Am stars and tidally driven abundance anomalies

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Abstract. We present preliminary results from a systematic study of the chemical abundances of Am stars in order to search for possible abundance anomalies driven by tidal interaction in binary systems. The behaviour of the Am peculiarities with respect the orbital elements and rotation of the Am star is studied. We confirm the well known anti-correlation of the Am peculiarities with the rotation of the star. However, apart from this effect there seems to exist a correlation of the Am peculiarity with the eccentricity and orbital period as well.
Key words: stars: chemically peculiar - stars: abundances - binaries: close

Am звездите и химическите аномалии, поддържани от приливни взаимодействия

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Ние представяме предварителни резултати от систематично изследване на химическите обилия на Am звезди с цел търсене на възможни химически аномалии, поддържани от приливните взаимодействия в двойни системи. Изследвано е поведението на Am пекулярностите в зависимост от орбитните елементи на двойните системи и въртенето на първичния компонент. Ние потвърждаваме добре известната анти-корелация между Am пекулярностите и въртенето на звездата. Обаче, изглежда, че освен този ефкт съществува и корелация на пекулярността с ексцентрицитета и орбитния период на системата.

1 Introduction

The Am stars is a subgroup of Chemically Peculiar stars (CP stars) on the upper Main Sequence. The spectra are characterized by unusually weak spectral lines of light elements like C, Mg, Ca and Sc and contrary, abnormally strong lines of the iron peak and heavier elements. As the other CP stars, Am stars are also slow rotators. There is no presence of magnetic fields into the frameworks of the detectable limits. Am stars do not show any photometric and spectral variations, too.

The obtained peculiarities appear to be due to microscopic selective diffusion driven mainly by the radiation presure and the gravity. The diffusion operates below the deepest He II convection zone until it disapears because of settling of He. Then it proceeds more effectively below the H+HI convection zone. Rotation was found to play a key role in this process as it induces a large scale mixing which could disturb the slow diffusion process. According to Charbonneau & Michaud (1991) the rotational velocity less than about 90 kms^{-1} is required for diffusion to prevail and the Am phenomenon to occur.

The Am peculiarity seems to depend on the orbital elements in a binary system as well. Budaj (1996, 1997), Iliev et al. (1998), Feňovčík et al. (2004)

studied the dependencies between the rotational velocity, orbital period, eccentricity, radii, evolutionary status and the abundances of Ca, Fe and Li in Am stars. They concluded that there are a number of subtle effects which are difficult to be understood within only the framework of the rotation and atmospheric parameters (determined by the age and the mass of the stars) as agents determing the Am peculiarity. The Am phenomenon seems to be more pronounced in binaries with eccentric orbits and also at longer orbital periods provided that the binary components are relatively close when orbital periods are $P_{\rm orb} < 180^d$.

The majority of Am stars are members of binary systems. This gives us a chance to study the influence of the companion star of the system on the stellar hydrodynamics. In order to explore the possible dependence of Am peculiarity on the orbital elements of the binary system we started a systematic spectroscopic investigation of Am stars.

2 Observations and sample stars

The observations were carried out with the 2-m RCC telescope of BNAO-Rozhen in the frame of our project on Am stars in binary stars. Each star from the list was observed in two spectroscopic regions - 6400-6500 Å(Ca-region) and 6660-6760 Å(Li-region). The Photometrics AT200 CCD camera with SITeSI003AB 1024x1024 chip (24μm pixels) was used in the Third camera of the Coudé spectrograph. The spectra obtained have had a typical resolution R=32000 and S/N ratio of about 300.

IRAF standard procedures were used for bias subtraction, flat-field normalization and wavelength calibration. The telluric lines were removed by using the spectra of hot fast rotating stars. The wavelength calibration had an rms error of 0.005 Å.

A few tens of Am binaries from Budaj (1996) were chosen to be studied in details. The following criteria were applied in order to compile the star's list: targets with the declination $\delta > -10^\circ$ and brighter than the 7-th magnitude in V-filter. In order to cover a full range of eccentricities and avoid strong synchronization effects we have chosen only stars with orbital periods $10^d < P_{\rm orb} < 180^d$. No constraints were put on the rotational velocity.

3 Atmospheric parameters and atomic data

The atmospheric parameters have been obtained by using photometry data. The *uvbyβ* indices (de-reddened using the UVBYBETA code of Moon & Dworetsky (1985)) were taken from Renson(1991). We used Geneva and UBV photometry from Mermilliod, Mermilliod & Hauck (1997). The atmospheric parameters were derived from both *uvbyβ* and Geneva photometry. If both estimates were available we accepted their rounded mean as the best choice for model atmosphere parameters. In the case of *uvbyβ* photometry, we used the TEFFLOGG code of Moon & Dworetsky (1985), but Smalley & Dworetsly (1995) was also consulted. In the case of Geneva photometry we used the calibration of Künzli et al. (1997). All these stars seem to be SB1 binaries or have only a very weak secondary spectrum, hence the possible influence of their companions on photometry was neglected.

A detailed spectrum synthesis of the spectral regions was accomplished using the code SYNSPEC (Hubeny, Lanz & Jeffery 1994, Krtička 1998). Model atmospheres were interpolated from Kurucz (1993). The VALD atomic line database (Kupka et al. 1999) was used to create a line list for the spectrum synthesis. Over 2000 lines were used in each spectral region. Unfortunately, the accuracy of the atomic data is still not sufficient and the above mentioned data were complemented by data from Budaj & Iliev (2003) who calibrated many gf-values on the solar spectrum.

4 Results

As a result of the synthetic spectrum fitting analysis the abundances of many elements were obtained. They were usually expressed relative to the Sun in terms of $[N/H] = \log(N/H)_\star - \log(N/H)_\odot$. Taking into account the accuracy of the atmospheric parameters, as well as the atomic data, the abundances of Al, Si, S, Ca and Fe are generally determined within ≤ 0.2 dex, while the abundances of the other elements, which mainly occur in weak blends, are only approximate.

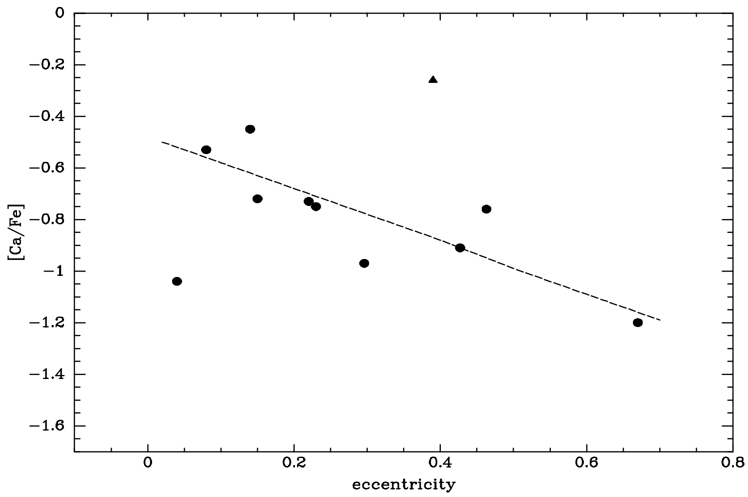

Fig. 1. [Ca/Fe] versus the eccentricity of the orbit. A possible dependence is drawn with dashed line. HD 198391 is denoted by a triangle.

According to Feňovčík (2004) the Am peculiarities (mainly Ca deficit and Fe overabundances) should be represented in a most reliable way through the values of [Ca/Fe]. The reason was that these two elements showed an opposite behavior and the ratio between them should multiply the effect of the Am abnormalities. Moreover, this ratio should be much less sensitive to the uncertainty in the effective temperatures since both calcium and iron lines behave in the same manner - get weaker with increasing the temperature. In this paper we studied the dependence of [Ca/Fe] on the orbital elements of the binary systems (eccentricities and orbital periods) as well as on the projected rotational velocity of the primary stars.

Up to now thirteen stars from our sample were fully processed. Two of them, HD 178449 and HD 18778 have found not to be Am stars since their [Ca/Fe] ratios are greater than zero (the value of [Ca/Fe] equals to zero means the solar abundances). That is why they were excluded from the figures.

In Fig.1 the dependence of [Ca/Fe] from the eccentricity of the orbit was shown. Despite of the dispersion it was obvious that there was a corelation between [Ca/Fe] and the eccentricites. A linear curve illustrating this correlation was drawn with dashed line. The [Ca/Fe] ratio decreases and the Am peculiarity increases when the eccentricities are increased.

In the next figure (Fig.2) the behavior of [Ca/Fe] was presented when the orbital periods were changed. Again, the [Ca/Fe] ratio decreases (Am peculiarity increases) when the orbital periods of the binary systems is increased.

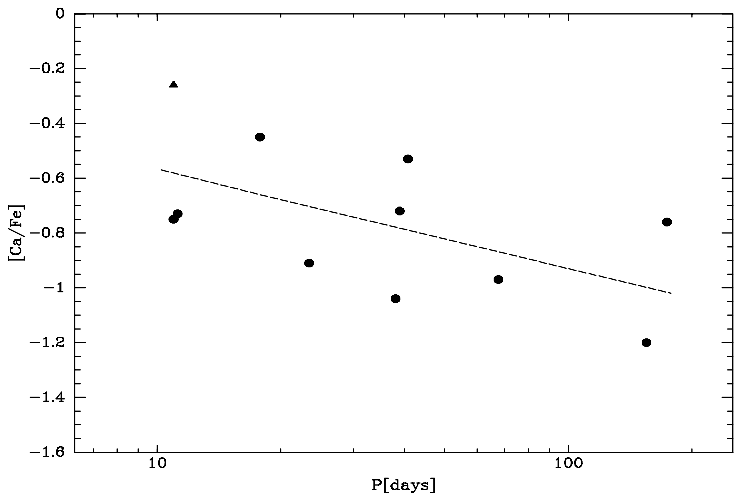

Fig. 2. [Ca/Fe] versus the orbital period. The symbols are the same as in the previous figure

The dependence of the Am peculiarities from the projected rotational velocity of the primary of the binary system was also studied. When the star rotated slowly the Am abnormalities could be manifested more clearly (Fig.3). As it is seen from the figure one star, HD 198391, denoted by a

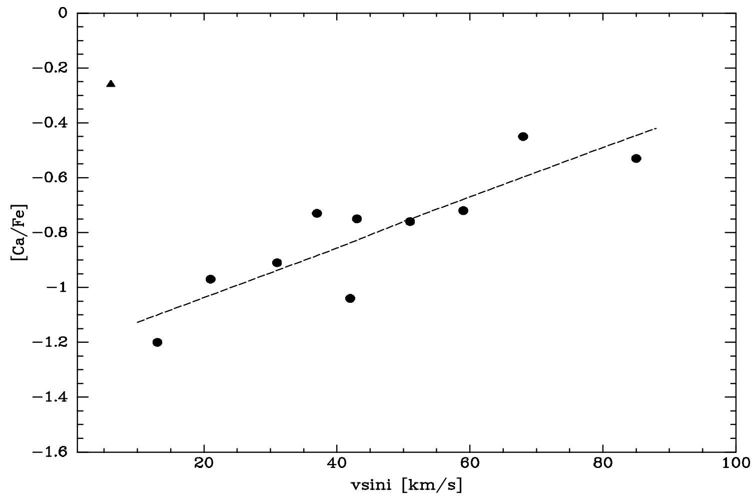

Fig. 3. [Ca/Fe] versus the projected rotational velocity. The symbols are the same as in the previous figure

triangle, was distinguished from the common trend. This star was the hottest amongst the sample stars. According to Budaj & Iliev (2003) HD 198391 was not a typical Am star. It could be a transitional star between Am and the hotter HgMn stars because of its position close to the region occupied by HgMn stars on HRD and also of the obtained abundances (for more details see Budaj & Iliev (2003)).

Conclusions

In this paper we present results from the systematic study of chemical abundances of Am binaries in order to search for possible abundance anomalies driven by the tidal interaction in these binary systems. We conclude that there is a clear anticorrelation of the Am peculiarities with the rotation of the star. However, apart from this effect there seems to be a correlation of the Am peculiarity with the eccentricity and orbital period as well. An analysis of a larger sample of objects is necessary to disentangle this complex behaviour of the Am phenomenon.

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