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UNISTELLAR EVSCOPE 2: TECHNICAL SPECIFICATIONS, USER COMMUNITY, AND PROSPECTS FOR APPLICATION

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ABSTRACT. The Unistellar eVscope 2 represents a new generation of compact astronomical instruments that combine portability, automation, and digital networking to empower both professional and citizen astronomers. This study evaluates the telescope's technical performance, educational potential, and scientific applications, particularly in exoplanet transit photometry. Based on the comparison of our observational data obtained within the Unistellar global network and professional OGLE data, we showed the great possibility of this approach. Our results demonstrate that high-quality light curves can be produced even under sub-optimal conditions, and compact digital telescopes can play an essential role in expanding observational coverage and in training the next generation of astronomers. The Unistellar network model, combining technological innovation, social participation, and data integrity, stands as a powerful example of how future astronomy will operate at the intersection of professional and citizen science.

Keywords: exoplanets: observations: photometry: transits; citizen astronomy: Unistellar.

АНОТАЦІЯ. Телескопи Unistellar представляють нове покоління компактних астрономічних приладів, які поєднують портативність, автоматизацію та цифрові мережі, та розширюють можливості як професійних, так і цивільних астрономів. Наше дослідження оцінює технічні можливості телескопу Unistellar eVscope2, його освітній потенціал та наукове застосування, зокрема у фотометрії транзитів екзопланет. На основі порівняння наших спостережень, отриманих у співпраці з глобальною мережею Unistellar, та професійних даних проєкту OGLE, ми продемонстрували великий потенціал такого підходу. Ми показали, що спостережні дані, які отримують при взаємодії у спільноті Unistellar Global Network, навіть за ненайкращих умов, дозволяють будувати високоякісні криві блиску при змінах по току від зорі на рівні 1–2%, тому компактні цифрові телескопи можуть відігравати важливу роль в отриманні якісних спостережних даних, у навчанні наступного покоління астрономів підвищенн інтересу до астрономії та розширенні кола непрофесійних спостерігачів. Ми підтвердили ефективність eVscope2 як інструмента для наукових досліджень, освітніх проєктів та міжнародної співпраці.

Окрім основних спостережних можливостей, Unistellar eVscope2 демонструє перехід до моделі розподіленої спостережної екосистеми, у межах якої тисячі малих інструментів колективно створюють науково цінні результати, що служать базою для професійних досліджень. Поєднання спостережень у режимі реального часу, автоматичного розпізнавання подій і інтеграції з науковими базами даних робить такі інструменти потужним ресурсом не лише для досліджень транзитів екзопланет, але й для більш широкого кругу задач, таких, як астрономічний моніторинг змінних зір, термінові спостереження несподіваних астрономічних явищ, спільні наукові спостережні кампанії тощо. Демократизуючи доступ до неба, телескопи та спільнота Unistellar сприяють науковій грамотності, дозволяючи навіть аматора і студентам брат участ глобальни дослідницьких ініціативах. Таким чином, він стимулює міжпоколінну співпрацю й формування нової моделі наукового колективу – синергії між науковцями, освітянами та ентузіастами, спрямованої на розвиток сучасної культури науки.

Результати нашого дослідження показують, що компактні малоапертурні цифрові телескопи можуть відігравати значущу роль у формуванні майбутнього покоління астрономів і дослідників. Мережа Unistellar, яка поєднує технологічні інновації, соціальну участь і цивільну науку, демонструє реальний приклад того, як майбутня астрономія функціонуватиме на межі професійної та аматорської діяльності.

Ключові слова: екзопланети: спостереження: фо тометрія: транзити; цивільна астрономія: Unistellar.

1. Introduction

The modern approach to observational astronomy allows for obtaining significant results using small telescopes. Many tasks require a large number of individual measurements of magnitudes by standard methods. The Unistellar program and community are a great example of productive collaboration between professionals and citizen science in the direction of exoplanet transits observations, in particular (Bonney et al., 2014).

The search for exoplanets is one of the most dynamic areas of modern astrophysics, offering insights into planetary formation, orbital dynamics, and habitability beyond the Solar System. Among the observational methods, transit photometry - the measurement of periodic dips in stellar brightness as a planet passes in front of its host star has proven exceptionally productive (Winn & Fabrycky, 2015). The most interest light curves allowed detecting compound transits, like as VLT observations of the light curve of TRAPPIST-1 during the triple transit of 11 December 2015 (Gillon et al., 2016), Kepler observations of the Kepler-1625b super-Jupiter and it's Neptune-sized exomoon, orbiting of the planet (Teachey & Kippin, 2018), and exotic light curve BD+05 4868 Ab, which arose due to disintegration of the exoplanet (Hon et al., 2025). In the all cases the dept of the transit is on the level of $0.05 - 0.12$ form common flux.

While large professional surveys such as Kepler, TESS, and PLATO dominate the field, smaller instruments increasingly contribute through citizen-science initiatives. The Unistellar eVscope 2, with its integrated sensor, automated pointing, and mobile-app control, demonstrates how distributed telescope networks can enhance temporal coverage and community engagement in real research.

2. Instrument Specifications and Methodology

The Unistellar eVscope 2 is a compact digital reflector telescope with the following base parameters:

- Mirror diameter: 114 mm;
- Focal length: 450 mm ($f/4$);
- optical tube length 549 mm;
- Sensor: Sony IMX347, 7.7 MP;
- Limiting magnitude 18.2^m;
- Field of view: $34.2 \times 45.6\,arcmin$;
- Scale $1.33''/pix$;
- Weight: $\approx 9\,kg$;
- Motorized ALT-AZ mount;
- Slew speeds max $4°/s$;
- Control: Smartphone application;
- Capabilities: battery autonomy ≈ 9 h, storage 64 GB, automatic alignment, live stacking, and transit photometry.

Observations were performed through the Unistellar citizen-science network, which connects professional astronomers, educators, and amateurs worldwide. Uniform optical properties of the Unistellar telescope family provide a consistent combination of the network observations; it was studied in Perrocheau et al. (2022), Graykowski et al. (2023), Peluso et al. (2023), and Sgro et al. (2023).

Each participant of the Unistellar community contributes calibrated photometric data that can be merged and cross-validated with professional databases. The observer can process the individual frames (in the *fits* format) and obtain the light curve by himself. However, the best results are obtained in the centralized standard analysis, which includes the comparison with model systems also.

Our test frames, obtained before the transit observations, showed that the limiting magnitude for our Unistellar eVscope 2, is 16^m. It agrees with the limiting magnitude in the base parameters, because 18.2^m value was obtained in countryside mode with longer exposure. Nevertheless, for our tasks 16^m is sufficient: in the frames received at altitudes of more 45°, we detected weaker stars confidently. The main part of the program stars have magnitudes at level $12 - 14^m$, so using Unistellar is valid.

Anastasia Pechko was a leading observer of our team. We obtained transit light curves for 2 confirmed exoplanets: TOI-2046b, created in 2020, and TrES-3b (TOI-2126.01), created in 2007; transit light for 2 candidate planets: TOI-7343.01 TOI, created in April of 2025, and TOI-7425.01 created in May 2025-05-01.

The information about our objects from the TOI list was obtained from the NASA Exoplanet Archive (Street et al., 2024). For all transits, we determined the mid-transit time, the duration and depth of the transit, and the duration of the magnitude decrease/increase.

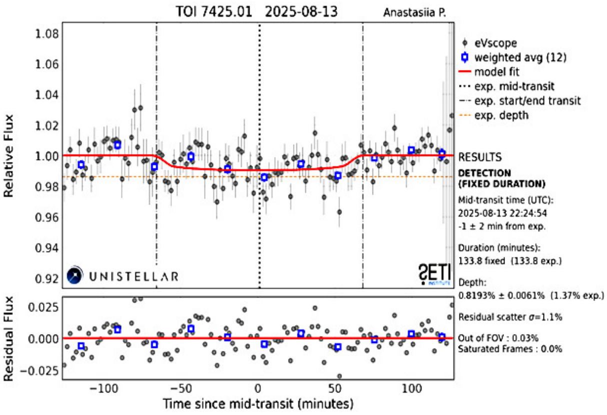

Figure 1: Transition light curve for TOI-7425.01 with the weakening of flux on the level 0.82%. The upper panel with relative flux: individual data are shown as grey dots with corresponded error bars, weighted average points are shown as squares and the synthetic light curve is a solid line. The bottom panel residual flux: the average value is zero. The legend is shown on the right

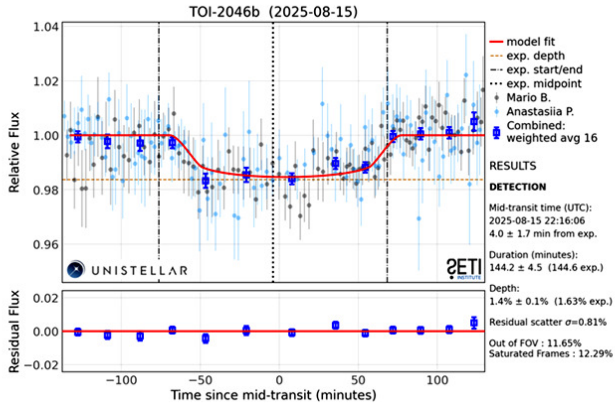

Figure 2: Transition light curve for TOI-2046b, reduced by 2 different observers. The legend as in Fig. 1

In all four transits, the parent star magnitudes were about 12^m, the individual error for current magnitude was at the level about 0.007 of the relative flux, and the depths of the transit were from 0.82% to 1.97% of the full flux. The accuracy of the transit's time frames is on the level of 2% and is in good agreement with the TOI forecast. The transit light curve with the least weakening of flux for our observations (0.82%) is presented in Fig. 1.

15^{th} on August 2025, Anastasia Pechko and our team conducted exoplanet transit observations, later combined in the Unistellar Community with independent data from another observer. The combined light curve was generated through weighted averaging, which effectively reduced noise and increased the signal-to-noise ratio. It is shown in Fig. 2. The comparison of data from two geographical locations confirmed consistency within measurement uncertainties. The improvement in curve smoothness demonstrates the power of collaborative photometry, where multiple observers contribute to a single scientifically robust data set.

The combined light curve shows a flux decrease of about $1-1.5\%$, typical for hot Jupiter type planets, and a duration close to two hours. The agreement between independently reduced data sets verifies the reliability of the Unistellar calibration pipeline and emphasizes the efficiency of data stacking and noise reduction. Even under moderate light pollution, the resulting signal-to-noise ratio was sufficient to clearly detect the ingress and egress phases.

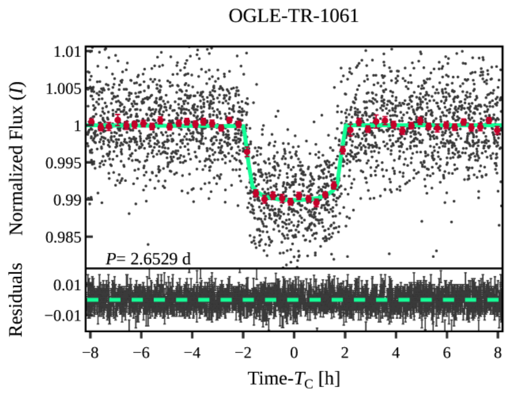

Figure 3: Transition light curve for OGLE-TR-1061

3. The comparison with OGLE transits and discussion

In our observation we obtained the typical values of the transit light curve parameters. The OGLE data base (*https://ogledb.astrouw.edu.pl/*) contains higher quality photometry data for different variables. One section in the OGLE contains 99 transiting planet candidates in the Galactic bulge (Mróz et al., 2023), with the probability ranging from 0.80 to 1.00. We select 4 transit light curves for comparison with our results. The typical OGLE transit for OGLE-TR-1061b is present in Fig. 3, from *https://ogledb.astrouw.edu.pl/*.

We see the transit depth at about the 1% level, but the scatter of individual points is practically the same as in our observations. We can also point out that the data in Fig. 3 were collected over 10 years. So, our one-night data gives comparable results with long-time observations. More, the OGLE data were obtained using a fully automated 1.3 *m* Warsaw University Telescope Las Campanas Observatory, Chile. It's an excellent place for photometry, and the excellent equipment;

however, due to modern methods of data reduction, we have the results on eVscope 2 practically on the same level. So, the obtained results confirm that compact automated telescopes can achieve scientifically valuable photometric precision even under light-polluted urban conditions.

Over the past decade, small-aperture telescopes have become effective tools for observing transits. Wide Angle Search for Planets, WASP program is two successful robotic observatories. The base equipment of the WASP program is lenses with an aperture of 111 mm (Pollacco et al., 2016). The Unistellar telescopes, having practically the same aperture, can provide wide support for professional observations. Examples of the successful work of the eVscope are observations of the comets 12P/Pons-Brooks and C/2023 A3 (Tsuchinshan-ATLAS) 11, when their magnitudes were greater than 16^m (Graykowski et al., 2024).

4. Conclusion

The quality of the Unistellar eVscope 2 and modern methods of data reduction allow us to use this telescope and analogs as an effective tool for research, outreach, and international collaboration. The hundreds of Unistellar users, distributed across all continents, excluding Antarctica, open new possibilities for:

- Long-term exoplanet monitoring, including transit-timing-variation (TTV) analysis and orbital refinement.
- Asteroid occultation studies, contributing to the characterization of small Solar System bodies.
- Rapid follow-up of transient phenomena such as supernovae and comets.
- Educational engagement, allowing students and teachers to participate in authentic scientific research.
- Citizen science integration, supplying complementary datasets to major space missions (TESS, Kepler, PLATO).

We showed the Unistellar eVscope 2 provides reliable exoplanet light curves, validating its use in scientific and educational contexts. Collaborative data merging within the Unistellar community significantly improves measurement accuracy and minimizes systematic errors. The study demonstrates that citizen science networks can meaningfully contribute to professional astrophysical research.

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