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QUESTIONS CONCERNING LONG-PERIOD VARIABLE STARS.

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The American Association of Variable Star Observers may properly take pride in its contributions to our knowledge of long-period variable stars. Its members have sent in long lists of magnitudes of stars that might otherwise have gone unobserved. For many years these raw data have been processed and made available to astronomers by the office in the Harvard College Observatory. When I was observing large numbers of long-period variables for radial velocity, I selected the stars from mean light curves prepared by Leon Campbell from AAVSO data. In making my detailed observing program I relied heavily on predictions made in his office. More recently Mr. Campbell and Mrs. Mayall have supplied me with accurate light curves of numerous variables for certain intervals, data indispensible for detailed spectroscopic studies. I am sure Dr. Joy would likewise express appreciation for the light curves necessary to his extended investigations of Omicron Ceti.

Much invaluable photometric and spectroscopic information concerning long-period variable stars has now been accumulated. But we are only wading in the shallow waters of the ocean of physical reality. Let us not turn back now in weariness or apprehension. Rather, let us resolutely prepare for fact-finding voyages into the deep waters.

Here are a few questions concerning long-period variables which I hope will bring to mind some of the interesting and important things we do not yet know:

A 1. How stable are the light cycles?

2. Are the periods tending to become shorter?
If R Hydrae and R Aquilae can shorten their periods significantly in a cetury or two, perhaps the oscillations are in general not so stable as we sometimes assume.

B. 1. Are there significant correlations between spectral type and the characteristics of the light curve? in the Me variables, the period and amplitude increase with advancing type.

2. Are the cycles of the N-type variables less regular than those of M- and S- types? Why?

3. Is a wide, flat minimum s sign of symbiosis?
In an early Harvard survey of the forms of the light curves, the curve of R Aquarii was mentioned as an extreme example. The minimum of Omicron Ceti is also somewhat broad.

Mean light-curves are important for many statistical studies. Because the possibility of progressive changes has been illustrated by R Hydrae and R.Aquilae, we ought to draw up reliable light-curves every decade for scores, or preferably for hundreds, of long period variables.

For some of the brighter variables, the AAVSO should distribute predicted curves for 5-year intervals, with a new set every 3 or 4 years. Such curves would be most useful to spectroscopists and others in planning detailed observing programs; and they would aid early recognition of any unusual behavior of a variable. Mrs. Mayall has already made an excellent beginning with predicted

curves for 9 variables.

C. 1. What is the physical meaning of deviations from mean curves such as abnormally high and abnormally low maxima, quick irregularities etc? What peculiarities do the spectra show at such times?

2. Do N-type variables actually have more jagged curves than other types or does their extreme redness make for unusually large errors?

The delineation of irregularities must be done thoughtfully, making sure that any abrupt changes are intrinsic, not introduced by some random or systematic error. If there is any doubt it would seem sensible to assume smoothness. An error on this side would be less serious than to drawirregularities that are not real; we would have less to unlearn. Regarding his choice of a physician, a friend of mine once said, ''I consult Dr. A rather than Dr. B because he knows fewer things that ain't so''.

Individual light-cycles as well as mean light-curves are important. We need to know not only the average behavior but all possible deviations. Exactly how and when this information will lead to fuller understanding we do not know. If we did, the process of gathering it wouldn't be research. It might be cataloguing or classifying, but it wouldn't be basic research. It is clear that complete and exact knowledge of light-curves is indispensable to satisfactory understanding of problems that at present are baffling.

D. 1. In Omicron Ceti, why are the S-type characteristics more pronounced at some maxima than at others?

2. Can an S-type star turn into an M-type, or vice versa?

3. Are S-type variables relatively young stars?

E. Why do variables with periods of aboub 200 days have higher space-velocities than variables with longer periods? We do not know; but Dr. Walter Baade has provided us with a label for the compartment in which an assortment of high-velocity stars may be kept. The label is ''Stellar Population of Type II''.

F. What is Technitium, an unstable element, doing in the atmospheres of S-type stars?

G. What causes the fluctuation in light?

To this, the $64 question, we have no respectable answer. For cepheid variation, the hypothesis of volume pulsation is so attractive and so plausible that it has gained a wide following. Not only is this hypothesis popular, it might even be true. When we ask the stars - and it is not a bad idea to ask them - they seem to nod at least partial assent. On the simplest theory, the phases of the light curvesand of the velocity curves do not check, but a combination of volume pulsation with a running wave may harmonize them.

In long-period variables, however, the evidence for volume pulsation is so meager that skepticism is warranted. Even if a pulsation of this sort sets the period- and this is by no means certain- we still must seek physical explanations of manyextraordinary spectroscopic phenomena. The bright spectral lines must be examined more closely, for in the curious details of their behavior may lie the key which will eventually unlock the mystery.

The absorption spectrum behaves, in the main, in a fairly

normal fashion. At maximum light the dark lines indicate a higher temperature and a brighter absolute magnitude than at other phases. Their displacements change but little with phase, sometimes not at all, sometimes in a curve of small amplitude with a flat maximum near the time of maximum light. Changes in velocity from one cycle to another may be greater than the observed change in any one cycle.

The bizarre behavior of the bright lines is still highly mysterious although it does yield certain general indications. The cyclical sequence of phenomena seems to be a one-way process. Perhaps it could be compared with breakers that advance from the ocean with a roar and a magnificent display of white foam, but the returning water runs back down the beach smoothly and quietly. A more apt comparison might be with a series of rockets discharged at regular intervals. One sees repeated upward flights with similar spectacular sequences of flashes and colors, but the return to earth of the dead stick is not visible.

To learn about long-period variables by detailed and prolonged studies of their light-curves and of their spectra is certainly the hard way, but any other way will be longer and harder and far, far less certain. Don't let the good work of the AAVSO cease! Nothing, no nothing can take the place of a lot of well established facts. Theories without sufficient facts are sophomoric exercises that keep the tools of analysis free from rust and ready for use. Theories based on essential facts, capable of coordinating existing knowledge and of predicting quickly and correctly many results from a minimum of data, are monuments of science and guide posts of advancing civilization.

In conclusion, may I quote a paragraph I wrote about fifteen years ago? I think it is still true:

'' The numerous problems of variable stars appear to be divided into two groups: on the one hand are those of individual stars, and on the other those concerning relationship to the whole stellar system. Increasing knowledge and insight will tend to draw together and unify diverse phases of present research. Eventually problems of both groups will probably be seen as different aspects of one unified interpretation. It is impossible to predict how or whem the next great advance will come. The present difficulties are so interesting, however, that we might almost regret to see them solved except for the confident expectation that the solution will lead to new problems still more fascinating.''