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High–Precision Radial Velocities of Southern Solar–Type Stars

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ABSTRACT: With a small telescope and conventional techniques we have achieved external radial–velocity errors for bright stars of only ±50 m/s by using an optical fibre feed between telescope and spectrograph. In a search for low–mass companions to solar–type dwarf stars, intrinsic radial–velocity variability was detected in some IAU radial–velocity standard stars but no convincing evidence was found of the presence of low-mass companions to the dwarfs.

1. INTRODUCTION

Conventional techniques for measuring stellar radial velocities involve observing an emission lamp before and after the stellar exposure to provide wavelength calibration. Irregular guiding and thermal and mechanical flexure, which mimic Doppler shifts, affect the stellar and comparison spectrum lines in different ways, limiting the radial–velocity precision to about ±200 m/s (see Marcy & Benitz 1989, Duquennoy & Mayor 1991). For applications where the amplitude of any radial–velocity changes is very small — such as searches for brown–dwarf or planetary companions — a higher precision is preferable. The typical approach is to impose some wavelength fiducial on the stellar spectrum itself, as recommended by Griffin & Griffin (1973). Such techniques (e.g., Campbell & Walker 1979) often require rather specialized instrumentation and reduction techniques.

In a programme to examine a number of southern solar–type stars for the presence of low–mass companions, we have used a conventional technique and yet have achieved random errors of only 50 m/s. Instead of tracing the false Doppler shifts mimicked by instrumental instabilities by using a superimposed wavelength reference, we have attempted only to reduce the magnitude of these shifts. This has been achieved by the use of a single optical fibre feed between the telescope and échelle spectrograph. Light scrambling in the fibre eliminates guiding errors while the thermal and mechanical stability of the spectrograph in this configuration minimizes flexure errors.

2. INSTRUMENTATION

The Mt. John radial–velocity programme uses a 1-m $f/8$ Cassegrain telescope, a high dispersion échelle spectrograph in a thermally–regulated environment and a liquid–nitrogen cooled 1872 element Reticon diode array. The spectrograph is interfaced to the telescope via a 25 m length of Spectran 820 step index 105 μm core diameter fibre.

Observations are made in order 46, where the dispersion is about 1.75 Å/mm giving a coverage of 45 Å from 4989 Å to 5034 Å. The width of each pixel

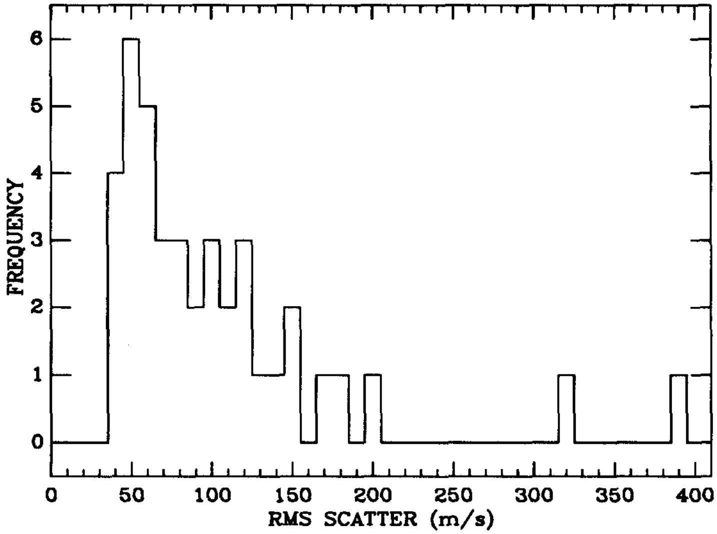

FIGURE 1. Distribution of rms radial-velocity scatter for stars in the Mt. John radial-velocity programme.

corresponds to about 1550 m/s in radial velocity. The system is described in more detail by Murdoch & Hearnshaw (1991).

3. OBSERVATIONS AND REDUCTIONS

From late 1988 to mid 1991, observations were made monthly of 29 bright solar-type dwarfs and 10 IAU radial-velocity standard stars. The aim was to search for low-mass companions to the dwarf stars in the sample. The dwarfs were chosen to be brighter than $V = 5.0$ and to have spectral type between F5 and K5 but to exclude known spectroscopic binaries and fast rotators. The IAU standards were originally included for use as correlation templates although that idea was abandoned because of the subsequent discovery of variability of many of the standards.

Relative radial velocities were obtained by digital cross correlation on a personal computer with the correlation template being a spectrum of the same star. Corrections to the solar-system barycentre were then applied, with the final reduction step being the application of a correction based on the mean velocity of 14 apparently non-variable stars in each monthly run, since there appeared to be systematic errors in each run which were dependent on the instrumental set-up. These probably arose from asymmetrical placing of the image of the fibre output end on the spectrograph slit. Despite a technical problem with the detector which stopped observations for a period of six months, an average of 25 observations was made of each star over the course of the programme.

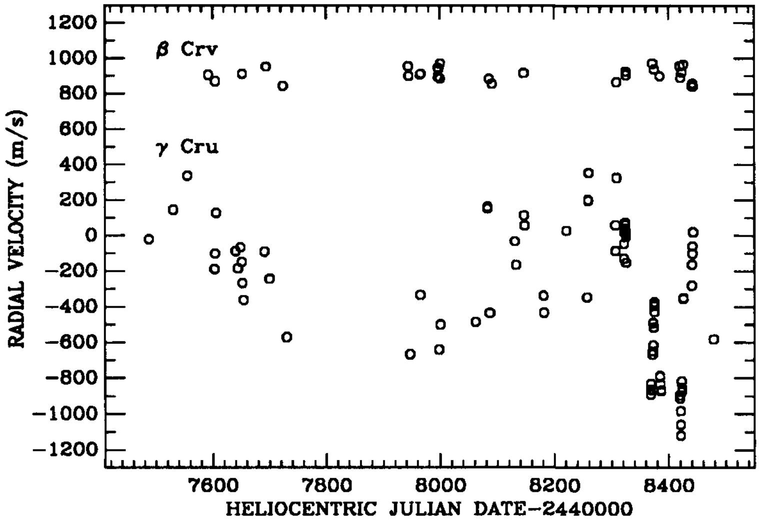

FIGURE 2. Radial velocities for two of the stars in the Mt John radial–velocity programme. The relative zero–points are arbitrary.

4. PERFORMANCE AND RESULTS

Figure 1 shows the distribution of rms radial–velocity scatters for all the stars. The stars with the least scatter are probably constant in radial velocity and show a radial–velocity scatter representative of the precision of the system, which can be seen to be about ±50 m/s. Most of the stars with high rms scatter (towards the right of the histogram) are giant IAU standard stars rather than programme dwarfs. Figure 2 shows the radial velocities of the IAU standard γ Cru (M3.5 III) along with the velocities of β Crv (G5 II), another standard and one of the typical non-varying stars. Although no unique period stands out in the data, γ Cru is clearly variable both from the range in its radial velocities compared to β Crv and from the fragments of a radial–velocity curve obtained on periods of intensive observation (Murdoch *et al.* 1992). This star and several other giants in the programme are likely to be semi-regular red variables.

Apart from a couple of stars in the sample which turned out to be spectroscopic binaries with companions of stellar mass, none of the dwarf stars showed convincing evidence of variability due to centre–of–mass motion with an orbital companion.

5. REFERENCES

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