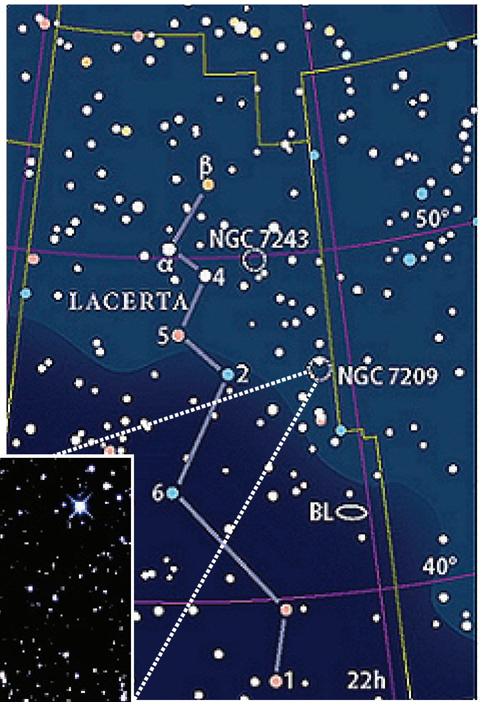
SS Lacertae: The non-eclipsing eclipsing binary

Among the brighter members of the open cluster NGC 7209, SS Lacertae has gained considerable attention during the past decades due to its extraordinary behavior, not typical of eclipsing systems: the complete cessation of eclipses in the middle of the twentieth century. SS Lac belongs to a small class of triple systems in which changes due to dynamical effects can be seen over a single human lifetime.

The discovery of variability of SS Lacertae is attributed to Henrietta Leavitt by Pickering (1907). The first light curve was published by Hoffmeister (1921) and was based on visual observations made from 1915 to 1918. Knowledge about the light variations of the SS Lacertae system, when it was still an eclipsing binary, comes entirely from visual and photographic measurements that go back more than a century but are, unfortunately, of rather poor quality.

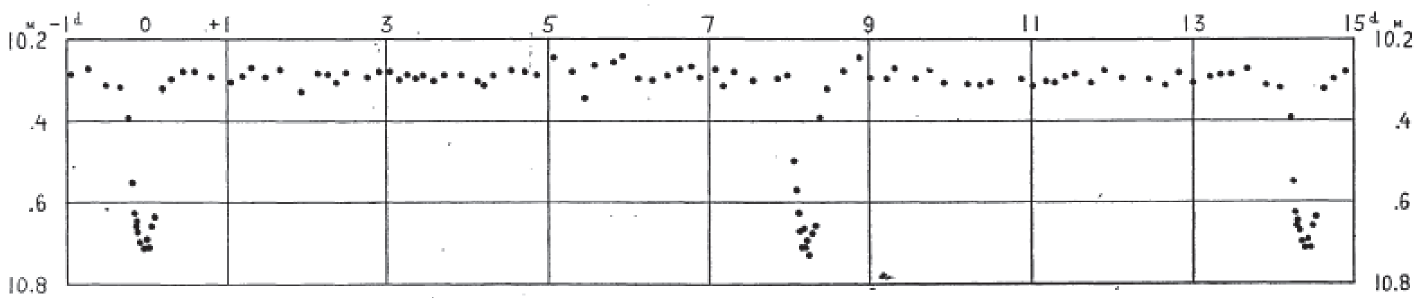
One of the most important early photographic light curves of SS Lac was published by Dugan and Wright in 1935, distinguishing SS Lacertae as an eclipsing system with a period of 14.4 days. Measurements were based on the data from plates obtained at the Harvard College Observatory. Eclipses were observed photographically and visually early in the 20th century, but stopped some 60 or 70 years ago.

The orbit of SS Lac is clearly eccentric (e=0.11; Zakirov & Azimov, 1990), as shown by the displacement of the secondary eclipse: eclipses were of equal depth with the secondary eclipse occurring at a phase of 0.57 (Schiller et al., 1991).



Open cluster NGC 7209 lies in Lacerta. It is well-detached from the backround sky in a field spanning the apparent diameter of the full Moon. SS Lacertae is marked with a white arrow on the left image.

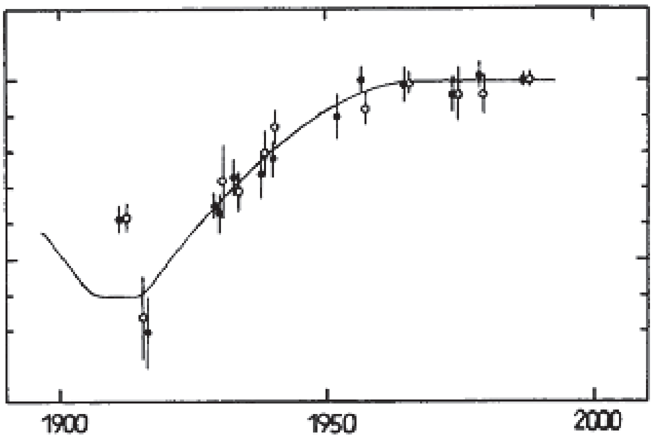
A number of scenarios have been proposed to explain this phenomenon. The cessation of eclipses in a binary star is a rare phenomenon that can most often be explained by the presence of a third object in the system inducing perturbations in the orbital elements of the inner pair (Torres, 2001). Lehmann (1991) re-measured original plates material from the Sonneberg Observatory (1890-1989), presenting the first evidence that the depth of the eclipses had changed over the years. He proposed a hypothesis that visible cessation of eclipses is due to the presence of an unseen third star in the system, which is gradually changing the inclination angle of the inner pair. It is not clear, however, whether the cessation of eclipses in SS Lac was gradual, as asserted by Lehmann (1991), or whether it happened suddenly (see Milone et al. 1992).



Mean photographic light curve of SS Lacertae showing a 14.4-days period. The average photographic magnitude at normal brightness is 10.28, and 10.69 in minimum (historic chart from Dugan & Wright,1935)

Higher resolution spectroscopic observations made by Etzel, Volgenau, & Nguyen (1996) did show double lines in the spectra, and this was immediately confirmed by Stefanik et al. (1996) and Etzel & Volgenau (1996). A double-lined spectroscopic orbit for SS Lacertae was published by Tomasella & Munari (1998) showing that the binary was intact and that the period had not changed significantly. This left little doubt that the reason the system is no longer eclipsing is a change in the orientation of the orbit, most likely brought about by the presence of a third star in the system. (Torres & Stefanik, 2000).

Adding to its interest, SS Lac is a member of the open cluster NGC 7209, and therefore other information such as estimates of the age, distance, and metal abundance is available. Proper-motion studies of SS Lac have shown that it shares the mean motion of NGC 7209 on the plane of the sky. The probability of membership, according to Platais (1991), is 97%.



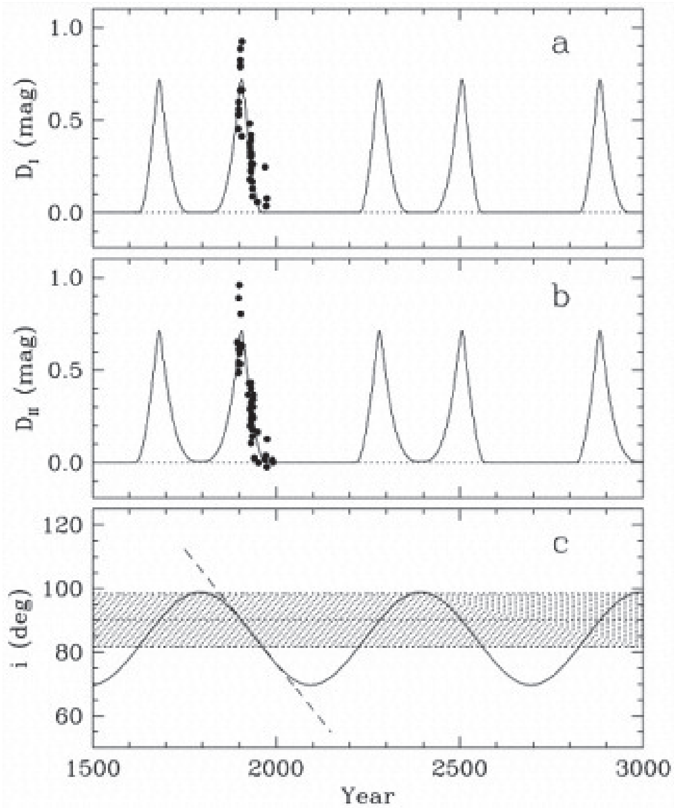
Right: The disappearance of the eclipsing amplitude of SS Lacertae. Filled circles represent primary minima, while open circles correspond to secondary minima. The graph is from (Lehmann, 1991; IBVS 3610)

Remeasured Harvard plates data and other available published data sets revealed that the depth of the primary minimum increased between the 1890s and early 1900s and decreased in the 1920s and 1930s. According to this data, the largest eclipse amplitude was around 1911 (Milone et al., 2000).

From photographic archive examination, Mossakovskaya (1993) concluded that the cessation of eclipses in SS Lac had occurred between the mid-1930s and the 1940s, although a limit in the 1950s was suggested initially by Zakirov & Azimov (1990). Twelve spectra obtained during 1982-1984 revealed only single lines and no detectable radial-velocity variation.

Few examples of this phenomenon are known, among them are:

- *AY Mus* (Soderhjelm, 1974)
- *IU Aur* (Harries, Hilditch, & Hill, 1998; Schiller, 1981)
- *RW Per* (Schaefer & Fried, 1991)
- *V907 Sco* (Lacy, Helt & Vaz, 1999)

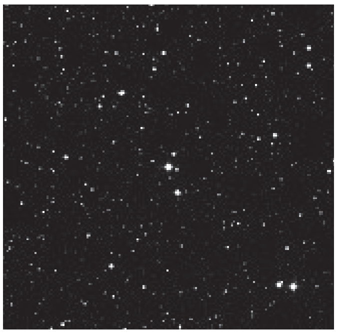


Long-term behavior of the eclipse amplitudes for the primary (a) and secondary (b) minima, resulting from the fit to the measurements based on the regression of the nodes effect. The cycle repeats with a period Pnode = 600 yr (see text). Panel (c) displays the expected behavior of the inclination angle according to this model. The shaded area represents the range in which eclipses are possible (Torres, 2001)

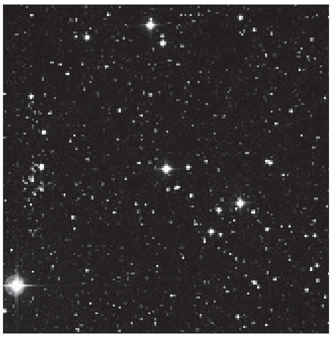
On 1996 July 1.47 UT, spectroscopic observations provided a velocity difference of 174 km/s between the components, corresponding to orbital phase 0.78 from the eclipse ephemeris of Dugan and Wright (1935). That confirmed past assumptions: SS Lac was still a binary system. (Etzel et al., 1996; IAUC, 6429, 2)

The most difficult problem faced by all researchers attempting to fit the light curves of SS Lac has been the fact that the inclination angle of the binary changes with time. Further extensive spectroscopic observations were presented by Torres & Stefanik (2000), which demonstrated the existence of a third body.

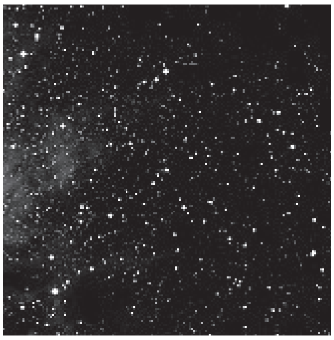
Torres & Stefanik determined the orbital elements of the distant third object, with a period of about 679 days and a slightly eccentric orbit. They also detected apsidal motion for the first time for the SS Lac system. The nodal cycle is found to be 600 yr, within which two eclipse "seasons" occur, each lasting about 100 yr. The non-eclipsing status of the system is expected to continue, no further eclipses are expected until shortly after the year 2200, if the present model of orbital motions in the SS Lac system is correct (Torres, 2001). Clearly, if SS Lacertae was an eclipsing binary, the dynamical nature of this system has changed dramatically.



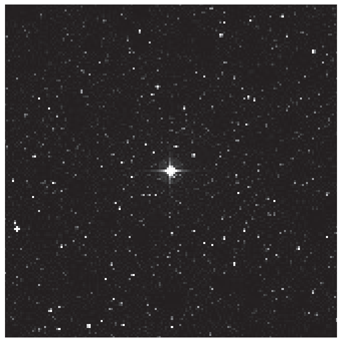
RW Per



IU Aur



V699 Cyg



AH Cep

Known eclipsing systems with an observed or possible cessation of eclipses, or with changing minima depths (upper: 15 arc mins DSS field of view)

Object Designation	RA (J2000)	DEC (J2000)	Period	Mag. Range	Reference
RW Persei	04 20 16.8	+42 18 52	13.198904	9.68 - 11.36 V	Olson et al., 1992; AJ, 103, 256
IU Aurigae	05 27 52.4	+34 46 58	1.81147536	8.19 - 8.83 V	Özdemir et al., 2003; A&A, 403, 675
SV Gemini	06 00 41.0	+24 28 26	4.0061216	10.55 – 10.62 V	Guilbault et al., 2001; IBVS, 5090, 1
HS Hydrae	10 24 36.8	-19 05 33	1.568042	8.07 - 8.61 V	Zasche & Paschke, 2012; A&A, 542, 23
V0685 Cen	11 24 26.6	-57 43 40	1.190964	9.4 - 9.8 p	Mayer et al., 2004; IBVS, 5563, 1
AY Muscae	11 31 40.3	-65 16 17	3.205558	10.51 - 10.8 B	Söderhjelm, 1975; A&A, 42, 229
V907 Scorpii	17 56 55.6	-34 45 01	3.776277	8.61 - 9.2 V	Lacy et al., 1999; AJ, 117, 541
V699 Cygni	20 17 00.3	+39 08 20	1.55152	12.0 - 13.0 p	Zakirov & Azimov, 1991; IBVS, 3667, 1
SS Lacertae	22 04 41.6	+46 25 38	14.41629	10.1 - 10.5 p	Torres, 2001; AJ, 121, 2227
AH Cephei	22 47 52.9	+65 03 44	1.7747505	6.78 - 7.07 V	Drechsel et al., 1989; A&A, 221, 49
QX Cassiopeiae	23 58 43.1	+61 09 39	6.00471	10.19 - 10.7 V	Bonaro et al.,2009; BAAS, 41, 301

Ivan Adamin

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