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PERIOD ANALYSIS OF RADIAL VELOCITY OF PLEIONE

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RESUMEN

A partir de 363 medidas de velocidad radial de líneas de envolventes en espectros de Pleione entre 1938 y 1988, se demuestra que esta estrella es un sistema binario con un período de 218.0 d, cuya órbita tiene una excentricidad de 0.60. Se discute la naturaleza de la secundaria y el origen de la envoltura circunestelar.

ABSTRACT

From 363 averaged RVs of shell lines measured on spectra of Pleione between 1938 and 1988, we demonstrate that this star is a binary system with a period of 218.0d, whose orbit has an eccentricity of 0.60. We discuss the nature of the secondary and the origin of the circumstellar shell.

Key words: **BINARIES: SPECTROSCOPIC — CIRCUMSTELLAR MATTER — STARS: EMISSION LINE: Be — STARS: INDIVIDUAL (PLEIONE)**

1. INTRODUCTION AND OBSERVATIONAL DATA

The Be-shell star Pleione (28 Tau, B8Vpe) has shown a first shell phase in 1938–54, an emission phase in 1954–72, then a second shell phase in 1972–88 (Hirata 1995). Since 1988, a new and strong emission phase is developing on H, Fe II and Cr II lines, which results from the expansion of the circumstellar shell, with a tendency to become more spherical (Ballereau et al. 1994). We describe here the results of period analysis of radial velocities (RVs) of shell lines during each and both shell episodes. The material from which the RVs of shell lines (Fe II, Ti II, Cr II, Fe I, H I) were obtained is composed of high/medium dispersion photographic spectrograms taken in Japan (131 spectra) and France (25 spectra). To our sample we added RVs collected from the literature, dealing with both shell episodes. In all, we gathered 363 averaged RVs over 15389 days.

2. PERIOD ANALYSIS AND ORBITAL ELEMENTS

Figures 1a and 1b show the overall variation of the mean RVs for the two shell phases. They display a gradual decrease, which begins in the mid epoch of each phase. Three methods for period analysis were adopted: Stellingwerf's (1978) PDM, the CLEAN algorithm (Roberts et al. 1987) and dispersion through a least-squares fitting to a sine function (LSQ). Figure 2 shows our results for both shell phases, and consists of the Θ-statistic diagram from PDM, the power spectrum from CLEAN, and the window function, from top to bottom (abscissa is in d^{-1}). A dominant peak at 218d appears in PDM and CLEAN, which allows us to conclude that Pleione has a 218d period in the RVs of its shell lines. An estimation of error in the value of the period leads to P=218.0±0.5d. Table 1 gives the orbital elements derived from the individual data sets, and from the combination of both. The observed and calculated velocity curves are shown in Figure 3. We see that no noticeable difference is observed between the two shell phases.

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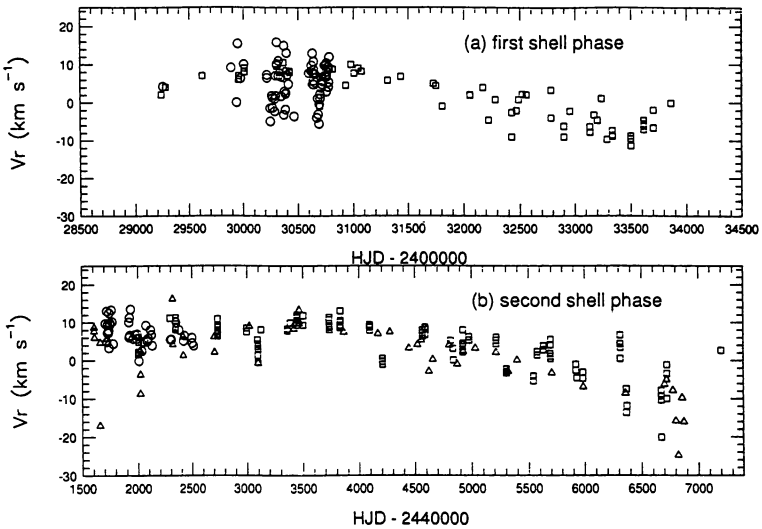

Fig. 1. Overall variation of radial velocity in the first shell phase (a) and the second shell phase (b) of Pleione.

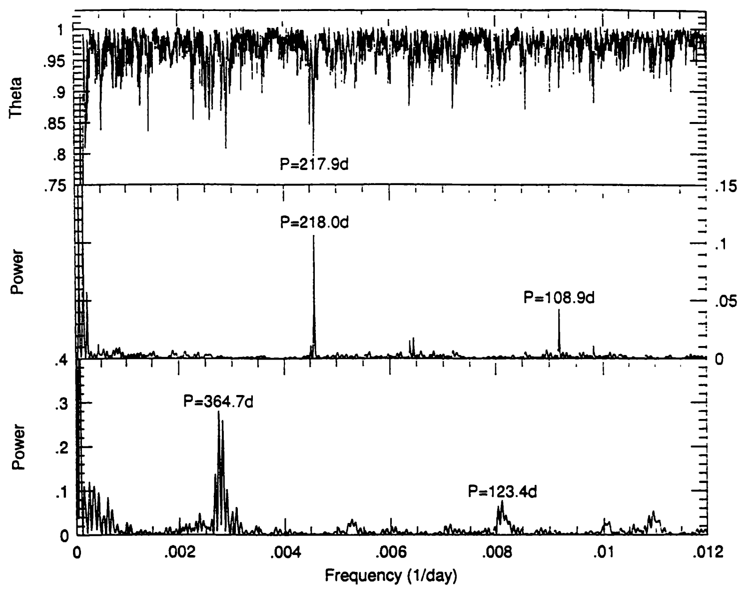

Fig. 2. Result of period analysis, by combining the data of the first and the second shell phases.

TABLE 1

ORBITAL ELEMENTS

Shell phase	n	e	K_1 km s^{-1}	ω (^{0})	γ km s^{-1}	$\Delta\phi$
1st and 2nd	363	0.60±0.04	5.9±0.4	149±5	−0.3±0.2	0.06±0.01
1st	141	0.59±0.07	5.5±0.5	158±9	−0.2±0.3	0.04±0.02
2nd	222	0.65±0.09	7.0±0.9	151±7	−0.5±0.3	0.06±0.01

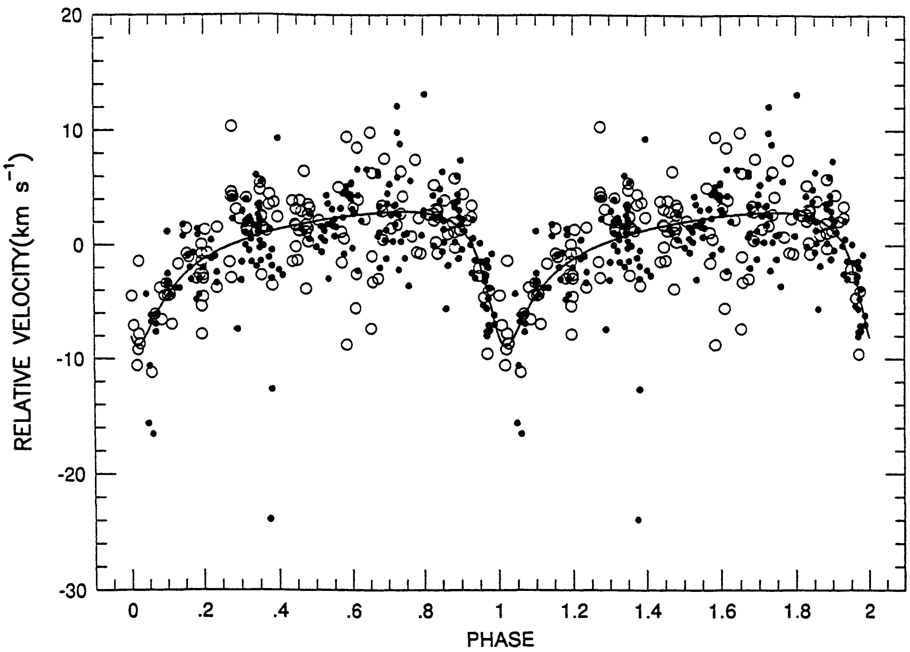

Fig. 3. Resulting velocity curve, with data of the first shell phase (open circles) and the second shell phase (filled circles). The best-fit curve is shown with the following parameters : $K_1 = 5.9$ km s^{-1}, e = 0.60, ω = 149° and P = 218.0 d.

3. CANDIDATE FOR THE SECONDARY STAR

Because the secondary of Pleione is not observable, and the system is known as a soft X-ray source (Stauffer et al. 1994), we will discuss its nature from the point of view of binary evolution scenarios.

a) Possibility of a Roche-lobe filling secondary in the mass transfer stage:

The Roche-lobe overflow should occur at the periastron passage (high eccentricity). However, we did not find spectroscopic evidence for mass flow in our material, and thus conclude that the secondary of Pleione does not fill its Roche lobe and does not supply mass to the primary.

b) Possibility of a neutron star or a black hole:

We exclude this hypothesis due to the lack of hard X-ray emission.

c) Possibility that the secondary is a low- mass dwarf:

We conclude that this is the most probable case, though we cannot exclude the possibility that the secondary is a helium star or a white dwarf.

We may ask which star supplies mass to the disk surrounding the B8 primary. It is not a later-type dwarf, since it has no strong wind and does not fill its Roche lobe; it is not a helium star because the wind from such a star is spherical, and the capture rate in the case of Pleione is too small ($10^{-4} - 10^{-5}$) to explain the mass accumulation rate in the envelope of Pleione calculated by Hirata et al. (1982) for the second shell phase ($10^{-10} M_\odot$). The circumstellar gas around the B8 primary thus seems to be supplied by the primary itself.

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