

All-Sky X-ray Surveys and SASIR

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Special thanks to the eROSITA team, esp.
P. Predehel, N. Cappelluti, G. Hasinger

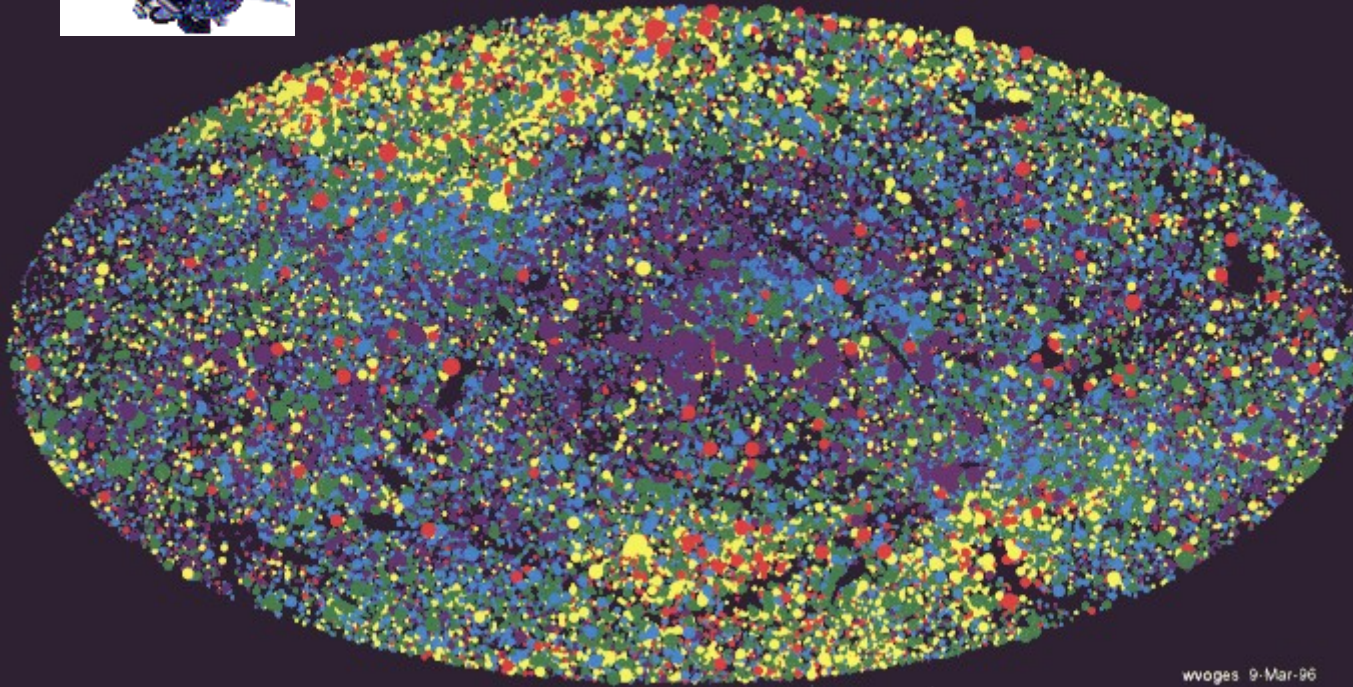
X-ray Synergies

- ♦ X-ray Synergies are essential in surveys.
 - AGNs, Supermassive black hole accretion
 - Normal galaxies: X-ray binary populations, Supernova remnants. Galaxy Outflows...
 - Clusters of galaxies: Hot gas in the deep gravitational potential well.
 - WHIMs (Warm Hot Intergalactic Medium)
 - X-ray binaries (Neutron stars, black holes, Cataclysmic Variables)
 - Stellar Coronae
 - Galactic Center
 - Galactic Supernova Remnants



ROSAT ALL-SKY SURVEY Sources

Aitoff Projection
Galactic II Coordinate System



wvoges 9-Mar-96

Energy range: 0.1 - 2.4 keV

Approximately 120,000 X-ray sources detected and catalogued (public) from the RASS

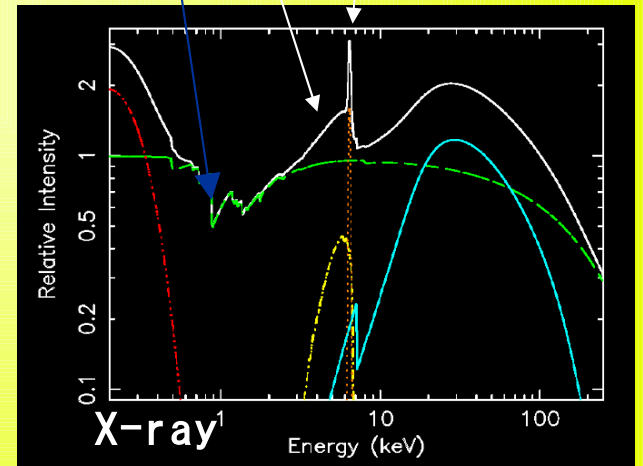
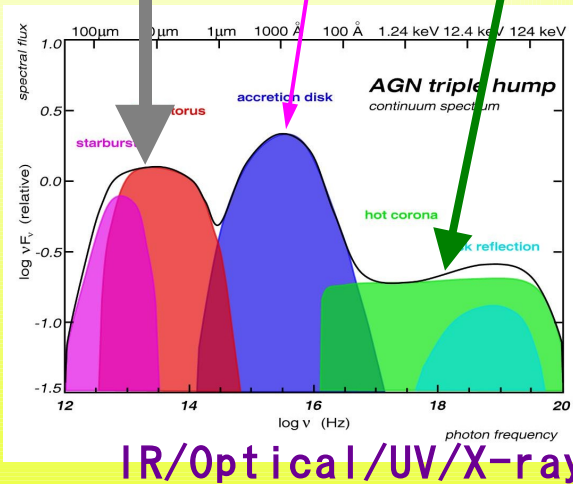
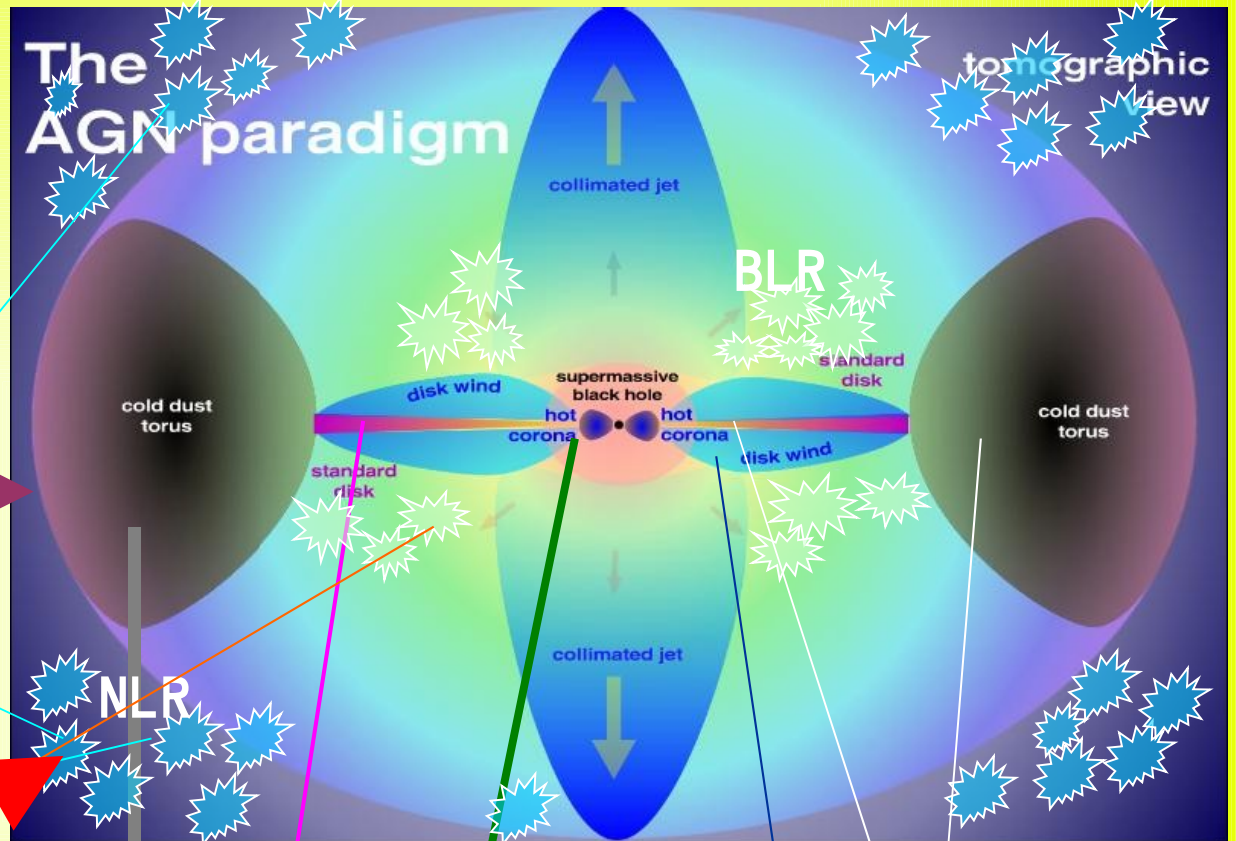
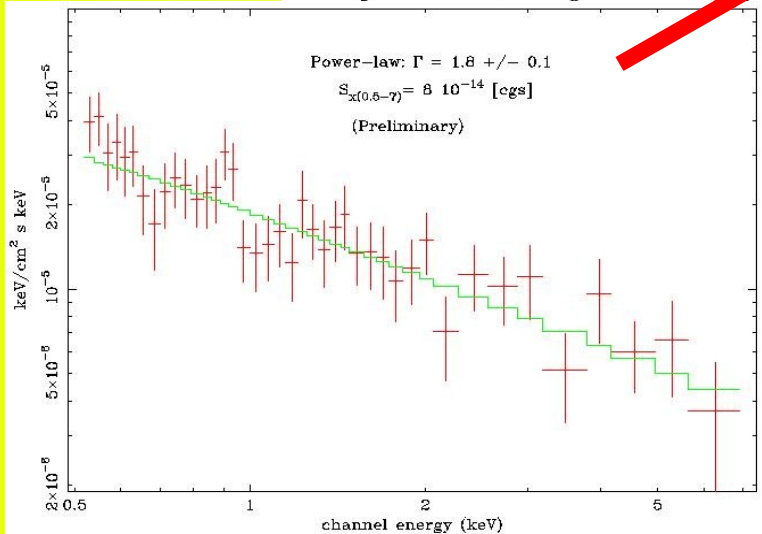
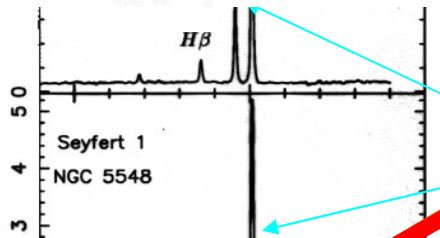
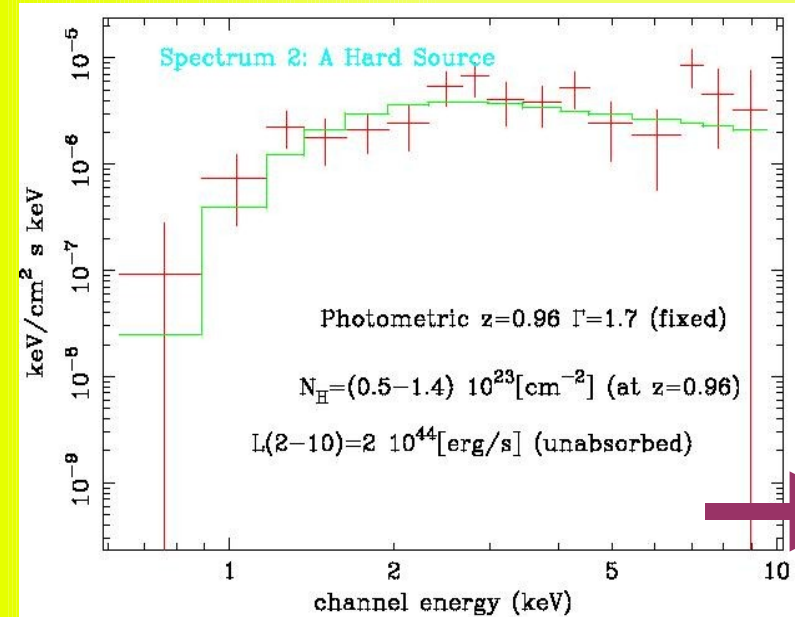
Past Survey

- ROSAT (1990–1999) All-Sky Survey (RASS)
 - First all-sky imaging survey. The first 6 months of the ROSAT mission was dedicated to the all-sky survey.
 - Well archived (at www.xray.mpe.mpg.de/rosat/ as well as heasarc.gsfc.nasa.gov)
 - Source catalogs (RASS-Bright source catalog/Faint source catalog)
 - Source removed surface brightness maps.
 - Photon event data, associated calibration files
 - Soft X-ray ($0.1 < E[\text{keV}] < 2.4$), not sensitive to obscured (type 2) AGNs.
 - Sensitive to clusters of galaxies.
 - Will be superseded by eROSITA

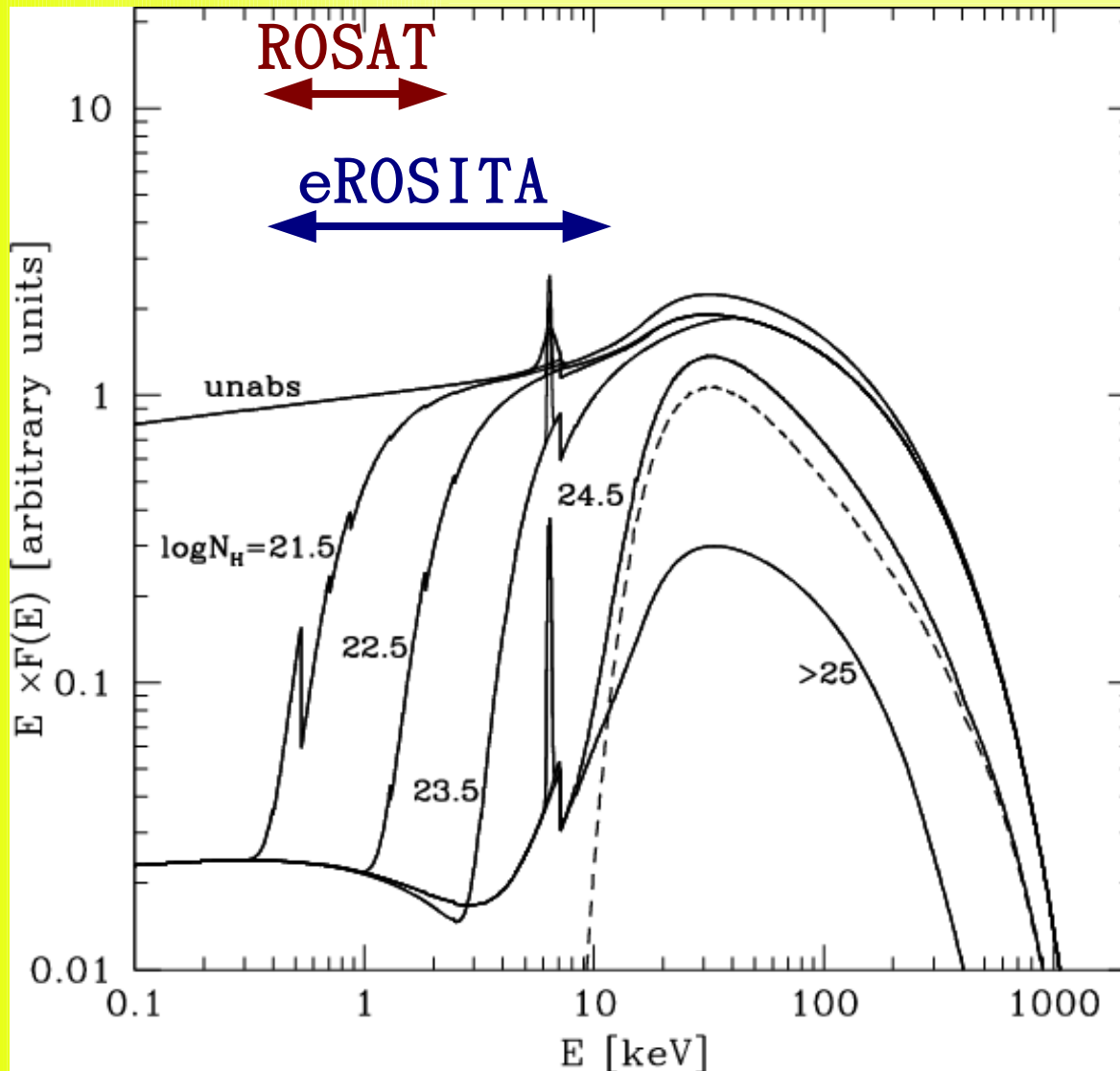
Coming Up Next

- **eROSITA** (extended ROSITA)
 - PI Institution: Max-Planck Institut fuer extraterrestrische Physik (Germany)
 - PI: Peter Predehl (taken over from Guenther Hasinger)
 - Almost dedicated large-area X-ray imaging survey mission.
 - To be on board the Russian Spectrum-XG mission (to be launched in 2011?).
 - Harder X-ray ($0.2 < E[\text{keV}] < 12$, similar to Chandra/XMM), sensitive to obscured AGNs up to the Compton-thin limit ($N_{\text{H}} < 10^{24} \text{ cm}^{-2}$).
 - It still emphasizes softer X-rays ($E < 2 \text{ keV}$), because its main purpose is to detect numerous high-z clusters to do precision Cosmology.

AGN Central Engine



AGN X-ray Spectrum



$\log N_H [\text{cm}^{-2}]$
<24 : Compton-thin
>24 : Compton-thick

ROSAT is sensitive to unabsorbed AGNs

eROSITA (ASCA/XMM/Chandra/Suzaku) are sensitive to absorbed (Compton-thin) AGNs.

Historical Development



First X-ray all-sky survey with an imaging telescope



To extend the all-sky survey towards higher energies (Launched, but failed)

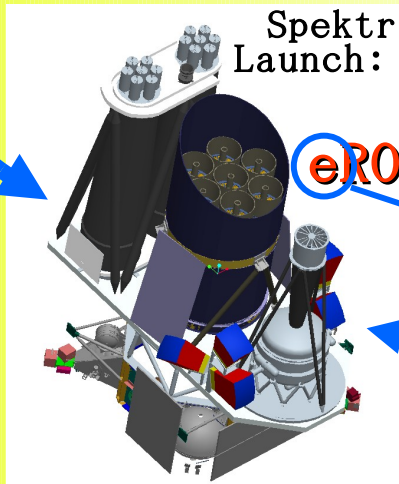
Negotiations between Roskosmos and ESA on a "new" Spectrum-XG mission (2005)

Agreement between Roskosmos and DLR (2007)

ABRIXAS science on the International Space Station (Did not happen.)

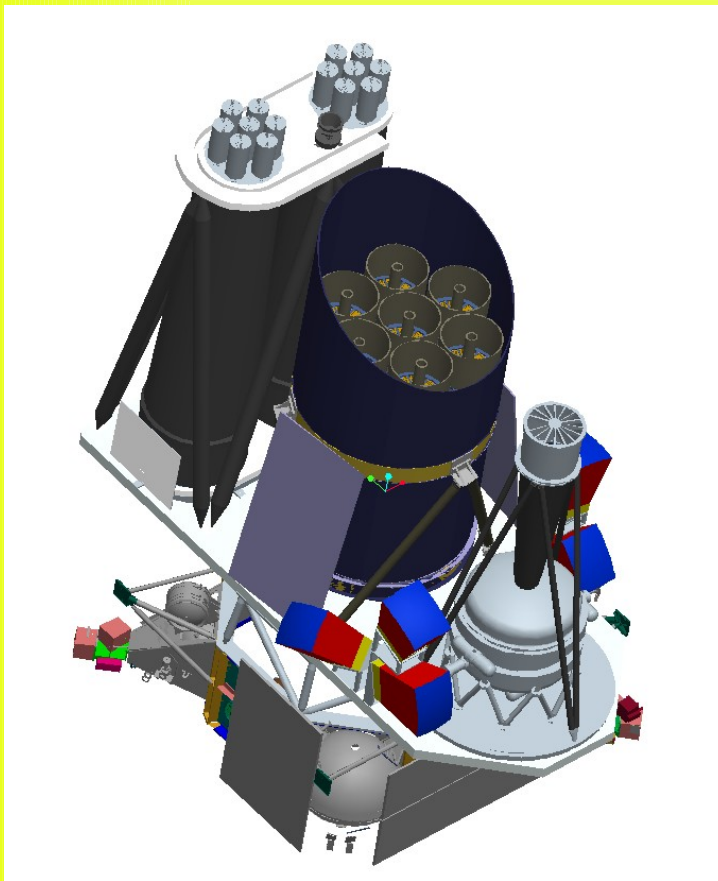


Spektr-RG Launch: 2011



Dark Energy Clusters of Galaxies 10^5

Courtesy of P. Predehl & eROSITA team



SRG-Mission

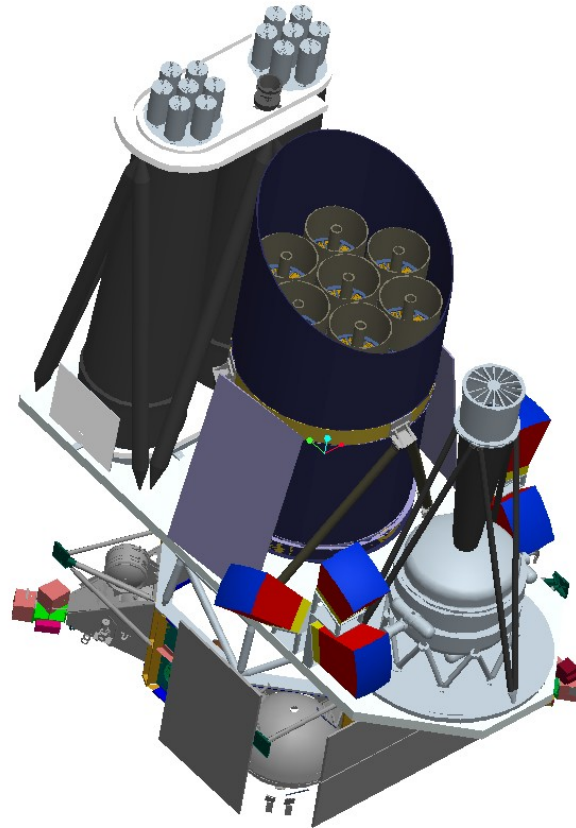
Other instruments on board?

ART: More Effective ares in harder band
(2-12 keV) (IKI, Russia+MSFC, USA, USA
funding proposal to “Mission of
Opportunity” not accepted)

LOBSTER (U. Leicester): Sky Monitoring (No
UK funding)

SRG-Mission

- С п е к т р р е н т г е н -
г а м м а (SRG)
- Launch: 2011 from Baikonur
- Launcher: Soyuz-Fregat
- Platform: Navigator (Lavochkin)
- Orbit: 600 km, 30° inclination
- Payload: ART-XC (IKI)
LOBSTER (LU+...)
eROSITA (MPE+...)
SRC (SRON, ISAS,
GSFC, +MPE)
- Mission: 4 yrs survey + 1 yr pointing
+ ...



Other payloads on SXG -- not sure...

Courtesy of P. Predehl & eROSITA team

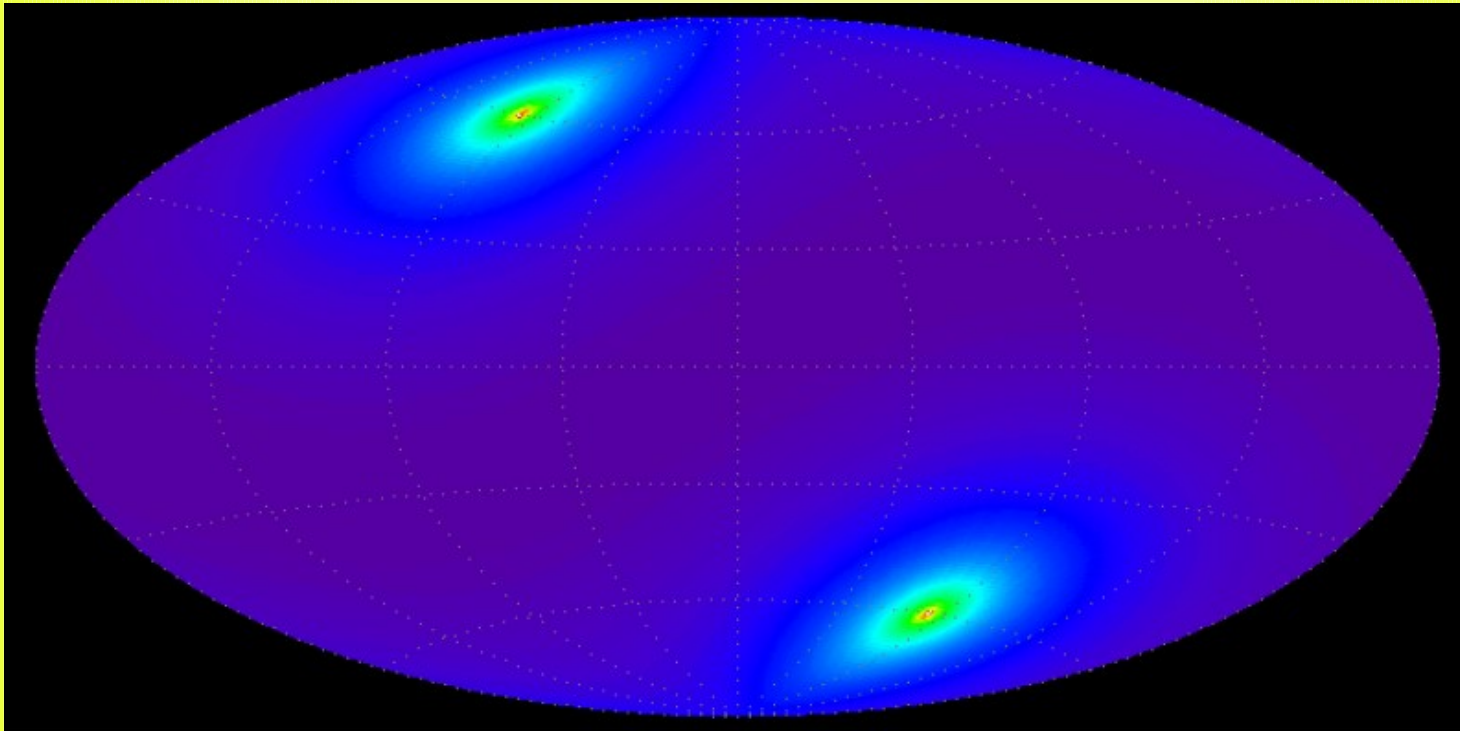
Design Driving Science

- Detection of 100,000 Cluster of Galaxies, $N(z)$, $P(k)$, Baryon Acoustic Oscillations
- Will detect 3,000,000 AGNs
- Extragalactic Survey (20,000 sqd, 2yrs)
- Deep Survey (200 sqd, $\frac{1}{2}$ yr)
- Pointing (1 yr)
- All-sky Survey (1 yr) + add. pointing (lifetime)
- Increase of effective area
 - 27 \rightarrow 54 mirror shells per module (7)
- Increase of Field of View
 - $2 \times 2 \text{cm}^2 \rightarrow 3 \times 3 \text{cm}^2$

eROSITA 

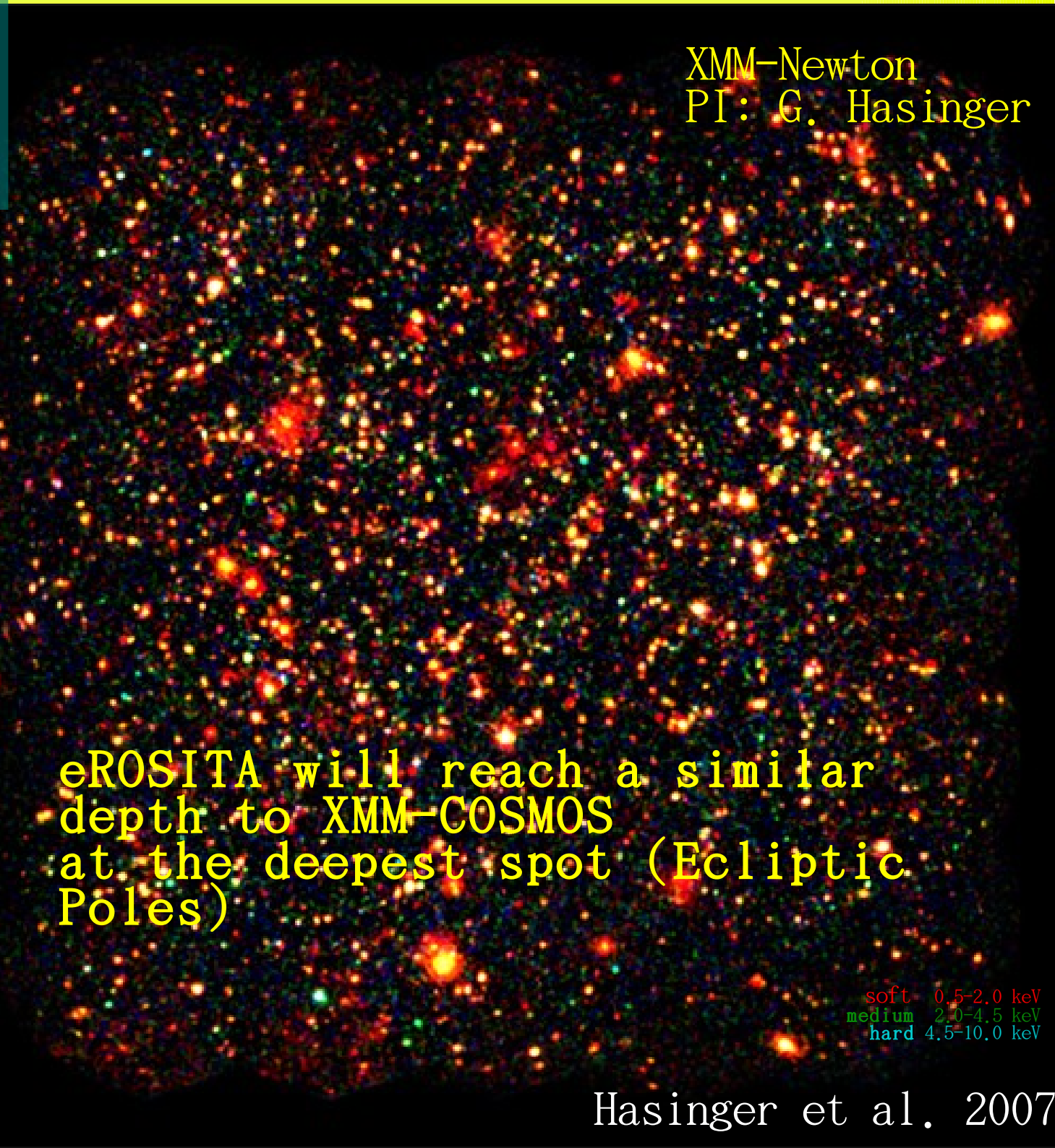
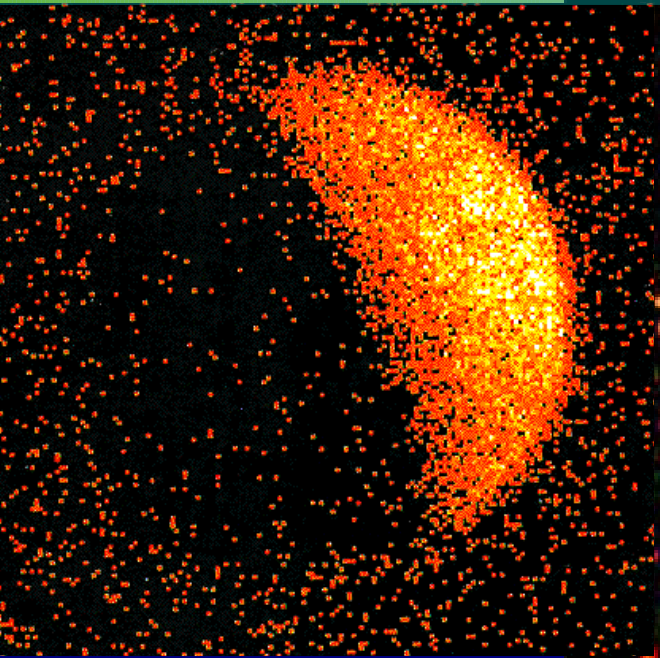
Courtesy of P. Predehl & eROSITA team

Exposure Map



Exposure:
~ 1.5 ksec at equator, ~ 32 ksec at poles

Courtesy of P. Predehl & eROSITA team



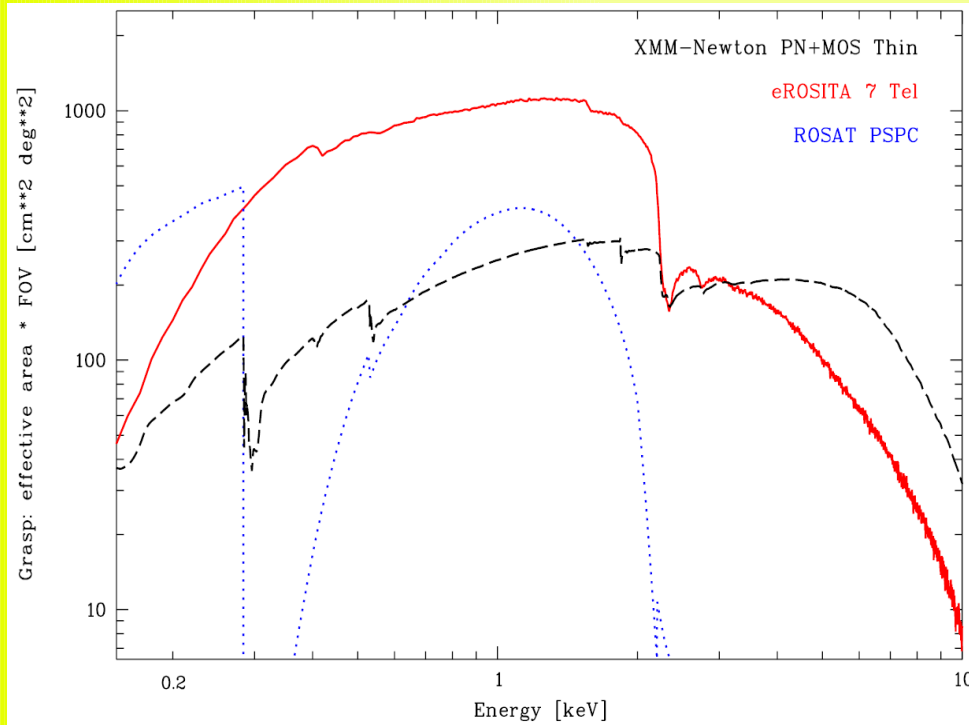
A03: 800 ks of XMM
[25x32 ks pointings]
→ reduction/analysis
completed
~1400 AGN detected
~70 clusters/diffuse
sources

A04: 600 ks (Total = 1.4 Ms)
of XMM
→ reduction completed
~2000 sources detected at the
cey (Cappelluti+2008, submitted)

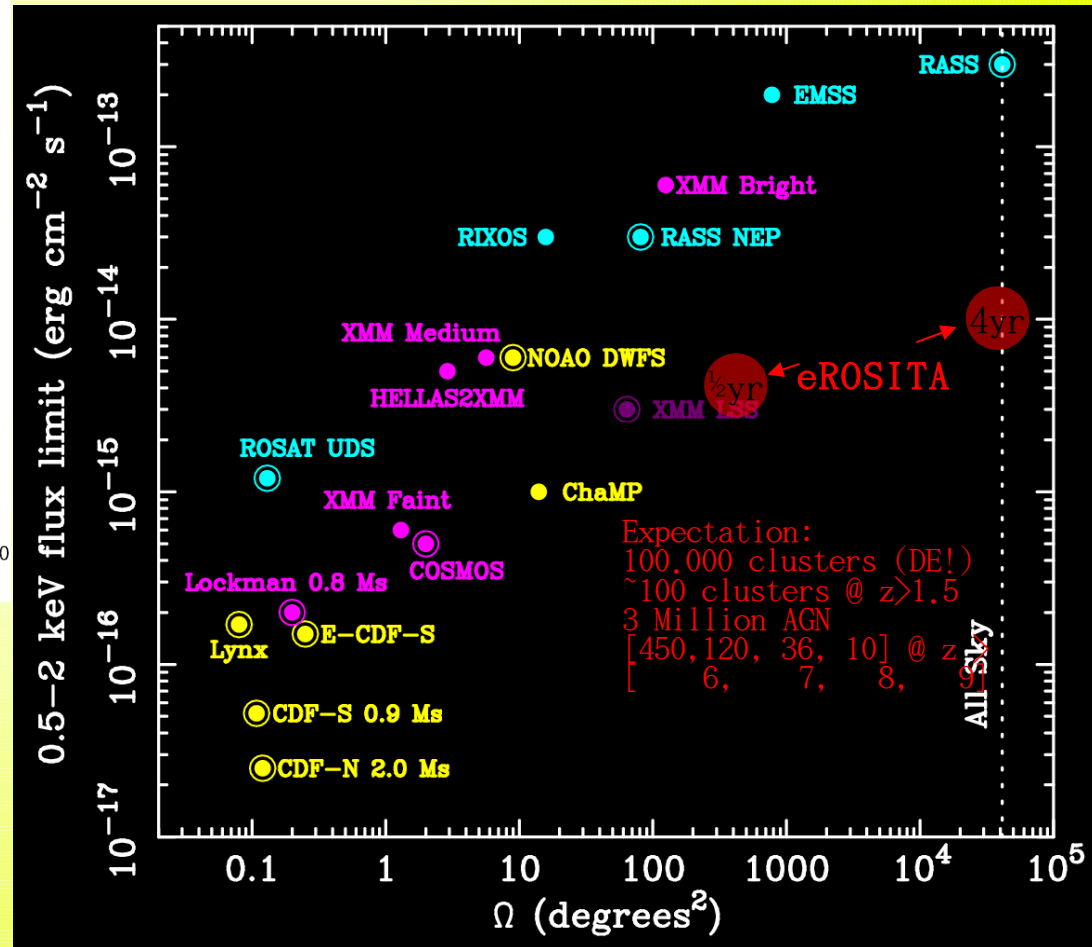
eROSITA will reach a similar
depth to XMM-COSMOS
at the deepest spot (Ecliptic
Poles)

soft 0.5-2.0 keV
medium 2.0-4.5 keV
hard 4.5-10.0 keV

eROSITA Sensitivity F/ Ω

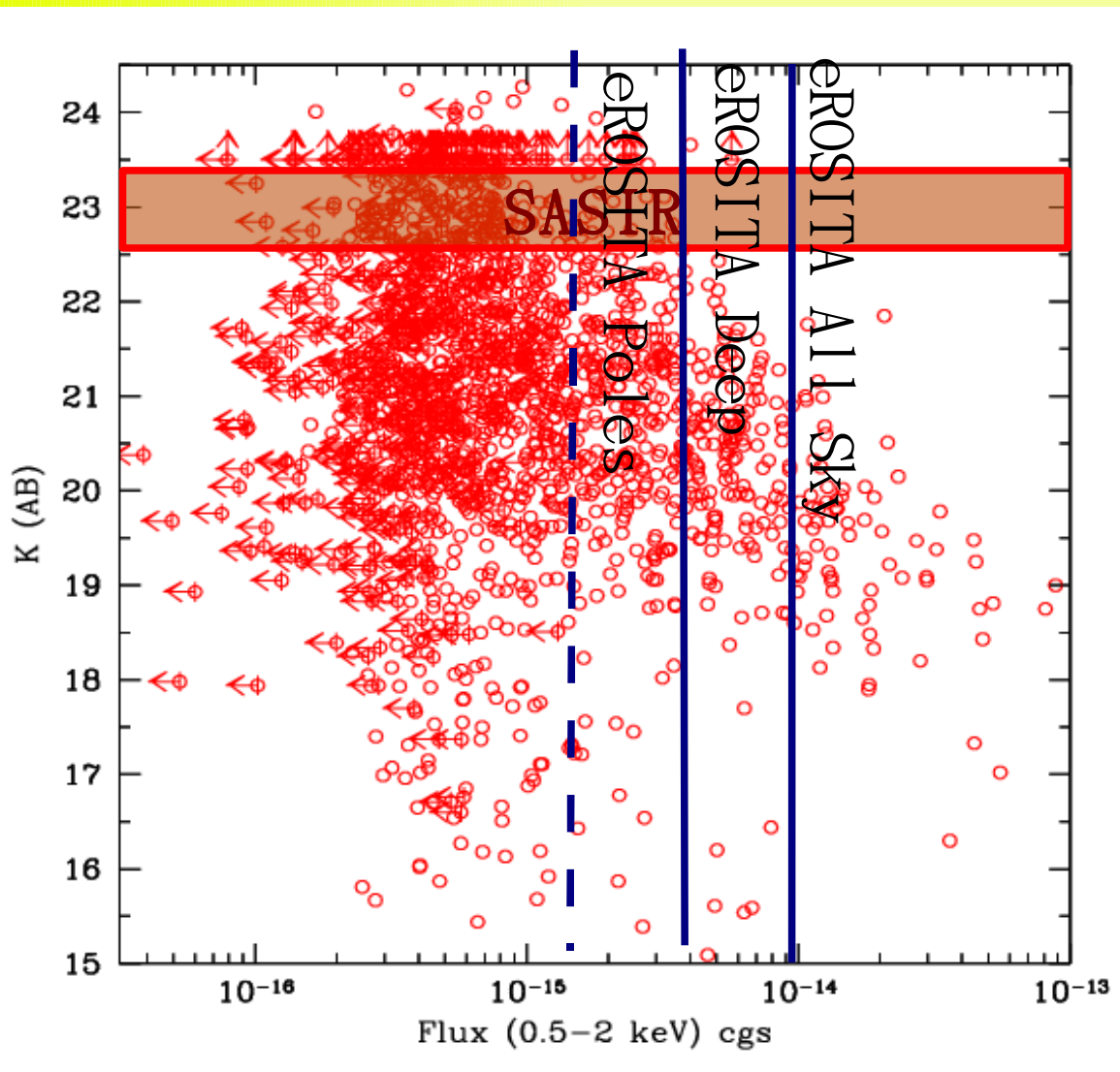


Depth x Survey Area
 $\sim 50 \times$ ROSAT
 $\sim 2 \times$ XMM-Newton (MOS+PN)



Courtesy of P. Predehl & eROSITA team

Matching of eROSITA AGNs and SASIR



MPE People have know-hows on source detection, cataloging, archiving etc. Expect comprehensive public point source catalog by the time SASIR is operational.

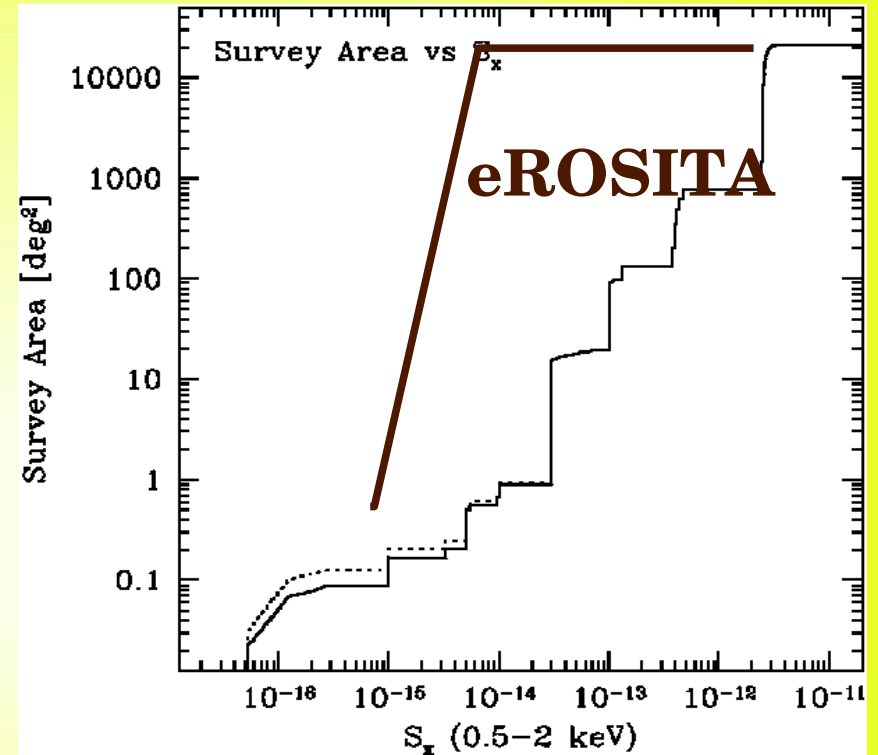
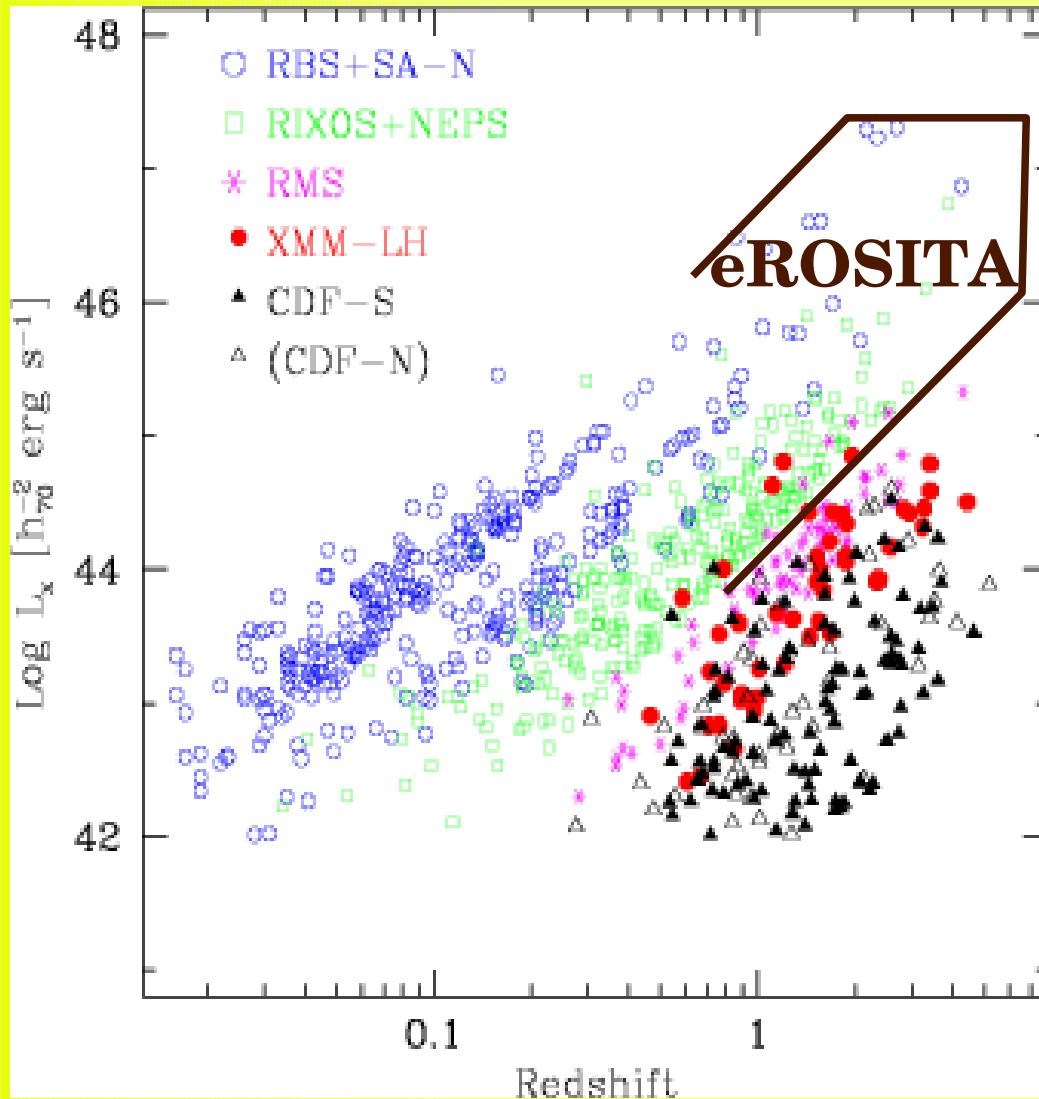
X-ray flux vs K(AB) from a deeper survey. Courtesy of F. Civano/C-COSMOS.

SASIR will detect almost all X-ray point sources detected by eROSITA in the K-band.

eROSITA and SASIR

- ◆ Identification of X-ray source counterpart from multiple candidates ($\sim 20\%$ of X-ray sources)
 - YJKs photometry is essential for photometric redshift of $z > 1.2$ AGNs to catch strong lines like $H\beta$, $H\alpha$, $[OIII]$.
 - IR variability also helps to identify X-ray source counterpart.
- ◆ At $z > 5$, UV \rightarrow NIR
 - Luminosity and z dependence of optical-to-X-ray luminosity ratio (α_{ox} , effective spectral index between 2 keV and 2500Å) including $z > 5$ QSOs. (M_{BH} and Eddington Ratio).
 - Bolometric luminosity function of AGNs? (obscured and unobscured).

Combined X-ray sample

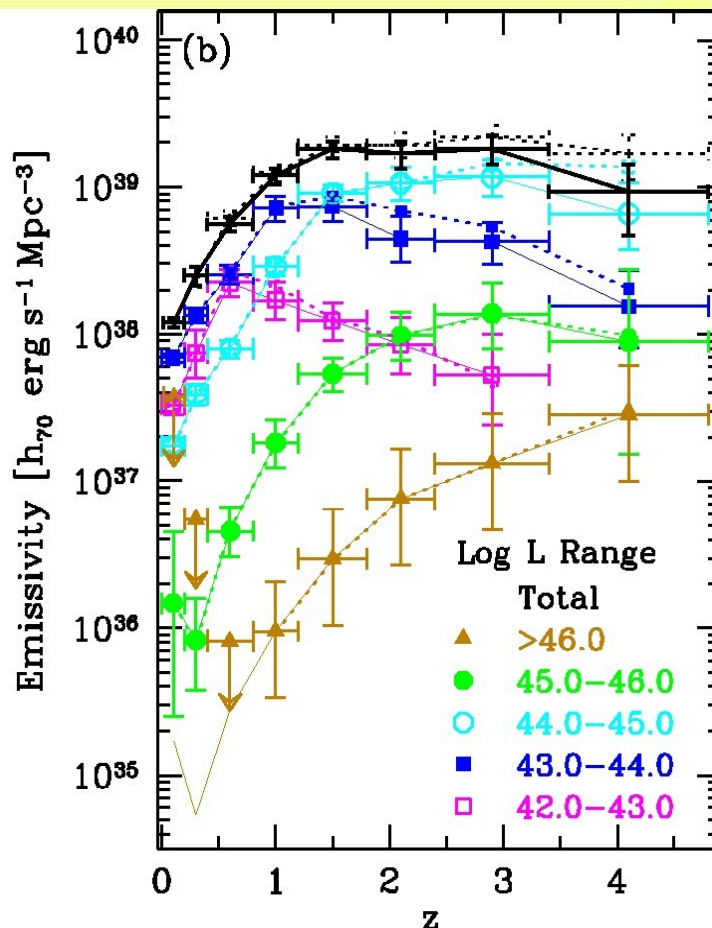
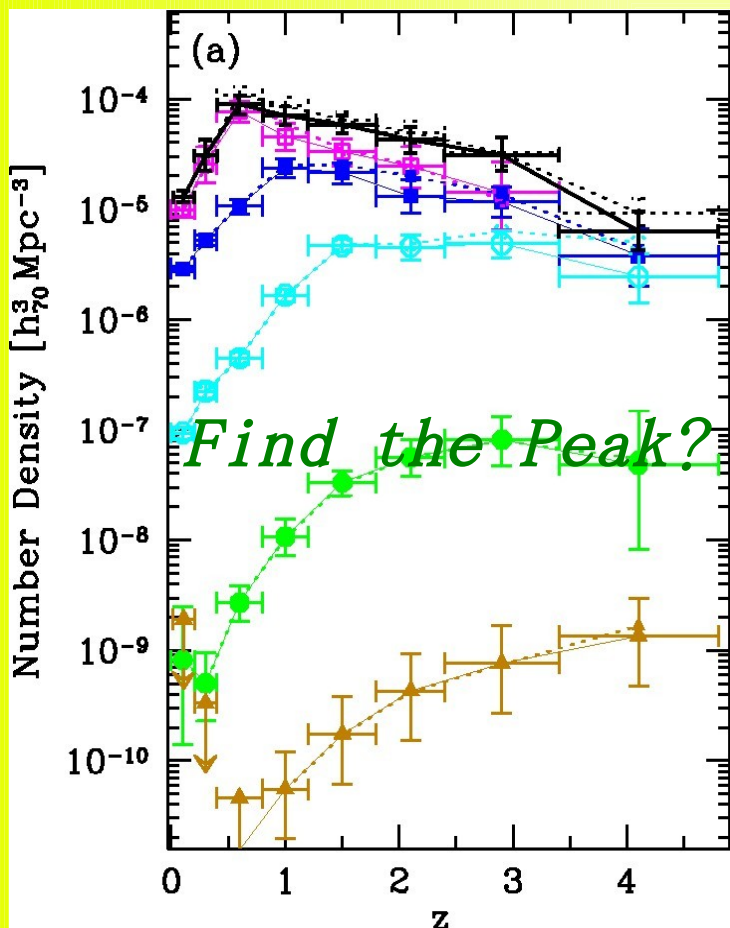


+eROSITA, of course, IDs will be hard

Current Combination of X-ray selected type 1 AGNs/QSOs from various surveys. We limited ourselves to type 1 to make use of ROSAT in the brighter end.
(Hasinger, TM, Schmidt 2005)

Evolution of Number/Luminosity Density

⇒ Anti-hierarchical AGN evolution or Down-sizing



Low Luminosity AGNs Peak at $z < 1$
High Luminosity (QSO) Peak at $z > 2$

The opposite sense to intuition based on hierarchical structure formation scenario !! (cf. Wiythe & Loeb 2003 semianalytical model)

eROSITA and SASIR

- Counting most luminous "type 2" QSOs.
- Does the fraction of "obscured" AGNs evolve with redshift at the most luminous end?
- Identification of $z \gtrsim 1$ clusters by cross-matching extended X-ray emission with clusters of IR galaxies (Next talk?)

I plan to be at MPE mid Oct-mid Nov. and will have a chance to talk with eROSITA people for possible Synergy or at least scientific merit of combining the data.

X-ray All Sky Surveys Higher Energies ?

- *Swift* (BAT) Slew Survey (e.g. Markwardt et al. 2005, Tueller 2008 and going on...)
- Hard X-ray (14–195 keV). Detects highly obscured AGNs, even to Compton-thick AGNs.
- 103 AGNs and growing (up to 200 AGNs?)
- Similar Work with *Integral* (e.g. Sazonov+ 2007)
- The above surveys are too shallow for general *SASIR* interests. 2MASS depth should be good enough...
- *MAXI*: All-Sky X-ray Monitor on ISS Japan experimental module: 3 years from 2009. Not contemporary with *SASIR*, but may give the list of interesting X-ray variable objects.
- *EXIST?*: Does anybody know what's going on?

Summary

- ♦ All Sky Survey with eROSITA, basically superceding the ROSAT All-Sky survey, will make a sensitive all-sky survey imaging in the 0.2–12 keV range.
- ♦ The depth is very well matched with SASIR for AGNs. SASIR data will be very helpful in identifying X-ray source candidates, measuring photo- z 's ($z > 1.2$) of AGN/QSOs.
- ♦ Also the eROSITA+SASIR is a superb combination in identifying $z > 1$ clusters.