Discussion to the paper of KOCH

HALL: In extrapolating main sequence binaries backwards, what exactly did you do?

KOCH: We permitted the sample stars, such as Y Cyg, AR Aur, and others, to move back along EZER-CAMERON tracks until they achieved contact with each other. In this simple-minded, limiting way of doing things, neither mass nor momentum loss is permitted.

LLOYD EVANS: There are several known eclipsing binaries in young clusters, e.g. V 702 Sco in NGC 6383.

KOCH: Thank you. There are also assorted binaries within the fields of several associations.

Variations of the Period of AH Virginis

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AH Virginis was discovered by GUTHNICK and PRAGER (1929) and since that time the system was observed photographically, visually and, more recently, photoelectrically. The variable belongs to the class of eclipsing binaries of the W UMa type. It has a period of 0.41 days and spectrographic as well as photometric elements have been derived by CHANG (1948) and BINNENDIJK (1960), respectively. The most interesting result of discussions by KWEE (1958), BINNENDIJK (1960), HERCZEG (1962), and PURGATHOFER and PROCHAZKA (1967) is the fact that the residuals between the observed and the computed epochs of minima cannot be represented by a linear relation and show the tendency of producing sudden variations in the period of the system.

Recent photoelectric observations made by the writer in 1970 and again in 1971 and represented by a mean curve in Fig. 1 show clearly that the light curve changed significantly during one year. It also shows that it is not possible to combine observations over extended time intervals and sometimes not even over a few observing nights.

Since observations of AH Vir extend for about 40 years involving nearly 40,000 revolutions the residuals of the epochs of minima should provide important information about the changes of the period of the system. A plot of the O — C's of the primary and secondary minima versus time is shown in Figs. 2 and 3 respectively. Although there is a large scatter of points apparent in the graphs, especially among the visual observations, one may see that adopting the mean period of 0.40751846 days the relation between J. D. 2425000 and J. D. 2435000 is best represented by a downsloping line, or in other words, that the average period became shorter by 0.040 seconds as compared with the adopted value. At about J. D. 2435000 a change in the period occurred, at this time in the opposite direction making the average period longer by 0.35 seconds. The change of the period is considerable making the actual period equal to 0.40752189 days. With this new period a nearly horizontal line can be fitted to the O — C's as seen in the inserts to Figs. 2 and 3. However, indications are that since 1970 (the last three points in the inserts) a further increase of the period might have occurred.

From spectroscopic determinations of the orbital period the mass of the two stars is given as 1.36 and 0.57 solar masses. Since the semimajor axis of the system is also known one finds, by differentiating Kepler's harmonic law formula that

$$-\frac{\Delta P}{P} = \frac{2\Delta m}{m}$$

where m is the total mass of the system. From observations the value of $\Delta P/P$ is 9×10^{-6} and, therefore, the mass loss is given as 2×10^{28} grams. This amount of mass loss is of the same order as observed in nova outbursts, and, consequently, should lead to optical phenomena associated with nova like objects. Since no appreciable increase in brightness of AH Vir has ever been reported the validity of this estimate of mass loss seems to be in doubt. On

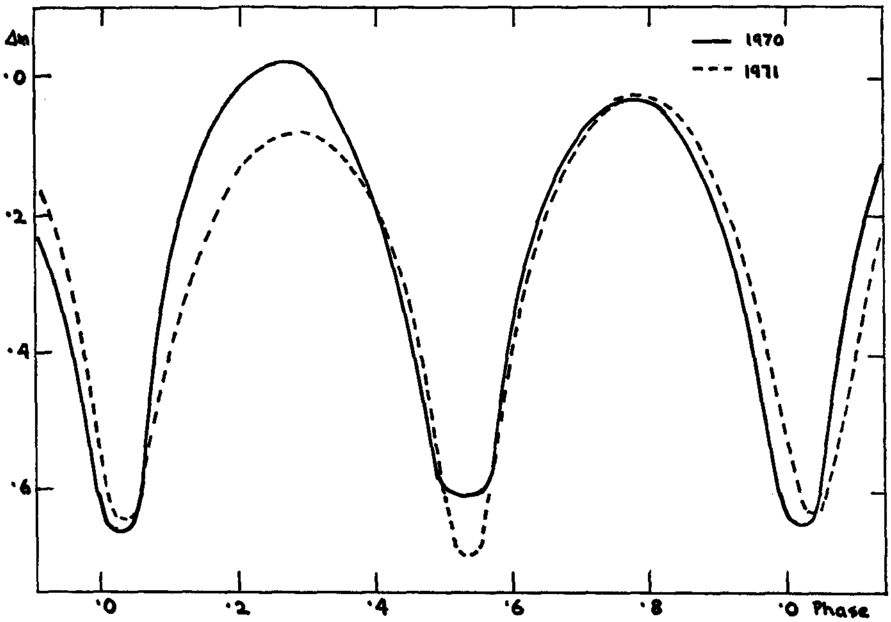

Fig. 1: The mean light curve of AH Vir in May, 1970 and April, 1971.

the other hand, mass loss is likely to take place since, according to BINNENDIJK (1960), the greater star exceeds the Jacobian limiting surface in the direction of the equatorial b-axis. Further evidence for mass loss taking place is in the presence of luminous clouds which, in turn, are responsible for variations in the shape of light curves as shown in Fig. 1. The process of mass loss is thus relatively slow and its effect is in filling the space between the primary and secondary stars with tenuous gas. The motion of the secondary star would, therefore, be similar to the motion of earth's satellites affected by the resistance of the upper atmosphere.

Following STERNE's (1960) treatment the effect of the air drag force on the motion of a spherical satellite moving in a circular orbit is given by the following expression:

$$\dot{P} = -3\,C_D\,\pi\,A a\,\varrho/m$$

where C_D ist the aerodynamic drag coefficient and, in our case, it is of the order of magnitude of unity,

A is the crossectional area of the secondary star,
a is the semimajor axis of the system,
ϱ is the density of the medium and
m is the mass of the secondary star.

Substituting for the known quantities one gets for the density

$$\varrho = 2 \times 10^{-7}\ \text{gram/cm}^3.$$

If the volume of the space contained between the inner and outer equipotential surfaces is considered assuming a uniform density the total mass present is found to be

$$M = 2 \times 10^{28}\ \text{grams},$$

a value which should be considered just accidentally equal to that indicated by the ejection hypothesis.

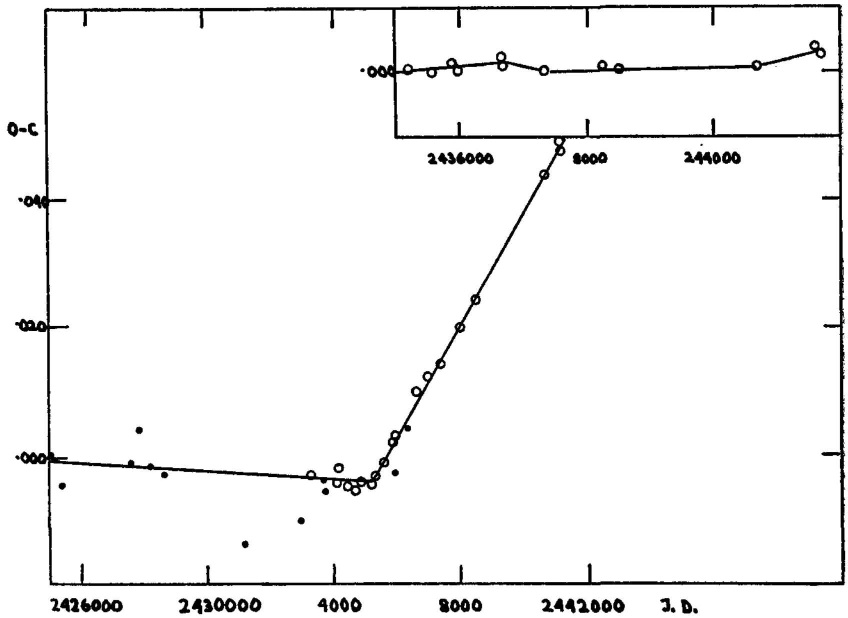

Fig. 2: Time residuals of primary minima of AH Vir. The points are photographic or visual observations, the open circles are photoelectric observations.

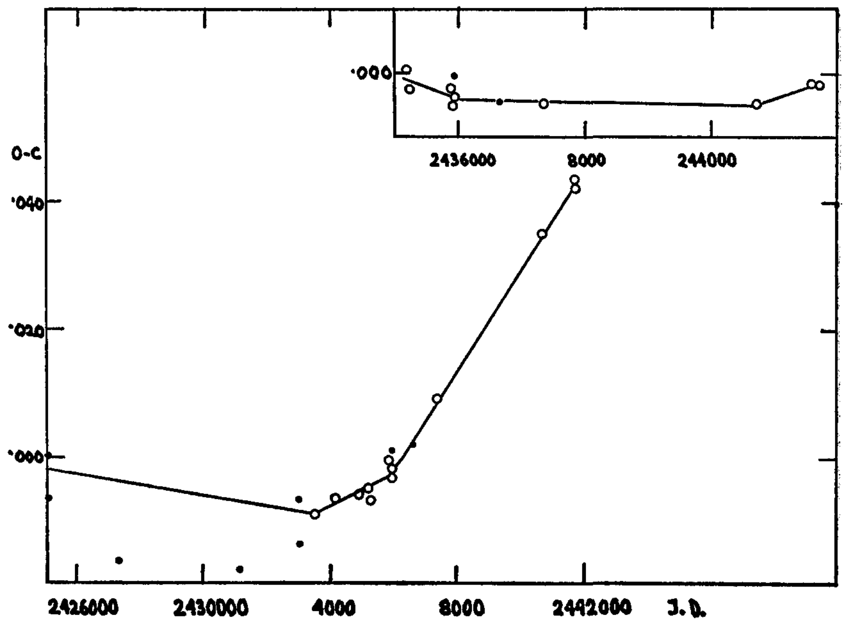

Fig. 3: Time residuals of secondary minima of AH Vir. The symbols are the same as in Fig. 2.

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There is a further implication to the above treatment. In view of the presence of a medium of variable density, both accelerations and decelerations of orbital periods should be observed. From the distribution of O—C's one finds that this is the case of AH Vir.

Although the actual situation is certainly more complicated than this simple-minded approach the merit of this approach is in producing a mechanism for variations of periods of binary systems acting in both directions.

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Discussion to the paper of BAKOS

SINVHAL: During the interval of mass transfer from the first Lagrangian point to the second one, would one expect a change in the light curve of the system? I believe it should be so and if so, can then be used to verify this hypothesis of mass transfer.

BAKOS: Yes, it is the case. BINNENDIJK traced the changes in maxima of the light curve to the presence of a luminous cloud. Similar effects might be present in any light curve.

LOCHER: Does your $\dot{P}$ equation assume that the gas is at rest in the non-rotating frame?

BAKOS: Yes, the gas is at rest. The effect of the gas moving would change results by less than 10%. Also the assumption of uniform density is reasonable, although, most likely, we have floating clouds in the system.

PERCY: The fact that the „event" which occured was a relatively *abrupt* one is interesting for theoretical reasons. Do such abrupt period changes occur in other stars of this type?

BAKOS: Yes. Dr. HERCZEG published a paper containing many such systems.

THOMAS: An increase of the period could also be caused by mass transfer from the secondary to the primary component.

BAKOS: It does not take place, because the secondary does not fill its Roche lobe.

F. B. WOOD: I might remark that if you assume the ejections to be violent, you must then take account of Newton's third law. This allows you to explain the observed period change with a smaller amount of mass loss, and by varying assumptions as to the place of ejection, you can explain either lengthening or shortening of the period.

BAKOS: Effects can not be violent since otherwise they would show up in the light curve. However, I have to agree with your remark.

HERCZEG: This is an interesting and original approach to a very difficult problem and I think it is important to persue this line, too. Nevertheless, I see some difficulty in ascribing a unique value to the mass loss as required by the abrupt change of period. The value, in fact can depend very sensitively on the direction of mass loss and modifications of the numbers involved may well obtain a factor 10 or so.

Furthermore, I should like to report some mild disagreement with the speaker, concerning the reality of those smaller bands in the O-C diagram.

Photoelectric accuracy is usually high enough to substantiate deviations of this size but probably not in the case of such a disturbed system as AH Vir with strongly variable light curve. I would tend to believe that the only well-established feature of the O-C diagram is the considerable abrupt increase about 1950.

BAKOS: I agree with your remark and the bands are supposed to show that mass loss is taking place more or less continuously on a small scale. However, the explanation of bands could be different and only further observations could show their meaning.