THE SYMBIOTIC NOVAE

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ABSTRACT. A small number of symbiotic stars are characterized by a single nova-like outburst with a very slow time evolution and several years of permanence at maximum. We describe in detail RR Tel and discuss the main properties of these objects.

1. INTRODUCTION

Two kinds of nova-like outburst can be identified in the symbiotic phenomenon, the Z And-type with non-periodic recurrent maxima, and the RR Tel-type with only one single event recorded in their historical light curve. Allen (1980) listed seven stars having the character of very slow novae or symbiotic novae: AG Peg, RT Ser, RR Tel, V1016 Cyg, HBV 475 (V1329 Cyg), HM Sge and AS 239 (V2110 Oph). More recently a similar behaviour was observed in the symbiotic, nova-like variable PU Vul. Table 1 summarizes the main data on these eight symbiotic novae. With respect to classical novae, their light curve is characterized by a slow rise to maximum and an even slower decline (or no decline at all), and in some cases a small amplitude of the visual outburst. The light curves of symbiotic novae are shown in Fig.1. The oldest symbiotic nova is AG Peg which in the middle of the past century underwent a major nova-like outburst with a very slow increase of the visual luminosity, and a still longer decline to the present magnitude which is close to the pre-outburst luminosity (Fig.1). Presently AG Peg displays a typical symbiotic spectrum with a cool continuum showing strong TiO bands, characteristic of an M3 giant star, prominent emission lines of low and high ionization, and a hot continuum extending to the far-UV (e.g. Hutchings et al. 1975; Penston and Allen 1985). It should be noted that without the knowledge of the AG Peg light curve so many years back, its nova-like nature would have not been recognized on the basis of its present behaviour, and especially the many differences with other 'classical' symbiotic novae, such as RR Tel, V1016 Cyg and HM Sge. It is thus conceivable that several other symbiotic objects actually belong to the category of symbiotic novae, but, because of the long time scale involved, their main nova-like outburst has not been recorded.

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Table 1. The Symbiotic Novae (1)

star	To (a)	l''	b''	magnitude (b)	(c)	(d)	spectrum (e)	(f)	IR (g)	notes (h)
AG Peg	1855	69	-30	9	6	8.3	M3		S	2
RT Ser	1909	14	+10	>16	9.5	13	M	A8	S	2
V2110 Oph	1940:	05	+04	-	11:	22	>M3		D	2,4
RR Tel	1944	342	-32	14v	6	11	M	F5	D	h,2
V1016 Cyg	1964	75	+06	14	11	11	M	neb	D	h,5
V1329 Cyg	1966	78	-05	14v	11.5	13-14	M5	neb	S	6
HM Sge	1975	54	-03	>17	11	11	M	neb	D	h,5
PU Vul	1978	63	-09	15v	8.8	8.8	M4	A7	S	2

Notes to the table:
a. Beginning of the outburst. b. Pre-outburst magnitude. c. Maximum luminosity. d. Post-maximum (present) magnitude. e. Cool spectral component. f. Equivalent spectral type at maximum. g. Infrared type (S=stellar, D=dust). h. Periodic variations in the IR.
References: 1. Allen (1980). 2. Kenyon (1986). 3. Adams and Joy (1928). 4. Allen (1978). 5. Ciatti et al. (1978). 6. Grygar et al. (1979).

2. RR TELESCOPII

In this section we discuss in detail RR Tel which could be considered as the best representative of the category of symbiotic novae. Much of the following discussion also applies to other symbiotic novae. The star was discovered as variable by Mrs. Fleming (1908) many decades before its main outburst. Later Mrs. Mayall (1949) from the analysis of 600 Harvard observations from 1889 to 1947 found that during 1889 to 1930 RR Tel showed little evidence of periodic variability, the observed range being about 1.5 mag with maxima ranging from 12.5 to 14 mag. After 1930 the variations appeared clearly periodic with a mean period of about 387 days and an amplitude of about 3 mag. As discussed below, this periodicity with the same period is now observable in the IR (Feast et al. 1983). In late 1944 the periodicity stopped and the star rapidly brightened from mpg=14 to 10 in a few days, then rose to the seventh magnitude by mid 1945. The following years RR Tel remained at maximum luminosity until 1949, reaching the sixth magnitude during 1948, then gradually faded to the present V=10 in about 14 years (see e.g. Kenyon 1986). The outburst of RR Tel was discovered in 1949, three years after the outburst. It was a lucky chance that the star was still at maximum and that major spectral changes occured after the discovery. The early spectral evolution of RR Tel was followed at the Bosque Alegre and Radcliffe Observatories. We shall discuss the Bosque Alegre spectra on the basis on a reproduction of unpublished data kindly provided me by Jorge Sahade. The first spectrum was taken in April 1949 and showed a continuum with many absorption lines of singly ionized metals. Some absorptions are flanked at longer wavelengths by a weak emission compo-

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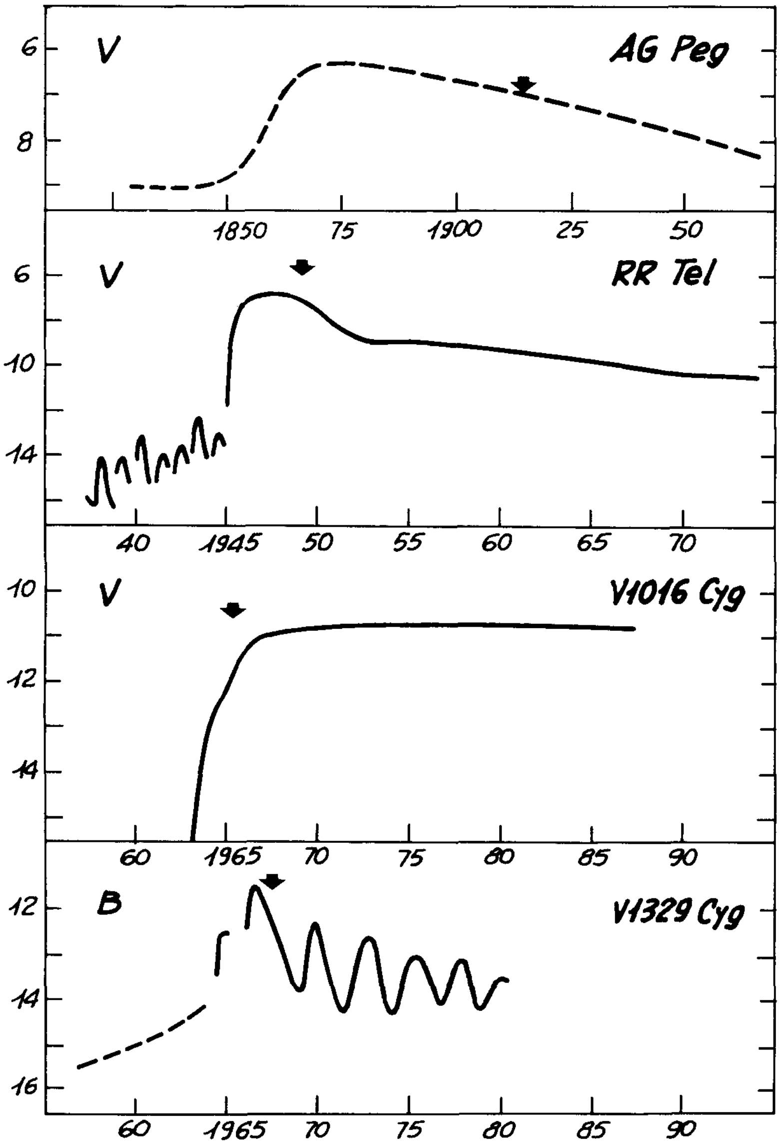

Fig.1 The light curves of four symbiotic novae. Note the different decline rates (in AG Peg the abscissa scale is contracted). The arrows indicate the time of the first spectroscopic observations.

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nent indicating a P Cygni profile. This emission became more prominent in July 1949. By September 11 the continuum is weaker and the emission lines dominate the spectrum of RR Tel, although the mean line excitation is still low. The first spectra obtained at Radcliffe were discussed by Thackeray (1950) who found in June-August 1949 strong absorptions of CaII and hydrogen. Also TiII was present in absorption, while Hβ was absent, probably filled-in by emission. Mayall (1949) reports on low quality, low dispersion spectra taken when RR Tel was at maximum brightness. All these earlier observations agree in giving an F-supergiant spectral type (cF5, according to Thackeray 1950). In a later paper, Thackeray (1977) reports that the relative shift of the absorption lines was of -100 km/s. The remarkable spectral change occurred between August and September 1949 was first noted by Thackeray (1950) who found that in his spectra all the absorption lines disappeared and a rich emission line spectrum appeared with prominent hydrogen, CaII and especially FeII emission.

The spectral evolution of RR Tel in the following years is best described by Thackeray (1977). Since 1949 the star showed a gradual increase of the mean ionization of the emission line spectrum. HeII and NIII appeared around August 1950 (see also Pottasch and Varsawsky 1960). These authors also identified HeI absorption with a velocity of -685 km/s (in 1951) and -865 km/s (in 1952), indicating the presence of a high expansion velocity in RR Tel. Then between 1951 and 1952 [OIII] and [NeIII] flared while the permitted FeII lines faded (Thackeray 1977). The increase of the level of ionization continued through 1953 and 1954 and is best illustrated by the sequential appearence of higher and higher ionization stages of iron, from FeIII to FeVII (Fig.2). Presently RR Tel displays a very rich emission line spectrum both at optical and UV wavelengths. A comprehensive discussion of its UV spectrum was given by Penston et al. (1983). RR Tel also has a strong IR excess which could be due to thermal dust emission. However, the near-IR appears variable with a period of 387 days - the same as that found during the pre-outburst phase - and with a large amplitude typical of that of Miras (Feast et al. 1983). The presence of a late type star is also supported by the marginal identification of TiO bands in the visible (Thackeray 1977). It should be noted that long period fluctuations of the visual luminosity of RR Tel was found by Heck and Manfroid (1985) and Kenyon and Bateson (1984). The period of 374 days is close to the above reported values and should be associated with the Mira pulsation, although the optical spectrum is dominated by the emission lines.

3. DISCUSSION

Symbiotic novae have the common caracteristic of having undergone one single major outburst, and to be symbiotic. Since among the few so far identified symbiotic novae there exists a variety of behaviour and of time scales, it would be important to understand whether they represent an extreme case of symbiotic stars or they are more related to the category of novae. Let us discuss the different aspects of the phenomenon.

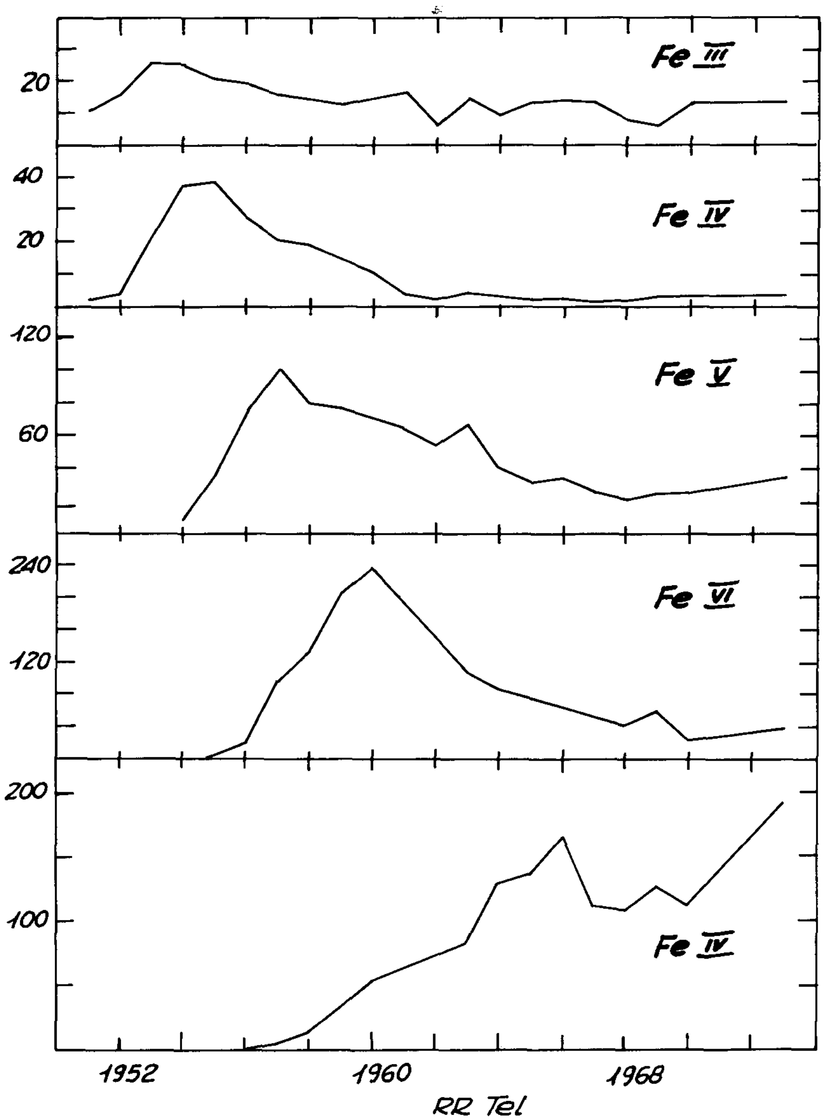

Figure 2. The sequential evolution of the iron emission lines in RR Tel from 1951 to 1970 (from Thackeray 1977). The gradual increase of the ionization of the emitting envelope is indicated by the appearence of successive ionization stages.

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The pre-outburst phase is rather well known only for RR Tel and V1329 Cyg. Both showed large amplitude, periodic variations which are attributed for RR Tel to Mira pulsation and for V1329 Cyg to eclipses of a binary system. For these stars and V1016 Cyg the spectrum at minimum was M. The M spectrum was also observed in PU Vul during its deep fading of 1980, and in AG Peg and RT Ser after decline from maximum. In V1016 Cyg and HM Sge which have not (yet) declined after the maximum, the M spectrum in the optical is hidden by the strong continuum and line emission from the circumstellar region. In these stars the presence of a late type spectral component is shown by the large amplitude, Mira type variations of the near-IR (Table 2). These variations are also observed in RR Tel and imply that the cool spectral component is the main contributor to the near-IR spectrum. The spectrum however does not peak in the near-IR as expected. Kenyon et al. (1986) have studied the IR energy distribution of three D-type symbiotics, including the symbiotic novae RR Tel and HM Sge, and concluded that their IR spectrum is consistent with those of highly reddened Mira variables. Thus they suggest that the cool, Mira-type component is embedded in a dense dust shell while the hot source lies outside the shell. In these systems, the evidence of a late type component is also indicated by the marginal presence of TiO bands in the optical, and by the steam absorption in the IR. The conclusion is that in these symbiotic novae (and in the other symbiotic stars as well) there is clear evidence for the presence of an M 'star'.

The observations and energy balance considerations also imply that there is another component which is responsible for the outburst. The presence of a binary system is without doubt in AG Peg and V1329 Cyg. In the other objects the radial velocity appears constant, but it is difficult to decide whether this is due to a very long orbital period, as suggested by Kenyon et al. (1986), or to the inclination of the orbit with respect to the line of sight. The strong UV radiation of the hot component should destroy the circumstellar dust, as it could have happened in AG Peg and V1329 Cyg which S-type symbiotics. The persistence of dust in the D-type symbiotics should be explained by a larger separation of the system. Note that Friedjung et al. (1984) have suggested that the deep minimum of PU Vul in 1980 could be explained by dust condensation and hidding of the warm, A-type component.

The rise to maximum was rather fast in RR Tel, V1329 Cyg and HM Sge (Table 2), but very slow in V1016 Cyg and especially in AG Peg and RT Ser. Thus this different behaviour is apparently not related to the other features of the symbiotic novae. The amplitude of the 'outburst' ranges from 3 to >6 magnitudes. In most cases this should be attributed to the presence of the M companion, which is bright (with respect to the peak luminosity) in AG Peg, and very faint in RT Ser, V2110 Oph and HM Sge. Yet this cannot explain the slowness of AG Peg and RT Ser.

The spectrum at maximum in another intriguing problem. RT Ser, RR Tel and PU Vul displayed an intermediate (A-F) spectral type, similar to that of classical novae (without however the large violet displacements of the absorption lines). No such spectrum was observed in the other symbiotic novae. Nevertheless this should be possibly caused by the lack of early spectral observations. For instance V1016 Cyg was first observed spectroscopically near the end of its long lasting rise phase. The first spectra of V1329 Cyg were taken one year after its light maximum (Fig.1). It should also be recalled that in RR Tel the A-type spectrum disappeared probably in a few days at the beginning of September 1949. Should this star have been spectroscopically observed since mid September instead of April-June 1949, we should have lost the A-type phase. Thus the absence of this phase in some symbiotic novae could be an observational effect. What is also important to remark is the presence of rapid spectral change also in these very slow novae.

In general in symbiotic novae emission lines are rather narrow in comparison with novae. But there are a number of interesting exceptions. Crampton et al. (1970) found in V1329 Cyg the [NeIII] and [OIII] lines with a multiple structure with peaks extending from -240 to +250 km/s. Crampton et al. also discovered on the continuum several broad and shallow emission features which can be identified with WN5-type spectral features with an expansion velocity of about 2300 km/s. In the UV spectrum of AG Peg the high ionization lines (NV, CIV, NIV, HeII) present a broad and complex structure resembling that of WR stars (Penston and Allen 1985) and implying radial velocities of several 100 km/s. Broad WR features were also observed in the otpical and UV spectrum of RR Tel (e.g. Thackeray 1977; Penston et al. 1983; Ponz et al. 1982). In this star, as discussed above, high velocity P Cygni profiles were observed during its decline phase. Thus in symbiotic novae there is evidence for the presence of hot high velocity regions, although most of the emitting region is generally characterized by a low velocity field. A 'stratification' is also suggested by the correlation between emission line width and ionization energy (e.g. Penston et al. 1983; Muratorio and Friedjung 1982).

Another puzzle of the symbiotic phenomenon is the light curve after maximum. Four objects displayed a gradual fading which took several years or decades. The e-folding decline time varied from 7-9 years for RT Ser and RR Tel to 40 years for AG Peg. In the case of V1329 Cyg the decline time was derived from a fit of the UV emission line flux variation, taking into account the 950 days periodicity (Nussabaumer et al. 1986). It should be mentioned that Allen (1981) and Willson et al. (1984) from the analysis of the X-ray flux in the three symbiotic novae, RR Tel, V1016 Cyg and HM Sge, suggested a very slow decline of the flux after the outburst. Willson et al. give an e-folding decay time of 5 to 50 years, which is in agreement with the visual decay time of RR Tel. Three recent symbiotic novae, V1016 Cyg, HM Sge and PU Vul, are still at maximum, which means that their decay time should be larger than 38 to 125 years (see Table 2).

Like in RR Tel discussed above the spectral evolution of symbiotic novae after outburst is in general similar to that of classical novae, except for the much longer time scale, with a gradual increase of the mean ionization of the emission line spectrum. This is best observed in RR Tel, V1016 Cyg, HM Sge and V1329 Cyg. In the first three stars the nebular spectrum appeared at maximum luminosity, and in V1016 Cyg and HM Sge the nova-like spectral evolution occurred at constant visual magnitude. (It should be noted that in these stars, and in most symbiotic objects as well, emission lines largely contribute to the broad band photometry, so that care should be taken in the interpretation of their

Table 2. Characteristic times scales

star	rise (a)	decay (b)	Mira (c)	orbit (d)	K (e)	ref.
AG Peg	16	40	-	816.5	5.1	1,2
RT Ser	14	7:	-	-	-	1
RR Tel	<0.3	9	374.2	-	-	1,3
V1016 Cyg	2-3	>125	472	-	n	4
V1329 Cyg	0.3	12-20	?	950	62	5
HM Sge	<0.4	>65	500-600	-	n	4
PU Vul	1	>38	-	-	n	1

Notes to the table: (a) Rise time (total) in years. (b) 1/e decay time (years). (c) Period (in days) of the Mira pulsation. (d) Orbital period (days). (e) Semi-amplitude (in km/s) of the radial velocity curve (n= no variation observed). References: (1) Kenyon 1986. (2) Hutchings et al. 1975. (3) Feast et al. 1983. (4) Ciatti et al. 1978; Taranova and Yudin 1983; Willson et al. 1984. (5) Nussbaumer et al. 1986; Grygar et al. 1979.

light curves). This is one main difference with classical novae. In the case of PU Vul the A-type maximum spectrum is still present eight years after the outburst, with the star still at maximum. Perhaps this could be related to the much lower expansion velocities observed in symbiotic novae.

We should finally recall the important results recently obtained in the radio which are described in the volume Radio Stars (Hjellming and Gibson 1985) and discussed by Viotti (1987). Of particular interest is the discovery of radio nebulae around some symbiotic novae with complex structures, such as jets, halos and bipolar nebulae which might be associated with the outburst and their binary nature. Also important is the time evolution of the radio emission of HM Sge (e.g. Kwok 1982) and of the 'radio nova' CH Cyg (Taylor et al. 1986). These phenomena are described elsewhere is this volume.

We may conclude that, in spite of the many important results so far obtained especially outside the optical region, the phenomenon of the symbiotic novae is still not well understood, and their relationship with novae open to discussion. Also the present list of symbiotic novae is far from being statistically significant. Fields which should require future work are the optical and UV emission lines observed at high resolution for the study of the circumstellar gas dynamics, high spatial resolution imagery in the UV, visual and IR, high resolution near-IR spectroscopy of the cool components, and, finally, a systematic search of nova-like events associated with symbiotic systems.

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