The EASST Network and BHTOM Platform for Coordinated Microlensing Studies

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Natural formalism of microlensing

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A NATURAL FORMALISM FOR MICROLENSING

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ABSTRACT

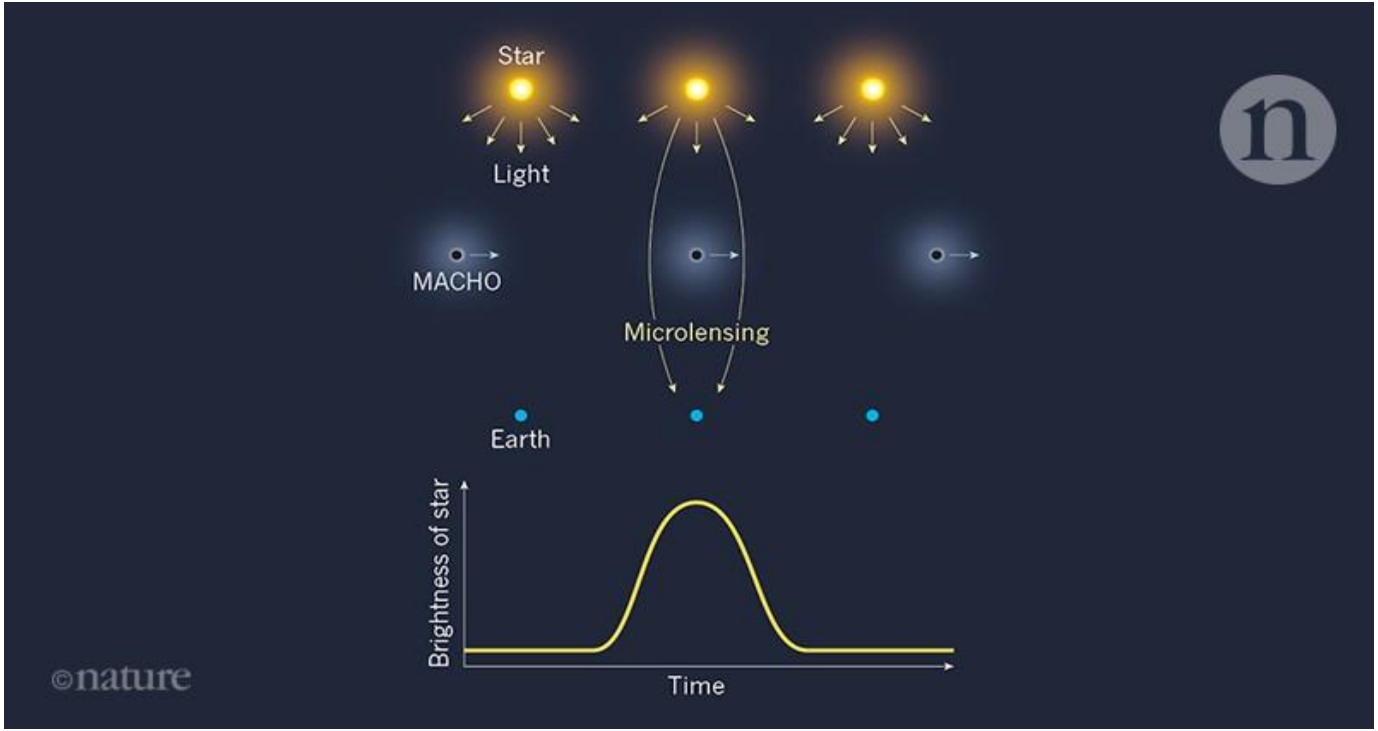
If the standard microlensing geometry is inverted so that the Einstein ring is projected onto the observer plane rather than the source plane, then the relations between the observables (θ_E, $\tilde{r}_E$) and the underlying physical quantities (M, π_{rel}) become immediately obvious. Here θ_E and $\tilde{r}_E$ are the angular and projected Einstein radii, M is the mass of the lens, and π_{rel} is the lens-source relative parallax. I recast the basic formalism of microlensing in light of this more natural geometry and in terms of observables. I then find that the relations between observable and physical quantities assume an exceptionally simple form. In an appendix, I propose a set of notational conventions.
Subject headings: astrometry — gravitational lensing

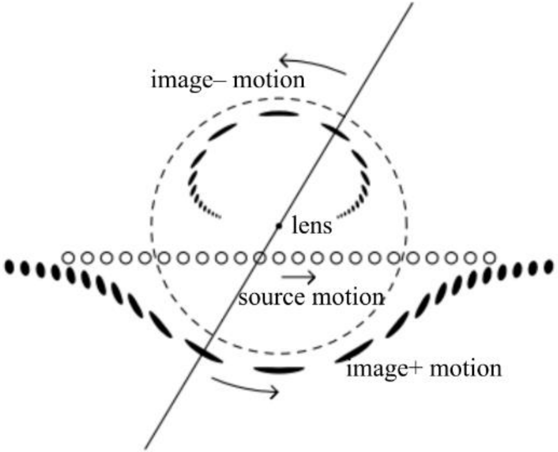
1. INTRODUCTION

The geometry of point-lens microlensing (Einstein 1936; Refsdal 1964; Paczyński 1986) is so simple that students can derive all the basic results in a few hours. Nonetheless, this geometry has never been boiled down to its essence: the relationship between the underlying physical quantities and the observables. In particular, the "Einstein ring radius" r_E,

Gould (2000) ApJ, 542, 785

Point-lens microlensing





configuration of the images for the moving source

$$\theta_{\mathrm{E}} = \left(\frac{4GM}{c^2} \frac{D_{\mathrm{ds}}}{D_{\mathrm{d}} D_{\mathrm{s}}} \right)^{1/2}$$

angular Einstein Radius for point mass M

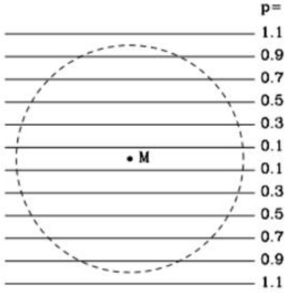


Fig. 4.— The geometry of gravitational lensing is shown. The lensing mass M is located at the center of the Einstein ring, which is marked with a dashed line. The twelve horizontal lines represent relative trajectories of the source, labeled with the value of dimensionless impact parameter p.

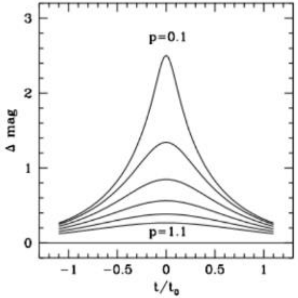
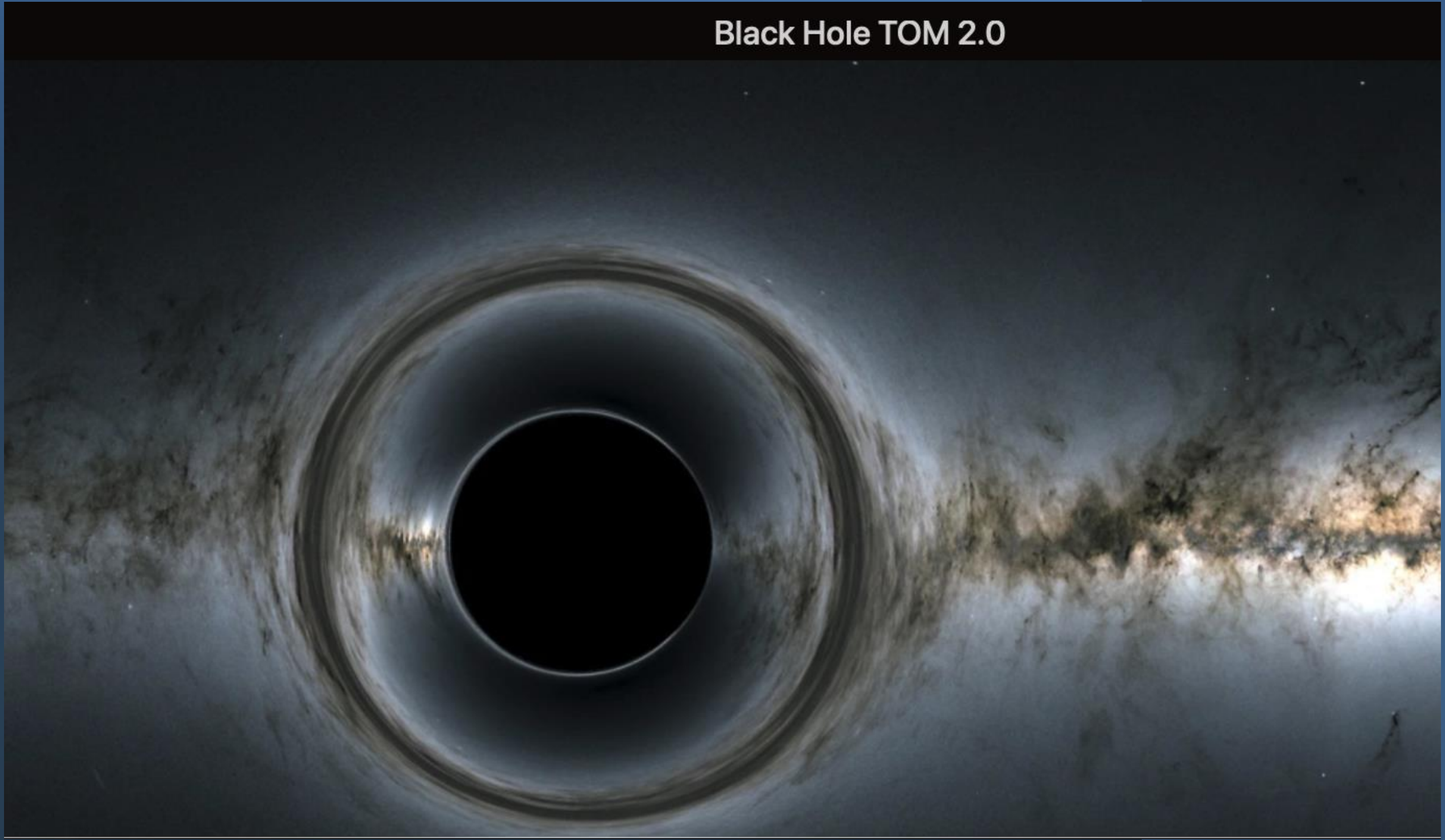
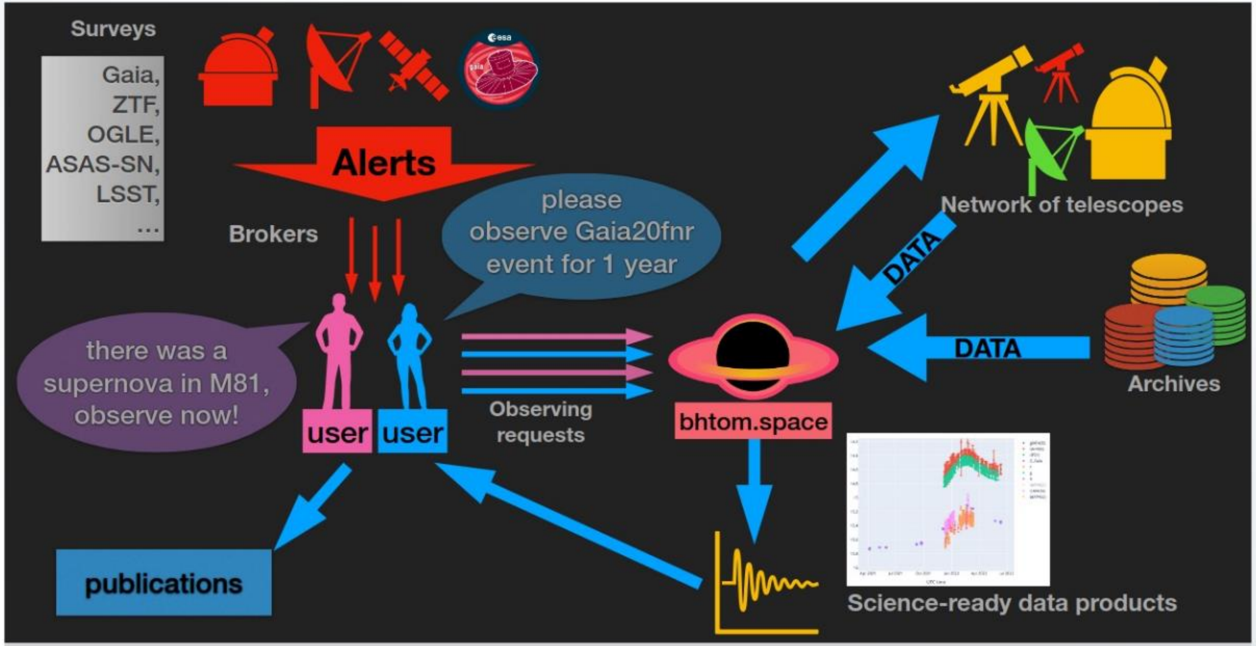


Fig. 5.— The variation of the magnification due to a point gravitational lensing is shown in stellar magnitudes as a function of time. The unit t_0 is defined as the time it takes the source to move a distance equal to the Einstein ring radius, r_E. The six light curves correspond to the six values of the dimensionless impact parameter: $p = 0.1, 0.3, 0.5, 0.7, 0.9, 1.1$.

Paczyński 1996 - formation of a light curve


Black Hole TOM 2.0



BHTOM is a cutting-edge web-based platform designed to coordinate a global network of telescopes, manage astronomical observations, and process the resulting data efficiently.

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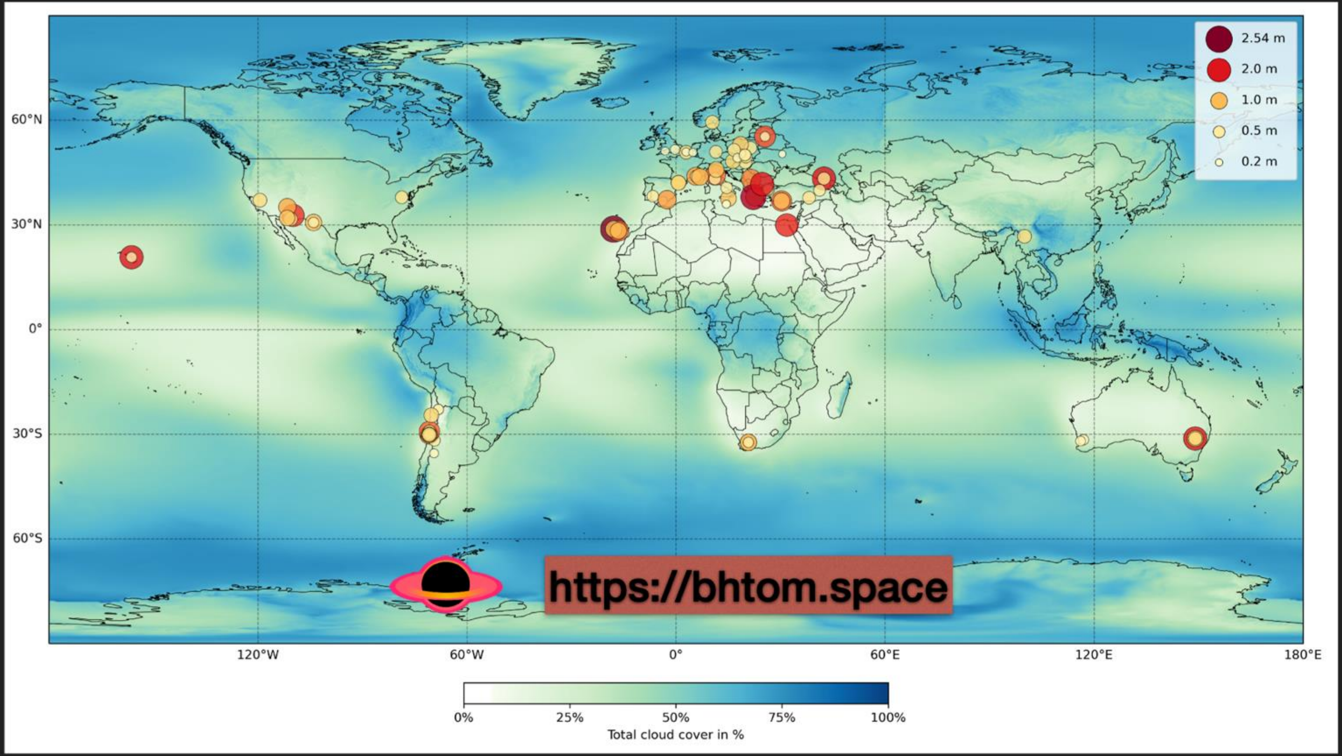
LUKASZ WYRZYKOWSKI - GAIA SCIENCE ALERTS

GLOBAL TELESCOPE NETWORK since 2013 to support Gaia Science Alerts

ACME

OPTICON RadioNet Pilot

- ~130 telescopes
- sizes 0.25 - 2.5 m
- manual
- robotic
- with good weather
- with poor weather
- volunteering
- via proposals
- professional
- amateur
- outreach
- educational



map by K.Kotysz & P.Mikołajczyk


Molėtai Astronomical
Observatory

PUBLICATIONS USING BHTOM

Full orbital solution for the binary system in the northern Galactic disc microlensing event Gaia16aye*

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…rden[103], V. L. Hoette[95], K.
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…ov[76,87], D. G. Zhukov[76], J.

Monthly Notices of the Royal Astronomical Society

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Advance Access publication 2022 July 12

Photometric and spectroscopic study of the burst-like brightening of two *Gaia*-alerted young stellar objects

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CrossMark

Lens mass estimate in the Galactic disk extreme parallax microlensing event Gaia19dke

M. Maskoliūnas[1], Ł. Wyrzykowski[2], K. Howil[2], K. A. Rybicki[2], P. Zieliński[3], Z. Kaczmarek[4], K. Kruszyńska[2], M. Jabłońska[2], J. Zdanavičius[1], E. Pakštienė[1], V. Čepas[1], P. J. Mikołajczyk[2,8], R. Janulis[1], M. Gromadzki[2], N. Ihanec[2], R. Adomavičienė[1], K. Šiškauskaitė[1], M. Bronikowski[2,7], P. Sivak[2], A. Stankevičiūtė[2], M. Sitek[2], M. Ratajczak[2], U. Pylypenko[2], I. Gezer[5], S. Awiphan[9], E. Bachelet[10], K. Bąkowska[3], R. P. Boyle[12], V. Bozza[32,33], S. M. Brincat[13], U. Burgaz[11], T. Butterley[29], J. M. Carrasco[14], A. Cassan[38], F. Cusano[15], G. Damljanovic[6], V. S. Dhillon[22], M. Dominik[39], F. Dubois[16], H. H. Esenoglu[17], R. Figuera Jaimes[34], A. Fukui[19], C. Galdies[20], A. Garofalo[15], V. Godunova[21], T. Güver[17,18], J. Heidt[22], M. Hundertmark[36], I. Izviekova[3], B. Joachimczyk[3], M.K. Kamińska[39], K. Kamiński[39], S. Kaptan[17,18], T. Kvernadze[24], O. Kvaratskhelia[24], S. Littlefair[22], O. Michniewicz[24], N. Nakhatutai[35], W. Ogłoza[42], J. M. Olszewska[39], M. Polińska[39], A. Popowicz[23], J. K. T. Qvam[26], M. Radziwonowicz[2], A. Słowikowska[37,3], A. Simon[30,31], E. Sonbas[40,41] M. Stojanovic[6] Y. Tsapras[36], S. Vanaverbeke[16], R. W. Wilson[29], M. Zejmo[24], S. Zola[28],

The Astrophysical Journal, 899:130 (8pp), 2020 August 20

Gaia 18dvy: A New FUor in the Cygnus OB3 Association

E. Szegedi-Elek[1], P. Ábrahám[1,2], Ł. Wyrzykowski[3], M. Kun[1], Á. Kóspál[1,2,4], L. Chen[1], G. Marton[1,2], A. Moór[1,2], C. Kiss[1,2], A. Pál[1,2,5], L. Szabados[1], J. Varga[1,6], E. Varga-Verebélyi[1], C. Andreas[7], E. Bachelet[8], R. Bischoff[7], A. Bódi[1,9], E. Breedt[10], U. Burgaz[11,12], T. Butterley[13], J. M. Carrasco[14], V. Čepas[15], G. Damljanovic[16], I. Gezer[3], V. Godunova[17], M. Gromadzki[3], A. Gurgul[3], L. Hardy[18], F. Hildebrandt[7], S. Hoffmann[7], M. Hundertmark[19], N. Ihanec[3], R. Janulis[15], Cs. Kalup[1], Z. Kaczmarek[3], R. Könyves-Tóth[1], M. Krezinger[1], K. Kruszyńska[3], S. Littlefair[18], M. Maskoliūnas[15], L. Mészáros[1], P. Mikołajczyk[20], M. Mugrauer[7], H. Netzel[21], A. Ordasi[1], E. Pakštienė[15], K. A. Rybicki[3], K. Sárneczky[1], B. Seli[1], A. Simon[22], K. Šiškauskaitė[15], Á. Sódor[1], K. V. Sokolovsky[23,24,25], R. Szakáts[1], L. Tomasella[26], Y. Tsapras[19], K. Vida[1,2], J. Zdanavičius[15], M. Zieliński[3], P. Z…

Single lens mass measurement in the high magnification microlensing event Gaia19bld located in the Galactic Disk

K. A. Rybicki,[★1] Ł. Wyrzykowski,[1] E. Bachelet,[2] A. Cassan,[3] P. Zieliński,[1] A. Gould,[4,5] S. Calchi Novati,[6] J.C. Yee,[7] Y.-H. Ryu,[8] M. Gromadzki,[1] P. Mikołajczyk,[9] N. Ihanec,[1] K. Kruszyńska,[1] F.-J. Hambsch,[10,11] S. Zola,[12] S. J. Fossey,[13] S. Awiphan,[14] N. Nakharutai,[15] F. Lewis,[16,17] F. Olivares E.,[18] S. Hodgkin,[19] A. Delgado,[19] E. Breedt,[19] D. L. Harrison,[19,20] M. van Leeuwen,[19] G. Rixon,[19] T. Wevers,[19] A. Yoldas,[19] A. Udalski,[1] M. K. Szymański,[1] I. Soszyński,[1] P. Pietrukowicz,[1] S. Kozłowski,[1] J. Skowron,[1] R. Poleski,[1] K. Ulaczyk,[21,1] P. Mróz,[1,22] P. Iwanek,[1] M. Wrona,[1] R.A. Street,[2] Y. Tsapras,[23] M. Hundertmark… Gandi,[5] C. Henderson,[6] Y. Shvartzvald,[25] W. Zang…

SN 2018zd: An Unusual Stellar Explosion as Part of the Diverse Type II Supernova Landscape

Jujia Zhang,[1,2,3,4★] Xiaofeng Wang,[5,6] József Vinkó[7,8,9] Qian Zhai,[1,2,3,4] Tianmeng Zhang,[10] Alexei V. Filippenko,[12,13] Thomas G. Brink,[12] WeiKang Zheng,[12] Łukasz Wyrzykowski,[14] Przemysław Mikołajczyk,[14] Fang Huang,[15] Xinhan Zhang,[5] Huijuan Wang,[10,11] Jame… A. Bódi,[7,18] G. Csörnyei,[7,8] O. Hanyecz,[7] I… R. Könyves-Tóth,[7,8] A. Ordasi,[7] A. Pál,[7,8] G. Zsidi[7,8,19]

The *Gaia* alerted fading of the FUor-type star Gaia21elv

Zsófia Nagy,[1,2★] Sunkyung Park,[1,2] Péter Ábrahám,[1,2,3] Ágnes Kóspál,[1,2,3,4] Fernando Cruz-Sáenz de Miera,[1,2] Mária Kun,[1,2] Michał Siwak,[1,2] Zsófia Marianna Szabó,[1,2,5,6] Máté Szilágyi,[1,2,3] Eleonora Fiorellino,[7] Teresa Giannini,[8] Jae-Joon Lee,[9] Jeong-Eun Lee,[10] Gábor Marton,[1,2] László Szabados,[1,2] Fabrizio Vitali,[8] Jan Andrzejewski,[11] Mariusz Gromadzki,[12] Simon Hodgkin,[13] Maja Jabłońska,[12] Rene A. Mendez,[14] Jaroslav Merc,[15] Olga Michniewicz,[11] Przemysław J. Mikołajczyk,[12,16] Uliana Pylypenko,[12] Milena Ratajczak,[12] Łukasz Wyrzykowski,[12] Michał Zejmo,[11] Paweł Zieliński[17]

AT2021uey: A planetary microlensing event outside the Galactic bulge

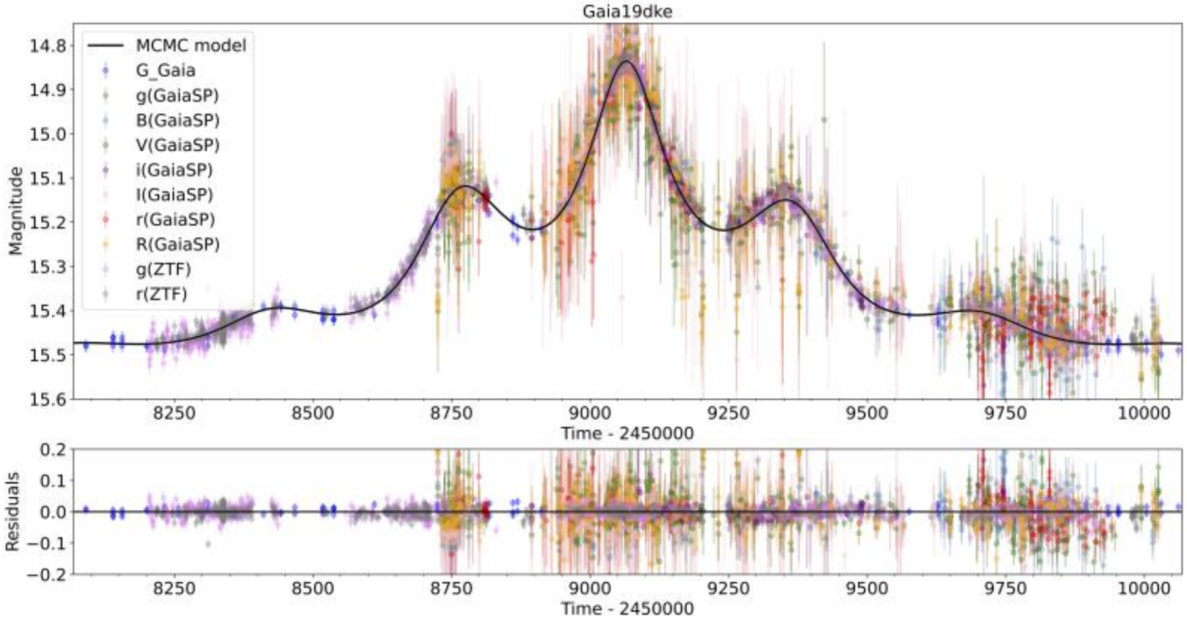
Ban, M.[1], Voloshyn, P.[2,3], Adomavičienė, R.[4], Bachelet, E.[5,6], Bozza, V.[7,8], Brincat, S. M.[9], Bruni, I.[10], Burgaz, U.[11], Carrasco, J. M.[12], Cassan, A.[5], Čepas, V.[4], Dominik, M.[13], Dubois, F.[14], Figuera Jaimes, R.[15], Fukui, A.[16,17], Galdies, C.[18,19], Garofalo, A.[10], Hundertmark, M.[20], Kruszyńska, K.[1], Kulijanishvili, V.[21], Kvernadze, T.[21], Logie, L.[14], Maskoliūnas, M.[4], Mikołajczyk, P. J.[1,22], Mróz, P.[1], Narita, N.[16,17,23], Pakštienė, E.[4], Peloton, J.[3], Poleski, R.[1], Qvam, J. K. T.[24], Rau, S.[14], Rota, P.[7,8] Rybicki, K. A.[1,25], Street, R. A.[26], Tsapras, Y.[20], Vanaverbeke, S.[14], Wambsganss, J.[20], Wyrzykowski, Ł.[1], Zdanavičius, J.[4], and Zieliński, P.[27]

See ***Gaia19dke***, Extreme Parallax Microlensing Event Maskoliunas et. al. 2024

Discovered: August 2019 by Gaia Science Alerts.
Location: Cygnus constellation.
Duration: 5+ years; exceptionally long.

Data Sources:

- Gaia photometry (191 data).
- Ground-based follow-up: ~ 3000 observations from 30+ telescopes.
- Spectroscopy: Low- and high-resolution spectra (SPRAT, FLOYDS, PEPSI).
- High-resolution imaging: Gemini North with 'Alopeke.



Light curve of Gaia19dke microlensing event with data from *Gaia* and follow-up observations, spanning from JD = 2458062 to JD = 2460062. The black line is the mode of the chains from the MCMC model. The bottom panel shows the residuals with respect to the mode solution.

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https://doi.org/10.1051/0004-6361/202554236

Astronomy & Astrophysics

See AT2021uey
Ban M et. al. 2025

AT2021uey: A planetary microlensing event outside the Galactic bulge

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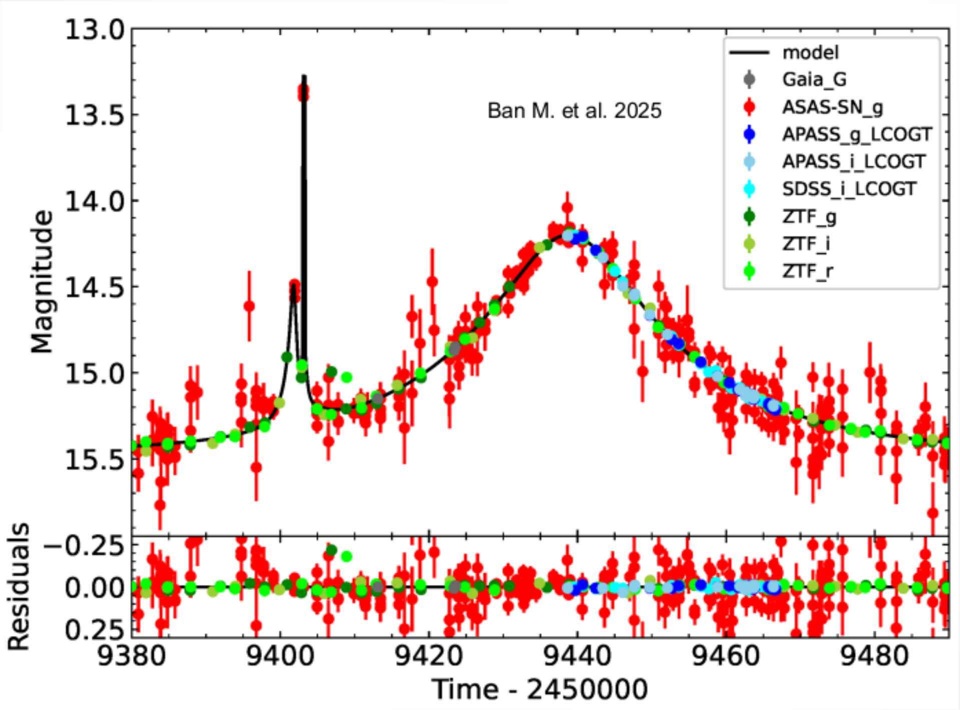
ABSTRACT

We report the analysis of a planetary microlensing event AT2021uey. The event was observed outside the Galactic bulge and alerted both space- (*Gaia*) and ground-based (ZTF and ASAS-SN) surveys. From the observed data, we find that the lens system is located at a distance of ~1 kpc and comprises an M-dwarf host star of about half a solar mass, orbited by a Jupiter-like planet beyond the snowline. The source star could be a metal-poor giant located in the halo according to the spectral analyses and modelling. Hence, AT2021uey is a unique example of the binary-lens event outside the bulge that is offered by a disc-halo lens-source combination.

See AT2021uey
Ban M et. al. 2025

Source star:
Type: metal-poor giant star
(halo population)

Lens system:
Type: M-dwarf star
Mass: ~ 0.49 +0.16/−0.18 $M_{\odot}$
Distance: ~1.04 kpc
Planet Jupiter-mass, beyond snow line



Ban M. et al. (2025), A&A 697, A57 offers a strong example: Photometric data and fitted light curve of the planetary microlensing event *AT2021uey*. The event was observed outside the Galactic bulge and alerted both space (*Gaia; Gaia Collaboration 2016)* and ground-based (*ZTF; Bellm et al. 2019; Masci et al. 2019* & *ASAS-SN; Shappee et al. 2014)* surveys.

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THE FOUNDATION

EASST - who are we?

European Astronomical Society of Small Telescopes is a non-profit organisation based in Poland. It was founded in 2025 by prof. Łukasz Wyrzykowski, an astrophysicist at the Astronomical Observatory of the University of Warsaw and the National Centre for Nuclear Research.

Our mission

EASST is dedicated to bringing astronomy closer to people. Our mission is to inspire a broad audience to explore the universe and actively participate in global research.

SUMMARY

-European Astronomical Society of Small Telescopes (EASST)

❑Non-profit organisation dedicated to bringing astronomy closer to people. Our mission is to inspire a broad audience to explore the universe and actively participate in global research.

-Black Hole Target Observation Manager (BHTOM)

❑Unique citizen science platform that connects professional and amateur astronomers. BHTOM empowers the international astronomical community to collaborate, plan observations, and exchange knowledge.

-With contributions from nearly 130 telescopes worldwide, many operated by amateur observers, BHTOM facilitates coordinated observations, automated data processing, and collaboration across the global astronomical community. The following microlensing events were investigated:

❑*Gaia16aye, Gaia18cbf, Gaia19bld, Gaia19dke, and rare planetary AT2021uey Lb discovery.*

Join us!

TEAM

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Marius Maskoliūnas

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RCL
Research Council of Lithuania

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Thank you for your attention

Nordic-Baltic Astronomy Days, Turku, Finland May 26-29, 2026