Active OB stars: structure, evolution, mass loss, and critical limits
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Discussion – Winds and magnetic fields of active OB stars

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Abstract. The discussion on winds and magnetic fields of active OB stars was carried out by S. Owoki, G. Wade, M. Cantiello, O. Kochukhov, M. Smith, C. Neiner, T. Rivinius, H. Henrichs and R. Townsend. The topics were the ability to detect small and large scale magnetic fields in massive stars and the need to consider limits on photometric variability of the star surface brightness.

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Discussion

The discussion of session 2 was first driven by the invited talk about observations of magnetic fields by V. Petit, who reviewed modern spectropolarimetric methods used to diagnose magnetic fields of massive stars. The discussion was mostly focused on large and small scale magnetic fields, their strengths, and on the possibility of detecting great complex fields.

Stan Owocki compared the large complex magnetic fields that are actually detected on massive stars with spectropolarimetry with those strong fields seen at small scale in the Sun. He explained that in the case of very strong fields well spread over the star, the rotational modulation allowed us to see a modulation-signal. However, he wondered what would happen if some stars present small complex magnetic fields, as solar-like spots, or have large and complex fields with different scales and different polarization, and the two fields canceled on the disc. How could we see those? The answer to that issue is really important because people, for a long time, have been wondering whether magnetic fields might play an important role in the Be phenomena. Brown & Cassinelli proposed for instance to use a magnetic field moment arm to have a sub-critical rotation and that moment arm then swept up the matter to reach Keplerian orbits. On the other hand, numerical simulations (Owocki and collaborators) rather suggest that large scale magnetic fields are really incompatible with Keplerian discs because these discs have shear. This is in stark contrast with observational results (presented in some posters at this symposium) bringing strong evidence that the disc of Be stars are generally Keplerian. We note however that, at the same time, very strong complex field might play an important role in ejecting material from the star into the orbit.

Another issue that was mentioned was the long-term V/R variations observed in many Be discs. If they really are interpreted as one-arm modes, they imply the precession of features as the material is going around the star every day while the one-arm actually goes around the star every few years. The precession of orbits thus indicates the existence of very small perturbation of 1/r potential. Since the perturbation amplitude is on the scale of the rotation period over the precession period, it means that there could have very large magnetic forces and large scale forces, other than the 1/r gravity as a potential acting on the material. Therefore, it is clear that it is of great importance to make the distinction between what could be observed at large scale versus small scale or in other words to state why fields cannot be detected if/because they are too complex.

From the observational point of view, G. Wade answered that in upper main sequence stars, and perhaps to some extent in evolved stars, it is possible to establish the existence of strong stable large scale magnetic fields, which are oblique to stellar rotation axes and do not appear to correlate strongly with the physical properties of the stars. This phenomenon was well-established in the '40 by Babcock, and strengthened by people like J. Landstreet and the Russian team during the '70 and '80. G. Wade also stated that nowadays this phenomenon was globally understood and details were being investigated. However, it is clear that although the measured quantity is a vector, for sufficiently complex fields or sufficiently weak fields, it is possible that magnetic fields could remain below the detection threshold. Therefore, the field could be certainly present but still remain undetectable. Those kind of fields, that had been illustrated in the talks by Kochukhov and Petit (this volume), are examples of the kind of complex dynamo generated magnetic fields observed routinely in active type stars. It is worth mentioning that the activity expressed by these stars is significantly greater than the one seen in the Sun.

G. Wade made the point that, at the present time, the state-of-art is that "we are barely able to detect a magnetic field similar to that of the Sun in a Sun-like star and, probably in most cases, barely might be highly stretch. However, we are certainly not able to detect a similar field in a B-type star". While thousands of lines can be worked with when multi-line-techniques are used in late-type stars, like G-type stars, the reality is that only tens of lines can be used in the case of a B star.

G. Wade's conclusion is that it is absolutely possible that fields of that sorts could be highly below the detection threshold. He also commented that M. Cantiello and himself were discussing about the degree of complexity in fields that could be predicted with Cantiello's sub-surface convection models. It is very likely that fields like these are probably not detectable in B-type stars either, using today techniques. Furthermore, Cantiello gave orders of magnitude for the amplitude of complex magnetic fields. He explained that when looking at the equipartition fields in the convective regions the magnetic field strength got up to Kilogauss, but if the field got to the surface by buoancy instability, the density had basically to be rescaled and the magnetic fields got up to hundreds, maybe two hundreds gauss (unless there was something special, like erupting like-tubes where the fields are stronger). He remarked that the average field would have been up to hundreds of gauss, but not bigger than that and could present very complex scales. In addition, G. Wade commented, for example, that in the case of our Sun the field was complex, and the strongest regions had fields of the order of Kilogauss. He explained that since those magnetic fields could not be possibly detected, there was no reason for believing that such fields did exist. He stated that it was certainly true that it wouldn't have been detectable using today techniques. Nevertheless, this point can be regarded as over-pessimistic as magnetic fields in solar-type stars have already been detected by P. Petit.

In order to give an answer to the magnetic field scale, O. Kochukhov invited theoreticians to provide observers with a power spectrum because it would help to calculate the Stoke parameters. He explained that if the scale of the magnetic fields was small, smaller than the mean photon path-length, magnetic fields would not be observable. However, if the spectrum contained features at that scale, of a few degrees, it would be possible to do something. In relation to this last comment, T. Rivinius brought in mind the case of γ Cas which is a rapid rotator. He speculated that if it just was a matter of a few degrees, or how quick the star rotates, γ Cas should be easily resolved in a few degrees. To this particular problem, C. Neiner explained that if the magnetic fields were of the order of a Kilogauss, like those fields found in M. Smith's model, they would had been detected by now, even if the scale of the field was small because of the very big $v \sin i$ of that star. She added that they had observed γ Cas with stellar high-resolution spectropolarimeters, as NARVAL and ESPaDOnS, during many nights and they were not able to detect any field in the photospheric lines. Still, she stated that there might be very marginal magnetic signatures in the Fe II lines. So, if there is a magnetic field in that star it is in the disc and not in the star. Moreover, G. Wade pointed out that there were families of field topologies, that were going to be undetectable in any data set and so that came down to absence of evidence being not evidence of absence. Even though, theoreticians would be able to provide with a model, the field could be hidden in the noise and certainly remain undetectable.

On the other hand, M. Smith mentioned that, particularly for γ Cas, they had four lines of independent evidence of magnetic field. One of them obtained under the bolometric light-curve, which was a very robust reproducible result. The real issue with this star would be then to explain the production of X-ray of 10^8 degrees, 12 Kev at least, without a magnetic field! There are now eight stars sharing the same global properties, one of which gives plasma temperature twice that of γ Cas. Therefore, M. Smith argued that we are looking in a fairly, rare, a very small subgroup of stars and might not be easy to extrapolate σ Ori's and even the HD 37776 successes other than by the photometric signature that went out to 2 or 3 Kilogauss.

Rich Townsend remarked that rotation modulation and surface spot leading to photometric variability were not necessary signs of magnetic field. It is worth mentioning that some works presented in this volume, showing also spectroscopic variability due to surface inhomogeneities, are not associated with magnetic fields. In contrast to the previous examples, H. Henrichs mentioned the particular case of σLup, a B1 V star with a magnetic field that phases exactly with the 3 days photometric period, and the maximum field coincides with the maximum bright.

The need to consider the limits on photometric variability of the surface brightness of massive stars was highlighted by Owocki. He argued, in particular, that the photometric variation is directly related to the presence of CIRs in the wind of these stars and the best way to make a CIR is to have a bright spot on the stellar surface. Therefore, he suggested that high-precision photometric data like those delivered by MOST (or CoRoT) could put tight constraints on Cantiello's model and wondered if that model could predict a bright magnetic spot, versus the case of the Sun where the magnetic spots are actually dark.

Cantiello explained that the envelope calculation gave spots in excess of 200 K respect to the rest of the photosphere, but of course, it would also depend on how many spots were there. It was difficult to define the filling factor of the magnetic field to determine the factor of fluctuation in the luminosity.

Another important reason to look at photometric variations is related to the topology of the wind. In order for a magnetic field to channel the wind, a large scale magnetic field is needed and it must have a large η_* (as defined in a series of papers by Owocki and Ud-doula) but in order to have an effect in perturbing the base of the wind, it should be on smaller scales and more complex. In any case, the signature would be in brightness variations, thus the importance of having very small limits for the detection of photometric variations.

R. Townsend indicated that, probably, the limit for periodical photometric variations that we could get from ground based observations is around 10 millimagnitudes. He also remarked that with space satellite (MOST, CoRoT) we could see all sort of interesting variations that showed off nowadays.

The session on winds and magnetic fields ended on these comments.