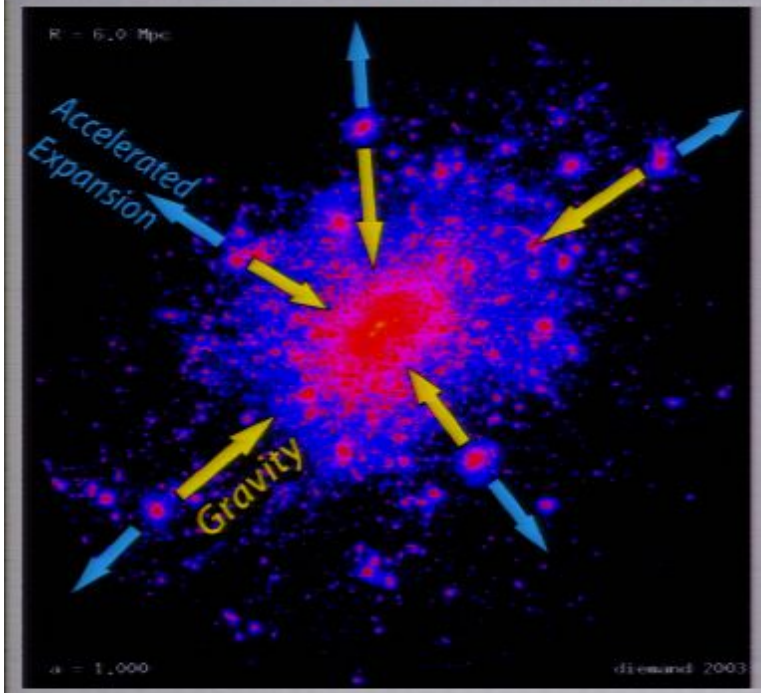
Title: Recent advances and future challenges for using galaxy clusters in cosmology

Date: Apr 29, 2010 09:00 AM

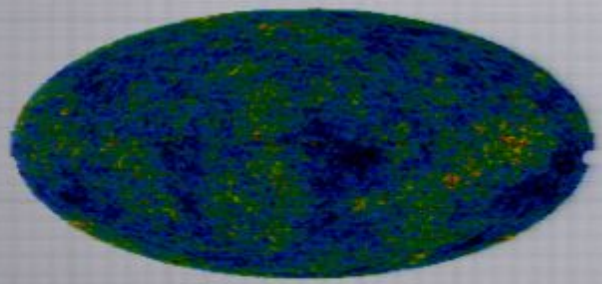
URL: http://pirsa.org/10040096

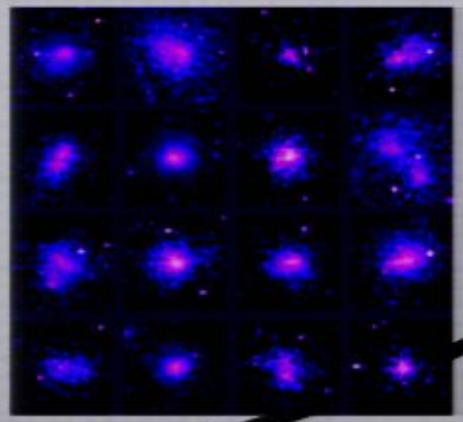
Abstract: X-ray surveys and deep Chandra observations recently provided ~10% accurate measurements of the total mass in nearly 100 galaxy clusters at z=0-0.9. These data clearly show the effect of Dark Energy on slow-down of the structure growth at z<1. THe combination of the structure growth measurements with other cosmological observations substantially improves the constraints on the Dark Energy equation of state parameter. More advanced applications include constraints on the deviations from General Relativity on 10-100 Mpc scales. Will the situation improve in the future when samples of 10^3-10^5 clusters are available? I will review the current "bottlenecks", and discuss possible strategies for using future cluster data for "precision cosmology".

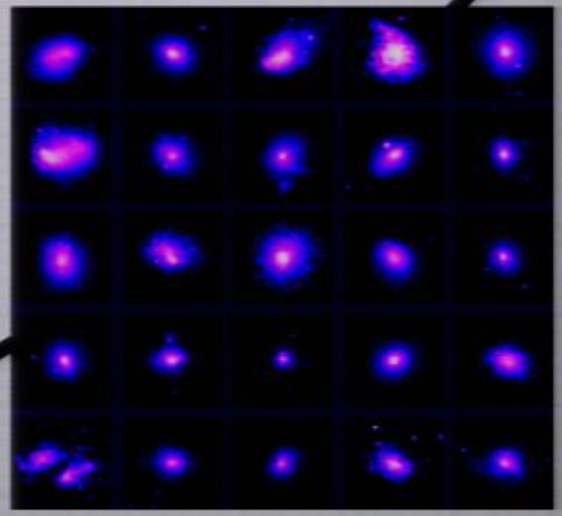


RECENT ADVANCES AND FUTURE CHALLENGES FOR USING GALAXY CLUSTERS IN COSMOLOGY

A.VIKHLININ





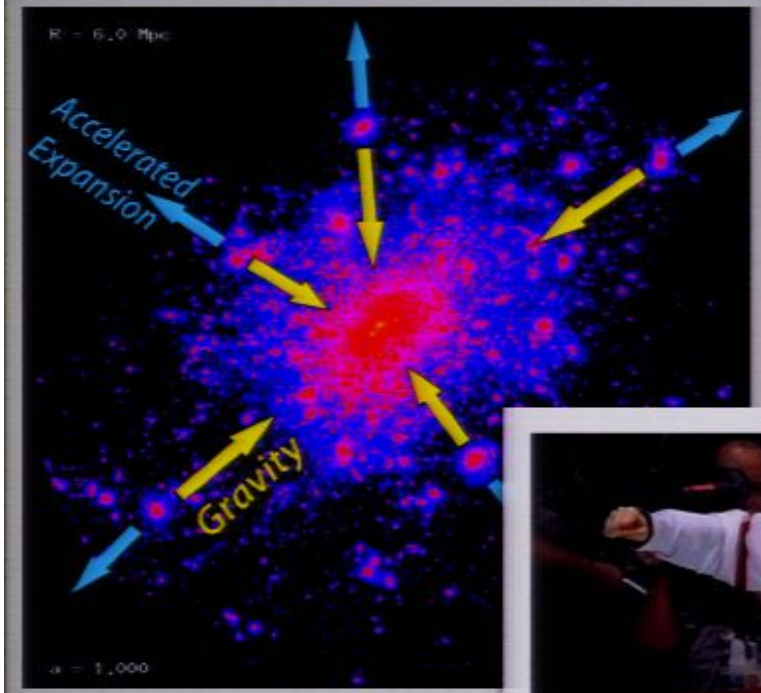


Dark Energy fraction

Time

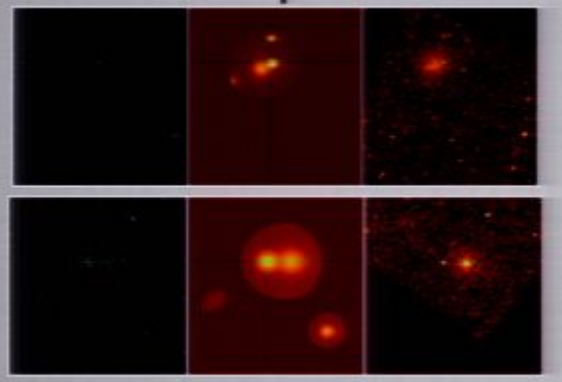
$z = 1000$ $z = 0.5$ $z = 0$

RECENT ADVANCES AND FUTURE CHALLENGES FOR USING GALAXY CLUSTERS

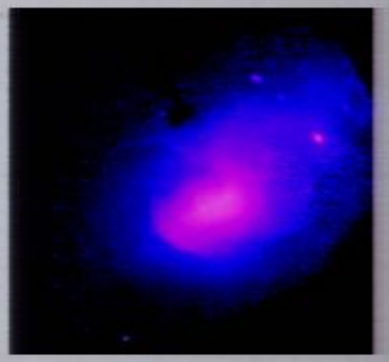


X-RAY COSMOLOGY: CURRENT STATE

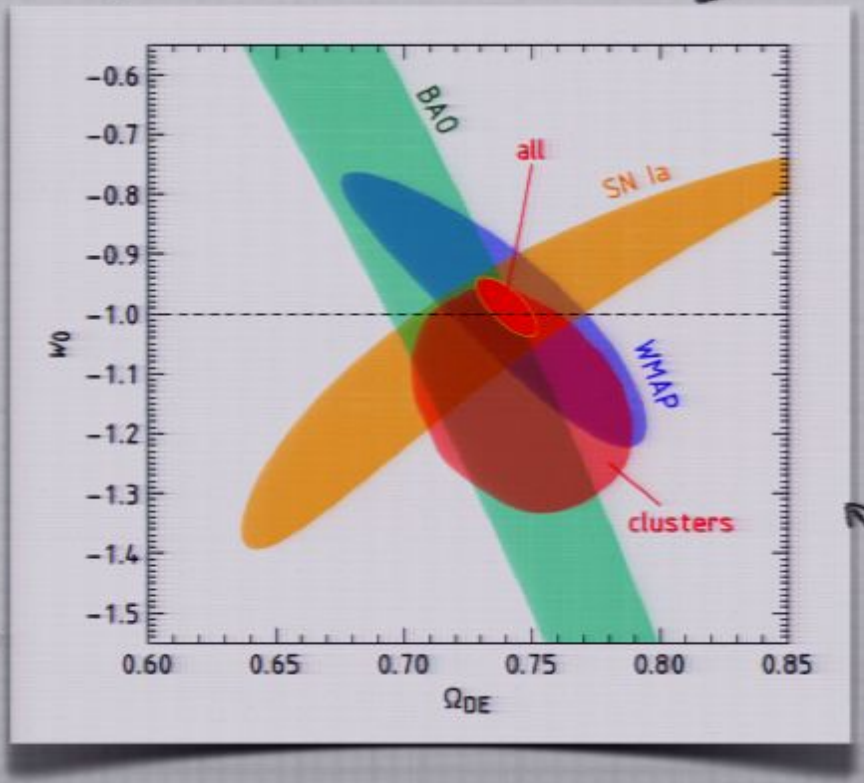
Cluster samples: *ROSAT*



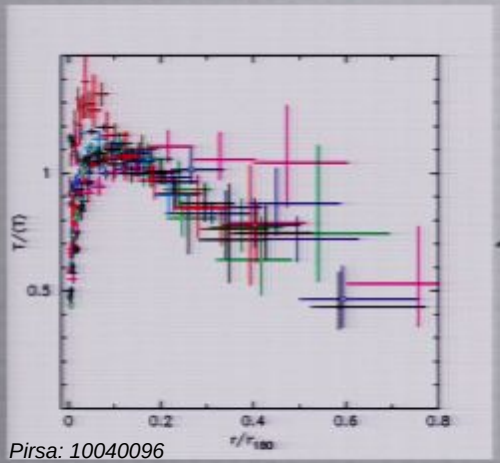
Cluster physics:
Chandra & simulations



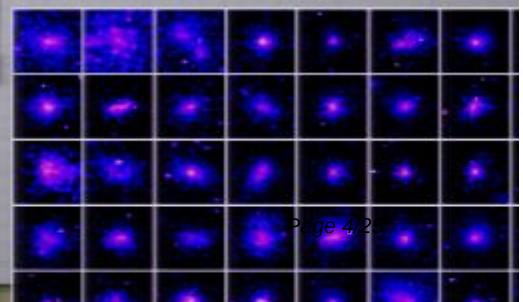
Dark Energy
constraints



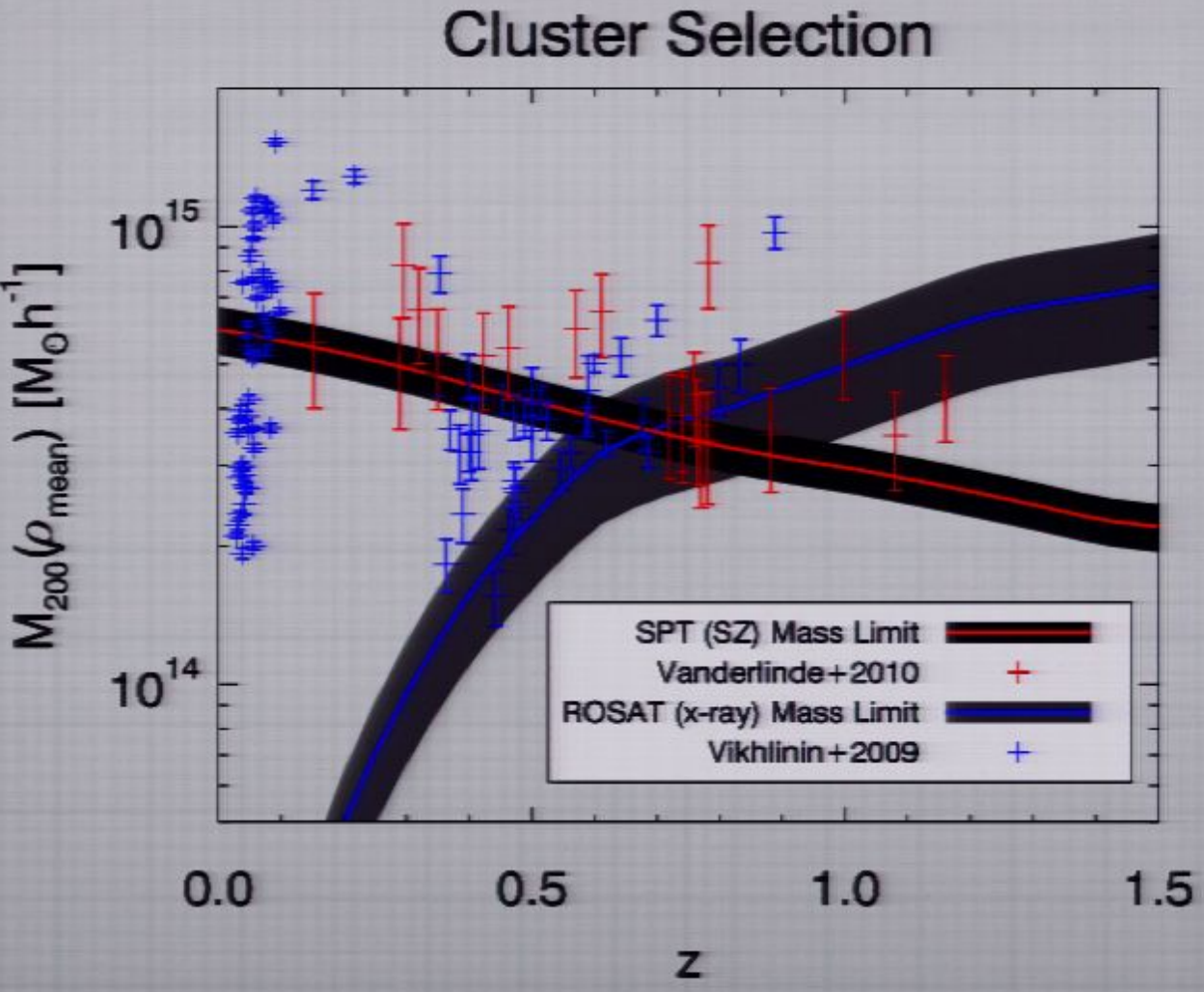
Detailed properties:
Chandra & *XMM*



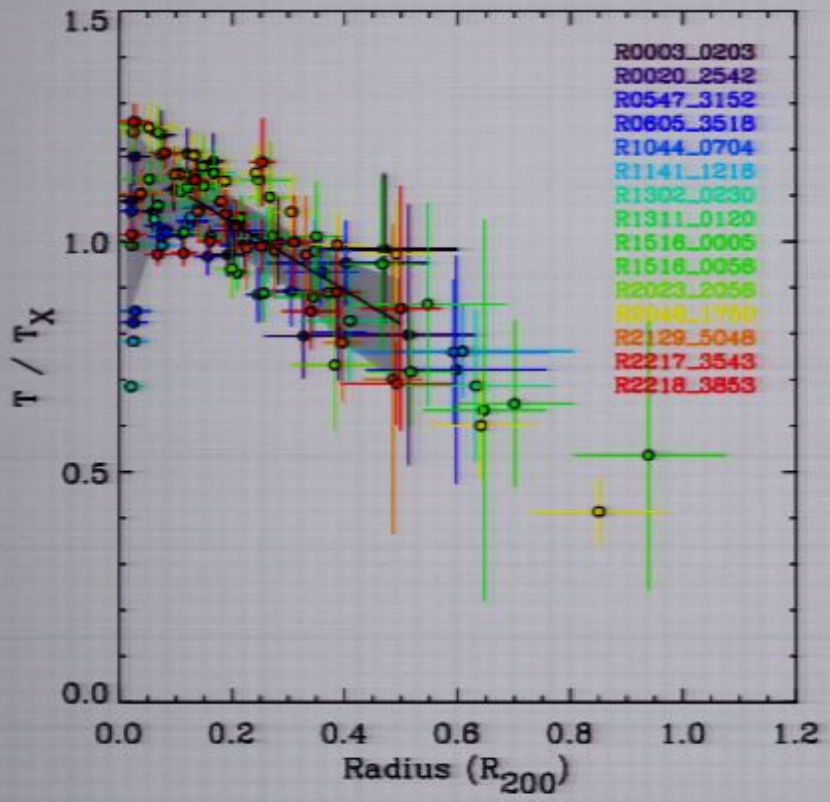
Sensitivity: *Chandra*

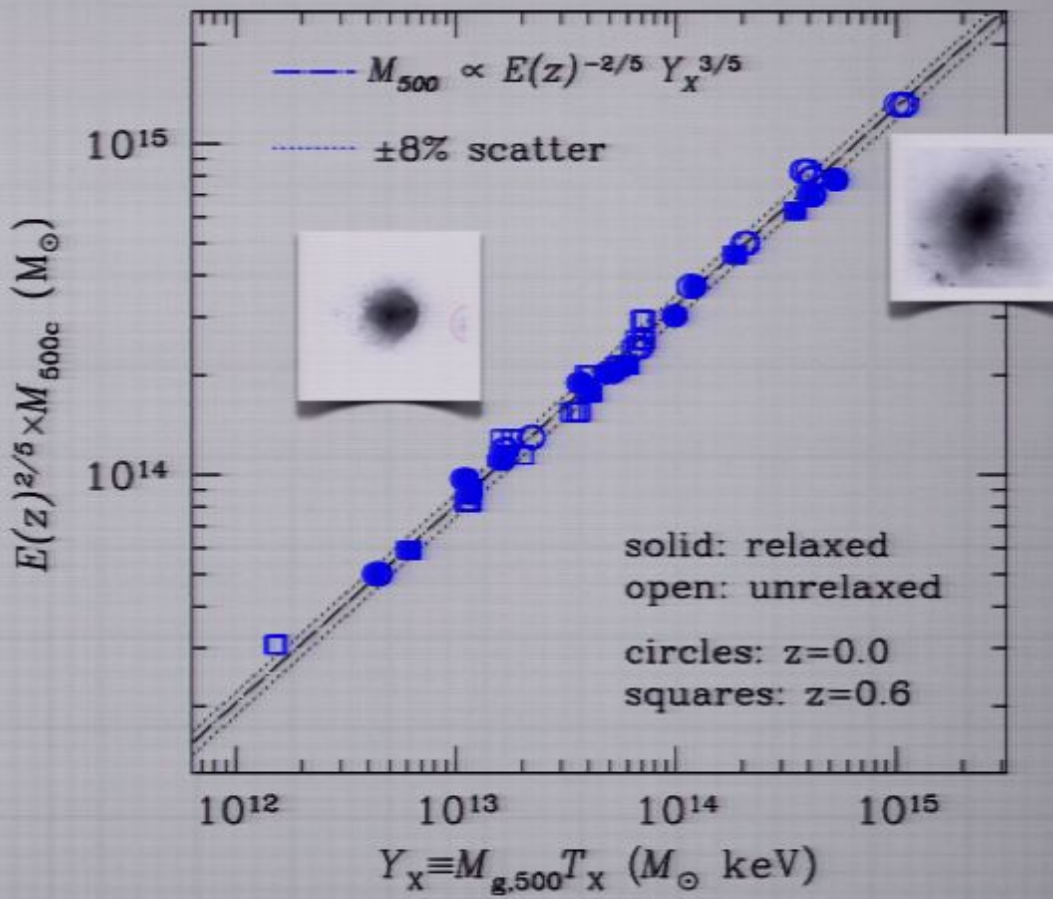


CLUSTER SELECTION



DETAILED DATA, NEW MASS PROXIES





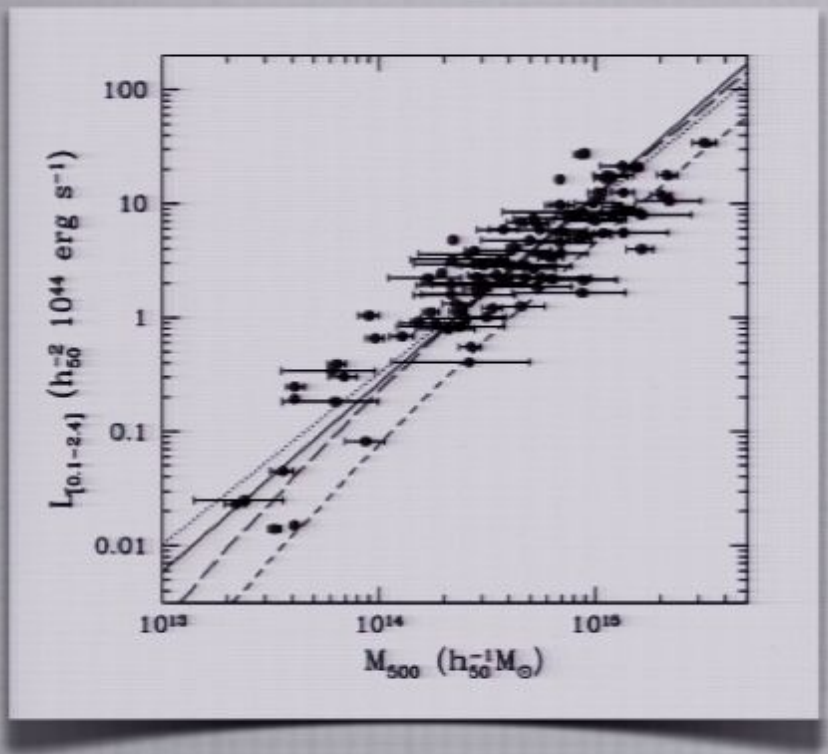
- **Detailed $T(r)$, $\rho(r)$ measurements**

  Pointecouteau '05, V06, Pratt et al. '07

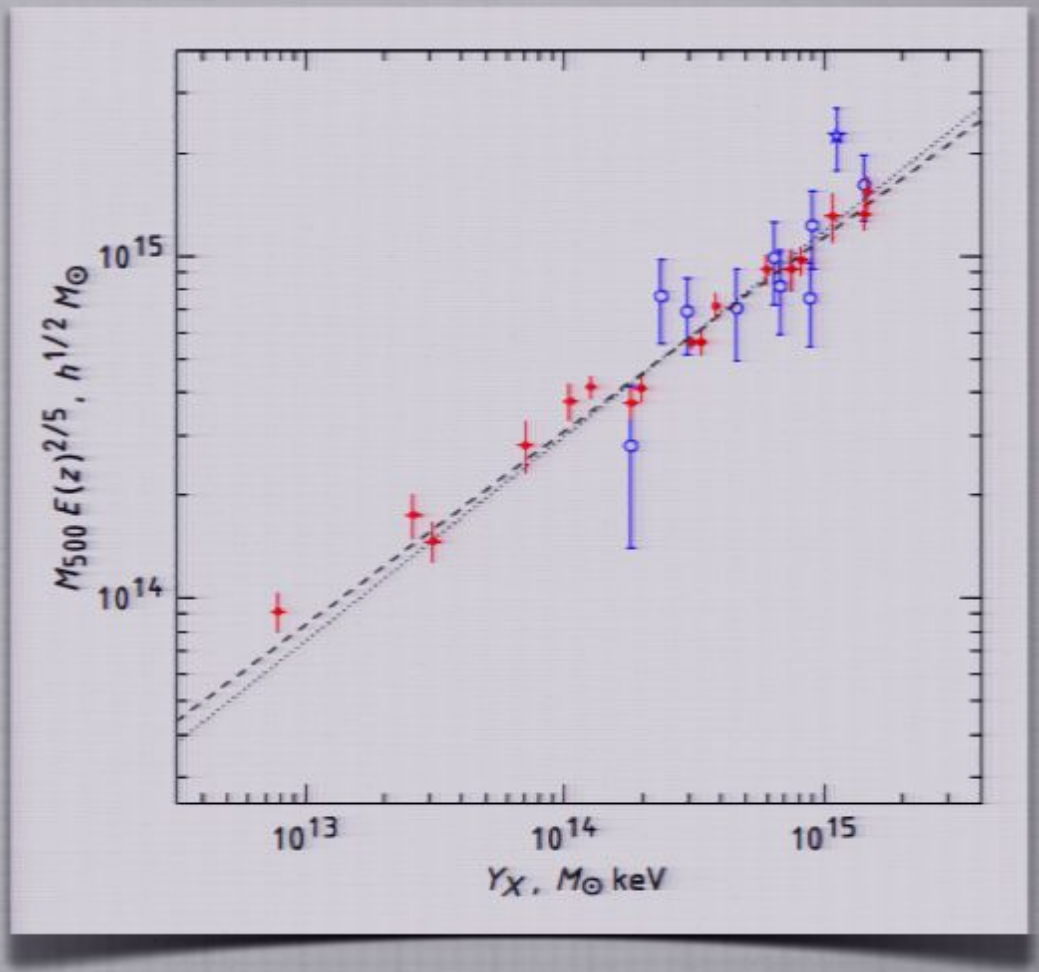
- **New M_{tot} proxies (simulations)**

  Kravtsov, Nagai, A.V.

MASS CALIBRATION



Before *Chandra*

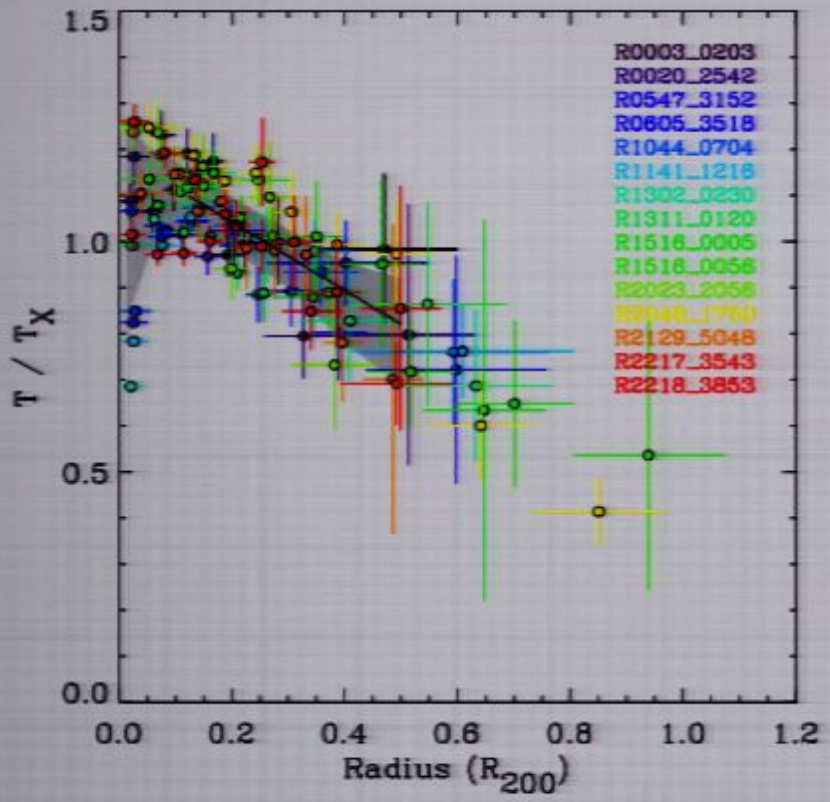


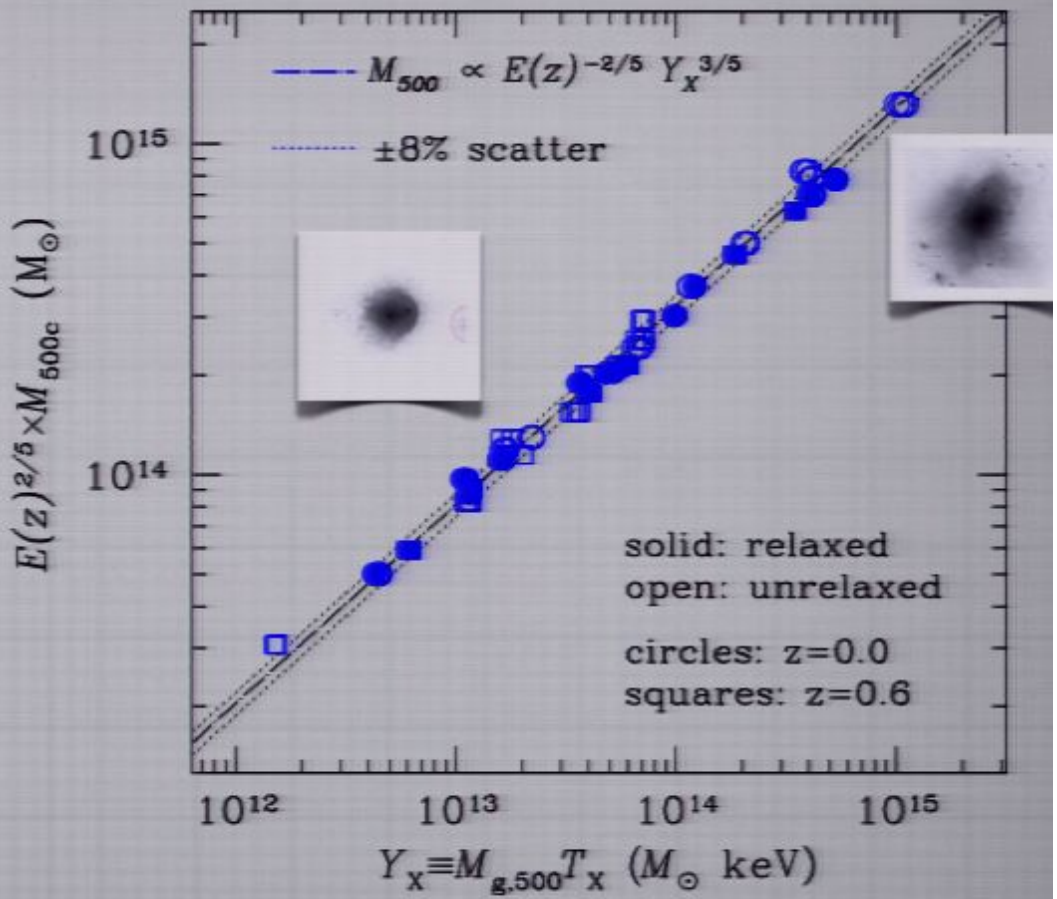
• – *Chandra*, hydrostatic ○ – Weak lensing, Hoekstra '07

Systematic errors:

$\Delta M/M < 9\%$ at $z=0$ $\qquad M/Y^{0.6} \sim E(z)^{-2/5} \pm 5\%$ at $z=0.5$

DETAILED DATA, NEW MASS PROXIES





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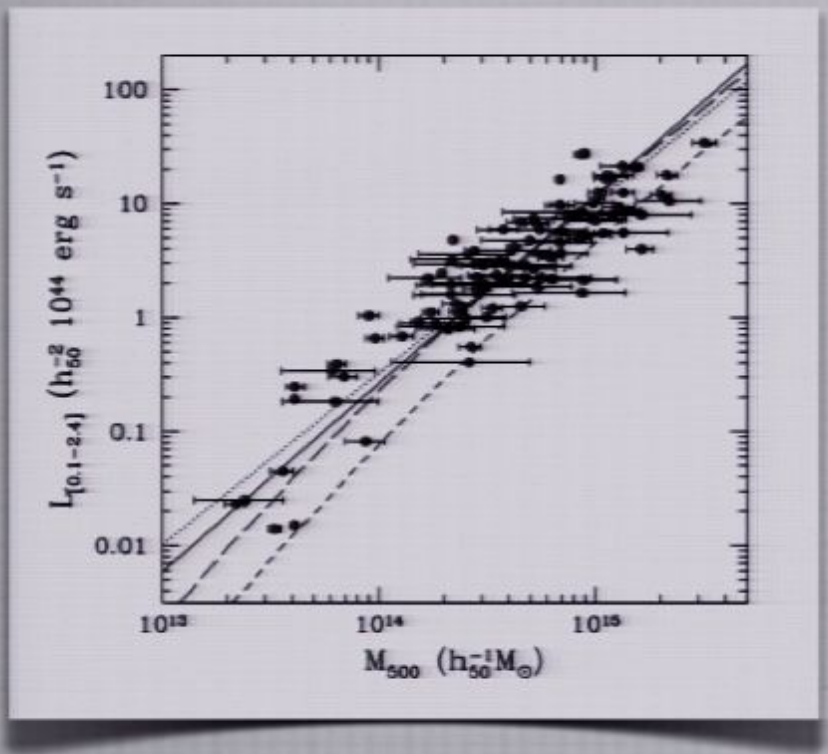

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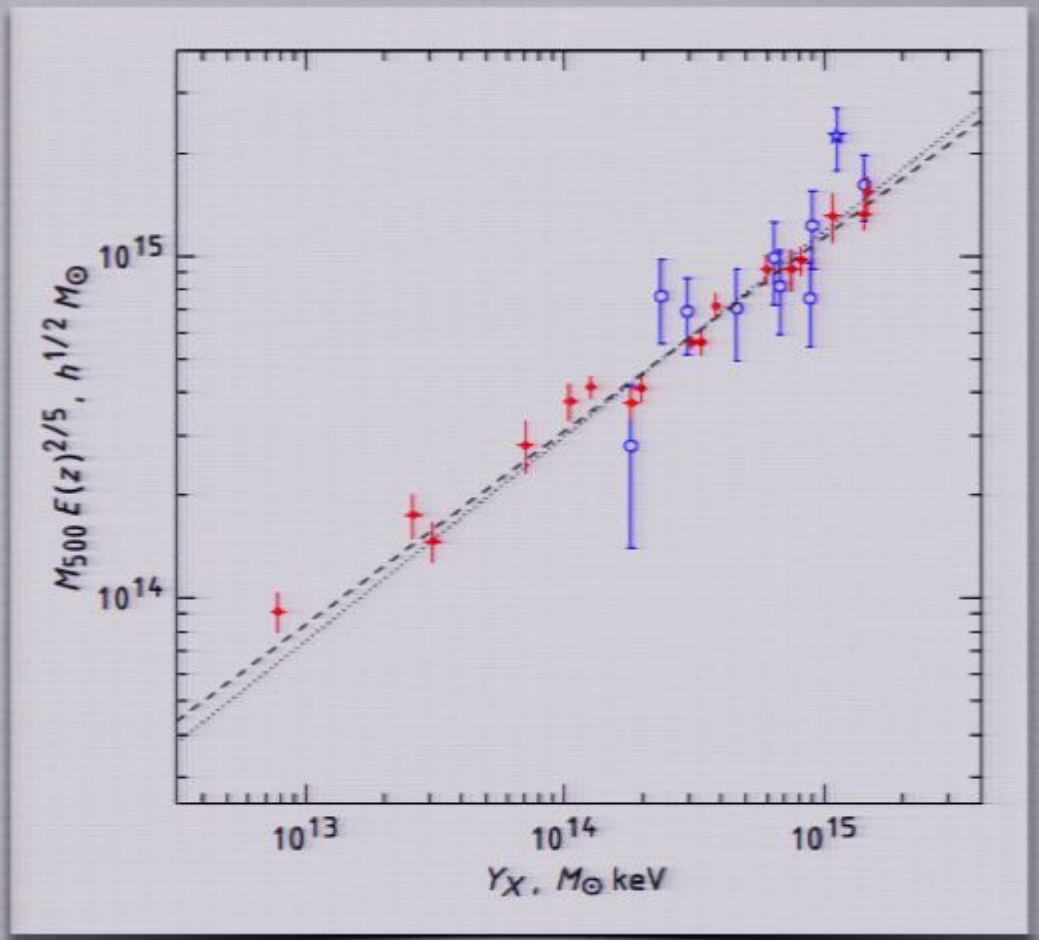

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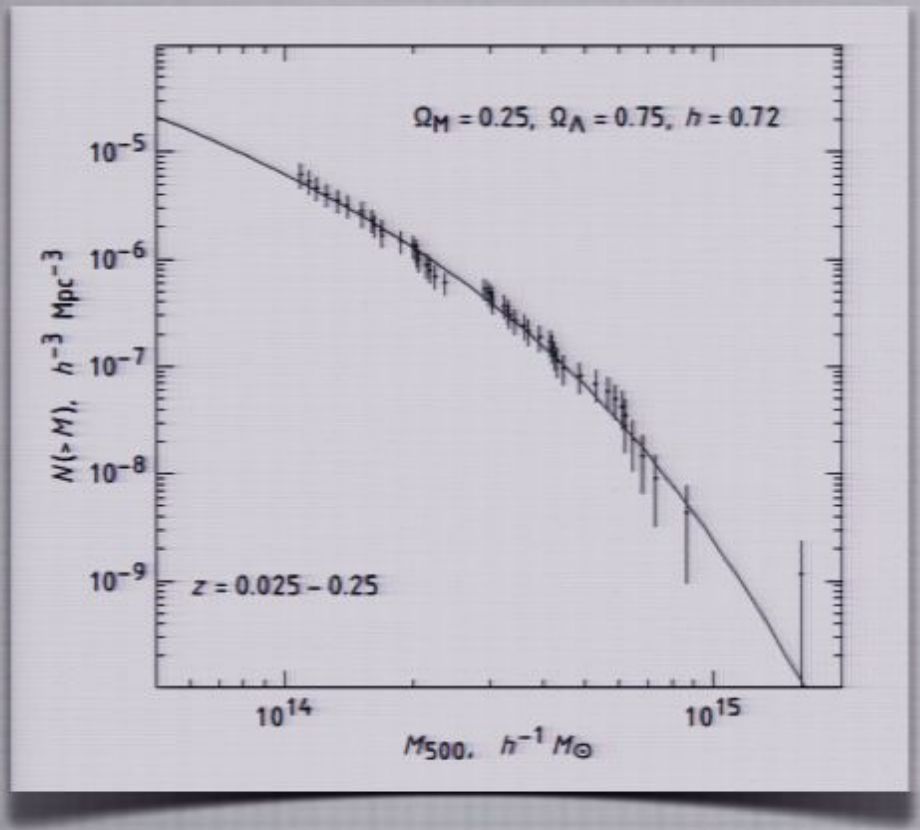
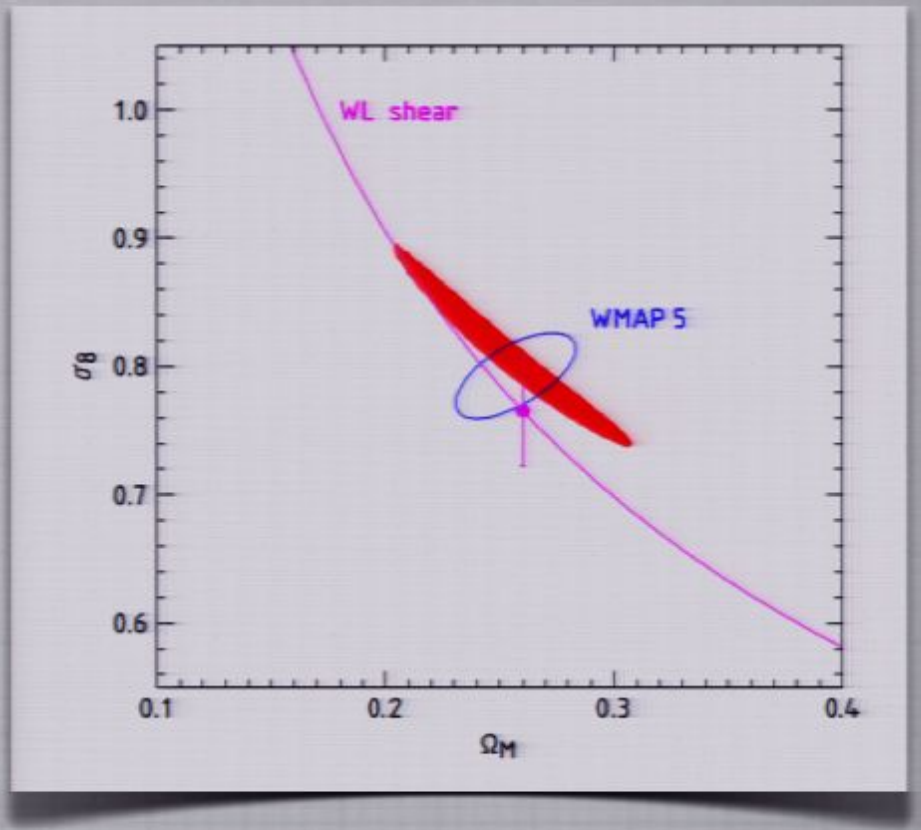
CLUSTER MASS FUNCTION TEST

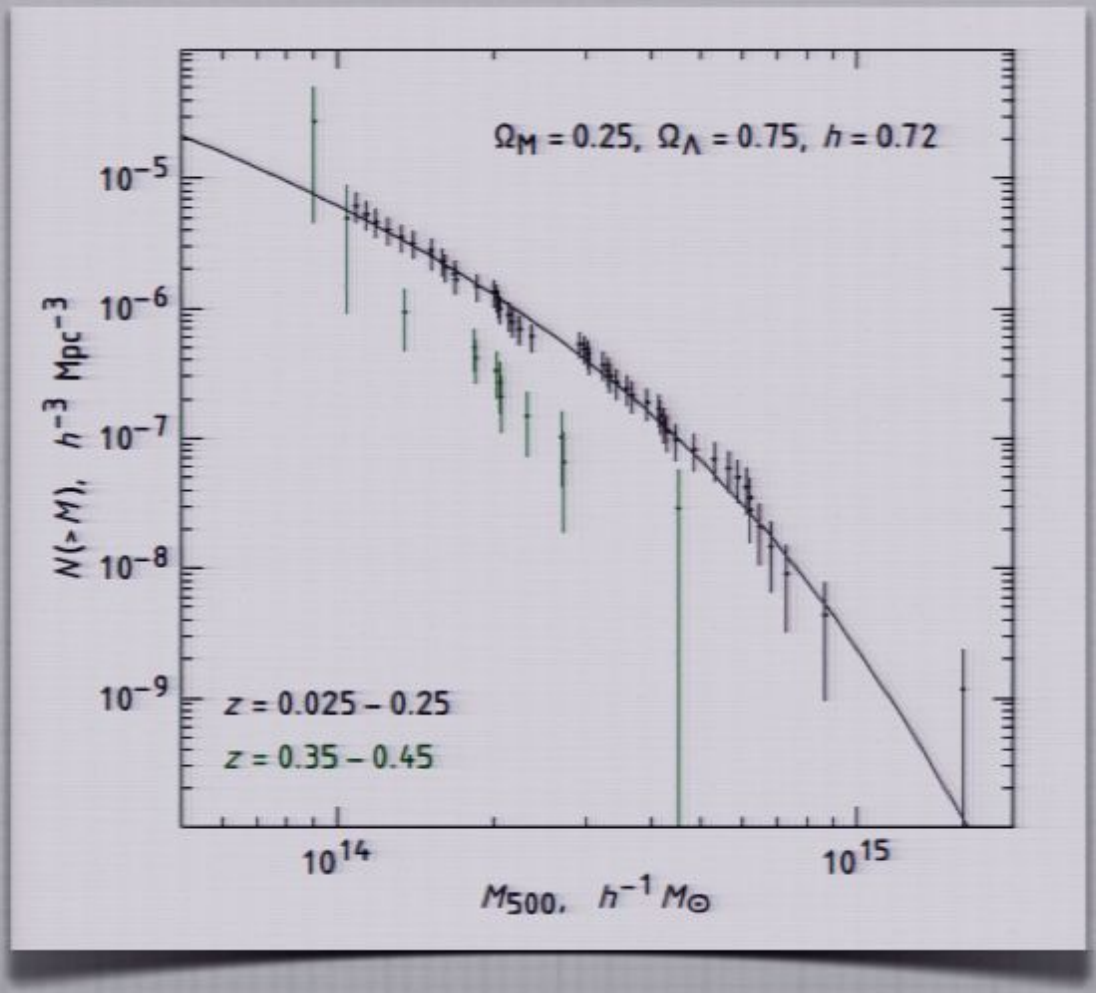




- 50 clusters $\Longrightarrow$ σ_8 to $\pm 1.5\%$ ($\pm 3\%$ sys)

2009 ApJ 692 1060

CLUSTER MASS FUNCTION TEST



Measure σ_8 at $z \approx 0$ *and* $z = 0.35$–0.45

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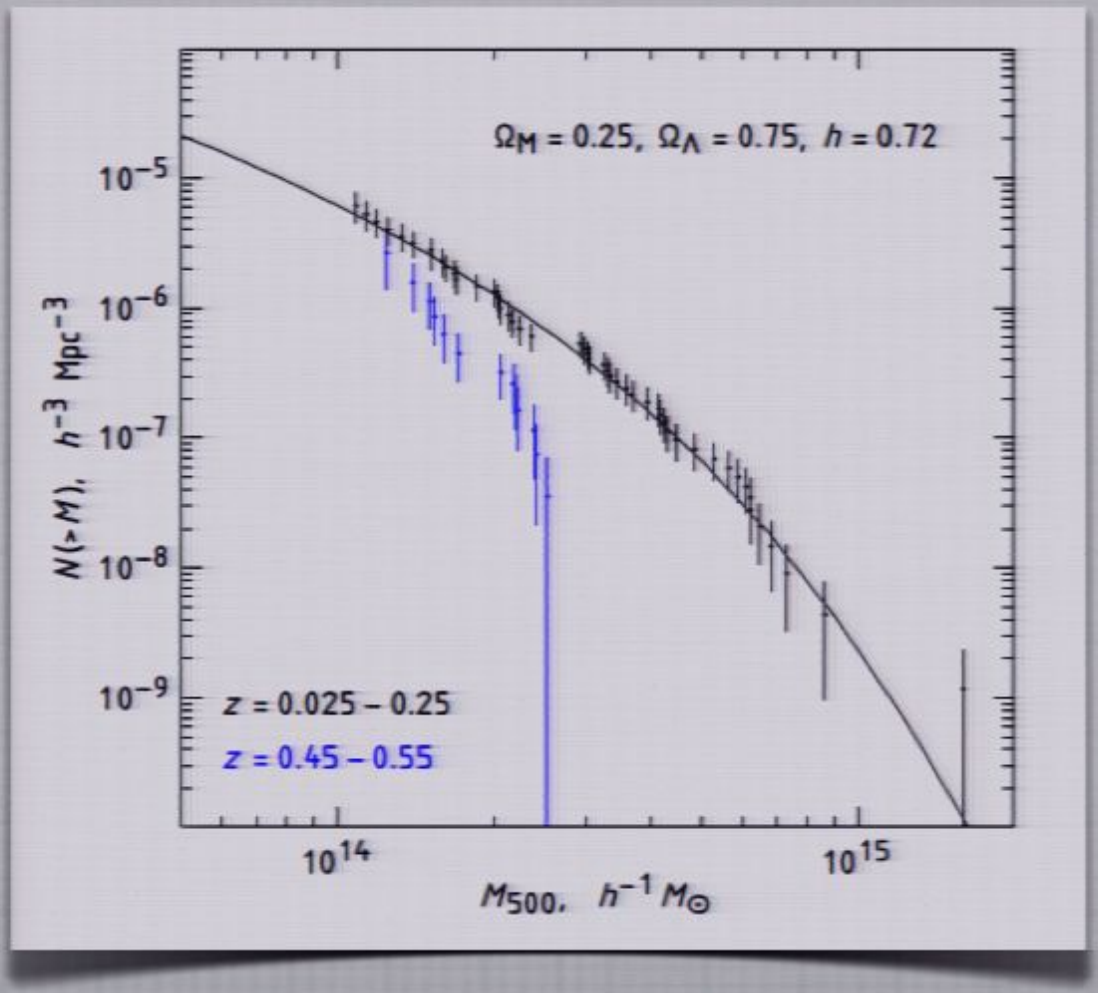

Measure σ_8 at $z \approx 0$ *and* $z = 0.35–0.45$ *and* $z = 0.45–0.55$

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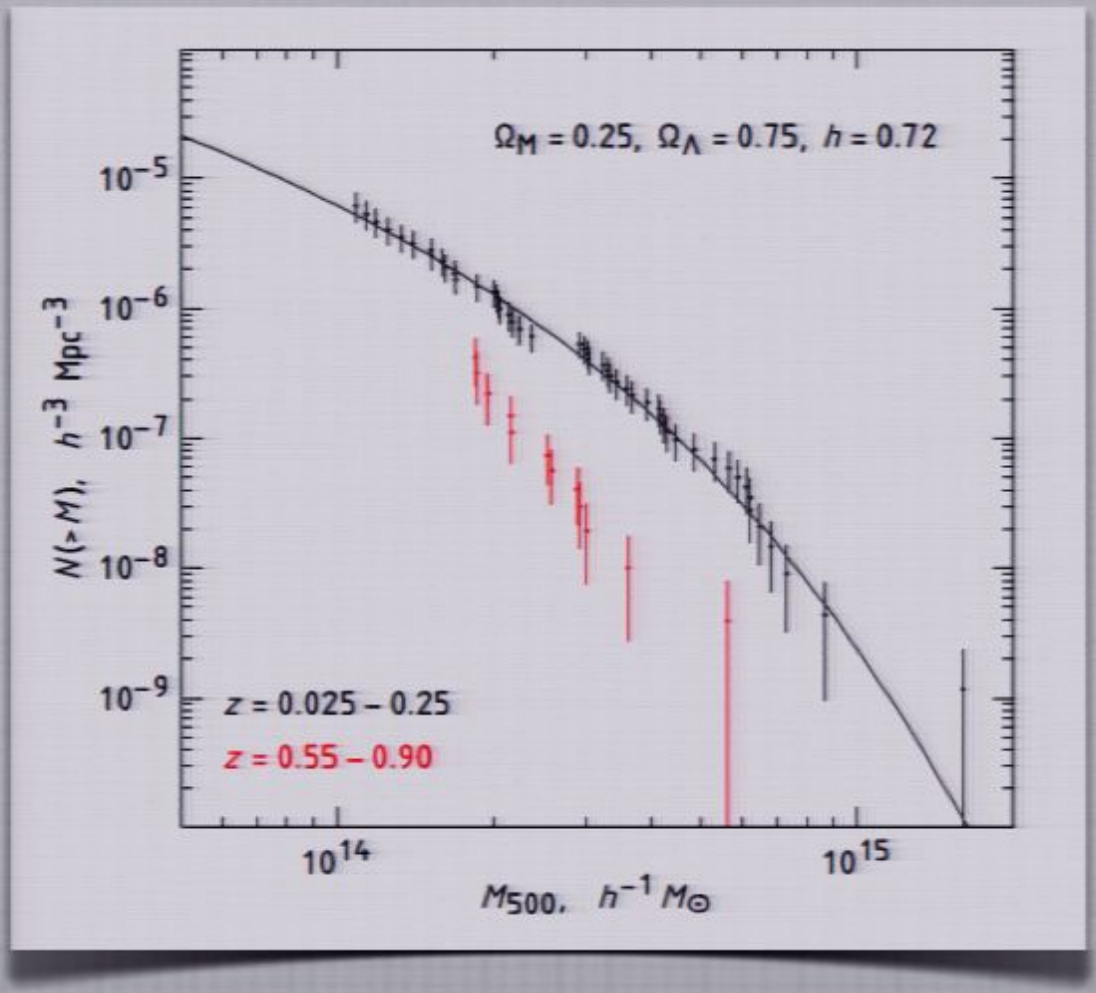

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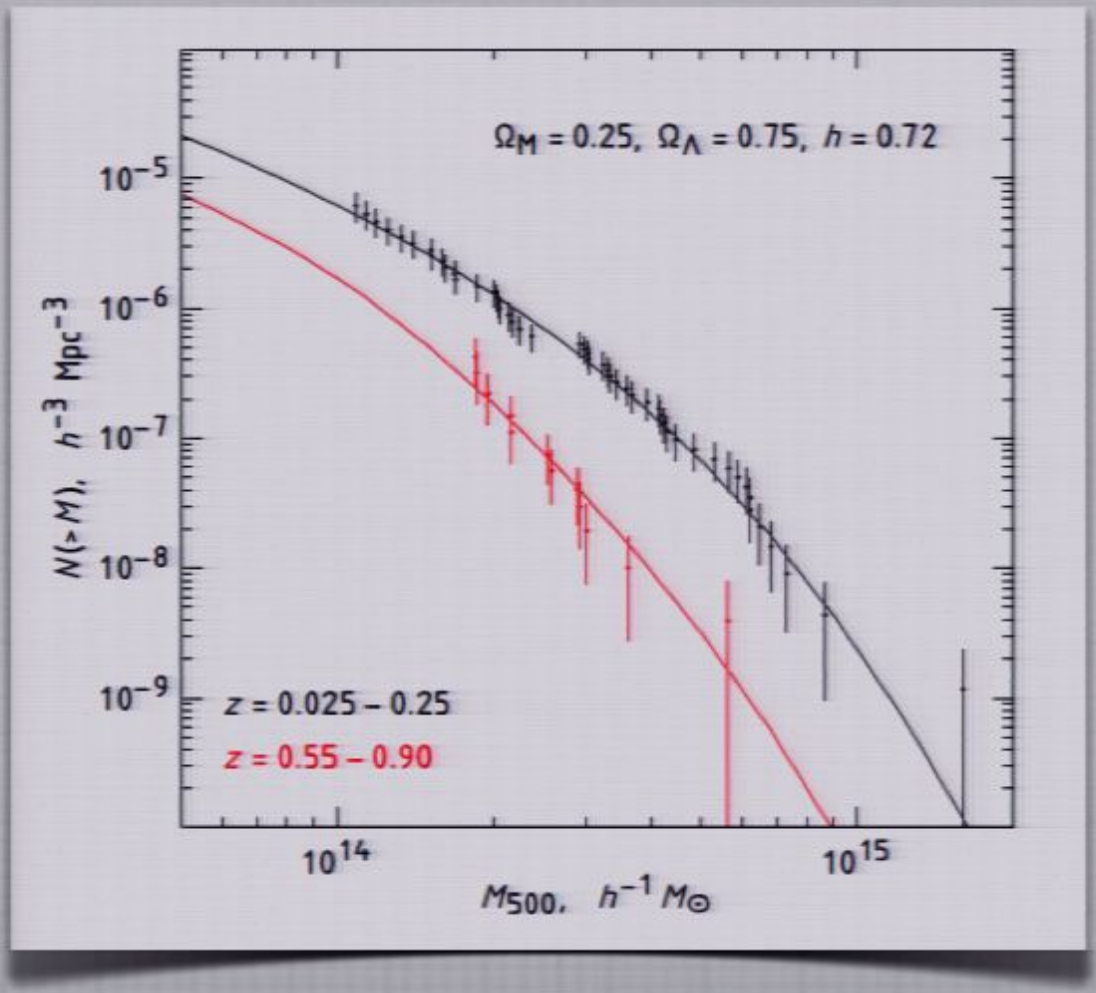

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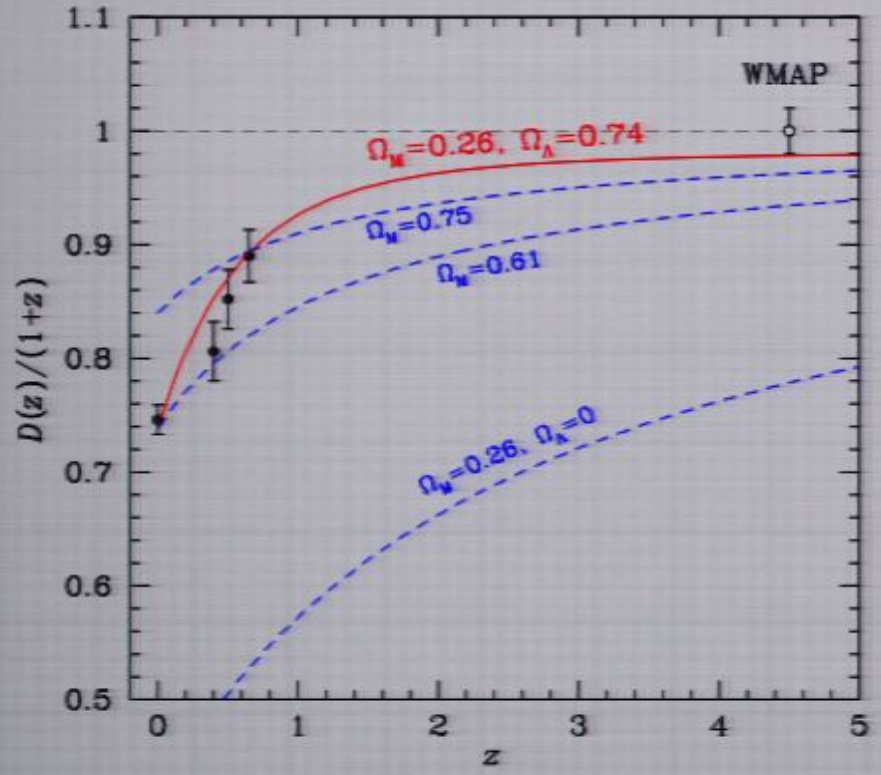
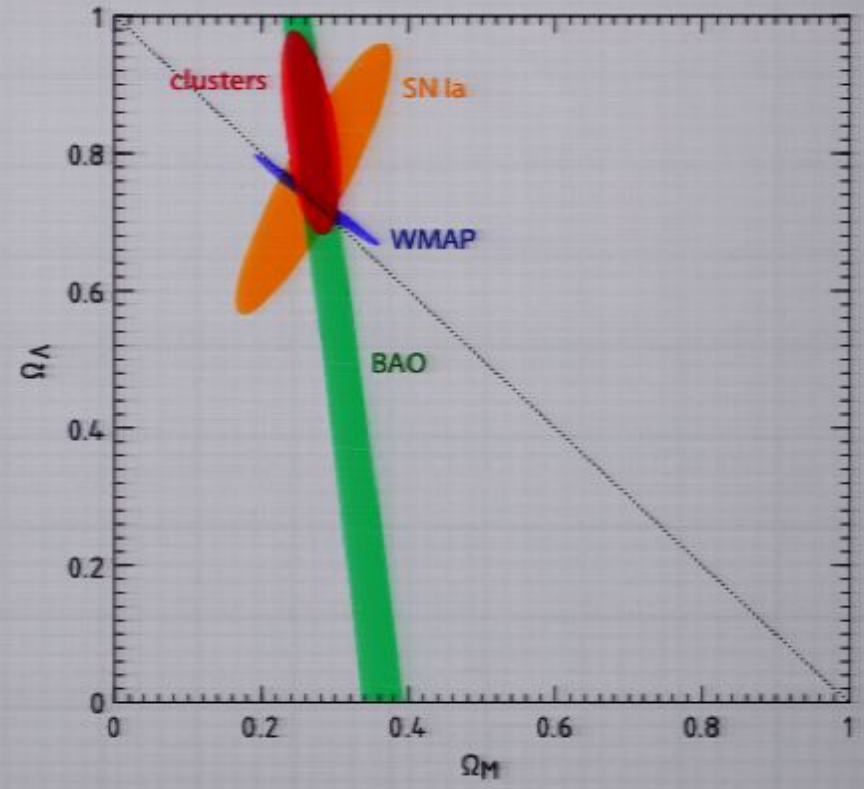
CLUSTERS DETECT Λ & CONSTRAIN *w*





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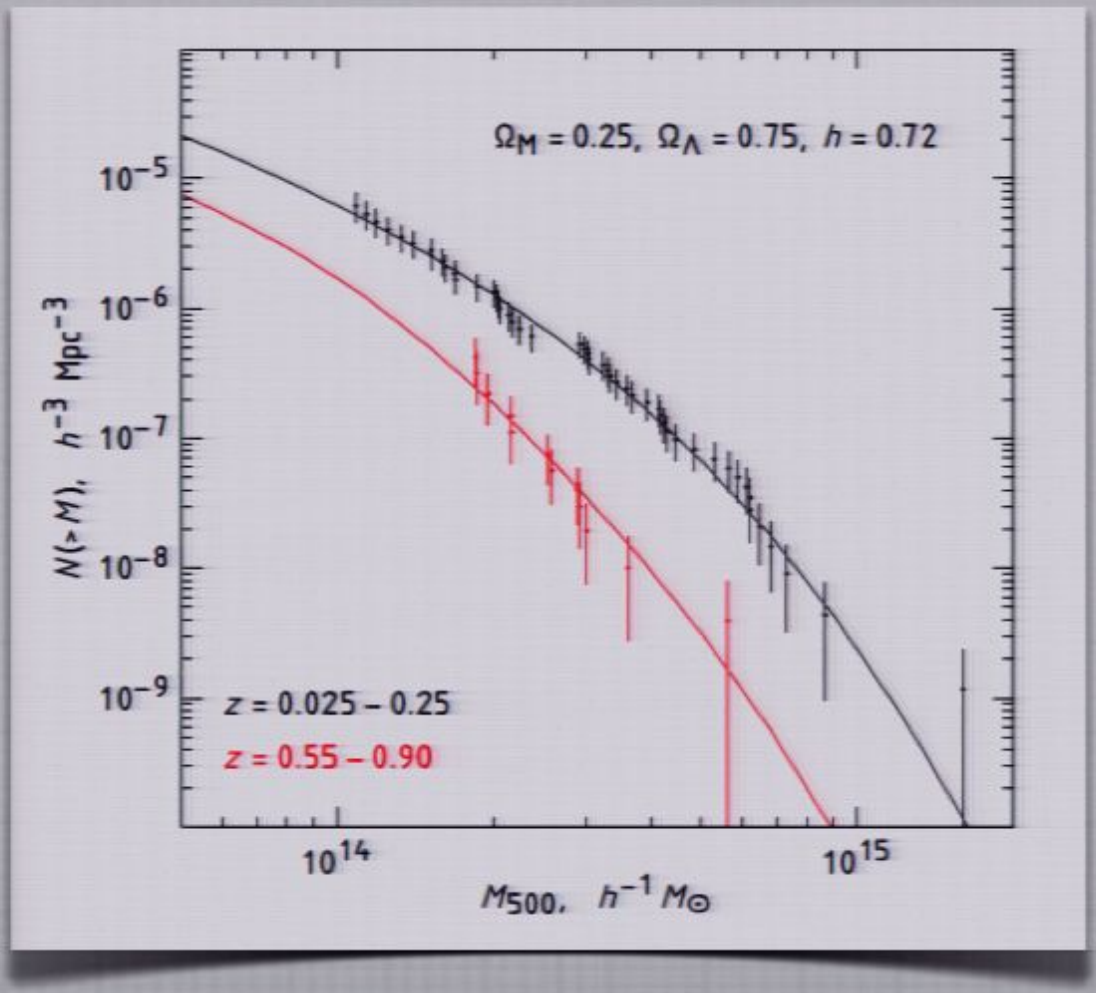

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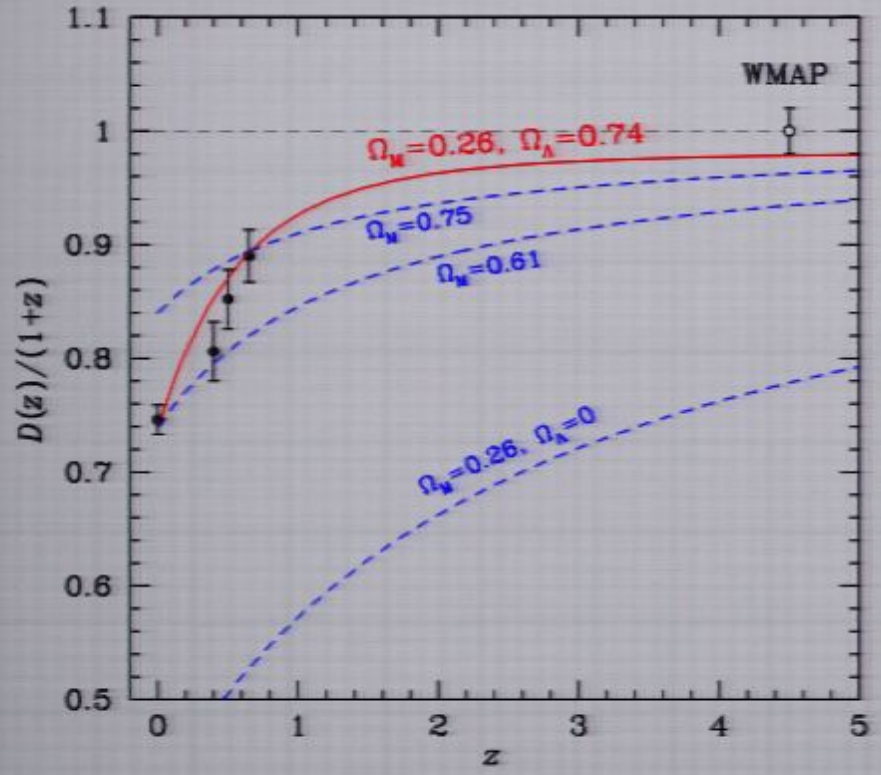

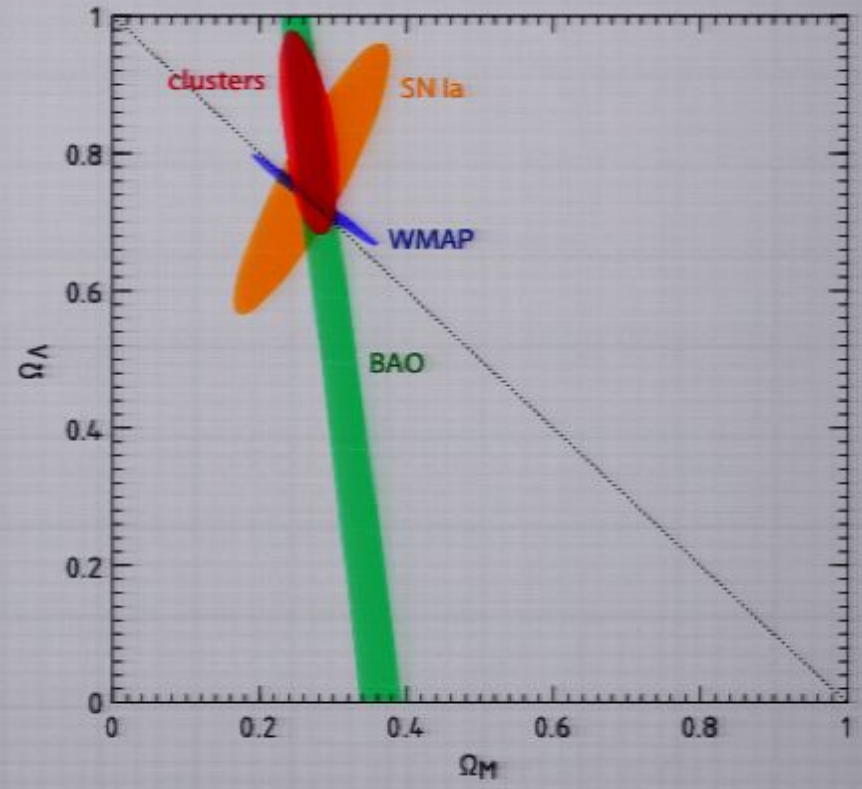

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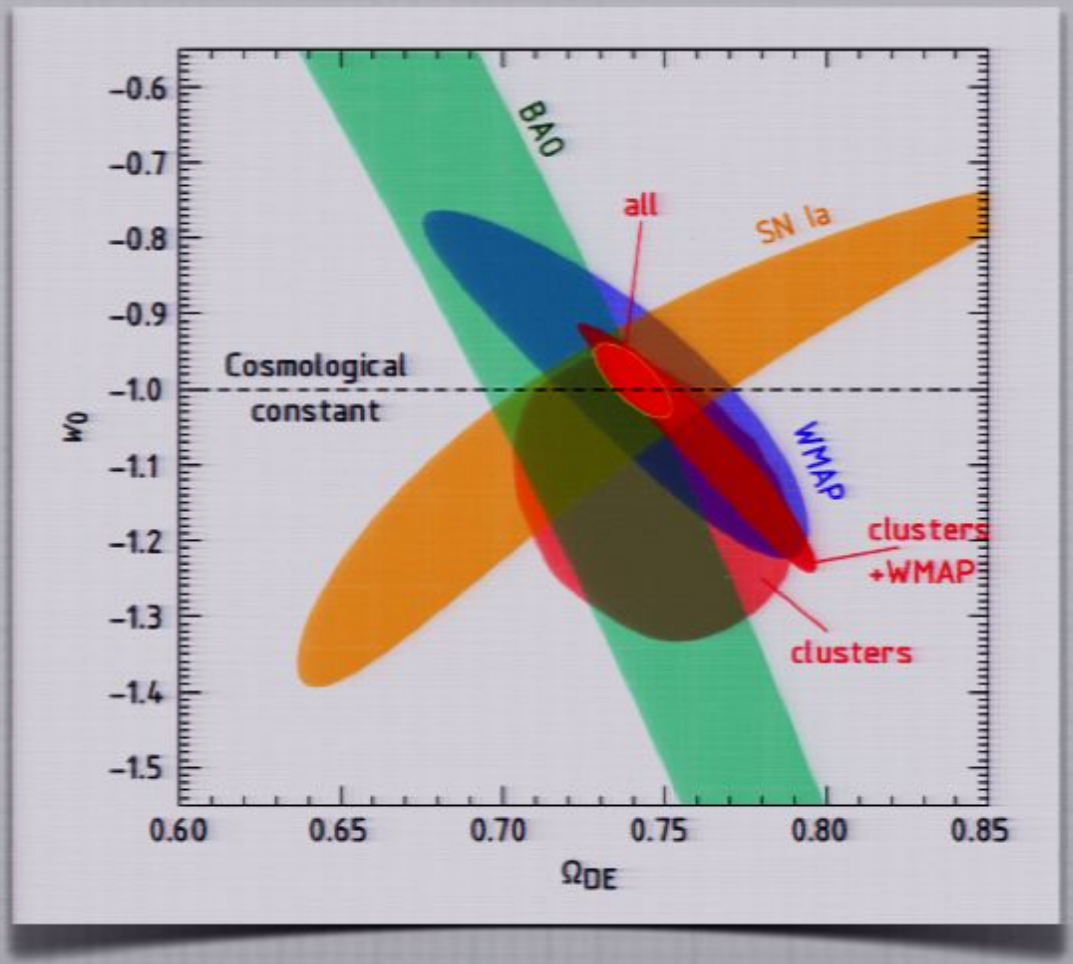
w_0 FROM COMBINATION OF METHODS



$w_0 = -0.99 \pm 0.045\ (\text{stat}) \pm 0.039\ (\text{sys})$ $(\pm 0.067$ without clusters$)$ (± 0.076)

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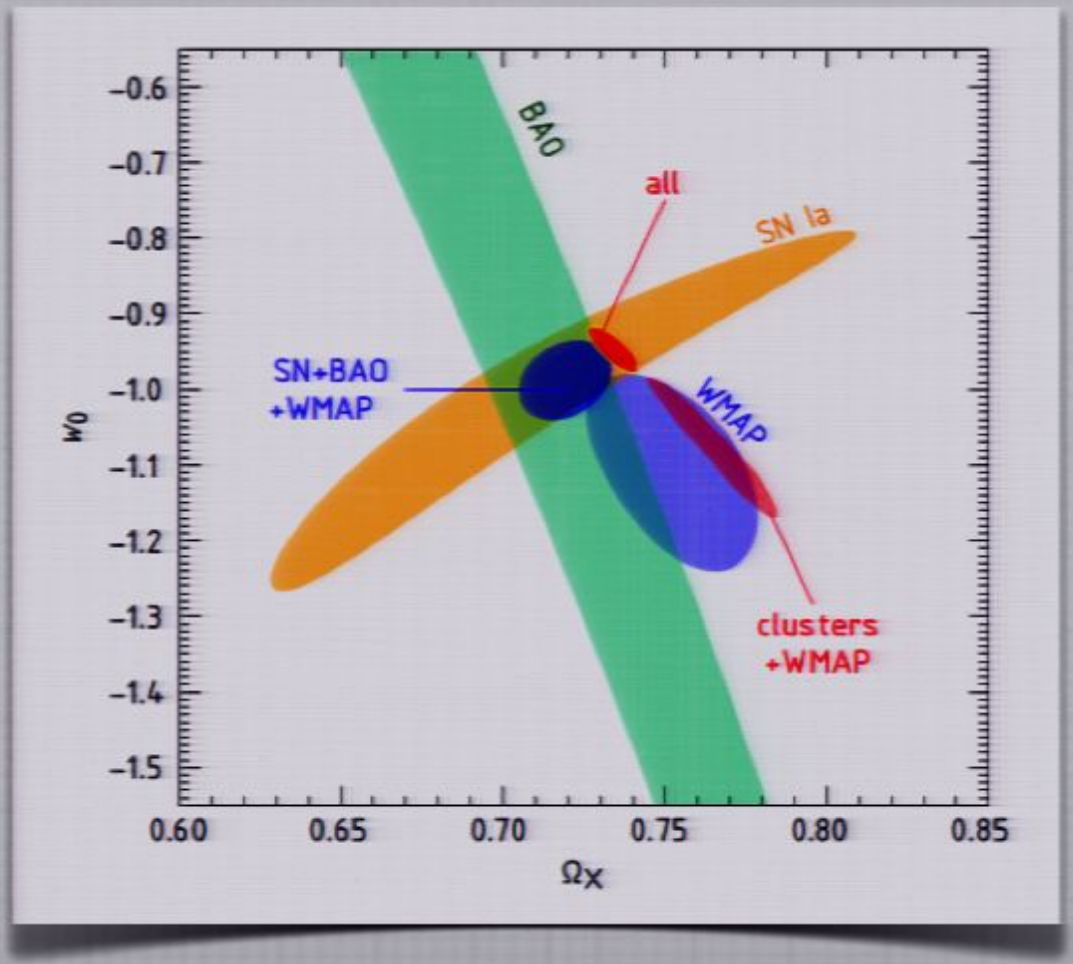
w_0 — LATEST AND GREATEST



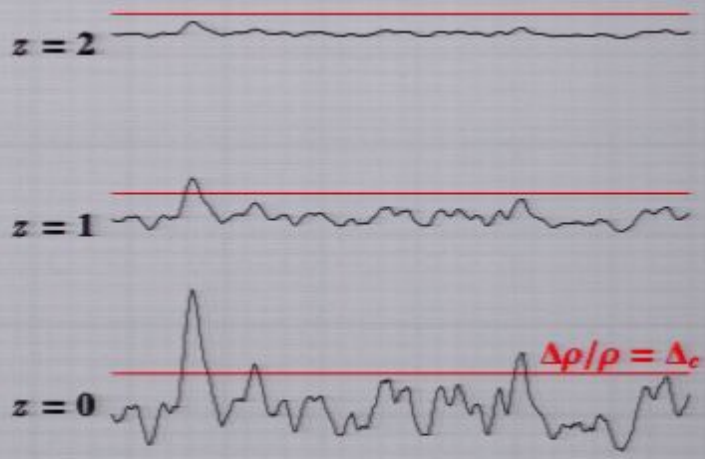
$w_0 = -0.951 \pm 0.029\ (\text{stat}) \pm 0.047\ (\text{sys})$

GR & CLUSTER FORMATION THEORY

- **Linear growth:**

$$\ddot{\delta} + 2H(z)\,\dot{\delta} - \tfrac{3}{2}H(z)^2\Omega_M(z)\,\delta = 0$$

- **Non-linear collapse:**

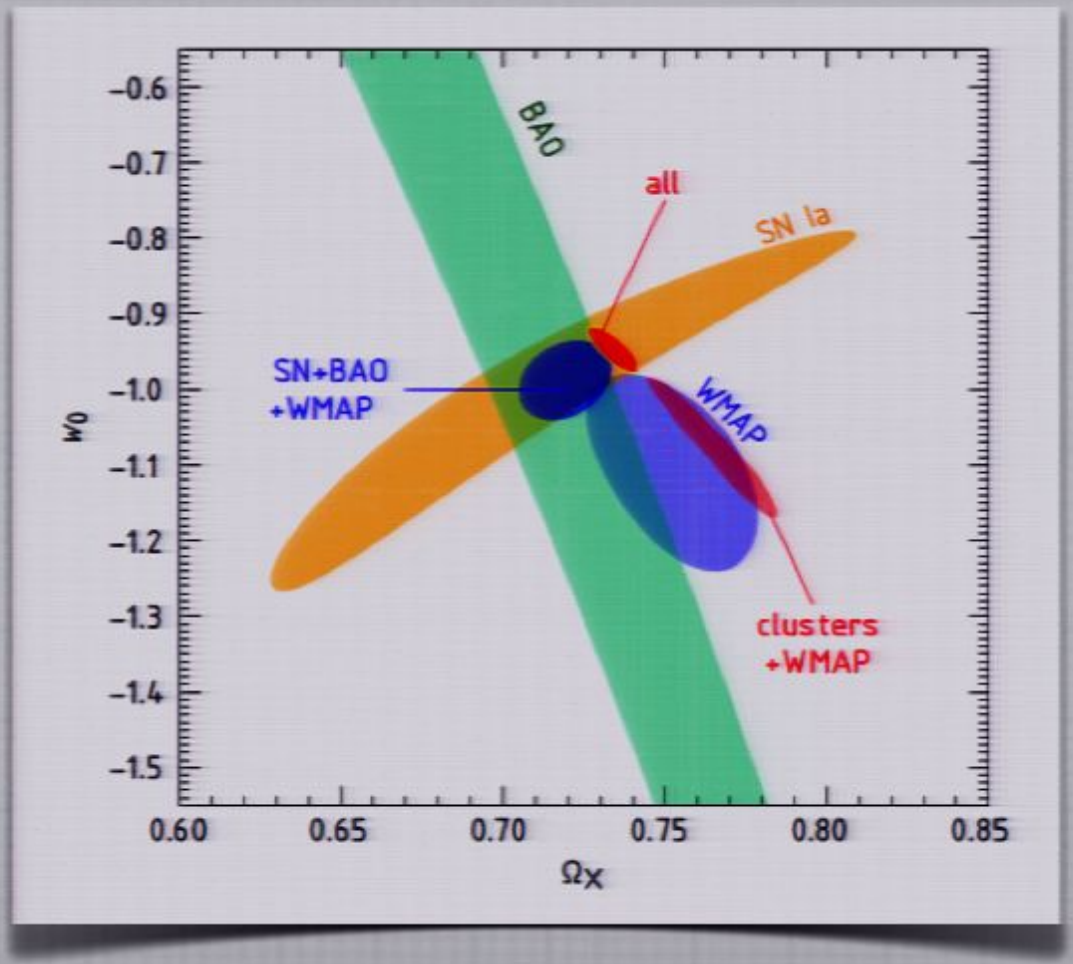


Universal form for $dN/d\sigma(M)$

- **Mass-observable relations:**

Some affected: $M \sim T^{3/2}H(z)$, some not: $M \sim M_{\rm gas}$

w_0 — LATEST AND GREATEST



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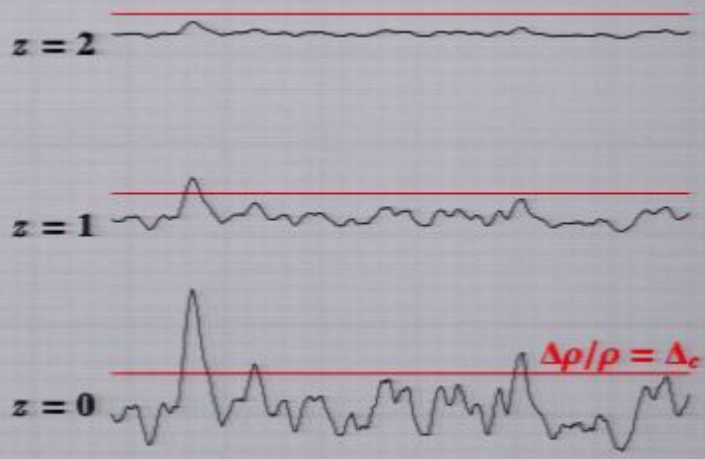

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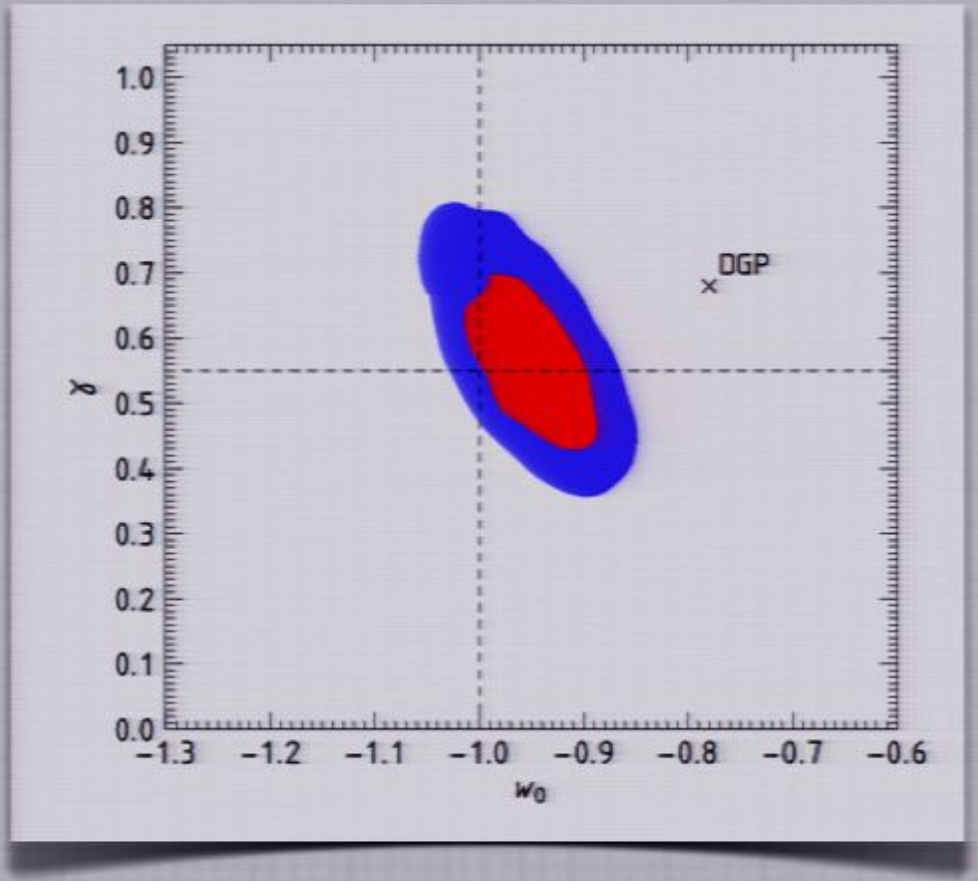
NULL TEST: GROWTH INDEX



- Growth index, γ:

$$d\ln D/d\ln a = \Omega_M(a)^\gamma$$

- $\gamma \approx 0.55$ for wCDM
- $\gamma = 0.55 \pm 0.08$ measured ± 0.10 without WMAP reference

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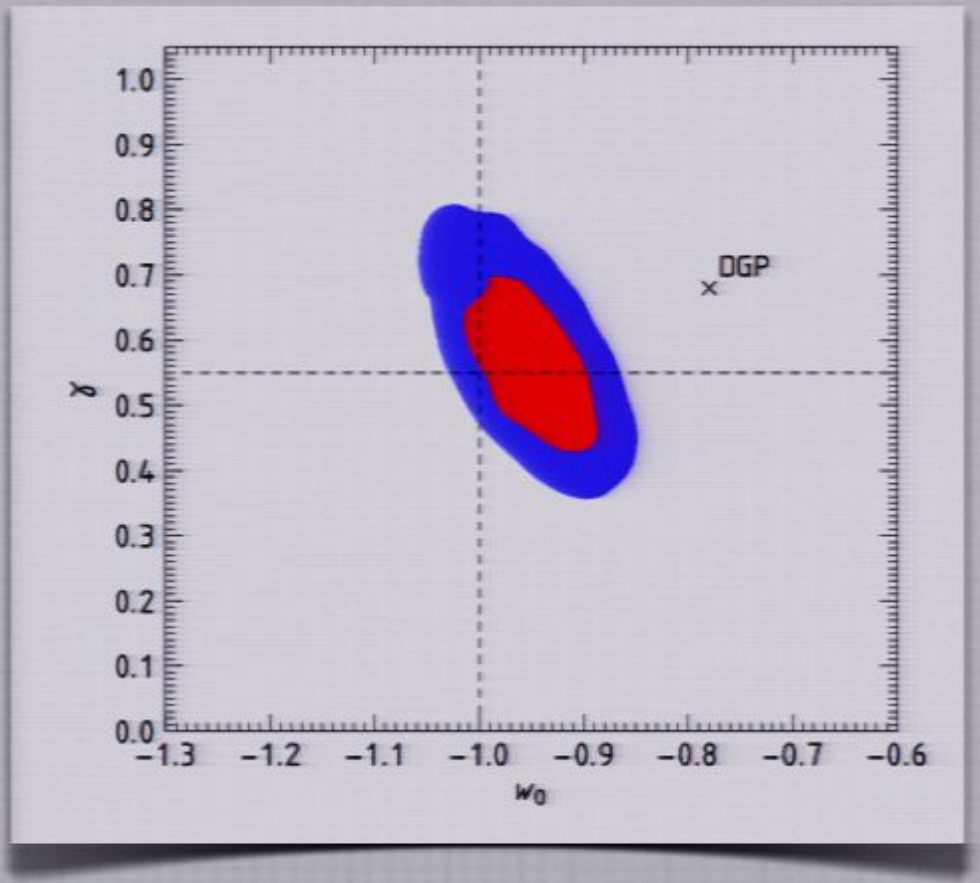

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