Colliding-wind binaries as non-thermal X-ray emitters: an observational investigation from XMM-Newton to next generation X-ray observatories

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Abstract: *The investigation of massive stars in the radio domain revealed about 25 years ago that some of them are synchrotron emitters, showing that these objects are able to accelerate particles up to relativistic velocities. In this context, non-thermal emission processes such as inverse Compton scattering are expected to be at work in the high-energy domain. For this reason, an observational campaign devoted to the X-ray investigation of non-thermal radio emitters has been carried out with XMM-Newton. However, considering the rather strong thermal X-ray emission from these systems below 10 keV, XMM-Newton does not appear to be the ideal observatory to detect their putative non-thermal (NT) X-rays. As a consequence, the advent of next generation X-ray observatories with a bandpass extending significantly above 10 keV (SIMBOL-X, XEUS or NeXT) is expected to provide important results related to the non-thermal high-energy emission from colliding-wind binaries and their capability to accelerate particles.*

The XMM-Newton era…

• A sample of NT emitting O-type stars has been selected for dedicated observations with XMM-Newton in order to investigate the nature of their X-ray emission between 0.5 and 10 keV.

• In several cases, these observations provided strong indications for the presence of a companion, in agreement with the "standard" scenario where NT radio emitters are binary or higher multiplicity systems (see 1 for a review on this topic, and for catalogs of Wolf-Rayet and O-type NT emitters).

• This campaign allowed to characterize in detail the X-ray spectrum of several targets listed below. In the context of this discussion, the case of HD159176 is worth considering, even though it is not a non-thermal radio emitter.

• It appears that NT radio emitters do not exhibit NT X-rays in the XMM-Newton bandpass, however HD159176 is a good candidate for NT X-ray emission (see 2).

• Other targets have been recently proposed in the context of the Seventh Announcement of Opportunity of XMM-Newton.

	9 Sgr (9)	**HD93250 (10)**	**HD168112 (3)**	**HD167971 (4)**	**CygOB2#8A (5)**	**HD159176 (2)**
Multiplicity	Binary	Suspected binary	Suspected binary	Triple	Binary	Binary
Period	Long period	Long period?	Long period	3.32 d + long period	21.908 d	3.367 d
X-rays	Soft + hard	Soft + hard	Soft + hard	Soft + hard	Soft + hard	Soft
Nature of hard X-rays	Most probably thermal	Most probably thermal	Most probably thermal	Most probably thermal	Definitely thermal	Power law tail
Synchrotron (radio)	Yes	Yes	Yes	Yes	Yes	No

The lack of detection of NT X-ray is interpreted as due to the fact that any putative NT X-ray emission would be dominated by the thermal emission from the colliding winds, in addition to that produced by individual stellar winds in the massive binary system (at least in the XMM-Newton bandpass, i.e. below 10 keV). In order to get rid of this difficulty, one needs to investigate the harder X-ray domain, where the thermal contribution is not so strong. A detailed discussion of this issue can be found in (1).

… and the age of next generation X-ray observatories

The most critical requirements for future X-ray observations are (a) a bandpass extending significantly higher than 10 keV, and (b) a significantly improved sensitivity in the latter spectral domain with respect to INTEGRAL.

XEUS (ESA)

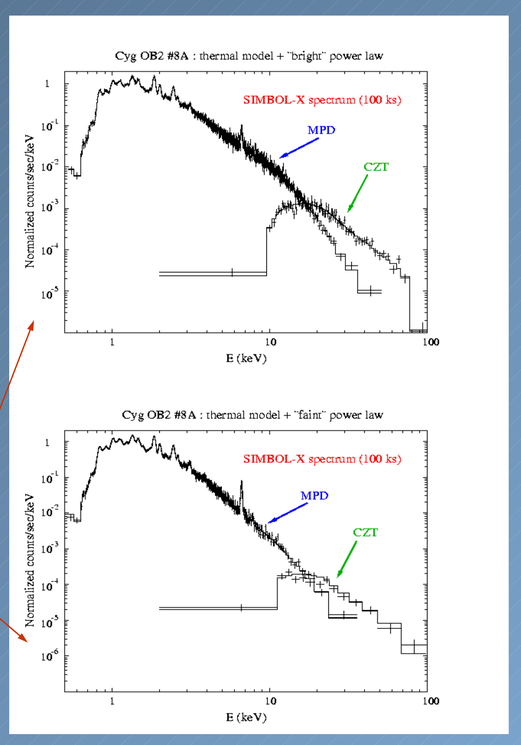
• L-class mission proposed in the context of ESA's Cosmic Vision plan (2015-2025) and recently selected for assessment
• unprecedented sensitivity in the soft X-rays, with requirement expressed by the scientific community to allow the bandpass to go up to 40 keV (or even higher?)

NeXT (JAXA)

• multi-instrument mission whose launch is expected in 2012
• improved sensitivity in the hard X-rays thanks to multilayer Pt/C supermirrors enhancing substantially the collecting area in the hard X-ray domain (above 10 keV)

SIMBOL-X (CNES & ASI)

• formation flight mission whose launch is expected in 2012
• science case focused on hard X-rays and NT processes in galactic and extragalactic sources
• NT emitting massive stars proposed in the core programme (e.g. Cyg OB2 #8A…)
• simulated spectra suggest promising results using both soft and hard detectors onboard the satellite (see 7, and figures on the right for the particular case of Cyg OB2 #8A for two different assumptions concerning the NT flux)



What we expect in the future…

• up to now, studies in the hard X-rays only provided upper limits on the NT flux, leading to restricted constraints on the underlying physics (6),
• the next step will consist in the detection of NT emitting massive stellar systems in order to determine their flux, and to characterize their spectral shape (spectral index, change in the slope of the power law), and confront the observations to recent models (8,11),
• as we are dealing in most cases with binary systems, phase-locked variations in the non-thermal emission processes should be studied in order to investigate the change in the physical properties of the acceleration and NT emission region with phase..

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