A METHOD FOR DETERMINING RADIAL VELOCITIES FROM OBJECTIVE PRISM PLATES

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Abstract. A simple method by which radial velocities of stars may be determined from Schmidt telescope objective prism plates is described, and the results from the initial application of the method are given.

The possibility of determining radial velocities from objective prism plates by either comparing two prism plates taken with the dispersions in opposite directions or by comparing an objective prism plate with a direct plate was first investigated by Schwarzschild (1913) and later re-examined by Schalén (1954) and others. These studies showed that the removal of the systematic terms in the position shifts of the spectral lines involved considerable mathematical difficulties. One way around this problem is to use a specially designed prism that minimizes the systematic terms, such as has been applied successfully by Fehrenbach. We shall show that the mathematical problems can also be greatly simplified through use of a Schmidt telescope with a curved field.

Consider the case of two objective prism plates of the same region of the sky taken with their dispersions in opposite directions. For a selected group of stars the positions of the center of a given spectral line have been measured on each plate, with the plate in each case oriented such that the Y measurements are parallel to the direction of the dispersion. If the two sets of Y measurements are compared, the difference in the values for any point in the field (for example, for a certain star) may be written as

$$\Delta Y = B_{00} + B_{10}\cdot X + B_{01}\cdot Y + B_{20}\cdot X^2 + B_{11}\cdot X\cdot Y + B_{02}\cdot Y^2 + \cdots, \qquad (1)$$

where the variables of the expansion may be either in the coordinates of one of the plates or the average of both plates.

Equation (1) is valid independent of the type of the telescope used in obtaining the plates, and in general the zero and first order terms, which express the zero point difference, the scale difference, and the relative rotation of the coordinate systems, will always be significant. However, for the second order and higher order terms the situation is different. In the common case of a flat field telescope and therefore a tangential projection of the sky on the plate the second order (and higher) terms can be made to be insignificant only if the tangential points of the two plates coincide to better than a fraction of a minute of arc (Konig, 1962). Otherwise the three second order terms will all be significant and distinct. On the other hand, in the case of a telescope with a spherical focal surface, such as the classical Schmidt system, one has a concentric projection of the sky on the plate and it can be shown that independent of where the origins of the coordinate systems are chosen the second order terms of Equation (1) have the relations

$$B_{20} = B_{02} = K, \quad \text{an instrumental constant}^* \\ B_{11} = 0. \tag{2}$$

The neglected higher order terms are also insignificant as long as the field is not too large.

Thus, with objective prism plates from a Schmidt telescope one can place the origins of the coordinate systems on a certain spectral line of the star whose radial velocity is to be determined, measure the positions on the plates of the same line for a surrounding group of comparison stars, and then use the measures from the comparison stars to determine the three significant coefficients of Equation (1) B_{00}, B_{10}, and B_{01}. The value of B_{00} is then a direct measure of the radial velocity of the program star relative to the average velocity of the comparison stars. Of course, the value of the instrumental constant K must first be known, but this can easily be determined, either empirically by measuring a large number of stars and solving Equation (1) or theoretically from the angle of the prism and its refractive index for the wavelength under consideration.

The method described has been used to derive radial velocities for a number of the metal-weak stars found in the Southern Objective Prism Survey. These stars are believed to be high velocity Population II objects. The velocities of all such stars found in a five degree by twenty degree region centered on $\alpha = 14^{\rm h}$ and $\delta = -32°$ were determined using plates taken with the Curtis Schmidt Telescope located on Cerro Tololo and equipt with a four degree glass prism that gives a dispersion of 225 Å mm^{-1} at Hγ. At this dispersion between three and seven lines out of the H and K lines of Ca II, the G band, and the lines of the hydrogen Balmer series could be measured in the program star spectra, the exact number depending on the spectral type and on the density of the spectrum. The instrumental constant K was derived both empirically and theoretically, with the two results in good agreement. For the center of our wavelength region the value was $K = 0.37 \times 10^{-4}$ mm^{-1}.

The radial velocities determined are given in Table I. For all but one star the tabulated value is the mean of two independent solutions from two different plate pairs. Based on the deviations between the separate solutions, the external error of a listed velocity is ± 38 km s^{-1}. However, this figure and the velocities themselves are provisional. To date all lines used have been given equal weight (in spite of the fact that the reductions from certain lines consistently show smaller scatter than for others) and the rest wavelengths of the line centers for the program star spectra have been assumed to be the same as for normal spectra (which may not be the case due to different degrees of line blending in the metal-weak spectra). Consideration of these effects when sufficient material is available should increase the accuracy of the determinations. Nevertheless, the data do confirm that the metal-weak stars are indeed high velocity objects,

* It is noted that in the absence of the objective prism, i.e. for a comparison of two direct Schmidt plates, one would have $K = 0$.

TABLE I

Radial velocities of metal-weak stars (from pairs of objective prism plates)

CD	Sp.	m	V	
$-29°11424$	G pec	10.5	-226	$\bar{m} = 11.1$
$-30°11745$	(G pec)	10.6	-122	$\bar{V} = +93$ km s^{-1}
$-31°10642$	(F pec)	12.6	$+\ 34$	$\sigma_v = 167$ km s^{-1}
$-31°11777$	G pec	10.0	$+182$	
$-32°10234$	G pec	10.6	$+122$	
$-33°\ 9314$	(G pec)	9.8	$+452$	
$-33°\ 9729$	(G pec)	11.1	$+210$	
$-34°10114$	G pec	10.7	$+\ 24$	
[a]	G pec	11.0	$+188$	
[a]	G pec	10.2	$+\ 80$	
[a]	F pec	11.6	$-\ 1$	
[a]	F pec!	11.7	$-\ 5$	
[a]	F pec	11.9	$+346$	
[a]	(F pec)	11.9	$-\ 30$	
[a]	F pec	12.3	$+140$	

[a] Identification to be published when the definitive velocities are available.

with both the average velocity and the velocity dispersion agreeing with what one would expect for such a sample of stars. For comparison, Table II presents the same data as Table I for a small number of metal-weak stars in the same general region of the sky for which radial velocities had previously been determined from slit spectra (Contreras and Stock, 1972).

TABLE II

Radial velocities of metal-weak stars (from slit spectra)

CD	Sp.	m	V	
$-36°10569$	K pec	11.8	$+305$	$\bar{m} = 10.8$
$-36°12669$	G pec	10.7	$+151$	$\bar{V} = +151$ km s^{-1}
$-36°12830$	G pec	10.7	-116	$\sigma_v = 179$ km s^{-1}
$-37°12742$	G pec	10.7	$+\ 36$	
$-38°10956$	G pec	10.3	$+380$	

References

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