CONSTRAINTS ON THE CESSATION OF ECLIPSES IN SS LACERTAE AND THEIR IMPLICATIONS FOR SYSTEM EVOLUTION[1]

E.F. Milone and C.R. Stagg
RAO, Department of Physics and Astronomy, The University of Calgary, 2500 University Dr., NW, Calgary, Alberta, Canada T2N 1N4

S.J. Schiller
South Dakota State University, Department of Physics, Box 2219, Brookings, South Dakota 57007-0395

ABSTRACT SS Lac, a probable member of the open cluster NGC 7209, and a target system of several apsidal motion programs and of our binaries-in-clusters program for the past decade, is no longer eclipsing. The sudden disappearance of eclipses is now well documented. Zakirov and Azimov (*IBVS* 3487, 1990) and Schiller *et al.* (*BAAS* 23, 879, 1991) announced the current nonexistence of eclipses based on extensive photometry. Photographic and visual observations indicate cessation in the 1950-1951 season. Here we describe recent radial velocity work, modeling of published light curves, plans for further investigation and discuss implications of the cessation for system evolution.

INTRODUCTION

Hoffmeister (1921) discovered the variability of SS Lac and suggested a period of 1.201499^d with a rapid periodic term; however, a different period (14.41629^d) for this eccentric orbit binary was established by Dugan and Wright (1935) and confirmed by Wachmann (1936). Its membership in the open cluster NGC 7209 is attested from proper motion surveys and proximity on the sky. Three separate pm studies (Artiukhina 1961, Lavdovsky 1962, and van Schewick 1966) identify SS Lac as a probable member. SS Lac lies near the blue turn off of the cluster CMD, offering the prospect of determining the cluster turn-off mass and the evolutionary state of the binary components. Dugan and Wright

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(1935) published only a mean pg light curve distilled from 45 years of HCO plates, but noted that the minima were equally deep with the secondary eclipse occurring at $\phi = 0.57^{p}$. Assuming i = 90° they found e = 0.11. They also claimed that a series of 12 plates from one particular night covered the descending branch of PM and suggested a 12^{h} eclipse with totality lasting at least 2^{h}. Wachmann (1936) confirmed the 14^{d} ephemeris from Bergedorf photographic plates. Data of Tashpulatov (1964) also show equal depth and provide the first direct evidence of the cessation of eclipses. The data indicate that, up to Oct. 20, 1949, at least one plate taken during the expected minima showed low light level, while after that date, no low light levels were seen again. His data indicate that the first eclipse following the Oct. 20, 1949 minimum during which an eclipse was not detected was that of Aug. 27, 1951. In the data available to us, there is no obvious indication of a gradual change in amplitude of light variation as asserted by Lehmann (1991).

PHOTOELECTRIC CONFIRMATION

Subsequent independent photoelectric photometry by Schiller & Milone and by Zakirov & Azimov (1990) have consistently failed to show any eclipses. The photoelectric data will be discussed elsewhere in detail, but the phased Schiller-Milone data are shown in Fig. 1. As a check on the correct identification, the chart given by Wright (1937) was compared to HCO plates on which the variation is seen (Hazen 1990 -*private communication*). The cessation in eclipses is both real and total.

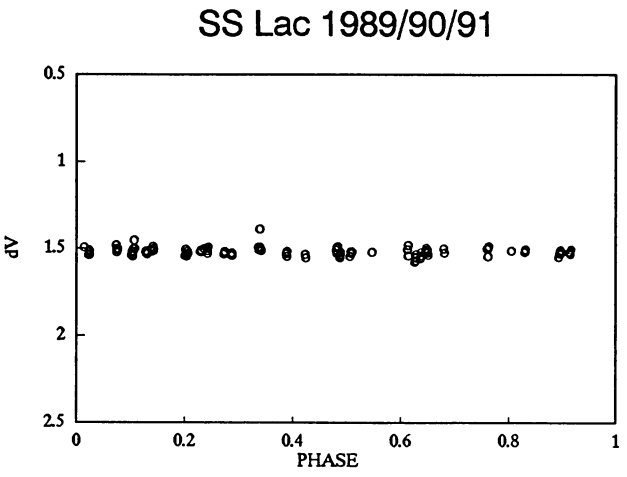

Fig. 1. Differential V data of SS Lac from the *RADS* photometer, *RAO*, 1989-91.

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RADIAL VELOCITY DATA

The observed light curve change suggests an alteration in orbital parameters. In support of our binaries-in-cluster program, photographic, reticon, and most recently, CCD spectra at 15 and 30 Å/mm were obtained at *DAO*, Victoria, B.C. beginning with the 1983-4 season. All of the photographic and much of the reticon data have been reduced, with the help of Hill's (1982) software packages REDUCE and VCROSS. The cross-correlations were performed with the spectrum of A3V star HD 27962, the radial velocity of which is given by Wilson (1963) as 34.7 ± 0.5 km/s. The results indicate no significant variation within the uncertainty of a single RV measurement of SS Lac, estimated to be ±15 km/s.

CONSTRAINTS

If the Dugan & Wright ephemeris was correct, the case appears convincing that the system has ceased to be eclipsing. A nagging doubt comes from two times of minima in Hoffmeister's list and one of Tashpulatov (1964) which have residuals of order 1^d. However, Hoffmeister's period did not satisfy the minima of Dugan and Wright, and the longer period was confirmed by Wachmann's independent data and analysis.

There is no evidence of a change in brightness of the system. A search for evidence of third light in the light curves of Dugan and Wright, Wachmann, and of Tashpulatov, has been undertaken but has thus far proven inconclusive. However on the basis of published light curves, we have digitized their data and carried out analyses with our version of the Wilson-Devinney program with simplex enhancement (Milone *et al.* 1992; Kallrath *et al.* 1992) to study model uniqueness. The results, seen in Table I, effectively confirm the conclusions of Dugan and Wright based presumably on their detailed data list.

This leads us to conclude that eclipse conditions have changed radically. While several possibilities come to mind, the relative constancy in radial velocity precludes an *astrophysical* explanation, *viz.*, a sudden change in the radius of one of the components, alone. More likely explanations involve changes in period, apsidal motion, or inclination. Such changes would need to be brought about through collisions with another cluster member, or, more likely, a wide binary.

The distance of NGC 7209 is ~900 pcs so that any transverse motion would be difficult to detect over intervals of decades. In two years a relative transverse motion of 10 km/s would result in a traversal of ~2 au or ~2 x 10^{-3} arc sec. However, the separation of the formerly eclipsing pair is ~0.2 au, assuming masses appropriate to B9 dwarfs, *viz.*, 2.75 $M_\odot$. Therefore an interaction over a timescale of a few orbital revolutions is reasonable. Although we have no strong evidence of third light in our analyses, it would be instructive to examine the system

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with speckle interferometry to further set constraints on the separation of system components, and to use high resolution spectroscopy to further constrain radial velocity variation. To improve upon the light curve analyses, a study of Harvard plate material is planned (the Dugan & Wright measurements are apparently unarchived and only covered to 1935). Finally, we continue photoelectric monitoring. This work was supported by a *Research Corporation* grant to SJS and and by *NSERC* of Canada to EFM. P. Griffin, J. McVean. P. Radao obtained the recent *RAO* pep data and B.J. Sugars carried out the simplex modeling work.

TABLE I Preliminary Model Parameters

parameter	star 1	system	star 2	units
a*		0.205		au
e		0.12 ± 0.01		
i		87.4 ± 0.2		deg
ω		11.0 ± 0.2		
q*		1.0		
Ω	13.4 ± 0.9		13.1 ± 0.7	
T	10351*		10351 ± 119	K
L (pg)	6.19 ± 0.65		6.44	4π
x*	0.475		0.475	
σ (mse)†		0.021		

* fixed and unadjusted † all other errors are p.e.

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