eROSITA on SRG

Andrea Merloni,
on behalf of Peter Predehl (MPE)
Mapping the Universe

"Constrained"
Hydro simulations
e.g. J. Sorce+2016

Courtesy of K. Dolag (LMU)
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Mapping the Universe
In X-rays

- A signature of clusters is the detection of hot (~$10^7$ K) ICM
- Clusters are exponentially sensitive tracers of growth of structures
- Cosmological constraints with (well calibrated) ROSAT samples ~100 obj.

Images courtesy of K. Dolag (LMU), M. Mühlegger (MPE), O. Hahn (ETH)

Rosati, Norman, Borgani 2002

Simulation of an eROSITA field

Diffuse X-ray emitting gas traces the massive knots of the cosmic web (Clusters)

Point sources (Quasars) signpost the growth of black holes
SRG will be launched when all interface test have been completed, and everything is ready!

i.e. not before 06/2018, hopefully in 09/2018

Current Issues:

• Spacecraft – radiocomplex, hardware
• Adaption to PROTON+block-DM launcher
After 10 years of development...

More than 90 Mio € of money spent...

**eROSITA is ready**

- It is completely calibrated, with performance as expected
- It is completely assembled
- It passed successfully end-to-end & acceptance tests
- It has been shipped to NPOL
- All functional tests have been performed successfully.
eROSITA: the Project

**PI: Peter Predehl; PS: A. Merloni** (MPE)

**Core Institutes (DLR funding):**
- MPE, Garching/D
- Universität Erlangen-Nürnberg/D
- IAAT (Universität Tübingen)/D
- SB (Universität Hamburg)/D
- Astrophysikalisches Institut Potsdam/D

**Associated Institutes:**
- MPA, Garching/D
- IKI, Moscow/Ru
- USM (Universität München)/D
- AIA (Universität Bonn)/D

**Industry:**
- Media Lario/I
- Kayser-Threde/D
- Carl Zeiss/D
- Invent/D
- Telescope Structure
- pnSensor/D
- IberEspacio/E
- RUAG/A
- HPS/D,P
- MLI
- + many small companies

**MPE: Scientific Lead Institute, Project Management**
- Instrument Design, Manufacturing, Integration & Test
- Data Handling & Processing, Archive etc.
7+1 Mirror assemblies

- 54 nested gold-coated nickel mirror shells
- Focal length: 1.6 m, Field of view: 1 degree (diameter)
- On-axis Half-Energy width (HEW) ~16.1” (nominal)
- X-ray baffle (10μm precision alignment): 92% stray light reduction
- Calibration of all 8 telescopes at PANTER completed in June 2016
Focal Plane Mapping

Al Kα (1.49 keV)
HEW = 18.1″ (on axis)
~ 24.8″ (FoV avg.)

Cu Kα (8 keV)
HEW = 15.4″ (on axis)
~42″ (FoV avg.)

eROSITA, XRU, 6/2017
Cameras Calibration

- **3.3 Billion** calibrated events! (K. Dennerl, N. Meidinger)
- **Spectral resolution** at all measured energies within specs ($R \approx 20$ @1.5keV)
- Extremely **good uniformity**
- Only weak dependence on CCD and electronics temperature (unlike XMM)
- Very accurate absolute energy reconstruction (<0.06%)

ΔE=49eV @0.28keV

=77eV @1.5keV

=136eV @6.4keV
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eROSITA first light
all 7 cameras with calibration source
Ti-K (4.51 keV)

eROSITA end-to-end test
PANTER / MPE
2016-Oct-21
Transport to SVO, 20.1.2017
Transport to LA, 25.1.2017
SRG: Mission Profile

**Launch window**: Sep.-Oct. 2018 from Baykonour, Proton–Block-DM

**3 Months**: flight to L2, PV and calibration phase

**4 years**: 8 all sky surveys (eRASS:1-8; scanning mode: 6 rotations/day)
  - Re-visit LMC & SMC every ~month (to $L_{0.5-2\text{ keV}} \sim 10^{34}$ \text{erg/s})

**2.5 years**: pointed observations, including ~20% GTO. 1 AO per year

**Ground Segment**: 2 x 70m antennas (Bear Lakes and Ussirisk), daily contact (up to ~4 hours); telemetry transfer directly to MPE via Moscow NPOL/IKI Control Center

eROSITA, XRU, 6/2017
ART-XC

PI: M. Pavlinsky (IKI)

- Energy range: 5-30 keV
- FOV: ∅ 34’
- On-axis resolution ≤ 1’
- Energy resol. 10% at 14keV
- Time res. 1ms
Effective Area and Grasp

Effective Area: \(~1700\, \text{cm}^2\) (FoV avg. @1keV)

- Effective area at 1keV comparable with XMM-Newton
- Factor \(~7-8\) larger surveying speed
- 4 years dedicated to all sky survey (with est. 70-80\% efficiency)
**eROSITA surveys in context**

Point sources sensitivity

- eRASS:1 = after 6 months
- eRASS:8 = after 4 years

Extended sources sensitivity

All sky: $10^{-14}$ (0.5-2 keV)
2$\times10^{-13}$ (2-10 keV) [erg/cm$^2$/s]

All sky: $3.4 \times 10^{-14}$ (0.5-2 keV)

Merloni et al. 2012
RASS vs. eROSITA vs. XMM

ROSAT all-sky survey  eRASS:8 (simulated)  XMM-XXL

Image credits: MPE, eRosita_DE consortium, XMM-XXL
Approx. Number of X-ray sources detected per year (from published catalogs, not corrected for duplications)
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At the end of its first year of operations, eROSITA will have detected as many new sources as have been catalogued in 50 years of X-ray astronomy.
All massive clusters

- 110k clusters with >50 net counts ("secure" detections)
- 23k clusters with accurate redshift determination from X-ray alone
- ~2k clusters with accurate temperature determination from X-ray spectra
3 Million AGN: physics and cosmology

- The most luminous AGN, tracers of large scale structure: the “quasar” mode of AGN feedback
- (Obscured and Un-obscured) accretion history
- High-z AGN
- Huge effective volume, BAO with biased tracers
- SED vs. L, L/L_{EDD}
- Soft spectral response
- Uninterrupted view!

<z>=1

\langle L_X \rangle = 10^{44}
And More…

• Provide a detailed view of the compact objects (NS, BH) population of the Milky Way

• Survey of 600k active (young, magnetic) stars

• Map the diffuse X-ray emission and the hot ISM in the Milky Way and in the Solar neighborhood

• Study nearby star-forming galaxies and galaxy groups

• Provide a dynamical view of the X-ray sky and identify transients and variable sources, including 1000’s TDEs

• Serendipity…

Spectroscopic follow-up

- **SDSS IV/SPIDERS (2019-2020)**
  - ~8,000 redshifts of RASS & XMMSL AGN (~85% complete follow-up of r<17 RASS and XMMSL sources) + 4,000 RASS Clusters (CODEX sample)
  - eROSITA follow-up over a ~700 deg$^2$ area in the NGC: reach >80% completeness for eRASS:1/2 (~20,000 AGN + Cluster gals. spectra)

- **After Sloan 4: SPIDERS-II (2020-2024)**
  - SDSS + LCO full-sky coverage complete follow-up of eRASS:3 over ~10,000 deg$^2$ (300k AGN spectra to i=21.5, 80k galaxies in 10k clusters)

- **VISTA/4MOST (2022-2027)**
  - Complete, systematic follow-up of both Clusters and AGN from eROSITA: reach >90% completeness for eRASS:8
  - ~700k AGN spectra 0<z<6
  - Up 10 100k high resolution (R~20000) spectra of QSO for IGM studies
  - ~1M galaxies in ~50k X-ray selected clusters (Clusters clustering, RSD, velocity dispersion, gravitational redshift)
Working with eROSITA

- **eROSITA is a PI instrument**
  - Scientific exploitation of data shared between the partners: 50% MPE and 50% IKI, West/East (gal. coord.)
  - German data public after 2 yrs, 3 releases (‘20, ‘22, ‘24; TBC)
  - Proprietary access via eROSITA_DE (/RU) consortium
  - Projects/papers regulated by working groups

- **Working Groups:**
  - Science: Clusters/Cosmology, AGN, Normal galaxies, Compact objects, Diffuse emission/SNR, Stars, Solar System, Time Domain Astrophysics
  - Infrastructure: Data analysis and catalogues, Multiwavelength follow-up, Calibration, Background

- **Collaboration policy (German Consortium):**
  - Individual External Collaborations (proposal to WGs)
  - Group External Collaborations (team-to-team MoUs)
Thank you!

The X-ray Sky

Large Scale Structure

SN Remnants

Neutron Stars

AGN

Clusters