SUPERSOFT SOURCES

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1. Introduction

Supersoft X-ray sources are a new class of luminous X-ray binaries discovered with the X-ray telescopes of the *Einstein* and *ROSAT* satellites and extensively studied in the optical with ground based telescopes, in the UV with *IUE* and *HST* and in X-rays with *ROSAT*, *Beppo-SAX* and *ASCA* (cf. Kahabka & van den Heuvel 1997, van Teeseling 1997). The luminosities derived for a first sample of supersoft sources studied with moderate resolution X-ray spectroscopy (using *Beppo-SAX LECS* and *ASCA SIS* detectors, Parmar et al. 1997, Ebisawa et al. 1997) have been predicted to follow Iben's stability line (Iben 1982), i.e. the location in the Hertzsprung-Russell diagram which separates the plateau phase from the cooling phase. This is not unreasonable as any system experiencing steady-state accretion, i.e. accretion at a rate equalling about the nuclear burning rate will be found close to the stability line. If the accretion rate exceeds this limit then the white dwarf gets bloated and disappears in X-rays. If the accretion rate falls below this limit the white dwarf envelope cools, the luminosity as well as the temperature ceases and the source enters unstable recurrent nuclear burning. From the population synthesis calculations of Yungelson (1996) follows that there exit for the Milky Way a few sources at any epoch which are more massive than 1.2 $M_{\odot}$. They are expected to be extremely X-ray bright and may be standard candles (cf. Table 1 and Figure 1 for the brightest known supersoft sources per galaxy Milky Way to NGC 55). Their spectral distribution is expected to be similar to that of the extremely hot galactic source RXJ0925.7-4758 (it peaks at 1 keV and the flux is distributed from 0.5 to 2 keV, see Figure 2 for the *ASCA* spectrum of RX J0925.7-4758 (and CAL 87) as derived by Ebisawa et al. 1997).

TABLE 1. The brightest observed supersoft source per host galaxy. Given are distance, galaxy, source name, *ROSAT PSPC* count rate, variability (transient) and an estimate of the mass of the white dwarf.

Distance (kpc)	galaxy	source name	Count rate (1/s)	variab.	M_{WD} ($M_{\odot}$)	Ref.
2	Milky Way	V 1974 Cyg	76	t	1.0-1.1?	[10]
50	LMC	RXJ0513.9-6809	2	t	1.0-1.35?	[6,15]
500	NGC6822	RXJ1944.9-1448	0.0012	?	~1.0?	[4]
700	M31	RXJ0045.5+4154	0.03	t	1.3-1.38?	[17]
1300	NGC55	RXJ0016.0-3914	0.01	t	~1.1-1.3?	[13]

2. Supersoft transients

Transient supersoft sources have been discovered in the Magellanic Clouds and in M31 with the *ROSAT* X-ray telescopes. Some turned out to be recurrent like the LMC transient RX J0513.9-6951 (cf. Southwell et al. 1996) and the M31 transient RX J0045.5+4154 (White et al. 1994). Supersoft sources can be well explained by steady nuclear burning white dwarfs. The timescale

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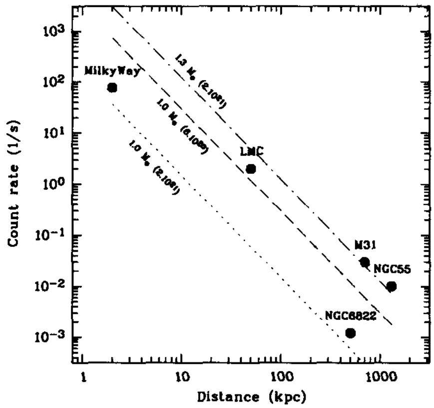

Figure 1. Observed *ROSAT PSPC* count rate versus distance for the brightest (known) supersoft source per galaxy compared with the count rate predicted from non-LTE spectra (Hartmann & Heise 1997) assuming an intensity dependence with distance $D \propto D^{-2}$. The normalisation depends on the mass of the white dwarf and the absorbing Hydrogen column density (lines are given for $M_{\rm WD} = 1.0\ M_\odot$, $N_{\rm H} = 2.10^{21}$ and $N_{\rm H} = 6.10^{20}$ and $M_{\rm WD} = 1.3\ M_\odot$, $N_{\rm H} = 2.10^{21}$).

of steady nuclear burnir is determined by the nuclear burning time scale which can be 10^{-1} to 10^6 years depending on the mass of the white dwarf. Observing transient phenomena in X-rays in these objects with time scales of a few 100 days as in RX J0513.9-6951, RX J0045.5+4154 and CAL 83 (Kahabka et al. 1996) has been explained as contraction/expansion of the white dwarf envelope triggered possibly by temporary variations (increase) in the mass accretion rate. There appears to be an anticorrelation between the X-ray and optical flux changes (cf. Alcock et al. 1996, 1997 for the *MACHO* light curves of these objects). The mechanism underlying such a mass transfer enhancement is not yet clear. It has been proposed to be triggered by magnetic star spot activity of the donor star (cf. Southwell 1996 for RX J0513.9-6951) or by a density wave passing through the disk (cf. Kahabka 1997 for CAL 83). In a recent work Hachisu & Kato (1997a,b) applied optically thick wind models to reproduce the optical light curves of the recurrent sources RX J0513.9-6951 and RX J0019.8+2156 (~40 years recurrence time). They demonstrate that optically thick winds exist in these systems for a considerable fraction of time. During these periods the X-ray emission from the white dwarf is (predicted) to be unobservable in agreement with observations for RX J0513.9-6951. RX J0019.8+2156 is supposed to be presently not in an optically thick wind phase and is therefore visible in X-rays but is expected to enter into a wind phase and disappear in X-rays in a few years. The white dwarf masses estimated for these two objects by applying optically thick wind models are 1.35 and 0.6 $M_\odot$ which reflects the difference in the recurrence periods. It has independently been suggested that modelling the X-ray spectra allow to constrain the mass of the white dwarf assuming that the X-ray spectra are the signatures of steady nuclear burning and the deduced temperatures and luminosities (assuming spectral models like LTE and non-LTE) relate to the mass of the white dwarf (cf. the dependences deduced by Iben (1982) for the plateau and the stability line). There are some differences in the temperatures and luminosities deduced with these models but non-LTE models are favored to be the most reliable description. The temperatures and luminosities inferred with these models can e.g. be compared with the temperatures and luminosities predicted by calculations like those of Iben (1982) (cf. also the work of Sion & Starrfield, 1994). Recent HST UV observations have made it possible to independently constrain the Hydrogen column in the direction towards the source (Gänsicke et al. 1997, van Teeseling 1997) and *Beppo-SAX* and *ASCA SIS* X-ray observations to constrain the effective temperature and luminosity by applying non-LTE white dwarf atmosphere models

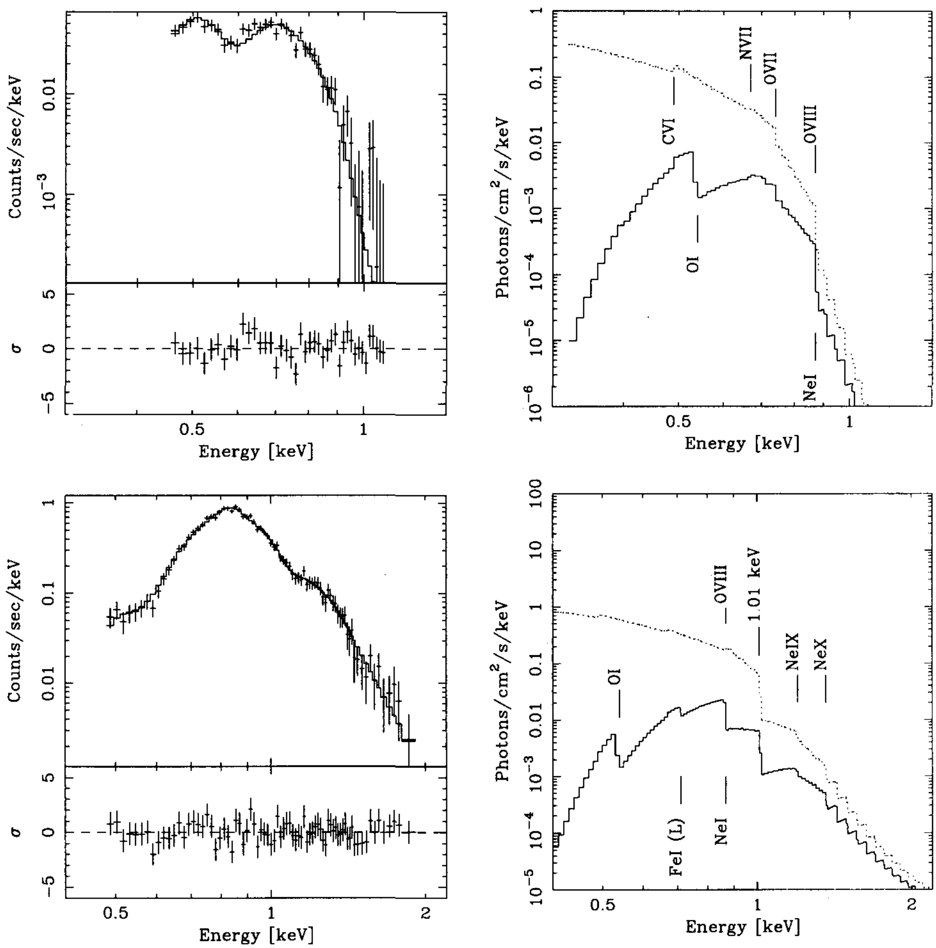

Figure 2. *ASCA* spectra of CAL87 (upper panel) and RX J0925.7-4758 (lower panel) together with best-fit NLTE model (log g=9 and 10 respectively) (from Ebisawa et al. 1997).

(Hartmann & Heise 1997). A first link to white dwarf masses has thus been achieved.

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