Detection and characterization of transiting exoplanets

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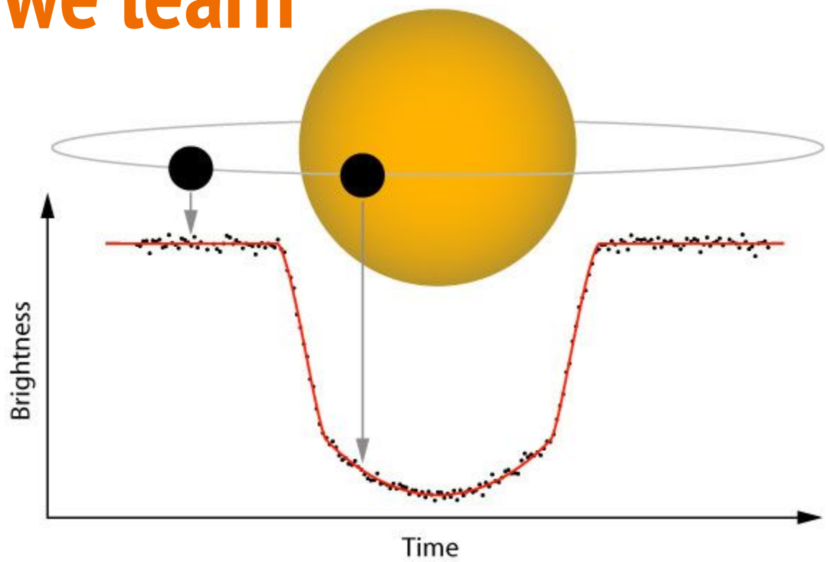
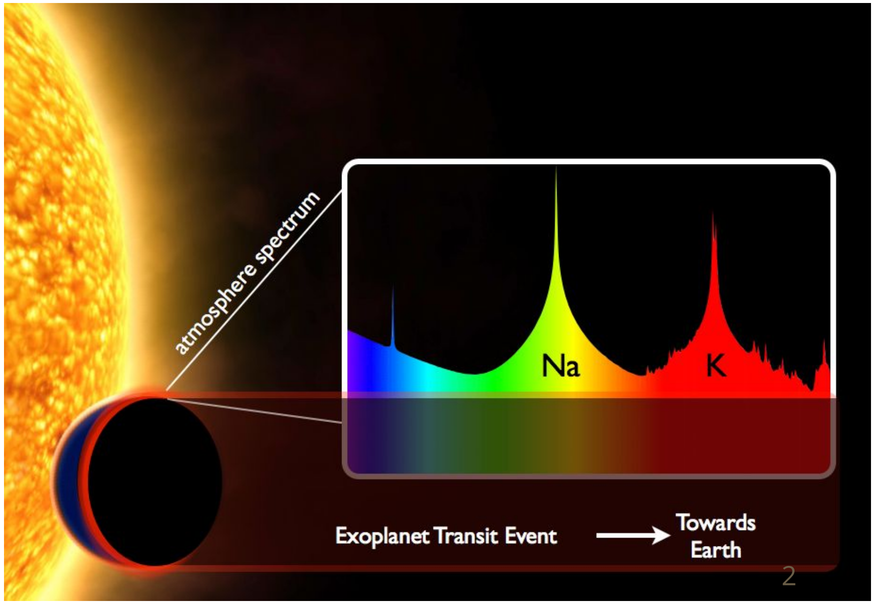
Transiting planets: what can we learn

- ***Transiting exoplanets***: planets orbiting around stars other than the Sun, whose orbital plane is seen (nearly) edge-on: tiny decrease of stellar flux, mainly dependent on $(R_{planet}/R_{star})^2$ (but also on orbital period and inclination)
- ***Exoplanetary atmospheres*** can be characterized by measuring the transit depth at different λ, because the *apparent* radius *R*(λ) is depending on absorption/scattering processes within the planetary atmosphere
- ***Transit Time Variations (TTV)***: additional planets may be discovered by detecting modulations in the orbital period of the known planet, due to gravitational perturbations
- **Dynamical characterization** of the system, including constraining the spin-orbit angle through the RML effect, the eccentricity through the phase of the secondary eclipse...
- ...a lot of additional interesting planetary and **stellar science**! (activity, CLV, rotation, ...)



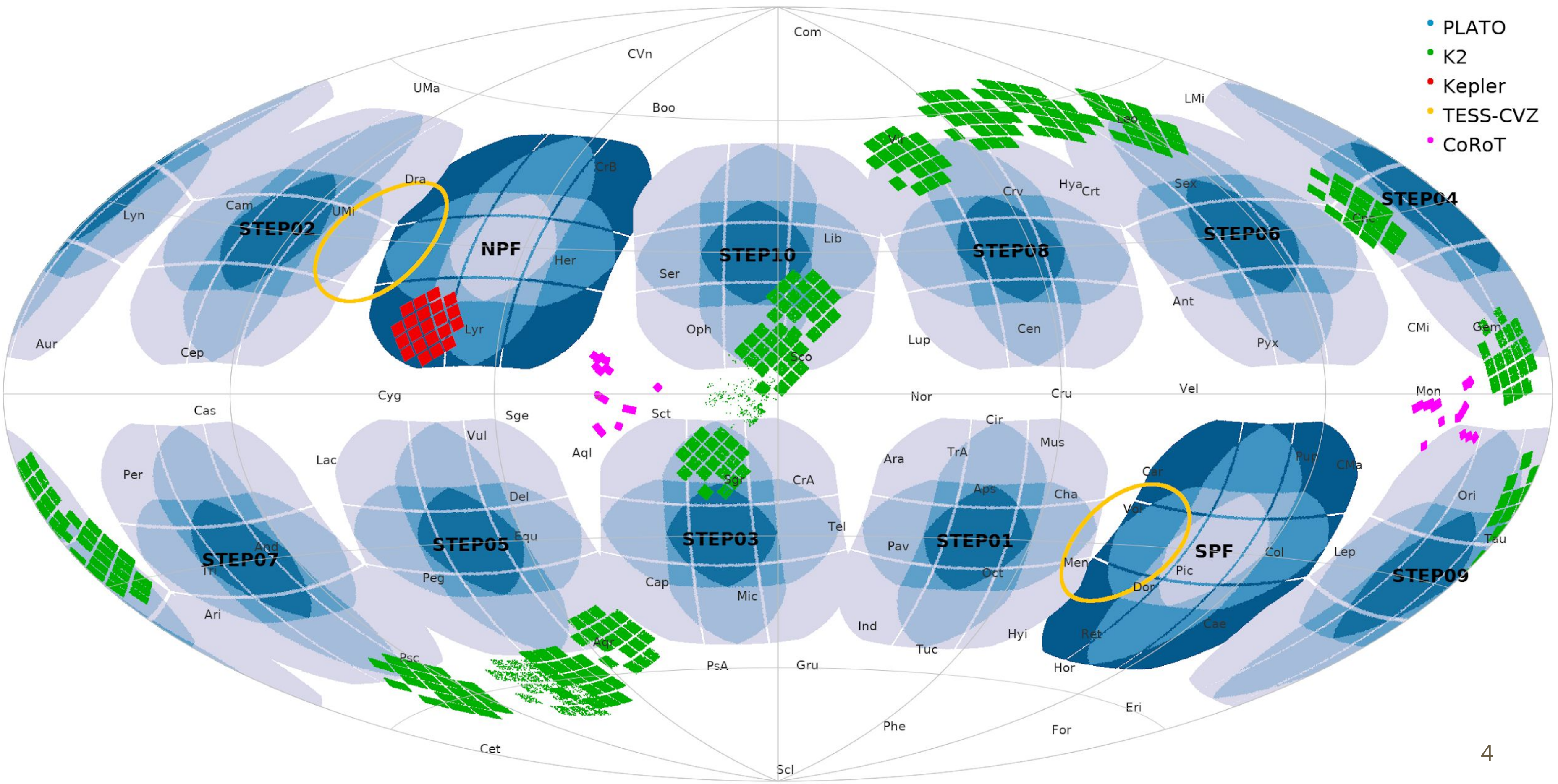


The PLATO mission

- ESA M-class mission (launch: 2026) in L2 to search for **planetary transits down to the habitable Earth-like planets around bright, nearby Sun-like stars**
- An array of 26 small (*D*=11 cm) telescopes yielding a very large FOV (>2,000 deg^2)
- INAF-OAPD and DFA-UNIPD staff deeply involved not only on the technological side, but also on science
- **Plato Input Catalog** (PIC) with responsibilities by Claudi, Desidera, Granata (UNIPD), Montalto (UNIPD), Nascimbeni, Ortolani (UNIPD), Piotto (UNIPD, brach leader); **TTV analysis** (Nascimbeni), **Multi-planet system science** (Desidera), **Follow-up imaging** (Desidera, Mesa, Nascimbeni), plus contributions in other WGs

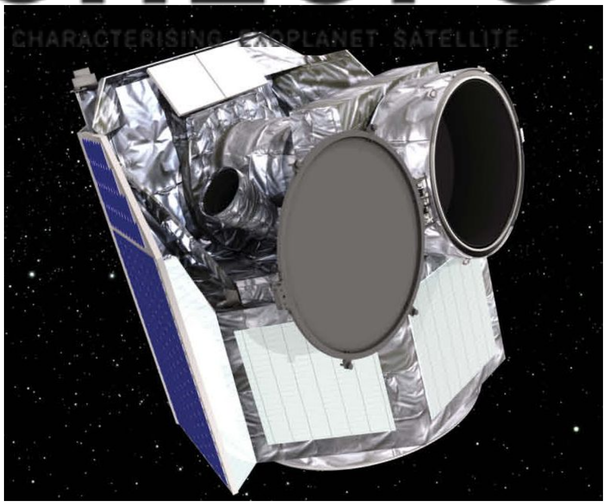
The Plato sky

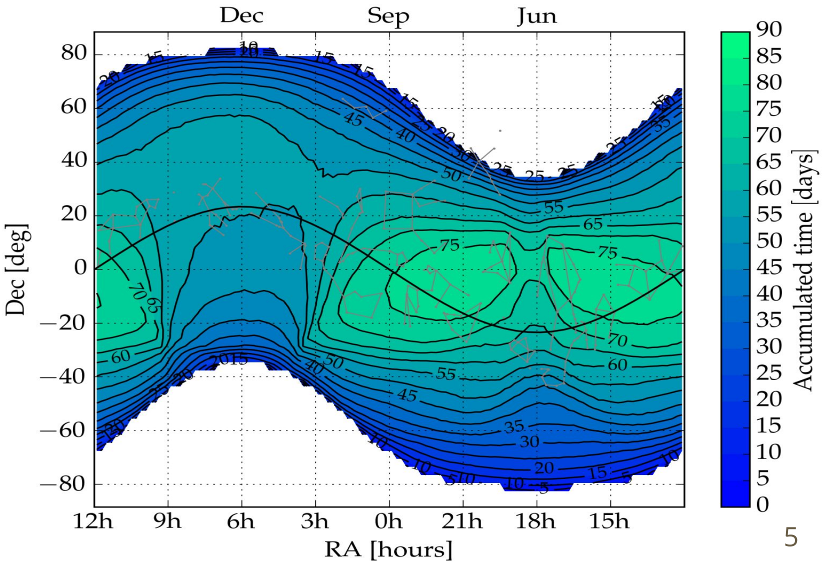
- Up to ~50% of the whole sky covered, photometry done on board, large preparatory work required to select the stars and coordinate the follow-up observations



CHEOPS

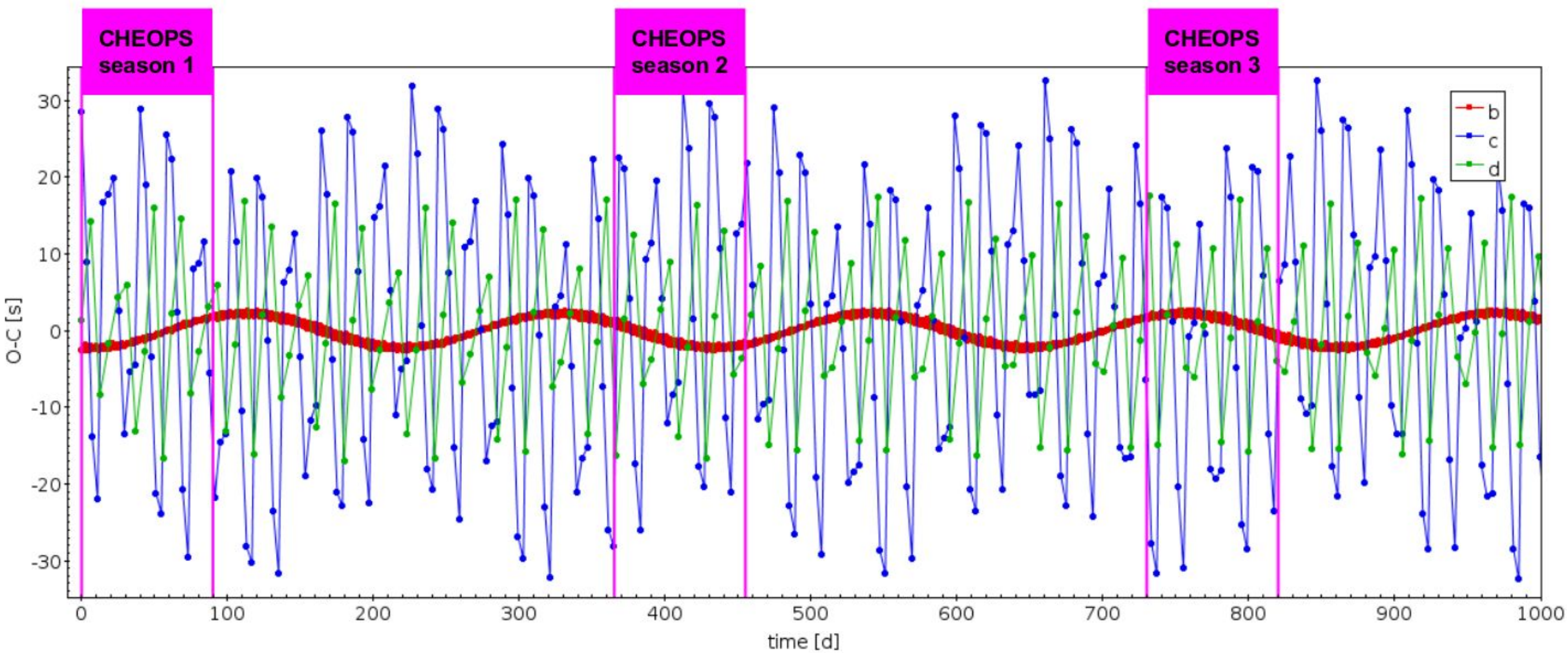
- ESA S-class mission (launch: late 2019) to **characterize transiting planets** through single-band, ultra-high-precision photometry.
- **Single-target telescope**. Able to point (mostly) anywhere in the sky on schedule.
- Multi-faceted **GTO program** with six subprograms: TRANSIT.FIND, MR.IMPROVE, EXPLORE, ATMO.CHAR, FEATURE.CHAR, ANCILLARY
- Members of the *core science team*: Nascimbeni, Piotto (UNIPD)
- Within the GTO, **responsibilities** of two high-priority programs based on TTV analysis: «*M-R relation within planetary systems*» and «*TTV search for inner/outer perturber of warm jupiters*»





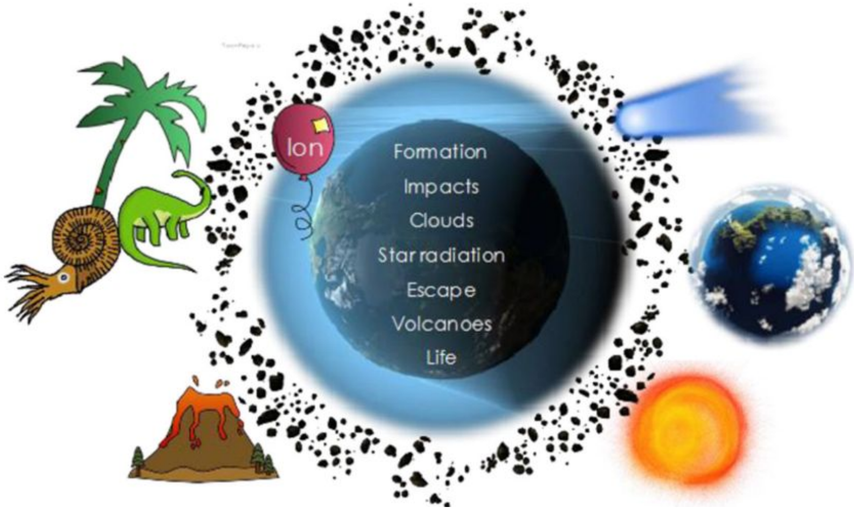
CHEOPS

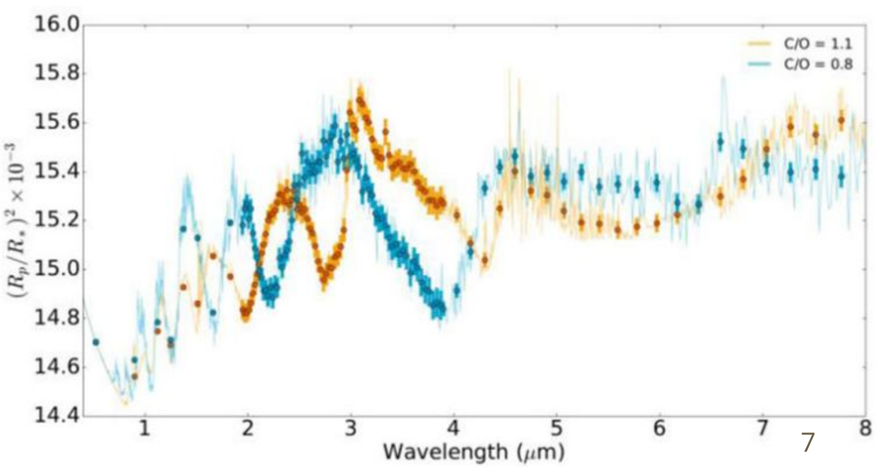
- The ability of CHEOPS to point nearly “anywhere, anytime” during its 3.5-yr nominal mission makes it a perfect follow-up machine for the TESS candidate planets;
- Also, science cases requiring measurements with a large baseline (such as TTV systems or tidal decay) fit perfectly the CHEOPS observing strategy



ARIEL

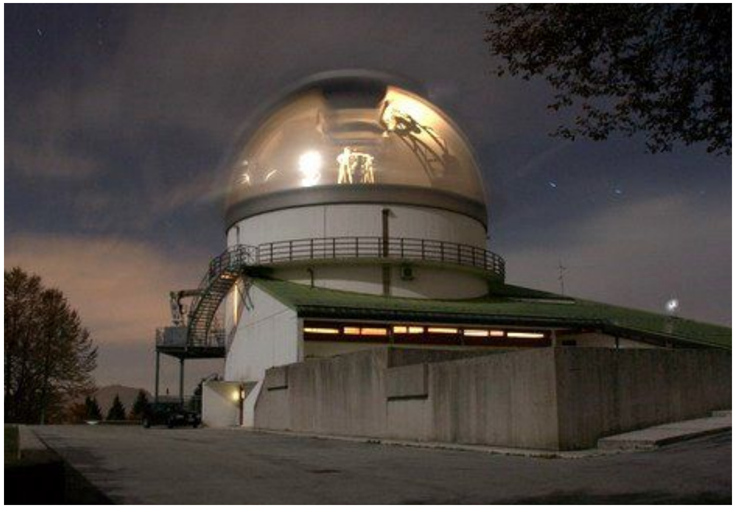
- Atmospheric Remote-sensing Infrared Exoplanet Large-survey, ESA M-class mission (launch: ~2028) in L2
- A 1.2m telescope equipped with a NIR-MIR spectrograph (1.9-7.8 μm) + VIS/NIR photometry to deliver **transmission and emission spectra of exoplanets**
- First mission dedicated to measuring the **chemical composition and thermal structures** of hundreds of transiting exoplanets, from hot super-Earths to temperate gas giants.
- INAF-OAPD involved in **modeling of exoplanetary atmospheres** (Alei, talk), **target selection** (Alei), **TTV systems** (Nascimbeni) and **contaminant analysis** (Nascimbeni)

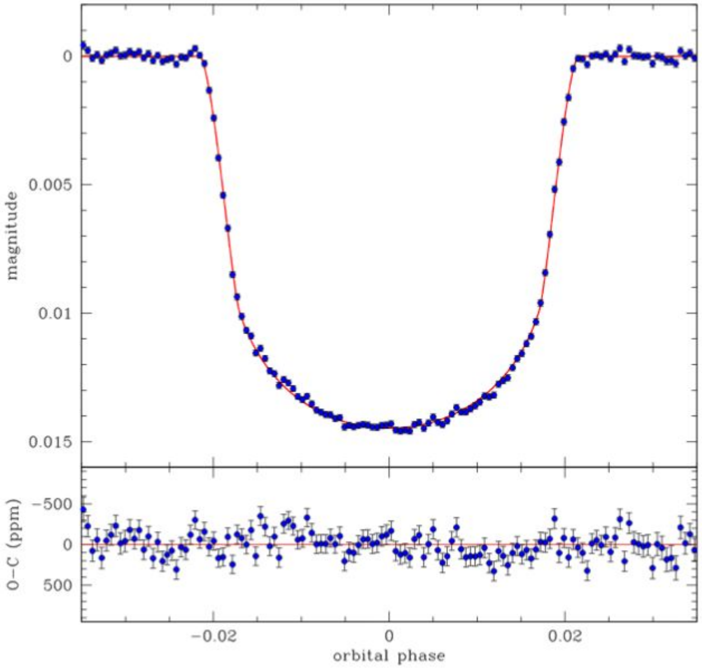




The TASTE project

- Multi-site long-term campaign to monitor a selected sample of transiting planets, based at Asiago (PI: Nascimbeni+ 2011a, 2011b, 2013) mostly with the 1.82m Copernico telescope.
- Main aim: ***TTV analysis*** and refinement of the orbital/physical parameters also in support of atmospheric characterization studies (incl. GAPS)
- Mostly based on **hot-Jupiters** and Neptunian planets (easiest ones to be followed-up from the ground)
- **Impressive data quality**: <1 mmag RMS per minute on typical targets, presently one of the best achievements on telescopes of this class





The TASTE project

- 11 refereed papers, 2 in preparation, 1 master's thesis, PhD students training
- 564h of imaging data gathered (2010-2019) on 63 planets (incl. fillers)
- Introductory paper: HAT-P-3b, HAT-P-14b. Most accurate light curve on a 2-m class telescope (Nascimbeni+ 2011a)
- TTV analysis of the HAT-P-13b system. Confirmation of a candidate TTV signal (Nascimbeni+ 2011b)
- TTV analysis of the WASP-3b system. No conclusive evidence, but TTV signal possible due to stellar activity (Nascimbeni+ 2013a)
- TTV analysis of the HAT-P-20b and WASP-1b systems. Starspots and rotational period (Granata+ 2014)
- Follow-up observations of XO-2b (Damasso+ 2015).