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Spectral analysis of the binary sdB star Feige 36

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Abstract. The sdB stars Feige 36 is a short-period, single-lined spectroscopic binary. Atmospheric parameters and abundances are determined from high-resolution Keck spectra. Feige 36 lies near the zero-age extreme Horizontal Branch position in the HRD. Line shifts of He I, 6678Å and 4921Å are likely to be caused by an ^{3}He/^{4}He isotopic anomaly. He, C,O, and Mg are found to be strongly depleted (≈1 dex), while the underabundance of N, Al, and Si is smaller (0.4–0.7dex). S and Fe are almost solar, whereas Ar is even enriched. This puzzling abundance pattern is probably caused by diffusion.

1. Introduction

The sdB star Feige 36 was recently discovered to display periodic radial velocity variations. The amplitude of K=134.6km/s and a period of 8.503h was determined from low resolution optical spectra (Saffer & Reid, in prep.). Hence it is a close binary system consisting of a hot sdB star and a cool companion unseen in the spectra. The system belongs to a rare case of binaries like HW Vir or AA Dor. Heber (1992) lists seven similar to Feige 36 with known periods between 0.12 d and 872d. Recently, Saffer et al. (1998), Koen et al. (1998) and Kilkenny et al. (1998) added another seven sdB binaries with undetected companions and determined orbital periods.

2. Spectral Analysis

A low resolution blue (3700Å – 5100Å) spectrum was obtained at KPNO (R. Saffer) and two high resolution optical spectra were taken with the HIRES spectrograph at the Keck I telescope covering the wavelength range from 4280Å to 6710Å. We present a quantitative spectral analysis of these data. Fully line blanketed LTE models as well as partially blanketed NLTE models (Napiwotzki

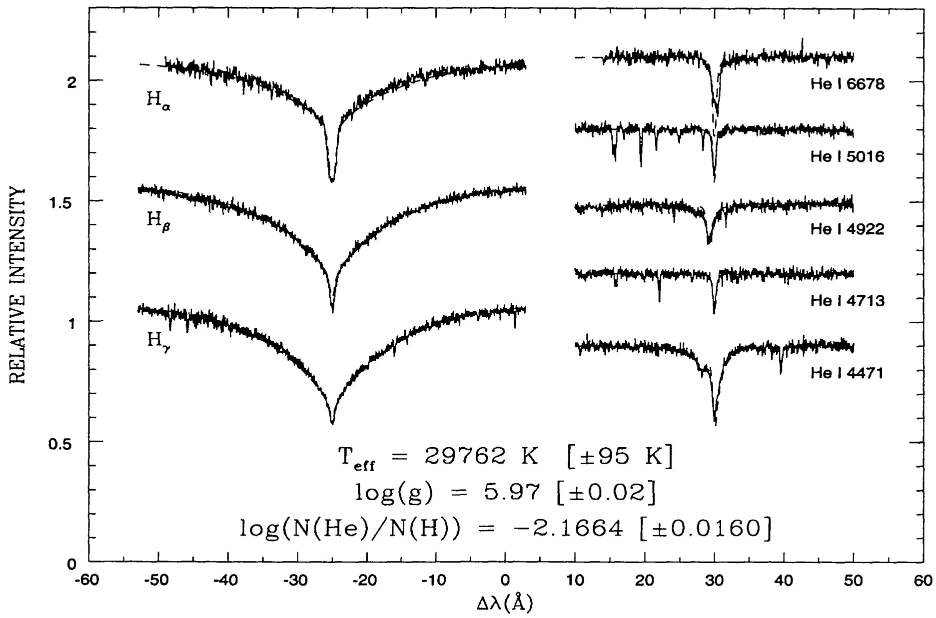

Figure 1. Fit of Balmer and He I lines (Keck spectrum) of Feige 36 using the grid of NLTE model atmospheres of Napiwotzki (1997).

1997) are used to determine effective temperature, gravity and helium abundance from the Balmer and He I lines observed at low and high spectral resolution.

The atmospheric parameters were derived from the low and high resolution spectra using the NLTE model atmosphere grid of Napiwotzki (1997) and calculating the χ^2 deviations using a modified version of Bergeron and Saffer's computer program (see Saffer et al., 1994). The fit of the He I and Balmer lines from the Keck spectrum is shown in Fig. 1.

The results from low and high resolution spectra agree within error bars:

low resolution:	$T_{\rm eff} = 29\,500$ K,	$\log g = 5.84$,	$\log(n_{\rm He}/n_{\rm H}) = -2.00$.
high resolution:	$T_{\rm eff} = 29\,800$ K,	$\log g = 5.97$,	$\log(n_{\rm He}/n_{\rm H}) = -2.17$.
adopted:	$T_{\rm eff} = 29\,700$ K,	$\log g = 5.9$,	$\log(n_{\rm He}/n_{\rm H}) = -2.1$.

Helium is deficient by about 1 dex, which is typical for sdB stars as are the derived temperature and gravity.

The subluminous B stars have been identified with the extended (or extreme) Horizontal Branch (EHB, Heber, 1986). Its atmospheric parameters place Feige 36 close to the zero age EHB in the $T_{\rm eff}$, $\log g$ plane confirming that it is in the core helium burning phase of evolution.

3. Helium Line Shifts

Line shifts of the He I lines 4921Å and 6678Å (see Fig. 2) are observed in the Keck spectrum while the He I line 4713Å is unshifted (see Fig. 2). This is

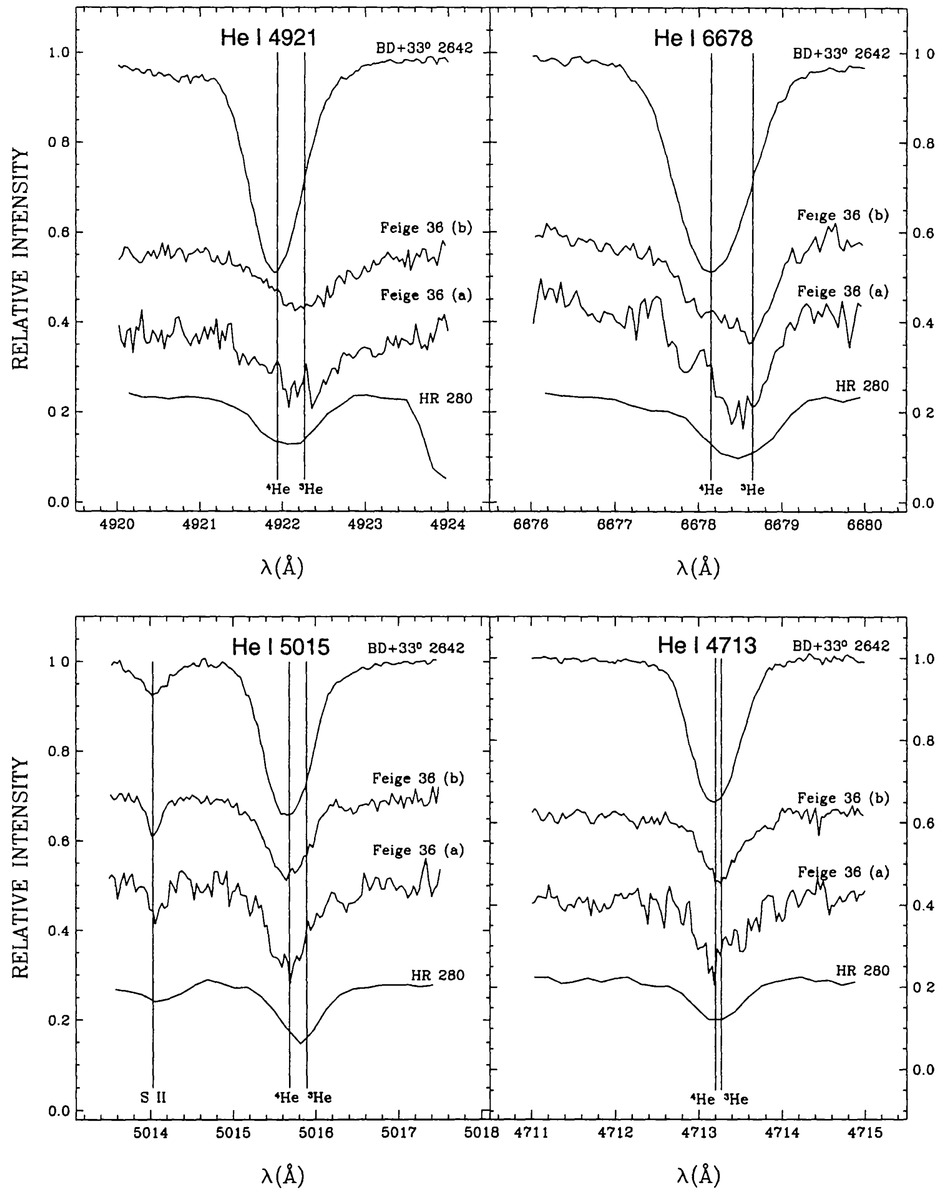

Figure 2. Observed line profiles of He I 4921Å and 6678Å (upper panel) He I 4713Å and 5015Å (lower panel) of Feige 36 (2 Keck spectra) compared to the PAGB star BD+33°2641 and the ^{3}He star HR 280 (Hartoog & Cowley (1979). The laboratory line positions (^{3}He and ^{4}He) are marked. Note the displacement of He I 4921Å and 6678Å (upper panel) towards the ^{3}He position in Feige 36 and HR 280. He I 4713Å is unshifted, consistent with the laboratory data in all stars. He I 5015Å does not show the expected shift in Feige 36, see text.

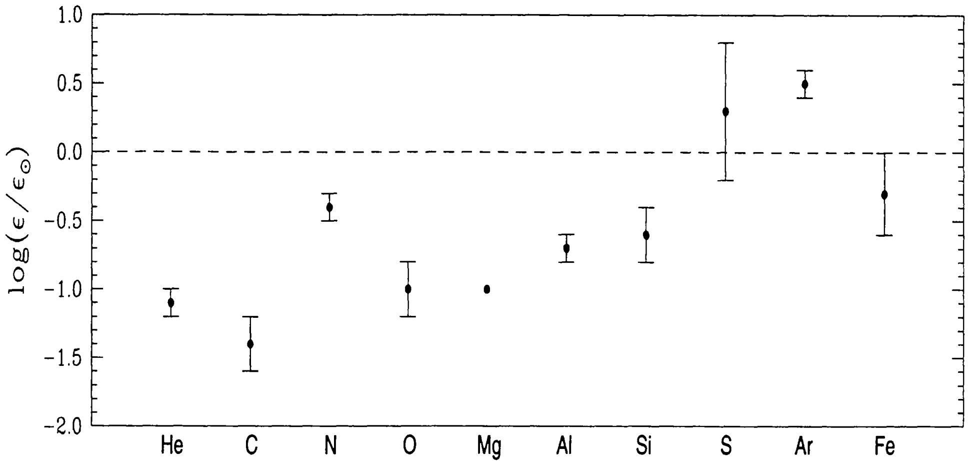

Figure 3. Resulting elemental abundances of Feige 36 relative to the solar values.

consistent with the isotopic line shifts for ^{3}He. Laboratory measurements (Fred et al., 1951) indicate that 6678Å and 4921Å display the largest isotopic line shifts of all He I lines in the observed spectral range whereas for 4713Å only a very small isotopic shift has been measured in the laboratory. Therefore it might be tempting to attribute the line shift to the presence of a large amount of ^{3}He in the atmosphere of Feige 36. However, the He I 5015Å line does not show the line shift expected from experiment. This puzzle can only be solved by detailed modelling of the blended line profiles, which is beyond the scope of this paper. If the line shifts are confirmed to be caused by the ^{3}He isotope anomaly, Feige 36 would be only the second sdB star (besides SB 290, Heber, 1991) and the fifth blue Horizontal Branch star known to show this anomaly (Heber, 1991).

4. Abundance Analysis

Spectral lines of the species C II, N II, O II, Mg II, Al III, Si III, S II, S III, Ar II and Fe III can be identified.

Measured equivalent widths are analysed using curves of growth calculated from line blanketed LTE model atmospheres. Figure 3 plots the mean abundances relative to the sun. A vanishing microturbulent velocity is consistent with the N II and O II data, although a microturbulent velocity as high as 5km/s cannot be ruled out. Carbon, oxygen and magnesium are depleted by about 1 dex or more with respect to solar composition whereas nitrogen, aluminium and silicon are only slightly depleted and sulfur and iron are almost solar. Argon is even slightly enriched.

The ^{3}He isotope anomaly and the non-solar abundance pattern are probably caused by diffusion, i.e. by the interplay of gravitational settling and radiative levitation.

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