All-Sky X-ray Surveys
and
SASIR

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Special thanks to the eROSITA team, esp.
P. Predeh hel, 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, Calaclysmic Variables)
  - Stellar Coronae
  - Galactic Center
  - Galactic Supernova Remnants
Approximately 120,000 X-ray sources detected and catalogued (public) from the RASS
Past Survey

  - 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[keV]<2.4), not sensitive to obscured (type 2) AGNs.
  - Sensitive to clusters of galaxies.
  - Will be superseded by eROSAITA
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[keV]<12, similar to Chandra/XMM), sensitive to obscured AGNs up to the Compton-thin limit (N_H<10^{24} cm^{-2}).
  - It still emphasizes softer X-rays (E<2 keV), because its main purpose is to detect numerous high-z clusters to do precision Cosmology.
AGN Central Engine

Spectrum 2: A Hard Source

Photometric $z=0.96 \Gamma=1.7$ (fixed)

$N_H=(0.5-1.4) \cdot 10^{25} [\text{cm}^{-2}]$ (at $z=0.96$)

$L(2-10)=2 \cdot 10^{44} [\text{erg/s}]$ (unabsorbed)

channel energy (keV)

Hβ

Seyfert 1

NGC 5548

Power-law, $\Gamma = 1.8 \pm 0.1$

$S_{[3.6-8]} = 6 \cdot 10^{-14} [\text{erg s}^{-1}]$

(Preliminary)

IR/Optical/UV/X-ray
AGN X-ray Spectrum

ROSAT is sensitive to unabsorbed AGNs

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

From Gilli et al. 2007
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 (Launched, but failed)

**ROSITA**
2002
ABRIXAS science on the International Space Station (Did not happen.)

**Spektr-RG**
Launch: 2011

**eROSITA**

**Dark Energy**

Clusters of Galaxies $10^5$

Negotiations between Roskosmos and ESA on a "new" Spectrum-XG mission (2005)
Agreement between Roskosmos and DLR (2007)

Courtesy of P. Predehl & eROSITA team
ART: More Effective areas 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**

- **Спектр рентгена-гамма** (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, 2 yrs)
- 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
CXC Extragalactic Surveys workshop

+ MAMBO, CFHT, Bolocam and (future) others

COSMOS major components (in order of appearance):

- HST/ACS (I-band 590 orbits I(AB)~27)
- Subaru imaging (~25 nights - b,v,r,i,z=26/27)
- VLA (265 hours 24–μJy)
- GALEX deep (200 ks, AB~25)
- XMM-Newton (800 ks 10–15 cgs)

2004-2005:

- XMM-Newton (600 ks)
- VLT (540 hours) & Magellan (12+ nights)
- SPITZER-IRAC (200 hours - ~1 μJy)

2006:

- SPITZER-MIPS (200 hours - ~70 μJy)
- Chandra (1.8 Ms)

AO3: 800 ks of XMM [25x32 ks pointings] → reduction/analysis completed
~1400 AGN detected
~70 clusters/diffuse sources

AO4: 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)

Hasinger et al. 2007

Cosmos Survey 2 deg² (PI: N. Scoville)
eROSITA Sensitivity

F/Ω

Depth x Survey Area
~ 50 × ROSAT
~ 2 × 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 (~20% of X-ray sources)
  - YJHKs photometry is essential for photometric redshift of z>1.2 AGNs to catch strong lines like Hβ, Hα, [OIII].
  - IR variability also helps to identify X-ray source counterpart.

- At z>5, UV→NIR
  - Luminosity and z dependence of optical-to-X-ray luminosity ratio (α_{ox}, effective spectral index between 2 keV and 2500A) including z>5 QSOs. (M_{BH} and Eddington Ratio).
  - Bolometric luminosity function of AGNs? (obscured and unobscured).
Combined X-ray sample

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)

+eROSITA, of course, IDs will be hard
Evolution of Number/Luminosity Density

⇒ Anti-hierarchical AGN evolution or Down-sizing

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

Low Luminosity AGNs Peak at $z<1$

High Luminosity (QSO) Peak at $z>2$
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 $z \sim 1$ 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.