

Search for unknown exoplanets by detection of transit timing variations

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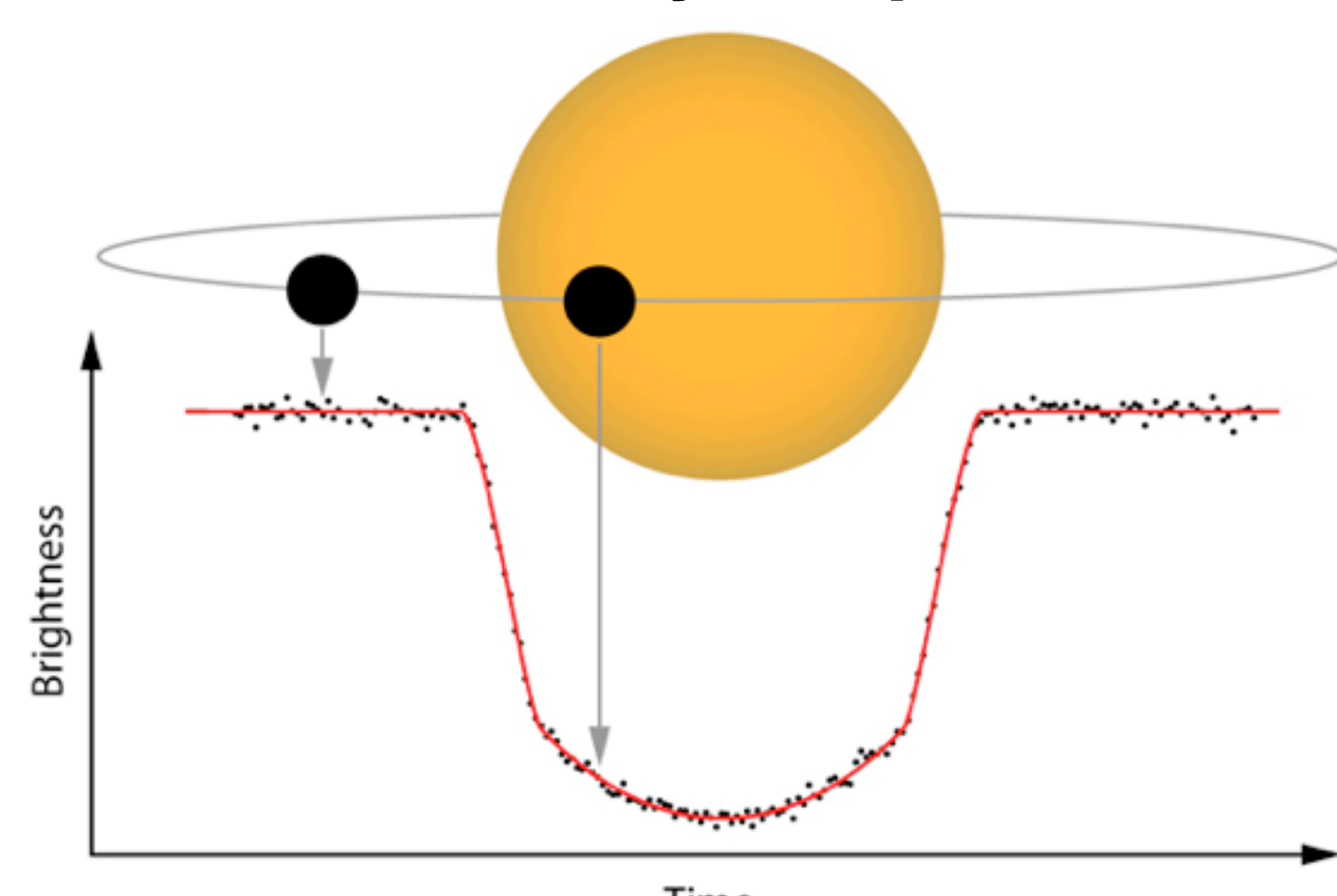
Abstract

About 500 exoplanets have been detected to date. Among them about 90% planets have been detected by the radial velocity (RV) method. However, if observed from outside of the solar system, planets less-massive than Jupiter and Saturn will not be detected by the RV method. We aim at detecting such planets, i.e., terrestrial exoplanets in other planetary systems by the transit timing variation (TTV) method. The transit periods of a known transit planet will not be constant, if there are additional planets in an already known transit planetary system.

Introduction

* More than 100 known transit exoplanets have been discovered

Transit by exoplanet



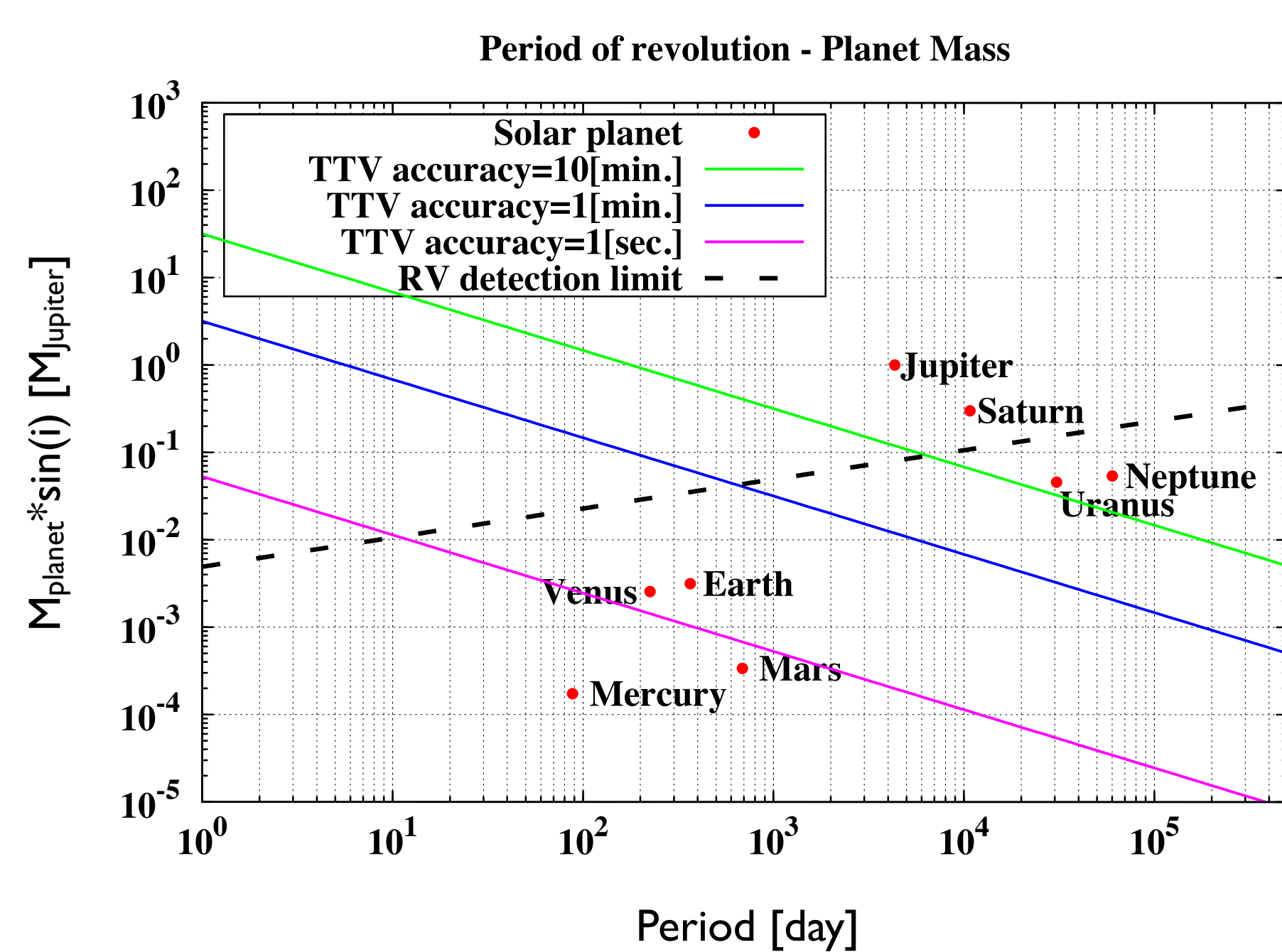
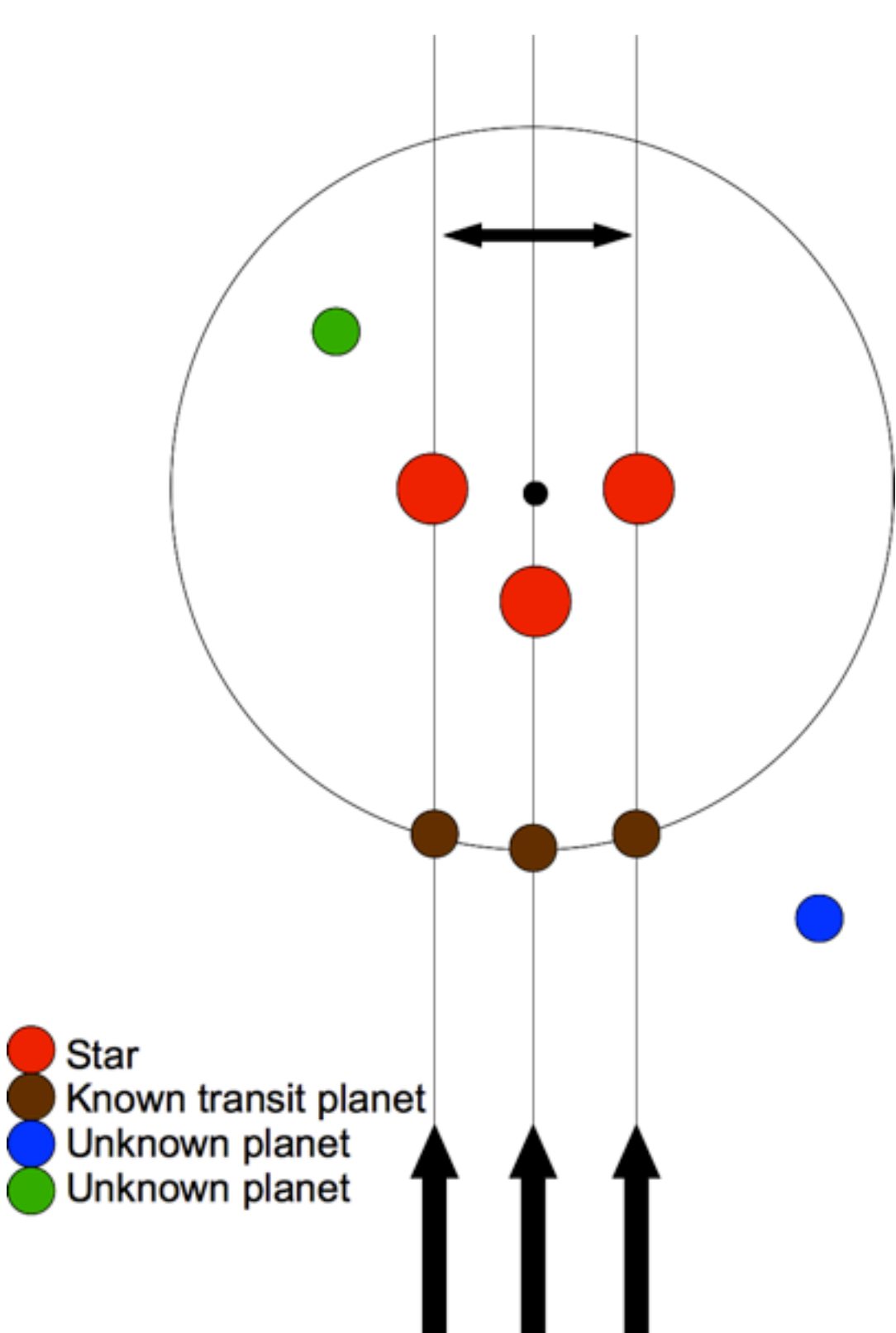
- The planet's orbit is parallel with the line of sight from the Earth
- The planet moves in front of the star
- Star's flux decreases periodically

* **What is TTV (Transit Timing Variation) ?**

TTV is a variation of observed transit timing

* **Why do TTVs occur ?** (Agol et al. 2005)

1. star's orbital motion around barycenter (left below figure)



RV detection limit: 1m/s accuracy by HARPS (Mayor et al. 2009)

2. gravitational scattering by additional planets

* **Previous study**

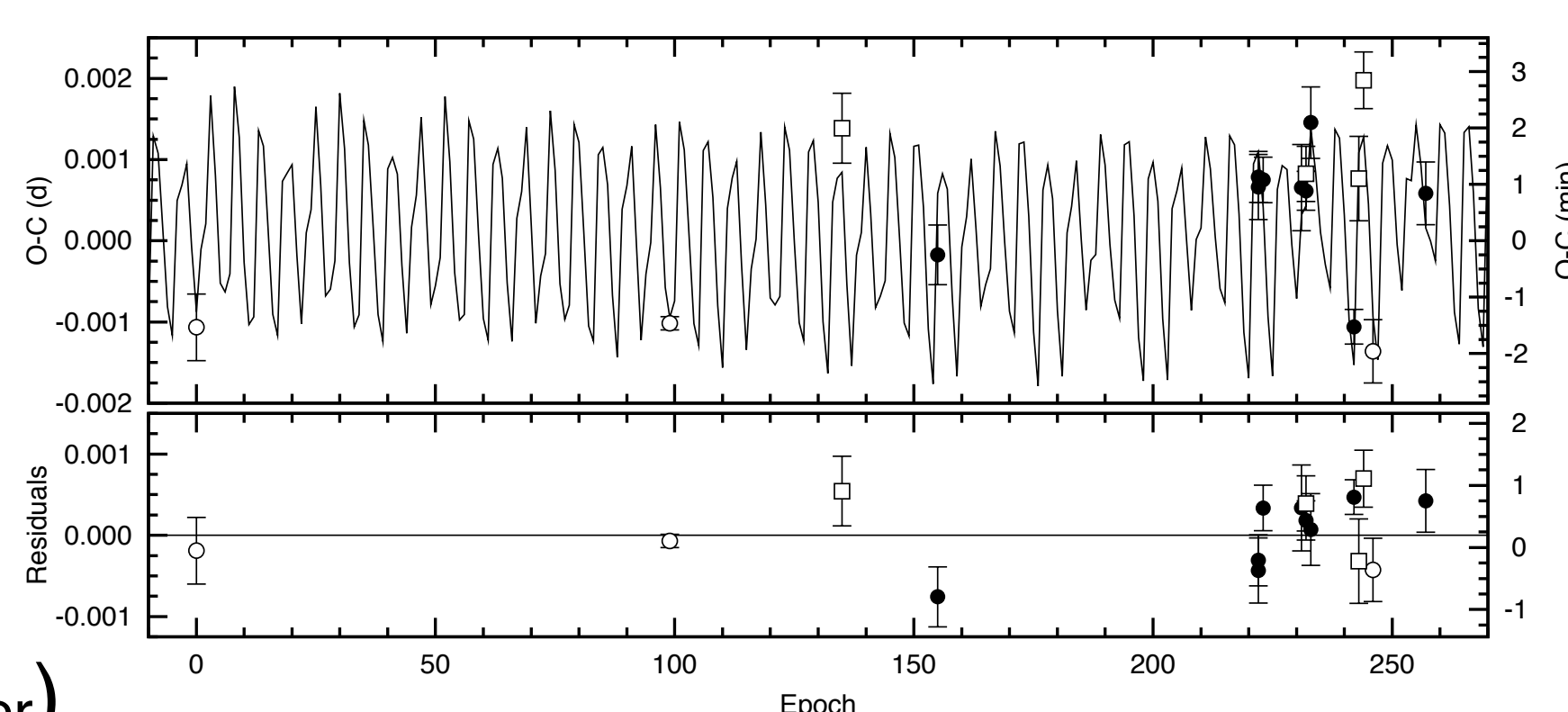
Maciejewski et al. (2010)

- known transiter:

WASP-10b ($M_b=3 M_{\text{Jupiter}}$)

- detected planet:

WASP-10c ($M_c=0.1 M_{\text{Jupiter}}$)



Observations & Data reduction

* **Site:** KISO Observatory

(the University of Tokyo)

* **Location:** Nagano Prefecture

(137:37:42.2E, 35:47:38.7N)

* **Instruments**

- Schmidt Telescope (Aperture: 105 cm)

- Detector: 2kCCD (FOV: 50' * 50')

- Filter: R band

* **Observing period**

Aug. 2010 - Jan. 2011 (12 nights)

* **Target:** XO-3b (known transit planet)

star's magnitude V: 9.91 mag

transit depth: 5 mmag

* **Exposure time:** 30 sec. or 60 sec.

* **Interval:** about 2 min. or about 2.5 min.

* **Total observation time:** about 6 hours

* **Observational technique:**

Using defocus to earn more photons

* **Data reduction** (Using IRAF)

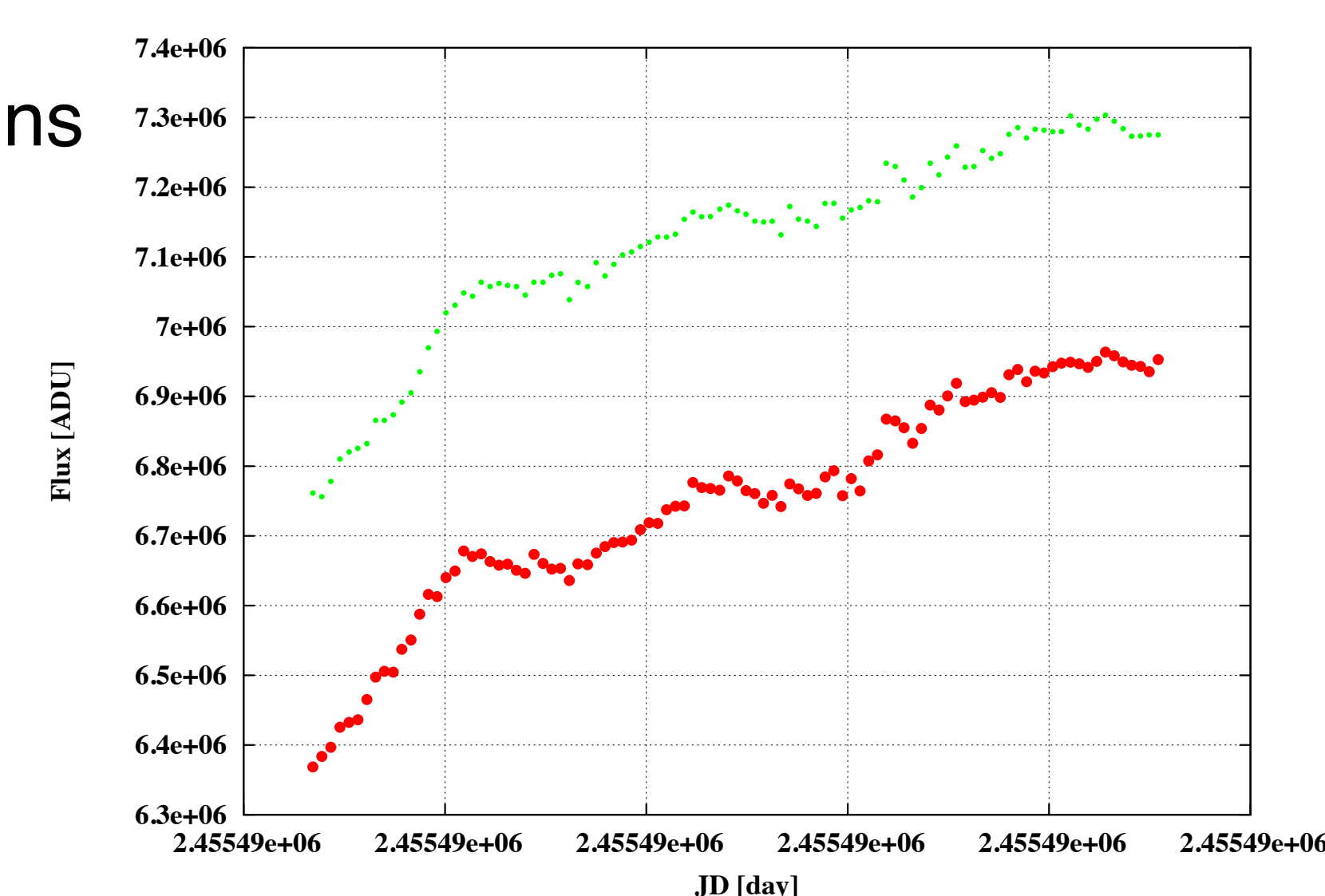
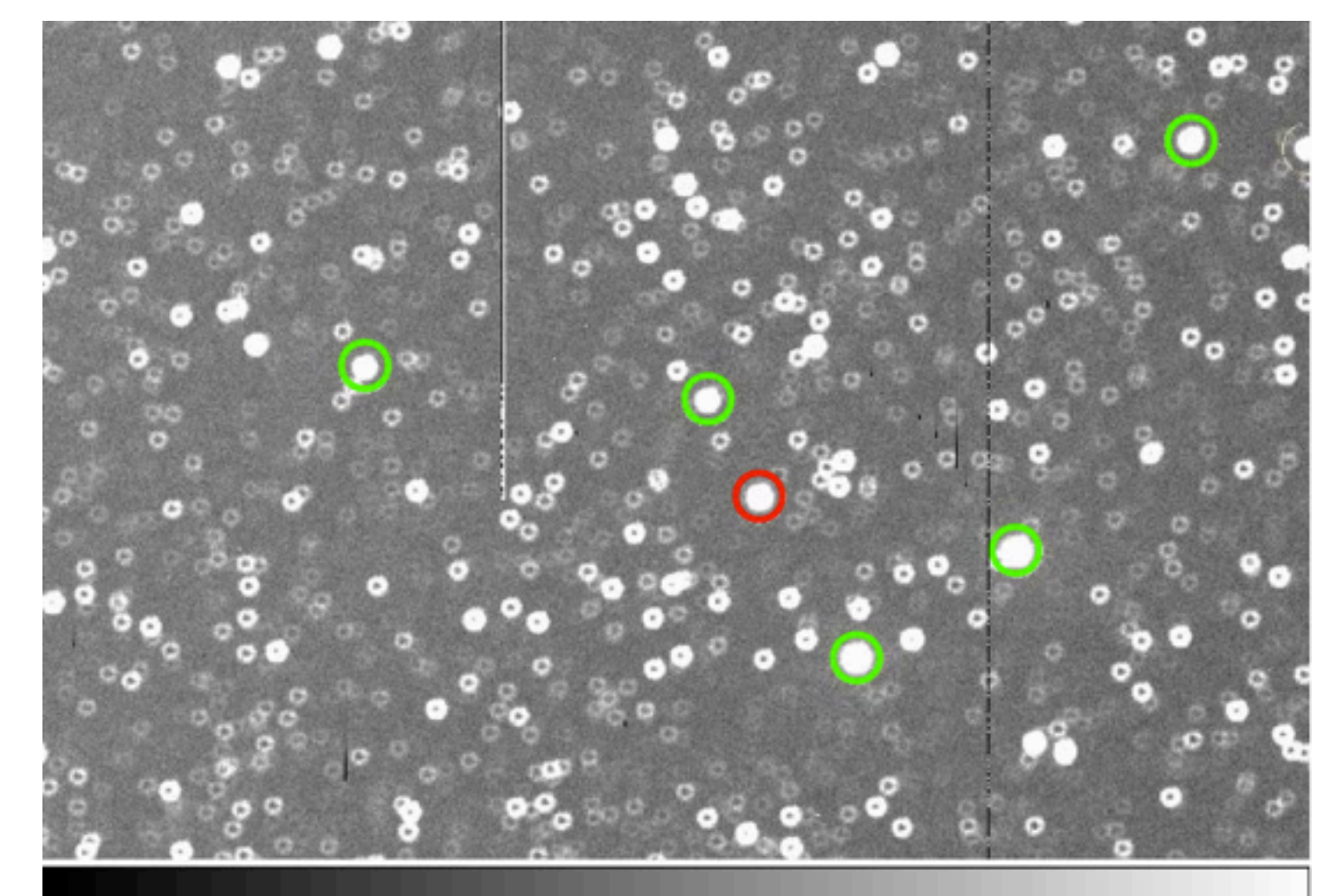
1. bias correction

2. flat fielding (dome flat)

3. aperture photometry (right figure)

(XO-3 & reference stars)

4. differential photometry



Results

* **Transit observations**

Oct. 17, 2010 (right figure)

- photometric accuracy: ~ 0.9 mmag

- accuracy of time: ~ 67 sec.

Nov. 5, 2010

- photometric accuracy: ~ 2 mmag

- accuracy of time: ~ 177 sec.

Nov. 18, 2010

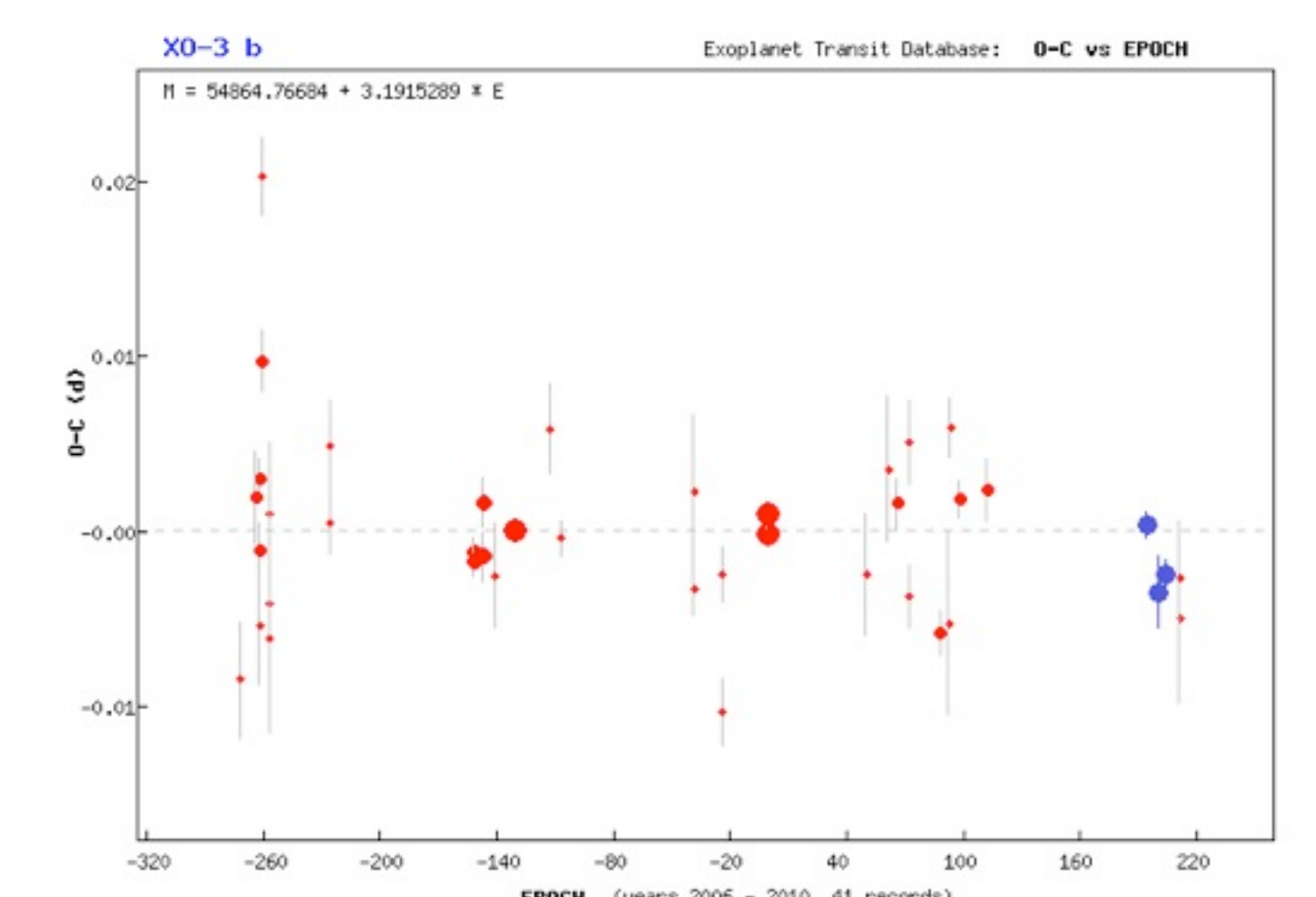
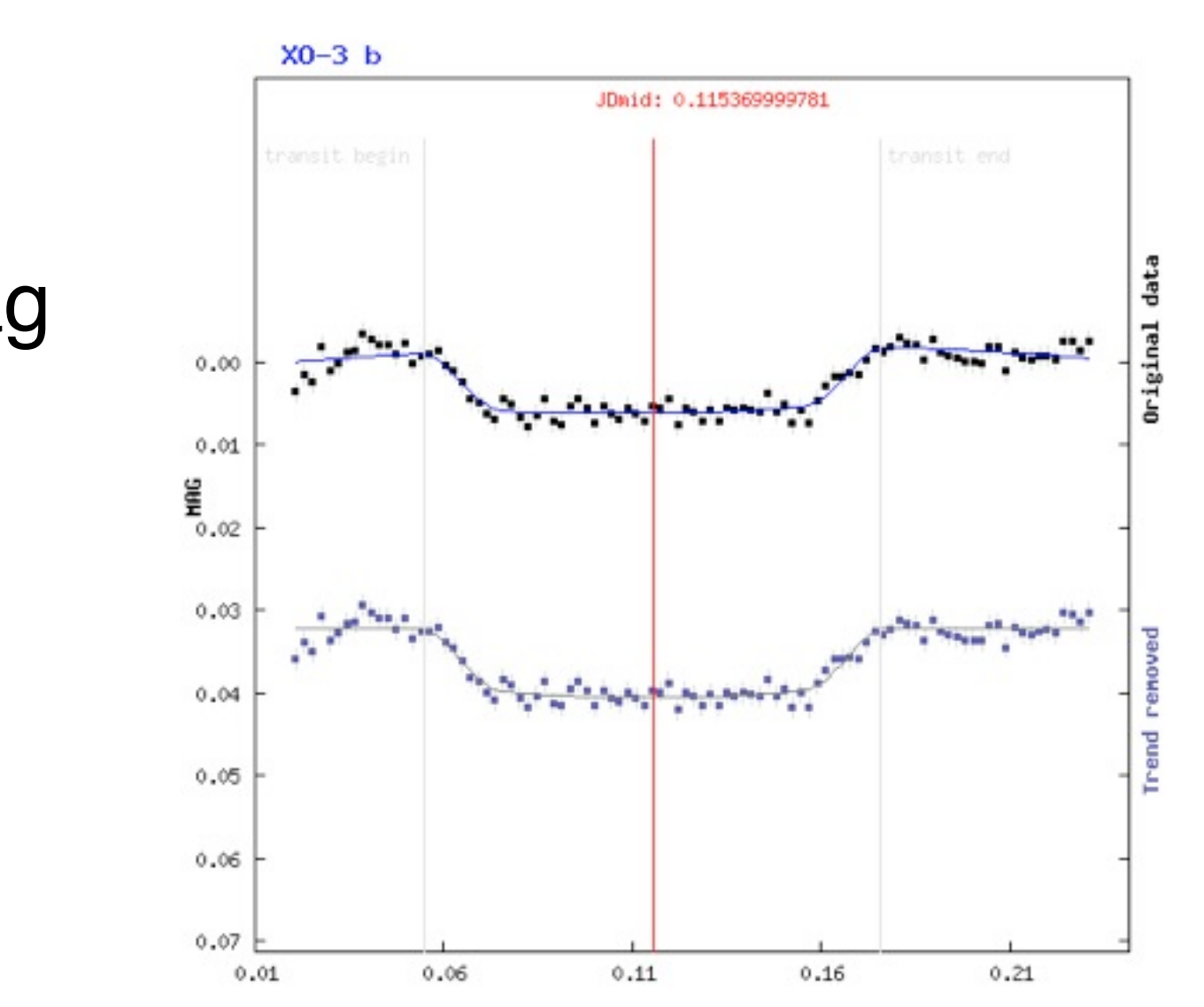
- photometric accuracy: ~ 1 mmag

- accuracy of time: ~ 70 sec.

* **Obtained TTV** (right figure)

- Differences of observed and predicted transit timing are calculated.

- We detected several minutes TTVs in 2 transit observations.



We used online site "Exoplanet Transit Database". - Blue points: our data
(<http://var2.astro.cz/ETD/>) - Red points: other's data

Conclusion

* We made TTV observations of a known transit exoplanet XO-3b to detect additional unknown exoplanets.

* We obtained 3 transit data, and detect 2 TTVs in these data.

* We need to continue observations for XO-3b to confirm these TTVs.