Magnetic Bp and Ap stars in the H-R diagram

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Abstract. The positions in the H-R diagram of strongly magnetic Ap and Bp stars are compared with those of normal main sequence stars of types B7 to F2, with a view to investigating possible differences in evolutionary status between magnetic and non-magnetic stars. The normal B7–F2 stars fill the whole width of the main sequence band with some concentration towards the ZAMS, whereas the magnetic stars are only rarely found close to either the zero-age or terminal-age sequences.

Key words: H-R diagram – magnetic stars

1. Introduction

The evolutionary status of Bp and Ap stars was hardly settled in the past. Estimates on their evolution were based on the membership of magnetic stars in open clusters or associations, on their membership in binary systems, or on indirect arguments inferred from the assumption of a rigid rotator geometry. More recently, it was advocated that Ap and Bp stars are distributed uniformly across the width of the main sequence (North 1993; Wade 1997), or alternatively that the magnetic stars are near the end of their main sequence life (Hubrig & Schwan 1991; Hubrig & Mathys 1994; Wade et al. 1996). One open question was whether part of the apparent inconsistency between these results might be related to the fact that not all Ap and Bp stars are necessarily strongly magnetic.

Now, with the release of the Hipparcos data, it has become possible to determine the evolutionary state of magnetic stars with more reliability. In order to understand the physical processes taking place in B and A stars, we investigated possible differences of evolutionary state between magnetic and non-magnetic stars.

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2. Basic data

2.1. Sample of magnetic stars

For the present study, Hipparcos parallaxes and photometric data have been compiled exclusively for two groups of stars with strong, well-established magnetic fields on their surface. The first group consists of stars known to have spectral lines resolved into their magnetically split components when observed in unpolarized light (Mathys et al. 1997). The second group includes Bp and Ap stars for which the mean quadratic magnetic field has been determined through application of the moment technique (Mathys 1988; Mathys 1995; Mathys & Hubrig 1997). While the first group is strongly biased against rapidly rotating objects, the second one is not affected by this bias.

Accurate Hipparcos parallaxes ($\sigma(\pi)/\pi < 0.2$) are available only for 23 stars with magnetically resolved lines and for 12 stars with known mean quadratic magnetic fields. Thus the whole sample contains 35 magnetic stars.

Effective temperatures of the magnetic stars have been derived from $uvby\beta$ data or from photometric data in the Geneva system. In almost all cases these temperatures are in good agreement with the spectral type classification taken from the literature. For 5 hot stars with mean quadratic field determinations, the discrepancy is rather large, up to a few thousand Kelvin. For these stars, effective temperatures were inferred from detailed spectroscopic studies available in the literature or from the spectral types.

2.2. Sample of normal B and A stars

In order to compare the positions of strongly magnetic Ap and Bp stars in the H-R diagram with those of normal main sequence stars, we selected all normal single main-sequence stars of spectral types B7 to F2 from the BS catalogue, with accurate Hipparcos parallaxes. This sample consists of a total of 416 stars at distances below 100 pc ($\pi > 10$ mas).

For all stars in both samples, we applied corrections for IS absorption and duplicity (for magnetic stars), and also the LK correction (Lutz & Kelker 1973).

3. Analysis and results

We find that the normal B7–F2 stars fill the whole width of the main sequence band with some concentration towards the ZAMS. Magnetic stars are only rarely found close to either the zero-age or terminal-age sequences.

No clear evidence of an evolution of magnetic field strengths across the main sequence is found. But we note that the stars with the strongest magnetic fields in most cases appear in the middle of the main-sequence band. This implies that they should already have spent a considerable fraction of their life on the main sequence. A possible interpretation of the distribution of magnetic stars in the

H-R diagram might be that magnetic stars represent a transitory phase in the evolution of normal stars across the main sequence. Since the region occupied by non-magnetic stars in the H-R diagram fully overlaps that where the magnetic stars are found, it would then appear that not all B and A stars pass through a "peculiar" phase.

A Kolmogorov-Smirnov test applied between the distributions of the normal stars and of each group of magnetic stars has shown that the distribution of the values of $\log g$ for the sample of stars with magnetically resolved lines differs from the distribution for non-magnetic stars at a significance level of 99.2%. For the whole sample of magnetic stars, the difference with the non-magnetic stars is significant at the 92.6% level.

4. Discussion

In order to test the theories of magnetic field origin, it would be important to probe the evolution of the magnetic field strength across the main sequence. Our sample of magnetic stars is too small to provide a really stringent test. The sample could be only marginally enlarged by incorporating stars with strong longitudinal fields and accurate Hipparcos parallaxes. Another relevant issue that should be considered is the evolutionary state of chemically peculiar B and A stars without detectable or with very weak magnetic fields.

The study of the magnetic field geometry in stars of various ages and rotation rates will provide important clues to test theoretical predictions. Several mechanisms have been proposed by which the angle between magnetic and rotation axes might change during the main-sequence life time. Therefore one goal for observers should be to provide theorists with constraints on the distribution of magnetic field geometries.

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