COMMISSION 30: RADIAL VELOCITIES (VITESSES RADIALES)

Report of Meetings 24 July - 1 August 1991

PRESIDENT: D. W. Latham SECRETARY: R. P. Stefanik

I. *Business Meeting.*

The business meeting of Commission 30 was held on Friday 26 July 1991 (session 4). The following items were on the agenda:

I.1. PRESIDENT'S REPORT.

Measured in terms of the number of new high-quality radial velocities obtained for stars and galaxies, the last three years must be the most productive in the history of the Commission. On the stellar side, the CORAVEL and CfA groups continued to mass produce thousands of velocities for a variety of ambitious survey projects, usually of quite faint objects and with precisions often better than 500 m s^{-1}, while Roger Griffin has continued to observe in Cambridge, publishing spectroscopic orbits like clockwork and rapidly closing in on photoelectric orbit number 100. Other traditional centers for stellar velocity work in Canada, Argentina, Australia, and the United States continued to be active, while several new efforts in New Zealand, the Soviet Union, and the United States started producing results, soon to be followed by an effort in Beijing. Together these efforts have produced fundamentally important new insights in the overall characteristics of the binaries in various stellar populations. Theories of star formation will now have to confront these new observational results.

The long-standing Canadian effort to monitor a small sample of bright stars with very high precision was joined by sustained efforts in Texas, Arizona, and California. Altogether, more than 100 stars are now being monitored at the 5 to 20 m s^{-1} level, and we may expect this activity to expand substantially in the future, as interest in the search for extrasolar planets grows, both in support of NASA's ambitious SETI Microwave Observing Project Targeted Search, which is fully funded in 1991 and expects to run through the end of the millennium, and as part of NASA's proposed new initiative, Towards Other Planetary Systems, which is not yet funded. The one sour note here is that Bruce Campbell has decided to leave astronomy and has resigned from Commission 30 and the IAU.

On the galaxy side, the interest in the large-scale structure and velocity flows in the universe has been intense, and enormous progress has been made with redshift surveys. Originally we had planned a scientific session in Commission 30 to discuss the latest results in this field, but there was so much duplication with sessions scheduled in the Cosmology and Galaxy Commissions, that we chose to avoid heavy overlap and changed the schedule. There have been at least two significant developments in the technology of measuring galaxy redshifts. New CCD spectrographs are coming into use, often with multiple fiber feeds. Several groups are now able to obtain more than 100 redshifts per night of telescope time, and this number may eventually approach 1000. There is even an effort to build a special telescope facility specifically for the project to measure a million redshifts.

Thus there should be little wonder that the task of keeping track of all the new observational results is rapidly becoming very daunting. Through the selfless efforts of M. Barbier, and D. S. Evans before her, the stellar radial velocity catalogs have almost been kept up to date. However, M. Barbier is scheduled to retire in 1994, and I have invited her to review her efforts so that we may discuss how this work might be continued in the future. On the galaxy side there are at least three major efforts to keep track of the redshifts that have been observed world wide, but here I suspect the situation will rapidly get out of hand, and not just because the numbers of observations are increasing so rapidly. There is the additional problem that most of the objects are so faint that they do not appear in any catalogs. Indeed, the first step for most redshift surveys is to make the photometric and astrometric observations necessary to create an observing list! The galaxy observers have one advantage anyway, namely that galaxies don't have variable velocities due to orbital motion or pulsation, and multiple observations are not needed to test for variable velocity.

With stars, one of the main interests is to detect and interpret velocity variations, especially at low amplitudes. To detect long-period low-amplitude variations there must be good stability in the instrumental zero points, and to combine

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data from one telescope to the next, the relative zero points must be well determined. These are two of the reasons why there has been so much effort to establish a new set of Radial Velocity Standard Stars. Among the galaxy observers, the attitude towards standards and comparing velocity zero points is much more casual. This is a problem which should be faced. Perhaps this Commission can force some progress by proposing a list of radial velocity standard galaxies, both emission and absorption line objects.

As an indication of the scientific vitality of the Commission, I mention three of the meetings and conferences that we have cosponsored and helped plan:

-Workshop on Large-Scale Structures and Peculiar Motions in the Universe. Rio de Janeiro, Brazil, 23-27 May 1989.
-Evolutionary Processes in Interacting Binary Stars. IAU Symposium No. 151. Córdoba, Argentina, 5-8 August 1991.
-New Frontiers in Double and Multiple Star Research. IAU Colloquium No. 135, Atlanta, Georgia, 5-10 April 1992.

Inside the IAU bureaucracy there are two ongoing debates, one about the Transactions A, the Commission Reports on Astronomy, and the other about the format of the General Assembly. I have supported the view that the time has come for the Reports on Astronomy to be discontinued. In my experience the Transactions A serve very little use, but their preparation extracts a heavy penalty of forced labor from the Commission Presidents. In support of this view I refused to prepare a report for Commission 30, so none appears in Transactions XXIA. (At this point a majority of the Commission members present indicated support for continuing the Reports on Astronomy. One member, an ex-president of another Commission, indicated strongly that they should be discontinued.)

For some purposes the Commission structure of the IAU is reasonably effective. It provides a well-defined population of senior scientists that can be called on for advice and services, for example to referee proposals for Symposia and Colloquia, to prepare Reports on Astronomy, and to organize the scientific sessions at the General Assemblies. In principle the Commission officers have all indicated their willingness to accept these responsibilities, although in practice many officers are very busy people who do not have lots of time to spare. When it comes to organizing the scientific sessions at the General Assemblies, the performance of the various Commissions can be quite spotty. Another problem is that the Commission officers tend to be the "old boys," and this is one of several reasons why new work by young astronomers often fails to get represented properly.

How can the scientific sessions at the General Assemblies be made more consistently excellent? Inevitably this will only happen if the session organization is taken out of the hands of the individual Commission officers. As documented in Information Bulletin 66, Derek McNally has suggested that scientific sessions be organized by Program Committees for the eight sectors: solar system, sun, stars, ISM, the Galaxy, galaxies, cosmology, and instrumentation. This might indeed be a good way to improve the quality and uniformity of the scientific sessions. Of course, some activities are best left with the Commissions and Working Groups. I have in mind such things as efforts to set up new systems of standards.

I have run into a serious problem in my efforts to organize the Commission 30 scientific sessions for General Assembly XXI. Several of the speakers who I invited to give key papers decided not to attend the General Assembly, but instead to attend one of the associated Symposia and Colloquia. They explained that they could not afford to be away for the extended time needed to attend both the General Assembly and the associated Symposium or Colloquium. In several cases I was told that the associated Symposium or Colloquium would provide a more stimulating use of the limited time and travel resources available. Thus, it appears that the associated Symposia and Colloquia are diluting the scientific content of the General Assembly. Perhaps the prohibition of associated Symposia and Colloquia would solve this problem. Another far out idea might be to run the associated Symposia and Colloquia exclusively at the General Assembly, thus providing the lion's share of the science. If you can't lick them, join them. The bottom line is that I agree the time has come to make some adjustments to the format of the General Assembly, and I like many of the suggestions that D. McNally published in Information Bulletin 66. The next General Secretary, J. Bergeron, also wants to make some changes in the way scientific sessions are organized, so look for some evolution in the format of the General Assembly starting in 1994.

I.2. MEMBERSHIP.

The Commission voted to welcome the following new members and consultants of Commission 30;

T. R. Beers (USA)
R. J. Davis (USA)
A. W. Irwin (Canada)
J.-C. Mermilliod (Switzerland)
N. I. Morrell (Argentina)
P. S. Pellegrini (Brazil)
N. Samus (USSR)
A. Tokovinin (USSR)
J. L. Tonry (USA)
G. Solivella (Argentina)
G. A. H. Walker (Canada)
A. Duquennoy (consultant, Switzerland)

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I.3. COMMISSION OFFICERS.

The Commission voted to approve the following slate of officers for 1991-1994:

President: G. Burki (Switzerland), *Vice-President*: C. Scarfe (Canada)
Organizing Committee: J. Andersen (Denmark), L. N. da Costa (Brazil), A. P. Fairall (South Africa), K. Freeman (Australia), J. B. Hearnshaw (New Zealand), and D. W. Latham (USA).

I.4. WORKING GROUP ON RADIAL VELOCITY STANDARD STARS.

A scientific session was devoted to reports on the progress towards a new set of IAU Radial Velocity Standard Stars (see report below). It was clear that a great deal of work remains to be done in this area, and the Commission voted to continue the Working Group for the period 1991-1994, with the following members: R. P. Stefanik, (chairman, USA), J. Andersen (Denmark), A. Duquennoy (Switzerland), J. B. Hearnshaw (New Zealand), R. D. Mathieu (USA), and C. Scarfe (Canada). The Working Group itself met for two hours on Tuesday 30 July 1991 (see report below).

I.5. CATALOGS.

M. Barbier reported on her work with radial velocity catalogs in Marseille. The Bibliographic Catalogue, published by M. Barbier and M. Petit, (A&AS 85, 885, 1990), takes into account references from 1970 to 1985. The first Radial Velocities Catalogue was published (A&AS 80, 77, 1989) and gives new mean radial velocities till 1980. The next Catalogue is expected to be published in 1992, and will give new velocities up till 1985. Unfortunately, M. Barbier plans to retire in 1994, and she asked for help in identifying a way to continue these cataloging efforts after her retirement. The Commission asked the Working Group on Radial Velocity Standard Stars to review the catalog situation and to make recommendations. The Commission considered reestablishing a Working Group on Mean Radial Velocities, but recommended instead that issues related to combining data from different observatories should be handled by the Working Group on Radial Velocity Standard Stars.

II. *Scientific Meetings.*

Commission 30 held a total of five formal scientific sessions, one of them jointly with Commission 33. In addition, Commission 30 members presented several papers in the dual session "Binary stars, radial velocities, and open cluster memberships," organized by Commission 37, the dual session "Distribution of gas and stars in the Milky Way," organized by Commission 33, and in Joint Commission Meeting VII "High-redshift galaxies and large-scale structure."

II.1. BINARIES IN STELLAR POPULATIONS.

This meeting was organized and chaired by D. W. Latham. It took place on Wednesday morning 24 July 1991 (sessions 1 and 2). The purpose was to report on the great strides which are being made in our understanding of the characteristics of binaries in several different stellar populations, for example in the disk and halo of our Galaxy, and in open clusters. Much of the progress is coming with spectroscopic binaries, where most of the orbital periods are less than 1,000 days. To a large extent this is a fruition of several large efforts begun 10 and even 20 years ago. Of special importance are the large surveys of carefully selected samples that have been monitored for several years. These samples are just beginning to get large enough so that the distributions of the orbital characteristics for the binaries have some statistical reliability. As a result, we are gaining fundamentally important results about the statistical properties of binaries, which will now confront the theorists who work on the formation and evolution of binary and multiple systems.

As the time duration of some of the longer-lasting surveys is extended, we find that quite a few spectroscopic orbits with periods in the range 1,000 to 10,000 days are being derived. Thus the gap between spectroscopic orbits and visual orbits is being narrowed. In recognition of this growing overlap between two techniques which have historically been independent, there will be an IAU Colloquium, No. 131, on New Frontiers in Double and Multiple Star Research, to be held near Atlanta, 5-10 April 1992.

A session on Binaries in Stellar Populations should begin with a presentation on pre-main-sequence binaries. Ten years ago this would have been a very easy paper to present, because only one or two pre-main-sequence binaries were known. Actually, this was pretty embarrassing, because we knew that there were lots of main-sequence binaries. Was it really possible that stars decided to get together to become binaries only after they arrived on the main sequence? But radial-velocity studies of large samples in star-forming regions such as Taurus-Auriga, Orion, NGC 2264, and Ophiucus have turned up quite a number of spectroscopic binaries, and now there are more than ten published orbital solutions. An especially interesting case is the classical T Tauri star GW Orionis, with a circular orbit despite the relative long period of 242 days. The spectrum for the infrared excess from this system has a dip near 10 μ, indicating a gap in its accretion disk at the distance where the companion is circling.

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One of the interesting issues in the study of the orbital characteristics of binaries in a coeval sample is the transition between circular orbits at shorter periods and a distribution of eccentric orbits at the longer periods. There seems little doubt that the short period binaries originally had also a distribution of orbital eccentricities, but tidal mechanisms have circularized all the orbits with close separations, and therefore short periods. Some experts argue that orbital circularization happens mostly during the pre-main-sequence stage while the stars are still swollen and collapsing. Other experts argue that circularization happens mostly during the long main-sequence lifetime of the binaries. This is an issue where observations should be able to make a contribution, but the results are still ambiguous. Perhaps both mechanisms are important.

The new results show that the binary populations in the disk and halo must have started out with essentially the same characteristics, although both stellar evolution and orbital evolution have effected the characteristics observed now for the halo. In particular, the frequency of spectroscopic binaries in the halo appears to be about 20%, indistinguishable from the disk and open clusters.

The following scientific contributions were presented:
David W. Latham: An Overview of Binaries in Stellar Populations.
Virginia Trimble: The Origin of the Halo Binary Myth.
Gilbert Burki: Binaries amongst the Supergiants and Cepheid Variables.
Michel Mayor: The Characteristics of Binaries amongst Solar-Type Dwarfs in the Disk.
David W. Latham: The Characteristics of Binaries amongst Halo Dwarfs.
Michel Mayor: The Characteristics of Binaries in Open Clusters.

II.2. THE IMPACT OF RADIAL VELOCITY OBSERVATIONS ON GALACTIC STRUCTURE AND EVOLUTION.

This joint meeting with Commission 33 was organized by D. W. Latham and chaired by M. Mayor. It took place on Saturday morning 27 July 1991 (session 1). The purpose was to report on the progress which has been made towards understanding the structure, kinematics, chemistry, and evolution of the disk and halo of the Milky Way, from radial-velocity observations of both stars and gas.

The following scientific contributions were presented:
Leo Blitz: The Shape of the Disk.
David W. Latham: The Structure, Kinematics, Chemistry, and Evolution of the Thick Disk and Halo.
Michel Grenon: Connections between the Disk, Halo and Bulge.
Dante Minniti: The Kinematics and Chemistry of the Bulge.

II.3. RADIAL VELOCITY STANDARD STARS.

This meeting was organized and chaired by D. W. Latham. It took place on Saturday morning 27 July 1991 (session 2). The purpose was to report on the progress made towards the goal of establishing a new set of late-type IAU Radial Velocity Standard Stars with individual mean velocities and absolute zero point of the system good to 100 m s^{-1}. The agreement on the zero point for solar-type dwarfs, based on observations of minor planets at three observatories, appears to be close to the 100 m s^{-1} goal. However, there is a significant color effect, resulting in a disagreement of 1 km s^{-1} or more for the reddest stars. At the blue end of the main sequence, new techniques have been applied and progress is being made in the monitoring of potential candidates for standard stars. As more observations accumulate, the evidence grows that most of the late-type giants have low-amplitude velocity variations, as do some of the late-type dwarfs. The session ended with a lively discussion of what work should be done next.

The following scientific contributions were presented:
David W. Latham: An Overview of the Efforts towards New Radial Velocity Standard Stars.
Alan H. Batten: Standard Star Observations at Victoria.
Robert P. Stefanik: Standard Star Observations at the Center for Astrophysics.
Michel Mayor: Standard Star Observations with CORAVEL.
Helmut A. Abt: Fekel's Observations of Early-Type Candidate Standards at Kitt Peak.

II.4. NEW TECHNIQUES.

This meeting was organized and chaired by D. W. Latham. It took place on Tuesday afternoon 30 July 1991 (session 3). The original purpose was to review the efforts at several observatories to develop techniques for very high precision in the range 5 to 50 m s^{-1}. Unfortunately, only two of the nine groups doing this work were represented at the General Assembly.

The following scientific contributions were presented:
David W. Latham: Towards Higher Precision; An Overview of Efforts Around the World.
Thomas G. Barnes: The Texas Program.
R. de la Reza: A Search for T Tauri Bínaries among IRAS Stars.

III. *Working Group on Radial-Velocity Standard Stars.*

A meeting of the Working Group on Radial Velocity Standard Stars took place on Tuesday morning 30 July 1991, attended by those members present at the General Assembly (R. P. Stefanik, M. Mayor, G. Burki, and D. W. Latham). The Working Group discussed recommendations in the following areas:

-Procedures for reporting to the astronomical community the present status of the Radial Velocity Standard Stars.
-Work on Radial Velocity Standard Stars to be done over the next three years.
-Priorities and guidelines for cataloging efforts in the future.
-Publication procedures and formats for all results.

Despite the hopes expressed at General Assembly XX in Baltimore, we are still not in a position to publish a definitive list of new IAU Radial Velocity Standard Stars, because of two problems. First, we have the vexing question of the color dependence of the zero point comparison between Victoria, CORAVEL, and CfA. The fact that the Victoria and CfA zero points agree quite well should not be interpreted as conclusive evidence that the problem lies with CORAVEL, because there are several types of systematic problems which could still plague the CfA and Victoria systems. Further work should be done to clarify the source of the color problem. Second, quite a number of the present set of IAU Radial Velocity Standard Stars are clearly variable, and several now have reliable orbital solutions. Even among the "future primary standard star candidates" published in the Commission 30 report in Transactions XXB, where an attempt was made to eliminate stars with significantly variable velocities, several additional candidates are now suspected to be variable. The problem is that there will always be suspected variables as more data with better precision are accumulated. Where should the line be drawn?

III.1. REPORTING THE STATUS OF THE RADIAL VELOCITY STANDARD STARS.

An attempt should be made to communicate to the astronomical community the identity of those IAU Radial Velocity Standard Stars which are variable at a semi-amplitude larger than 1 km s^{-1} or whose IAU velocity appears to be in error by more than 1 km s^{-1}. The Working Group agreed that a revised list of IAU Radial Velocity Standard Stars should be provided to the *Astronomical Almanac* in which such stars have been removed from the list of approved standards. To avoid possible confusion that might result from the publication of interim velocities, only the present IAU velocities should be listed. To inform astronomers which stars were removed from the primary list, a second table should be provided in the *Astronomical Almanac*, listing those stars and giving a short reason why they were demoted. This way astronomers may have some hint about the reasons for the fall from grace of their favorite standard stars.

To stimulate progress towards the establishment of a new set of primary IAU Radial Velocity Standard Stars, the Working Group recommended that the teams who are working on this project at individual observatories should each publish a status report describing their efforts and listing their individual velocity measurements. This will make it much easier for the Working Group to compare the results from the different teams, which can not be done at one or two short meetings during the crowded schedule of a General Assembly.

The chairman of the Working Group should assemble and maintain a catalog of the IAU Radial Velocity Standard Stars plus the candidates for the new list of standards, listing the best value presently available from all the teams measuring these stars as well as the IAU velocity, and containing notes on any variability either confirmed or suspected. This catalog should be made available in electronic and/or paper form upon request to the chairman, R. P. Stefanik at the Center for Astrophysics: stefanik@cfa.harvard.edu (internet) or stefanik@cfa (bitnet).

III.2. WORK FOR THE NEXT THREE YEARS.

In consideration of the good agreement between CORAVEL, CfA, and Victoria for the G dwarfs, where the zero point has been established by observations of minor planets, a modest set of G dwarf stars should be selected as candidates for a subset of primary standards which might be ready for adoption by the next General Assembly. The extensive monitoring of nearby solar dwarfs carried out by the CORAVEL team over the past decade should be drawn upon to define a list of one or two dozen candidate stars which are unlikely to have large velocity variations. The candidates should be distributed around the equatorial region of the sky to allow access from both hemispheres. These stars should then be observed by other teams with the highest precision possible, both to allow comparisons of the zero points and to further

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check for variable velocities.

To investigate possible sources of the color term in the zero-point comparison, observations of the main sequence of nearby open clusters should be used, to as faint and red limits as possible. The Hyades cluster is a good candidate, but care should be taken to adopt exactly the same convergent point when comparing the results for specific stars in this cluster as measured by various instruments. Attempts should also be made to develop calculated spectra for use as templates with instruments which record spectra, where the correlations are computed digitally. Unfortunately, the models and molecular line lists are not yet good enough to extend this approach to very cool stars.

For those stars which appear to have velocity variations which are strictly periodic, attempts should be made by the various teams to see if they get the same orbital solutions from their independent data sets. Here the goal is to extend our knowledge of low-mass companions of stars.

Establishing a satisfactory system of standard stars of early spectral types (O-B-A) will require several years of additional effort. Continued monitoring of Fekel's list of candidates is strongly encouraged.

III.3. CATALOG PRIORITIES.

The Working Group discussed the various catalogs which are needed, and recommended the following priorities:

1. Maintain a bibliographic catalog. One of the main goals of this effort is to make sure that the SIMBAD data base is as accurate and up-to-date as possible. The team in Strasbourg does not have the resources or expertise to evaluate the literature critically, so this must be done by someone with considerable experience in the radial velocity field. Ideally this catalog should be updated on an annual basis. An astronomer must be found who can continue this work after M. Barbier retires in 1994.

2. Maintain a spectroscopic orbit catalog. Alan Batten has already retired and will no longer be able to work towards a ninth edition of his catalog of spectroscopic orbits. Here again it is important to have an expert who can make a critical evaluation of the published orbits, following the tradition established by Batten. However, the Working Group recommended that all published orbital solutions for each star should be included in a concise format, to allow the user to make an independent evaluation of the status of the solutions. David Latham volunteered that this work could move to the Center for Astrophysics, where it could be included as part of the effort to document the characteristics of the target star candidates for NASA's SETI Microwave Observing Project.

3. Maintain a mean velocity catalog. Hopefully an astronomer can be found to continue this work after M. Barbier retires in 1994. Such a catalog can be used for statistical studies and research on Galactic structure, so it would be useful if it included photometry where available. With the increase in the number of different instruments being used for velocity measurements, a new weighting scheme should be devised, based on the actual precision achieved by each system.

For all these catalogs epoch 2000 positions should be used, as officially recommended by the IAU, and the names of stars should follow IAU recommendations as closely as possible (IAU Transactions XXB, p. S36, 1988).

III.4. PUBLICATION OF RESULTS.

The Working Group supports strongly the long-standing IAU recommendation that all individual velocity measurements should be published, not just for variable stars, but also for stars that appear to be constant. With each velocity (expressed in km s^{-1}) an estimate of the error should be given. The heliocentric Julian Day for the middle of the exposure should be used, not the modified Julian Day. The values for the velocities and times should be given to one more place than is significant. In the header for each star, not only should the star name be given, following the IAU recommendations documented in the preceding section, but also the epoch 2000 coordinates should be listed. This redundancy is very valuable for identifying errors, and for assisting in the preparation of observing lists.

To assist in the preparation of merged catalogs of individual velocities from various observatories and in the preparation of a mean velocity catalog, the Working Group recommends that an electronic and/or magnetic version of the results in ASCII format be prepared when each publication is accepted, and should be sent to a central repository, presumably the astronomer who takes over the responsibility for the mean velocity catalog. The recommended format for every velocity includes the header information, to facilitate chronological merging:

Star name (16 characters); position "hh:mm:ss.s sdd:mm:ss" (epoch 2000); instrument code (4 characters); velocity "svvv.vvv" and error "vv.vvv"; heliocentric Julian Day minus 2,400,000 "ddddd.dddd"; and comments, such as alternative names. It is envisioned that the person in charge of the central repository would assign a numerical code to identify the instrument and publication, and this would also be included with each entry. Each field would be separated by a blank space, to enhance readability and ease of proofreading.

III.5. CANDIDATE RADIAL VELOCITY STANDARD STARS

For more than a decade, Francis K. Fekel has been monitoring the velocities of bright early type stars which might be suitable candidates for eventual service as radial velocity standard stars, using a variety of instruments: Kitt Peak photographic, McDonald Observatory photographic, McDonald Observatory Reticon blue (4500A) and red (6375A), and Kitt Peak CCD blue (4500A) and red (6430A). His three primary early type standards are 68 Tau, θ Leo, and o Peg, with adopted velocities of +38.9, +7.7, and +8.5 km s^{-1}. In Table 1 his mean velocities are compared with published values from Lick (Publ. Lick. Obs. vol. 16), Morse, Mathieu, and Levine (1991 AJ, 101, 1495 and private communication)

Table 1. Candidates for radial velocity standard stars with early spectral types

HD	HR	Name		α (2000)	δ	V	Sp	v_{rot}	Fekel	Lick	Morse	Liu
1438	70	26	And	00 18 42	+43 47 28	6.11	B8 V	20			+3.3	
3360	153	17 ζ	Cas	00 36 58.2	+53 53 49	3.66	B2.5 IV	18	+0.5	+2.0	−0.3	+2.1
14252	675	10	Tri	02 18 57.0	+28 38 33	5.03	A2 V	18	−0.1	−0.2	−0.6	+0.6
23408	1149	20	Tau	03 45 49.5	+24 22 04	3.87	B8 III	35			+6.5	+7.6
23607				03 47 19.2	+24 08 23	8.25	A7 V	12			+5.1	+4.4
23873				03 49 21.6	+24 22 53	6.60	B9.5 V	85			+6.5	+6.3
26912	1320	49 μ	Tau	04 15 32.0	+08 53 32	4.29	B3 IV	89			+14.9	
27638	1369	59 χ	Tau	04 22 34.9	+25 37 45	5.37	B9 V	250			+14.4	
27962	1389	68 δ^3	Tau	04 25 29.3	+17 55 41	4.29	A2 IV-V	8	+38.9	+36.3	+38.7	+38.4
28114	1397			04 26 21.0	+08 35 24	6.06	B6 IV		+13.4			
34078	1712	AE	Aur	05 16 18.2	+34 18 43	5.96	O9.5 V	5			+52.8	
35708	1810	114	Tau	05 27 38.0	+21 56 13	4.88	B2.5 IV	20	+18.4	+15.8	+17.0	+20.4
38899	2010	134	Tau	05 49 32.9	+12 39 04	4.91	B9.5 V	21	+20.9	+22.0	+21.6	+24.4
43112	2222			06 15 08.5	+13 51 04	5.91	B1 V	25			+37.3	
58142	2818	21	Lyn	07 26 42.8	+49 12 42	4.64	A0mA1 IV	14	+26.9	+25.9	+26.0	
61555	2948			07 38 49.3	−26 48 07	4.5	B3 V	60			+24.1	
61556	2949			07 38 49.7	−26 48 13	4.8	B7 V	80			+25.5	
65900	3136			08 01 13.8	+04 52 47	5.65	A1 V	29	+44.2		+43.9	
72688	3383			08 34 01.5	−02 09 05	5.81	A1 V	4	+3.7			
77484				09 02 50.6	+00 24 30	7.8	B9.5 V	100			+27.2	
92728	4187	39	UMa	10 43 43.3	+57 11 57	5.80	A0 V	14	−14.9		−16.9	
95418	4295	48 β	UMa	11 01 50.4	+56 22 56	2.37	A0mA1 IV	40	−13.4		−14.4	
97633	4359	70 θ	Leo	11 14 14.3	+15 25 46	3.34	A2 IV	18	+7.7		+5.3	
107966	4717	13	Com	12 24 18.4	+26 05 55	5.18	A3 IV	44	+0.3		−2.5	
112413	4915	12 α^2	CVn	12 56 01.6	+38 19 06	2.90	A0 IIIp	20			+0.4	
128167	5447	28 σ	Boo	14 34 40.7	+29 44 42	4.46	F2 V	8	+0.0			
145570	6031	15 ψ	Sco	16 11 59.9	−10 03 51	4.94	A3 IV	34	−7.6			
145647	6035			16 11 28.7	+16 39 56	6.08	A0 V	40	−13.5			
147394	6092	22 τ	Her	16 19 44.3	+46 18 48	3.89	B5 IV	37	−17.8	−13.8		
155763	6396	22 ζ	Dra	17 08 47.1	+65 42 53	3.17	B6 III	37	−16.2			
166182	6787	102	Her	18 08 45.4	+20 48 52	4.36	B2 IV	37	−14.3			−14.1
179761	7287	21	Aql	19 13 42.6	+02 17 38	5.15	B8 II-III	12	−4.9	−4.8	−5.9	−3.7
186568	7512			19 43 51.3	+34 09 45	6.05	B8 III	14	−8.4		−8.8	−6.5
193432	7773	8 ν	Cap	20 20 39.7	−12 45 33	4.76	B9.5 Va+	18	−2.2	−2.8	+0.5	
196426	7878			20 37 18.2	+00 05 50	6.22	B8 IIIp	6	−18.6			
196821	7903			20 39 10.5	+21 49 03	6.08	A0 III	18	−32.8			−29.2
209459	8404	21	Peg	22 03 18.9	+11 23 11	5.80	B9.5 V	4	+0.4		+0.6	+4.5
214994	8641	43 o	Peg	22 41 45.3	+29 18 27	4.79	A1 IV	4	+8.5	+7.9	+9.1	+10.6
217811	8768			23 02 45.1	+44 03 32	6.39	B2 V	10	−10.2		−11.2	

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and Liu, Janes, and Bania (1991 ApJ, 377, 141). Other published velocities for some of these stars may be found in Wolf (1978 ApJ, 222, 556), and Abt and Levy (1978 ApJS, 36, 241). In addition to the Fekel list, Table 1 also includes three candidates from Morse *et al.* with very early spectral types, two candidates in the Pleiades proposed as possible standards by Liu *et al.*, and six candidates from the Lindroos catalog of wide pairs suggested as possible standards by Mathieu, Latham and Morse (the velocities for these six are listed in the column under Morse).

For more than a decade there have been major efforts at the Center for Astrophysics, Geneva Observatory, and Dominion Astrophysical Observatory to monitor the IAU radial velocity standard stars with late spectral types. The status of these efforts is summarized in table 2, where stars have been removed if their velocity varied by more than 1 km s^{-1}.

Table 2. Candidates for radial velocity standard stars with late spectral types

HD	HR	Name	α (2000)	δ	V	Sp	IAU	CfA	COR	DAO
693	33	6 Cet	00 11 15.8	−15 28 05	4.89	F6 V	+14.7	+14.69	+14.92	+15.09
3712	168	18 α Cas	00 40 30.4	+56 32 15	2.23	K0-IIIa	−3.9			−4.26
3765			00 40 49.1	+40 11 14	7.36	dK5	−63.0	−62.80		
4128	188	16 β Cet	00 43 35.3	−17 59 12	2.04	G9.5	+13.1	+13.49	+12.71	+13.16
4388			00 46 27.0	+30 57 06	7.51	K3 III	−28.3	−27.63		
8779	416		01 26 27.2	−00 23 55	6.41	gK0	−5.0	−3.83	−4.72	
9138	434	98 μ Psc	01 30 11.1	+06 08 38	4.84	K4 III	+35.4	+34.25	+33.59	
12029			01 58 41.8	+29 22 47	7.80	K2 III	+38.6			
12929	617	13 α Ari	02 07 10.3	+23 27 45	2.00	K2-IIIab	−14.3		−15.02	−14.51
18884	911	92 α Cet	03 02 16.7	+04 05 23	2.53	M1.5 IIIa	−25.8	−25.51	−26.79	−25.30
22484	1101	10 Tau	03 36 52.3	+00 24 01	4.28	F9 IV-V	+27.9	+28.06	+27.85	+27.95
23169			03 43 52.8	+25 43 36	8.75	G2 V	+13.3			
26162	1283	43 Tau	04 09 09.9	+19 36 33	5.50	K1 III	+23.9	+25.02	+24.26	+24.79
29139	1457	87 α Tau	04 35 55.2	+16 30 33	0.85	K5+ III	+54.1	+54.51	+53.55	+54.25
29587			04 41 36.3	+42 07 06	7.29	dG2	+112.4	+111.81		
32963			05 07 55.7	+26 19 42	7.72	G2 V	−63.1			
36079	1829	9 β Leo	05 28 14.7	−20 45 35	2.84	G5 II	−13.5	−13.81	−14.37	
42397			06 11 34.7	+25 00 35	8.03	G0 IV	+37.4			
51250	2593	18 μ CMa	06 56 06.6	−14 02 37	5.00	K2 III + B9 V	+19.6	+18.46	+17.53	
62509	2990	78 β Gem	07 45 18.9	+28 01 34	1.14	K0 IIIb	+3.3	+2.83	+3.23	
65583			08 00 32.2	+29 12 44	7.00	dG7	+12.5	+14.68		
65934			08 02 11.1	+26 38 18	7.94	G8 III	+35.0			
66141	3145		08 02 15.8	+02 20 04	4.39	K2 III	+70.9	+72.07	+71.14	+71.45
75935			08 53 49.9	+26 54 48	8.63	G8 V	−18.9			
80170	3694		09 16 57.1	−39 24 05	5.33	K5 III-IV	+0.0		+0.00	
81797	3748	30 α Hya	09 27 35.2	−08 39 31	1.98	K3 IIIa	−4.4	−4.18	−5.31	−4.35
84441	3873	17 ε Leo	09 45 51.0	+23 46 27	2.98	G1 IIab	+4.8		+4.38	+4.40
86801			10 01 34.3	+28 33 59	8.88	G0 V	−14.5			
89449	4054	40 Leo	10 19 44.1	+19 28 15	4.79	F6 IV	+6.5	+6.41	+6.00	+6.43
90861			10 29 53.6	+28 34 52	7.20	K2 III	+36.3	37.83		
92588	4182	33 Sex	10 41 24.1	−01 44 29	6.26	sgK1	+42.8	+42.88	+42.24	
102494			11 47 56.4	+27 20 25	7.44	G8 IV	−22.9	−21.94		
102870	4540	5 β Vir	11 50 41.6	+01 45 53	3.61	F9 V	+5.0	+4.48	+4.31	+4.38
103095	4550		11 52 58.7	+37 43 07	6.45	G8 Vp	−99.1	−98.51		−98.58
107328	4695	16 Vir	12 20 20.9	+03 18 45	4.96	K0.5 IIIb	+35.7	+36.67	+35.91	+36.48
108903	4763	γ Cru	12 31 16.7	−57 04 51	1.63	M4 III	+21.3		+20.25	
109379	4786	9 β Crv	12 34 23.2	−23 23 48	2.65	G5 IIb	−7.0	−7.86		
112299			12 55 28.1	+25 44 23	8.66	F8 V	+3.4	+4.53		
114762			13 12 19.7	+17 31 00	7.31	dF7	+49.9	+49.32	+49.03	
122693			14 02 52.1	+24 33 48	8.21	F8 V	−6.3	−5.34		

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Table 2. Continued

HD	HR	Name		α (2000)	δ	V	Sp	IAU	CfA	COR	DAO
123782	5300	13	Boo	14 08 17.2	+49 27 29	5.25	M2 IIIab	−13.4	−14.25		
124897	5340	16 α	Boo	14 15 39.6	+19 10 57	−0.04	K1.5 III	−5.3	−5.01	−5.98	−5.30
126053	5384			14 23 15.2	+01 14 30	6.27	G1 V	−18.5	−19.40	−19.47	
132737				14 59 52.5	+27 09 35	8.02	K0 III	−24.1	−22.57		
136202	5694	5	Ser	15 19 18.7	+01 45 55	5.06	F8 IV-V	+53.5	+54.66	+54.30	+54.45
140913				15 45 07.7	+28 28 10	8.21	G0 V	−20.8	−19.85		
144579				16 04 56.7	+39 09 23	6.66	dG8	−60.0	−59.50		
145001	6008	7 κ	Her	16 08 04.4	+17 02 49	5.00	G5 III	−9.5	−10.36	−10.77	−10.33
146051	6056	1 δ	Oph	16 14 20.6	−03 41 39	2.74	M0.5 III	−19.8	−19.00	−20.24	−19.14
149803				16 35 54.2	+29 44 44	8.40	F7 V	−7.6	−6.54		
150798	6217	α	TrA	16 48 39.8	−69 01 39	1.92	K2 IIb-IIIa	−3.7	−3.50		
154417	6349			17 05 16.7	+00 42 09	6.01	G0 V	−17.4	−16.87	−16.81	−16.92
157457	6468	κ	Ara	17 25 59.8	−50 38 01	5.23	G8 III	+17.4		+17.22	
161096	6603	60 β	Oph	17 43 28.2	+04 34 02	2.77	K2 III	−12.0	−12.33	−12.86	−12.18
168454	6859	19 δ	Sgr	18 20 59.5	−29 49 42	2.70	K2.5 IIIa	−20.0		−20.84	
171232				18 32 35.9	+25 29 21	7.73	G8 III	−35.9	−36.00		
171391	6970			18 35 02.2	−10 58 38	5.14	G8 III	+6.9	+7.39	+7.10	
182572	7373	31	Aql	19 24 58.0	+11 56 39	5.16	G7 IV	−100.5	−100.26	−100.33	−100.27
		+28 3402		19 35 00.2	+29 05 13	9.05	F7 V	−36.6	−36.67		
186791	7525	50 γ	Aql	19 46 15.4	+10 36 48	2.72	K3 II	−2.1		−3.38	−1.97
187691	7560	54 ο	Aql	19 51 01.5	+10 24 56	5.11	F8 V	+0.1	+0.02	−0.19	−0.05
194071				20 22 37.4	+28 14 47	8.13	G8 III	−9.8	−9.43		
203638	8183	33	Cap	21 24 09.5	−20 51 08	5.77	K0 III	+21.9	+22.27	+21.65	
204867	8232	22 β	Aqr	21 31 33.3	−05 34 16	2.91	G0 Ib	+6.7	+6.68	+6.02	+6.71
206778	8308	8 ε	Peg	21 44 11.0	+09 52 30	2.39	K2 Ib-II	+5.2		+2.63	
212943	8551	35	Peg	22 27 51.4	+04 41 44	4.79	K0 III-IV	+54.3	+54.39	+53.85	+54.26
213014				22 28 11.3	+17 15 48	7.70	dG8	−39.7	−39.57	−40.27	
213947				22 34 36.4	+26 35 52	7.53	K4 III	+16.7	+15.91		
222368	8969	17 ι	Psc	23 39 56.9	+05 37 35	4.13	F7 V	+5.3	+5.52	+5.58	+5.60
223094				23 46 25.3	+28 42 13	7.45	K5 III	+19.6	+20.22		
223311	9014			23 48 32.3	−06 22 50	6.07	gK4	−20.4	−20.22	−20.76	
223647	9032	1 γ	Oct	23 52 06.7	−82 01 08	5.11	G5 III	+13.8		+14.50	

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CfA: R. P. Stefanik and D. W. Latham, CfA Digital Speedometers, Cassegrain echelle spectrographs/photon-counting Reticon detectors at 1.5-m Wyeth Reflector, Oak Ridge Observatory, and 1.5-m Tillinghast reflector, Whipple Observatory, as reported at IAU General Assembly XXI, Buenos Aires, 1991; V(minor planet system) = V(table) + 0.00.

COR: M. Mayor, G. Burki and A. Duquennoy, CORAVEL Spectrometers on the 1.5-m Danish Telescope, European Southern Observatory, La Silla, as reported at IAU General Assembly XX, Baltimore, 1988. V(minor planet system) = V(table) + 0.40.

DAO: C. D. Scarfe, A. H. Batten and J. M. Fletcher, photographic spectrometer, coude spectrograph, 1.2-m reflector, Dominion Astrophysical Observatory, Publ. Dom. Astrophys. Obs., 28, 21, 1990.

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For more than a decade, the CORAVEL team has been monitoring a sample of nearby solar-type stars drawn from the Gliese Catalogue. In Table 3 we list their solar-type stars which have no obvious velocity variations. The final five columns give the mean CORAVEL radial velocity, the velocity *rms*, the number of observations, the time span of the observations in days, and the projected equatorial velocity. These stars should be useful for comparing the velocity zero points of different systems with an absolute zero point based on observations of minor planets. In particular, the use of these stars should help eliminate possible systematic errors as a function of color or luminosity.

Table 3. CORAVEL candidates for radial velocity standard stars with solar-type spectra

HD	HR	Name		α (2000)	δ	V	Sp	CORAVEL		N_{obs}	Days	v sin i
1461	72			00 18 40.4	−08 03 04	6.46	G0 V	−10.45	±0.26	12	3658	2.4
1835	88	9	Cet	00 22 50.3	−12 12 37	6.38	G3 V	−2.58	±0.28	20	2926	6.8
16895	799	13 θ	Per	02 44 10.2	+49 13 47	4.12	F7 V	+24.38	±0.27	11	4456	8.9
22879				03 40 19.7	−03 12 51	6.74	F9 V	+120.32	±0.28	59	4841	3.5
31966				05 00 33.6	+14 22 59	6.72	G5 V	−18.38	±0.24	13	2624	2.2
32923	1656	104 μ	Tau	05 07 25.1	+18 38 41	5.01	G4 V	+20.33	±0.31	22	4788	1.5
39881	2067			05 56 01.6	+13 56 04	6.67	G5 IV	+0.09	±0.25	16	2618	1.5
65583				08 00 32.8	+29 13 43	6.94	G8 V	+14.54	±0.25	81	4385	2.3
111395	4864			12 48 48.2	+24 50 29	6.31	G7 V	−9.20	±0.24	16	3320	3.0
118576A				13 37 13.0	+30 05 04	9.32	G8 V	+3.40	±0.40	14	4431	2.8
118576B				13 37 14.3	+30 05 12	10.53	G0	+3.59	±0.42	13	4431	1.4
126053	5384			14 23 14.5	+01 14 54	6.30	G1 V	−19.49	±0.26	198	4215	2.3
130948	5534			14 50 15.2	+23 54 41	5.85	G1 V	−2.64	±0.35	19	4871	6.7
131156	5544	37 ξ	Boo	14 51 22.7	+19 06 09	4.55	G8 V	+0.86	±0.22	15	4854	5.1
140538	5853	23 ψ	Ser	15 44 01.8	+02 31 02	5.88	G2.5 V	+18.69	±0.30	15	4867	2.1
146233	6060	18	Sco	16 15 36.4	−08 21 45	5.50	G2 Va	+11.56	±0.16	13	3812	3.1
154417	6349			17 05 16.8	+00 42 26	6.01	F8.5 IV-V	−16.95	±0.29	230	4797	6.0
161797	6623	86 μ	Her	17 46 28.6	+27 43 52	3.41	G5 IV	−16.71	±0.30	20	3743	1.8
187691	7560	54 ο	Aql	19 51 00.7	+10 25 03	5.10	F8 V	−0.16	±0.27	229	4826	4.0
190360	7670			20 03 34.7	+29 54 15	5.71	G6 IV+	−45.90	±0.25	20	4787	1.6
197076	7914			20 40 44.7	+19 55 52	6.45	G5 V	−35.86	±0.24	15	4312	2.2
217014	8729	51	Peg	22 57 27.1	+20 46 05	5.49	G2.5 IVa	−33.73	±0.23	22	4423	1.9

For more than a decade, a Canadian team has been monitoring about a dozen bright solar-type stars (Campbell, Walker, and Yang 1988, ApJ, 331, 902; Walker, Yang, Campbell, and Irwin 1989, ApJ, 343, L21) using a hydrogen-fluoride technique on the Canada France Hawaii Telescope. In Table 4 we list the nine solar-type stars in their program which show a total velocity range of less than 200 m s^{-1}. These stars should also be useful for comparing the velocity zero points of different systems.

Table 4. CFHT candidates for radial velocity standard stars with solar-type spectra

HD	HR	Name		α (2000)	δ	V	Sp	Range
10700	509	τ	Cet	01 44 10.0	−15 56 58	3.50	G8V	80
19373	937	ι	Per	03 08 57.5	+49 36 53	4.05	G0 V	70
20630	996	κ^1	Cet	03 19 20.7	+03 22 08	4.83	G5 V	100
90839	4112	36	UMa	10 30 38.6	+55 58 52	4.80	F8 V	120
102870	4540	β	Vir	11 50 39.2	+01 46 07	3.61	F8 V	90
114710	4983	β	Com	13 11 55.3	+27 51 57	4.26	G0 V	90
115617	5019	61	Vir	13 18 28.0	−18 17 47	4.74	G6 V	90
131156	5544	ξ	Boo A	14 51 22.7	+19 06 09	4.55	G8 V	180
188512	7602	β	Aql	19 55 18.5	+06 24 48	3.71	G8 IV	80