The A-Star Puzzle
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Panel discussion section B

Chair: **N. Piskunov**

Section organizer & key-note speaker: A. Noels, J. Montalbán, C. Maceroni
Invited speakers: M. Marconi, M. Yıldız,
Contribution speakers: M. Yıldız, F. Royer, R. Arlt

Discussion

Piskunov: I would like to start this discussion with evolutionary aspects. There are a few recent developments both observational and theoretical. So, some might disagree and others might agree that there are many things happening concerning the pre-Main sequence evolution of early A type and Ap stars and that is what makes them different. Would anybody like to comment?

Mathys: A result that has raised controversy in the past few years is the claim by Hubrig *et al.* (2000, ApJ 539, 352) that Ap stars with mass below $3\,M_{\odot}$ become observably magnetic only once they have completed approximately 30% of their Main sequence lifetime. However, this study was restricted to slowly rotating stars (mostly with $P >$ 10 d.), and the validity of its results for Ap stars with typical rotation periods of 2 - 4 d. could be questioned. Swetlana Hubrig has now addressed this point with new observations. The first results that she has recently presented at another conference are fully consistent with the conclusions of the original work. The recent discovery of a strong magnetic field in HD 66318 by Bagnulo *et al.* (2003, A&A 403, 645), a $2\,M_{\odot}$ star which, based on its membership in an open cluster, has completed only 16% of its MS lifetime, suggests that the 30% limit is not strict and may vary from star to star, e.g., according to field strength. But it does not by itself question the deficiency of magnetic stars close to the ZAMS.

Cowley: This is a question to those experts in the structure of stars. Upper MS stars have convective cores and radiative envelopes. Lower MS stars have the opposite structure. Is there ever a time or range of stellar mass where a star could be fully convective or fully radiative, or perhaps could the star oscillate from one structure to the other? Finally, are there uncertainties, perhaps in the stellar opacities, that could modify your answer?

Noels: You are talking about the models at the transition between the pp chain and the CNO cycle, which occurs at about $1.1\,M_{\odot}$. Low mass stars burn hydrogen through pp chain while more massive stars undergo CNO cycle reactions on the MS. The pp chain reactions are much less temperature sensitive than the CNO cycle reactions so low mass stars have no convective cores on the MS but they have a convective envelope. On the other hand, more massive stars have a convective core, but no convective envelope, due to a lower opacity in the external layers. In other words, increasing the mass favours the appearance of a convective core at the same time that it lessens the extent of the convective envelope. These two effects compete with each other so there are no fully radiative nor fully convective stars on the MS. The only fully convective structures are found high on the Hayashi track during the PMS phase.

The transition is very sensitive to the physical parameters and your question is very interesting indeed. This is especially true for the opacities and the chemical composition.

For α Cen for example, whose mass is $1.1\,M_\odot$, changing by a small amount the metallicity, can change the structure, from no convective core (Z high enough for the luminosity to be sufficiently small for pp chain) to a small convective core (lower Z meaning a higher luminosity and the CNO cycle).

Mathys: I wish to call attention to a result that may be important to understanding rotation in Ap stars. While the general deficiency of short-period binaries ($P_{\rm orb} < 2.5\,{\rm d}$) among Ap stars is well known, it is less known that among the dozen Ap stars with a rotation period longer than 30 days, known to be SB1 stars, there is at most one that may have an orbital period shorter than 100 days. In other words it seems that very long rotation periods in binary systems occur only if the orbital period is very long too.

Kubát: How could the stellar oblateness of rapidly rotating stars affect the processes in stellar envelopes?

Talon: The oblateness becomes significant (of order 10%) for stars rotating faster than about $150\,{\rm km\,s^{-1}}$. In that case, the temperature of the atmosphere will vary according to latitude.

Arlt: Can you comment on the interaction between magnetic fields and meridional circulation?

Moss: The problem of meridional circulation and magnetic fields was studied intensively about 15 to 20 years ago. The numerical results agreed with earlier analytical work. For axisymmetric fields, a state of approximate uniform rotation along joint field/streamlines is obtained (very locally the angle between the **B** and **v** vectors may not be near zero). With nonaxisymmetric fields, the probable end state is near-uniform global rotation. Given a strong, continually present, field, the magnetorotational instability will be inhibited. The MRI works well with a weak vertical field (for the upper limit, see Arlt, this proceedings, p. 103).

Talon: There was some recent numerical simulation by Pascale Garaud about the interaction of some weak magnetic field with meridional circulation. In that case, the end state is not solid body rotation, and some circulation remains, although its shape is strongly modified.

Krtička: There are new measurements of the CNO cycle cross sections. How does this influence the properties of hot stars?

Noels: We have tested the effect of the cross section of $^{14}{\rm N}({\rm p},\gamma)^{15}{\rm O}$ in an A star. With a smaller cross section, the time needed to reach equilibrium of the CNO abundance in the CNO cycle is larger. Remember that this reaction is the slowest in the CNO cycle. So the "second loop" in the approach to the MS is longer and the ZAMS has a slightly higher $T_{\rm eff}$. The MS itself as to its duration or its HR track is not significantly affected. However, it has been shown that in globular clusters the effect is quite important in lowering the luminosity of the turn-off. The ages determined by fitting of isochrones are affected by about $0.7{\times}10^9$ years.

YILDIZ: Before the opacity projects, there were systematic differences between the models and observations. Now, it seems that there is no such systematics in the early type stars. The problem is probably not with the opacity or the nuclear reactions since uncertainties in them would cause systematic differences. However, a rich variety of rotational properties of A type stars may be the dominant factor for the differences between observational and theoretical results pertaining to the stellar structure.

NOELS: You said that OPAL opacities have solved many problems, which is true, especially for Cepheids. However, the opacities have not had their last word! With the new CNO solar abundances, recently obtained by Asplund *et al.* (2004, A&A, 417, 751), the solar convective envelope is too shallow to reproduce the helioseismic data. To get a better agreement with the helioseismological (inversion) model, an increase of opacity is needed. Near the bottom of the convective envelope, Mike Seaton (OP Project) indeed finds an increase of about of 7% in the values he obtains versus the OPAL opacities.

TALON: There is another example of a case where some opacities were not properly taken into account but which had no real impact on models except in the determination of the beryllium abundance; this is the missing UV opacity.

GREVESSE: Comment on the missing "near UV" opacity In the Sun, using 1D photospheric models and classical opacity sources, the predicted flux below about 400 nm is always greater than the observed one. The abundance of Be derived from the two Be II lines around 313 nm is smaller than the meteoritic value. A few years ago, Balachandran & Bell (1998, Nature, 392, 791) and more recently M. Asplund (but using new 3D models) have shown that when an extra opacity source is taken into account in this spectral region the disagreement disappears and the Solar Be abundance is NOW in perfect agreement with the meteoritic value! The origin of this missing opacity in the blue and UV could be found in the filling by quite a large number of very faint atomic lines due to Iron group elements which simulates a quasicontinuous opacity which adds to the well known continuous opacity sources (H, H^-) below 400 nm.

MATHYS: A semantic point in this session: differential rotation has been used to refer to two different situations. On the one hand, the rotation velocity difference between stellar interior and atmosphere and on the other hand, difference of (surface) velocity between pole and equator. This is potentially confusing.