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# PHOTOMETRY OF THE 1994–1995 ACTIVE PHASE OF AG Dra

The high-velocity, symbiotic star AG Dra ($\alpha_{2000}$=16$^h$01$^m$41$^s$.1, $\delta_{2000}$=+66°48′10″) in mid 1994 entered a new active phase which was characterized by a rapid brightening from the quiescent magnitude of V=9$^m$.8/9$^m$.9 in May 1994 to V=8$^m$.3 in July (Mattei, 1995). Then the star faded back to minimum in November 1994. Similarly (but unexpectedly) to the previous active phases of 1980-82 and 1985-86, a secondary light maximum occurred in July 1995, followed by a gradual decrease to quiescence. Because of the uniqueness of the event, and for being AG Dra known to be an intense supersoft X-ray source, a campaign of multiwavelength observations was organized, and optical photometry was collected in coordination with space IUE and ROSAT observations (Greiner et al., 1996).

Broad–band BVRI photometry of AG Dra was obtained during July 1994–January 1996 with the 30 cm, F/4.5 telescope at Greve (Firenze), and with the 50 cm, F/4.5 telescope at Vallinfreda (Roma). Both telescopes are equipped with an SBIG ST6 CCD detector. The photometric accuracy was excellent during most nights, the m.s. errors being of 0$^m$.03 in B, 0$^m$.02 in V, 0$^m$.03 in R, and 0$^m$.02 in I. As for the photometric sequence we have used the secondary standards listed in Table 1, whose photometric data were obtained using stars from Landolt's (1992) catalogue.

In addition, three colour UBV photometry was obtained during December 1993–February 1996 with a single channel photoelectric photometer, mounted at the Cassegrain focus of the 60 cm, F/12.5 telescope of the National Astronomical Observatory "Rozhen". The star BD +67°925 having V=9$^m$.88, B–V=0$^m$.56 and U–B=–0$^m$.04 (Skopal & Chochol 1994) was used as a comparison star. The m.s. errors are not larger than 0$^m$.02 in U and B, and 0$^m$.01 in V. The observational data are listed in Table 2.

Figure 1 gives the five-colour light curve of AG Dra during its 1994–1995 active phase. The observations cover mainly the declining phases following the primary (June 1994) and secondary (July 1995) light maxima. No U–band observations were obtained during the 1994 maximum but that phase was also covered by the UBV observations of Skopal and Chochol (1994). The figure shows that AG Dra varied in all the colours, but the amplitude of the variation was larger (and the decline steeper) for the shorter wavelengths. In particular, the variation of the U magnitude during the 1995 outburst – when compared to its value during quiescence – indicates an increase by a factor larger than 5 of the radiation near the Balmer jump. The variation was quite large also in B, with a flux increase (with respect to quiescence) of more than 2.1 and 1.3 magnitudes for the 1994 and 1995 outbursts, respectively. It should be noted that during the minimum phase, i.e. between the two light maxima, the U and B fluxes were well above their quiescent values.

Table 1. The BVRI photometric sequence

| Star | $\alpha_{2000}$ | $\delta_{2000}$ | B | $\sigma$ | V | $\sigma$ | R | $\sigma$ | I | $\sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|
| a | $16^h03^m25^s$ | $+66°37'31''$ | 11.93 | .02 | 11.13 | .02 | 10.74 | .03 | 10.34 | .01 |
| b | $02^m54^s$ | $41'34''$ | 11.83 | .02 | 11.12 | .02 | 10.75 | .03 | 10.37 | .02 |
| c | $03^m27^s$ | $45'16''$ | 10.99 | .02 | 10.43 | .02 | 10.10 | .03 | 9.82 | .01 |
| d | $04^m09^s$ | $40'02''$ | 11.67 | .03 | 11.04 | .02 | 10.71 | .03 | 10.39 | .01 |
| e | $00^m41^s$ | $39'33''$ | 12.45 | .03 | 12.00 | .01 | 11.66 | .03 | 11.39 | .01 |
| f | $01^m41^s$ | $38'50''$ | 12.22 | .02 | 11.72 | .01 | 11.37 | .03 | 11.05 | .03 |
| g | $00^m56^s$ | $42'57''$ | 13.20 | .09 | 12.27 | .02 | 11.78 | .03 | 11.32 | .01 |

Finally, we remark that unexpectedly during the light maxima AG Dra significantly varied also in the I–band which is near the maximum of the energy spectrum of the cool stellar component.

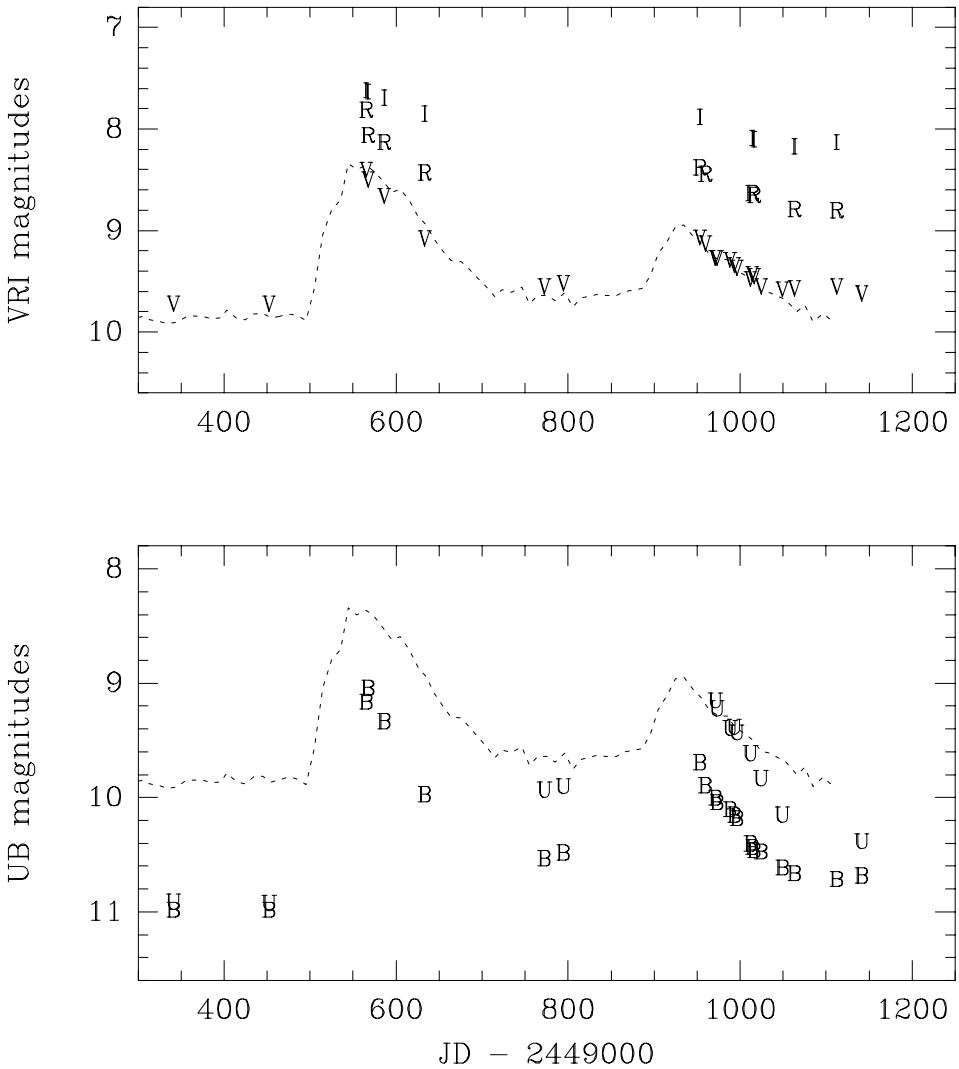


Figure 1. The five–colour light curve of AG Dra from December 1993 to February 1996. For comparison, the AAVSO visual light curve (10-day means, Mattei 1995) is shown as a dotted line

Table 2. Photometric observations of AG Dra

| Date | JD−2400000 | n | U | B | V | R | I |
|---|---|---|---|---|---|---|---|
| 19 Dec 93 | 49341.2 | 3 | 10.92 | 10.99 | 9.73 | — | — |
| 10 Apr 94 | 49452.5 | 2 | 10.93 | 10.99 | 9.73 | — | — |
| 31 Jul 94 | 49565.4 | 1 | — | 9.17 | 8.41 | 7.82 | 7.63 |
| 2 Aug 94 | 49567.4 | 1 | — | 9.05 | 8.51 | 8.07 | 7.64 |
| 21 Aug 94 | 49586.4 | 1 | — | 9.34 | 8.67 | 8.14 | 7.70 |
| 7 Oct 94 | 49633.4 | 1 | — | 9.98 | 9.09 | 8.44 | 7.86 |
| 24 Feb 95 | 49772.6 | 2 | 9.94 | 10.54 | 9.56 | — | — |
| 18 Mar 95 | 49794.6 | 4 | 9.91 | 10.49 | 9.53 | — | — |
| 23 Aug 95 | 49953.4 | 1 | — | 9.70 | 9.08 | 8.39 | 7.89 |
| 29 Aug 95 | 49959.5 | 1 | — | 9.90 | 9.14 | 8.45 | — |
| 10 Sep 95 | 49971.3 | 2 | 9.16 | 10.01 | 9.28 | — | — |
| 12 Sep 95 | 49973.3 | 3 | 9.23 | 10.05 | 9.28 | — | — |
| 27 Sep 95 | 49988.4 | 2 | 9.40 | 10.11 | 9.30 | — | — |
| 2 Oct 95 | 49993.2 | 3 | 9.39 | 10.16 | 9.35 | — | — |
| 5 Oct 95 | 49996.4 | 3 | 9.44 | 10.19 | 9.38 | — | — |
| 21 Oct 95 | 50012.2 | 2 | 9.62 | 10.41 | 9.49 | — | — |
| 23 Oct 95 | 50014.3 | 2 | — | 10.44 | 9.44 | 8.64 | 8.10 |
| 24 Oct 95 | 50015.3 | 1 | — | 10.44 | 9.44 | 8.65 | 8.12 |
| 25 Oct 95 | 50016.3 | 4 | — | 10.47 | 9.46 | 8.66 | 8.11 |
| 2 Nov 95 | 50024.3 | 3 | 9.84 | 10.48 | 9.56 | — | — |
| 27 Nov 95 | 50049.3 | 2 | 10.16 | 10.62 | 9.59 | — | — |
| 11 Dec 95 | 50063.3 | 4 | — | 10.67 | 9.58 | 8.80 | 8.18 |
| 29 Jan 96 | 50112.3 | 1 | — | 10.72 | 9.56 | 8.81 | 8.14 |
| 27 Feb 96 | 50141.6 | 3 | 10.39 | 10.69 | 9.63 | — | — |

These results can be interpreted in the light of a three spectral component model of AG Dra, in which the red and near IR is dominated by the cool star spectrum, while the blue and near UV radiation arises from the circumstellar nebula ionized by the radiation of the hot star (whose contribution to the near UV is thought to be negligible).

In this model the optical outbursts should be associated with the increase of the size of the nebula, which is the result of the increased flux of UV photons from the outbursting hot source. The U–band excess of AG Dra is therefore due to the nebular Balmer continuum, which has largely increased during the outbursts. The nebular emission appears also to contribute to the longer wavelengths, and the amplitude of the variation at different wavelengths can be in principle used to determine the relative contribution of the nebular and cool star components. In this regard, it is of particular interest that during the light maxima AG Dra largely varied also in the I–band (900 nm). This implies that at the light maximum the "nebular spectrum" should have contributed to at least 40% of the red/near-IR radiation of AG Dra. This contribution rises to more than 70% in V, and to $>\sim 85\%$ in B. We also argue that the contribution of the nebular emission to the red might possibly be not negligible also during the quiescent phase of AG Dra. Therefore, some care should be taken when using the VRI colours (and the photospheric spectral line depth as well) for the determination of the red star's spectral type and luminosity class.

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