Monitoring Satellite Brightness: A Python-Based Pipeline for Accurate Brightness Estimation of LEO Satellites

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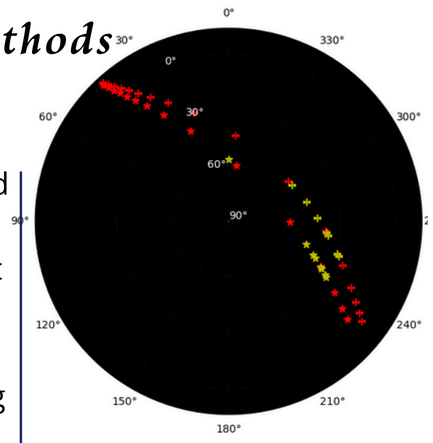
01. Abstract & Introduction

The increasing number of Low Earth Orbit (LEO) satellite constellations has raised significant concerns in the astronomical community due to their impact on night sky observations [1]. These LEO satellites can be extremely bright, visible to the naked eye, and can significantly impact data analysis and limit certain scientific research. To evaluate their effect on data it is necessary to measure their brightness using visual magnitude, which is a direct measure of a satellite's interference with astronomical observations [1,2]. This study introduces a Python-based pipeline for analyzing images of artificial satellites observed at the Oukaimeden Observatory. The pipeline calculates the apparent magnitudes of observed objects and facilitates direct comparisons of their reflective brightness across multiple observations.

02. Observational methods

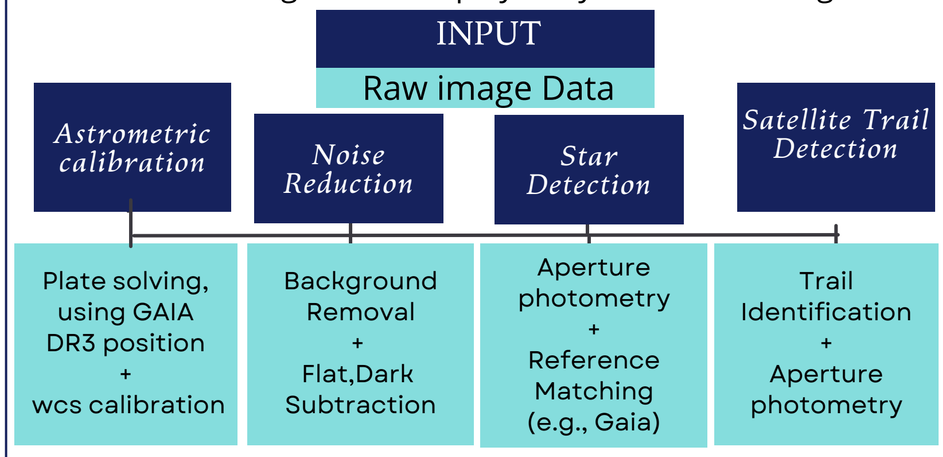
The visual analysis in this study was conducted using two optical telescopes: the HAO and MOSS. These telescopes are robotic instruments installed at the Oukaimeden Observatory. We employed a sidereal tracking mode using a scanning method with a single exposure time for observing satellites. This ensured that the satellite trails appeared in a single image without extending beyond the borders.

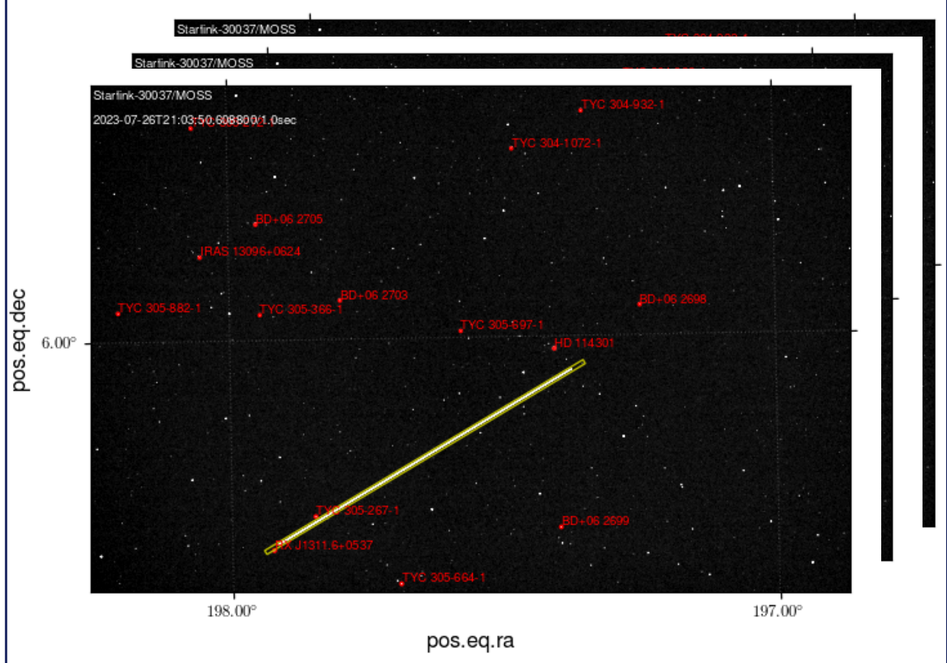


Our code uses the latest TLE data and Skyfield package to determine the date/time (UT and RA/Dec of visible LEO sat from a given location.

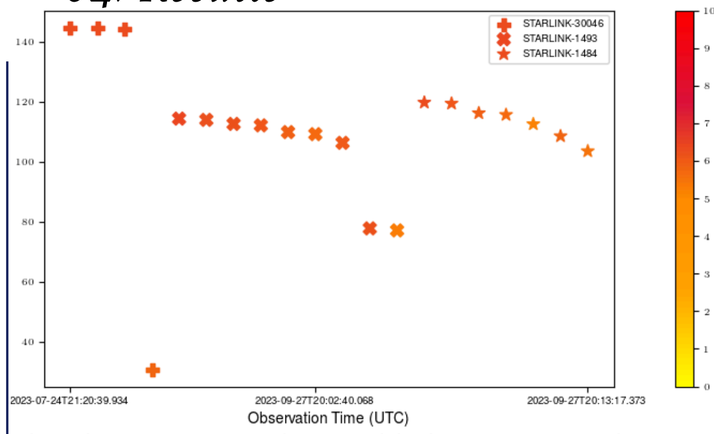
03. Data Processing

Data processing consists of measuring the Satellite's apparent magnitude, which is determined by comparison with nearby stars of known magnitudes displayed by the Gaia catalog.





04. Results



The photometric analysis yielded an accurate phase curve, presenting the range-corrected V-band magnitude as a function of phase angle and time.

05. Conclusion

The pipeline effectively calculates satellite brightness from observational data, improving our ability to monitor and understand the impact of artificial satellites on optical observations. It provides valuable insights for future research and mitigation strategies to address satellite interference in astronomy.

06. Acknowledgment

This pipeline uses the following packages:

- ▶ Astrometry with Astrometry.net
- ▶ Photometry using Photutils, an Astropy package
- ▶ Skyfield, a package for computing positions for LEOSat.

07. References

[1]. Olivier R. Hainaut and Andrew P. Williams. Impact of satellite constellations on astronomical observations with ESO telescopes in the visible and infrared domains, 636:A121, April 2020.

[2]. Sangeetha Nandakumar, et al. The high optical brightness of the BlueWalker 3 satellite. 623(7989):938–941, November 2023.