The need for realistic ray-tracing simulations: how well can we constrain the inner structure of galaxy clusters?

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Motivations

Why constructing a simulation pipeline for mimicking observations?

- simulations tools for testing several techniques that are commonly applied to the data are largely requested both from observers and theoreticians. Such tools have been used also by the lensing community. A famous example is the STEP (Heymans et al. 2005; Massey et al. 2006)

- simulations resembling as closely as possible the observations are important to facilitate the comparison between theoretical predictions and observations

- simulation tools are also required for planning future missions: what kind of science will be possible with next generation instruments

DUNE (see talk by A. Refregier on Friday)

Mission baseline:

- 1.2m telescope
- Visible: 0.5 deg^2, pixels 0.10'', shapes, band: broad I
- NIR: 0.5 deg^2, pixels 0.15'', photometry, bands: Y,J,H
- PSF FWHM 0.23'', 2.2 pix/FWHM (vis)
- GEO (or HEO) orbit with Soyuz Launch
- 4-year mission

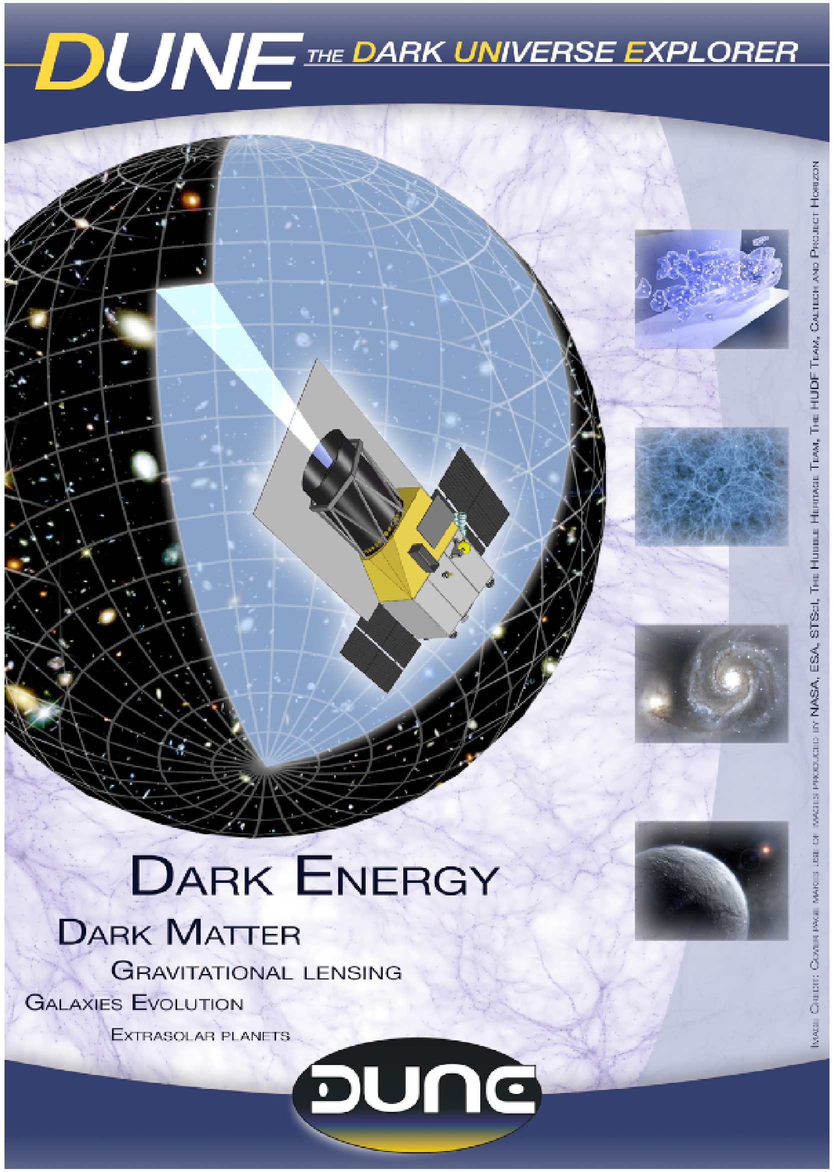
Surveys:

- Wide Extragalactic: 20000 deg^2, 40 galaxies/amin^2, median z~1, I~24.5, Ground complement for other bands and spectropscopy (with ESO)
- Medium Deep Survey: 100 deg^2
- Galactic plane: extend to 4pi coverage
- Microlensing planet survey: 4 deg^2

Requirements:

Tight control of systematics

→ Progress in CNES phase 0, synergy with GAIA



Requirements

Our simulator should be:

- flexible: we would like to simulate optical observations with any telescope, filter, etc.
- reliable both in the weak lensing and in the strong lensing regime
- source shapes are more important for weak lensing but may be important also for strong lensing, for example if we want to learn something about the presence of substructures in the lenses or for arc statistics
- lensing must be realistic: we want to be able to include the lensing effects produced by any mass distribution, including the effects of the LSS

Skylens!☺

Meneghetti et al. in prep.

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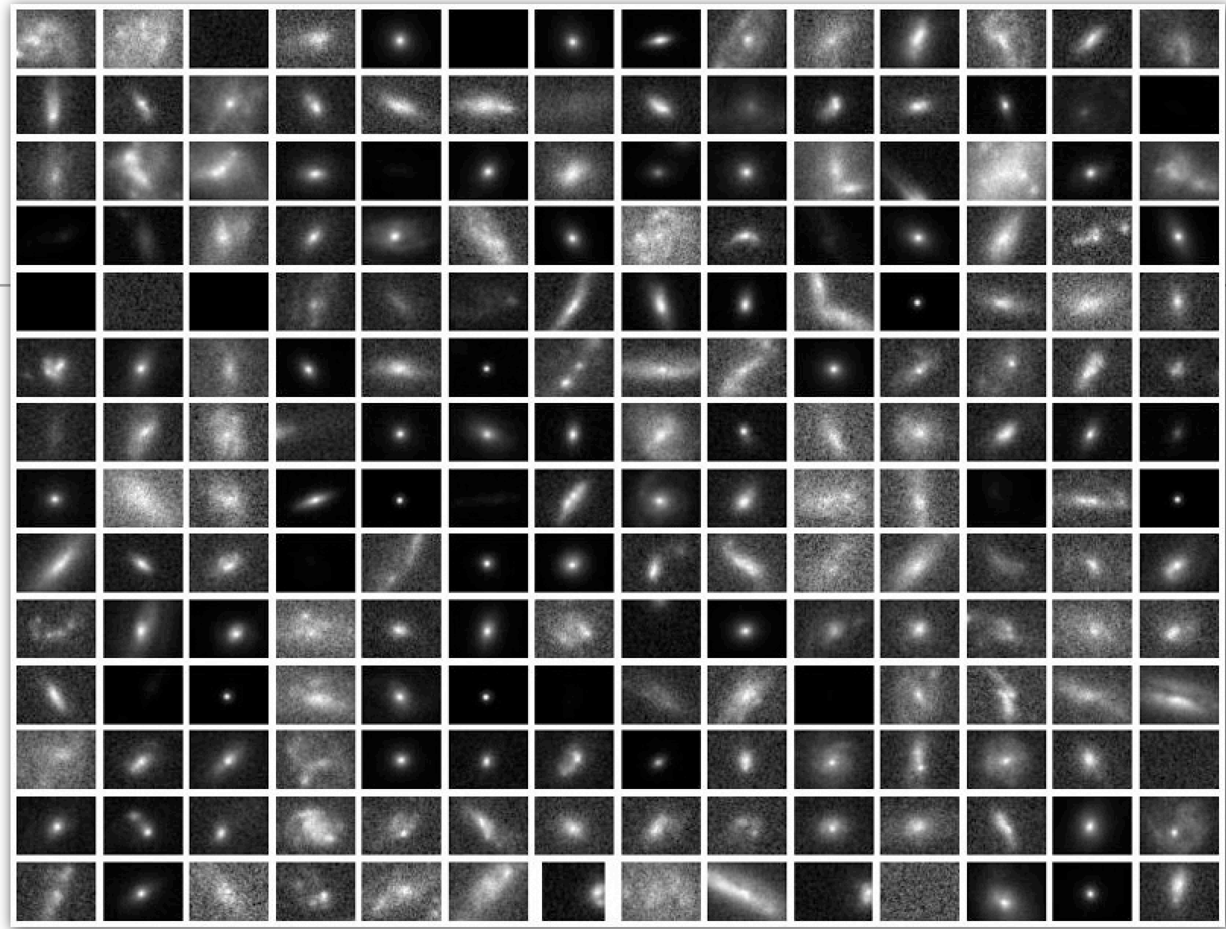
real galaxies



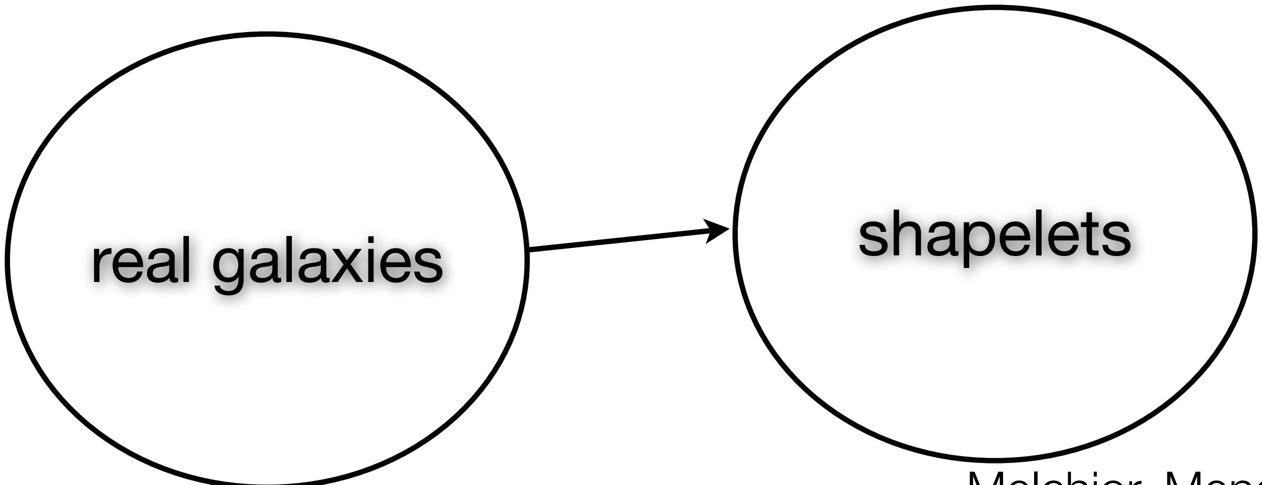
GOODS-ACS archive
+COMBO17

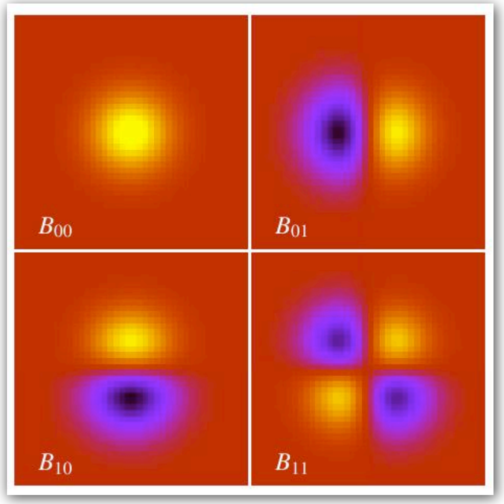
Skylens!☺

$$I(\vec{x}) = \sum_{n_1,n_2=0}^{\infty} I_{\vec{n}} B_{\vec{n}}(\vec{x} - \vec{x}_c, \beta)$$

$$I_{\vec{n}} = \int d^2x I(\vec{x}) B_{\vec{n}}(\vec{x}, \beta)$$

Meneghetti et al. in prep.





Melchior, Meneghetti, Bartelmann & Schirmer (2007)
(see also Massey et al. 2004,2006)

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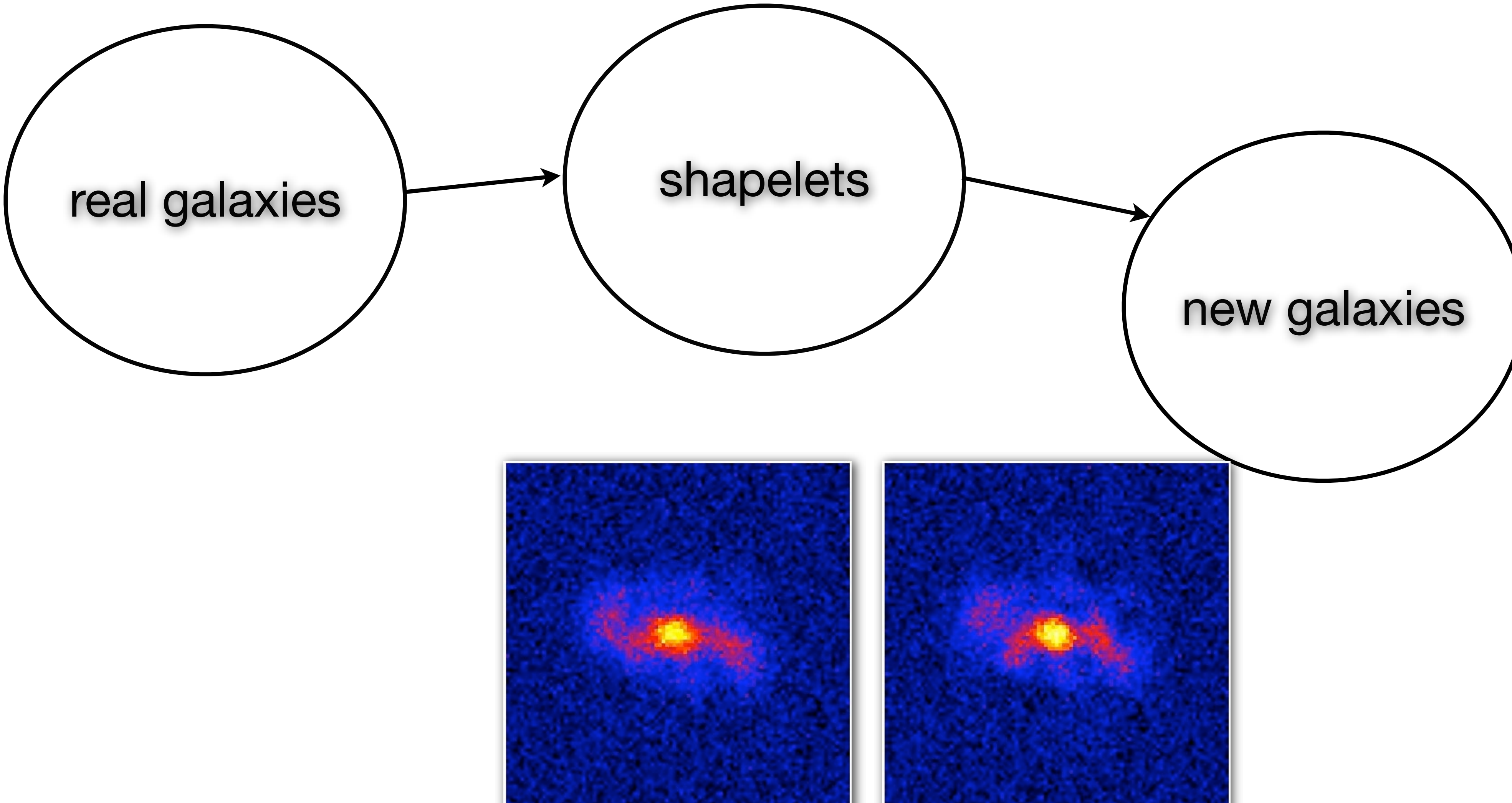

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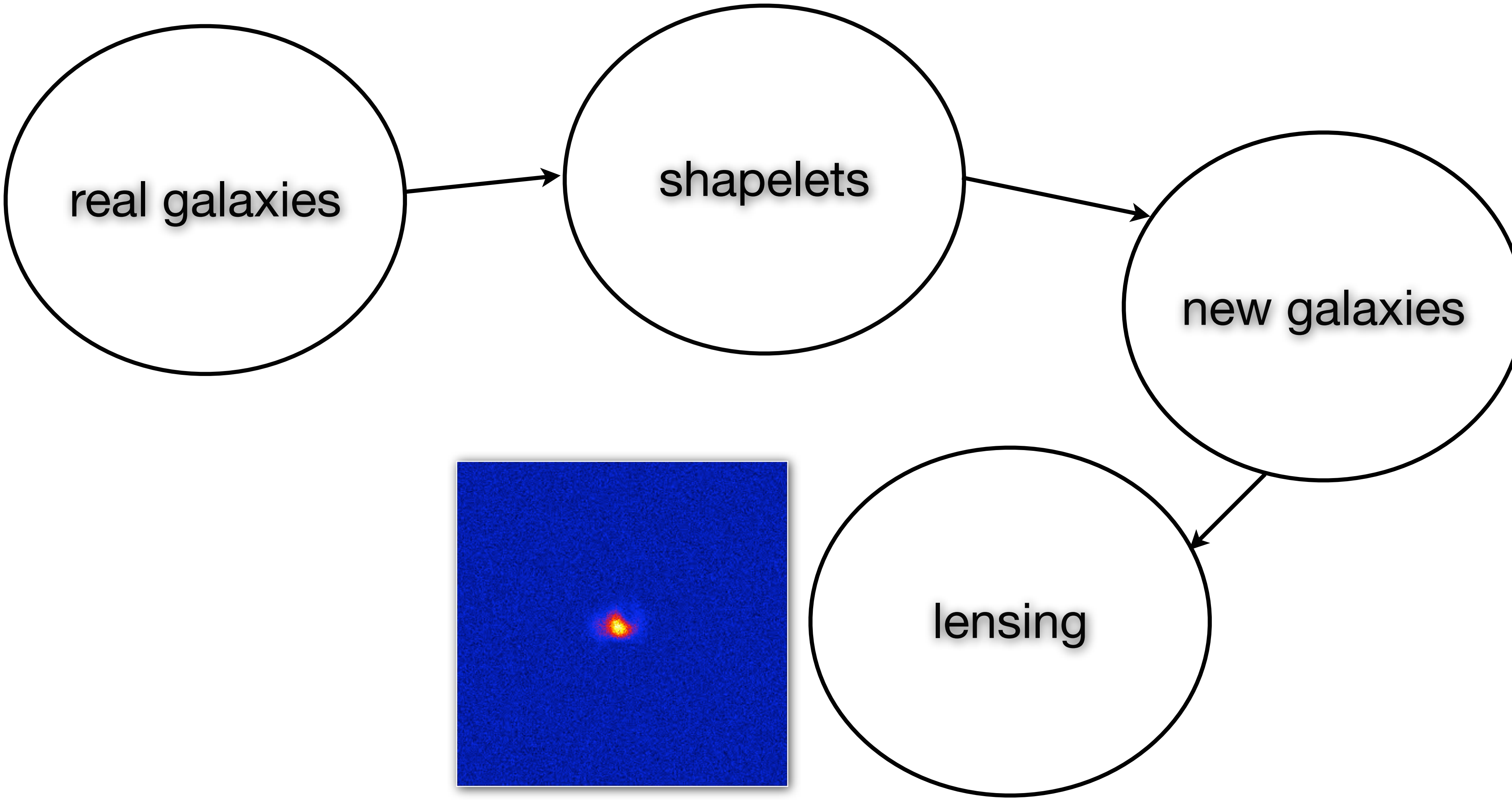

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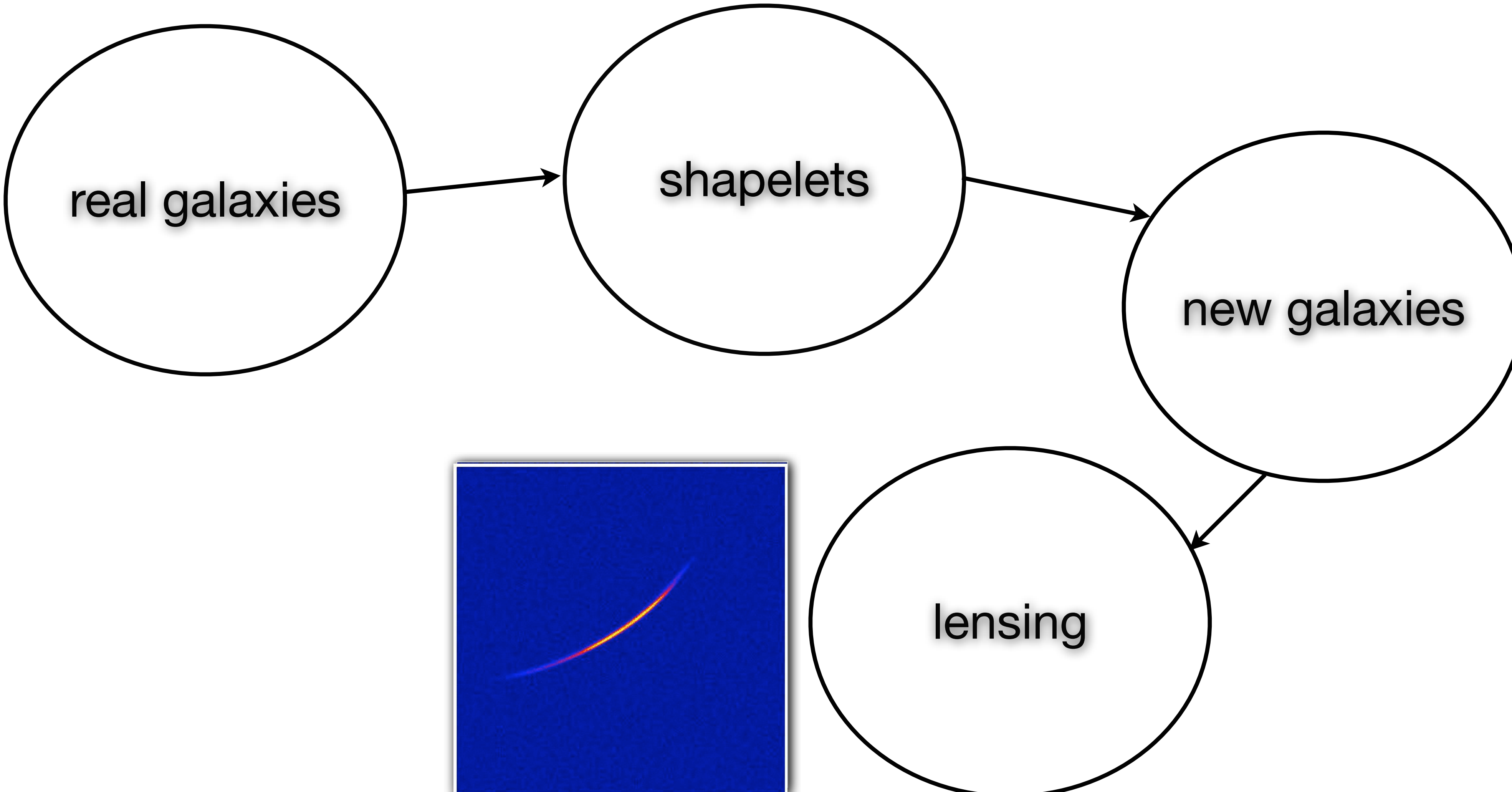

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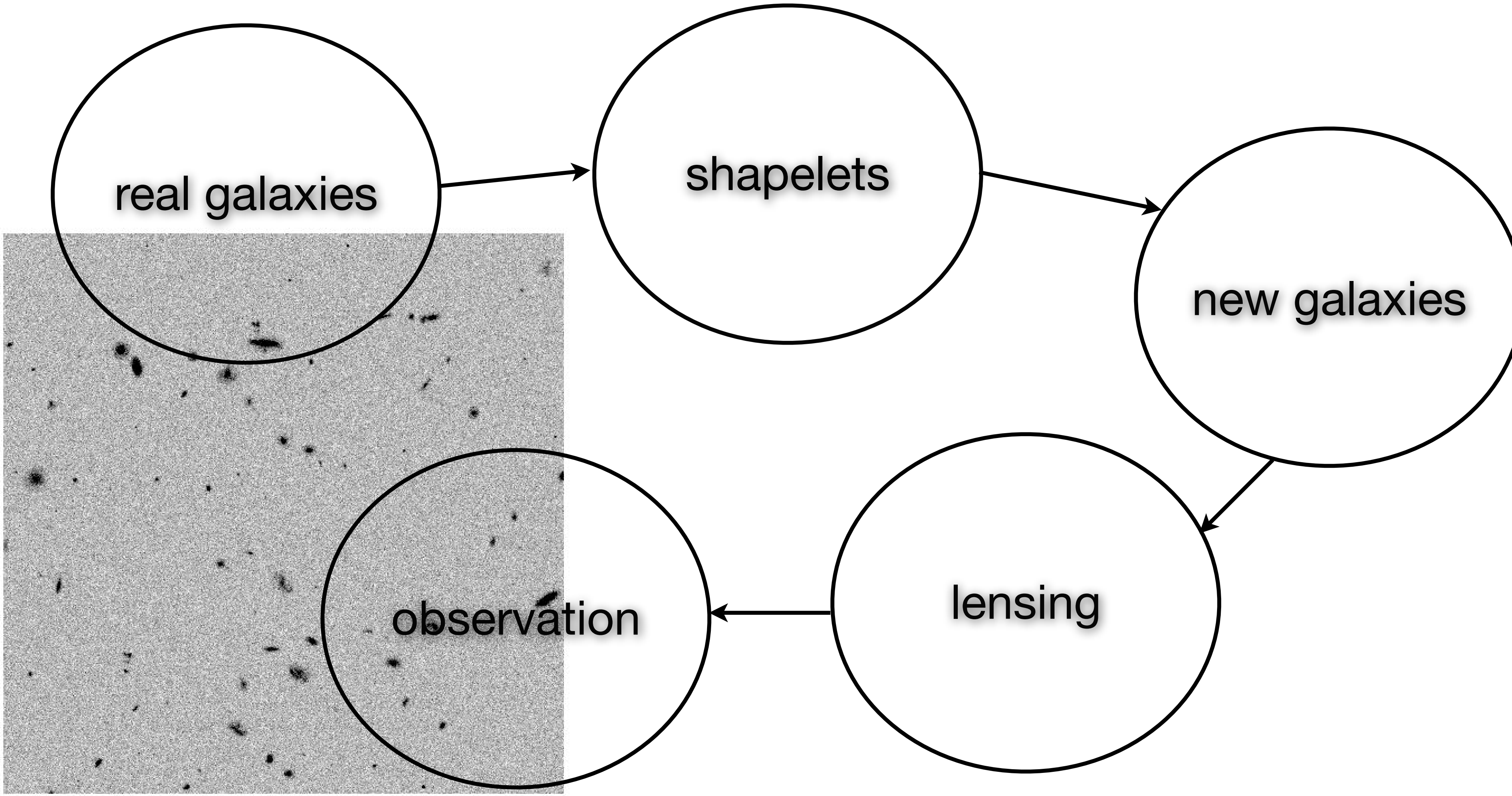

Some features

- Easy to change instrumental set-up and atmospheric conditions
- Model for varying the PSF across the field
- use semi-analytic models to populate numerical clusters with galaxies (G. De Lucia, K. Dolag)
- different SEDs can be assigned to different galaxy morphologies
- observed luminosity functions and redshift distribitions (VVDS, Zucca et al. 2006; Paltani et al. 2007)

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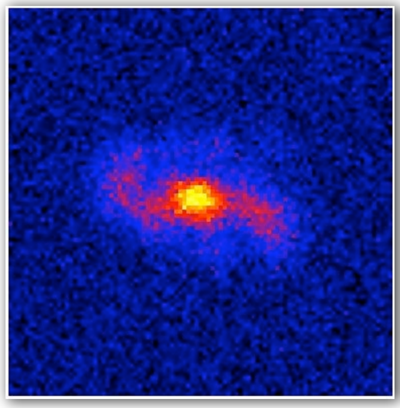
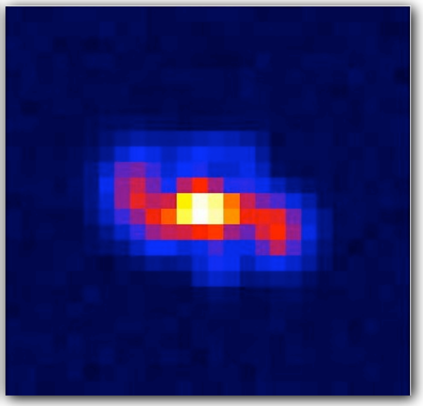
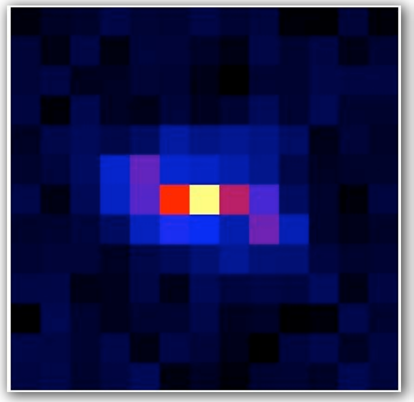


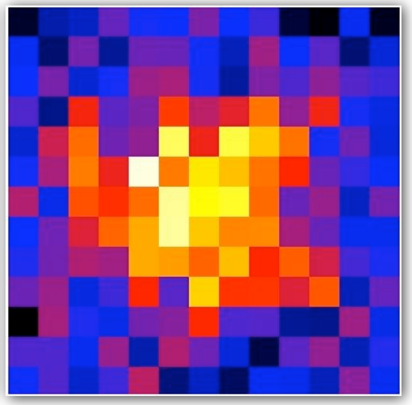
HST z



DUNE Riz



LBT R



LBT R bad seeing

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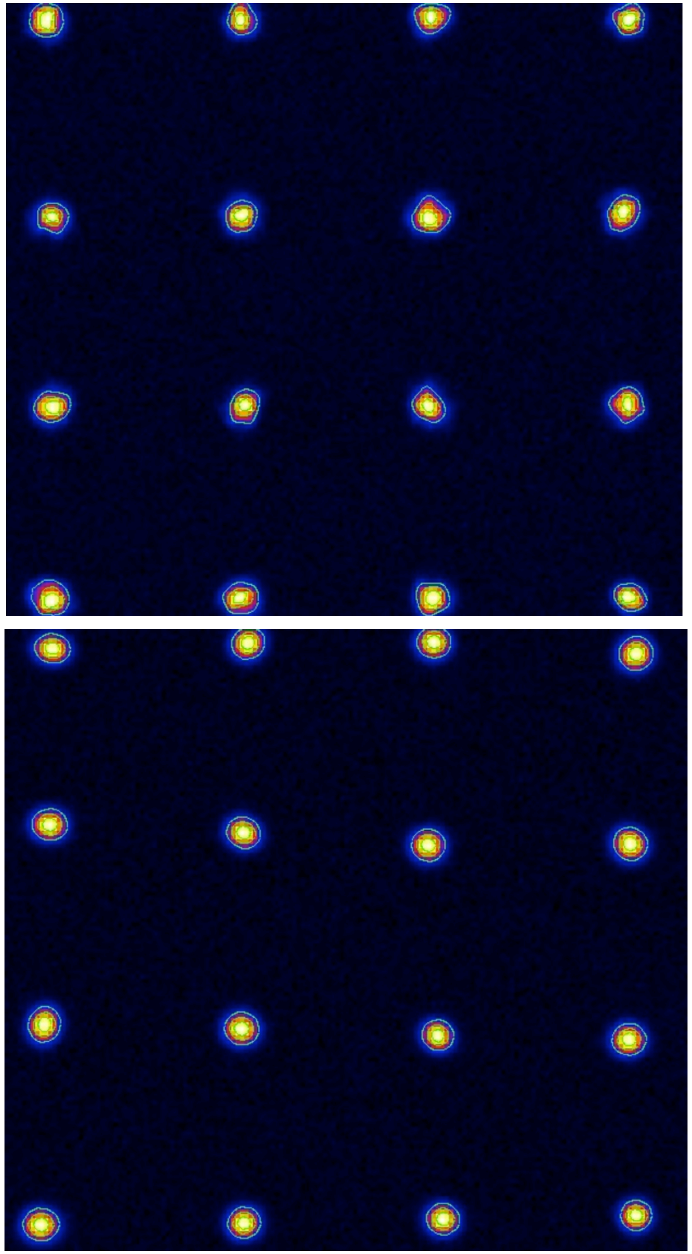

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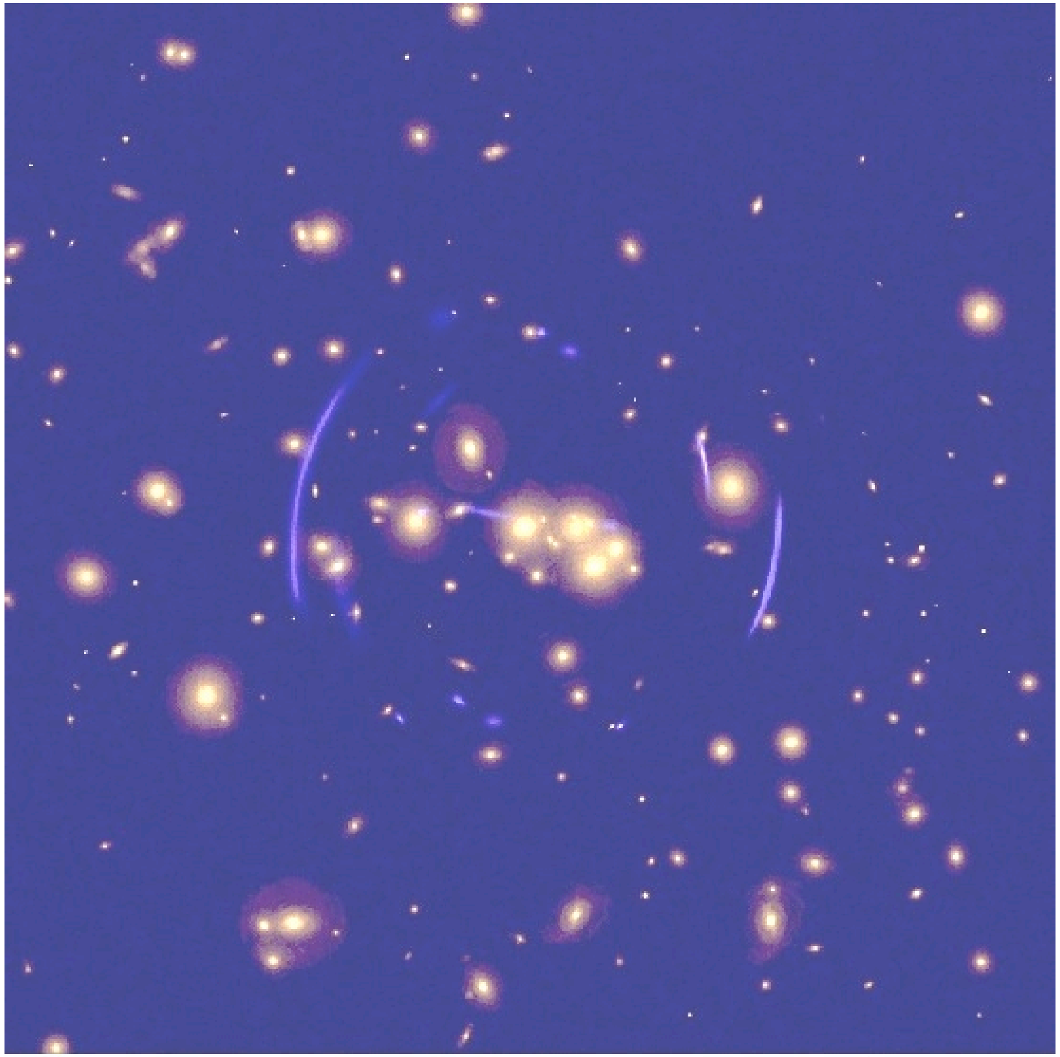


Focussing on galaxy clusters

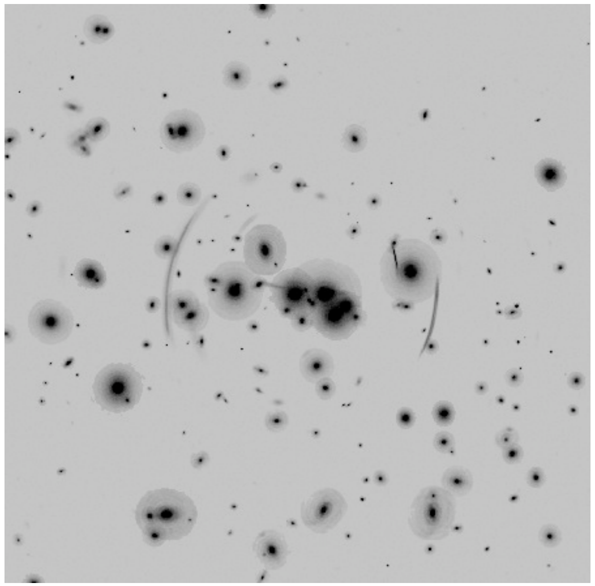
Many open questions regarding how well we can constrain the inner structure of galaxy clusters using lensing:

- Mass estimates from strong lensing are often in disagreement with mass estimates at larger radii (e.g. weak lensing and X-ray). Why?

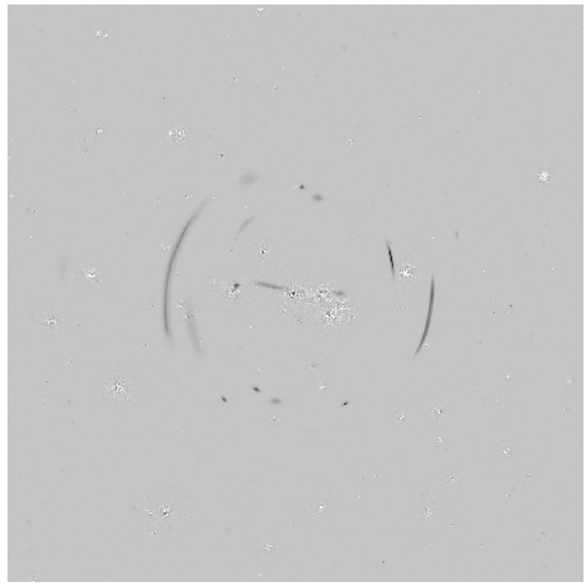
- Many clusters can be fitted by profiles with a wide range of inner slopes. Is it possible to use clusters to test the predictions of the CDM scenario?

- What is the amount of substructures in galaxy clusters and how do they affect the strong lensing properties of their hosts?

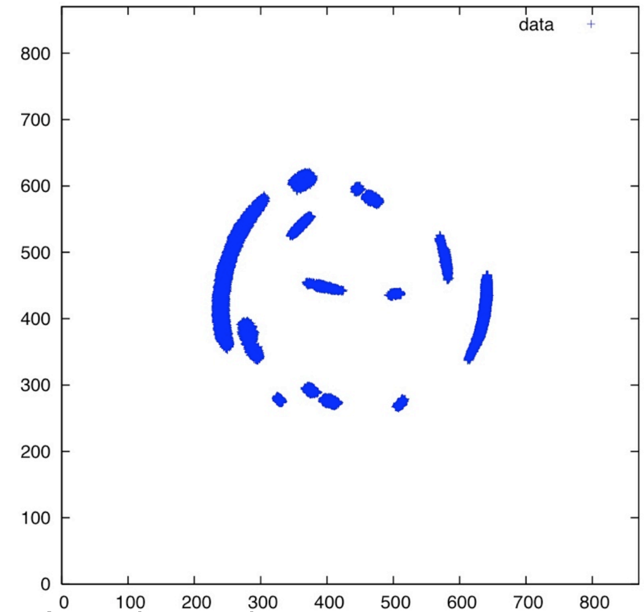
Exercise 1: strong lensing masses



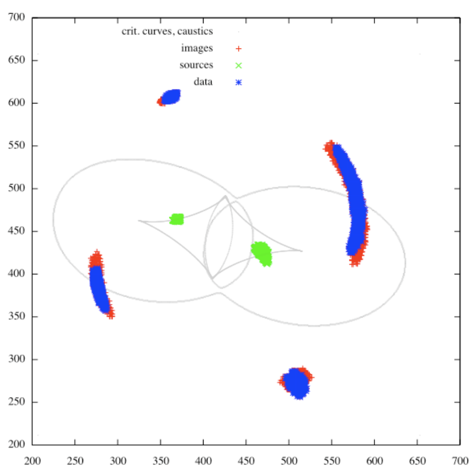
Reduced image



Foreground subtraction



Arc detection

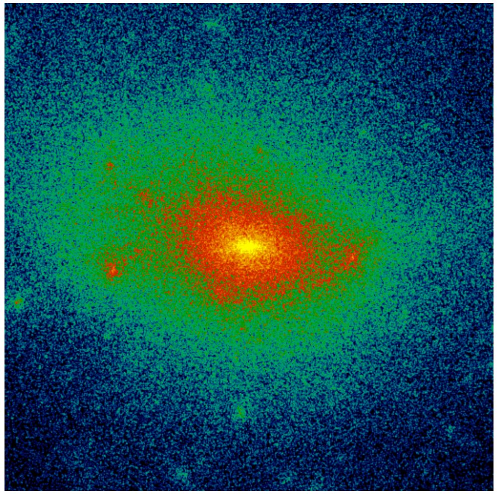


Arc fitting

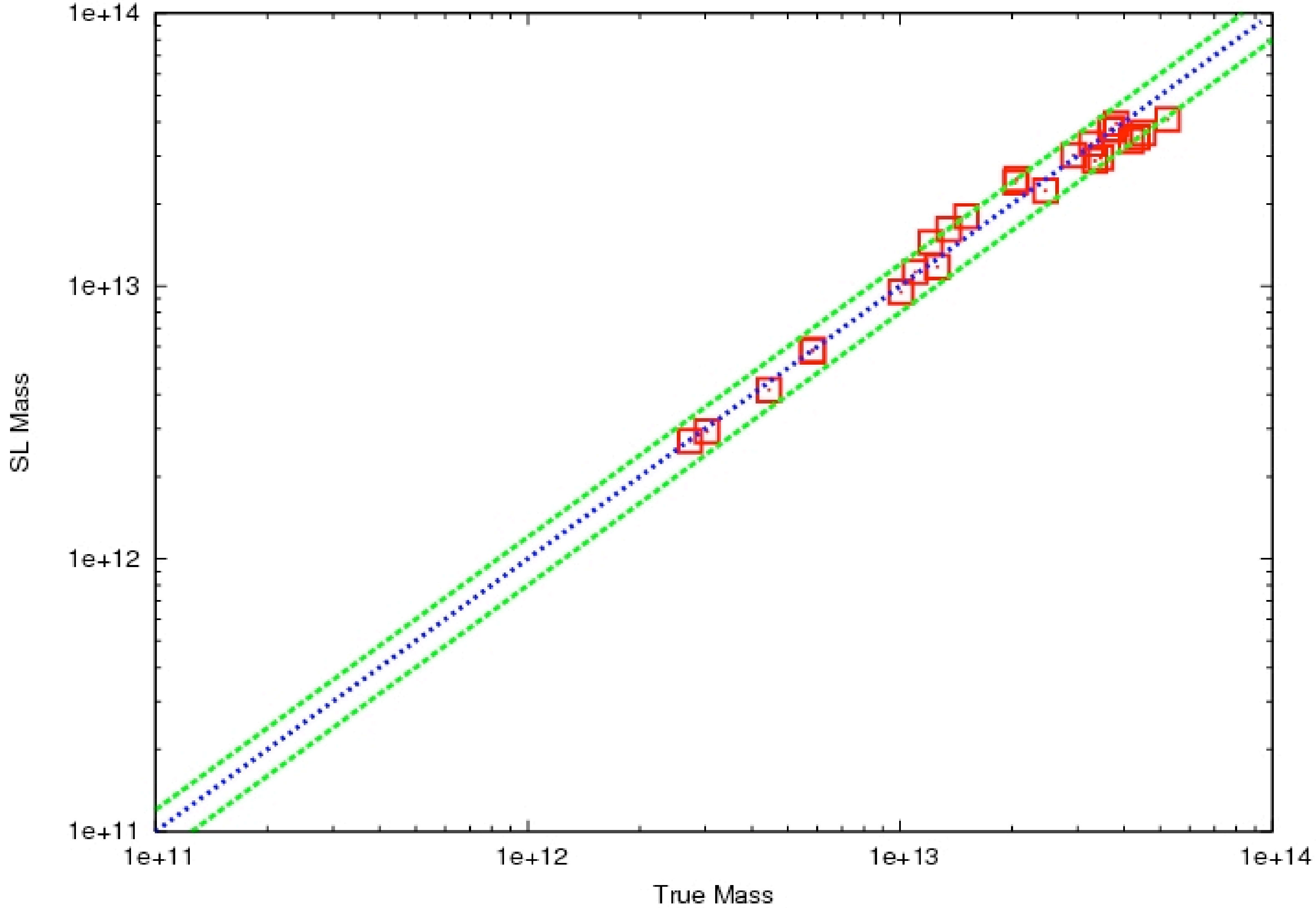
Fit based on the code by Comerford, Meneghetti, Bartelmann & Schirmer (2006)

Fitting with NFW components -> r_s, rho_s

Derive mass profile from fit parameters, compare to simulation



Masses in the strong lensing regions



(Similar results obtained by Jullo et al. 2007)

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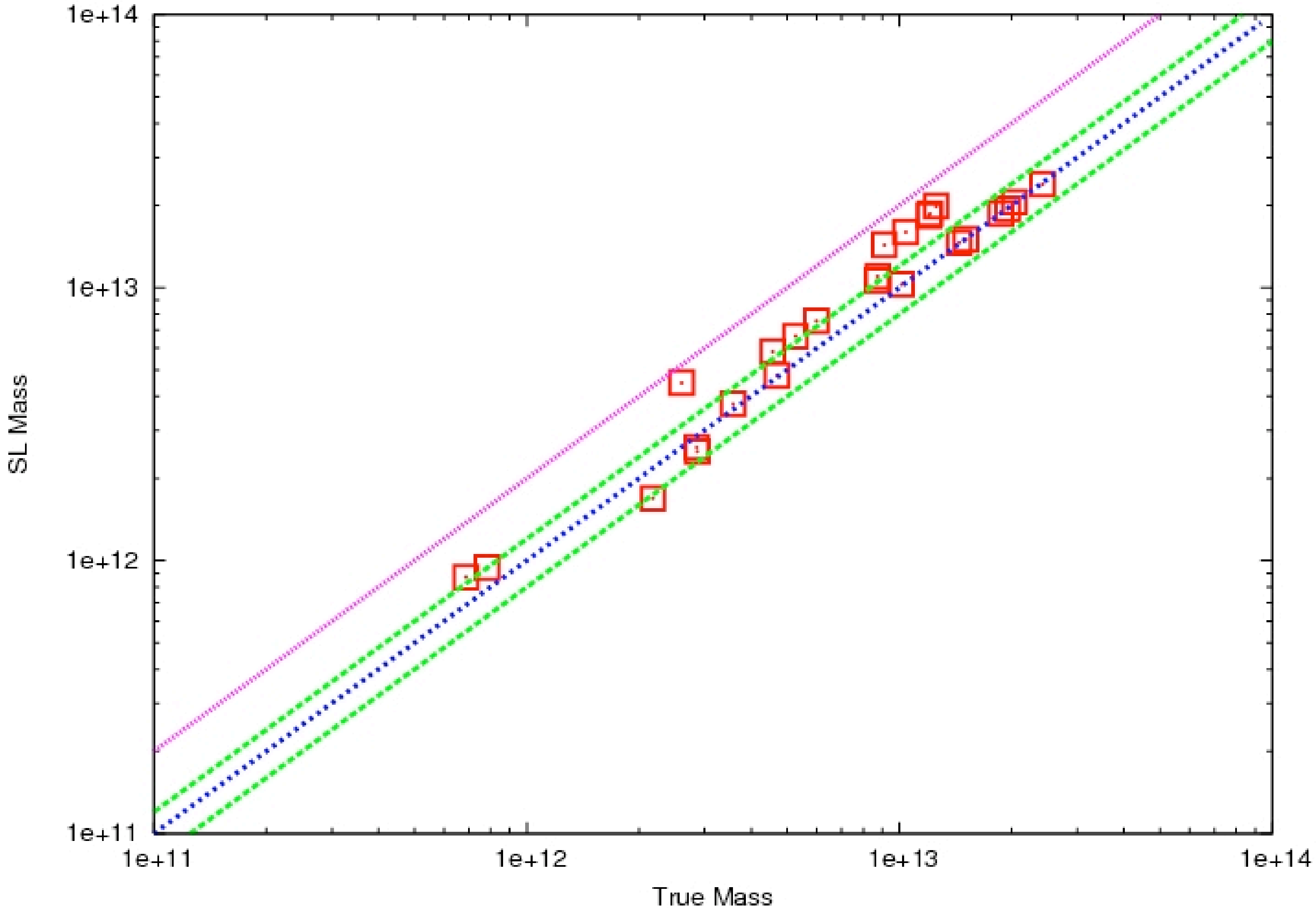
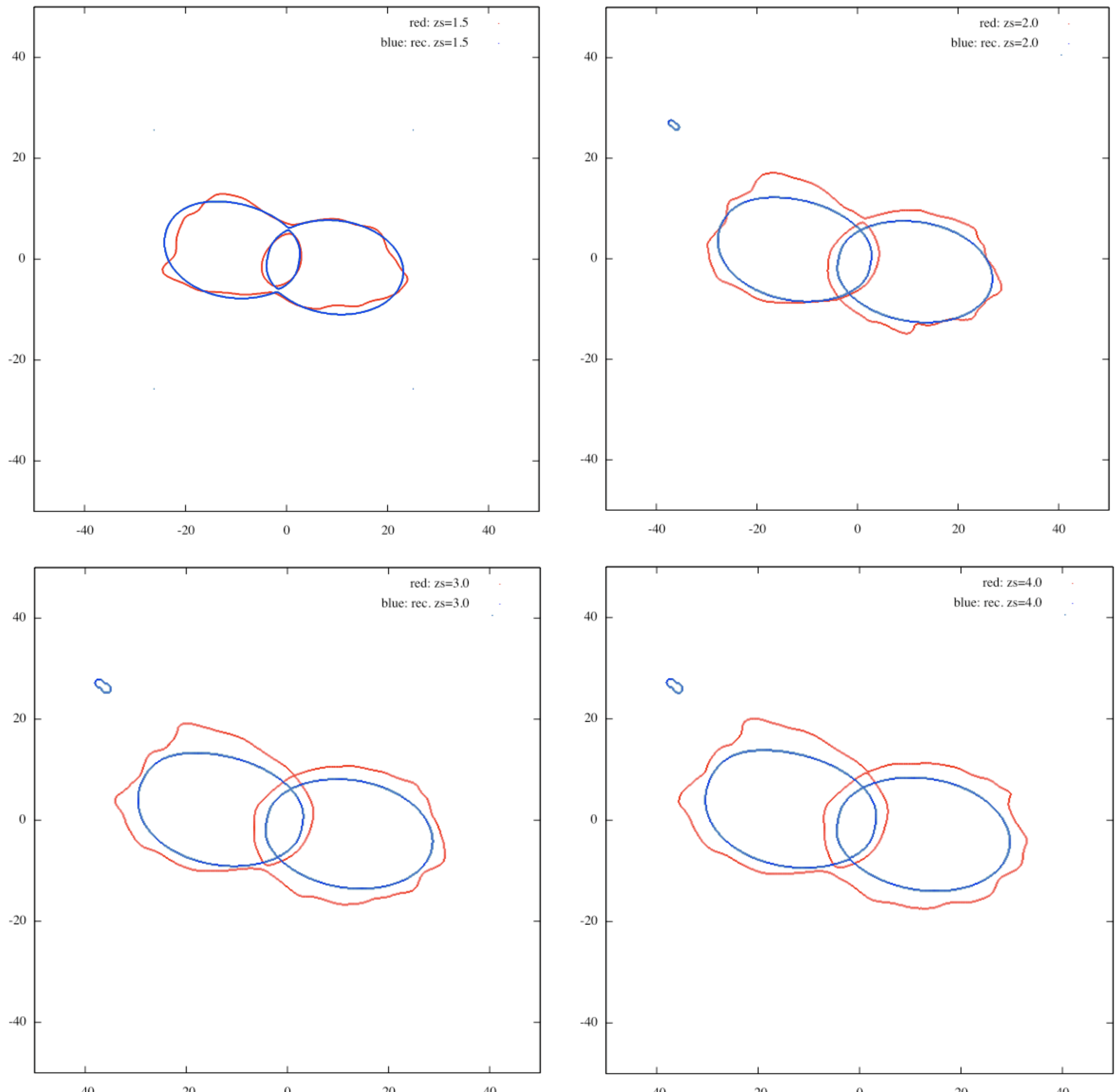


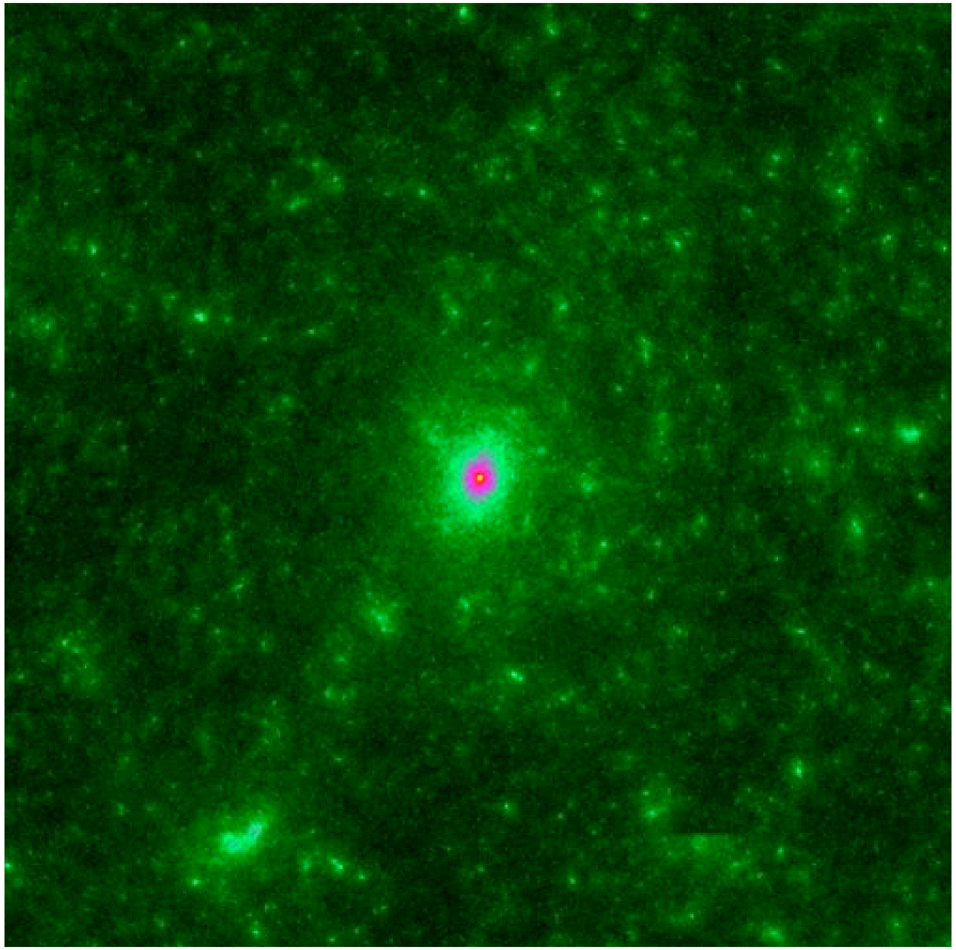
(Similar results obtained by Jullo et al. 2007)

Critical line reconstruction

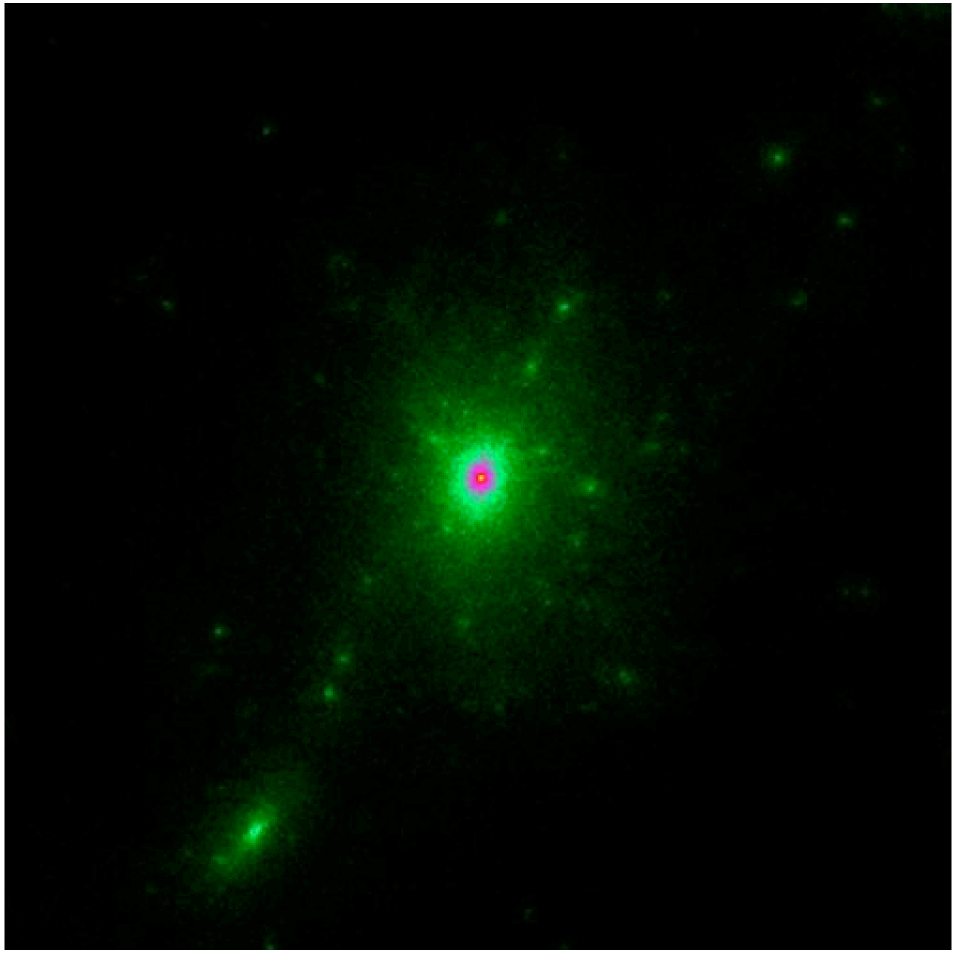


(see Meneghetti, Jain, Bartelmann & Dolag, 2004)

KP19927

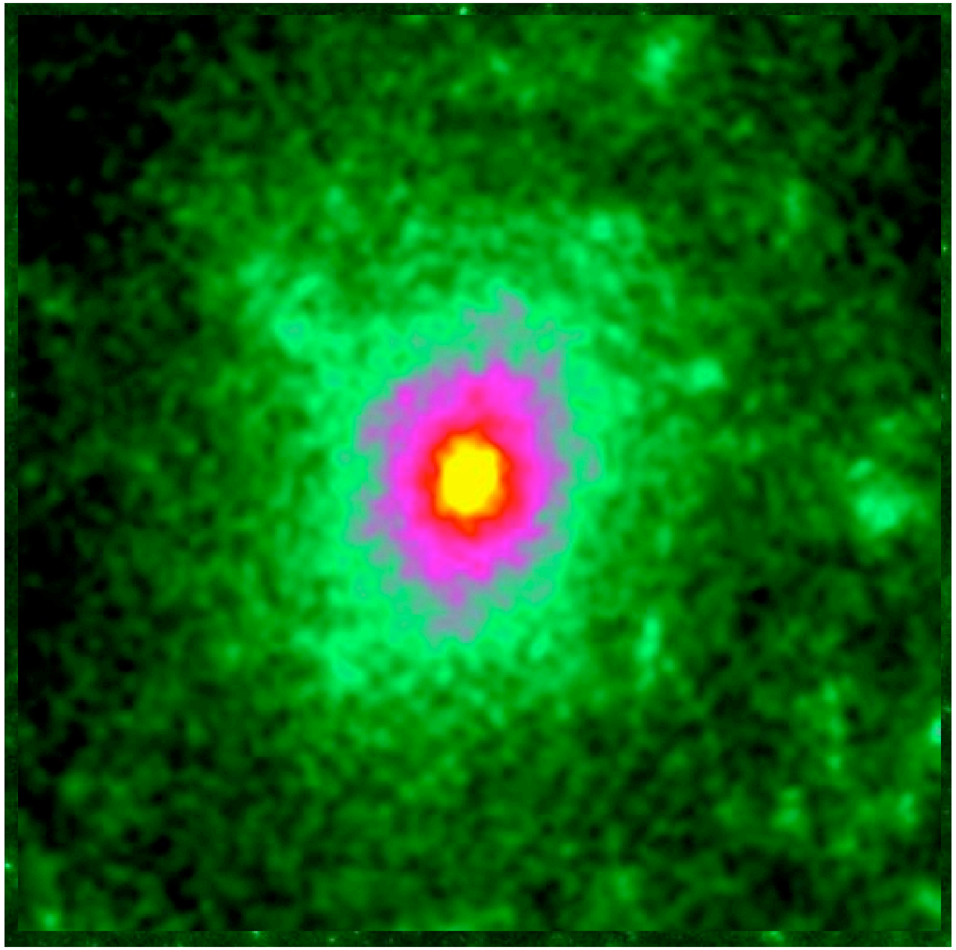


Multiplane simulation



Single plane simulation

KP19927



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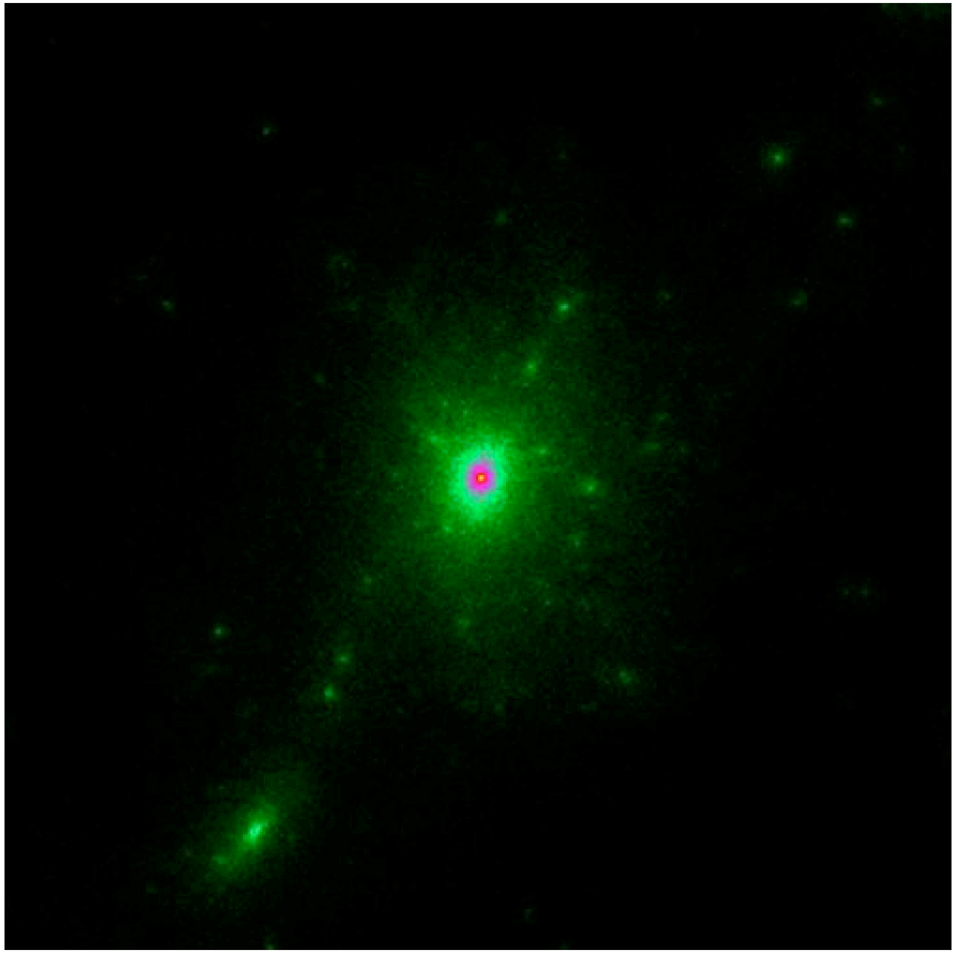

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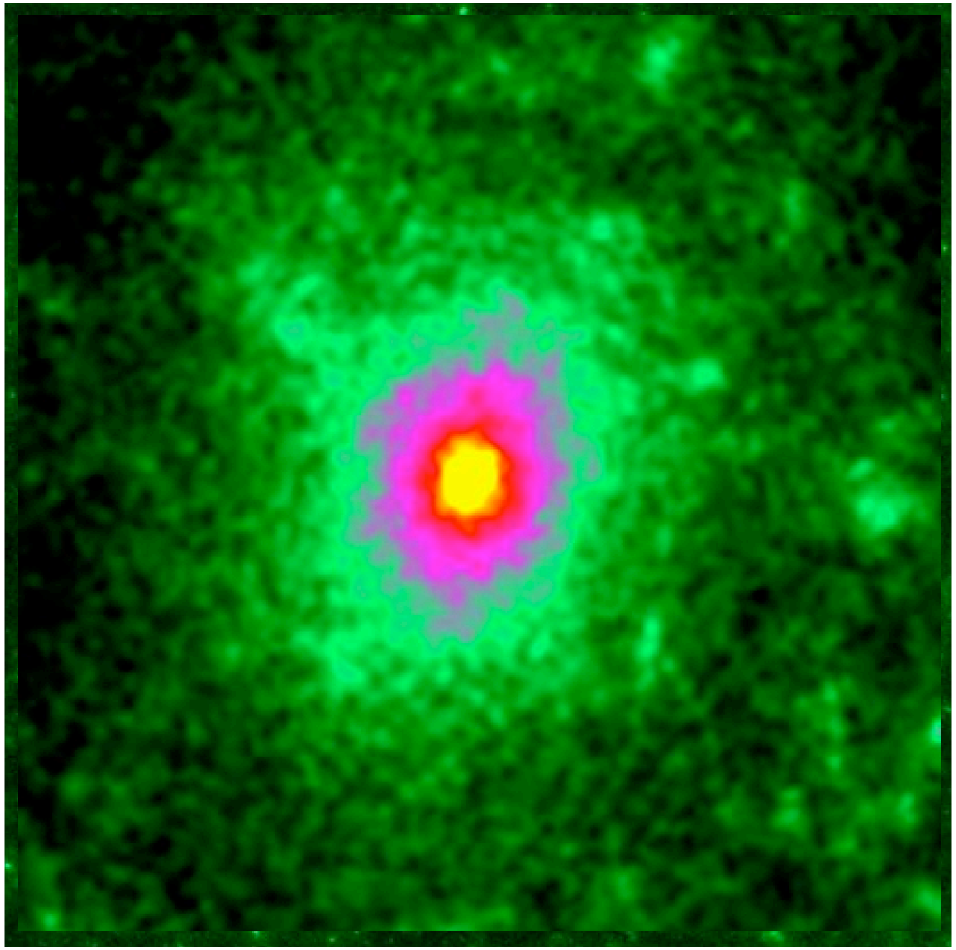

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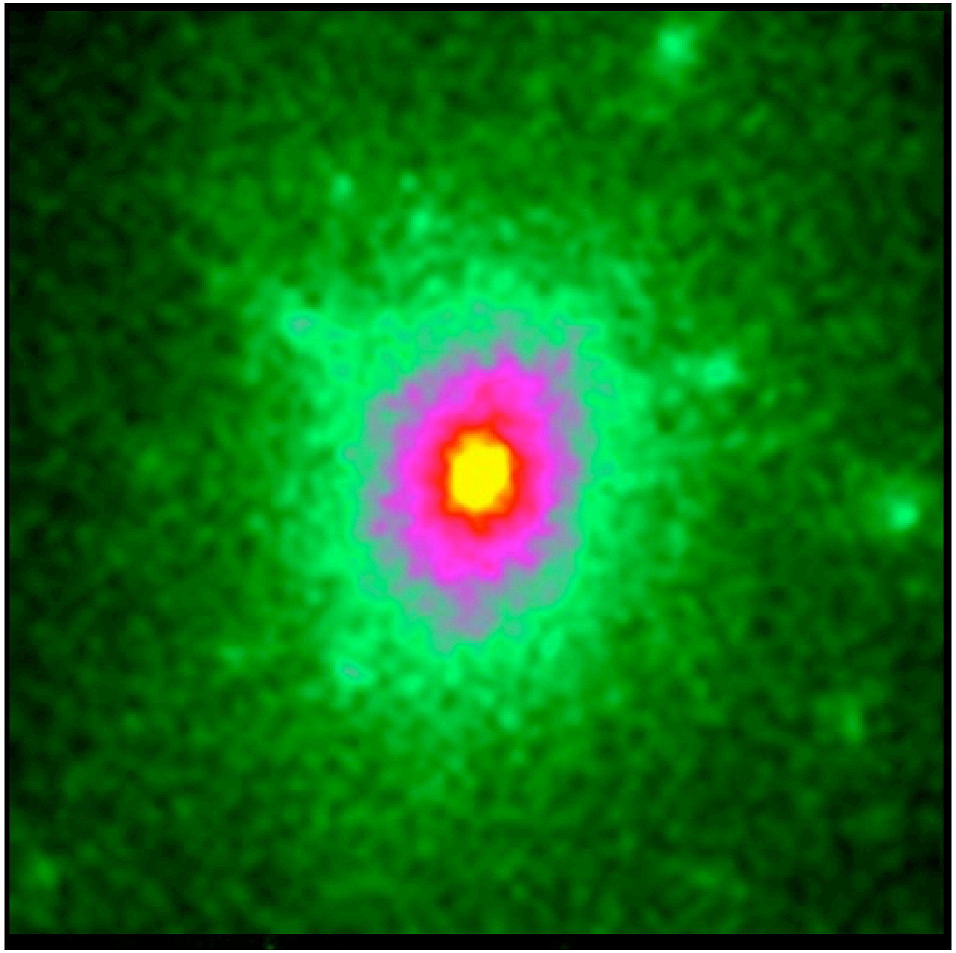
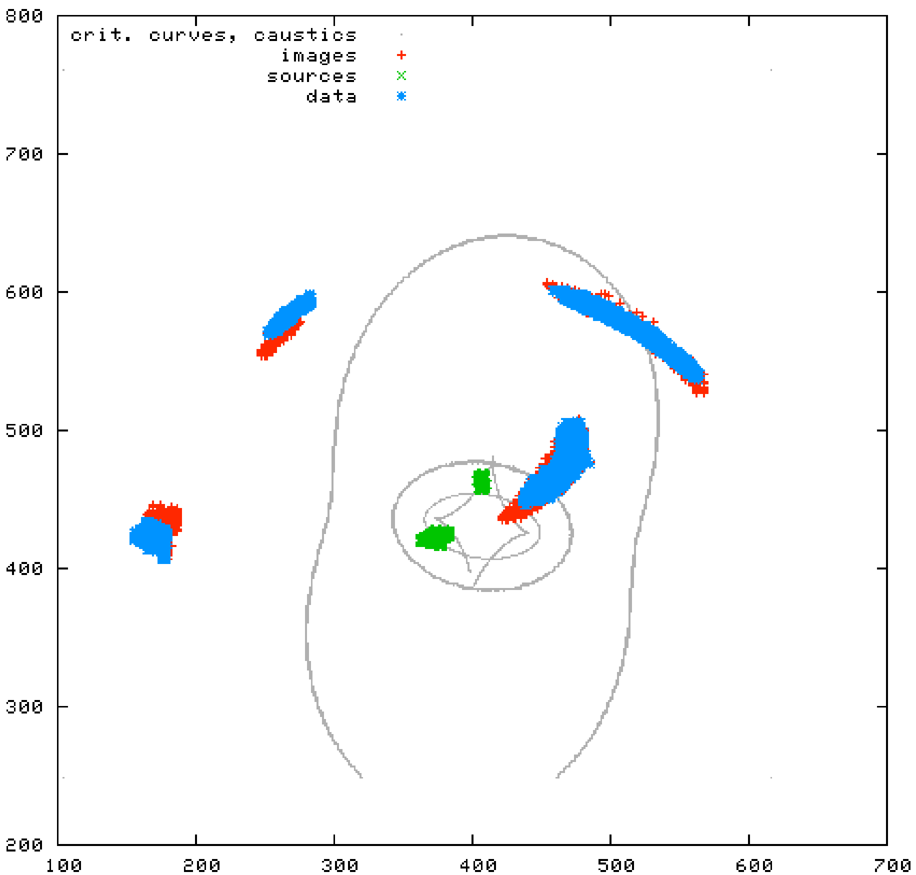


Single plane simulation

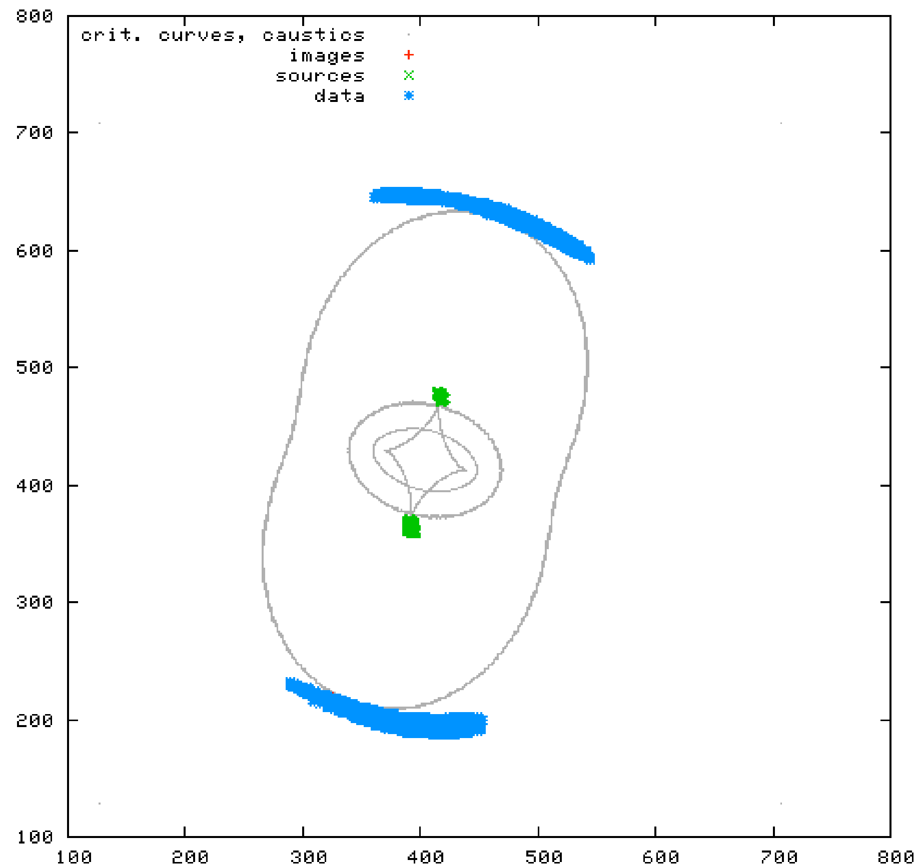
KP19927: reconstructions



rs=193 Kpc/h

ks=0.31

e=0.12 p.a=76 deg

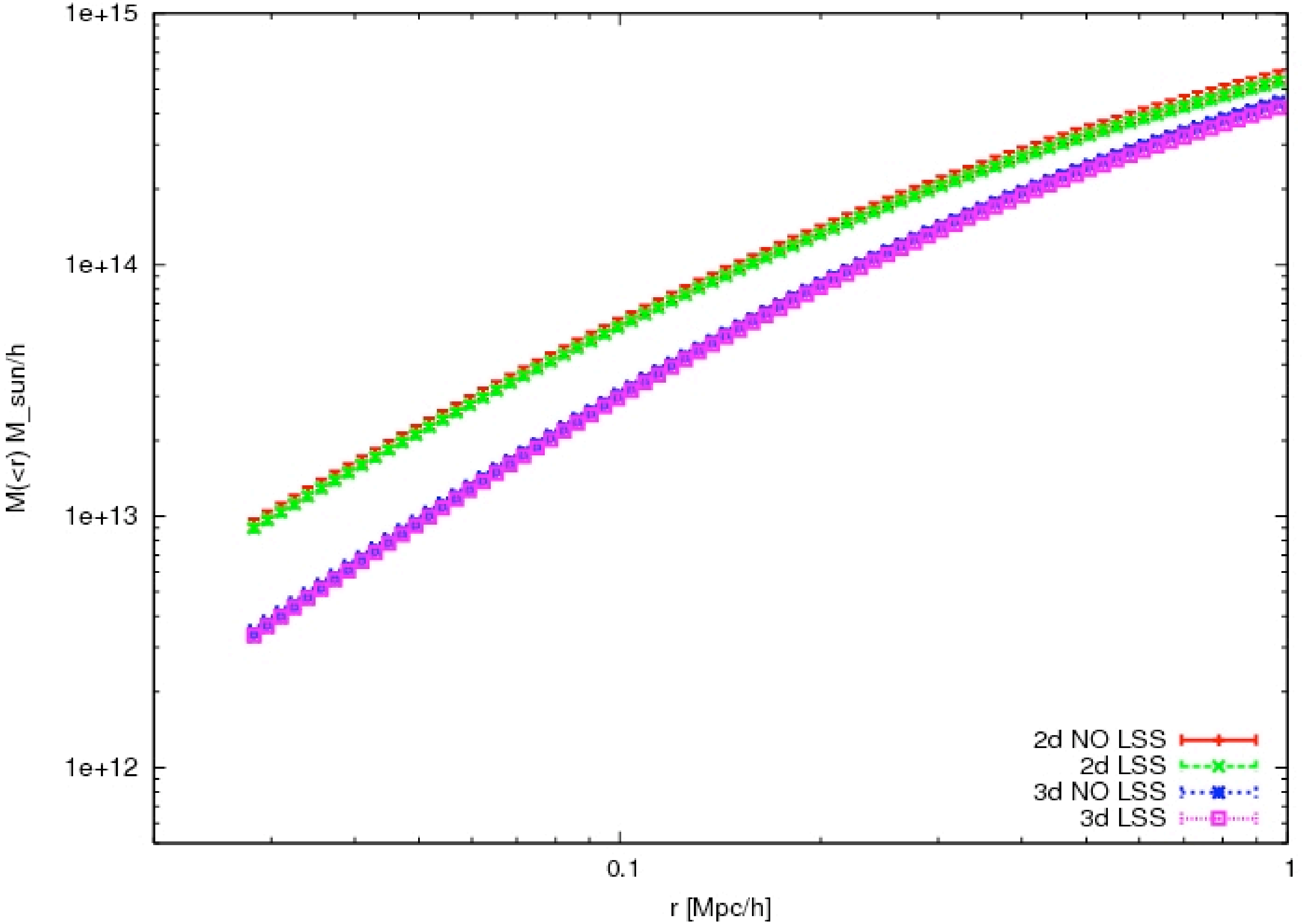


rs=210 Kpc/h

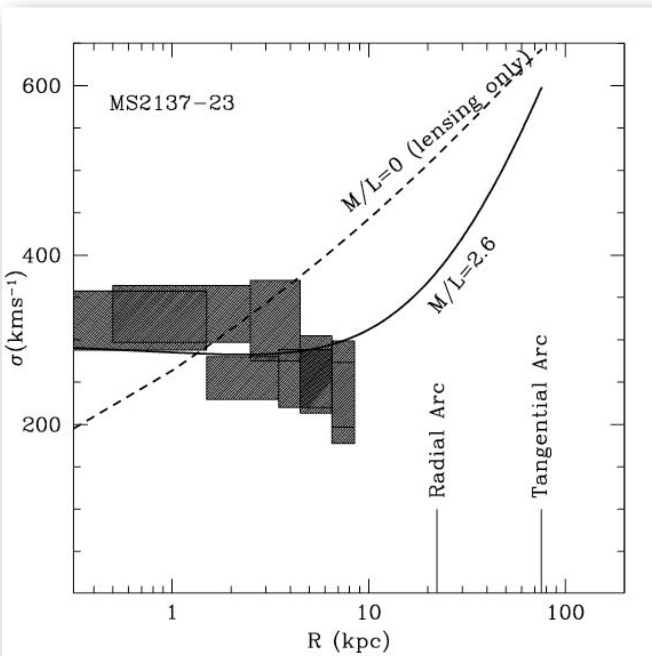
ks=0.29

e=0.12 p.a=81 deg

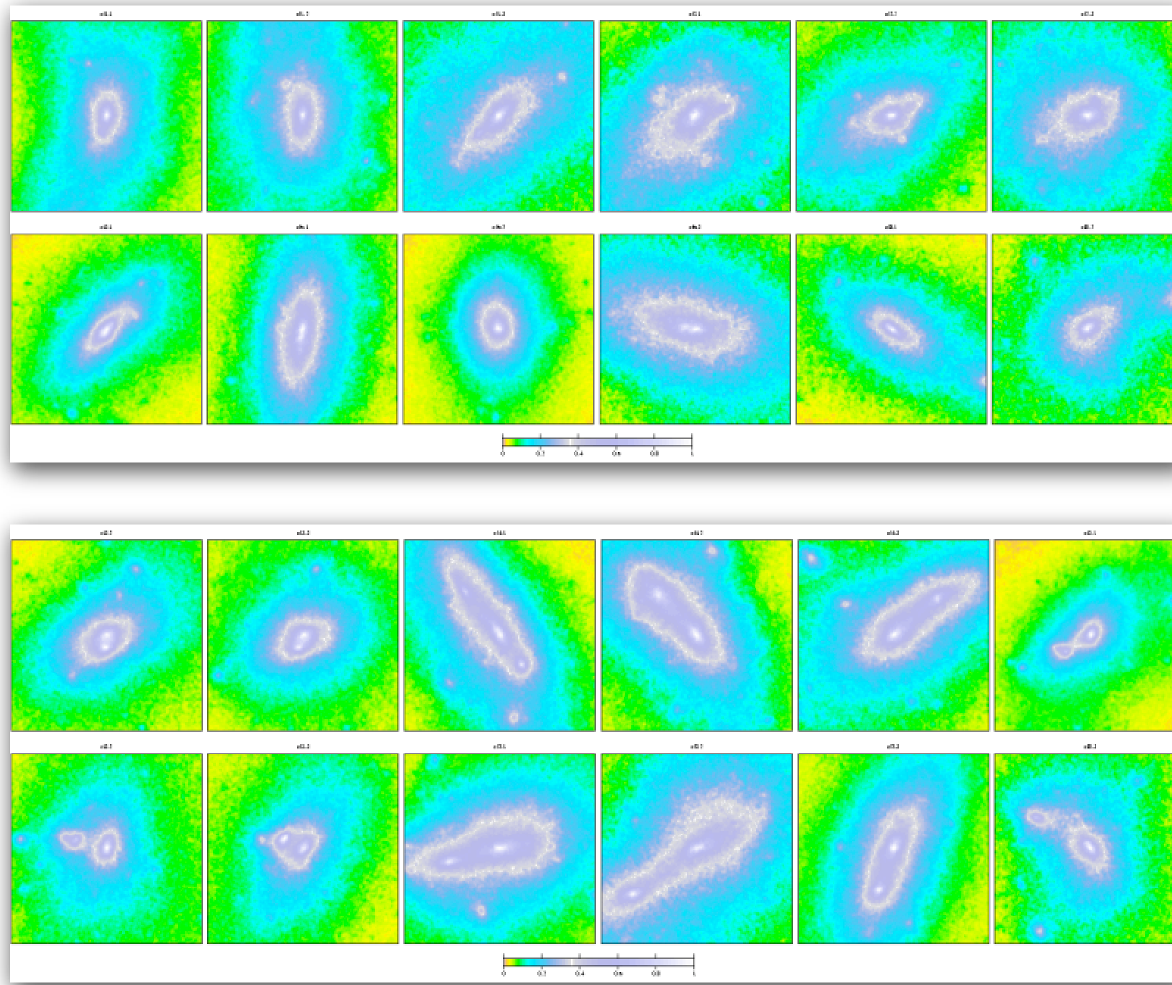
Effects of the LSS



Exercise 2: inner slope of dark-matter profiles

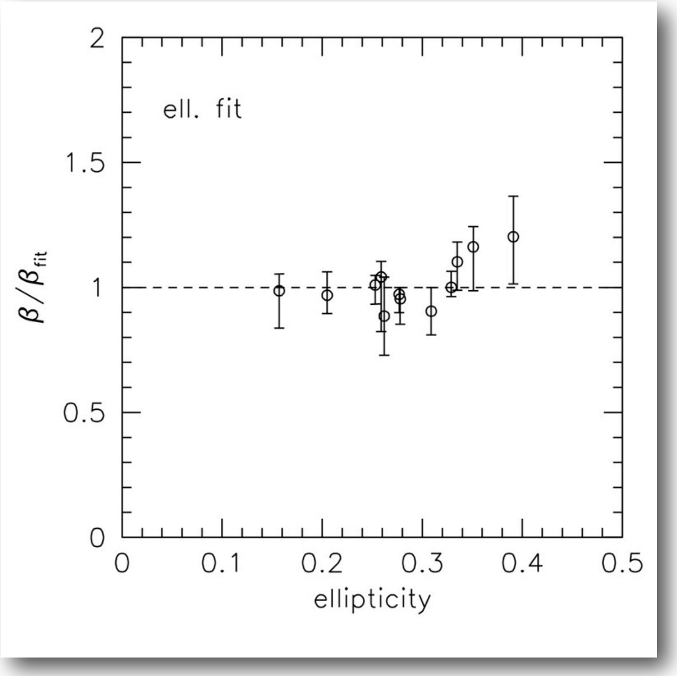


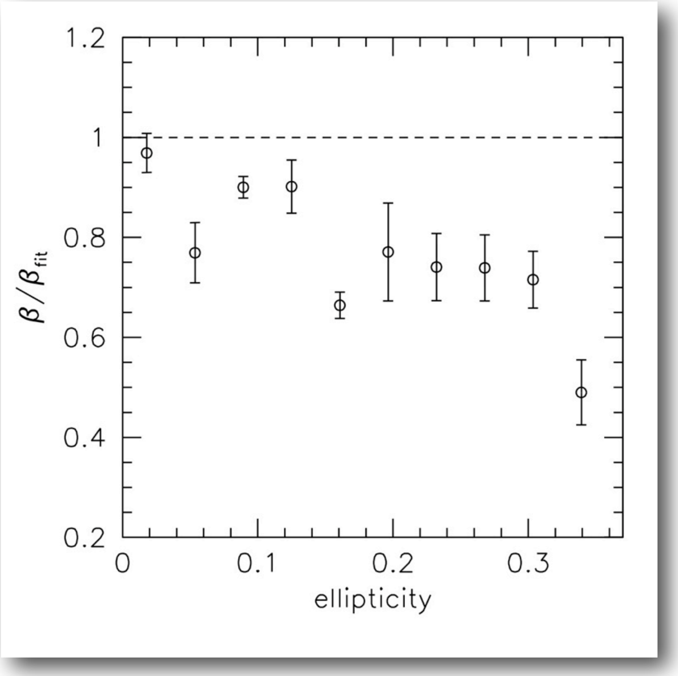
Sand et al. 2004



Meneghetti, Bartelmann, Jenkins & Frenk, 2005

Inner slope determinations

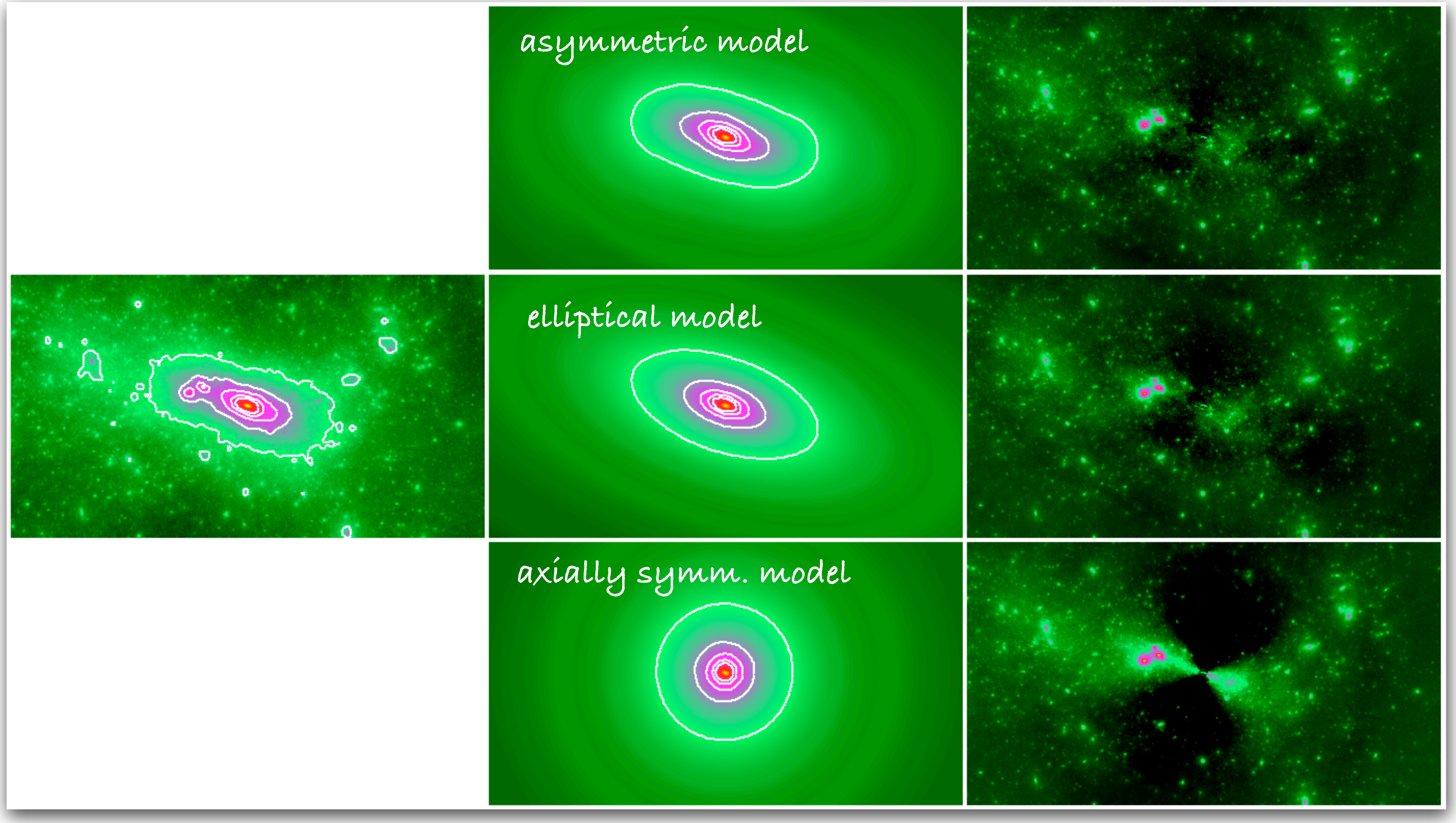




- In clusters with substructures <u>we were not able to measure the inner slope</u>
- By modeling "regular" clusters with the proper ellipticity, <u>we were able to recover the input inner slopes</u>
- Underestimating the ellipticity lead to underestimate the inner slope

Exercise 3: substructures and asymmetries in clusters

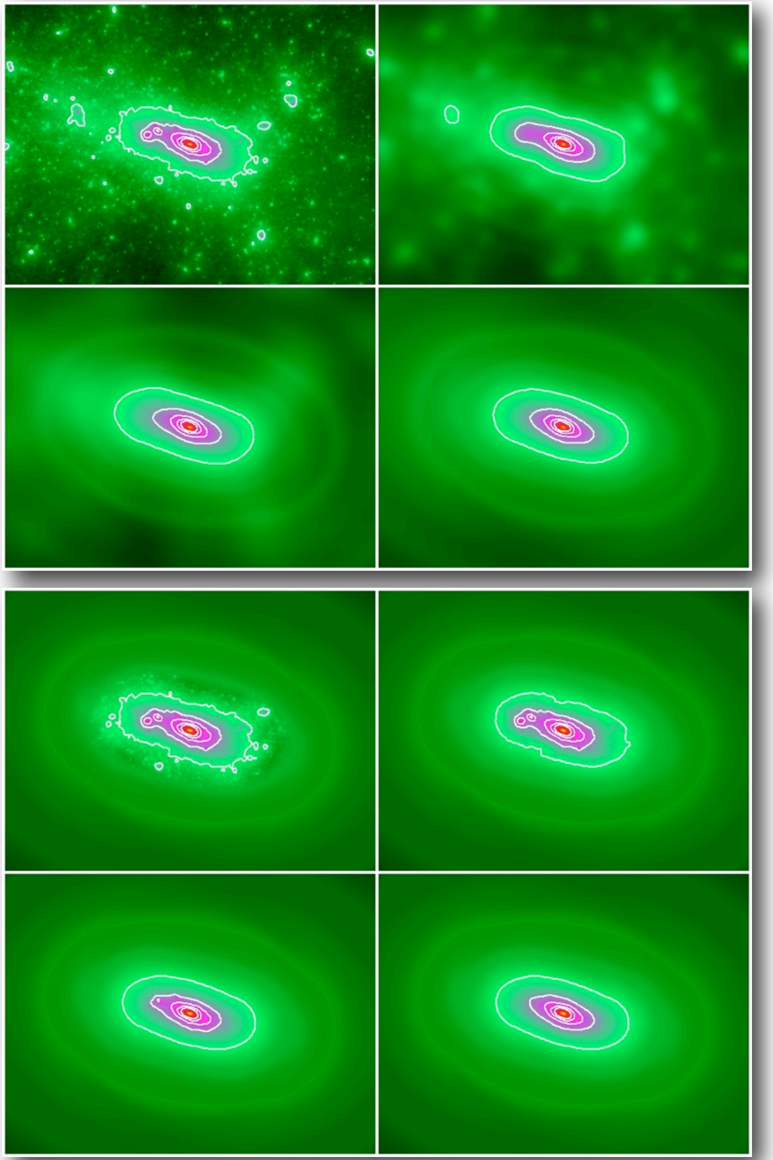
Meneghetti, Argazzi, Moscardini, Pace, Bartelmann, Li, Oguri, 2006



Filtering substructures

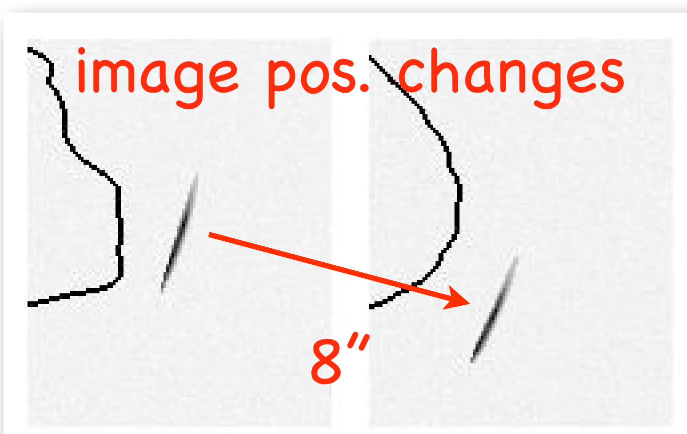
- Redistribute the mass in substructure all around the cluster conserving the mass profile

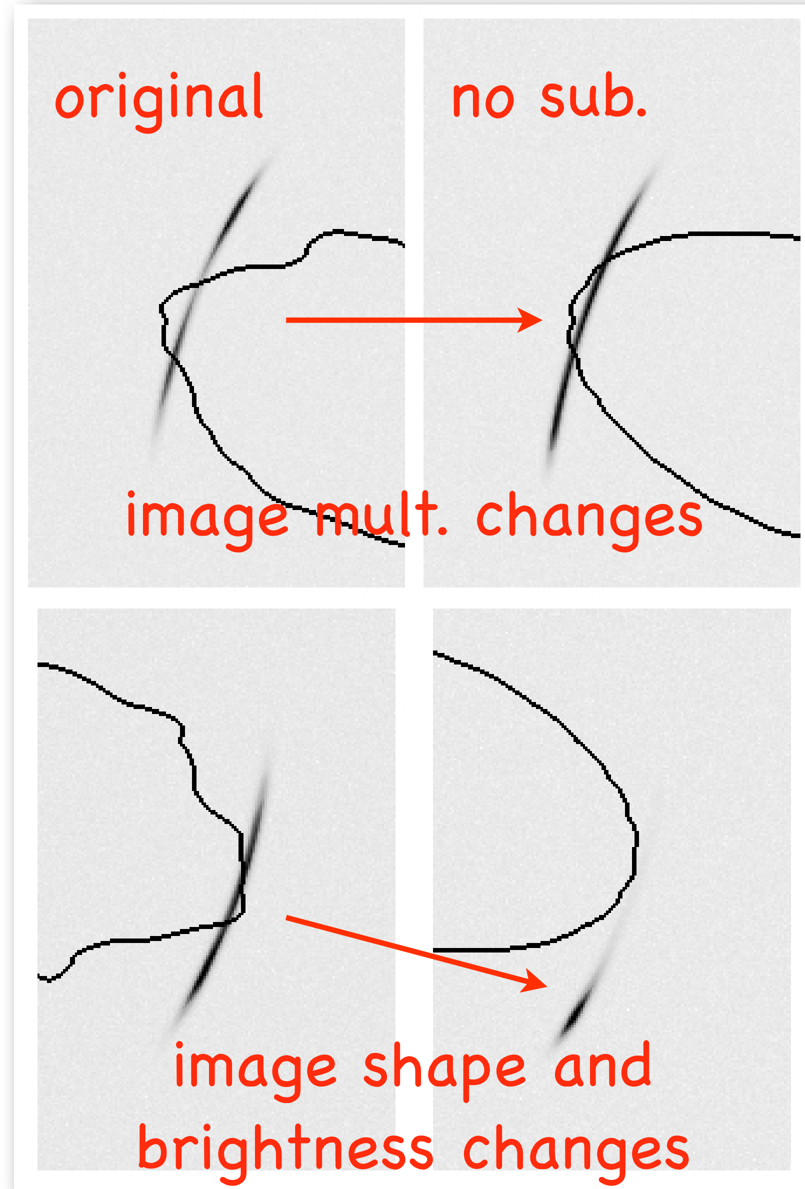
- Filter substructures outside a given radius



Effects of substructures on the arcs

Cluster	proj.	inc. mult. [%]	dec. mult. [%]	shift > 5″ [%]	ΔB
$g8_{hr}$	x	21.2	9.8	26.6	-2.3/+2.4
	y	19.7	3.9	11.1	-1.7/+0.8
	z	23.7	10.1	15.5	-2.5/+1.6
$g1$	x	47.0	1.0	24.0	-1.9/+1.1
	y	26.1	0.0	20.0	-1.7/+0.7
	z	24.5	0.0	29.5	-2.5/+0.8
$g8$	x	24.0	4.0	27.0	-1.7/+1.0
	y	35.4	9.5	51.1	-2.1/+2.1
	z	31.2	6.1	28.2	-2.5/+0.5
$g51$	x	33.1	6.2	44.7	-2.3/+1.7
	y	35.6	5.1	65.7	-2.5/+1.3
	z	39.1	6.2	54.3	-1.5/+1.3
$g72$	x	36.0	4.0	79.4	-2.5/+2.1
	y	62.5	0.0	57.1	-2.4/+0.0
	z	22.5	0.0	70.9	-2.4/+1.7
mean		32.1	4.4	40.3	-2.1/+1.3





Summary

- A suite for doing realistic ray-tracing simulations exists!
- We are open to new collaborations and, of course, to your suggestions for improving the code
- Present work: preparation of the DUNE proposal, lensing constraints on the inner structure of galaxy clusters, testing the arcfinder, arc statistics
- Future work:
  - testing shear measurements in clusters?
  - combine Skylens with simulators in other wavebands (see e.g. XMAS2 by Rasia et al. 2007 for simulating X-ray observations with Chandra and XMM-Newton)

Collaborators

Collaborators

- Stefano Ettori (OABO)
- Lauro Moscardini (UniBo)
- Elena Rasia (UMich)
- Klaus Dolag (MPA)
- Julie Comerford (Berkeley)
- Pasquale Mazzotta (Rome)
- Francesco Pace (ZAH)
- Matteo Maturi (ZAH)
- Annamaria Donnarumma (UniBo-OABO)
- Matthias Bartelmann (ZAH)
- Andrea Grazian (OARome)
- Mario Radovich (OANa)
- Peter Melchior (ZAH)
- Gabriella De Lucia (MPA)
- Stefano Borgani (UniTS)