SXC: A Microcalorimeter Instrument for the Spectrum-X-Gamma Mission

Randall Smith for the SXC Collaboration

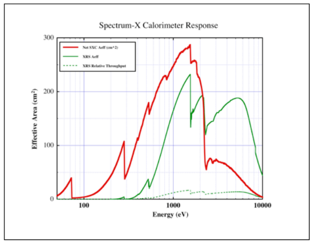
ABSTRACT: Spectrum-X-Gamma is a Russian mission to be launched in 2011. The primary instrument is eROSITA, provided by MPE in Garching, which will make a 4-year all sky survey in the 0.1-10keV range using an array of seven telescopes. An M.O.U. between DFG and ROSCOSMOS has been signed and both instrument and spacecraft are fully funded. Smaller instruments include LOBSTER — a wide-field monitor from Leicester, and ART — a hard X-ray telescope from IKI. At the invitation of scientists at IKI who would like to add a microcalorimeter instrument to obtain spatially-resolved precision spectra of a number of massive clusters of galaxies during an initial 6-month pointed phase, we proposed SXC — the Spectrum-X Calorimeter — to perform this function and to obtain a detailed spectral map of the soft X-ray diffuse background during the 4-year survey phase. This instrument will use an eighth eROSITA mirror and a 6 × 6 microcalorimeter array similar to the one launched on Suzaku with improved infrared blocking filters to enhance the low-energy response. This combination results in effective areas of 33 cm^2 at 6 keV, 280 cm^2 at 1.5 keV, and 100 cm^2 below the carbon edge at 0.28 keV. The field of view is 11' × 11' with 1.8' square pixels. The mirror has a half-power diameter ~15", so the pixels are sharply defined. Energy resolution is 6 eV FWHM with a goal of 4 eV. Science goals are to determine turbulent velocities in the hot gas of massive clusters, to make precision measurements of cluster temperature and abundances from carbon to nickel, and to disentangle the contributions of the Galactic halo, disk, local hot bubble, and solar wind charge exchange to the soft X-ray background. The 4-year survey will provide high-quality spectra for every 5° × 5° area on the sky with useful spectral information on much finer scales, and very high precision and sensitivity to weak lines when larger areas are averaged. The intention is to make all the data public on a short time scale.

Detector: 6 x 6 array with 0.815 x 0.815 mm^2 pixels, 6 eV @ 6 keV, T_{op} = 50 mK. (Alternative design originally developed for XRS.) 11' x 11' f.o.v.

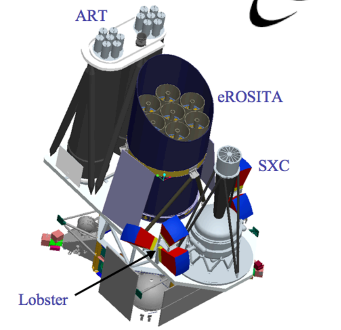
Mirror: eRosita (15'' HPD, 400 cm^2 @ 1 keV, 40 cm^2 @ 6 keV)

Cooler: NeXT design (mechanical pre-coolers + ADR, LHe for reliability)

Lifetime requirement > ½ year, potential >5 years

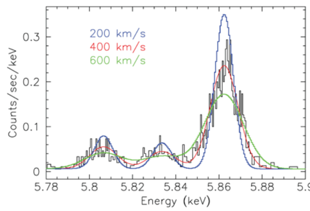


Net effective area for the Spectrum-X Calorimeter instrument. The mirror is slightly larger than the XRS mirror, but has a much shorter focal length, making the effective area smaller at high energies. However, the field of view is 14 times larger than XRS, so net throughput is larger all to way to 10 keV for a source that fills its 11 arc-minute field.

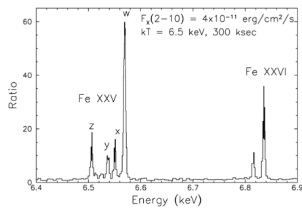


Support: The Mission of Opportunity line would be the most logical avenue for pursuing support of the Spectrum-X Calorimeter. Unfortunately, there was no explorer NRA last year, and the one expected at the end of this year is not soon enough for the SXG schedule. The very short time remaining before launch required a commitment by the end of September this year. The only timely proposal opportunity was the ROSES APRA. ISAS/JAXA will provide an effectively cryogen-free (no consumables) cooling system. MPE is contributing an eighth eROSITA mirror, and SRON will provide the telescope structure, integration, and management. We proposed the U.S. contribution as a sub-orbital class experiment with an extremely high science return relative to NASA investment.

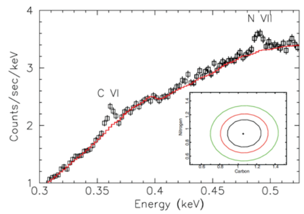
1. 6-month pointed phase: Long observations of 20-40 nearby clusters primarily to determine velocity dispersions. Temperature profiles and abundances will also be obtained to beyond the virial radii.



Simulated 300 ks SXC exposure of A1413. Similar exposures will yield turbulent velocity measurements for any of the 30-40 brightest hot clusters. In this simulation of the Fe XXV lines, the input turbulent velocity of 400 km/s is easily distinguished from models with lower and higher values.

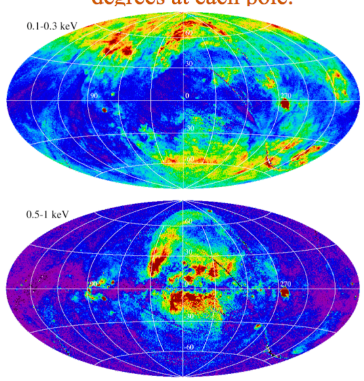


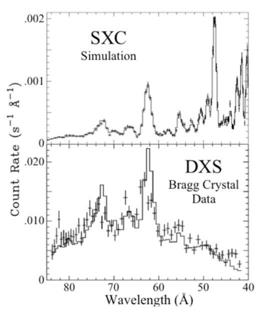
The pointed phase will yield 30 to 40 high-quality Fe line spectra. Shown here are Fe lines from a hot cluster at redshift 0.02, plotted as a ratio to the bremsstrahlung continuum. Four of the He-like lines are visible, as are the two H-like lines, allowing detailed plasma diagnostics.



C and N abundances can be measured at the ±20% level from a cluster with a flux of 4× 10^{-11} ergs/cm^2/sec. The inset shows the 68, 90, and 99% confidence contours for the C and N abundance with respect to solar.

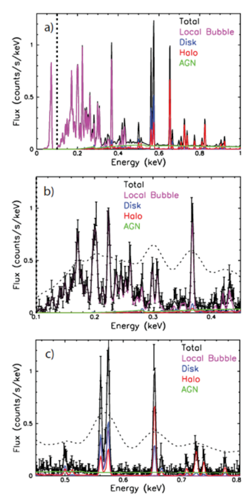
2. 4-year all sky survey: This will be eight ROSAT-type surveys in succession, with the high-coverage scan poles moved about half way from the ecliptic poles toward the Galactic poles, and wobbled to provide uniform deep coverage of about 100 square degrees at each pole.



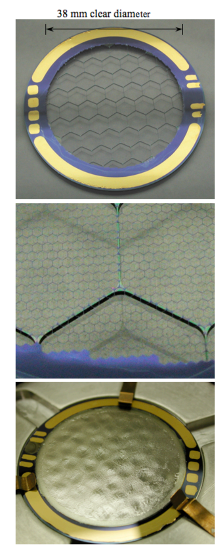


The bottom panel shows the only existing high resolution spectrum of the 1/4-keV diffuse background, obtained by the Diffuse X-ray Spectrometer experiment that flew as an attached shuttle payload. No physical emission model provided a satisfactory fit. The fit shown is the best found: a 10^6 K equilibrium thermal spectrum with independent depletions in Si, Mg, and Fe. The upper spectrum shows a simulation of the SXC sky survey result from the same region of sky near the Galactic plane using the same model.

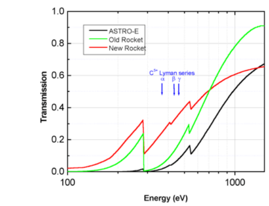
Figure at right shows spectrum expected for a typical mid-latitude field of 5° x 5° extent from the 4-year survey. There will be approximately 1600 independent spectra of this quality over the full sky, and considerably more detail in the high-exposure regions around the survey poles. Useful spectral diagnostics can be obtained on much smaller areas, and larger areas can be averaged to search for very faint spectral features. 1.8' pixels allow efficient removal of point sources and other interferences.
The expanded sections in the lower panels show the same spectrum with ideal CCD resolution as dashed lines. Nominal identifications of various components are given in the legend.
The high spectral resolution and excellent statistics allow detailed plasma diagnostics and identification of charge exchange contributions.



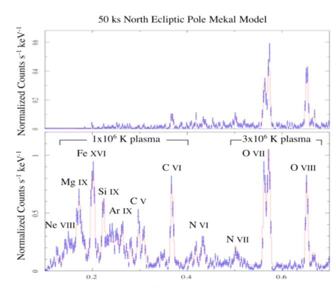
You do need thin filters . . .



Top: *Two-level silicon support mesh for infrared blocking filters. Gold bars are electrical contacts for an integral deicing heater that can be used to safely remove contaminants such as those that have degraded* Chandra *and* Suzaku *instruments.*
Center: *Detail showing 350 μm pitch front mesh. The deicing heater is ion-implanted into this front level.*
Bottom: *Filter consisting of 20 nm of aluminum on 50 nm of polyimide attached to mesh. This filter can support almost 1 p.s.i. pressure differential.*



Infrared blocking filter transmission curves, showing net transmission for set of five filters. The old rocket filters had much better transmission than the XRS filters, but were exceedingly delicate and not suitable for an orbital instrument. The new rocket filters are even thinner, but are quite robust due to the silicon mesh support. The SXC filters will be very similar to the new rocket filters.



Typical 5° x 5° field from the 4-year all sky survey. The simulation is for a multi-component fit to Suzaku observations near the North Ecliptic Pole. The lower panel shows the result using filters similar to the new sounding rocket filters. The upper panel shows the same observation assuming filters identical to those used for the XRS instrument on Suzaku. *Note that there is almost no information about the ubiquitous $1x10^6$ K component.*