*Complementary Approaches to Double and Multiple Star Research,*
*IAU Colloquium 135, ASP Conference Series, Vol. 32, 1992*
*Harold A. McAlister and William I. Hartkopf (eds.)*



# Detection of Spectroscopic Triples

TSEVI MAZEH & YUVAL KRYMOLOWSKI
School of Physics and Astronomy, Tel Aviv University,
Tel Aviv 69978, Israel

DAVID W. LATHAM
Harvard–Smithsonian Center for Astrophysics, 60 Garden St.,
Cambridge, MA 02138, USA

Several binary stars detected by the Center for Astrophysics (CfA) radial–velocity surveys were found to be members of triple systems. We present two examples, each requires a different analysis to discover its multiplicity.

One example is G176-46, a double–lined halo star of the Carney & Latham (1987) high proper–motion survey. The secondary star (G176-46b) displays large radial velocity variations, in contrast with the primary (G176-46a), which is constant within the error limits. Figure 1 shows two cross correlations of the stellar spectra against the same calculated template taken at different times, which indicate that only the secondary's peak changes its position. A similar variation was observed previously for ADS 8811 (Mazeh & Latham 1988).

We have found the secondary radial velocity to vary with a period of 10.44 days, and therefore conclude that G176-46b is a member of a short–period binary system. The orbital solution has an amplitude of 38 km s$^{-1}$ and eccentricity of 0.05.

The relative velocity of G176-46a and the center–of–mass of G176-46b is about 5.5 km s$^{-1}$. This value is small when compared with the line–of–sight velocity dispersion of the nearby stars, which is almost 20 km s$^{-1}$. Thus, the probability of an accidental alignment within 1$''$ is very small. We consequently conclude that G176-46a, G176-46b, and its unseen companion form a hierarchical triple system. Estimates for the long periods are 30–300 years (Latham *et al.* 1992). The small but significant eccentricity of the close binary could be due to the presence of a third star (Mazeh 1990).

The second example is G38-13, another high proper–motion single–lined binary with a short period of 23.2 days. Table 1 shows the elements of the orbital solution of the short period.

**TABLE 1.** Orbital elements of the short–period binary G38-13

| | | | | |
|---|---|---|---|---|
| $P =$ | 23.259 | $\pm$ | 0.013 | d |
| $\gamma =$ | -158.62 | $\pm$ | 0.51 | km s$^{-1}$ |
| $K =$ | 13.25 | $\pm$ | 0.71 | km s$^{-1}$ |
| $e =$ | 0.07 | $\pm$ | 0.05 | |
| $\Omega =$ | 231 | $\pm$ | 46 | deg |
| $T =$ | 7818.63 | $\pm$ | 2.9 | J.D. |

The r.m.s. error of this solution is 3.7 km s$^{-1}$, much larger than the typical error obtained by the CfA speedometers for similar stars. Indeed, the residuals vary with a period of about 645 days. We therefore conclude that G38-13 is a

https://doi.org/10.1017/S0252921100006308 Published online by Cambridge University Press

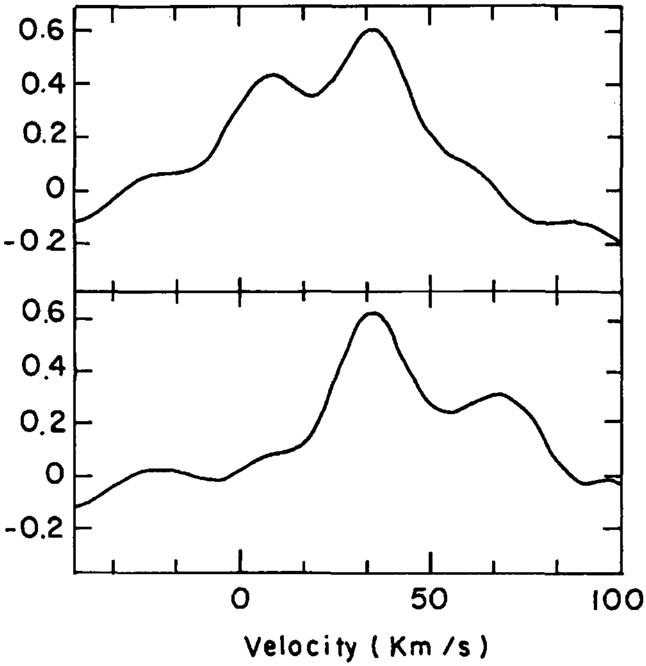


**FIGURE 1.** Two typical cross–correlations of G176-46

hierarchical triple system. The period ratio (27:1) and major–axis ratio (15:1) are large enough for such a triple system to be stable.

The long–period motion induces large errors in the short period elements, so we cannot ignore its variation when solving for the inner binary. Hence we have developed a numerical iterative code to solve simultaneously for the elements of both motions. The solving process goes in three phases:

1. Orbital solution for the short–period motion.
2. Orbital solution for the long–period motion using the residuals of the short–period motion.
3. Simultaneous solution to find the eleven elements of the combined motion (five Keplerian elements for each orbit, and the center–of–mass velocity).

All three phases of the solving procedure use a quadratic approximation for iterations. The iterations are in some cases very sensitive to the first guess of the orbital period; we therefore start each phase with a preliminary search to find the best starting period.

The starting point of the last phase is made of the solutions obtained in the first stages. The results of the simultaneous solution are shown in Figure 2 and Table 2. The substantially improved errors of the short period elements demonstrate the effectiveness of the last phase of our code.

https://doi.org/10.1017/S0252921100006308 Published online by Cambridge University Press

**TABLE 2.** Orbital elements of the combined motion

| | | | | |
|---|---|---|---|---|
| $P =$ | 23.2437 | $\pm$ | 0.0035 | d |
| $\gamma =$ | -160.02 | $\pm$ | 0.22 | $km\,s^{-1}$ |
| $K =$ | 12.79 | $\pm$ | 0.17 | $km\,s^{-1}$ |
| $e =$ | 0.078 | $\pm$ | 0.013 | |
| $\Omega =$ | 192 | $\pm$ | 10 | deg |
| $T =$ | 7815.93 | $\pm$ | 0.6 | J.D. |
| $P_2 =$ | 642.4 | $\pm$ | 4.0 | d |
| $K_2 =$ | 7.38 | $\pm$ | 0.49 | $km\,s^{-1}$ |
| $e_2 =$ | 0.27 | $\pm$ | 0.04 | $km\,s^{-1}$ |
| $\Omega_2 =$ | 127.57 | $\pm$ | 6.6 | deg |
| $T_2 =$ | 7972.7 | $\pm$ | 10.0 | J.D. |

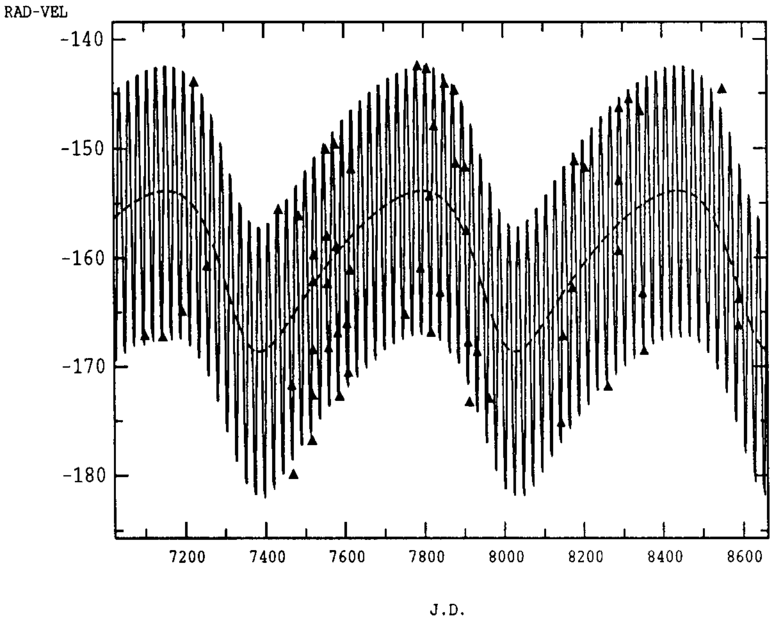


**FIGURE 2.** Solution for the combined motion of G38-13

## REFERENCES

Carney, B. & Latham, D.W. 1987, *AJ*, **93**, 116

Latham, D.W., Mazeh, T., Stefanik, R.P., Davis, R.J., Carney, B. W., Krymolowski, Y., Laird, J.B., Torres, G., & Morse, J.A. 1992, *AJ*, submitted

Mazeh, T. 1990, *AJ*, **99**, 675

Mazeh, T. & Latham, D.W. 1988, *Ap&SS*, **142**, 131

https://doi.org/10.1017/S0252921100006308 Published online by Cambridge University Press