# A SEARCH FOR VEGA-LIKE FIELDS IN OB STARS

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**Abstract.** Very weak magnetic fields (with a longitudinal component below 1 Gauss) have recently been discovered in the A star Vega as well as in a few Am stars. According to fossil field scenarios, such weak fields should also exist in more massive stars. In the framework of the ANR project Imagine, we have started to investigate the existence of this new class of very weakly magnetic stars among O and B stars thanks to ultra-deep spectropolarimetric observations. The first results and future plans are presented.

Keywords: stars: magnetic fields, stars: individual:  $\gamma$  Peg, stars: individual:  $\iota$  Her

## 1 Introduction

The magnetic fields present in OBA stars are of fossil origin, i.e. they result from the seed field present in the molecular cloud from which the star was formed, rather than being produced by a currently active dynamo like in the Sun. This original field may have also been enhanced during the early phases of the life of the star, when it was fully convective, however such a dynamo early in the star's life is no longer active.

This fossil magnetic field relaxes onto a stable oblique mainly dipolar field detectable at the stellar surface (Duez et al. 2010). According to observations, this happens in  $\sim 10\%$  of the OBA stars (e.g. Wade et al. 2014b). Fossil field scenarios predict that the remaining  $\sim 90\%$  of OBA stars should host very weak fields, either because of a bifurcation between stable and unstable large-scale magnetic configurations in differentially rotating stars (Lignières et al. 2014) or because those 90% of stars did not reach a stable configuration yet (Braithwaite & Cantiello 2013). Such very weak fields were recently discovered in some A stars: Vega (Lignières et al. 2009), Sirius (Petit et al. 2011), and a few Am stars (see Blazere et al., these proceedings). They are called "Vega-like" fields.

In the frame of the ANR Imagine project, we aim to test the existence of such very weak fields in more massive (OB) stars.

## 2 First results

We have accumulated high resolution, high signal-to-noise spectropolarimetric Narval observations of the bright slowly rotating B2 star  $\gamma$  Peg. We analysed these observations using the Least-Squares Deconvolution (LSD) technique (Donati et al. 1997) to derive magnetic Zeeman signatures in spectral lines and the longitudinal magnetic field. With a Monte Carlo simulation we derived the maximum strength of the field possibly hosted by  $\gamma$  Peg. We found that no magnetic signatures are visible in the very high quality spectropolarimetric data. The average longitudinal field measured in the Narval data is  $B_l = -0.1 \pm 0.4$  G (see Fig. 1; Neiner et al. 2014). The precision we reached is thus similar to the one used for the field detection in A stars. We derive a very strict upper limit on the strength of any dipolar field possibly hidden in the noise of our data of  $B_{pol} \sim 40$  G.

A similar study on the B3 star  $\iota$  Her was performed with high resolution, high signal-to-noise spectropolarimetric ESPaDOnS data (Wade et al. 2014a). The same analysis technique was used. No Zeeman signatures were detected in the Stokes V profiles. The longitudinal magnetic field in the average profile was measured to

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Fig. 1. LSD Stokes V (top), Null polarisation (middle) and I profiles (bottom) of  $\gamma$  Peg. Stokes V shows no magnetic signature. Taken from Neiner et al. (2014).

be  $B_l = -0.2 \pm 0.3$  G. Again, the precision is similar to the one used for the field detection in A stars. An upper limit of the dipolar field strength of  $B_{pol} \sim 8$  G is derived by Wade et al. (2014a). However, note that their method for extracting dipolar field upper limits is less conservative than the one we used for  $\gamma$  Peg.

From these two studies we conclude that no magnetic field is detected in either of the two B stars, despite having reached a precision of the longitudinal magnetic field measurement similar to the one used to detect very weak fields in A stars.

## 3 Detectability of Vega-like fields in OB stars

To check the detectability of Vega-like fields in OB stars, we can compare the observations of  $\gamma$  Peg and  $\iota$  Her with synthetic Stokes V profiles corresponding to the surface magnetic field strength and geometry of Vega, but computed for the spectral characteristics of  $\gamma$  Peg and  $\iota$  Her. For this we used the magnetic maps of Vega from Petit et al. (2010), with model line parameters and  $v \sin i$  corresponding to our observations of  $\gamma$  Peg and  $\iota$  Her. Since the inclination of the rotation axis is not known for either star, two test values were used.

The results for  $\iota$  Her were presented in Wade et al. (2014a). They conclude that is is unlikely a magnetic field identical to Vega's field would have been detected, unless the observations were made from a particularly favorable angle. However, they also conclude that a magnetic field with the same geometry but ~4 times stronger would almost certainly have been detected.

Here we present the maps of the magnetic field (Fig. 2) and Stokes V line profiles (Fig. 3) we would have observed if  $\gamma$  Peg hosted the same field as Vega, either with the same inclination angle as Vega ( $i = 7^{\circ}$ ), or with  $i = 45^{\circ}$ . Since the rotation period of  $\gamma$  Peg is unknown, and our observations (distributed over one month) likely cover several rotational cycles, we consider a rotationally averaged model line profile. For  $\gamma$  Peg we find similar results to  $\iota$  Her: a magnetic field identical to Vega's field is unlikely to have been detected, but one  $\sim 4$ times stronger would have likely been detected.

We conclude that, to detect a field like the one of Vega but on an early B star, we would need to measure longitudinal fields with a precision of 0.1 G (rather than 0.3-0.4 G reached for  $\iota$  Her and  $\gamma$  Peg and sufficient



Fig. 2. Maps of the field of Vega applied to  $\gamma$  Peg as seen at various phases (top to bottom) and under two different inclination angles. Left:  $i=7^{\circ}$  as for Vega. Right:  $i=45^{\circ}$ .



Fig. 3. Expected (rotationally averaged) Stokes V profile if  $\gamma$  Peg hosted a magnetic field identical to that of Vega, for two different inclination angles, compared to the mean observed profile.

for A stars). While it is unlikely we would have detected a magnetic field identical to Vega's field on  $\gamma$  Peg or  $\iota$  Her, we would have likely detected a field with a peak strength approximately four times as strong as that of Vega. The precision required for O stars is probably even higher.

#### 4 Future work and conclusions

To investigate the presence of Vega-like fields in OB stars, it will be necessary to reach a precision on the longitudinal field measurements of at least 0.1 G. This will require the co-addition of many Narval, ESPaDOnS or HarpsPol observations to reach a huge signal-to-noise, i.e. it will require a large amount of telescope time for each target. We will thus very carefully select the best O and B targets and propose observations of only a few optimal stars.

In this way we will test the existence of a new class of very weakly magnetic stars, currently only observed among A stars, and characterise it. The existence of this new class of objects among all OBA stars would lead to a revolution similar to the one we underwent 15 years ago with the discovery of intermediate fields in OB stars.

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