THE ZERO-POINT OF THE IAU STANDARD VELOCITY SYSTEM

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ABSTRACT. Radial velocities of bright IAU standards have been obtained photographically over the past decade using the long camera of the DAO 1.2 meter telescope's coudé spectrograph. Most of the stars observed have been found to be constant in velocity to better than 0.15 km/s over that interval. The mean velocities agree with the IAU velocities, on the average, within 0.10 km/s, although mean velocities of some individual stars differ considerably more than this from the IAU value. A preliminary determination of the zero point of the long camera system, and hence of the IAU system, has been made from observations of the asteroid Vesta, whose actual radial velocity has been calculated from its orbital elements.

One of the optical configurations of the coudé spectrograph of the Dominion Astrophysical Observatory (DAO) 1.2 meter telescope includes a mosaic of four 150 mm by 175 mm gratings with 830.77 grooves per mm, used with a camera mirror of focal length 2433 mm (96 inches). This "long camera" provides a reciprocal dispersion of 2.4 Å/mm in the second order blue region; it is described in detail by Richardson (1968). Light is admitted to the spectrograph via an image slicer designed specifically for this camera, and the resolution is about $\lambda/\Delta\lambda \simeq 100{,}000$. The spectrograph has been used chiefly photographically since its first use in the 1960's, but in recent years the radial-velocity spectrometer described by Fletcher et al. (1982) has superseded photographic plates as the most frequently-used detector.

Experience has shown that this spectrograph provides highly consistent radial velocities over several years of operation (Scarfe 1983). Both Scarfe et al. (1983) and Batten et al. (1984) have published studies of visual binary stars in which the scatter about the velocity curve defined by the adopted elements is of order 0.25 km/s for photographic observations obtained over at least thirteen years. It thus seems that the spectrograph is sufficiently stable for a study

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of the reliability of the system of standard velocity stars in current use.

The IAU system of standard velocity stars is basically that of Pearce (1957), which was adopted by the Union at the General Assembly in 1955. Additional fainter stars chosen by Heard and Fehrenbach (1973) were adopted by the IAU in that year. Most of the observations that were used in selecting the standard stars were obtained using Cassegrain spectrographs whose dispersion and resolution were considerably inferior to those available in modern coudé instruments, and which were subject to temperature fluctuations and instrument flexure, from which a coudé spectrograph is largely free. Several papers criticizing the IAU system have already been published (Griffin 1975, Batten et al. 1983). But these too were based on observations with equipment less stable and precise than the long camera, although much superior to that used to obtain the original data for the standards.

As a further check on the long camera's reliability, IAU standard stars have been observed by the author on most of the nights over the past ten years in which the instrument has been used. Because the stability of the spectrograph has been established, the data may also be used to provide a test of the standard star system. The stars observed are largely from Pearce's Table I (bright standards) with only two of the brighter objects from his Table II (faint standards) being included, in order to keep exposure times under an hour, and so to leave time for program stars. Although none of them have been followed for as long as ten years, as recommended by Griffin (1975), it seems worthwhile to provide this progress report.

All the spectra are on IIaO photographic plates and have been measured using the DAO's ARCTURUS oscilloscopic measuring machine, using a set of lines chosen by J.M. Fletcher in the region 4325-4525 Å, and listed by Scarfe et al (1983). The results to date, from 62 spectra of 12 stars, are summarized in Table I, where the standard error in the fifth column is that of a single observation about the mean for the star. The r.m.s. value of this standard error is 0.15 km/s, and one observation of γ Aquilae, which differed from the mean of the other three by more than six times this r.m.s. value, has been omitted. The mean value of the difference $\bar{V} - V_{IAU}$, with each star weighted by either the number of observations or its square root, is

$$\bar{V} - V_{IAU} = -0.07 \pm 0.10 \text{ km/s}$$

where the uncertainty is the standard error of the mean. Individual stars, in particular 5 Serpentis and β Virginis, give mean velocities substantially and consistently different from the IAU value, but show no sign of variability.

Although all the stars observed, with the possible exception of γ Aquilae, show constancy of velocity, their true radial velocities remain unknown. Thus although they may be used to check the consistency of a spectrograph, they cannot be used to determine the absolute size of any systematic error which may be present, and which may or may not vary with the velocity of the object being observed. This may be done only using objects in the solar system, whose radial velocity may be calculated from their orbital elements and those of

Table I. Mean Velocities

Star	HD	No. Obs.	$\bar{V}$ (km/s)	SE (km/s)	$\bar{V}-V_{IAU}$ (km/s)	Interval (years)
α Cas	3712	4	-4.21	0.13	-0.31	1980-1984
α Ari	12929	5	-14.51	0.14	-0.21	1980-1984
10 Tau	22484	2	27.76	0.16	-0.14	1979
α Tau	29139	1	54.18		0.08	1982
β Gem	62509	17	3.19	0.15	-0.11	1976-1983
β Vir	102870	7	4.38	0.16	-0.62	1976-1984
α Boo	124897	7	-5.32	0.14	-0.02	1977-1984
5 Ser	136202	2	54.48	0.24	0.98	1983
β Oph	161096	3	-12.28	0.06	-0.28	1982-1984
γ Aql	186791	3	-1.97	0.05	0.13	1976-1983
β Aqr	204867	1	6.52		-0.18	1982
ι Psc	222368	10	5.58	0.11	0.28	1975-1983

the earth. The brighter asteroids are perhaps the most suitable of these objects since their images are usually smaller than the seeing disk, and thus they illuminate the spectrograph collimator much as stars do. (This advantage is less marked for a spectrograph using an image slicer since the collimator illumination is determined mainly by the slicer rather than by the image falling upon it, and is thus less subject to the effects of seeing than is that of a slit spectrograph). Objects in the solar system behave as moving mirrors and the radial velocity measured for them is to a very high approximation the scalar sum of their heliocentric and geocentric velocities plus a correction for the earth's rotation (Sher 1968).

As a first attempt to use asteroids to detect a systematic error in the radial velocities obtained with the coudé spectrograph, two plates of Vesta were obtained close to the time of its opposition in 1983 December. The exposures were close to eight hours, but the resulting broadening of the lines due to the change of the relative velocity of the asteroid and the telescope is negligibly small. They were compared with velocities kindly provided by B.G. Marsden, calculated from the osculating elements from the 1983 Minor Planet Ephemerides, and accurate to ±0.01 km/s. The results are as follows

U.T. Date	V_{Obs} (km/s)	V_{Calc} (km/s)	O-C (km/s)
1983 Dec 24.31	5.43	5.14	0.29
1984 Jan 15.25	14.55	14.30	0.25

The first observation is better exposed than the second, and the weighted mean residual (O-C) is 0.28 km/s, with an uncertainty close to 0.15 km/s, the r.m.s. value for the stellar observations.

The spectrograph thus appears, on the basis of these preliminary data, to give velocities too positive by 0.28 ± 0.15 km/s. It follows that the IAU system as defined by the sample of twelve stars so far observed, is too positive by 0.35 ± 0.18 km/s. This agrees with the result obtained by Batten et al. (1983), using the spectrometer, for the difference between the system of the bright IAU standards and the mean residual for asteroids. It is clear, of course, that the present result is based on very few observations, and more are needed to confirm or revise it. This in turn requires continued effort to maintain the stability of the spectrograph and if possible to improve it. This becomes increasingly important since observations of potentially greater accuracy than those described here are now being made (Campbell 1983).

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REFERENCES

Batten, A.H., Harris, H.C., McClure, R.D. and Scarfe, C.D. 1983. Publ. Dom. Astrophys. Obs. 16, 143.

Batten, A.H., Fletcher, J.M., and Campbell, B. 1984. Publ. Astron. Soc. Pacific 96, 903.

Campbell, B. 1983. Publ. Astron. Soc. Pacific 95, 577.

Fletcher, J.M., Harris, H.C., McClure, R.D. and Scarfe, C.D. 1982. Publ. Astron. Soc. Pacific 94, 1017.

Griffin, R.F. 1975. Mon. Not. Roy. Astron. Soc. 171, 407.

Heard, J.F. and Fehrenbach, C. 1973. Trans. IAU. 15a, 409.

Pearce, J.A. 1957. Trans. IAU. 9, 441.

Richardson, E.H. 1968. J. Roy. Astron. Soc. Canada 62, 313.

Scarfe, C.D. 1983. in IAU Coll. No. 62, Current Techniques in Double and Multiple Star Research, ed. R.S. Harrington and O.G. Franz. Lowell Obs. Bull. 9, 93.

Scarfe, C.D., Funakawa, H., Delaney, P.A., and Barlow D.J. 1983. J. Roy. Astron. Soc. Canada 77, 126.

Sher, D. 1968. J. Roy. Astron. Soc. Canada 62, 105.