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ON THE POSSIBILITIES OF COLLIDING WINDS AND ACCRETION FROM STELLAR WINDS

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It is widely accepted that the phenomenon of colliding winds takes place in binaries containing Wolf-Rayet and O-type stars where both components have a significant mass loss ($\sim 10^{-6} M_\odot$ yr^{-1}) and terminal velocities of the order of 3000 km s^{-1}. Girard and Willson[1] consider that colliding winds exist in symbiotic novae, where the primary is a late giant and the secondary is a white dwarf undergoing a thermonuclear outburst. A configuration of colliding winds has also been proposed[2] for the system α Sco (M1·5 I + B2·5 V). On the other hand, detached binary stars containing a late giant and a hot secondary component, an early-type main-sequence star, or a white dwarf (in other words, Zeta-Aurigae-type stars and some symbiotic stars) are usually considered in terms of accretion from a stellar wind; see Reimers & Che-Bohnenstengel[3,13] and Livio[4].

The purpose of this note is to propose a criterion which will permit determination of the type of interaction which will occur in a detached binary system, if we know some properties of the components. The criterion is applied to a few stars. By analogy with the theory of gravimagnetic rotators we will compare the pressure of the accreting matter and the pressure of the wind of the hot component at a distance equal to the accretion radius. If the giant wind can penetrate to a distance less than the accretion radius, R_a, then the hot-star wind will not be able to prevent accretion (see Lipunov[5] and references therein). So we formulate the following condition at $R = R_a$:

$$\left(\frac{P_a}{P_h}\right) \quad \begin{cases} > 1 \text{ — accretion from stellar wind} \\ < 1 \text{ — colliding winds} \end{cases} \qquad (1)$$

where P_h is the pressure of the hot-star wind and P_a is the pressure of the matter which the hot component would be able to accrete from the wind of the giant.

We have

$$P_h = \dot{M}_h\, v_h/(4\pi R^2)$$

where $\dot{M}_h$ and v_h are the mass-loss rate and the velocity of the hot wind, and the accretion radius is given by:

$$R_a = 2GM/v^2_{rel}$$

Here v_{rel} is the relative velocity between the hot star and the wind of the giant, expressed in terms of the giant-wind velocity, v_g, and the orbital velocity, v_o, as $v^2_{rel} = v^2_g + v^2_o$.

The accretion pressure can be written as

$$P_a = \dot{M}_a\, v_{rel}/(2\pi R^2).$$

The mass accretion rate $\dot{M}_a$ is given by Livio and Warner[6] as

$$\dot{M} = R_a^2\, v_{rel}\, \dot{M}_g/(4d^2\, v_g) \qquad (2)$$

where d is the distance between the components and $\dot{M}_g$ is the mass-loss rate of the giant. Consequently, at $R = R_a$, by substituting in (1) we obtain

$$\left(\frac{P_a}{P_h}\right) = \frac{R^2_a\, \dot{M}_g\, v^2_{rel}}{2d^2\, \dot{M}_h\, v_h\, v_g} \qquad (3)$$

This formula can be expected to produce more accurate results for $R_a \ll d$, because (2) is calculated for the case of a homogeneous medium. If (P_a/P_h) is less than one at $R = R_a$, then the wind of the hot component is sufficiently strong to prevent accretion. If it is greater than one, the accreting matter will suppress the hot wind and a process of accretion from the stellar wind will develop.

We must note that these results are not applicable to systems such as Wolf-Rayet + O-stars, where other effects (such as radiation and gas pressure) will inhibit accretion.

We now apply the criterion to a few stars. The data for the cool components are collected in Table I. To calculate the mass-loss rates of the hot components we used the formula of Andriesse[7]:

$$\dot{M} = 10^{-13\cdot 4}\, (L/L_\odot)^{3/2}\, (R/R_\odot)^{9/4}\, (M/M_\odot)^{-9/4}\, M_\odot\ \mathrm{yr}^{-1},$$

where luminosities, radii, and masses are taken from Allen[8] according to the spectral type. We will consider that the terminal velocity of the hot wind is equal to 1000 km s^{-1} in all cases. The adopted quantities and the calculated ratio (P_a/P_h) are shown in Table II. In cases when the orbit is not circular, the ratio is calculated at periastron and apastron.

There is no doubt that in the case of 22 Vul accretion from stellar wind occurs. The systems ζ Aur, 32 Cyg, and δ Sge are close to the critical point $P_a\,(R_a) = P_h\,(R_a)$. It seems probable that a process of stellar-wind accretion does take place in these binaries, but the uncertainties in the adopted data do not permit us to be sure.

TABLE I

Adopted parameters for cool components

System	$\dot{M}_g$ $10^{-8} M_\odot yr^{-1}$	v_g *km s*$^{-1}$	*a* $R_\odot$	*Source*
ζ Aur	0·63	40	981	(10)
32 Cyg	2·8	60	1100	(10)
31 Cyg	>1·0	80	2530	(10)
δ Sge	2·0	28	2365	(11)
α Sco	70	17	176 500	(12)
22 Vul	6·0	160	133	(13)
AG Peg	20	10	630	(14, 15)
Sym. Novae	100	15	4300	(1)

Note: a is the orbital semimajor axis

TABLE II

Adopted parameters for hot components

System	*Sp.*	$\dot{M}_h$ $10^{-10} M_\odot yr^{-1}$	v_{rel} *km s*$^{-1}$	R_a $R_\odot$	(P_a/P_h) (at $R=R_a$)
ζ Aur	B8	0·53	89–52	205–590	2·0–1·0
32 Cyg	B8	0·53	90–70	200–330	3·3–1·5
31 Cyg	B4	6·0	91–85	370–420	0·04–0·02
δ Sge	B9	0·28	43	780	3·5
α Sco	B2·5	21	20	10200	0·02
22 Vul	B9	0·28	162	54	40·0
AG Peg		10	40	165	0·12
Sym.Novae		100	18	1200	0·02

Very intriguing is the case of 31 Cyg. Like ζ Aur, 32 Cyg, and 22 Vul, an accretion wake is observed in this star[3]. On the other hand, Stevens *et al.*[9] have speculated that structures formed by the colliding winds are observed in Zeta-Aurigae binaries. So it seems that 31 Cyg is the most plausible candidate for colliding winds among this type of star. Our result for α Sco is in agreement with the model of colliding winds[2].

For a typical symbiotic nova such as HM Sge or V1016 Cyg, following Girard and Willson[1], we consider the primary to be a Mira variable and the secondary a $1M_\odot$ white dwarf. The white dwarf has undergone a hydrogen shell flash, and after this eruption it has considerable mass loss. With the adopted parameters, wind collision will take place; but the mass-loss rate of the white dwarf will decrease in course of time, and, when (P_a/P_h) reaches unity at $R = R_a$, accretion from the stellar wind will begin.

AG Peg is a symbiotic nova also, but this star has been observed for a long time and more-reliable data exist for the components. Different models have been proposed for this star; with the adopted mass-loss rates, our calculations confirm the colliding-winds model proposed by Tomov[14].

To conclude, we can say that the predictions of criterion (3) agree with previously proposed models.

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SPECTROSCOPIC BINARY ORBITS FROM PHOTOELECTRIC RADIAL VELOCITIES

PAPER 112: HD 198950

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HD 198950 is a hitherto neglected star of about the ninth magnitude or a little fainter, about 2° north-following the fourth-magnitude ε Aquarii. It is one of 30 stars, all of about the same magnitude and all classified as type K0 in the *Henry Draper Catalogue*, which were discovered to be spectroscopic binaries in the Cambridge radial-velocity survey[1] of the 'Clube Selected Areas'. At a declination of −8° it is right on the limit of the part of the sky accessible to the radial-velocity spectrometer at the coudé focus of the Cambridge 36-inch reflector, which has been the principal source of data for this paper and for most of the others in this series. Just one degree due north of HD 198950 is a sixth-magnitude star (HR 7998), which has served a useful purpose in enabling the telescope's focus — apt to change considerably with position in the sky — to be set more satisfactorily than on the faint star itself. No better magnitude than the $9^{m}\!\cdot\!2$ given in the *H.D. Catalogue*[2], and itself derived from the *B.D.*[3] with the application of a systematic correction, is known for HD 198950, nor any spectral type more modern than the *H.D.* K0.

The radial velocity of HD 198950 has been measured on 52 occasions, as listed in Table I, which includes observations made in each of the last 20 years. The poor observing conditions encountered at low altitudes in the Cambridge sky have resulted in accidental errors appreciably larger than usual, and have prompted maximum advantage to be taken of opportunities to use spectrometers elsewhere at lower latitudes and larger telescopes. Altogether 18 of the measures in Table I, about one third of the total, stem from such spectrometers. In the derivation of the orbit, which is illustrated in Fig. 1, those measures have been