The Herbig Ae Star PDS2

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Abstract We present a preliminary abundance analysis of the isolated Herbig Ae star PDS2 (CD -53 251, 2MASS J01174349-5233307). Our adopted model has $T_{\text{eff}} = 6500\text{K}$, $\log(g) = 3.5$. It is likely that PDS2 belongs to the class of young stars with abundances resembling the $\lambda$ Bootis stars.

1. Introduction

PDS2 was noted in the Pico dos Dias (PDS) survey of the IRAS Point Source Catalog of objects as a possible Herbig Ae or Be star. Vieira, et al. [8] discuss the PDS survey in addition to giving photometric data as a part of their large study of HAe/Be candidate stars. They assign a distance of 340 pc, and give the colors $U-B = 0.01$, and $B-V = 0.38$. Sartori, et al. [7] included PDS2 in their analysis of Herbig Ae/Be candidates, and classified its SED as Group 2, with “far-IR emission corresponding to intermediate values of IR excess.” Bernabi, et al. [2], and Marconi, et al. [5], have studied pulsations of PDS2, while Hubrig, et al. [4] announced a detectable magnetic field.

In addition to these interesting properties, PDS2 is a young object at quite a high galactic latitude with no obvious relation to a star-forming region. Nevertheless, its claim to youth is based on its infrared colors and mass accretion rate (Pogodin, et al. [6]).

2. Observations of the present study

This work is based primarily on HARPS spectra of PDS2 obtained from the ESO archive. We downloaded two sets of nine spectra, obtained on the nights of 11/12 November 2008. An additional nine were obtained on 13 November 2008. On each night, the spectra were taken within a few hours of one another. We attempted to allow for the small differences in radial velocity, but ultimately concluded that straight averages (for each night)
were better. The averaged spectra were still rather noisy. The spectra from 11 December were clearly of higher quality than those from 13 November; all measurements were therefore based on the former set of spectra. We worked from a Fourier-filtered spectrum, illustrated in Fig. 1.

In addition to the HARPS spectra, we used X-shooter spectra obtained on 28 June 2010 by Pogodin, et al. [6].

3. Fixing the atmospheric parameters

As a part of their work on accretion, Pogodin, et al. [6] made an effort to fix the model atmospheric parameters for PDS2. They concluded that $T_{\text{eff}} = 7000\text{K}$, $\log(g) = 4.0$, and $v\sin(i) = 30\text{ km s}^{-1}$. It is particularly straightforward to refine the atmospheric parameters of stars in this temperature-gravity range as:
Figure 2. Observed (x-shooter, (black) and calculated (red/gray) profile for $T_{\text{eff}} = 6500$K.

- the Balmer lines are very sensitive to $T_{\text{eff}}$, and nearly insensitive to gravity;
- the lines of species such as Fe I, Cr I, or Ni I are similarly insensitive to gravity;
- one can determine the Fe abundance from weak Fe I (or other neutral metallic) lines, and the microturbulence, $\xi_t$, from strong Fe I lines; and
- the surface gravity then follows from corresponding lines of the second spectra (e.g. Fe II, Ni II, etc.).

Very good agreement for the Balmer profiles was obtained from models with $T_{\text{eff}} = 6500$ K, both from HARPS and x-shooter spectra. The problem
Table 1. Abundances of several elements in PDS2.

| El    | log($N/N_{tot}$) ±(sd) | n | (log($N/N_{tot}$)$_\odot$) | [N] |
|-------|------------------------|---|---------------------------|-----|
| C I   | 3.53 0.14 3            |   | 3.61                      | +0.08 |
| S I   | 4.85 0.06 6            |   | 4.92                      | +0.07 |
| Ti I  | 7.08 0.16 6            |   | 7.09                      | +0.01 |
| Ti II | 7.21 0.07 3            |   | 7.09                      | -0.11 |
| Cr I  | 6.52 0.31 12           |   | 6.40                      | -0.12 |
| Cr II | 6.49 0.06 11           |   | 6.40                      | -0.09 |
| Fe I  | 4.83 0.09 8            |   | 4.54                      | -0.29 |
| Fe II | 4.76 0.13 17           |   | 4.54                      | -0.22 |
| Zn I  | 7.76 0.13 3            |   | 7.48                      | -0.28 |

of normalization of echelle spectra was palliated somewhat by the narrower profiles of the relatively cool PDS2, compared to hotter Herbig Ae stars. Additionally, the part of the profiles most sensitive to the temperature is the near wing, where the line depths vary from ca. 0.15 to 0.4. A calculated H$_\gamma$ profile for $T_{\text{eff}}$ = 6600K is slightly too strong, but perhaps acceptable. The fit for $T_{\text{eff}}$ = 6700 is unacceptable.

An overall check on the atmospheric parameters is to see that abundances from weak lines of the first and second spectra of well-determined species agree (see Tab. 1). From the iron and titanium equilibria, we conclude that PDS has a somewhat lower gravity than Procyon—we adopt log($g$) = 3.5.

4. The metal lines

Fig. 3 contrasts a HARPS spectrum PDS2 (black) with a UVESPOP archival spectrum [1] of Procyon (red/gray). The Procyon spectrum was convoluted with a $v\sin(i) = 10$ km s$^{-1}$ rotational profile to approximately match the observed PDS spectrum.

Generally, the metallic lines in Procyon are stronger, indicating slightly larger abundances, as is found from an equivalent width analysis. Because the numerous neutral lines are insensitive to gravity, and the temperatures of the two stars are nearly the same, within the errors, this is a direct indication of relative metal weakness in PDS2. Note that the two S I lines
not influenced by blending are not weaker in PDS2. This again comports with the quantitative analysis, and the overall assessment that PDS2 shows mild λ Boo characteristics, since sulfur is a volatile element.

5. Conclusions

The abundances in PDS2 depart mildly from solar. However, they do so systematically, showing mild depletions of refractory elements. The volatile elements have normal abundances, with the exception of zinc, which is clearly depleted. This zinc anomaly is a problem for theories that suggest volatility as a key to the abundance pattern. The same difficulty holds for the λ Boo stars, as noted, for example, by Heiter [5].

Figure 3. Metal and neutral sulfur lines in Procyon (red/gray) and PDS2 (black). Decimal fractions of wavelengths (in Angstroms) are given.
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