OBSERVATIONS OF TRANSITING EXOPLANETS USING SMALL TELESCOPES FROM THE EUROPLANET TELESCOPE NETWORK

Europlanet Summer School 2023

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OBJECTIVE:

Ground-based follow-up observations of confirmed transiting exoplanets, using the 35/51 cm Maksutov telescope, via the Europlanet Telescope Network.

1- TELESCOPE:

Molėtai Astronomical Observatory (MAO) – Vilnius University, Lithuania:

- 31/51 cm Maksutov-system f/3.5 telescope (13.78" aperture);
- Generally operated remotely;
- Apogee Alta U47 CCD;
- Rc and Clear filters;
- Bortle class 4 location; long winter nights; Nordic Twilight;

2- PLANNING:

ExoWorlds Spies Transit Scheduler (ExoClock project):

- ExoClock project: prioritization system, minimum telescope aperture
- Custom horizon altitude
- ARIEL target list – Edwards B. & Tinetti G. 2022
- https://www.exoworldsspies.com/en/scheduler/

Swarthmore Transit Finder service (Tapir package) – Jensen E. L. N. 2013:

- NASA Exoplanet Archive database, TESS Objects of Interest, Exoplanet Watch targets, and custom targets
- Day/night definition (sunset, civil twilight, nautical twilight, astronomical twilight)
- Moon phase and distance
- https://astro.swarthmore.edu/transits/

3- OBSERVING:

Proposals:

- MAO (fixed proposal cycle per quarter period, deadline 30 days before, reviews within 15 days after deadline)
- Europlanet Telescope Network (submitted per semester, reviews within 2 months)
- Target selection based on ExoClock's prioritization system
- Transit mid-times in support to the ExoClock project
- Main programme and backup programme

Service observations:

- Dr. Erika Pakštienė (co-investigator) – Senior researcher
- Liaison with the observatory's technical staff
- Monthly observation plans (suggested integration times)
- Target selection per observing condition (favorable weather)
- Studies for the characterization of the telescope
- Observations in Rc or Clear (per target)

4- ANALYSIS:

AstroImageJ (AIJ) v5 – Collins K. A. et al. 2017:

- Image calibration (bias, darks, flats, science images, FITS headers)
- Data reduction (differential photometry)
  - AAVSO comps (RA/DEC) or Automatic comps by brightness
  - Automatic aperture size per radial profile
  - Variable aperture photometry (seeing variations)
  - Automatic comp star selection for the ensemble (exhaustive optimization)
  - Sigma clipping (outliers)
- Detrending (BIC minimization: AIRMASS, J.D., radial profile, sky-background level, FITS X and Y coordinates, total counts for the comps, peak intensity, roundness, etc)
- Transit model fit (Simple chi-squared minimization)
- No uncertainties for transit parameters (transit depth, mid-transit time, etc)
- Export detrended light curve data in BJD(TDB) or HJD(UTC)

ExoClock's online version of HOPS – Kokori A. et al. 2023:

- Transit model fit (MCMC sampling)
  - Uncertainties for transit parameters (transit depth and mid-transit time)
  - Fit diagnostics metrics (transit SNR, transit depth drift, O-C, auto correlation for residuals, Shapiro test for outliers)
  - Tips to improve the results (strong outliers, different comparison stars and aperture sizes, detrending, points having strong systematics at the start or end)

5- REPORTING:

ExoClock Project: online version of HOPS (MCMC) – Kokori A. et al. 2023:

- HOPS (HOlomon Photometry Software) – Tsiaras A. 2019
- Effective telescope aperture (21.08"/53.5cm in our case)
- Transit SNR metric
- https://www.exoclock.space/database/observations

Exoplanet Transit Database (ETD): via Czech Astronomical Society TRESCA database (non-linear least squares) – Poddaný S. et al. 2010:

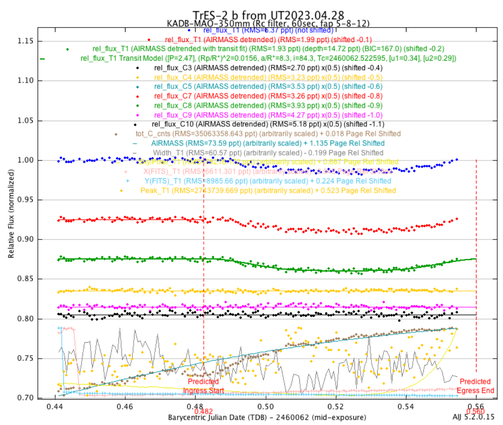
- Data quality index (DQ: 1 – 5)
- http://var2.astro.cz/EN/tresca/index.php?lang=en

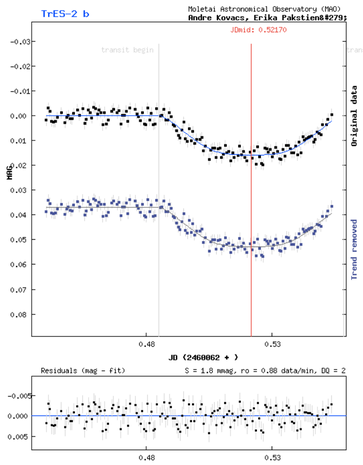
NASA Exoplanet Watch: via AAVSO Exoplanet Database and Online version of EXOTIC (MCMC)

- EXOTIC (EXOplanet Transit Interpretation Code) – Zellem R. et al. 2023
- In and outside of transit observations
- https://exoplanets.nasa.gov/exoplanet-watch/results/
- https://app.aavso.org/exosite/submit

6- INTERESTING RESULTS:

TrES-2 b (11.05 R-mag, 15.53 mmag depth): under ideal conditions (~2ppt RMS)





TrES – 2b 2023-04-28

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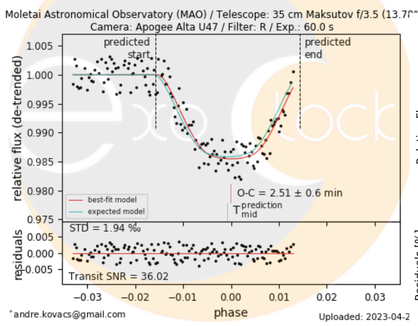
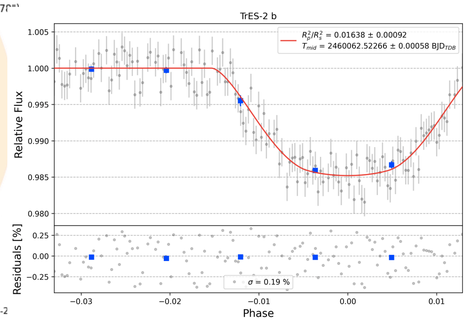
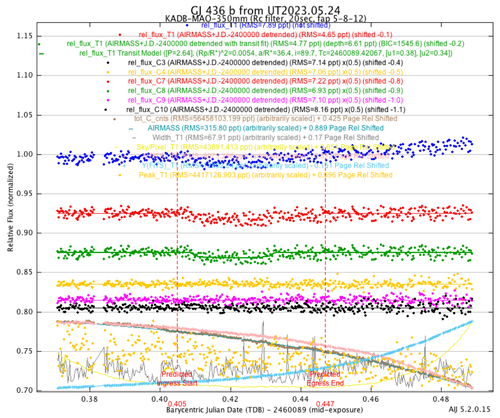
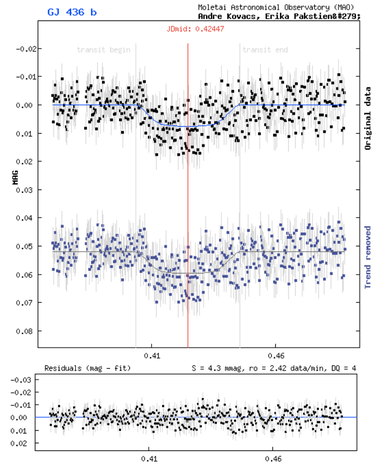




GJ 436 b (10.272 R-mag, 7.12 mmag depth): under astronomical twilight (~4.8ppt RMS)





GJ436b 2023-05-24

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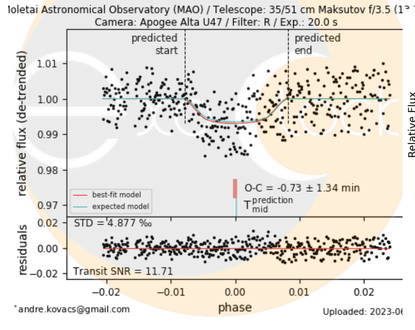

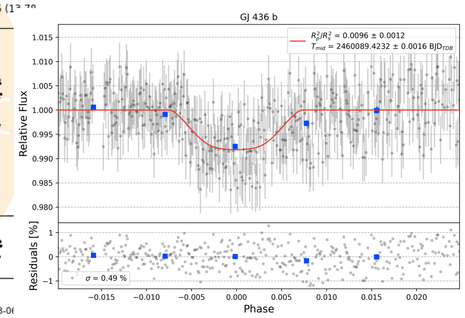

REFERENCES:

Edwards, B., & Tinetti, G. (2022). The Ariel Target List: The Impact of TESS and the Potential for Characterizing Multiple Planets within a System. *The Astronomical Journal*, 164(1), 15;

Jensen, E. (2013). Tapir: A web interface for transit/eclipse observability. *Astrophysics Source Code Library*, ascl-1306;

Collins, K. A., Kielkopf, J. F., Stassun, K. G., & Hessman, F. V. (2017). AstroImageJ: image processing and photometric extraction for ultra-precise astronomical light curves. *The Astronomical Journal*, 153(2), 77;

Kokori, A., Tsiaras, A., Edwards, B., Jones, A., Pantelidou, G., Tinetti, G., ... & Naves, R. (2023). ExoClock project. III. 450 new exoplanet ephemerides from ground and space observations. The Astrophysical Journal Supplement Series, 265(1), 4;

Tsiaras, A. (2019, September). HOPS: the photometric software of the HOlomon Astronomical Station. In *Epsc-dps joint meeting 2019* (Vol. 2019, pp. EPSC-DPS2019);

Poddaný, S., Brát, L., & Pejcha, O. (2010). Exoplanet Transit Database. Reduction and processing of the photometric data of exoplanet transits. *New Astronomy*, 15(3), 297-301;

Zellem, R., Andrews, R., Blaser, E., Engelke, J., Fatahi, T., Fitzgerald, M., ... & Varghese, J. (2023). EXOTIC: EXOplanet Transit Interpretation Code. *Astrophysics Source Code Library*, ascl-2302.

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