Ross 4—A Possible Recurrent Nova?

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Abstract Archival photographic data have been used to study the suspected variable Ross 4 = NSV 1436. The star is found generally to be fainter than 15th magnitude but occasionally becomes brighter than 13. The available data suggest the object is a cataclysmic variable, possibly of the recurrent nova type.

1. Introduction

Between 1925 and 1931 F. Ross of Yerkes Observatory published ten lists of suspected new variable stars. Now known as the Ross variables, these objects were discovered when Ross compared photographic plates he had taken with plates taken with the same telescope some ten to twenty years earlier by E. E. Barnard.

The plates were taken with a telescope that actually consisted of three instruments on the same mounting: 10-inch and 6-inch refractors for photographs and a guide telescope (Barnard 1905). Because both Barnard and Ross obtained simultaneous exposures with the 10-inch and 6-inch telescopes, Ross could confirm that a suspected variable was not a plate defect. This was particularly important in the many cases when the object was clearly visible at one epoch but not seen at the other.

Most of the Ross variables have since been confirmed, while a few of the suspects seen at just one epoch have been found to be minor planets (Bedient 2003; Marsden 2007). There remain, however, a number of objects that are still unconfirmed or for which the variability is uncertain. One of these is Ross 4 (NSV 1436). This was one of the first variables Ross discovered, when he noticed that an object located at R.A. $03^h\ 54^m\ 01^s$, Dec. +42° 29.5' (1875) was at 11th magnitude on Barnard's plate taken 1904 November 1 but only 15th magnitude on his comparison plate of 1925 Jan. 14 (Ross 1925). Ross 4 is seen as a blend of two close stars on the digitized Palomar Sky Survey.

Bedient (2004) was the first to notice that the Ross 4 coordinates precessed to J2000 (R.A. $04^h\ 02^m\ 38^s$, Dec. +42° 50' 38") coincide with those of an X-ray

source (1RXS J040239.4+425037). He gathered brightness data from archival images as well as from new observations with the Hawaii 2.2-m telescope. The 2.2-m images showed the star blend is composed of three stars in a line running roughly north-south. All archival data identified by Bedient showed Ross 4 below 15th magnitude. The magnitudes from the recent images, presumably from CCD photometry, had it varying between 16 and 19.

Because Yerkes Observatory has the original discovery plates, as well as a number of other images of this field, we decided to review this material to confirm the exceptionally bright 1904 observation and to see what could be learned about this star.

2. Observations

We first verified Ross's findings. We used his own identification card and his markings on the 1925 plate to unambiguously identify the star and confirm his coordinates. The star was indeed bright on the two 1904 plates taken with the 10-inch and 6-inch cameras and faint on both 1925 plates. We next established a comparison sequence to be used to make eye estimates of the variable. A print was made of the field and ten nearby stars that ranged in *B* magnitude from 11.7 to 17.3 were selected. The *B* magnitudes were determined from the *Tycho* catalogue (Høg *et al.* 2000) when available, otherwise by averaging the values in the *USNO B1.0* (Monet *et al.* 2003) and *GSC 2.3* (Bucciarelli *et al.* 2008) catalogues. Our comparison stars and adopted magnitudes are given in Table 1. We believe the relative magnitudes of our sequence are accurate to 0.2m, but there may be a zero point error that is larger.

The Yerkes plate collection contains plates taken with the various Yerkes telescopes as well as a number of plate sets from instruments at McDonald Observatory, Dearborn Observatory, and the University of Illinois Observatory. We were able to locate the field of Ross 4 on eighty plates taken with five different instruments. All but six of the plates are unfiltered blue (photographic) exposures. Ross also recorded one visual observation with the Yerkes 40-inch refractor. The observation dates ranged from 1904 to 1952, but a sizable number of the plates are pairs taken on the same night. While some shorter-exposure plates only go to about $B = 12$, most plates recorded stars fainter than $B = 14.5$ and the forty-three deepest plates reach $B = 15.5$–17.

The magnitude of Ross 4 (or its upper brightness limit) was estimated independently by three of us. Estimates were made by linearly interpolating between two convenient comparison stars when the star was seen, otherwise by determining the faintest comparison star visible. Ross 4 and its two companion stars are blended on our plates and our estimates correspond to their combined light. The adopted magnitudes along with the corresponding heliocentric Julian Dates are given in Table 2. We estimate they have uncertainties of 0.3m relative to the comparison sequence. The few estimates not from blue sensitive plates are given at the end of the table.

3. Results

The derived light curve is shown in Figure 1. Points indicate magnitudes where the blended stars were seen; dashes indicate a few of the "fainter-than" limits. One sees that the Ross 4 blend is usually below 15.8m but there are occasional outbursts when the star becomes brighter than 13m. In particular, two outbursts were observed—the one in 1904 and another in 1948. The 1904 event was recorded only on two plates taken simultaneously with the 10-inch and 6-inch cameras. The 1948 outburst was recorded on three plates taken on two different nights. There is some suggestion of variability during quiescence. The few visual, photovisual, and red observations give little useful information.

The 1948 pre-outburst, outburst, and post-outburst observations provide some sparse data on the eruption time scale. These data are plotted in Figure 2. On HJD 2432852 the star was at about 16.5. The next observation was thirty-three days later when the star was at 12.7. The brightness had fallen to 14.3 two days after and 109 days after maximum the star was again fainter than 15.5. Thus, the duration of the outburst was less than 140 days and likely much less. The blue magnitude change was at least 4 magnitudes, and perhaps as large as 6. The rapid and large magnitude changes suggest Ross 4 is a cataclysmic variable. This is supported by the X-ray emission. Our time coverage is insufficient to say how frequently outbursts occur, but it is possible the star is a recurrent nova. Searches for additional outbursts would obviously be worthwhile.

4. Acknowledgements

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Table 1. Comparison sequence.

GSC 2.3 number	*Adopted B*	*(B–V)*	*GSC 2.3 number*	*Adopted B*	*(B–V)*
NCEH000476	11.7	1.0	NCEH000561	15.5	0.9
NCEH000514	14.1	1.5	NCEH004305	15.8	1.0
NCEH000480	14.4	0.7	NCEH000534	15.8	1.7
NCEH000553	14.6	1.9	NCEH005343	16.6	0.9
NCEH000552	15.2	1.5	NCEH004954	17.3	1.0

Table 2. Observed magnitudes for Ross 4.

Plate number[1]	*Local Date*	*Exp. (min)*	*HJD – 2400000*	*Mag.*
Barnard plates				
10B-127	1904-11-01	136	16786.674	13.0
6B-127	1904-11-01	136	16786.674	12.8
10B-437	1907-10-28	140	17877.637	<15.8
6B-437	1907-10-28	140	17877.637	<15.8
10B-915	1914-09-19	67	20395.797	<15.8
6B-915	1914-09-19	64	20395.797	<14.1
10B-916	1914-09-20	98	20396.762	<15.8
6B-916	1914-09-20	98	20396.762	<15.8
10B-918	1914-09-24	51	20400.743	16.1:
6B-918	1914-09-24	51	20400.743	15.8:
10B-920	1914-10-20	120	20426.643	<15.8
6B-920	1914-10-20	120	20426.643	<15.5
10B-926	1914-10-24	270	20430.775	<15.8
6B-926	1914-10-24	270	20430.775	<14.6
10B-934	1914-11-22	200	20459.821	16.0:
6B-934	1914-11-22	200	20451.821	16.0
10B-1386	1919-12-19	140	22312.571	<14.4
6B-1386	1919-12-19	140	22312.571	<14.4
10B-1465	1920-08-20	97	22588.802	<14.1
6B-1465	1920-08-20	97	22588.802	<14.4
Ross plates				
6R-19	1924-12-27	120	24147.559	<14.6
10R-22	1925-01-14	120	24165.560	16.4
6R-22	1925-01-14	120	24165.560	16.2
10R-191	1927-01-23	120	24904.657	<14.6
3R-191	1927-01-23	120	24904.657	16.4

Table 2 continued on following pages

Table 2. Observed magnitudes for Ross 4, cont.

Plate number[1]	*Local Date*	*Exp. (min)*	*HJD – 2400000*	*Mag.*
10R-402	1928-10-24	120	25544.810	<15.5
6R-402	1928-10-24	120	25544.810	16.0
3gR-402	1928-10-24	120	25544.810	<14.6
10R-412	1928-11-12	120	25563.740	<15.8
3gR-412	1928-11-12	120	25563.740	<14.6
10R-622	1929-12-05	90	25951.760	<15.2
3gR-622	1929-12-05	90	25951.760	<15.8
3pgR-757	1930-07-30	20	26188.839	<14.4
3pgR-760	1930-07-31	20	26189.833	<11.7
5R-786	1930-10-18	180	26268.839	16.1
10R-1260	1934-10-10	240	27722.000	17.3:
Illinois plates				
383	1940-09-27	60	29900.899	<16.6
384	1940-09-27	10	29900.924	<14.6
422	1940-10-26	60	29929.690	16.8:
423	1940-10-26	10	29929.715	<14.6
424	1940-10-26	60	29929.741	16.7
425	1940-10-26	10	29929.766	<14.1
426	1940-10-26	60	29929.792	17.4
427	1940-10-26	10	29929.817	<14.6
445	1940-11-01	60	29935.757	<15.5
446	1940-11-01	10	29935.787	<11.7
919	1947-11-08	10	32498.668	<11.7
920	1947-11-11	60	32501.551	<11.7
921	1947-11-11	60	32501.600	<14.6
922	1947-11-11	10	32501.625	<11.7
929	1947-12-08	60	32528.658	16.6:
930	1947-12-08	10	32528.684	<14.4
933	1947-12-13	30	32533.6[2]	<15.5
941	1948-01-14	60	32565.666	<15.8
942	1948-01-14	10	32565.691	<14.4
973	1948-03-04	60	32615.571	<14.6
1047	1948-10-05	50	32830.771	<15.2
1048	1948-10-05	9	32830.792	<15.2
1051	1948-10-25	60	32850.627	<15.5
1052	1948-10-25	10	32850.657	<14.1
1059	1948-10-26	60	32851.734	16.8:
1060	1948-10-26	10	32851.760	<15.2

Table 2 continued on next page

Table 2. Observed magnitudes for Ross 4, cont.

Plate number[1]	*Local Date*	*Exp. (min)*	*HJD – 2400000*	*Mag.*
1061	1948-10-26	50	32851.786	<15.8
1062	1948-10-28	60	32853.689	<15.8
1063	1948-10-28	10	32853.714	<14.1
1079	1948-11-29	60	32886.610	12.5
1083	1948-11-29	60	32885.794	12.9
1097	1948-12-01	60	32887.622	14.5
1123	1949-03-18	60	32994.614	<15.8
1124	1949-03-18	10	32994.639	<11.7
McDonald plates				
C 076	1952-01-26	10	34037.590	15.8
C 078	1952-01-26	10	34037.642	15.8
C 080	1952-02-01	10	34043.593	15.8
C 082	1952-02-01	10	34043.691	15.8
Non-pg data[3]				
Yerkes visual	1925-12-07	—	24492.6[2]	14.8
3vR-402	1928-10-24	120	25544.810	<12.7
3vR-412	1928-11-12	120	25563.740	<12.6
3vR-622	1929-12-05	90	25951.760	<12.7
3pvR-757	1930-07-30	20	26188.839	<10.7
3pvR-760	1930-07-31	20	26189.833	<10.7
Dearborn 1637	1942-10-07	5	30640.748	<12.7

Notes: 1. Initial number in Barnard and Ross plate designations indicates the telescope aperture in inches; Illinois plates with a 4-inch camera; McDonald plates with the 82-inch reflector; Dearborn plate with the 10.5-inch red camera. 2. Time not recorded so Julian Date is approximate. 3. Visual, photovisual and red magnitude estimates.

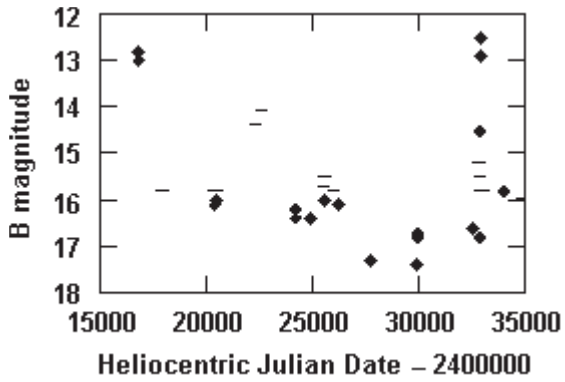

Figure 1. The light curve for Ross 4 from 1904 to 1952. Diamonds represent observed magnitude; lines represent brightness upper limit (fainter-than).

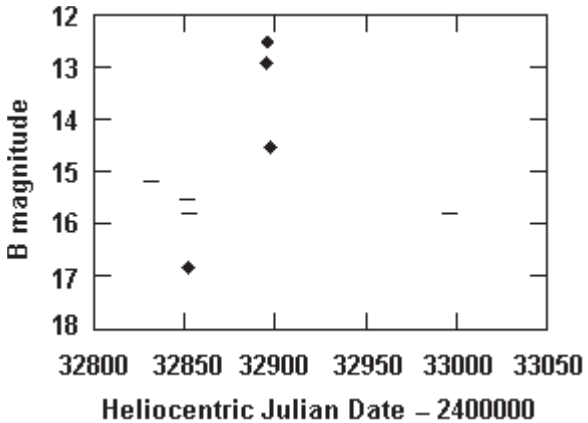

Figure 2. The light curve around the 1948 outburst. Diamonds represent observed magnitude; lines represent brightness upper limit (fainter-than).