NSV 5658, NSV 5660 and a new RR Lyrae variable in Canes Venatici

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While observing the suspected variable stars NSV 5658 and NSV 5660, the writer found one of the comparison stars to be a previously unknown RR Lyrae variable. This star is at 12h 27m 18s +48° 07′ (1950) and has a visual range of 11.2–11.9. It spends 0.14 of each period in rising from minimum to maximum and belongs to the RRab subgroup. Future maxima can be predicted from the elements Max = JD Hel. 2446641.535 + 0.563636 × *E*. It is probable that both NSV 5658 and NSV 5660 are constant and that the earlier reports of their variability are a result of observers using the RR Lyrae variable as a comparison star.

Introduction

The variability of the 12th-magnitude star in Canes Venatici, now know as NSV 5658, was first proposed in 1929 by Tseraskaya.[1] In reporting the discovery, Blažko suggested that the star was a short-period variable, that is to say, either a cepheid, an RR-Lyrae variable, or an eclipsing binary, showing noticable variations from one night to the next. This was contradicted in 1931 by Prager,[2] who found no variations of greater than 0.1 mag, but then, in 1933, Rügemer[3] announced an independent rediscovery of the variability of this star. In the same study Rügemer found the variability of the nearby star, also of the 12th magnitude, which is now known as NSV 5660. His observations suggested that both stars were short-period variables, but were too few in number to reveal their periods. Florya and Kukarkin[4] in 1935, and Weber[5] in 1956, confirmed the variability of both of these stars but, again, could not clinch the matter by identifying their periods. In 1982 the editors of the *New Catalogue of Suspected Variable Stars*[6] (the NSV) summarised our knowledge of these two stars with the details listed in Table 1.

Observations

The writer started observing NSV 5658 and NSV 5660 in 1986. The observations were made with a 200-mm reflector using the comparison stars shown in Figure 1. The magnitudes are based on visual estimates and hence are only approximate. Initially it was assumed that if the stars were variable then they would turn out to be Cepheids, as sug-

Table 1. Details of NSV 5658 and NSV 5660 taken from the NSV.[6]

	NSV 5658	NSV 5660
Right ascension (1950)	12h 27m 26s	12h 27m 35s
Declination (1950)	+47° 55′.4	+48° 07′.0
Range (photographic)	11.4–12.4	12.0–13.0
Type	Cepheid?	Cepheid?
Spectrum	G2	K3

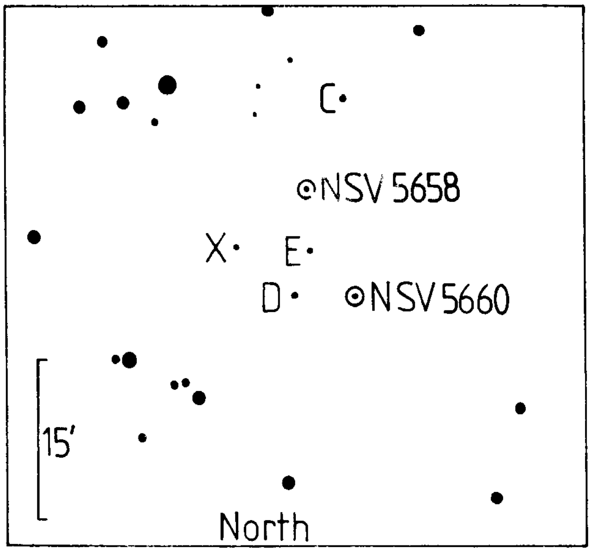

Figure 1. Chart for NSV 5658 and NSV 5660. The following approximate magnitudes are based on visual estimates: C = 11.5, X = 12.2, E = 12.4. D is the new RR Lyrae variable.

gested in the NSV, and because Cepheids do not show noticable variations within a few hours, observations were only made at a rate of one per day.

After a few weeks it became apparent that NSV 5658 was more or less constant relative to its most suitable comparison star, star C, but NSV 5660 was showing marked variations relative to star D. The fact that NSV 5660 was seen near maximum and minimum about an equal number of times suggested that it could not be an eclipsing binary because such stars tend to show a marked preference for maximum. Following the assumption that the star was a Cepheid, a possible period of 5.33 days was identified and a preliminary report was sent to *The Astronomer* magazine.[7]

Almost immediately, however, two problems were found with the idea that NSV 5660 was a Cepheid. First, its spectral type of K3 is not what one would expect for a 5-day Cepheid. F and G are the most common spectral types amongst Cepheids and K is only found in the most luminous long-period ones and, even then, only when they are near minimum. The second problem is that Canes Venatici is the wrong part of the sky for a 12th-magnitude Cepheid. Classical Cepheids show a strong tendency to cluster about the plane of the Galaxy, and faint ones are particularly rare at high galactic latitudes (NSV 5660 is at $b = +68°.86$). The W Virginis-type Cepheids show less of a concentration about the galactic plane but they are themselves quite rare objects and are outnumbered by thirty-five to one by the RR Lyrae variables.[8] So, *a priori*, it would be much more likely for NSV 5660 to be an RR Lyrae variable than a Cepheid. However, the problem of the spectral type remains, K3 being even less suitable for an RR Lyrae variable than it is for a Cepheid, but it was thought possible that the NSV spectral type could be wrong. The obvious solution to all these problems was simply to go out and look to see if NSV 5660 really did show the rapid variations characteristic of an RR Lyrae variable.

Intensive observations commenced at 10.18 GMAT on 1986 July 29 with the field not very well placed in the north-west and getting lower. The triangle of stars NSV 5658, NSV 5660 and star D was quite hard to see but it was clear that D was noticably fainter than the other two, and this was so until 11.31. Then, at 12.04 GMAT, the writer was surprised to find star D standing out as much the brightest star in the field, clearly brighter than both NSV 5658 and NSV 5660. It was not NSV 5660 that was the variable but its comparison star, star D! Such a sudden rise of over half a magnitude in less than an hour is typical of an RR Lyrae variable of the RRab subgroup.

The writer continued to observe star D on every possible occasion, further reports being sent to *The Astronomer*,[9,10] until a change of employment in late 1986 forced him to suspend telescopic observing. However, three years later another change of circumstances allowed some further observations to be made in 1989 and 1990. In all, 154 estimates of the brightness of star D relative to NSV 5660 were made between 1986 April 29 and 1990 March 30. In addition, estimates were made of the brightnesses of NSV 5658 and NSV 5660, relative to each other and relative to star C, in order to check on their constancy.

Discussion

Star D was seen to brighten suddenly, in a manner similar to that observed on 1986 July 29, on five occasions. The following list gives the observed times of mid-rise, that is, the times on each rise when star D was estimated to be equal in

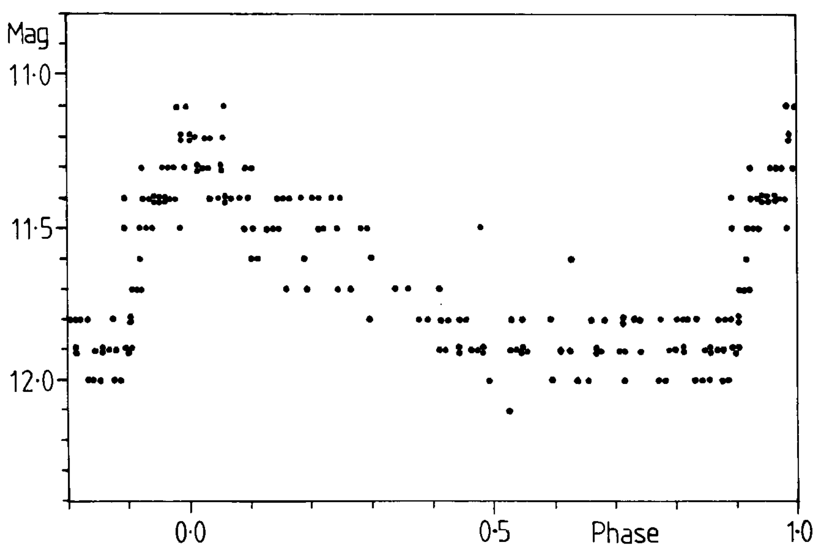

Figure 2. Light curve of the new RR Lyrae variable assuming that NSV 5660 is constant at 11.6. The phase is relative to the epoch and period given in Table 2.

Table 2. Details of the new RR Lyrae variable.

Right ascension (1950)	12h 27m 18s
Declination (1950)	+ 48° 07′
Type	RRab
Range (visual)	11.2–11.9
Epoch of maximum	JD Hel. 2446641.535
Estimated error in epoch	0.010d
Period	0.563636d
Estimated error in period	0.000004d
M -m	0.14P

brightness to NSV 5660. The figures in parentheses are estimated errors.

JD Hel. 2446641.499 (0.005)
6667.415 (0.010)
6689.400 (0.005)
7695.494 (0.005)
7973.364 (0.005)

The second of these timings was thought to be less reliable than the others because it was based on only three estimates made under rather poor conditions. The successive intervals between the more reliable timings are 47.901, 1006.094 and 277.870 days, respectively, which are all very close to whole-number multiples of 9.58176 days. This implies that the true period is either equal to 9.58176 days or else a sub-multiple thereof. In addition, a lower limit of 0.134 days can be placed on the true period because, on 1986 July 29, the star had been followed continuously for that length of time without the variations repeating themselves. This restricts the possible values of the true period to $(9.58176/n)$ days where n is a whole number in the range 1 to 71, inclusive. For each of these possible periods a light-curve was constructed but only for $n = 17$, which corresponds to a period of 0.563633 days, did the observations form a coherent light-curve. The period was then refined to 0.563636 days by comparing the residuals for the four reliable timings of mid-rise.

Figure 2 shows the result of folding all of the observations on the 0.563636-day period. The light-curve is that of a typical RR Lyrae variable of the RRab subgroup, showing a steep rise to a sharp maximum followed by a slower decline to a broad, flat minimum. Table 2 lists the deduced properties of the new RR Lyrae variable.

So far in this analysis it has been assumed that NSV 5660 is constant and this assumption has apparently been vindicated by the identification of the period of, and construction of a coherent light-curve for star D. If NSV 5660 were variable then one would have expected this to have contributed to the scatter in Figure 2. However, even if all of the scatter was caused by variations in NSV 5660, the amplitude of NSV 5660 could not be much more than 0.2 mag. As it is, the scatter can quite adequately be explained as observational errors, especially as the star was rather faint and not easy to observe in the instrument used. So, the level of the scatter in Figure 2 can actually be used as evidence *against* the variability of NSV 5660.

Neither is there any clear evidence for the variability of NSV 5658 or NSV 5660 in the estimates of the differences between them and star C. These estimates are summarised in Table 3. Note that the differences are positive when the star is brighter than its comparison star. The first thing to notice is that the standard deviation for the difference between NSV 5658 and NSV 5660 is only 0.11 mag which, for visual observations, is consistent with the difference being constant. The differences between NSV 5658 and C, and C and NSV 5660 show slightly greater standard deviations but these are based on fewer estimates. Compare these with the standard deviation of 0.26 mag for the difference between NSV 5660 and star D, which we know is variable. There is a minor peculiarity in that the difference between NSV 5658 and NSV 5660 is only about half the sum of the differences between NSV 5658 and C, and C and NSV 5660. However, these are based on relatively small numbers of estimates of which about half were made in the first few weeks of observing and so are likely to be less accurate. This is because at that time the writer did not know of the variability of D and may have allowed subconscious bias to distort the estimates to fit his expectation of its being constant. Only about a fifth of the estimates of NSV 5658 relative to NSV 5660 were made in those first weeks.

Table 3. Summary of the estimates of NSV 5658 and NSV 5660.

Star	*Comparison star*	*Mean diff. (mags)*	*SD (mags)*	*No. of estimates*
NSV 5658	C	+0.00	0.13	49
C	NSV 5660	+0.19	0.15	45
NSV 5658	NSV 5660	+0.10	0.11	105
NSV 5660	D	+0.04	0.26	154

So, if either NSV 5658 or NSV 5660 is variable then their amplitudes can be no more than 0.2 mag, but it is most probable that they are both constant. The earlier reports of their variability are quite easy to explain. Apart from star D, there are few stars of similar brightness to the two NSV objects in the field, so star D would be a natural choice for a comparison star. If this is correct then all the observers in the previous studies, except Prager, probably used star D as a comparison star. Unfortunately, this cannot be tested because none of their papers indicate which comparison stars were used.

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Received 1990 May 8; accepted 1990 June 13