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ON THE VARIABILITY OF EARLY A-TYPE SUPERGIANTS

S.J. ADELMAN[1], B. ALBAYRAK[1,2]

[1] Department of Physics, The Citadel,171 Moultrie Street, Charleston, SC 29409 USA, e-mail: adelmans@citadel.edu

[2] Ankara University, Science Faculty, Astronomy and Space Sciences Department, 06100 Tandoğan, Ankara,Turkey, e-mail: albayrak@astro1.science. ankara.edu.tr

Lucy (1976) performed an harmonic analysis of the radial velocities of the A2Iae supergiant Deneb (α Cyg = HR 7924 = HD 197345), especially those of Paddock (1935), which indicated that this star pulsated in 16 different modes with periods between 6.9 and 100.8 days. Photometry by Fath (1935) showed definite variability with an amplitude of 0.05 mag. The photometric and radial velocity variations may be correlated. Radial velocity measurement sets exist for a number of early A supergiants, but there are no extensive data sets obtained in any modern photometric system. This is somewhat surprising as these are among the brightest stars in our Galaxy and similar stars are seen in other nearby spiral galaxies.

With the photometry from the Hipparcos satellite (ESA 1997), we have examined the Hipparcos data from Deneb and other A0 to A5 supergiants included in the 5th edition of the Bright Star Catalogue (Hoffleit & Warren 1991). Table 1 contains for each star the stellar identifications (Name, HR, HD, and HIP numbers), the spectral type, the number of transits which were photometrically accepted, the mean magnitude in the Hipparcos photometric system, the standard error of this magnitude, the amplitude which we take to be the difference between the 95th percentile and 5th percentile magnitudes, and any period which is given. The amplitudes and standard errors are correlated although there may be slightly different relations for Ia and Ib stars.

Figure 1 shows the standard errors plotted against the Hipparcos photometric mean magnitudes with the values for the Ia stars indicated by plus signs, Iab stars by open diamonds, and Ib stars by crosses. The photometric amplitudes of the Ia stars are greater than those of the Ib stars with the Iab stars intermediate. This result confirms Maeder (1980)'s conclusion that for supergiants of any spectral type the amplitudes increase with luminosity. His peak-to-peak amplitudes for A0-A9 stars are 0.051 and 0.039 mag for spectral types Ia and Ib, respectively, results similar to those in Table 1. Further Deneb, the brightest early A supergiant, has an amplitude of variability similar to those of other Ia stars.

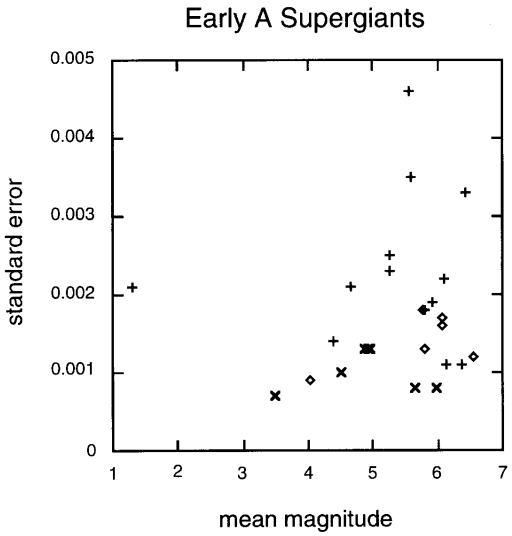

Figure 1. The standard errors of the Hipparcos photometry of A0 to A5 supergiants as a function of Hipparcos magnitude. The standard errors are correlated with the amplitudes of variability. Plus signs represent luminosity class Ia stars, open diamonds class Iab stars, and crosses luminosity class Ib stars

Table 1: Stellar and Photometric Parameters

Name	HR Number	HD Number	HIP Number	Spectral Type	Accepted Transits	Mean mag. (mag.)	Standard Error (mag.)	Amplitude (mag.)	Periods (days)
	618	12953	9990	A1 Iae	122	5.8124	0.0018	0.06	6.36100
	641	13476	10379	A3 Iab	103	6.5633	0.0012	0.05	
9 Per	685	14489	11060	A2 Ia	128	5.2723	0.0025	0.07	
	825	17378	13178	A5 Ia	123	6.3677	0.0011	0.04	
	964	20041	15192	A0 Ia	102	5.9277	0.0019	0.05	
	1040	21389	16281	A0 Iae	78	4.6710	0.0021	0.04	
	2074	39970	28154	A0 Ia	125	6.1182	0.0011	0.05	
13 Mon	2385	46300	31216	A0 Ib	44	4.5019	0.0010	0.02	
	2874	59612	36431	A5 Ib	116	4.9210	0.0013	0.03	
3 Pup	2996	62623	37677	A2 Iabe	165	4.0152	0.0009	0.03	
30 Leo	3975	87737	49583	A0 Ib	98	3.5034	0.0007	0.03	
	4144	91533	51623	A2 Iab	113	6.0751	0.0016	0.06	
	4169	92207	52004	A0 Iae	106	5.5513	0.0046	0.11	1.33238
	4228	93737	52827	A0 Ia-Iab	122	6.0714	0.0017	0.08	
	4438	100198	56201	A3 Iae	127	6.4184	0.0033	0.14	
o^2 Cen	4442	100262	56250	A2 Ia	126	5.2534	0.0023	0.05	
	4541	102878	57741	A2 Iab	140	5.7611	0.0018	0.06	
	4563	103516	58103	A3 Ib	137	5.9641	0.0013	0.04	
	4578	104035	58427	A3 Ib	140	5.6577	0.0008	0.03	
	4876	111613	62732	A2 Iabe	174	5.8116	0.0013	0.06	
ι^2 Sco	6631	161912	87294	A2 Ib	72	4.8648	0.0013	0.05	
	6825	167356	89470	A0 Ia	74	6.1064	0.0022	0.05	2.35950
42 Cyg	7835	195324	101067	A1 Ib	162	5.9906	0.0008	0.03	
Deneb	7924	197345	102098	A2 Iae	110	1.2966	0.0021	0.07	
10 Cep	8334	207260	107418	A2 Ia	115	4.3911	0.0014	0.05	
6 Cas	9018	223385	117447	A3 Iae	138	5.5888	0.0035	0.09	

Figure 2 shows the light curve for Deneb. Those of the other A-type supergiants in Table 1 are similar. It is very difficult to determine periods with methods such as the Scargle periodogram as the way the stars' magnitudes were sampled is not consistent with the assumptions of the mathematic methods. One can deduce evidence for a period of order two weeks, but without more complete light curves the results are open to question. It is unclear whether for Deneb the periods found with more complete light curves will in fact be those deduced by Lucy. These periods and their relative contributions contain information about the hydrodynamics of the stellar atmosphere. How they change from location to location in the HR diagram or equivalently how they change as the stars evolve is unknown.

The light curve of Deneb and those of the early A supergiants examined demonstrate that such stars are relatively moderate or large amplitude variables. With automated telescopes of modest aperature, it should be possible to obtain the type of data needed to better deduce their periods of variability. For a given star an observation or two (or perhaps more) every clear night for several years when it is observable is what is required.

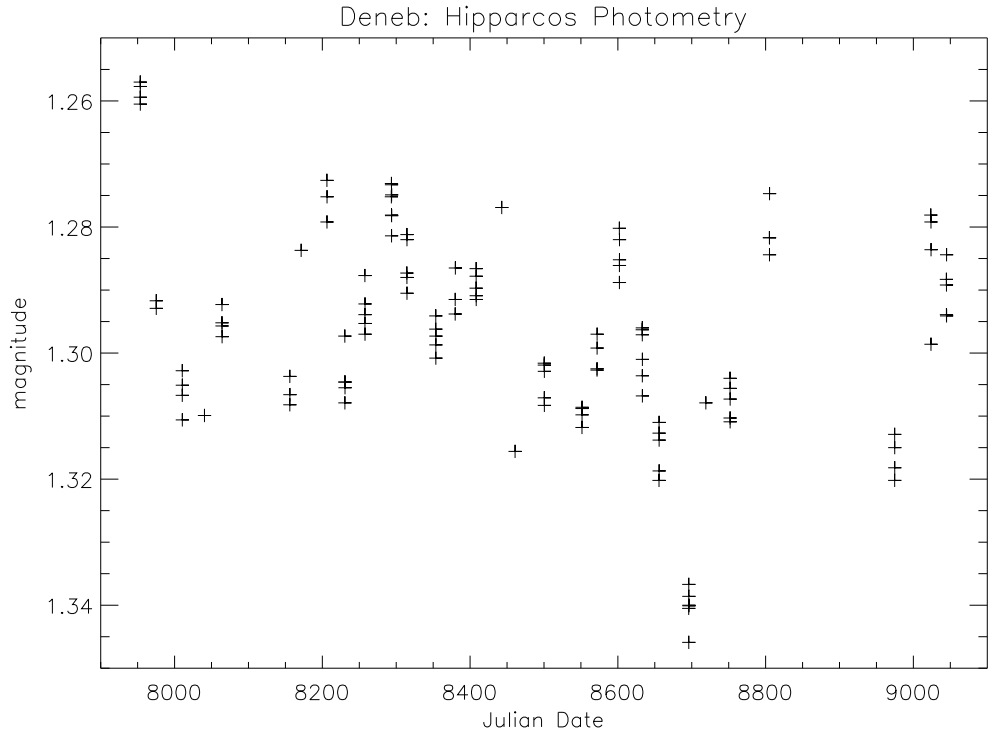

Figure 2. The Hipparcos photometry of Deneb as a function of Julian date

Table 1 also includes the periods found by the Hipparcos team for three of these stars. For HR 618 a light curve was published. But there is still a scatter of 0.03 mag. around mean curve which indicates that perhaps only one period was found. For HR 4169 no light curve is illustrated. HR 6825 is not an Ap Si star as indicated by the Hipparcos catalog. Its photometry fits its mean light curve better than that for HR 618.

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