

Probing the BLR geometry and kinematics for quadruply lensed quasar Q2237+0305 with time series.

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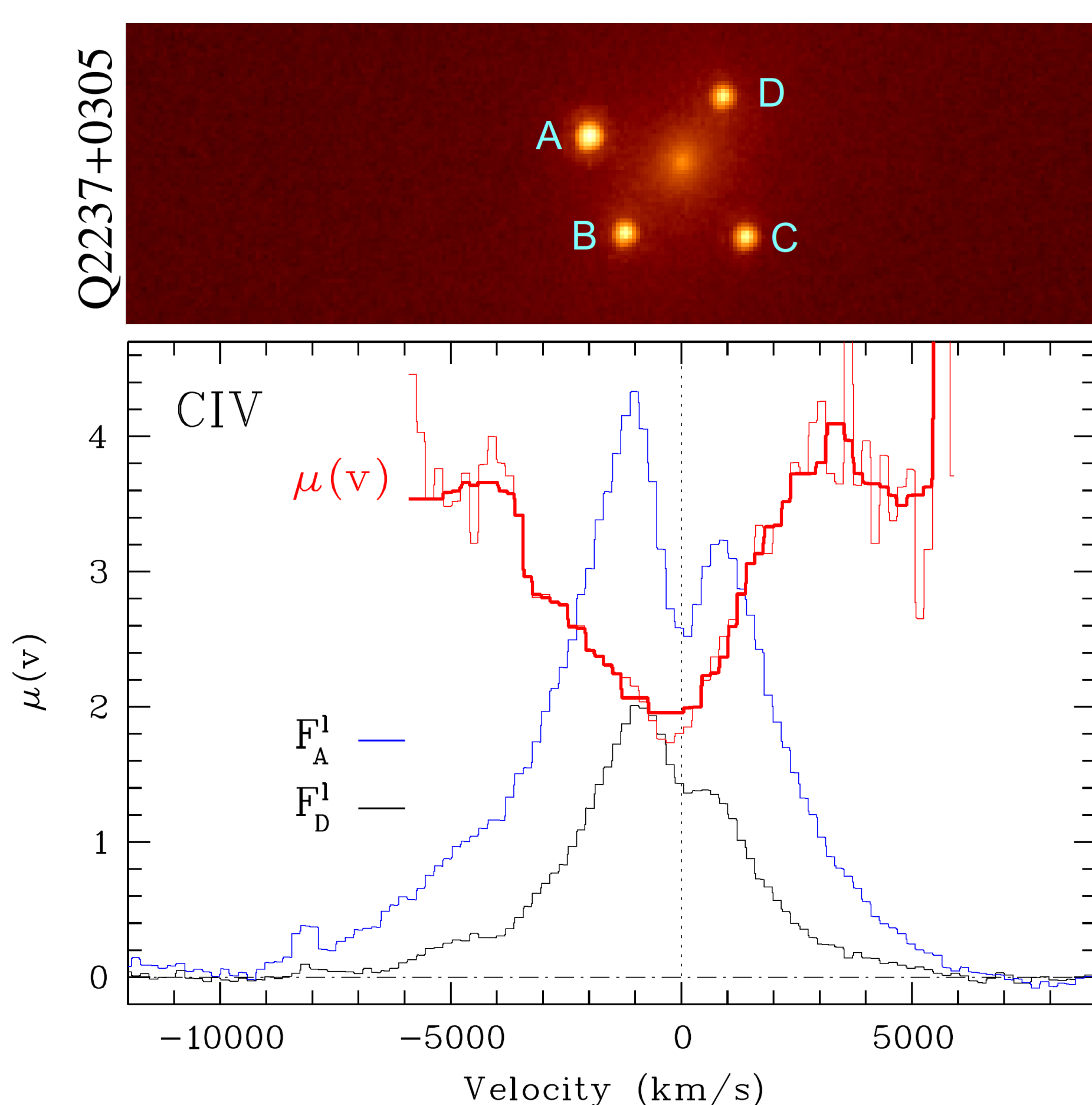
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1. Introduction

- Gravitational lenses are a powerful cosmic laboratories for simultaneously probing various astrophysical phenomena. Microlensing is a natural event that occurs when the light emitted by a quasar is bent and focused by the gravity of a single star in the foreground galaxy, causing a temporary increase in the quasar's brightness.
- The past observations of Q2237+0305 have revealed that image D remains unaffected by microlensing while image A has been subject to high magnification during monitoring period (Eigenbrod et al. 2008). We use archival data to study the geometry and size of CIV emitting broad line region (BLR) using the probabilistic approach developed by Hutsemékers et al. (2019).

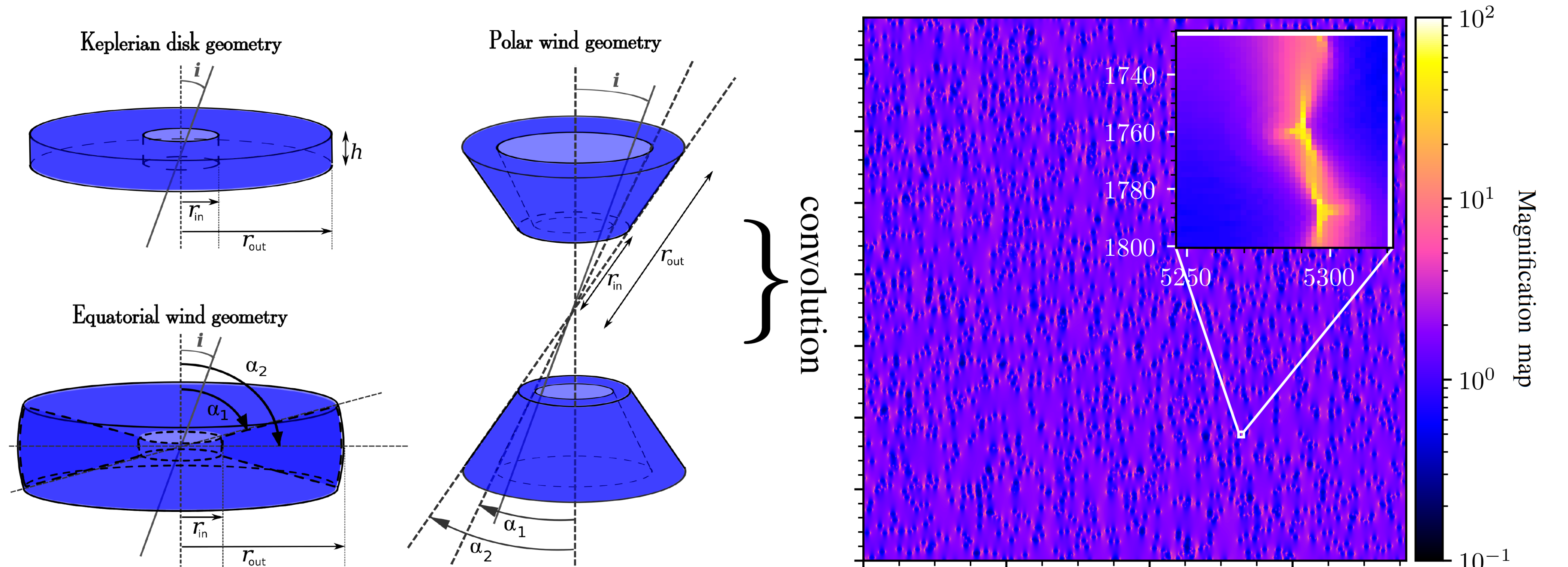
2. Observational data

- The system has been spectro-photometrically monitored from October 2004 to December 2007 with the FORS1 instrument (ESO Very Large Telescope).
- Multi-object spectroscopy (MOS) observing mode was deployed.



4. Microlensing simulations

- We assumed a flat universe with cosmological parameters: $H_0 = 68 \text{ km s}^{-1} \text{ Mpc}^{-1}$, $\Omega_m = 0.31$, $\Omega_\Lambda = 0.69$. Microlensing map was computed using the code MICROLENS (Wambsganns 1999) for a convergence $\kappa_s = 0.394$ for matter in compact objects, $\kappa_c = 0$ for continuously distributed matter.
- We considered 3 representative BLR models: Keplerian disk (KD), biconical polar (PW) and radial (EW) equatorial wind. We used Monte Carlo radiative transfer code STOKES (Marin et al. 2012) for modeling BLR emission.



3. Microlensing indices

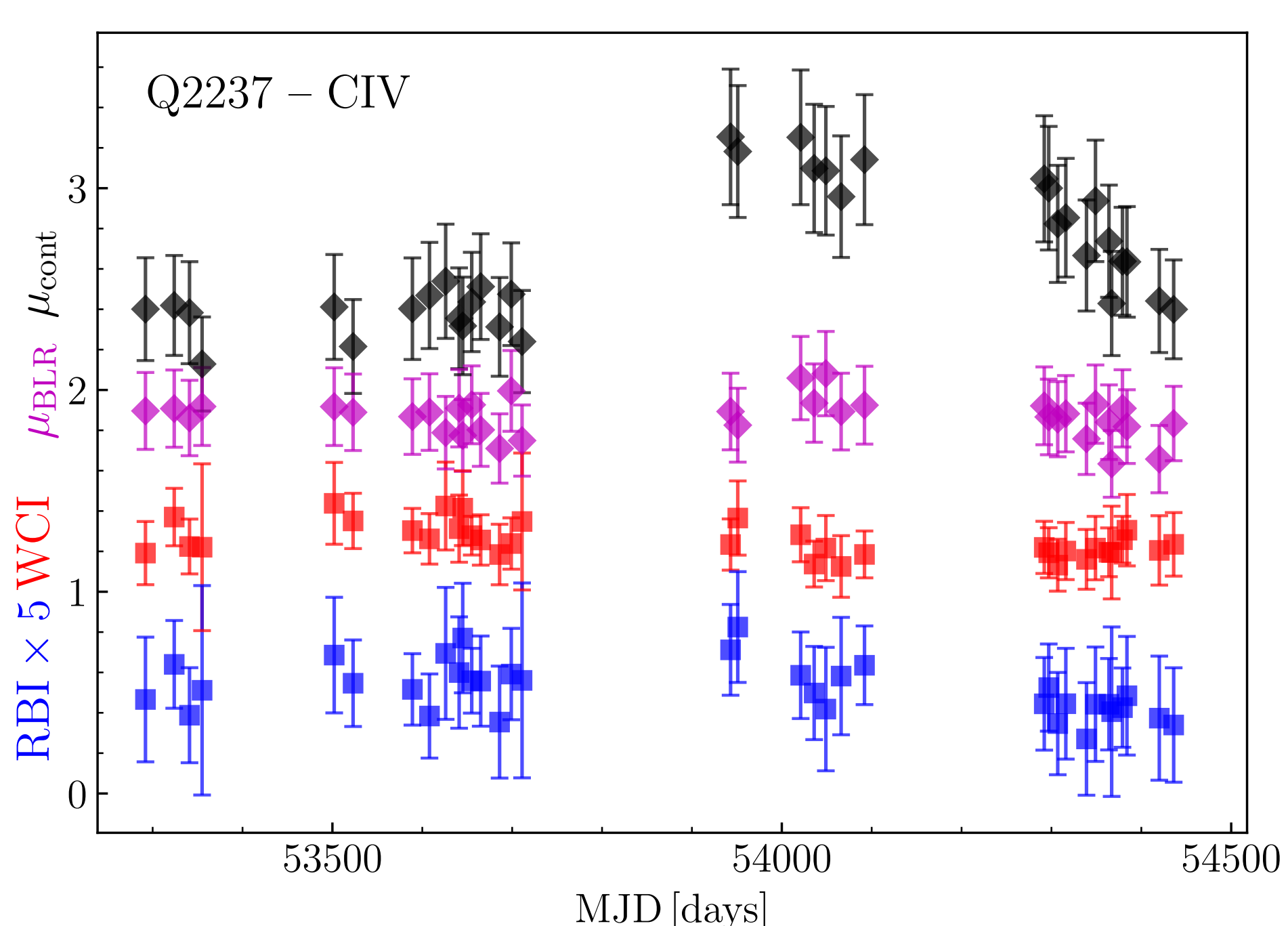
- Microlensing deformation can be well reproduced by 4 observable indices (Braibant 2017). These are magnification of the underlying continuum μ^{cont} ; the magnification of the broad emission line μ^{BLR} ; wing/core WCI and red/blue RBI indices that characterize line distortions:

$$\mu^{BLR} = \frac{1}{M} \frac{\int_{v_-}^{v_+} F_A^l(v) dv}{\int_{v_-}^{v_+} F_D^l(v) dv}, \quad (1)$$

$$WCI = \frac{\int_{v_-}^{v_+} \mu(v) / \mu(v=0) dv}{\int_{v_-}^{v_+} dv}, \quad (2)$$

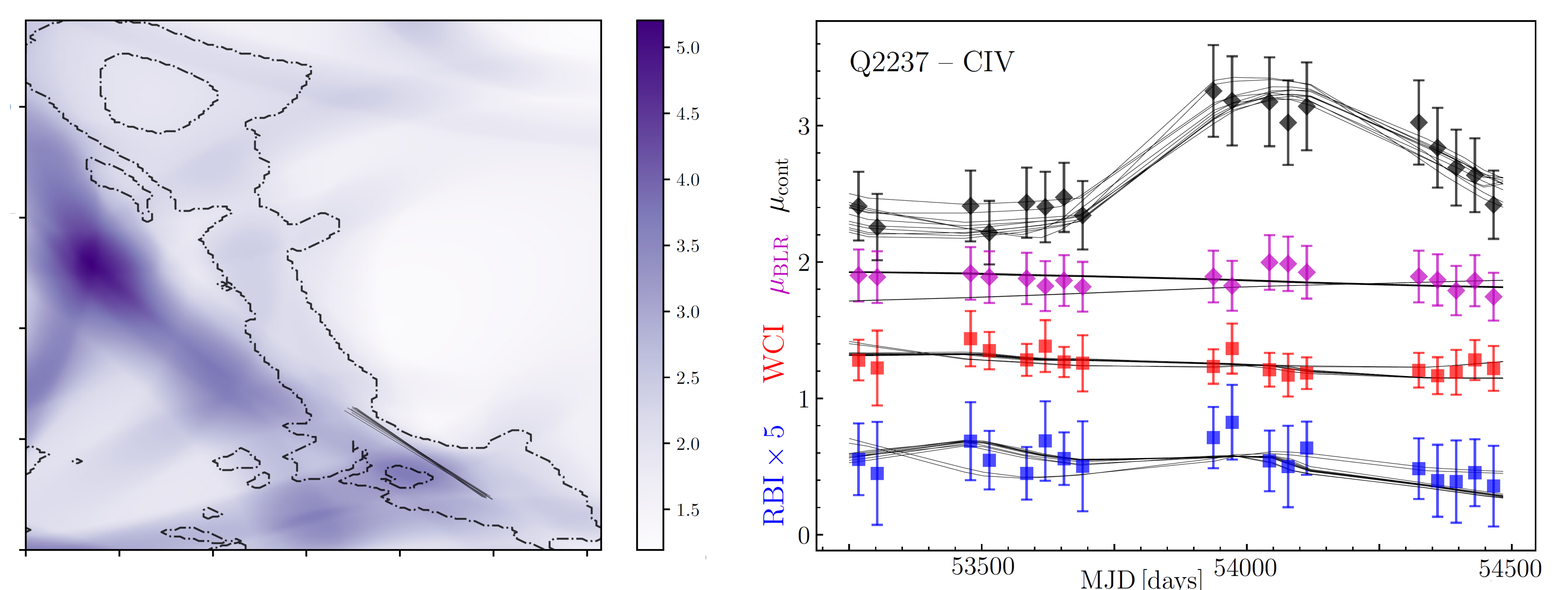
$$RBI = \frac{\int_0^{v_+} \log \mu(v) dv}{\int_0^{v_+} dv} - \frac{\int_{v_-}^0 \log \mu(v) dv}{\int_{v_-}^0 dv}, \quad (3)$$

$$\mu(v) = \frac{F_A^l(v)}{M \times F_D^l(v)}. \quad (4)$$



5. Caustic crossing

- Microlensing effect over a fixed period of time is simulated by a linear motion of a point source over a convolved (distorted) image for a given transversal velocity and in arbitrary direction.
- For each BLR model, we identify possible regions that could reproduce the observed indices. Within each region, we sample a large number of tracks and compare them with observations.



6. Summary

- Relative probabilities of different BLR models and viewing inclination.

	CIV time-series			
	KD	PW	EW	ALL
22°	34	0	0	34
34°	21	9	1	31
44°	23	3	1	27
62°	7	1	0	8
All i	85	13	2	

7. Conclusions

- We find that KD is the most likely model followed by PW, while EW is almost completely rejected.
- The effective BLR size is $r_{1/2}(\text{CIV}) = 58 \pm 20$ light days.
- The preferred geometry and size are in excellent agreement with previous reports by Hutsemékers & Sluse (2021).
- Further tests of the method are needed for other quadruply lensed quasars.