INTRODUCTORY REMARKS ON SPECTROSCOPIC PARAMETERS

By HELMUT A. ABT

Kitt Peak National Observatory, Tucson, Arizona

I hope that you will excuse a relative newcomer to this field and a spectroscopist for presenting his views, which may be somewhat different than those of others. I would like to enumerate the aims of research on visual systems and the needs of the field, particularly for spectroscopic data, as I see them.

I. Aims of Multiple-Star Astronomy. (1). *Statistics of multiple systems.* We would like to know the fraction of stars that are visually double, triple, etc. and in each case as a function of spectral type. For instance, is the frequency of visual doubles the same for Population II stars as for Population I stars? Or are the frequencies of visual doubles the same for stars off the main sequence as for their antecedents on the main sequence? For such information a negative result on duplicity is as important as a positive result, i.e. we wish to know which stars are *not* seen to be visually double as well as which ones are seen as doubles.

Also, we wish to know whether the luminosity function for stars in multiple systems is the same or different than for single stars, namely the van Rhijn or Luyten luminosity function. We note that in open clusters there often seems to be a deficiency of low-luminosity stars relative to those expected.

Many other such questions regarding statistics of multiple systems can be formulated.

(2). *Masses.* The importance of work on visual systems for obtaining stellar masses is well-enough known to this group not to warrant further discussion.

(3). *Luminosities.* There are many special kinds of stars that are relatively rare and therefore not found in clusters, although they may occur in visual systems: examples are S stars (π^1 Grus) and certain kinds of eclipsing binaries (β Lyrae). The brightest Wolf-Rayet star, γ Velorum, seems to be a member of a small visual group. By establishing membership in these groups and studying the characteristics of the normal companions, one can determine the luminosities of the abnormal stars. Also, one can calibrate the luminosities of normal stars, as was done recently for the B stars by Murphy.

(4) *Statistics of Orbital Parameters.* We wish to learn the distributions of the various orbital parameters, such as the frequency distributions of various periods, separations, eccentricities, inclinations to the galactic plane, etc. For this work we must be careful that our procedures do not bias our results or that appropriate corrections are made for them.

II. Difficulties. At this point I would like to make a plea for more cooperation in our research on visual systems. I realize that the greatest deficiency is for more spectroscopic data, and I believe that this lack can be met in coming years. Appreciable work has already been done at the Dominion Astrophysical Observatory and elsewhere. We appreciate the efforts of Drs. Dommanget, Muller, and others to specify needs for data. On the other hand, spectroscopists would like to see more positional work done on widely-spaced systems, such as common-proper-motion and Orion-type systems.

There are severe difficulties standing in the way of truly joint work on visual systems. Let us enumerate some of these, although most of these are so well known that they only need be mentioned.

1. The extremely long periods of systems in which the components can be observed separately by spectroscopists and photometric observers.

2. The paucity of nearby systems involving early-type stars.

3. The faintness (for spectroscopists) of late-type dwarfs and white dwarfs.

4. The broad spectral lines among most early-type stars. For instance, two F0 V stars at $V = 6.0$ mag with $a = 0''.5$ and $i = 30°$ will have $K_1 = K_2 = 8$ km/sec. Such a pair cannot be observed individually by spectroscopy and their lines will generally be too broad for resolution. If one star is fainter, the system can be treated as a single-lined spectroscopic binary, but to measure this velocity amplitude, one would like a dispersion giving a probable error of about one-tenth the amplitude, or 0.8 km/sec. Currently this probable error can be obtained only if the line widths correspond to a projected rotational velocity of less than 100 km/sec. The fraction of main-sequence stars for which this is true is only about 27% of the B stars, 36% of the A's, and 92% of the F's. The remaining early-type stars usually have too broad lines for the detection of motion in visual systems.

5. Difficulty in getting separate spectra and photometry in short-period systems, such as many of those having known orbital elements.

III. Current Needs. (1). *Compilations of known data.* Here I wish to discuss the needs for, primarily, spectroscopic data for visual systems. One need is a better way to find the radial velocities of individual stars. For some observatories the published measures are found in a few volumes of their publications, but for other observatories one may have to search through a hundred volumes of the *Astrophysical Journal.* After doing much of this kind of searching, I decided to compile a *Bibliography of Stellar Radial Velocities.* This has been done with Mrs. Eleanor S. Biggs and the 512-page volume is available. It is based on a search through 1100 volumes of astronomical literature; it lists 44,000 references for 25,000 stars.

Even so, an interested person will find that for most of the radial veloci-

https://doi.org/10.1017/S0252921100150390 Published online by Cambridge University Press

ties measured at the Mount Wilson Observatory, the individual velocities and dates of observation were never published; only the undated means of several measures are given. Half of the radial velocities measured to date were obtained at the Mount Wilson Observatory. Therefore I have been compiling the individual velocities and dates. The catalog for the first twelve hours of right ascension was published as *Astrophysical Journal Supplement No. 179*. The data for 12–20^h is complete and preprints are available.

We might consider a more comprehensive catalog, namely one giving all the available pertinent spectroscopic data for individual visual systems. Those data would be the radial velocities or a summary of the velocity data, the spectral types and spectral peculiarities, and the rotational velocities. We should consider the advisability of compiling such a catalog (perhaps combined with other types of data on visual systems, such as photometry and positional results), although I think that it is too early to compile the spectroscopic data because the gaps in our knowledge are so large. This brings us to the next need.

(2). *More basic data.* Most visual systems, even those with known orbital elements, lack MK spectral types. We hope to make some progress on this at Kitt Peak.

As Dr. Hardie has pointed out so well, we need much more photometry of components of visual systems, both for the widely-spaced common-proper-motion and Orion-type systems and for the intermediately-spaced doubles. You are well aware of the progress made by Drs. Strand, Worley, Muller, Hardie, Franz, and others.

Many more radial velocities are needed, both in closely-spaced systems having known orbital elements or in systems in which radial velocities will aid in the determination of orbital elements, as well as for the more widely-spaced systems to establish physical association. I might mention here a program of this sort being done at Kitt Peak. Starting in 1966 Dr. N. B. Sanwal and I have been obtaining coudé spectra (mostly of 13 A/mm dispersion) of many visual systems. Initially they included all stars in the Worley catalog brighter than $V = 6^m.5$ and north of $-30°$ declination. To date we have accumulated 958 spectra, of which Sanwal has measured 419. In addition, we obtained from the Lick Observatory the Mills spectra obtained by Dr. Elizabeth Roemer in 1953-58 and of 152 such spectra, 137 have been measured. In addition, other systems of interest have been added to the program.

Another need is for data on rotational velocities of early-type stars in visual systems. Many spectroscopists have had the experience of learning or computing that a system will have a periastron passage with an expected radial-velocity change of, say, 5 km/sec and then discover upon taking one

spectrum that the lines are too hopelessly broad to detect that motion. Thus we would like to know in advance which systems have sharp or broad lines, so at Kitt Peak we are collecting such data.

We sincerely hope that substantial progress will be made in the coming years in these spectroscopic programs and that the cooperation with other observers of visual systems will increase greatly.

Discussion

Abt was asked if radial-velocity measurements in the red spectral region would be feasible, provided that standard wavelengths became available. He did not favor this possibility because of the much lower accuracy. Strand mentioned L. Fredrick's work in the red region with the Carnegie image tube which is believed to have succeeded in faster recording of spectra.

Batten reported on the radial-velocity observations of selected close visual binaries which are continuing at Victoria. Although a dispersion as high as 2.4 A/mm is employed for some pairs, 6th and perhaps 7th magnitude objects can be reached. On the program are nearby pairs like Procyon, 70 Oph, 61 Cyg, the triple-lined ADS 8189 and also the wide pair ADS 9537 which is composed of two contact pairs. Dommanget mentioned that spectroscopic observations of the components in wider pairs may help to distinguish between physical and optical doubles.

Walker discussed the close pair ADS 14859 which contains an F2 Ib Cepheid with a period of 3.335 days and has a spectral-photometric parallax of 0".002. Despite the small magnitude difference, the spectrum is single-lined, and the probable blending may cause the radial-velocity variation, like the light amplitude, to be underestimated. From a tentative orbit with a period of 660 years, a combined mass of 11.2 $M_{\odot}$ is derived. Abt says that there is still a discrepancy between Cepheid masses as inferred from pulsational and from evolutionary considerations, and Walker's result may help resolve the issue. Unfortunately, particular cases like this are not frequent and visual doubles still provide little data on the high-luminosity classes, Population II stars, etc.

Franz reported on his B,V light curves of ADS 3934 $A = UV$ Aur, a carbon-Mira type star of luminosity class II, and Beardsley reported on the visual short-period system ψ Sgr = ADS 12214 which contains a double-lined sub-system.

Concluding the session, Dommanget expressed great appreciation for the increased astrophysical interest in double-star problems. At previous meetings (such as the Berkeley IAU meeting in 1961 and later ones) he had felt disappointment in the isolation of double-star research and the lack of response to its recommendations, but the present discussion indicated a different response which was very gratifying to all present.