SYMBIOTIC STAR AG PEGASI - RETROSPECT AND PROSPECTS

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Symbiotic star AG Peg (HD 207757), which is still declining from the outburst in the last century, appears to be related to the very slow RT Serpentis type novae: binary stars consisting of a cool M giant and a hot component, which underwent outburst.

1. PHOTOMETRY

AG Peg was ninth magnitude star before the year 1850. Then it slowly rised in brightness and reached fifth magnitude in 1885. After the sudden drop of brightness in 1892 due to the dust formation in expanding envelope, the star returned to the sixth magnitude and then it was continuously decreasing in brightness (Lundmark, 1921; Rigollet, 1947; Belyakina, 1968). Nowadays the decrease of brightness is 0.021 mag/yr (Fernie, 1985).

Belyakina (1968) found 0.3 mag variations in brightness. The variations follow the 800 days spectroscopic (orbital) period discovered by Merrill (1929). Belyakina (1970) showed that the variations of brightness could be caused by the reflection effect: ultraviolet radiation of the hot component heats up the facing hemisphere of the cool component. Hutchings et al. (1975) suggested that the hot component rotates rapidly and ejects material which streams toward the cool component. A bright region on the M star responsible for 0.3 mag light variation is heated by collisions from the impinging stream. Many authors tried to improve the period: P = 827 days (Meinunger, 1981), P = 820 days (Belyakina, 1985), P = 816.5 days (Fernie, 1985), P = 813 days (Paul and Luthardt, 1987).

Infrared photometry shows that AG Peg contains a normal M giant without any evidences of variability. AG Peg lies near the locus of non-variable M giants in (J-K), (K-L) diagram (Feast et al. 1983).

Ultraviolet broad band photometry on the Orbiting As-

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tronomical Observatory 2 showed that the hot component is luminous UV source (Gallagher et al. 1979).

2. SPECTROSCOPY

Since Mrs. Fleming´s discovery of emission hydrogen lines in the spectrum of AG Peg taken at Harvard College Observatory in 1893 the spectroscopic behaviour of AG Peg has been progressively more complex. On the first spectra AG Peg resembled a peculiar Be star with P Cygni profiles of hydrogen and faint emission lines of singly ionized metals. In 1915 He I appeared in absorption (Merrill, 1916), in 1920 He I went from absorption to emission. The TiO bands belonging to the cool component appeared in 1920 and became more conspicuous as a blue continuum faded. From the begining of 1922 the spectrum has been gradually developing features characteristic of symbiotic stars evolving to Wolf-Rayet type. In 1931 He II emission appeared and the level of ionization represented by emission lines continuously increased (Merril 1929, 1932, 1942, 1951a, 1959). The narrow absorption lines of the M giant have been gradually emerging and from 1943 many of them could be accurately measured to obtain radial velocity curve of the M giant. By about 1950 P Cygni profiles vanished from hydrogen lines. In 1960s N V lines were detected.

Merrill in many papers pointed out that emission lines exhibited variations both in radial velocities and intensities with 800 days period, but relative phasing of different lines did not coincide. In 1920s He I lines were $\approx$ 160 days out of phase with H I lines, in 1950s the lines nearly coincided. The mean velocity derived from hydrogen lines decreased from + 16 km/s in 1915 to - 27 km/s in 1952. Merrill (1951 b) found that He I 3888 A exhibits multiple absorption components with velocities from - 56 km/s to - 428 km/s. Kolotilov (1975) found absorption component in the line He I 10830 A at velocity - 460 km/s.

Periodic radial velocity variations of narrow absorption lines of M giant were used for determination of spectroscopic orbit. The spectroscopic elements determined by different authors are in Table I. Assuming reasonable estimate of orbital inclination ($40° < i < 60°$) and cool star mass 3-4 $M_\odot$ the f(m) derived by Hutchings et al. (1975) yields the mass $\approx$ 1 $M_\odot$ for the hot component.

AG Peg is the brightest symbiotic star in UV region with well developed UV continuum and bright emission lines. Broad lines with P Cygni profile resemble a Wolf-Rayet wind. They arise close to the hot component. Narrow semi-forbidden emission lines are formed near the cool M giant. UV spectra are discussed in the papers: Keyes and Plavec (1980 a,b), Slovak (1982), Penston and Allen (1985) and in the work Chochol et al. (1987a) in this book.

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TABLE I

	Cowley and Stencel (1973)	Hutchings et al. (1975)	Slovak (1987)	Garcia and Kenyon (1987)
P (days)	830	820	818.7	796
K_1 (km/s)	5.6	5.5	4.85	6.4
γ (km/s)	-16.8	-16.3	-16.23	-14
e	0.25	0.23	0.235	-
ω	251°	222°	154°	-
T_o (JD)	2439045	2440928	2444514.6	-
f (m)	0.014 $M_\odot$	0.013 $M_\odot$	0.009 $M_\odot$	0.022 $M_\odot$

Spectrophotometric investigation of AG Peg made by Boyarchuk (1966) showed that the hot component is a WN6 type star, the cool one M3 III star. Gaseous clouds, which surrounds the system have T_e = 17 000 K, $n_e = 7x10^6$ cm^{-3}, R ≈ 10^5 $R_\odot$ and mass M ≈ 0.001 $M_\odot$. Keyes and Plavec (1980 a, b) classified the cool component as M1.7 III star with an effective temperature 3570 K. A distance of 500 pc and a radius of cool component 56 $R_\odot$ were derived supposing the luminosity class III. UV continuum could be fitted by a model of stellar atmosphere with T_{eff} = 30 000 K and log g = 4.5 (reddening E_{B-V} = 0.12) or 100 000 K black body with superimposed Balmer continuum. Kenyon and Webbink (1984) showed that UV colour-colour diagnostic indicated a hot stellar source with T_{eff} = 57 500 K (reddening E_{B-V} = 0.15). Kenyon and Fernandez-Castro (1987) classified the cool component from TiO and VO indices as M3.0 ± 0.4 III star.

3. RADIO OBSERVATIONS

AG Peg was one of the first symbiotic stars detected in the radio. VLA observations show three sources of radio emission: a nebular sphere with a diameter of 1".5, that has had an average expansion velocity of 15 km/s since about 1850 when ejection began, a point source, and a condensation of material inside the large nebula (Hjellming, 1985).

4. BINARY MODELS

There is no doubt that AG Peg is interacting binary. According to generally accepted models the cool star loses the matter by Roche lobe overflow or by stellar wind and this material is accreted onto main sequence star or white dwarf. The cool star in AG Peg is substantially smaller than corresponding Roche lobe radius (285 $R_\odot$ according to Hutchings et al. 1975), so that cool M giant can lose the matter only by stellar wind. The wind could be accreted on a cool white dwarf. Outburst observed in the last century could be explained by a degenerate flash, which led to an expansion to A-F supergiant (Kenyon and Truran, 1983). Described spectroscopic and photometric development after the outburst is in agreement with the model.

Hutchings et al. (1975) surprisingly found that the matter in AG Peg is transferred from the hot rapidly rotating component towards the cool one. They left the puzzle of the origin of the outburst a century ago. Penston and Allen (1985) tried to explain this puzzle in the frame of thermonuclear event model. The hot component loses the mass by the high velocity wind. The ionization of the hot component extends close to the surface of M giant and there gives rise to the lower-velocity emission. Ablation tail of this emission gives the illusion of a stream of gas flowing from the hot component to the cool one.

Chochol et al. (1987ab) showed that UV observations could be explained in agreement with Hutchings et al.(1975) model. The model seems to be supported also by the computation of spectroscopic orbit for the cool component for periods 813 - 827 days using the RV data published by Cowley and Stencel (1973) and Hutchings et al. (1975). The photometric minimum does not occur in spectroscopic conjuction but precedes the conjuction from 0.03 (period 813 days) to 0.09 (period 827 days) of the period (from 25 to 75 days) indicating the presence of a bright spot on M giant due to the collision of the stream from the hot component with M giant.

AG Peg is still declining from the outburst in last century. The conservation of angular momentum when the star shrinks could lead to the rotational shedding of mass. An envelope of hot star could be transferred to the cool one. As it was shown by Kříž (1982) the star rotating at the critical velocity forms the inner excretion disk which encircling the star. Excretion disk takes away the mass, the angular momentum and the rotational energy from the central star. The disk could extend to the corresponding Roche-lobe, where the transported matter overflows to the companion. In AG Peg the inner excretion disk is supported not only centrifugally but also by the wind from the cool component. Some kinds of disk instabilities could cause the outburst in last century. From evolutionary point of view the hot component of AG Peg could be a helium subdwarf in "post case B" of mass transfer.

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