The eROSITA Bulletin

No.7, April 2016

The 2015 meeting of the German eROSITA consortium was held in Bamberg on October 12-13

1. Overall project status and milestones

eROSITA:
The final calibration of all eight Mirror Assemblies (MA = mirror module + baffle) is still ongoing in our PANTER facility, while the calibration of all Camera Assemblies (CA = filter wheel + camera + electronics) is underway in the smaller PUMA facility at MPE (see section 2 below).

In parallel, we have started the preparation for the complete telescope integration (figure on p.10): each of the seven MA-CA pairs will be mounted first, thereby precisely adjusting the distance between mirror and camera to the individual focal lengths which has been measured during the mirror calibration.

During a series of tests performed at Lavochkin Association on April 4 and 5, it appears that the remaining open issues concerning the interface between eROSITA and the spacecraft have been finally solved.

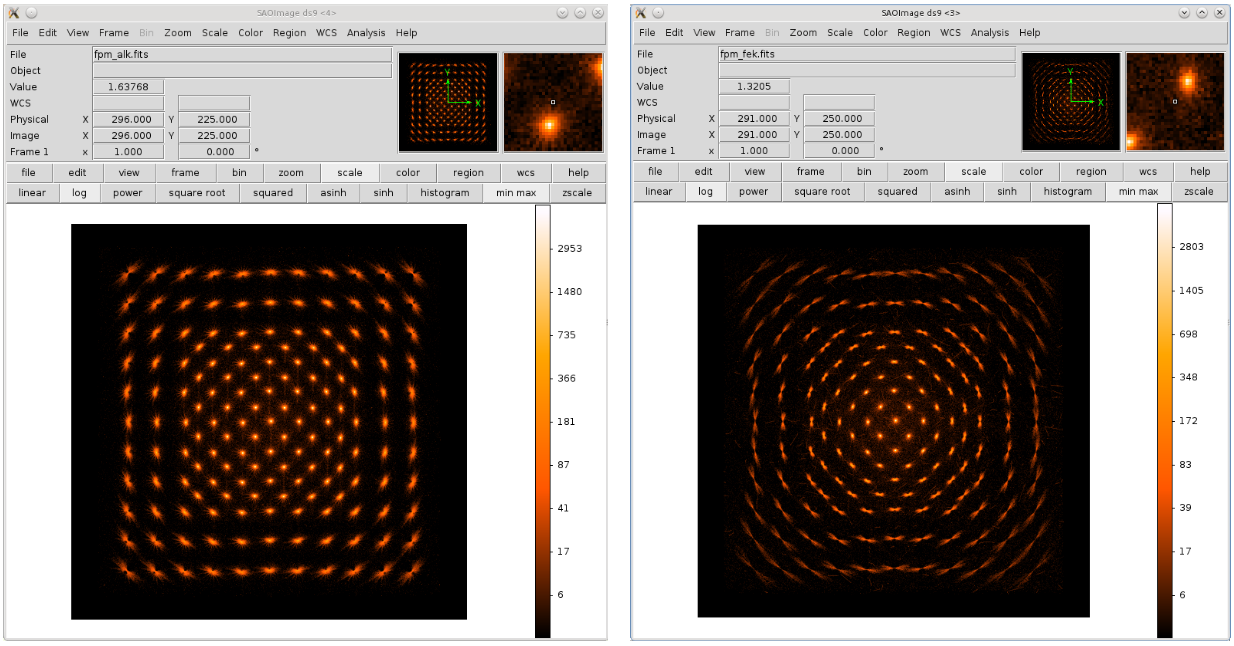
Delivery Acceptance Review (DAR) by DLR will take place between 24.5.2016 (date of the first DAR meeting at MPE) and 23.6.2016 (DAR closure in Bonn).

SRG:
The spacecraft is assembled in porto-flight configuration, waiting for the integration of the radio complex FM, expected for May 2016. The creation of the ground control segment is ongoing, with

no delays. The SRG Ground Control Centre will be operative in the second quarter of 2017, and a compatibility test with the MPE GCS is scheduled for the beginning of 2017. The launch vehicles are available, and the SRG launch is confirmed for the 25th of September 2017.

2. Progress in mirrors and detectors calibration

In the MPE test facilities PANTER and PUMA, calibration of the flight model mirror assembly and detectors, respectively, is ongoing. At the time of writing (beginning of April) mirror assemblies FM1 to FM5 are tested, calibrated and ready for integration, with FM6 undergoing its calibration campaign. At the same time, cameras FM1 to FM4 are also ready for integration, with FM5 currently being calibrated in PUMA. By the end of April, we expect all 7 FM mirrors and cameras to be ready for integration. The figure below shows a PSF scan over the entire detector area (1 degree diameter, as the eROSITA telescope FoV) for FM2 mirror at Al-Kα (left) and Cu-Kα(right) energies.

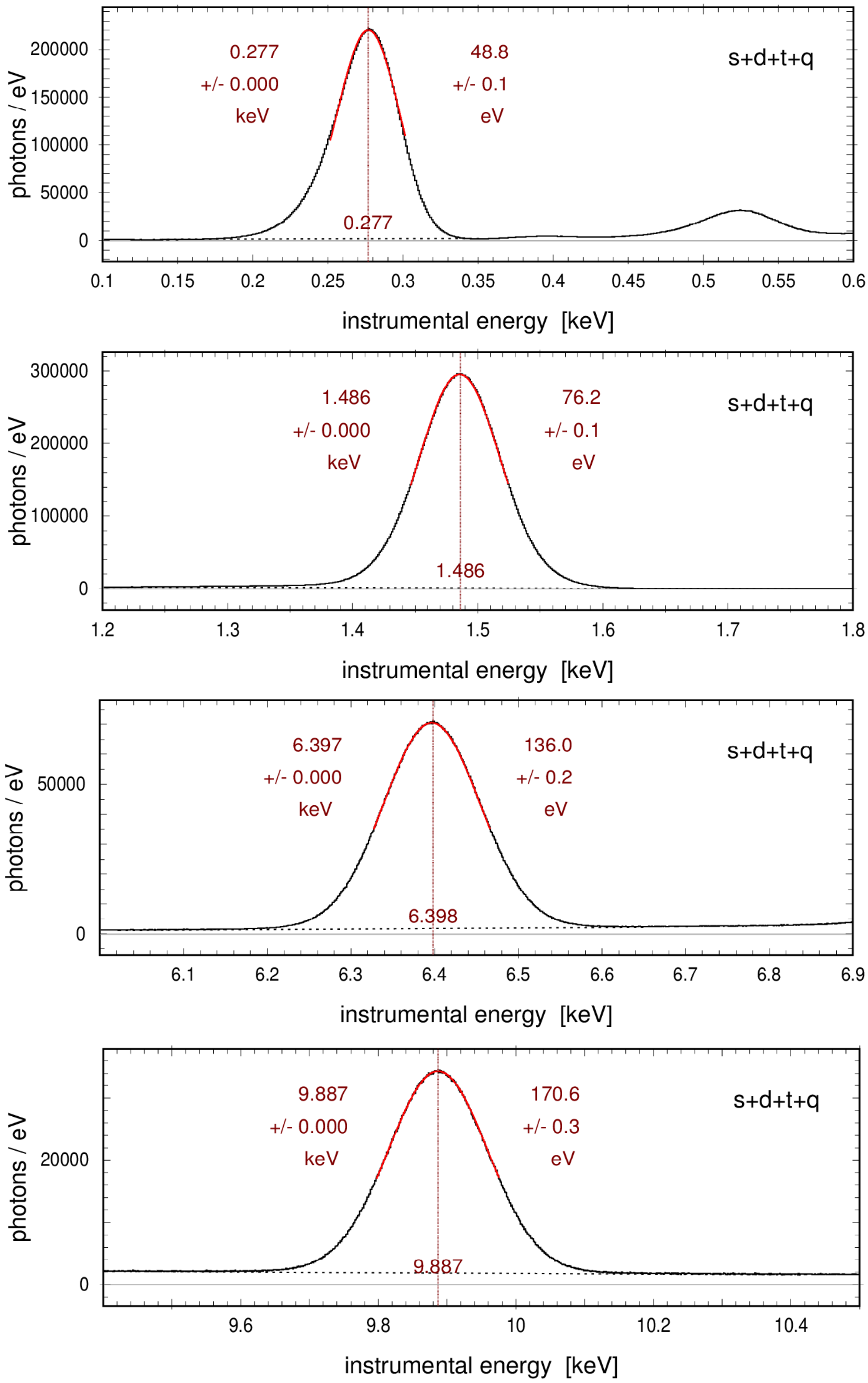


PSF mapping at two different energies: Al-Kα (left) and Cu-Kα (right). The data were collected at PANTER during the test and calibration campaign of the Flight model mirror assembly FM2.

The mirror performance is well within the expectation, with a measured on-axis HEW of 16.3" and 14.7" for Al-Kα and Cu-Kα, respectively. The much stronger vignetting of the system at higher energies is evident in the right panel.

Cameras calibration tests have also provided very good results, with the energy resolution of the FM1 camera (without an on-chip filter) outperforming all expectations. The figure in the next page shows the reconstructed spectra for C-Kα, Al-Kα, Fe-Kα, and Ge-Kα, covering almost the whole energy range. Not only the spectral resolution is superb, but also the precision to which the absolute energy can be reconstructed for all patterns is outstanding: the deviation is below 1 eV except for Fe-Kα, where it is ~1 eV.

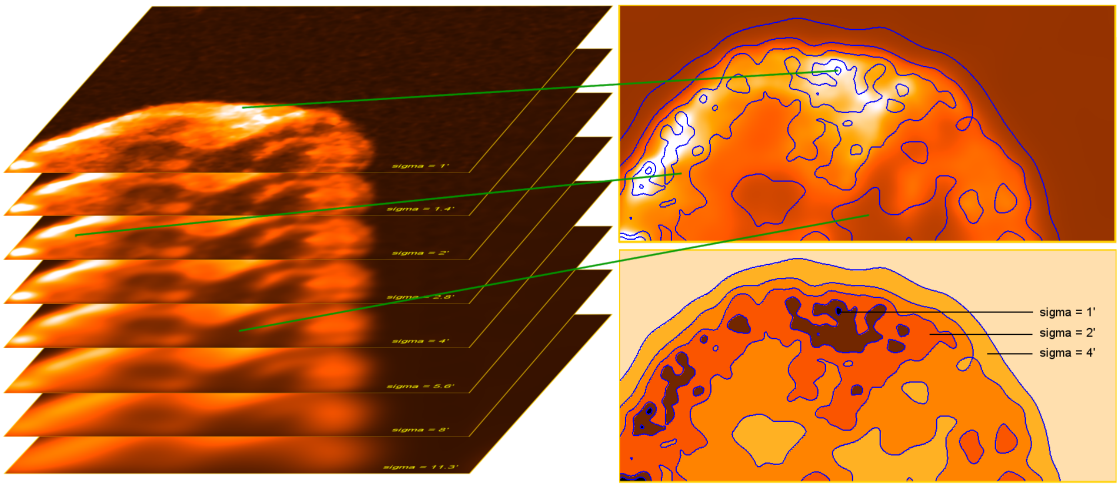
The detectors showed also extremely high level of uniformity in their response, and only weak dependence on temperature of CCD and electronics (unlike XMM-EPIC pn!).



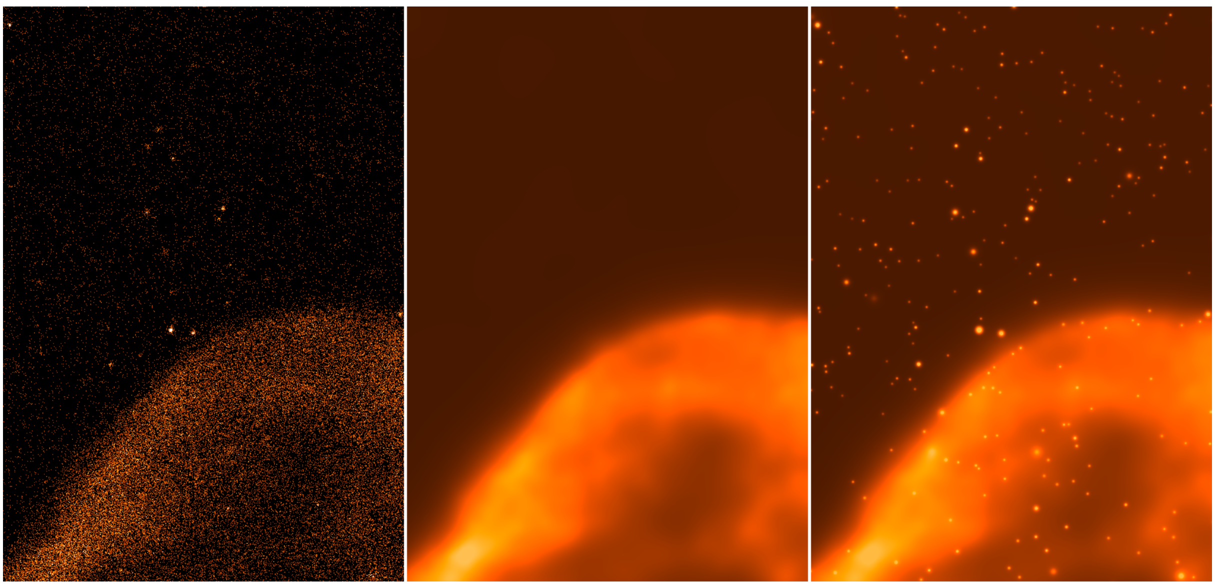
FM1 camera energy resolution tests. From top to bottom, the four panels show the response to monochromatic illumination at the energies of C-Kα, Al-Kα, Fe-Kα and Ge-Kα, respectively. 's+d+t+q' means sum of singles, doubles, triples, and quadruples, i.e. all events are used for the energy reconstruction.

3. A new algorithm for the background determination in the eSASS detection chain

Tests of the eSASS source detection chain on simulated sky fields with strong spatial background variations revealed that the classic spline fitting algorithm, which has so far been used in the "erbackmap" task, does not yield satisfying detection results in all cases. Therefore, a new adaptive filtering method to determine the background was developed and added as optional algorithm to "erbackmap".



Left: Stack of 8 smoothed, area corrected maps with kernel sizes sigma = 1.0 - 11.3 arcmin. Bottom right: Map indicating the kernel size necessary to reach the desired signal-to-noise threshold of 30.0 (black: sigma=1.0 arcmin, light yellow: sigma=5.6 arcmin). Upper right: Final background map, the contours indicate areas of equal smoothing kernels.



Left: 1.2 deg x 1.7 deg part of the Cygnus loop simulation. Middle: Background map resulting from adaptive smoothing. Right: Ermldet source map visualising the final source list.

The procedure uses a science image, where the regions of obvious X-ray sources are masked out ("cheesed image") and 8 Gaussian kernels with increasing widths to calculate 8-fold stacks of the following images:

- "cheesed images" convolved with the Gaussian kernels;
- "cheese mask" convolved with the Gaussian kernels;
- signal-to-noise maps for each kernel size.

The convolved images are divided by the convolved mask to correct for the masked areas. The stack of signal-to-noise maps is evaluated pixel by pixel to find the kernel size necessary to reach the requested signal-to-noise ratio. Then the final background map is compiled pixel by pixel by interpolating between the 2 convolved maps whose signal-to-noise ratios bracket the given SNR. The algorithm was applied to a simulation of the eROSITA survey sky field containing the Cygnus loop (see figures in the previous page).

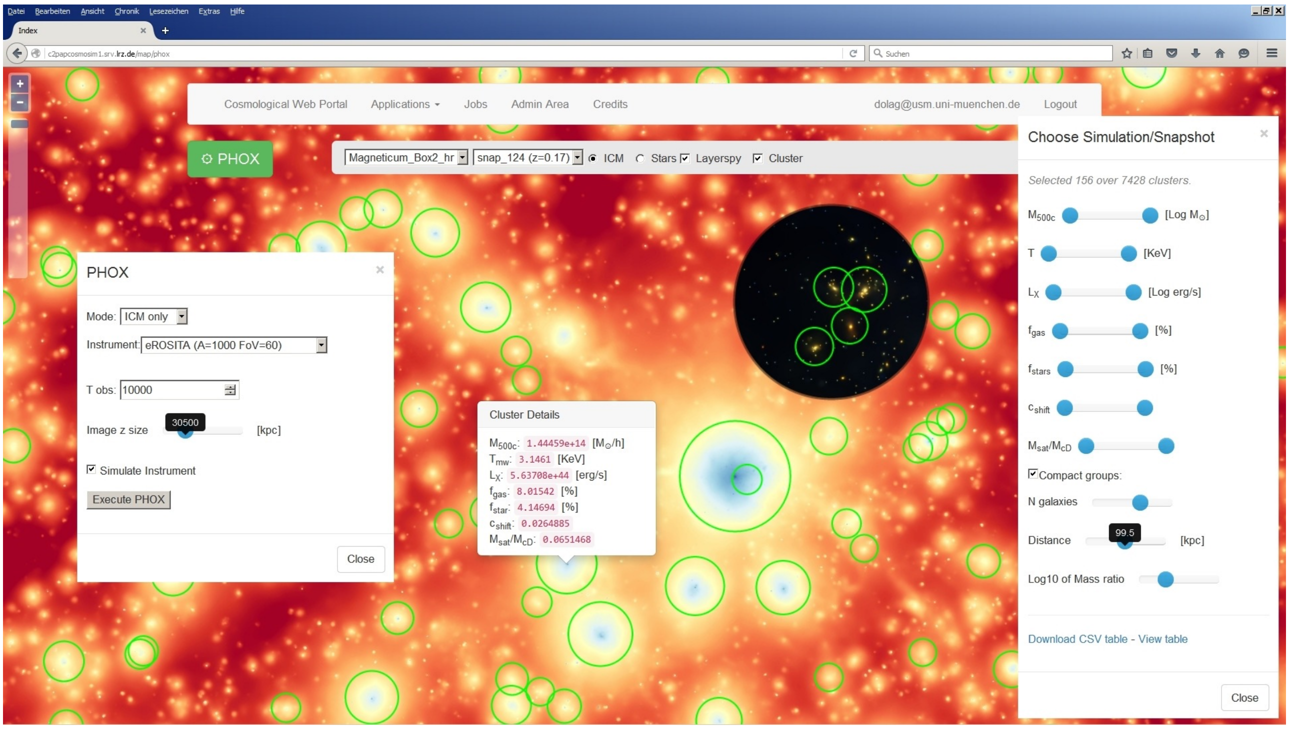
4. Cosmological Web Portal opened for testing in the cluster WG

The outcome of a large set of cosmological, hydro-dynamical simulations (Magneticum, www.magneticum.org) is now made available to the eROSITA_DE community within a first test operation of the cosmological simulation web portal (c2papcosmosim1.srv.lrz.de). Users are able to access data products extracted from the simulations via a user-friendly web interface, browsing through visualizations of cosmological structures, while guided by metadata queries helping to select galaxy clusters and galaxy groups of interest. At the moment, *Phox* is the first enabled service on this platform and allows to perform virtual X-ray observations, where FITS files with photon lists are returned in the so called *simput* format, taking the specifications of various, existing and future X-ray telescopes into account. In addition, for eROSITA, the instrument simulator *sixte* can be enabled, returning the expected event files for the 7 CCD detectors.

The visual front-end allows to explore the cosmological structures within the simulation based on panning through and zooming into high resolution, 256 megapixel size images available for 40 outputs of the simulation at various redshifts. Generally, two different visuals can be used. Either the diffuse baryonic medium is visualized, color coded according to its X-ray emission, or the stellar component is visualized according to the density of the stars and color coded by the mean age of the stellar population. In addition, the position of galaxy clusters and groups can be overlaid as circles and an information panel on the cluster properties gets visible as soon as a galaxy cluster or group is selected. The user is allowed to perform complex queries of the meta-data of the galaxy clusters and groups. This can be done interactively by using an offered interface and allows to select clusters based on different, physical properties. The available meta-data allow not only to select clusters by their mass or temperature, but also by their gas and star fraction and even by some dynamical state indicators, such as center shift or stellar mass fraction between central galaxy and satellite galaxies.

The *Phox* service allows to perform synthetic X-ray observations of the ICM component of the selected galaxy cluster. Here the user can choose the size of the region of the simulation to be included along the line of sight (currently up to 100 Mpc) as well as to also include photons from the AGN (which are self consistently included within the original, hydro-dynamical, cosmological simulations). The service, as soon as executed, returns then the idealized list of observed photon events according to the instrument specification (effective area and field of view) and the chosen observing time. For some specific X-ray instruments, among them eROSITA, the user can request additional the results of a instrument simulation based on *sixte* which then returns event files which takes the actual instrument specifications (like energy dependent effective area and beam smearing) into account.

The results can be used to explore the theoretical performance of eROSITA for detecting realistic clusters and groups across cosmic time. It also allows to easily explore how good their properties can be inferred from idealized observations selecting systems with different mass and different dynamical state. [A. Raganin (LRZ and Excellence Cluster Universe) & K. Dolag (LMU and MPA)]

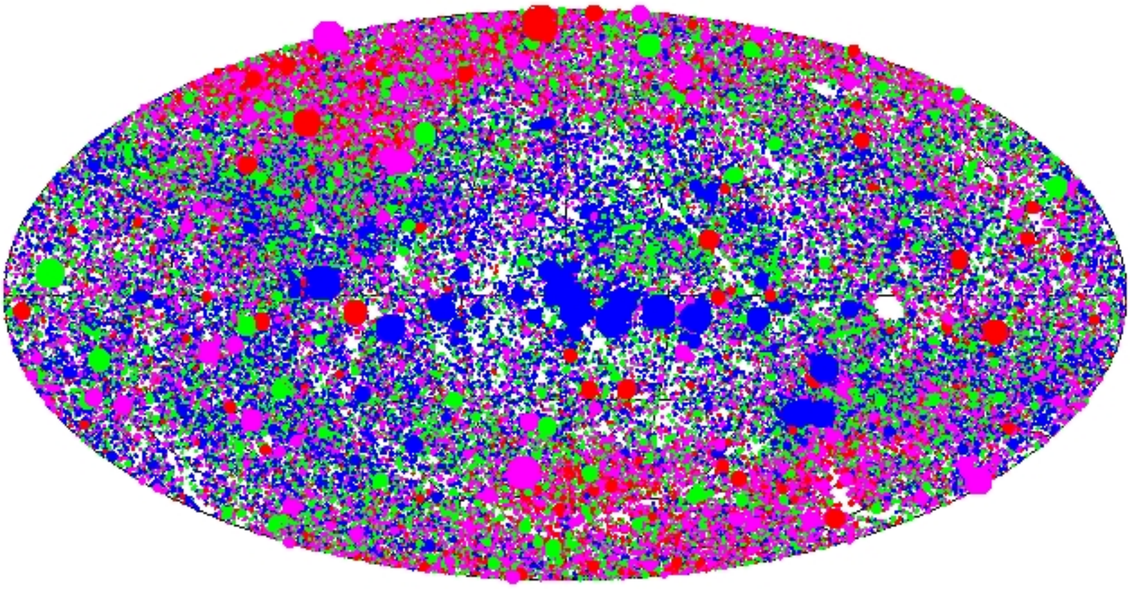


The graphical interface of the web portal, selecting the Magneticum/Box2/hr simulation at z=0.17, visualizing the diffuse media with the layer-spy option for the stellar component active (top right circle) and clusters and groups overlaid as circles. The pop-up shows the properties of the currently chosen cluster. On the right, the cluster restriction interface, which also allows to download all meta data of the actually selected clusters as CSV table. The left window shows the Phox service interface.

5. Scientific highlights

A new view of the X-ray sky: the second ROSAT all-sky survey catalog 2RXS: Scientists at the Max Planck Institute for Extraterrestrial Physics (MPE) have revisited the all-sky survey carried out by the ROSAT satellite, to create a new image of the sky at X-ray wavelengths. The now published "2RXS catalogue" provides the deepest and cleanest X-ray all-sky survey to date, which will only be superseded with the launch of eROSITA.

In the 1990s, the ROSAT X-ray satellite performed the first deep all-sky survey with an imaging telescope in the 0.1-2.4 keV energy band, increasing the number of known X-ray sources by a factor of approximately 100. The goal of the new analysis was to improve the reliability of the catalogue, by re-analysing the original photon event files, using an advanced detection algorithm and a complete screening process.



Aitoff projection in Galactic coordinates of the sky distribution of 2RXS sources. The size of the symbols scales with source count rate and the colours represent different spectral characteristics (increasing hardness ratio from red to blue).

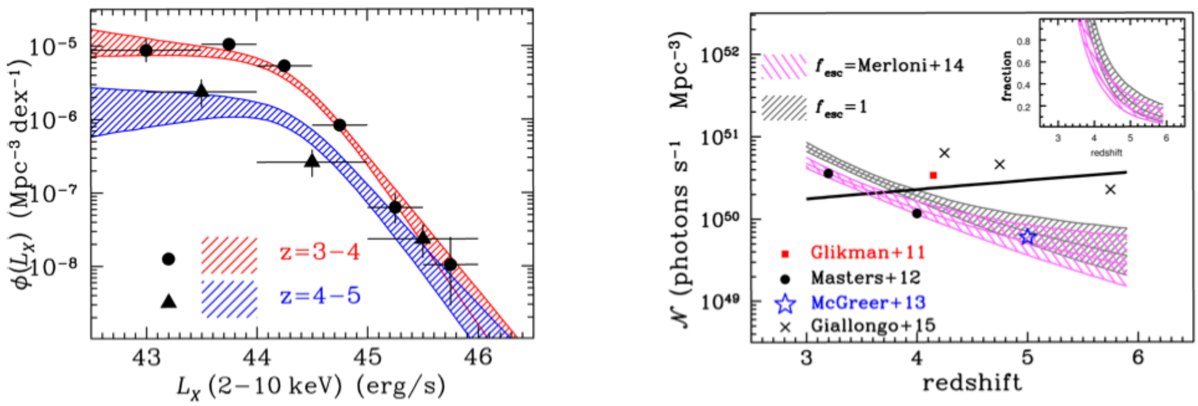
An important feature of the new catalogue is a statistical assessment of the reliability of the sources. Because of the extreme sensitivity and low background of the ROSAT PSPC instrument, cosmic X-ray sources can be identified with the detection of just a few photons. These are sometimes difficult to distinguish from random fluctuations, and the new catalogue provides an assessment of this effect, based on simulated data.

The catalogue contains more than just a list of sources, for example X-ray images and overlaid X-ray contour lines for each of the detections are provided. For many sources, X-ray light curves were created to shows how the sources vary in brightness on intra-day timescales. For the brightest sources X-ray spectral fits were performed based on three basic spectral models, a power law, a thermal-plasma and a black-body emission model.

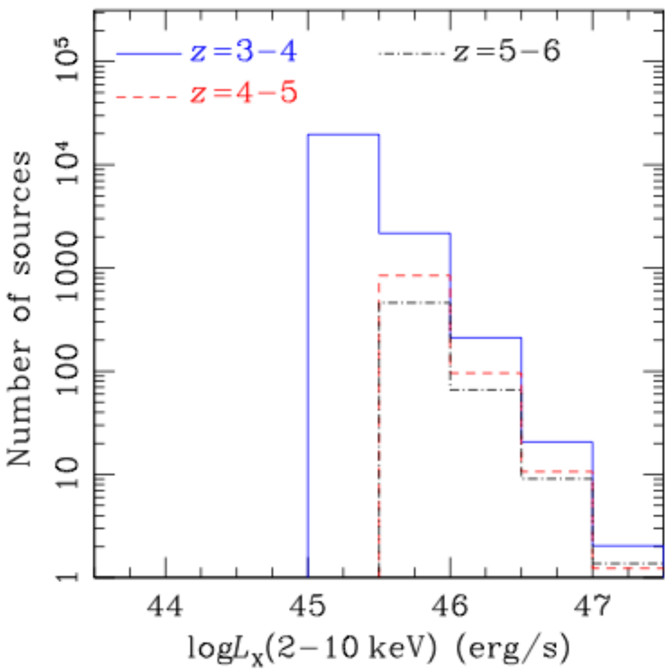
With the new catalogue, the astrophysical community will now be able to explore these objects in the X-ray sky with more confidence, and with considerably more information. Additionally, the experience gained by the high-energy group at MPE in creating the new ROSAT all-sky survey X-ray source catalogue will be integrated in the data reduction analysis and scientific exploration of the forthcoming eROSITA all-sky survey. [Credit: Boller et al., A&A, 588, 103]

The high redshift luminosity function of X-ray AGN: The luminosity function of AGN at high redshifts, z>3, provides constraints on both the formation history of the first Supermassive Black Holes and the role of Active Nuclei in the re-ionisation of the Universe. Selection at X-ray wavelengths allows estimates of the AGN space density to much fainter accretion luminosity levels compared to e.g. UV/optical studies.

In Georgakakis et al. (2015) one of the largest samples of high redshift (z=3-5) X-ray selected AGN has been assembled by combining both pencil-beam/deep (AEGIS, COSMOS, CDFN, CDFS) and wide-area/shallow surveys (XMM-XXL) fields. This allowed constraints on the AGN space density over a luminosity baseline of more than 3 orders of magnitude (see figure below, left panel). A Bayesian methodology has been developed to provide robust constraints on the AGN space density by propagating into the analysis uncertainties in the determination of both the redshift (e.g. photometric redshift errors) and the accretion luminosity of individual sources. It was found that the AGN space density decreases rapidly in the redshift interval z=3-5. As a result the contribution of X-ray AGN to the ionising UV photon-rate density needed to keep the Universe ionised at z>4 is small. Using the luminosity function estimates at z>3, predictions are made on the expected number of high redshift AGN that eROSITA surveys will detect as a function of luminosity and redshift (see figure). [Credit: Georgakakis et al., 2015, MNRAS, 453, 1946]



Left: Space density of AGN in two redshift intervals z=3-4 (filled circles and red regions) and z=4-5 (filled triangles and blue regions). The data points show non-parametric estimates of the AGN space density, while the shaded regions show a particular parametrisation for the luminosity function of AGN. Right: Hydrogen ionising photon rate density as a function of redshift. The shaded regions are the constraints from the X-ray luminosity functions shown on the left under different assumptions on the escape fraction of AGN photons. The grey-shaded region assumes an escaping fraction of unity, i.e. ignoring obscuration effects close to the supermassive black hole; the pink-shaded region assumes the luminosity-dependent Type-1 AGN fraction of Merloni et al. (2014). The data points are results in literature. The thick black line in the plot shows the photon rate density required to keep the Universe ionised at any given redshift. The ratio between the shaded regions and the black line are presented in the inset plot. Even in the extreme case of unity escape fraction the photon rate density produced by the declining X-ray AGN population is insufficient to keep the Universe ionised at z>4.



Number of high-redshift AGN as a function of 2–10 keV X-ray luminosity that the eROSITA 4-year All Sky Survey is expected to detect. The LDDE parametrization of the X-ray luminosity function is used for the predictions. Results for three redshift intervals are plotted, z = 3–4 (blue solid), z = 4–5 (red dashed) and z = 5–6 (black dot–dashed). The predictions for the latter redshift bin are extrapolations of the model. The numbers are for 0.5 dex wide luminosity bins.

6. Recent bibliography

Scientific papers published since the last bulletin and mentioning "eROSITA" in their abstract in the period July 2015 - March 2016 (from ADS):

- **Desai et al.**, *CosmoDM and its application to Pan-STARRS data*, JInst, 10, C06014 (2015)
- **Aghanim et al.**, *The Good, the Bad, and the Ugly: Statistical quality assessment of SZ detections*, A&A, 580, 138 (2015)
- **Worpel & Schwope**, *XMM-Newton and optical observations of the eclipsing polar CSS081231: 071126+440405*, A&A, 583, 130 (2015)
- **Köhlinger, Hoekstra & Eriksen**, *Statistical uncertainties and systematic errors in weak lensing mass estimates of galaxy clusters*, MNRAS, 453, 3107 (2015)
- **Simm et al.**, *Pan-STARRS1 variability of XMM-COSMOS AGN. I. Impact on photometric redshifts*, A&A, 584, 106 (2015)
- **Hofmann et al.**, *Thermodynamic perturbations in the X-ray halo of 33 clusters of galaxies observed with Chandra ACIS*, A&A, 585, 130 (2016)
- **Robrade**, *eROSITA - Nearby Young Stars in X-rays*, To appear in "Young Stars and Planets Near the Sun", Proceedings of IAU Symposium No. 314 (Cambridge University Press), J.H. Kastner, B. Stelzer, S.A. Metchev, eds (2016)
- **Dawson et al.**, *The SDSS-IV Extended Baryon Oscillation Spectroscopic Survey: Overview and Early Data*, AJ, 151, 44 (2016)
- **LaMassa et al.**, *On R-W1 as A Diagnostic to Discover Obscured Active Galactic Nuclei in Wide-area X-Ray Surveys*, ApJ, 818, 88 (2016)
- **Boller et al.**, *Second ROSAT all-sky survey (2RXS) source catalogue*, A&A, 588, 103 (2016)

7. Upcoming meetings and events

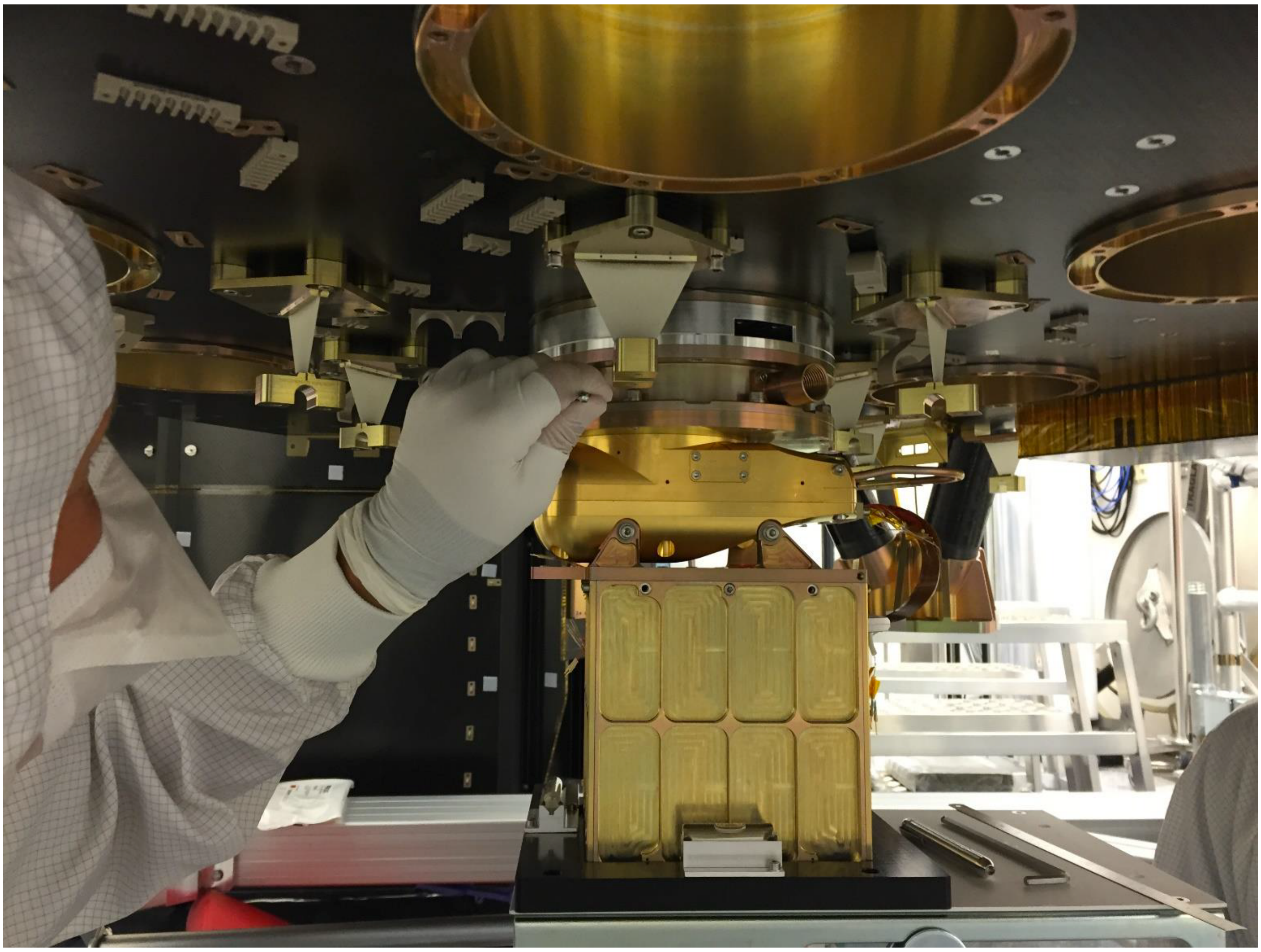
Next eROSITA_DE Consortium Meeting will be held in Tübingen on September 26-28.

A **Bachelor Student summer school in Physics** will be held in Bad Honnef, near Bonn on August 22-26. One of the workshops will be "*From black holes to dark energy: unveiling the wildest regions in the universe with X-ray space telescopes*". More info at www.gradschool.physics.uni-koeln.de/summerschool/summerschool.html

Meetings of General Interest (May 2016 - December 2016; from CADC):

- Junction, TX, USA, May 2-6: *Stellar Remnants at the Junction: Comparing Accreting White Dwarfs, Neutron Stars, and Black Holes*
- European Space Astronomy Centre (ESAC), Villafranca del Castillo, Madrid, May 9-11: *XMM-Newton: The next decade*
- Cambridge, MA, USA, May 16-19: *The Ninth Harvard-Smithsonian Conference on Theoretical Astrophysics: The transient sky*
- Brookhaven National Lab and Stony Brook University, NY, USA, May 22-25: *Cross-correlation Spectacular with LSST: Exploring Synergies Between LSST and External Datasets to Discover Fundamental Physics*
- OHP, Saint Michel l'Observatoire, France, May 23-28: *Vth School of Astroparticle Physics : Physics of the Universe in X-rays*
- Malaga, Spain, May 30-June 3: *Blazars through Sharp Multi-Wavelength Eyes*
- Carnegie Mellon University, Pittsburgh, PA, USA, June 6-10: *Statistical Challenges in Modern Astronomy VI*

- Mykonos island, Greece, June 15-18: *Hot spots in the XMM sky: Cosmology from X-ray to radio*
- Belgrade, Serbia, June 20-24: *LSST @ Europe2*
- Edinburgh, UK, June 26 - July 1: *SPIE Astronomical Telescopes + Instrumentation 2016*
- Heidelberg, Germany, June 27 - July 1: *Illuminating the Dark Ages: Quasars and Galaxies in the Reionization Epoch*
- ESO, Garching, Germany, June 27 - July 1: *Active Galactic Nuclei: what's in a name?*
- Dolomites, Italy, July 3-8: *ACW16: Alpine Cosmology Workshop 2016*
- Athens, Greece, July 4-8: *EWASS 2016: European Week of Astronomy and Space Science*
- University of Warwick, Coventry, UK, July 25-29: *EuroWD16: 20th European White Dwarf Workshop*
- Istanbul, Turkey, July 30 - August 7: *41st COSPAR Scientific Assembly and Associated Events*
- Kuche, Xinjiang Province, China, August 1-5: *Evolution Cycles in X-ray Binaries and Active Galaxies*
- Dartmouth College, Hanover, NH, USA, August 7-11: *The Hidden Monsters: Obscured AGN and Connections to Galaxy Evolution in the Era of NuSTAR and WISE*
- Cambridge, MA, USA, August 16-19: *Chandra Science for the next Decade*
- Santarcangelo di Romagna, Italy, September 5-9: *Crossing the Rubicon: the fate of gas flows in galaxies*
- Bochum, Germany, September 12-16: *Annual Conference of the German Astronomical Society (AG) 2016*
- Ljubljana, Slovenia, September 12-16: *IAU Symposium 324: New Frontiers in Black Hole Astrophysics*
- Arbatax (OG), Sardinia, Italy, September 19-23: *Breaking the Limits: Super-Eddington Accretion on Compact Objects*
- Villanova University, Pennsylvania, USA, October 10-14: *Hot-wiring the Transient Universe V*
- Amsterdam, The Netherlands, October 10-14: *11th INTEGRAL Conference: Gamma-Ray Astrophysics in Multi-Wavelength Perspective*
- Kathmandu, Nepal, October 16-21: *Shining from the heart of darkness: black hole accretion and jets*
- San Pedro de Atacama, Chile, November 27 - December 2: *Wide-field variability surveys: a 21st-century perspective*
- Hiroshima, Japan, November 28 - December 2: *Panoramas of the Evolving Cosmos (The 6th Subaru International Conference)*
- Kavli Institute for Cosmology, Cambridge, UK, December 5-9: *Galaxy clusters - physics laboratories and cosmological probes*



The integration of the eROSITA Mirror and Camera Assemblies (shown here) requires an extreme accuracy: the individual focal length (1600mm) of each pair has to be matched within 50µm. The metrology system has been developed at MPE.

IMPRINT
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