THE NATURE OF RECURRENT NOVAE

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ABSTRACT

The observational properties and outburst histories of each member of the small class of recurrent novae are reviewed, with the objective of identifying the outburst mechanisms for these systems. Examples are found of both accretion-powered outbursts (T CrB and RS Oph) and thermonuclear-powered outbursts (T Pyx and U Sco). Outburst properties which might be used in future to distinguish between these mechanisms are identified. Many erstwhile recurrent novae (VY Aqr, RZ Leo, V616 Mon, V1195 Oph, V529 Ori, WZ Sge, and V1017 Sgr) appear to be misclassified examples of other types of cataclysmic variables.

The recurrent novae are a small class of objects intermediate between classical novae and dwarf novae, reaching luminosities in outburst comparable with those of classical novae, but having multiple recorded outbursts as well, like dwarf novae. Spectroscopically, the recurrent novae show evidence of high-velocity shell ejection in outburst, like the classical novae.

Both accretion events onto main sequence stars (Webbink 1976; Livio, Truran, and Webbink 1986) and thermonuclear runaways on white dwarfs (Starrfield, Sparks, and Truran 1985) have been proposed as energy sources for these outbursts. The accretion model appeals to dynamical phenomena — the collision of a burst of mass from a Roche lobe-filling giant with the surface of the accreting star, or its collapse into a circumstellar ring — to reproduce the extremely rapid

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light curve development typical of most recurrent novae. Viscous evolution of an accretion disk is unable to produce outbursts lasting only a fraction of a binary orbital period. Thermonuclear models, on the other hand, demand white dwarf masses very nearly equal to the Chandrasekhar mass, and accretion rates in a fairly narrow range ($\sim 10^{-7}$ to 10^{-8} $M_\odot$ yr^{-1}) to achieve strong outbursts recurrent on timescales as short as those observed. We have reviewed the existing observations of all known or putative recurrent novae in an attempt to determine which, if either, of these models is appropriate to each one individually (Webbink, Livio, Truran, and Orio 1986).

Accretion-powered recurrent novae are exemplified by T CrB (1866, 1946) and RS Oph (1898, 1933, 1958, 1967, 1985). Both systems show a characteristic shock-type ejection at maximum, a phenomenon readily accounted for by the accretion model. In T CrB, the principal maximum is followed at some interval by a secondary maximum, in which the optical continuum overwhelms nebular emission. This secondary maximum is presumably due to viscous decay of an accretion disk formed in the principal outburst (Webbink 1976). An accurate orbital ephemeris is available for this system (Kenyon and Garcia 1986), and it can be shown from constraints on heating of the giant companion that the secondary maximum corresponds to a bolometric brightening. RS Oph appears to be a more evolved counterpart to T CrB, in which the main sequence star has become so bloated, due to the higher mean mass transfer rate, that no disk is formed (Livio, Truran, and Webbink 1986). In both cases, the ultraviolet continuum and high excitation emission lines are so weak in quiescence as to exclude accretion rates onto white dwarfs high enough to produce viable thermonuclear models for their outbursts.

Thermonuclear-powered recurrent novae are represented by T Pyx (1890, 1902, 1920, 1944, 1966) and U Sco (1863, 1906, 1936, 1979). In neither case do ultraviolet observations at quiescence exist. However, the optical ultraviolet continuum of U Sco (Hanes 1985) evidently arises from an accretion disk, with a deduced mass accretion rate appropriate to a thermonuclear model. In T Pyx, the optical ultraviolet continuum appears to be stellar in origin, but it is intrinsically bright enough to conceal the requisite accretion disk. In both cases, the spectroscopic evolution through outburst is approximately that of classical novae (Catchpole 1969; Barlow, et al. 1981), in contrast with T CrB and RS Oph, which show rapidly decreasing ejection velocities and the appearance of strong, high-excitation coronal emission during decline. The thermonuclear model demands such small envelope masses for recurrent novae ($\lesssim 10^{-6}$ $M_\odot$) that the opacities of their envelopes at maximum light should be extremely electron-scattering dominated, and such novae should therefore be emission-line objects, even at maximum. This prediction is verified in T Pyx (spectra at maximum do not exist for U Sco). The difference in outburst timescales (extremely fast for U Sco, rather slow for T Pyx) is attributable to the much higher base luminosity of the quiescent white dwarf in T Pyx.

The remaining objects proved, for the most part, to be dwarf novae

(VY Aqr, RZ Leo, V1195 Oph, and WZ Sge). V616 Mon (1917, 1975) is now considered a prototypical recurrent soft X-ray transient source. V529 Ori (1678) is of indeterminate nature, but there is no reason to believe it to have recurred. V1017 Sgr (1901, 1919, 1973) is more properly considered a symbiotic star, but it may represent an interesting hybrid case, with both thermonuclear (1919) and accretion (1901, 1973) events.

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