MARIA MITCHELL'S OBSERVATIONS OF MIRA, 1856-1859

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Abstract

Maria Mitchell's comparisons of o Ceti with surrounding stars are reduced with modern magnitudes to give the light curve for the maxima in early 1857 and two cycles later in late 1858. The state of astronomical photometry at the time is briefly reviewed.

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In the winter of 1856-57 and again two years later Maria Mitchell observed Mira. I have not found her original observations, but among her notes preserved in the Maria Mitchell Memorabilia (Item 32, page 122) is a summary in her handwriting. It is evident that this is just a summary extracted from the original, not only because the ink is uniform, but also because of such parenthetical inserts as "(Here come in other notes)." The purpose of the compilation seems clear: it is to derive the period. The purpose of the observations is not obvious. From what I know of Maria's attitude in general, I would say that she likely felt that the heavens should be watched to find out what is going on, nothing more specific or more complicated than that.

There were observations on 42 nights. They were not systematized and quantified like modern variable star observing. Except for three nights when Mira was described as equal to γ Cet (3.6 on the AAVSO chart), there was only one observation that lends itself easily to translationinto modern variable-star-observing terms. "Mira above γ (Cet, 3^{m}6) but nearer to that than α (Cet, 2^{m}7)." I translate this to 3^{m}3.

The other observations are of four types. First, comparison is made with the preceding observation, as in "Mira has brightened decidedly."

Second, comparison is made with a single comparison star, as in "Mira differs little from γ but I think it brighter" or, on January 22 and 23, 1857, during a particularly bad cold spell (Kendall 1896), "Ther. at zero. I still think Mira brighter than γ^1 Eridani but the weather does not permit good obs." Also, commenting on two such comparisons on the same night, Maria wrote: "Mira a good deal brighter than γ Ceti, brighter than γ^1 Eridani (3^{m}.0)."

Third, comparison is made with a subjective magnitude standard, as in "I looked at it with the transit instrument and tho't it above the 6th mag."

The fourth type of observation is perhaps the most interesting. An estimate is made based on the ease of visibility in the illuminated field of the transit instrument, as in "On the 5th it would not bear the whole light of the lamp used in illuminating but on the 6th it was easily seen -- I tried different degrees of light in effacing it and compared it with other stars in this way, by noting which star was more easily blotted out...."

This promising method turned out to be puzzling. On January 1, 1857, Maria "didn't think Mira = γ Ceti with comet seeker" but "In the transit inst. Mira bore more light than γ perhaps because of the color of the light." I would have thought that white γ Cet (A3, **B-V** =

+0.09) would contrast more with the much cooler light than ruddy Mira. I suppose Maria's lamp burned whale oil. Could it have been nearer to an A-star than to an M-star in color? Or is the problem due to chromatic aberration in the direct comparison of stars of different color? It was common in the 19th century to speak of a large star where we would say a bright one.

The problem of color is interesting and familiar to anyone making visual comparisons. On January 5, 1857, "Mira's color is so different from that of γ that I determine to change the star of comparison for one more resembling it in hue." On January 12, 1857, "I began to compare it with γ^1 Eridani which it resembles in color but is much smaller...γ^1 is more yellowish than Mira but nearer to the color than γ Ceti." In the Bright Star Catalogue (Hoffleit 1982) where the designation of γ^1 Eri does not occur, we find that γ Eri, M0.5, has **B-V** = 1.59. But alas, γ Eri is not close enough in the sky. On hazy January 13,1857, "Mira is brighter than γ Ceti. γ^1 Eridani not to be seen." Closer to the horizon, it might have been lost in haze.

We recognize the problems in that the sequence stars should have the same color and should also be nearby. Our observation inevitably suffers if we cannot satisfy both conditions.

The ground haze that interfered with γ Eri is all too familiar to those of us who have observed southern stars from Nantucket. Maria's observation of the maximum of 1858 suffered severely from this problem. On November 1, 1858, she saw Mira brighter than α Psc ($3^m.8$), nearly as bright as Fomalhaut ($1^m.2$) but, nontheless, not as bright as α Cet ($2^m.7$). It must be that Fomalhaut, at declination -30°, was in the haze.

Nowhere in any of this was Maria trying to produce magnitudes for Mira. It seems not to have been a light curve that she was after, but only the dates of maximum. She chose "about Jan. 15, 1857" because of an observation on that night. Perhaps she was helped by an implied light curve. She noted that Mira passed γ Cet on the ascent on December 25, 1856, and on the descent on January 25, 1857. The curve compiled by the AAVSO shows a maximum at just this time. Maria Mitchell's 1858 maximum was less secure. The relevant observations are on October 10, November 1 ("Nearly as bright as Fomalhuat"), and November 30, with nothing in between. Yet Maria is so bold as to summarize her compilation in these words: "Began to brighten Oct. 10th reached its maximum in 22 days in 29 days had diminished decidedly."

The light curve compiled by the AAVSO shows the 1858 maximum at or just slightly after JD 2400000. November 1, 1858, was JD 2399985. Maria calculated 327.5 days for the period. Prager's formula VII for 1847 to 1862 (Prager 1934),

$$JD_{max} = 2395988 + 334.1\ E, \qquad (1)$$

gives JD 2399329 and JD 2399997, compared with Maria's JD 2399330 and JD 2399985, respectively.

I have turned Maria's descriptive language into 42 magnitude estimates listed in Table I. The estimated uncertainty is 0.2 to 0.5 magnitude. The light curve is shown in Figure 1. It is in close agreement with the curve compiled by the AAVSO and it fills in no gaps, adds nothing to what was known. The interest in Maria's observations is the glimpse that they give us of early variable star work.

Eventually we have learned not to try to compare a variable with itself at a previous time, but to compare it with one or more sequence stars. We have learned to prefer interpolation between two comparison

stars to estimated differences between the variable and a single comparison. Not everyone has learned to look at a whole light curve rather than a single, bright point when deciding on the date of maximum, but the AAVSO and the other organized groups who have learned the lesson well, know the advisability of collecting observations from all observers, so that one observer's cloudy night is filled in by another observer's clear sky. Today we define magnitudes very carefully, a difference of one magnitude corresponding to a ratio of 2.512... (the fifth root of 100) in the amount of light received. In Maria Mitchell's time the idea of defining stellar magnitudes so as to give numerical information about the light received from the stars was just gaining currency. She seems to have been one of those who thought of but did not use a scheme for comparing the amount of light received. There is a Journal entry for October 21, 1854 (Kendall 1896) that she has seen "to-day in the 'Monthly Notices,' a plan for measuring the light of stars by degrees of illumination - an idea which had occurred to me long ago, but which I had not practised." I find nothing in the Monthly Notices to indicate that she refers to illumination of the field, the method that she did use two years later, but there is a paper by Dawes (1851) in which the phrase "telescopic illuminating power" is used in this sense: twice the illuminating power can be obtained by using twice the area of the objective. In Maria's copy of this issue there is a pencilled note on the fly-leaf referring to this paper, so I am confident that it is the one to which her Journal entry refers. In it we find Rev. Dawes collecting many opinions as to how to extrapolate beyond the sixth magnitude, whether with a ratio of 2.0 for a whole magnitude, 2.0 for a half magnitude (= 4.0 for a whole magnitude), or by no constant ratio. The idea of fixing on a ratio was just at its start and this paper of Dawes' was referenced by Pogson (1856) when he proposed the ratio 2.512 that was eventually adopted. Pogson's motivation, incidentally, was to have magnitudes to which one could apply the inverse square law to predict the brightness of minor planets. His measures, by Dawes' method on stars to which magnitudes had been assigned in various catalogues, gave a ratio near 2.4. Other measures known to him gave values in the range 2.4 to 2.8. He chose 2.512 not because there is any virtue in having the first magnitude stars exactly 100 times as bright as the sixth, as so many textbooks would have us believe, but because this ratio was handy in calculations involving the inverse square law. The computations were easier, in those days of long-hand arithmetic, if he chose the ratio so that the reciprocal of one-half of its logarithm was exactly five.

I have taken the time to present these considerations because they help to set the historical tone. They refer, however, primarily to the extension of the magnitude scale beyond sixth magnitude. The magnitudes of the lucid stars were in close agreement in all catalogues even before the mathematical ratio was agreed upon, and, although Maria used telescopes, she did not observe Mira except when it was of naked-eye brightness. She could have assigned magnitudes to Mira without ambiguity. That she did not probably reflects only that she did not feel the need for magnitudes when it was the period that she was after. Still today, at the Maria Mitchell Observatory, we often bypass magnitudes, sometimes just using estimates on an entirely arbitrary scale, in our project of analyzing pulsation periods, but we most emphatically do look at the entire light curve, not just isolated bright observations.

Maria Mitchell's very early variable star observing is unfamiliar in some ways but thoroughly familiar in others. I feel very much at home with a little sketch that she gives of a finding chart with the variables and comparison stars identified and with the comment: "(I am not quite sure of this figure)." Sure enough, the star identified as μ looks more like ξ^2 Cet to me. Then, most familiar of all, Maria found herself wondering whether one of her comparison stars was variable. In fact, μ Cet is NSV 909 (Kholopov et al.1982), type = δ

Sct?, no suspected amplitude given. Since Maria was thinking in half-magnitude terms I doubt that she had picked up any real variation of Cet, but in her suspicion she had certainly anticipated what was to become a perennial problem.

I am grateful to the AAVSO for providing me with a copy of the light curve of o Cet and finding charts.

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TABLE I

Maria Mitchell's Observations of Mira

Date	JD	Mag.	Date	JD	Mag.
1856 Nov. 19	2399273	6.0:	1857 Jan. 22	2399337	2.8:
Dec. 6	290	5.5:	Jan. 23	338	2.8:
Dec. 9	293	5.5:	Jan. 25	340	3.3
Dec. 13	297	5.5:	Jan. 30	345	3.2
Dec. 15	299	4.5	Feb. 6	352	3.3
1856 Dec. 18	2399302	4.3	1857 Feb. 11	2399357	3.6
Dec. 22	306	4.2	Feb. 13	359	3.9
Dec. 25	309	3.8	1858 Sep. 8	931	6.0:
Dec. 27	311	3.6	Sep. 12	935	6.0:
Dec. 29	313	3.6	Sep. 13	936	5.5:
1857 Jan. 1	2399316	3.6	1858 Sep. 29	2399952	5.5:
Jan. 4	319	3.6	Oct. 6	959	5.5:
Jan. 5	320	3.4	Oct. 10	963	5.0:
Jan. 6	321	3.3	Nov. 1	985	3.3:
Jan. 7	322	3.3	Nov. 30	2400014	3.8
1857 Jan. 8	2399323	3.4	1858 Dec. 3	2400017	3.6
Jan. 12	327	3.4	Dec. 6	020	3.3
Jan. 13	328	3.3:	Dec. 25	039	3.9
Jan. 15	330	2.7	Dec. 27	041	4.3
Jan. 20	335	2.8	1859 Jan. 2	047	[4.7
1857 Jan. 21	2399336	2.8	1859 Jan. 9	2400054	6.0:

Note: Maria's comparisons with neighboring stars were transformed to magnitudes by reference to modern magnitudes from the AAVSO chart for o Cet and the Bright Star Catalogue.

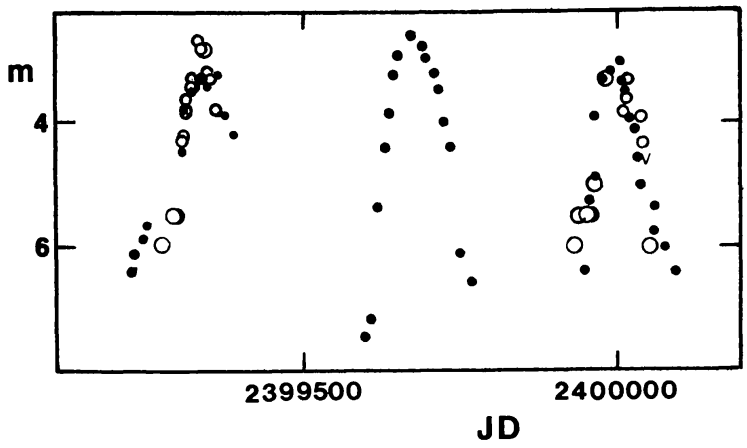

Figure 1. The light curve of Mira, JD 2399200 to 2400100. The dots are AAVSO data. The open circles are from Maria Mitchell's notes. The larger size indicates that the assignment of a magnitude is believed to be less reliable. The "v" indicates the variable was fainter than the magnitude given.