OBSERVED AND COMPUTED SPECTRAL LINE PROFILES

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Abstract. For the diagnostics of stellar surface structure, studies of "ordinary" line profiles may prove inadequate. However, hydrodynamic models may be constrained by second-order quantities, such as line asymmetries and wavelength shifts (and especially the differential behavior between lines of different excitation potential, ionization stage, and height of formation, as well as by the time dependence).

The next generation(s) of model atmospheres will handle three-dimensional physical processes in stars, such as radiation-coupled (magneto) hydrodynamics, and to follow events in time from the inner convection zone, out through the photosphere and chromosphere, into the stellar wind (Atroshchenko & Gadun 1994; Dravins et al. 1993; Freytag & Steffen 1995; Ludwig et al. 1994; Nordlund 1985; Nordlund & Dravins 1990; Spruit et al. 1990; Stein & Nordlund 1989).

To constrain and guide the development of such models, diagnostic tools beyond classical spectral line profiles are needed. Since (except for the Sun) most of the fine structure on stellar surfaces will likely remain spatially unresolved for the nearest future, spatially averaged tools must be used, e.g. ordinary stellar spectra integrated over the full stellar disk (Atroshchenko et al. 1990; Dravins 1990; Dravins & Nordlund 1990a; 1990b; Kiselman & Nordlund 1995; Lites et al. 1989; Ludwig & Steffen 1995; Solanki et al. 1995; Steffen et al. 1995).

However, experience shows that "ordinary" line profiles are often unable to segregate between competing models: variation of free parameters such as temperature runs with depth, amount of "turbulence", or the stellar rotation may fortuitously reproduce similar line shapes.

K. G. Strassmeier and J. L. Linsky (eds.), Stellar Surface Structure, 519–521.

https://doi.org/10.1017/S0074180900083534 Published online by Cambridge University Press

More promising among spectral diagnostics appear to be second-order quantities for spectral lines, such as asymmetries and wavelength shifts, and especially their differential behavior between lines of different excitation potential, ionization stage, and height of formation, as well as the time dependence in these quantities. Although not simple to measure, an observational advantage is that such data can be obtained also as averages over many similar lines, thus [statistically] diminishing the problem of line blends, and permitting the study also of fainter stars (Allende Prieto et al. 1995; Dravins 1982; 1987a; 1987b; 1992; 1994; Gray 1982; Gray & Nagel 1989; Gray et al. 1992; Toner & Gray 1988).

Among novel types of line diagnostics, the potential of "astrometric" radial velocities seems especially promising. For the Sun, its absolute convective lineshifts can be studied because the solar motion is known from planetary system dynamics: thus observed spectroscopic lineshifts can be interpreted as originating (in addition to solar motion) from gravitational redshift, convective blueshift, and other atmospheric phenomena (Cavallini et al. 1985; Deming et al. 1987; Dravins et al. 1981; 1986; Jiménez et al. 1988; Nadeau 1988; Nadeau & Maillard 1988; Pallé et al. 1995; Puschmann et al. 1995; Samain 1991; Wallace et al. 1988).

For other stars, determinations of their center-of-mass motion, are becoming possible with space astrometry. Already on HIPPARCOS, an observing program was carried out for stars in moving clusters to determine "astrometric" radial velocities, using parallaxes, proper motions, and the cluster apex geometry, but without using any spectroscopic information. Expected accuracies here are on the order of 300 m/s, while future astrometry missions have the potential for substantial improvement.

In the future, additional data should become available also from (a) space-based stellar photometry with micromagnitude precision, allowing the observation of time variability of stellar irradiance due to the time evolution of convective (granular) features; (b) the use of adaptive optics on very large telescopes, permitting diffraction-limited imaging of surface features on giant stars as well as spatially resolved spectroscopy across stellar disks; (c) high-resolution imaging of stellar surfaces through long baseline optical interferometry and optical aperture synthesis.

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The CfA gang. *Left to right:* Robert Kurucz, Gene Avrett, Andrea Dupree.

Interesting perspective ...at the Belvedere Palace. *Very left:* Henk Spruit and Marma Fernandez-Figueroa, *very right:* John Butler.