eROSITA Studies of Narrow-Line Seyfert 1 Galaxies

Th. Boller et al.

Max-Planck-Institut für extraterrestrische Physik

Abstract

The broad band, large effective area and high spectral resolution of this important new mission will allow the best X-ray studies of NLS1 to date. We will measure their soft and hard X-ray continua, their spectral features, and their strong flux and spectral variability and compare the timing and spectral complexity with previous missions. eROSITA spectra will allow (1) precision fitting of the soft X-ray excess and hard X-ray power law, and comparision with previous multi-epoch X-ray observations (2) studies of broad and ionized iron K line mission and comparision with previous and present X-ray missions, (3) studies of ionized gas along the line of sight, and (4) measurements of the Compton reflection continuum, (5) study of relativistic Fe K and Fe L lines and time lag measurements. eROSITA light curves will allow (1) studies of rapid and nonlinear X-ray variability, (2) power spectrum analyses, and (3) measurements of spectral variability.

Scientific Background

All previous and present X-ray missions have shown many narrow-line Seyfert 1 galaxies (hereafter NLS1; see Osterbrock & Pogge 1985 and Goodrich 1989) to have remarkable X-ray properties compared to Seyfert 1 galaxies with broader Balmer lines. NLS1 are generally characterized by steep soft X-ray spectra with photon indices for simple power-law fits up to about 5. Detailed spectral modeling shows that NLS1 often have very strong soft X-ray excess components compared to their hard X-ray tails. A clear anticorrelation is found between the ROSAT spectral softness and the Hβ full-width at half-maximum intensity (FWHM) in type 1 Seyferts (e.g. Boller, Brandt & Fink 1996) and quasars (e.g. Laor et al. 1997). This is remarkable as the X-ray spectra of most Seyfert 1 type galaxies are formed predominantly within ≈ 5 Schwarzschild radii of their black holes, while Seyfert optical permitted lines are formed in a separate and significantly larger region. It appears that the anticorrelation between Hβ FWHM and ROSAT spectral softness is part of a more general set of relations which involve the Boroson & Green (1992) primary eigenvector, and it has been suggested that NLS1 may be those Seyfert 1s which are accreting at relatively high fractions of the Eddington rate (Boller & Tanaka 2005). NLS1 often show sharp spectral cut-offs in the high energy spectrum, an open question which is still controversional discussed after the Risaliti et al. (2013) NUSTAR Nature paper and the response from Miller et al. (2013). eROSITA might offer a new option to investigate that spectral feature with an independent X-ray mission.

NLS1 can also show remarkably rapid and large-amplitude X-ray variability. One spectacular object, the radio-quiet, ultrasoft NLS1 IRAS 13224–3809, shows persistent giant-amplitude variability events by factors of 35–60 on timescales of just a few days, most likely due to strong relativistic effects (Boller, Brandt, Fabian & Fink 1997). The ROSAT HRI light curve of IRAS 13224–3809 is nonlinear in character, suggesting that the X-ray emission regions on the accretion disk interact nonlinearly or are affected by nonlinear flux amplification. Dramatic flux and spectral variability has also been seen in other NLS1 such as Zwicky 159.034 (Brandt, Pounds & Fink 1995; Grupe et al. 1995a), WPVS007 (Grupe et al. 1995b), 1H 0707–495 (Hayashida 1997), RX J 0947.0+4721 (Molthagen et al. 1997), PHL 1092 (Brandt 1995; Forster & Halpern 1996) and Mrk 766 (e.g. Leighly et al. 1996).

XMM-Newton observations have established the light bending model, supported by the first simultaneous detection of both Fe K and Fe L lines and a reveberation lag between the primary power law and the reflected emission (Fabian et al. 2009),

Here we propose to extend the world-wide successful X-ray studies of ultrasoft NLS1 using eROSITA.

Scientific Goals and Advantages of eROSITA for the Study of Ultrasoft NLS1

As we discuss below, the capabilities of eROSITA are ideally suited to the study of ultrasoft NLS1.The proposed eROSITA observations of ultrasoft NLS1 will allow us to

(1) Examine the shape of the soft X-ray excess and the transition region between the soft X-ray excess and the hard X-ray power law. eROSITA will allow precision fitting of the soft X-ray excess (in ultrasoft NLS1 the soft X-ray excess extends up to about 1 keV). We will use the code of Ross & Fabian (2005) to constrain the black hole mass, accretion rate and spin by fitting the precise eROSITA data. We will search for correlations between the strength and shape of the soft X-ray excess and the slope of the hard X-ray continuum. Such relations are expected if photons from the soft excess are interacting with the accretion disk corona, and there are hints of such effects based on eROSITA data (Boller 2011).

(2) Compare the relative amounts of soft and hard X-ray flux to explore the plausibility of isotropic reprocessing models for the creation of the soft X-ray excess. In ultrasoft NLS1 with steep 2–10 keV spectra, reasonable estimates suggest that the soft X-ray excess contains several times more luminosity than the entire hard X-ray tail (e.g. Done 2008). This is important because models in which the hard X-ray tail is isotropically reprocessed into the soft X-ray excess have trouble explaining such relative luminosities.

(3) Precisely measure the shape of the intrinsic 2–10 keV continuum. XMM-Newton observations suggest that ultrasoft NLS1 have very interesting and steep 2–10 keV continua, and eROSITA will allow these continua to be probed with similar precision. eROSITA will allow a search for intrinsic 2–10 keV continuum curvature, which has been suggested for at least some NLS1.

(4) Constrain the amount of Compton reflection and determine whether the reflection is from an ionized or a neutral accretion disk. The large effective area of eROSITA is needed.

(5) Study iron K line emission. Relativistic iron K line emission will constrain the inclination and conditions of the relativistic region of the disk.

(6) Study X-ray absorption by ionized gas along the line of sight. Some NLS1, including our targets IRAS 13224–3809 and 1H 0707–495, have been suggested to have blueshifted oxygen edges around 1.1 keV (Leighly et al. 1997). However, the precise nature of these claimed features is not yet clear and the power of eROSITA is needed to settle this issue.

(7) Study rapid and large-amplitude X-ray flux variability. eROSITA will allow us to measure the variability power spectra of ultrasoft NLS1. We will constrain nonlinear variability and will search for any quasi-periodic oscillations (e.g. Papadakis & Lawrence 1995 and references therein).

(8) Study X-ray spectral variability. Some NLS1 have shown strong spectral variability in which the soft X-ray excess and hard X-ray power law can vary separately. We will search for lags between soft X-ray and hard X-ray variations. We will also search for variations of the slope of the hard X-ray power law, as have been seen in some NLS1. These can constrain the size of the accretion disk corona and its electron-positron pair content (see Haardt, Maraschi & Ghisellini 1997). It will be especially interesting to search for spectral variability during nonlinear flaring events, as this could suggest the presence of a new X-ray emission mechanism that operates during these times.

(9) Critically examine the possible analogy between ultrasoft NLS1 and ultrasoft Galactic black hole candidates (see Pounds, Done & Osborne 1995).

(10) Measure the high-energy sharp spectral cut-offs with eROSITA and compare this with previous XMM-Newton measurements.

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