Dark lenses through the dust:

microlensing in the near-infrared with the VVV survey

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Dark lenses through the dust:
microlensing in the near-infrared with the VVV survey

Collaborators:
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Łukasz Wyrzykowski, Kornel Howil, Maja Jabłońska *(OAUW, Warsaw)*
Eamonn Kerins, David Specht *(Jodrell Bank, Manchester)*

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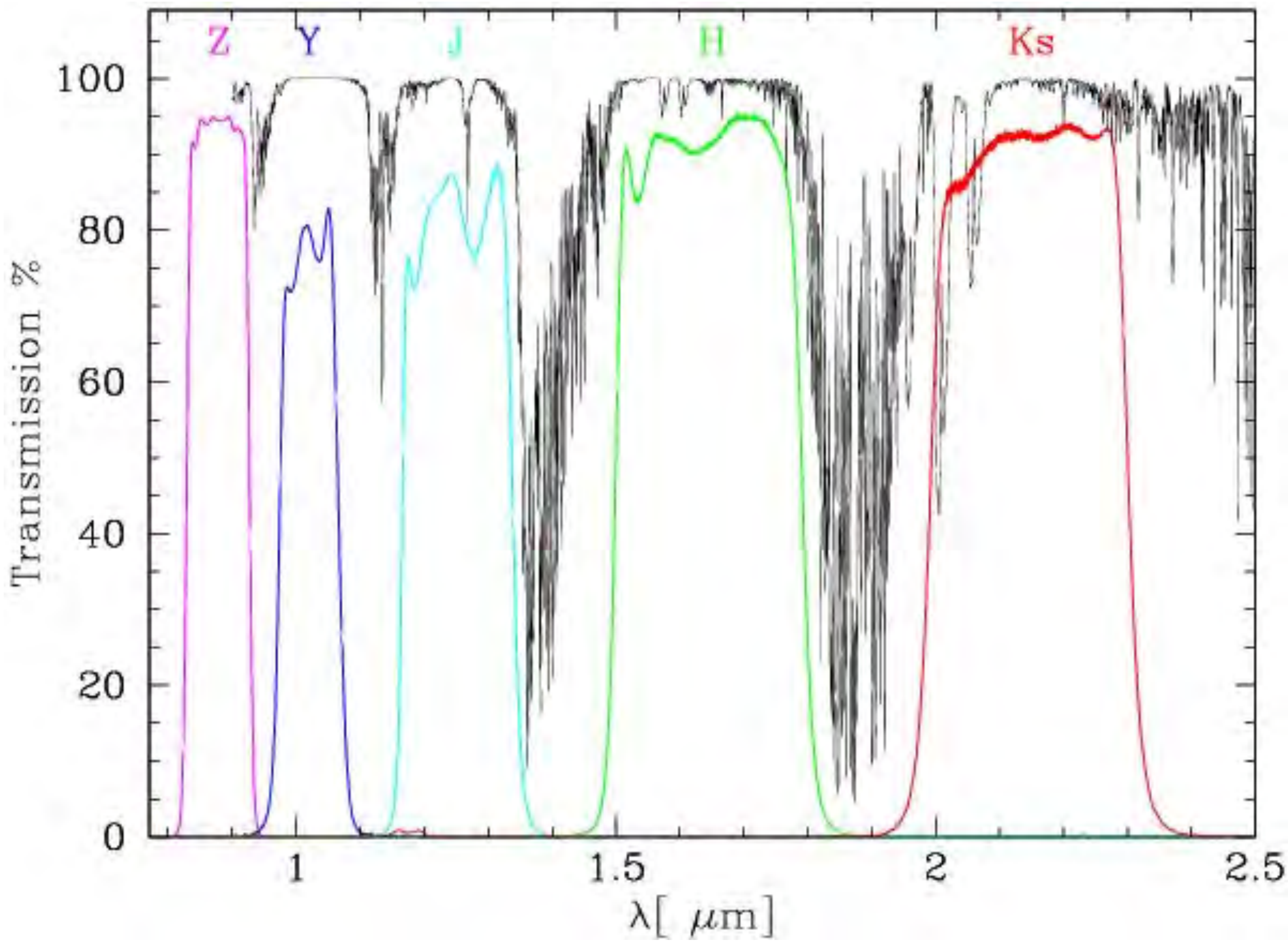
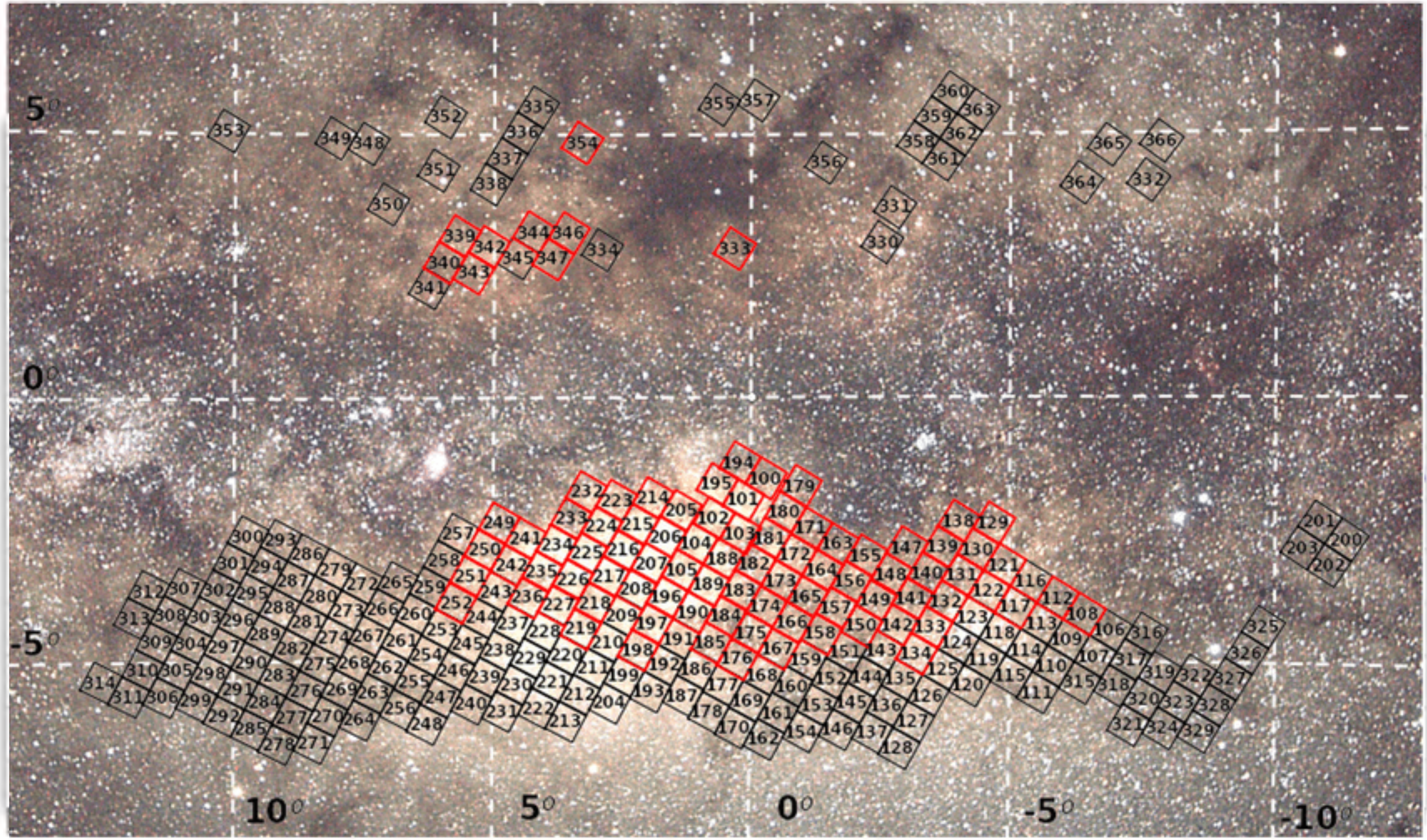
- VISTA - a 4.1 meter telescope with a near-infrared camera (VIRCAM)
- VVV - IR variability survey on VISTA; the first large-scale, multi-epoch infrared map of the Galactic Bulge and disk
- 1959 microlensing events found in VVV with a machine learning classifier (Husseiniova et al. 2021)



Why VVV?

OGLE-III fields (Wyrzykowski et al. 2016)



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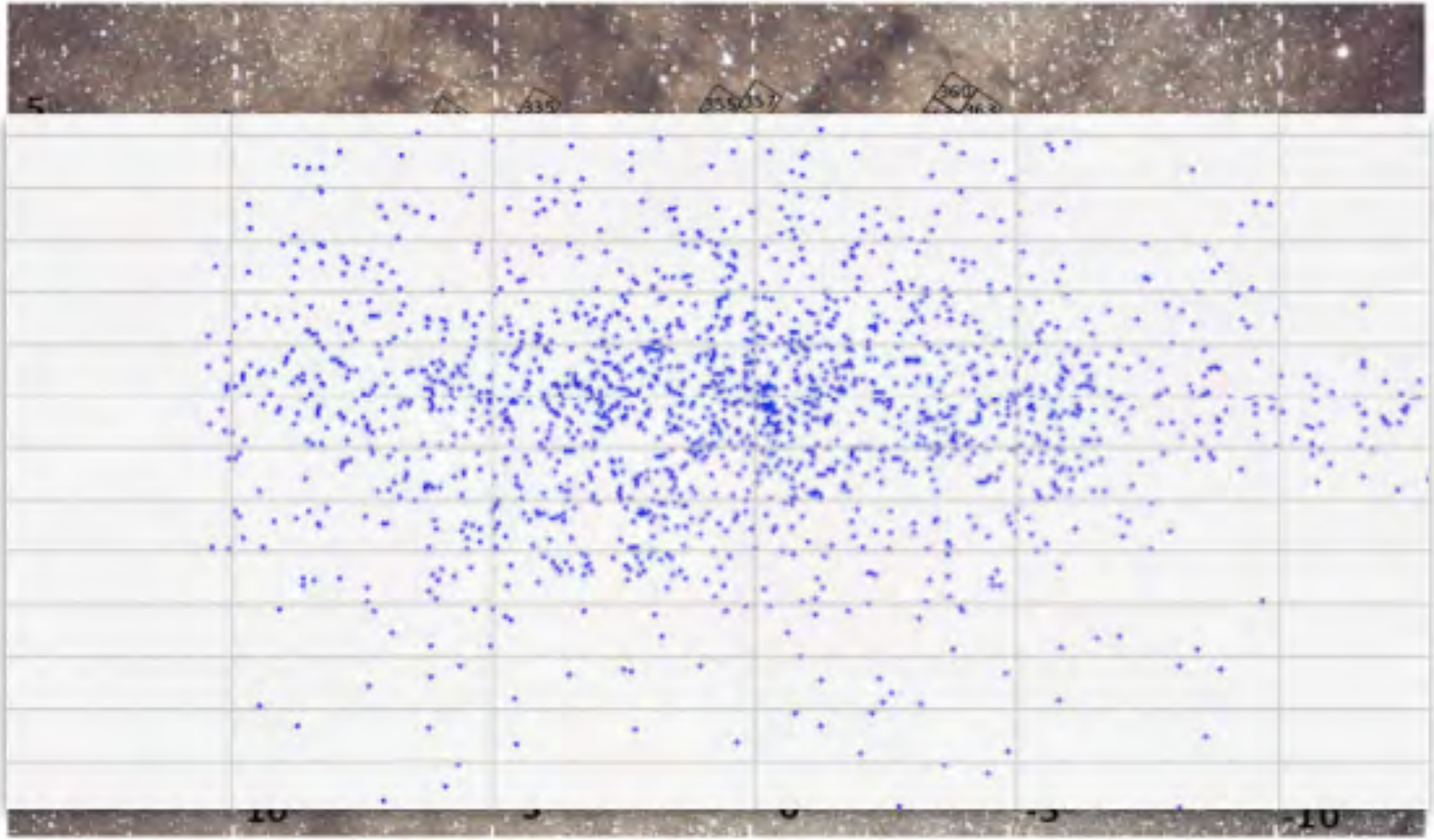
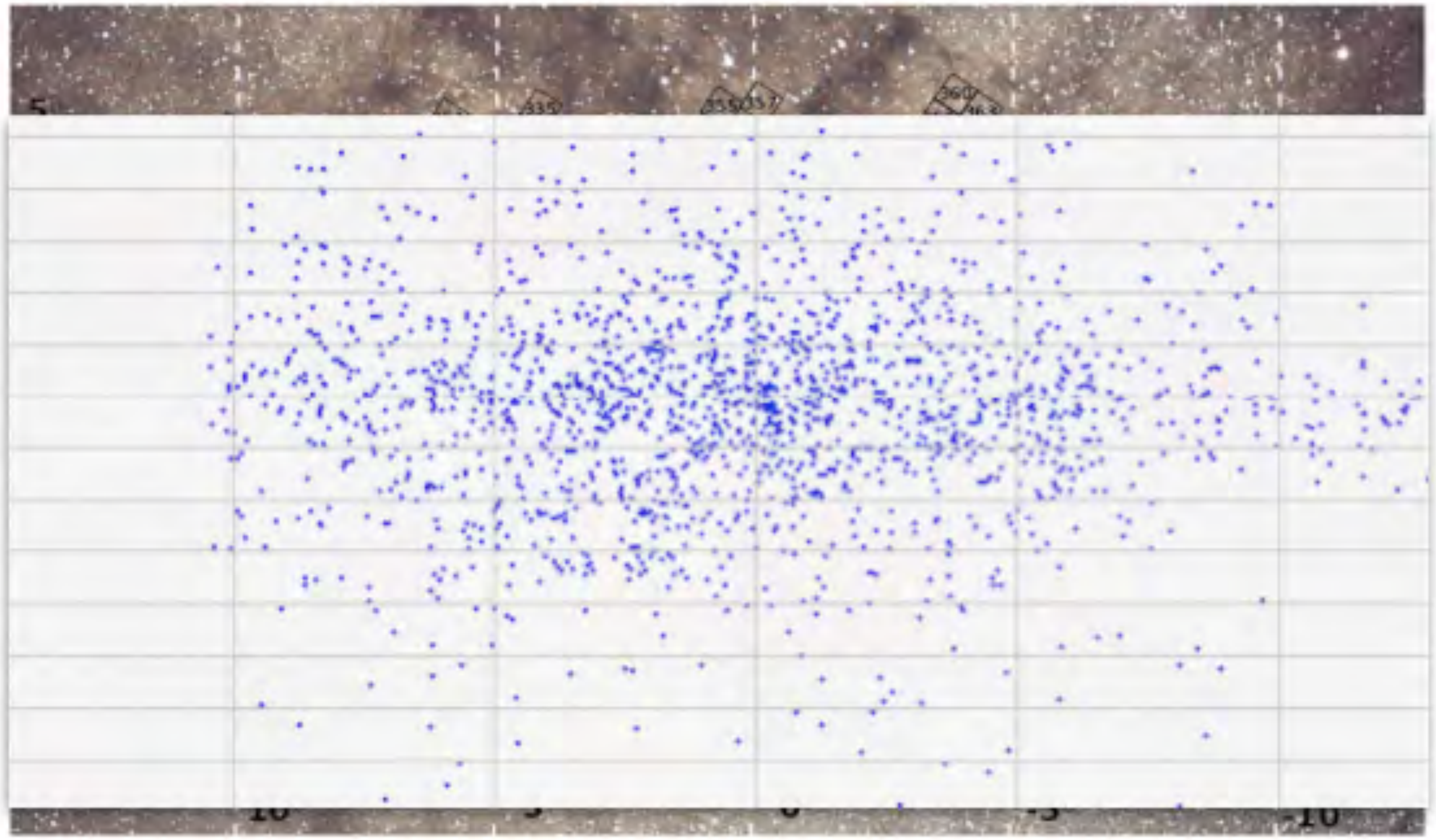


1959 VVV microlensing events
(Husseiniova et al. 2021 sample)

Why VVV?

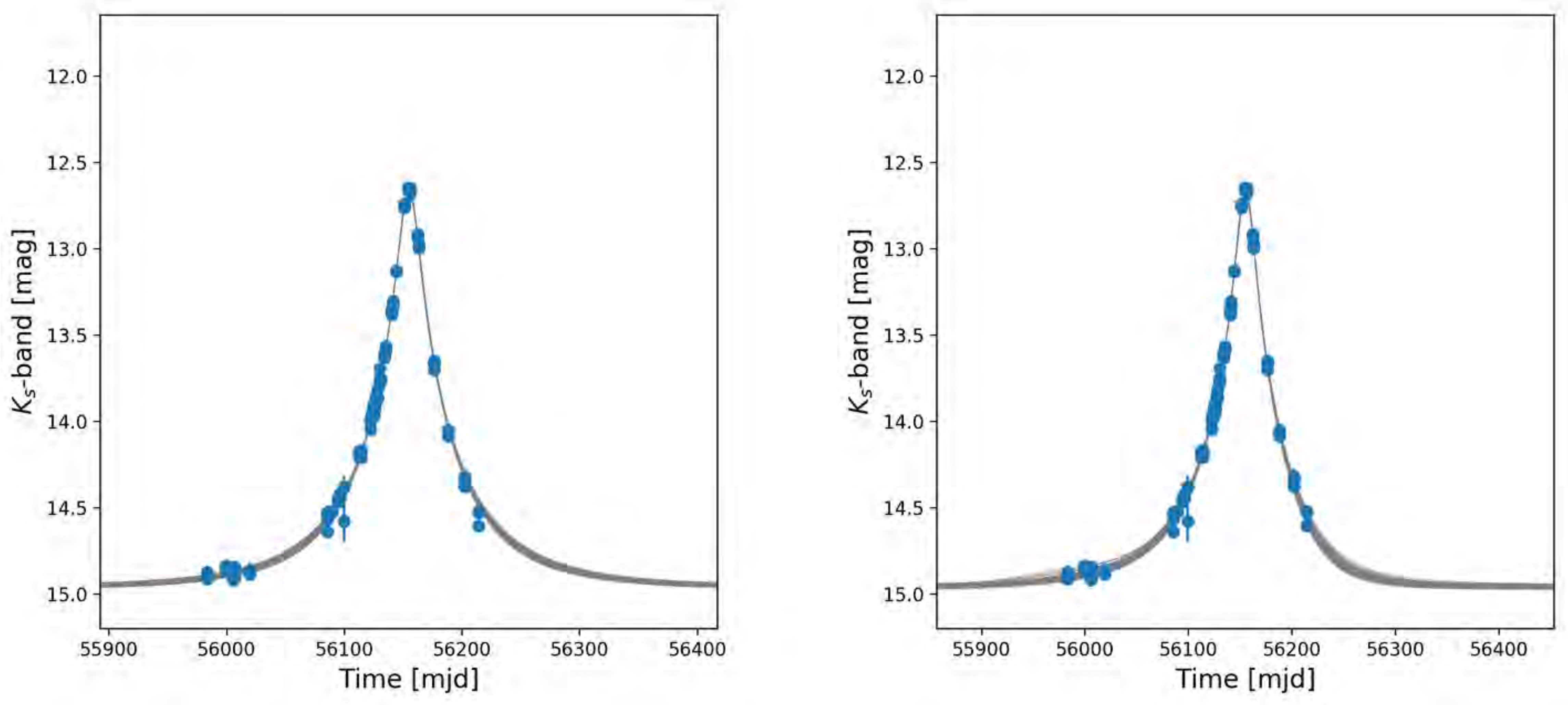
low-latitude regions



- higher stellar density, higher event rate (Gould 1995)
- massive (>10 $M_\odot$) BHs should reside there (Jonker+ 2021)
- opportunity to study Galactic Bulge structure

Lightcurve modelling

- no-parallax and parallax models for all 1959 events

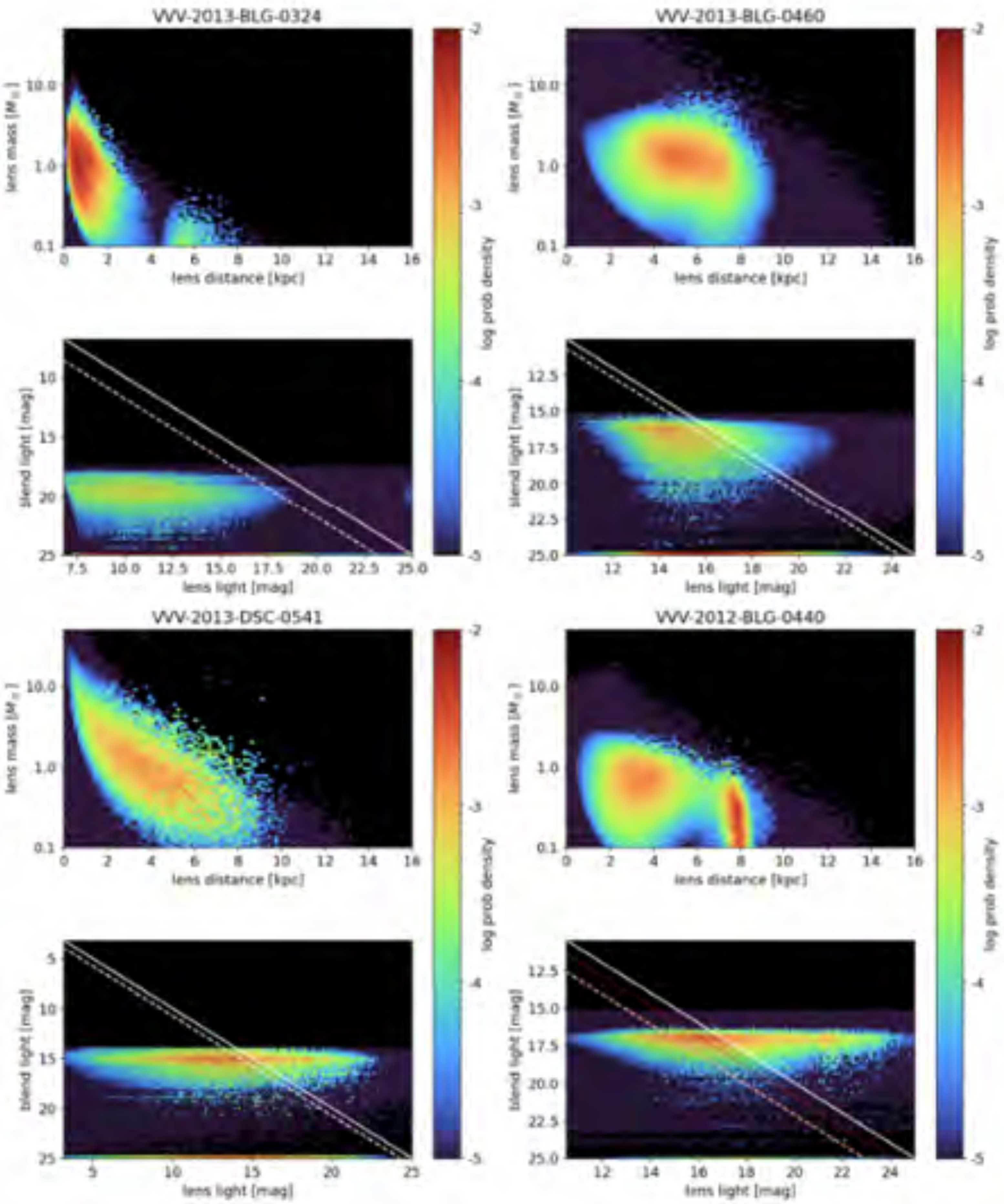


- nested sampling used; code publicly available: github.com/zofiakaczmarek/nested_ulens_parallax/

- events with strong parallax chosen using the Bayes factor (K>100)

Dark lenses

DarkLensCode - inferring lens parameters

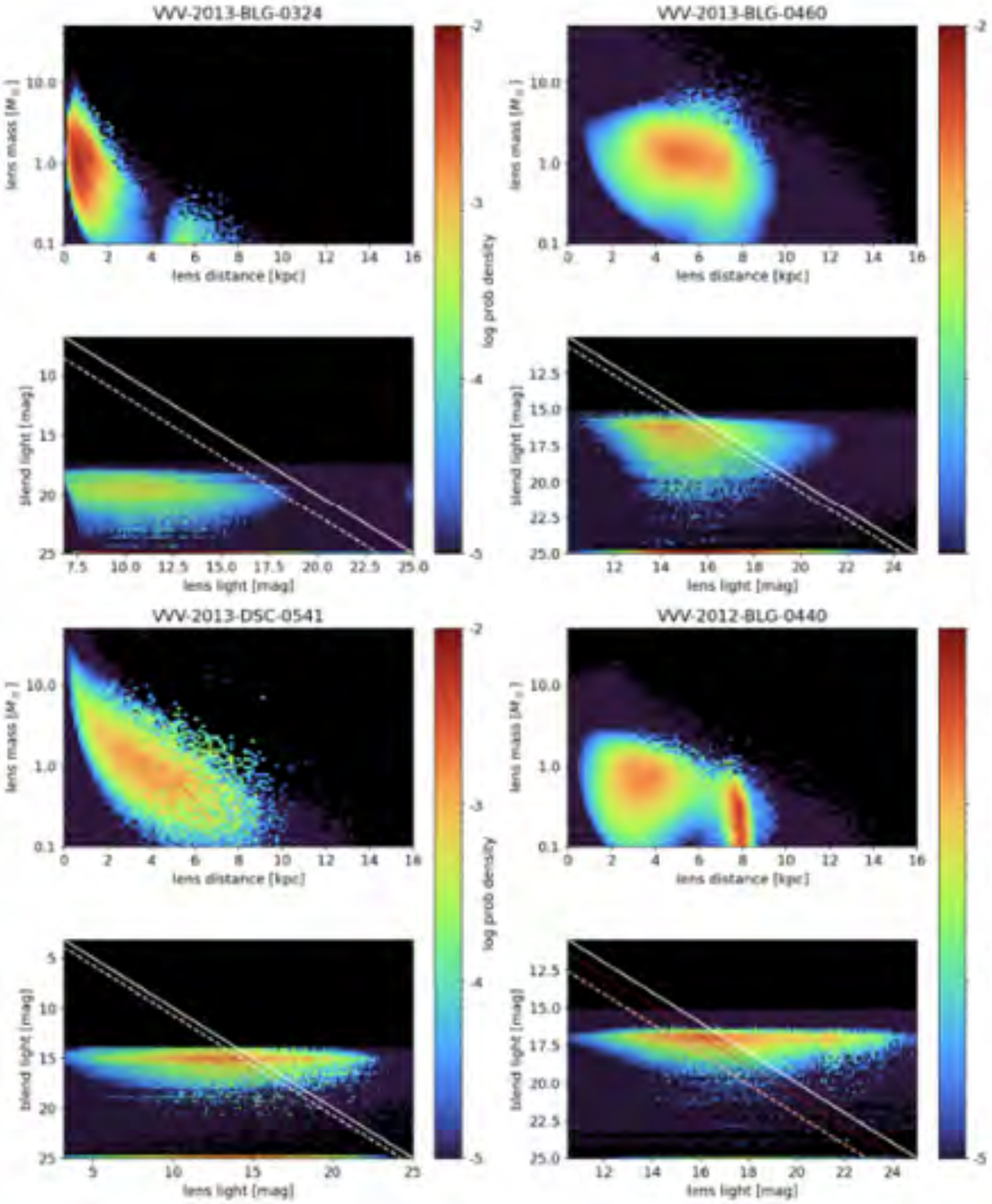


see Kornel Howil's talk!

Kaczmarek et al. 2022

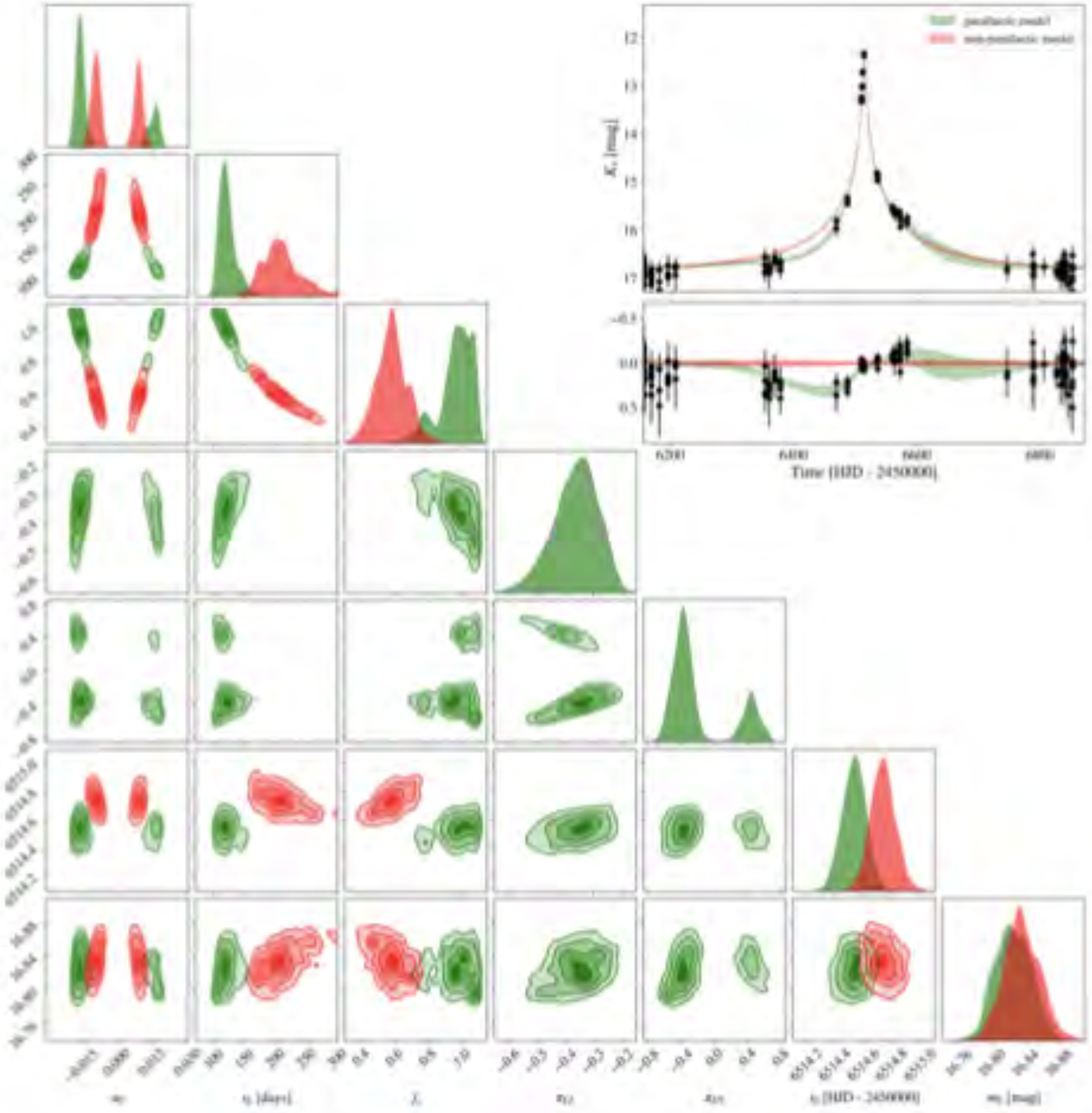
Dark lenses

DarkLensCode - inferring lens parameters



2 new strong NS/WD candidates

Best candidate event (VVV-2013-BLG-0324)

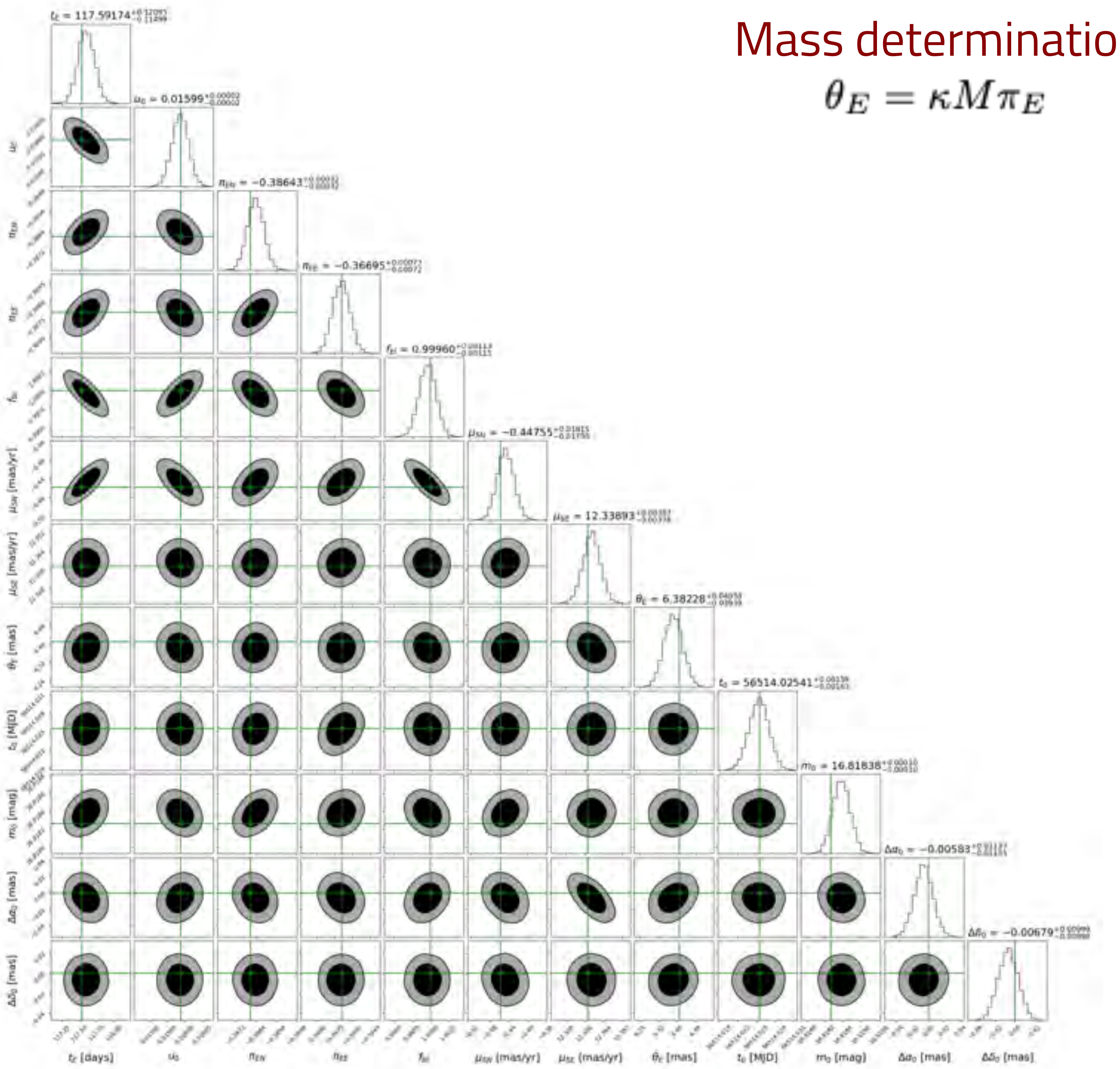


$$M_{lens} = 1.46^{+1.13}_{-0.71} M_\odot$$

Kaczmarek et al. 2022

Coming soon!

Roman Space Telescope



Mass determination:

$$\theta_E = \kappa M \pi_E$$

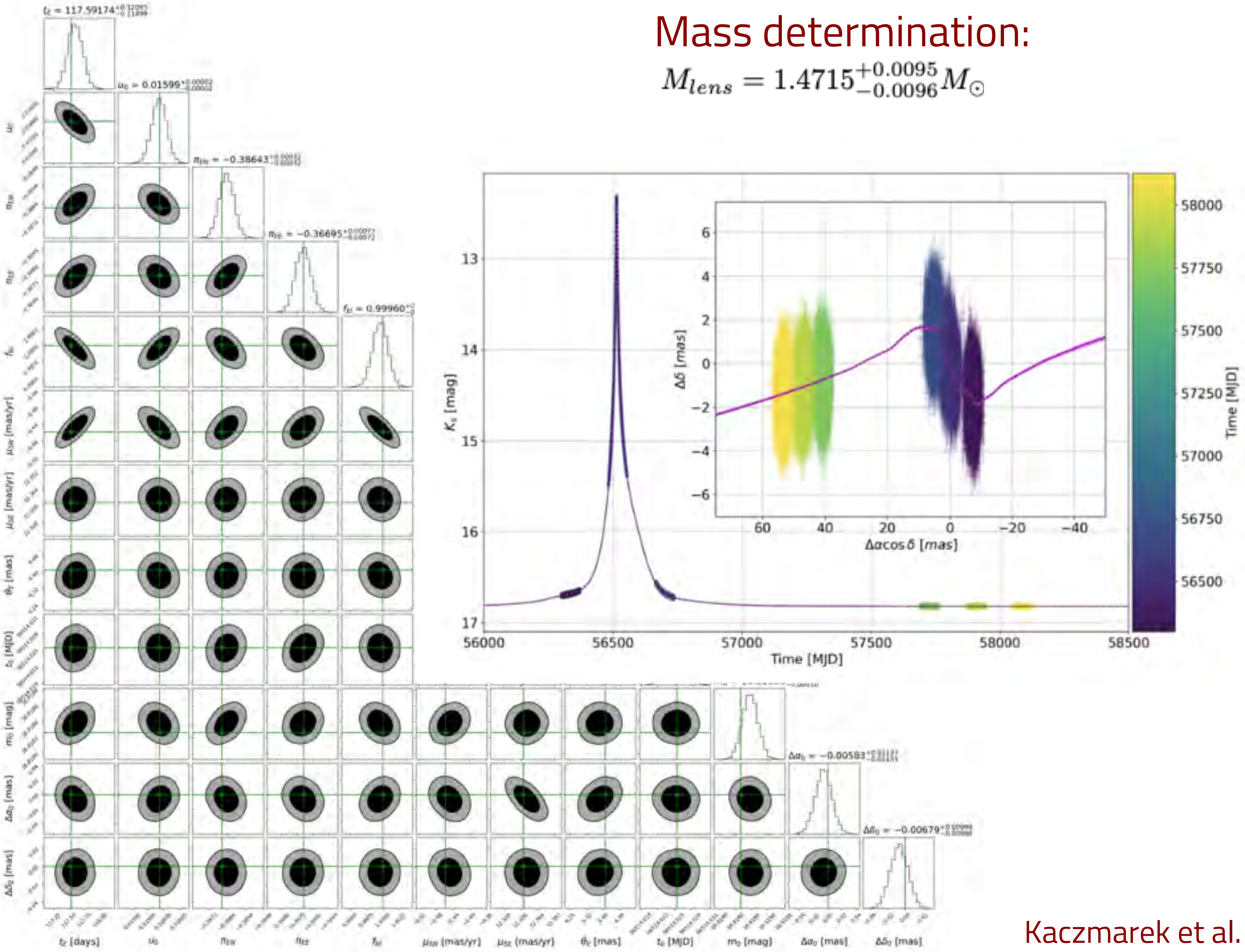
Kaczmarek et al. 2022

Coming soon!

Roman Space Telescope

Mass determination:

$$M_{lens} = 1.4715^{+0.0095}_{-0.0096} M_{\odot}$$

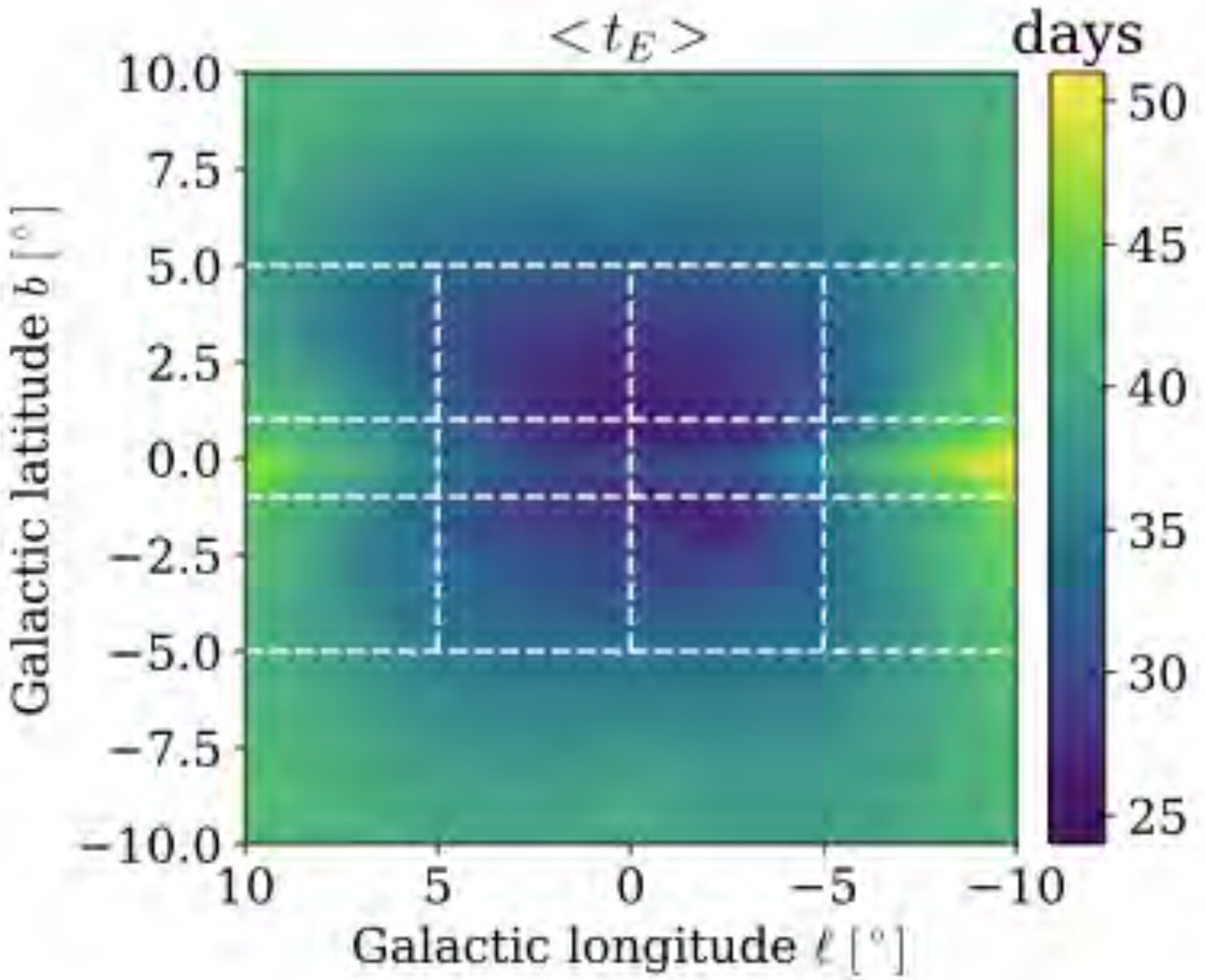


Kaczmarek et al. 2022

Timescale distribution

We get predictions from The Manchester-Besançon Microlensing Simulator - **MaBμlS** (Specht et al. 2020) and bin down our events:

MaBμlS

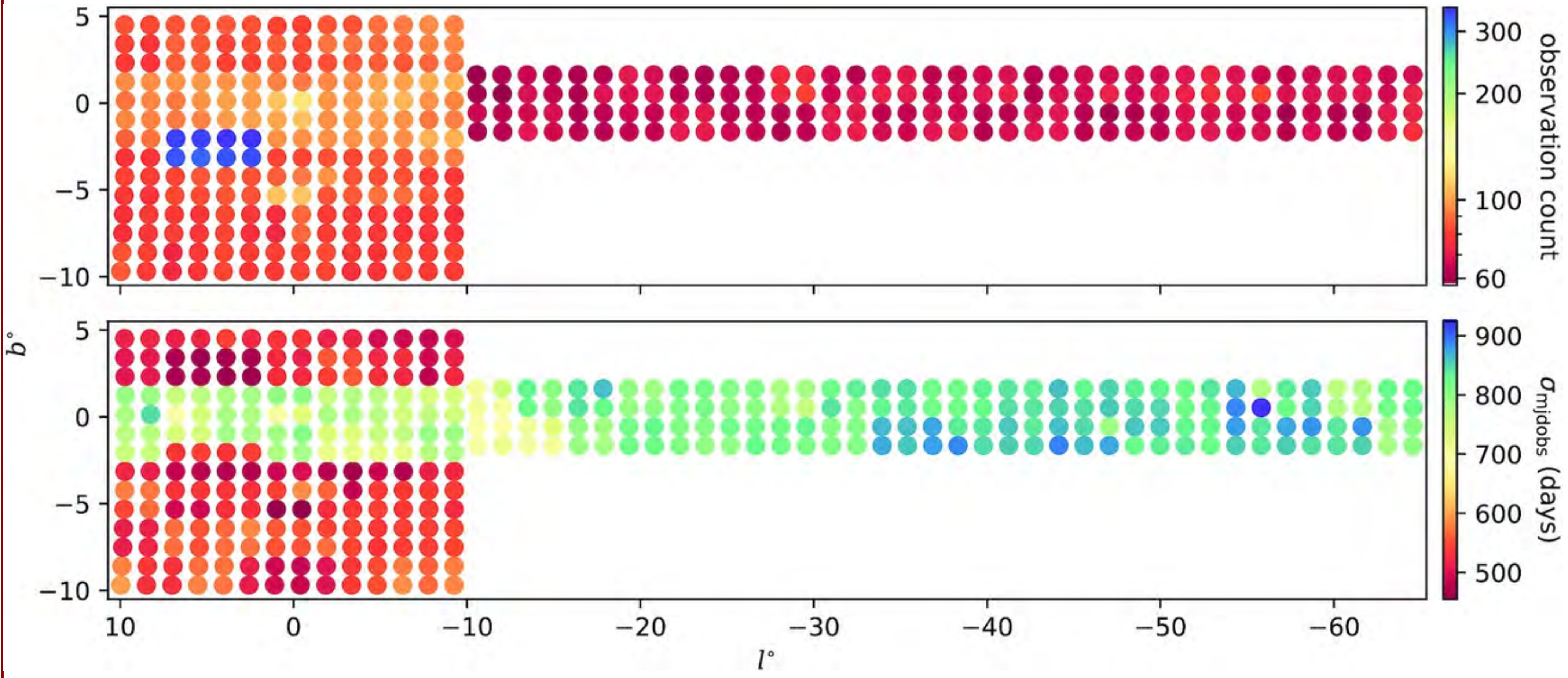


our dataset

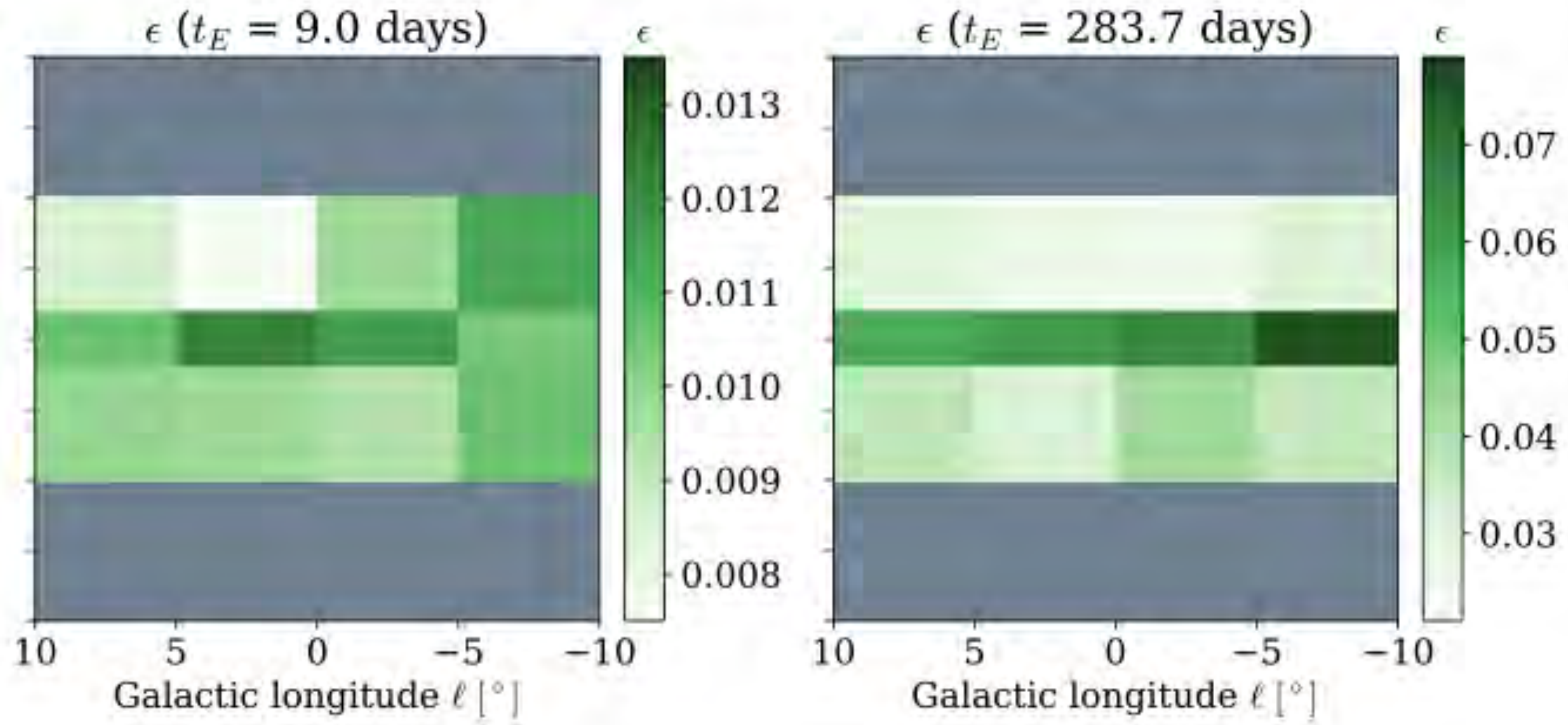
bin 1 76 events	**bin 2** 139 events	**bin 3** 134 events	**bin 4** 43 events
bin 5 122 events	**bin 6** 268 events	**bin 7** 247 events	**bin 8** 113 events
bin 9 75 events	**bin 10** 190 events	**bin 11** 143 events	**bin 12** 52 events

Kaczmarek et al. (in review)

Detection efficiency



VVV observing pattern
Husseiniova et al. 2021



simulated event
recovery efficiency
Kaczmarek et al. (in review)

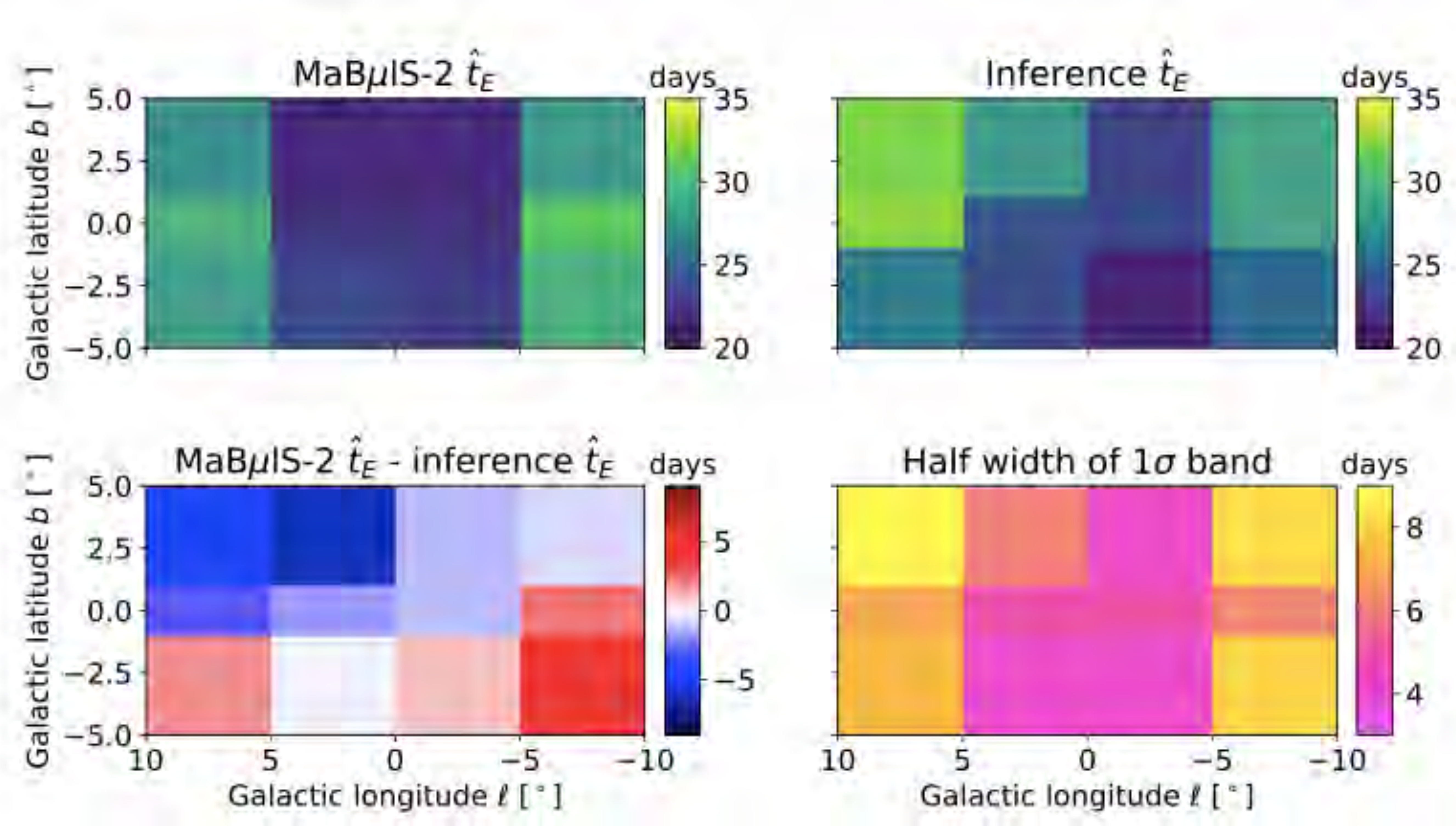
Hierarchical inference

Microlensing events can have different degeneracies
$\rightarrow$ simply taking one point estimate per event would not work.

We use a forward-modelling approach based on Bayesian statistics (for more details, see Hogg+ 2010):

- we construct a parametric function: $$f_\alpha(t_E)$$
- we derive the likelihood for a set of parameters α given all the samples for the entire dataset, using Bayesian statistics:
$$L_\alpha = \prod_{n=1}^{N} \frac{1}{K} \sum_{k=1}^{K} \frac{f_\alpha(t_{E_{n,k}})}{p_0(t_{E_{n,k}})}$$
- we sample the parameter space of possible α

Results

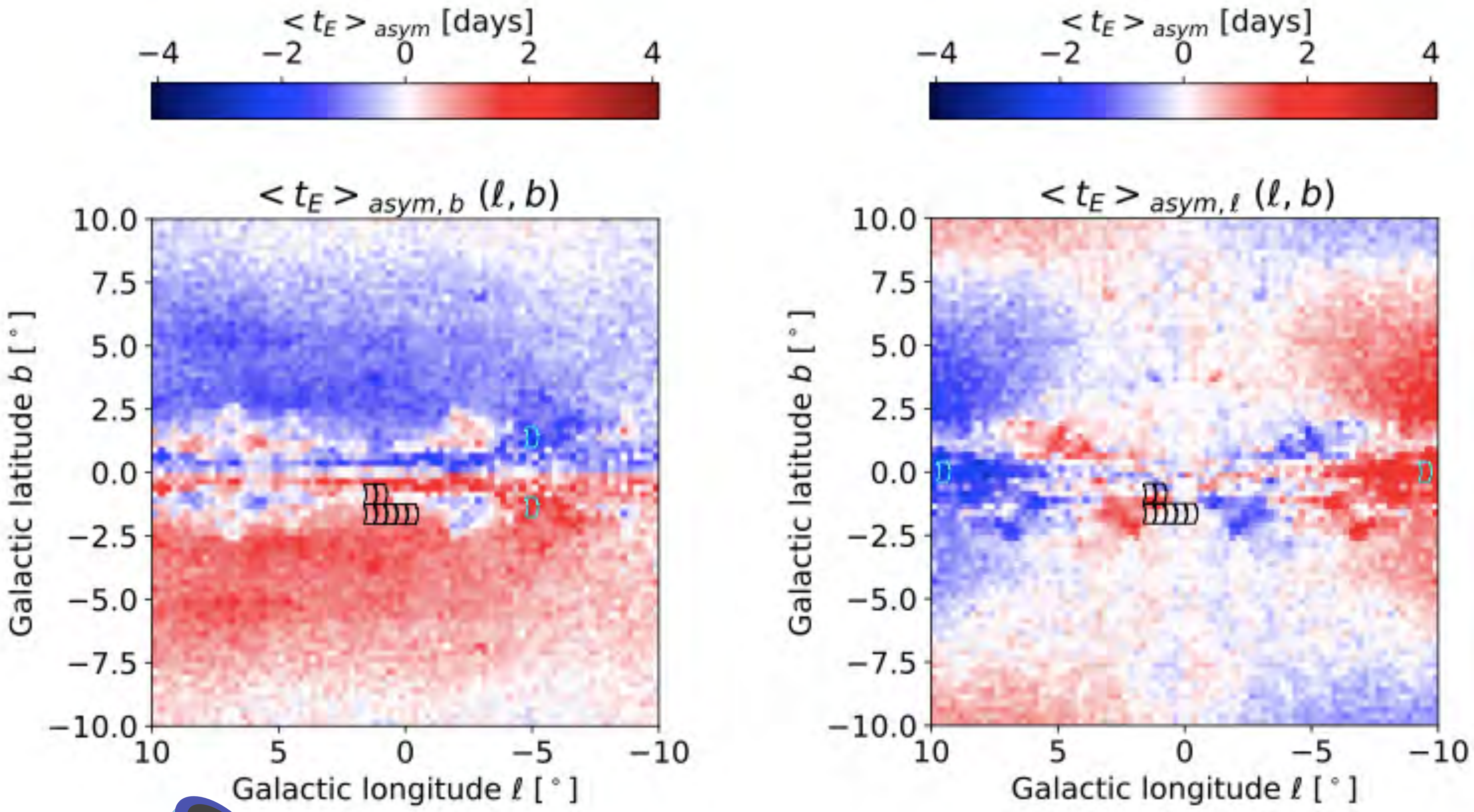


Peaks of the timescale distribution - spatial variations

Kaczmarek et al. (in review)

Coming soon!

Roman Space Telescope



We propose optimal *Roman* fields to pinpoint the asymmetry signal

Kaczmarek et al. (in review)

Take-home messages

We analysed a dataset of 1959 lensing events found in the VVV survey.

This is a unique sample covering low-latitude regions - most events are only accessible to NIR and were studied for the first time.

We developed a public nested sampling code to automatically model lightcurves.

We conducted a search for dark lenses and present new strong candidates.

We also find agreement in our spatial distribution of event timescales with Milky Way simulations.

With Roman Space Telescope, we can do all of the above... but with much more precision!

Thank you for your attention!

Papers:

- Kaczmarek, McGill, Evans, Smith, Wyrzykowski, Howil and Jabłońska, 2022, *Dark lenses through the dust: parallax microlensing events in the VVV*, MNRAS, 514, 4815
- Kaczmarek, McGill, Evans, Smith, Golovich, Kerins, Specht and Dawson, 2024, *Spatially resolved microlensing timescale distributions across the Galactic bulge with the VVV survey*, submitted to MNRAS, in review

Code: github.com/zofiakaczmarek/nested_ulens_parallax/