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Research Note

An analysis of the photometric variation of the symbiotic star AG Draconis in quiescence

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Abstract. The photometric variations of the symbiotic binary AG Dra have been analyzed. Changes in the U band variations in quiescence between orbital cycles are most easily explained by changes in the cool component wind. The small variations of B and V in quiescence seem to require an additional mechanism. Period analysis of the data from the quiescent stage between two outbursts (1986 - 1994) gave a value for the period in the U band near the orbital period. However new periods were detected with the values of 356 and 350 days in the B and V bands respectively, which is strikingly close to the interval between the two large maxima in B and V, seen during activity.

Key words: stars: novae, cataclysmic variables – stars: binaries: symbiotic – stars: individual: AG Dra

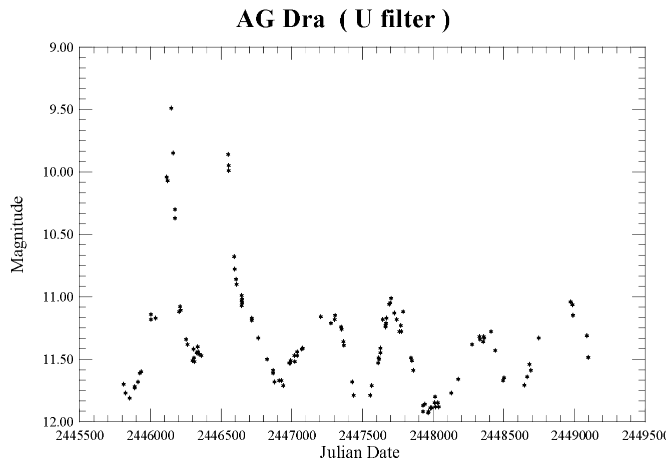

Fig. 1. Photoelectric observations of AG Dra in the U colour.

1. Introduction

Symbiotic stars are now understood as strongly interacting binaries with a compact component (thought to be usually a white dwarf), accreting matter from a cool giant companion. They undergo at certain times " activity ", often explained for most symbiotic stars as due to episodes of thermonuclear burning of matter accreted by the white dwarf.

AG Dra, belongs to the class of yellow symbiotic stars (Friedjung, 1988, 1997) having a K type giant component. It is metal underabundant and has a high radial velocity of -140 $\mathrm{km.s^{-1}}$ suggesting that it belongs to the halo population. These have been disagreements about its distance and the luminosities of its stellar components; its cool giant is probably more luminous than a normal class III giant (Huang *et al.* 1994 and Mikolajewska *et al.* 1995). A study of photometric observations, which have a much better time coverage than that of spectra, can help to illuminate the physics of this star.

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2. Observations and data analysis

The photoelectric observational material discussed in this paper was obtained in the framework of the international campaign for symbiotic stars launched by Hric and Skopal (1989). All data were published in a few papers of this series (see Hric *et al.* 1996 and references therein). For our analysis we used data including some from the time of activity of AG Dra in 1985 - 86 (the 2 relatively low light maxima are designated b1 and b2 by Viotti *et al.* 1996) and from the following epoch of quiescence. Light curves in the U, B and V colours are shown in Figs. 1 - 3.

We have in the following figures shown all data in phase diagrams using the ephemeris of Meinunger (1979):

$$\mathrm{JD_{max}(U) = 2443886 + 554E}$$

Each cycle is marked by its own symbol to distinguish better the temporal development of the photometric behaviour. Observations in the first orbital cycle are denoted by crosses, those of the second by open circles, the third by diamonds, the fourth by open stars, the fifth by snow flakes and the sixth by dots. It should be noted that Meinunger's period (554

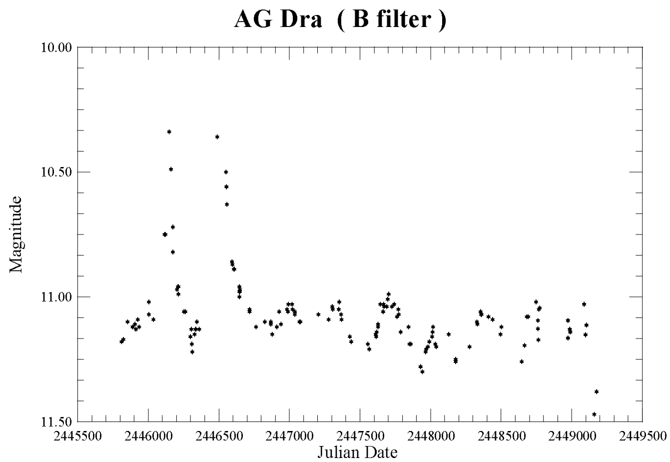

Fig. 2. Photoelectric observations of AG Dra in the B colour.

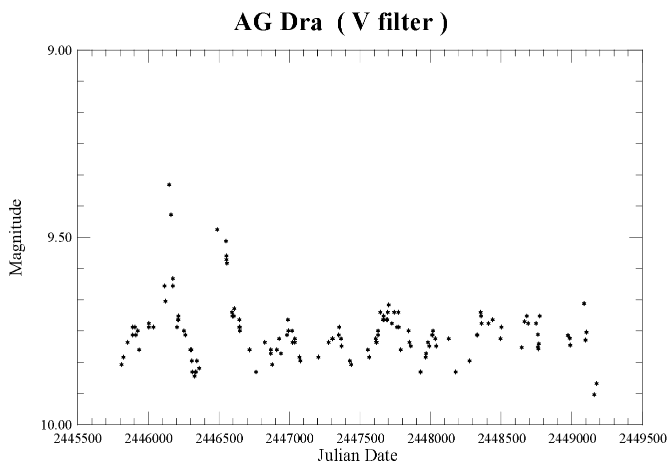

Fig. 3. Photoelectric observations of AG Dra in the V colour.

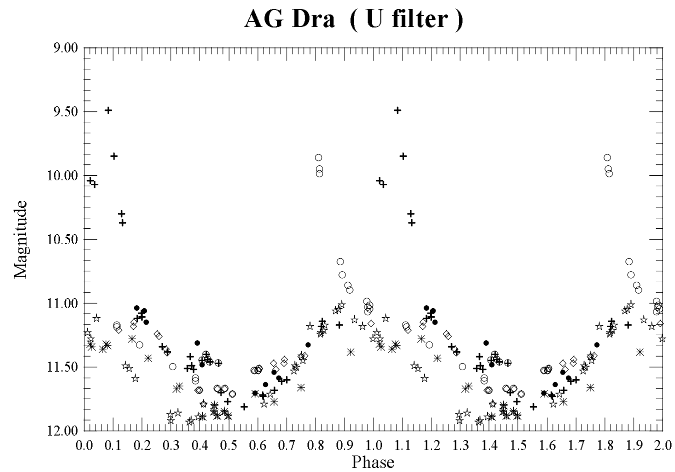

Fig. 4. The phase diagram of the light curve of AG Dra according Meinunger's ephemeris in the U colour.

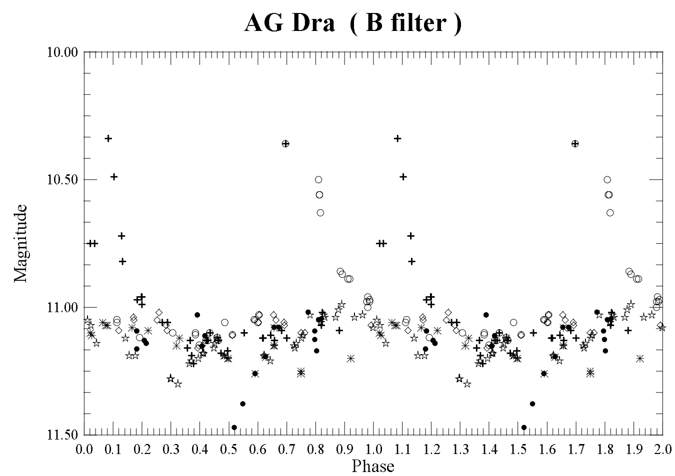

Fig. 5. The phase diagram of the light curve of AG Dra according Meinunger's ephemeris in the B colour.

days) coresponds better to the minima and not very exactly to maxima. In a following step we superposed data in such a way that maxima of each cycle overlap each other. The phase diagrams in U, B and V colours are shown in Figs. 4 - 6, respectively, while overlapped cycles are displayed in Fig. 9 for U band.

We see firstly that variations are especially pronounced in U (the amplitude of 1 mag). The amplitude of all variations (including outburst activity) decreases towards longer wavelengths (see Figs. 1 - 3). Fig. 4 shows that the minima in U appear to be relatively regular during the activity of 1985 - 86. The maxima which differ however to a large extent during activity, still differ somewhat during quiescence. The variations in B and V are small in quiescence, with the amplitudes of 0.3 and 0.2 mags respectively. The latter appear to be fairly well correlated with each other, but much less correlated with the variations in U. At some times one even may have the impression of an anticorrelation.

We have obtained from the period analysis by the phase dispersion minimization method by Stellingwerf (1978) and by Fourier transformation method (Kurtz 1985) new periods of 592 days (7 % longer than the Meinunger period) for U, 356 days for B and 350 days for V respectively for data obtained between outbursts (JD 46910 - 49098). In support of our new periods in B and V bands we show phase diagrams of the light curves with these periods in Figs. 7 and 8. The light variations are much more visible in these diagrams than in the previous ones. We suggest that this result indicate reality of the period around 350 days. The period analysis in the U colour involving only 4 maxima in quiescence may be affected by the postoutburst activity of this star as well as by the lack of exact periodicity found by us. Therefore we doubt the significance of the difference between our value for the period and the orbital one. We detect an absolutely new period around 350 days in the B and V bands, which we might connect with a mechanism in the vicinity of the cool component or in its atmosphere. What is particularly noticeable is that the shorter period is quite close to the interval between the 2 peaks observed by us in activity, which is also near 350 days in B and V.

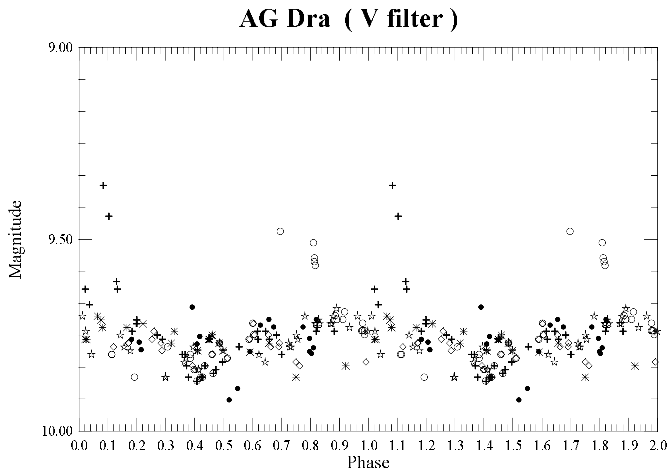

Fig. 6. The phase diagram of the light curve of AG Dra according Meinunger's ephemeris in the V colour.

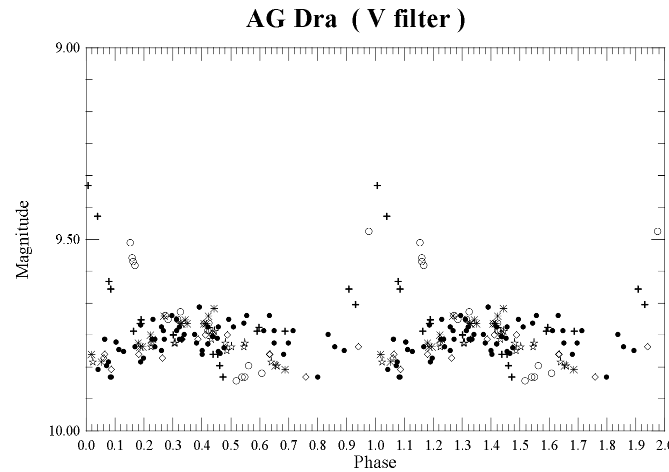

Fig. 8. The phase diagram of the light curve of AG Dra with 350 days period in the V colour.

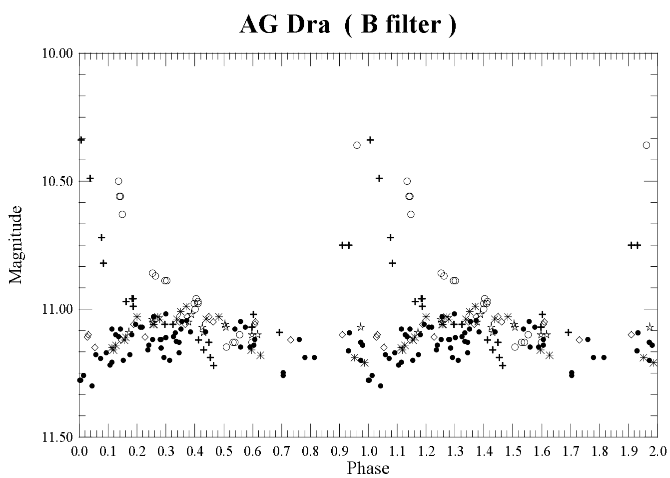

Fig. 7. The phase diagram of the light curve of AG Dra with 356 days period in the B colour.

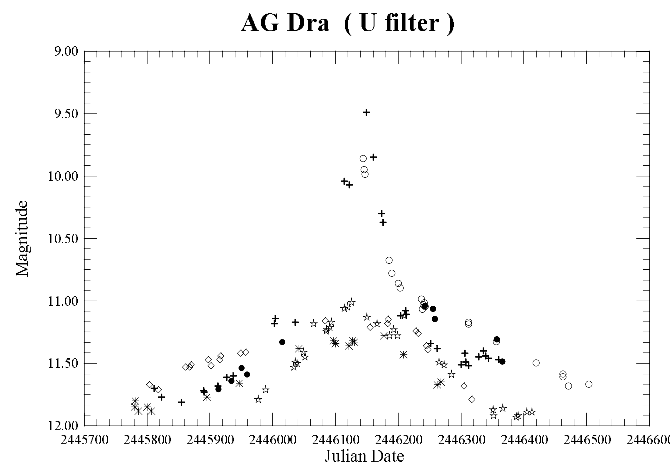

Fig. 9. The overlap cycles of light variation of AG Dra in U are presented for better separation of each cycle from the others.

3. Interpretation

Among the features which need interpretation, we may mention the lack of exact periodicity in the U variations, the apparently different nature of the variations in B and V, as well as the presence of an additional period to the orbital one of Meinunger, detected in B and V and perhaps also in the interval between the two light peaks seen during activity.

If we investigate the cause of variations in U, we can firstly note that the contribution of the radiation due to the hot compact component of the binary should be not more than about 10 % in the U band (0.1 magnitudes) during quiescence according to the temperatures and radii indicated, by the results of Mikolajewska *et al.* (1995) and of Greiner *et al.* (1997). These results assume that the hot component radiates as a black body. Mikolajewska *et al.* 1995 reached their conclusions by analyzing the ultraviolet spectrum observed with IUE, while Greiner *et al.* 1997 used X-ray observations made by the ROSAT satellite. It seems from these results and from the period analysis that the quiescence variations in U can be explained by varying visibility of an ionized gaseous region, which is in fact the wind from the giant ionized by the hot radiation. This is also indicated by the presence of strong Balmer continuum radiation.

The orbital modulations in the U band are almost certainly not produced by Rayleigh scattering. The log cross section of one hydrogen atom is near -25.9 in the U band according to Nussbaumer *et al.* 1989. For a cool component mass loss rate of $2\text{x}10^{-7}\text{M}_{\odot}.\text{yr}^{-1}$ at a velocity of 30 km.s^{-1} (distance 2.5 kpc) given by Mikolajewska *et al.* 1995, the amount of Rayleigh scattering of the wind is negligible in U.

The changes in the orbital variation in U are probably due to a lack of constancy of the wind from the cool component at least in quiescence, as there is no clear evidence for significant temperature changes of the compact component at such times (Greiner *et al.* 1997). In any case the ROSAT PSPC quiescence intensities observed by these authors at times near that of our photometry were almost constant. Proga *et al.* 1998 suggest the acceleration of ionized regions of the wind from the cool components of symbiotic binaries by thermal pressure of the plasma, which can moreover vary with illumination and small changes in the stellar mass loss rate. In addition wind acretion by the compact component is also unstable in such situations (Ruffert 1996 and Benensohn *et al.* 1997). The changes in the phases and shapes of U maxima, also suggest varying deviations from axial symmetry of the ionized parts of the cool star wind.

The small quiescence variations in B and V are different than those in U. This could suggest the presence of an additional mechanism, perhaps connected with the cool giant, whose radiation becomes more important at longer wavelengths. One possibility is the pulsation of the cool giant, but this is still far from sure. In any case the near equality between this period and the separation of maxima during activity, might suggest a relation between the physical processes of the cool giant and the modulation of activity in active phases.

It clearly turned out that the data must be analyzed separately for the quiescent and the active stages. In any case, we find a striking indication that the 350 days periodicity is connected to the maxima of outbursts during the activity. On the other hand, the 550 days orbital period is very well detected in the overall long-term data with removed outbursts' peaks in all three colours. Such analysis is beyond the scope of this paper and is going to be the subject of our next study.

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