ARIEL SCIENCE, MISSION & COMMUNITY 2020 CONFERENCE
14-16 January 2020 @ ESA/ESTEC, Noordwijk, The Netherlands

Exploiting the transit timing capability of ARIEL high-precision photometry

Luca Borsato - luca.borsato@inaf.it
Valerio Nascimbeni, Giampaolo Piotto

Key points

ARIEL InfraRed Spectrometer (AIRS), R = 30 – 200 between 1.95 and 7.8 μm.

Chromatic light-curves from the spectra

Fine Guidance Sensors (FGS), 3 photometric channels, between 0.5 and 1.2 μm and low resolution NIR spectrometer at 1.2 – 1.95 μm.

High precision photometry at zero cost

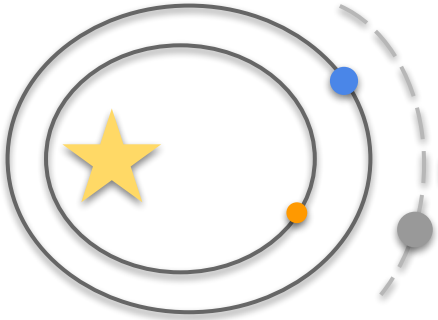
+ Cadence of up to 5 Hz, simultaneously at multiple wavelengths.
+ Targeting bright stars will lead to high SNR light curves.
+ Uninterrupted observation of transit, out-of-transit and phase-curves.

Fast sampling of the light curve

timing, ingress/egress, and second order effects (rings, moons, etc)

IR photometry: smaller impact from limb darkening and stellar activity

Transit Timing Variation (TTV)



P ≠ const
mutual interaction
among planets

Agol+ 2005; Holman & Murray 2005

Transit Timing Variation (TTV)
w.r.t
Linear Ephemeris
$T_{0,lin} = T_{0,ref} + P \times N$

Establish **planetary nature** of transiting planets

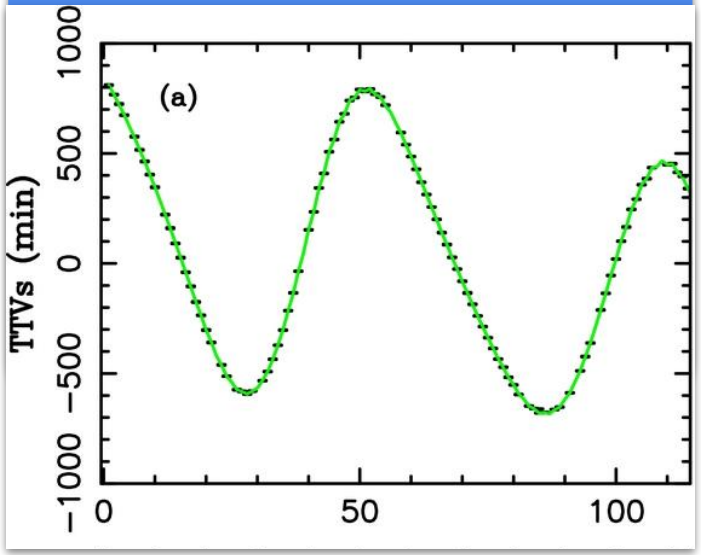
- multi-planet system characterisation
- **mass** of the perturber (perturbers if more than one planets)
- orbital **parameter determination** and degeneracy breaking

architecture characterisation: ~MMR, formation and evolution processes

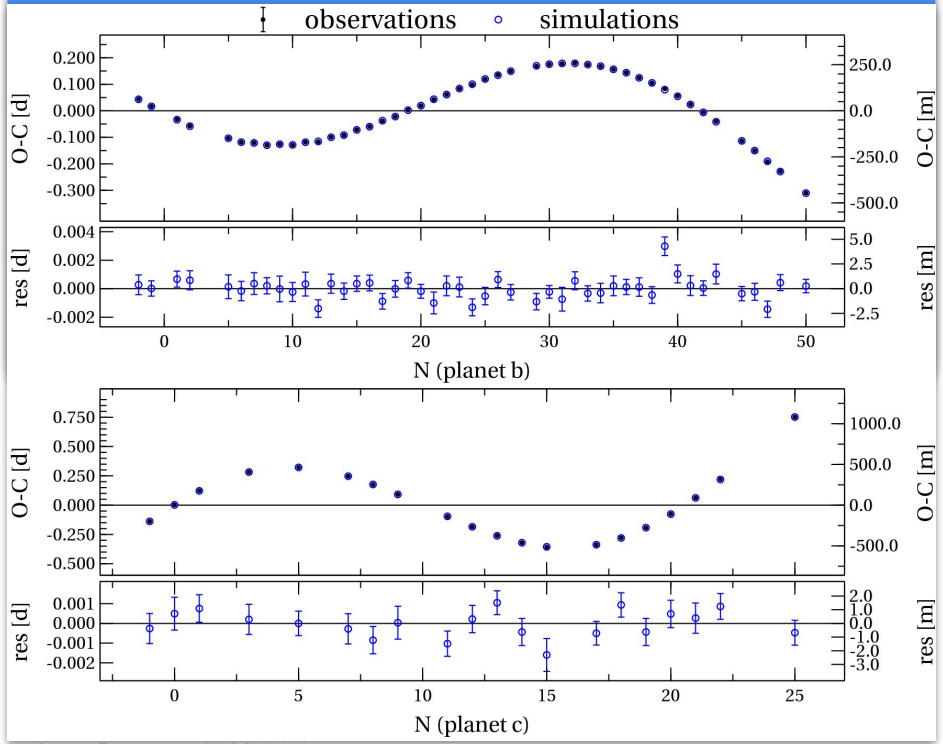
complementary to RV for mass determination

Transit Timing Variation (TTV)

KOI-142.01 – King of TTVs
close MMR 2:1
Nesvorný+ 2013



Kepler-9 – 2 transiting planets
close MMR 2:1 => anticorrelated TTV
Borsato+ 2014, 2019



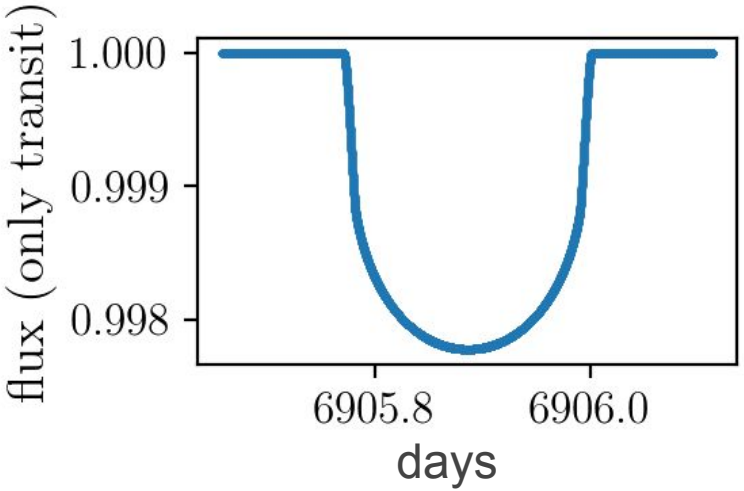
set up ARIEL timing

ArielRad noise ppm/h for FGS 1 & 2 + noise floor 20 ppm

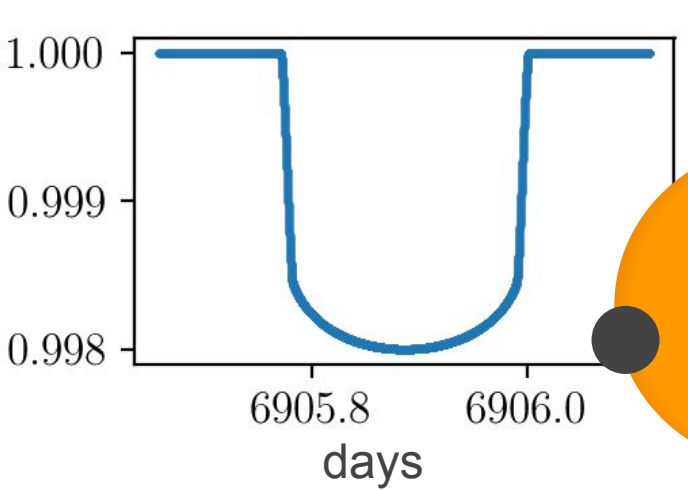
K2-24 b

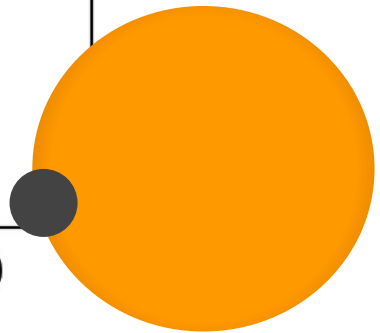
Kmag = 9.18, M=1.07$M_{\odot}$, R=1.16$R_{\odot}$, Rp=5.4$R_{\oplus}$ (Neptune-size), P=20.89d

FGS1 noise 54 ppm/h



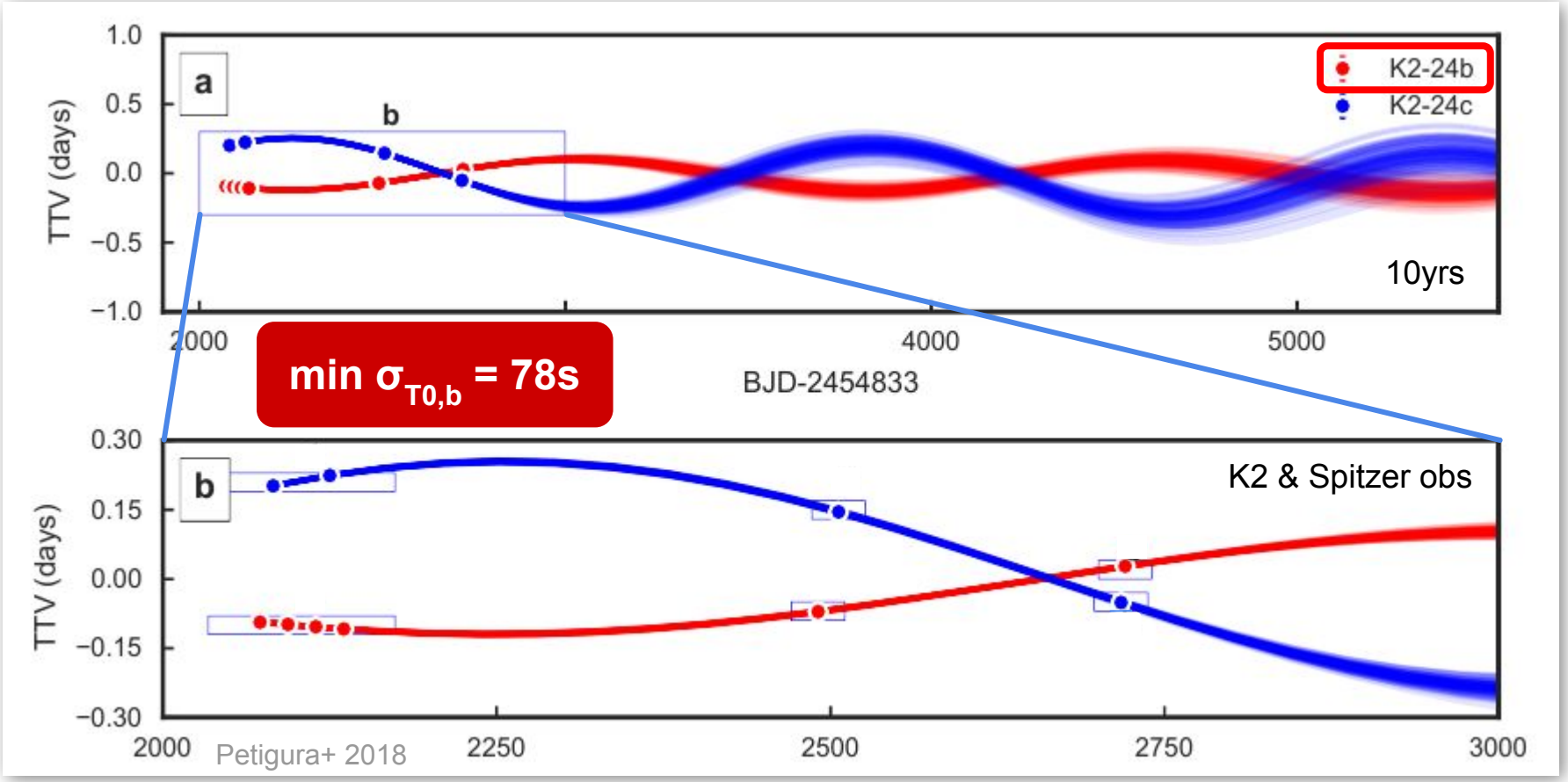
FGS2 noise 44 ppm/h



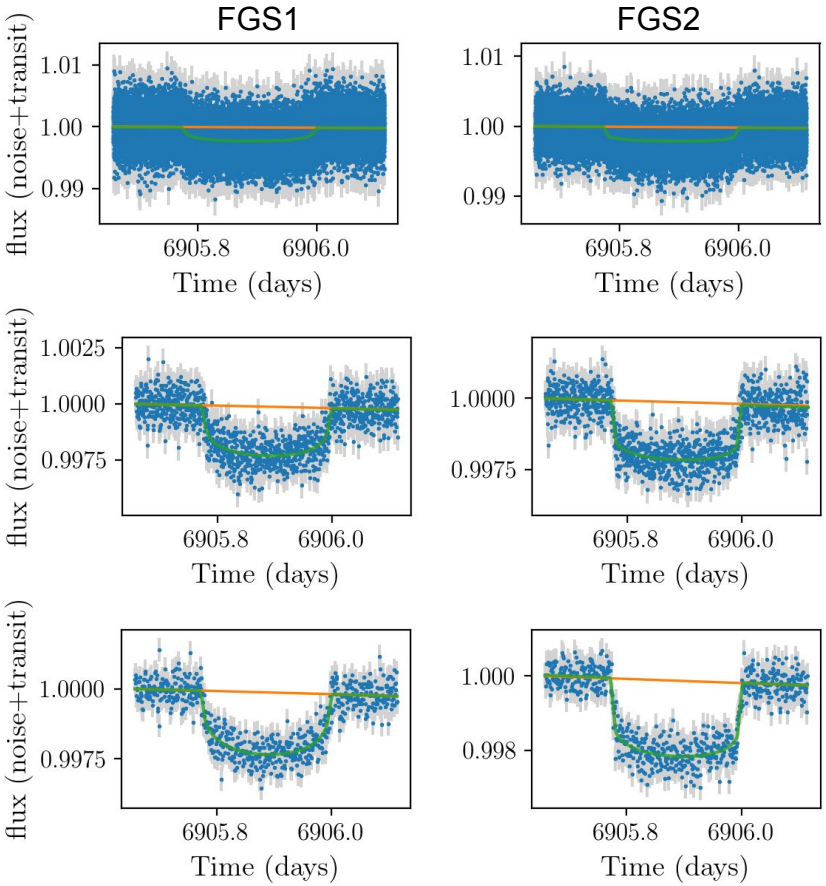


transit model with **batman** (Kreidberg 2015)

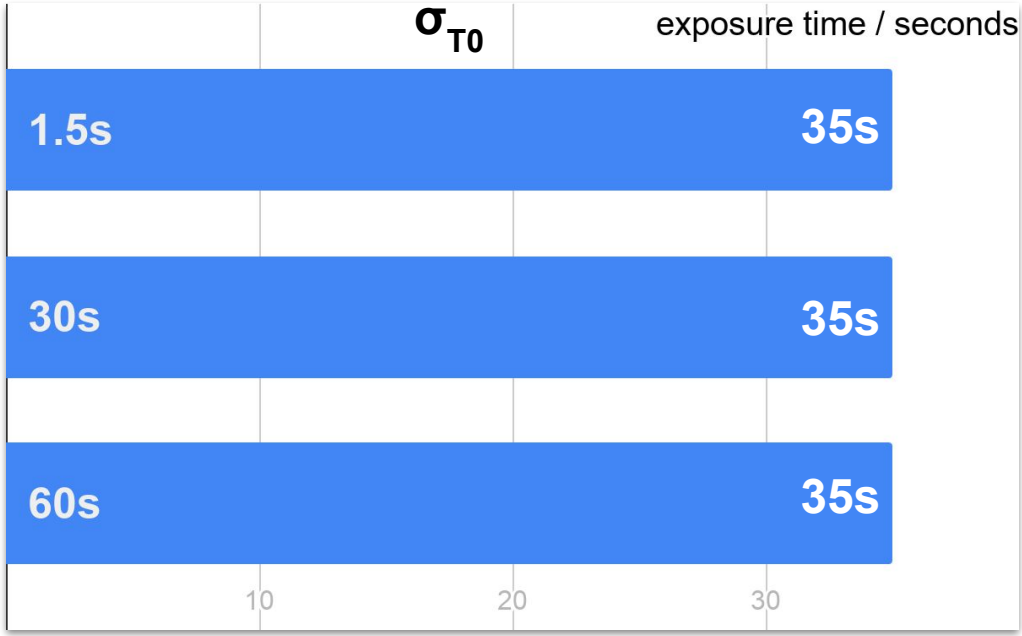
K2-24 and the TTV baseline



K2-24 b

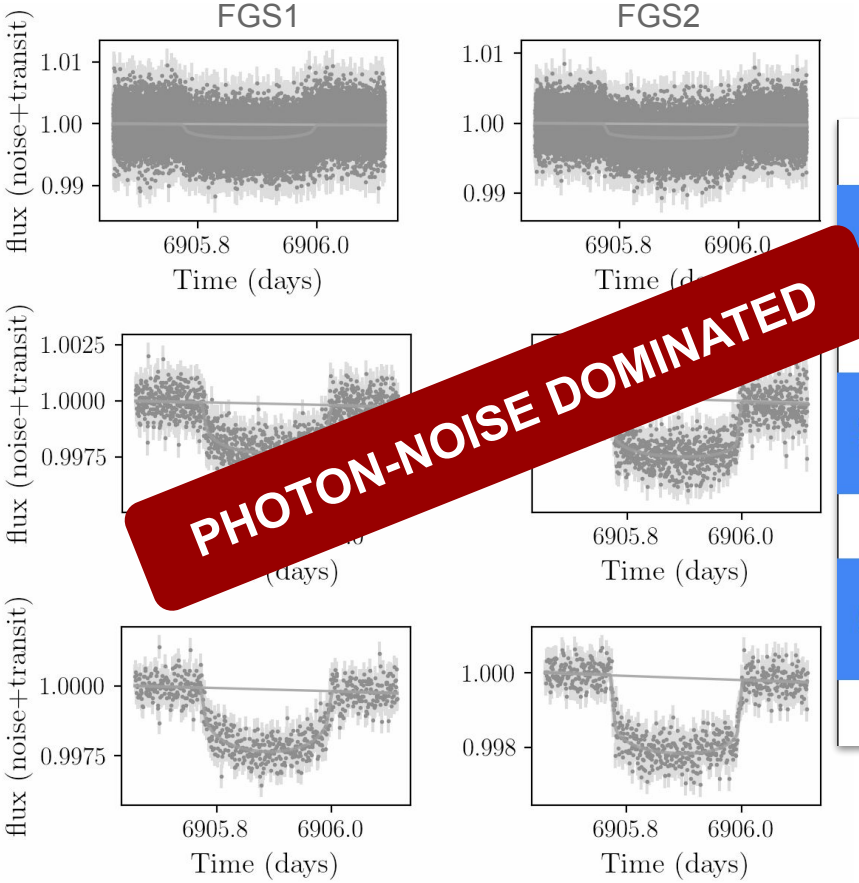


batman (Kreidberg 2015) + **emcee** (Foreman-Mackey+ 2012)



Kepler/K2: min $\sigma_{T0,b}$ = 78s

K2-24 b



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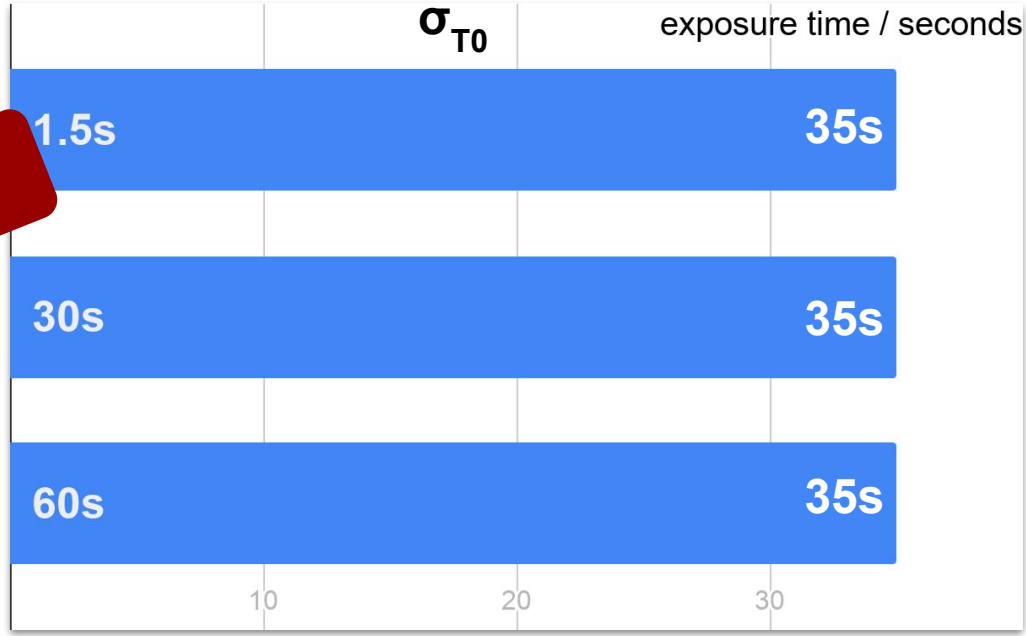
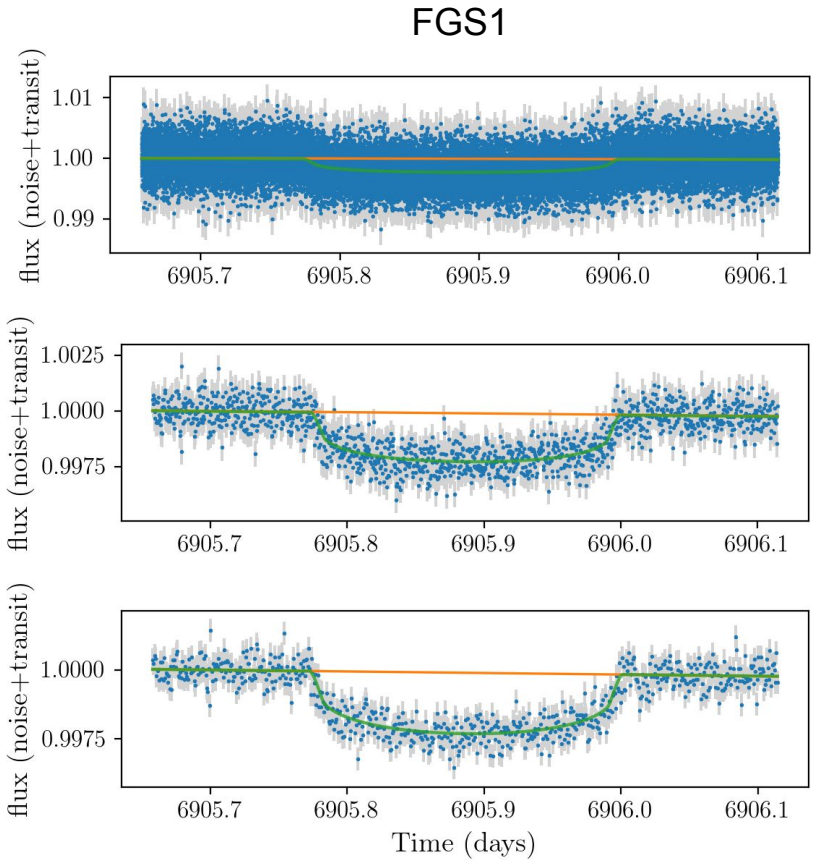


K2-24 b … what if …



with one FGS channel of ARIEL we will obtain a transit time with an error of

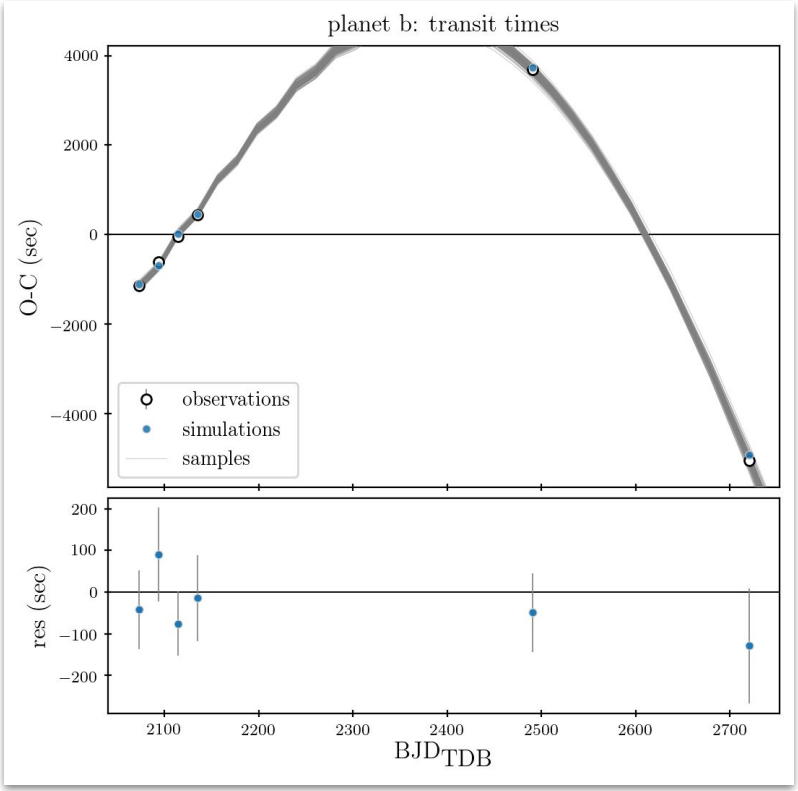
$\sigma_{T0,b} \sim 53s$

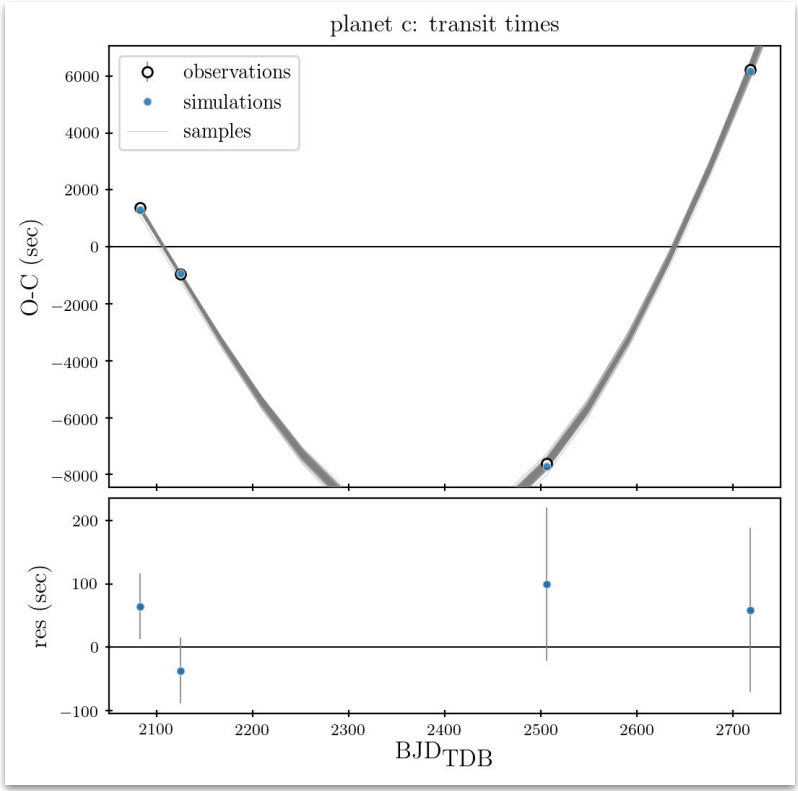
that is still better than Kepler/K2-Spitzer, where

$\min \sigma_{T0,b} = 78s$

K2-24 Dynamical fit

synthetic Transit Times and Radial Velocities (realistic uncertainties and scatter)

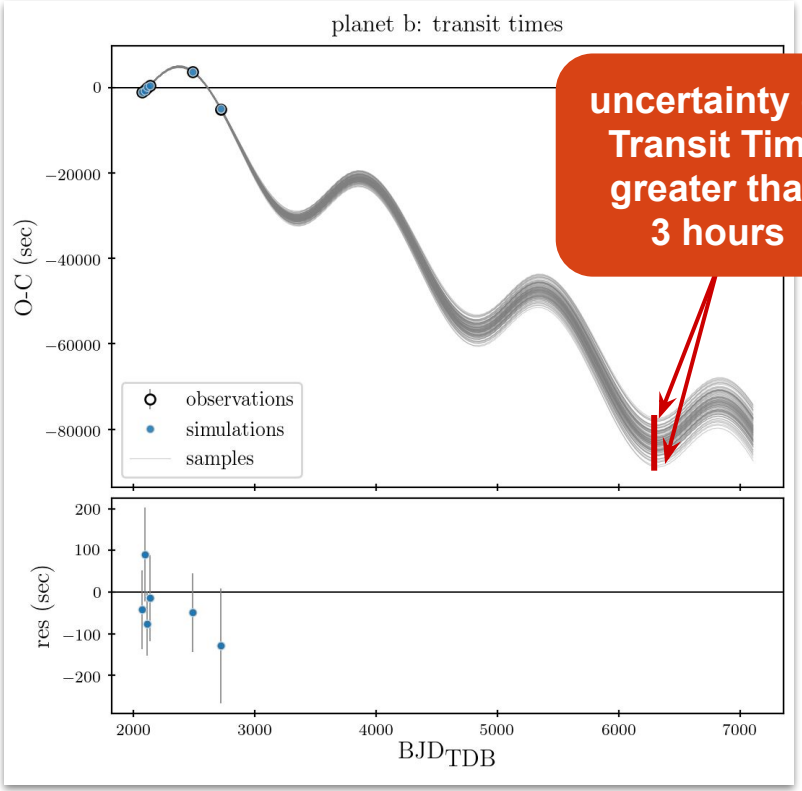


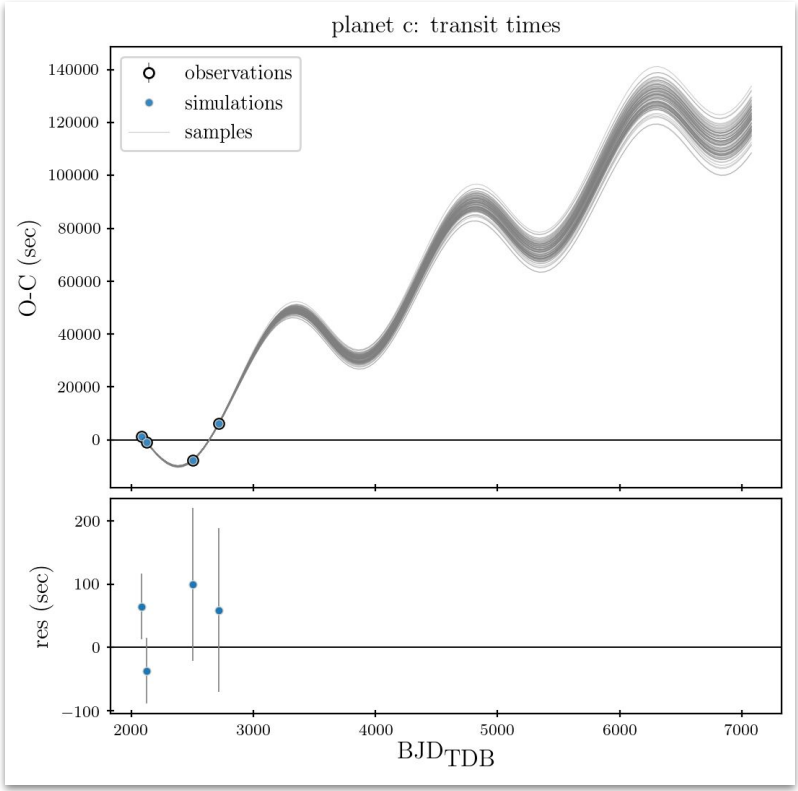


dynamics with **TRADES**@https://github.com/lucaborsato/trades (Borsato+ 2014, 2019; Malavolta+ 2017)

K2-24 Dynamical fit

extended orbital integration to ARIEL launch (2028)





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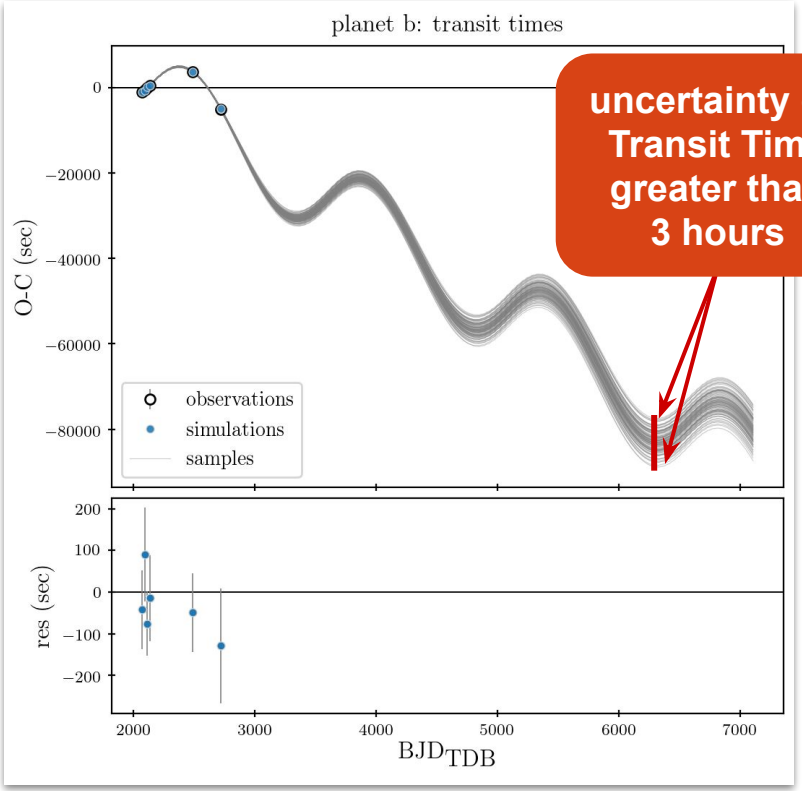
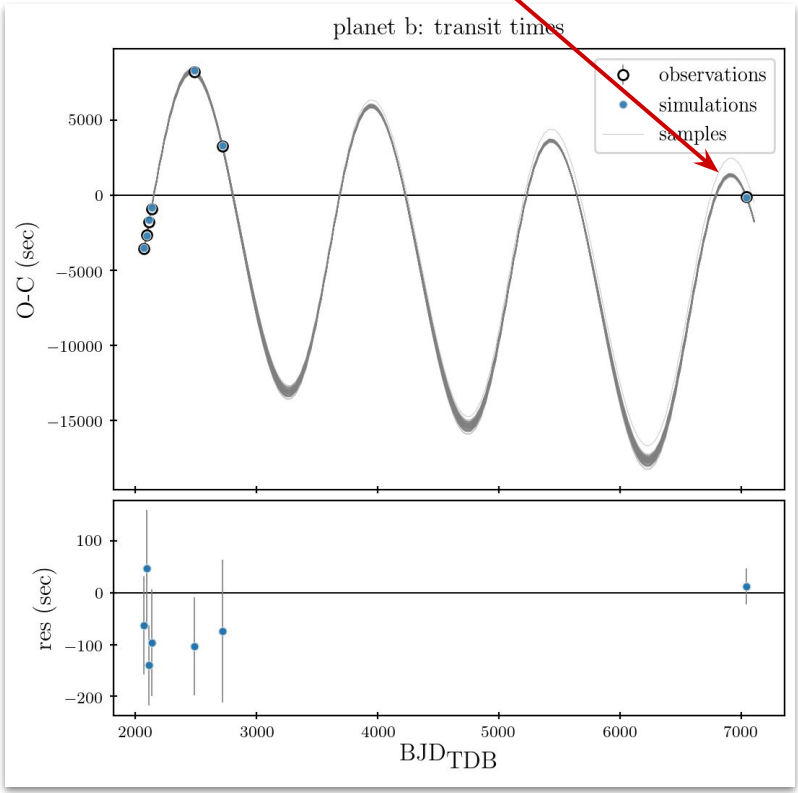


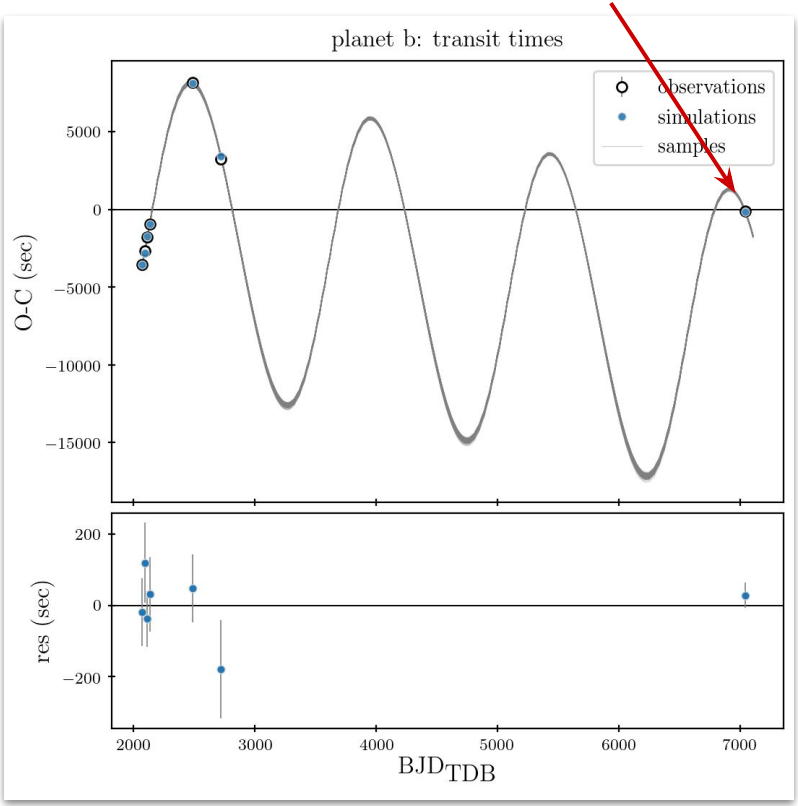
dynamical fit with **1 Transit time** from ARIEL of **K2-24b**

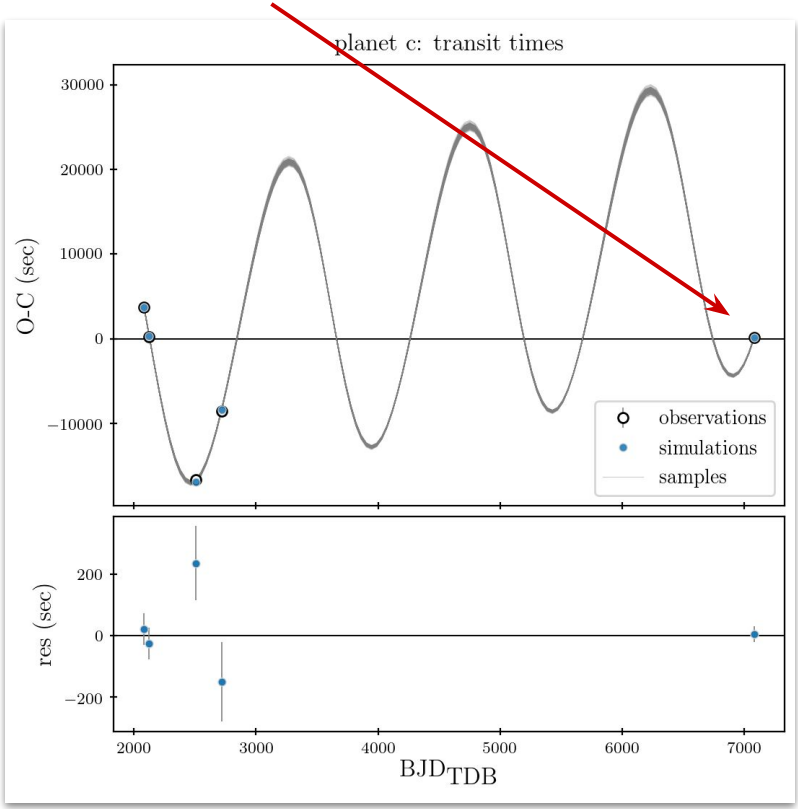


dynamics with **TRADES**@https://github.com/lucaborsato/trades (Borsato+ 2014, 2019; Malavolta+ 2017)

K2-24 Dynamical fit

dynamical fit with 1 Transit time from ARIEL of **K2-24b** and 1 Transit time of **K2-24c**

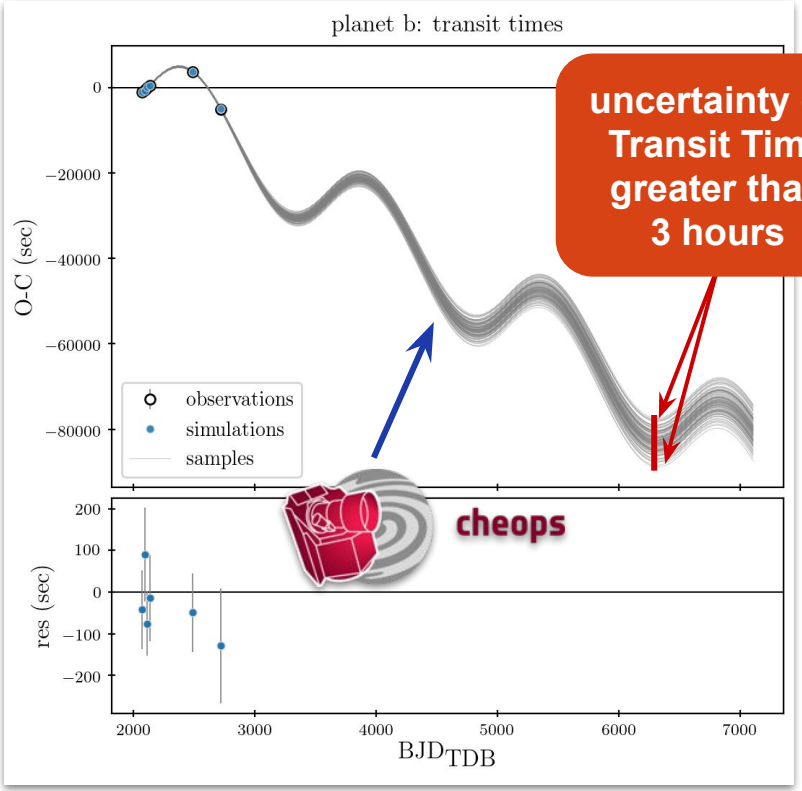


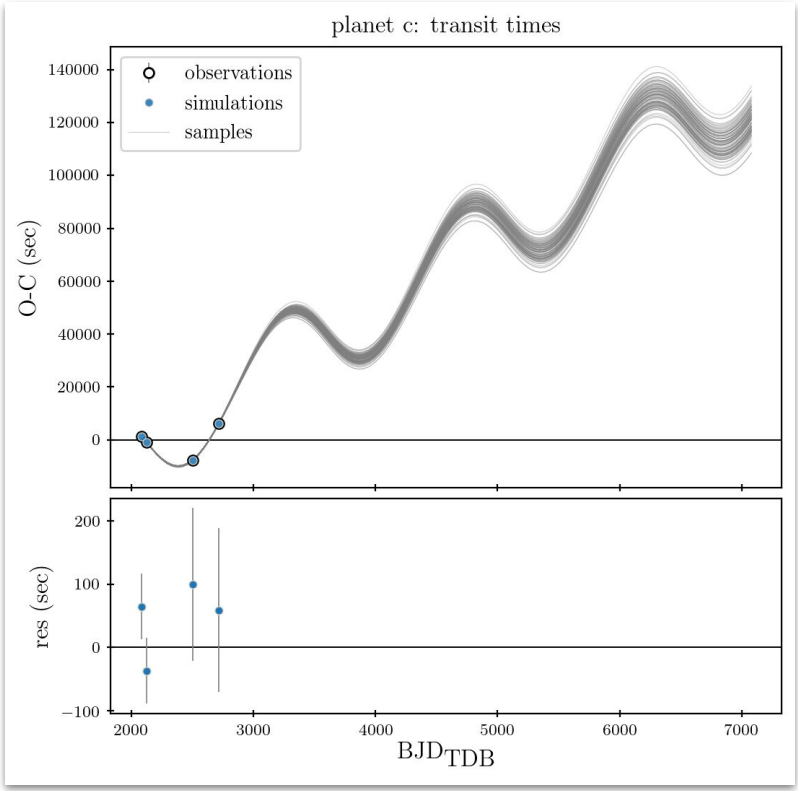


dynamics with **TRADES**@https://github.com/lucaborsato/trades (Borsato+ 2014, 2019; Malavolta+ 2017)

K2-24 CHEOPS synergy

extended orbital integration to ARIEL launch (2028)





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take-home message

- **transit timing with ARIEL FGS1&2:** better precision (2x) than Kepler/K2
- increase of the TTV baseline: **improvement of the orbital parameters** (incl. masses) in known multi-planet systems
- with ~10 ARIEL transits it is possible to independently **detect TTV signals** allowing us to determine **planetary masses** with a precision better than 20% in the **Earth-Neptune regime**
- **synergy with CHEOPS** ⇒ ephemeris refinement
- this is part of the work within WG High Cadence-Precision Photometry:

  Luca Borsato, Gyula Szabo, Giampaolo Piotto, Valerio Nascimbeni, Robert Szabo, Kristián Vida, Amaury Triaud, Carole Haswell, Dave Waltham