Spectroscopic classification of microlensing events alerted by Gaia

or why we do not trust Gaia parallax measurements?

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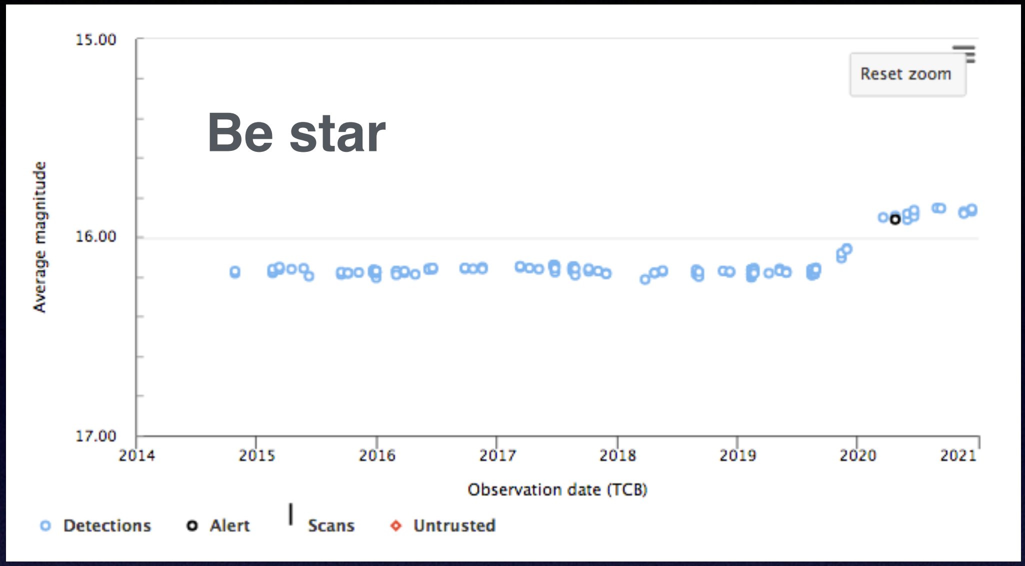
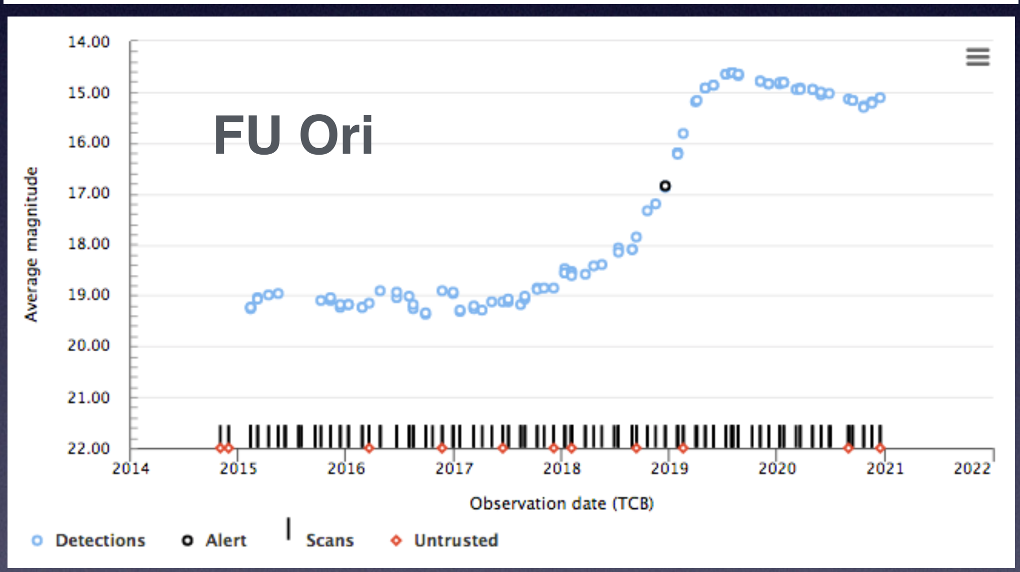
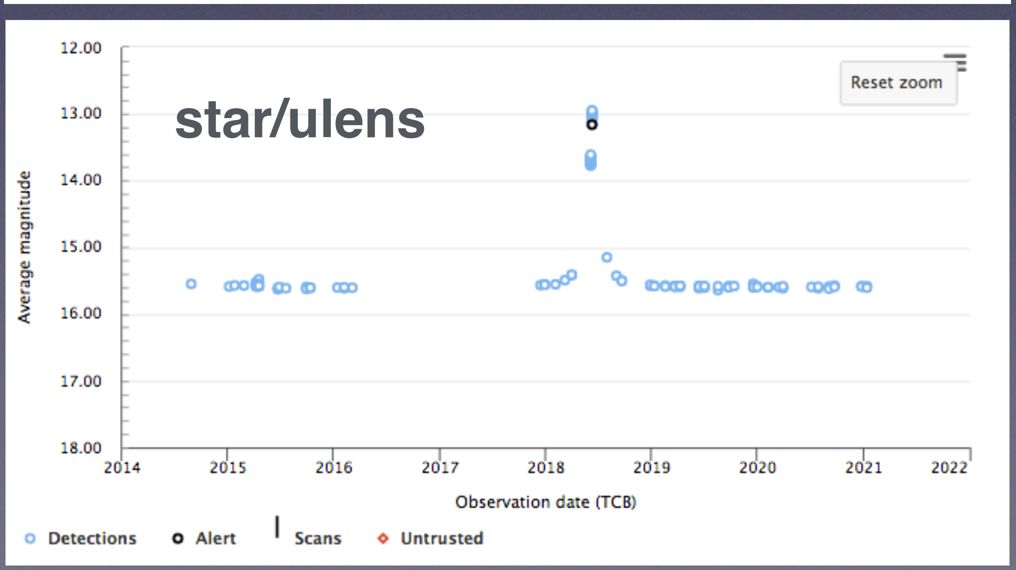
- INT Support Astronomers
- NOT Suport Astronomers
- VLT Support Astronomers
- **Klaus G. Strassmeier, Ilya Ilyin** and Large Binocular Telescope Team

Why do we need spectroscopy?

- to distinguish genuine microlensing events from other types of outbursts and variables (Be-type stars, YSOs, AGBs, CVs, etc.)
- to select a sample of microlensing events for which an intensive ground-based follow-up monitoring is continued
- Gaia Alerts are usually not classified by AlertPipe, only ~25% of objects is classified
- the most interesting targets can be studied in detail - determination of stellar parameters, line-of-sight extinction, etc.
- to get spectroscopic distance estimation to the source - essential in solving the microlensing model



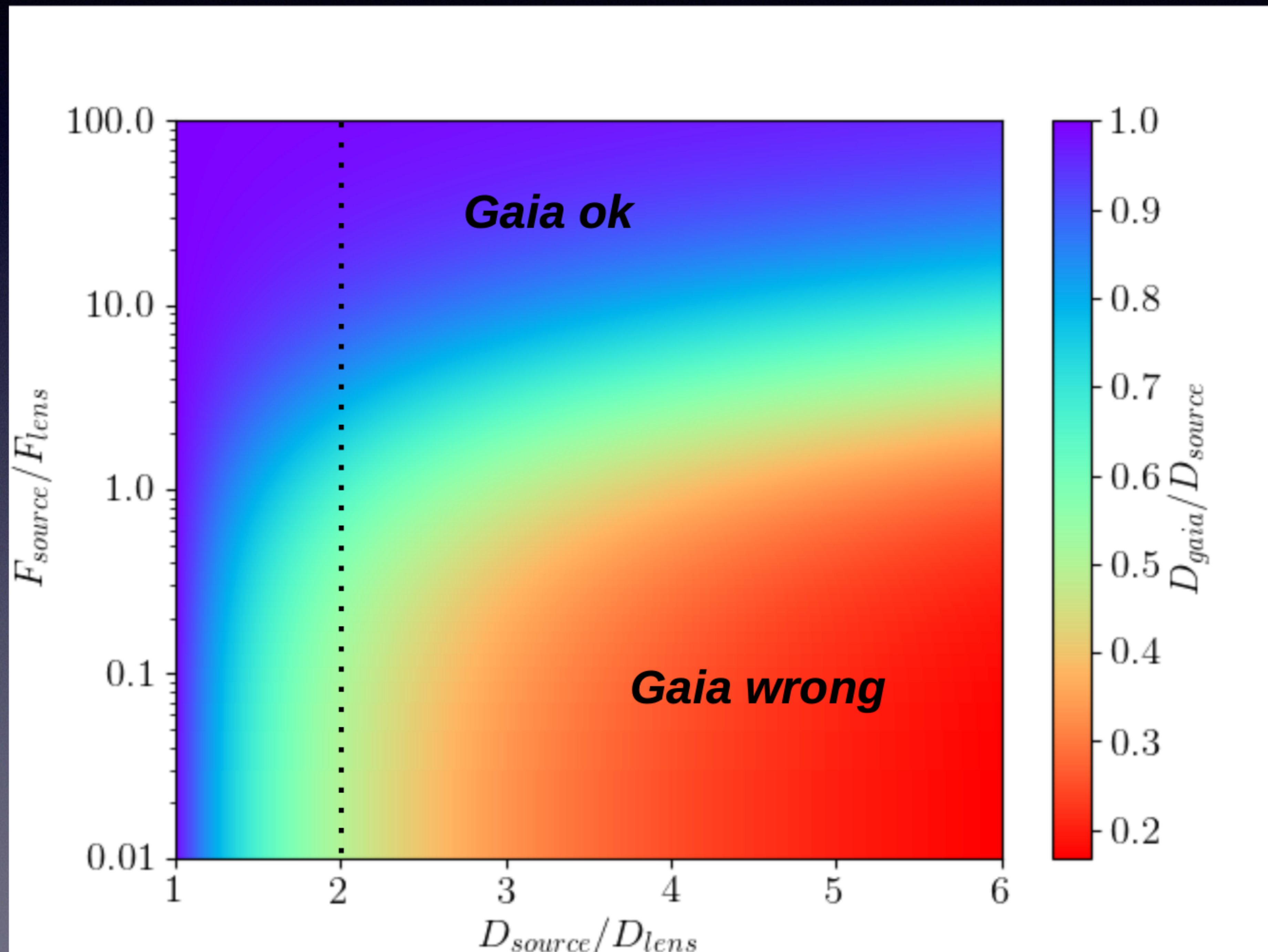




But there are Gaia parallaxes…

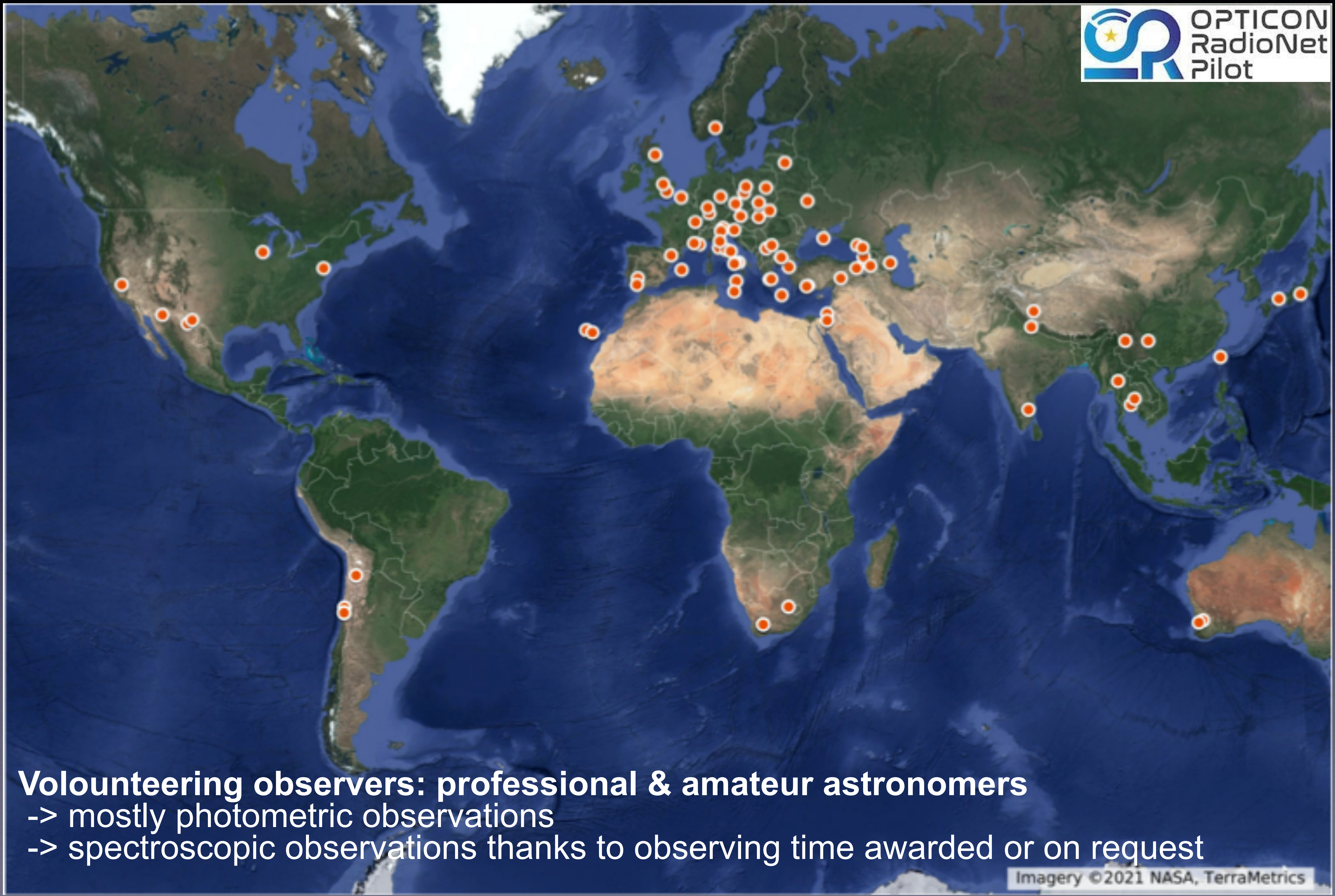
Gaia mission delivers precise parallax measurements among others, but for some objects, e.g., microlensing events, this measurement can be wrong due to astrometric microlensing (centroid shift motion during the event)

- F_{source} - flux from the source
- F_{lens} - flux from the lens
- D_{source} - distance to the source
- D_{lens} - distance to the lens
- D_{gaia} - distance from parallax measured by Gaia
- Red colours indicate where Gaia severely underestimates the distance of the source and claims <30% of the real value
- For the most typical distances in the Milky Way (dotted line), Gaia distances give ~80% of real values even if the source is 10 times brighter than the lens



Courtesy: Krzysztof Rybicki

ORP follow-up network



Volounteering observers: professional & amateur astronomers

-> mostly photometric observations

-> spectroscopic observations thanks to observing time awarded or on request

Telescopes in use

- for low-resolution spectra

2-m ShAO/UAGS
R ~ 2000

10-m SALT/RSS
R ~ 1000

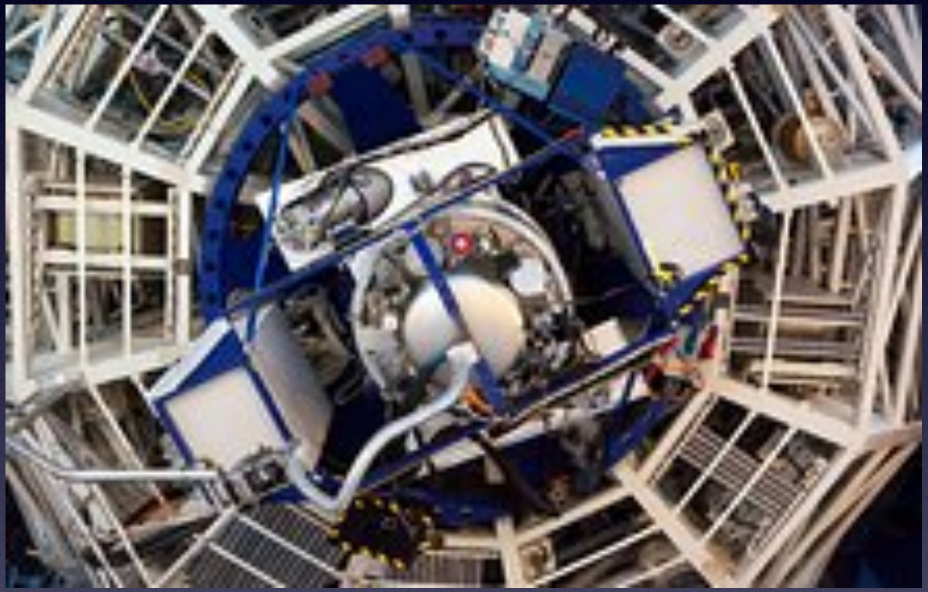
2-m LT/SPRAT
R ~ 350

8-m Gemini/GMOS N&S
R ~ 2000

Telescopes in use

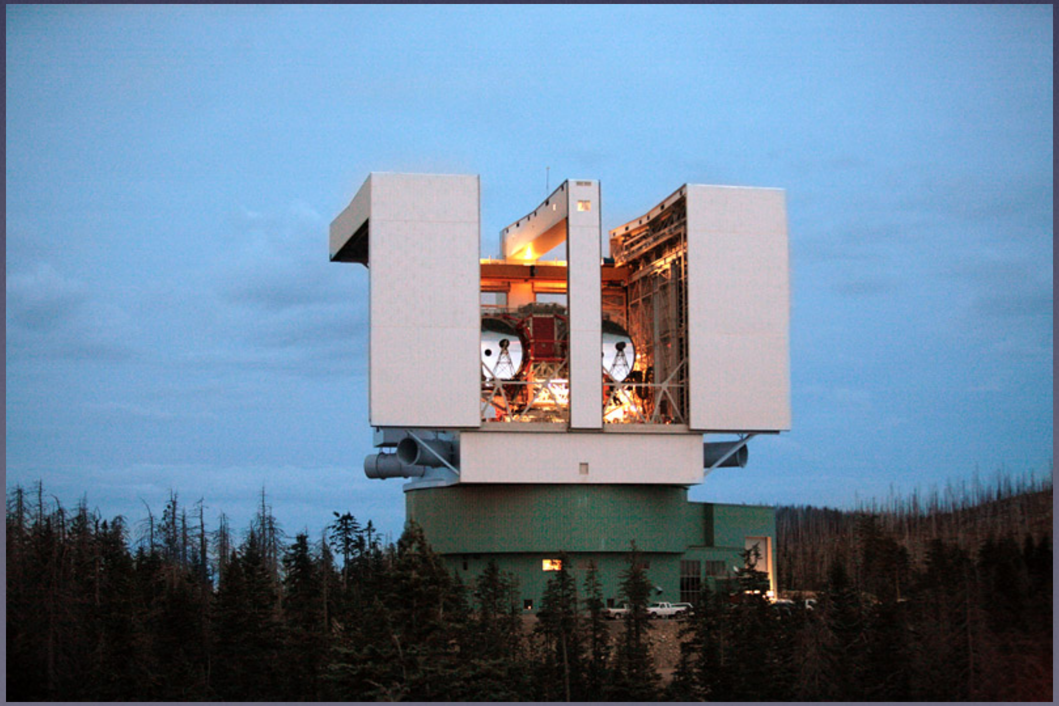
- for high-resolution spectra

8-m VLT/X-Shooter
R ~ 17000



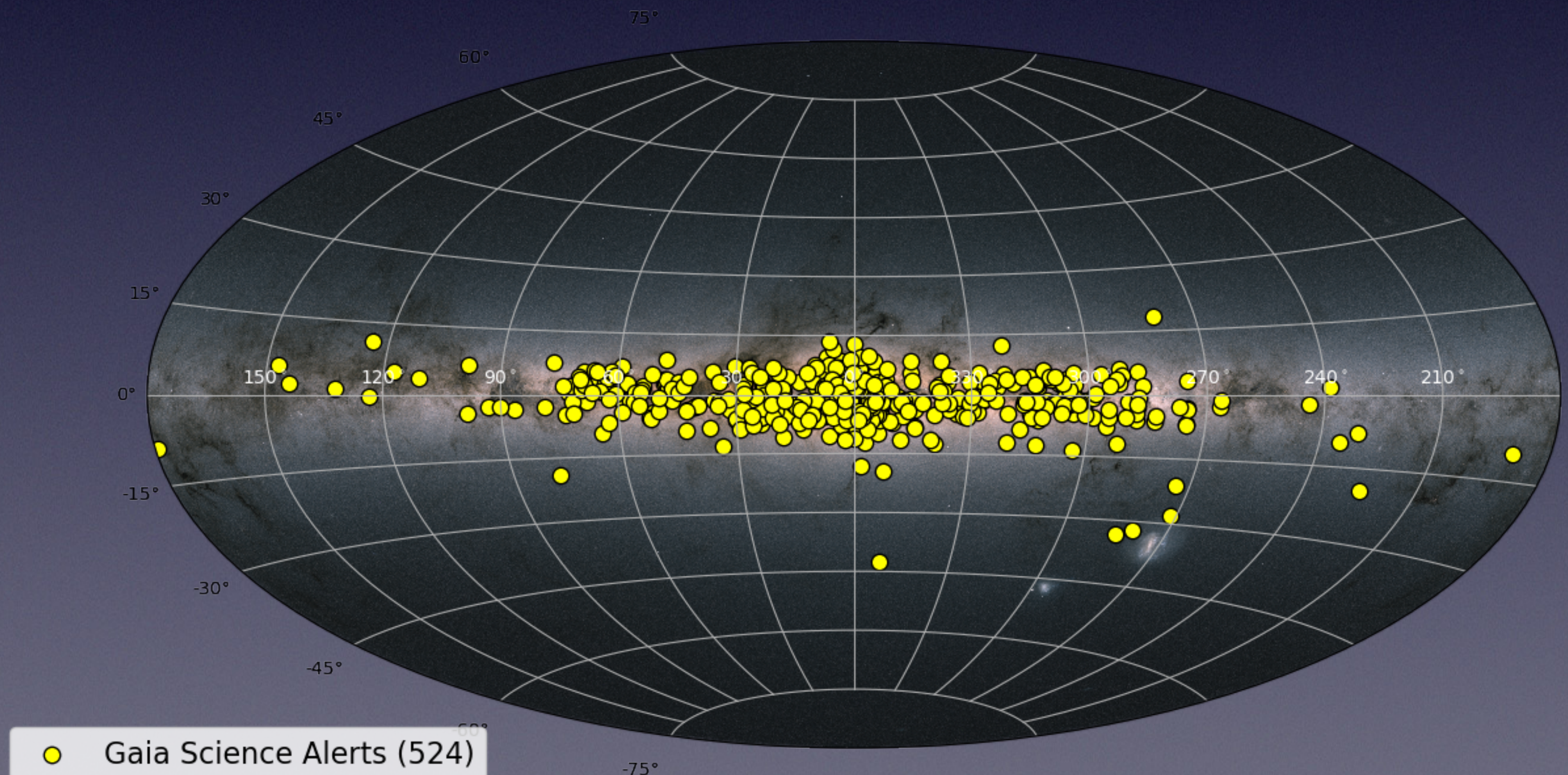
10-m SALT/HRS
R ~ 40000

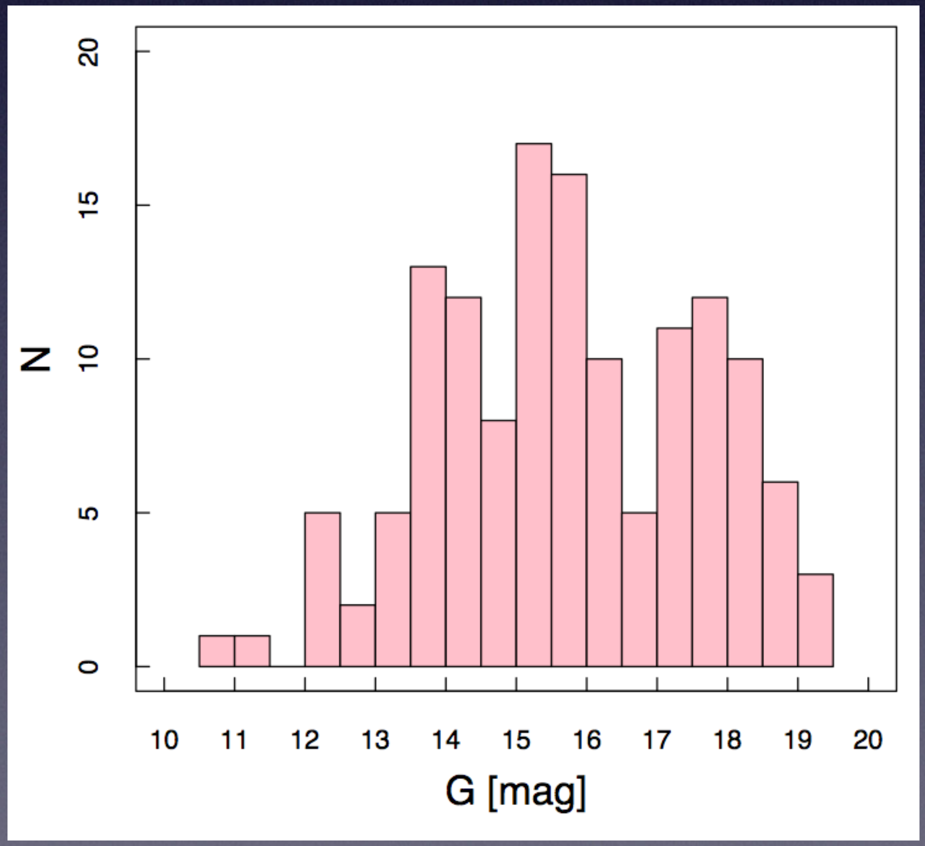
2x8.4-m LBT/PEPSI
R < 250000



Observed targets

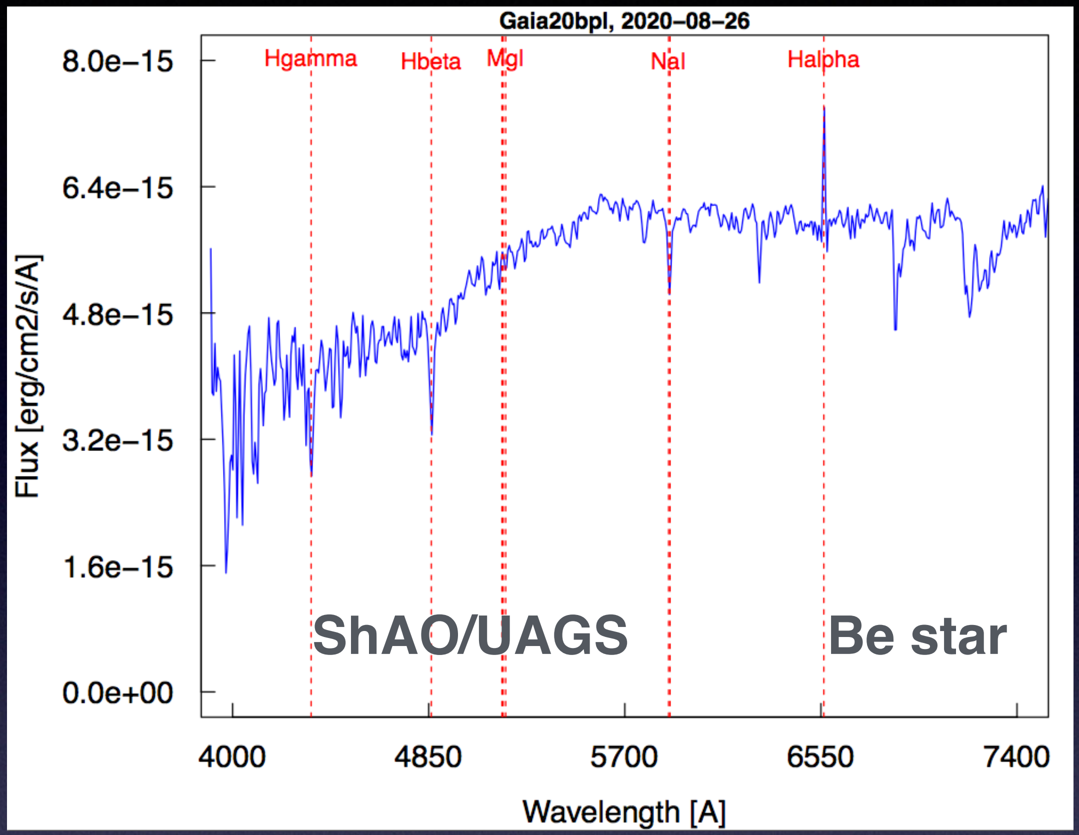
- **524** microlensing event candidates detected by Gaia until now
- spectra collected for **190** objects (low- and high-resolution in total)
- high-resolution data for **35** targets

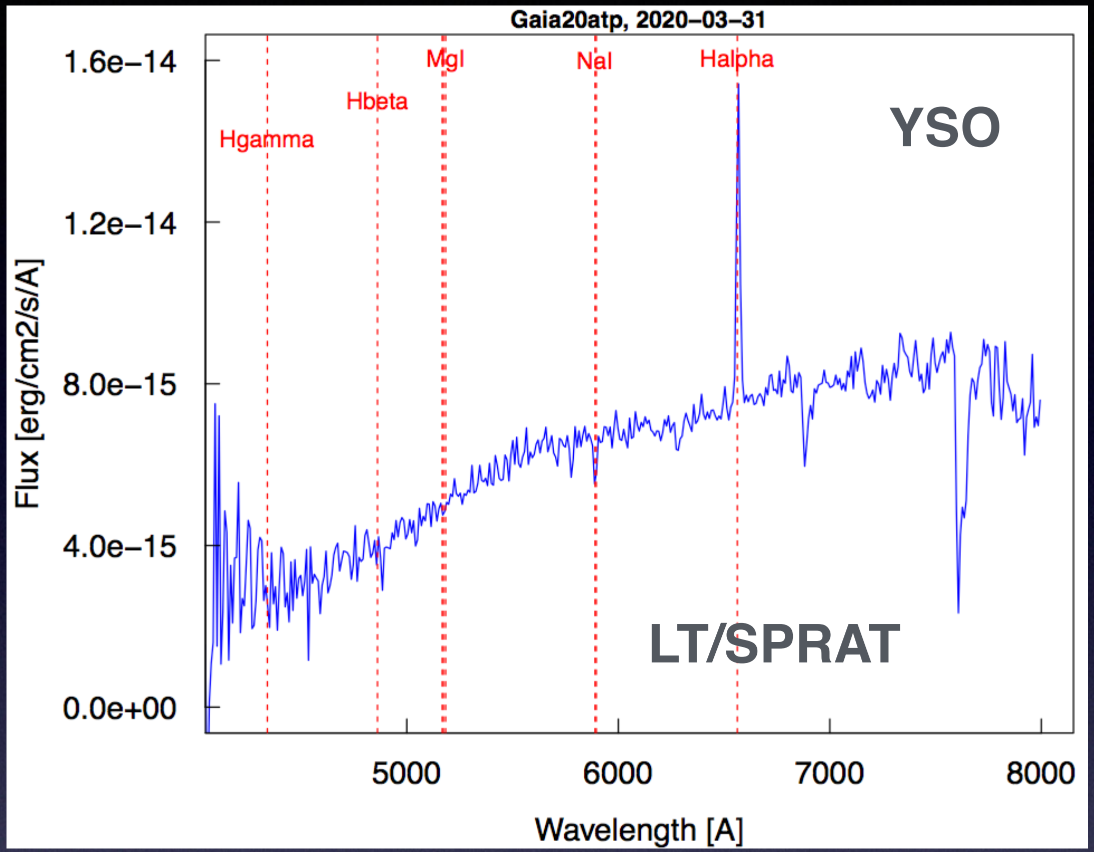


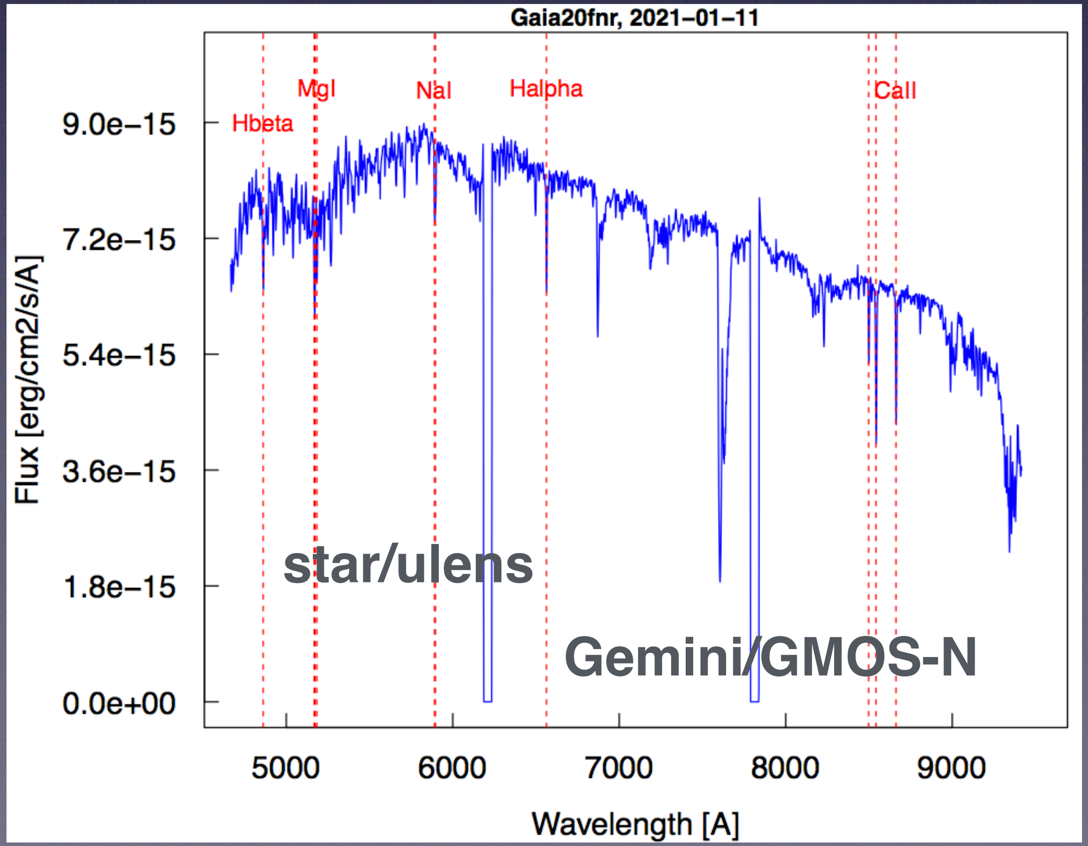


Courtesy: Katarzyna Kruszyńska

Low-res data







- classification of Gaia Alerts based on prominent spectral features and shape of the continuum

- division on two groups:
  -> **ulens** („normal" stars) and
  -> **non-ulens** (Be stars, YSOs, CVs, Miras, etc.)

High-res data

- absorption line analysis - parameters determination (Teff, logg, [M/H])
- synthetic spectra modelling based on ATLAS9 and/or MARCS models, different radiative transfer codes implemented in *iSpec* framework (Blanco-Cuaresma 2019)
- matching of obtained spectra with templates (low-res and high-res) - extinction in the direction to the source

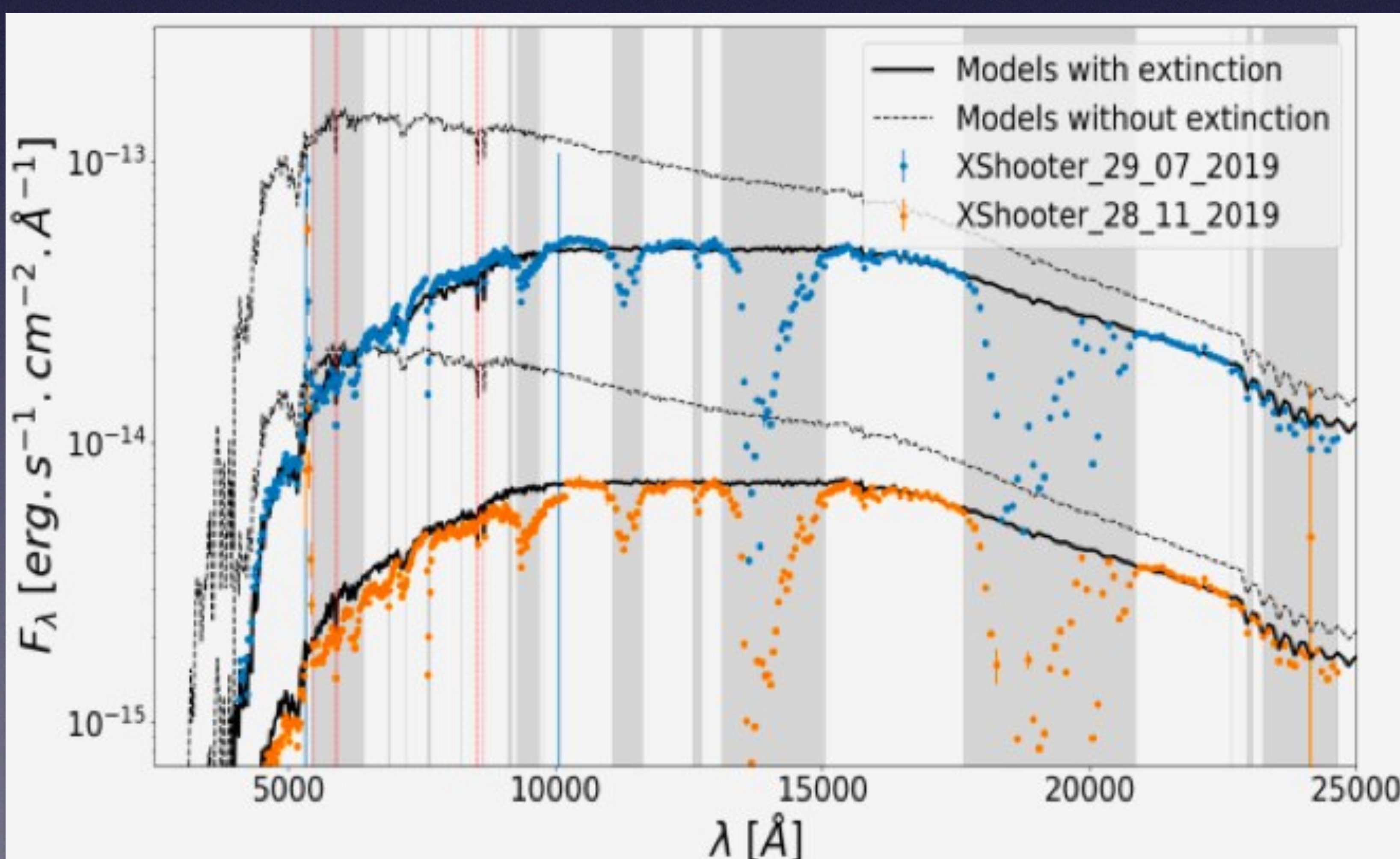
Teff, logg, [M/H]

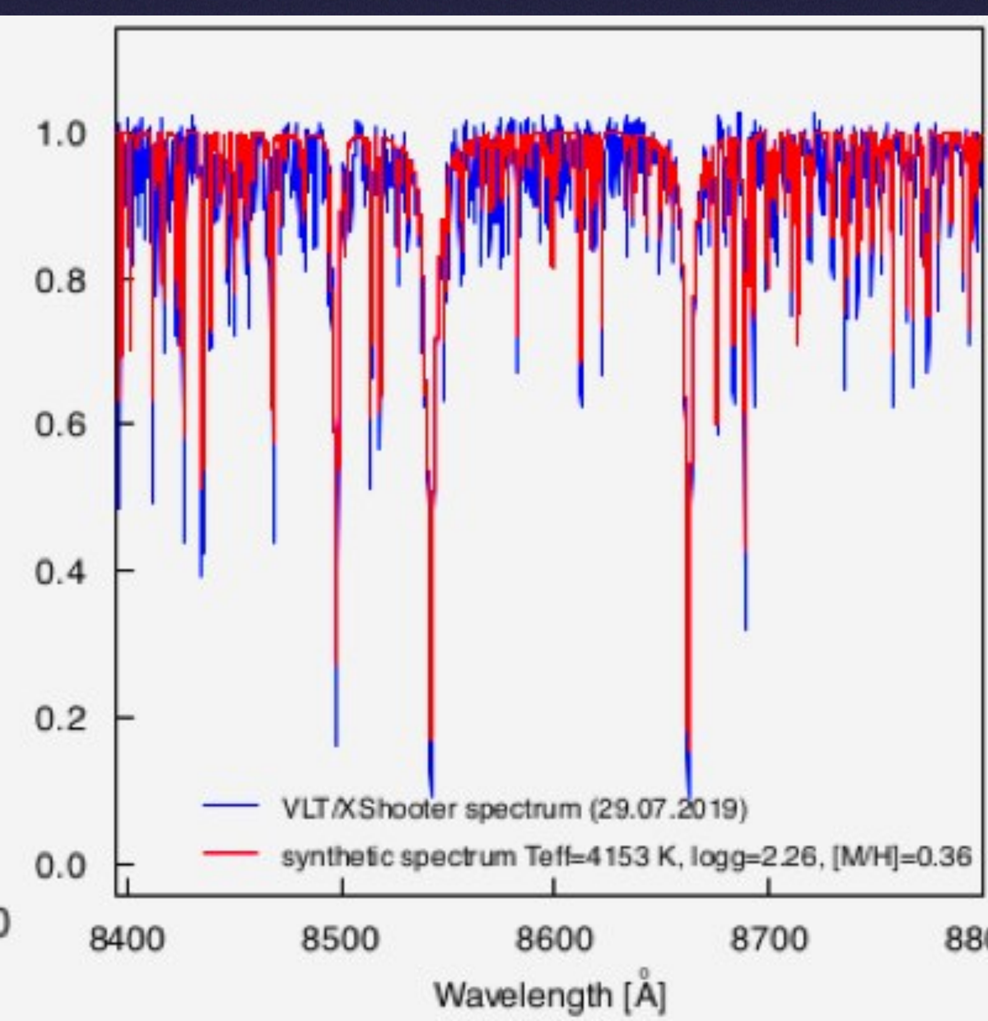
↓ **stellar isochrones, empirical relations**

R, M, Mv, Av

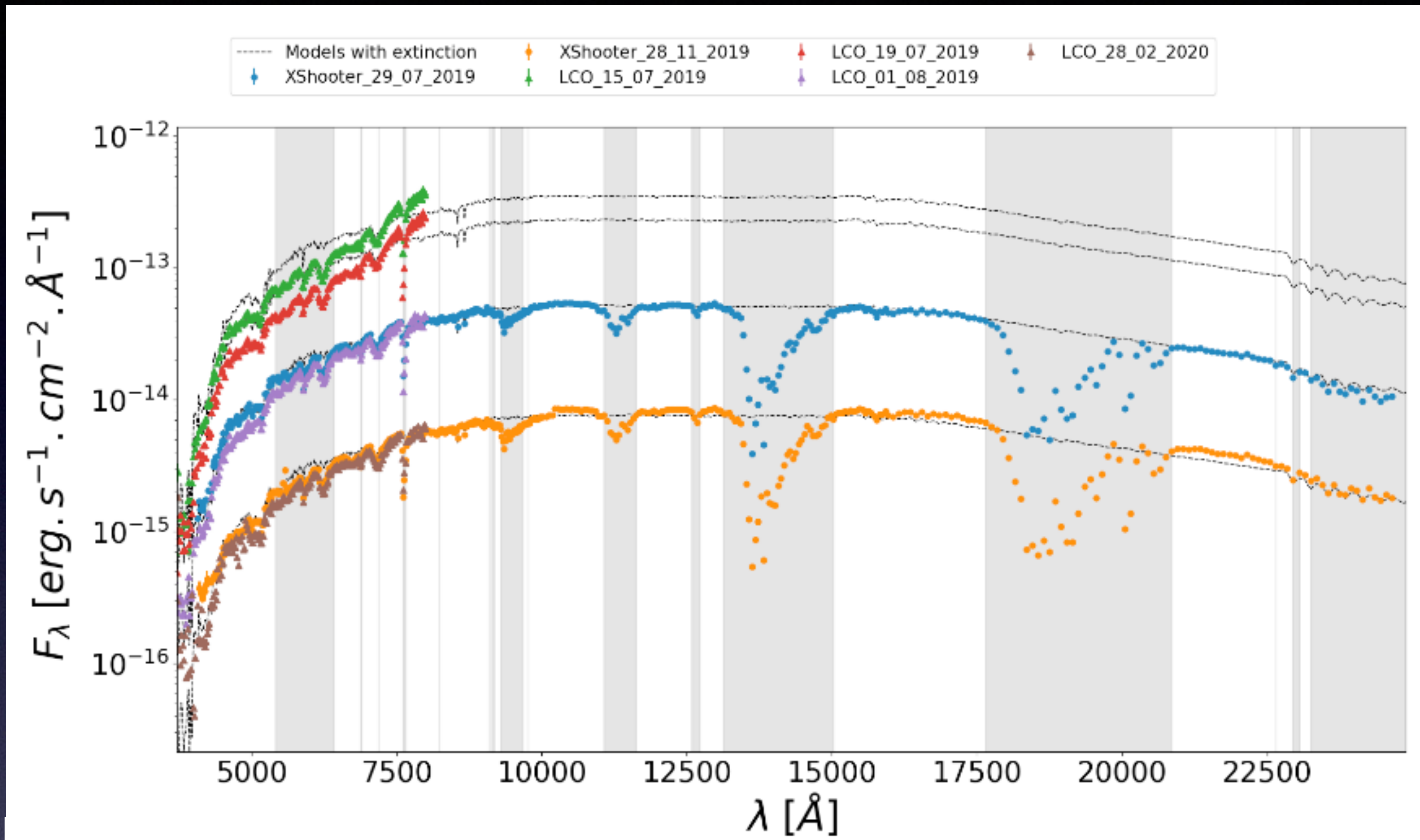
↓ **+ visual magnitude**

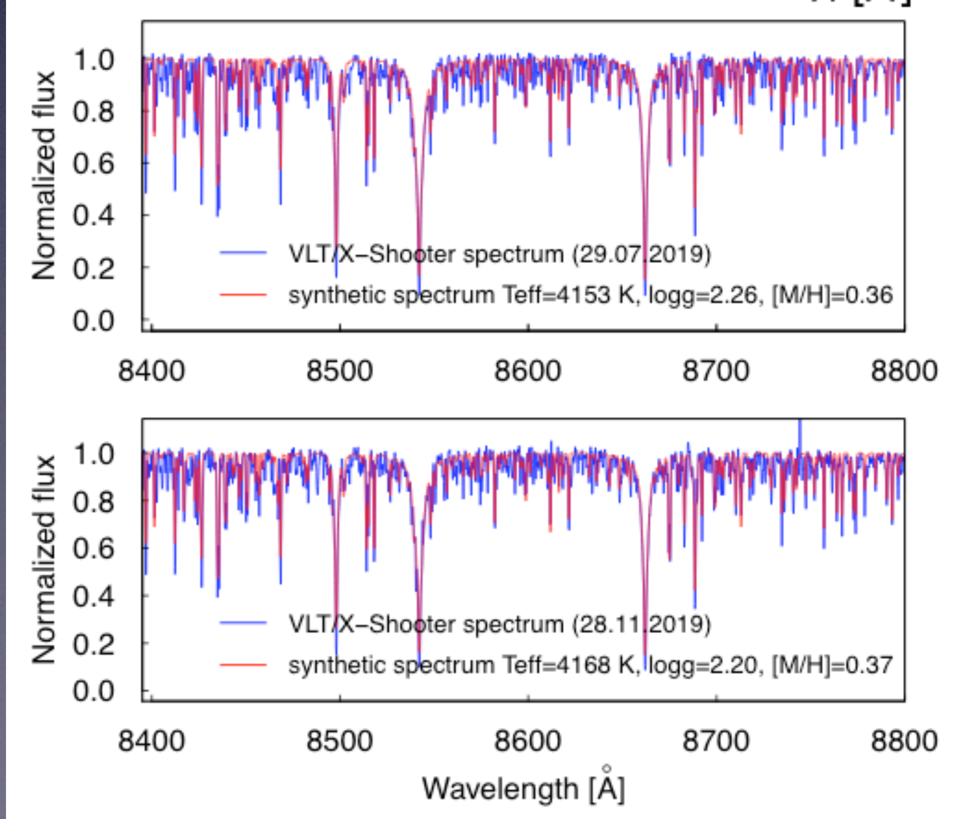
Ds





Gaia19bld





Teff = 4159 +/- 139 K
logg = 1.89 +/- 0.42
[M/H] = 0.42 +/- 0.20 dex
Mv = -1.0 +/- 0.3 mag
Av = 2.23 +/- 0.07 mag
Ds = 8.4 +1.4/-1.8 kpc

Ds_DR2 = 8.9 +2.7/-1.8 kpc
(Bailer-Jones et al. 2018)

Bachelet, Zieliński et al. 2022
Rybicki et al. 2022
Cassan et al. 2022

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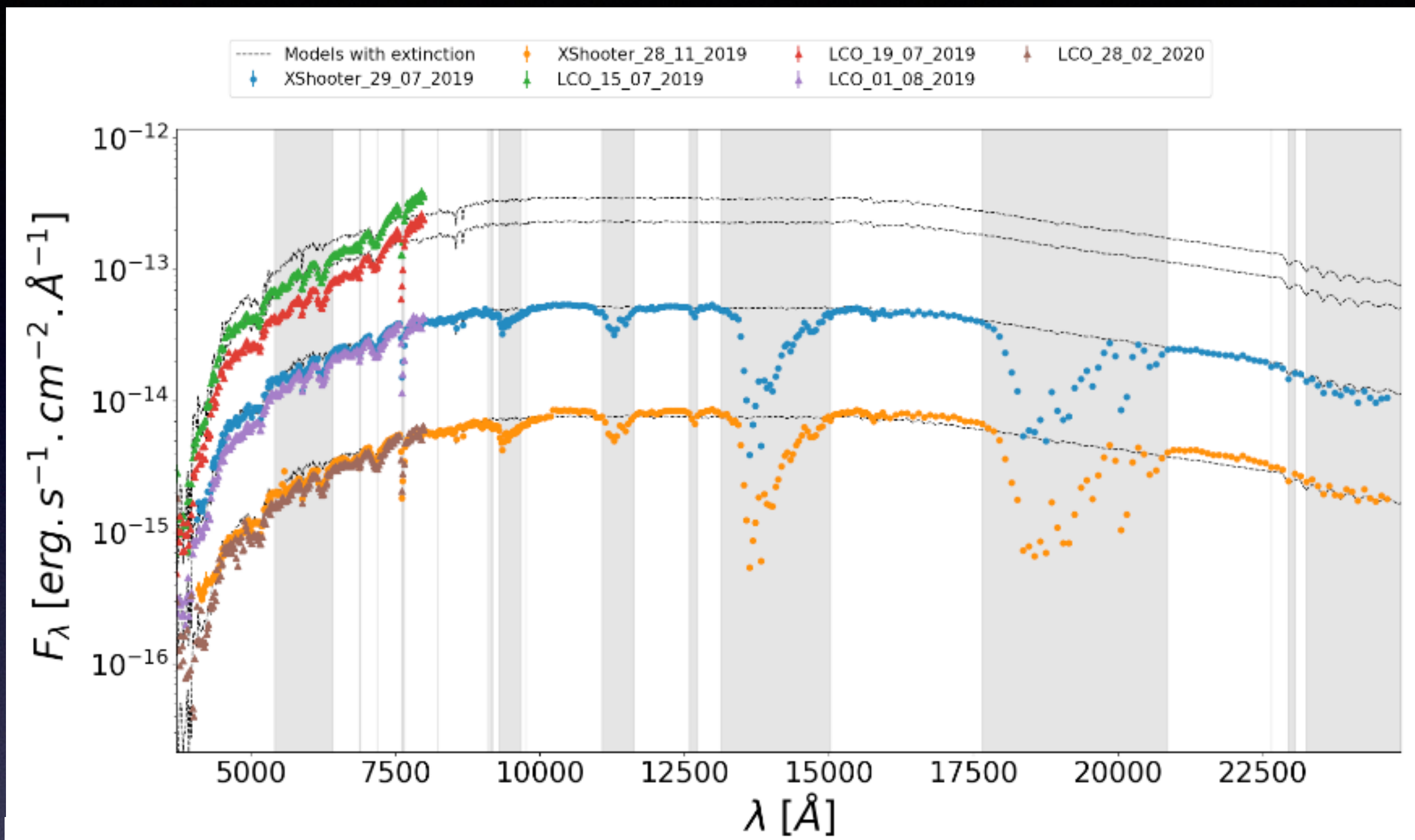

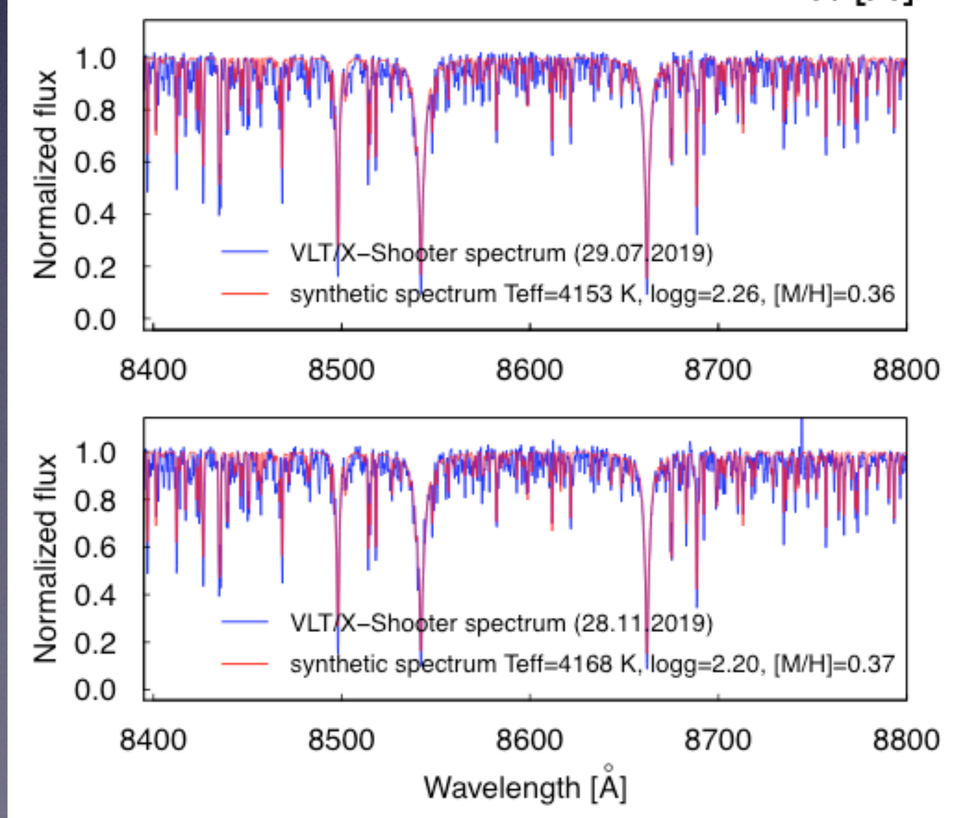

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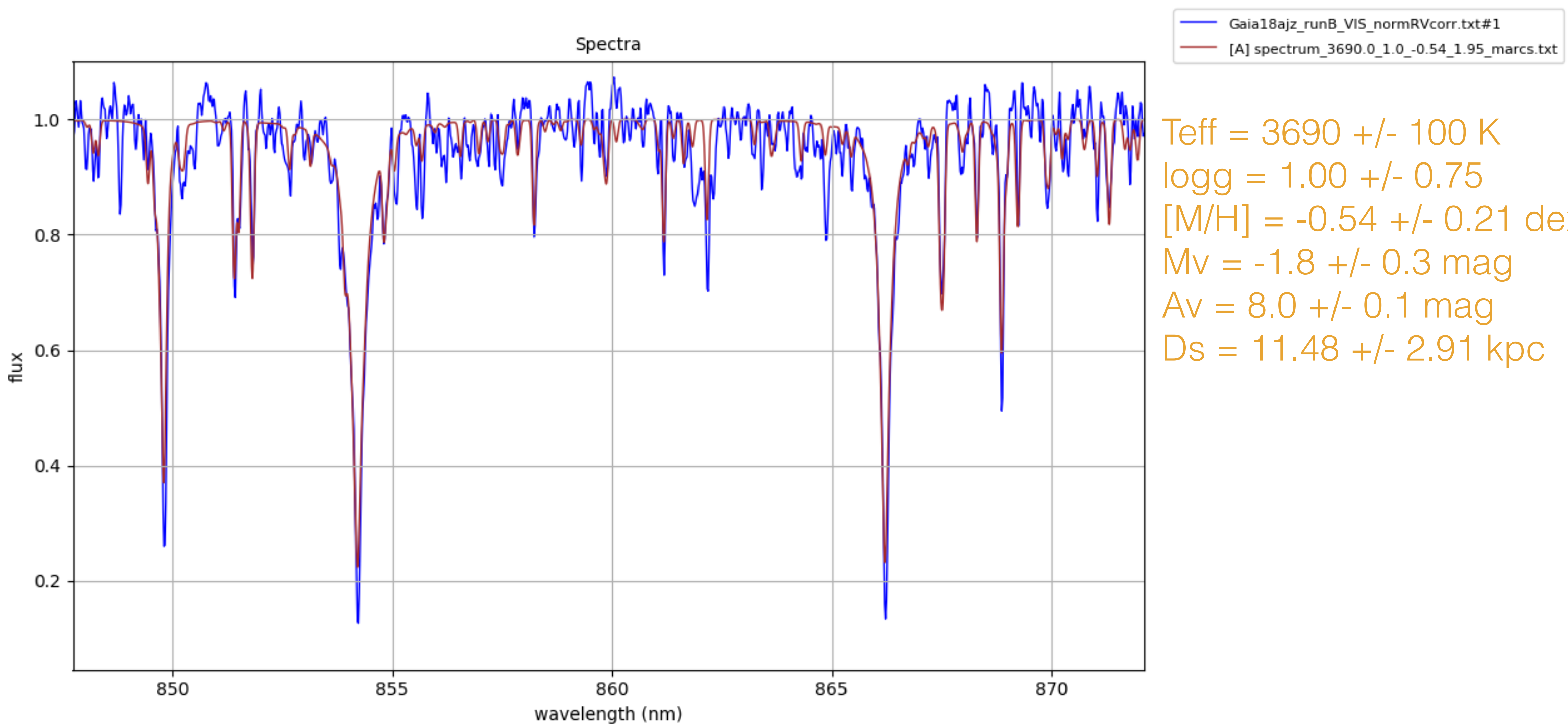
Gaia parallax: 0.08 +/- 0.02 mas
RUWE = 0.99

Bachelet, Zieliński et al. 2022
Rybicki et al. 2022
Cassan et al. 2022

Gaia18ajz

Distance source	GaiaDR2 Bailer-Jones et al. (2018)	GaiaEDR3-geo	GaiaEDR3-photogeo	Spectroscopic distance our work
		Bailer-Jones et al. (2021)		
Values [kpc]	$3.62^{+6.03}_{-2.28}$	$3.39^{+5.35}_{-2.29}$	$4.41^{+5.79}_{-3.07}$	11.48 ± 2.91



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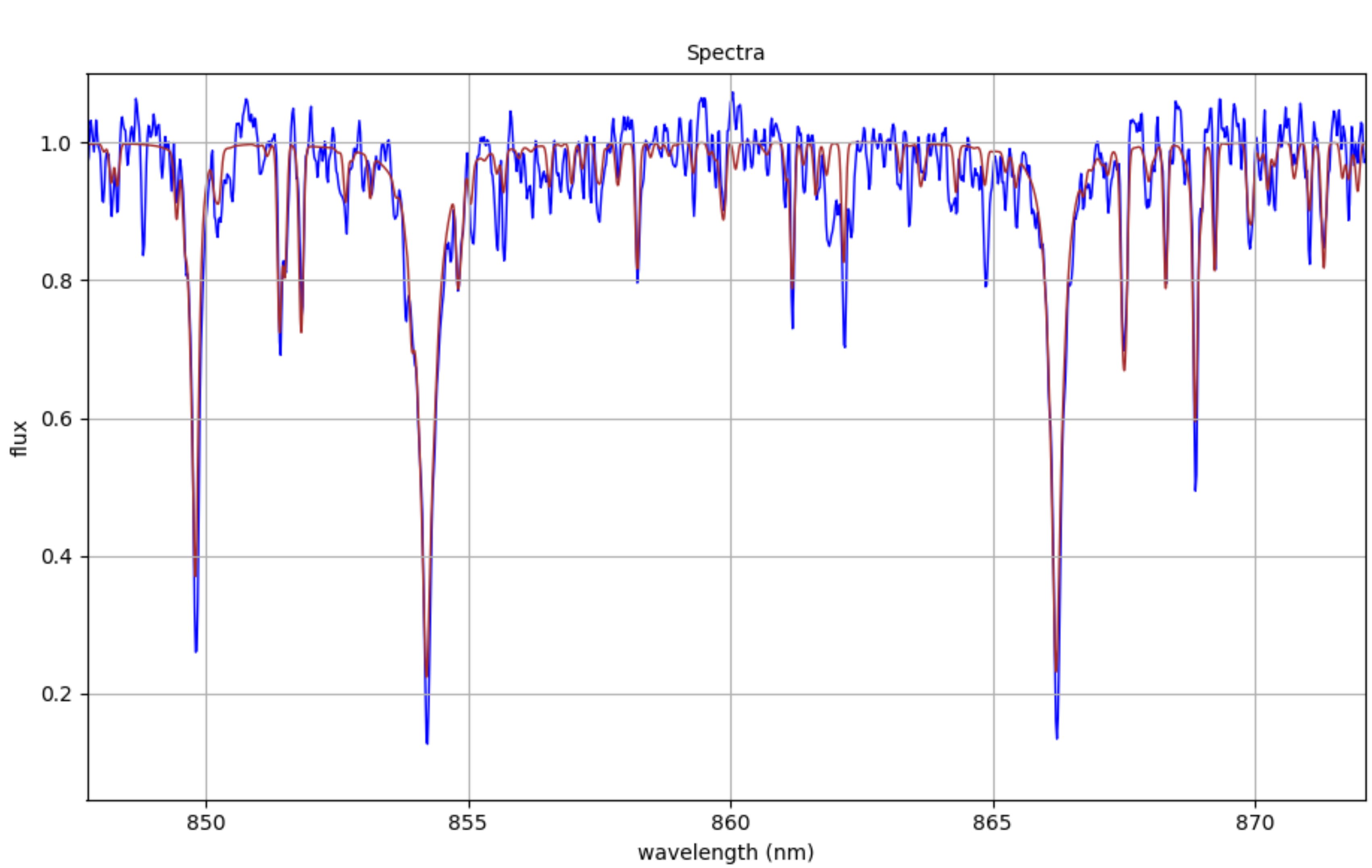

Teff = 3690 +/- 100 K
logg = 1.00 +/- 0.75
[M/H] = -0.54 +/- 0.21 dex
Mv = -1.8 +/- 0.3 mag
Av = 8.0 +/- 0.1 mag
Ds = 11.48 +/- 2.91 kpc

Gaia parallax:
1.52 +/- 0.54 mas
RUWE = 1.53
(>1.4 limit of tolerance)

Summary

- Follow-up spectroscopy is crucial for classification of microlensing events and target selection for further monitoring
- **27%** of observed targets classified as microlensing events, and **73%** as other stars (Be stars, YSOs, CVs, etc.)
- Detailed analysis also possible - physical parameters determination (Teff, logg, [M/H]) and line-of-sight extinction (Av)
- Spectroscopic + photometric analysis in progress - more results will be published soon!
- Independent way for distance estimation that can be compared with other measurements, i.e. Gaia parallaxes (looking for systematic effects for objects with big errors and high RUWE)
- Be careful when using Gaia parallaxes!

Thank you!

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