Stars as Suns: Activity, Evolution, and Planets
IAU Symposium, Vol. 219, 2004
A. K. Dupree and A. O. Benz, Eds.

X-rays from M-type Giants – Signs of Late Stellar Activity?

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Abstract. We present recent X-ray and optical observations of five M-type giants which were detected as strong X-ray sources. One of these stars, HR 5512, shows short-term variations in both X-ray flux as well as in the shape of the Hα and Ca II H+K lines, and it rotates much faster than M-type giants usually do. No indication of binarity has been found for this star. We propose that the X-ray emission of HR 5512 is related to a large degree of stellar activity. For two other stars (15 Tri, HR 7547) radial velocity observations seem to indicate spectroscopic binarity.

1. Introduction

X-ray emission from late-type giants originates from hot coronal plasma and indicates the degree of magnetic stellar activity. A strict *X-ray dividing line* (XDL) in the HR diagram approximately vertically at spectral type K 3 has been proposed by, e.g., Haisch et al. (1992). This concept, which implied that the coolest and most luminous giants are devoid of hot stellar coronae, had to be revised in view of more sensitive ROSAT observations (Hünsch et al. 1996, Hünsch & Schröder 1996, Schröder et al. 1998). In particular, the so-called hybrid stars, simultaneously showing hot coronae and cool stellar winds, are strong X-ray emitters on the right-hand side of the XDL (Reimers et al. 1996).

Schröder et al. (1998) suggested an observational scenario which describes the evolution of stellar activity in terms of mass-dependent evolution of stellar structure and angular momentum: Massive stars tend to develop a large degree of stellar activity as they cross the Hertzprung gap and remain active as supergiants or bright giants even at their advanced evolutionary stages. Low-mass stars are already spun-down on the main-sequence and show only a small amount of activity as they ascend the red giant branch or stay in the "clump" region. The XDL (or at least the sudden drop of observed X-ray luminosities) can thus be understood as a consequence of the closely parallel running evolutionary tracks in the HR diagram for stars of a wide range of masses. Yet, even within this scenario, the M III-type giants, which are quite old low-mass stars on the RGB or AGB, should not exhibit a large degree of stellar activity.

Surprisingly, 11 (among 482) M-type giants have been found to coincide positionally with X-ray sources detected in the course of the ROSAT all-sky survey (Hünsch et al. 1998a). As discussed in more detail by Hünsch et al. (1998b), three of them are uncertain identifications, two stars are of symbiotic or cataclysmic nature, and two stars have optical companions that are more likely to be responsible for the X-ray emission. However, a recent *Chandra* observation has shown that the X-ray source attributed to the triple system α Her (M5II + close pair of G8III and A9IV-V) consists of two separated sources of which one almost exactly coincides with the M-type giant α^1 Her. Therefore, five M-type giants are good candidates for genuine X-ray emission (see Table 1).

Table 1. M-type giants detected as X-ray sources. Data are from the Bright Star catalogue, the distances are measured by *Hipparcos*.

Star	HD	Sp.type	V	B-V	d(pc)	M_V	notes
15 Tri	16058	M3IIIa	5.35	1.66	~200	–1.5:	
HR 5512	130144	M5IIIab	5.63	1.57	280	–1.59	
42 Her	150450	M2.5IIIab	4.90	1.55	115	–0.41	visual binary
α^1 Her	156014	M5Ib-II	3.48	1.44	117	–1.87	visual binary
HR 7547	187372	M2III	6.12	1.64	380	–1.76	spec. binary

2. X-ray observations

Four of five M-type giants have been observed with the ROSAT PSPC and HRI, and with the *Chandra* HRC detectors. In the cases of 15 Tri, HR 5512, and α^1

Her, the ROSAT all-sky survey detections have been confirmed by *Chandra* with a positional accuracy of <1 arcsec. A recent observation of HR 7547, however, failed to detect an X-ray source at the position of the star.

Table 2 lists the X-ray luminosities derived at different epochs with different instruments. The ROSAT all-sky survey (RASS) was performed between July 1990 and January 1991.

Table 2. X-ray luminosities L_x (in erg cm^{-2}s^{-1}) of the stars as derived by the ROSAT and *Chandra* observatories.

HD	$\log L_x$ RASS	$\log L_x$ ROSAT-HRI	date ROSAT-HRI	$\log L_x$ *Chandra*-HRC	date *Chandra*-HRC	notes
16058	30.8:	30.8:	02-1998	30.8:	01-2001	
130144	30.30	–	–	31.15	06-2001	1st obs.
130144				30.5	06-2003	2nd obs.
150450	29.41	–	–	–	–	
156014	(30.77)	–	–	30.07	07-2003	α^1 Her (M5Ib-II)
156015	30.77	–	–	30.72	07-2003	α^2 Her (G8III+A9)
187372	30.64	–	–	<30.2:	05-2003	

3. Optical spectroscopy

Spectroscopic observations in the Ca II H&K and Hα regions were carried out between January and June 2002. The spectra were obtained by using a Photometrics CCD camera at the Coudé spectrograph of the 2m telescope at the Bulgarian National Astronomical Observatory on Mt. Rozhen (BNAO). The resolution is 0.2 Å, except for the two Ca spectra obtained in June 2002, where it is 0.1 Å. The S/N ratio in the Hα region is $\geq$150. Data reduction was carried out with the programme package IPS (Smirnov et al. 1993). The continuum fitting for the Hα region followed the procedure described in Eaton (1995).

Residual intensities R_c and equivalent widths (EW) of the temperature sensitive photospheric Ca I 6572.78 Å line were studied in comparison to Hα. Eker (1986) argues that, as the surface area covered by active regions increases, the EW of the temperature sensitive Ca I line grows while Hα is filled-in due to increasing core emission. The relative intensity $I_{C\ K}/I_{3950}$ of the Ca K emission peak to the pseudo-continuum at 3950 Å was used as a measure of the Ca II K emission strength and its variability, The M6III giant g Her = HD 148783 was observed as an inactive reference. Table 3 lists the line measurements:

4. Radial and rotational velocities

The projected rotational velocities $v \sin i$ and radial velocities RV were obtained with the CORAVEL spectrometer (Baranne et al. 1979) attached to the 1m Swiss telescope at Haute-Provence Observatory. Standard calibration was applied according to de Medeiros & Mayor (1999). Long-term variations in RV seem to be present in the cases of 15 Tri and HR 7547 (see Table 4).

Table 3. Relative and residual intensities R_c and equivalent widths of the Calcium and Hα lines.

HD	Date (2002)	Ca K I/I_{3950}	Hα R_c	Hα EW(Å)	Ca 6573 R_c	Ca 6573 EW(Å)
16058	31.01.	0.59	0.22	1.04	0.49	0.28
130144	29.01.	0.41	0.30	0.68	0.51	0.25
	30.01.	0.49	0.32	0.68	0.52	0.24
	28.06.	0.43	0.26	0.88:	0.59	0.37
150450	29.01.	0.41	0.22	1.01	0.44	0.28
	30.01.	0.37	0.22	1.01	0.44	0.28
	27.06.	0.40	0.21	1.02	0.45	0.34
187372	22.05.		0.22	1.04	0.51	0.30
	23.05.	0.54				
	28.06.	0.53				
148783	28.06.	0.18				

Table 4. Radial (RV) and rotational ($v \sin i$) velocities

HD	RV (km/s)	σ_{RV} (km/s)	N	$v \sin i$ (km/s)	notes
16058	–7.08	0.75	4	5.4	SB, long period
130144	–21.92	0.36	4	11.3	
150450	–55.76	0.47	2	2.5	
187372	–0.97	2.56	12	4.4	SB, long period

5. Results

The optical spectroscopic data show that four X-ray emitting M-type giants have enhanced Ca K core emission compared to the "X-ray quiet" semi-regular variable giant g Her. In addition, HR 5512 shows significant variations in both Ca II K emission and Hα lines. Especially interesting is the observed anti-correlation between the Hα and Ca I 6573 Å residual intensities, which may be related to stellar activity in a similar way as in the RS CVn systems. Contrary to HR 5512, 42 Her does not exhibit such large spectral variations. Unfortunately, the data for 15 Tri and HR 7457 are still too sparse.

While the X-ray emission of 15 Tri stays remarkably constant at three different epochs, HR 5512 shows large variations in its X-ray luminosity. However, it cannot be stated from the existing rather short observation duration whether a flare could be responsible for the flux increase observed in June 2001.

6. Conclusions

Certainly, the most interesting star of our small sample of X-ray emitting M-type giants is HR 5512. It does not only show strong variations in the emission of X-rays and Ca II K as well as changes in the Hα line profile, it also has a significantly higher rotational velocity than the other stars. We propose that the X-ray emission of HR 5512 is related to strong stellar activity.

Currently, there is no indication for HR 5512 to be a binary. 15 Tri and HR 7547 are probably binaries, but of rather long period, only, and their rotation rate seems to be only slightly higher than average for this class of stars. It is unclear whether the observed X-ray emission is related to their binary nature. Hünsch et al. (1998b) have demonstrated that a possible companion star is not likely the source of the observed large X-ray emission, considering the rather high age of the stars. Additionally, the absence of emission lines (e.g. Balmer) disagrees with the hypothesis of these stars being symbiotic systems.

At present, the observational data are still too sparse to drive any conclusions about the origin of enhanced stellar activity in these M-type giants. If faster rotation plays a role, the question arises why these stars have higher rotational velocities than usual. We note that also a few low-mass but fast rotating and thus quite active giants have been found (Fekel & Balachandran 1993). Possible yet still speculative explanations for fast rotating low-mass giants could be tidal effects induced by a (even widely separated) stellar companion, the dredge-up of angular momentum stored in the stellar core or the engulfment of planetary companions.

Unfortunately, we do not yet have optical data for α^1 Her, which only recently turned out to be an X-ray source besides the visual G-type companion. As discussed in more detail by Hünsch et al. (1998b), this star is probably more massive and younger than the other M-type giants and can be assumed to be another hybrid star.

Acknowledgments. This work has been supported by the Deutsche Forschungsgemeinschaft (DFG) under grants 436 BUL 113/123/0-1, HU 546/7-1, and KON 124/2003, and by the Deutsches Zentrum für Luft- und Raumfahrt (DLR) under grant 50 OR 9617.

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