Search for low-mass companions to X-ray emitting A-type stars

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Summary. There is no obvious theory that would explain X-ray emission from main-sequence A-type stars. Therefore, the X-ray emission identified with these stars on basis of low spatial resolution X-ray observations is usually attributed to magnetic activity from unknown late-type companion stars. We systematically study the literature and public 2 MASS data in search for binaries among A stars. This way, we identify new candidate counterparts for the X-ray sources in at least 60 % of the A-type stars claimed to be detected in the *ROSAT* All-Sky Survey. There is marginal evidence that this fraction decreases from early to late A spectral type, possibly indicating the onset of intrinsic X-ray emission for the latest A stars which may have deep enough convection zones to support magnetic activity.

1 The mysterious X-ray emission from A stars

For stars on the main-sequence two mechanisms are known to be responsible for the observed X-ray emission: In O- and early B-type stars the X-rays are produced by instabilities arising in their strong radiatively driven stellar winds [4, 3], and in late-type stars a solar-like magnetic dynamo is thought to heat and confine hot coronal plasma, which is a tracer of stellar activity [5].

No X-ray emission is expected from stars whose spectral types are late B and early A, because they do not drive strong enough winds nor do they possess convective zones necessary to sustain a magnetic dynamo. Nevertheless, X-ray detections of these stars have been repeatedly reported throughout the literature (see Stelzer et al. 2003 [9]). In absence of a theoretical explanation, the X-ray emission of main-sequence late B-type and early A-type stars is commonly attributed to unresolved late-type companions. Many A and B stars are known or suspected binaries. But the connection between their multiplicity and their X-ray properties has never been investigated systematically.

In this contribution we examine the sample of A stars in the solar neighborhood detected in X-rays during the *ROSAT* All-Sky Survey (RASS). The aim is to search for alternative counterparts to the X-ray sources, either bound companions to the A stars or unrelated nearby objects.

2 Search for new counterparts

The sample studied here is composed of all 248 X-ray sources identified with an A-type star in the RASS (see Hünsch et al. 1998 [2]; hereafter H98). The optical identifications of the X-ray sources in H98 are based on a cross-correlation between A, F, G, and K stars from the Bright Star Catalog [1] and RASS X-ray sources, using a $90''$ cut radius ($\Delta_{\rm ox}$). We investigate the reliability of these identifications by examining the sky region near the A stars and the X-ray sources with the aim to uncover other objects that may replace the A stars as counterparts to the X-ray sources. To this end we use different approaches: A literature search for known spectroscopic and visual binaries among the A-type stars identified with a RASS source (Sect. 2.1), analysis of 2 MASS archival data (Sect. 2.2).

2.1 Known Binaries among X-ray emitting A stars

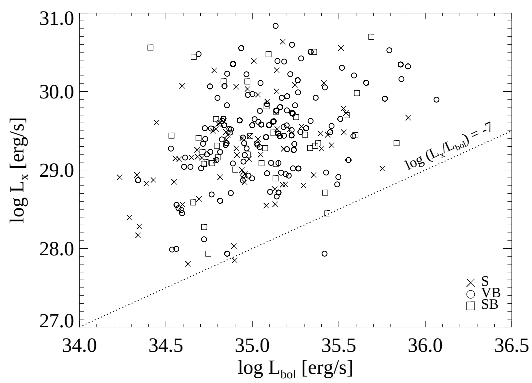

Fig. 1. $\log L_{\rm x} - \log L_{\rm bol}$ diagram for A stars identified with X-ray sources detected in the RASS; data from H98. The dotted line marks the empirical $\log{(L_{\rm x}/L_{\rm bol})}$ relation for O-type stars. The large spread observed for the A-type stars and their location above this line, show that they are not wind-driven X-ray sources.

Fig. 1 shows the A star sample from H98 in a $\log L_{\rm x} - \log L_{\rm bol}$ diagram. Bolometric luminosities were computed from the V band magnitudes, X-ray luminosities adopted from H98. Spectroscopic binaries (SB), visual binaries (VB), and supposedly single stars (S) are marked with different plotting symbols. There are 72 (~ 29 %) A-type stars in the total sample of 248 that are not known to be multiples so far: 42 are spectroscopic binaries, 87 are visual binaries, 47 binaries have both spectroscopic and visual components.

2.2 2-MASS objects near X-ray emitting A stars

In a search for alternative counterparts to the RASS X-ray sources assigned previously to A stars we are exploring the 2 MASS archive, using the following selection criteria for candidate IR counterparts:

- Separation to X-ray position $< 90''$, corresponding to the X-ray/opt. identification radius $\Delta_{\rm ox}$ applied by H98. This way we ensure that the A-type stars are among the 2 MASS counterparts.

– Object with photometry quality flag 'A', 'B' or 'C' in all three bands JHK, or object identified with an original A star X-ray counterpart from H98.

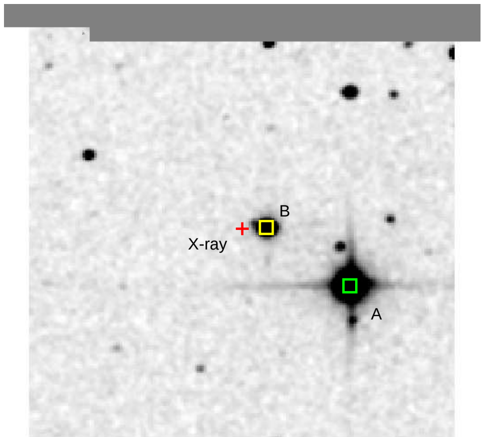

Fig. 2. $180'' \times 180''$ 2 MASS K band image of HR 1490 centered on the RASS X-ray position (marked with a cross). The A star itself (brightest object in the field) and the known visual companion are labeled 'A' and 'B', respectively. Clearly the X-ray source must be identified with the known visual companion at a separation $10.3''$; whereas the A star originally identified as counterpart is separated from the X-ray position by $52''$.

An example of the results is shown and discussed in Fig. 2. In total, among 248 examined 2 MASS fields within $90''$ of an A star there are: 41 fields with one 2 MASS source closer to the X-ray position than the A star, and 45 fields with more than one 2 MASS source closer to the X-ray position than the A star. For almost all fields with offsets $\Delta_{\rm ox} > 40''$ in H98 there is at least one other 2 MASS source closer to the X-ray position than the A star. This suggests that the excessively large opt./X-ray identification radius applied by H98 yielded mostly spurious identifications beyond $40''$.

3 Assigning new counterparts to the X-ray sources

We tentatively assign new counterparts to the X-ray sources using two different approaches:

1. We exclude the A star as X-ray emitter whenever there is another object within $40''$ of the X-ray position, i.e. either a visual companion, or another 2 MASS object, or a spectroscopic companion. This way the original sample of 248 A star X-ray emitters reduces to 28 X-ray sources without known alternative counterpart, i.e. for a fraction of $\sim 90\,\%$ a new object has been identified that may be responsible for the X-ray emission.
2. We consider as counterpart always the object which is closest to the X-ray position, i.e. either a visual companion, or a spectroscopic companion, or another 2 MASS object. This leaves a total of 91 out of 248 X-ray sources associated with an A star, i.e. a fraction of $\sim 60\,\%$ have possible new counterparts.

Finally, we examine the fraction of new counterparts as a function of spectral type (Fig. 3). A slight, but at most marginally significant, decrease in the fraction

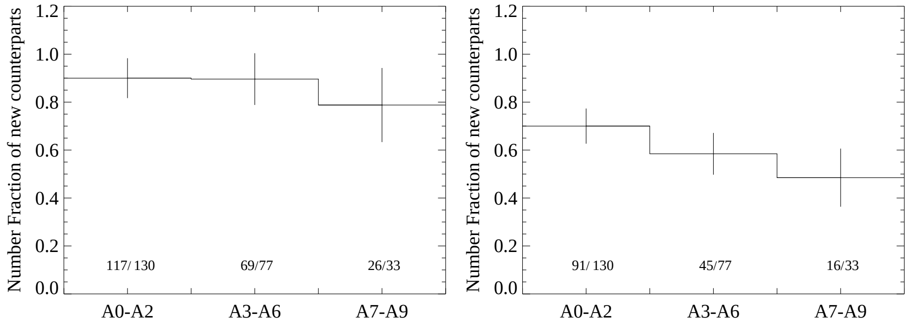

Fig. 3. Fraction of objects where a counterpart not identical with a single A star was identified among known companions or 2 MASS objects: *left* - objects other than the A star within 40″ of X-ray position, *right* - closest optical/IR objects to X-ray source (for details see text in Sect. 3). Eight stars classified Ap or Am are omitted.

of new counterparts is suggested for the latest spectral types. If real, this effect could indicate the onset of intrinsic emission from A stars. The minimum depth of a convective envelope able to support magnetic activity is not well established. Based on previous observations the onset of significant dynamo action has been placed somewhere between spectral type A7 and F4 [6, 7].

Outlook: The question whether A stars are intrinsic X-ray emitters or not is being pursued also by (1) X-ray imaging with high spatial resolution to pinpoint the position of the X-ray source, (2) spectroscopy of the candidate counterparts to establish if they are late-type (active) stars, (3) IR imaging with high spatial resolution using adaptive optics searching for additional close visual counterparts (see Stelzer et al. 2005 [8]).

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