1985JAVSO..14....8P

VISUAL AND PHOTOGRAPHIC ORBITAL MEAN LIGHT CURVES OF THE RECURRENT NOVA T CORONAE BOREALIS

MICHAEL PEEL
17 Manor Close
Hoghton
Preston PR5 0EN
England

Abstract

Mean orbital light curves of T CrB at quiescence are derived from previously unreduced 1872-1904 visual estimates of T. W. Backhouse and partly concurrent Harvard photographic observations. They agree in showing ellipsoidal minima with different depths, an irregularity near where hot-spot influence might be expected, and primary minima not midway between secondary minima. A marginally refined orbital period of 227.52 ± 0.05 days is suggested.

* * * * *

1. Introduction

Between 1866 and 1904 the British amateur astronomer T. W. Backhouse made 405 quantifiable, but previously unreduced, visual estimates of the brightness of the recurrent nova T CrB (1866, 1946), mostly with a 4-inch Cooke refractor at Sunderland, Co. Durham. T CrB is today generally considered to be an interacting binary system consisting of a hot primary star into whose vicinity a lobe-filling red giant secondary is shedding material. Bailey (1975) used visual and Harvard photographic photometry to derive an orbital period of 227.64 ± 0.1 days, based on the light variations ascribed to the ellipticity effect. His visual mean curve, made from British Astronomical Association Variable Star Section pooled estimates showed primary and secondary minima of equal depth. Orbital inclination was estimated to be not more than 68°. Previous determinations of the orbital period, among them an estimate of 227.5 ± 0.15 days (Paczynski 1965), used spectroscopic observations of radial velocity.

2. Reduction of the Backhouse Estimates

The visual estimates (Backhouse 1905), usually one set on each observing night, were made by both the Argelander step method and the fractional method. On many nights, step intercomparisons of the comparison stars were recorded in addition to those involving the variable. Although Argelander steps, unlike Pogson steps, are not intended to be constant from night to night, I have used them as if they were. All available step estimates were used to arrive at "Backhouse" magnitudes for comparison stars. That is, I listed all direct step comparisons between comparison stars and also all indirect comparisons between a pair of comparison stars when both had been compared directly with the variable. This allowed the preparation of a list of comparison stars in order of brightness with the mean intervals between them measured in Backhouse steps. Backhouse used idiosyncratic and varying ways of recording step differences, including not just numbers but also punctuation marks (e.g.",", ";", and ":") and words (e.g."equal", "scarcely", "barely", "slightly", and "rather"). In the introduction of his book he provides a translation of these symbols in terms of step numbers.

To assign magnitudes to Backhouse's comparison stars, the most frequently used pair of them, BD +26°2761 and BD +26°2764, were given the magnitudes in the current BAA Variable Star Section comparison chart, namely $9\overset{\mathrm{m}}{.}76$ and $10\overset{\mathrm{m}}{.}06$, respectively. This is notwithstanding the fact that Backhouse several times records the impression that the interval between these stars is less than usual. The magnitudes for Backhouse's other comparison stars were based on these standards. The mean value of a Backhouse step is a remarkably small $0\overset{\mathrm{m}}{.}046$.

Once the comparison star sequence was available, the variable star measures were reduced with a computer program capable of handling both step and fractional estimates. When both methods were used on a single night, each carried the same weight in calculation of the mean. Backhouse was rarely content with just one step estimate on a given night, though he often limited himself to a single fractional estimate.

3. Orbital Period

There was a drop of $0\overset{\mathrm{m}}{.}29$ in annual mean magnitude between 1871 and 1872, which was taken to signal the end of the post-nova secondary maximum outburst activity, begun in 1866, and the restoration of quiescence. The annual mean magnitude for 1872 was only $0\overset{\mathrm{m}}{.}05$ brighter than the overall mean for 1872 to 1904. Data between 1866 and 1871 were excluded from further consideration.

A periodogram search (Warner and Robinson 1972) of the 322 data points between 1872 and 1904 shows a high peak at 227.8 ± 1.5 days.

Six minima are well enough discernible in the plot of visual magnitude against Julian date to be dateable. Table I lists these dates, with type of minimum, subjectively assigned weight, and orbital period derived by comparison with a 1956 absorption line spectroscopic conjunction on Julian date 2435687 ± 2 (Paczynski 1965), assuming an unchanged orbital period. The orbital period of 227.5 days found by Paczynski was relied upon to give the cycle count and type of minimum. The weighted mean orbital period derived is 227.52 ± 0.05 days.

Taking outburst dates in 1866 and 1946 as Julian dates 2402734 and 2431860 (Campbell 1947), respectively, this period fits 128.015 ± 0.03 orbits between outbursts. An exact fit is certainly not ruled out. An approximate fit here has previously been noted by J. E. Isles (Webbink 1977).

4. Quiescent Light Curves

The visual mean curve in Figure 1 shows primary and secondary minima with depths of $0\overset{\mathrm{m}}{.}21$ and $0\overset{\mathrm{m}}{.}17$, respectively. The shallower minimum, near phase 0.0, has the hot primary star and the extended lobe of the red giant irradiated by it directed towards the observer. (Note that while the position of zero phase in Figure 1 conforms with that in Paczynski's radial velocity diagram, it defies the convention in eclipsing binary light curves in which zero phase is located at primary minimum, when the hotter star is eclipsed.)

Unlike the photographic mean curve shown by Bailey, the curve in Figure 1 uses only the 236 Harvard data (Anon. 1920) between 1892 and 1911, a time of evident quiescence. It omits data from in and around 1913 and 1914, when there were minor outbursts. (On Julian dates 2419912 and 2420269 the star reached $10\overset{\mathrm{m}}{.}55$, respectively 5.7 and 3.6 standard deviations brighter than the mean magnitudes of the 10% phase bins centered around the phases for these dates in Figure 1 quiescent data).

The photographic curve shows primary and secondary minima with depths of $0\overset{\mathrm{m}}{.}50$ and $0\overset{\mathrm{m}}{.}26$. This difference, corroborated by the visual curve, suggests for the first time the presence of the reflection effect in this star.

The two primary minima are not positioned midway between the secondary minima, being some 0.02 or 0.03 phase units closer than this to the secondary minima following. This appears to be the first evidence for orbital eccentricity in this system.

The approximately 15% dip in the photographic light curve near phase 0.85 (with an apparently corresponding irregularity nearby in the visual curve), about 54° of orbital revolution before conjunction, may indicate some kind of obscuration of a hot-spot. Use of a piece of tracing paper reveals an interesting degree of symmetry in the photographic light curve about zero phase, showing an A, B, C, B, A equivalence between features near phases 0.75, 0.9, 0.0, 0.1, and 0.25.

5. Acknowledgements

I wish to thank Dr. E. N. Walker for patient help and discussion, while absolving him of responsibility for the views expressed here. Mr. D. McAdam kindly supplied a photograph of the T CrB field to help in establishing the sequence. This article is entirely dependent on the remarkable but neglected observations of T. W. Backhouse.

REFERENCES

Anon. 1920, *Ann. Harvard Coll. Obs.* *84*, 121.

Backhouse, T. W. 1905, *Observations of Variable Stars made in the Years 1866-1904*, Sunderland.

Bailey, J. 1975, *Journ. Brit. Astron. Assoc.* *85*, 217.

Campbell, L. 1947, *Pop. Astron.* *55*.

Paczynski, B. 1965, *Acta Astron.* *15*, 197.

Warner, B. and Robinson, E. L. 1972, *Month. Not. Roy. Astron. Soc.* *159*, 101.

Webbink, R. F. 1977, *Brit. Astron. Assoc. Var. Star Sec. Circ.* *32*, 1.

TABLE I

Visual Minima Observed by Backhouse

JD (2410000+)	Type	Weight	Derived Period
4858	I	5	$227^{d}.520$
4970	II	1	227.533
7591	I	3	227.498
7820	I	3	227.486
8838	II	1	227.534
8942	I	1	227.617
			227.52 mean

TABLE II

Adopted Magnitudes for Backhouse's Comparison Stars for Figure 1 Estimates

Backhouse Designation	BD Catalog Number (or position)	Magnitude
k	BD +26 2758	9.532
f	BD +26 2761	9.76
h	BD +26 2756	9.912
l	BD +26 2764	10.06
v	BD +26 2759	10.292
w	(8' sf f)	10.578

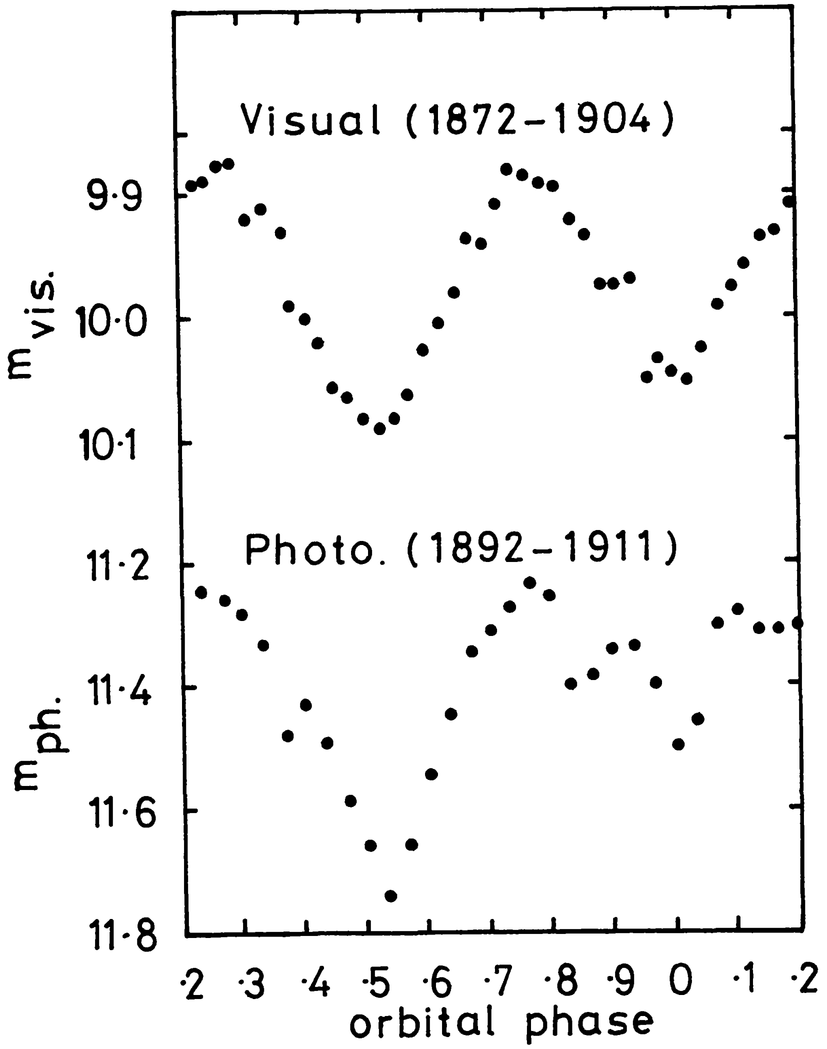

Figure 1. Mean orbital light curves for the quiescent T CrB for period 227.52 days. The visual curve uses 322 Backhouse estimates in 2 groups of 21 phase bins, the second group shifted 1/2 bin width and overlapping the first. The photographic curve uses 236 Harvard observations in 2 groups of 15 bins. 40 of the Backhouse observations fell between 1892 and 1904 and so are concurrent with the Harvard series. Epoch for the phase is Julian date 2400194, chosen arbitrarily, and the ephemeris is $JD_{(Min\ II)} = 2400194 + 227.52\ E$.