Contribution to the proceedings of ‘Astrophysical Dynamics’
(Evora, April 14-16, 1999); to appear in Ap&SS.
Preprint available at http://www.xray.mpe.mpg.de/~skomossa

THE EXCEPTIONAL X-RAY PROPERTIES OF THE NLSY1 GALAXY RX J0134.3-4258

STEFANIE KOMOSSA AND DIETER BREITSCHWERDT
Max-Planck-Inst. extraterrestrische Physik, Postfach 1603, 85740 Garching, Germany; skomossa@xray.mpe.mpg.de
JOCHEN GREINER
Astrophys. Institut Potsdam, 14482 Potsdam, Germany
AND
JANEK MEERSCHWEINCHEN
Weststrasse 19, 3063 Obernkirchen 2, Germany

Abstract. The Narrow-line Seyfert 1 galaxy RX J0134.3-4258 was detected during the *ROSAT* all-sky survey with an ultrasoft spectrum (Greiner 1996). Our later pointed observation led to the discovery of drastic spectral variability. Here, we present the first detailed analysis of the soft X-ray properties of this peculiar source.

1. Introduction and data analysis

RX J0134-42 is a Narrow-line Seyfert 1 (NLSy1) galaxy at redshift z=0.237 (Grupe 1996). It exhibited an ultrasoft spectrum during the *ROSAT* all-sky survey (RASS) in Dec. 1990. Interestingly, the spectrum had changed to flat in our subsequent pointed observation (Dec. 1992). The strong spectral variability which was also noted by Grupe (1996) is explored in detail below (for the full analysis, see Komossa 1999)[1]. Such spectral variability is rare among AGN, and provides important information on the intrinsic emission mechanism and/or the properties of surrounding reprocessing material.
<u>*RASS observation*</u>. When fit by a single powerlaw, the spectrum of RX J0134-42 turns out to be one of the steepest among NLSy1s with photon index $\Gamma_x \approx -4.4$ (cold absorption was fixed to the Galactic value, $N_{\rm Gal} = 1.59\,10^{20}$

[1]First results of this study were presented by Komossa & Fink (e.g., 1997b) and Komossa & Greiner (1999); another study by Grupe et al. (1999) is underway.

TABLE 1. Comparison of different spectral fits to RX J0134-42: (i) single powerlaw (pl), (ii) accretion disk model after Shakura & Sunyaev, and (iii) warm absorber. Γ_x was fixed to −2.2 in (ii) and (iii). 'S' = RASS observation, 'P' = pointing.

obs.	powerlaw$^{(1)}$			acc. disk + pl$^{(1)}$			warm absorber$^{(1)}$		
	$N_{\rm Gal}^{(2)}$	$\Gamma_{\rm x}$	$\chi^2_{\rm red}$	$M_{\rm BH}^{(3)}$	$\frac{\dot M}{M_{\rm edd}}$	$\chi^2_{\rm red}$	log U	log $N_{\rm w}$	$\chi^2_{\rm red}$
S	0.16	−4.4	0.5	1	0.1	0.6	0.5	23.1	0.6
P	0.16	−2.2	1.4						

$^{(1)}N_{\rm H}$ fixed to $N_{\rm Gal}$ $^{(2)}$in 10^{21}cm^{-2} $^{(3)}$ black hole mass in 10^5M$_\odot$, fixed

cm^{-2}). One efficient mechanism to produce such a steep X-ray spectrum is the presence of a 'warm absorber', highly ionized material found in the nuclei of about 50% of the Seyfert galaxies (e.g., Komossa & Fink 1997a,b). There are also indications that the flat-state spectrum is still mildly warm-absorbed (Fig. 1). In fact, a warm-absorbed, intrinsically *flat* powerlaw provides a successful alternative fit to the RASS data. A large column density $N_{\rm w}$ (of the order 10^{23} cm^{-2}) is needed to account for the ultrasoft observed spectrum. When we fix $\Gamma_{\rm x} = -2.2$, the value observed during the later pointing, and use $N_{\rm H} = N_{\rm Gal}$, we obtain $\log N_{\rm w} = 23.1$ and an ionization parameter $\log U = 0.5$. This model gives an excellent fit (${\chi^2}_{\rm red} = 0.6$). A number of further models were applied, some summarized in Tab. 1.

Pointed observation. The fit of a single powerlaw to the spectrum of RX J0134-42 yields a photon index $\Gamma_{\rm x} = -2.2$ ($\chi^2_{\rm red} = 1.4$), much flatter than during the RASS observation. For this model fit, two kinds of residuals are apparent (Fig. 1): (i) the first data point (below 0.15 keV) indicates a higher countrate than predicted by the model. This data point significantly influences the value of $\chi^2_{\rm red}$, and if it is excluded from spectral fitting, we obtain $\chi^2_{\rm red} = 1.0$ and $\Gamma_{\rm x} = -2.1$. Formally, a very low-temperature soft excess could be present in the spectrum of RX J0134-42 but was not fit since constrained by only one data point. The second deviation from the powerlaw is (ii) an underprediction of the countrate in the energy range ∼0.4–0.9 keV (Fig. 1) indicative of the presence of absorption edges, as observed in AGNs where warm absorbers are present. However, again, the deviations from the powerlaw are only defined by few bins, and we thus assume in the following that the spectrum during the pointed observation essentially represents the intrinsic, un-distorted continuum.

Temporal analysis: The mean countrate is nearly constant from RASS (0.30 cts/s) to pointed (0.24 cts/s) observation. During the latter, the lightcurve (see Fig. 2 of Komossa & Greiner 1999) reveals variability by a factor ∼2.

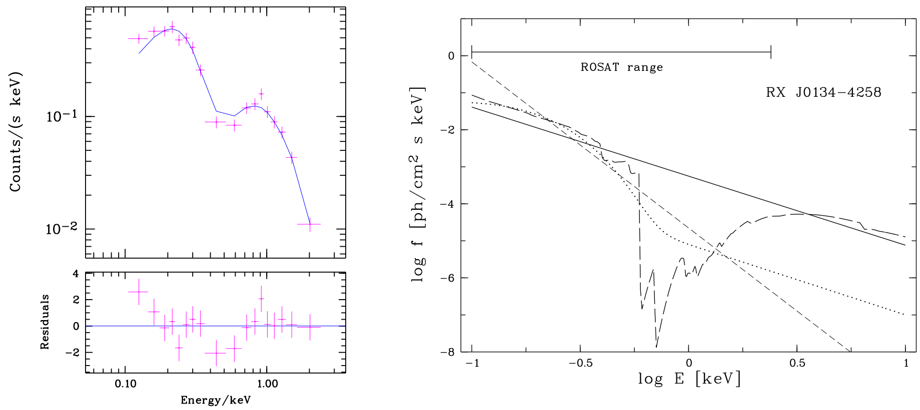

Figure 1. *Left*: The upper panel gives the observed X-ray spectrum (crosses) of RX J0134-42 (pointed observation) and powerlaw model fit (solid line), the lower panel displays the residuals. *Right*: Comparison of different spectral models (corrected for detector response) sucessfully fit to the *ROSAT* survey observation of RX J0134-42 (broken lines) and the pointed observation (solid line). Short-dashed line: single powerlaw with $\Gamma_x = -4.4$; long-dashed: warm-absorbed flat powerlaw; dotted: powerlaw plus soft excess, parameterized as a black body.

2. Discussion: Variability mechanisms

Warm absorption. One mechanism that might explain the spectral variability in RX J0134-42 is warm absorption because this is an efficient way to produce variable, and steep X-ray spectra (e.g., Komossa & Fink 1997a,b). Note, that Grupe (1996) argued against the presence of a warm absorber based on the erroneous statement that warm absorption could not produce a steep soft X-ray spectrum. Examination whether, and under which conditions, a warm absorber is indeed a viable description of the X-ray spectrum, and whether it is the only one, has to be based upon detailed modeling and careful consideration of alternatives:

The most suggestive scenario within the framework of warm absorbers is a change in the *ionization state* of matter along the line of sight, caused by *varying irradiation* by a central ionizing source. One problem arises immediately, though: In the simplest case, *lower* intrinsic luminosity would be expected to cause the *deeper* observed absorption in 1990. However, the source is somewhat *brighter* in the RASS observation. If one wishes to keep this scenario, one would have to assume that the ionization state of the absorber still reflects a preceding (unobserved) low-state in intrinsic flux.

Alternatively, gas heated by the central continuum source may have *crossed the line of sight*, producing the steep RASS spectrum, and has (nearly) disappeared in the 1992 observation. This scenario explains most naturally the nearly constant countrate from RASS to pointed observation,

because the countrate is dominated by the soft energy part of the spectrum (below 0.7 keV) which is essentially unaffected by warm absorption. The transient passage of a BLR cloudlet would be consistent with the scenario proposed by Rodriguez-Pascual et al. (1997) who suggested the presence of *matter-bounded* BLRs in NLSy1 galaxies to account for some of their peculiar optical properties.
Alternatives: (I.) It is important to keep in mind the short duration of the RASS observation, and both, an intrinsically steep powerlaw and a strong soft excess fit the X-ray spectrum as well. Variability in only one component seems to be problematic, though, since the nearly constant countrate has to be accounted for. (II.) A spectral change with constant countrate is reminiscent of one class of Galactic black hole (BH) transients. In fact, the potential similarity of NLSy1s with Galactic BH candidates has been repeatedly mentioned but has never been explored in more detail (see Komossa 1999 for more comments on this possibility). (III.) Finally, it is also possible that the constant countrate is pure coincidence: Both, variable soft excesses *and* variable powerlaws (often of constant shape) have been observed in AGN and these two might have compensated each other to produce nearly constant total countrate.

3. Summary and conclusions

RX J0134-42 underwent a drastic X-ray spectral transition from steep ($\Gamma_x \simeq -4.4$) to flat ($\Gamma_x \simeq -2.2$) between our two *ROSAT* observations separated by 2 yr, while the mean countrate remained nearly constant. We examined several scenarios that might account for this peculiar behavior, with focus on the presence of a warm absorber. We find that a reaction of the ionized material to continuum changes requires non-equilibrium effects to be at work. Alternatively, and more likely, a cloud of warm gas may have passed our line of sight. Variability of both components in the framework of a powerlaw-plus-soft-excess spectral description provides an alternative explanation. High spectral resolution observations at soft X-ray energies will provide further clues on the nature of this interesting source.

References

Greiner J., 1996, Lecture Notes in Physics 472, 285
Grupe D., 1996, PhD Thesis, Universität Göttingen
Komossa S., Fink H., 1997a, A&A 322, 719
Komossa S., Fink H., 1997b, Lecture Notes in Physics 487, 250; astro-ph/9612185
Komossa S., Greiner J., 1999, in 'High Energy Processes in Accreting Black Holes', J. Poutanen & R. Svensson (eds), ASP conf. ser. 161, in press; astro-ph/9810105
Komossa S., 1999, A&A, submitted
Rodriguez-Pascual P.M., Mas-Hesse J.M., Santos-Lleo M., 1997, A&A 327, 72