Initial mass function of the Galactic bulge from binary microlensing events

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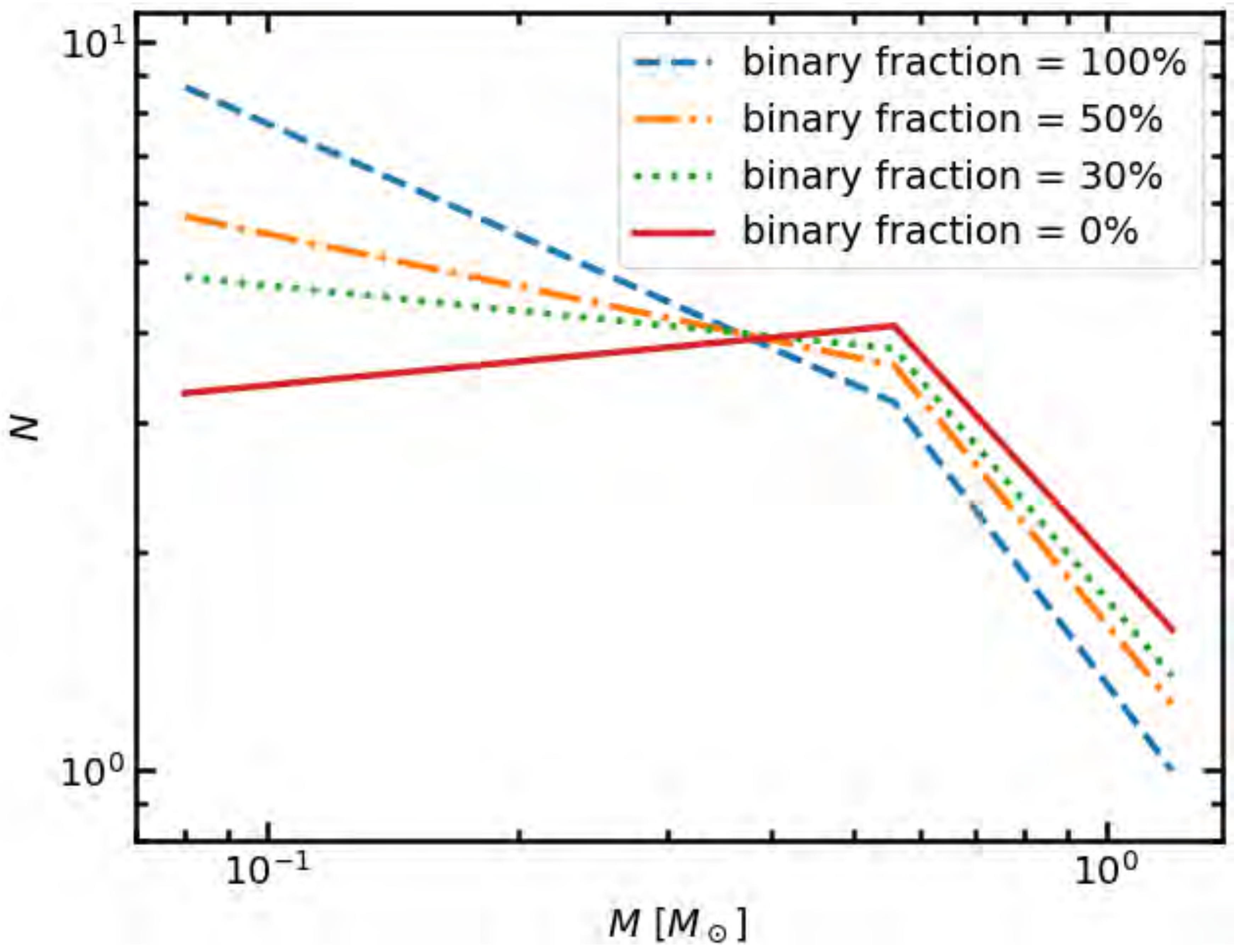
Gravitational microlensing to obtain the Bulge IMF

- No method to probe **low-mass, unresolved binaries** uniformly
- Microlensing depends primarily on the lens mass, larger event rates in crowded regions
  $\rightarrow$ IMF of the low-mass stars in the Bulge

based on Calamida et al. (2015)



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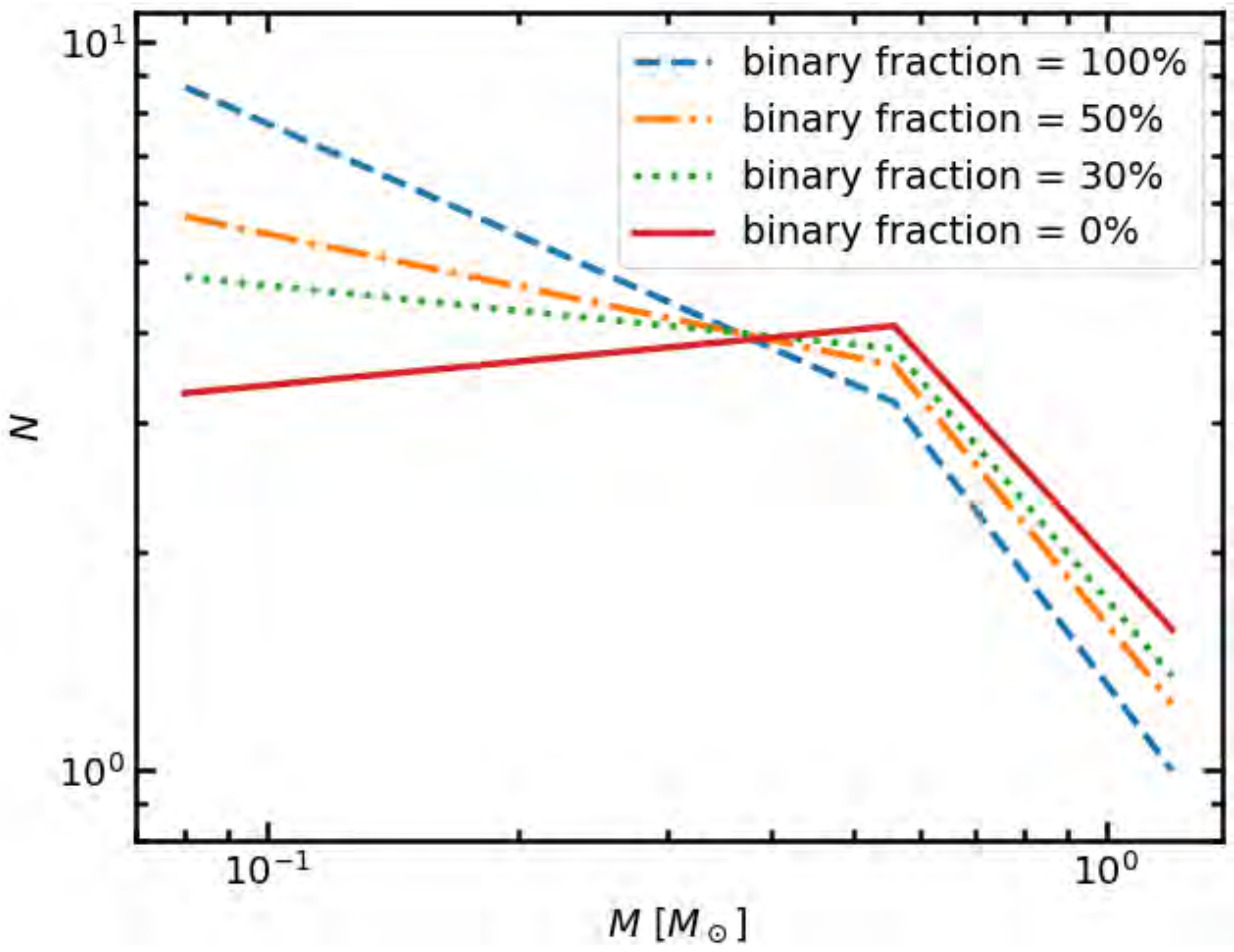

- Calamida et al. (2015): luminosity function from *HST*, IMF of two power laws with break in 0.5 $M_\odot$
- **Goal:** obtain a fully automated approach for detection and analysis of binary events (1L2S, 2L1S)
- Large statistics, detection efficiency $\rightarrow$ binary fraction, mass ratio $\rightarrow$ IMF

1 Event modeling: PSPL → 1L2S and 2L1S

$$A = \frac{u^2 + 2}{u\sqrt{u^2 + 4}} \text{ , where } u = \sqrt{u_0^2 + \frac{(t - t_0)^2}{t_E^2}} \qquad \theta_E = \sqrt{\frac{4GM}{c^2}\frac{D_S - D_L}{D_L D_S}}$$

- Non-standard light curves
  - Binary source:
  - Binary lens (q, s, α):
  - Finite source, parallax ($t_E > 30$–40 d), xallarap, …

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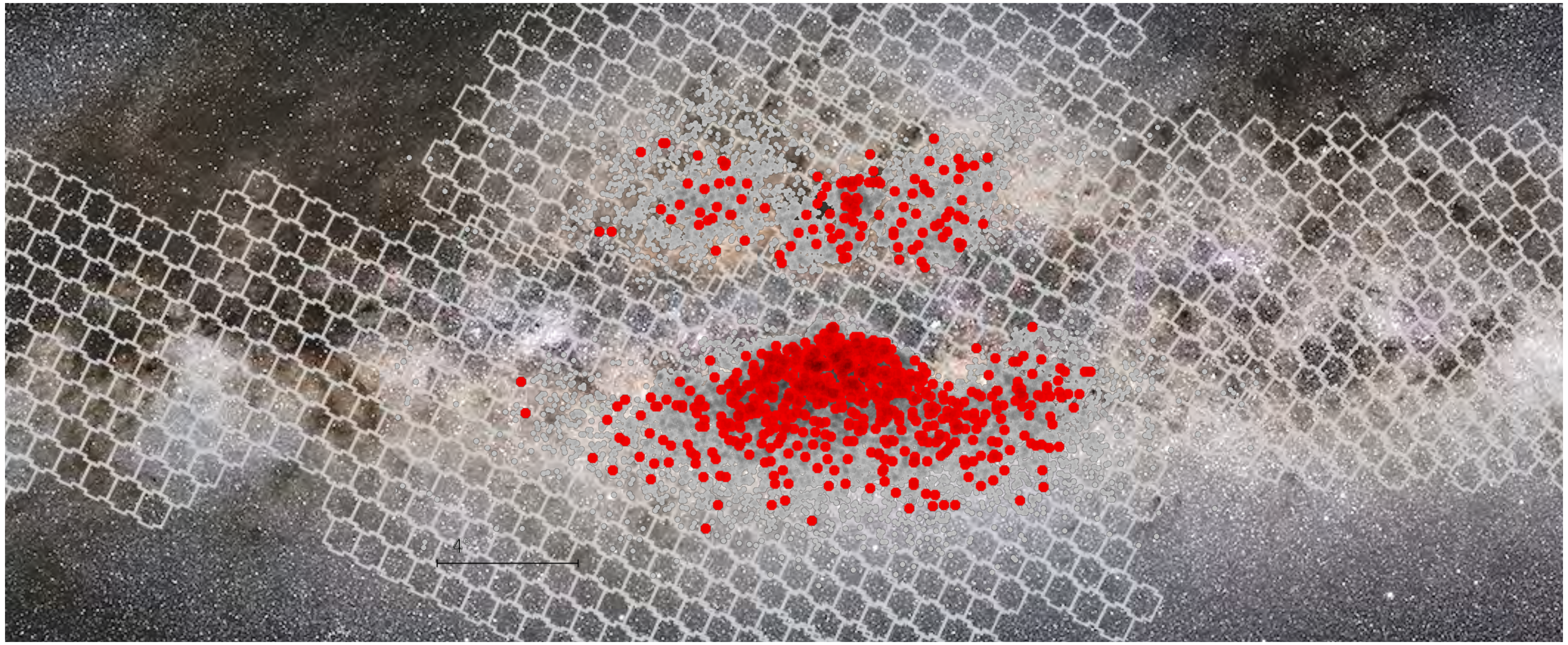
- Non-standard light curves
  - Binary source: $a_\perp^{\text{source}} = \left(\frac{t_{0,2} - t_{0,1}}{t_E}\right)\theta_E D_S$
  - Binary lens (q, s, α): $a_\perp^{\text{lens}} = s \cdot \theta_E D_L$
  - Finite source, parallax (t_E > 30–40 d), xallarap, …
- Caustics in 2L1S, degeneracies e.g. mass-distance (broken with inclusion of parallax), mass-μ_{rel}/velocity, close/wide degeneracy

2 Data: OGLE proprietary and alerts

- OGLE-IV proprietary data; OGLE, MOA and KMT alerts
- Compilation of ~**800 binaries**: from the literature and inspection of alerts
- More binaries in denser fields with higher cadence (e.g. BLG505*, BLG504, BLG500)



Background: ESO/S.Brunier, OGLE/J. Skowron

3 Detection of binary events: method

- **Mróz et al. (2017, 2019):** 360d window, three consecutive points $>3\sigma$ above $F_{baseline}$, [...], χ^2/ dof ≤ 2, $n_{bump} = 1$

- **Optimization to flag binary events:**
  - Check for secondary bump after removing datapoints of first bump
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- Challenge: binaries similar to PSPL, confusion of 1L2S / wide 2L1S, several morphologies

- False positives, cataclysmic variables

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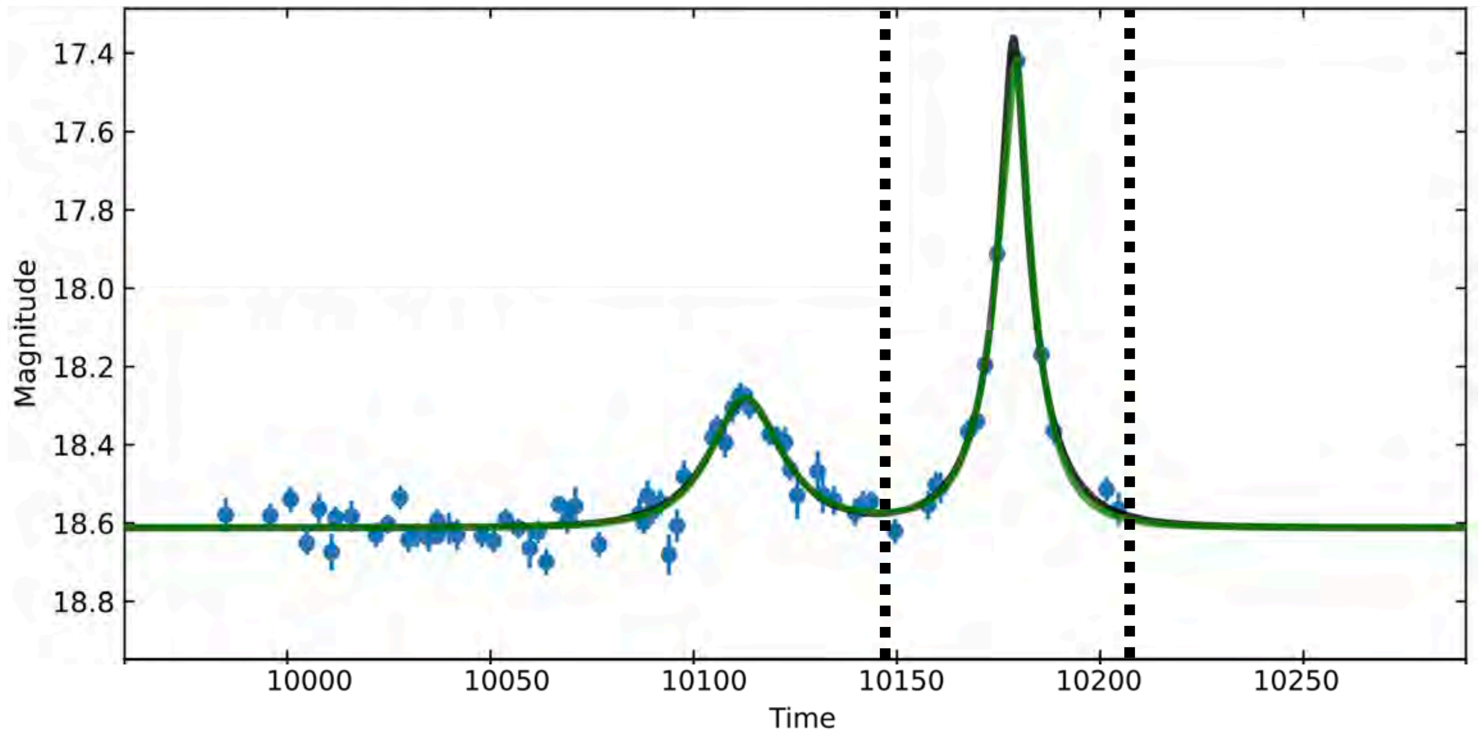

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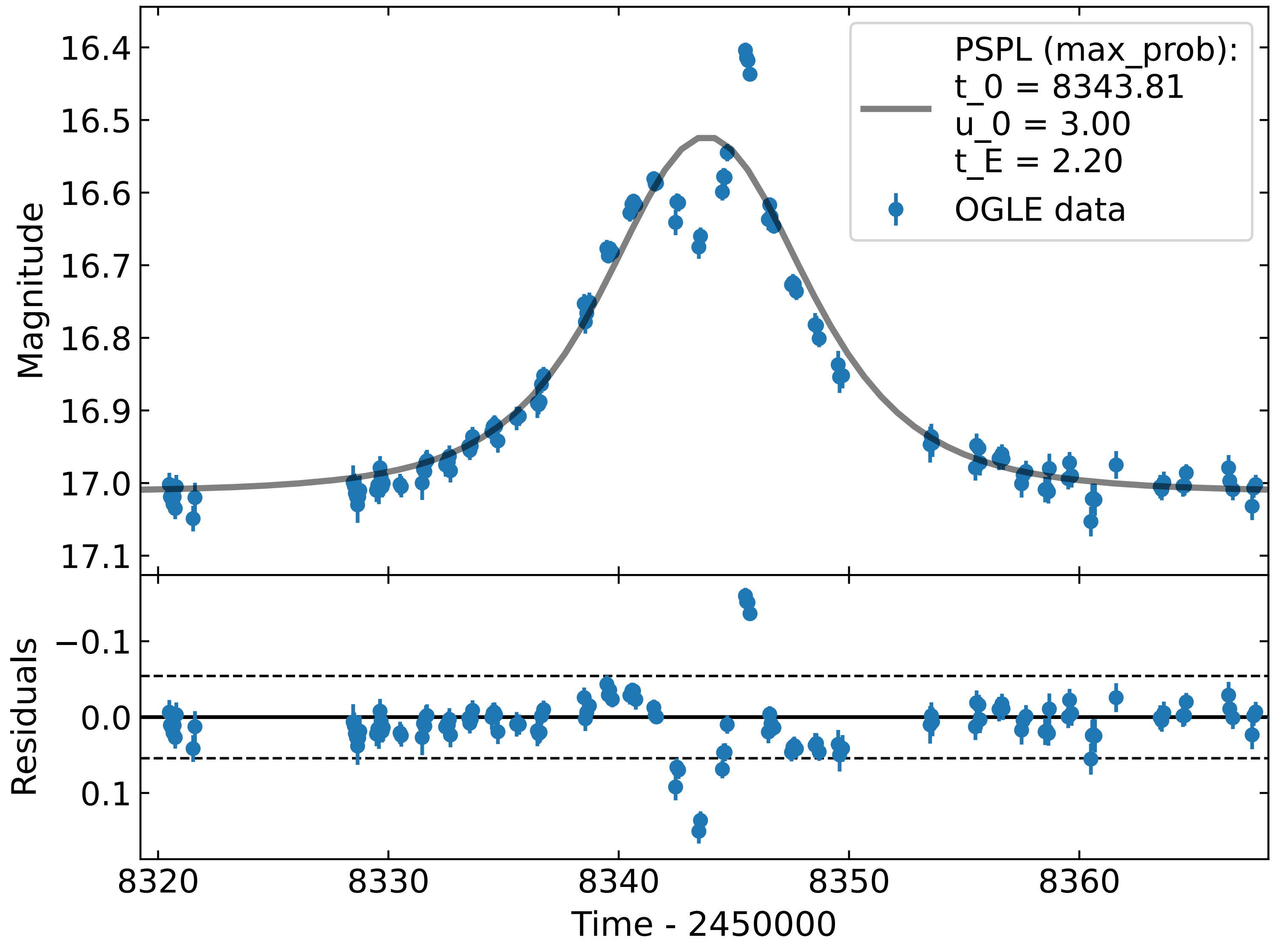

3 Detection of binary events: BLG505 (chips 01-10)

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- Retrieved all the binaries in compilation (three looks like PSPL in OGLE)
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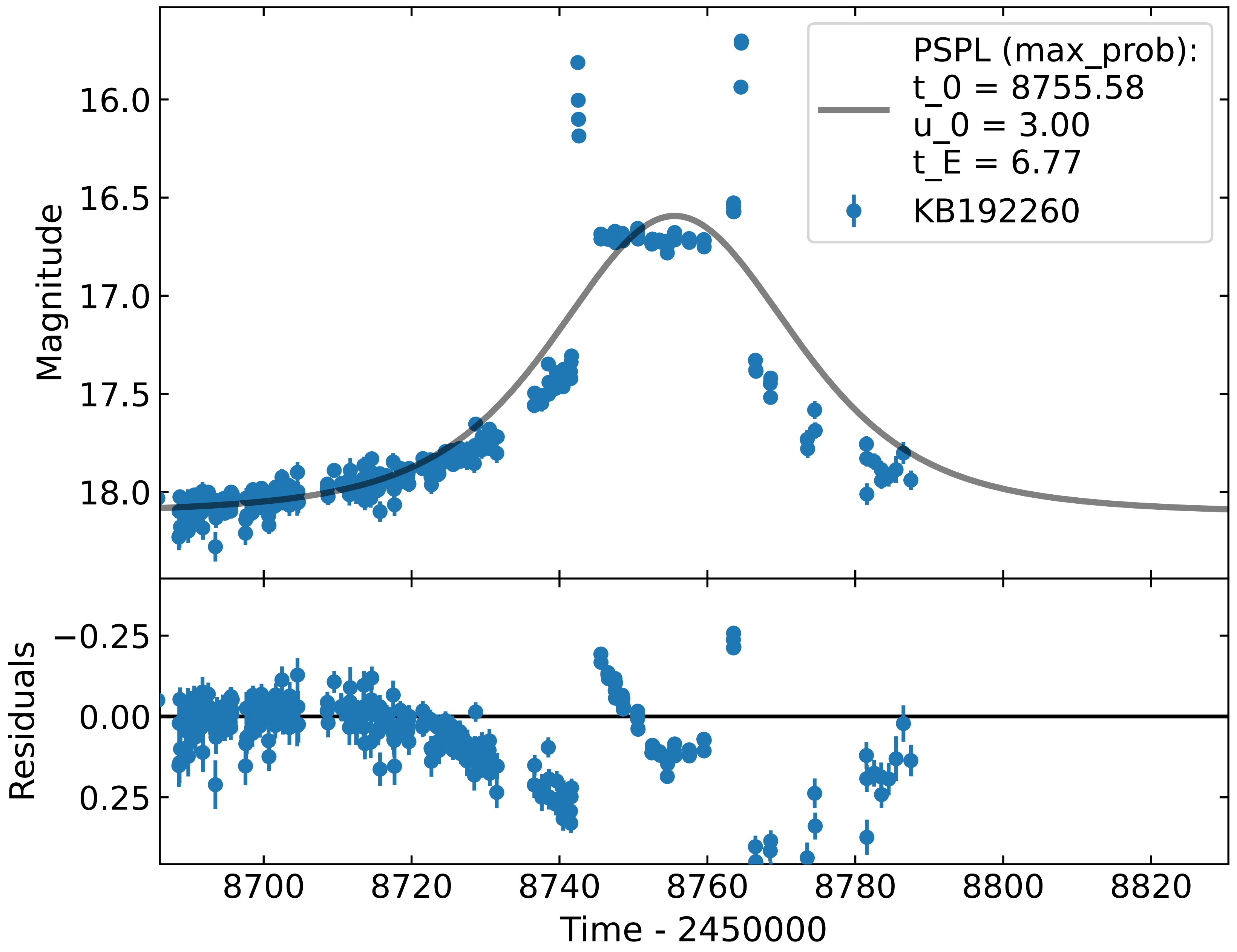

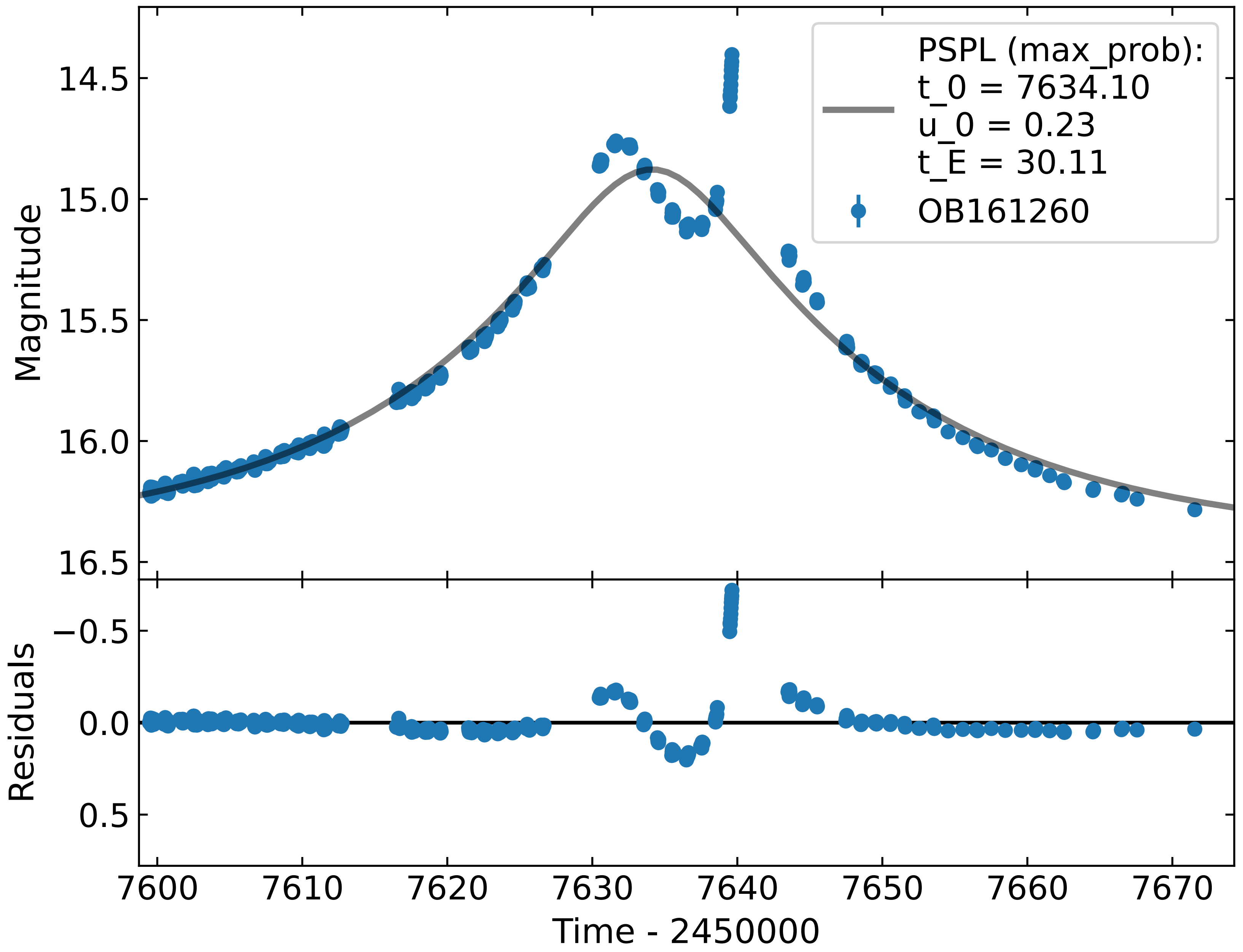

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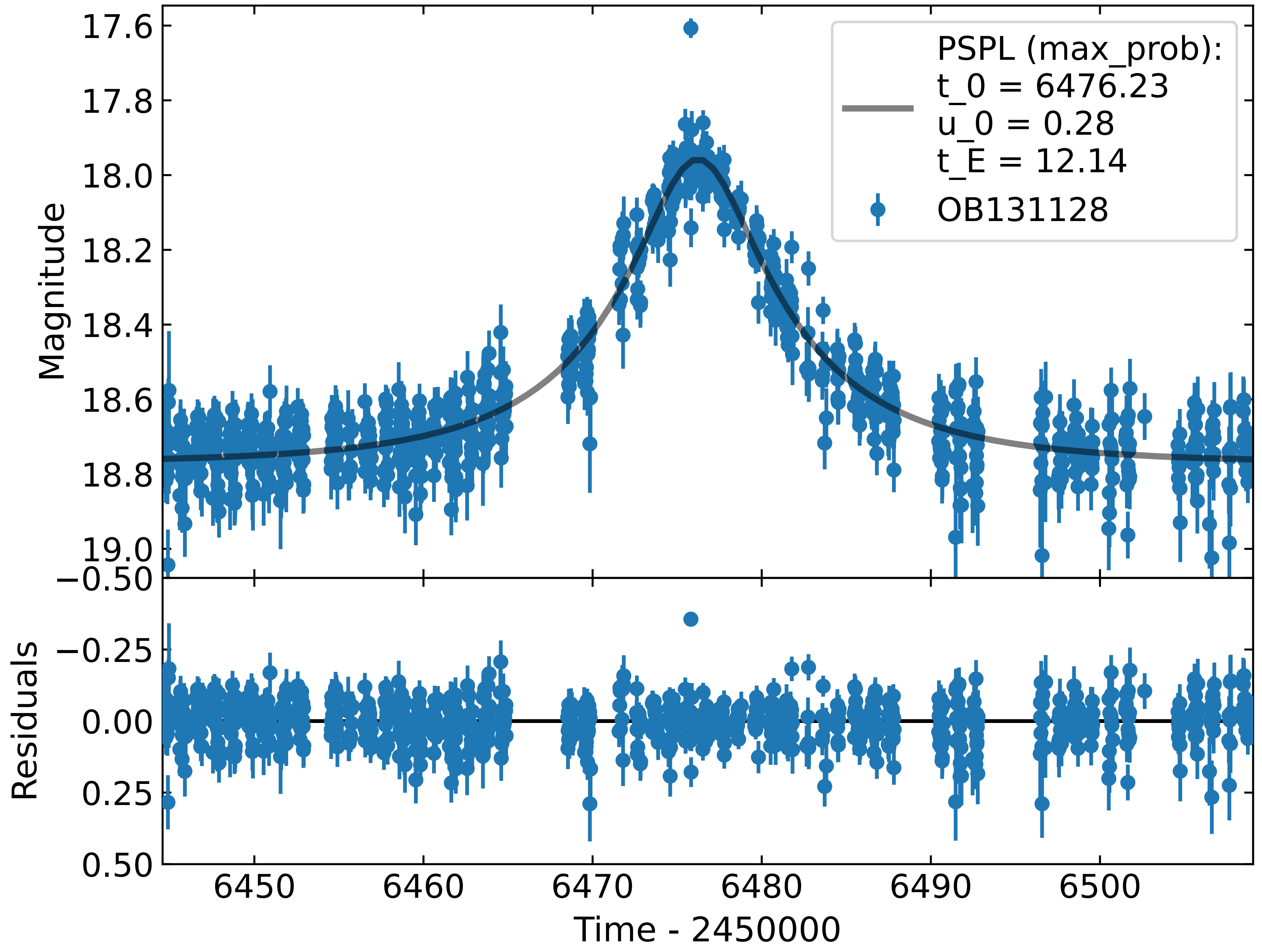

4 Automated model fitting: method

- Steps with MulensModel (Poleski & Yee 2019):
  1. Two PSPL from scipy.optimize → quick 1L2S fit
  2. **Split data** in the minimum between the peaks
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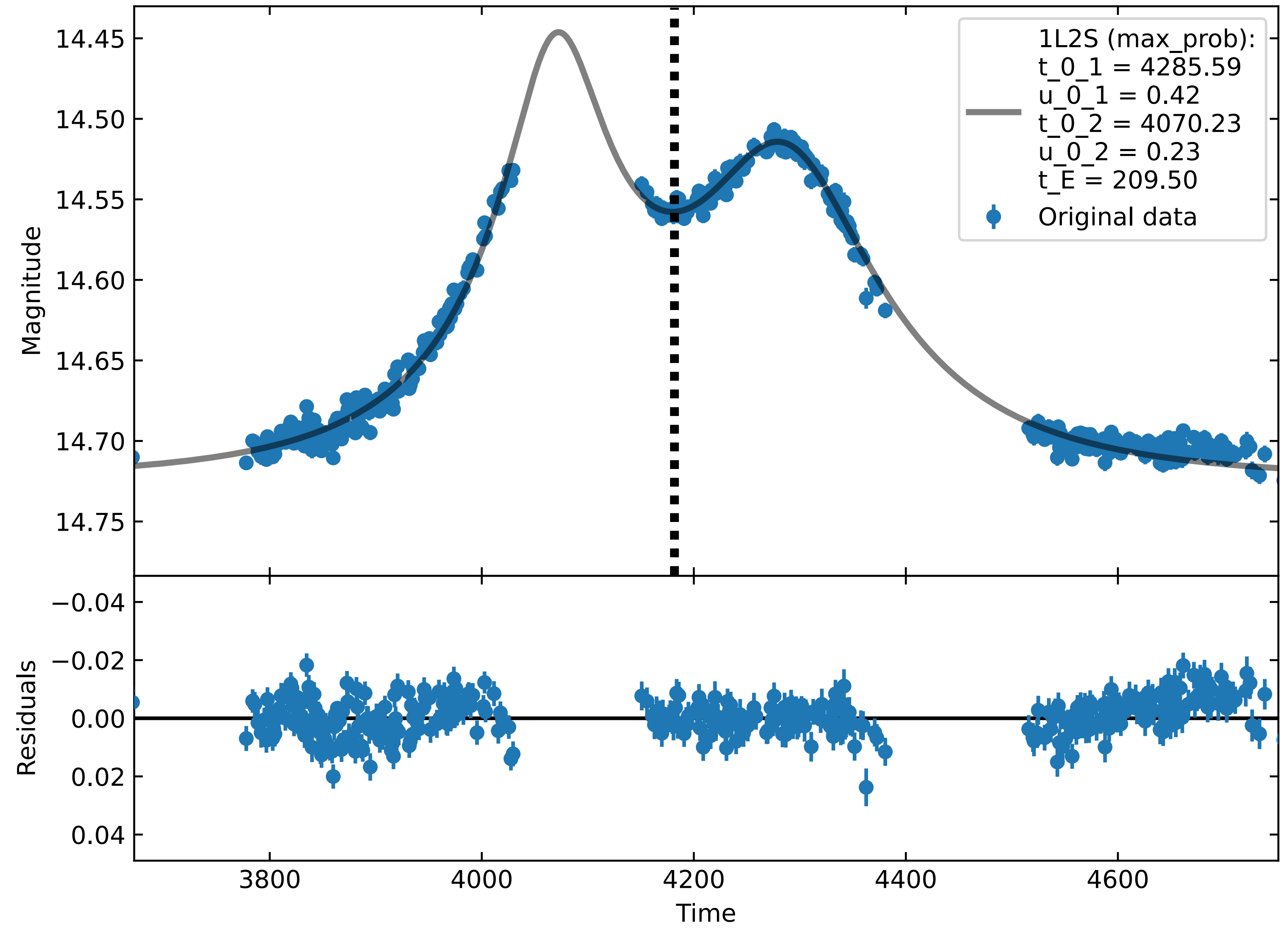
BLG225.8.163880 (Wyrzykowski et al. 2016)



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- **1L2S:** $t_{0,1}$, $u_{0,1}$, $t_{0,2}$, $u_{0,2}$, t_E (plus two source fluxes and blending flux)

- 2xPSPL with blending_flux=0 give initial parameters for 2L1S:
  - t_0, u_0, t_E, q, s, α in terms of $\{t_{0,i}, u_{0,i}, t_{E,i}\}_{1,2}$

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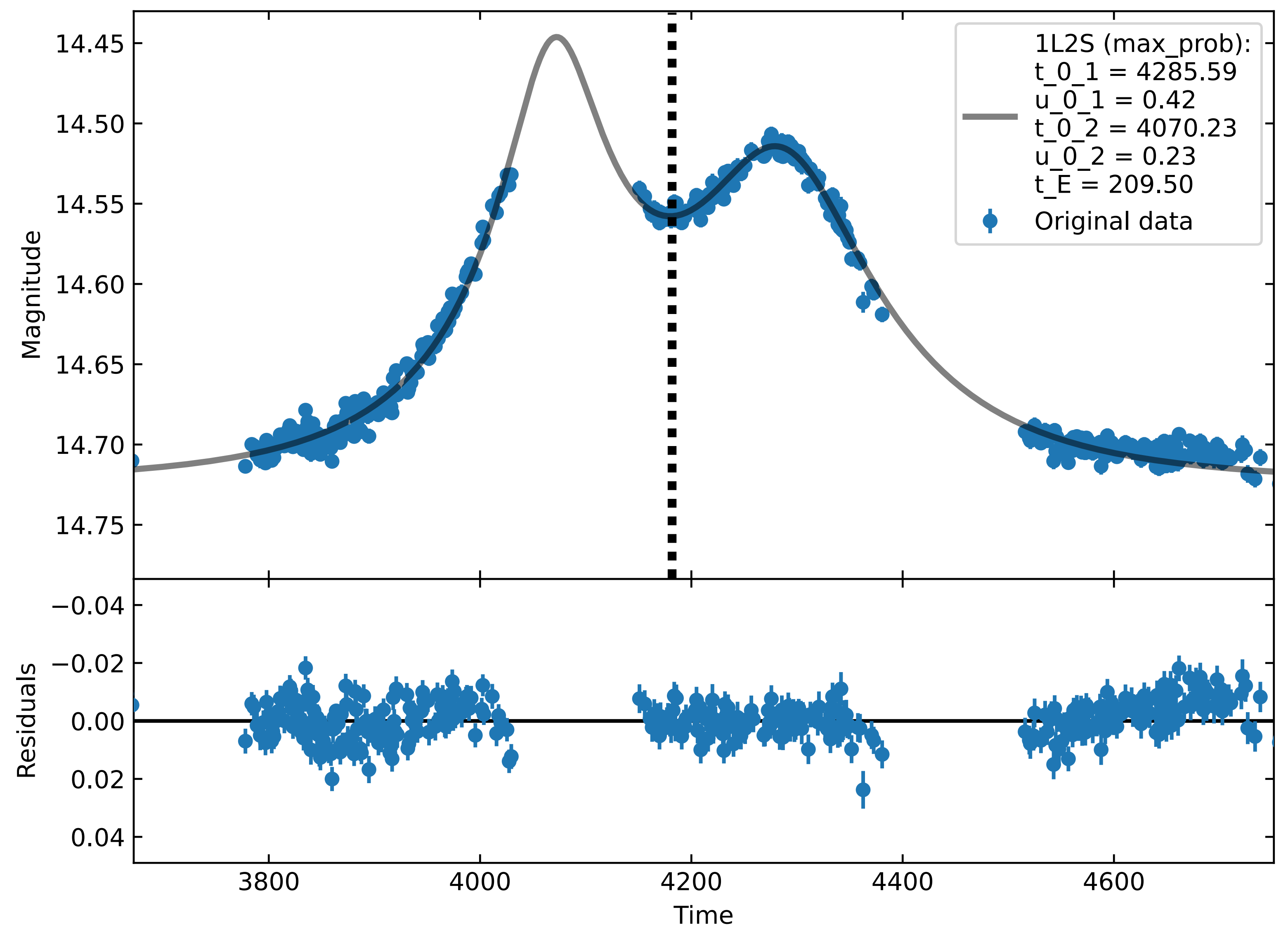
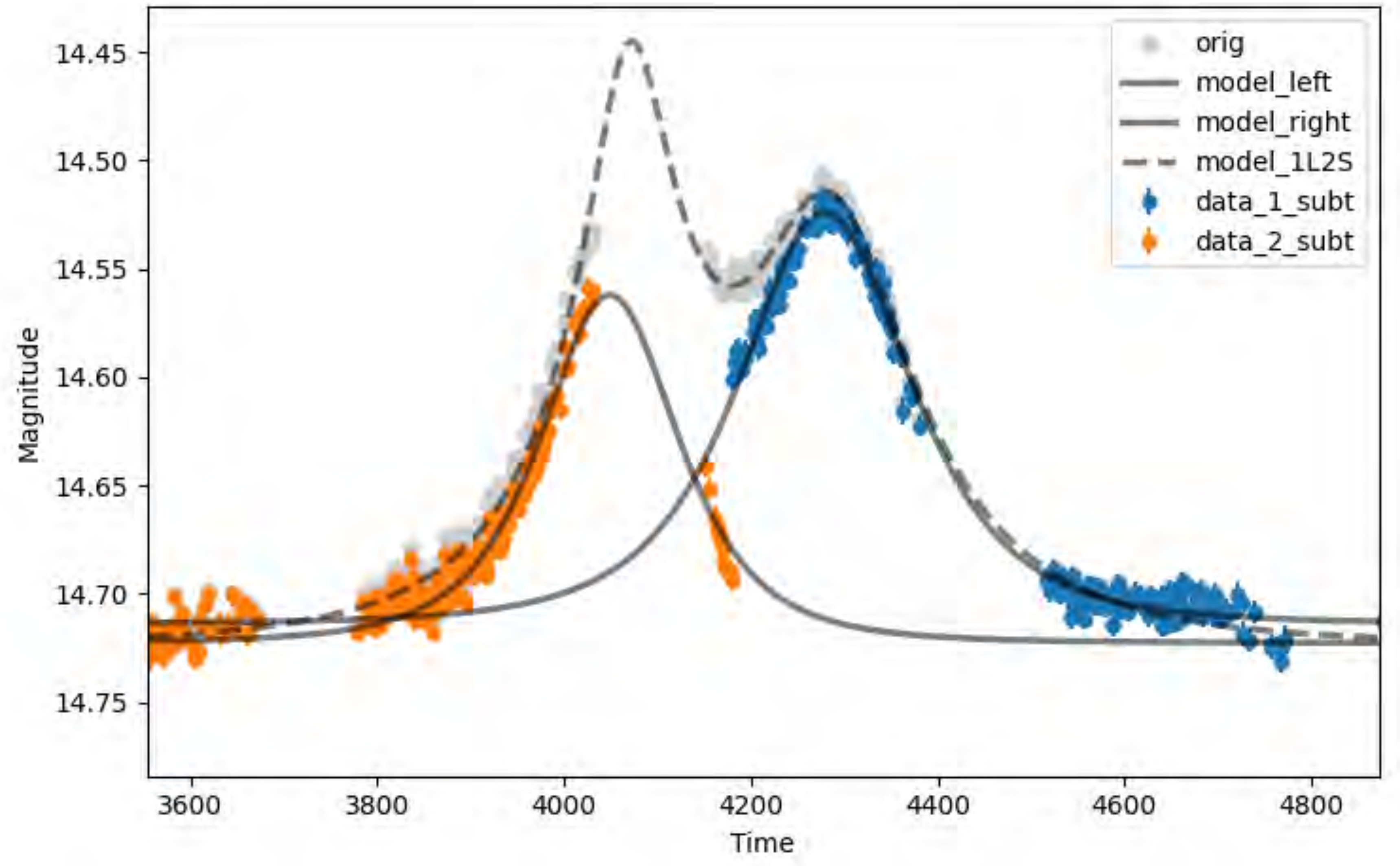
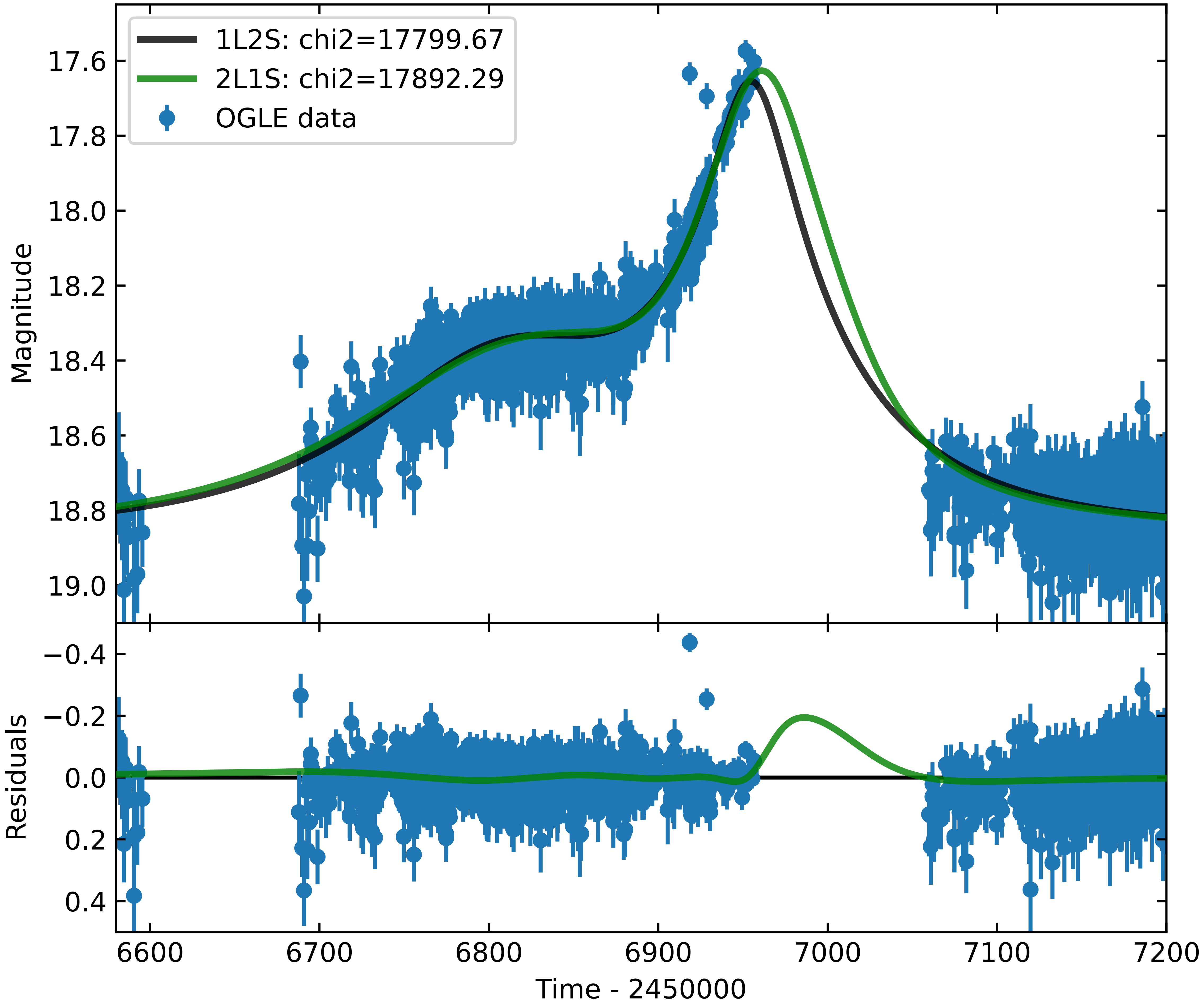
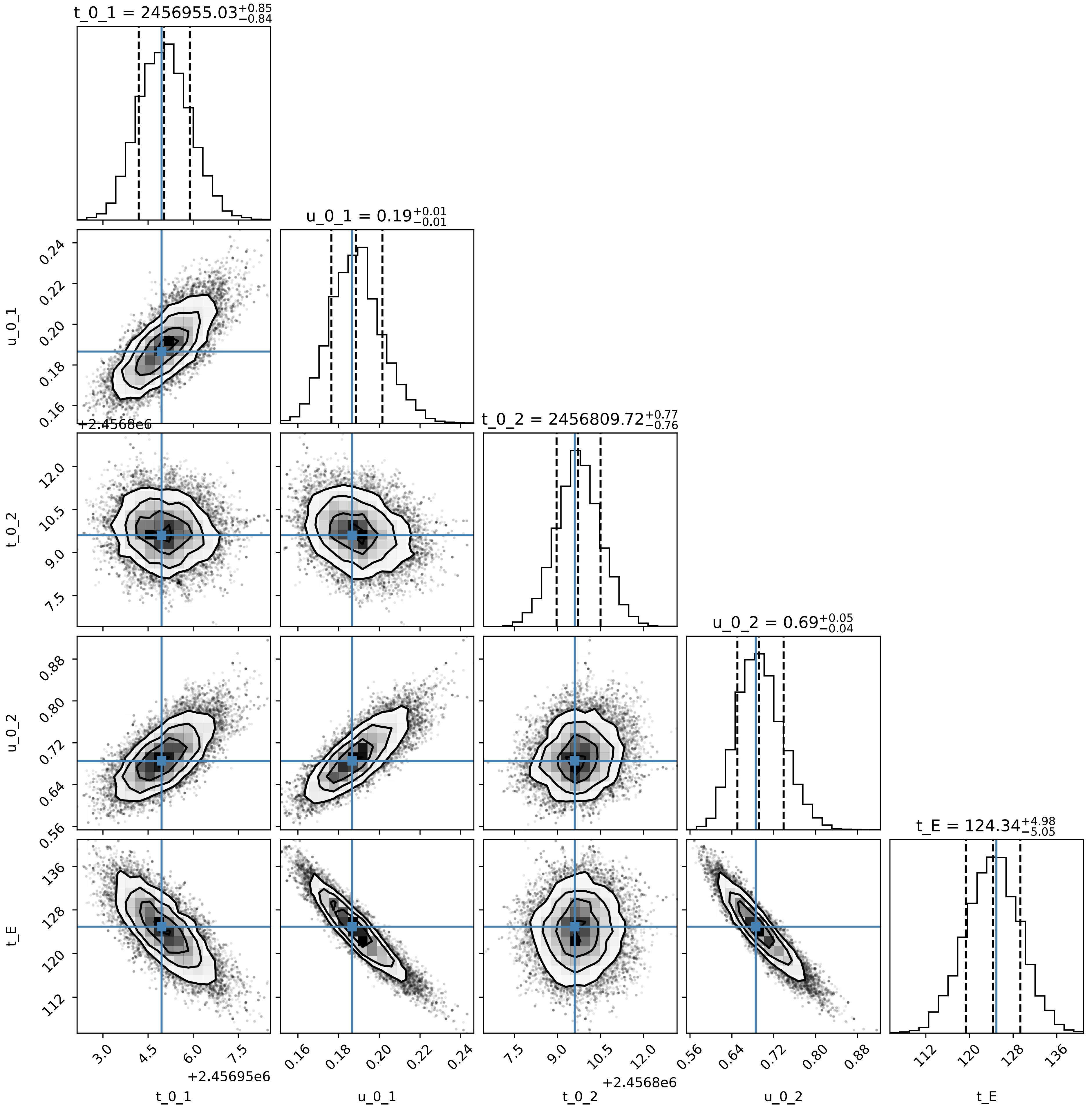




4 Automated model fitting: BLG505 event not in alerts





5 Next steps

- Improve and test pipelines with benchmarks, caustics and extreme cases
- Check the best approach to obtain detection efficiency

- Future: Get constraints for the binary fraction and mass distribution, and finally the IMF for this lower-mass regime of the Bulge

Thank you!