The 1990 Outburst of VY Aqr

M. DELLA VALLE and T. AUGUSTEIJN, ESO

Introduction

The sixth outburst of VY Aqr in the last eight years was recorded by several amateur observers on June 30.75 U.T. 1990 (IAUC 5046). Thanks to the extensive monitoring, the observed maximum m_V = 10.4, should be very close to the true one. The spectroscopic and photometric observations began at La Silla some nights later, with the ESO 1.5-m and the Dutch 90-cm. The visual lightcurve, represented in Figure 2, has been derived by plotting the magnitudes published in the IAU Circulars (5046, 5053) and the Walraven photometry obtained at the Dutch telescope. Figure 2 shows reproduced on the same scale the light curves observed during the other five recent outbursts (see Table 1).

Originally, VY Aqr was believed to be a fast nova (Payne-Gaposchkin, 1957). This was due to the large amplitude of the outburst recorded in 1907 (~ 10 m_{pg}), and to the fact that the second eruption in order of discovery was detected only in 1962 (Strohmeier, 1962). On the other hand, the lightcurve of this star does not fit in many respects that of a *classical nova.* In particular it does not satisfy the well established relationship between the magnitude at maximum and the rate of decline (Capaccioli et al., 1989) or between the amplitude of the outburst and the rate of decline (Warner, 1987). On the contrary, the amplitudes and the recurrence times of its outbursts fit very well to the *Kukarkin-Parenago* relation for Dwarf Novae (DN) : A(mag) = 1.85 ± 0.44 + 1.40 ± 0.23 × logτ_r (days) (van Paradijs, 1985). However, the most marked differences from novae come from the analysis of the spectra. Both at maximum and at minimum the spectra of VY Aqr are not at all comparable to those of a classical nova.

In principle, the occurrence of outbursts of large amplitude (7–10 mag) at intervals of years would allow us to include this star among the class of the *recurrent novae* (see Kholopov et al., 1985), but in recent years a number of

TABLE 1: *Recorded VY Aqr Outbursts*

Year	Maximum	Band
1907	8.4	pg
1929	8.0	pg
1934	9.0	pg
1942	11.0	pg
1958	10.5	pg
1962	9.7	pg
1973	9.5	pg
1983	10.3	m_V
1986	10.3	m_V
1987	10.7	m_V
1988	10.4	m_V
1989	11.1	m_V
1990	10.4	m_V

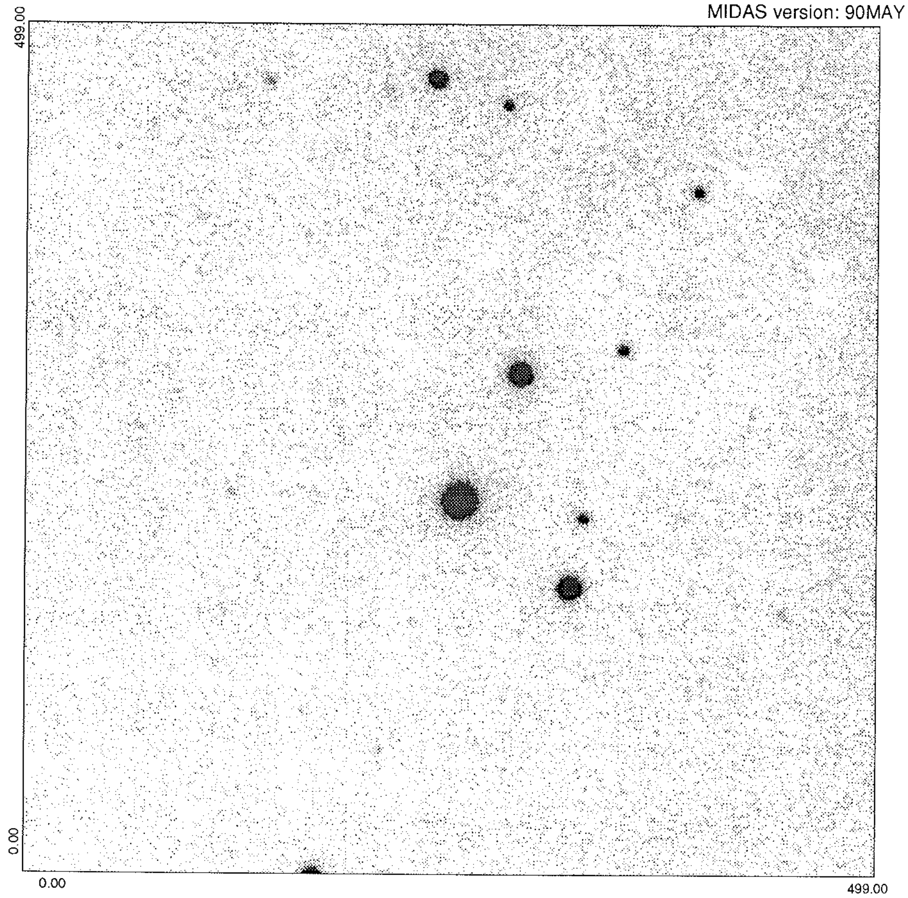

Figure 1: *VY Aqr, the bright star near the centre of the picture, during the recent outburst. The image was taken with the NTT-EMMI through an R filter on July 9 by Della Valle and Oosterloo.*

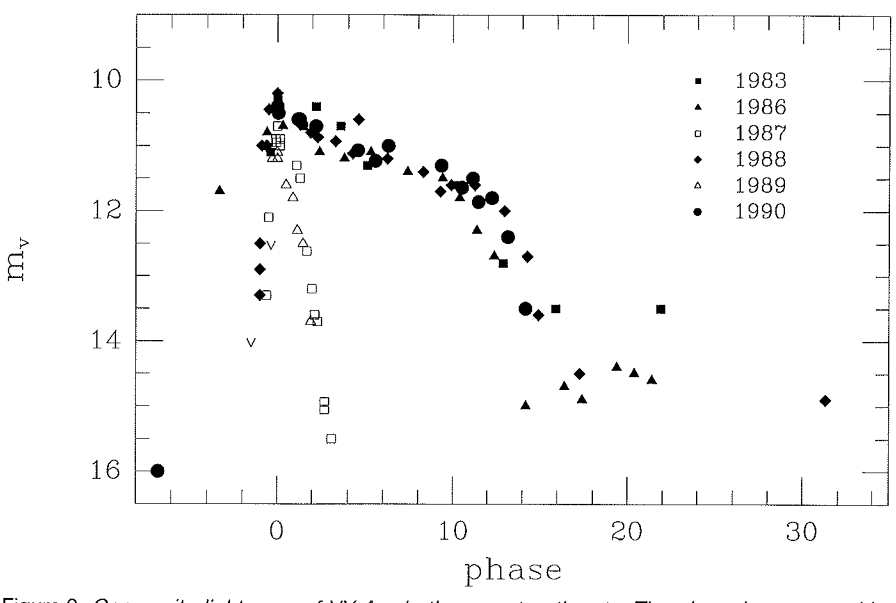

Figure 2: *Composite lightcurve of VY Aqr in the recent outbursts. The phase is expressed in days after the maximum.*

observations argue against this view. In particular: (a) the low excitation spectrum which characterized VY Aqr at minimum (Hendry, 1983), (b) the short recurrence time exhibited by the stars in the last years, and (c) the spectrum at maximum typical of a DN in outburst.

Roughly speaking, DNe form a fairly homogeneous class of variables. Their lightcurve is characterized by relative long intervals of quiescence, generally from some weeks to some months, interrupted by sudden rises in the brightness (typically 2–6 mag) which last less than one or two days. The subsequent decline takes typically a few days to a week.

Most of the DNe exhibit a spectrum at minimum of low excitation with strong Balmer lines in emission, superimposed on a faint, blue continuum. Weak emission lines of HeI are also present whereas the forbidden lines, quite common in the spectra of the novae at this stage, are generally missing. As a DN increases in brightness, the continuum becomes stronger and in place of the emissions, shallow absorption lines appear, frequently filled in with emission. This type of spectrum was exactly what was observed (Augusteijn and Della Valle, 1990) during the recent outburst.

According to the current models, the absorptions probably arise from the inner, rapidly rotating portions of the disk surrounding the primary. The emission comes from the outer layers rotating in a quasi-Keplerian way.

Among the DNe, due to the large amplitude and the relatively long recurrence time, VY Aqr represents a quite peculiar case. Actually, similar photometric behaviours have been recognized only in a handful of objects, like: DX And, UZ Boo, WX Cet, RZ Leo, UV Per, WZ Sag, SW Uma, and perhaps V1195 Oph.

The Observations

Our observations were made on July 4–6, 1990, at the ESO 1.5-m telescope, equipped with the Boller and Chivens spectrograph and the CCD (GEC #14 chip). Initially, we collected 33 spectra of VY Aqr in the 405–504 nm region, with a dispersion of 59 Å mm^{-1}. The brightness of the object ($m_V \simeq 10.5$) allowed us to keep a quite high temporal resolution (168 s). In the following nights, spectra covering the whole optical range (375–680 nm) of VY Aqr and V 3885 Sgr, and in the range 375–505 nm of IX Vel and RW Sex were also taken. Finally, a new set of 21 spectra of VY Aqr in the 405–504 nm region, with a dispersion of 59 Å mm^{-1} with a temporal resolution of 300 s were obtained. From a rough reduction performed with IHAP at the telescope, we derived the spectra shown in Figures 3–6. The Walraven photometry in V has been reduced to the Johnson's V band through the colour equation: $V_J = 6.886 - 2.5 V_W - 0.082 (V-B($_W$ (Pel, 1985).

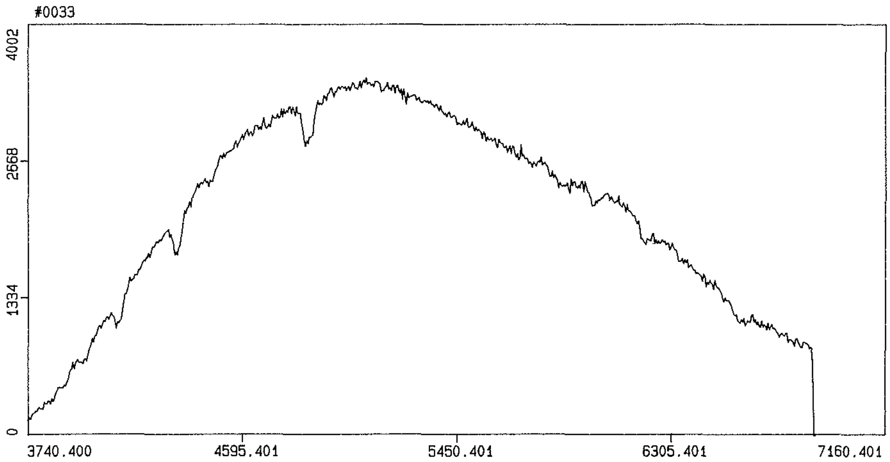

Figure 3: *4-minute Boller and Chivens spectrum of VY Aqr during the 1990 outburst. The spectrum is calibrated in wavelengths and corrected for flat field and sky subtraction.*

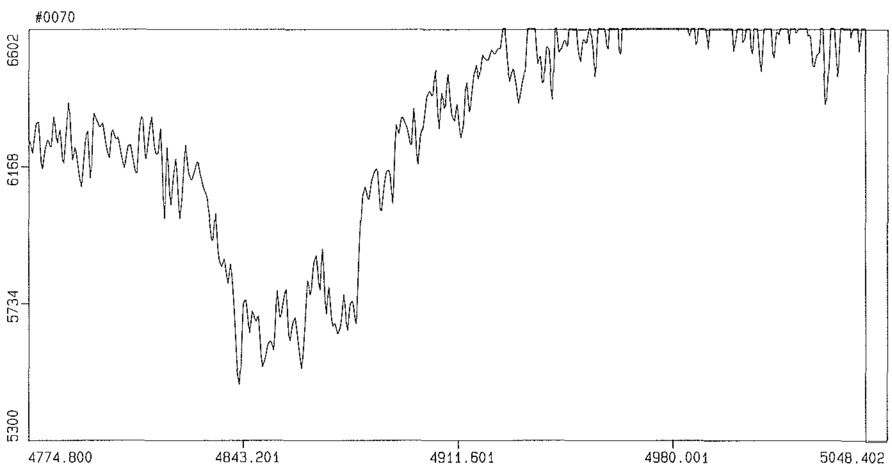

Figure 4: *The Hβ absorption with the central re-emission.*

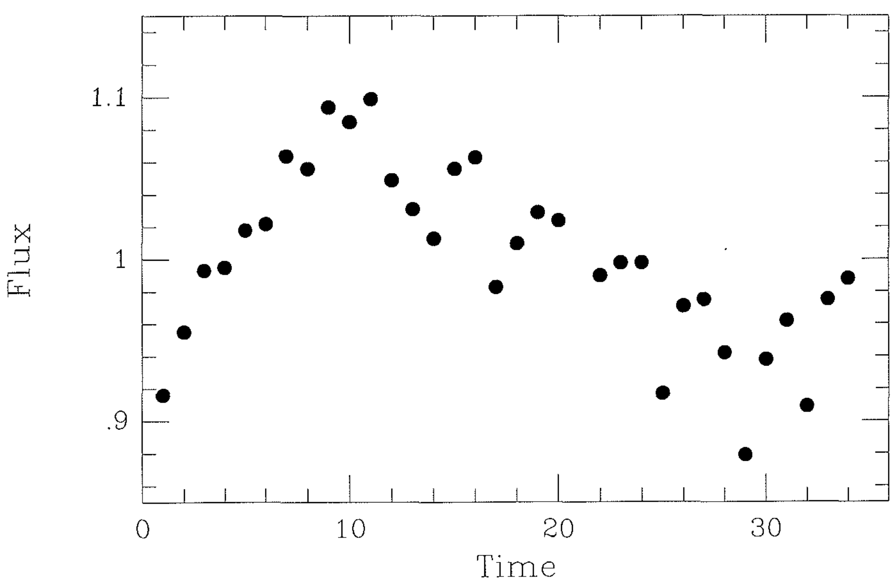

Figure 5: *Plot of the integrated flux (arbitrary unit) for 33 spectra of VY Aqr versus time. One unit in the abscissa corresponds to 168 s.*

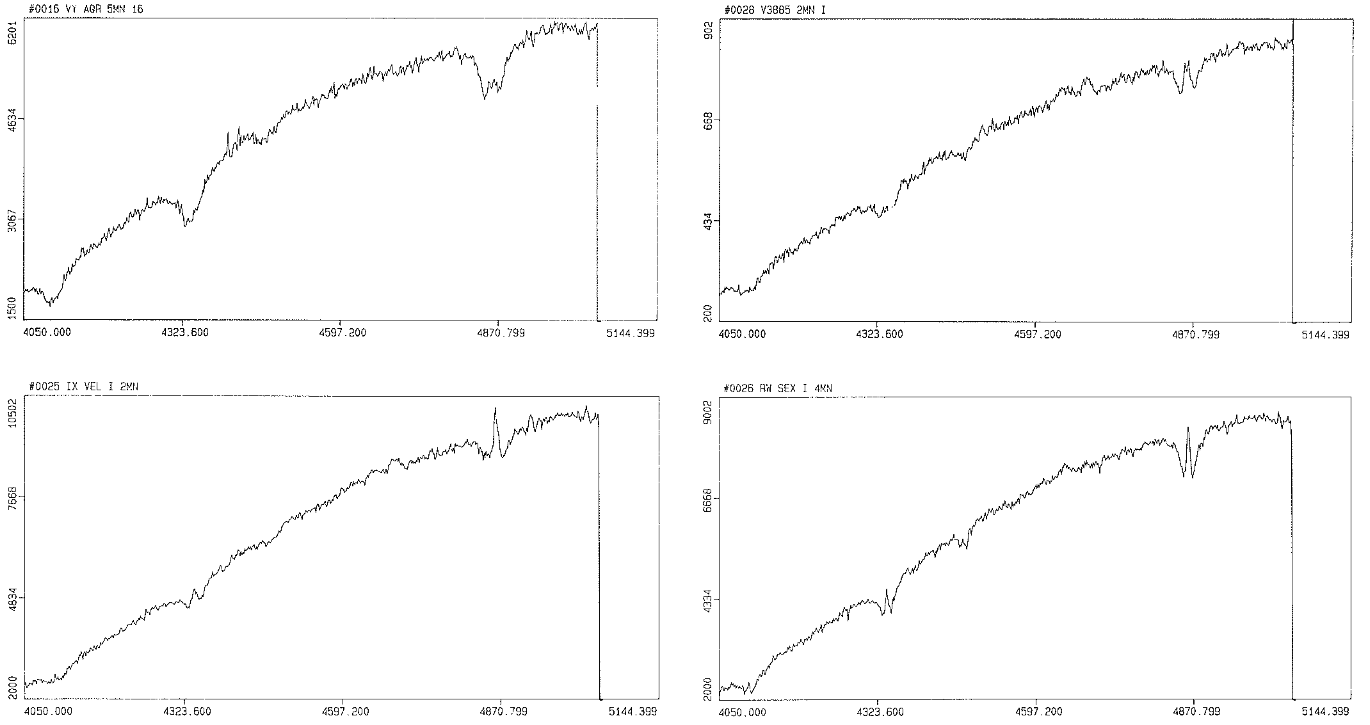

Figure 6: *The spectrum of VY Aqr at maximum, in comparison with the "normal stage" spectra of three UX UMa stars: V 3885 Sgr, IX Vel, and RW Ser.*

Results

A quick glance at Figure 2 shows clearly that VY Aqr undergoes two different types of outbursts. The 1983, 1986, 1988, and 1990 outbursts are distinguished from the ones in 1987 and 1989, by the longer duration and the greater brightness (~0.5 mag). It is worth noting that a qualitatively similar behaviour is found in the lightcurves of a sub-class of DNe; the SU Ursae Majoris stars. They exhibit, apart from the normal outbursts, the so-called *superoutbursts.* In the case of VY Aqr, differences between the two types of outbursts can also be seen from the spectroscopy. The spectrum recorded on July 5 (Figure 3), shows shallow absorption due to Balmer lines, HeI and possibly NI (599.9 and 600.8, mult. 16), superimposed on a fairly strong continuum. The H lines appear variously filled in with emission and in some cases appear double-peaked. In particular, the emission profile of Hβ is split into several components (Fig. 4). The absorption profiles for the H and He lines were measured and compared with the description of the spectrum of VY Aqr obtained during the "normal" maximum of 1987 (Leibowitz et al., 1987). In the 1990 outburst, the observed value for the FWZI of Hβ corresponds to ~5000 km s^{-1}, a 40% greater value than that observed in 1987.

According to the current knowledge, two mechanisms are believed to explain the DN explosions. In the *disk-instability* model the quiescent state is characterized by an accretion rate from the disk onto the white dwarf (WD), smaller than the mass transfer rate from the secondary to the disk. As a result of this, when the density in the disk has reached a critical value, the disk suddenly changes its low mass transfer rate onto the WD, to a high accretion rate state, originating an outburst. Later, due to a decline in the density of the disk, the DN returns to the minimum. In the *mass-transfer-instability* model, the quiescent state is characterized by the same values of accretion rate from the secondary to the disk and from the disk to the WD. In this view, the outbursts should be caused by bursts of the mass-transfer rate from the secondary to the WD. The two different types of eruptions observed in VY Aqr would perhaps suggest that the star can undergo both these mechanisms.

Figure 5 has been obtained by plotting the integrated flux (between 405 and 514.4 nm) derived for the 33 high temporal resolution spectra, versus time. The variation in the flux detected from the star, is consistent with a period of 0.059 ± 0.005 days. In agreement within the errors to the superhump period of 0.064 days reported by Warner and Livio (1987).

Finally, in Figure 6, we compare the spectrum at maximum (405–504 nm) of VY Aqr to those of three UX UMa stars, V3885 Sgr, IX Vel and RW Sex, observed during their "normal" stage. The strict similarity with the spectrum of VY Aqr points clearly to a classification of the UX UMa stars as DNe continuously in outburst, rather than Nova-like, as normally reported.

This fact is consistent with Krautter et al.'s (1981) suggestion, that the UX UMa star TT Ari was undergoing, before 1980, a standstill stage similar to the long period of activity exhibited by the Z Cam type DN.

References

Augusteijn, T., Della Valle, M.: 1990, IAUC No. 5048.
Capaccioli, M., Della Valle, M., D'Onofrio, M., Rosino, L.: 1989, p. 1622.
Hendry, E.M.: 1983, *Inf. Bull. Var. Stars,* No. 2381.
Khopolov et al.: 1985, *The General Catalogue of Variable Stars.*
Krautter, J., Klare, G., Wolf, B., Wargau, W., Drechsel, H., Rahe, J., Vogt, N.: 1981, *Astron. Astrophys.,* **98,** 27.
Leibowitz, E.M., Laor, A., Mazeh, T., Brosch, N.: 1987, IAUC No. 4418.
Payne-Gaposchkin, C.: 1957, *The Galactic Novae,* p. 199.
Pel, J.W.: 1985, Internal Report, Leiden Observatory.
Strohmeier, W.: 1962, *Inf. Bull. Var. Stars,* No. 15.
van Paradijs, J.: 1985, *Astron. Astrophys.,* **144,** 199.
Warner, B.: 1987, *Mon. Not. R. Astr. Soc.,* **227,** 23.
Warner, B., Livio, M.: 1987, *Astrophys. Journ. Lett.,* **322,** L95.