Prediction and Search for free-floating planets in the KMTNet survey

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Microlensing Free-floating planets (FFPs)

Planetary mass

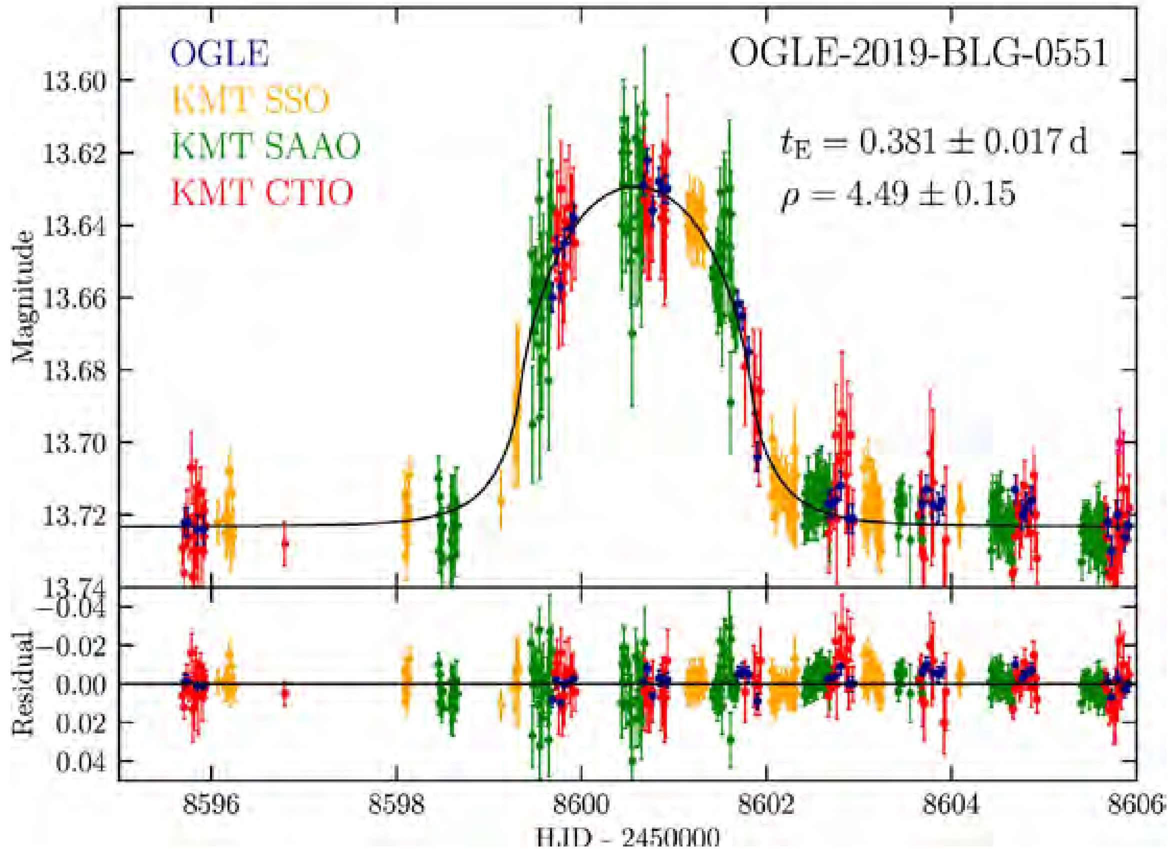
⇩

Short timescale $t_{\mathrm{E}} \lesssim 1\ d$

Small $\boldsymbol{\theta_E}$ $(\sim\boldsymbol{\mu as})$

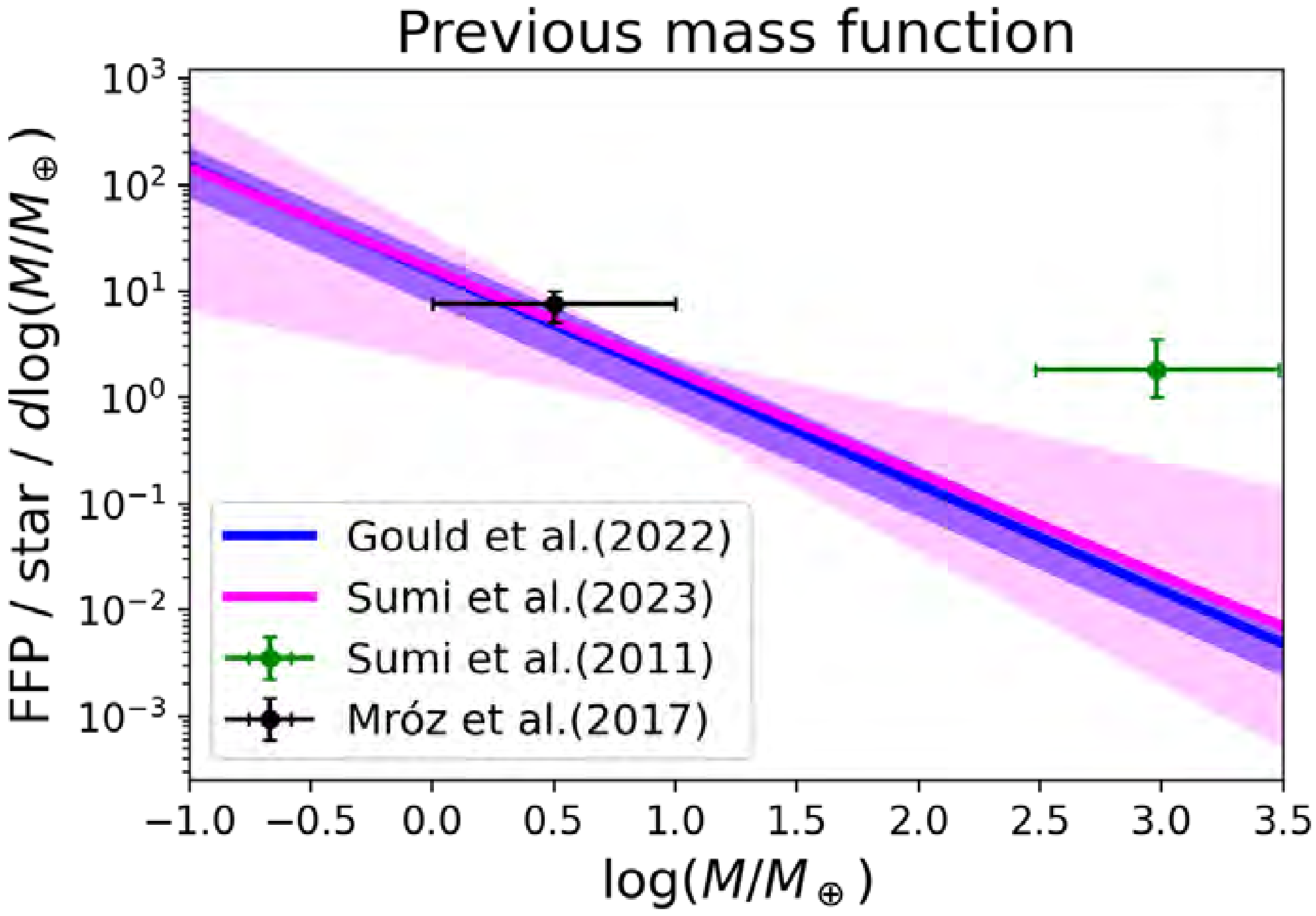
⇩

Finite source point lens (FSPL) effect



Mróz et al. 2020

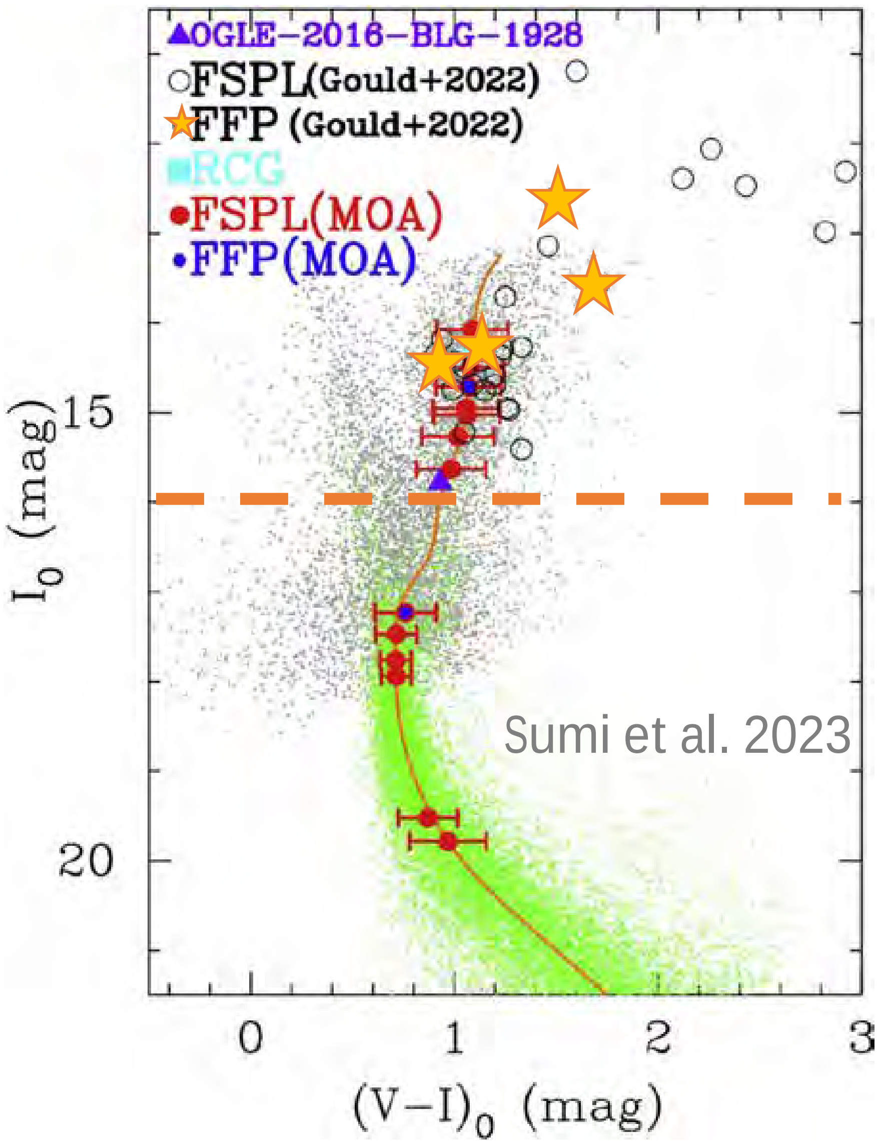
Free-floating planets are common



However…

Survey	Minimum of θ_E (μas)
OGLE	0.842 ± 0.064
MOA	0.90 ± 0.14
KMT	4.35 ± 0.34

KMT search strategy: Giant source



Why Giant source:

- High S/N
- Large angular size: FSPL effect

Total known FFP candidates:

- 4 for 6 years (2016-2022)

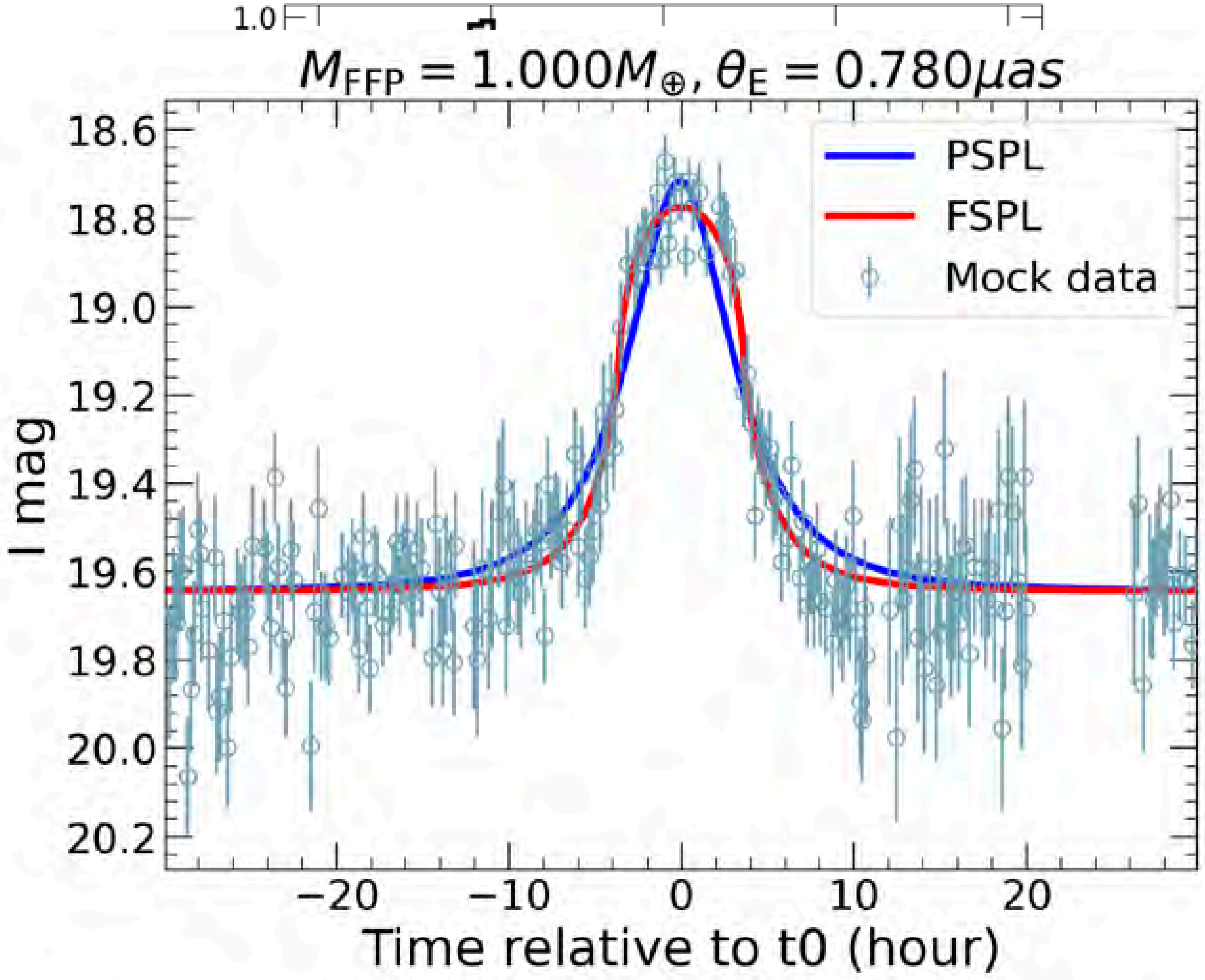
- **Only 4 with $\theta_{E,min} = 4.34\ \mu as$ on giant sources?**
- **Any beyond giant source?**

Are there more under-discovered FFPs?

Simulation → Is the number and minimal θ_{E} reasonable for KMTNet?

Systematic search → Are there *actually* more FFPs in KMTNet data?

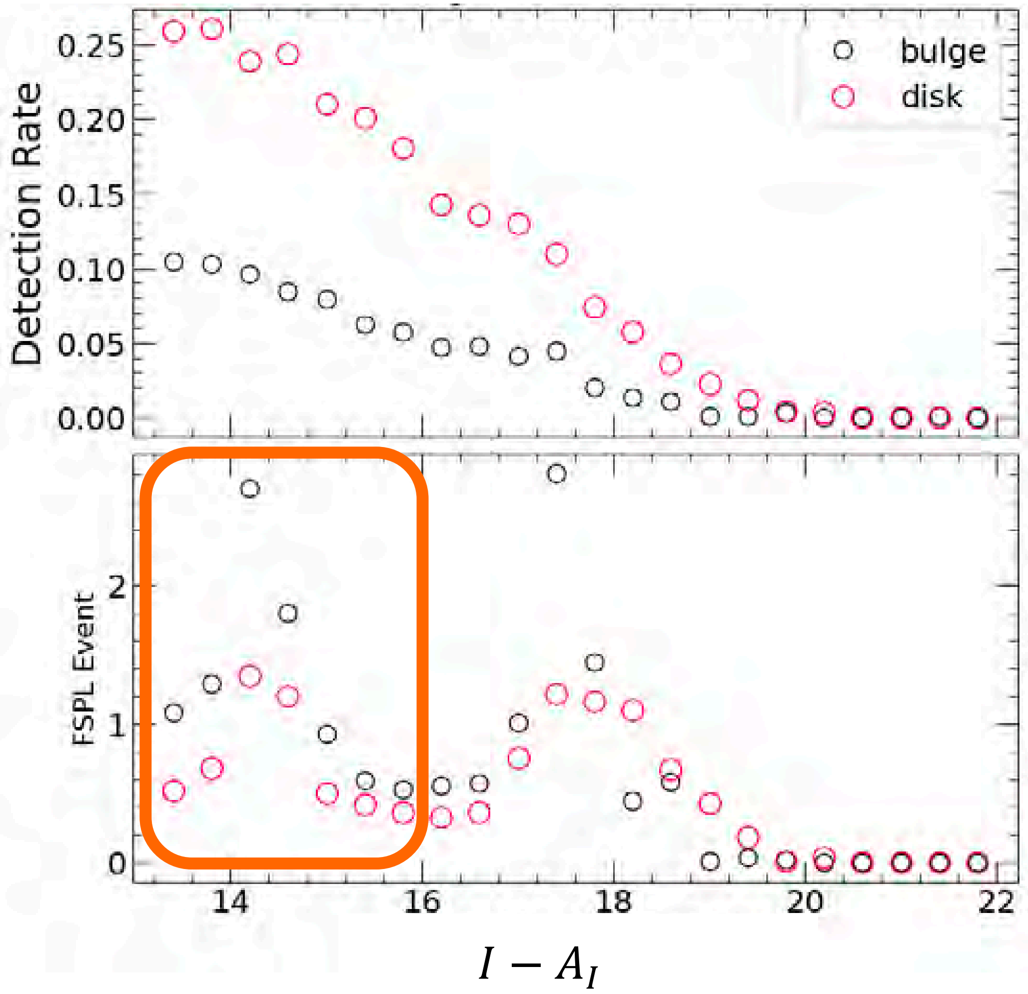
Quasi-image level simulation



Observation time and noise level from KMTNet real image

Predictions: Earth-mass FFP + Giant source

- $10^{-0.5} - 10^{0.5}\ \boldsymbol{M}_{\oplus}$, 18.79 /star (Mass function from Gould+2022)

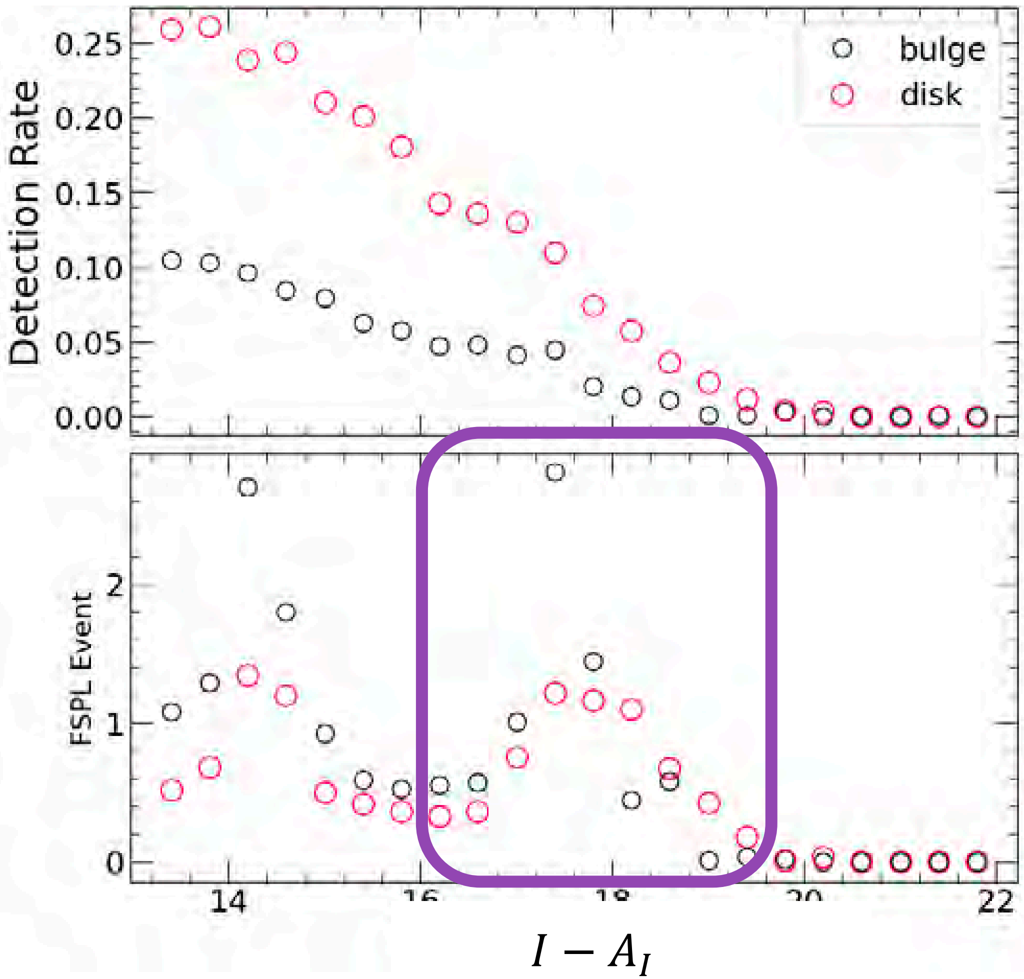


KMT 6-year survey we expect:

- Giant source: 13.9
- $\theta_{\mathrm{E},min} \sim 0.31\ \mu as$
- $\theta_{\mathrm{E}} < 1\ \mu as$: 1.63 /year

Predictions: Earth-mass FFP + Fainter source

- $10^{-0.5} - 10^{0.5}\ \boldsymbol{M}_{\oplus}$, 18.79 /star (Mass function from Gould+2022)



KMT 6-year survey we expect:

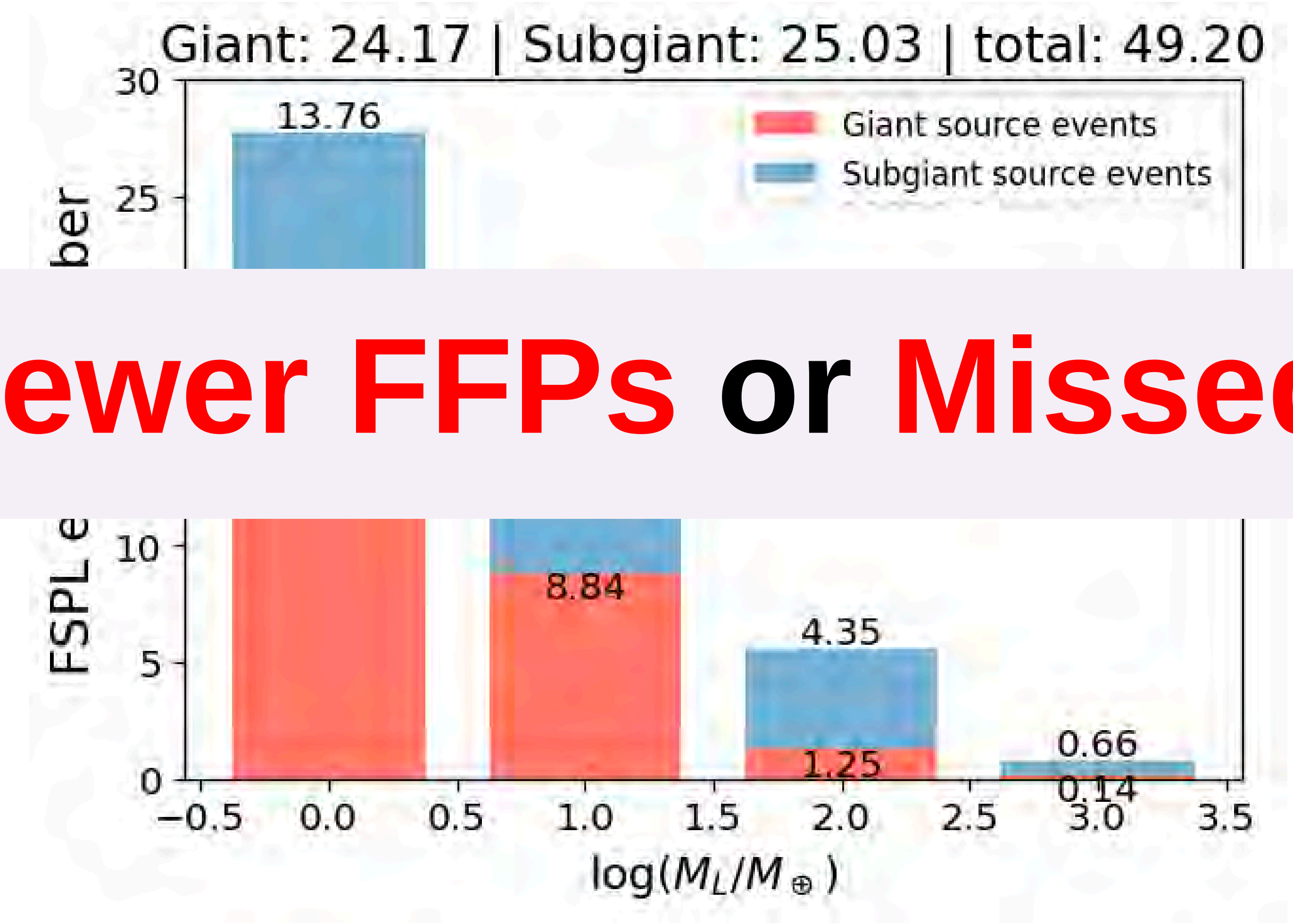
- Giant source: 13.9
- **Fainter source: 13.8**
- **Total: 27.7**

- $\theta_E < 1\ \mu as$: 1.63 + **1.21** /year

= **2.84** /year

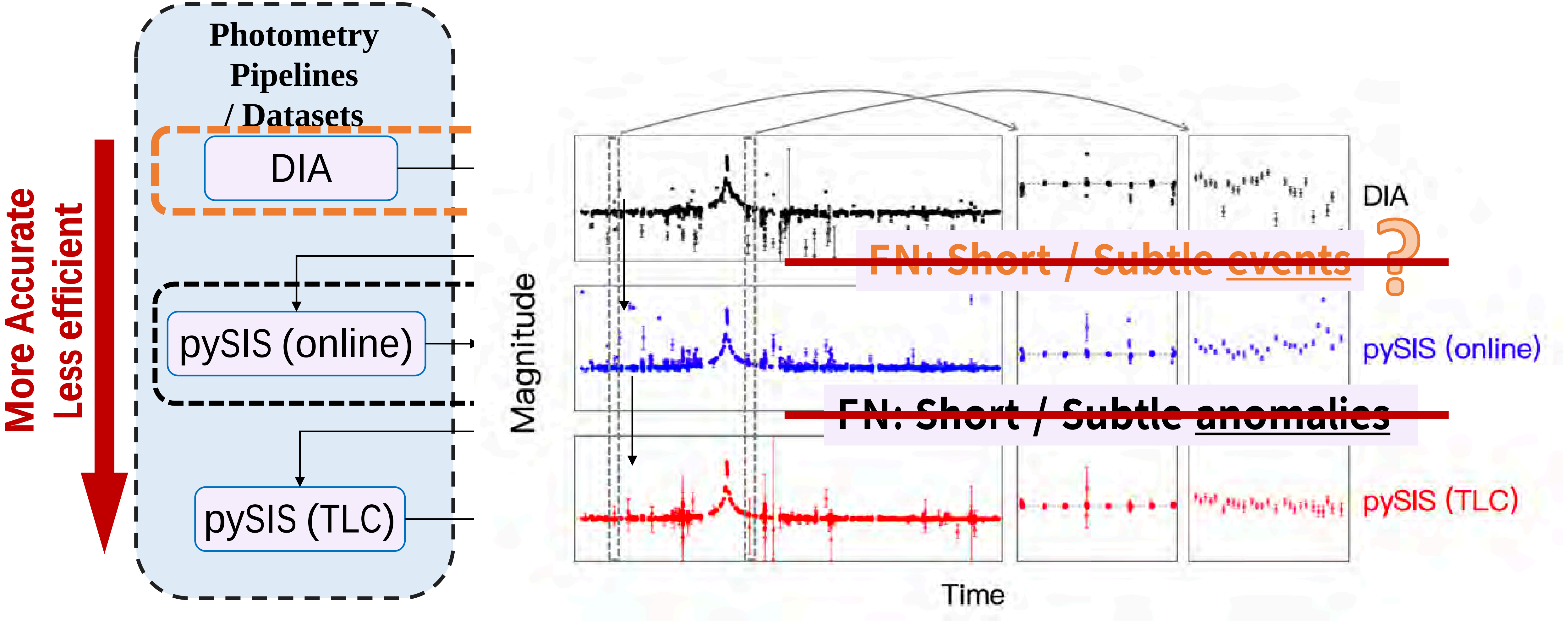
Predictions

- **The total expected detection number**
  - Mass function from Gould+2022



Fewer FFPs or Missed?

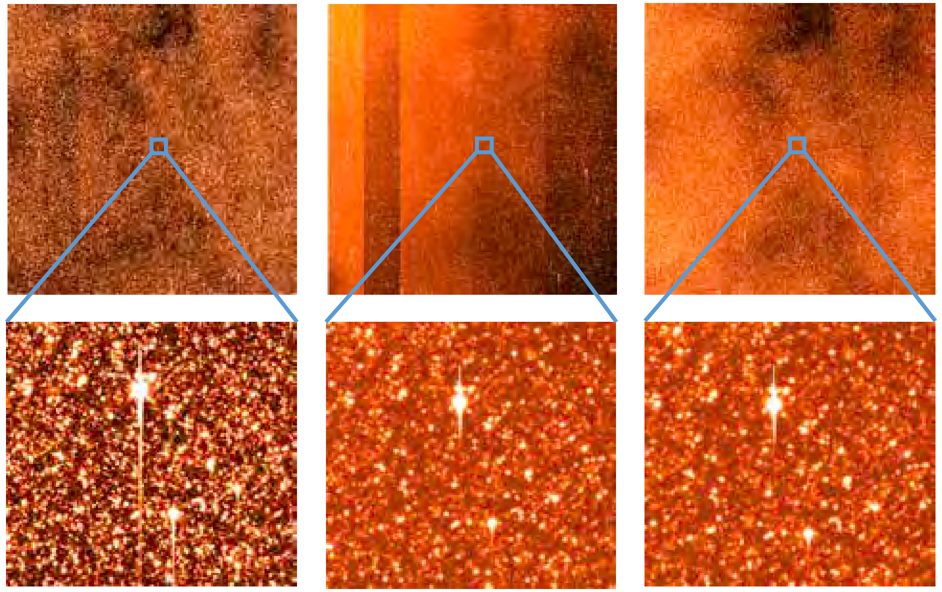
Where are the missing FFPs?



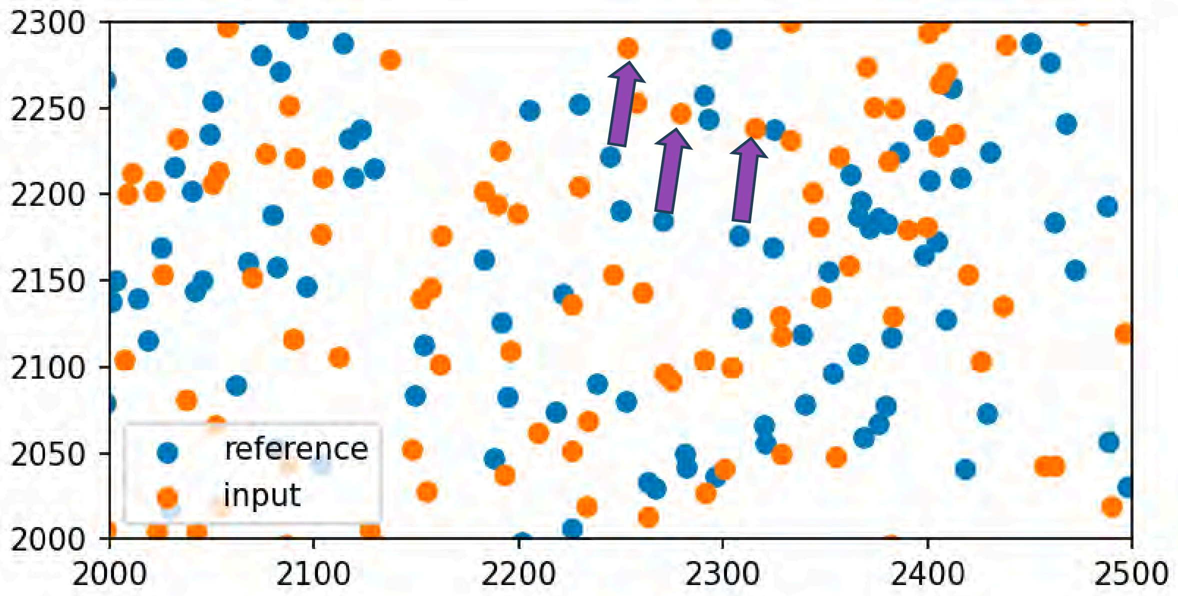
KMT full-frame photometry pipeline

Challenge:

- Ground-based 3 sites => Parameter variation
- Dense stars => Precise differential imaging needed
- Large FOV => Large distortion and misalignment



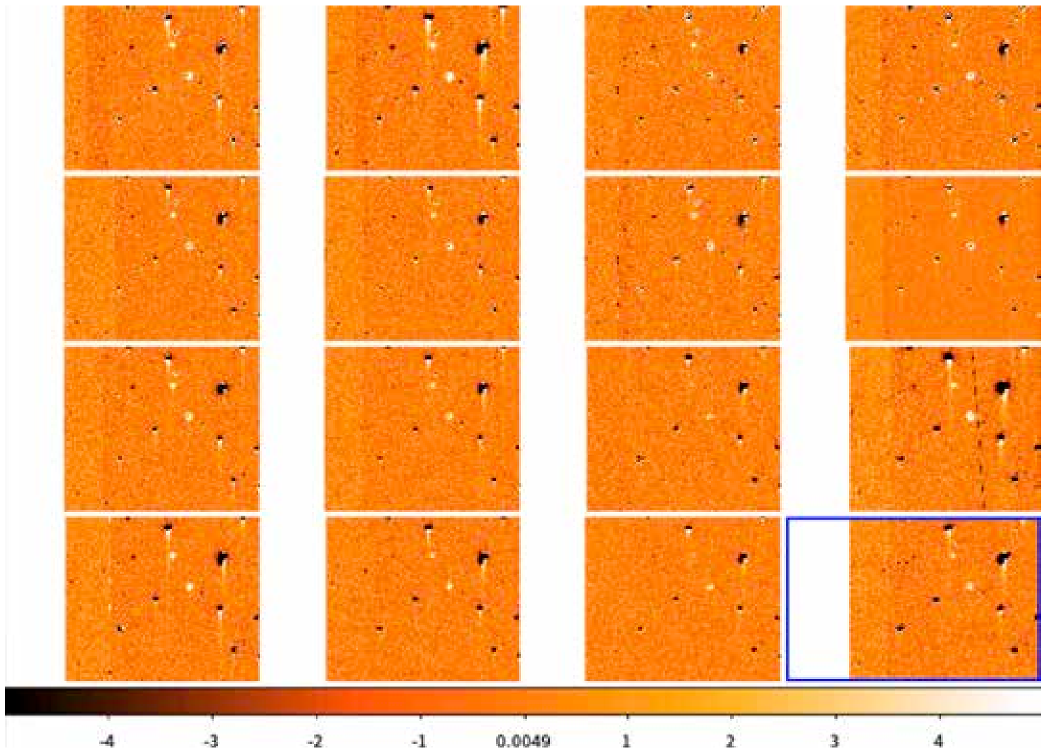
Parameter variations & misalignment



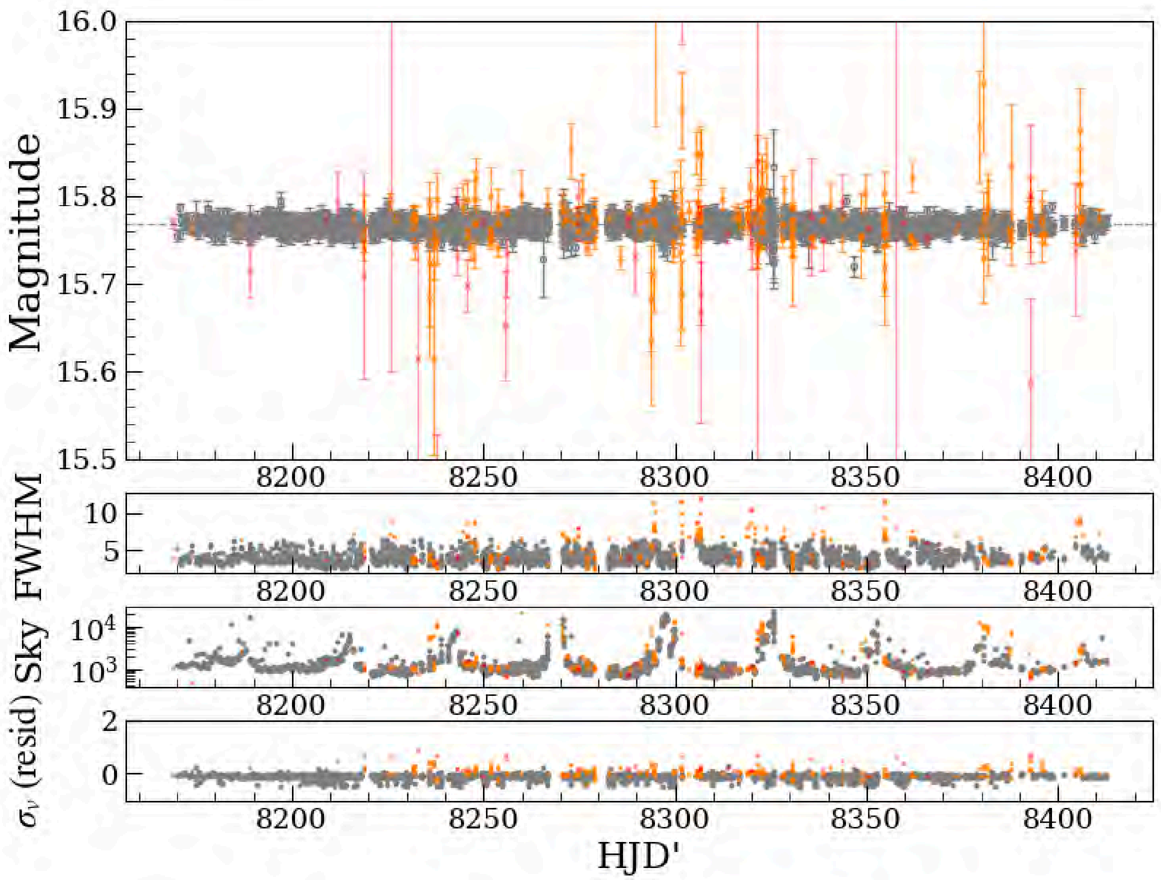
Residuals < ~0.04 arcsec (0.1pixel)

Photometry

Subtract images – pySIS (TLC)



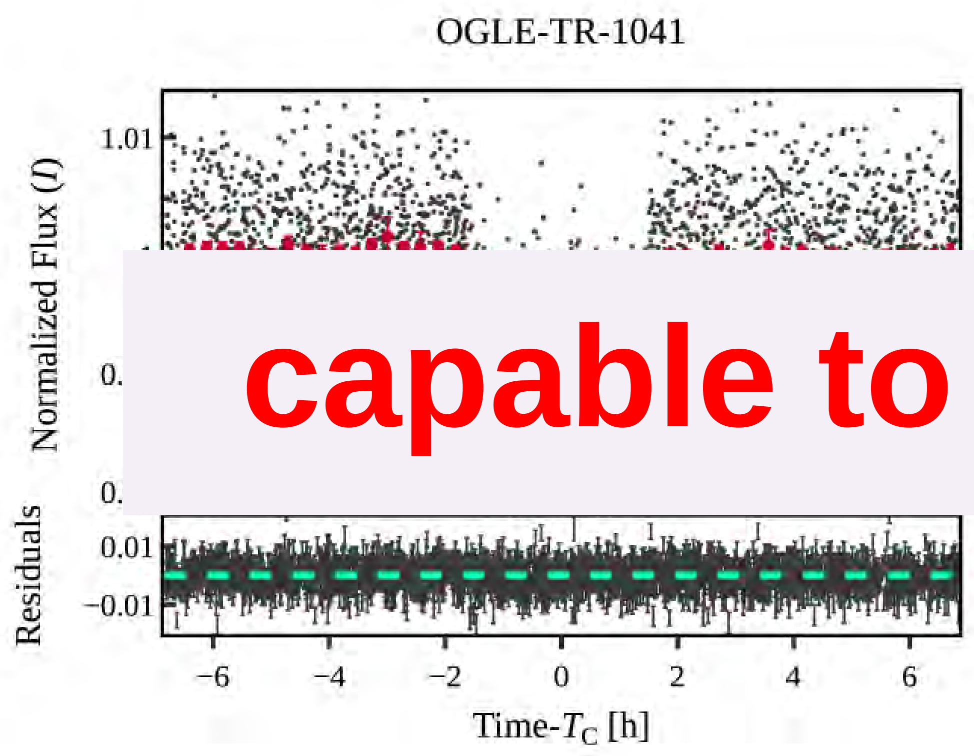
Light curves

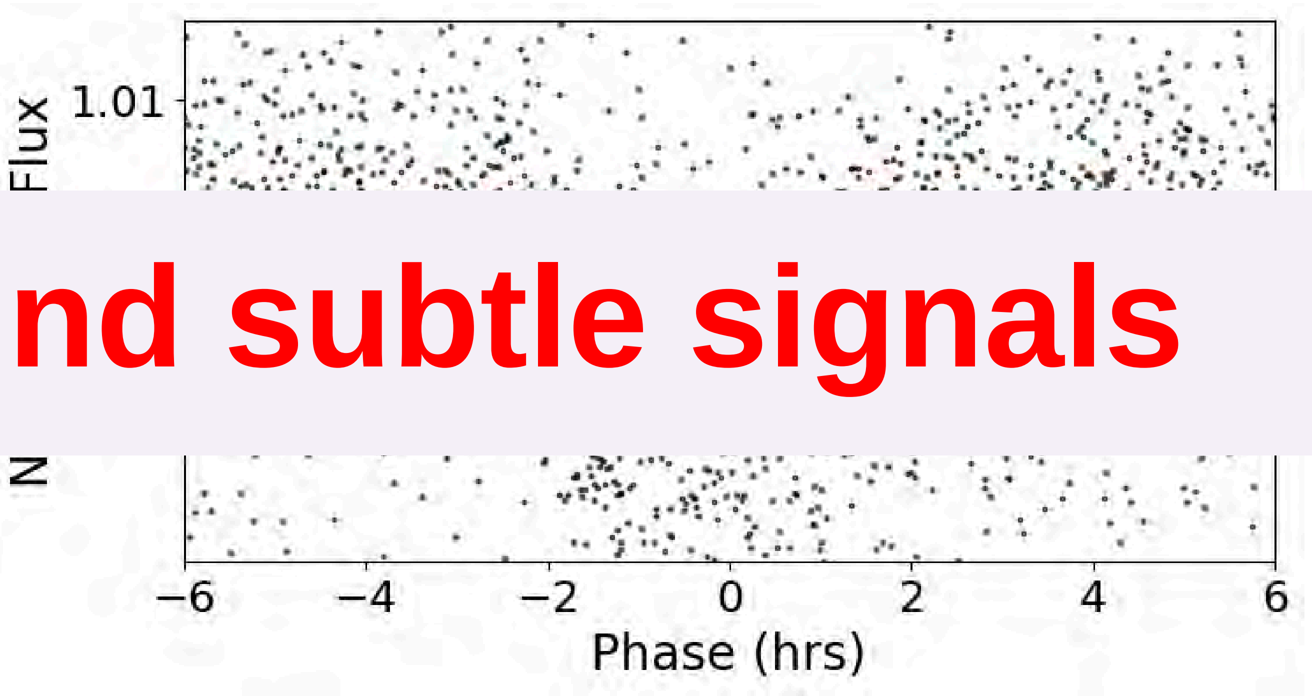


Testing Photometry: subtle dip by transit

Example: Apply to Transit Light curves

$\Delta F / F \sim 0.008$ (KMT 1 year data)





capable to find subtle signals

(Mróz et al. 2023)

Take-home messages

- KMT: powerful but only 4 FFPs with large θ_{E}
- Simulation: expect >40 and smaller FFPs
- Full-frame photometry pipeline: capable to find subtle signals
  - Re-process the KMT images and systematically search for the missing FFPs