RAPID MASS ACCRETION IN THE SYMBIOTIC STAR AG DRA

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ABSTRACT. The mass accretion process onto the hot component of AG Dra and its explosive phenomena are discussed. The hot component seems to be a massive white dwarf ($M > 1\ M_\odot$). The mass accretion rate is estimated to be about $10^{-7} M_\odot$/year. Many properties of the explosive phenomena agree with those of mild hydrogen flashes expected from this rapid mass accretion.

1. Introduction

AG Draconis (BD +67°922) is a rather peculiar symbiotic star, because it has high galactic latitude (l = 100°, b = +41°), high negative radial velocity ($\sim$-140 km sec^{-1} of absorption lines : Wilson, 1943; 1945; Roman, 1953; Huang, 1982), and a relatively early type cool component (K3$\sim$5 III : Doroshenko and Nikolov, 1967; Belyakina, 1969; Viotti et al., 1983; etc.). Its spectra in the optical region show strong emission lines of H I, He I, He II and the unidentified bands at λ 6830 and 7088 A, while no nebular emission lines are seen (Iijima et al., 1986). Many works made in the recent years in 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 following elements,

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

Viotti et al. (1984) proposed an eclipsing binary model. On the other hand, Iijima et al. (1986) presented an elliptical binary model in which the light variation is due to a change of mass transfer rate which drives a variation of free-free emission from a gaseous envelope around the hot component. In any case, the photometric period may correspond to the orbital period of the binary system. In this paper the mass accretion process onto the hot component and its explosive phenomena are discussed.

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2. Mass accretion process

Since the orbital period is very long, an accretion disk may not be formed around the hot component. For this reason a model of spherically symmetric mass accretion is considered. It is assumed that the gravitational energy is released only on the surface of the accreting star and that its radiation can be approximated by a single black-body function. In this case the luminosity of the hot component is given as,

$$L_{hot} = 4\pi R^2 \sigma T^4 = G \dot{M} M / R, \qquad (1)$$

where G is the gravitational constant and σ is the Stefan-Boltzmann constant. The temperature of the hot component is

$$T = (G \dot{M} M / (4\pi\sigma R^3))^{1/4}.$$

If we give the mass (M) and the radius (R) in the solar units and the mass accretion rate ($\dot{M}$) in $M_\odot$/year, we have

$$T = 4.32 \times 10^5 \dot{M}^{1/4} M^{1/4} R^{-3/4} \quad \text{(degree)}. \qquad (2)$$

The temperature of the hot component of AG Dra in the quiescent stage is about 150000 K which is derived from the intensities of He II 4686 and He I 4471 relative to H_β obtained on August 5, 1980 (Blair et al., 1983) using the formula of Iijima (1982). The luminosity of the hot component in the ultraviolet region at nearly the same time is 1.9×10^{39} erg cm^{-1} sec^{-1} at λ 1340 A (June 27, 1980: Viotti et al., 1984) and that of the X ray radiation in the range 0.2 - 1.0 keV is $1 \sim 5 \times 10^{32}$ erg sec^{-1} (April 11, 1980: Anderson et al., 1981), where the distance to AG Dra is assumed to be 700 pc (Anderson et al., 1981). Using the ultraviolet luminosity and the temperature, we have a radius of the hot component 0.02 $R_\odot$ (Allen, 1973). Kenyon and Webbink (1984) obtained similar results ($R = 0.014\ R_\odot$ and $T = 166000$ K) in their analysis of the ultraviolet radiation. These results suggest that the hot component is very likely a white dwarf. The expected X ray radiation in the range 0.2 - 1.0 keV is 1.0×10^{32} erg sec^{-1} (Allen, 1973) which well agrees with the observed value.

Substituting the radius 0.02 $R_\odot$ and the temperature 150000 K in equation 2, we have

$$\dot{M} = 1.1 \times 10^{-7} / M. \qquad (3)$$

Since the mass of white dwarfs is of the order of 1 $M_\odot$, the mass accretion rate onto the hot component is about 10^{-7} $M_\odot$/year. This accretion rate is much higher than the mass loss rate from a K type giant (Reimers, 1978). Possibly the cool component of AG Dra has an extended atmosphere which fills its Roche lobe ($R \sim 240\ R_\odot$, where $M_1 = 4\ M_\odot$, $M_2 = 1\ M_\odot$ and $P = 554$ days: Paczyński, 1971). If the mass accretion is not spherically symmetric, still higher accretion rate is required.

3. Explosions

Figure 1 shows the light variation of AG Dra since 1920 (Robinson, 1969; Belyakina, 1969; Burchi, 1980; Taranova and Yudin, 1982; Wenzel, 1985; Iijima et al., 1986). Results of the photoelectric photometries are plotted after the conversion to photographic magnitudes. As seen in Fig. 1, AG Dra has become active with an interval of about 15 years since 1930. This interval roughly corresponds to ten cycles of the period of Meinunger (1979). I tentatively propose the following elements,

$$\text{JD (active)} = 2422660 + 5540 \times E \text{ (days)},$$

and the positions of phase zero are indicated by an arrow in Fig. 1. All points with $m_{pg} < 10$, except only one at JD 2426756.7, are included in the phase 0.0 ± 0.1. Such a periodical variation was not seen before 1930 (Robinson, 1969) and smaller outbursts have been observed also on other phases.

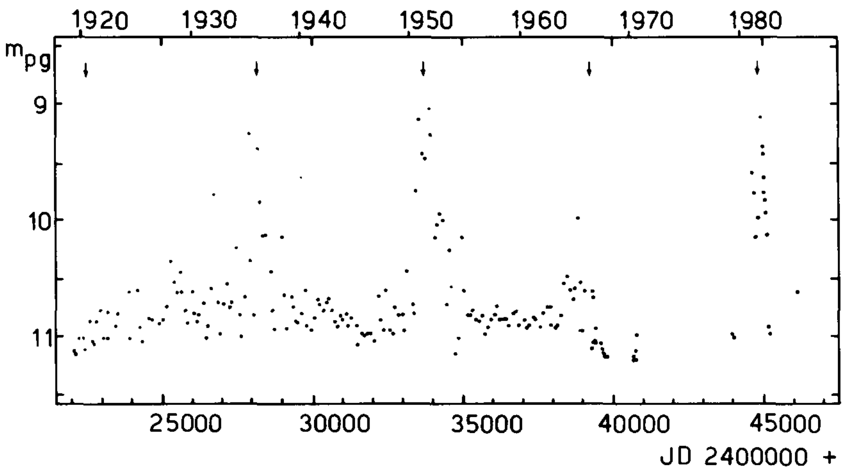

Fig. 1. Photographic magnitudes of AG Dra since 1920. Arrows indicate the phase of explosions (see text)

Many properties of the explosive phenomena of AG Dra seems to be explained with a model of mild hydrogen flashes on a massive white dwarf with rapid mass accretion. The sequence "A" of the model of Sion et al. (1979), where $M = 1.2\ M_{\odot}$ and $\dot{M} = 1.03 \times 10^{-7}\ M_{\odot}$/year, seems to well represent the explosive phenomena. Equation 3 gives a similar mass accretion rate $0.9 \times 10^{-7}\ M_{\odot}$/year in the case of $M = 1.2\ M_{\odot}$. The interval of the hydrogen flashes in their model is 17 years which agrees with that of the active stages of AG Dra. Sion et al. (1979) showed that significant mass loss does not occur on the hydrogen flashes. This is consistent with the lack of nebular emission lines (Iijima et al., 1986). On the other hand, there exist also some disagreements between the model (Sion et al., 1979) and the explosive phenomena of AG Dra. The luminosity of the hot component on the explosion in 1980 – 81 is $\log(L/L_{\odot}) = 3.3$ which is derived using the ultraviolet luminosity 2.4×10^{40} erg cm^{-1} sec^{-1} at λ 1340 A (Jan. 8, 1981: Viotti et al., 1984) and the intensities of He II 4686 and He I 4471 (Feb. 5, 1981: Blair et al., 1983) which give a temperature 160000 K. This luminosity is about one order of magnitude lower than that of the hydrogen flashes (Sion et al., 1979). The radius of the hot component (0.02 $R_\odot$) is larger than usual radii of massive white dwarfs. In the model one hydrogen flash occurs in each period; while two or more outbursts have been observed in one active stage of AG Dra (Robinson, 1969; Viotti et al., 1984). Weak outbursts have occurred with shorter time scale (Robinson, 1969; Luthardt, 1985). The large radius of the hot component may be an effect of a shell of accreted matter on the white dwarf. The other disagreements remain as open questions. Further works are waited.

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