Discovery of a new EA+BY variable star combining K2 and IAC80 photometric data in the context of observacional practice subject of VIU Master degree

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Brief Abstract

We present the discovery of a new EA+BY variable estar by six **students** of the Astronomy and Astrophysics Master degree of **Valencian International University (VIU)** in the context of the **observational practice** subject. We explain our initial target searching throughout **K2** data, the planning and execution of the observations with the **IAC80** telescope in order to acquire short-cadence photometry, and data **reduction** and **analysis**. Unfortunately, the period uncertainty propagated throughout more than three years since the K2 detection caused that our ephemeris failed and thus we measured the flat area of the light curve. Even so we were able to register the star adding an entry in the AAVSO VSX database.

Context

- One of the main features of the Astronomy and Astrophysics **Master Degree** of the **Valencian International University** is the **observational practice** in a professional observatory. This group was designated to observe during 8th-10th of May, 2020 (almost full moon) with IAC80 telescope at Teide Observatory, in Tenerife island.

- We tried to search for a project as much interesting as possible from the scientific point of view. We planned to study **planetesimal transits** of WD 1145+017 b, **new previously found variability** of EPIC 248690431 and **Dumbbell Nebula morphology**. Due to several problems with the CCD camera **CAMELOT2** installed on IAC80, we decided to focus on EPIC 248690431 and Dumbbell Nebula.

- Several Master Degree **subjects** were essential to carry out this project: **Classical Astronomy and Astronomical Instrumentation**, **Exoplanets and Astrobiology**, **Astronomical Image Processing, Stellar Astrophysics** and **Optical and Infrared Astronomy**.

- We organized the work through several videoconferences and through the Kanban methodology, implemented on a Trello board, throughout the whole Project.

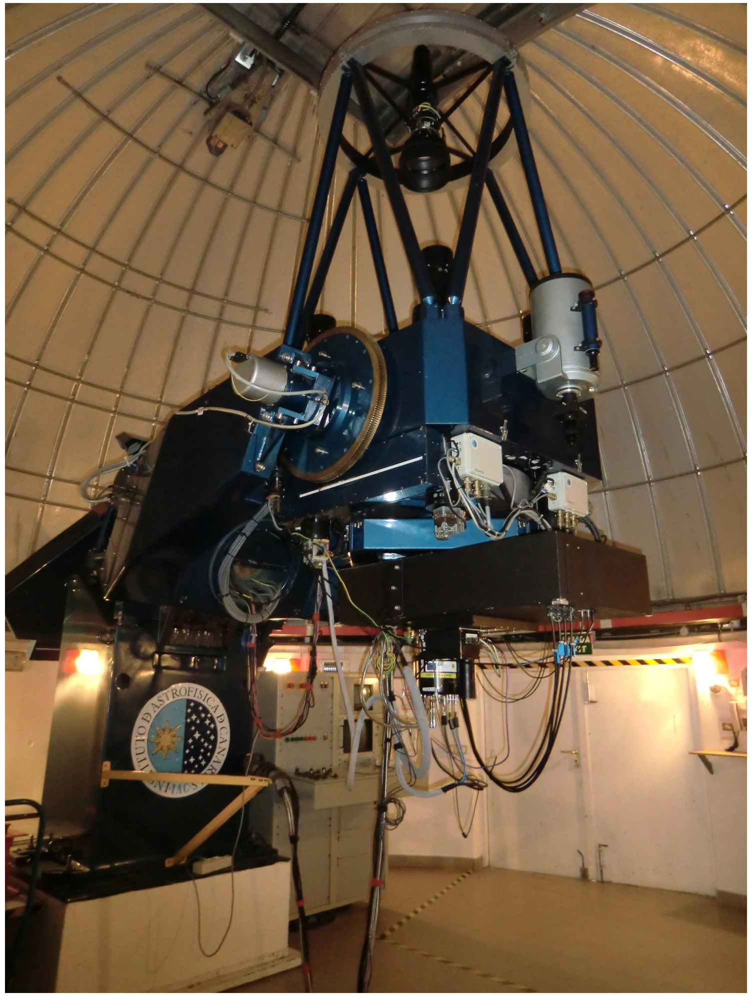


Figure 1. IAC80 telescope. Credit: Paula García.

Methods

- We analysed thousands of *K2 Self Flat Fielding* light curves (Vanderburg & Johnson, 2014) for visible targets from Tenerife in May 2020 with an automatic search based on BLS algorithm (Kovács et al. 2016), in order to find short-period unpublished transiting signals.

- For the signals found, we computed their transit ephemeris to find out if any of them would transit in the three reserved observing nights. We also used STARALT to check that the target was separated by at least 30 degrees of the full moon, to avoid photometric contamination (Fig. 2). Luckily, we found a target (EPIC 248690431) transiting every 6h that satisfied all the above conditions.

- We made an observation proposal for the IAC80 to acquire short-cadence photometry and we also participated remotely in data collection with the indications of telescope operators.

- Data analysis:
  - We performed data reduction of bias subtraction and flat-field division.
  - We performed relative photometry throughout a custom Python pipeline.
  - We fitted the data including a linear baseline model

$$B = a_0 + \sum_i a_i p_i$$

to account for possible correlations between the photometry and parameters p_i as airmass, seeing, integration time, xy CCD positions and background.

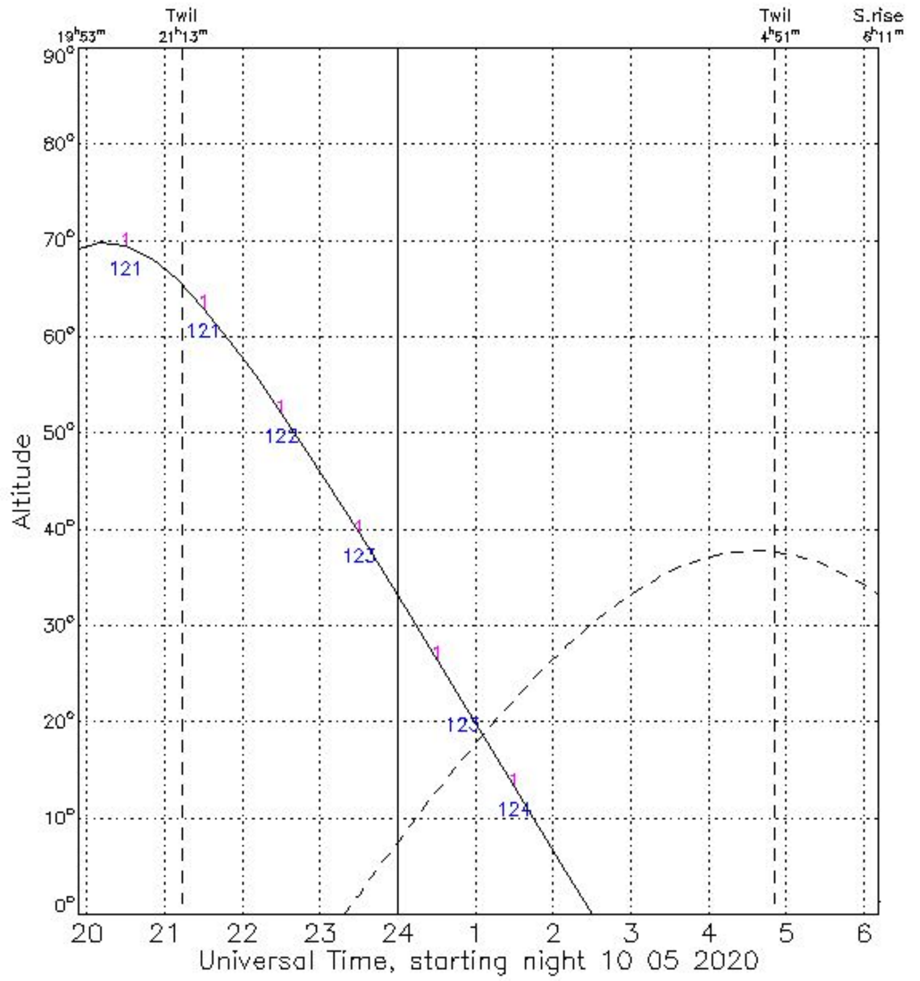


Figure 2. Trajectory of EPIC 248690431 for 10th of May 2020 from el Teide Observatory (solid line) along with the moon trajectory (dash dotted line) with 83% illumination. Transit ephemeris indicated a mid-point transit at 22:30 h UTC. With a 1h transit duration, we would have enough time span to observe much of the transit.

Results I. K2 data

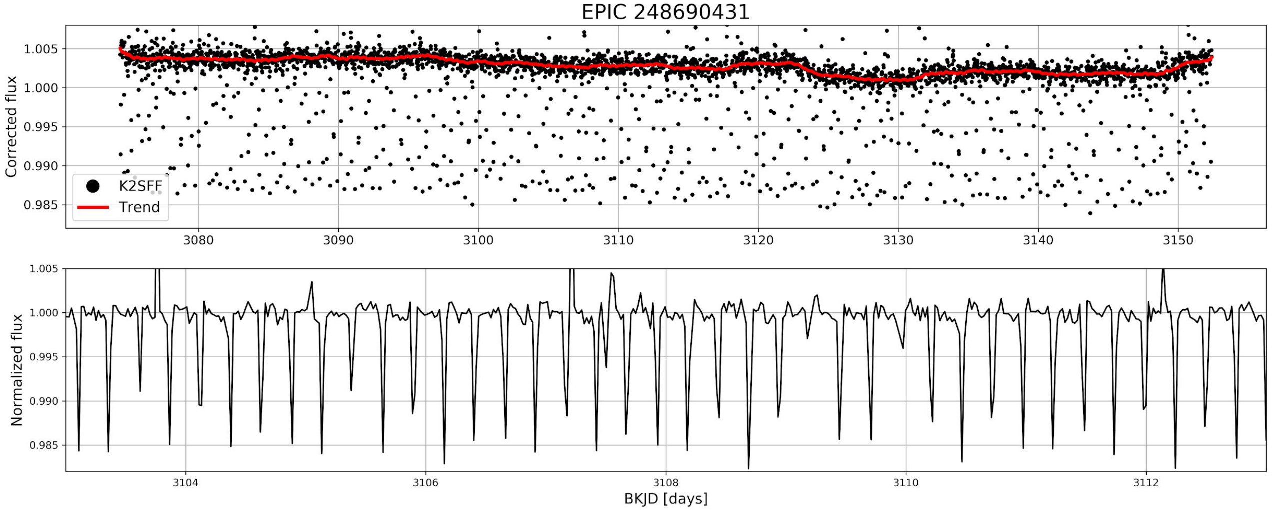


Figure 3. Top: K2SFF light curve for EPIC 248690431 along with the trend line (in red) corresponding to a moving median of 1.5-day boxcar size (72 data points). Bottom: Eclipses of the new variable star after detrending.

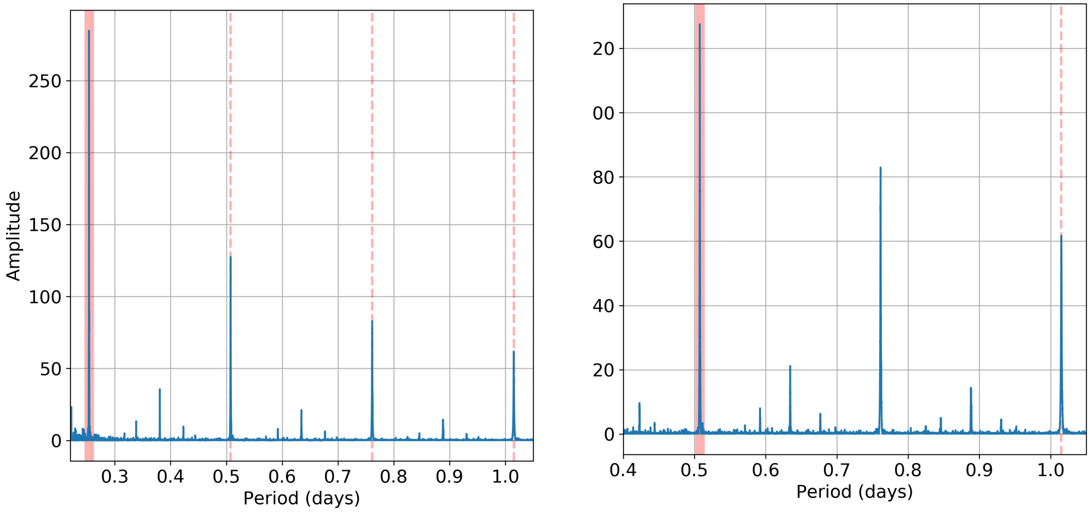


Figure 4. Left. BLS periodogram for EPIC 248690431 showing a principal periodicity at 0.2538 d (red). Dash dotted lines indicate the harmonics of the main period. The associated phase-folded light curve shows apparently a single main dip. However, multiplying the period by 2, subtly the primary minimum can be distinguished from the secondary. **Right:** True orbital period 0.5075 d obtained constraining the periodicities.

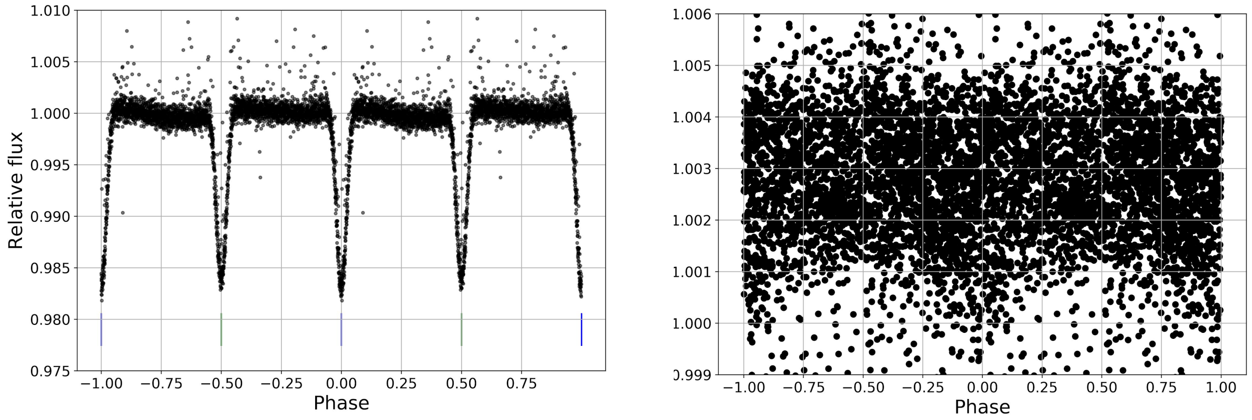


Figure 5. Left: Phase-folded light curve showing the primary (blue lines) and secondary eclipses (green lines). **Right**: Another slight periodicity is found every 22 days. This modulation is most likely due to the stellar rotation, thus being one of their components a By Draconis variable.

Where does the signal come from?

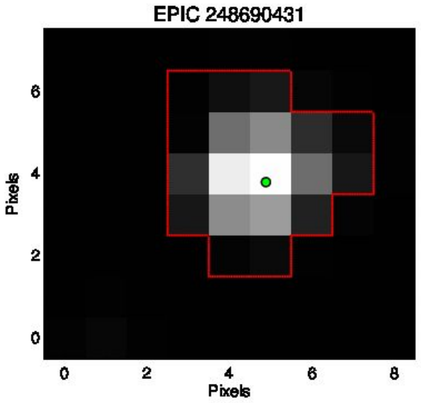


Figure 6. K2SFF considered photometric aperture. The large pixel scale factor of Kepler (3.98"/px) is not enough to distinguish possible contaminant sources.

Figure 7. Pan-Starrs1 image shows a nearby contaminating source at 4.3" (red) **within the Kepler aperture**. Another not visible closer star at 1.2" (purple) is detected in Gaia DR2.

The observed dip δ' is related to the hypothetical dip in a companion δ within the same aperture:

$$\delta' = \frac{\delta}{\gamma} = \frac{\delta}{1 + 10^{0.4\,\Delta m}}$$

To explain δ' = 0.017 it would be necessary:

60% dip (not credible).
21% dip (very unlikely).

So we consider that the signal comes from the primary star.

Results II. K2 + IAC 80 data

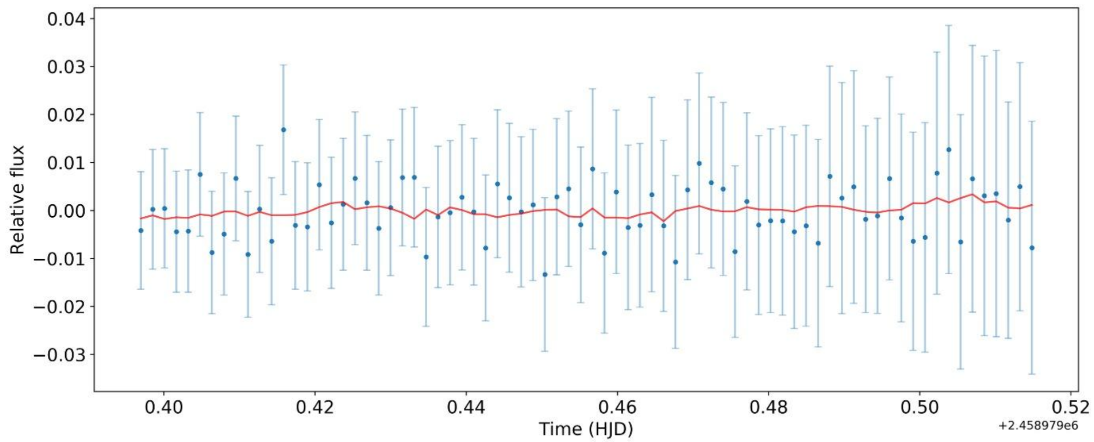


Figure 8. Light curve and baseline model for EPIC 248690431 extracted from IAC80 (9th of May).

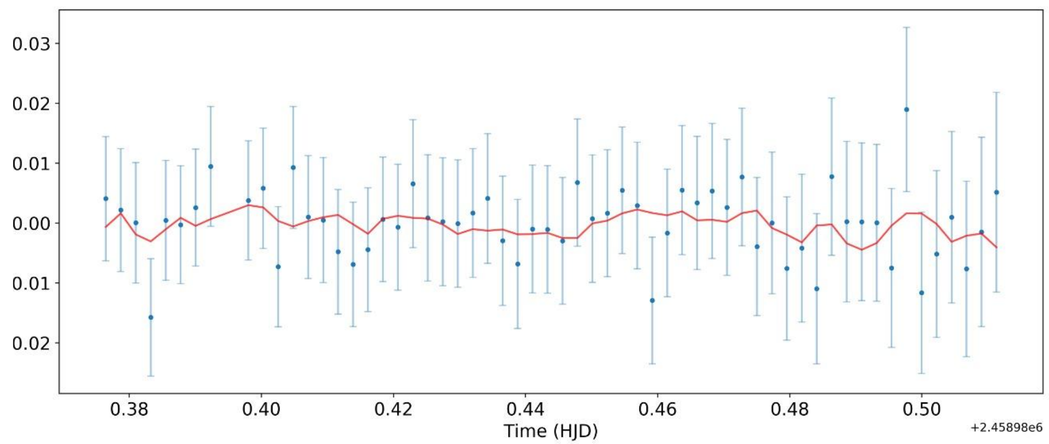


Figure 9. Light curve and baseline model for EPIC 248690431 extracted from IAC80 (10th of May).

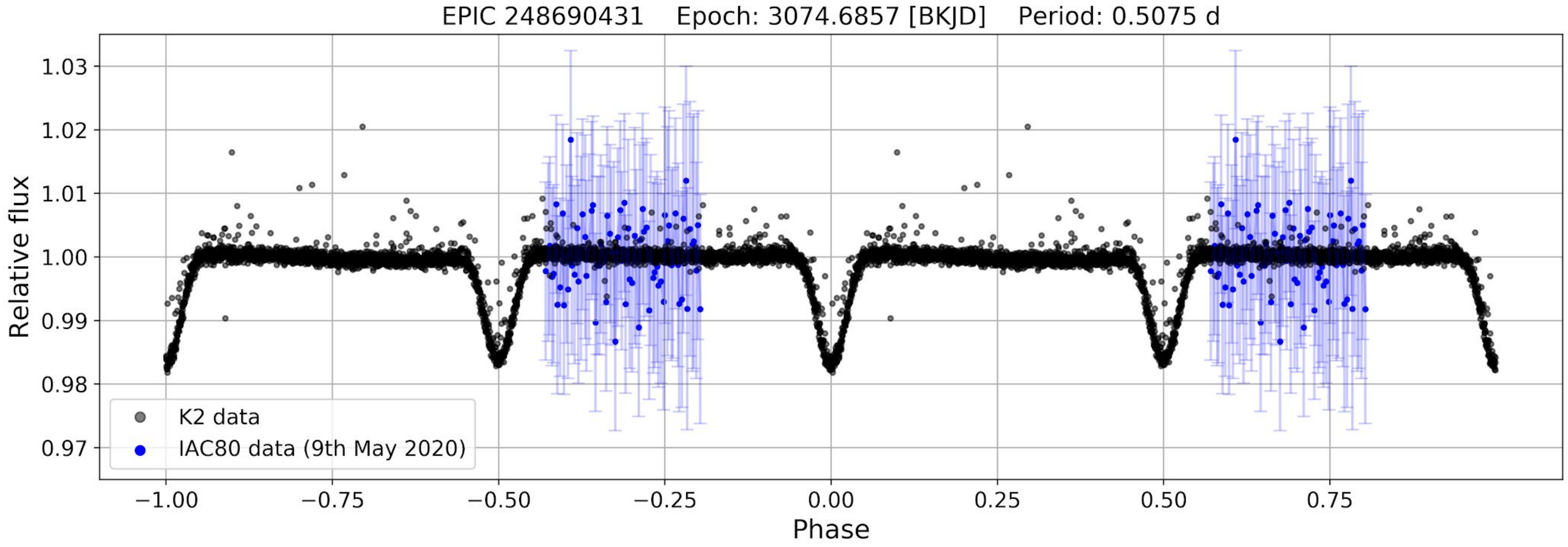


Figure 10. Phase-folded light curve for EPIC 248690431 combining K2 and IAC80 data. Unfortunately, transit ephemeris calculation failed due to the period uncertainty propagation. Moreover, the great IAC80 data dispersion would have made detection difficult with a low SNR, surely standing at the limits of detectability.

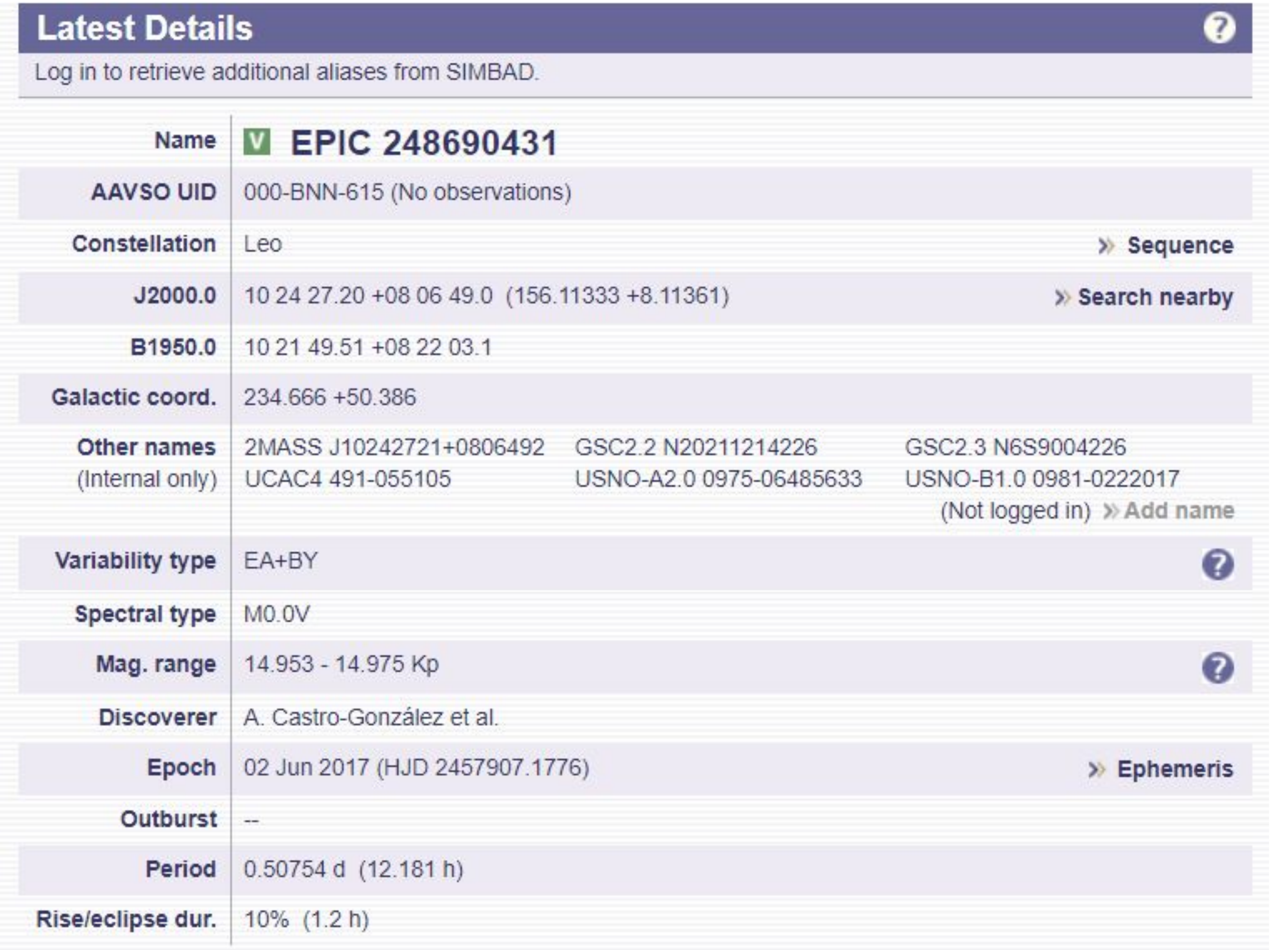
Future & Impact

- Longer exposure times with IAC80 (for example in service mode) in **photometric nights** are needed in order to perform precision aperture photometry for each star to identify BY and EA components.

- Beyond detection itself, a future more detailed analysis (e.g. taking spectrums, RV measurements, etc) is required to extract accurate stellar parameters and to delve into the system peculiarities.

- This work has made possible improve the knowledge and familiarization with several astronomical softwares, from **IRAF** and **Fotodif** or **Period04** and **VSTAR** to custom made **Python pipelines**.

This work also exemplifies how Master degree students with practical subjects can produce **modest scientific results while having a good time**, encouraging their **first steps in their future research careers**.


Latest Details

Log in to retrieve additional aliases from SIMBAD.

Name	V EPIC 248690431	
AAVSO UID	000-BNN-615 (No observations)	
Constellation	Leo	» Sequence
J2000.0	10 24 27.20 +08 06 49.0 (156.11333 +8.11361)	» Search nearby
B1950.0	10 21 49.51 +08 22 03.1	
Galactic coord.	234.666 +50.386	
Other names (Internal only)	2MASS J10242721+0806492 GSC2.2 N20211214226 GSC2.3 N6S9004226 UCAC4 491-055105 USNO-A2.0 0975-06485633 USNO-B1.0 0981-0222017	(Not logged in) » Add name
Variability type	EA+BY	?
Spectral type	M0.0V	
Mag. range	14.953 - 14.975 Kp	?
Discoverer	A. Castro-González et al.	
Epoch	02 Jun 2017 (HJD 2457907.1776)	» Ephemeris
Outburst	--	
Period	0.50754 d (12.181 h)	
Rise/eclipse dur.	10% (1.2 h)	

Figure 11. VSX entry for EPIC 248690431.