The nature of the late B-type stars HD 67044 and HD 42035

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Abstract While monitoring a sample of apparently slowly rotating superficially normal bright late B and early A stars in the northern hemisphere, we have discovered that HD 67044 and HD 42035, hitherto classified as normal late B-type stars, are actually respectively a new chemically peculiar star and a new spectroscopic binary containing a very slow rotator HD 42035 S with ultra-sharp lines (ve sin i = 3.7 km s−1) and a fast rotator HD 42035 B with broad lines. The lines of Ti II, Cr II, Mn II, Sr II , Y II, Zr II and Ba II are conspicuous features in the high resolution SOPHIE spectrum (R = 75000) of HD 67044. The Hg II line at 3983.93 Å is also present as a weak feature. The composite spectrum of HD 42035 is characterised by very sharp lines formed in HD 42035 S superimposed onto the shallow and broad lines of HD 42035 B. These very sharp lines are mostly due to light elements from C to Ni, the only heavy species definitely present are strontium and barium. Selected lines of 21 chemical elements from He up to Hg have been synthesized using model atmospheres computed with ATLAS9 and the spectrum synthesis code SYNSPEC48 including hyperfine structure of various isotopes when relevant. These synthetic spectra have been adjusted to high resolution high signal-to-noise spectra of HD 67044 and HD 42035 S in order to derive abundances of these key elements. HD 67044 is found to have distinct enhancements of Ti, Cr, Mn, Sr, Y, Zr, Ba and Hg and underabundances in He, C, O, Ca and Sc which shows that this star is not a superficially normal late B-type star, but actually is a new CP star most likely of the HgMn type. HD 42035 S has provisional underabundances of the light elements from C to Ti and overabundances of heavier elements (except for Fe and Sr which are also underabundant) up to barium. These values are lower limits to the actual abundances as we cannot currently place properly the continuum of HD 42035 S. More accurate fundamental parameters and abundances for HD 42035 S and HD 42035 B will be derived if we manage to disentangle their spectra. They will help clarify the status of the two components in this interesting new spectroscopic binary.

Keywords stars: early-type – stars: abundances – stars: chemically peculiar - stars: spectroscopic binary

1 Introduction

We have recently undertaken a spectroscopic survey of all apparently slowly rotating bright early A stars (A0-A1V) and late B stars (B8-B9V) observable from the northern hemisphere. The incentive is to search for rapid rotators seen pole-on or new chemically peculiar B and A stars which have thus far remained unnoticed. This project addresses fundamental questions of the physics of late-B and early-A stars: i) can we find new instances of rapid rotators seen pole-on (other than Vega) and study their physical properties (gradient of temperature across the disk, limb and gravity darkening), ii) is our census of Chemically Peculiar stars complete up to the magnitude limits we adopted? If not, what are the physical properties of the newly found CP stars?. The abundance results for the A0-A1V sample have been published in [Royer et al. (2014)]. The selection criteria were: a declination higher than...
−15°, spectral class A0 or A1 and luminosity class V and IV and magnitudes $V$ brighter than 6.65 and a $v_s \sin i$ less than 65 km s$^{-1}$. The B8-9 sample employs the same criteria, except for the $V$ magnitude brighter than 7.85 as these B stars are intrinsically brighter in the V band where SOPHIE reaches its maximum efficiency. Most of the stars of that B8-9 sample (40 stars) have been observed in December 2014 with SOPHIE, the échelle high-resolution spectrograph at Observatoire de Haute Provence yielding spectra coving the 3900 Å–6800 Å spectral ranger over 39 orders at a resolving power $R = 75000$. A careful abundance analysis of the high resolution high signal-to-noise ratio spectra of the A stars sample has allowed to sort out the sample of 47 A stars into 17 chemically normal stars (i.e. whose abundances do not depart by more than ±0.20 dex from solar values), 12 spectroscopic binaries and 13chemically peculiar stars (CPs) among which five are new CP stars. The status of these new CP stars still needs to be fully specified by spectropolarimetric observations to address their magnetic nature or by exploring new spectral ranges which we had not explored in this first study. Indeed, the abundance analysis of the A stars sample in [Rover et al. 2014] relied only on four spectral regions: 4150–4300 Å, 4400–4790 Å, 4920–5850 Å, and 6000–6275 Å, avoiding Balmer lines and atmospheric telluric lines.

We have now started to examine the B9-B8V sample using the full wavelength coverage provided by SOPHIE to search for new Chemically Peculiar stars. We have already reported on the discovery of 4 new HgMn stars ([Monier et al. 2015]) whose spectra display strong Hg II lines at 3984 Å and strong Mn II lines. These new HgMn stars are HD 18104, HD 30085, HD 32867, HD 53588. In the process of our analysis of the B9-B8V sample, we have just found that HD 67044, currently classified B8 in SIMBAD, is actually another new CP star, most likely another new HgMn star and that HD 42035, classified B9V, actually is a new spectroscopic binary containing a slow rotator which we will refer to as HD 42035 S (S for “sharp” lines) and a fast rotator, HD 42035 B (B for ”broad” lines). A bibliographic query of the CDS for HD 67044 and HD 42035 actually reveals only 4 and 26 publications respectively. Neither HD 67044 nor HD 42035 appear in [Cowley's classification (1972)] of the bright B8 stars. The purpose of this paper is to report on the detection of strong Ti II, Cr II, Mn II, Sr II, Y II, Zr II, Ba II lines and a weak Hg II line in the spectrum of HD 67044 and perform a line identification of all the very sharp lines of HD 42035 S. We also have determined the abundances of 17 chemical elements for HD 67044 using spectrum synthesis to quantify the enhancements and depletions of these elements. As several of the lines of HD 42035 S are blended with those of HD 42035 B, we have only been able to derive provisional abundances for HD 42035 S using lines little affected by the fast rotator.

2 Observations and reduction

HD 67044 and HD 42035 have been observed at Observatoire de Haute Provence using the high resolution ($R = 75000$) mode of the SOPHIE échelle spectrograph [Perruchot et al. 2008] in December 2014. The $\frac{S}{N}$ ratio of the spectra are about 130 and 174 at 5500 Å respectively. The observations log is displayed in Table 1. The data are automatically reduced to produce 1D extracted and wavelength calibrated échelle orders. Each reduced order was normalised separately using a Chebychev polynomial fit with sigma clipping, rejecting points above or below 1 $\sigma$ of the local continuum. Normalized orders were merged together, corrected by the blaze function and resampled into a constant wavelength step of about 0.02 Å (see [Rover et al. 2014] for more details).

The radial velocities of HD 67044 and HD 42035 were derived from cross-correlation techniques, avoiding the Balmer lines and the atmospheric telluric lines. The normalized spectrum was cross-correlated with a synthetic template extracted from the POLLUX database [Palacios et al. 2010] corresponding to the parameters $T_{\text{eff}} = 11000$ K, log $g = 4$ and solar abundances. A parabolic fit of the upper part of the resulting cross-correlation function yields the Doppler shift, which is then used to shift spectra to rest wavelengths. The radial velocities of HD 67044 and HD 42035 are collected in Table 2.

3 The line spectrum of HD 67044

Several spectral regions have been used to establish the chemical peculiarity of HD 67044. First, the red wing of H$_\alpha$, which lies in order 3, harbors the Hg II $\lambda$ 3983.93 Å line and several Zr II and Y II lines likely to be strengthened in CP stars. After proper correction for the stellar radial velocity, we found that HD 67044 does show the Hg II $\lambda$ 3983.93 Å line as a feature absorbing about 2%, and also strong lines of Y II at 3982.59 Å and of Zr II at 3991.13 Å and 3998.97 Å. The Y II, Zr II and Hg II lines in the spectral range 3980 to 4000 Å are displayed in figure 1 together with the synthetic spectrum fitting best this spectral interval. Several other lines of Y II

http://pollux.graal.univ-montp2.fr
and Zr II are strong absorbers in the spectrum of HD 67044 and have been used to derive the abundances in these elements. Second, we examined the region from 4125 Å to 4145 Å (order 6) for the Si II lines at 4128.054 Å and 4130.894 Å and the Mn II line at 4136.92 Å. In an HgMn star, the Mn II line at 4136.92 Å should be strong whereas it should be absent in any comparison normal late B-type star. Furthermore, the lines of Mn II at 4206.37 Å and 4252.96 Å should also be enhanced in the spectra of HgMn stars (Gray & Corbally 2002). These three Mn II lines correspond to moderately strong features in HD 67044, they usually are broad lines absorbing 5% of the local continuum. Several other strong Mn II lines could be found and have been used to derive the abundance of manganese.

We find that the strongest expected lines of Ti II, Cr II, Mn II Sr II, Y II, Zr II, Ba II are all indeed strong features in the spectrum of HD 67044. In Table 3, we give a list of the strongest unblended lines of these species together with abundance determinations.

The presence of the Hg II 3983.93 Å line and of several strong Mn II and Sr II, Y II and Zr II lines led us to conclude that HD 67044 is actually another new HgMn star and should be reclassified as such. The abundance determinations presented in next paragraph do confirm this proposal.

### Table 1 Observation log

| Star ID | Spectral Type | V | Observation Date | Exposure Time (s) | S/N |
|---------|---------------|---|------------------|-------------------|-----|
| HD 67044 | B9V           | 7.48 | 2014-12-16       | 2169              | 130 |
| HD 42035 | B9V           | 6.55 | 2014-12-18       | 750               | 174 |

### 4 The line spectrum of HD 42035

The high resolution spectrum of HD 42035 is characterised by very sharp lines originating in HD 42035 S. A first estimate of the projected equatorial rotational velocity of HD 42035 S has been obtained by Fourier transform analysis (Fig. 2), using the two Fe II lines at 4508.29 and 4515.34 Å. From the position of the first zero of the Fourier transform, we derived a value of $v_\text{e} \sin i = 3.7 \pm 0.2$ km s$^{-1}$. A close inspection of the spectral region around the Mg II triplet at 4481 Å reveals that the spectrum of HD 42035 is actually a composite spectrum containing shallow and broad lines coming from HD 42035 B onto which are superimposed redshifted very sharp lines coming from HD 42035 S. In the SOPHIE spectrum of HD 42035 obtained in December 2014, the sharp lines of the Mg II triplet are displaced, after correction for the barycentric velocity of the Earth, by about +53.0 km s$^{-1}$ with respect to their laboratory positions. A comparison in figure 3 of our SOPHIE spectrum of HD 42035 with an archival ELODIE spectrum (R=42000) obtained in December 2000 (also corrected for barycentric velocity of the Earth) reveals large radial velocity variations of the sharp lines of the Mg II triplet and possibly a change of the asymmetry of the broad and shallow Mg II line formed in HD 42035 B. Indeed the shallow line had an extended blue wing in December 2014 whereas it had an extended red wing in December 2000. Recent spectroscopy obtained at DAO by E. Griffin confirms large radial velocity variations of the sharp lines and support the binary nature of this star. The composite nature of the spectrum is seen in many features, we show in figure 4 the region of Multiplet 7 of O I.

We have measured the centroids of all sharp lines of HD 42035 S absorbing more than 2% of the normalized flux by adjusting gaussians. This yields wavelengths accurate to ±0.02 Å. Seven hundred and thirteen line centers were thus measured. In order to identify these lines, a model atmosphere was computed using ATLAS9 (Kurucz 1992) with 72 layers for the effective temperature and surface gravity of HD 42035 (see par. 5.1) and a solar composition. A synthetic spectrum was then computed using SYNSPEC48 (Hubeny & Lanz, 1992) over the entire range 3900 Å to 6800 Å for solar abundances and a microturbulent velocity 0.0 km s$^{-1}$. It was further convolved with the ROTIN3 routine (provided with SYNSPEC48) for the FWHM of SOPHIE and the $v_\text{e} \sin i$ of HD 42035 S. We found that the following species are definitely present in HD 42035 S: He I, C I, C II, Mg II, N I, O I, Na I, Mg I, Mg II, Al I, Al II, Si I, Si II, S II, Ca I, Ca II, Sc I, Sc II, Ti II, V II, Cr I, Cr II, Mn II, Fe I, Fe II, Co II, Sr II and Ba II.
Fourier transforms of the Fe II lines at 4508.29 and 4515.34 Å (solid lines) and of a synthetic profile with a $v_t \sin i = 3.7$ km s$^{-1}$ at a spectral resolution of 75000. On the velocity displayed on the x-axis, the position of the first zero yields the projected equatorial rotational velocity.

Fig. 3 Comparison of the composite Mg II triplet profile of HD 42035 taken 14 years apart: SOPHIE spectrum (solid line) and archival ELODIE spectrum (dashed line). The vertical lines depict the laboratory wavelengths of the Mg II triplet.

(see Table 5). In contrast, the following elements have very few lines identified and therefore their presence is not confirmed: P II (only one line) and Nd II (only one line). We note the absence of Y II lines and that of lines of Hg II and Pt II characteristic of HgMn stars. Also the lines of Zr II are weak and we could only use one unblended line, $\lambda$ 4443.008 Å to derive the zirconium abundance. A few sharp lines have triangular profiles, they all can be identified as Fe II lines

In Table 5, we have indicated as “broad” and sometimes “asymmetric” the lines which show a broad shallow component originating in HD 42035 B which can sometimes show an asymmetry. These broad and shallow lines are due to N I, O I, Mg II, Si II, Ti II and Fe II. From these identifications, we can infer that HD 42035 B probably has an effective temperature which cannot differ much from that of HD 42035 S. A rough estimate of its projected rotational equatorial velocity has been obtained by adjusting the broad component of the composite Mg II triplet profile at 4481 Å with a model of effective temperature $10740$ K, log $g = 3.80$, solar metallicity and yields $v_t \sin i$ about $150 \pm 25$ km s$^{-1}$.

5 Abundance determinations

5.1 Fundamental parameters determinations

For HD 67044, we have adopted the effective temperature $T_{\text{eff}} = 10519$ K and surface gravity log $g = 3.72$ derived by Huang et al. (2010) from fitting the Hγ profiles to prediction of model atmospheres. Indeed HD 67044 does not have Strömgren’s photometry which precludes applying Napiwotzky’s UVBYBETA procedure to derive its fundamental parameters. A spectrum synthesis of the Hγ profile was run to confirm these parameters. For HD 42035, the effective temperature, $T_{\text{eff}} = 10740$ K, and surface gravity, log $g = 3.80$, were also taken from Huang et al. (2010). Applying Napiwotzky’s procedure to the Strömgren’s photometry of
HD 42035 yields very similar fundamental parameters. The effective temperature obtained in this manner is probably a complex mean of the individual effective temperatures of HD 42035 S and HD 42035 B as the Strömgren’s photometry most likely measured the combination of the lights of both stars. The adopted effective temperatures, surface gravities, projected equatorial velocities and radial velocities of HD 67044 and HD 42035 S are collected in Table 2.

5.2 Model atmospheres and spectrum synthesis calculations

Plane parallel model atmospheres assuming radiative equilibrium and hydrostatic equilibrium were computed using the ATLAS9 code (Kurucz 1992). The linelist was built from Kurucz (1992) gfall18sep15.dat and its revision gfall18sep15.dat which includes hyperfine splitting levels. A grid of synthetic spectra was computed with SYNSPEC48 (Hubeny & Lanz 1992) to model the lines of He I, C II, O I, Mg II, Al I and Al II, Si II, Ca II, Sc II, Ti II, Cr II, Mn II, Fe II, Sr II, Y II, Zr II, Ba II and Hg II lines. Computations were iterated varying the unknown abundance until minimization of the chi-square between the observed and synthetic spectrum was achieved. The microturbulent velocity was first assumed to be 1.5 km s\(^{-1}\) (in agreement with the run of \(v_{\text{micr}}\) with \(T_{\text{eff}}\) we established in Gebran et al. (2014)).

The synthesis of the Fe II lines of various strengths how- ever imposed a lower \(v_{\text{micr}} = 0\) km s\(^{-1}\) for HD 67044 typical of an HgMn star. A null microturbulent velocity was also finally adopted for HD 42035 S after unsuccessful attempts to model the Fe II lines with higher velocities.

5.3 The derived abundances of HD 67044

We have used only unblended lines to derive the abundances. There are actually few unblended lines as the projected equatorial velocity of HD 67044 broadens significantly the lines. For a given element, the final abundance is a weighted mean of the abundances derived for each transition. These final abundances and their estimated uncertainties for HD 67044 are collected in Table 3 (the determination of the uncertainties is discussed in Royer et al. 2014). Table 3 contains for each analysed species the adopted laboratory wavelength, logarithm of oscillator strength, its source, the logarithm of the absolute abundance normalised to that of hydrogen (on a scale where \(\log(N_H) = 12\)) for each transition, and the final abundance and estimated uncertainty. In this work, we adopted Asplund et al. (2009) abundances for the Sun as a reference.

The iron abundance, which is found to be about solar in HD 67044, has been derived mostly by using several Fe II lines of multiplets 37, 38 and 186 in the range 4500–4600 Å whose atomic parameters are critically assessed in NIST\(^3\) (these are C+ and D quality lines). These lines are widely spaced and the continuum is fairly easy to trace in this spectral region. Their synthesis always yields consistent iron abundances from the various transitions with very little dispersion. The iron abundance is probably the most accurately determined of the abundances derived here. The NLTE abundance correction for the \(\lambda 4471.48\) Å He I line is very small as shown by Lenk (1983) for early A-type stars and we have not corrected for it. We find that the following species are underabundant: He, C, O, Si, Ca, Sc while Mg, V, Fe and Ni show mild enhancements (less than 5 times solar) and Ti, Cr, Mn, Sr, Y, Zr, Ba and Hg show pronounced overabundances (larger than 5 times solar), the largest overabundance being for Hg. The Sr-Y-Zr triad is inverted, yttrium being more abundant than strontium and zirconium. The general trend is that the heaviest elements are the most overabundant.

5.4 The provisional abundances for HD 42035 S

Assuming an effective temperature of 10740 K, \(\log g = 3.80\) and a solar composition, for HD 42035 S, we have derived provisional abundances for HD 42035 S which are collected in Table 4. The effective temperature of HD 42035 S is probably different from this mean value so that the derived abundances are rough estimates only. Furthermore, placing a continuum level in the composite spectrum of HD 42035 turned out to be difficult because of the presence of the rotationally broadened lines and of the continuum of HD 42035 B. The provisional abundances we derive here are therefore affected by systematic errors due to (at least) the possibility of an improper placement of the continuum (too low compared to what it actually is). As a consequence, the residual fluxes \(\Delta F_c\) are likely to be too large, placing the continuum higher would decrease these residual fluxes.

Table 2  Fundamental parameters

| Star ID  | \(T_{\text{eff}}\) | \(\log g\) | \(v\sin i\) | \(V_{\text{rad}}\) |
|----------|-----------------|---------|------------|----------|
|          |                 |         | (km s\(^{-1}\)) | (km s\(^{-1}\)) |
| HD 67044 | 10519           | 3.72    | 45.0       | 14.50    |
| HD 42035 S | 10740          | 3.80    | 3.7        | 53.00    |

\(^3\)http://kurucz.harvard.edu/linelists/gfnw/gfall28sep15.dat

\(^4\)http://ww.nist.gov
and therefore lead to higher abundances. We therefore consider that the provisional abundances derived here are lower limits. The actual abundances of HD 42035 S must be larger than these lower limits. To minimize this effect we chose to synthesize sharp lines which were as little as possible blended with the broad lines of HD 42035 B. Realistic abundances will only be derived if we manage to disentangle the spectrum of HD 42035 S from that of HD 42035 B.

We find that the light elements up to Z=21, C, O, Mg, Al, Si, S, Ca and Sc are all underabundant. The scandium deficiency is large (about 4% of the solar scandium abundance). The elements heavier than Z=21 are overabundant except for Ti, Fe and Sr which are underabundant. The zirconium overabundance has been derived from only one unblended line and thus should be taken with caution. The absence of detection of the two strongest Y II lines at 3982.60 Å and 5662.92 Å implies that yttrium must be solar or underabundant.

6 Conclusions

We find that HD 67044, hitherto classified a normal B8 star, displays underabundances of He, C, O, Si, Ca and Sc, mild overabundances of Mg, V, Fe and Ni and pronounced enhancements of Ti, Cr, Mn, Sr, Y, Zr, Ba and Hg. We therefore propose that HD 67044 actually is a new HgMn star and should be reclassified as such. Current monitoring of HD 67044 suggests that the Hg II line at 3983.93 Å is probably variable. One possible interpretation is that HD 67044 has one or several spots of overabundant Hg over its surface. More observations are planned to address this issue.

The high resolution spectrum of HD 42035 appears to be a composite spectrum where redshifted very sharp lines originating from HD 42035 S are overimposed onto the broad shallow lines originating from HD 42035 B. The presence of a very slow rotator and a fairly fast rotator inside the same system suggests that the semi-axis of the orbit must be large. A FT analysis of the sharp lines of HD 42035 S yields a very low projected equatorial velocity \( v_e \sin i = 3.7 \text{ km s}^{-1} \) which makes this star one of the very few late-B type slow rotators. The identification of 713 very sharp lines reveals that most of the lines are due to elements up to Nickel. Strontium and Barium are also present. Assuming a similar effective temperature and surface gravity for HD 42035 S and HD 42035 B, we have derived provisional abundances for HD 42035 S. Light elements up to Z=22 appear to be underabundant in HD 42035 S whereas heavier elements are overabundant with the exception of Fe and Sr. These preliminary abundances are lower limits of the actual abundances of HD 42035 S because we are probably placing the continuum too low. A complete follow-up of this new spectroscopic binary will hopefully enable a proper disentangling of the spectra of HD 42035 S and HD 42035 B and help characterize fully the nature of each of these components, in particular the nature and abundance pattern of HD 42035 S.

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Table 3: Elemental Abundances for HD67044. References are MA60 for Martin (1960), DR2006 for Drake (2006), NS81 for Nussbaumer & Storey (1981), KZ91 for Butler, K. & Zeippen, C. J. (1991), W96 for Wiese et al. (1996), HBGV91 for Hibbert et al. (1991), Si98 for Siegel et al. (1998), K79 for Kaufman & Hagan (1979), H99 for Hannaford (1999), Ma01 for Matheron et al. (2001), Sh61 for Shenstone (1961), LD99 for Lawler & Dakin (1999), FMW for Fuhr et al. (1988), PTP for Pickering et al. (2002), SN14 for Sansonetti & Nave (2014), NJ13 for Nave & Johansson (2013), T89 for Theodosiou (1989), RU98 for Raassen & Uylings (1998), PBL95 for Pinnington et al. (1995), NBS for Miles & Wiese (1969), KO83 for Kostyk & Orlov (1983), Bie11 for Biémont et al. (2011), L06 for Lüngh et al. (2006), MCS75 for Meggers et al. (1975), BL48 for Biemont et al. (1981), KL01 for Kling et al. (2001), DSVD92 for Davidson et al. (1992), SR01 for Sansonetti & Reader (2001), Do03 for Dolk et al. (2003), NIST for the online database (http://physics.nist.gov/PhysRefData/ASD/), and Kurucz (http://kurucz.harvard.edu/linelists/gfhyperall/) for the gfhyperall.dat linelist.

| Element | λ (Å) | log(gf) | Ref.       | log(X/H) |
|---------|-------|---------|------------|----------|
| He I    | 4471.470 | -2.211  | Ma60/DR2006 | -1.17    |
| He I    | 4471.474 | -0.287  | Ma60/DR2006 | -1.17    |
| He I    | 4471.485 | -1.035  | Ma60/DR2006 | -1.17    |
| He I    | 4471.683 | -0.339  | Ma60/DR2006 | -1.17    |
| He I    | 5875.598 | -0.584  | NS81       | -4.06    |
| C II    | 4267.001 | 0.563   | NS81       | -4.10    |
| C II    | 4267.261 | 0.716   | NS81       | -4.10    |
| O I     | 6155.759 | -1.516  | Ma60/DR2006 | -1.13    |
| O I     | 6155.613 | -0.339  | Ma60/DR2006 | -1.13    |
| O I     | 6155.615 | 0.409   | Ma60/DR2006 | -1.13    |
| O I     | 6155.625 | -0.339  | Ma60/DR2006 | -1.13    |
| O I     | 6155.640 | 0.138   | Ma60/DR2006 | -1.13    |
| O I     | 6155.966 | -0.214  | Ma60/DR2006 | -1.15    |
| Mg II   | 4390.572 | -0.523  | Si98       | -4.25    |
| Mg II   | 4427.994 | -1.208  | Si98       | -4.29    |
| Mg II   | 4481.126 | 0.749   | BL48       | -4.27    |
| Mg II   | 4481.150 | -0.553  | BL48       | -4.27    |
| Mg II   | 4481.325 | 0.594   | BL48       | -4.27    |
| Al I    | 4663.056 | -0.244  | K79        | -5.56    |
| Al I    | 3944.006 | -0.635  | H99        | -5.60    |

\[ \frac{\text{He}}{\text{H}} = -0.15 \pm 0.15 \text{ dex} \]

\[ \frac{\text{C}}{\text{H}} = -0.60 \pm 0.15 \text{ dex} \]

\[ \frac{\text{O}}{\text{H}} = -0.22 \pm 0.20 \text{ dex} \]

\[ \frac{\text{Mg}}{\text{H}} = 0.15 \pm 0.18 \text{ dex} \]

\[ \frac{\text{Al}}{\text{H}} = 0.15 \pm 0.18 \text{ dex} \]
| Element | \( \lambda \) (Å) | \( \log gf \) | Ref. | \( \log(X/H)_* \) |
|---------|----------------|------------|------|----------------|
| Si II   | 4128.054       | 0.359      | Ma01 | -4.52          |
| Si II   | 4130.894       | 0.552      | Ma01 | -4.56          |
| Si II   | 4190.72        | -0.351     | Sh61 | -4.54          |
| Si II   | 5041.024       | 0.029      | Ma01 | -4.56          |
| Si II   | 5055.984       | 0.523      | Ma01 | -4.54          |
| Si II   | 5056.317       | -0.492     | Ma01 | -4.52          |
| Si II   | 6347.11        | 0.149      | Ma01 | -4.54          |
| Si II   | 6371.37        | -0.082     | Ma01 | -4.56          |
| Ca II   | 3933.663       | 0.135      | NIST/T89 | -6.02    |
| Ca II   | 5019.971       | -0.28      | NIST/T89 | -6.06    |
| Sc II   | 4246.822       | 0.242      | LD89 | -9.05          |
| Sc II   | 4670.407       | -0.580     | LD89 | -9.09          |
| Sc II   | 5031.021       | -0.400     | LD89 | -9.07          |
| Sc II   | 5526.813       | -0.77      | LD89 | -9.07          |
| Ti II   | 4163.644       | -0.128     | PTP  | -5.97          |
| Ti II   | 4287.873       | -2.020     | PTP  | -6.01          |
| Ti II   | 4290.210       | -0.848     | PTP  | -5.99          |
| Ti II   | 4294.090       | -1.100     | PTP  | -5.96          |
| Ti II   | 4300.042       | -0.442     | PTP  | -5.97          |
| Ti II   | 4411.072       | -0.6767    | PTP  | -6.01          |
| Ti II   | 4468.492       | -0.620     | FMW  | -5.99          |
| Ti II   | 4549.622       | -0.105     | PTP  | -5.97          |
| Ti II   | 4563.758       | -0.96      | Kurucz | -5.99    |
| Ti II   | 5129.156       | -1.239     | KO83 | -5.97          |
| Ti II   | 5188.687       | -1.220     | PTP  | -6.00          |
| Ti II   | 5336.780       | -1.700     | PTP  | -6.01          |
| Cr II   | 4558.644       | -0.660     | SN14 | -5.39          |
| Cr II   | 4558.787       | -2.460     | SN14 | -5.39          |
| Cr II   | 5237.322       | -1.160     | SN14 | -5.43          |
| Cr II   | 5308.421       | -1.810     | SN14 | -5.39          |
| Cr II   | 5313.581       | -1.650     | SN14 | -5.41          |
| Cr II   | 5502.086       | -1.990     | SN14 | -5.43          |
| Mn II   | 4206.368       | -1.54      | KL01 | -5.59          |
| Mn II   | 4259.19        | -1.44      | KL01 | -5.63          |
| Fe II   | 4233.162       | -1.810     | NJ13 | -4.34          |
| Fe II   | 4258.148       | -3.500     | NJ13 | -4.30          |
| Fe II   | 4273.326       | -3.350     | NJ13 | -4.32          |
| Fe II   | 4296.566       | -2.900     | NJ13 | -4.30          |
| Element | λ (Å) | log g f | Ref. | log(X/H) |
|---------|-------|---------|------|---------|
| Fe II   | 4491.397 | -2.640  | NJ13 | -4.34   |
| Fe II   | 4508.280  | -2.300  | NJ13 | -4.32   |
| Fe II   | 4515.333  | -2.360  | NJ13/RU98 | -4.34 |
| Fe II   | 4520.218  | -2.600  | NJ13/RU98 | -4.32 |
| Fe II   | 4522.628  | -1.990  | NJ13/RU98 | -4.34 |
| Fe II   | 4549.195  | -1.770  | NJ13/RU98 | -4.30 |
| Fe II   | 4549.466  | -1.730  | NJ13/RU98 | -4.30 |
| Fe II   | 4555.888  | -2.250  | NJ13/RU98 | -4.32 |
| Fe II   | 4923.921  | -1.210  | NJ13 | -4.34   |
| Fe II   | 5275.997  | -1.900  | NJ13 | -4.30   |
| Fe II   | 5316.609  | -1.780  | NJ13/RU98 | -4.32 |
| Fe II   | 5506.199  | 0.860   | NJ13 | -4.30   |

\[
\left[ \frac{Fe}{H} \right] = 0.18 \pm 0.18 \text{ dex}
\]

| Sr II   | 4215.519 | -0.173 | PBL95 | -7.67   |

\[
\left[ \frac{Sr}{H} \right] = 1.40 \pm 0.25 \text{ dex}
\]

| Y II    | 3982.592 | -0.560 | Bie11 | -6.71   |
| Y II    | 5662.922 | 0.340  | Bie11 | -6.75   |

\[
\left[ \frac{Y}{H} \right] = 3.05 \pm 0.25 \text{ dex}
\]

| Zr II   | 3991.127 | -0.310 | L06   | -7.11   |
| Zr II   | 3998.965 | -0.520 | L06   | -7.09   |
| Zr II   | 4442.992 | -0.420 | L06   | -7.07   |
| Zr II   | 4457.431 | -1.220 | L06   | -7.09   |
| Zr II   | 4496.962 | -0.890 | L06   | -7.07   |
| Zr II   | 5112.270 | -0.850 | L06   | -7.11   |

\[
\left[ \frac{Zr}{H} \right] = 2.30 \pm 0.25 \text{ dex}
\]

| Ba II   | 4934.077 | -0.156 | NBS   | -7.63   |
| Ba II   | 6141.713 | -0.032 | DSVD92 | -7.59  |

\[
\left[ \frac{Ba}{H} \right] = 2.18 \pm 0.25 \text{ dex}
\]

| Hg II   | 3983.931 | -1.510 | SR01/Do03 | -7.21  |

\[
\left[ \frac{Hg}{H} \right] = 3.70 \pm 0.25 \text{ dex}
\]
### Table 4  Provisional Elemental Abundances for HD42035 S

| Element | $\lambda$ (Å) | log $gf$ | Ref. | log($X/H$) |
|---------|---------------|--------|------|-----------|
| C II    | 4267.001     | 0.563  | NS81 | -3.63     |
| C II    | 4267.261     | 0.716  | NS81 | -3.63     |
| C II    | 4267.261     | -0.584 | NIST | -3.63     |

$[\text{C}] / H = -0.15 \pm 0.15$ dex

| Element | $\lambda$ (Å) | log $gf$ | Ref. | log($X/H$) |
|---------|---------------|--------|------|-----------|
| O I     | 6155.961     | -1.363 | HBGV91 | -3.47     |
| O I     | 6155.971     | -1.011 | HBGV91 | -3.47     |
| O I     | 6155.989     | -1.120 | HBGV91 | -3.47     |
| O I     | 6156.737     | -1.487 | HBGV91 | -3.47     |
| O I     | 6156.755     | -0.898 | HBGV91 | -3.47     |
| O I     | 6156.778     | -0.694 | HBGV91 | -3.47     |
| O I     | 6158.149     | -1.841 | HBGV91 | -3.47     |
| O I     | 6158.172     | -0.995 | HBGV91 | -3.47     |
| O I     | 6158.187     | -0.409 | HBGV91 | -3.47     |

$[\text{O}] / H = -0.30 \pm 0.20$ dex

| Element | $\lambda$ (Å) | log $gf$ | Ref. | log($X/H$) |
|---------|---------------|--------|------|-----------|
| Mg II   | 4390.572     | -0.530 | Si98 | -4.94     |
| Mg II   | 4427.994     | -1.201 | Si98 | -4.94     |
| Mg II   | 4481.126     | 0.730  | BL48 | -4.94     |
| Mg II   | 4481.150     | -0.570 | BL48 | -4.94     |
| Mg II   | 4481.325     | 0.575  | BL48 | -4.94     |

$[\text{Mg}] / H = -0.52 \pm 0.18$ dex

| Element | $\lambda$ (Å) | log $gf$ | Ref. | log($X/H$) |
|---------|---------------|--------|------|-----------|
| Al II   | 5593.27      | +0.41  | K79  | -5.83     |
| Al II   | 6243.40      | +0.67  | K79  | -5.83     |

$[\text{Al}] / H = -0.30 \pm 0.20$ dex

| Element | $\lambda$ (Å) | log $gf$ | Ref. | log($X/H$) |
|---------|---------------|--------|------|-----------|
| Si II   | 4128.054     | 0.306  | Ma01 | -5.05     |
| Si II   | 4130.88      | 0.464  | Ma01 | -5.05     |
| Si II   | 4190.72      | -0.351 | Sh61 | -4.85     |
| Si II   | 5041.024     | 0.174  | Ma01 | -4.80     |
| Si II   | 5055.984     | 0.441  | Ma01 | -4.85     |
| Si II   | 5056.317     | -0.535 | Ma01 | -4.75     |
| Si II   | 6347.11      | 0.230  | Ma01 | -4.85     |
| Si II   | 6371.37      | -0.080 | Ma01 | -4.85     |

$[\text{Si}] / H = -0.43 \pm 0.18$ dex

| Element | $\lambda$ (Å) | log $gf$ | Ref. | log($X/H$) |
|---------|---------------|--------|------|-----------|
| S II    | 4162.665     | 0.830  | Kurucz | -4.97 |

$[\text{S}] / H = -0.30 \pm 0.20$ dex

| Element | $\lambda$ (Å) | log $gf$ | Ref. | log($X/H$) |
|---------|---------------|--------|------|-----------|
| Ca II   | 3933.663     | -0.135 | NIST/T89 | -5.94 |
| Ca II   | 5019.971     | -0.257 | NIST/T89 | -5.94 |

$[\text{Ca}] / H = -0.30 \pm 0.20$ dex

| Element | $\lambda$ (Å) | log $gf$ | Ref. | log($X/H$) |
|---------|---------------|--------|------|-----------|
| Sc II   | 4246.86      | 0.242  | LD89 | -10.23     |
| Sc II   | 4314.06      | -0.10  | LD89 | -10.23     |
| Sc II   | 4400.38      | -0.51  | LD89 | -10.23     |
| Sc II   | 5031.021     | -0.400 | LD89 | -10.23     |

$[\text{Sc}] / H = -1.40 \pm 0.18$ dex

| Element | $\lambda$ (Å) | log $gf$ | Ref. | log($X/H$) |
|---------|---------------|--------|------|-----------|
| Ti II   | 4163.644     | -0.130 | PTP  | -7.20     |
| Ti II   | 4287.873     | -1.790 | PTP  | -7.20     |
| Ti II   | 4290.210     | -0.850 | PTP  | -7.28     |
Table 4—Continued

| Element | \(\lambda\) (Å) | log\(gf\) | Ref. | log(\(X/H\))_* |
|---------|-----------------|------------|------|-----------------|
| Ti II   | 4300.042        | -0.440     | PTP  | -7.20           |
| Ti II   | 4411.072        | -0.670     | PTP  | -6.98           |
| Ti II   | 4549.62         | -0.470     | PTP  | -7.20           |
| Ti II   | 4563.77         | -0.960     | Kurucz | -7.20      |
| Ti II   | 5129.156        | -1.400     | KO83  | -7.20          |
| Ti II   | 5188.687        | -1.050     | PTP  | -7.28           |
| V II    | 4005.706        | -0.460     | Kurucz | -7.30      |
| V II    | 4023.360        | -0.880     | Kurucz | -7.30      |
| V II    | 4035.610        | -0.960     | Kurucz | -7.30      |
| Cr II   | 4558.650        | -0.660     | SN14  | -5.93           |
| Cr II   | 4558.78         | -2.460     | SN14  | -5.93           |
| Cr II   | 5237.329        | -1.160     | SN14  | -6.02           |
| Cr II   | 5308.440        | -1.810     | SN14  | -6.02           |
| Cr II   | 5502.067        | -1.990     | SN14  | -6.02           |
| Mn II   | 4206.368        | -1.566     | KL01  | -5.77           |
| Mn II   | 4259.19         | -1.589     | KL01  | -5.77           |
| Fe II   | 4233.172        | -2.000     | NJ13  | -5.50           |
| Fe II   | 4258.154        | -3.400     | NJ13  | -4.90           |
| Fe II   | 4273.326        | -3.258     | NJ13  | -4.80           |
| Fe II   | 4296.570        | -3.010     | NJ13  | -4.90           |
| Fe II   | 4491.405        | -2.690     | NJ13  | -5.32           |
| Fe II   | 4508.281        | -2.210     | NJ13  | -5.32           |
| Fe II   | 4515.334        | -2.490     | NJ13/RU98 | -5.20  |
| Fe II   | 4520.221        | -2.600     | NJ13/RU98 | -5.20  |
| Fe II   | 4522.628        | -2.030     | NJ13/RU98 | -5.50  |
| Fe II   | 4549.197        | -1.870     | NJ13/RU98 | -4.50  |
| Fe II   | 4549.467        | -1.750     | NJ13/RU98 | -5.50  |
| Fe II   | 4555.888        | -2.290     | NJ13/RU98 | -5.20  |
| Fe II   | 4923.927        | -1.320     | NJ13  | -5.32           |
| Fe II   | 5276.002        | -1.940     | NJ13  | -5.20           |
| Fe II   | 5316.615        | -1.850     | NJ13/RU98 | -5.20  |
| Fe II   | 5506.195        | 0.950      | NJ13  | -5.02           |
| Ni II   | 5058.38         | +0.85      | Kurucz | -4.75      |
| Ni II   | 5059.17         | +0.54      | Kurucz | -4.75      |
| Sr II   | 4077.709        | 0.148      | PBL95  | -0.93          |
| Sr II   | 4215.520        | -0.173     | PBL95  | -0.93          |
| Y II    | 5662.93         | 0.16       | MCS75  | -9.78          |
| \(\frac{[Fe/H]}{[H]}\) | = -0.66 ± 0.18 dex |
| \(\frac{[Ni/H]}{[H]}\) | = 1.00 ± 0.25 dex |
| \(\frac{[Sr/H]}{[H]}\) | = -0.46 ± 0.25 dex |
| \(\frac{[Y/H]}{[H]}\) | = 0.00 ± 0.25 dex |
| Element | $\lambda$ (Å) | log $gf$ | Ref. | log($X/H$)$_*^*$ |
|---------|---------------|---------|------|------------------|
| Zr II   | 4443.008      | -0.330  | L06  | -8.69            |
|         |                |         |      |                  |
|         | $[\text{Zr}\ H] = 0.70 \pm 0.25$ dex |
| Ba II   | 4554.029      | +0.170  | NBS  | -9.31            |
| Ba II   | 4934.076      | -0.156  | NBS  | -9.31            |
| Ba II   | 6496.897      | -0.380  | DSVD92 | -9.31          |
|         | $[\text{Ba}\ H] = 0.48 \pm 0.25$ dex |
| Corr. λ (Å) | Lab. λ (Å) | Ident. | $E_{\text{low}}$ (cm$^{-1}$) | log($gf$) | Rem. |
|-------------|------------|--------|------------------|--------|-----|
| 3900.54     | 3900.550   | Ti II  | 9118.260         | -0.45  |     |
| 3902.95     | 3902.945   | Fe I   | 12560.933        | -0.47  |     |
| 3903.26     | 3903.268   | V II   | 11908.270        | -0.89  |     |
| 3903.74     | 3903.756   | Fe II  | 60807.228        | -1.49  |     |
| 3905.52     | 3905.525   | Si I   | 15394.369        | -1.09  |     |
| 3905.64     | 3905.644   | Cr II  | 42986.619        | -0.90  |     |
| 3906.03     | 3906.035   | Fe I   | 44929.549        | -1.83  |     |
| 3913.46     | 3913.468   | Ti II  | 8997.710         | -0.53  |     |
| 3914.50     | 3914.503   | Fe II  | 13474.411        | -4.05  |     |
| 3918.52     | 3918.528   | Fe II  | 47674.718        | -2.10  |     |
| 3918.95     | 3918.965   | C II   | 131724.372       | -0.51  |     |
| 3920.63     | 3920.635   | Fe II  | 60625.451        | -1.20  |     |
| 3921.99     | 3922.004   | Fe II  | 72603.502        | -1.06  |     |
| 3922.90     | 3922.908   | Mg I   | 35051.263        | -3.53  |     |
| 3927.92     | 3927.920   | Fe I   | 888.132          | -1.59  |     |
| 3930.30     | 3930.297   | Fe I   | 704.007          | -1.59  |     |
| 3930.34     | 3930.344   | Fe II  | 13673.186        | -4.03  |     |
| 3932.00     | 3932.023   | Ti II  | 9118.260         | -1.78  |     |
| 3933.23     | 3933.245   | Fe II  | 78690.849        | -3.39  |     |
| 3933.34     | 3933.345   | V II   | 47101.889        | -2.69  |     |
| 3933.66     | 3933.663   | Ca II  | 0.000            | 0.13   |     |
| 3935.95     | 3935.962   | Fe II  | 44915.046        | -1.86  |     |
| 3938.29     | 3938.290   | Fe II  | 13474.411        | -3.89  |     |
| 3938.97     | 3938.970   | Fe II  | 47674.718        | -1.85  |     |
| 3944.00     | 3944.006   | Al I   | 0.000            | -0.62  |     |
| 3945.20     | 3945.210   | Fe II  | 13673.186        | -4.25  |     |
| 3947.29     | 3947.295   | O I    | 73768.202        | -2.28  |     |
| 3947.48     | 3947.481   | O I    | 73768.202        | -2.43  |     |
| 3951.94     | 3951.930   | Ni II  | 94705.927        | -2.78  |     |
| 3951.965    | 3951.965   | V II   | 11908.270        | -0.74  |     |
| 3960.89     | 3960.899   | Fe II  | 58631.532        | -1.42  |     |
| 3961.51     | 3961.520   | Al I   | 112.061          | -0.32  |     |
| 3968.46     | 3968.469   | Ca II  | 0.000            | -0.17  |     |
| 3979.51     | 3979.505   | Cr II  | 45730.581        | -0.73  |     |
| 4002.08     | 4002.083   | Fe II  | 22409.852        | -3.47  |     |
| 4002.53     | 4002.543   | Fe II  | 48039.087        | -1.71  |     |
| 4002.93     | 4002.936   | V II   | 11514.760        | -1.81  |     |
| 4003.28     | 4003.283   | Cr II  | 52297.808        | -0.60  |     |
| 4005.24     | 4005.242   | Fe I   | 12560.933        | -0.61  |     |
| 4005.70     | 4005.706   | V II   | 14655.630        | -0.46  |     |
| 4012.50     | 4012.496   | Cr II  | 45669.369        | -0.89  |     |
| 4015.47     | 4015.474   | Ni II  | 32523.540        | -2.42  |     |
| 4023.36     | 4023.388   | V II   | 14556.090        | -0.88  |     |
| 4024.54     | 4024.547   | Fe II  | 36252.917        | -2.48  |     |
| Corr. Lab. Ident. | $\lambda$ (Å) | $\lambda$ (Å) | $E_{low}$ (cm$^{-1}$) | log($gf$) | Rem. |
|------------------|----------------|----------------|----------------------|---------|------|
| Ti II            | 4025.12        | 4025.131       | 4897.650             | -1.98   |      |
| He I             | 4026.26        | 4026.201       | 169086.766           | -2.629  |      |
| He I             | 4026.26        | 4026.201       | 169086.766           | -1.453  |      |
| He I             | 4026.26        | 4026.201       | 169086.766           | -0.705  |      |
| He I             | 4026.26        | 4026.201       | 169086.843           | -1.453  |      |
| He I             | 4026.26        | 4026.201       | 169086.843           | -0.976  |      |
| Ti II            | 4028.33        | 4028.343       | 15257.430            | -1.00   |      |
| He I             | 4028.77        | 4028.750       | 128599.162           | -0.12   |      |
| Cr II            | 4030.34        | 4030.358       | 25033.700            | -3.56   |      |
| Fe II            | 4030.358       | 4030.373       | 88723.398            | -0.99   |      |
| Mn I             | 4030.72        | 4030.730       | 0.000                | -0.47   |      |
| Fe II            | 4031.45        | 4031.442       | 38164.195            | -3.11   |      |
| Fe II            | 4032.94        | 4032.935       | 36252.917            | -2.70   |      |
| Fe II            | 4035.61        | 4035.627       | 14461.750            | -0.96   |      |
| Cr II            | 4037.95        | 4037.972       | 52321.010            | -0.56   |      |
| Fe II            | 4044.00        | 4044.012       | 44929.549            | -2.41   |      |
| Fe I             | 4045.80        | 4045.812       | 11976.238            | 0.28    |      |
| Fe II            | 4048.83        | 4048.830       | 44915.046            | -2.15   |      |
| Cr II            | 4049.09        | 4049.097       | 52297.808            | -0.86   |      |
| Cr II            | 4051.93        | 4051.930       | 25033.700            | -2.19   |      |
| Ti II            | 4053.82        | 4053.834       | 15265.619            | -1.21   |      |
| Cr II            | 4054.08        | 4054.076       | 25046.759            | -2.47   |      |
| Fe II            | 4057.46        | 4057.461       | 58666.256            | -1.55   |      |
| Fe II            | 4061.77        | 4061.782       | 48039.087            | -2.65   |      |
| Fe I             | 4063.59        | 4063.594       | 12560.933            | 0.07    |      |
| Ni II            | 4067.03        | 4067.031       | 32499.529            | -1.29   |      |
| Fe II            | 4069.88        | 4069.883       | 47674.718            | -2.75   |      |
| Fe II            | 4070.64        | 4070.630       | 60625.451            | -3.01   |      |
| Fe II            | 4070.632       | 4070.632       | 62151.561            | -2.98   |      |
| Cr II            | 4070.83        | 4070.840       | 52321.010            | -0.75   |      |
| Ni II            | 4071.04        | 4071.007       | 32523.540            | -3.47   |      |
| V I              | 4071.57        | 4071.564       | 15572.030            | -0.19   |      |
| Fe I             | 4071.73        | 4071.738       | 12968.554            | -0.02   |      |
| Co II            | 4072.08        | 4072.097       | 25147.370            | -4.72   |      |
| Cr II            | 4072.56        | 4072.561       | 29951.880            | -2.41   |      |
| Si II            | 4072.70        | 4072.709       | 79338.550            | -2.37   |      |
| Si II            | 4075.44        | 4075.452       | 79355.019            | -1.40   |      |
| Fe II            | 4075.93        | 4075.954       | 20516.959            | -3.38   |      |
| Si II            | 4076.78        | 4076.780       | 79338.502            | -1.67   |      |
| Ti I             | 4077.16        | 4077.15        | 17423.855            | -0.65   |      |
| Sr II            | 4077.71        | 4077.709       | 0.000                | 0.17    |      |
| Cr II            | 4110.98        | 4110.990       | 30307.439            | -2.02   |      |
| Cr II            | 4111.003       | 4111.003       | 25033.700            | -1.92   |      |
| Fe II            | 4111.85        | 4111.877       | 48039.087            | -2.16   |      |
| Corr. λ (Å) | Lab. λ (Å) | Ident. | $E_{low}$ (cm$^{-1}$) | log$(gf)$ | Rem.  |
|------------|------------|--------|----------------------|-----------|-------|
| 4113.23    | 4113.212   | Cr II  | 25046.749            | -2.27     |       |
| 4118.54    | 4118.545   | Fe I   | 28819.952            | 0.29      |       |
| 4119.51    | 4119.524   | Fe II  | 20516.959            | -4.92     |       |
| 4120.85    | 4120.846   | P II   | 103339.144           | -2.87     |       |
| 4122.66    | 4122.668   | Fe II  | 20830.582            | -3.38     |       |
| 4124.77    | 4124.787   | Fe II  | 20516.959            | -4.20     |       |
| 4127.03    | 4127.057   | Cr II  | 45730.581            | -1.77     |       |
| 4128.06    | 4128.054   | Si II  | 79338.502            | 0.32      | Mult 2|
| 4128.74    | 4128.748   | Fe II  | 20830.582            | -3.77     |       |
| 4130.88    | 4130.872   | Si II  | 79355.019            | -0.82     | Mult 2|
| 4130.894   | 4130.894   | Si II  | 79355.019            | 0.48      | Mult 2|
| 4132.05    | 4132.058   | Fe II  | 12968.554            | -0.65     |       |
| 4132.42    | 4132.419   | Cr II  | 30307.439            | -2.35     |       |
| 4142.23    | 4142.259   | S II   | 127825.085           | 0.24      |       |
| 4143.42    | 4143.415   | Fe I   | 24574.652            | -0.20     |       |
| 4143.86    | 4143.868   | Fe I   | 12560.933            | -0.45     |       |
| 4145.07    | 4145.060   | S II   | 127976.340           | 0.23      |       |
| 4145.78    | 4145.781   | Cr II  | 42897.990            | -1.16     |       |
| 4153.06    | 4153.068   | S II   | 128233.187           | 0.39      |       |
| 4156.82    | 4156.799   | Fe I   | 22838.320            | -0.62     |       |
| 4160.63    | 4160.623   | Fe II  | 22939.357            | -5.04     |       |
| 4161.08    | 4161.075   | Cr II  | 42986.619            | -2.470    |       |
| 4161.52    | 4161.535   | Ti II  | 8744.250             | -2.360    |       |
| 4162.67    | 4162.665   | S II   | 128599.162           | 0.83      |       |
| 4167.30    | 4167.299   | Fe II  | 90300.626            | -0.56     |       |
| 4171.88    | 4171.903   | Cr II  | 25042.811            | -2.38     |       |
| 4173.44    | 4173.461   | Fe II  | 20850.582            | -2.18     |       |
| 4177.68    | 4177.692   | Fe II  | 20516.959            | -3.75     |       |
| 4178.84    | 4178.862   | Fe II  | 20830.582            | -2.48     |       |
| 4179.42    | 4179.42    | Cr II  | 30864.459            | -1.77     |       |
| 4181.73    | 4181.732   | Cr II  | 93574.441            | -2.38     |       |
| 4187.03    | 4187.039   | Fe I   | 19757.031            | -0.55     |       |
| 4187.82    | 4187.805   | V II   | 32299.271            | -1.62     |       |
| 4190.72    | 4190.707   | Si II  | 108820.600           | 0.20      |       |
| 4191.43    | 4191.430   | Fe I   | 19912.494            | -0.67     |       |
| 4192.02    | 4192.065   | Ni II  | 32523.540            | -3.06     |       |
| 4195.38    | 4195.365   | Fe II  | 61041.746            | -3.88     |       |
| 4196.17    | 4196.19    | Fe II  | 90042.781            | -3.04     |       |
| 4198.11    | 4198.134   | Si II  | 108778.702           | -0.30     |       |
| 4198.29    | 4198.304   | Fe I   | 19350.891            | -0.72     |       |
| 4199.09    | 4199.093   | Fe II  | 37227.326            | -3.99     |       |
| 4199.095   | 4199.095   | Fe I   | 24574.652            | 0.25      |       |
| 4199.48    | 4199.491   | Fe II  | 89924.175            | -0.23     |       |
| 4200.49    | 4200.521   | Fe II  | 90067.346            | -0.30     |       |
Table 5—Continued

| Corr. Lab. λ (Å) | Lab. λ (Å) | Ident. | $E_{low}$ (cm$^{-1}$) | log($gf$) | Rem. |
|------------------|------------|--------|----------------------|----------|------|
| 4200.91          | 4200.898   | Si II  | 101024.349           | -0.67    |      |
| 4202.02          | 4202.029   | Fe I   | 11976.238            | -0.71    |      |
| 4202.52          | 4202.522   | Fe II  | 54902.315            | -2.33    |      |
| 4205.58          | 4205.595   | Fe II  | 90386.527            | -0.30    |      |
| 4210.35          | 4210.343   | Fe I   | 20019.633            | -0.87    |      |
| 4215.52          | 4215.519   | Sr II  | 0.000                | -0.14    |      |
| 4219.36          | 4219.360   | Fe I   | 28819.952            | 0.12     |      |
| 4224.85          | 4224.860   | Cr II  | 42986.619            | -1.73    |      |
| 4226.72          | 4226.728   | Ca I   | 0.000                | 0.24     |      |
| 4227.42          | 4227.427   | Fe I   | 26874.547            | 0.23     |      |
| 4230.38          | 4230.375   | Ni I   | 30619.440            | -2.12    |      |
| 4232.47          | 4232.488   | Ca I   | 39464.809            | -2.60    |      |
| 4232.87          | 4232.849   | Si II  | 97972.086            | -1.00    |      |
| 4233.17          | 4233.172   | Fe II  | 20830.582            | -2.00    |      |
| 4233.62          | 4233.602   | Fe I   | 20019.633            | -0.60    |      |
| 4233.97          | 4233.977   | V I    | 15688.870            | -0.02    |      |
| 4234.15          | 4234.167   | Nd II  | 1470.105             | -0.99    |      |
| 4235.44          | 4235.421   | Cr II  | 86782.041            | -2.49    |      |
| 4235.92          | 4235.936   | Fe I   | 19562.437            | -0.34    |      |
| 4238.81          | 4238.791   | Mn II  | 14781.190            | -3.63    |      |
| 4242.36          | 4242.364   | Cr II  | 31219.350            | -0.59    |      |
| 4244.77          | 4244.779   | Ni II  | 32523.540            | -3.11    |      |
| 4246.82          | 4246.826   | Sc II  | 2540.950             | 0.32     | hfs 3 lines |
| 4247.81          | 4247.805   | Ti I   | 16106.075            | -3.63    |      |
| 4250.10          | 4250.119   | Fe I   | 19912.594            | -0.41    |      |
| 4250.42          | 4250.437   | Fe II  | 61974.931            | -1.75    |      |
| 4250.79          | 4250.787   | Fe I   | 12560.933            | -2.81    |      |
| 4251.72          | 4251.717   | Mn II  | 49882.153            | -1.06    |      |
| 4252.61          | 4252.632   | Cr II  | 31117.390            | -2.02    |      |
| 4252.96          | 4252.962   | Cr II  | 91955.392            | -2.95    |      |
| 4252.963         |              | Mn II  | 49889.858            | -1.14    |      |
| 4254.34          | 4254.336   | Cr I   | 0.000                | -0.11    |      |
| 4254.51          | 4254.522   | Cr II  | 47354.440            | -0.97    |      |
| 4258.15          | 4258.154   | Fe II  | 21812.055            | -3.40    |      |
| 4258.33          | 4258.340   | Fe II  | 21308.04             | -4.13    |      |
| 4259.19          | 4259.191   | Si II  | 97972.086            | -1.30    |      |
| 4260.47          | 4260.474   | Fe I   | 19350.891            | -0.02    |      |
| 4261.92          | 4261.913   | Cr II  | 31168.581            | -1.53    |      |
| 4263.86          | 4263.869   | Fe II  | 62049.023            | -1.71    |      |
| 4267.00          | 4267.001   | C II   | 145549.272           | 0.61     |      |
| 4267.25          | 4267.261   | C II   | 145570.705           | 0.77     |      |
| 4269.26          | 4269.277   | Cr II  | 31082.940            | -2.17    |      |
| 4271.14          | 4271.153   | Fe I   | 19757.031            | -0.35    |      |
| 4271.77          | 4271.760   | Fe I   | 11976.238            | -0.16    |      |
| Corr. Lab. | Lambda (Å) | Ident. | $E_{low}$ (cm$^{-1}$) | log($gf$) | Rem. |
|-----------|------------|--------|------------------------|-----------|------|
| 4273.32   | 4273.326   | Fe II  | 21812.055              | -3.26     |      |
| 4274.78   | 4274.797   | Cr I   | 0.000                  | -0.23     |      |
| 4275.76   | 4275.779   | Ti I   | 18825.781              | -1.13     |      |
| 4278.15   | 4278.159   | Fe II  | 21711.917              | -3.82     |      |
| 4282.42   | 4282.403   | Fe I   | 17550.180              | -0.81     |      |
| 4284.18   | 4284.188   | Cr II  | 31082.940              | -1.86     |      |
| 4286.27   | 4286.280   | Fe II  | 62171.614              | -1.62     |      |
| 4287.87   | 4287.872   | Ti II  | 8710.440               | -2.02     |      |
| 4290.21   | 4290.219   | Ti II  | 9395.710               | -1.12     |      |
| 4294.09   | 4294.099   | Ti II  | 8724.250               | -1.11     |      |
| 4294.90   | 4294.91    | Fe I   | 26351.038              | -2.71     |      |
| 4296.56   | 4296.572   | Fe II  | 21812.055              | -3.01     |      |
| 4299.21   | 4299.206   | Ti I   | 14106.633              | -0.01     |      |
| 4300.04   | 4300.049   | Ti II  | 9518.060               | -0.77     |      |
| 4301.91   | 4301.914   | Ti II  | 9363.620               | -1.16     |      |
| 4303.17   | 4303.176   | Fe II  | 21812.055              | -2.49     |      |
| 4306.92   | 4306.916   | Cr II  | 47372.533              | -1.18     |      |
| 4307.89   | 4307.863   | Ti II  | 9395.710               | -1.29     |      |
| 4312.85   | 4312.864   | Ti II  | 9518.060               | -1.16     |      |
| 4314.06   | 4314.076   | Sc II  | 4987.790               | -0.10     | 5 hfs lines |
| 4314.29   | 4314.310   | Fe II  | 21581.638              | -3.48     |      |
| 4314.97   | 4314.975   | Ti II  | 9363.620               | -1.13     |      |
| 4318.16   | 4318.188   | Fe II  | 63559.489              | -1.98     |      |
| 4319.40   | 4319.413   | Fe II  | 61726.078              | -2.12     |      |
| 4319.67   | 4319.680   | Fe II  | 63272.974              | -1.76     |      |
| 4320.34   | 4320.340   | Ni II  | 113407.314             | -2.72     |      |
| 4320.72   | 4320.725   | Sc II  | 4883.570               | -0.26     |      |
| 4320.93   | 4320.960   | Ti II  | 9395.710               | -1.97     |      |
| 4321.32   | 4321.309   | Fe II  | 63465.106              | -1.83     |      |
| 4324.97   | 4324.984   | Sc II  | 4802.870               | -0.44     | 2 hfs lines |
| 4325.53   | 4325.540   | Fe II  | 49100.978              | -2.31     |      |
| 4325.75   | 4325.762   | Fe I   | 12968.554              | -0.01     |      |
| 4326.65   | 4326.639   | Mn II  | 42537.180              | -1.25     |      |
| 4337.93   | 4337.915   | Fe II  | 8710.440               | -1.13     |      |
| 4351.76   | 4351.769   | Fe II  | 21812.055              | -2.10     |      |
| 4354.33   | 4354.344   | Fe II  | 61726.078              | -1.39     |      |
| 4357.56   | 4357.584   | Fe II  | 49100.978              | -2.11     |      |
| 4361.24   | 4361.247   | Fe II  | 49506.935              | -2.11     |      |
| 4362.10   | 4362.099   | Ni II  | 32499.529              | -2.72     |      |
| 4362.95   | 4362.924   | Cr II  | 45669.369              | -1.89     |      |
| 4363.26   | 4363.255   | Mn II  | 44899.820              | -1.91     |      |
| 4367.65   | 4367.659   | Ti II  | 20891.660              | -1.27     |      |
| Corr. Lab. Ident. | $E_{low}$ (cm$^{-1}$) | log($gf$) | Rem. |
|-------------------|----------------------|-----------|-----|
| $\lambda$ (Å) | $\lambda$ (Å) |
| 4368.24 | 4368.242 | O I | 76794.977 | -2.03 |
| 4368.258 | O I | 76794.977 | -2.25 |
| 4369.39 | 4369.411 | Fe II | 22409.852 | -1.67 |
| 4383.54 | 4383.545 | Fe I | 11976.238 | 0.20 |
| 4384.09 | 4384.094 | Fe II | 50212.823 | -2.28 |
| 4384.31 | 4384.319 | Fe II | 21430.359 | -3.50 |
| 4384.65 | 4384.637 | Mg II | 80619.500 | -0.79 |
| 4385.38 | 4385.387 | Fe II | 22409.852 | -2.57 |
| 4386.83 | 4386.844 | Ti II | 20951.620 | -1.26 |
| 4387.95 | 4387.930 | He I | 17134.897 | -0.887 |
| 4390.57 | 4390.514 | Mg II | 80650.022 | -1.49 |
| 4390.572 | Mg II | 80650.022 | -0.53 |
| 4391.82 | 4391.791 | Cr II | 44307.091 | -2.60 |
| 4391.820 | S II | 128233.197 | -0.56 |
| 4394.05 | 4394.051 | Ti II | 9850.900 | -1.59 |
| 4395.03 | 4395.033 | Ti II | 8744.250 | -0.66 |
| 4395.80 | 4395.817 | Fe II | 90487.811 | -1.20 |
| 4399.76 | 4399.772 | Ti II | 9975.920 | -1.27 |
| 4400.38 | 4400.379 | Sc II | 4883.570 | -0.51 |
| 4404.74 | 4404.75 | Fe I | 12560.933 | -0.14 |
| 4407.67 | 4407.678 | Ti II | 9850.900 | -2.47 |
| 4409.51 | 4409.516 | Ti II | 9930.690 | -2.57 |
| 4411.06 | 4411.07 | Ti II | 24961.031 | -1.06 |
| 4413.58 | 4413.601 | Fe II | 21581.638 | -3.87 |
| 4415.12 | 4415.122 | Fe I | 12968.554 | -0.62 |
| 4416.82 | 4416.830 | Fe II | 22409.852 | -2.60 |
| 4417.71 | 4417.719 | Ti II | 9395.710 | -1.47 |
| 4418.32 | 4418.330 | Ti II | 9975.920 | -2.46 |
| 4418.94 | 4418.957 | Fe II | 64087.418 | -1.84 |
| 4419.61 | 4419.604 | Cr II | 94365.189 | -0.26 |
| 4427.99 | 4427.994 | Mg II | 80619.500 | -1.21 |
| 4431.60 | 4431.605 | Fe II | 64040.884 | -1.77 |
| 4434.99 | 4434.988 | Mg II | 80650.022 | -0.91 |
| 4443.80 | 4443.794 | Ti II | 8710.440 | -0.70 |
| 4444.29 | 4444.299 | Fe II | 50157.455 | -3.70 |
| 4444.53 | 4444.539 | Fe II | 50157.455 | -2.53 |
| 4446.22 | 4446.237 | Fe II | 48039.087 | -2.44 |
| 4449.60 | 4449.616 | Fe II | 63984.792 | -1.59 |
| 4450.47 | 4450.482 | Ti II | 8744.250 | -1.45 |
| 4451.54 | 4451.551 | Fe II | 40506.935 | -1.84 |
| 4455.26 | 4455.266 | Fe II | 50512.823 | -2.14 |
| 4461.42 | 4461.439 | Fe II | 20830.582 | -4.11 |
| 4461.70 | 4461.706 | Fe II | 50212.823 | -2.05 |
| 4464.44 | 4464.450 | Ti II | 9363.620 | -2.08 |
| Corr. Lab. Ident. | E$_{low}$ (cm$^{-1}$) | log($gf$) | Rem. |
|------------------|----------------------|-----------|------|
| $\lambda$ (Å)    | $\lambda$ (Å)       |           |      |
| 4468.49 Ti II    | 9118.260             | -0.60     |      |
| 4471.48 He I    | 169086.767           | -2.212    |      |
| 4471.48 He I    | 169086.767           | -1.036    |      |
| 4471.48 He I    | 169086.767           | -0.287    |      |
| 4471.48 He I    | 169086.843           | -1.035    |      |
| 4471.48 He I    | 169086.843           | -0.558    |      |
| 4472.92 Fe II   | 22939.357            | -3.43     |      |
| 4476.01 Fe I    | 22946.815            | -0.97     |      |
| 4476.01 Fe II   | 90901.125            | -1.03     |      |
| 4478.64 Mn II   | 53597.132            | -0.95     |      |
| 4480.71 Fe II   | 50212.823            | -2.39     |      |
| 4481.12 Mg II   | 71490.190            | 0.74      |      |
| 4481.15 Mg II   | 71490.190            | -0.56     |      |
| 4481.34 Mg II   | 71491.064            | 0.59      |      |
| 4487.48 Fe II   | 62049.023            | -2.14     |      |
| 4488.31 Ti II   | 25192.791            | -0.82     |      |
| 4489.17 Ca II   | 68056.909            | -0.61     |      |
| 4489.17 Ca II   | 68056.909            | -0.61     |      |
| 4489.183 Ca II  | 22810.356            | -2.97     |      |
| 4491.40 Fe II   | 23031.299            | -2.70     |      |
| 4493.52 Ti II   | 8710.440             | -2.73     |      |
| 4493.529 Fe II  | 63876.319            | -1.43     |      |
| 4494.54 Fe I    | 17726.988            | -1.14     |      |
| 4501.26 Ti II   | 8997.710             | -0.75     |      |
| 4507.09 Fe II   | 62689.878            | -1.92     |      |
| 4508.27 Fe II   | 23031.299            | -2.21     |      |
| 4511.77 Cr II   | 52297.808            | -1.37     |      |
| 4512.02 Fe II   | 61974.931            | -2.18     |      |
| 4515.32 Fe II   | 22939.357            | -2.48     |      |
| 4515.59 Cr II   | 67369.139            | -1.11     |      |
| 4515.609 Fe II  | 50212.823            | -2.21     |      |
| 4518.33 Ti II   | 8710.440             | -2.55     |      |
| 4520.21 Fe II   | 22637.205            | -2.60     |      |
| 4522.63 Fe II   | 22939.357            | -2.03     |      |
| 4524.98 Fe II   | 86124.299            | -3.43     |      |
| 4528.60 Fe I    | 17550.180            | -0.82     |      |
| 4529.50 Ti II   | 12676.970            | -2.03     |      |
| 4529.569 Fe II  | 44929.549            | -3.19     |      |
| 4533.96 Ti II   | 9975.920             | -0.77     |      |
| 4534.16 Fe II   | 23031.299            | -3.47     |      |
| 4539.58 Cr II   | 32603.400            | -2.53     |      |
| 4541.06 Fe II   | 61973.931            | -2.48     |      |
| 4541.51 Fe II   | 23031.299            | -3.05     |      |
| 4549.21 Fe II   | 47674.718            | -1.97     |      |

3 Eu II hfs lines
| Corr. Lab. Ident. | E<sub>low</sub> (cm<sup>-1</sup>) | log(<i>f</i>) | Rem. |
|-----------------|-----------------|-------------|-----|
| λ (Å)           | λ (Å)           |             |     |
| 4549.47         | 4549.474        | Fe II       | 22810.356 | -1.75 |
| 4549.62         | 4549.617        | Ti II       | 12774.689 | -0.45 |
| 4552.40         | 4552.400        | Cr II       | 93966.448 | -4.09 |
| 4552.410        | S II            | 121528.718  | -0.10 |
| 4553.63         | 4553.623        | Cr I        | 31008.995 | -3.95 |
| 4554.03         | 4554.03         | Ba II       | 0.000    | 0.02   | 15 hfs lines |
| 4554.99         | 4554.988        | Cr II       | 32836.680 | -1.38 |
| 4555.88         | 4555.893        | Fe II       | 22810.356 | -2.29 |
| 4558.64         | 4558.650        | Cr II       | 32854.311 | -0.66 |
| 4559.06         | 4559.079        | Fe I        | 35379.205 | -3.67 |
| 4563.74         | 4563.761        | Ti II       | 9850.900  | -0.96 |
| 4565.72         | 4565.74         | Cr II       | 32603.400 | -2.11 |
| 4571.96         | 4571.968        | Ti II       | 12676.970 | -0.53 |
| 4576.34         | 4576.340        | Fe II       | 22939.357 | -3.04 |
| 4579.52         | 4579.527        | Fe II       | 50212.823 | -2.51 |
| 4580.05         | 4580.063        | Fe II       | 20830.582 | -3.73 |
| 4582.82         | 4582.835        | Fe II       | 22939.357 | -3.10 |
| 4583.82         | 4583.837        | Fe II       | 22637.205 | -2.02 |
| 4588.20         | 4588.199        | Cr II       | 32836.680 | -0.63 |
| 4589.93         | 4589.958        | Ti II       | 9975.920  | -1.79 |
| 4590.75         | 4590.736        | Fe II       | 50187.813 | -3.99 |
| 4591.00         | 4591.004        | Fe II       | 63272.974 | -2.25 |
| 4592.05         | 4592.049        | Cr II       | 32854.949 | -1.22 |
| 4593.60         | 4593.606        | Fe II       | 62049.023 | -2.41 |
| 4593.81         | 4593.827        | Fe II       | 23317.632 | -4.92 |
| 4596.00         | 4596.015        | Fe II       | 50212.823 | -1.84 |
| 4598.47         | 4598.494        | Fe II       | 62945.040 | -1.50 |
| 4616.12         | 4616.124        | Cr I        | 7927.443  | -1.19 |
| 4616.62         | 4616.629        | Cr II       | 32844.760 | -1.29 |
| 4618.81         | 4618.803        | Cr II       | 32854.949 | -1.11 |
| 4620.50         | 4620.521        | Fe II       | 22810.356 | 3.28  |
| 4621.40         | 4621.418        | Si II       | 101023.046| -0.54 |
| 4621.71         | 4621.696        | Si II       | 101024.349| -1.68 |
| 4625.89         | 4625.893        | Fe II       | 48039.087 | -2.20 |
| 4628.76         | 4628.786        | Fe II       | 63272.974 | -1.74 |
| 4629.32         | 4629.339        | Cr II       | 22637.205 | -2.37 |
| 4631.87         | 4631.873        | Fe II       | 63465.106 | -1.87 |
| 4364.07         | 4364.070        | Cr II       | 32844.760 | -1.24 |
| 4635.30         | 4635.316        | Fe II       | 48039.087 | -1.65 |
| 4638.04         | 4638.050        | Fe II       | 62171.614 | -1.52 |
| 4640.80         | 4640.812        | Fe II       | 62171.614 | -1.88 |
| 4648.93         | 4648.944        | Fe II       | 20830.582 | -4.39 |
| 4656.97         | 4656.981        | Fe II       | 23317.632 | -3.63 |
| 4663.05         | 4663.046        | Al II       | 85481.348 | -0.28 |
| Corr. Lab. (Å) | Lab. Ident. | $E_{low}$ (cm$^{-1}$) | log($gf$) | Rem. |
|---------------|-------------|----------------------|-----------|------|
| 4663.70       | Fe II       | 23317.632            | -4.27     |      |
| 4665.55       | Ni II       | 55299.649            | -1.82     |      |
| 4666.75       | Fe II       | 22810.356            | -3.33     |      |
| 4670.16       | Fe II       | 20830.585            | -4.10     |      |
| 4673.28       | Si II       | 103556.025           | -0.60     | Broad |
| 4680.90       | Fe I        | 37162.745            | -2.51     |      |
| 4702.98       | Mg I        | 35051.263            | -0.67     |      |
| 4716.26       | S II        | 109831.595           | -0.32     |      |
| 4730.38       | Mn II       | 43339.420            | -2.15     |      |
| 4731.45       | Fe II       | 23317.632            | -3.36     |      |
| 4739.74       | Mg II       | 93311.112            | -0.82     |      |
| 4755.73       | Mn II       | 43528.639            | -1.24     |      |
| 4764.72       | Mn II       | 43537.180            | -1.35     |      |
| 4771.73       | C I         | 60393.138            | -2.12     |      |
| 4779.98       | Ti II       | 16515.860            | -1.37     |      |
| 4805.09       | Ti II       | 16625.110            | -1.10     |      |
| 4812.35       | Cr II       | 31168.581            | -1.80     |      |
| 4815.56       | S II        | 110268.595           | 0.18      |      |
| 4820.80       | Fe II       | 831366.488           | -0.69     |      |
| 4824.12       | Cr II       | 31219.350            | -1.22     |      |
| 4826.88       | Mn I        | 31076.421            | -1.42     |      |
| 4831.19       | Fe II       | 61041.746            | -2.77     | Broad |
| 4833.20       | Fe II       | 21430.359            | -4.78     |      |
| 4836.22       | Cr II       | 31117.390            | -2.25     |      |
| 4848.25       | Cr II       | 31168.581            | -1.14     |      |
| 4864.31       | Cr II       | 31117.390            | -1.37     |      |
| 4871.30       | Fe I        | 23110.937            | -0.41     |      |
| 4872.11       | Fe I        | 21244.836            | -0.60     |      |
| 4873.46       | Ni I        | 29832.811            | -0.47     |      |
| 4874.02       | Ti II       | 24961.031            | -0.79     |      |
| 4876.41       | Cr II       | 31082.940            | -1.46     |      |
| 4883.28       | Fe II       | 82853.660            | -0.64     |      |
| 4884.600      | Cr II       | 31117.390            | -2.08     |      |
| 4890.76       | Fe I        | 23192.497            | -0.43     |      |
| 4891.48       | Cr II       | 31150.901            | -3.04     |      |
| 4891.492      | Fe I        | 22996.673            | -0.14     |      |
| 4893.82       | Fe II       | 22810.356            | -4.45     |      |
| 4901.60       | Cr II       | 52321.010            | -0.83     |      |
| 4908.15       | Fe II       | 83308.193            | -0.30     |      |
| 4911.19       | Ti II       | 25192.791            | -0.34     |      |
| 4912.45       | Cr II       | 52297.808            | -0.95     |      |
| 4913.29       | Fe II       | 82978.679            | 0.01      |      |
| 4918.98       | Fe I        | 23110.937            | -0.37     |      |
| Corr. Lab. (Å) | Corr. Lab. (Å) | Ident. | $E_{low}$ (cm$^{-1}$) | log($gf$) | Rem. |
|----------------|----------------|--------|----------------------|-------------|--------|
| 4920.49        | 4920.502       | Fe I   | 22845.868            | 0.06        |       |
| 4921.931       | 4921.931       | HeI    | 171134.897           | -0.443      |       |
| 4921.99        | 4922.006       | Ni II  | 112719.745           | -0.60       |       |
| 4923.92        | 4923.927       | Fe II  | 23317.632            | -1.32       |       |
| 4925.34        | 4925.343       | S II   | 109560.686           | -0.24       |       |
| 4948.06        | 4948.096       | Fe II  | 83136.488            | -0.32       |       |
| 4948.77        | 4948.793       | Fe II  | 83459.671            | -0.01       |       |
| 4951.57        | 4951.584       | Fe II  | 83136.488            | 0.18        |       |
| 4952.64        | 4952.657       | Fe II  | 83459.671            | -0.65       |       |
| 4953.96        | 4953.987       | Fe II  | 44929.549            | -2.76       |       |
| 4957.27        | 4957.298       | Fe I   | 22996.673            | -0.34       |       |
| 4957.58        | 4957.596       | Fe I   | 22650.414            | 0.13        |       |
| 4958.82        | 4958.822       | Fe II  | 82713.536            | -0.65       |       |
| 4967.89        | 4967.897       | Fe I   | 33801.571            | -0.53       |       |
| 4968.81        | 4968.832       | Fe I   | 33946.932            | -2.57       |       |
| 4977.02        | 4977.035       | Fe II  | 83558.539            | 0.04        |       |
| 4984.48        | 4984.488       | Fe II  | 83308.193            | 0.01        |       |
| 4990.50        | 4990.509       | Fe II  | 83308.193            | 0.18        |       |
| 4991.43        | 4991.440       | Fe II  | 82853.660            | -0.57       |       |
| 4992.01        | 4992.024       | Ni II  | 98822.511            | 0.99        |       |
| 4992.35        | 4992.358       | Cr II  | 47354.440            | -4.78       |       |
| 4999.17        | 4999.180       | Fe II  | 82853.660            | -0.48       |       |
| 5000.72        | 5000.743       | Fe II  | 22409.852            | -4.74       |       |
| 5001.48        | 5001.479       | Ca II  | 60533.018            | -0.52       |       |
| 5001.94        | 5001.959       | Fe II  | 82853.660            | 0.90        |       |
| 5003.42        | 5003.414       | Ni II  | 101144.633           | 0.70        |       |
| 5004.19        | 5004.195       | Fe II  | 82853.660            | 0.50        |       |
| 5005.74        | 5005.742       | Cr I   | 27728.811            | -2.60       |       |
| 5006.11        | 5006.119       | Fe I   | 22845.868            | -0.62       |       |
| 5006.84        | 5006.841       | Fe II  | 83713.536            | -0.43       |       |
| 5007.44        | 5007.447       | Fe II  | 83726.362            | -0.36       |       |
| 5007.73        | 5007.739       | Fe II  | 82978.679            | -0.20       |       |
| 5008.98        | 5009.022       | Fe II  | ?                    | 83459.671   | -0.41 |
| 5009.55        | 5009.567       | S II   | 109831.595           | -0.09       |       |
| 5014.05        | 5014.042       | S II   | 113461.537           | 0.03        |       |
| 5014.062       | 5014.062       | Ni II  | 100332.090           | -0.70       |       |
| 5014.067       | 5014.067       | Cr II  | 84604.840            | -2.14       |       |
| 5014.95        | 5014.942       | Fe I   | 31805.070            | -0.25       |       |
| 5015.73        | 5015.755       | Fe II  | 83459.671            | -0.05       |       |
| 5018.44        | 5018.440       | Fe II  | 23317.632            | -1.22       |       |
| 5021.56        | 5021.594       | Fe II  | 82978.679            | -0.30       |       |
| 5022.41        | 5022.420       | Fe II  | 83459.671            | -0.06       |       |
| 5022.78        | 5022.792       | Fe II  | 82978.679            | -0.02       |       |
| 5026.79        | 5026.806       | Fe II  | 83136.488            | -0.22       |       |

**Table 5—Continued**
| Corr. Lab. | Lab. Ident. | $E_{low}$ (cm$^{-1}$) | log($g_f$) | Rem. |
|-----------|-------------|----------------------|----------|------|
| $\lambda$ (Å) | $\lambda$ (Å) |                      |          |      |
| 5030.61  | 5030.630    | Fe II                | 82978.679 | 0.40 |
| 5031.01  | 5031.010    | Sc II                | 10944.560 | -0.26 |
| 5031.88  | 5031.898    | Fe II                | 83990.065 | -0.78 |
| 5032.42  | 5032.434    | Si II                | 83990.065 | -0.78 |
| 5032.68  | 5032.712    | Fe II                | 83978.679 | 0.61 |
| 5035.69  | 5035.708    | Fe II                | 8359.709  | -2.47 |
| 5041.02  | 5041.024    | Si II                | 81191.341 | 0.29 |
| 5045.11  | 5045.114    | Fe II                | 83136.488 | -0.13 |
| 5047.64  | 5047.641    | Fe II                | 83136.488 | -0.07 |
| 5052.97  | 5055.984    | Si II                | 81251.320 | 0.59 |
| 5056.31  | 5056.317    | Si II                | 81251.320 | -0.36 |
| 5056.70  | 5056.713    | Cr II                | 69954.088 | -1.68 |
| 5058.38  | 5058.376    | Ni II                | 10357.203 | 0.85 |
| 5059.17  | 5059.20     | Ni II                | 99132.784 | 0.54 |
| 5060.24  | 5060.257    | Fe II                | 84266.557 | -0.52 |
| 5061.70  | 5061.718    | Fe II                | 83136.488 | 0.22 |
| 5065.07  | 5065.097    | Fe II                | 84131.564 | -0.45 |
| 5067.88  | 5067.893    | Fe II                | 83308.193 | -0.20 |
| 5070.89  | 5070.899    | Fe II                | 83136.488 | 0.24 |
| 5072.00  | 5071.981    | Fe II                | 90898.872 | -1.62 |
| 5072.27  | 5072.281    | Ti II                | 25192.791 | -0.75 |
| 5074.05  | 5074.053    | Fe II                | 54904.221 | -1.97 |
| 5075.76  | 5075.764    | Fe II                | 84326.910 | 0.28 |
| 5078.26  | 5078.296    | Fe II                | 83990.065 | -1.18 |
| 5082.23  | 5082.230    | Fe II                | 83990.065 | -0.10 |
| 5086.30  | 5086.306    | Fe II                | 83990.065 | -0.48 |
| 5087.30  | 5087.303    | Fe II                | 83713.536 | -0.50 |
| 5089.22  | 5089.214    | Fe II                | 83308.193 | -0.03 |
| 5093.56  | 5093.576    | Fe II                | 83713.536 | 0.11 |
| 5097.27  | 5097.271    | Fe II                | 83713.536 | 0.31 |
| 5100.71  | 5100.127    | Fe II                | 83726.362 | 0.70 |
| 5106.10  | 5106.097    | Fe II                | 83812.317 | -0.95 |
| 5106.109 | 5106.109    | Fe II                | 83308.193 | -0.28 |
| 5117.03  | 5117.034    | Fe II                | 84131.564 | -0.13 |
| 5127.86  | 5127.866    | Fe II                | 44929.549 | -2.53 |
| 5129.14  | 5129.152    | Ti II                | 15257.430 | -1.39 |
| 5132.66  | 5132.699    | Fe II                | 22637.205 | -4.18 |
| 5139.46  | 5139.462    | Fe I                 | 23711.453 | -0.57 |
| 5143.88  | 5143.880    | Fe II                | 84266.557 | 0.10 |
| 5144.34  | 5144.355    | Fe II                | 84424.372 | 0.18 |
| 5145.78  | 5145.772    | Fe II                | 83990.065 | -0.40 |
| 5146.10  | 5146.127    | Fe II                | 22810.356 | -3.91 |
| 5148.94  | 5148.907    | Fe II                | 83990.065 | -0.40 |
Table 5—Continued

| Corr. Lab. λ (Å) | Lab. Ident. Eₗ₀w (Å) | log(gf) Rem. |
|------------------|-----------------------|-------------|
| 5149.46 5149.465 | Fe II 84266.557 | 0.40 |
| 5150.47 5150.489 | Fe II 84266.557 | -0.12 |
| 5151.27 5151.247 | Cr II 70316.899 | -3.21 |
| 5160.84 5160.839 | Fe II 44915.046 | -2.64 almost triangular |
| 5163.58 5163.544 | Fe II 84685.198 | -1.90 |
| 5165.69 5165.633 | N I 94770.879 | -2.18 broad Fe II 5165.649 ? |
| 5165.709 5165.748 | N I 94793.489 | -3.35 Fe II 5165.751 ? |
| 5166.55 5166.555 | Fe II 84326.910 | -0.03 triangular |
| 5167.33 5167.321 | Mg I 21850.405 | -1.03 |
| 5169.03 5169.033 | Fe II 23317.632 | -0.87 |
| 5170.78 5170.777 | Fe II 84326.910 | -0.36 |
| 5180.30 5180.314 | Fe II 83812.317 | 0.04 |
| 5185.53 5185.520 | Si II 103560.025 | -0.27 broad |
| 5185.555 5185.555 | Si II 103560.156 | -0.39 |
| 5185.88 5185.913 | Ti II 15265.639 | -1.35 |
| 5186.85 5186.873 | Fe II 84424.372 | -0.30 |
| 5188.67 5188.680 | Ti II 12758.110 | -1.21 |
| 5191.43 5191.428 | Cr II 30307.439 | -3.36 |
| 5192.35 5192.344 | Fe I 24180.861 | -0.42 |
| 5193.72 5193.682 | Fe II 93987.462 | -3.30 |
| 5194.38 5194.384 | Fe II 179893.560 | -3.21 |
| 5194.89 5194.892 | Fe II 84424.372 | -0.15 |
| 5197.56 5197.577 | Fe II 26055.422 | -2.10 |
| 5199.11 5199.122 | Fe II 83713.536 | 0.10 |
| 5200.78 5200.804 | Fe II 83812.317 | -0.37 |
| 5201.43 5201.468 | Cr II 69954.088 | -1.65 |
| 5203.63 5203.638 | Fe II 83812.317 | -0.05 |
| 5210.53 5210.539 | Sc I 20236.860 | 0.43 |
| 5213.98 5213.960 | Fe II 84257.779 | -0.22 |
| 5215.34 5215.349 | Fe II 83713.536 | -0.01 |
| 5215.81 5215.844 | Fe II 83726.362 | -0.23 |
| 5216.85 5216.854 | Fe II 84710.686 | 0.39 |
| 5216.863 5216.863 | Fe II 84527.779 | 0.61 |
| 5218.85 5218.842 | Fe II 83726.362 | -0.21 |
| 5222.36 5222.361 | Fe II 84844.832 | -0.33 |
| 5223.24 5223.260 | Fe II 83812.317 | -0.41 |
| 5223.80 5223.800 | Fe II 83713.536 | -0.59 |
| 5224.40 5224.411 | Fe II 83990.065 | -0.57 |
| 5225.34 5225.306 | Cr II 86691.551 | -0.66 |
| 5226.00 5225.968 | Fe II 83812.317 | -0.41 |
| 5226.54 5226.543 | Ti II 12628.731 | -1.30 |
| 5227.48 5227.481 | Fe II 84296.829 | 0.80 |
| 5228.61 5228.648 | Cr II 86078.899 | -4.01 |
| 5228.68 5228.695 | Fe II 93487.649 | -3.70 |
| Corr. λ (Å) | Lab. λ (Å) | Ident. | $E_{low}$ (cm$^{-1}$) | log($gf$) | Rem. |
|------------|------------|--------|------------------------|----------|------|
| 5232.49    | 5232.496   | Cr II  | 32836.680              | -2.09    |      |
| 5232.77    | 5232.787   | Fe II  | 83726.362              | -0.06    |      |
| 5232.94    | 5232.940   | Fe II  | 23711.453              | -0.19    |      |
| 5234.29    | 5234.271   | V II   | 18269.490              | -4.42    |      |
| 5234.62    | 5234.625   | Fe II  | 25981.630              | -2.05    |      |
| 5237.32    | 5237.329   | Cr II  | 32854.311              | -1.16    |      |
| 5237.32    |            | Cr II  | 86782.041              | -0.58    |      |
| 5239.80    | 5239.813   | Fe II  | 84326.910              | -0.46    |      |
| 5245.45    | 5245.455   | Fe II  | 84326.910              | -0.51    |      |
| 5246.77    | 5246.768   | Cr II  | 29951.880              | -2.45    |      |
| 5247.95    | 5247.952   | Fe II  | 84938.177              | 0.63     |      |
| 5249.39    | 5249.437   | Cr II  | 30307.439              | -2.43    |      |
| 5251.23    | 5251.233   | Fe II  | 84844.832              | 0.51     |      |
| 5253.65    | 5253.641   | Fe II  | 84296.829              | -0.09    |      |
| 5254.91    | 5254.929   | Fe II  | 26055.422              | -3.23    |      |
| 5256.92    | 5256.938   | Fe II  | 23317.632              | -4.25    |      |
| 5257.12    | 5257.122   | Fe II  | 84685.198              | 0.03     |      |
| 5260.24    | 5260.259   | Fe II  | 84035.139              | 1.07     |      |
| 5262.31    | 5262.317   | Fe II  | 85048.600              | -0.36    |      |
| 5264.18    | 5264.177   | Fe II  | 84710.686              | 0.36     |      |
| 5264.79    | 5264.812   | Fe II  | 26055.422              | -3.19    |      |
| 5272.39    | 5272.397   | Fe II  | 48039.087              | -2.03    |      |
| 5274.96    | 5274.964   | Cr II  | 32836.680              | -1.29    |      |
| 5275.98    | 5276.002   | Fe II  | 25805.329              | -1.94    |      |
| 5278.91    | 5278.938   | Fe II  | 47674.718              | -2.41    |      |
| 5279.87    | 5279.876   | Cr II  | 32854.311              | -2.10    |      |
| 5280.05    | 5280.054   | Cr II  | 32854.949              | -2.01    |      |
| 5284.09    | 5284.109   | Fe II  | 23317.632              | -3.19    |      |
| 5291.65    | 5291.666   | Fe II  | 84527.779              | 0.58     |      |
| 5298.85    | 5298.860   | Fe II  | 84844.832              | -1.13    |      |
| 5302.38    | 5302.402   | Mn II  | 79569.268              | 0.23     |      |
| 5303.40    | 5303.395   | Fe II  | 66012.752              | -1.61    |      |
| 5305.85    | 5305.853   | Cr II  | 30864.459              | -2.36    |      |
| 5306.17    | 5306.180   | Fe II  | 84870.863              | 0.22     |      |
| 5308.41    | 5308.408   | Cr II  | 32836.680              | -1.81    |      |
| 5310.68    | 5310.687   | Cr II  | 32844.760              | -2.28    |      |
| 5313.57    | 5313.563   | Cr II  | 32854.949              | -1.65    |      |
| 5315.07    | 5315.086   | Fe II  | 85048.600              | -0.38    |      |
| 5315.55    | 5315.563   | Fe II  | 66377.284              | -1.46    |      |
| 5316.21    | 5316.225   | Fe II  | 84035.139              | 0.34     |      |
| 5316.77    | 5316.784   | Fe II  | 25981.630              | -2.91    |      |
| 5318.06    | 5318.057   | Fe II  | 84527.779              | -0.14    |      |
| 5318.74    | 5318.750   | Fe II  | 84035.139              | -0.57    |      |
| 5322.23    | 5322.234   | Fe II  | 84326.910              | -0.52    |      |
| Corr. Id. | Lab. Id. | Ident. | $E_{low}$ (cm$^{-1}$) | log($gf$) | Rem. |
|-----------|---------|--------|----------------------|-----------|------|
| $\lambda$ (Å) | $\lambda$ (Å) | |
| 5324.18 | 5324.179 | Fe I | 25899.986 | -0.24 |
| 5325.55 | 5325.553 | Fe II | 25981.630 | -2.60 |
| 5329.12 | 5329.096 | O I | 86625.757 | -2.08 | triplet |
| 5329.70 | 5329.690 | O I | 86627.777 | -1.41 |
| 5330.76 | 5330.741 | O I | 86631.453 | -1.12 |
| 5334.86 | 5334.869 | Cr II | 32844.760 | -1.56 |
| 5336.78 | 5336.771 | Ti II | 12758.110 | -1.70 | broad |
| 5337.74 | 5337.732 | Fe II | 26055.422 | -3.89 |
| 5339.59 | 5339.585 | Fe II | 84296.829 | 0.54 |
| 5347.19 | 5347.190 | Fe II | 85172.810 | -0.28 |
| 5362.86 | 5362.869 | Fe II | 25805.329 | -2.74 |
| 5366.20 | 5366.207 | Fe II | 84710.686 | -0.27 |
| 5370.31 | 5370.309 | Fe II | 84710.686 | -0.82 |
| 5375.83 | 5375.827 | Fe II | 85048.600 | -0.75 |
| 5375.847 | 5375.847 | Fe II | 84296.829 | -0.29 |
| 5383.35 | 5383.369 | Fe I | 34782.420 | 0.50 |
| 5387.04 | 5387.063 | Fe II | 84863.353 | 0.52 |
| 5393.83 | 5393.847 | Fe II | 84296.829 | -0.30 |
| 5395.84 | 5395.857 | Fe II | 85495.303 | 0.36 |
| 5401.60 | 5401.521 | Mg II | 93799.630 | -0.45 | triplet broad |
| 5401.556 | 5401.556 | Mg II | 93799.750 | -1.88 |
| 5402.05 | 5402.059 | Fe II | 85184.734 | 0.50 |
| 5404.14 | 5404.117 | Fe I | 34782.420 | 0.54 |
| 5404.151 | 5404.151 | Fe I | 35767.561 | 0.52 |
| 5405.07 | 5405.099 | Fe II | 85184.734 | -1.01 |
| 5405.71 | 5405.663 | Fe II | 84870.863 | -0.44 |
| 5407.62 | 5407.604 | Cr II | 30864.459 | -2.09 |
| 5408.80 | 5408.811 | Fe II | 48039.087 | -2.39 |
| 5414.05 | 5414.073 | Fe II | 25981.630 | -3.79 |
| 5414.85 | 5414.862 | Cr II | 55023.098 | -1.78 |
| 5415.19 | 5415.199 | Fe I | 35379.205 | 0.50 |
| 5420.88 | 5420.922 | Cr II | 30307.439 | -2.36 |
| 5424.05 | 5424.068 | Fe I | 34843.954 | 0.52 |
| 5425.24 | 5425.257 | Fe II | 25808.329 | -3.36 |
| 5427.80 | 5427.826 | Fe II | 84292.193 | -1.66 |
| 5428.66 | 5428.655 | S II | 109560.686 | -0.01 |
| 5429.96 | 5429.988 | Fe II | 85462.859 | 0.46 |
| 5432.95 | 5432.967 | Fe II | 26352.767 | -3.63 |
| 5435.77 | 5435.775 | O I | 86627.777 | -1.66 |
| 5436.86 | 5436.862 | O I | 86631.453 | -1.51 |
| 5436.868 | 5436.868 | Cr II | 86980.102 | -0.47 |
| 5442.35 | 5442.351 | Fe II | 85048.600 | -0.30 |
| 5444.40 | 5444.387 | Fe II | 85495.303 | -0.18 |
| Corr. (Å) | Lab. (Å) | Ident. | $E_{low}$ (cm$^{-1}$) | log($g$) | Rem. |
|----------|----------|--------|---------------------|---------|------|
| 5445.79  | 5445.807 | Fe II  | 85048.600           | -0.11   |      |
| 5450.07  | 5450.099 | Fe II  | 85679.698           | -0.53   |      |
| 5453.83  | 5453.855 | S II   | 110268.595          | 0.56    |      |
| 5455.42  | 5455.454 | Fe I   | 34843.954           | 0.30    |      |
|          | 5455.879 | Cr II  | 33618.941           | -3.00   |      |
| 5455.90  | 5455.932 | Fe II  | 84527.779           | -0.52   |      |
| 5457.73  | 5457.730 | Fe II  | 85728.806           | -0.17   |      |
| 5465.93  | 5465.931 | Fe II  | 85679.698           | 0.52    |      |
| 5466.40  | 5466.461 | Si II  | 101023.046          | -0.20   |      |
| 5466.89  | 5466.849 | Si II  | 101024.349          | -1.34   |      |
|          | 5466.894 | Si II  | 101024.349          | -0.04   |      |
| 5473.59  | 5473.590 | Fe II  | 85172.810           | -0.79   |      |
|          | 5473.614 | S II   | 109560.686          | -0.12   |      |
| 5475.81  | 5475.829 | Fe II  | 84685.198           | -0.18   |      |
| 5478.36  | 5478.365 | Cr II  | 33694.151           | -1.91   |      |
| 5479.40  | 5479.401 | Fe II  | 85172.810           | -0.41   | triangular |
| 5482.30  | 5482.308 | Fe II  | 85184.734           | 0.43    |      |
| 5487.62  | 5487.619 | Fe II  | 85462.859           | 0.36    |      |
| 5492.08  | 5492.079 | Fe II  | 85679.698           | -0.18   |      |
| 5492.39  | 5492.399 | Fe II  | 84685.198           | -0.06   |      |
| 5493.82  | 5493.833 | Fe II  | 84685.198           | 0.21    |      |
| 5502.08  | 5502.067 | Cr II  | 33618.941           | -1.99   |      |
| 5502.67  | 5502.671 | Fe II  | 85184.734           | -0.14   |      |
| 5503.21  | 5503.211 | Fe II  | 84685.198           | -0.09   |      |
|          | 5503.212 | Cr II  | 33417.991           | -2.31   |      |
| 5506.18  | 5506.195 | Fe II  | 84863.353           | 0.95    |      |
| 5507.05  | 5507.072 | Fe II  | 84870.863           | -0.32   |      |
| 5508.61  | 5508.606 | Cr II  | 33521.110           | -2.11   |      |
| 5510.75  | 5510.779 | Fe II  | 85184.734           | 0.00    |      |
| 5525.12  | 5525.125 | Fe II  | 26352.767           | -4.61   | triangular |
| 5528.40  | 5528.405 | Mg I   | 35051.263           | -0.62   |      |
| 5529.06  | 5529.053 | Fe II  | 84870.863           | -0.25   |      |
| 5529.93  | 5529.932 | Fe II  | 54273.640           | -1.87   |      |
| 5532.08  | 5532.088 | Fe II  | 84870.863           | -0.33   |      |
| 5534.82  | 5534.847 | Fe II  | 26170.181           | -2.93   |      |
| 5544.76  | 5544.763 | Fe II  | 84863.353           | 0.12    |      |
| 5549.00  | 5549.001 | Fe II  | 84870.863           | -0.23   |      |
| 5554.93  | 5554.914 | Fe II  | 85679.698           | -0.64   |      |
| 5567.84  | 5567.842 | Fe II  | 54283.218           | -1.89   |      |
| 5577.94  | 5577.915 | Fe II  | 85462.859           | -0.14   |      |
| 5586.77  | 5586.756 | Fe I   | 27166.817           | -0.21   |      |
| 5587.08  | 5587.114 | Fe II  | 54275.638           | -2.18   |      |
| 5588.21  | 5588.220 | Fe II  | 85462.859           | 0.09    |      |
| 5593.27  | 5593.300 | Al II  | 106920.564          | 0.41    |      |
Table 5—Continued

| Corr. $\lambda$ (Å) | Lab. $\lambda$ (Å) | Ident. | $E_{low}$ (cm$^{-1}$) | $\log(gf)$ | Rem. |
|---------------------|---------------------|--------|-----------------------|-------------|------|
| 5606.14             | 5606.151            | S II   | 110766.562           | 0.16        |      |
| 5615.61             | 5615.644            | Fe I   | 26874.547            | -0.14       |      |
| 5627.47             | 5627.458            | Cr II  | 87858.560            | 0.21        |      |
| 5640.32             | 5640.346            | S II   | 110508.706           | 0.15        |      |
| 5643.86             | 5643.880            | Fe II  | 61726.078            | -1.46       |      |
| 5645.38             | 5645.392            | Fe II  | 85184.734            | 0.08        |      |
| 5648.90             | 5648.904            | Fe II  | 85184.734            | -0.24       |      |
| 5657.91             | 5657.935            | Fe II  | 27620.411            | -4.10       |      |
| 5658.18             | 5658.111            | Ni II  | 53037.932            | -2.15       |      |
| 5658.79             | 5658.820            | Fe II  | 85184.734            | -0.72       |      |
| 5659.98             | 5660.001            | S II   | 110313.403           | -0.07       |      |
| 5691.00             | 5690.994            | Fe II  | 86124.299            | -0.20       |      |
| 5716.50             | 5716.59             | Fe II  | 62689.878            | -2.26       | broad |
| 5726.55             | 5726.557            | Fe II  | 86416.331            | -0.02       |      |
| 5747.87             | 5747.884            | Fe IV  | 44929.549            | -2.91       |      |
| 5780.13             | 5780.128            | Fe II  | 86124.299            | 0.32        |      |
| 5780.35             | 5780.336            | Fe II  | 86416.331            | -0.37       |      |
| 5783.61             | 5783.630            | Fe II  | 86416.331            | 0.21        |      |
| 5784.43             | 5784.448            | Fe II  | 86599.737            | 0.06        |      |
| 5813.67             | 5813.677            | Fe II  | 44929.549            | -2.75       |      |
| 5835.48             | 5835.492            | Fe II  | 47674.718            | -2.37       | triangular |
| 5854.19             | 5854.192            | Fe II  | 86599.737            | -0.19       |      |
| 5875.10             | 5875.097            | Fe II  | 87572.430            | -2.36       |      |
| 5875.614            | 5875.614            | He I   | 169086.766           | -0.339      |      |
| 5875.615            | 5875.615            | He I   | 169086.766           | -0.409      |      |
| 5875.625            | 5875.625            | He I   | 169086.843           | -0.339      |      |
| 5875.640            | 5875.640            | He I   | 169086.843           | 0.138       |      |
| 5957.56             | 5957.559            | Si II  | 81191.341            | -0.30       |      |
| 5978.93             | 5978.930            | Si II  | 81251.320            | 0.00        |      |
| 5990.97             | 5990.980            | C I    | 69710.660            | -3.58       |      |
| 5991.36             | 5991.376            | Fe II  | 25428.783            | -3.56       |      |
| 6071.38             | 6071.426            | Fe II  | 86416.331            | -0.19       |      |
| 6084.09             | 6084.111            | Fe II  | 25805.329            | -3.81       |      |
| 6103.49             | 6103.496            | Fe II  | 50142.788            | -2.17       | triangular |
| 6113.31             | 6113.322            | Fe II  | 25981.630            | -4.16       |      |
| 6143.04             | 6143.026            | Fe II  | 60956.779            | -3.82       |      |
| 6147.74             | 6147.741            | Fe II  | 31364.440            | -2.72       |      |
| 6149.25             | 6149.258            | Fe II  | 31368.450            | -2.72       |      |
| 6155.98             | 6155.961            | O I    | 86625.757            | -1.40       | 3 lines |
| 6156.78             | 6156.778            | O I    | 86627.777            | -0.73       | 3 lines |
| 6158.18             | 6158.187            | O I    | 86631.453            | -0.44       | 3 lines |
| 6175.13             | 6175.146            | Fe II  | 50187.813            | -1.98       |      |
| 6179.39             | 6179.384            | Fe II  | 44915.046            | -2.60       |      |
| 6239.79             | 6231.750            | Al II  | 105441.498           | 0.40        |      |
Table 5—Continued

| Corr. λ (Å) | Lab. λ (Å) | Ident. | $E_{low}$ (cm$^{-1}$) | log($gf$) | Rem. |
|-------------|------------|--------|-----------------------|-----------|------|
| 6238.39     | 6238.392   | Fe II  | 31364.440             | -2.63     |      |
| 6239.62     | 6239.614   | Si II  | 103556.025            | 0.19      | 3 lines |
| 6239.93     | 6239.953   | Fe II  | 31368.450             | -3.44     |      |
| 6243.40     | 6243.367   | Al II  | 105470.928            | 0.67      |      |
| 6247.55     | 6247.557   | Fe II  | 31387.949             | -2.33     |      |
| 6347.09     | 6347.109   | Si II  | 65500.472             | 0.30      | broad |
| 6371.35     | 6371.371   | Si II  | 65500.472             | 0.00      | broad |
| 6402.23     | 6402.246   | Na I   | 134041.838            | 0.36      |      |
| 6416.92     | 6416.919   | Fe II  | 31387.949             | -2.74     |      |