Clustering of dark matter halos on the light-cone

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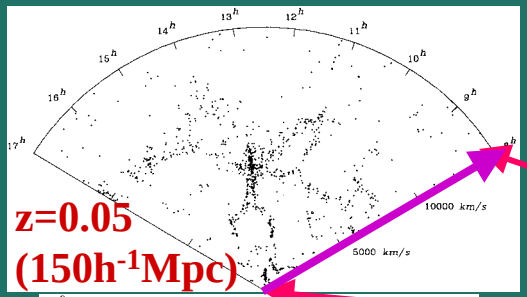
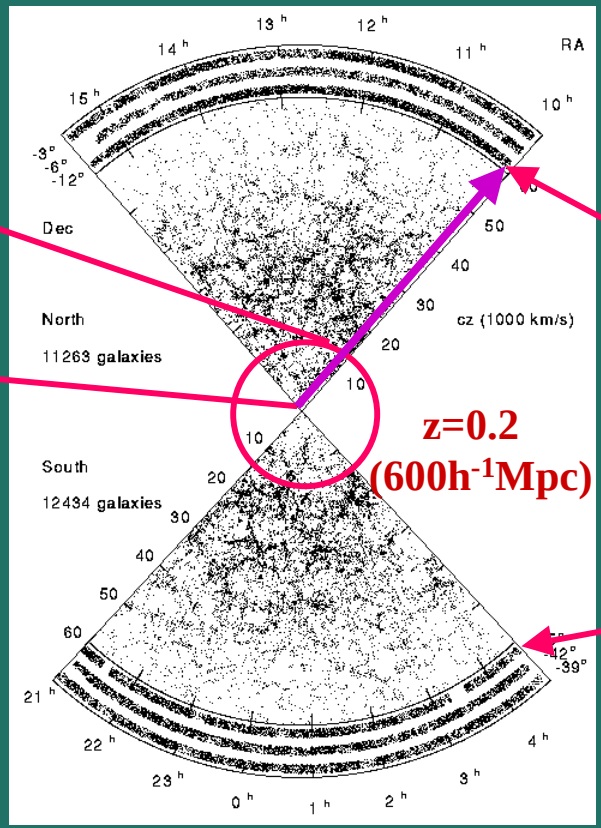
Clustering on the light-cone

1986



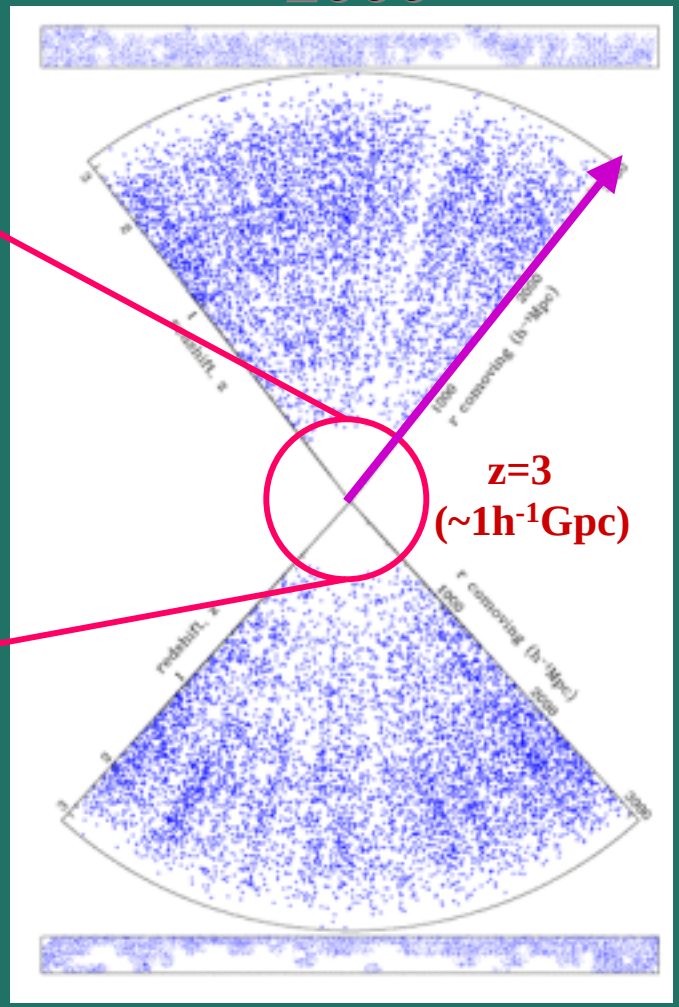
CfA redshift survey:
de Lapparent et al.(1986)

1996



Las Campanas redshift survey:
Schectman et al. (1996)

2000



2dF QSO survey: Shanks et al. (2000)

- ***Evolution along the light-cone is essential in the current surveys !***

Cosmological light-cone effects

- ***linear and nonlinear gravitational evolution***
- ***redshift-space distortion due to peculiar velocity***
  - linear distortion (the Kaiser effect)
  - nonlinear distortion (finger-of-god effect)
- ***evolution of objects on the light-cone***
  - number density (magnitude-limit, luminosity function, etc.)
  - object-dependent biasing relative to mass distribution
- ***observational selection function***
  - magnitude-limit and luminosity function
  - shape of the survey boundary

Matsubara, Szapudi & Suto (1997); Mataresse et al. (1997)
Yamamoto & Suto (1998); Suto, Magira, Jing, Matsubara & Yamamoto (1999)

Predicting clustering on the light-cone

- ***redshift-space distortion***

$$\xi(r;z) = \frac{1}{2\pi^2}\int_0^\infty k^2 dk P_{nl}^R(k,z)\, f(k,\beta,\sigma_{\rm 1D,vel})\frac{\sin kr}{kr}$$

gravitational nonlinear evolution

linear and nonlinear redshift-space distortion

- ***average over the light-cone***

$$\xi^{LC}(r) = \frac{\int_{z_{\rm min}}^{z_{\rm max}} dz\, \xi(r;z)[\phi(z)n(z)]^2 \frac{dV_c}{dz}}{\int_{z_{\rm min}}^{z_{\rm max}} dz\, [\phi(z)n(z)]^2 \frac{dV_c}{dz}}$$

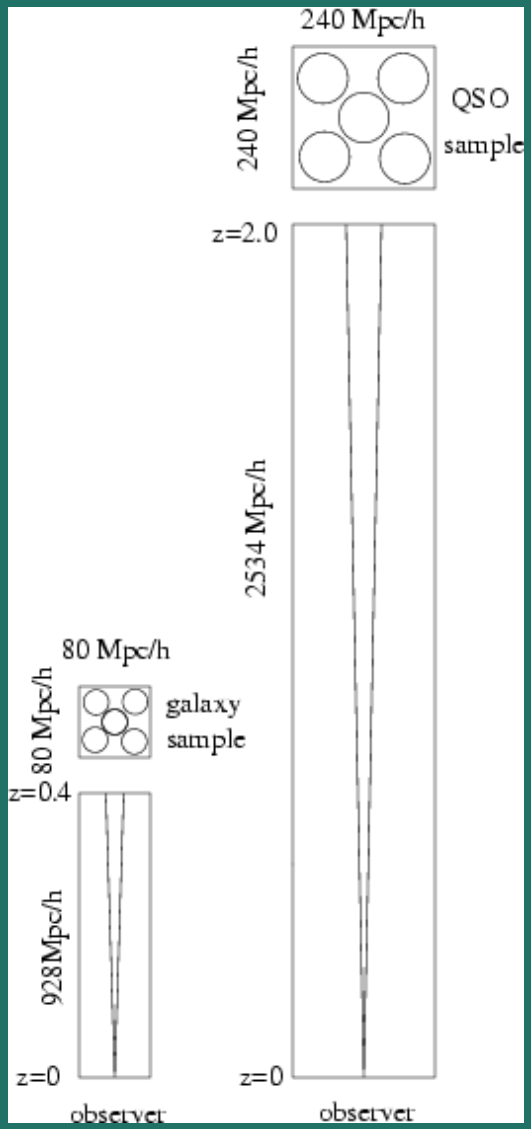
comoving volume element

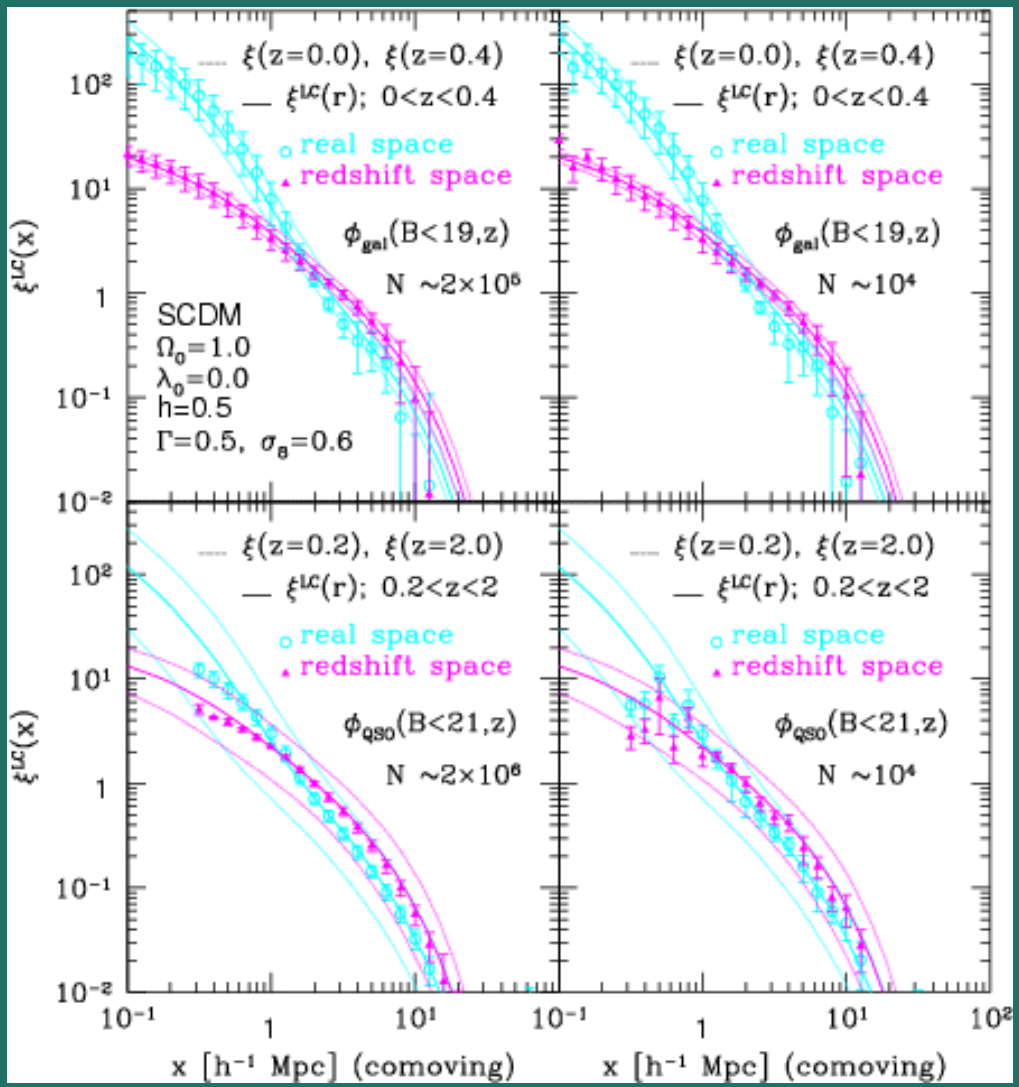
selection function

mean number density

Hamana, Colombi & Suto (2001)

Correlation functions of dark matter on the light-cone

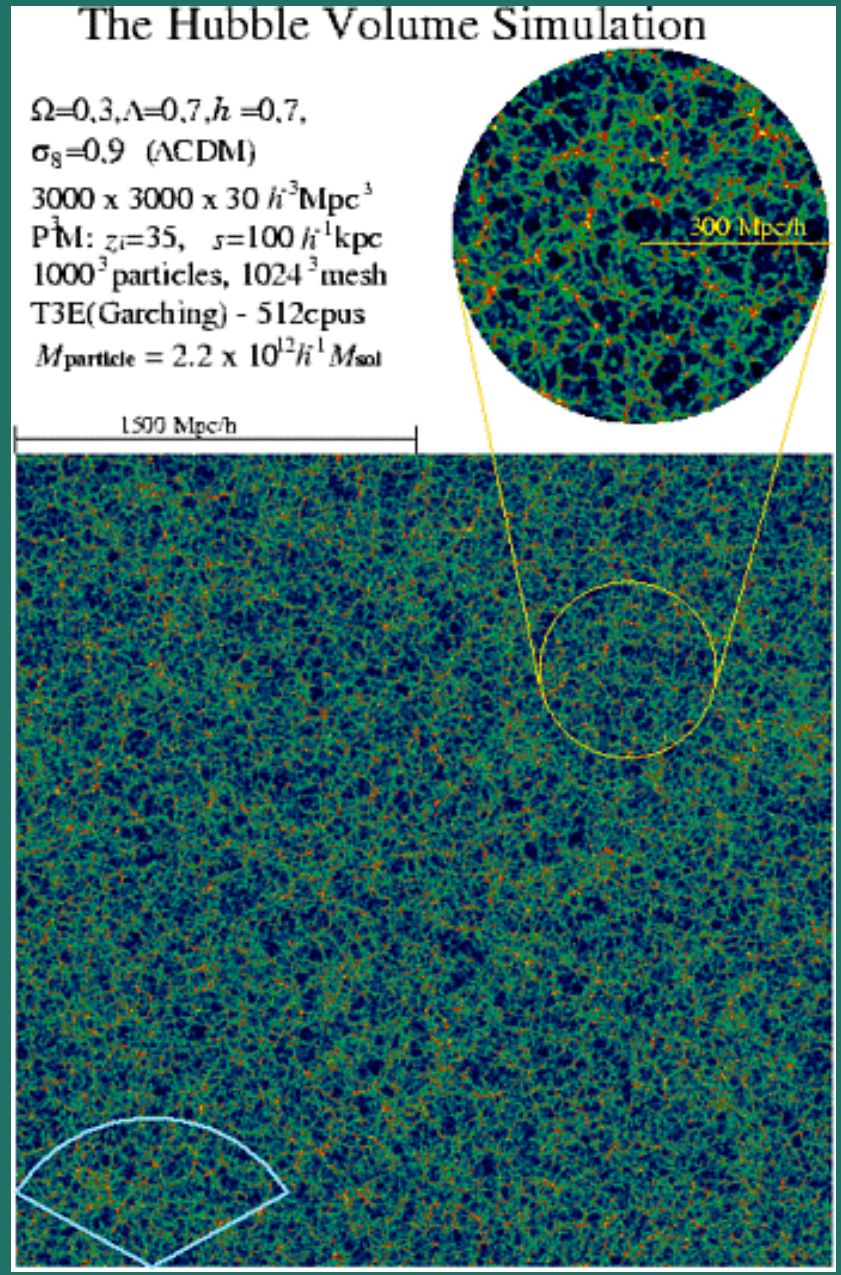




Hamana, Colombi & Suto (2001)

Hubble volume simulation

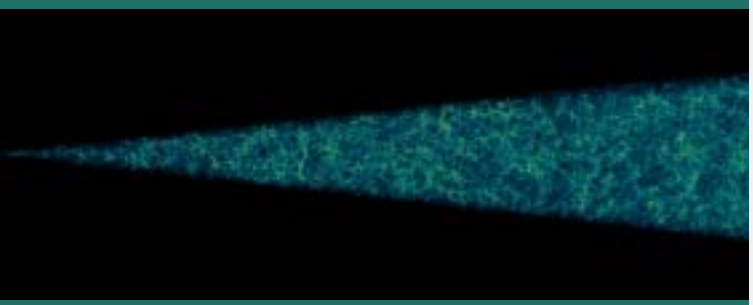
- P^3M N-body simulation
- $N=10^9$ particles in a $(3000h^{-1}Mpc)^3$ box
- **Λ**CDM: $\Omega_0=0.3$, $\lambda_0=0.7$, $h=0.7$, $\sigma_8=0.9$
- $m_{particle}=2.2\times10^{12}h^{-1}M_{sun}$
- $\varepsilon_{grav}=100h^{-1}kpc$

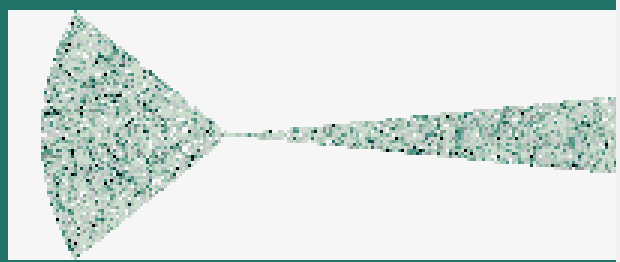


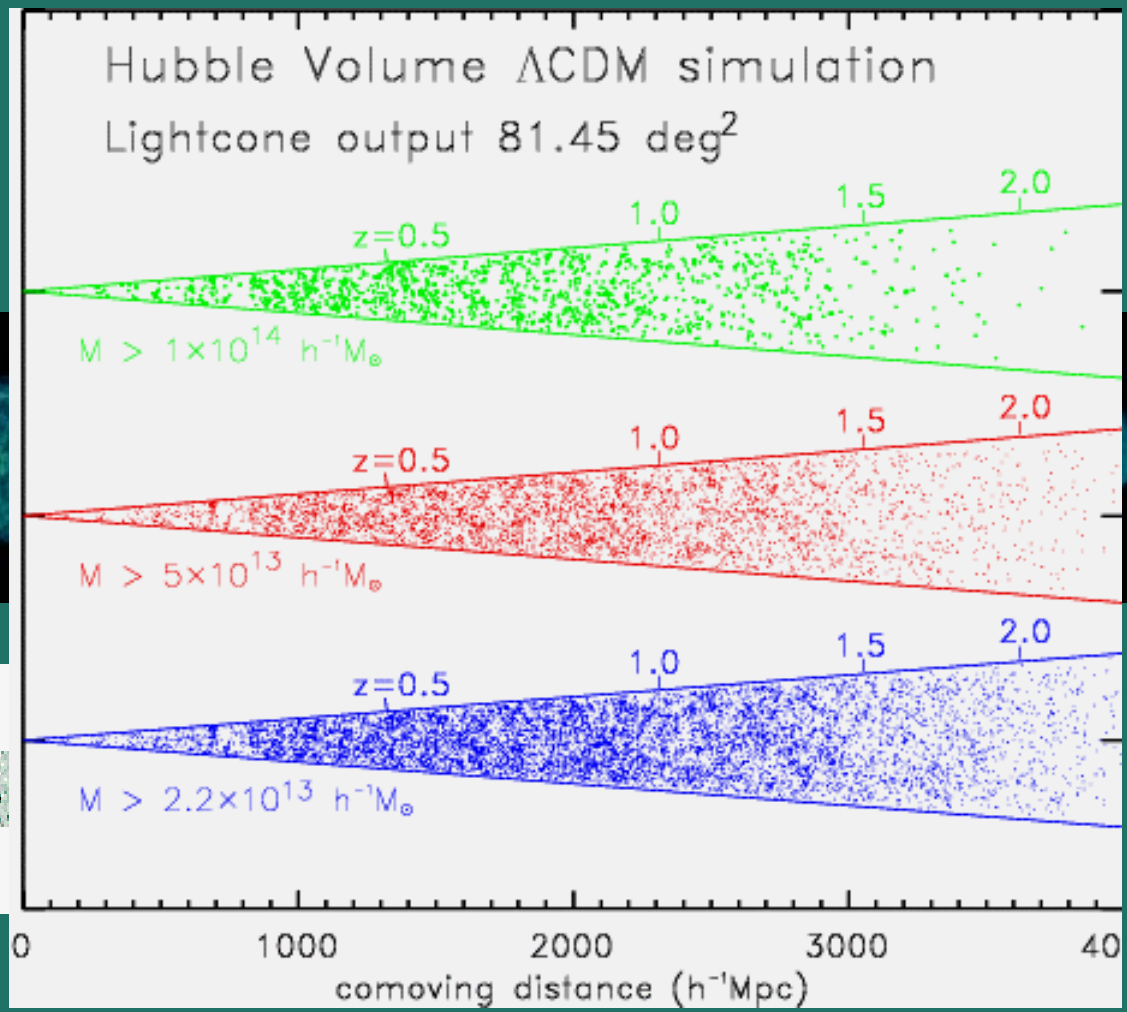
The Virgo Consortium
http://www.physics.isa.umich.edu/hubble-volume/

Light-cone output from the Hubble volume LCDM simulation

http://www.physics.isa.umich.edu /hubble-volume/ lightcones.htm

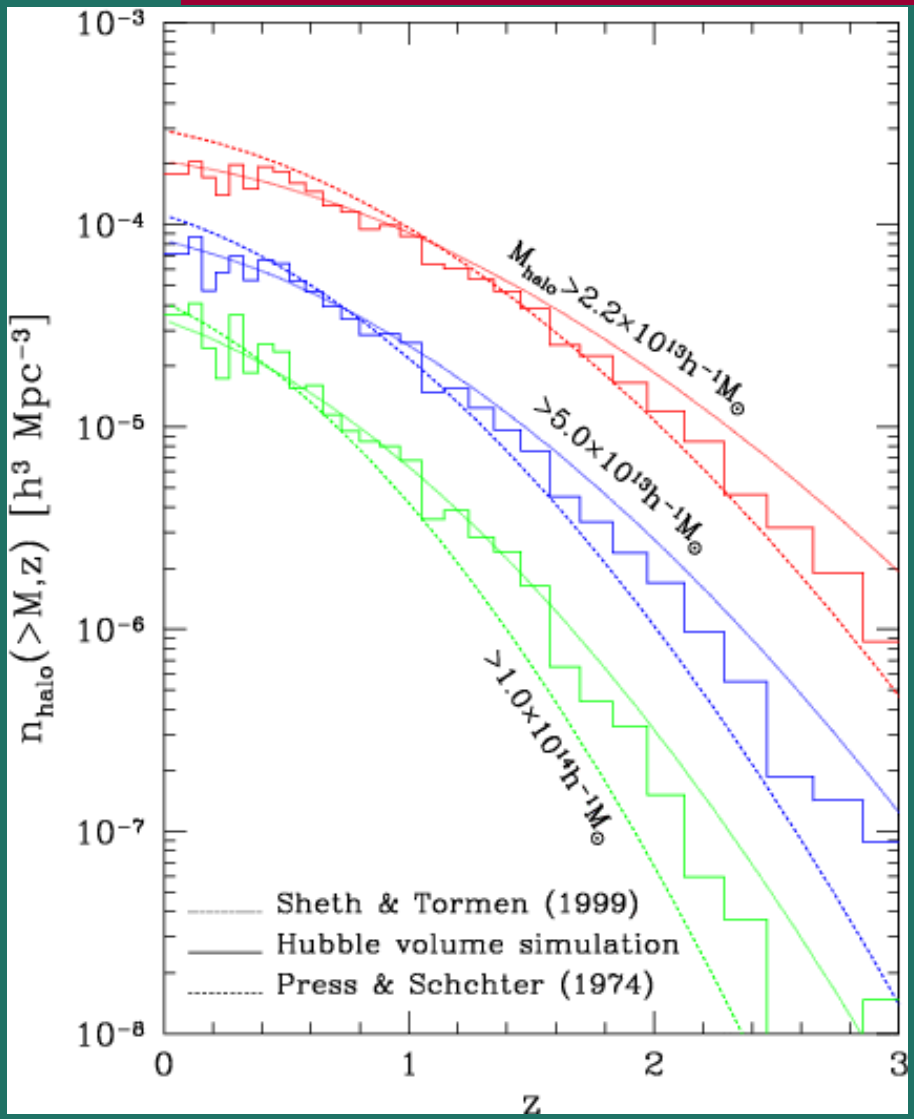






Hamana, Yoshida, Suto & Evrard (2001)

Mass function of dark halos



- an analytical mass function of Press & Schechter (1974) underpredicts, while an empirical correction by Sheth & Tormen (1999) overpredicts, the Hubble volume simulation data at high mass.

Hamana, Yoshida, Suto & Evrard (2001)

a phenomenological model for scale- and mass-dependent halo biasing

- ***mass-dependence (Jing1998;Sheth & Tormen 1999) + scale-dependence (Taruya +YS 2000) in halo biasing***

$$b_{halo}(M,R,z) = b_{\rm ST}(M,z)[1 + b_{\rm ST}(M,z)\sigma_{\rm mass}(R,z)]^{0.15}$$

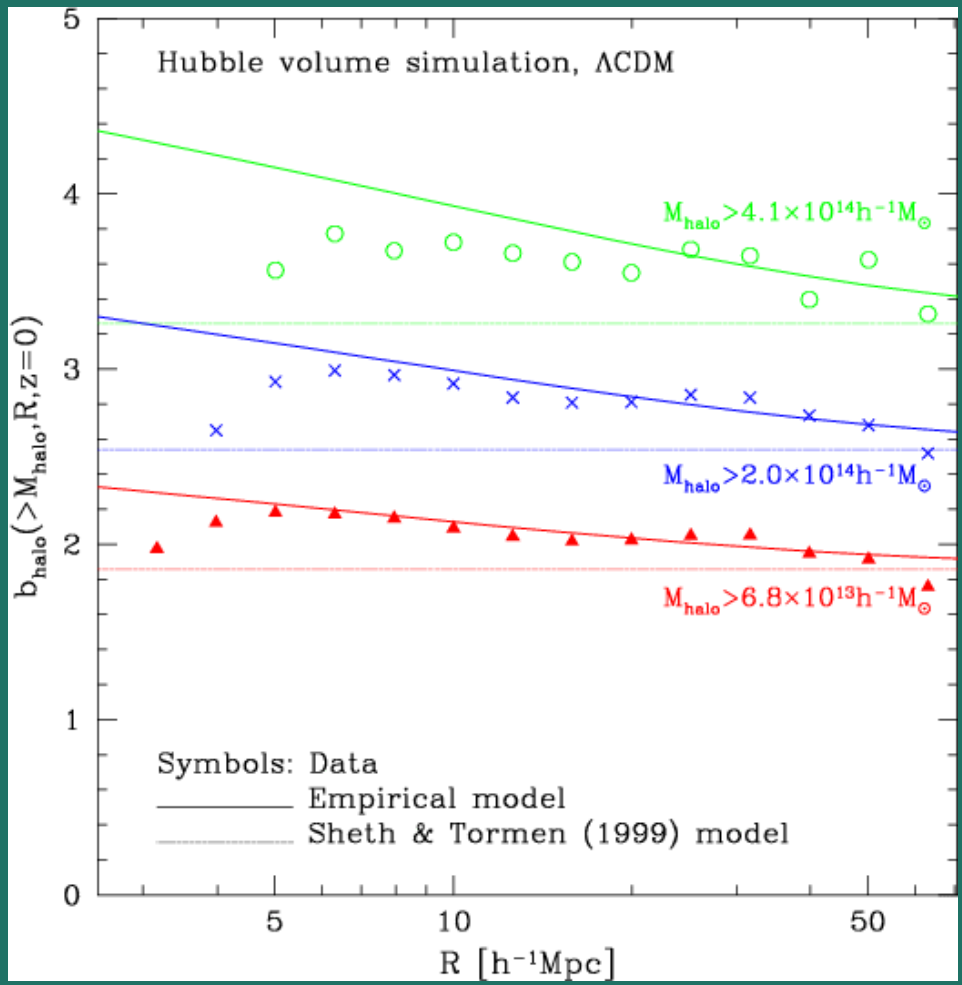
$$\xi_{halo}(M,R,z) = b_{halo}^2(M,R,z)\,\xi_{\rm mass}(R,z)$$

- ***average over the light-cone***

$$\xi_{halo}^{LC}(>M,r) = \frac{\displaystyle\int_{z_{\rm min}}^{z_{\rm max}} dz \int_M^\infty dM \xi_{halo}(M,R,z) n_{\rm ST}^2(M,z) \frac{dV_c}{dz}}{\displaystyle\int_{z_{\rm min}}^{z_{\rm max}} dz \int_M^\infty dM\; n_{\rm ST}^2(M,z) \frac{dV_c}{dz}}$$

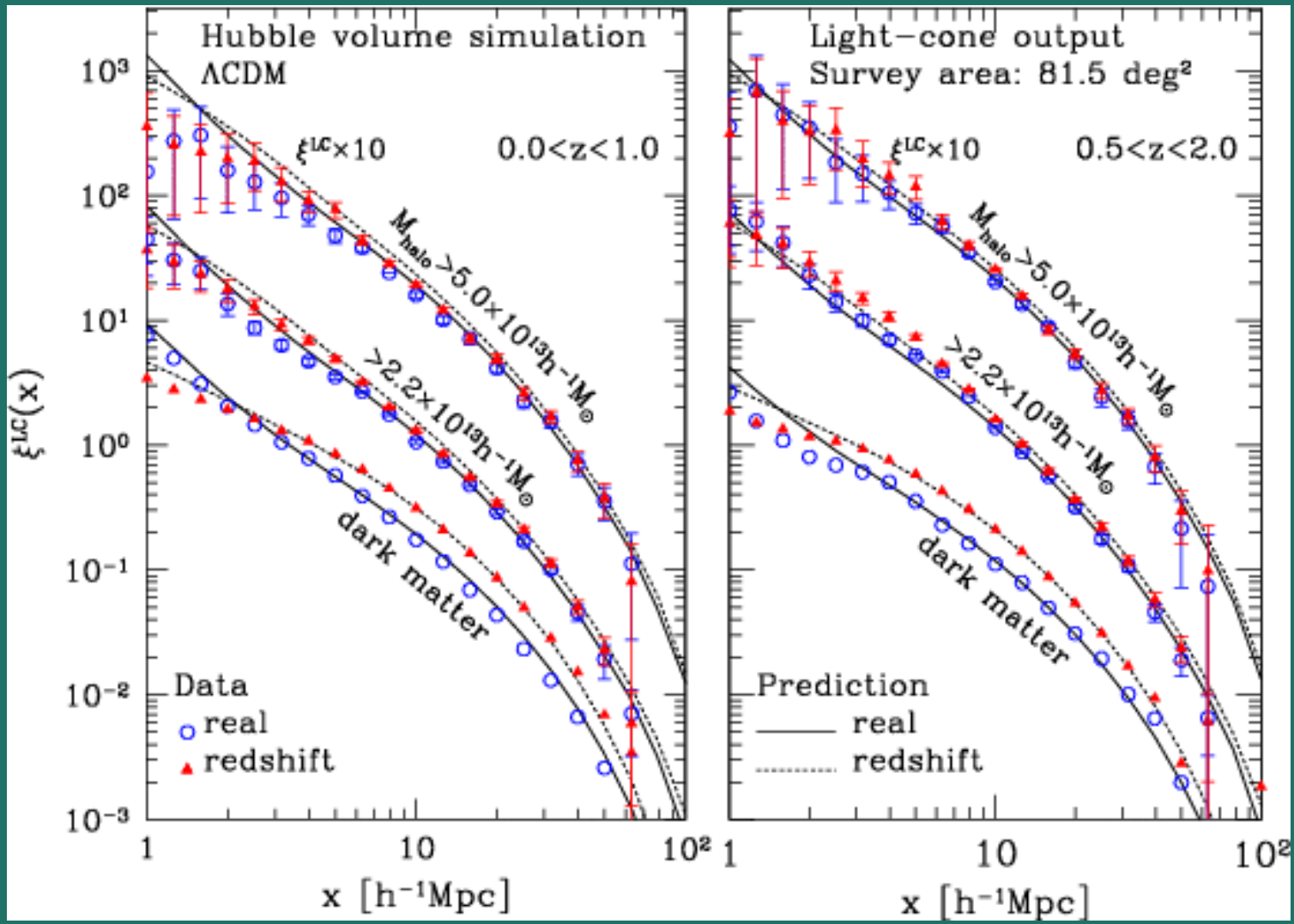
Hamana, Yoshida, Suto & Evrard (2001)

Scale- and mass-dependent halo biasing



Hamana, Yoshida, Suto & Evrard (2001)

Correlation functions of halos on the light-cone



Hamana, Yoshida, Suto & Evrard (2001)

Conclusions

- We have developed a phenomenological model to describe the clustering of dark matter halos on the light-cone.
- Our model shows a reasonable agreement with the halo catalogue from the Hubble volume LCDM simulation.
- We are working on an application of the halo clustering model to that of X-ray clusters and QSOs.

A brief history of Gerhard Boerner from Japanese side

- born on April 20, 1941
- got a ph.D in particle physics (superviser: Werner Heisenberg)
- stayed in Kyoto, Japan as a post-doc at Yukawa Hall (director: Hideki Yukawa)
- wrote a first paper in astrophysics with Hans Bethe and Katsuhiko Sato (= my thesis superviser)
- his brilliant post-doc at MPIA (=Yipeng Jing) joined my group at Tokyo in 1997-2000
- a visiting professor at University of Tokyo in February and March,2001 which led to a first joint paper with me (Jing, Boerner & YS) on PSCz survey in March 2001

論語 卷第二學而第四章

A great Chinese philosopher, Confucius (孔子), was born in 551, B.C. at 中国山東省曲阜.

子曰、吾十有五而志于學、三十而立、四十而不惑、五十而知天命、六十而耳順、七十而從心所欲不踰矩。

Konfuzius sprach:
„Mit fünfzehn war ich begierig zu lernen.
Mit dreißig festigte ich meine Position.
Mit vierzig hatte ich keine falschen Vorstellungen.
Mit fünfzig kannte ich mein Schicksal.
Mit sechzig wußte ich die Wahrheit aus allem herauszuhören.
Mit siebzig konnte ich den Wünschen meines Herzens folgen,
ohne dabei Unrecht zu tun.“

還暦: 十干×十二支=六十干支

- ***十干: old Chinese view of the world***
  - **甲乙丙丁戊己庚辛壬癸**
  - correspond to 5 elements (wood, fire, land, metal, water) × 2 sides (front, back) = 10 combinations
  - note that this idea already realized the necessity of the ``quintessence'' unlike the ancient Greeks (air, earth, fire, water), and in fact 5 solar planets were named after them
- ***十二支: old Chinese calendar***
  - **子丑寅卯辰巳午未申酉戌亥**
  - corresponds to 12 animals (mouse, horse, tiger, rabbit, dragon, snake, cow, sheep, monkey, hen, dog, pig)
- ***Each year is labeled by a pair of 十干 and 十二支***
  - 2001(**辛巳**metal snake), 2002(**壬午**water horse),,,
- This labeling has a periodicity of 60 years, and therefore the 60th birthday has a very special meaning.

Wearing a red vest at the 60th birthday

- 60 years old = 0 year old (mod 60 years)
- a 0 year-old baby looks red ; actually a Japanese word for a baby is ``aka-chan'' (**赤ちゃん**) meaning a red kid.
- Thus it is customary in Japan (how about in China ?) to celebrate a 60th birthday (return calendar: **還暦**) by wearing something red, often a red vest.

Congratulations for beginning another cycle of 60 years, Gerhard !

有朋自遠方来、
不亦楽乎