Contrib. Astron. Obs. Skalnaté Pleso **55/3**, 362 – 365, (2025)
https://doi.org/10.31577/caosp.2025.55.3.362

octans: Observed calculated diagram and light curves

M. Niaei[1,2] and **Ö. Baştürk**[3,4]

[1] *Ankara University Graduate School of Natural and Applied Sciences, Department of Astronomy and Space Sciences, Ankara, Türkiye (E-mail: astrosek@science.ankara.edu.tr)*

[2] *Informatics and Information Security Research Center, Türkiye*

[3] *Ankara University, Faculty of Science, Department of Astronomy and Space Sciences Ankara, Türkiye*

[4] *Ankara University Astronomy and Spaces Sciences Research & Application Center, Kreiken Observatory, Incek Blvd., Ankara, Türkiye*

Received: November 15, 2024; Accepted: March 3, 2025

Abstract. `octans` is a `Python` library designed for easy and robust calculation of light curve extrema timings and the construction of O-C diagrams. It also provides access to various databases to retrieve light curves and extrema times. While `octans` includes a user-friendly GUI (which is under construction), its primary focus is on sophisticated algorithms for deriving extrema timings from binary and variable star light curves.

Key words: light curve – minima – propagation of uncertainty

1. Introduction

A light curve measures periodic changes in flux from a celestial body over time, driven by external (extrinsic) or internal (intrinsic) properties. The unique features of a light curve reveal valuable information about the source. Changes in the orbital periods of binary stars can provide valuable insights into their orbital characteristics and the interactions between their components. These variations are visualized by plotting differences between observed timings of extrema ("O") and those computed from a linear ephemeris ("C"), forming O-C diagrams.

To create an O-C diagram, one must measure extrema times on a light curve. Various methods, such as the bisector of chords, Kwee-van Woerden (Kwee & van Woerden, 1956), direct measurement or determining local minima from the derivative of a fit function (Pilarčík et al., 2012), and Fielder (Pilarčík et al., 2012) techniques, have been employed to achieve the task. These methods involve finding the extremum point of a minimum profile in a discrete dataset. Most available software lack robust error propagation for these measurements. `octans` emphasizes accurate uncertainty estimation, though some techniques, such as frequency analysis and Kwee-van Woerden method, either lack or underestimate error assessments due to their limitations.

2. octans code

`octans` is written in Python based on frequently used libraries in astronomy such as `astropy`, `astroquery`, `numpy`, pandas, `lightkurve` and more.

2.1. Light curve handling and retrieval

To handle light curve data, an `XLightCurve` object can be created using time, flux, and optionally flux error values. Observers can input their light curve data with built-in Python functions or libraries like `pandas` and `astropy`. For external data sources, `octans` provides methods to retrieve data from various astronomical archives and databases, including `Kepler` Borucki et al. (2010), `TESS` Ricker et al. (2015), `ASAS` Shappee et al. (2014), `var_astro`* Czech Astronomical Society (2024), and `ETD`* Czech Astronomical Society (2024).This is accomplished via the `Portal` class. Note that options marked with * may be modified or removed due to change in terms of use of VarAstro.

2.2. Measurements of minima timings

Light minima measurements are vital for observing eclipsing binaries, marking eclipse times on a light curve and aiding in studying orbital period changes. If the period varies, minima timings will deviate from those predicted by a fixed linear ephemeris.

2.3. Methods of measurement

`octans` has multiple classes where it encapsulate the data and functionalities. For instance to store time and error in time `octans` employs a class called `Minima`. It stores the timing as `astropy.time.Time` and its uncertainty as `astropy.time.TimeDelta`.

In order to analyze the time-series itself `octans` uses a class called `XLightCureve` which is inherited from `lightkurve.lightcurve`. So it already comes with all the functionalities of the object. `octans` adds some other functions on top of that.

2.4. Construction of an O-C diagram

`octans` employees a dataclass called `Minima`. It encapsulates each measured time and its associated uncertainty (must be called observed). Having an observed minimum time is enough to create an O-C diagram. Equipped with a previously observed minimum time and the period of variability one can calculate the expected minima timings and store them in `Minima` dataclass. The next step would be the comparison of these values.

2.5. An example run

A sample code to retrieve O-C diagram from data available in VarAstro is shown in Listing 1 and the result is shown in Figure 1.

Listing 1 Retrieving O-C data from VarAstro using `octans`

```
from octans import Portal, Period
from matplotlib import pyplot as plt

name = "XY LEO"

# Create a Portal and Period Object
portal = Portal.from_name(name)
period = Period.from_name(name)

# Retrieve Periods from all available sources
# and get the value obtained from VarAstro
period_values = period.all()
var_astro_period_value = period_values[period_values["source"] == "
    VAS"].iloc[0].P

# Retrieve minima times from VarAstro
var_astro_minimas = portal.var_astro()

# Create O-C
var_astro_oc = var_astro_minimas.oc(period=var_astro_period_value)
var_astro_oc.smooth(s=0.02).plot(
    marker=".", color="red", linestyle="None"
)
plt.title(f"O-C Diagram of {name}")
plt.xlabel("Time (JD)")
plt.ylabel("O-C (JD)")
plt.tight_layout()
plt.show()
```

3. Conclusion

`octans` is a user-friendly software tool for astronomical light curve analysis, hosted on `GitHub` (`https://github.com/mshemuni/octans`) and available on `PyPi` (`pip install octans`). It operates with the reliability of widely-used `Python` packages, ensuring robust and efficient performance.

Acknowledgements. We thank TÜBİTAK for their support with the 1001 grant for our project 122F358.

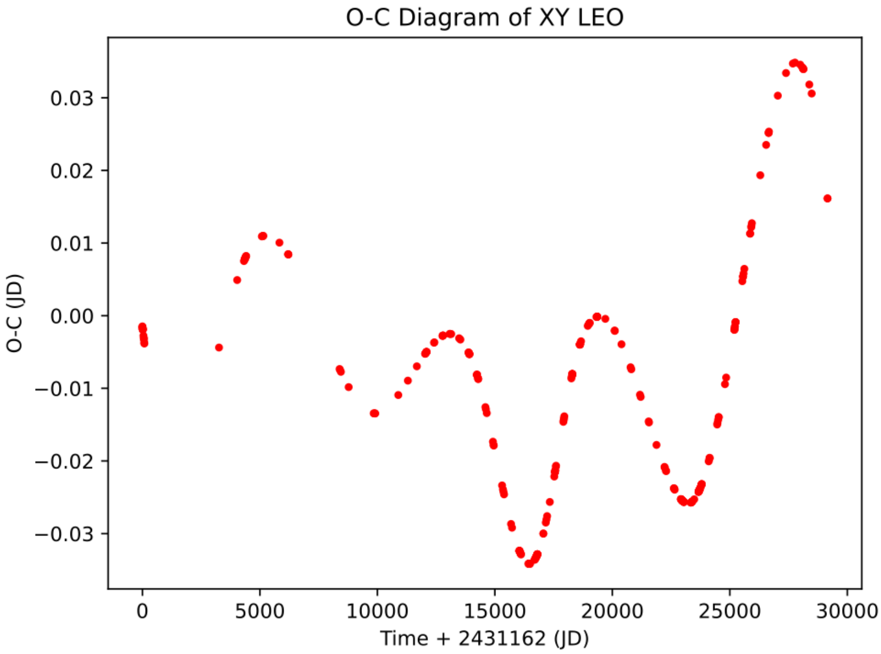

Figure 1. OC diagram generated via `octans`

References

Borucki, W. J., Koch, D. G., Basri, G., et al., Kepler's Planet-Detecting Mission. 2010, *Science*, **327**, 977, DOI:10.1126/science.1185402

Czech Astronomical Society. 2024, VarAstro: A Database of Variable Stars, accessed: 2024-11-05

Kwee, K. K. & van Woerden, H., A method for computing accurately the epoch of minimum of an eclipsing variable. 1956, *Bulletin Astronomical Institute of the Netherlands*, **12**, 327

Pilarčík, L., Jelínek, M., & Hudec, R., Several Methods of Estimating Times of Minima in Cataclysmic Variables And Some Fesults for EX Dra. 2012, in *Proceedings of the WDS 2012* (Matfyzpress), 116–122

Ricker, G. R., Gilbert, H., Larsen, J., et al., Transiting Exoplanet Survey Satellite (TESS). 2015, *Journal of Astronomical Telescopes, Instruments, and Systems*, **1**, 014003, DOI:10.1117/1.JATIS.1.1.014003

Shappee, B. J., Holoien, T. W.-S., Dilday, B., et al., The All-Sky Automated Survey for Supernovae (ASAS-SN). 2014, *The Astrophysical Journal*, **788**, 48, DOI:10.1088/0004-637X/788/1/48