

ATOMIC SPECIES IN THE SPECTRUM OF THE HG-MN STAR HD 53244

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RESUMEN

Presentamos la identificación de líneas del espectro de la estrella Bp de Hg-Mn HD 53244 (γ CMa) en el intervalo espectral $\lambda\lambda 3700 - 6700 \text{ \AA}$. Este objeto es miembro del cúmulo abierto austral Cr 121. La comparación de su espectro con otros de estrellas de Hg-Mn de campo muestra que comparte muchas de las anomalías espectrales pero también presenta algunas diferencias.

ABSTRACT

Line identifications are presented for the Hg-Mn Bp star HD 53244 (γ CMa), in the spectral region $\lambda\lambda 3750 - 6700 \text{ \AA}$. This object is a member of the southern open cluster Cr 121. Comparison of the spectrum of HD 53244 with other field Hg-Mn stars shows that it shares many of their spectral anomalies but that also some differences exist.

Key Words: stars: chemically peculiar — stars: line identification — stars: individual (HD 53244)

1. INTRODUCTION

The identification of lines in stellar spectra is one of the basic operations in stellar spectroscopy. The main purpose of this task is to determine the element responsible for each observed spectral line. Today, complete identification studies in which one attempts to identify every absorption feature are rarely done but they are badly needed. This research is part of our current program for producing line identification lists and elemental abundances among southern chemically peculiar (CP) stars. For this paper we selected the Hg-Mn star HD 53244. It is a member of the open cluster Collinder 121 (Feinstein 1967). It was observed by Hipparcos (HIP 34045).

This peculiar star was classified as B8 II (Houk & Cowley 1975) and B8 III in several papers in the literature. In fact, HD 53244 is a Hg-Mn peculiar star or CP3 in the classification scheme of Preston (1974). It was first classified as a manganese star of the α And class by Morgan (1933). Some years later (Bidelman 1962a,b) identified the nature of the line $\lambda 3984 \text{ \AA}$ as produced by Hg II and HD 53244 became a Hg-Mn star. It is included as such in the cata-

logues of Renson, Gerbaldi, & Catalano (1991) and Schneider (1981). *UBV* photoelectric photometry was published by several authors; there are more than a dozen measurements in the literature. Also, *ubvy* photoelectric photometry has been provided by more than half a dozen sources. The most recent values for the *UBV* photometry are those provided by Fernie (1983), ($B - V = -0.13 \text{ mag}$, $U - B = -0.45 \text{ mag}$). The *ubvy - β* photometry was taken from Hauck & Mermilliod (1998).

The radial velocity published by Wielen et al. (1999) is 32 km s^{-1} and the rotational velocity, 30 km s^{-1} , was derived by Abt, Levato, & Grosso (2002). Very recently Briquet et al. (2010) found variable line profiles of Hg line and they derived a rotation period of 6.16 days for HD 53244.

2. OBSERVATIONAL MATERIAL

The spectra of HD 53244 were obtained by NM with the Jorge Sahade 2.15 m telescope at Complejo Astronómico El Leoncito (CASLEO) and the EBASIM bench echelle spectrograph with a Roper Scientific 1340 \times 1310 CCD back illuminated detector with a pixel size of 20μ . Two spectra of the star were obtained covering the visual range $\lambda\lambda 3700 - 5500 \text{ \AA}$ and another two covering the red portion $\lambda\lambda 4600 - 6700 \text{ \AA}$. The EBASIM spectrograph uses gratings as cross dispersers. We have used one grating with $226 \text{ lines mm}^{-1}$. The S/N ratio of

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the spectra was around 300 and they were taken in March, 2008. The resolving power was 40000 at 5000 Å. There was no more than a 20% difference among the equivalent width measurements of the same lines in different orders of the echelle spectra. The spectra were reduced using IRAF⁴ standard procedures for echelle spectra, and were normalized order by order with the CONTINUUM task of the same package. The resolution of the spectra was 0.04 Å/px. Extensive description of EBASIM spectrograph has been published by Simmons & Levato (1996) and by Pintado & Adelman (2003).

3. LINE IDENTIFICATIONS

The line identification techniques have been extensively reviewed by Cowley & Adelman (1990) and by Gulliver & Stadel (1990). Also the subject was addressed by Cowley (1995). Cowley & Adelman (1990) in particular compared the results of the classical technique for line identification with the WCS (wavelength coincidence statistics). As HD 53244 is an early type Bp star, we have used the classical technique for line identification based on the following precautions: (a) we use the highest resolution spectra on hand (EBASIM, 40000 resolving power), (b) we try to identify all the possible lines in the wavelength range, (c) we require that the strongest laboratory lines of each atomic species be present. The stellar lines were identified using the general compilation by Moore (1945) as well as the more specialized references: for Si II Shenstone (1961), for P II we used the NIST tables⁵, for Ti II Huldt et al. (1982), for Mn II Iglesias & Velasco (1964), for Fe II Johansson (1978), Nave et al. (1994) and some few lines from Kurucz⁶, while for the rare earths we have used the DREAM⁷ database. We used a $\Delta\lambda$ interval of 0.15 Å to search for the possible contributors to each spectral feature. HD 53244 is not a very low rotator. The $v \sin i$ value derived from our EBASIM spectra is around 30 km s⁻¹ and agrees with the Abt et al. (2002) determination. So we chose the interval ± 0.15 Å because the total width due to rotation for lines at 4000 Å is around 0.4 Å. Empirically, it is demonstrated that on our spectra one may note the presence of a companion line with less than half of that value. We have not used the synthetic computation of the spectra for line identification because

that technique involves theory and several assumptions and simplifications of the real physical situation in Bp-Ap stars. The technique we have applied has been extensively justified in Cowley (1995).

Table 1 lists the line identifications. The first column shows the mean wavelength λ in Å as measured on HD 53244 and corrected by Doppler shift to the laboratory frame. The second column lists the equivalent width in Å measured in our spectra. The values are averages of two spectra. Column 3 lists the identification of the ion producing the line (the symbol ? means that the identification is doubtful). Column 4 provides the multiplet number or the source of the identification. The rest wavelengths are indicated in Column 5, while Column 6 provides the relative intensity of the line. The intensities are a measure of the depth of the line with respect to the continuum and they were estimated with a very rough scale in which lines (at the wavelength given) with a depth smaller than 4% correspond to intensity $I = 1$, those between 4% and 6% correspond to $I = 2$; 6% to 10%, to $I = 3$; 10% to 15%, to $I = 4$; 15% to 20%, to $I = 5$; 20% to 30%, to $I = 6$; 30% to 40%, to $I = 7$; 40% to 60%, to $I = 8$; 60% to 80%, to $I = 9$; and 80% to 100%, to $I = 10$.

In the vicinity of the Balmer lines, the intensities for the metal lines are measured with respect to the hydrogen line wings. The intensities for the Balmer lines are measured with respect to a continuum extrapolated across them.

Let us comment, next, the results for some atomic species:

- H I. The first line measured from the short wavelength region is $\lambda 3759$.
- He I. There are several lines identified.
- C II. (Moore 1945) lines of multiplets 4 ($\lambda 3918$ and $\lambda 3920$) and $\lambda 4267$ are present; lines of multiplet 2 ($\lambda 6578.05$ and $\lambda 6582.88$) were also found among the telluric lines present in the 6500 Å region.
- N I is not present.
- O I. We identified three lines of O I in the $\lambda 5300$ region. They belong to multiplets 12 and 13 and one line of multiplet 3. We have also identified lines of multiplet 10 ($\lambda 6155.99$ blended with $\lambda 6156.78$) and also we found $\lambda 6158.19$. We have also found the line of multiplet 9 $\lambda 6456.01$. So the presence of O I is certain.
- O II. The identification is very doubtful, only one line is probably present.
- Ne I. There are several lines identified, multiplets 1, 3, 5, 6, 9, 11 and 13.
- Na I. There are many telluric lines present in the region, only $\lambda 5889$ was identified.

⁴IRAF is distributed by the National Optical Astronomical Observatories which is operated by the Association of Universities for Research in Astronomy, Inc., under a cooperative agreement with the National Science Foundation.

⁵<http://physics.nist.gov/cgi-bin/AtData/lines.form>.

⁶www.kurucz.harvard.edu/atoms/2601/gf2601.lines.

⁷<http://www.umh.ac.be/astro/dream.shtml>.

TABLE 1
LINE IDENTIFICATION

λ [Å]	W_{eq}	Identification				λ [Å]	W_{eq}	Identification			
		Element	Mult.	λ_{lab}	Intensity			Element	Mult.	λ_{lab}	Intensity
3700.00					50.40	0.027	YII	6	50.35	1	
59.22	0.081	TiII	13	59.30	3	52.40	0.065	MnII	I	52.42	2
		FeII	154	59.46		60.99	0.031	FeII	212	60.90	2
61.48	0.018	TiII	13	61.33	1	68.75		CaII			4
		CrII	11	61.66		70.07		He			6
		TiII	107	61.88		75.69	0.034	MnII	I	75.74	1
		CrII	11	61.85		79.48	0.037	CrII	183	79.51	1
63.79	0.037	MnII	I	63.76	2	83.91	0.009	HgII		83.94	1
65.63	0.014	CrII	20	65.56	1	86.22	0.031				1
67.89	0.028	MnII	I	67.94	1	87.68	0.011	TiII	11	87.61	1
68.78	0.009	HeI	65	68.81	1/2	91.20	0.030	ZrII ?	30	91.14	1
70.69		H11			7	95.31	0.014	MnII	I	95.32	1
78.32	0.054	MnII	I	78.32	2	99.84	0.013				1
79.62	0.019	FeII	23	79.58	1						
83.33	0.100	FeII	14	83.35	3	4000.00					
84.23	0.092	CeIII ?			3	00.02	0.006	MnII	I	00.04	1/2
97.90		H10			7	02.58	0.030	FeII	190	2.54	1
98.28	0.049	FeII	14	98.28	2			CrII	166	2.48	
						03.62	0.013				1
3800.00						04.69	0.021				1
01.38	0.022	MnII	I	01.63	1	09.35	0.042	HeI		09.25	1
		CrII	-	01.21	3	12.45	0.019	TiII	11	12.40	1
12.36	0.013	MnII	I	12.24	1			CrII	183	12.50	
		MnII	I	12.52		15.50	0.037	NiII	12	15.50	2
14.19	0.025	FeII	153	14.12	1	18.24	0.018	ZrII ?	54	18.38	1
17.30	0.024	MnII	I	17.26	1	20.95	0.041				2
19.55	0.087	HeI			3	26.06		HeI			6
20.43	0.042	FeI	20	20.43	2	28.41	0.012	TiII	87	28.36	1
24.84	0.059	FeII	29	24.91	2	32.95	0.021	FeII	126	32.95	1
		MnII	I	25.04		34.06	0.016	ZrII ?	42	34.10	1
27.08	0.014	FeII	153	27.08	1	37.91	0.032	CrII	194	37.98	1
35.39		H9			8	40.26	0.018	ZrII	54	40.24	1
38.80	0.024	MnII	I	39.05	1	44.44	0.061	PII	30	44.49	2
41.79	0.019					48.81	0.032	FeII	172	48.83	1
42.99	0.025	ZrII	7	43.03	1	50.60	0.027				
43.26	0.010	MnII	I	43.32	1	53.97	0.012	TiII	87	53.83	1
44.10	0.022	MnII	I	44.17	1			CrII	19	54.09	
45.17	0.072	FeII	127	45.18	2	57.46	0.051	FeII	212	57.46	2
48.24	0.059	MgII	5	48.24	2	61.76	0.020	FeII	189	61.79	1
49.51	0.035	NiII	11	49.58	2	63.85	0.029				
50.95	0.034	OII	NI	51.03	1	64.48	0.028	FeII	29	64.57	1
		SII	50	50.93				TiII	106	64.35	
53.58	0.041	SiII	1	53.66	2	65.40	0.015				1
56.00	0.078	SiII	1	56.02	4	66.94	0.054	NiII	11	67.05	2
60.92	0.014	FeII	0	60.92	1	69.96	0.014	FeII	188	69.88	1
62.55	0.084	SiII	1	62.60	3	72.48	0.027	CrII	26	72.56	1
63.95	0.016	FeII		63.95	1	73.76	0.031				1
65.74	0.021	CrII	167	65.60	1	75.43	0.028	SiII	3.01	75.45	1
		CrII	130	65.99		78.50	0.013				1
67.56	0.022	HeI	20	67.48	1	80.94	0.080				2
		HeI	20	67.63		83.63	0.100	MnII	I	83.66	3
71.82	0.035	HeI	60	71.82	1						
78.90	0.037	MnII	I	79.00	1	4100.00					
88.65	0.007	HeI	2	88.65	1/2	01.76		H δ			6
89.05		H8			6	07.90	0.022				1
						09.30	0.059	MnII ?	I	09.20	2
3900.00						10.72	0.111	MnII	I	10.62	2
00.48	0.028	TiII	34	00.56	1			CrII	18	11.01	
05.94	0.075	FeII	173	06.04	2	20.90	0.028	HeI			1
		CrII	167	05.64		22.69	0.019	FeII	28	22.64	1
11.76	0.018					24.75	0.013	FeII	22	24.79	1
13.48	0.056	TiII	34	13.48	2	28.05	0.132	SiII	3	28.07	4
17.25	0.020	MnII	I	17.32	1	30.85	0.092	SiII	3	30.89	4
19.03	0.036	CII	4	18.98	1	36.90	0.020	MnII	I	36.90	1
20.66	0.048	CII	4	20.68	2	40.37	0.022	MnII	I	40.44	1
26.51	0.052	HeI	68	26.53	2	43.80	0.039	HeI			1
32.09	0.040	TiII	34	32.02	1	45.68	0.013	CrII	162	45.77	1
33.62	0.145	CaII			5	49.33	0.065	ZrII ?	41	49.22	2
35.91	0.032	HeI	57	35.91	1	53.20	0.010	SII	44	53.10	1
38.92	0.037	FeII	190	38.97	1	63.62	0.019	TiII	105	63.63	1
47.38	0.043	OI	3	47.29	1	67.24	0.040	FeII	K88	67.30	1

TABLE 1 (CONTINUED)

λ [Å]	W_{eq}	Identification				λ [Å]	W_{eq}	Identification			
		Element	Mult.	λ_{lab}	Intensity			Element	Mult.	λ_{lab}	Intensity
		FeIII	118	66.86		65.22	0.030	MnII	I	65.22	1
71.54	0.039	MnII	I	71.51	2	67.69	0.011	TiII	105	67.65	1
73.59	0.090	FeII	27	73.45	2	69.36	0.006	FeII	28	69.40	1/2
		TiII	21	73.53		73.03	0.018				1
78.67	0.058	FeII	28	78.86	2	74.59	0.016	TiII	93	74.84	1
		PII	S	78.46				ScII	14	74.46	
81.75	0.016	CrII	181	81.50	1			YII	13	74.94	
84.54	0.013	MnII	I	84.45	1	79.64	0.014	MnII	I	79.67	1
91.32	0.030				1	84.56	0.026	MgII	10	84.64	1
						85.34	0.034	FeII	27	85.39	1
4200.00								PII	NI	85.31	
00.28	0.029	MnII	I	00.27	1	87.88	0.098	HeI		87.93	3
03.08	0.016	FeII	K88	02.99	1	90.57	0.013	MgII	10	90.58	1
05.37	0.034	MnII	I	05.38	1	93.33	0.032	MnII	I	93.38	1
06.31	0.056	MnII	I	06.37	2	94.96	0.043	TiII	19	95.00	2
22.26	0.012	CrII	180	22.00	1	95.77	0.008	FeIII	4	95.78	1
24.62	0.032	CrII	31	24.08	1	99.80	0.026	TiII	51	99.79	1
		CrII	162	24.89							
33.14	0.057	FeII	27	33.17	2	4400.00					
		CrII	31	33.27		00.74	0.020				1
35.16	0.012				1	07.74	0.004	TiII	51	07.68	1
35.62	0.027	YII	5	35.73	1	09.49	0.007	TiII	61	09.51	1
		FeII	K88	35.39		11.10	0.009	TiII	115	11.10	1
37.95	0.014	MnII	I	37.87	1	11.99	0.003	TiII	61	11.92	1
38.80	0.022	MnII	I	38.79	1	15.20	0.003	FeI	41	15.12	1
42.36	0.056	MnII	I	42.33	1	16.80	0.035	FeII	27	16.83	1
		CrII	31	42.38		17.76	0.002	TiII	40	17.72	1
44.23	0.023	MnII	I	44.25	1	19.41	0.007	FeIII	4	19.59	1
46.55	0.073	ScII ?	7	46.83	2	20.73	0.019	PII	NI	20.71	1
		CrII	31	46.41		27.92	0.017	MgII	9	28.00	1
50.44	0.013	FeII	K	50.44	1	30.93	0.012	FeIII	4	30.95	1
51.73	0.043	MnII	I	51.74	2	34.03	0.019	MgII	9	33.99	1
52.97	0.045	MnII	I	52.96	2			MnII	I	34.06	
54.47	0.004	CrII	D	54.52	1	37.51	0.017	HeI			1
59.07	0.029	MnII	I	59.20	1	41.84	0.007	TiII	40	41.73	1
61.99	0.022	CrII	31	61.92	1	43.76	0.039	TiII	19	43.78	1
63.89	0.012	FeII	J	63.90	1	50.43	0.015	TiII	19	50.50	1
67.19	0.061	CII	6	67.02, .27	2	51.53	0.008	FeII		51.55	1
70.84	0.014				1	55.26	0.009	FeII	J	55.27	1
73.31	0.019	FeII	27	73.32	1	61.93	0.015				1
75.59	0.029	CrII	31	75.57	1	63.07	0.017				1
78.38	0.008	SII	40	78.50	1/2	68.49	0.043	TiII	31	68.52	1
82.45	0.044	MnII	I	82.47	2	71.51	0.182	HeI			5
83.94	0.039	CrII	31	84.21	1	75.24	0.013	PII	NI	75.26	1
		MnII	I	83.77		78.64	0.026	MnII	I	78.64	1
86.24	0.004	FeII	J	86.31	1/2	81.17	0.187	MgII	4	81.13	6
87.95	0.022	TiII	20	87.88	1			MgII	4	81.33	
		MnII	I	88.07		89.14	0.028	FeII	37	89.18	1
90.19	0.042	TiII	41	90.22	2			CrII	J	89.11	
92.24	0.036	MnII	I	92.24	2	91.38	0.029	FeII	37	91.40	1
94.24	0.024	TiII	20	94.09	1	93.68	0.011	TiII	18	93.53	1
		SII	49	94.43				FeII	222	93.58	
96.57	0.026	FeII	28	96.57	1	99.31	0.029	PII	NI	99.24	1
4300.00						4500.00					
00.08	0.037	TiII	41	00.06	2	01.31	0.037	TiII	31	01.27	1
03.10	0.044	FeII	27	00.17	2	08.24	0.038	FeII	38	08.28	2
07.96	0.047	MnII	I	08.16	2	15.29	0.039	FeII	37	15.34	2
		TiII	41	07.87		18.99	0.012	MnII	I	18.96	1
09.52	0.003	YII	5	09.62	1	20.20	0.030	FeII	37	20.22	1
12.91	0.013	TiII	41	12.87	1	22.57	0.046	FeII	38	22.63	2
14.46	0.013	MnII	I	14.38	1	24.83	0.018	SII	45	24.95	1
15.10	0.006	TiII	41	14.97	1	29.55	0.003	TiI	82	29.48	1
20.69	0.008	ScII	15	20.74	1	33.98	0.030	TiII	50	33.97	1
25.06	0.007	MnII	I	25.04	1	39.54	0.009	CrII	39	39.62	1
26.63	0.045	MnII	I	26.64	3	41.51	0.022	FeII	38	41.53	1
30.13	0.011	TiII	94	30.23	1	46.66	0.014	CrII	J	46.62	1
40.47		H γ			6	49.42	0.100	FeII	186	49.21	4
43.92	0.054	MnII	I	43.98	2			FeII	38	49.47	
48.42	0.030	MnII	I	48.40	1			TiII	82	49.62	
51.79	0.053	FeII	27	51.77	2	52.42	0.010	SiIII	2	52.62	1
56.62	0.018	MnII	I	56.62	1			SII	48	52.38	
63.22	0.019	MnII	I	63.26	1	55.07	0.015	CrII	44	55.02	1

TABLE 1 (CONTINUED)

λ [Å]	W_{eq}	Identification				λ [Å]	W_{eq}	Identification			
		Element	Mult.	λ_{lab}	Intensity			Element	Mult.	λ_{lab}	Intensity
55.92	0.013	FeII	37	55.89	2	4900.00					
58.56	0.048	CrII	44	58.66	2	01.60	0.013	CrII	190	01.65	1
63.77	0.024	TiII	50	63.72	1	11.13	0.015	TiII	114	11.18	1
65.74	0.010	CrII	30	65.77	1	13.29	0.020	FeII	J	13.29	1
67.87	0.008	SiIII	2	67.83	1/2	21.77	0.133	HeI			3
71.89	0.034	TiII	82	71.96	1	23.87	0.063	FeII	42	23.93	2
74.86	0.005	SiIII	2	74.76	1/2	31.30	0.018				1
76.39	0.029	FeII	38	76.33	1	43.51	0.021	PII	NI	43.53	1
79.58	0.007	FeII	J	79.52	1	48.80	0.010	FeII	J	48.80	1
82.87	0.020	FeII	37	82.84	1	51.52	0.014	FeII	J	51.59	1
83.80	0.074	FeII	38	83.83	2	54.18	0.011	FeII	J	53.98	1
88.13	0.027	PII	NI	88.04	3	69.63	0.039	PII	NI	69.71	1
		CrII	44	88.22		76.95	0.019	FeII	J	77.04	1
89.83	0.031	CrII	44	89.89	1	77.50	0.038	FeII	J	77.03	1
		PII	NI	89.86				FeII	J	77.93	
92.03	0.023	CrII	44	92.07	1	80.14	0.006				1
96.02	0.021	FeII	D	96.02	1	84.49	0.010	FeII	J	84.49	1
98.39	0.013	FeII	219	98.53	1	90.59	0.012	FeII	J	90.51	1
						91.66	0.010				1
4600.00						93.36	0.003	FeII	J	93.35	1
02.04	0.034	P II	NI	02.08	1						
00.44	0.029				1	5000.00					
16.60	0.022	CrII	44	16.64	1	01.90	0.034	FeII	J	01.92	2
18.78	0.023	CrII	44	18.82	1	04.22	0.025	FeII	J	04.20	1
20.56	0.017	FeII	38	20.52	1	07.40	0.030	FeII	J	07.45	1
21.65	0.023	SiII	7.05	21.42	1	09.54	0.012	SII	7	09.54	1
				21.72		15.73	0.056	FeII	J	15.75	2
25.86	0.002	FeII	186	25.91	1	18.41	0.080	FeII	J	18.45	3
29.26	0.037	FeII	37	29.34	1	21.60	0.010	FeII	J	21.59	1
31.99	0.003	FeII	219	31.90	1	22.77	0.018	FeII	J	22.79	1
34.12	0.020	CrII	44	34.16	1	26.90	0.013	FeII	J	26.80	1
35.27	0.022	FeII	186	35.32	1	30.67	0.030	FeII	J	30.63	1
40.91	0.004	FeII	J	40.84	1	32.40	0.017	SII	7	32.41	1
56.99	0.007	FeII	43	56.98	1/2	35.68	0.027	FeII	J	35.71	1
58.36	0.011	PII	NI	58.31	1	40.96	0.086	SiII	5	41.02	3
66.70	0.008	FeII	37	66.75	1/2	47.66	0.029	FeII	J	47.64	1
70.13	0.010	FeII	25	70.18	1/2			HeI			
73.16	0.017	SiII	7.15	73.27	1	56.16	0.122	SiII	5	55.98	4
								SiII	5	56.32	
4700.00						61.64	0.018	FeII	J	61.72	1
08.72	0.043	NeI	11	08.85	2	67.79	0.018	FeII	J	67.89	1
13.18	0.045	HeI			2	75.74	0.024	FeII	J	75.76	1
16.16	0.008	SiII	9	16.27	1/2	82.22	0.013	FeII	J	82.23	1
17.30	0.016	MnII	I	17.26	1	89.17	0.012	FeII	J	89.21	1
27.77	0.036	MnII	I	27.84	1	93.54	0.023	FeII	J	93.56	1
30.36	0.022	MnII	I	30.40	1	97.24	0.018	FeII	J	97.27	1
31.52	0.011	FeII	43	31.45	1						
38.20	0.045	MnII	I	38.29	2	5100.00					
		MnII	I	38.29		00.72	0.056	FeII	J	00.74	2
55.71	0.054	MnII	I	55.73	3	02.47	0.029	MnII	I	02.52	1
64.74	0.054	MnII	I	64.73	2	03.30	0.004	SII	7	3.30	1/2
70.15	0.033				1	06.16	0.021	FeII	J	06.11	1
76.47	0.025				1	23.19	0.020	FeII	J	23.19	1
79.89	0.020	TiII	92	79.98	1	27.50	0.018	FeII	J	27.85	1
84.56	0.025				1	44.16	0.012	FeII	J	43.88	1
91.76	0.011	MnII	I	91.81	1			FeII	J	44.36	
						45.71	0.010	FeII	J	45.78	1
4800.00						49.24	0.036	FeII	J	48.94	2
04.90	0.013	TiII	92	05.09	1			FeII	J	49.46	
		FeII	J	04.73		57.58	0.024	FeII	J	57.51	1
06.86	0.026	MnII	I	06.82	1	60.87	0.016	FeII	J	60.85	1
11.91	0.023	MnII	I	11.62	1	63.22	0.013	FeII	J	63.00	1
		CrII	30	12.36				FeII	J	63.58	
15.61	0.012	SiII	9	15.55	1	66.47	0.020	FeII	J	66.56	1
24.08	0.032	CrII	30	24.13	2	69.00	0.080	FeII	J	69.03	3
26.63	0.017	FeII	J	26.68	1	77.46	0.042	FeII	J	77.39	2
30.17	0.011	MnII	I	30.06	1			MnII	I	77.65	
36.13	0.008	CrII	30	36.22	1	83.51	0.014	MgI	2	83.60	1
47.67	0.019	MnII	I	47.61	1	85.86	0.018	TiII	86	85.90	1
48.28	0.017	CrII	30	48.24	1	91.48	0.023	PII	NI	91.41	1
61.33		H β			6	97.56	0.036	FeII		97.58	2
76.41	0.029	CrII	30	76.41	1	99.16	0.009	FeII	J	99.12	1
83.25	0.011	FeII	J	83.28	1						

TABLE 1 (CONTINUED)

λ [Å]	W_{eq}	Identification				λ [Å]	W_{eq}	Identification			
		Element	Mult.	λ_{lab}	Intensity			Element	Mult.	λ_{lab}	Intensity
5200.00											
01.00	0.012	FeII	J	00.81	1	95.92	0.019	FeII	J	93.59	
02.40	0.010	SiII	23	02.41	1			FeII	J	95.86	1
		SiII	23	02.41		5400.00					
03.69	0.018	FeII	J	03.64	1	02.00	0.033	FeII	J	02.06	1
12.70	0.001	SII	39	12.61	1	05.19	0.012	FeII	J	05.10	1
13.87	0.015	FeII	J	13.99	1	08.76	0.024	FeII	J	8.81	1
15.54	0.028	FeII	J	15.34	1	09.70	0.031	PII	NI	09.72	1
		FeII	J	15.82		14.53	0.028	FeII	J	14.05	1
16.77	0.028	FeII	J	16.85	2			FeII	J	14.84	
18.88	0.008	FeII	J	18.84	1	19.19	0.017	XeII	NI	19.15	1
25.56	0.032	FeII	J	25.25	1	21.92	0.015	MnII	I	21.92	1
		FeII	J	25.36		25.82	0.067	FeII	J	25.82	2
		FeII	J	25.98				PII	NI	25.88	
27.43	0.037	FeII	J	27.48	2	27.70	0.008	FeII	J	27.82	1
32.90	0.020	FeII	J	32.78	1	29.90	0.014	FeII	J	29.99	1
34.53	0.049	FeII	J	34.29	2	32.85	0.019	SII	6	32.82	1
		FeII	J	34.62		42.35	0.005	FeII		42.35	1/2
37.62	0.023	CrII	43	37.34	1	44.43	0.012	FeII	J	44.39	1
		FeII	J	37.95		45.87	0.013	FeII	J	45.81	1
39.71	0.013	FeII	J	39.81	1	50.68	0.019	PII	NI	50.74	1
41.14	0.015	FeII	J	41.08	1	53.86	0.015	SII	6	53.83	1
43.03	0.006	FeIII	113	43.3	1	66.40	0.050	SiII	7.03	66.43	2
45.12	0.015	FeII	J	45.08	1	72.84	0.014	FeII	J	72.86	1
46.75	0.003	CrII	23	46.75	1/2	75.79	0.009	FeII	J	75.83	1
47.94	0.021	FeII	J	47.95	1	82.30	0.019	FeII	J	82.31	1
49.40	0.017	CrII	23	49.40	1	87.66	0.023	FeII	J	87.62	1
51.32	0.027	FeII	J	51.23	1	92.14	0.018	FeII	J	92.08	1
53.46	0.068	FeII	J	53.64	2			FeII	J	92.40	
		PII	NI	53.52		93.66	0.011	FeII	J	93.63	1
54.77	0.010	FeII	J	54.64	1	98.53	0.015	FeII	J	98.57	1
57.25	0.020	FeII	J	57.11	1	99.77	0.033	PII	NI	99.73	1
60.25	0.041	FeII	J	60.26	2						
64.34	0.043	FeII	J	64.18	2	5500.00					
		FeII	J	64.80		02.99	0.024	FeII	J	02.68	1
69.98	0.015	FeII	J	70.03	1			FeII	J	03.22	
72.35	0.018	FeII	J	72.40	1	06.27	0.036	FeII		06.20	2
75.91	0.060	FeII	J	75.99	2	10.69	0.055	FeII	J	10.67	2
79.79	0.023	CrII	43	79.88	1			FeII	J	10.78	
84.14	0.025	FeII	J	84.11	1	28.93	0.004	FeII	J	29.06	1
91.91	0.040	FeII	J	91.67	2	29.74	0.005	FeII	J	29.92	1
		XeII	NI	92.22		31.99	0.008	FeII	J	32.09	1
94.29	0.034	MnII	I	94.32	1	34.86	0.025	FeII	J	34.83	1
95.52	0.064	MnII	I	95.40	2	44.66	0.019	FeII	J	44.76	1
96.60	0.025				1			FeII	J	44.20	
97.13	0.021	MnII	I	97.06	1	48.65	0.015	FeII	J	48.21	1
99.30	0.061	MnII	I	99.39	2	59.06	0.030	SII	61	59.06	1
								MnII	I	59.05	
5300.00						61.43	0.010	FeII	J	61.52	1
02.50	0.053	FeII	J	02.55	2	63.46	0.010	FeII	J	63.40	1
06.18	0.011	FeII	J	06.18	1	67.76	0.019	FeII	J	67.84	1
13.58	0.017	CrII	43	13.59	1	70.58	0.041				1
16.39	0.122	FeII	J	16.23	5	78.06	0.032	FeII	J	77.92	1
		FeII	J	16.62				MnII	I	78.15	
		FeII	J	16.78		88.16	0.018	FeII	J	88.22	1
25.53	0.018	FeII	J	25.55	1			FeII	J	88.05	
29.51	0.014	OI	12	29.10	1	5600.00					
		OI	12	29.68		06.08	0.011	SII	11	06.15	1
30.72	0.031	OI	12	30.74	1	39.96	0.022	SII	14	39.97	1
		NeI	9	30.78		45.43	0.010	FeII	J	45.40	1
34.85	0.013	CrII	43	34.88	1	46.93	0.003	SII	14	47.03	1/2
36.73	0.032	TiII	69	36.78	1	48.80	0.008	FeII	J	48.90	1
39.55	0.040	FeII	J	39.59	2	51.56	0.006	FeII	J	51.54	1
44.68	0.035	PII	NI	44.71	1	55.32	0.005	FeII	J	55.36	1/2
46.23	0.017				1	57.86	0.003	FeII	J	57.92	1/2
62.84	0.047	FeII	J	62.87	2	60.18	0.014	FeII	J	60.15	1
66.25	0.014	FeII	J	66.21	1	64.70	0.009	SII	11	64.78	1
70.34	0.010	FeII	J	70.30	1	68.78	0.003	FeII	J	68.64	1/2
72.36	0.022	XeII	NI	72.39	1	69.58	0.011	SiII	7.33	69.56	1
75.91	0.011	FeII	J	75.84	1	86.92	0.013				1
86.95	0.066	FeII	J	87.06	2	91.38	0.011	FeII	47	91.38	1
		PII	NI	86.88							
93.70	0.013	FeII	J	93.85	1						

TABLE 1 (CONTINUED)

λ [Å]	W_{eq}	Identification				λ [Å]	W_{eq}	Identification				
		Element	Mult.	λ_{lab}	Intensity			Element	Mult.	λ_{lab}	Intensity	
5700.00												
16.51	0.007	FeII	J	16.58	1/2	79.33	0.035	FeII	J	79.39	1	
48.30	0.006	NeI	13	48.30	1	6200.00						
80.18	0.021	FeII	J	80.13	1	38.49	0.049	FeII	J	38.39	2	
83.79	0.014	FeII	J	83.63	1	39.65	0.029	FeII	J	39.34	1	
								FeII	J	39.90		
						47.42	0.053	FeII	J	47.37	2	
5800.00						61.75	0.003	FeII	J	61.72	1/2	
26.30	0.020	FeII	J	26.11	1	66.44	0.026	NeI	5	66.50	1	
		FeII	J	26.51		69.28	0.004	FeII	J	69.34	1/2	
52.38	0.012	NeI	6	52.48	1	71.27	0.014	FeII	J	71.21	1	
75.62	0.168	HeI	11	75.62	6	73.63	0.005	FeII	J	73.59	1/2	
		HeI	11	75.65		82.64	0.012	MnII	K	82.52	1	
78.57	0.013	FeII	J	78.53	1	94.02	0.022	FeII	J	94.14	1	
79.84	0.017	FeII	K09	79.79	1							
80.80	0.013	FeII	K09	80.84	1	6300.00						
81.87	0.019	NeI	1	81.89	1	05.32	0.023	FeII	J	05.29	1	
82.82	0.022	FeII	K09	82.78	1	31.97	0.011	FeII	J	31.95	1	
84.99	0.034	FeII	J	85.02	1	34.42	0.026	NeI	1	34.43	1	
89.95	0.013	NaI	1	89.95	1	40.23	0.010	FeII	J	40.24	1	
91.36	0.018	FeII	J	91.33	1	47.09	0.151	SiII	2	47.09	6	
95.38	0.012	FeII	J	95.35	2	49.55	0.009	FeII	J	49.58	1/2	
97.96	0.015	FeII	J	98.03	1	57.22	0.028	FeII	J	57.16	1	
98.90	0.044	SiIII	K	98.79	2	62.54	0.004	FeII	J	62.48	1/2	
						67.34	0.009	FeII	J	67.41	1/2	
5900.00						71.36	0.132	SiII	2	71.36	5	
01.25	0.010	FeII	J	01.39	2	83.21	0.026	NeI	3	82.99	1	
02.60	0.029	FeII	J	02.82	1							
11.86	0.022				1	6400.00						
14.50	0.018	FeII	J	14.53	1	02.25	0.035	NeI	1	02.24	1	
21.39	0.025				1	07.14	0.015	FeII	J	01.25	1	
27.18	0.016	SiI	21	27.15	1	11.07	0.008	MnII	K	11.00	1/2	
44.41	0.028	FeII	J	44.38	1	15.57	0.014	FeII	J	15.56	1	
44.89	0.026	NeI	1	44.83	1	16.92	0.021	FeII	J	16.92	1	
48.42	0.029	FeII	J	48.42	1	25.75	0.014	FeII	J	25.74	1	
55.67	0.016	FeII	J	55.70	1	33.43	0.025				1	
57.52	0.100	SiII	4	57.56	3	40.44	0.005	FeII	J	40.48	1/2	
61.62	0.029	FeII	J	61.71	1	46.52	0.008	FeII	J	46.40	1/2	
65.52	0.036	FeII	J	65.63	1	48.32	0.008	FeII	J	48.22	1/2	
75.88	0.033	NeI	1	75.53	1	52.92	0.009	MnII	K	52.88	1/2	
		XeII	NI	76.46		55.94	0.020	OI	9	56.01	1	
78.97	0.048	SiII	4	78.97	2	56.38	0.046	FeII	J	56.38	2	
83.96	0.015	FeII	J	83.86	1	58.62	0.013	MnII	K	58.56	1	
						59.93	0.031	PII	K	59.94	1	
6000.00						62.21	0.020	MnII	20	62.21	1	
24.16	0.064	PII	NI	24.18	2	63.20	0.017	MnII	20	63.20	1	
34.00	0.049	PII	NI	34.04	2	78.12	0.020	FeII	J	78.14	1	
43.04	0.074	PII	NI	43.12	3	82.30	0.044	FeII	J	82.20	2	
45.50	0.012	FeII	J	45.46	1	91.61	0.051	TiII	91	91.56	1	
49.49	0.007	FeII	J	49.45	1/2			FeII	J	91.67		
60.93	0.021	FeII	J	60.99	1	93.11	0.009	FeII	J	93.03	1	
69.63	0.006	FeII	J	69.67	1/2	94.46	0.046	MnII	K	94.42	2	
71.43	0.009	FeII	J	71.42	1							
74.41	0.012	NeI	3	74.34	1	6500.00						
84.19	0.006	FeII	J	84.11	1/2	03.13	0.045				2	
87.76	0.030	PII	NI	87.82	1	06.40	0.025	NeI	3	06.53	1	
89.76	0.004	CrII	87	89.69	1	10.76	0.028	FeII	J	10.73	1	
96.29	0.017				1	31.12	0.035	FeII	J	31.16	1	
						41.27	0.018	FeII	J	41.37	1	
6100.00						42.68	0.040	FeII	J	42.63	2	
05.33	0.006	MnII	K	05.27	1/2	55.67	0.019	MnII	K	55.69	1	
22.55	0.032	MnII	K	22.45	1	62.82		H α			6	
28.91	0.023	MnII	K	29.04	1	73.54	0.037	FeII	J	73.49	5	
43.01	0.021	NeI	1	43.06	1	78.03	0.033	CII	2	78.05	1	
47.77	0.016	FeII	J	47.77	1	82.84	0.012	CII	2	82.85	1	
49.19	0.018	FeII	J	49.25	1	85.32	0.016	MnII	K	85.24	1	
56.57	0.040	OI	10	56.78	1	98.24	0.008	FeII	J	98.31	1/2	
		OI	10	55.99								
58.18	0.031	OI	10	58.19	1	6600.00						
63.53	0.013	FeII	J	63.60	1	00.81	0.009				1	
65.56	0.031	PII	NI	65.59	1	04.30	0.006	FeII	K09	04.30	1/2	
68.32	0.013	MnII	K	68.35	1	11.32	0.005	FeII	K09	11.40	1	
75.24	0.005	FeII	J	75.14	1/2	22.04	0.014	FeII	J	21.98	1	
		FeII	J	75.44		47.62	0.005	FeII	J	47.70	1/2	

TABLE 2
COMPARISON OF HD 53244 WITH OTHER HG-MN STARS

Atomic Species	HD 53244	HD 175640	HD 186122	HD 144206	112 HerA	HR 7361	HR 7245	HR 7143
He I	Pres	Pres	Abs	Pres	Pres	Pres	...	...
Be II	...	Pres	...	...	...	...	...	...
B II	...	Abs	...	...	...	...	...	...
C I	Abs	Pres	Abs	Pres	Abs	Abs	Pres	Pres
C II	Pres	Pres	Abs	Pres	Pres	Pres	Pres	Pres
N II	Abs	Abs	Abs	...	...	...	...	...
O I	Pres	Pres	Pres	Pres	Pres	Pres	...	...
O II	Doub	Pres	Pres	Pres	Abs	Pres	...	...
Ne I	Pres	Pres	Pres	...	...	...	...	...
Na I	Pres	Pres	Pres	...	...	...	...	...
Mg I	Abs	Pres	Abs	Pres	Abs	Abs	Doub	Pres
Mg II	Pres	Pres	Pres	Pres	Pres	Pres	Pres	Pres
Al I,II	...	Abs	Pres	...	Pres	Abs	...	...
Si II	Pres	Pres	Pres	Pres	Pres	Pres	Pres	Pres
Si III	Pres	Pres	Abs	Pres	Pres	Pres	...	...
P II	Pres	Pres	Pres	Pres	Pres	Pres	Pres	Abs
S I	Abs	Pres	Abs	Pres	Pres	...	...	...
S II	Pres	Pres	Abs	Pres	Pres	...	...	...
Ca I	Abs	Pres	...	Pres	Pres	Pres	...	...
Ca II	Pres	Pres	...	Pres	Pres	Pres	...	...
Sc II	Pres	Pres	...	Pres	Pres	Pres	Doub	Abs
Ti II	Pres	Pres	Pres	Pres	Pres	Pres	Pres	Pres
Cr I	Abs	Pres	Pres	Pres	Abs	Abs	Abs	Pres
Cr II	Pres	Pres	Pres	Pres	Pres	Pres	Pres	Pres
Mn I	Abs	Pres	Pres	Pres	Abs	Pres	Pres	Pres
Mn II	Pres	Pres	Pres	Pres	Pres	Pres	Pres	Pres
Fe I	Abs	Pres	Pres	Pres	Pres	Pres	Pres	Pres
Fe II	Pres	Pres	Pres	Pres	Pres	Pres	Pres	Pres
Fe III	Pres	...	...	Pres	Pres	Pres	Pres	Pres
Co II	...	Doub	Pres	...	Abs	Abs	...	...
Ni II	Pres	Pres	Pres	Pres	Abs	Pres	...	...
Cu I	Abs	Pres	...	...	...	...	...	...
Cu II	Abs	...	Pres	...	...	...	...	...
Zn II	...	Abs	Pres	...	...	...	...	...
Ga I,II	Abs	Pres	Pres ^a	Pres	Pres	Pres	Pres	Pres
As II	...	Doub	Pres	...	...	...	...	...
Br II	...	Pres	...	...	...	...	...	...
Sr II	Abs	Pres	...	Pres	Pres	Doub	Pres	Pres
Y II	Pres	Pres	...	Pres	Doub	Pres	Pres	Pres
Zr II	Doub	Pres	...	Pres	Pres	Abs	Abs	Abs
Rh II	...	Pres	...	...	...	...	...	...
Pd I,II	...	Pres	...	...	...	...	...	...
Xe II	Pres	Pres	Pres	Abs	Pres	Pres	...	...
Ba II	...	Pres	...	Pres	Abs	Abs	...	...
Ce II	...	Pres	...	...	...	...	...	...
Ce III	...	Abs	...	...	...	...	...	...
Pr II	...	Abs	...	...	...	Abs	...	...
Pr III	...	Doub	...	...	...	Abs	...	...
Nd III	...	Pres	...	...	Abs	Abs	Abs	Abs
Yb II,III	...	Pres	...	...	...	...	...	...
Os II	...	Doub	...	...	...	...	...	...
Ir II	...	Pres	...	...	...	...	...	...
Pt II	Abs	Pres	...	...	Abs	Abs	Abs	Abs
Au II	Abs	Pres	...	...	Abs	Abs	Abs	Abs
Hg I	...	Pres	Pres	Pres	Abs	Abs	...	...
Hg II	Pres	Pres	Pres	Pres	Pres	Pres	Pres	Pres
T_{eff}	13.781	12.050	13.000	12.000	13.450	13.650	12.293	12.050
$v \sin i$	30	20	20	20	20	15	15	20

Notes: Abs = Absent, Pres = Present, Doub = Doubtful.

^aCastelli et al. (2009) did not observe Ga for this star on optical UVES spectra. Smith & Dworetzky (1993) studied the star in the ultraviolet using IUE spectra. Maybe also HD 53244 would show Ga in the ultraviolet.

- Mg I is not present.
- Mg II. We have identified lines of multiplets 4, 5, 9 and 10.
- Si II. Several lines were identified from multiplets. 1, 3, 4, 5, 7.03, 7.05, 7.33.
- Si III. Lines of Multiplet 1 are present.
- P II. Several lines were identified. We have used NIST tables.
- S I is not present.
- S II. A lot of lines were identified using Moore's tables (Moore 1945).
- Ca I is not present.
- Ca II $\lambda 3933$ and $\lambda 3968$ are present.
- Sc II. The most intense lines are identified using Moore Tables (Moore 1945); $\lambda 4246$ blended with Cr II, $\lambda 4320.74$ and $\lambda 4374.46$ blended with Ti II.
- Ti II. We have identified a lot of lines. Very probably this element is overabundant.
- Cr II. A lot of lines were identified using Moore's tables. There are no lines of Cr I.
- Mn II. Using the tables from Iglesias & Velasco (1964) we have identified a lot of lines. Mn is very well represented.
- Fe I. There are no lines. Probably the effective temperature ($T_{\text{eff}} = 13781$ K) is too high.
- Fe II. A lot of lines are present. We have used Moore's tables. For $\lambda > 4800$ Å we have used Johansson (1978) and the more recent table by Nave et al. (1994).
- Fe III. We have identified lines of multiplet 4.
- Ni II. We have identified only two lines, $\lambda 4015.50$ and $\lambda 4067.05$.
- Cu II is not present.
- Y II. We identified $\lambda 3950.35$ (multiplet 6), $\lambda 4235.73$, $\lambda 4309.62$ (multiplet 5) and $\lambda 4374.94$ (multiplet 13).
- Zr II. The most intense line $\lambda 4149$ is ambiguously present although other weaker lines are identified $\lambda 3843.03$ (multiplet 7), $\lambda 3991.14$ (multiplet 30), $\lambda 4018.38$, $\lambda 4040.24$ (multiplet 54) and $\lambda 4034.10$ (multiplet 42); we think that the presence of this element is doubtful.
- Xe II. The most intense lines are identified using the NIST tables.
- Hg II. The line $\lambda 3983$ is definitely present.

We have not identified lines of Ga II and Sr II. We have not identified rare earths nor Au and Pt. The red regions of the spectra of HD 53244 have many telluric lines and it was difficult to identify with certainty some lines.

Thus, H I, He I, C II, O I, Ne I, Na I, Mg II, Si II, P II, S II, Ca II, Sc II, Ti II, Cr II, Mn II, Fe II, Fe III,

Ni II, Y II, Xe II, Hg II are definitely present. O II and Zr II are doubtful. There are a number of unidentified lines. These are likely to be lines of atomic species which have been already identified.

4. COMPARISON WITH OTHER FIELD BP-AP STARS AND COMMENTS

Line identification lists have been published for several other HgMn stars. In Table 2 we have indicated the atomic species present in the blue, visual and red regions of HD 53244. The spectrum in the photographic region of HD 53244 is compared in the table with those of other Hg-Mn stars: HD 144206 (Adelman, Gulliver, & Rayle 2001), HD 186122 (Sadakane et al. 2001), HD 175640 (Castelli & Hubrig 2004), and 112HerA, HR 7361, HR 7245 and HR 7143 (Guthrie 1985).

Effective temperatures were obtained from Smith & Dworetzky (1993) for HD 144206, HD 186122, 112 HerA and HR 7361; Heacox (1979) for HR 7245; Cenarro et al. (2007) for HD 175640 and HR 7143. For HD 53244 we used $uvby - \beta$ mean colors from Hauck & Mermilliod (1998) and the TEMPLOGG program Rogers (1995) to obtain this parameter. The $v \sin i$ were taken from Abt et al. (2002).

As is usually the case, Hg-Mn stars seem to differ one from another. The Hg-Mn phenomenon seems to be heterogeneous with star to star diversity. Probably the absence of Ga I, II and Sr II is the distinctive feature in HD 53244. It does not appear to be identical to any of the other stars in Table 2 although it shares many of their anomalies. Many of the atomic species which are present are represented by only a few lines. Differences in the magnetic field strength and configuration, apparent rotational velocity, effective temperature, surface gravity, elemental distributions on the stellar surface (see the recent paper by Briquet et al. 2010), and the exact wavelength region studied may well hide some of the underlying similarities.

There is no evidence in the spectra of HD 53244 of doubly ionized rare-earth lines. This lack of identifications may be due to the choice of the region studied (Adelman 1974).

The major similarity occur between HD 53244 and HD144206, which share almost the same anomalies except for the absence of Ga in the former. We conclude that HD 53244 appears to be a Hg-Mn star without Ga or rare earth elements.

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