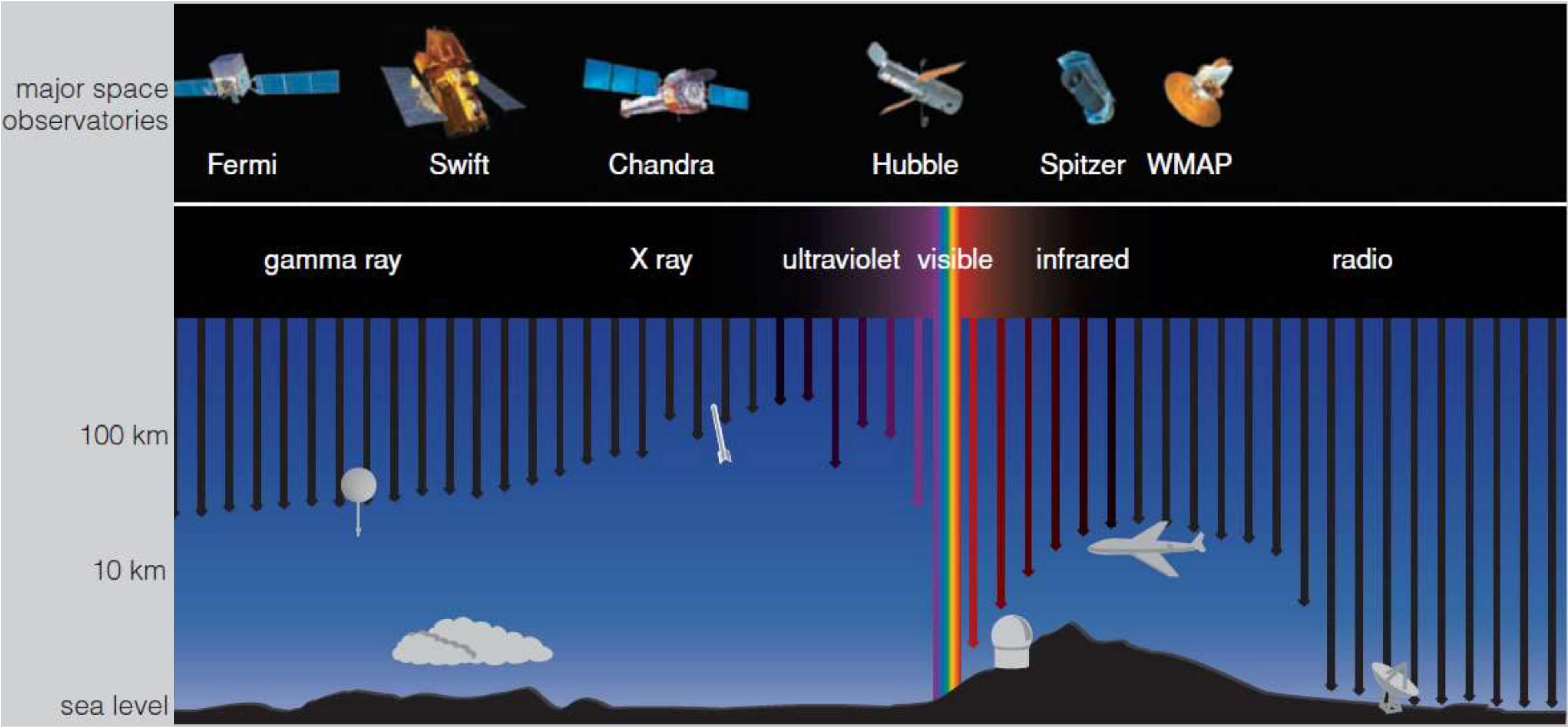
# Space Astronomy

Jorge Meléndez

# Why?


major space observatories
Fermi
Swift
Chandra
Hubble
Spitzer
WMAP
gamma ray
X ray
ultraviolet
visible
infrared
radio
100 km
10 km
sea level

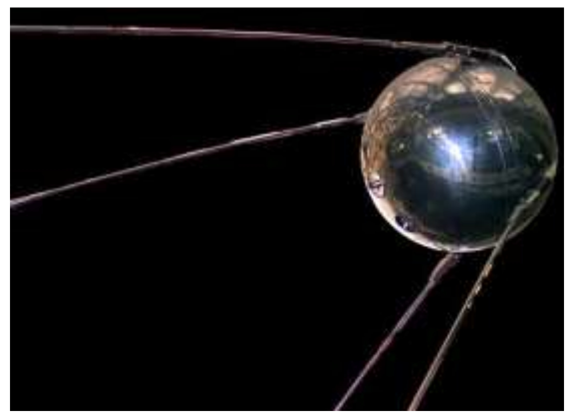
# Why?

*Q. Jl R. astr. Soc.* (1979) **20**, 29–36

# History of the Space Telescope*

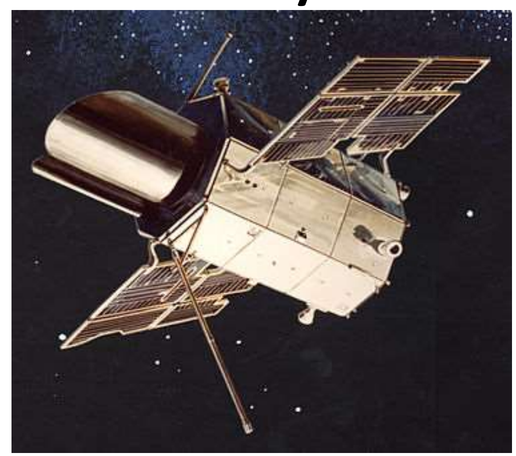
*Lyman Spitzer, Jr*
Princeton University Observatory, Princeton, New Jersey, USA
(Received 1978 October 18)

- 1946: discussed the advantages of having an space telescope



- 1957: Sputnik 1
- 1958: NASA

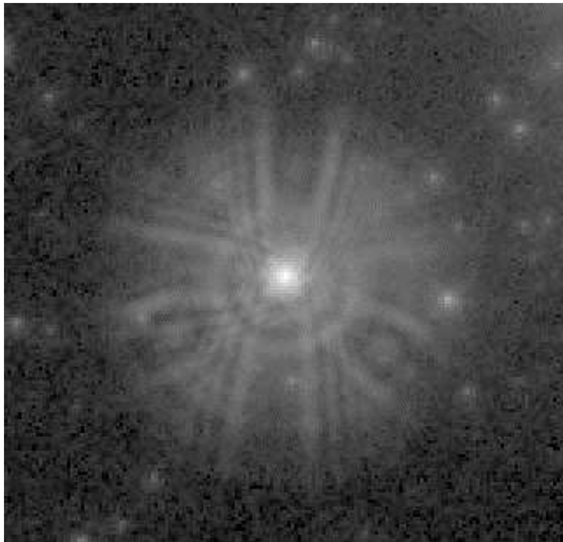
- 1962: Ariel 1 (British); solar observations in the UV and X-rays
- 1962: Orbiting Solar Observatory (NASA); UV, X-ray, and gamma-ray solar spectra
- Orbiting Astronomical Observatory - OAO (NASA)



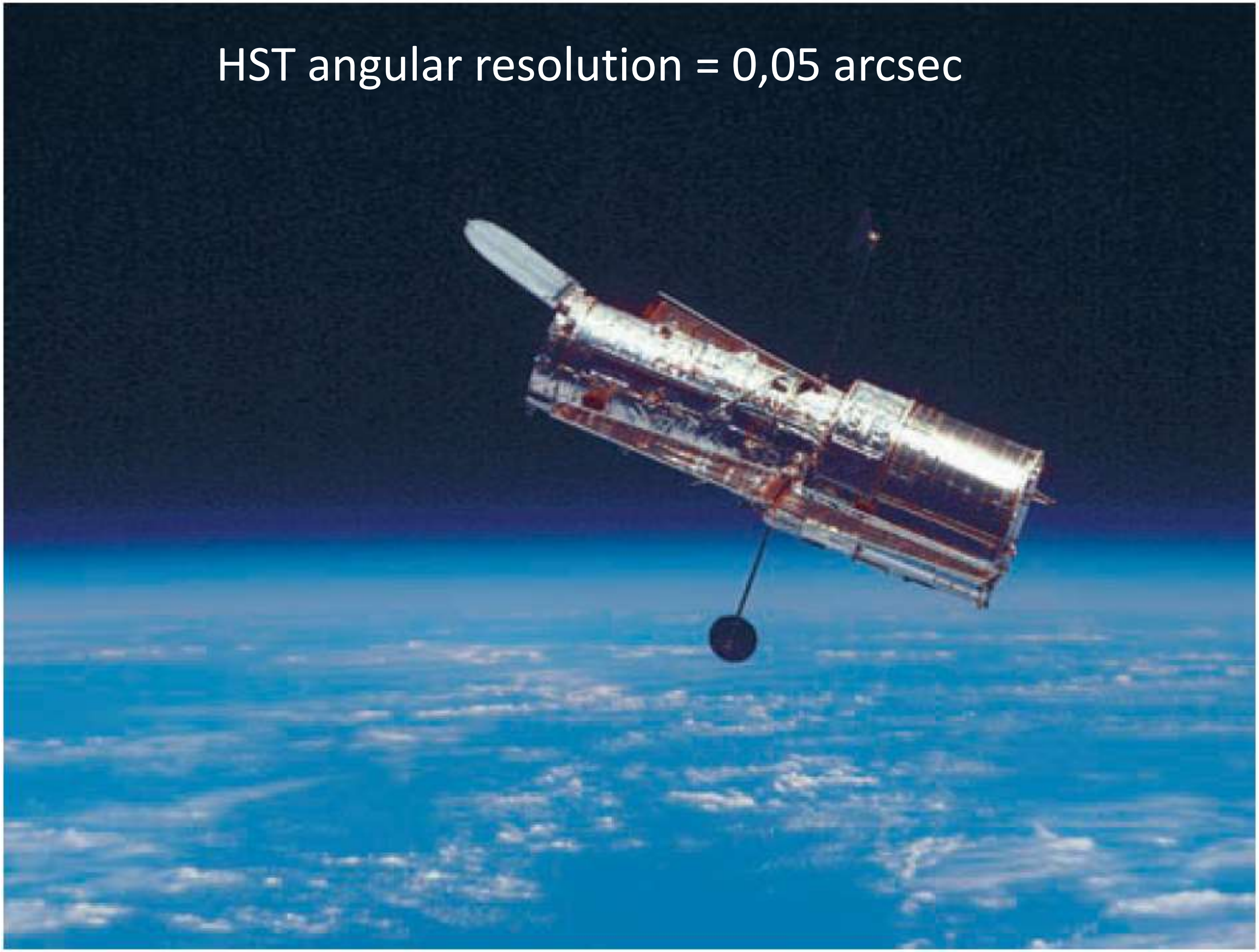
- 1966: OAO-1: failure
- 1968: OAO-2: UV spectra
- 1970: OAO-B: failure
- 1972-1981: OAO-3 (Copernicus), UV and X-ray
- 1978: NASA+ESA: International Ultraviolet Obs.

# Hubble Space Telescope

- 1970: 3m space telescope with launch for 1979
- 1974: budget cut, then 2,4m telescope, drop 1,5m testing space telescope, include ESA (15%)
- 1978: approved by congress, aimed for launch in 1983. Perkin-Elmer in charge of the mirror, but there were large delays and price increased.
- Launched on April 24, 1990.
- Original cost estimate: 400 million
- Final cost: 2,5 billion

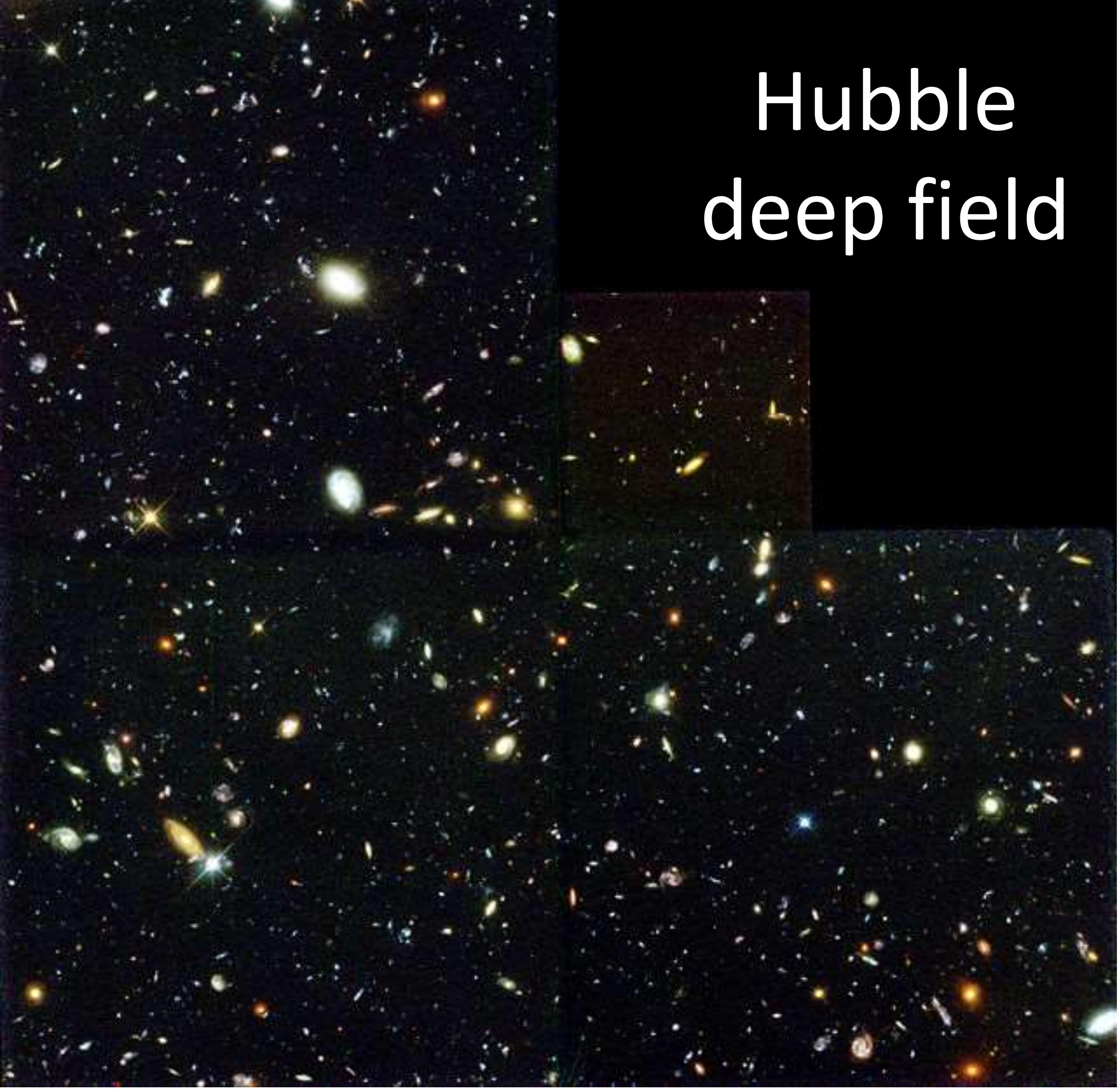


Hubble PSF with flawed optics

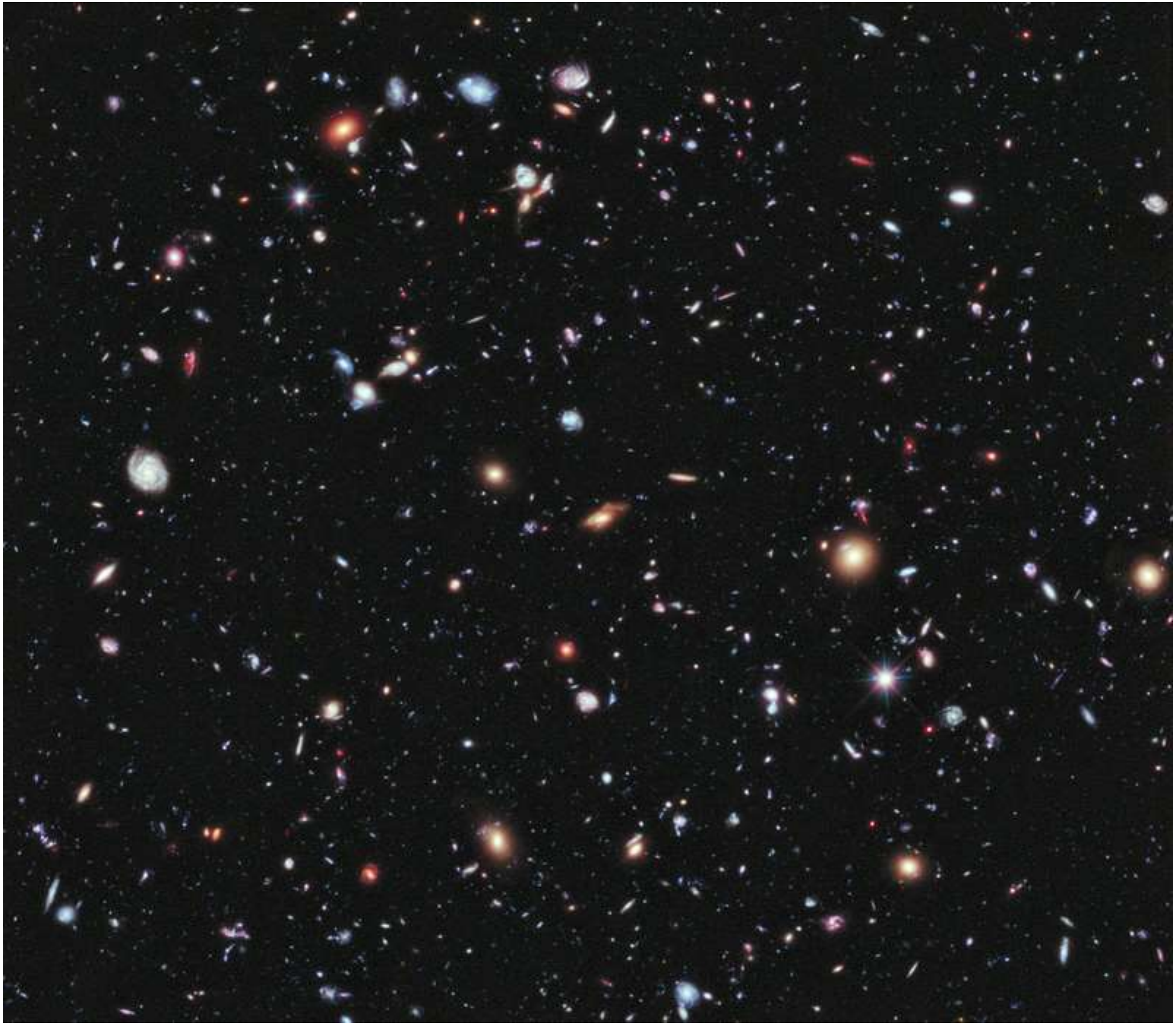



The Hubble Space Telescope orbits Earth. Its position above the atmosphere allows it an undistorted view of space. Hubble can observe infrared and ultraviolet light as well as visible light.

# Hubble deep field



- 2,5 arcmin
- 342 separate exposures
- 10 days
- About 3000 galaxies



# HST XDF

- 2,3 x 2 ‘
- 2 million seconds
- 23 days
- About 5500 galaxies

# Observations made by HST of supernovae contributed to research on the expansion of the universe

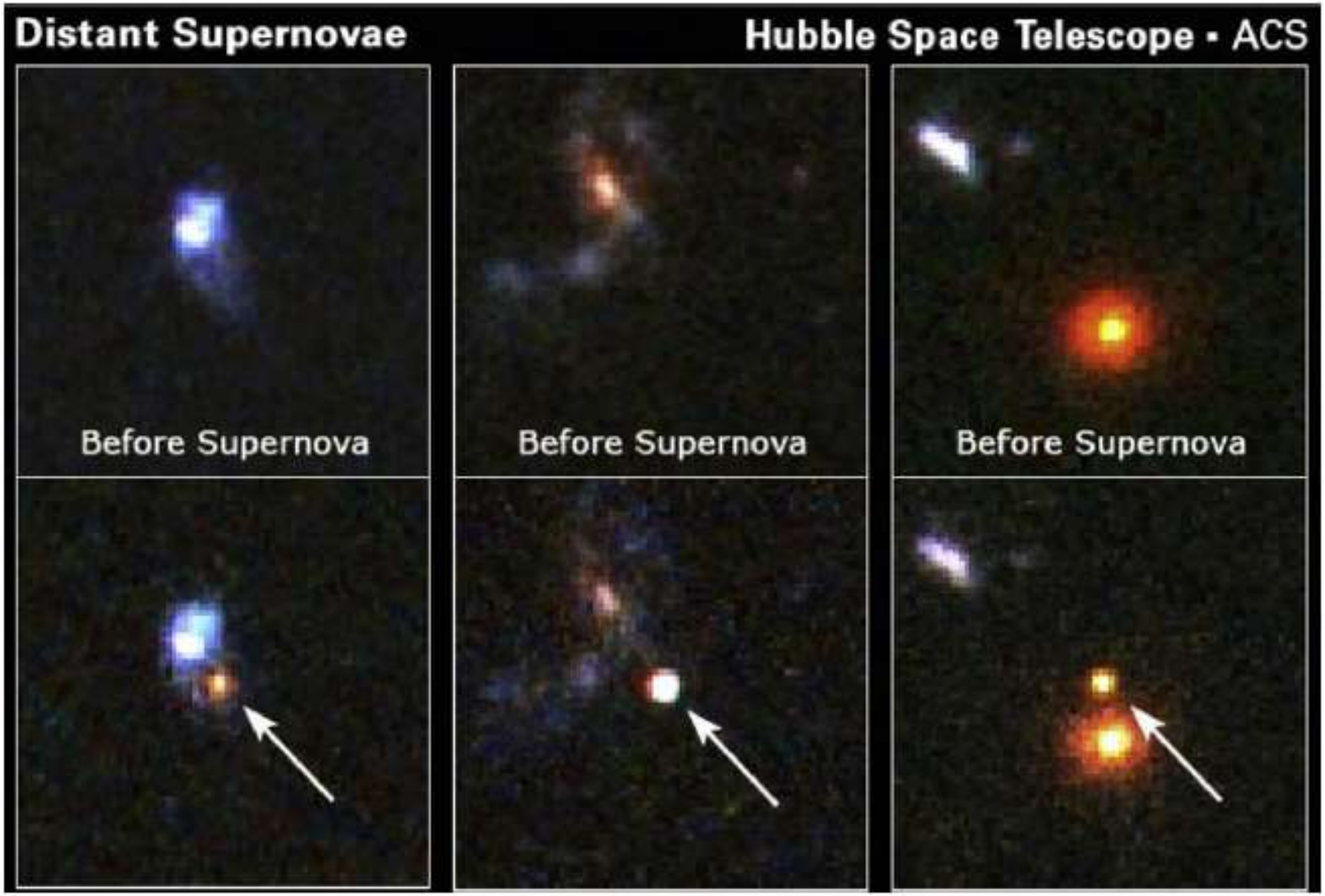
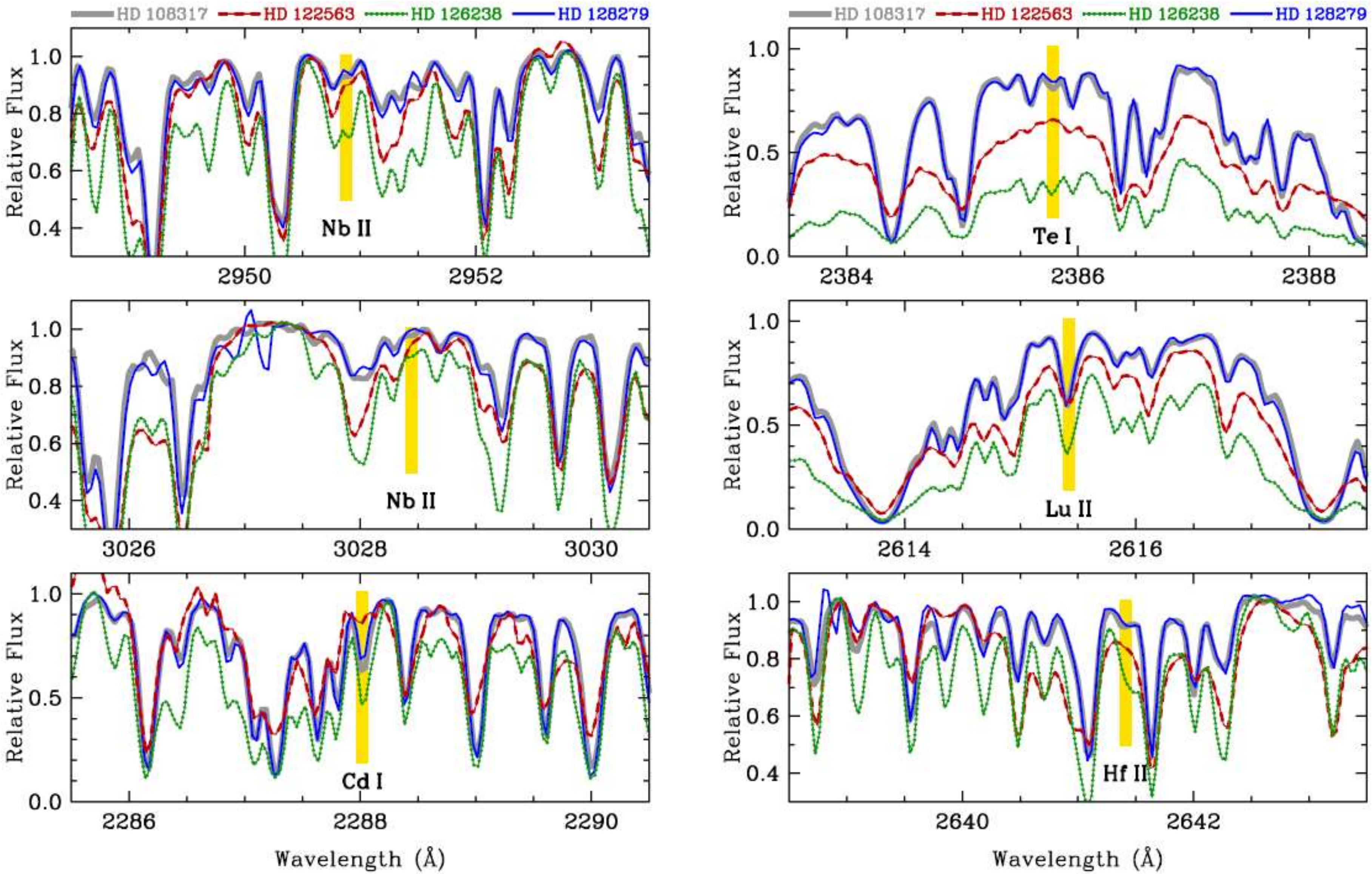


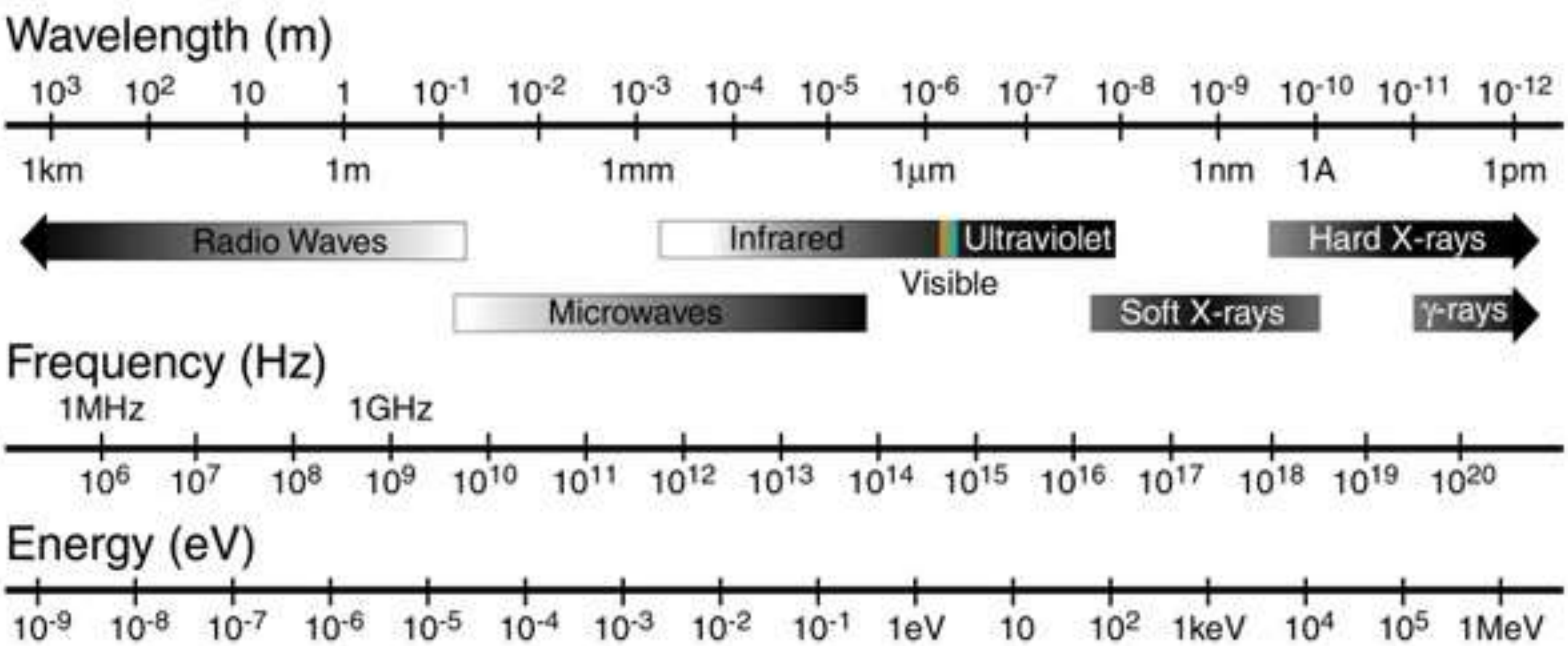

Fig. 6. HST discovery of distant Supernovae.

# NEW *HUBBLE SPACE TELESCOPE* OBSERVATIONS OF HEAVY ELEMENTS IN FOUR METAL-POOR STARS*

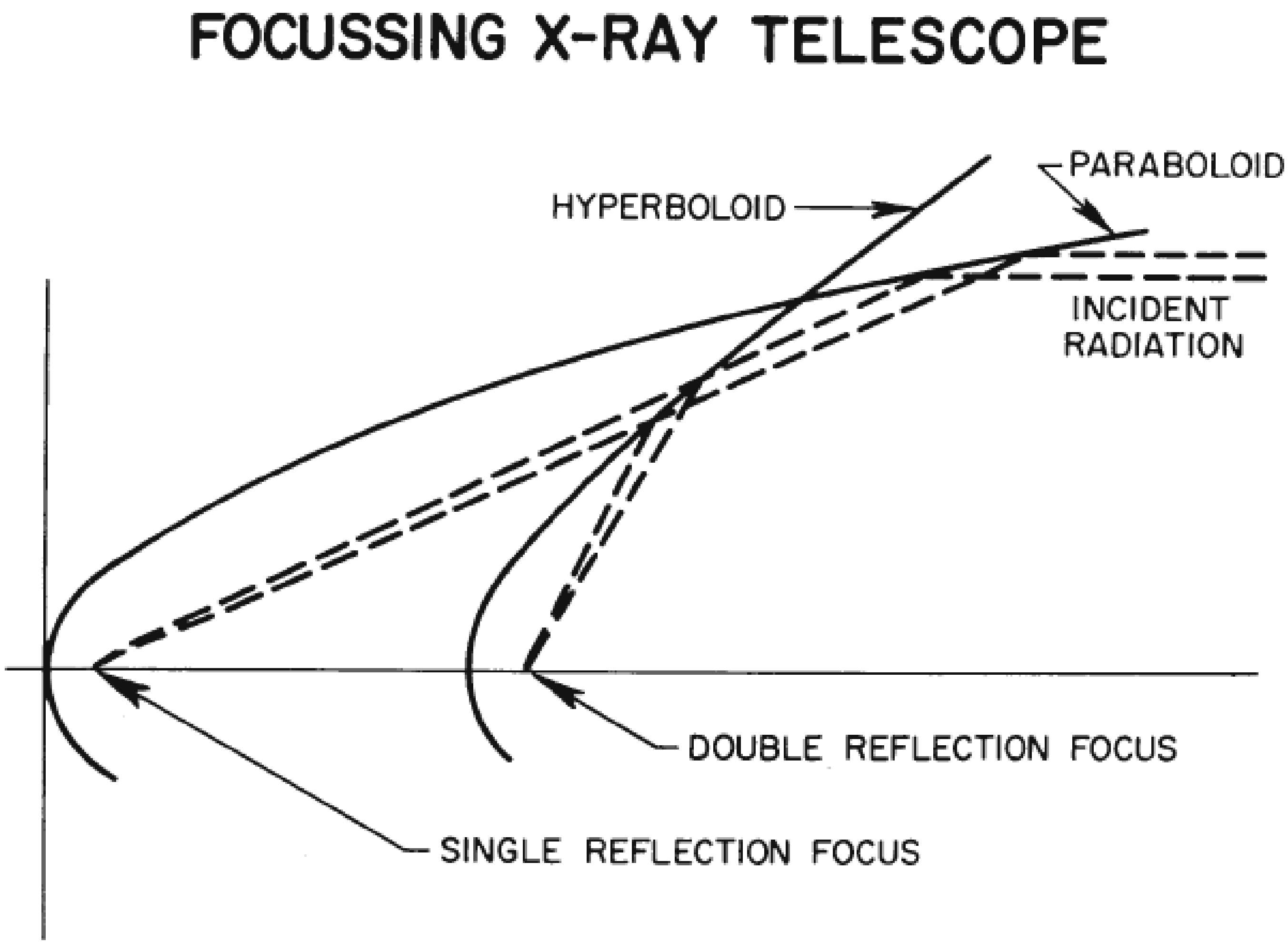
IAN U. ROEDERER[1], JAMES E. LAWLER[2], JENNIFER S. SOBECK[3], TIMOTHY C. BEERS[4,5,6], JOHN J. COWAN[7], ANNA FREBEL[8], INESE I. IVANS[9], HENDRIK SCHATZ[5,6,10], CHRISTOPHER SNEDEN[11], AND IAN B. THOMPSON[1]



# X-ray astronomy



# X-ray astronomy




Exp Astron (2009) 25:143–156

# Primeira imagem em raios-X do Sol (1965)

1965ApJ...142.1274G

## LETTERS TO THE EDITOR

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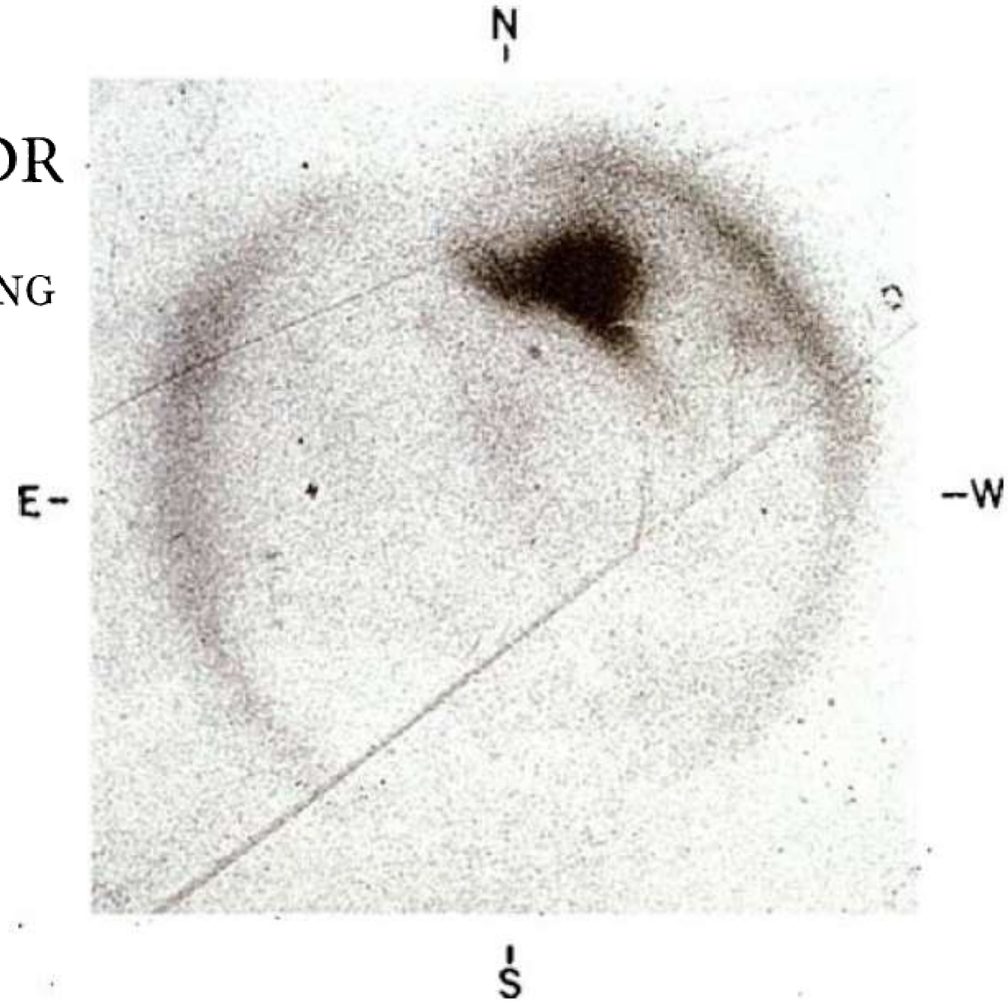
### SOLAR X-RAY IMAGES OBTAINED USING GRAZING INCIDENCE OPTICS*

R. Giacconi
W. P. Reidy
T. Zehnpfennig
and
J. C. Lindsay
W. S. Muney

August 4, 1965

American Science and Engineering, Inc.
Cambridge, Massachusetts
and
Goddard Space Flight Center
Greenbelt, Maryland



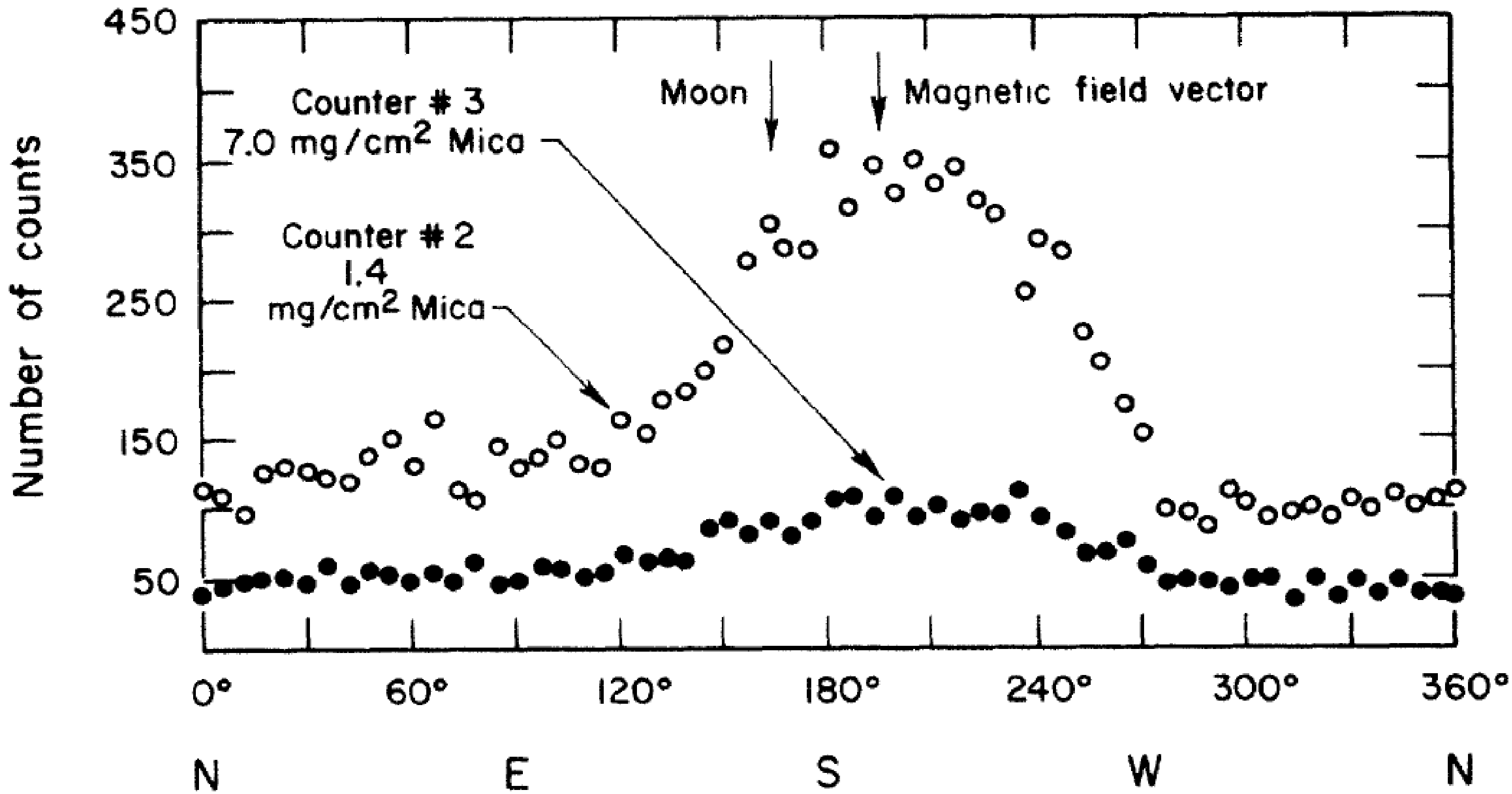
PHYSICAL REVIEW LETTERS

VOLUME 9 DECEMBER 1, 1962 NUMBER 11


# EVIDENCE FOR X RAYS FROM SOURCES OUTSIDE THE SOLAR SYSTEM*


Riccardo Giacconi, Herbert Gursky, and Frank R. Paolini

American Science and Engineering, Inc., Cambridge, Massachusetts


Sco X-1 and the isotropic X-ray background

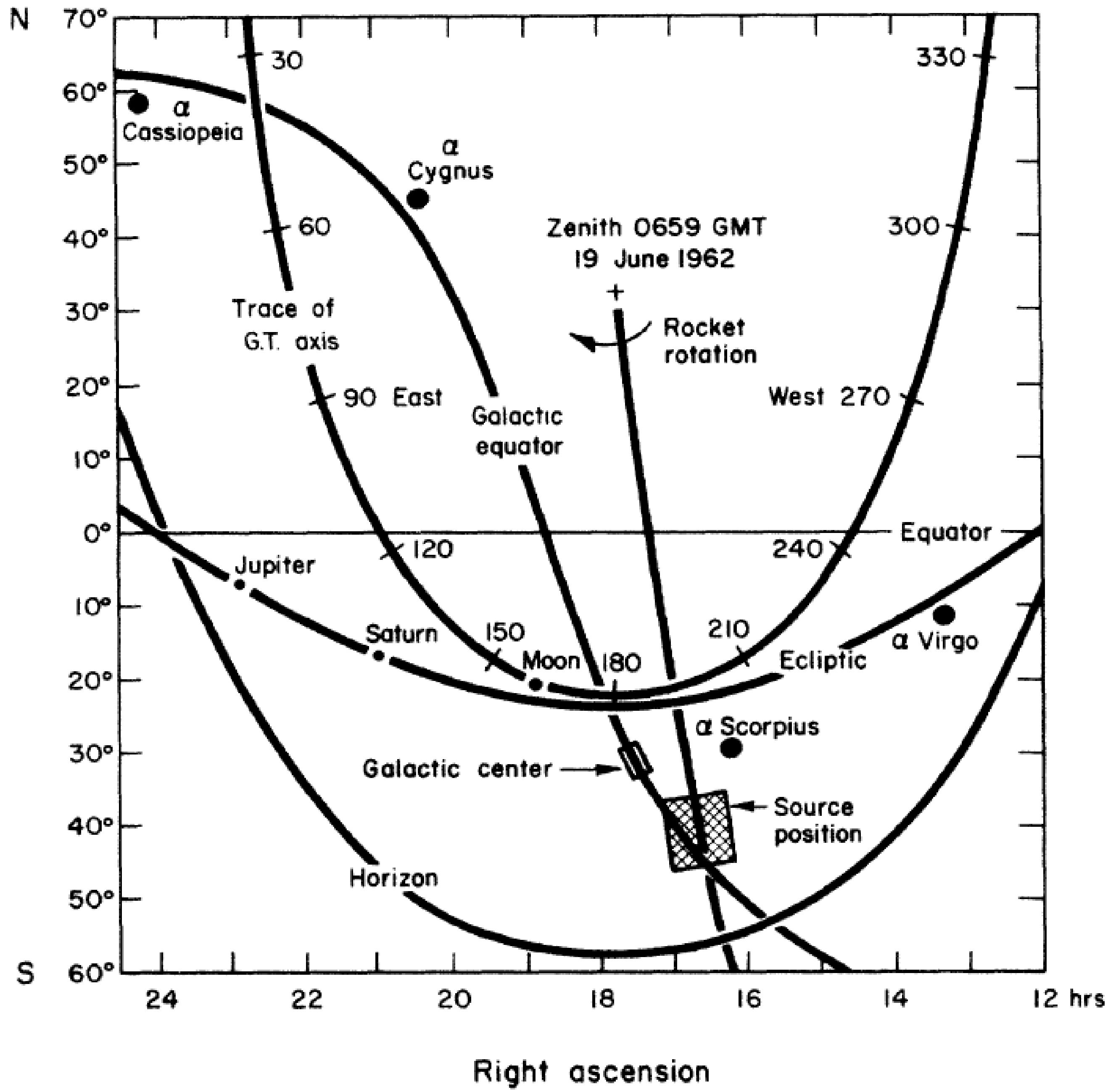
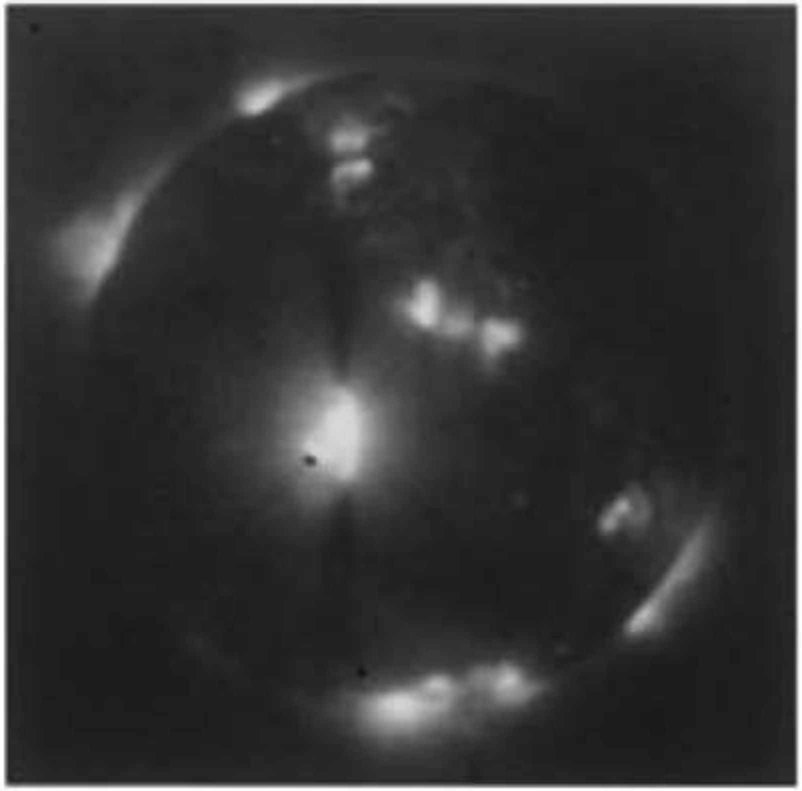
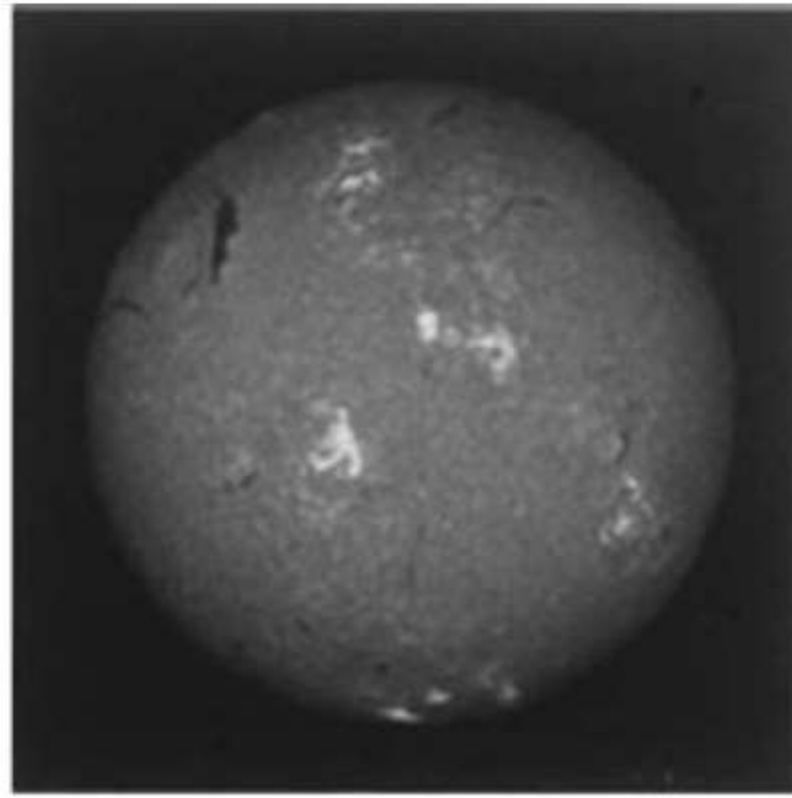



FIG. 2. Chart showing the portion of sky explored by the counters.

# X-RAY PHOTOGRAPHS OF THE SUN TAKEN BY A ROCKET-BORNE X-RAY TELESCOPE ON 8 JUNE 1968



4 MICRON ALUMINIZED MYLAR FILTER



SIMULTANEOUS Hα PHOTOGRAPH
(COURTESY OF ESSA)

Exp Astron (2009) 25:143–156

# Skylab images (1973)

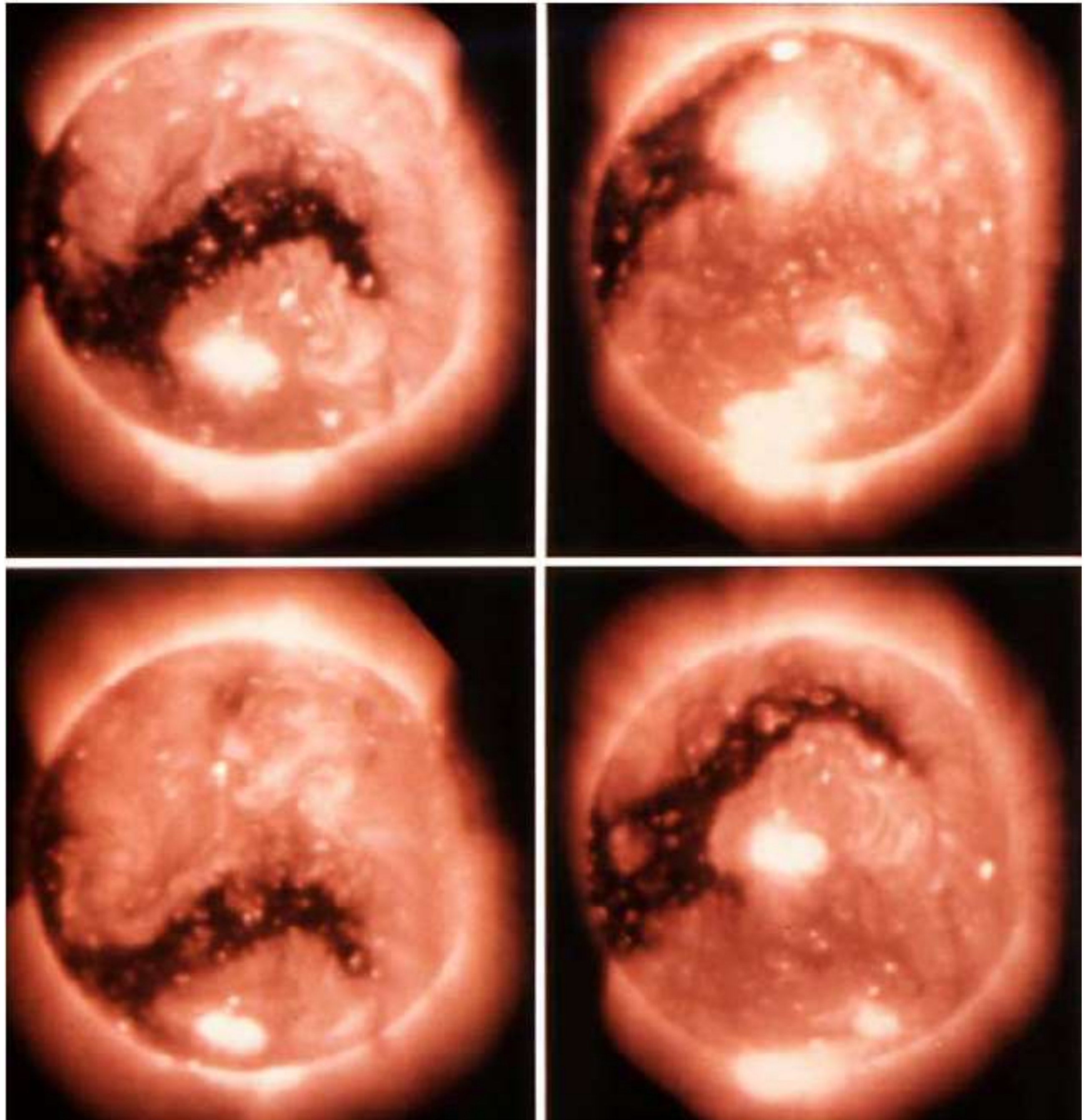


Fig. 4 X-ray pictures of the Sun during a solar rotation

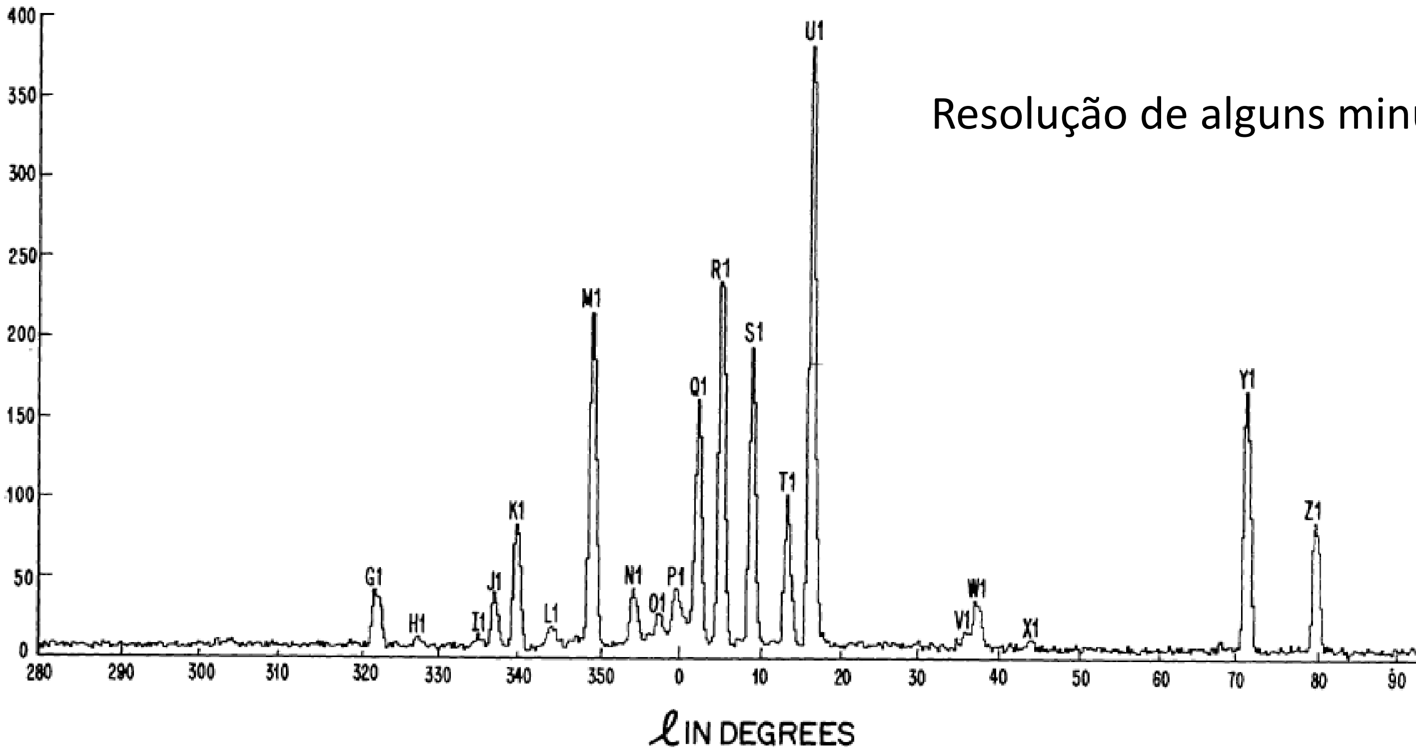
Exp Astron (2009) 25:143–156

THE ASTROPHYSICAL JOURNAL, 165:L27–L35, 1971 April 15

# AN X-RAY SCAN OF THE GALACTIC PLANE FROM *UHURU*

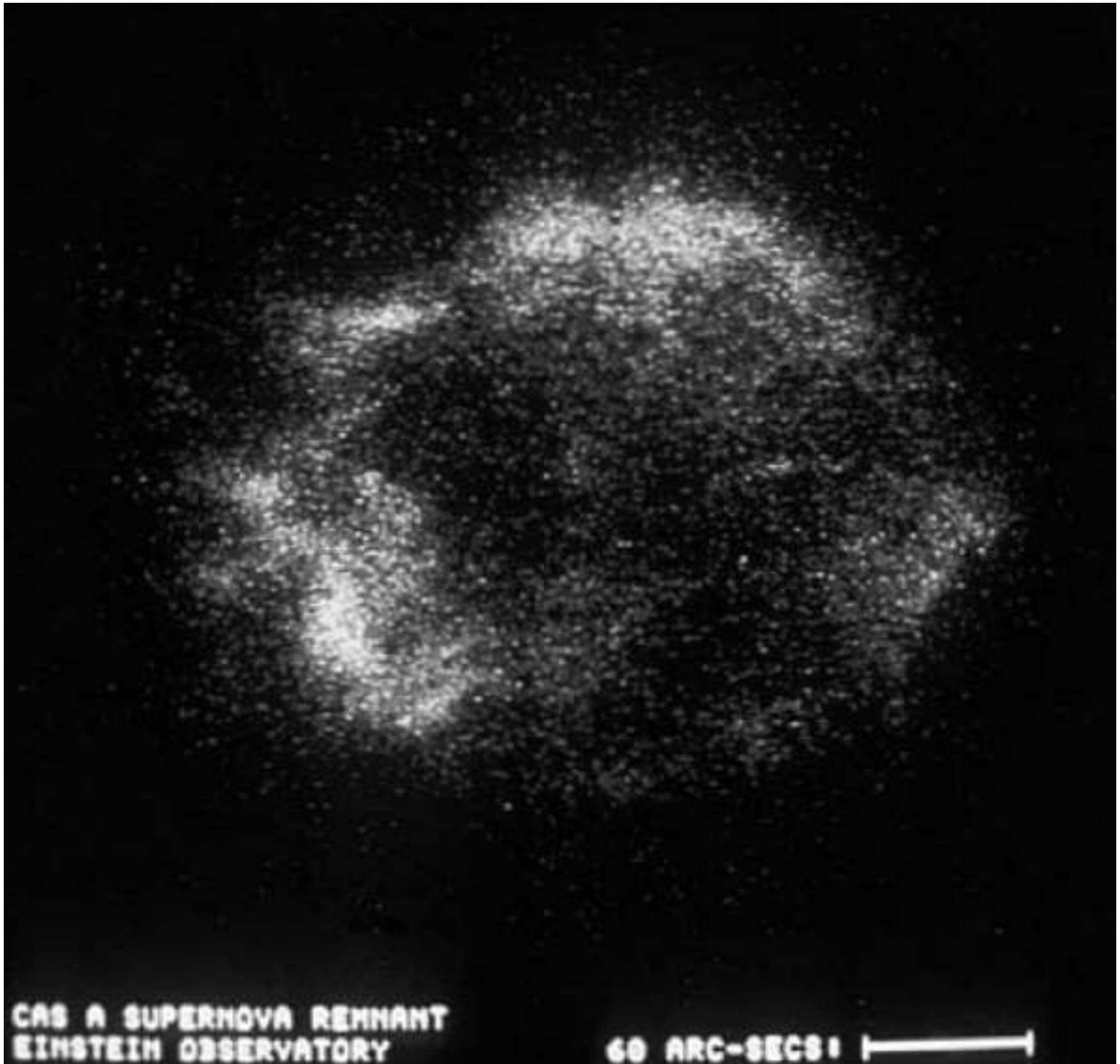
R. GIACCONI, E. KELLOGG, P. GORENSTEIN,
H. GURSKY, AND H. TANANBAUM
American Science and Engineering, Inc., Cambridge, Massachusetts 02142

This is the first of four Letters reporting preliminary results from the first of NASA's small astronomy satellites, *Uhuru*. The satellite is designed to conduct a survey of the X-ray sky in the 2–20-keV energy range to an ultimate sensitivity of about $5 \times 10^{-4}$ the flux of the Crab Nebula. In this first Letter we report on a scan of the galactic plane in which we see twenty-nine discrete sources, of which seven have not been reported previously.




Resolução de alguns minutos de arco

# Einstein Observatory (1978), NASA





60 cm X-ray telescope

**Fig. 7** An X-ray picture of the Cas A Supernova

Exp Astron (2009) 25:143–156

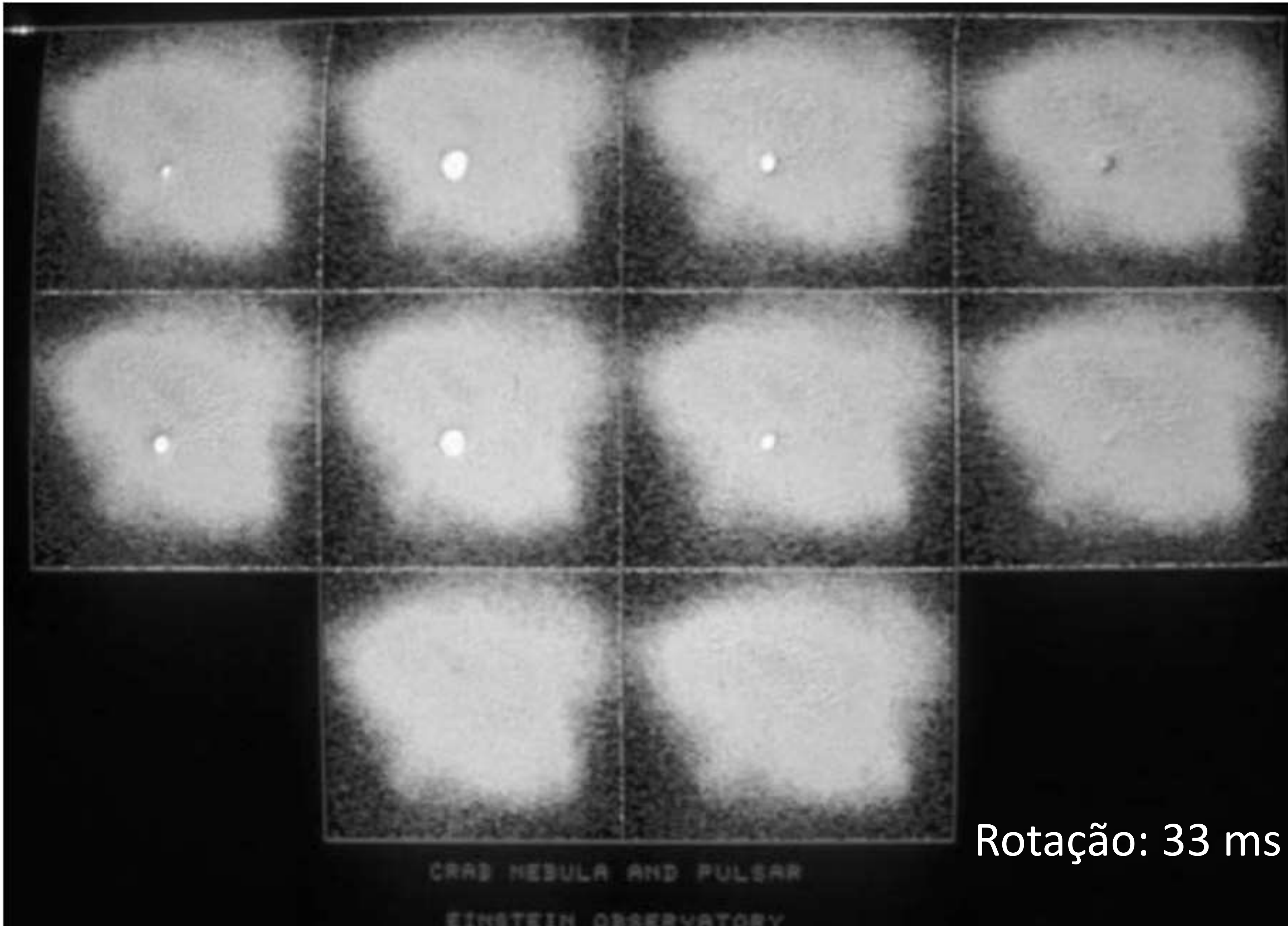



**Fig. 8** The Crab Nebula and its Pulsar in X-rays

Exp Astron (2009) 25:143–156


Einstein
Resolução ~ 5”

Stellar X-ray sources in M-31

Exp Astron (2009) 25:143–156

# HIGH-RESOLUTION X-RAY SPECTROSCOPY OF M87 WITH THE *EINSTEIN* OBSERVATORY: THE DETECTION OF AN O VIII EMISSION LINE[1]

C. R. CANIZARES, G. W. CLARK, T. H. MARKERT, C. BERG, M. SMEDIRA,
D. BARDAS, H. SCHNOPPER, AND K. KALATA

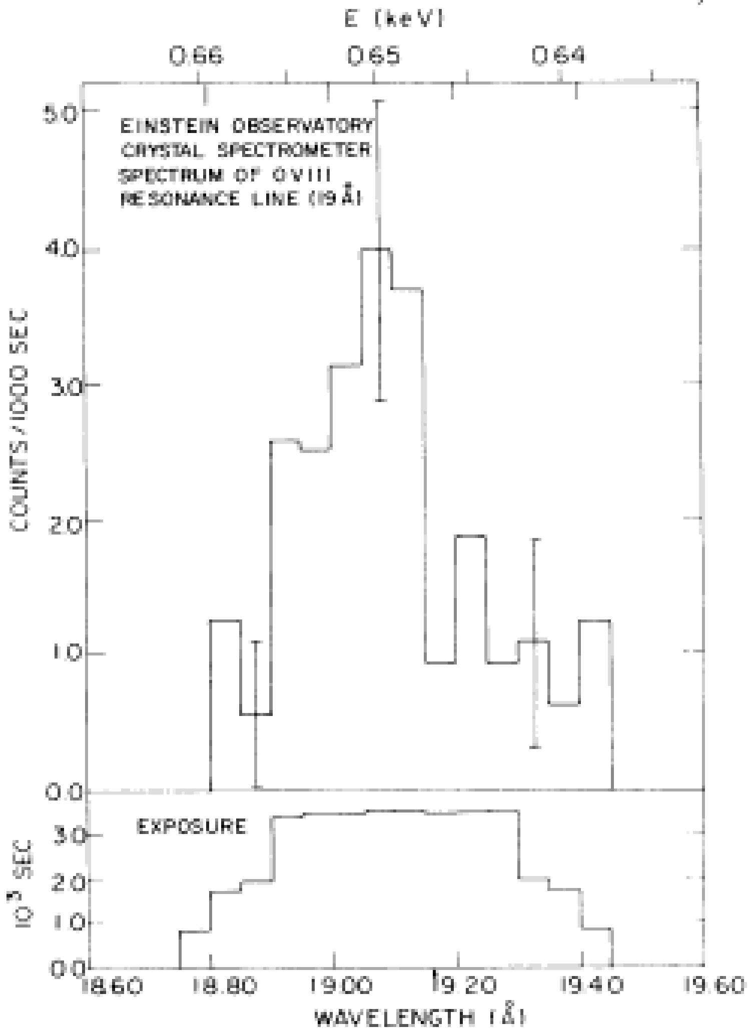



FIG. 2.—Spectrum of M87 in the vicinity of the Lα line of O VIII. The upper curve shows the count rate versus wavelength corrected for exposure. The exposure is shown in the lower curve. The redshifted wavelength of the line is 19.05 Å.

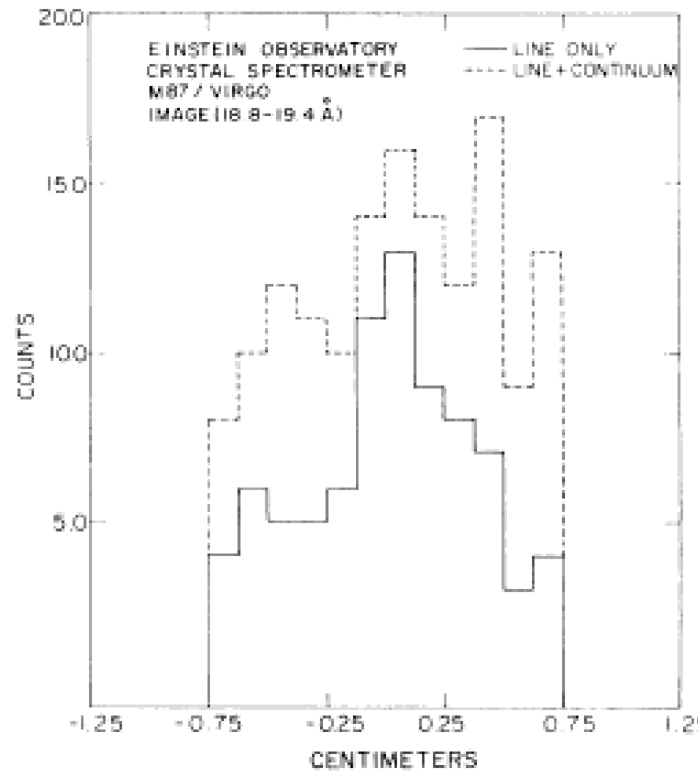
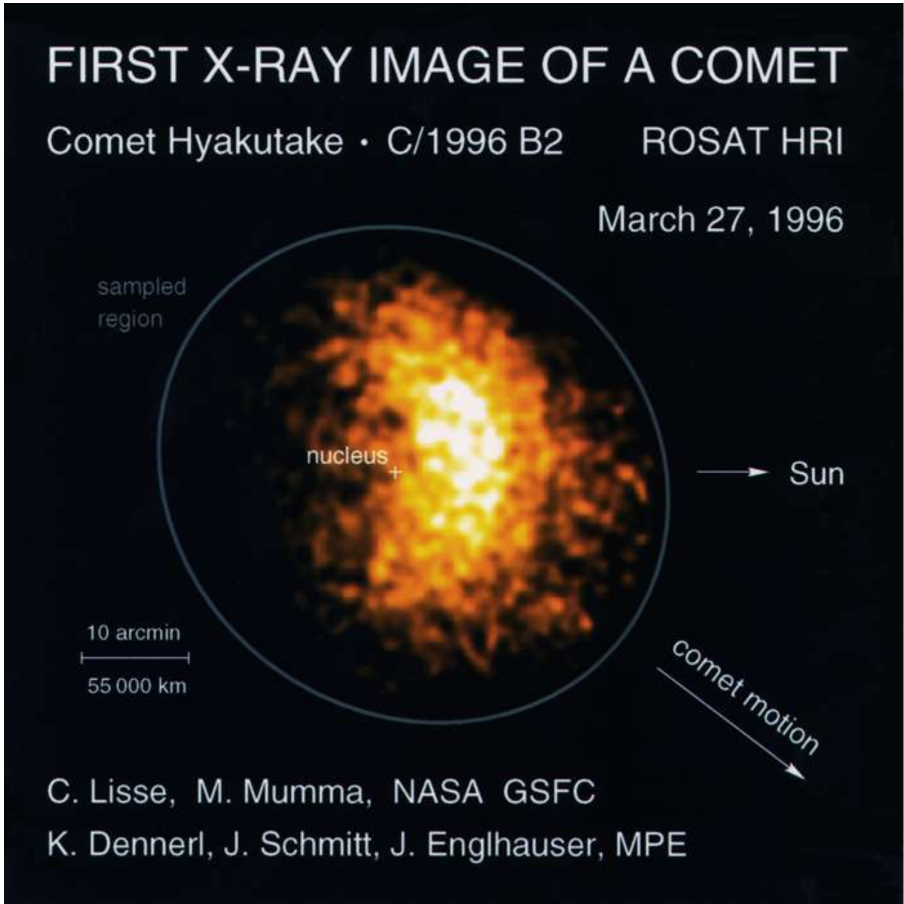



FIG. 3.—Histogram of counts versus position in the detector corrected for image motion showing the projection of the astigmatic image of the source formed by X-rays in the O VIII Lα line and in the line plus continuum (mainly background). The scale is ∼1 mm per arcmin on the sky, and the expected width of the M87 image is ∼4 mm.

THE ASTROPHYSICAL JOURNAL, 234:L33–37, 1979 November 15

# ROSAT (Germany + USA + UK), 1990-99

- 84cm X-ray telescope
- X-ray all sky survey, over 150 000 objects
- Detailed morphology of supernova remnants and cluster of galaxies
- Detection of isolated neutron stars
- Discovery of X-ray emission from comets



# Star formation history of Canis Major R1

## I. Wide-Field X-ray study of the young stellar population★

J. Gregorio-Hetem[1], T. Montmerle[2], C. V. Rodrigues[3], E. Marciotto[1], T. Preibisch[4], and H. Zinnecker[5]

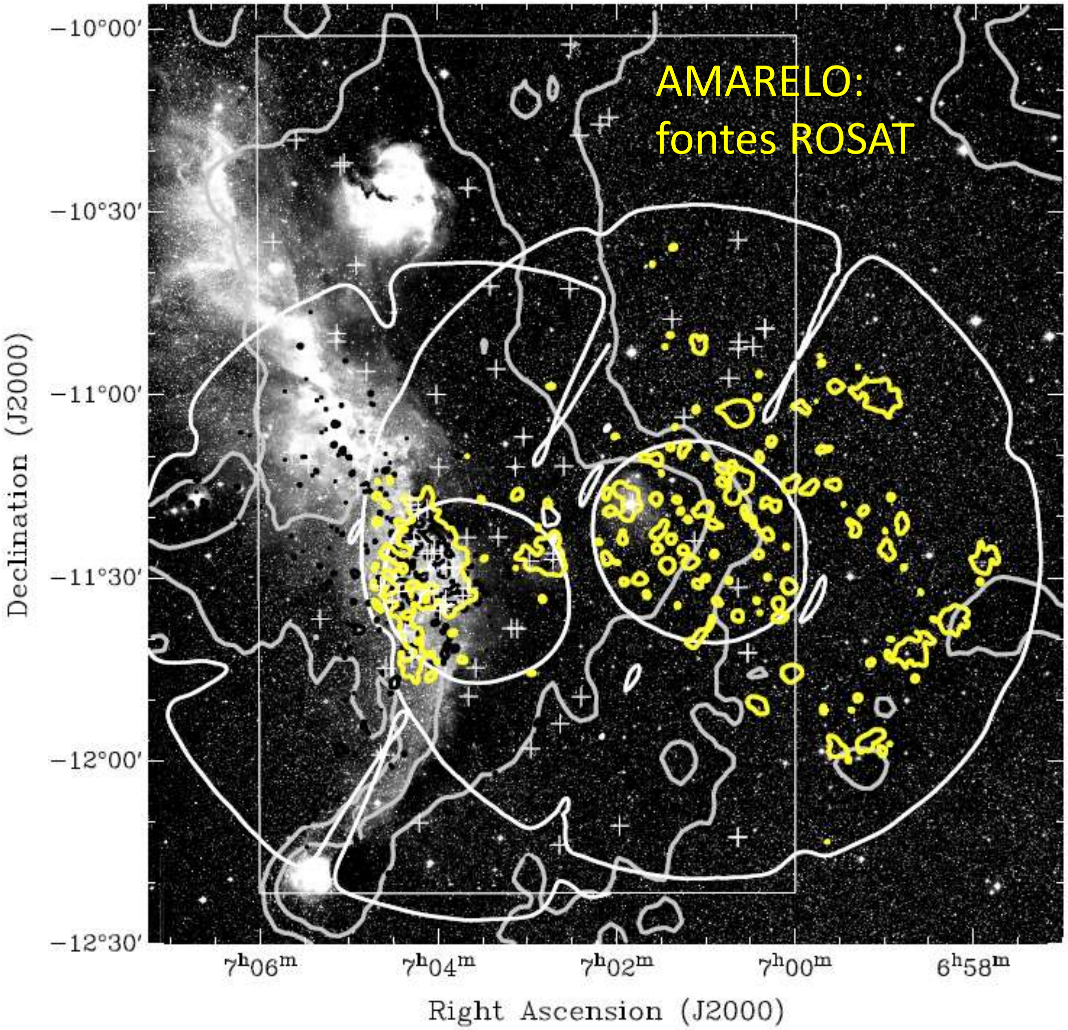
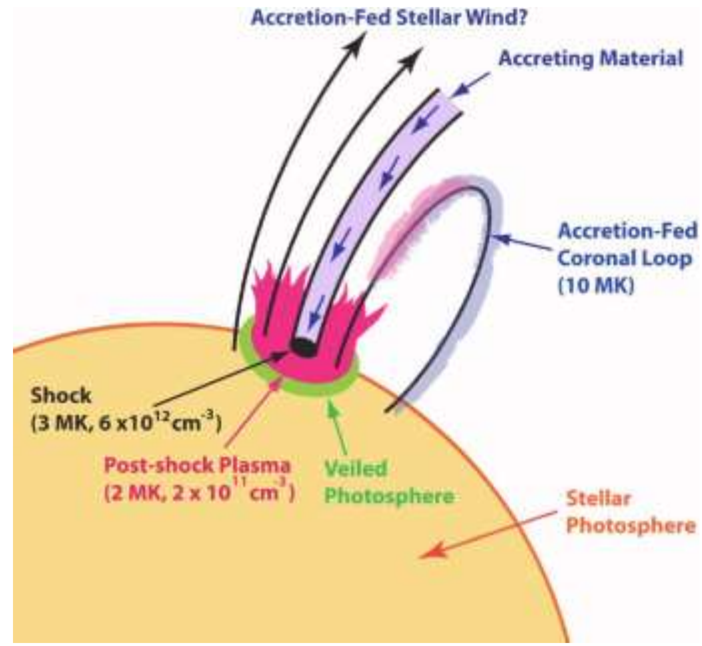



Fig. 2. *ROSAT* PSPC X-ray contours and fields-of-view superimposed on a digitized POSS(R) image of the CMa R1 region. Grey contours show the same *IRAS-ISIS* data at 100 μm as Fig. 1. The observations of Field 1 are indicated by yellow contours and of Field 2 by black contours. The white crosses indicate the association members identified in the optical survey by Shevchenko et al. (1999), within the area outlined by a white rectangular box.

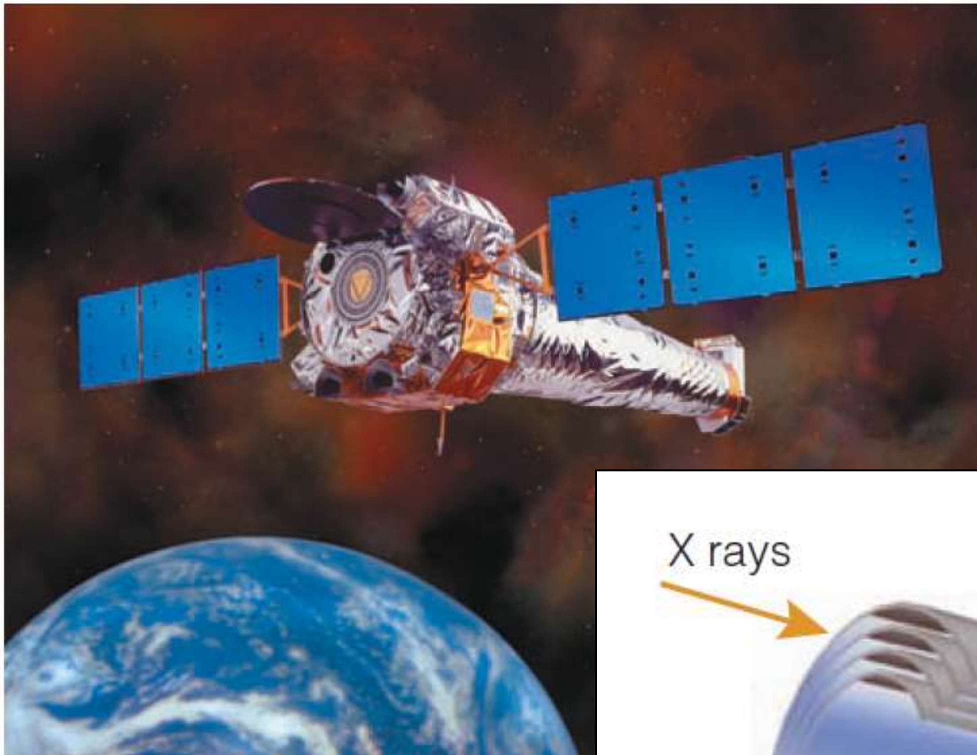



A schematic diagram of the surface of TW Hydrae, illustrating where strong X-ray emission might arise. Accreting material can produce winds and shocks at the stellar photosphere; some parameters are specified. Credit: N. Brickhouse, et al, 2010

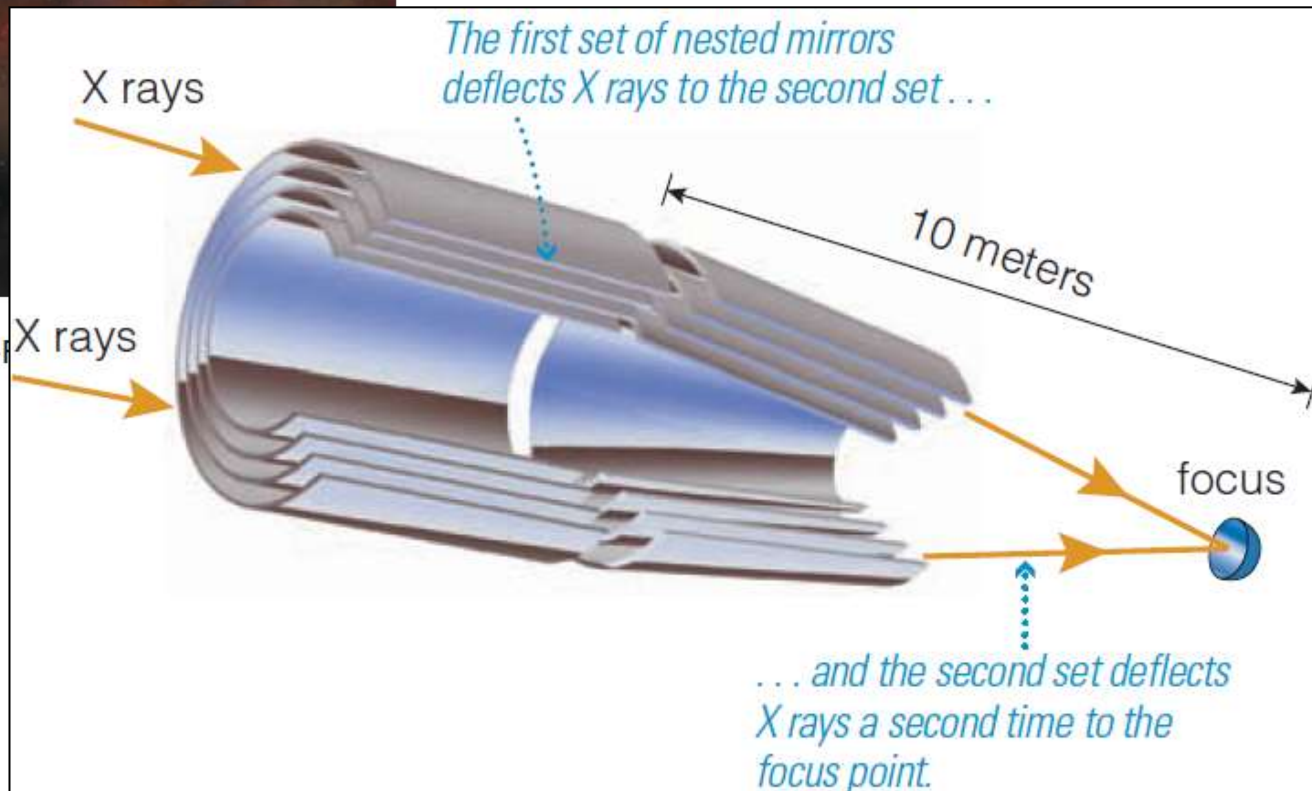
A&A 506, 711–727 (2009)

# **Chandra** (NASA), 1999

- 0.1 - 10 keV
- 1,2 m telescope
- 0,5 arcsec resolution



**a** Artist illustration of the Chandra X-
orbits Earth.




**b** This diagram shows the arrangement of Chandra's X-ray mirrors. There are two sets of cylindrical mirrors, one near the front of the telescope and one farther back. Each mirror is 0.8 meter long and between 0.6 and 1.2 meters in diameter.

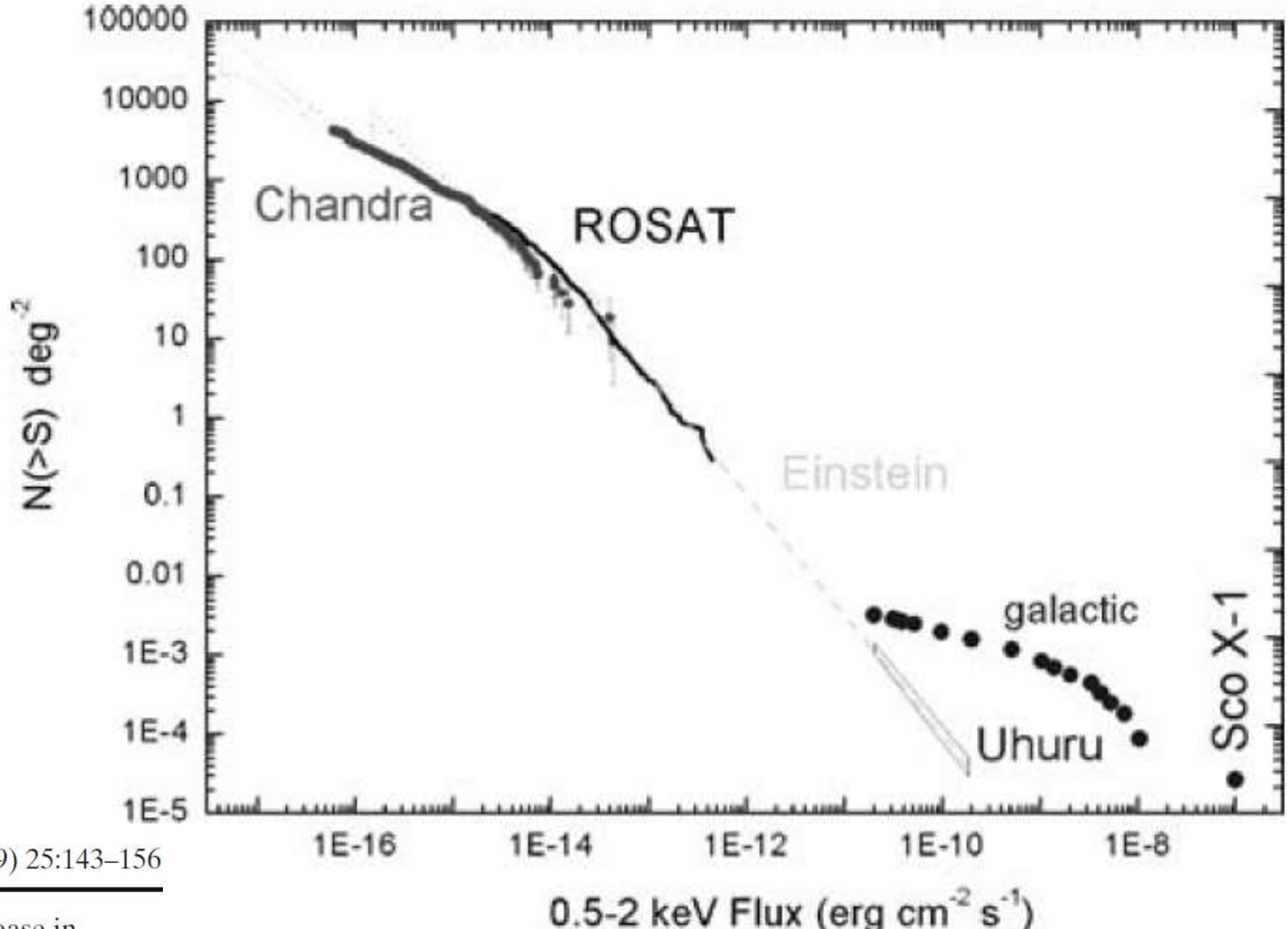
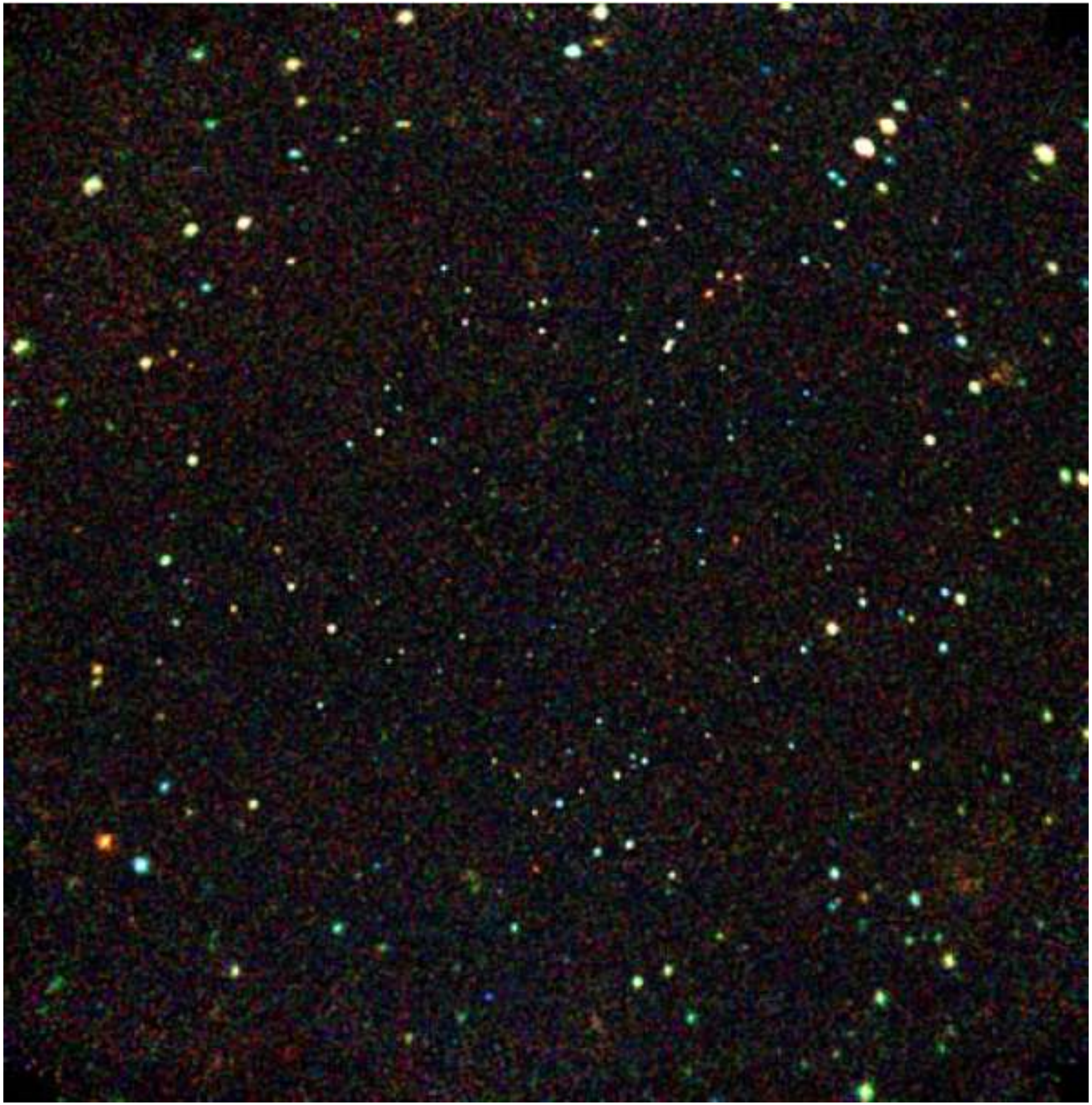



**Fig. 12** The increase in sensitivity from the rocket observation of Sco X-1 in 1962 to the observations by the *Chandra* Observatory in CDFS

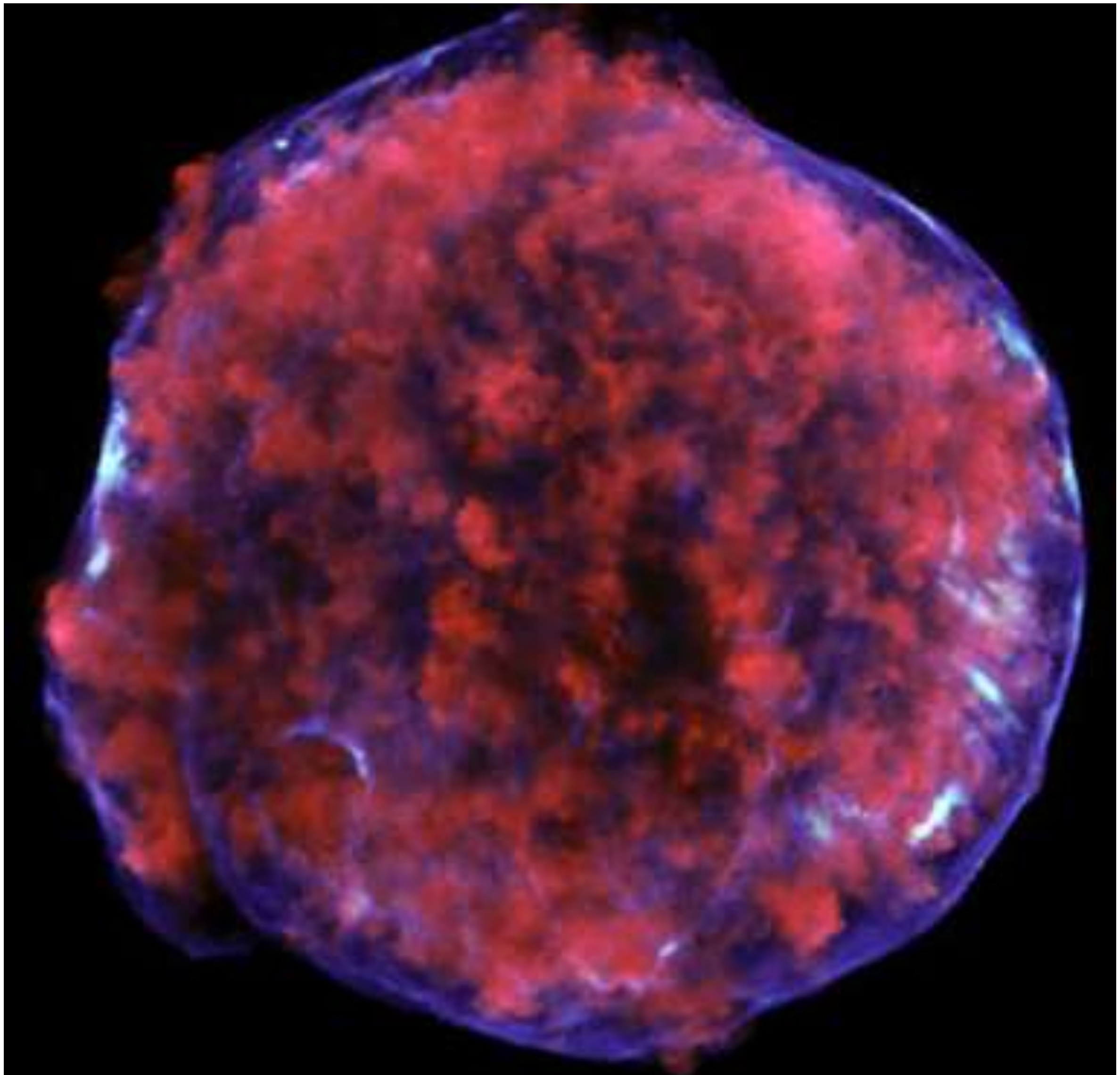
Chandra deep field image

One-million-second exposure

(mostly AGNs)

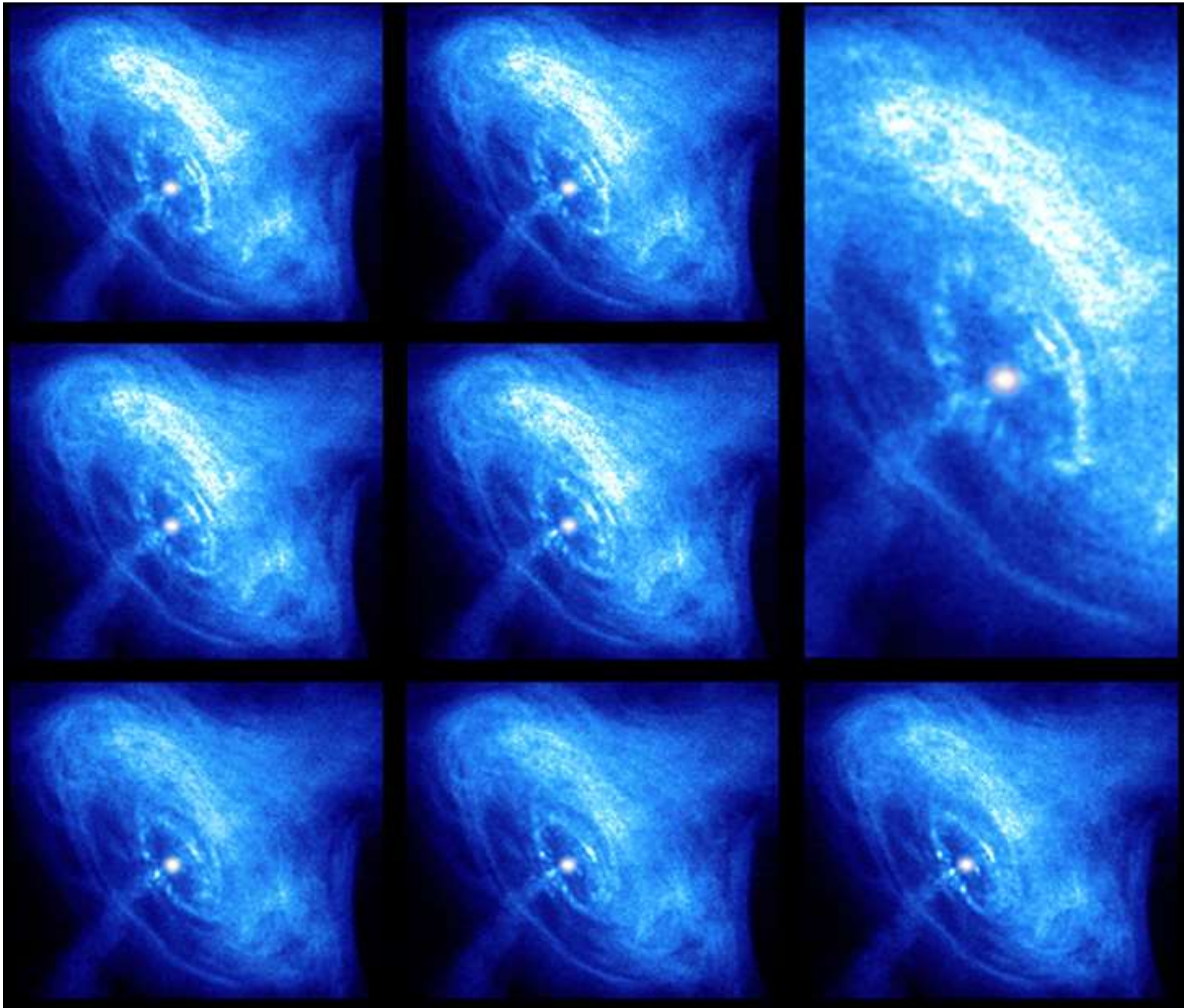


# Tycho Supernova remnant in x-ray (Chandra)

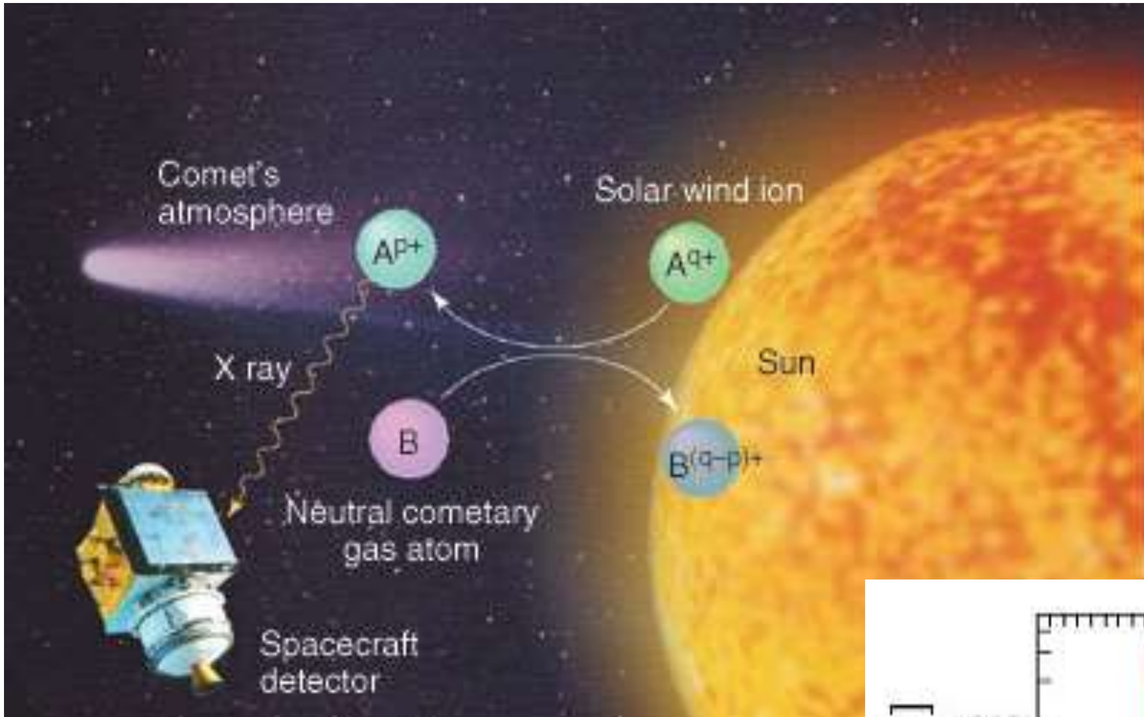


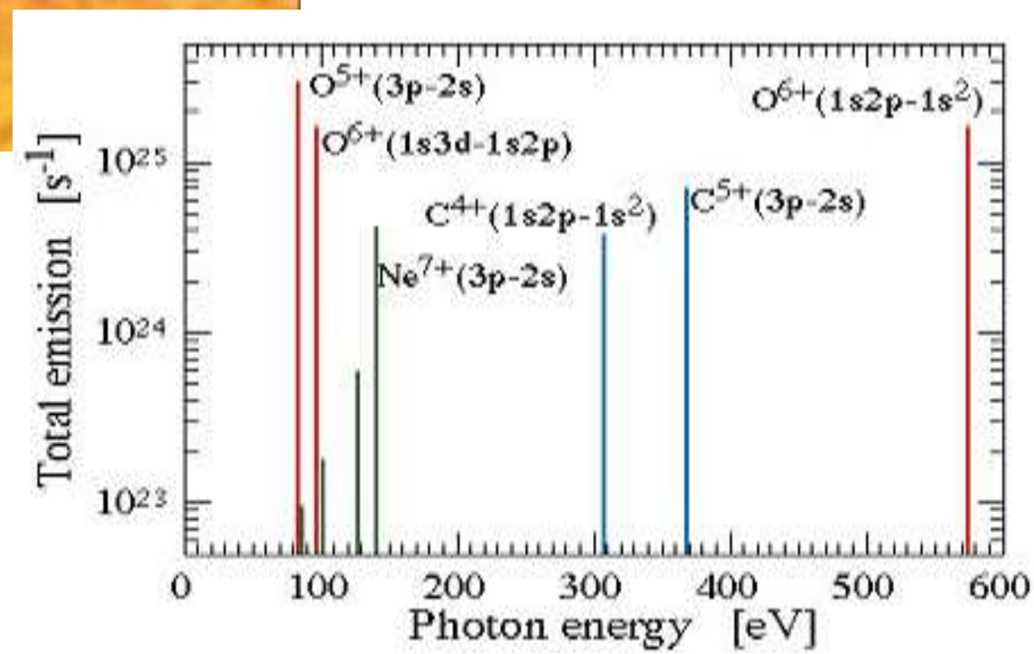
# Crab Nebula observed over several months





# Charge transfer reactions in comets

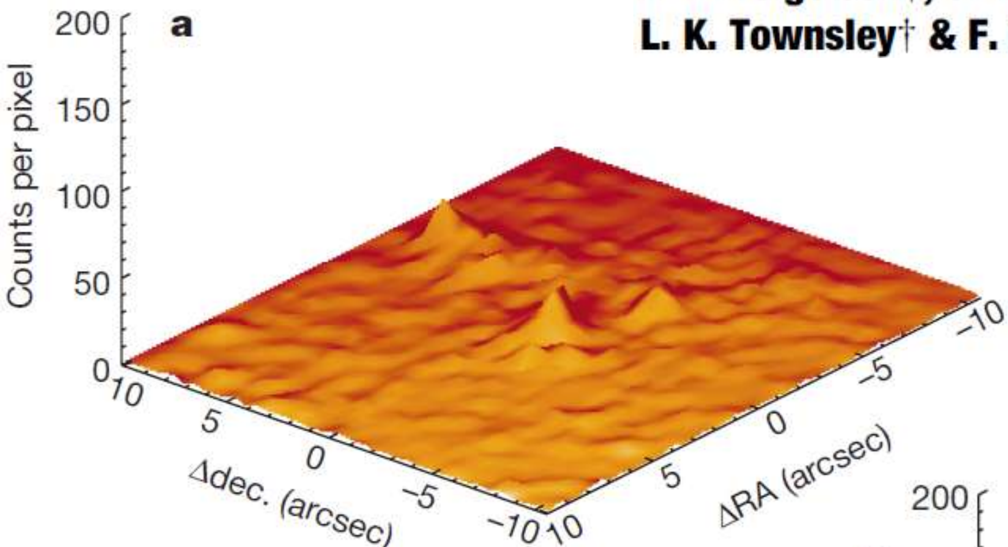


letters to nature
NATURE | VOL 413 | 6 SEPTEMBER 2001

# Rapid X-ray flaring from the direction of the supermassive black hole at the Galactic Centre

**F. K. Baganoff*, M. W. Bautz*, W. N. Brandt†, G. Chartas†, E. D. Feigelson†, G. P. Garmire†, Y. Maeda†‡, M. Morris§, G. R. Ricker*, L. K. Townsley† & F. Walter‖**



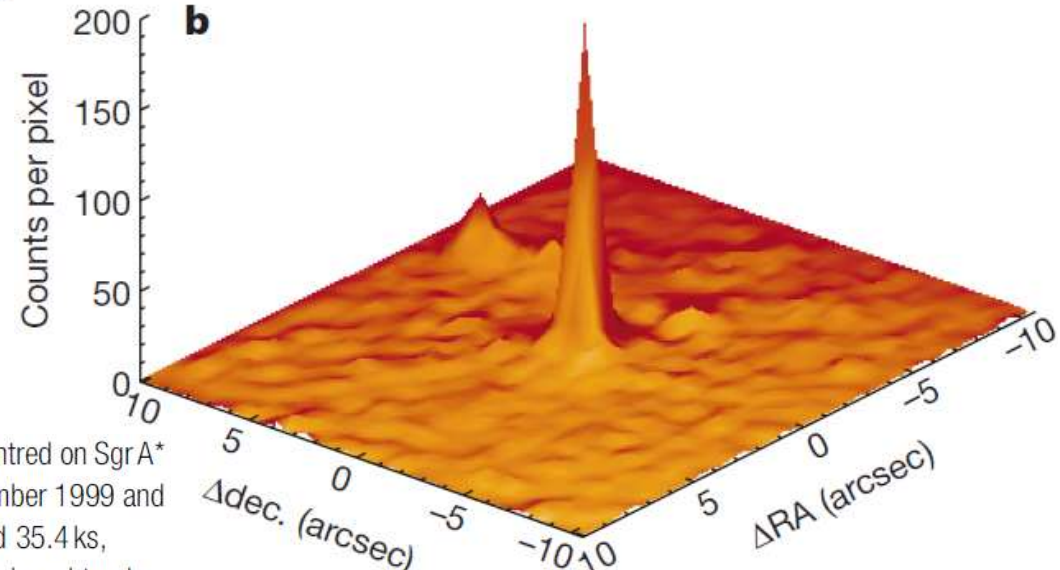
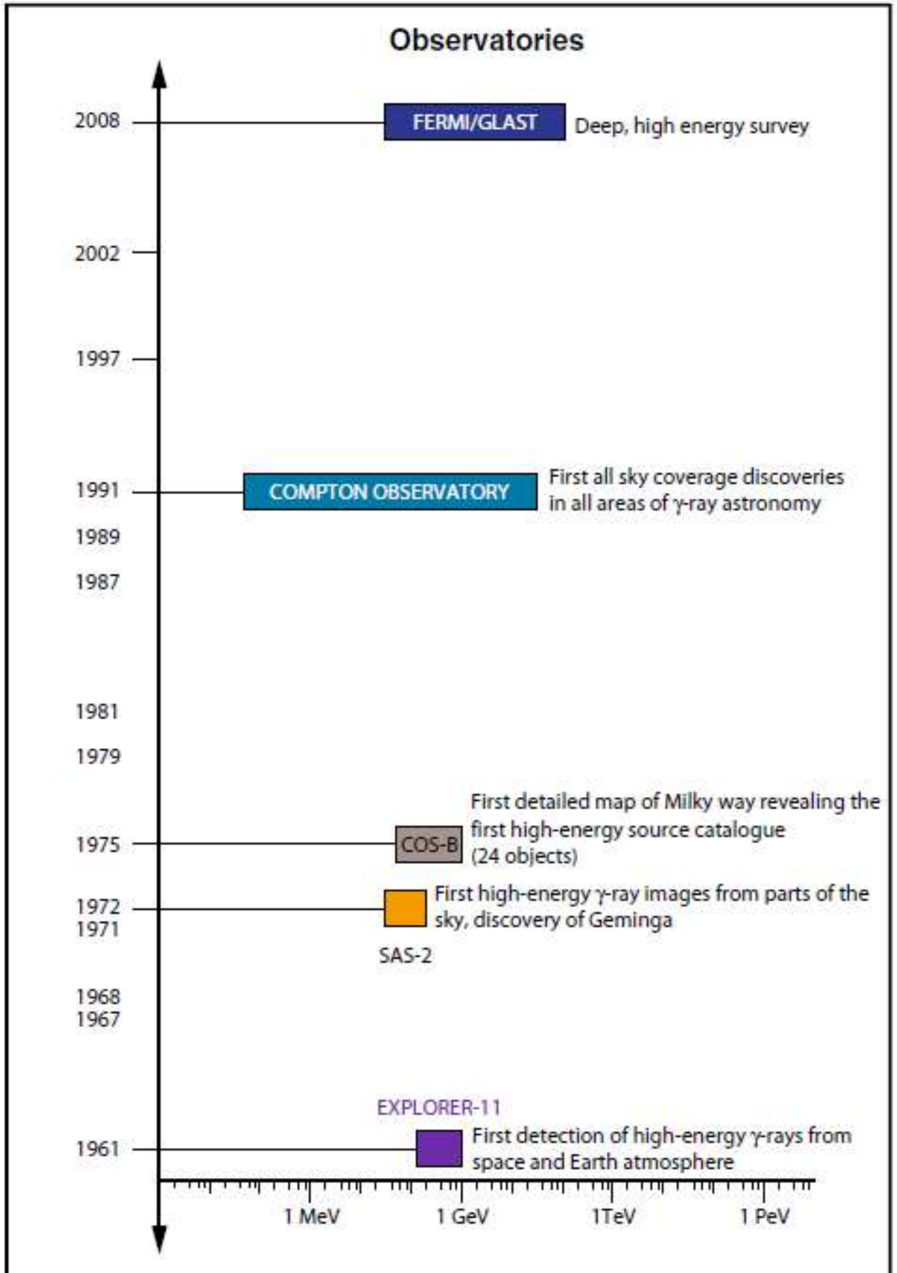
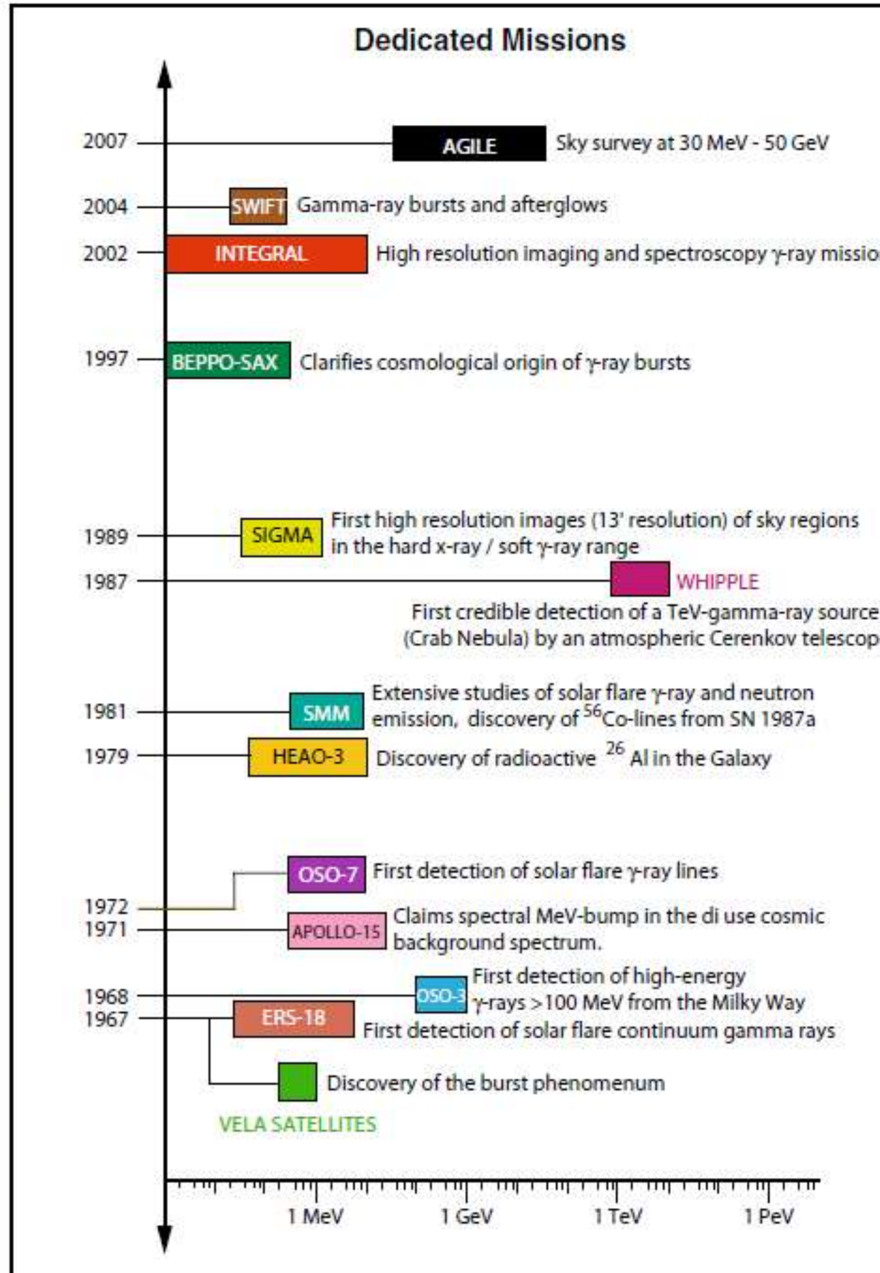



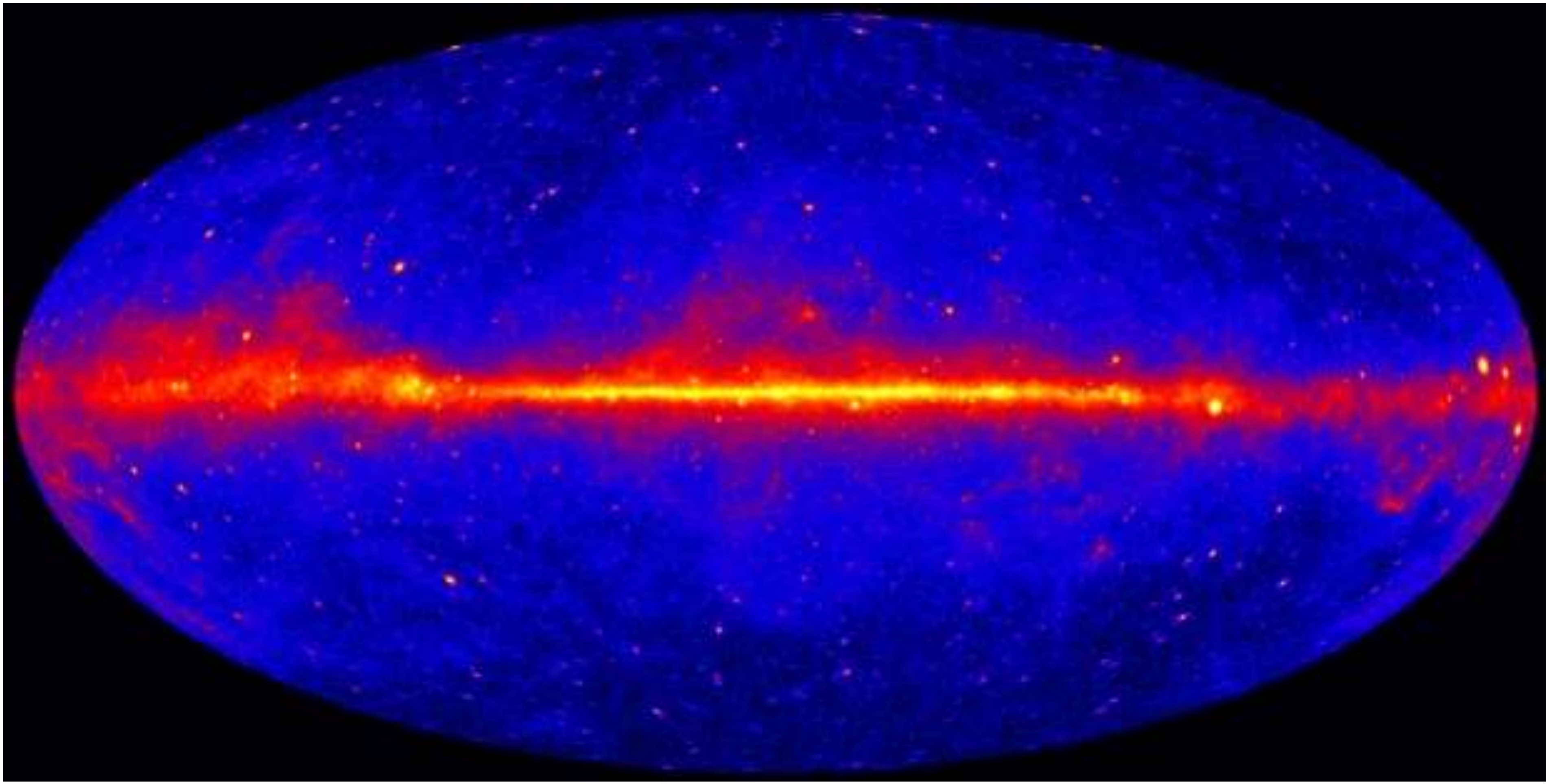

**Figure 1** Surface plots of the 2–8 keV counts within a 20″ × 20″ field centred on Sgr A* at two epochs. The data were taken with Chandra ACIS-I on (**a**) 21 September 1999 and (**b**) 26–27 October 2000. The effective exposure times were 40.3 ks and 35.4 ks, respectively. The spatial resolution is 0.5″ per pixel. An angle of 1″ on the sky subtends a projected distance of about 0.04 pc at the galactocentric distance of 8.0 kpc (ref. 30). The

# Gamma ray Astronomy

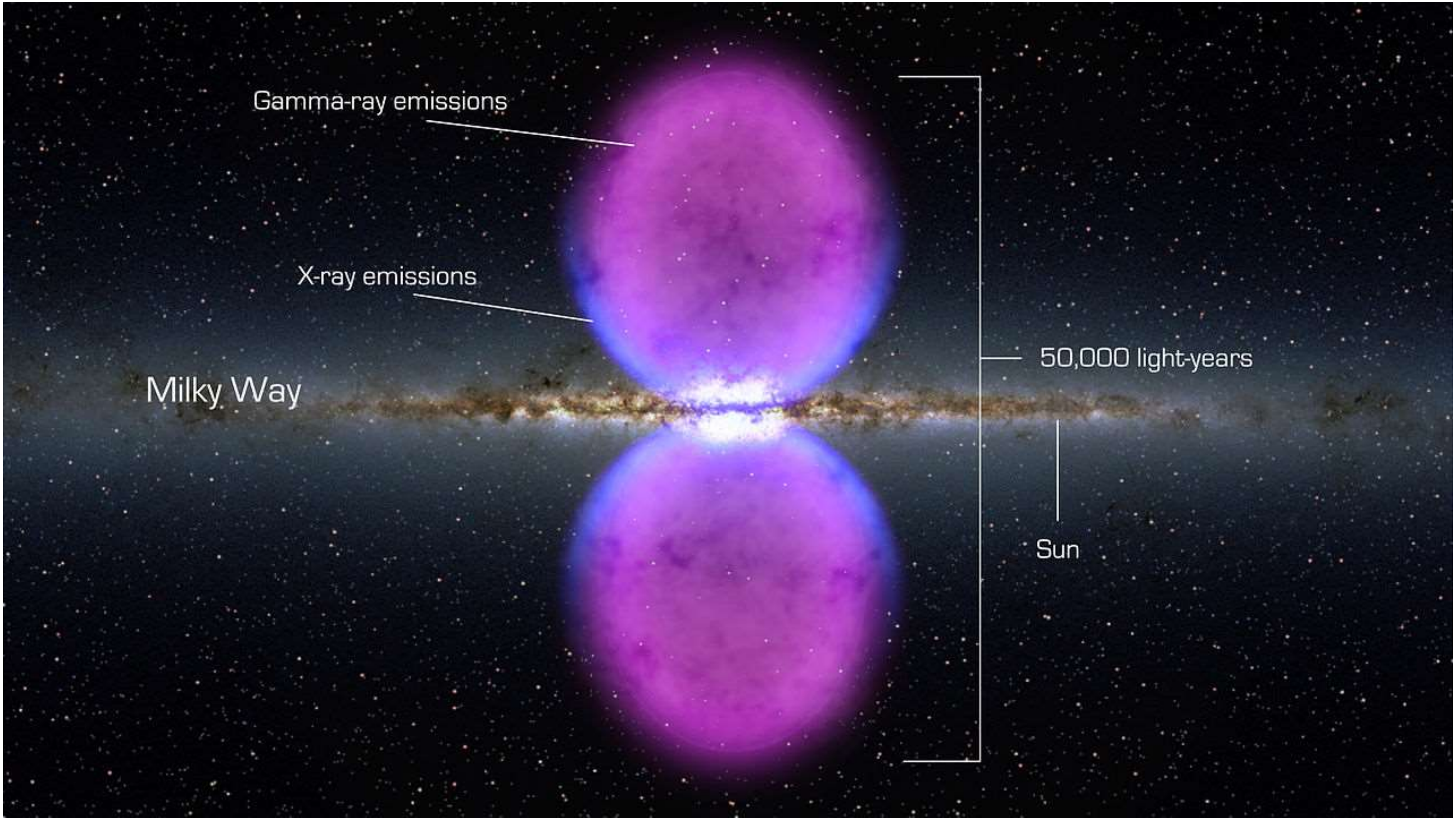


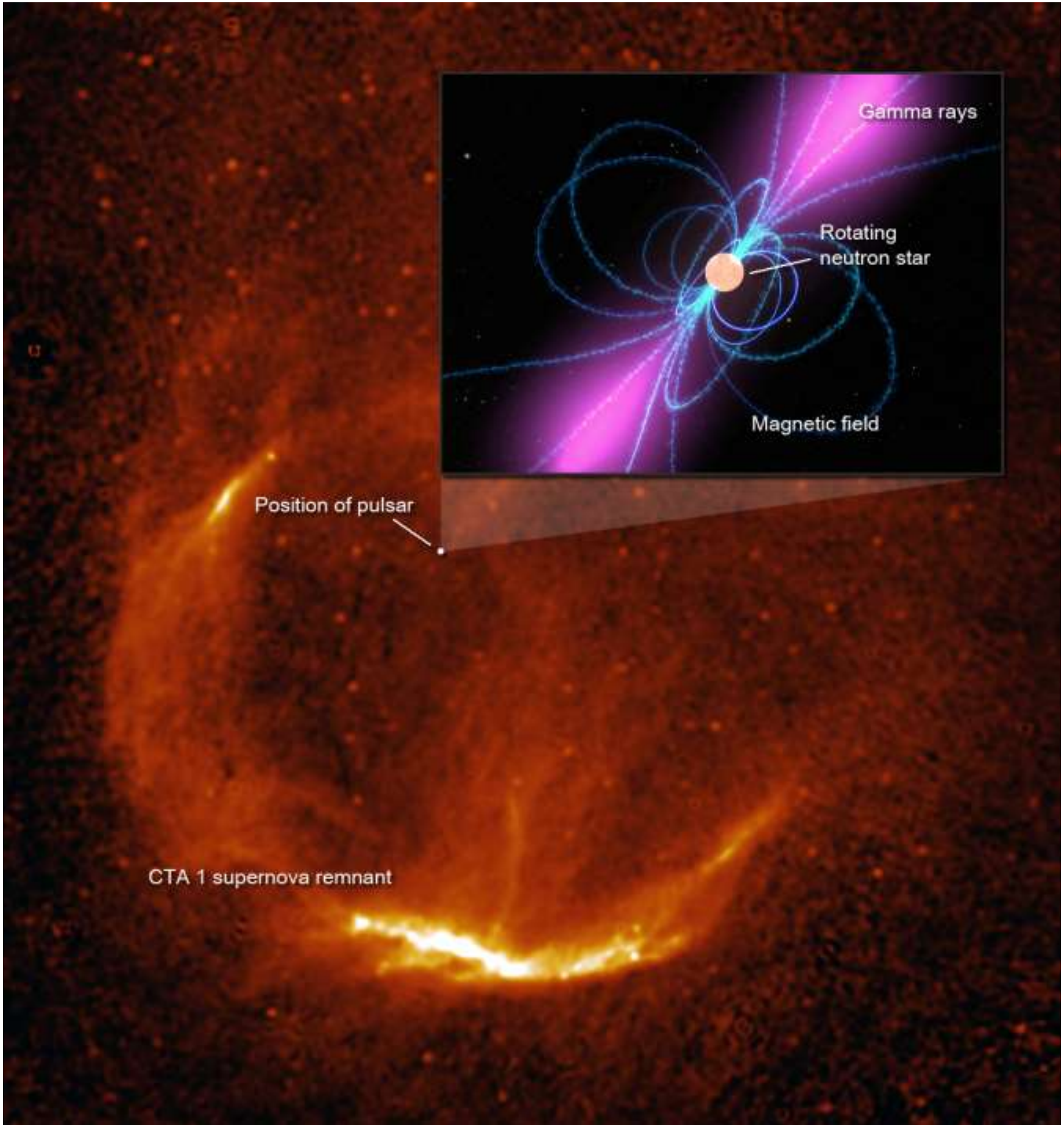



# The sky at energies > 1 GeV based on five years of data NASA's Fermi

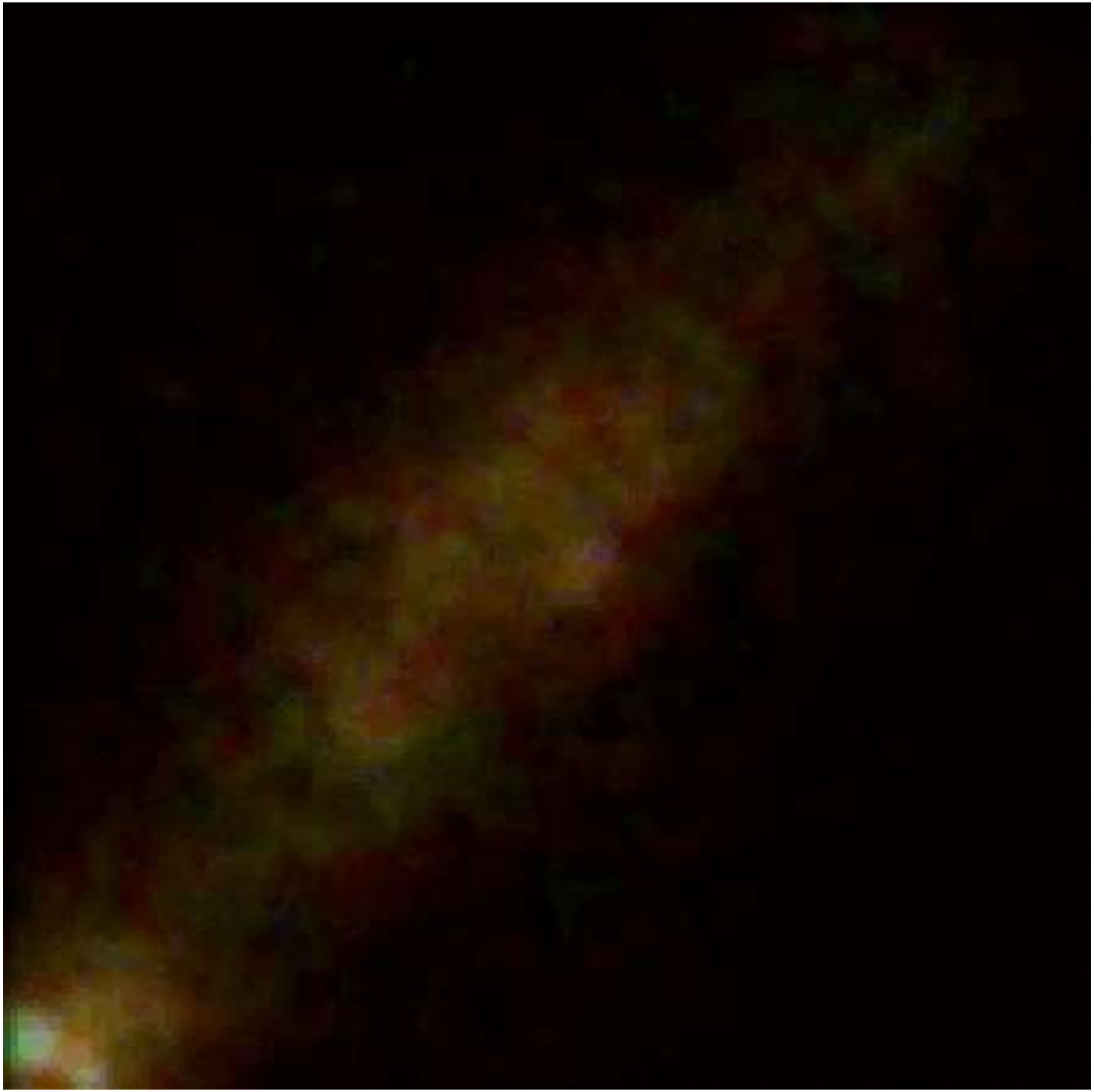


# X-ray/gamma-ray bubbles of the Milky Way (© Fermi)



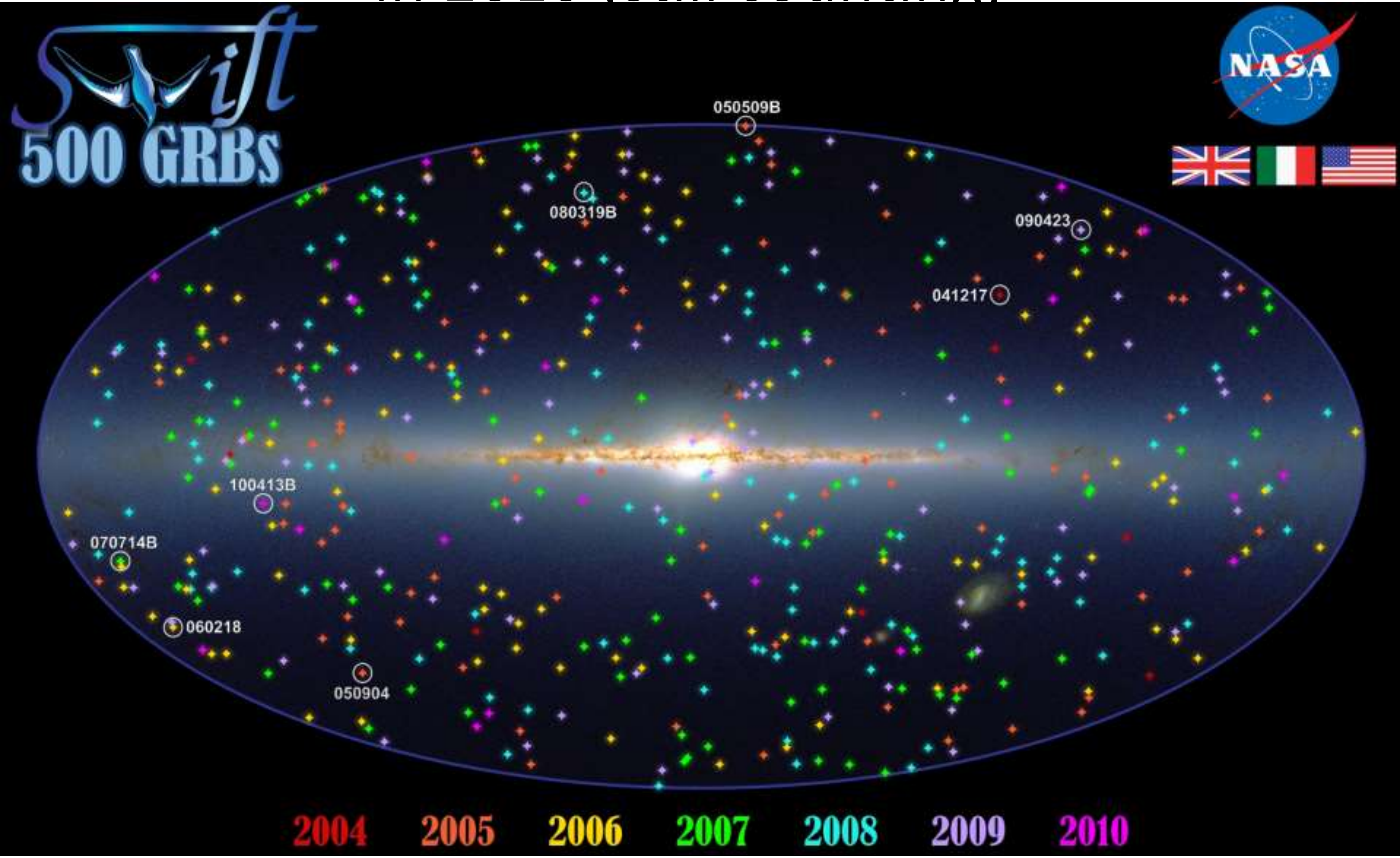



Gamma Ray Pulsar in the CTA 1 supernova remnant © Fermi

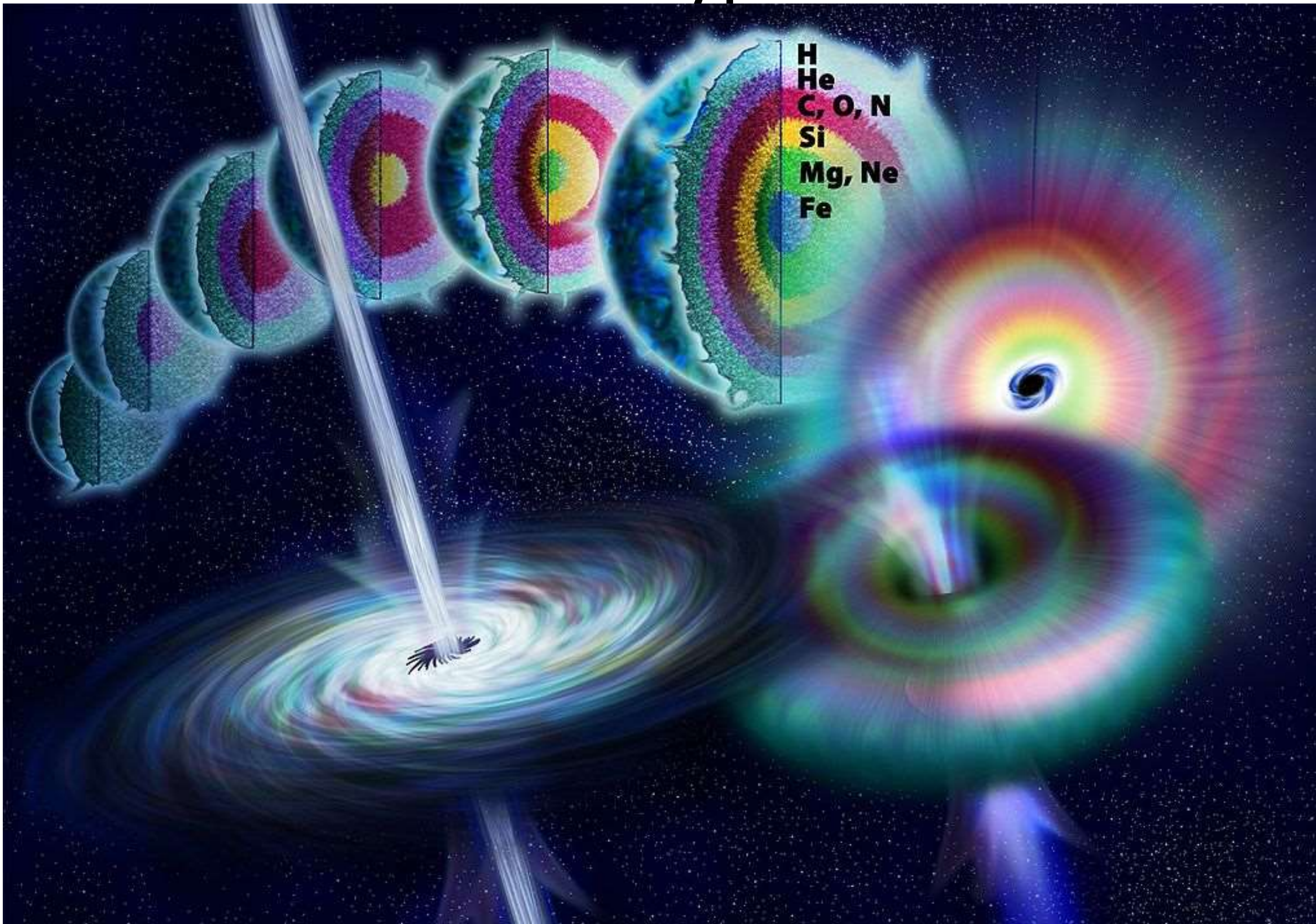


Cycle of pulsed gamma rays from the [Vela pulsar](#) © Fermi

# NASA's Swift satellite observed the 500$^{th}$ GRB in 2010 (still counting)



# GRB from hypernovae



Available online at www.sciencedirect.com

SciVerse ScienceDirect

Advances in Space Research 50 (2012) 1–55

ADVANCES IN SPACE RESEARCH
(a COSPAR publication)

www.elsevier.com/locate/asr

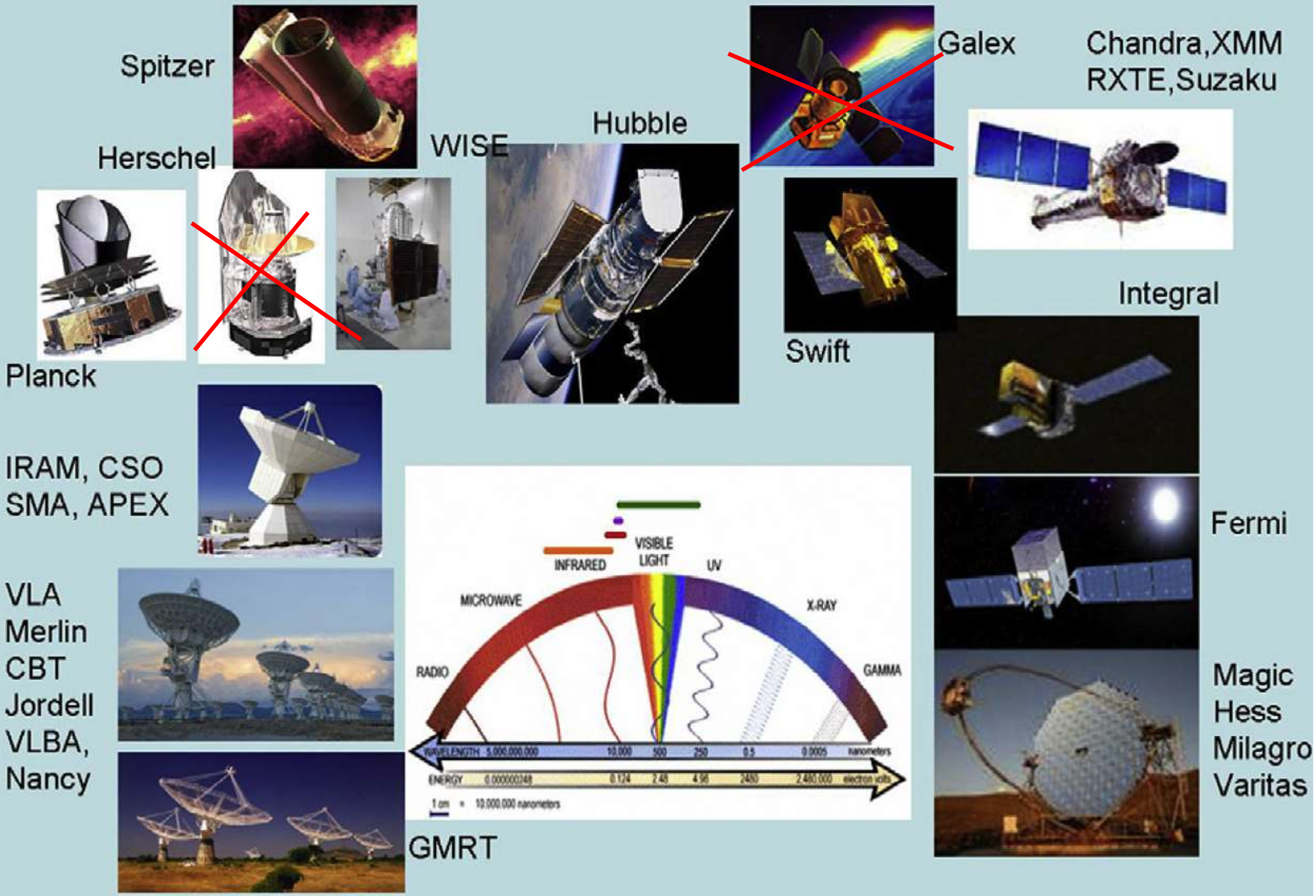
Review

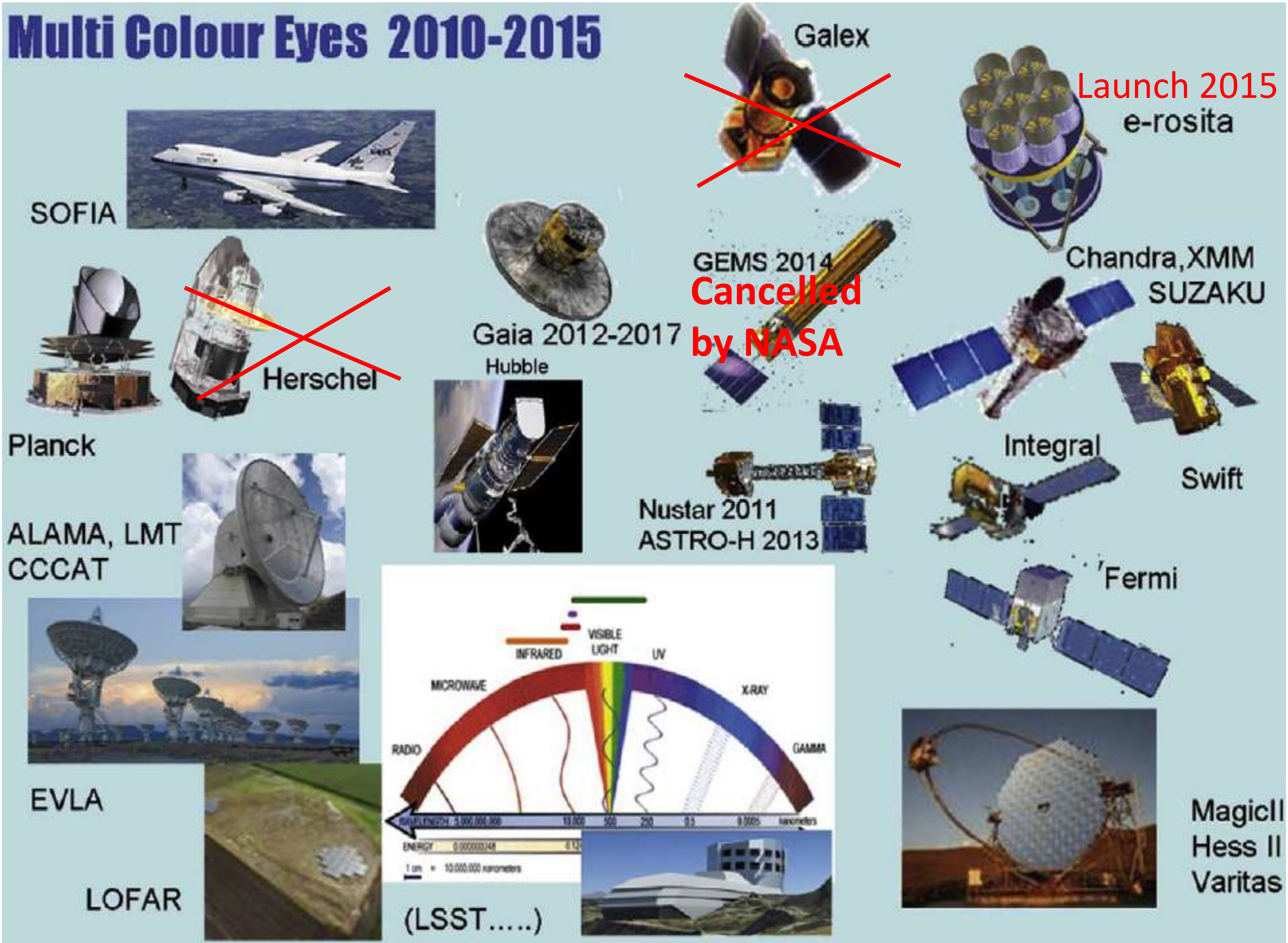
# Future of Space Astronomy: A global Road Map for the next decades

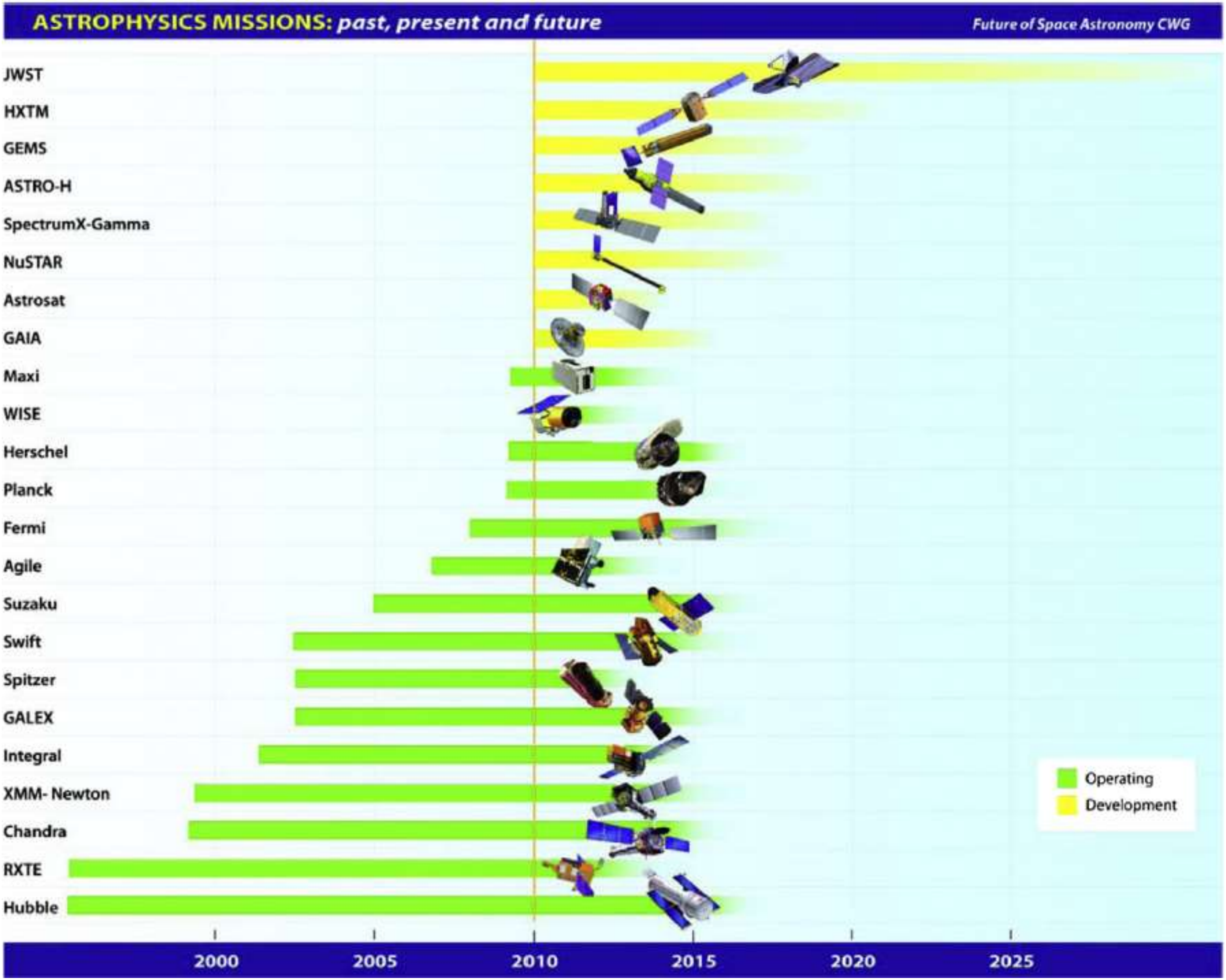
Pietro Ubertini[a,*], Neil Gehrels[b], Ian Corbett[c], Paolo de Bernardis[d], Marcos Machado[e], Matt Griffin[f], Michael Hauser[g], Ravinder K. Manchanda[h], Nobuyuki Kawai[i], Shuang-Nan Zhang[j], Mikhail Pavlinsky[k]

[a] *Institute for Space Astrophysics and Planetology, INAF, Via del Fosso del Cavaliere 100, 00133 Rome, Italy*
[b] *Astroparticle Physics Laboratory, NASA-GSFC, Greenbelt, MD 20771, USA*
[c] *IAU–UAI Secretariat, F75014 Paris, France*
[d] *Department of Physics, Sapienza University of Rome, P.le A. Moro 2, 00185 Rome, Italy*
[e] *Comisión Nacional de Actividades Espaciales, 1063 Buenos Aires, Argentina*
[f] *School of Physics and Astronomy, Cardiff University, The Parade, Cardiff CF24 3AA, UK*
[g] *Space Telescope Science Institute, Baltimore, MD 21218, USA*
[h] *Tata Institute of Fundamental Research, 400005 Mumbai, India*
[i] *Department of Physics, Tokyo Institute of Technology, Tokyo 152-8551, Japan*
[j] *Key Laboratory of Particle Astrophysics, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China*
[k] *Russian Academy of Science, 117997 Moscow, Russia*

# Multi Colour Eyes – Present (2012)




Multi Colour Eyes 2010-2015
Galex
Launch 2015
e-rosita
SOFIA
GEMS 2014
Cancelled
by NASA
Chandra,XMM
SUZAKU
Gaia 2012-2017
Hubble
Herschel
Planck
Integral
Swift
Nustar 2011
ASTRO-H 2013
ALAMA, LMT
CCCAT
Fermi
VISIBLE
LIGHT
INFRARED
UV
MICROWAVE
X-RAY
RADIO
GAMMA
EVLA
LOFAR
(LSST.....)
MagicII
Hess II
Varitas


ASTROPHYSICS MISSIONS: past, present and future
Future of Space Astronomy CWG
JWST
HXTM
GEMS
ASTRO-H
SpectrumX-Gamma
NuSTAR
Astrosat
GAIA
Maxi
WISE
Herschel
Planck
Fermi
Agile
Suzaku
Swift
Spitzer
GALEX
Integral
XMM- Newton
Chandra
RXTE
Hubble
Operating
Development
2000
2005
2010
2015
2020
2025

# Multi Colour Eyes > 2018

JAXA + ESA + NASA
Launch 2022?

??
SPICA
2018-2021

Launch 2018

JWST

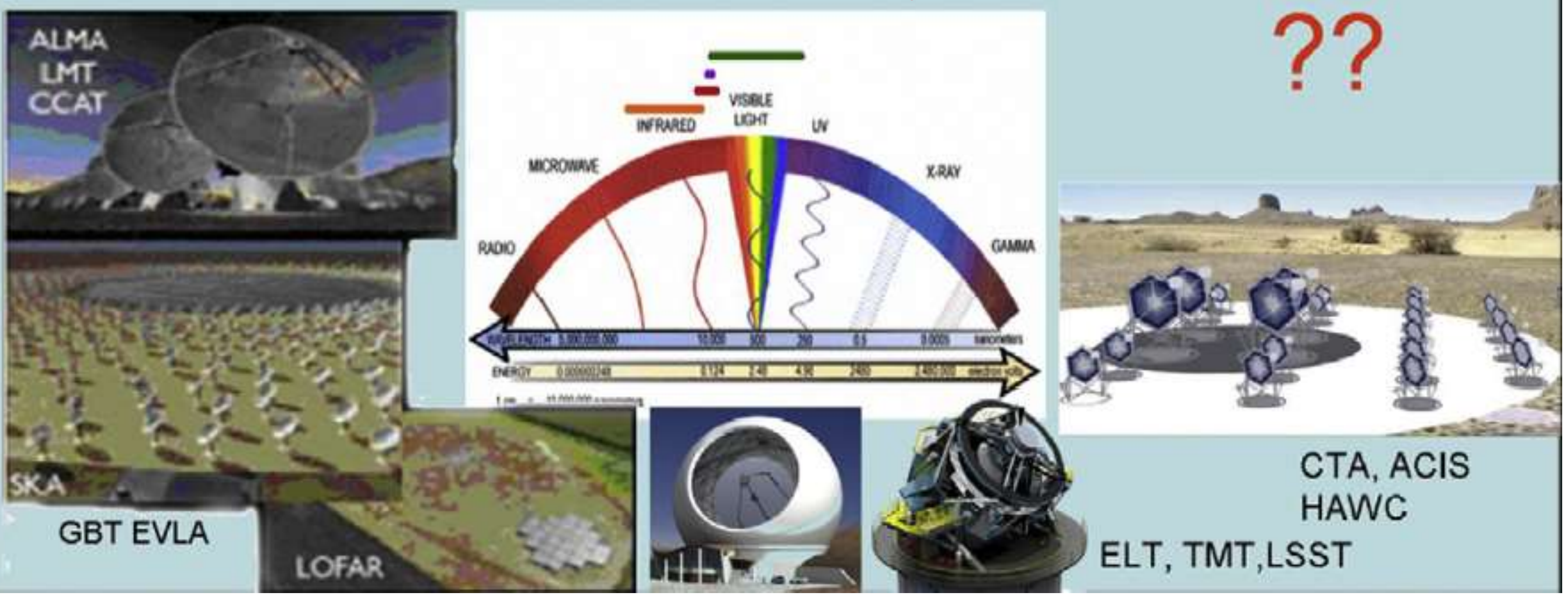
ASTRO-H
Japan, 2015

ESA (originally IXO including NASA, Jaxa), launch 2028

ATHENA ??

??

??




GBT EVLA

CTA, ACIS
HAWC

ELT, TMT,LSST


ASTROPHYSICS MISSIONS: future
Future of Space Astronomy CWG
Athena-NGO-Juice CV Large
WFIRST-NASA DS
ESA - Cosmic Vision-M3
ESA-CV Euclid
ESA-CV Solar Orbiter
NASA EXPLORER
JWST
HXMT
GEMS
ASTRO-H
SpectrumX-Gamma
NuSTAR
Astrosat
GAIA
Development
Under selection E/M Class
Under selection L Class
2010
2015
2020
2025
2030
2035