

# HOW TO HELP GAIA SPACE MISSION FIND BLACK HOLES



**Łukasz Wyrzykowski**  
(*pron. Woo-cash Vi-zhi-kov-ski*)



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University of Warsaw, Poland**



[GAIA.ASTROUW.EDU.PL](http://GAIA.ASTROUW.EDU.PL)

[BHTOM.SPACE](http://BHTOM.SPACE)

RAPAS

25.November 2023



LW

[@ASTROUW.EDU.PL](mailto:LW@ASTROUW.EDU.PL)

# TEAM

<https://gaia.astrow.edu.pl>



Warsaw University Astronomical Observatory



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(postdoc)



Milena Ratajczak  
(postdoc)



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University

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Kornel Howil  
(BSc student)



Uliana Pylypenko  
(MSc student)



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UNIVERSITY

Zofia Kaczmarek  
(PhD student)

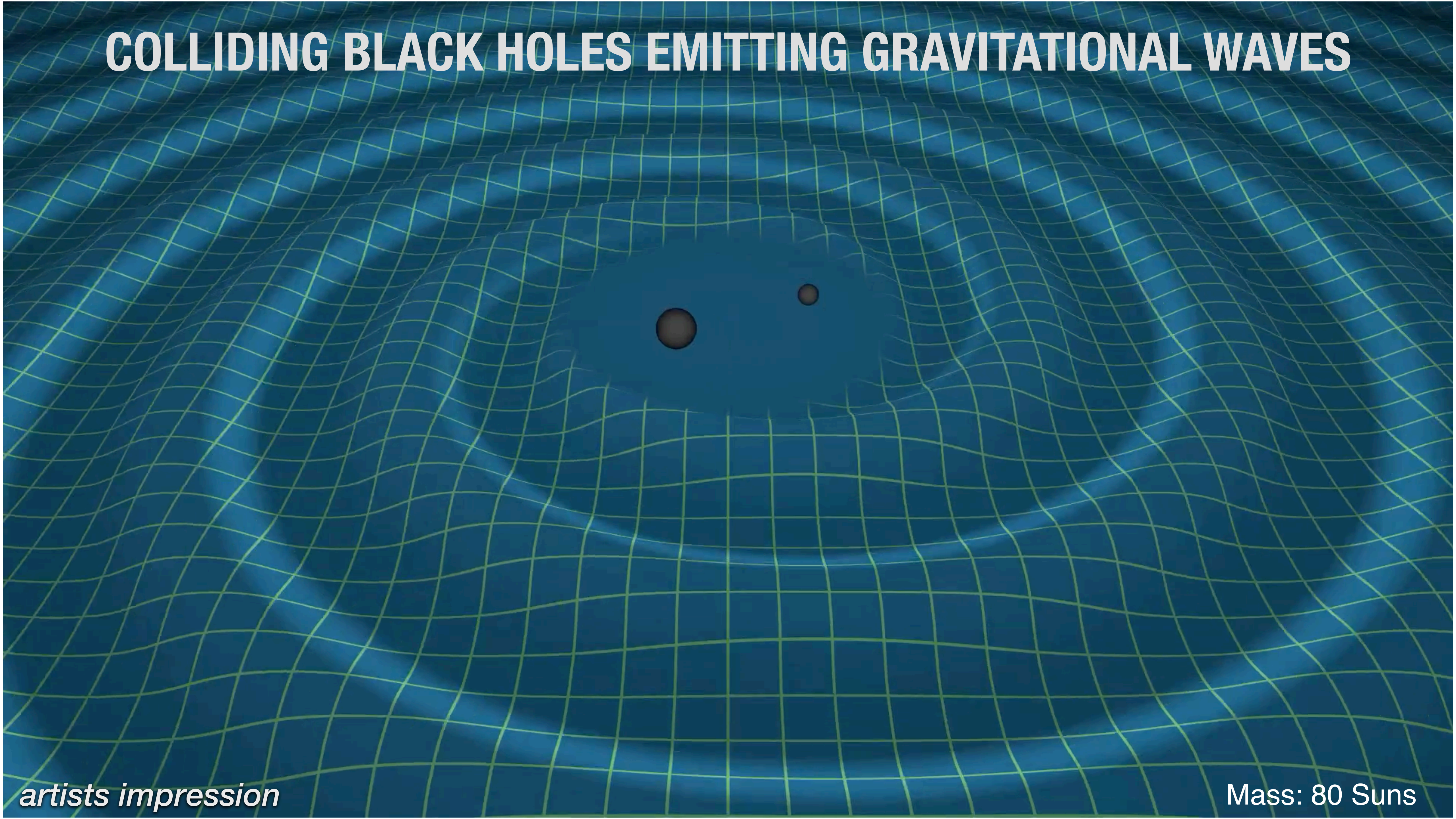
Former contributors: Maja Jabłońska, Piotr Trzcionkowski, Kacper Raciborski



Funding:



# COLLIDING BLACK HOLES EMITTING GRAVITATIONAL WAVES

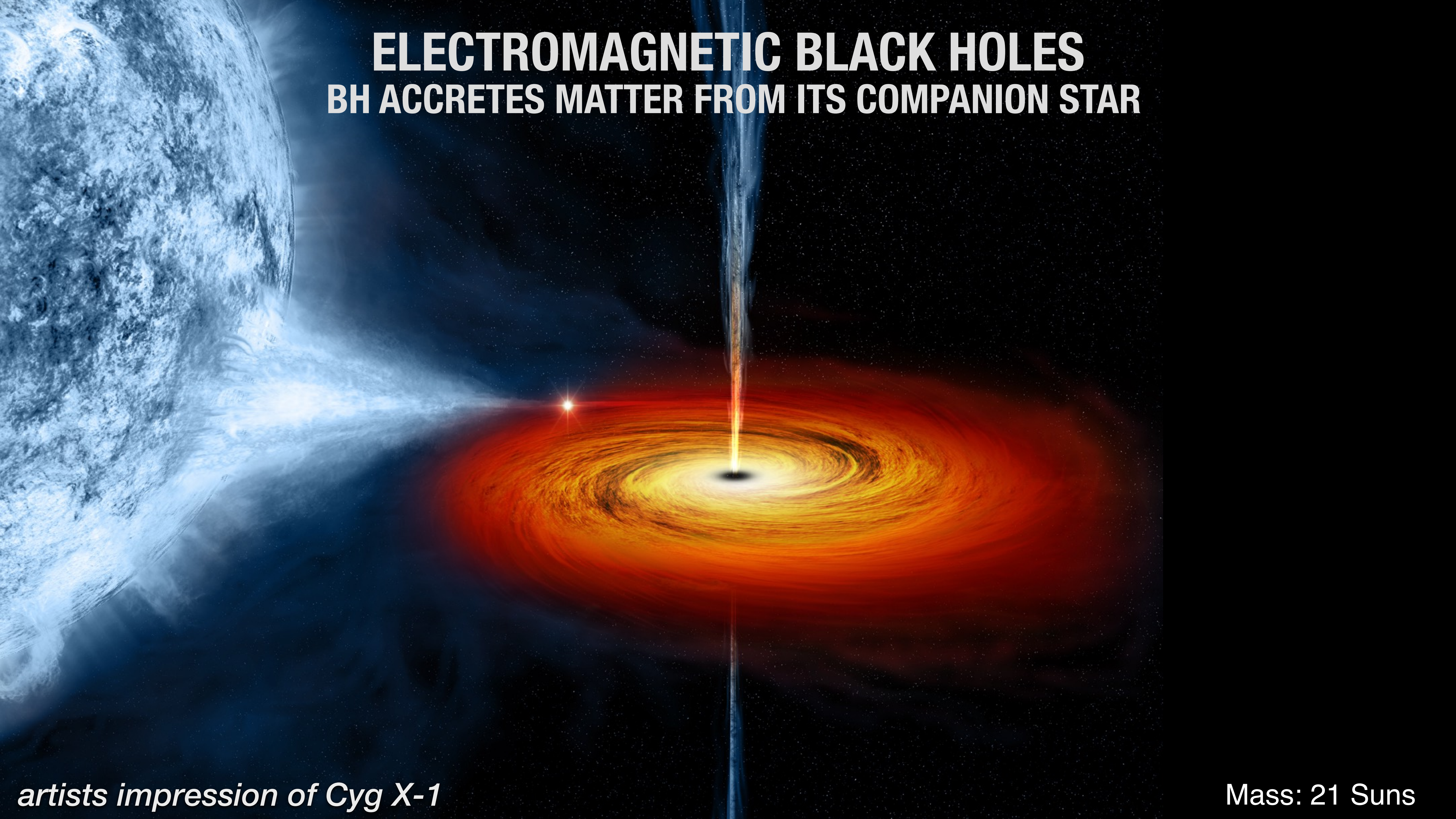


*artists impression*

Mass: 80 Suns

# ELECTROMAGNETIC BLACK HOLES

## BH ACCRETES MATTER FROM ITS COMPANION STAR



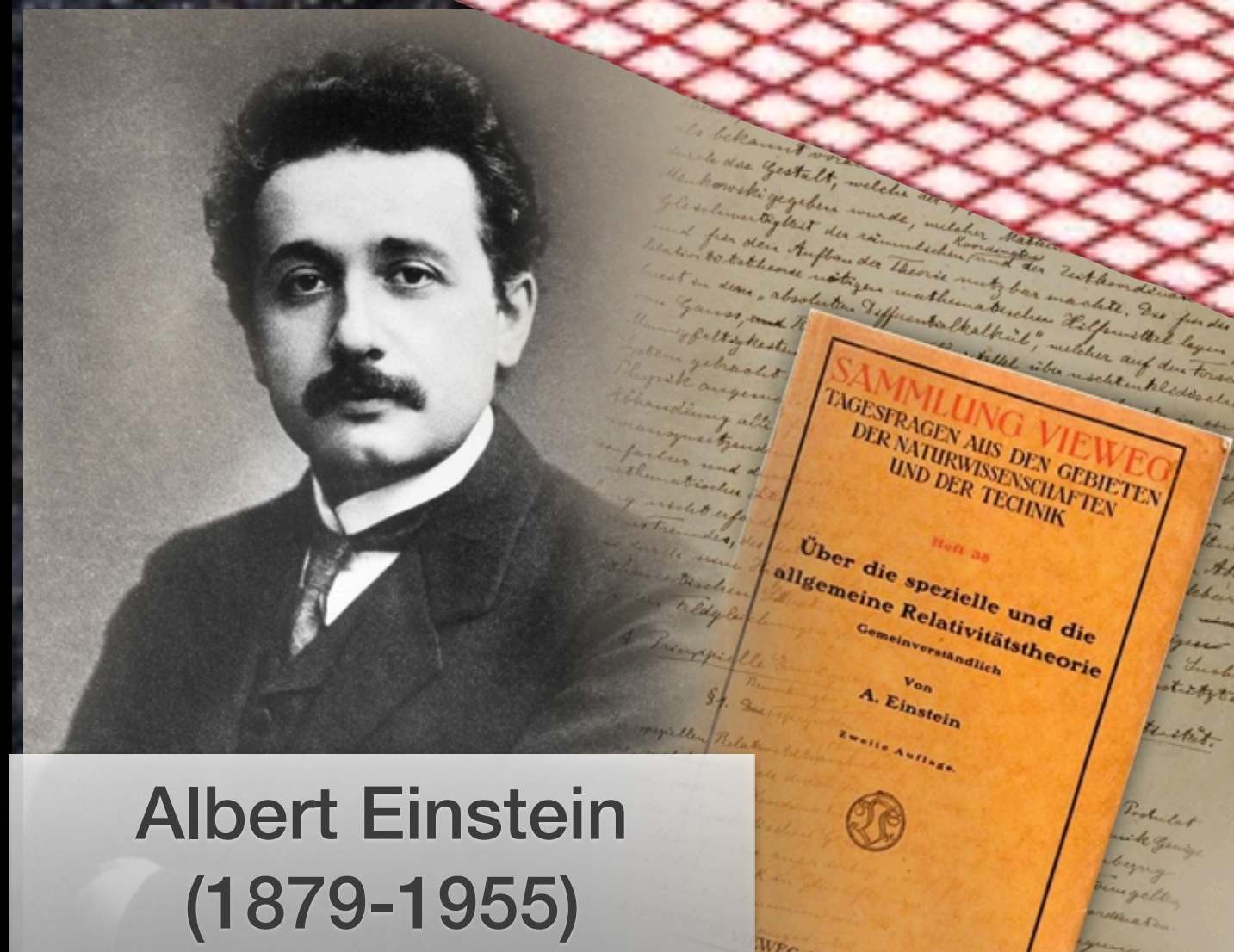
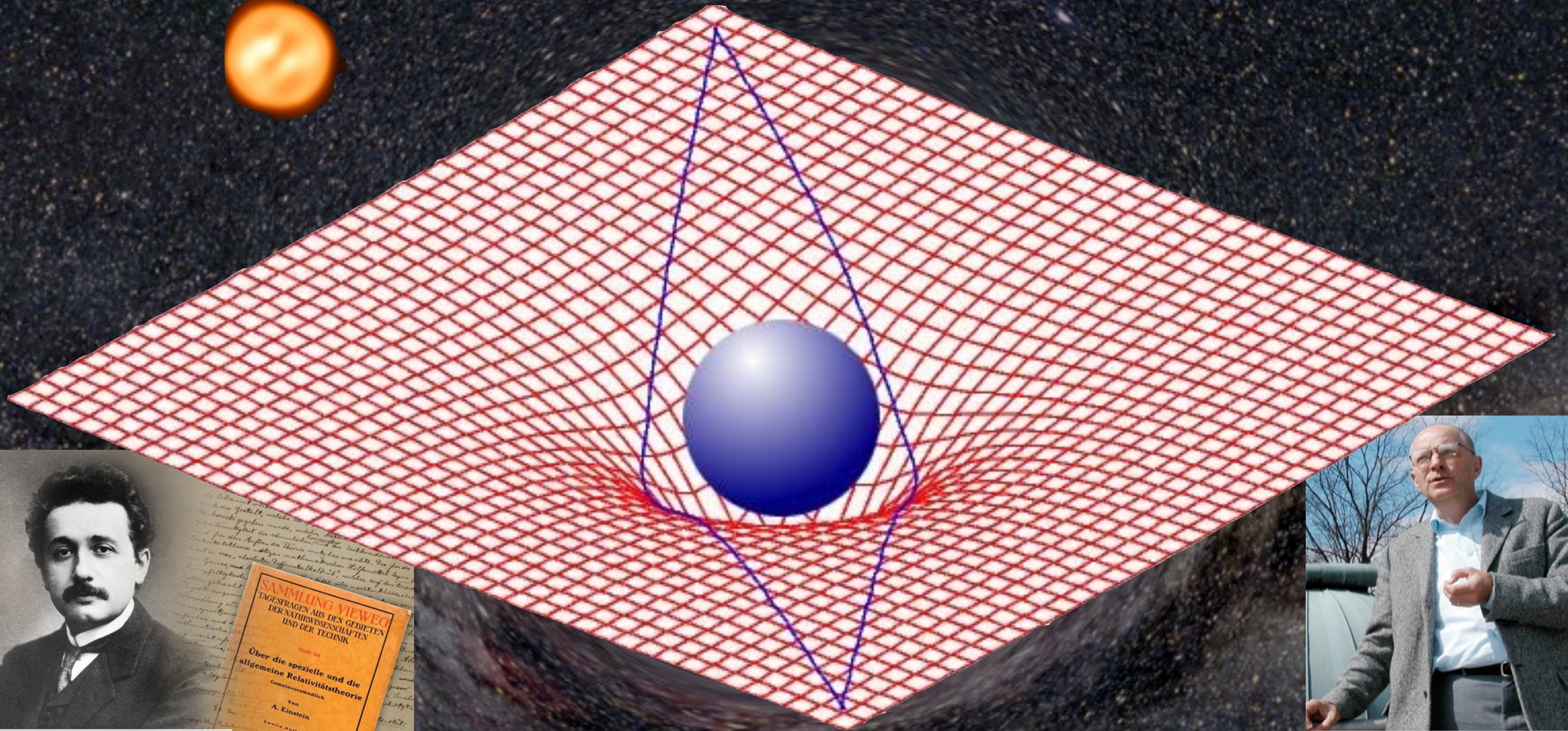
*artists impression of Cyg X-1*

Mass: 21 Suns

*real data*

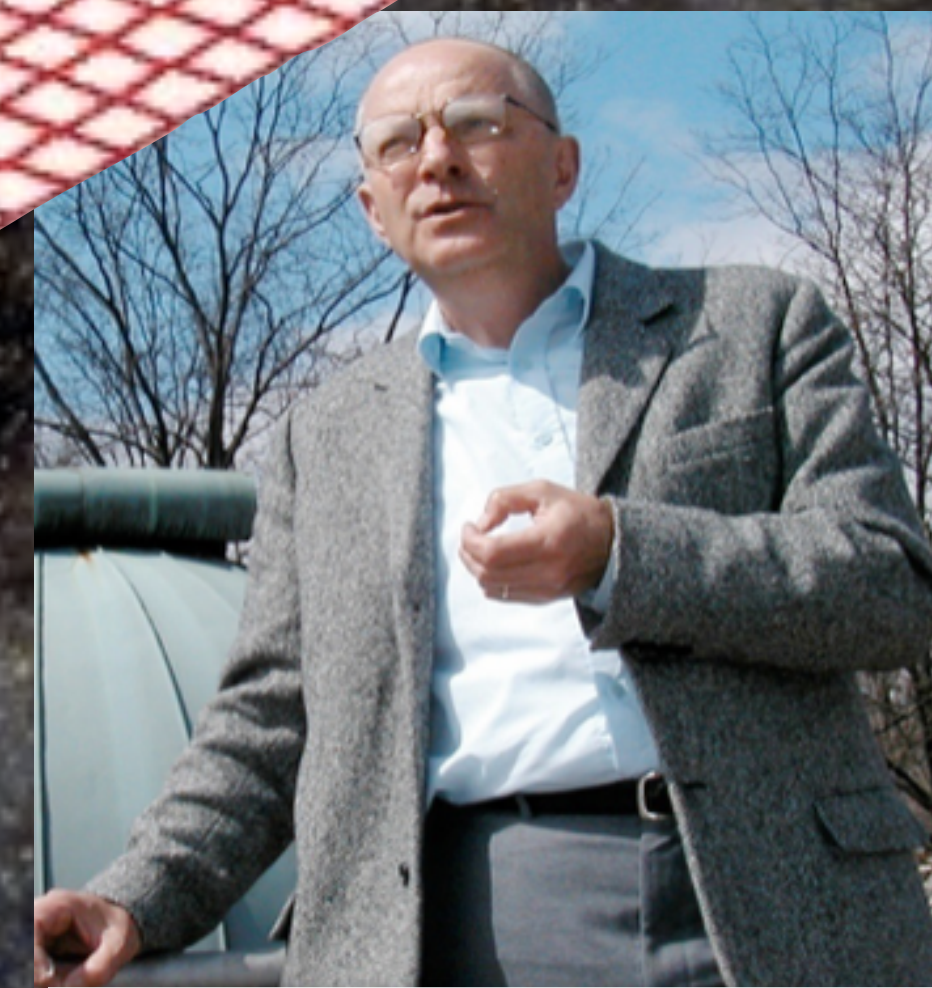
Mass: 7 Suns

# GRAVITATIONAL MICROLENSING



Albert Einstein  
(1879-1955)

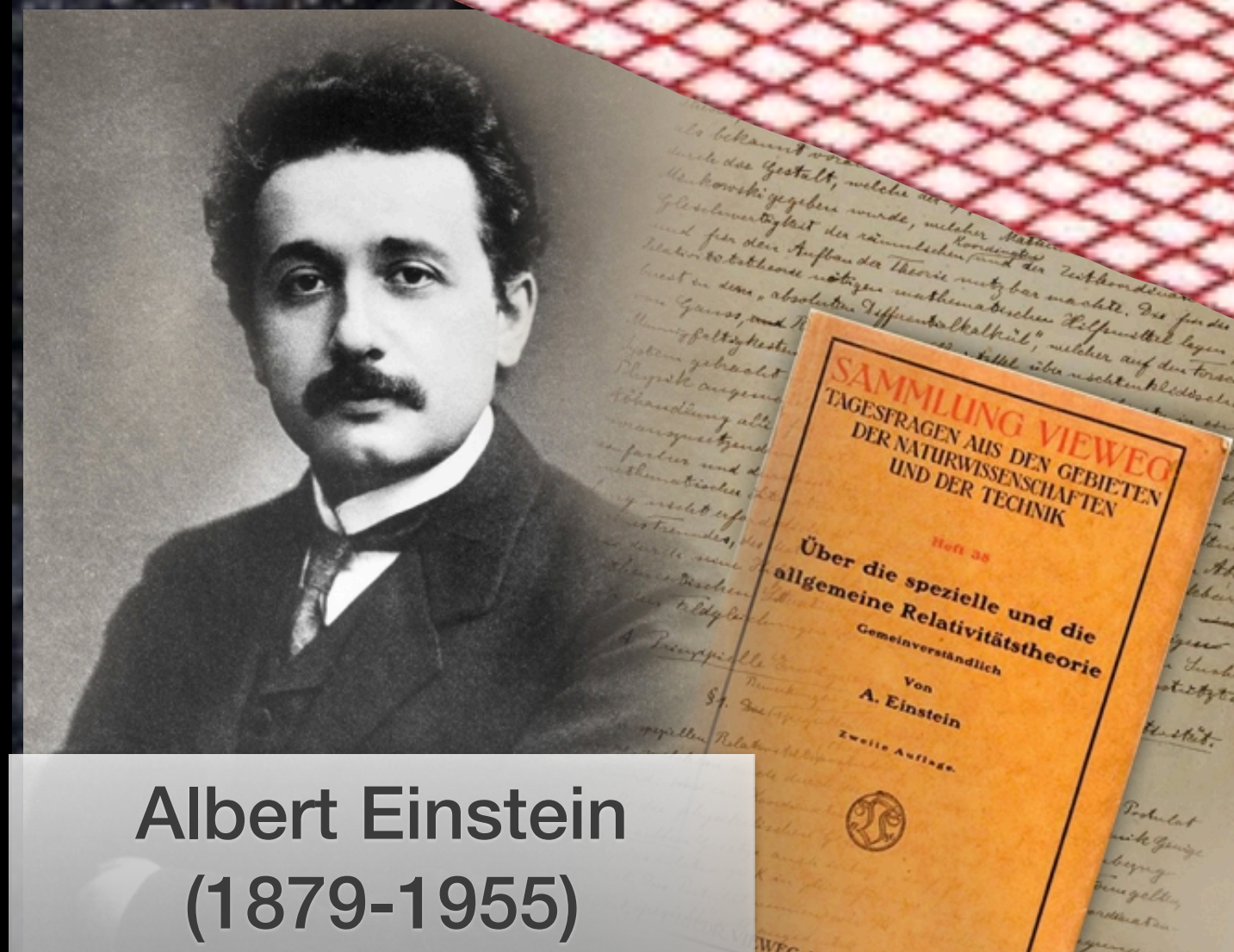
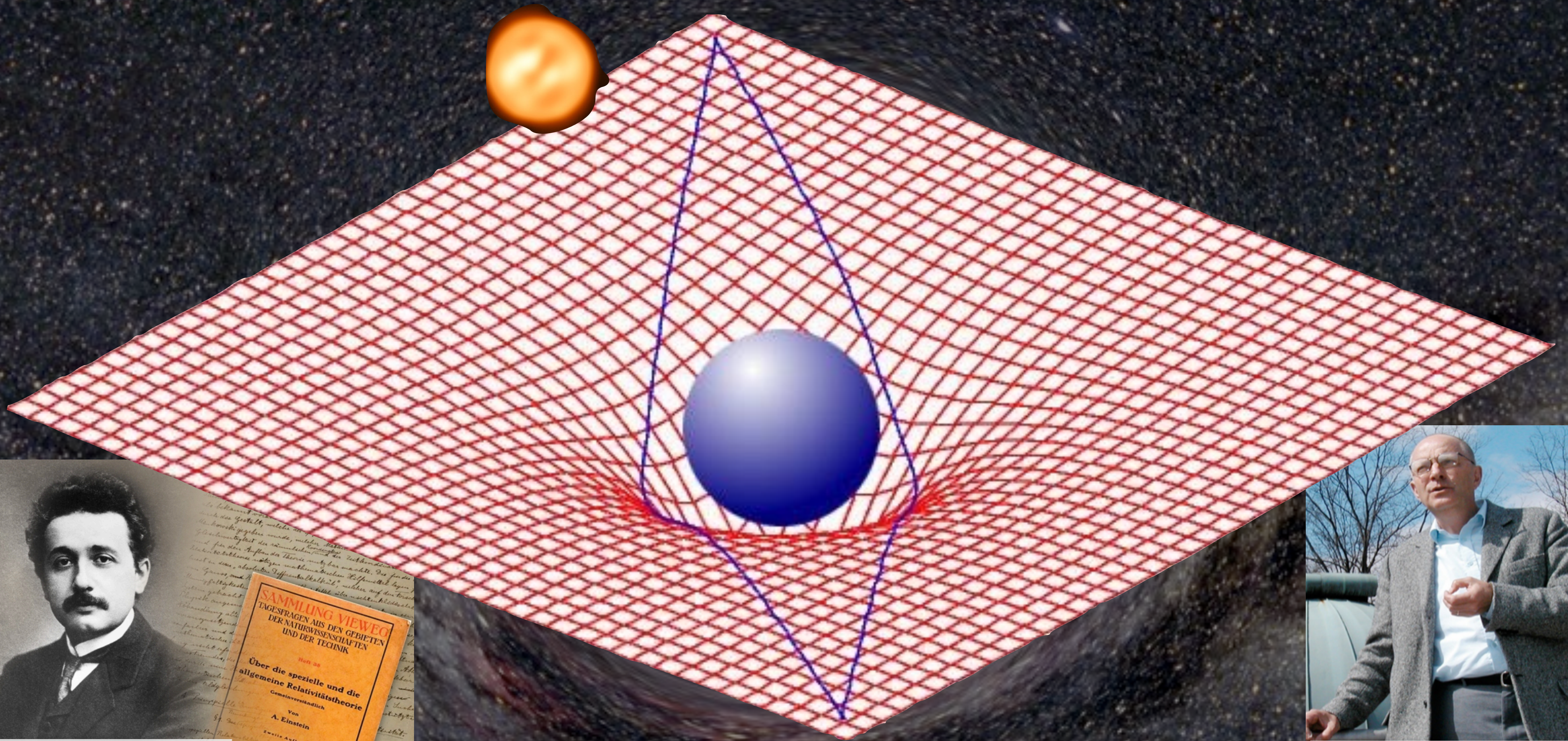
1915



Bohdan Paczyński  
(1940—2007)

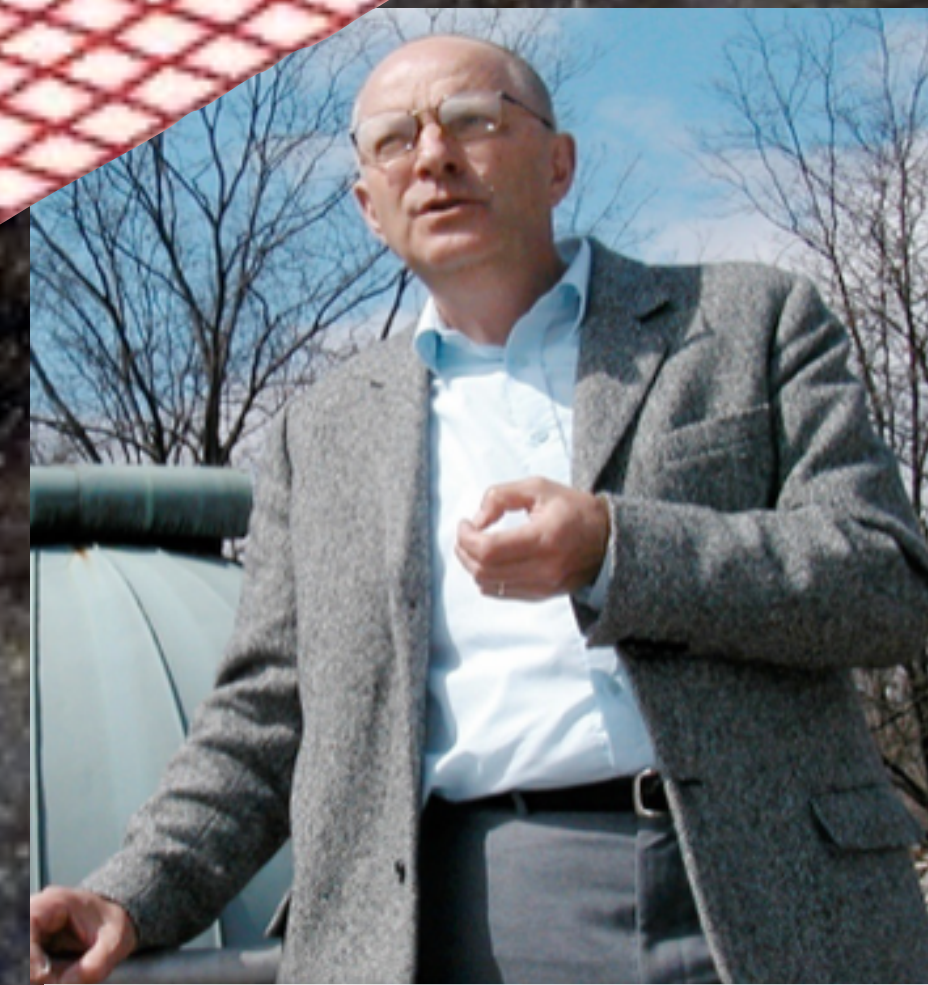
1986

# GRAVITATIONAL MICROLENSING



Albert Einstein  
(1879-1955)

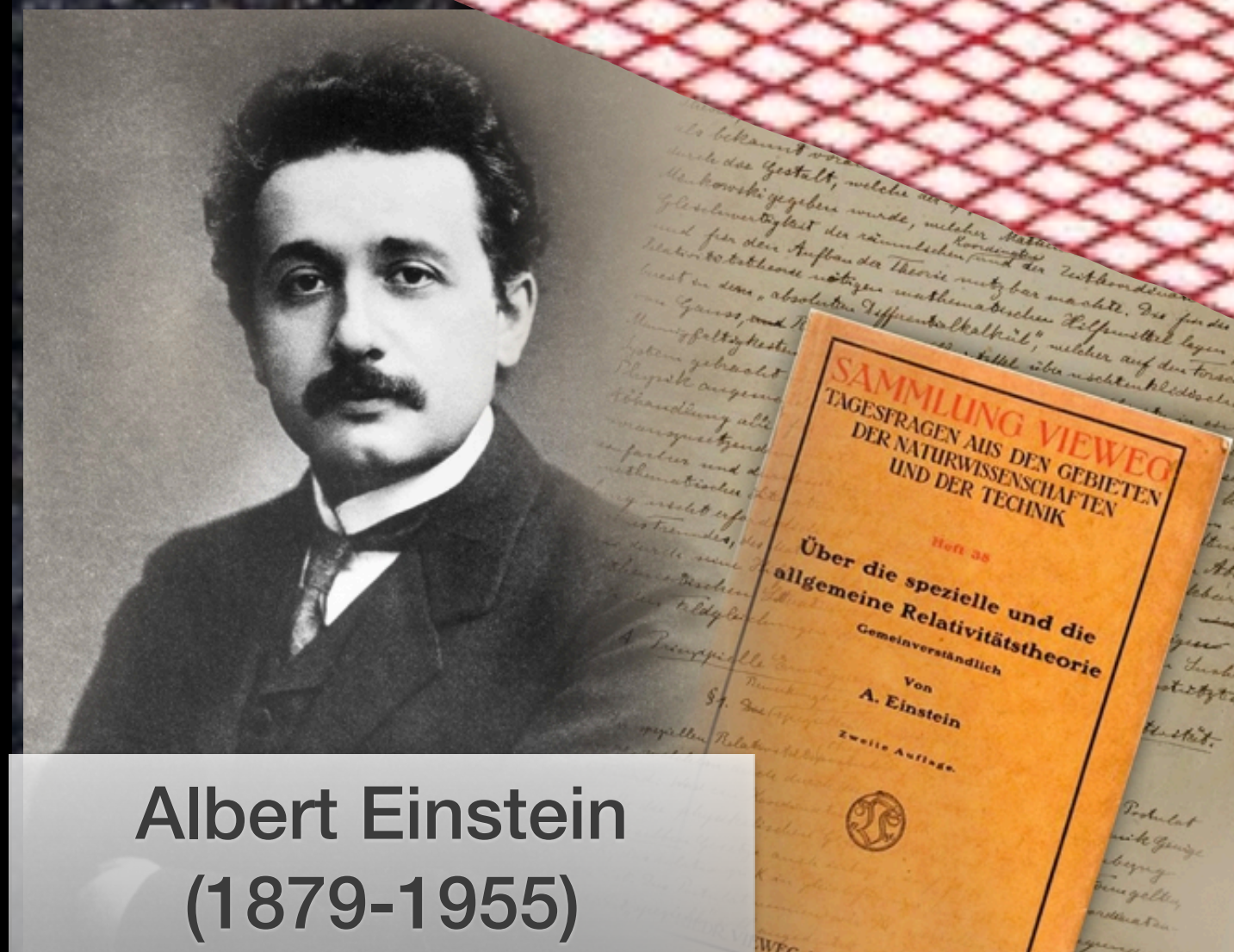
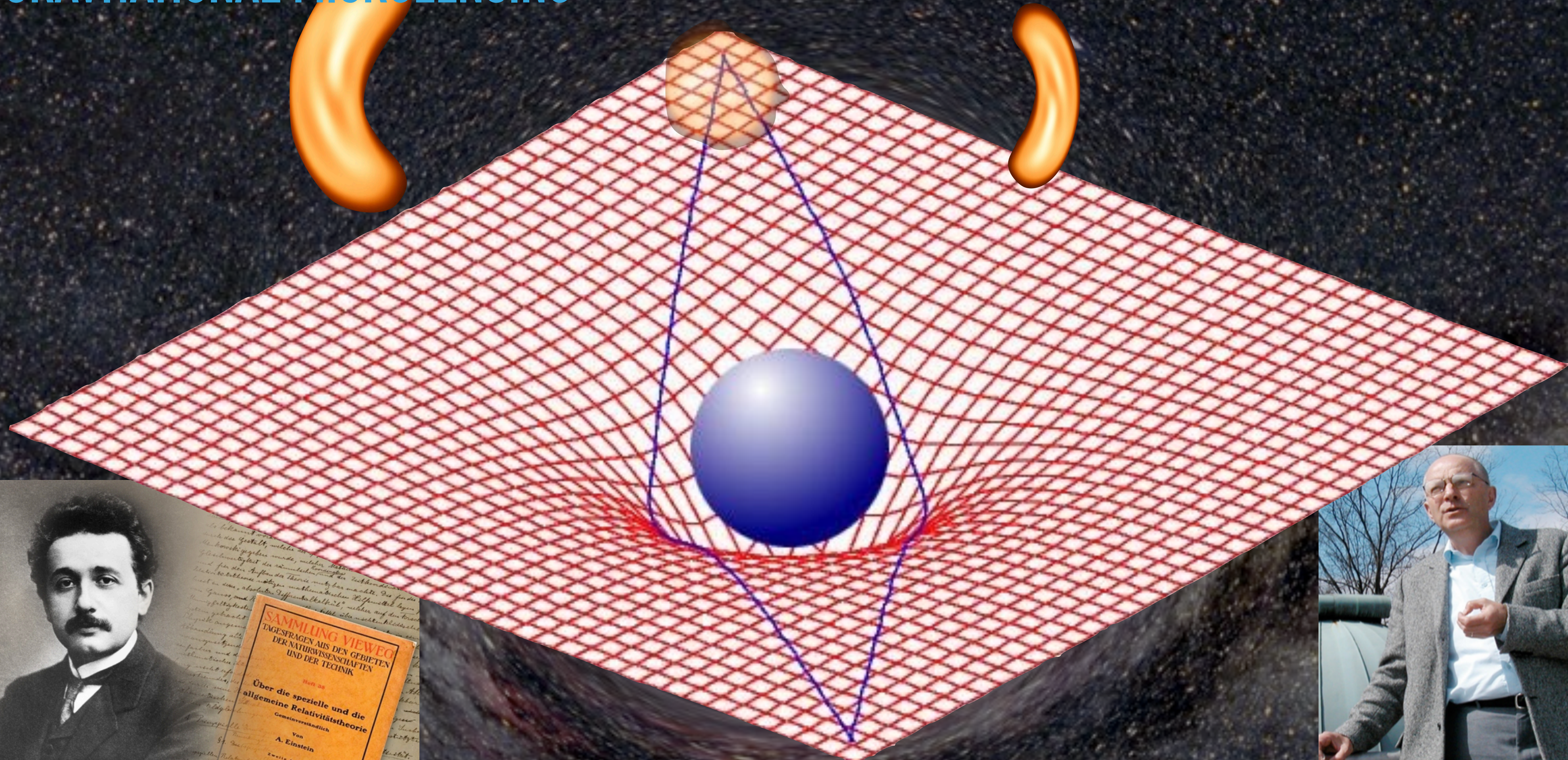
1915



Bohdan Paczyński  
(1940—2007)

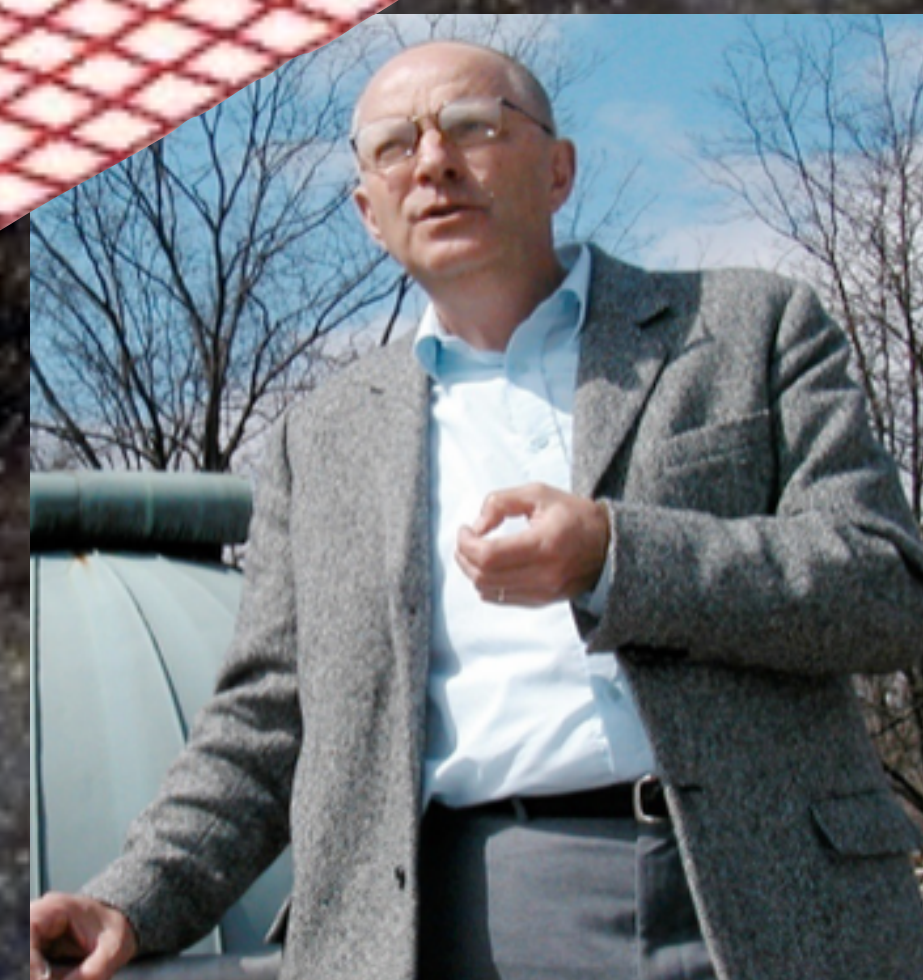
1986

# GRAVITATIONAL MICROLENSING



Albert Einstein  
(1879-1955)

1915

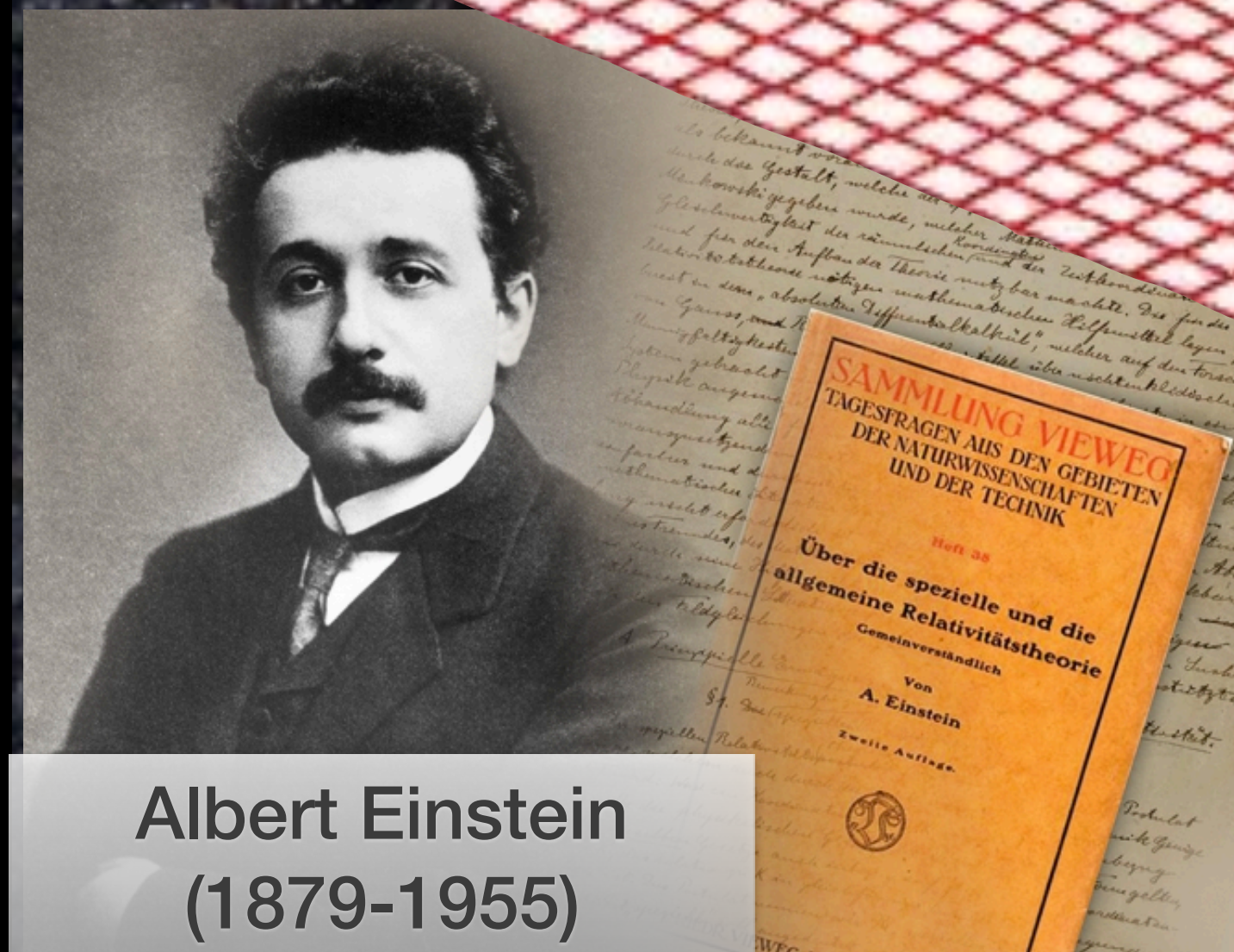
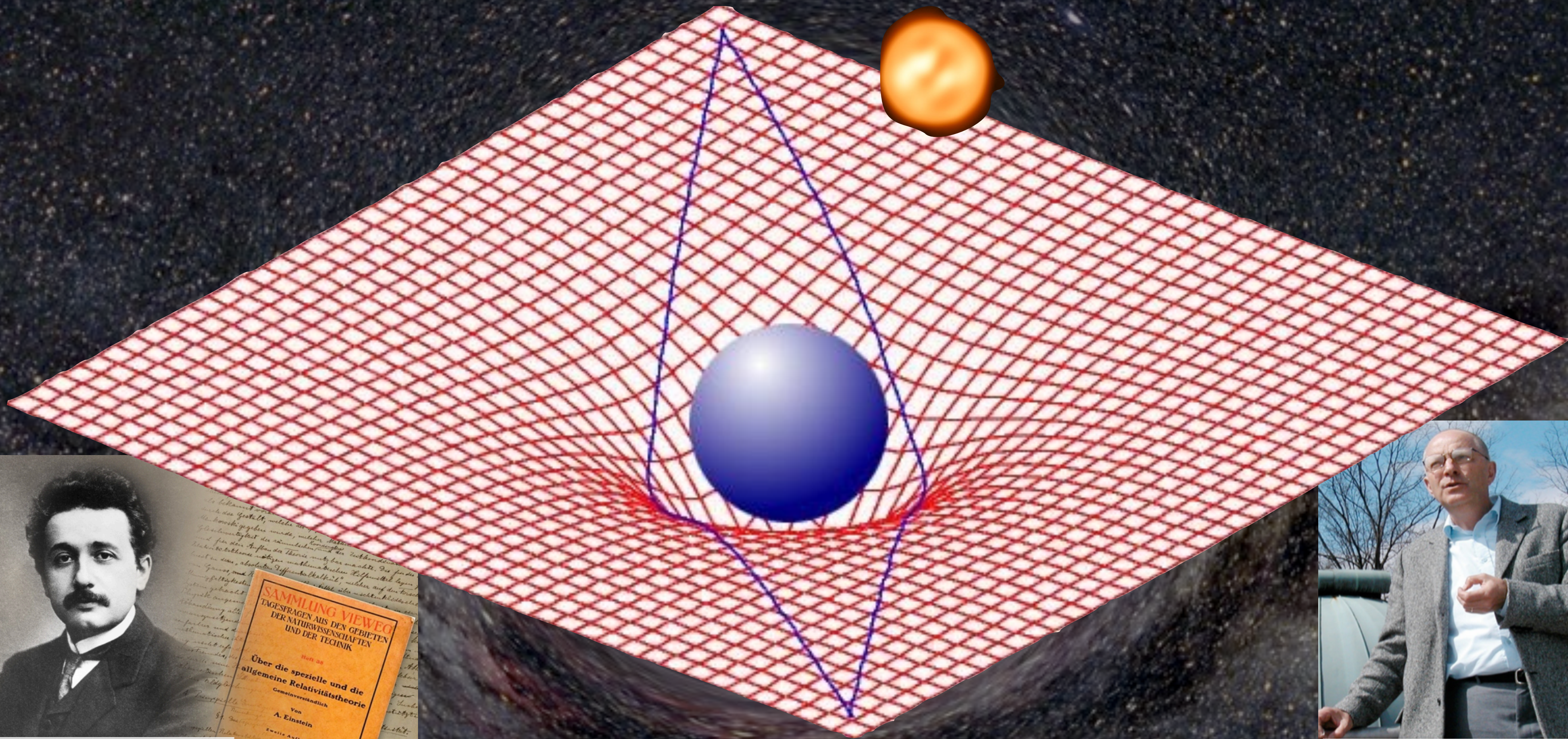


Bohdan Paczyński  
(1940—2007)

1986



# GRAVITATIONAL MICROLENSING

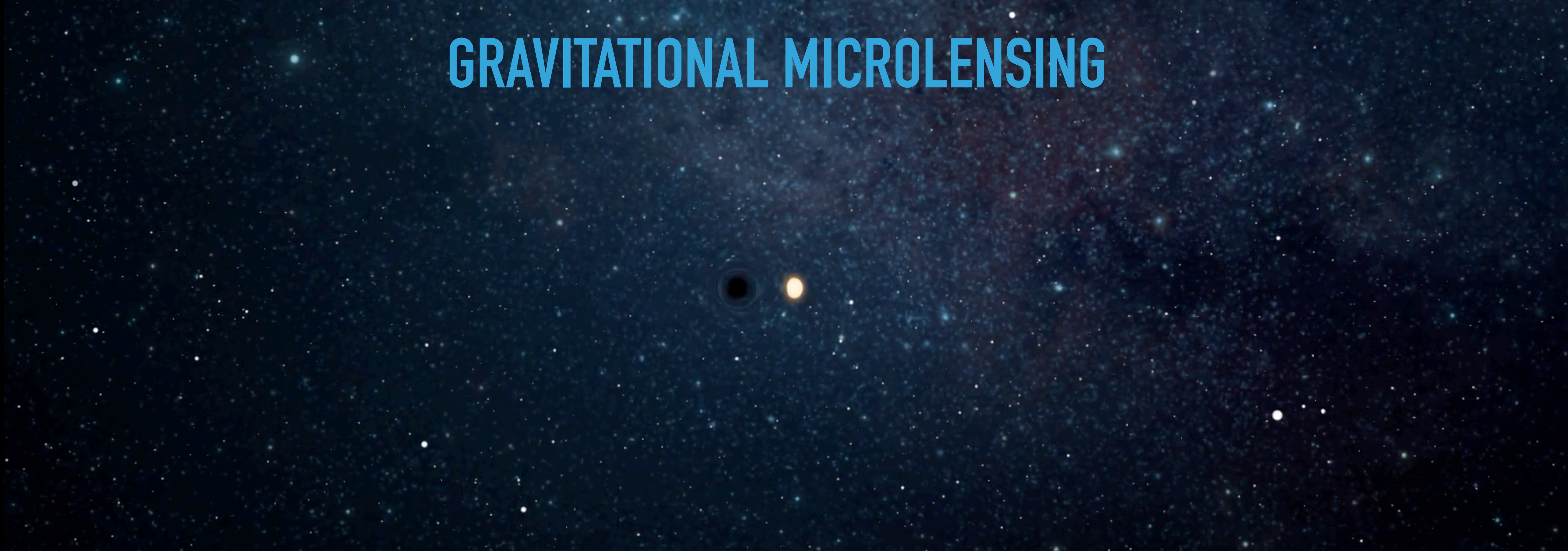


1915

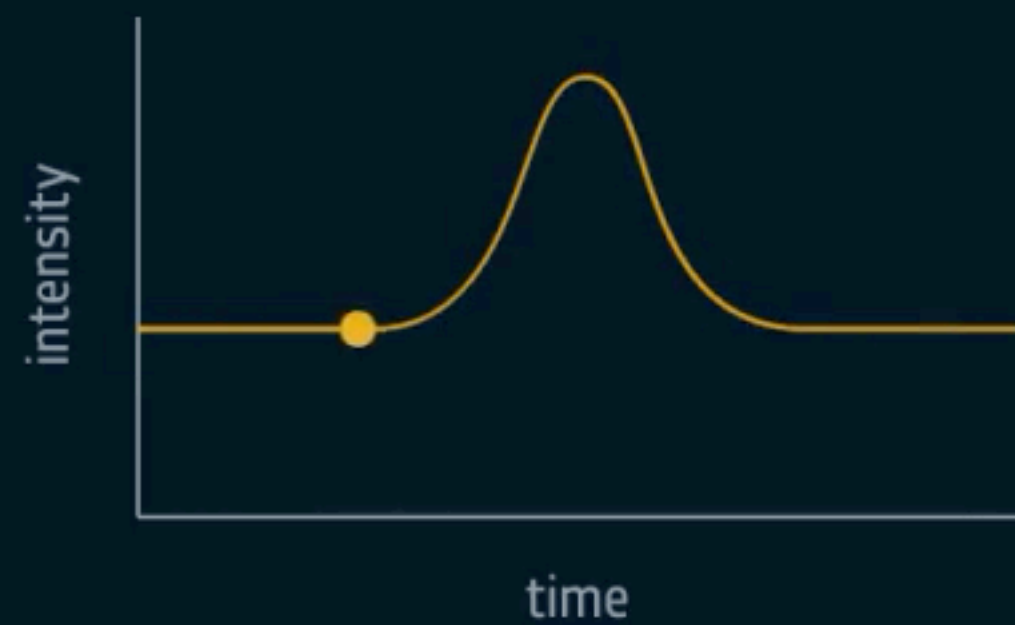


1986

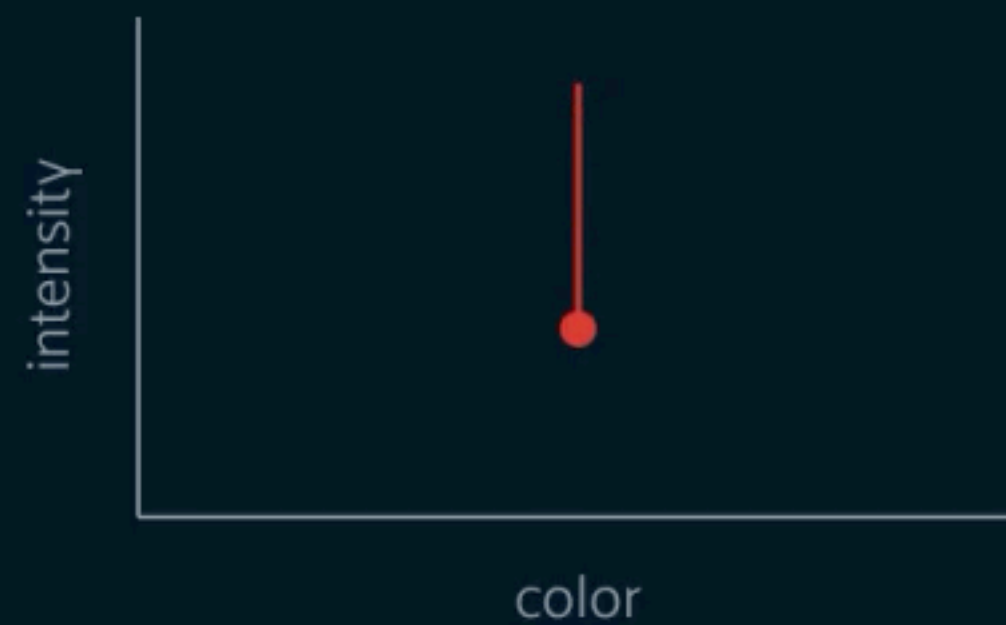
# GRAVITATIONAL MICROLENSING



**Light intensity**



**Color/Intensity**



**Radial velocity**



**See from afar**



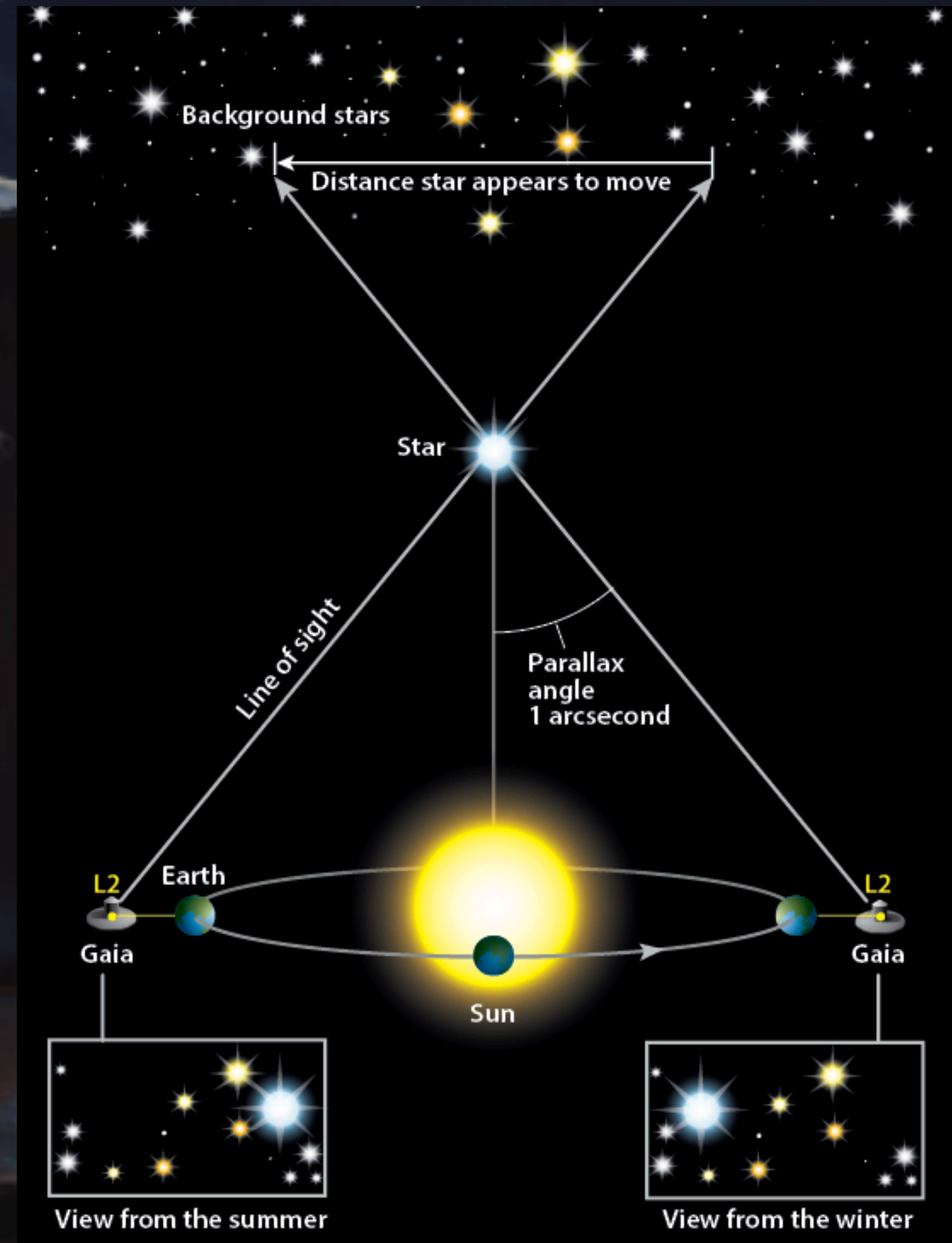
# GAIA SPACE MISSION



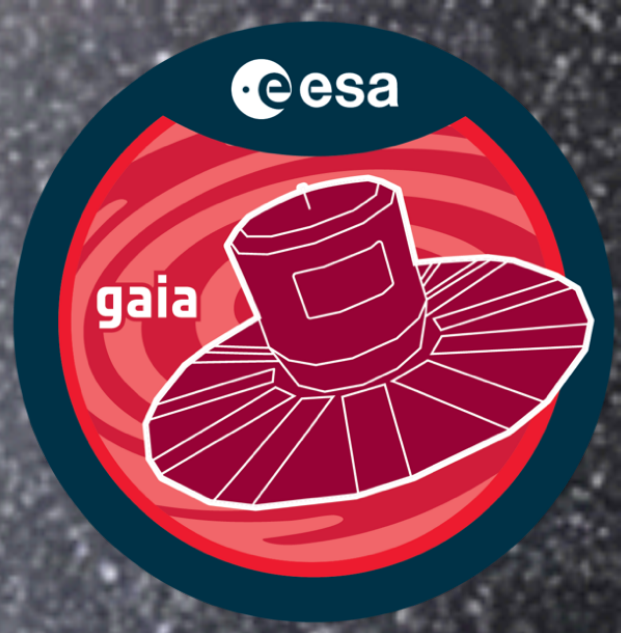
# GAIA SPACE MISSION



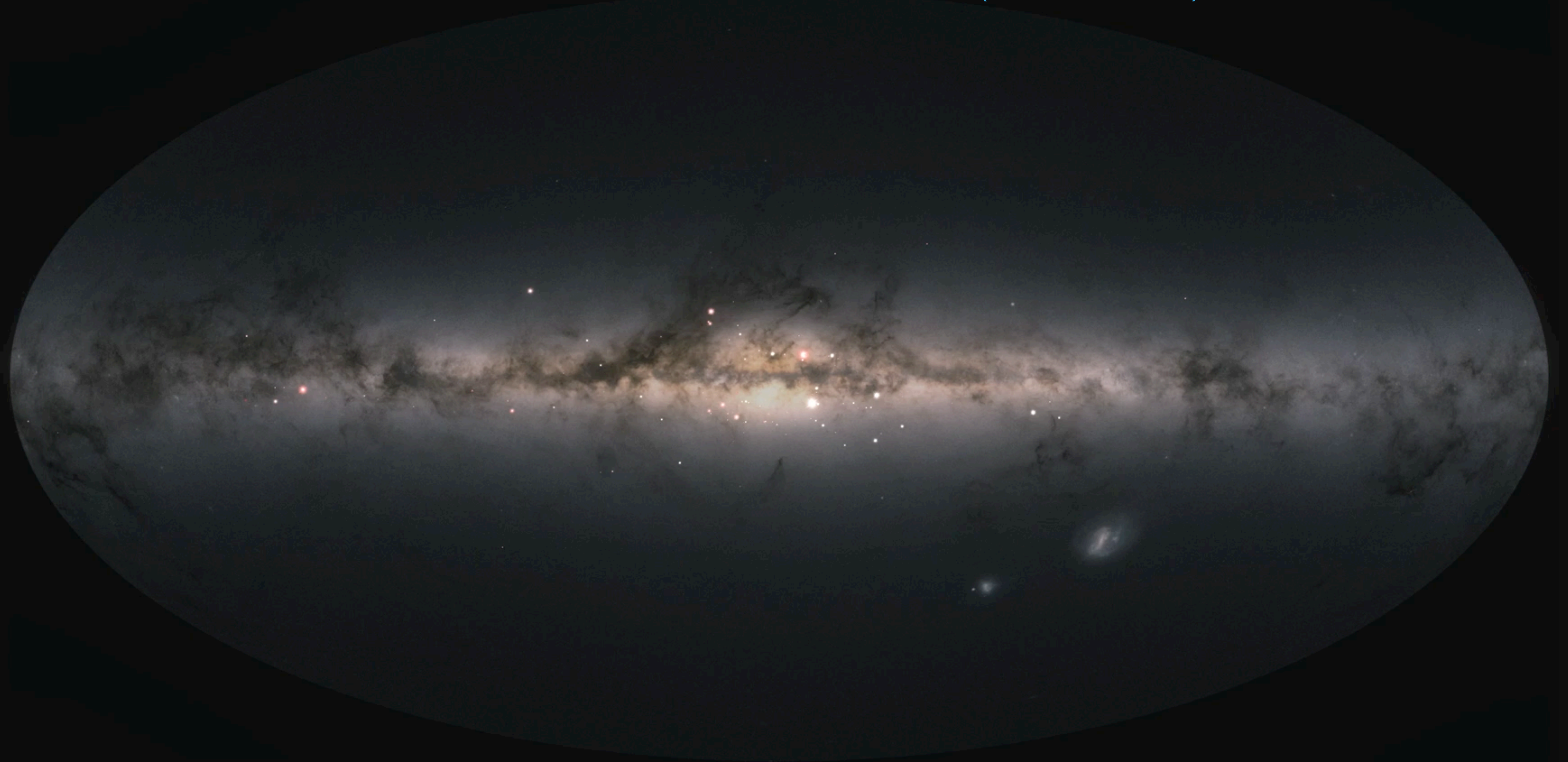
- ▶ ESA mission
- ▶ launched in 2013 (planned to operate until 2025)
- ▶ located in L2
- ▶ 10m in diameter
- ▶ two 1.4m mirrors
- ▶ depth:  $G \sim 20.5 \text{ mag}$
- ▶ 2 billion sources
- ▶ Photometry, astrometry and spectroscopy
- ▶ Data published through Gaia Data Releases (DR3: June 2022, DR4: ~2025)



# GAIA SPACE MISSION



# GAIA MICROLENSING EVENTS (2014-2018)



# BHTOM TELESCOPE NETWORK ▶ since 2013, built for Gaia Alerts



 UP TO 1.0 m (53)  1.0-2.0 m (21)  2.0+ m (5) 80 OPTICAL | 3 INFRARED

# BHTOM TELESCOPE NETWORK

▶ since 2013, built for Gaia Alerts

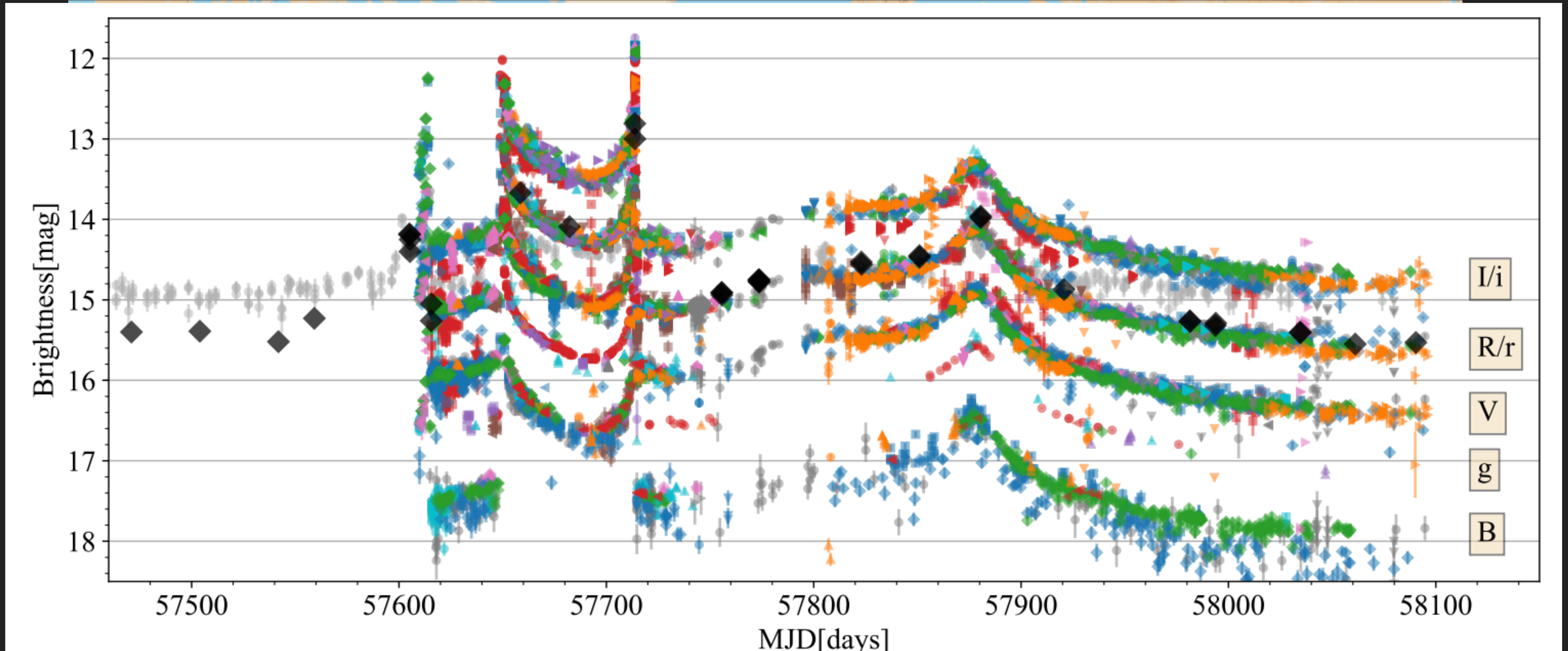


UP TO 1.0 m (53) 1.0-2.0 m (21) 2.0+ m (5) 80 OPTICAL | 3 INFRARED



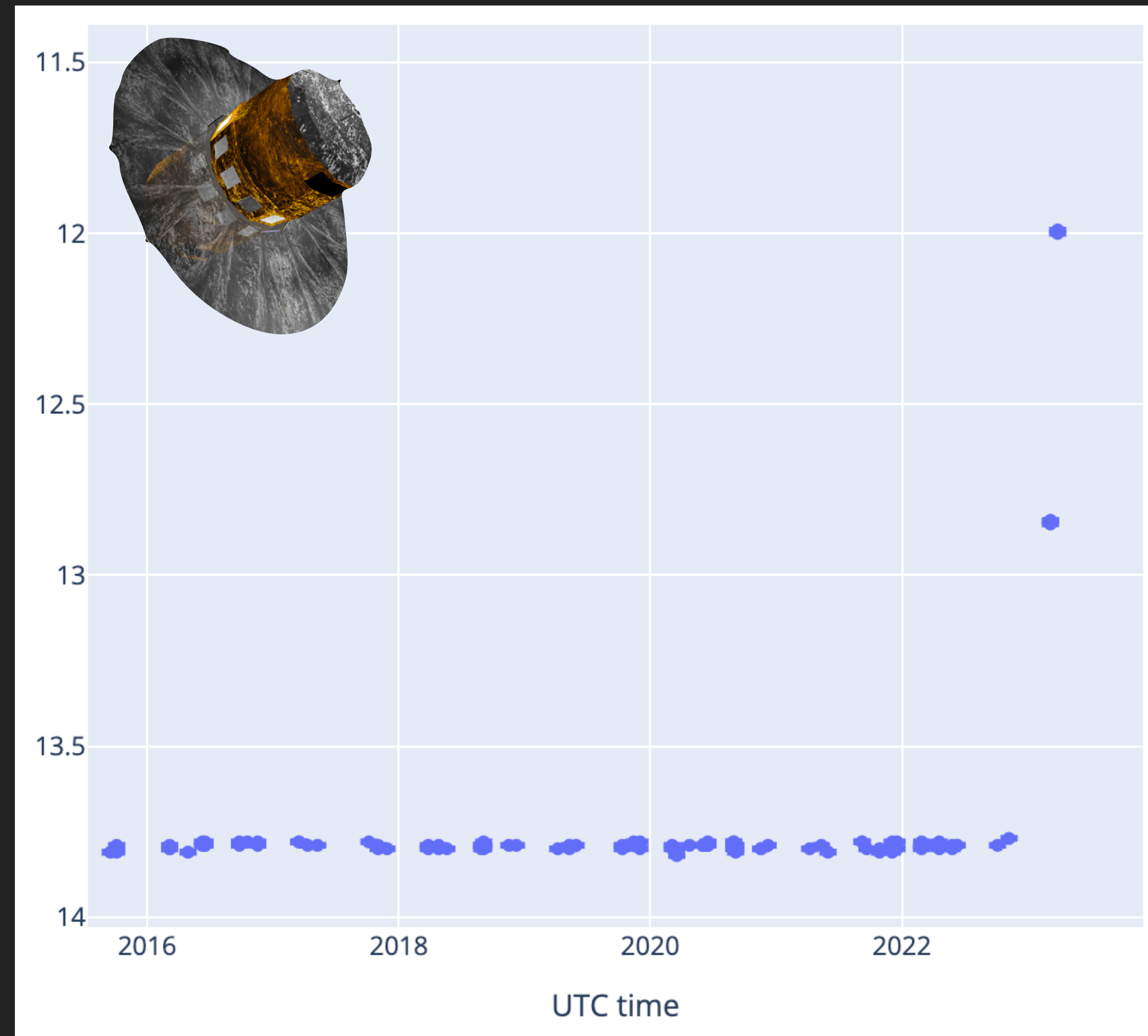
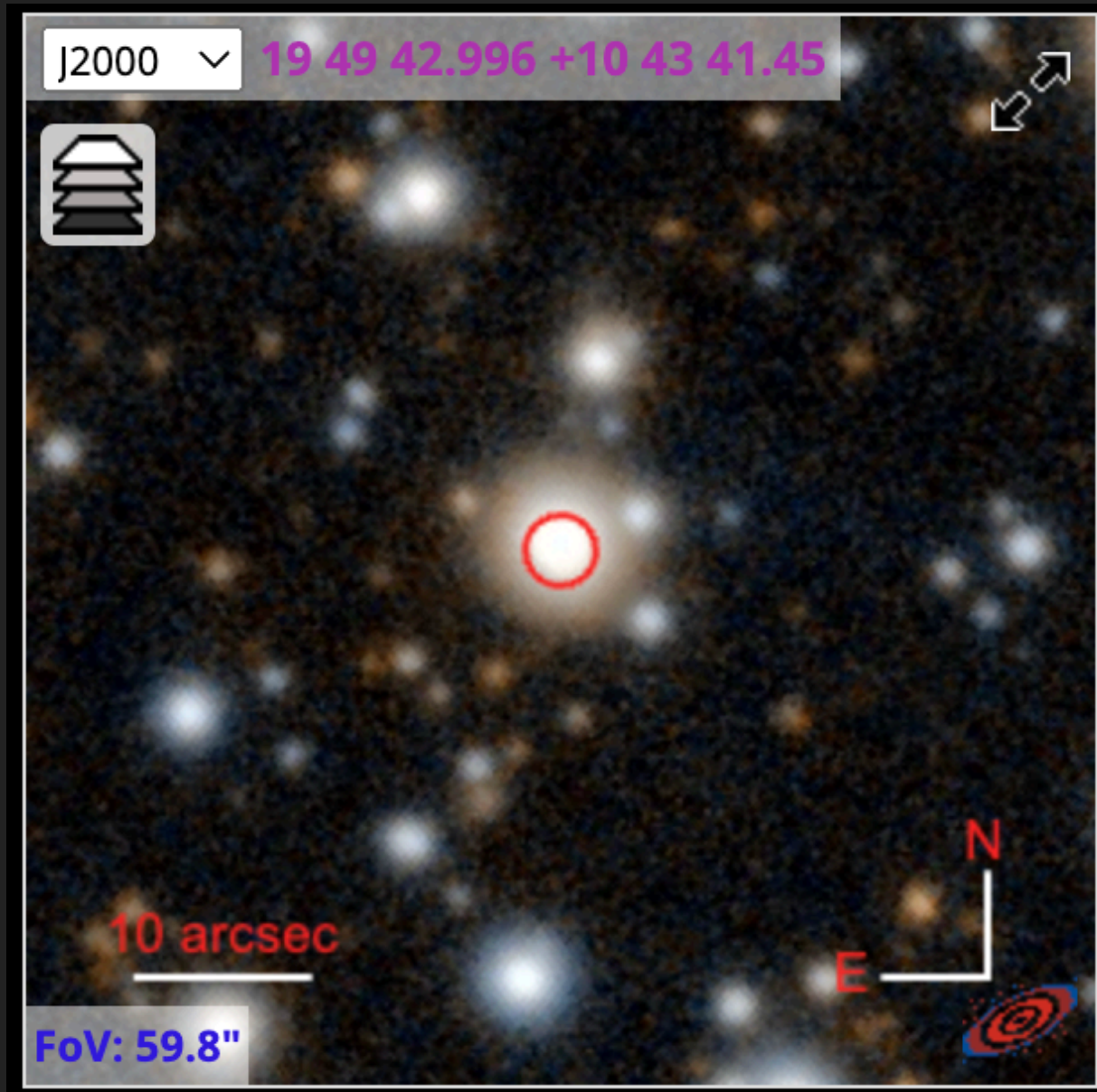
# BHTOM TELESCOPE NETWORK

▶ since 2013, built for Gaia Alerts

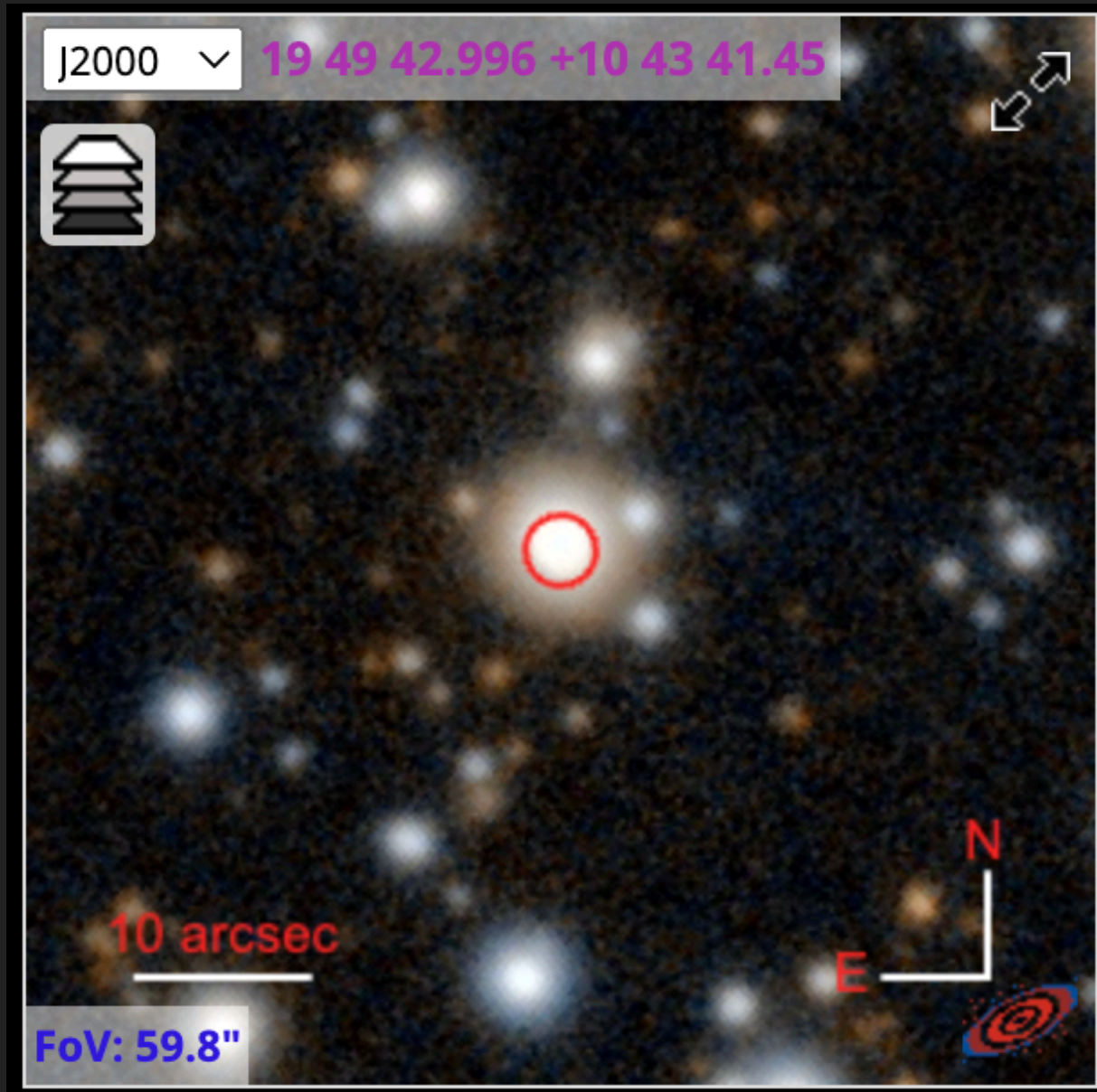


UP TO 1.0 m (53) 1.0-2.0 m (21) 2.0+ m (5) 80 OPTICAL | 3 INFRARED

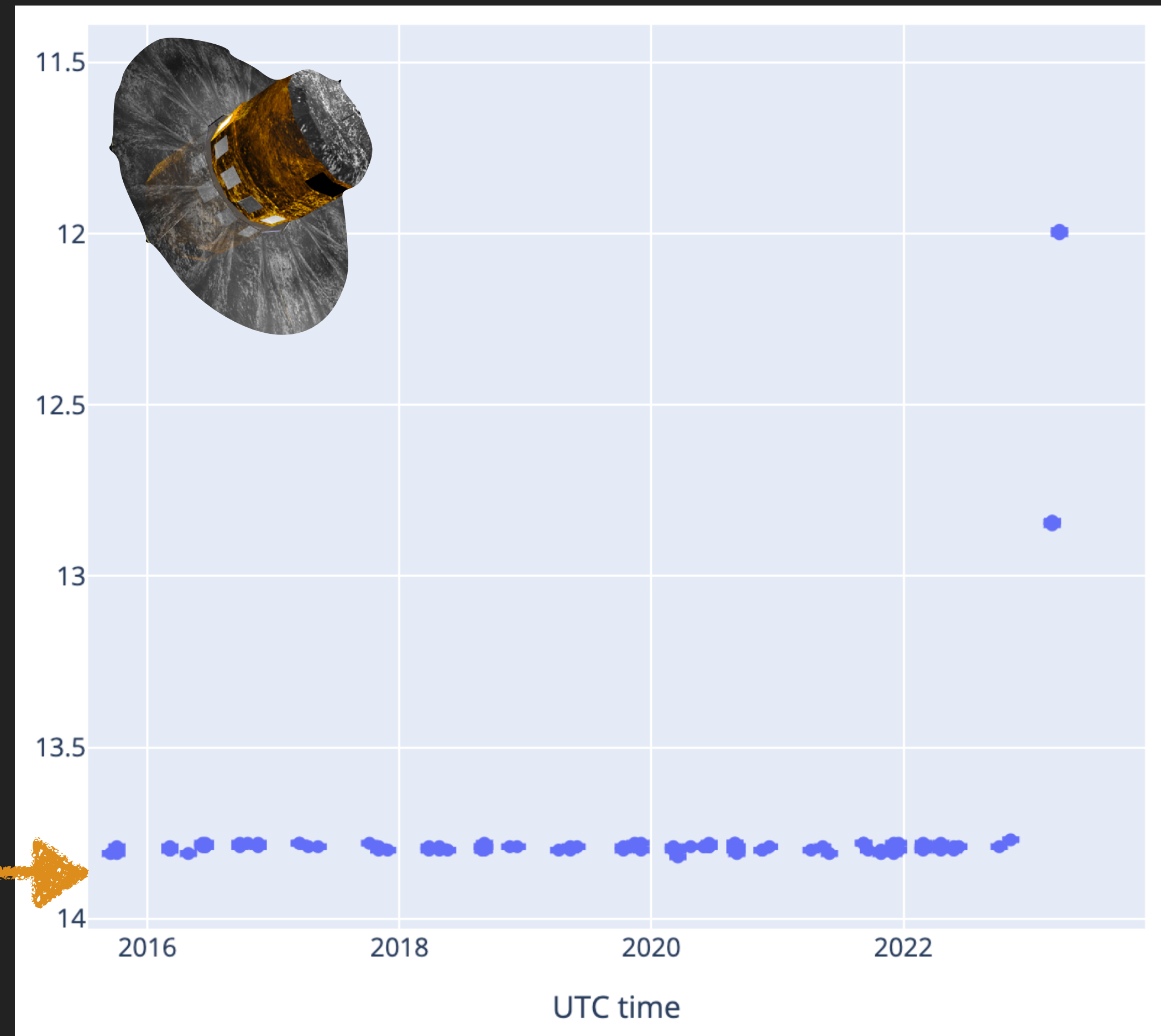
# GAIA23BAY ▶ Example bright alert in the Eagle constellation



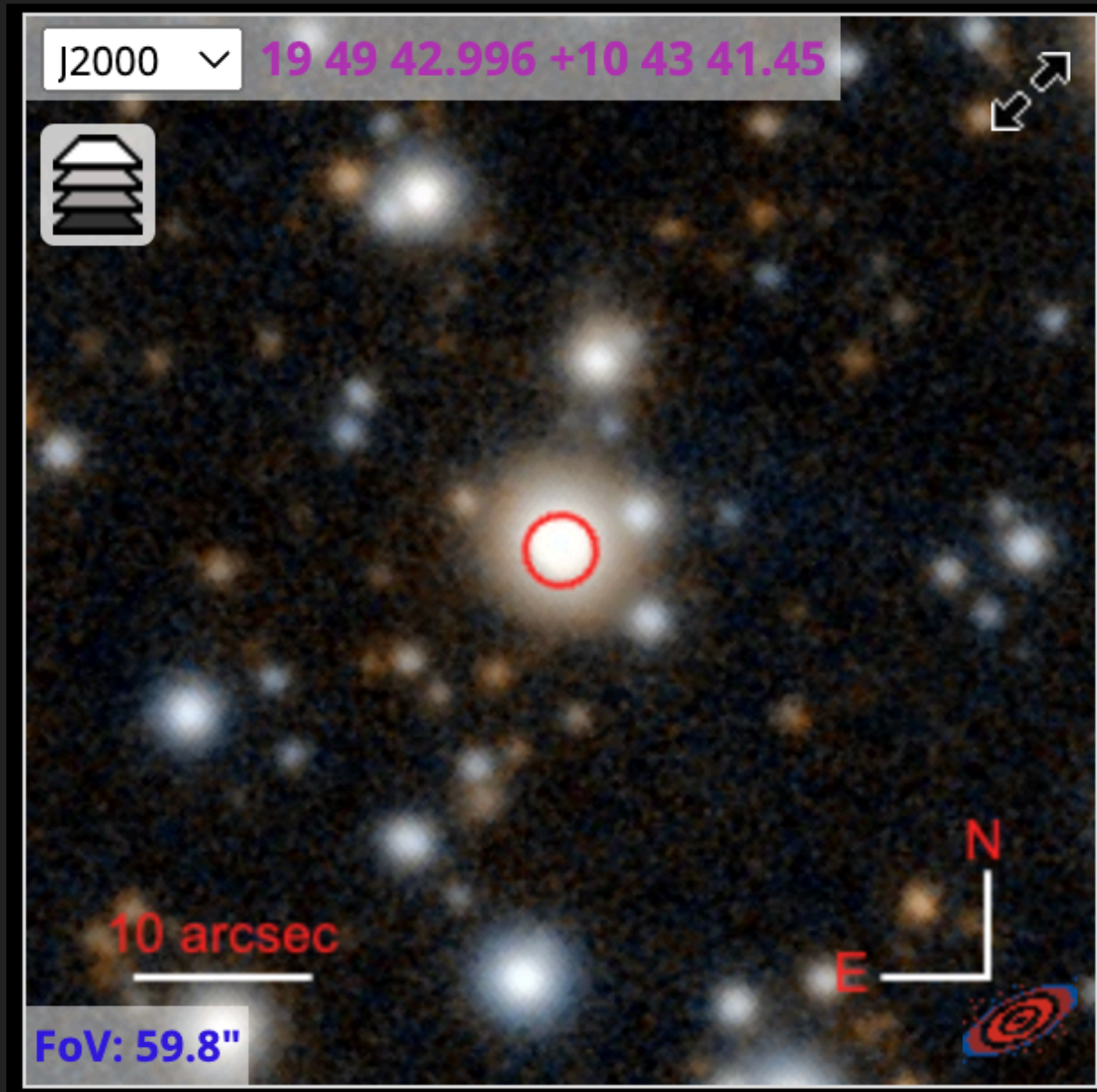
# GAIA23BAY ▶ Example bright alert in the Eagle constellation



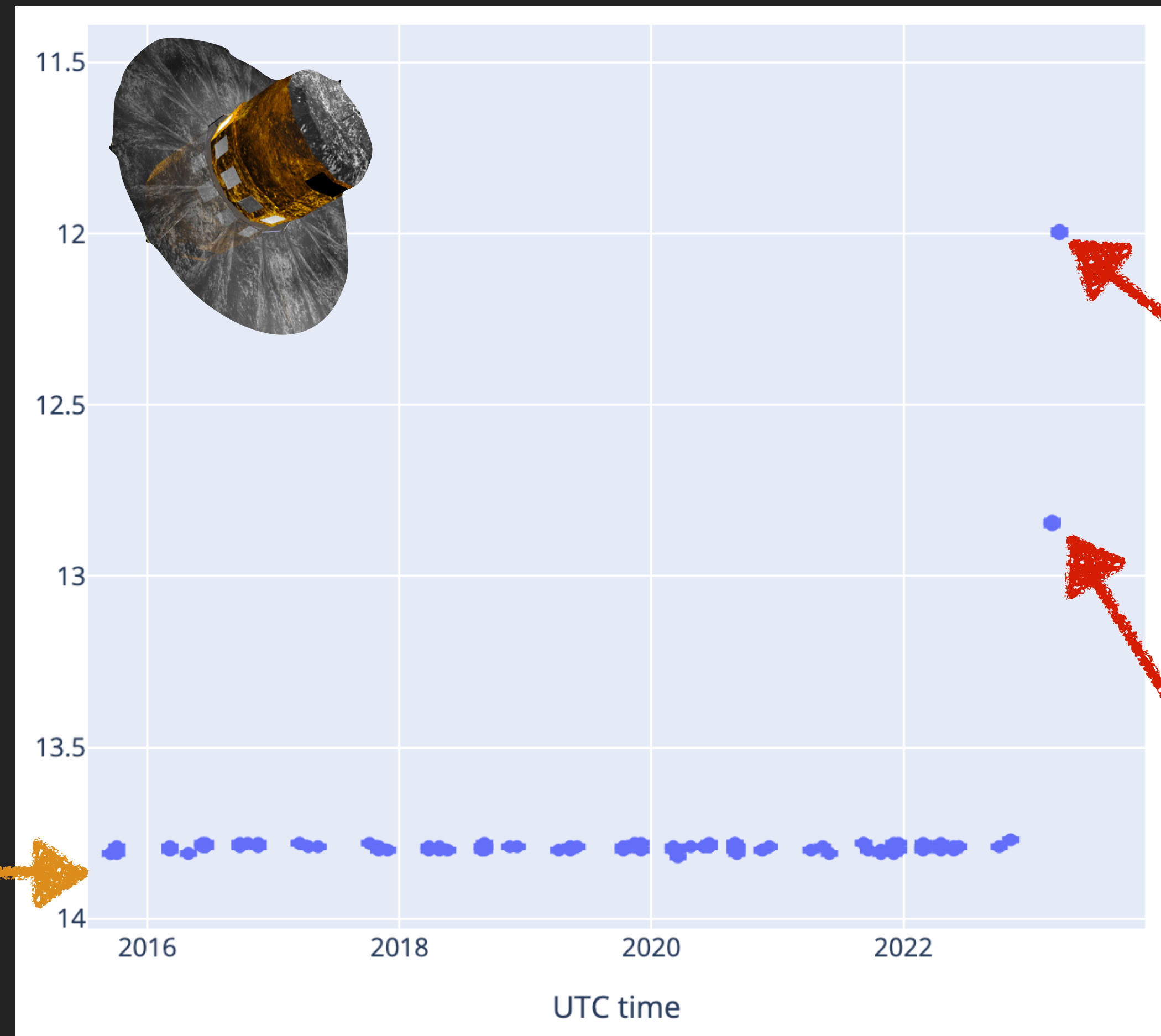
the star does not change its brightness for years



# GAIA23BAY ▶ Example bright alert in the Eagle constellation



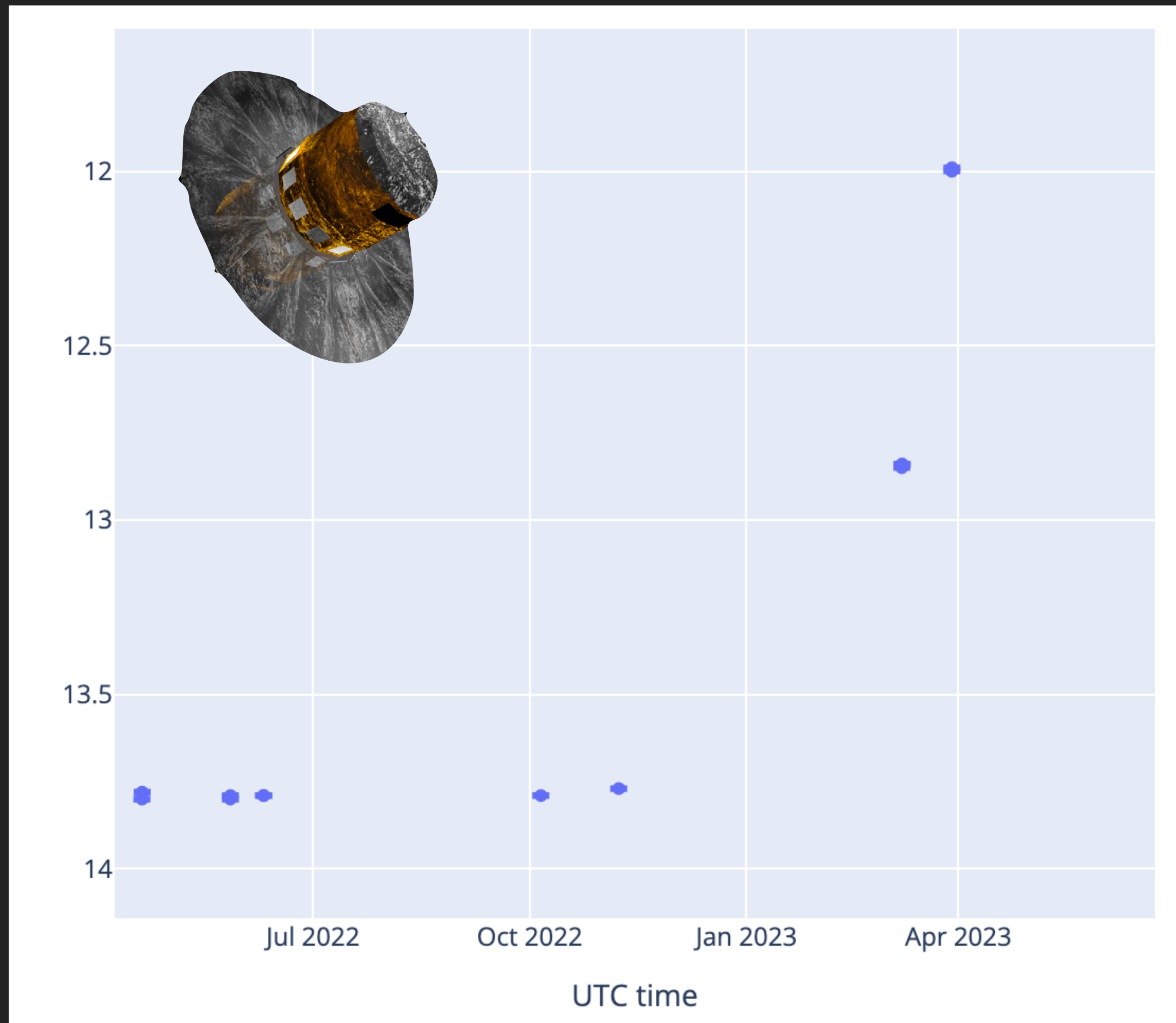
the star does not change its brightness for years



and another one

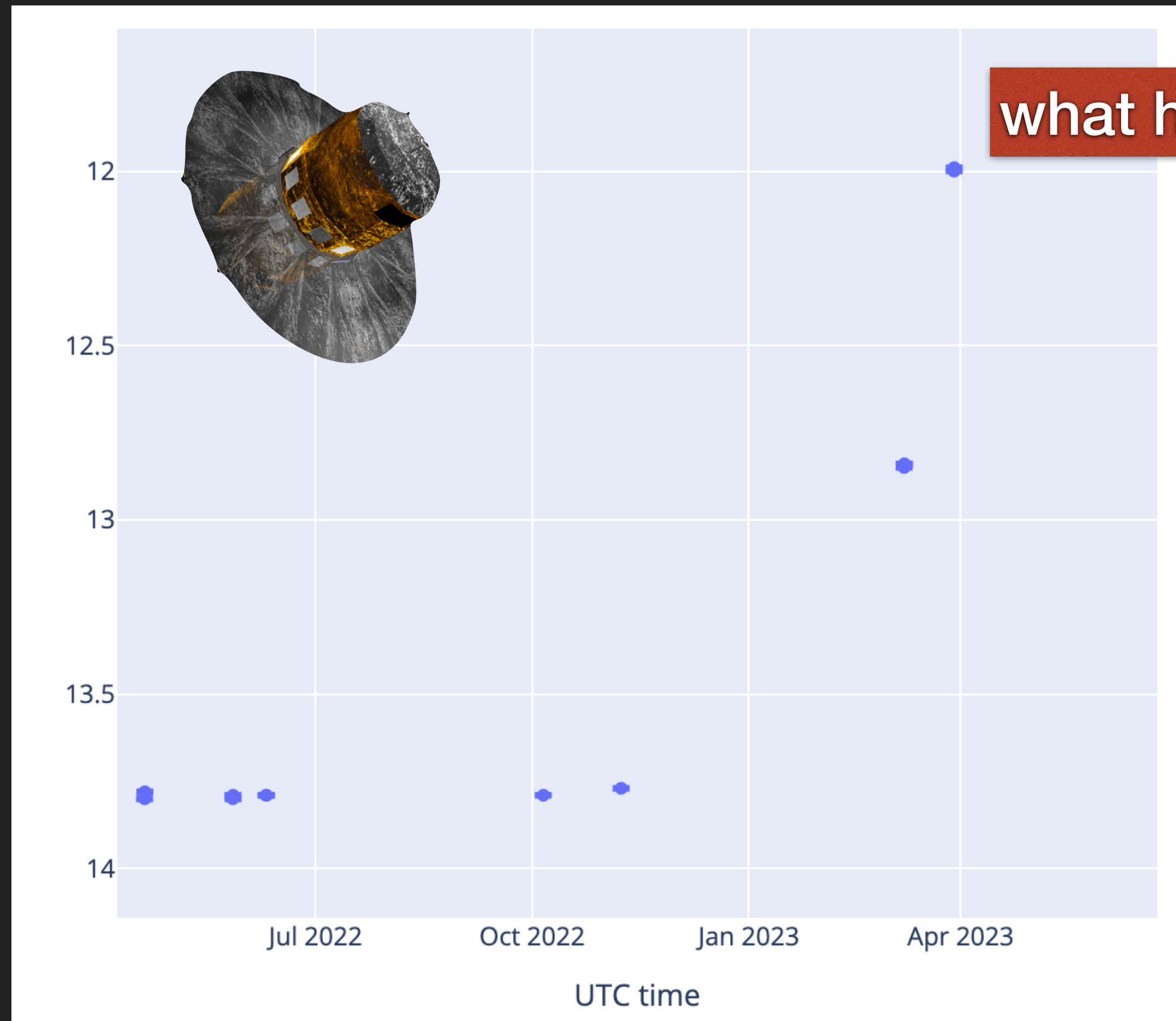
alert - sudden rise in brightness

# GAIA23BAY ▶ Example bright alert in the Eagle constellation



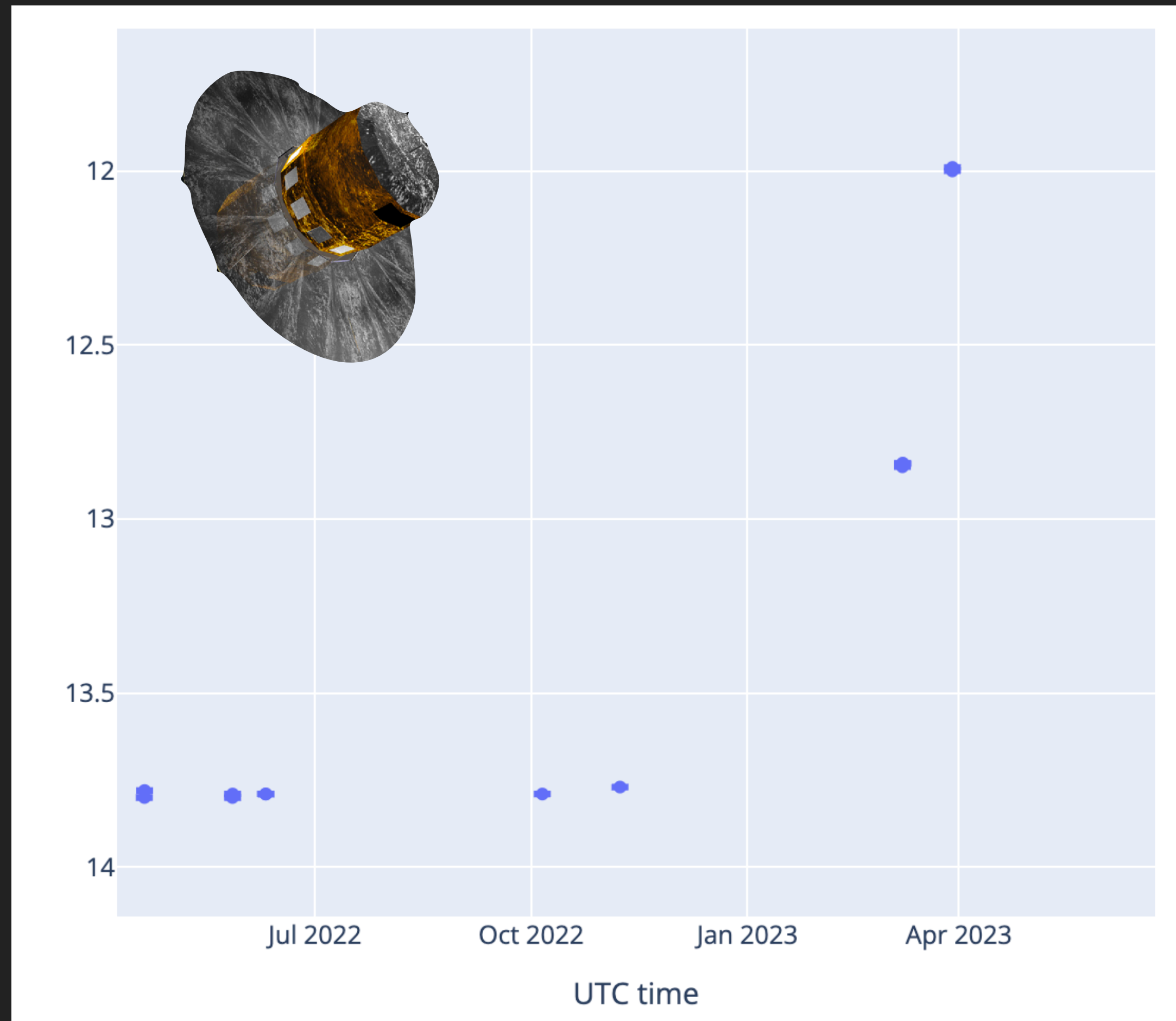
Gaia-only data

# GAIA23BAY ▶ Example bright alert in the Eagle constellation

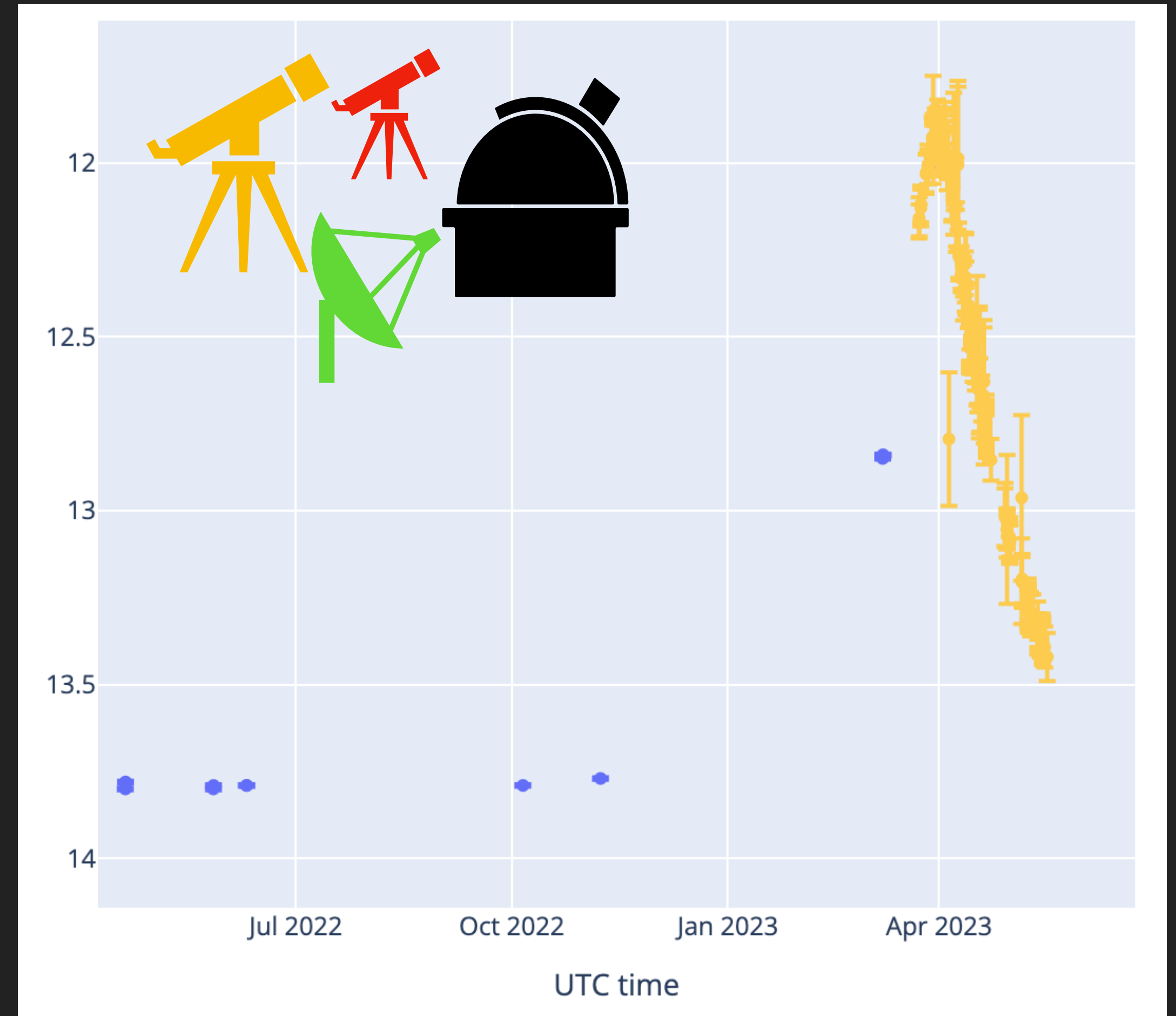


Gaia-only data

# GAIA23BAY ▶ Example bright alert in the Eagle constellation

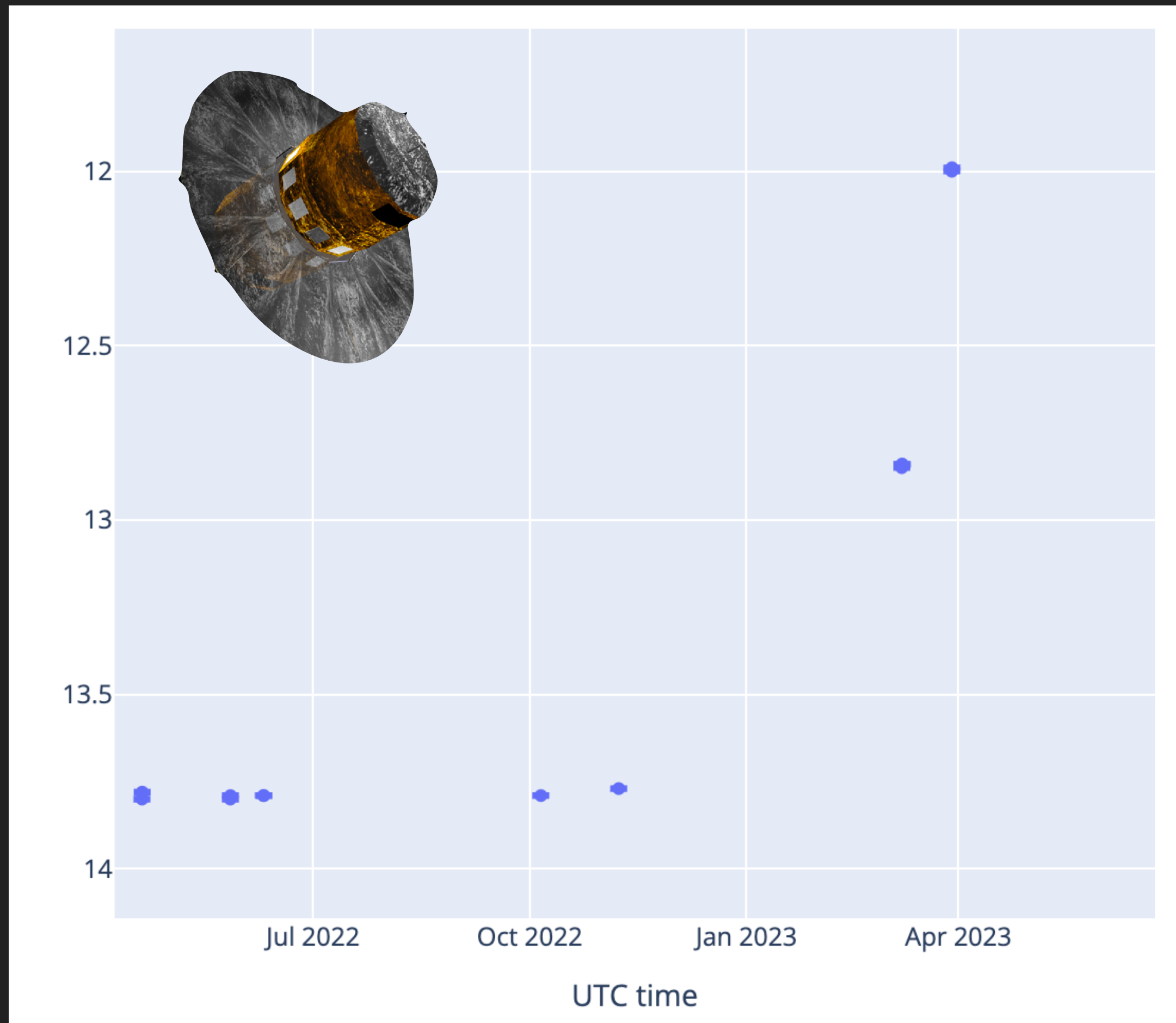


tylko Gaia

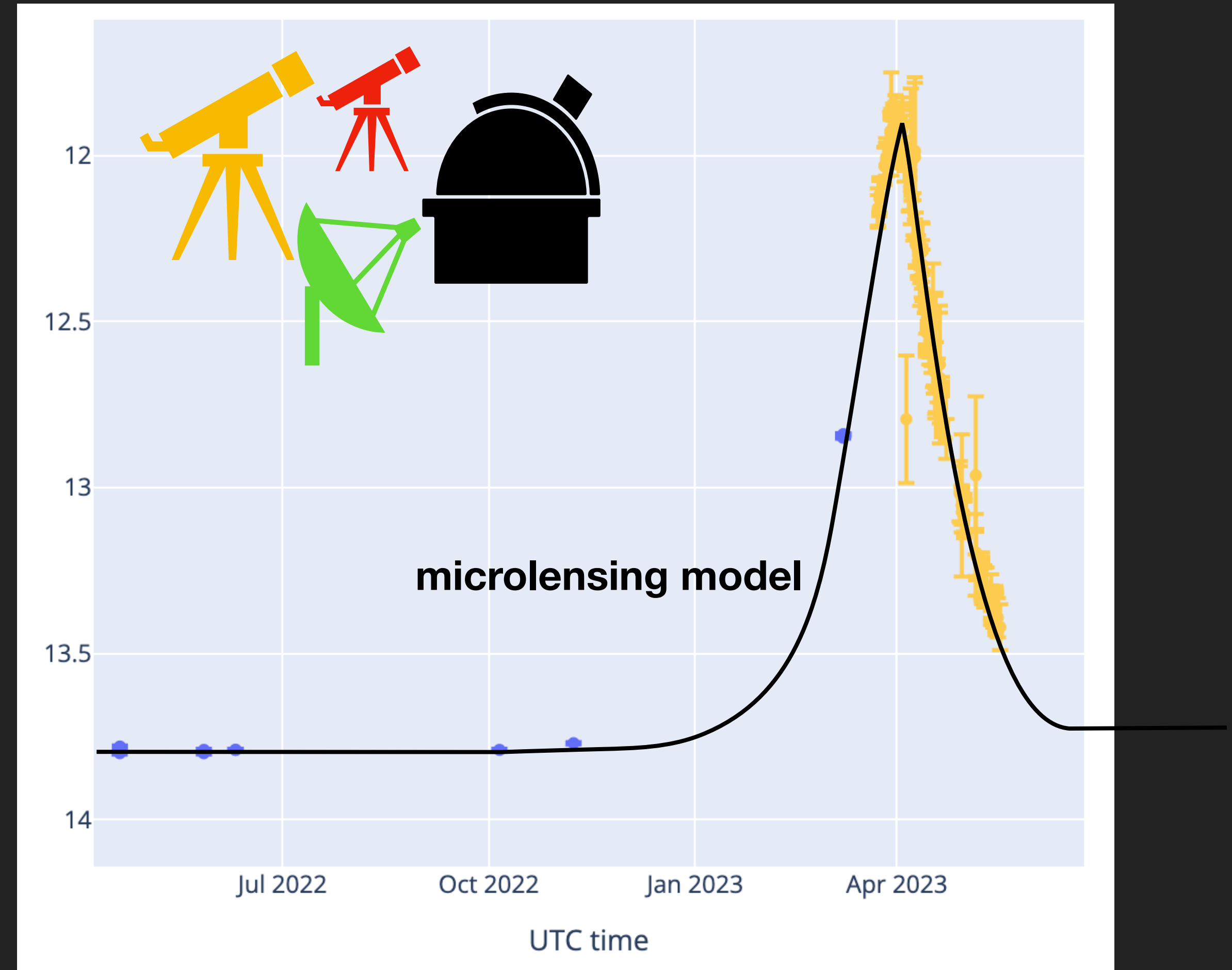


Gaia+network of small telescopes

# GAIA23BAY ▶ Example bright alert in the Eagle constellation



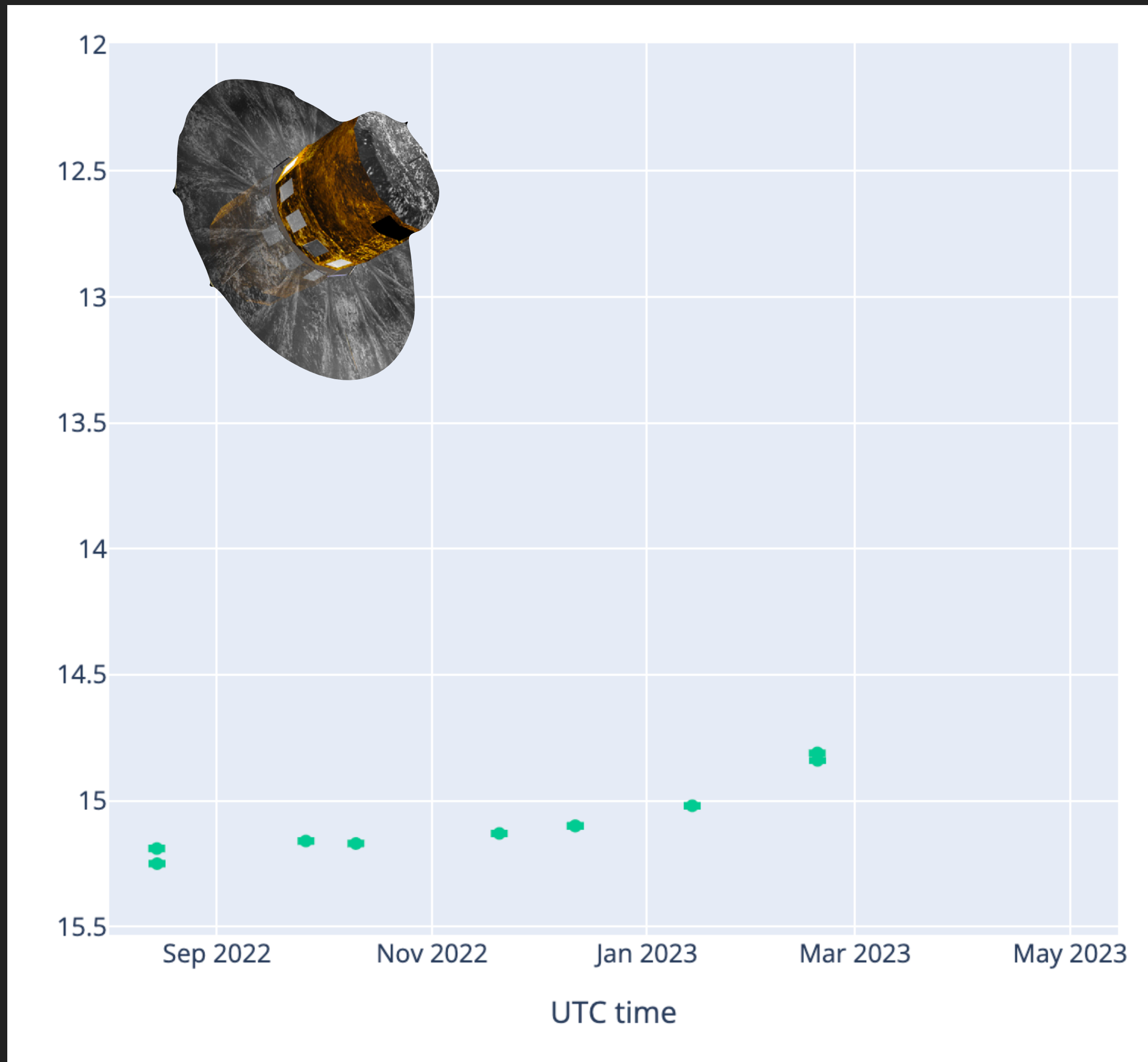
tylko Gaia



Gaia+network of small telescopes

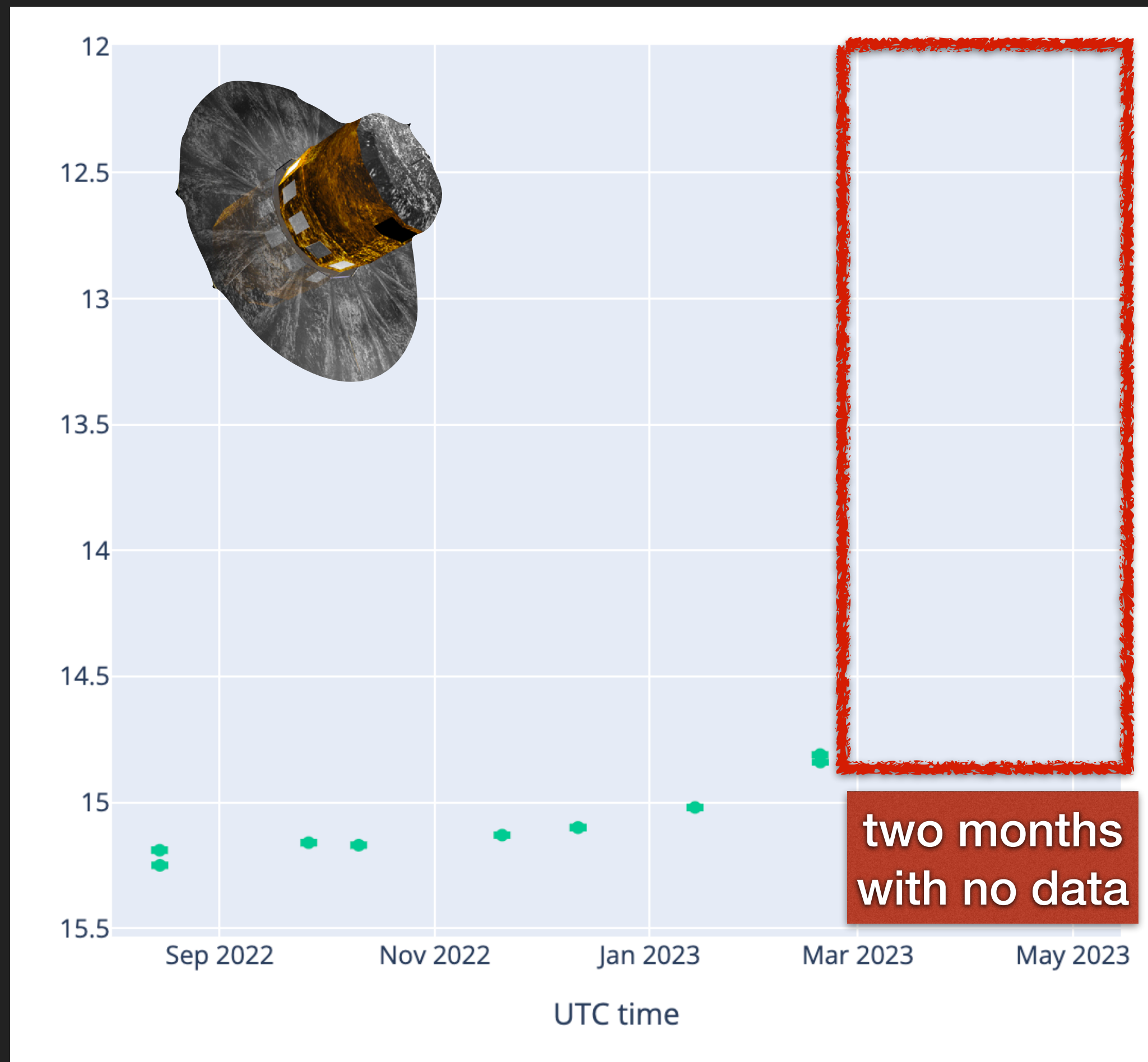


# GAIA23ATS ▶ Example alert in Pisces Australis



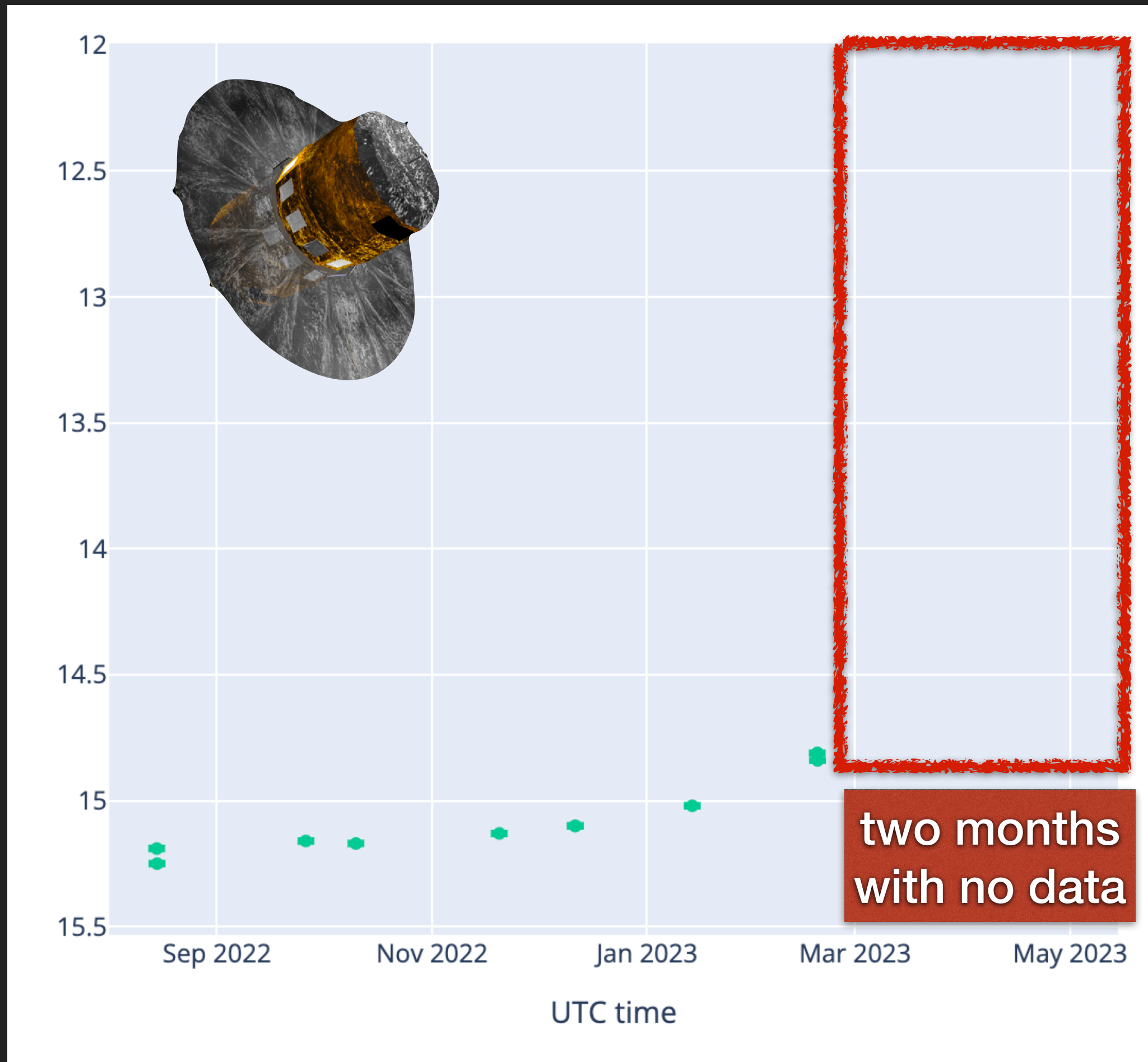
Gaia-only data

# GAIA23ATS ▶ Example alert in Pisces Australis

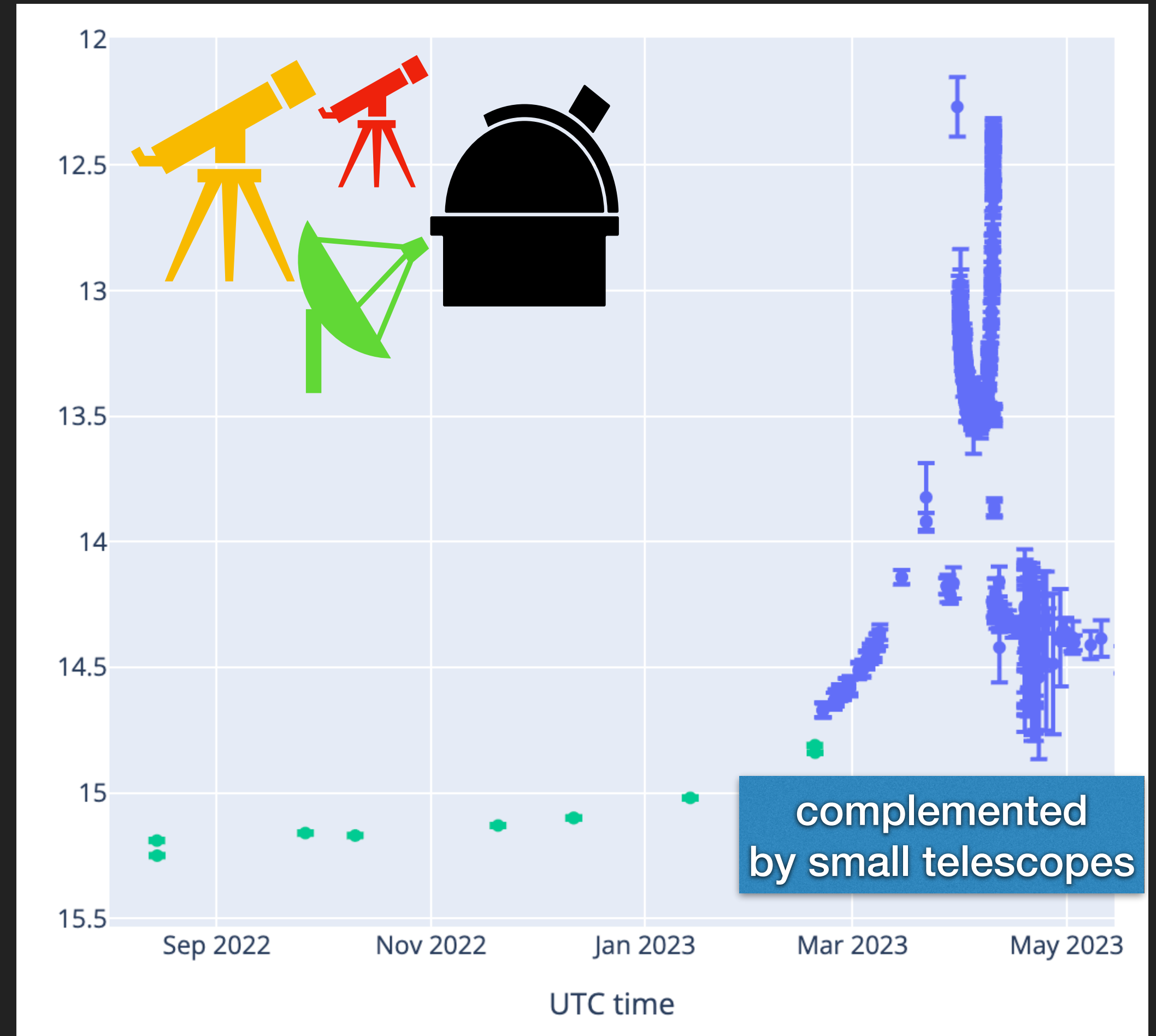


Gaia-only data

# GAIA23ATS ▶ Example alert in Pisces Australis



Gaia-only data



Gaia+network of small telescopes

# BHTOM

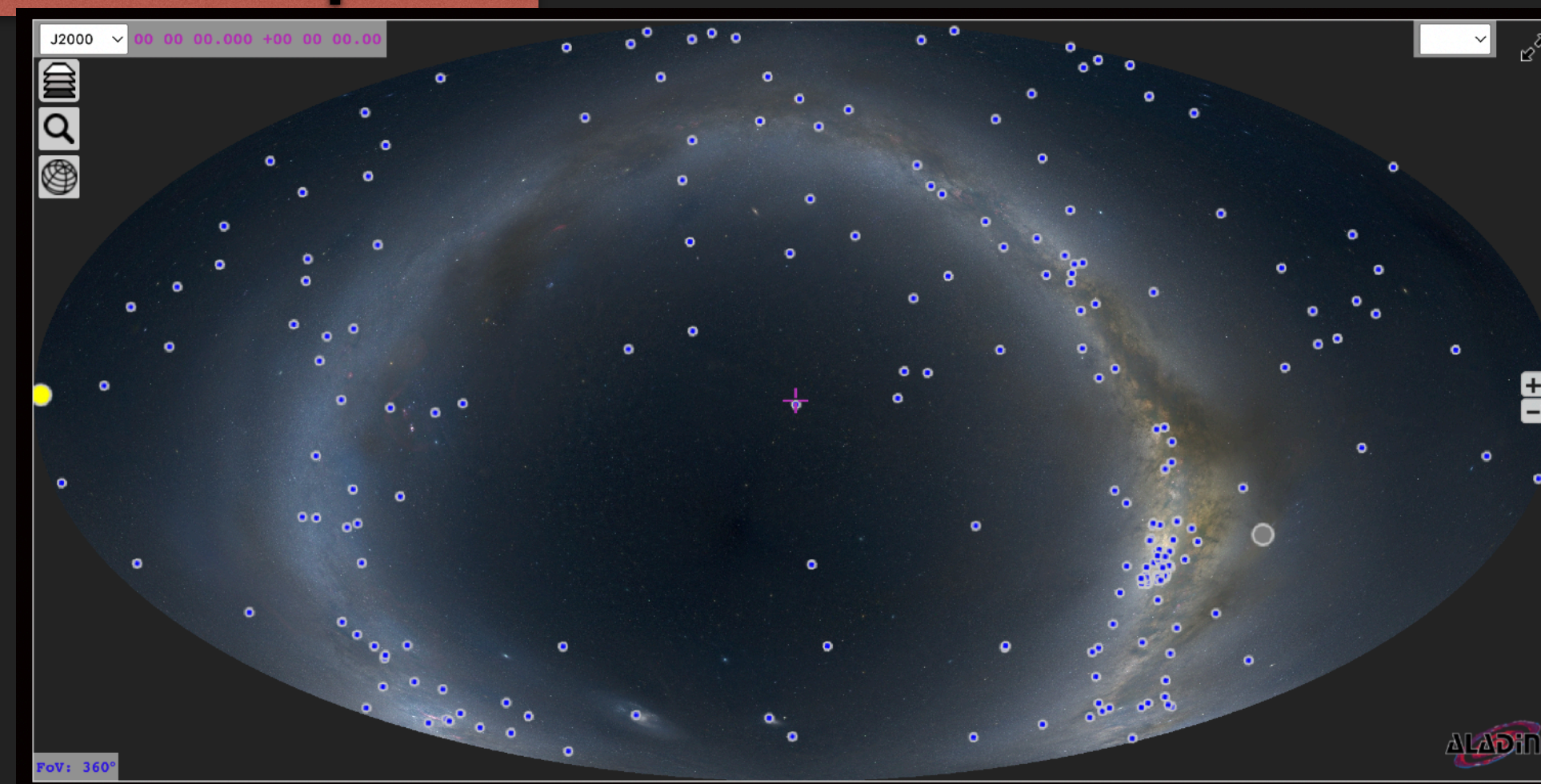


<https://bhtom.space>



///AkondLab.

- ▶ coordination of long-term monitoring of targets
- ▶ any time-domain target can be added
- ▶ dynamical prioritization of target
- ▶ robot-friendly with API end-point



Names	RA	Dec	Nobs	Last Gm	Last	priority	Sun	Class		
Gaia18acq	22:05:42.324	+03:39:17.064	982	20.2	Gaia/r	9.99	2023-09-18	799.0	155	long_period_variable
Gaia22bpl	10:38:42.425	-61:15:49.680	903	12.7	Gaia/r	9.99	2023-09-18	208.6	64	microlensing_event
Gaia22awa	19:04:51.962	-08:34:00.660	1602	15.0	Gaia/r	9.99	2023-09-17	770.1	111	microlensing_event
ZTF19abflrit	18:24:23.314	-24:36:42.053	842	15.2	Gaia/r	0.0	2023-09-21	770.1	100	long_period_variable

target prioritization

- ✓ Gaia Alerts
- OGLE EWS
- TNS
- ANTARES
- Simbad
- NED
- JPL Horizons

automated target grabbing

**Gaia22dkv**

Name: Gaia22dkv

Ra,Dec: 151.76898 -66.18089

Galactic (l,b): 287.36783 -8.410186

Constellation: Carina

Discovered: 2022-08-16 22:08:56

Class: Microlensing Event

Description: very bright gal.plane microlensing event with a planet

Phot.Class: Red Giant 89.0%

Last MJD: 60184.81287

Last G Mag: 13.2

Cadence requested (d): 100.0

Sun Separation (deg): 66.0

Other names:

- GAIA\_ALERTS: Gaia22dkv
- GAIA\_DR3: 5246137870147780736
- NEOWISE: NEOWISE: 151.76898 -66.18089

**Photometry**

Photometry plot showing magnitude vs date from 2010 to 2024. The plot shows a steady decline in magnitude from approximately 11.5 to 13.5, with a sharp increase starting around 2022, indicating a microlensing event. Data points are color-coded by filter: GSA(G), V(GaiaSP), I(GaiaSP), R(GaiaSP), I(GaiaSP), g(GaiaSP), B(GaiaSP), r(GaiaSP), WISE(W2), WISE(W1).

target details with all archival and multiwavelength data

# BHTOM – FROM IMAGE REQUEST TO SCIENCE-READY LIGHT CURVES

- ▶ Automatically upload your FITS images - PSF photometry done for you!
- ▶ Standardisation of observations from any filter to Gaia Synthetic Photometry
- ▶ Downloadable and science-ready

We process data from any camera!  
CCD or CMOS

Photometry   Models   Spectroscopy   Observe   Observations   Publication   **Manage Data**   Manage Groups

### Upload a data product

Here you can upload your photometric and spectroscopic observations for this target. Please refer to the BHTOM manual for details. Example CSV formats for [photometry](#) and [spectroscopy](#). Note, we require MJD (Modified Julian Date = JD-2400000.5) in the photometry file!

SExtractor format is required for instrumental photometry. FITS is not supported for spectra yet.

Non-detections are marked with error  $\geq 99.0$  (e.g. 99.0, 99.9 etc.)

For photometric FITS processing choose the observatory from the list. You can add a new observatory [here](#).

**You can upload up to 5 files at once.**

You can also use a python script for external fits upload: [data upload script](#)

Choose a Files

No file chosen

Data product type

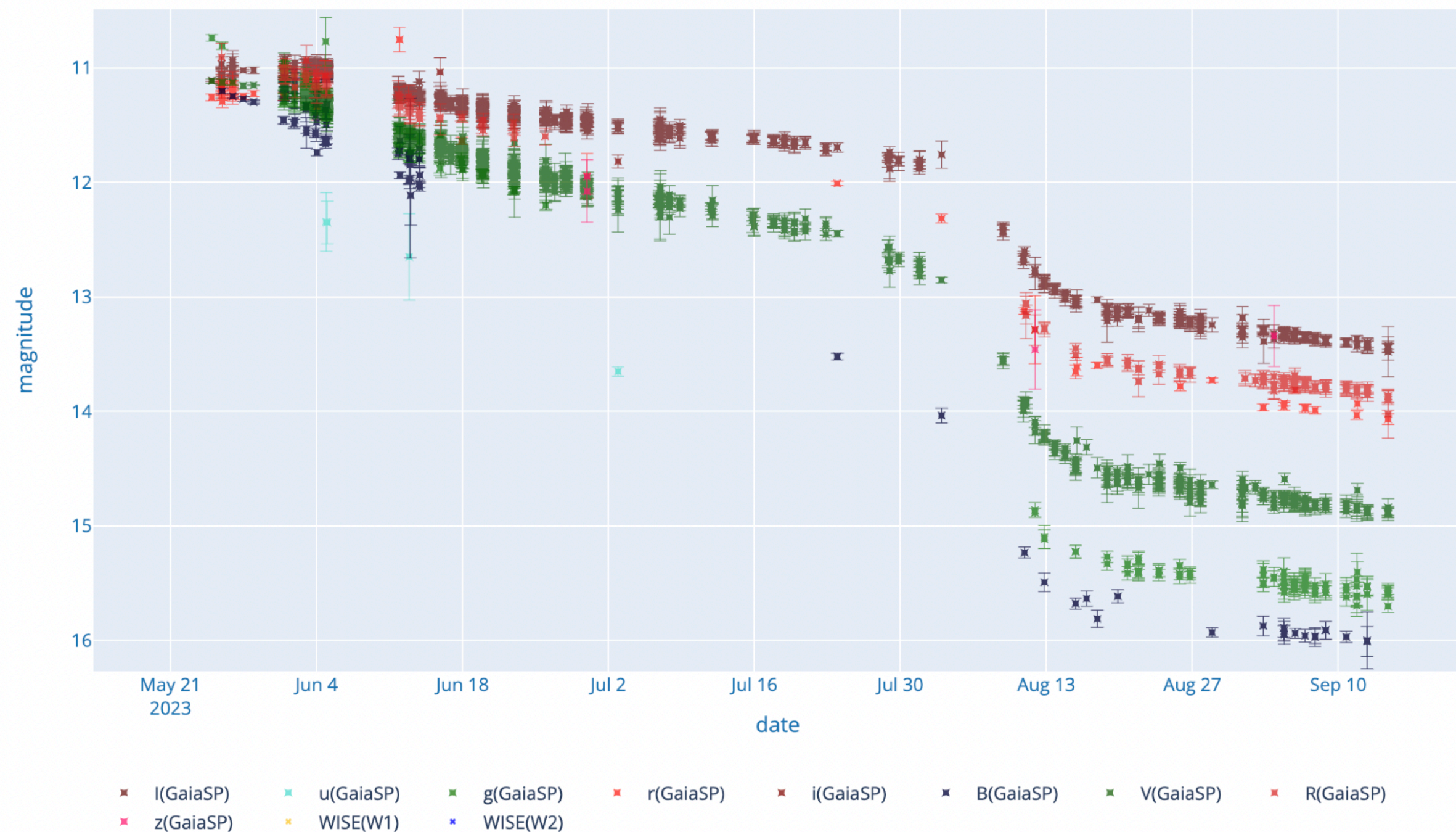
- Photometry - SExtractor format
- Photometry - Non-Detections
- FITS File
- Spectroscopy

Observatory Name	Lon	Lat	Observatory API ID (ONAME)	Comment
Adiyaman 60-cm telescope / Andor iKon-M 934	38.22541	37.751703	Adyu60_Andor-934	PlaneWave 24" CDK on ASA DM16...
Adonis observatory / Moravian G2 1600 camera	357.074618	50.91524	Adonis_G2-1600	Sky-watcher quattro F4 250 mm...
Aristarchos 2.3-m telescope / TEK2K camera	22.196111	37.984444	ARISTARCHOS_TEK2K	Aristarchos 2.3 m telescope, ...
Asiago Astrophysical Observatory / 67/92-cm Schmidt telescope / Moravian G4-160000	-11.568825	45.84944	AsiagoAO-0.67_G4-16000	Schmidt 67/92 Telescope, Mora...
Astrolab IRIS Observatory / SBIG camera	357.087333	50.817222	Astrolab-IRIS_SBIG	68-cm NMPT telescope. Public ...
ASV 1.4 m Milankovic Telescope / Andor iKon-L CCD camera	338.45	43.15	ASV1.4_Andor	The Astronomical Station Vido...
ATA50 with Apogee Alta U230	318.75611111	39.904752	ATA50_AltaU230	51 cm RC telescope on ASA Dir...
AZT-8 telescope / Moravian C4-16000	329.484243	50.307068	AZT-8_C4-16000	AZT-8 telescope, Lisnyky obse...
Białków 60-cm Cassegrain / ANDOR iKon-L DW432 camera	343.341944	51.474167	BIALKOW_ANDOR-DW432	Białków station, Wrocław Univ...
Danish 1.54-m telescope / DFOSC CCD instrument	-70.7403	-29.263	DANISH_DFOSC-FASU	1.54 m Danish Telescope at La...
Flarestar Observatory (code:	345.530289	35.910192	Flarestar-MPC171_G2-1600	Meade SSC-10

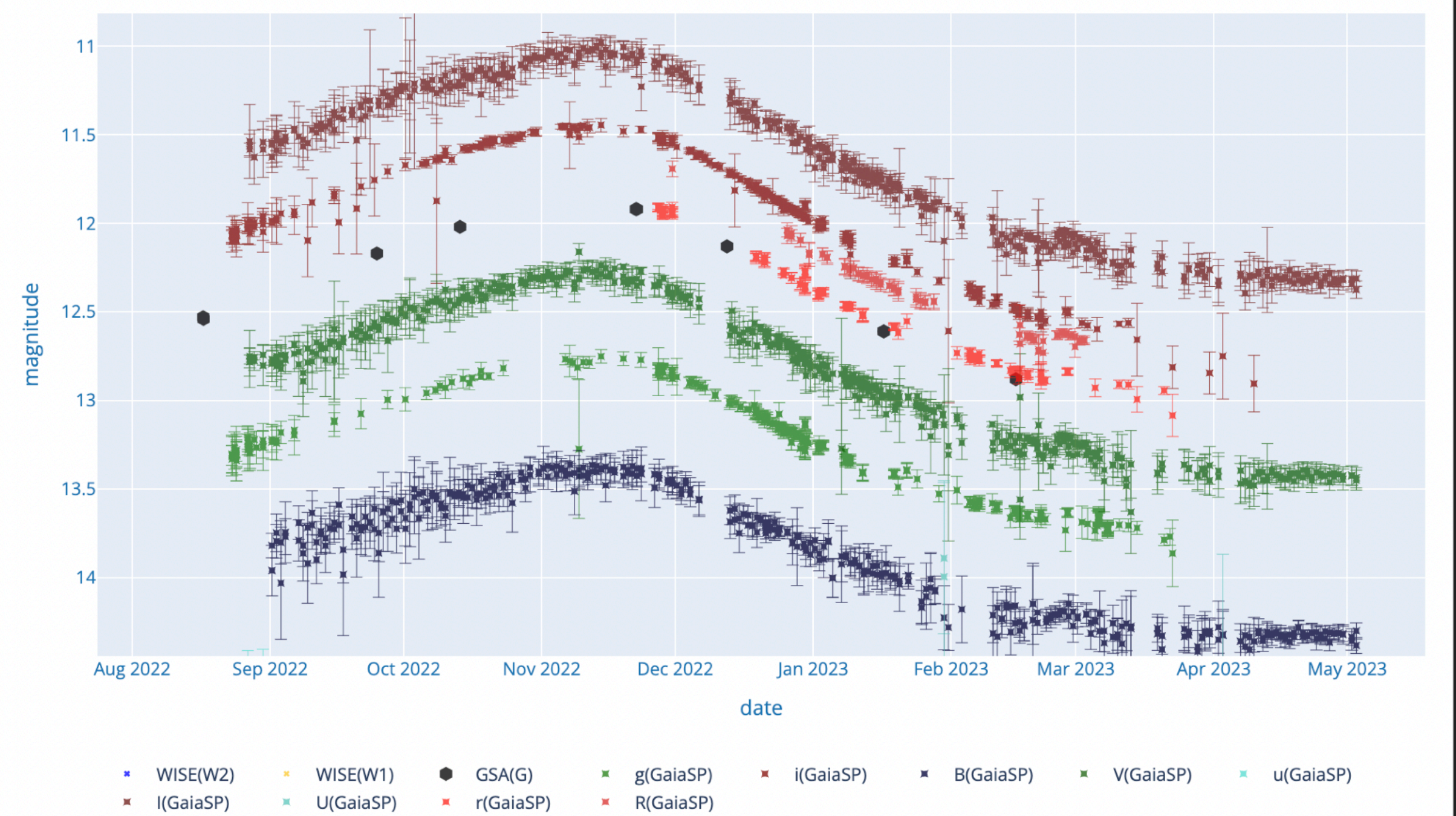
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- ▶ Downloadable and science-ready

SN2023ixf



Gaia22dkv -planetary microlensing event



# BHTOM – PUBLICATION ▶ All observers acknowledged as co-authors

Photometry Models Spectroscopy Observe Observations **Publication** Manage Data Manage Groups

Generate LaTeX target description

### Photometry Stats

Facility	Filters	Number	Min MJD	Max MJD
ALLWISE	WISE(W1), WISE(W2)	41	55369.64	55556.85
CRTS	CRTS(CL)	284	53479.24	56476.45
Gaia Alerts	GSA(G), G(GAIA_ALERTS)	270	56882.22	59948.55
NEOWISE	WISE(W1), WISE(W2)	461	56656.33	59739.5
PS1	PS1(g), PS1(r), PS1(i), PS1(z)	4	55727.28	56137.46
ZTF	ZTF(zg), ZTF(zr), ZTF(zi)	353	58203.3	60064.27

Download photometry stats as LaTeX table

## Generate LaTeX description for Gaia21fkl

ChatGPT-generated title:

"Puppis-Powered: Unlocking the Mysteries of Gaia21fkl's Black Hole Candidate!"

Copy/paste to your paper

Prompt used for the title

Suggest a catchy title about a black hole candidate found with microlensing named Gaia21fkl, found in the constellation Puppis.

ChatGPT-generated LaTeX target description:

Gaia21fkl was discovered by  $\textit{Gaia}$  Science Alerts (GSA) on 2021-12-03 18:50 (MJD = 59551.78491) and was made available on the GSA website <http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia21fkl/>. Transient name server designations for this event are Gaia21fkl (GAIA\_ALERTS) 5712117323266396544 (GAIA\_DR3) NEOWISE+J116.61824\_-21.87556 (NEOWISE) CRTS+J116.61824\_-21.87556 (CRTS) PS1\_81741166182359645 (PS1). It has equatorial coordinates RA, Dec(J2000.0)= 07:46:28.378, -21:52:32.016 and galactic coordinates  $l, b = 238.551541, 1.520389$  in the constellation Puppis. A finding chart with the event's

Copy/paste to your paper

Prompt used

Rephrase and keep LaTeX:  $\quad \textit{Gaia21fkl}$  (tns) according to the IAU transient name server) Gaia21fkl was discovered by  $\textit{Gaia}$  Science Alerts (GSA) on 2021-12-03 18:50 (MJD = 59551.78491) and was posted on the GSA website <http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia21fkl/>. Other surveys' names include: Gaia21fkl(GAIA\_ALERTS) 5712117323266396544(GAIA\_DR3) NEOWISE+J116.61824\_-21.87556(NEOWISE) CRTS+J116.61824\_-21.87556(CRTS) PS1\_81741166182359645(PS1) . The event was located at equatorial coordinates RA, Dec(J2000.0)= 07:46:28.378, -21:52:32.016 and galactic coordinates  $l, b = 238.551541, 1.520389$  in constellation Puppis. The finding chart with the





# WORKSHOPS SINCE 2010



**GAIA SCIENCE ALERTS WORKSHOP**

Wednesday 29 June - Friday 1 July 2011, at the Institute of Astronomy, University of Cambridge

**DETAILS AND REGISTRATION**  
<http://www.ast.cam.ac.uk/iaa/research/gaia/>

**GAIA SCIENCE ALERTS WORKSHOP**

For more information e-mail: [gaiaalerts@ast.cam.ac.uk](mailto:gaiaalerts@ast.cam.ac.uk)

© 2011 Institute of Astronomy, Madingley Road, Cambridge CB3 0HA. Telephone: +44 (0)1223 337348



**Gaia Science Alerts Verification and Follow-up Workshop**

Wednesday 29 June - Friday 1 July 2011, at the Institute of Astronomy, University of Cambridge

**DETAILS AND REGISTRATION**  
<http://www.ast.cam.ac.uk/iaa/research/gaia/>

For more information e-mail: [gaiaalerts@ast.cam.ac.uk](mailto:gaiaalerts@ast.cam.ac.uk)

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**GAIA SCIENCE ALERTS WORKSHOP**

BOLOGNA 6-7 SEPTEMBER 2012

**GAIA SCIENCE ALERTS WORKSHOP**

BOLOGNA 6-7 SEPTEMBER 2012

Registration deadline: 15 August. Contact: [gaia2012@ast.cam.ac.uk](mailto:gaia2012@ast.cam.ac.uk)

Further details at: <http://www.ast.cam.ac.uk/iaa/wikis/gsaaw/wiki/index.php?title=Workshop2012main>



**Gaia Science Alerts**



**FIFTH GAIA SCIENCE ALERTS WORKSHOP**

UNIVERSITY OF WARSAW 9-12 SEPTEMBER 2014

DETAILS AND REGISTRATION: <http://www.astrow.edu.pl/gaia2014>

Status of Gaia  
 First Alerts and preliminary results from the Verification Phase | Gaia alerts follow-up campaigns | Science with Gaia transients: Supernovae, Microlensing, Novae, TDEs, CVs, YSOs | Current/planned multi-wavelength transient surveys and synergies

Workshop Organising Committee:  
 Lukasz Wyrzykowski, Simon Hodgkin, Gerry Gilmore, Nicholas Walton, Szymon Kozłowski, Heather Campbell, Morgan Fraser, Nadejda Blagoderova



**Gaia Science Alerts Workshop 2015**

Liverpool John Moores University (UK)

10-13 November 2015

- Follow-up observations
- Automated classification
- Gaia Alerts Publisher
- Science cases
- Robotic telescopes
- Outreach
- Transient surveys
- Hands-on sessions

Details: [www.ast.cam.ac.uk/iaa/wikis/gsaaw/wiki/index.php/Workshop2015main](http://www.ast.cam.ac.uk/iaa/wikis/gsaaw/wiki/index.php/Workshop2015main)  
 Contact: [gaiaalerts@ast.cam.ac.uk](mailto:gaiaalerts@ast.cam.ac.uk)



**7th Gaia Science Alerts Workshop**

7-9 December 2016 \* SRON Utrecht NL

**SRON**

Partnership Institute for Space Research



**8th OPTICON Gaia Science Alerts Workshop**

6-8 December 2017  
 Warsaw, Poland

Details and registration: <https://tinyurl.com/gaiaaworkshop>

Workshop Organizing Committee:  
 Lukasz Wyrzykowski, Simon Hodgkin, Krzysztof Rybicki, Katarzyna Kruszyńska



**The 9th OPTICON GAIA SCIENCE ALERTS WORKSHOP**

8-10 OCTOBER 2018  
 Vipava, Slovenia

**WORKSHOP ORGANIZING COMMITTEE**  
 Lukasz Wyrzykowski, Andreja Gomboc, Simon Hodgkin, Kasia Kruszyńska, Nada Ihanec, Tanja Petrushevska, Katja Bricman, Aurora Clerid

- Overview of the Gaia mission
- Overview of the Gaia Science Alerts
- Gaia Alerts highlights
- Gaia Alerts and DR2
- Machine-learning classification of transients
- New photometric calibration server
- Organizing the follow-up

**DETAILS AND REGISTRATION**  
<https://tinyurl.com/gaiaalerts2018>



**10th OPTICON Gaia Science Alerts Workshop**

Astronomical Observatory, University of Catania, Sicily, 18-20 December 2019

update on the Gaia mission  
 update on the improvements in the Gaia Alerts  
 Gaia Alerts highlights and results  
 synergies with radio, X-ray and high energy  
 new members of the telescope network  
 new photometric calibration server  
 organization of the follow-up  
 future plans

**Workshop Organizing Committee**  
 Lukasz Wyrzykowski (Warsaw), Giuseppe Leto (INAF), Simon Hodgkin (Cambridge), Kasia Kruszyńska (Warsaw), Nada Ihanec (Warsaw), Flavio Calderone (INAF-OACT), Giancarlo Bellazzini (INAF-OACT)

More information and registration: <https://tinyurl.com/gsaaw10>



**11th OPTICON Gaia Science Alerts Workshop**

from the comfort of our homes

18-22 January 2021

- update on Gaia mission
- Gaia Alerts highlights and results
- future of alerts and extension of Gaia
- improvements in Gaia Alerts
- new photometric calibration server
- synergies with radio, X-ray and high energy observations
- new members of the telescope network
- organization of the follow-up

**Organizing Committee:**  
 Lukasz Wyrzykowski, Simon Hodgkin, Rob Beswick, Marius Maskollunas, Kasia Kruszyńska, Nada Ihanec, Gerry Gilmore

**DETAILS AND REGISTRATION:**  
<https://tinyurl.com/gsaaw2021>



**12TH GAIA SCIENCE ALERTS WORKSHOP**

2021 NOV 8-12

**FIRST ORP-TIME DOMAIN MEETING**

UPDATES ON THE GAIA MISSION  
 GAIA ALERTS UPDATES AND HIGHLIGHTS  
 NEW PHOTOMETRIC CALIBRATION SERVER  
 NEW MEMBERS OF THE TELESCOPE NETWORK  
 SYNERGIES WITH RADIO WITHIN OPTICON-RADIONET PILOT GRANT

**LOCATION**  
 Institute of Astrophysics-FORTH at the island of Crete, Greece  
 on-line  
<https://tinyurl.com/12GSAW2021>

**REGISTER ONLINE**  
<https://tinyurl.com/12GSAW2021>

**ORGANISING COMMITTEE**  
 LUKASZ WYRZYKOWSKI (WARSAW), YASSIÖU CHAMANDARIS (FORTH), SIMON HODGKIN (CAMBRIDGE), ROB BESWICK (MANCHESTER), KASIA KRUSZYŃSKA (WARSAW), GERRY GILMORE (CAMBRIDGE), MARIUS MASKOLLUNAS (VILNIUS)



**13th ORP and Gaia Science Alerts Workshop**

4-7 October 2022  
 Pula, Sardinia

<https://bit.ly/gaiaalerts2022>

**Workshop Organizing Committee:**  
 Lukasz Wyrzykowski (Warsaw), Milena Ratajczak (Warsaw), Simon Hodgkin (Cambridge), Charles Galdies (Malta), Stephen M. Brincaat (Malta), Gerry Gilmore (Cambridge), Maja Jablonka (Warsaw), Marius Maskollunas (Vilnius)



**14th Gaia Science Alerts and ORP Time-Domain Workshop**

Valletta, Malta  
 2-5 October 2023  
<https://bit.ly/gaiaalerts2023>

Gaia mission and Alerts BHTOM follow-up system highlights and results synergies with radio telescope network organization opportunities

**Workshop Organizing Committee:**  
 Lukasz Wyrzykowski (Warsaw), Milena Ratajczak (Warsaw), Simon Hodgkin (Cambridge), Charles Galdies (Malta), Stephen M. Brincaat (Malta), Gerry Gilmore (Cambridge), Maja Jablonka (Warsaw), Marius Maskollunas (Vilnius)

**RECORDINGS: [HTTP://WWW.AST.CAM.AC.UK/IOA/WIKIS/GSAAW/WIKI](http://www.ast.cam.ac.uk/iaa/wikis/gsaaw/wiki)**

Lukasz Wyrzykowski

***Merci pour votre attention!***

**We welcome new telescopes  
and new targets!**



**BHTOM**

**Łukasz Wyrzykowski**  
(pron. *Woo-cash Vi-zhi-kov-ski*)


Astronomical Observatory,  
University of Warsaw, Poland



[HTTP://SLACK.BHTOM.SPACE/](http://SLACK.BHTOM.SPACE/)  
[HTTP://BHTOM.SPACE](http://BHTOM.SPACE)



LW  
[@ASTROUW.EDU.PL](mailto:LW@ASTROUW.EDU.PL)

A 3D rendered satellite component, possibly a camera or sensor, is shown against a starry space background. The component is a dark, cylindrical structure with a flat top and a circular base. A central black circle is positioned above the top surface, flanked by two bright blue lens flares. The text "extra slides" is overlaid in white on the front of the cylinder.

**extra slides**

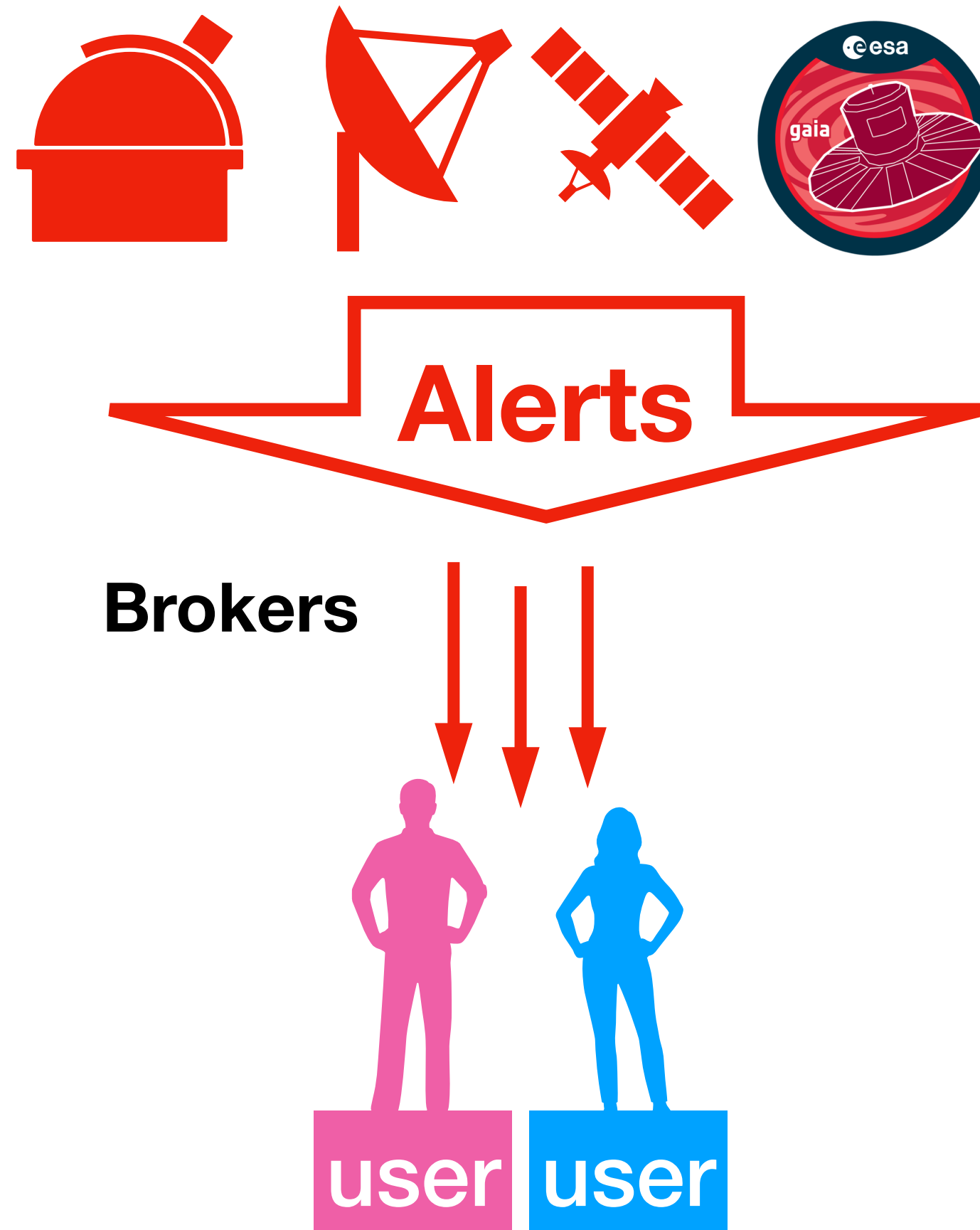
## Surveys

Gaia,  
ZTF,  
OGLE,  
ASAS-SN,  
LSST,  
...



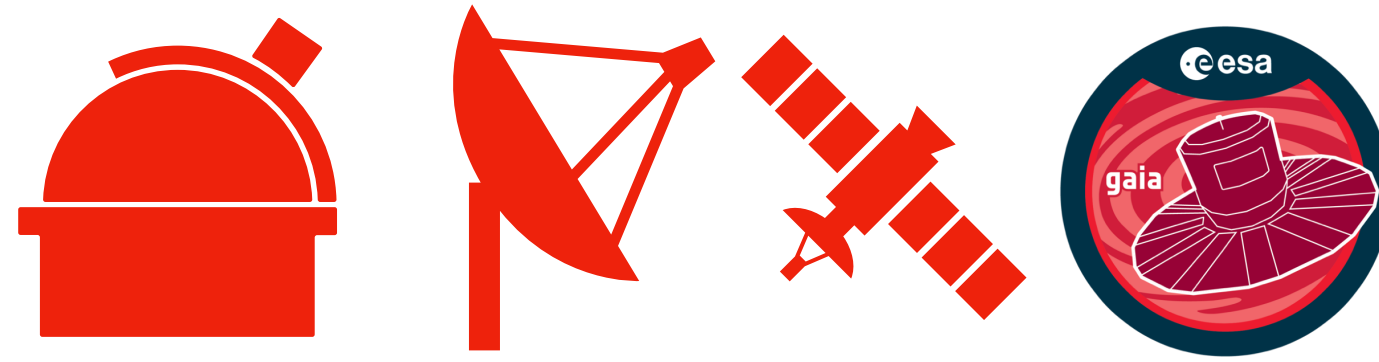
## Surveys

Gaia,  
ZTF,  
OGLE,  
ASAS-SN,  
LSST,  
...



## Surveys

Gaia,  
ZTF,  
OGLE,  
ASAS-SN,  
LSST,  
...

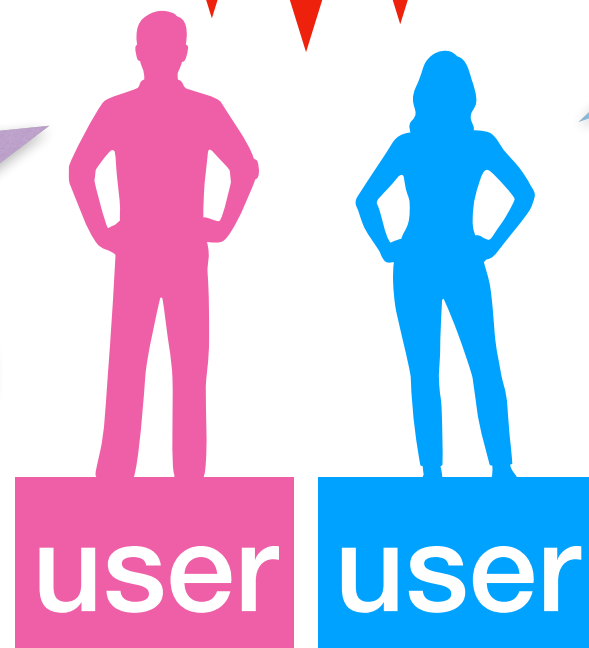


**Alerts**

**Brokers**

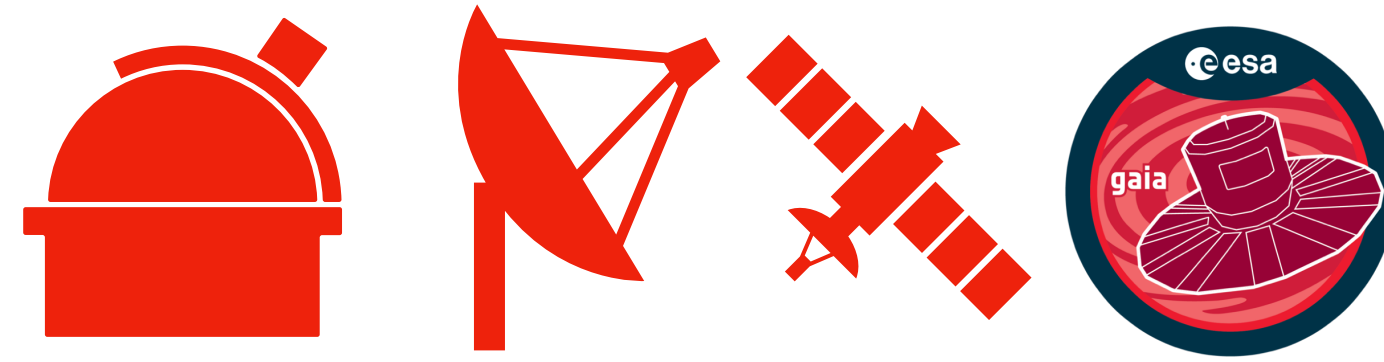
please  
observe Gaia20fnr  
event for 1 year

there was a  
supernova in M81,  
observe now!



## Surveys

Gaia,  
ZTF,  
OGLE,  
ASAS-SN,  
LSST,  
...

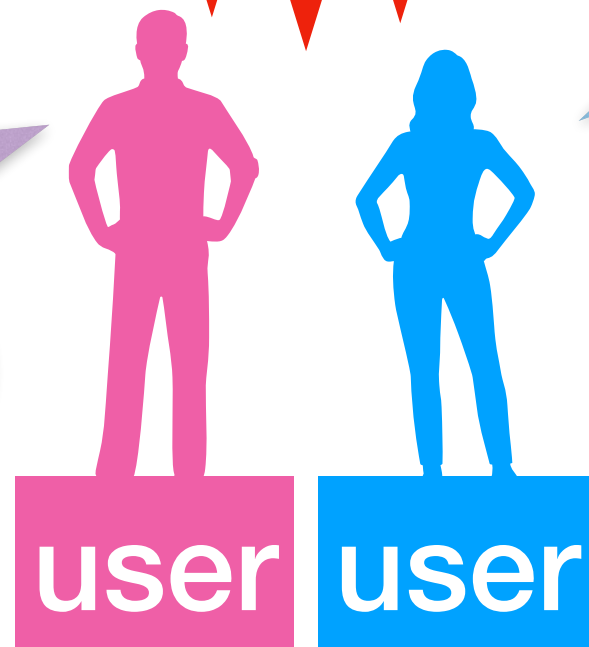


**Alerts**

**Brokers**

please  
observe Gaia20fnr  
event for 1 year

there was a  
supernova in M81,  
observe now!

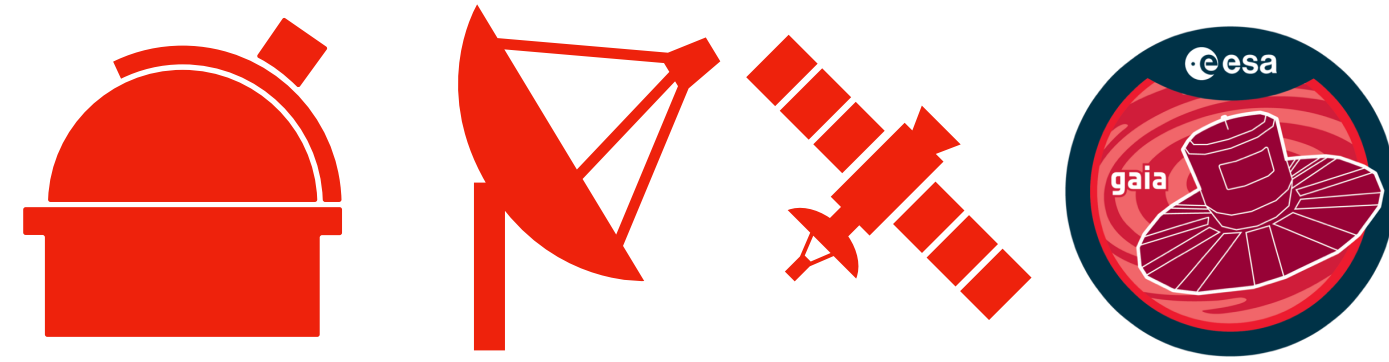


Observing  
requests

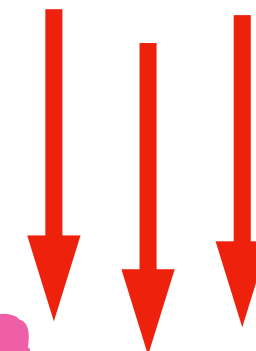
**bhtom.  
space**

**Surveys**

Gaia,  
ZTF,  
OGLE,  
ASAS-SN,  
LSST,  
...

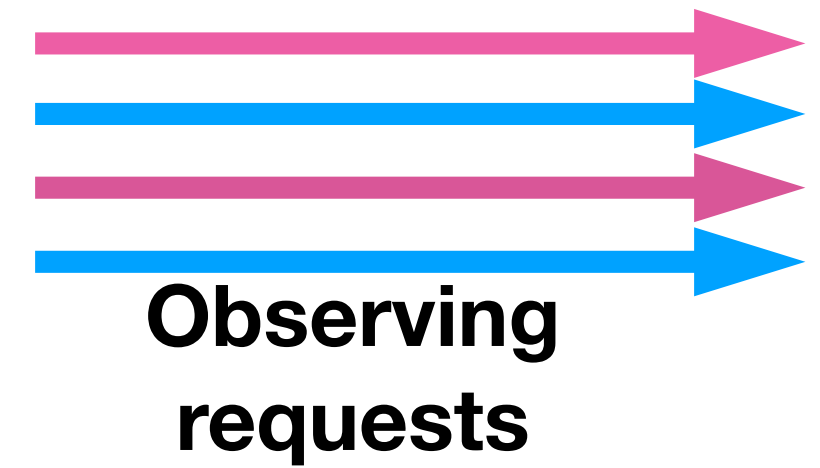
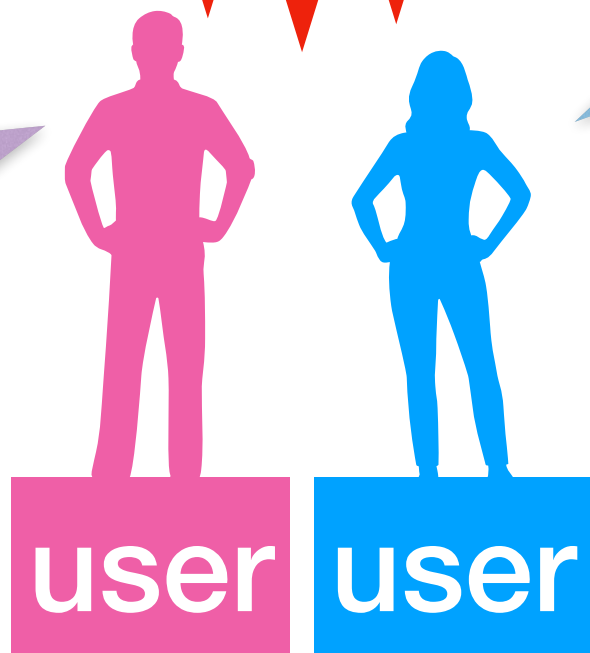


**Brokers**

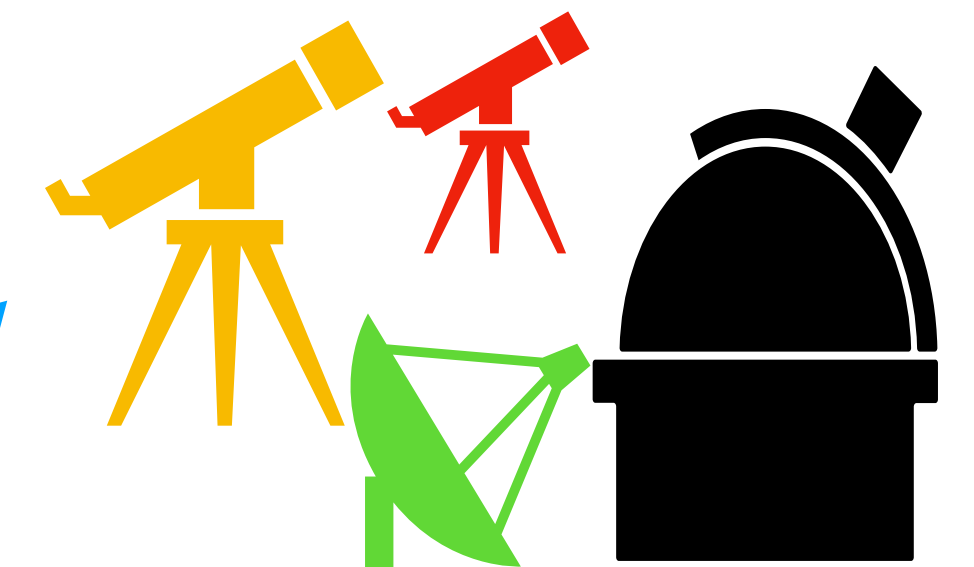
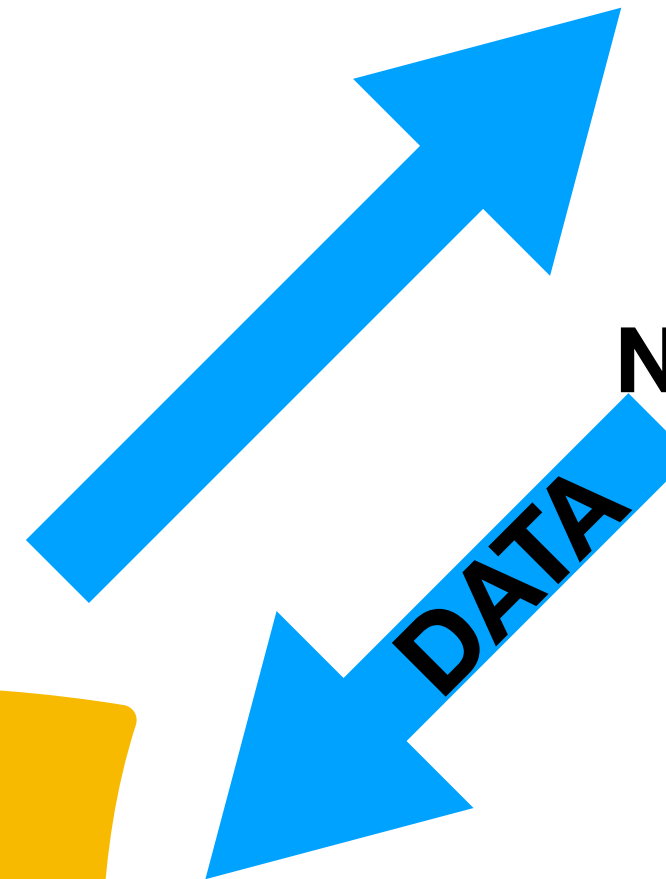


please  
observe Gaia20fnr  
event for 1 year

there was a  
supernova in M81,  
observe now!



**bhtom.  
space**

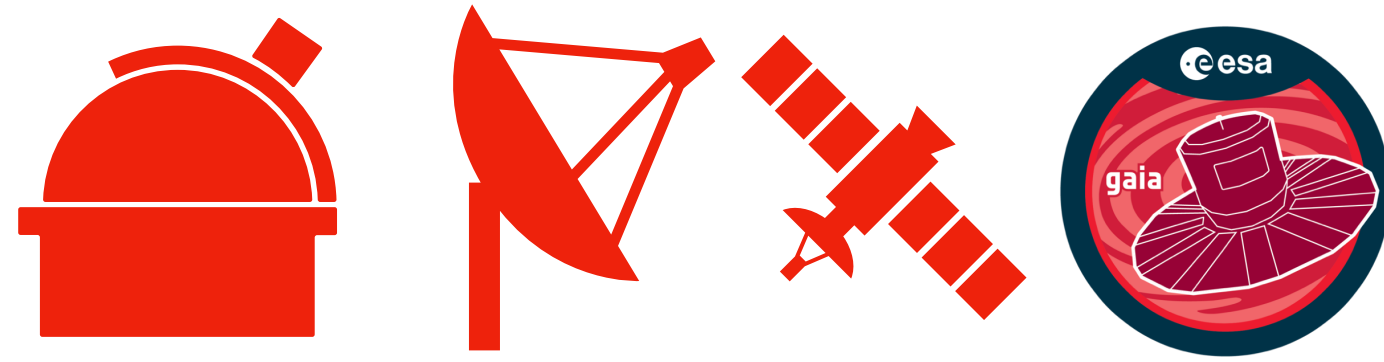


**Network of telescopes**



**Surveys**

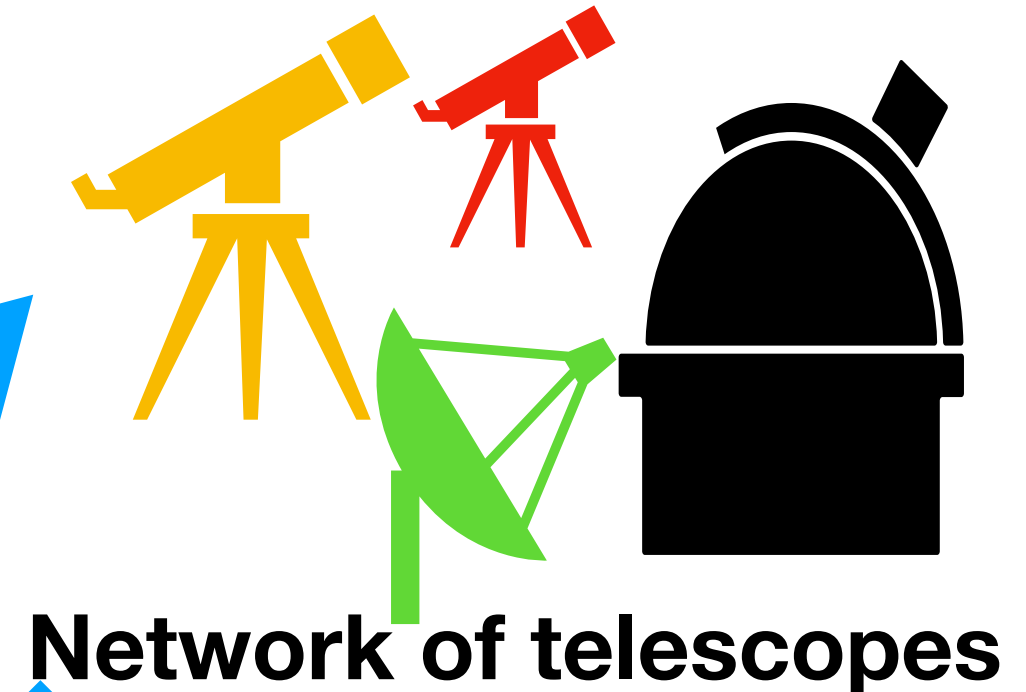
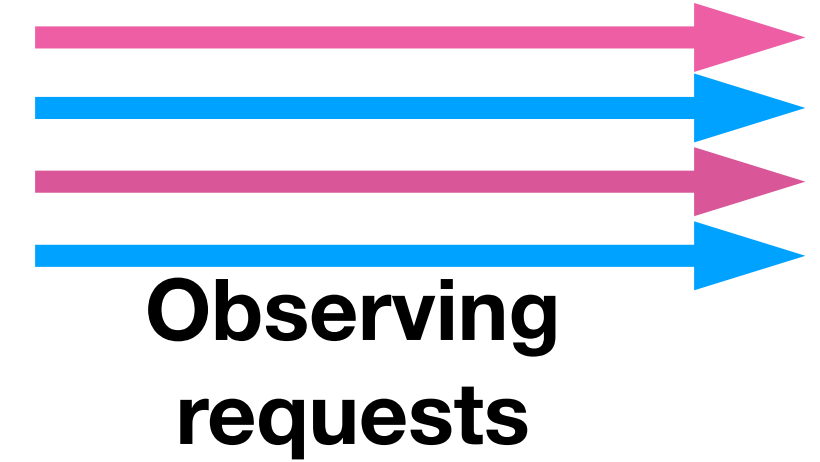
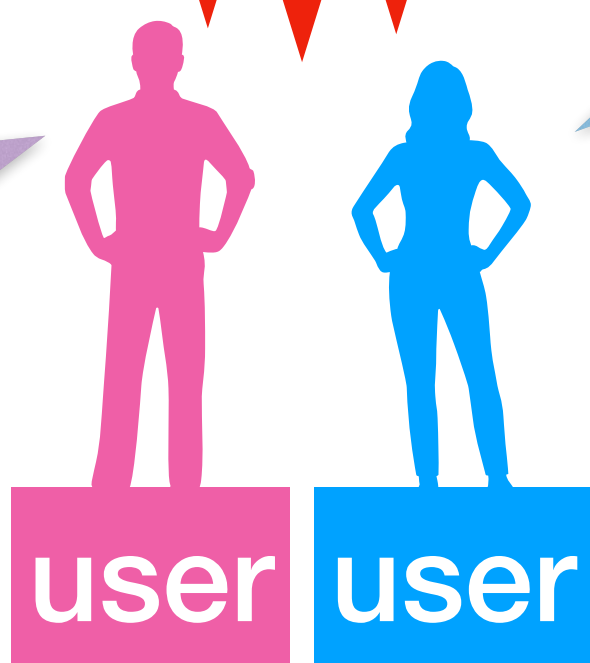
Gaia,  
ZTF,  
OGLE,  
ASAS-SN,  
LSST,  
...



**Brokers**

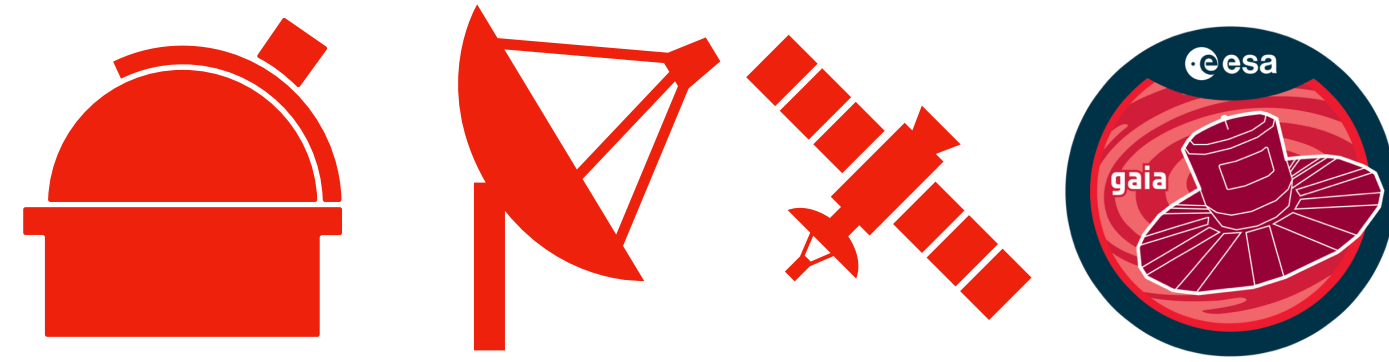
please  
observe Gaia20fnr  
event for 1 year

there was a  
supernova in M81,  
observe now!

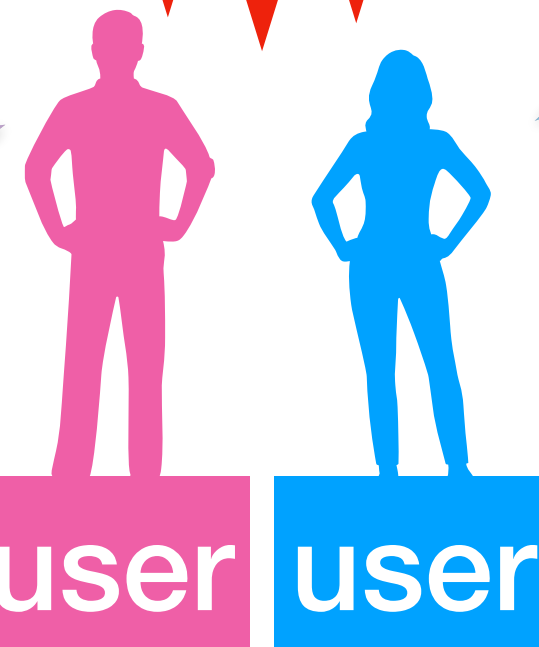


### Surveys

Gaia,  
ZTF,  
OGLE,  
ASAS-SN,  
LSST,  
...



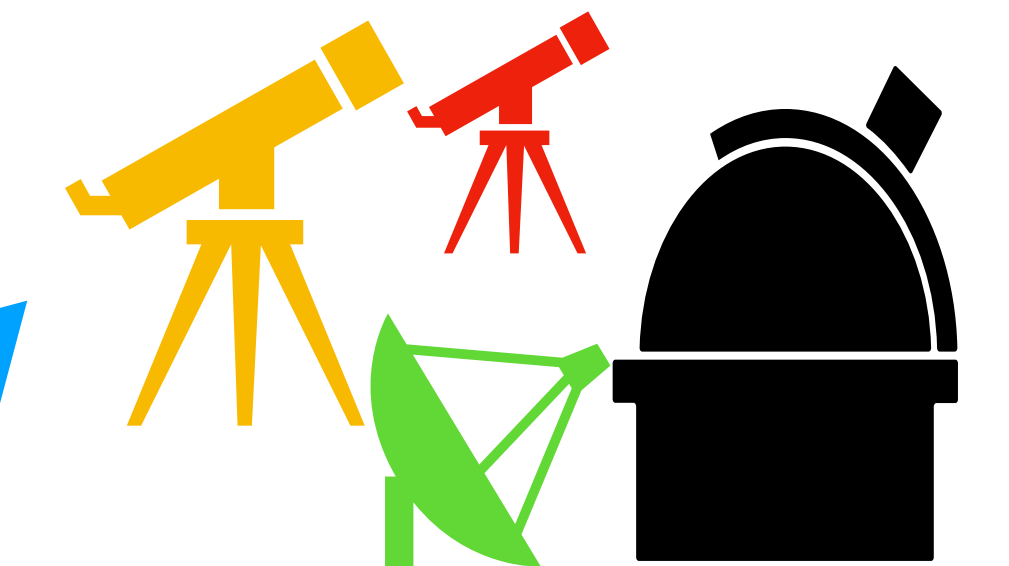
**Brokers**



please  
observe Gaia20fnr  
event for 1 year



**Observing  
requests**

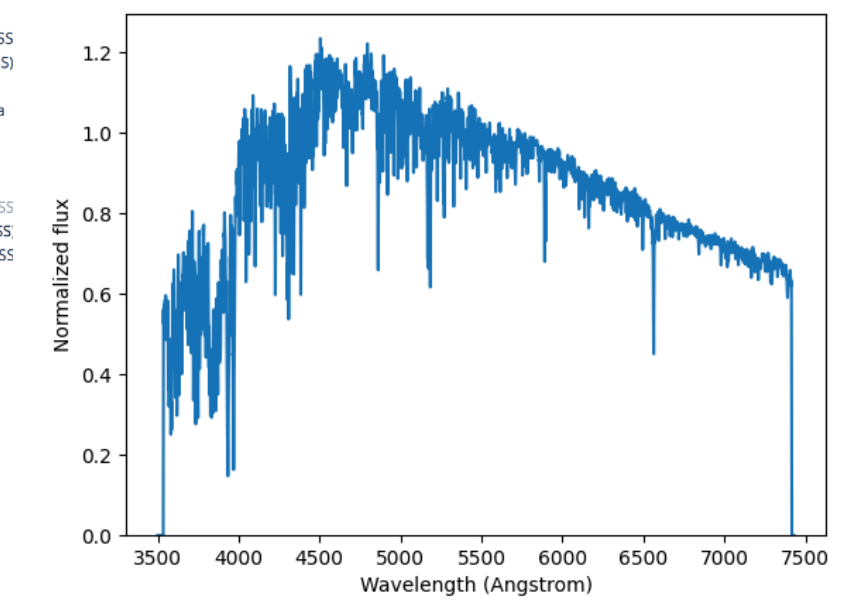
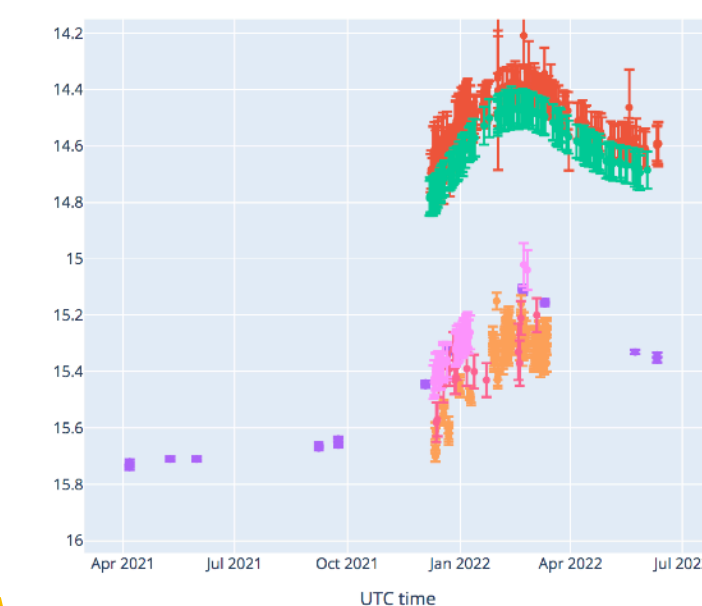
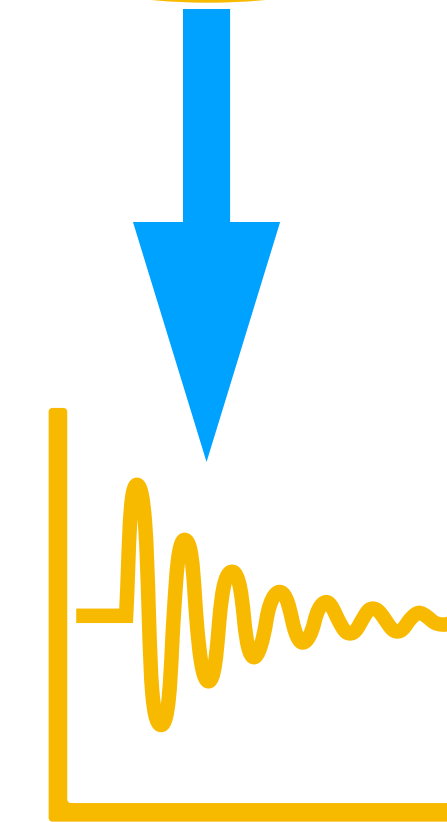


**Network of telescopes**



**Archives**

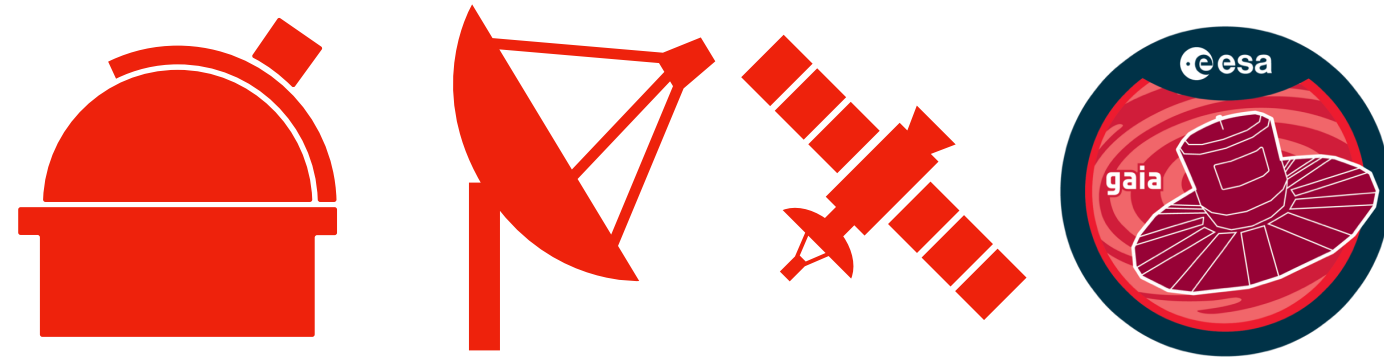
there was a  
supernova in M81,  
observe now!



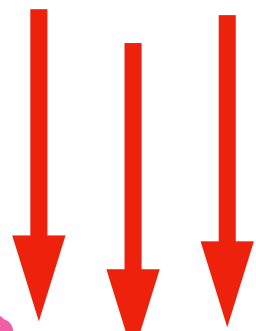
**Science-ready data products**

### Surveys

Gaia,  
ZTF,  
OGLE,  
ASAS-SN,  
LSST,  
...

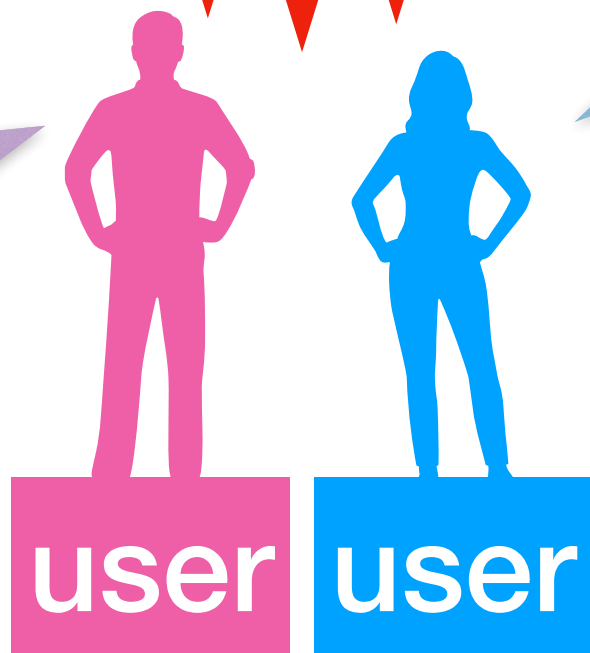


**Brokers**

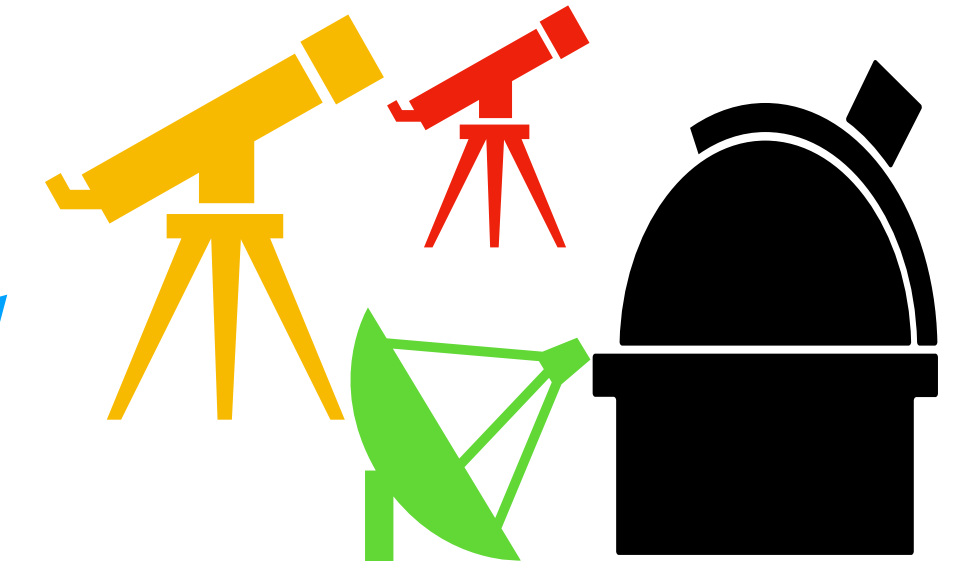


please observe Gaia20fnr event for 1 year

there was a supernova in M81, observe now!



**Observing requests**

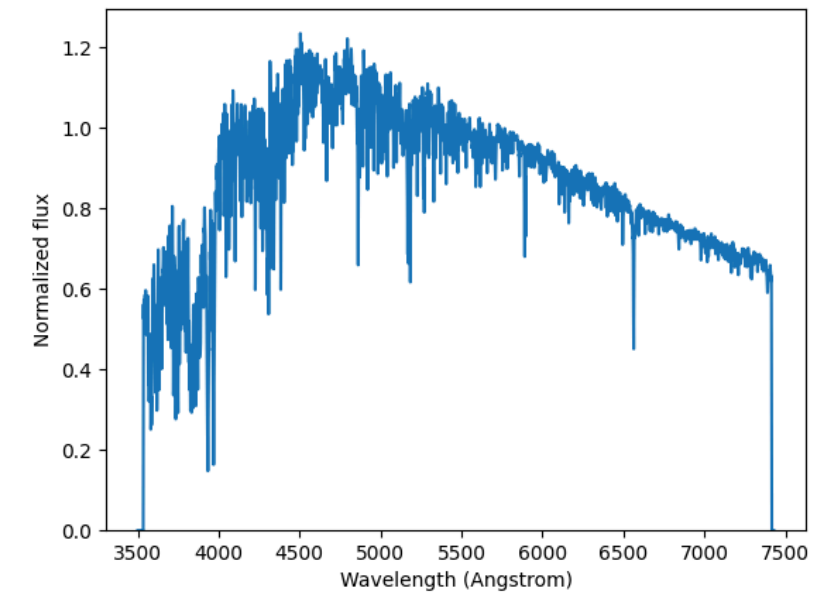
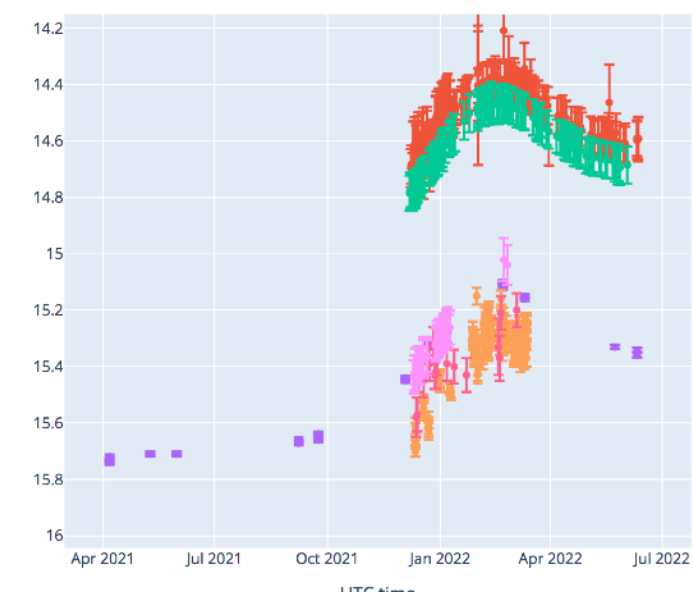
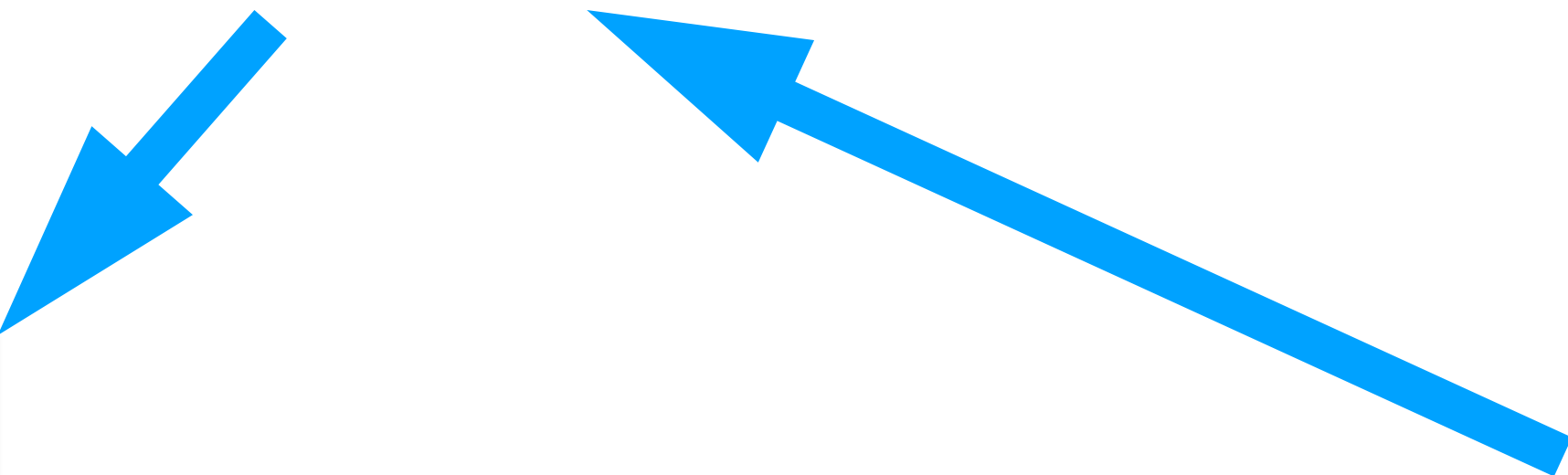


**Network of telescopes**



**Archives**

**publications**



**Science-ready data products**

# PUBLICATIONS USING BHTOM

THE ASTROPHYSICAL JOURNAL, 899:130 (8pp), 2020 August 20  
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E. Szegedi-Elek<sup>1</sup>, P. Abraham<sup>1,2</sup>, Ł. Wyrzykowski<sup>3</sup>, M. Kun<sup>1</sup>, Á. Kóspál<sup>1,2,4</sup>, L. Chen<sup>1</sup>, G. Marton<sup>1,2</sup>, A. Moór<sup>1,2</sup>, C. Kiss<sup>1,2</sup>, A. Pál<sup>1,2,5</sup>, L. Szabados<sup>1</sup>, J. Varga<sup>1,6</sup>, E. Varga-Verebélyi<sup>1</sup>, C. Andreas<sup>7</sup>, E. Bachelet<sup>8</sup>, R. Bischoff<sup>7</sup>, A. Bódi<sup>1,9</sup>, E. Breedt<sup>10</sup>, U. Burgaz<sup>11,12</sup>, T. Butterley<sup>13</sup>, J. M. Carrasco<sup>14</sup>, V. Čepas<sup>15</sup>, G. Damjanovic<sup>16</sup>, I. Gezer<sup>3</sup>, V. Godunova<sup>17</sup>, M. Gromadzki<sup>3</sup>, A. Gurgul<sup>3</sup>, L. Hardy<sup>18</sup>, F. Hildebrandt<sup>7</sup>, S. Hoffmann<sup>7</sup>, M. Hundertmark<sup>19</sup>, N. Ihanec<sup>3</sup>, R. Janulis<sup>15</sup>, Cs. Kalup<sup>1</sup>, Z. Kaczmarek<sup>3</sup>, R. Könyves-Tóth<sup>1</sup>, M. Krezinger<sup>1</sup>, K. Kruszyńska<sup>3</sup>, S. Littlefair<sup>18</sup>, M. Maskoliūnas<sup>15</sup>, L. Mészáros<sup>1</sup>, P. Mikołajczyk<sup>20</sup>, M. Mugrauer<sup>7</sup>, H. Netzel<sup>21</sup>, A. Ordasi<sup>1</sup>, E. Pakštienė<sup>15</sup>, K. A. Rybicki<sup>3</sup>, K. Sárneczky<sup>1</sup>, B. Seli<sup>1</sup>, A. Simon<sup>22</sup>, K. Šiškauskaitė<sup>15</sup>, Á. Sódor<sup>1</sup>, K. V. Sokolovsky<sup>23,24,25</sup>, R. Szakáts<sup>1</sup>, L. Tomasella<sup>26</sup>, Y. Tsapras<sup>19</sup>, K. Vida<sup>1,2</sup>, J. Zdanavičius<sup>15</sup>, M. Zieliński<sup>3</sup>, P. Z

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



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

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

## AT2021uey: A planetary microlensing event outside the Galactic bulge

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

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

Łukasz Wyrzykowski<sup>1,\*,\*</sup>, P. Mróz<sup>1</sup>, K. A. Rybicki<sup>1</sup>, M. Gromadzki<sup>1</sup>, Z. Kołaczekowski<sup>45,79</sup>, M. Zieliński<sup>1</sup>, P. Zieliński<sup>1</sup>, N. Britavskiy<sup>4,15</sup>, A. Gomboc<sup>35</sup>, K. Sokolovsky<sup>19,31,66</sup>, S.T. Hodgkin<sup>6</sup>, L. Abe<sup>89</sup>, G.F. Aldi<sup>20,80</sup>, A. AlMannai<sup>62,100</sup>, G. Altavilla<sup>72,7</sup>, A. Al Qasim<sup>62,100</sup>, G.C. Anupama<sup>8</sup>, S. Awiphan<sup>9</sup>, E. Bachelet<sup>63</sup>, V. Bakis<sup>10</sup>, S. Baker<sup>100</sup>, S. Bartlett<sup>50</sup>, P. Bendjoya<sup>11</sup>, K. Benson<sup>100</sup>, I.F. Bikmaev<sup>76,87</sup>, G. Birenbaum<sup>112</sup>, N. Blagorodnova<sup>24</sup>, S. Blanco-Cuaresma<sup>15,74</sup>, S. Boeva<sup>16</sup>, A.Z. Bonanos<sup>19</sup>, V. Bozza<sup>20,80</sup>, D.M. Bramich<sup>62</sup>, I. Bruni<sup>25</sup>, R.A. Burenin<sup>84,85</sup>, U. Burgaz<sup>21</sup>, T. Butterley<sup>22</sup>, H. E. Caines<sup>34</sup>, D. B. Caton<sup>93</sup>, S. Calchi Novati<sup>83</sup>, J.M. Carrasco<sup>23</sup>, A. Cassan<sup>29</sup>, V. Čepas<sup>56</sup>, M. Cropper<sup>100</sup>, M. Chruslińska<sup>11,24</sup>, G. Clementini<sup>25</sup>, A. Clerici<sup>35</sup>, D. Conti<sup>91</sup>, M. Conti<sup>48</sup>, S. Cross<sup>63</sup>, F. Cusano<sup>25</sup>, G. Damjanovic<sup>26</sup>, A. Dapergolas<sup>19</sup>, G. D'Agó<sup>81</sup>, J. H. J. de Bruijne<sup>27</sup>, M. Dennefeld<sup>29</sup>, V. S. Dhillon<sup>30,4</sup>, M. Dominik<sup>31</sup>, J. Dziedzic<sup>1</sup>, O. Erceg<sup>32</sup>, M. V. Eiselevich<sup>86</sup>, H. Esenoglu<sup>33</sup>, L. Eyer<sup>74</sup>, R. Figuera Jaimés<sup>31,53</sup>, S. J. Fossey<sup>34</sup>, A. I. Galeev<sup>76,87</sup>, S. A. Grebenev<sup>84</sup>, A. C. Gupta<sup>99</sup>, A. G. Gutae<sup>76</sup>, N. Hallakoun<sup>112</sup>, A. Hamanowicz<sup>11,36</sup>, C. Han<sup>2</sup>, B.

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

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

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

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THE ASTROPHYSICAL JOURNAL, 899:130 (8pp), 2020 August 20  
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## Gaia 18dvy: A New FUor in the Cygnus OB3 Association

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY  
 MNRAS 515, 1774–1787 (2022)  
 Advance Access publication 2022 July 12  
<https://doi.org/10.1093/mnras/stac1915>

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

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

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

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

Jujia Zhang,<sup>1,2,3,4\*</sup> Xiaofeng Wang,<sup>5,6</sup> József Vinkó<sup>7,8,9</sup>, Alexei V. Filippenko,<sup>12,13</sup> Thomas G. Brink,<sup>12</sup> Wei-Kang Przemysław Mikołajczyk,<sup>14</sup> Fang Huang,<sup>15</sup> Xinhao Zhang,<sup>5</sup> Huijuan Wang,<sup>10,11</sup> James A. Bódi,<sup>7,18</sup> G. Csörnyei,<sup>7,8</sup> O. Hanyecz,<sup>7</sup> I. R. Könyves-Tóth,<sup>7,8</sup> A. Ordasi,<sup>7</sup> A. Pál,<sup>7,8</sup> G. Zsidi<sup>7,8,19</sup>

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### Gaia21elv

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