Contact Binary Systems

THE MASIVE BINARY SV CENTAURI

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ABSTRACT. Current light synthesis models of SV Centauri require a highly overcontact system with an 8000K temperature discontinuity between components. Current evolutionary models support the overcontact status, and describe the system as in the final stage of rapid mass transfer prior to mass reversal, calculated to occur within 2500 years. Light synthesis simulation provides a poor fit to the observations, and requires an *ad hoc* assumption to fit the substantial O'Connell effect.

IUE spectra have been reported to indicate the presence of a 200 000K source of small dimensions in the system. New spectrum synthesis results demonstrate there is no hot spot, but there is extra radiation longwards of 200nm that is unaccounted for by the overcontact model.

Postulated presence of an accretion disk around the mass gainer prospectively overcomes the observational anomalies. Formation of the accretion disk apparently violates the Lubow-Shu criterion. A reasonable scenario nonetheless supports accretion disk formation. Conflict with the theoretical models can be resolved on the postulate that the spherical accretion assumed in those models render them inapplicable to this system.

1. INTRODUCTION

All current models of SV Centauri agree that it is an overcontact binary with the common photosphere nearly in concidence with the outer limiting surface through the L2 point. The most recent component masses are by Dreschel *et al.* (1982a), with values of $9.6\mathcal{M}_\odot$ and $7.7\mathcal{M}_\odot$. The system has the largest known rate of period change and the period is decreasing. The most direct interpretation is that the more massive component is the mass donor. The fact that the secondary, less massive component, is hotter is consistent with this interpretation.

Light synthesis analyses of the light curves are by Wilson and Starr (1976), Rucinski (1976), and Dreschel *et al.* (1982a). These analyses adopt the Roche model and assume the photosphere is an equipotential surface. They lead to an intercomponent temperature discontinuity of $\simeq$ 8000K at the neck joining the two components, derived from the difference in depths of the minima. This result, juxtaposed with the very large degree of overcontact, is counterintuitive and leads to the suspicion that something is wrong with the model. The adopted

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polar temperatures of the components are 23 000K and 16 200K. The temperature discontinuity is such a large fraction of the polar temperatures that the common envelope would be strongly baroclinic and the assumption of an equipotential photosphere could not be maintained.

Dreschel *et al.* (1982a) discovered circumstellar material moving outward with velocity greater than the escape velocity. In a subsequent publication Dreschel *et al.* (1982b, p.205) proposed an alternate model with mass loss via a stellar wind through the L3 point, with the lost mass originating in the less massive component. Linnell (1991) gives reasons for rejecting that model.

2. LIGHT SYNTHESIS SIMULATION

The *UBV* light curves by Dreschel *et al.* (1982a) display an appreciable O'Connell effect. None of the existing photometric studies includes a simulation of this effect. The O'Connell effect usually appears in cool systems where an explanation based on cool starspots in a convective envelope is appropriate. That explanation is not applicable to SV Cen. Also, the fit to the *UBV* data, with optimum Roche model parameters, is poor (Linnell 1991). This fit includes an *ad hoc* representation of the O'Connell effect with a single hot region on the advancing face of the less massive component. The sense of the photometric discrepancies is interesting. The fit to primary minimum, when the hot mass gainer is undergoing eclipse, is fairly good. The theoretical light curve through secondary minimum predicts too large a light loss, as if the projected size of the mass gainer assigned by the Roche model is too large.

If the Roche model is wrong, what would be a reasonable model which still would preserve the picture of a system in the final stage of mass transfer before mass reversal? One possibility would be a semidetached system with an accretion disk surrounding the mass gainer. The hot secondary would be an immediate consequence, in accordance with observation. There would be no physical difficulty with the large temperature discontinuity. The larger mass donor would be eclipsed by a flattened accretion disk, with a nearly main sequence size secondary at its center, at secondary minimum. This should give a smaller theoretical light loss than produced by the large overcontact Roche model component, again in accordance with observation. Is there additional evidence to support this idea?

3. SPECTRUM SYNTHESIS RESULTS

A new spectrum synthesis facility for binary stars has recently been placed in operation (Linnell & Scheick 1989). This program has been used to study low dispersion *IUE* data obtained by Dreschel *et al.* (1982a). In their study, Dreschel *et al.* found that black body representations of the continuum for the two components, based on their light synthesis solution, left residuals from the *IUE* continuum which could be represented by a 200 000K hot spot. Synthetic spectra give a much better representation of the continuum, for individual components, than does the black body law. The result of the spectrum synthesis study is that the spectral evidence for a hot spot disappears, but is replaced by evidence for extra continuum radiation longwards of 200nm (Linnell 1991). An inviting hypothesis is that the extra radiation is the signature of the cool outer rim of the accretion disk.

4. PROBLEMS

The accretion disk hypothesis must withstand a number of challenges. The hot region on the advancing face of the mass gainer, if assigned physical reality, might be taken to be the signature of the mass transfer stream impacting the accretion disk. But the impact point normally should be on the trailing face, not the advancing face. We can escape this trap by postulating that the accretion disk has an outer edge that extends almost to contact with the donor, as might be appropriate to the large mass transfer rate. The potential energy liberated when the mass transfer stream reaches the accretion disk rim is small enough to be neglected. Thereafter, the large mass transfer stream merges with the accretion disk and dissipation rises rapidly, reaching a maximum when the transfer stream has completed part of a revolution around the mass gainer (Livio, Soker, & Dgani 1986, Livio 1989, p.328). This produces the hot region on the advancing face, in accordance with the O'Connell effect simulation.

Lubow & Shu (1975) discuss the conditions under which an accretion disk may form. The size of a main sequence star whose mass equals that of the SV Cen secondary, in comparison with the size of its enclosing Roche lobe, is too small for an accretion disk to form on the Lubow and Shu theory. Lubow and Shu did not discuss the dynamic response of the mass gainer to the incoming mass flux, or the structure of the accretion disk. We avoid this problem by suggesting that when the mass loser first encounters its inner Roche lobe, by evolutionary expansion, the resulting mass stream through L1 impacts the mass gainer as in the Lubow and Shu model. The localized heating by this impact produces a gas bubble which, by viscous shear, is spread in the equatorial plane. The buildup of an equatorial disk continues, leading to an accretion disk.

Perhaps the most serious theoretical objection to the accretion disk proposal is the many papers that predict accretion on a radiative envelope will cause the gainer to expand until it fills its Roche lobe, leaving no room for an accretion disk. See Nakamura & Nakamura (1982,1985), Sybesma (1986), and DeGreve (1989, p.127) as samples of many papers on the subject. Nakamura & Nakamura explicitly simulate the SV Cen system and derive an overcontact status comparable to that derived by existing light synthesis analyses. All of the theoretical papers assume spherical accretion, an assumption different from that visualized here. The present proposal is that the boundary layer between the accreting star and the accretion disk occupies only a small range in latitude, leaving a large fraction of the accreting star photosphere free to radiate its accretion luminosity. The calculated current mass transfer rate for SV Cen is $4.0 \times 10(-4)\mathcal{M}_{\odot}$ /yr (Wilson & Starr 1976). A comparison with β Lyrae is of interest. The calculated mass transfer rate for β Lyrae is $1.0 \times 10(-4)\mathcal{M}_{\odot}$ /yr (Hubeny & Plavec 1991). If the spherical accretion model were applied to the β Lyrae gainer, the suspicion is that the outcome would be very different from the current observationally-determined model of an essentially main sequence star at the center of an accretion disk (Hubeny & Plavec 1991).

A further problem arises when a rough model for the accretion disk is calculated (Linnell 1991). The available space for the accretion disk is so narrow in the lateral dimension that the proposed accretion disk almost certainly would overflow the Roche lobe. Is that bad? A strong magnetic field may well be generated in accretion disks (Balbus & Hawley 1991, Hawley & Balbus 1991), and this field may retain the accretion disk around the mass gainer even if the disk overflows the Roche lobe. The observational arguments in favor of an accretion disk are substantial. A major current difficulty in testing the proposed model is the lack of a suitable computer model. Both a light synthesis model and spectrum synthesis model are needed in which both stellar components and the accretion disk contribute importantly to the calculated flux.

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