New Sights for NEOSSat:

A Big Shift for a Little Satellite

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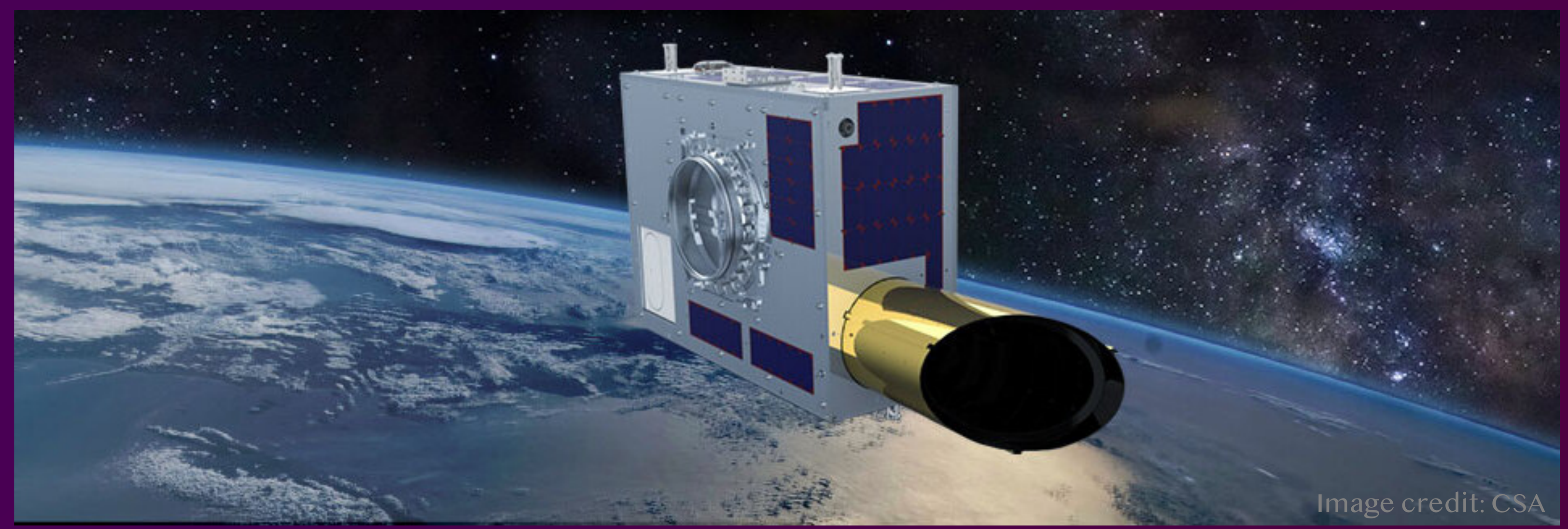
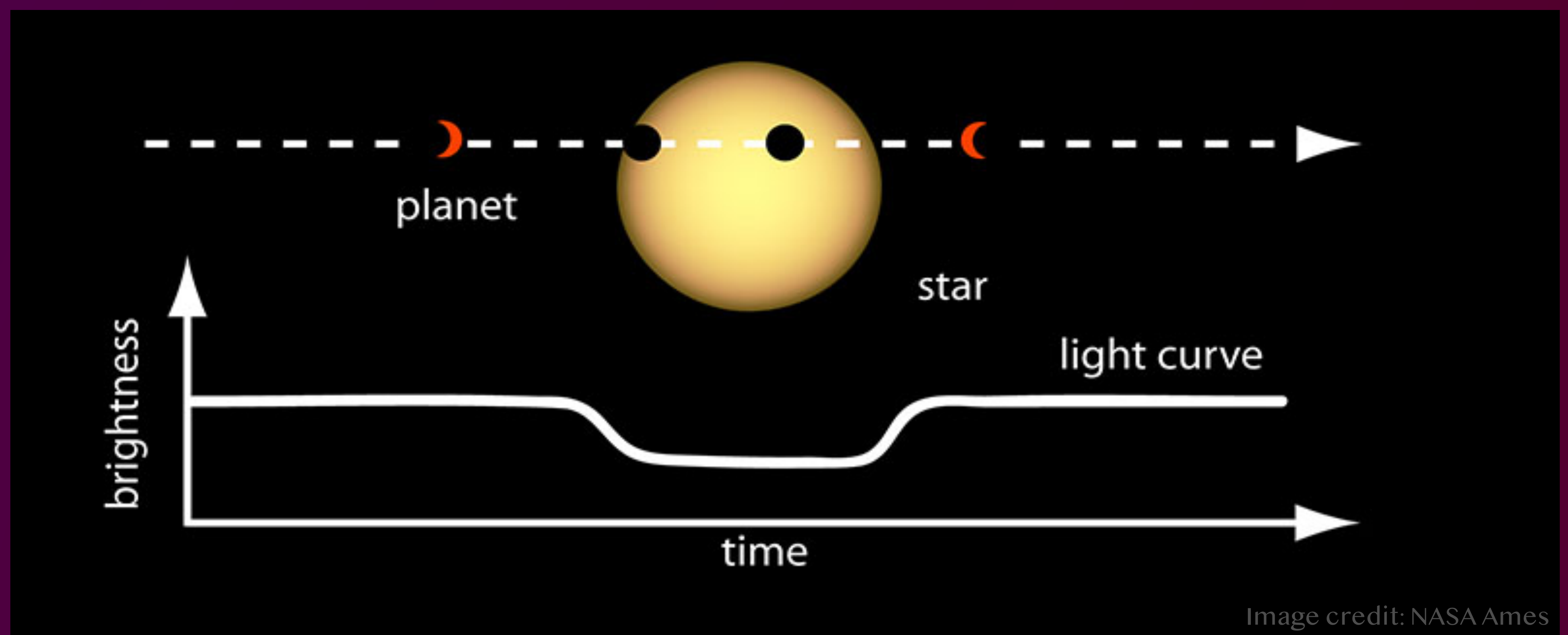


WHAT IS NEOSSAT?

The Near Earth Object Survey Satellite (NEOSSat) is a **Canadian microsatellite** jointly operated and funded by the Canadian Space Agency and Defence Research and Development Canada. It was launched in 2013 with the goal of tracking near-Earth asteroids as well as satellites and space debris. NEOSSat has a sun-synchronous pole-to-pole orbit, allowing a continuous viewing zone along some portion of the ecliptic throughout the year. It is equipped with a 15-cm aperture telescope with a maximum FOV of 0.86 x 0.86 degrees and a spatial resolution of 3 "/pix. NEOSSat has recently undergone a re-engineering to handle a new observing mode that allows for long-duration stable pointing and accurate photometric measurements.

PROJECT GOALS

Recently the NEOSSat team has begun a Guest Observation (GO) program calling for proposals to do science beyond the original instrument goals. Our team made two successful proposals: One is to thoroughly investigate the instrument's new stable-pointing mode to assess its capability as an exoplanet observer. The second is to use the advantages of a space-based observatory to observe long-duration transits that are extremely challenging from the ground.



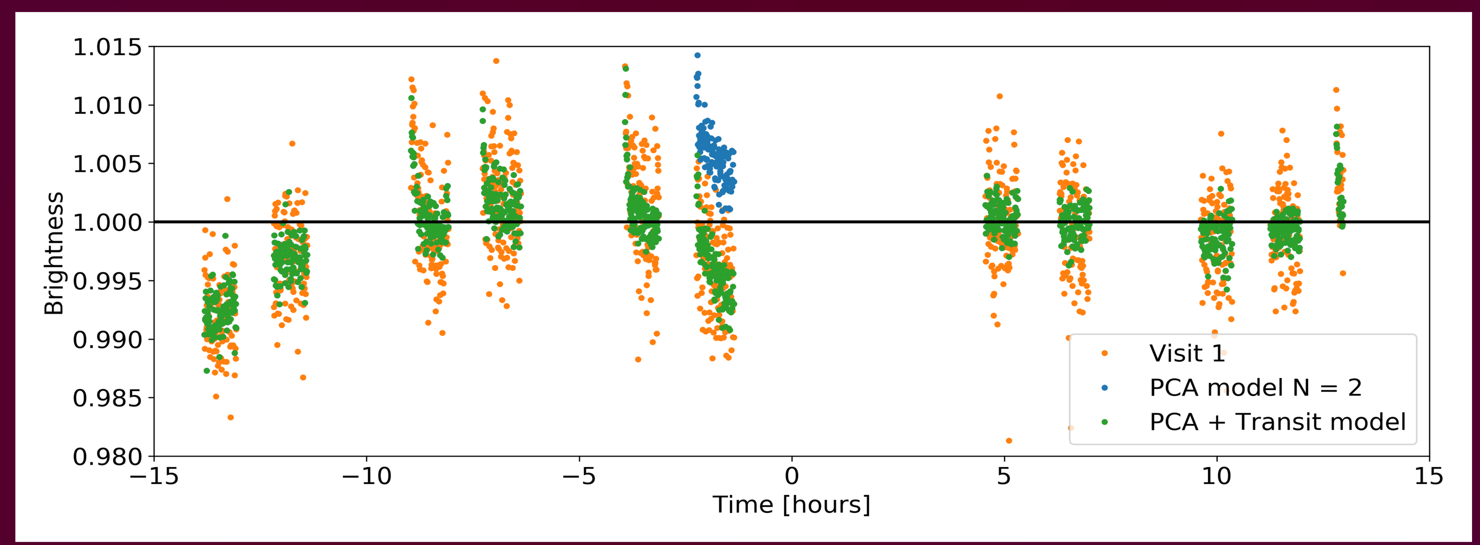
Exoplanet Transit

A transit occurs when a planet's orbit takes it across the disk of a star as viewed from the observer's point of view. A signature dip in the star's brightness is caused as the planet blocks a portion of the starlight. The shape and timing of the light curve can be analyzed to deduce properties of the planet and its orbit.

DATA REDUCTION

Raw NEOSSat images contain a component of systematic noise caused by electronic interference between the CCD camera and other onboard electronics, which manifests as a wave-like pattern on the detector. We correct for this electronic noise by performing Fourier analysis on the overscan region of the detector to determine the dominant frequencies in the pattern, and fitting a model including these frequencies to the science area of the images. Once this correction has been performed on all dark frames and science images, we combine the dark frames into a master dark, and subtract it from the science images. Finally we extract aperture photometry on all sources above a certain brightness cut using aperture radii from 2.5 to 7. 5 pixels in half pixel increments.

Although designed to observe objects in our own Solar System, NEOSSat is proving to be an excellent exoplanet observatory!

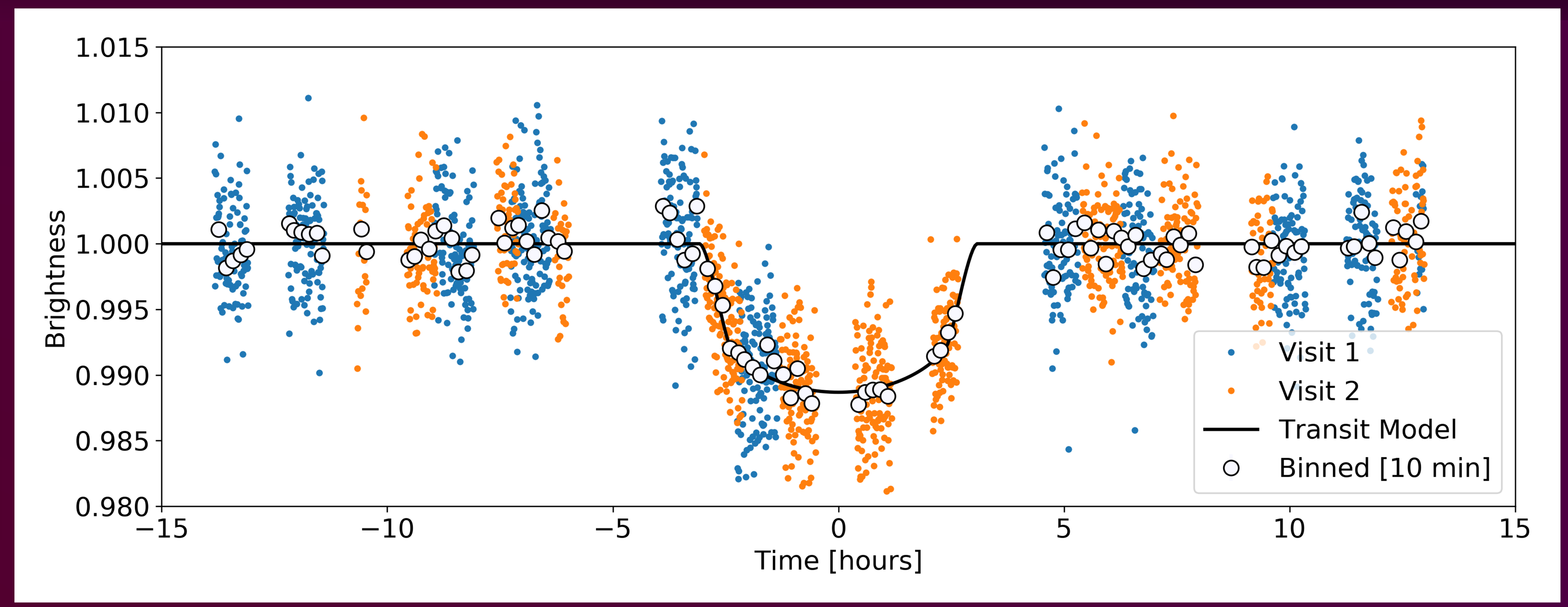


PCA Example:

Orange points are the normalized flux of the target. Blue points represent the first two components of the PCA model. The PCA model overpredicts the flux when the target star deviates from the trends common to all reference stars. Green points show the addition of a transit model which brings the PCA into agreement with the flux.

DATA ANALYSIS

The extracted light curves contain residual trends that are caused by variations in the detector temperature and the quality of the stray light shielding as NEOSSat's orientation with respect to the Earth/Sun/Moon changes. In order to remove these trends we select a set of around 15-25 isolated stars across the field and perform a principal component analysis (PCA) to isolate the dominant trends common to all stars. We then correct the target light curve by fitting the first few PCA components to the light curve while either masking out the (expected) in-transit points or jointly with a transit-model. A finalized light curve is shown in the top right figure. Typically the first 2 PCA components are sufficient to remove the residual trends.



Light Curve

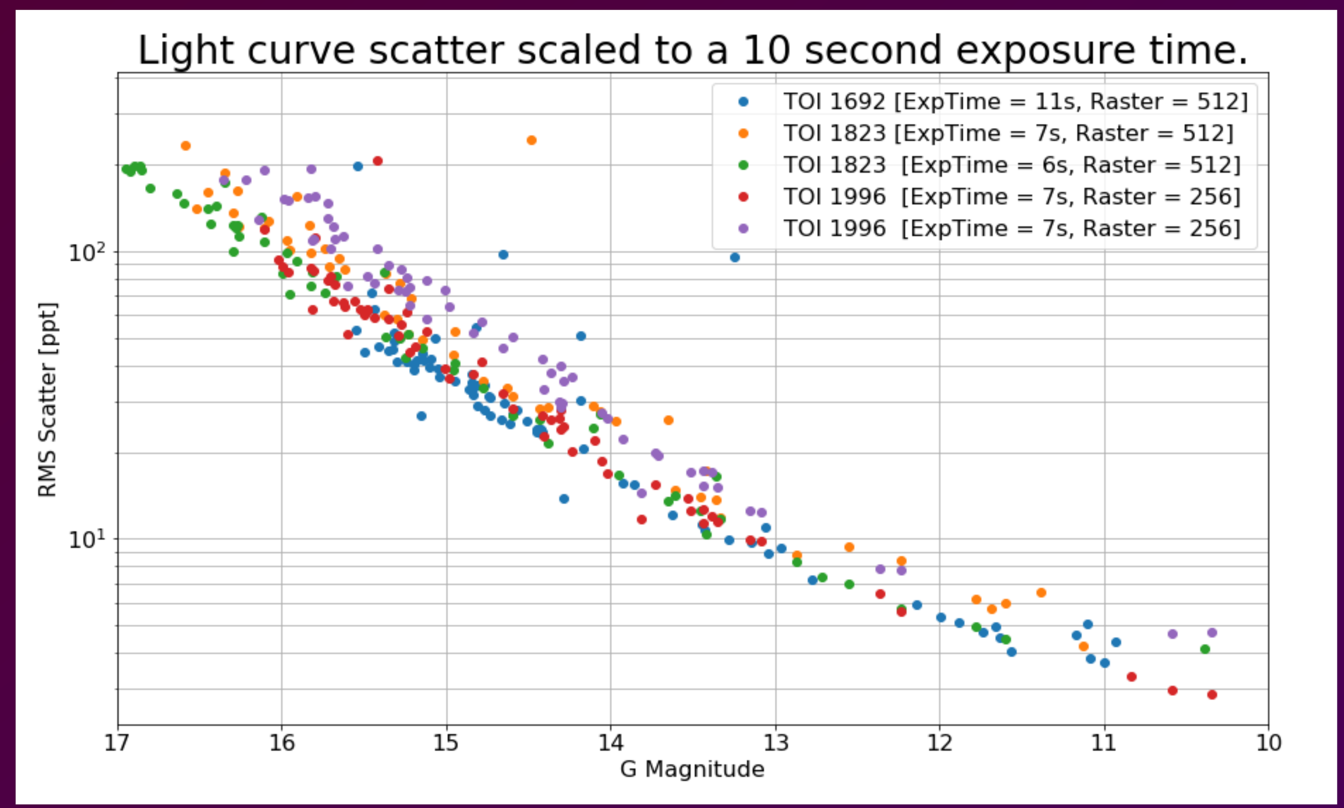
Observations of two transits of the same exoplanet allow us to piece together a more complete light curve. The gaps are caused by necessary breaks in NEOSSat's viewing (e.g. Earth-eclipse, engineering processes, etc.)

RESULTS

We are finding that NEOSSat's new observing mode can provide the precision required to observe many exoplanet light curves. For a G = 13 target, we achieve around 10 ppt precision with 10-second exposures. This precision obviously improves with bining, and is better for brighter targets. It also scales roughly with Poisson noise if we make longer or shorter exposures (keeping below saturation, of course).

DISUSSION

NEOSSat has proven to be many things. First off, it is a relatively accessible Canadian space-based observatory. The new Guest Observation program has opened it up to a wide range of projects that will promote, support, and demonstrate Canadian excellence in astronomical science and instrumentation. Furthermore, we are hoping to provide an example of how an instrument's design goals do not fully determine what it can be used for. Here, an observatory designed to catalogue and understand our own Solar System is proving itself capable of probing distant worlds. We hope we can inspire others to think of other projects NEOSSat is capable of.



RMS Plot:

In order to display several observations of different exposure times together, we scaled their RMS values to match a 10-second exposure using Poisson noise scaling:

$$RMS_{(scaled)} = RMS\sqrt{\frac{Exptime}{10s}}$$

The observations follow a distinct RMS-magnitude relation.