APSIDAL MOTION IN MAIN-SEQUENCE BINARY STARS

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1. INTRODUCTION

Early studies of apsidal motion in binary stars showed a marked discrepancy between observational results and theoretical expectation (Schwarzschild, 1958; Kopal, 1965). Improvements in theory (Petty, 1973; Odell, 1974; Stothers, 1974) have led to much closer agreement. However, recent observational results (Giménez & García-Pelayo, 1982; Monet, 1980) have provided much more data with which to test theoretical results.

A number of evolutionary sequences for main-sequence stars have been computed, in which the apsidal motion constant k_2 has been obtained for each stellar model. These evolutionary sequences show good agreement with observed apsidal motion in intermediate mass main-sequence binary pairs and confirmation of some of the observations of k_2 by Giménez et al (1982). If the success of the theory is accepted, Monet's (1980) method for testing stellar models with observations of apsidal motion in non-eclipsing systems may be modified to obtain an estimate for the mass and age of a binary system from the observed apsidal motion. Details of these results are reported by Jeffery (1984).

2. THEORETICAL MODELS

The evolution of the internal density distribution of a star depends upon the mass of the star. A comparison with the evolution of the surface gravity provides a comparison with observable quantities (Giménez & García-Pelayo, 1982). The rate of evolution of the apsidal motion constant can be measured by the quantity $\partial \log k / \partial \log g$, which is found to increase with mass. Giménez et al suggested a similar conclusion after comparing their observations with appropriate ZAMS models.

A. Maeder and A. Renzini (eds.), Observational Tests of the Stellar Evolution Theory, 415–417.

For the evolution of a 10.9 $M_\odot$ model, we obtained good detailed agreement with Stothers (1974). This agreement persisted in explaining the observed apsidal motion of Y Cyg, AG Per and CW Cep. However, if models for a star of the appropriate mass ($\sim 4\ M_\odot$) are used, the discrepancy between the observed apsidal motion (Semeniuk, 1967) and the observed stellar radii (Smak, 1967) of CO Lac cannot be resolved.

3. SPECTROSCOPIC SYSTEMS

By rearranging Kopal's (1965) equations, Monet (1980) obtained an approximate equation relating orbital parameters of an apsidal motion system (P, U, e), on one side, to stellar parameters (q, R_i, k_i, M) on the other. By estimating stellar parameters from the stellar spectral type (using Adelman's (1978) effective temperature calibration and Stothers' (1974) stellar models), Monet showed that it is possible to compare observed apsidal motion with theory for a number of non-eclipsing systems. Using a complete set of evolutionary sequences, we find that apsidal motion in main-sequence pairs may usually be accounted for by the evolution of the components.

4. STELLAR MASSES AND AGES

An adaption of this approach requires that theoretical models produce relations of the form

$$S_c = S_c\ (M,\ q,\ t,\ X,\ Z)$$
$$T_c = T_c\ (M,\ t,\ X,\ Z) \qquad (1)$$

where S is a 'structure' parameter and T is the effective temperature, t is age and X, Z represent composition. Meanwhile, observations yield

$$S_o = S_o\ (P,\ U,\ e)$$
$$T_o = T_o\ (Sp) \qquad (2)$$

where Sp is spectral type. Further details may be found in Jeffery (1984). Assuming a composition and mass ratio, q, (1) may be inverted so that the observed quantities yield a mass and age

$$M = M\ (S_o,\ T_o)$$
$$t = t\ (S_o,\ T_o). \qquad (3)$$

Applying this method to eclipsing systems with known masses (Popper, 1980), the 'apsidal motion' masses are in good agreement with the orbital masses (Table 1). This gives confidence in this method as an independent way of estimating masses and ages for binary systems showing apsidal motion.

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TABLE 1

System	Sp	P (days)	U (years)	M (Popper)	M (apsidal motion)
Y Cyg	09.8IV	2.996	54	16.7 (0.5)	17.4 (2.8)
C W Cep	B0.5V	2.729	69	11.8 (0.2)	13.0 (2.1)
α Vir	B1V	4.015	130	10.8 (1.3)	12.9 (2.1)
u Her	B2.5V	2.051	107	7.3 (1.0)	6.90 (1.1)
A G Per	B5pV	2.029	76	4.53 (0.07)	4.44 (0.7)

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