

## COSMOLOGY

## IN THE ACS ERA

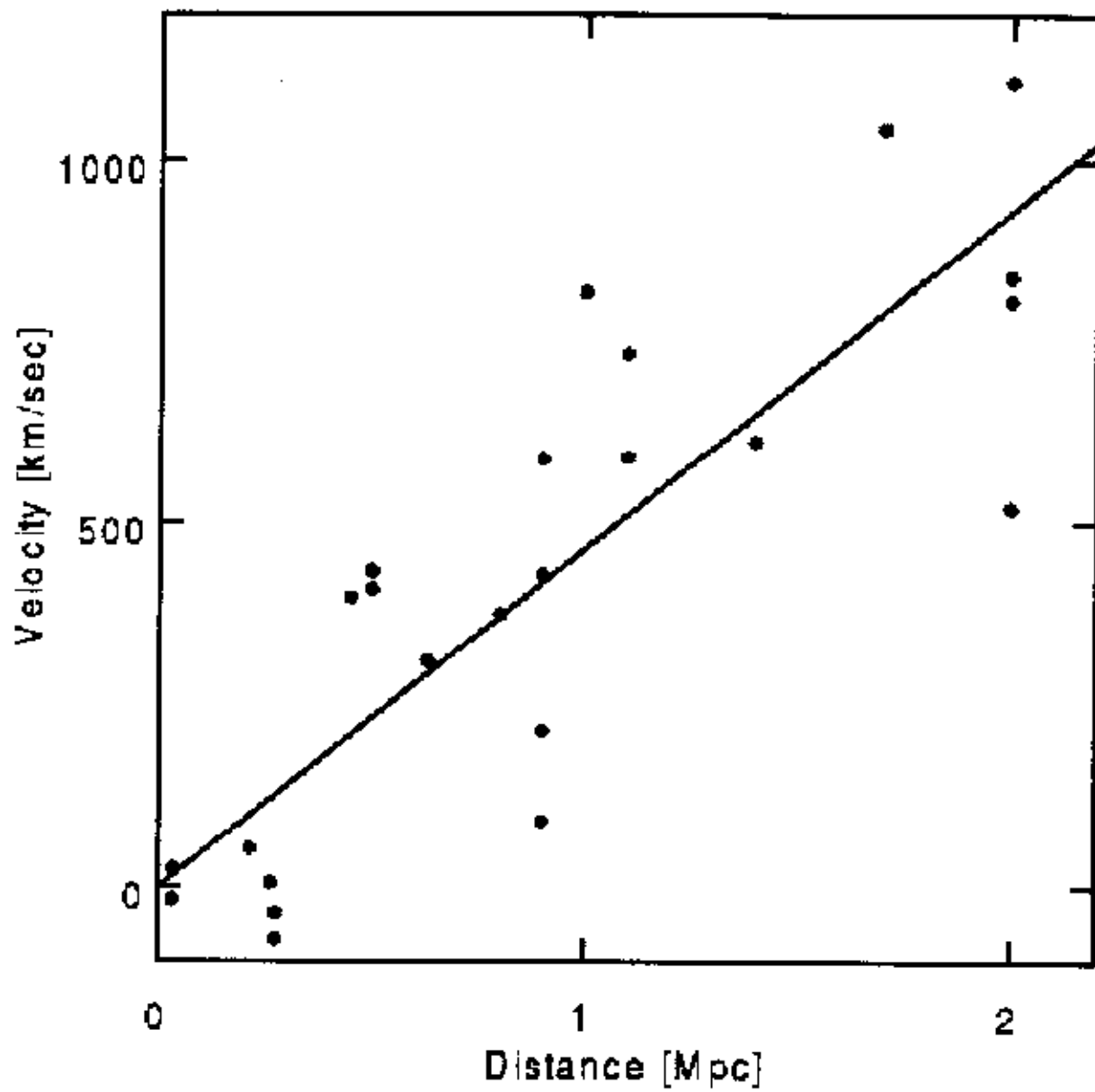
## Observational / Experimental

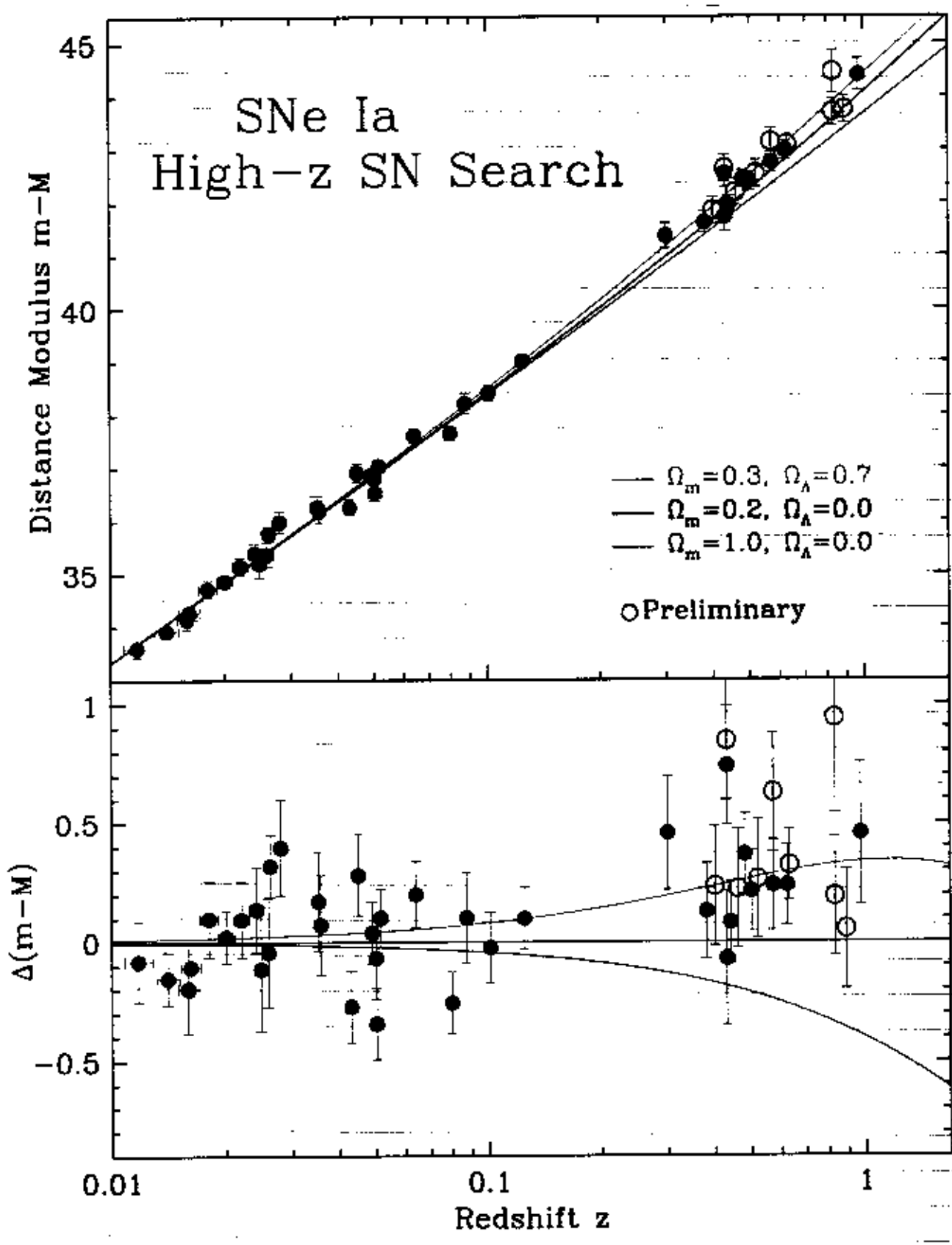
- quantitative
- precision measurements
- large data volumes

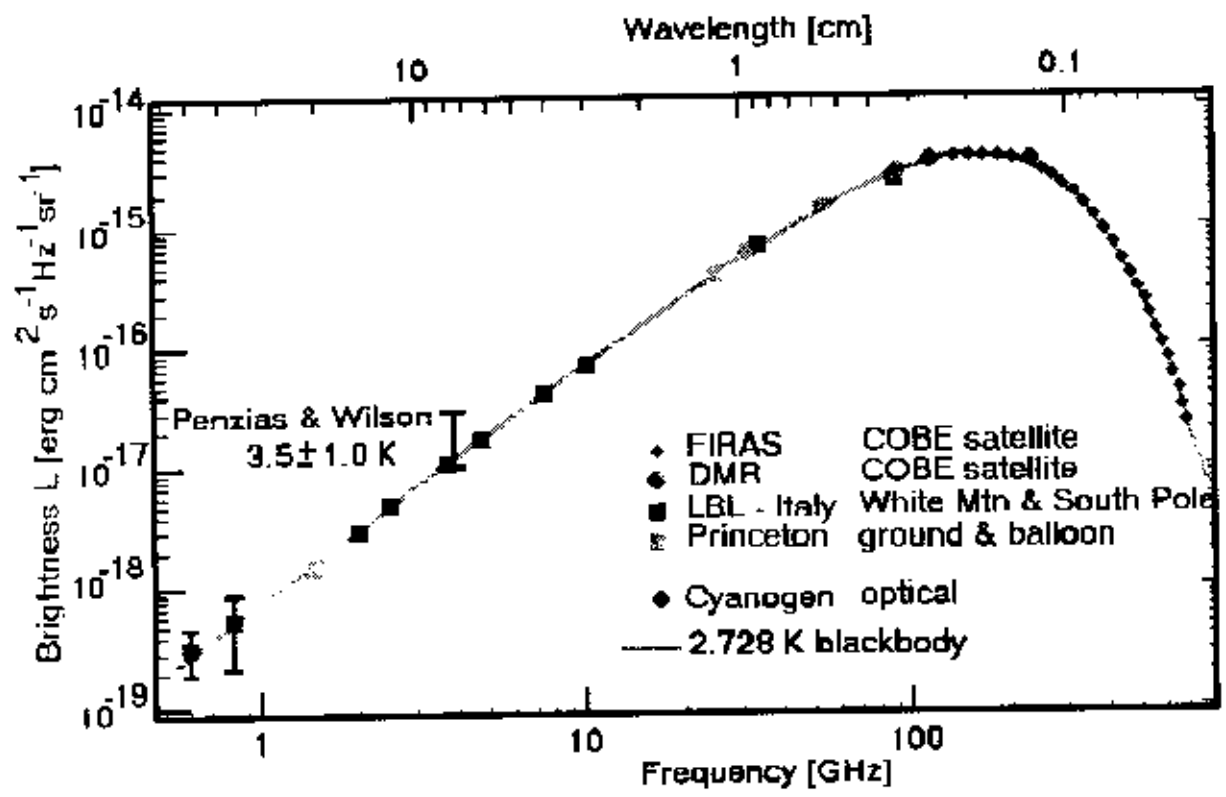
## Theoretical!

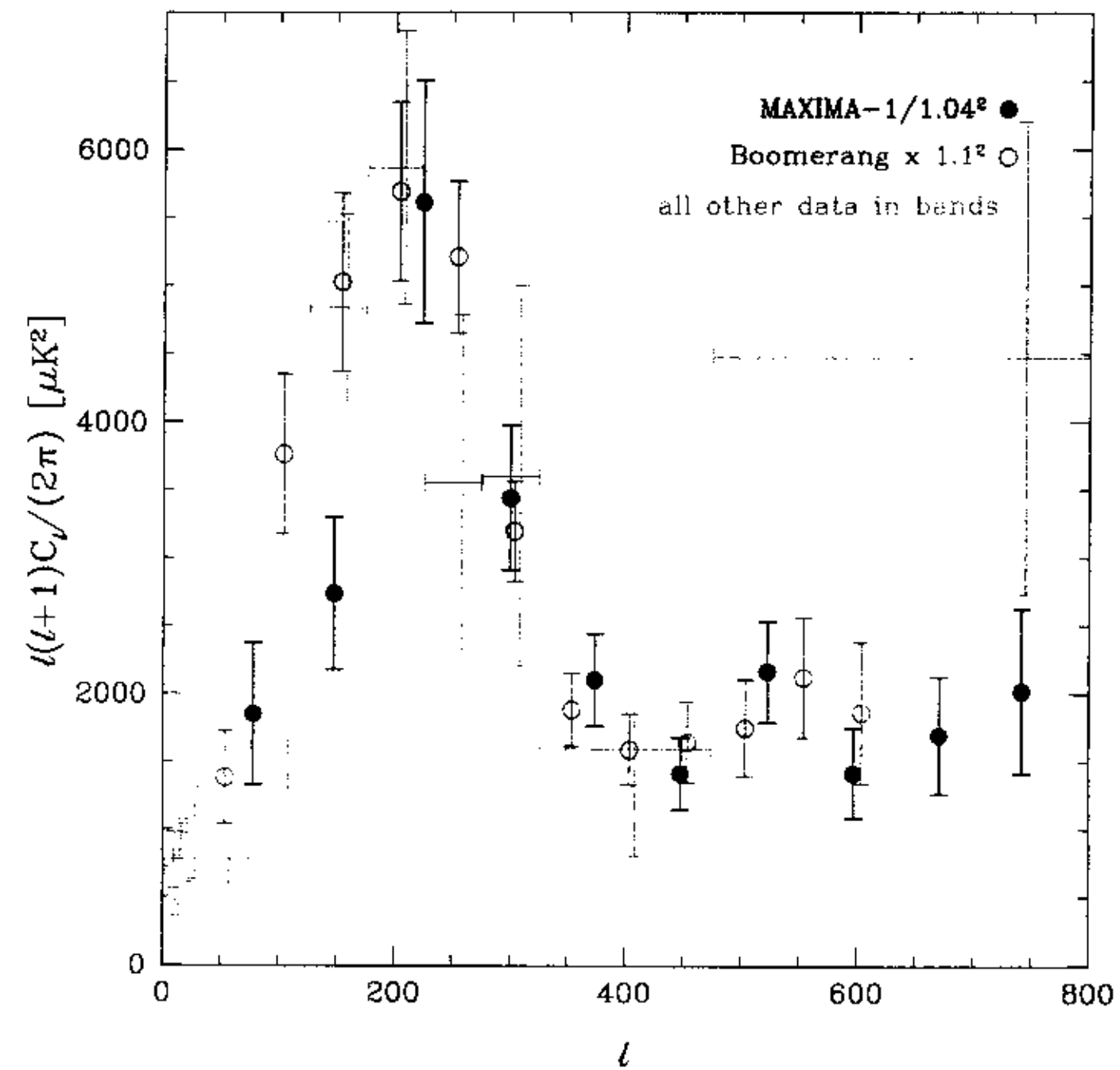
- relevant + robust "first principles" calculations for some problems
- powerful numerical simulations, "empirical theory"
- speculative attempts to answer questions about the deep nature and origin of the physical world

# Hubble's Hubble Diagram



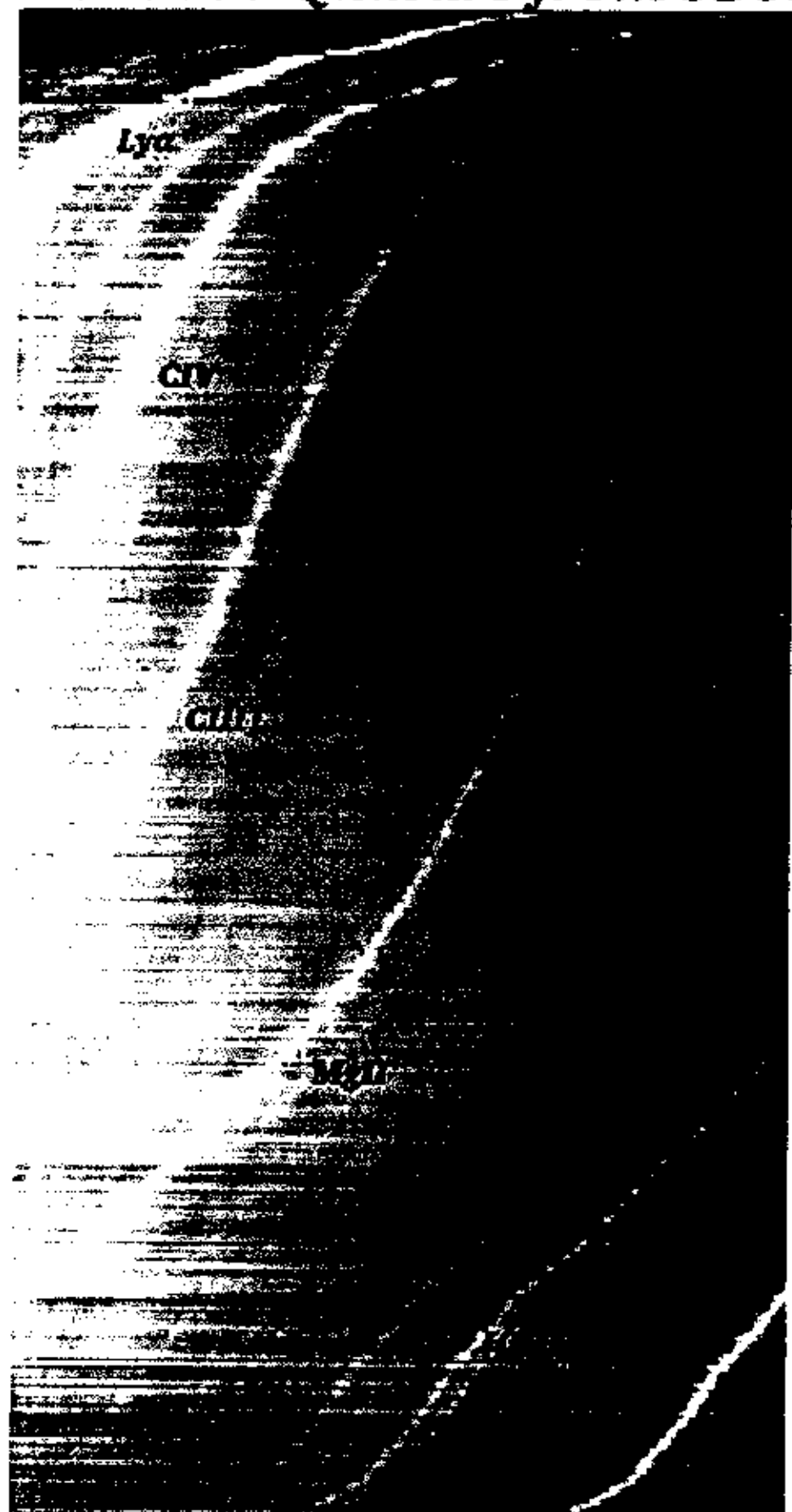






# First 8000 Quasars from SDSS

$z = 5$



$z = 1$

$z = 0$

4000A

9000A

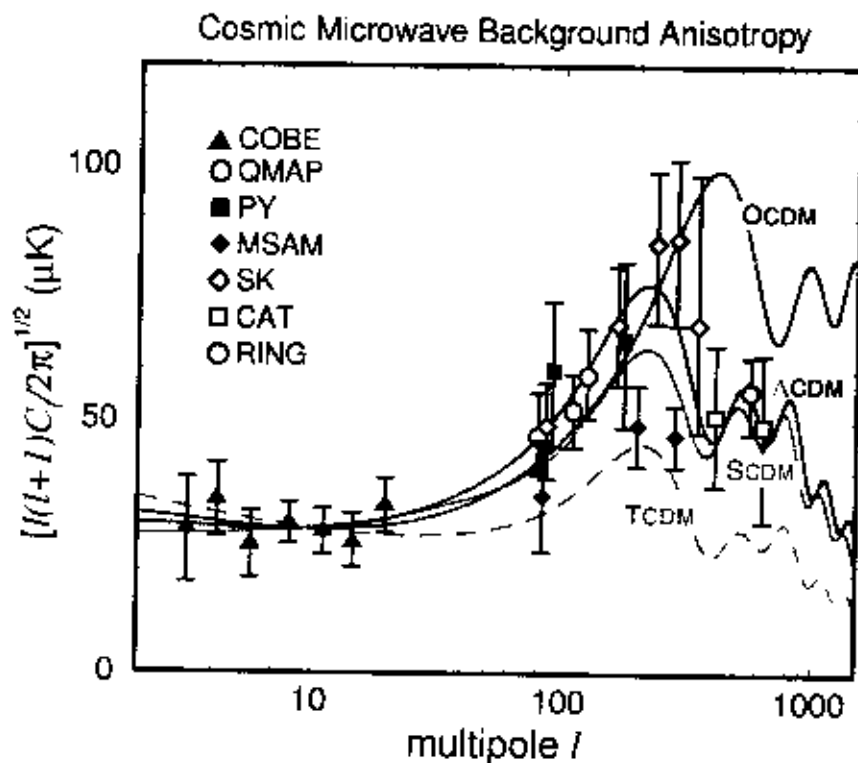


Figure 5: The cosmic microwave background temperature anisotropy is presented as a function of angular scale. (The multipole  $l$  corresponds roughly to an angular scale of  $\pi/l$  radians). Flat models ( $\Omega_m + \Omega_\Lambda = 1$ ) produce a peak at  $l \approx 200$  (about one degree on the sky). Open models have a peak that is shifted to smaller scales (larger  $l$ 's). (The height of the peak depends on additional parameters, including  $\Omega_m$ ,  $\Omega_\Lambda$ ,  $\Omega_b$ ,  $H_0$ , tilt; here we use the canonical values.) The observational data points include the COBE measurements on large scales (small  $l$ 's) and other published, multi-frequency ground- and balloon-based observations.

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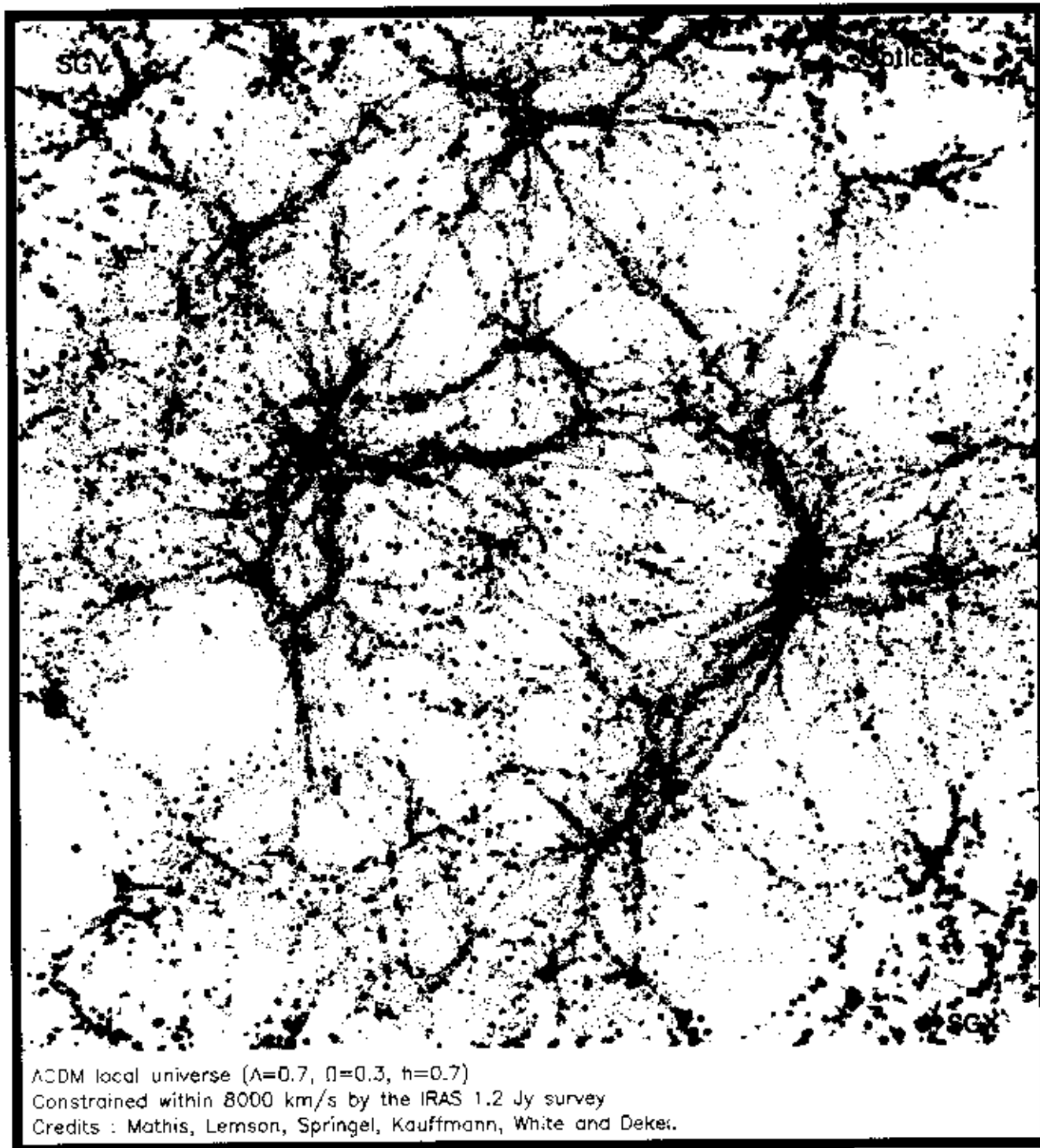
VingD  
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+ you are here



$Z=0$

$M_B \leq -19.5$

2082 gal

## THE MAIN AGENDA FOR COSMOLOGY IN THE DECADE(S) AHEAD

- Does any combination of the various cosmological parameters and nature/properties of the dark matter satisfy all of the reliable observational/experimental constraints? (Is the current paradigm viable?)
- If so, what are they and what are their confidence intervals?
- Does this "solution" of cosmology (if it exists) make sense in terms of fundamental physics?

あまり良く知らない事柄ほど  
世の中では固く信じられがち  
である。

Nothing is so firmly believed  
as that which we least know.

*Michel de Montaigne*

複雑な問題は、往々にして、  
簡単かつ容易に理解できる  
間違った解を持つ。

Complex problems have  
simple, easy to understand  
wrong answers.

*Thomas Gold*

$$\Omega_m + \Omega_\Lambda + \Omega_k = 1$$

### The Cosmic Triangle

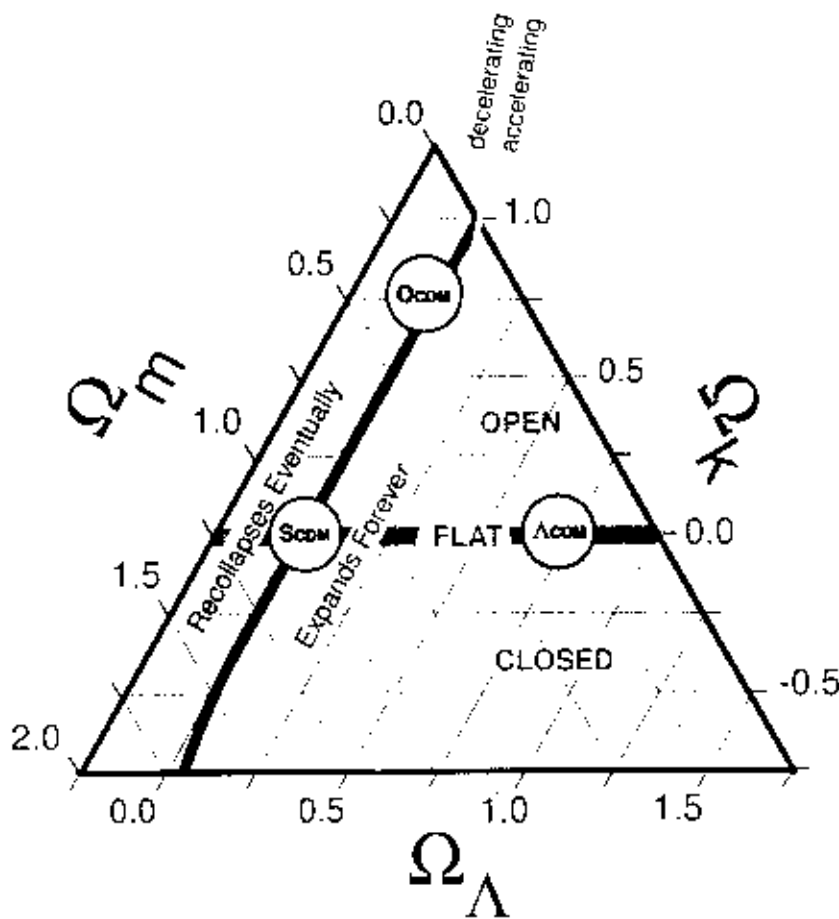


Figure 1: **The Cosmic Triangle** represents the three key cosmological parameters -  $\Omega_m$ ,  $\Omega_\Lambda$ , and  $\Omega_k$  - where each point in the triangle satisfies the sum rule  $\Omega_m + \Omega_\Lambda + \Omega_k = 1$ . The blue horizontal line (marked Flat) corresponds to a flat universe ( $\Omega_m + \Omega_\Lambda = 1$ ), separating an Open universe from a Closed one. The red line, nearly along the  $\Lambda = 0$  line, separates a universe that will expand forever (approximately  $\Omega_\Lambda > 0$ ) from one that will eventually recollapse (approximately  $\Omega_\Lambda < 0$ ). And the yellow, nearly vertical line separates a universe with an expansion rate that is currently decelerating from one that is accelerating. The location of three key models are highlighted: standard cold-dark-matter (SCDM) is dominated by matter ( $\Omega_m = 1$ ) and no curvature or cosmological constant; flat ( $\Lambda$ CDM), with  $\Omega_m = 1/3$ ,  $\Omega_\Lambda = 2/3$ , and  $\Omega_k = 0$ ; and Open CDM (OCDM), with  $\Omega_m = 1/3$ ,  $\Omega_\Lambda = 0$  and curvature

## The Cosmic Triangle Observed

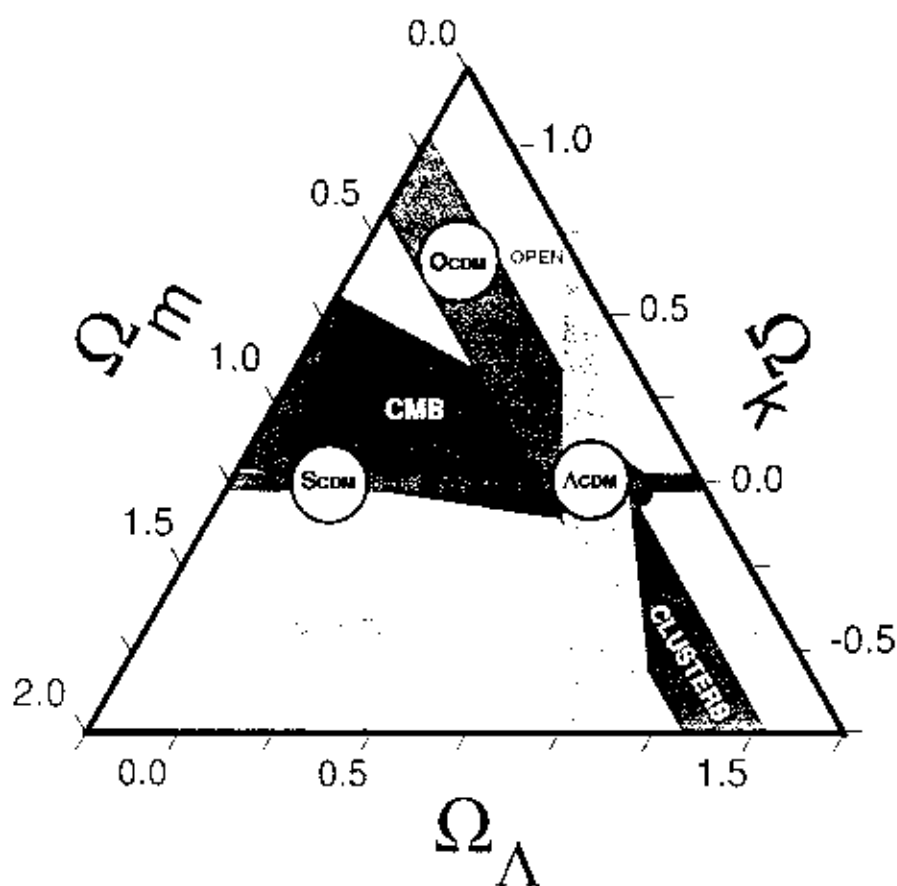


Figure 6: **The cosmic triangle observed** represents current observational constraints. The constraints determined from the different methods discussed in the paper are shown by the three color bands (each representing  $1\text{-}\sigma$  uncertainties). The red band represents the constraints placed by clusters of galaxies (including the mass-to-light method; baryon fraction; and cluster abundance evolution); the results indicate a low-density universe. The blue band represents the constraints placed by the supernovae observations; the results point to an accelerating universe. The green band describes current results from the cosmic microwave background anisotropy at high-red shifts; the results suggest a flat universe. The three independent bands intersect



How Can ACS (High Latitude Surveys)  
Most Effectively Contribute to the  
Main Cosmology Agenda?

My preliminary answers (ranked!):

- 1) weak lensing: essentially equivalent to low redshift "CMB"; theory is in excellent shape, physics well understood
- 2) high  $z$  galaxy cluster evolution: theory is in good shape & effects to be measured are enormous
- 3) high  $z$  SN (esp. SNIa): theory is weak & effects are small to moderate, but excellent empirical properties

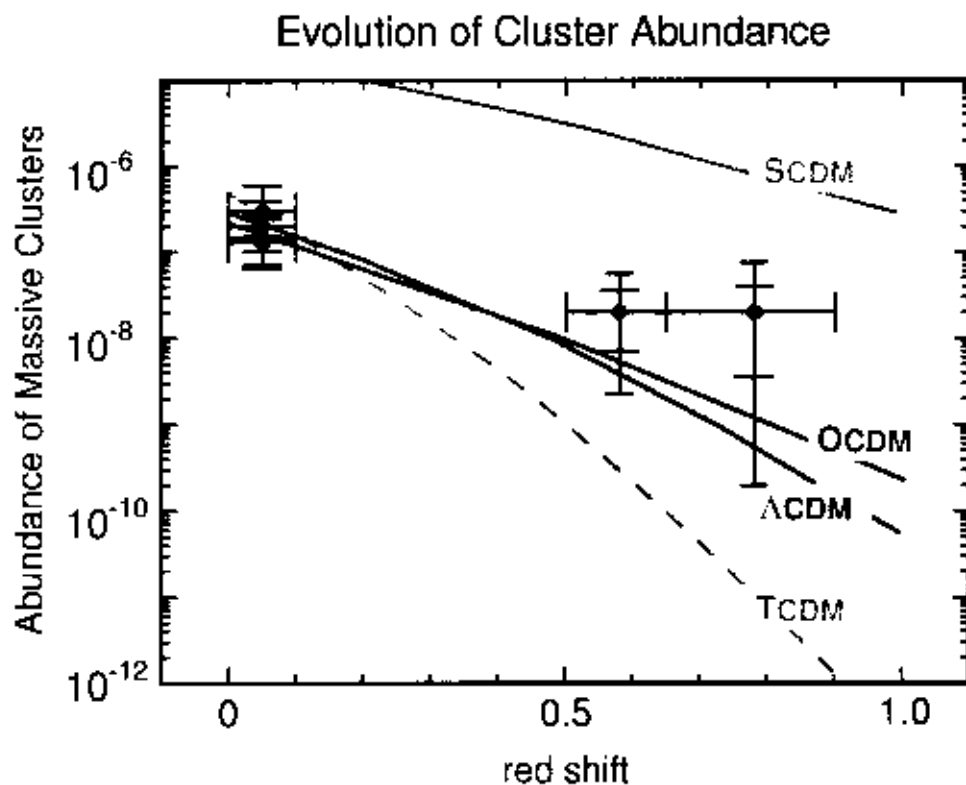


Figure 2: **The evolution of cluster abundance** (for massive clusters above a given mass threshold) as a function of red shift is compared with observations [29]. All models, except SCDM, match the observed cluster abundance at  $z \sim 0$ ; also, all four models are normalized to the cosmic microwave background fluctuations on large scales (see text). The observational data points (with 1- and 2- $\sigma$  error-bars) show only a slow evolution in the cluster abundance, consistent with low  $\Omega_m$  models and inconsistent with  $\Omega_m = 1$  models.