Determining a star's spectral type using multicolor photometry

Abstract We present the spectral type determination of a UV type variable star (NGCA-V29). The observations needed to achieve this were done using a 16 inches Ritchey-Chretien telescope with an SBIG STL-6303 CCD camera. The data was taken in the course of 1 night in V, R and I photometric filters. The data has been calibrated with dark and flat frames in MAXIMDL (1997 Diffraction Limited), the darks being calibrated first with bias frames. After the calibration process, using AstroImageJ (Karen, A. C.; et al., 2017) we performed the photometric analysis.

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1. Introduction

Photometry is the science of measuring the light. This process is very widely used in astronomy to research the brightness of stars. Apart from this, knowing a star's color is also very important to determine it's temperature or how covered in dust it is.

NGCA-V29 is a variable star of UV type discovered by Gabriel Cristian Neagu and Manole Diana Maria by datamining the TESS database (Ricker, G. R.; et al., 2014) . The star is at a distance of 17.58 +/- 0.01 pc and it's average magnitude in the r filter is 15.3 (Henden, A. A.; et al., 2018) . Other names of this star are: 2MASS J11084947+3955129, LP 214-42 and WISEA J110849.14+395510.9, these being taken from SIMBAD.

Figure 1. The star's entry in the Variable Star Index (VSX)
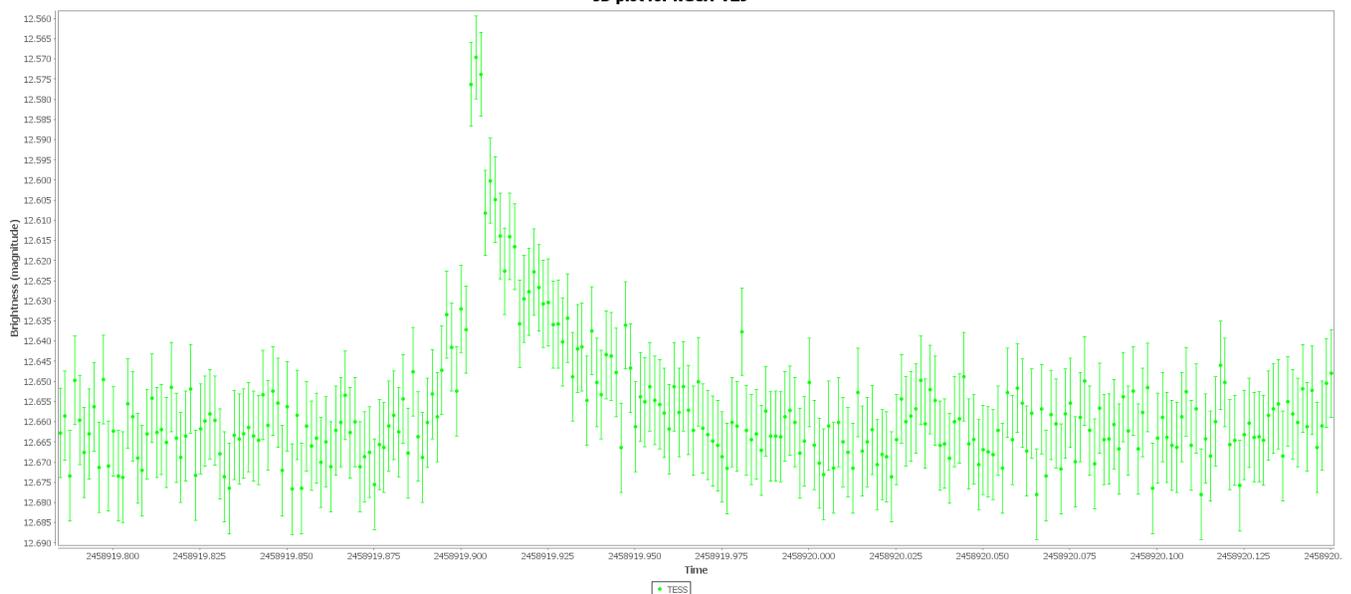
Figure 2. The JD plot of the star using TESS data showing a stellar eruption

1.1 Photometric systems

A photometric system is, in astronomy, a set of optical filters with a known sensitivity to incoming light. Depending on what photometric system is used, a set of standard stars is provided for calibration. Those filters are characterized by the widths of their passbands:
-broadband (wider than 30nm)
-intermediate (10-30nm)
-narrowband (>10nm)

For this study we used the BVRI system, more specificaly V, R and I filters. The V filter is

centered on 551nm and the R filter is centered on 658nm. Those filters are in the category of Visible light filters, while the I filter, centered on 806nm is a near infrared filter.

1.2 CCD photometry

There are more types of photometry available to use for astronomers. In this study, we used differential photometry. Other types are:
-absolute photometry
-relative photometry
-surface photometry

While the first three are usualy used for stars, surface photometry is mostly used to analyse galaxies and nebulae.
Depending on the goal of a study, photometry can be performed in ultraviolet, visible and infrared wavelengths of the electromagnetic spectrum.

The CCD camera, SBIG STL-6303E used by us, has the KAF-6303E/LE sensor with a total of 6.3 million pixels. The array consists of 3072 x 2048 pixels, each pixel measuring 9 microns. Full well capacity is 100000 e-, and the Dark Current e-/p/s at 0 degrees Celsius is 0.3e-, while the read noise is 13.5e- RMS.

An image downloads in an average of 15 second and the peak QE is 68%. The CCD camera has an internal mechanical shutter for dark frames plus an electronic shutter for short exposures.
Power requirements: 10 – 18VDC, 12VDC nominal, Universal 110 - 220VAC to 12VDC desktop supply provided (extension cord and 12VDC field power cord are optional).
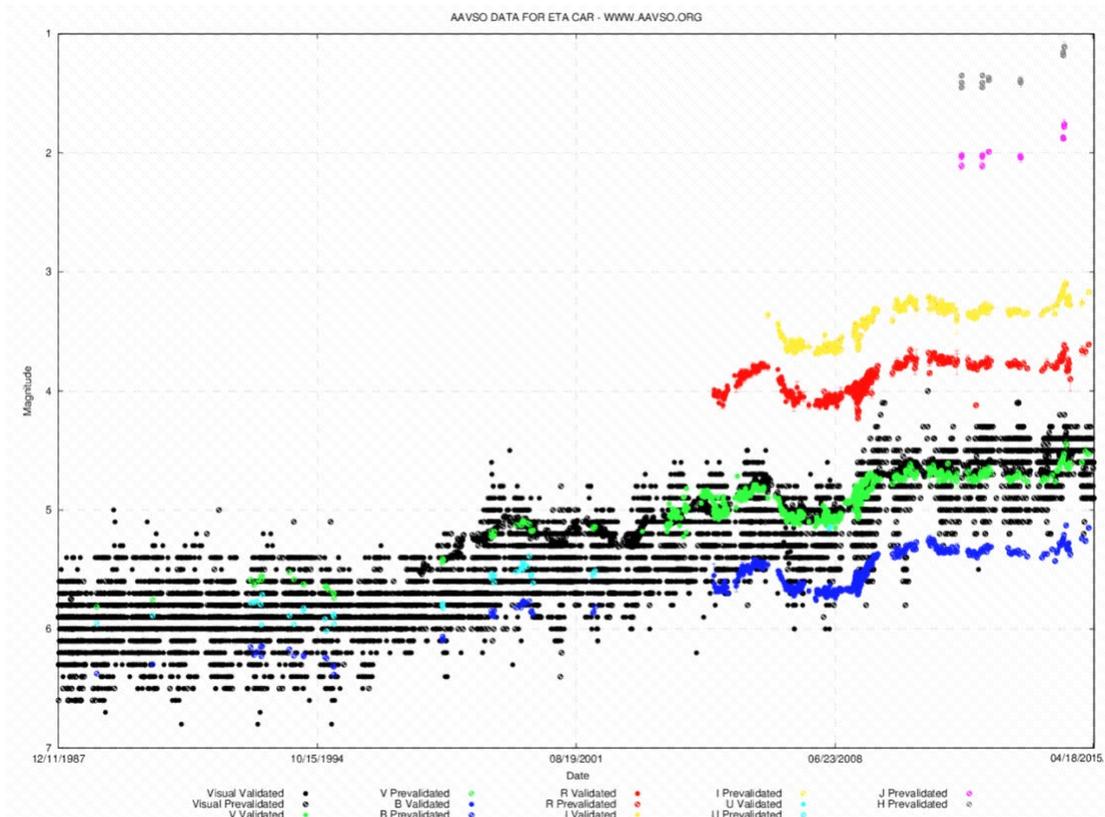
Figure 3. The AAVSO data for Eta Carinae using diferent filters

As seen in this plot, stars have diferent brightness in diferent filters. Depending on the diference between the magnitude in one filter and the magnitude in another, it is possible to determine it's color.

2. Methodology of data acquisition

We performed multicolor photometry on the target star, NGCA-V29 using the 0.4m Ritchey Chretien telescope at the Galati Astronomical Observatory. We took 3 images per filter using V, R and I photometric filters. For each image we used 60 seconds exposures. The data was calibrated dark and flat field corrected before the reduction. We stacked the images în the coresponding filters using median stacking method using MAXIMDL.

3. Data reduction

The photometric analysis was performed in AstroImageJ using the following comparation stars:

Name	Mag (V)	Mag (R)	Mag (I)
2MASS J11085525+3955016	13.74 (APASS)	13.3 (USNO-A2.0)	13.66 (USNO-B1.0)
2MASS J11091976+3957352	13.76 (APASS)	13.4 (USNO-A2.0)	13.59 (USNO-B1.0)
2MASS J11082537+4000492	13.53 (APASS)	13.1 (USNO-A2.0)	13.62 (USNO-B1.0)

Table 1. The comparation stars used for the diferential photometry

After the reduction we got the following results:

Name	V	R	I	V-R	V-I	R-I
NGCA-V29	16.01 +/- 0.03	14.63 +/- 0.02	13.16 +/- 0.02	1.38	2.85	1.47

Table 2. The reduced data

4. Spectral type determination

Using the charts available at https://www.stsci.edu/~inr/intrins.html, we matched our color indexes with the spectral types. Both the V-R and V-I colors indicate a M4.5 spectral type star. Knowing this, we can now determine if it's a giant, a supergiant or a main sequence star.

4.2 Distance calculation

Stellar parallax is the seeming shift of a star's location against the background objects. To calculate the distance, we used the parallax method, where:

$$D= 1/P$$

D= distance în pc
P= parallax în arcsec

Parallax (mas)	Error (mas)
56.87	0.29

Table 3. The Gaia data needed for the distance calculation

From this data it results that the distance to the star is 17.58 +/- 0.01 pc

4.3 Absolute magnitude calculation

The formula to calculate a star's absolute magnitude is:

m = M – 5 + 5 * log(distance),

where:
m= apparent magnitude
M= absolute magnitude

from this, the absolute magnitude is equal to 7.05

The Hertzsprung-Russell diagram is a dispersion diagram of stars presenting the relationship between the stellar abolute magnitude against their spectral types or temperatures. The creation în 1911, by Ejnar Hertzsprung and Henry Russell, în 1933 was a huge step în understanding how stars evolve.
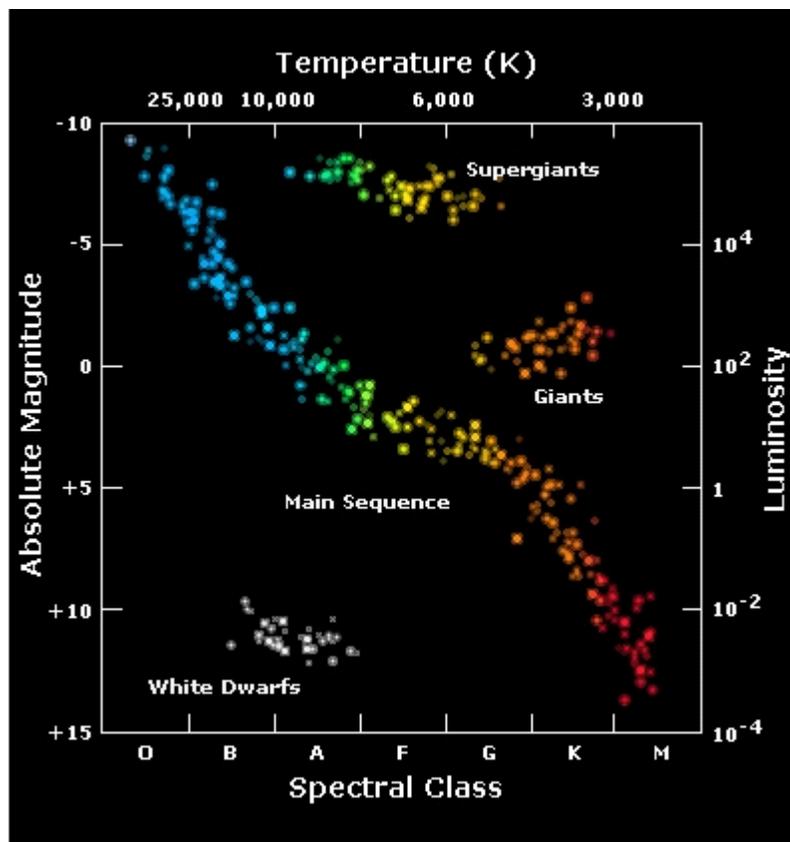

Fig. 2 The Hertzsprung-Russell diagram

Using this scatter plot, we conclude that the star is located on the main sequence.

5. Conclusion

From the data presented above, we conclude that the star's spectral type is M4.5V. This is conclusive with the measurements from 2003AJ....126.3007R.
The method of determining the spectral type of a star using photometric filters is useful în areas where the galactic reddening is minimal, to confirm a star's variability type.

6. Acknowledgements

Mentor's pedagogical evaluation

The student, doing this extrascholar activity, developed the following abilities:

-theoretical and practical knowledge regarding CCD photometry

-practical abilities regarding the use of the observatory's equipment

-knowledge in using the softwares: Autoslew, MaxIm DL and AstroImageJ

Competences gathered following the extrascholar activity:

-competences in scientific investigation in the domain of photometry

-competences in scientific language communication

-competences in teamwork

-competences in critical thinking regarding the observatory's activities

-methodological competences

-digital competences in using astronomical softwares

-competences in data reduction

-competences in analyzing and interpreting data and information obtained

   The student, during the activity, has shown the following attitudes and values:

-coherence and correctitude in utilizing specific scientific language

-interest and curiosity in scientific research

-attention in astronomical observations

-perseverence and precision in obtaining scientific data

-creativity during the observation program

Figure 4. Diana Manole (the student), preparing for an observation session

Figure 5. Ovidiu Tercu (the mentor) with Diana Manole (the student)

Figure 6. NGCA-V29 finderchart generated with DSS images

References

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