jusqu'à 6700° K. au second maximum, plus haut que le 12 février où cependant l'étoile était plus brillante et les émissions beaucoup plus intenses.

Il faut peut-être rapprocher ce fait de celui observé dans les étoiles Be, qui montrent un spectre continu assez différent de celui des étoiles B normales, les gradients absolus étant d'autant plus élevés (température plus basse) que les émissions sont plus fortes. En 1947, la température de couleur est de nouveau voisine de 4200° K., de 3900° K. de 1948 à 1952.

RY Scuti(4) est une binaire spectroscopique très fortement rougie. Son excès de couleur est très élevé, +0,64. Les bandes moléculaires d'origine interstellaire non encore identifiées: 4430, 5781, 5797, 6203, 6284 A. sont présentes. Plusieurs éléments, He I, N III, C III, montrent quelques unes de leurs raies en émission, d'autres en absorption. Ce phénomène a déjà été observé, dans 9 Sagittée par P Swings et O. Struve. On observe les raies brillantes de He II, de [N II], de [O III] et, très particulièrement développées, celles de [Fe III], et les raies d'absorption de N II et probablement de O II. Enfin, on peut voir, sur nos clichés, de faibles bandes d'absorption qui appartiennent très probablement aux plus fortes têtes de bandes de TiO mais qui sont beaucoup moins marquées que dans les trois étoiles dont nous venons de parler. Nos observations, 5 juillet 1948, 19 et 20 avril 1952, se placent au voisinage du minimum principal, et l'on peut penser que l'étoile chaude étant en arrière de l'autre étoile, l'atmosphère de celle-ci produirait l'absorption de TiO.

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23. EVIDENCE FOR AND AGAINST THE BINARY NATURE OF SOME TiO-He II-NEBULAR VARIABLES, AND THE POSSIBLE AMPLIFICATION OF B-STAR ERUPTIONS BY A COOL COMPANION

By MARTIN JOHNSON. (*Presented by* O. Struve)

1. This problem might be deprecated as requiring for its solution more evidence than now exists; but, even though it cannot yet be conclusively solved, it will introduce some consideration of possible interactions between binary components and between different atmospheric regions of a single star, which may help to explain other peculiar variable spectra.

The spectra called 'combination' or 'symbiotic', and studied in detail by Swings and Struve(1), by Merrill(2), by Payne-Gaposchkin(3) and others, have only been proved binary in one or two cases, although each combines the spectrum of a hot star and a cool star often with nebular lines and irregular nova tendencies. We first arrange into an order of decreasing eruptiveness six stars which combine the extremes of TiO and He II: in brackets we quote the periodicity of M type suggested by various authors for the cool spectrum, associated with Merrill's phase-lag of 1/5 period between permitted and forbidden lines.

T CrB: nova, 6 mag. range, 1866, 1946 (230 day),
Z And: nova, 3 mag. range, 1939, 1946 (650–715 day);
AX Per: irregularity 2 mag. range, nebular lines of post-nova type.

CI Cyg: (similar);

R Aqr: irregularity 2 mag. range, with photographed inner and outer nebulosity (387 day);

RW Hya: irregularity 1 mag. range (370 day).

The following types for comparison will be useful to recall, since each contains some resemblance and significant differences:

(*a*) Other repetitive novae (RS Oph, T Pyx, N Sag, U Sco).

(*b*) Observed B and M components of the visual binary α Sco which has nebulosity but no irregularity or pulsation.

(*c*) B and M binary without nebulosity (omicron Cet).

(*d*) B and M spectra with [Fe II] (W Cep, WY Gem).

(*e*) Less directly comparable, but offering clues to one or other feature, are η Car, RY Sct, P Cyg shells, tail-enveloped binaries (β Lyr), prominence binaries (ζ Aur), binaries with ring round one component (RW Tau), rings round both components (UX Mon), rings of differing velocity in same binary (RZ Sct, RY Per), and ringed single stars (γ Cas). Some of these descriptions may come under revision, but have been usefully suggestive.

2. Owing to the rarity of direct evidence, a binary structure for the six stars has the status of a hypothesis; it merely implies that simultaneous extremes of high and low excitation seem more understandable if we envisage two separated objects rather than one single object. I propose to question this hypothesis by examining the support and the difficulties of the implication. Some writers mention 'companion star' in inverted commas and some as accepted fact. α Sco is undoubtedly a nebular binary, but with [Fe II] and not He II, and it lacks the eruptiveness of the others. A companion to Z And had been described (4) with definite properties but only in theory. Merrill (5) has evaluated a very tentative binary orbit for R Aqr with reservations. In a recent study of rates of change in fluorescence (6), I wrote in terms of the binary model, and have been reminded that it is not the only model, as the distances which I discussed could refer also to a single star with widespread nebulosity round it. Some of the obstacles to a binary explanation are as follows:

(i) Neither mutual eclipses nor orbital velocities have been extracted from the complexity of light fluctuation and velocity fluctuation. But so long as the number of stars is small, favourable orientation of orbital plane to line of sight cannot be statistically expected in any given fraction of the number. Doppler shifts due to each component as a whole will be very difficult to disentangle from the large and widely fluctuating motions of gases erupting from one or both components. The lag between emission and absorption velocities in Mira stars, and Merrill's 1/5 period lag of forbidden lines, means that the periodicities quoted above may involve orbital as well as pulsatory motion. Hence the lack of detection of orbits may mean their concealment under gas velocity, rather than evidence of their non-existence.

(ii) The binary hypothesis sets a difficult task for theories of simultaneous evolution if very hot and very cool components are supposed to be traceable to a common origin. The extent of this difficulty cannot be estimated until the origin of binaries is more understood.

(iii) An obstacle, which we later suggest may be capable of removal, is the difficulty of understanding the interaction between the components of the hypothetical binary. These stars show irregularity of light which amounts to nova outbreak in the most disturbed, hence no binary explanation is adequate unless it shows why B and M spectra which are quiescent in separated single stars become unstable when associated.

3. We now note some of the corresponding obstacles which face any alternative hypothesis that both hot and cool spectra come from a single star:

(i) A model of Mira (7) type, where TiO absorption occurs outside bright H, is possible only if the scale of prominence activity is so enlarged, compared with that on the Sun, as to allow He II to dominate the spectrum instead of being as faint as in the solar outer irregularities. It is not easy to postulate reasons for such magnified eruptiveness in models already known to fit a single star: amplification of prominences by binary structure we consider later.

(ii) In some models of red giants, with two phases and a hot core, it might be suggested that since no polytrope model is adequate, there may be surges from the deeper material to the surface, especially when sources of energy production are in course of change. This would seem a more probable cause of an isolated nova outbreak than of the more frequent minor irregularities observed. It is also difficult to envisage maintenance of temperature in the material drawn from the interior.

(iii) A purely external cause of irregularity is possible, such as Gaposchkin's(8) variation of the star due to variation in interstellar nebulosity, for instance through changing rates of accretion. Since nothing is yet known of the density gradients in interstellar material, this suggestion remains untested.

4. Binary explanations which would escape the objection 2 (iii) might be approached by combining the gaseous rings mentioned in 1 with the large prominence activity which had no obvious source in a single star: we shall proceed to discuss, tentatively, whether the rings could cause amplification of the usual small prominences to more noticeable activity showing as irregularity of the star's total luminosity. 'Rings are very common in binaries, perhaps even universal' (Struve)(9), but their evolutionary distinction from the rings of single stars, e.g. γ Cas, is not fully known. For instance the RY Per or RZ Sct kinds have been suggestively associated not with extruded material but remnants of a pre-binary state. Ring rotation combined with pulsation, as in Baldwin's(10) model of γ Cas, will offer a novel situation if extrusion of Kuiper's(11) type of binary tail were envisaged, notably in the way in which any local prominence might become first suppressed by the ring and later released on an enhanced scale.

In enquiring why a binary combination should be more eruptive than the similar two stars separated, two alternatives must be distinguished, (*a*) that the condition for one component to exhibit TiO while the other shows He II only arises at a unique stage of evolution which is also an epoch characterized by internal instability. This possibility must await further knowledge of binary evolution, so we turn to the other alternative, (*b*) that one of the pair has some effect of reducing the local or surface stability of the other.

It is not difficult to show that the greatest allowable effects of reflection or absorption of the radiation from one component intercepted by the other must be negligible for stability, and that even mutual tidal distortion is unlikely to produce the outbursts of T CBr or Z And. Nor is it necessary that a circulating ring round the binary extruded by Kuiper's mechanism should by itself be unstable, except for gradual spiral expansion and lateral spread. Even if one of the pair were pulsating as an M star, the effect would be of density maxima in the spiral, soon smoothed by viscous drag, rather than stimulation of explosiveness in the subsurface.

5. Consider, however, the intrusion of a local prominence into the circulating ring. Of Kuiper's two models of ring and tail extrusion, which he considered in studying β Lyr, his 'A' process is more relevant to this case, and indeed he gave as possible examples of it T CrB, Z And, and AX Per.

Hoyle and Lyttleton(12) have described how, where the less massive component is a giant, it supplies the material to the common orbital stream enveloping also the more massive. If, at suitable phase in the spin and orbit of each star relative to the pulsation maxima of the red component, a prominence intruded radially from the B star into the stream circulating from the M star around both, there would be some arrestment of the circulation which when deprived of tangential velocity would become subject to accretion into the B atmosphere for the same reason which allows capture of arrested interstellar nebulosity in the accretions of Hoyle and Lyttleton. The amount would depend on densities, interaction being small if prominence and stream were so rarefied as to experience only little viscous drag.

When the prominence rises within the zone covered by the stream, and at such phase of the rotation, revolution, and expanding portion of the pulsation cycle, that it is prevented from escape, there will occur local changes in opacity and the ionization in the captured material which is less than that of its new environment. These will affect both terms

$$\left\{\left(\frac{d \ln T}{d \ln P}\right)_{\text{rad.}} - \left(\frac{d \ln T}{d \ln P}\right)_{\text{adiab.}}\right\}$$

representing the consequences of abnormal gradients upon stability. A corresponding effect at greater depths has been invoked by Biermann(13) and others as origin of ordinary novae, but here the eruption after suppressed instability can be much slighter because less deep-seated in origin. The work of Gerasimovic(14) and of Miss Underhill(15) has shown the nearness to instability of B star surface layers, and prominence activity is therefore probable at all times, but only under an optimum coincidence of timing which provides temporary suppression will the incessant prominences become amplified to visible irregularity in the star's total brightness. Much calculation would be needed to separate the initial instability, the intermediate stage of suppression of relieving convective transport, and final eruption of stored energy, with their successive effects on luminosity due to expansion, temperature, and fluorescence. Favourable circumstances giving eruption of the T CrB or Z And intensity would be unusual, and the slighter eruptiveness of the others more common. Calculations of instability have so far only been approachable through theories of thermodynamic gradients designed for an atmosphere initially in equilibrium, and require much supplementing. The fact that the undoubted blue-red pair α Sco is very quiescent but is a widely separated pair, raises the query as to how small an orbit must be for interaction of prominence with stream to store energy towards amplification in this way: it might also be asked whether prominence and ring could not also occur in a single star, with reversion of the amplifier process to a non-binary explanation.

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24. THE SPECTRUM OF WY VELORUM

By Jorge Sahade. (*Presented by* J. W Swensson)

WY Velorum(1) is a southern peculiar star discovered at Harvard(2) as being variable both in light and spectrum.

The available light observations start as far back as 1890. The first reference(2) to magnitude observations covers the years 1890–1922 and is based on 101 photographs which are distributed rather evenly throughout the interval, they show that from 1890 to 1901 there was a slow and apparently steady increase in light from magnitude 9·8 to 9·2; and since 1902 the light has slowly decreased. The magnitude was 10·1 in May