Probing the Quasar Broad Line Region with Microlensing

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in collaboration with

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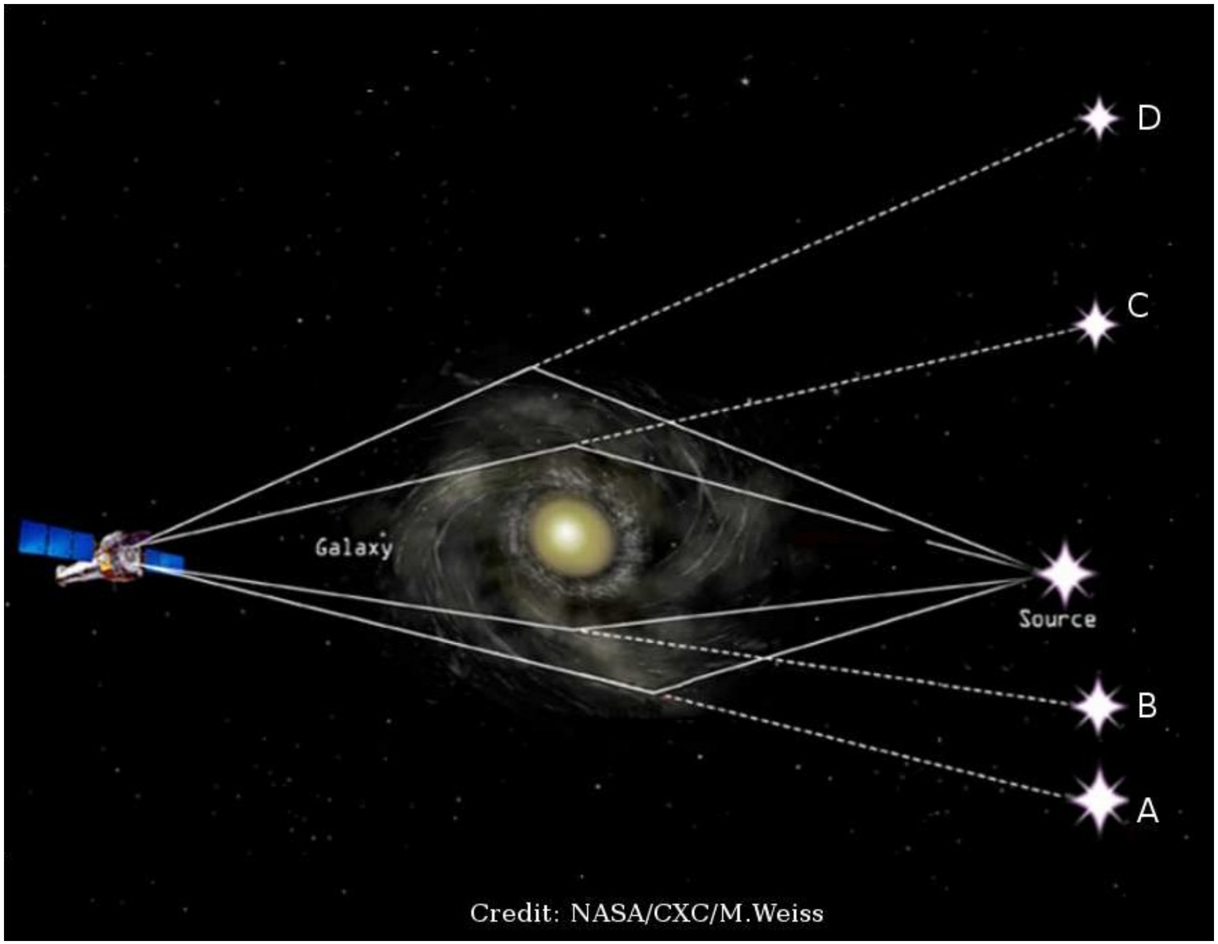
Gravitational microlensing



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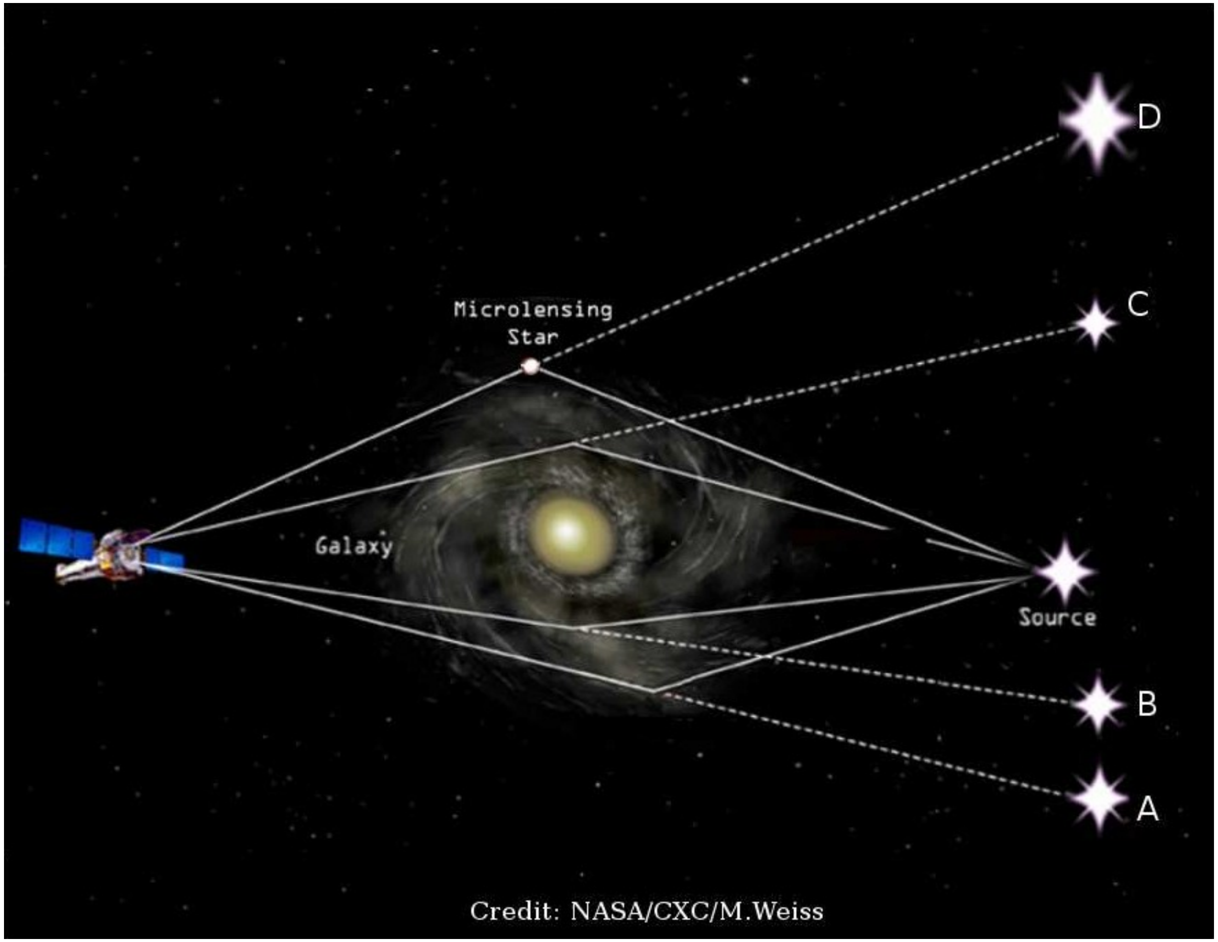
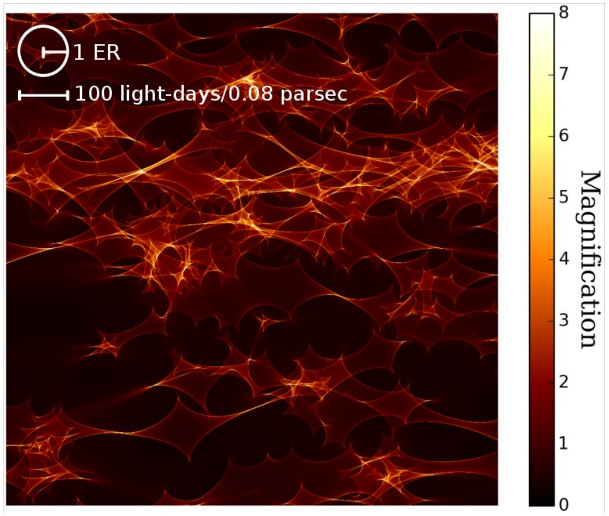


Many stars + galaxy tidal field
=> complex magnification pattern



$$\mu \sim 1+\sqrt{r_E/r_s}$$

$$r_E \sim \sqrt{M}\sqrt{D_s D_{ls}/D_l}$$

$$r_E \sim 10 \quad ld$$

$for\ z_l=0.5 \quad z_s=2.0 \quad M=0.3\,M_{sun}$

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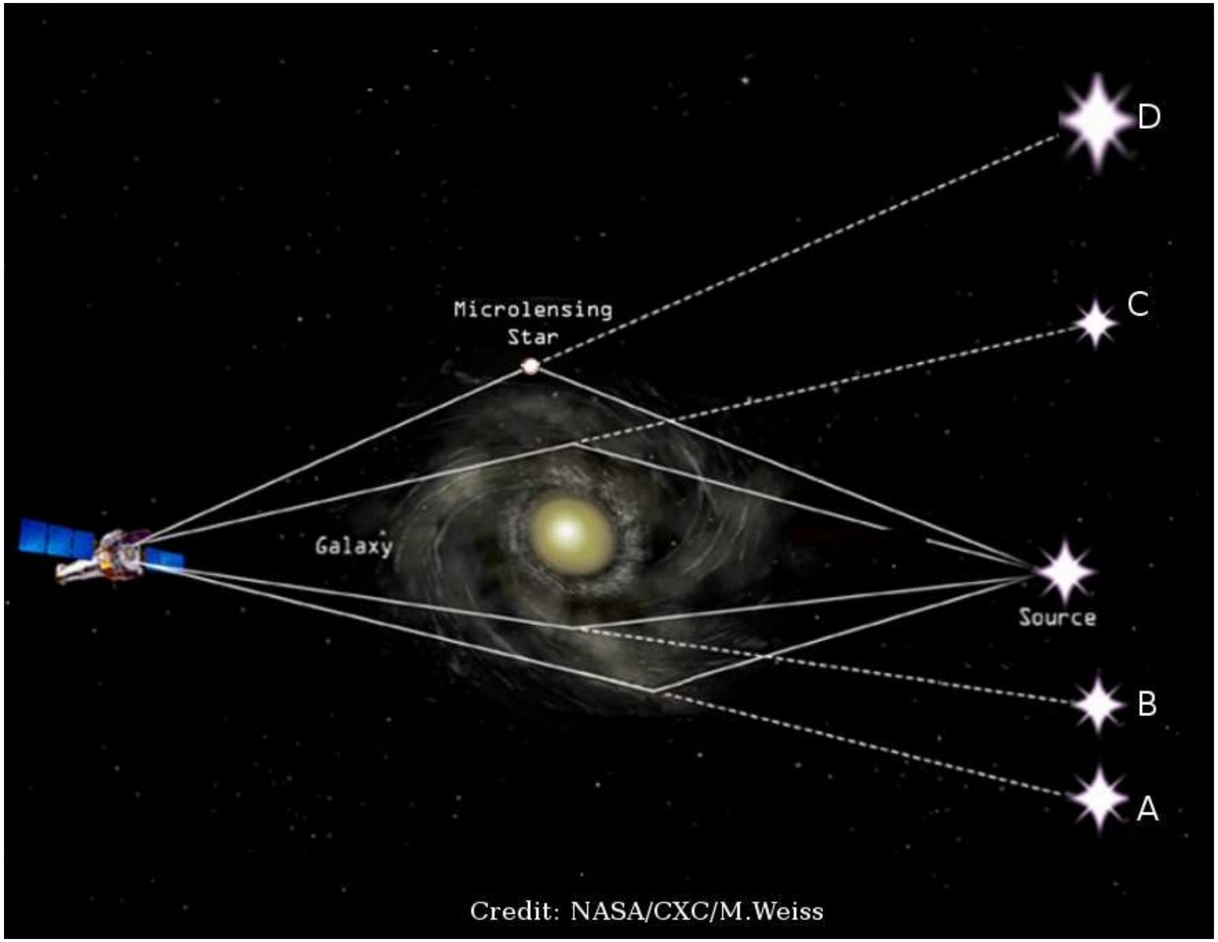

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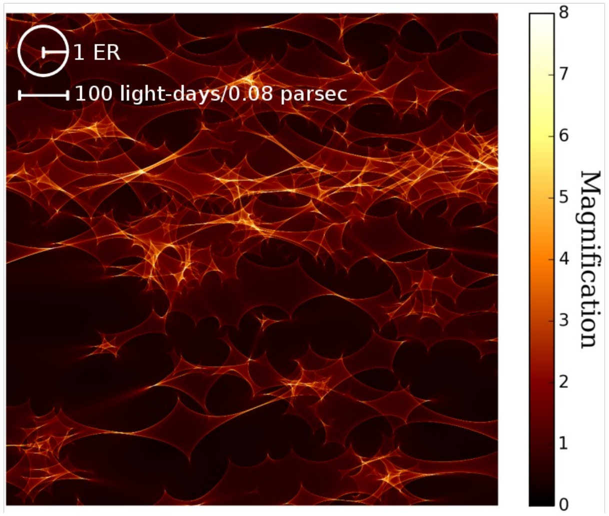

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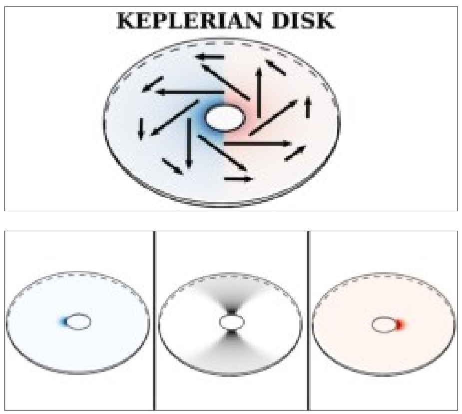
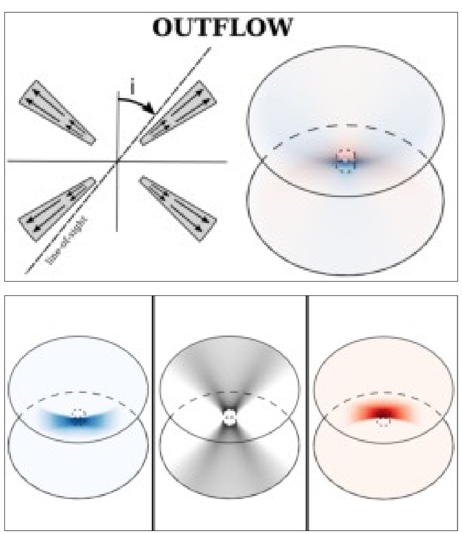
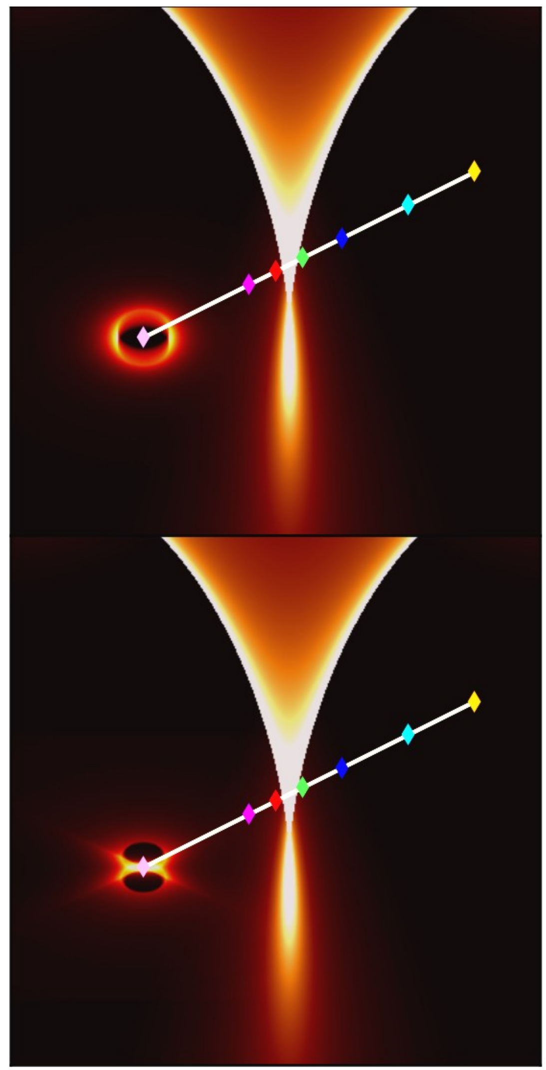
Microlensing provided
important constraints on the continuum source size and structure

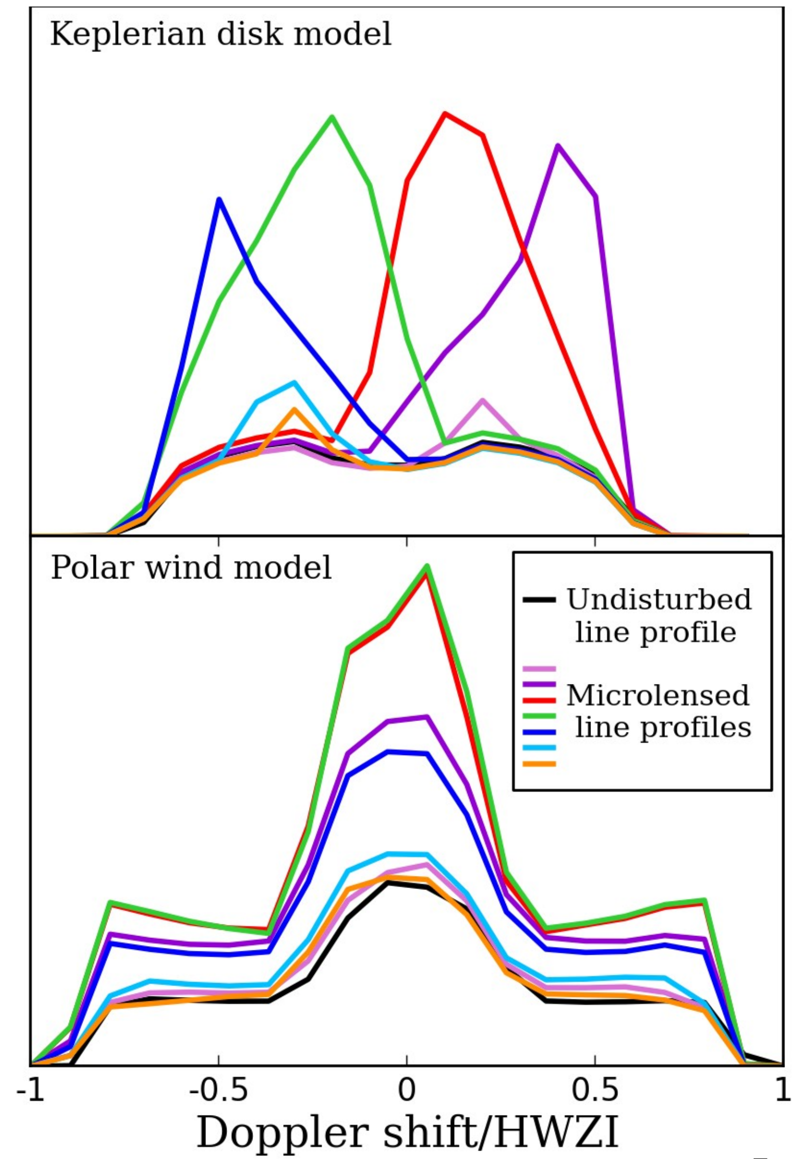
(e.g., Blackburne+2011, Jiménez-Vicente+2014)

Microlensing of the BLR

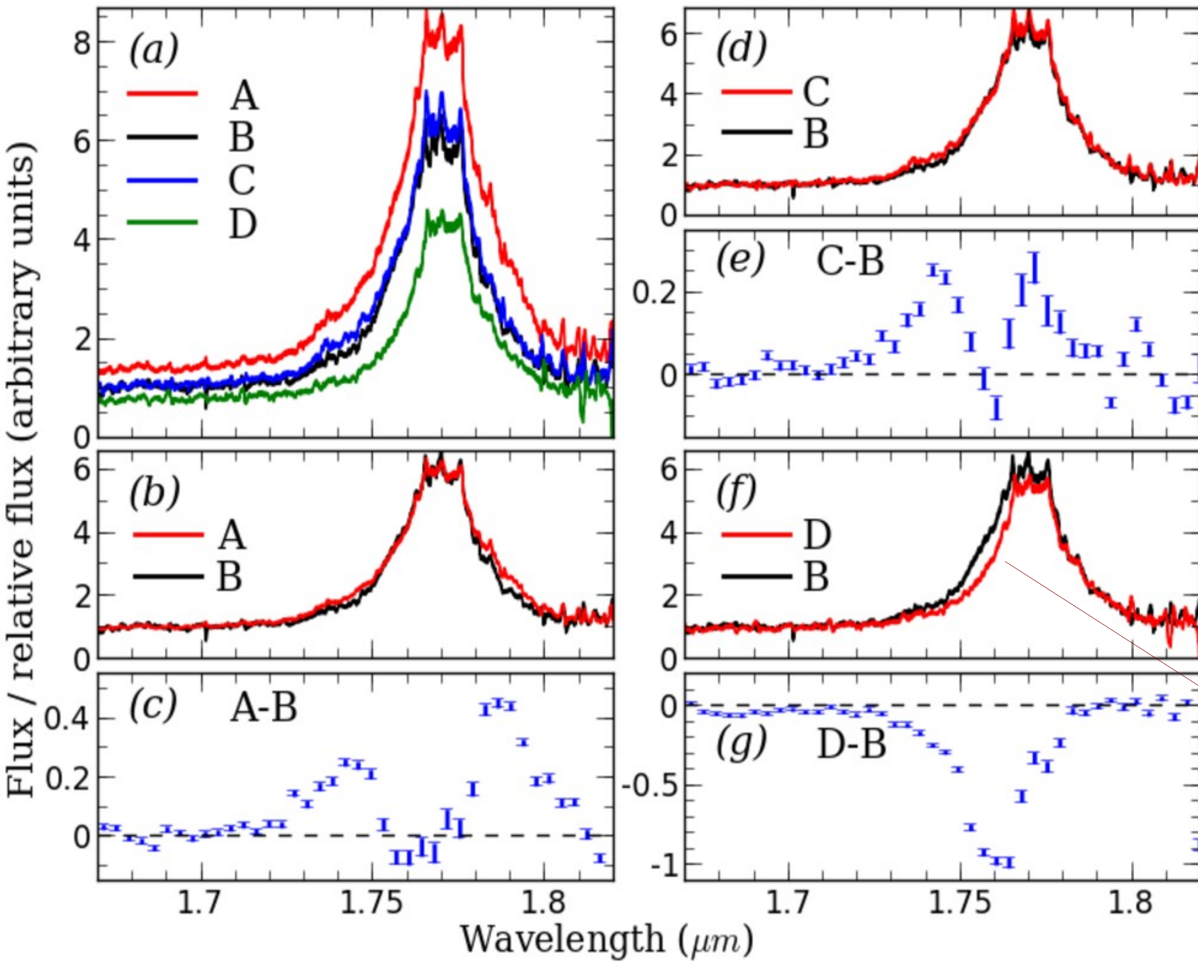


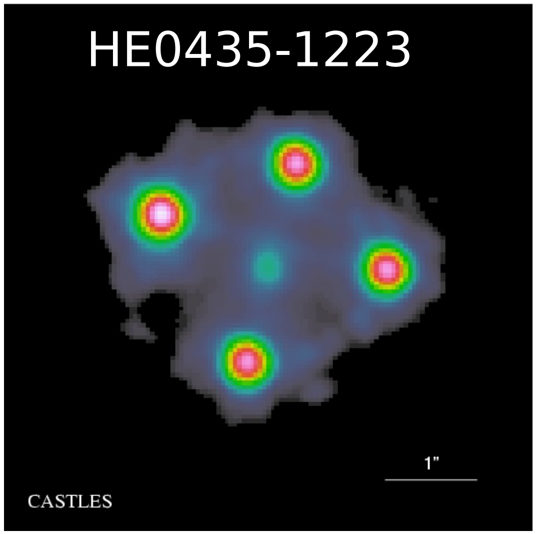






Microlensing of Hα : an example





z_s = 1.7 z_l = 0.5

Clear microlensing effect in the spectrum of image D compared to image B which is not or weakly microlensed *(Braibant+2014)*

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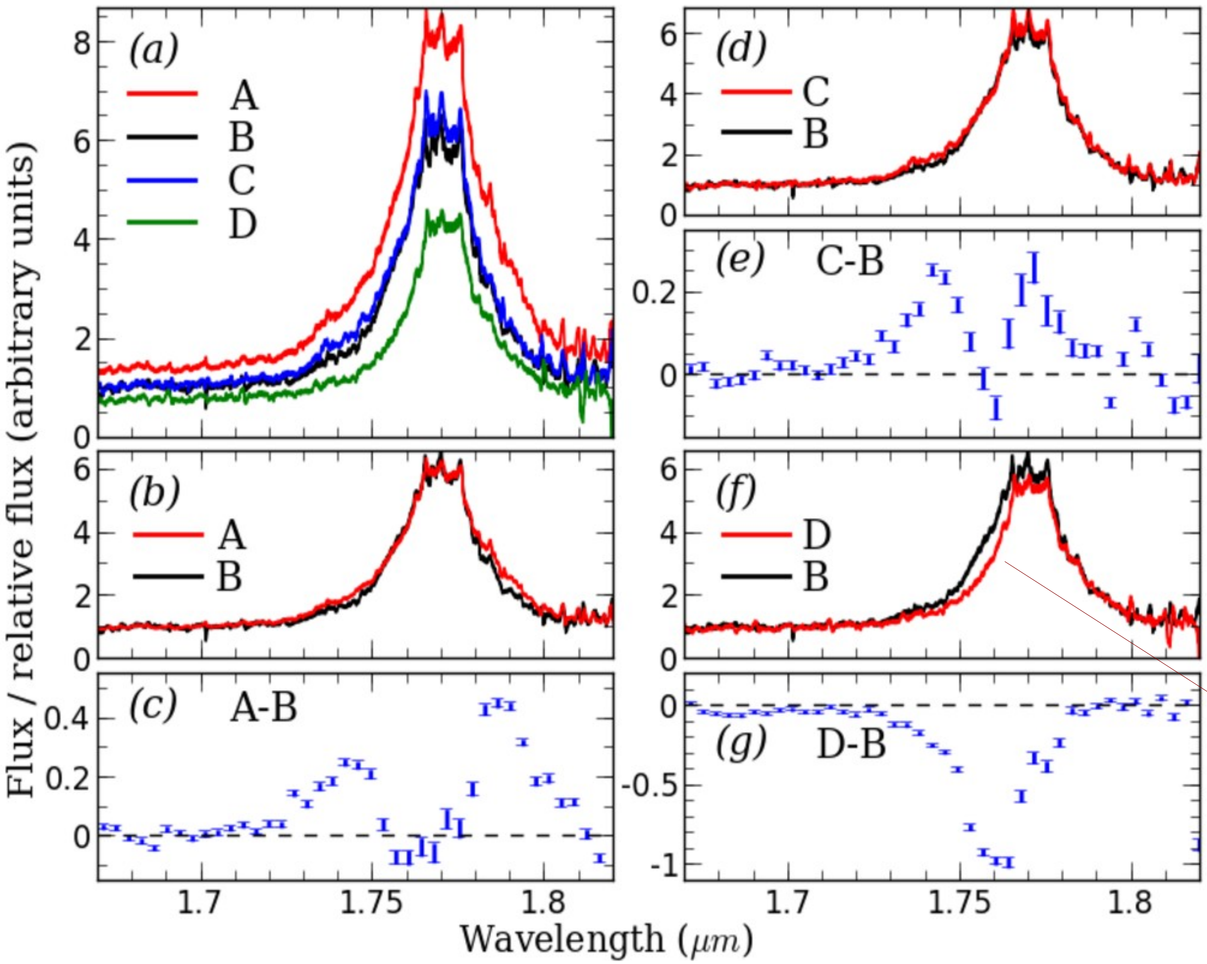

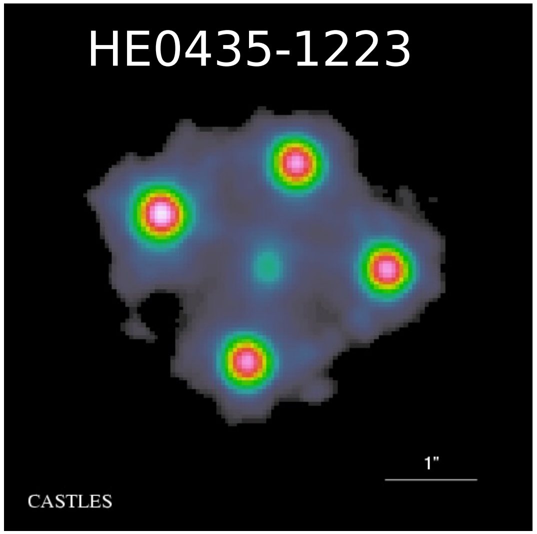

$z_s = 1.7 \quad z_l = 0.5$

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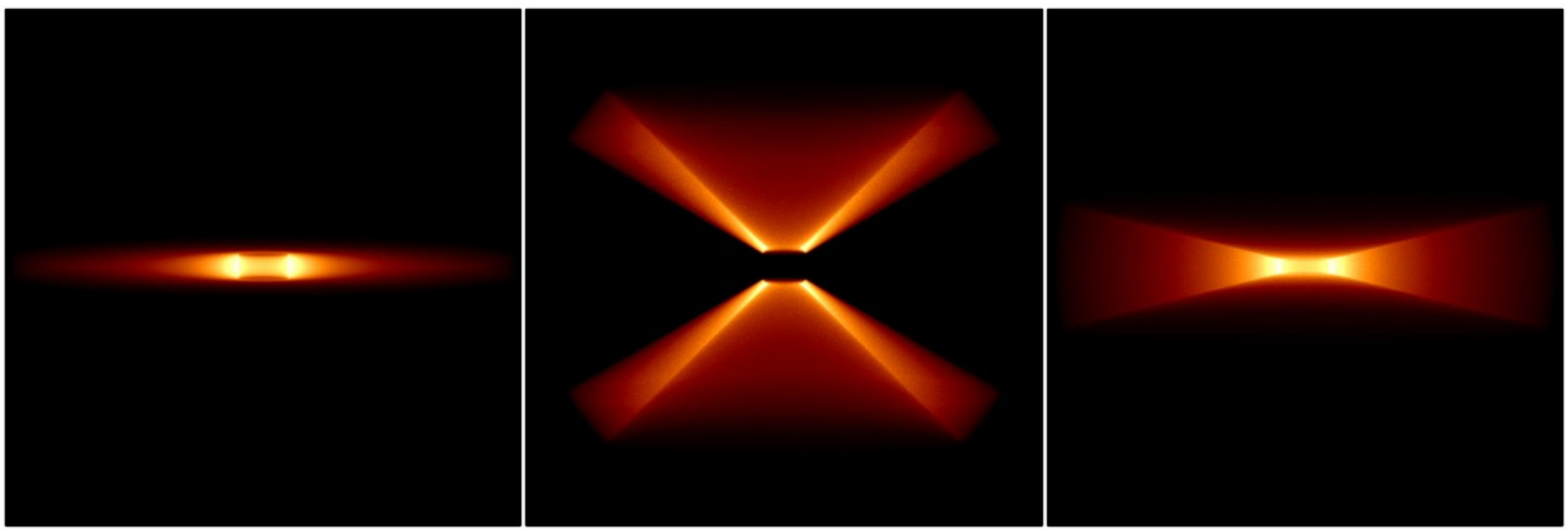
(Braibant+2014)

Microlensing of the BLR, identified by line profile distortions, is common in lensed quasars
(Sluse+2012, Guerras+2013)

BLR microlensing simulations

➔ The BLR is modeled with the Monte-Carlo radiative transfer code STOKES *(Goosmann+2007, 2014; Marin+2012)*

Keplerian disk Polar wind Equatorial wind



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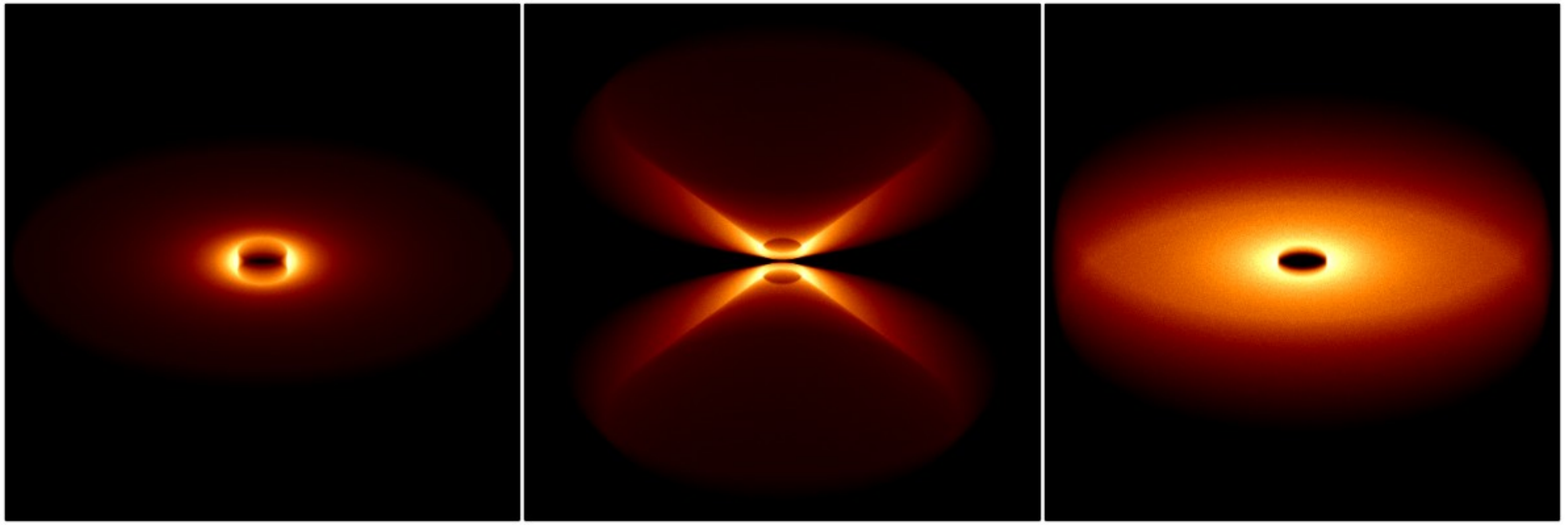
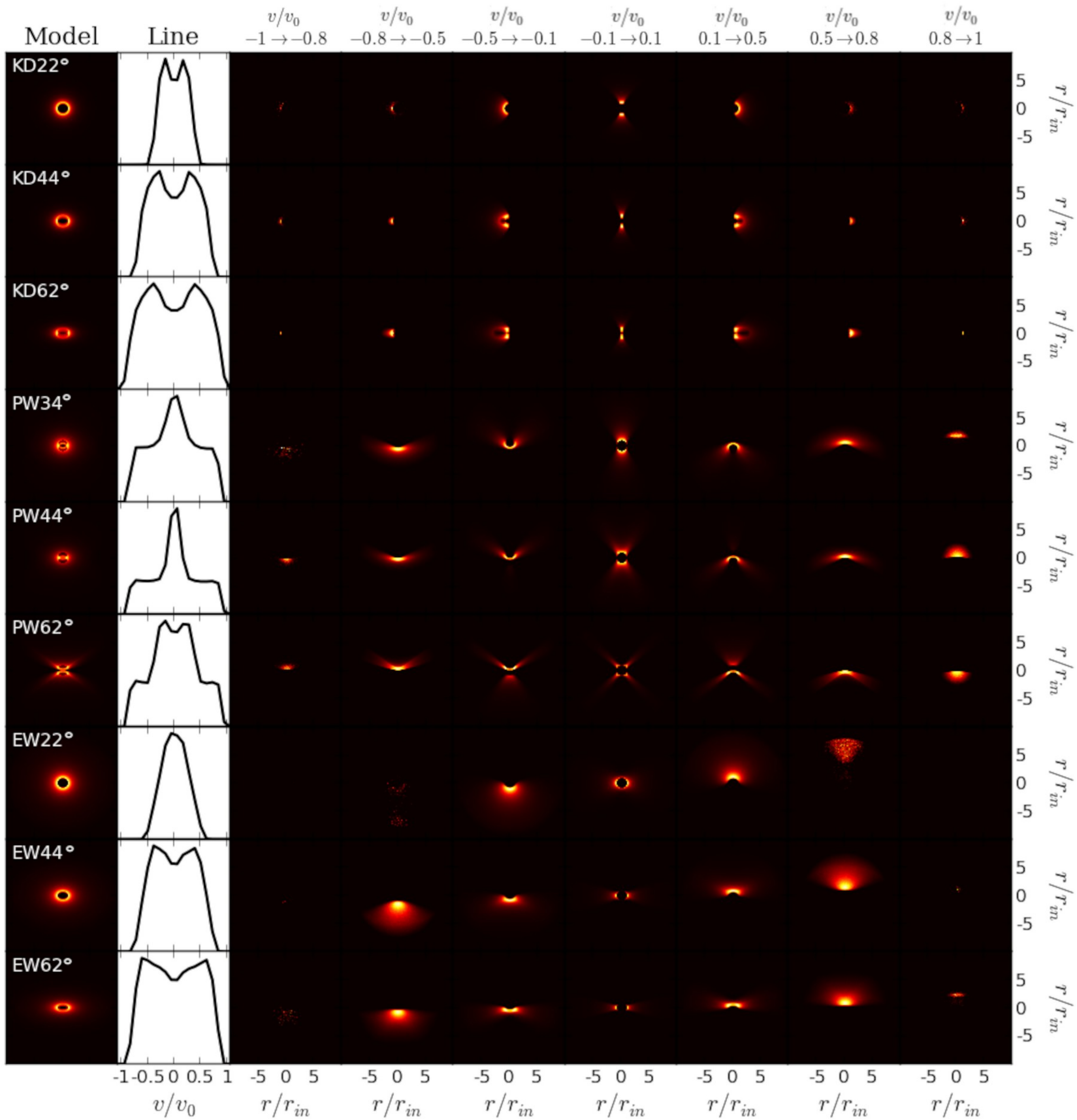


with various inclinations, sizes, emissivities

BLR microlensing simulations

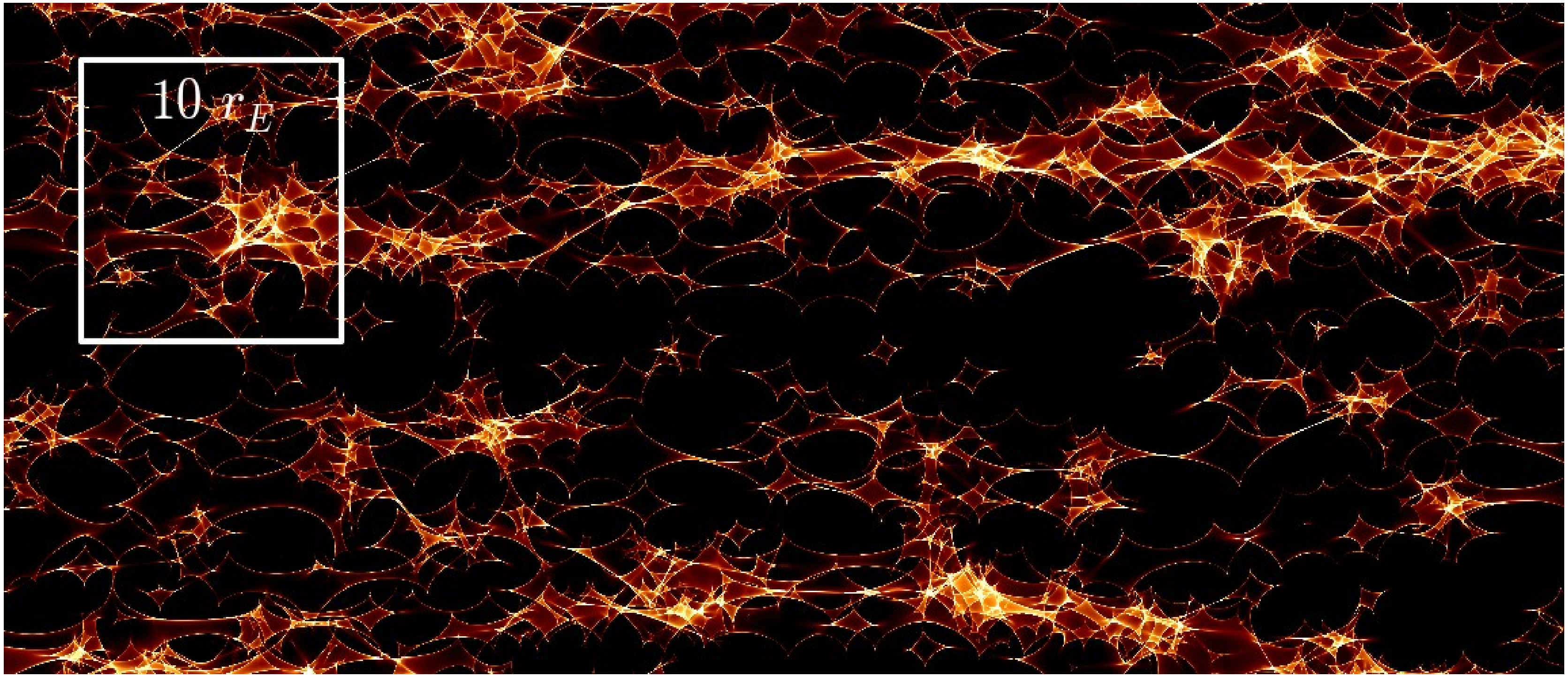
Monochromatic images of the BLR



BLR microlensing simulations

➔ The monochromatic images of the BLR are convolved with microlensing magnification maps characteristic of the system

➔ Different map orientations are considered



BLR microlensing simulations

➔ Microlensed emission line profiles are reconstructed at each position on the magnification maps

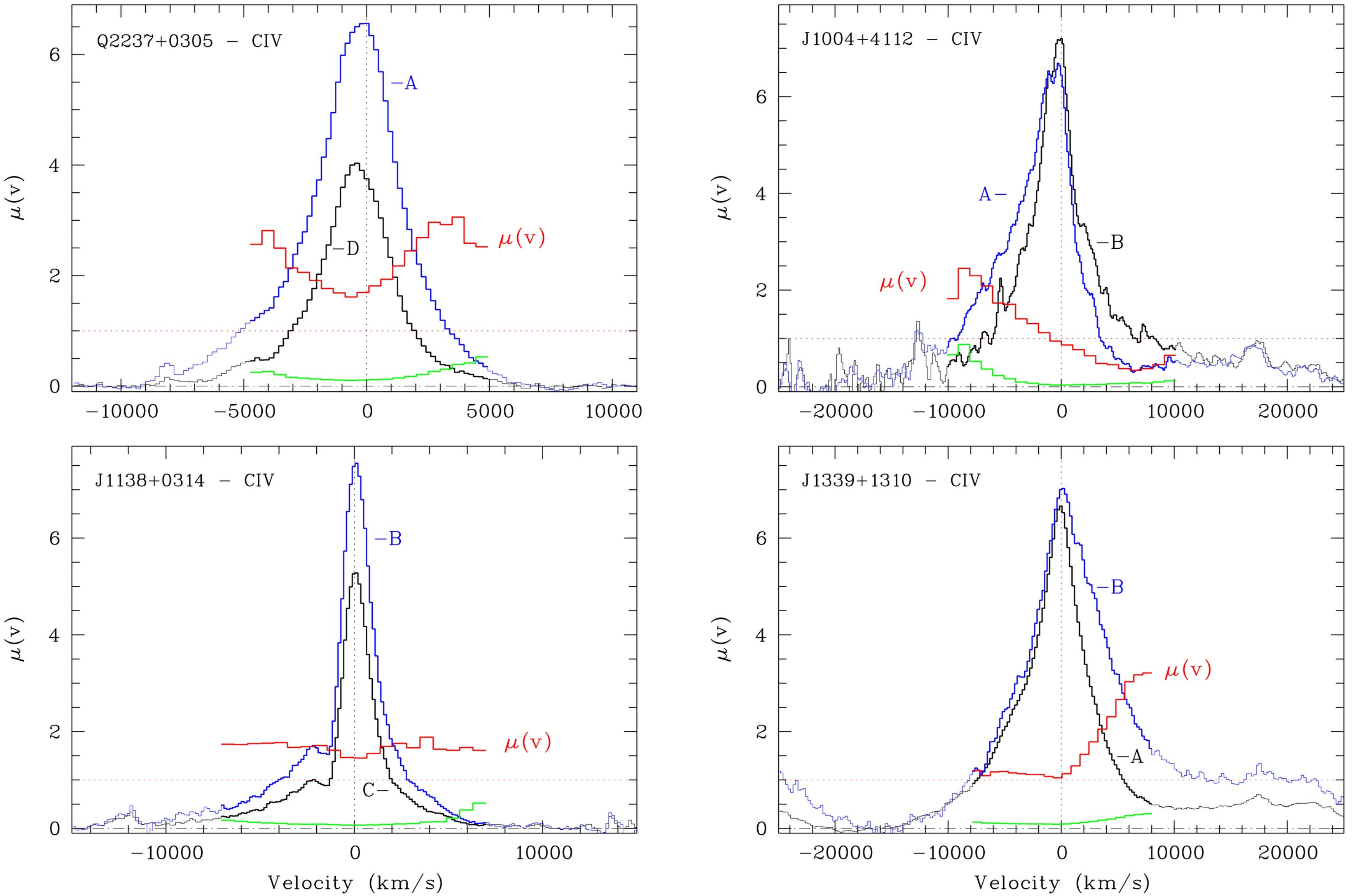
➔ The continuum source is simultaneously modeled and magnified by the same caustics

➔ The thousands of simulated microlensed line profiles are characterized by the magnification profile *μ(v)* and/or quantities integrated over the line profile that can be compared with the observations

➔ Comparison with observations is done through a Bayesian scheme that provides the probabilities of the different models, and the size of the BLR

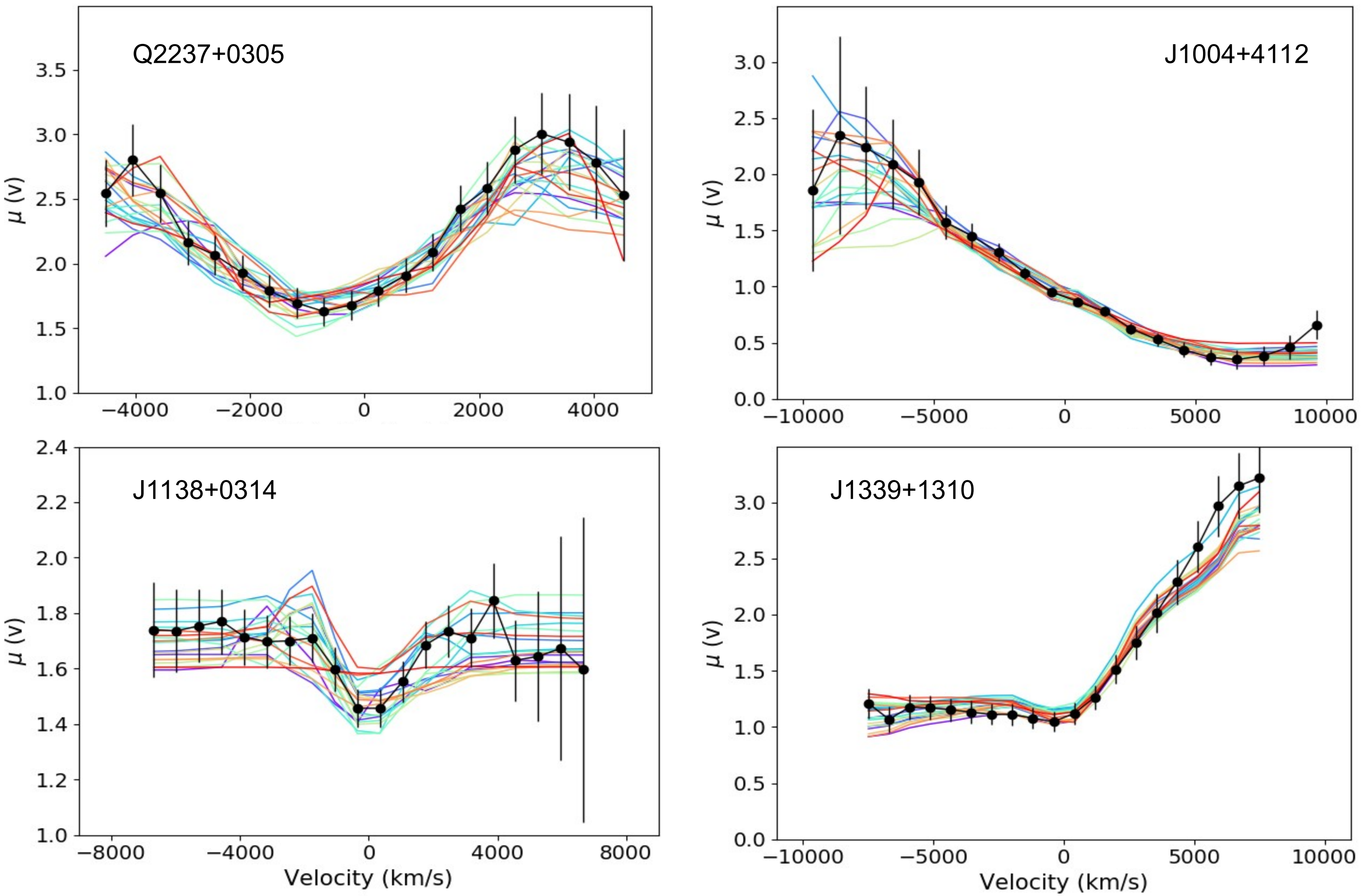
(Braibant+2017, Hutsemékers+2019, 2021, 2023)

Observed magnification profiles



Measuring μ(v) requires a reference spectrum not or weakly microlensed and the macro-amplification factor between the two images

Simulated μ(v) reproduce the observations

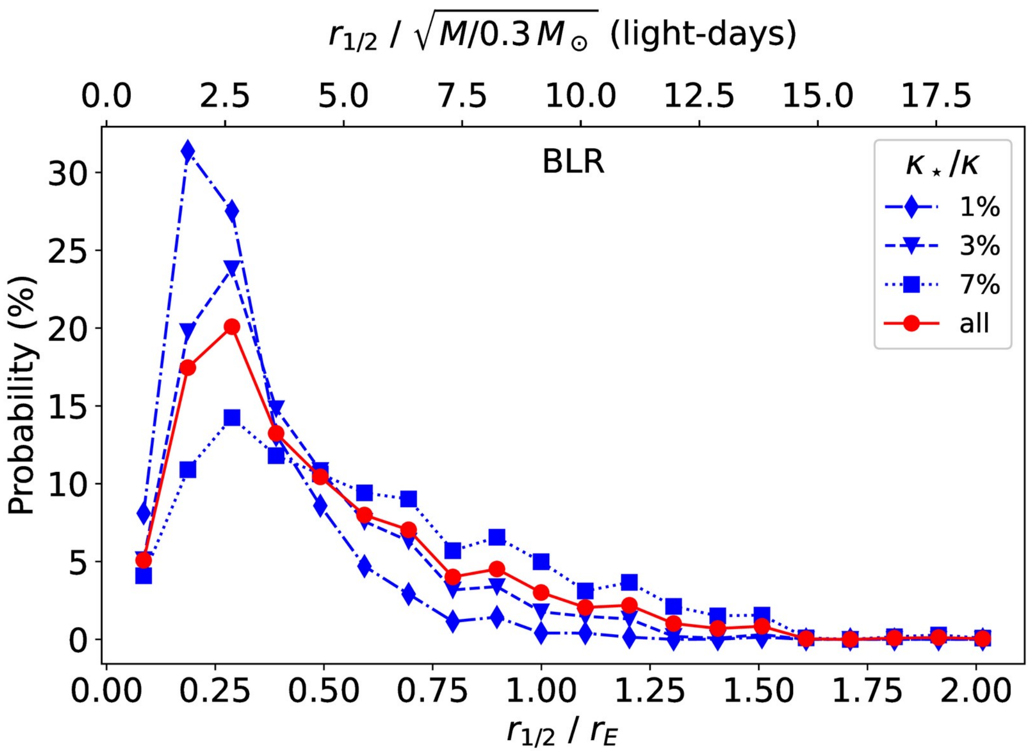


Example of results : J1004+4112

Map orientation : $\leq 30^o$ (first three columns), $\geq 60^o$ (last three columns)

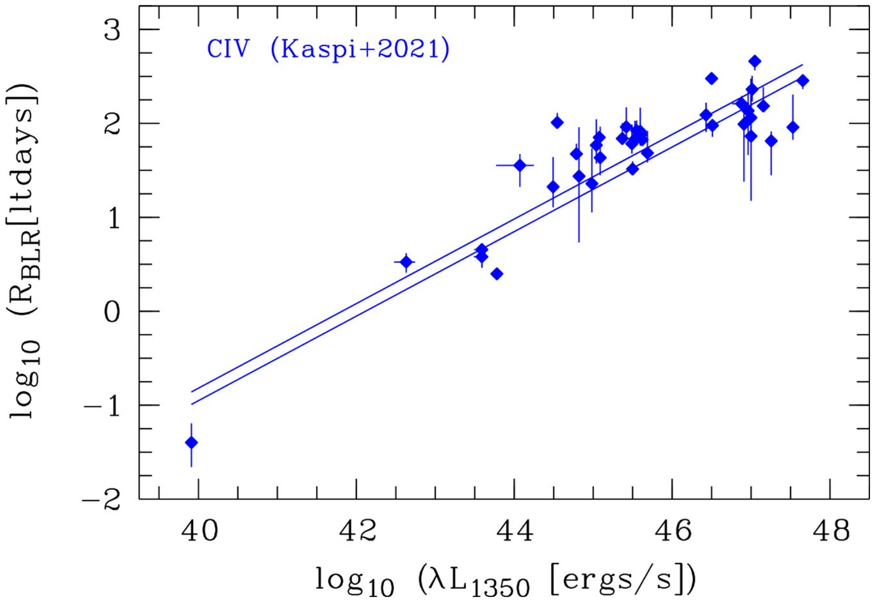
	KD	PW	EW	KD	PW	EW
22°	0	0	17	51	0	0
34°	0	0	27	31	0	0
44°	0	0	24	16	0	0
62°	0	2	29	2	0	0
All i	0	2	97	100	0	0

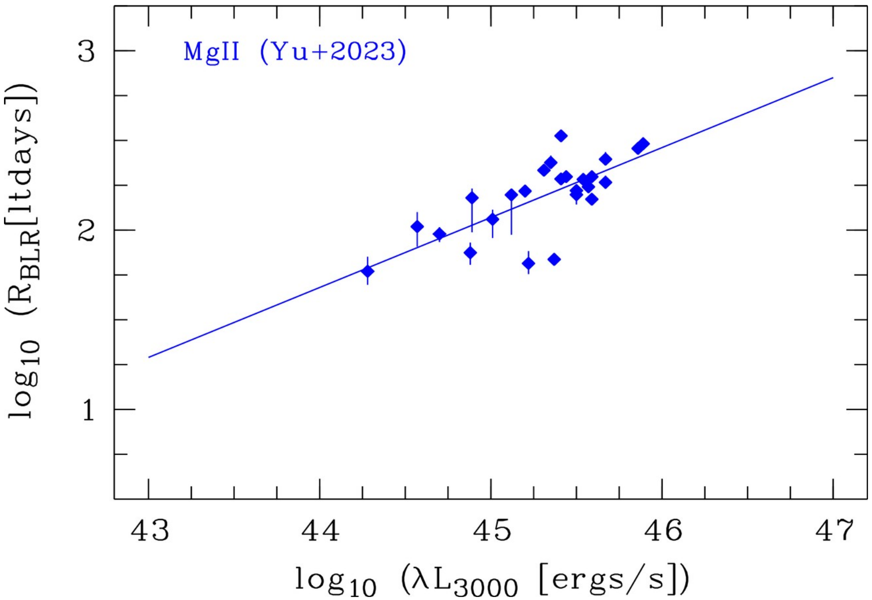
=> The KD and EW models are the most likely, but the final selection may depend on the magnification map orientation w.r.t. the BLR axis

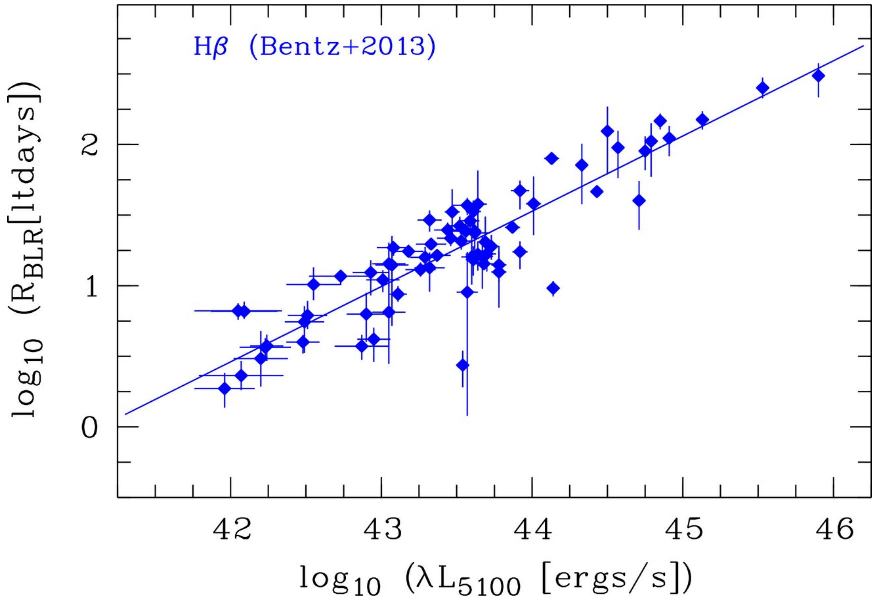


=> $R_{1/2}$(CIV) = 2.8 ± 1.9 light days

R_{BLR} : microlensing vs reverberation mapping *(preliminary)*







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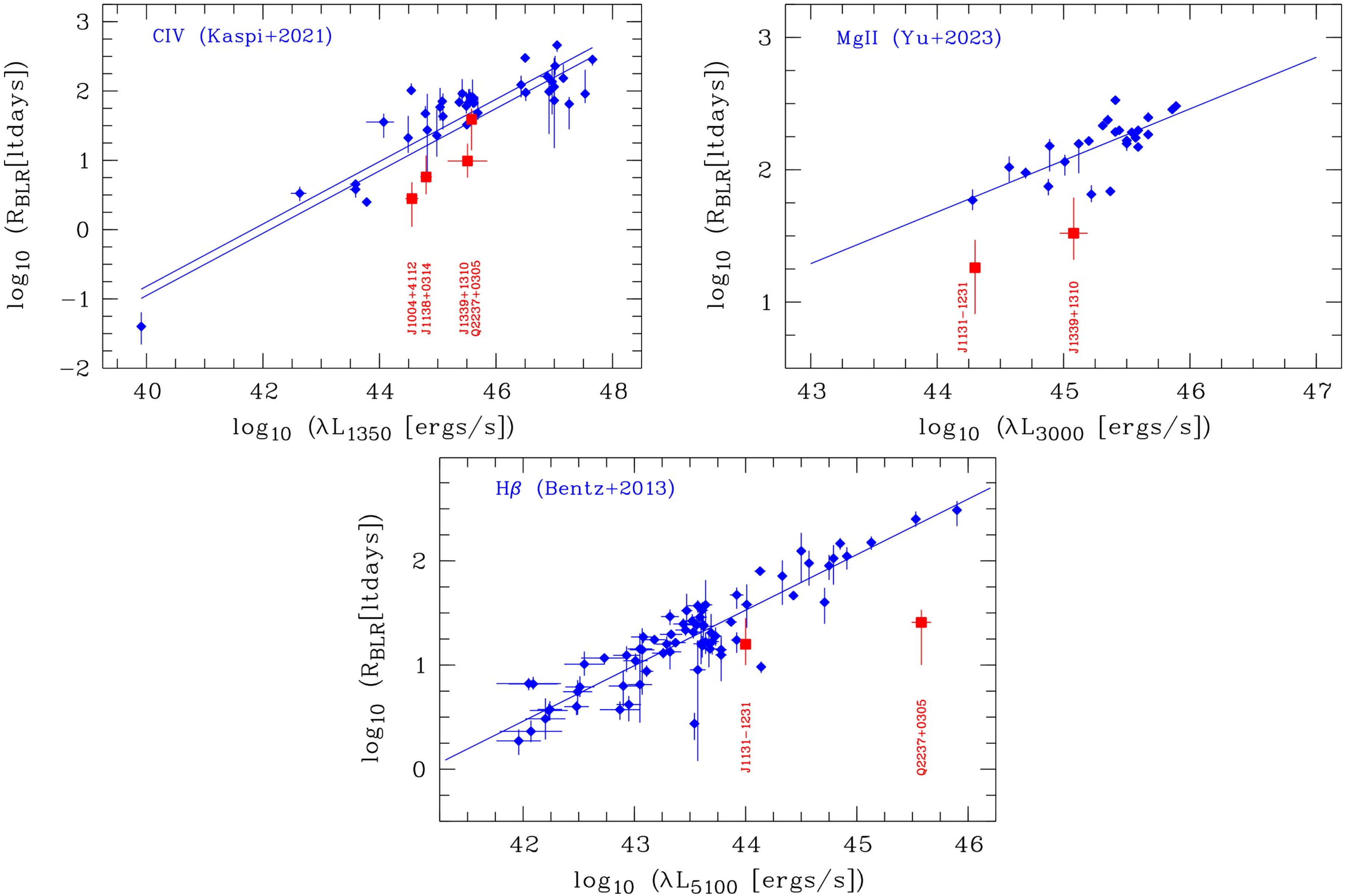

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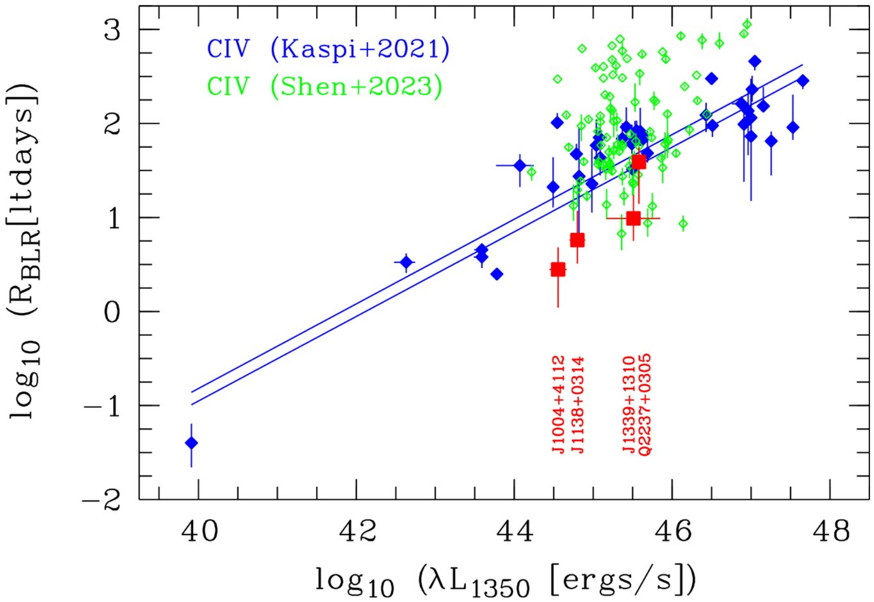

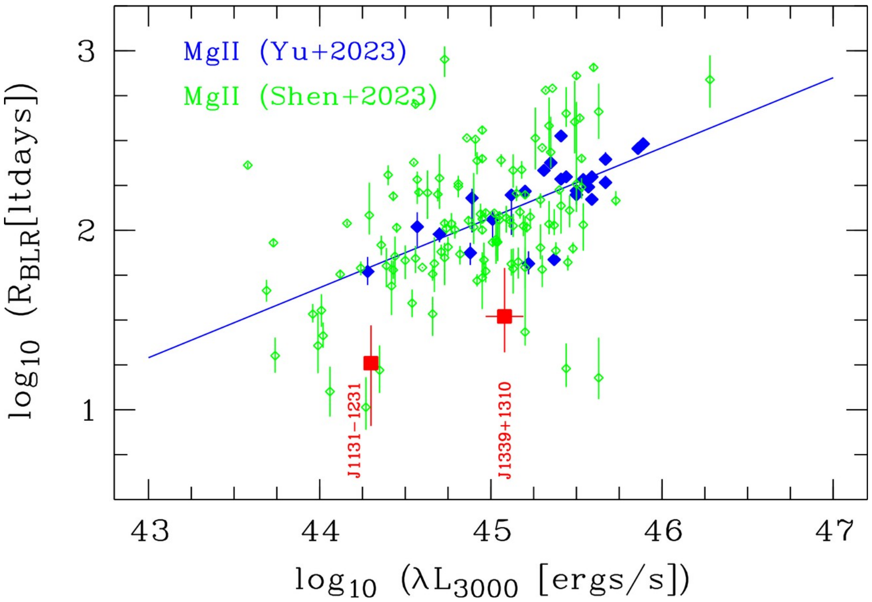

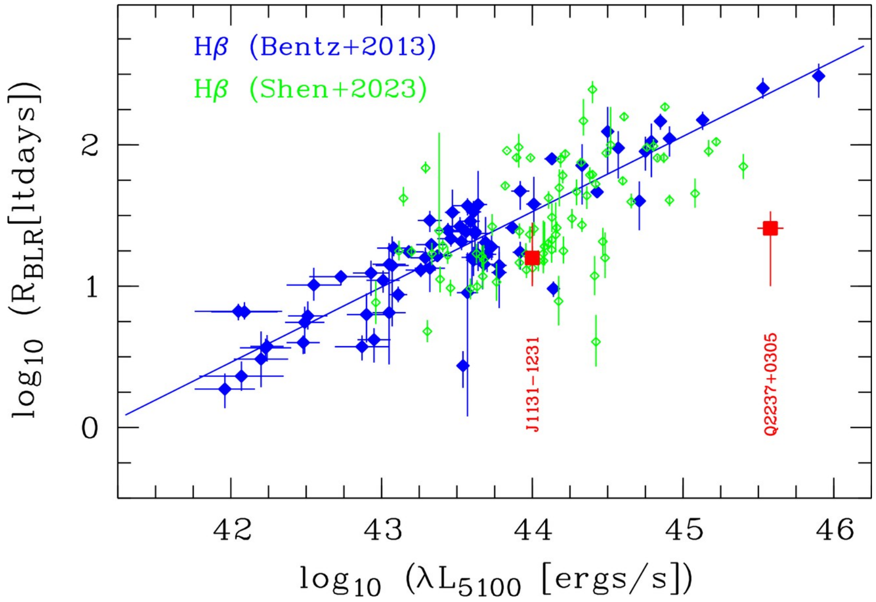

Conclusions

➔ *The BLR size and kinematics can be determined with microlensing, complementing RM measurements, especially for high-redshift quasars*

➔ *Single epoch high S/N data can be used, but a clear line deformation, a reference spectrum, and the macro-magnification factors are required*

➔ *Flattened BLR geometries are favored for all lines, but the distinction between KD and EW is often degenerate with the map orientation*

➔ *Mixed (dis-)agreement between microlensing and RM BLR sizes. Systematically smaller ? Underestimated dispersion ? Bias ?*

On-going and future work:

➔ *Analysis of time series of line profile deformations (poster by D. Savic)*

➔ *Join RM and microlensing analysis in some objects*

➔ *Increase the sample, especially at high redshift*