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Speckle–Spectroscopic Studies of Late–Type Stars

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ABSTRACT: The existing and new observing techniques for combined speckle–spectroscopic studies of binary stars are briefly reviewed. The late–type dwarf stars are particularly rewarding since simultaneous spatial and spectroscopic resolution is possible for a large number of systems. A list of new candidates for the interferometric resolution is given. These studies can make an important contribution to the data on stellar masses and also provide some insight into the binary formation mechanisms when applied to multiple systems.

1. INTRODUCTION

It is well known that the increased spatial resolution offered by the interferometric observing techniques was exploited to bridge the gap betweeen spectroscopic and visual binaries. Further progress can be made through the use of differential speckle interferometry and long–baseline interferometers. On the other hand the number of late–type spectroscopic binary orbits is steadily increasing due to the systematic observations with radial–velocity spectrometers using either optical (CORAVEL) or digital correlation. The distribution of binaries over $\log P$ is not flat but has a broad maximum at $P = 10^5$ days (Duquennoy & Mayor 1991). It is then not surprising that most new orbits have long periods and small amplitudes and some are good candidates for direct resolution.

The purpose of this paper is to show the type of data that are being obtained and to indicate possible areas of future work.

The overlap between speckle and spectroscopic techniques can be visualized via the apparent magnitude – period diagram. Such a diagram is given in Figure 1 for binary stars of spectral type K0 with equal components. At any given angular separation the fainter stars have longer periods. To obtain a spectroscopic orbit we need to resolve double lines and this places an upper limit on the orbital period. It is clearly seen that the increased resolution improves dramatically the number of objects that can be studied by complementary techniques since the upper part of the diagram is populated much more densely than the lower part. The zone of overlap is greatly reduced for early–type stars and for giants since they are much brighter and hence have longer periods at given visual magnitude and angular separation. For early–type stars the situation is further complicated by their rapid axial rotation which reduces the periods of double–lined binaries. This is why the largest number of candidates for complementary speckle–spectroscopic orbits can be found among late–type dwarf stars.

The approximate positions of three binary systems of spectral types G–K that were observed recently by speckle interferometry and spectroscopy are shown on Figure 1. We have recently calculated combined speckle–spectroscopic orbits of these stars that will be published elsewhere.

Most of the radial velocity observations were made by us using the correlation radial velocity meter (Tokovinin 1987). We have also contributed to the

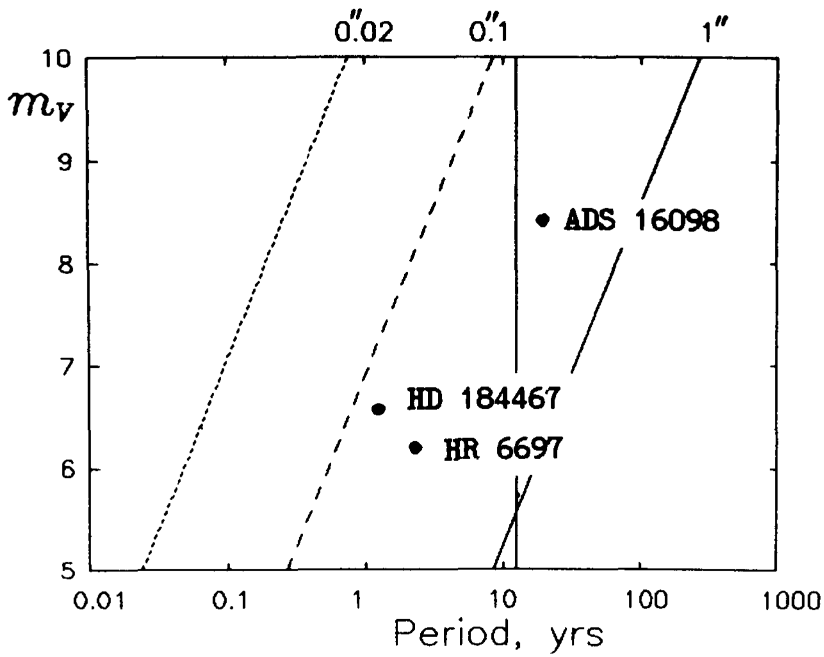

FIGURE 1. The visual magnitude m_V versus orbital period P for binaries of spectral type K0 V with equal components. Angular separations and the limiting period of double-lined systems are plotted. The approximate positions of the 3 binaries studied here are shown.

available speckle data with the help of a pupil-plane interferometer (Tokovinin 1979) that has been used on a 1-m telecope since 1981 (see references in McAlister & Hartkopf 1988).

Final orbital elements and their errors were calculated by the standard least-squares method. The Fortran program ORBIT, adapted for IBM PC-compatible computers, is used in this study. It is highly interactive and enables us to fix the values of some elements or change the measurement errors that are used to assign the weights to individual observations. Thus some points can be effectively removed from the data set. χ^2 is computed at each iteration to show the convergence. Graphs of the radial velocity or visual orbit can be seen on the screen when desired. It helps greatly to identify outlying observations or to assign radial velocity measurements of double-lined systems to particular components.

2. CANDIDATES FOR SPECKLE-SPECTROSCOPIC STUDIES

We give in Table 1 the list of potentially interesting candidates for the direct interferometric resolution that comes from our radial velocity work. No spectroscopic orbits are yet published for most of these stars. Some have already been

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resolved, but systematic observations are needed to obtain reliable combined orbits in the future. Comments on individual systems are given below.

TABLE 1. Candidates for interferometric resolution

Name	R.A., Dec. (1950)	m_V	Sp.	P	Sep.
HD 137763	$15^h25^m27^s$ −09°10′12″	6.89	K1V	2.44^y	0″.12
+11° 2874	$15^h49^m46^s$ +11°01′36″	9.35	M0V	< 1	0″.08
+55° 1823	$16^h15^m59^s$ +55°23′48″	9.96	M1e	> 1	0″.12
HD 166865	$18^h03^m54^s$ +80°00′00″	5.68	F7V	3.3	0″.015
HD 183255	$19^h25^m02^s$ +49°21′12″	8.01	K3V	0.46	0″.025
HD 186922	$19^h40^m40^s$ +76°18′12″	8.08	K0V	10–20	0″.17
+56° 2737	$22^h12^m13^s$ +56°52′18″	9.83	K0V	2?	0″.09?

HD 137763: The binary with exceptionally high eccentricity e=0.976 (Tokovinin 1991; Duquennoy *et al.* 1992). According to the latter publication it was resolved in the infrared but optical speckle resolution seems possible as well since the lines of the secondary are marginally visible in the optical spectrum. The astrometric orbit can also be determined.

+11° 2874 = Gliese 600 was found to be a double–lined binary with equal components during the radial velocity survey of K and M dwarfs (Tokovinin 1992a) and was resolved by speckle interferometry at the 6-m telescope (Balega *et al.* 1991).

+55° 1823 = Gliese 616.2 was resolved by Blazit *et al.* (1987) and was seen to be double–lined by us with maximum velocity difference of 22 km s^{-1}. It is also known as a flare star CR Dra. No speckle observations were made since discovery!

HD 166865 = ADS 11061 A = 40 Dra A was noted to be double–lined at some epochs. The components are almost equal. It must be an easy object for the long–baseline interferometers. The component B it itself a spectroscopic binary with the period of 10.52 days (Batten *et al.* 1989).

HD 183255 = GJ 1237 is a double–lined binary with a recently published orbit and Δm = 1.12 mag (Tokovinin 1991). It was unresolved at the 6-m telescope in 1989 (Balega *et al.* 1991) although this observation was made at favorable orbital phase.

HD 186922 = Gliese 765.2 = Mlr 224 is a visual binary that was observed to be double–lined in 1990, the velocity difference reaching 12 km s^{-1}. The preliminary orbital period is 14 years (A. Duquennoy, private communication). Speckle coverage of the periastron is urgently needed.

+56° 2737 = Gliese 851.4 is seen to be double–lined with a noticeable magnitude difference.

The convergence of speckle and spectroscopic techiques towards the combined orbits comes from both ends. Thus we have selected some of the late–type pairs recently discovered by P. Couteau and observed them in radial velocity. Some of them are likely to have short orbital periods and double lines.

3. PROSPECTS FOR FUTURE

The tedious accumulation of observing data will lead in the coming years to the determination of a considerable number of combined speckle/spectroscopic orbits of late-type stars provided the observers pay sufficient attention to these objects.

Many more systems like ADS 16098 with somewhat shorter periods and smaller angular separations still go undiscovered. A dedicated speckle survey or a radial-velocity survey might lead to their discovery. In both cases it is necessary to repeat observations during several years although double lines or a double speckle peak can be seen immediately. We would prefer the radial velocity survey since it has better completeness and the short-period spectroscopic systems can be resolved later by long-baseline interferometers when they are available.

The accumulation of the data on stellar masses and the detailed study of the mass-spectral type relation is the evident result of combined speckle-spectroscopic studies of binary systems. It is however not the only one. The true orientation of the orbital plane in space that is determined by these studies was so far of little use. When these data become more numerous, interesting statistical conclusions will possibly be made. It will be particulary interesting to investigate relative orientation of orbital planes in multiple systems. It is a challenging observing task since both direct resolution and spectroscopic data are needed for short- and long-period orbits of hierarchical systems.

There is an evident difficulty to resolve double lines of systems with periods greater than 15 years that are still unresolved on the slit of the spectrograph. Lines can be blended even at the highest spectroscopic resolution since the intrinsic linewidths are of the order of few $\mathrm{km\,s^{-1}}$ and the velocity amplitudes are of the same order. Differential speckle interferometry can help here just as in the case of insufficient spatial resolution. The curve of differential speckle displacements vs wavelength has two extrema, and their separation is directly related to the radial velocity difference of the components. Further details on this technique can be found in our recent paper (Tokovinin 1992b). We currently begin experiments to test this technique on our radial velocity meter.

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