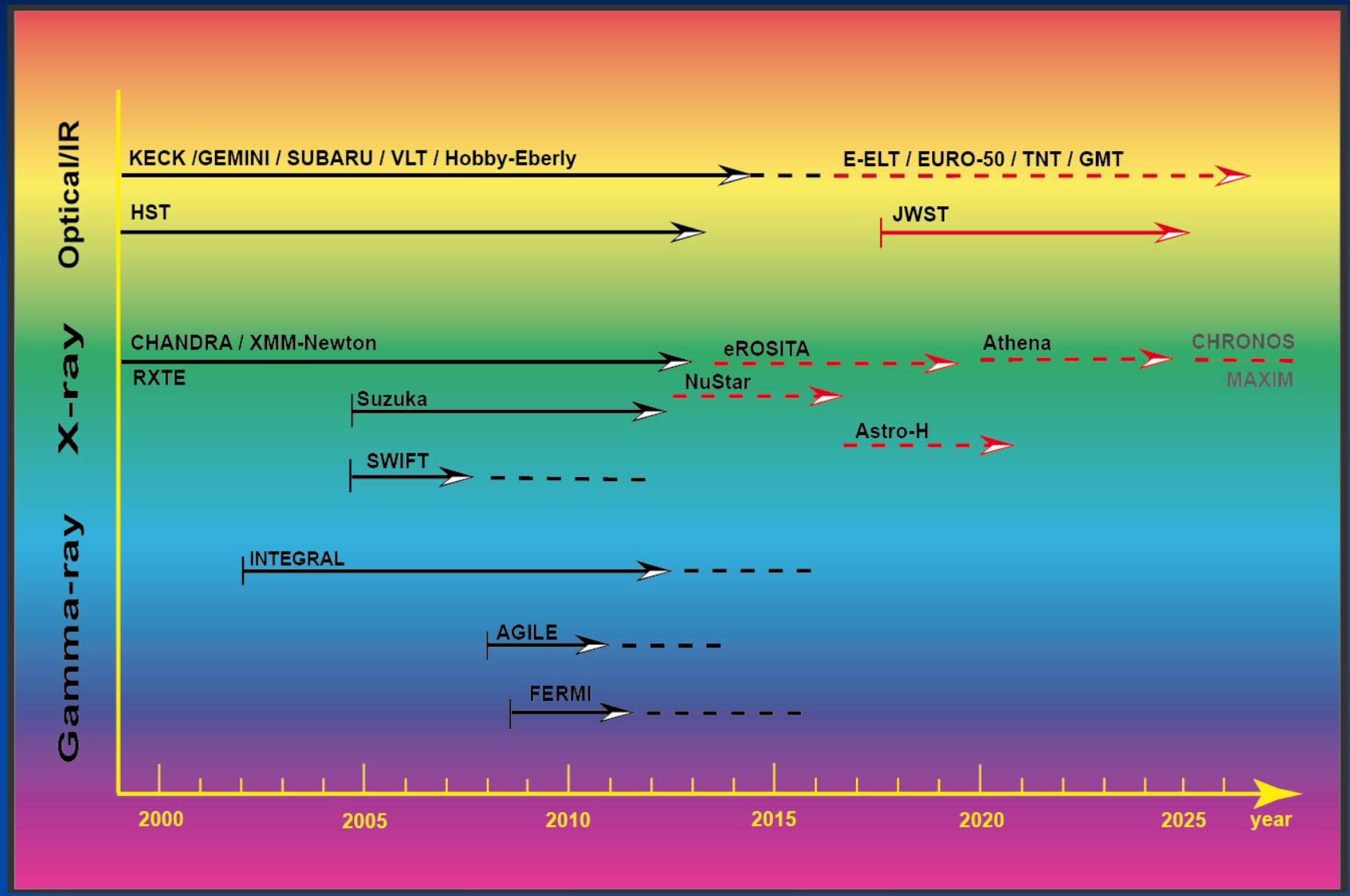
The eROSITA All-Sky Survey

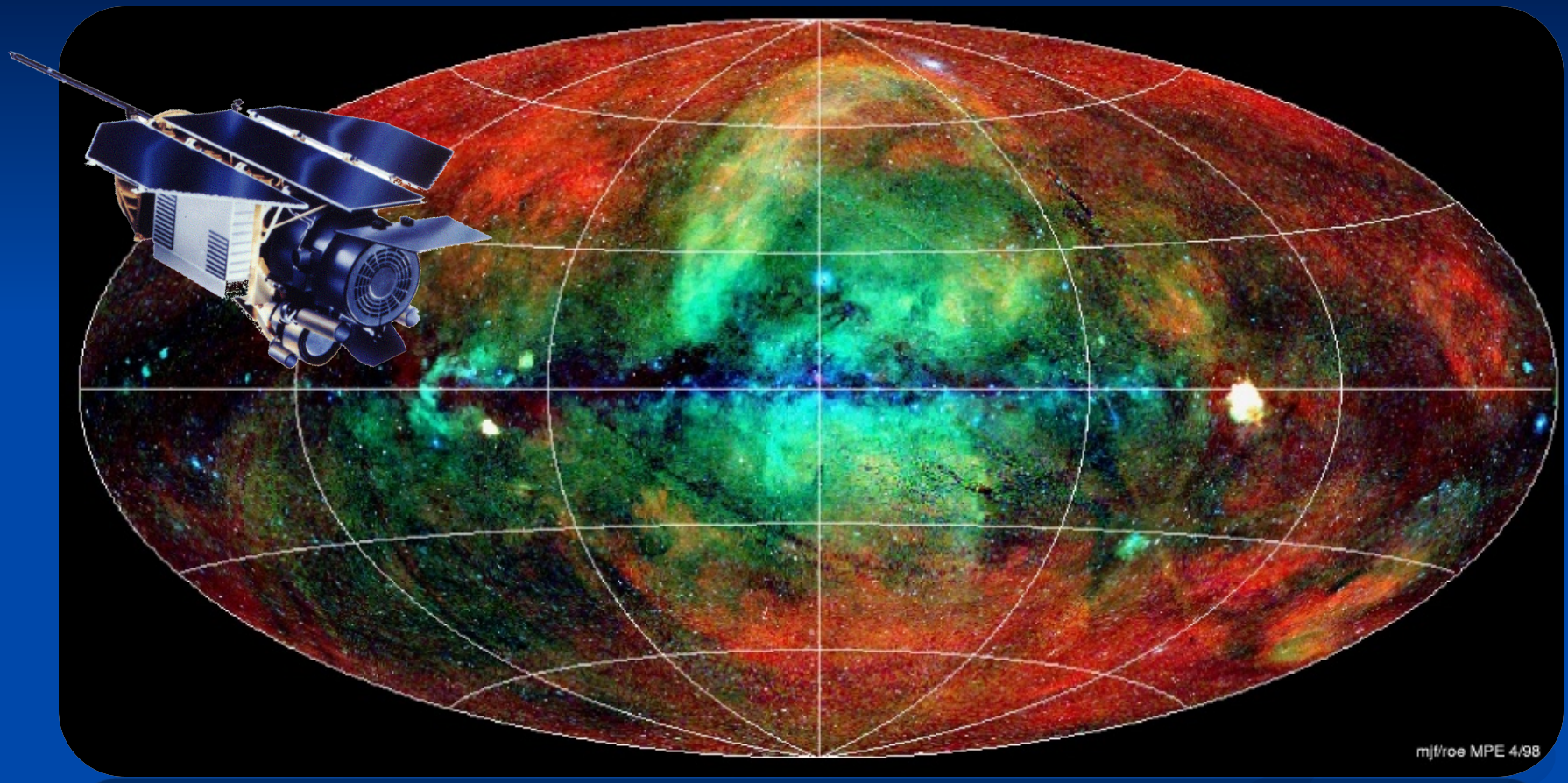
W.Becker on behalf of the eROSITA Team

Max-Planck Institut für extraterr. Physik

Observatories and mission timelines



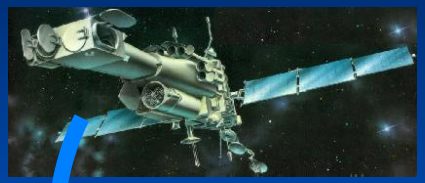
Basic Scientific Idea ….



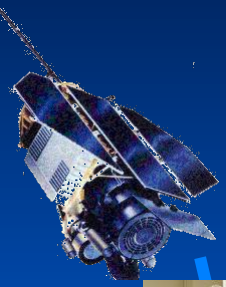
to extend the ROSAT all-sky survey up to 10 keV with an XMM-Newton type sensitivity

Historical Development

Spectrum-XG
Jet-X, SODART, etc



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

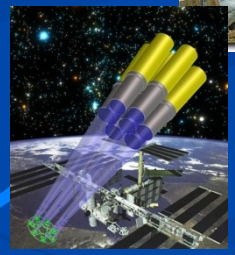


ABRIXAS 1999
To extend the all-sky survey
towards higher energies

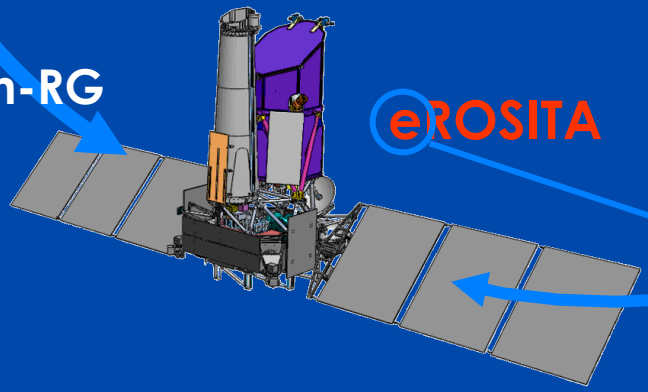
Negotiations between Roskosmos and ESA
on a "new" Spectrum-XG mission (2005)

Agreement between Roskosmos and DLR (2007)

ROSITA 2002
ABRIXAS science on the
International Space Station



Spectrum-RG



eROSITA

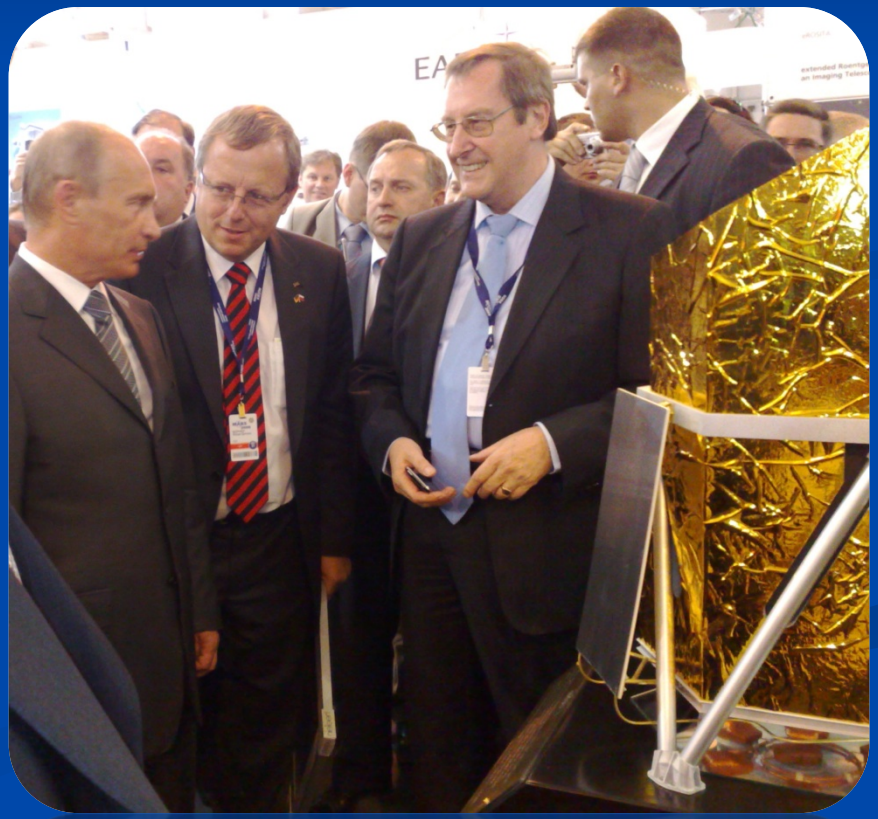
Dark Energy
10^5 Clusters of Galaxies

extended ROentgen Survey with an Imaging Telescope Array

eROSITA status: completely approved and funded

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

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



Mission scenario & Instrument specification

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

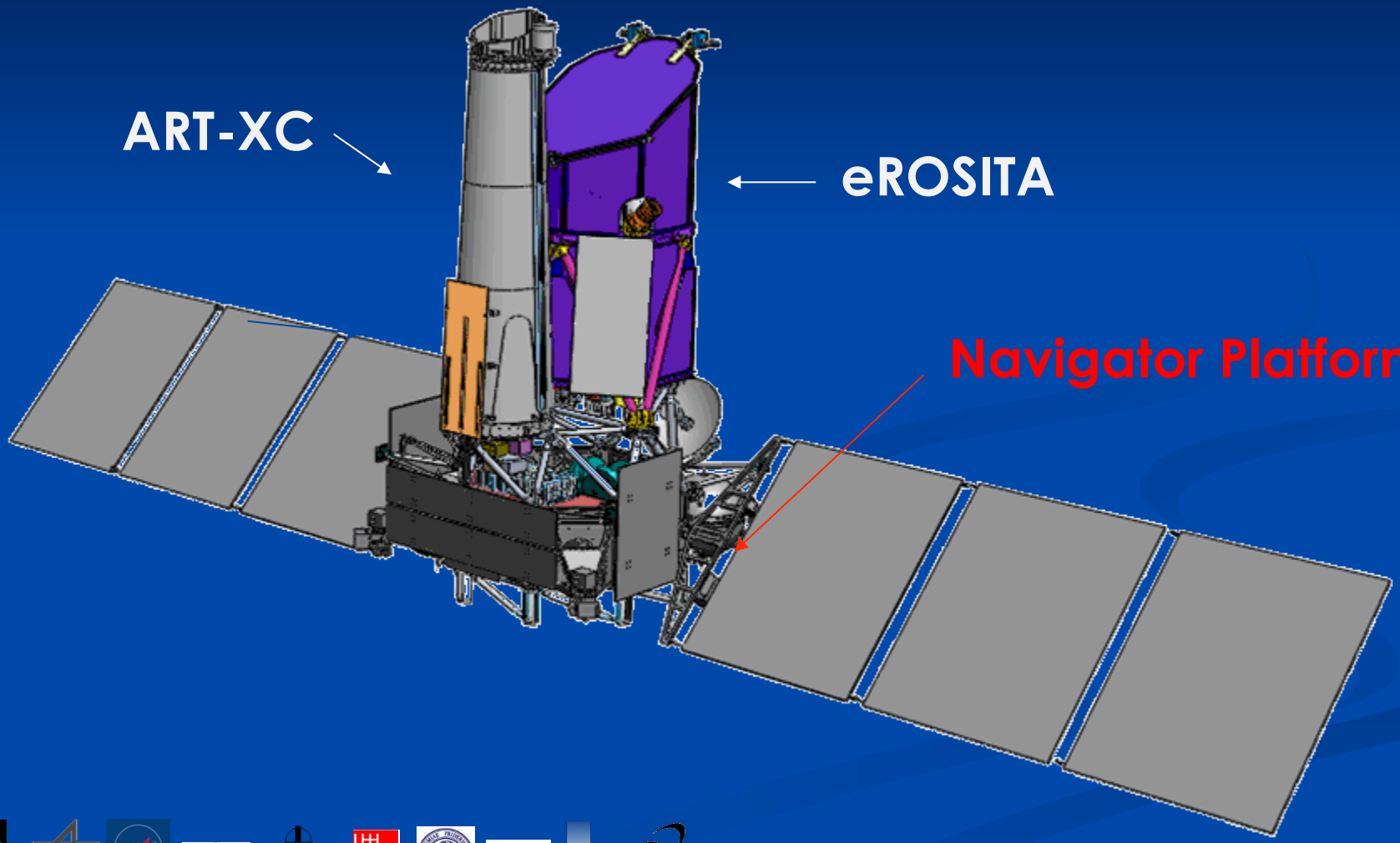
- Energy range 0.5 - 10 keV
- FOV: 1 degree
- All-sky survey sensitivity ~ 6 x10^{-14} erg cm^{-2} s^{-1} ~ (10 – 30) x ROSAT
- Deep survey field(s) (~100 sqdeg) with 5×10^{-15} erg cm^{-2} s^{-1}
- Temporal resolution ~ 50 ms
- Energy resolution ~ 130 ev @ 6 keV / 80 ev @ 1.5 keV
- Angular resolution ~ 15" (20" survey)

eROSITA: Launch date ....

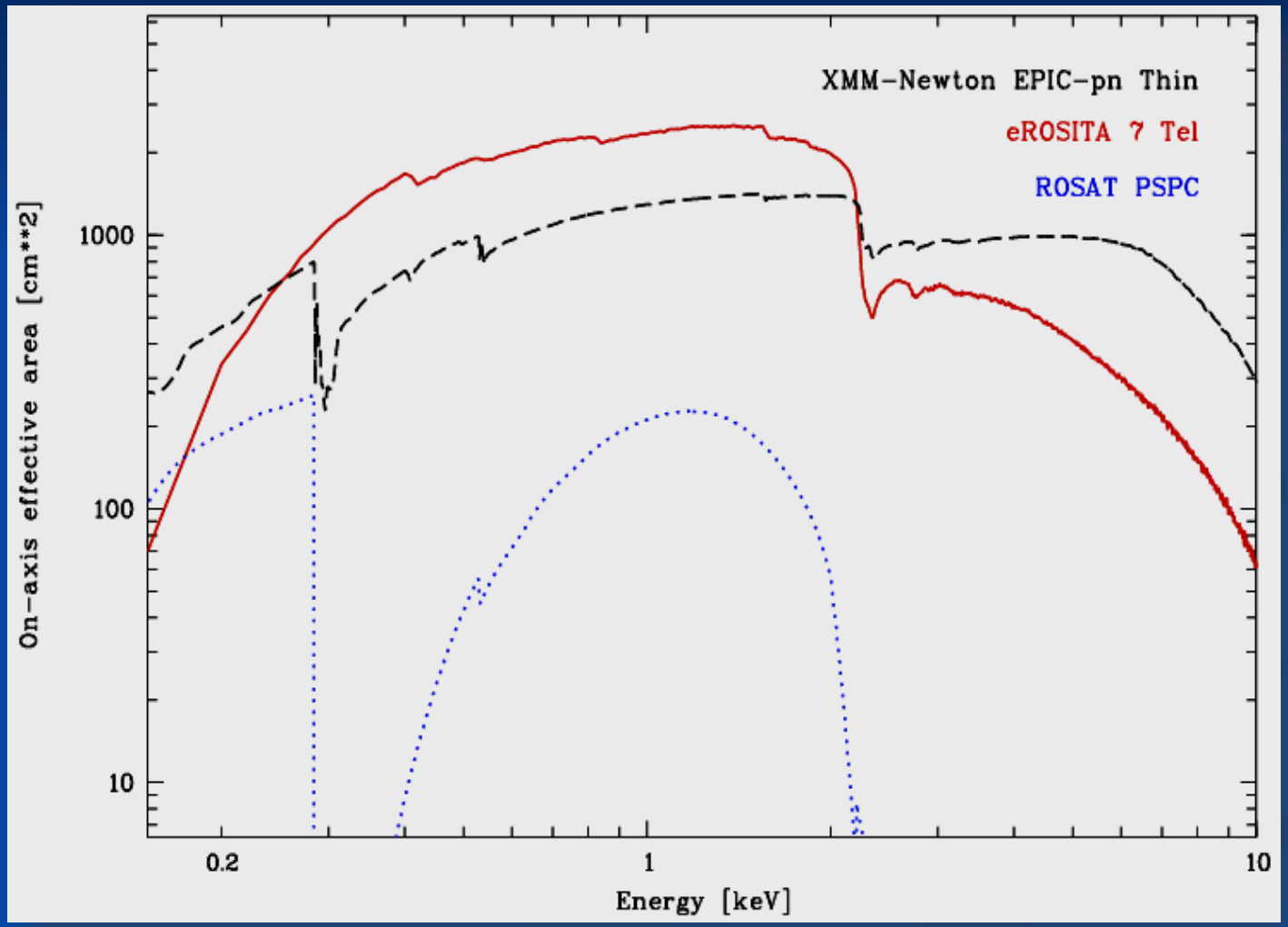
Nov. 20th / 16:45

2012

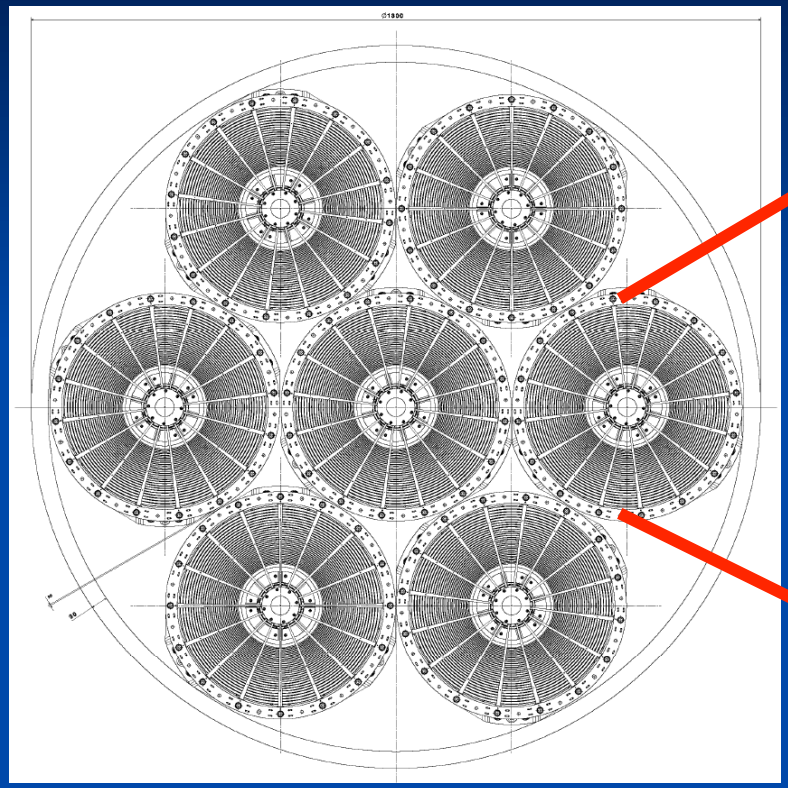
eROSITA on Spectrum-RG

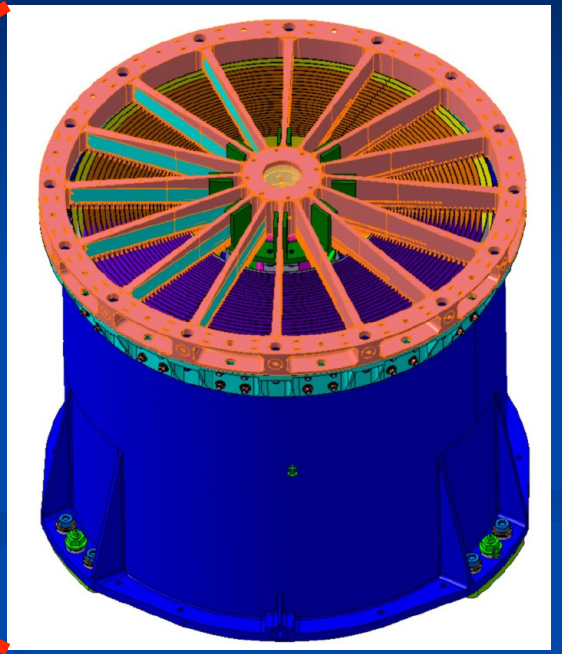


eROSITA: effective area 2400 cm^2 @ 1keV



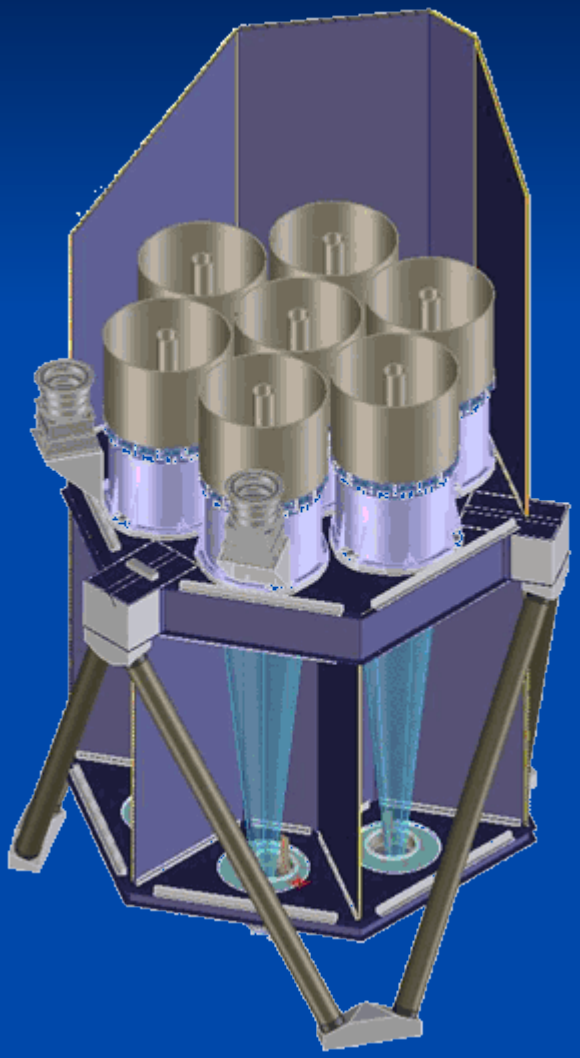
eROSITA: Mirror System





- 7 Mirror Modules, 54 shells each, 360mm Ø, f=1.600mm
- inner 27 shells to be replicated from old ABRIXAS mandrels

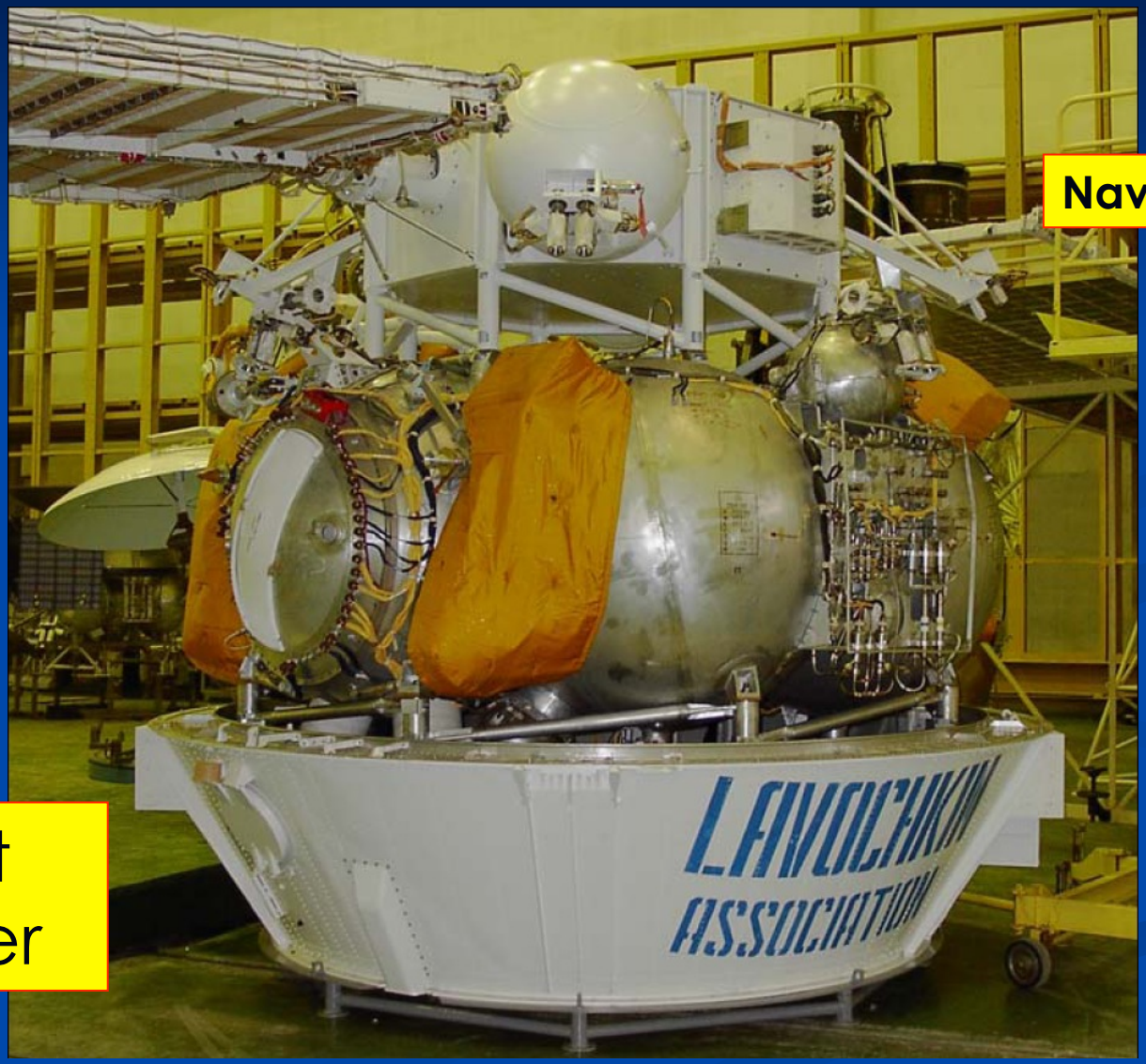
eROSITA Telescope Array



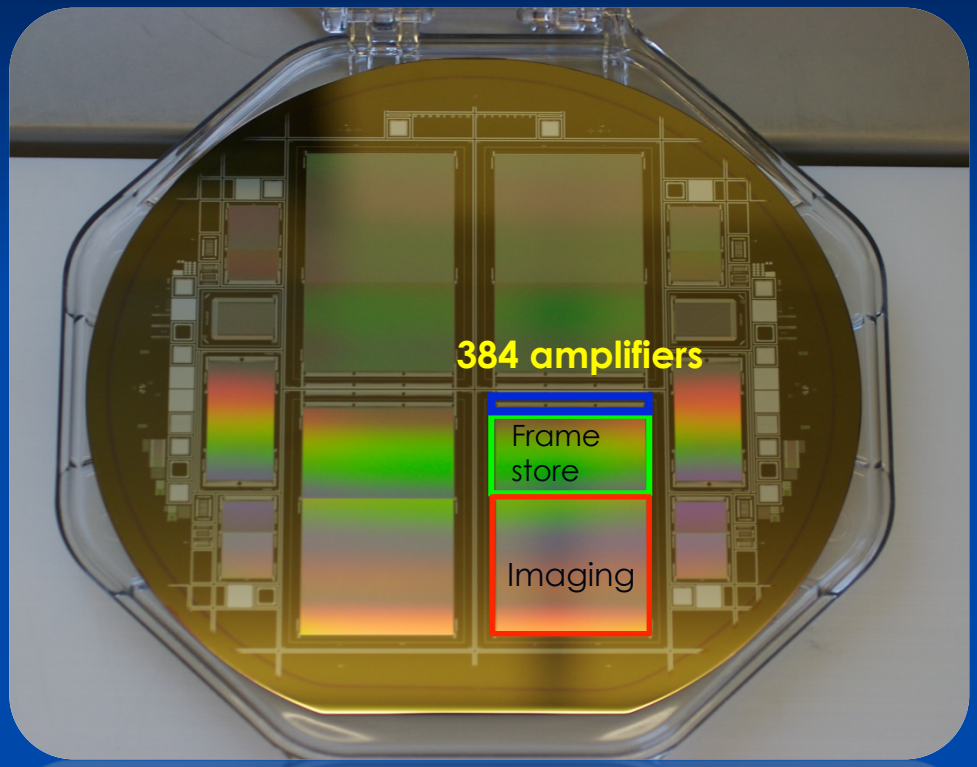
7 Mirror Systems

- ∅ 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

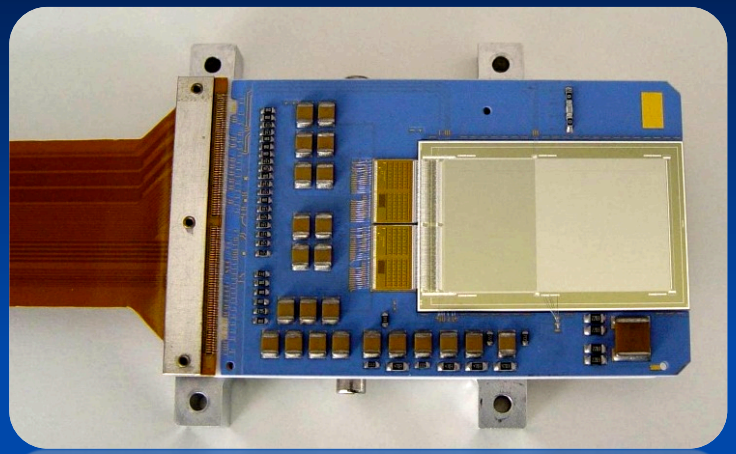
eROSITA: Navigator and Booster



eROSITA: Advanced XMM pn-CCD



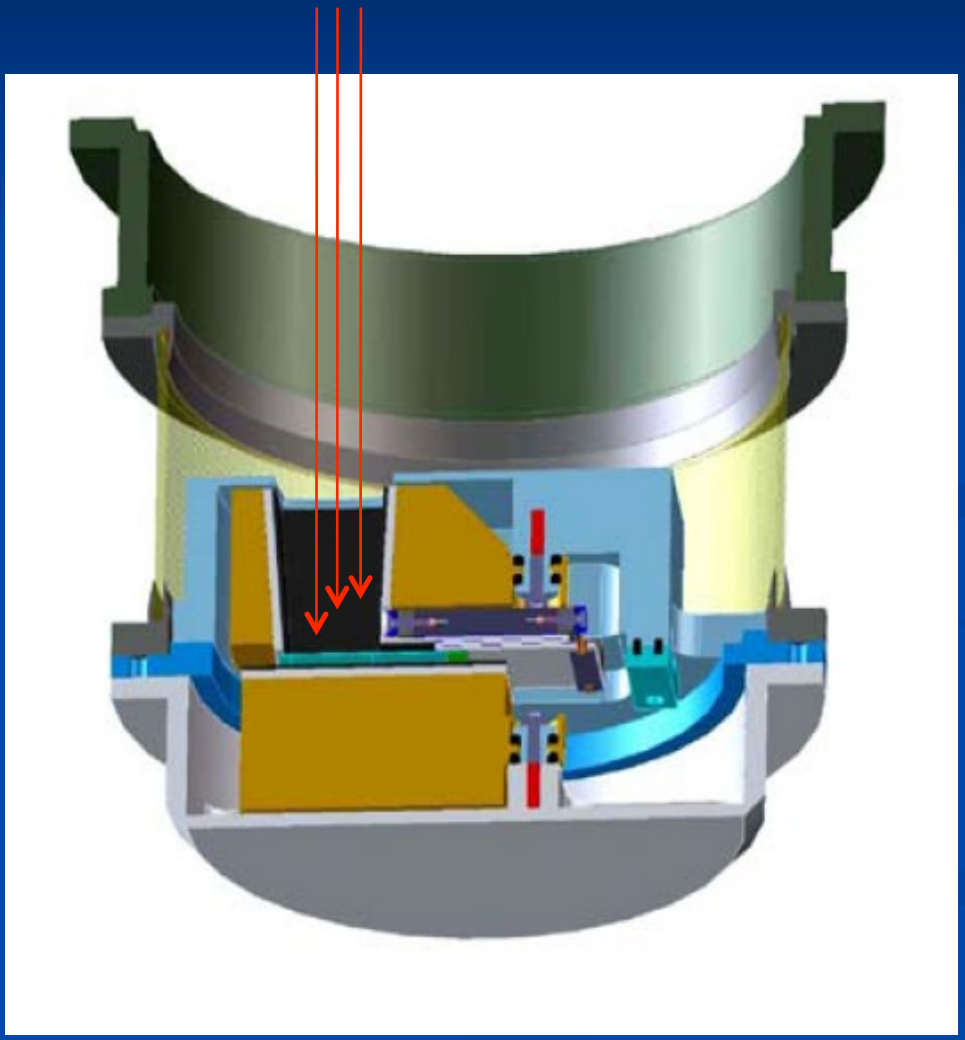
eROSITA pn-CCD flight devices



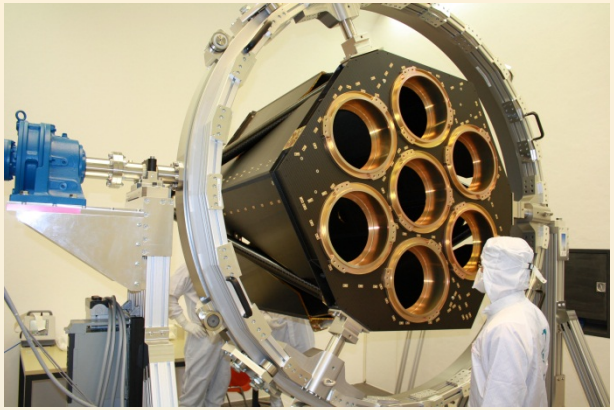
– 7 individual cameras

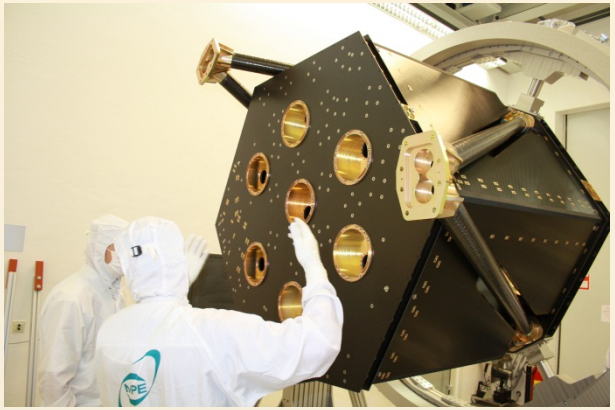
- 256 × 256 pixel, 75µm
- frame store area
- faster read-out
- 40% reduced out-of-time events
- temporal res. 50 ms

eROSITA: Focal Plane



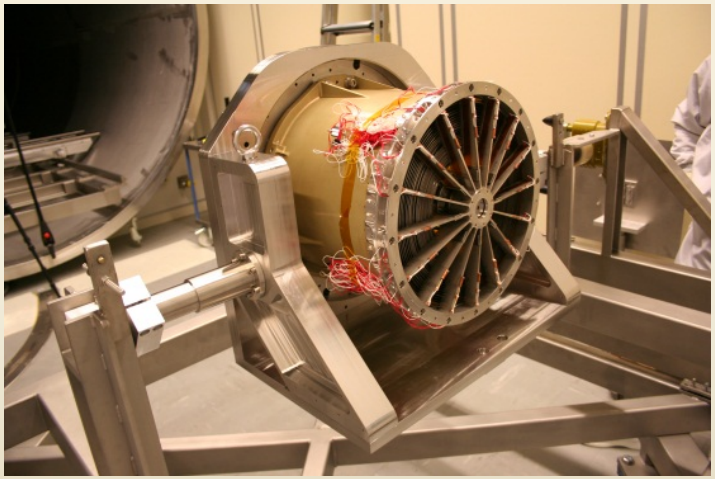
eROSITA Status

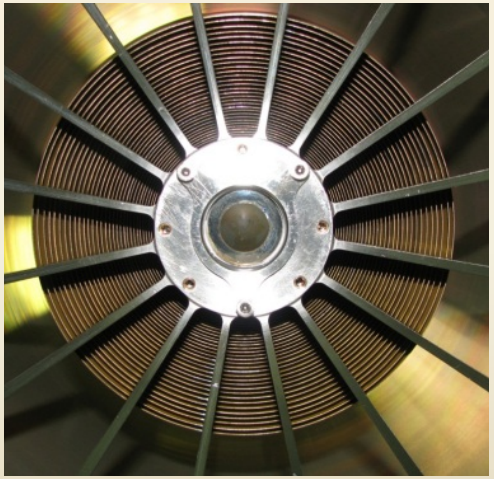




Telescope Structure

ready for integration of subsystems &components





Mirror Modules

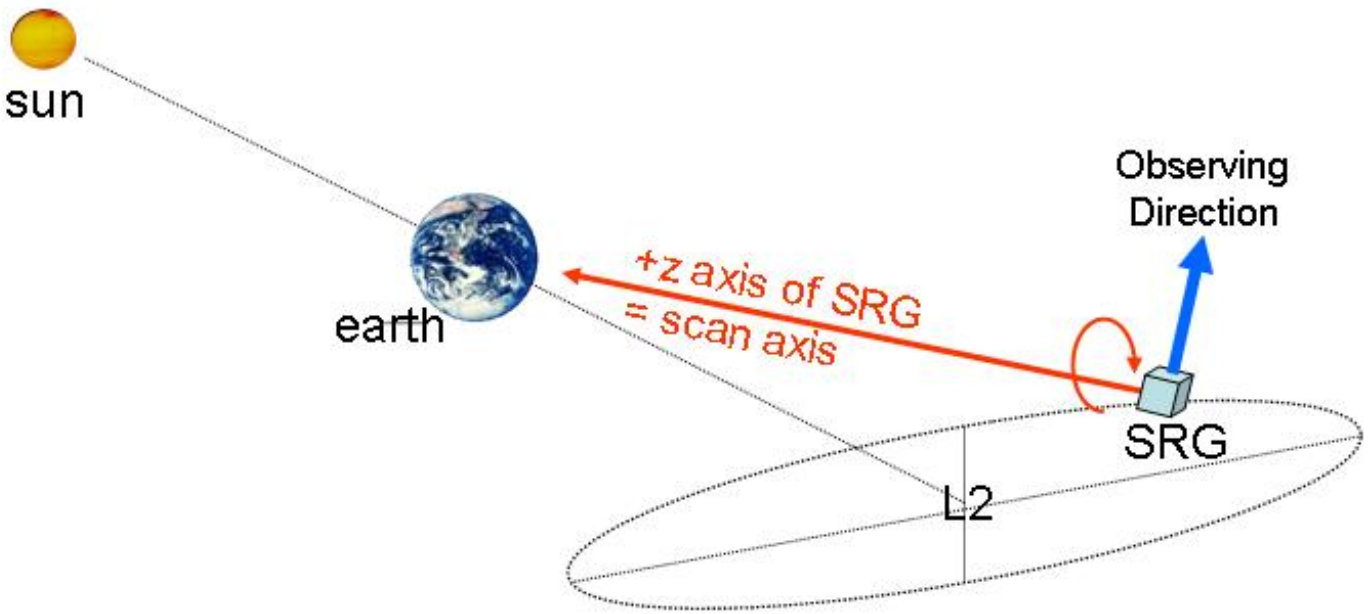
FM-production running

FM1 (31 shells) in spec.
FM2 (15 shells) in spec.

15 arcsec HEW, on-axis

eROSITA: Mission geometry during all-sky survey

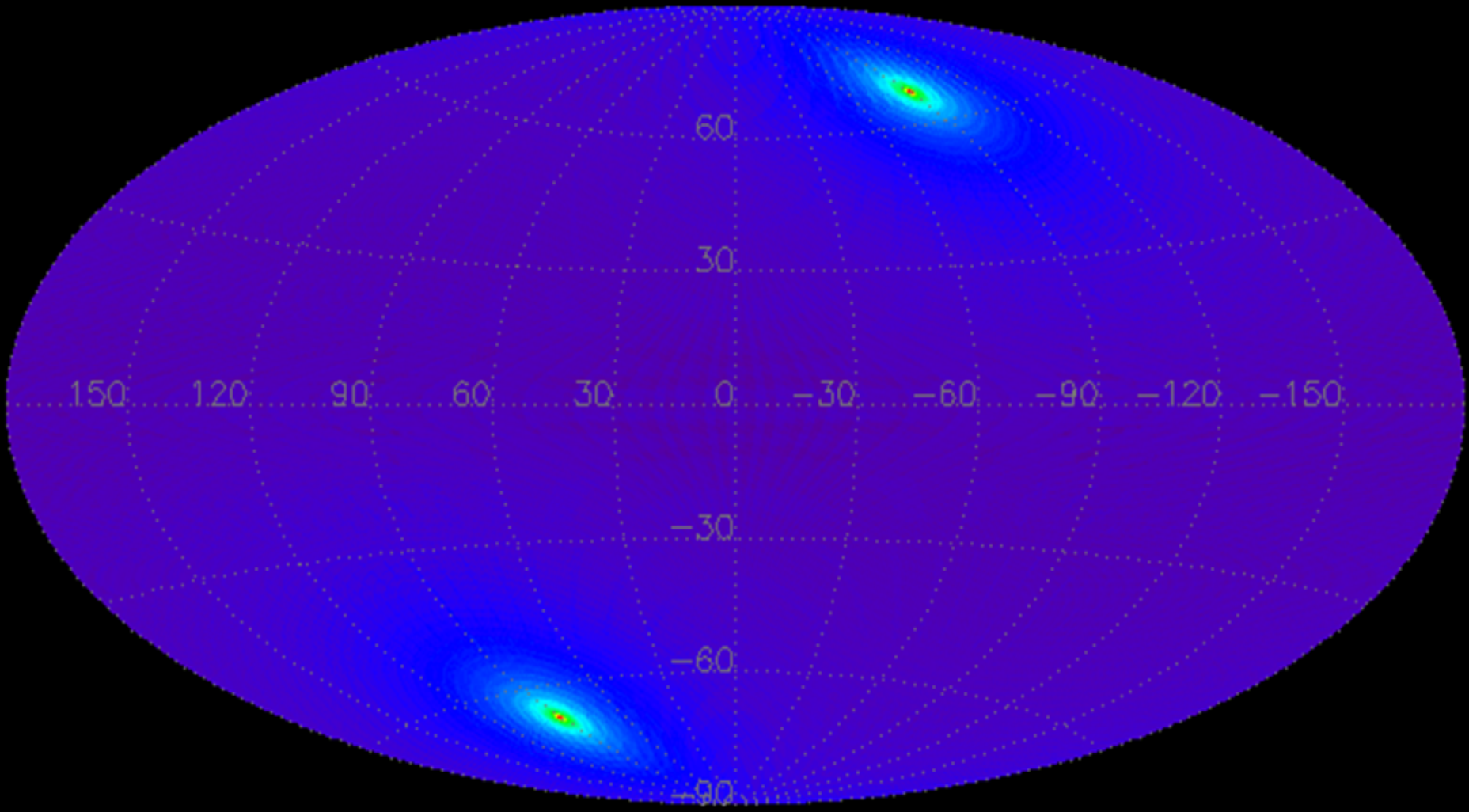
eROSITA L2 halo-orbit



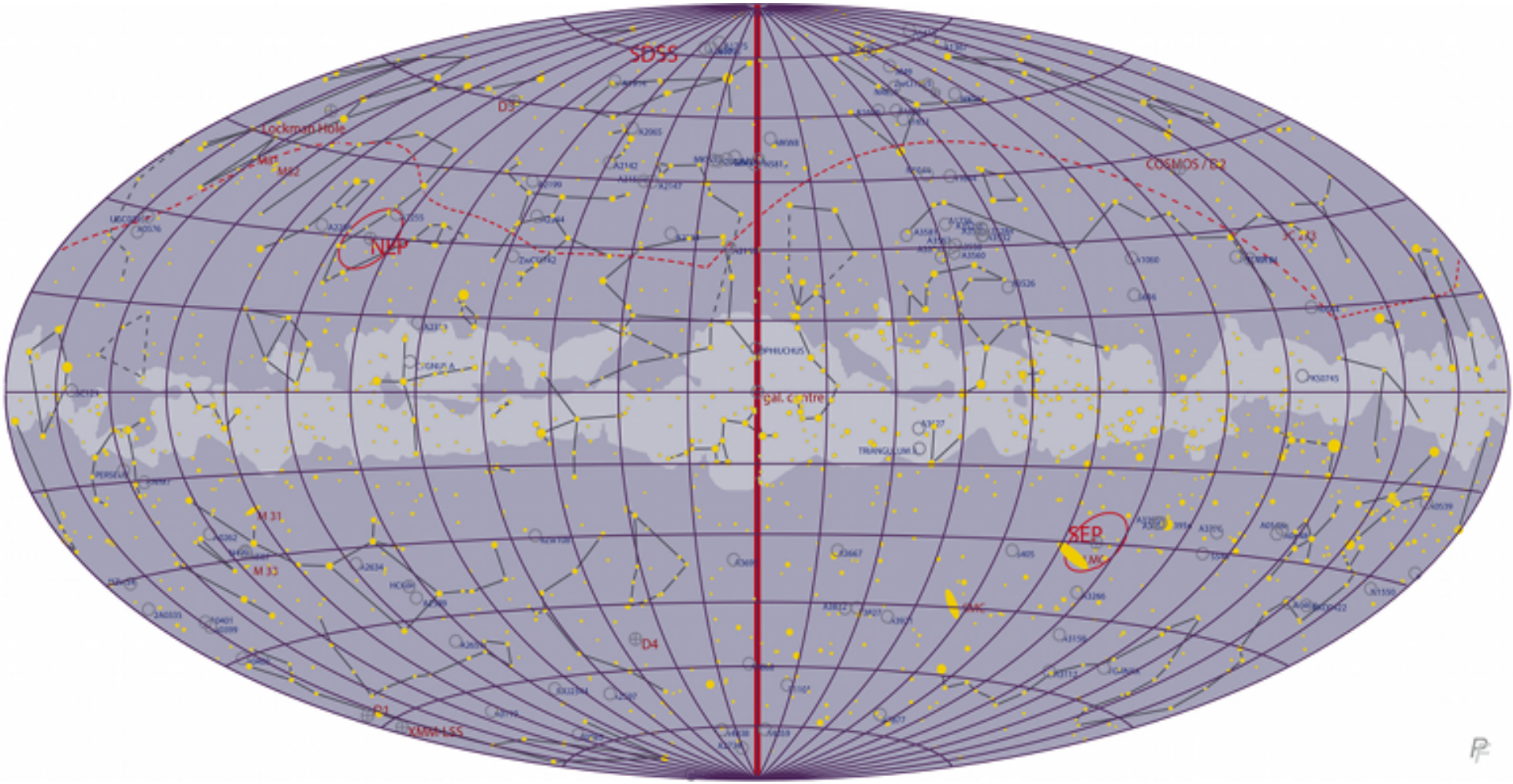
SRG is continuously rotating around the z-axis which always points to the earth

eROSITA: Exposure Map

~ 3-5 ksec in the plane



Sky (German/Russian) division



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, …

What's about Neutron Stars ?

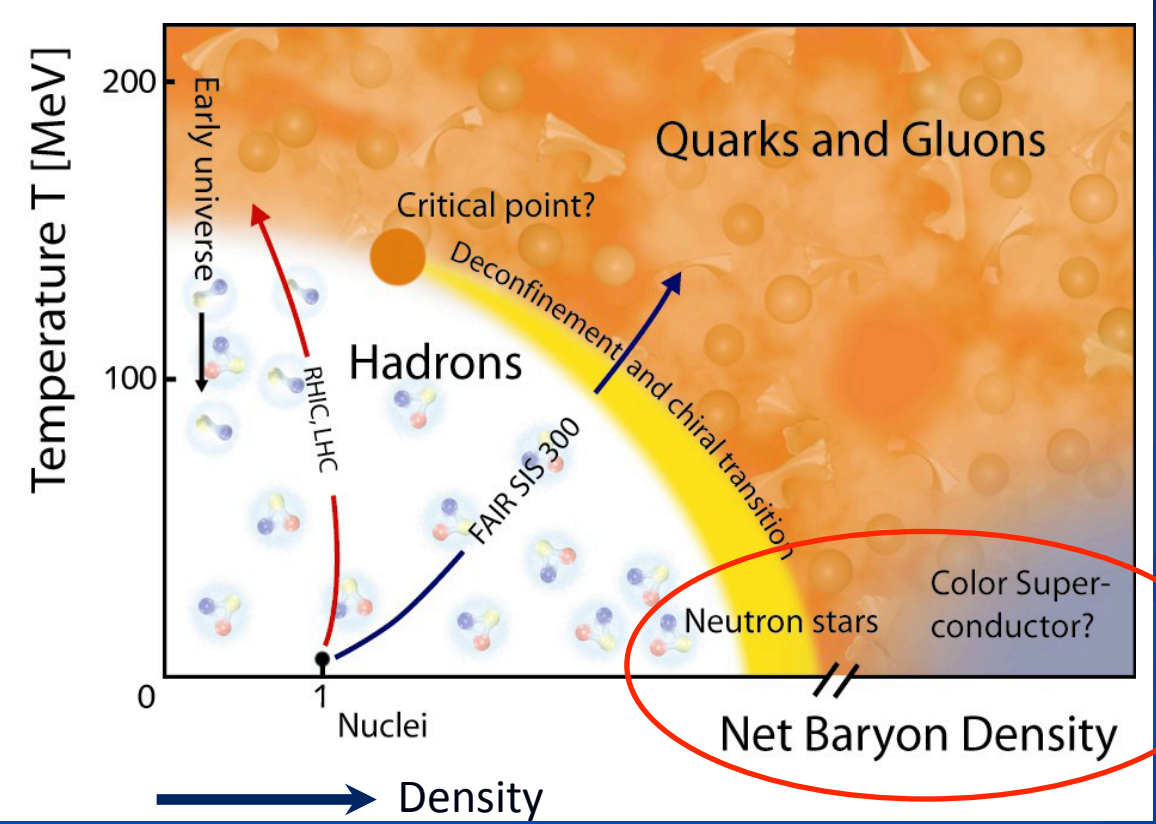
Neutron stars are the most compact objects which can be studied through direct observations (BHs can be observed only indirectly)

Extreme stellar parameters:

Mass	1,4 solar masses
Radius	10 km
Density	> 500 Million tons per cm^3
Gravitation	10 Billion g
Magnetic field	100 Billion Gauss
Rotation period	down to Milliseconds

- Neutron stars are quasi "Gigantic Atomic Nuclei" in the universe
- But why is it important to study these objects ?

Neutron stars probe the low temperature -- large density region of the QCD phase diagram

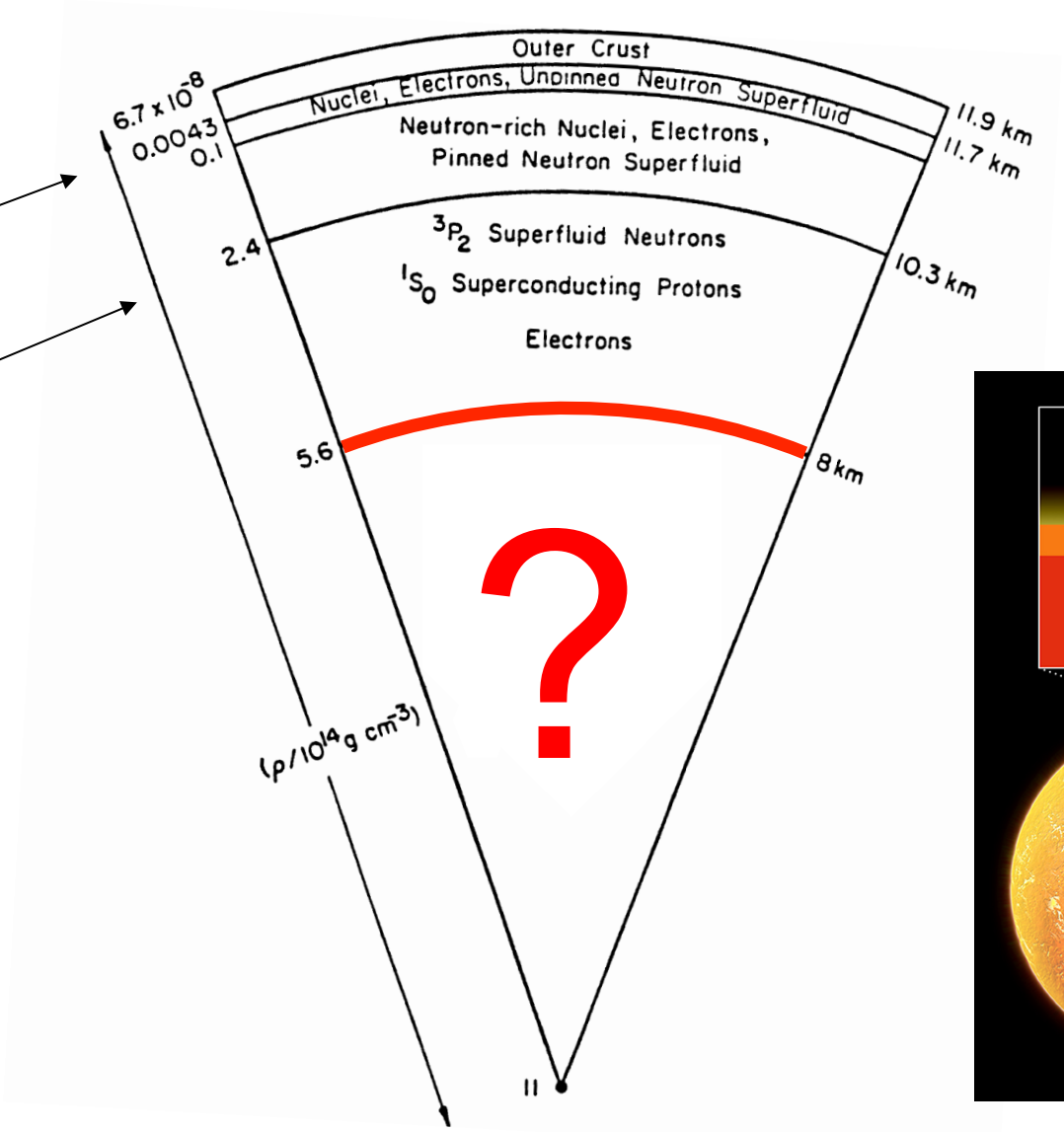


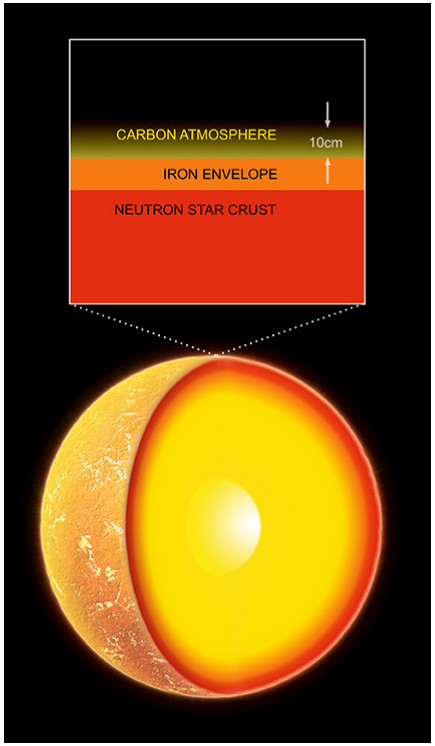
→ Equation Of State of cold nuclear matter at high density ?

Slice plane through a 1.4 Mo Neutron Stars

Neutron drip point

Nuclear density

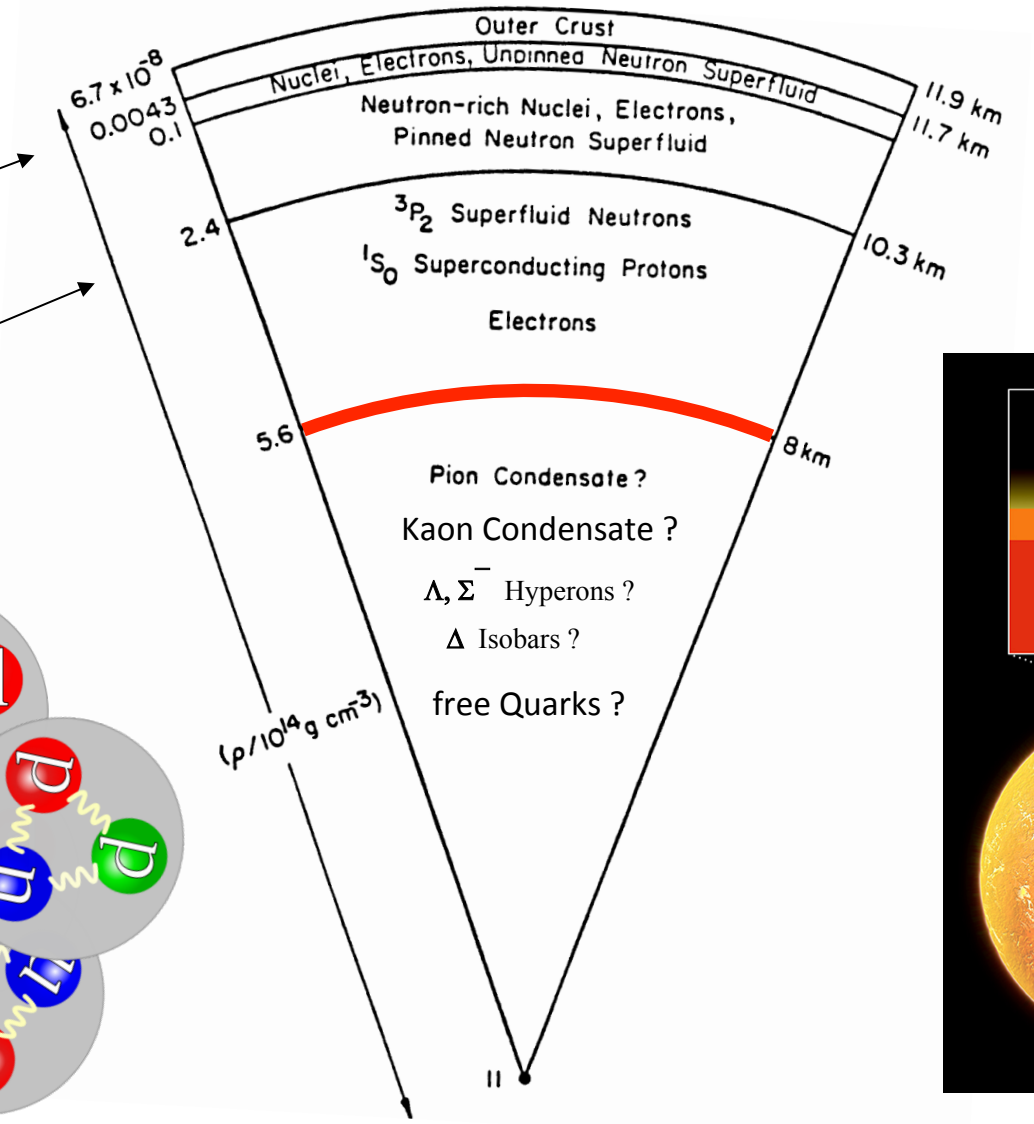


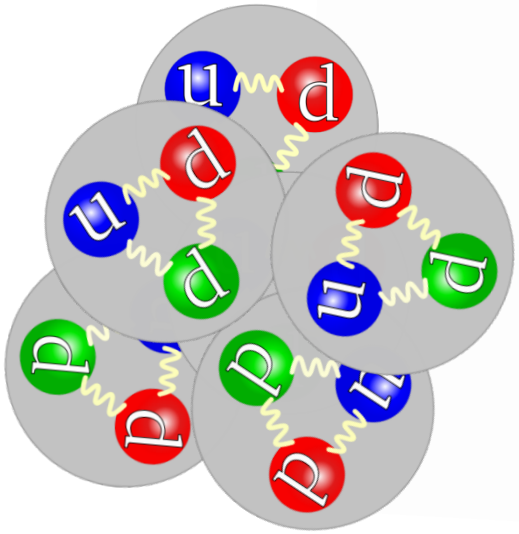


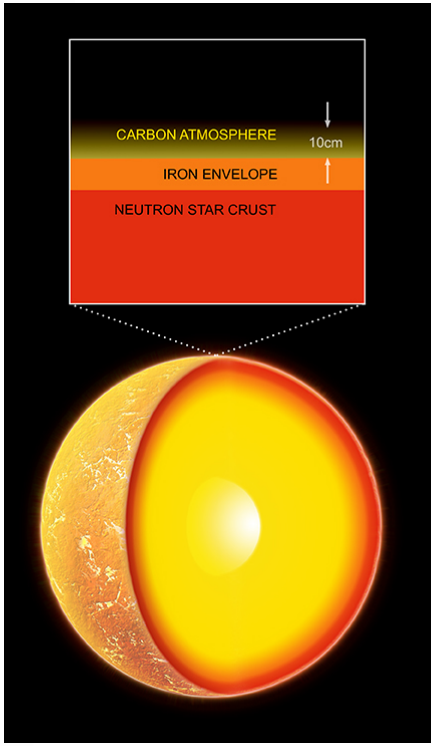
Slice plane through a 1.4 Mo Neutron Stars

Neutron drip point

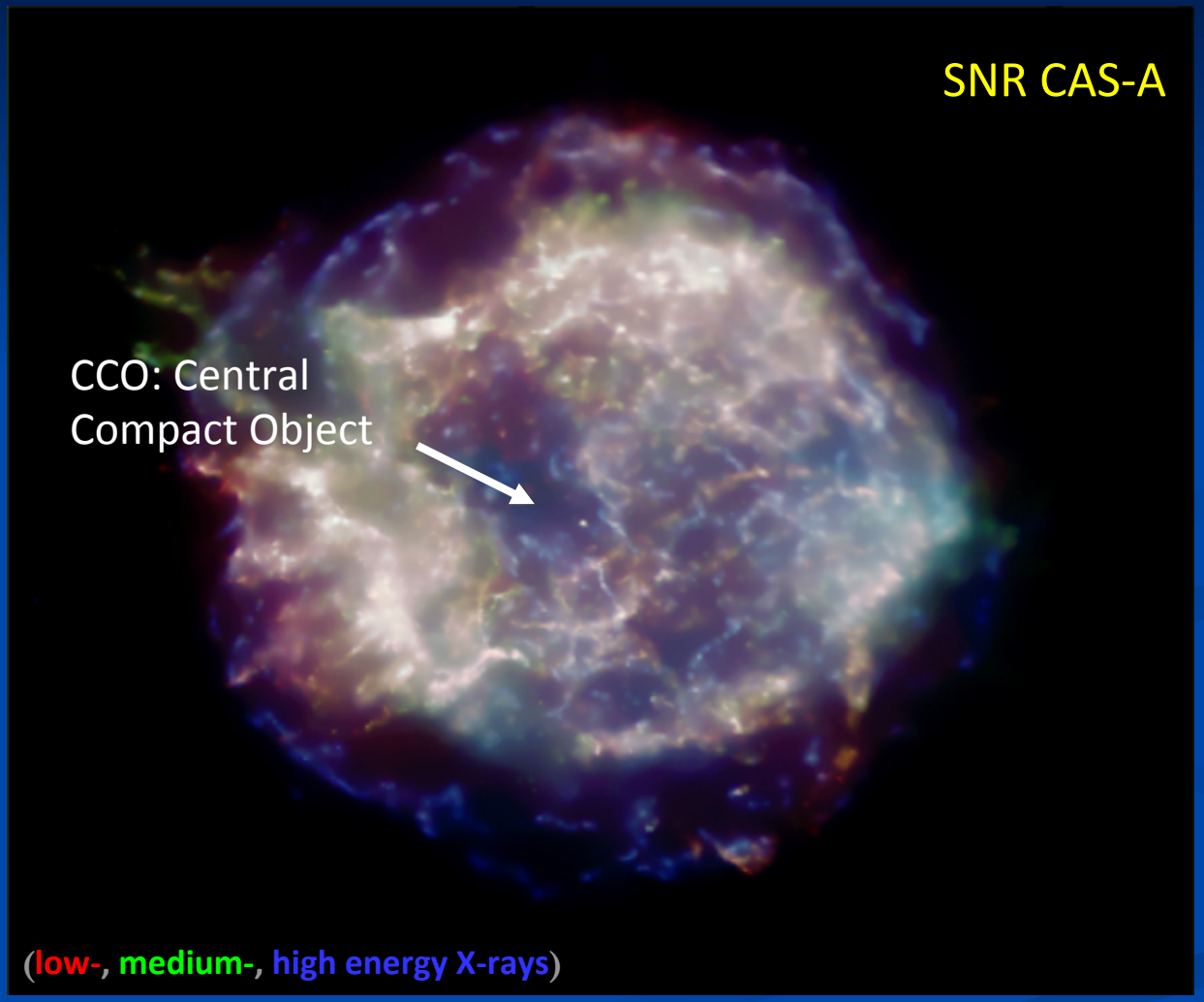
Nuclear density







Neutron stars represent an endpoint of stellar evolution



CCO has a temperature in the million degree range → spectrum peaks in X

Neutron Star Cooling

$$\frac{dE}{dt} = C_{\mathrm{v}} \frac{dT_i}{dt} = -L_\nu - L_\gamma + \sum_k H_k$$

The details on neutron star cooling depend strongly on the neutron star EOS, i.e. on the interaction of the particles sustaining the star

Neutron star cooling is sensitive to the EOS of cold dense mater !

Neutron Star Cooling ← → EOS of cold dense nuclear mater

Neutron star cooling…..

$$\frac{dE}{dt} = C_{\mathrm{v}} \frac{dT_i}{dt} = -L_{\nu} - L_{\gamma} + \sum_k H_k$$

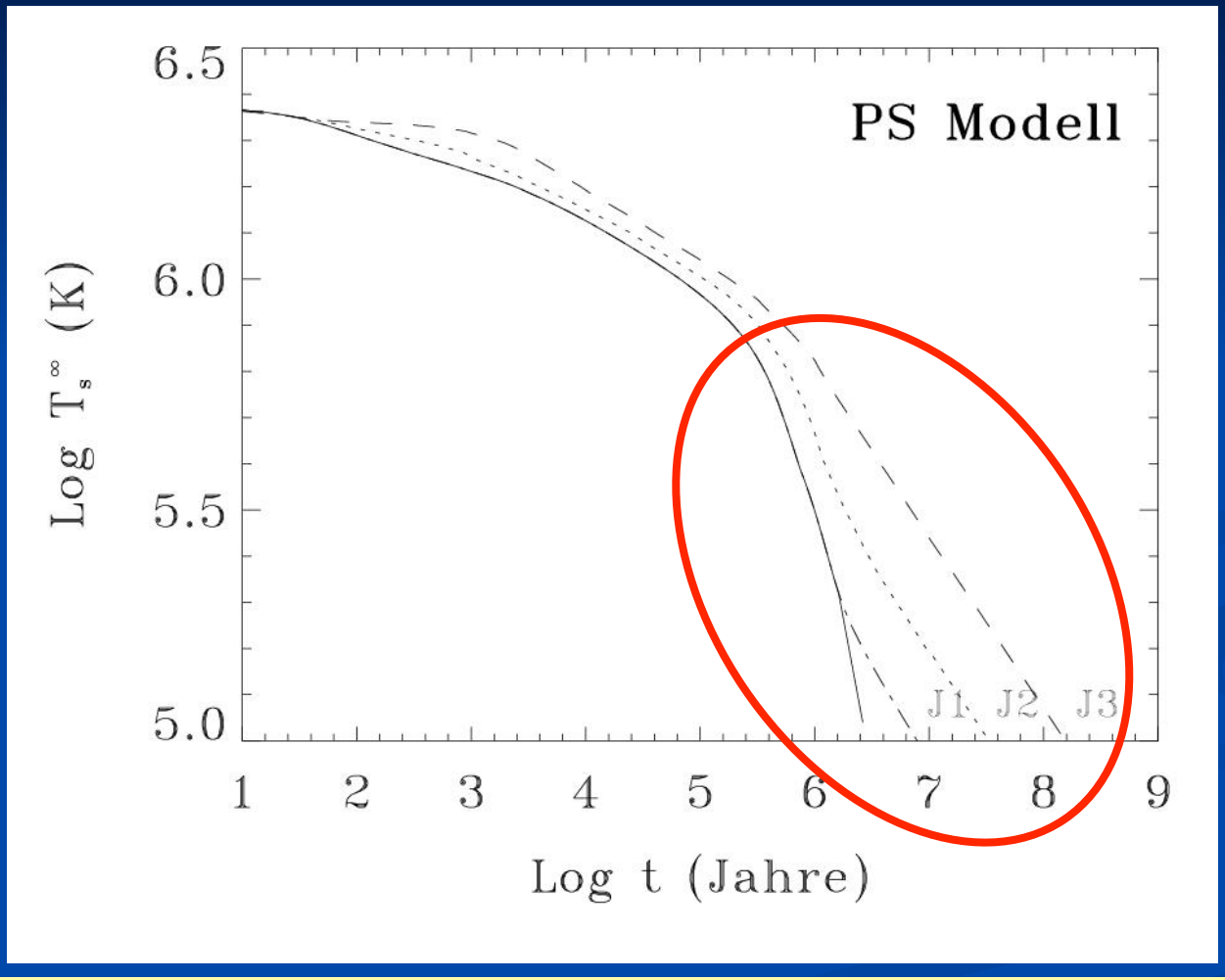
C_{v} : Specific heat capacity

L_{ν} : Neutrino luminosity

L_{γ} : Thermal luminosity

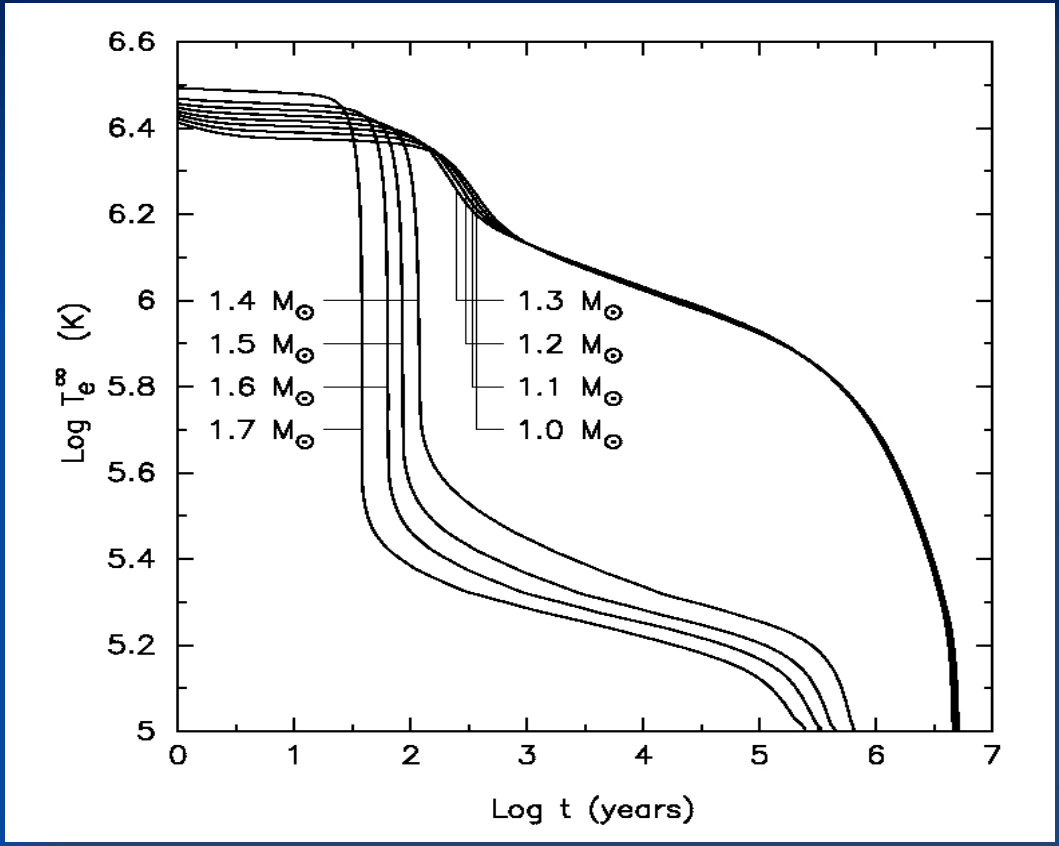
$\sum_k H_k$: Neutron star heating by e.g. vortex creep of superfluid neutrons or roto-chemical heating

Neutron Star Cooling ← → EOS of cold dense nuclear mater



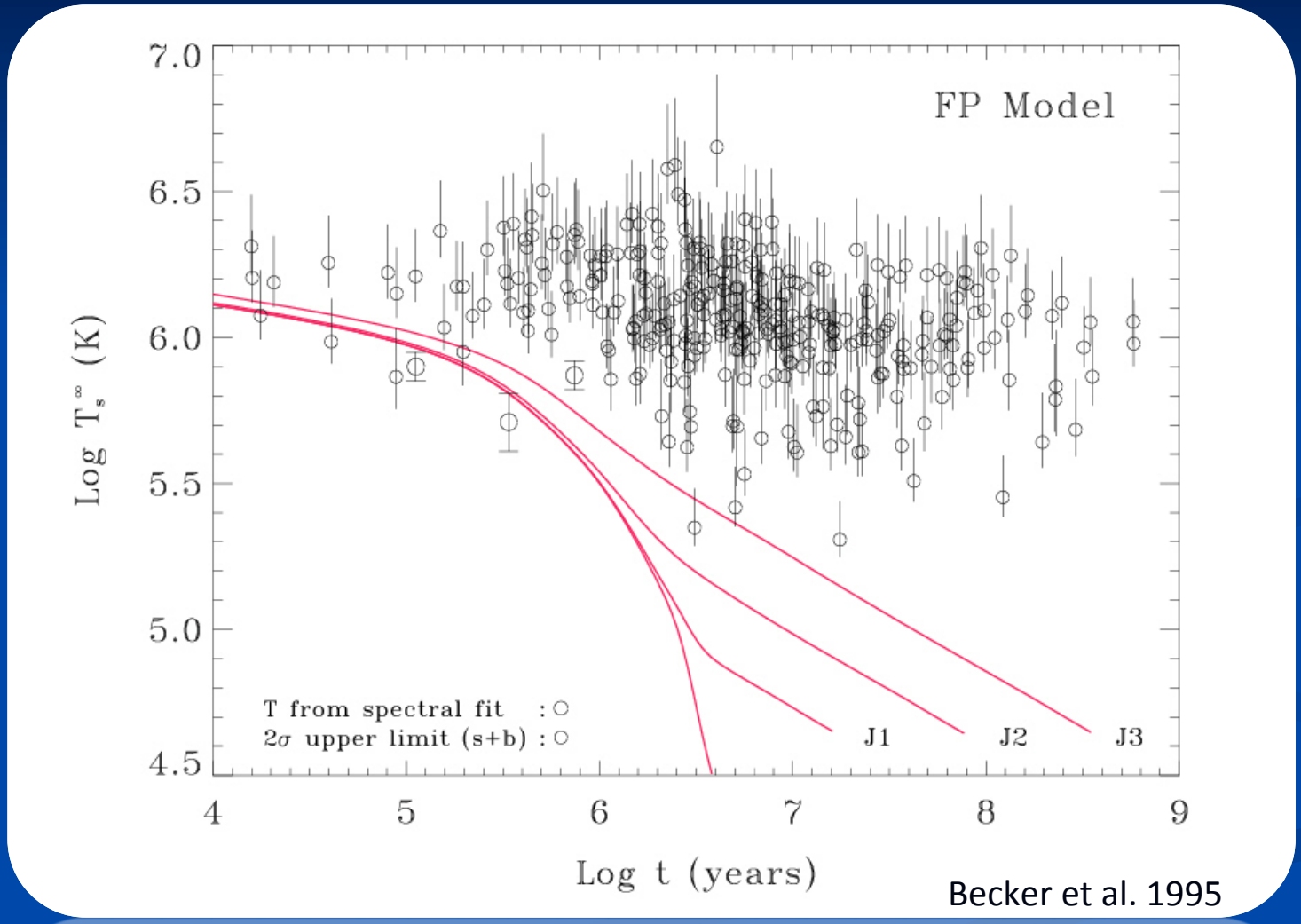
Neutron star cooling depends on heating rates

Neutron Star Cooling ← → EOS of cold dense nuclear mater



Observing thermal spectra from neutron stars yields the surface temperature AND the emitting area and hence the radius → R

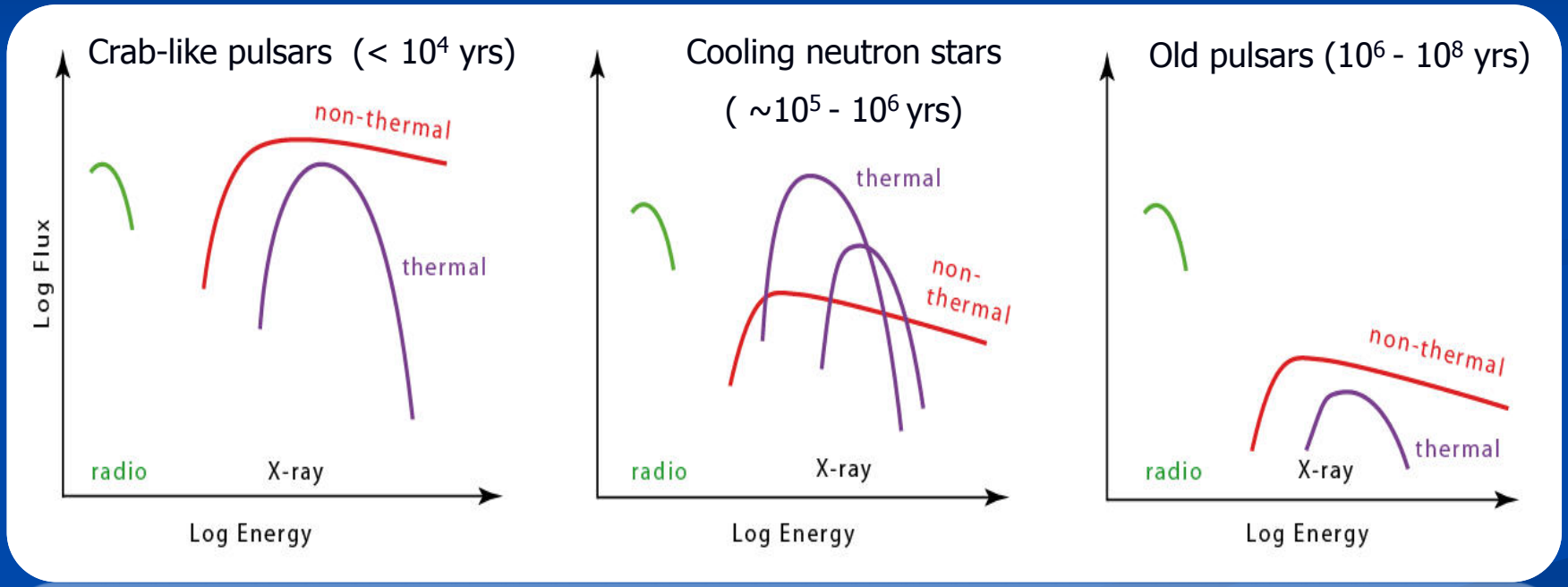
Temperature upper limits for all neutron stars in the survey



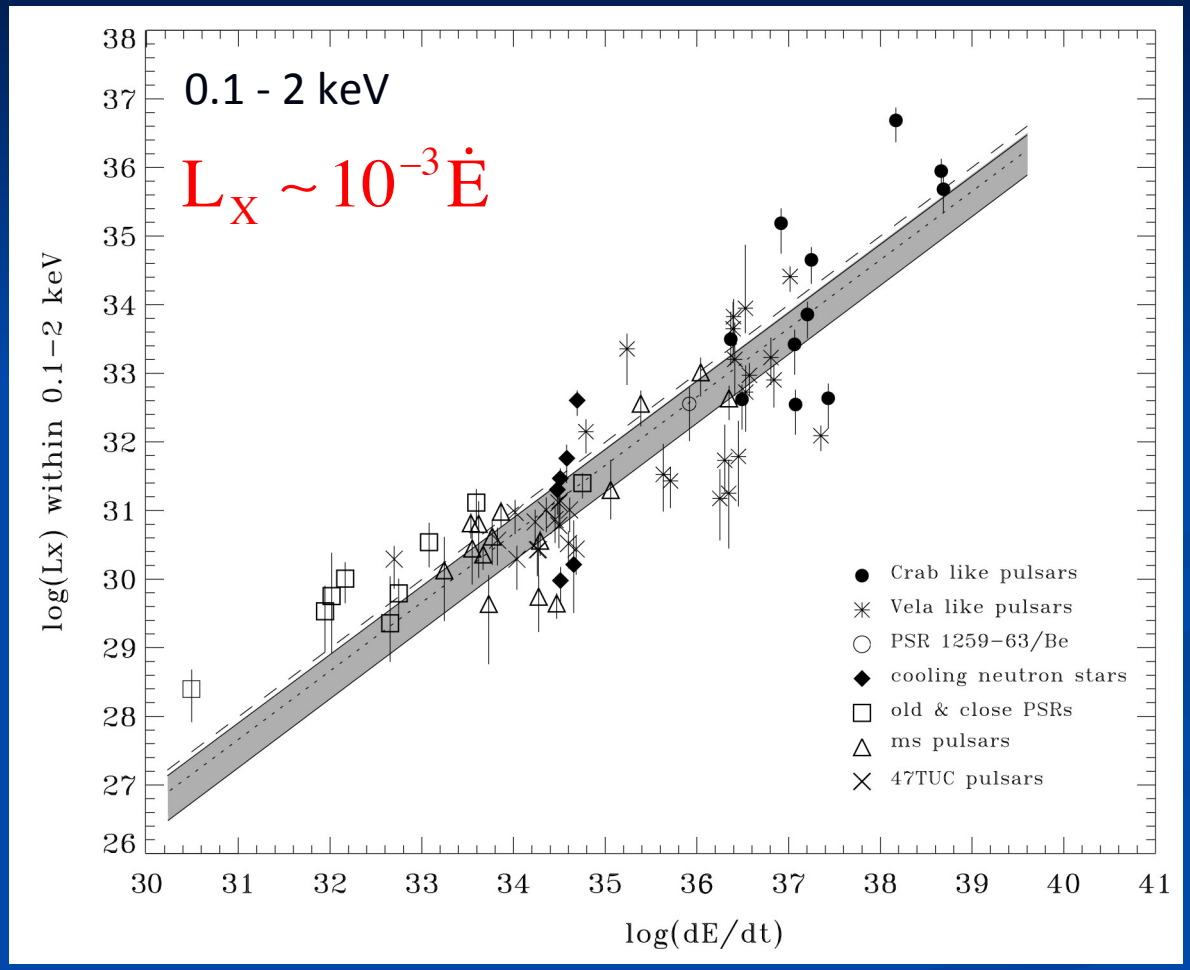
Becker et al. 1995

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

X-ray emission properties scale with age



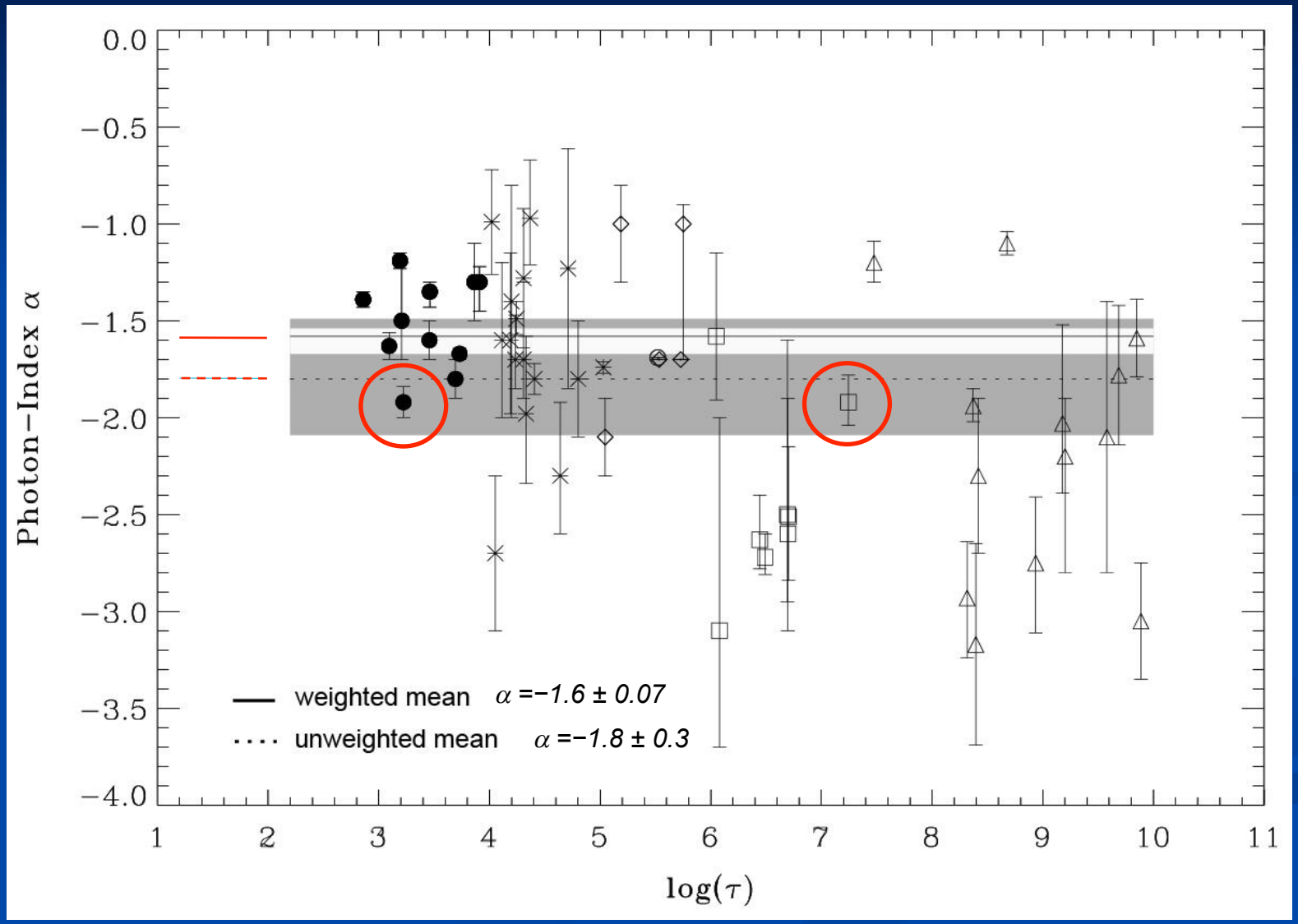
The X-ray Efficiency of Rotation-Powered Pulsars



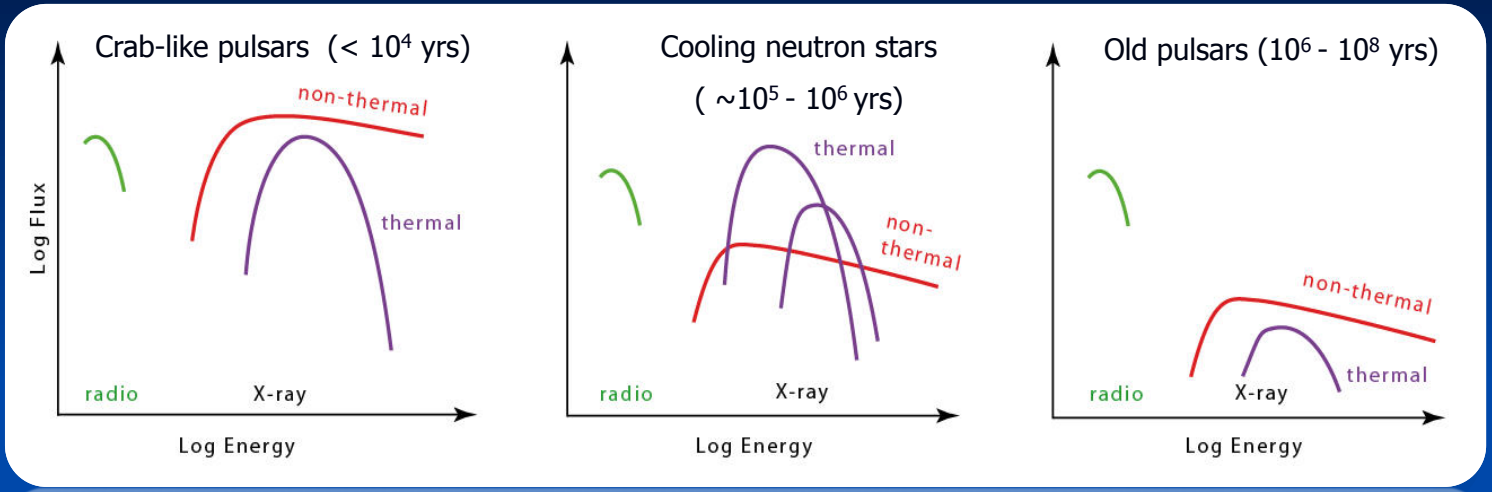
Becker et al. 2010

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

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

All pulsars will be detected with a photon statistics sufficient to perform a detailed spectral and timing analysis !

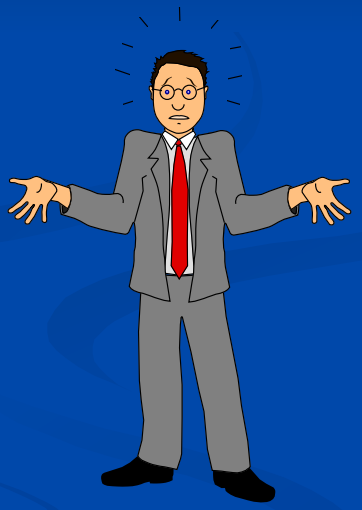
Still many open questions …

General:

- 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, a Magnetar or a CCO ?

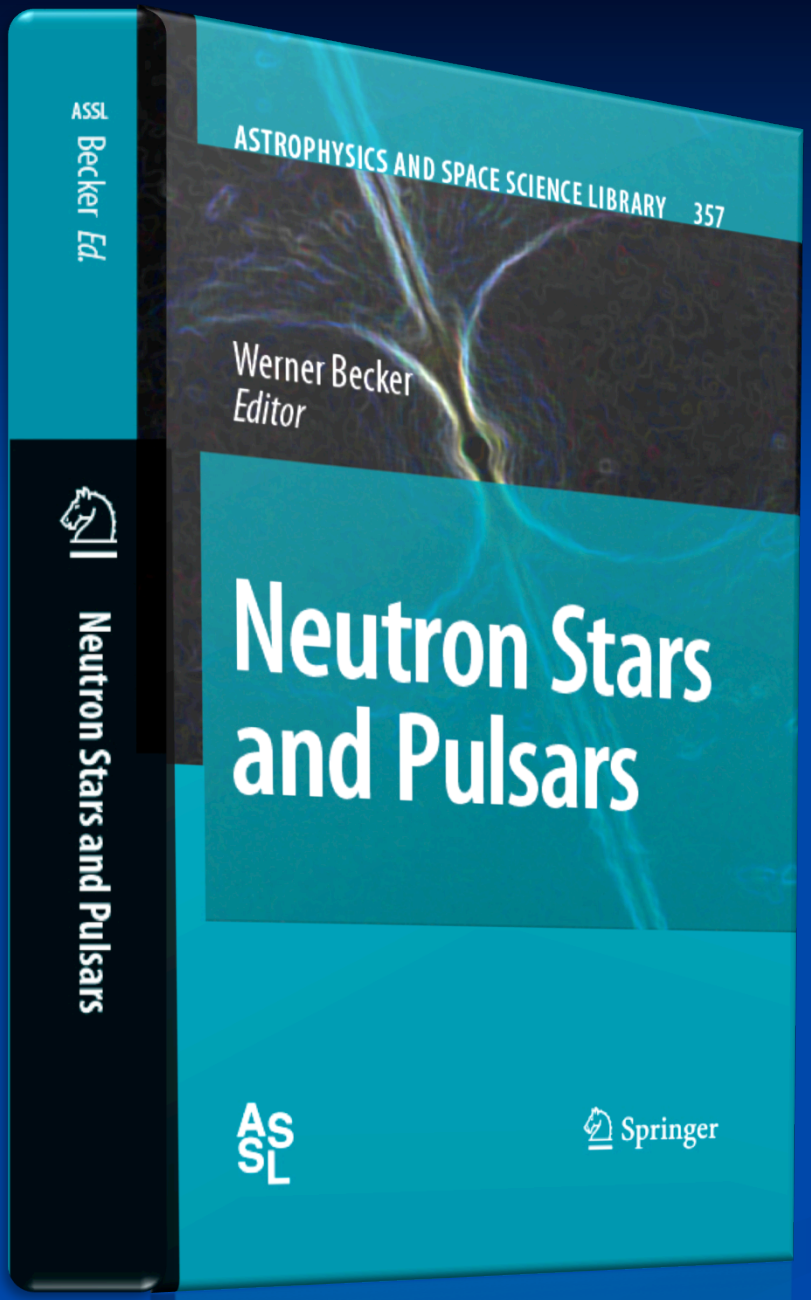
EOS:

- 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 neutron star's magnetosphere ?



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ASSL 357

W. Becker, MPE, Garching, Germany

Neutron Stars and Pulsars

Written for students, post-docs and professionals

Keywords:

- Gravitational Waves from Spinning Neutron Stars
- Isolated Neutron Stars and Millisecond Pulsars
- Neutron Star Cooling and Magnetic Field Evolution
- Particle Acceleration and Interactions in Pulsar Magnetospheres
- Pulsar Wind Nebulae
- Radio and high Energy Emission from Rotation-Powered Pulsars
- Soft Gamma-ray Repeaters and Magnetars
- Structure of Neutron Stars and EOS

"What have we learned about the subject and how did we learn it?"

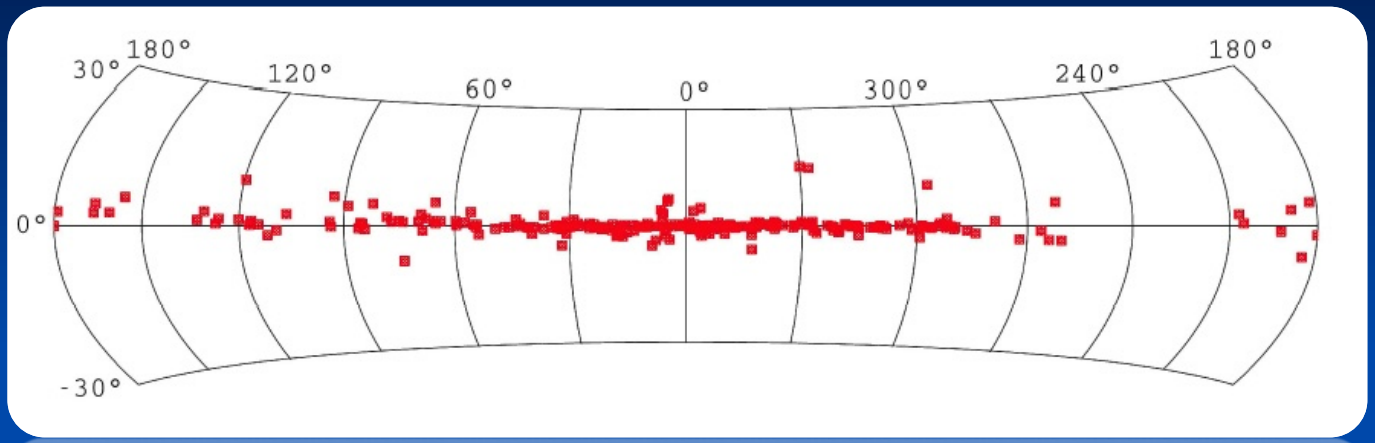
"What are the most important open questions in this area?"

"What new tools, telescopes, observations, and calculations are needed to answer these questions?".

With contributions from:
D.Lorimer, R.N. Manchester, M. McLauglin, A.G. Lyne, M. Kramer, W. Becker, R. Turolla, J. Grindlay, V.E. Zavlin, F. Weber, D. Page, S. Tsuruta, U. Geppert, M. Ruderman, J. Arons, J. Kirk, O.C. de Jager, K.S. Cheng, A.K. Harding, J.M.E. Kuipers, K. Hurley, M. Weisskopf, D.A. Smith, D.J. Thompson, R. Prix

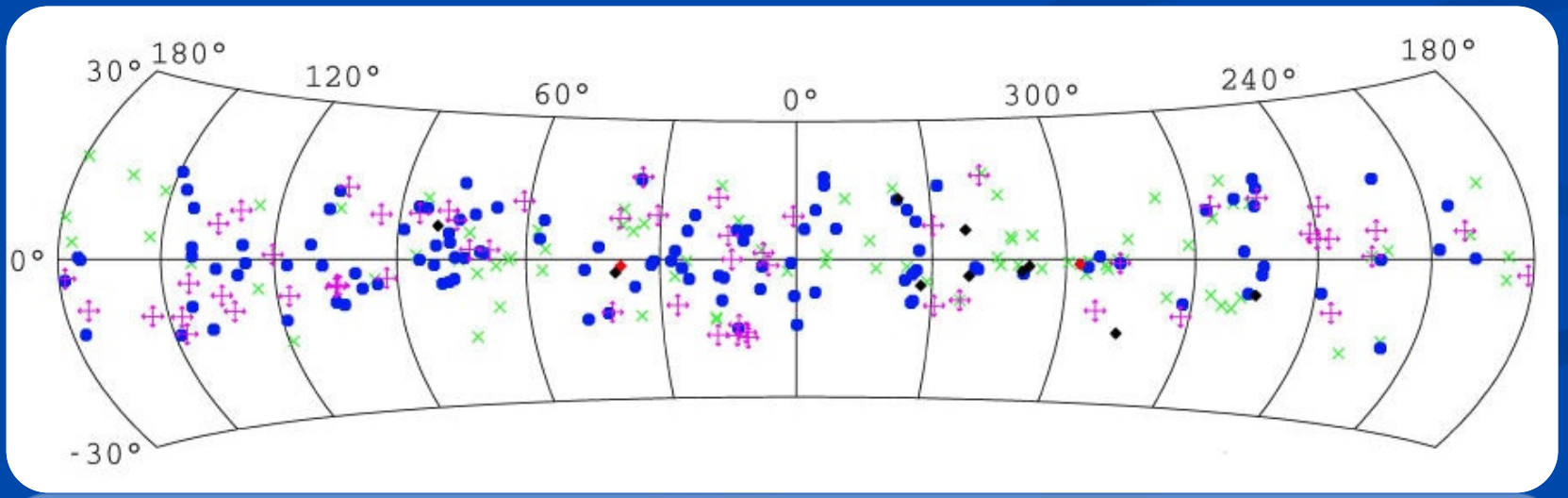
What can eROSIT do on Supernova Remnants?

eROSITA: Supernova research

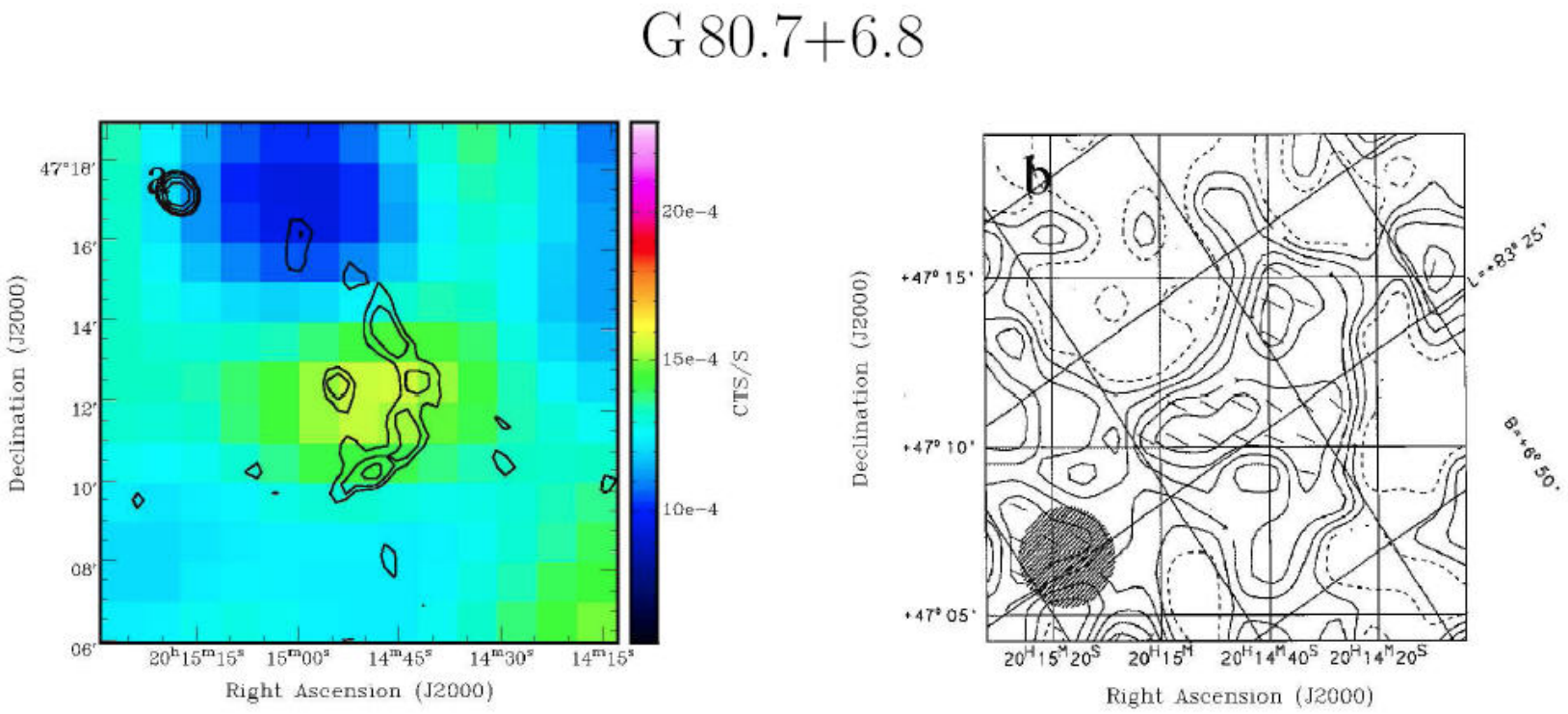


~270 known Galactic SNRs

RASS: 215 SNR candidates

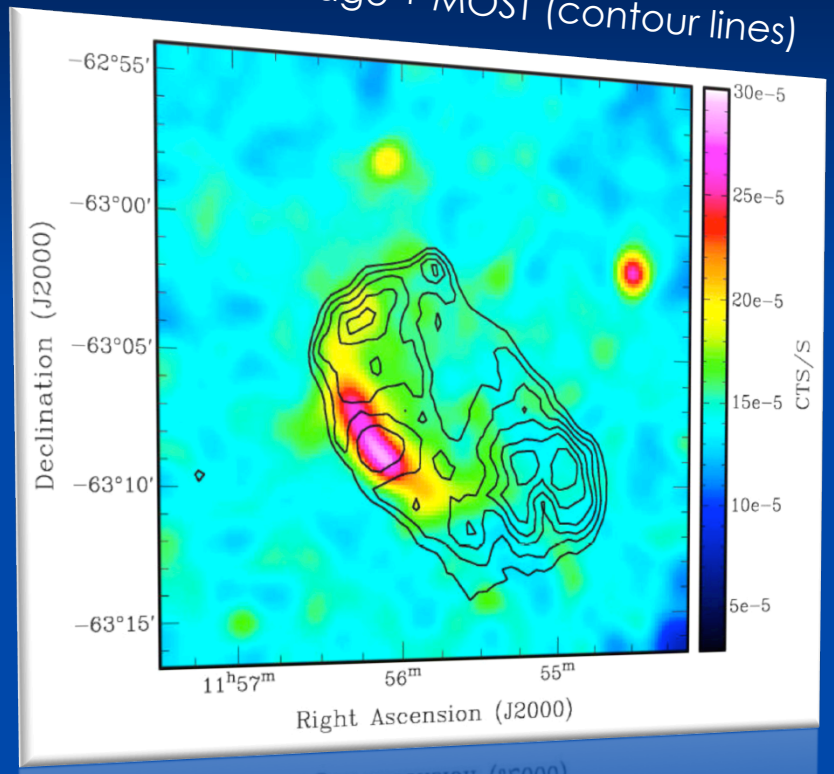


Supernova remnant candidates in the RASS

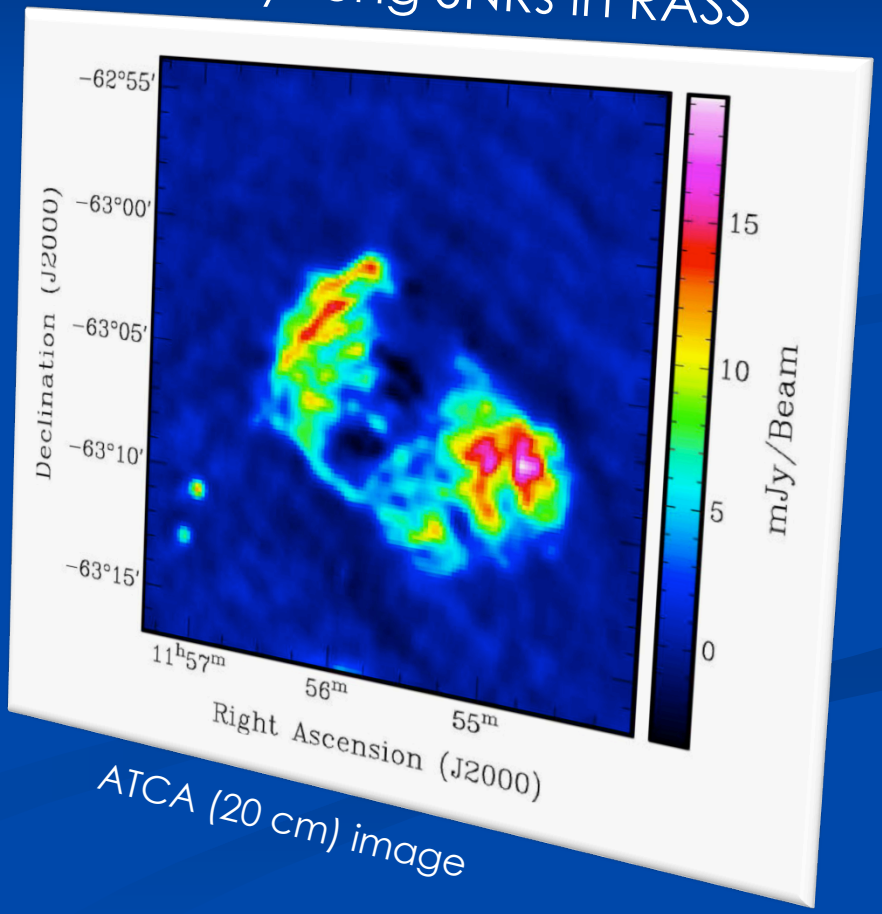


Supernova research with eROSITA: G296.7-0.9

ROSAT RASS image + MOST (contour lines)



new young SNRs in RASS



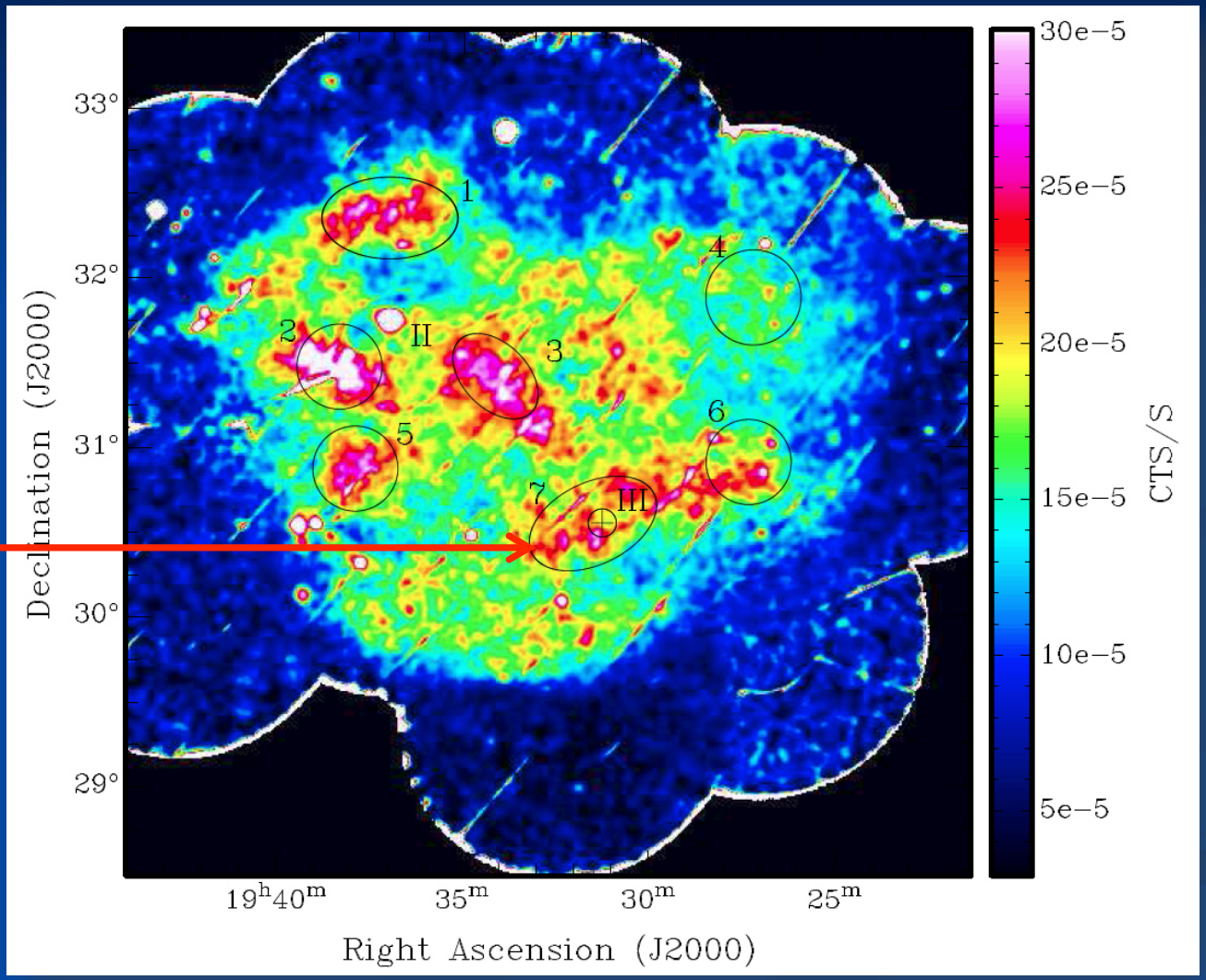
ATCA (20 cm) image

eROSITA: on extended supernova remnants …

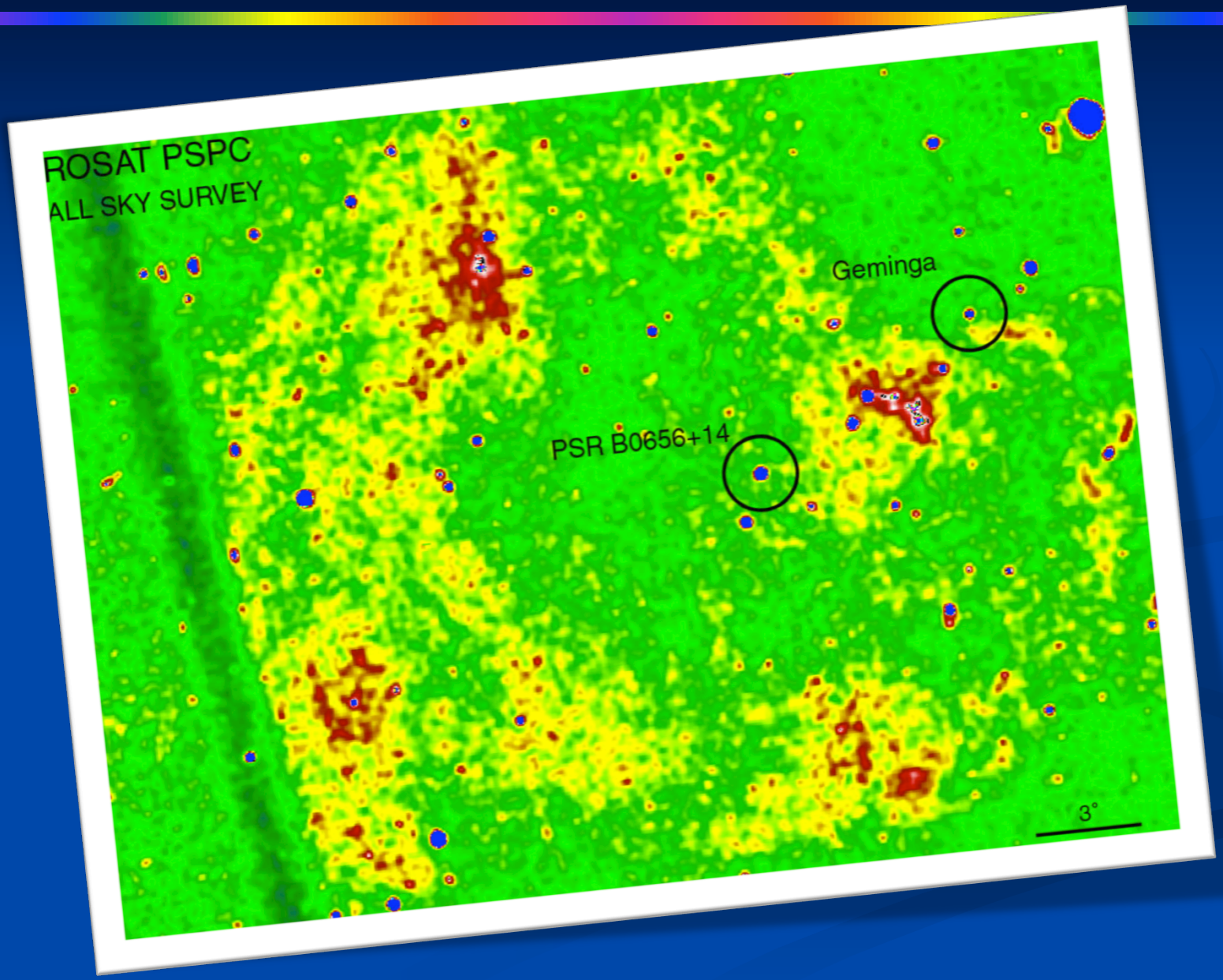
G 65.3+5.7

Extent of SNR:
3 degrees

PSR J1931+30



eROSITA: on extended supernova remnants …



http://www.mpe.mpg.de/erosita/erosita2011/index.html

… so stay tuned for eROSITA !