X-Ray Astronomy

Prospects for the eROSITA Cluster Survey

Cluster number estimates and image simulations

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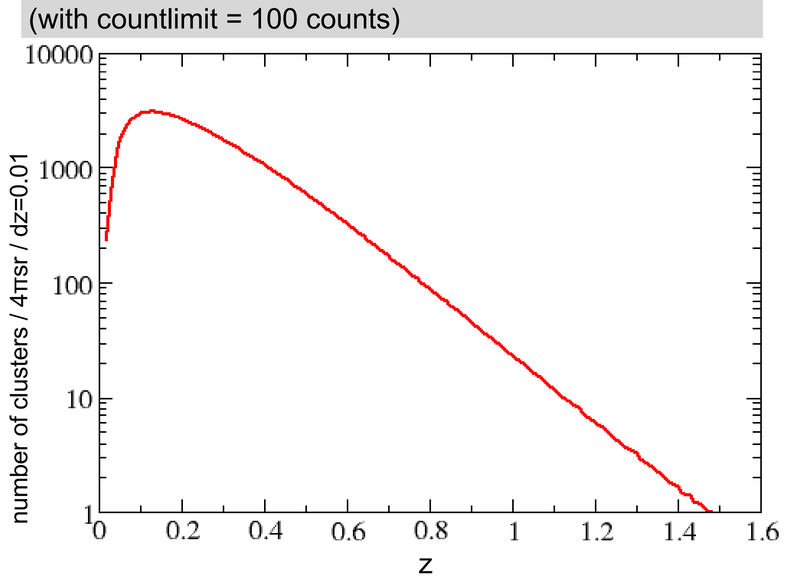
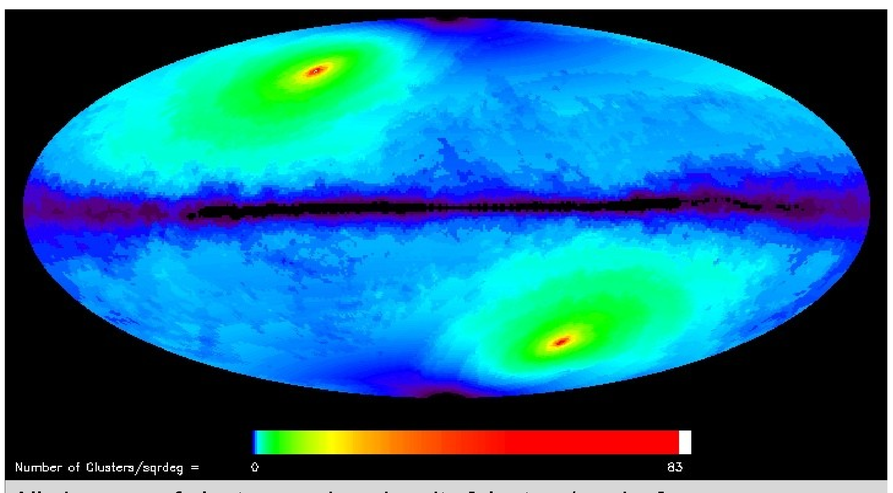
Abstract: One of the main goals of the eROSITA[1] mission is the study of cosmological parameters using **(i)** the large-scale structure of the universe traced by galaxy clusters and **(ii)** the redshift resolved cluster mass function. Both aspects require a sophisticated cluster detection algorithm and a well defined cluster selection function. We estimate the number of galaxy clusters which can be found in the eROSITA all sky survey and present an eROSITA image simulator.

For estimating the number of clusters detectable in the eROSITA all sky survey, depending on galactic coordinates and redshift, a luminosity function was derived from a cluster mass function $\Phi(M,z)$[2] by applying an M-L relation[3]. The cluster temperature was linked to luminosity by an L-T relation[4].
Using xspec, we produced a countrate lookup table as a function of the cluster's redshift z, luminosity L and of galactic hydrogen absorbing column density nH. Based on an exposure map (assumptions: 4 year mission, 80% efficiency) and an nH-allsky map[5], a cluster number density N(l,b,z) was calculated. See the two representations of this function on the right.

Redshift distribution of cluster number density:
~500 clusters with redshift z>1 will be discovered.
(with countlimit = 100 counts)





All sky map of cluster number density [clusters/sqrdeg],
conservative countlimit = 100 counts.
⟶ 79912 clusters detected, 69809 with |b|>20°. With a more relaxed countlimit for the regions of lower exposure, the mission goal of detecting 100 000 clusters of galaxies will be well achievable.

Due to the extended nature of galaxy cluster X-Ray emission (as opposed to point sources), the exact count limit depends strongly on various cluster parameters and the X-Ray background. In order to determine a robust sky coverage function, an image simulator has been developed. It will also be used to develop and test various source detection and characterization methods and eventually to compute the survey selection function. The eROSITA simulator takes three components as input:
1. A map of surface brightness [erg/cm^2/s/deg^2] in the 0.5-2.0keV band which is derived from a light-cone (redshift range: 0<z<6) based on a cosmological/hydrodynamical simulation[7,8]. It contains emission from hot gas in galaxy clusters and groups and the filaments of the cosmic web. **2.** A list of AGN positions (randomly distributed, clustering according to large scale structure planned for later) following the logN-logS relation observed in the COSMOS field[6]. **3.** The background countrate estimated for the planned eROSITA orbit at Lagrangian point L2.
The code then applies Poisson statistics to produce a photon event list before the photons are redistributed according to a field-of-view averaged survey PSF. The output image is obtained by binning the event list in 9.67” image pixels. In a later version the code will also apply subpixel resolution based on split events (distribution of the charge cloud produced in the detector over more than one detector pixel).

The average survey Point Spread Function is composed of several components:
A raytracing simulation provides the offaxis blurring. A Gaussian with 15" HEW (requirement for the onaxis PSF) was added to account for optical errors of the mirror system. Additional uncertainties come from attitude errors as well as thermal and mechanical deformations of the telescope structure.
All components add up to a total half energy width of ~ 30" (see image below).

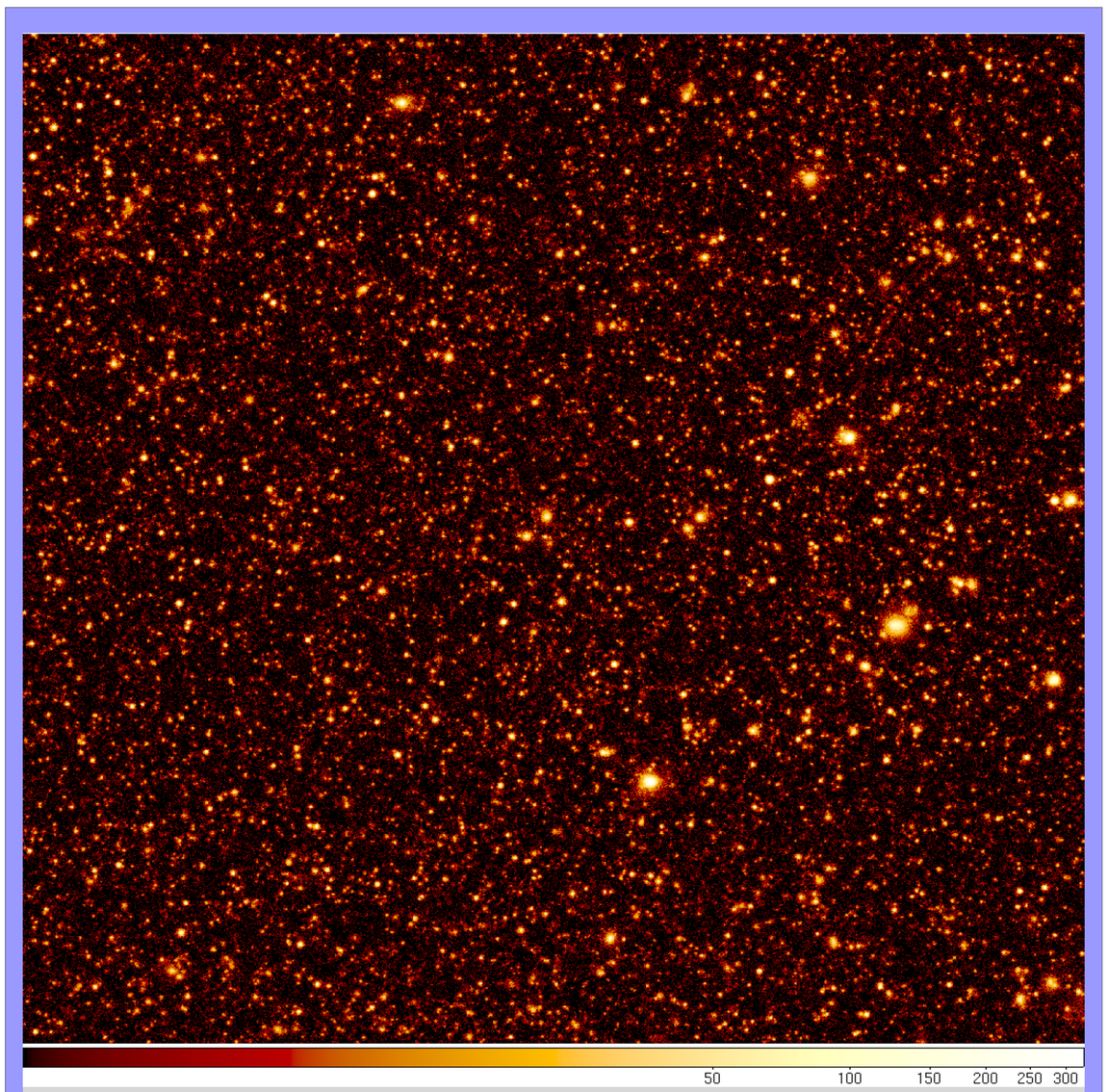
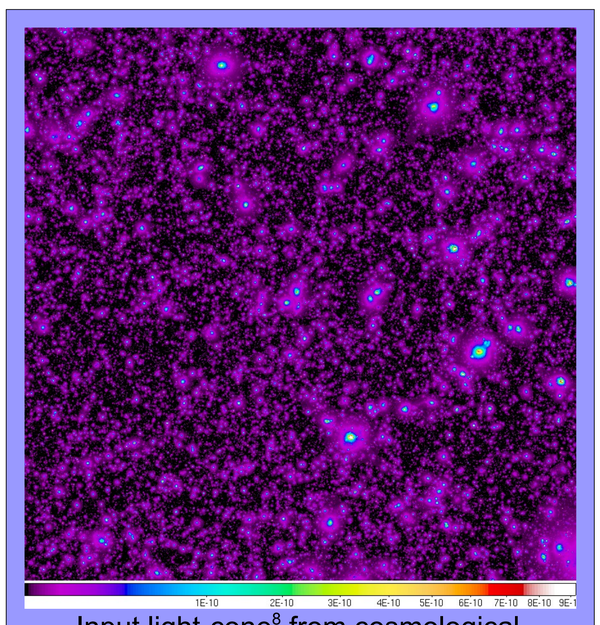
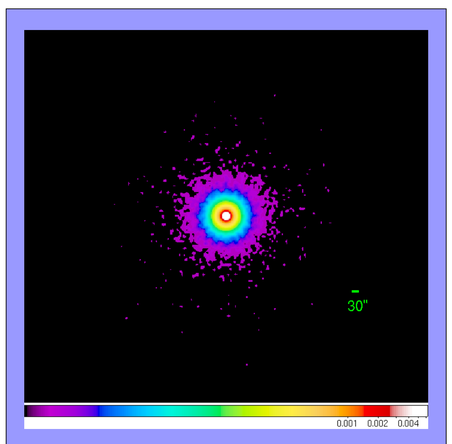


Image simulation: 3.7°x 3.7° scan, 30ks exposure, 0.5-2.0keV band



Input light-cone[8] from cosmological hydrodynamical simulation[7]



PSF: averaged over 61' FOV (log scale)

AGN logN-logS:
from COSMOS field[6]

Background estimation
for L2-Orbit

References:
1) Predehl et al.: eROSITA, in UV, X-Ray, and Gamma-Ray Space Instrumentation for Astronomy XV, Proc. of SPIE Vol. 6686, 668617, (2007)
2) Evrard et al.: Galaxy Clusters in Hubble Volume Simulations: Cosmological Constraints from Sky Survey Populations, ApJ 573, 7-36, 2002
3) Reiprich & Böhringer: The Mass Function of an X-Ray Flux-limited Sample of Galaxy Clusters, ApJ 567, 716-740, 2002
4) Markevitch: The LX-T Relation and Temperature Function for Nearby Clusters Revisited, ApJ 504, 27-34, 1998
5) http://lambda.gsfc.nasa.gov/product/foreground/f_images.cfm, composite from Hartmann et al. (1997) and Dickey & Lockman (1990)
6) Cappelluti et al.: The XMM-Newton Wide-Field Survey in the COSMOS Field. II. X-Ray Data and the logN-logS Relations, ApJS 172, 341-352, 2007
7) Borgani et al.: X-ray properties of galaxy clusters and groups from a cosmological hydrodynamical simulation, MNRAS 348, 1078-1096, 2004
8) Roncarelli et al.: Properties of the diffuse X-ray background in a high-resolution hydrodynamical simulation, MNRAS 368, 74-84, 2006

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