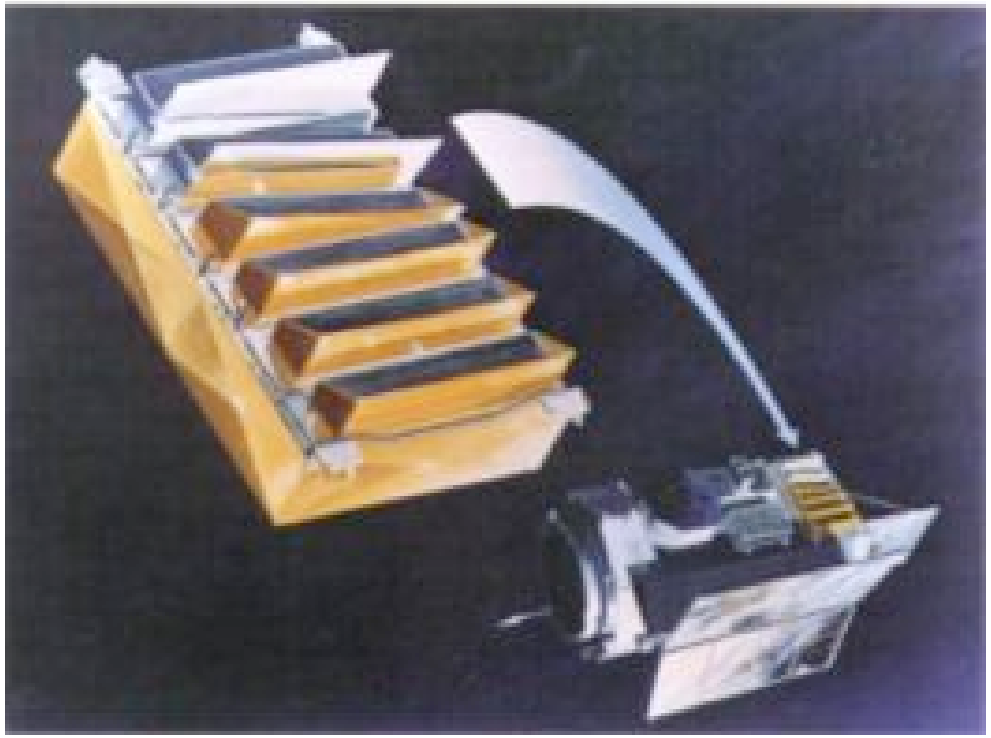


Experiment B-5,
Solid State
Spectrometer

Ge & Si crystals were cooled with solid methane and ammonia.

PI: Elihu Boldt
NASA Goddard
Space Flight Center

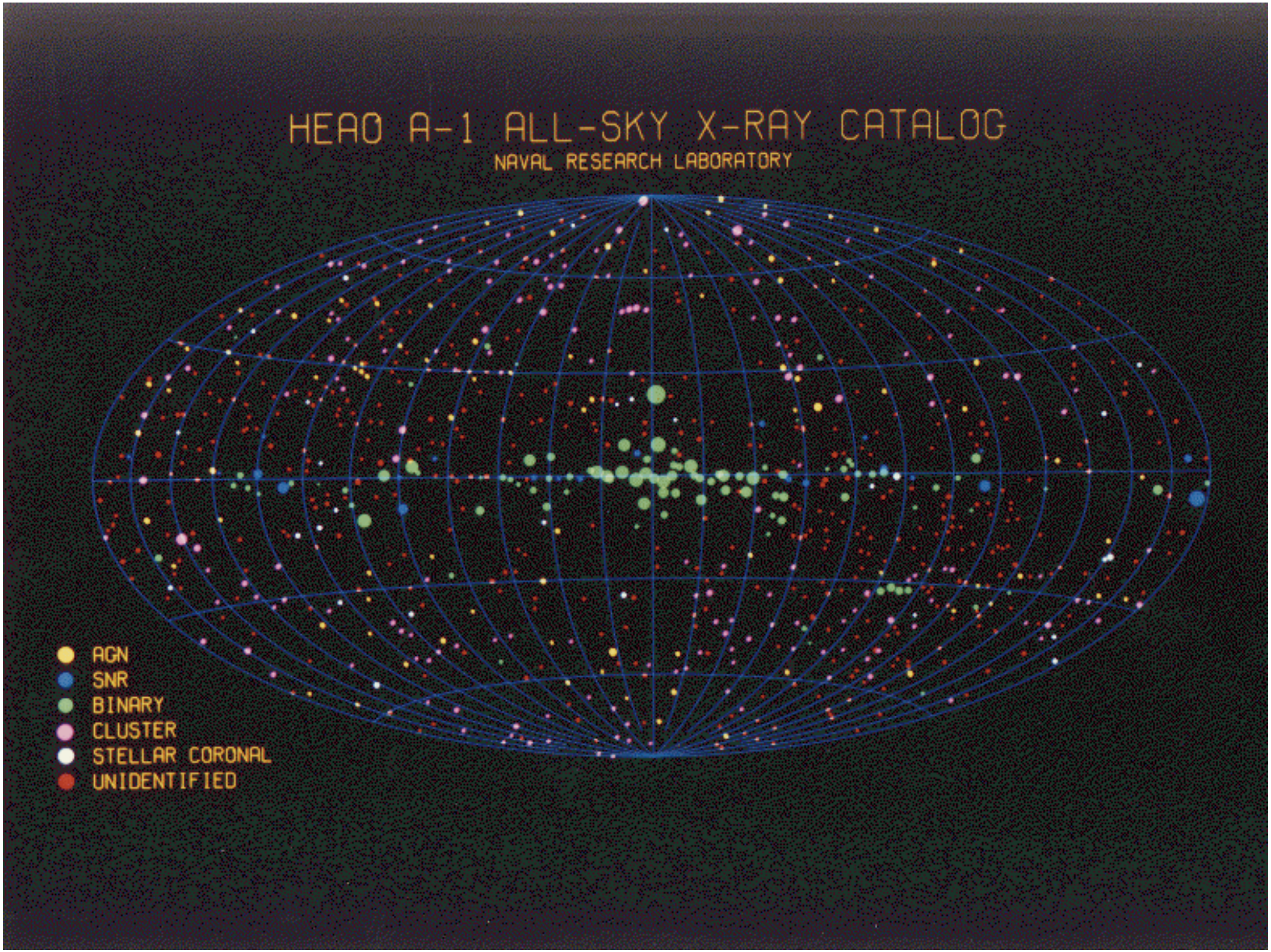


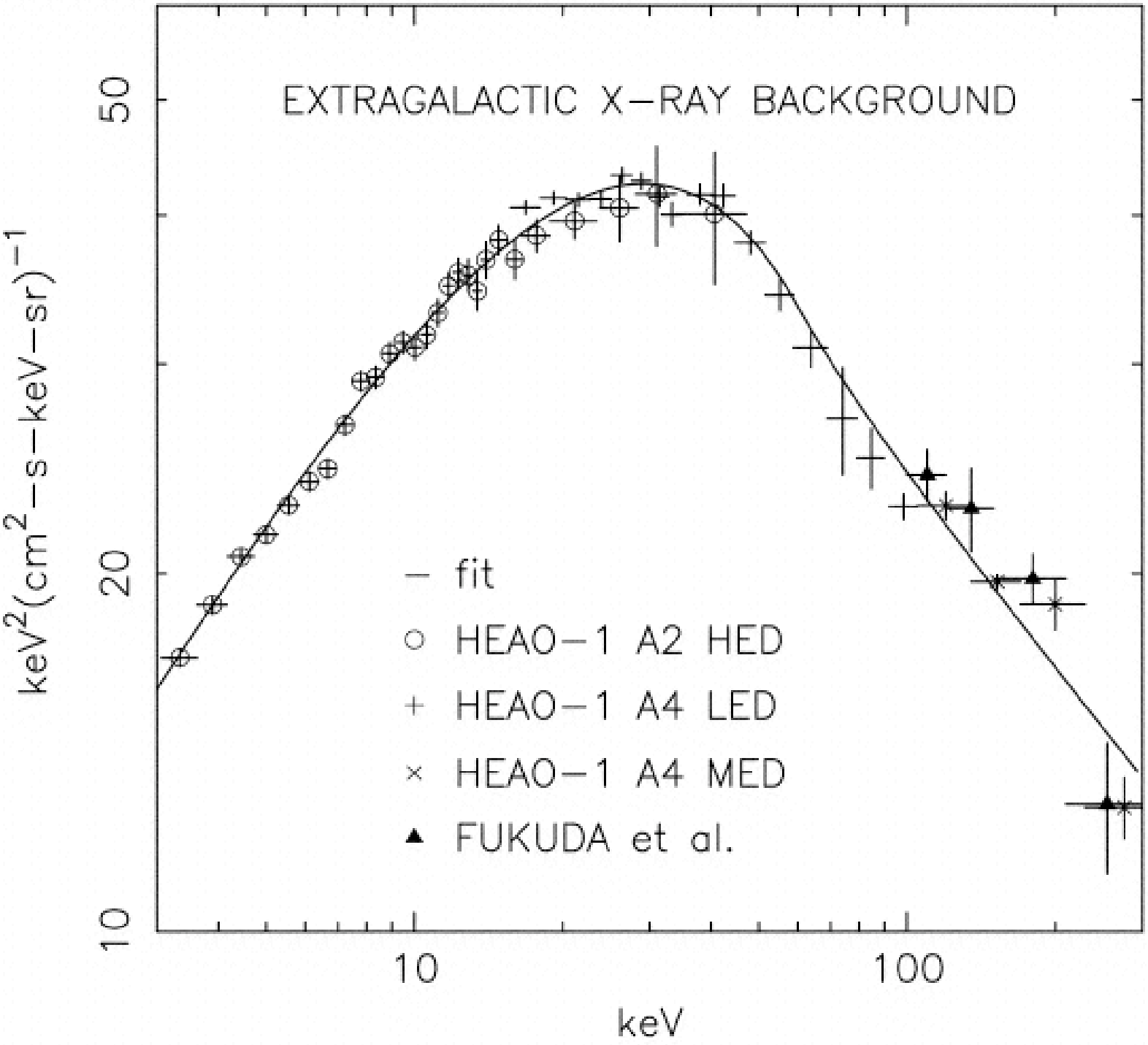


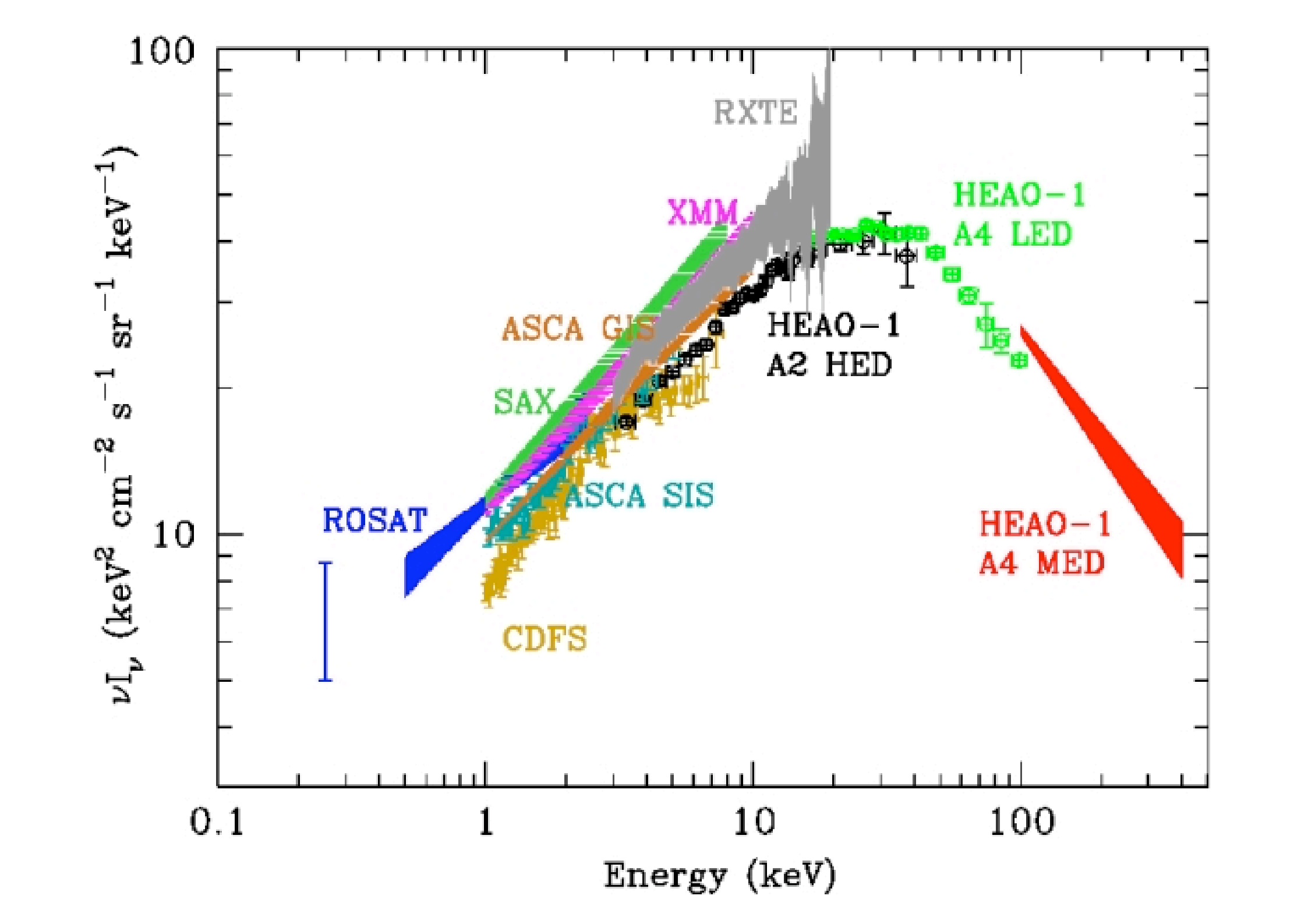
Esperiment A-2
Cosmic X-Ray
Detector

6 collimated
proportional counters
with thin windows,
energy range 0.2 - 60
keV

PI: Elihu Boldt GSFC
NASA


HEAO A-1 ALL-SKY X-RAY CATALOG
NAVAL RESEARCH LABORATORY
AGN
SNR
BINARY
CLUSTER
STELLAR CORONAL
UNIDENTIFIED


EXTRAGALACTIC X-RAY BACKGROUND
fit
HEAO-1 A2 HED
HEAO-1 A4 LED
HEAO-1 A4 MED
FUKUDA et al.
keV^2(cm^2-s-keV-sr)$^{-1}$
50
20
10
10
100
keV


100
10
0.1
1
10
100
Energy (keV)
νI_ν (keV^2 cm^{-2} s^{-1} sr^{-1} keV^{-1})
RXTE
XMM
ASCA GIS
SAX
ASCA SIS
ROSAT
CDFS
HEAO−1
A2 HED
HEAO−1
A4 LED
HEAO−1
A4 MED

HEO-1

Lifetime : 12 August 1977 - 9 January 1979

Energy Range : 0.2 keV - 10 MeV

A1 - Large Area Sky Survey experiment (LASS) : 0.25-25 keV, eff. area 7 modules each of 1350 - 1900 cm2, FOV varied between 1° X 4° to 1° x 0.5° for finest collimators.

A2 - Cosmic X-ray Experiment (CXE) : six separate proportional counters

Low Energy Detectors (LED) 0.15-3.0 keV, eff. area 2 detectors of 400 cm^2 each

Medium Energy Detector (MED) 1.5-20 keV, eff. area 1 detector at 800 cm^2

High Energy Detector (HED) 2.5-60 keV, eff. area 3 detectors at 800 cm^2 each

MED and HEDs had various FOV settings, 1.5° x 3°, 3° x 3° and 3° x 6°

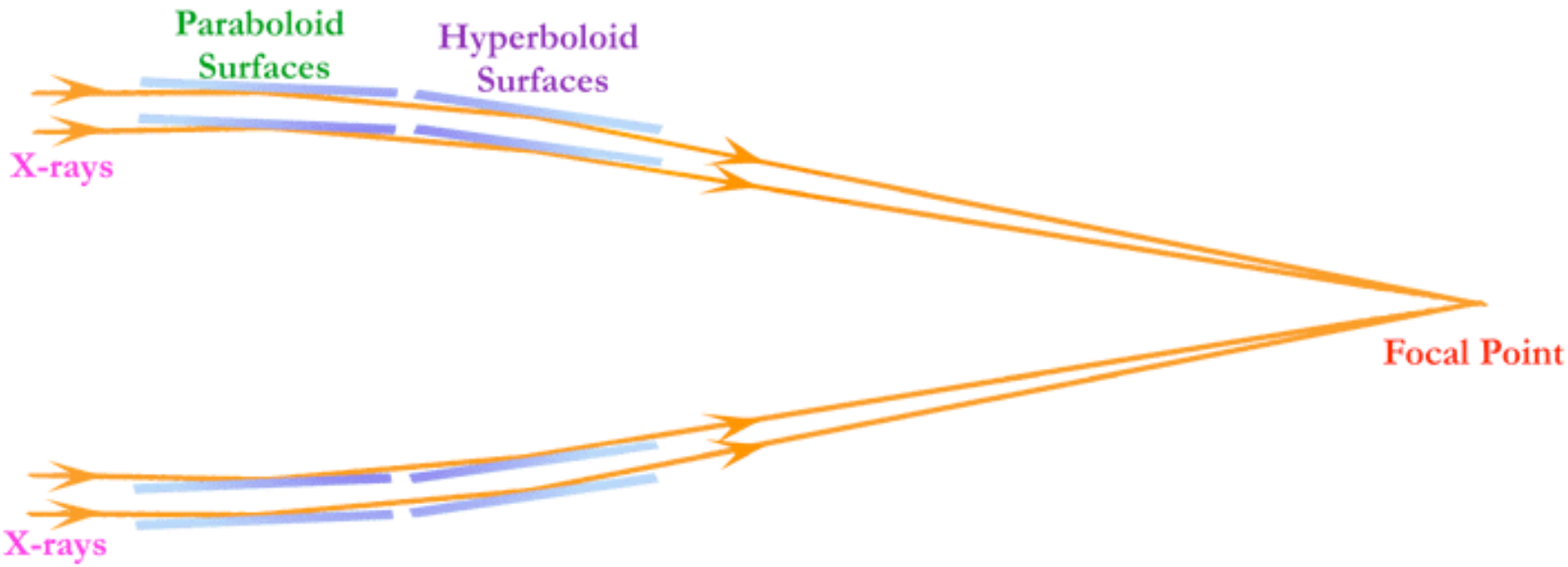
A3 - Modulation Collimator (MC) :
0.9-13.3 keV, eff. area 2 collimators 400 cm2 (MC1) & 300 cm^2 (MC2), FOV 4° X 4°

A4 - Hard X-Ray / Low Energy Gamma Ray Experiment :
seven inorganic phoswich scintillator detectors

Low Energy Detectors 15-200 keV, eff. area 2 detectors 100 cm^2 each, FOV 1.7° x 20°

Medium Energy Detectors 80 keV - 2 MeV, eff. area 4 detectors 45 cm^2 each, FOV 17°

High Energy Detector 120 keV - 10 MeV, eff. area 1 detector 100 cm^2, FOV 37°



Basic principle of X-Ray mirrors

HEAO-2, later renamed Einstein, photo Perkin-Elmer Corp.

First X-Ray telescope to produce images

12 November 1978
April 1981

The Einstein Observatory (HEAO-2)

First high resolution spectroscopy and morphological studies of supernova remnants.

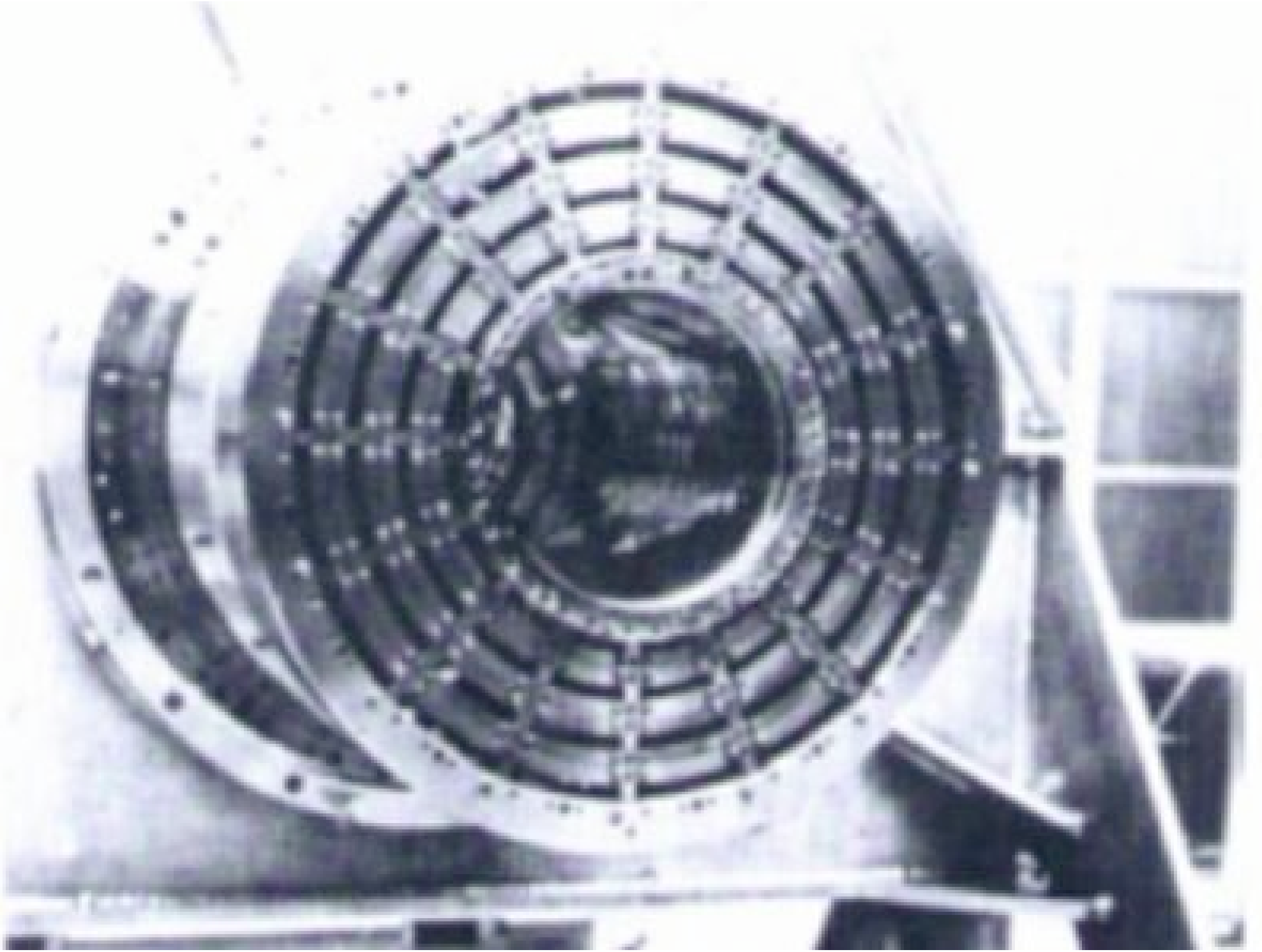
Recognized that coronal emissions in normal stars are stronger than expected.

Resolved numerous X-ray sources in the Andromeda Galaxy and the Magellanic Clouds.

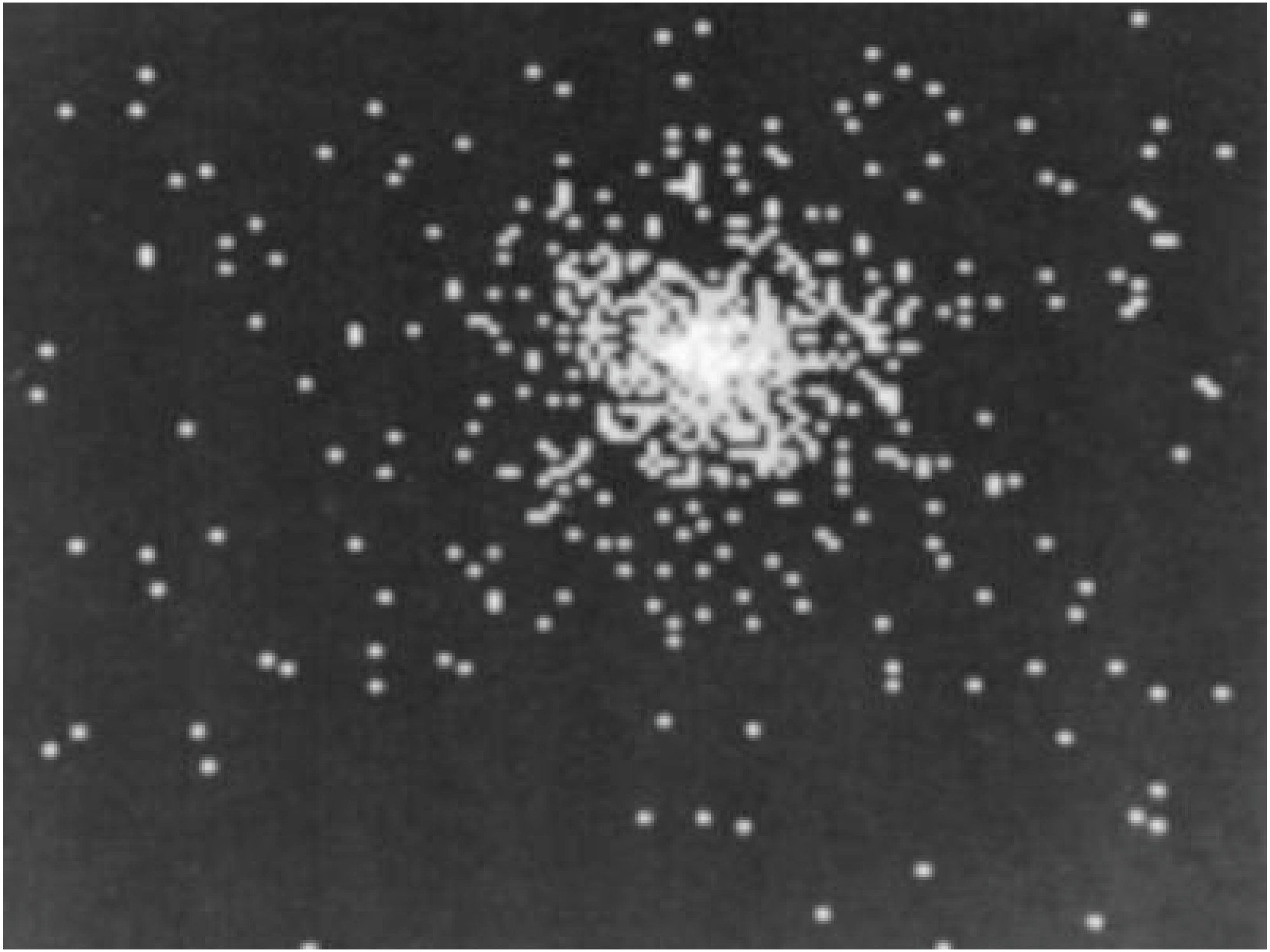
First study of the X-ray emitting gas in galaxies and clusters of galaxies revealing cooling inflow and cluster evolution.

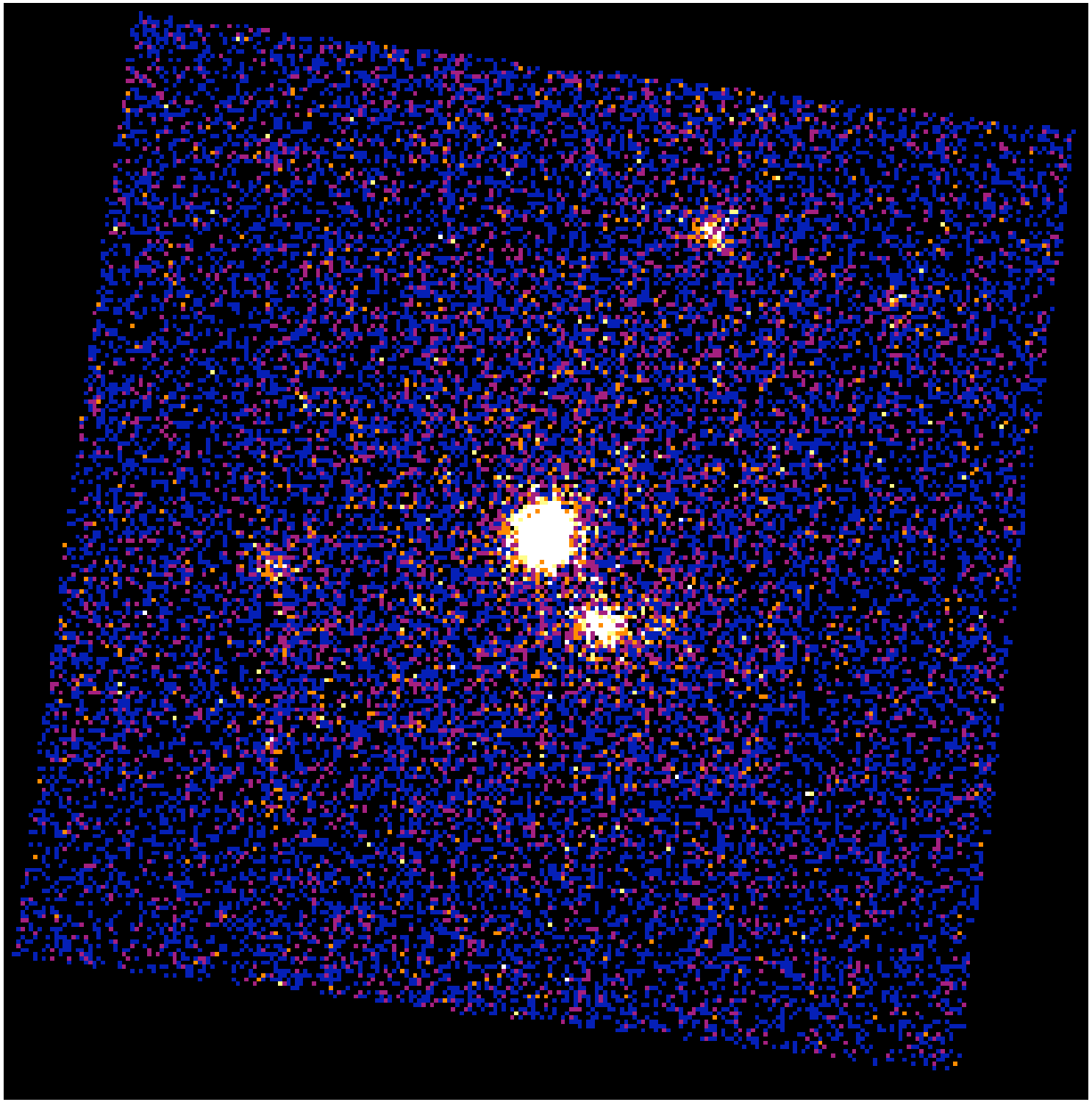
Detected X-ray jets from Cen A and M87 aligned with radio jets.
First medium and Deep X-ray surveys

Discovery of thousands of "serendipitous" sources

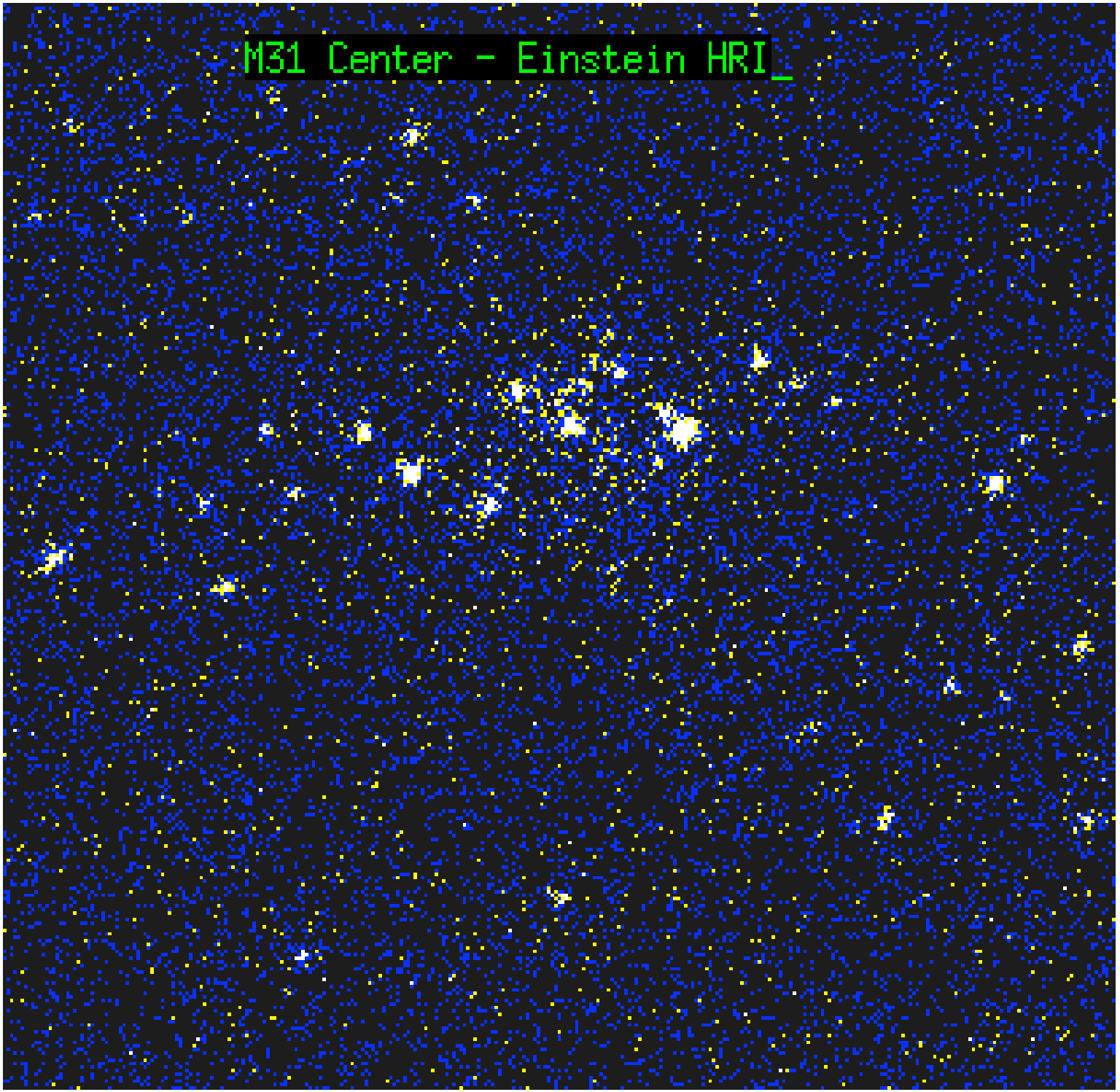


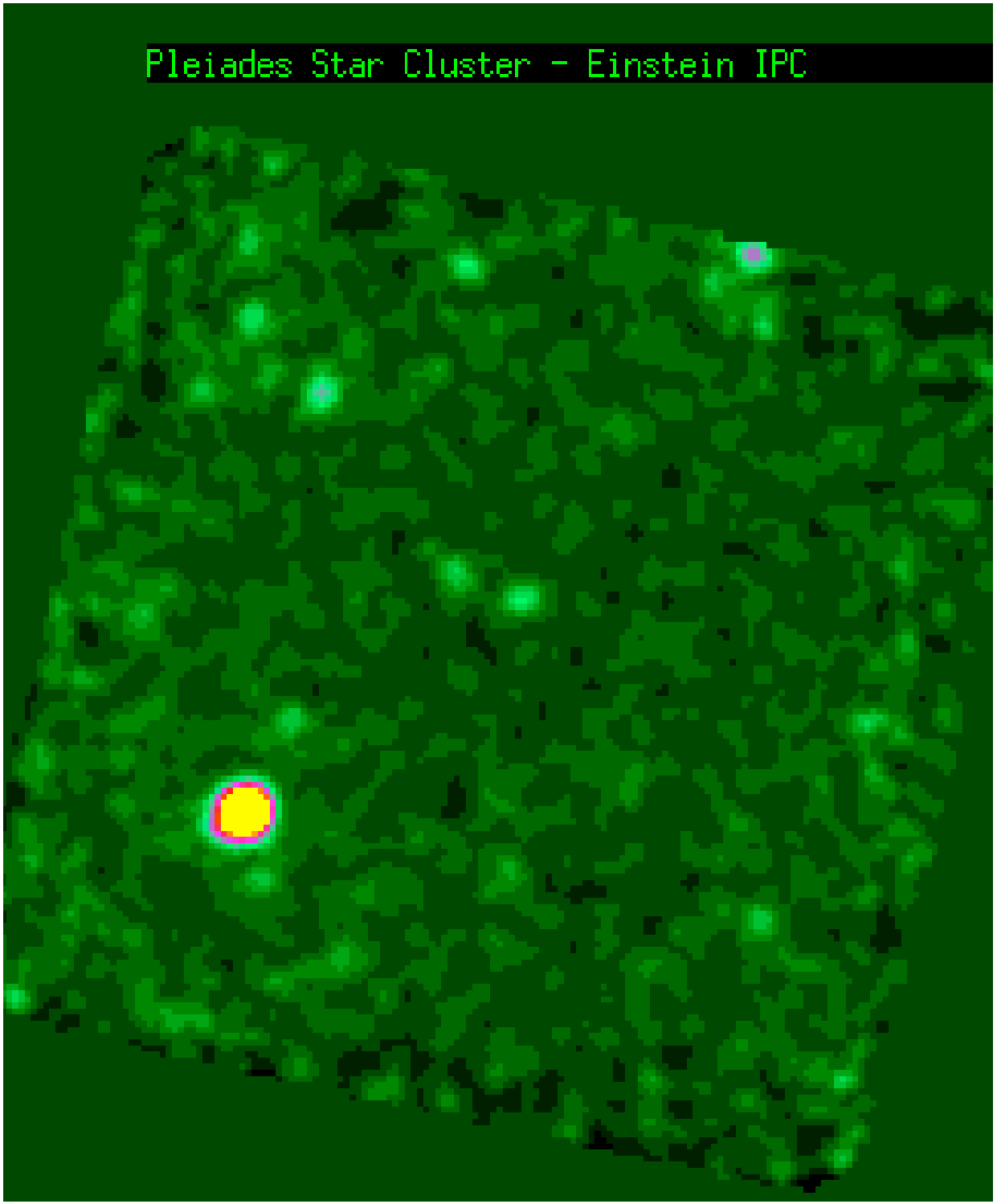
X-Ray telescopes calibration facility

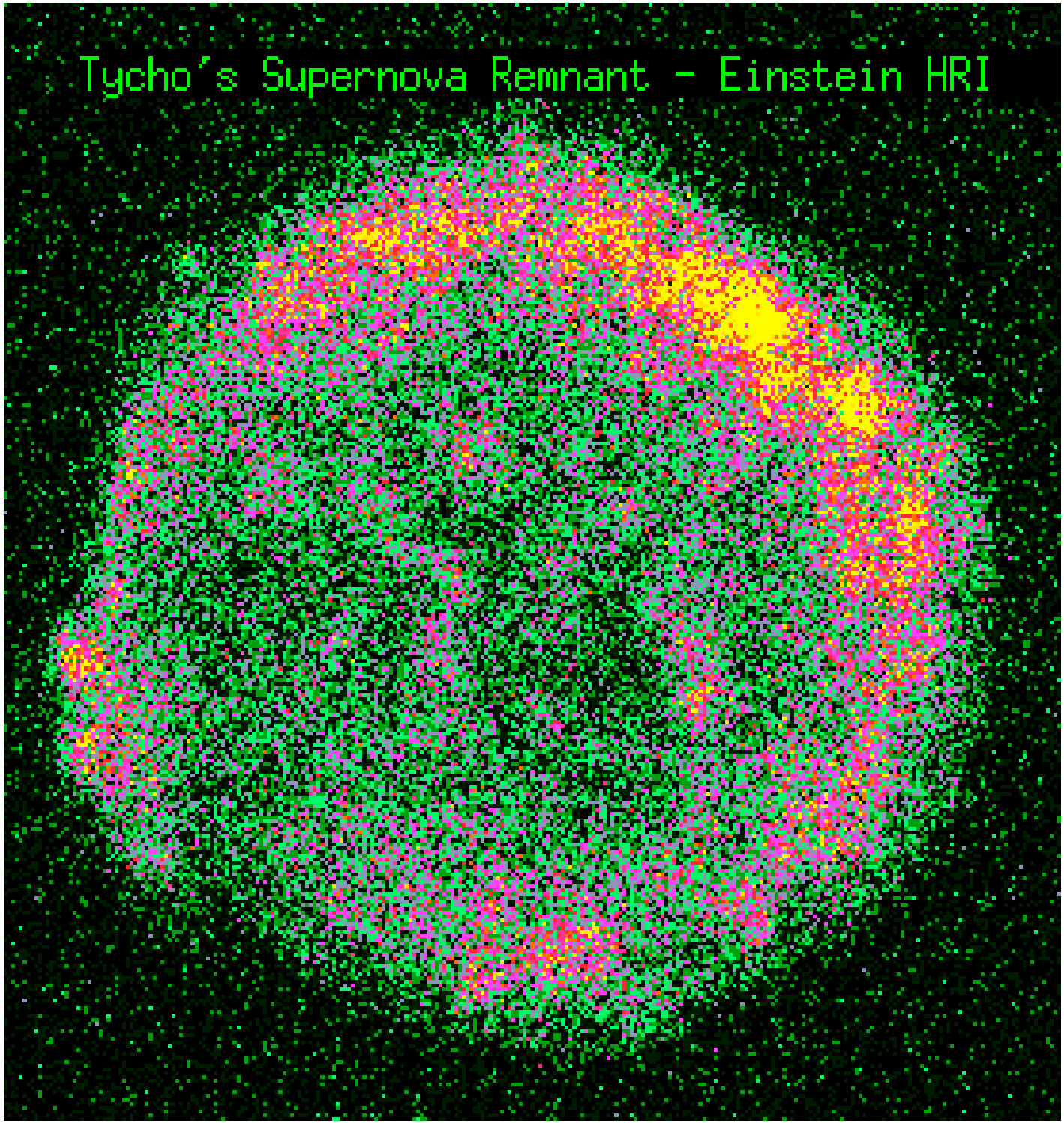


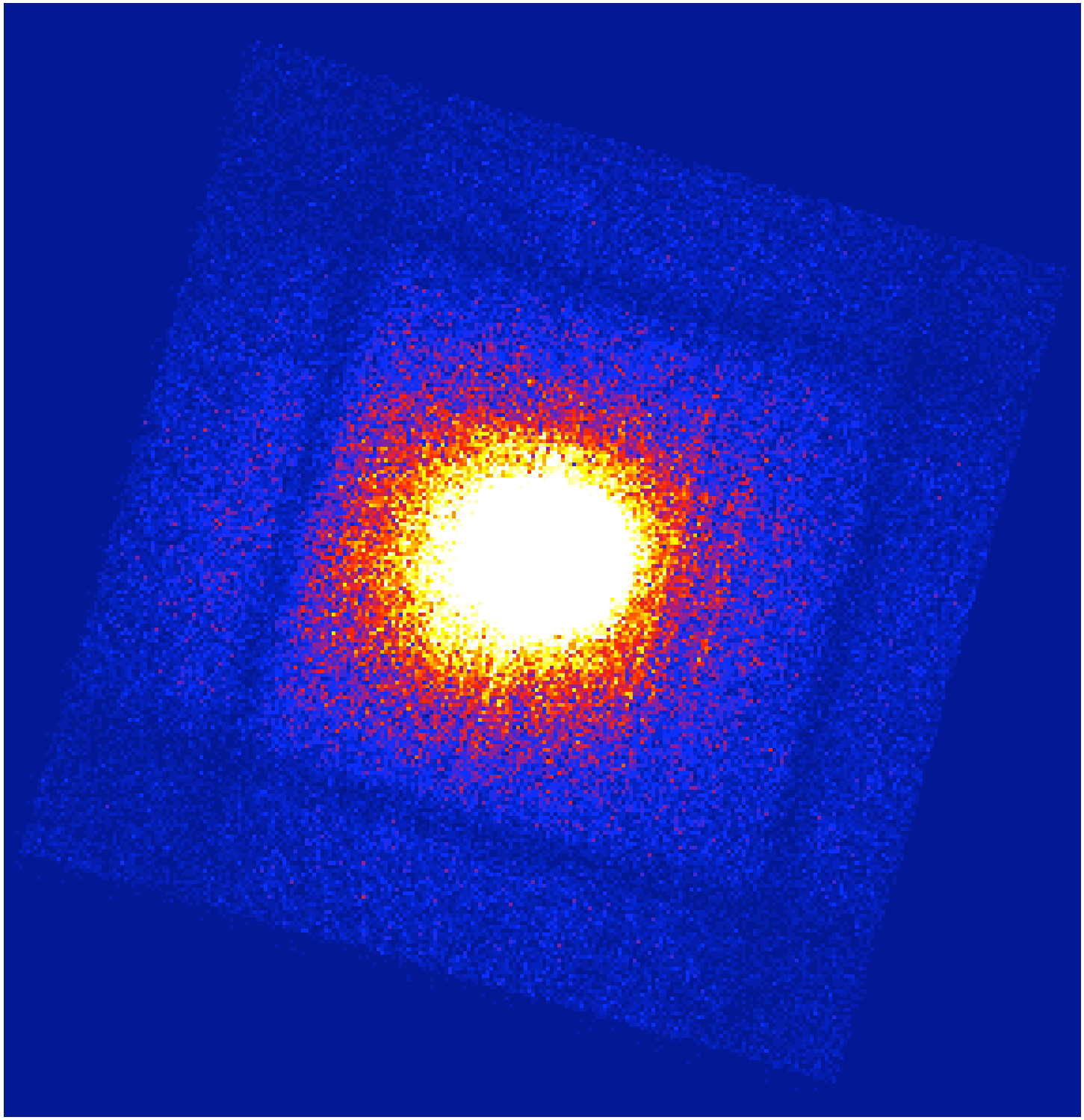


Hyadis star cluster in X-Rays from Einstein


M31 Center - Einstein HRI

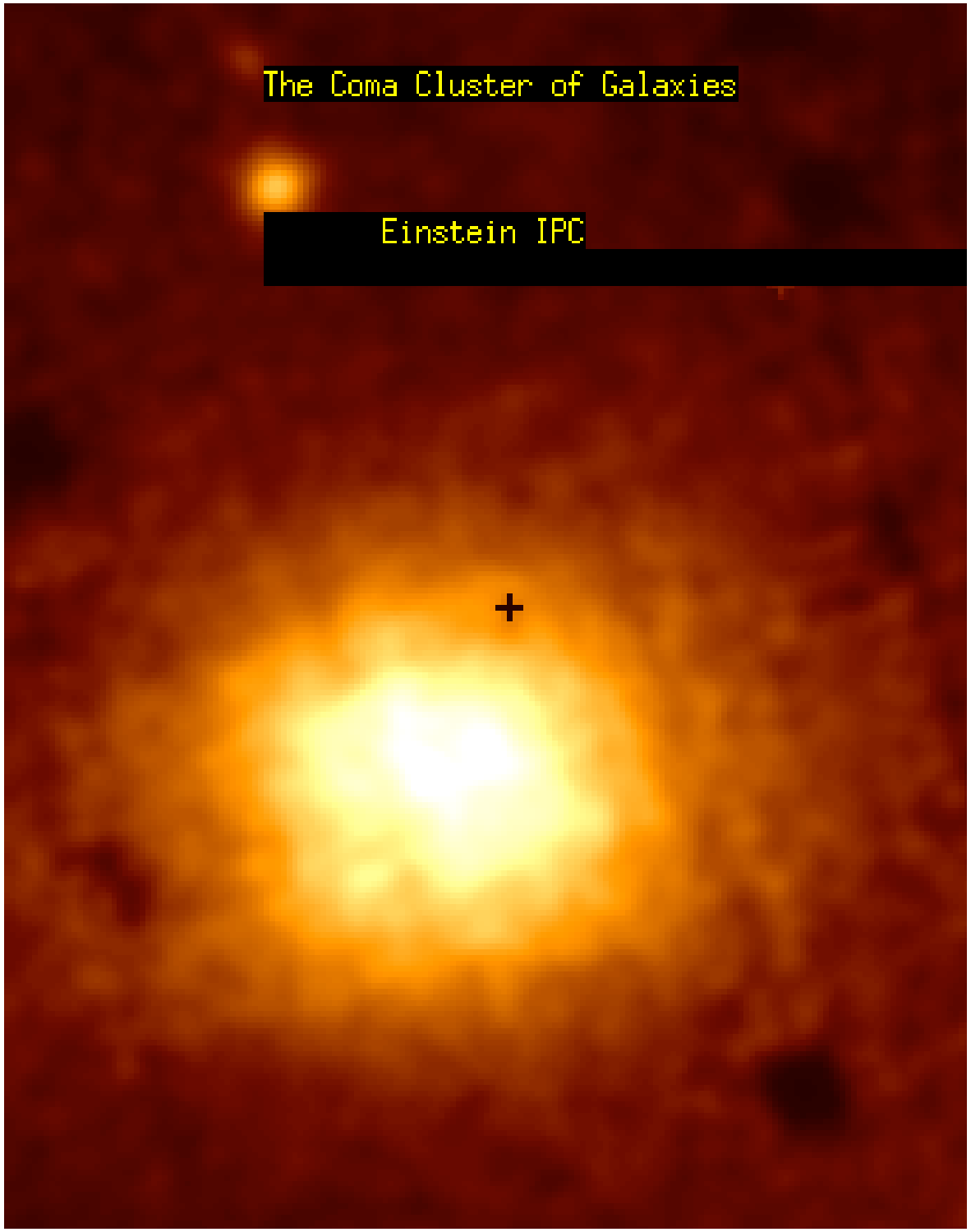

Pleiades Star Cluster - Einstein IPC


Tycho's Supernova Remnant - Einstein HRI



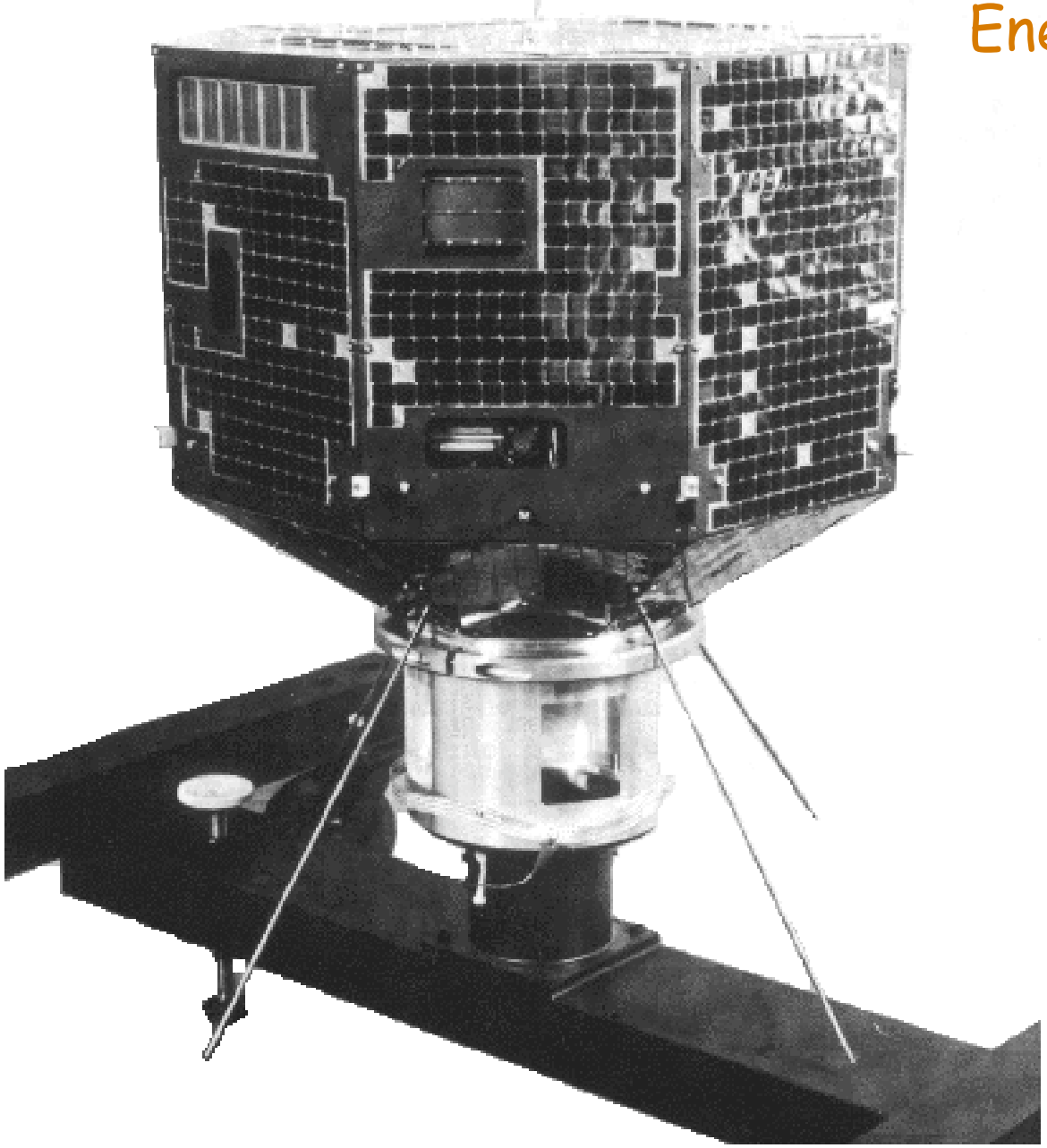
Perseus galaxy cluster

Single galaxies are not resolved but diffuse gas among galaxies well detected. Intercluster space until then was assumed "empty"


The Coma Cluster of Galaxies
Einstein IPC

Lifetime : 21 February 1979 - 16 April 1985

Energy Range : 0.1 - 100 keV



Hakucho (Swan)

Payload:

Very Soft X-ray (VSX) experiment 0.1-0.2 keV
Four units of proportional counters
each with eff area ~ 78 cm^2
Two parallel to the spin axis FOV = 6.3° X 2.9° FWHM two offset FOV = 24.9° X 2.9° FWHM

Soft X-ray (SFX) 1.5-30 keV Six units of proportinal counters.
Parallel to the spin axis : Two FOV 17.6 deg FWHM; eff area=69 cm^2 each
Two FOV 5.8 deg FWHM; eff area=40&83 cm^2
Two offset FOV = 50.3° X 1.7° FWHM eff area =32 cm^2 each.
Hard X-ray (HDX) 10-100 keV scintillator
FOV 4.4° X 10.0° FWHM eff area =45 cm^2

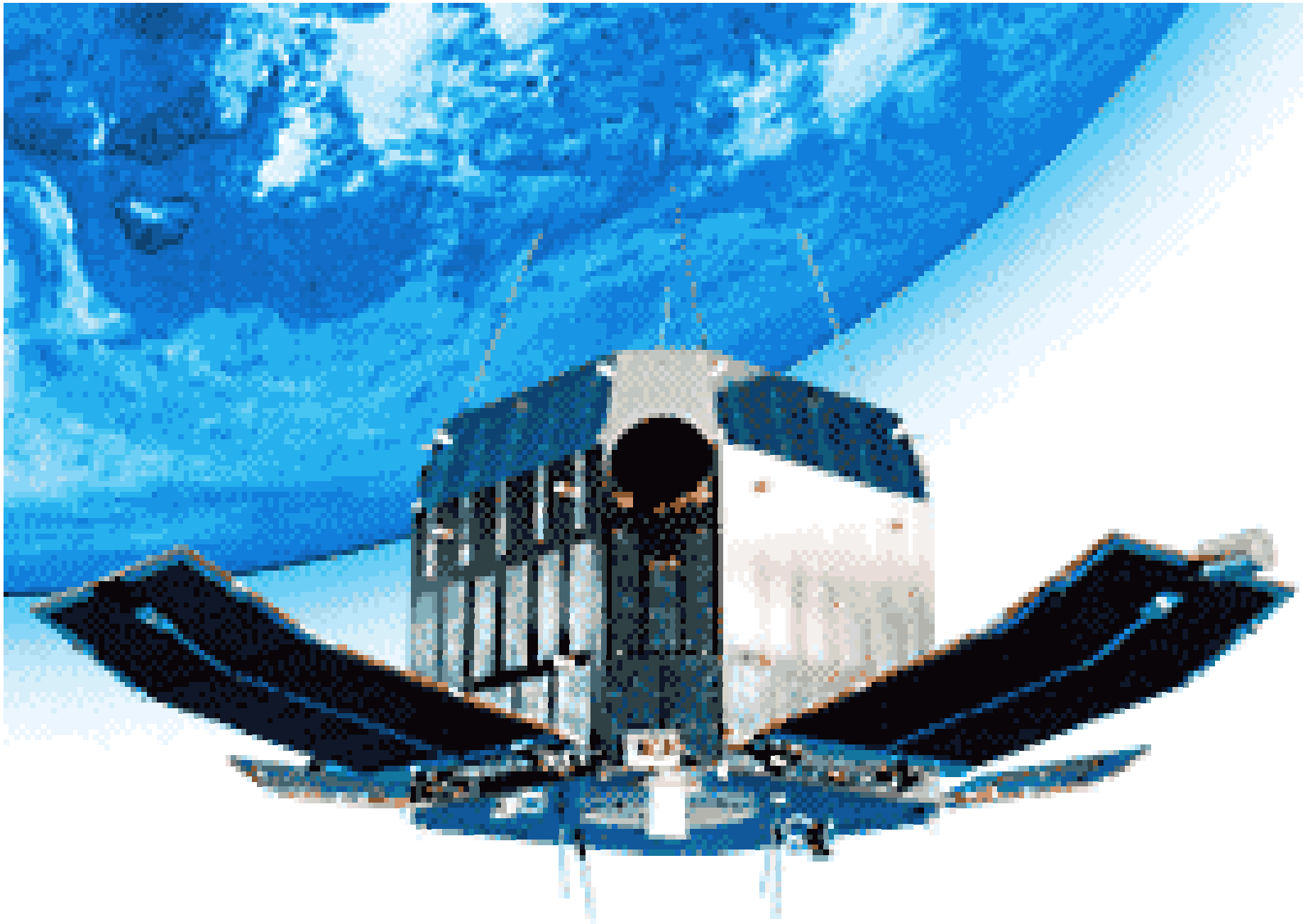
The Hakucho (Swan) [CORSA-B]

Discovery of soft X-ray transient Cen X-4
and Apl X-1

Discovery of many burst sources

Long-term monitoring of X-ray pulsar (*e.g.* Vela X-1)

Discovery of 2 Hz variability in the Rapid Burster
later named Quasi Period Oscillation



TENMA Astro-B

TENMA (Pegasus)

Lifetime : February 20, 1983 - November, 22 1985

Energy Range : 0.1 keV - 60 keV

Payload

Gas Scintillator Proportional Counter: 10 units of 80 cm^2 each, FOV ~ 3deg (FWHM), 2 - 60 keV

X-ray focusing collector: 2 units of 7 cm^2 each, 0.1 -2 keV

Transient Source Monitor: 2 - 10 keV

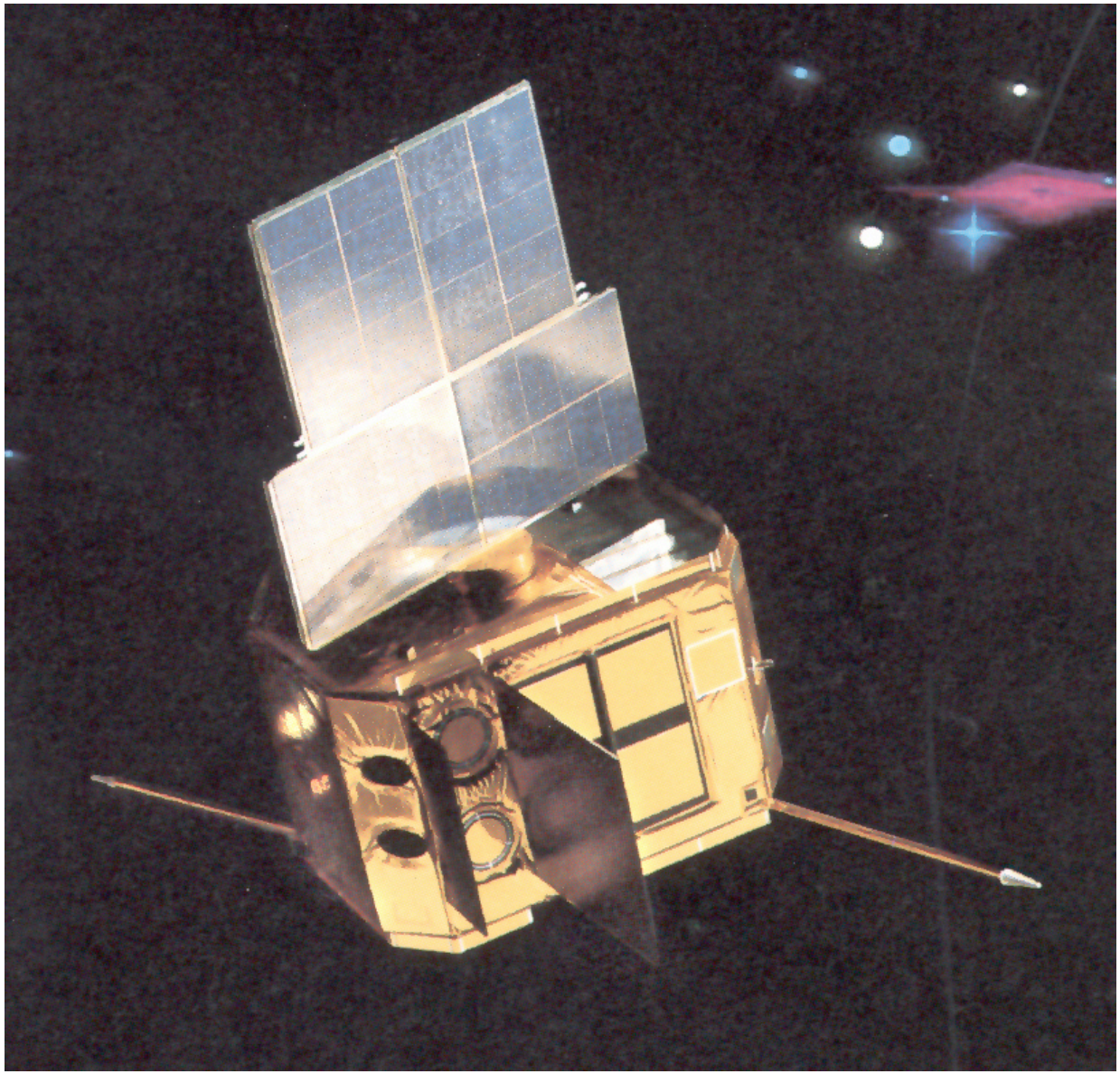
Radiation Belt Monitor/Gamma-ray burst detector

Tenma [Astro B]

Discovery of the Iron helium-like emission from the galactic ridge

Iron line discovery and/or study in many LMXRB, HMXRB and AGN

Discovery of an absorption line at 4 keV in the X1636-536 Burst spectra



EXOSAT ESA

launch: 26 may 1983

End 9 april 1986

Very eccentric: orbit duration 90 h

Energy range: 0.05-2 keV & 1-50keV

EXOSAT

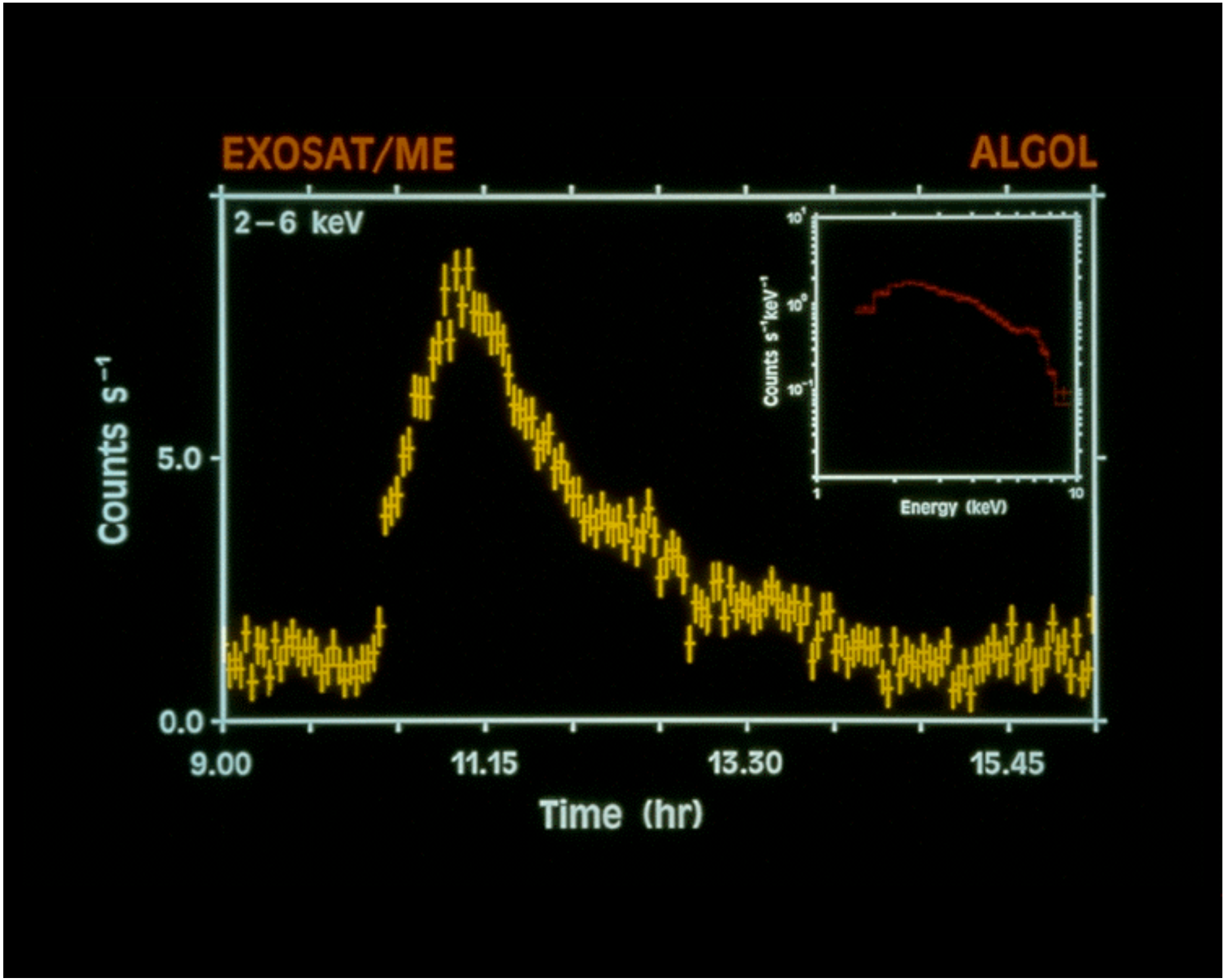
Discovery of the Quasi Period Oscillations in LMXRB and X-ray Pulsars

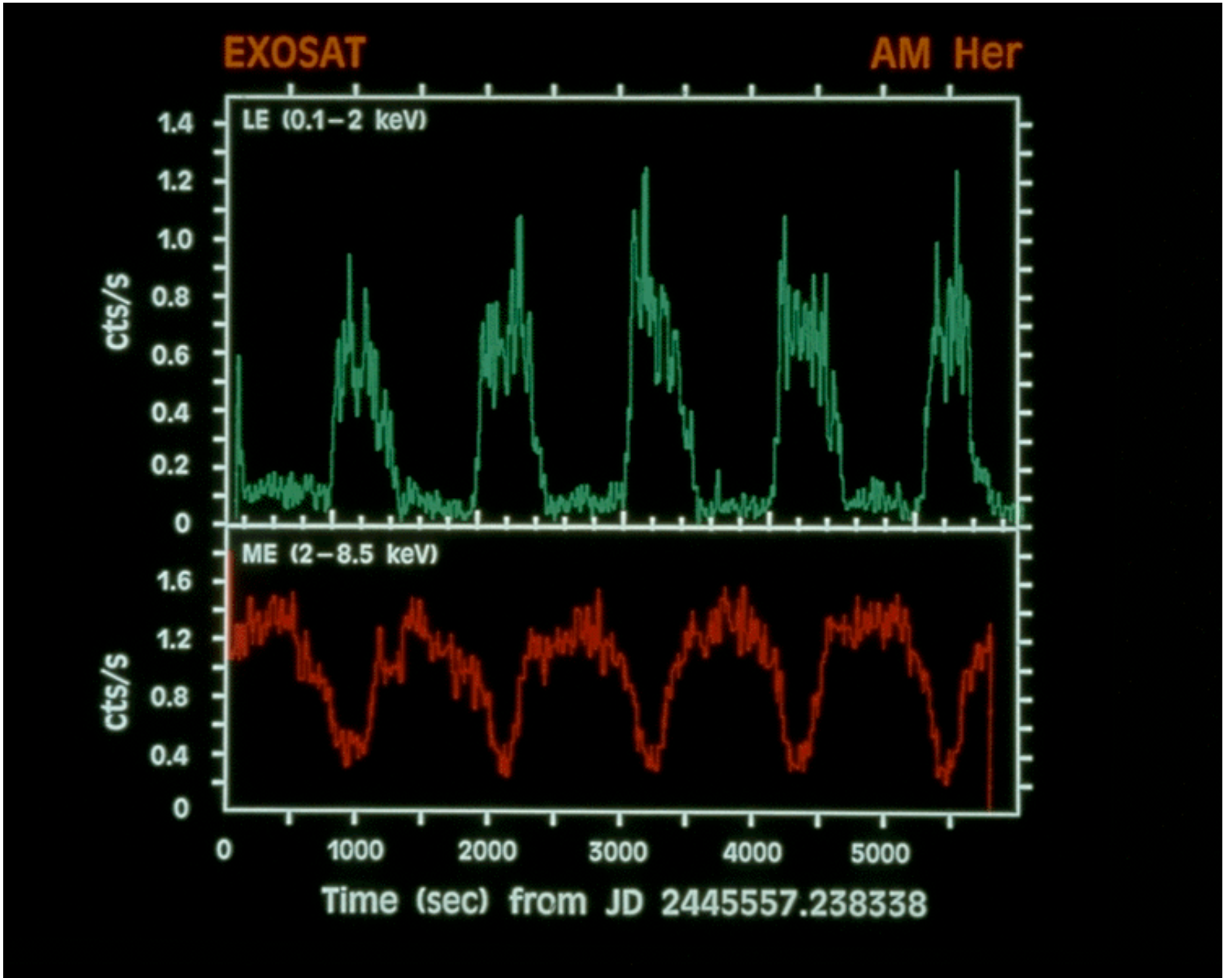
Comprehensive study of AGN variability

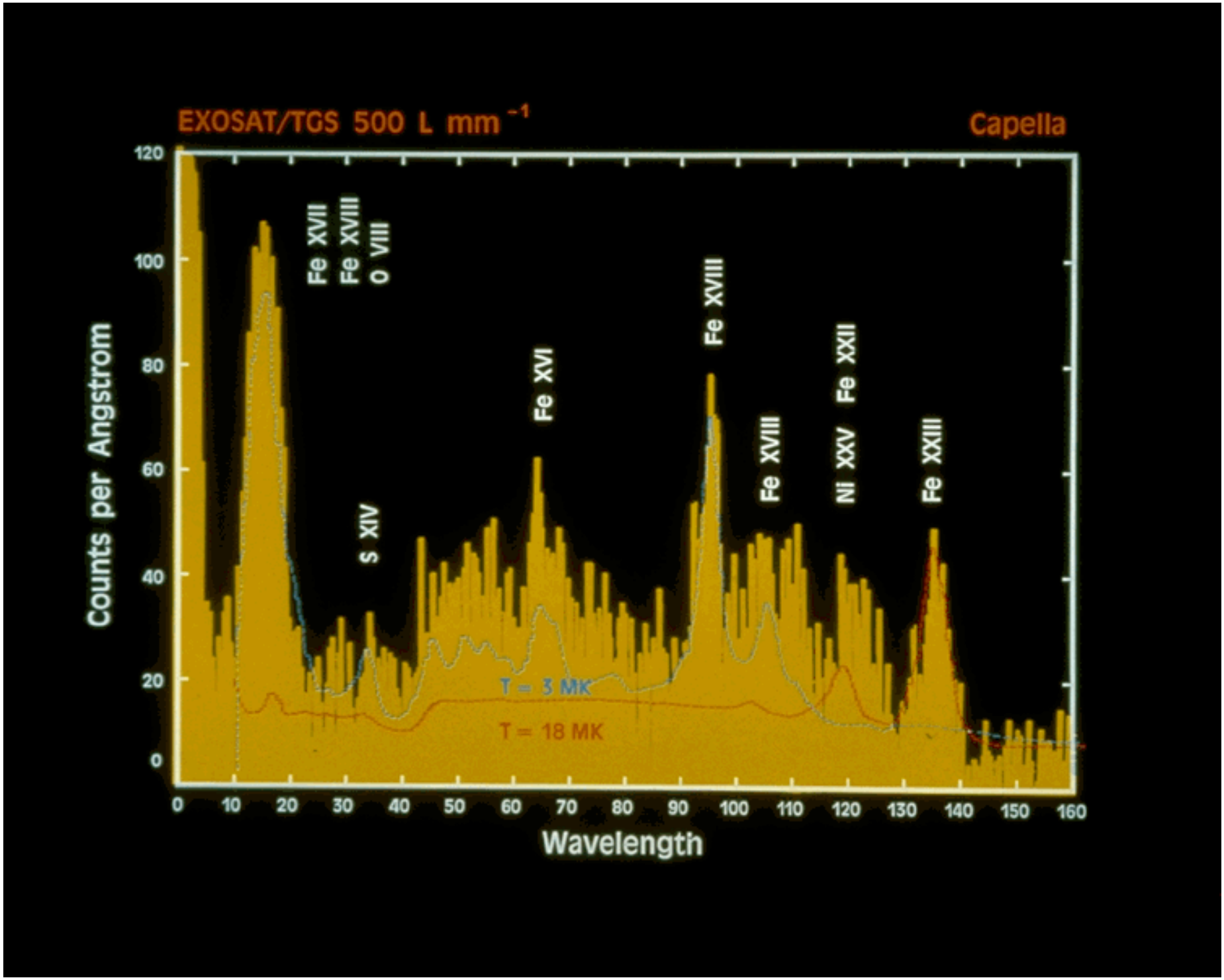
Observing LMXRB and CV over many orbital periods

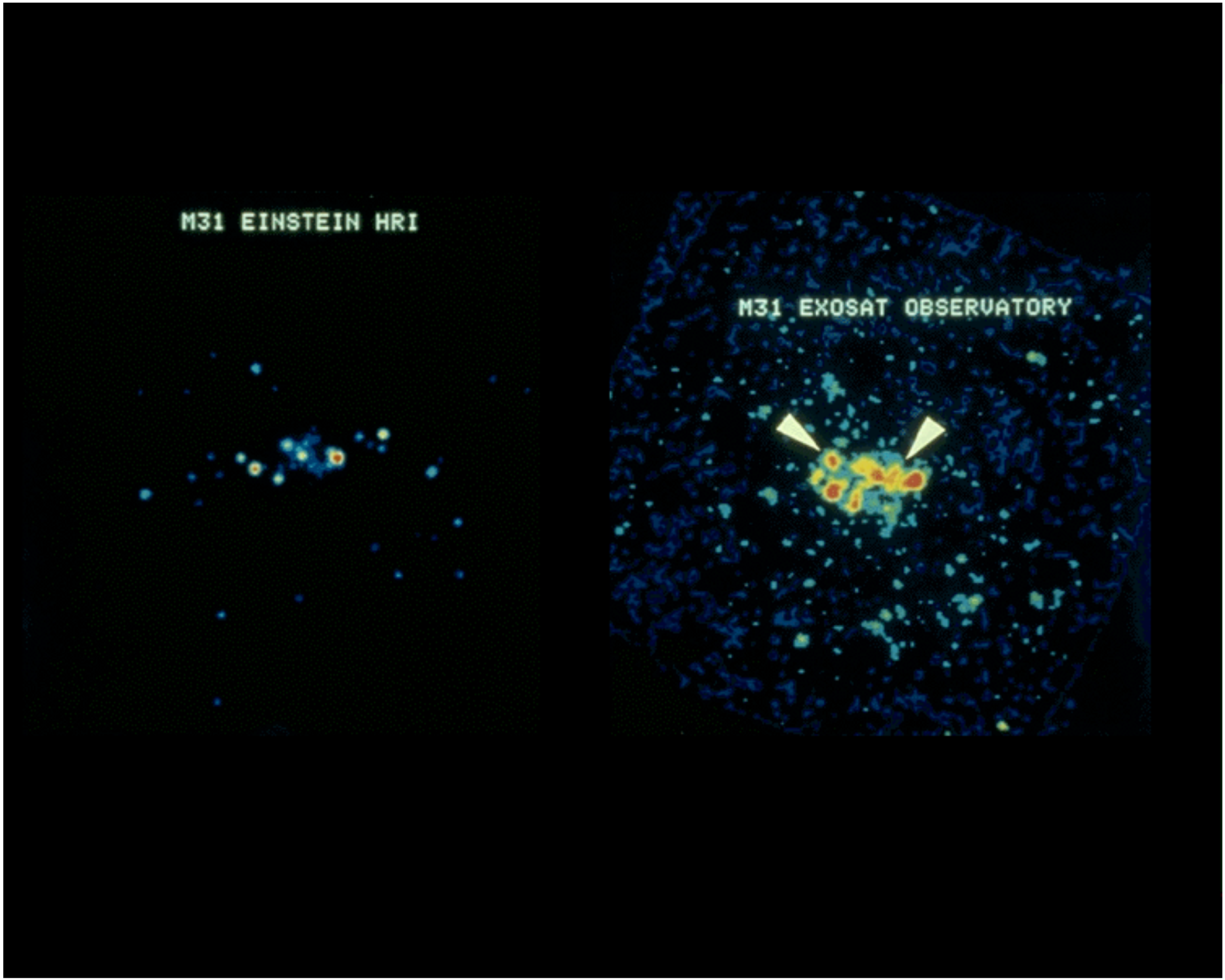
Measuring iron line in galactic and extra galactic sources

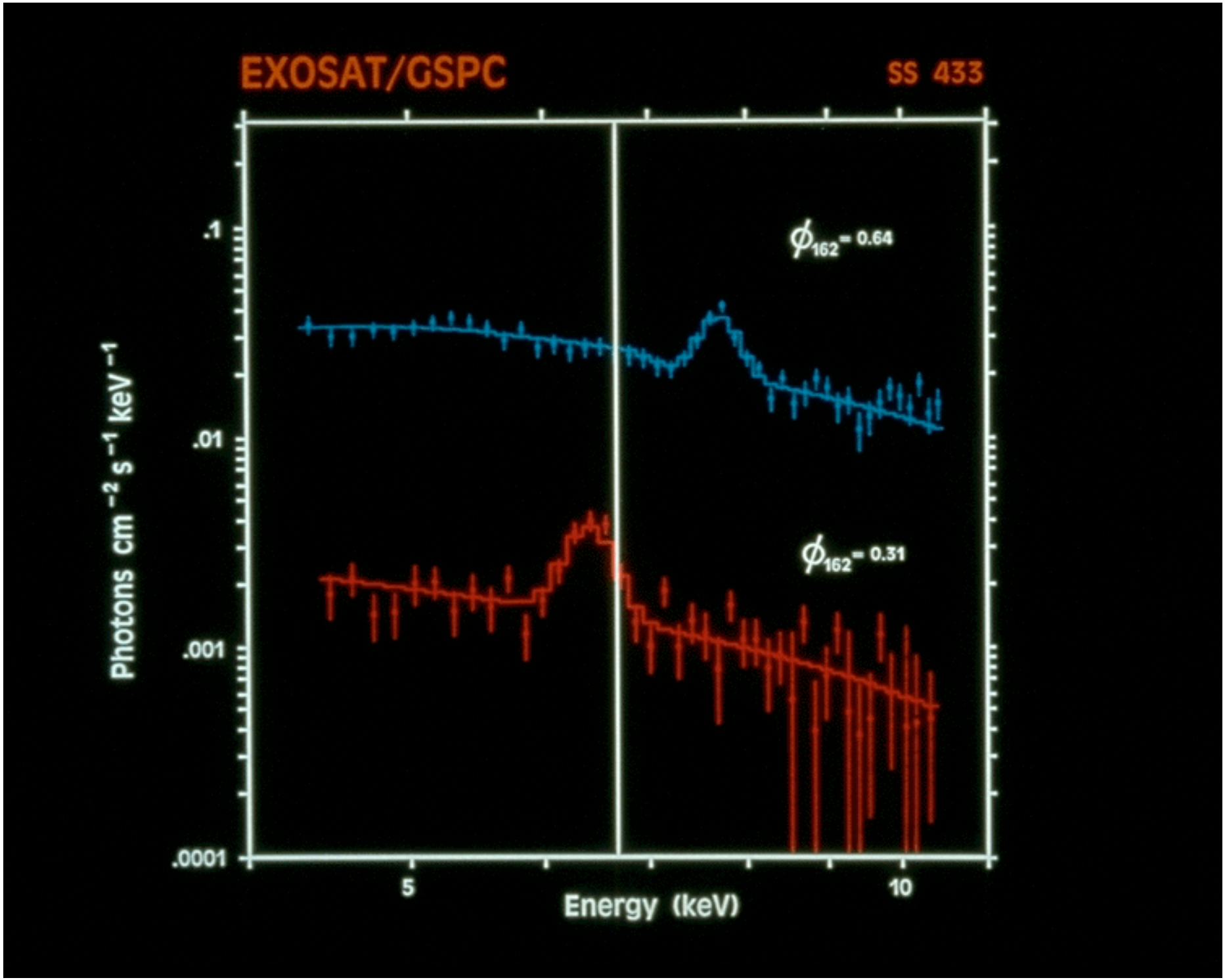
Obtaining low-energy high-resolution spectra

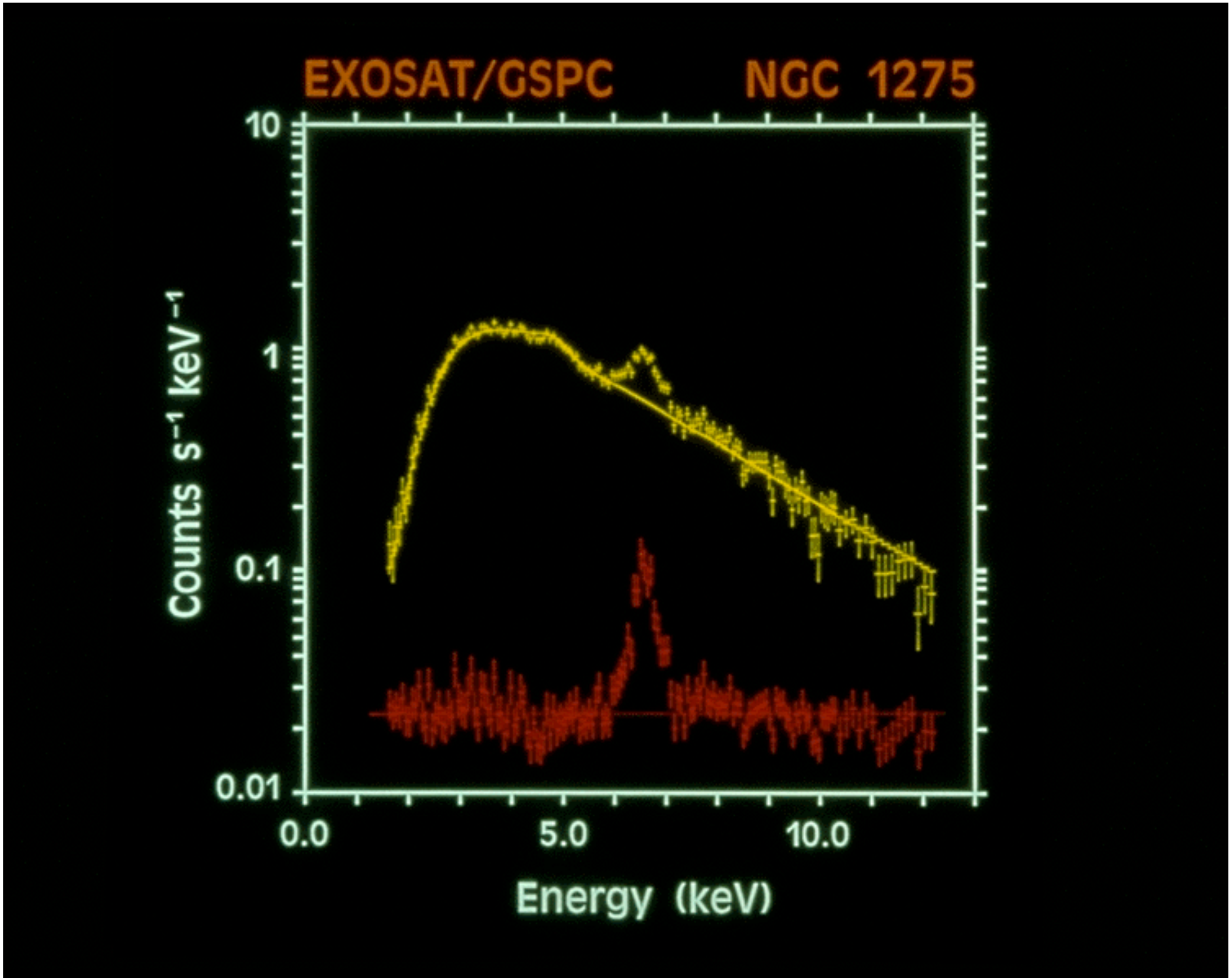

EXOSAT/ME
ALGOL
2–6 keV
Counts s⁻¹
5.0
0.0
9.00
11.15
13.30
15.45
Time (hr)
Counts s⁻¹keV⁻¹
Energy (keV)
1
10

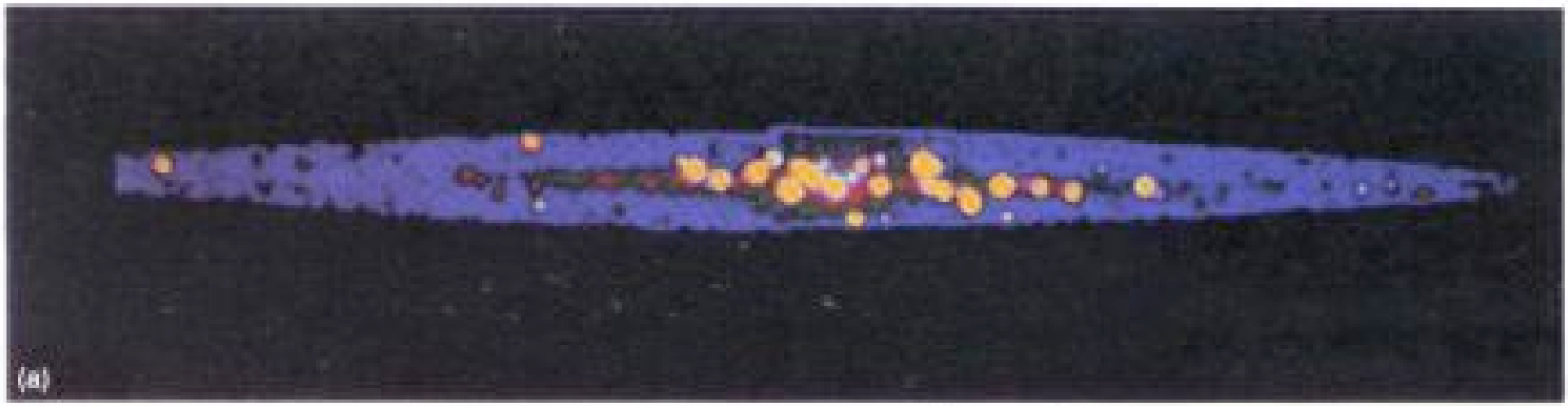

EXOSAT
AM Her
LE (0.1–2 keV)
ME (2–8.5 keV)
cts/s
cts/s
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
1.6
1.2
0.8
0.4
0
0
1000
2000
3000
4000
5000
Time (sec) from JD 2445557.238338

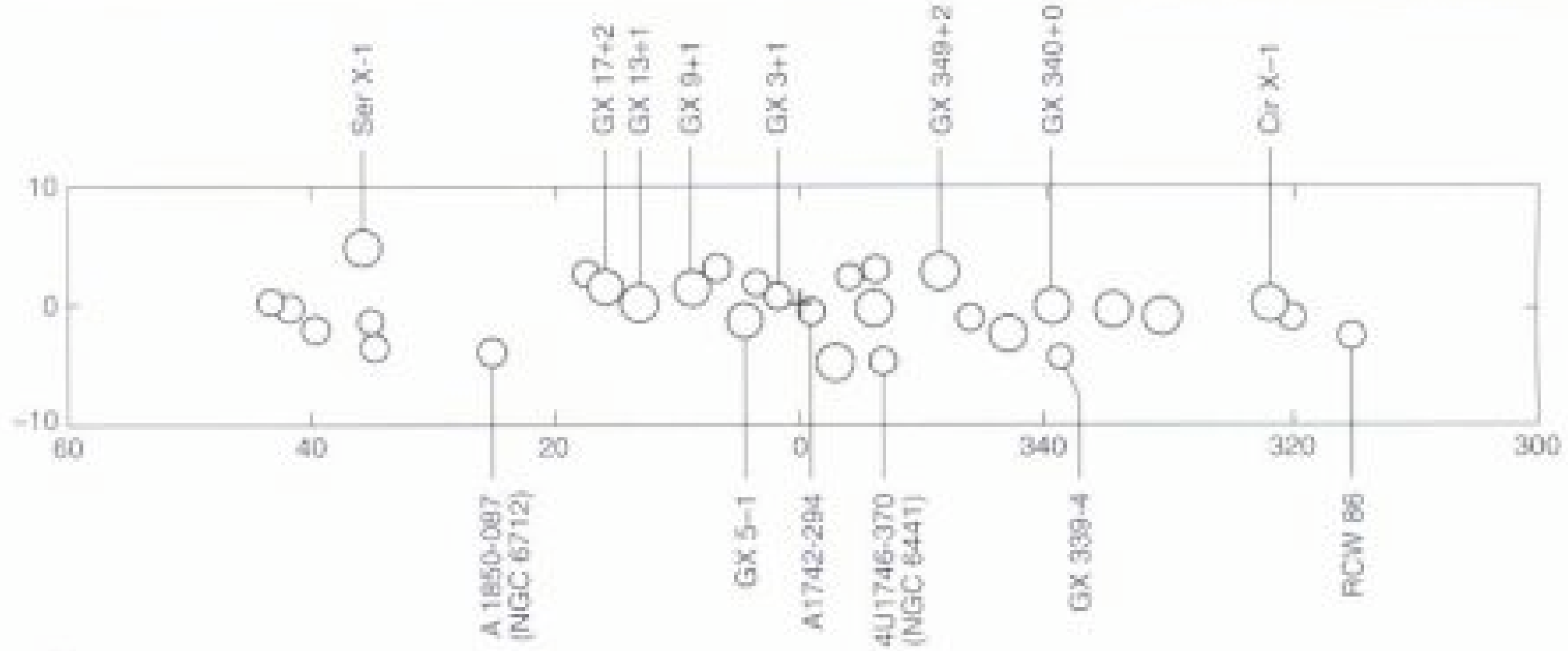

EXOSAT/TGS 500 L mm $^{-1}$
Capella
Counts per Angstrom
Wavelength
Fe XVII
Fe XVIII
O VIII
S XIV
Fe XVI
Fe XVIII
Fe XVIII
Ni XXV
Fe XXII
Fe XXIII
T = 3 MK
T = 18 MK
0
20
40
60
80
100
120
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160

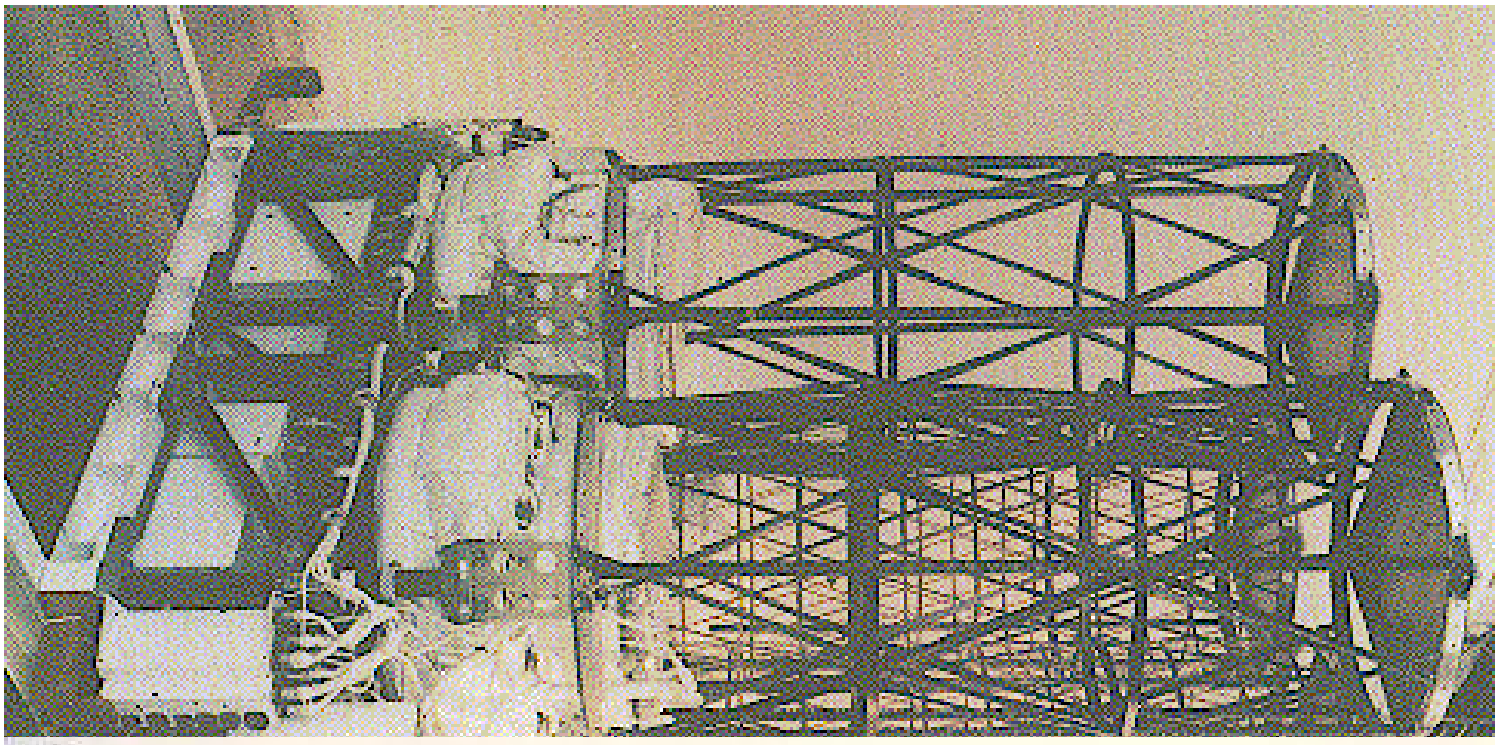

M31 EINSTEIN HRI
M31 EXOSAT OBSERVATORY

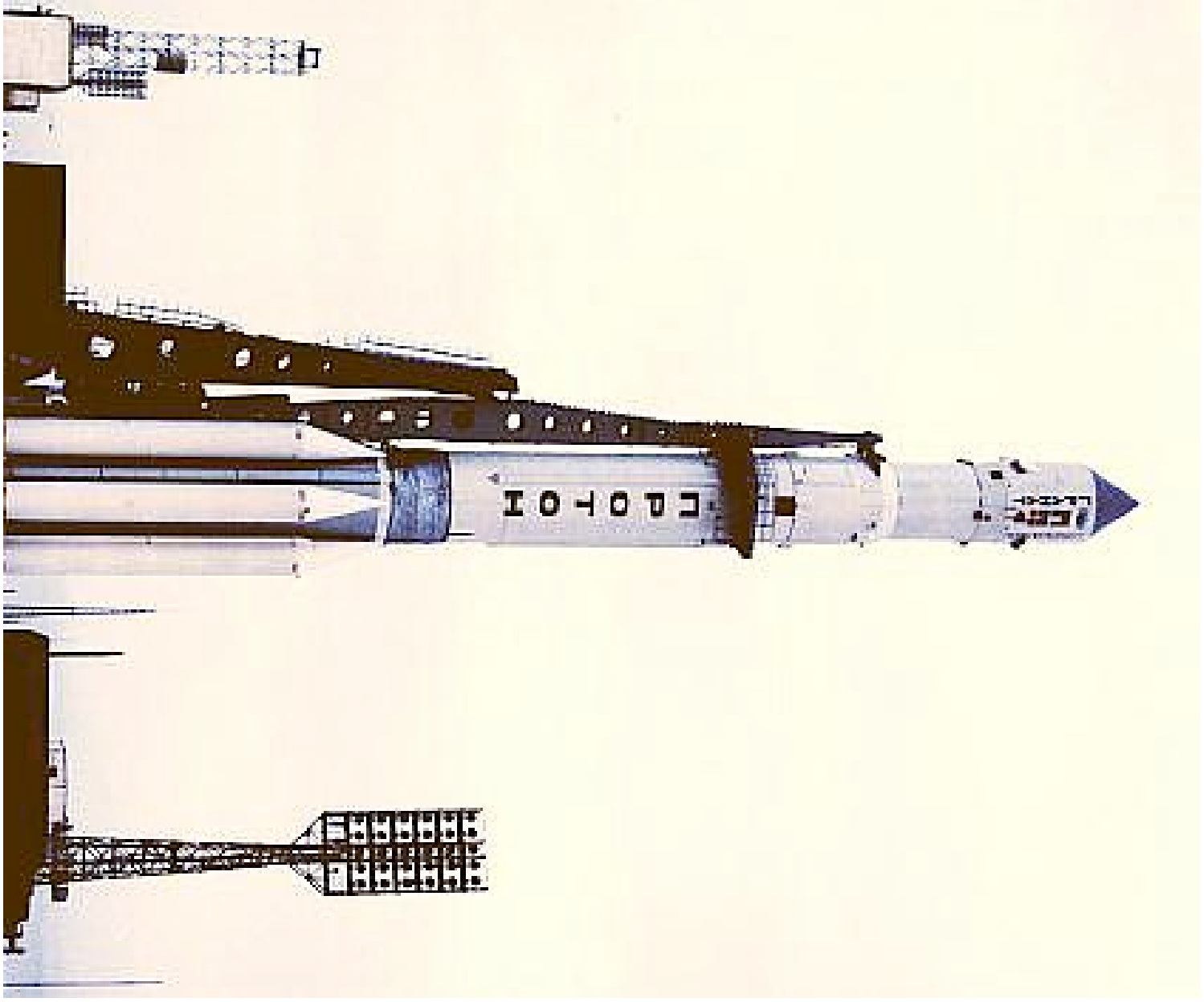

EXOSAT/GSPC
SS 433
ϕ_{162}= 0.64
ϕ_{162}= 0.31
Photons cm $^{-2}$ s $^{-1}$ keV $^{-1}$
.1
.01
.001
.0001
5
10
Energy (keV)


EXOSAT/GSPC
NGC 1275
10
1
0.1
0.01
Counts s⁻¹ keV⁻¹
0.0
5.0
10.0
Energy (keV)


(a)


Ser X-1
GX 17+2
GX 13+1
GX 9+1
GX 3+1
GX 349+2
GX 340+0
Cir X-1
10
0
-10
60
40
20
0
340
320
300
A 1850-087 (NGC 6712)
GX 5-1
A1742-294
4U1746-370 (NGC 6441)
GX 339-4
RCW 86





Coded-mask X-ray telescope (SIGMA)
0.03-1.3 MeV, eff. area 800 cm², FOV 5°x5°

Coded-mask X-ray telescope (ART-P)
4-60 keV, eff. area 1250 cm², FOV 1.8°x1.8°

X-ray proportional counter spectrometer (ART-S)
3-100 keV, eff. area 2400 cm² at 10 keV, FOV 2°x2°

All-sky monitor (WATCH)
6-120 keV, eff. area 45 cm², FOV All-sky

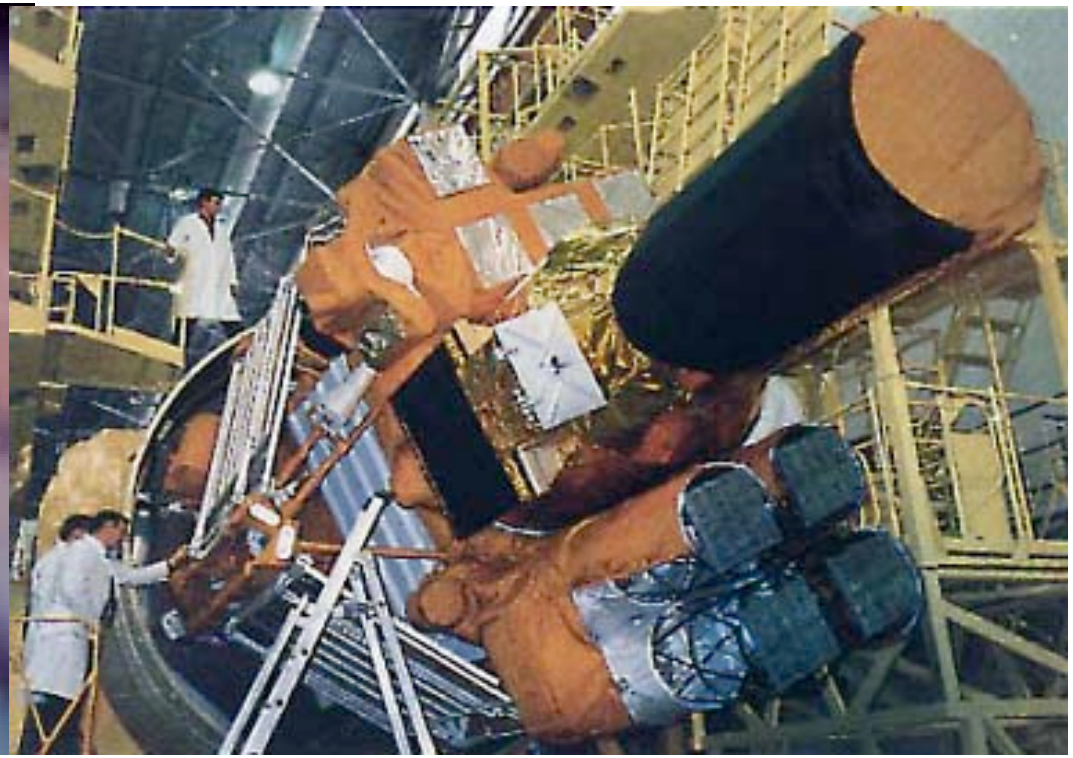
Gamma-ray burst experiment (PHEBUS)
0.1-100 MeV, 6 units of 100 cm² each, FOV All-sky

Gamma-ray burst experiment (KONUS-B)
0.02-8 MeV, 7 units of 315 cm² each, FOV All-sky

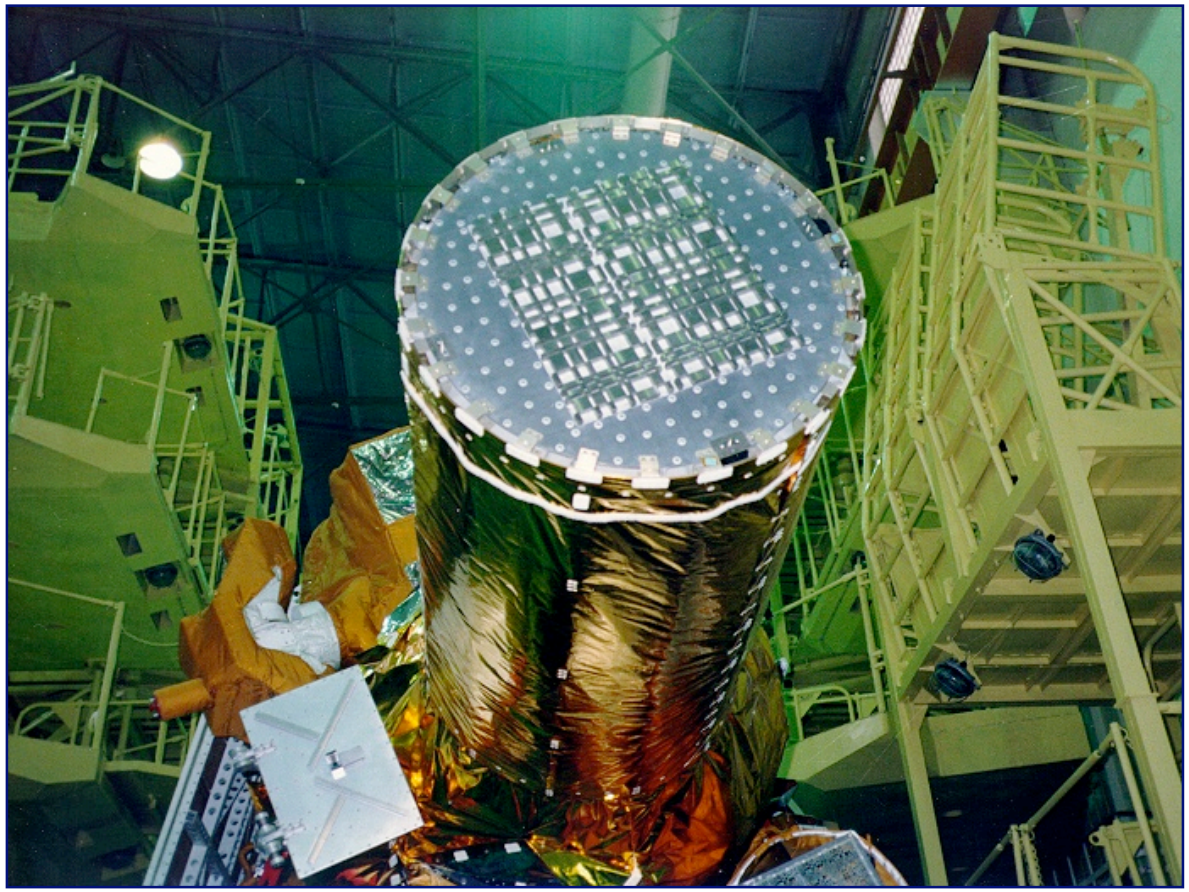
Gamma-ray burst experiment (TOURNESOL)
0.002-20 MeV), FOV 5°x5°

Lifetime : December 1, 1989 - November 27, 1998

Energy Range : 2 keV - 100 MeV



SIGMA aboard GRANAT: The precursor

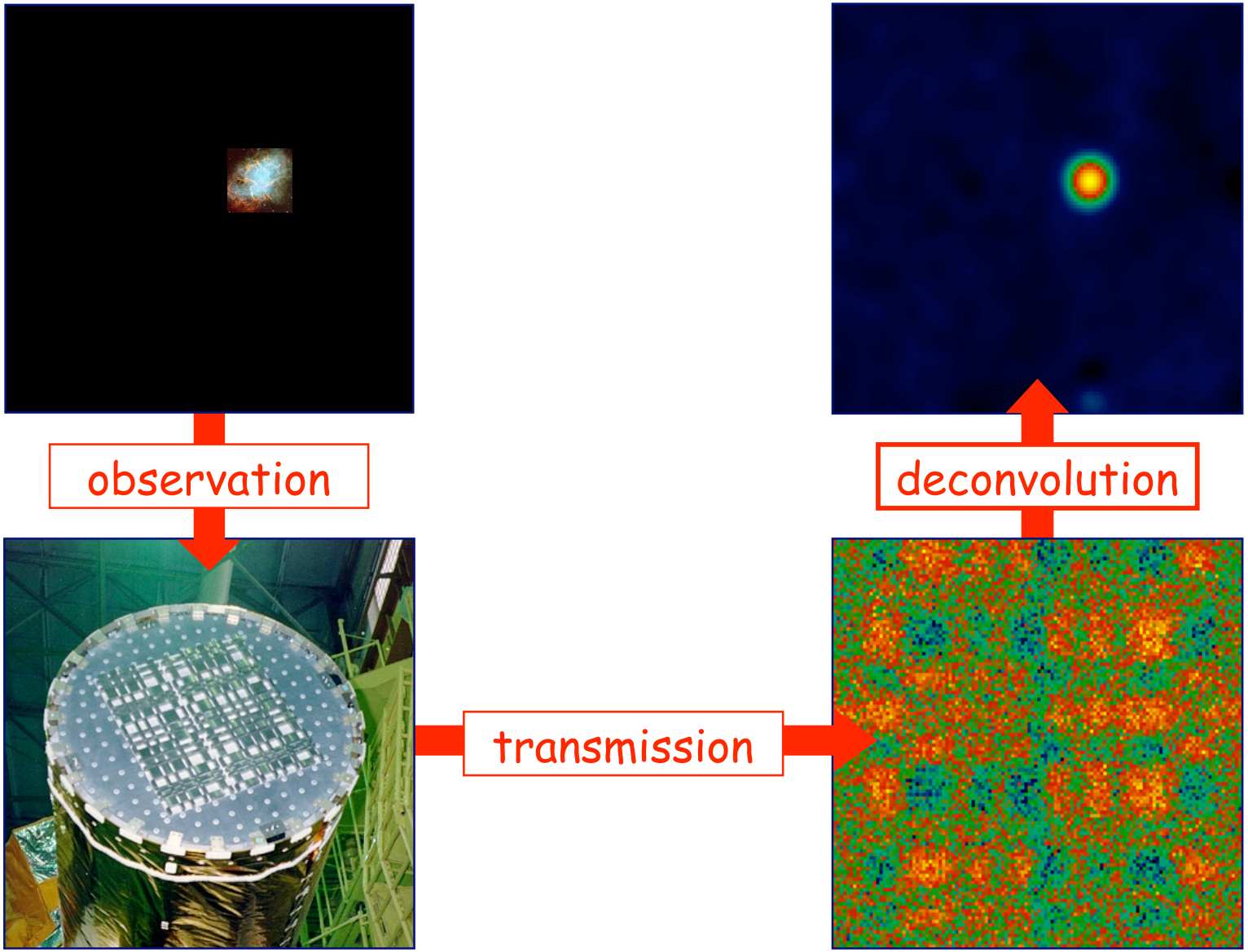


First space coded mask telescope in operation from 1990 to 1997

Energy range: 35 keV - 1.3 MeV

Source location accuracy: 30″ - 5′

It works!

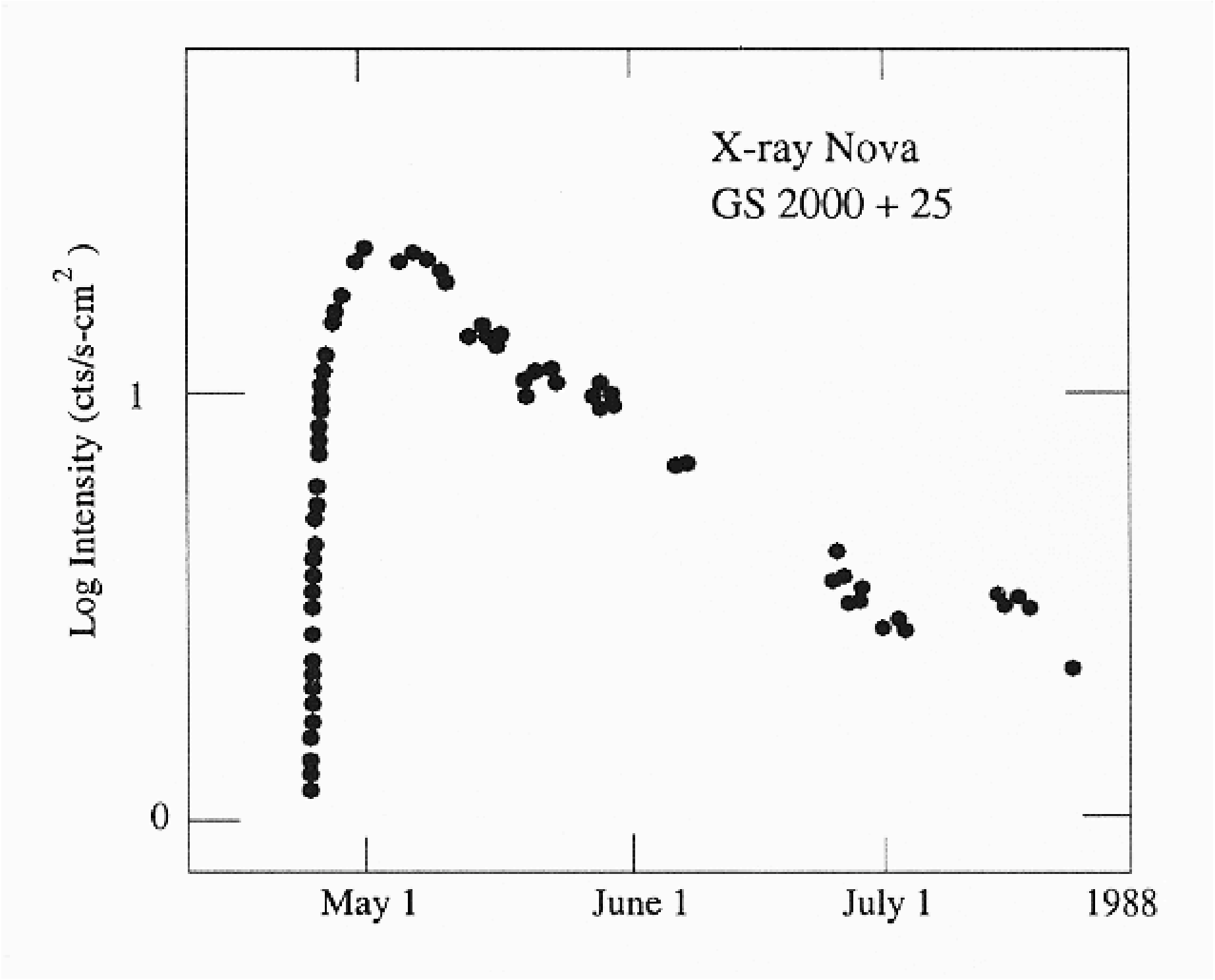


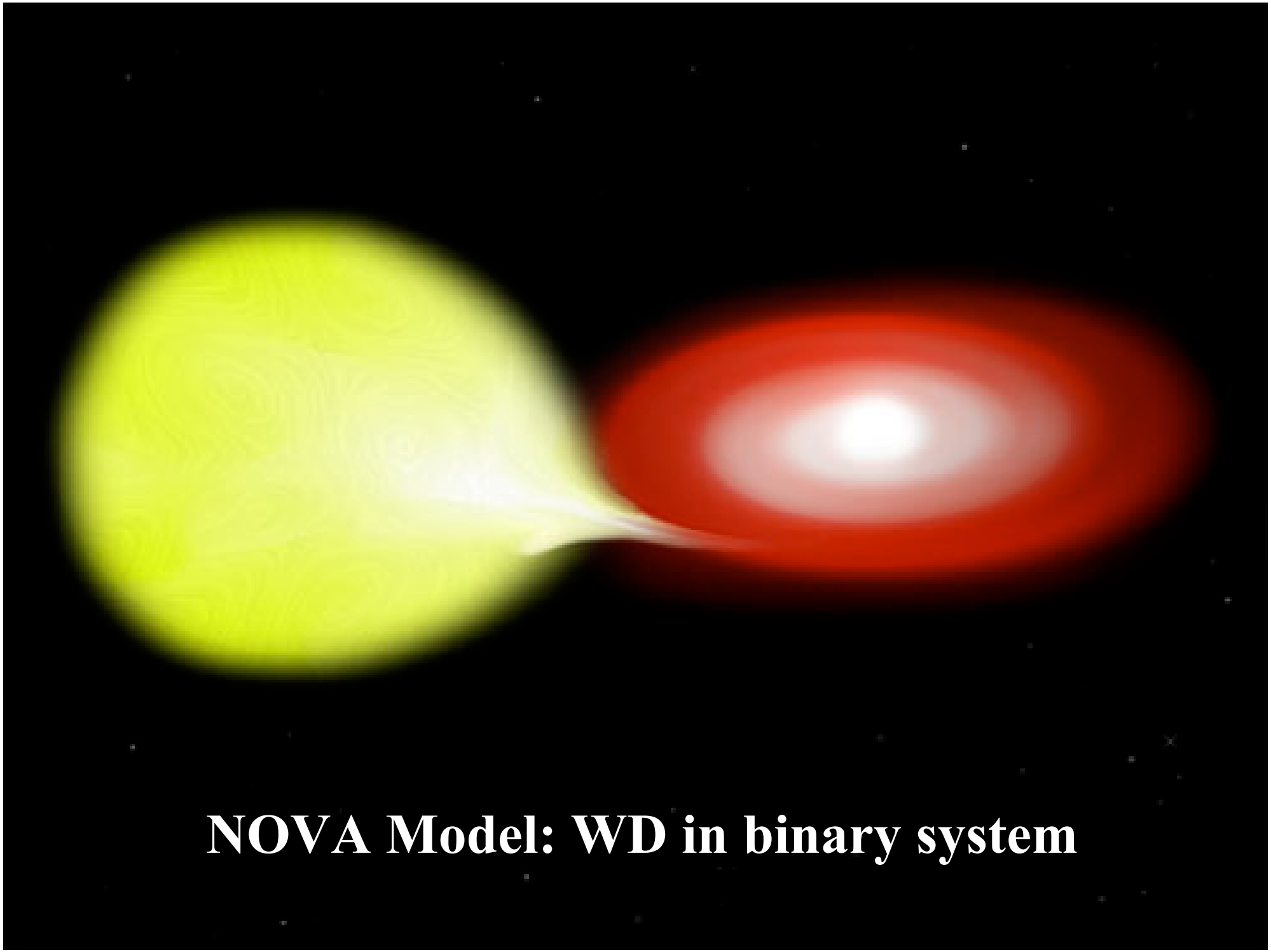
Granat

A very deep (more than 5 million sec.) imaging of the galactic center region.

Discovery of electron-positron annihilation lines from the Galactic "micro-quasar" 1E1740-294 and the X-ray Nova Muscae.

Study of spectra and time variability of black hole candidates.


X-ray Nova
GS 2000 + 25
Log Intensity (cts/s-cm^2)
1
0
May 1
June 1
July 1
1988


NOVA Model: WD in binary system

The Ginga Satellite

Lifetime : February 5, 1987 - November 1, 1991

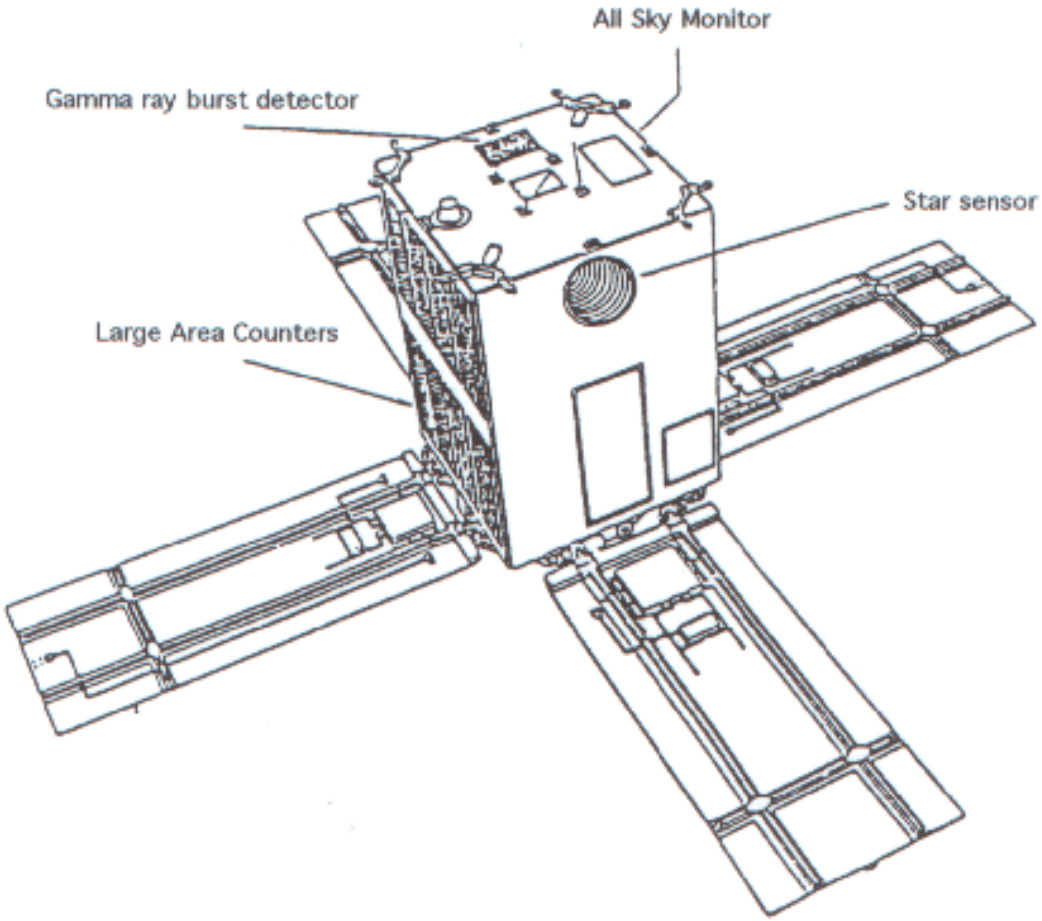
Energy Range : 1 - 500 keV

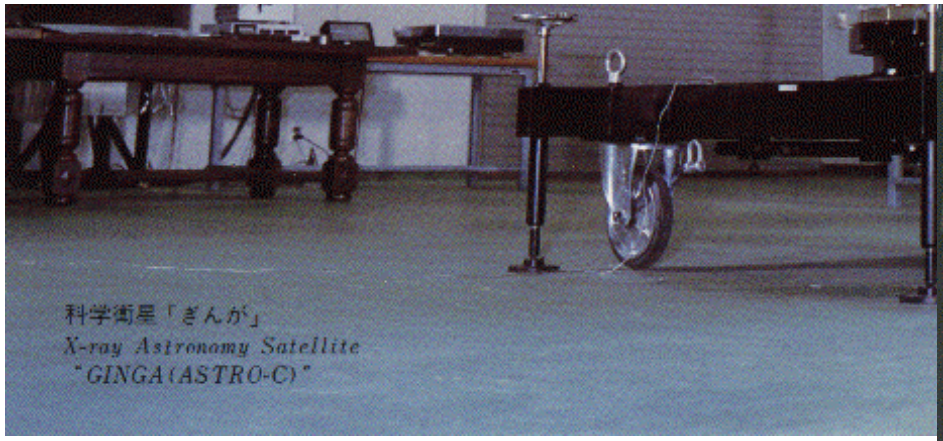
Payload :

Large Area Proportional Counter (LAC) 1.5-37 keV
Eff. area = 4000 cm^2, FOV = 0.8° x 1.7°

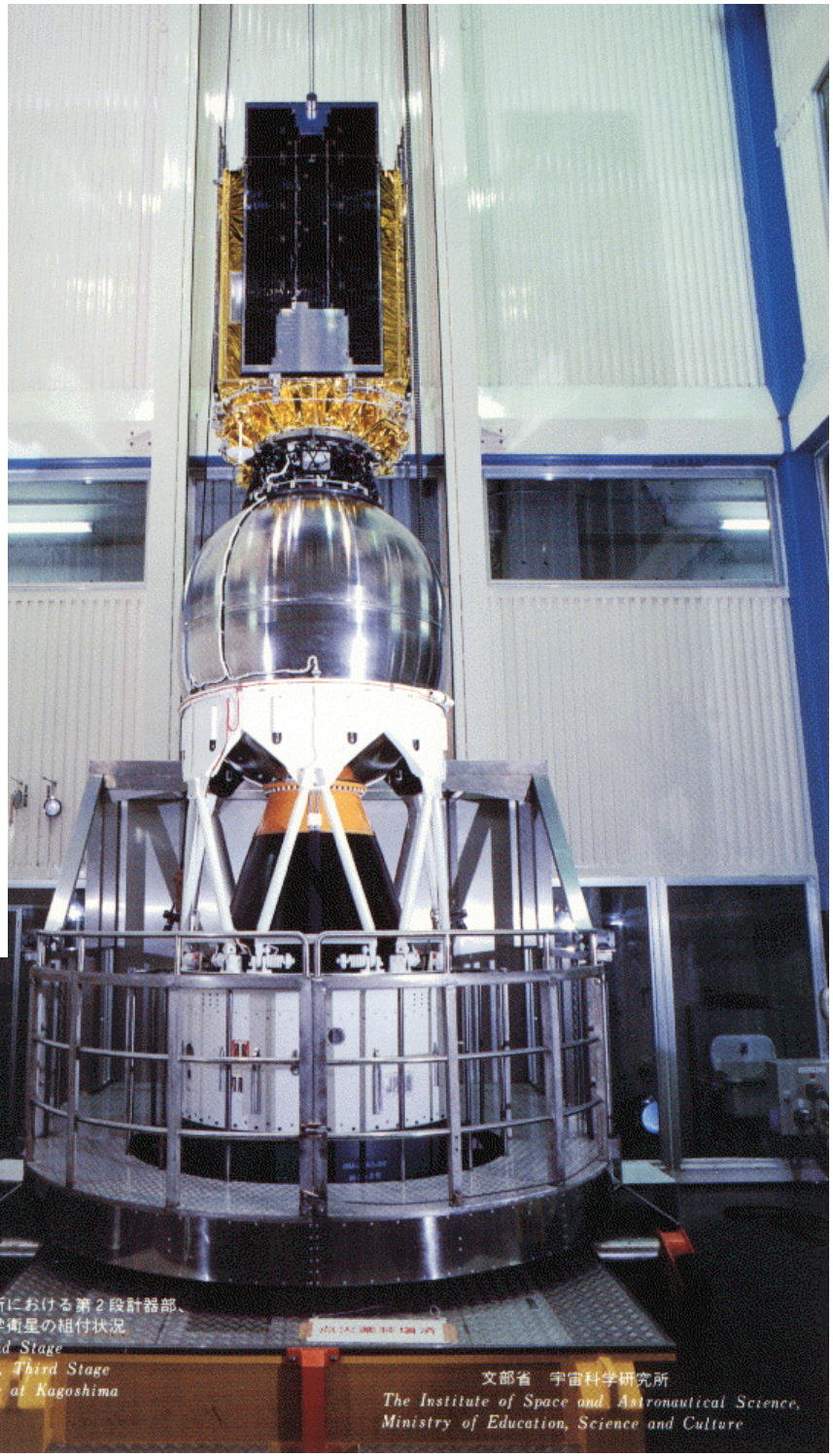
All-Sky Monitor (ASM) 1-20 keV
Eff. area = 70 cm^2, FOV = 1° x 180°

Gamma-Ray Burst Detector (GBD) 1.5-500 keV
Eff. area = 60 cm2 (SC) and 63 cm^2 (PC), FOV = All-sky





科学衛星「ぎんが」
X-ray Astronomy Satellite
"GINGA (ASTRO-C)"



鹿児島宇宙空間観測所における第２段計器部、第３段モータ及び科学衛星の組付状況
Integration of Second Stage Instrumentation Bay, Third Stage Motor, and Satellite at Kagoshima Space Center

文部省　宇宙科学研究所
The Institute of Space and Astronautical Science, Ministry of Education, Science and Culture

GINGA

Discovery of transient Black Hole Candidates and study of their spectral evolution.

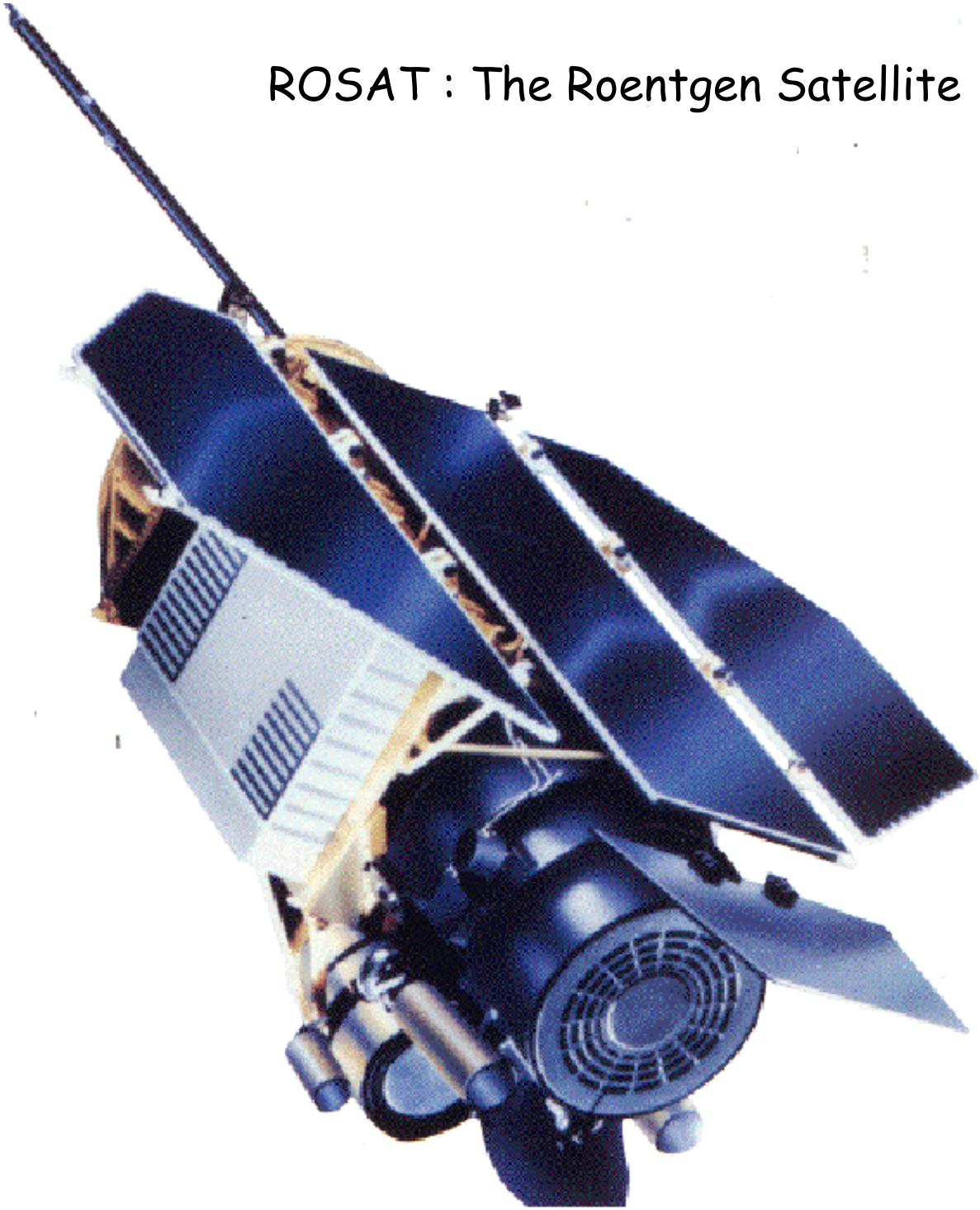
Discovery of weak transients in the galactic ridge.

Detection of cyclotron features in 3 X-ray pulsars: 4U1538-522, V0332+53, and Cep X-4.

Evidence for emission and absorption Fe feature in Seyfert probing reprocessing by cold matter.

Discovery of intense 6-7 keV iron line emission from the galactic center region.

ROSAT : The Roentgen Satellite



Lifetime : 1 June 1990 - 12 February 1999

Energy Range : X-ray 0.1 - 2.5 keV , EUV 62-206 eV

Special Feature : All sky-survey in the soft X-ray band

An X-ray telescope used in conjunction with one of the following instruments (0.1-2.5 keV)

Position Sensitive Proportional Counter (PSPC) 2 units : detector B, used for the pointed phase, & detector C ,used for the survey FOV 2 ° diameter eff area 240 cm^2 at 1 keV energy resolution of deltaE/E=0.43 (E/0.93)-0.5

High Resolution Imager (HRI) FOV 38 ' square ; eff area 80 cm^2 at 1 keV
~ 2 arcsec spatial resolution (FWHM)

A Wide Field Camera with its own mirror system
(62-206 eV) FOV 5 ° diameter

X-ray all-sky survey catalog, more than 150000 objects
XUV all-sky survey catalog (479 objects)

Source catalogs from the pointed phase (PSPC and HRI) containing ~ 100000 serendipitous sources

Detailed morphology of supernova remnants and clusters of galaxies.

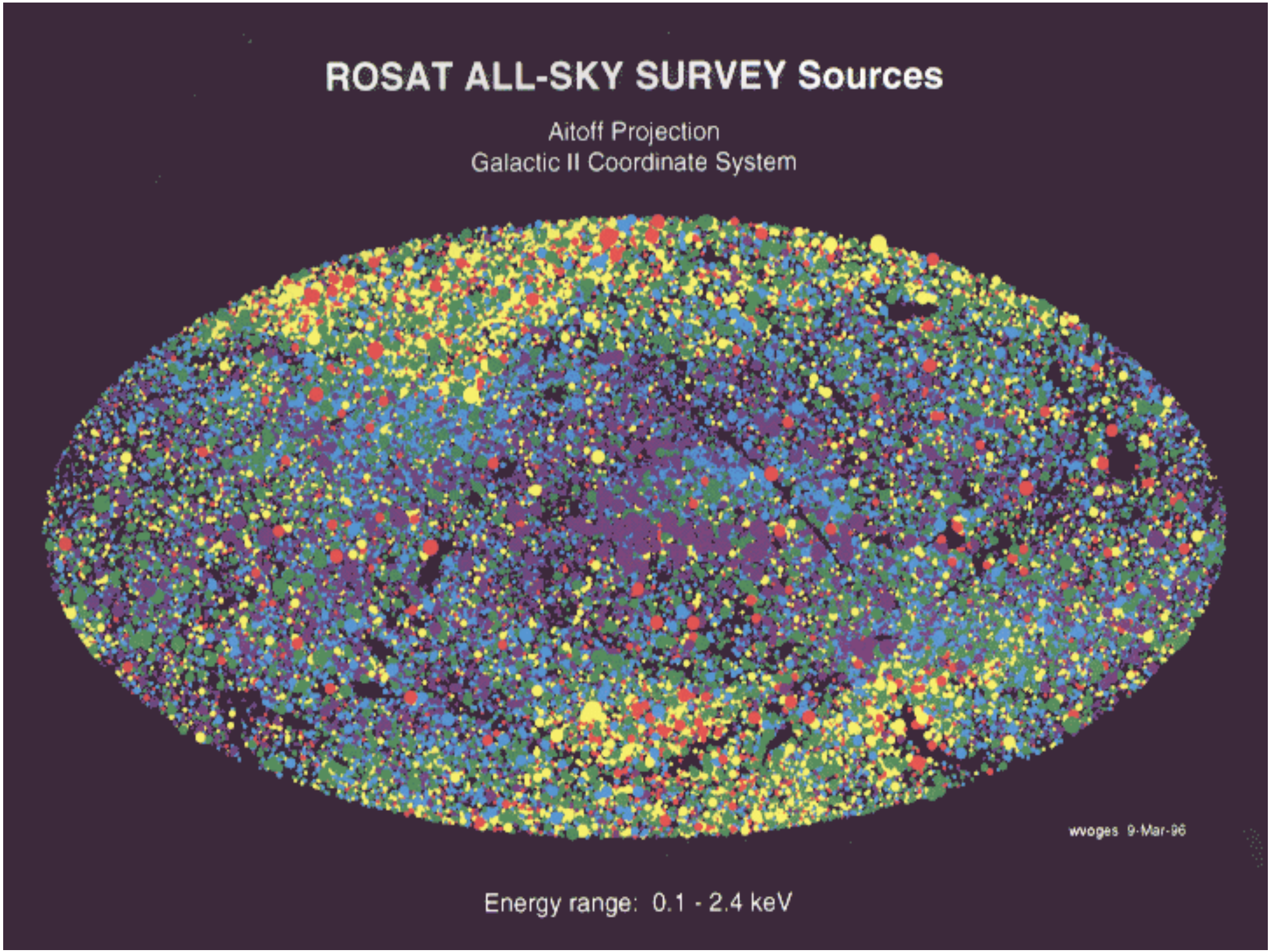
Detection of shadowing of diffuse X-ray emission by molecular clouds.

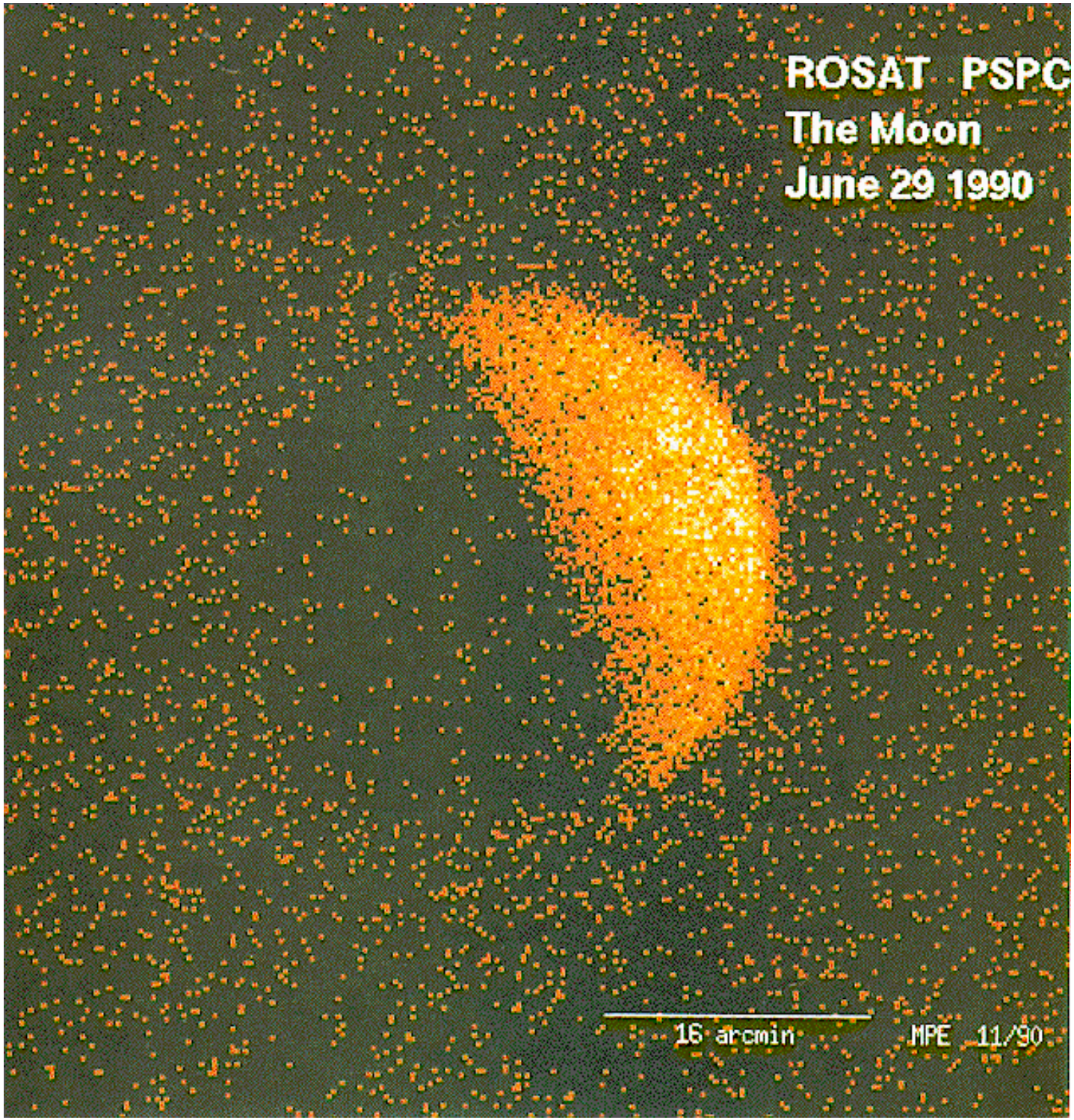
Detection (Finally!) of pulsations from Geminga.

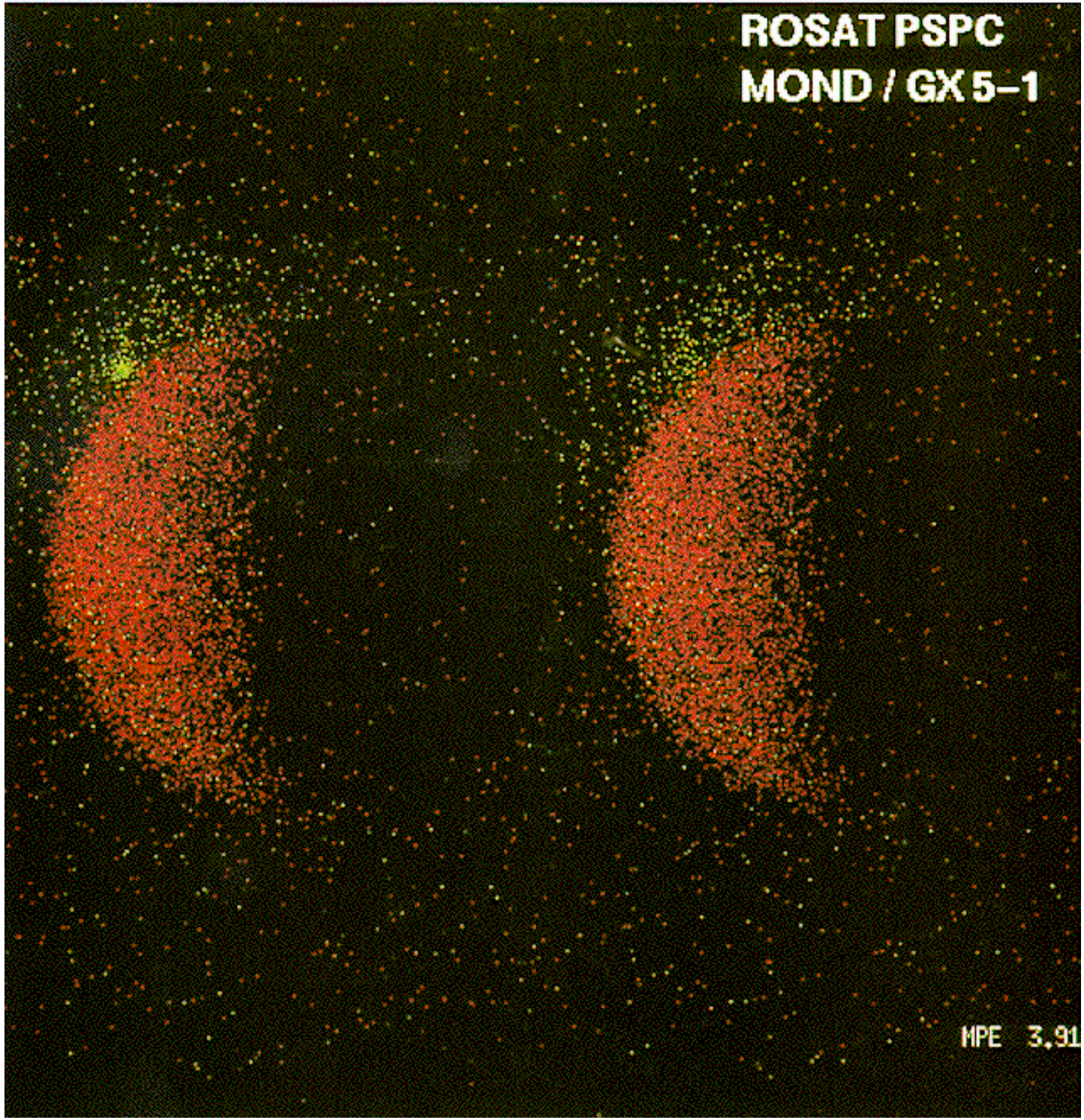
Detection of isolated neutron stars.

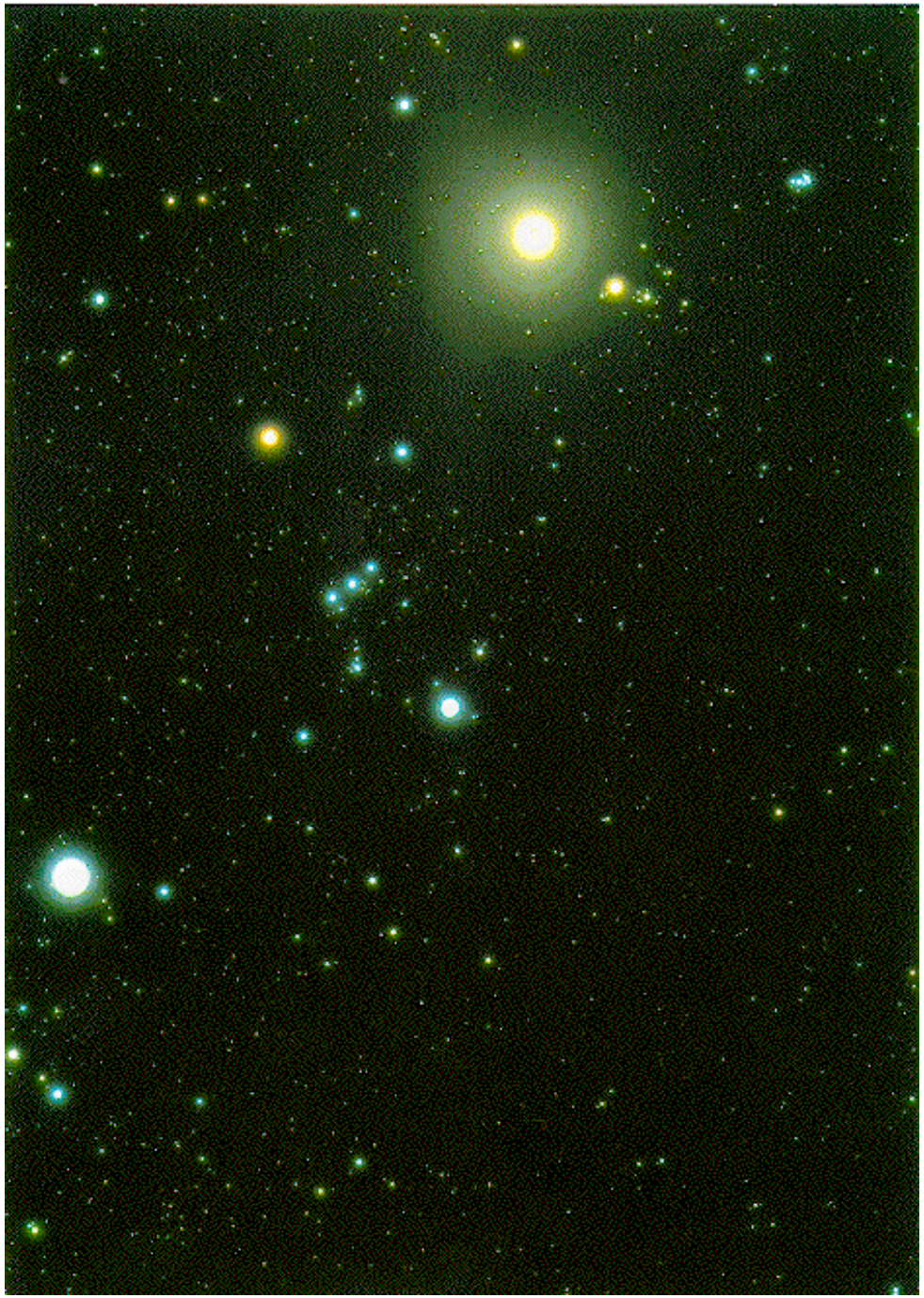
Discovery of X-ray emission from comets.

Observation of X-ray emission from the collision of Comet Shoemaker-Levy with Jupiter

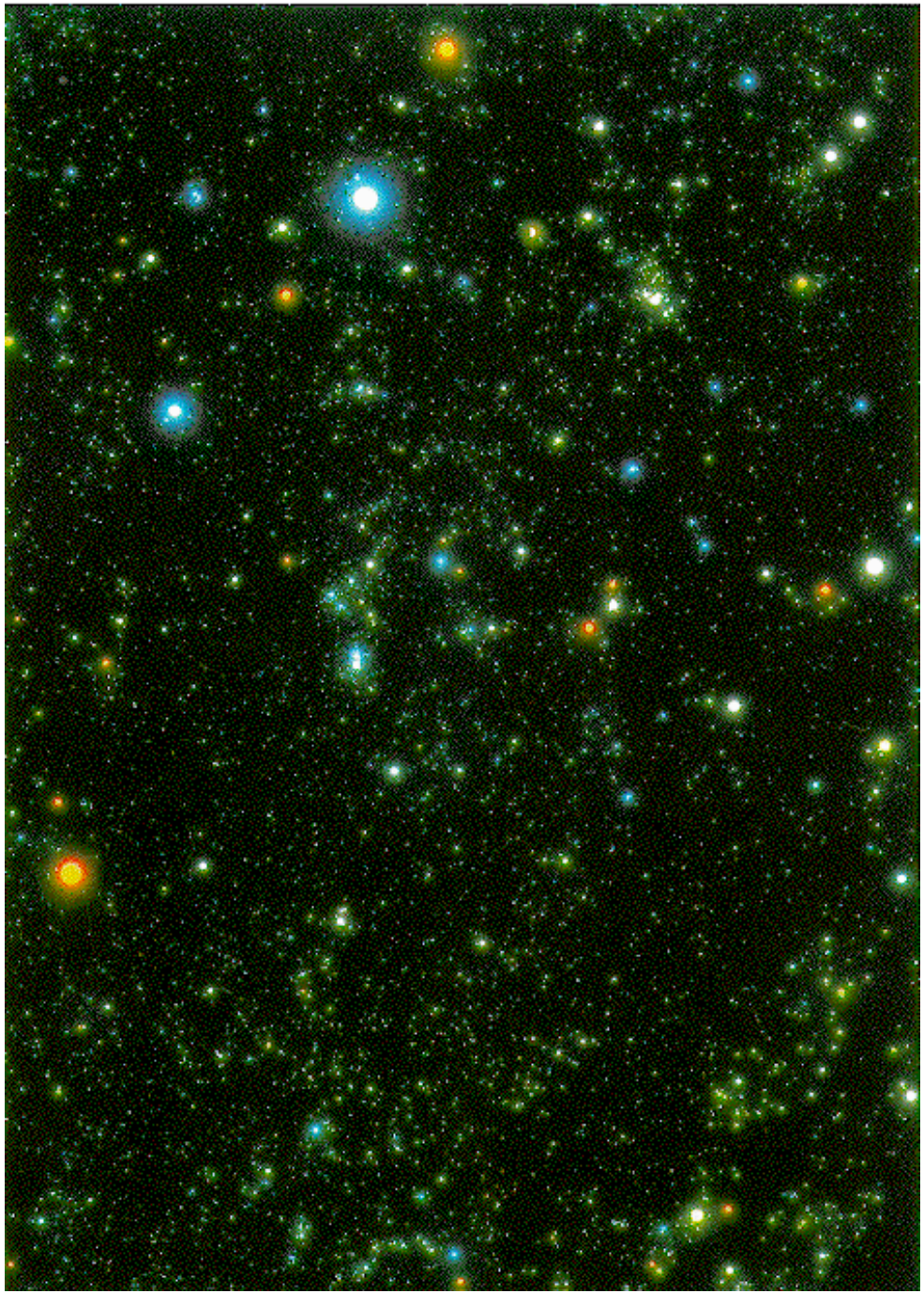

ROSAT ALL-SKY SURVEY Sources
Aitoff Projection
Galactic II Coordinate System
wvoges 9-Mar-96
Energy range: 0.1 - 2.4 keV


ROSAT PSPC
The Moon
June 29 1990
16 arcmin
MPE 11/90


ROSAT PSPC
MOND / GX 5–1
MPE 3.91

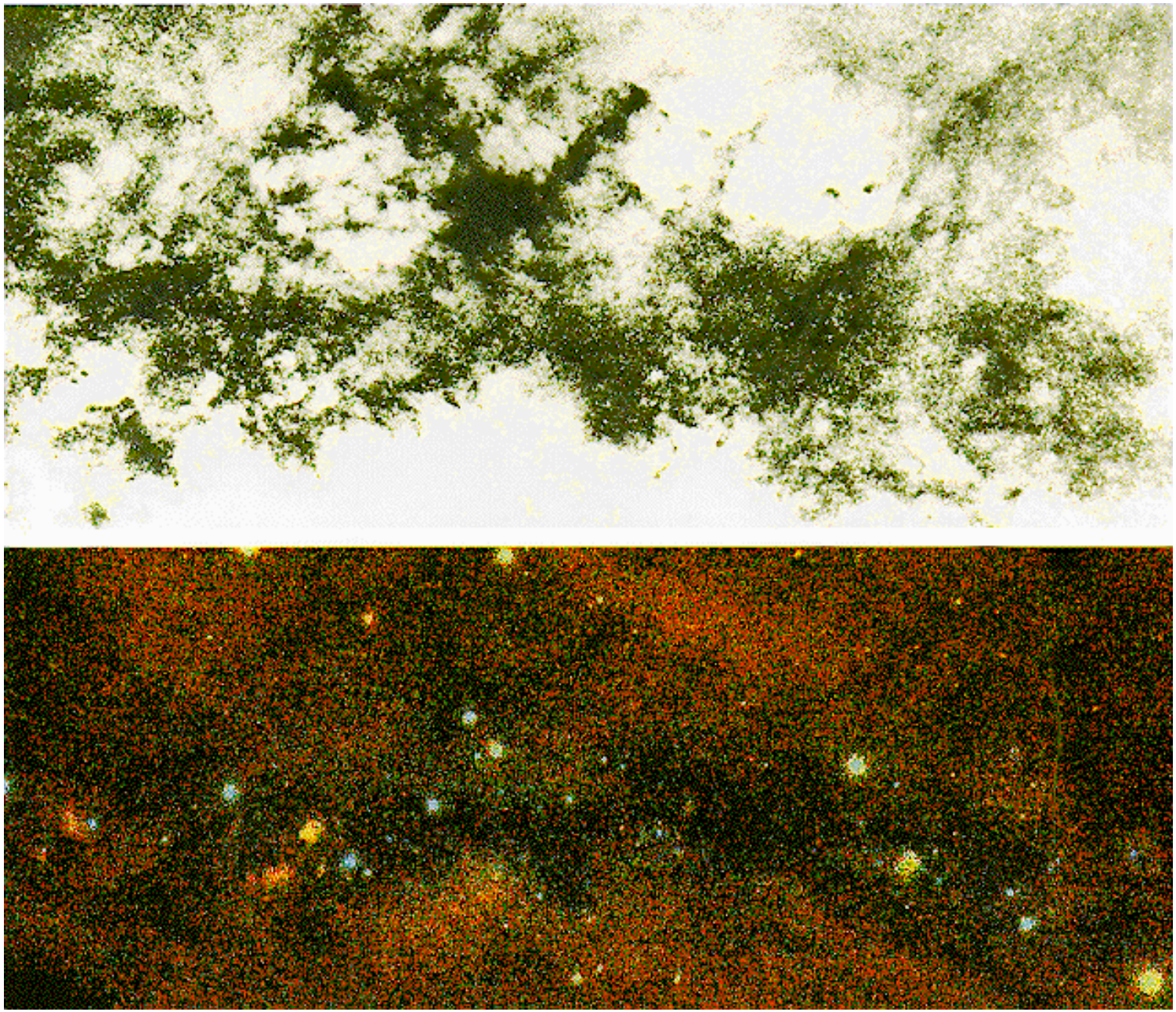


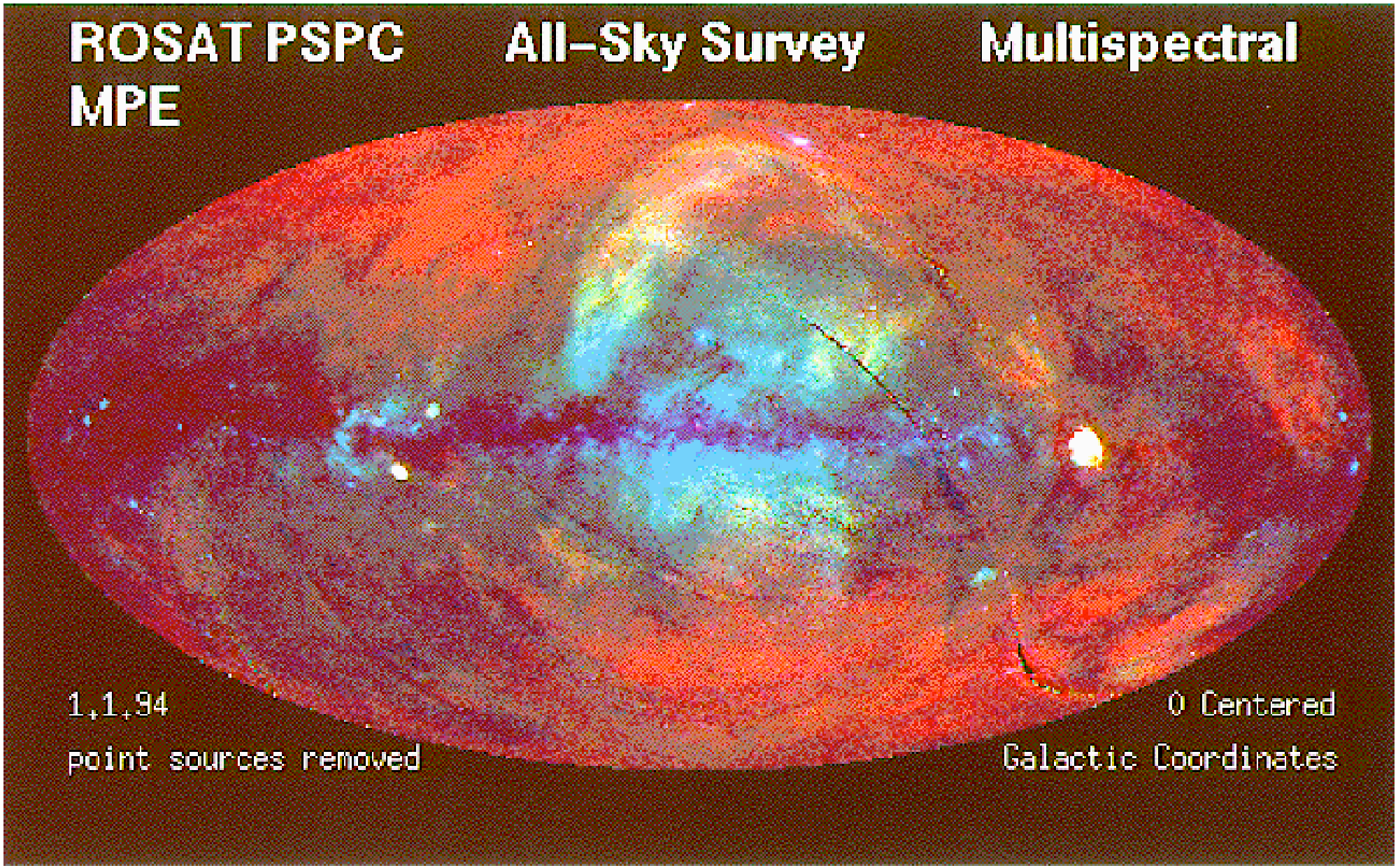
Orion optical image

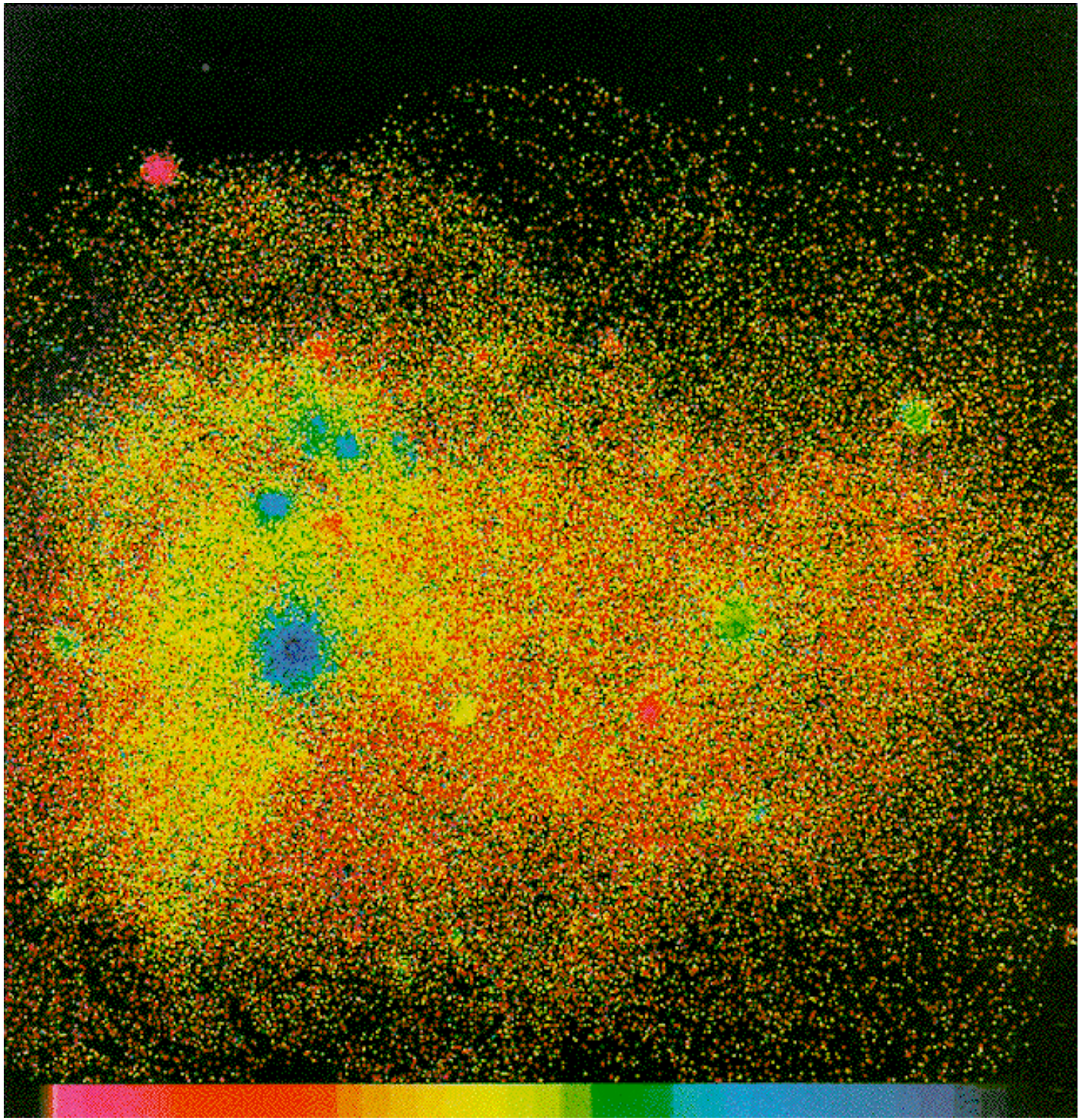


Orion X-Ray image

Galactic Center optical and ROSAT view



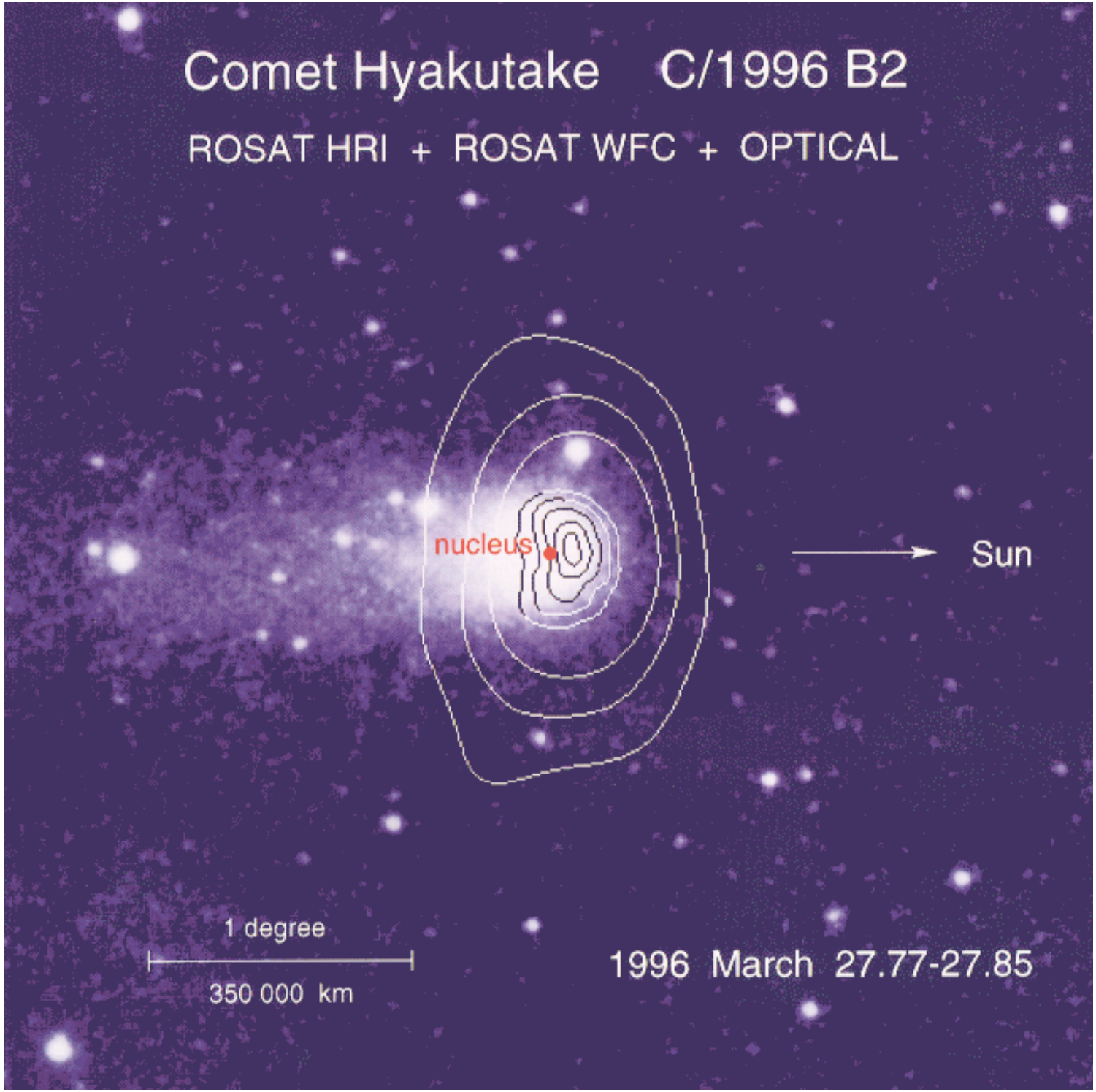

ROSAT PSPC All-Sky Survey Multispectral
MPE
1.1.94
point sources removed
0 Centered
Galactic Coordinates

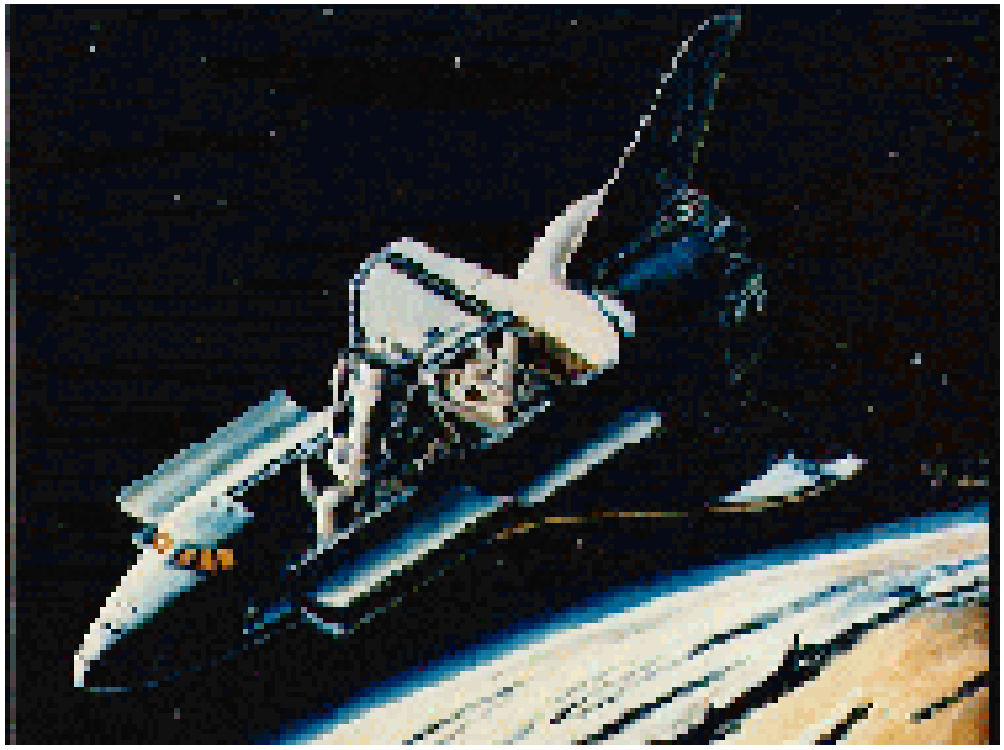


Large Magellanic Cloud

ROSAT

T Map


Comet Hyakutake C/1996 B2
ROSAT HRI + ROSAT WFC + OPTICAL
nucleus
Sun
1 degree
350 000 km
1996 March 27.77-27.85



Payload :

Two Co-Aligned Telescopes each with a segmented Si(Li) solid state spectrometer (detector A and B) composite of five pixels.

Total FOV 17.4 ´ diameter, Central pixel FOV 4 ´ diameter

Total area 765 cm^2 at 1.5 keV, and 300 cm^2 at 7 keV

Lifetime : December 2 1990 - December 11 1990

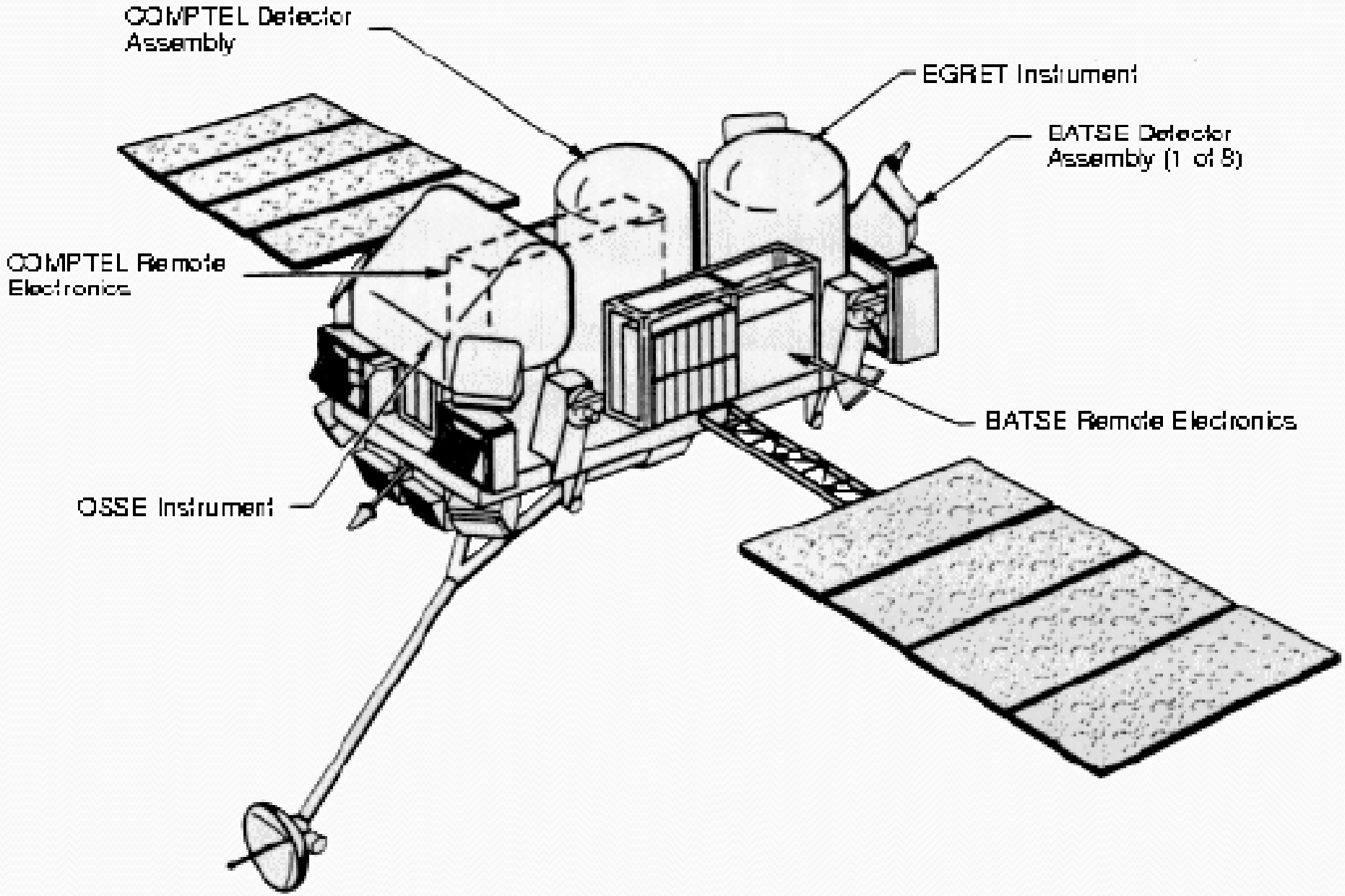
Energy Range : 0.3 - 12 keV

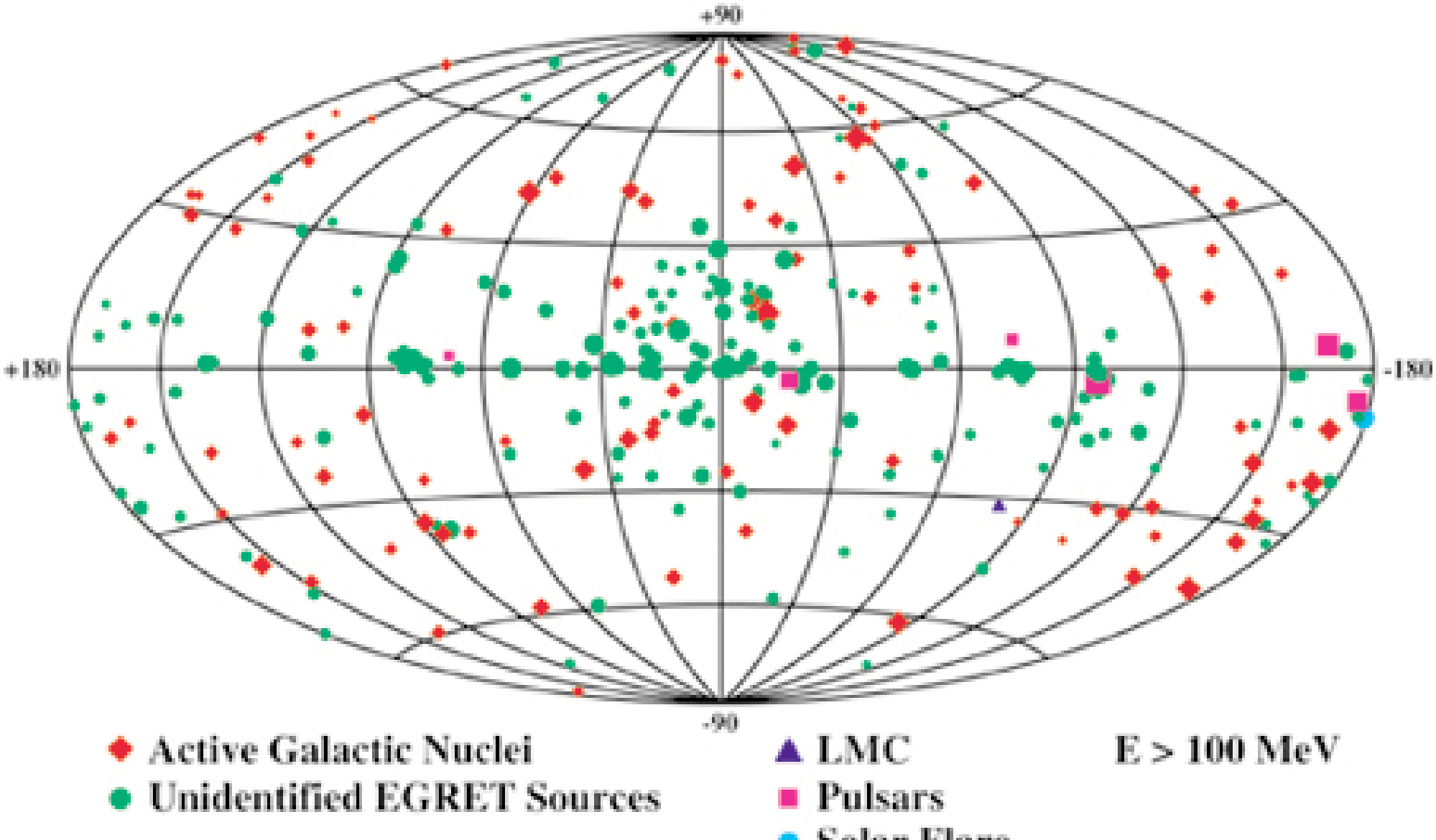
The Broad Band X-ray Telescope (BBXRT)

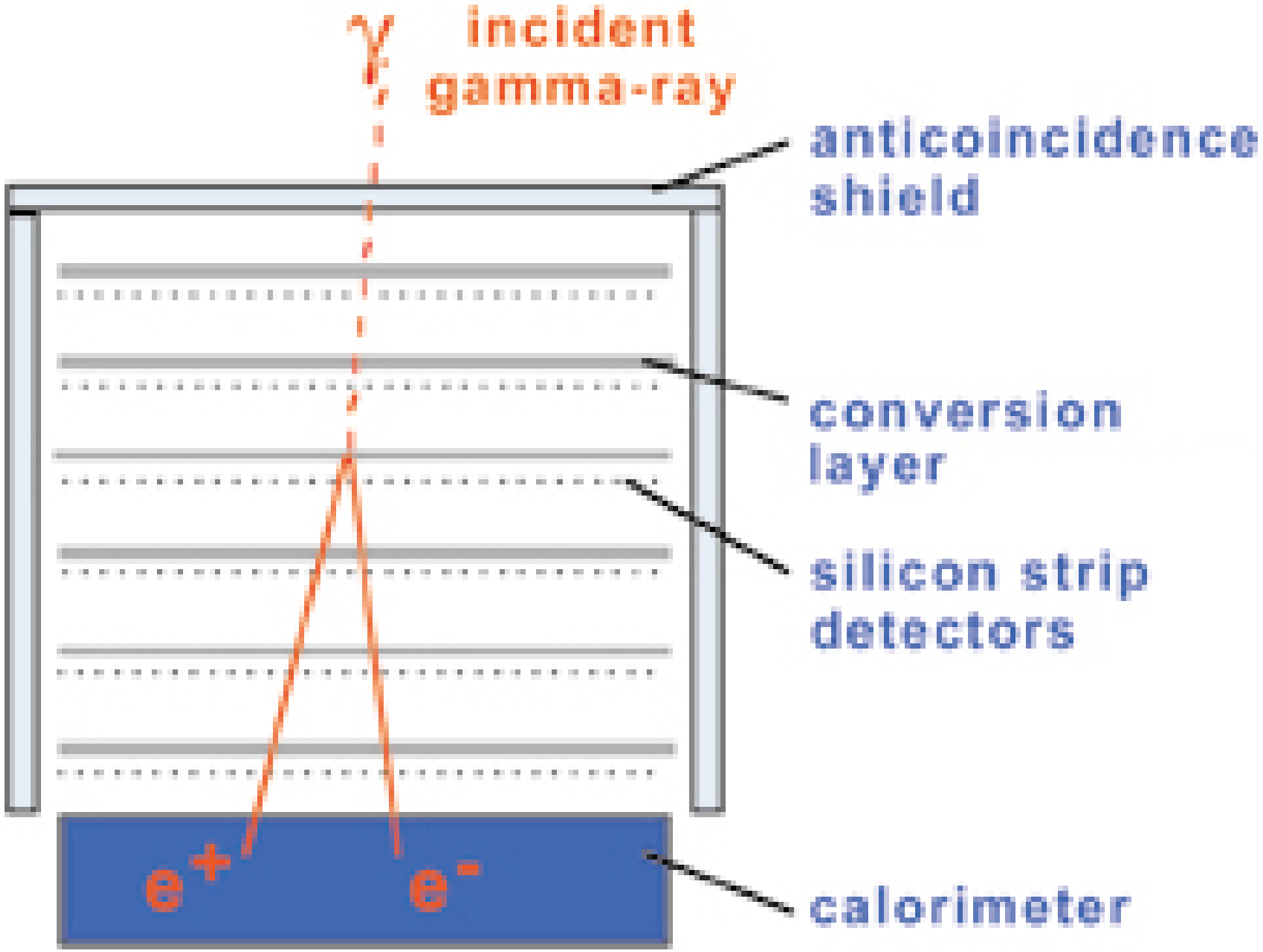
Resolved iron K line in the binaries Cen X-3 and Cyg X-2

Detect evidence of line broadening in NGC 4151

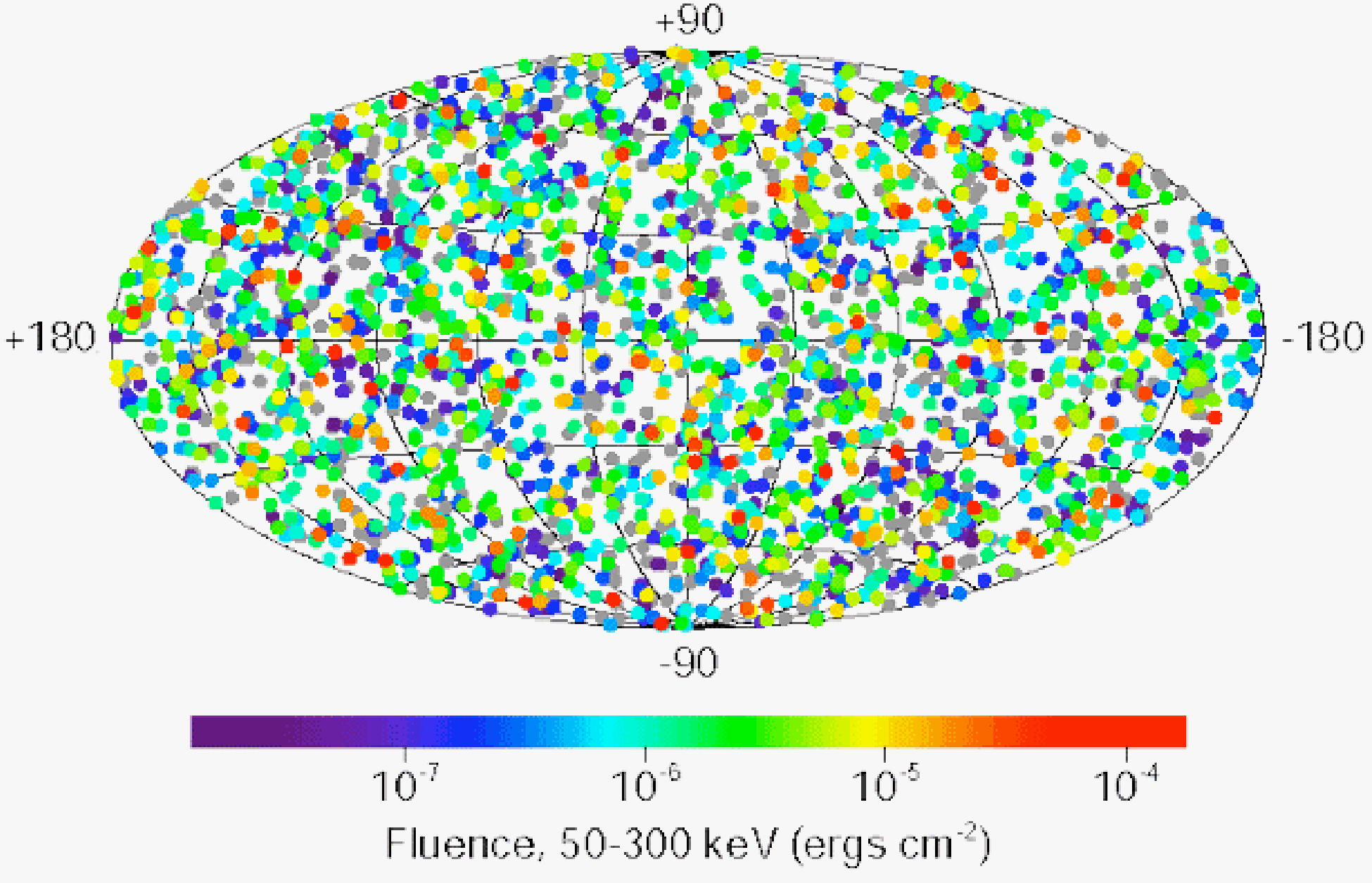
Study of cooling flow in clusters


COMPTEL Detector Assembly
EGRET Instrument
BATSE Detector Assembly (1 of 8)
COMPTEL Remote Electronics
BATSE Remote Electronics
OSSE Instrument


+90
+180
-180
-90
Active Galactic Nuclei
Unidentified EGRET Sources
LMC
Pulsars
Solar Flare
E > 100 MeV


γ
incident
gamma-ray
anticoincidence
shield
conversion
layer
silicon strip
detectors
e+
e-
calorimeter

2704 BATSE Gamma-Ray Bursts



Compton Gamma-Ray Observatory (CGRO)

The Discovery of an isotropic distribution of the Gamma-ray burst events

Mapping the Milky Way using the 26 Al Gamma-ray line

Discovery of Blazar Active Galactic Nuclei as primary source of the highest energy cosmic Gamma-rays

Discovery of the "Bursting Pulsar"

ASCA (Advanced Satellite for Cosmology and Astrophysics) Japan & USA

Lifetime : February 20, 1993 - March 2, 2001

Energy Range : 0.4 - 10 keV

Special Features :

First X-ray mission to combine imaging capability with broad pass band, good spectral resolution, and a large effective area

Payload :

Four X-ray telescopes each composed of 120 nested gold-coated aluminum foil sufaces (total eff area 1,300 cm^2 @ 1 keV, spatial resolution 3´ half power diameter, FOV 24´ @ 1 keV) working in conjunction with one of the following detectors:

Gas Imaging Spectrometer (GIS; 0.8-12 keV)
Two Imaging Gas Scintillation Proportional Counters (IGSPC)
FOV 50´ , spatial resolution ~0.5' at 5.9 keV,and energy resolution of 8 % at 5.9 keV,Eff area (GIS+XRT) 50 cm^2 @ 1 keV

Solid-state Imaging Spectrometer (SIS; 0.4-12 keV)
Two CCD arrays of four 420 X 422 square pixel chips,
FOV 22´ X 22´ ,
Spatial resolution 30", energy resolution of 2 % at 5.9 keV ,
Eff area (SIS+XRT) 105 cm^2

ASCA

Broad Fe lines from AGN, probing the strong gravity near the central engine

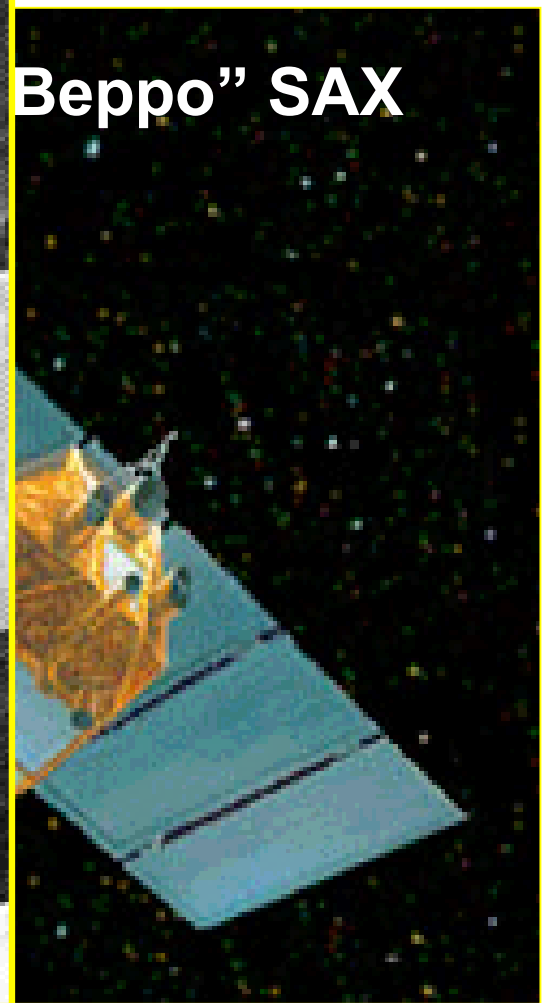
Lower than solar Fe abundance in the coronae of active stars

Spectroscopy of interacting binaries

Non-thermal X-rays from SN 1006, a site of Cosmic Ray acceleration

Abundances of heavy elements in clusters of galaxies, consistent with type II supernova origin

Giuseppe “Beppo” Occhialini



SAX

First arc-minutes position of GRBs.

Position determination on rapid time scale

First X-ray follow-up observations and monitoring of the GRB

Broad band spectroscopy of different classes of X-ray sources

Lifetime : 30 April 1996 - 30 April 2002

Energy Range : 0.1 - 300 keV

Special Features : Broad-band energy

Payload :

The Narrow field Instruments (NFI):

Four Xray telescopes working in conjnction with one of the following detectors:

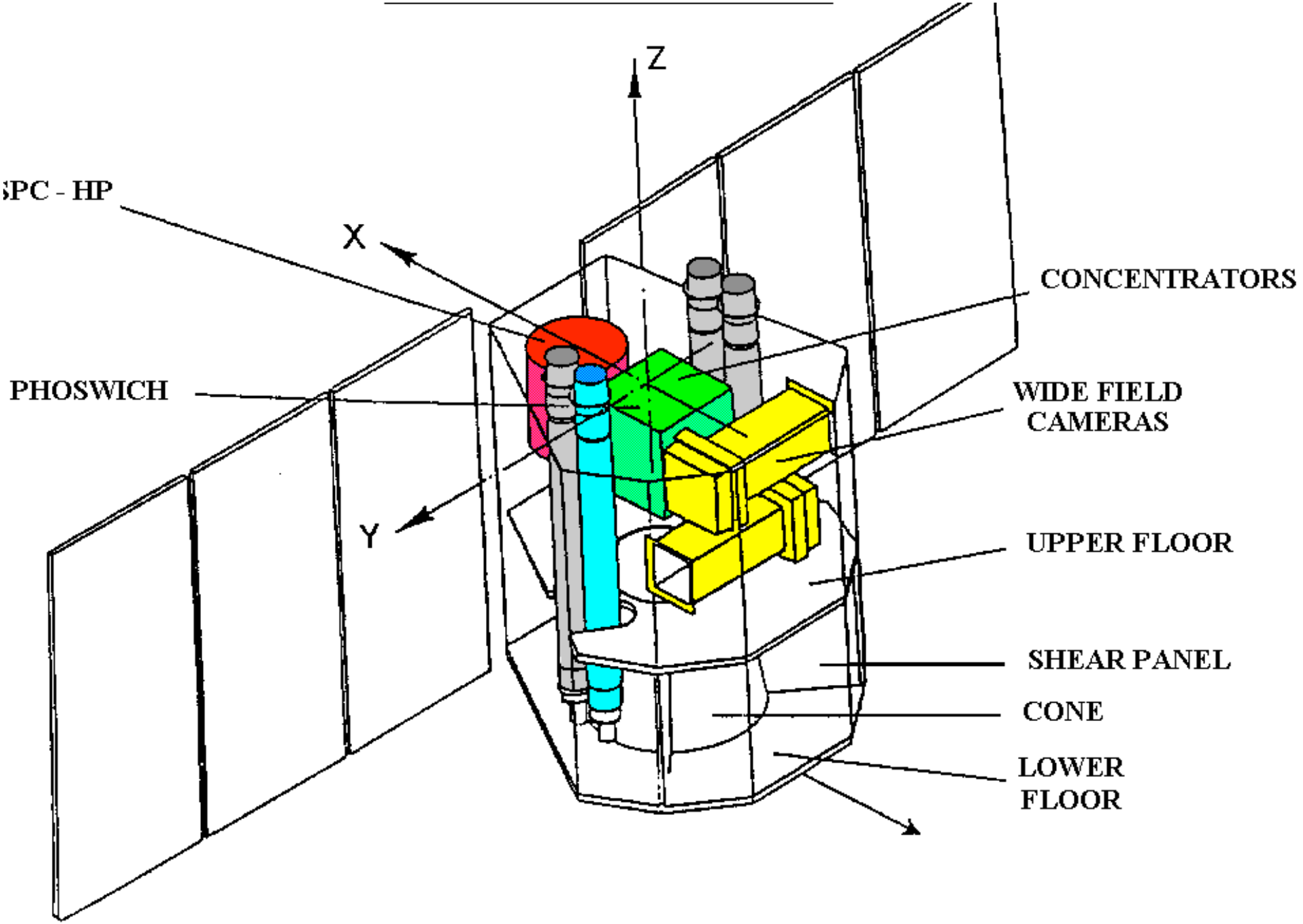
Low Energy Concentrator Spectrometer (LECS) (one unit) 0.1-10 keV, eff area 22 cm^2 @ 0.28 keV, FOV 37´ diameter, angular resolution 9.7´ FWHM @ 0.28 keV.

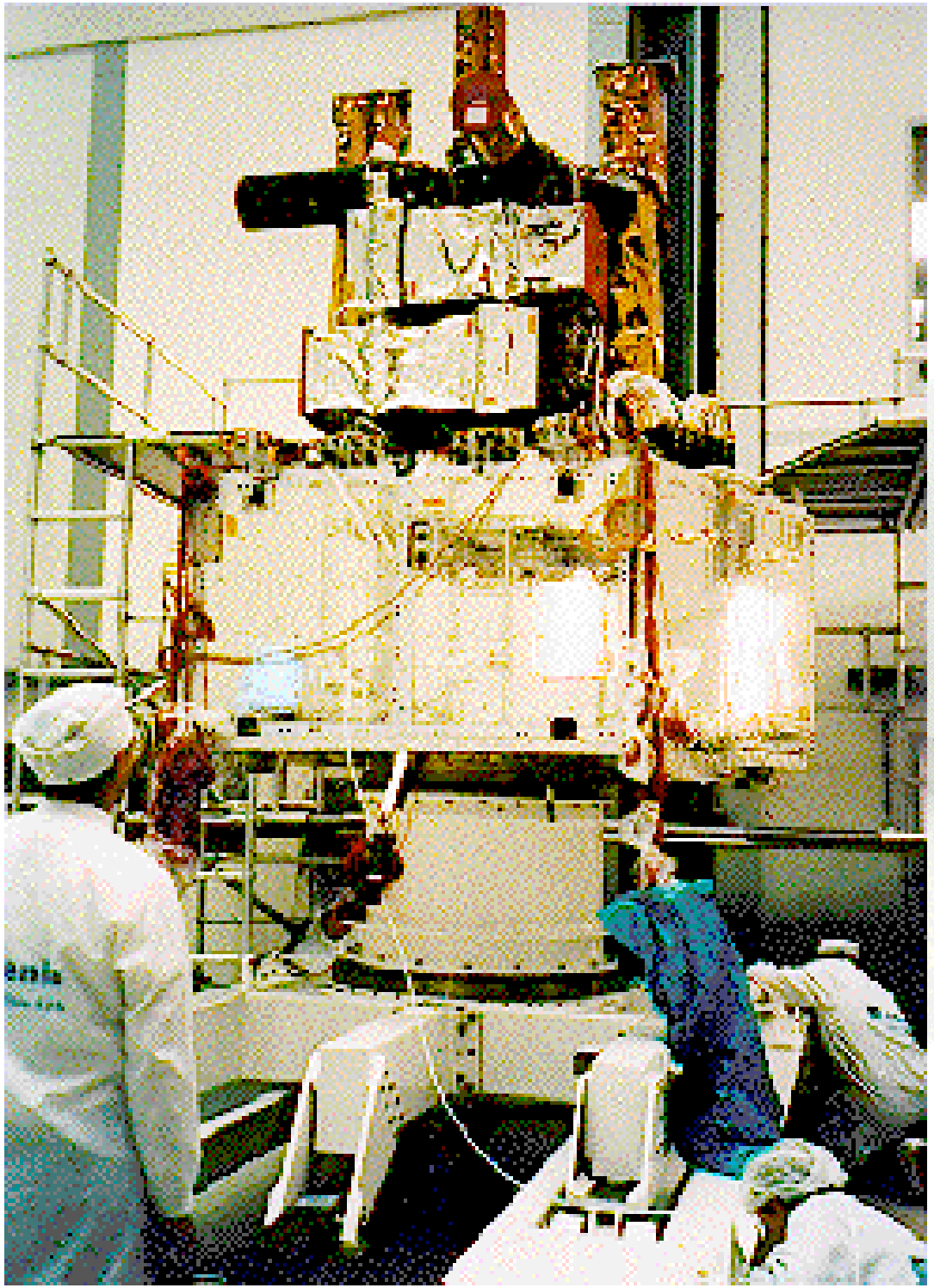
Medium Energy Concentrator Spectrometer (MECS) (three units) 1.3-10 keV, eff area total 150 cm^2 @ 6 keV, FOV 56´ diameter, angular resolution for 50% total signal radius 75" @ 6 keV.

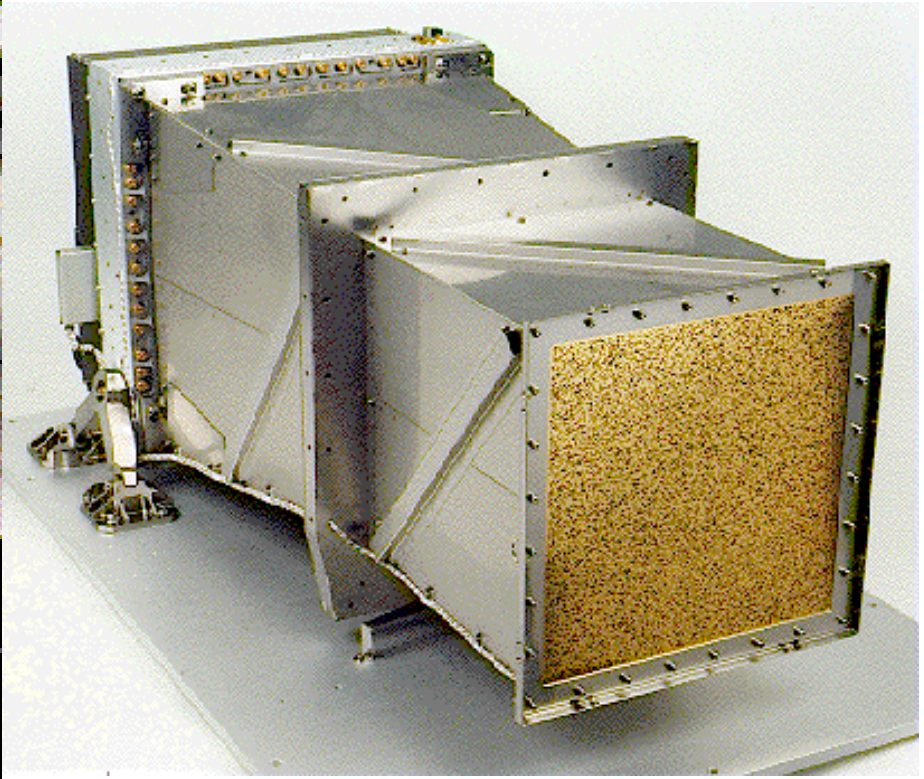
High pressure Gas Scintillator Proportional Counter (HPGSPC) 4-120 keV, eff area 240 cm^2 @ 30 keV

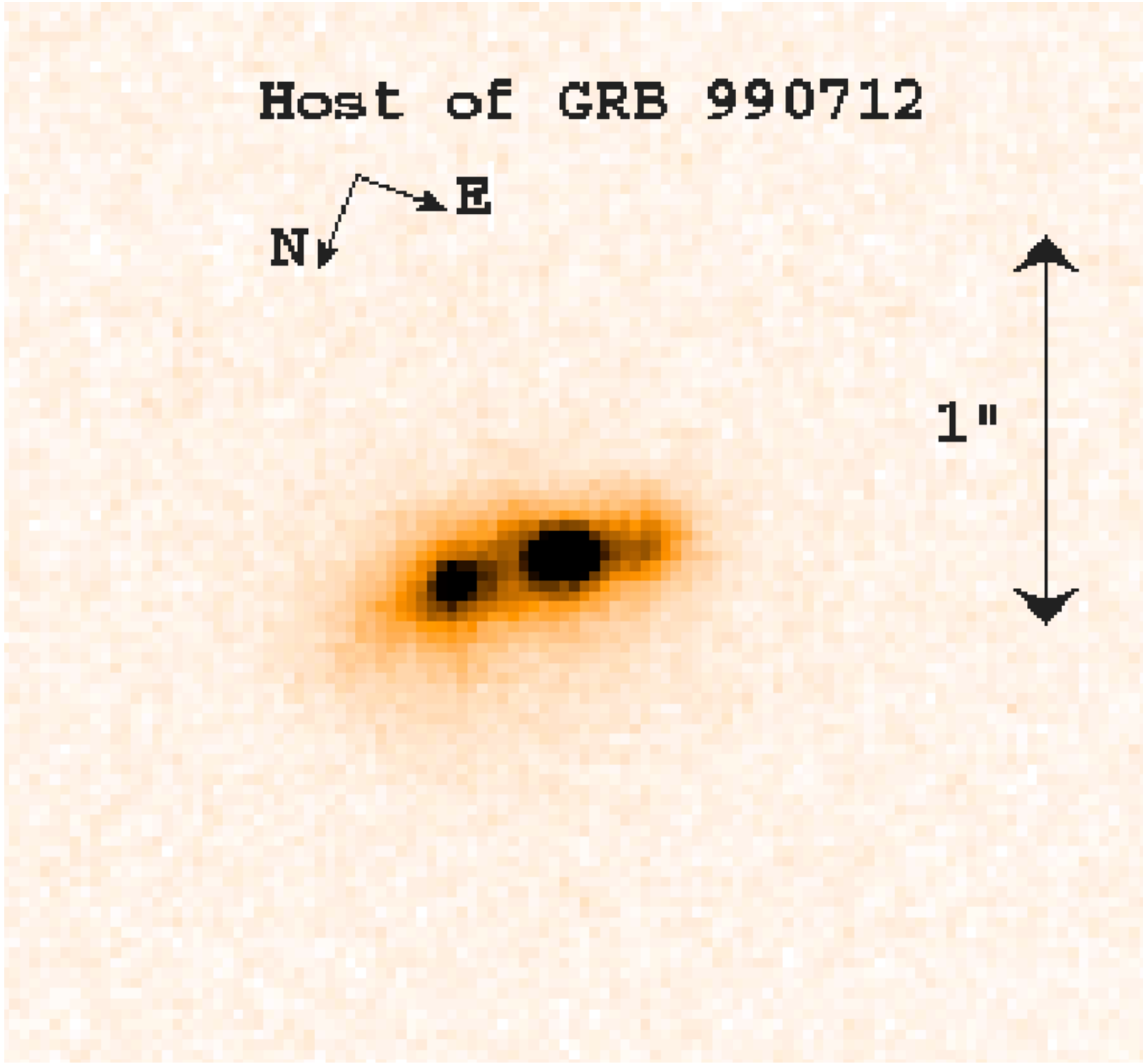
Phoswich Detection System (PDS) 15-300 keV. The lateral shields of the PDS are used as gamma-ray burst monitor in the range of 60-600 keV. Eff area 600 cm^2 @ 80 keV

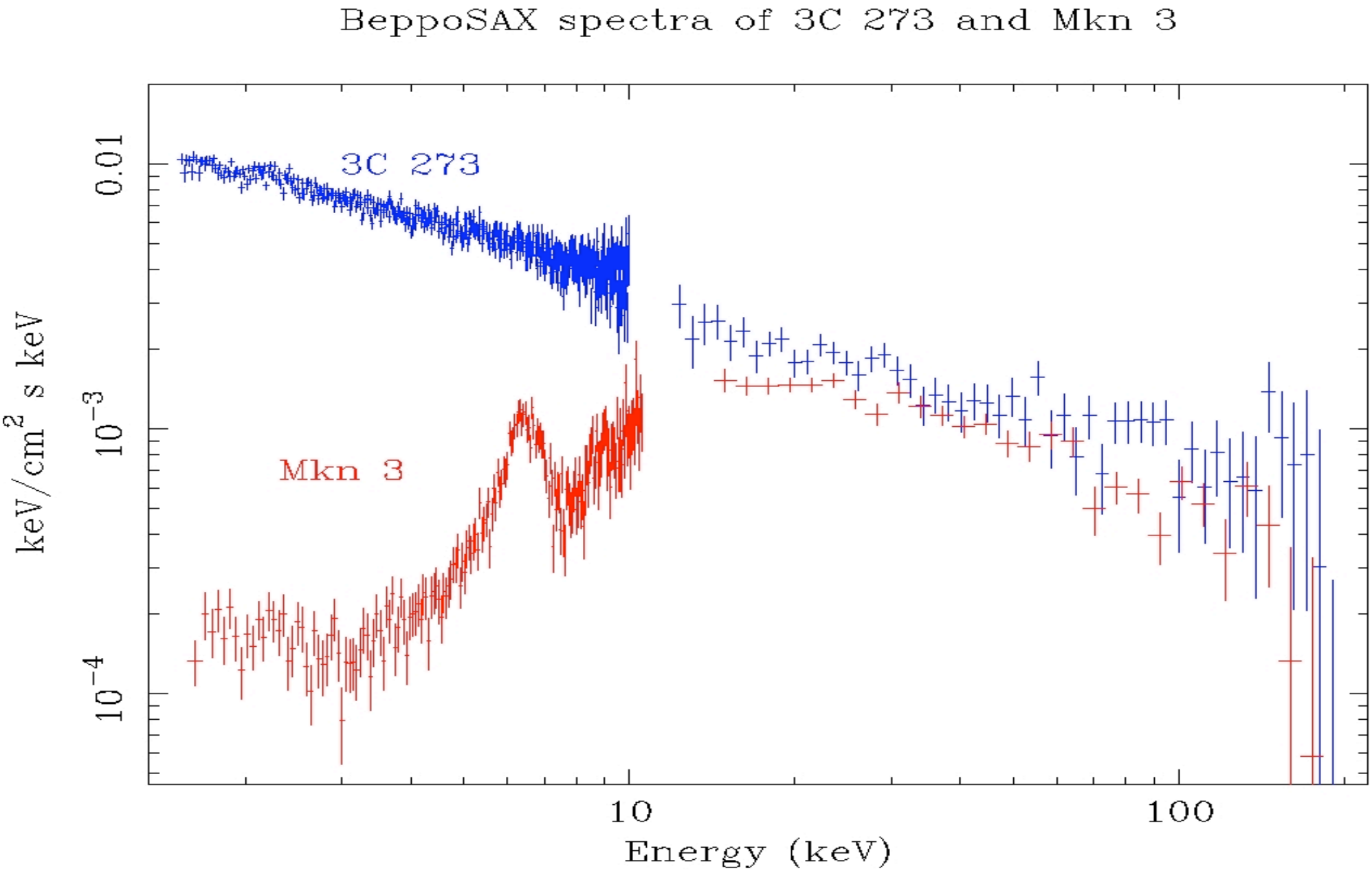
Wide Field Camera (2 units) 2-30 keV with a field of view 20 deg X 20 deg. The WFC are perpendicular to the axis of the NFI and point in opposite directions to each other. Eff area 140 cm^2.

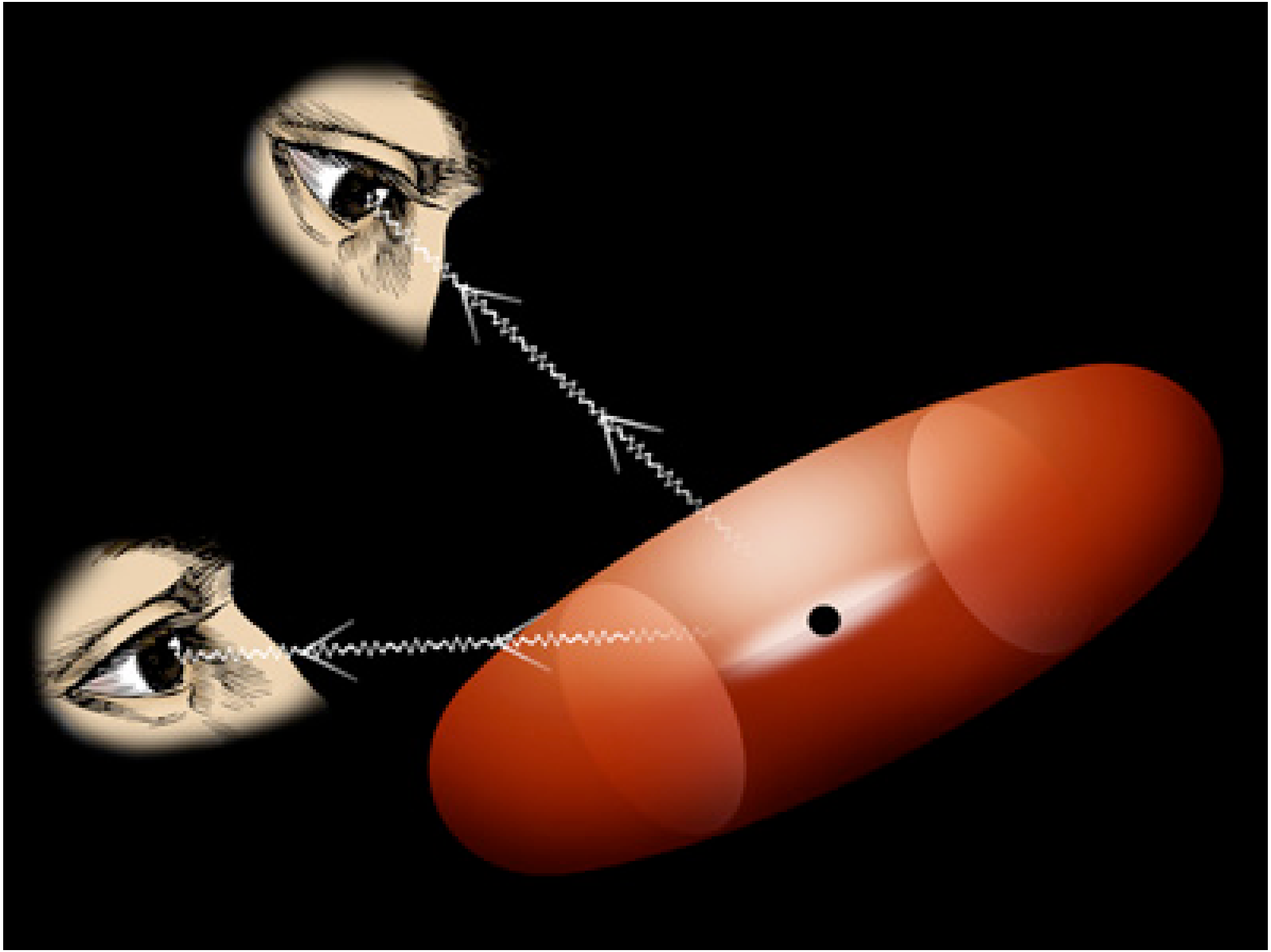

SPC - HP
Z
X
Y
CONCENTRATORS
PHOSWICH
WIDE FIELD
CAMERAS
UPPER FLOOR
SHEAR PANEL
CONE
LOWER
FLOOR

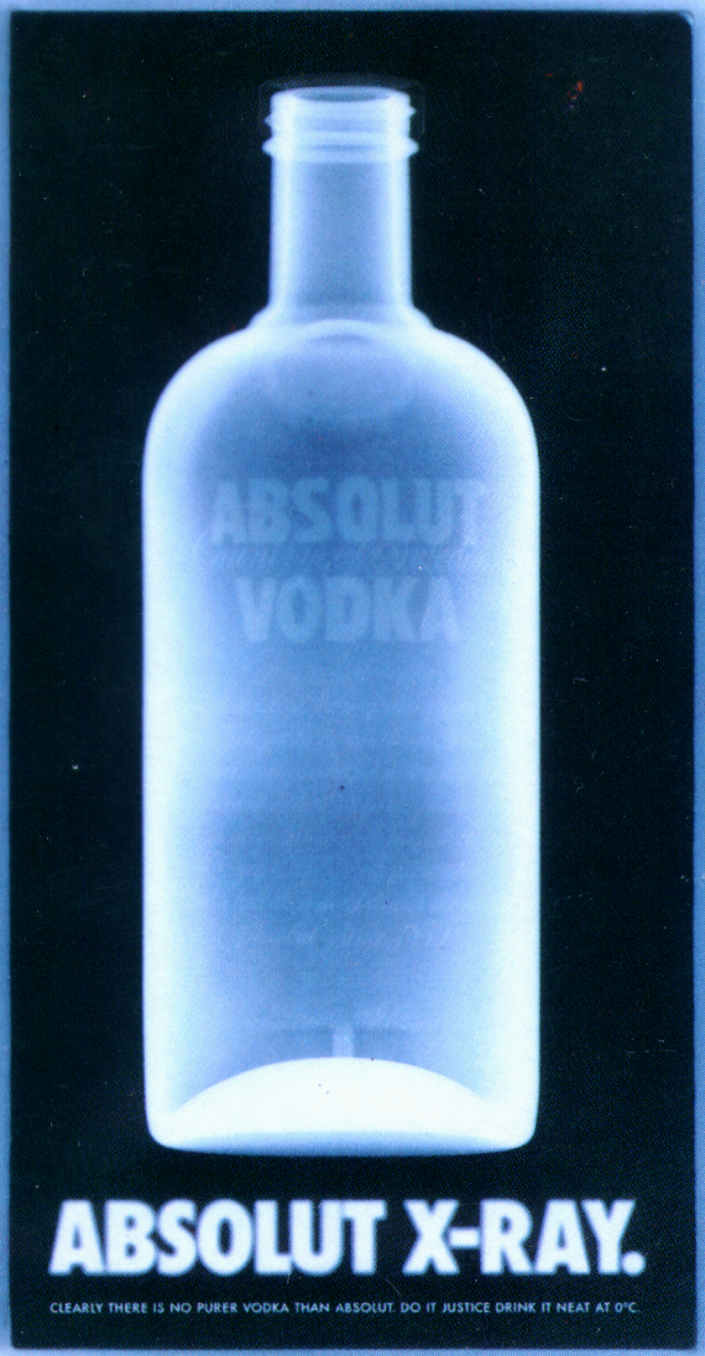





Host of GRB 990712
N
E
1"


BeppoSAX spectra of 3C 273 and Mkn 3
3C 273
Mkn 3
0.01
10^{-3}
10^{-4}
keV/cm^2 s keV
10
100
Energy (keV)





ABSOLUT X-RAY.

CLEARLY THERE IS NO PURER VODKA THAN ABSOLUT. DO IT JUSTICE DRINK IT NEAT AT 0°C.

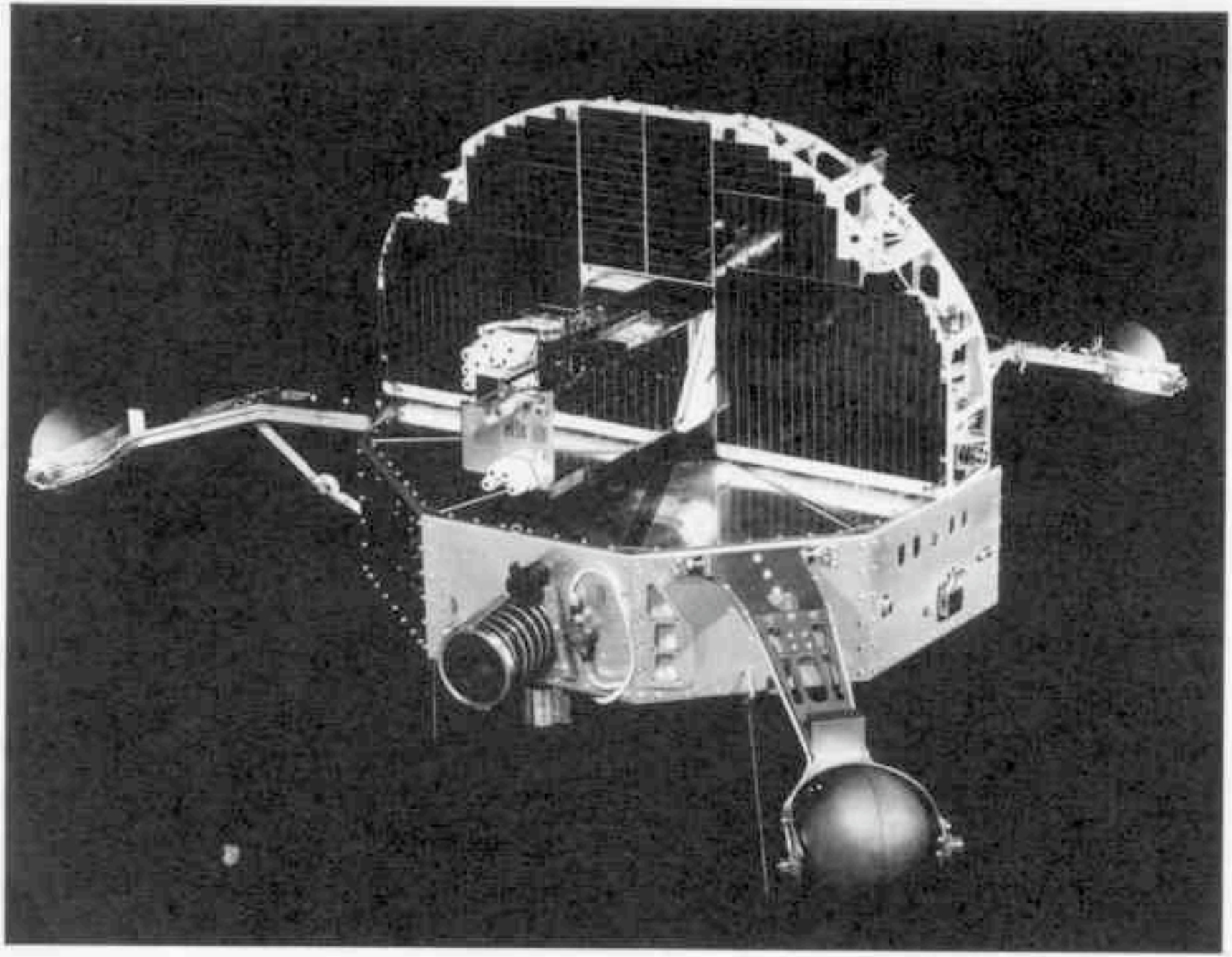
PROMOCARD N° 717

Absolut Vodka Collection n° 47

HEAO-3

Sky survey of gamma-ray narrow-line emission

Orbiting Solar Observatory 6 with booms deployed (Ball Bros. Research Corp. photo)



Viviamo tutti nelle fogne ma alcuni di noi guardano le stelle

Oscar Wilde