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Using the Radial Velocity Spectrometer at the Dominion Astrophysical Observatory

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Abstract. Two observing runs have been undertaken at the Dominion Astrophysical Observatory (DAO) using the radial velocity spectrometer (RVS). About 800 observations have been performed with both the K and F masks. All cross-correlation profiles have been divided by the corresponding flux monitor records and full gaussian functions have been fitted in order to determine the profile centers. A number of IAU standard radial velocity stars have been observed, with a typical internal precision for a given star of about 100 m s^{-1}, which is a factor of two or three better than the usually adopted value for the RVS. Zero-point offsets between these observations and the standard values were also investigated.

1. Introduction

Absolute radial velocity measurements are part of a larger project (Skuljan et al. 1997) started at the University of Canterbury in order to test the reality of *moving groups* proposed by Olin Eggen. Some of the northern hemisphere stars from the program list were observed from the DAO in 1997 June-July (13 + 8 nights) and again in 1998 March-April (14 nights), using the RVS on the 1.2-m telescope. For a description of the instrument see e.g. Fletcher et al. (1982).

Although it was possible to obtain the radial velocities while observing, all the files containing the raw observational data were taken back to New Zealand to be re-analyzed. This allowed us to examine the cross-correlation profiles in more detail and try various methods for locating the correlation minimum.

2. Reduction procedure

About 400 observations with the RVS were performed during the 1997 run, using both the K and F masks. The great majority (84 per cent) of all observations were done with the K mask (K96OCT3087) and only 16 per cent with the F mask (F96SEP0187). All 1998 observations (also about 400) were done with the K mask.

The standard procedure to locate the minimum of a cross-correlation profile is to fit a parabola to its central part. However, the profile can be successfully approximated by a gaussian function. In that case all the data points (central part plus far wings) can be used to find the minimum. Some examples of cross-correlation profiles are presented in Figure 1A. The raw data do not always follow a perfect gaussian shape. This happens because the overall flux

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can fluctuate during the observation (scintillation noise and transparency fluctuations), especially if the weather conditions are not very good and only a few scans are done. However, if the raw profile is divided by the flux monitor record, such fluctuations disappear and the ratioed profile always has a regular gaussian shape, which is affected primarily by photon noise.

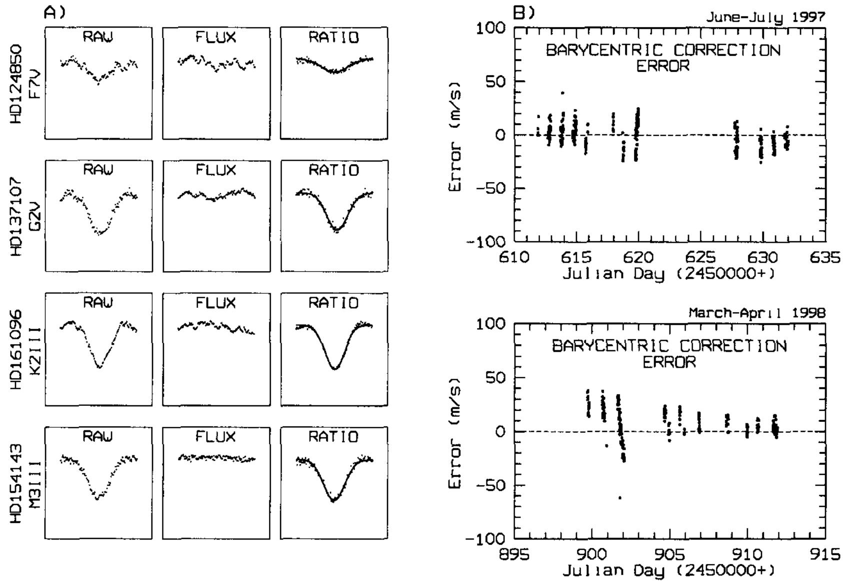

Figure 1. A) Some cross-correlation dips. Column RATIO gives the profile obtained by dividing the RAW profile with the FLUX record during the observation. Gaussians (solid lines) are good fits to the ratioed profiles. B) Barycentric correction incorporated in the DAO on-site reduction procedure suffers from a significant systematic error (up to 40 $\mathrm{m\,s^{-1}}$).

The barycentric correction (i.e. reduction for the observer's motion) is also done during the observation, using the DAO on-line software. However, we have detected a significant systematic error in the original barycentric correction algorithm, as shown in Figure 1B. This effect has been removed from our results.

3. Radial velocities

All radial velocities have been computed using the ratioed data, with gaussian profiles fitted and barycentric corrections re-computed. The comparison lamp observations have then been used to correct the velocities slightly for a slow drift during an observing night (typically a few hundreds of meters per second).

A number of IAU standard radial velocity stars, as well as the dusk sky, have been observed in order to calibrate the measurements. The velocities obtained for some of them are presented in Figure 2. Two different measures of the quality have been computed for each star: the standard deviation for all measured points

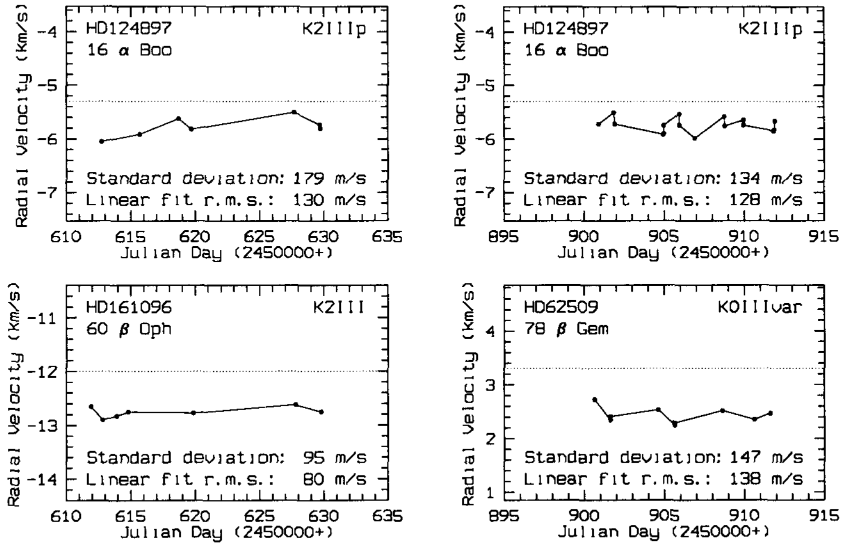

Figure 2. Measured radial velocities for some standard stars. A horizontal dashed line is used to mark the standard IAU value.

and the r.m.s. error of a linear fit to the data. The r.m.s. error is usually slightly better than the standard deviation, but in any case a typical uncertainty for our measurements is about 100 $\mathrm{m\,s^{-1}}$, which is a factor of two or three better than the usually adopted value for the RVS.

4. Standard system

Using the standard star measurements, it is possible to find the transformation that will bring all our velocities to the IAU standard system. This is usually done by computing the *zero point*, assuming that the measured values differ from the standard ones by a common constant offset. But first we have to determine the zero-point difference between the two masks using the stars that have their velocities measured with both masks. The difference ($F_{1997} - K_{1997}$) ranges from 1.5 to 2 $\mathrm{km\,s^{-1}}$, which is different from $F_{old} - K_{old} = 0.85 \pm 0.05$ $\mathrm{km\,s^{-1}}$ found by Fletcher et al. (1982), probably due to the different masks used in 1982. Our value, derived from 12 stars, is $F_{1997} - K_{1997} = 1.77 \pm 0.05$ $\mathrm{km\,s^{-1}}$, if we simply take the arithmetic mean with a corresponding standard error.

The residual velocities between our values and standard ones are presented in Figure 3. A weak correlation with spectral type and luminosity class seems to exist in our 1997 measurements, but we have not got enough data to investigate this peculiarity any further. There is, however, a systematic shift between the two runs: $DAO_{1998} - DAO_{1997} = -0.36 \pm 0.07$ $\mathrm{km\,s^{-1}}$, derived from 35 stars.

Finally, if we bring all the observations to the system of the K mask in 1998, by applying first the F–K difference for 1997 and then the systematic shift for 1997, we can use the standard stars to derive the zero offset relative to the

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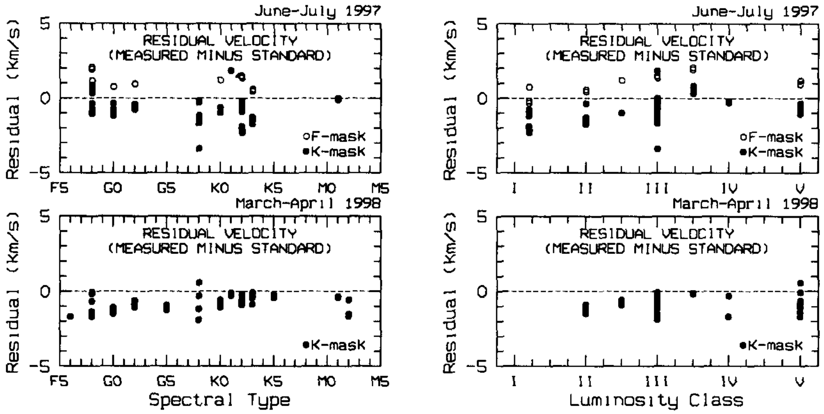

Figure 3. Residual velocities (measured minus standard ones) versus spectral type (left) and luminosity class (right).

IAU system. We find it to be $\mathrm{DAO}^{\mathrm{K}}_{1998} - \mathrm{IAU} = -0.92 \pm 0.16\ \mathrm{km\,s^{-1}}$, which is $0.44\ \mathrm{km\,s^{-1}}$ different from the result given by Fletcher et al. for the old mask ($\mathrm{DAO}_{\mathrm{OLD}} - \mathrm{IAU} = -0.06 \pm 0.14\ \mathrm{km\,s^{-1}}$ for the mid-point between the two masks, or $\mathrm{DAO}^{\mathrm{K}}_{\mathrm{OLD}} - \mathrm{IAU} = -0.48\ \mathrm{km\,s^{-1}}$ for their K mask only).

Discussion

Scarfe: If you had carried on to a slightly broader scan, you would no longer have seen a gaussian profile.

Skuljan: I was clever enough not to do it.

Popper: How many spectral orders are in your observations? If only a short stretch of spectrum is employed, it may have some lines particularly sensitive to temperature or pressure, introducing velocity effects dependent on spectral class or luminosity. If many orders or a large spectral range are used, such effects are averaged out.

Skuljan: It is a single-order spectrum, not an échelle spectrum, that is used with the RVS. I cannot remember how wide it is.

Fletcher: 700 Å.

References

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