The last stand before Rubin: semi-automated inverse modeling of galaxy-galaxy strong lensing systems

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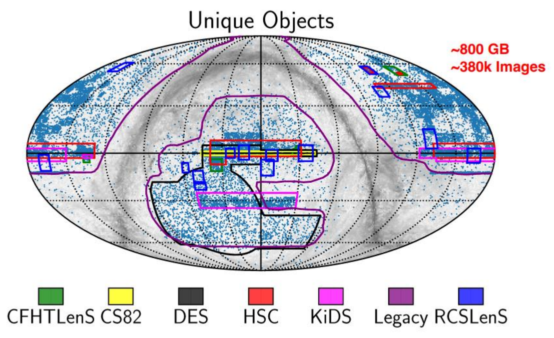
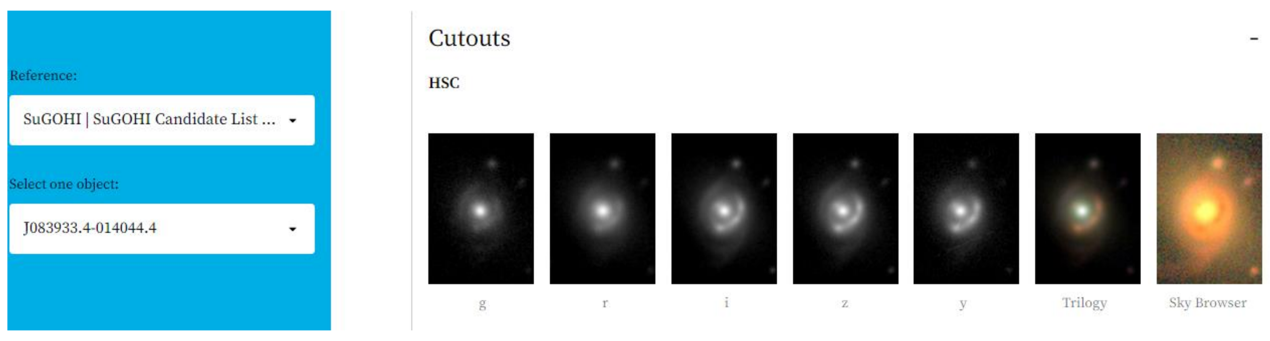
Compilation of SL candidate systems

- 31569 candidate SL systems
- **Cutouts** on the current wide-field sub-arcsecond seeing surveys
  - HSC, DES, Legacy, KiDS, CFHTLS, CS82, +
- Crossmatch with **spectroscopic surveys**
  - SDSS, Gama, +
- 4167 **Single lens galaxies**
- Aggregated data





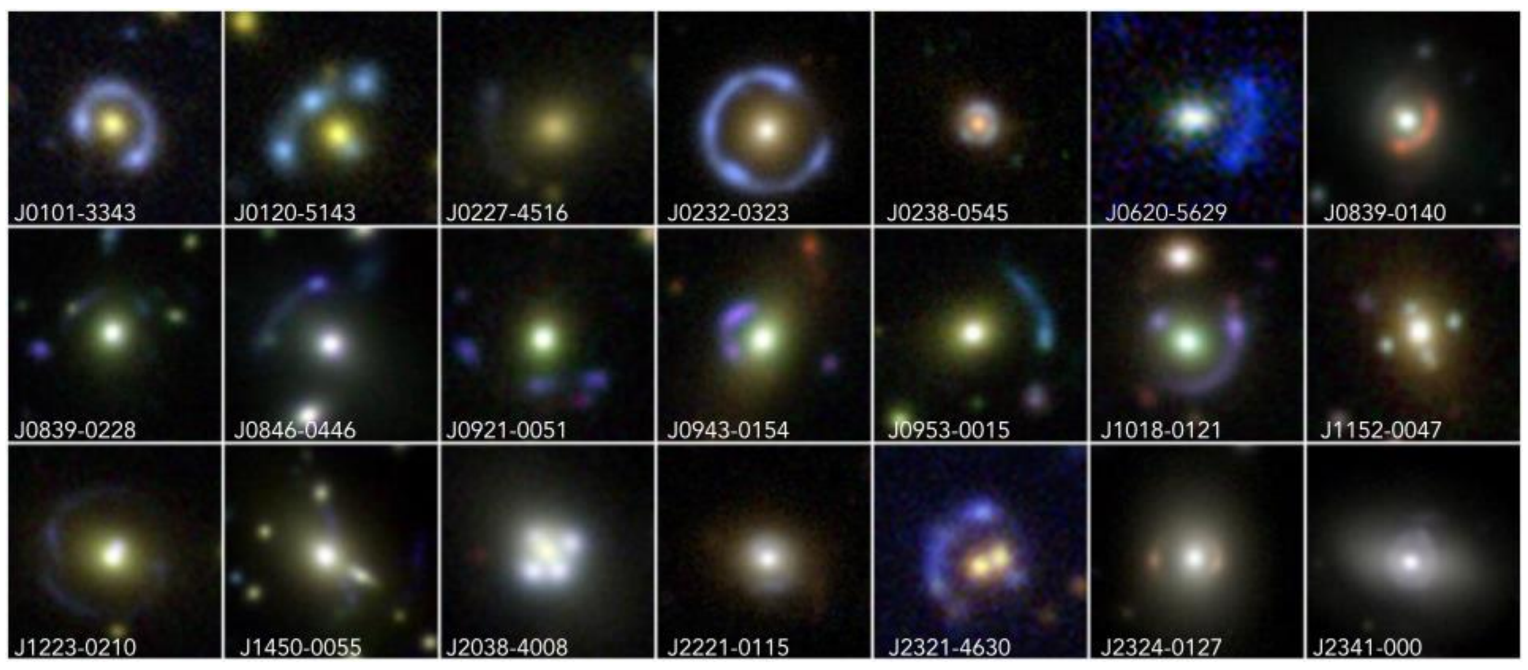
Oliveira+ (In prep.)

The last stand before LSST!

SOAR 2022A & 2022B data

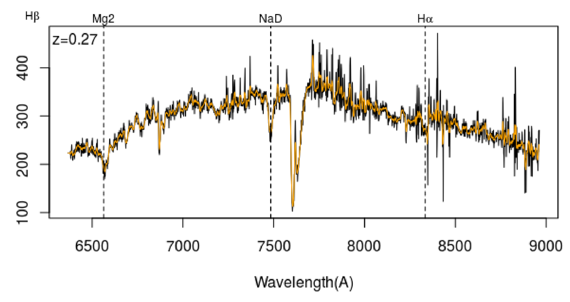
Many applications require σ_v (including tests on modify gravity)

- 21 strong lenses
- Single slit: spectra of lens and images
- Aim: **lens velocity dispersions**

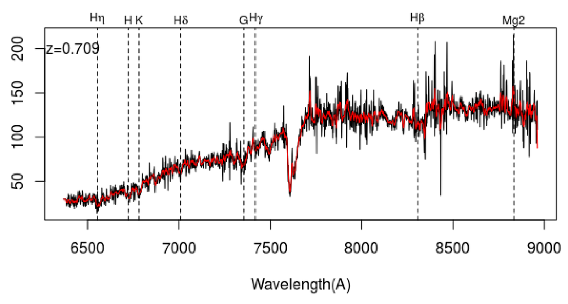


Makler+,JP,+,2022

J0839-0140



Lens spectrum

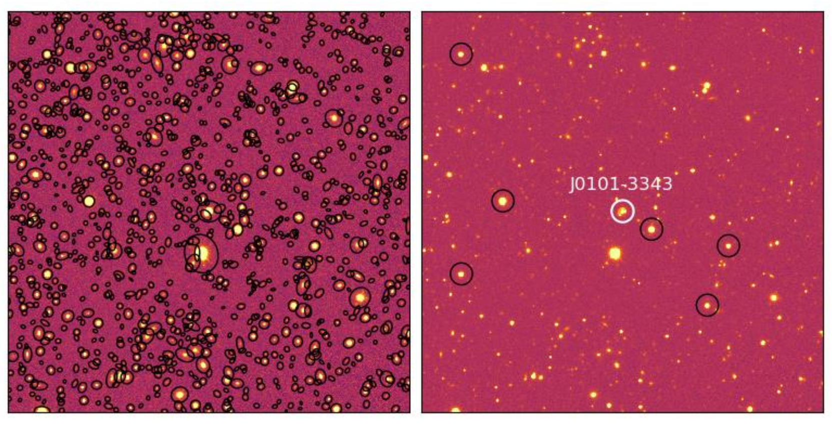


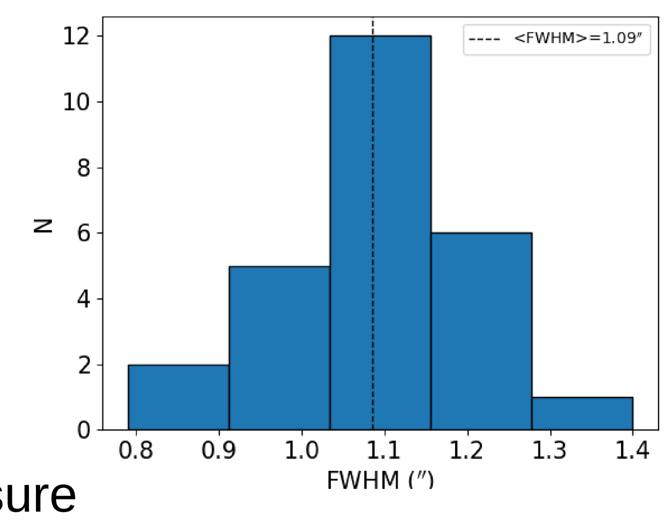
Source spectrum

- $M_\star = 9 \cdot 10^{11}\, M_\odot$
- $z_l^{(s)} = 0.27$
- $z_s^{(s)} = 0.71$
- $\sigma_v = 288 \pm 15$ km/s

Lens light modeling

- PSF extraction





- **Identified** star candidates in each exposure
- Applied **cuts** in the stellarity classifier factor (given by the **SExtractor** output)
- For the remaining candidates, we fitted a Gaussian profile and obtained for each of them measurements of **FWHM**
- We derived as the seeing the **mean measurement** of the set of individual measurements of FWHM

- Lens light subtraction

Sérsic light profile

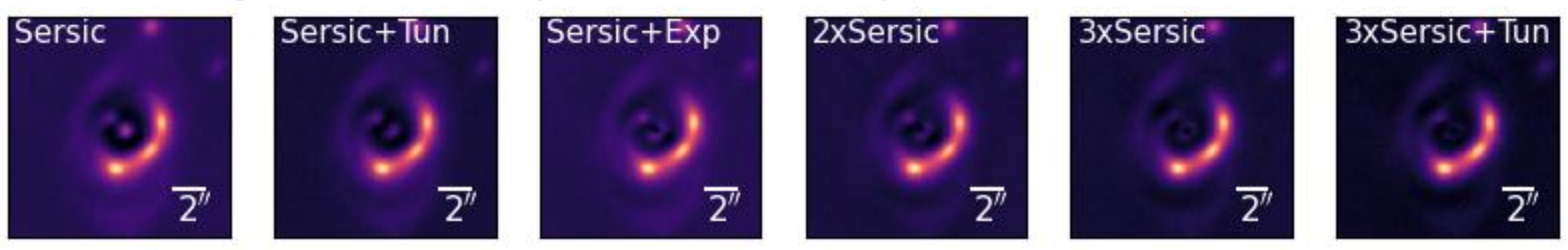
$$I_n = I_0 \exp\left\{-c_n\left[\left(\frac{r}{r_{\rm eff}}\right)^{\frac{1}{n}} - 1\right]\right\}$$

Masking arcs to fit the lens light profile

ETG (Bulk + Disk profile)

$$I_{\rm lens}(r) = I_n(r) + I_1(r)$$

Iteractive process to improve the lens light subtraction



Modeling pipeline

- Modeling Pipeline for single lens systems

Session	Phase	Component	Model	Prior Info
Source Parametric	SP1	Lens Mass	SIE+Shear	-
		Source Light	Sérsic	-
Source Inversion	SI1	Lens Mass	SIE+Shear	SP1
		Source Light	MPR	-
	SI2	Lens Mass	SIE+Shear	SP1
		Source Light	MPR	SI1
Lens Power-Law	LPL	Lens Mass	EPL+Shear	SI2
		Source Light	MPR	SI1

Building on Etherington et al.

- **Source parametric**: Guess the best fit parameters for the lens mass

$$I_n = I_o exp\left\{-c_n\left[\left(\frac{r}{r_e}\right)^{1/n} - 1\right]\right\}$$

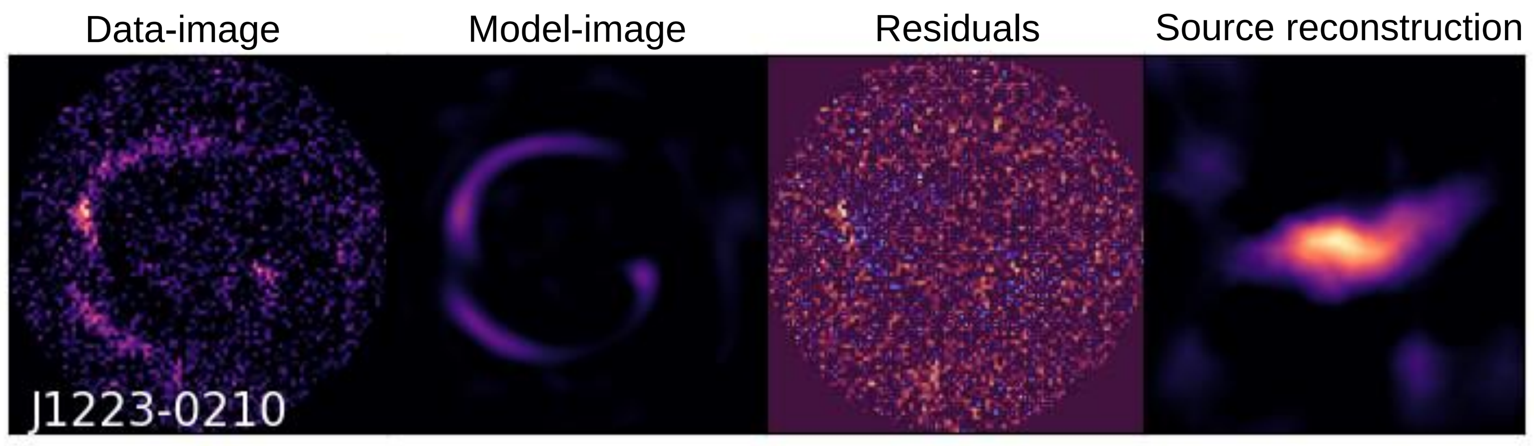
- **Source Inversion**: Pixelized source reconstruction

$$\boldsymbol{M_c(\eta,\psi)r = d + n}$$

- **Total mass**: Power-law distribution for the lens mass

$$k(x,y) = \frac{3-\alpha}{1+q}\left(\frac{\theta_E}{\sqrt{x^2+y^2/q^2}}\right)^{\alpha-1}$$

- Modeling results for J1223-0210



Example applications

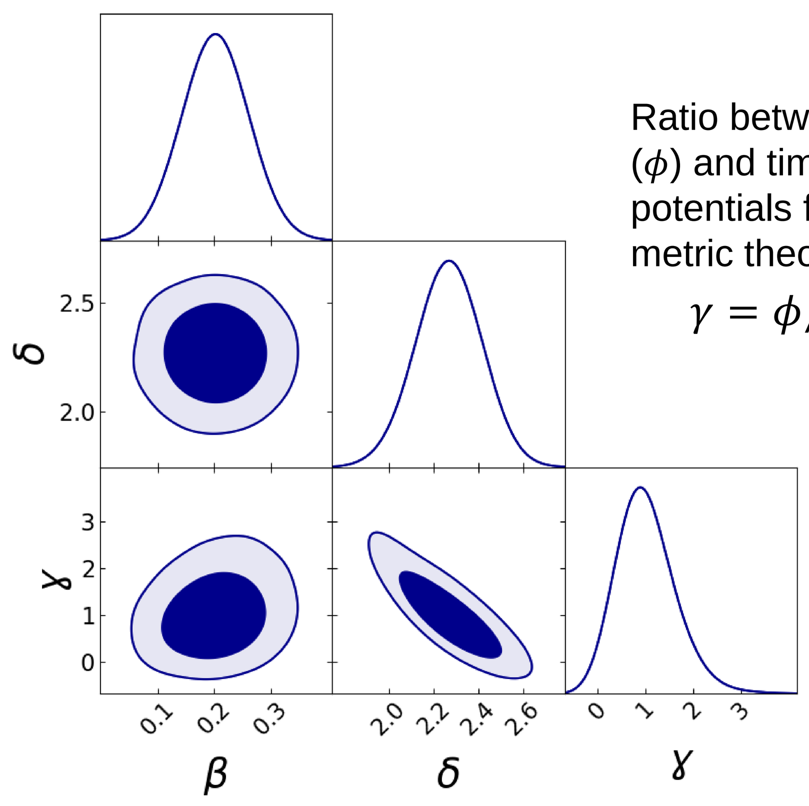
Combining modeling and spectroscopic analysis we can:

- Test **modify gravity** with the slip parameter (γ)

Generic metric:

$$d\tau^2 = dt^2\left(1-\frac{2M}{r}\right) - dr^2\left(1-\frac{2\gamma M}{r}\right) - r^2 d\phi^2$$

For General Relativity (GR): $\gamma_{\rm GR} = 1$



Ratio between space (ϕ) and time (φ) potentials for general metric theories:

$$\gamma = \phi/\varphi$$

Components:

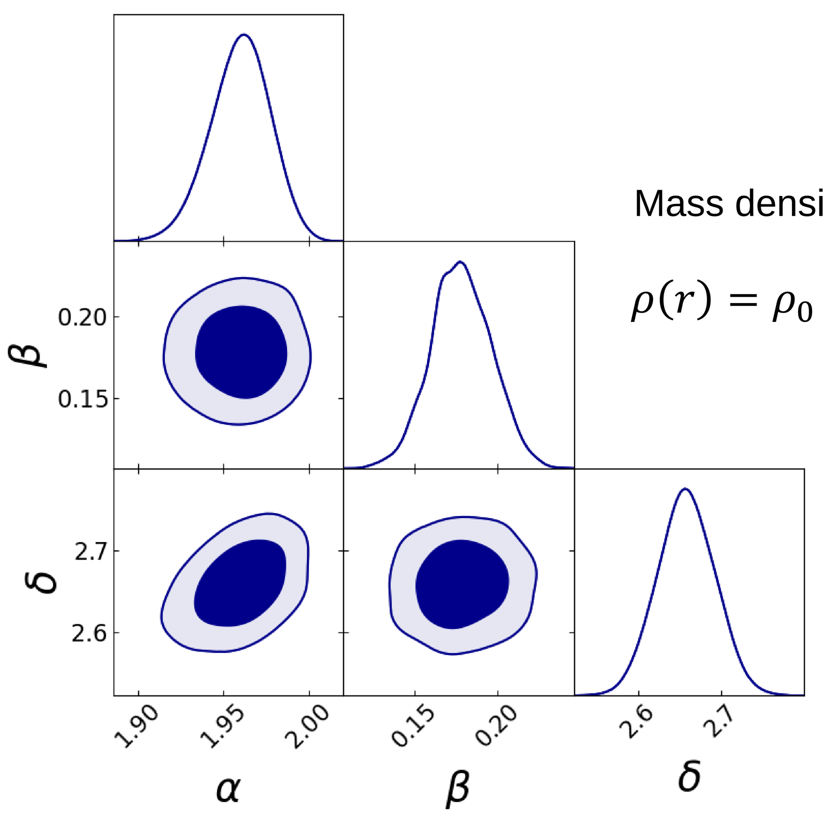
$\beta(r) = 1 - \sigma_t^2/\sigma_r^2$ Anisotropy parameter

$\nu(r) = \nu_0\left(\frac{r}{r_0}\right)^{-\delta}$ Brightness profile

For the **SOAR sample** we obtained:

$$\gamma = 1.17\,^{+0.29}_{-0.33}$$

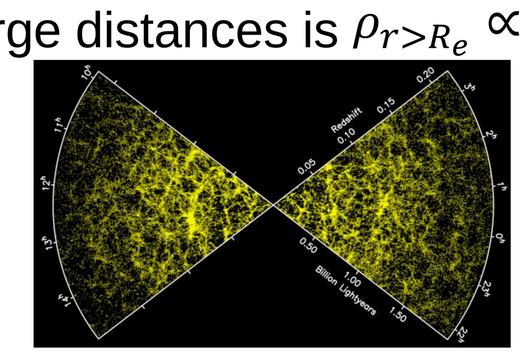
- Infer **Dark-Matter** slope profile



Mass density profile

$$\rho(r) = \rho_0\left(\frac{r}{r_0}\right)^{-\alpha}$$

Large scale simulations predicts that the density profile of halos at large distances is $\rho_{r>R_e} \propto r^{-3}$



However, observational data and simulations shows that at galaxy scales the total density profile is close to **isothermal**. For **galaxy-scale** systems on the **SOAR sample**:

$$\alpha = 1.96 \pm 0.02$$

Future work

- Classify systems according to their properties
- Provide detailed modeling analysis for hundreds of systems
- Provide self-contained modify gravity tests with full information for light and density profiles on a system-by-system basis using our modelling with less external priors
- Use our sample to provide extensive database for ML applications on real data (classification, regression, segmentation...)