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Multiplicity of Late–Type B Stars with HgMn Peculiarity

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Abstract. Observations at various wavelengths of late B–type stars exhibiting strong overabundances of the chemical elements Hg and Mn in their atmospheres indicate that these stars are frequently found in binary and multiple systems. We carried out a survey of 56 stars using diffraction–limited near–infrared imaging with the NAOS–CONICA at the VLT. Thirty–three companion candidates in 24 binaries, three triple, and one quadruple system were detected. Nine companion candidates were found for the first time in this study. Five objects are likely chance projections. The detected companion candidates have K–magnitudes between $5\overset{m}{.}95$ and $18\overset{m}{.}07$ and angular separations ranging from $< 0\overset{\prime\prime}{.}05$ to $7\overset{\prime\prime}{.}8$, corresponding to linear projected separations of 13.5 – 1700 AU. Our study clearly confirms that HgMn stars are frequently members of binary and multiple systems. Taking into account the companions found by other techniques, the multiplicity fraction in our sample may be as high as 91%. The membership in binary and multiple systems seems to be a key point to the understanding of abundance patterns in these stars.

Key words: stars: binaries: close – stars: chemically peculiar – techniques: high angular resolution

1 Introduction

Chemically peculiar (CP) stars are main–sequence A and B type stars in the spectra of which the lines of some elements are abnormally strong or weak. The class of CP stars is roughly represented by three subclasses: the magnetic Ap and Bp stars, the metallic–line Am stars, and the HgMn stars, which are late B–type stars showing extreme overabundances of Hg (up to 6 dex) and/or Mn (up to 3 dex).

About 150 stars with a HgMn peculiarity are currently known (Renson & Manfroid, 2009). Most of them are rather young objects found in young associations such as Sco–Cen, Orion OB1, or Auriga OB1. In contrast to classical Bp and Ap stars with large-scale organized magnetic fields, HgMn stars generally do not show overabundances of rare earth elements, but exhibit strong overabundances of heavy elements, such as W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, or Bi. Another important distinctive feature of these stars is their slow rotation ($\langle v \sin i \rangle \approx 29$ km/s, Abt et al., 1972). The number of HgMn stars decreases sharply with increasing rotational velocity (Wolff & Wolff, 1974). Evidence that stellar rotation does affect abundance anomalies in HgMn stars is provided by a rather sharp cutoff in these anomalies at a projected rotational velocity of 70 – 80 km/s (Hubrig &

Mathys, 1996).

The mechanisms responsible for the development of chemical anomalies of HgMn stars are not yet fully understood. The abundance patterns may however be connected with binarity and multiplicity. More than 2/3 of HgMn stars are known to belong to the spectroscopic binaries (Hubrig & Mathys, 1995).

2 Observations and Results

We carried out the observations of 56 HgMn stars with the NAOS–CONICA (NACO; Lenzen et al., 2003; Rousset et al., 2003) on the VLT in the service mode between October 2004 and March 2005, and again between November 2005 and February 2006. We used the S13 camera of NACO, which provides the smallest available pixel scale of 13.3 milliarcsec and the field–of–view of $13\farcs6$. All data were collected through a *Ks* filter in the image auto-jitter mode, where the object is observed at typically 20 different image positions with random offsets between them. Since all our sources are bright in V, we used the visible wavefront sensor of the NAOS.

The observed sample was mainly selected from the "Catalogue and Bibliography of Mn–Hg Stars" (Schneider, 1981) taking into account the accessibility from the VLT. A few targets not listed in this catalogue were selected on the basis of previous spectroscopic studies of late B–type stars, in which HgMn peculiarity was detected.

In total we have found 24 binaries, three triple systems, and one quadruple system in our survey. Out of the 33 companion candidates, we infer that five are chance projections. Nine companion candidates were detected for the first time. A detailed description of the astrometric and photometric results is presented in Table 2 of Schöller et al. (2010).

The images of the resolved objects are shown in Fig. 1. All the images are displayed using a logarithmic scale. In the images with the closest companion candidates, showing just the inner $1''$, this logarithmic scale had to be adapted to enhance the image details. The same modification was applied to HD 33904.

3 Discussion

We have announced the detection of 33 companion candidates in 24 binaries, three triples, and one quadruple system. The detected companion candidates have K magnitudes between $5\overset{m}{.}95$ and $18\overset{m}{.}07$ and angular separations ranging from $< 0\farcs05$ to $7\farcs8$, corresponding to linear projected separations of 13.5 – 1700 AU. The companion candidates around HD 21933, HD 33904, HD 53244, HD 53929, HD 66259, HD 72208, HD 90264, HD 101189, and HD 221507 were detected by us for the first time. Five companion candidates are very likely to be chance projections.

In our survey, we found in 28 of the 56 studied systems with a HgMn primary at least one visual companion star, which gives a multiplicity fraction of 50%. This is quite high compared with similar surveys of B type stars. McAlister et al. (1993) studied 211 stars of spectral type B with speckle interferometry at visible wavelengths and obtained a binary fraction of 13.9%. Roberts et al. (2007) studied 70 B stars in the I band with adaptive optics and found 16 companions (of which they concluded that four are not physically bound), leading to a binary fraction $\leq 22.9\%$. Duchêne et al. (2001) surveyed a sample of 60 OB stars in the NGC 6611 cluster with adaptive optics in the K band and found a binary fraction of $18 \pm 6\%$, restricting themselves to a separation range of $0\farcs1$ to $1\farcs5$, corresponding to 200 – 3000 AU, a range where less than half of our companions are found. Kouwenhoven et al. (2005) studied the binarity of A and B stars in the OB association Sco OB2 with adaptive optics using a *Ks* filter. Sixty-five of the 199 stars in their sample have at least one companion, leading to a binary fraction of 32.7%. If one restricts the survey to the 83 B type stars, we find that 23 stars are in multiple systems, giving a multiplicity fraction of 27.7%. While our stellar

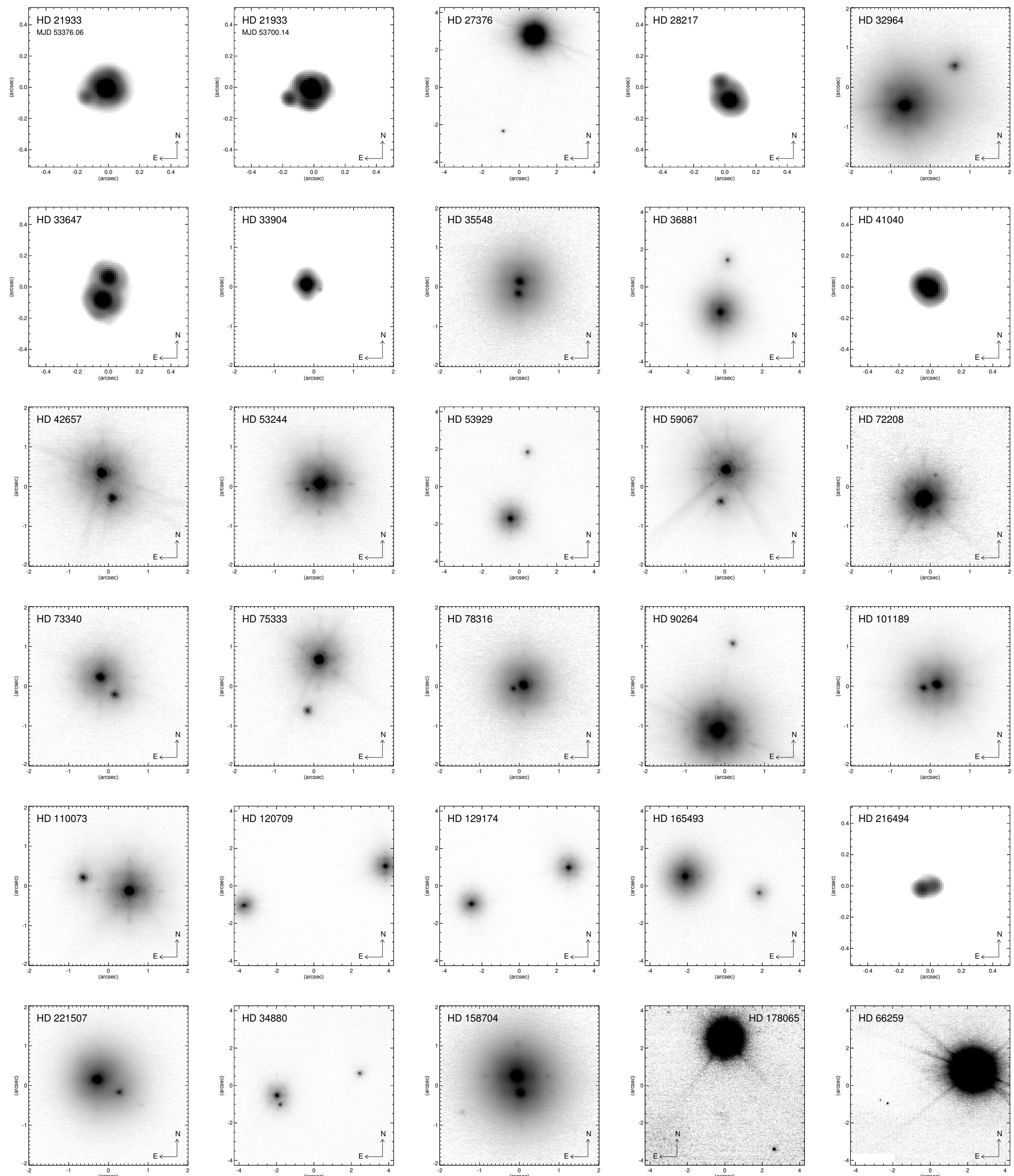

Figure 1: Images of the companions detected in our VLT/NACO survey.

Table 1: Overview of the known multiplicity of objects studied in this paper

HD	SB1	SB2	Astrometric or Visual	HD	SB1	SB2	Astrometric or Visual
1909		X		65950	X		
7374	X		1	66259	X		<1>
11753	X		1	66409	X		1
14228			1	68099	x		
19400			1	68826		XX[d]	
21933	x		<1>	70235			
23950	x			71066		x	3
27295	X			71833			1
27376		X	$2+\underline{1}$	72208	X		<1>
28217	X		$\underline{1}$	73340			$\underline{1}$
29589	x		1	75333	X		$1+\underline{1}$[e]
31373	x			78316	X		$\underline{1}$
32964		X	$1+\underline{1}$	90264	X		<1>
33647		X	$\underline{1}$	101189			<1>
33904			<1>	110073	X		$\underline{1}$
34364		X[a]		120709	X		$\underline{1}$
34880		X	$\underline{2}$	124740		X	
35548		X	$\underline{1}$[b]	129174	X		$1+\underline{1}$
36881	X		$\underline{1}$	141556	X[a]		
37752				144661	x		
38478				144844		X	1
42657	x		$1+\underline{1}$	158704		X	$\underline{1}$
49606	X		1	165493	X		$\underline{1}$
51688	x		1	178065		X	
53244	x		<1>	216494		X	$\underline{1}$
53929	x		<1>	221507			<1>
59067			$3+\underline{1}$	224926			
63975							
65949	X			41040	X	X	$\underline{1}$[c]

Remarks:
[a]There are hints for a third component in these systems.
[b]The visible component is identical with the SB2 system.
[c]The visible component is identical with the SB1 system.
[d]HD 68826 consists of two SB2 systems.
[e]In fact, we see the two visual components as one.

sample is quite heterogeneous in parallax, the parallax of Sco OB2 from their paper (they quote a distance of 130 pc, corresponding to a parallax of 7.7 mas) is quite similar to the average parallax of our sample (7.3 ± 4.4 mas). The projected linear separations in their sample (29 to 1600 AU) are also quite comparable to ours (13.5 to 1700 AU). Oudmaijer & Parr (2010) observed a sample of 36 B stars and 37 Be stars with NACO on the VLT with exactly the same camera setting as used in our study. The only difference is their use of a narrow–band filter, centered on Brγ, in relation to our *Ks* filter. However, their sample is farther away than ours, 4.9 ± 2.7 mas for the B stars and 4.4 ± 2.8 mas for the Be stars. They find 21 binaries (10 for the B stars, 11 for the Be stars), leading to a binary fraction of 28.8%. Compared to these similar studies, our sample contains a significantly higher number of stars harboring a companion.

We note that the inspection of SB systems with a late B–type primary in the 9th Catalogue of Spectroscopic Binary Orbits (Pourbaix et al., 2004) indicates a strong correlation between the HgMn peculiarity and membership in a binary system. Among the bright well–studied SB systems with late B–type slowly rotating ($v \sin i < 70$ km/s) primaries with an apparent magnitude of up to $V \approx 7$ and orbital periods between 3 and 20 days, apart from HD 177863, all 21 systems have a primary with a HgMn peculiarity. Based on this, it cannot be excluded that most late B–type stars formed in binary systems with certain orbital parameters become HgMn stars.

In Table 1, we present the list of the observed HgMn stars with notes about their multiplicity. For each object, we indicate whether it is known to be an SB1 or SB2 and how many astrometric or visual companions are known. A lower case x indicates that there are hints of an SB system, which has not yet been confirmed. Numbers in brackets in the last column indicate objects first found in this study, while underlined numbers indicate the objects that we were able to confirm. Of the 56 HgMn stars studied, 32 are confirmed SB systems, 11 are potential SB systems, and 38 have visual companions. Only four of the potential SB systems do not have a visual companion. It is especially intriguing that out of the 56 HgMn stars in the sample studied, only five stars, HD 37752, HD 38478, HD 63975, HD 70235, and HD 224926 are not known to belong to a binary or multiple system. This results in a multiplicity rate of 91%.

The results of our study clearly confirm that HgMn stars are frequently found in binary and multiple systems. However, companionship cannot be established based on K photometry alone, and acquiring data with a near–infrared spectrograph is essential to establish their true companionship. Future spectroscopic observations in the near–infrared should be used to accurately determine the mass of the companions, and explore the physics in their atmospheres by comparing the observed and synthetic spectra.

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