eROSITA aboard SRG

Peter Predehl
Max-Planck-Institut für extraterrestrische Physik

credit: Roscosmos

eROSITA Collaboration

Core Institutes (DLR funding):
MPE, Garching
University Erlangen-Nürnberg
IAAT (University Tübingen)
SB (University Hamburg)
Leibniz-Institute for Astrophysics Potsdam

Associated Institutes:
USM (LMU Munich)
AIFA (University Bonn)

Russian Partner Institute:
IKI, Moscow

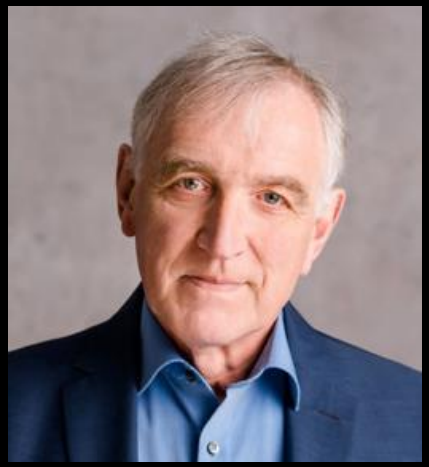
Industry:

Media Lario/I	Mirrors, Mandrels
Tecnotron/D	PCBs
Kayser-Threde/D	Mirror Structures
Carl Zeiss/D	ABRIXAS-Mandrels
Invent/D	Telescope Structure
pnSensor/D	CCDs
IberEspacio/E	Heatpipes
RUAG/A	Mechanism
HPS/D,P	MLI

+ many small companies

NPOL – Lavochkin Association

MPE: Scientific Lead Institute (PI), Project Managment
Instrument Design, Manufacturing, Integration & Test
Data Handling & Processing, Archive etc.



Principal Investigator

Peter Predehl
(2008-2020, MPE)

Project Scientist

Andrea Merloni
(MPE)

SRG Lead Scientist in Ru

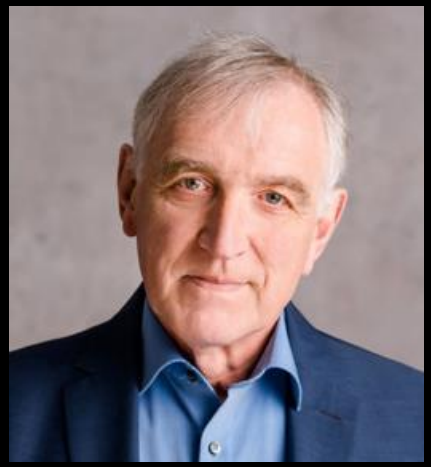
Rashid Sunyaev
(MPE)

Director

Kirpal Nandra
(MPE)

Principal Investigator

Andrea Merloni
(since July 2020, MPE)



Peter Predehl
(MPE)

SRG Lead Scientist in Ru

Rashid Sunyaev
(MPE)

Director

Kirpal Nandra
(MPE)

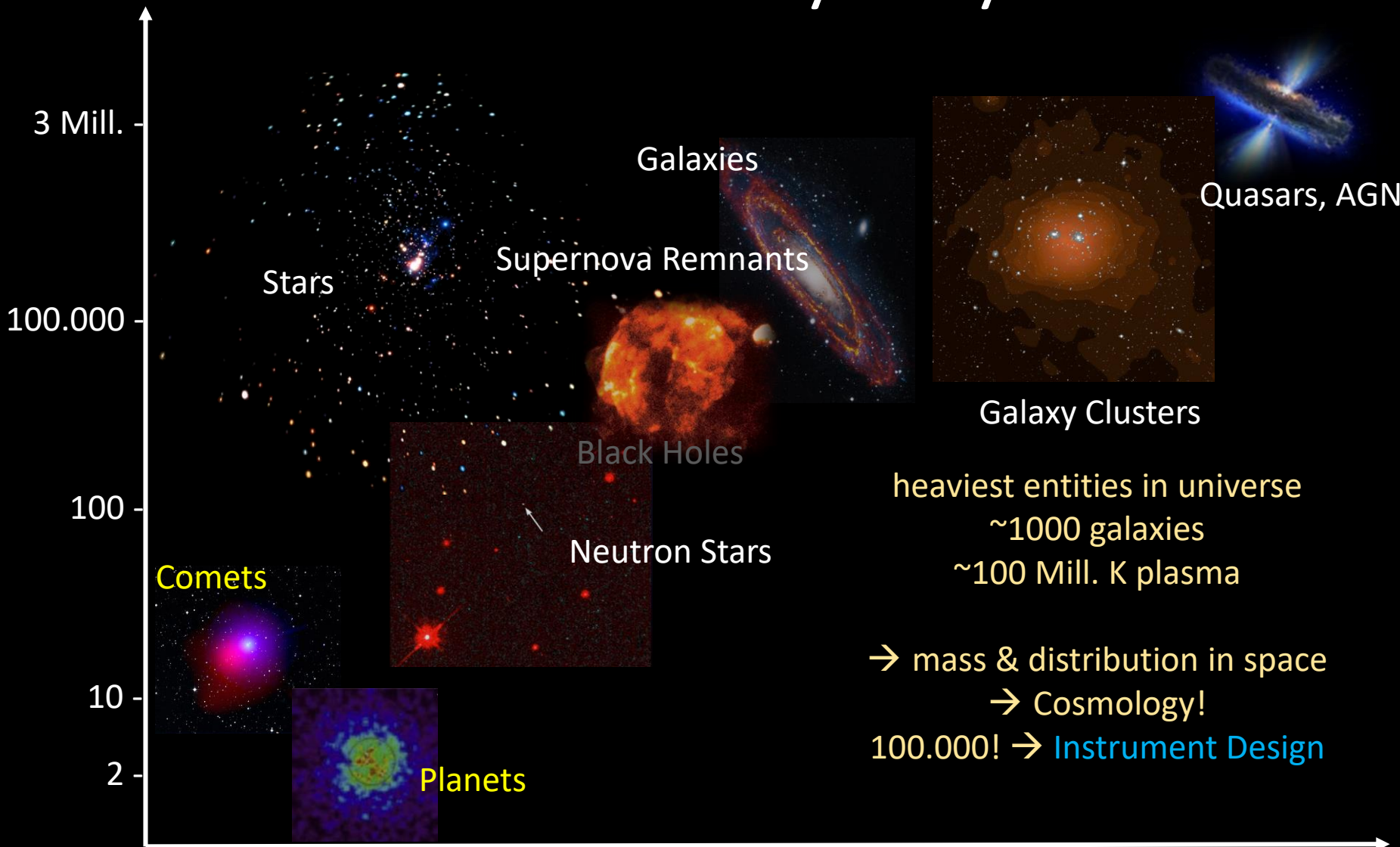
Mikhail Pavlinsky *1959; †2020

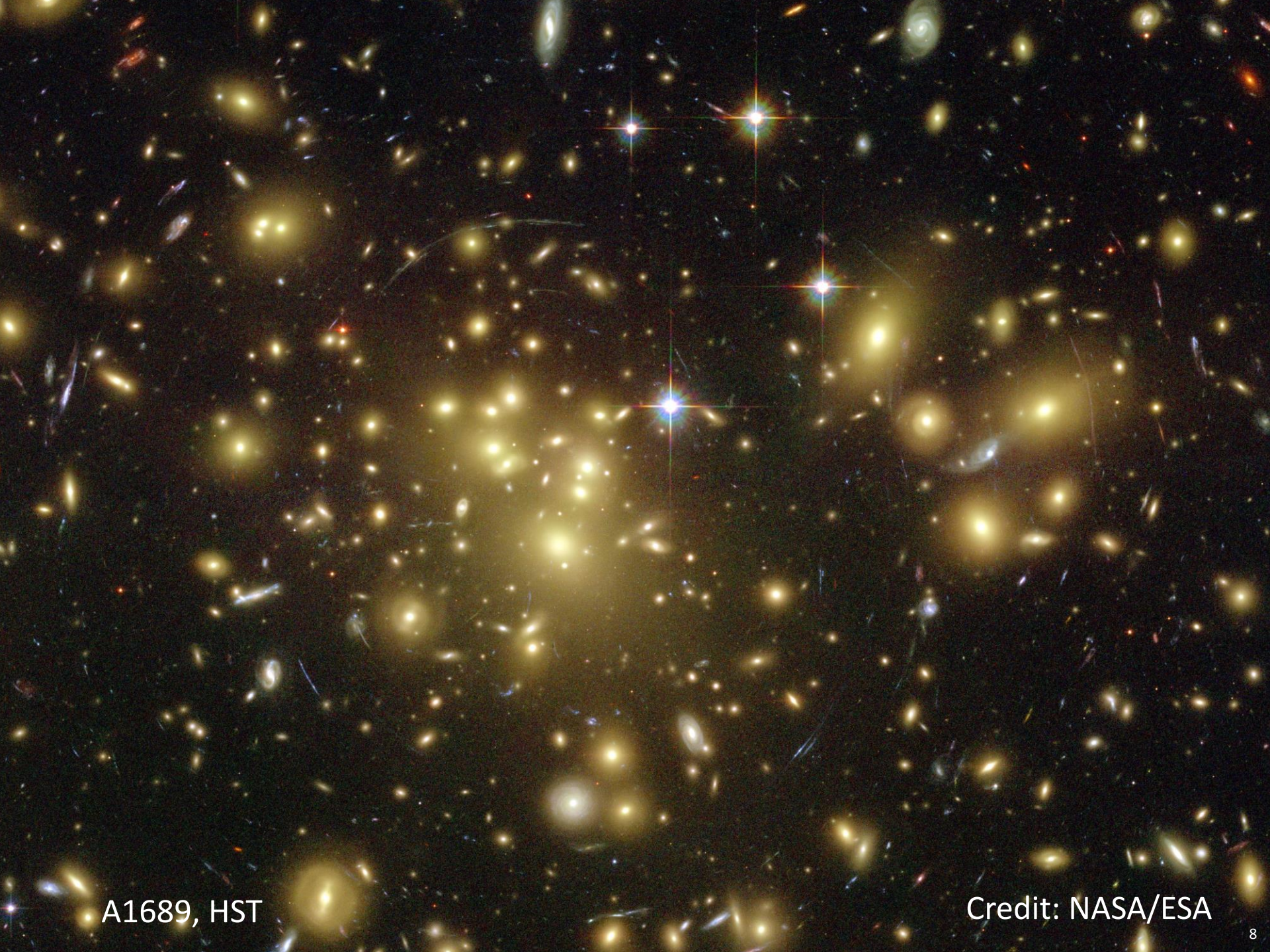
ART-XC Principal Investigator (IKI)

Outline

- The X-ray Sky
- Design Driving Science
- Instrument, Operations, Performance
- Early Results, Pretty Pictures

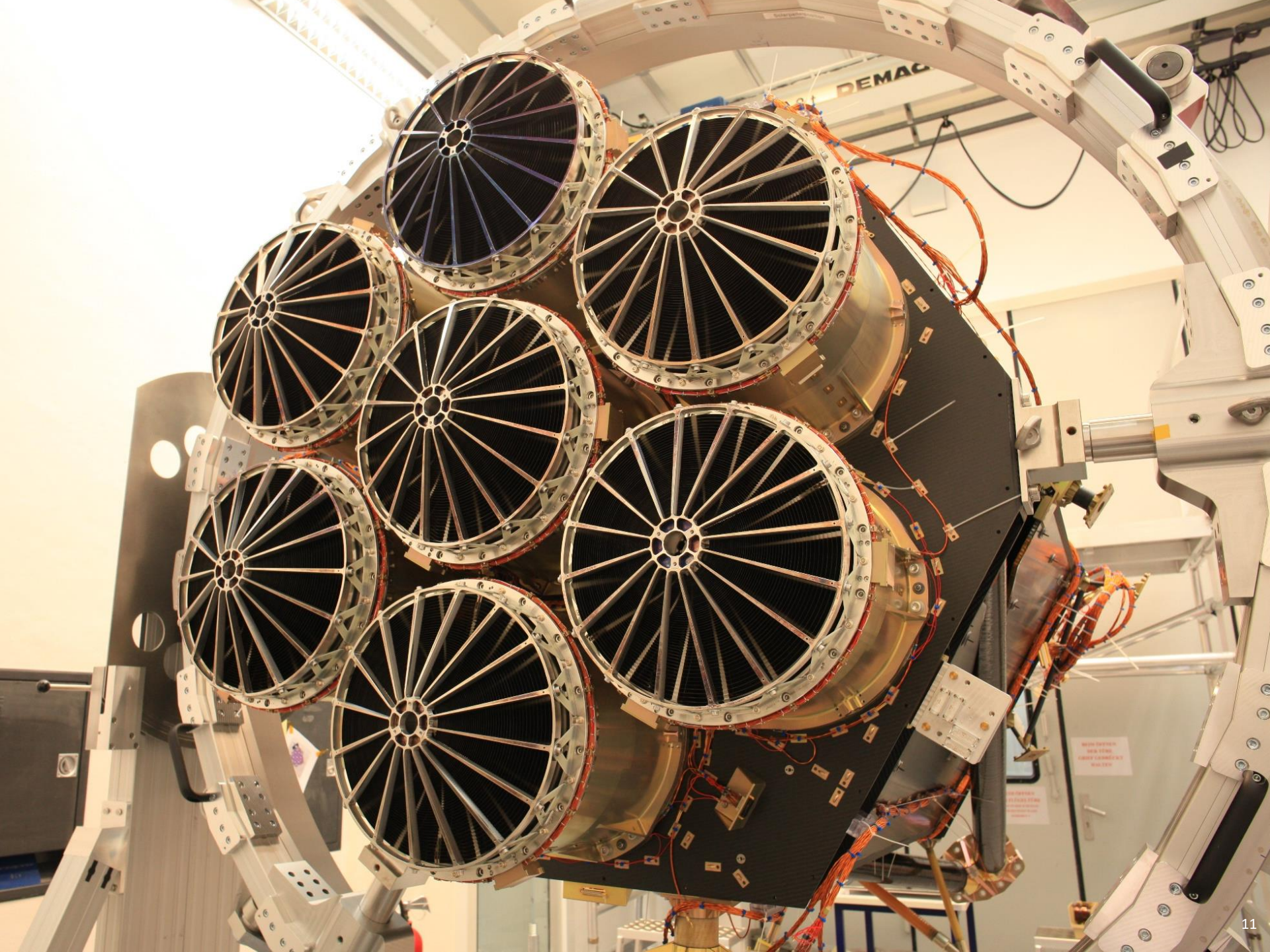
The X-ray Sky

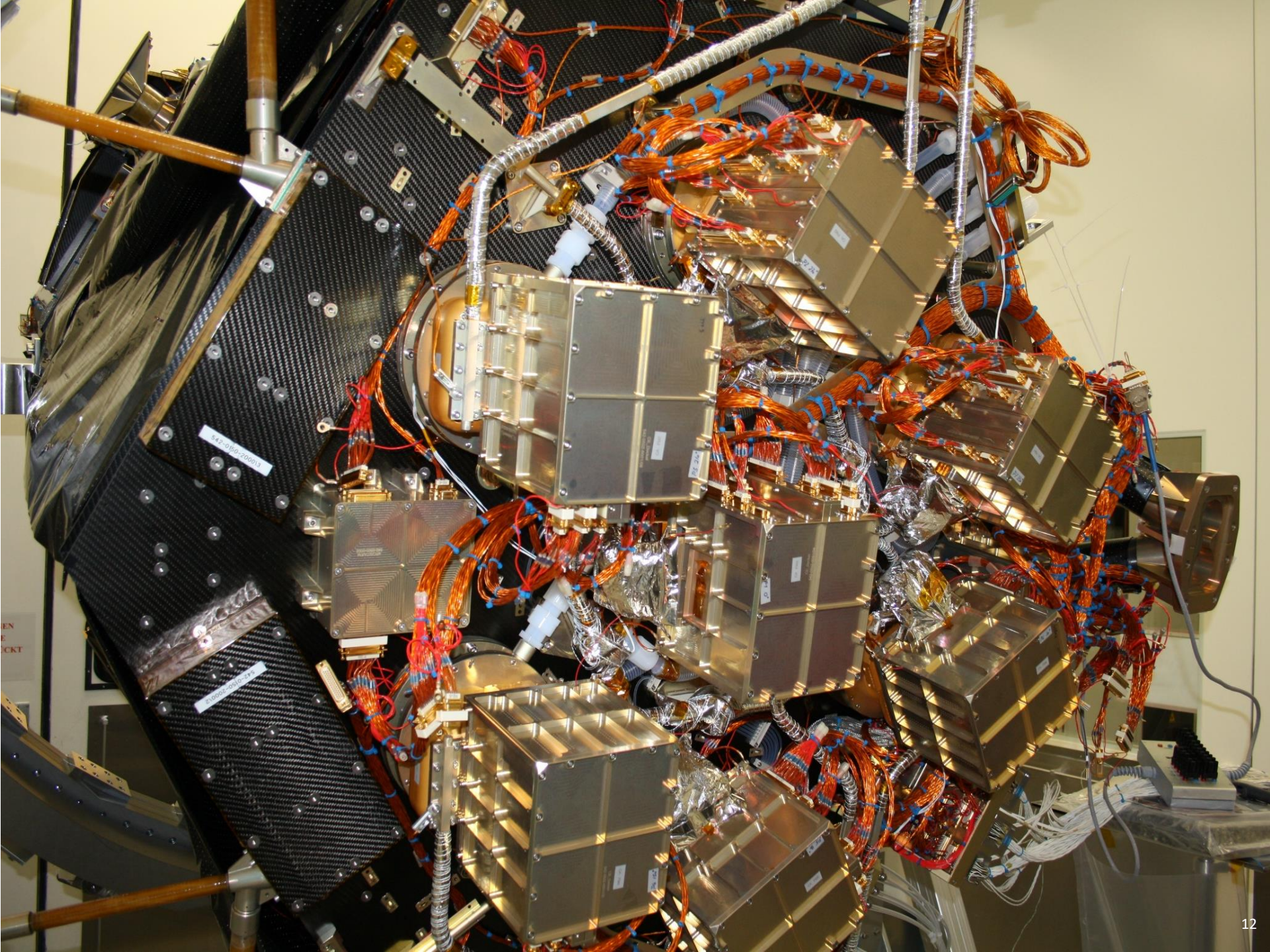

3 Mill.
100.000
100
10
2
Stars
Galaxies
Supernova Remnants
Black Holes
Neutron Stars
Comets
Planets
Quasars, AGN
Galaxy Clusters
heaviest entities in universe
~1000 galaxies
~100 Mill. K plasma
→ mass & distribution in space
→ Cosmology!
100.000! → Instrument Design
100 Mill. km
100
10.000
2 Mill.
6 Bill.
light years

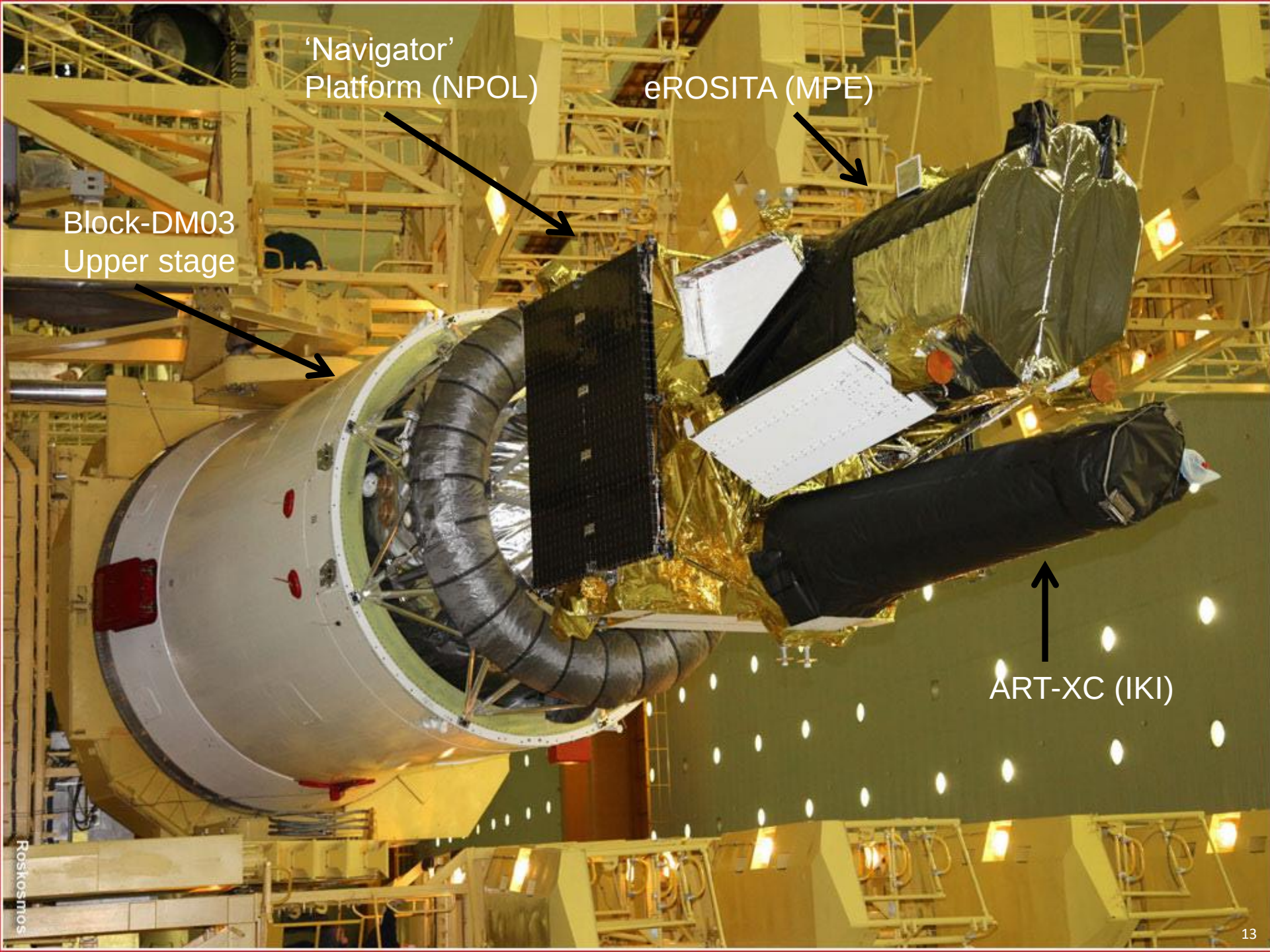

A1689, HST
Credit: NASA/ESA

A1689, Chandra

Credit: NASA/CXC



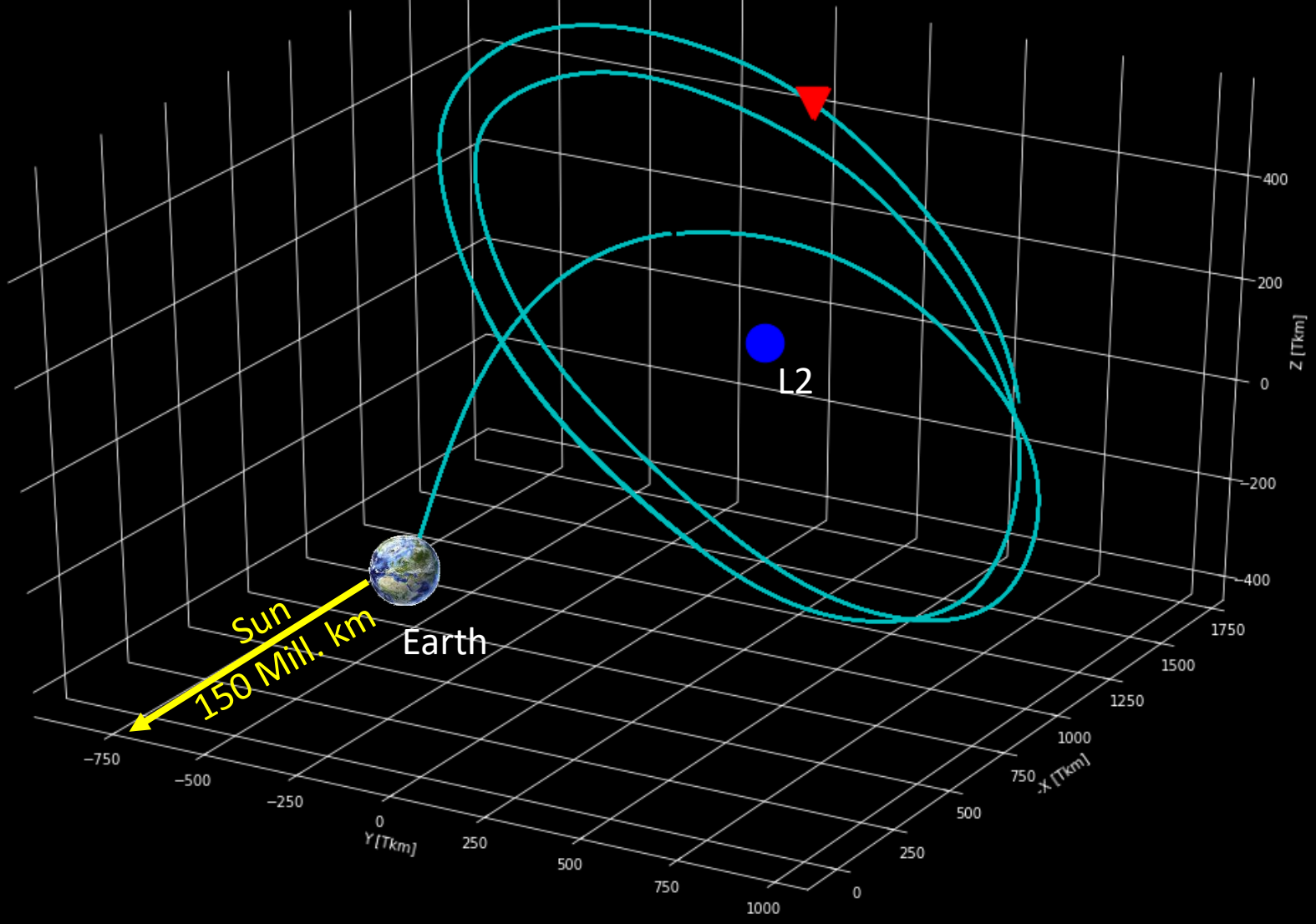



‘Navigator’
Platform (NPOL)
eROSITA (MPE)
Block-DM03
Upper stage
ART-XC (IKI)
Roskosmos

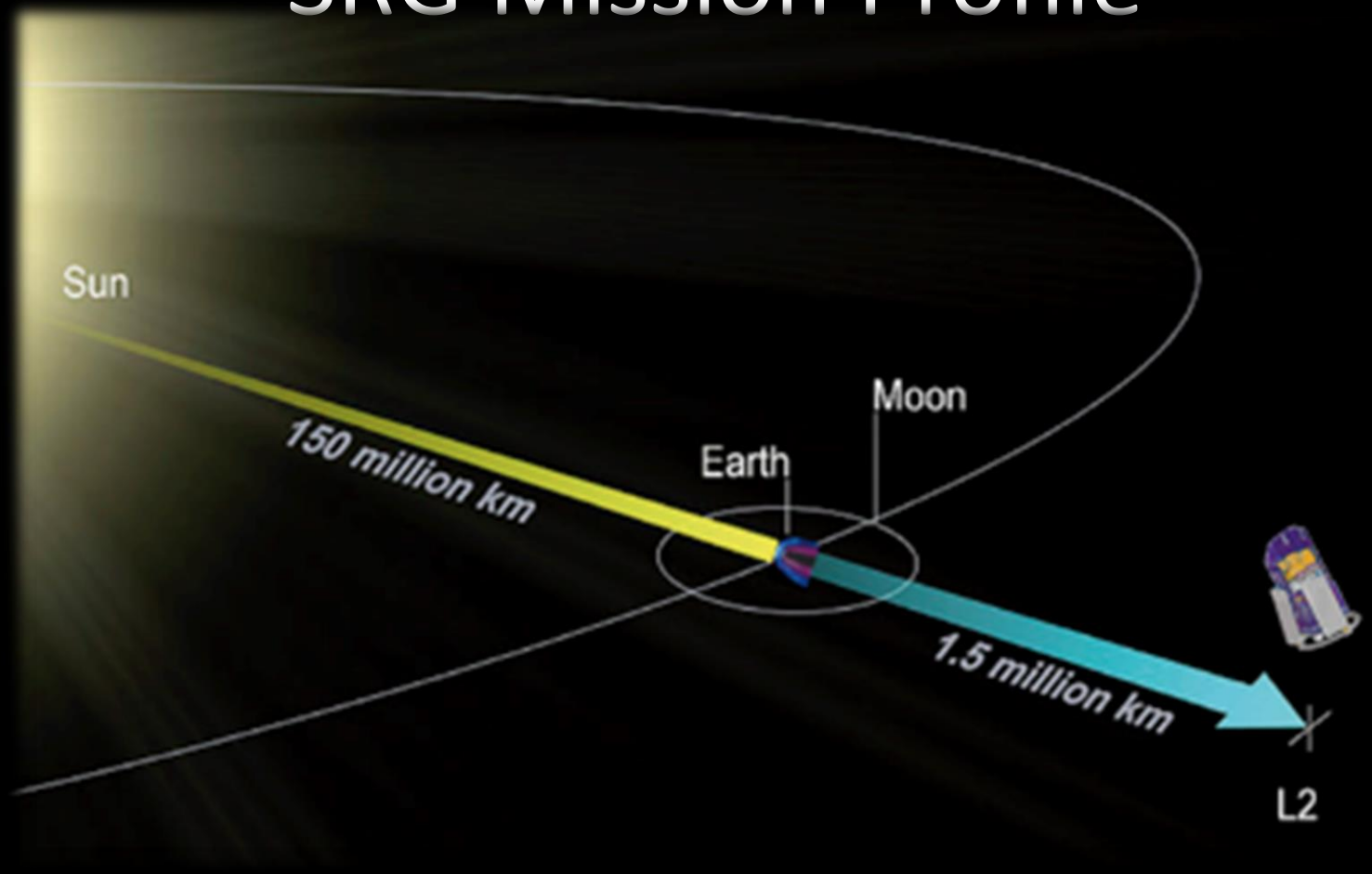
13.07.2019, 17:31

credit: Roscosmos

04.08.2020, 11.42



SRG Mission Profile



- **4 years**: 8 all sky surveys (6 rotations/day)
- **2.5 years**: pointed observations
- **Ground Segment**: 2 x 70m antennas (Bear Lakes and Ussuriysk),
  daily contact (up to ~4 hours);
  data transfer directly to MPE via Moscow NPOL / IKI

Operations Team at MPE

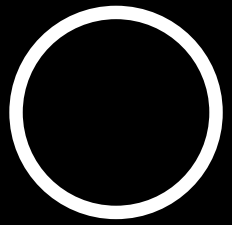
eROSITA's advantage

Grasp @1keV:

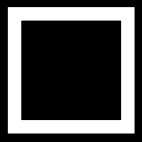
- 5×XMM-Newton
- 100×Chandra ACIS today
- 4 years fully dedicated to all-sky survey

Moon diameter
30 arcmin

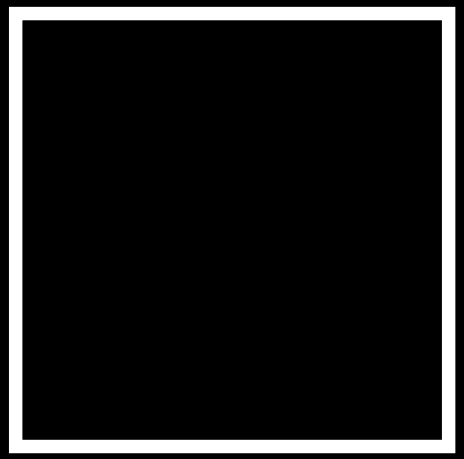
XMM-Newton
Field of view ~ 30 arcmin



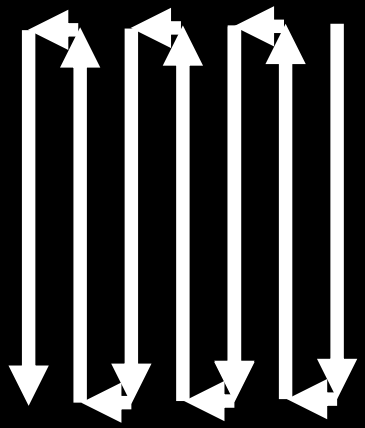
Chandra
Field of view ~ 17 arcmin



eROSITA
Field of view ~ 62 arcmin



+



Scanning feature

Galactic views

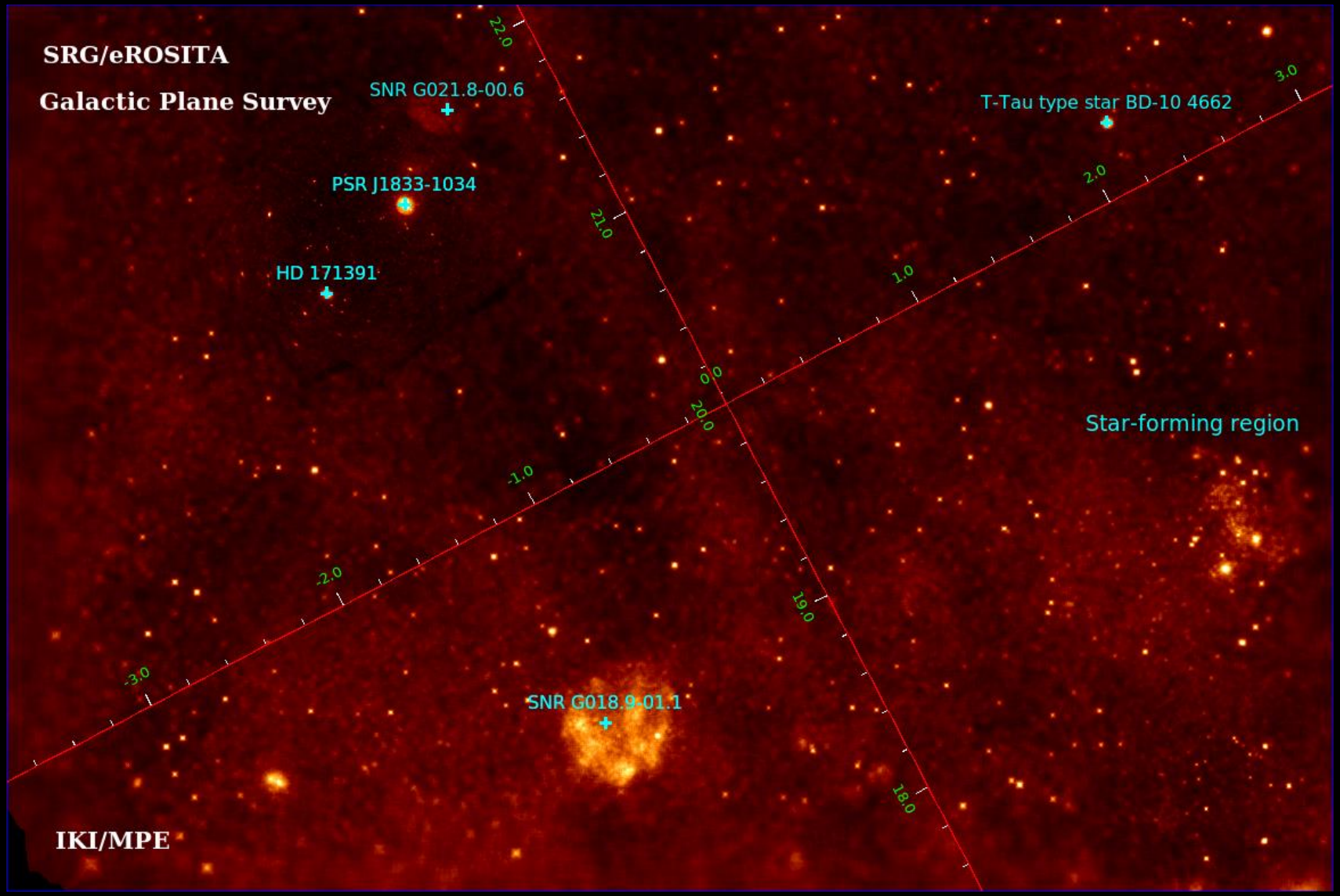
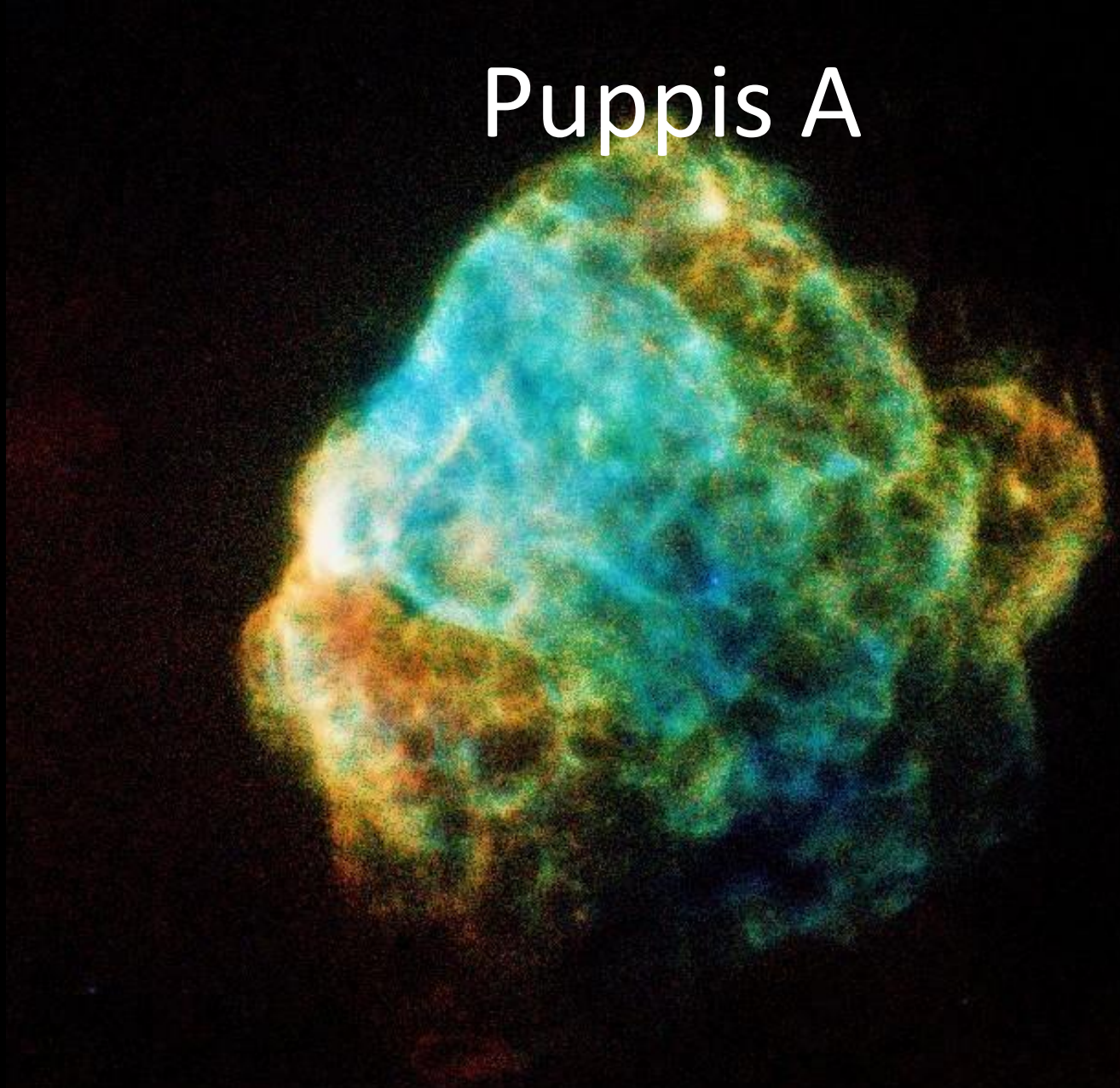
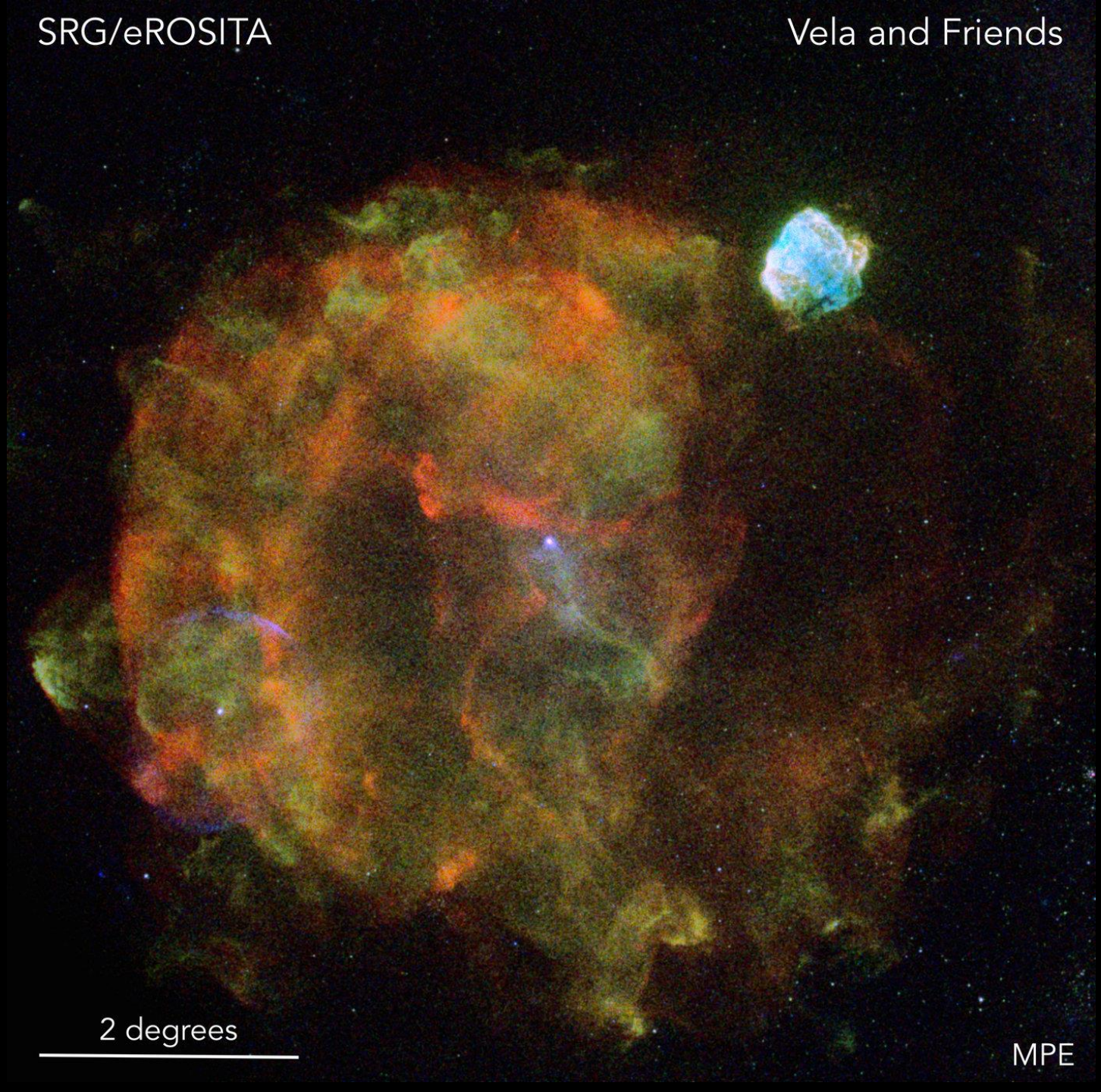
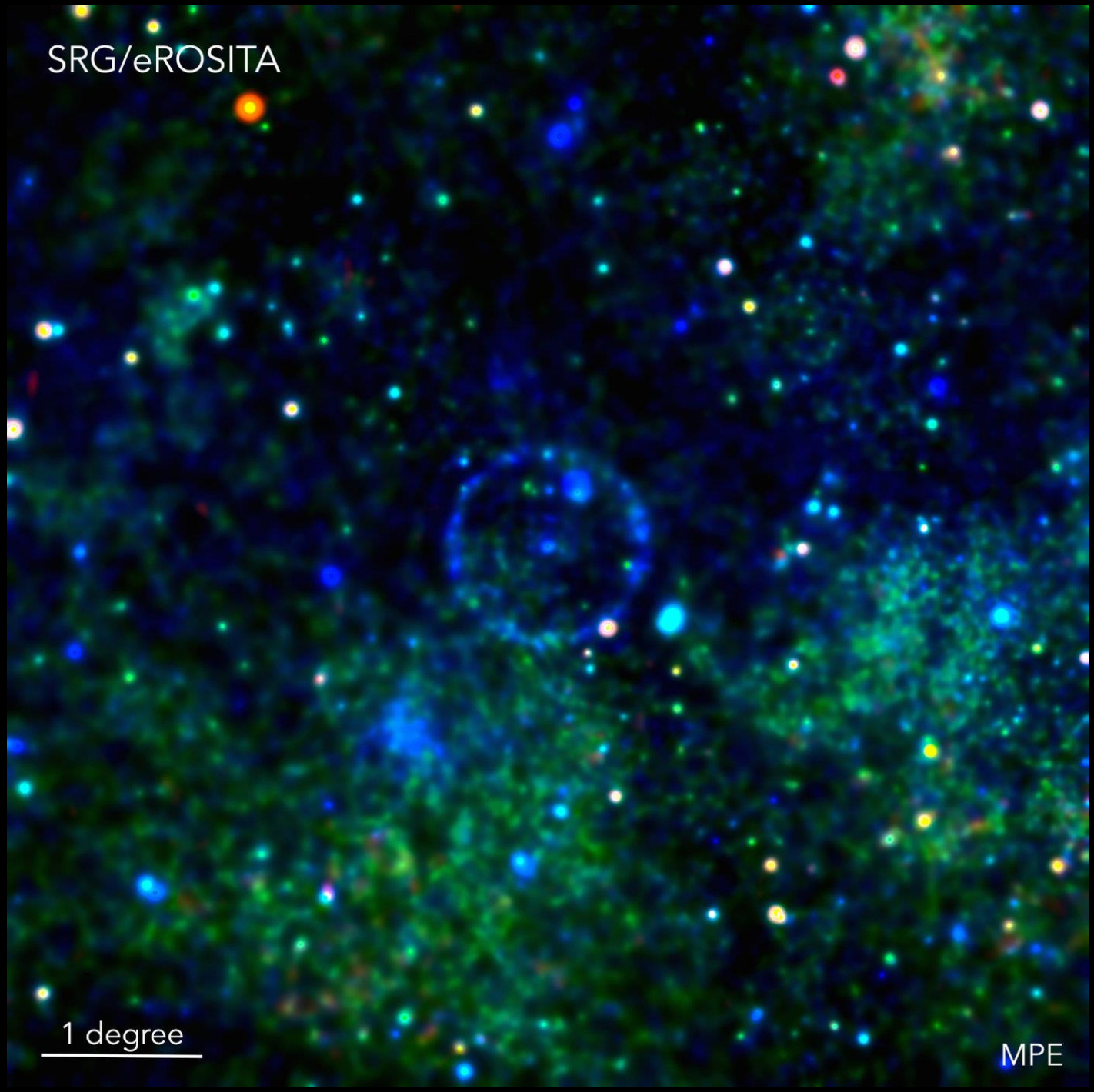


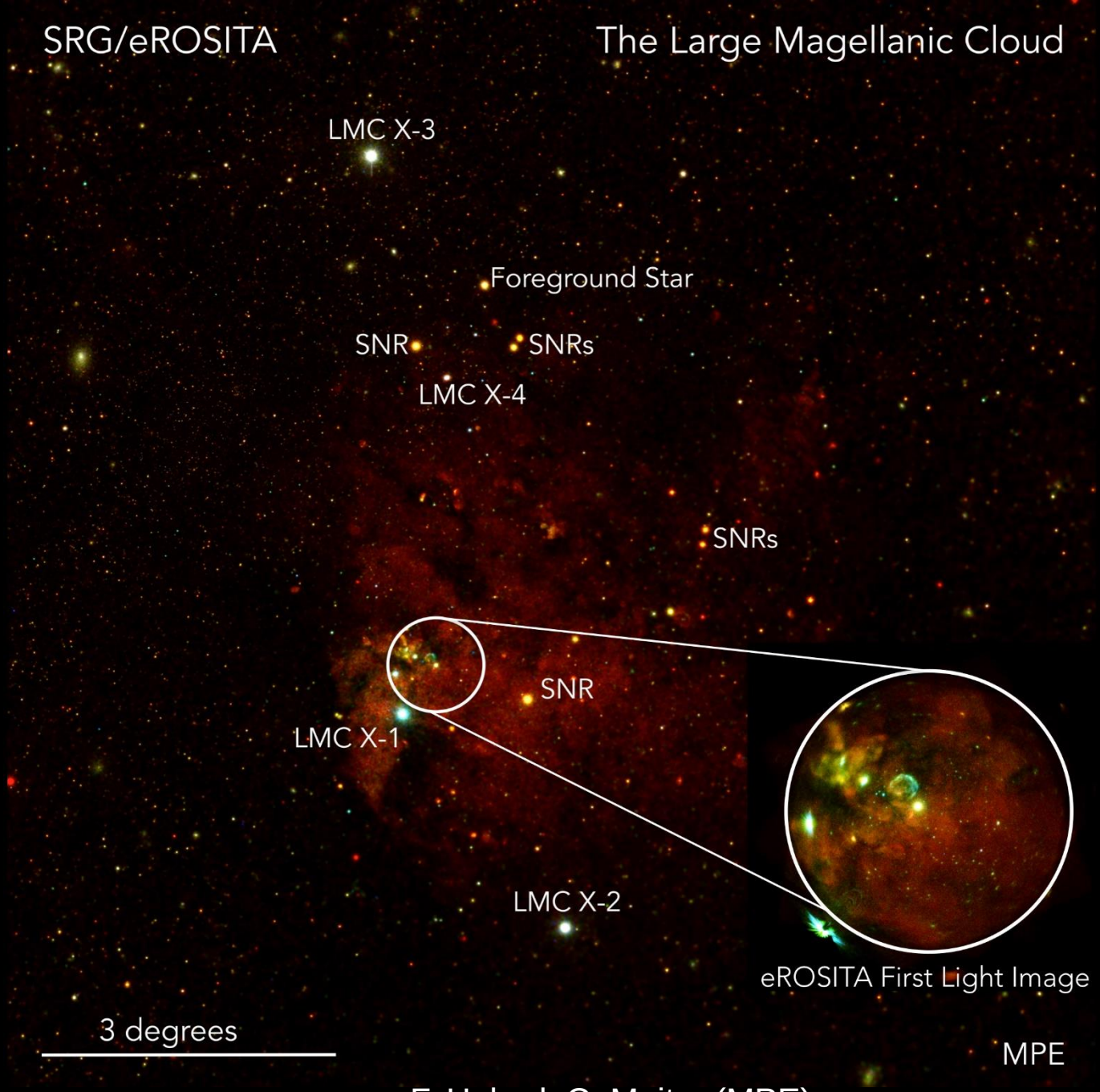
Image credit: R. Sunyaev, IKI

Puppis A

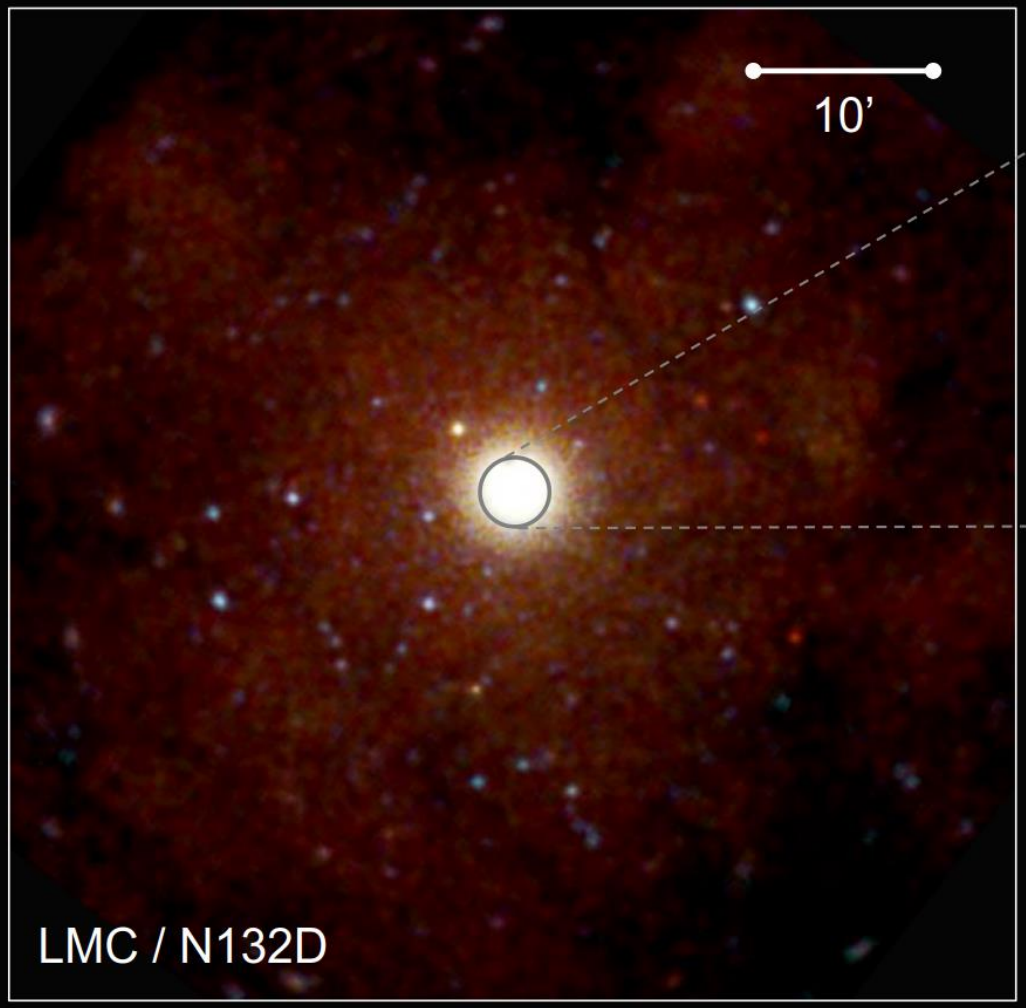



SRG/eROSITA
Vela and Friends
2 degrees
MPE


SRG/eROSITA
1 degree
MPE



F. Haberl, C. Maitra (MPE)

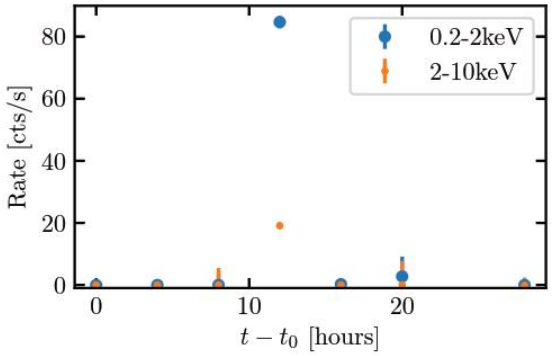


Credits: MPE/IKI, K. Dennerl (MPE)

Selected eROSITA_DE Discoveries of Transients

Bright Fast Transient of unknown nature

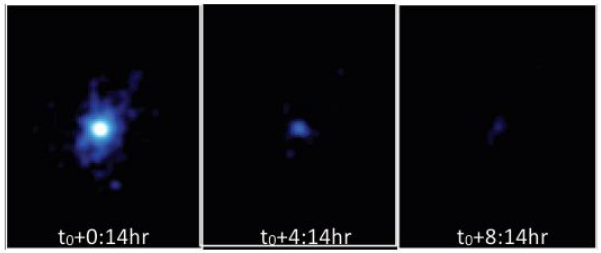
(Wilms et al., ATel #13416)



J. Wilm &NRTA team

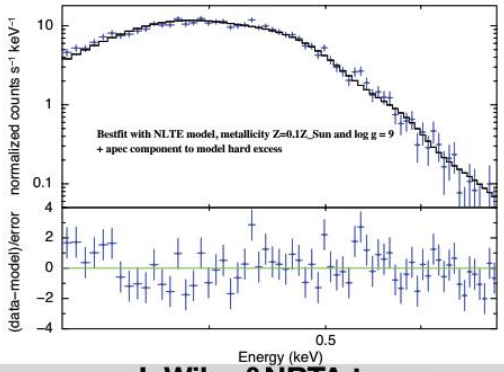
Afterglow of Fermi/GBM Gamma-ray Burst

(Weber et al., GCN #26988)



Super-Soft Phase of Classical Nova ASAS-SN18jj

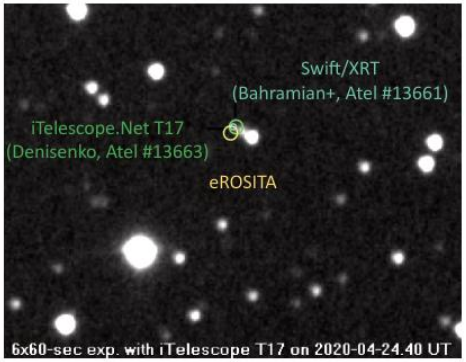
(Ducci et al., ATel #13545)



J. Wilm &NRTA team

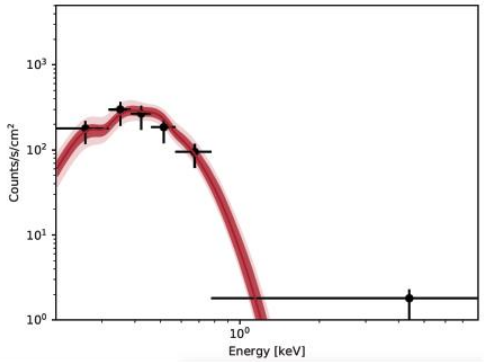
Bright Transient with Optical Counterpart

(Gokus et al., ATel #13657)



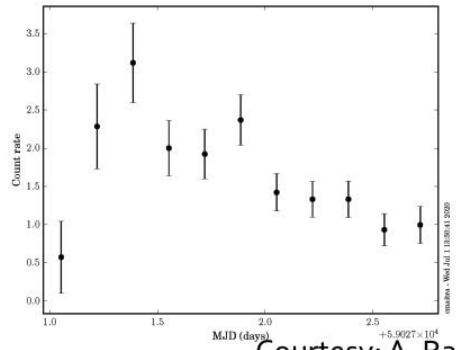
TDE or extreme NLSy1 ?

(Malyali et al., ATel #13712)



Bright Transient with Galactic Origin

(Rau et al., ATel #13844)

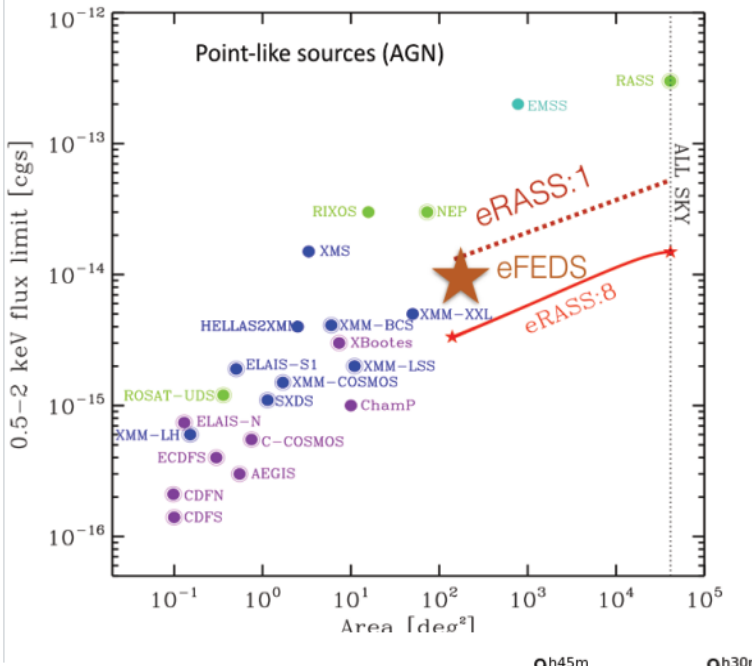


Courtesy: A. Rau, TDA

+: Be+WD binaries in SMC & LMC (Haberl et al., ATels #13709, 13789); Be/X-ray binary pulsar in LMC (Haberl et al., ATel #13828); Transitional Milli-second Pulsar (König et al., ATel #13765), and more

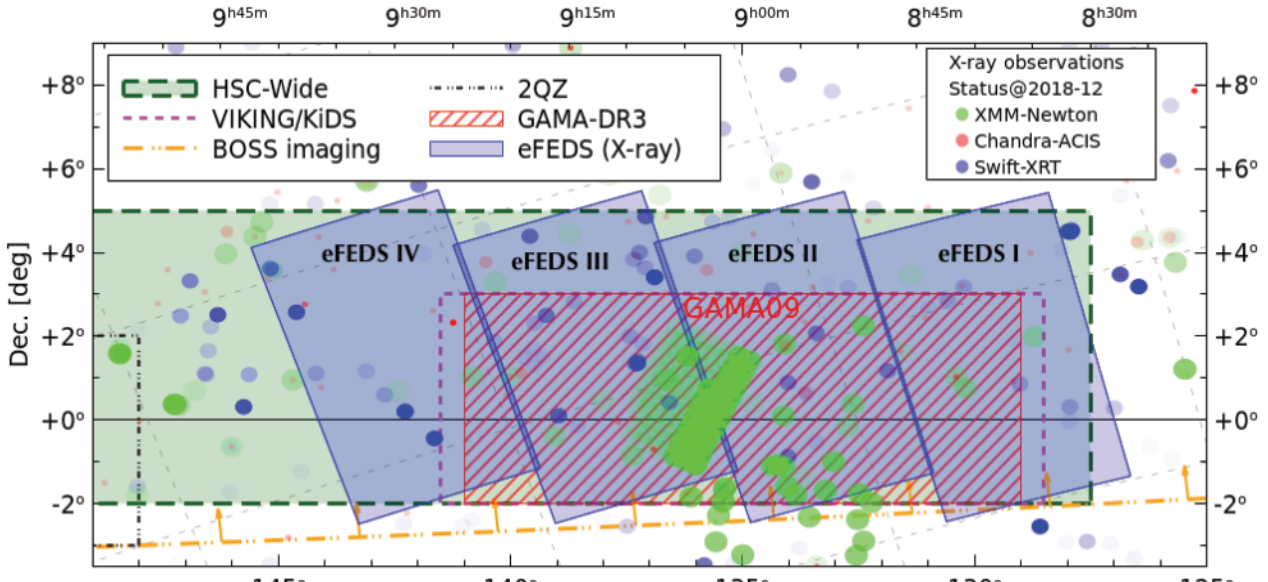
eFEDS: eROSITA Full Equatorial-Depth Survey
(done by middle Nov. 2019)

PIs: Georgakakis Bulbul



- Main goals:
  - Cluster Mass Calibration (HSC lensing, dynamics)
  - AGN evolution, luminous AGN host properties

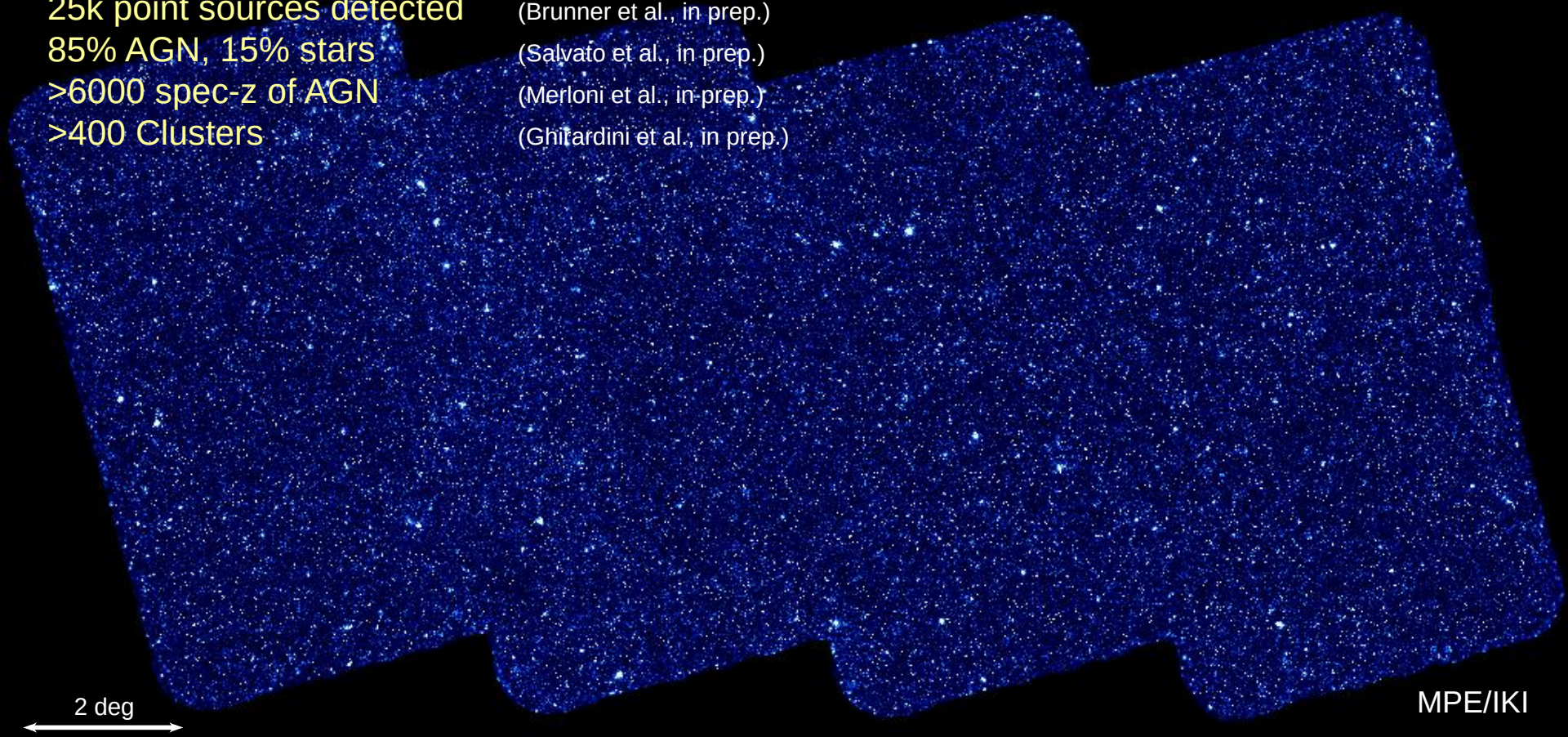
- Ancillary data:
  - Subaru HSC, Viking, DeCALS, unWISE, Kids
  - GAMA, 2dF, and more spectroscopy
  - By March spectroscopy from dedicated SDSS-IV plates



eFEDS: a preview of eRASS:8

25k point sources detected
85% AGN, 15% stars
>6000 spec-z of AGN
>400 Clusters

(Brunner et al., in prep.)
(Salvato et al., in prep.)
(Merloni et al., in prep.)
(Ghirardini et al., in prep.)

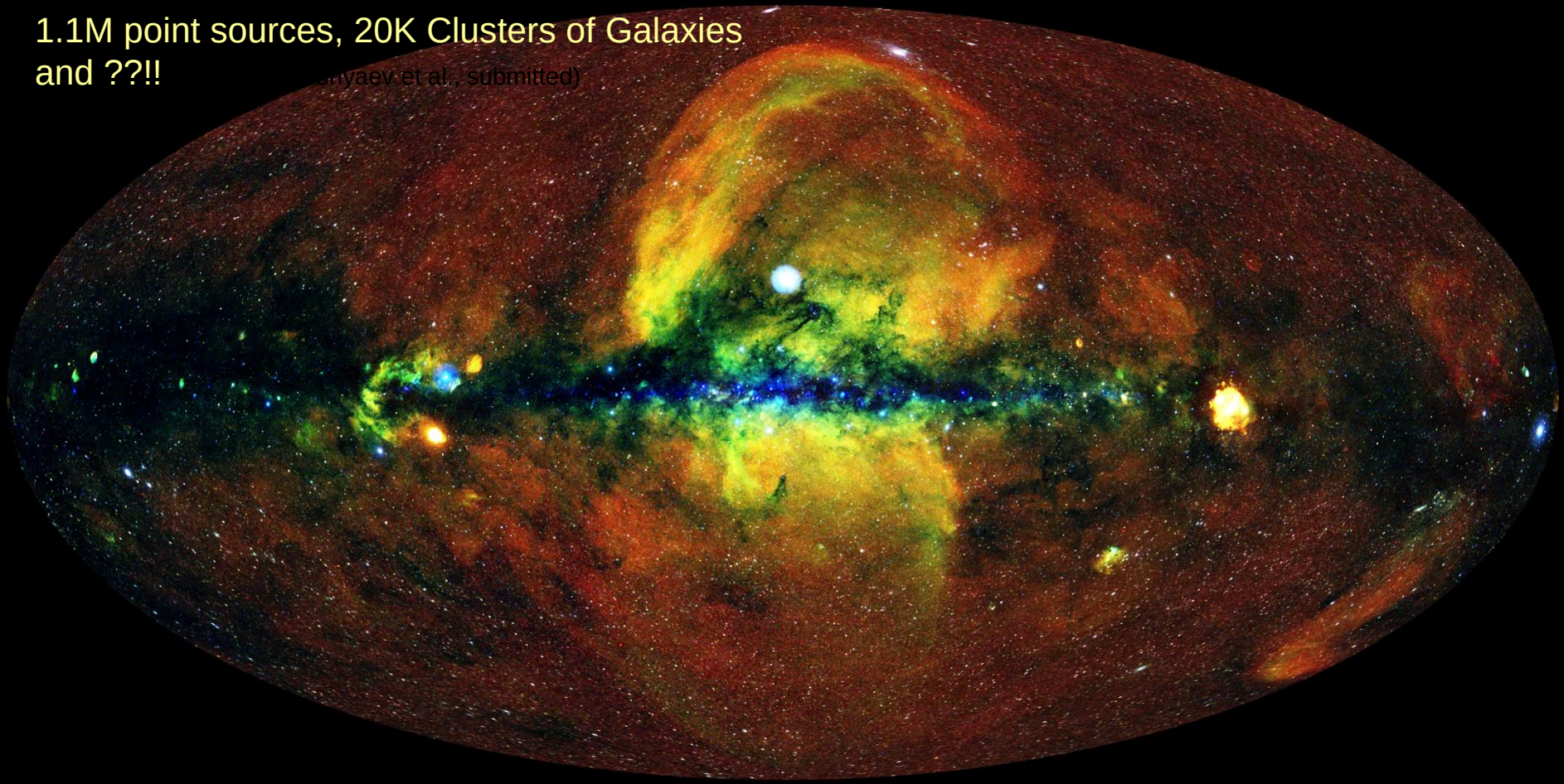


Credit: H. Brunner, M. Ramos-Ceja

Exposure corrected image in the 0.5–2.0 keV band

SRG/eROSITA 0.3-2.3 keV - RGB Map

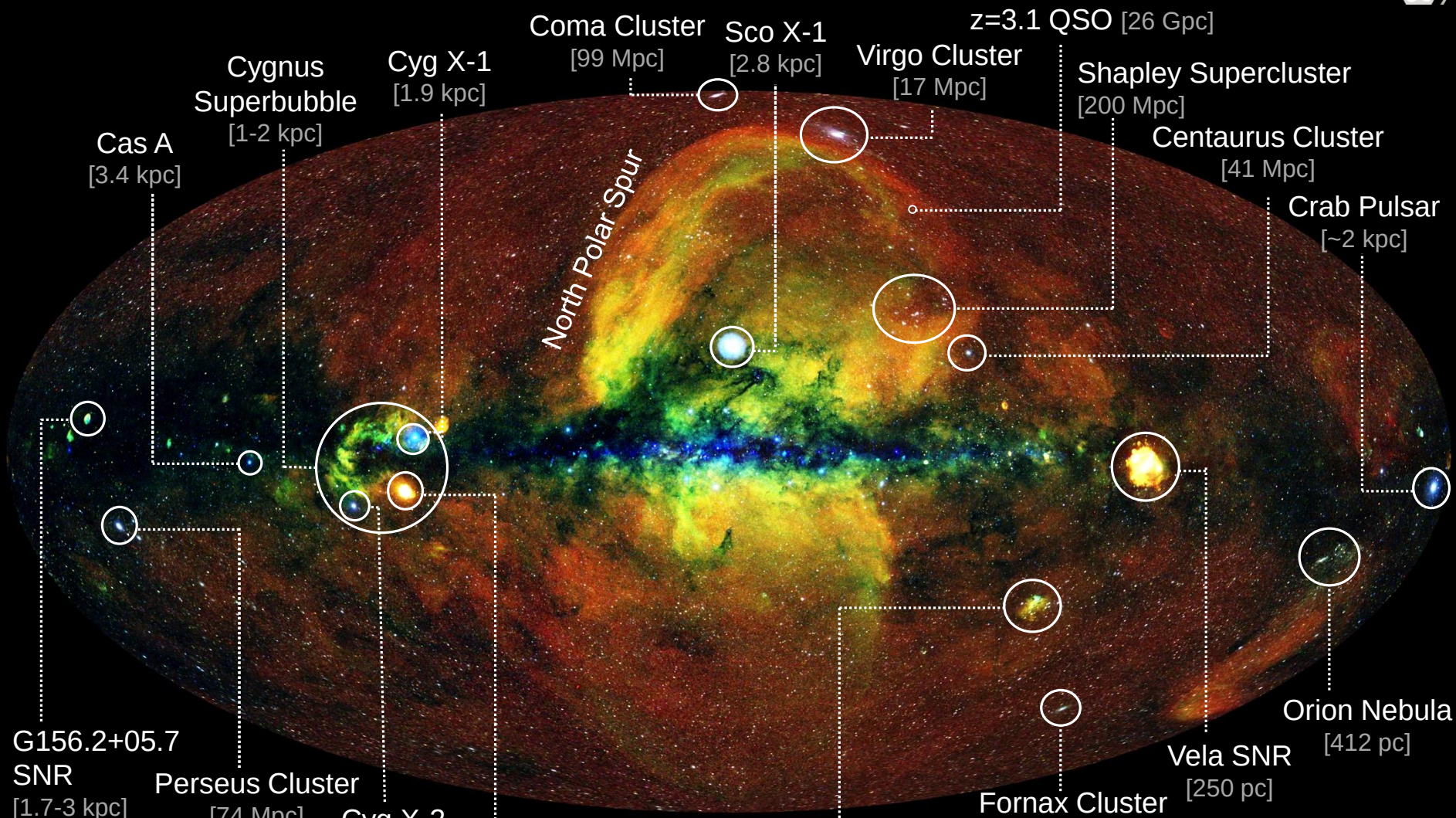
1.1M point sources, 20K Clusters of Galaxies
and ??!!



J. Sanders, H. Brunner (MPE), E. Churazov, M. Gilfanov (IKI), and eSASS team

MPE

Navigating the eROSITA X-ray sky



IKI

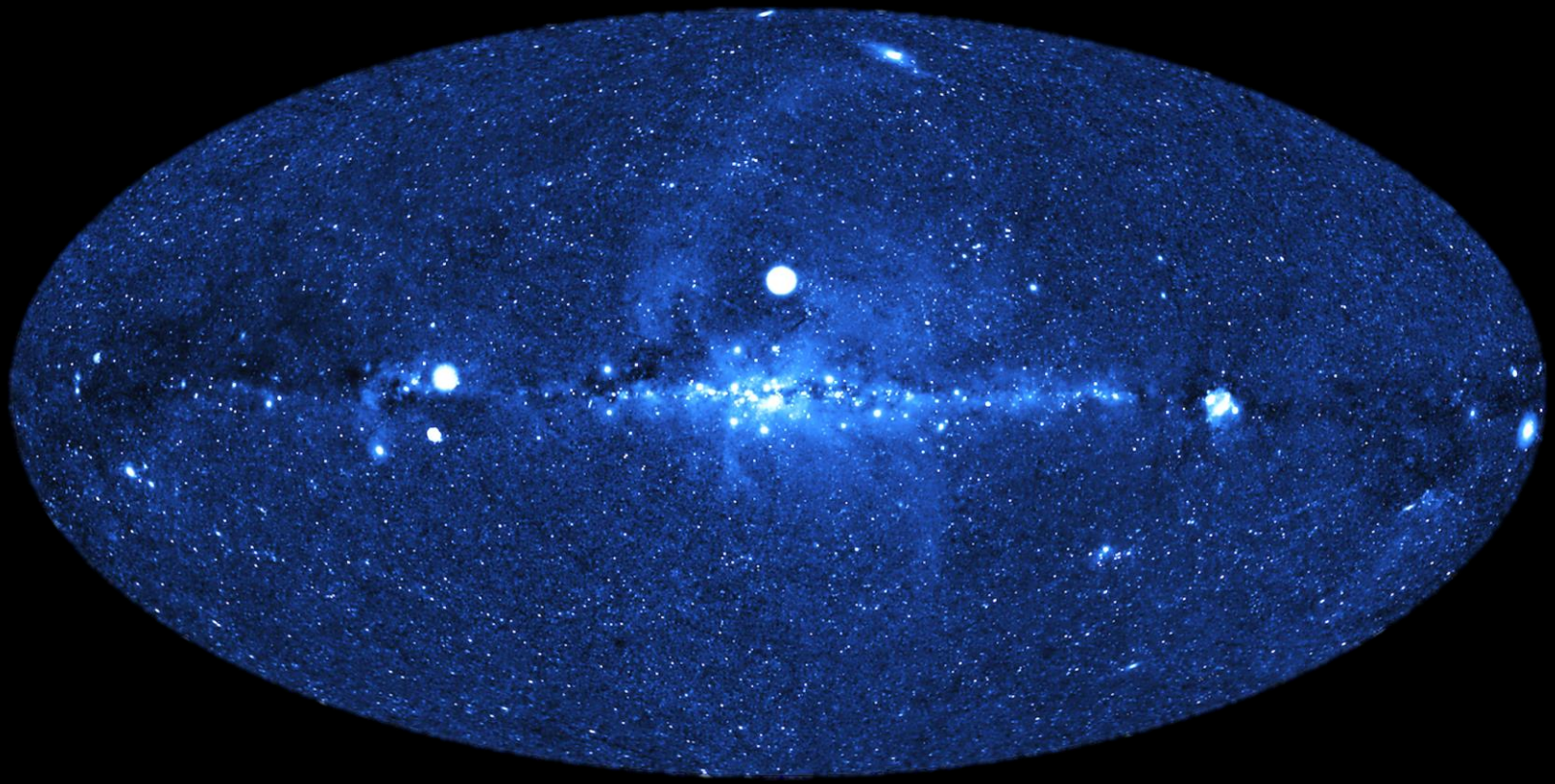
MPE

Credit: Merloni

Tracers of Large Scale Structure

SRG/eROSITA

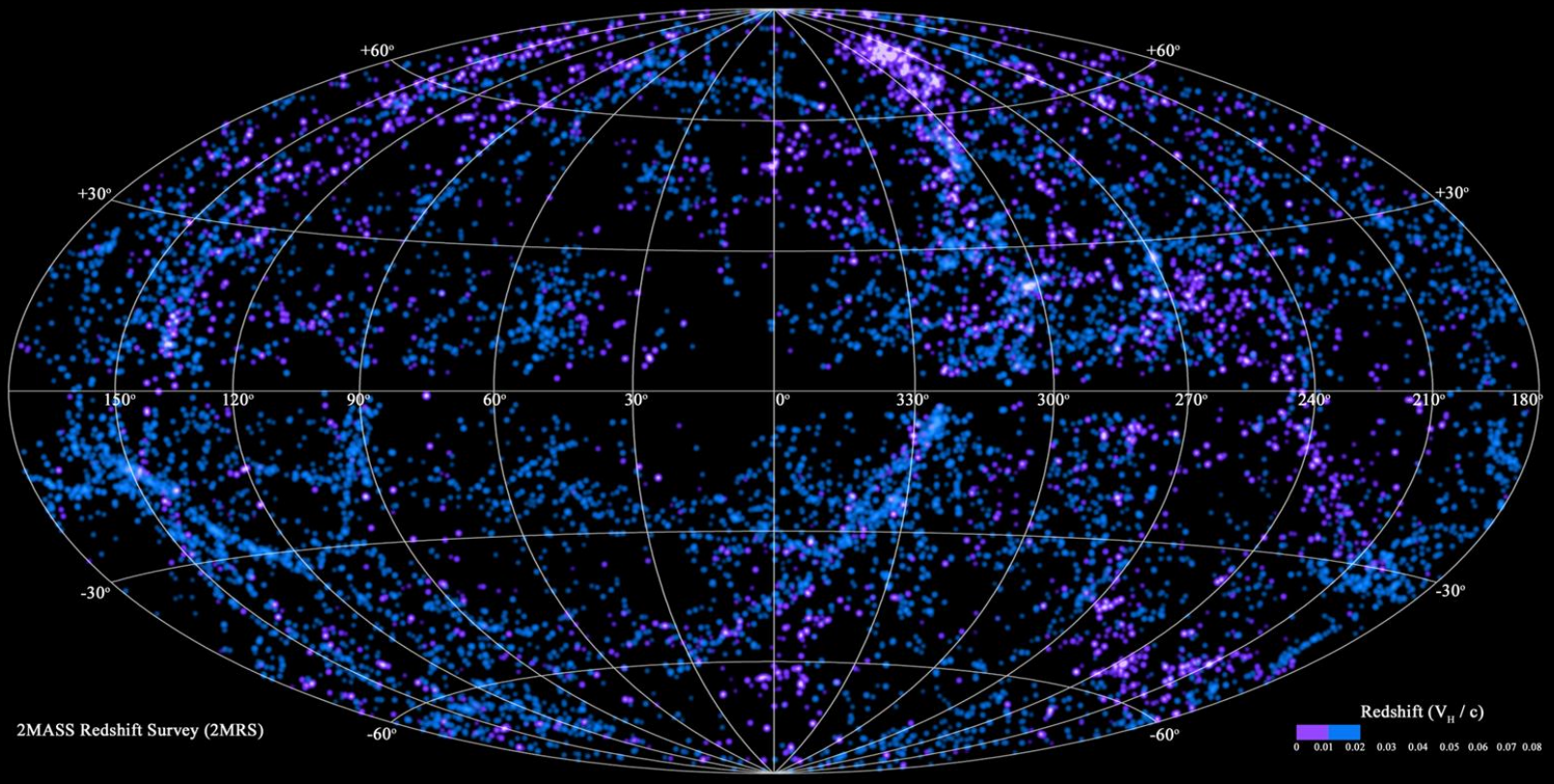
1-2.3 keV



IKI

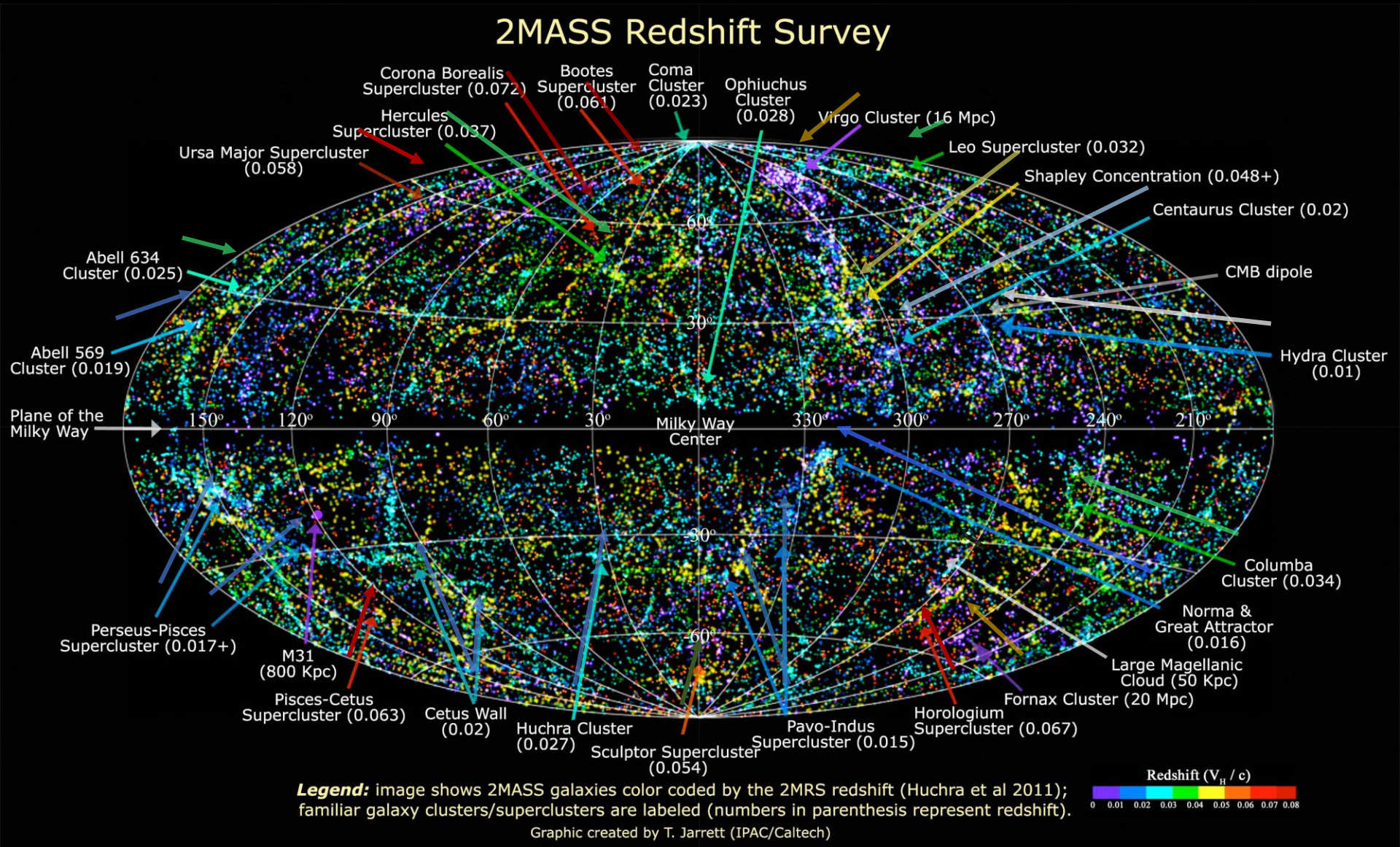
MPE

Tracers of Large Scale Structure



D<88 Mpc

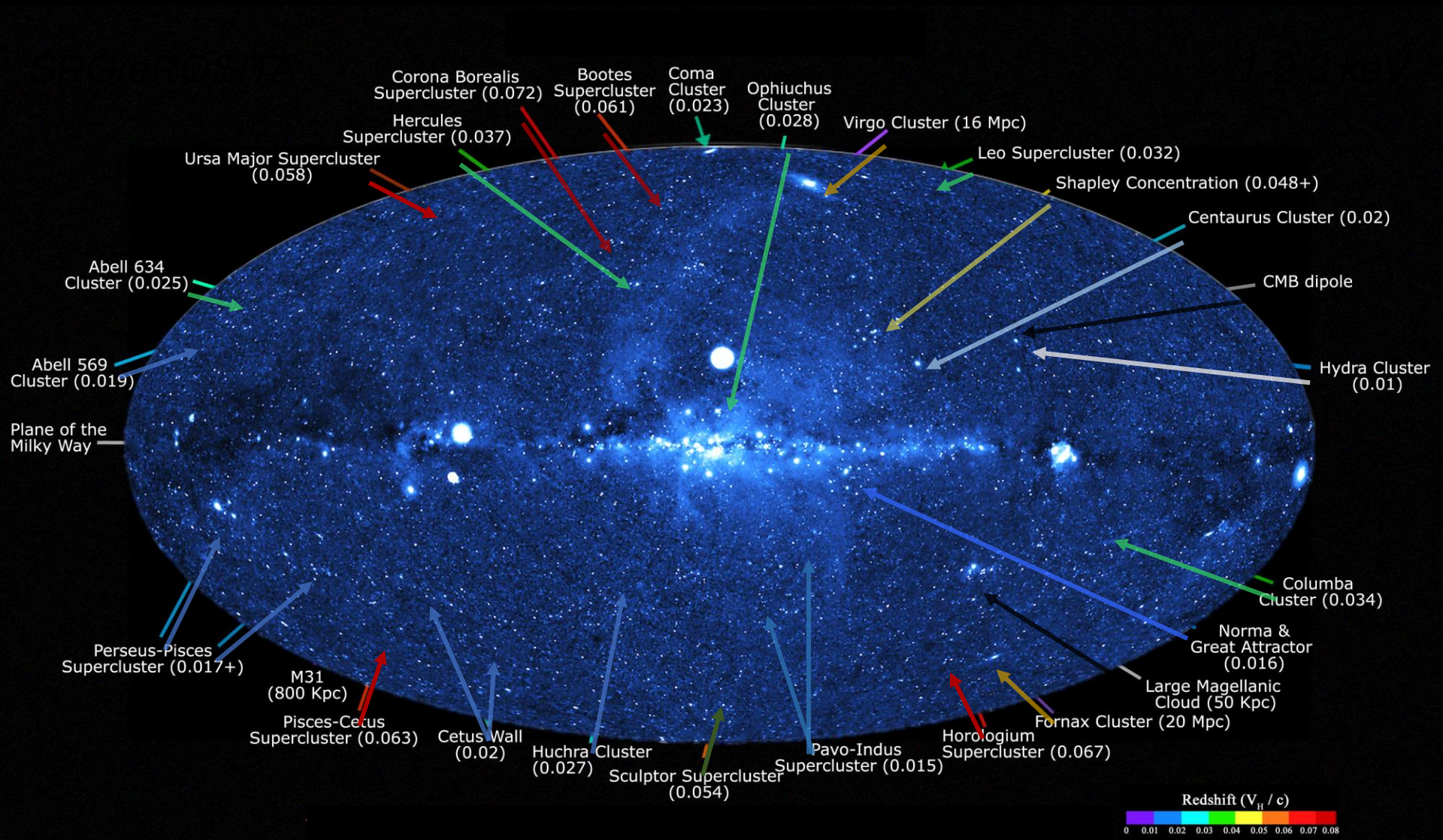
Tracers of Large Scale Structure



Legend: image shows 2MASS galaxies color coded by the 2MRS redshift (Huchra et al 2011); familiar galaxy clusters/superclusters are labeled (numbers in parenthesis represent redshift).

Graphic created by T. Jarrett (IPAC/Caltech)

Tracers of Large Scale Structure



eRASS:1, The first All-Sky Survey

- Started on December 13, 2019, after a 2-months long Calibration and Performance Verification Program
- Completed on June 11, 2020
- Uniform exposure ~200s; up to 36ks at the Ecl. Poles
- Almost no background flares, flexible mission planning: no gaps in exposure
- ~400 Million 0.12-5keV calibrated photons
- About 1 Million sources detected (~80% AGN; 20% Stars)
  - Almost double the number of known X-ray sources
- ~20k clusters, up to z~1
- Numerous transients discovered; fine tuning vetting mechanisms, followup resources

eRASS:8, the legacy

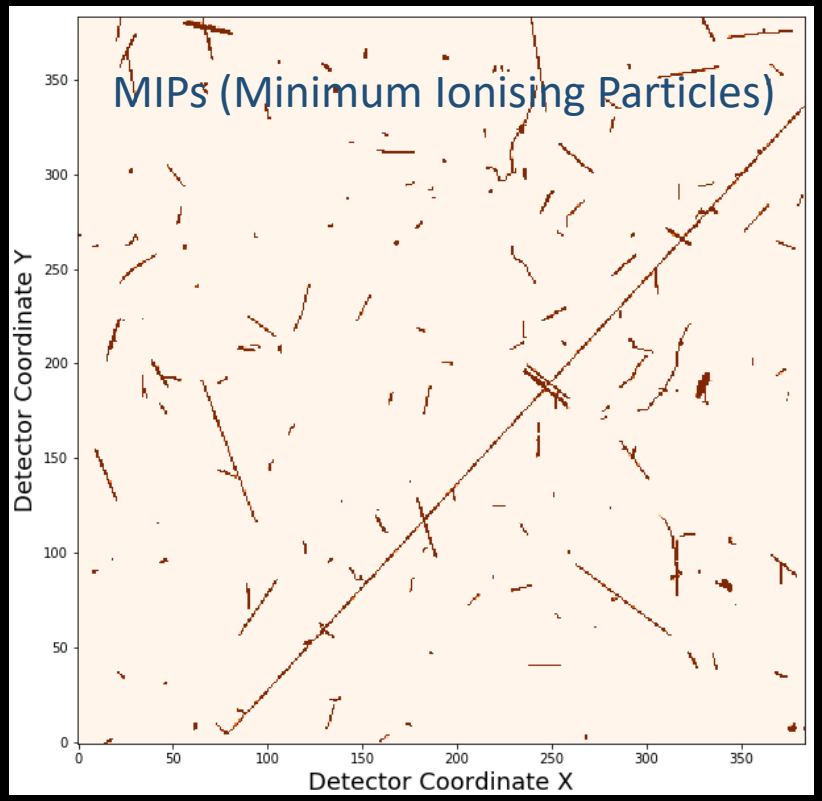
- All clusters more massive than ~$2 \times 10^{14} M_{\odot}$
- >3 Million AGN (<z>~1 and <Lx>~10^{44} ergs/s)
- Compact objects (NS, BH) population of the Milky Way
- Population study of 750k active (young, magnetic) stars
- Nearby star-forming galaxies and galaxy groups
- Dynamical view of the X-ray sky and identify transients and variable sources, including 1000's TDEs
- Serendipity…
- **Data release policy** (German data only)
  - PV/Cal data – after 1 year: early 2021
  - Survey: eRASS1, eRASS4, eRASS8 - 2 years after completion
  - Pointed phase follows survey, open AO w/GTO – 1 year

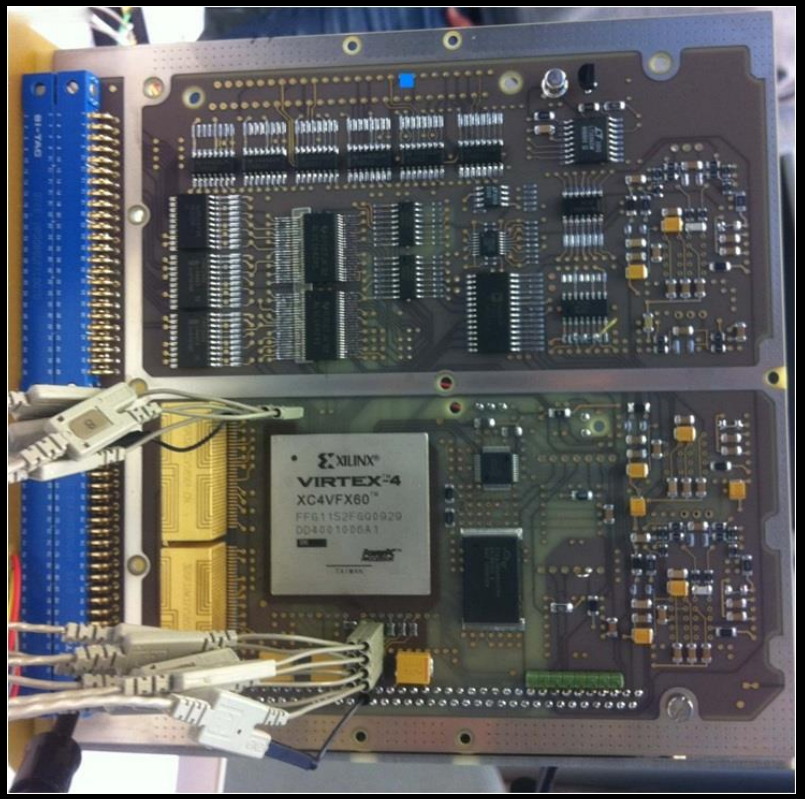
Photo: V. Burwitz (MPE)

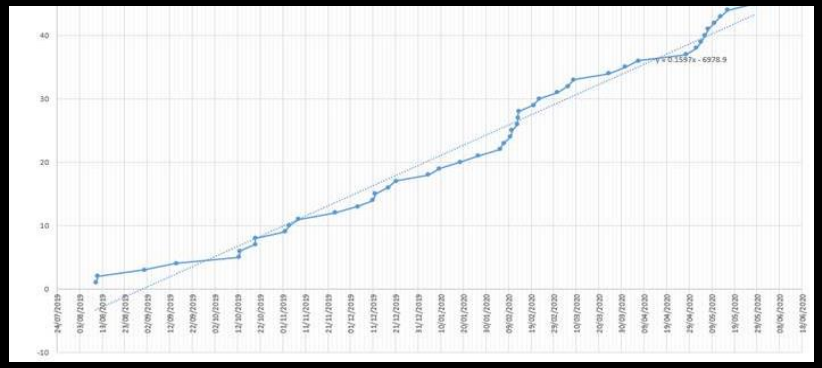
Follow us on Twitter:
@eROSITA_SRG

Большое спасибо!

FPGA & Cosmic Rays



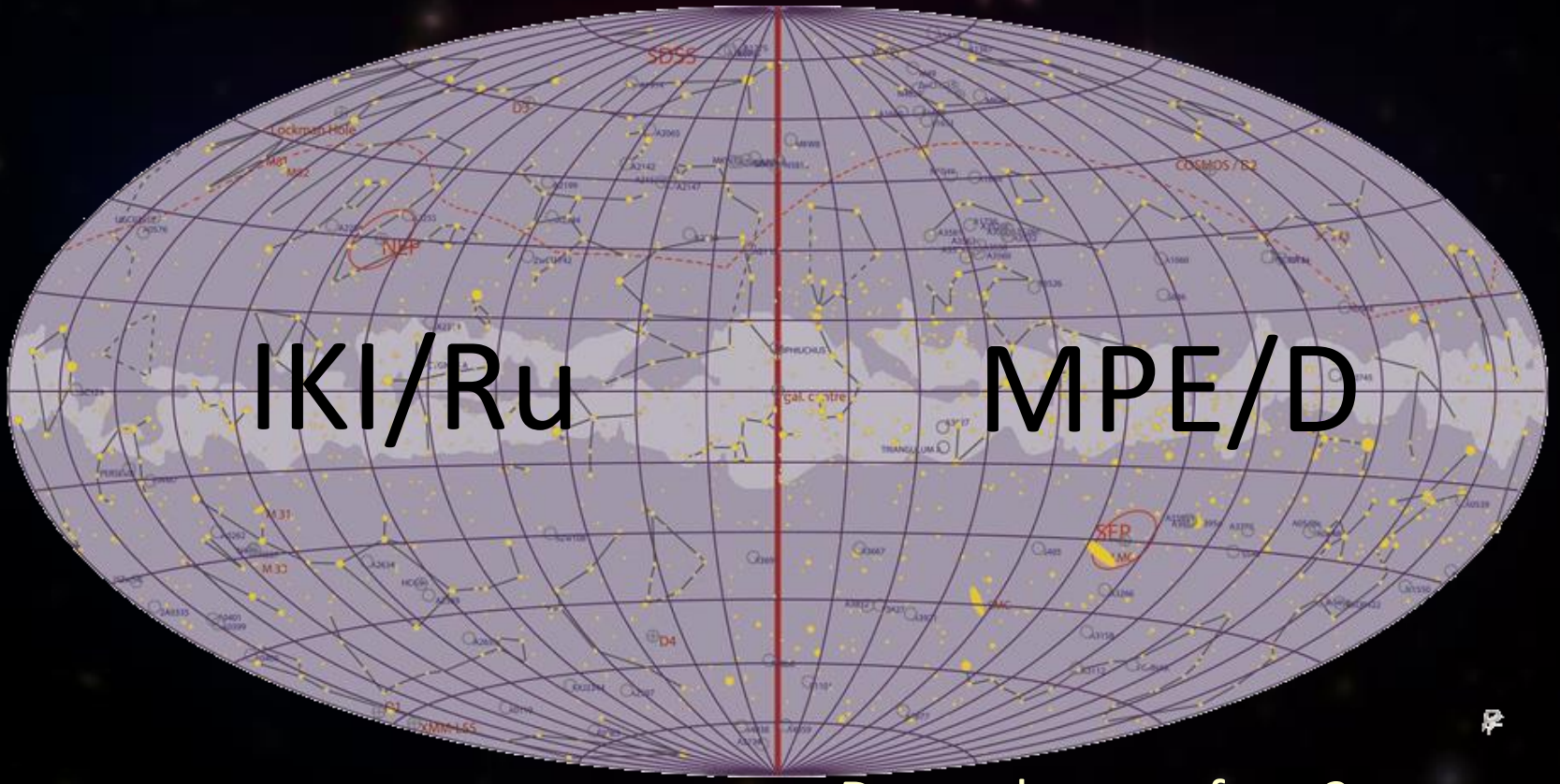




CE susceptible to cosmic rays
FPGA not completely triple redundant

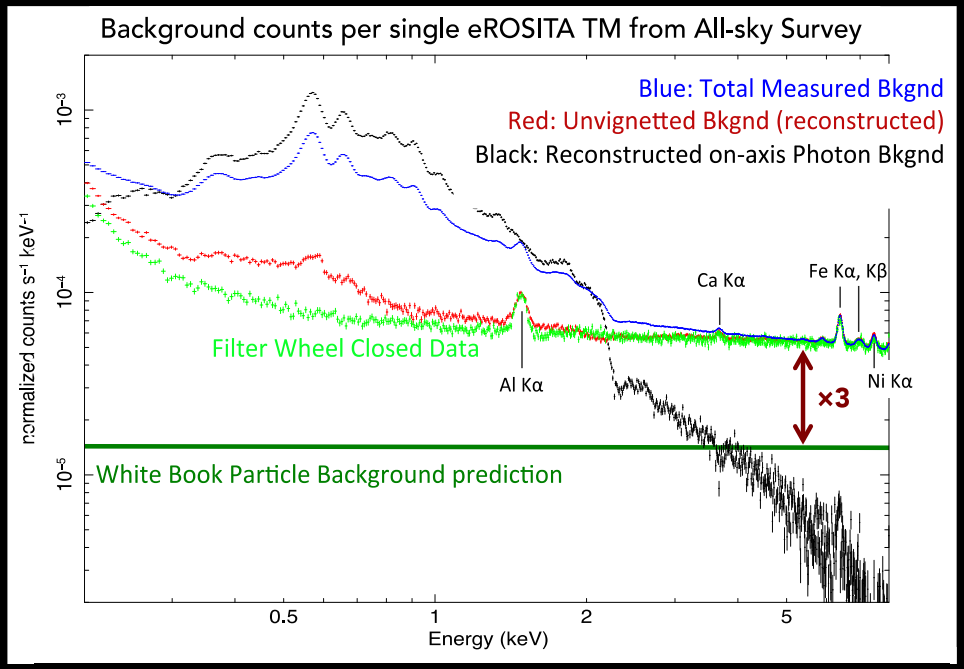
In total 45 events similar to this:
CE4 Image was corrupted.
CE4 Nominal function after reset.

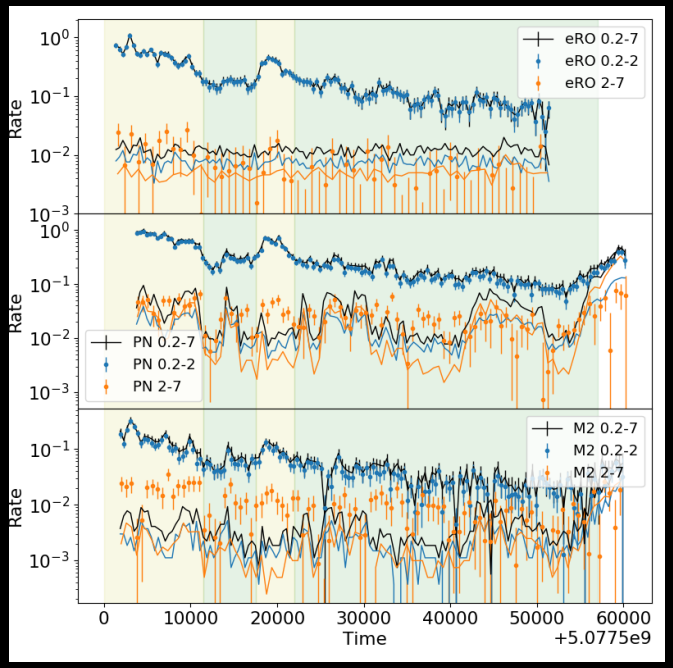
Data Share



Data releases after 2 years, incrementally 6, 18, 48 months.
Pointed Phase: Open to world wide community

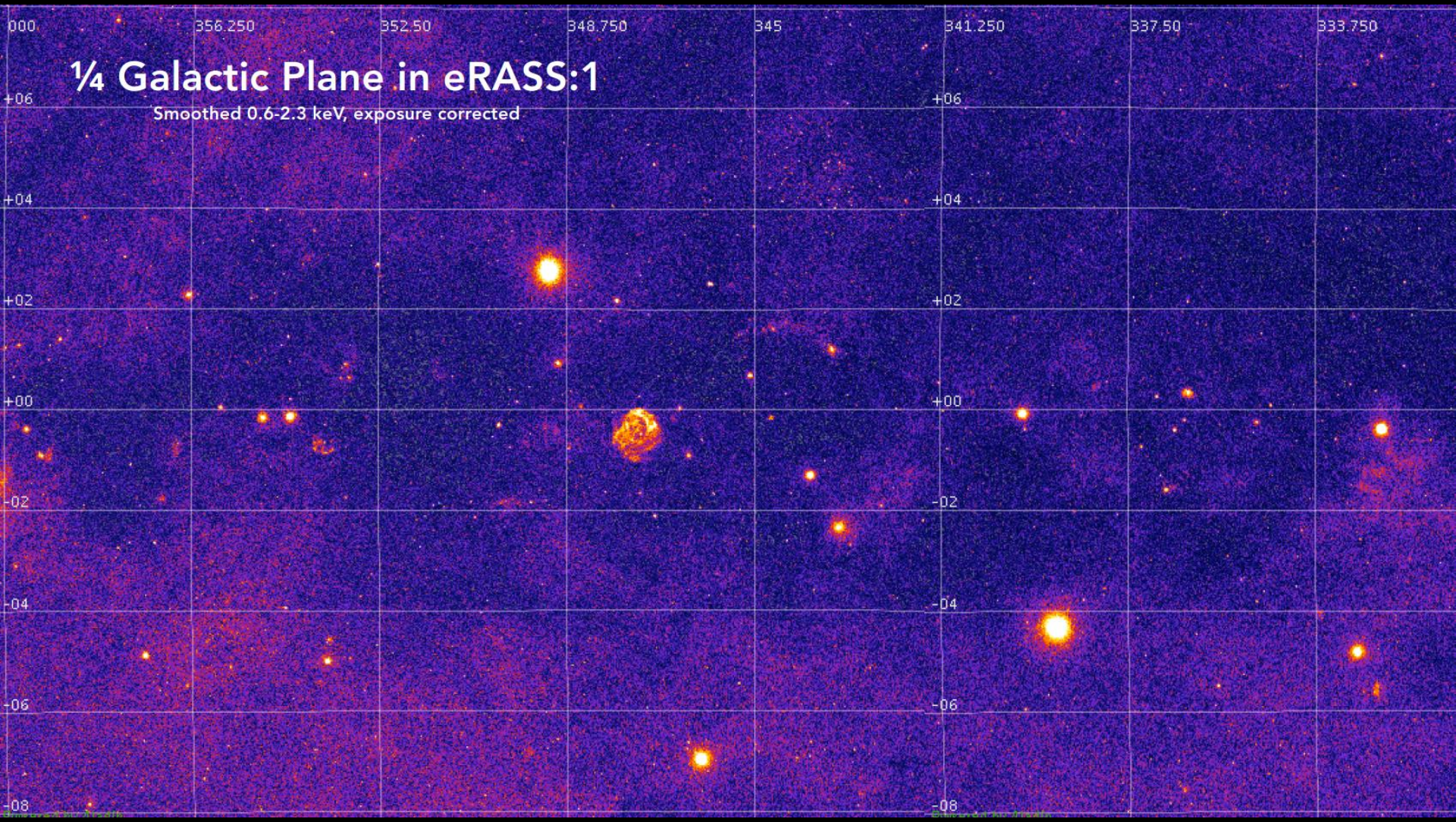
Cosmic Particle Background

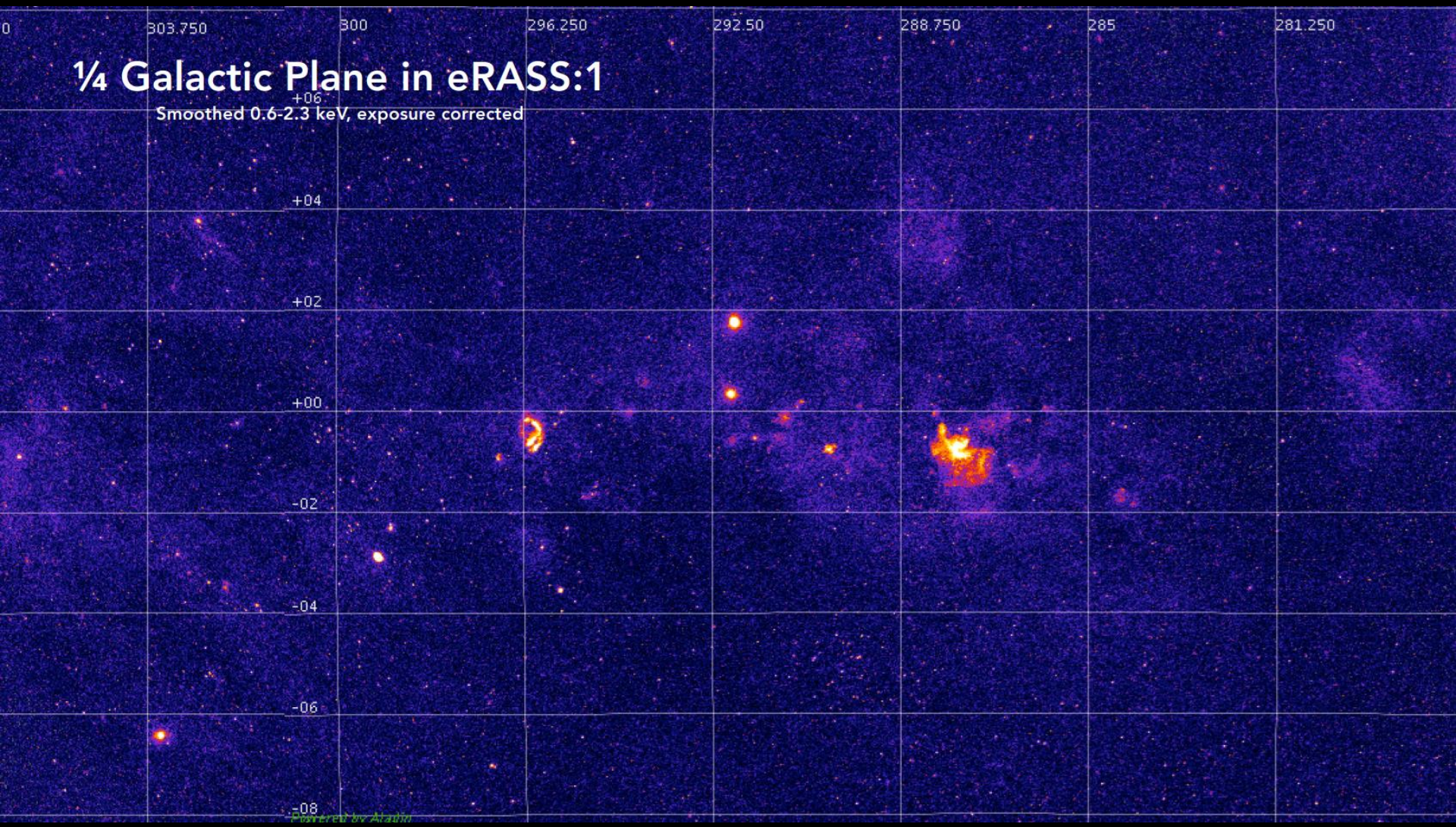




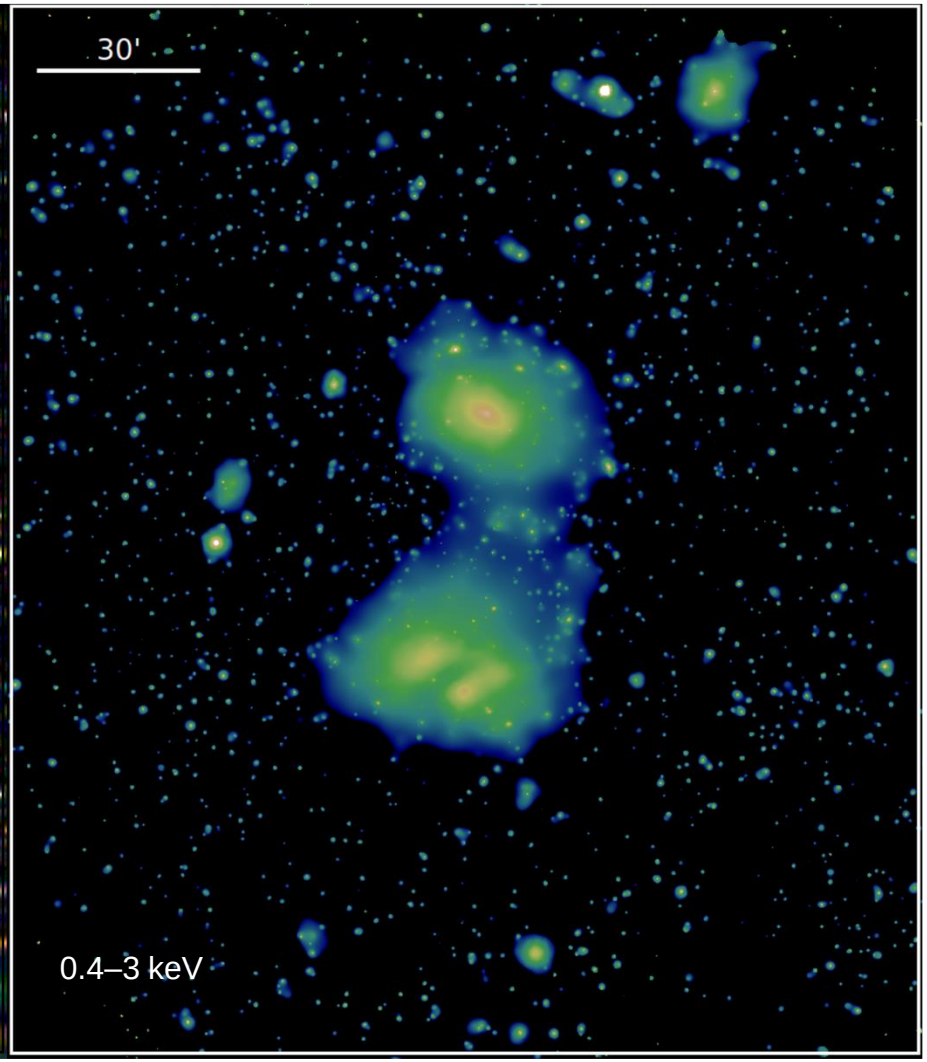
Brusa, Churazov, Dennerl, Eckert, Freyberg, Pacaud

1) A factor of ~3 higher particle bkgnd than predicted
2) Less fluorescence lines than EPICpn due to graded shields
3) Nevertheless an iron line whose origin is ~~not completely~~ almost clear
4) Background much less variable than in the XMM and Chandra data


¼ Galactic Plane in eRASS:1
Smoothed 0.6-2.3 keV, exposure corrected
000
356.250
352.50
348.750
345
341.250
337.50
333.750
+06
+04
+02
+00
-02
-04
-06
-08

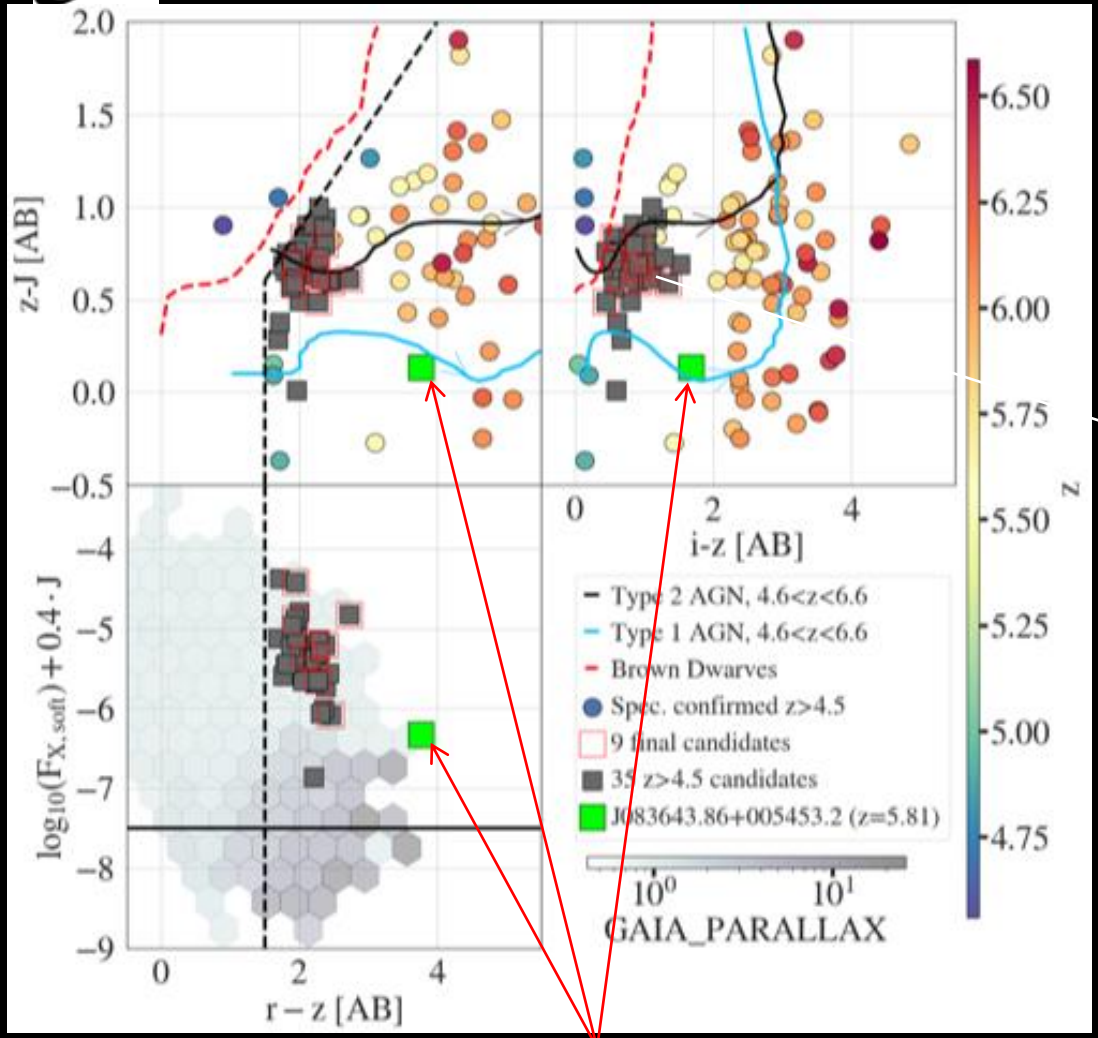

¼ Galactic Plane in eRASS:1
Smoothed 0.6-2.3 keV, exposure corrected
0
303.750
300
296.250
292.50
288.750
285
281.250
+06
+04
+02
+00
-02
-04
-06
-08
Powered by Aladin

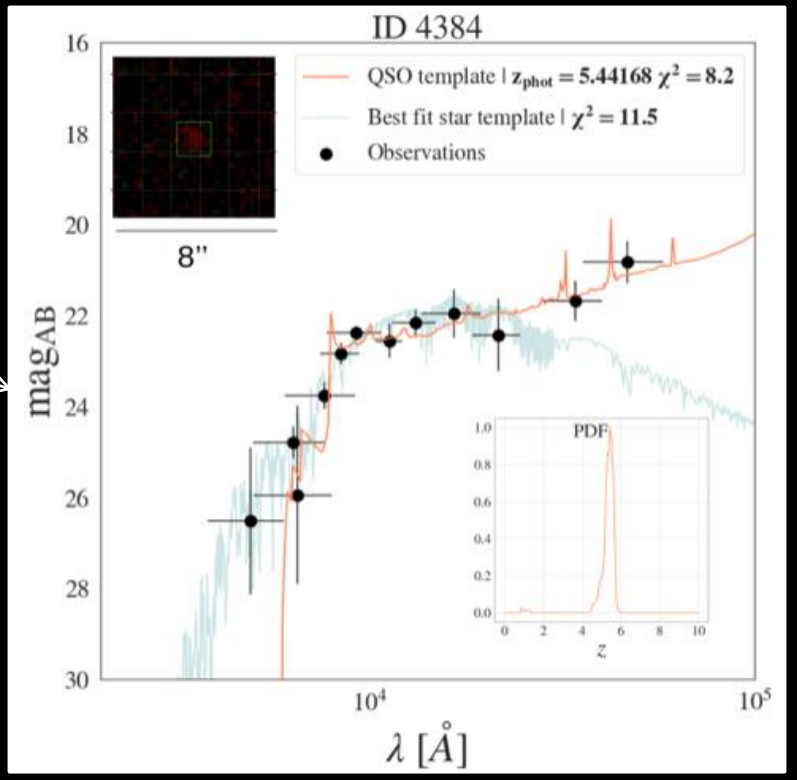
A3391/A3395



T. Reiprich (Univ. Bonn), M. Ramos-Ceja (MPE), F. Pacaud (Univ. Bonn), D. Eckert (Univ. eneva), J. Sanders (MPE), N. Ota (Univ. Bonn), E. Bulbul (MPE), V. Ghirardini (MPE),

Searching for High-z QSOs





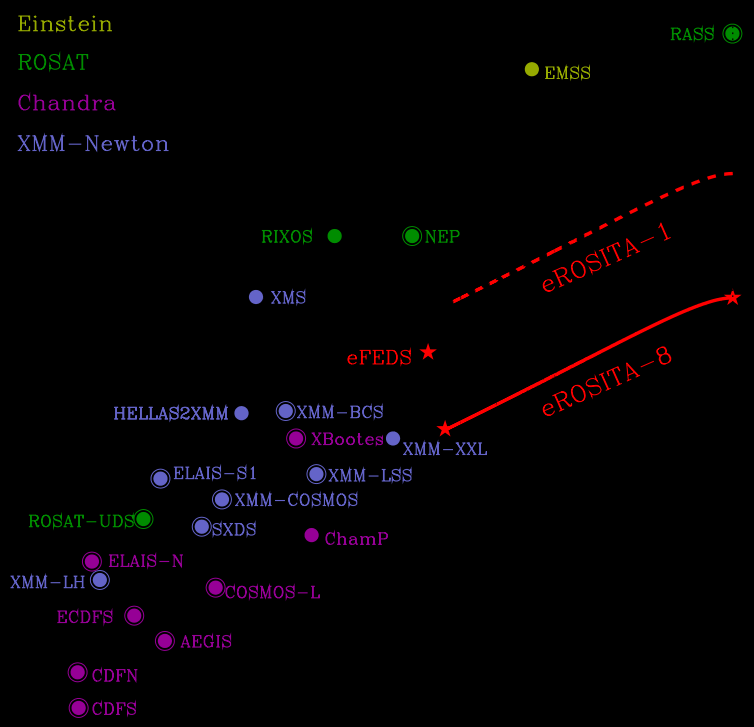
35 z>4.5 candidates, including some very robust photo-z (see above)

One z=5.81 (known) QSO detected in eFEDS:
The highest redshift X-ray ‘blind’ detection

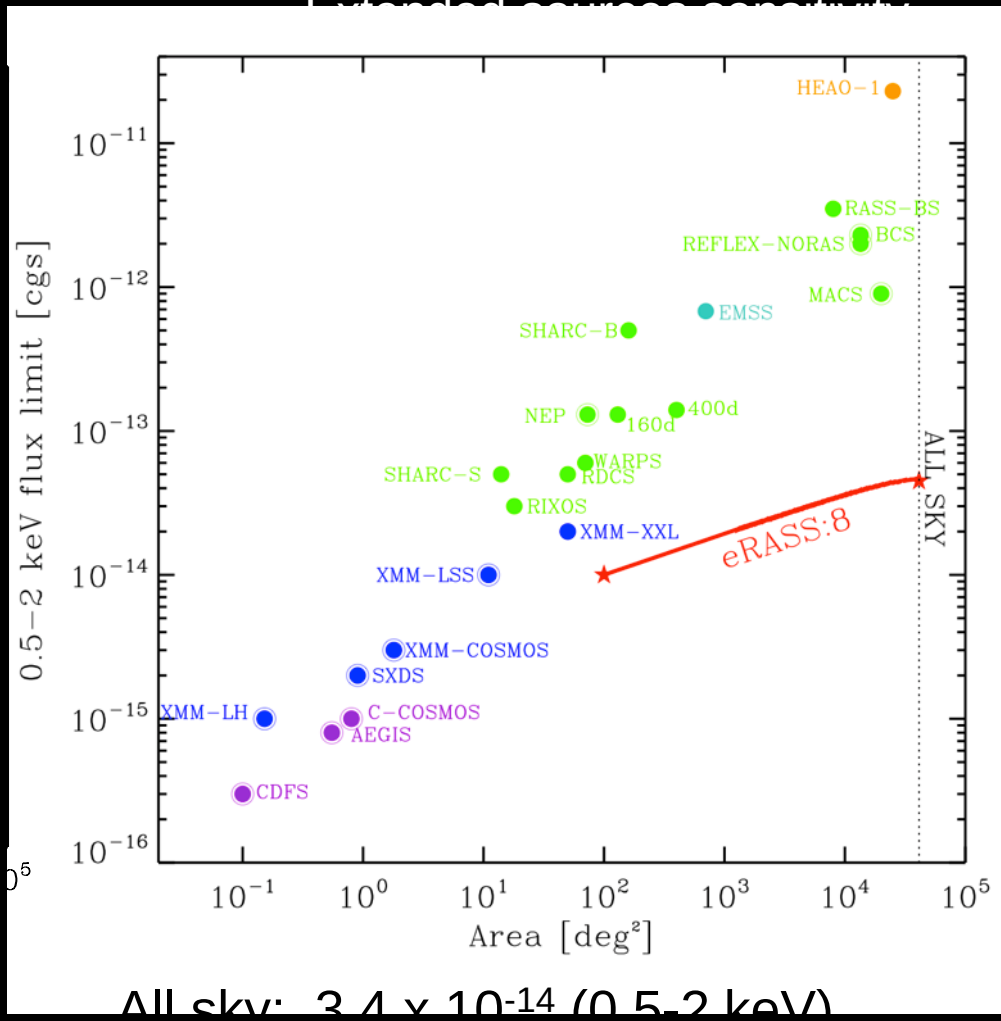
Wolf, Salvato+ in prep

eROSITA surveys in context

Point sources sensitivity



Extended sources sensitivity



All sky: 3.4 x 10^{-14} (0.5-2 keV)

Merloni et al. 2012