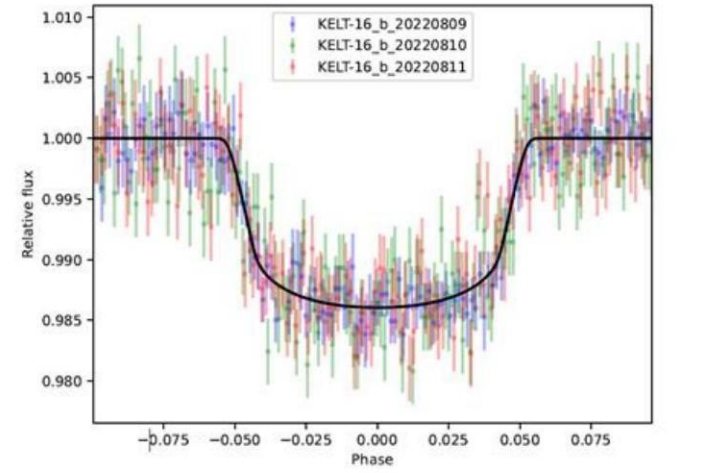
Exoplanets

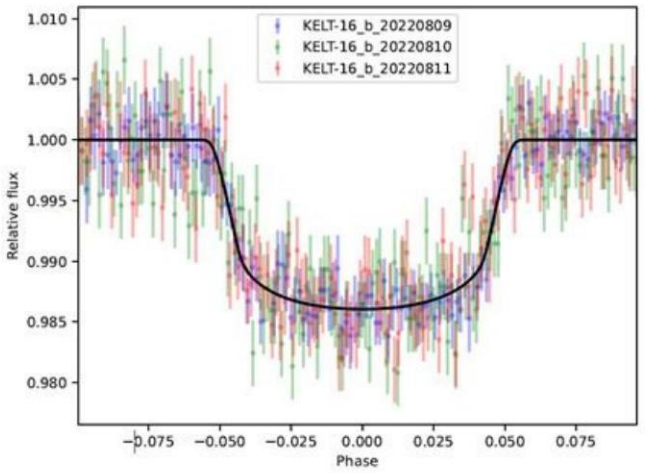
Challenging Objects for Citizen Science



Pieter Vuylsteke

(special thanks to Siegfried Vanaverbeke)

October 2022 – VVS weekend



Who am I ?

- Variable stars in the 80's

- Started astronomy again at the end of 2020

- Astrophotography,
  and again : **variables**

- Author of **AstroPie and ExoPie :**
  astrophotometry with a bag of tricks.

- Don't like presentations, **but can't keep my mouth shut.**

Observe an exoplanet yourself ???

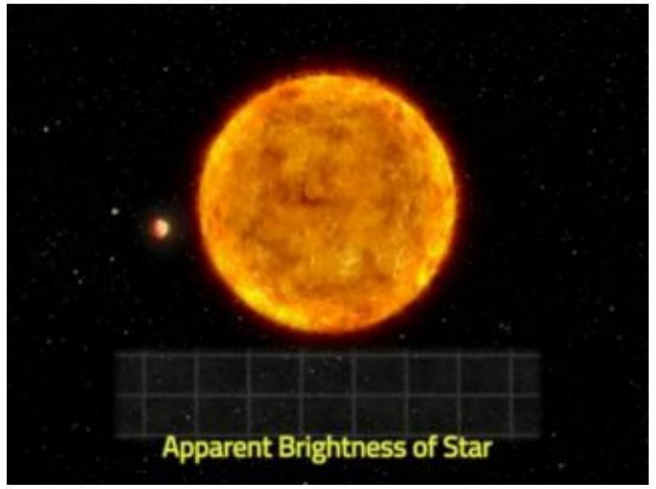


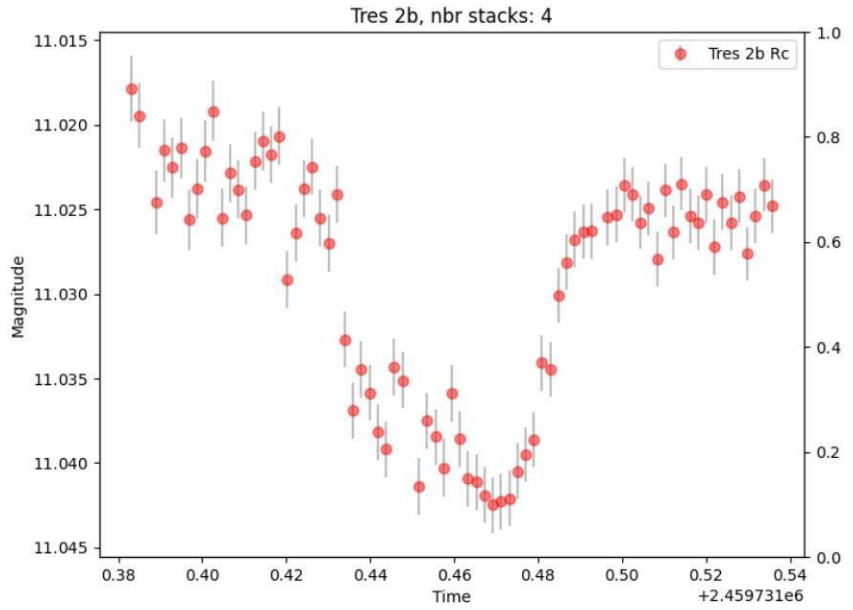
Figure: NASA

- Planet in front of the star -> star less bright.

- Effect : 0.040 to < 0.001 magnitude.

- In this example : 15 millimagnitude

- Duration of coverage : **a few hours**



Why observe?

- Main reason : THEREFORE.

- Because it's not easy : challenge !

- Parameters to be deduced from the shape of the lightcurve : the radius of the planet, duration of a planetary year, duration of the eclipse

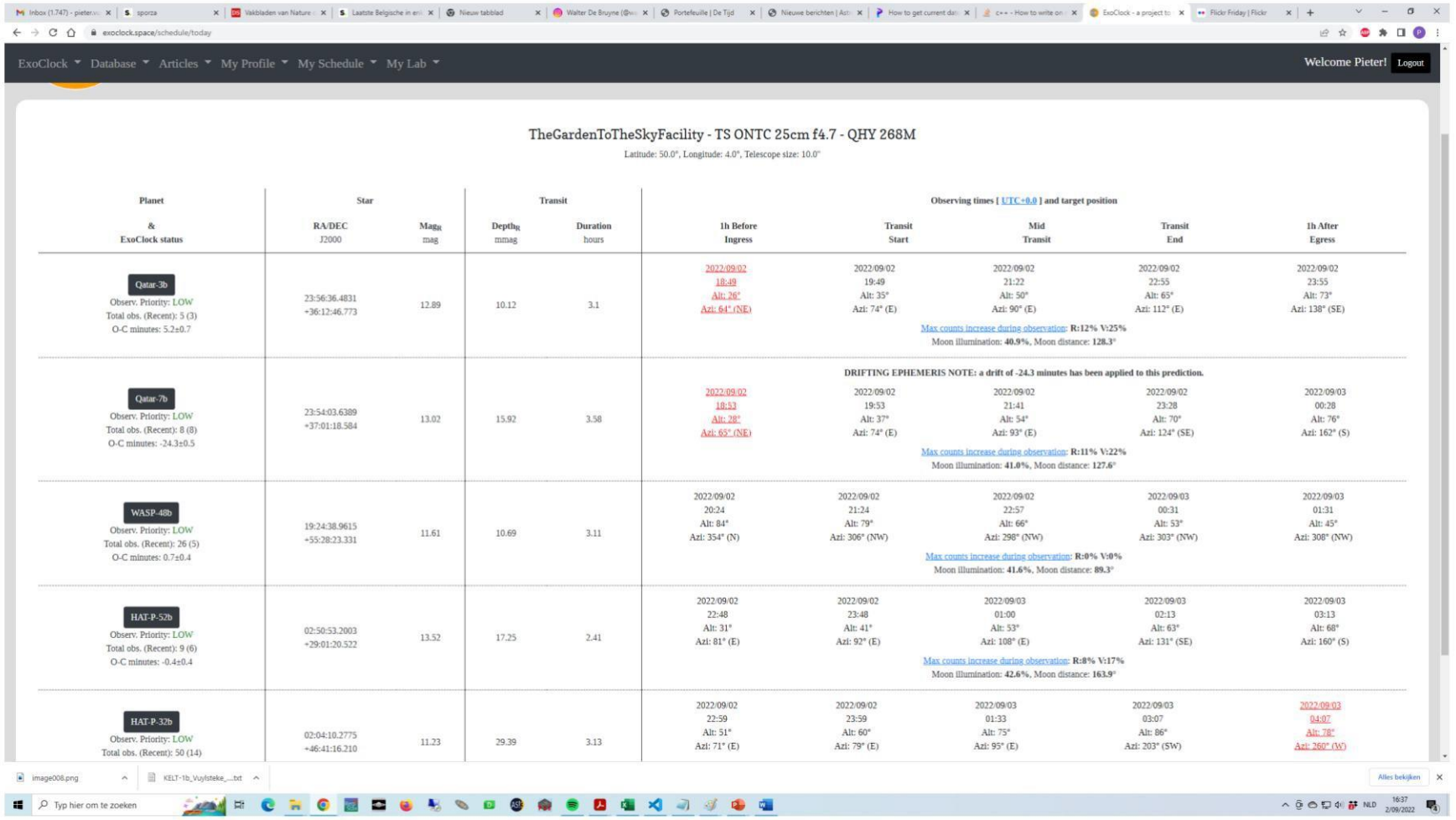
...

Let’s get to work ! But, um, when?

Exoclock.space :

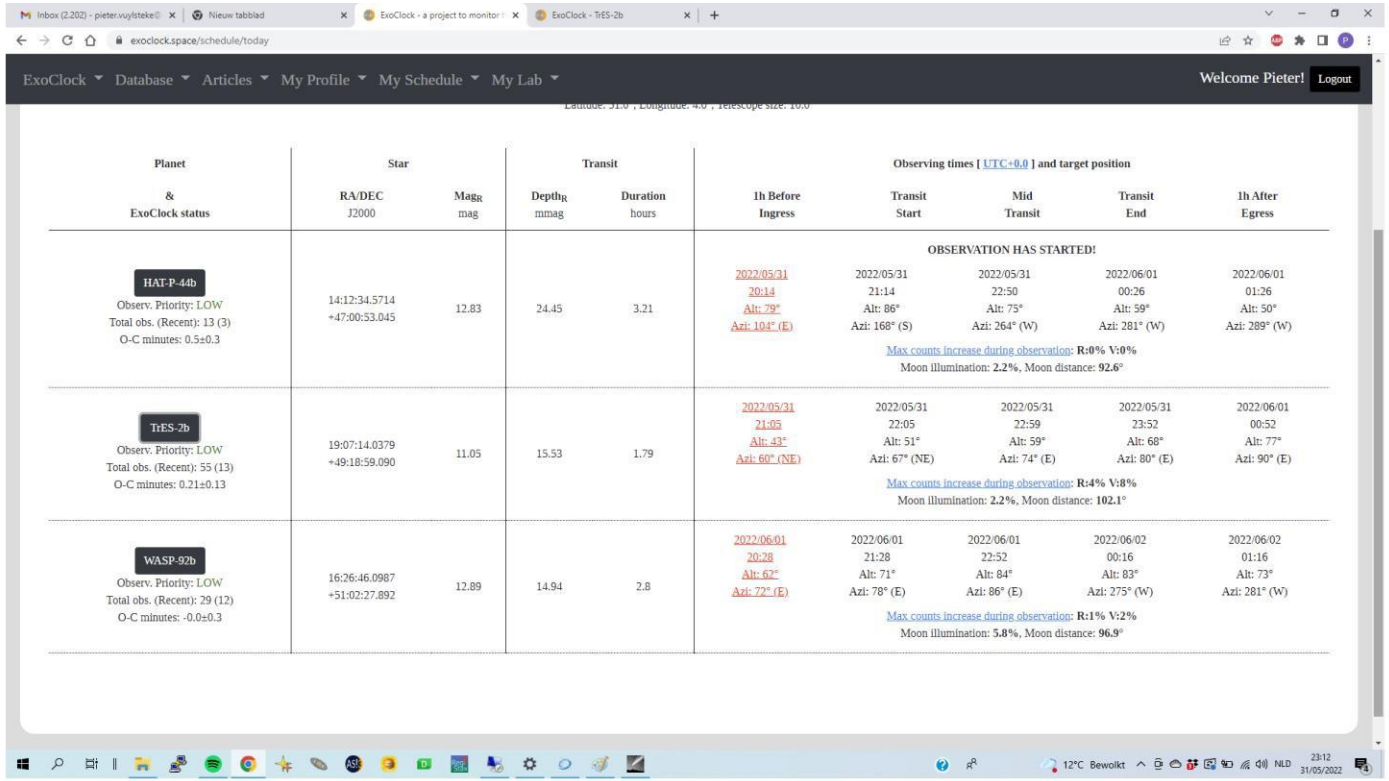
Open Science :

- monitoring the ephemerides
- fostering the democratisation of science.



Example: Tres-2b

- On the Exoclock website:



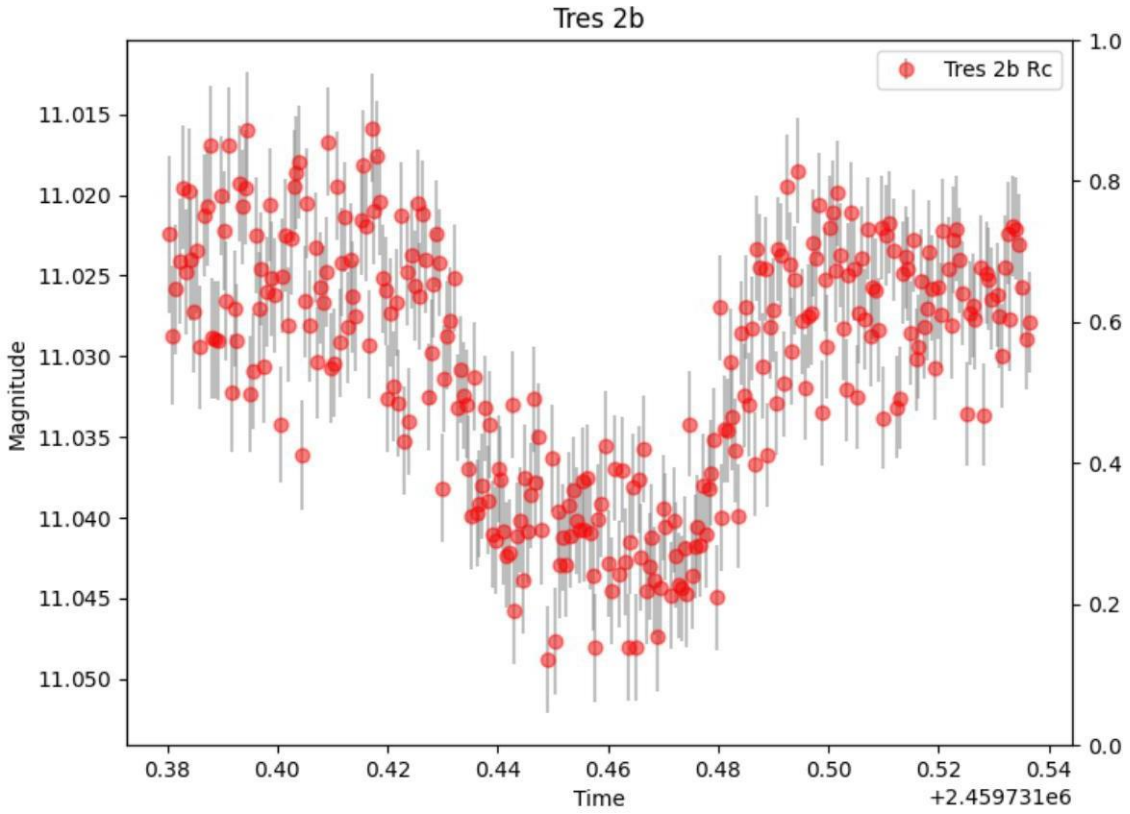
- Start :

  one hour before the start of transit
  until one hour after the end of transit

  23h05 -> 2h52

- Magnitude 11,05
- Dip : 15,53 mmag
- Duration : 1h79
- Altitude : 43 deg -> 77 deg

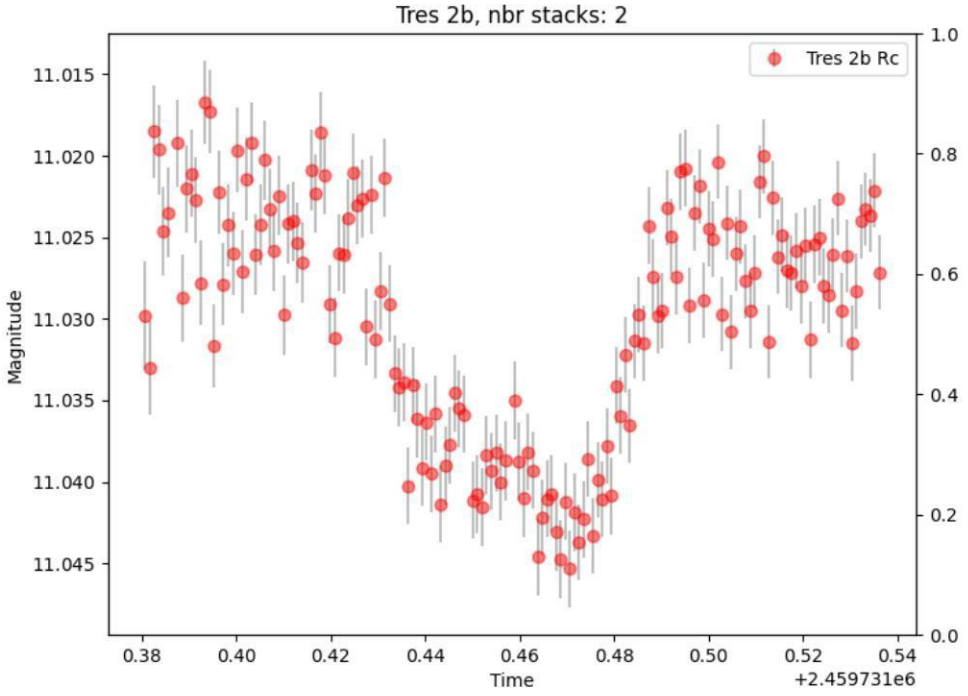
Tres-2b, 31 May 2022



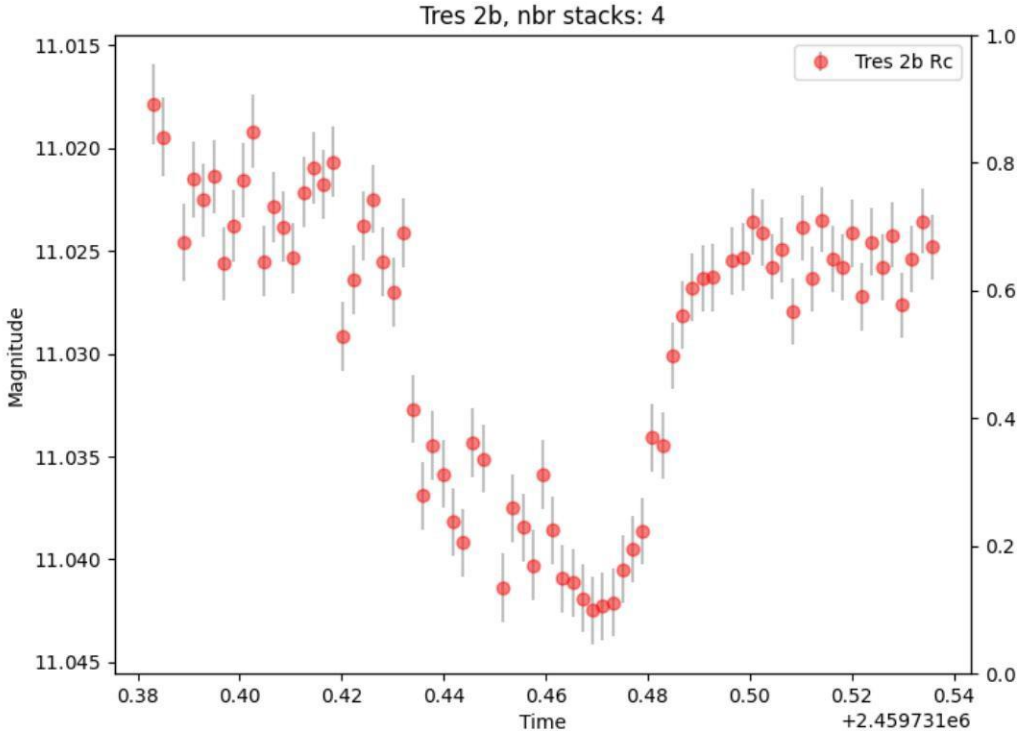
- Observation : 23h07 -> 2h52
- Red filter used
- 320 exposures of 40 seconds
- Keep the recording time of the exposures constant.
- Here 40 s,
  (today I chose 120 s)

Stacking.

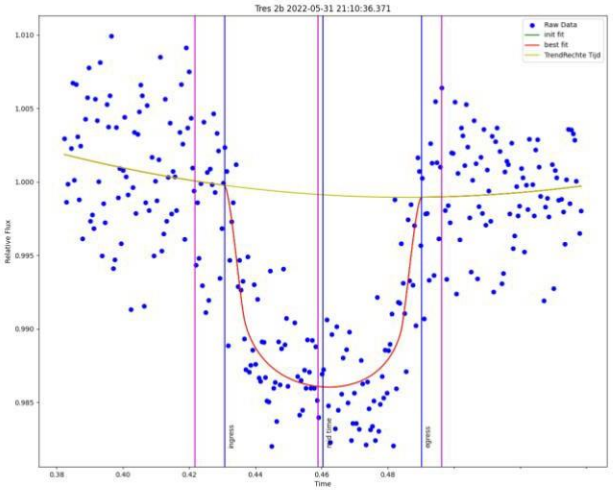
Number of stacked photos : 2



Number of stacked photos = 4



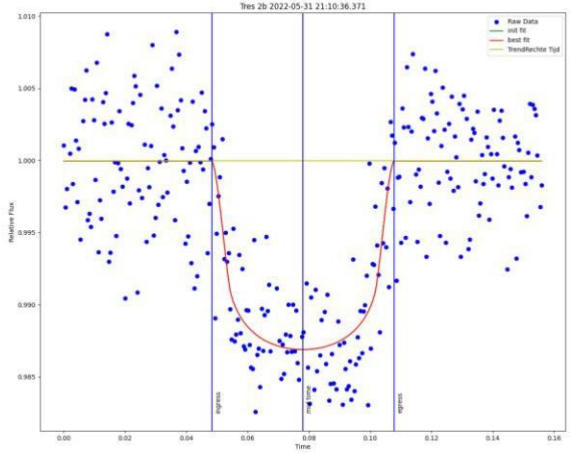
What do we learn today ?



Raw data

Detrended data :

influence of atmosphere removed



Parameters are calculated by optimizing the variables in the theoretical formulas so that everything fits best.

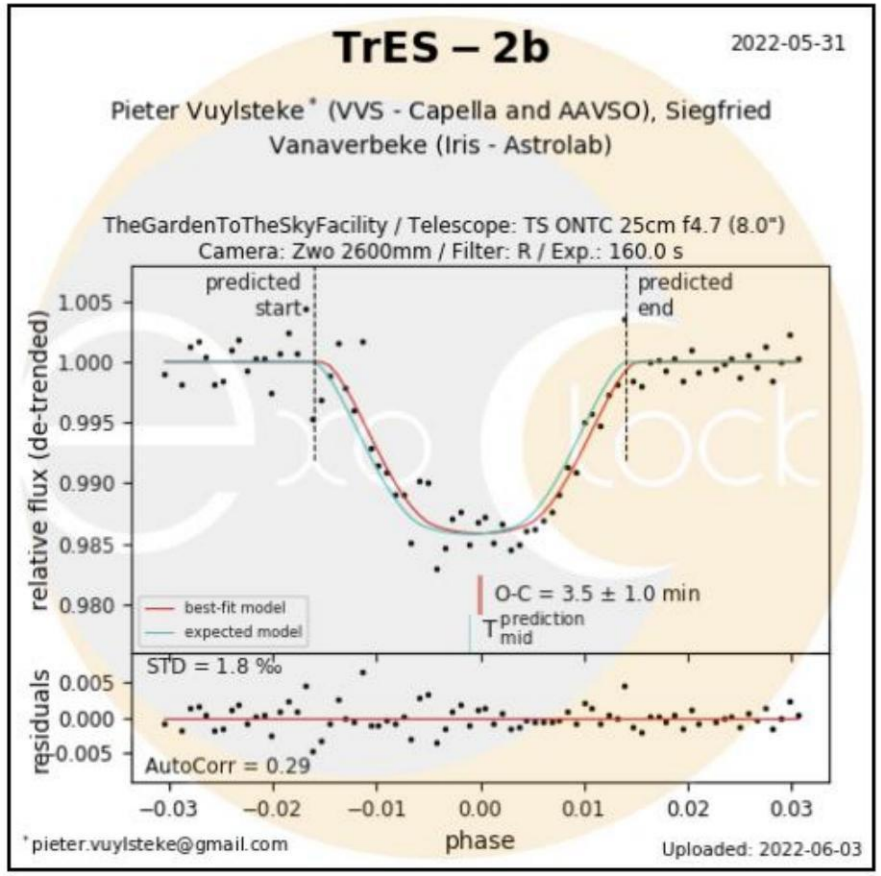
Step 1 : the atmosphere (detrending)
Airmass, …

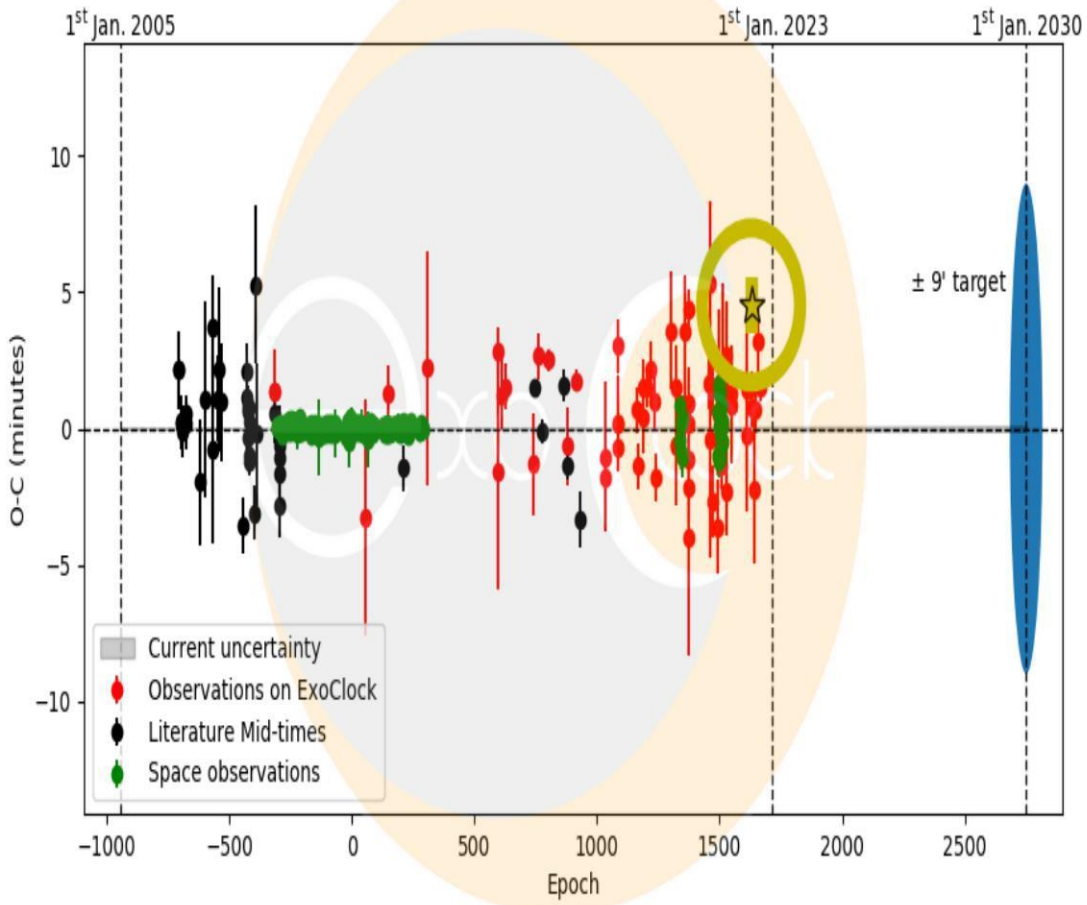
Step 2 : The planetary system
Eclipse duration, planet size, orbital inclination, dark edges of the star(limb darkening), …

Result for Tres 2b, 31 May 2022 :

- Planet radius : 0.107 (0.1254) * stellar radius
- Eclipse duration : 1h52m (1h47m)

Then upload the data in Exoclock





Fine Tuning Needed!

- **Visual** estimate of the brightness of a star :
  accuracy of about **0.100 magnitude.**

- Photometry of a star, with amateur equipment: accuracy of about **0.020 magnitude**

- Photometry of a star, with amateur equipment, and bag of tricks : accuracy to **a few millimagnitudes**

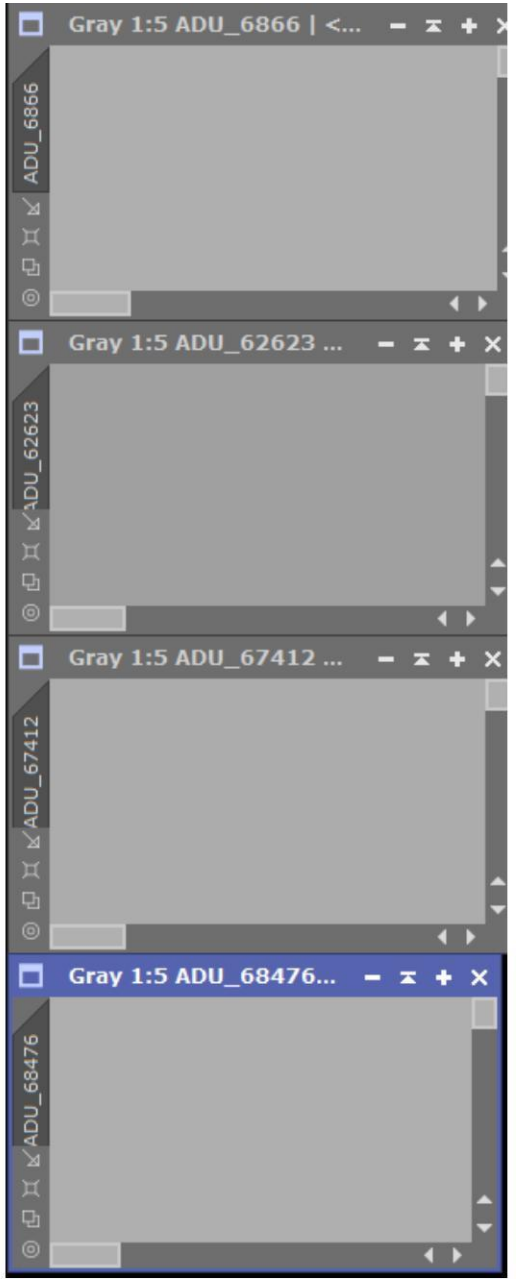
- m1 – m2 = -2,5 Log10 (Flux1 / Flux2)

Basis

0.1 quantity

0.020 quantity

0.003 quantity



Problem 1: the garden.

- My observatory, **TheGardenToTheSkyFacility,** is (unsurprisingly) in my garden

- Altitude above sea level : 70 meters

- Wind: yes.
  When the wind blows.

- Dark : at night, sometimes.
  can't really complain, 20.4 SQM

Solutions :

- A Johnson-Cousins RED filter,
- Staying high above the horizon (airmass < 2.0)

Problem 2: the telescope

My scope is a 25 cm f4.7 Newton, with a 2.5" Coma Corrector.

No matter how well you adjust it, a photo will always contain traces of:

- Remaining Coma
- Tilt
- Collimation errors
- Tracking errors
- Vignetting
- Changing focus

Solutions :

- Larger mirror -> more stable curve
- “Aperture photometry”, and no “PSF photometry”.
- 2.5“ focuser and APS-C sensor for the camera (more comparison stars)
- AstroPie’s box of tricks

Problem 3: The camera

Photometry can only be as accurate as the quality of the camera's recordings.

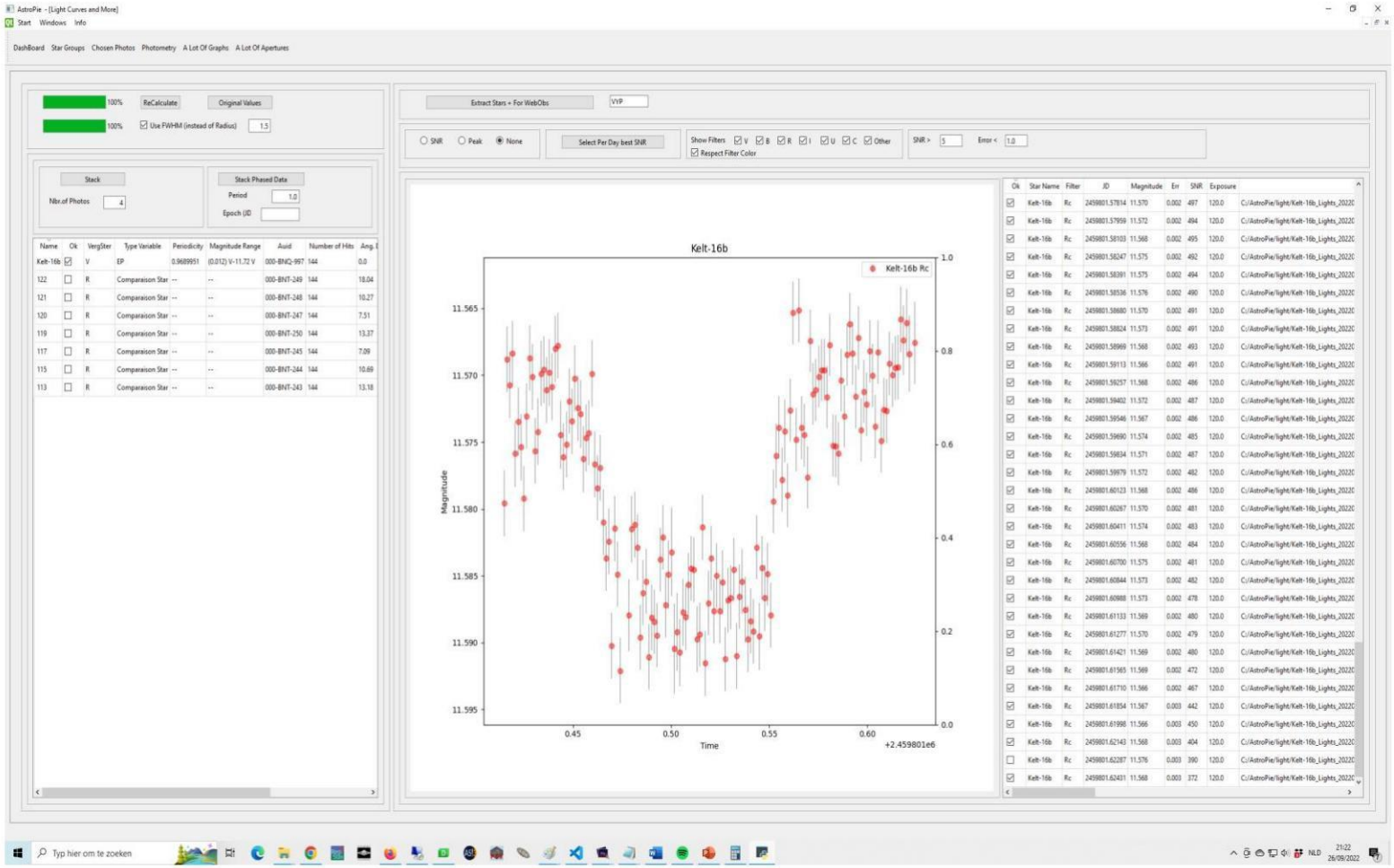
Systematic errors Include :

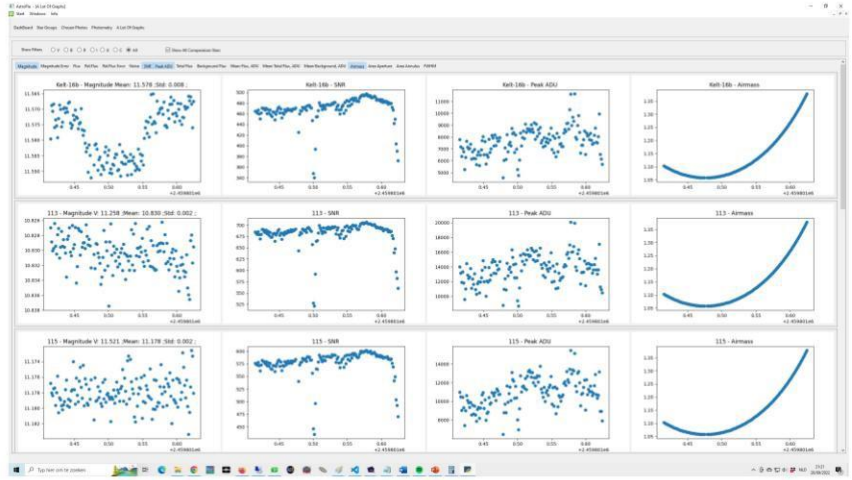
noise, warm pixels, cold pixels, hot pixels, bad lines, vignetting, satellite trails, airplanes, …

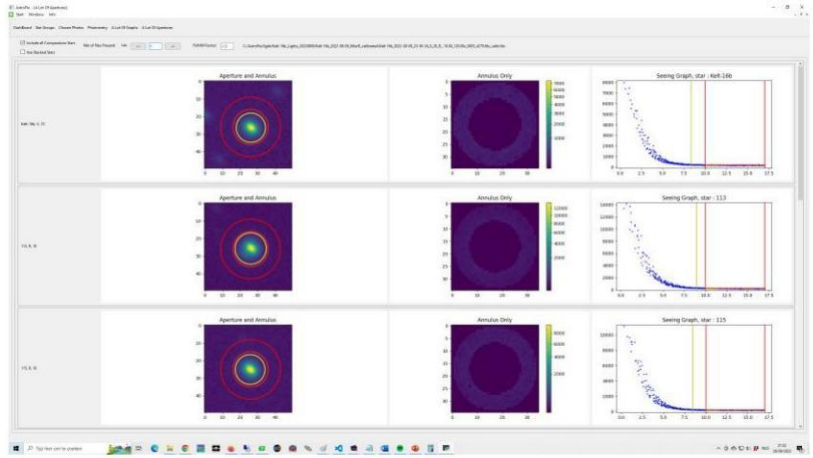
Solutions :

- Cooled modern 16 bit mono camera with a CMOS sensor
- Meticulous calibration
- AstroPie's bag of tricks

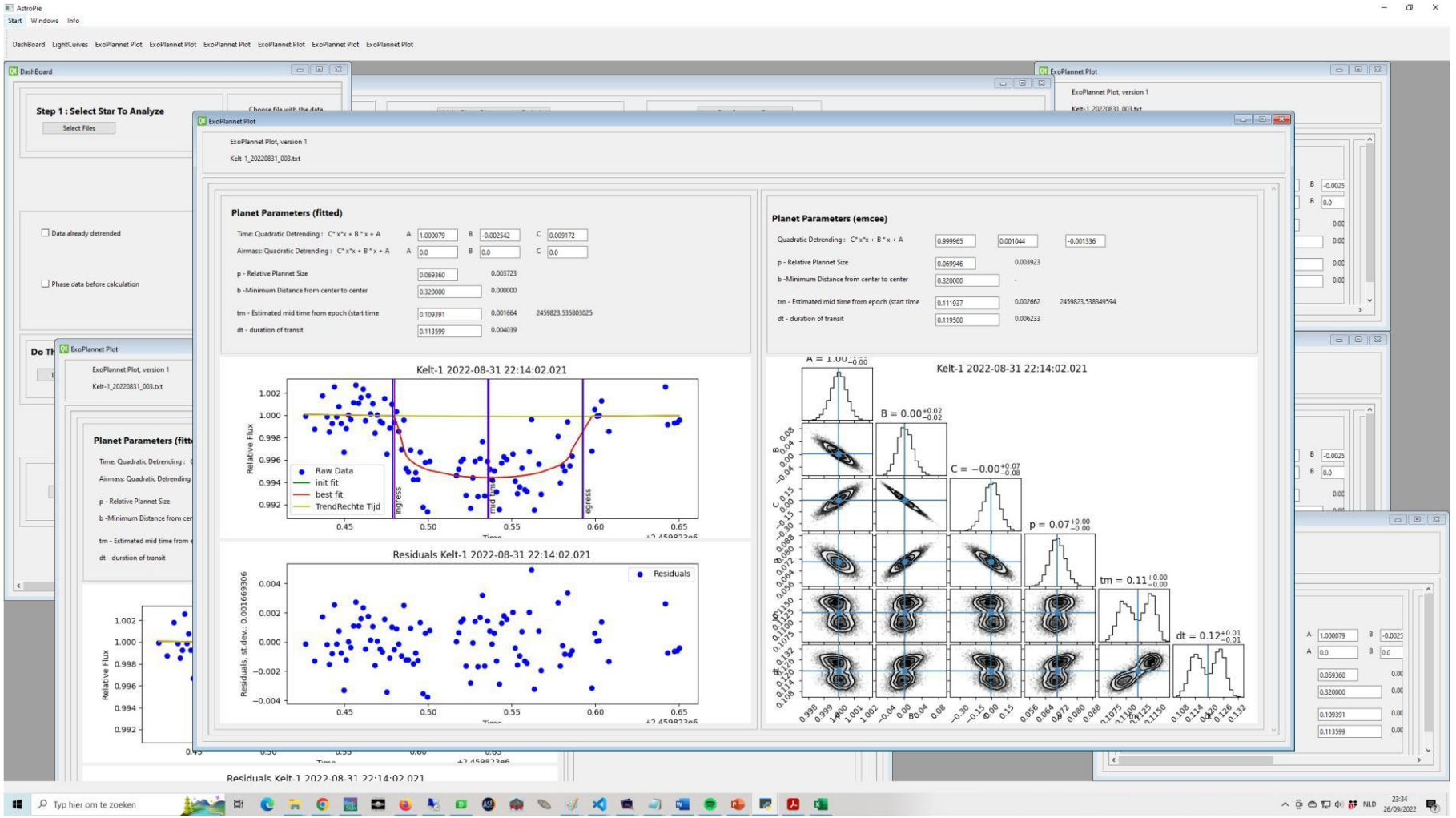
Photometry : AstroPie (written by myself)







PlanetoCalculation : ExoPie.



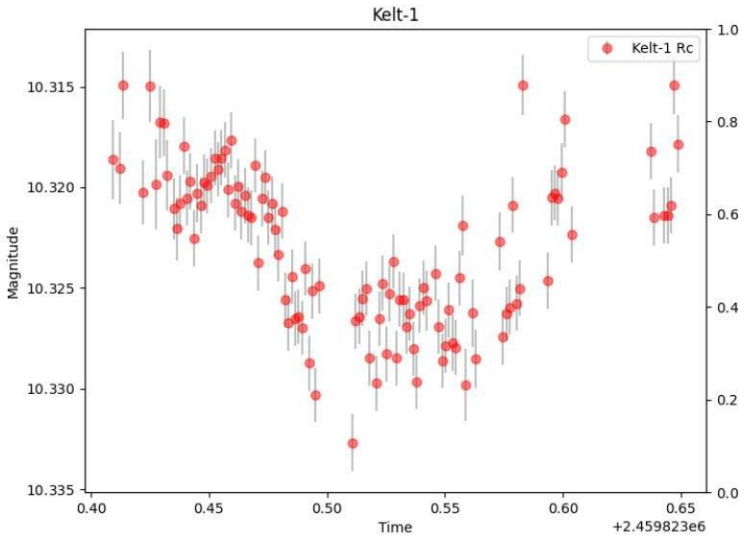
Just call a helpline…

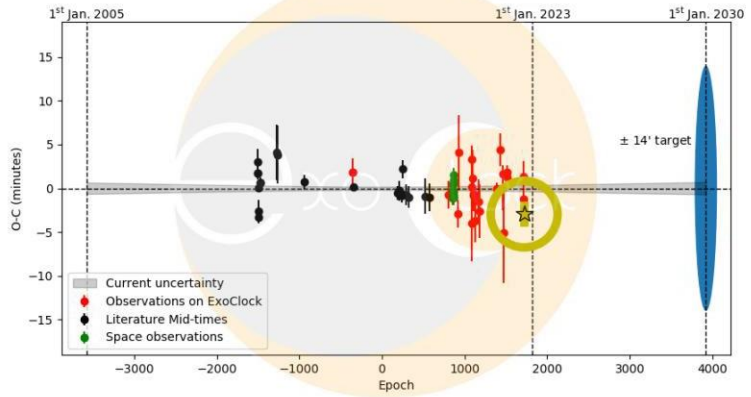
- Siegfried Vanaverbeke
- Franky Dubois
- Hubert Hautecler

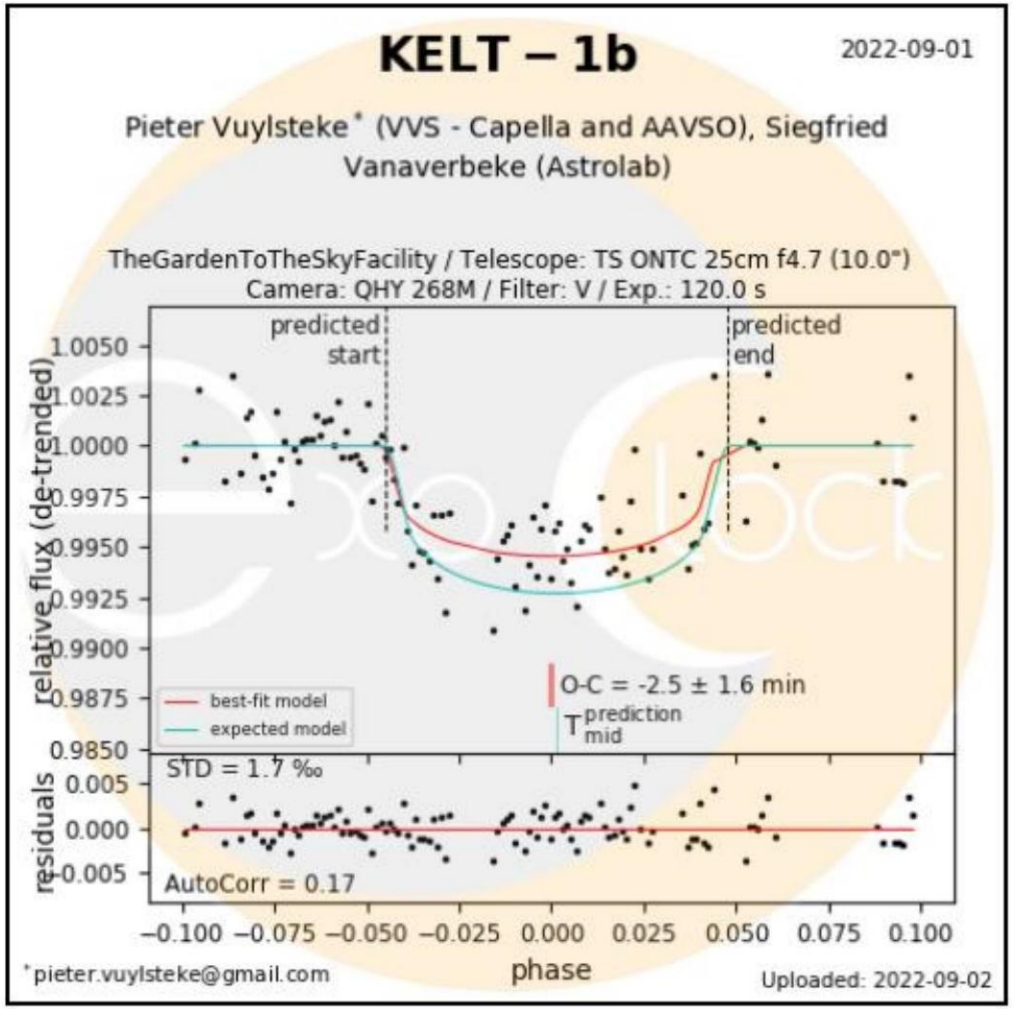
With more people, more results !

Trial case : Kelt-1 : dip of 7 mmag ?

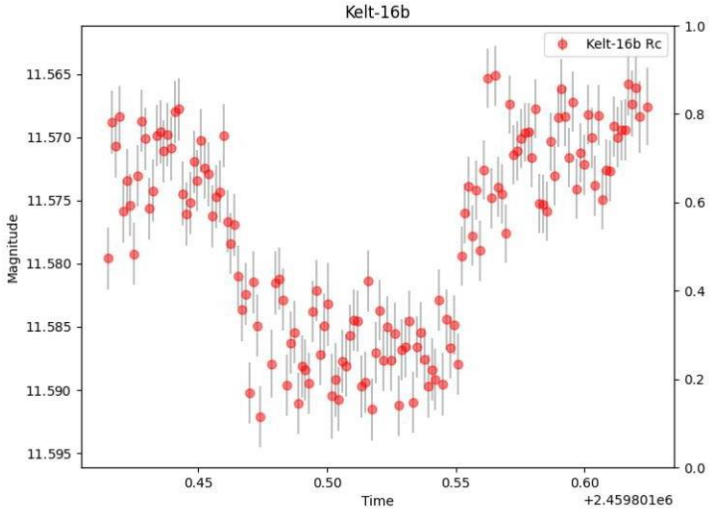
(a lot of wind, some rising veil clouds)

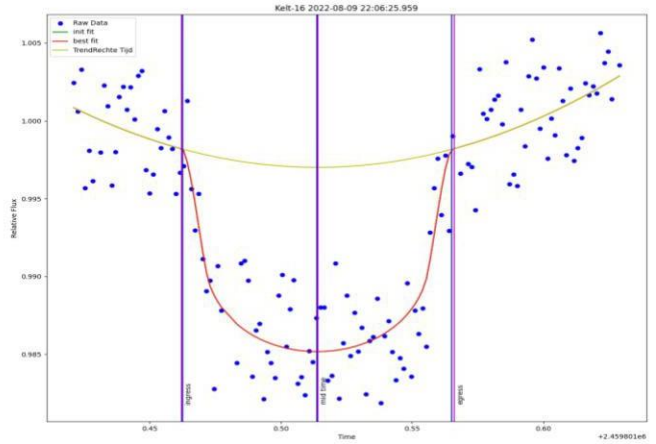


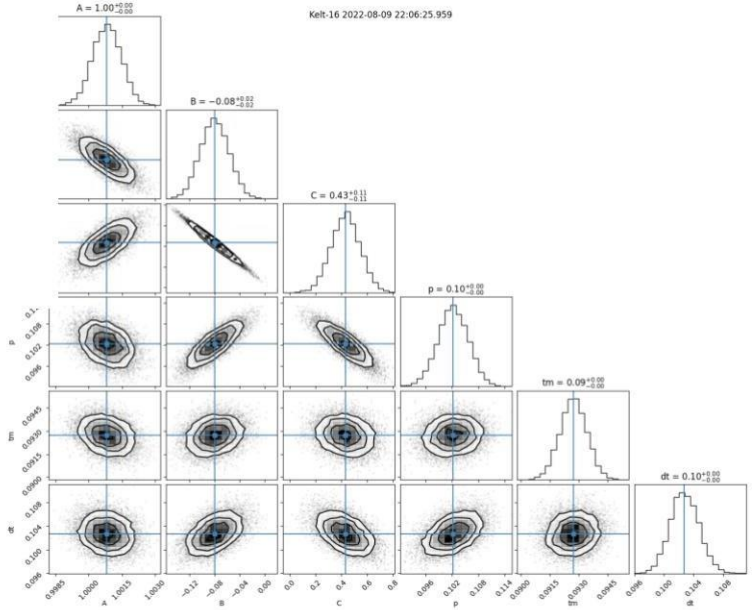




Kelt-16b, 09 August 2022 (dip: 14.77 mmag)

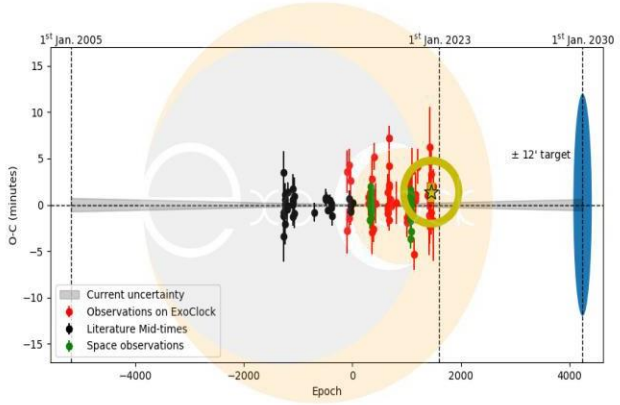




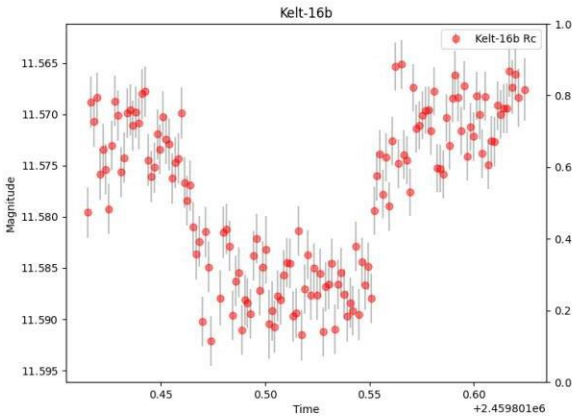


Planet Radius : 0.102 Rstar +/- 0.003
Literature : 0.107 Rstar

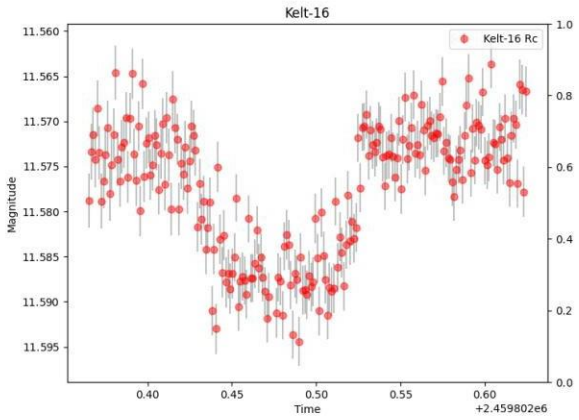
Eclipse duration : 2h28.32 +/- 0.48
Literature : 2h29.4



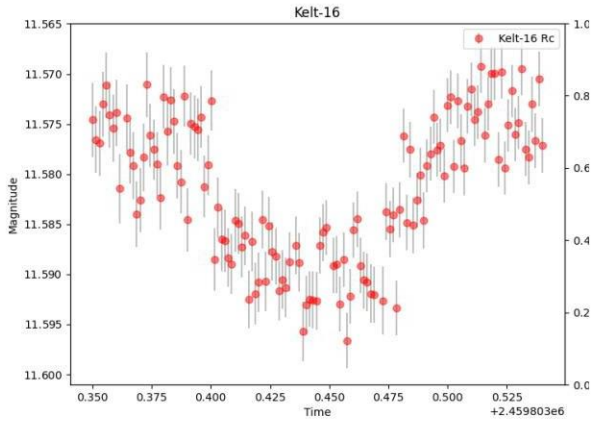
Combining observations : 4x Kelt-16b



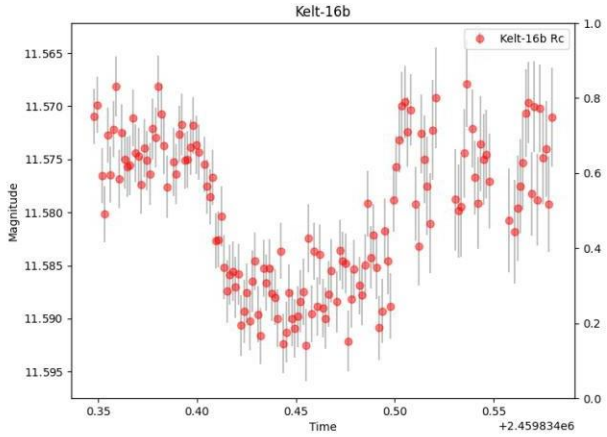
09 / 08 / 2022



10 / 08 / 2022



11 / 08 / 2022



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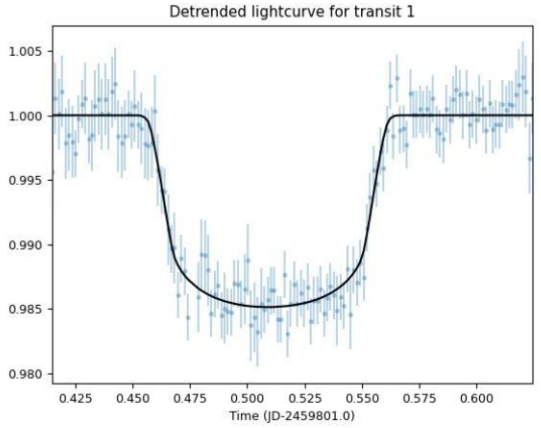
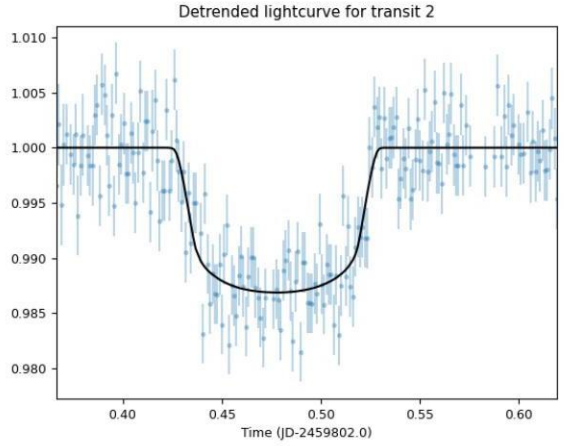
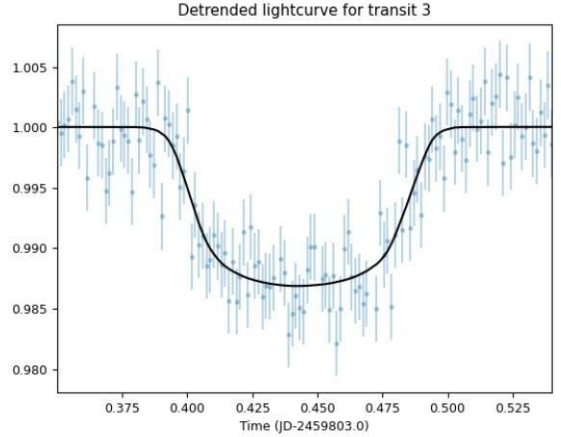
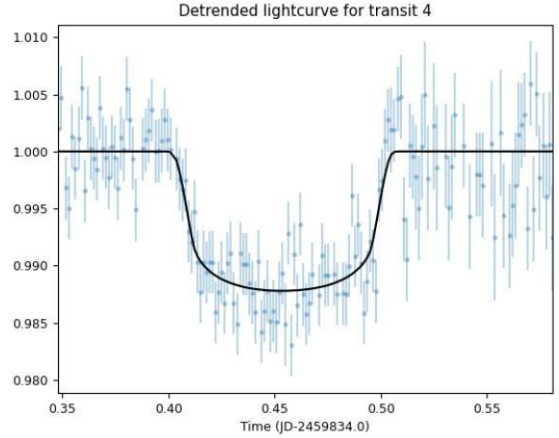
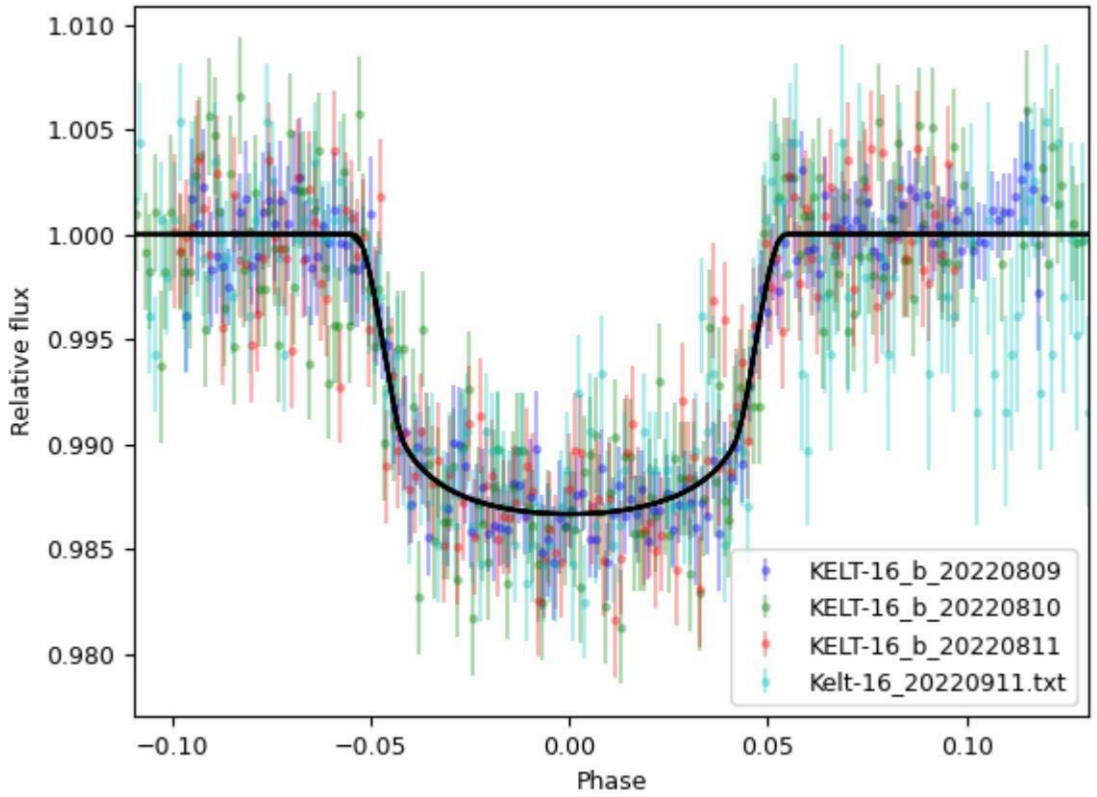








All together now (analyse by Siegfried Vanaverbeke)



• **Orbital period :**

0.968 995 1 ± 0.000 002 2 days

literature value:

0.968 992 962 ± 0.000 000 097 days

so : difference with literature =

0.000 002 days = 0.17 seconds.

• **Planet radius :**

1,4486 + 0,0197 / - 0.022 (Jupiter radius)

Planet Radius :

0.1070 ± 0.0014 (stellar radius)

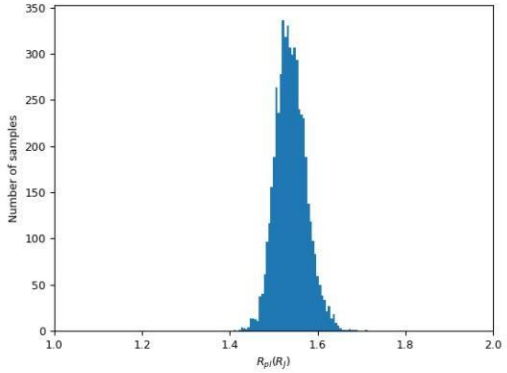
literature: 0.107 ± 0.0013

• **Eclipse duration :** 2.25 +/- 0.0024 hours

literature : 2.49 hours.

Kelt-16b : planet diameter estimate

09/08/2022



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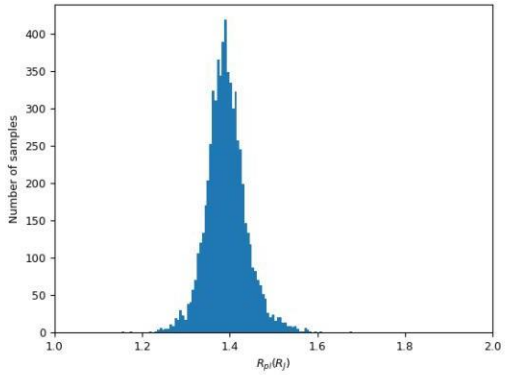

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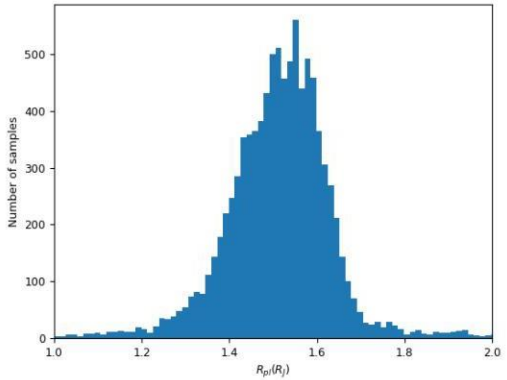

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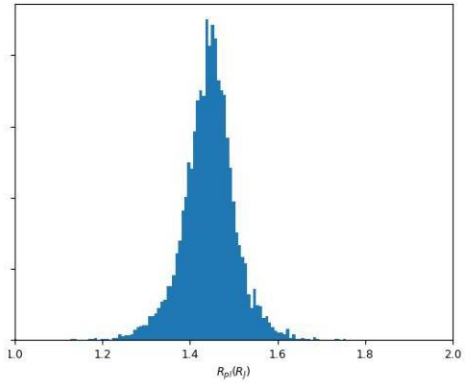
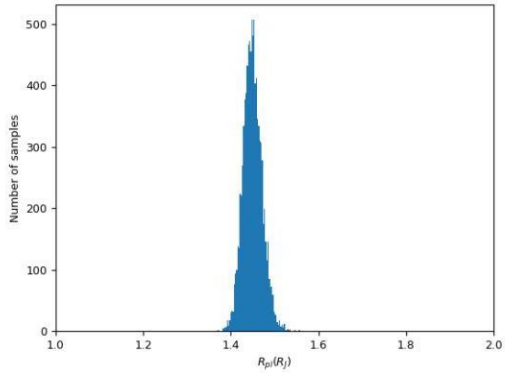


All together now

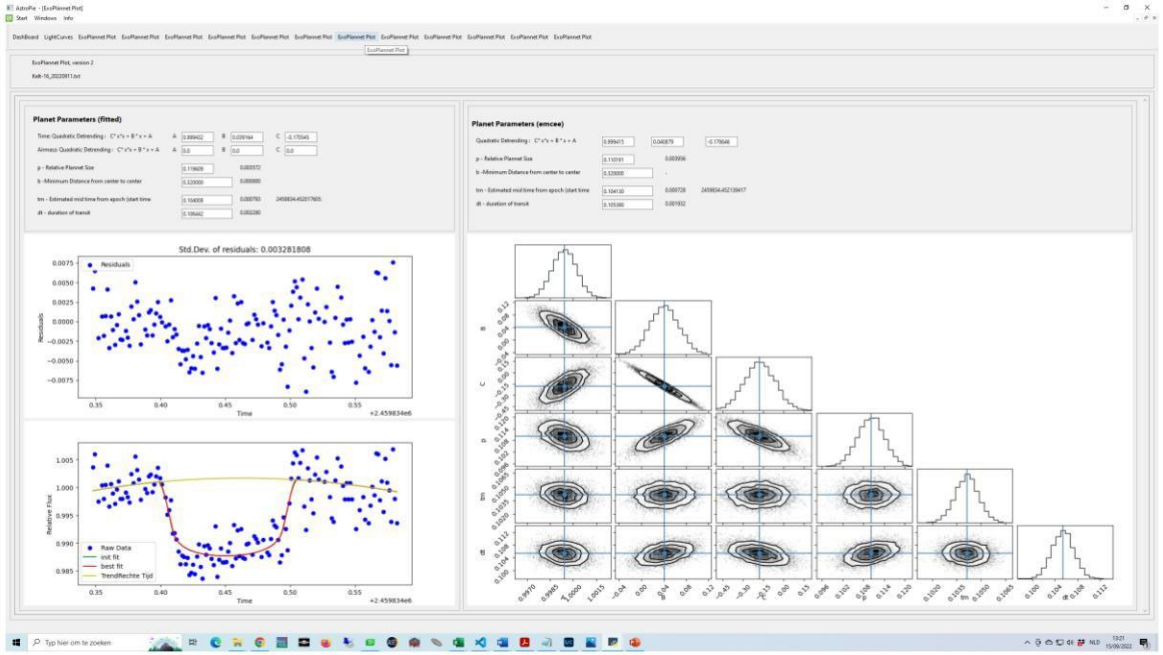


Combining lightcurves narrows down the planet radius !

Future plans

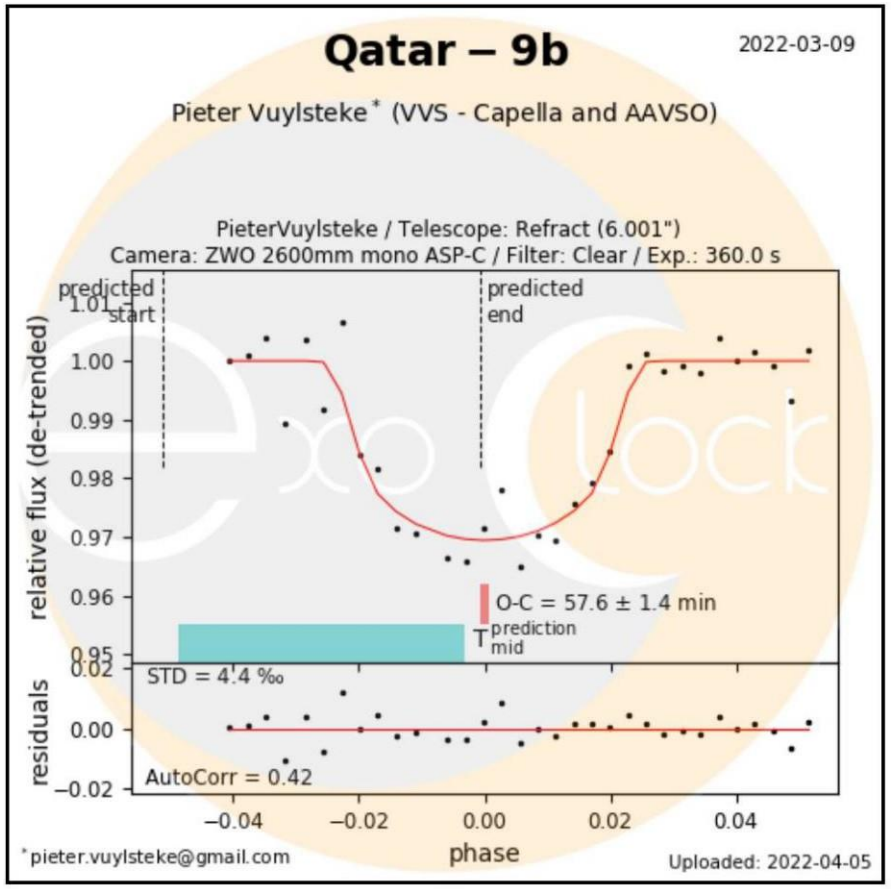
- Engage amateur astronomers to participate in synchronous observing campaigns.
- Possibility to detect “Transit Timing Variations” • Interested in joining ?
  Mail : pieter.vuylsteke@gmail.com

- **The pleasure of the pudding is in the cooking, the eating, and the sharing.**



The End.

Magn : 13.83, dip : 31.38 mmmag



Magn: 10,24, dip : 21,47mmag