Searching for Exoplanet Transit Changes with NEOSSat

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Introduction

We present NEOSSat observations of WASP-80b, which are used to search for systematic changes in the planet's transit signature. This includes a slow drift in the orbital period and any Transit Duration Variations (TDVs). These data are part of a larger study to search for transit variations among known hot Juipters.

Motivation

- Observations of exoplanets have shown that planetary systems can look completely unlike the solar system. Of particular interest are hot Jupiters, gas giants that orbit remarkably close to their stars.
- Long-term, systematic changes in orbital periods and TDVs can reveal the dynamics of the system and aid in understanding planetary system evolution. This goes beyond typical Transit Timing Variations (TTVs).
- Such changes can arise from a number of factors, such as:
  - Tidal interactions between a close-in planet and its star, causing long-term period changes
  - Stellar oblateness and weak interactions between planets, causing a slow evolution of the inclination and eccentricity vectors
- At least two planets have shown a measurable drifts in their periods. WASP-12b has a measured $\dot{\mathrm{P}} = -29 \pm 3\ \mathrm{ms\ yr^{-1}}$ [1]. TESS observed WASP-4b and found it arrived 81 s earlier than predicted [2].

Data Reduction

A calibration and analysis pipeline has been developed in Python that is successful in correcting for nonlinear systematic noise in the NEOSSat data. In addition to standard bias and dark subtraction calibration procedures, this pipeline includes:

- Fourier analysis of an overscan region in the CCD to remove frequencies associated with periodic electronic noise (Figure 1)
- A local median subtraction on 16x16 pixel subsections to correct for a sensitivity gradient in the CCD
- A star-finding routine that classifies stars based on a 2D Gaussian fit and is successful even in the case of high background counts

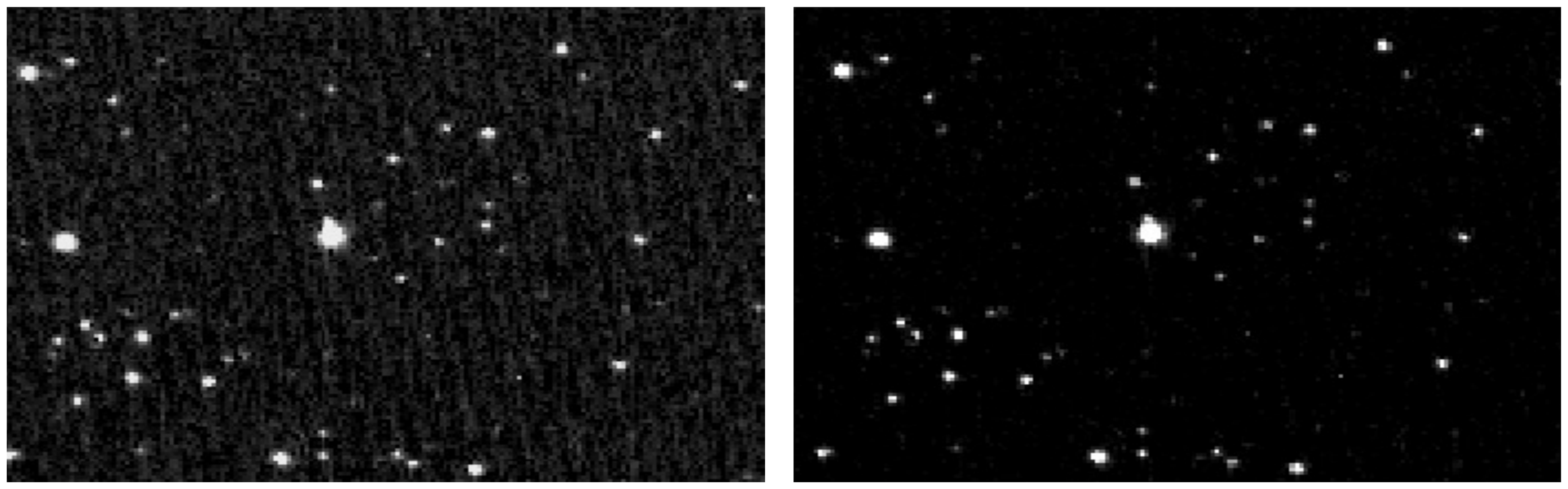

Figure 1: an image of WASP-80 taken on August 2, 2020 before (left) and after (right) removing Fourier frequencies associated with the periodic electronic noise

Preliminary Results

A best-fit model from data of three transits of WASP-80b from August – December 2020 can be seen in Figure 2. A fourth transit was excluded due to high noise, but can be seen in grey. These results have shown that the period of WASP-80b has likely been stable since being observed in 2013, therefore reducing the uncertainty in the period.

- The transit center was found to be $2459159.52453^{+0.00028}_{-0.00056}$ BJD within the 68% credible interval, which agrees with the predicted value of 2459159.524394 BJD from observations in 2013 [3]
- These observations have reduced uncertainty in the period to $3.06785234^{+0.00000036}_{-0.00000063}$ days
- If period is changing, smaller than $-12\ \mathrm{ms\ yr^{-1}}$ in magnitude

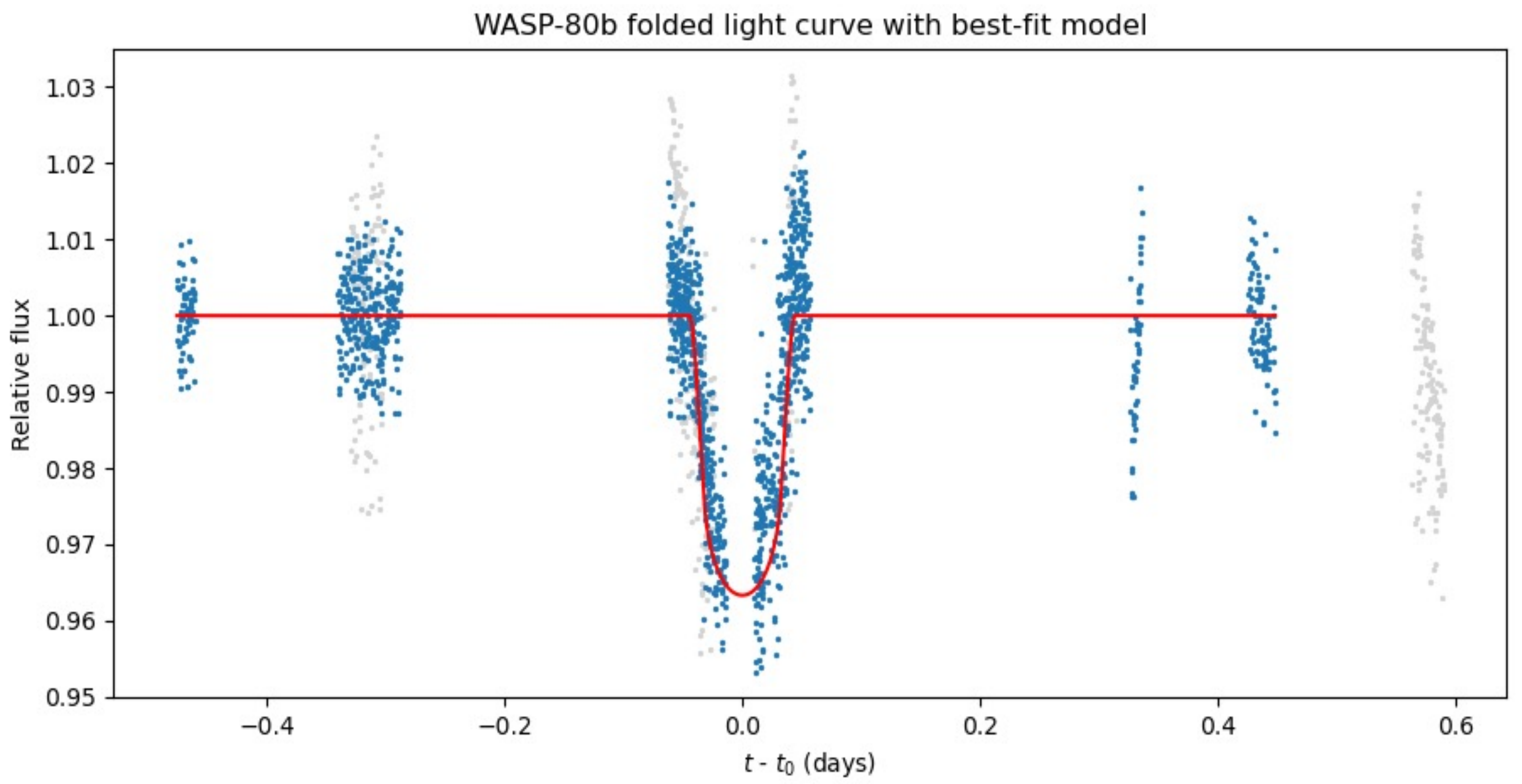

Figure 2: Best-fit transit model (red) of folded WASP-80b light curve (blue), with excluded data seen in grey. Data were taken by NEOSSat from August– December 2020 with 20 s exposures.

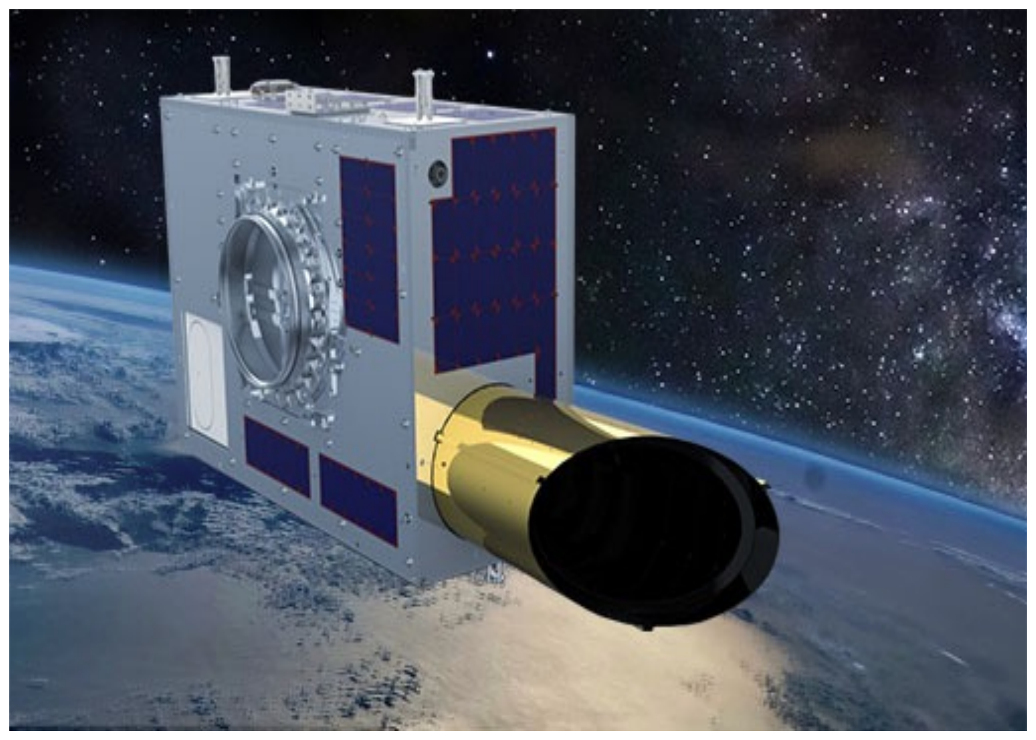

Figure 3: NEOSSat (credit: CSA)

What is NEOSSat?

- The Near Earth Object Space Surveillance Satellite (NEOSSat) is a Canadian experimental optical microsatellite in a low-Earth orbit (LEO) that was launched on February 25, 2013.
- NEOSSat data have recently been made available to a wider scientific audience and are being used to capture exoplanet transits.

Specifications:

- F/6, 15 cm Cassegrain telescope
- 0.85 x 0.85 degree FOV
- 3”/pixel scale
- 300 – 1100 nm bandwidth

Future Work

- Further analysis of NEOSSat data of WASP-19b and WASP-52b will be done, refining the analysis pipeline as needed.
- Data from the Transiting Exoplanet Survey Satellite (TESS) will be used to continue the search for period changes and duration variations
- If transit changes are detected, numerical simulations will be used to explore potential causes

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