CHROMOSPHERIC VELOCITY FIELDS DIAGNOSTICS FROM CaII AND MgII EMISSION PROFILES[*]

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ABSTRACT. We discuss the present limits to the velocity field diagnostics in stellar chromospheres achievable with ESO CAT+CES and IUE high resolution spectra.

1. INTRODUCTION

Standard line formation theory - including hydrostatic equilibrium (HE) - explains the emission profiles of CaII H and K, and MgII h and k in late type stars as an effect of the outward temperature rise in the chromosphere on these collision dominated lines. Realistic stellar atmosphere models must take into account the breakdown of HE, revealed in the form of velocity fields. High resolution and very high S/N spectra are required to obtain quantitatively useful information on these velocity fields, which may have different physical mechanisms of origin, different length scales, and different senses of motion. On the basis of our experience with ESO CAT+CES and IUE high resolution spectra (Table I), here we describe the methods employed and the accuracy achievable in velocity field diagnostics from the CaII H and MgII h and k emissions. The general presence of interstellar contamination in MgII h and k, even for nearby stars (Vladilo et al. 1986), is taken into account.

2. WAVELENGTH CALIBRATION

After the standard wavelength calibration of the spectra to the laboratory rest frame by means of calibration lamps, we reduce the wavelength scale to the the stellar photosphere in order to measure chromospheric motions relative to that frame. The accuracy achievable using the stellar radial velocity for producing a photospheric wavelength scale is not enough for our purposes, so we recalibrate the

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[*] Based on ESO observations collected at La Silla (Chile) and IUE observations collected at Villafranca del Castillo (Spain)

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initial (laboratory) wavelength scale using a set of n photospheric unblended absorptions covering the spectral range around the chromospheric line under study. We use Gaussian fits to the selected lines to measure their central wavelengths, λ^{FIT}, in the laboratory scale. Typical errors on λ^{FIT}, for CAT+CES spectra in the CaII region, are of about 0.5 mA (40 m/s).

The average $\langle \delta\lambda \rangle = 1/n \ \Sigma_{i=1,n} \ (\ \lambda_i^{FIT} - \lambda_i^{LAB})$, where λ^{LAB} is the laboratory wavelength of the selected photospheric line, is assumed to be a measure of the mean photospheric velocity, and the wavelength scale is accordingly corrected.

The dispersion $\sigma = \{\Sigma_{i=1,n} \ (\delta\lambda_i - \langle\delta\lambda\rangle)^2/(n-1)\}^{1/2}$, with $\delta\lambda_i = (\ \lambda_i^{FIT} - \lambda_i^{LAB})$, gives an estimate of the wavelength calibration error and of the accuracy of the assumption of a single photospheric velocity. From solar measurements integrated over the disk, the wavelength shifts and asymmetries of weak metallic lines are of several 10^2 m/s (Dravins et al., 1981; Gray, 1988), and this gives a limit to the precision available using photospheric lines as a reference. Typical values of σ for CAT+CES spectra in the CaII region are 2 to 3 mA (150 to 250 m/s), of the same order as the velocity dispersion in the solar photosphere. For IUE spectra in the MgII region, σ is of the order of 30-40 mA (3-4 km/s).

3. TWO-COMPONENTS MODEL

After the correction to the photospheric rest frame we measure the central wavelengths of the emission and the self-reversal - $\delta\lambda_{EM}$ and $\delta\lambda_3$ respectively - by a least square fit with two Gaussian components, one in emission, the other in absorption. If we postulate that the emission peak is formed in a single layer just above the photosphere, and the self-reversal in a specific layer higher in the chromosphere (two-components model), then $\delta\lambda_{EM}$ and $\delta\lambda_3$ give an estimate of the bulk radial velocities of these layers. Use of Gaussian profiles is generally justified by the resulting goodness of the fit.

We measured $\delta\lambda_{EM}$ and $\delta\lambda_3$ for a sample of 18 CaII H spectra of 4 late-type dwarfs and found a good correlation between $(\delta\lambda_3-\delta\lambda_{EM})$ and the blue-to-red intensity ratio, I_{2V}/I_{2R} (Crivellari et al. 1987, Fig.4). The accuracy achievable using the two-components model with Gaussian fits is shown by the fact that the range in $(\delta\lambda_3-\delta\lambda_{EM})$ spanned by that correlation is less than 2 km/s, i.e. one half the CAT+CES $FWHM_{INSTR}$.

TABLE I

	CaII in dwarfs	MgII in dwarfs and giants
References	Crivellari et al.(1987)	Vladilo et al. (1987)
Instruments	1.4m CAT ESO+Reticon	0.45m IUE+SEC Vidicon
$FWHM_{INSTR}$	3.75 km/s	20 km/s
S/N (continuum level)	few x 10^2	~ 20
S/N (bottom photospheric abs.)	~ 40	few units

We have measured $\delta\lambda_{EM}$ in the MgII h and k lines for 7 dwarfs and 15 giants with emission wings uncontaminated by interstellar absorption (Vladilo et al., 1987). We do not find any significant displacement of the emission with respect to the photosphere in dwarfs. This can be explained by the fact that the error on $\delta\lambda_{EM}$ induced by the wavelength calibration (3-4 km/s) is greater than the range of chromospheric velocities inferred from our CaII H measurements in dwarfs. A peculiar phenomenon is present in the giants, where the MgII k emission does show a significant red-shift (almost 5 km/s on the average), whereas the h emission does not.

We have also measured (same ref.) $\delta\lambda_3$ in a group of 8 dwarfs and 7 giants with self-reversals uncontaminated by interstellar absorption. A mean red-shift of about 7 km/s of the self-reversals with respect to the photosphere is present in both dwarfs and giants. Gaussian fits to the self-reversals in giants cannot reproduce the observed profile, which is asymmetric.

4. ASYMMETRY MEASUREMENTS

To measure the asymmetry of the emission component we adopt the method of the median bisector (Kulander and Jefferies, 1966). The emission profile is divided into n equally spaced intensity levels. For each level the quantity $m_{EM} = (\lambda_V + \lambda_R)/2 - \lambda_0$ is evaluated, where λ_V and λ_R correspond to the intersection between the intensity level and the blue and red emission wing respectively, and λ_0 is the photospheric rest wavelength. The optimal choice of n depends on the number of resolution elements included in each side of the emission profile, R. Typically, for dwarfs, $R \cong 4$ for CaII H (CAT+CES spectra), while $R \cong 1$ for MgII h and k (IUE spectra) so that asymmetry measurements are meaningless with IUE data. We estimate a conservative error of $\pm 4mA$ (± 300 m/s) for each single m_{EM} measurement in the CaII H CAT+CES spectra. In fact, we found evidences of curved bisectors in CaII H spectra of ξ BooA and 70 OphA with amplitudes of the shifts smaller than 1 km/s (Crivellari et al. 1987), confirming the accuracy and the utility of the asymmetry measurements.

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