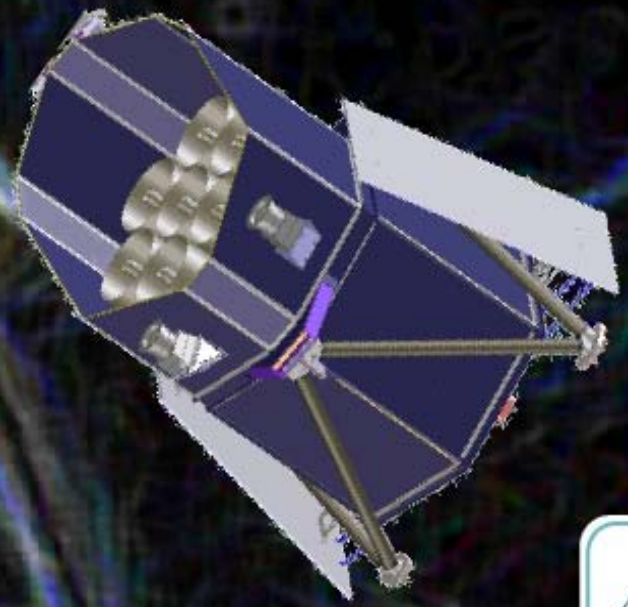
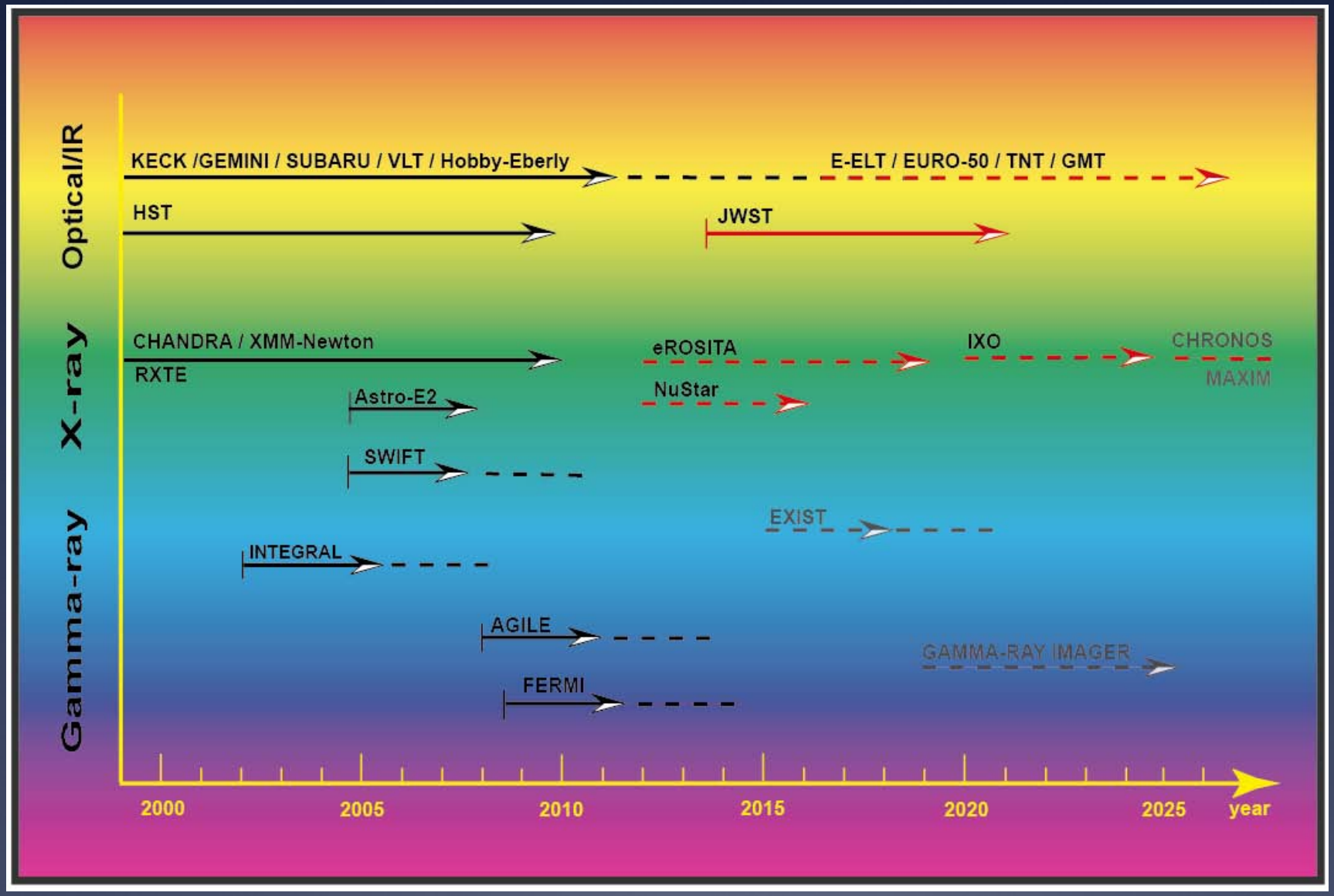
Exploring the X-ray Sky with eROSITA



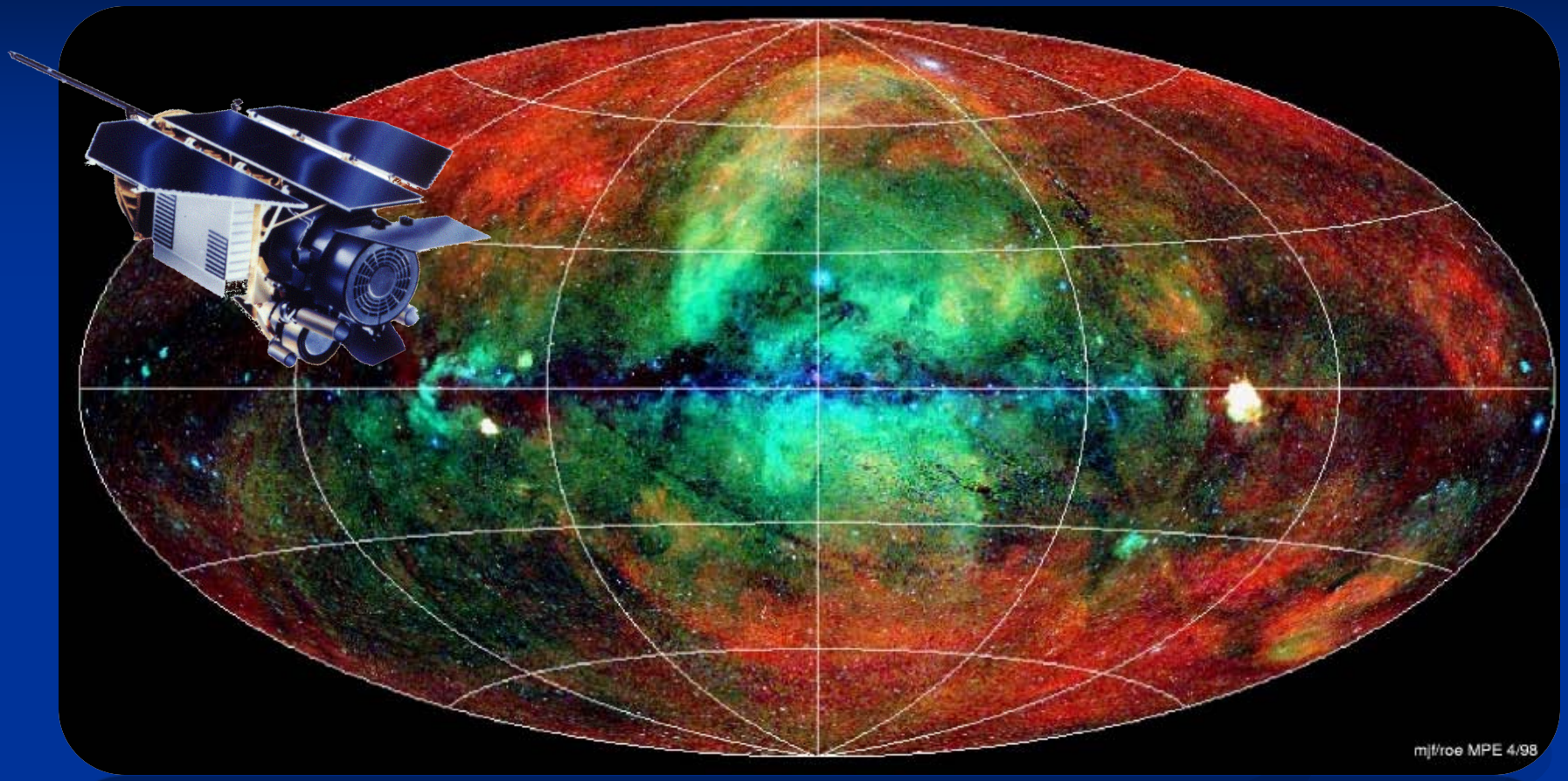
W.Becker *for the eROSITA Team*

Max-Planck Institut für extraterr. Physik

Observatories and mission timelines



Basic Scientific Idea ....



to extend the ROSAT all-sky survey up to 12 keV
with an XMM type sensitivity

Historical Development

Spectrum-XG
Jet-X, SODART, etc

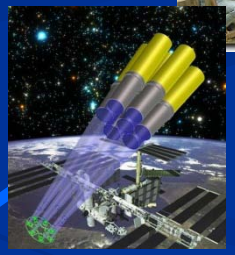
ROSAT 1990-1998
First X-ray all-sky survey
with an imaging telescope

ABRIXAS 1999
To extend the all-sky survey
towards higher energies

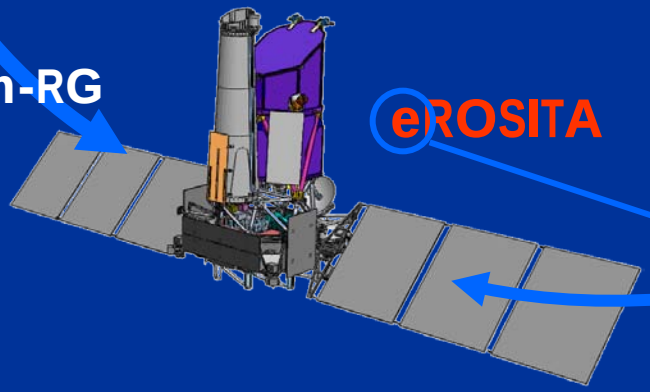
Negotiations between Roskosmos and ESA
on a "new" Spectrum-XG mission (2005)

Agreement between Roskosmos and DLR (2007)

ROSITA 2002
ABRIXAS science on the
International Space Station



Spectrum-RG



eROSITA

Dark Energy
10^5 **Clusters of Galaxies**

extended ROentgen Survey with an
Imaging Telescope Array

Mission scenario & Instrument specification

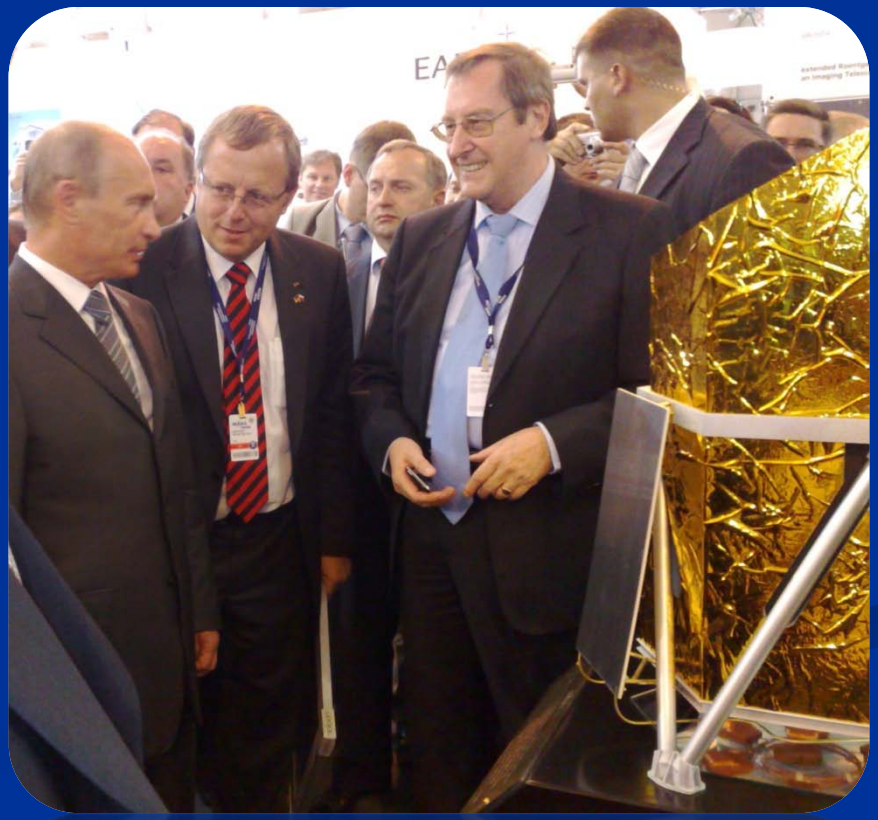
- 3 month calibration & science verification phase
- 4 yrs all-sky survey (8 sky coverages)
- 2.7 yrs pointed observations

- Energy range 0.2 - 12 keV
- FOV: 1 degree
- All-sky survey sensitivity ~ 6 x10^{-14} erg cm^{-2} s^{-1} ~ (10 – 30) x ROSAT
- Deep survey field(s) (~100 sqdeg) with 5×10^{-15} erg cm^{-2} s^{-1}
- Temporal resolution ~ 50 ms
- Energy resolution ~ 130 ev @ 6 keV / 80 ev @ 1.5 keV
- Angular resolution ~ 15” (20” survey)

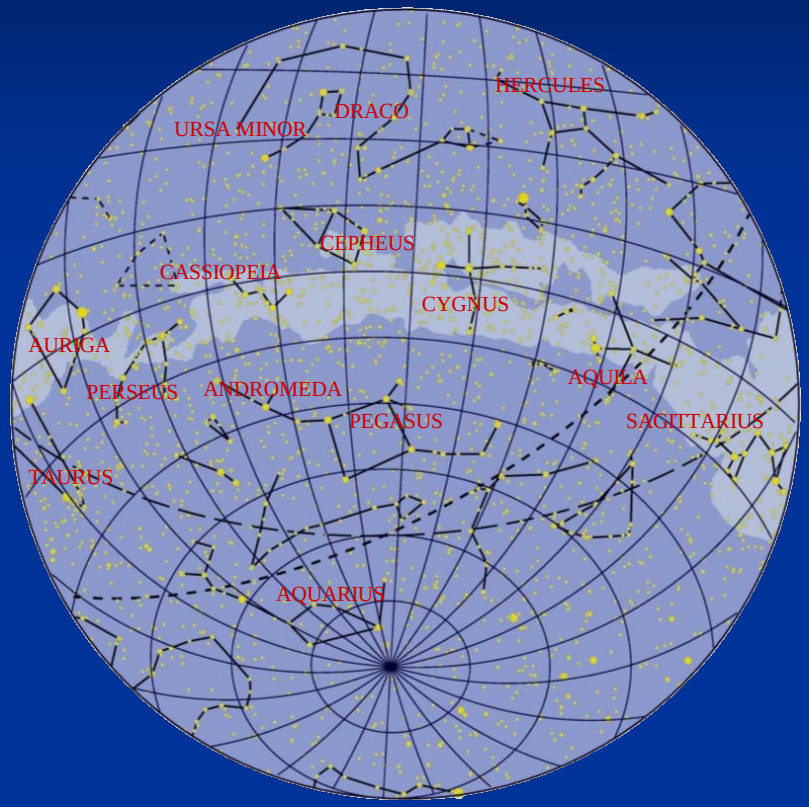
eROSITA status: completely approved and funded

Signature of the "Detailed Agreement"
(Reichle, Wörner, Perminov)

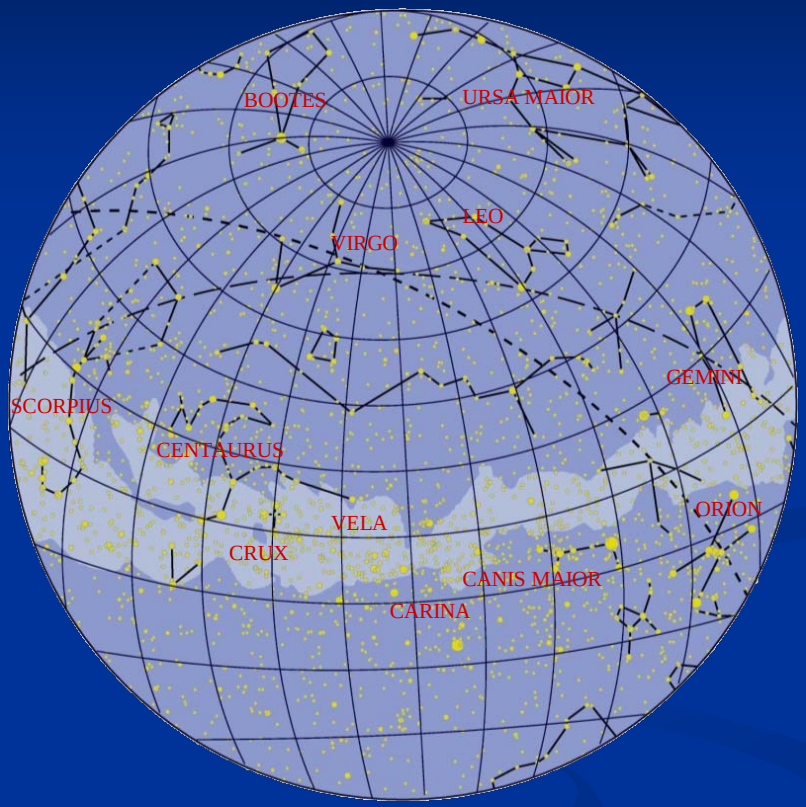
Mr. Putin gets informed about *Dark Energy*...



50:50 data share between Ru / Germany



HEMISPHAERA ORIENTALIS



HEMISPHAERA OCCIDENTALIS

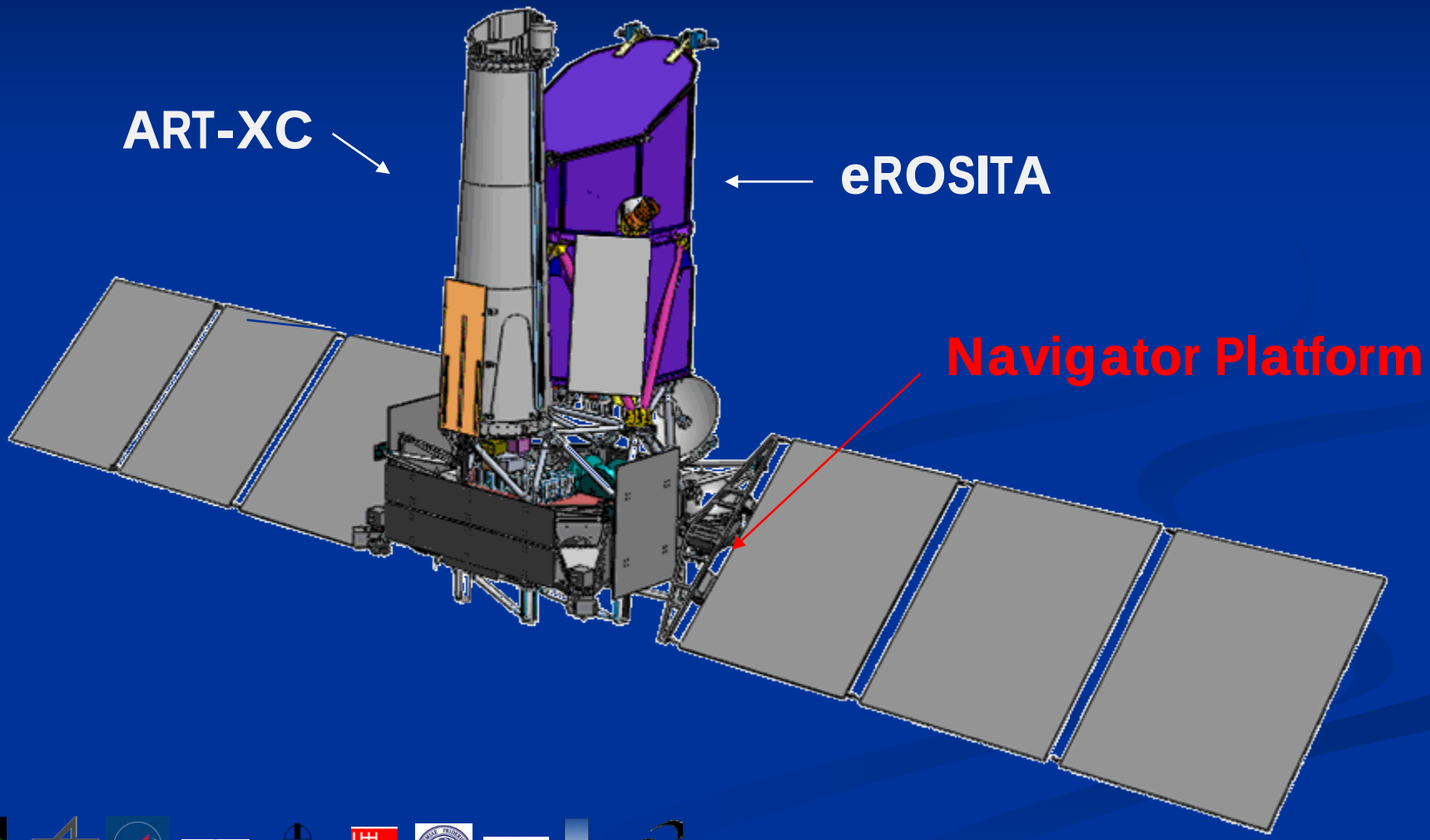
Actual definition depends on mission planning

eROSITA: Launch date ....

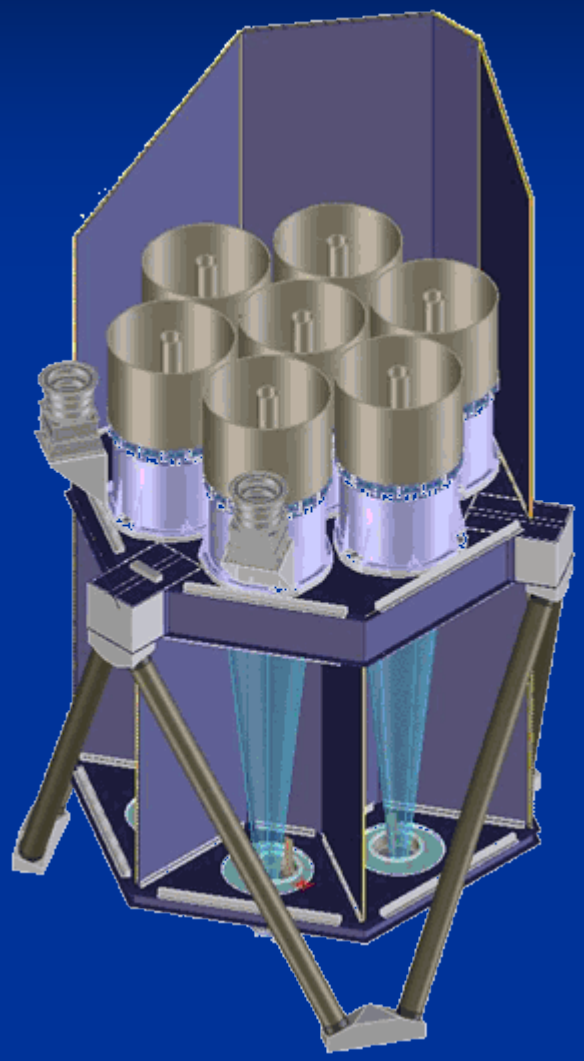
Nov. 20th / 16:45

2012

eROSITA on Spectrum-RG



eROSITA Telescope Array



7 Mirror Systems

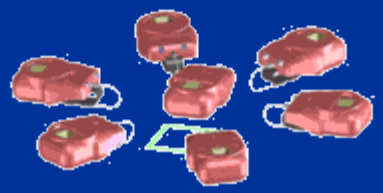
- ∅ 36 cm
- 54 nested gold-coated nickel-shells
- A_{eff} ~ 2400 cm^2 (1 keV, on-axis)
- Grasp ~700 cm^2 deg^2 at 1 keV

eROSITA Telescope Array

7 Mirror Modules

-- Spider Wheel

-- Mirror Interface Structure (MIS)



7 Cameras

– CCD-Module in Casing (-80°C)

– Cu-Proton-Shield (20°C)

eROSITA Telescope Array

7 Mirror Modules

-- Spider Wheel

-- Mirror Interface Structure (MIS)

7 Cameras

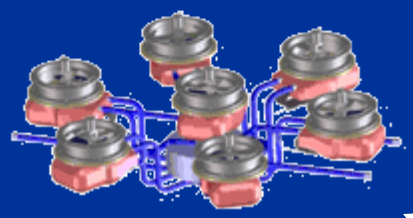
- CCD-Module in Casing (-80°C)
- Cu-Proton-Shield (20°C)
- Adapter, Filterwheel + Fe^{55} cal. source

eROSITA Telescope Array

7 Mirror Modules

-- Spider Wheel

-- Mirror Interface Structure (MIS)

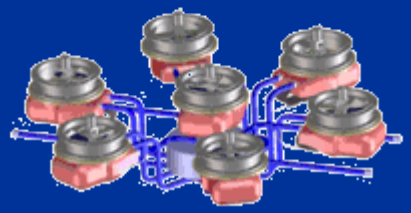


7 Cameras

- CCD-Module in Casing (-80°C)
- Cu-Proton-Shield (20°C)
- Adapter, Filterwheel + Fe^{55} cal. source
- Heatpipes & Latent Cold Storage

eROSITA Telescope Array

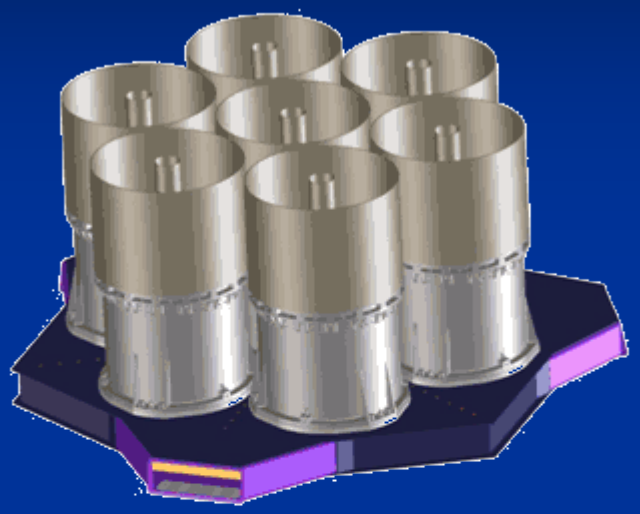
Baffles (X-ray., opt., therm.)



7 Cameras

- CCD-Module in Casing (-80°C)
- Cu-Proton-Shield (20°C)
- Adapter, Filterwheel + Fe^{55} Calsource
- Heatpipes & Latent Cold Storage

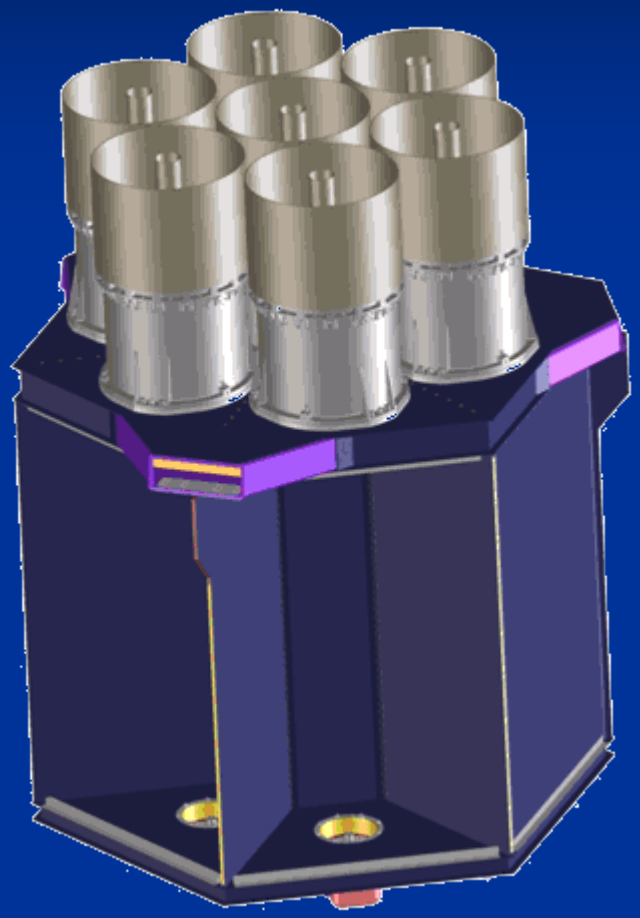
eROSITA Telescope Array



Mirror platform

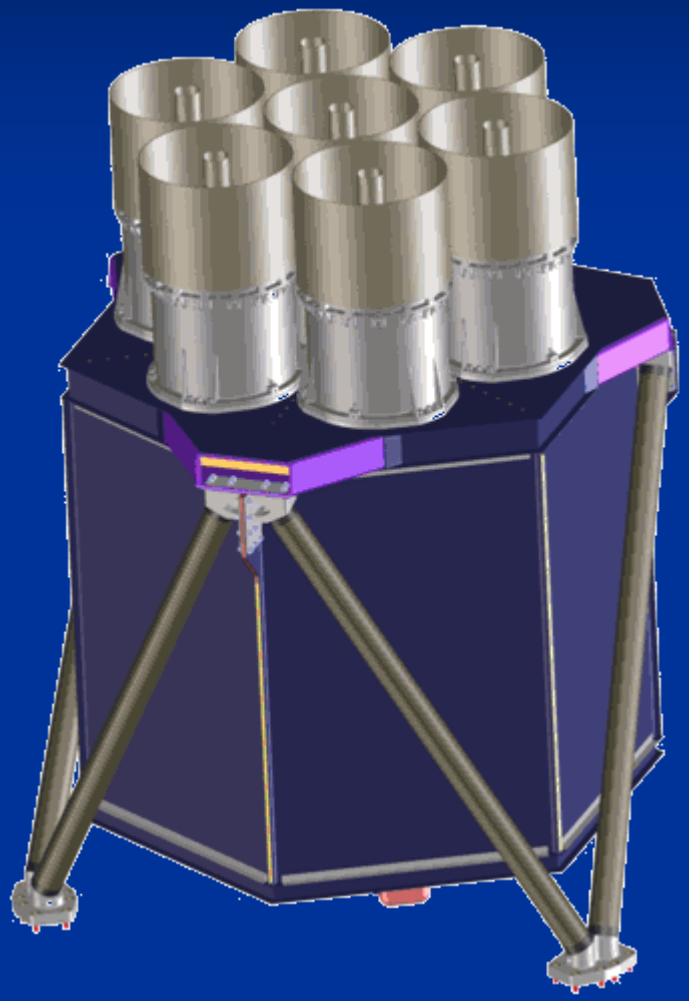
Camera platform

eROSITA Telescope Array



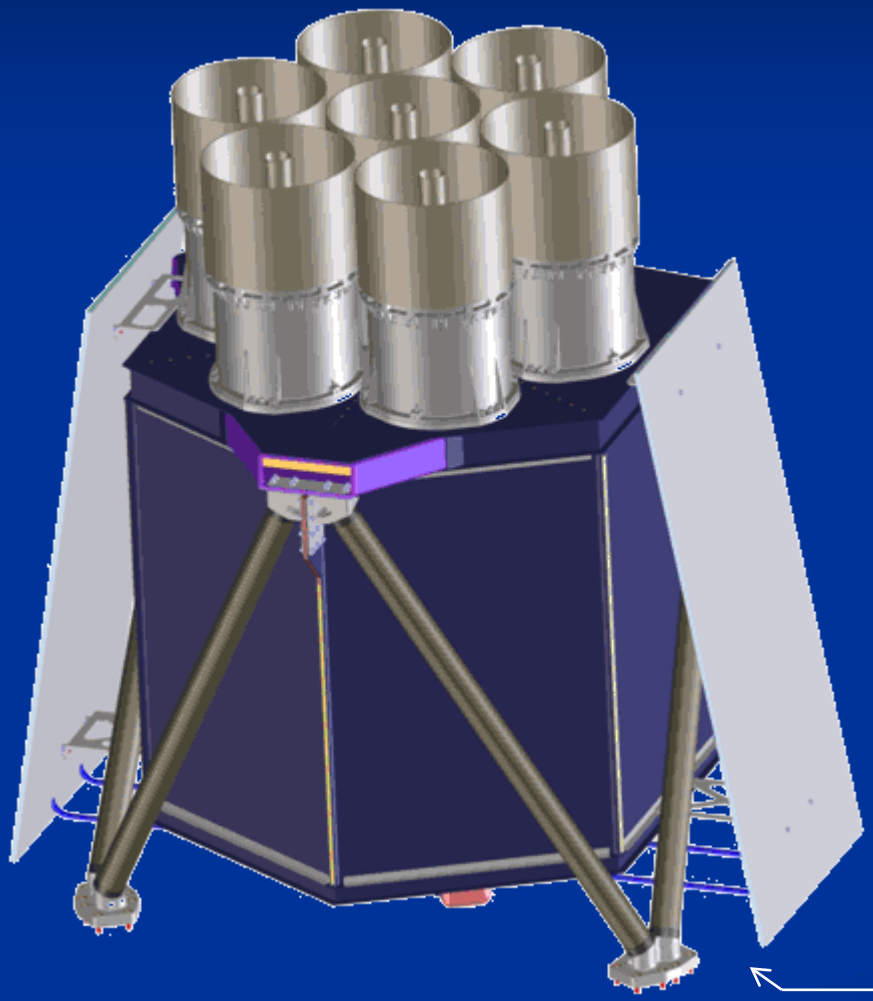
Optical bench

eROSITA Telescope Array



Hexapods (CFRP tubes)

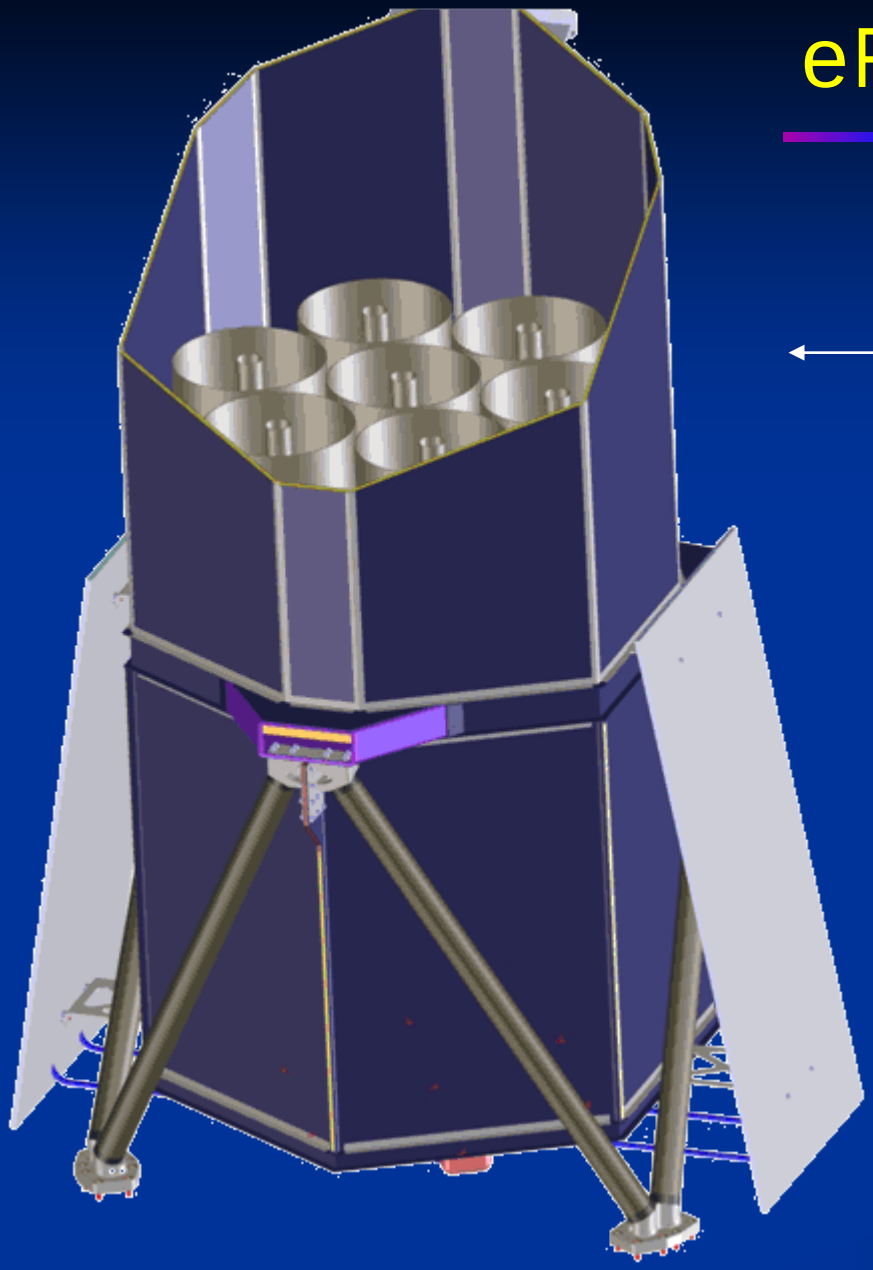
eROSITA Telescope Array



Radiators

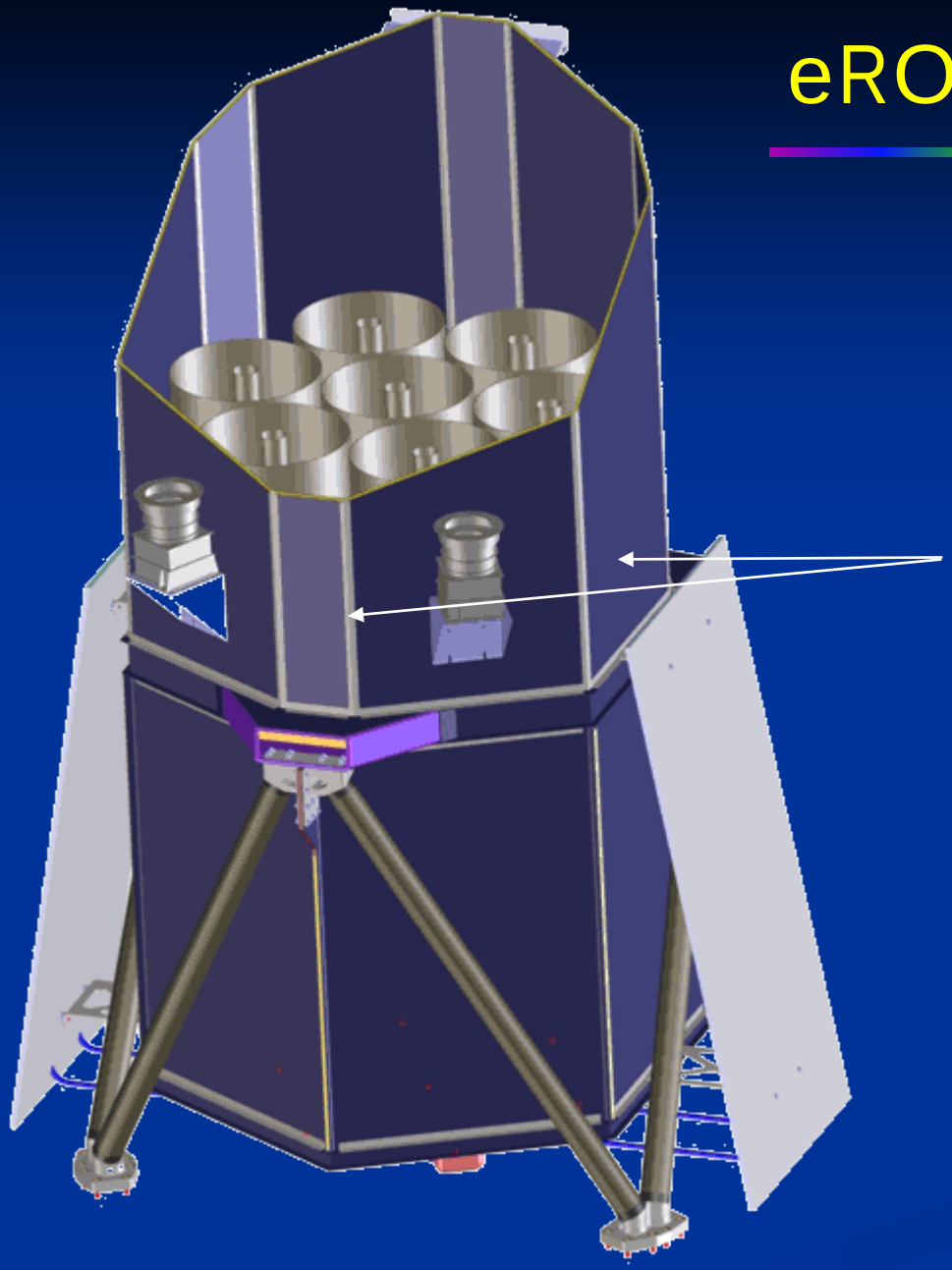
– Variable Conductance Heatpipes

eROSITA Telescope Array

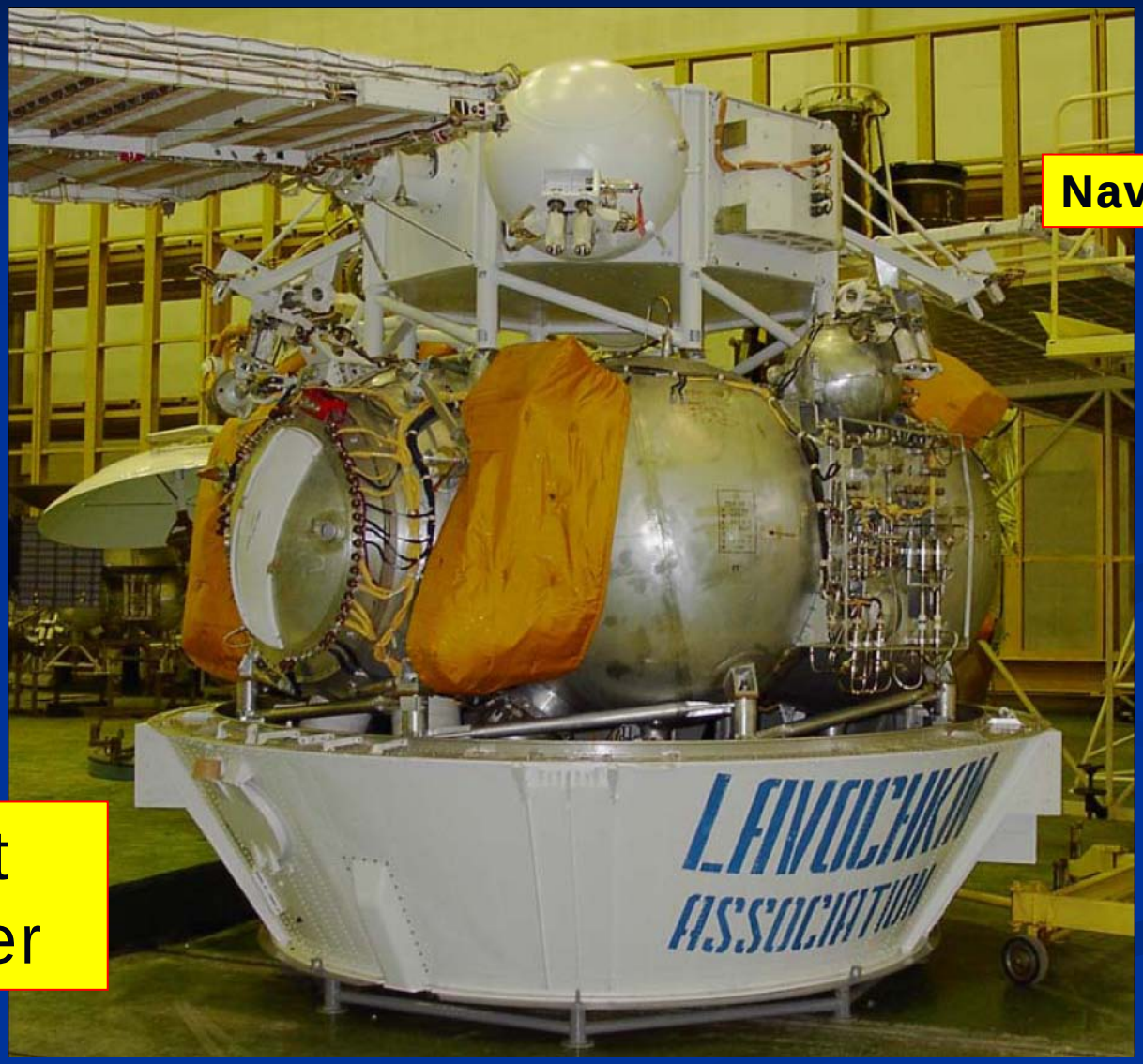


Sunshield

eROSITA Telescope Array



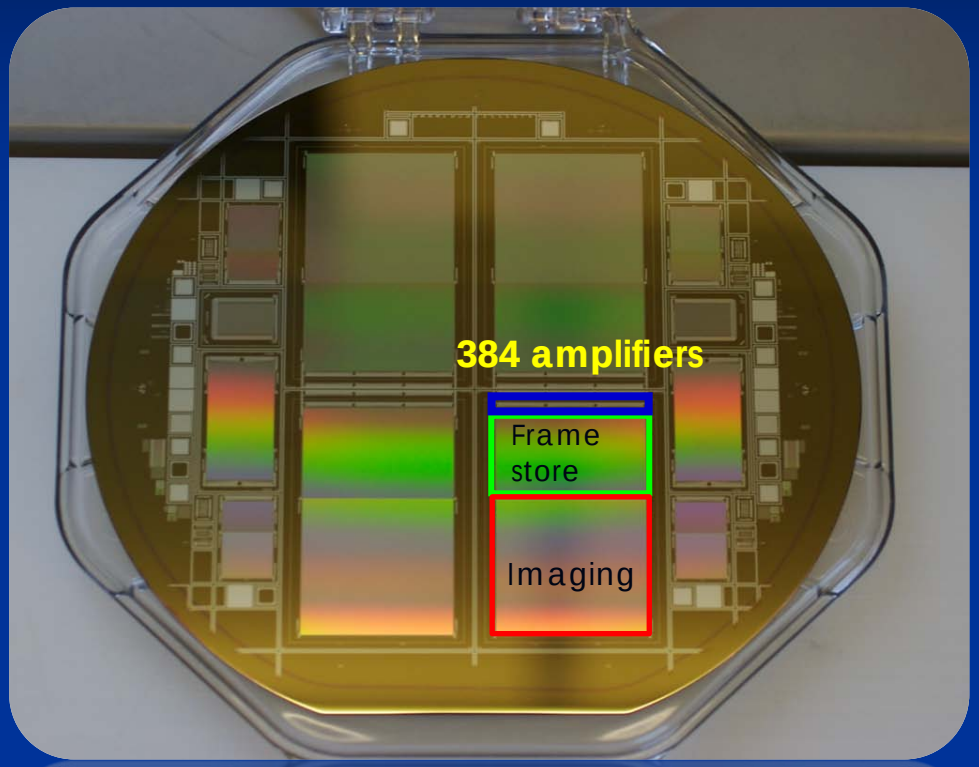
eROSITA: Navigator and Booster



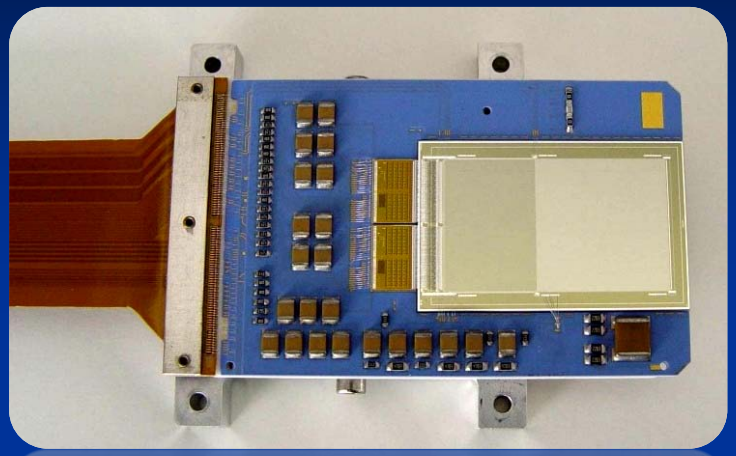
Navigator

Fregat Booster

eROSITA: Advanced XMM pn-CCD



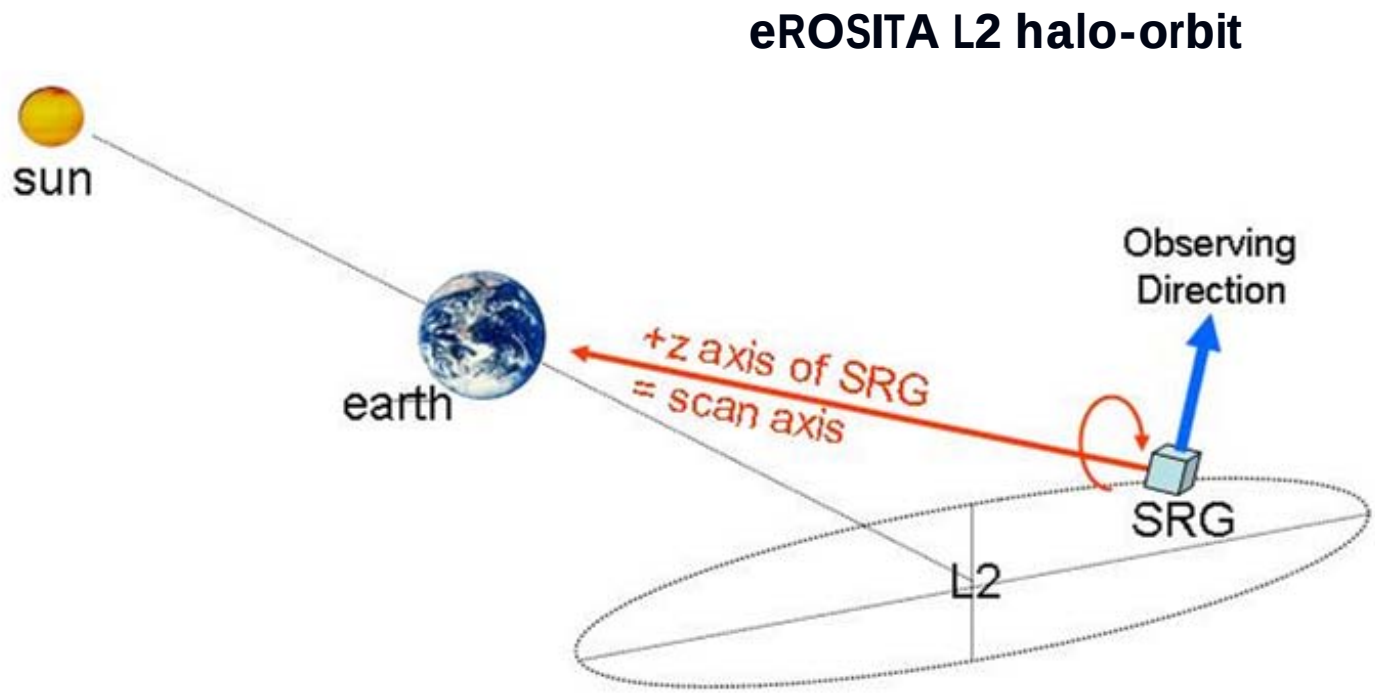
eROSITA pn-CCD flight devices



– 7 individual cameras

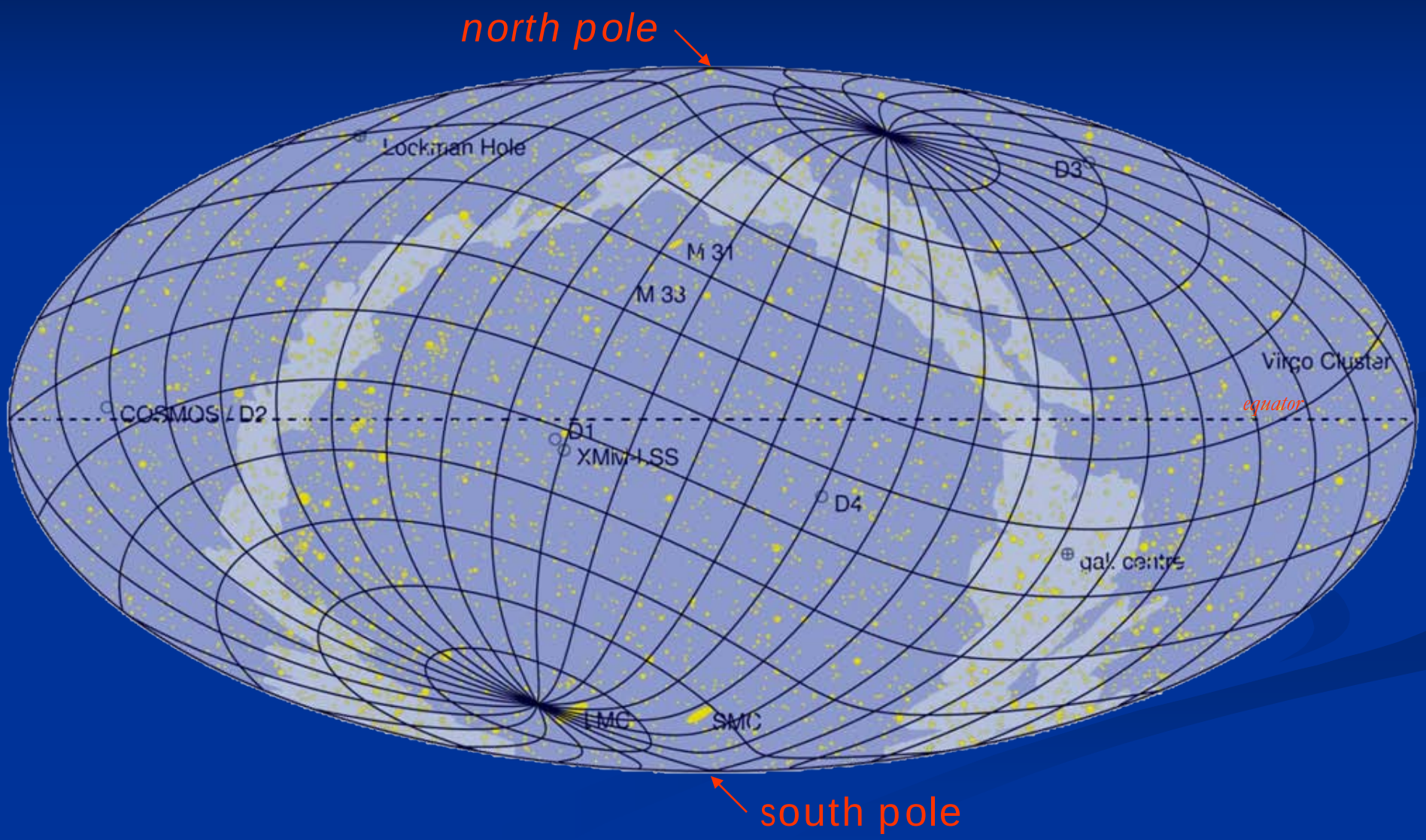
- 256 × 256 pixel, 75µm
- frame store area
- faster read-out
- 40% reduced out-of-time events
- temporal res. 50 ms

eROSITA: Mission geometry during all-sky survey



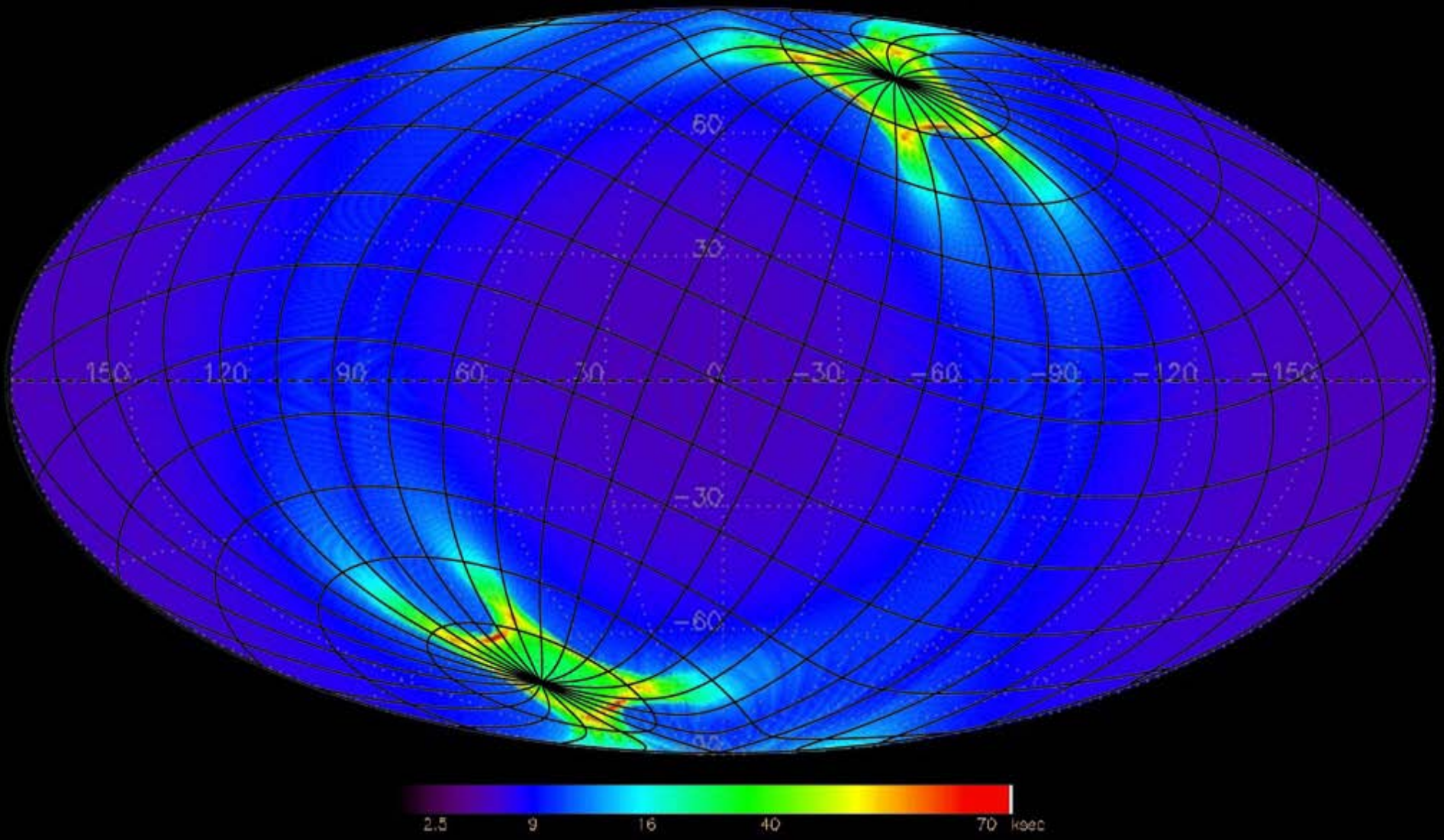
SRG is continuously rotating around the z-axis which always points to the earth

eROSITA: Scan geometry along ecliptical meridians

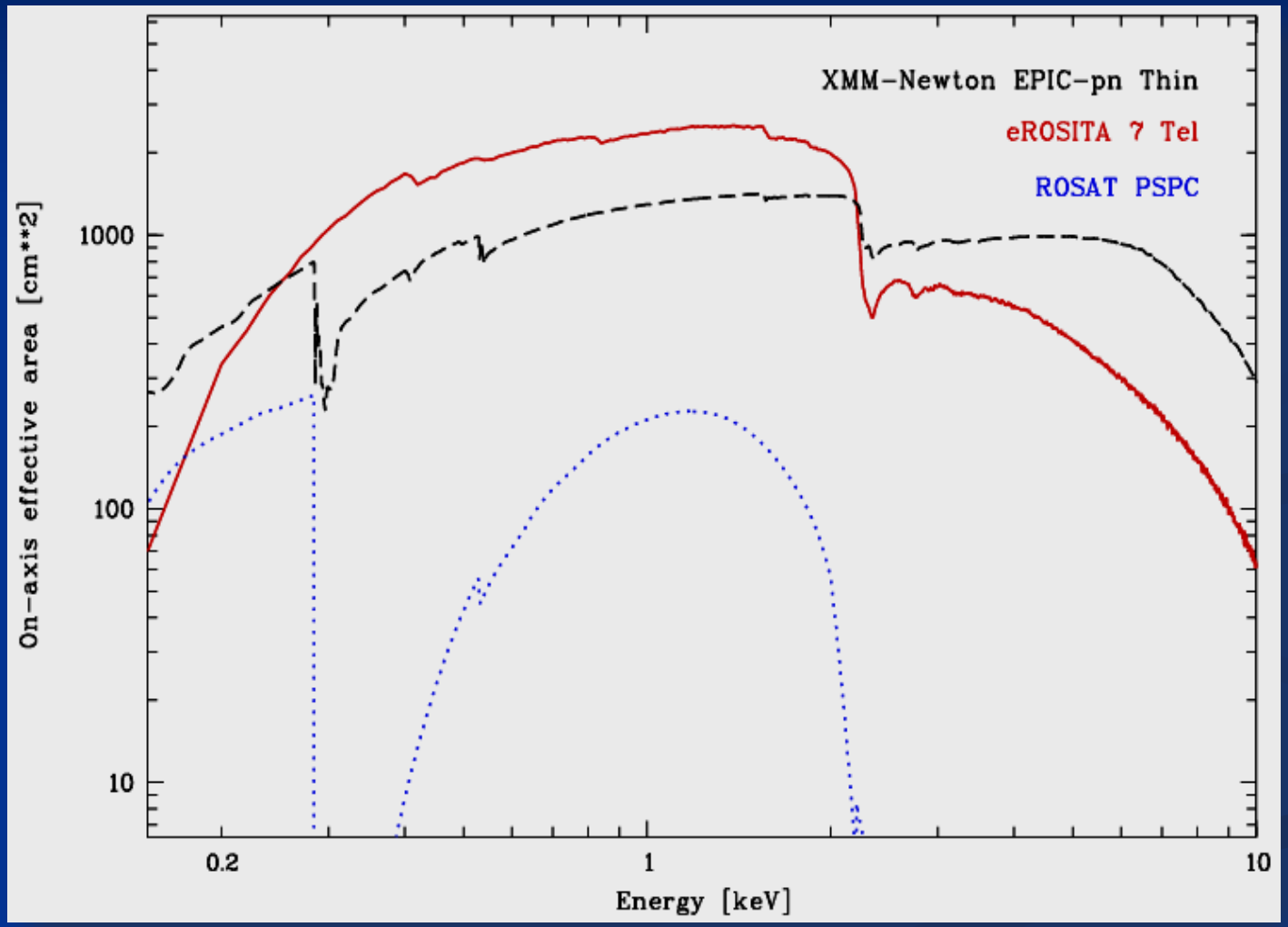


eROSITA: Exposure Map

~ 15 ksec in the plane

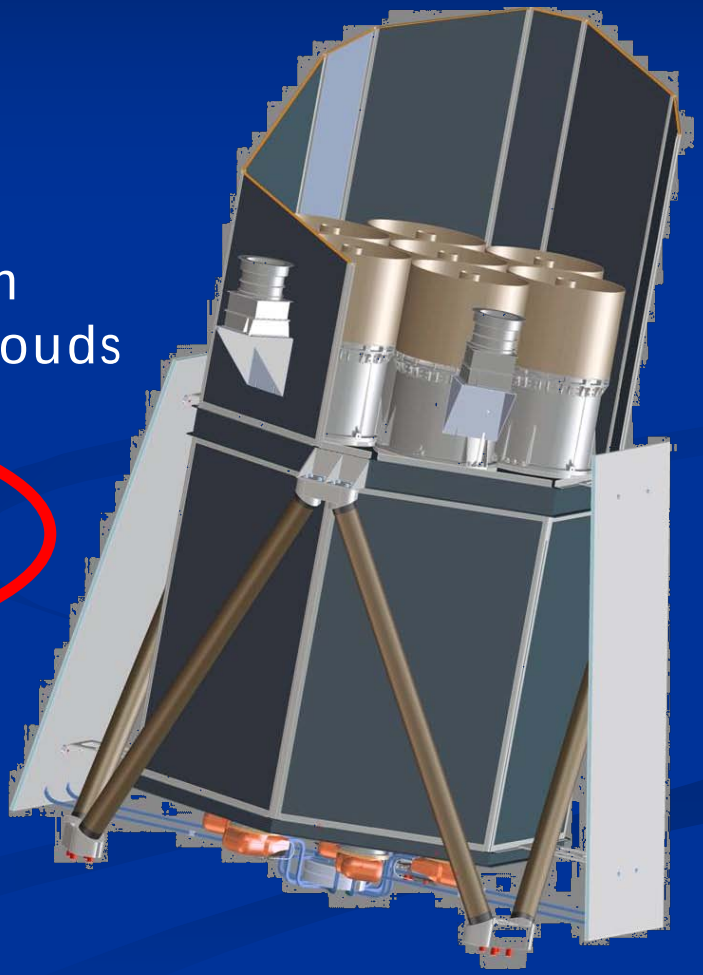


eROSITA: effective area 2400 cm^2 @ 1keV

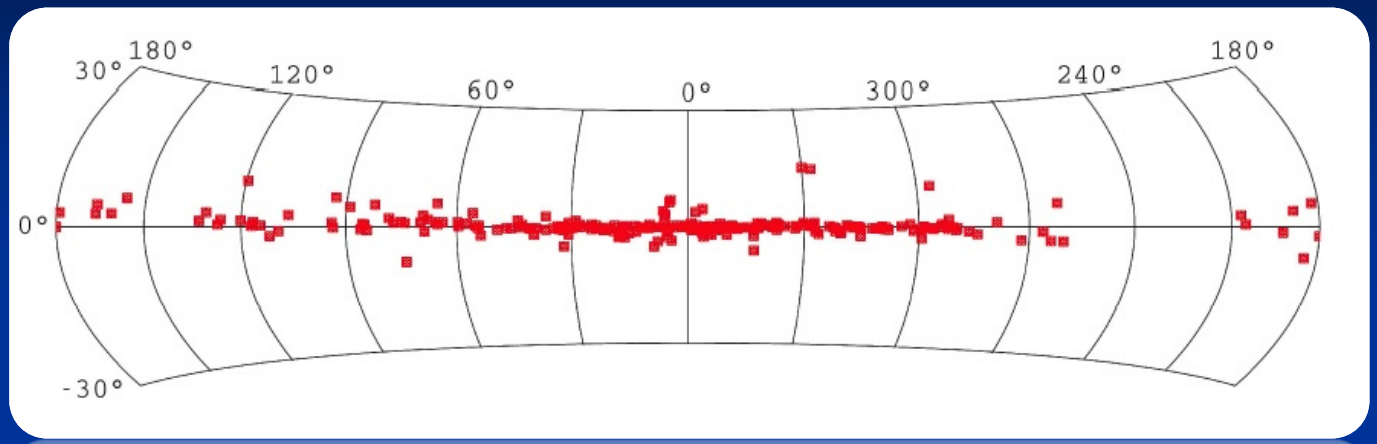


eROSITA: Science Goals ....

- detection of 100.000 clusters of galaxies
  → exploring the nature of dark energy
- detection of ~3 mill. AGN, many of them hiding behind obscuring gas and dust clouds
- + relevance for lots of other galactic and extragalactic scientific topics like SNRs, PSR, stars, ...

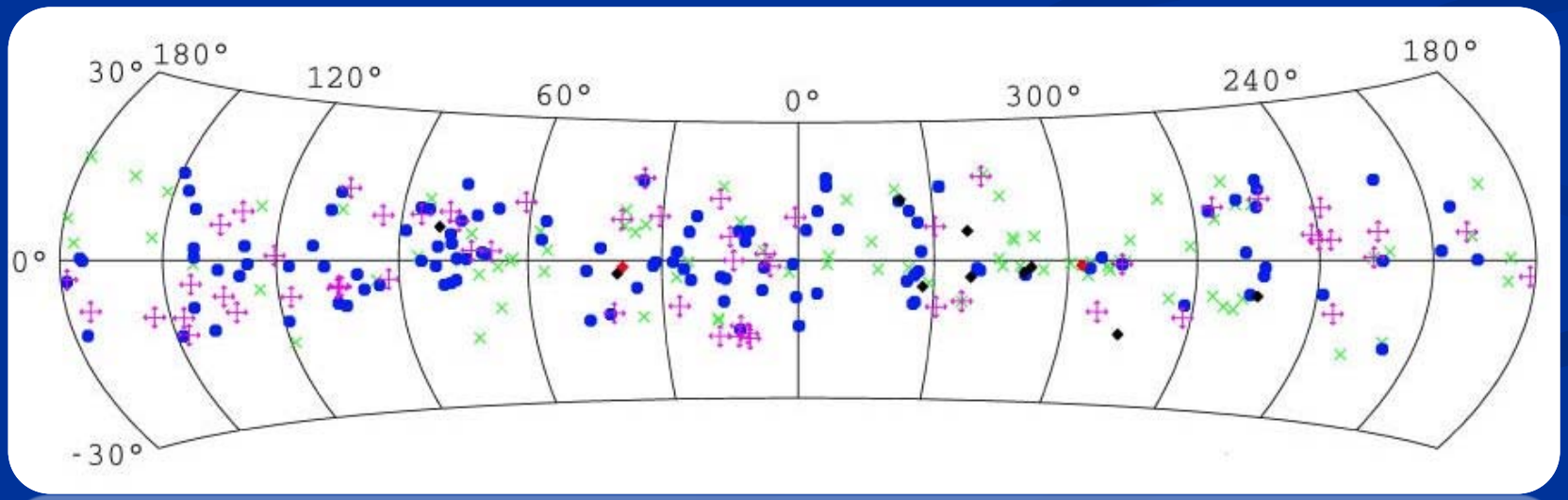


eROSITA: Supernova research

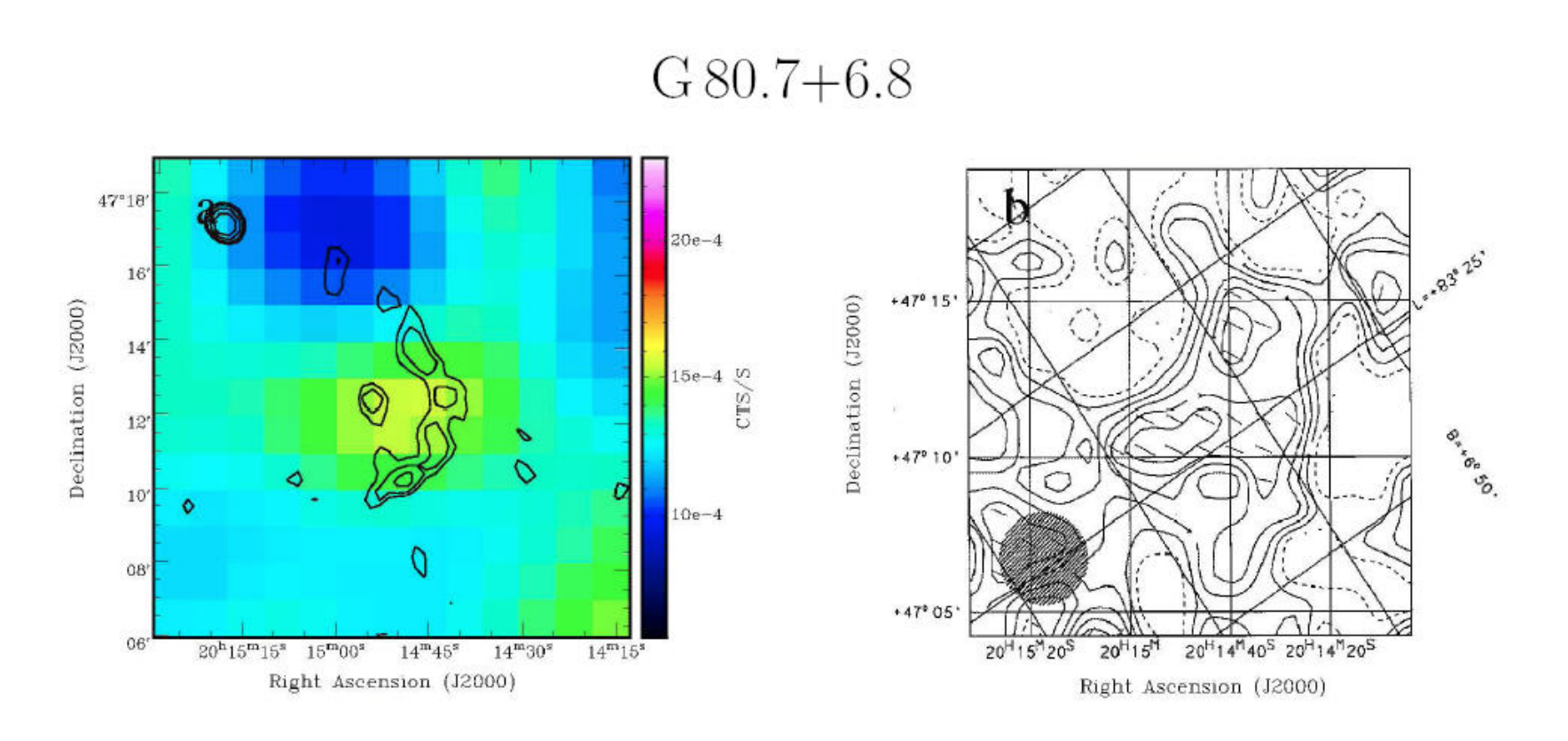


~270 known Galactic SNRs

RASS: 215 SNR candidates

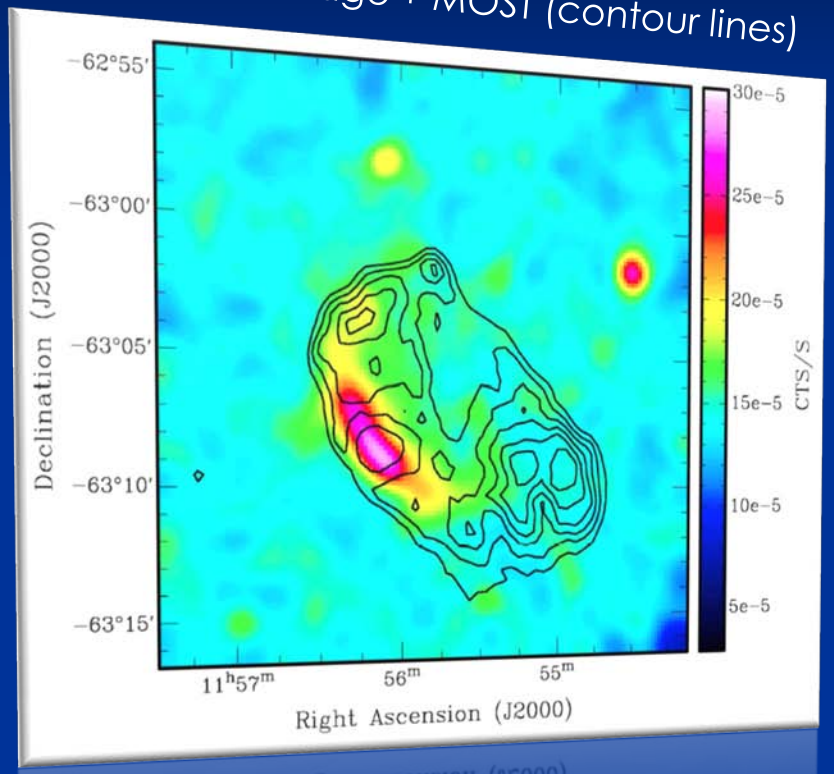


Supernova remnant candidates in the RASS

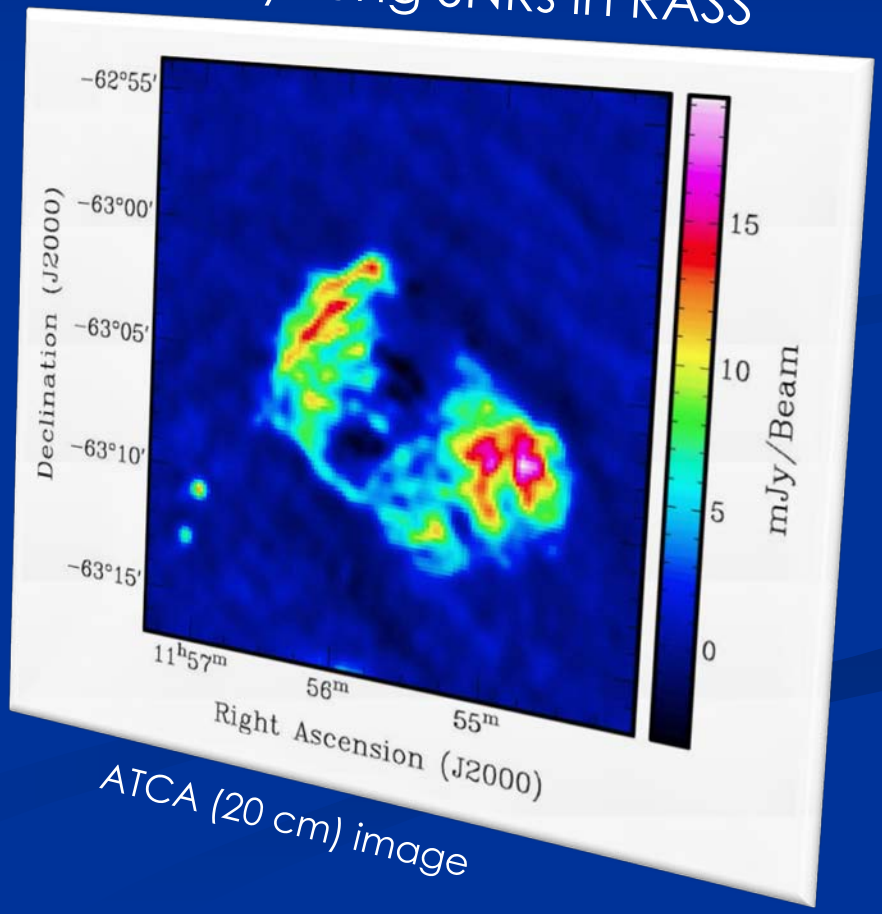


Supernova research with eROSITA: G296.7-0.9

ROSAT RASS image + MOST (contour lines)



new young SNRs in RASS

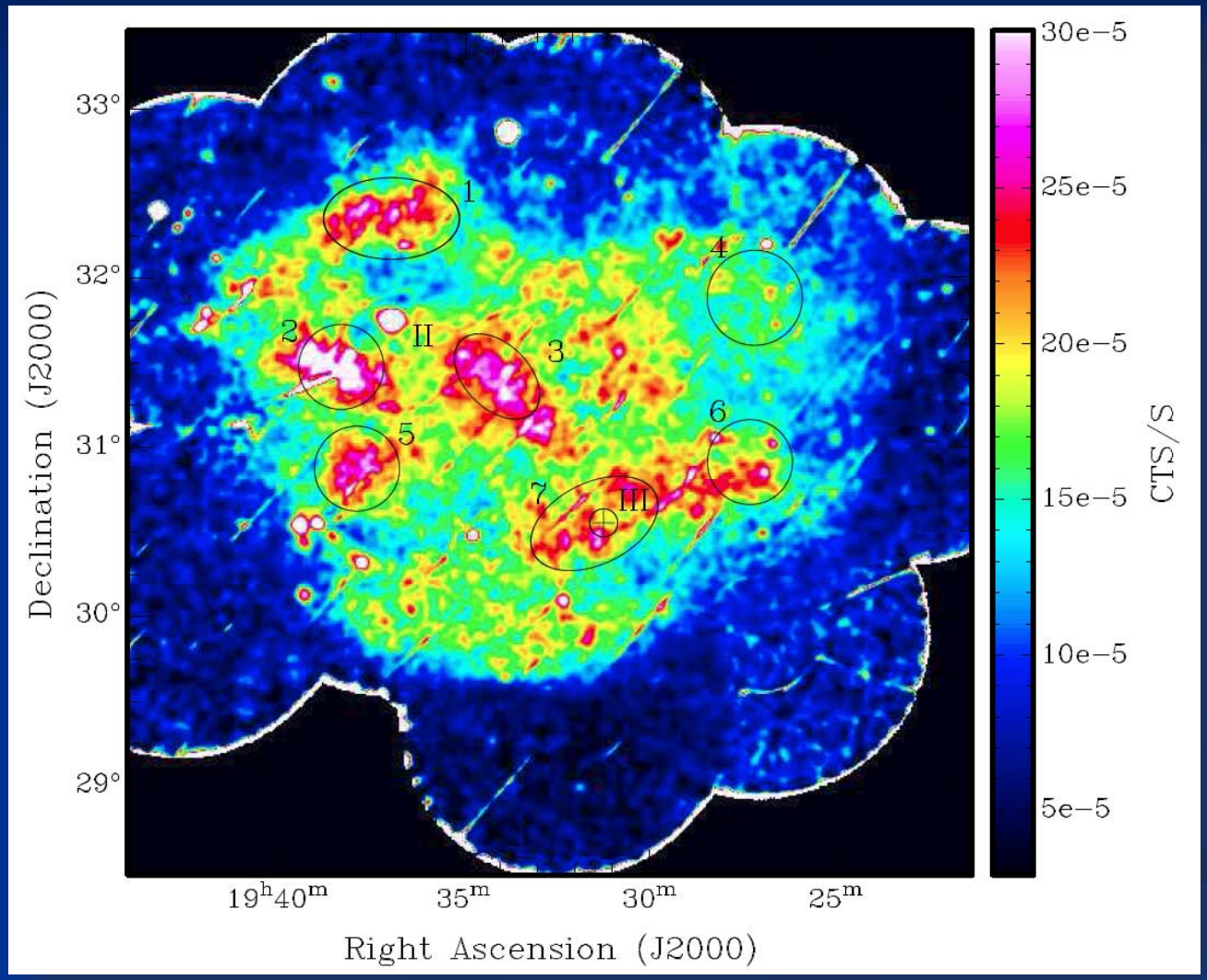


ATCA (20 cm) image

eROSITA: on extended supernova remnants ...

G 65.3+5.7

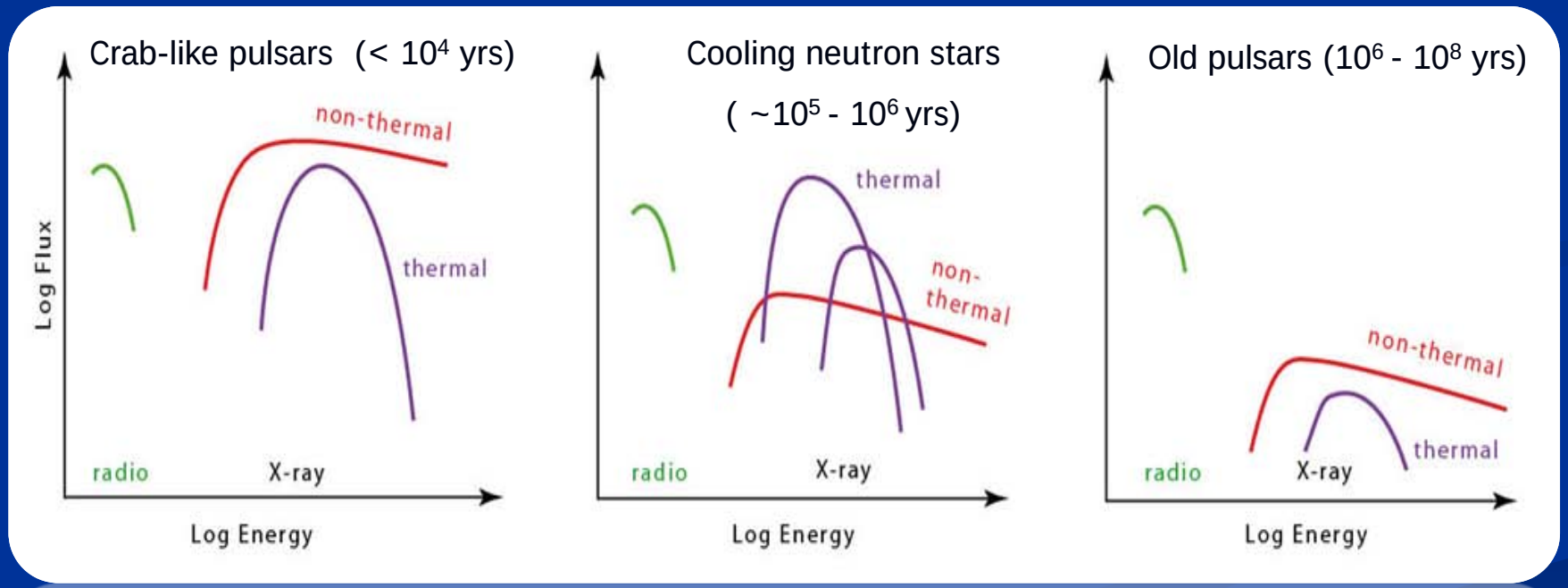
Extent of SNR:
3 degrees



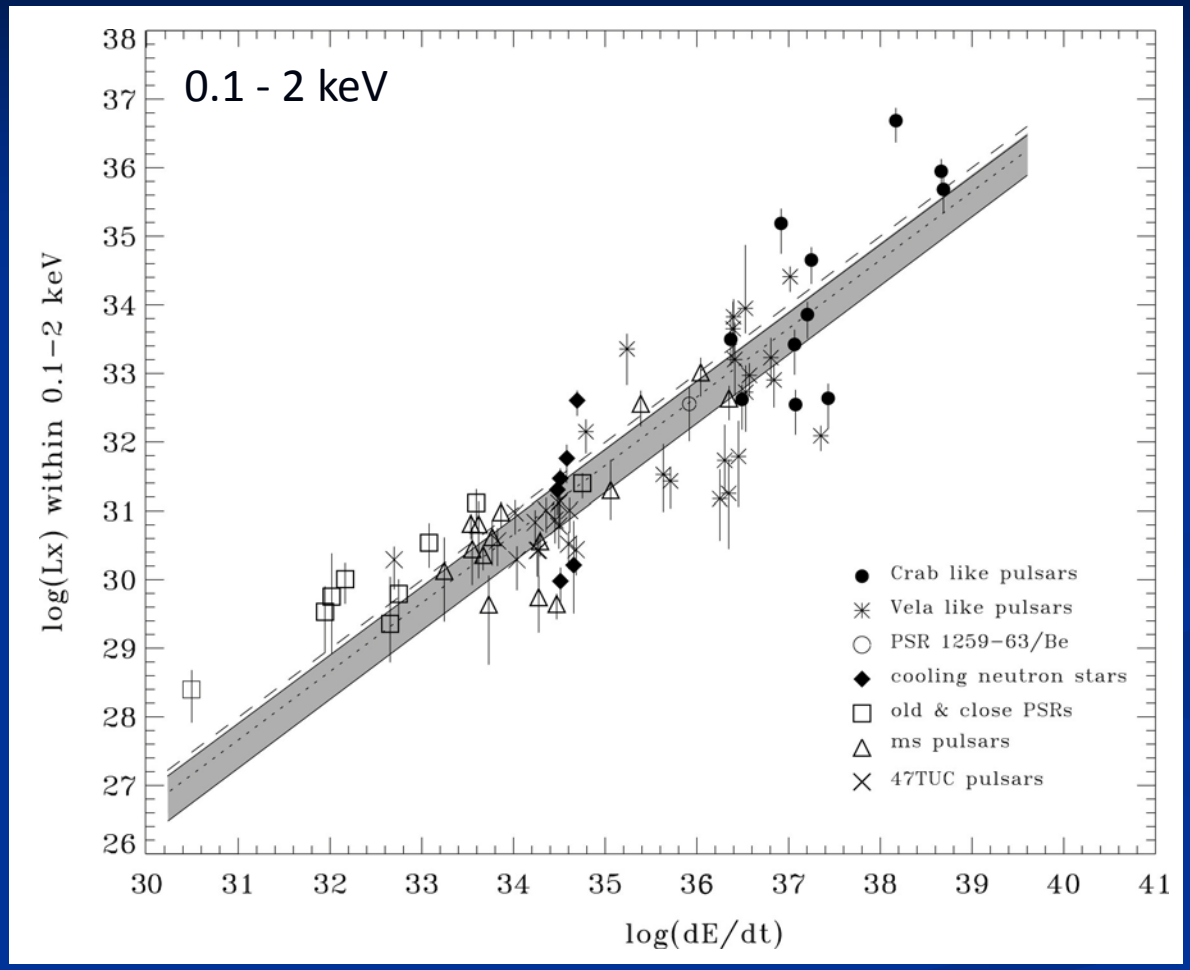
What's about Pulsars ?

How many pulsars will be detected in the all sky survey?

X-ray emission properties scale with age



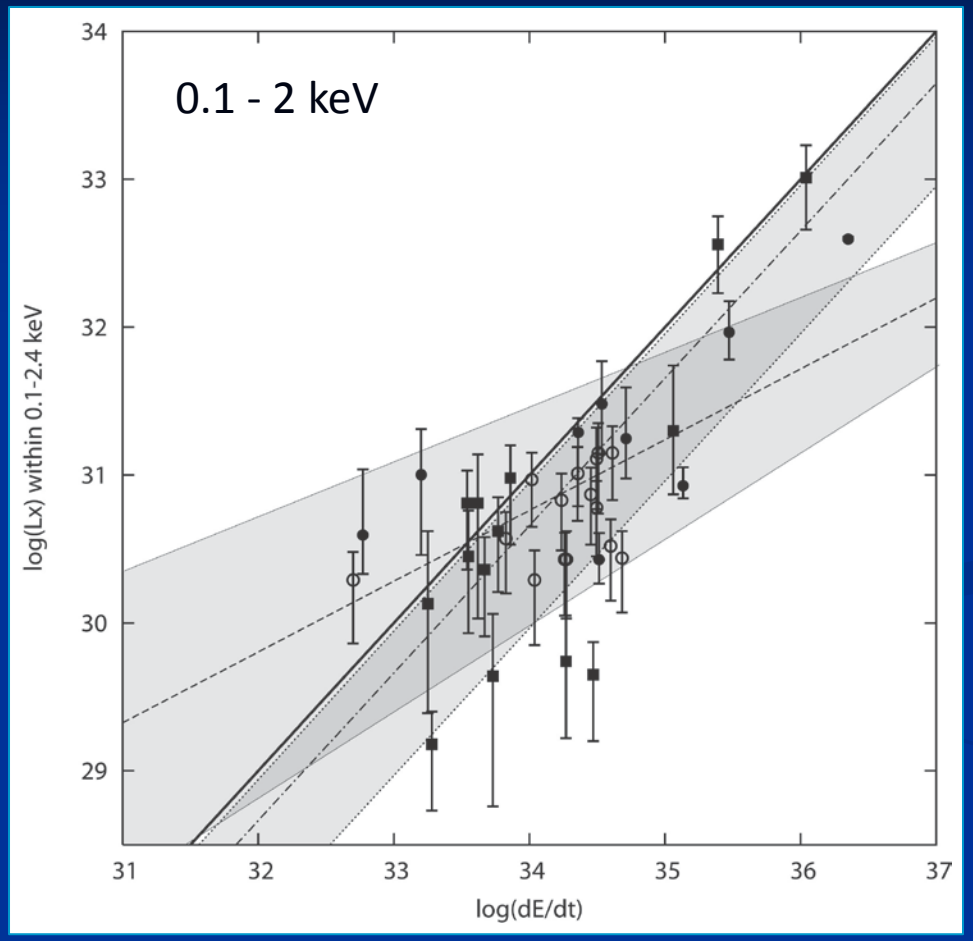
The X-ray Efficiency of Rotation-Powered Pulsars



Becker et al. 2010

$$L_x(0.1-2\,\mathrm{keV}) = 10^{-3.24^{+0.26}_{-0.66}}\,\dot{E}^{0.997^{+0.008}_{-0.001}}$$

The X-ray Efficiency of Rotation-Powered Pulsars



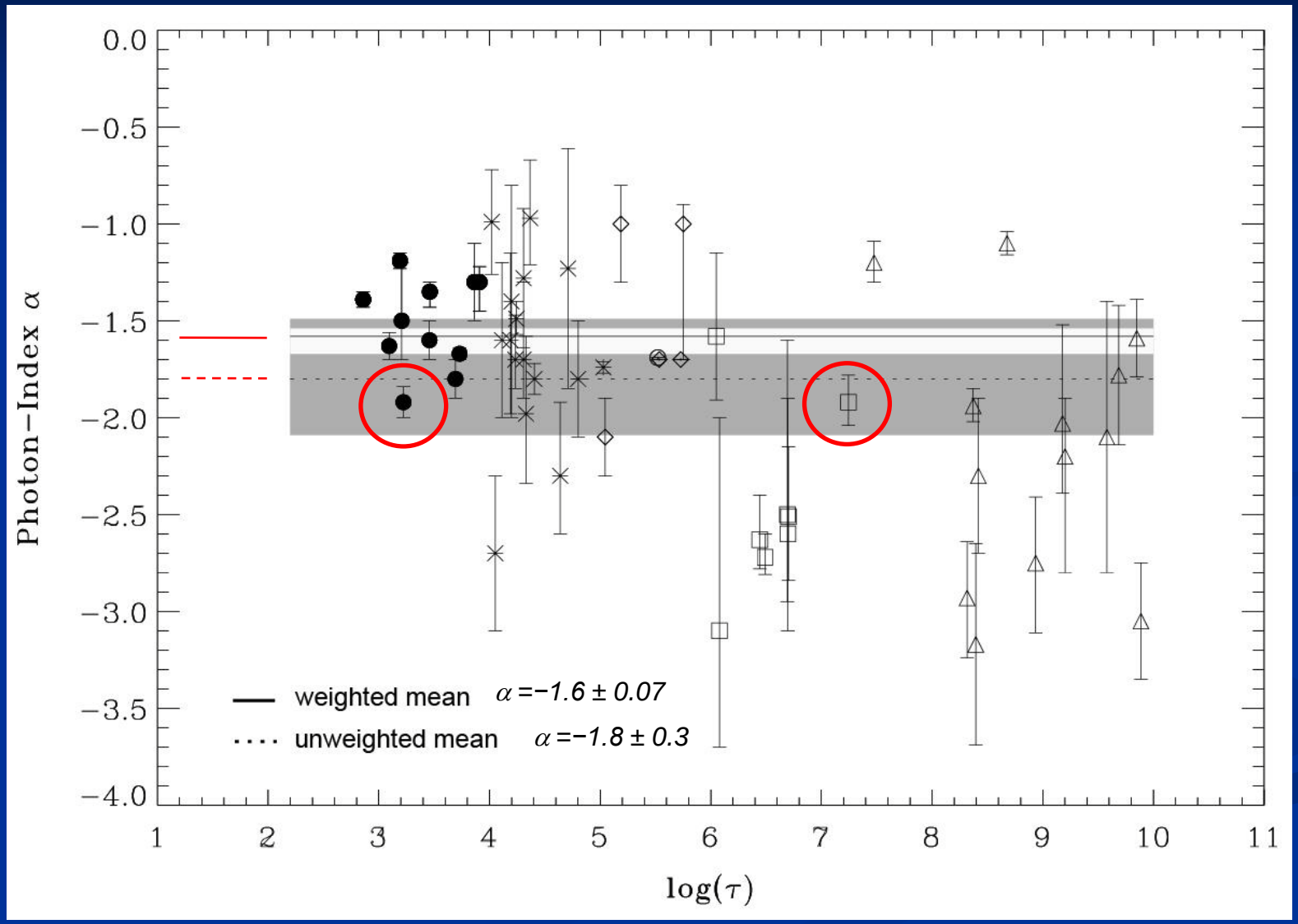
Efficiency of 47 Tuc MSPs vs. galactic plane MSPs

NOT significantly different

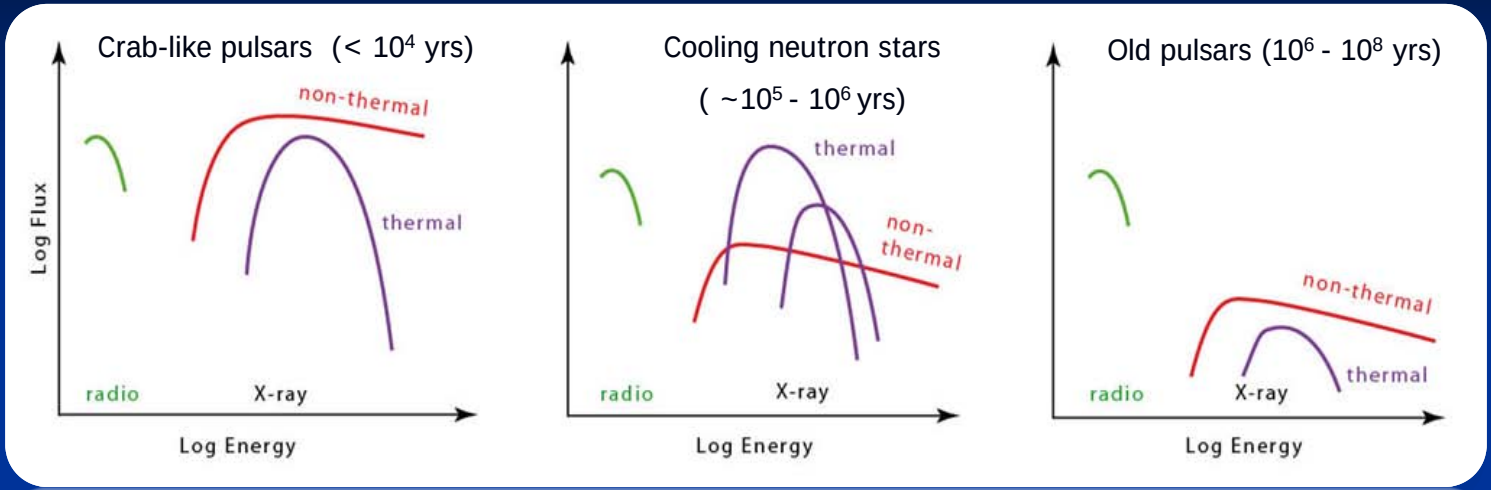
Becker et al. 2010

$$L_x(0.1 - 2\,\mathrm{keV}) = 10^{-3.24^{+0.26}_{-0.66}}\,\dot{E}^{0.997^{+0.008}_{-0.001}}$$

X-ray emission properties scale with spin-down age



How many pulsars will be detected in the all sky survey?



Simulations:

- for pulsars detected in X-rays we adopted their observed spectral parameters
- for pulsars not detected by now we used:

1. Pulsar parameters (e.g. age, distance, $\dot{E}$) from the ATNF-Catalog (Manchster & Hobbs)
2. Thermal surface component: Neutron star cooling model (Tsuruta et al 2007)
3. Thermal hot-spot component : Polar cap model from Harding (2002)
4. Non-thermal component: assuming $L_x = 10^{-3}\,\dot{E}$ + power-law spectrum with α=1.8

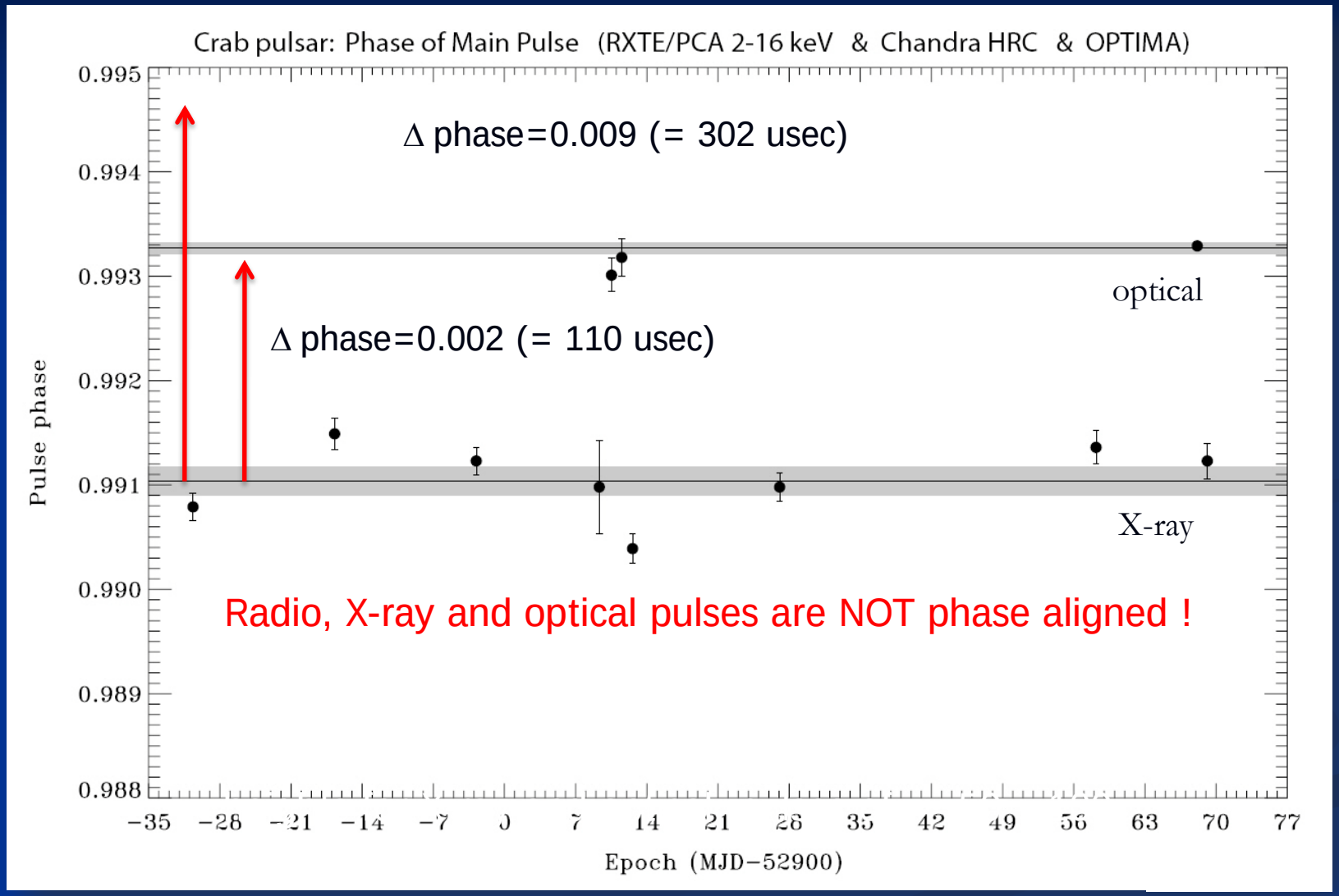
How many pulsars will be detected in the all sky survey?

Survey duration	Detections
½ year	43
1 year	55
1 ½ year	66
2 years	72
2 ½ years	82
3 years	90
3 ½ years	93
4 years	~100

- age < 10^3 yrs: all
- 10^3 < age < 10^5 yrs: ~40 (out of ~90)
- 10^5 < age < 10^6 yrs: ~30 (out of ~255)
- age > 10^6 yrs (without ms-PSR): ~20 (out of ~1053)
- for ms-PSRs: ~12 (out of ~150)

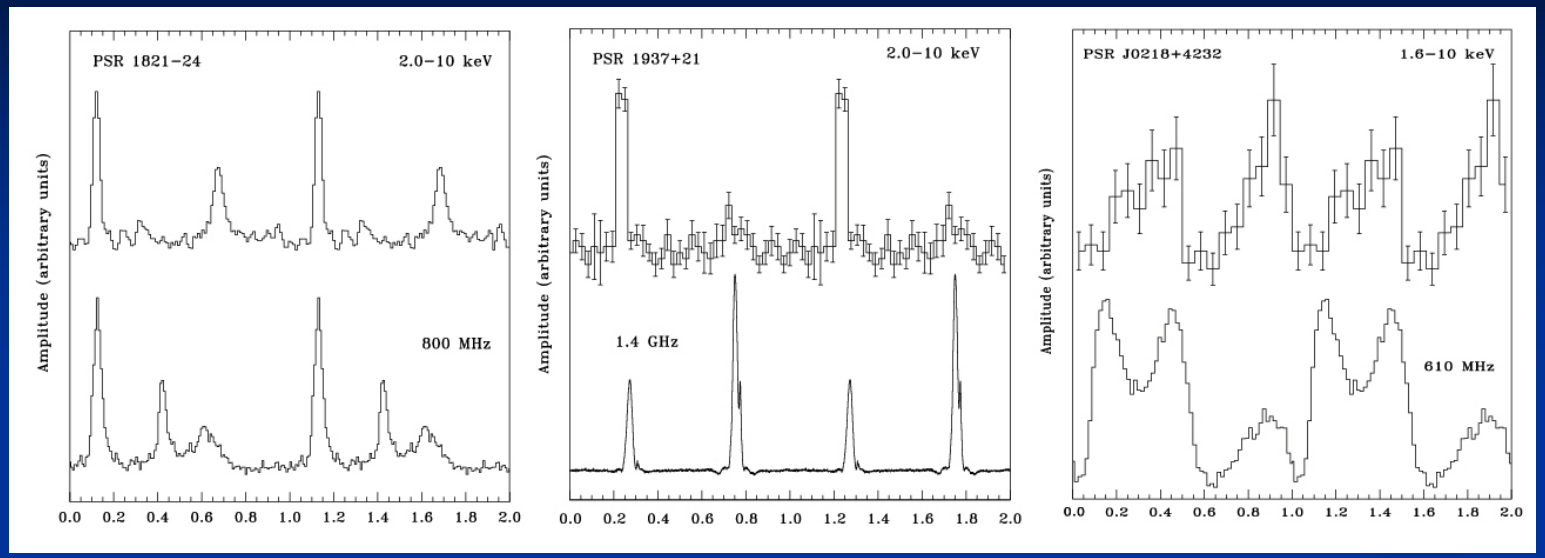
- Most pulsars will be detected with a photon statistics sufficient to perform detailed spectral analysis !

On the Crab Pulsar's Relative Pulse Arrival



Improves the numbers obtained by *Rots et al.* and *Kuiper et al. 2004*

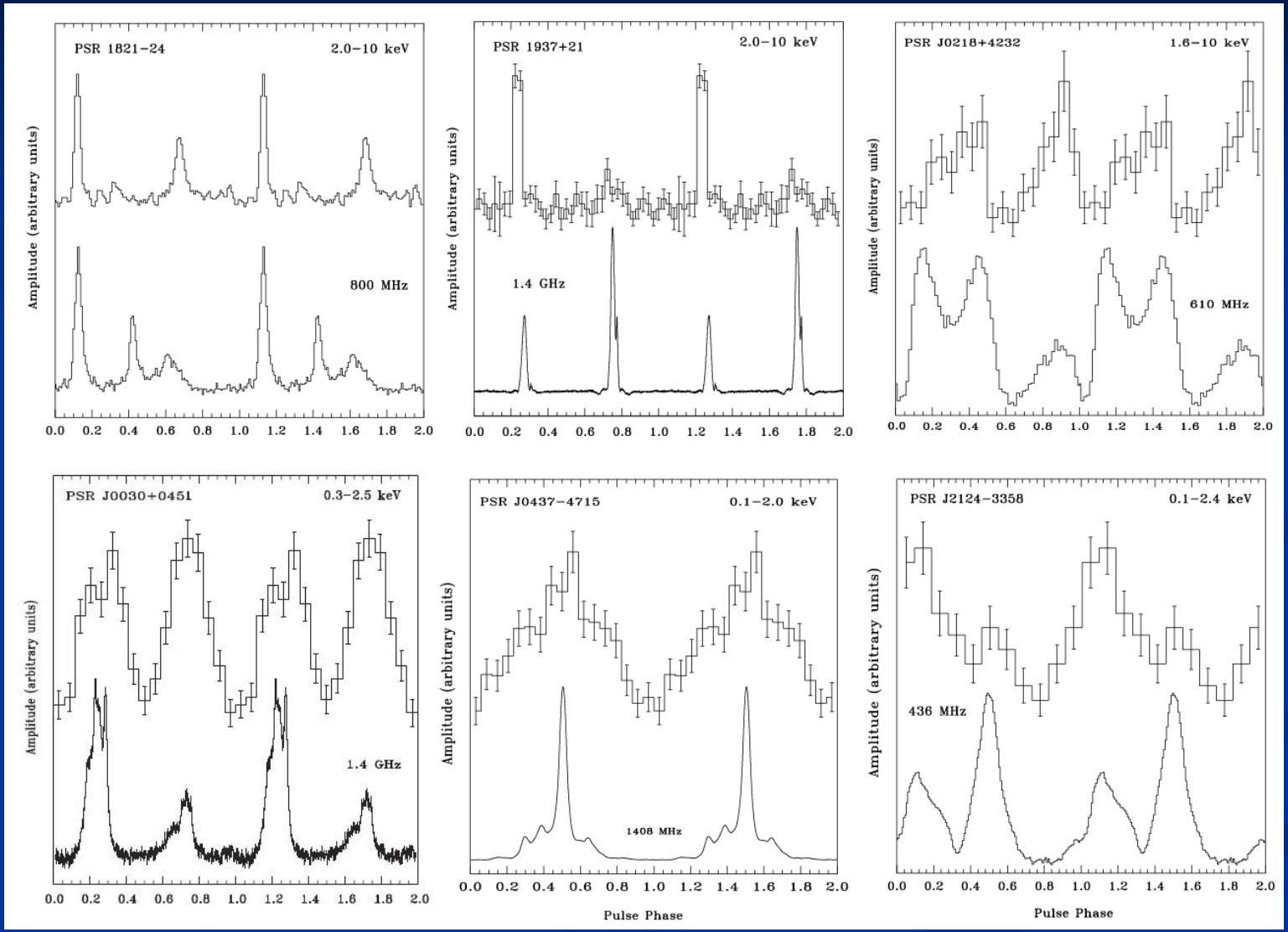
6 of 10 X-ray Pulse Profiles of Millisecond Pulsars



Pulsed fraction between ~ 30 - 100%

Becker 2009

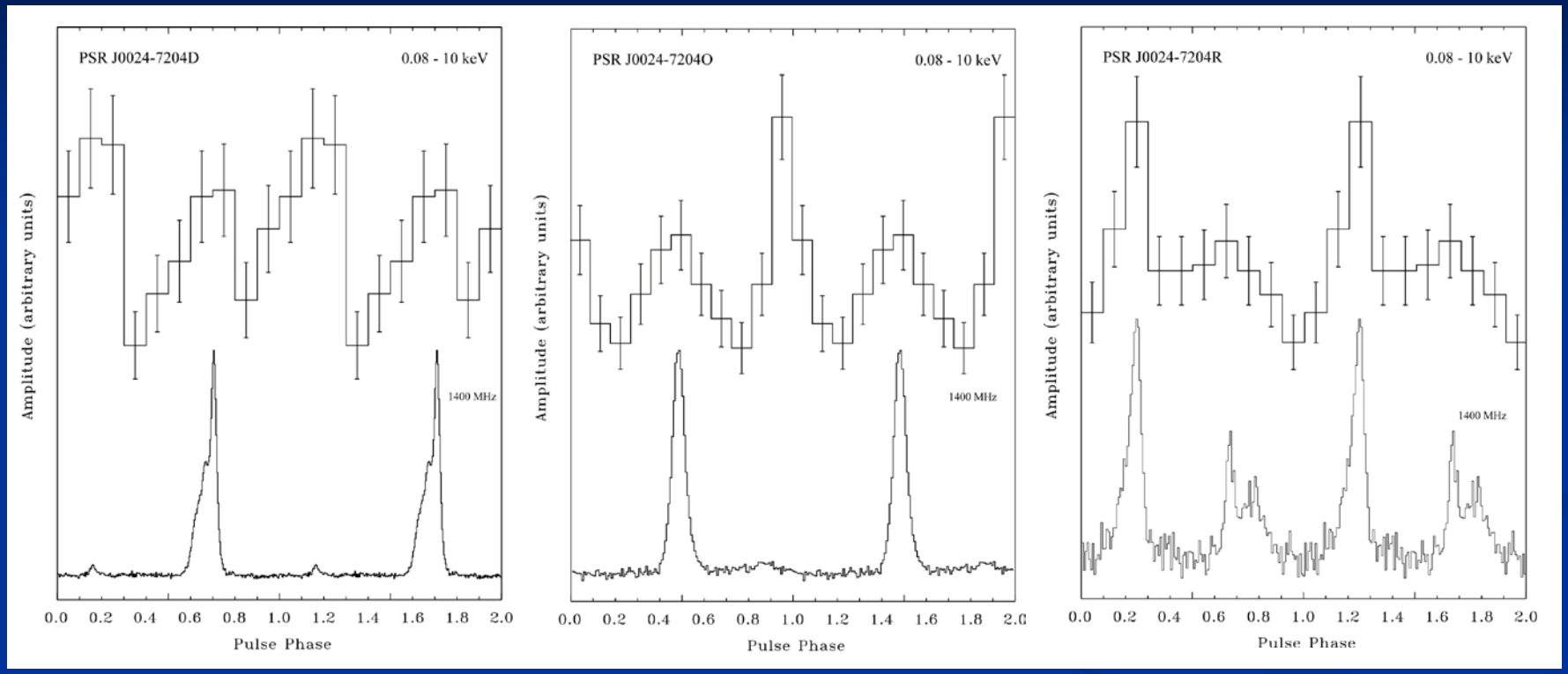
6 of 10 X-ray Pulse Profiles of Millisecond Pulsars



Pulsed fraction between ~ 30 - 100%

Becker 2009

X-ray Pulse Profiles of 47 Tuc Millisecond Pulsars



Becker, Huang, Prinz 2010

Still many open questions ……

- How are the different manifestations of neutron stars related to each other?
- What are the physical parameters which differentiate AXPs/SGRs/CCOs/XDINs/PSRs ?
- What decides that a collapsing star will end in a Crab-like pulsar or in a CCO ?

❖ EOS:

- What is the maximal upper bound for a neutron star mass ?
- What is the range of possible neutron star radii ?
- Is there any exotic matter in neutron stars (do strange stars exist) ?

❖ Emission Process:

- How can we relate e.g. the spectra observed at radio, optical, X- and gamma-rays to get a general understanding of the emission processes operating in the NS magnetosphere ?

... so stay tuned for eROSITA !

eROSITA team ...

PI: Peter Predehl

Co-Is: Hans Böhringer, Ulrich Briel, Hermann Brunner, Evgeniy Churazov, Michael Freyberg, Peter Friedrich, Günther Hasinger, Eckhard Kendziorra, Dieter Lutz, Norbert Meidinger, Mikhail Pavlinsky, Andrea Santangelo, Jürgen Schmitt, Axel Schwope, Matthias Steinmetz, Lothar Strüder, Rashid Sunyaev, Jörn Wilms, Nico Cappelluti, Alexis Finoguenov, Marcella Brusa

System Engineer: Josef Eder
Product Assurance: H. Bräuninger, M. Hengmith
Electronics Engineering: W. Bornemann, O. Hälker, S. Hermann, W. Kink, S. Müller, Th. Schanz, O. Hans
Mechanical Engineering: H. Huber, Chr. Rohé, L. Tiedemann, R. Schreib, B. Mican, K. Lehmann, H. Eibl, F. Huber, R. Sandmair
Mirror System, PANTER: P. Friedrich, W. Burkert, M. Freyberg, B. Budau, V. Burwitz
Cooling, Thermal Engineering: M. Fürmetz
CCD-Camera: N. Meidinger, Robert Hartmann, E. Pfeffermann, G. Schächner, J. Elbs, S. Ebermayer
Attitude: A. Schwope
Calibration, Analysis: G. Hartner, K. Misaki, U. Briel, K. Dennerl, R. Andritschke, Chr. Tenzer
Laboratory, Tests: M. Vongehr, L. Hirschinger, K. Dittrich, F. Schrey
Ground Software, Simulation: H. Brunner, N. Cappelluti, G. Lamer, M. Mühlegger, J. Wilms, I. Kreykenbohm, Chr. Schmid
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- Univ. Tübingen/D
- Univ. Hamburg/D
- Univ. Erlangen-Nürnberg/D
- Astrophysikalisches Institut Potsdam/D
- Max-Planck-Institut für Astrophysik/D

Industry:

Kayser-Threde/D	Mirror System
Media Lario/I	Mirror Modules
Carl Zeiss/D	Mirror Mandrels
Invent/D	Telescope Structure
pnSensor/D	CCDs