

30. COMMISSION DES VITESSES RADIALES STELLAIRES

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MEMBRES: MM. Adams, Campbell, Frost, Guthnick, Harper, Joy, J. H. Moore, Neubauer, Pearce, Sanford, Shajn, Struve, Young.

I. GENERAL PROGRESS

The three years that have elapsed since the Harvard meeting of the Union have witnessed steady progress in the determination of radial velocities. While the three large Pacific Coast Observatories have naturally been able to make the greatest additions to radial velocity work, the Yerkes Observatory, the Simeiz Observatory and the Observatory of the University of Michigan have also made valuable contributions. It is a pleasure to report that there will soon be three major accessions to the list of observatories capable of determining radial velocities. The David Dunlap Observatory of the University of Toronto with its 74-inch telescope, which should be in operation soon after the meeting, will have radial velocities as a prominent feature of its programme. The McDonald Observatory of the University of Texas with an 80-inch telescope now under construction should be ready to commence operations in 1936 and will undertake an extensive radial velocity programme. The Radcliffe Observatory at Oxford has now been granted permission by the Courts to remove to Pretoria, South Africa, and will establish there a 74-inch reflecting telescope, which will also be largely employed in the determination of the urgently needed radial velocities of the southern stars fainter than 5.5 visual magnitude. The Commission may, I believe, congratulate itself that substantial assistance in the preliminary steps leading to this permission of removal was provided by our action at the last meeting in presenting a resolution to the Union, duly passed by the General Assembly, pointing out the urgent need for additional radial velocities in the southern sky, and strongly supporting the project of the Radcliffe Observatory to establish a large telescope at Pretoria.

The radial velocity programme at the Mt Wilson Observatory during the past three years has included the following stars: Boss stars of types F, G, K and M fainter than visual magnitude 5.5; stars of large proper motion and a selected group of double stars ranging in magnitude to about 10; faint Cepheid variables; N- and R-type stars; and a considerable number of O- and B-type stars, some with bright lines and peculiar spectra, and others with interstellar sodium and calcium lines. In addition a list of 437 stars in the Selected Areas is under observation. The greatest progress has been made on the Boss stars, Cepheid variables and N- and R-type stars, and the radial velocities of approximately 500 stars belonging to these groups have been determined during the past three years.

At present the radial velocity programme is being reconsidered and a considerable number of stars between magnitudes 6.5 and 9.5 has been added to the general list. Stars with measured trigonometric parallaxes and proper motions are given preference. About 150 stars, which have been investigated by Prof. Hertzsprung and thought to be possible members of the Taurus Cluster, are included in the observing programme. In general the attempt is made to secure material in the observations of radial velocity which will bear directly upon physical investigations of spectra and determinations of spectroscopic parallax.

Three main programmes of radial velocity determinations are under way at the Lick Observatory. The first concerns the radial velocities of members of the galactic

star clusters with special attention to those clusters which are of importance for the study of galactic rotation. By means of a two-prism spectrograph with cameras of 6 inches and 3.5 inches focal lengths stars as faint as $11^m.0$ photographic can be obtained with the former and $12^m.5$ with the latter. The present programme, which relates to 72 clusters, contains 534 stars brighter than $10^m.5$ and 133 between $10^m.5$ and $12^m.5$ and is well advanced. Of these clusters 53 are at distances 700 to 5000 parsecs, especially suitable for the study of galactic rotation, while preparations are under way for observations of 24 additional clusters selected for great distance and even distribution in galactic longitude. The second programme includes 413 stars of classes Oe5 to B5, all those in the Henry Draper Catalogue between 0° and -23° which range between $7^m.0$ and $11^m.0$ visual. For the fainter stars a 6-inch camera on a two-prism spectrograph is being used and the observations are well advanced except between 7^h and 18^h R.A., for which two or three seasons will be required. The third programme, of the observation for radial velocities of about 800 stars of spectral classes F to M and of visual magnitude 8.5 to 8.6, which was mentioned in the last report, is in a well advanced stage both as to observation and measurement as less than a hundred spectrograms are required to complete two for each star. It is expected that this programme will be completed during 1935. In addition to these three extended programmes a number of high dispersion spectrograms of binaries of long period are being secured.

The radial velocity work of the Dominion Astrophysical Observatory during the past three years has been mainly concerned with stars of spectral classes A and B and with spectroscopic, eclipsing, and close visual binaries. The observing on an extensive programme of 800 A stars is practically completed and the work of preparation for publication is under way. Work is in progress on a programme of about 800 O to B5 stars fainter than visual magnitude 7.5 and north of the equator, but it will require several years to complete. The radial velocities of 477 miscellaneous stars of classes F to Mo, for 105 of which no velocity had previously appeared, have been published. Compared with the Lick Catalogue, the Victoria velocities are 0.9 km./sec. more negative, agreeing with the difference previously found for A-type stars. The orbits of ten spectroscopic binaries, four of which are eclipsing, have been completed and a revision of numerous former orbits effected with generally little change in elements. In addition some fifteen spectroscopic binaries of O-, B- and A-types, and twelve faint eclipsing variables are under investigation. Auxiliary programmes in progress include (a) a programme of 118 "c" stars fainter than $6^m.0$ north of the equator in which 60 additional spectra are required and (b) a small programme of 20 faint members of the Ursa Major Group, types A to M, of which 66 spectrograms have been secured.

The Yerkes Observatory is at present engaged in the re-observation of spectroscopic binaries with orbits determined 20 or more years ago, to investigate possible changes in the elements. A series of observations for the determination of the radial velocities of stars with very broad lines is being organized, primarily of those objects for which the velocities have been given as estimates rather than measures. Three-prism spectrograms will be obtained on emulsions of high contrast, and the measures will be made on a specially designed microphotometer with, it is hoped, equal precision to that obtained on sharp-lined spectra. In addition a detailed study is to be undertaken of the radial velocities of stars with variable absorption lines to find whether the velocity changes with the variation in line intensities. The radial velocity programme for the McDonald Observatory has not yet been definitely laid down but will include a determination of the radial velocities of faint

stars and also of the radial velocities of single stars and of spectroscopic binaries with high precision. The high precision radial velocities of single stars are for the purpose of a re-determination of the solar parallax and for the study of possible convection currents, and in spectroscopic binaries for the presence of perturbations. It is hoped the McDonald telescope will be ready for operation by the end of 1935.

The Observatory of the University of Michigan has been engaged mainly in the study of spectroscopic binaries and other stars with variable radial velocities. In the case of Be stars it has been found that variable emission lines have been associated with variable velocities, while in the case of long-period Cepheids, studies with respect to differences of velocity from lines originating at different atmospheric levels have been published for several stars. Long series of spectrograms of many irregular variables have been measured and the study is being continued. Work on several O-type binaries and on the re-determination of the orbits of a number of the brighter binaries is under way, while studies of the orbits and rotation effects of five eclipsing binaries have been completed.

Radial velocity observations at the Simeiz Observatory appear to be energetically pursued as, since the last meeting, the velocities of 343 stars, 301 about magnitude 6.25 and 42 standard velocity and other brighter stars, and the orbits of four binaries have been completed and published. A programme of B8 to A0 stars of visual magnitude about 7.0 is being observed with smaller dispersion, about 74A per mm. at $H\gamma$, in which about 900 spectrograms have been obtained and partly measured. This programme, for the determination of the radial velocities of some 250 stars, is being planned for investigating the systematic motions including galactic rotation. Observations have been completed of the stars brighter than 7.4 in Comae Berenices for the study of the radial velocities, proper motions and parallaxes of the members of the group, while observations of six spectroscopic binaries are in progress, and it is probable that many more down to 6^m.5 will be undertaken. About twenty constant velocity stars in addition to the standard stars are being systematically observed to furnish a check on the radial velocities.

The spectroscopic work at Berlin-Babelsberg has been mainly experimental, looking towards improvement in the optical and mechanical features of the equipment. However, an investigation of the wave-lengths, intensities and identification of the lines in early-type spectra is in progress with the glass spectrograph while, with the quartz spectrograph, the spectra of Wolf-Rayets stars and of selected gaseous nebulae for comparison, and also of some faint variables are being investigated.

2. REPORT OF SUB-COMMITTEES

REPORT OF SUB-COMMITTEE ON STANDARD VELOCITY STARS

The value of the comparison of the results of different observers for stars observed in common has become increasingly apparent with the rapid increase in the number of radial velocities and the diversity of the instruments used in the observations. As a result of the experience of the past three years by several observers, it seems clear that the provisional list of standard velocity stars, given as Table II in the Report of the Commission des Vitesses Radiales Stellaires (*Transactions of the International Astronomical Union*, 4, 181, 1932) should be enlarged to include brighter stars of advanced spectral type, and more stars which can be observed in common in the northern and southern hemispheres.

The members of this committee have made a study of stars suitable for these pur-

poses and suggest the following list of both bright and faint stars, many of which can be observed with high dispersion. Slight corrections have been applied to the velocities of some of these stars to make them conform to the system of the *General Catalogue of the Radial Velocities of Stars, Nebulae and Clusters* (Lick Observatory Publications, 18, 1932). While there does not seem to be any good reason to omit any of the very bright standard stars given in Vol. 3, p. 171, of these *Transactions*, it seems desirable in the future to use for these stars the revised values of the *General Catalogue* which differ on the average by 0.2 km. from those given in Vol. 3.

Recommended Standard Velocity Stars

H.D.	Name	Mag.	Type	α (1900)	δ (1900)	p.c. Vel. km./sec.	
3765	Lal.	1045	7.5	K5	0 ^h 35 ^m .3	+39° 40'	-62.9 ± 1.2
8779	Boss	320	6.5	G0	1 ^h 21 ^m .3	- 0° 55'	- 6.3 ± 1.3
9138	μ Piscium		5.1	K5	1 ^h 24 ^m .9	+ 5° 38'	+35.0 ± 0.4
26162	Boss	952	5.7	K1	4 ^h 3 ^m .3	+19° 21'	+24.0 ± 0.5
29587	Groom.	864	7.3	G1	4 ^h 34 ^m .5	+41° 57'	+105.0 ± 1.9
33725	Cin.	674	8.0	K0	5 ^h 7 ^m .1	- 9° 13'	+ 5.4 ± 1.5
35410	Boss	1300	5.2	G6	5 ^h 19 ^m .4	- 0° 59'	+20.6 ± 0.5
44131	Boss	1599	5.2	M1	6 ^h 15 ^m .0	- 2° 54'	+47.0 ± 0.3
65583	Lal.	15565	6.9	G7	7 ^h 54 ^m .3	+29° 31'	+14.2 ± 0.5
66141	Boss	2130	4.5	K2	7 ^h 57 ^m .1	+ 2° 37'	+70.9 ± 0.3
89449	Boss	2741	5.0	F5	10 ^h 14 ^m .3	+19° 59'	+ 6.2 ± 0.1
92588	Boss	2846	6.4	K0	10 ^h 36 ^m .3	- 1° 13'	+43.6 ± 0.5
95735	Boss	2935	7.6	M2	10 ^h 57 ^m .8	+36° 38'	-86.6 ± 1.7
103095	Boss	3112	6.5	G8	11 ^h 47 ^m .2	+38° 26'	-97.6 ± 0.8
107328	Boss	3213	5.1	K1	12 ^h 15 ^m .3	+ 3° 53'	+35.4 ± 0.3
110418	Boss	3308	7.2	K5	12 ^h 36 ^m .8	- 6° 57'	- 0.7 ± 0.6
114762	Cin.	1695	7.8	F9s	13 ^h 7 ^m .5	+18° 3'	+49.6 ± 0.3
123782	Boss	3631	5.4	M2	14 ^h 4 ^m .6	+49° 56'	-13.5 ± 0.4
142661	Boss	4053	6.7	G0	15 ^h 50 ^m .7	- 1° 52'	-38.3 ± 1.0
144579	Groom.	2305	6.8	G8	16 ^h 1 ^m .5	+39° 26'	-60.1 ± 0.4
145001	κ Herculis		5.3	G5	16 ^h 3 ^m .6	+17° 19'	- 9.9 ± 0.3
174142	Lal.	34958	7.9	K2	18 ^h 44 ^m .1	-10° 29'	-53.4 ± 1.5
184467	Groom.	2875	6.7	K5	19 ^h 29 ^m .4	+58° 23'	+11.2 ± 0.9
187691	\circ Aquilae		5.2	G0	19 ^h 46 ^m .2	+10° 10'	- 0.5 ± 0.3
203525	Boss	5490	6.2	K4	21 ^h 17 ^m .6	- 9° 45'	+12.6 ± 0.5
212943	Boss	5790	4.9	K0	22 ^h 22 ^m .8	+ 4° 12'	+53.9 ± 0.3
213014	Lal.	43876	7.5	G9	22 ^h 23 ^m .4	+16° 45'	-40.3 ± 0.7
218209	Fed.	4371	7.5	G2	23 ^h 1 ^m .2	+67° 53'	-21.4 ± 0.5
223311	Boss	6109	6.3	K1	23 ^h 43 ^m .4	- 6° 56'	-25.2 ± 0.4

This committee recommends to the Commission des Vitesses Radiales Stellaires that Table I of Standard Velocity Stars of type O and B be retained as given in the *Transactions of the International Astronomical Union*, 4, and that Table II be replaced by the more comprehensive table listed in this report.

W. S. ADAMS
J. H. MOORE
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REPORT OF SUB-COMMITTEE ON WAVE-LENGTHS

At the Harvard meeting in 1932, approval was given to the tables of wave-lengths for class O and B stars suggested by Pearce, and for class A stars suggested by Harper, and these tables have met with general adoption. No changes are indicated in the wave-lengths for class A stars, but an accurate interferometric determination of the wave-lengths of the three stages of silicon lines appearing in the O and B

stars, which has recently been made by Jackson, seems to require a revision of these particular wave-lengths. The changes in the *S*_{IV} and *S*_{III} lines are insignificant, but in the *S*_{III} lines, they amount on the average to -1.8 km./sec. and the new values are undoubtedly preferable. The previously adopted and revised values are given in the table below.

Revised Silicon Wave-Lengths

Stage	Wave-lengths of vol. iv, 1932	Revised wave-lengths
<i>S</i> _{IV}	4088.863	4088.862
<i>S</i> _{IV}	4116.104	4116.103
<i>S</i> _{II}	4128.053	4128.051
<i>S</i> _{II}	4130.884	4130.876
<i>S</i> _{III}	4552.654	4552.622
<i>S</i> _{III}	4567.872	4567.841
<i>S</i> _{III}	4574.777	4574.758

It was stated in the last report that the publication of tables of wave-lengths for late-type spectra which are frequently measured by the spectro-comparator or by comparison with solar or stellar standards, would be of doubtful value. However, it has been found at Victoria and elsewhere that micrometer measurements seem to give more consistent results than measures by the spectro-comparator, so that a system of wave-lengths suitable for one-prism dispersion with a linear scale of about 40A per mm. would probably prove generally useful. While the difficulty that the effective wave-length of some lines will vary with the dispersion and spectral types and with exposure and development still remains, there are a sufficient number of lines whose wave-lengths are fairly constant to justify the preparation and publication of such a table. The table given below of wave-lengths of lines in late-type stars valid with one prism dispersion is the result of measures of a large number of plates at Mt Wilson and Victoria. While the Revised Rowland Tables were used as a guide, the recommended values are really adjusted wave-lengths based on residuals from a large number of plates. They should therefore not be considered as final but rather as the values found generally useful for radial velocity measures of late-type spectra. While the third decimal place is hardly significant it is added in conformity with general practice.

The first section of the table contains the recommended wave-lengths of 34 lines compiled by Adams and in the next parallel column the wave-lengths of 24 of these lines compiled by Harper. Excluding the three lines marked by asterisks, where the relatively large differences appear to depend on the resolution employed, and which consequently should not generally be used, the difference in wave-length between Mt. Wilson and Victoria is quite as small as can be expected and, on the average, is only 0.017A, equivalent to about 1 km./sec. As the differences do not appear systematic, they will probably be practically averaged out when a dozen lines or so are measured, and may be considered negligible in comparison to other sources of error.

The second section of the table gives the recommended wave-lengths of lines which do not appear so frequently. In the case of the Mt Wilson lines, they are mainly of use in under-exposed spectrograms and with faint late-type dwarfs, and this is obvious from being nearer the position of maximum intensity in stellar spectra, more towards the red than the first list. The starred line in this section also should not be used as the wave-length appears to vary with type or resolution. The Victoria wave-lengths are of additional lines, which Mr Harper has found useful

when the measurable lines in the principal list are too few in number. In the table are columns for the principal elements concerned in the formation of the line, and for the spectral types over which the given wave-length is valid. It is believed by the sub-committee that the use of the suggested wave-lengths, or slight modifications of them indicated by experience, will give radial velocities sensibly free from error due to this cause, and it is hoped the lists will be found generally useful.

The table for three-prism dispersion, prepared at the Yerkes Observatory, is the result of a joint study by Frost and Struve, with the collaboration of many other Yerkes observers, of the measures of standard velocity stars with the Bruce three-prism spectrograph. The first part of the table contains the wave-lengths of 34 lines which are considered to remain constant over the types concerned from F5 to K2. The recommended wave-lengths are given in the first column and are the unweighted means for the 15 stars in the following columns. The individual adjusted wave-lengths in each star have been included so that users may have a check upon the precision of the values and on any possible systematic trend with type. In the second section of the table, the wave-lengths of 10 lines considered to vary with type are given. While the scatter is rather large for some lines it is believed that, in general, the progression with type is real. It is suggested by Struve that it be left to the individual worker to decide whether the recommended or certain other mean values should be used, as experience in conjunction with the data supplied by the tables will be the best guide. Wave-lengths farther into the violet would be more useful with spectrographs having the central ray at $H\gamma$, but additional lines can be added with much less difficulty than with one-prism dispersion.

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Wave-Lengths of Principal Lines for One-Prism Work

Suggested wave-lengths		A-H	Elements	Spectral Types
Adams	Harper			
3933.684	.664	+ .020	Ca II	F-M
3968.494	.465	+ .029	Ca II	F-M
3970.078	.075	+ .003	He	F
4005.256	—	—	Fe	F-M
4045.827	.808	+ .019	Fe	F-M
4063.607	.635	— .028	Fe	F-M
4071.751	.733	+ .018	Fe	F-M
4077.728	.732	— .006	Sr II	F
4101.750	.749	+ .001	H δ	F-G
4132.069	—	—	Fe	F-G
4143.740	.704	+ .036	Fe blend	F-M
4202.042	.066	— .024	Fe	G-K
*4215.545	.731	— .186	Sr II	F
4226.742	—	—	Ca	F-G
4235.951	.929	+ .022	Fe	F-G
4250.465	.479	— .014	Fe blend	F-M
4254.348	.353	— .005	Cr	G-M
*4260.488	.415	+ .073	Fe	F-M
4271.545	—	—	Fe blend	G
4271.580	.586	— .006	Fe blend	K-M
4282.622	.621	+ .001	Fe, Ca blend	K-M
*4289.542	.721	— .179	Ca, Cr blend	G-M

Suggested wave-lengths

Suggested wave-lengths		A-H	Elements	Spectral types
Adams	Harper			
4307.914	.939	-025	Fe, Ti II	G-K
4314.635	—	—	Sc II, Ti II, Fe, etc.	M
4314.668	—	—	Sc II, Ti II, Fe, etc.	G-K
4320.816	—	—	Sc II, Ti II	G-K
4320.884	—	—	Sc II, Ti II	M
4325.618	.652	-034	Sc II, Fe	G-K
4340.477	.504	-027	H γ	F-M
4383.559	.565	-006	Fe	F-G
4404.763	.742	+021	Fe	F-M
4408.368	—	—	V, Fe, V	M
4415.137	.153	-016	Fe	F-M
4427.258	—	—	Ti, Fe	G-M

Additional Lines

Suggested wave-lengths		Elements	Spectral Types
Adams	Harper		
3961.537	—	Al	K-M
*4030.769	4030.646	Mn	F-M
—	4035.683	V II, Mn	G-K
—	4092.478	Fe, Co, Mn, V, Ca	G-K
—	4118.681	Fe, Co	G-K
—	4127.840	Fe, V	G-K
—	4134.483	Fe, V	G-K
—	4191.555	Fe	G-K
4274.761	—	Ti, Cr blend	K-M
4318.660	—	Ca, Ti	K-M
4337.057	—	Fe	M
4351.848	—	Cr, Fe II, Mg blend	G-K
4379.240	—	V	K-M
4435.226	—	Ca, Fe, Ca blend	K-M
4454.910	—	Ca, Mn, Ti mainly	K-M
4461.809	—	Fe, Fe, Mn blend	G-M
4482.214	—	Fe blend	M
4494.575	—	Fe	F-M
4496.862	—	Ce	M
4508.293	—	Fe II	F-M
4522.707	—	Fe II, Ti blend	G
4522.809	—	Ti	K-M
4531.040	—	Cr, Co, Fe blend	G
4531.084	—	Cr, Co, Fe blend	K-M
4571.583	—	Mg, Ti II blend	M
4861.344	—	H β	F-M

REPORT OF SUB-COMMITTEE ON CO-OPERATION IN RADIAL VELOCITY WORK

The sub-committee has given consideration to the subject of further co-operation in radial velocity observations, especially to the question of the most efficient service to be rendered to observers by this committee.

A survey of present programmes for the determination of radial velocity reveals that there is perhaps a need of closer co-operation on the part of observers in obtaining these data for spectroscopic binaries and for variable stars in order to avoid

unnecessary duplication of effort. Accordingly a letter was addressed to the seven observatories now engaged in this work, Victoria, Mt Wilson, Michigan, Berlin-Babelsberg, Simeiz, Yerkes and Lick, requesting information concerning lists of these special stars on their present programmes of observation. On the basis of the data furnished it appears that several of these observatories have under way rather extensive programmes of such observations, the lists from the seven observatories containing 377 stars. Of these twenty-two are being observed at two observatories and three stars appear on the programmes of three institutions. While this duplication is perhaps less than was to be expected, and in a few cases is doubtless desirable, nevertheless it does represent some needless waste of effort.

In order that the present cases of overlapping observations may be corrected and to prevent further duplication in the future, your committee has adopted the following tentative procedure. Copies of these lists have been forwarded to each of the seven observatories, calling attention to the objects appearing on more than one programme and requesting the observers to communicate with one another at once concerning future observations of the stars in question. To make possible the continuation of this service, it is suggested that each observer send, once a year, to the chairman of the sub-committee, data for stars added to or removed from his list. To this end it is requested that such lists be sent early in December and these will be distributed to interested observers in January of each year.

The present method of securing co-operation in the determination of the radial velocities of spectroscopic binaries and variable stars has been put in operation by your committee, as a means of obtaining information as to the most practical and efficient procedure for accomplishing the desired end. Doubtless it will require modification to adapt it to the needs of various observers. While the data are now distributed to observatories engaged in radial velocity work, the information will be furnished to others who may desire it.

The sub-committee further wishes to offer its services to those who may desire its assistance in arranging new programmes of radial velocity work in order that needless duplication may be avoided.

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3. SUBJECTS FOR CONSIDERATION BY THE COMMISSION

(a) The publication of manuscript tables, compiled by Dr R. K. Young, containing the longitude and latitude for every degree in declination between 0° and 90° and for every 4 m. in right ascension in the first and third quadrants would be very useful in radial velocity work. From these values those for the other quadrants and for negative declinations follow simply. An additional table for the value of $\log b$ and a graph for the constant c in Schlesinger's formula

$$v = b \sin (\odot - \lambda) + c$$

enables the reduction for the velocity of the earth to be made in two or three minutes, a great saving of time over the tedious transformation of co-ordinates.

(b) A method for checking "reductions to the sun" suggested by Dr Adams is provided by a simple mechanical instrument designed by W. H. Christie and described in *The Journal R.A.S.C.*, September, 1934, which will give values correct to a few tenths of a kilometre.

(c) Dr E. B. Frost suggests encouragement of the use of discharge tubes as sources of comparison spectra, in view of the many advantages of such tubes over the ordinary arc or spark in air.

(d) A letter just received from the President of the French National Committee communicates a recommendation for consideration by Commission 30 at the Paris meeting:

That Commission 27 (Étoiles Variables) and Commission 30 (Vitesses Radiales) organize simultaneous observations by photometric and spectrographic methods, of eclipsing variables at or near the time of eclipse.

(e) Discussion and disposal of reports of sub-committees.

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