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Feige 86

Gaia confirms its Horizontal Branch nature

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Abstract. The halo star Feige 86 was considered in the 1960’s and 1970’s a solar metallicity chemically peculiar, He-weak B type star. Margherita Hack was the first to study its UV spectrum acquired with the IUE satellite. Later studies of this star by Hack and collaborators suggested that, in spite of the fact its iron abundance is slightly above solar, the star is a Pop II Horizontal Branch star. The high abundance of Fe and other iron-peak elements is due to an atmospheric phenomenon, probably related to diffusion, that increases their abundance above the intrinsic abundance of the star. The parallax measured by the Gaia satellite confirms this hypothesis and makes this bright star an ideal prototype of stars in this evolutionary state.

Key words. Stars: Population II – Stars: horizontal-branch – Stars: individual: Feige 86

1. Introduction

Feige 86, also known as BD +30 2431, was included as number 86 in the list of “underluminous blue stars”, by Feige (1958), based on plates of the National Geographic - Palomar Sky Survey. This research followed the analogous research of Humason & Zwicky (1947) that was initially aimed at finding white dwarfs at high Galactic Latitude, but although it did find some, many of these “faint blue stars” are of different catagories “remote main-sequence stars, horizontal-branch and galactic-halo stars, underluminous hot stars” (Feige, 1958). The first high resolution spectroscopic study of this star is due to Sargent & Searle (1967) who noted the weakness of the He I lines for a star of this colour and a large number of faint and sharp P II lines, not observed in normal B-type stars. Apart from these peculiarities the metallicity appeared to be solar. Sargent & Searle (1967) also noticed the similarity of the spectrum of Feige 86 with that of the B peculiar star 3 Cen A. From this point on Feige 86 was considered a Pop I star with chemical peculiarities. In the attempt to better understand the nature of this star, Margherita Hack observed its spectrum with the IUE satellite at low resolution (Hack 1979) and high resolution (Hack 1980). In these papers she could confirm the stellar parameters of optical investigations, however a full chemical investigation of these IUE spectra had to wait fifteen more years and many complementary

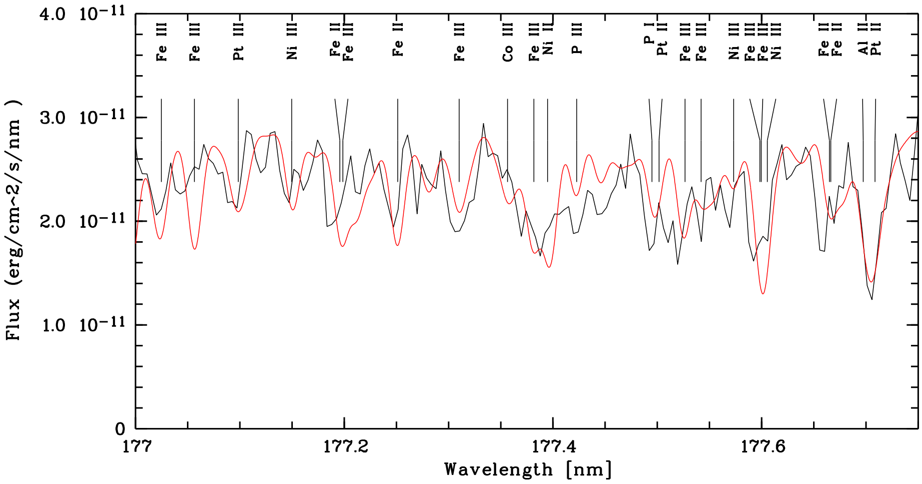

Fig. 1. A portion of IUE high resolution spectrum SWP20127, compared with a synthetic spectrum computed using the stellar parameters and abundances of Bonifacio et al. (1995)

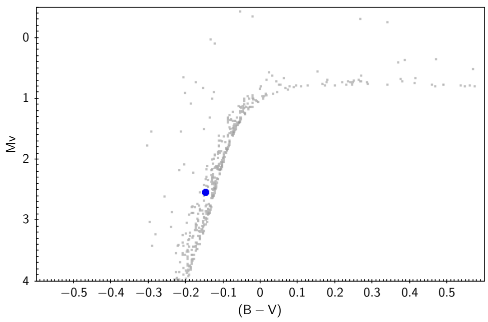

Fig. 2. The position of Feige 86 in the colour-magnitude diagram (blue dot). Compared with a synthetic HB.

ground based observations (Bonifacio, Castelli & Hack 1995). The UV spectrum of a B star is very complicated to intepret, full of blends, dominated by doubly ionized species for many of which wavelengths and gf values are poorly known, as illustrated in Fig.1.

Bonifacio et al. (1995) determined T_{eff} = 16430 K and log g = 4.20 and the abundances for 32 elements. The surface gravity is in agreement with log g = 4.12, derived from the Gaia parallax. The higher gravity of log g = 4.56 derived by the NLTE analysis of Németh (2017) is not consistent with the Gaia parallax. Kafando et al. (2016) re-analysed the UVES spectrum observed by Hubrig et al. (2009) and deduced similar effective temperature T_{eff} = 16111 K and but a lower surface gravity g = 3.78, however with a large error of *pm*0.6 dex that makes it compatible with the surface gravity implied by the Gaia parallax. With the parameters and abundances of Bonifacio et al. (1995), we computed an ATLAS 12 model and synthetic spectra. In Fig. 1 we show a portion of one of the high resolution IUE spectra. In particular we note the Pt II 177.7086 nm line, that is blended with the 177.6973 nm Al II line. The rest of the spectrum is poorly reproduced, although the Pt II 177.5016 nm and 177.0985 nm Pt III lines can be probably be safely detected as is the P III 177.4228 nm line, albeit probably with a wrong gf value in the computed spectrum.

2. A Horizontal Branch star!

The super solar iron abundance ([Fe/H]=+0.36) and the similarity with 3 Cen A had convinced the community that Feige 86 is a Pop I peculiar B star. Bonifacio, Castelli & Hack (1995) examined the kinematics of Feige 86, adopting a photometric parallax and found that it is inconsistent with that of a thin disc Pop I star, they thus concluded that Feige 86 is a Pop II Horizontal

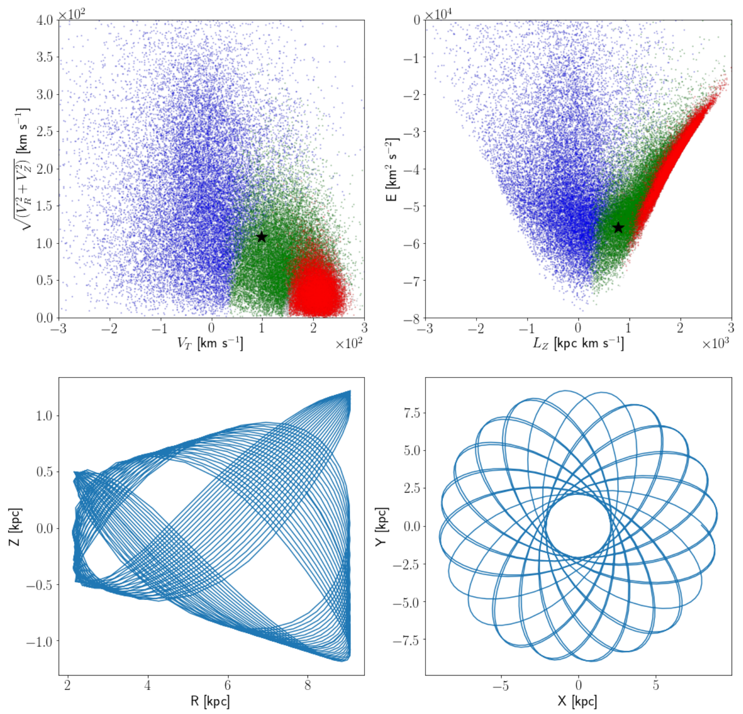

Fig. 3. Toomre diagram, Energy-angular momentum diagram and orbit of Feige 86, shown as a black star symbol. The background sample stars, shown in blue are the Turn-Off stars of Bonifacio et al. (2021).

Branch star. Its "intrinsic" metallicity is probably –0.5 or –1.0 and the photospheric supersolar abundance is the result of some atmospheric phenomenon, probably diffusion, responsible also for low He abundace, the ratio ^{3}He/^{4}He = 0.28 (Caffau et al. 2014) and the high abundance of P. We now have a precise parallax and proper motions for this star and we can re-examine the issue. In Fig. 2 we show a colour-magnitude diagram with the position of Feige 86, compared with a BASTI synthetic HB (http://basti.oa-teramo.inaf.it/, evolutionary tracks from Pietrinferni et al. 2004, 2006) for a metallicity Z = 0.0080 and a chemical composition with $[\alpha/Fe]$=+0.4. The synthetic HB is derived from the theoretical evolutionary tracks in the BASTI database, and the user specifies a mean mass for the HB stars and a dispersion in masses, the code assumes a gaussian distribution of masses. For the HB shown in Fig. 2 we specified a mean mass of 0.49 $M_{\odot}$ with a dispersion of 0.05 $M_{\odot}$. Using the Gaia parallax and proper motions we can integrate its orbit for an assumed Galactic Potential. We used the `galpy` code (http://github.com/jobovy/galpy, Bovy et al. 2015) to compute orbital parameters and actions using the `MWPotential2014` potential. This potential is fully described in Bovy et a. (2015), and is the result of a fit to some observational constraints. It is an axysymmetric potential with an exponential bulge, that is cut-off 1.9 kpc from the centre, a Halo of NFW type (Navarro Frenk & White,

1997) with a scale radius of 16 kpc and a disc of Miyamoto-Nagai type (Miyamoto & Nagai 1975) with scale length of 3 kpc and scale height of 0.28 kpc. In order to classify the star dynamically, in Fig.3 we show the stellar orbit (bottom panels), the Toomre diagram (top left) and the orbital energy *vs* angular momentum plane (E *vs* L_Z, top right). Feige 86 is shown with a star symbol. In each diagram we have classified the stars as thin disc (red), thick disc (green) and halo (blue), according to the kinematical criteria of Bensby et al. (2014). Feige 86 is clearly a thick disc star, its orbit has a high eccentricity (0.62) and it is confined within 1.2 kpc from the Galactic Plane.

3. Conclusions

The Gaia parallax has clearly demonstrated the underluminosity of Feige 86, implying an HB nature. In fact it is probably similar to the HB stars in in the Globular Clusters NGC 6752 and NGC 6397 studied by Hubrig et al. (2009). All the six stars studied (3 in each of the two clusters) are He-weak, the P abundance is measured in 5 out of six stars and displays overabundances of one to almost 2 dex above the solar values, at the same time the Fe abundances range from -0.15 to +0.69 dex with respect to the solar value, these correspond to large overabundances with respect to the cluster metallicities: [Fe/H]=–2.04 for NGC 6937 and [Fe/H]=–1.43 for NGC 6752 (Gratton et al., 2001). These anomalies are quite similar to those observed in Feige 86 and leave open the possibility that the star has an intrinsic metallicity as low as –2.0, although its thick disc kinematics makes an intrinsic metallicity around –1.0 more likely. Hubrig et al. (2009) remarked that these stars are indeed spectroscopically similar to non-magnetic HgMn stars, like HD 175640 (Castelli & Hubrig, 2004). Hubrig et al. (2009) also showed that Feige 86 displays an isotopic anomaly, the Hg II line at 398.4 nm seems composed only of the heaviest Hg isotope, ^{204}Hg, that in the solar system composition accounts for only about 7% of the Hg.

Although it is generally accepted that an atmospheric phenomenon is responsible for these chemical anomalies both in HB stars and in HgMn stars we still lack a quantative model that allows to reproduce these anomalies.

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