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High Resolution Spectroscopy of the Star Feige 34

Han I.[1], Burlakova T.[2], Valyavin G.[3], Kim H. S.[4], Galazutdinov G.[5], Zharikov S. V.[3], Lee B.–C.[1], Kim K.–M.[1], Kholtygin A.[6], Shulyak D.[7], Chavez M.[8], Bertone E.[8]

[1] Korea Astronomy and Space Science Institute, Youseong–Gu, Daejeon, Republic of Korea
[2] Special Astrophysical Observatory, Nizhny Arkhyz, Russia
[3] Observatorio Astronómico Nacional SPM, Instituto de Astronomía, Universidad Nacional Autónoma de México, Ensenada, BC, México
[4] Department of Astronomy and Atmospheric Science, Kyungpook National University, Daegu, Korea
[5] Department of Astronomy and Atmospheric Science, Seoul National University, Seoul, Korea
[6] Sobolev Astronomical institute, St.–Petersburg State University, Russia
[7] Institute of Astrophysics, Göttingen University, Göttingen, Germany
[8] INAOE — Instituto Nacional de astrofísica, Óptica, y Electrónica, Tonantzintla, Puebla, Mexico

Abstract. We present high–resolution spectral observations of the hot subdwarf sdO star Feige 34. The stellar spectrum demonstrates absorption Balmer and He II lines superposed with a narrow Hα emission, typical for hot subdwarfs. As suggested in several previous studies, this emission may be originated from the orbiting red dwarf companion, or from a giant Jovian planet. To examine this possibility we have carried out an extensive set of high–precision measurements of the star's radial velocity variation. Measurements of all the spectral features revealed no signatures of the variability on characteristic times from days to a few years. No evidences for the presence of any anticorrelation between the radial velocities measured by absorption and emission spectral lines due to spectroscopic binarity were found with an amplitude higher than 0.5 ± 0.4 km/s. These findings support an idea that the observed emission is just a non–LTE inversion in the uppermost atmospheric layers of the subdwarf.

Key words: stars: individual (Feige 34) – stars: radial velocity variation – stars: hot subdwarf stars

1 Introduction

Hot sdB and very hot sdO subdwarf stars (Greenstein & Sargent, 1974; Heber, 1986; Saffer et al., 1994; Williams et al., 2001a,b; Maxted, 2004) represent a late evolutionary stage of some stars during their evolution to white dwarfs. These stars are located at the blue end of the Horizontal Branch (HB), forming the so–called Extended Horizontal Branch stars (EHB, for details see Greenstein & Sargent, 1974).

The spectral analysis of sdB stars (Saffer et al., 1994) has shown that they possess hydrogen–dominated atmospheres with $T_{eff} \approx 30000$ K and considerable gravities ($5 \leq \log g \leq 6.5$). Except for hydrogen, their spectra often indicate the presence of helium and some other elements in their atmospheres. Generally, the sdB stars are understood as a homogeneous class of stars (Greenstein & Sargent, 1974; Maxted, 2004) having helium burning cores of nearly white dwarf masses ($\sim 0.6\, M_{\odot}$), and very low mass hydrogen envelopes ($\leq 0.02\, M_{\odot}$, Saffer et al., 1994).

In contrast to sdBs, very hot sdO stars are likely to be a heterogeneous group of stars (Maxted, 2004, and references therein), exhibiting a wider range of gravities and luminosities than the sdB stars. They have helium–enriched atmospheres with temperatures much higher than the sdB stars.

While the evolutionary status of all hot subdwarf stars is more or less well understood, the question of how they arrived at the EHB is still open to debate (Stark & Wade, 2003, see introduction in, and references therein). In particular, there is still no unambiguous answer to the question of whether the hot subdwarf stars (or part of them) descend from single red giant progenitor stars. What are the evolutionary mechanisms which could lead the stars to become the core helium burning objects with such low hydrogen envelope masses? How did the giant progenitors of these stars loose their envelopes? Interaction of stars in binary systems (Mengel et al., 1976) could be among the reasons for such a premature mass loss. Motivated by these reasons, we have undertaken collaborative high-resolution spectral monitoring of some individual brighter hot subdwarfs, which could be observed in the high–resolution spectral mode with 2–m class telescopes.

In this study we present first results of spectral, multi-epoch observations of the sdO star Feige 34. We analyse the binarity of Feige 34 first suspected by Thejll et al. (1991) via photometric observations of the abnormal flux excess at long wavelengths indicative of the presence of an unresolved late–type component.

2 Observations and Data Reduction

The observations of the star Feige 34 were carried out with the high–resolution Echelle Spectrograph (BOES) of the Bonhuynsan Observatory installed at the 1.8–m telescope of the Korean Astronomy and Space Science Institute. The spectrograph and observational procedures are described by Kim et al. (2000, 2007). The instrument is a moderate–beam, fibre–fed high–resolution spectrograph which incorporates 3 STU Polymicro fibres of 300, 200, and 80 μm core diameter (corresponding spectral resolutions are $\lambda/\Delta\lambda = 30\,000$, 45 000, and 90 000 respectively). The lower (R 30 000) resolution mode was employed in the present study.

These observations were also supported by an observing run at the 2.1–m telescope of the San–Pedro Martir Astronomical Observatory of the National Astronomical University of Mexico (Observatorio Astronómico Nacional, SPM: OAN SPM). With this instrument we obtained additional series of spectra of Feige 34 using their moderate–dispersion, high–resolution echelle–spectrograph (HiRes from here and hereafter) with the resolving power of about 20 000 and effective working wavelength range from 4000 Å to about 8000 Å.

About 101 spectra of Feige 34 were recorded in the course of about 20 observing nights from January 2006 to April 2008. Typical exposure times from 10 min (at the HiRes of the OAN SPM) to 30 min (at the BOES) allowed to achieve $S/N \sim 20$ at each of the individual exposures.

The reduction of spectral material was carried out using the DECH image processing code (Galazutdinov, 1992) as well as IRAF packages. The general steps are standard and include the removal cosmic ray traces, the subtraction of the electronic bias and scattered light, the extraction of spectral orders, division by the flat–field spectrum, normalization to the continuum and wavelength calibration.

In Fig. 1 we present all the observable spectral features which were used for radial velocity measurement. The Hα line has central inversion core first observed by Tytler & Rubenstein (1988). This emission could be due to the presence of an orbiting cool M or K red dwarf component, or a non–LTE effect of the subdwarf's atmosphere. The investigation of a probable anticorrelated behaviour of radial velocities measured by this inversion peak with radial velocities measured by all the other absorption lines was the main goal of current presentation.

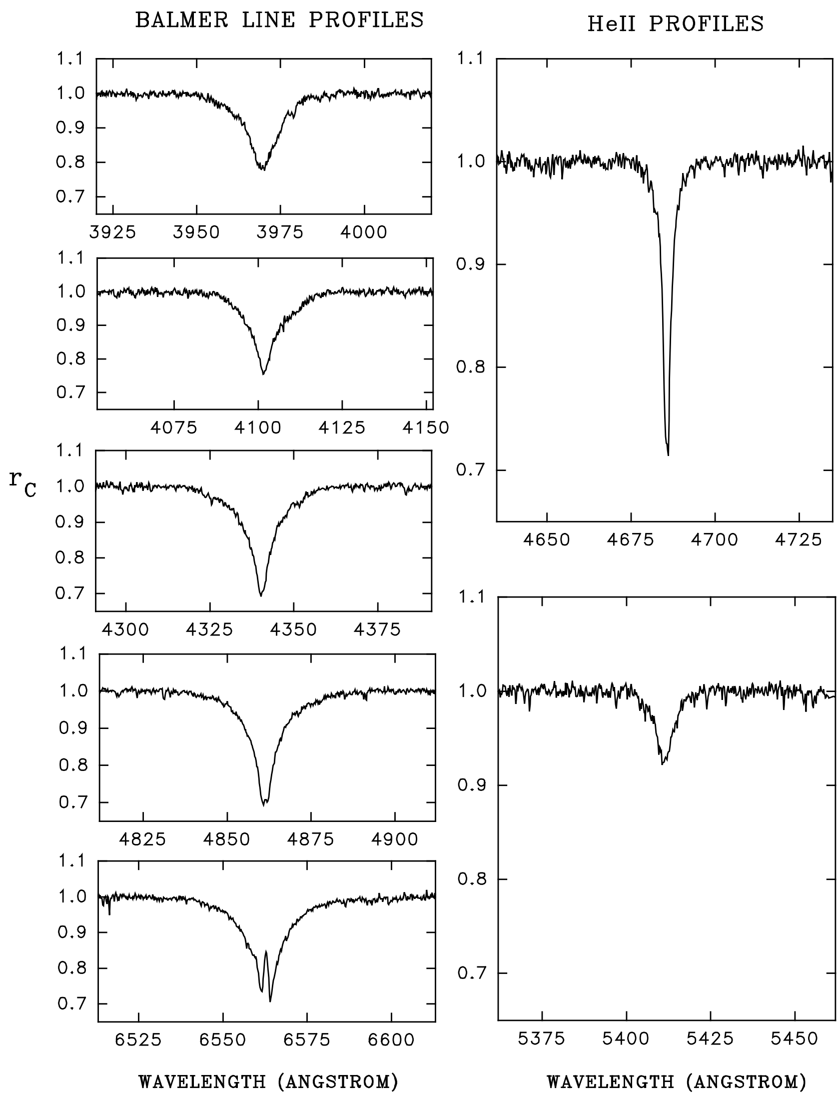

Figure 1: The Balmer (left plot) and He II (right plot) line profiles obtained during the high–resolution (R 30 000) spectral observations with the BOES

3 Search for Radial Velocity Variations in Feige 34

For the search of radial velocity variation we used the standard cross-correlation method. These relative measurements were then transformed to absolute heliocentric radial velocities of the star in order to use similar measurements for this star performed by other authors (Maxted et al., 2001) several years earlier.

Weighting and averaging individual data, we derived mean radial velocity of -12.8 ± 0.3 km/s based on the measurements of the Hα emission, and -12.0 ± 0.5 km/s from the measurements of the helium absorption line. No signatures for anticorrelation, typical for binary stars were found on the time scale of about one thousand days. This finding supports the idea that the observed emission is just a non–LTE inversion in the uppermost atmospheric layers of the hot subdwarf. (However, this may also imply that the amplitude of the variation is below the detection limit due to a very low mass of the companion, or nearly zero $\sin i$ of the orbital orientation.)

4 Discussion

We have presented new high–resolution spectral observations of the hot sdO subdwarf star Feige 34. The stellar spectrum demonstrates typical for the hot subdwarfs absorption Balmer and hydrogen lines, superposed with a narrow Hα emission component.

Our measurements have shown that there is no any difference in radial velocities measured using the group of absorbtion lines and separatively by the Hα emission (the group "Emission"). For both groups, the measurements are very well correlated with each other. We therefore conclude that even if the anticorrelation in radial velocities due to an orbiting star exists, its amplitude should be lower than 0.5 km/s. In this case, assuming the hot subdwarf's mass to be of $0.6\,M_{\odot}$, orbital inclination $i = 45°$ and one year orbital period, this amplitude corresponds to an orbiting planet of about $0.01\,M_{\odot}$. Or, assuming the secondary component to be a $0.6\,M_{\odot}$ red dwarf, emitting the Hα emission, we meet face–to–face with a nearly zero orbital inclination, and/or very long, hundred of years, orbital periods. Alternatively, we assume that the observed Hα emission is an intrinsic property of the star's non–LTE atmosphere.

We also rule out the possibility of a nebular origin of this emission. As suggested by Chu et al. (2001), a large flux from the Hα emission component and its shape with an FWHM of $\sim$70 km/s rule out a hypothesis of an interstellar origin of this emission. The absence of forbidden-line emissions as well excludes the possibility that the Hα emission arises from a typical circumstellar planetary nebula.

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