KODAIKANAL OBSERVATORY
BULLETIN Number 191

Narrow Band Photometry of Rho Puppis

A. Thulasi Doss

Abstract

Monochromatic flux values of the dwarf Cepheid Rho Puppis have been evaluated over the cycle from observations made in the 1967 season through four narrow band filters centred at 3858 Å 4310 Å, 4720 Å and 5875 Å. The amplitudes at the above wavelengths are 0.17, 0.14, 0.12 and 0.09 magnitudes respectively. The effective temperature variation over a cycle is 320°K. Photoelectric light curves have also been obtained in Blue and Yellow colours and amplitude of light variations are $0^m.15$ and $0^m.09$ respectively. The period is further improved as 0.14088067 day.

Introduction

Simultaneous spectrophotometric and spectral observations of the short period pulsating star Rho Puppis have been reported recently by Danziger and Kuhi (1967) and Bessel (1967). Earlier works on this star have been summarised by Danziger and Kuhi who have obtained at minimum light an effective temperature of $T_e = 6071°K$ ($\theta_e = \frac{5040}{T_e} = 0.83$) and a low mass of 0.2 solar masses. They suggest that the star may be pulsating in a higher harmonic. This result has been criticized by Bessel who obtains values of θ_e and mass to be 0.74 and 2.0 respectively and hence concludes that the star may be pulsating in the first overtone.

Ponsen (1962) has determined the mean light curve of Rho Puppis through a blue filter and improved the period combining all the observed epochs of maximum since the discovery by Eggen (1956), as well as from the radial velocity data.

The present study is undertaken to determine θ_e for different phases from both (B-V) colour curves using interference filters. It was also of interest to investigate the constancy of the value of period derived by Ponsen.

Observations

The star was observed photoelectrically at Kodaikanal during January and February 1967, with a photometer attached to the 20cm Cooke refractor. An unrefrigerated RCA 1P21 photomultiplier tube was used and the amplified output was recorded on a Brown recording potentiometer. The star was observed on 5 nights during January 1967 with the aid of standard B, V filters. The comparison stars were ξ Puppis and 11 Puppis. On one night in February Rho Puppis was observed through four narrow band interference filters with ξ Puppis and 11 Puppis as comparison stars. These two stars were later tied in with α Tau, ξ Ori, π^3 Ori and Leo for absolute flux determinations on Oke's (1961) system of standards.

Characteristics of the four narrow band filters used are given below:

Peak transmission wavelength	Width at half intensity
3858Å	94Å
4310Å	75Å
4720Å	46Å
5875Å	66Å

The light curves

The observations of Rho Puppis through B and V filters on 18, 21, 22, 23 and 24 January 1967 have been reduced to magnitudes outside the atmosphere by applying extinction corrections. The difference in magnitude between ξ Puppis and the variable have been computed. It was seen that the maximum light occurred about 20 minutes later than the computed epoch with Eggens ephemeris (JD 2435555·911+·141 E) and 16 minutes earlier than the computed epoch with Ponsen's ephemeris (JD 2437330·425+14088141E). The latter period is preferred as it has taken into account all the photometric and radial velocity measurements over a large interval from 1897 to 1963. Combining with the present epoch the period has been further improved as 0·14088067 days.

Hence the present ephemeris can be given as Max. J.D. (Hel) 2439512·244+0·14088067E.

It is with this present ephemeris that all the phases (heliocentric) in terms of period were computed. The Δm against phase for blue and yellow are given in tables I and II. The instrumental (B-V) colours that are determined are converted to standard (B-V) colours using linear transformations. The values are given in Table III and plotted in Figure 1 along with the blue light curve.

TABLE I

Blue observations of Rho Puppis

J. D. Helio-centric	Phase	Δm	J. D. Helio-centric	Phase	Δm
2439512.1377	0.2448	.255	2439513.2523	0.1568	1.303
1474	0.3138	.251	2571	0.1909	1.283
1502	0.3336	.239	2578	0.1959	1.271
1543	0.3627	.224	2641	0.2406	1.265
1620	0.4173	.213	3057	0.5359	1.208
1648	0.4372	.221	3113	0.5758	1.213
1689	0.4664	.214	3182	0.6246	1.218

TABLE I—*Contd.*

J.D. Helio-centric	Phase	Δm
2439512.1724	0.4912	1.201
1779	0.5302	1.219
1814	0.5551	1.203
1849	0.5799	1.211
1877	0.5997	1.211
1946	0.6487	1.201
1974	0.6684	1.211
2029	0.7077	1.218
2071	0.7375	1.245
2085	0.7474	1.252
2113	0.7673	1.263
2161	0.8013	1.273
2175	0.8115	1.288
2203	0.8311	1.290
2238	0.8564	1.304
2259	0.8709	1.313
2300	0.9001	1.307
2321	0.9149	1.335
2384	0.9596	1.341
2411	0.9788	1.353
2425	0.9887	1.329
2453	0.0092	1.354
2481	0.0241	1.347
2495	0.0391	1.341
2550	0.0781	1.333
2564	0.0811	1.322
2585	0.1029	1.320
2627	0.1327	1.314
3071	0.4478	1.222
3127	0.4877	1.226
3141	0.4975	1.220
3161	0.5118	1.221
3411	0.6892	1.239
3439	0.6452	1.252
3479	0.7325	1.257
3495	0.7417	1.259
3814	0.9752	1.356
3849	0.0000	1.347
2439514.3863	0.2065	1.307
3891	0.2264	1.299
3898	0.2314	1.295
3911	0.2406	1.287
3918	0.2455	1.280
3922	0.2484	1.281
3946	0.2654	1.276
3953	0.2704	1.276
3974	0.2853	1.264
3995	0.3082	1.267
2439513.3238	0.6643	1.233
3293	0.7035	1.237
3289	0.7005	1.261
3418	0.7923	1.277
3474	0.8333	1.303
3661	0.9646	1.338
3752	0.0399	1.340
3807	0.0688	1.338
3870	0.1136	1.317
4161	0.3207	1.238
4210	0.3549	1.215
4252	0.3847	1.211
4266	0.3945	1.208
4300	0.4188	1.203
4342	0.5906	1.192
2439514.2759	0.4231	1.238
3309	0.8120	1.302
3349	0.8416	1.314
3543	0.9817	1.359
3564	0.9945	1.364
3585	0.0094	1.364
3606	0.0241	1.359
3627	0.2390	1.357
3641	0.0489	1.349
3661	0.0632	1.350
3682	0.0799	1.348
3710	0.0979	1.346
3724	0.1078	1.343
3745	0.1227	1.335
3752	0.1279	1.325
3773	0.1426	1.329
3786	0.1519	1.322
3800	0.1619	1.315
3825	0.1767	1.319
3835	0.1881	1.317
3842	0.1916	1.315
3856	0.2015	1.310
2439515.1842	0.8702	1.310
1856	0.8800	1.313
1870	0.8972	1.318
1884	0.9000	1.322
1898	0.9099	1.329
1911	0.9192	1.333
1925	0.9291	1.338
1940	0.9398	1.335
1953	0.9490	1.339
1967	0.9589	1.333

TABLE I—*contd.*

J.D. Helio-centric	Phase	Δm	J.D. Helio-centric	Phase	Δm
2439514.4009	0.3101	1.255	2439515.1995	0.9788	1.340
4036	0.3294	1.264	2009	0.9887	1.352
4057	0.3442	1.255	2023	0.9994	1.345
4092	0.3691	1.235	2036	0.0079	1.345
4113	0.3840	1.213	2050	0.0177	1.344
4141	0.4039	1.228	2064	0.0276	1.344
4154	0.4131	1.229	2092	0.0475	1.340
4175	0.4280	1.203	2120	0.0675	1.338
4189	0.4379	1.200	2141	0.0839	1.335
4307	0.5217	1.200	2161	0.0965	1.334
4321	0.5316	1.205	2189	0.1164	1.329
4356	0.5564	1.219	2203	0.1263	1.325
4377	0.5714	1.218	2217	0.1362	1.325
4398	0.5863	1.294	2231	0.1462	1.316
4439	0.6154	1.197	2245	0.1561	1.314
			2259	0.1660	1.309
2439515.1516	0.6388	1.196	2256	0.1710	1.305
1529	0.6480	1.194	2693	0.1902	1.303
1550	0.6700	1.205	2300	0.1952	1.297
1564	0.6729	1.210	2314	0.2051	1.296
1578	0.6829	1.212	2328	0.2150	1.290
1585	0.6879	1.216	2349	0.2300	1.287
1620	0.7127	1.224	2370	0.2449	1.282
1634	0.7226	1.231	2391	0.2597	1.278
1648	0.7325	1.238	2401	0.2569	1.282
1675	0.7516	1.254	2543	0.3676	1.232
1689	0.7616	1.256	2578	0.3925	1.225
1703	0.7715	1.259	3029	0.7126	1.272
1720	0.7832	1.266	3043	0.7225	1.267
1731	0.7913	1.274	3113	0.7722	1.275
1759	0.8113	1.282	3134	0.7871	1.281
1773	0.8205	1.282	3148	0.7971	1.278
1786	0.8304	1.293	3168	0.8113	1.291
1800	0.8404	1.292			
1814	0.8503	1.299			
1828	0.8603	1.304			

TABLE II

Yellow Observations of Rho Puppis

J. D. Helio-centric	Phase	Δm	J. D. Helio-centric	Phase	Δm
2439509.1953	0.3598	0.522	2439513.2543	0.1711	0.561
2016	0.4045	0.516	2606	0.2157	0.566
2085	0.4536	0.507	2654	0.2498	0.547

TABLE II—*Contd.*

J.D. Helio-centric	Phase	Δm	J.D. Helio-centric	Phase	Δm
2439509.2210	0.5423	0.508	2439513.3148	0.6005	0.516
2266	0.5870	0.503	3210	0.6445	0.519
3161	0.2172	0.571	3266	0.6842	0.526
3196	0.2420	0.547	3321	0.7233	0.534
3314	0.3088	0.534	3370	0.7580	0.542
3370	0.3655	0.527	3346	0.7411	0.562
3426	0.4046	0.519	3710	0.9999	0.600
3467	0.4344	0.519	3779	0.0488	0.597
3509	0.4642	0.512	3828	0.0837	0.592
3557	0.4981	0.508	3904	0.1377	0.578
3620	0.6139	0.508	4182	0.3350	0.525
3789	0.6629	0.506	4238	0.3745	0.532
3946	0.7034	0.543	4279	0.3747	0.523
3995	0.8092	0.557	4286	0.4088	0.505
4036	0.8382	0.563	4326	0.4372	0.514
4085	0.8731	0.579	4370	0.4684	0.516
4134	0.9078	0.590	4441	0.5188	0.501
4175	0.9367	0.594	4425	0.5075	0.503
4231	0.9768	0.589			
			2439515.1439	0.5841	0.501
2439512.1307	0.1959	0.546	2335	0.2200	0.543
1668	0.4521	0.517	2356	0.2399	0.541
2002	0.6892	0.515	2384	0.2548	0.540
2279	0.8858	0.588	2411	0.2739	0.543
2599	0.1128	0.590	2564	0.3825	0.513
3092	0.4060	0.511	3036	0.7176	0.568
3279	0.5955	0.504	3127	0.7822	0.546
3460	0.7311	0.543	3154	0.8013	0.547
			3411	0.8418	0.594
			3627	0.1369	0.562

TABLE III

(B-V) colour and θ_e values of Rho Puppis

J.D. Heliocentric	Phase	(B-V)	θ_e
2439509.1946	0.3549	+0.358	0.743
2002	0.3946	+0.360	0.745
2078	0.4486	+0.364	0.748
2189	0.5272	+0.378	0.755
2252	0.5721	+0.370	0.752
2293	0.6012	+0.375	0.754

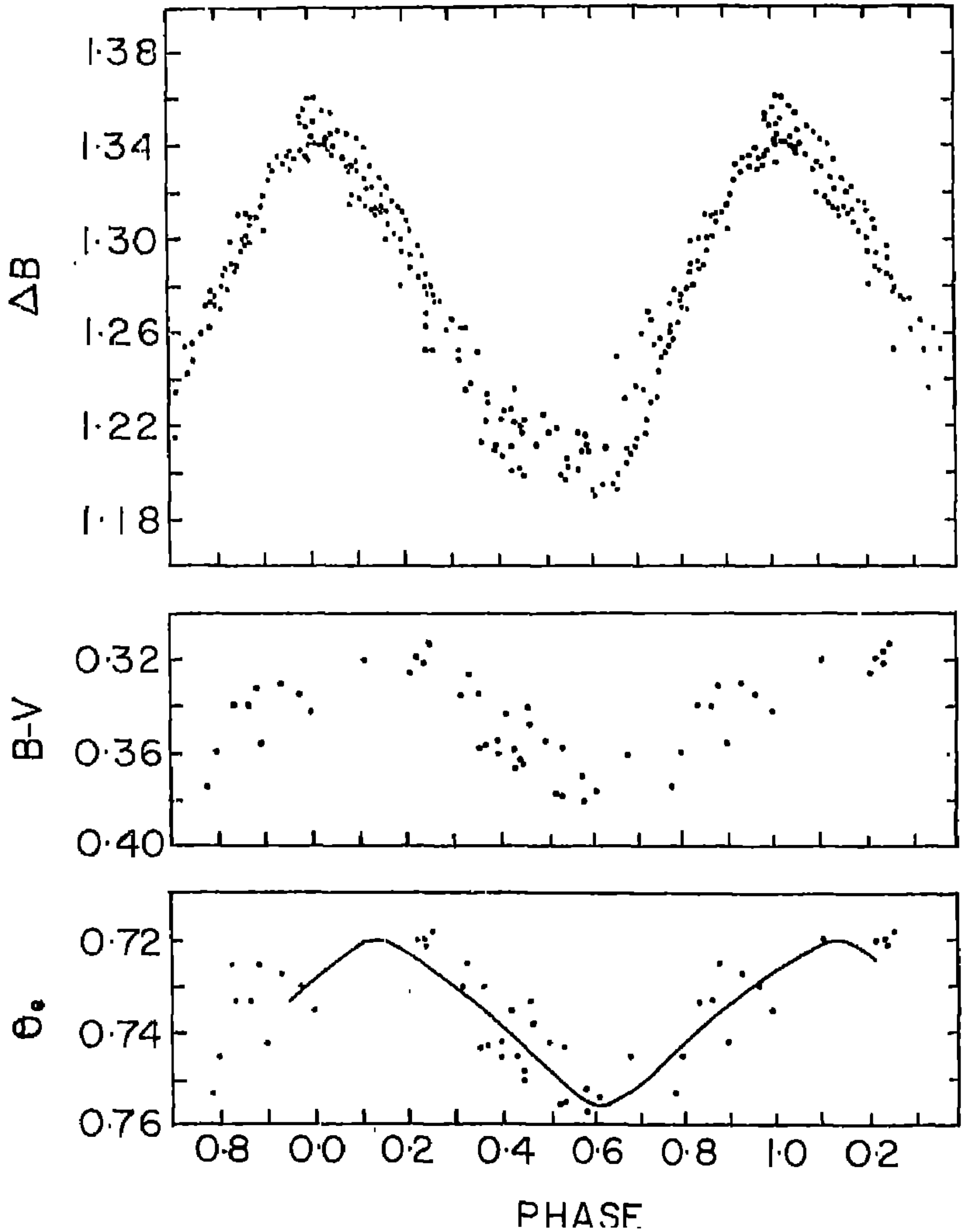

Figure 1—Light, colour and temperature curves of Rho Puppis.

TABLE III—*Contd.*

J.D. Heliocentric	Phase	(B-V)	θ_e
2439509.3154	0.2212	+0.319	0.720
3189	0.2370	+0.321	0.721
3300	0.3158	+0.335	0.730
3356	0.3556	+0.334	0.730
3460	0.4294	+0.359	0.745
3502	0.4592	+0.348	0.738
3550	0.4933	+0.355	0.742
3599	0.5281	+0.358	0.743
3932	0.7786	+0.374	0.753
3981	0.7992	+0.359	0.745
4029	0.8333	+0.339	0.733
4071	0.8631	+0.339	0.733
4120	0.8979	+0.355	0.742
4168	0.9319	+0.330	0.727
4217	0.9667	+0.334	0.730
2439512.1654	0.4422	+0.363	0.748
1759	0.5167	+0.377	0.755
1988	0.6792	+0.361	0.745
2273	0.8815	+0.331	0.725
2432	0.9944	+0.342	0.735
2592	0.1078	+0.320	0.720
3085	0.4578	+0.340	0.733
2439513.2597	0.2058	+0.325	0.724
4175	0.3301	+0.326	0.725
4224	0.3648	+0.357	0.743
4273	0.3996	+0.355	0.742
4293	0.4138	+0.343	0.735
4326	0.4372	+0.366	0.750
2439515.1432	0.5792	+0.380	0.757
2356	0.2349	+0.316	0.720
2377	0.2497	+0.313	0.718

The shape of the light curve agrees with that of Ponsen with a sharper maximum than minimum and with equally steep rising and descending branches. It is noted that a scatter of about $0^m.01$ was seen in the light curves. The mean amplitude in blue and yellow are $0^m.15$ and $0^m.09$ respectively.

Temperatures

The B-V colour variation with phase is utilised to derive the changes in effective temperature over a cycle. The values of effective temperatures against (B-V) obtained by Oke and Conti (1965) for the Hyades stars were utilised and θ_e with phase were computed for Rho Puppis. The values are given in Table III and also plotted in Figure 1. It can be seen from figure 1 that $\theta_e = .755$ at minimum and the variation is .035 over a cycle. The value of θ at minimum compares well with that obtained by Bessel ($\theta_e = .74$).

The effective temperature variation over a cycle was also studied by the observations taken through four interference filters.

The flux values with the filter 3859Å were not given a high weight in the slope determination due to the large blanketing corrections involved.

The monochromatic fluxes given by Oke for α Leo and ε Ori were utilised to derive that for 11 Puppis and ξ Puppis. The method given by Oke (1965) has been followed for determining absolute fluxes AB and effective temperatures θ_e. The absolute energy fluxes of ξ Puppis, 11 Puppis and Rho Puppis are given in Table IV. Figure 2 is a plot of the flux values of Rho Puppis for the different phases. It can be seen that the light amplitude decreases with increasing wavelength. The ranges are 0.17, 0.14, 0.12 and 0.09 magnitudes for 3859Å, 4310Å, 4720Å and 5875Å respectively.

TABLE IV

Monochromatic flux AB* and θ_e values of Rho Puppis

Time U.T	3858Å	4310Å	4720Å	5875Å	Phase	θ_e
February 7, 1967						
1621	3.649	3.108	2.870	2.733	0.1959	0.726
1632	3.699	3.112	2.887	2.744	0.2499	0.712
1640	3.739	3.134	2.885	2.739	0.2889	0.734
1648	3.733	3.132	2.900	2.782	0.3286	0.715
1655	3.753	3.159	2.911	2.783	0.3634	0.725
1710	3.787	3.177	2.931	2.792	0.4372	0.726
1734	3.782	3.181	2.916	2.779	0.5551	0.732
1742	3.783	3.179	2.921	2.765	0.5948	—
1758	3.766	3.131	2.883	2.765	0.6736	—
1812	3.745	3.113	2.873	2.737	0.7425	0.723
1819	3.735	3.101	2.853	—	0.7773	0.706
1827	3.736	3.074	—	—	0.8170	—
1856	3.614	3.039	2.807	2.714	0.9597	0.704
1912	—	3.042	2.808	2.693	0.0383	0.715
1917	3.612	3.036	2.808	2.716	0.0632	0.700
1934	3.650	3.065	2.834	2.720	0.1469	0.708
1940	3.610	3.070	2.838	2.751	0.1760	0.697
1947	3.632	3.107	2.857	2.748	0.2108	0.702
1954	3.649	3.104	2.868	2.762	0.2456	0.710
2001	3.643	3.125	—	2.762	0.2797	0.719
ξ Puppis	6.108	4.641	3.804	3.072		
11 Puppis	5.642	4.900	4.460	4.079		

*Flux AB = [$-2.5 \log F\nu +$ Const] normalised to m_v at 5556Å

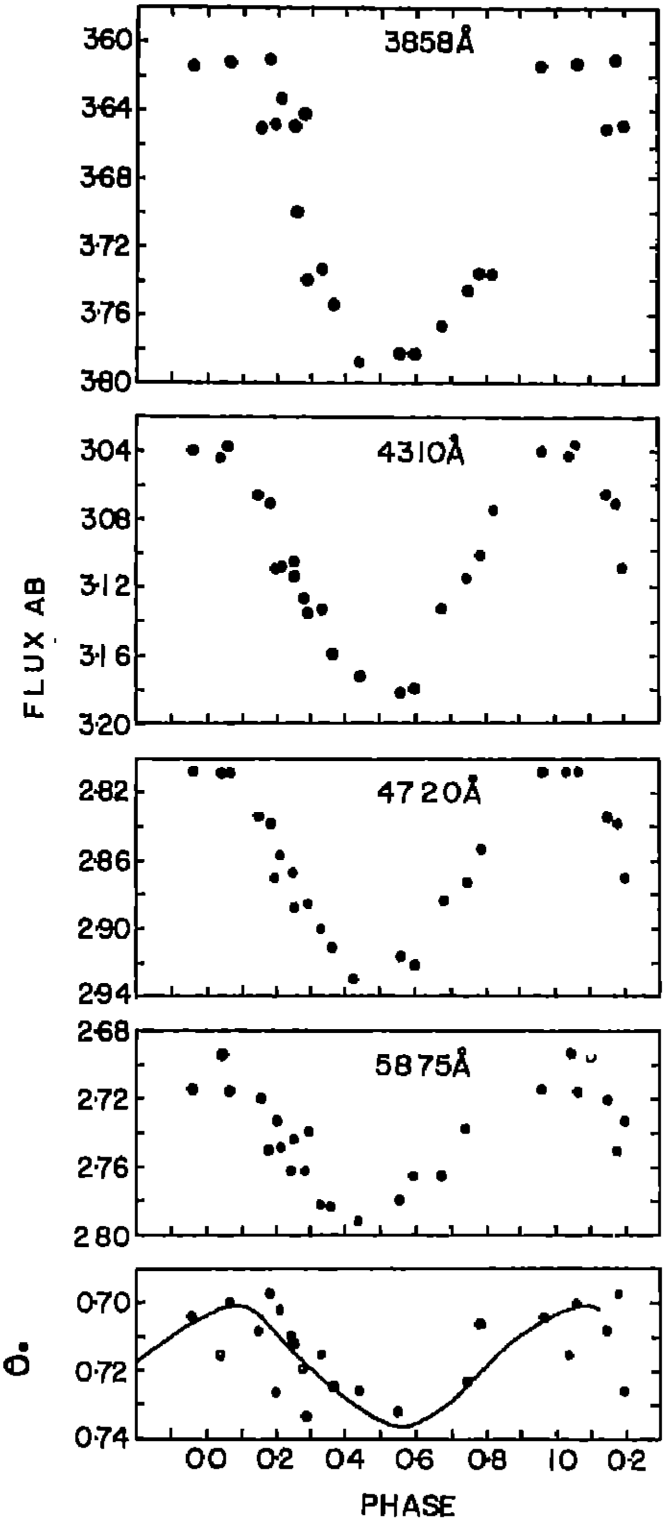

Figure 2— Light curves of Rho Puppis with four narrow band filters and the temperature variation over a cycle.

Assuming log g=-0.34 and the blanketing corrections given by Bessel, the θ_e variation over the cycle for Rho Puppis is derived and plotted in Figure 2.

It is seen that both θ_e curves in Figures 1 and 2 agree with each other in the amplitude, though there is a slight shift of .02 in θ_e scale. It is also seen that the minimum temperature occurs about 0.1P in phase after the minimum light. Even though the differential variations agree in amplitude and phase, the effective temperatures derived by Danziger and Kuhi are systematically lower by about 700°K. Our value of θ_e minimum for Rho Puppis confirms the results obtained by Bessel (θ_e -- .74) and not that of θ_e -- .83 obtained by Danziger and Kuhi.

The amplitude of θ_e from Figures 1 and 2 is .035 and hence the effective temperature variation over a cycle is 320°K. The earlier values reported were 300°K by Bappu (1959) and 280°K by Danziger and Kuhi.

Acknowledgements

The author is indebted to Dr. M.K.V. Bappu for suggesting this programme and for his continued guidance. I wish to thank Mr. C.V. Ramakrishna Rao and Mr. K.K. Kunju Kunju Kutty for their help during observations and computations.

Kodaikanal Observatory
July, 1969

REFERENCES

Bappu, M.K.V., 1959, Mon. Not. R. astr. Soc. **119**, 400

Bessel, M.S., 1967, Astrophys. J (Letters), **149**, L 67

Danziger, I. J., and Kuhi, L.V., 1967, Astrophys. J., **146**, 743

Eggen, O.J., 1956, Publ. astr. Soc. Pacific, **68**, 238

Oke, J. B., 1964, Astrophys. J., **140**, 689

Oke, J. B., 1965, A Rev. Astr. Astrophys., **3**, 23

Oke, J. B., and Conti., P. S., 1966, Astrophys. J., **143**, 134

Ponsen, J., 1963, Bull. astr. Inst. Netherl., **17**, 44.

MGIPCBE—S4—5DAOK/69- -21-4-1970—365.