On the evolutionary status of λ Bootis stars using Hipparcos data

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Abstract. Using the Hipparcos data, absolute magnitudes and thus the evolutionary status for the group of λ Bootis stars were derived. The origin of this small group of non-magnetic, chemically peculiar stars, still remains a matter of debate. Using new evolutionary tracks, an age determination could be provided to distinguish between the two competing theories - the diffusion/mass-loss and the accretion.

The results establish the members of this group as objects which are *very close to the Main Sequence*. This is supported by Pre-Main Sequence evolutionary tracks as well as by observational results. This contradicts prior conclusions that most of these stars are in the middle of their Main Sequence lifetime. The new results strongly support the predictions of the accretion theory.

Key words: Stars: λ Bootis – Stars: chemically peculiar – Stars: early type – Stars: fundamental parameters – Stars: pre-main sequence

1. Introduction

Using the Hipparcos parallaxes, absolute magnitudes for members of the λ Bootis group were determined. The origin of these non-magnetic, A to F-type metal-deficient dwarfs still remains controversial. The two main competing theories involve diffusion, either in combination with mass-loss (Michaud & Charland 1986), or accretion of interstellar matter as in post-AGB stars (Turcotte & Charbonneau 1993). The latter model requires that λ Bootis stars are very close to the Zero-Age Main Sequence. The recent discovery of λ Bootis stars in the young Orion OB1 association and in NGC 2264 (Paunzen & Gray 1997) seems to support the predictions of the accretion theory. But an age determination of galactic field stars by Iliev & Barzova (1995, hereafter IB95), on the other hand, resulted in evolved members. These stars were recalibrated using the accurate new absolute magnitudes as well as new stellar evolutionary tracks (CESAM; Morel 1997). Furthermore, Pre-Main Sequence models (Palla & Stahler 1993) were used to confirm the results.

Contrib. Astron. Obs. Skalnaté Pleso **27**, (1998), 479– 481.

2. The new Hipparcos data

Candidates as well as members of the λ Bootis group were taken from Paunzen et al. (1997) and Paunzen & Gray (1997). The Hipparcos data for the programme stars were extracted with the help of Simbad. The observed visual magnitudes were used to calculate the absolute magnitudes $M_{\rm V}$(H).

Possible correlations of the observed parallaxes with other astrophysical quantities (e.g. apparent distance, effective temperature, metallicity, etc.) were examined (see also Paunzen 1997). No systematic trend between the (old) photometrically calibrated and (new) absolute magnitudes has been detected. Although there are some individual differences, the overall validity of the "standard" calibration for the (chemically peculiar) λ Bootis stars is proven.

IB95 presented an age and mass determination for 20 well established λ Bootis stars (and Vega). They concluded that most of the investigated stars are in the middle of their Main Sequence evolution, which is believed to be inconsistent with the much favoured accretion theory. Only one star of their sample (HD 290799, a member of the young Orion OB1 association) seems to fulfill the predictions of the accretion theory. The Hipparcos data (available for 18 stars from IB95) were used to test their conclusions.

After the calibration of the programme stars in a $logT_{\rm eff}$ versus $logL/L_{\odot}$ diagram, the new CESAM models (Morel 1997) were used to determine the ages and masses. The initial parameters of the evolutionary tracks were $\mathrm{X} = 0.7$ and $\mathrm{Z} = 0.02$ (solar abundance); these values were found to be valid for the study of (chemically peculiar) λ Bootis stars by IB95. This seems to be appropriate because the main contribution to the overall metallicity is due to C, N and O (solar abundant in λ Bootis stars). Furthermore, there are strong indications that the λ Bootis phenomenon is restricted to the stellar surface (Holweger & Rentzsch-Holm 1995).

Due to the individual corrections to the absolute magnitude, all programme stars (except HD 193256 and HD 193281, a distant close binary system) are, within the errors, significantly *younger* and *less massive*. In order to test a possible Pre-Main Sequence hypothesis and thus the consistency with the accretion theory, the evolutionary tracks from Palla & Stahler (1993) were applied.

It turned out that six stars (HD 30422, HD 31295, HD 107233, HD 110411, HD 125162 (λ Bootis itself) and HD 183324) are indeed *very close to the Main Sequence*. This is proven by the individual results derived from the Pre- and Main Sequence tracks. For three additional stars (HD 38545, HD 111786 and HD 221756), both models are very close, resulting in the same conclusion with a high confidence. These findings contradict the results from IB95 and strongly support the accretion theory. The remaining nine programme stars are on the Main Sequence (using the appropriate models) but still significantly less evolved than reported by IB95 (see Fig. 2 therein).

These results are consistent with values for other low-mass "dusty" Pre-Main Sequence objects (see also Gerbaldi & Faraggiana 1993) such as Herbig Ae/Be stars or β Pictoris. The explanation for λ Bootis stars as true Pre-Main Sequence object could also lead to a solution for the apparent small number of members. A star with $2\,M_{\odot}$ needs only a few 10^6 years to reach the Main Sequence. The probability to find such objects is therefore very small compared to the lifetime on the Main Sequence (there is also only a similarly small number of Herbig Ae stars known). This conclusion is further strengthened by the lack of λ Bootis stars in open clusters older than 10^7 years (Paunzen & Gray 1997).

3. Conclusions

With the Hipparcos data, absolute magnitudes and evolutionary status (mass and age) for the group of λ Bootis stars were estimated. No systematic influence of the apparent distance, effective temperature, metallicity and rotational velocity was found on the difference between the photometrically calibrated and the "new" absolute magnitudes, thus proving the validity of the "standard" photometric calibration (e.g. in the Strömgren system) for these (chemically peculiar) stars.

It turned out that six stars (e.g. λ Bootis itself) are definitely *very close to the Main Sequence*, and this is also true, with a high probability, of three additional programme stars. These results contradict the conclusions of IB95 and support the accretion theory. The small number of λ Bootis stars (statistical effect due to the short "lifetime" on the Pre-Main Sequence) and the lack of them in open clusters older than 10^7 years further strengthen the accretion hypothesis.

Acknowledgements. This research was carried out within the working group *Asteroseismology-AMS* with funding from the Fonds zur Förderung der wissenschaftlichen Forschung (project *S7303-AST*). Use was made of the Simbad database, operated at CDS, Strasbourg, France.

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