A NON-ECLIPSING BINARY MODEL OF THE SYMBIOTIC STAR AG DRA

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ABSTRACT. The light variation of AG Dra is considered as a result of a variation of free-free emission from a gaseous envelope around the hot component. The emission measure of the envelope at a light maximum is estimated to be about $N_e^2 V = 6.5 \times 10^{59}$ cm^{-3}. The amplitude of the light variation in the U band should be less than 1.4 mag. which is consistent with the observed results. The emission measure of the envelope might vary according to a variation of mass transfer rate in an elliptical binary system.

1. Introduction

AG Dra (BD +67°922) is sometimes called as a yellow symbiotic star, because it has a relatively early type (K 3 ∿ 5 III) cool component (Doroshenko and Nikolov, 1967; Boyarchuk, 1969; Belyakina, 1969; Viotti et al., 1983; etc.). Many works made in the recent years covering the regions from X ray to infrared seem to support a binary model consisting of a K type giant and a hot compact star (Belyakina, 1969; Anderson et al., 1982; Taranova and Yudin, 1982; Kenyon and Webbink, 1984; Viotti et al., 1983; 1984). Meinunger (1979) found out that the luminosity in the U band periodically varies with the following elements,

$$JD \ (Max) = 2438900 + 554 \ (days) \times E.$$

The light curve is different from those of usual eclipsing binaries, namely the light minima are wide and there are significant fluctuations in their depth and phase (Meinunger, 1979; Oliversen and Anderson, 1982). After the large outburst in 1980 - 81 an anticipated light minimum on JD 2445326 and a maximum on JD 2445549 were not detected (Luthardt, 1985), which means that the light variation was strongly disturbed by the outburst. On the other hand, the light variation according to the elements of Meinunger (1979) reappeared in the new quiescent stage in 1983 - 84, that is a light minimum was observed on JD 2445850 (Phase 0.55) and it was again wide (Luthardt, 1985). In this paper a possible model to explain these phenomena is discussed.

481

2. Models

Viotti et al. (1984) proposed an eclipsing binary model and suggested
that the wide light minima may be due to a reflection effect of the radi-
ation from the hot component by the cool component. It seems difficult,
however, to explain the complete disappearance of the periodical light
variation with such models, because eclipsing phenomena are usually de-
tectable also during outburst stages (e.g. those of CI Cyg: Belyakina,
1983). Taranova and Yudin (1982) proposed another model in which the
light variation is due to a variation of free-free (f-f) emission from a
pulsating gaseous envelope around the hot component. Since the envelope
may be disturbed by outbursts, the light variation soon after the out-
burst is in agreement with this model. The reappearance of the same light
variation, however, seems to be inconsistent with this model, because
after the large disturbance very probably a new pulsation will start with
a different mode. It might be possible to overcome these difficulties
with an elliptical binary model, in which the light variation is due to a
variation of f-f emission from a gaseous envelope. The envelope, however,
does not pulsate by itself, but varies according to a variation of mass
transfer in the elliptical binary system. The envelope can be strongly
disturbed by outbursts, but since the physical parameters of the binary
are not changed, the same light variation will start again in the new
quiescent stage.

Viotti et al. (1984) showed that the continuum radiation of AG Dra in
the IUE ultraviolet region consists of two components. The one, which is
dominant in the region $\lambda < 2000$ A, has a steep energy distribution corre-
sponding to a black-body curve whereas the other one shows a rather flat
energy distribution. They suggested that these components may correspond
to the hot compact star and the accretion disk, respectively. It is also
possible, however, to construct a model of AG Dra assuming that the latter
component is due to f-f emission from a gaseous envelope, as follows. The
intensity of the flat component is 1.3×10^{31} erg sec^{-1} A^{-1} at 2860 A
(Viotti et al., 1984), where the distance to AG Dra is 700 pc (Anderson
et al., 1981). The contribution from the hot compact star ($R = 0.02$ R$_\odot$,
T = 150000 K : Iijima, 1987) to the continuum is about 10% of the observed
flux and that from the cool component (K 5 III) is nearly the same. Assum-
ing that 1.1×10^{31} erg sec^{-1} A^{-1} is due to the f-f emission, an emission
measure $N_e^2 V = 6.5 \times 10^{59}$ cm^{-3} is derived (Allen, 1973), where N_e is the
electron number density and V is the volume of the envelope. Since He II
4686 emission line was very strong (Blair et al., 1983), an electron tem-
perature 20000 K is used. The observation of Viotti et al. (1984) was made
at phase 0.96 (June 27, 1980), that is nearly on the phase of the maximum
U luminosity. Lower values will be found in other phases. In the U band
the f-f emission is about 2.6 times as bright as the cool component
(Allen, 1973). Infrared photometries showed that the luminosity of the
cool component is stable (Viotti et al., 1983), therefore the maximum am-
plitude of the light variation in the U band is given as $2.5 \times \log((2.6+1)/1)$
= 1.4 mag., which is consistent with the observed results (Meinunger, 1979;
Oliversen and Anderson, 1982). Further sources of the light variation,
for example eclipsing phenomena, are not necessary. The variation in the
V band should be less that 0.2 mag., which may correspond to the nearly

stable V magnitude (Meinunger, 1979; Luthardt, 1985).

Since we assumed that the intensity of the f-f emission varies according to a variation of mass transfer, the envelope should be included in the Roche lobe of the hot component: $\sim 130\ R_{\odot}$. This radius is derived using the formula of Paczyński (1971) under the assumption that the masses of the primary and the secondary are $4\ M_{\odot}$ and $1\ M_{\odot}$, and the orbital period is 554 days. If the electron density in the envelope is $10^{10} \sim 10^{11}\ cm^{-3}$, which is suggested from the lack of the forbidden lines (Blair et al., 1983), this requested condition is satisfied. In the case of $N_e = 5 \times 10^{10}$ cm^{-3} we have a radius $60\ R_{\odot}$ and a mass $1 \times 10^{-8}\ M_{\odot}$. The mass accretion rate onto the hot component is estimated to be $\sim 10^{-7}\ M_{\odot}$/year (Iijima, 1986). The mass transfer rate in the binary system seems to be high enough to maintain the envelope.

3. Conclusion

The light variations of AG Dra may be due to a variation of f-f emission from a gaseous envelope. The envelope, however, may not pulsate by itself, but probably varies according to a variation of mass transfer rate in the binary system. The emission measure of the envelope at a light maximum is about $6.5 \times 10^{59}\ cm^{-3}$ and a probable radius and a mass are $60\ R_{\odot}$ and $1 \times 10^{-8}\ M_{\odot}$. The maximum amplitudes of the light variation in the U and the V bands are 1.4 and 0.2 mags., which are consistent with the observed results (Meinunger, 1979; Luthardt, 1985).

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