TDCOSMO XXIII: Measurement of the Hubble constant from the doubly lensed quasar HE 1104-1805

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EAMA 11
Niigata - December 11th 2025

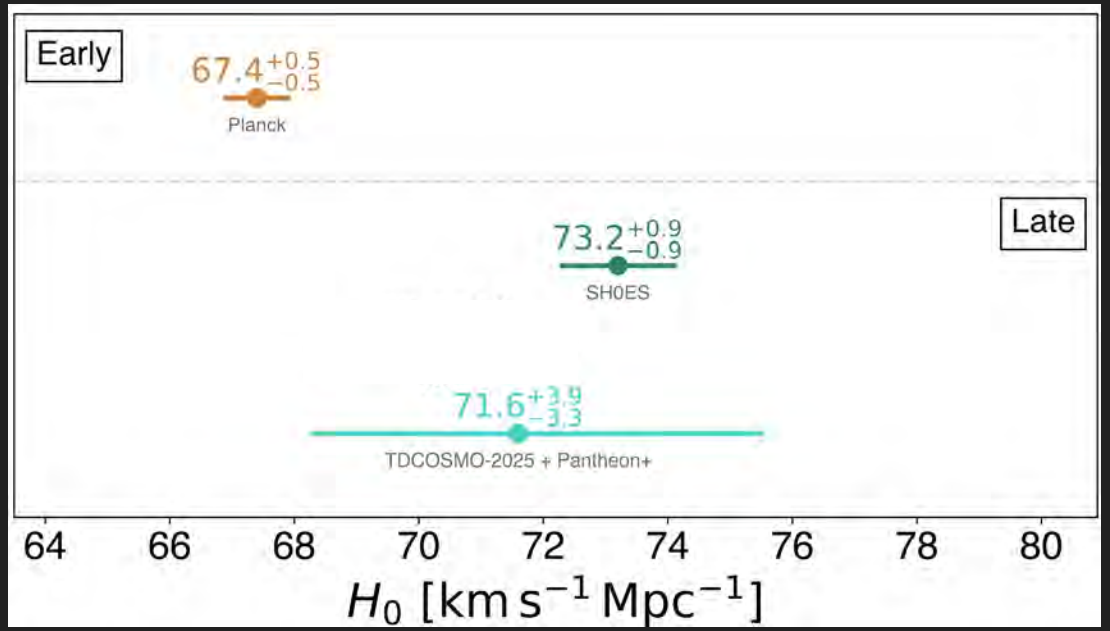


Hubble tension status

Growing tension between early and late universe measurements

Time delay cosmography is a direct measurement **independent** from all other methods

TDCOSMO 2025 perfected the method (see Ken Wong's talk) but 5% precision **not yet sufficient** to settle the debate



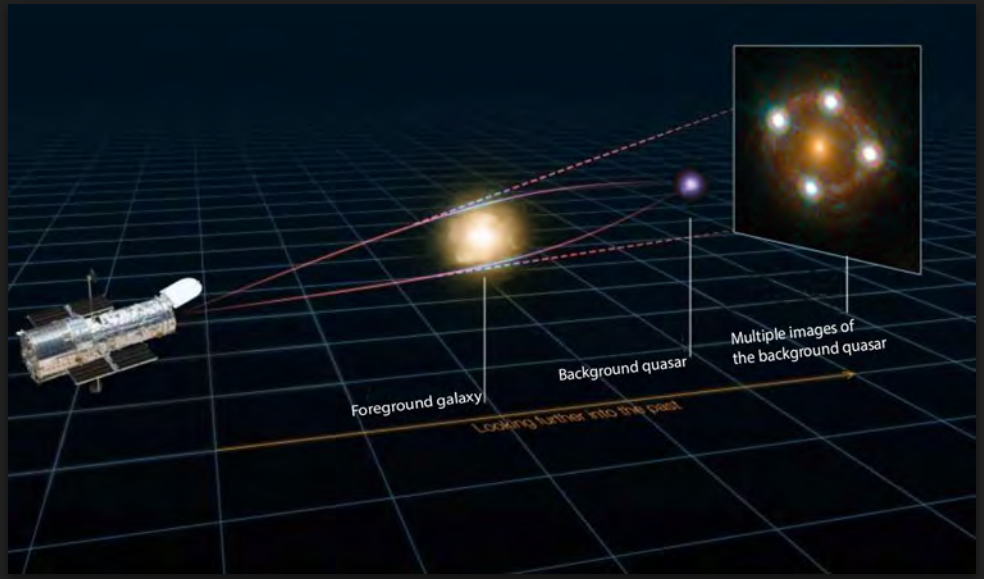
TDCOSMO 2025

Time Delay Cosmography



Credits: A.J. Shajib

Time Delay Cosmography



Time Delay distance $\propto H_0^{-1}$

$$\Delta t \propto D_{\Delta t} \Delta\Phi_{\text{model}}$$

Time delay

Fermat potential ≈ ***Mass***

Ingredients for H_0 measurement

1. **Time delay between two images**

   Long term monitoring (SMARTS, ECAM, WFI)

2. **Lens modelling**

   High resolution imaging (HST)

3. **External convergence**

   Wide Field Imaging (Subaru/HSC)

4. **Resolved velocity dispersion**

   Integral Field Unit spectra (VLT/MUSE)

5. **Mass-sheet transform treatment**

   Hierarchical analysis of a large sample of systems

$$H_0 \propto \frac{\Delta\Phi_{\rm model}(1-\kappa_{\rm ext})\lambda_{int}}{\boxed{\Delta t}}$$

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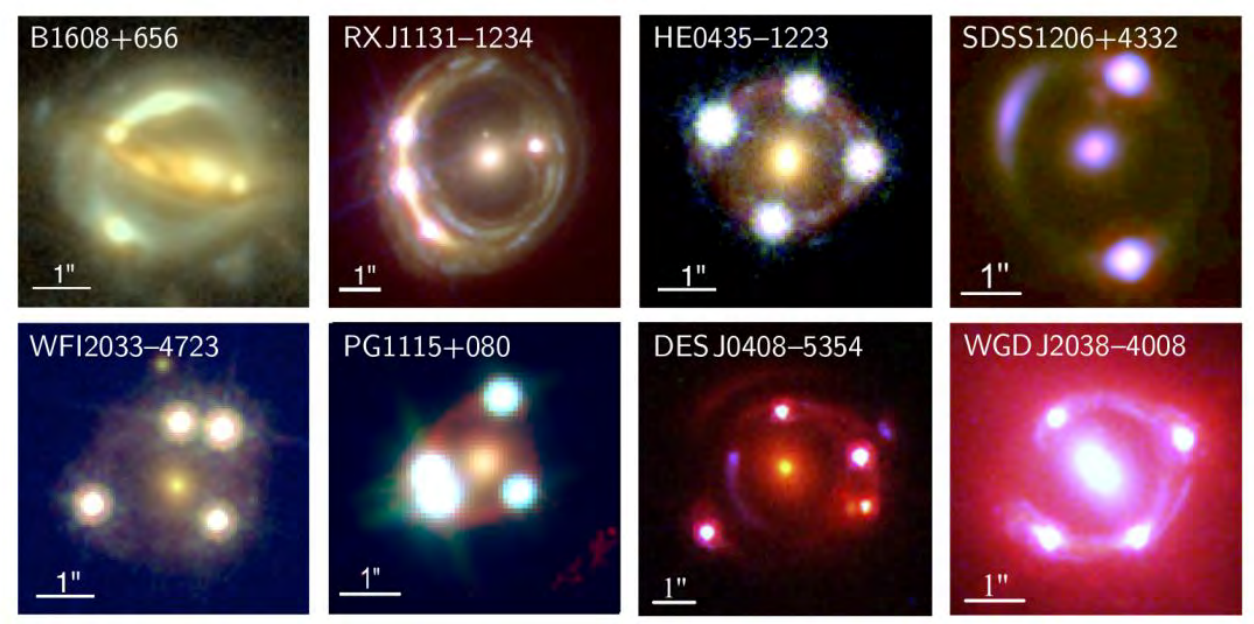
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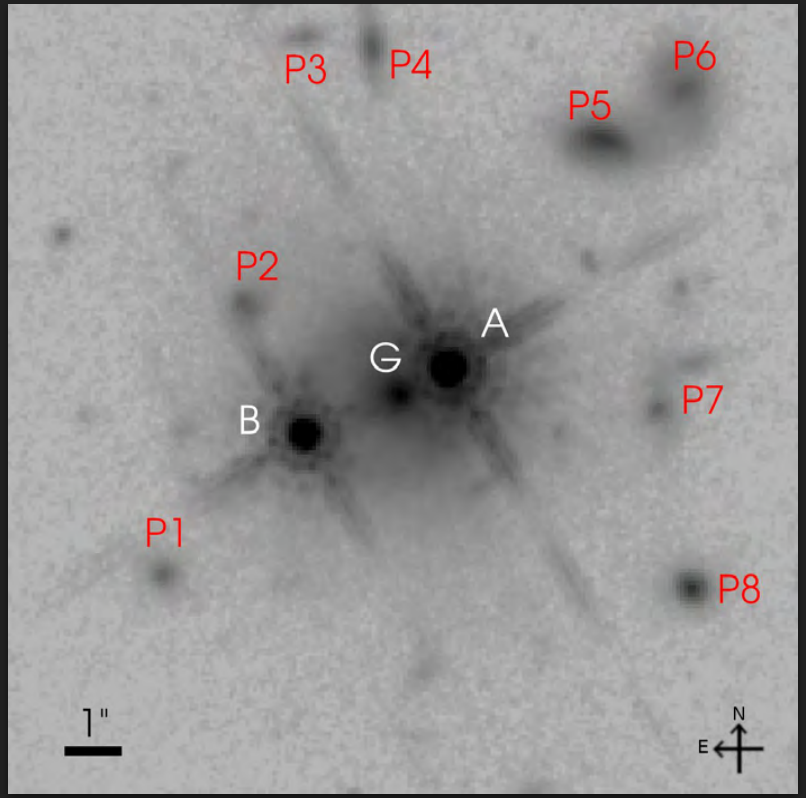
$$H_0 \propto \frac{\Delta\Phi_{\rm model}(1-\kappa_{\rm ext})\lambda_{int}}{\Delta t}$$

TDCOSMO sample is so far dominated by quads



Time delay cosmography with doubles

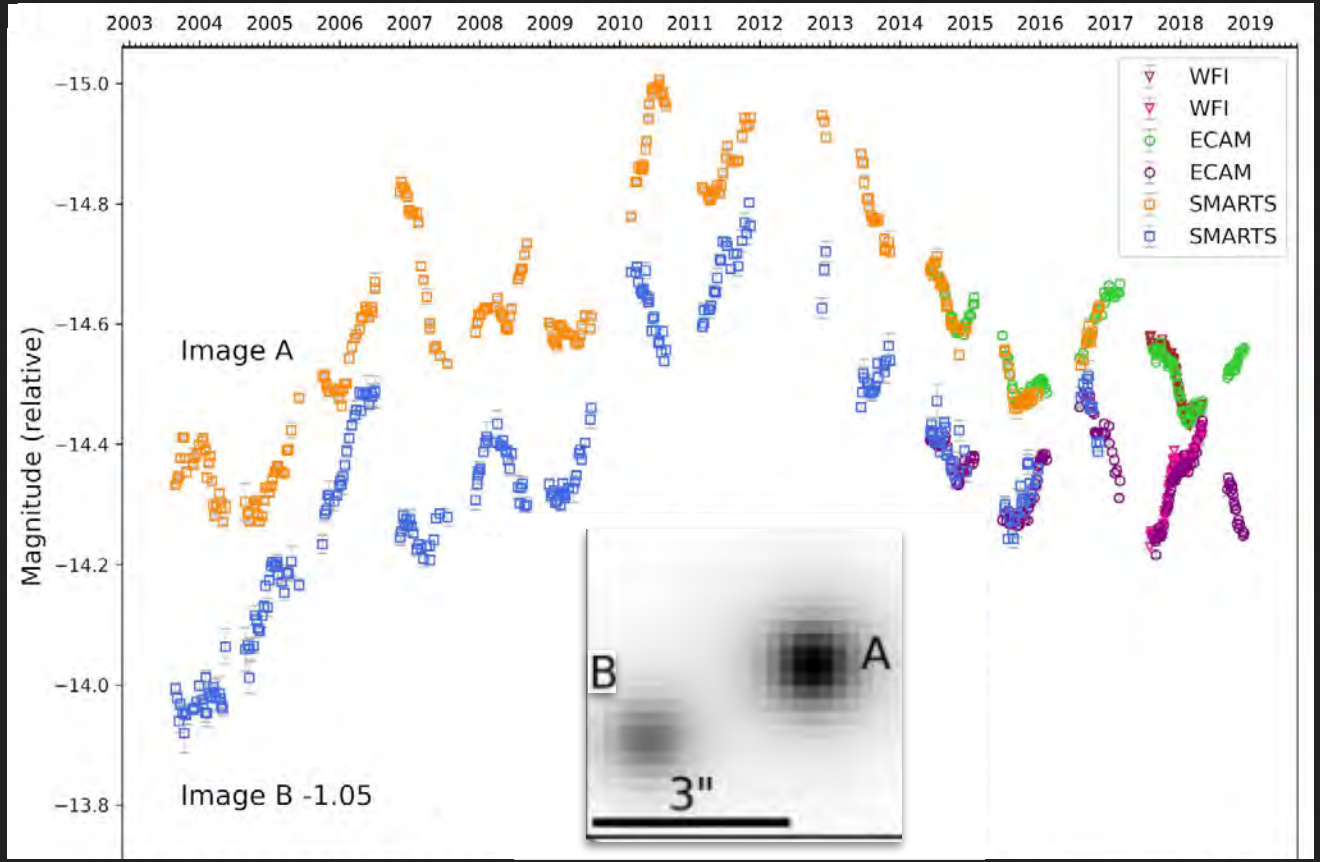
- **80%** of lenses are doubles
- Avoid selection **biases**
- Doubles have **longer** time delays
- HE1104 is the **first** double lensed source in the TDCOSMO sample



Time delay

14 years of monitoring

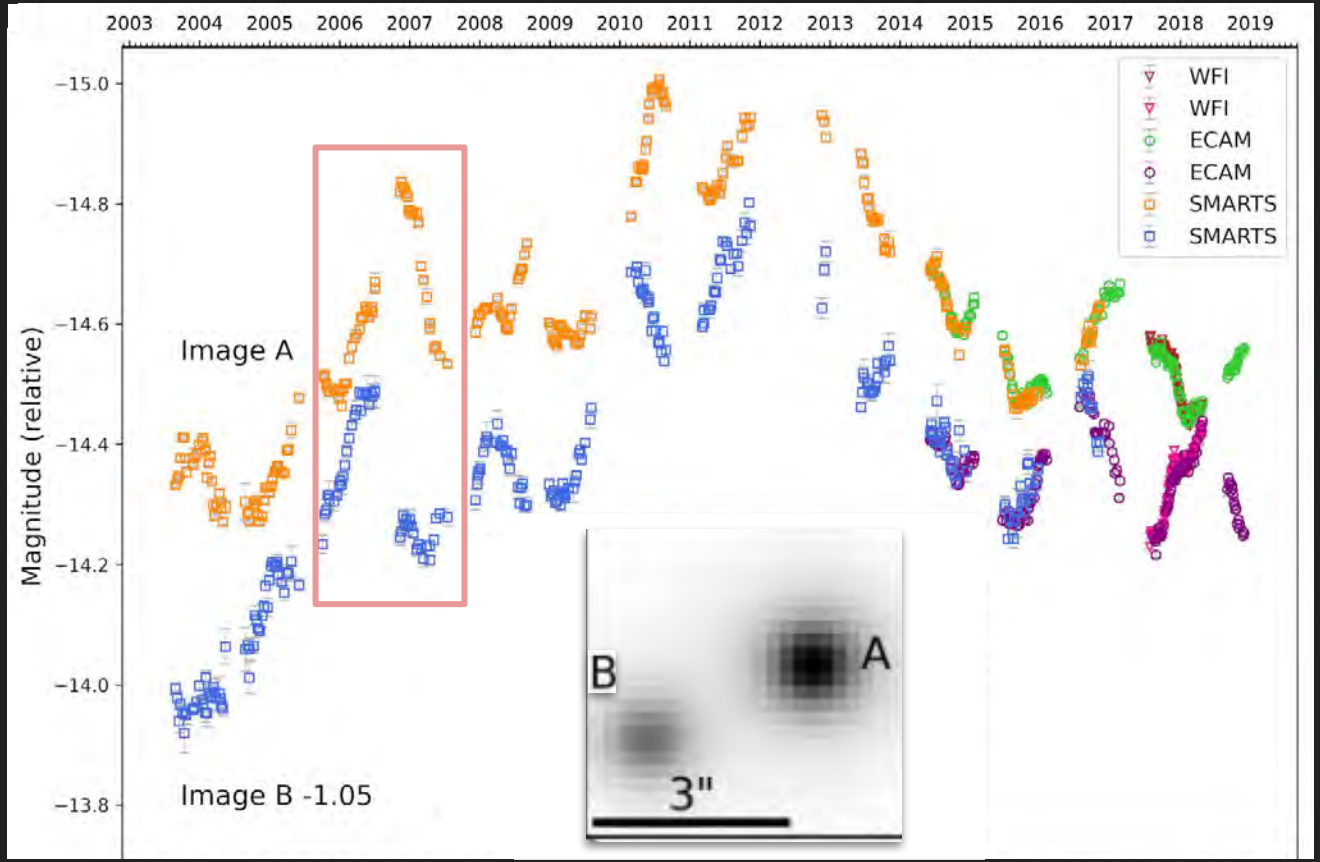
with 3 telescopes



Time delay

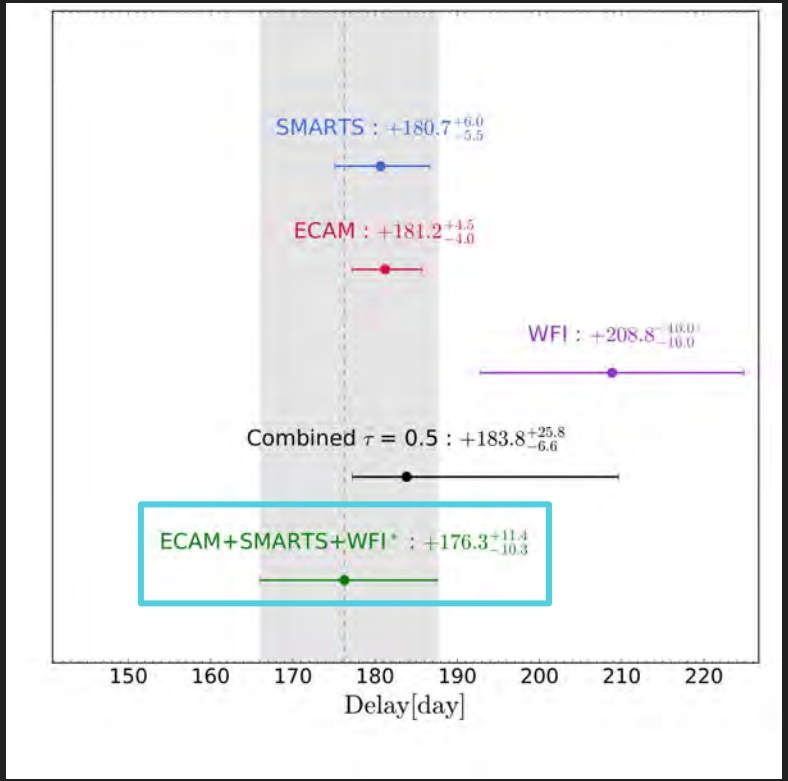
14 years of monitoring with 3 telescopes

Time shift to match similar features in both light curves



Time delay - Final measurement

8 % precision



Lens modelling - Data

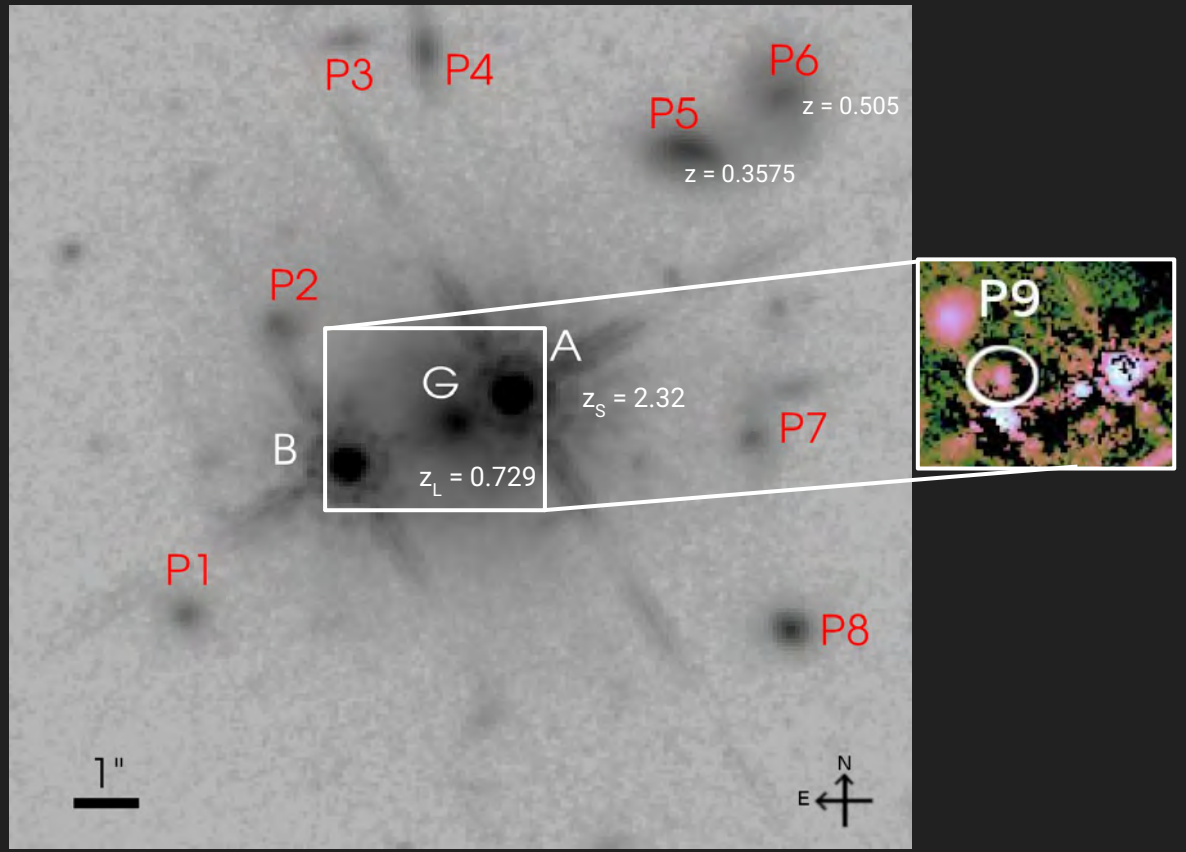
Main lens:

- Composite

  (2 mass components: Luminous and Dark matter)

- Power-law

  (1 mass component)



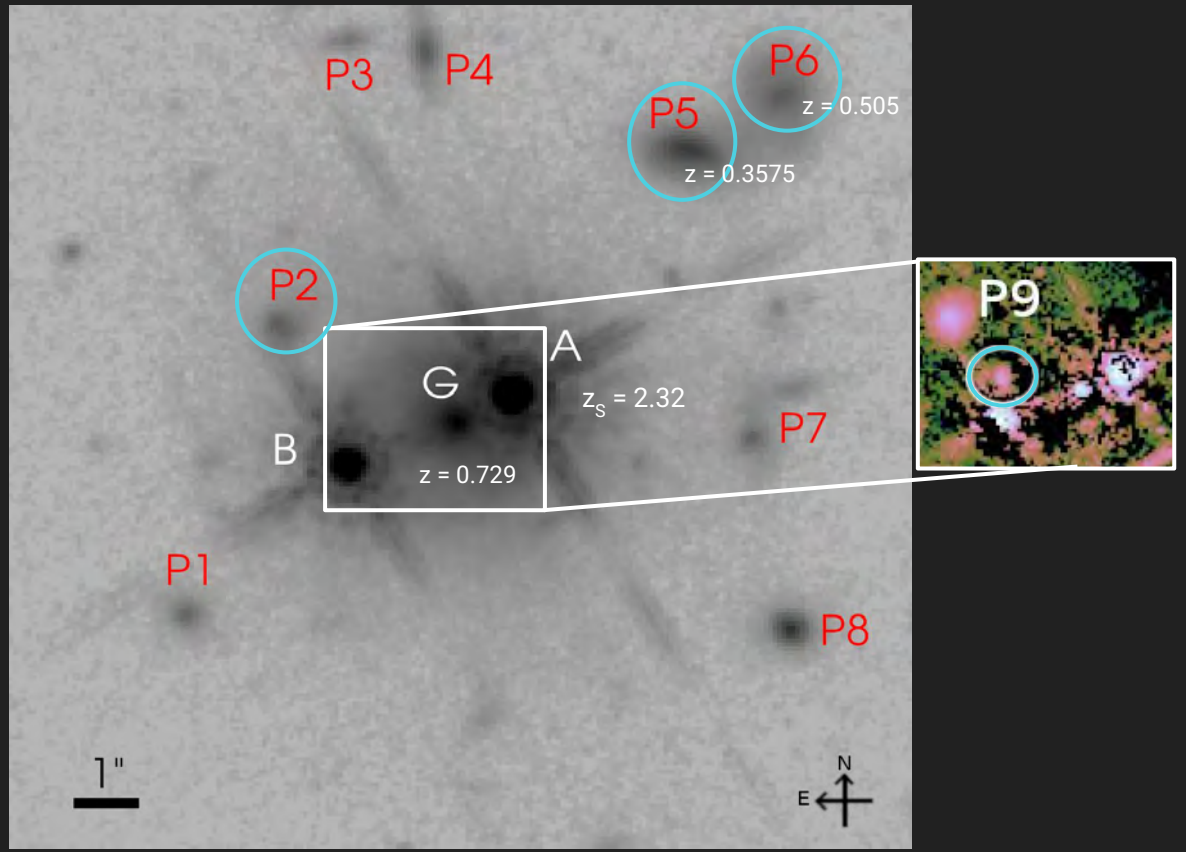
Lens modelling - Parametrisation

Main lens:

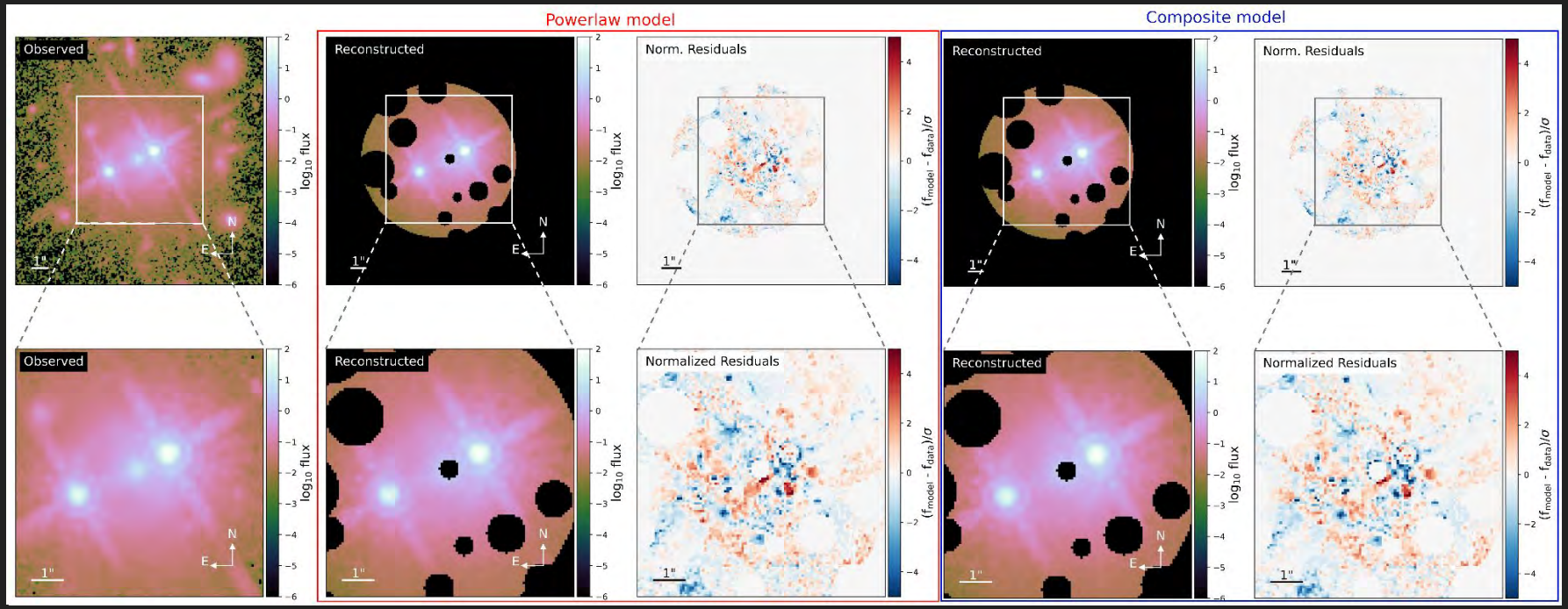
- Composite
- Power-law

Perturbers:

- Singular Isothermal sphere

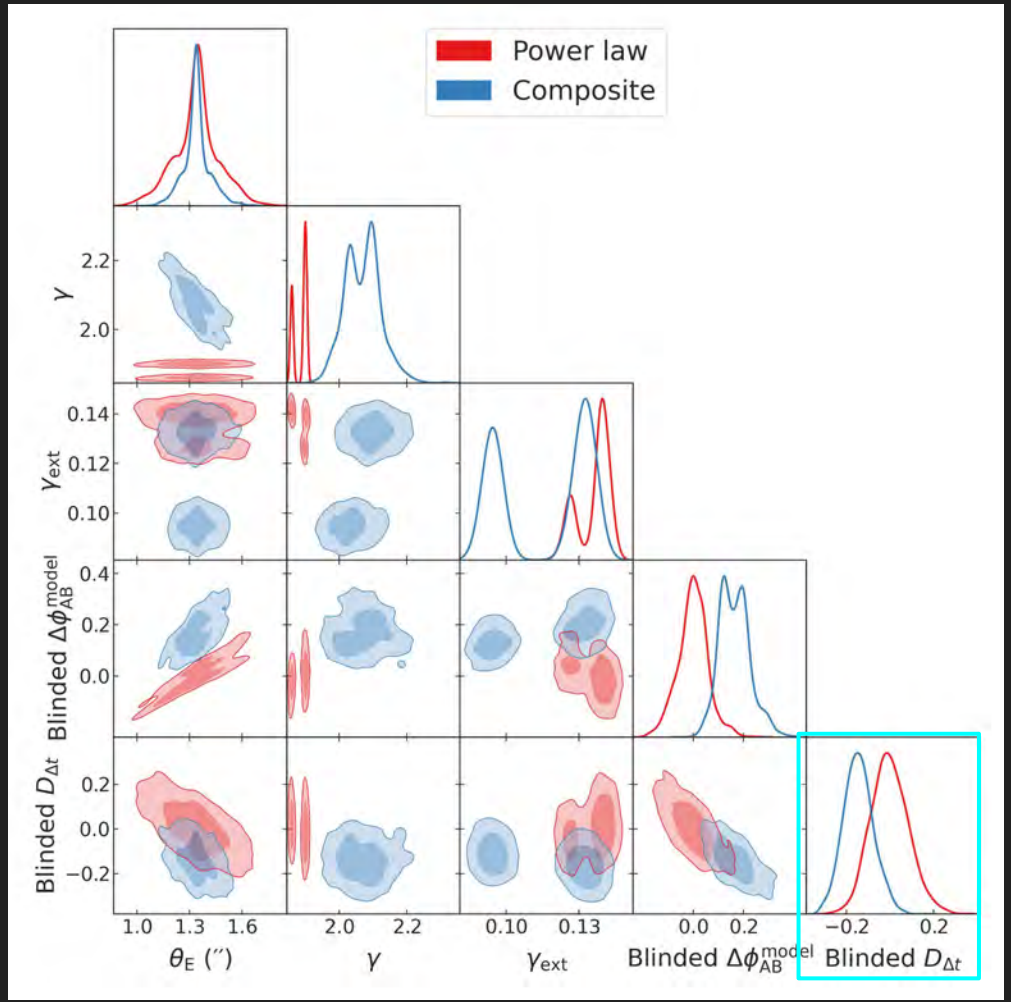


Lens modelling - Results

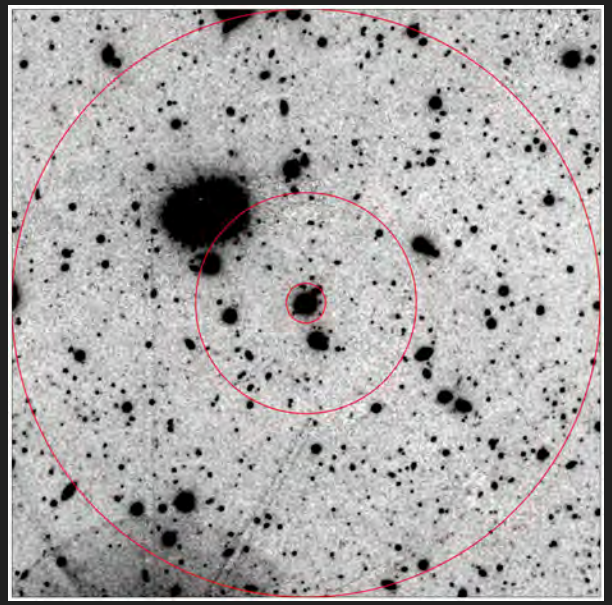


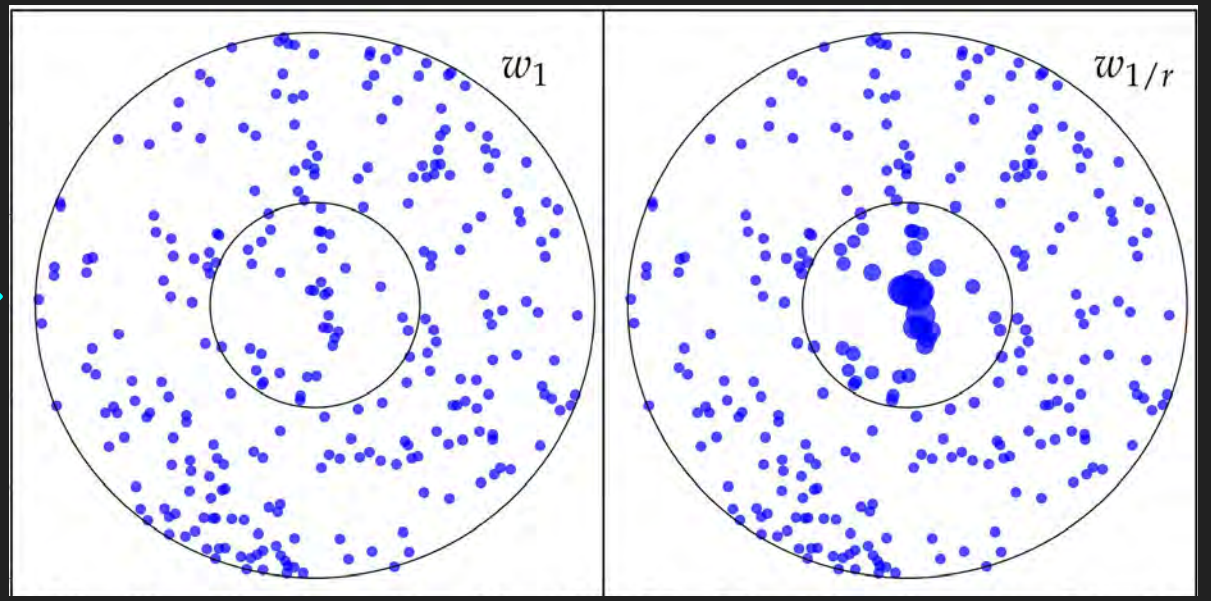
Model comparison

12% difference between both families



External convergence

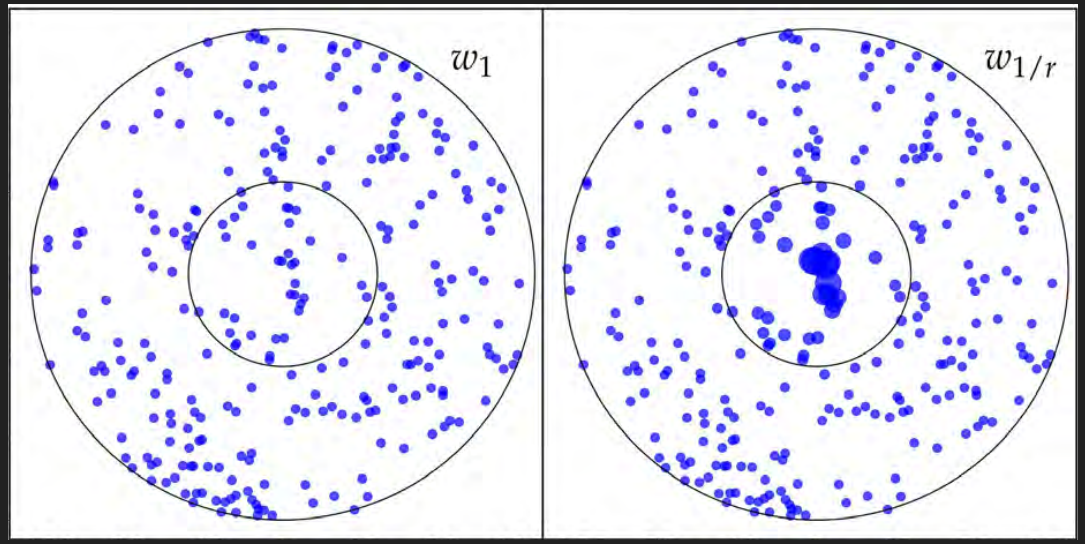


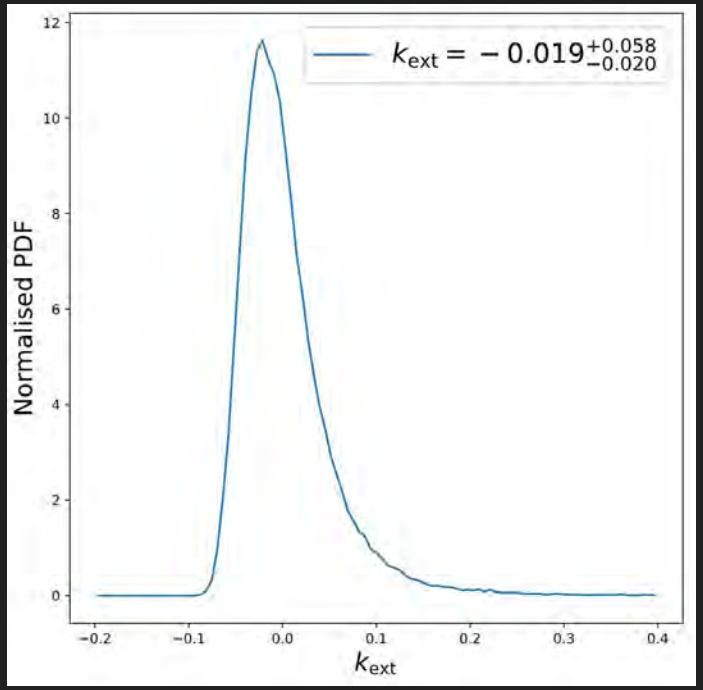


HSC i-band

Number counts with different weights

External convergence



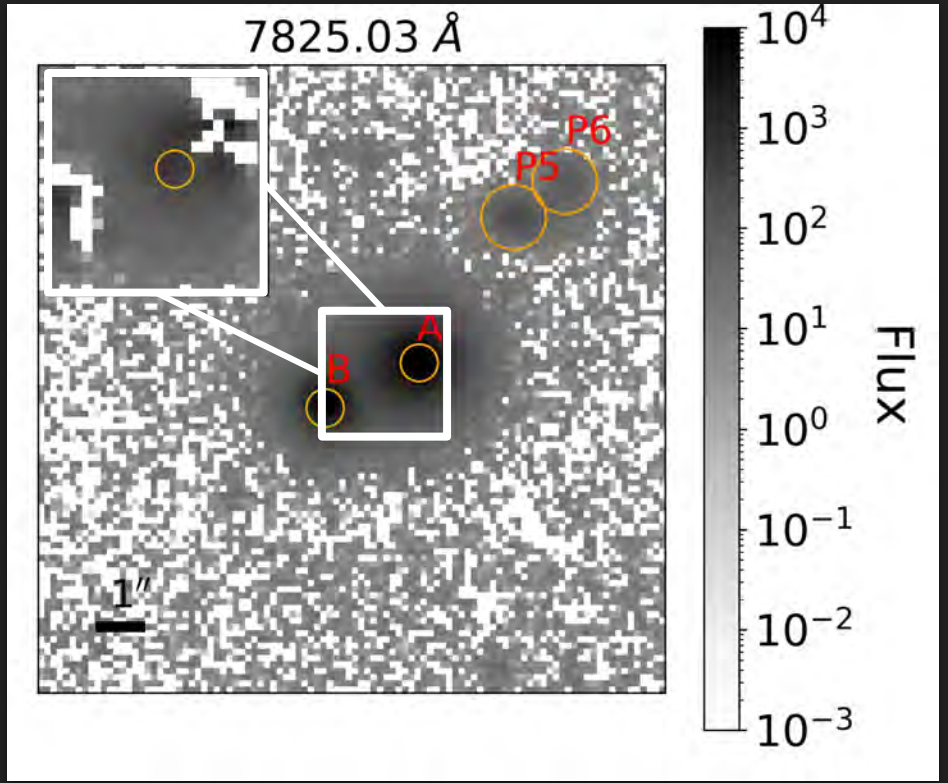


Number counts compared to Millenium simulation

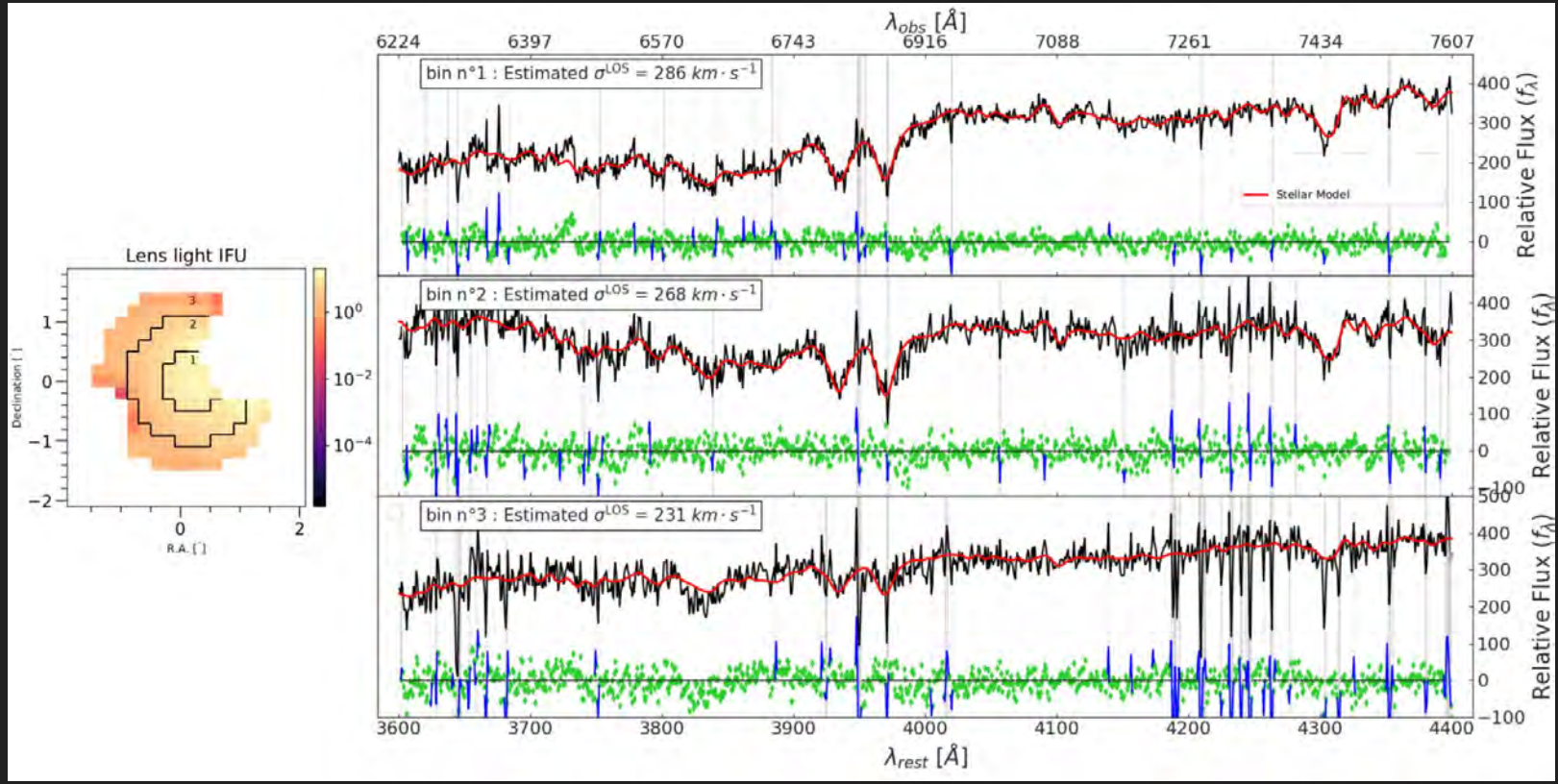
Velocity dispersion - Data

Very Large Telescope /MUSE

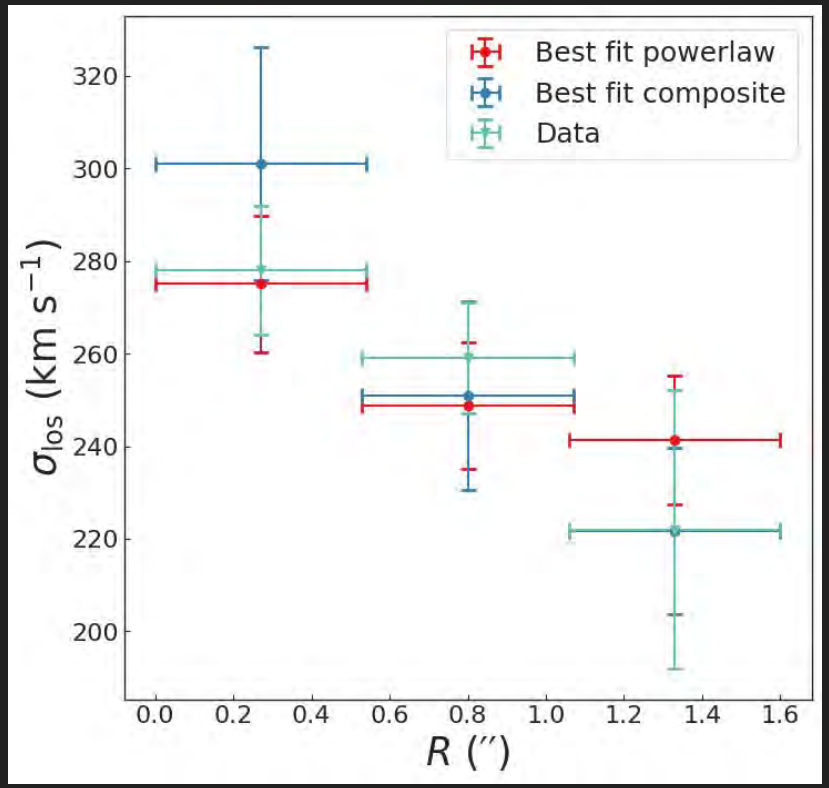
Integral Field Unit spectra

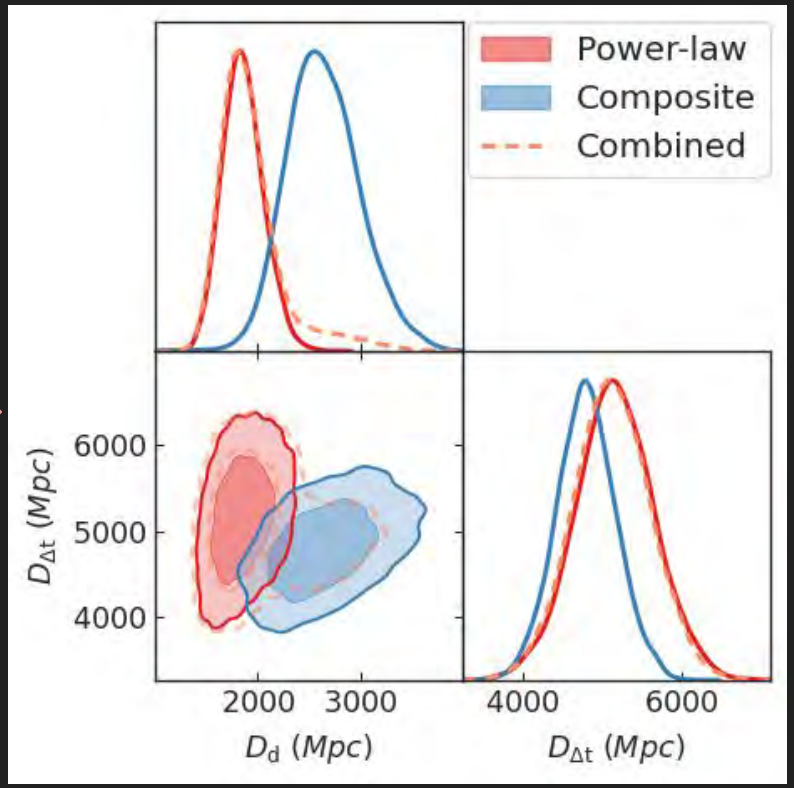


Velocity dispersion - Measurement



Kinematic fitting





H_0 at last!

$$H_0 \propto \frac{\Delta\Phi_{\rm model}(1-\kappa_{\rm ext})\lambda_{int}}{\Delta t}$$

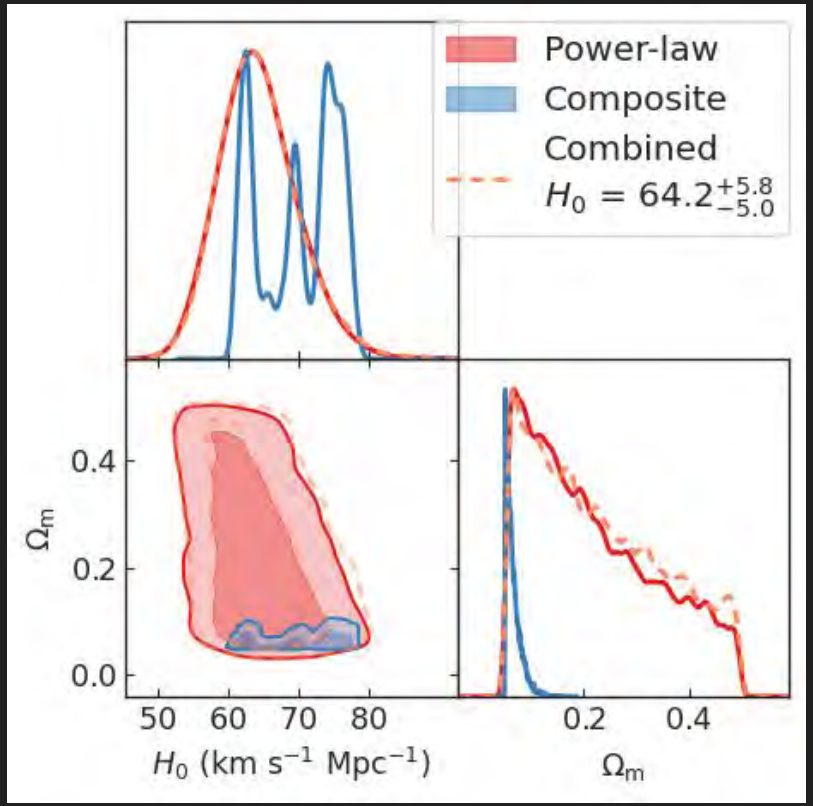
With a fixed mass sheet λ_{int}=1

$$H_0 = 64.2^{+5.8}_{-5.0} \times \lambda_{\rm int}\ {\rm km\cdot s^{-1}Mpc^{-1}}$$

8% precision

Comparable to quads (4-8% precision for λ_{int}=1)

Complete treatment of the mass-sheet degeneracy will be done in the next milestone



Summary

Full Time delay Cosmography analysis of a doubly lensed quasar:

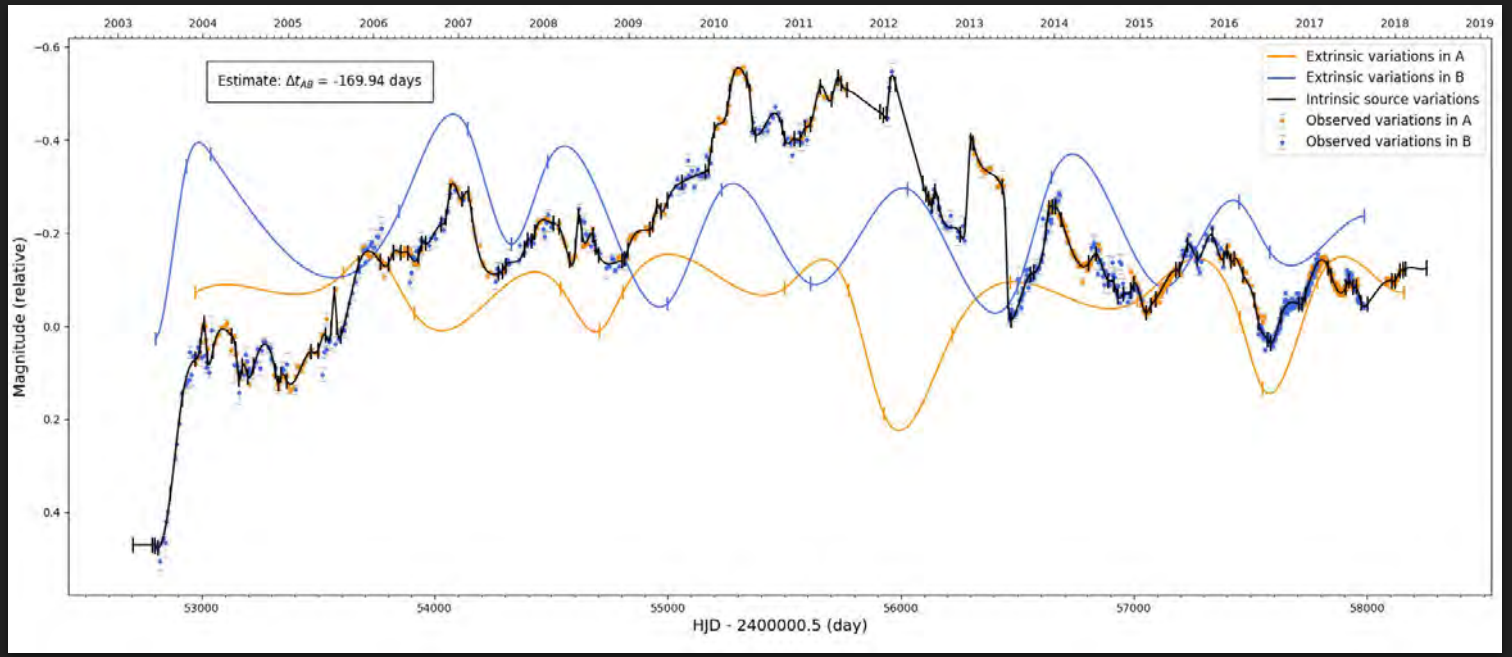
1. Time delay: 8% precision
2. Resolved velocity dispersion: 3 bins down to 8% precision
3. Time delay distance: Powerlaw model reaches 9% precision

Doubles are a viable tool to measure H_0!

Stay tuned for **TDCOSMO's next milestone** which will include this system to improve its precision.

Paic et al.(2025)
arxiv.org/pdf/2512.03178

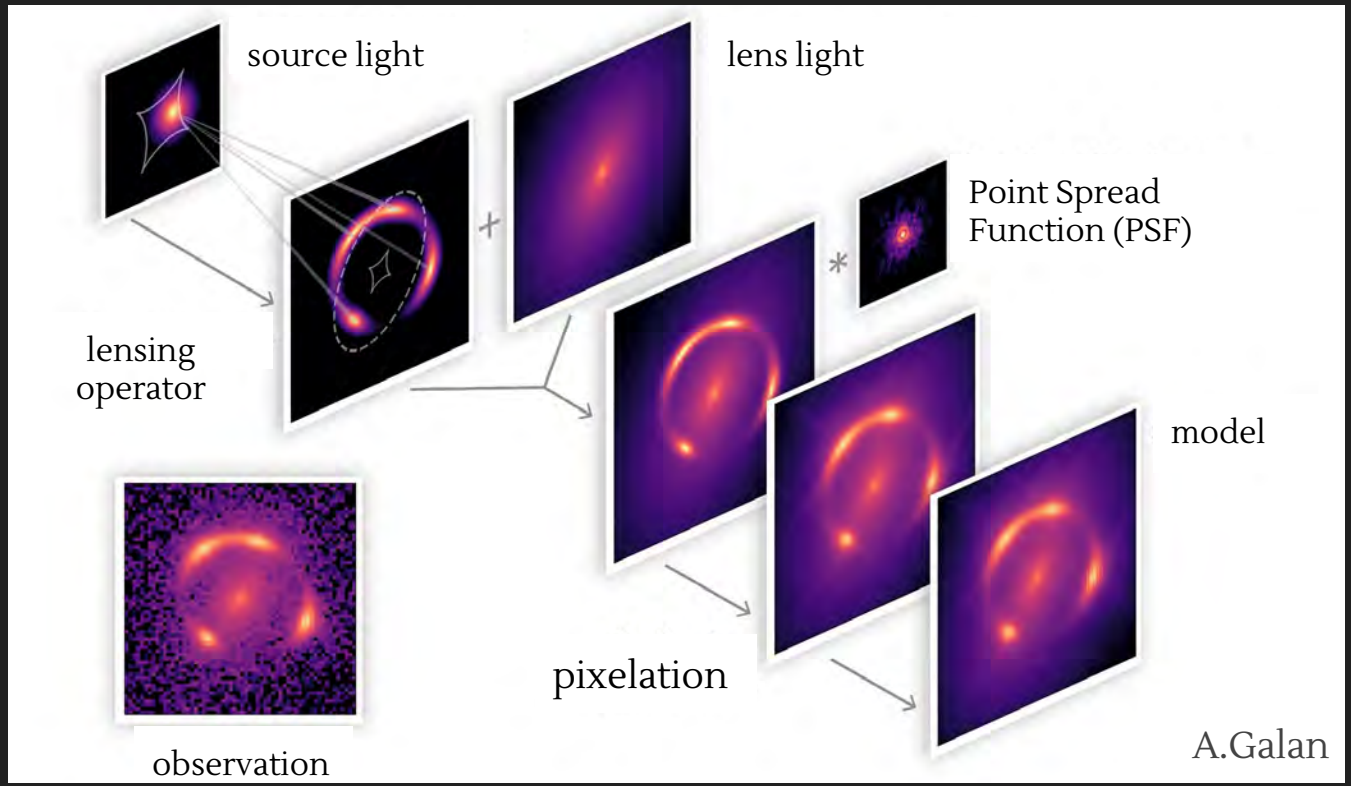
Time delay - Point estimate



$$\eta_{\rm intr} = 35 \text{ days} \quad \eta_{\rm ml} = 150 \text{ days}$$

Paic et al. (in prep)

Lens Model through image reconstruction



Mass sheet degeneracy (MSD)



$\kappa(\theta)$

β



$$\kappa_\lambda(\theta) = \lambda\kappa(\theta) + 1 - \lambda,$$
$$\beta_\lambda = \lambda\beta$$



$$H_{0,\lambda} = \lambda H_0,$$

$$\lambda = (1 - \kappa_{\rm ext})\lambda_{\rm int}.$$

External Internal