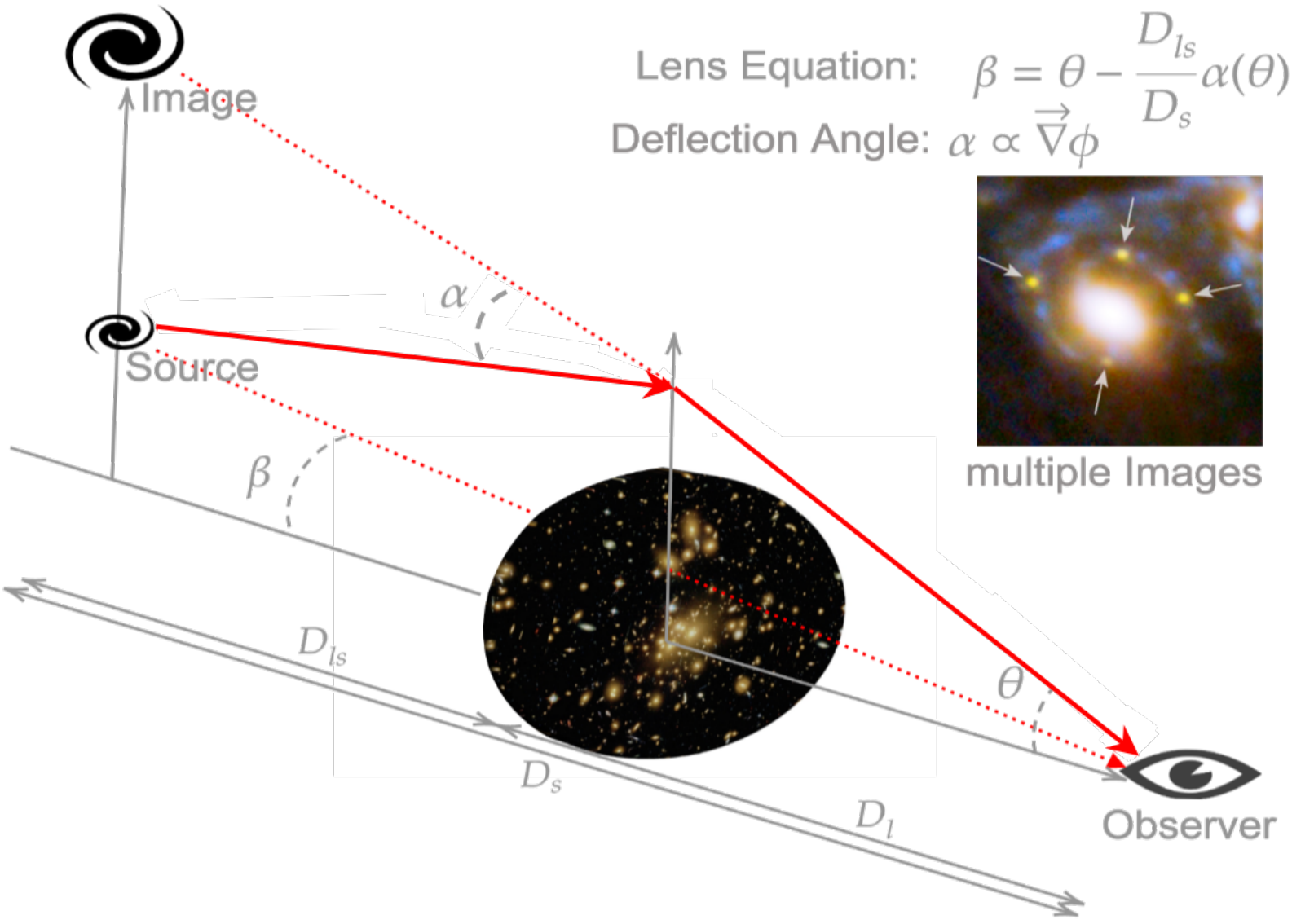
# High Precision Strong Lensing Mass Models with X-ray and Galaxy Kinematics Measurements: the Case of Abell S1063

Benjamin Beauchesne

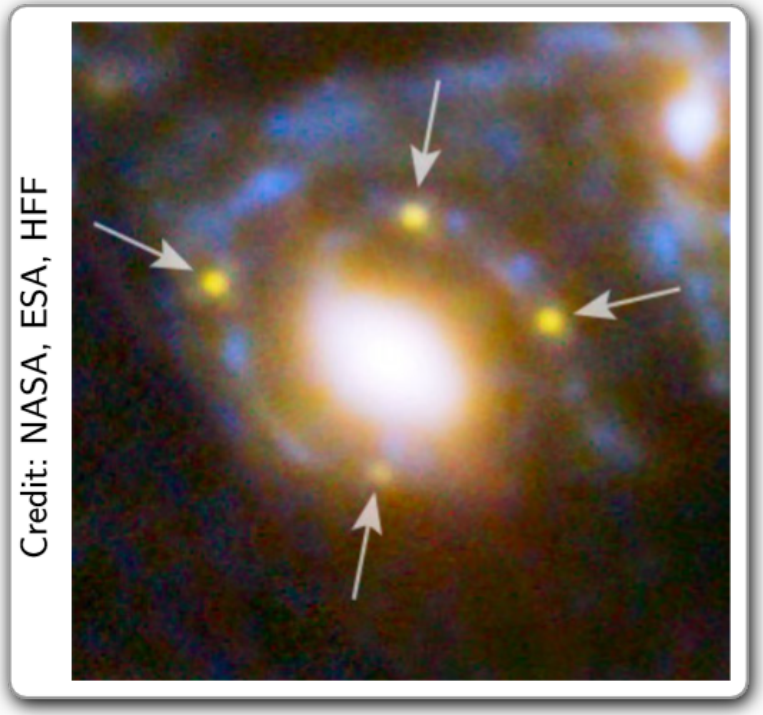
PhD Advisers: Pascale Hibon (ESO Santiago) and Jean-Paul Kneib (EPFL)
Collaborators: Joseph Allingham (SIfA), Benjamin Clément (EPFL), Dominique Eckert (UNIGE), Marceau Limousin (LAM) and Johan Richard (CRAL)


# Gravitational lensing effect

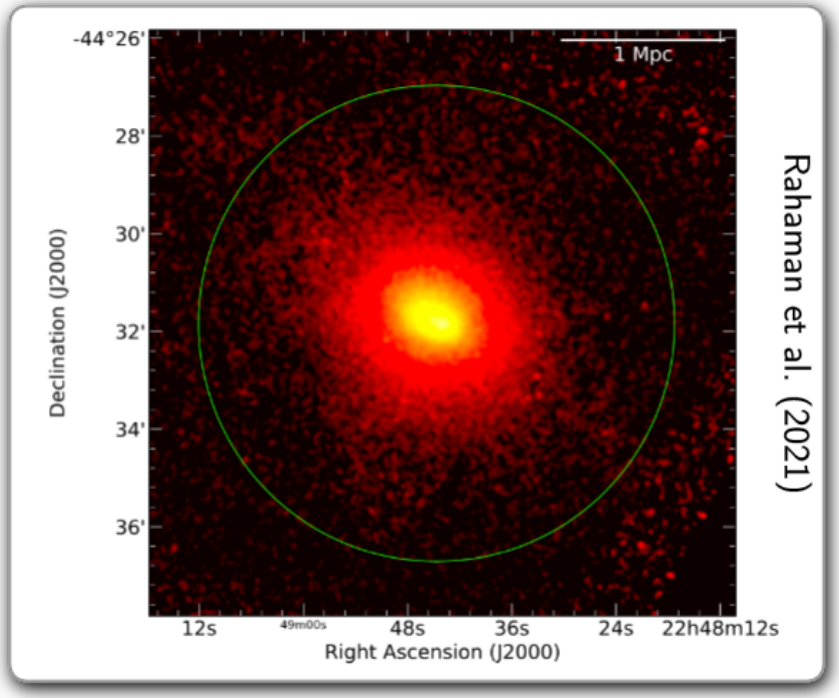


# Observations on galaxy clusters - 1

## Gravitational lensing:




## X-ray emission:

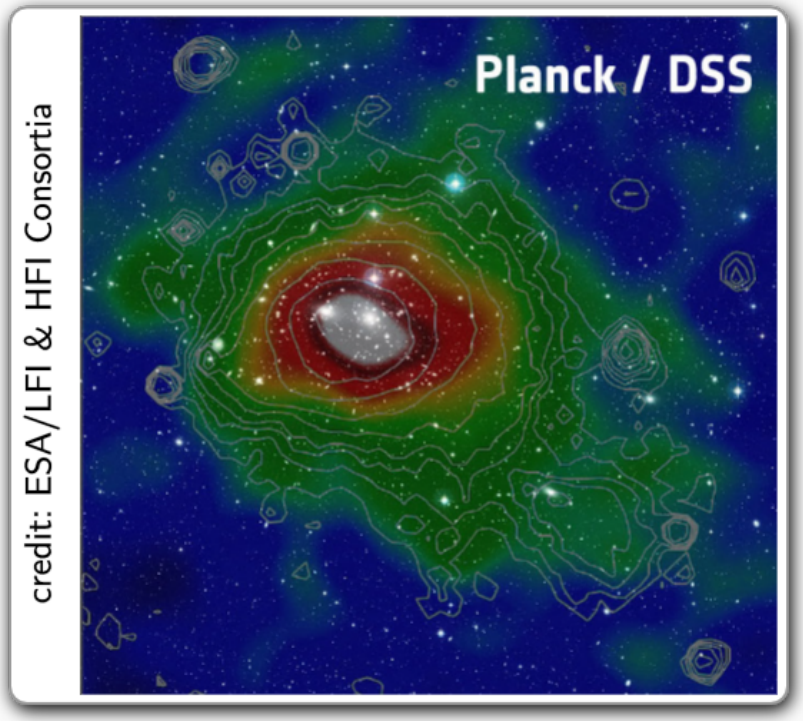



$$\vec{\alpha} \propto \int_{\mathbb{R}^2} d^2\vec{\theta'} \frac{\vec{\theta} - \vec{\theta'}}{||\vec{\theta} - \vec{\theta'}||^2} \Sigma(\vec{\theta'})$$

$$S_X \propto \int_{\mathbb{R}} n_e n_p \, dz$$

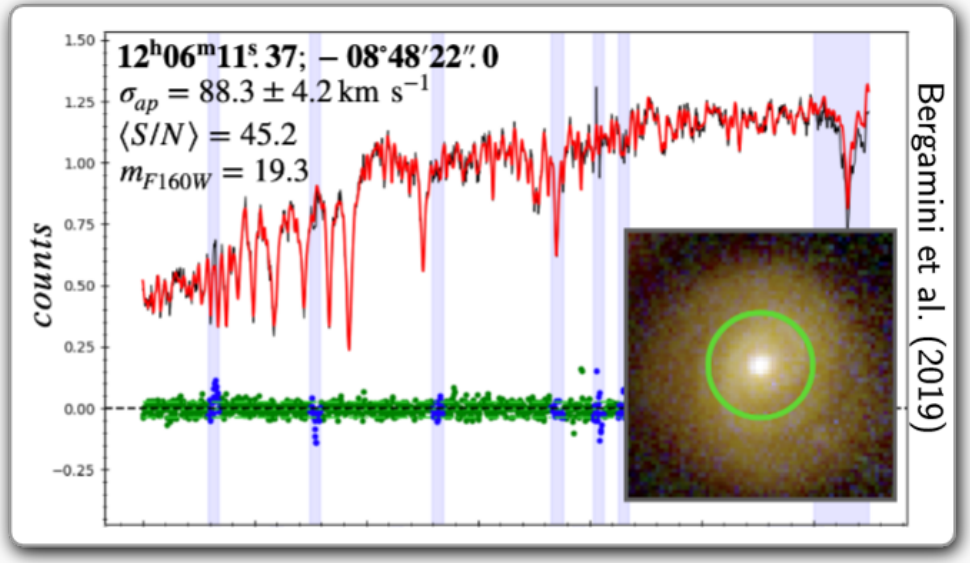
# Observations on galaxy clusters - 2

## Sunyaev–Zel'dovich effect:



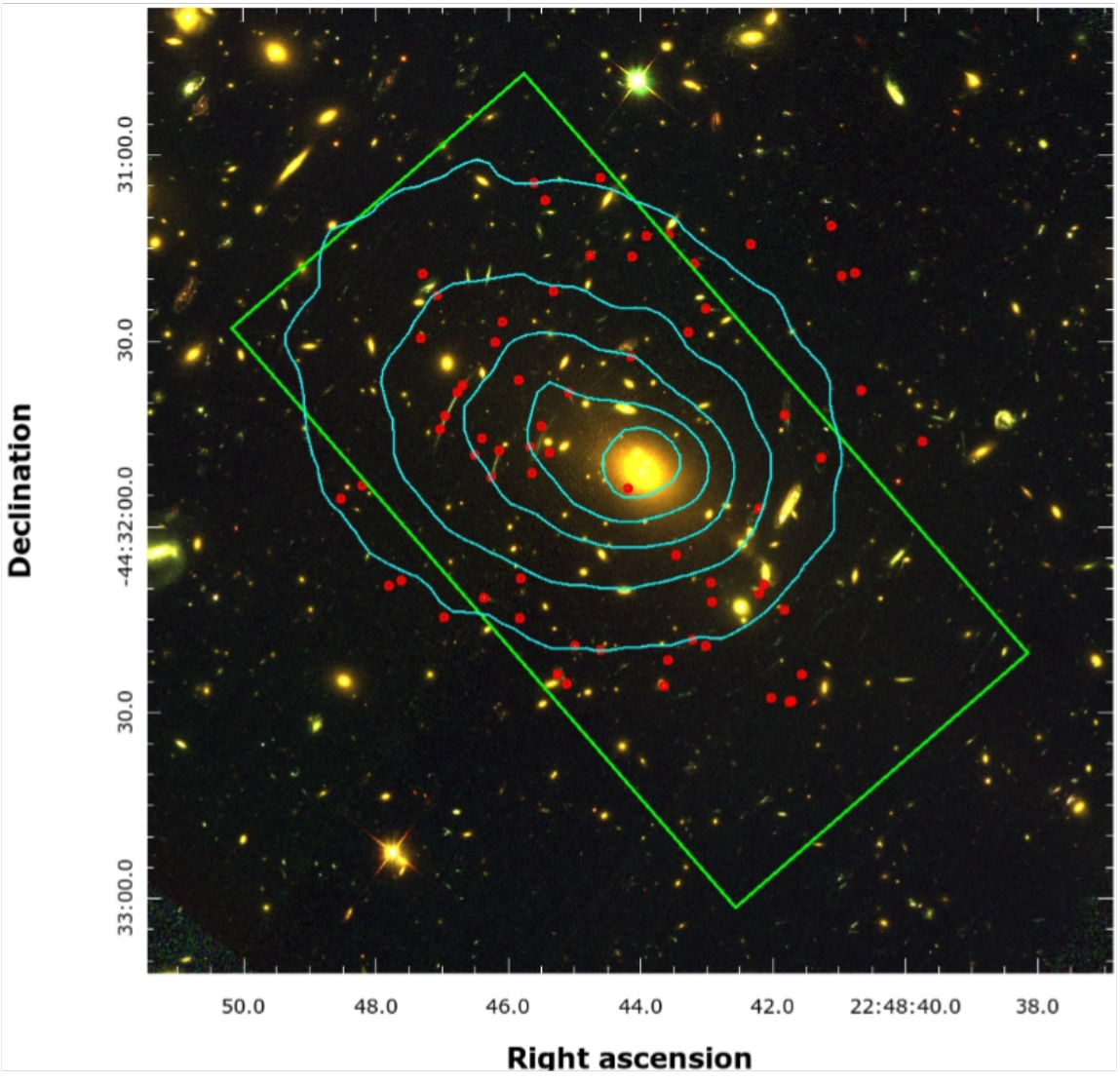

$$\frac{\Delta T_{SZ}(\nu)}{T_{CMB}} \propto \int_{\mathbb{R}} n_e T f(\nu; T)\, dz$$

## Photometry & spectroscopy:




- Faber&Jackson law
- Fundamental plane of elliptical galaxies
- Light-profiles
- ...

# Abell S1063



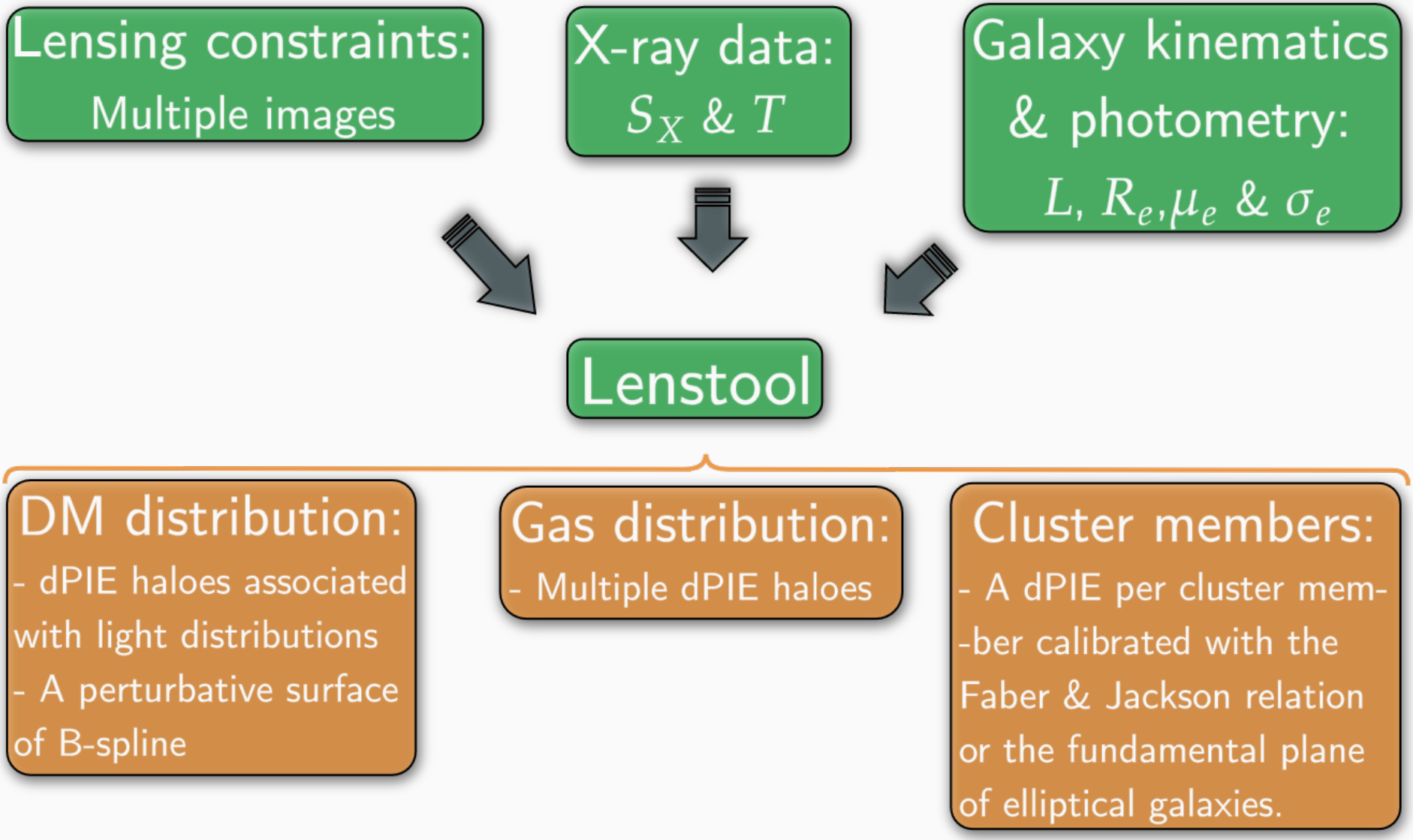

X-ray emission contour

MUSE FoV

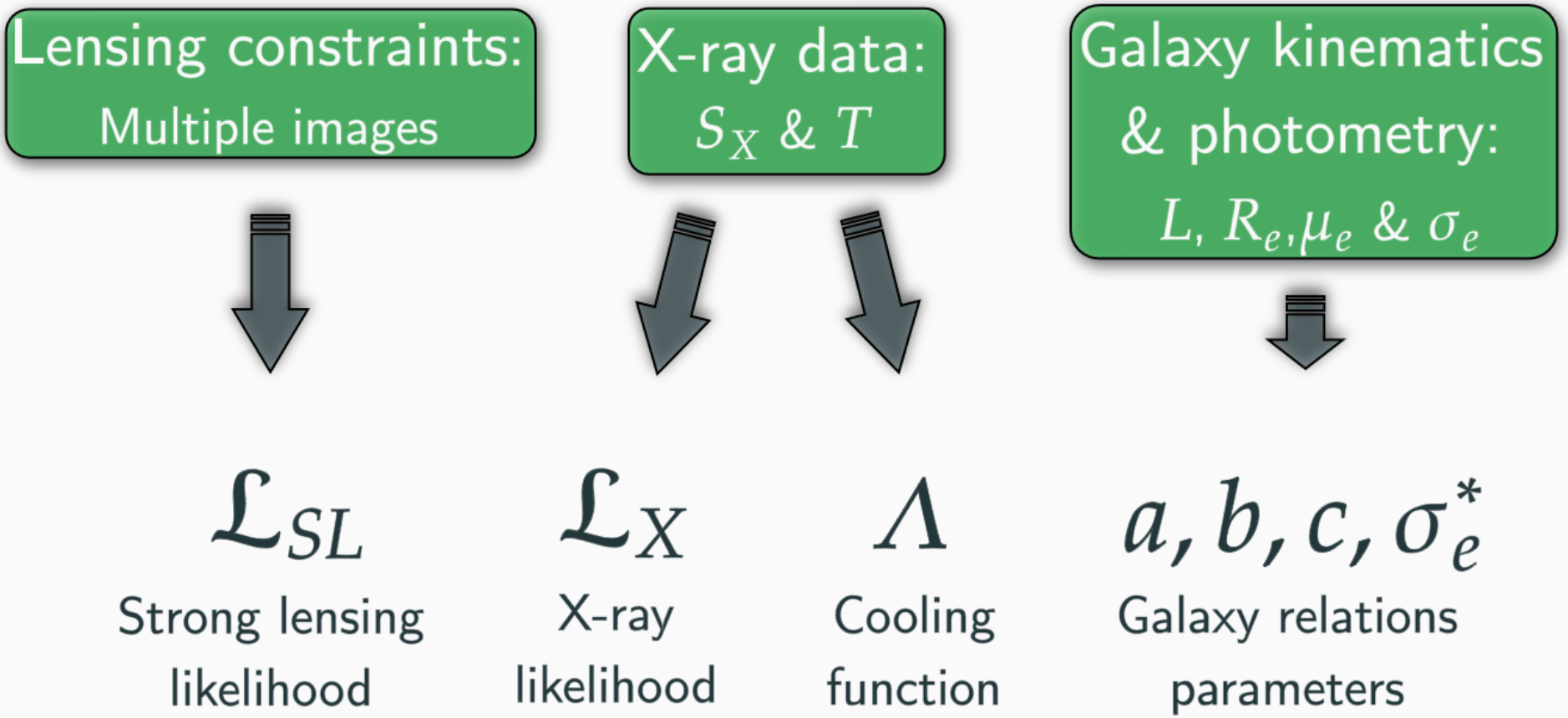
Multiply-imaged systems

HST images: Hubble Frontier Field and BUFFALO programs
MUSE data: 60.A-9345(A), 095.A-0653(A)
Chandra observations IDs: 4966, 18818, 18611

# Modelling overview - 1

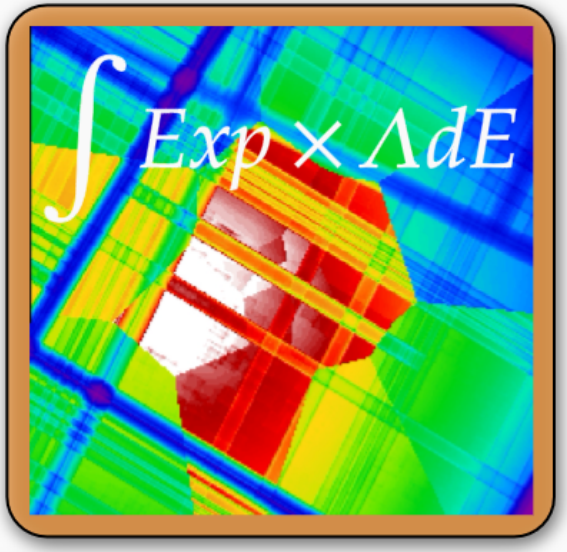


# Modelling overview - 2



# Gas distribution modelling


Plasma emission code (APEC)





Optimisation of the gas distribution through a Poisson likelihood implem--ented in Lenstool:

$$\log L = \sum_i D_i \log(M_i) - M_i - \log(D_i!)$$

$D_i$ : Data | $M_i$ : Model

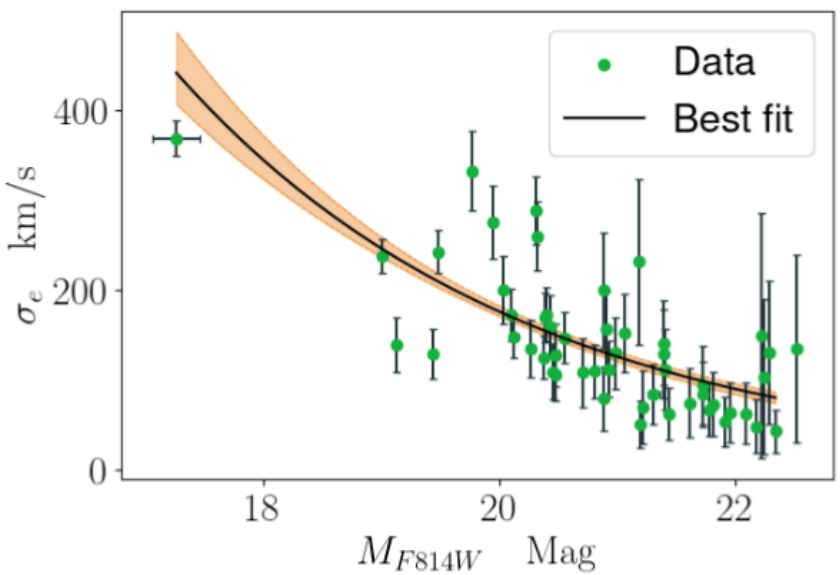
# Cluster member modelling

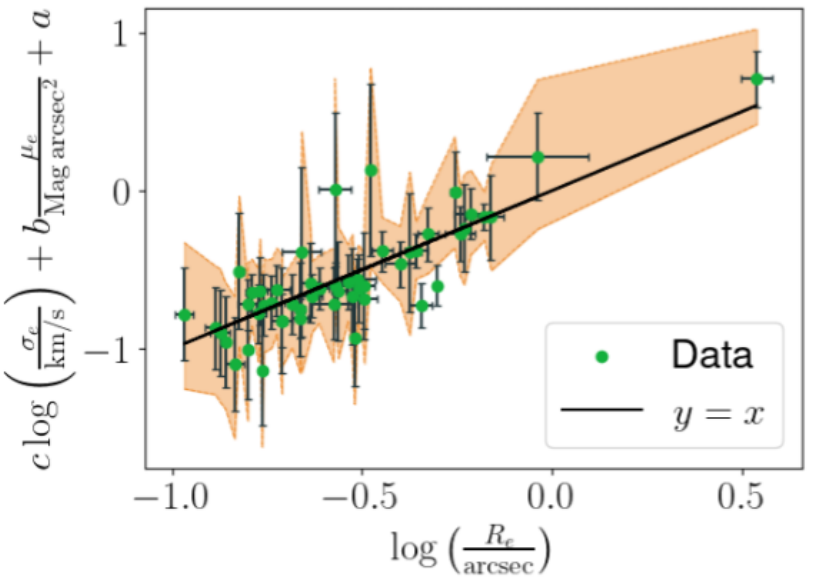
**Faber & Jackson relation:**

$$\sigma_e \propto L^{1/2c}$$

**Fundamental plane of elliptical galaxies:**

$$\log(R_e) = a + b\mu_e + c\log(\sigma_e)$$

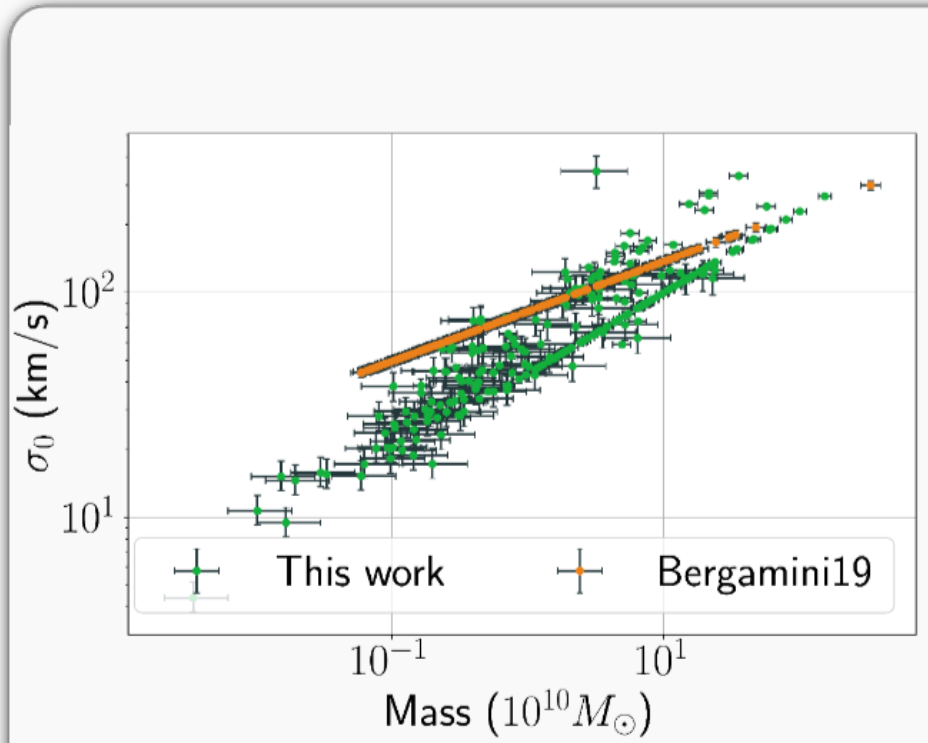


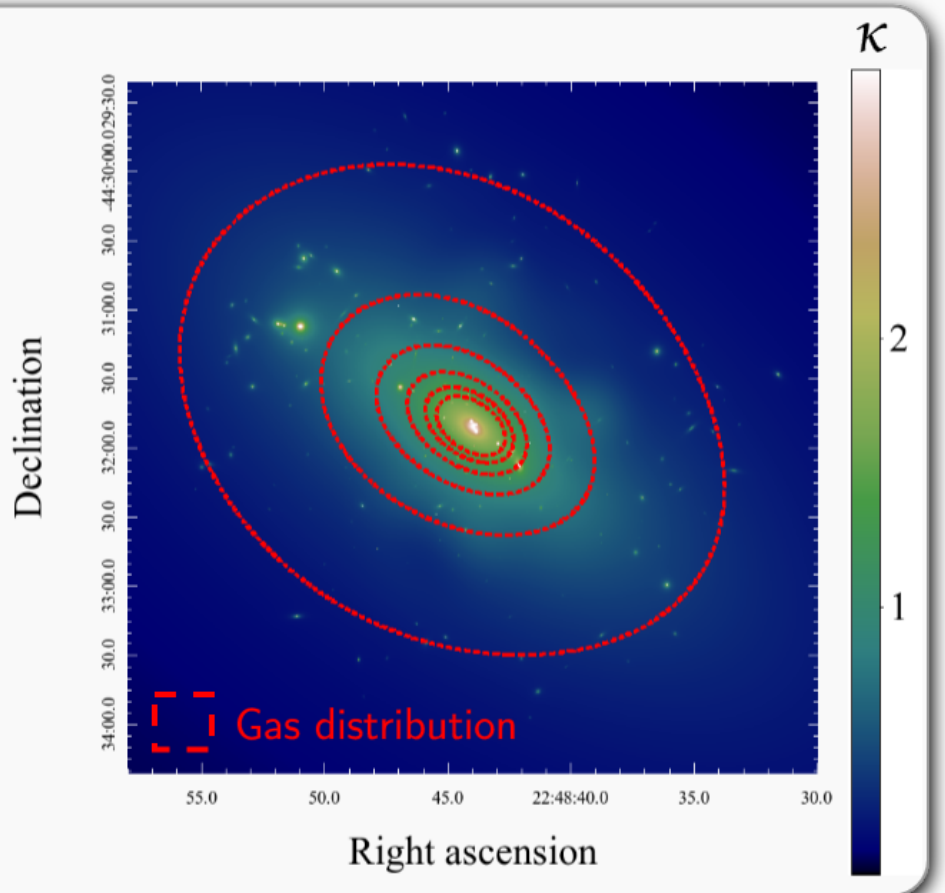

Beauchesne et al. (2022, in prep)

# Preliminary results : Mass distribution of each component

## Cluster member masses



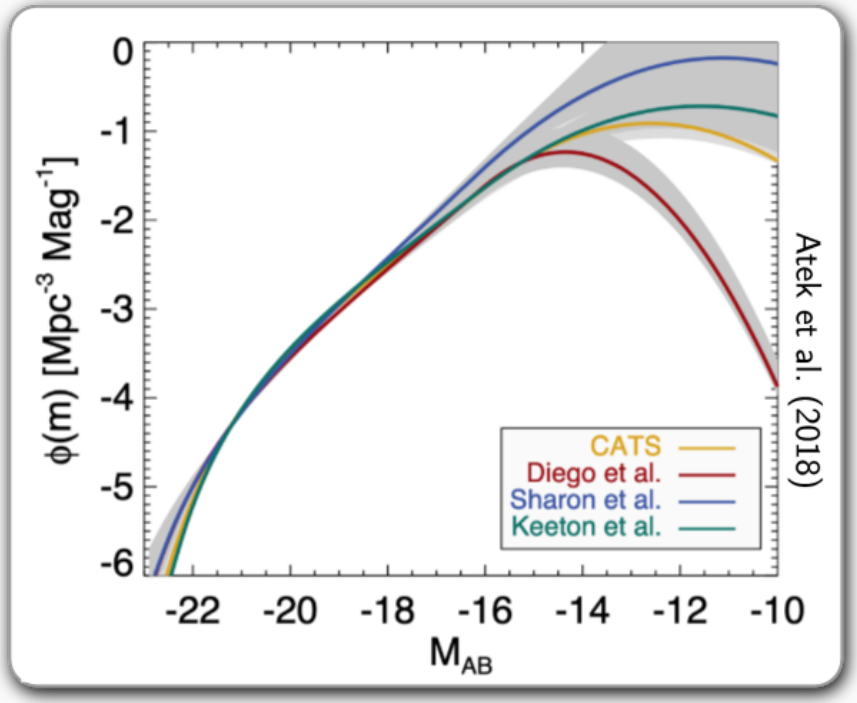

## Total and gas mass mapping




Beauchesne et al. (2022, in prep)

# Influence on high-redshift studies : Luminosity functions

UV luminosity function

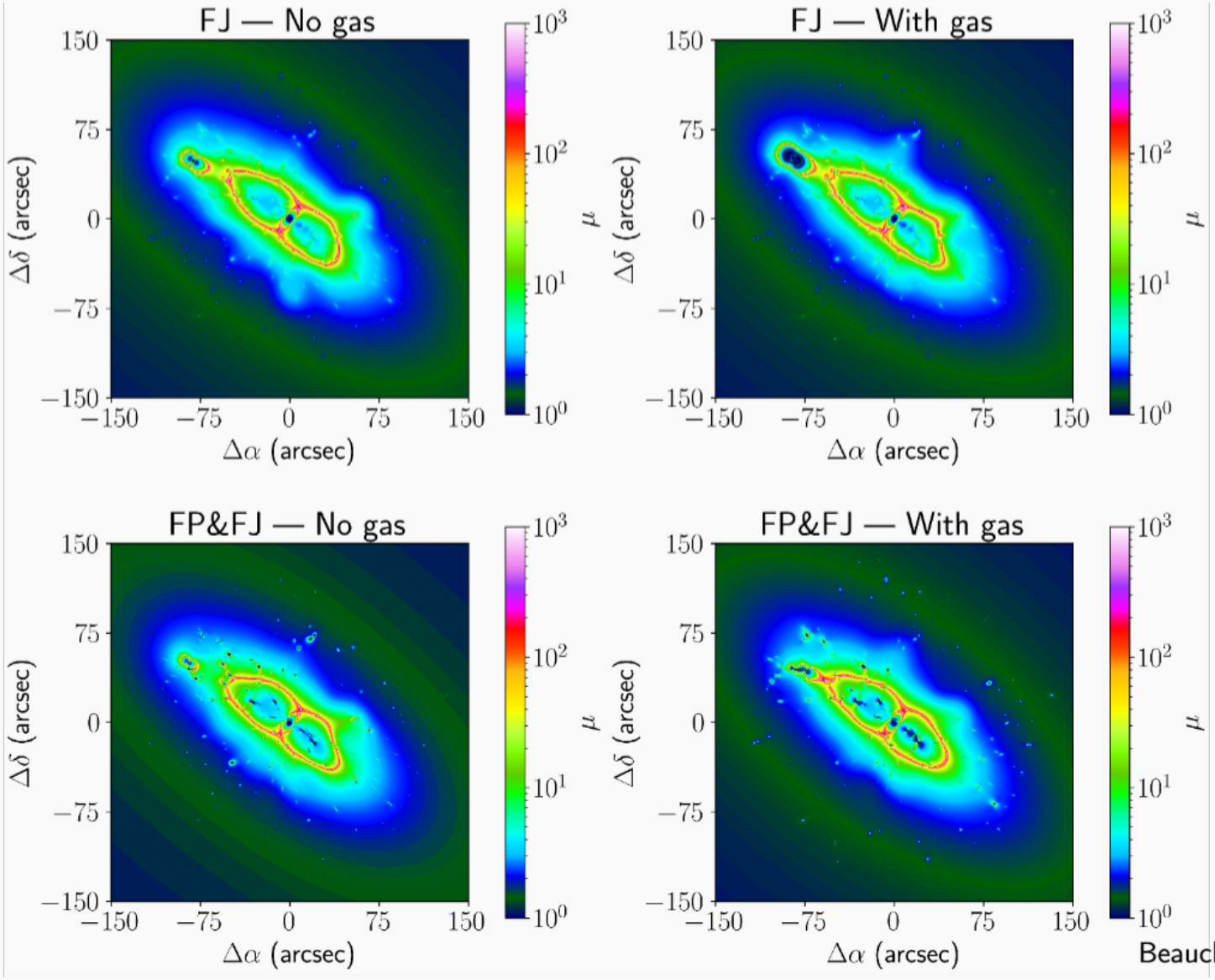



Affected by

$\rightarrowtail$ Realisation of galaxy positions and magnification.

$\rightarrowtail$ Lensed area in the source plane.

# Preliminary results : Magnification for sources at $z = 3$

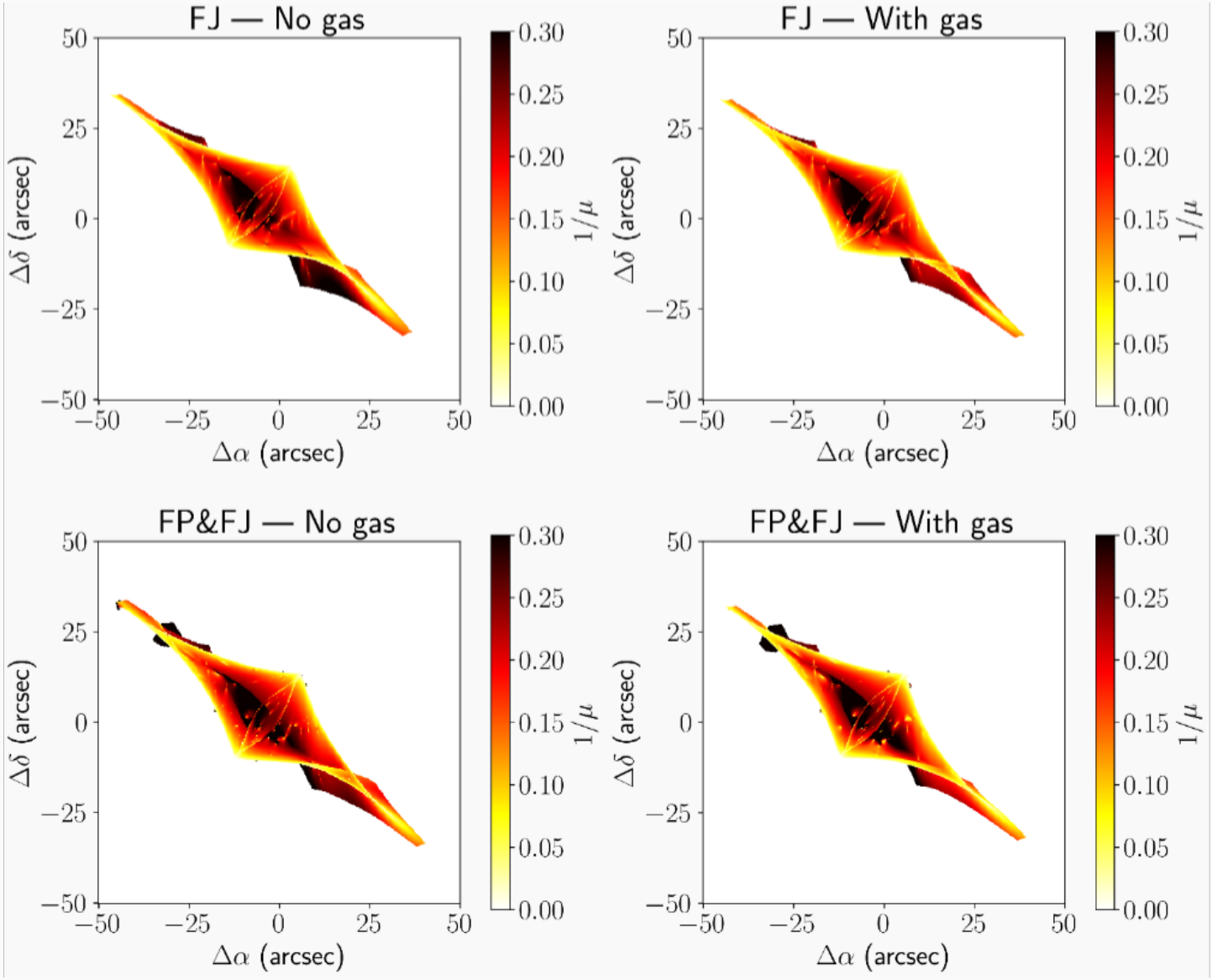



FJ: Faber & Jackson scaling

FP: Fundamental plane scaling

Beauchesne et al. (2022, in prep)

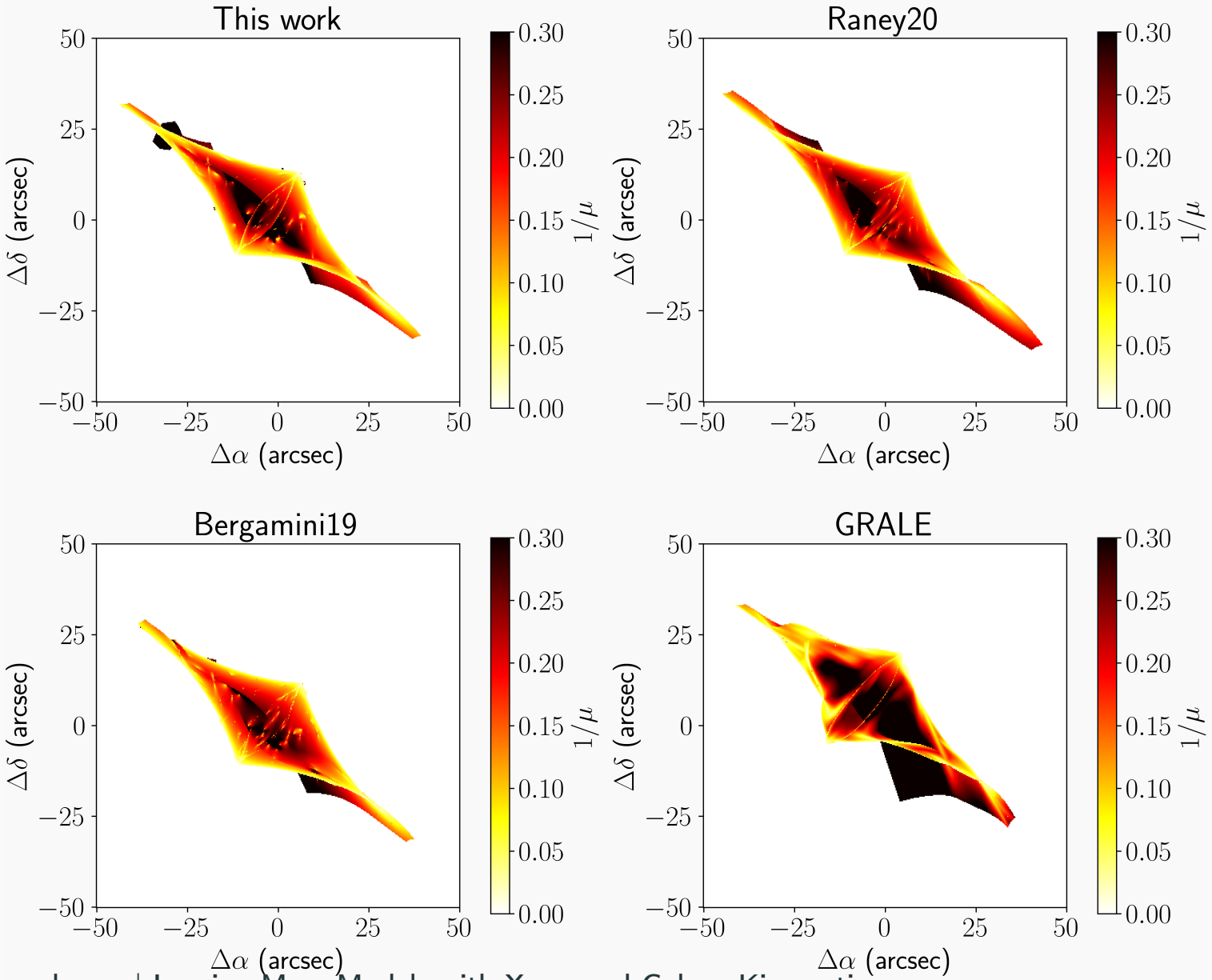
# Preliminary results : MUSE FoV in the source plane at $z = 3$




FJ: Faber & Jackson scaling

FP: Fundamental plane scaling

# MUSE FoV in the source plane at $z = 3$ - Other methods



# Conclusion

## Key points

- Mass model physically consistent with lensing, X-ray and galaxy kinematic measurements.
- Proper propagation of error measurements thanks to the joined MCMC sampling.
- Differences on the magnification from the past methodology are lower or on the scale of the discrepancy between others strong lensing methods.

## Future works

- Modelling of other clusters observed with MUSE+Chandra+HST.
- Assessment of the new method influence on the faint end of the Ly$\alpha$ luminosity functions.

# Thank you for listening