Magnetic Fields throughout Stellar Evolution
Proceedings IAU Symposium No. 302, 2013
P. Petit, M. Jardine & H. Spruit, eds.

doi:10.1017/S1743921314002324

New Experiments with Zeeman Doppler Mapping

Alex J. Martin[1,2], Stefano Bagnulo[1] and Martin J. Stift[3]

[1]Armagh Observatory, College Hill, Armagh,
BT61 9DG, United Kingdom
email: ajm@arm.ac.uk

[2]Keele University, Keele, Staffordshire,
ST5 5BG, United Kingdom

[3]Universittssternwarte Wien, Türkenschanzstr. 17,
A-1180 Wien, Austria

Abstract. We present recent experiments using a Levenberg-Marquardt algorithm and the polarised radiative transfer code COSSAM to produce a new ZDM code. Currently the code is able to recover the magnetic parameters of model stars with either a decentred dipole morphology or a morphology consisting of a centred dipole and a quadrupole, while simultaneously calculating multiple chemical abundances (including a basic stratification model). The ZDM code has been tested using both synthetic spectra and real, well studied stars. Additional features are currently being added such as a multipole morphology of arbitrary order and more sophisticated chemical stratification models.

Keywords. SNR, crosstalk, Ap Stars, ZDM, polarimetry

1. Introduction

With spectro-polarimetry instruments now on many of the large telescopes around the world, the study of magnetic fields in stars has taken a large step forward. Using Zeeman-Doppler Mapping it is potentially possible to determining the magnetic configuration of stars and the distribution of the chemical elements over the stellar surface. Several different codes are already available, and our motivation to develop a new one are: 1) to have a higher arbitrariness (by leaving the star's geometric orientation with respect to the observer as a parameter to be recovered); 2) to further explore the advantages of Ada computer programming language; 3) to expand the investigations on the reliability and uniqueness of the results. The latter point is of a special interest for us, because some recent stellar modelling results seem to contradict theoretical results from diffusion theory. Some experiments to recover the distribution of the chemical elements over the stellar surface have already been performed in the non magnetic case and will be presented elsewhere (Stift *et al.*, in prep). Here we present our very first tests to check the impact of spectral resolution, noise, and instrument artifacts on the inversion of the magnetic configuration.

2. Simulating the Observations

To perform our tests, we have considered a homogeneous atmosphere and we have parametrised the magnetic morphology by adopting a multipolar expansion as described, e.g., in Landolfi *et al.* (1998). For each observing set of 10 rotation phases we have considered six spectral lines of two different elements (Fe and Cr). We have considered: SNR = 1000, 300, 100, 30 and 10, over a spectral bin of 0.01Å; Spectal resolutions = 200000, 50000, 25000, 10000, 5000, 2500, 1000; and Crosstalks = 0%, 5%, 10% and 15%.

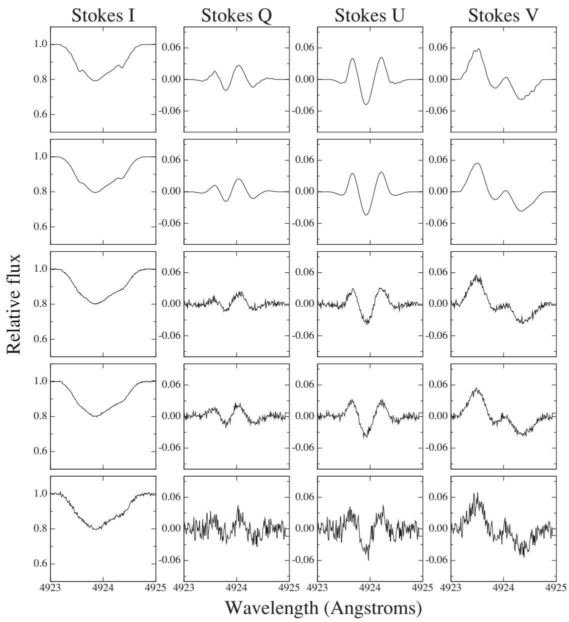

Figure 1. Signal degradation of Stokes $IQUV$ in percentage units with SNR on a spectral bin of 0.01Å. From top to bottom: 1. No Instrumental effects; 2. Spectral resolution: 60000; 3. Spectral resolution: 30000, SNR: 300; 4. Spectral resolution: 30000, SNR: 300, crosstalk 10%; 5. Spectral resolution: 30000, SNR: 100, crosstalk 10%. With the magnetic configuration not being recovered past, spectral resolution: 60000, SNR: 100, crosstalk 10%

3. Results and Conclusions

With no noise or crosstalk the inversion was successful even for the lowest values of spectral resolution, however, below a spectral resolution of 5000 the algorithm did not find the exact model values but, was reasonably close. With no crosstalk and perfect spectral resolution the algorithm recovered the model parameters down to a SNR of 100. In the case of no noise and perfect spectral resolution, for the majority of configurations the algorithm worked down to a crosstalk of 10%. However, we found that crosstalk can have a large impact when the magnetic field is weak or when the configuration leads to a majority Stokes V signal. If SNR and spectral resolution are both considered, with a spectral resolution of 60000 the algorithm is successful down to a SNR of 100 in all but the lowest field strengths. With the addition of crosstalk at 10%, the algorithm will successfully invert for a spectral resolution of 60000 and a SNR between 1000 and 300. Our results show that for a homogeneous atmosphere, if the magnetic configuration can be described by a low order multipolar expansion, and if all Stokes $IQUV$ are available and measured with a commonly available high-resolution spectropolarimeter, then the results are sufficiently robust. Our tests will continue by adding abundance spots, element stratification, and more complex magnetic configurations.

References

Amari, S., Hoppe, P., & Zinner, E., Lewis R. S. 1995, *Meteoritics*, 30, 490

Anders, E. & Zinner, E. 1993, *Meteoritics*, 28, 490

Bernatowicz, T. J., Messenger, S., Pravdivtseva, O., Swan, P., & Walker, R. M. 2003, *Geochim. Cosmochim. Acta*, 67, 4679

https://doi.org/10.1017/S1743921314002324 Published online by Cambridge University Press