FINAL COMMENTS

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I was deeply honored to be chosen for this particular duty even if only as a stand in, and it occurred to me, "why me?". I then realized I had had a good bit to do with binary stars over a good number of years. I was not personally acquainted with Sir William Herschel, though I have recently made a small contribution to the upkeep of his house in Bath. I am better acquainted with John Herschel, since my wife and I have published some of his papers. I did not know, obviously, the first Struve, and the last Otto Struve I only met personally on one or two occassions. We have recently begun to write the history of McDonald Observatory, and it comes over one that, during World War II and immediately after, under Otto Struve's direction, this organization was the most important astrophysical observational organization in the whole world, even though other things were being cut down by the war. If you look at Otto Struve's early work, you will find that he paid an extraordinary amount of attention to particular stars, many of them various types of binary, each of which, it seems, has become the prototype of important whole series of stars since that time.

When I looked at Worley's list of the most productive optical observers of double stars, I was happy to find that I had met the majority of them, and had been on quite good terms with several of them. One of them whom I never met personally, but have come to know through these researches on McDonald Observatory, was George van Biesbroeck, a Belgian engineer, a tiny little man, about whom an enormous number of stories has been told. He was indestructible. He died at the age of 94, having observed with the 82-inch at McDonald Observatory on his 82nd birthday, having observed with the 90-inch at Steward on his 90th birthday (it is not true that on that occasion he fell off the platform - that was on another night), and having stated that he was all ready for the 150-inch. I have a nice story about George van Biesbroeck that was told me by Willem van den Bos. It must have been on the 36-inch at Lick, and they were both in the dome. I have never operated that telescope, but I understand that it has a grip ring near the eye end, and that when you want to reset the telescope, you hang on to this ring and pull. Van den Bos was astonished to see van Biesbroeck undo the two clamps, hang on to the ring, push off into empty space, and sail through the darkness towards his next setting, saying the while, "don't be alarmed, I shall be down in a minute".

When I was in South Africa, van den Bos was there, as well as Finsen. Bill Finsen was the first person to make a real breakthrough in the improvement of the observation of visual double stars by the manufacture of his little eyepiece interferometer, the thing that made it possible to pass from 0.2 of an arc second in very good circumstances down to about 0.1 of an arc second. Those of you who don't know about this should look at the very last issue of Popular Astronomy, where Finsen gave an account of the particular device.

Finsen was a very remarkable man and an extremely expert instrument maker in his own right. For instance, he made a sun compass which could be put on the side of a truck during World War II which allowed people to navigate in the desert simply by observing the Sun. I remember one occasion when he wasn't in a speaking mood, and it turned out that he had made a small medical device

which opened up after a certain length of time and administered a certain drug. He was testing it out by walking around with this thing in his mouth and seeing whether it would open up and give out some flavored material after the lapse of the proper time.

Now I suppose I should say something about how I've been struck by all the papers in this colloquium, but I do not propose to start at page one and drag you through a recapitulation of the entire meeting. I think probably the first thing to say is that what we really need is a quick and dirty method of finding out whether stars are double. There is looking at them, a fairly quick method, but confined to rather wide ones. There is looking at spectra, but that can be a very long and miserable process. What of other methods? I will make a little toot of my own horn by saying that in the very restricted field in which I operate, we do, in a milli-second, in the twinkling of an eye, find occasionally that a star is double, but that is not something that can be relied on to go on for ever and ever. The Geneva photometric people will tell you they can detect double stars by doing photometry, and we did hear of a refractometer method, which we hope will fairly rapidly yield information of this kind. What we want to know is whether this disease of duplicity is at least as common among the stars as it is among the human race; that is to say, something like ninety per cent. Yet, with our observation methods, we do not come out with anything like the proportions that the theoretical studies seem to indicate.

Then suppose we have our double star. The general tenor has been to say, on the one hand, we have visual double stars, and on the other hand, we have spectroscopic double stars. It has always been an interesting question whether there was a difference between the two creatures, or whether they simply go into those two bins because of our different methods of looking at them. What we have heard has been essentially the attempt to erase this distinction by, on the one hand, pushing down separations that can be detected, by means of speckle interferometry, by means of long baseline interferometry, and the type of thing I remarked on previously. The essential thing is that these separations, to be really effective, have to be pushed down into the range between zero and ten arc-milliseconds. (May I say, that the proper way to pronounce that, is in the form arc-milliseconds, not milli-arc-seconds. Milliarc may be a young lady, but it is the second that is millied, not the arc.) We have on the spectroscopic side the improved means of detection by the improvement of signal-to-noise. You now get spectroscopic data with signal-to-noise ratios of hundreds or possibly even a thousand, where you can turn a single-lined spectroscopic binary into a double-lined spectroscopic binary because very small features are significant. If you can make these two approaches converge, then you have both a visual or astrometric orbit and a spectroscopic orbit, and you come out not only with the masses, but also with a parallax that has a very high degree of accuracy.

Looking at binary stars is the honest man's way of finding out what a stellar mass is. There shouldn't be any fudging, like saying these two stars look pretty much the same, so we'll split the total mass between them, or something of that sort. Thus, the only means whereby you've got absolutely essential data on which the enormous pyramid of mass-to-light ratios (which is the theoretician's way of talking about cosmology, the galaxy, and so on) is built is by looking at complete solutions of double line binaries. There, of course, the bugbear is the parallax, and one is very happy to hear of

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improved parallaxes. The essential thing, however, is not the absolute error of the parallax, but the proportional error. There must be some way these parallaxes can be found with a very small proportional error.

Now consider ordinary, reasonable multiple stars, where what we have in mind is the determination of masses. One should not simply state things in terms of trying to fix up the mass/luminosity relation. One should take a slightly broader view and say what we are looking at is trying to find masses of all kinds of stars and correlating their masses with other properties. For instance, take the masses of G-giants, which the theoreticians all say should be somewhere around one solar mass, and the few examples which have been found have turned up at about three solar masses.

We need to know something about the origin of double stars from their properties, and something about the origin of multiple stars. Then there are the strange creatures, only to be found from space. The X-ray sources, pulsars, and things of this sort.

We heard about some kinds of space astrometry where double stars are trouble stars, as well as other forms of astrometry where it is hoped that double stars will be discovered. A point which does come up is that guiding may be in trouble if the incidence of close double stars is as high as the theoreticians would have us believe. When thinking about Hipparcos, I had in mind the interesting thought that, when you are looking at an occultation of a star with the moon at first quarter, there is an Einstein displacement of the star, due to the gravitational field of the Sun, that will cause a systematic change in the time of the occultation of the order or 0.01 second, which is surprisingly large. I suppose this will be taken into account in the astrometric investigations of Hipparcos, where stars at vastly different points on the sky will be looked at.

Lastly, there is the question of trying to find planets. I think it is just as valuable, since there are so many places to look, to have had the discussion in this meeting telling us where not to look. In the past there have been, of course, many suggestions of dark bodies going around stars, causing perturbations. It occurred to me that perhaps we are, in that particular topic, at a point rather similar to the situation which obtained in 1830 with regard to parallaxes of stars, where we had a whole series of estimates of parallaxes which did not in fact hold water. Then came the latter 30's, where there were in fact some positive detections, and something similar may happen before the end of the century.