Scientific Justification

Govert Verberg, Friso Snel, Jurrian Meijerhof & Olivier Aartsen

11/03/2015

Distance measurement is a fundamental aspect of astronomy; in astronomical research it is usually essential to know the distance to the object being observed. One of the main techniques utilized to determine distances is the use of standard candles: objects with a known luminosity. Cepheids and RR Lyrae stars are examples of standard candles.

Cepheids are variable stars that pulse radially. Over time they change in both diameter and temperature which leads to brightness changes with a well-defined period and amplitude. In 1912 Henrietta Swan Lewitt discovered that there exists a relationship between the period and luminosity of Cepheid stars.

RR Lyrae stars were initially thought to be Cepheids. RR Lyrae stars vary in brightness in a similar way as Cepheid stars (Figure 1 shows a typical lightcurve of such a star). There are a few differences which cause RR Lyrae variable stars to be considered as a separate class of stars. RR Lyrae stars are far more common than Cepheids. They also have a shorter period, lower luminosity and lower metallicity compared to Cepheids. The period of the variation in brightness for RR Lyrae stars ranges from about 0.2 days to 1 day [1]. Unlike Cepheids there is no period-luminosity relation in RR Lyrae stars; instead, there is a relationship between its metallicity and luminosity.

The aim of this research is to determine the distance to the globular cluster NGC 5466, by observing RR Lyrae stars in this cluster. In 1917 Harlow Shapley used the positions of different globular clusters to get a better understanding of the structure of the Milky Way galaxy. One of the things he found is the approximate position of our sun in the Milky Way. Our research can help to get a more precise distance to a globular cluster and thus help to understand the structure of the Milky Way better.

The metallicity-luminosity relation can be used to find the luminosity of an RR Lyrae star, which means that the distance to the star can be calculated with the luminosity and the measured flux. This can be done with the distance modulus. RR Lyrae stars are too faint to be seen far away, but they can be used as standard candles for relatively nearby objects.

Since there is no spectrometer available we will use the values of metallicity that were obtained in a previous research on this cluster. A measurement of the peak flux, or another characteristic aspect of the light curve, in each period is needed. To achieve this, measurements on irregular intervals over more than one period are required. These measurements will be images of the target Globular Cluster in the V-filter. We will use these data to determine the mean flux. Additionally the phase dispersion minimization method will be used to determine the period. With these periods the absolute magnitude will be obtained using Fourier lightcurve decomposition. The relation between absolute magnitude and the fourier parameters has been determined empirically (Kovács et al. 2001) [2]. We will compare this value to the value obtained from the metallicity-luminosity relation.

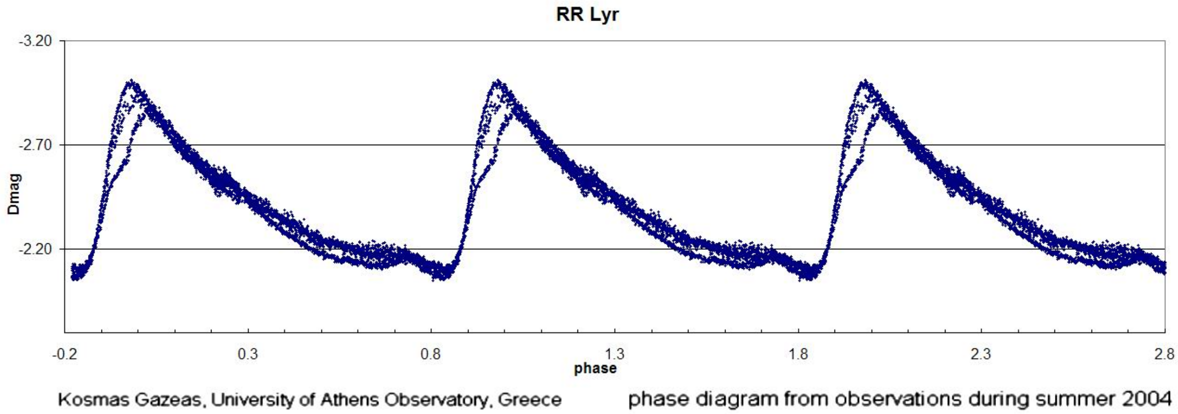

Figure 1: The lightcurve of the star RR Lyr

References

[1] Smith H.A., *Cambridge Astrophysics series 27: RR Lyrae Stars*, 1995, Cambridge University Press

[2] Kovács G. and Walker A. R., *Empirical Relations for Cluster RR Lyrae Stars revisited*, 2001, Astronomy & Astrophysics 371, 579-591

Technical Justification

Govert Verberg, Friso Snel, Jurrian Meijerhof & Olivier Aartsen

25/03/2015

The cluster we want to measure the distance of is NGC 5466. There are multiple reasons why this is a cluster well suited to this research. The first reason is because NGC 5466 has a high specific frequency of RR Lyrae stars, so it's more likely there will be a suitable star to use with limited measuring time. It's location is nearly perfect for measuring from La Palma in the first week of May. The coordinates of NGC 5466 are:
Right ascension: $14^{h}05^{m}27.3^{s}$
Declination: $+28^{\circ}32'04''$

The latitude of La Palma is $28^{\circ}40'$, nearly the same as the declination of NGC 5466. The sidereal time in May is 14 hours, again nearly the same as the right ascension of the cluster. The moon is at it's brightest during the first week of May but it's about 40 degrees away from the cluster so it will be possible to measure NGC 5466. Figure 2 contains all of this information in a plot.

The size of the cluster is about 11 arcminutes. One CCD of the INT can observe a field of 11 by 22 arcminutes so it's possible to measure the whole cluster in one exposure.

We will do our observations in the V-band, because the metallicity-luminosity relation is also determined in this band. The filter we want to use is WFCHARV (serial number 192), which has a central wavelength of 5425 $\AA$ and a full width half maximum (FWHM) of 975 $\AA$.

Because of the limited measuring time we want to aim our measurements at getting good data for one star in particular, rather than trying to do enough measurements to find periods for all the RR Lyrae stars in the NGC cluster. We will attempt to do this anyway with the data we collect, but aiming for one star in particular minimizes the total observing time required to obtain a good distance measurement.

The star we want to measure on is called V12 in past literature (Sawyer Hogg, 1973[3]). V12 is a good target star because it has a relatively low period of 0.293378 days (Ferro et al. 2007[1]) and is not located in the center of the cluster (as can be seen in figure 3). The relatively low period means there are more opportunities to measure the peak flux. V12 not being near the centre of the cluster is important because it means it can be resolved even when the conditions are poor.

If we want to use the data later to find the periods for every RR Lyrae star in NGC 5466, the exposure time needs to be short enough to not oversaturate any pixel, not just the pixels for V12. The brightest stars in the cluster have a magnitude of about 14. We used the exposure time calculating tool SIGNAL to find that we can use an exposure time of 10 seconds with a seeing of 1 arcsecond. When the seeing is 2 arcseconds or worse we can use an exposure time of 20 seconds. When the seeing is 1 arcsecond and V12 is at it's minimum luminosity we expect to get an S/N of 125. To improve the S/N without risking oversaturation we want to do two consecutive exposures for each measurement.

To determine the period of V12 we need a few randomly spaced out measurements and accurate measurements of the peak of V12's lightcurve. We have used past measurements (Ferro et al. 2008[1]) to estimate when the peaks will occur. We expect the brightness of V12 to be at its peak on the 4th of May at 02:16.

Therefore we would need to do some measurements in the night of 3-4 May at 22:35, 23:00, 23:30, 00:25, 02:00, 02:15, 02:35, 02:37 to determine the shape of the light curve. The part of the lightcurve we expect to measure here is shown in figure 1 between the red lines. Another expected peak is on 4 May at about 23:24. We want to do randomly spaced out measurements between 22:40 and 00:20. The expected part of the lightcurve of this timeslot is also shown in figure 1, between the blue lines. Besides that we need several more measurements in the other nights, the timing for these measurements is unimportant and can be done whenever the telescope is available.

References

[1] Ferro A.A., López, V.R., Giridhar S. and Bramich D.M., *CCD Photometry of the Globular Cluster NGC5466. RR Lyrae light-curve decomposition and the distance scale*, 2008, MNRAS 384, 1444

[2] Corwin T.M., Carney B.W., Nifong B.G., *BV Photometry of RR Lyrae Variables in the Globular Cluster NGC 5466*, 1999, AJ 118, 2875

[3] Sawyer Hogg H.B., *A Third Catalogue of Variable Stars in Globular Clusters comprising 2119 entries.*, 1973, Vol. 3, No. 6. p. 75

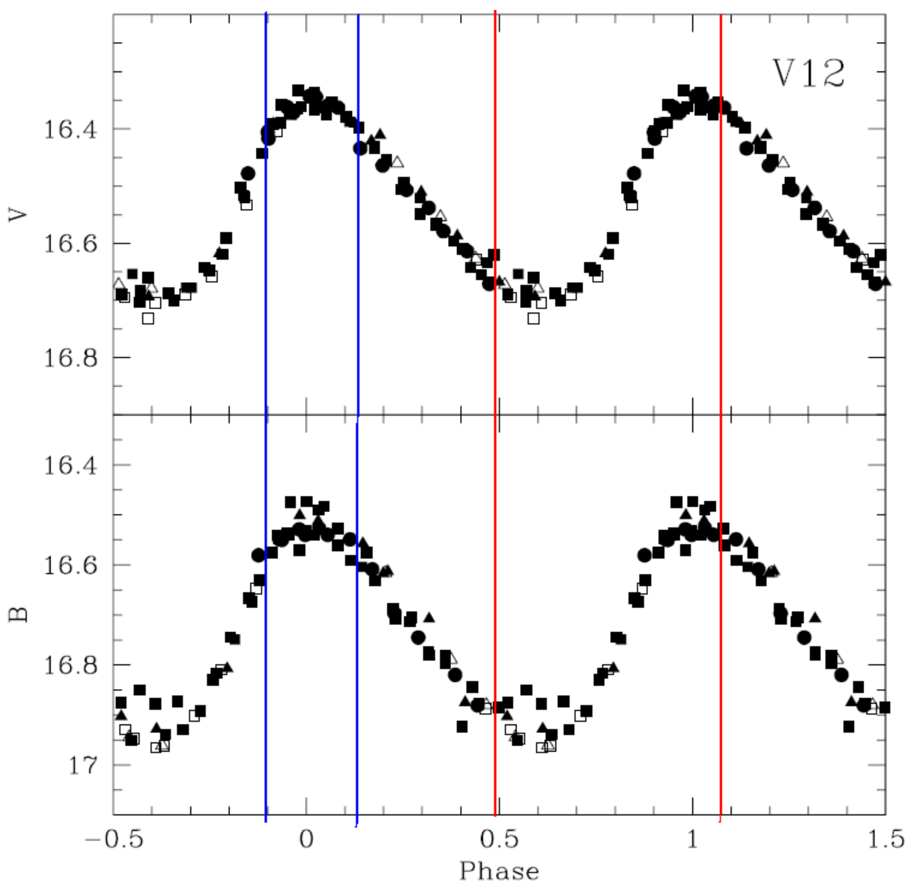

Figure 1: The lightcurve of the star V12 in the cluster NGC 5466.[2]

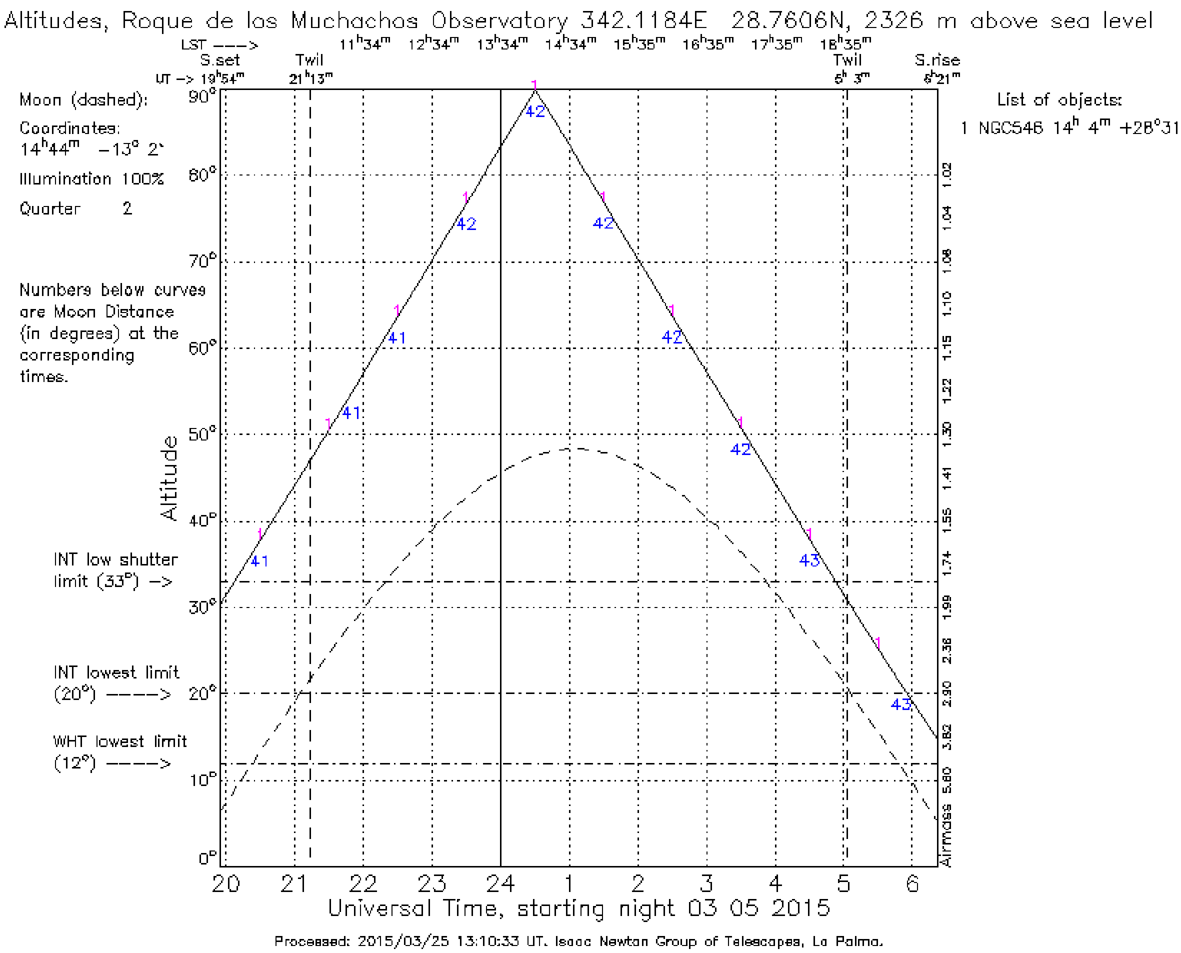

Figure 2: Plot of the declination of NGC 5466 during the night of 3 May 2015.

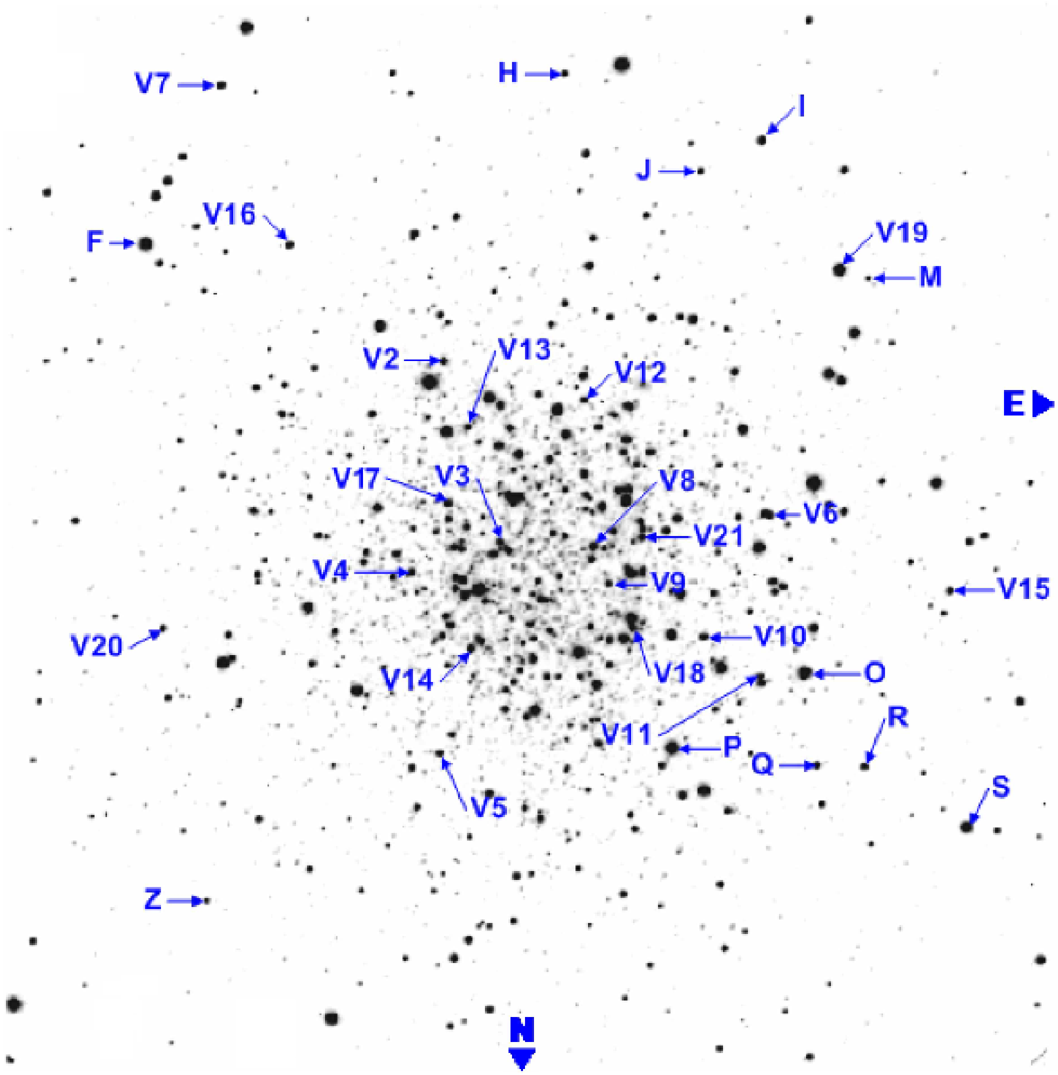

Figure 3: An image of the cluster NGC 5466.[1]