# Observations and Analysis of 2577 Litva

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## Introduction

Remote observations of small bodies are a cheap way to gather information about our celestial neighbors, especially when compared to robotic spacecraft missions. The information gathered can provide insights into topics ranging from solar system formation and evolution to impact mitigation. Additionally, with NASA focusing on visiting and capturing a small near earth body, these observations can perform invaluable support and information gathering roles.

We are specifically interested in the physical properties and structure of small bodies, features such as the bulk and grain density, porosity, and composition. Binary asteroid systems provide an invaluable resource for measuring these properties. In a binary system one or more smaller asteroids orbit about the primary, akin to a planet and moon system. If the orbital period of the secondary can be determined, it can be used in conjunction with Kepler's equations to determine the mass of the system. With brightness estimates on the two components, and assumptions about reflectance of the asteroids, the relative sizes of each body can be determined and their relative masses inferred. Together with volume estimates, the bulk density can be measured. If composition information is available or estimated, the difference between the grain densities and the bulk density will provide the bulk porosity and insights into the structure of the body.

We present the results from observations of asteroid 2577 Litva, a known binary. In our analysis we focus on error (uncertainty) budgeting, identification, and propagation. We use robust statistical methods and routines at each step of reduction and analysis to both determine physical properties with meaningful error estimates, and to show the applicability of making this type of measurement on relatively modest equipment.

## History of 2577 Litva

2577 Litva is a Mars-crossing asteroid discovered in 1975 by N. Chernykh. In 2009 the object was discovered to be a binary member of the Hungaria family [1]. Being a binary, the object warranted additional follow up as there are relatively few binaries known and opportunities to determine physical properties are extremely valuable. Merline et. al. observed the asteroid in June and August 2012, and again in August and October 2013 and discovered a second satellite [2].

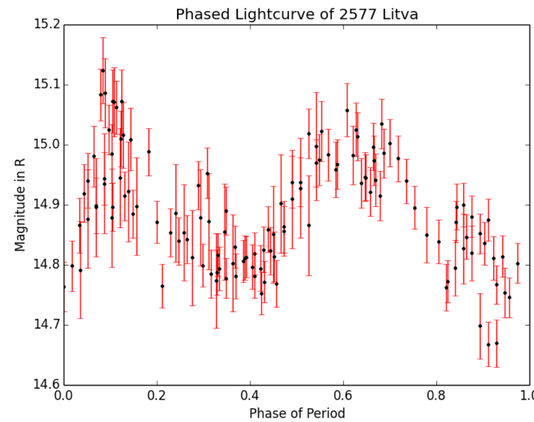


Figure 1: A subset of the collected lightcurve was phased about the published period. This produces a plot where the x-axis is the percentage (aka location) of one full rotation.

## Observations and Facilities

Our observations were taken in December 2013 and January 2014, with a baseline spanning several weeks. This was enough to ensure that several full periods were observed, getting complete phase coverage. The observations were taken at Robinson Observatory, located on campus at the University of Central Florida in Orlando. This facility features a 0.5 meter RitcheyChrétien telescope on a German equatorial mount. The data is collected on an SBIG 6303e full frame sensor, and analyzed with custom software written in the Python programming language. Figure 2 (next page) shows an example lightcurve from one night's observation, Figure 1 shows a subset of our observations phased about the published period which emphasizes our phase coverage and the shape of the light curve.

## Reduction and Analysis

When working with modest facilities and faint targets, robust routines specialized for low signal-to-noise scenarios are necessary. We make use of methodologies outlined in [3].Our suite of programs includes routines for accurately determining the centers of photometric distributions (least asymmetry centering and bayesian denoising), and routines for finding periods and how they change in time (such as Fourier analysis, Szego polynomial fitting, wavelet analysis). In this work we also make

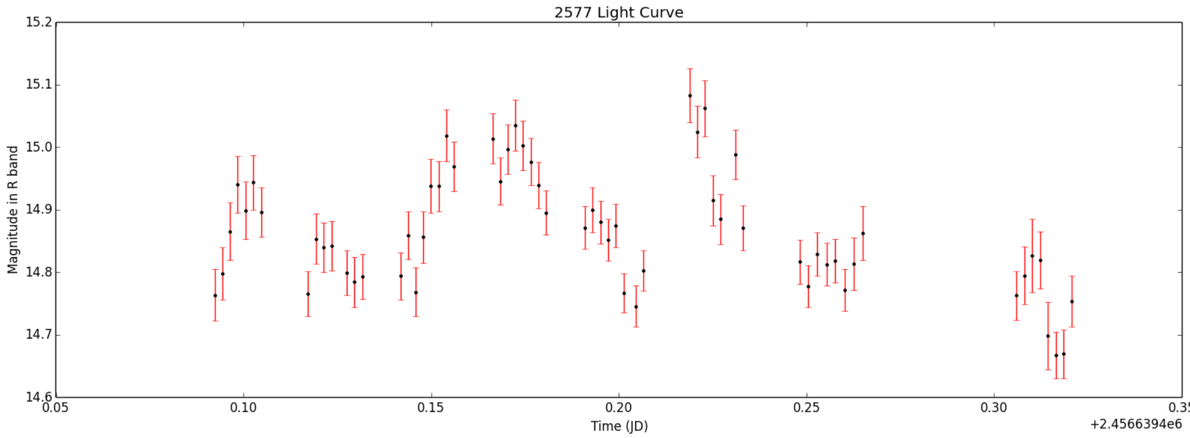


Figure 2: Sample Lightcurve from one nights observation.

extensive use of traditional Markov-Chain Monte Carlo [4] routines for tracking uncertainty propagation in the reduction of our data.

In the analysis of our data we use the routines from [3], some being standards like Fourier curve fitting, but in conjunction with differential evolution Markov-Chain Monte Carlo routines [5]. This methodology is a combination of genetic algorithms with traditional MCMC analysis. The advantage of this methodology is that it allows very fast searching of large parameter spaces, while preserving the bayesian inference on uncertainty distributions. This allows us to accurately and consistently generate error bounds on our measurements in a robust, systematic, and efficient way.

# References

[1] B. D. Warner, et al. 2577 Litva: A Hungaria Binary. *Minor Planet Bulletin*, 36:165–166, 2009. [2] W. J. Merline et. al. S/2012 (2577) 1. *Central Bureau for Astronomical Telegrams*, 9267, 2013. [3] N. Lust, et al. New Methodology for the Reanalysis of Low Signal Small Bodies. In *EPSC-DPS Joint Meeting 2011*, page 1512. 2011. [4] R. M. Neal. Probabilistic inference using markov chain Monte Carlo methods. Technical Report CRG-TR-93-1, University of Toronto, 1993. [5] Cajo J. Braak. A markov chain monte carlo version of the genetic algorithm differential evolution: Easy bayesian computing for real parameter spaces. *Statistics and Computing*, 16(3):239–249, 2006. ISSN 0960-3174. doi: 10.1007/s11222-006-8769-1.