

---

# **(Strong) Gravitational Lensing and Simulations**

**Stefan Hilbert (EC/USM),**

**many of you,  
Raul Angulo, Simon White,...**

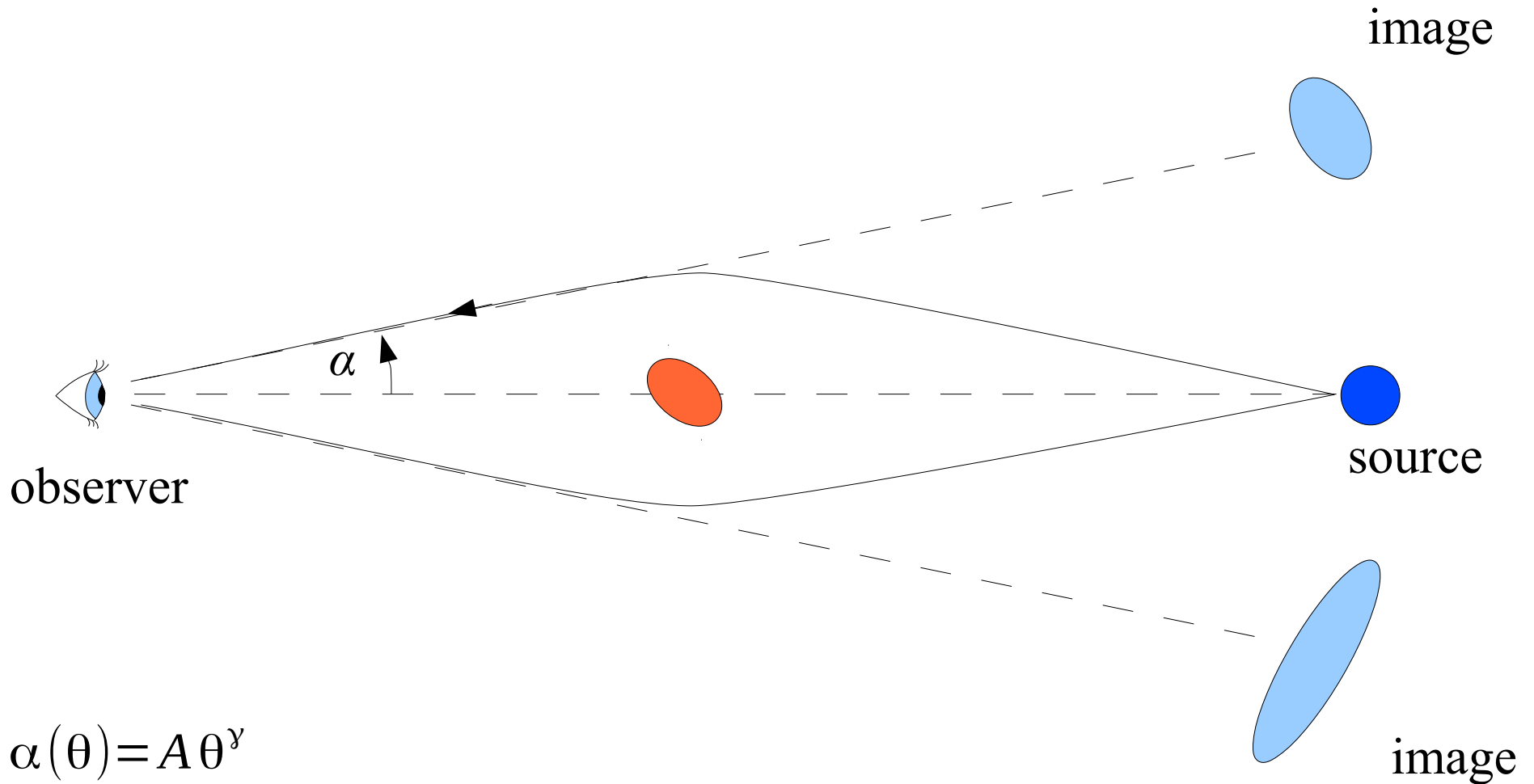
---

---

# Outline

- Introduction
- Galaxy strong lensing, time delays, and line-of-sight structures
- Substructure
- Summary

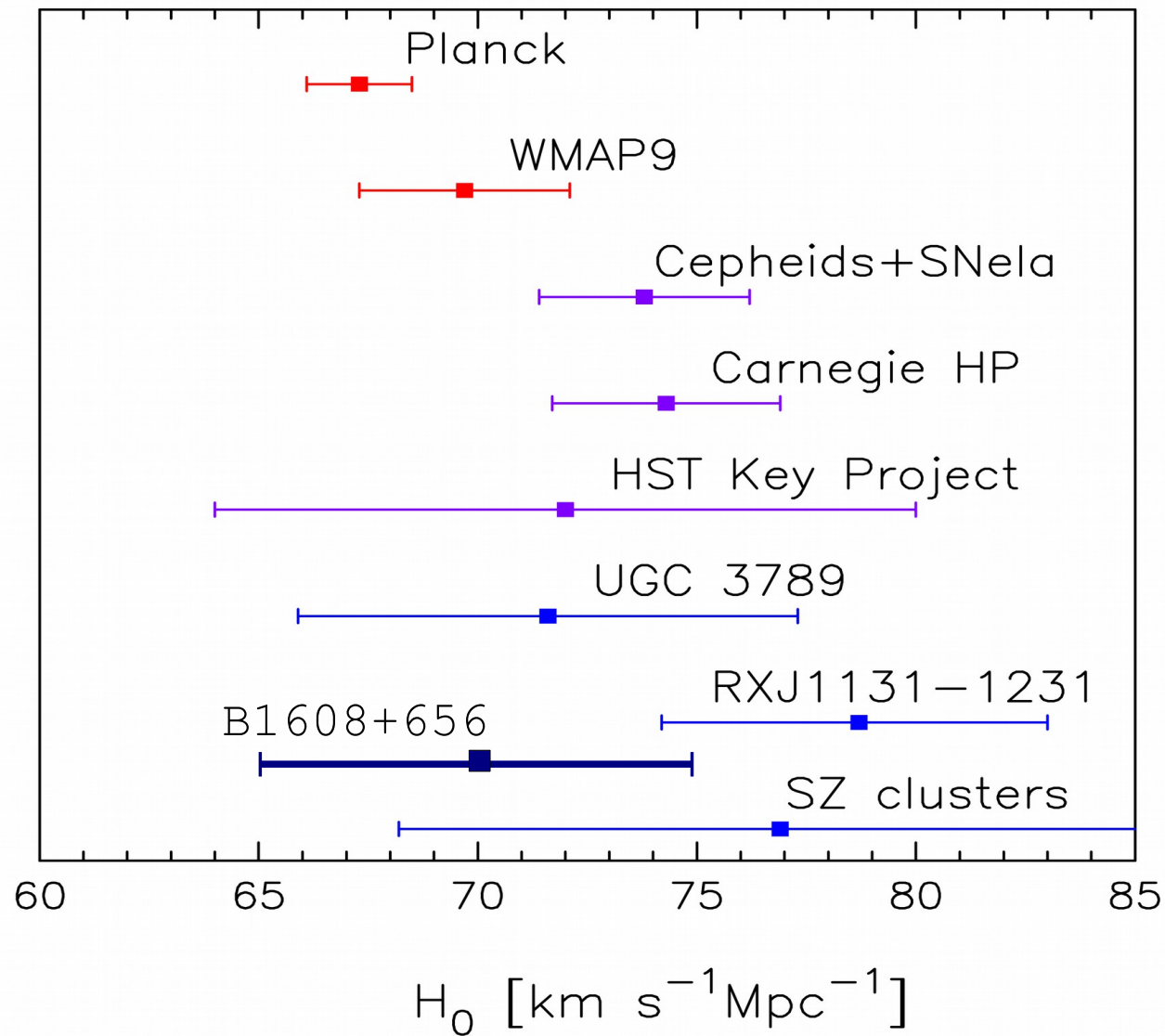
# Strong Lens Time Delays



# Strong Lens Time Delays

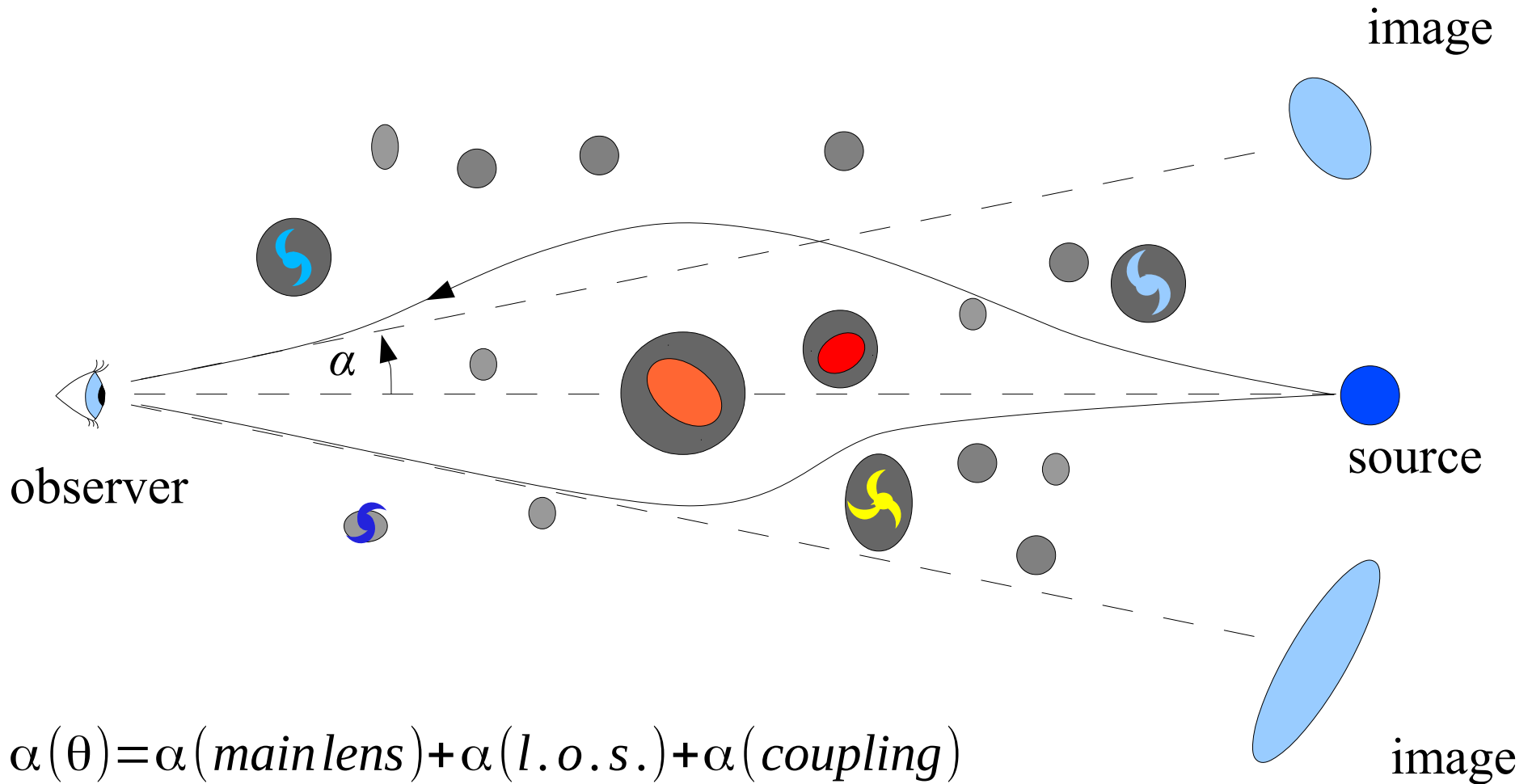
- $H_0$  excellent complement to CMB and other probes
- $H_0$  from strong lens time delays:
  - specific systematics (different from other probes)
  - one-step measurement (no ladder)
  - competitive single system constraints
  - few systems already, hundreds-thousands later

# Hubble Parameter $H_0$

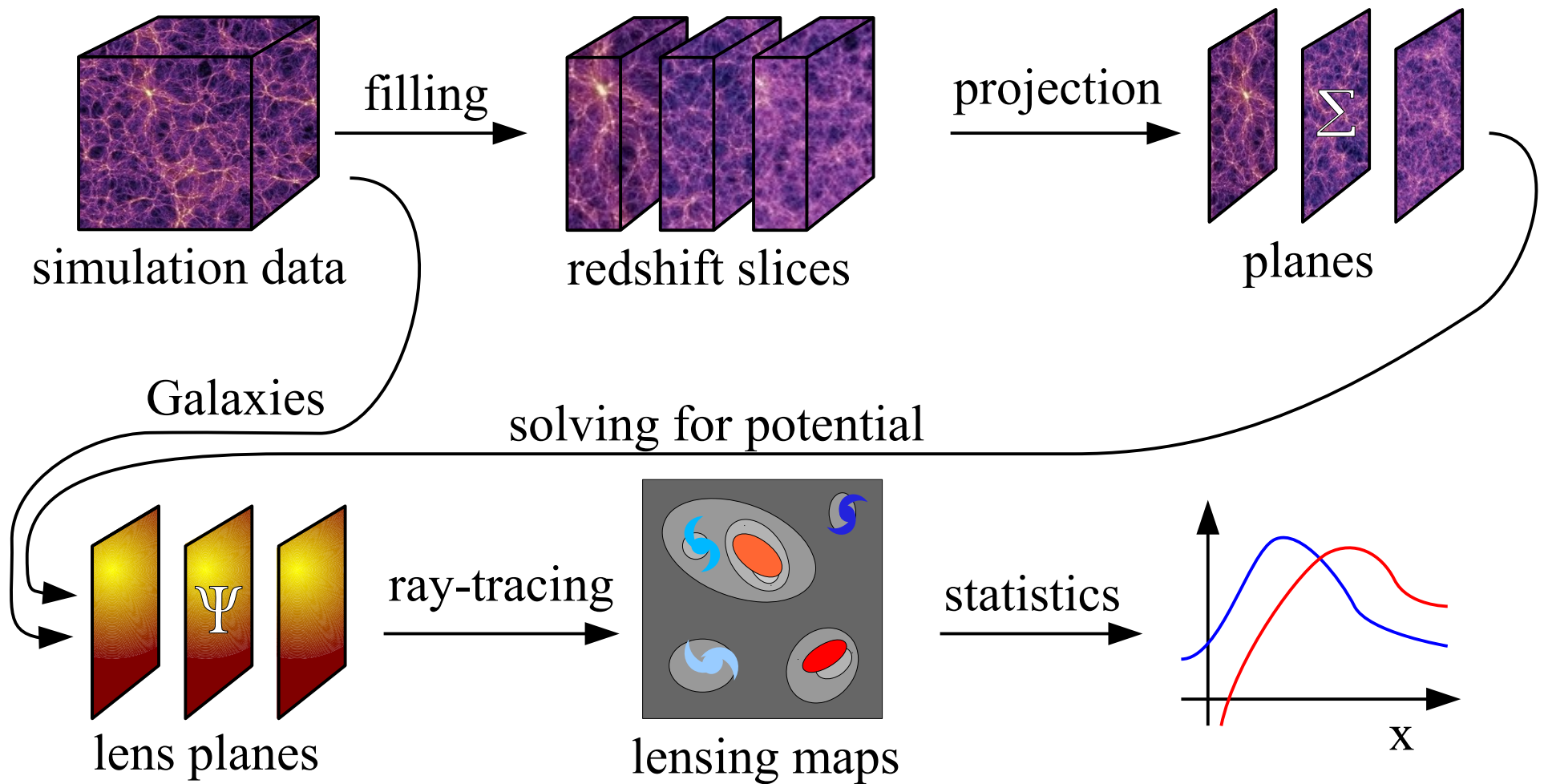


(source: Planck collaboration)

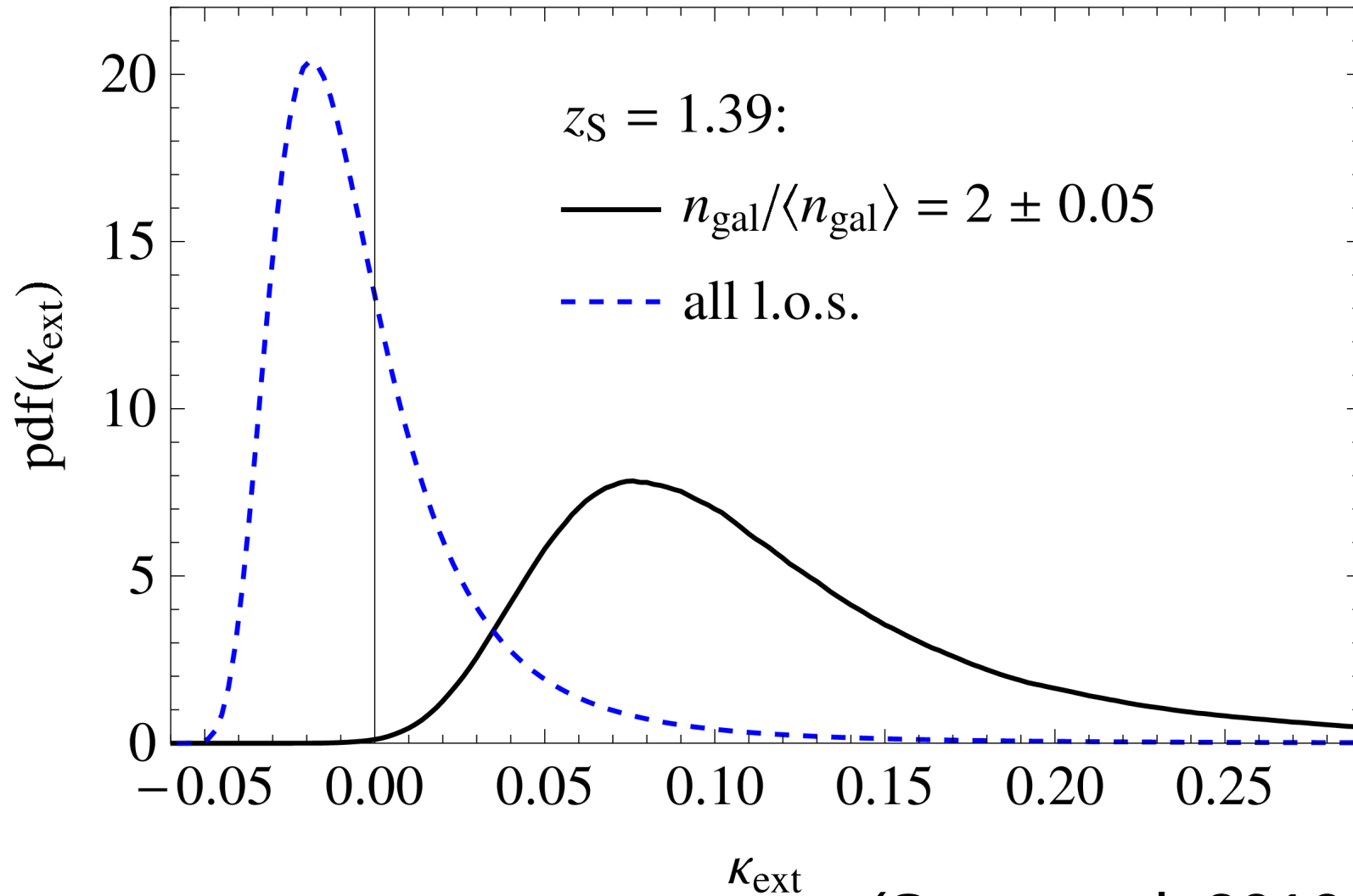
# Strong Lens Time Delays



# LOS Structures: Lensing Simulations



# Simple Aperture Counts



(Suyu et al. 2010, 2013)

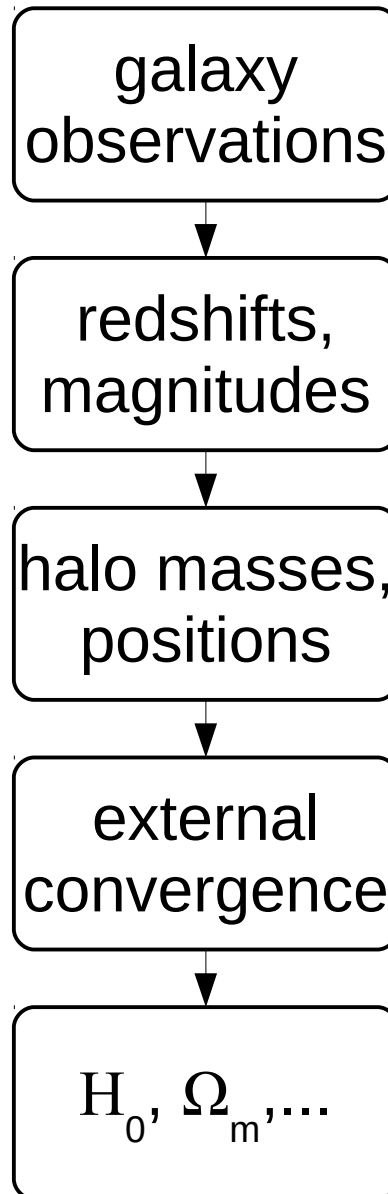


# Weighted Counts

- weighting by redshift, stellar mass, transverse separation
- requires (photo) redshifts
- reduces uncertainties by  $\sim 30\%$
- helps identify low-density l.o.s.

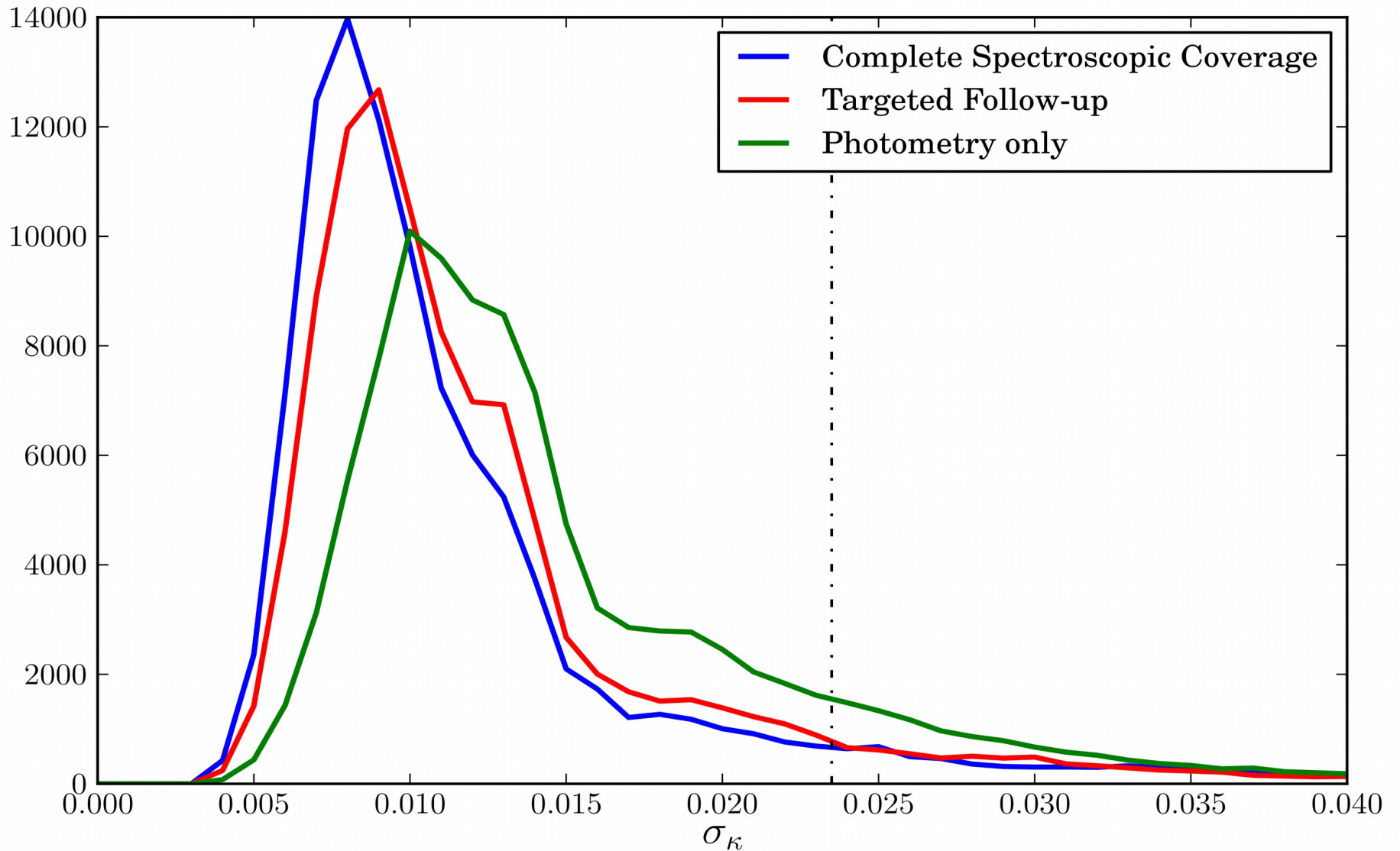
(Greene, et al. 2013)

# Halo Model Mass Reconstruction



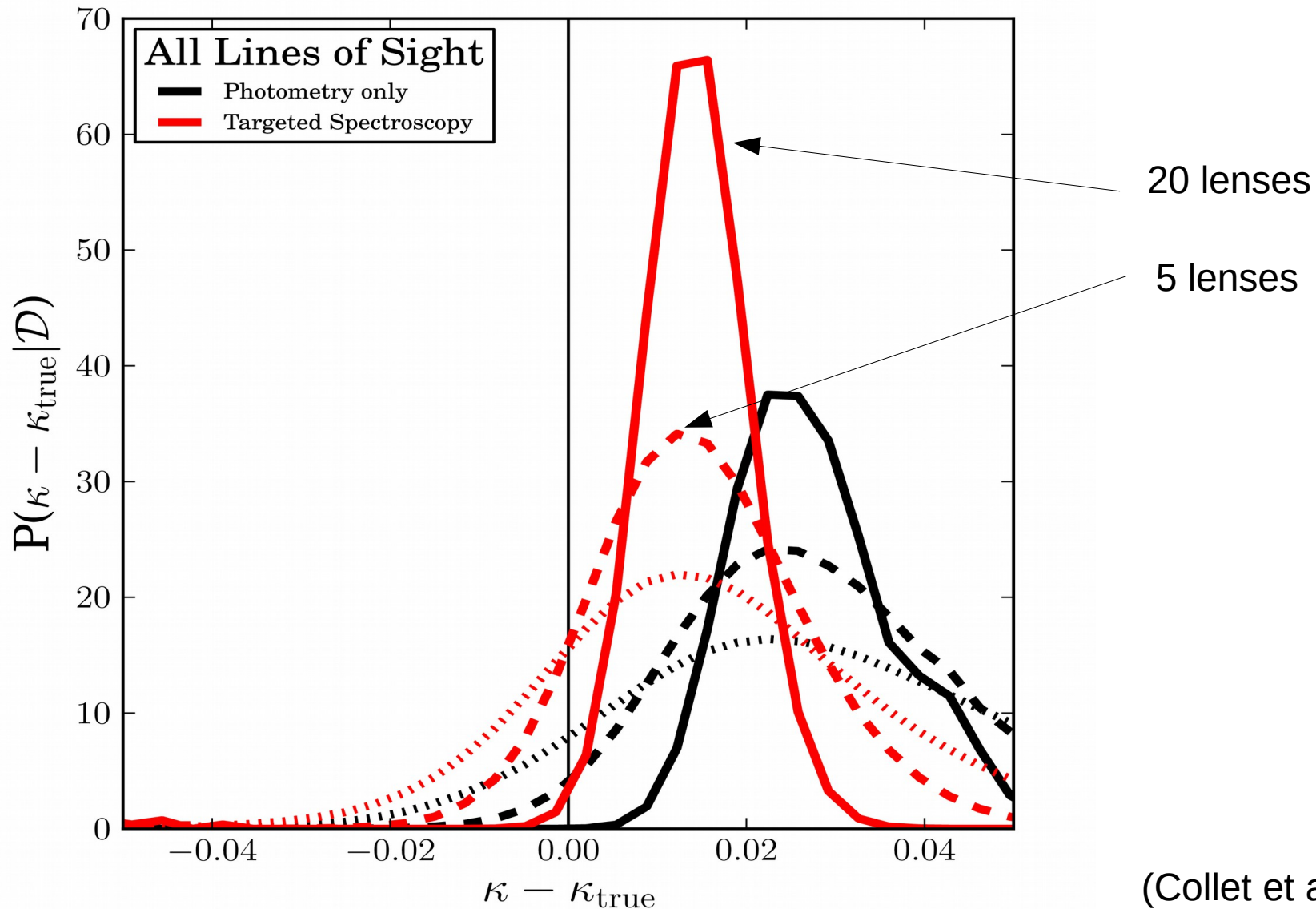
(Collet et al. 2013)

# Halo Model Mass Reconstruction: Scatter



(Collet et al. 2013)

# Halo Model Mass Reconstruction: Bias from Light-to-Mass Model

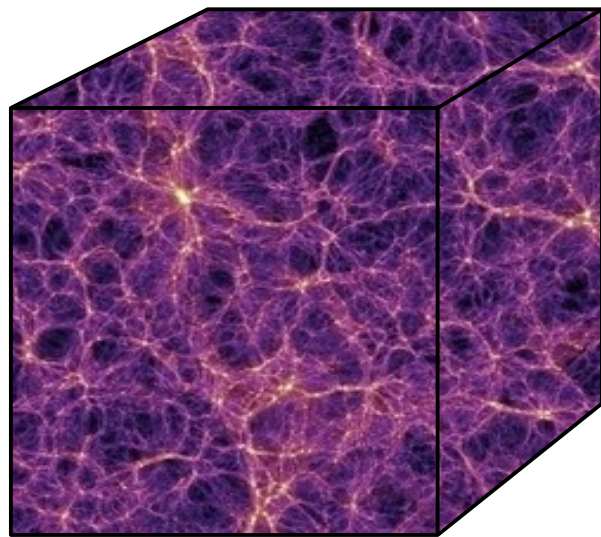


(Collet et al. 2013)

# Improvements?

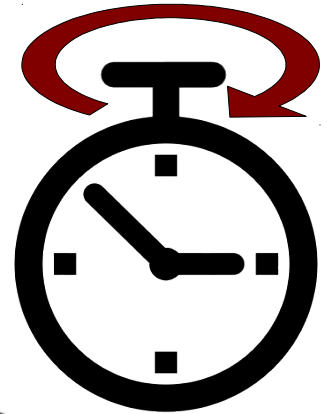
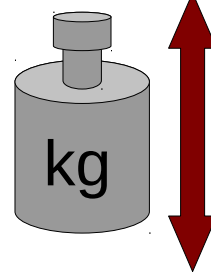
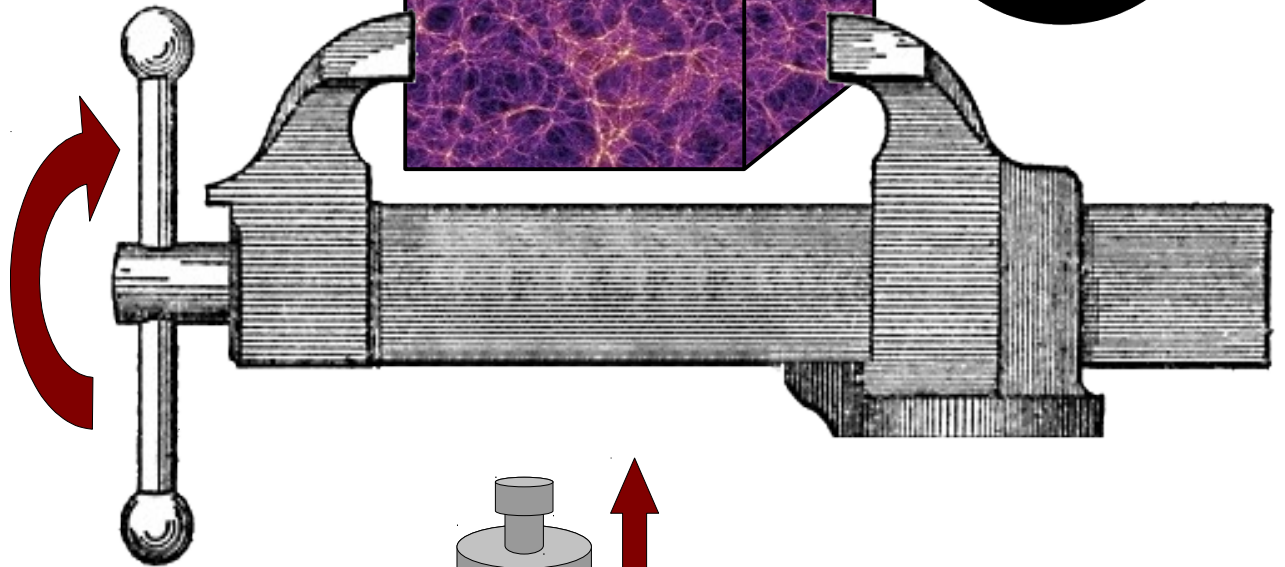
- better models for main lens
- better uncertainty conversion from los light to los mass (cosmology, galaxy model?)
- include coupling between los and main lens
- ...

# Cosmology Scaling

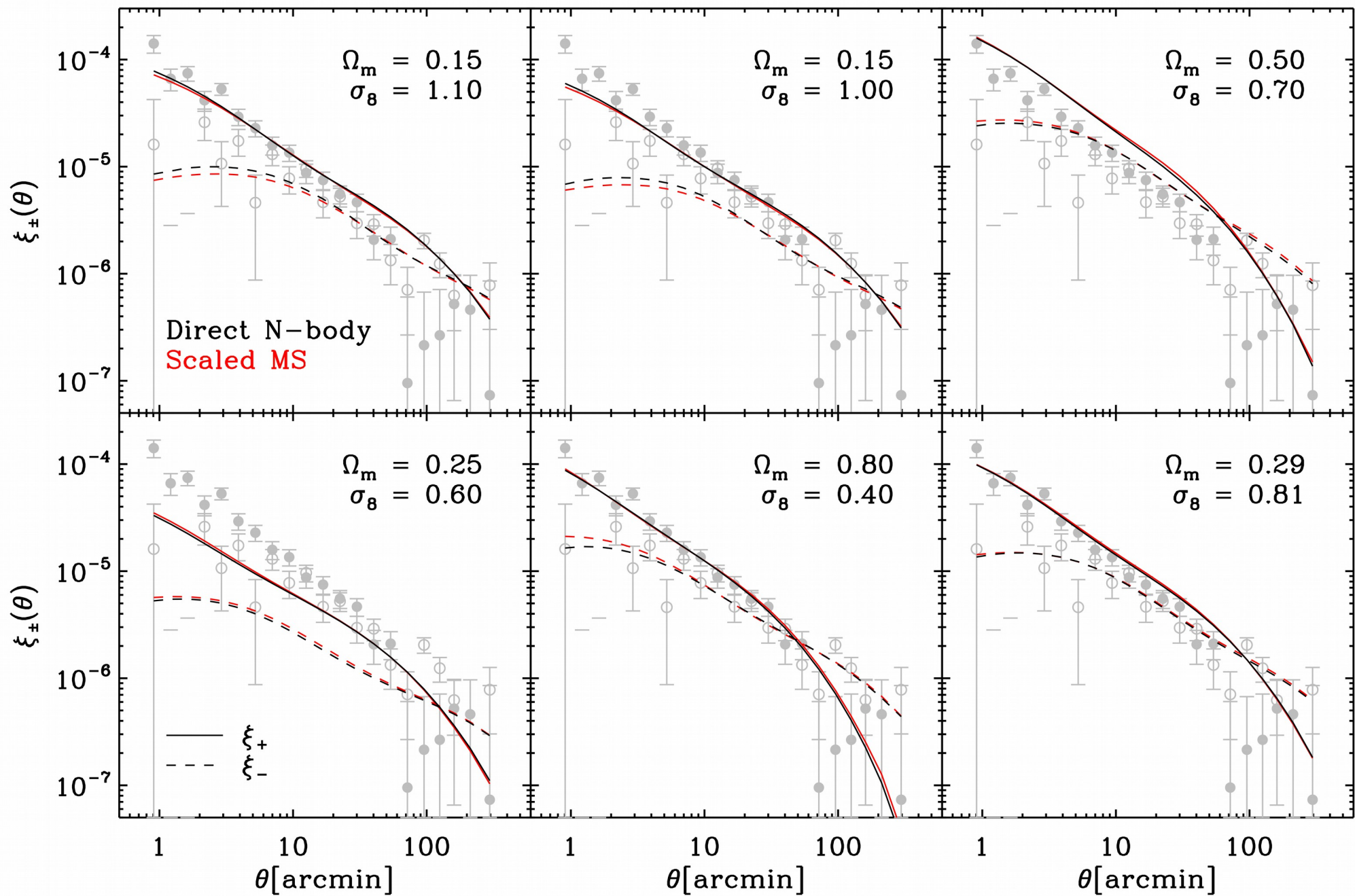


simulation data

rescaling →

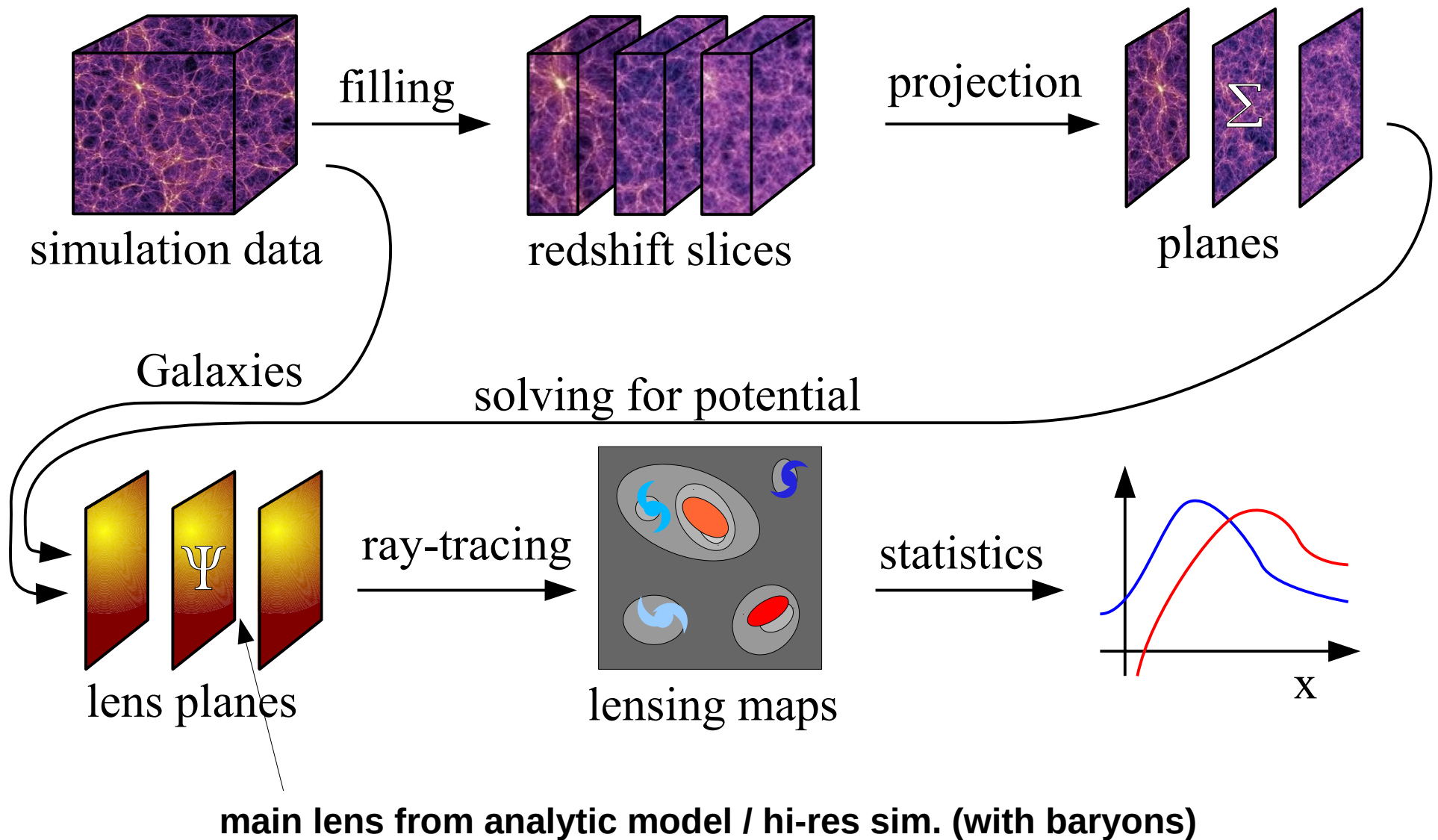


(Angulo & White 2010)



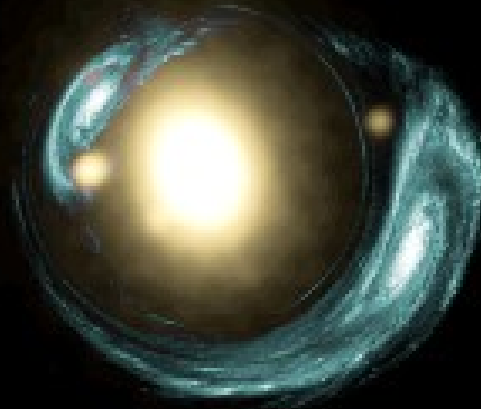
(Angulo & Hilbert 2014)

# LOS Structures: Lensing Simulations

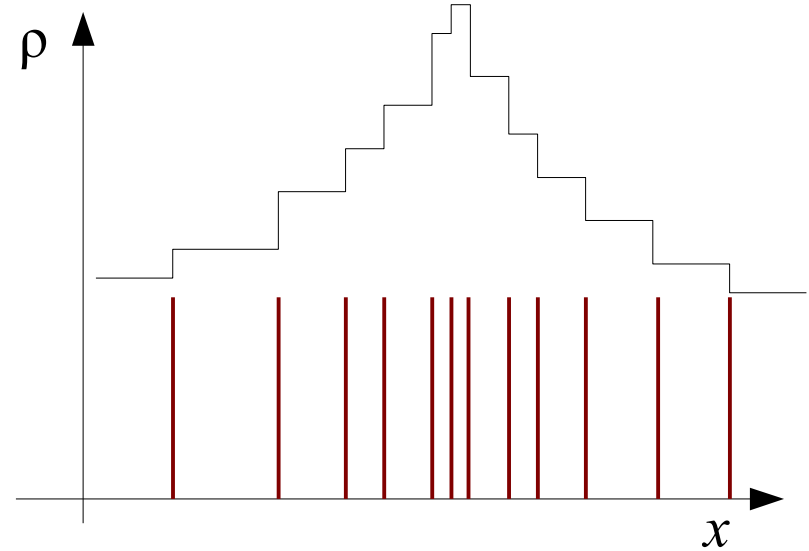
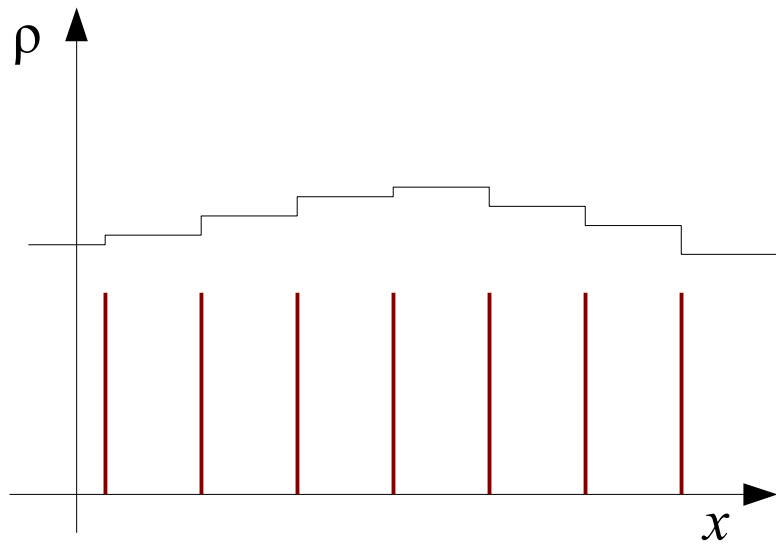
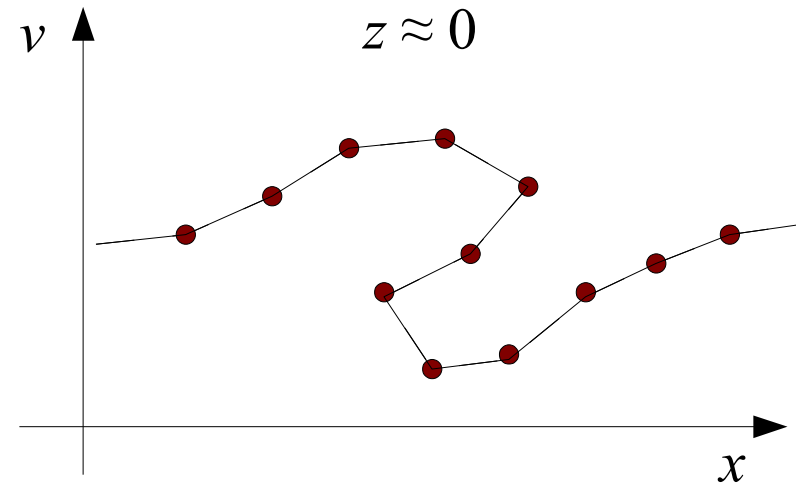
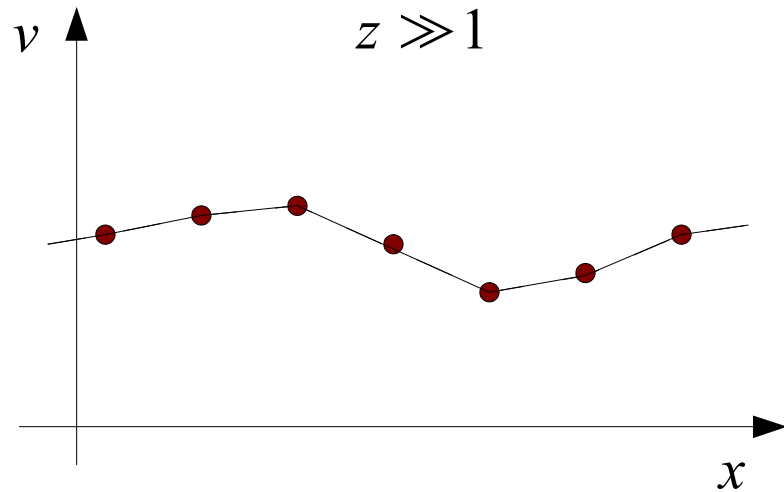




# Main Lens: Hi-Res Sim

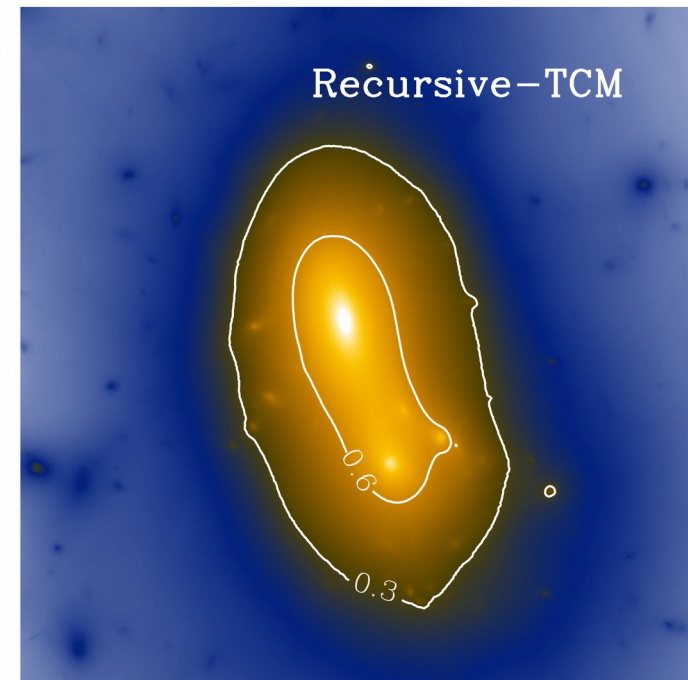
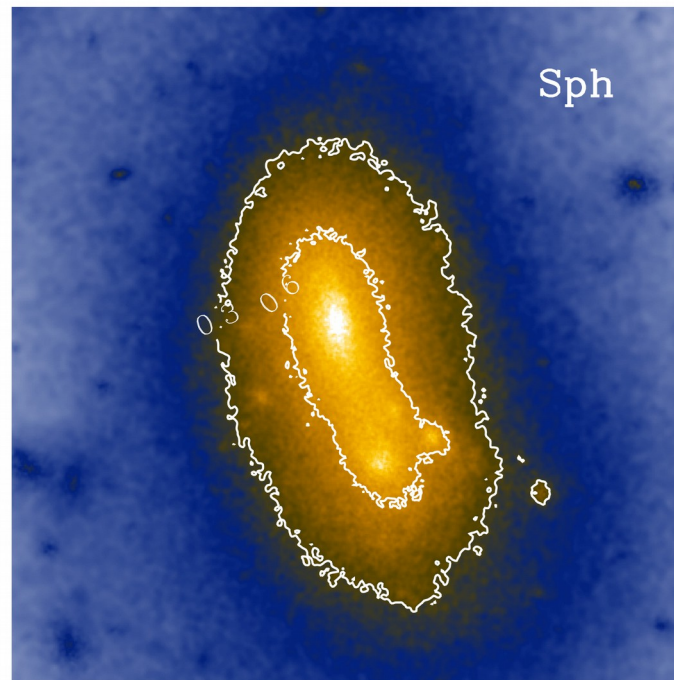
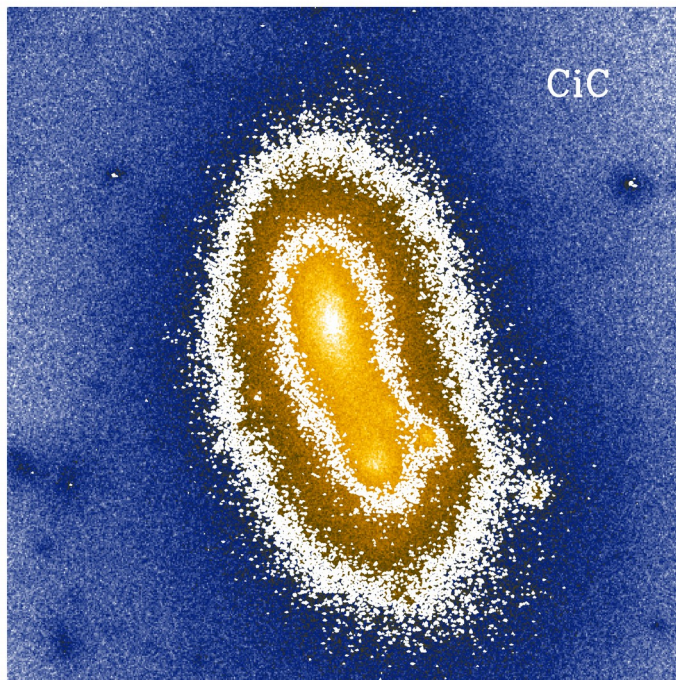


# Substructure: New Methods



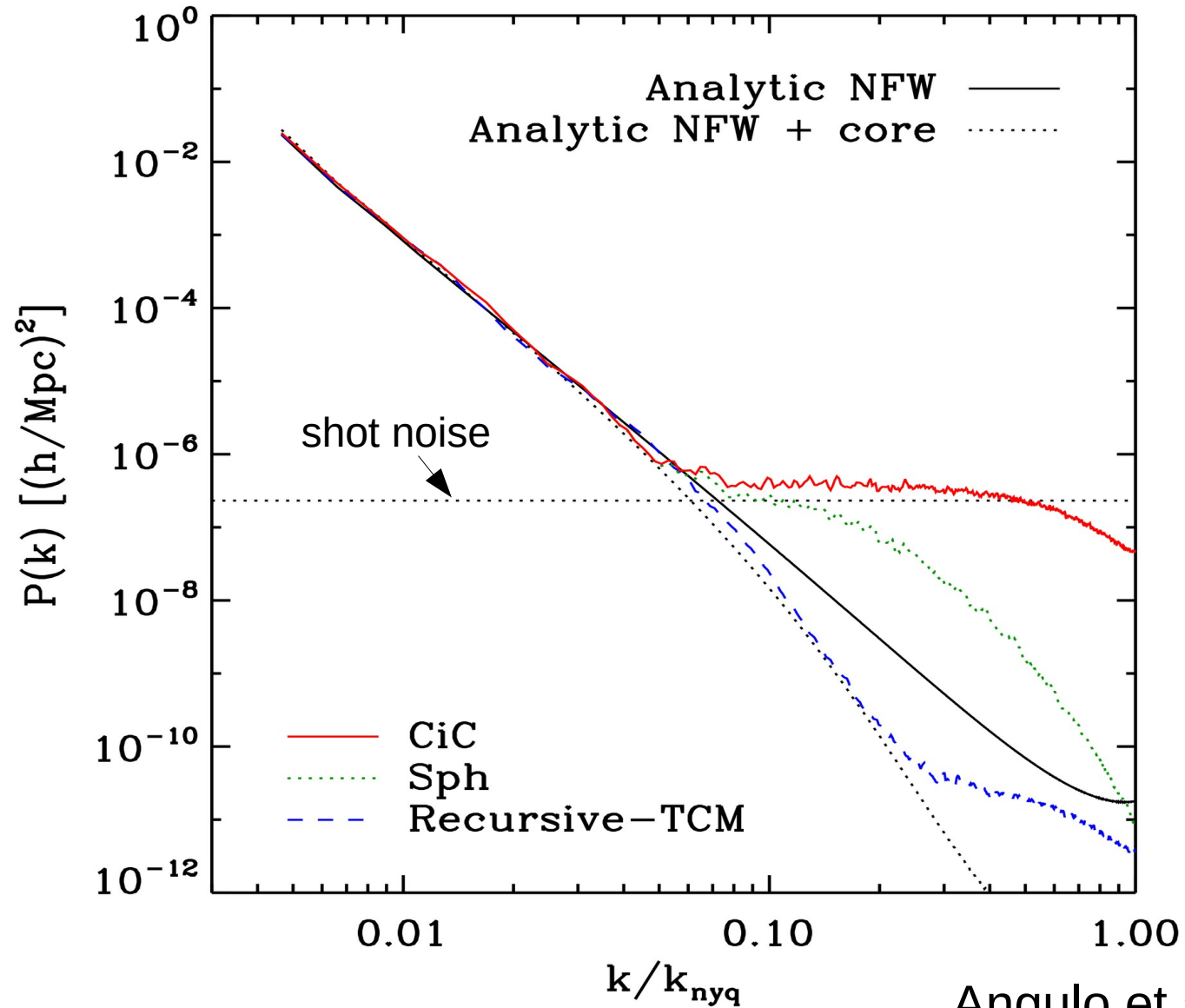
Abel et al. (2012)

# Comparison: Convergence



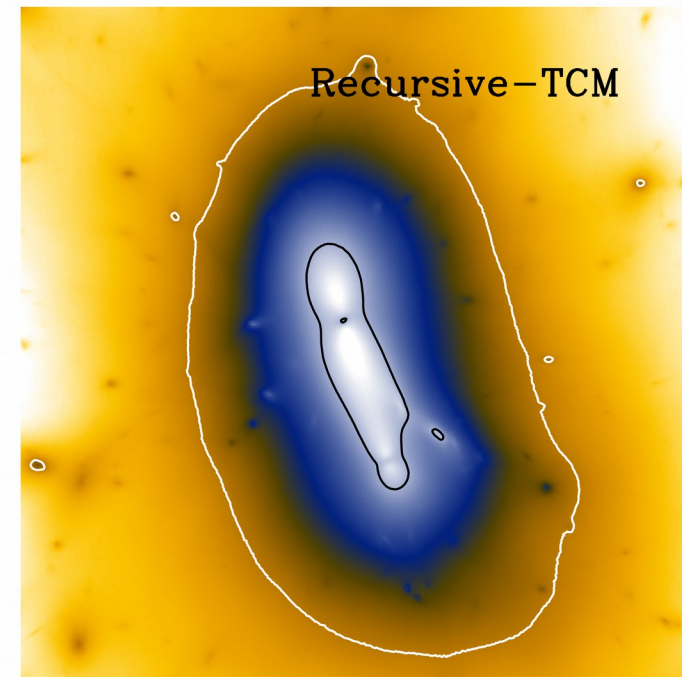
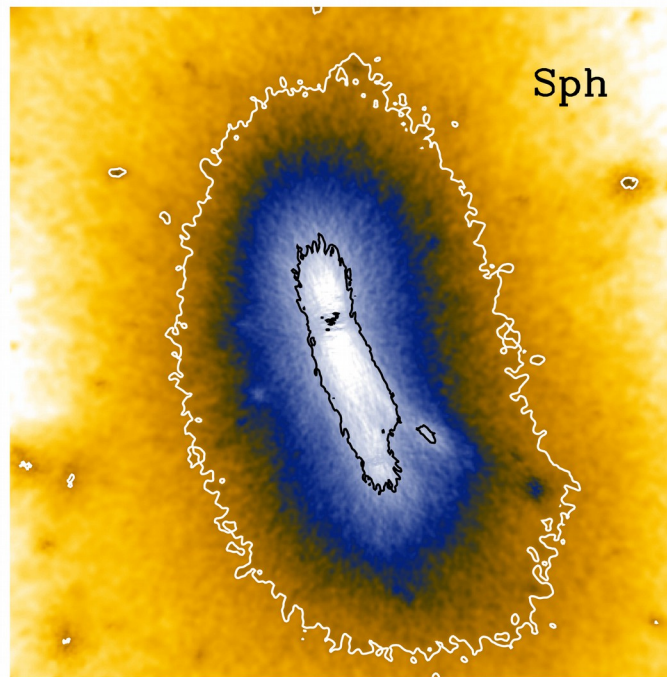
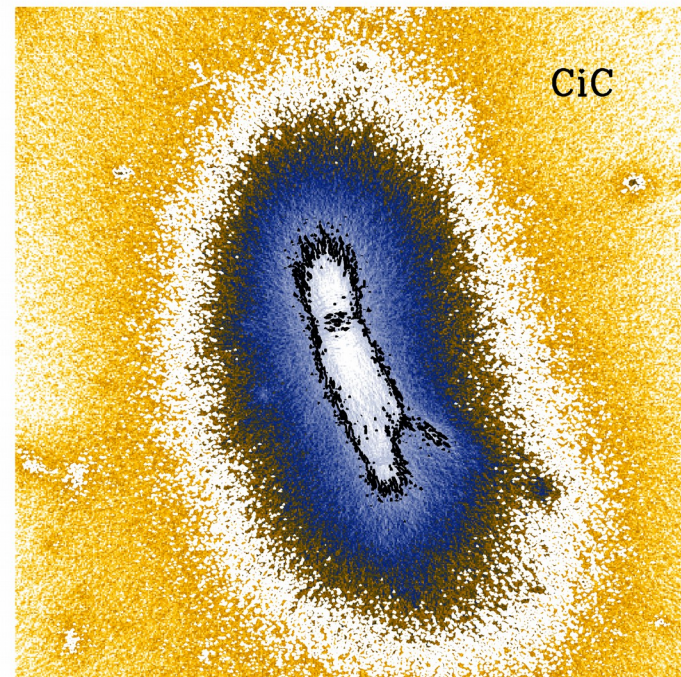
Angulo et al. (2013)

# Comparison: Convergence



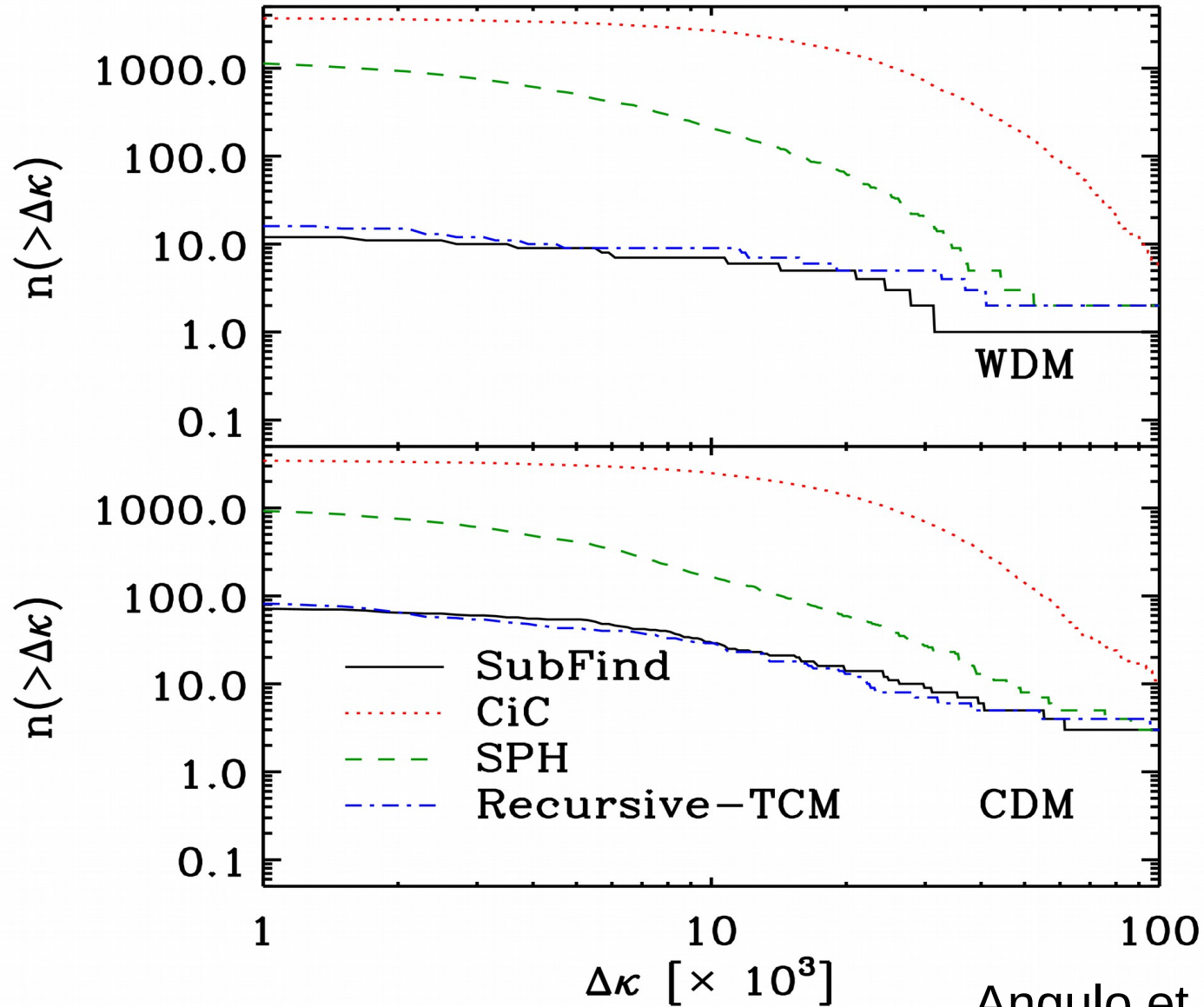
Angulo et al. (2013)

# Comparison: Magnification



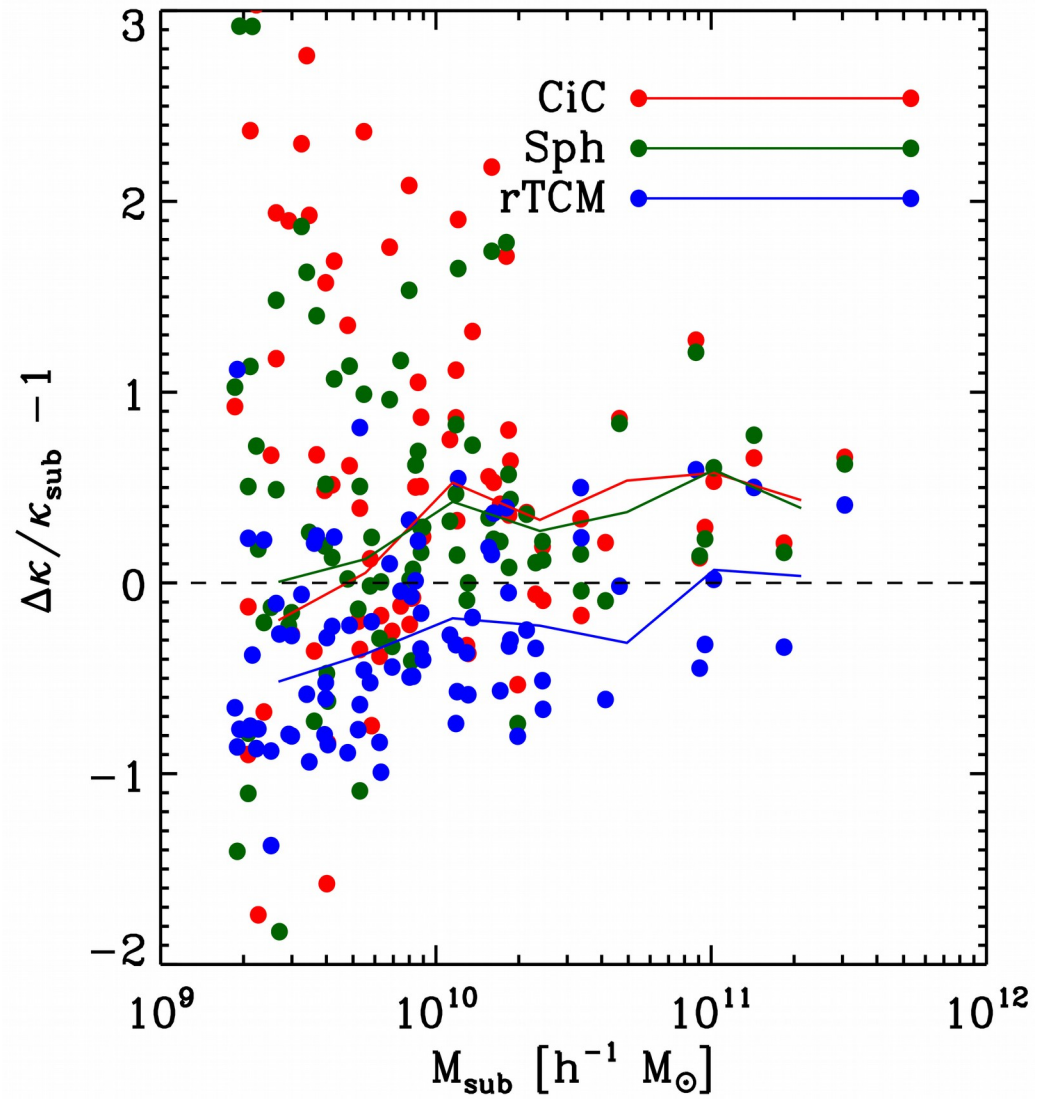
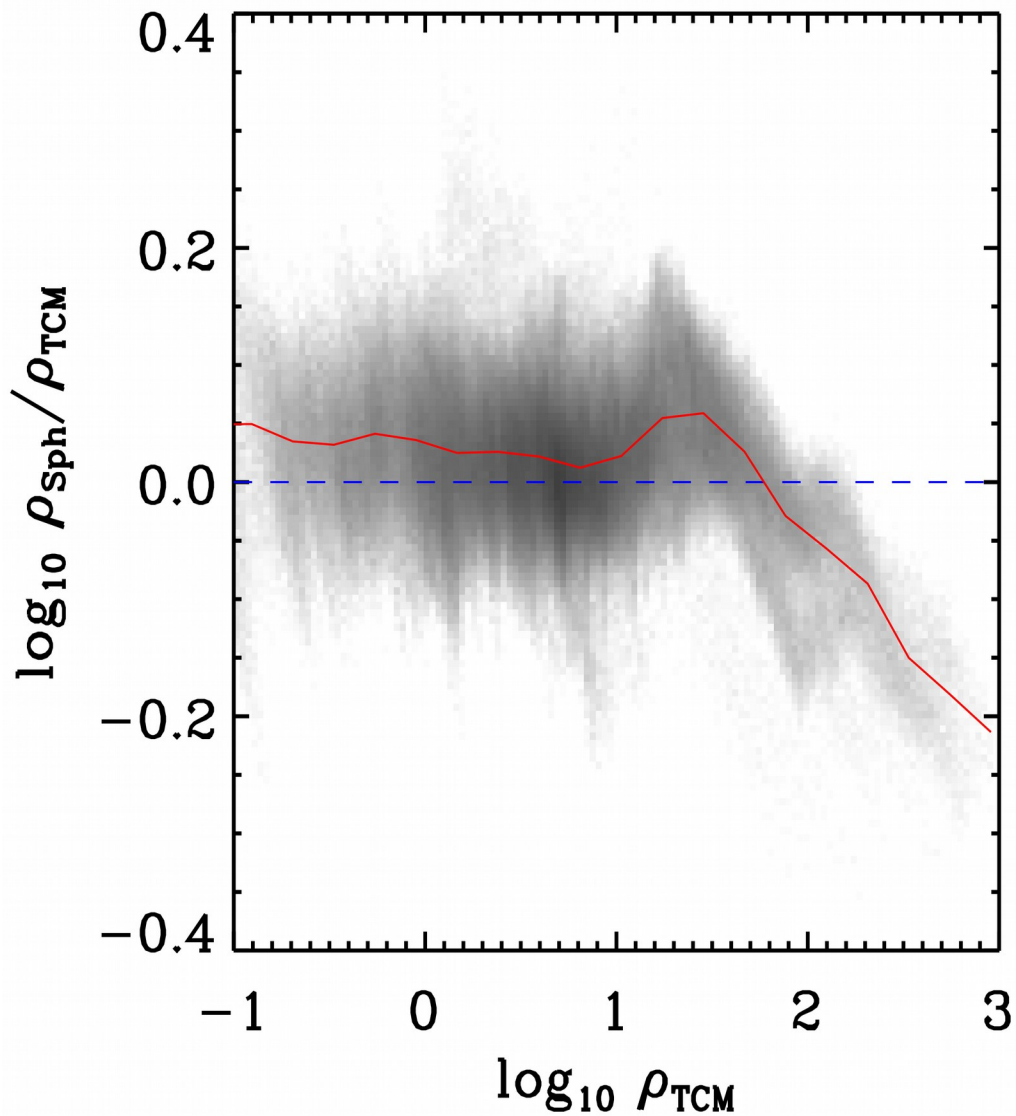
Angulo et al. (2013)

# Comparison: Peak Counts



Angulo et al. (2013)

# Problems: Bias



# Possible Solutions

- adaptive refinement (during simulation)
- higher order interpolations
- ...



---

# Summary

- strong lens time delays:
  - main lens models
  - los light  $\rightarrow$  los mass
  - joint modeling of main lens + los
- substructure:
  - abundance and profiles
  - intrinsic vs. los
  - improved lensing simulations

---

Thanks  
for  
Your Attention!