W URSAE MAJORIS STAR MODELS: OBSERVATIONAL CONSTRAINTS

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W Ursae Majoris stars can be understood as contact binary stars with a common envelope (Lucy 1968). They subdivide into two types: The A-type are earlier in spectral class than about F5, are believed to have radiative envelopes, and associate primary (deeper) eclipse minimum with transit eclipse. The W-type have spectral classes later than F5, are believed to have convective envelopes, and associate primary minimum with occultation eclipse. Controversy has surrounded the explanation of W-type light curves.

Four distinct models have been introduced to describe the envelopes or photospheres of W UMa stars. (1) The Rucinski hot secondary model directly explains W-type light curves on a postulational basis. Since 70%-90% of the emitted radiation from the secondary (less massive) component is believed to reach the secondary via circulation currents from the primary, there is an apparent thermodynamic mystery why the secondary should be hotter. (2) The Lucy Thermal Relaxation Oscillation (TRO) model argues that the secondary component is perpetually out of thermal equilibrium and that the components are in contact only during part of a given TRO cycle. During contact the photosphere is supposed to be barotropic. In this case primary minimum always associates with transit eclipse, in disagreement with observation for W-type systems. (3) The Shu et al. thermal discontinuity (DSC) model also argues for a barotropic photosphere but differs from Lucy on the gravity brightening exponent. The changes are insufficient to produce W-type light curves. (4) Webbink (1977), and, separately, Nariai (1976), argue for a baroclinic envelope. If the baroclinicity extends to the photosphere there is a possibility that W-type light curves could be explained. In particular, the Webbink scenario produces a hot secondary.

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On the other hand, an ingenious proposal by Mullan (1975) apparently rescues the Lucy model. The Mullan proposal populates the primary component photosphere with starspots. These reduce the average surface brightness, thereby reduce the light loss at transit eclipse, and produce W-type light curves. This proposal has been received favorably by many specialists in the binary star field.

The study of binary star color curves, in addition to light curves, provides helpful observational discrimination among competing models. Color curves produce good temperature diagnostics. A comparison of theoretical color curves with W UMa observational data appears in a recent paper (Linnell 1987), together with a discussion of the models described earlier. If one adopts a physically reasonable spot temperature contrast from the adjacent photosphere, it is possible to calculate the fractional coverage of the primary component necessary to produce the observed W-type light curve in the V band. The resulting B-V color curve then differs only slightly from the theoretical color curve for a barotropic photosphere. This color curve disagrees with observation. On the other hand, a hot secondary model has a corresponding B-V color curve in reasonable accordance with observation. Other objections to the starspot model are in the paper cited (Linnell 1987). The best accordance of all the visible wavelength data is with a hot secondary model.

An apparent difficulty for the hot secondary model is the uv data obtained by Eaton, Wu and Rucinski (1980) for W UMa, using the ANS satellite. If the hot secondary model is correct, the difference in eclipse depths increases in the uv. Rather than increasingly W-type, the observations at 2200 Å show a marginally A-type light curve. It should be noted that the starspot model is of no help here. Since starspots are cool, the emergent flux difference between spot and photosphere increases in the uv. Then the reduction in average surface brightness in the uv, for the primary component, cannot be less than in V. A W-type light curve in V, produced by the Mullan starspot model, will not become A-type in the far uv. A possible explanation of the uv observations is a uv excess on the primary component, produced by inferred flare activity (Linnell 1987).

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