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NU CENTAURI: A NEW BETA CEPHEI STAR

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ABSTRACT

Spectrographic observations of the single-lined binary, ν Centauri during the years 1968-1972 were utilised to derive fresh orbital elements of this system. The measured radial velocities indicate that the primary component is a β Cephei type with a period of 0.1750 days.

Key words: spectroscopic binaries — variable stars

1. Introduction

The binary character of ν Centauri was first announced by Palmer (1906) and the only orbit that exists for this system is by Wilson (1914) who found the orbit to be circular with a period of 2.62516 days. Its spectral type is B2 IV and the rotational velocity is of the order of 100 km s^{-1} (90 km s^{-1} -Slettebak, 1968; 100 km s^{-1} -Rajamohan, 1973). This is a member of the Scorpio-Centaurus association and absolute magnitude determinations for it range from -2.9 (Bertiau, 1958) to - 2.0 (Jones, 1971). Its light was reported to be variable by Bailey (1895).

2. The Observations

Twenty-nine spectrograms of ν Centauri obtained during the years 1968-1972 with the 51-cm reflector at Kodaikanal were supplemented with nine additional spectra obtained with the 102-cm reflector telescope at Kavalur. All the spectra were taken with the same grating spectrograph and have a mean dispersion of 47Å mm^{-1} at Hν. The lines measured and the wavelengths used are listed in table 1. Table 2 lists the plate number, phases computed from T, the time of periastron passage and the measured mean radial velocity obtained from the hydrogen and helium lines. Since the velocities in table 2, indicate that the primary component of ν Centauri may be a β Cephei type variable, fourteen spectrograms within an interval of four hours were obtained on 1974, April 26, at a dispersion of 26Å mm^{-1}. The measured radial velocities are listed separately in table 3. Though the velocities obtained for each line showed the general pattern of

Table 1. Wavelengths used for radial velocity measurement

Wavelength Å	Line
4471.326	He I
4387.928	He I
4340.468	H γ
4101.737	H δ
4026.140	He I
3970.074	H ϵ

the radial velocity changes to be discussed below, it must be mentioned that their behaviour is different from one another. The amplitude derived from the H γ line is the least, indicating a slight filling in of the line probably due to emission. However two spectra at phases 0.96 and 0.77 taken at a dispersion of 17Å mm^{-1} do not show any detectable emission at Hα. Hϵ is possibly affected by contamination with Ca II H and H 8 due to He I 3888 Å. I have therefore, used only H γ and H δ as representatives of the hydrogen lines and He I λ 4471 and 4388 as representatives of the helium lines in this object. He I λ 4026 was neglected because of its slightly different behaviour from those of He I λ 4471 and 4388.

3. The New Orbit

The orbital variations seem to be best represented by He I λ 4471 and 4388. Consequently, these lines were used in deriving the new orbit. A comparison with Wilson's radial velocity curve shows that the period must be increased from 2.62516 to 2.625275 days to bring the two observations into agreement. Though Wilson's measures are averaged

Table 2. Radial velocity measures of Nu Centauri

Plate No.	Julian Day of Observation	Phase (Period)	Observed radial Velocity He km s-l	Observed radial Velocity He km s-l	(O-C) He km s-l
	2400000 +				
722	39926 271	0.003	+ 26.9	+ 33.1	+ 3.6
1645	41404.365	0.028	+ 10.3	+ 45 2	− 6.3
1646	41404.385	0.036	− 5.6	+ 39.2	− 19.9
1858	41727.339	0.053	+ 19.4	+ 0.8	+ 10.2
1859	41727.356	0.059	+ 14.7	+ 6.3	+ 7.4
1474	41042.253	0.095	− 20.5	+ 37.7	− 20.5
1623	41399.299	0.098	− 44.5	- — --	− 40 7
2243	41785.228	0.104	+ 2.2	− 34.3	+ 7.6
1475	41042.303	0.114	+ 7.4	+ 41.8	+ 15.3
708	39921.335	0.123	− 9.0	+ 9.6	0.9
1435	41029.285	0.155	+ 5.8	+ 15.2	+ 22.0
1477	41042.441	0.166	− 32.1	+ 17.7	− 14.1
689	39916.426	0.254	− 8.5	+ 22.7	+ 17 6
1439	41032.304	0.306	− 40.8	+ 8.4	− 13.6
1440	41032.335	0.317	26.4	+ 19.1	+ 0.8
1467	41040.271	0.340	− 26.2	+ 11.4	+ 0.7
1769	41104.488	0.348	− 40.2	− 46.3	− 13.4
1656	41426.296	0 382	− 13.0	23.6	+ 12.7
1471	41040.424	0.398	+ 3 2	+ 10.1	+ 28.3
2204	41778.256	0.448	− 41.8	33.1	19.5
2205	41778.268	0.462	− 17.4	− 34.3	+ 4 4
1873	41728.490	0.491	− 7.3	− 19.5	+ 11.5
1874	41728.505	0.497	− 6.2	− 19.9	+ 12.6
1459	41038.254	0.572	− 11.9	+ 25.6	+ 0.1
1461	41038.368	0 611	− 30.5	+ 7.3	+ 22.7
1462	41038.410	0 631	— — –	+ 5 8	-- -- –
1445	41033.288	0 680	+ 18.4	+ 37.4	+ 17.6
1618	41398.257	0.701	− 8.3	+ 4 3	12 0
704	39920.290	0.725	+ 14 8	+ 29.8	+ 7.6
1658	41427.306	0.766	− 0 6	+ 52.2	− 14.1
1450	41036.240	0 805	+ 22.2	+ 25 2	+ 2.6
1452	41036.317	0.832	+ 17.5	+ 12 7	− 6.3
680	39916.328	0.836	+ 34.6	+ 6.3	+ 10.2
2256	41787.242	0.870	+ 20 5	+ 21.1	− 8.4
1455	41036.426	0.875	+ 28.5	+ 24.8	− 1.0
715	39923.333	0.885	+ 70.2	+ 48.3	+ 39.7
1464	41039.278	0.961	+ 18.0	+ 26.2	− 12.8
1611	41396.340	0.971	+ 41.0	− 5.9	+ 10 5

velocities obtained from both the hydrogen and helium lines, the need for change in the period is indicated by the individual lines as well as their average.

Thirty-four of the thirty- eight plates listed in table 2, were used to form eight normal places. All the points were treated with equal weight and the preliminary elements obtained by the method of Lehmann-Filhes were improved by the least square procedure of Schlesinger (1908). Following Sterne (1941) T was replaced by T_0 (T_0 is the time at which the mean longitude $\omega + M$ is zero).

Table 4 lists the final elements derived in this study as well as those derived by Wilson (1914) No probable errors are quoted for the orbital elements derived here since the scatter in the individual observations about the mean are large and whatever short period oscillations are present, have not been properly taken into account in deriving the new orbital elements. The computed radial velocity curve with the final elements together with the observed velocities from helium and hydrogen lines are shown in Figure 1.

4. Nature of Pulsations

The large deviations of the individual measurements from the computed curve indicate that oscillations other than orbital motion are present. An inspection of Figure 1 indicates that the situation is worse in the case of hydrogen line measures. Just immediately after the node on the descending branch of the radial velocity curve, where one expects the primary eclipse to occur if the inclination of the orbit were favourable, the hydrogen lines give large positive velocities. The hydrogen lines seem to be affected by gas streams and this conclusion is further augmented by the relative strengthening of He I λ 3965 line found on a few spectra indicating dilution effects. The behaviour of this line is found to vary even within a short period of four hours from an inspection of the spectra tabulated in table 3. I have therefore used the residuals found from the helium lines alone which are found to fit a period of 0.1750 days. These

Table 3. Radial velocity measures of Nu Centauri on 1974 April 26.

Plate No.	Mid exposure U.T. h m	Observed radial velocity Km s-l
2834	16 58	00.3
2835	17 15	− 14.6
2836	17 29	− 2 7
2837	17 44	− 3.5
2838	17 57	− 8.0
2839	18 10	− 1.2
2840	18 19	− 9.0
2841	18 30	− 15.1
2842	18 44	− 11.0
2843	18 55	− 8.6
2846	19 53	− 6.7
2847	20 08	− 13.6
2848	20 28	− 3.4
2849	20 46	+ 0.2

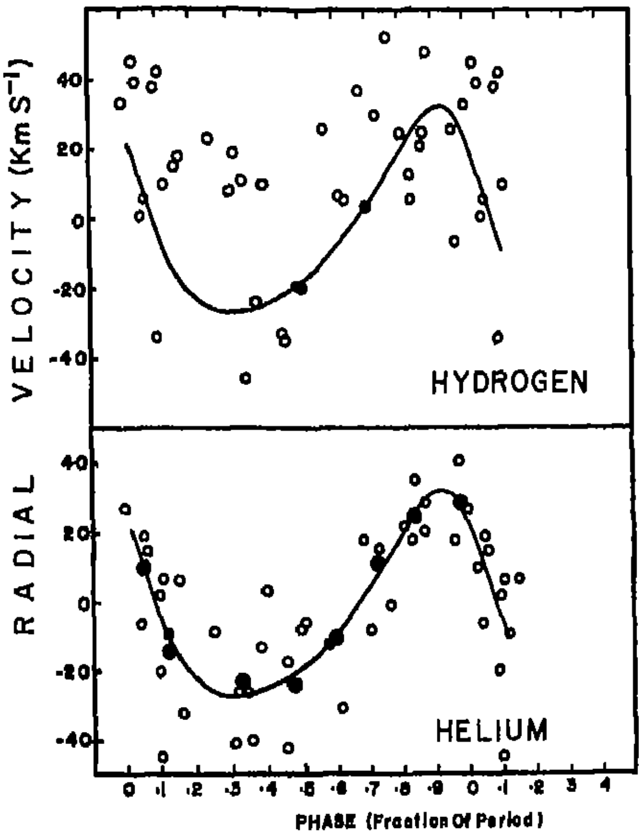

Figure 1. Radial velocity curve of ν Centauri. The open circles refer to measured velocities. The normal points used in deriving the new orbit are shown as filled circles. The continuous line refers to the computed curve from the final elements. The behaviour of hydrogen and helium lines are shown separately.

residuals are plotted against this period of 0.1750 days in Figure 2. This value of the period can at best be only provisional since observations are spread over a long interval of time and more than one dominant period seems to be present.

The presence of more than one dominant period is also suggested by the radial velocity observations of 1974 April 26. The measured radial velocities (mean of the hydrogen and helium lines) from fourteen spectra taken within an interval of four hours fit in very closely a period of 0.1750 days but the amplitude is only of the order of 10 km s^{-1} while the maximum amplitude of the residuals plotted in Figure 2 is of the order of 45 km s^{-1}. ν Centauri seems to be pulsating with at least two dominent periods close to 0.1750 days like other well known β Cephei type variables exhibiting multiple periodicities.

The position of ν Centauri in the H R diagram can be found from the observed UBV colours and the absolute magnitude derived either from astrometry or

Table 4. Orbital elements of Nu Centauri

R. E. Wilson	Present
P = 2.62516 days	2 625275 days
V_o = 8.06 ± 0 64 km s^{-1}.	-2.8 km s^{-1}.
K = 20.63 ± 0.77 km s^{-1}.	29.9 km s^{-1}.
e = 0.00	0.26
ω = –	44°.64
T = 2420301.39 ± 0 015 days	JD 2440855.608

the hydrogen line strengths. ν Centauri is a member of the Scorpio-Centaurus association. The absolute visual magnitude of ν Centauri derived from proper motions ranges from -2.0 (Jones, 1971) to -2.9 (Bertiau, 1958). Part of this difference is caused by the different fundamental systems of proper motions utilised by these two investigators. The measured equivalent width of H γ from two of our spectra is 4.8 Å leading to a value of M_v = -2.9 magnitudes. The H γ - M_v relationship used is that due to Balona and Crampton (1974). The photoelectric β index measured by Moreno and Moreno (1968) is 2.639 leading to M_v = -2.7 magnitudes when we utilise the calibration of Crawford (1973).

From the Q - θ_e relationship given by Lesh and Aizenmann (1973) and the photoelectric measures of Moreno and Moreno (1968) we derive θ_e = 0.235. A value of M_v = -2.8 and θ_e = 0.235 places ν Centauri within the β Cephei instability strip whereas Jones' (1971) value of M_v = -2.0 would move it out of the instability strip by more than 0.7 magnitudes. Also a value of M_v = -2.8 is consistent with the spectral type B2 IV assigned to ν Centauri.

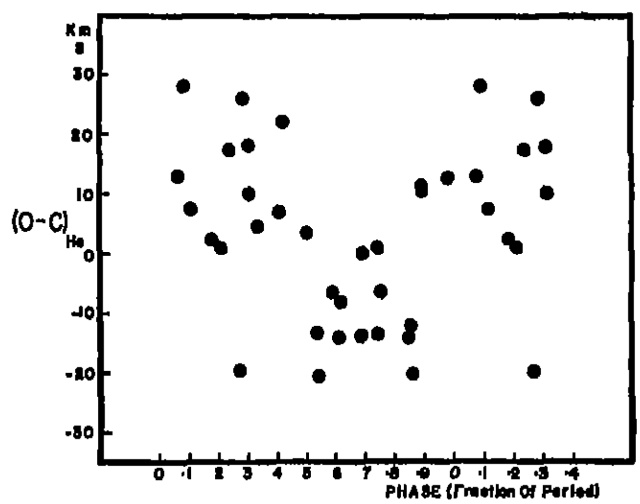

Figure 2. The residuals from helium lines plotted against period of 0.1750 days.

Though one finds normal stars too in the β Cephei instability strip, the radial velocity observations presented here strongly suggest that the primary component of ν Centauri is a β Cephei type variable. An inspection of the spectrograms also shows that the lines are broader than normal on a few plates, strongly suggesting the validity of this conclusion. Indeed these observations demonstrate that the primary component pulsates with a period of 0.1750 days. The fact that this period is exactly one fifteenth of the orbital period is intriguing. Extensive photoelectric and spectrographic observations to determine the exact values of the various periods of oscillations and the effects of gas streams as suggested by the behaviour of He I λ 3965 are necessary for further study of this interesting system.

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References

Bailey, S.I., 1895, *Havard Annals.*, 34, 214.

Balona, L., Crampton, D., 1974, *Mon. Not. R. astr. Soc.*, 166, 203.

Bertiau, F.C., 1958, *Astrophys. J.*, 128, 553.

Crawford, D.L., 1973, IAU Symposium No. 54, *Problems of Calibration of Absolute Magnitudes and Temperatures of Stars*, p. 93, eds. B. Hauck & B.E. Westerlund, D. Reidel, Publ. Co., Dordrecht, Holland

Jones, D.H.P., 1971, *Mon. Not. R. astr. Soc.*, 152, 231.

Lesh, J.R., Aizenmann, M.L., 1973, *Astron. Astrophys.*, 22, 229.

Moreno, A. G., Moreno, H., 1968, *Astrophys. J. Suppl. Ser.*, 15, 459.

Palmer, H. K., 1906, *Lick Obs. Bull.* 4, 97.

Rajamohan, R., 1973, *Proceedings of the Symposium on "Spectroscopic Studies of Astrophysical Interest"*, p. 121, eds. K. D. Abhyankar and P.K. Asundi, centre for advanced study in astronomy, Hyderabad.

Schlesinger, F., 1908, *Publ. Allegheny Obs.*, 1, 33.

Slettebak, A., 1968, *Astrophys. J.*, 151, 1043.

Sterne, T., 1941, *Proc. Nat. Acad. Sci. Am.*, 27, 175.

Wilson, R E , 1914, *Lick Obs. Bull.*, 8, 130.