

30. RADIAL VELOCITIES (VITESSES RADIALES)

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1. INTRODUCTION

This report covers the period June 1981 to June 1984 and includes some material from IAU Colloquium No. 88, October, 1984). The field of radial velocities has undergone a renaissance in the last few years as the new radial velocity machines have come into use. Not only can stars of much fainter magnitudes be reached, but the precision of the measured radial velocity has been increased by orders of magnitude. Instead of speaking of velocities accurate to kilometers per second it is now possible to measure velocities to tens of meters per second. Research programs, involving these new techniques are now underway involving the study of hundreds, and in some cases, thousands of faint stars.

At the Patras General Assembly Commission 30 meetings Philip proposed that an IAU Colloquium on Stellar Radial Velocities be held to discuss the new techniques and the results obtained with them. This proposal was subsequently ratified by the Executive Committee of the IAU as Colloquium No. 88 and was held at Union College, Schenectady, New York in October, 1984.

At the 16th General Assembly in Grenoble the commission set up two working groups, one dealing with the problems of compiling a Mean Radial Velocity Catalog from heterogeneous sources of material and the other dealing with the problems of standard radial velocity stars. The working groups met in Schenectady, at IAU Colloquium No. 88. M. Barbier reported that work was progressing well on the Bibliographic Catalog of Stellar Radial Velocities. A magnetic tape containing the catalog will be available in the next year. Barbier and Duflot have been working on the Catalog of Mean Radial Velocities and they are currently working on radial velocities published during 1970 - 75. As is reported in the section on Standard Stars, Batten recommends that the present system of IAU radial velocity standards be revised completely.

2. INSTRUMENTATION

Campbell and Walker (1984, IAU Coll. No. 88) list stellar precision Velocity Techniques in their Table 1 (shown on the next page).

Work continues with Griffin's original radial velocity spectrometer (Cambridge and Palomar Observatories). (30.120012 31.114008 32.120007 32.120009 32.120018 32.120025 34.120010 34.120011 34.120012 34.120026 88.09 Papers 54-60 in Observatory, 10-11 in J. Astrophys. Astr.).

Major additions to the numbers of stars with measured radial velocities have been made by CORAVEL (Haute-Provence Observatory and ESO, La Silla) and by the stellar radial velocity program at the Center for Astrophysics, (MMT Observatory, Whipple Observatory and Oak Ridge Observatory), the LPL Radial Accelerometer, the McDonald observatory Radial Velocity Spectrometer and radial velocities from CCD detectors (Kitt Peak National Obs.). The radial velocity program at Haute-Provence Observatory, using the objective prism continues, with a present focus on measuring the radial velocities of Hipparcos stars.

TABLE 1

Technique	Investigators	Velocity Range m/s
Telluric Lines + Phot. Spectra	Griffin and Griffin (1973)	50
Telluric Lines + Reticon	M. Smith (1982, 83)	6-11
PEPSIOS (3 Fabry-Perots)	Traub, Mariska, Carleton (1978)	3-46
Fabry-Perot Interferometer	Reay, Ring and Pietraszewski (1983)	4-20
Fiber image scrambler + Fabry Perot + Echelle + CCD	McMillan et al. (1984)	(15)
Fabry-Perots + Reticons	Cochran and Young (1984)	(1)
N2O absorption cell + FTS	Hall and Hinkle (1981)	20
HF absorption cell + Reticon	Campbell and Walker (1978)	12
Vacuum echelle spectrogr. + interferometer	Connes (1984)	(?)
Optical fiber + Coude spectrogr.	Heacox (1984)	(50)

Development work has been started towards a combined observing instrument and reduction package which will give on-line reduced velocities for a wide range of stars of spectral types OBAF (J. Andersen, Copenhagen and G. Hill, DAO, Victoria).

3. GALACTIC STRUCTURE

Programs on galactic structure are being conducted in a collaboration among the Geneva, Marseille, Copenhagen, ESO and Lund observatories, based on the two CORAVEL scanners in both hemispheres. Throughout this and following sections, the persons named are the proposers/coordinators for each program.

The radial velocities of stars from the catalog by Woolley et al. (Stars less than 25 pc from the Sun) are being determined by M. Imbert (Marseille) with CORAVEL. Ardeberg (Lund) and Lindgren (ESO) are determining radial velocities of faint metal-deficient F, G, and K stars.

Andersen and Nordstrom (Copenhagen) have observed the remaining 790 late-type stars in the Bright Star Catalog with CORAVEL and another 740 B - F4 stars have been observed photographically at ESO. The results have been published (Andersen and Nordström 1983 33.0020045 33.111009 33.111010 34.111003 88.14 Andersen et al. 1984 *Astron. Astrophys.*, in press). Preliminary data for some 700 stars were supplied for inclusion in the 4th edition of the Bright Star Catalog.

Current CORAVEL programs (Andersen, Nordström and Olsen, Copenhagen; Mayor, Geneva) include some 4000 F stars in the whole sky with known metal abundances (and ages) in order to study the evolution of the dynamical properties of this group.

Florsch, Marcout and Valbousquet have extended the search for high velocity stars, using objective prism plates taken with the Schmidt telescope at La Silla. In two 2X2 degree fields near the SMC only one high velocity star was found, to a limiting magnitude of 11.5 (88.15). This indicates that foreground high-velocity stars are probably rare among stars found in the direction of the Magellanic Clouds.

At Haute-Provence Observatory measures of radial velocities of stars in fields at galactic latitude +30° were continued with the objective prism on the Schmidt telescope. A study of the precision of the radial velocities obtained

(Fehrenbach, Burnage and Agniel 1982 32.111001) shows that with at least three plates per field, the precision was 4 km/s for all spectral types; these radial velocities were in the same system as that of the IAU standards. These measures are continuing in a program to measure radial velocities for Hipparcos stars. This accuracy is sufficient for the statistical study of stellar movements in the galaxy.

Fehrenbach and Duflot (88.18 88.19) have obtained 260 plates of 4X4 degrees with the small objective prism (PPO) of the OHP (magnitude 10 obtained in 2 X 10 min) and 132 plates of 4X4 degrees (magnitude 10 obtained in 2 X 15 min) taken with the large objective prism on the Franco-Liegeois telescope (SPO). This work has given about 12,000 spectra or the equivalent of 3,000 radial velocities, with four measures for each star.

For peculiar stars (Ap and Am) and isolated stars which do not justify the taking of a Schmidt plate, a program is underway to obtain individual spectra at 80 Å/mm with the 120 cm telescope at OHP. 2,500 spectrograms have been obtained. A study of 55 stars of large radial velocity in the direction of the Magellanic Clouds (Fehrenbach and Terzan 1984) found four stars to be subdwarfs and fourteen stars had large (U-B) excesses.

At the Copenhagen Observatory, Andersen and Nordström have been working on the completion of the radial velocities for the Bright Star Catalog. The B and F5 - M stars have been published and the measurements of the A0 - F4 stars have been completed and will be submitted for publication by the end of 1984. All together some 1,500 southern stars have been completed on this program, 740 stars having been observed photographically and 790 with CORAVEL.

Philip (1984 88.43) has combined four-color photometric data with radial velocity data for early-type stars at high galactic latitudes and finds he can classify stars as members of Pop I, Pop II and an intermediate population and confirm these photometric classifications by means of the velocity dispersions for each group. Similar trends of the velocity dispersion increasing with later population type have been obtained by Ardeberg and Lindgren (1984 88.13) and Adamson et al. (1984 88.42).

4. STAR CLUSTERS

Griffin and Gunn have had one observing run with their spectrometer on the Palomar 5 m telescope each year to continue a survey of radial velocities of candidates for Hyades membership. Observing time for this project has also been granted to Griffin at the DAO.

240 radial velocities measured with CORAVEL for 169 stars in the globular cluster 47 Tuc have been published (Mayor et al. 1983 34.154056) These data were used to show that the cluster rotates (Mayor et al. 1984 Astron. Astrophys. 134, 118). Thanks to complementary observations of stars near the center of the cluster, the velocity field $V(r,z)$ and the radial variation of the velocity dispersion have been established.

Similarly, the dynamics of Omega Cen have been investigated, on the basis of about 400 observations for 300 stars (Meylan and Mayor 1984 IAU Symposium No. 113, Mayor and Meylan 1984 88.52). The mean precision of the radial velocity measurements is 0.6 km/s in the case of 47 Tuc and 0.9 km/s for Omega Cen.

R. Peterson (1984 88.44, 88.45) has determined that the velocity dispersion for nine BHB stars in M 4 is ± 1.9 km/s. This low value has implications that the mass-to-light ratio in M 4 may be less than solar. Spectra, from 3,800 - 5,200 Å have been obtained of stars in 20 globular

clusters with the R-C spectrograph on the KPNO 4 m telescope. Eight remote globular clusters are included in the sample. Radial velocities for each star are being measured on a single axis Grant engine.

J. Mermilliod and Mayor have continued their survey of red giants (800 stars) in the fields of 150 open clusters, primarily for membership determination. Approximately 150 binaries have been discovered and 50 stars are suspected variables. Fifteen orbits have been obtained. They also pursued the observations of about 500 F5 - K0 dwarfs in several open clusters (Pleiades, Praesepe, Coma Ber, Alpha Per, IC 2391, IC 2602, NGC 6675 and Beta Scl). Twenty-five orbits have been determined among the numerous binaries discovered. As a byproduct of the survey, $v \sin i$ values have been determined in the Hyades, Pleiades, Praesepe and Coma Ber clusters. The discussion of these data and the comparison of the distributions have been published (Benz, Mayor and Mermilliod 1984 *Astron. Astrophys.* 138, 93).

About 100 stars in the corona of Praesepe, selected from the proper motion studies by Artjuhina (1966) have been tested for membership, with an appreciable rate of success. Membership has also been confirmed by photometric data obtained by E. Weis (Van Vleck Obs.).

In the Orion Ic association, stars with low $v \sin i$ values from the sample of Smith et al. (1983 *Astrophys. J.* 271, 237) have been observed for membership determination. Many stars with low $v \sin i$ are non-members and the $v \sin i$ distribution of the remaining stars is notably different from that obtained by Smith et al.

The orbits derived for stars in open clusters (dwarfs and giants) have been used to determine the initial eccentricity distribution (Mayor and Mermilliod 1983 *V'eme Journee de Strasbourg*, p. 45). This distribution differs completely from that of the visual binaries. The orbital parameters have also been used to test the circularization timescale by tidal forces (Mayor and Mermilliod 1984 *IAU Symposium No. 105*).

At the Harvard Smithsonian Center for Astrophysics echelle spectrographs have been used to measure the radial velocities of more than 10,000 stars with accuracies better than 1 km/s. Part of these data have been employed in the study of the dynamics and evolution of open and globular clusters.

Harris and McClure (1984 88.26) (DAO) have made a study of the radial velocities of about 50 giant-branch stars in NGC 188. Multiple observations of about 40 of these stars have revealed that more than 15% are binaries.

5. GALAXIES

A major accomplishment at the Harvard Smithsonian Center for Astrophysics was the completion of the the first phase of the CfA Redshift Survey, with results published for 2,400 galaxies brighter than a B magnitude of 14.5 and at high galactic latitudes (Huchra, Davis, Latham and Tonry 1983). The data from the CfA Redshift Survey and its extensions were used for a variety of applications, such as a study of the large-scale structure of the universe within 50 megaparsecs of the Sun (Davis, Huchra, Latham and Tonry 1982 *Astrophys. J.* 253, 432); several studies of groups and clusters of galaxies (e.g. Huchra and Geller 1982 *Astrophys. J.* 257, 432; Geller, Beers, Bothun and Huchra 1984 *Astron. J.* 89, 319; Beers, Geller, Huchra, Latham and Davis 1984 *Astrophys. J.* 283, 33; and a reanalysis of the Turner binary galaxies (White, Huchra, Latham and Davis 1982 *MNRAS* 203, 701). In collaboration with the Observatorio Nacional de Brasil, work was begun on the extension of the northern redshift survey to cover the southern skies (da Costa, Pellegrini, Nunes, Willmer and Latham 1984 *Astron. J.* 89). Altogether the facilities at

Mt. Hopkins have now been used to measure more than 6,000 galaxy redshifts.

Late-type supergiants in the direction of the Magellanic Clouds are being observed with CORAVEL. In the SMC, 232 F-M type stars have been measured, 207 of which are most probably SMC members (Maurice et al. 1984 *Astron. Astrophys. Suppl.* 57, 275). For the LMC, the corresponding numbers are 451 and 415 (Prevot et al. 1984 *Astron. Astrophys.* Submitted). 17 Cepheids in both clouds are being observed in order to determine their radial velocity curves (See section 7.)

V. S. Popov and G. D. Polyakova (Pulkova Observatory) report on radial velocities determined for 15 galaxies (photographic magnitudes 11.0 - 15.4) with the 6 meter telescope of the Special Astrophysical Observatory. Relative to the velocities in de Vaucouleurs's Second Reference Catalogue their velocities were about 275 km/s larger. A large difference was found in the case of NGC 7385 (88.53).

6. BINARIES

Griffin has continued to determine the orbits of spectroscopic binaries; about 70 orbits have been published during the triennium.

About 200 northern F-M supergiants have been observed with CORAVEL during the past 7 years. Nineteen new spectroscopic binaries have been discovered. The rate of detected SB among northern F-M1 stars is at present 21% without any dependence on spectral type or luminosity class. The total rate of binary systems among the same stars is in the range of 31-38% (Burki and Mayor 1984 *IAU Symposium No.* 105). A similar program for the southern supergiants has been undertaken from La Silla. Forty spectroscopic and eclipsing binaries are being observed continuously with CORAVEL (M. Imbert)

Using the techniques developed for measuring galaxy redshifts, the Harvard Smithsonian Center for Astrophysics have obtained radial velocities of stars in order to study the frequency and characteristics of binaries in a variety of populations, such as clusters, the disk, and the halo. The discovery of wide binaries with separations as large as 0.1 parsec is reported by Latham, Tonry, Bahcall, Soneira and Schecter (1984 *Astrophys. J. Lett.* 281, L41), while observational evidence that all the blue stragglers in M 67 are binaries is given by Peterson, Carney and Latham (1983 *Astrophys. J.* 279, 237) and Beers, Geller, Huchra, Latham and Davis 1984 *Astrophys. J.* 283, 33). Latham, Hazen-Liller and Pryor (1984 88.29) report on the discovery of a spectroscopic binary in the globular cluster M 3. The radial velocities for von Zeipel 164 varied with an amplitude of over 18 km/s and a period of a few years.

7. VARIABLE STARS

M. Imbert (Marseille) is observing 21 northern galactic Cepheids with B magnitudes brighter than 11th mag. using CORAVEL.

Two very small amplitude Cepheids (HD 9250 and HD 14462) have been discovered and the mean radii have been calculated (Burki and Benz 1982 32.122081). The monitoring of the strange classical Cepheid HR 7308 continues with CORAVEL at Haute-Provence Observatory. This star, which has the shortest period known for a classical Cepheid and whose amplitude varies by over a factor of 16 in 1200 days, is probably pulsating in the second radial overtone (Burki et al. 1982 31.122189). On the basis of new radial velocity light and color curves, the mean radii have been derived for 9 short period Cepheids (Burki). CORAVEL radial velocity curves have been obtained for four RR Lyrae stars: RR Cet, DX Del, BS Aqr and DY Peg. By using simultaneous photometric

observations the mean radii of these stars have been calculated (Burki et al. 1984 IAU Colloquium No. 82).

CORAVEL radial velocity curves have been completed for six Cepheids in the LMC and their radius variations have been determined (Imbert et al. 1984 Astron. Astrophys. Suppl. Submitted).

8. STANDARD STARS

Batten and others at Victoria have continued to observe IAU standard-velocity stars to check their constancy. A first discussion has been published (Batten et al. 1983 Pub. DAO 16, 143). Batten also discussed the whole concept of standard stars (with particular reference to standard-velocity stars) at IAU Symposium No. 111 (1984) and proposed that the Commission should consider a radical revision of the system of velocity standards (Batten 1984 88.36).

Scarfe has continued to make radial velocity observations using the DAO radial velocity spectrometer which has lead to a concern with the system of standard stars (1982 32.034158, 1983 Pub. DAO 16, 143).

IAU and potential high radial-velocity standard stars are being observed from both OHP and La Silla with CORAVEL. At La Silla about 1,000 measures of IAU standards have been obtained. The analysis of these data resulted in bringing to light a zero-point difference between the brighter and fainter IAU standard subsets:

$$V_r \text{ (IAU bright)} - V_r \text{ (IAU faint)} = 0.8 \text{ km/s.}$$

In addition, four standards, (HD 36673, 44131, 115521 and 156014) showed important variations during the period from 1981 to 1984 (Mayor and Maurice 1984 88.33).

Prevot and Rebeirot have made a study of η and χ Per and of the Perseus Arm. Anderson and Nordström (1984) have studied the standardization of radial-velocity observations and the influence of rotation.

9. ABSTRACT NUMBERS OF PAPERS 1981 -1983

In this section of the report the abstract numbers of all Radial Velocity papers in volumes 30 -34 of Astron. Astrophys. Abstracts are listed by topic. The papers to appear in the proceedings of IAU Colloquium No. 88 are indicated by 88.xx. (The abstract numbers and categories appear on the next two pages.) A more complete bibliography appears in the appendix of the proceedings of IAU Colloquium No. 88.

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BIBLIOGRAPHY	31.160029	32.031682	33.120019
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BUBBLES	34.002136	34.036101	30.112053
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