STUDY OF SPECTROSCOPIC BINARIES WITH THE OBJECTIVE PRISM METHOD †

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Introduction

The frequency distribution of SB's over apparent visual magnitude emerging from the catalogue of Batten et. al. (1978) shows a very steep decrease of the number of spectroscopically detected SB's already for such bright stars of magnitude 7. Considering the number of all stars in the individual magnitude intervals, we find a kind of completeness parameter of the spectroscopic surveys: If we scale it somewhat optimistically at 100% between 0 and 3 mag, we see a 50% decrease of the completeness of our knowledge of stellar radial velocities already for stars fainter than 4.5 mag.

This situation is mainly due to the fact that the measurement of radial velocities with conventional slit spectrographs is extremely laborious, requiring long exposure times at large telescopes for the exposure of only one spectrum at a time. - *Therefore more efficient methods for radial velocity determinations of fainter stars are urgently needed.*

One way is to search for more efficient spectrographs. The most efficient astro-spectrograph is the objective prism - telescope combination. It has two principle advantages: - 1) The highest possible light transmission, typically tenfold compared with a slit spectrograph. - 2) The objective prism utilizes the whole telescope field, allowing the simultaneous exposure of numerous (say more than 100) well exposed spectra. Both properties together yield a thousandfold increase of efficiency. Besides limitations due to sky background and seeing there is however a principle difficulty: The wavelength calibration problem.

Review of methods

This very serious problem was a challenge to all astronomer generations since the invention of the objective prism by Fraunhofer. A most elegant solution first proposed by pickering in 1887 is the use of a solution of $NdCl_3$ as an absorption filter, which produces absorption features in all stellar spectra against which the Doppler shifts of the stellar spectral lines could be measured. - Millman in 1931 and Bok and McCuskey in 1937 applied this filter to measure a larger number of objective prism radial velocities to a moderate accuracy.
(Such filters have great chances to be revived by recent attempts to improve slit spectrographic work. See for example the work of Campbell and Walker in 1979, who used hydrogen fluoride to impress some near infrared absorption lines directly onto the starlight.)

† based on observations collected at the European Southern Observatory, La Silla, Chile

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A second very obvious solution of the calibration problem is to compare the spectral line positions on an objective prism plate with the astrometric positions of the corresponding stars on a normal field exposure. This idea can immediately by improved, if the field exposure is replaced by a second objective prism exposure with reversed dispersion resulting in a doubling of the Doppler shifts to be measured. This so called "reversion method" was first proposed by Hale and Wadsworth and by Pickering in 1896.

Both exposures can be made on the same plate (after a small displacement in RA) or on different plates. - In the latter case one has all the problems of a large field astrometry, in the first case one has the opportunity of making differential measurements however at a slightly reduced limiting magnitude.

However, again we are faced with another very serious problem: The wavelength dependent distortion of the conventional prisms produces large apparent radial velocities, which vary over the field of the telescope.

It was the merit of Karl Schwarzschild to develope in 1913 the theory of prismatic refraction to an adequate accuracy in order to correct for such large instrumental effects.

Recently, Stock and Upgren in 1968 and Stock and Osborne in 1980 showed that the prismatic field distortion is much simpler to handle in the case of a sperical focal surface as it is realized in a Schmidt-telescope without field flattener.

Until now, the by far most accurate objective prism radial velocities have been obtained by the reversion method when applied to the direct vision and distortion-free *Fehrenbach-prism*. Essential improvement has been obtained by application of a special reduction method, developed by the author on 1976. (For details of a further simplification of the method, the reader is referred to Gieseking (1980).)

With this method the relative radial velocities of more than 600 stars of the earlier spectral types between B3 and F5 with magnitudes between 7 and 10 have been measured so far to an error of typically less than ± 7 km/s for a single measurement, *which is comparable to most published radial velocities of stars of this faintness and spectral types!!*

Summary of first results

Now I would like to discuss some results with respect to the investigation of spectroscopic binaries: By a statistical discussion of the error frequency distribution of about 4500 radial velocities (Gieseking, 1981a) a first advantage of the objective prism was demonstrated, which is due to its capability to produce an enormous number of very homogeneous data: The possibility of a very reliable identification of variable radial velocities. From this kind of statistical interpretation it is possible to give quantitative binarity-probabilities.

All the data analysed so far, revealed a 19% frequency of spectroscopic binaries. Taking into account the estimated upper limit of periods - and thus of binary separations - detectable at all by the observation material, this turns out to be such a high frequency that the fraction of close pairs is suggested to be significantly higher than assumed previously. 35 objects emerged with a 100% probability (individual identification) of radial velocity variability, most of them beeing newly detected binaries. For most of these objects first orbital elements could be derived. - After analysis of an equal amount of already available data, this number is expected to be doubled in the near future. The number of definitively identified (in that magnitude interval mostly newly discovered) SB's would then amount to 10% of all spectroscopically detected SB's known today!

Programmes

Due to the capability of the above described method to collect huge amounts of homogeneous radial velocity data, several problems can now be attacked more rigorously:

1) Comparative study of the binary frequency in open clusters, stellar associations and the general star field. - For such investigations quantitative probabilities are needed for the objects to belong to the cluster - , association- or field population. With reasonable effort these probabilities can be provided again only by the objective prism technique, as it is demonstrated by first results obtained for the open cluster NGC 3532 (Gieseking, 1981b). On the basis of the model applied in that paper quantitative membership probabilities can be derived for all individually or statistically identified binaries. The latter objects contribute according to their probability to be of binary nature, assuming that their mean radial velocities are near their γ - velocities.

2) Correlations of binary frequency with spectral type or other physical parameters.

3) General improvement of binary statistics and improvement of badly known orbits expecially of the fainter spectroscopic binaries.

4) Detection and investigation of long period SB's by forming normal points and improving the detection limit for small amplitudes.

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DISCUSSION

SCARFE: What is the limiting magnitude of your observations?

GIESEKING: The limiting magnitude is about 10.5 photographic. I am concerned mainly with the range of seven to ten magnitudes.

SCARFE: In view of the great incompleteness between magnitudes seven and ten, this technique is also very valuable for discovering new late-type binaries, even if ultimately the orbit needs to be determined by a method of higher precision.

ABT: What is the usable magnitude range for a single plate? What is the measuring time per spectrum?

GIESEKING: The range depends on emulsion type used, and, for example, with the IIaO plate we have a range of approximately two magnitudes. Magnitudes 7.5 to 10 produce photographic densities approximately between 0.7 and 2.3. I have a measuring rate of 4 minutes per radial velocity.

GIESEKING: The accuracy will increase by a factor of two if I move to G-type stars, but there are problems with the later type stars because of the moderate spectral resolution. For the late spectral types you need a correlation method of reduction, and we have tested this method applied to such spectra.

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