

### 13. THE REVISION OF THE GENERAL CATALOGUE OF RADIAL VELOCITIES

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The task of revising, or rather supplementing, the *General Catalogue of Radial Velocities* produced by R. E. Wilson in 1953 was entrusted to me by the Commission meeting at the Hamburg General Assembly. We are in the debt of Dr Buscombe, Secretary of our Commission, for urging on several occasions that this revision should be undertaken, and it is undoubtedly timely that it should be done. Progress has not been as rapid as it might have been had I not had the privilege of visiting the U.S.A. during these last months, but we have something to show for our work. It would be rash to predict a date for completion, and I doubt if the final manuscript will be ready in time for the Prague General Assembly. In the meantime I thank all those who have sent us lists of results and reprints, and I would urge them to continue to do this until we notify a final deadline for the present revision.

You all know R. E. Wilson's admirable work. I remind you that it contains 15 106 entries. As our revision stands at present we have used 9500 cards, each representing a star for which some new information is available. A total of 250 publications has been registered of which the content of 130 has been transferred to the record cards, much of the work being done by one of our able young ladies at the Cape, Miss Y. Z. R. Thomas, with various visiting astronomers, particularly Mr Stuart Malin and his wife, giving massive assistance. The remaining papers contain very few results each, and the situation as stated to me is that all these papers will require careful individual attention, even though their content in terms of numbers is rather small.

I am unable to divide the total of 9500 cards between totally new and previously observed stars, but I am reasonably certain that the two categories contain about equal numbers. We may thus expect the volume of the catalogue to be increased by about 30%. For the previously observed stars the situation runs all the way between extremes. I recollect a case where there are 152 old observations and one new one: as against this we have cases like HD 188088, listed in the old Catalogue as having a well-determined velocity based on four plates: at the Cape we have nearly 100 plates of this K-dwarf star, for many of which we cannot even determine a radial velocity owing to the complexity of the spectrum, which shows a degree of multiplicity which is certainly two and in all probability a good deal higher. The new Catalogue will thus not only supplement the old, but in addition some of the old entries will be totally replaced.

The absolute determination of radial velocities is a matter of very great difficulty. Nearly every worker in the field has been forced to have recourse to some degree of empiricism. We are content to adopt a uniform system which is somewhere near the truth. To a large extent this uniform system is provided by the general run of the stars in the original Wilson Catalogue. How far in error this system may be is unknown, but, in all probability, it is not wrong by more than one or two kilometres per second. The

deviation is probably large enough for us to demand caution in the discussion of smaller systematic motions. The acceptance of the original Catalogue as standard means that in an extension we should usually graft new results on to the old by the application of systematic corrections, much as R. E. Wilson did himself, while at the same time reducing inconsistencies. In some respects the original Catalogue is defective, and for the points I shall mention I have been much indebted for the opportunity to discuss problems both personally and in correspondence. First are the simple errata: for lists of these I am indebted to Dr Dorrit Hoffleit and to the Vatican astronomers who have published the galactic coordinates of the stars in the original Catalogue, and to a number of other individuals.

The chief scientific blot on Wilson's Catalogue seems to have been the incautious inclusion of F. J. Neubauer's B-star velocities, not published anywhere else. These velocities certainly have bad systematic errors, of the order of  $6 \text{ km s}^{-1}$  or more and large accidental errors, but the chief difficulty lies in their identification. Wilson's system of references to the literature was nothing like as complete as it should have been, especially in the case of stars with variable radial velocities. It is only going to be possible to deal with the suspect B-stars by a laborious process of picking them out one by one. I propose in general to adopt what has been called the Victoria-Pretoria system of B-star velocities and to give these over-riding weight as compared with a Lick observation of the same star if the latter is unpublished. I shall recommend the exclusion of Lick B-star velocities in cases where these appear to be unpublished and without independent support. I recognize that this may do an injustice to some of the Lick results and this is a great pity considering how much we owe to that Observatory. I do not want to hurt anybody's feelings, and when I have had time to come to firm proposals dealing with specific individual cases I shall take the opportunity to submit my views, either to the three observatories individually, or to the Session of the Commission in Prague. I shall indeed adopt this policy in all the difficult cases which arise, and I hope that we can later have expressions of opinion as to the correct course to follow.

Dr Feast has told me that he is somewhat dissatisfied with a number of the entries in the old Catalogue relating to long-period variables, in which the emission-line measures are genuine measures of radial velocity whereas certain of the absorption-line measures for these stars would appear to be empirical inferences from the emission-line measures and not true radial velocity measures at all. Where they can be identified, I propose to eliminate such measures from the Catalogue in consultation with him, and under guidance from the general body of my colleagues. I believe that it is also the case that many of the published velocities of RR Lyrae stars are observed values adjusted by an empirical correction based on an assumed relationship between light excursion and velocity excursion. Many velocities of RR Lyrae stars are now coming from Herstmonceux, the Cape, and elsewhere, and I think they will outweigh the older results in most cases.

I would be most grateful if any other difficult cases could be brought to my attention by specialists in various fields. I believe that there will be general agreement on the deficiencies of Wilson's reference system, and that you will share my desire to improve it, probably along the lines adopted by Dr Jaschek and his colleagues in the production of their spectral type catalogue. *The General Catalogue of Radial Velocities* is intended to be a collection of published and unpublished results, and so it is possible to include in the Catalogue the literature references to original sources. Obviously authors need not be bound by any erroneous values which they have inadvertently published. The correct

method of putting matters straight is for them to publish in the same journal as the original paper an appropriate list of errata. I am however considerably embarrassed by a number of authors who, in kindly submitting their papers for inclusion in the Catalogue, have made wholesale revisions of the published values, to such an extent that the corrected version is seriously different from the published one. I hope that colleagues will see my difficulty: if I take the modified paper and quote the original reference it will appear to later users of the Catalogue that I have employed incorrect values or made mistakes in arithmetic. If I describe the modified values as unpublished, which indeed they are, and omit the unmodified published values, I shall seem to have ignored a very considerable body of values published in the literature. This is a real dilemma: I think I must appeal to these authors themselves to publish their amended values with specific reference to their earlier publications, so as to remove a serious source of confusion.

I now turn to a consideration of the weights to be applied to various series of measures. I would like you to regard what I say as thinking aloud in the course of a search for the correct policy rather than as a statement of a well settled policy which I am determined to adopt. I am open to receive comments on this as well as the other problems, and I shall be very disappointed if I do not provoke useful discussion. My thoughts crystallise themselves along the lines of recommending how radial velocity programmes ought to be conducted. Most of my audience stands in no need of the considerations which I am about to advance, but I am anxious to read a set of concerted views into the record of this Symposium to serve as a guide to others not so well practised in the art. In theory, radial velocity measurement is absolute, and a single measure might be expected to differ from the correct value only by an observational error which might be assessed from the formal probable error of that measure. We know that in practice this is not so. Systematic errors come in from many sources depending on the dispersion: one example is the need to use empirical wavelengths for spectral features. Accidental errors are always larger than would be inferred from a simple consideration of formal probable errors. In coude spectrographs the formal errors go down, but real probable errors often remain large, or even increase, because of the difficulties of maintaining instrumental stability over pieces of equipment of which the physical size and complexity increase steadily with the years. Several speakers have already mentioned these problems and I am sure they will recur again and again. So we are all driven to lay down rigid procedures for obtaining and measuring our spectra, and to calibrate our instrumental system with reference to standard stars. If this calibration is to be of value the number of comparisons must be considerable: the set of comparisons must be a continuing one and be maintained throughout the programme: the physical conditions of the instruments employed must be maintained effectively constant, and the conditions under which the standard star spectra are obtained must be identical with those applying to the programme stars so that a real statistical control can be exercised. Thus a set of standard-star measure comprising, say, only half a dozen observations will not determine systematic corrections closely enough if, say, the true standard error of a standard-star measure is  $2 \text{ km s}^{-1}$  and the nominal probable error from four observations of a programme star is, say,  $0.5 \text{ km s}^{-1}$ . The tie-in is too weak, and to apply a systematic correction so determined may do more harm than good. If all the standard-star exposures are short while those of the programme stars are long, the standard-star measures will usually show a systematic error which may not really be applicable to the programme stars. If the observational programme is conducted in several runs, and in between them the dispersing elements

of the spectrograph are replaced by others, we shall not have a single, properly calibrated run. I could cite cases of radial velocity material submitted for the catalogue where all these errors of management, have been made. Fortunately in most cases only one such error has been committed at a time. From the Catalogue point of view, which is, after all, the point of view of the establishment of the best possible values from the data offered, runs of results which are too short, or inadequately tied in to existing standards lose much of their value. It is a counsel of perfection to urge observers to get their spectrographs working correctly and then to leave them severely alone over long periods, but it is counsel which ought to be given if we are to have accurate radial velocity measures, which are the only ones worth having. I would also urge authors to be frank about the correction procedures adopted, even though this can lead to difficulties with referees. Equally I would urge those among us who act as referees to welcome such frankness, since it is the sad truth that many worthy sets of radial velocity measures are not as accurate as they would like to represent themselves to be. An author may say 'The results have been corrected to the Mount Wilson Catalogue system' giving no details, where examination suggests that large and erratic corrections have been applied. Such an author is less likely to encounter trouble from referees than those who say frankly 'We have corrected our results by  $6 \text{ km s}^{-1}$ ', or whatever the value is. I prefer the latter. All the foregoing remarks are quotations from actual papers. Their relevance is that, whether the author successfully standardised his results or not, the catalogue compiler has to try to do it for him.

Accidental errors are often minimized in publication. Cases exist of authors who, having twice got the same answer for a star have published the result with a probable error of zero. This means that for some series of results the published errors cannot be taken on trust, and a separate investigation must be made to determine what weights ought to be applied. Again, I would urge authors to investigate carefully before publication what their real standard errors are, usually from studies of the dispersion of their measures of standard stars.

Now we come to the vexed question of format. There are only two general catalogues to my knowledge which are in terms of 1950.0 positions. These are Wilson's *General Catalogue of Radial Velocities* and the Boss *General Catalogue*. I believe Wilson's choice of equinox was determined by the fact that the vast majority of his stars appeared in the GC, so that the positions were immediately ready for transfer, and because he was working near the year 1950. In the construction of his Catalogue he introduced a new set of reference numbers, so that for most of his stars he has a serial number, a GC number or star name, and an HD number.

In laying out a revision several choices are available. The last 56 entries in the original Catalogue are called a supplement and their serial numbers are out of order for the right ascensions. We could simply continue this policy and add new stars in order with serial numbers above 15 106, but I do not think this is the right policy since all connection between the serial number and R.A. would be lost. Alternatively, we could adopt the decimal notation used in the *General Catalogue of Trigonometrical Parallaxes* for interleaving new entries between the old. If we were to do this we should begin by changing the numbers of the last 56 entries of the old Catalogue to the decimal notation and similarly add all the new items. I do not favour this for I have in mind the continuing necessity for later revision, and I would like to find a system which would permit easy later revisions. The scheme I propose is to omit the Wilson Catalogue serial numbers,



except that in the new version these would be incorporated in the notes, and to use HD numbers for the stars, or failing them, BD or other *Durchmusterung* numbers. My reasons for this proposal are the following: about 95% of the stars in the original Catalogue possess HD numbers, and I believe this to be true of the vast majority of the stars now being measured. Certainly most of the stars are more likely to have HD, a BD, or other DM number, simply because they are more numerous. The removal of the serial number and of other identifying numbers to the notes will give the room needed on the page if we are to try to include spectroscopic and photometric information.

If stars are identified by HD numbers in order, with *Durchmusterung* numbers interspersed on the basis of 1900.0 positions we shall have a catalogue arrangement which is similar to that adopted in the following catalogues—the *Henry Draper Catalogue* itself, of course; the Yale *General Catalogue of Trigonometrical Parallaxes*, the Yale *Bright Star Catalogue*, the Jaschek catalogue of spectral types, the Lick *Index Catalogue of Double Stars*, and some other general catalogues. I would propose also to give the positions for the year 2000.0. As an aside, let me say that one needs to distinguish between ease of finding the data for a given star, for which the identifying number and not the position is probably paramount, and the ease of finding any given star on the sky, for which contemporary coordinates can be readily found by linear interpolation between 1900.0 and 2000.0, in the majority of cases. I do not think my proposal should introduce any difficulty on either score, and will indeed make reference simpler. It will not be necessary for authors to undertake any updating of coordinates themselves.

Then there is the question whether we should try to supersede the old Catalogue by reprinting all valid information in it, together with new data in a single volume, or whether we should only print a supplement comprising only those stars for which new information is available. My preference is for the latter, but I am open to hear comments from my colleagues.

Finally, I should like to make some remarks on the completeness of the Catalogue, which is related very closely with its utility as a reference source. I am very well aware that in many academic centres of astronomical activity, stress is bound to be laid on the quality of originality in research, especially when research papers are incorporated into doctoral theses. Admirable though this is, it does have the effect of leaving unexplored some of the more obvious and, for the science of astronomy as a whole, very desirable areas of observation. For example, although the study of the motions, membership, and velocity dispersion of the Hyades cluster is of the highest importance for astronomy, there are about 75 members, or possible members, for which the radial velocities given in the *General Catalogue* are of class c or worse. Nearly all these stars are bright enough to be listed in the HD Catalogue. Again, no velocities have been determined at all for many of the stars listed in the new edition of the *Bright Star Catalogue*. As Dr Thackeray has pointed out, this is especially the case for stars in the southern sky, and for the later-type stars. Other examples could be cited of deficiencies of this kind which ought to be remedied, even at the price of foregoing, for a while, the challenge of more seductive and more difficult problems.

## DISCUSSION

*Underhill:* I approve of listing stars according to HD or DM numbers, but many faint stars in clusters only have numbers in rather incomplete photometric catalogues. I prefer

reference to a proper motion catalogue if possible. Regarding probable error, this is relatively meaningless if one has only a few observations and computes it by one of the usual formulae.

*Strand*: As far as the faint stars with proper motions are concerned they can be identified in the proposed catalogue by HZ (Humason-Zwicky) or LP (Leyden-Palomar 48-inch Schmidt telescope plates) numbers.

*de Vaucouleurs*: Are you interested in radial velocities of faint anonymous stars which are occasionally measured on nebular spectrograph plates of galaxies?

*Evans*: Yes.

*de Vaucouleurs*: It may be more convenient to give 1900 coordinates and 100-year precession rather than coordinates at two epochs.

*Blaauw*: Sometimes authors have published mean values of radial velocities with extremely small probable errors based on the small differences between their individual observations. These just happened by chance to come out nearly the same, and it would have been more correct to base the evaluation on internal error per observation.

*MacRae*: An estimate of a probable error, even one made from a small number of plates, is an independent estimate of that observer's precision of measurement. A value of zero, although unlikely to occur, is a significant value and should not be discarded.

*Heard*: Perhaps all observers should publish both internal and external probable errors so as to help the cataloguer to assess the precision of the results.

*Tatum*: Du Mond and Cohen (*Rev. mod. Phys.*, Oct. 1965) give good reasons for preferring standard deviations to probable errors.

*Buscombe*: I hope that both the emission and absorption velocities for long-period variables can be retained in the catalogue.

*Batten*: Do the majority of people here prefer coordinates at two epochs or at one epoch with precession for 100 years? In the Sixth Catalogue of Orbital Elements of Spectroscopic Binaries I can give either.

*Edmondson*: To be useful, the precision for 100 years should be computed for 1950, not 1900, in order to precess from 1900 to 2000.

*Wayman*: I would strongly advise making the record on punched cards available as early as possible and preferably before publication so that certain simple analyses would actually be included in the introduction, for example numerical estimates of systematic corrections.

Section II

RADIAL VELOCITIES FROM SLITLESS  
SPECTROGRAPHS