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MAGNETIC AND THERMAL PROPERTIES OF ϵ ERIDANI

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ABSTRACT We analyse high-quality spectra of ϵ Eri with the aim of determining its magnetic and thermal parameters. From a careful analysis we conclude that it is not possible to separate the field strength and filling factor of this star based on data obtained in the visible spectral range. The data do suggest, however, that the magnetic field of the star is concentrated in cool, starspot-like structures.

INTRODUCTION

Magnetic fields are responsible for a vast variety of active phenomena on cool stars but are difficult to measure. In the present contribution we analyse high quality spectra of ϵ Eri using the most sophisticated technique currently feasible to determine not only the magnetic field, but also the temperature in the magnetic features.

ANALYSIS

Carefully reduced spectra of ϵ Eri with S/N =250, $\lambda/\Delta\lambda$=100,000 and a large wavelength coverage are analysed (c.f. Mathys and Solanki 1989). We calculate synthetic profiles by numerically solving the Unno-Rachkovski equations, including magnetooptical effects, using the fast and stable DELO technique (Rees et al. 1989) at carefully selected disc positions and then integrate over the stellar disc. Care is also taken to use a realistic macroturbulence velocity function (radial-tangential macroturbulence, Gray 1988) and damping constants (following Simmons and Blackwell 1982). As atmospheres we use the new set of radiative equilibrium models of Kurucz (1991), which incorporate the effects of blanketing by millions of spectral lines and are almost identical to the best empirical models.

After testing the code on various data sets, approximately 100 different fits including a magnetic field were made to the ϵ Eri data, which explored the influence of the detailed strategy of the fit and of the choice of spectral lines and free parameters.

Here we discuss the results of fits to 2 pairs of lines only: Fe I 6173.3 Å (Landé g=2.5) and Fe I 6240.6 Å ($g_{eff} = 1.0$), both with excitation potential $\chi_e = 2.22$ eV; and Fe I 6820.2 Å ($g_{eff} = 1.5$) and Fe I 6842.6 Å (g=2.5), both with $\chi_e = 4.64$ eV.

RESULTS

Using these lines we have attempted to obtain the magnetic parameters of ϵ Eri in a 2-component model of a magnetic field of strength B covering a fraction f of the stellar surface, the rest of the surface being field-free. The first result is that the very presence of a magnetic field on ϵ Eri is somewhat uncertain ($\chi^2 = 1.6$ - 2.1 for $B = 0$ vs. $\chi^2 \approx 1$ for $B \neq 0$).

The second result is that, although χ^2 is reduced if B and f are free parameters of the fit, we cannot distinguish between different field strengths for this star. Even if all non-magnetic parameters except the macroturbulence ξ_{mac} are kept fixed, it is still possible to obtain fits of almost equal quality for totally different B and f values. As an example we show in Fig. I fits to the high excitation lines for fixed $B = 500$, 1000, 1500 and 2000 G, respectively (the χ^2 of all fits is close to 1.3). The low χ_e lines confirm these results, although they are in general less well reproduced. Thus, it is not possible to derive B and f separately from lines in the visible for cool stars unless they are much more active than ϵ Eri. All previous determinations of B and f separately for such stars are, we suspect, subjective.

By fitting all four lines simultaneously it is possible to constrain the temperature in the magnetic features. The best fit to all four lines is obtained for an effective temperature in the magnetic feature that is lower than in the non-magnetic atmosphere. χ^2 is 0.96 for this fit, compared to $\chi^2 = 3$ for a fit with equal T_{mag} and $T_{\mathrm{non-mag}}$. Also, $fB = 660$ G, compared to 100–200 G for the best fit with $T_{\mathrm{mag}} = T_{\mathrm{non-mag}}$. Our analysis suggests that magnetic fields on ϵ Eri are mainly concentrated in stellar spots, which are considerably cooler than the non-magnetic parts of the stellar surface. This conclusion must be considered preliminary, however, until it has been confirmed by fits to a larger number of lines.

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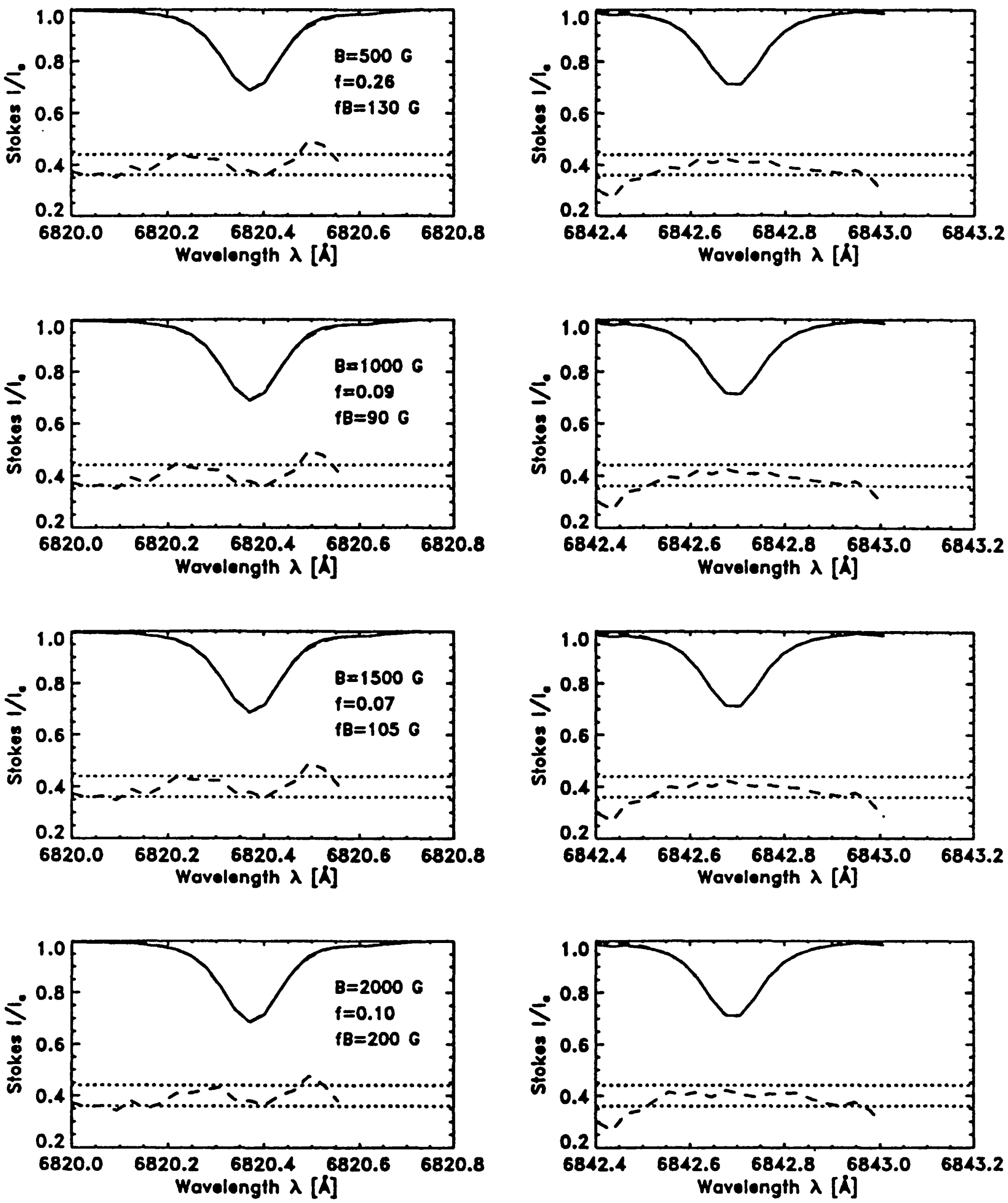

FIGURE I Observed (solid) and best fit (dashed) profiles of the two high-excitation Fe I lines with Landé g = 1.5 and 2.5, respectively. Fits allow for a field of strength B covering a fraction f of the surface. From top to bottom B is kept fixed at 500, 1000, 1500, 2000 G (f is free). The point by point errors of the fit are indicated by the almost horizontal curves centered around I/I_c=0.4 (they are magnified 10 times). The dotted horizontal lines indicate the 1σ level of the errors.