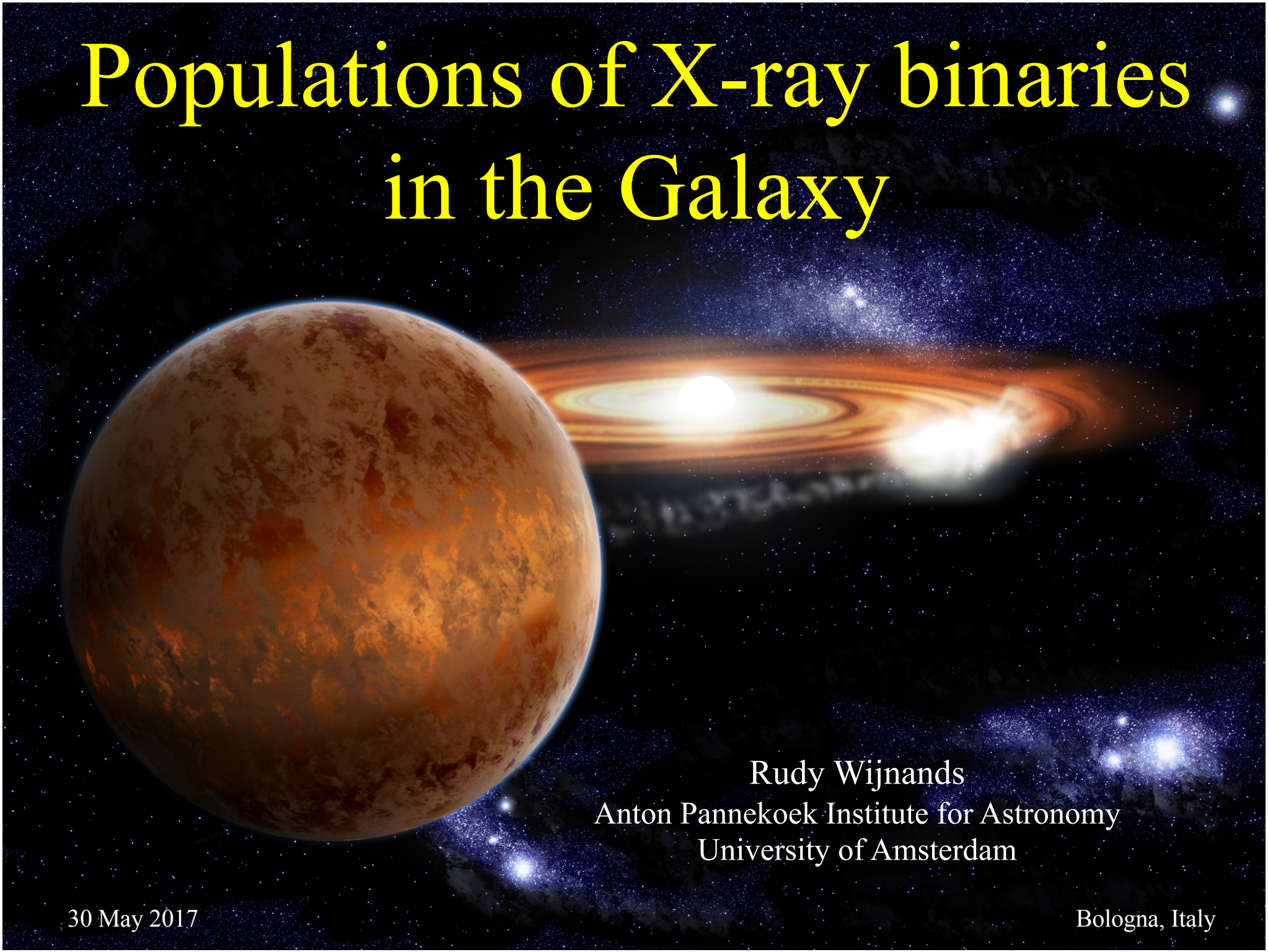
Populations of X-ray binaries in the Galaxy



Rudy Wijnands
Anton Pannekoek Institute for Astronomy
University of Amsterdam

30 May 2017

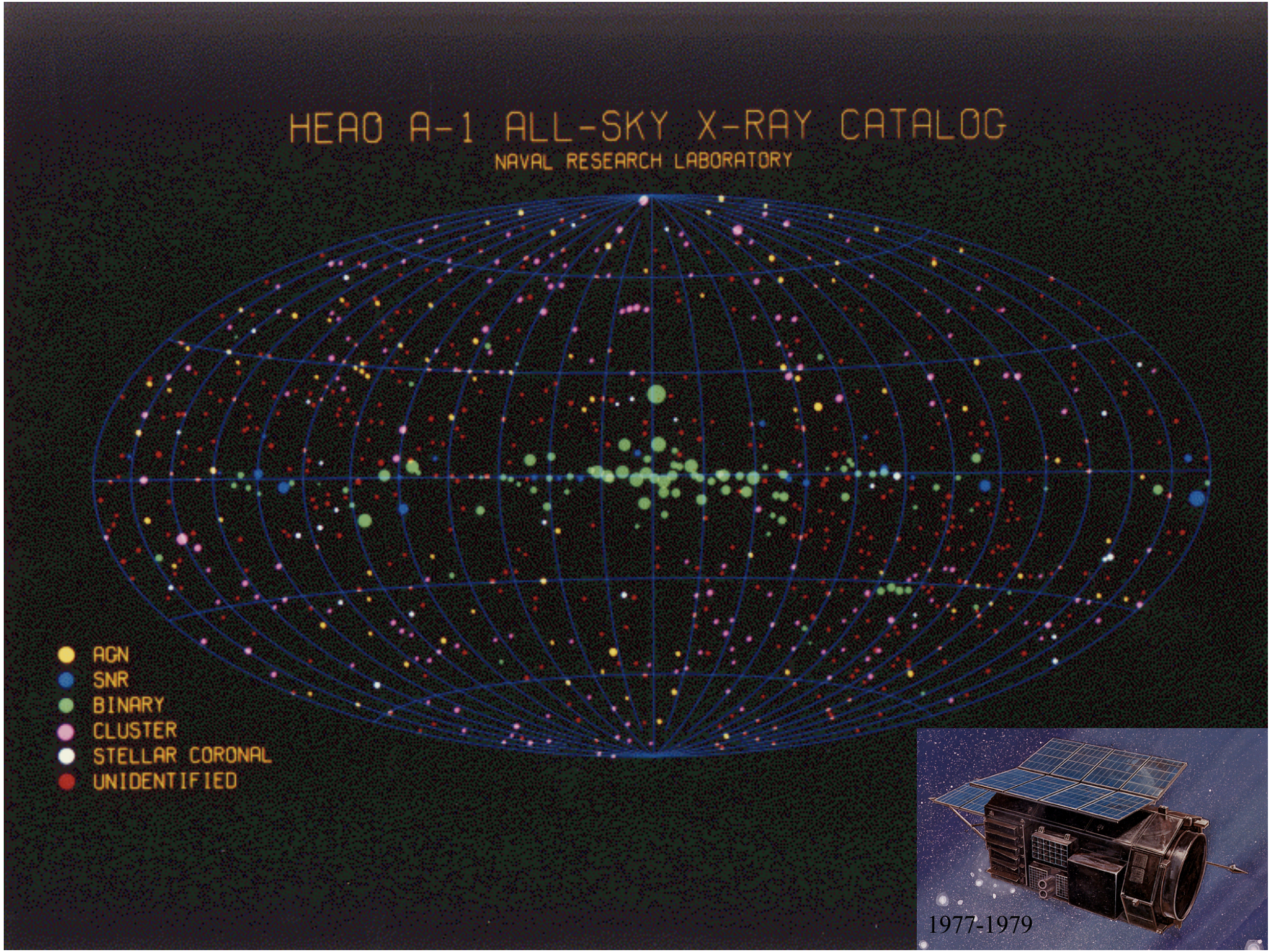
Bologna, Italy

Lecture 4

- Population of X-ray binary in the Galaxy
  - Where are they located and why there?
  - Difference in bulge and plane population
    - Globular clusters are special → we will not discuss them
  - Comparison with other galaxies
- X-ray binary feedback to the galaxies
  - Influence of X-ray binaries on galaxy evolution
  - Might change over cosmological time scales

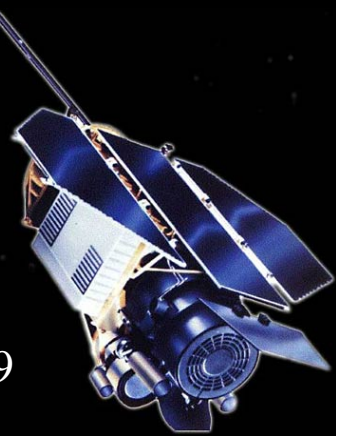
HEAO A-1 ALL-SKY X-RAY CATALOG

NAVAL RESEARCH LABORATORY

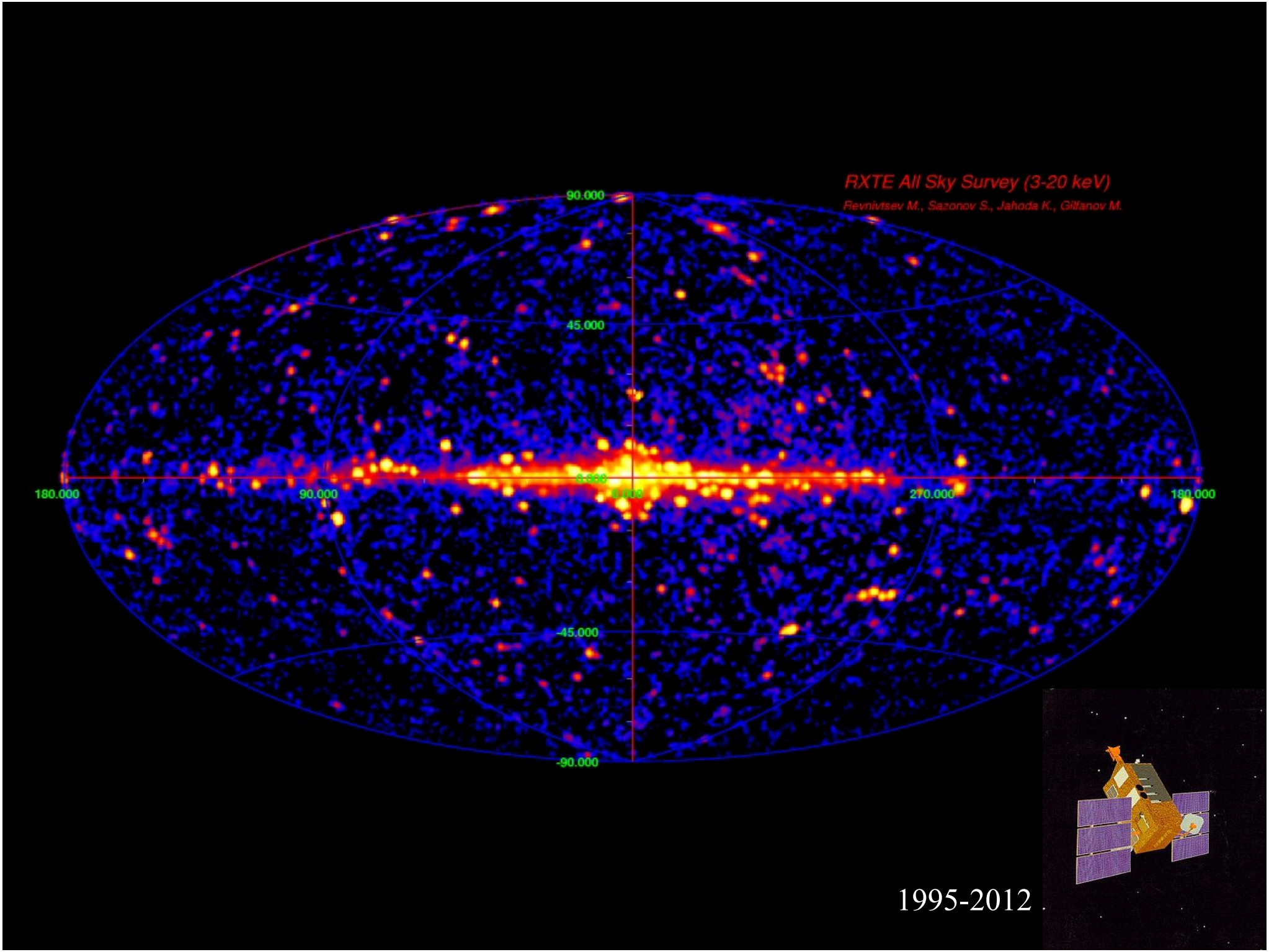


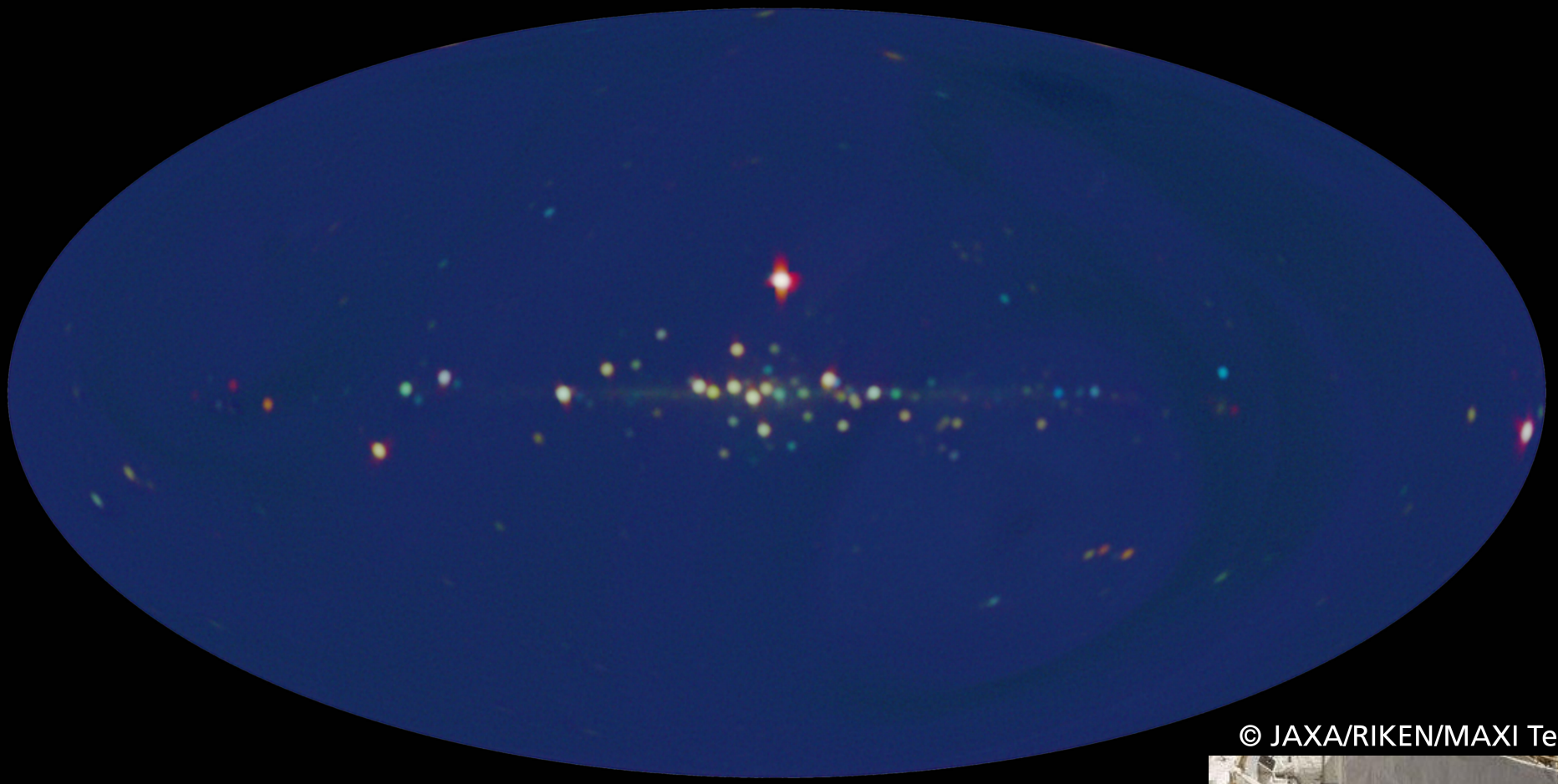
1977-1979

ROSAT



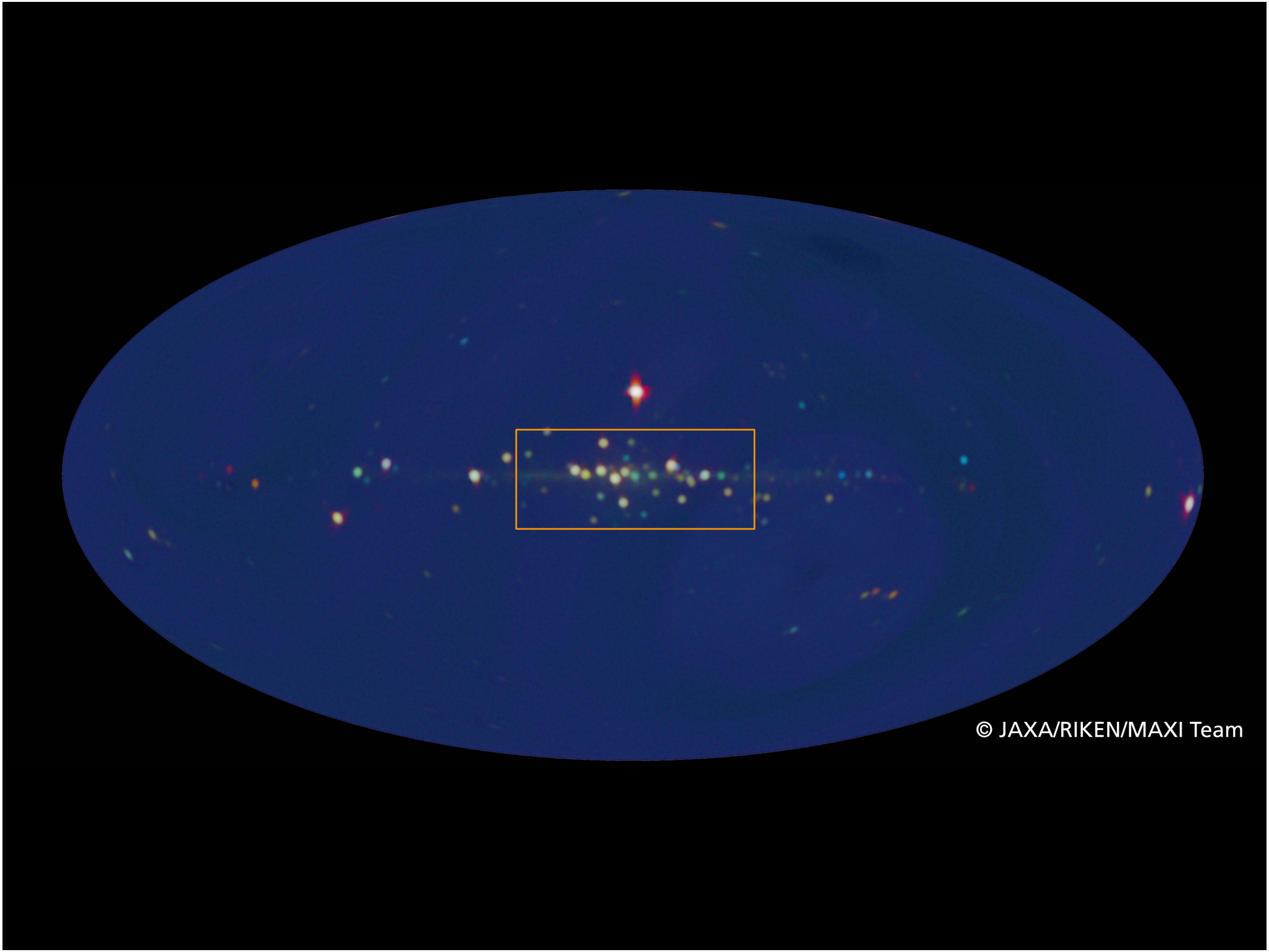
1990-1999

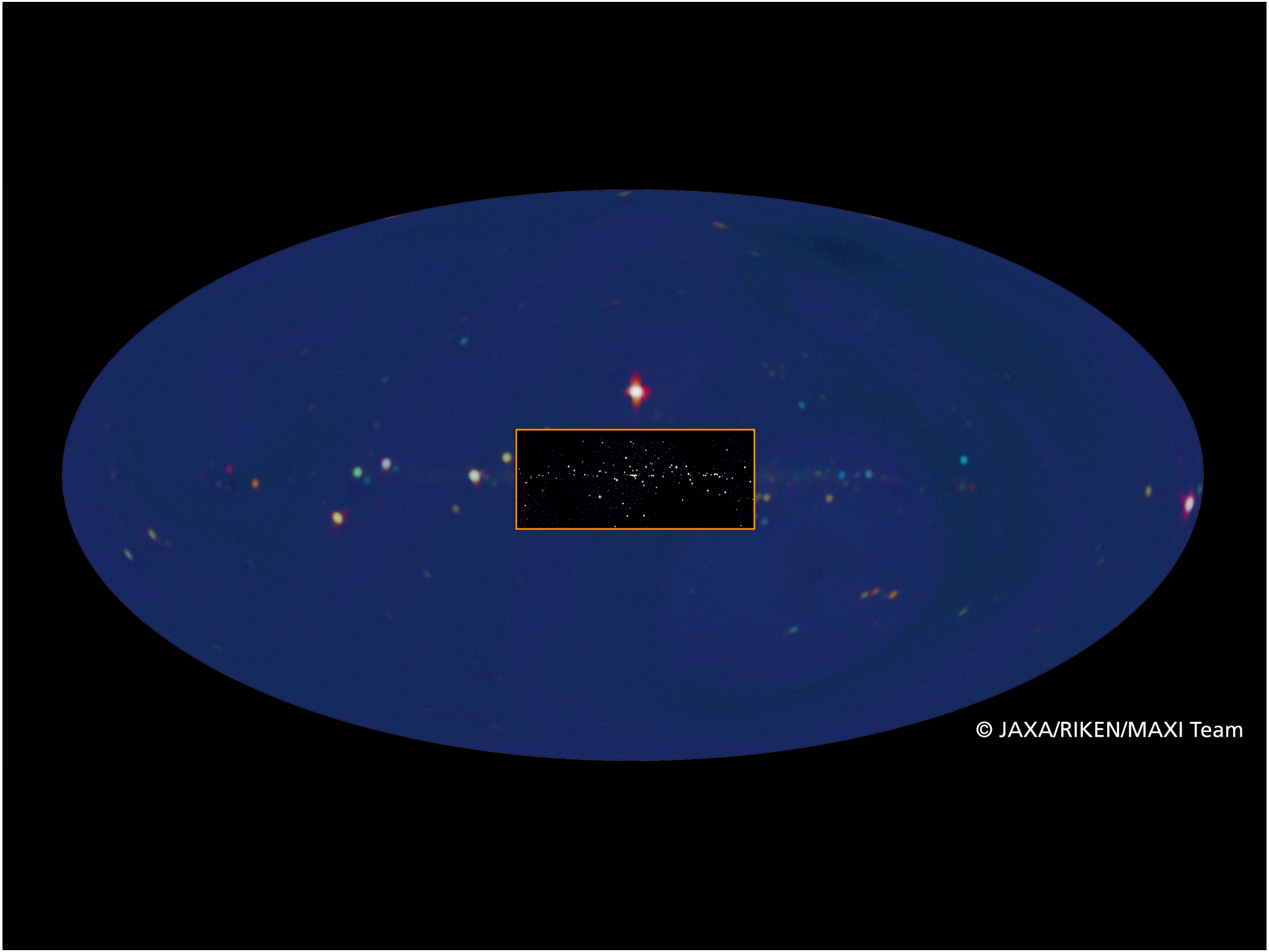

RXTE All Sky Survey (3-20 keV)
Revnivtsev M., Sazonov S., Jahoda K., Gilfanov M.
90.000
45.000
0.000
-45.000
-90.000
180.000
90.000
270.000
180.000
1995-2012

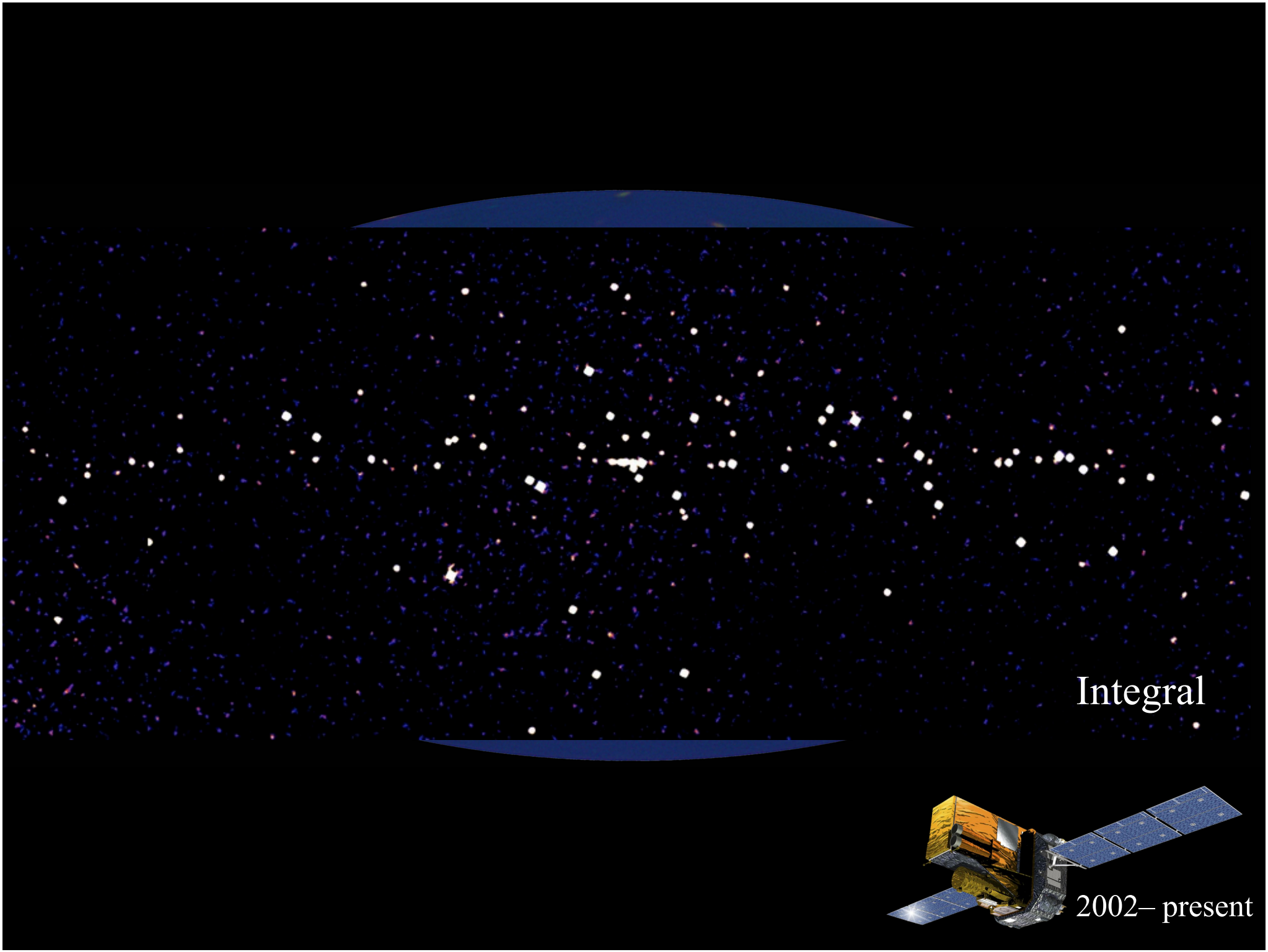


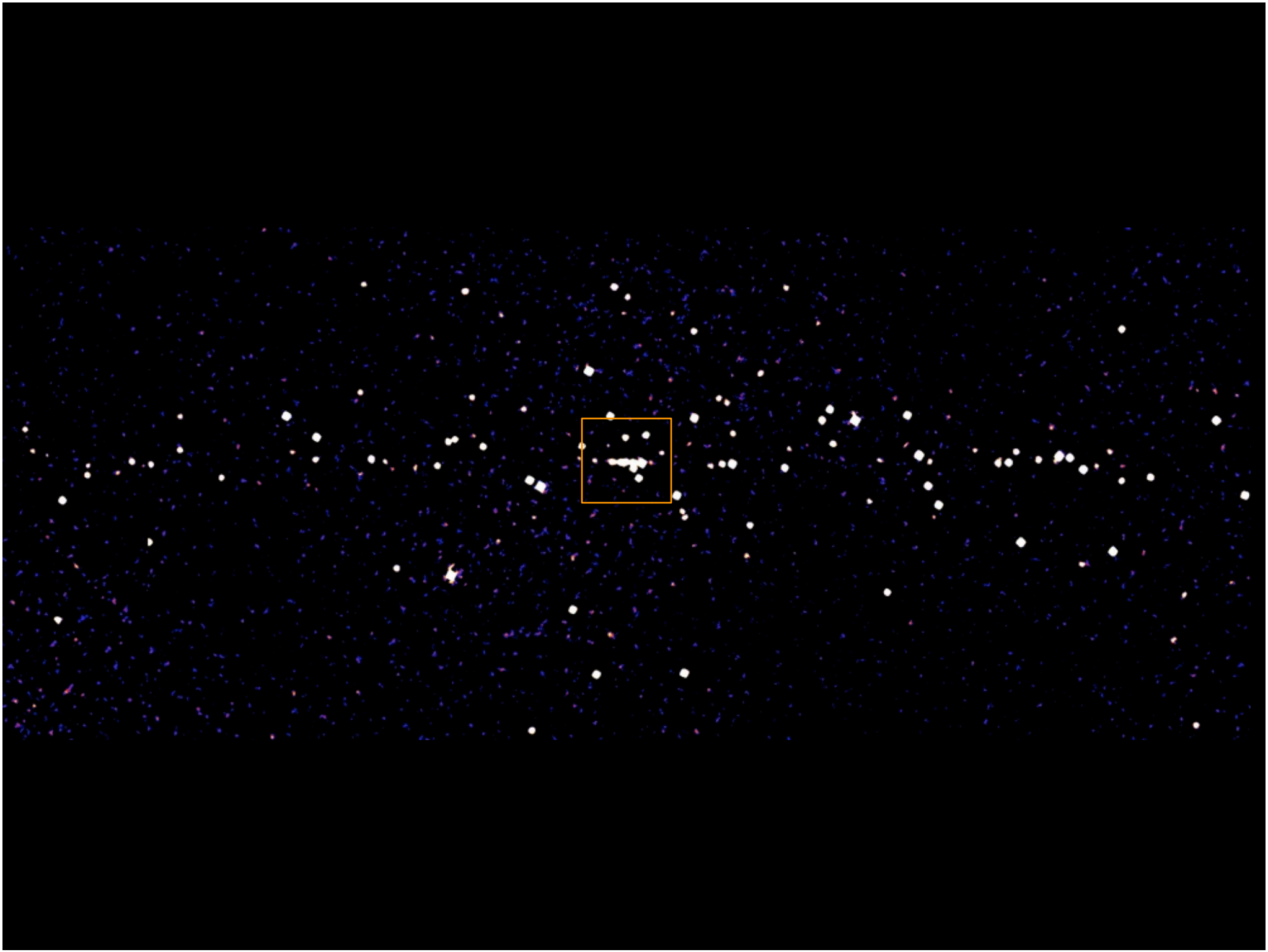
© JAXA/RIKEN/MAXI Team

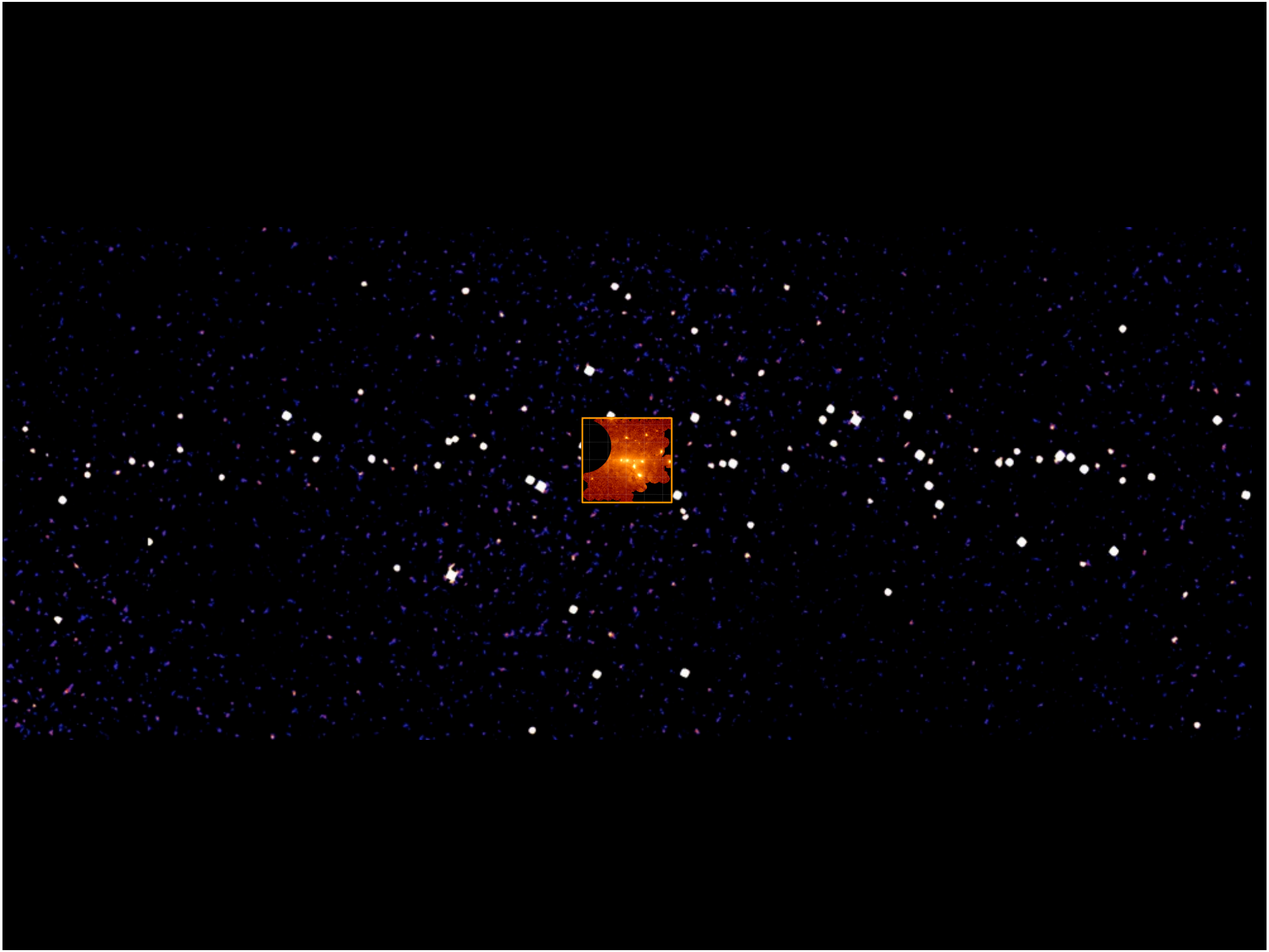
2009 - present

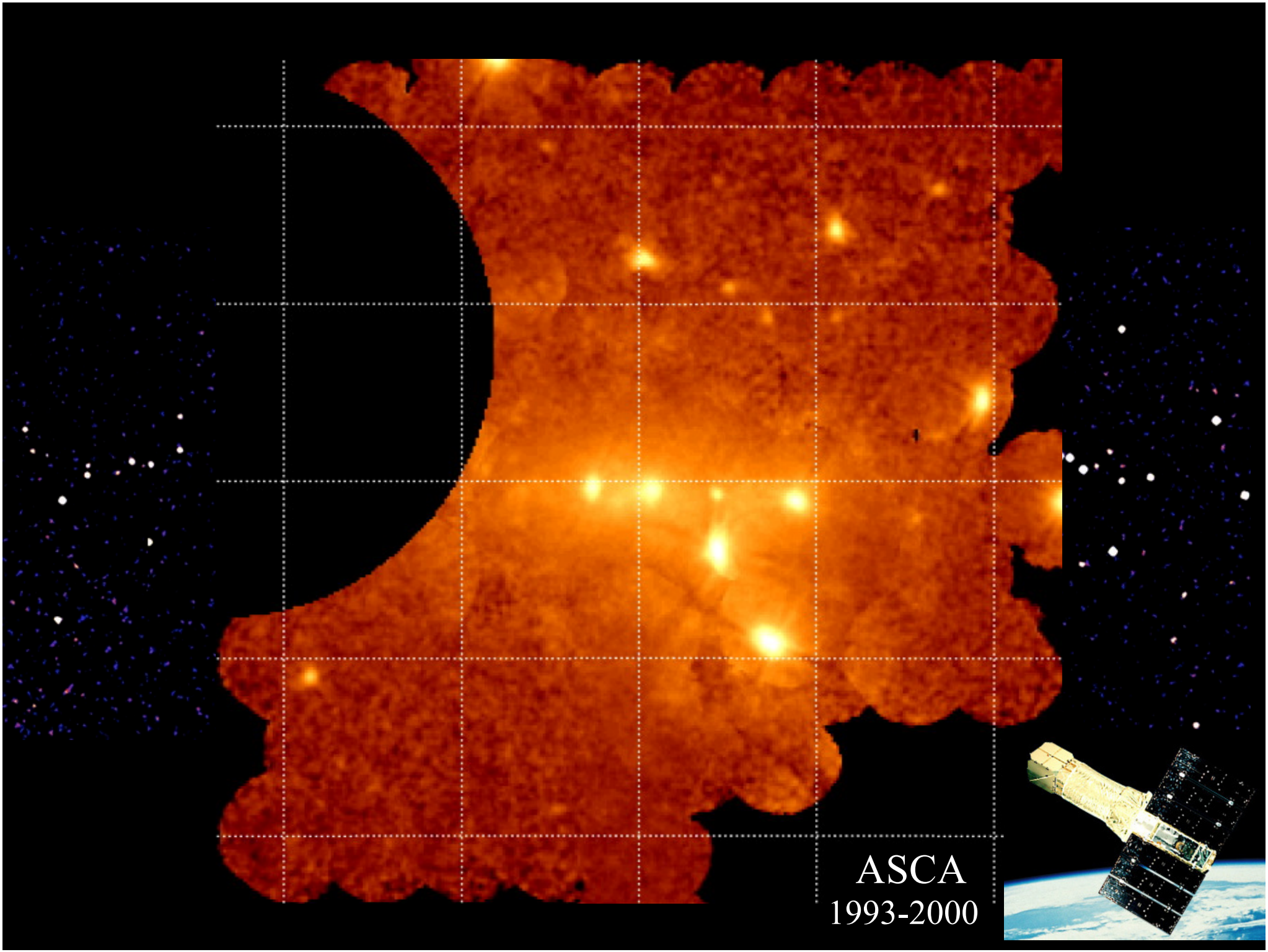

© JAXA/RIKEN/MAXI Team

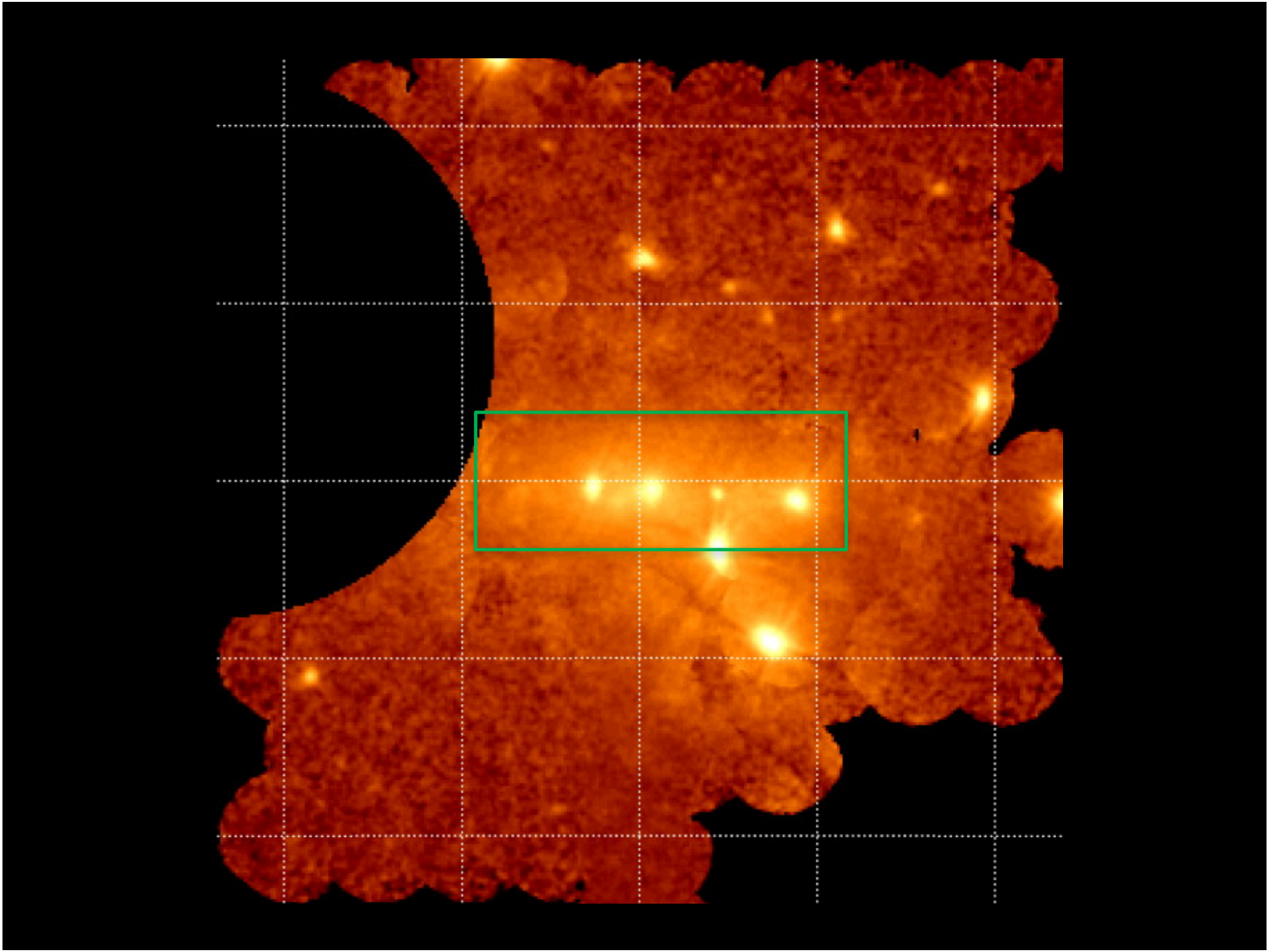

© JAXA/RIKEN/MAXI Team

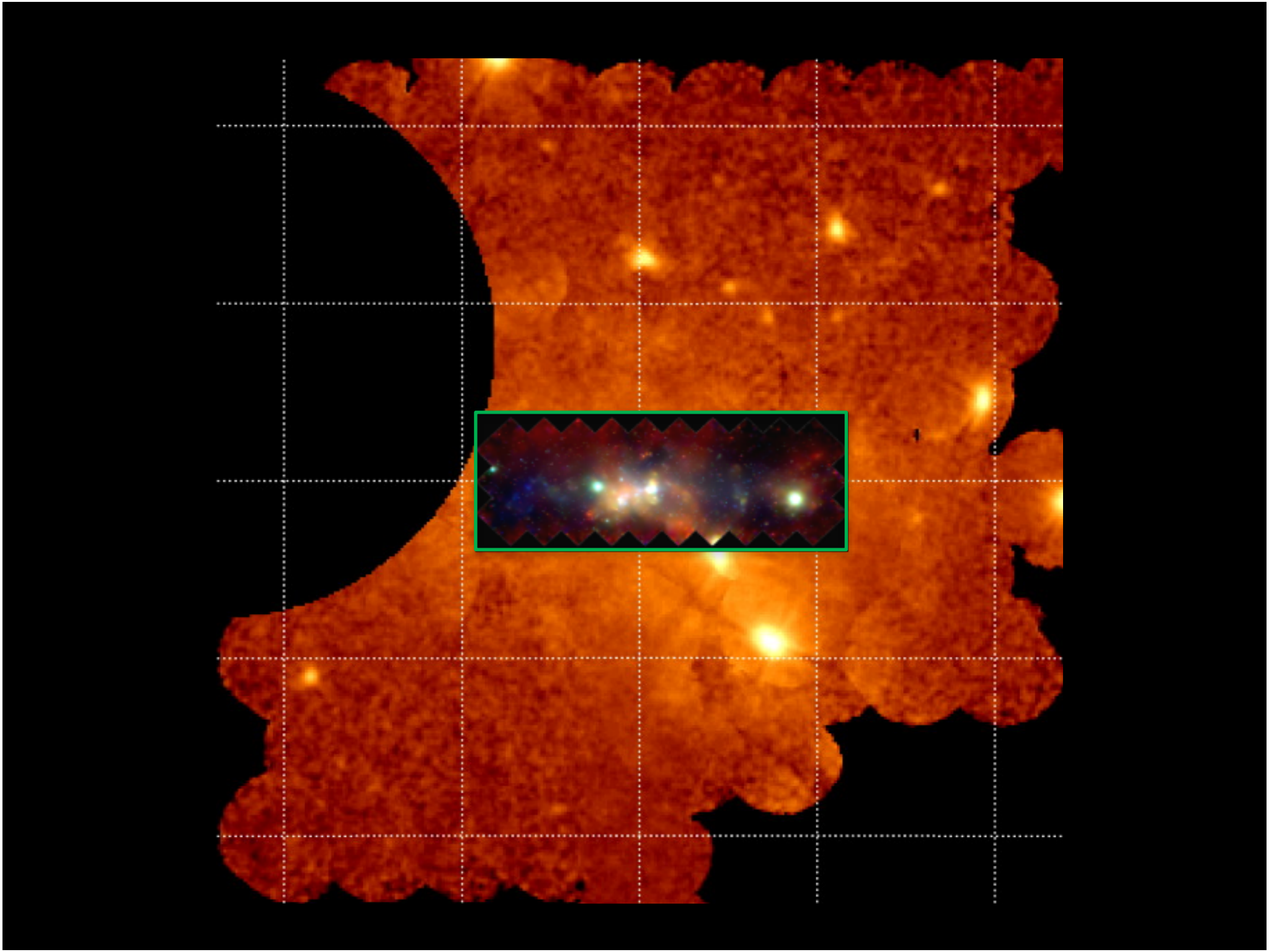

Integral
2002– present

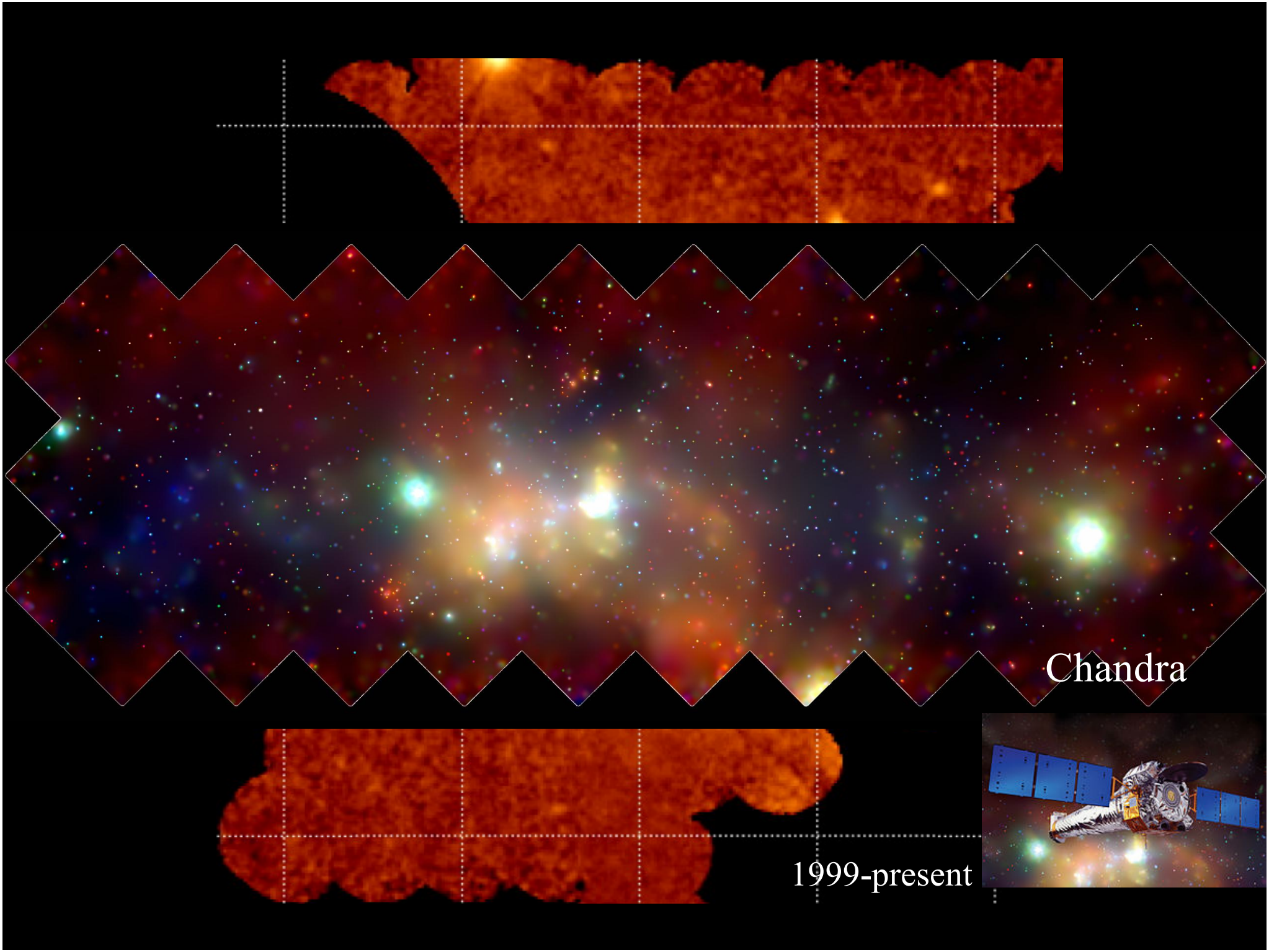


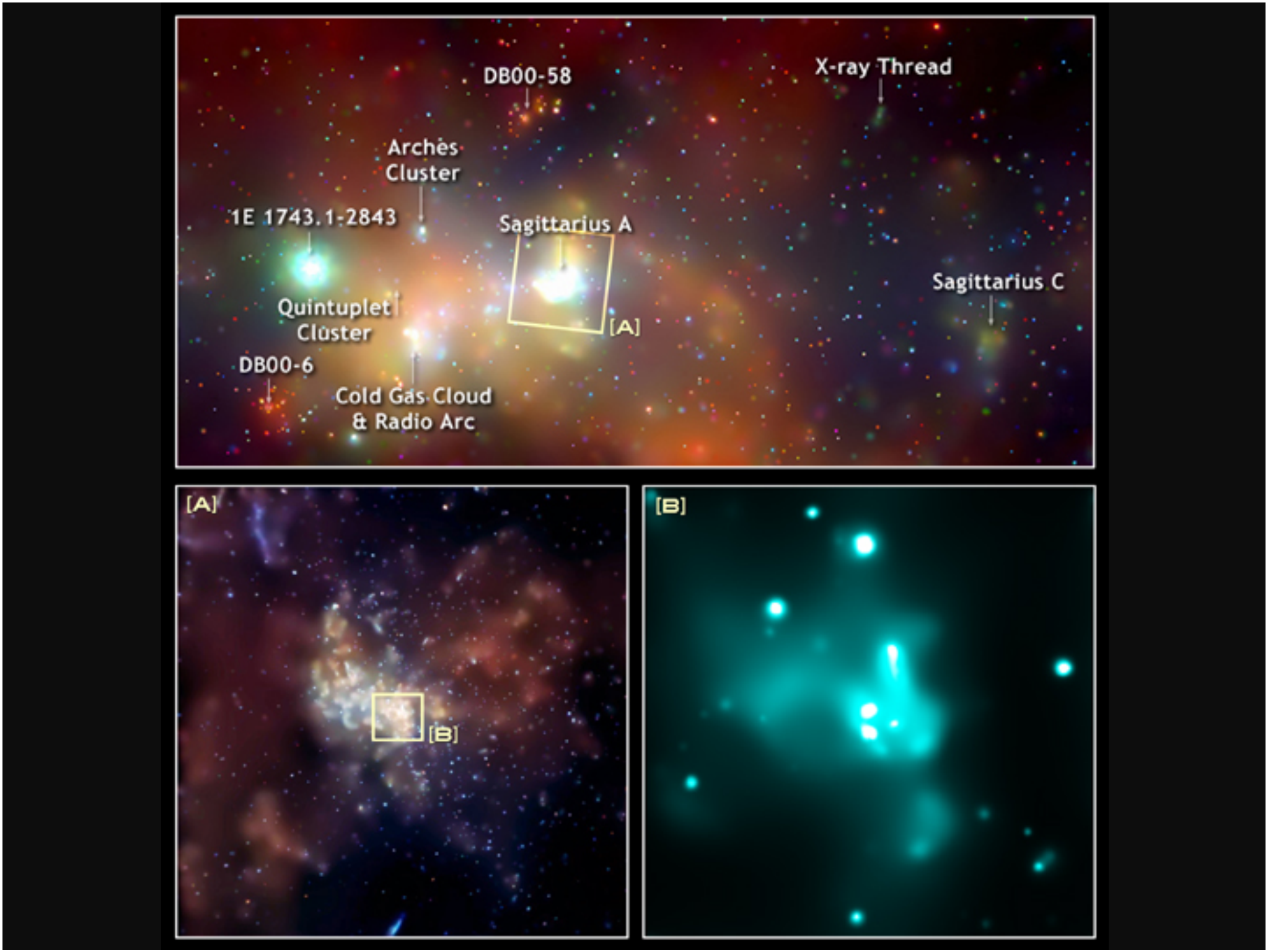



ASCA
1993-2000

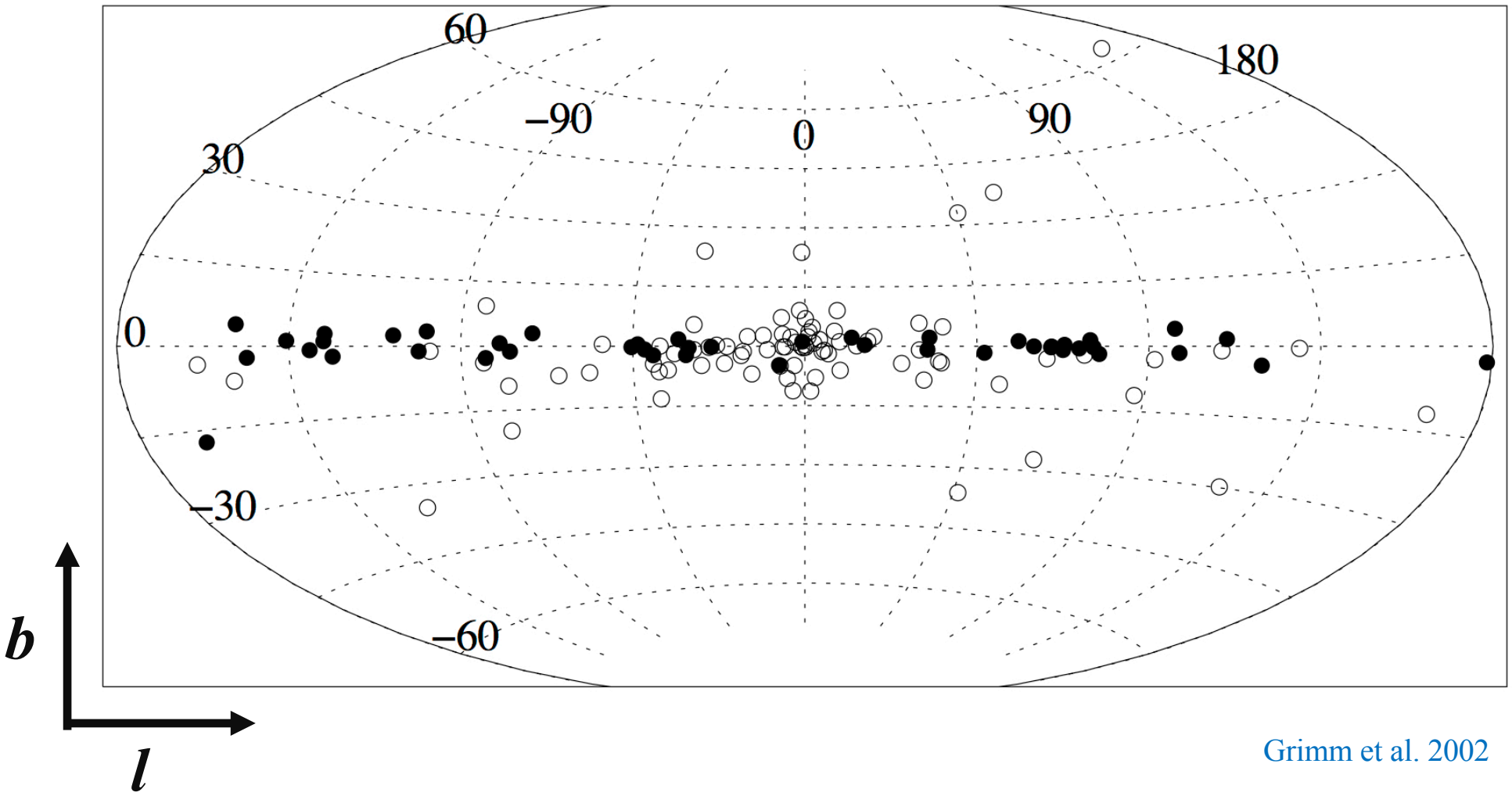





Chandra
1999-present

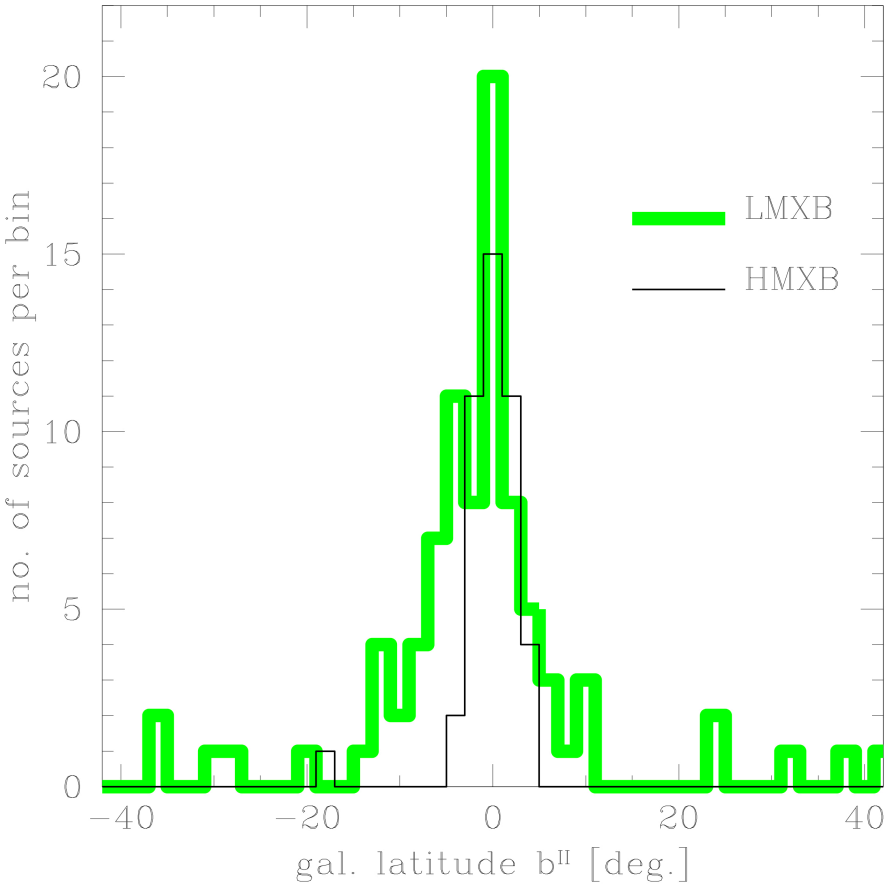

DB00-58
X-ray Thread
Arches
Cluster
1E 1743.1-2843
Sagittarius A
Sagittarius C
Quintuplet
Cluster
[A]
DB00-6
Cold Gas Cloud
& Radio Arc
[A]
[B]
[B]

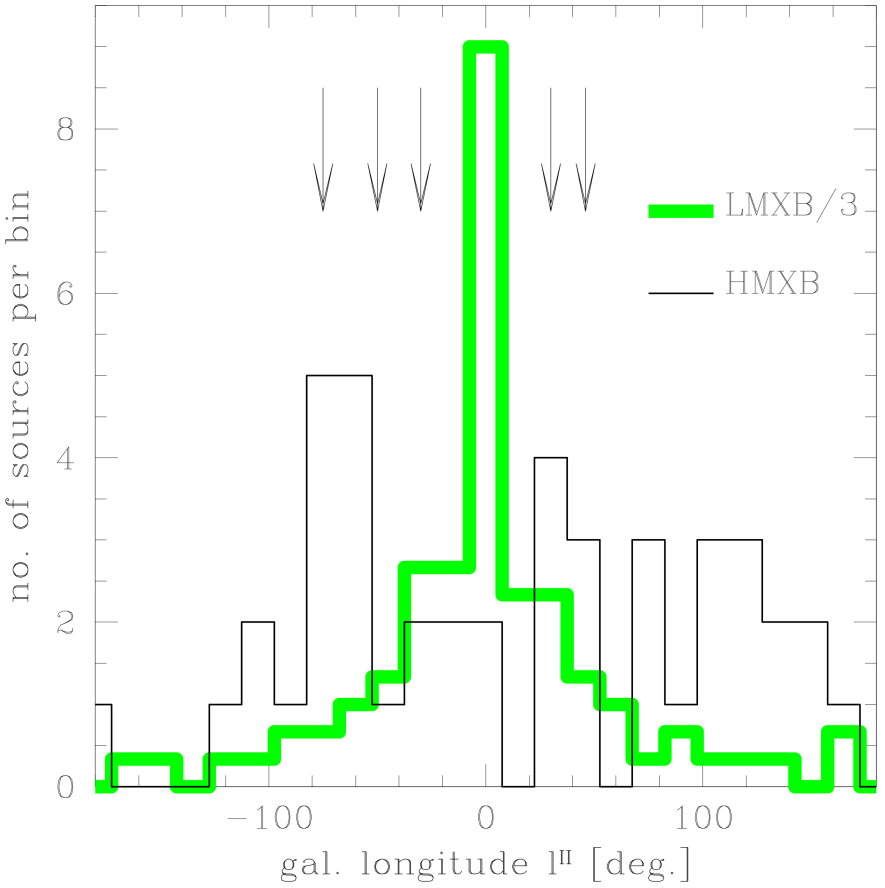
Galactic distribution of X-ray binaries



Grimm et al. 2002

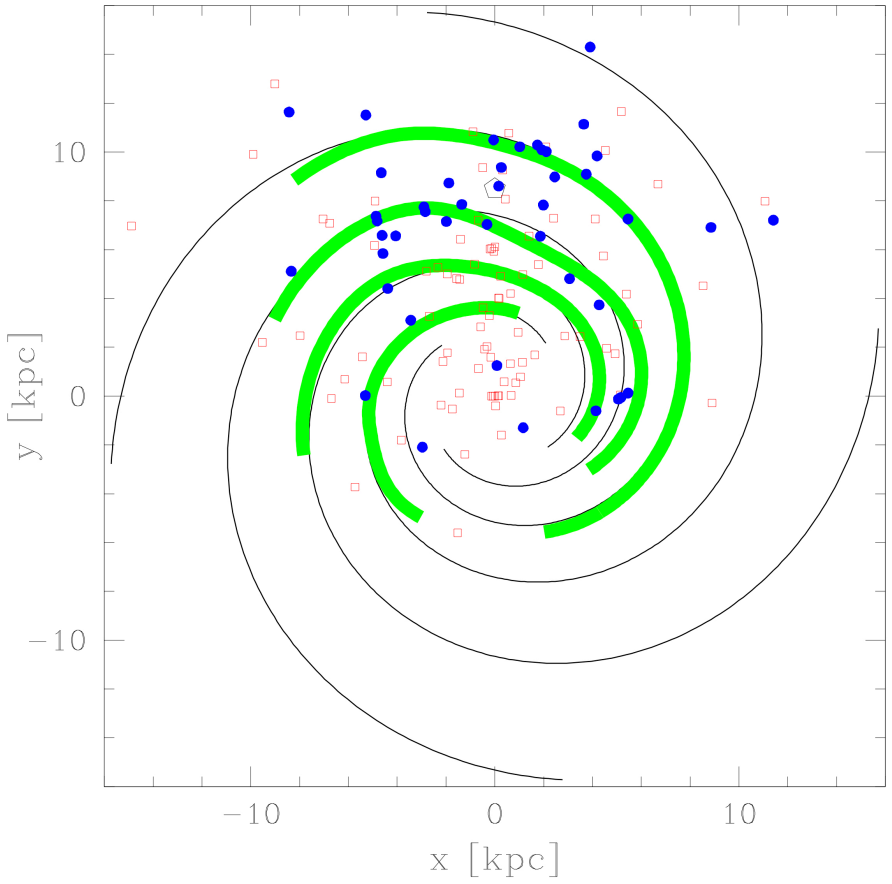
Galactic distribution of X-ray binaries

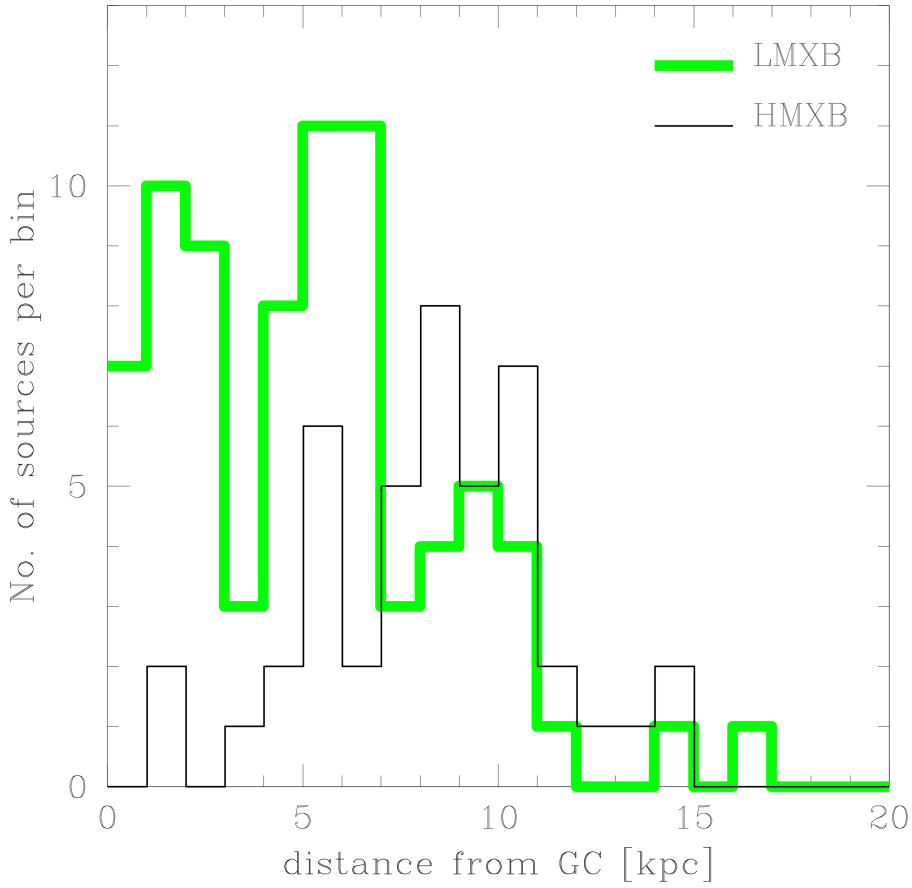




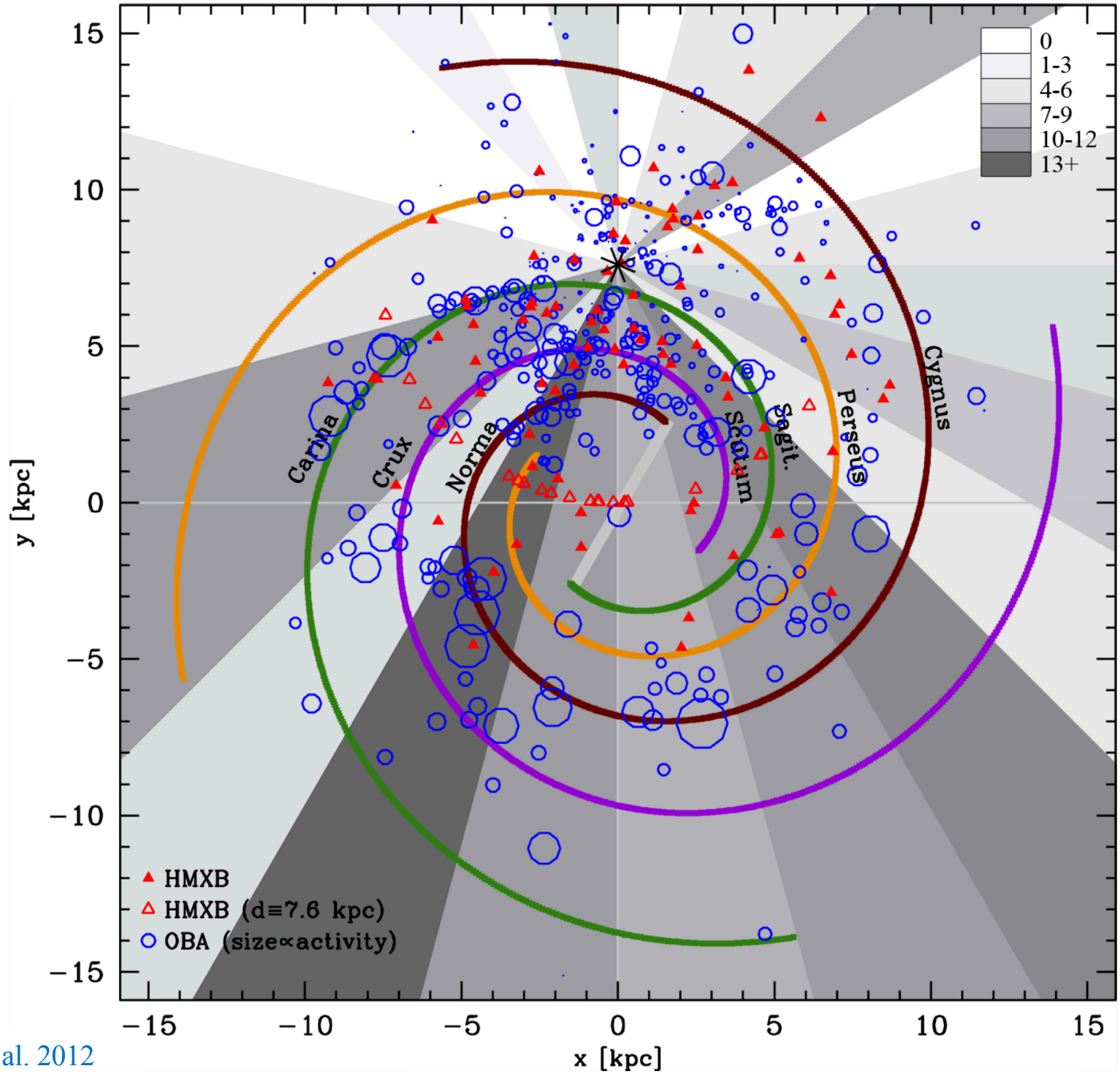
Grimm et al. 2002

Galactic distribution of X-ray binaries

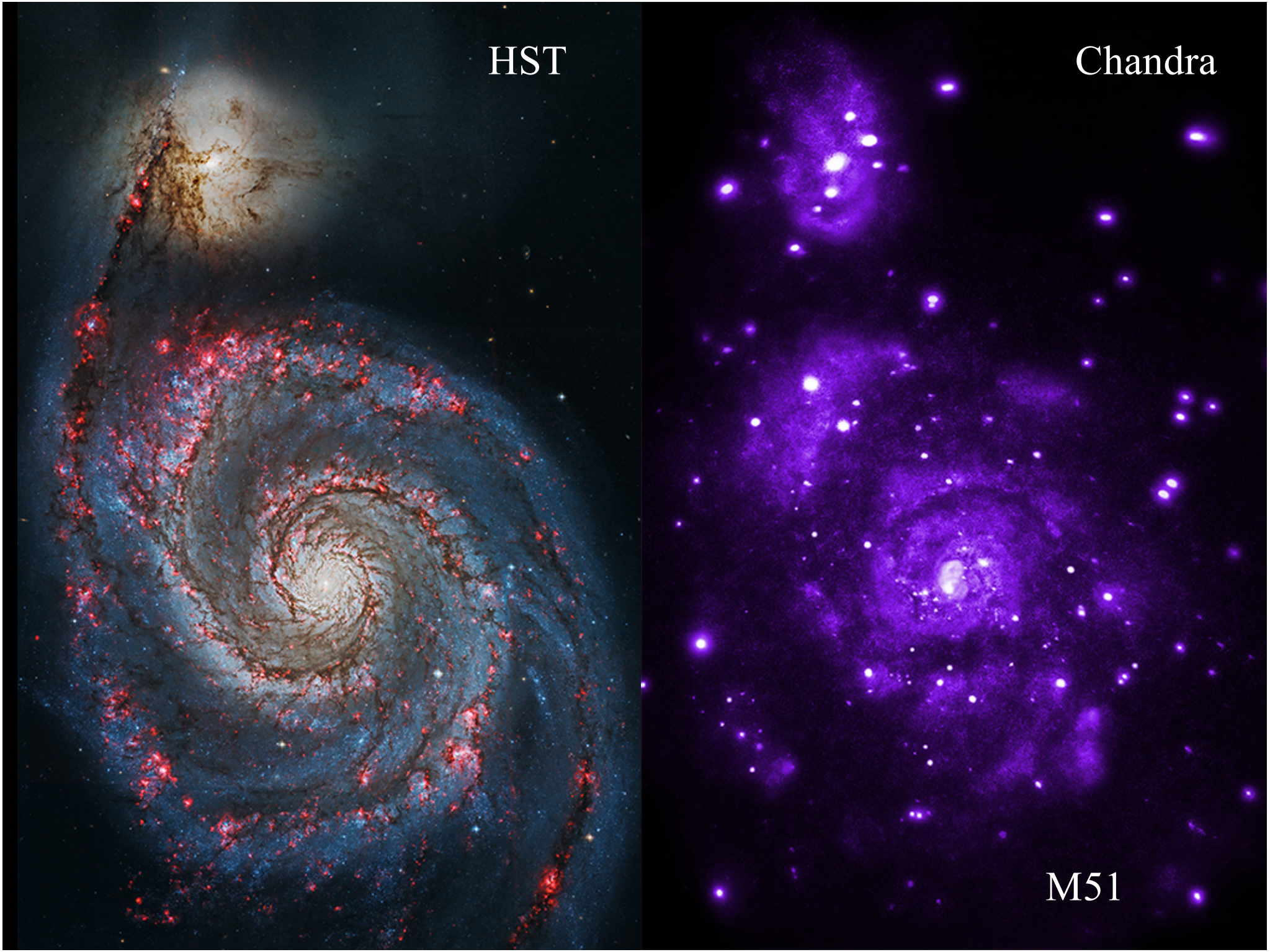


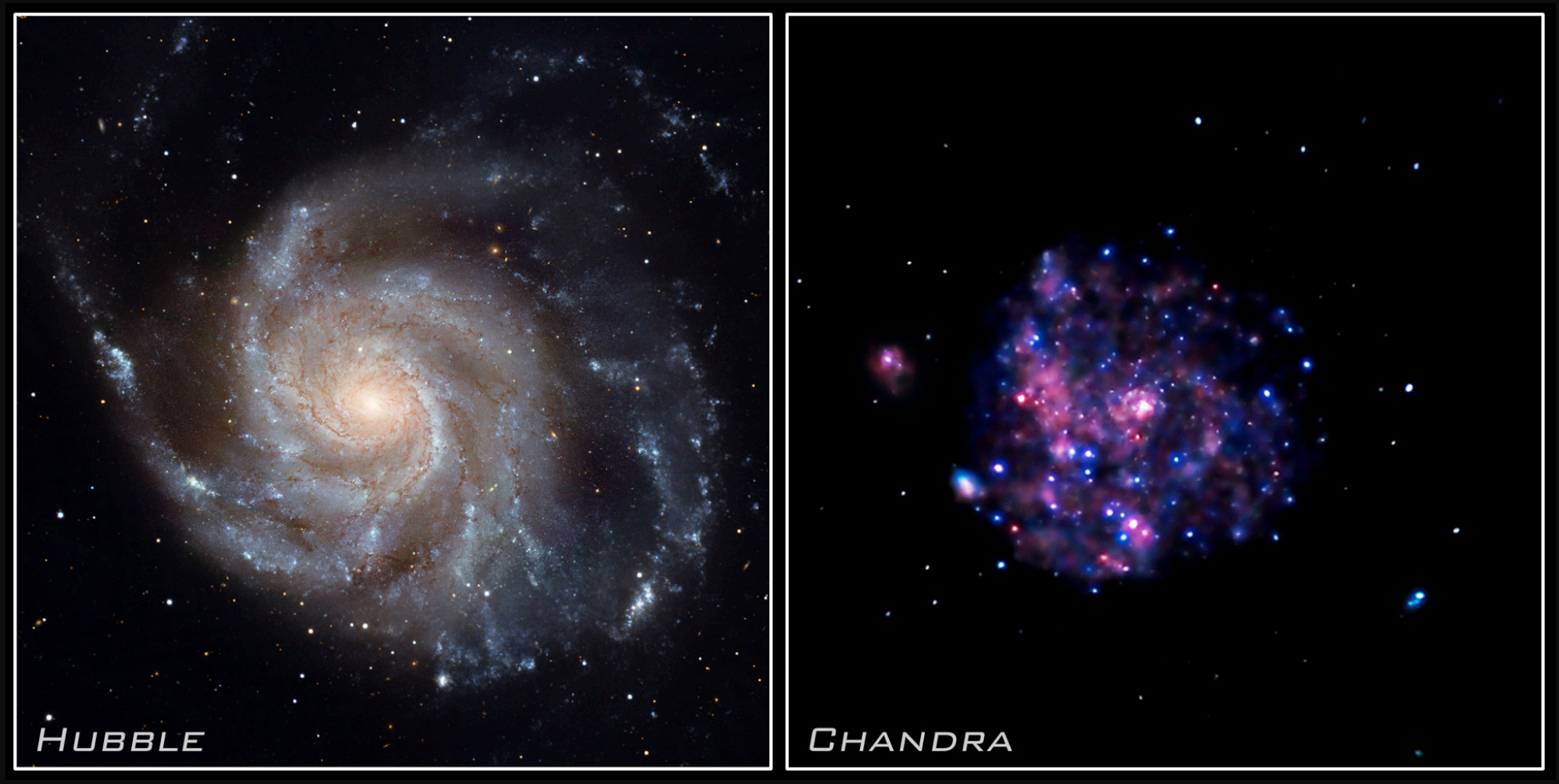


Grimm et al. 2002

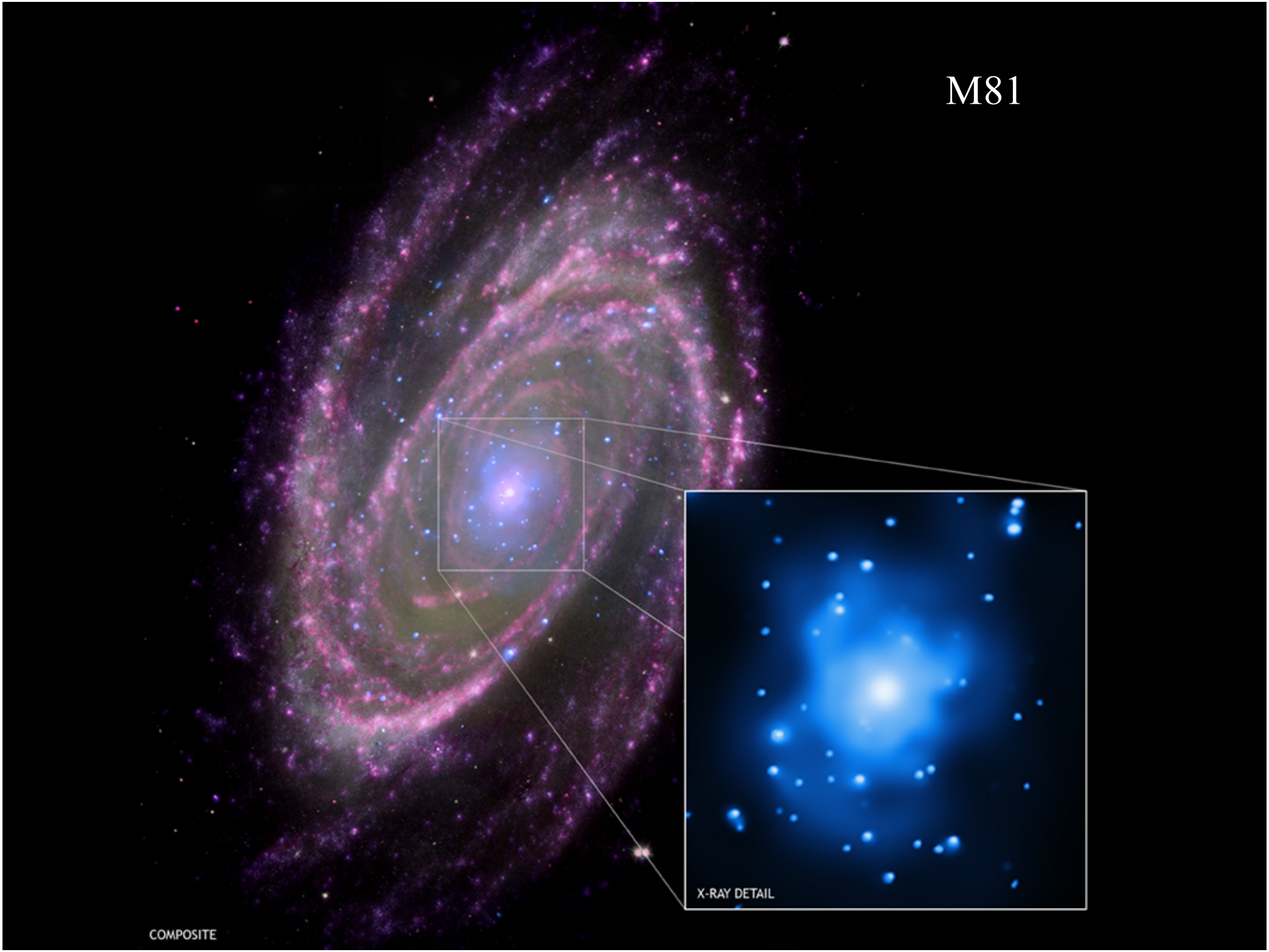


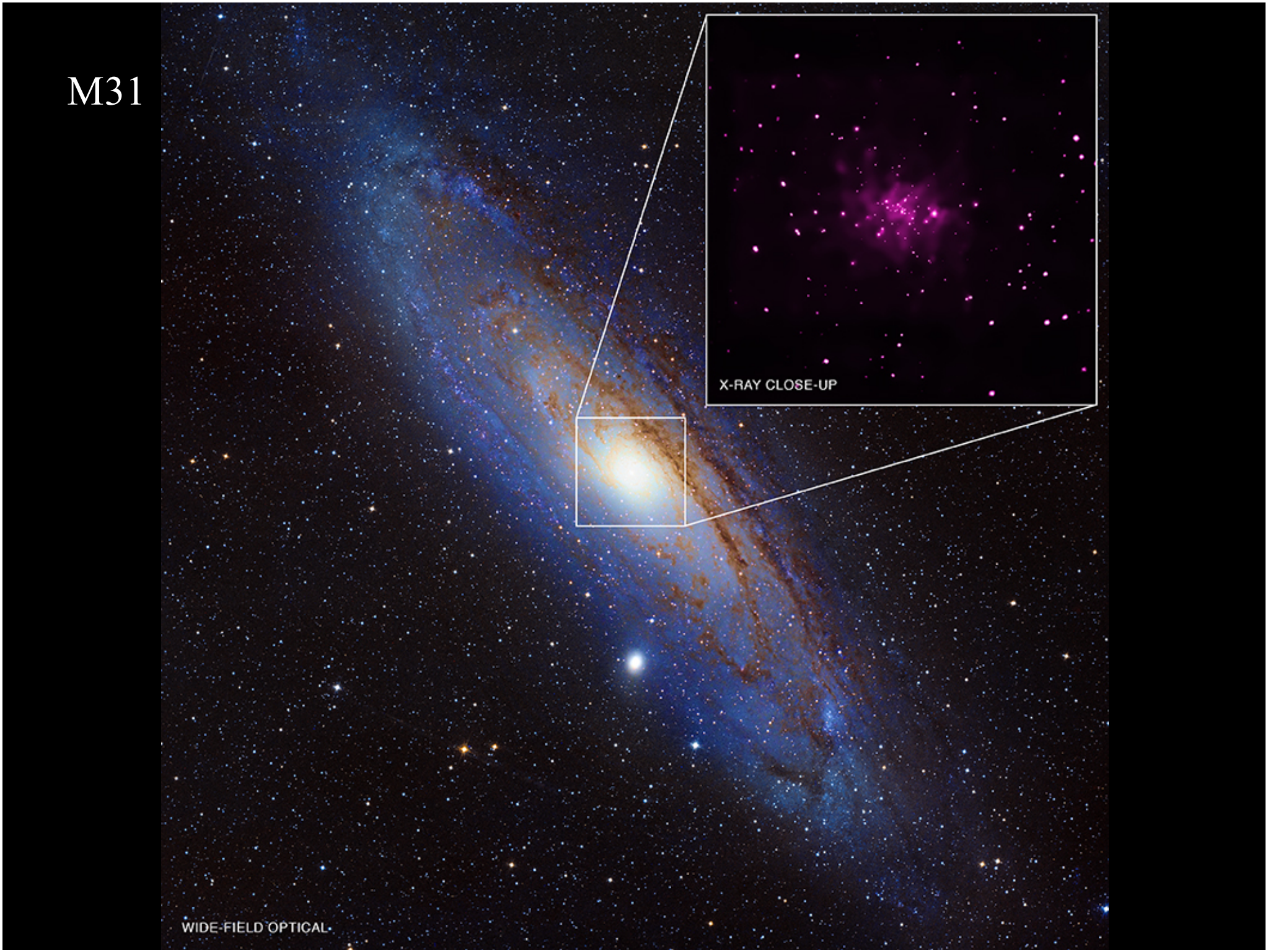
Bogdahee et al. 2012

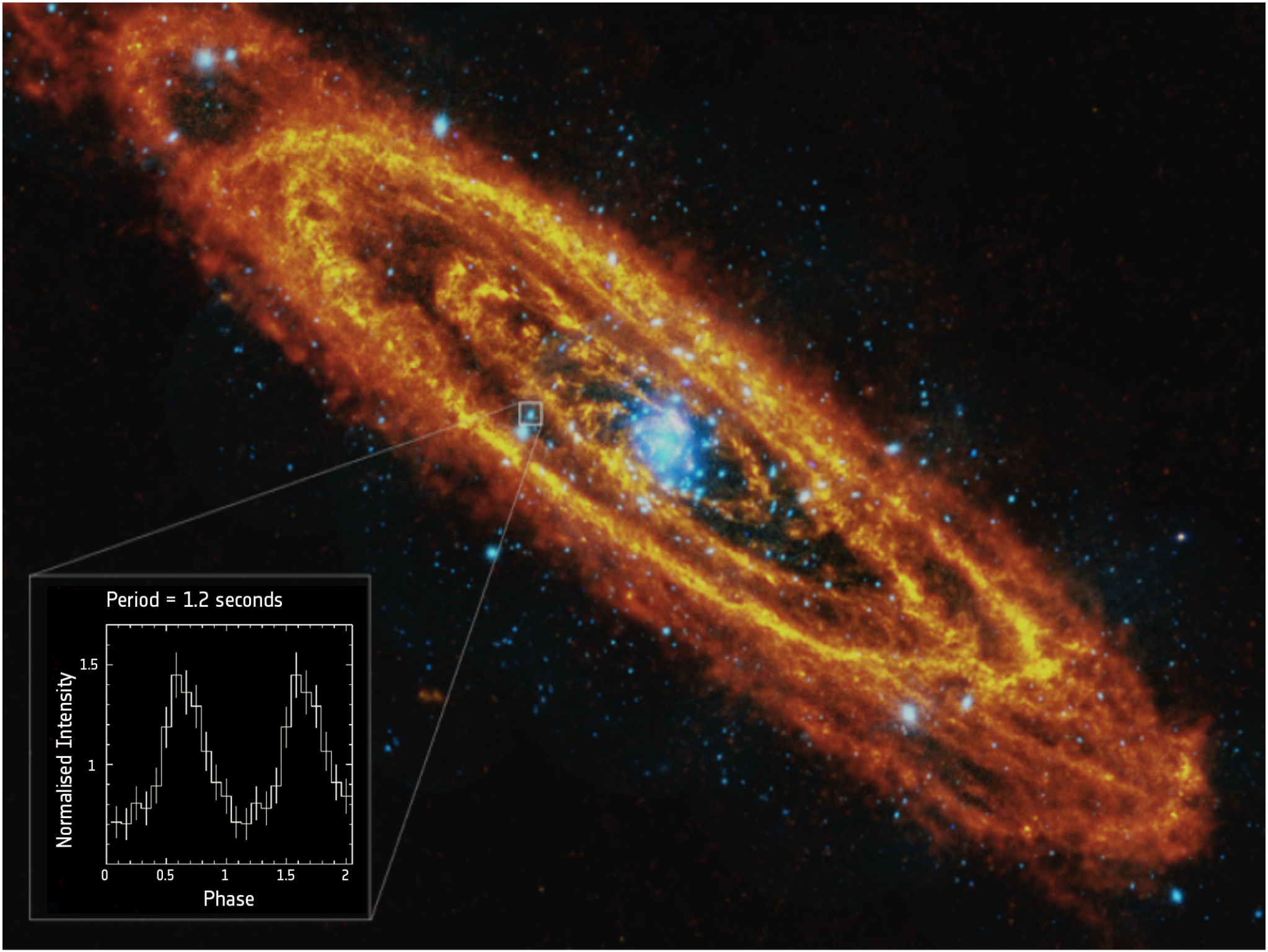

HST
Chandra
M51



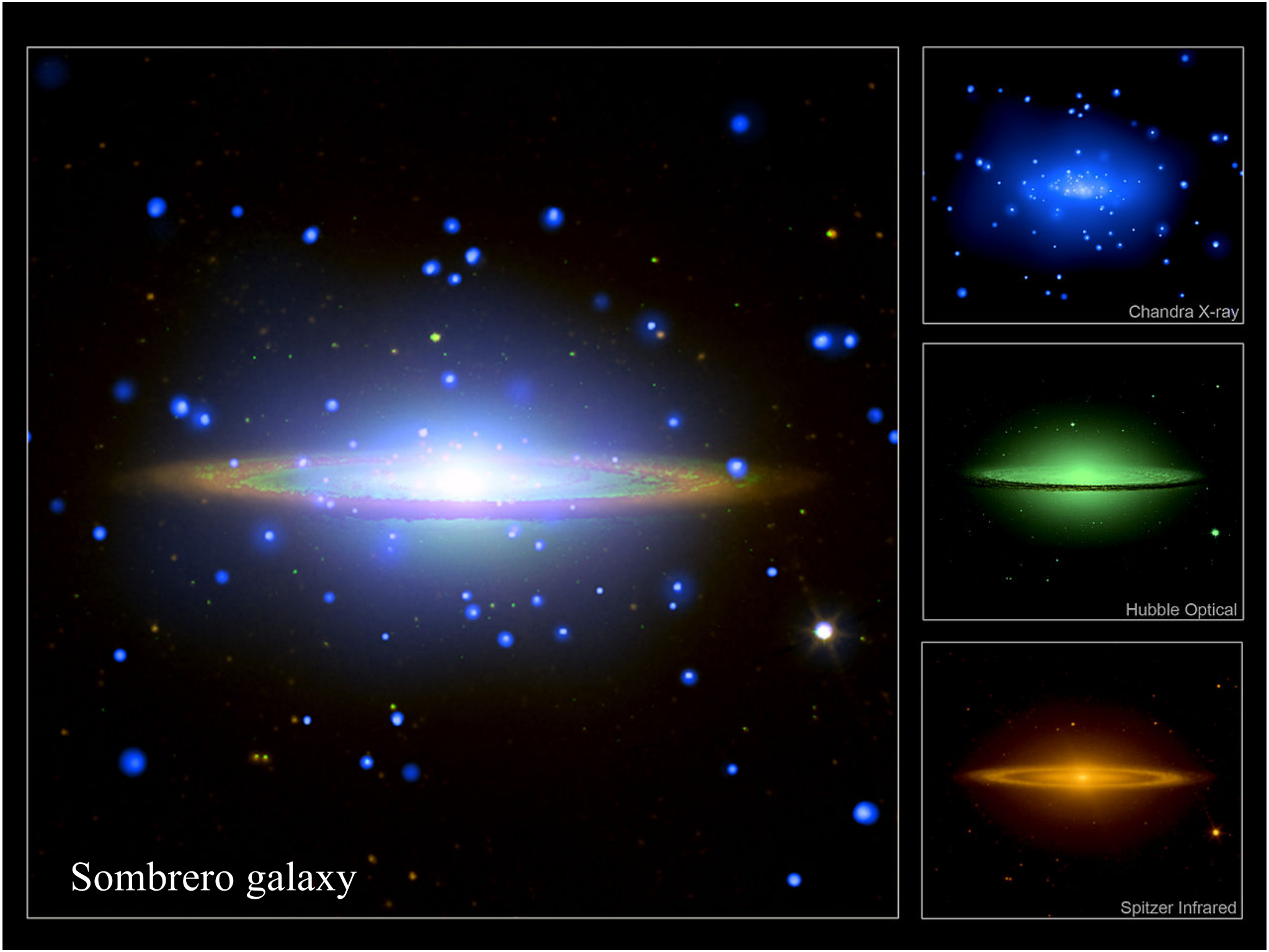
M101

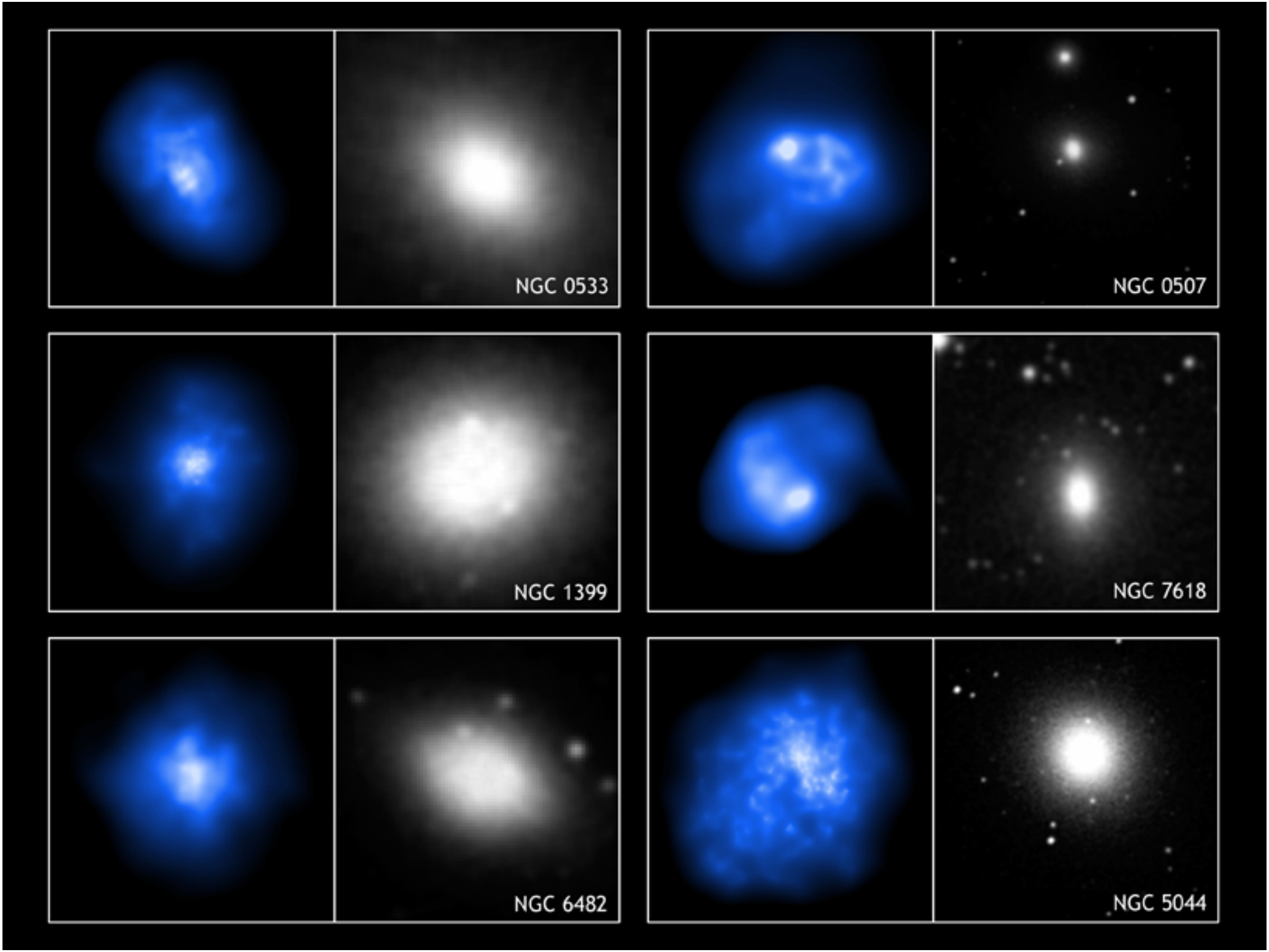

M81
X-RAY DETAIL
COMPOSITE

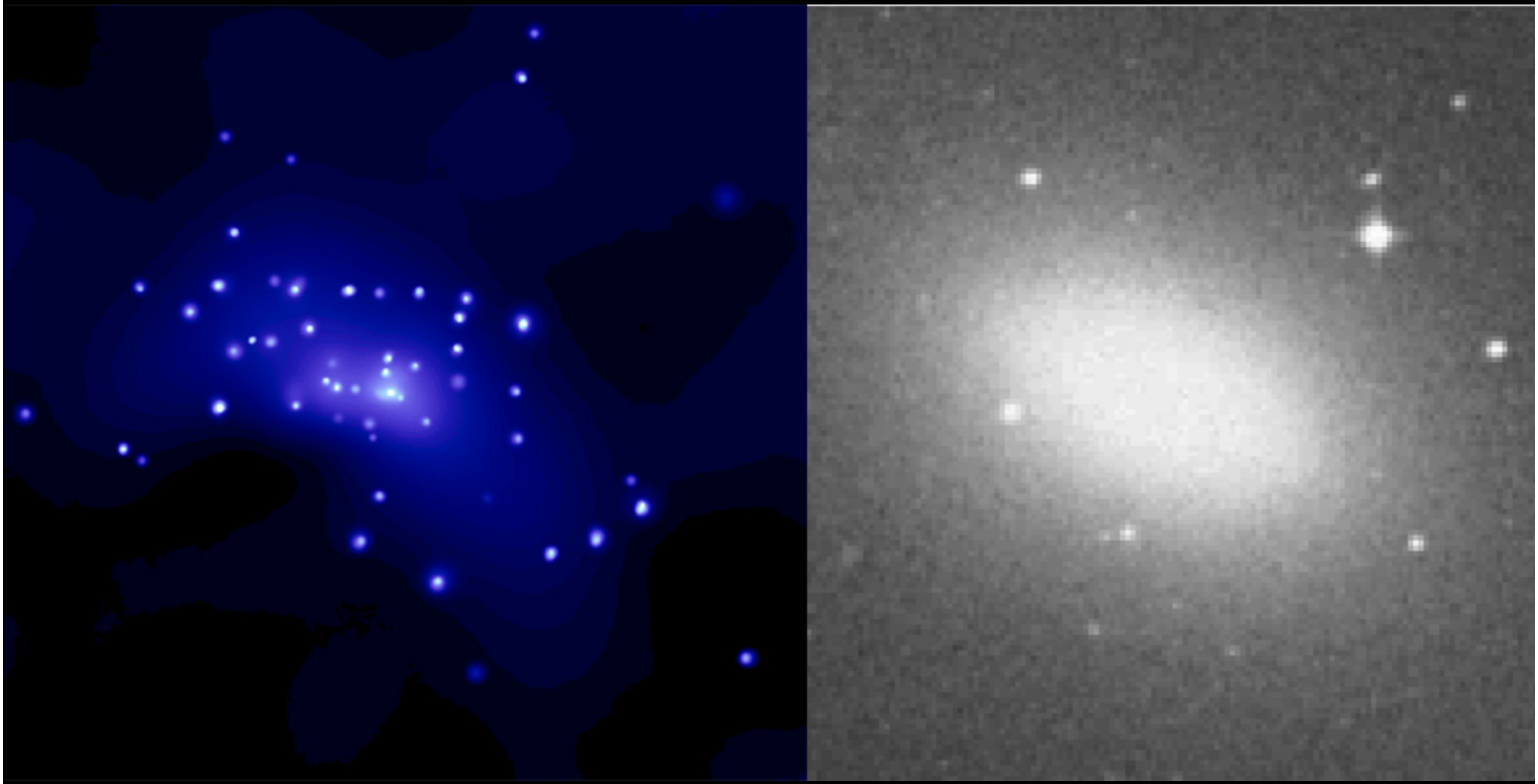

M31
X-RAY CLOSE-UP
WIDE-FIELD OPTICAL


Period = 1.2 seconds
Normalised Intensity
1.5
1
0
0.5
1
1.5
2
Phase

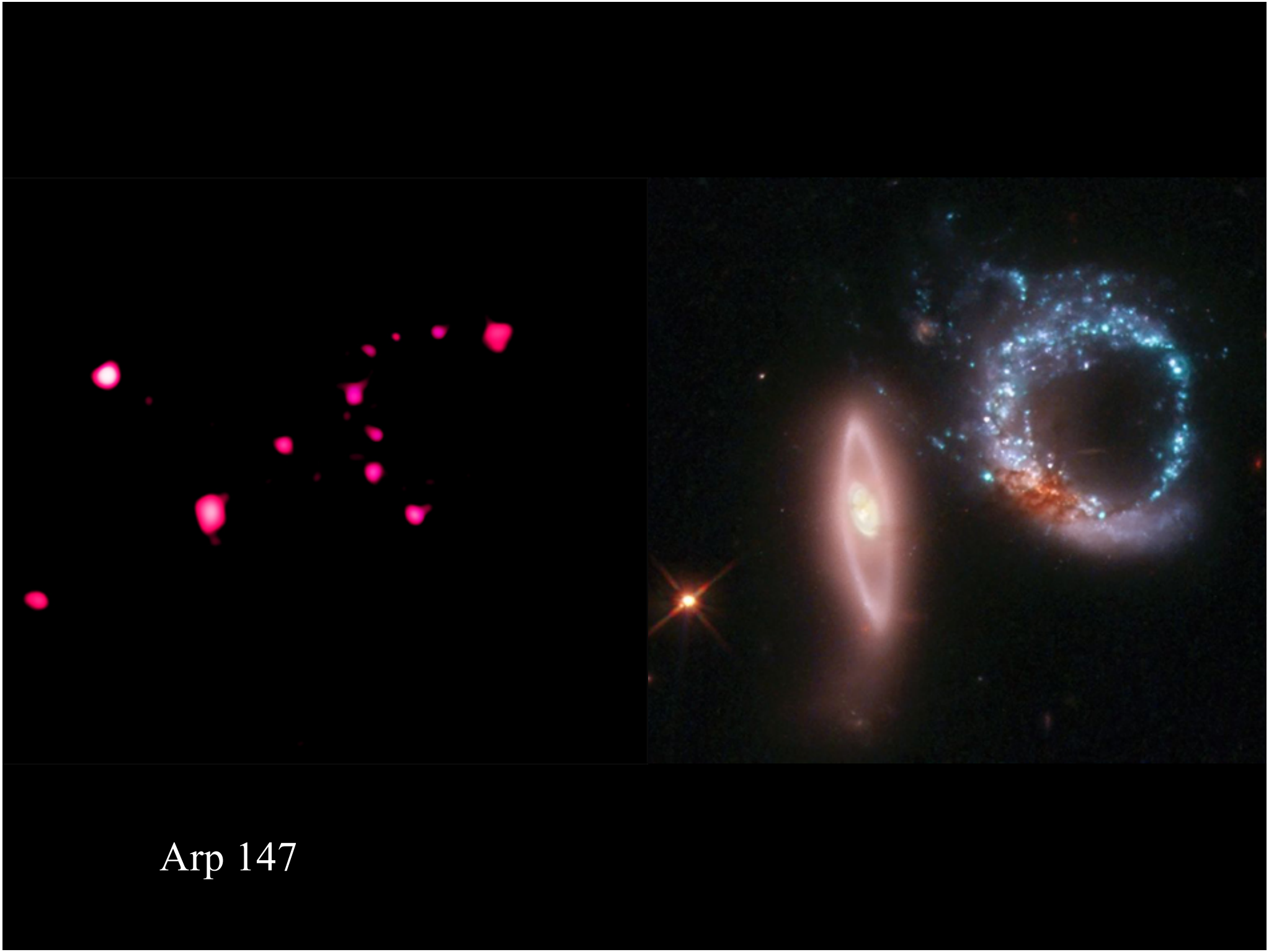

NGC 5746


Sombrero galaxy
Chandra X-ray
Hubble Optical
Spitzer Infrared

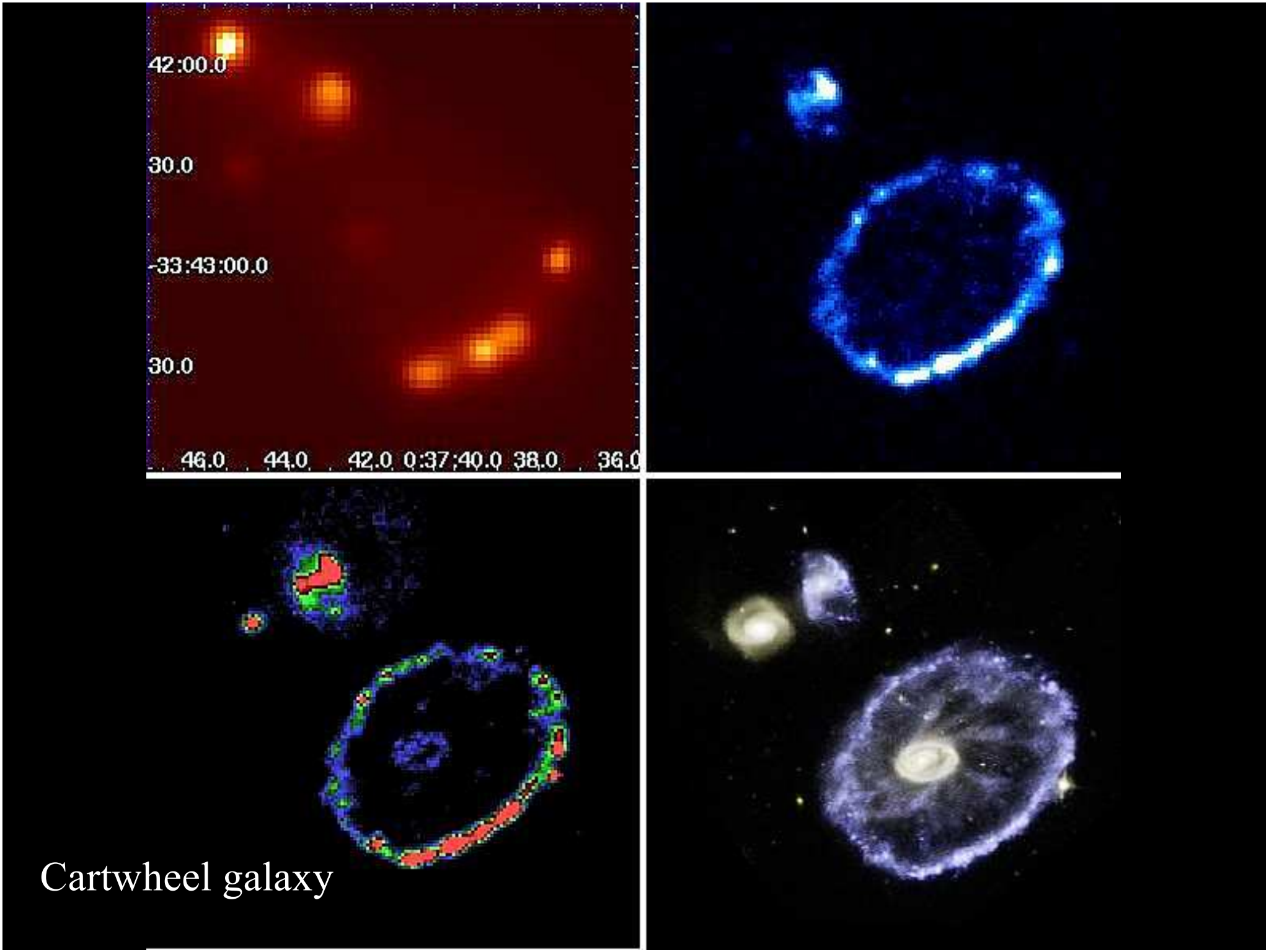

NGC 0533
NGC 0507
NGC 1399
NGC 7618
NGC 6482
NGC 5044

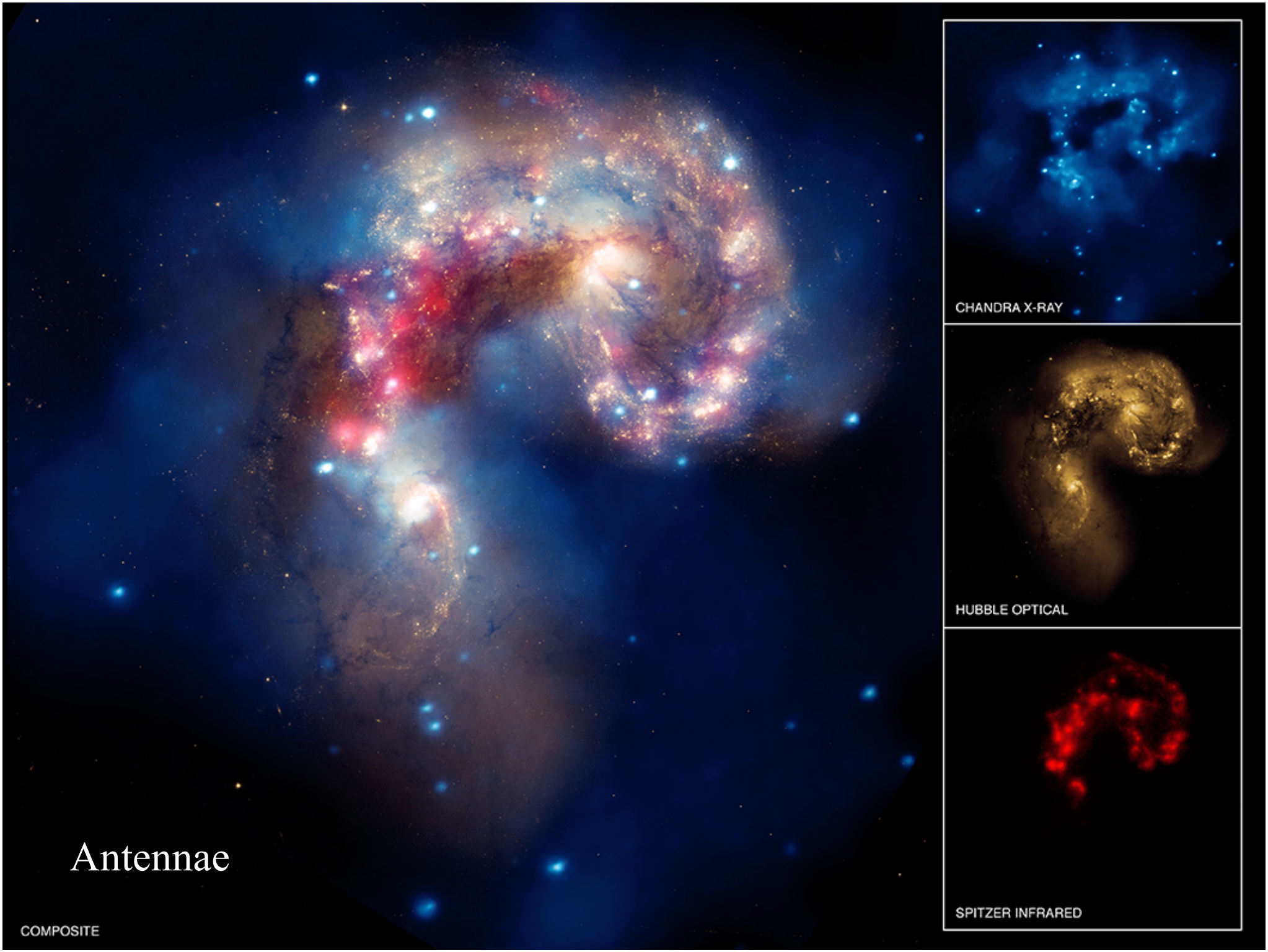


NGC 4697

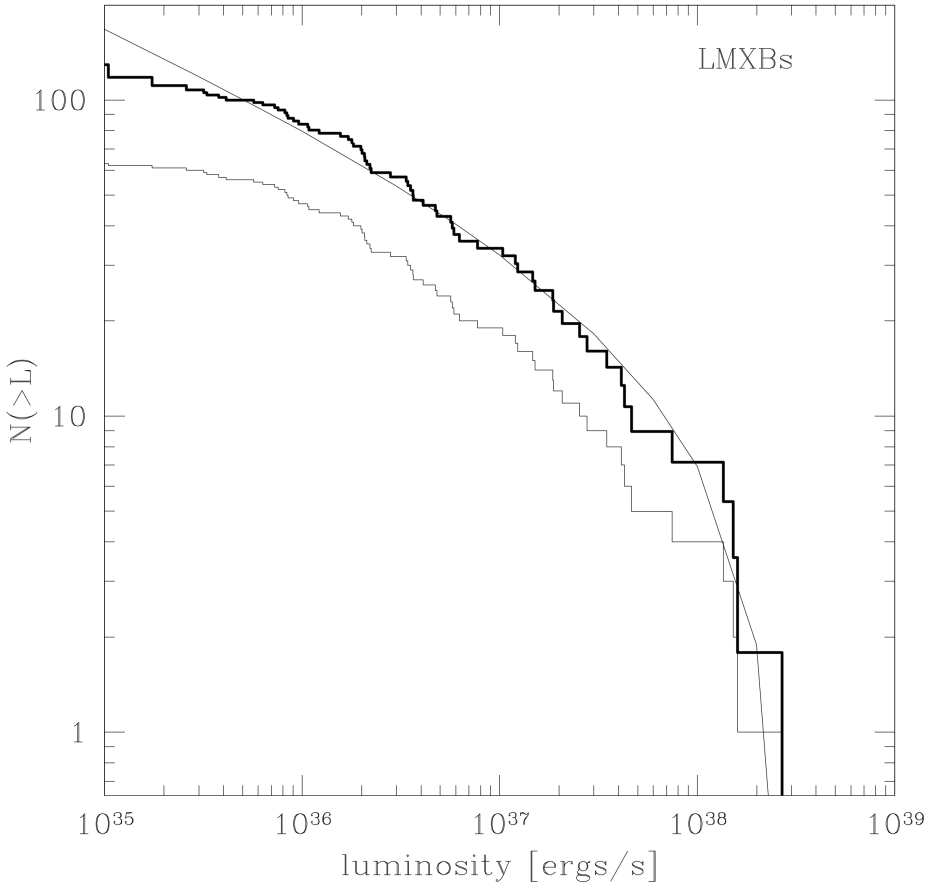


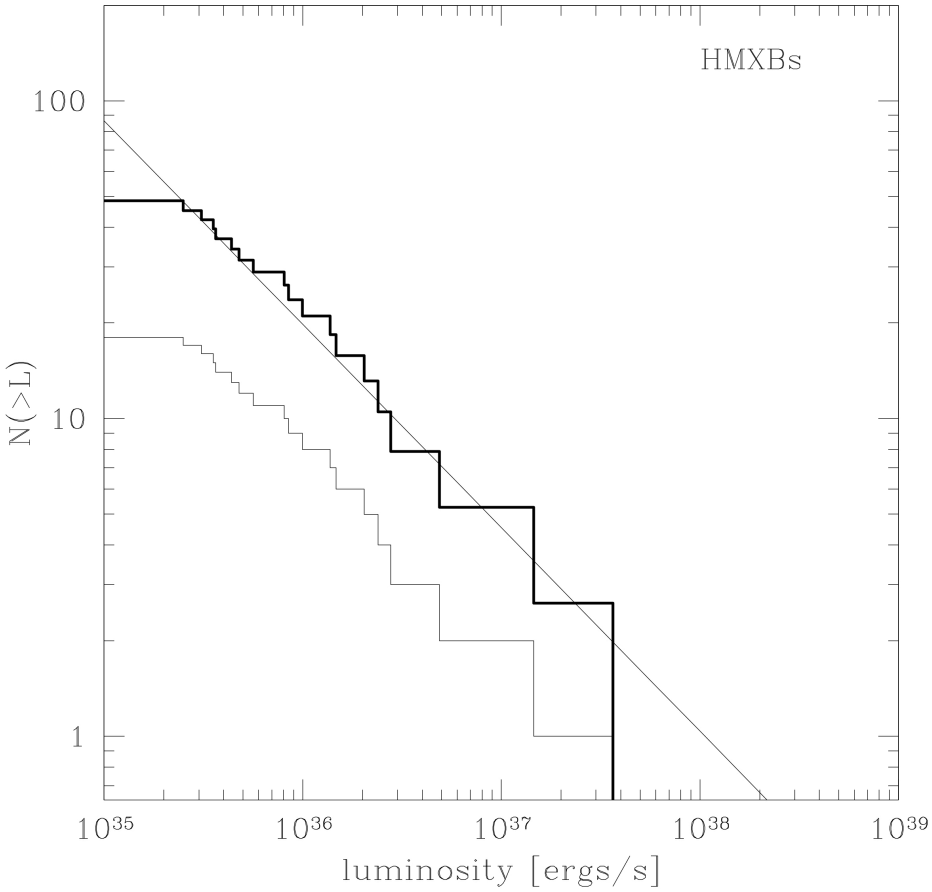
Arp 147


42:00.0
30.0
-33:43:00.0
30.0
46.0
44.0
42.0
0:37:40.0
38.0
36.0
Cartwheel galaxy


Antennae
COMPOSITE
CHANDRA X-RAY
HUBBLE OPTICAL
SPITZER INFRARED

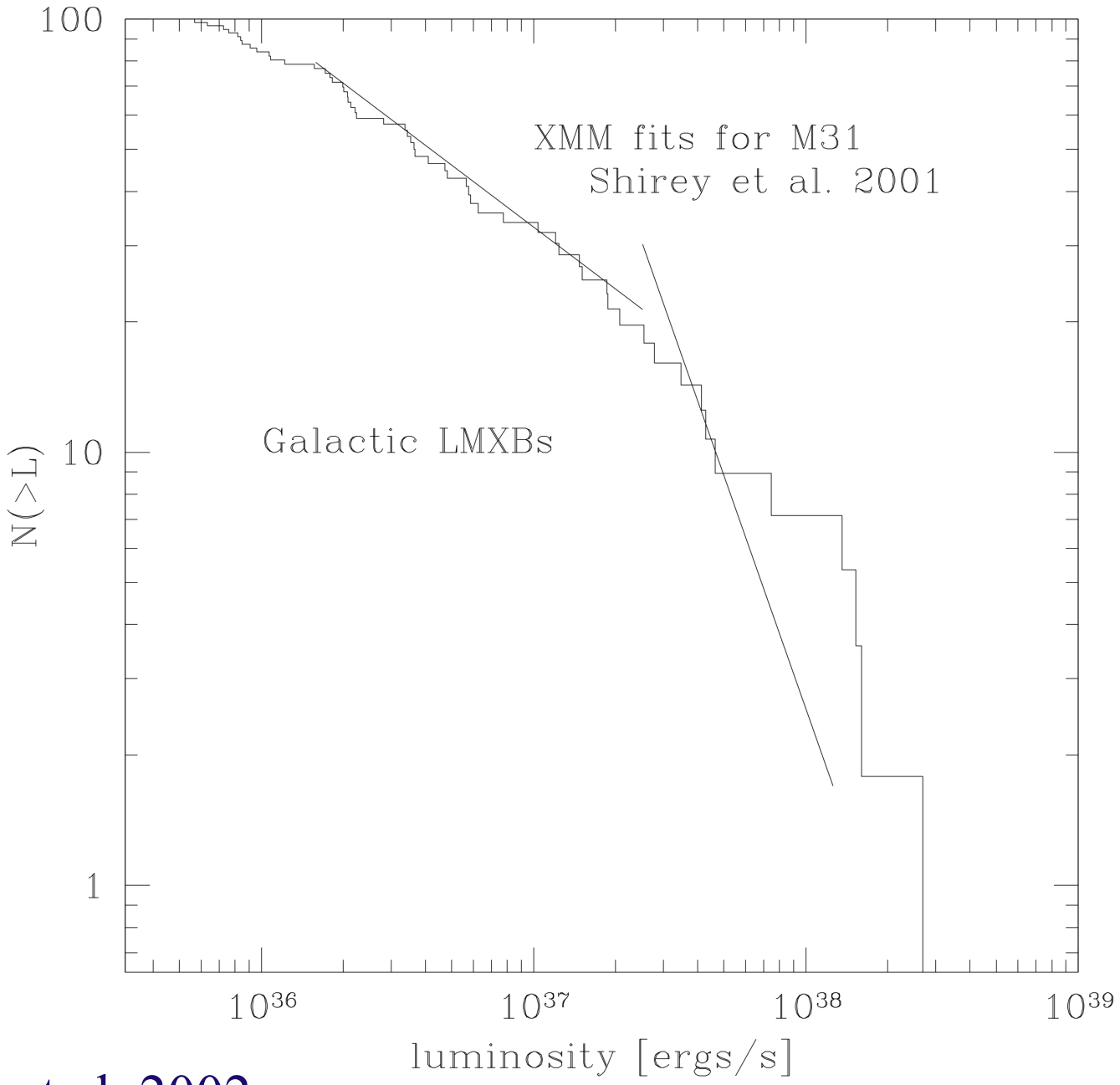
Cumulative luminosity function





Galaxy

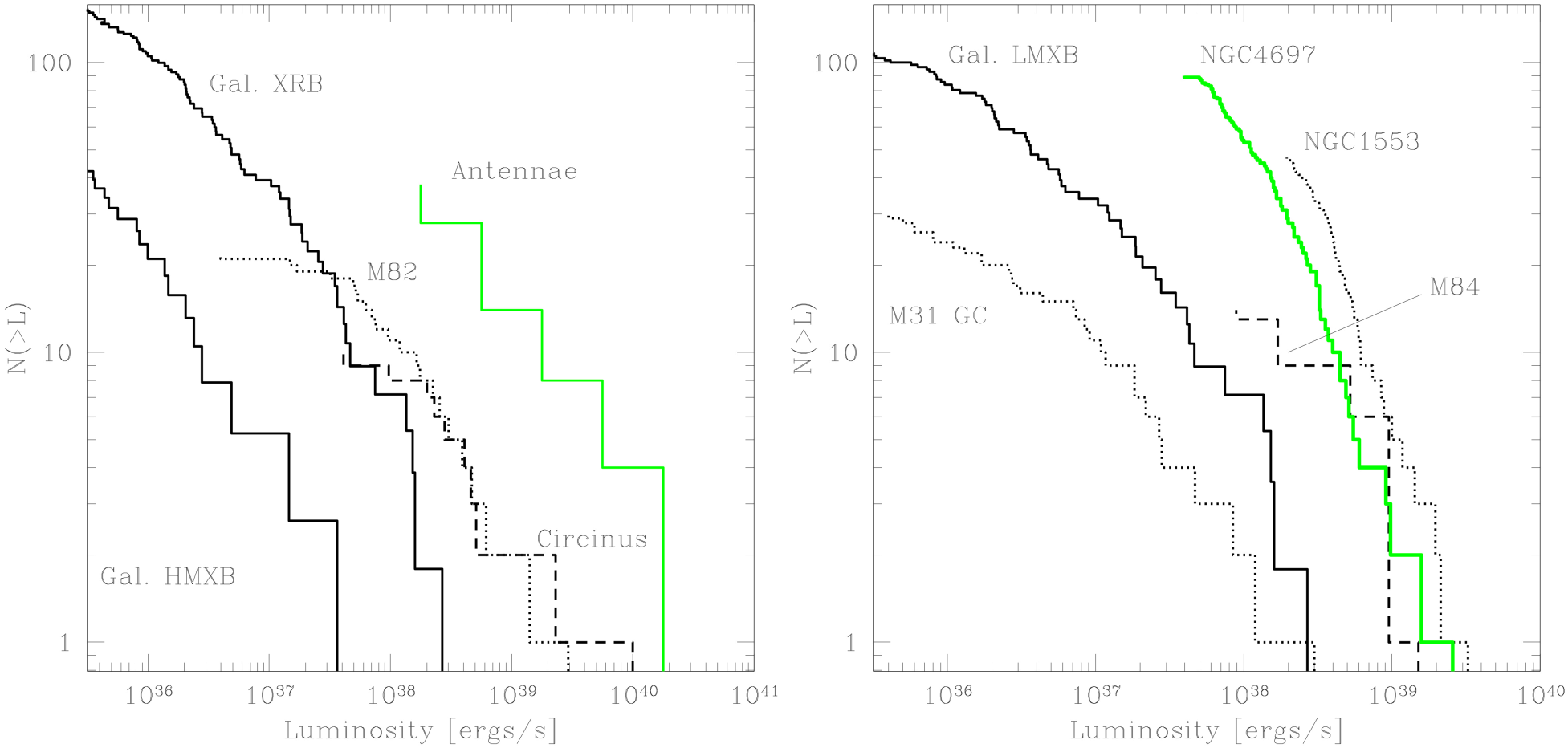
Grimm et al. 2002



Grimm et al. 2002

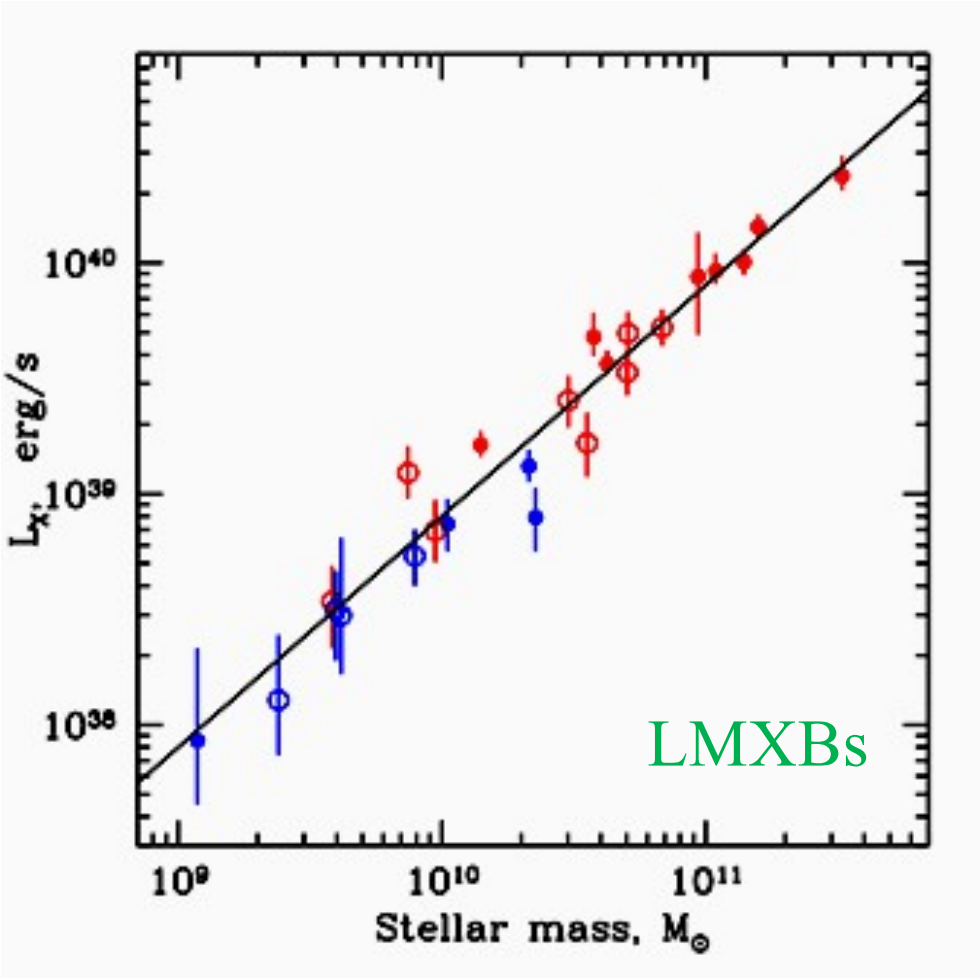
Star forming spiral galaxies

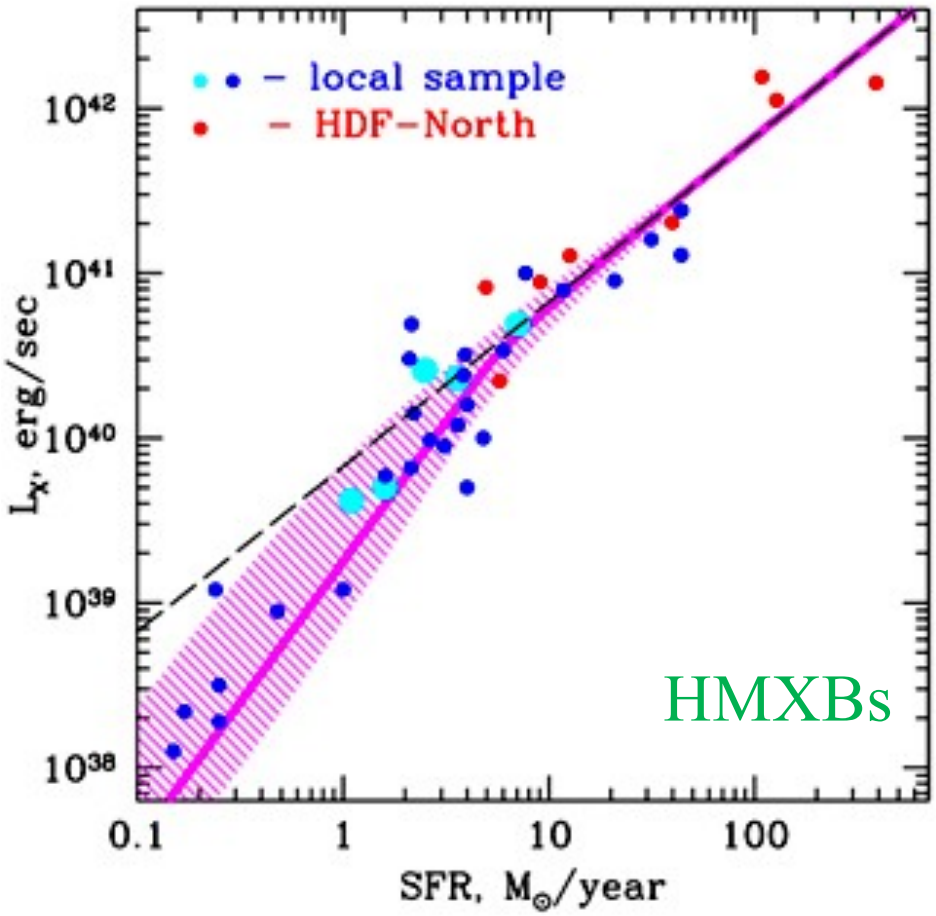
Elliptical galaxies



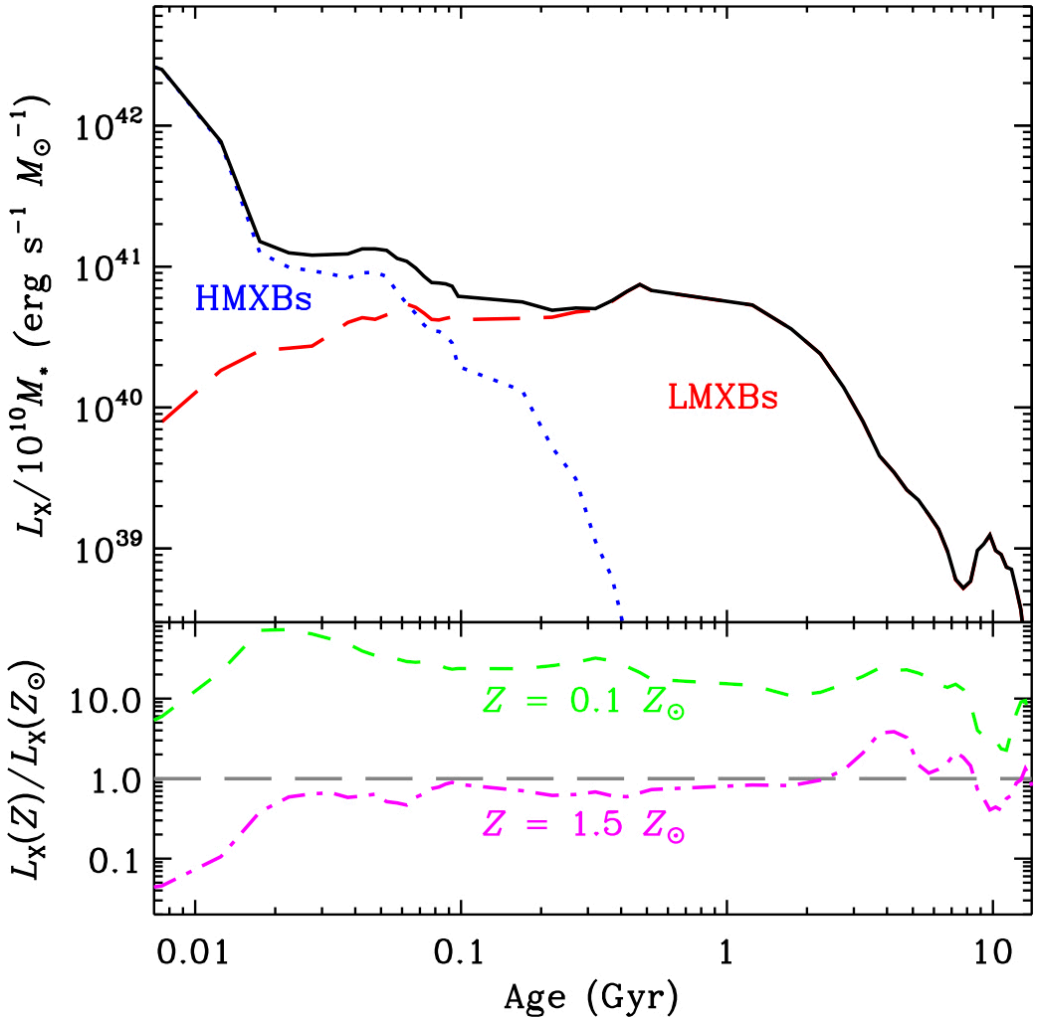
Grimm et al. 2002

Dependence of total mass and SFR





X-ray output in time after a simulated burst of star formation



Fargos et al. 2013

Conclusions of those population studies

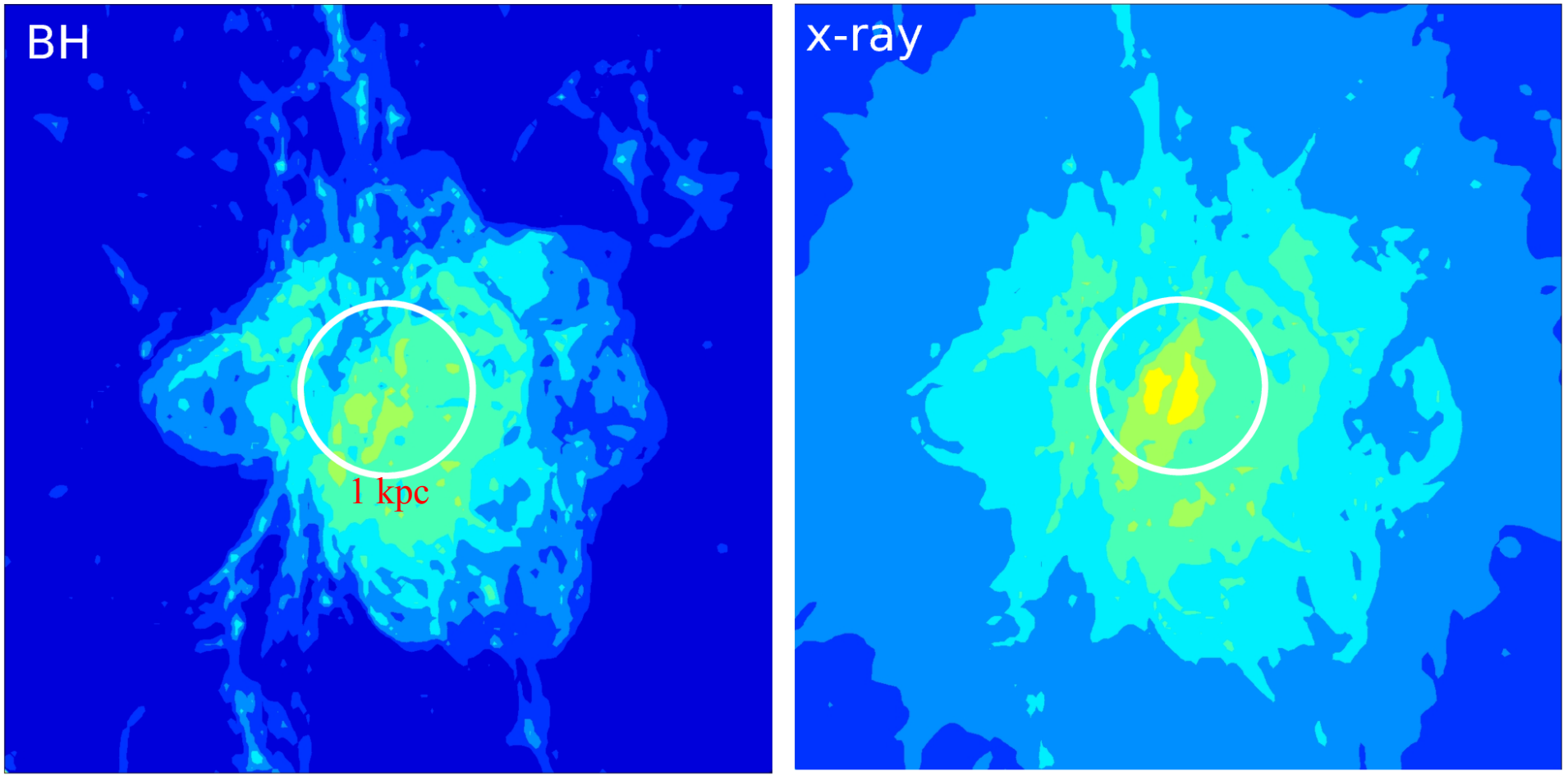
- LMXBs in the plane as well but they are concentrated in the Galactic bulge
  - Trace old population of stars
  - The live long and have time to move away from the plane
  - Total Lx depends on total mass of galaxy
- HMXBs are mostly in the plane
  - They are young and stay close to where they were formed
  - Time delay between star formation and HMXB activity (~5-10 Myr)
  - Total Lx depends on star formation rate

Feedback on galaxies

- X-ray binaries are bright X-ray sources
  - HMXBs could be a major source of X-rays in the early universe
- This X-rays can heat up the surrounding ISM/IGM
  - Important for ISM/IGM structure in galaxies?
  - Might keep ISM/IGM warm without much mass loss from galaxy
- X-ray binaries can drive powerful outflows
  - Add (kinematic) energy into ISM/IGM
  - Chemical enrich ISM?
- How does this feedback compare to other feedback mechanisms (SNe, AGN, stars)?
  - Impact on star formation activity (decreases it?)
  - How does this change (decrease) on cosmological time scales?

Without X-ray binary

With HMXB



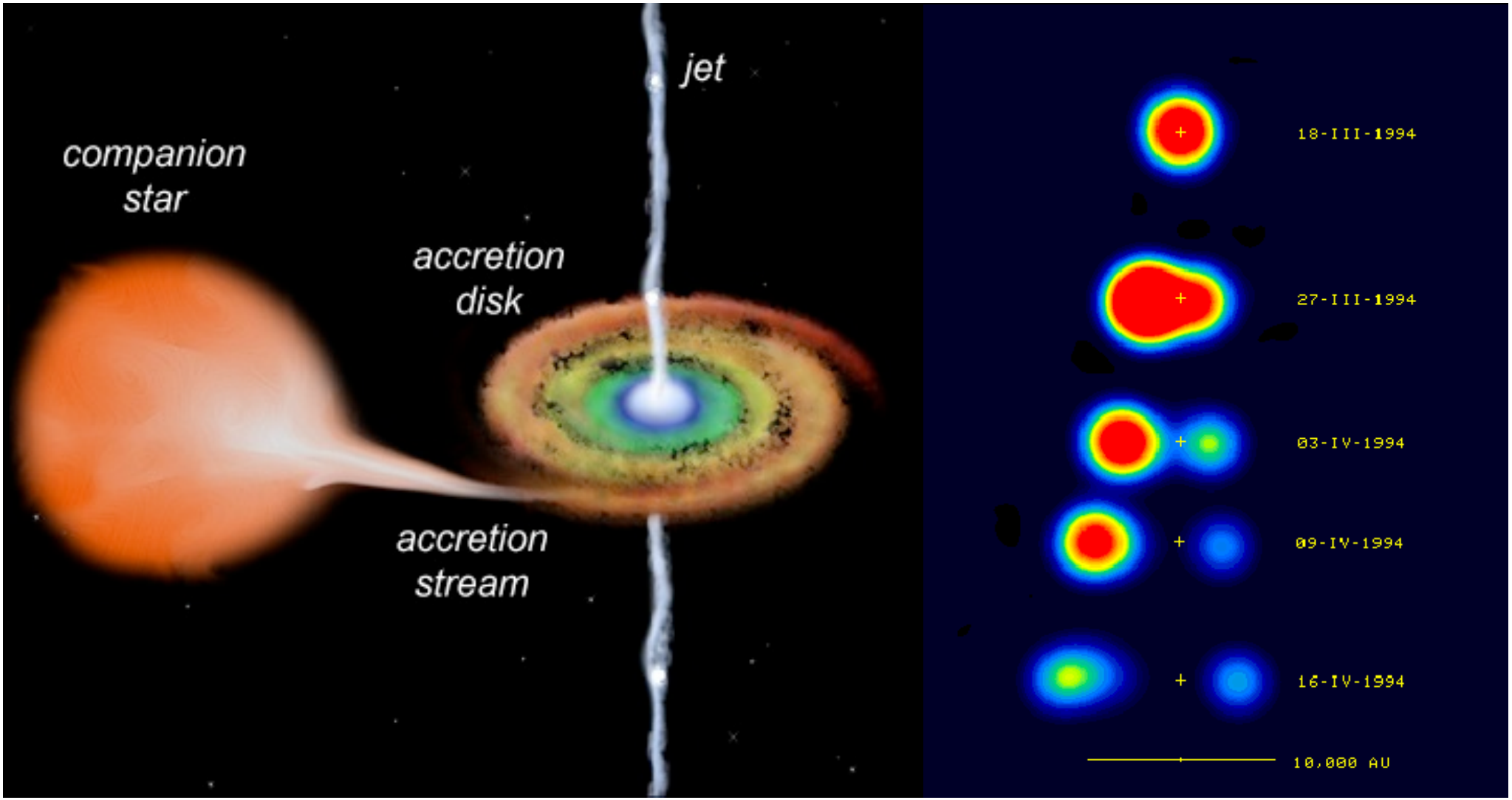
Chen et al. 2015

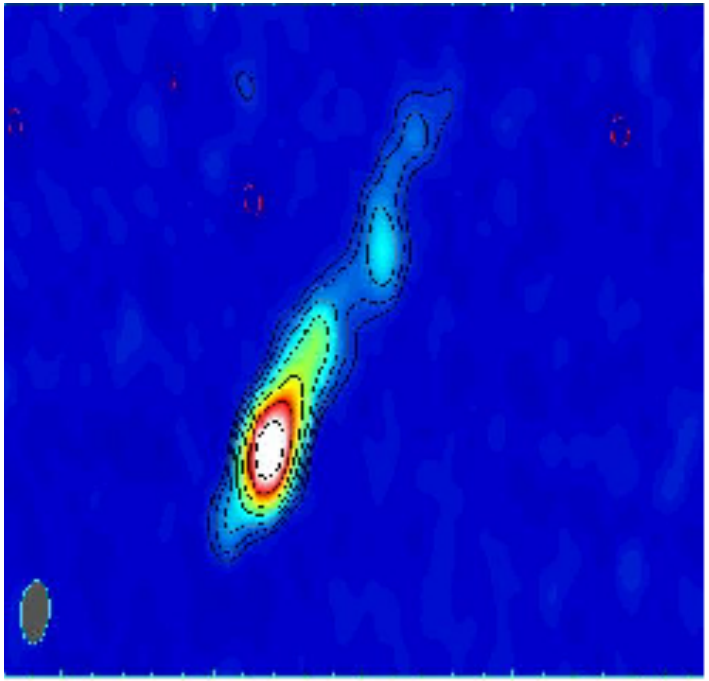
Simulation, 15 Myr after binary formation

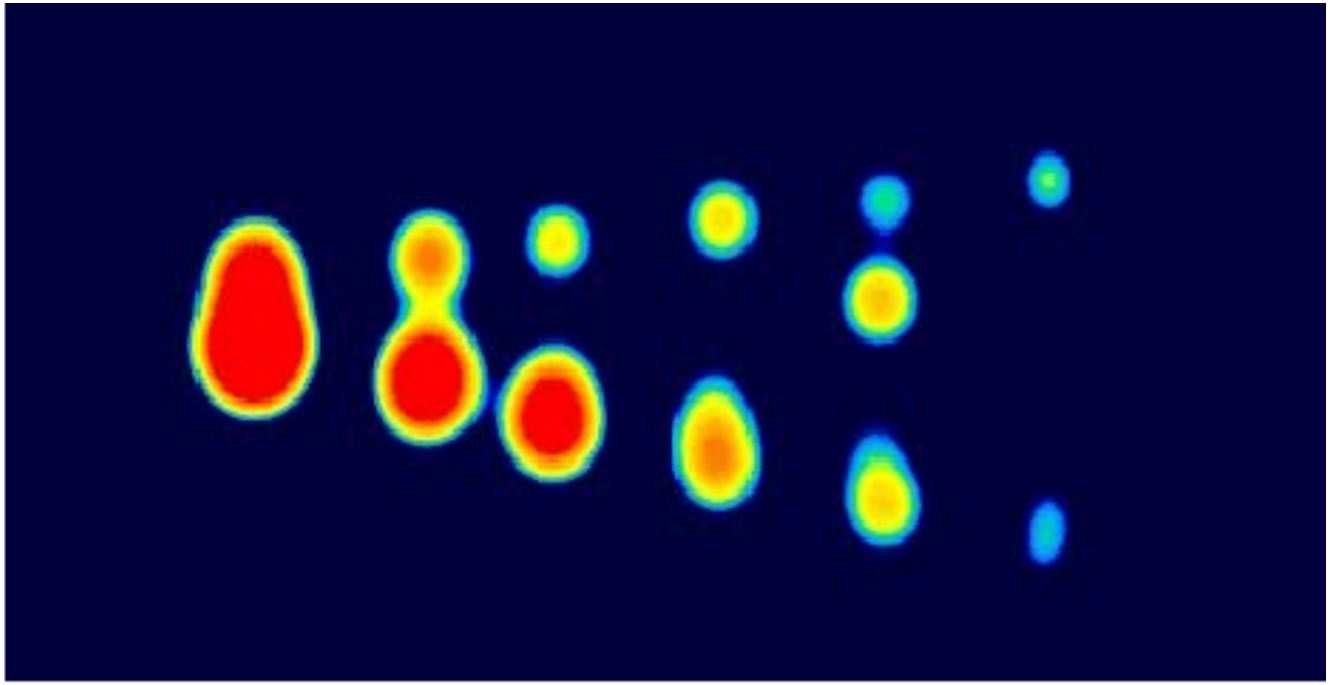
Feedback on galaxies

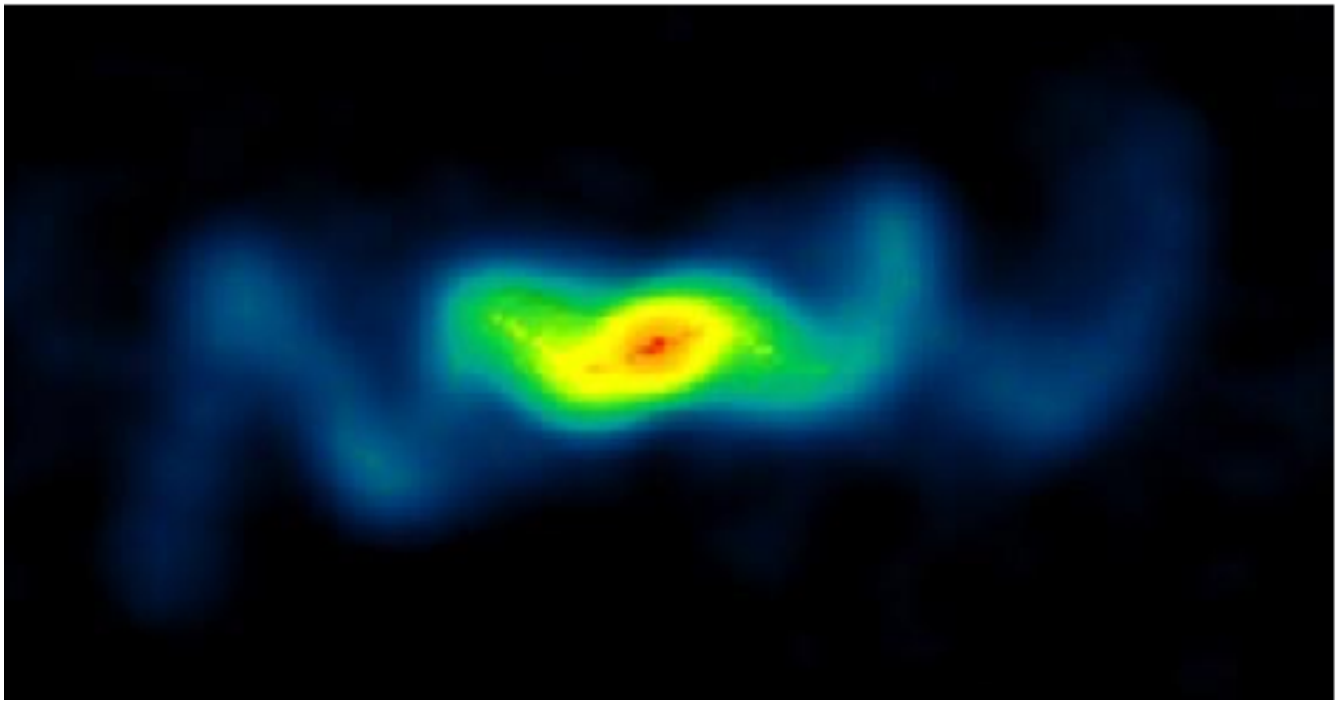
- X-ray binaries are bright X-ray sources
  - HMXBs could be a major source of X-rays in the early universe
- This X-rays can heat up the surrounding ISM/IGM
  - Important for ISM/IGM structure in galaxies?
  - Might keep ISM/IGM warm without much mass loss from galaxy
- X-ray binaries can drive powerful outflows
  - Add (kinematic) energy into ISM/IGM
  - Chemical enrich ISM?
- How does this feedback compare to other feedback mechanisms (SNe, AGN, stars)?
  - Impact on star formation activity (decreases it?)
  - How does this change (decrease) on cosmological time scales?

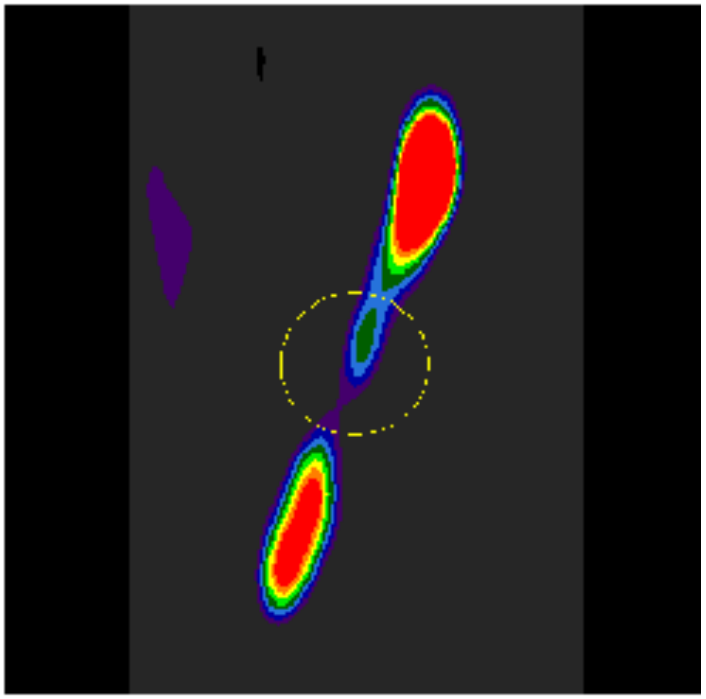
Jets in X-ray binaries

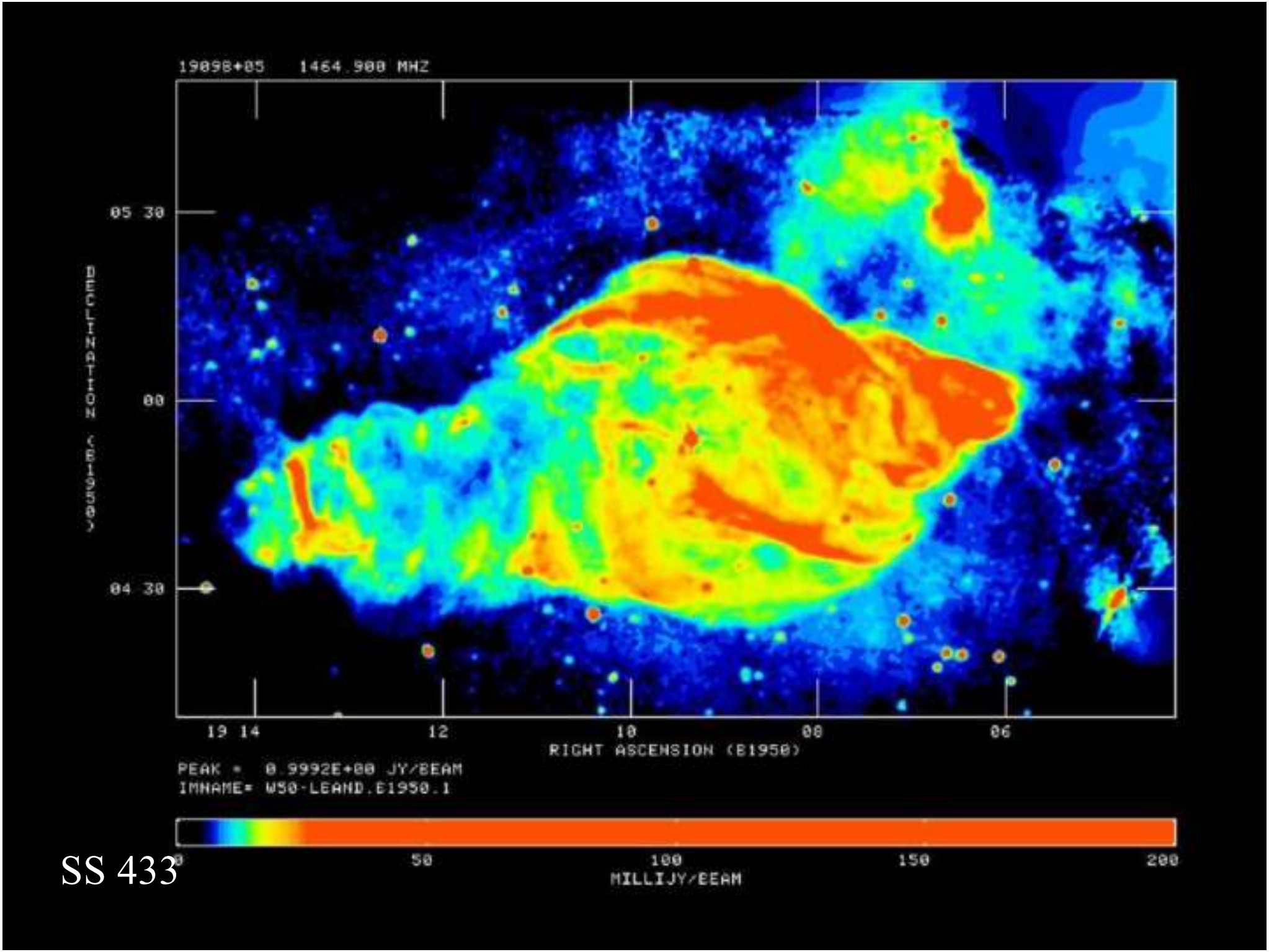




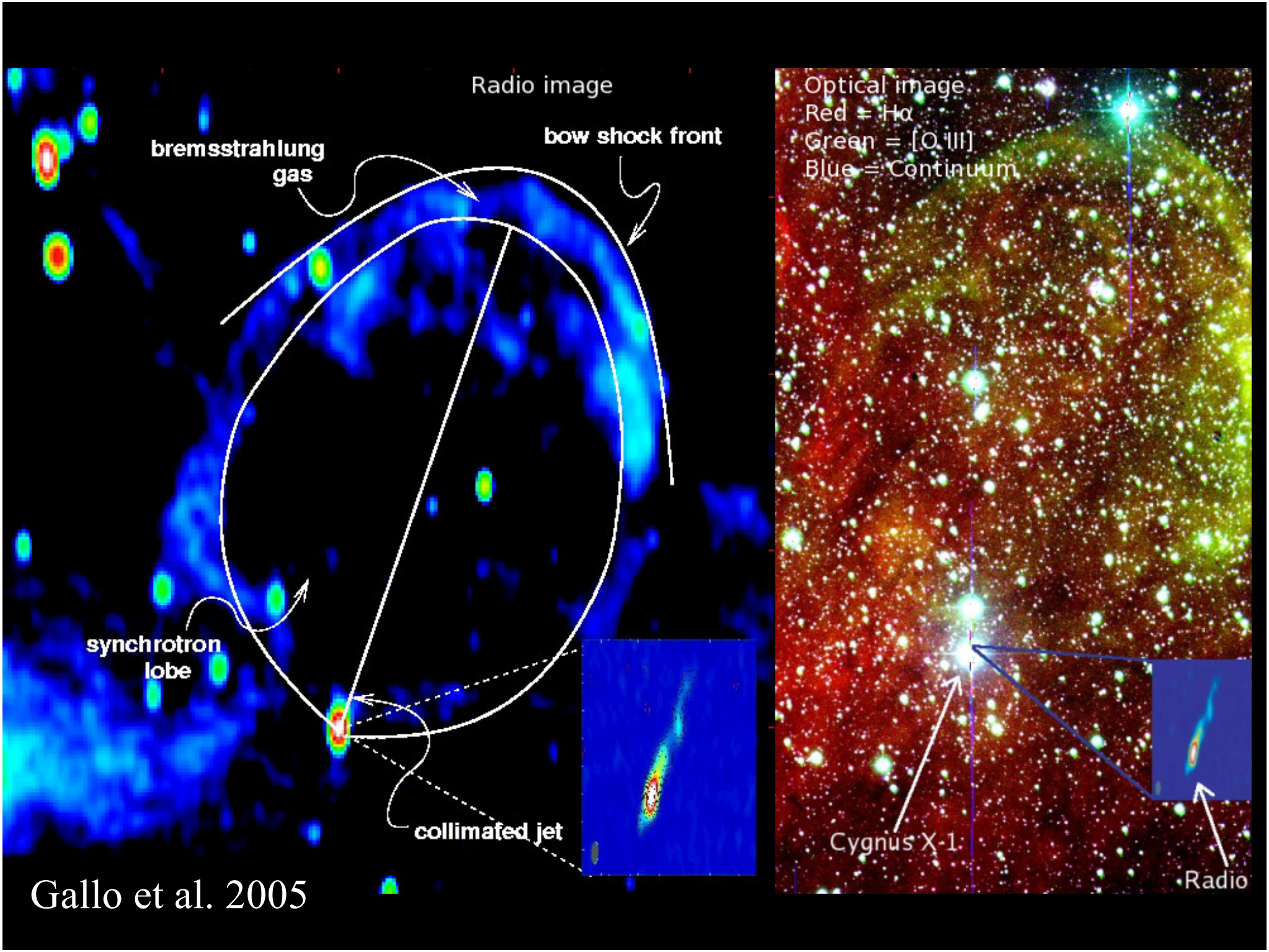







19098+05 1464.900 MHZ
05 30
00
04 30
DECLINATION (B1950)
19 14
12
10
08
06
RIGHT ASCENSION (B1950)
PEAK = 0.9992E+00 JY/BEAM
IMNAME= W50-LEAND.B1950.1
0
50
100
150
200
MILLIJY/BEAM

SS 433

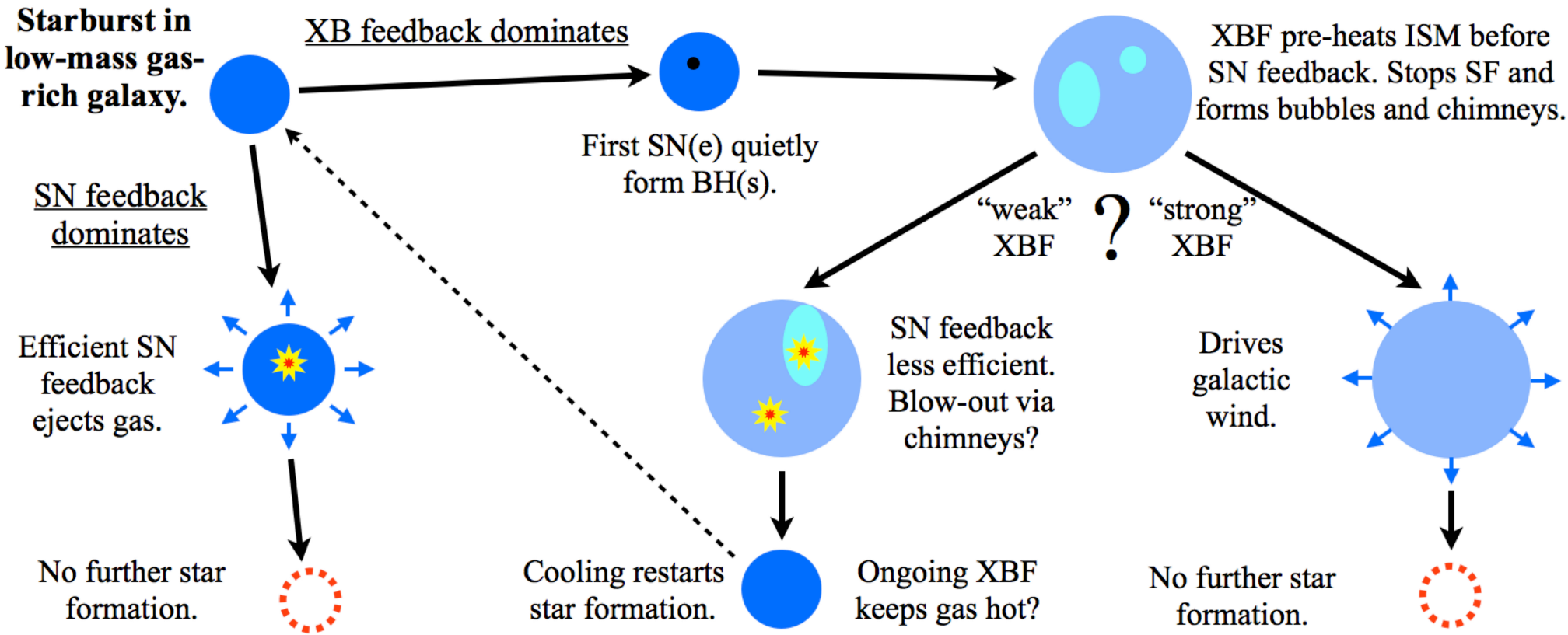


Gallo et al. 2005

Feedback on galaxies

- X-ray binaries are bright X-ray sources
  - HMXBs could be a major source of X-rays in the early universe
- This X-rays can heat up the surrounding ISM/IGM
  - Important for ISM/IGM structure in galaxies?
  - Might keep ISM/IGM warm without much mass loss from galaxy
- X-ray binaries can drive powerful outflows
  - Add (kinematic) energy into ISM/IGM
  - Chemical enrich ISM?
- How does this feedback compare to other feedback mechanisms (SNe, AGN, stars)?
  - Impact on star formation activity (decreases it?)
  - How does this change (decrease) on cosmological time scales?

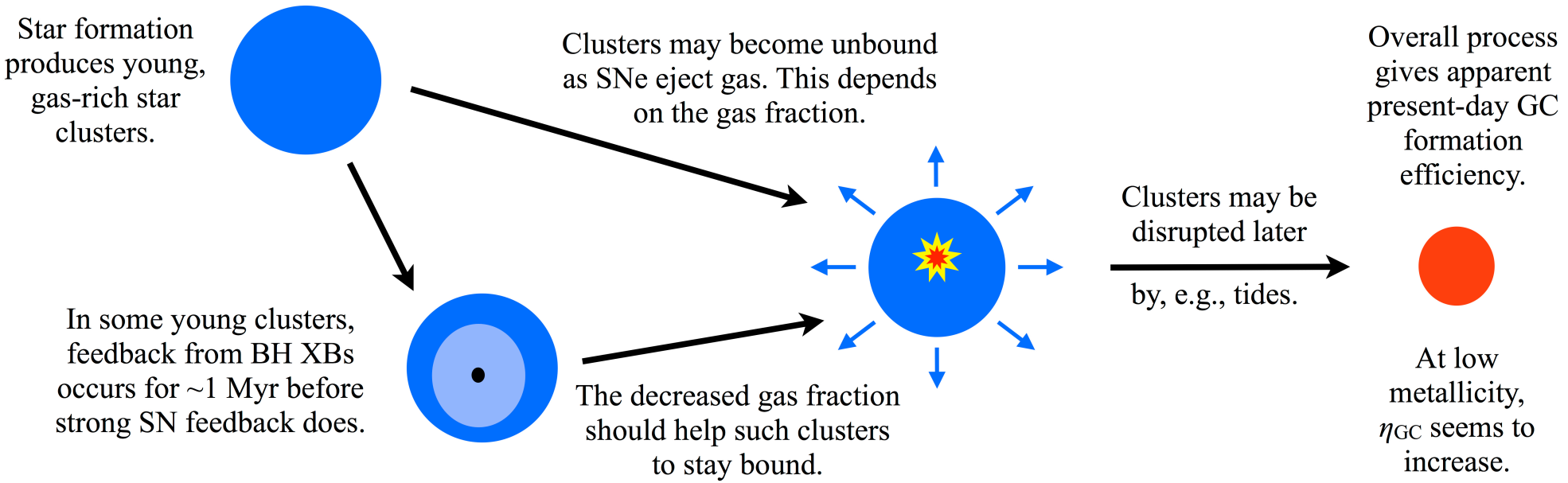
Complex interaction with X-ray binary feedback and star formation



Justham & Schawinski 2012

Effect of feedback on star clusters

$$\eta_{\text{formation}} \times (1 - \eta_{\text{disruption}}) \times \eta_{\text{survival}} = \eta_{\text{GC}}$$



Justham et al. 2015

Conclusions

X-ray binaries are very important sources

- Study accretion physics
- Study extreme physics in and around neutron stars and black holes
- Study binary evolution
- Study the feedback processes in galaxies