*Revista Mexicana de Astronomía y Astrofísica*, **46**, 339–348 (2010)

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

N. L. Maza,[1,2] H. Levato,[1,3] and Z. López-García[1,3]

*Received 2009 December 29; accepted 2010 July 15*

RESUMEN

Presentamos la identificación de líneas del espectro de la estrella Bp de Hg-Mn HD 53244 ($\gamma$CMa) en el intervalo espectral $\lambda\lambda 3700 - 6700$ Å. 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 ($\gamma$CMa), in the spectral region $\lambda\lambda 3750 - 6700$ Å. 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 $\alpha$And class by Morgan (1933). Some years later (Bidelman 1962a,b) identified the nature of the line $\lambda$ 3984 Å as produced by Hg II and HD 53244 became a Hg-Mn star. It is included as such in the catalogues of Renson, Gerbaldi, & Catalano (1991) and Schneider (1981). $UBV$ photoelectric fotometry 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), ($B-V = -0.13$ mag, $U-B = -0.45$ mag). The $ubvy - \beta$ 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 Astrónomico El Leoncito (CASLEO) and the EBASIM bench echelle spectrograph with a Roper Scientific 1340 × 1310 CCD back illuminated detector with a pixel size of 20$\mu$. Two spectra of the star were obtained covering the visual range $\lambda\lambda 3700 - 5500$ Å and another two covering the red portion $\lambda\lambda 4600 - 6700$ Å. The EBASIM spectrograph uses gratings as cross dispersers. We have used one grating with 226 lines mm$^{-1}$. The S/N ratio of

[1]Instituto de Ciencias Astronómicas, de la Tierra y del Espacio, San Juan, Argentina.
[2]Visiting astronomer Complejo Astronómico El Leoncito, Argentina.
[3]Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina.

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 IRAF[4] 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 tables[5], 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 Kurucz[6], while for the rare earths we have used the DREAM[7] 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 $\lambda$ 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 wavelewngths 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.

[4]IRAF 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.

[6]www.kurucz.havarard.edu/atoms/2601/gf2601.lines.

[7]http://www.umh.ac.be/astro/dream.shtml.

TABLE 1

LINE IDENTIFICATION

| | | Identification | | | | | | Identification | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\lambda$ [Å] | $W_{eq}$ | Element | Mult. | $\lambda_{lab}$ | Intensity | $\lambda$ [Å] | $W_{eq}$ | Element | Mult. | $\lambda_{lab}$ | 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 | | H$\varepsilon$ | | | 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$\delta$ | | | 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)

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

TABLE 1 (CONTINUED)

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

TABLE 1 (CONTINUED)

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

TABLE 1 (CONTINUED)

| | | Identification | | | |
|---|---|---|---|---|---|
| λ [Å] | $W_{eq}$ | Element | Mult. | $\lambda_{lab}$ | Intensity |
| 5700.00 | | | | | |
| 16.51 | 0.007 | FeII | J | 16.58 | 1/2 |
| 48.30 | 0.006 | NeI | 13 | 48.30 | 1 |
| 80.18 | 0.021 | FeII | J | 80.13 | 1 |
| 83.79 | 0.014 | FeII | J | 83.63 | 1 |
| 5800.00 | | | | | |
| 26.30 | 0.020 | FeII | J | 26.11 | 1 |
| | | FeII | J | 26.51 | |
| 52.38 | 0.012 | NeI | 6 | 52.48 | 1 |
| 75.62 | 0.168 | HeI | 11 | 75.62 | 6 |
| | | HeI | 11 | 75.65 | |
| 78.57 | 0.013 | FeII | J | 78.53 | 1 |
| 79.84 | 0.017 | FeII | K09 | 79.79 | 1 |
| 80.80 | 0.013 | FeII | K09 | 80.84 | 1 |
| 81.87 | 0.019 | NeI | 1 | 81.89 | 1 |
| 82.82 | 0.022 | FeII | K09 | 82.78 | 1 |
| 84.99 | 0.034 | FeII | J | 85.02 | 1 |
| 89.95 | 0.013 | NaI | 1 | 89.95 | 1 |
| 91.36 | 0.018 | FeII | J | 91.33 | 1 |
| 95.38 | 0.012 | FeII | J | 95.35 | 2 |
| 97.96 | 0.015 | FeII | J | 98.03 | 1 |
| 98.90 | 0.044 | SiIII | K | 98.79 | 2 |
| 5900.00 | | | | | |
| 01.25 | 0.010 | FeII | J | 01.39 | 2 |
| 02.60 | 0.029 | FeII | J | 02.82 | 1 |
| 11.86 | 0.022 | | | | 1 |
| 14.50 | 0.018 | FeII | J | 14.53 | 1 |
| 21.39 | 0.025 | | | | 1 |
| 27.18 | 0.016 | SII | 21 | 27.15 | 1 |
| 44.41 | 0.028 | FeII | J | 44.38 | 1 |
| 44.89 | 0.026 | NeI | 1 | 44.83 | 1 |
| 48.42 | 0.029 | FeII | J | 48.42 | 1 |
| 55.67 | 0.016 | FeII | J | 55.70 | 1 |
| 57.52 | 0.100 | SiII | 4 | 57.56 | 3 |
| 61.62 | 0.029 | FeII | J | 61.71 | 1 |
| 65.52 | 0.036 | FeII | J | 65.63 | 1 |
| 75.88 | 0.033 | NeI | 1 | 75.53 | 1 |
| | | XeII | NI | 76.46 | |
| 78.97 | 0.048 | SiII | 4 | 78.97 | 2 |
| 83.96 | 0.015 | FeII | J | 83.86 | 1 |
| 6000.00 | | | | | |
| 24.16 | 0.064 | PII | NI | 24.18 | 2 |
| 34.00 | 0.049 | PII | NI | 34.04 | 2 |
| 43.04 | 0.074 | PII | NI | 43.12 | 3 |
| 45.50 | 0.012 | FeII | J | 45.46 | 1 |
| 49.49 | 0.007 | FeII | J | 49.45 | 1/2 |
| 60.93 | 0.021 | FeII | J | 60.99 | 1 |
| 69.63 | 0.006 | FeII | J | 69.67 | 1/2 |
| 71.43 | 0.009 | FeII | J | 71.42 | 1 |
| 74.41 | 0.012 | NeI | 3 | 74.34 | 1 |
| 84.19 | 0.006 | FeII | J | 84.11 | 1/2 |
| 87.76 | 0.030 | PII | NI | 87.82 | 1 |
| 89.76 | 0.004 | CrII | 87 | 89.69 | 1 |
| 96.29 | 0.017 | | | | 1 |
| 6100.00 | | | | | |
| 05.33 | 0.006 | MnII | K | 05.27 | 1/2 |
| 22.55 | 0.032 | MnII | K | 22.45 | 1 |
| 28.91 | 0.023 | MnII | K | 29.04 | 1 |
| 43.01 | 0.021 | NeI | 1 | 43.06 | 1 |
| 47.77 | 0.016 | FeII | J | 47.77 | 1 |
| 49.19 | 0.018 | FeII | J | 49.25 | 1 |
| 56.57 | 0.040 | OI | 10 | 56.78 | 1 |
| | | OI | 10 | 55.99 | |
| 58.18 | 0.031 | OI | 10 | 58.19 | 1 |
| 63.53 | 0.013 | FeII | J | 63.60 | 1 |
| 65.56 | 0.031 | PII | NI | 65.59 | 1 |
| 68.32 | 0.013 | MnII | K | 68.35 | 1 |
| 75.24 | 0.005 | FeII | J | 75.14 | 1/2 |
| | | FeII | J | 75.44 | |
| 79.33 | 0.035 | FeII | J | 79.39 | 1 |
| 6200.00 | | | | | |
| 38.49 | 0.049 | FeII | J | 38.39 | 2 |
| 39.65 | 0.029 | FeII | J | 39.34 | 1 |
| | | FeII | J | 39.90 | |
| 47.42 | 0.053 | FeII | J | 47.37 | 2 |
| 61.75 | 0.003 | FeII | J | 61.72 | 1/2 |
| 66.44 | 0.026 | NeI | 5 | 66.50 | 1 |
| 69.28 | 0.004 | FeII | J | 69.34 | 1/2 |
| 71.27 | 0.014 | FeII | J | 71.21 | 1 |
| 73.63 | 0.005 | FeII | J | 73.59 | 1/2 |
| 82.64 | 0.012 | MnII | K | 82.52 | 1 |
| 94.02 | 0.022 | FeII | J | 94.14 | 1 |
| 6300.00 | | | | | |
| 05.32 | 0.023 | FeII | J | 05.29 | 1 |
| 31.97 | 0.011 | FeII | J | 31.95 | 1 |
| 34.42 | 0.026 | NeI | 1 | 34.43 | 1 |
| 40.23 | 0.010 | FeII | J | 40.24 | 1 |
| 47.09 | 0.151 | SiII | 2 | 47.09 | 6 |
| 49.55 | 0.009 | FeII | J | 49.58 | 1/2 |
| 57.22 | 0.028 | FeII | J | 57.16 | 1 |
| 62.54 | 0.004 | FeII | J | 62.48 | 1/2 |
| 67.34 | 0.009 | FeII | J | 67.41 | 1/2 |
| 71.36 | 0.132 | SiII | 2 | 71.36 | 5 |
| 83.21 | 0.026 | NeI | 3 | 82.99 | 1 |
| 6400.00 | | | | | |
| 02.25 | 0.035 | NeI | 1 | 02.24 | 1 |
| 07.14 | 0.015 | FeII | J | 01.25 | 1 |
| 11.07 | 0.008 | MnII | K | 11.00 | 1/2 |
| 15.57 | 0.014 | FeII | J | 15.56 | 1 |
| 16.92 | 0.021 | FeII | J | 16.92 | 1 |
| 25.75 | 0.014 | FeII | J | 25.74 | 1 |
| 33.43 | 0.025 | | | | 1 |
| 40.44 | 0.005 | FeII | J | 40.48 | 1/2 |
| 46.52 | 0.008 | FeII | J | 46.40 | 1/2 |
| 48.32 | 0.008 | FeII | J | 48.22 | 1/2 |
| 52.92 | 0.009 | MnII | K | 52.88 | 1/2 |
| 55.94 | 0.020 | OI | 9 | 56.01 | 1 |
| 56.38 | 0.046 | FeII | J | 56.38 | 2 |
| 58.62 | 0.013 | MnII | K | 58.56 | 1 |
| 59.93 | 0.031 | PII | K | 59.94 | 1 |
| 62.21 | 0.020 | MnII | 20 | 62.21 | 1 |
| 63.20 | 0.017 | MnII | 20 | 63.20 | 1 |
| 78.12 | 0.020 | FeII | J | 78.14 | 1 |
| 82.30 | 0.044 | FeII | J | 82.20 | 2 |
| 91.61 | 0.051 | TiII | 91 | 91.56 | 1 |
| | | FeII | J | 91.67 | |
| 93.11 | 0.009 | FeII | J | 93.03 | 1 |
| 94.46 | 0.046 | MnII | K | 94.42 | 2 |
| 6500.00 | | | | | |
| 03.13 | 0.045 | | | | 2 |
| 06.40 | 0.025 | NeI | 3 | 06.53 | 1 |
| 10.76 | 0.028 | FeII | J | 10.73 | 1 |
| 31.12 | 0.035 | FeII | J | 31.16 | 1 |
| 41.27 | 0.018 | FeII | J | 41.37 | 1 |
| 42.68 | 0.040 | FeII | J | 42.63 | 2 |
| 55.67 | 0.019 | MnII | K | 55.69 | 1 |
| 62.82 | | Hα | | | 6 |
| 73.54 | 0.037 | FeII | J | 73.49 | 5 |
| 78.03 | 0.033 | CII | 2 | 78.05 | 1 |
| 82.84 | 0.012 | CII | 2 | 82.85 | 1 |
| 85.32 | 0.016 | MnII | K | 85.24 | 1 |
| 98.24 | 0.008 | FeII | J | 98.31 | 1/2 |
| 6600.00 | | | | | |
| 00.81 | 0.009 | | | | 1 |
| 04.30 | 0.006 | FeII | K09 | 04.30 | 1/2 |
| 11.32 | 0.005 | FeII | K09 | 11.40 | 1 |
| 22.04 | 0.014 | FeII | J | 21.98 | 1 |
| 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 |
| $T_{\rm eff}$ | 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.
[a]Castelli et al. (2009) did not observe Ga for this star on optical UVES spectra. Smith & Dworetsky (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_{\rm 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 & Dworetsky (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 distintive 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.

The present work was partially supported through a grant from Consejo Nacional de Investigaciones Científicas y Técnicas de la República Argentina (CONICET PIP 1113). The authors thank the help provided by CASLEO personnel during the observing runs and an anonymous referee for helping to improve the presentation of this paper.

## REFERENCES

Abt, H. A, Levato, H., & Grosso, M. 2002, ApJ, 537, 359
Adelman, S. J. 1974, ApJS, 28,51
Adelman, S. J., Gulliver, A. F., & Rayle, K. E. 2001, A&A, 367, 597
Bidelman, W. P. 1962a, AJ, 67, 111
__________. 1962b, S&T 23, 140
Briquet, M., Korhonen, H., González, J. F., Hubrig, S., & Hackman, T. 2010, A&A, 511, 71
Castelli, F., & Hubrig, S. 2004, A&A, 425, 263
Castelli, F., Kurucz, R., & Hubrig, S. 2009, A&A, 508, 401
Cenarro, A. J., et al. 2007, MNRAS, 374, 664
Cowley, C. R. 1995, in ASP Conf. Ser. 81, Workshop on Laboratory and Astronomical High Resolution Spectra, ed. A. J. Sauval, R. Blomme, & N. Grevesse (San Francisco: ASP), 467
Cowley, C. R., & Adelman, S. J. 1990, PASP, 102, 1077
Feinstein, A. 1967, ApJ, 149, 107
Fernie, J. D. 1983, ApJS, 52, 7
Gulliver, A. F., & Stadel, J. G. 1990, PASP, 102, 587
Guthrie, B. N. G. 1985, MNRAS, 216, 1
Hauck, B., & Mermilliod, M. 1998, A&AS, 129, 431
Heacox, W. D. 1979, ApJS, 41, 675
Houk, N., & Cowley, A. P. 1975, Michigan Catalogue of Two Dimensional Spectral Types for HD Stars, Vol. 1 (Ann Arbor: University of Michigan)
Huldt, S., Johansson, S., Litzen, U., & Wyart, J. F. 1982, Phys. Scr., 25, 401
Iglesias, L., & Velasco, R. 1964, Publ. Inst. Opt. Madrid, No. 23
Johansson, S. 1978, Phys. Scr., 18, 217
Moore, C. E., 1945, A Multiplet Table of Astrophysical Interest (Princeton: Princeton Univ. Obs.)
Morgan, W. W. 1933, ApJ, 77, 330
Nave, G., Johansson, S., Learner, R. C. M., Thorne, A. P., & Brault, J. W. 1994, ApJS, 94, 221
Pintado, O. I., & Adelman, S. J. 2003, A&A, 406, 987
Preston, G. W. 1974, ARA&A, 12, 257
Renson, P., Gerbaldi, M., & Catalano, F. A. 1991, A&AS, 89, 429
Rogers, N. Y. 1995, Comm. Asteroseismol., 78
Sadakane, K., et al. 2001, PASJ, 53, 1223
Shenstone, A. G. 1961, Proc. Roy. Soc. London A, 261, 153
Schneider, H. 1981, Bull. Inf. CDS, 20, 113
Simmons, J., & Levato, H. 1996, Bol. Asoc. Argent. Astron., 40, 44
Smith, K. C., & Dworetsky, M. M. 1993, A&A, 274, 335
Wielen, R., Schwan, H., Dettbarn, C., Lenhardt, H., Jehreiss, H., & Jahrling, R. 1999, Veröff. Astron. Rechen-Inst. Heidelberg, 35, 1

Natalia L. Maza: Instituto de Ciencias Astronómicas, de la Tierra y del Espacio, Av. España 1512 Sur, J5402DSP, San Juan, Argentina (nmaza@icate-conicet.gob.ar).
Hugo Levato: Consejo Nacional de Investigaciones Científicas y Técnicas de la República Argentina (hlevato@icate-conicet.gob.ar).
Zulema López-García: Visiting Astronomer of Instituto de Ciencias Astronómicas, de la Tierra y del Espacio, Av.España 1512 Sur, J5402DSP, San Juan, Argentina (zlgarcia@icate-conicet.gob.ar).