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HON. CHARLES STEWART, *Minister*

W. W. CORY, C.M.G., *Deputy Minister*

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OTTAWA

R. MELDRUM STEWART, M.A., *Director*

Vol. IX

Astrophysics

No. 4

THE SPECTROSCOPIC SYSTEM NU ERIDANI

BY

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THE SPECTROSCOPIC SYSTEM NU ERIDANI

BY F. HENROTEAU, D.S.C.

The star ν Eridani ($\alpha = 4^{\text{h}} 31^{\text{m}}.3$, $\delta = -3^{\circ} 33'$) was discovered by the writer to be of the β Canis Majoris type.¹ As early as 1920 the short-period oscillation of radial velocity was recognized, as well as the large variation of amplitude of the oscillation, this being from 26 to 70 kilometres. The necessity of studying this star more thoroughly was recognized, and when the study of δ Ceti was completed as far as possible, ν Eridani was put on the observing list, and spectrograms were made every clear night between October 15, 1923, and January 23, 1924, as well as between October 1, 1924, and January 14, 1925.

The radial velocity determinations as obtained between these dates are given in Table I. The spectrograms were measured on the spectro-comparator, using the same standard spectrogram of β Canis Majoris as was used previously for other early class B stars.

It should be noted that the dates throughout have been entered on the basis of the day beginning at noon; this is to conform with the resolution adopted at the Cambridge meeting of the International Astronomical Union (1925) that the Julian day would still be counted as formerly.

The velocity curves plotted from these measures show not only a considerable variation in amplitude, but also marked differences in the inclinations of their different branches. Sometimes a very rapid rise is found, at other times a more gradual one.

If any variation of centre-of-mass velocity from curve to curve is present it is small and difficult to detect, being masked by the great variation in amplitude.

In spite of a long and systematic search, no period could be found to connect the different maxima or minima of the individual velocity curves.

Figures 1 and 2 exhibit graphically the distribution of radial velocities with respect to time on twelve different dates. The successive points have been connected by straight lines.

For the curves which are well determined amplitudes have been estimated, and a period of $7^{\text{d}}.9444$ was found which may possibly be that of variation of amplitude. The data used for this purpose are exhibited in Table II, where the first column gives the approximate Julian date of the observed amplitude, the second column its phase computed from the formula, Maximum = J.D. 2424066.7 + $7.9444E$, and the third the estimated amplitude. These have been plotted according to phase in figure 3, the curve having been drawn more or less arbitrarily to satisfy the observations.

¹ Pub. Dom. Obs., Vol. V, p. 56.

TABLE I—RADIAL VELOCITIES OF ν ERIDANI

Date	Julian Day	Velocity km.	Date	Julian Day	Velocity km.
1923 Oct. 15....	2423708.774 .807 .837 .871 .903	— 6.6 +12.5 +26.2 +27.8 +23.2	1923 Nov. 1.... Nov. 2....	2423725.824 2423726.642 .676 .712 .735	+ 3.8 — 2.1 — 3.3 + 6.4 +26.0
Oct. 16....	2423709.732 .762 .791 .820 .849	+46.5 +27.2 + 3.3 — 12.1 + 6.4		.758 .783 .803 Nov. 8.... 2423732.649 .669	+33.3 +40.1 + 8.6 +59.7 +44.9
Oct. 17....	2423710.712 .746 .776 .803 .831 .858 .890 .924	— 5.3 +26.0 +32.3 +37.4 +21.5 — 1.4 + 6.9 +17.7		.701 .718 .740 .769 .797 .822 Nov. 13.... 2423737.642 .664	— 14.0 — 9.9 — 14.4 +18.8 +39.6 +58.0 +31.2 +25.6
Oct. 21....	2423714.785 .837 .860 .881 .904	+23.5 — 7.2 — 1.4 + 5.4 +19.4		.717 .746 .799 Nov. 18.... 2423742.659 .714	+ 3.8 — 1.8 +22.1 +10.4 +40.4
Oct. 22....	2423715.697 .727 .752 .774 .794 .812 .831 .851 .877	—11.9 —10.1 +10.4 +29.9 +34.2 +48.0 +38.1 + 5.4 —12.3	Nov. 22....	2423746.604 .633 .662 .712 .741 .769 .818 Nov. 25.... 2423749.590 .624	+26.6 + 7.1 +14.3 +26.3 +19.4 +10.8 +10.4 + 9.9 +22.0
Oct. 26....	2423719.671 .697 .723 .746 .767 .790 .815 .841 .865 .892	+25.2 +16.3 + 0.9 + 4.1 +19.6 +19.8 +20.2 +27.1 +20.8 + 8.6		.654 .712 .740 Dec. 3.... 2423757.671 .581 .610 .636 .664	+50.2 +40.7 —11.6 +12.3 —12.6 +24.9 + 0.2 + 6.1 +13.0 +21.9
Oct. 28....	2423721.703 .724	+30.2 +12.4		.736 .767 .799 Dec. 9.... 2423763.557 .581	+ 8.5 + 0.4 + 4.2 + 1.7
Oct. 29....	2423722.772 .797 .820 .847 .876	+14.4 — 8.6 — 3.0 +16.2 +21.8	Dec. 11....	2423765.543 .569 .599 .661 Dec. 14.... 2423768.548 .585	+22.6 +40.8 —12.9 +16.4
Nov. 1....	2423725.648 .667 .716 .739 .760 .783 .803	— 0.4 +17.2 +55.6 +51.0 +13.1 — 9.2 — 8.6		.612 .638 .664 .705	+17.8 +13.1 — 2.2 + 0.7 +24.7

TABLE I—RADIAL VELOCITIES OF ν ERIDANI—Continued

Date	Julian Day	Velocity km.	Date	Julian Day	Velocity km.
1923 Dec. 14....	2423768.734 .763 .791	+25.6 +24.5 + 7.7	1924 Jan. 21.... Jan. 23....	2423806.571 2423808.450 .472 .497 .528 .556 .585 .614 .643 .675 .703 .732 .776 .797 .817 .835 .855 .876 .896 .914	+49.6 +27.1 +33.1 +32.2 +14.8 - 0.1 + 7.8 +15.1 +30.0 +37.4 +10.2 +37.9 +22.9 +14.2 - 3.6 -15.3 - 4.4 + 8.2 +24.6 +27.2
Dec. 17....	2423771.541 .567 .596 .623 .649 .678 .707 .733 .761 .790	+10.3 - 5.0 -10.1 + 5.5 +33.8 +42.1 +29.8 - 9.2 -13.0 + 0.8	Oct. 1....	2424060.752 .776 .797 .817 .835 .855 .876 .896 .914	+37.9 +22.9 +14.2 - 3.6 -15.3 - 4.4 + 8.2 +24.6 +27.2
Dec. 18....	2423772.632	-12.7			
Dec. 19....	2423773.548 .578 .609 .640 .672 .705	+ 7.1 +19.6 +28.4 + 2.5 - 4.7 - 4.3	Oct. 2....	2424061.760 .807 .831 .858 .888	+ 9.4 +29.1 +25.6 + 6.7 -10.4
Dec. 23....	2423777.594 .654 .704 .731 .754 .778	+15.1 - 7.2 +22.6 +41.2 +38.8 + 0.9	Oct. 3....	2424062.728 .753 .776 .799 .822 .848 .876 .903	+15.5 + 8.2 +15.3 +15.8 +21.4
Dec. 29....	2423783.616 .641 .668 .725	+18.2 +19.4 + 5.2 + 1.1			
1924 Jan. 1....	2423786.497 .524 .552 .581 .610	-21.0 -12.2 +22.0 +41.9 +45.7	Oct. 5....	2424064.767 .792	+26.0 +14.9 + 4.6 +11.5 - 9.5
Jan. 3....	2423788.519 .549 .597 .618 .639 .697 .751	+44.8 +33.7 -18.7 - 3.6 + 4.2 +49.7 - 1.4	Oct. 7....	2424066.756 .820 .920 .797 .819 .842 .865	-14.9 +29.9 - 1.2 +23.5 +48.8 +33.0 + 8.6
Jan. 7....	2423792.475 .500 .528 .548 .625 .651	+36.8 +23.2 + 7.9 + 5.0 +16.5 +25.5	Oct. 8....	2424067.724 .746 .767 .790 .813	+18.0 -10.7 -11.2 - 7.9 +11.2*
Jan. 14....	2423799.491 .518 .544	+16.9 + 8.6 + 4.0			
Jan. 21....	2423806.476 .501 .526 .547	-10.9 + 9.2 +26.9 +41.5	Oct. 9....	2424068.717 .743 .765 .785	+31.1 +32.7 +37.1 + 6.2

*Remeasured +16.5.

TABLE I—RADIAL VELOCITIES OF ν ERIDANI—Continued

Date	Julian Day	Velocity km.	Date	Julian Day	Velocity km.
1924 Oct. 9....	2424068.810 .830 .854 .879	- 1.0 + 4.1 + 7.1 +17.2	Oct. 23....	2424082.719 .744 .766 .816	+ 3.7 +11.1 +16.1 +35.0
Oct. 10....	2424069.710 .736 .760 .782 .801 .826 .851 .876 .903	+ 8.6 +28.9 +27.9 +15.8 +10.7 + 7.0 - 2.4 + 5.3 +17.4	Oct. 24....	2424083.703 .731 .760 .792 .824 .880	+18.0 +10.3 - 3.2 +22.4 +11.9 +11.3
Oct. 12....	2424071.712 .733 .753 .772 .793 .814 .835 .856 .876 .897 .919	+10.0 - 7.7 -16.4 - 1.7 +17.2 +28.0 +22.4 +34.3 +15.1 - 6.5 - 8.4	Oct. 26....	2424085.699 .726 .751 .773 .794 .815 .835 .857 .906	+16.0 +20.6 + 1.4 - 8.4 + 0.1 - 4.3 +12.6 +29.2 +18.3
Oct. 13....	2424072.715 .741 .760 .780 .800 .822 .843 .868	+33.6 +34.7 + 9.1 -11.5 -10.0 + 1.9 +17.9 +29.0	Oct. 27....	2424086.710 .734 .756 .779 .799 .806 .834 .862	+10.9 +33.1 +42.1 +40.9 + 5.8*
Oct. 16....	2424075.787 .808 .827 .846 .863 .881 .900 .919 .937	+ 5.1 +23.2 +29.1 +23.5 +24.9 +14.4 +11.4 + 5.1 + 0.7	Oct. 28....	2424087.769 .796 .821 .844 .867 .890 .915	+22.0 +48.5 +52.2 +14.6 -11.1 -18.8 - 4.6
Oct. 17....	2424076.715 .740 .762 .781 .798 .817	+16.5 +11.9 +12.9 + 9.0 + 5.2 +17.3	Oct. 29....	2424088.721 .738 .759 .776 .793 .810 .829	+ 0.2 -16.1 - 8.7 -14.9 - 2.1 +17.7 +34.4
Oct. 19....	2424078.749 .771 .792 .810 .849 .872 .894 .917	+27.4 +42.7 +43.3 +25.2 - 6.0 - 6.9 + 9.9 +31.4	Nov. 7....	2424097.697 .726 .748 .770 .792 .815 .837 .859	+47.4 +44.9 +13.0 - 9.5 +48.2 -20.0 - 2.4 +20.0 +29.4 +37.7 +28.6 + 4.8 -11.3 - 4.2
<hr/>					

*Remeasured +1.9.

TABLE I—RADIAL VELOCITIES OF ν ERIDANI—Continued

Date	Julian Day	Velocity km.	Date	Julian Day	Velocity km.	
1924 Nov. 10....	2424100.739 .763 .787 .810 .835 .862	− 8.1 + 1.8 +10.6 +23.2 +35.6 +33.3	1924 Nov. 30....	2424120.641 .659 .705 .725 .803 Dec. 4....	− 3.7 + 2.3 + 0.6 +14.6 + 8.8 +18.8	
Nov. 12....	2424102.597 .618 .637 .655 .697 .714 .733 .752 .772 .791 .811 .833 .855 .878	+15.1 +18.0 + 2.2 + 9.9 +12.7 +26.1 +15.6 +19.6 +21.0 +12.3 + 0.4 + 0.4 + 9.4 +23.4		.601 .620 .657 .709 .729 .752 .772 .794 Dec. 11....	+34.6 +29.6 + 5.1 + 6.7 + 5.0 +22.9 +22.9 +26.0 +16.7 +20.9 +10.5 + 1.9 − 2.5 + 5.3	
Nov. 16....	2424106.660 .700 .715 .731 .752 .776 .803 .828 .851 .874	+ 5.4 +37.2 +44.0 +56.4 +30.4 −15.7 −19.5 + 2.1 +15.1 +39.1	Dec. 14....	2424134.622 .644 .676 .709 .748 .770 Dec. 15....	+23.6 +47.6 +29.5 − 4.2 − 1.4 + 3.7 +47.7 + 6.1 +11.2	
Nov. 17....	2424107.597 .615 .632 .645 .660 .699 .714 .731 .748 .767 .791 .812 .831 .849	+55.6 +46.2 +24.3 −13.2 −21.3 −14.2 + 1.5 +16.4 +29.1 +48.6 +40.5 − 7.9 + 0.9 −17.4	Dec. 21....	2424141.533 Dec. 28....	.614 .635 .658 Dec. 31....	+ 2.1 + 7.1 +14.1 +16.4 + 1.1 + 6.6 +15.0 +29.5 +22.8 + 1.6 +17.7 −12.0 − 5.4 − 8.8
Nov. 18....	2424108.629	+29.5			.603	
Nov. 27....	2424117.699 .715 .731 .748 .766 .784 .805	+36.8 +19.4 − 4.2 − 4.8 − 0.1 + 9.5 +17.8			.619 .635 .649 .703 .731 1925 Jan. 6....	+29.7 +34.2 +39.2 + 6.7 −16.5 + 0.5
Nov. 28....	2424118.705 .720	+15.2 +13.0	Jan. 11....	2424157.509 2424162.501	−17.7	
Nov. 30....	2424120.601 .622	+30.8 +13.2		.520 .540 .559 .578	− 9.7 − 0.6 +28.3 +44.6	

TABLE I—RADIAL VELOCITIES OF ν ERIDANI—Concluded

Date	Julian Day	Velocity km.	Date	Julian Day	Velocity km.
1925 Jan. 11....	2424162.598 .619 .639 .658 .707	+50.6 +40.0 -12.1 -13.7 - 4.7	Jan. 14....	2424165.520 .541 .562 .582 .624 .646	+ 8.8 +17.9 +18.2 +28.6 +20.4 - 5.7

TABLE II—AMPLITUDES OF INDIVIDUAL CURVES

Julian Day	Phase	Observed Amplitude	Julian Day	Phase	Observed Amplitude
2423709.7.....	d. 0.5	km. 55	2424067.9.....	d. 1.2	km. 56
710.7.....	1.5	45	068.7.....	2.0	40
714.7.....	5.5	43	069.8.....	3.1	28
715.8.....	6.6	60	071.9.....	5.2	54
719.8.....	2.7	30	072.7.....	6.0	50
725.7.....	0.6	63	078.8.....	4.2	58
726.7.....	1.6	43	087.9.....	5.3	72
732.8.....	7.7	78	088.9.....	6.3	68
768.8.....	4.0	30	106.8.....	0.4	77
771.1.....	6.9	54	107.8.....	1.4	74
785.6.....	4.9	66	124.6.....	2.3	34
788.7.....	0.1	70	151.7.....	5.6	54
808.5.....	4.0	40	162.7.....	0.7	56

Of all stars of the β Canis Majoris type studied up to the present, ν Eridani is the one that shows the greatest amplitude variation of the radial velocity curve. It contrasts sharply with σ Scorpis, where there is apparently no amplitude variation, but a considerable variation of centre-of-mass velocity.

If we assume the short-period effect to be a physical one, and that in addition there is a secondary revolving about the primary in a period of $7^d.9444$, it follows that what has been called above the variation in centre-of-mass velocity represents simply the velocity of the primary in its orbit about the centre of mass of the system. Since this variation is too small to be easily detected, it is evident (on the assumption that the short-period effect is physical) that if a secondary exists it must be either very small or, more probably, very close to the primary; on the latter supposition it would cause strong tidal action on the primary, which might go far towards explaining the irregularities both in amplitude and in the shape of the curve.

The tentative explanation along these lines, which may be taken for what it is worth, would then be that the primary has an unsymmetrical figure of equilibrium, which may perhaps be most easily visualized as a Jacobian ellipsoid. The rotation of this unsymmetrical figure would give a short-period radial velocity curve, which would be

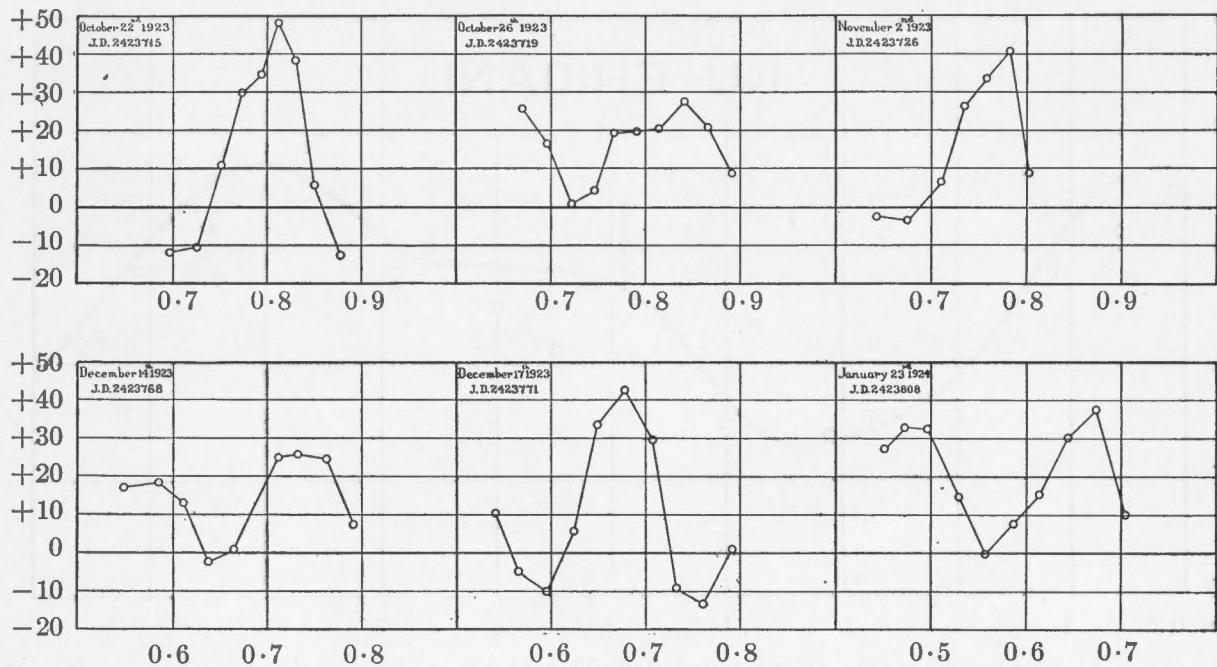


FIG. 1 Radial Velocities of Nu Eridani, 1923

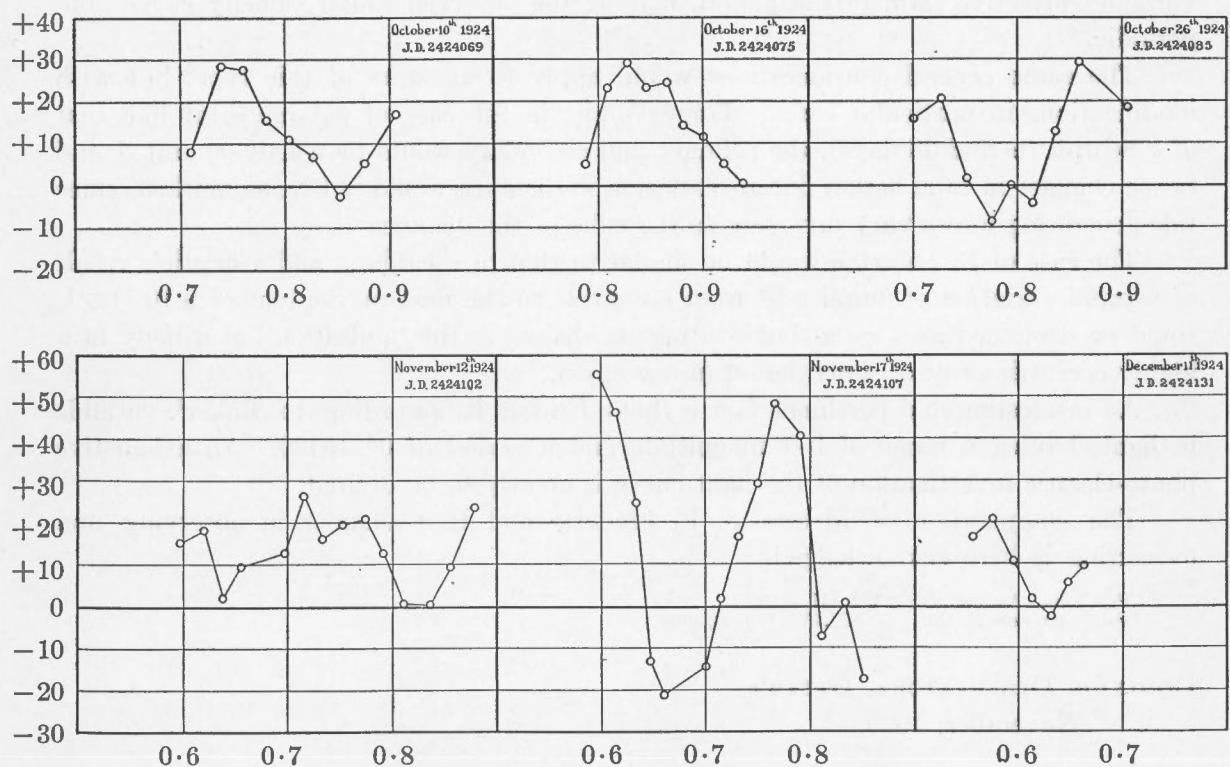


FIG. 2 Radial Velocities of Nu Eridani, 1924

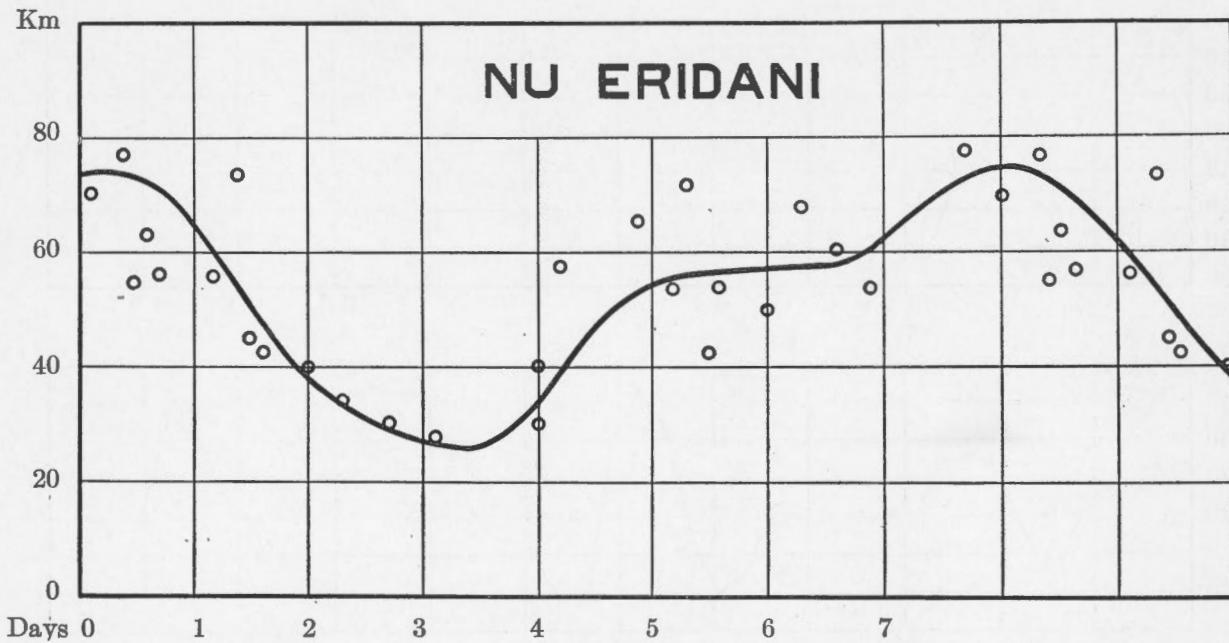


FIG. 3 Amplitudes of Nu Eridani

regular if uncomplicated by tidal action; the effect of the latter, however, caused by a near companion in a highly elliptical orbit, would give rise to a variable amplitude, whose maximum would correspond to periastron; the same causes would give rise to a variable corrective term in the period, making the observed radial velocity curve non-periodic.

The same general considerations would apply to all stars of this type, but with modifications in particular cases. For example, in the case of a large orbit like that of σ Scorpis (period 33 days), the primary and secondary would be widely separated, and hence changes in tidal action due to variation in distance would not be so marked, since tide-generating forces vary inversely as the cube of the distance.

The case of 12 Lacertae would be similar to that of ν Eridani, and Christie's result of a rapid variation of amplitude² from one cycle to the next on September 9-10, 1924, could be explained as a rapid but continuous change in the "pulsation" of a body in a highly eccentric orbit of short period (a few days).

An interesting and pertinent fact is that ν Eridani is, according to Baker³, variable in light, having a range of 0.1 magnitude and a period of $0^d.15430$. An exhaustive photo-electric investigation of the light curve is greatly to be desired.

The co-operation of Messrs. J. F. Frédette and R. Callander in observing and measuring is here acknowledged.

² Pub. Dom. Astroph. Obs., Vol. III, p. 223.

³ Pub. Astr. Soc. Pacific, Vol. XXXVIII, p. 93, 1926.

DOMINION OBSERVATORY, OTTAWA,
November, 1926.

