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A new class of X-ray sources: hot subdwarfs with compact companions

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Abstract. Hot subdwarfs represent very late evolutionary stages of low-mass stars that lost most of their envelope and are now in the core He burning phase. Mass loss in close binaries can explain the ejection of the massive H envelopes necessary to form hot subdwarfs. It is expected that many of these stars have white dwarf or neutron star companions. X-ray observations can unveil such compact companions, as shown in the case of HD 49798 and BD +37° 442. Searches for X-rays in other systems have been negative up to now, but they provided useful information on the poorly known winds of hot subdwarfs.

Key words. Stars: subdwarfs, individual: HD 49798, BD +37° 442 – X-rays: binaries

1. Introduction

Hot subdwarfs, spectroscopically classified in sdB (T<40,000 K) and sdO (T>40,000 K), lie in the HR diagram between the main sequence and the white dwarfs (WD). Many hot subdwarfs are in close binaries. Evolutionary models predict that their companions should be late type main sequence stars, as indeed observed in many sdB binaries, or compact objects.

The detection of X-rays, produced from accretion of the subdwarfs wind, can reveal such compact companions and give other important information on these systems, as shown by our recent results on the two sdO binaries HD 49798 and BD +37° 442. Accreting compact objects can also be used as probes to investigate the poorly known properties of the weak stellar winds of hot subdwarfs.

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2. Two sdO binaries with compact companions

HD 49798 is the brightest known sdO (V=8, L=10^4 $L_\odot$) and a well studied single-lined spectroscopic binary with orbital period of 1.55 days. The nature of its companion remained unknown until the *ROSAT* discovery of pulsed X-rays with P=13.2 s (Israel et al. 1997). This indicated the presence of a WD or a neutron star (NS), but due to the large uncertainty on the X-ray luminosity it was not possible to discriminate between the two possibilities.

In 2008, we observed HD 49798 with *XMM-Newton* at the orbital phase of the expected eclipse, never covered in previous X-ray observations. The measurement of the pulse delays induced by the orbital motion, together with the discovery of an X-ray eclipse lasting ∼1.3 hours, allowed us to derive the X-ray mass function as well as the system's inclination. This information, coupled to the optical mass function, gives the masses of the two stars: M_{sd}=1.50±0.05 $M_{\odot}$ for the subdwarf and M_x=1.28±0.05 $M_{\odot}$ for its companion (Mereghetti et al. 2009).

The high quality spectrum showed that the total luminosity is only $\sim 10^{32}$ erg s^{-1}, much smaller than that expected from a NS accreting in the stellar wind of HD 49798. We thus concluded that this system most likely contains one of the most massive WD with a dynamical mass measurement, which is also the one with the shortest spin period. At the end of the current He-burning phase, HD 49798 will expand and transfer mass at a higher rate. This could lead to an accretion induced collapse, thus forming a fast-rotating NS, or to a Type Ia SN explosion (Mereghetti et al. 2011b).

X-ray emission, with L$\sim 2 \times 10^{30}$ erg s^{-1}, was detected from this system also during the WD eclipse. This could be due to HD 49798 itself or to reprocessing of X-rays in the subdwarfs wind. Recent observations showing the presence of emission lines of N and Ne in the eclipse spectrum seem to favor the latter interpretation.

Prompted by these results, we observed with *XMM-Newton* another luminous sdO, BD +37° 442, which is spectroscopically very similar to HD 49798, but without evidence of a binary nature. This led to the discovery of soft X–rays with a possible periodicity at 19.2 s, implying that also BD +37° 442 has a NS or WD companion (La Palombara et al. 2012). Its X-ray emission is well described by a very soft blackbody (kT∼45 eV) plus a weaker power-law component, very similar to the spectrum of HD 49798. Optical spectroscopy to search for an orbital period in BD +37° 442 is ongoing.

3. sdB with candidate compact companions

We observed with *Swift/XRT* a small sample of sdB binaries with candidate compact companions selected by means of radial and rotational velocity measurements in the optical band (Geier et al. 2011). X-rays were not detected, with upper limits in the range $L_X \sim 10^{30} - 10^{31}$ erg s^{-1} (Mereghetti et al. 2011a). Although this negative result does not allow us to confirm the presence of compact stars, the upper limits on L_X can be converted into limits on the mass loss rates $\dot{M}_{\rm W}$ from the sdB stars. For the systems likely hosting WD the limits are above 5×10^{-11} $M_{\odot}$ yr^{-1}. Although they are not particularly constraining for the sdB wind properties, we note that they represent one of the few observational results in this field. More interesting constraints have been derived for the binaries likely containing NS or black holes (PG 1432+159, HE 0532–4503, PG 1232-136, and PG 1743+477). The lack of X-ray emission implies that the sdB stars in these systems have rather weak winds, with $\dot{M}_{\rm W} < 3 \times 10^{-13}$ $M_{\odot}$ yr^{-1}, significantly below the predictions of theoretical models (Vink & Cassisi 2002), if a solar metallicity is assumed. A metallicity below $Z = 0.3\ Z_{\odot}$ is required for these sdB stars to be consistent with the derived upper limits.

4. Conclusions

Thanks to the good sensitivity of the current satellites it is now possible to study the hot subdwarf stars also in the X-ray band, obtaining information unaccessible at other wavelengths. Based on the findings obtained for the first two subdwarf X-ray binaries, we can expect exciting results from more extensive and deeper X-ray observations of hot subdwarfs.

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