Galaxy formation and strong lensing

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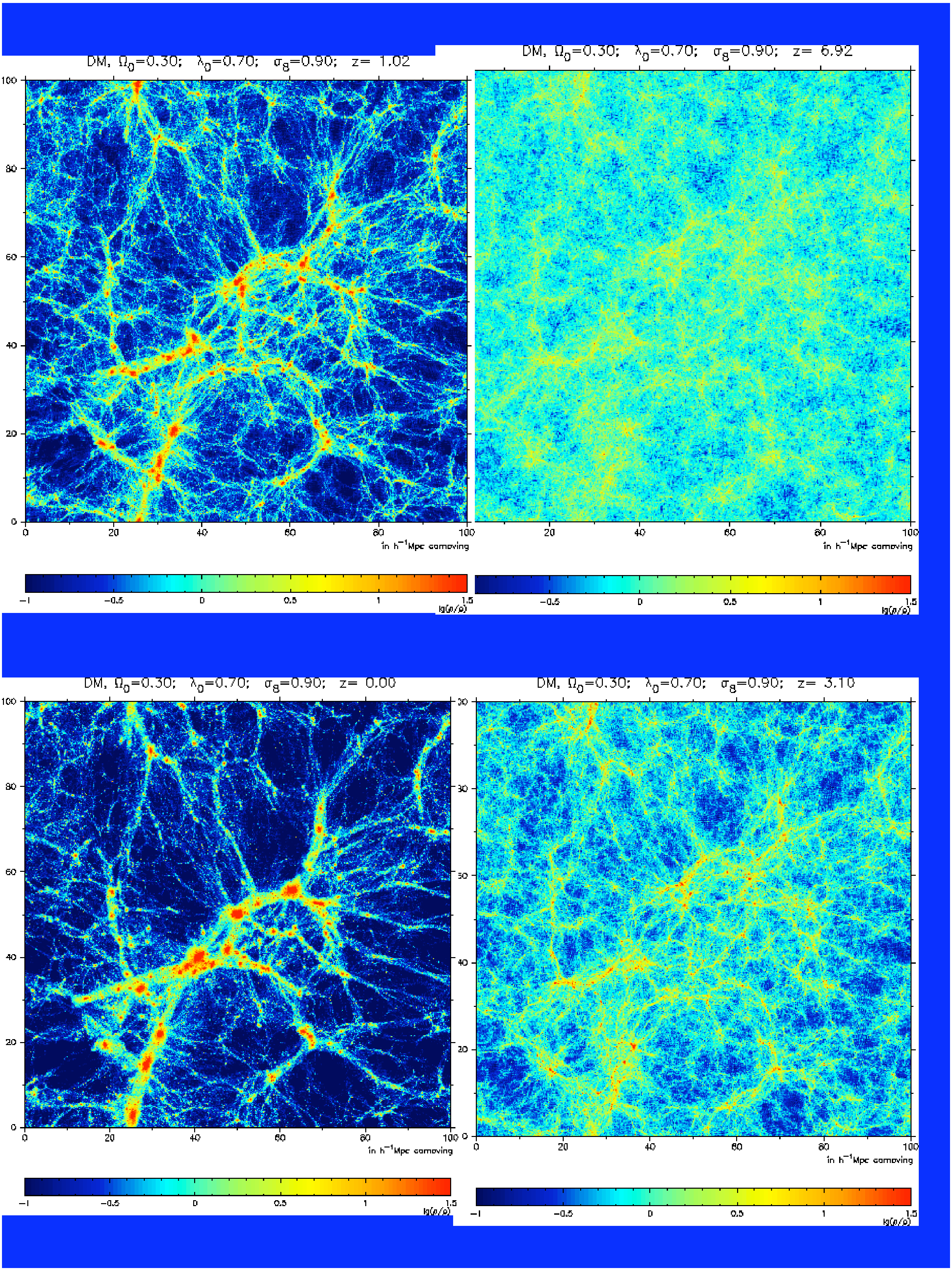
Content

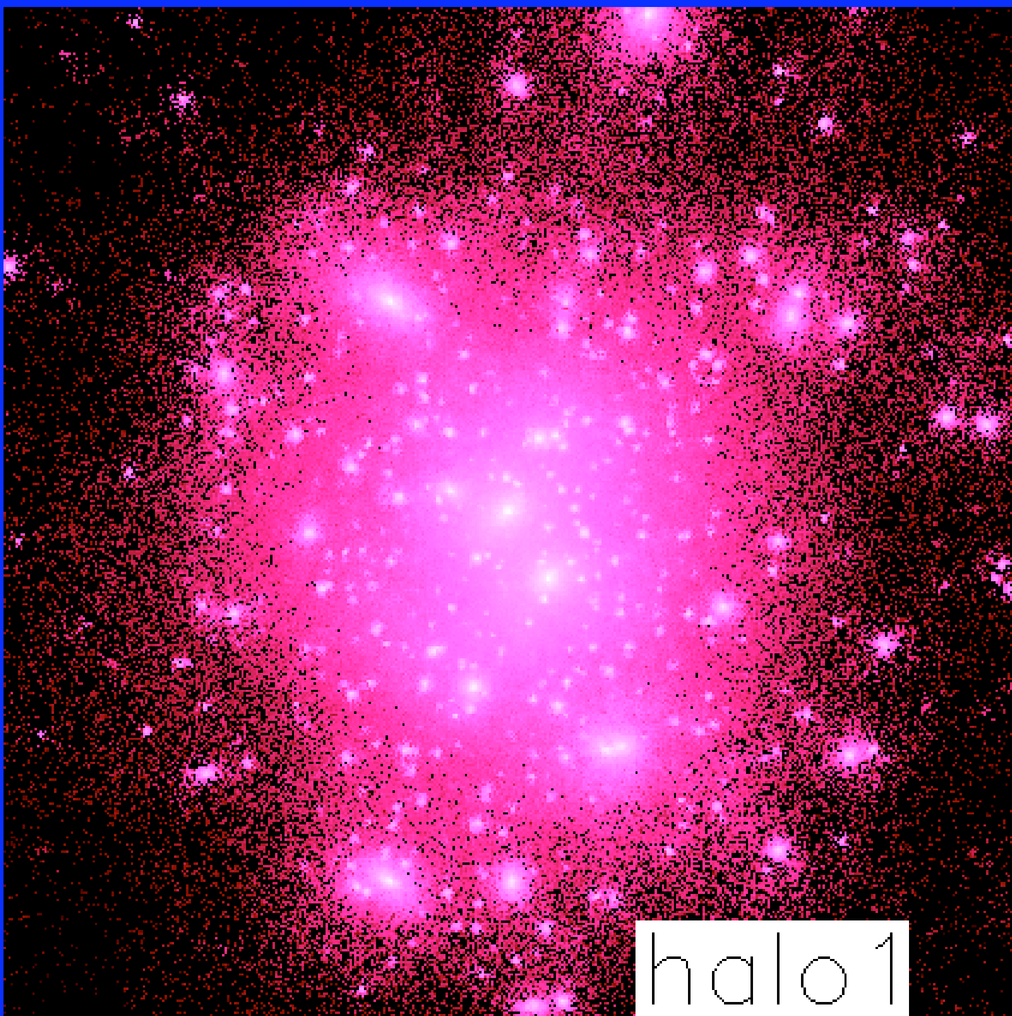
- Two recent works
  - Semi-analytical modeling of galaxy formation based on simulations (Kang X., YPJ, H.J.Mo, G. Boerner , astroph/0408475, ApJ)
  - Cross section for giant arcs with ray tracing; (Li, G.L., Mao, S., YPJ, Bartelmann, M. ,Kang, X., Meneghetti, M. astroph/0503172 (ApJ, submitted)
- Simulations in Shanghai

Cosmological N-body simulations (before 2002, Jing & Suto 2002)

	Box size (Mpc/h)	Softening (kpc/h)	Time steps	N_p
LCDM	100	10	5000	512^3
LCDM	25	2.5	5000	256^3
LCDM	300	40	1200	512^3
SCDM	100	20	1200	512^3
SCDM	300	60	1200	512^3



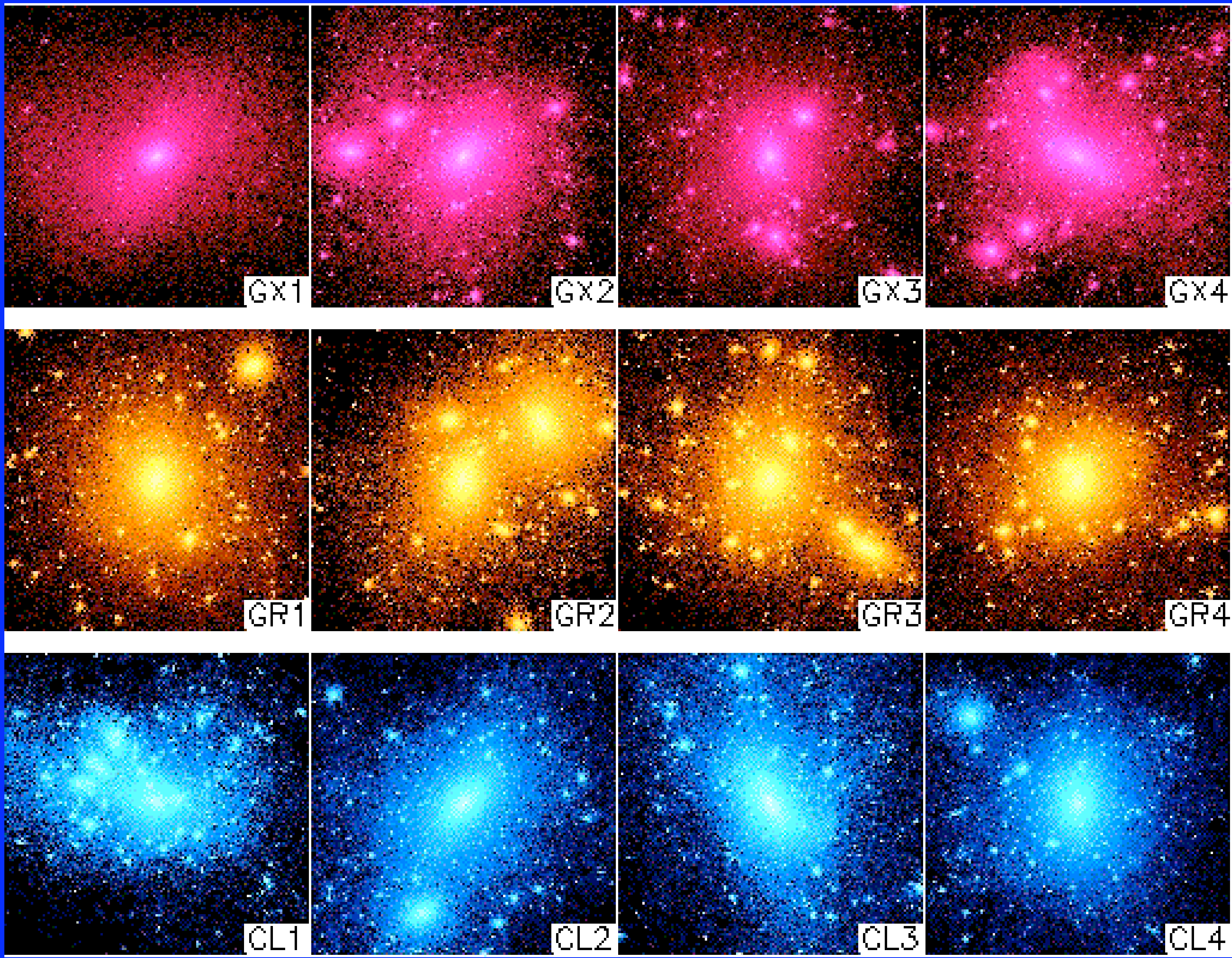
DM, Ω0=0.30; λ0=0.70; σ8=0.90; z= 1.02
DM, Ω0=0.30; λ0=0.70; σ8=0.90; z= 6.92
DM, Ω0=0.30; λ0=0.70; σ8=0.90; z= 0.00
DM, Ω0=0.30; λ0=0.70; σ8=0.90; z= 3.10
in h−1Mpc comoving
lg(ρ/ρ)


halo1

Halo simulations (before 2001)

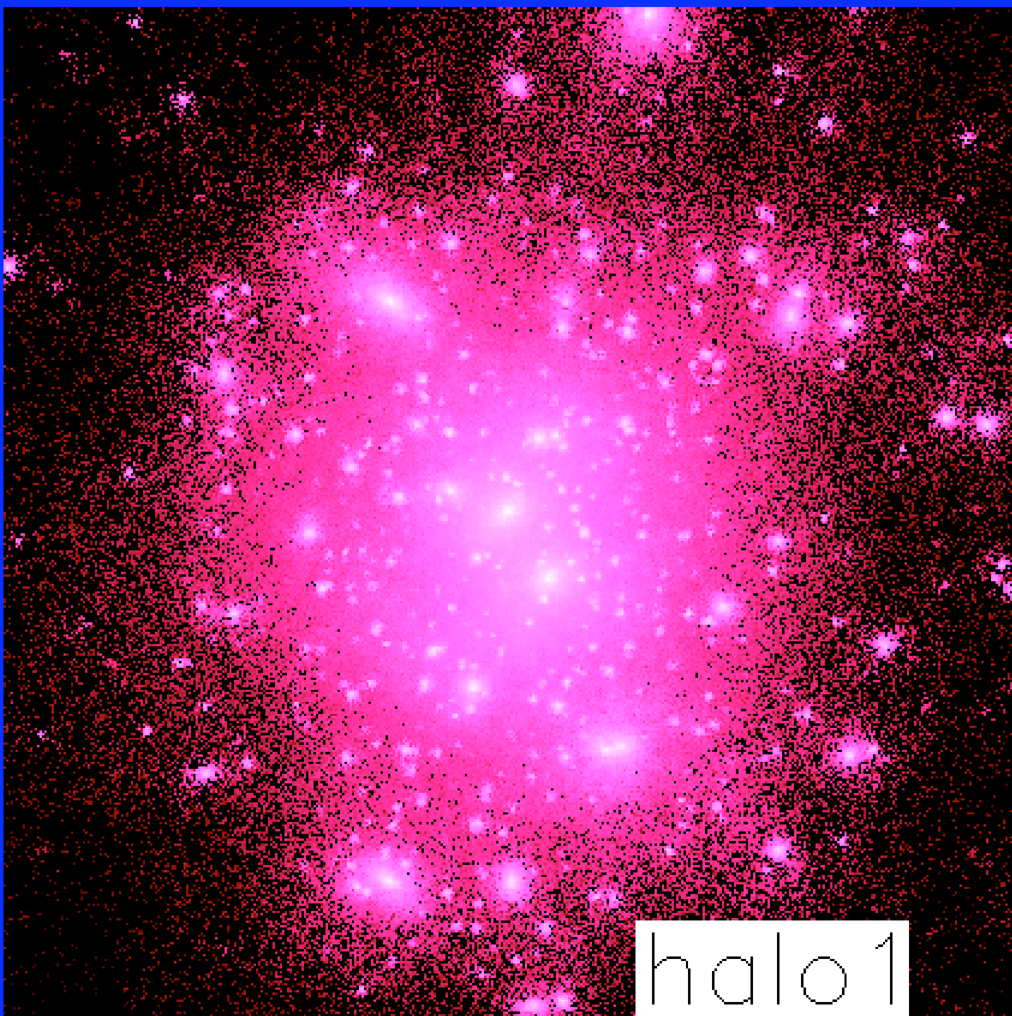
- The halo samples of Jing & Suto (2000, ApJL)
  - 12 halos, 4 each at galactic, group, and cluster mass;
  - 0.6—1.1 million particles with $r_{vir;}$
  - Force softening length $0.005r_{vir}$
  - Two halos replaced with new runs in this work
- 30 most massive halos (=> 10^{15} M_{sun}/h) in the LCDM model with 2 million particles (lensing, galaxy formation, halo internal structure)
- We plan to run bigger simulations ($10^{8\text{-}9}$particles)

JYP & Suto, Y. 2000, ApJ, 529, L69

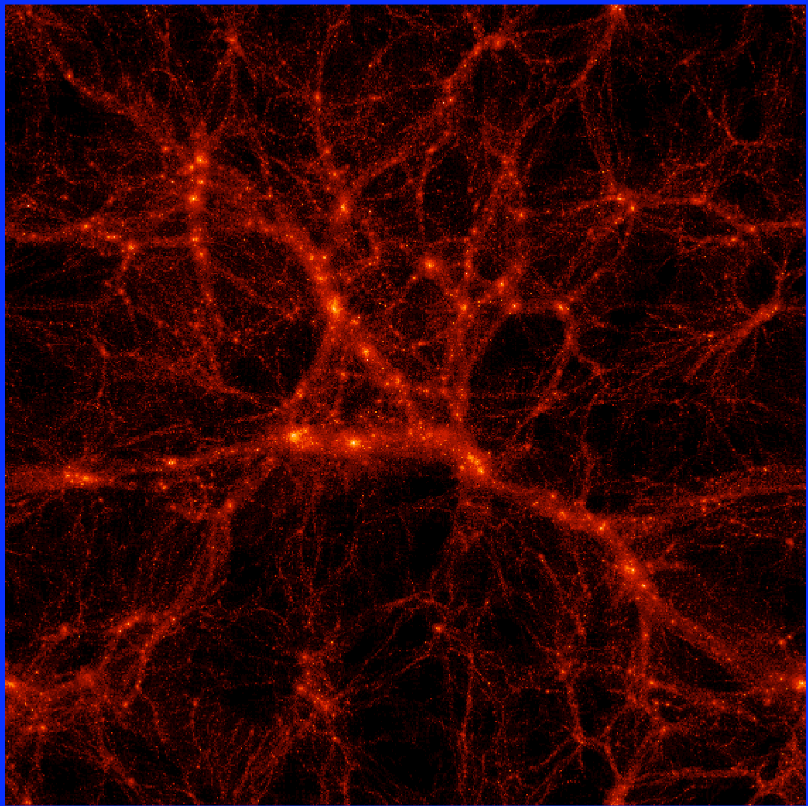


Semi-analytical modeling of galaxy formation based on N-body simulations

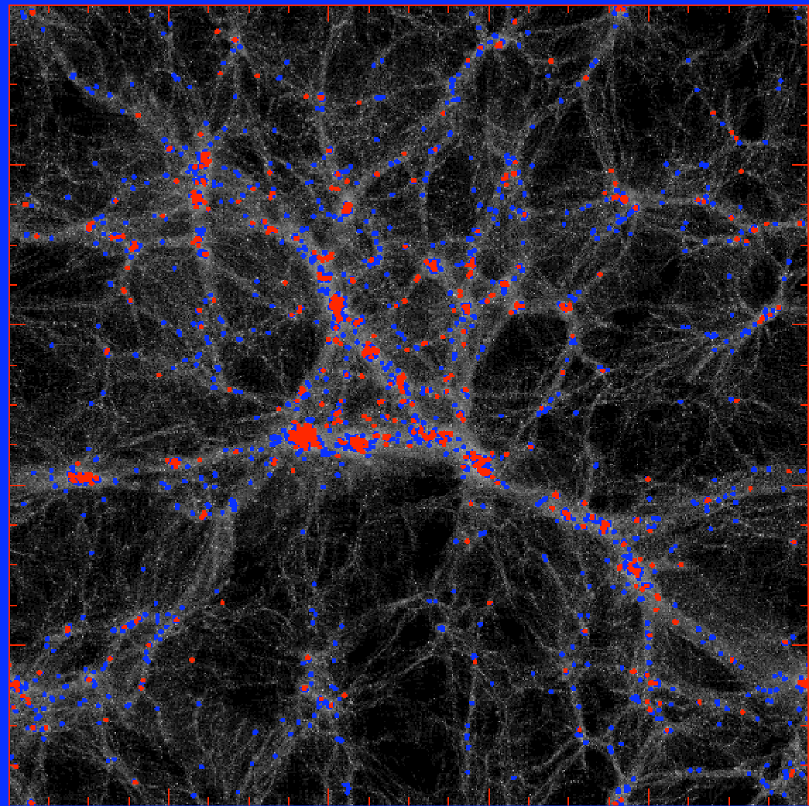
- Physical processes: heating, cooling, star formation and feedback, chemical evolution, dust extinction, SSP, galaxy mergers and morphology transformation; (quite complete compared with previous works)
- Subhalos well resolved;
- Galaxy mergers are dealt with much better than previous works
- A new recipe for switch off of cooling in massive halos; important for high redshift galaxies
- Kang X., YPJ, H.J.Mo, G. Boerner (2004), astroph/0408475, ApJ(in press)


halo1

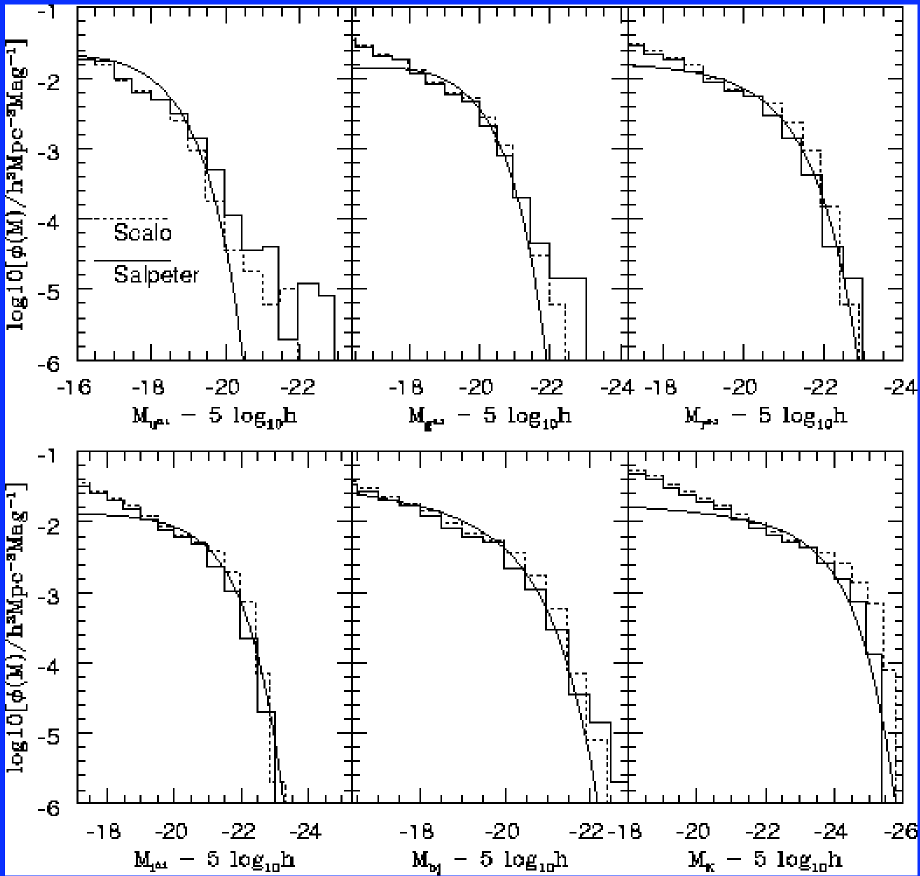
Dark matter



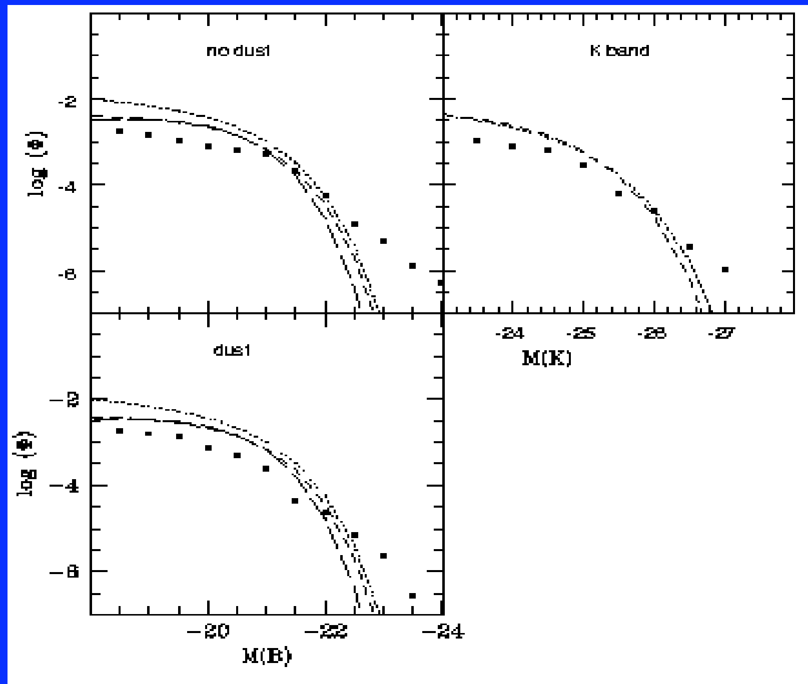
Galaxies: red for E;
blue for spirals



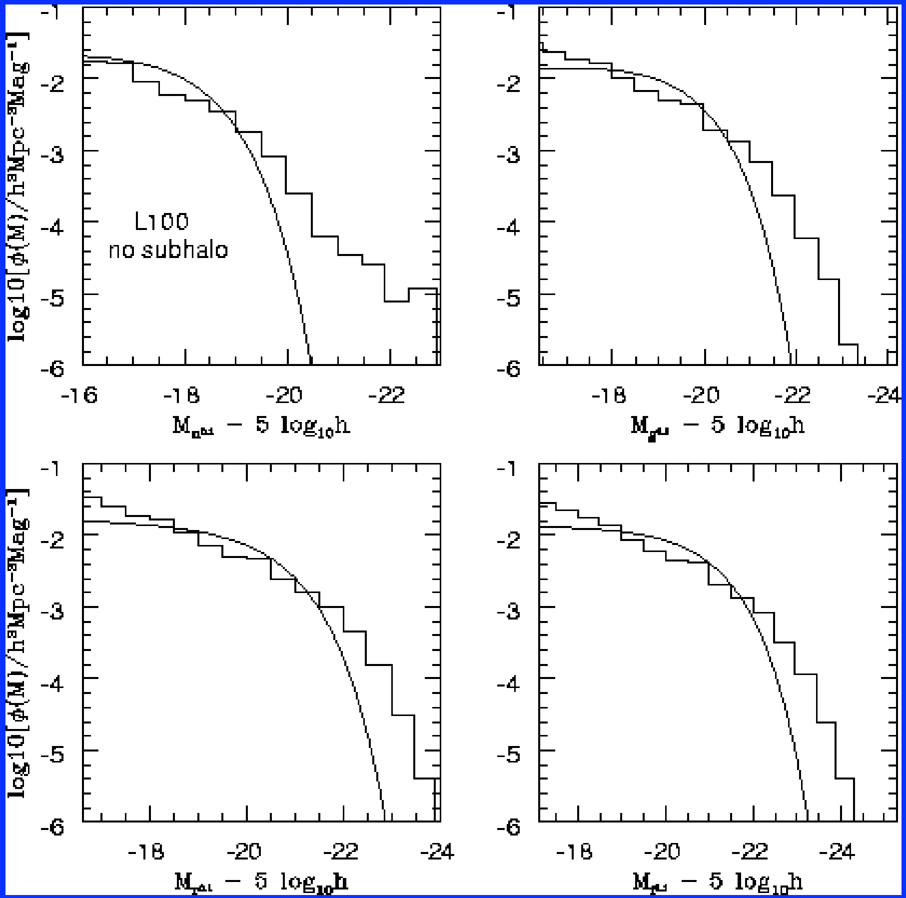
Luminosity Functions of galaxies from u to K bands (Kang et al. 2004)



Luminosity Functions if subhalos not resolved (Kauffmann et al. 1998); NOT Exponential; too many bright galaxies

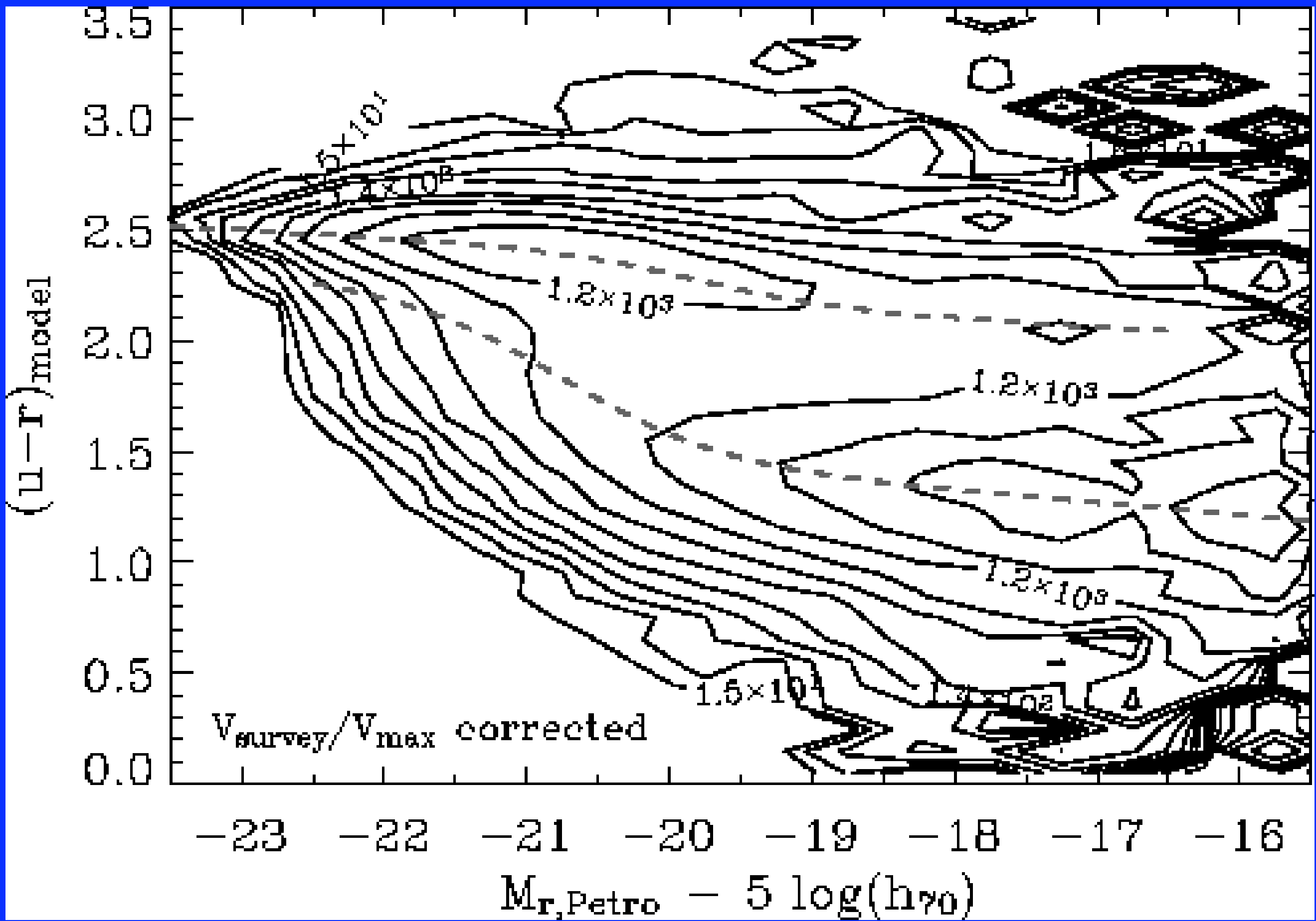


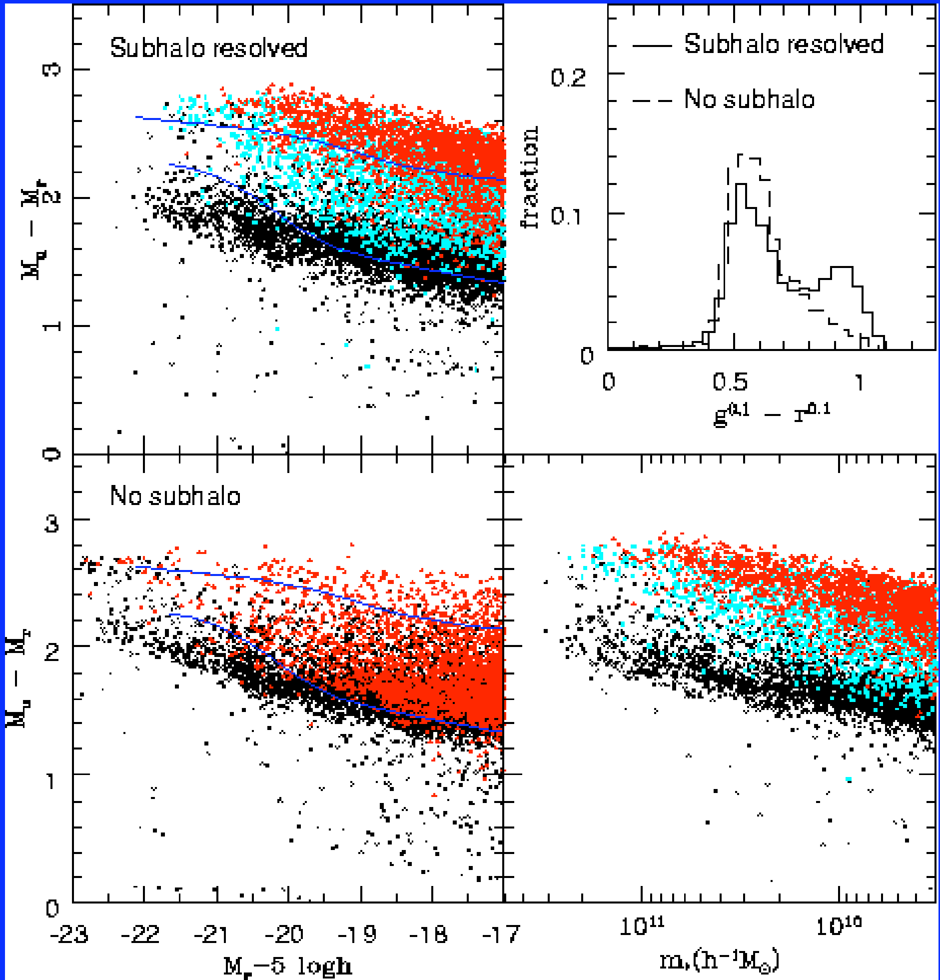
Luminosity Functions if subhalos not resolved (Kang etal. 2004); too many bright galaxies

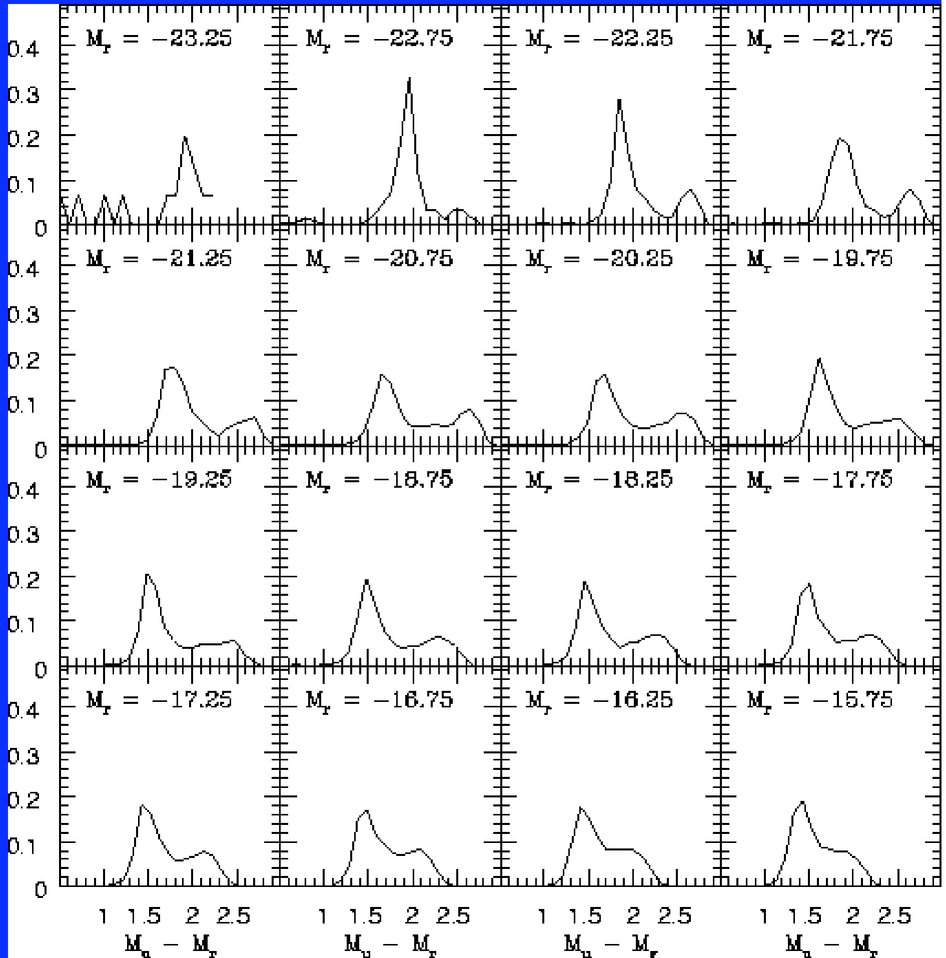


Reason: Merger of red bright satellite galaxies with the central galaxies is slower in the subhalo scheme

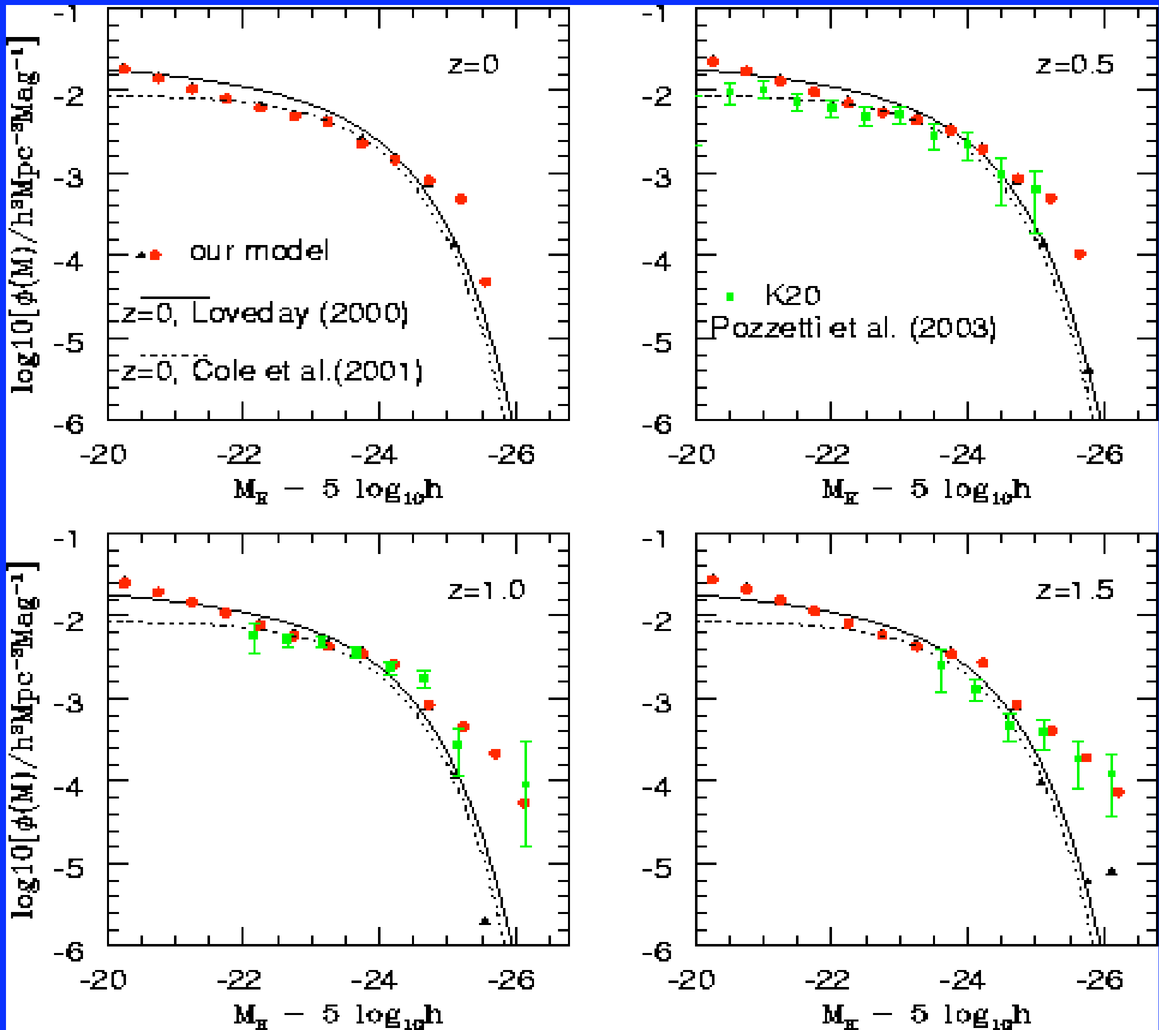
Bimodal distribution in the color-magnitude diagram (SDSS)



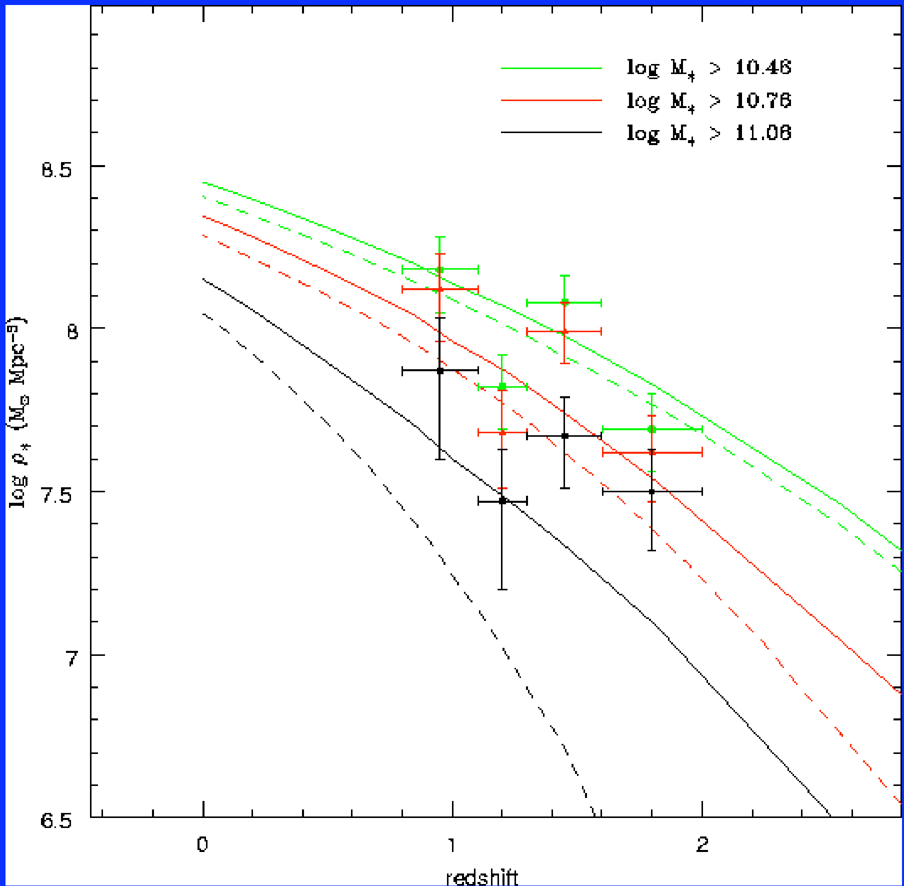


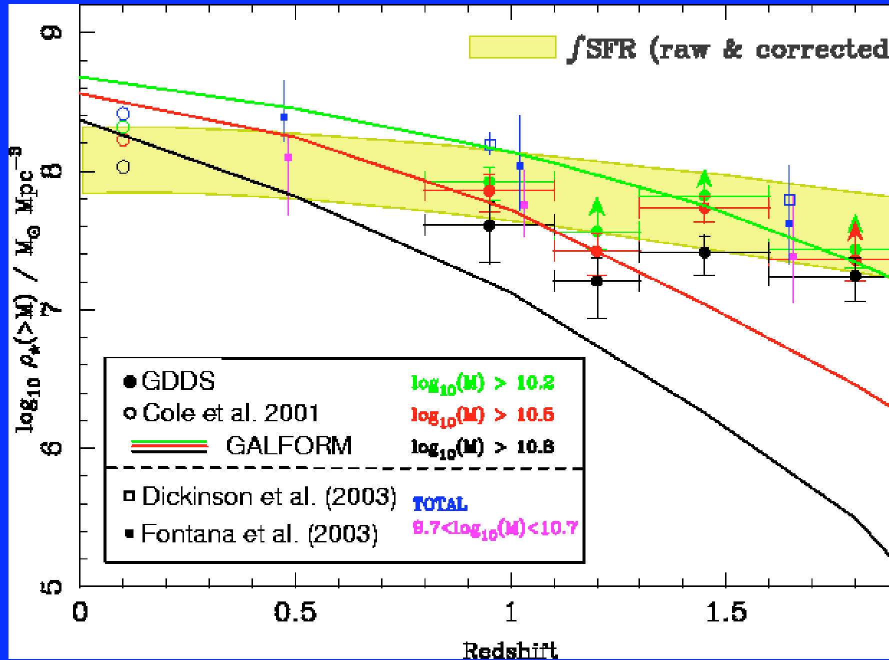


Subhalo resolved: the bimodal color-mag distribution is much better reproduced



We switch off cooling in massive halos with mass > 10^{13} $h^{-1}M_{\odot}$. The abundant massive galaxies can be reproduced.





Glazebrook et al. 2004, Nat.

New recipe for switching off cooling in massive halos: $>10^{13}\ h^{-1}M_{sun}$; no shortage of massive galaxies at high z, in contrast with previous work

Summary of the SAM work

- Semi-analytical modeling with subhalos resolved;
- Resolving subhalos important for improving modeling: LF, color-mag, high z galaxies, among others;
- For high z galaxies, cooling cutoff above certain halo mass is better; AGN necessary

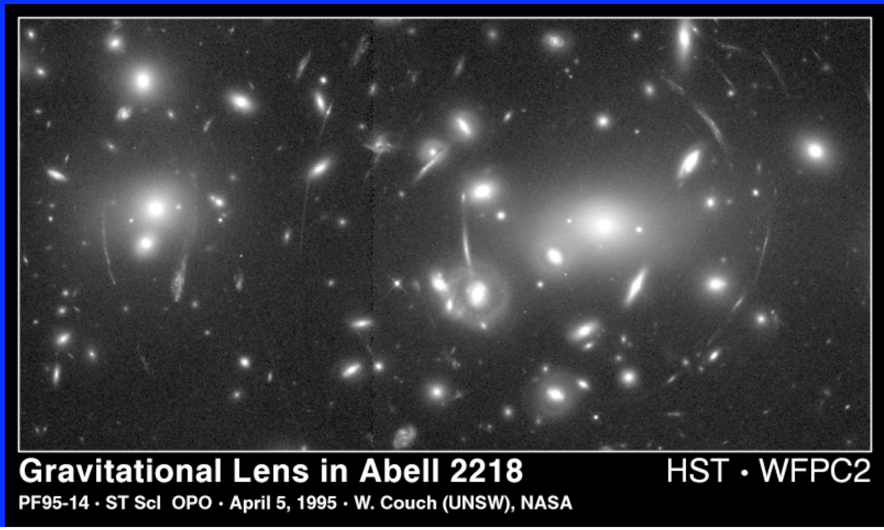
Cosmological N-body simulations (just finished; with L. Gao; V. Springel)

	Box size (Mpc/h)	Softening (kpc/h)	Time steps	N_p
LCDM	100	5	15000	1024^3(finished); Gadget2
LCDM	300	10	5000	1024^3 (z=0.1) P3M
LCDM	600	30	1200	1024^3 (finished)

Number of giant arcs in LCDM

- Using ray-tracing method to predict the number of giant arcs in LCDM;
- 512^3 particles in 300 Mpc/h box;
- Assuming sources with diameter of 0.5”;

Li, Guoliang, Mao, S., YPJ, Bartelmann, M. ,Kang, X., Meneghetti, M. astroph/0503172 (ApJ, submitted)



Lens Equations

- The lens mapping from the lens to source plane

$$\vec{y} = \vec{x} - \nabla\phi,$$

- the distortion of images

$$\frac{\partial y_i}{\partial x_j} = \begin{pmatrix} 1-\phi_{11} & -\phi_{12} \\ -\phi_{21} & 1-\phi_{22} \end{pmatrix}, \qquad (1)$$

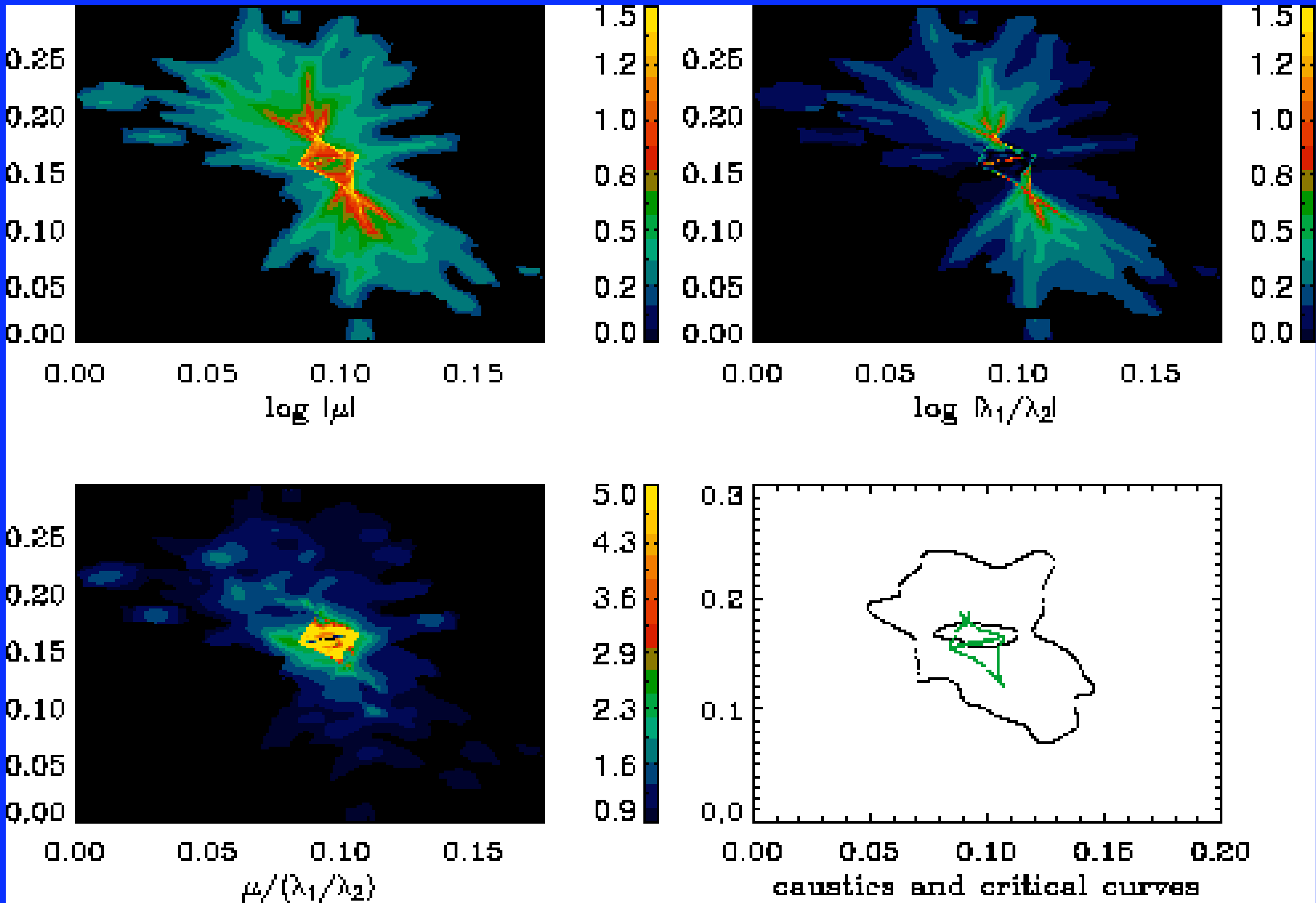
The eigenvalues of the Jacobian matrix are denoted as λ_1 and λ_2 ($|\lambda_1| \geq |\lambda_2|$)

- The (signed) magnification is

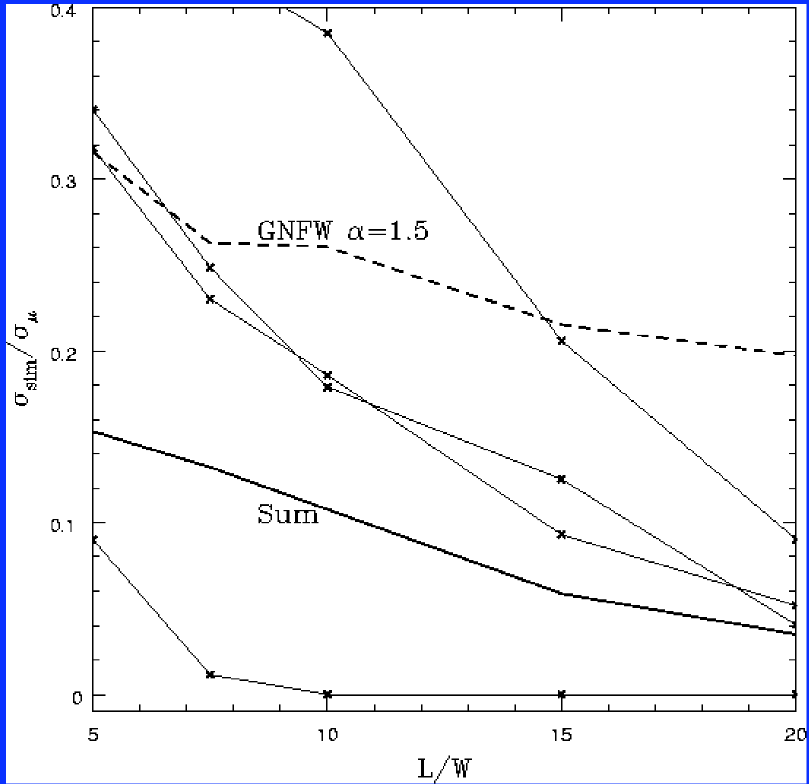
$$\mu = \frac{1}{\lambda_1 \lambda_2}.$$

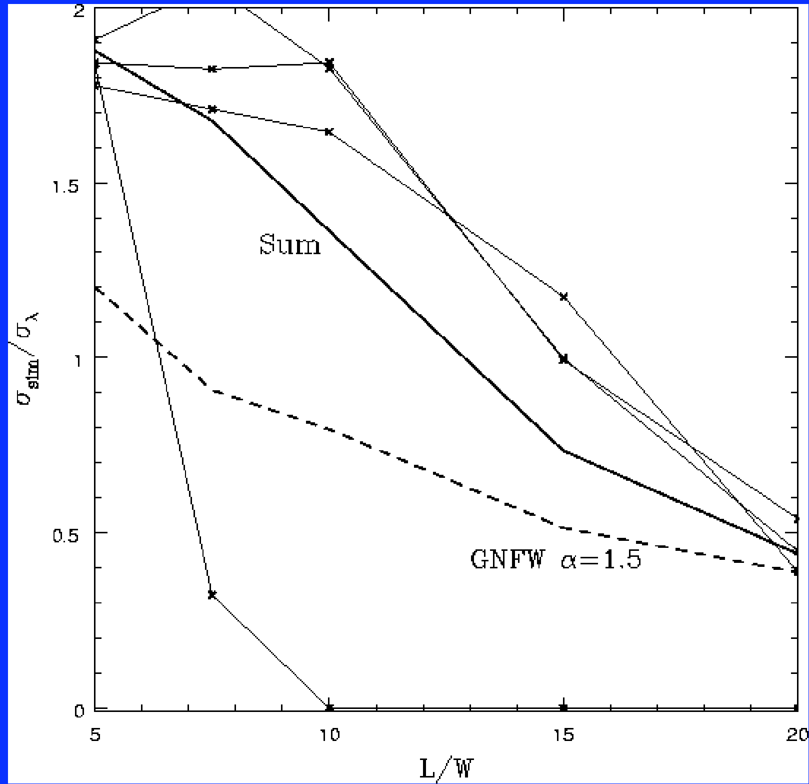
- For an infinitesimal circular source, L/W is simply given by

$$\frac{L}{W} = \frac{1/|\lambda_2|}{1/|\lambda_1|} = \lambda_1^2 |\mu|.$$



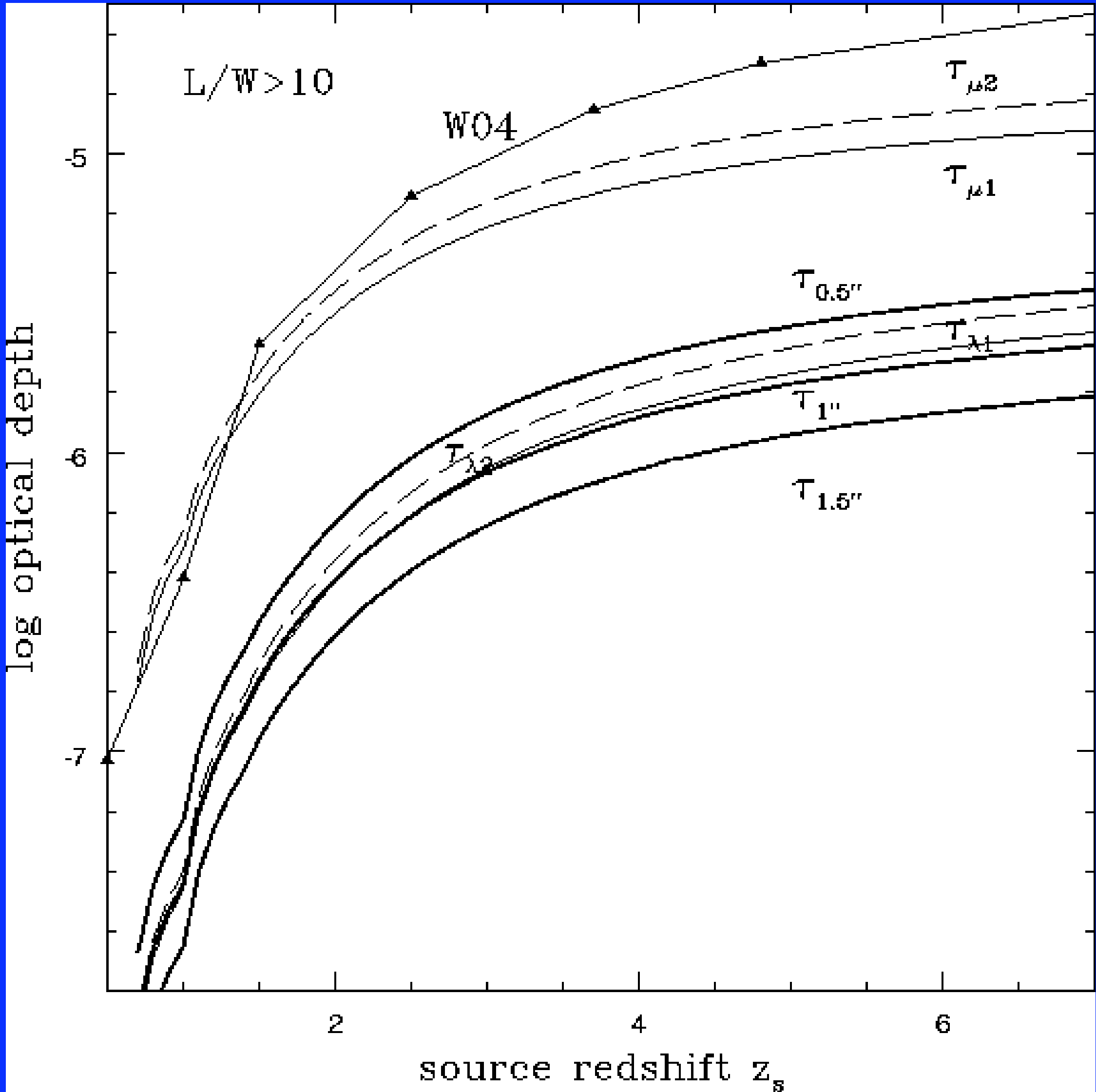
Magnification, ratio of eigenvalues, and their ratio (all on the source plane), and the caustics and critical curves





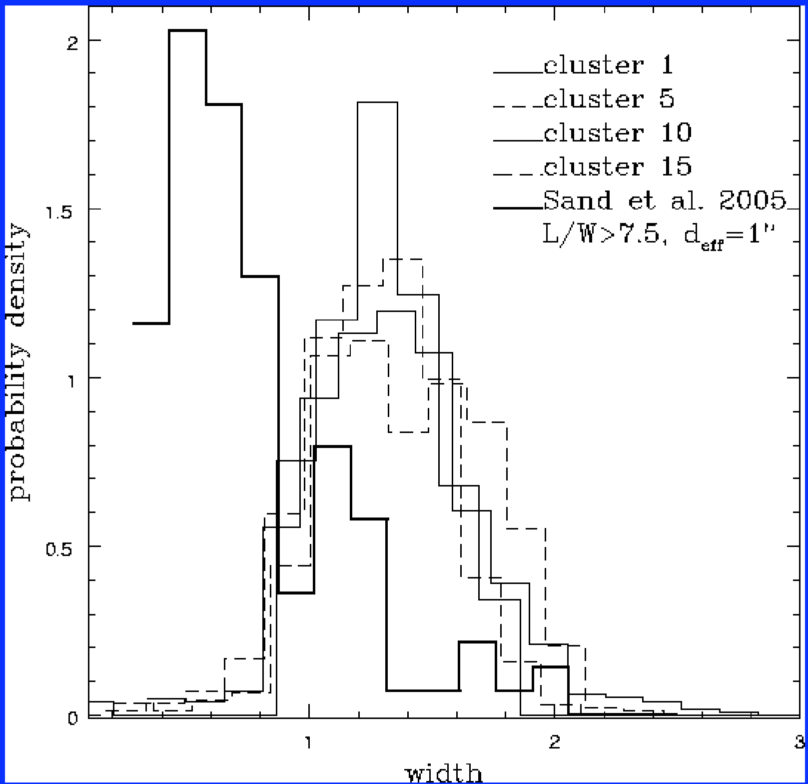
The ratio of the cross section obtained with ray-tracing (¶“$_{sim}$) to that of the approximation L/W=¶Ã(¶“$_{¶À}$)

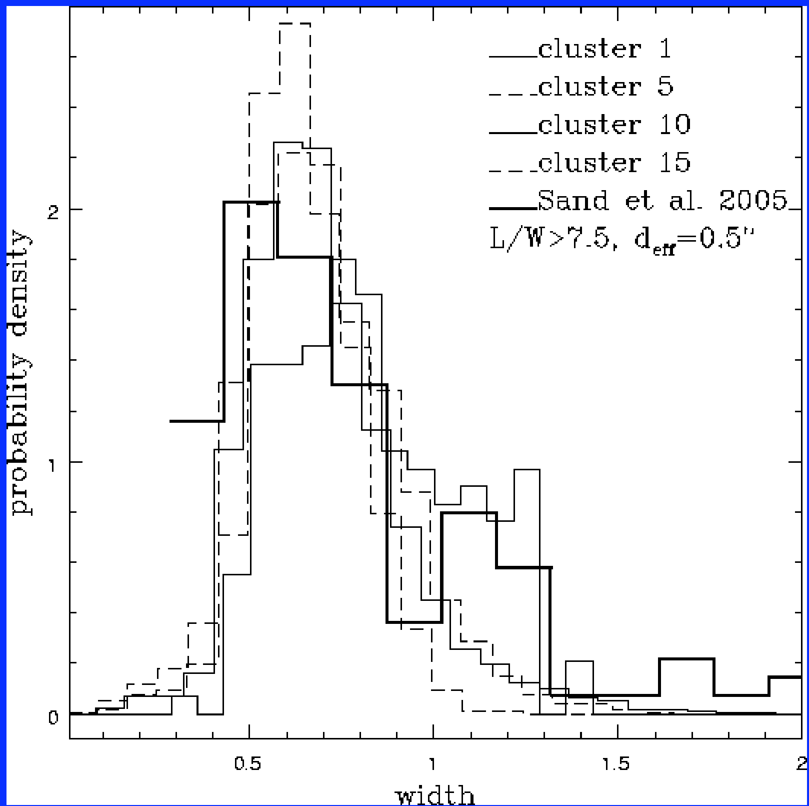
The ratio of the cross section obtained with ray-tracing (¶“$_{sim}$) to that of the approximation L/W=¶À/¶2À (¶“$_{¶À}$)



Lensing probability (optical depth) vs source redshift for giant arcs with L/W>10. The triangles are from Wambsganss et al. (2004) based on L/W=¶Ã overestimate!! L/W=¶À/¶À is much better

The diameter of the sources is 0.5” when compared with Sand et at (2005) collection.





Summary of modeling giant arcs

- With ray-tracing method, we found that the approximation L/W=¶Ã overestimates the cross section for giant arcs; L/W=¶À/¶2À is much better;
- The probability for producing giant arcs is an order of magnitude smaller in LCDM than observed; in contrast with Wambsganss et al. (2004)
- More work is needed in the LCDM, e.g. including gas cooling and star formation

Resolving discrepancies in literature

- Bartelmann et al. (1998): the cross-section for z_s=1 is a factor of 7 higher; because sigma_8=1.10 used;
- Wanbsganss et al. (2004): the cross-section is 5-10 times higher, because they used L/w=¶Ã(and sigma_8=0.95);
- Dalal et al. (2004): the cross-section is 5-10 times higher, because they got L/W by assuming rectangle for arcs (vs. ellipse in our model and in many observations)

Cosmological N-body simulations (just finished; with L. Gao; V. Springel)

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Hydro/N-body simulations (ongoing; in collaboration with V. Springel, L. Gao at MPA)

	Box size (Mpc/h)	Star formation	cooling	N_dm= N_gas
LCDM	100	yes	yes	512^3(z=2)
LCDM	100	no	no	512^3 (finished)

The simulations are run at the Shanghai supercomputer center (ShuGuang 4000; 2060 cpus; use 256 cpus)