NARROW-BAND PHOTOMETRY AND DIFFERENTIAL EFFECTS IN CLOSE BINARY SYSTEMS

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Abstract. The application of narrow-band photometry to close binary systems is considered, with particular attention to the effects of eclipses. Models are examined, first in which two normal absorption spectra are superposed and then in which a third emission component is present. The purpose of these models is to relate to narrow-band observations of a kind similar to some preliminary results presented for U Sge in Hα. It is shown that, under the conditions obtaining for such observations, the role of Doppler effects should be small, but that the observations should be sensitive to any difference between the limb darkening in the line and surrounding continuum.

In the three-component models, the emitting volume is pictured as (i) a chromospheric shell and (ii) an equatorial disk about the primary star. The expected modifications corresponding to such models of observations of primary eclipse are calculated. Possible applicability of the models to the preliminary observations is briefly considered.

1. Introduction

The use of narrow-band photometry as a potentially powerful and sensitive means of detecting line effects in stellar atmospheres has been pointed out in numerous studies since the pioneering work of Strömgren, Crawford and others.

In particular, the circumstance of eclipsing binarity can make highly significant additions to this effectiveness. The eclipsing star, by acting as a kind of screen, enables any differences in the centre to limb variation between the line and the surrounding continuum to be monitored. This can be particularly sensitive in cases of Algol-type systems exhibiting total or deep partial eclipses, where one star, though of comparable size to the other, may be of very different luminosity (cf. Guinan et al., 1976; Fletcher, 1964). This fact was pointed out in the early work of Redman (1936). Differential effects in the atmosphere of the brighter star should, in principle, be capable of receiving a significant amplification in detectability by the technique under discussion.

In Sections 3 and 4 we shall demonstrate how this occurs in relation to two models of slightly increasing complexity. Section 2 briefly reviews basic concepts and quantities. Some data for the system U Sge, for which we have made a few preliminary Hα observations, are reported and discussed in the final section.

2. Basic Quantities

It is useful to keep in mind the numerical values of several key particulars in relation to narrow-band differential photometry of close binary systems. A detailed account of the general subject of narrow-band photometry has been given by Golay (1974).
(i) Filters

Essentially, the proposed procedure involves comparison between flux measured in a narrow spectral region centred on a spectral line and the surrounding continuum, so that at least two optical filters are required. Ideally, the filters would have rectangular transmission profiles, such as might be produced by monochromator arrangements. In practice, interference filters seem more convenient to use, and they can be manufactured to have transmission characteristics allowing them to be applied to the given purpose. Such filters were used in the observations described later in this paper. Both filters are, in fact, centred on the line of interest: the narrow filter would have a half width $\Delta \lambda_n^{1/2}$ typically of order 20–30 Å and about one order of magnitude less than the corresponding half width of the wide filter $\Delta \lambda_w^{1/2}$. The peak transmission of the filters can generally be made to be $\sim 50\%$ or greater.

(ii) Equivalent Width

For convenience in relating to the observations to be discussed later, and since, in general, it has been a favoured line for observations of this type, we shall allow our notation to refer to the H$_\alpha$ line, though a similar treatment should be applicable to other lines.

The equivalent width $w_\alpha$ is then defined as

$$w_\alpha = \int_{\text{line profile}} \frac{l_c - l_\alpha(\lambda)}{l_c} \, d\lambda,$$

where $l_c$ is the mean continuum intensity (assumed independent of $\lambda$ over the range of the line profile) against which the line intensity $l_\alpha(\lambda)$ is referred. Typical values of $w_\alpha$ are of the order of a few ångströms for early type stars (see, for example, Williams, 1936). The Balmer series lines are, of course, actually much broader than this, with wings which may extend out to distances comparable to the edges of (though generally less than) the narrow-band transmission window for some stars.

(iii) Line Index

Let us consider the energy in unit time received through the narrow filter

$$E_n = k \int_{\Delta \lambda_n} I(\lambda)T(\lambda) \, d\lambda,$$

where, in addition to the luminosity function $I(\lambda)$ (essentially the same as in Equation (1)), we have introduced the transmission function $T(\lambda)$ and a scaling constant $k$. The range of integration corresponds to the transmission region $\Delta \lambda_n$ for which $T$ is non-zero.

Considering that, in the region $\Delta \lambda_n$, $I(\lambda)$ is accounted for by just the single line