The mass structure and IMF of massive ellipticals beyond z = 0.1

Matteo Barnabè

Dark Cosmology Center & Niels Bohr International Academy

Copenhagen University

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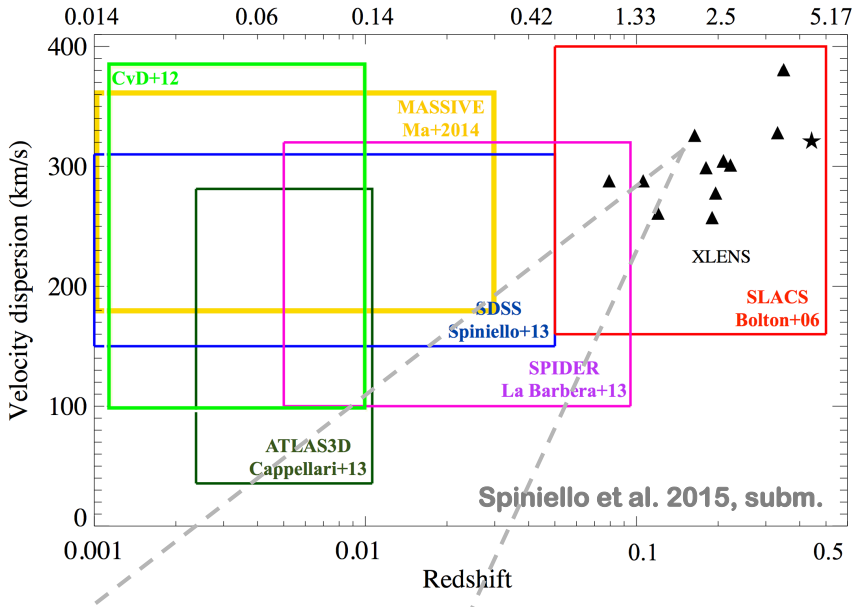
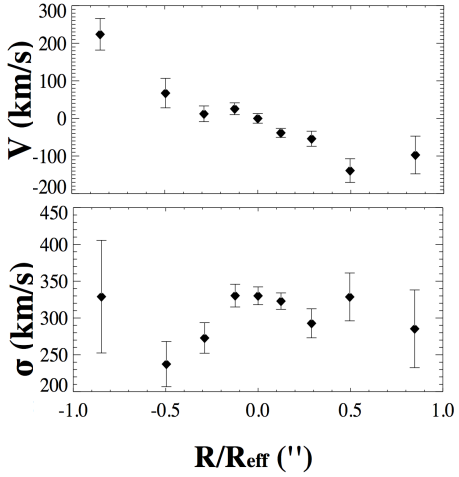




LENSING + DYNAMICS

- Disentangle contribution of dark and luminous mass without assumptions on IMF
- 3D mass structure of ETGs beyond z = 0.1

XLENS Survey

- 13 massive ETGs probing redshift range z ~ 0.10 - 0.45
- HST multi-band imaging of the lens structure
- Accurate spatially resolved kinematics up to 1-1.5 R_e
- High S/N X-Shooter spectra: spectroscopic SPS analysis of optical line-strength indices
- L+D+SPS: we can constrain IMF

See talk by Chiara Spiniello!

COMBINED LENSING AND DYNAMICS ANALYSIS

(CAULDRON code, Barnabè et al. 2012)

Gravitational Lensing Model

- Pixelated source reconstruction method

Dynamical Model

- Anisotropic Jeans equations (JAM, Cappellari 2008)
  - Free parameter: meridional plane orbital anisotropy ratio $b = \sigma_R^2/\sigma_z^2$

Mass Model

- Dark matter halo: axisymmetric generalized NFW density profile:

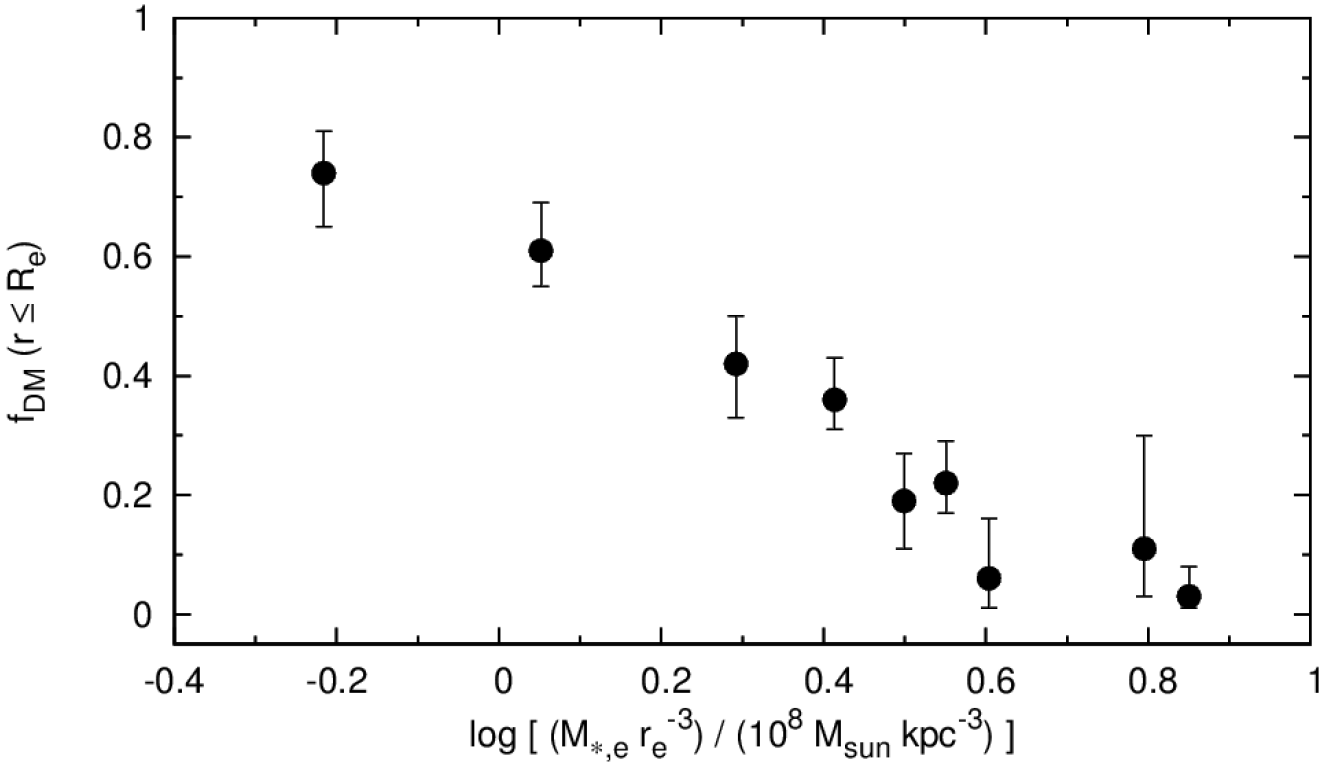
$$\rho_{\rm DM}(m) = \frac{\delta_c\,\rho_{\rm crit}}{(m/r_{\rm s})^{\gamma}\,(1+m/r_{\rm s})^{3-\gamma}} \qquad m^2 \equiv R^2 + \frac{z^2}{{q_{\rm h}}^2}$$

  - Free parameters: inner slope γ, 3D axial ratio q_h, concentration c_{-2}, virial velocity v_{vir}

- Luminous mass distribution: *multi-Gaussian expansion* (MGE) technique (Emsellem et al. 1999, Cappellari 2002) applied to SB profile.
  - Luminous mass distribution is self-gravitating, not just a tracer
  - Free parameter: baryonic mass M_{bar}

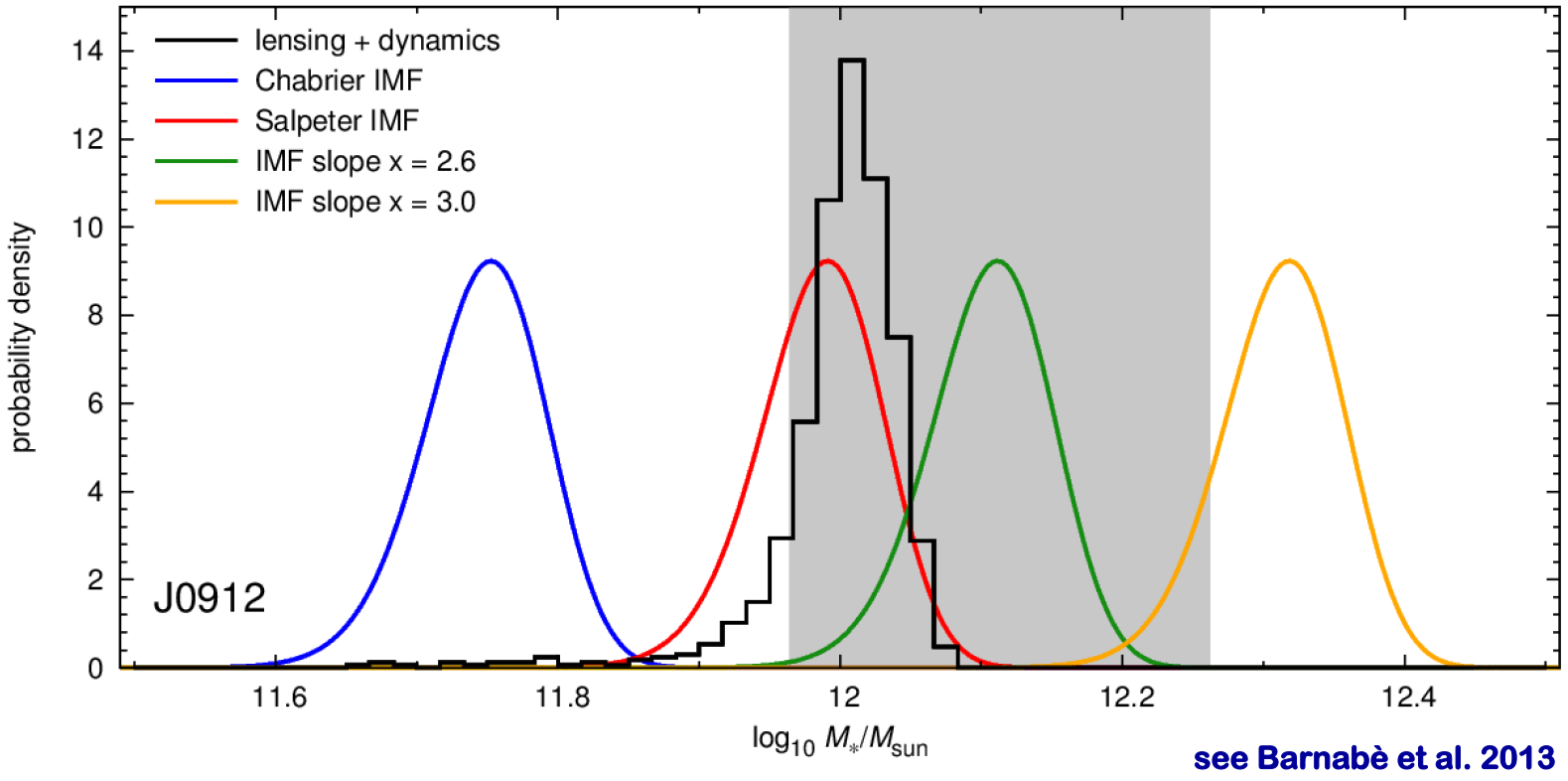
XLENS: DARK MATTER FRACTION

- dark matter contribution within r = effective radius, without any assumptions on the IMF
- f_{DM} ($\leq R_e$) is about 10 – 40% with scatter except for the two most massive galaxies (beyond $\sigma \sim 350$ km/s)
- the dark matter fraction f_{DM} is higher in galaxies with lower stellar mass density $\rho_* \propto M_e/r_e^3$ (cf. Sonnenfeld et al. 2014)



Barnabè et al., in prep.

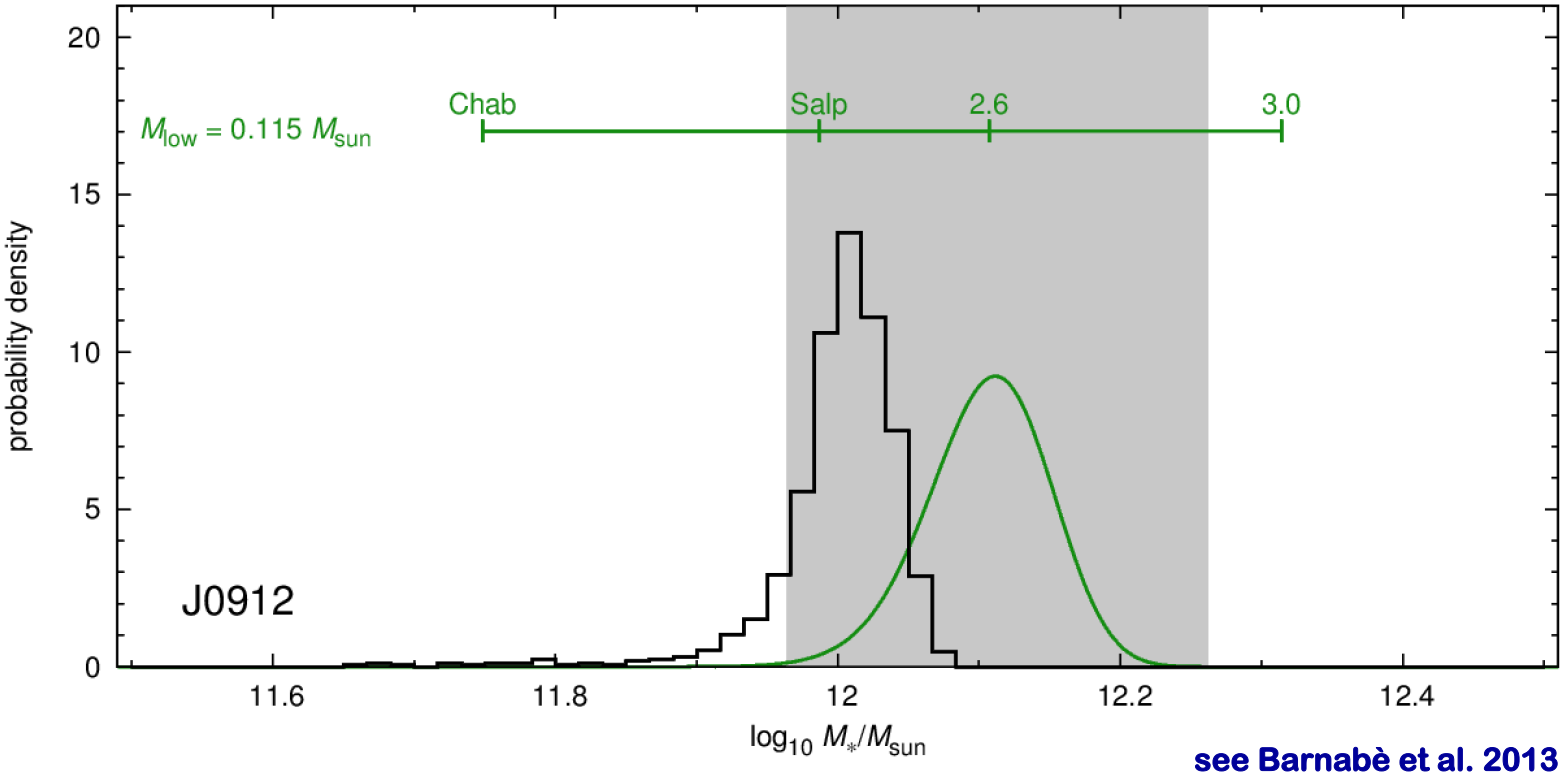
CONSTRAINING THE IMF SLOPE …



see Barnabè et al. 2013

- The stellar masses inferred from the combined L+D analysis (which makes *no assumptions* on the IMF) can be compared with the ones obtained from spectroscopic SSP modelling of optical line-strength indices, assuming various IMF low-mass slopes.
- From SSP modelling of X-Shooter spectra we can also obtain an *independent* inference on the IMF slope (see Spiniello et al. 2014, and Chiara's talk).

… AND THE IMF LOW-MASS CUT-OFF



see Barnabè et al. 2013

- M_{low} is crucial when determining the stellar mass-to-light ratio from stellar population evolutionary codes
- Low-mass stars with $M < 0.15\ M_{sun}$ have little effect on spectral lines but can contribute significantly to the total stellar mass
- Values from $M_{low} = 0.08$ to 0.15 are used in SP evolutionary codes
- We can determine joint constraints on both the IMF slope and low-mass cut-off

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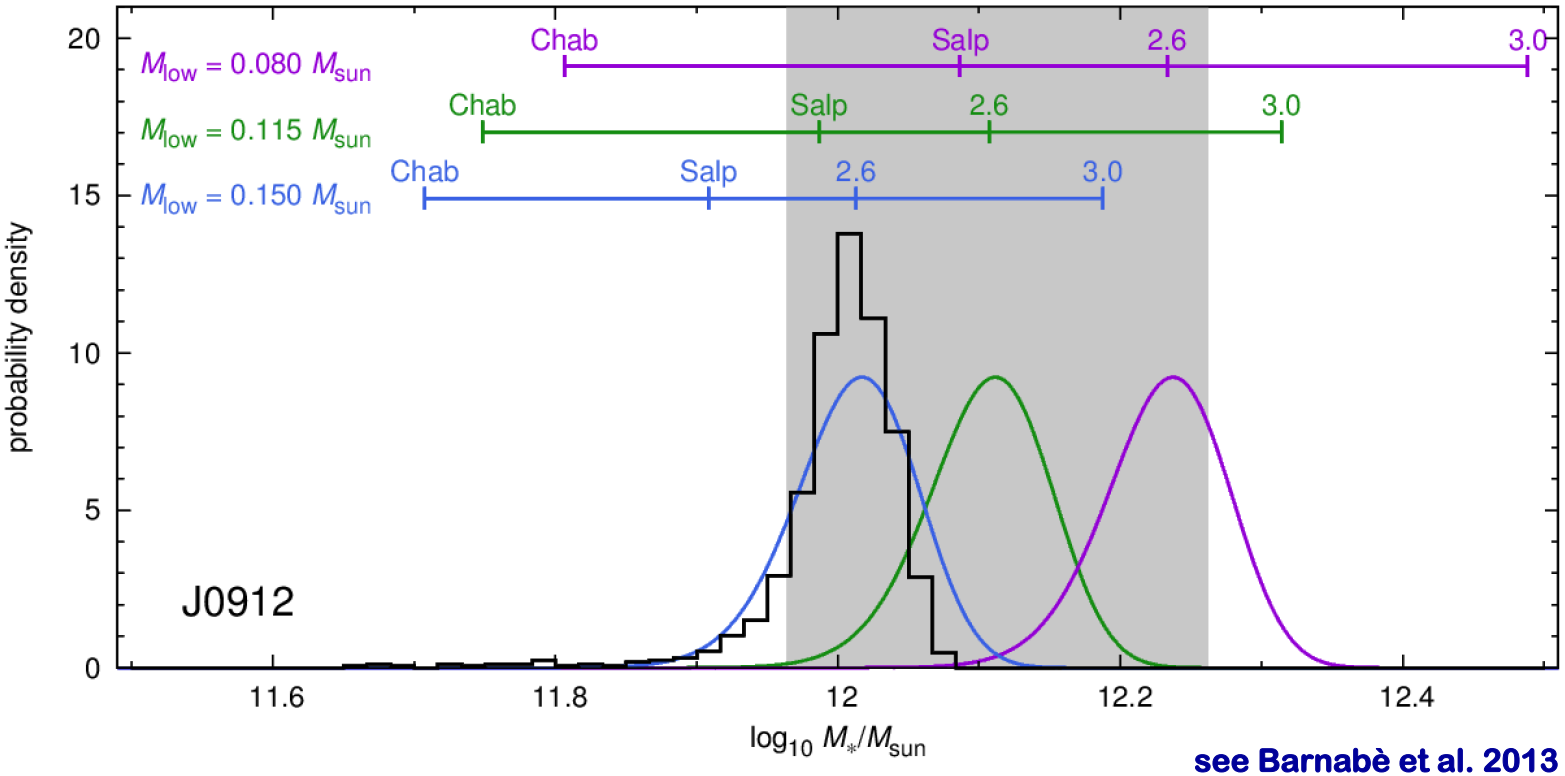

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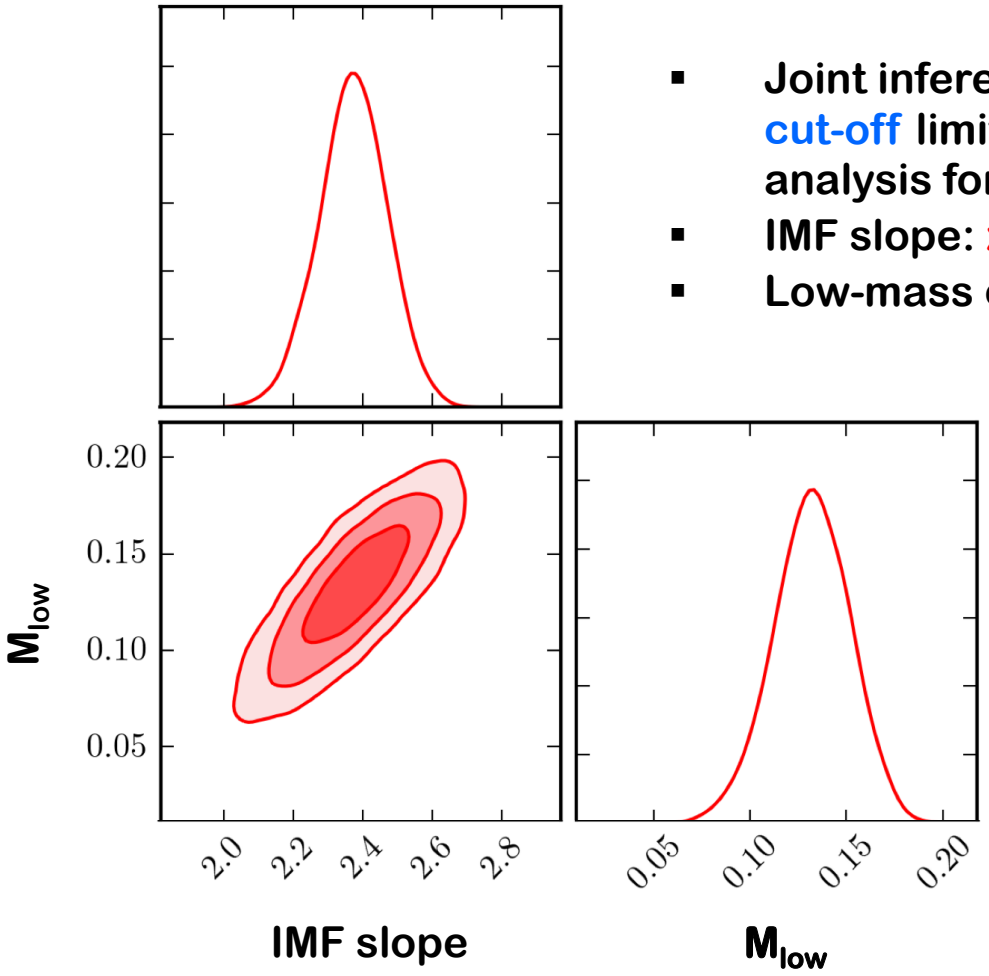
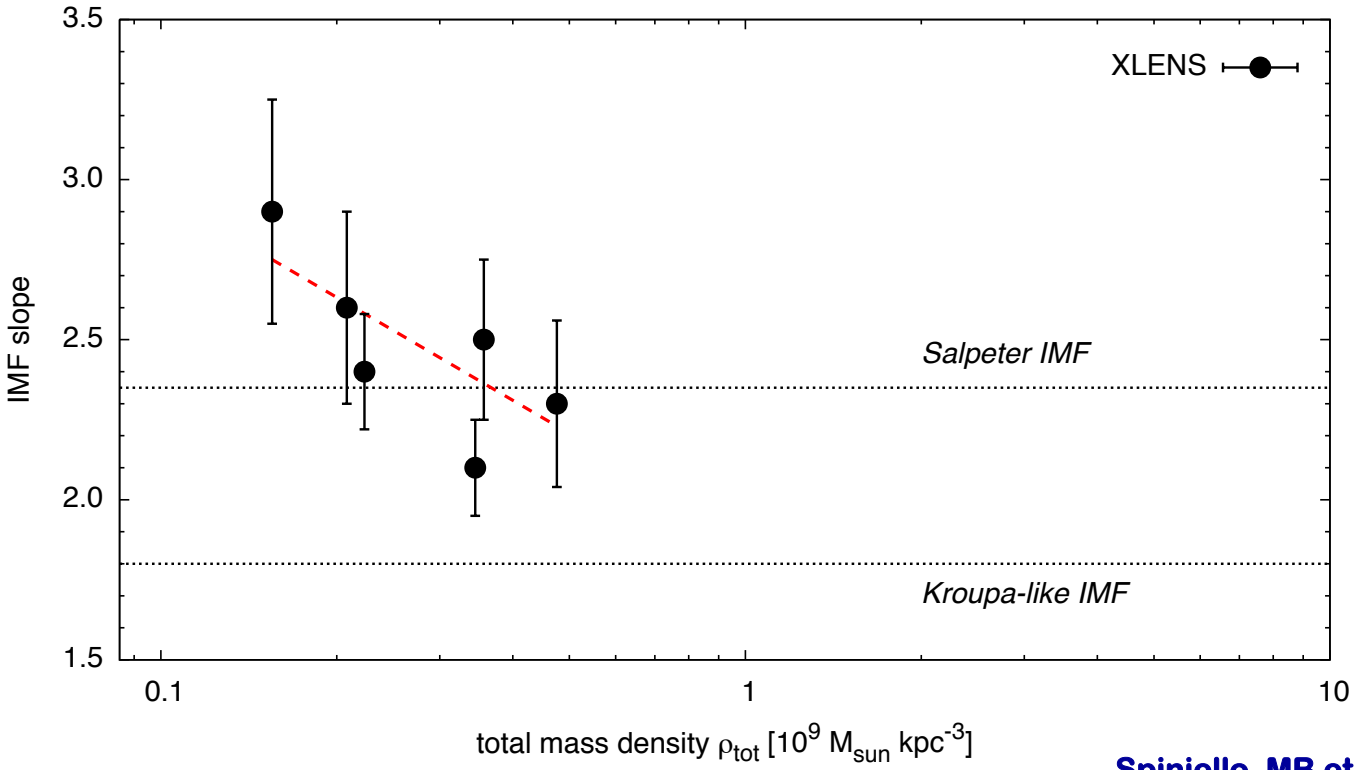
JOINT INFERENCE ON IMF SLOPE AND M_{Low}



- Joint inference on IMF slope and low-mass cut-off limit from combined L+D+SSP analysis for nine XLENS galaxies
- IMF slope: x = 2.41 ± 0.13 (Salpeter-like)
- Low-mass cut-off: $M_{low} = 0.144 \pm 0.027\ M_{sun}$

Spiniello, MB et al. 2015

IMF SLOPE ANTI-CORRELATES WITH TOTAL DENSITY



Spiniello, MB et al. 2015

- **Full Bayesian analysis to derive trends of IMF slope and M_{low} with physical quantities**
- **No relation between IMF slope and velocity dispersion σ when including effect of M_{low}**
- **Anti-correlation between IMF slope and total mass density**

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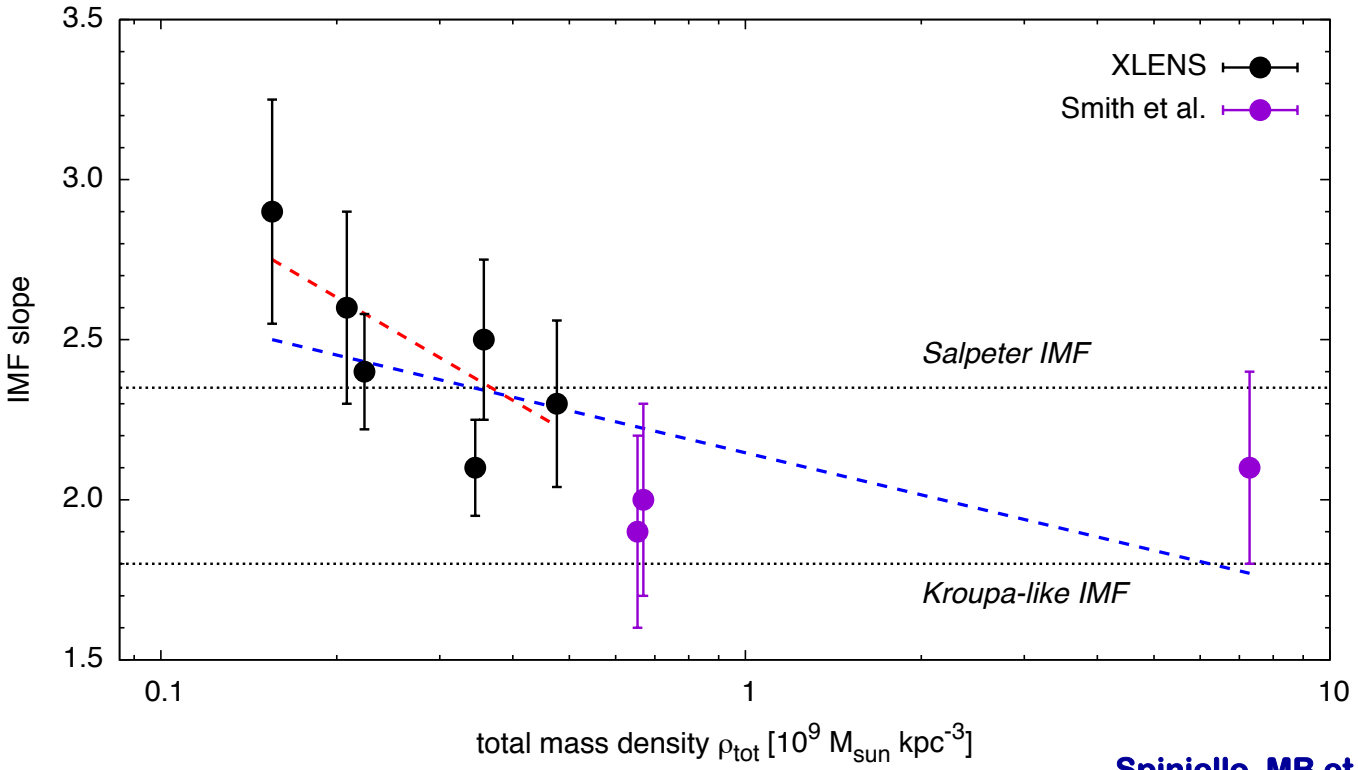

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- **Trend is consistent with the lenses found by Smith et al. 2015, that have high velocity dispersion but shallow (Kroupa-like) IMFs.**

SUMMARY

- **Mass structure of ETGs:**
  - The combination of gravitational lensing with high-res spatially resolved kinematics makes it possible to investigate the dark and luminous structure of massive ellipticals beyond the local Universe ($z > 0.1$).
  - Dark matter fraction (within 1 R_e): around 10-40% for typical ETGs, except for the most massive ellipticals which are DM dominated ($f_{DM} \geq 60\%$).
  - We can study dark halo properties within ETGs inner regions: slope, flattening (rounder than q_*), trend with stellar mass density.

- **Initial mass function of ETGs:**
  - Lensing + dynamics can break the degeneracy between f_{DM} and IMF
  - We derive joint constraints on the slope and low-mass cut-off of the IMF
  - IMF of XLENS galaxies is Salpeter-like, even when accounting for M_{low}
  - IMF slope does not correlate with σ, when accounting for M_{low}
  - IMF slope anti-correlates with total mass density (explains Smith et al. lenses)