

*Open Questions in Cosmology
Garching, August 2005*

Open questions in cosmology?

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Is the Universe finite or infinite?

Curvature?

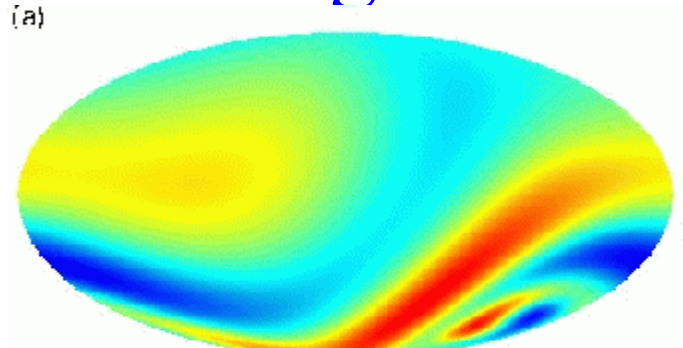
Topology?

Is the Universe eternal?

Recurrent bangs?

Heat death or Big Crunch?

Is the Universe homogeneous and isotropic?



What is the dark matter?

Is it Cold?

Dark?

(non-baryonic?)

Matter?

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Matter?

We need to detect it directly or
to observe its non-gravitational effects!

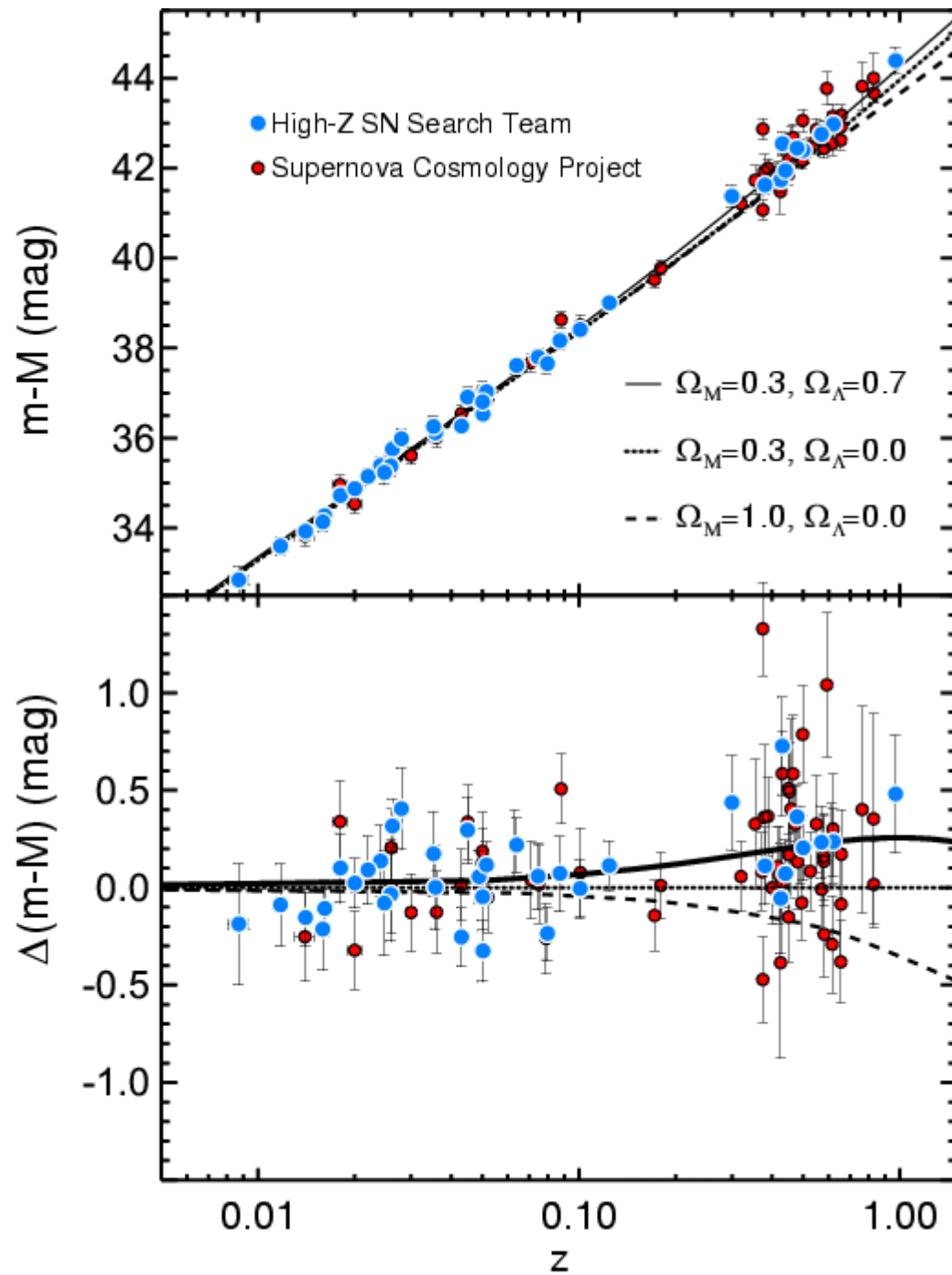
What is the dark energy?

Is it there?

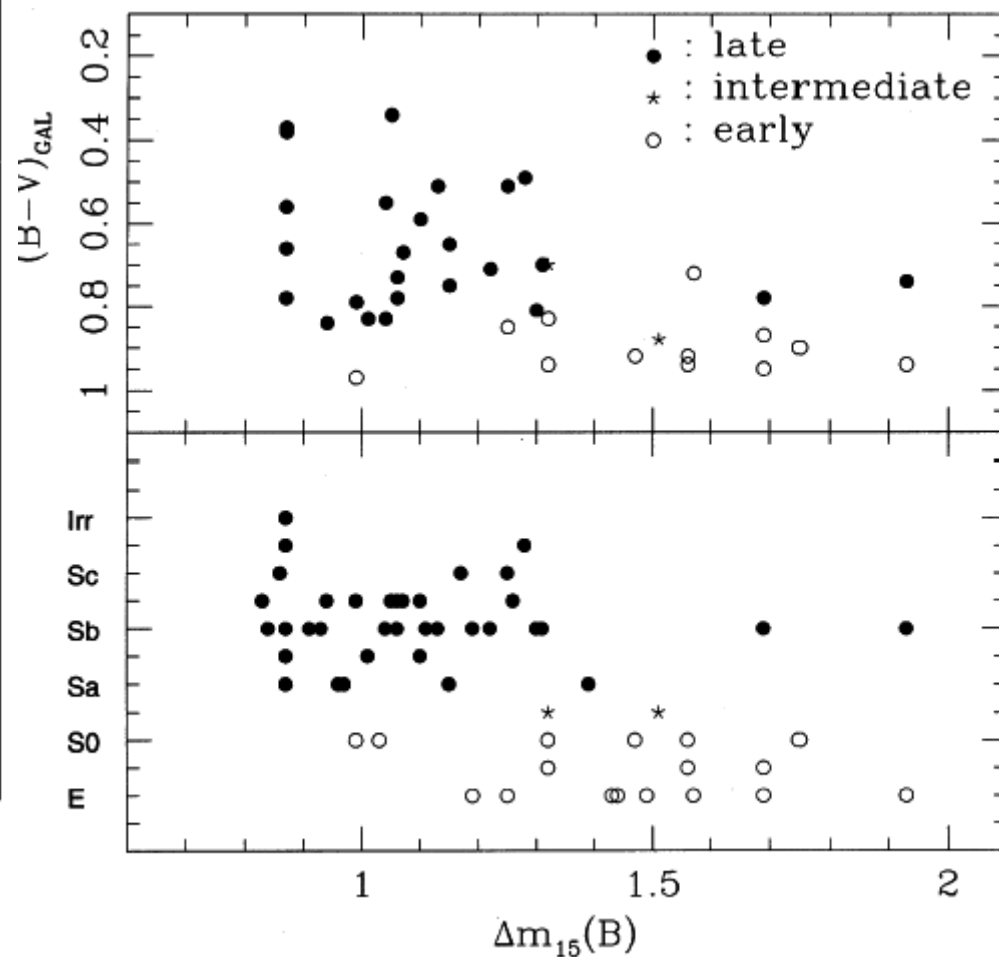
Is it Quintessence?

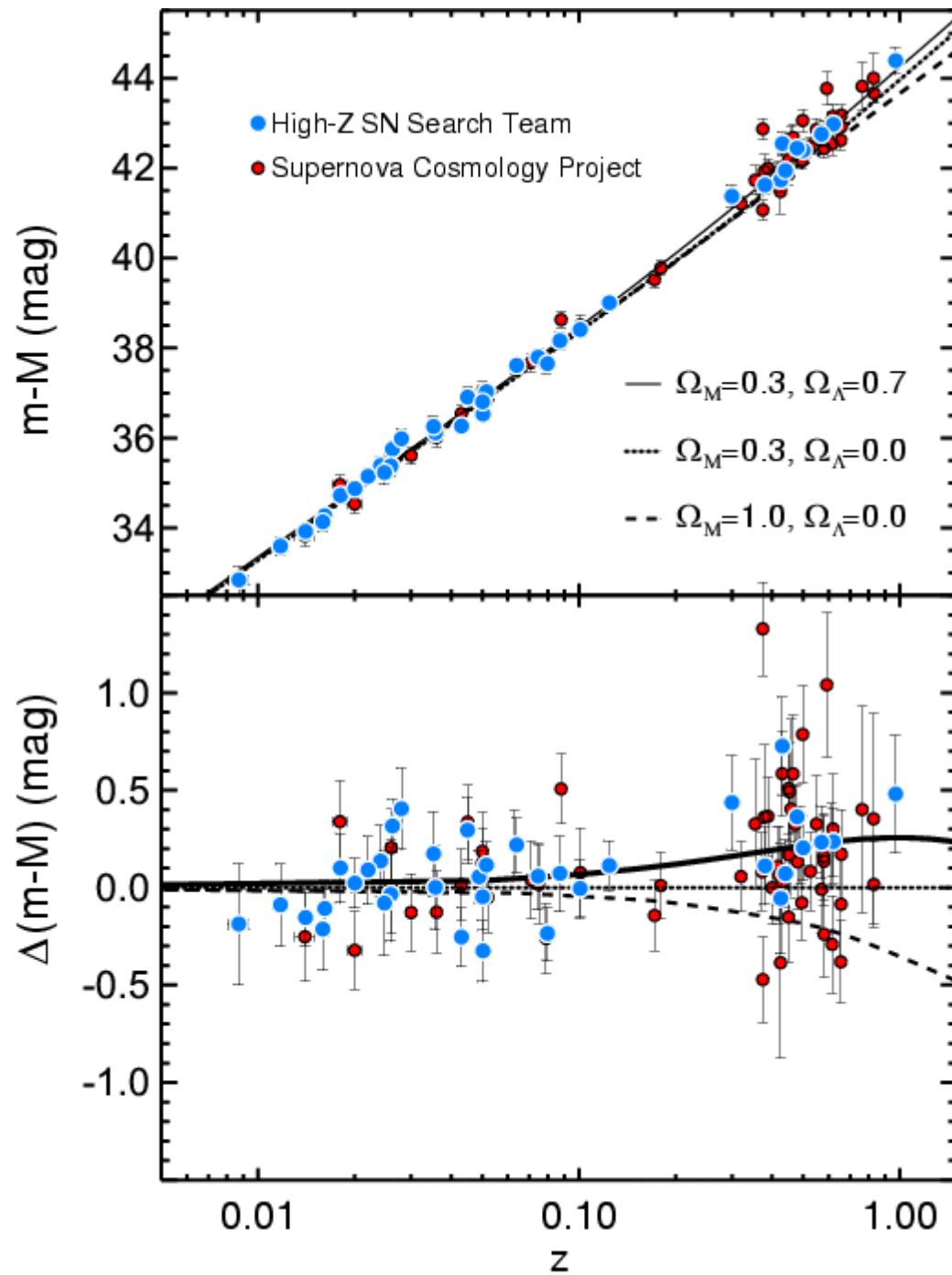
Does it interact with (dark) matter?

Is it a nonlinear effect of GR?

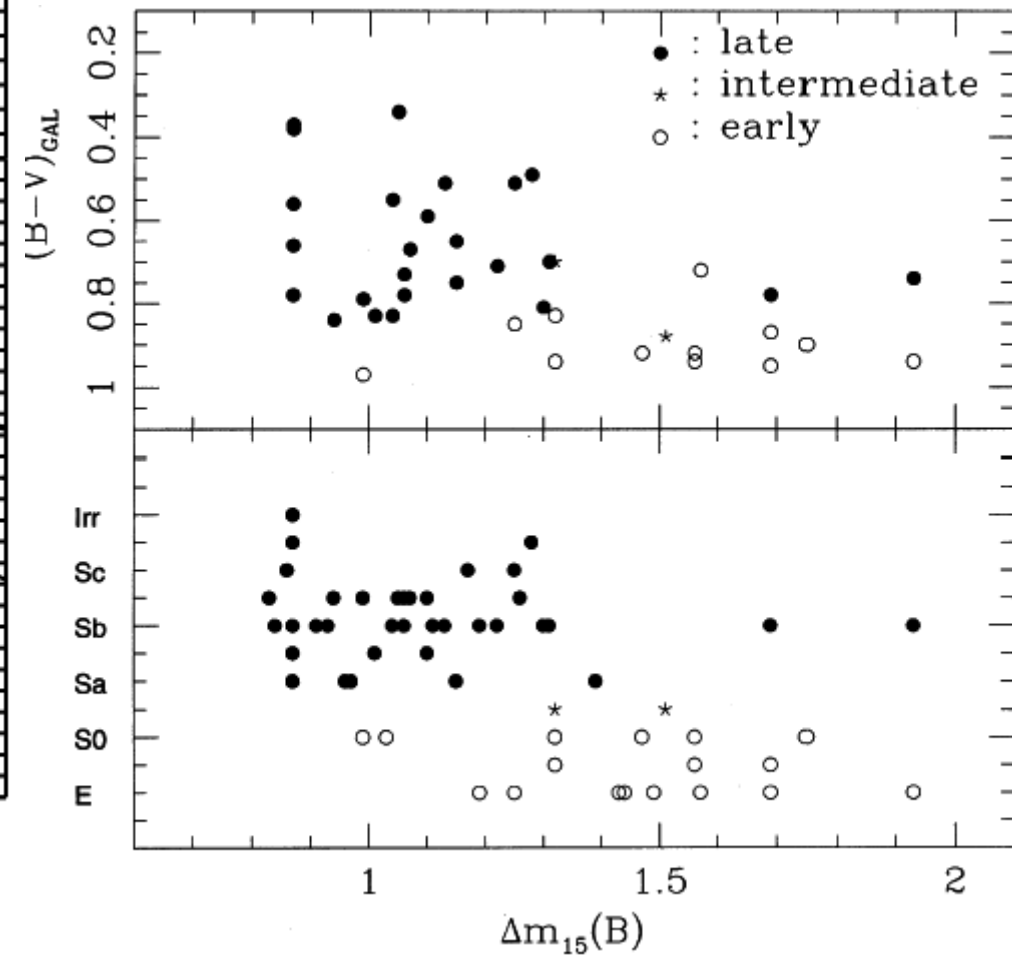


How sure is the acceleration?

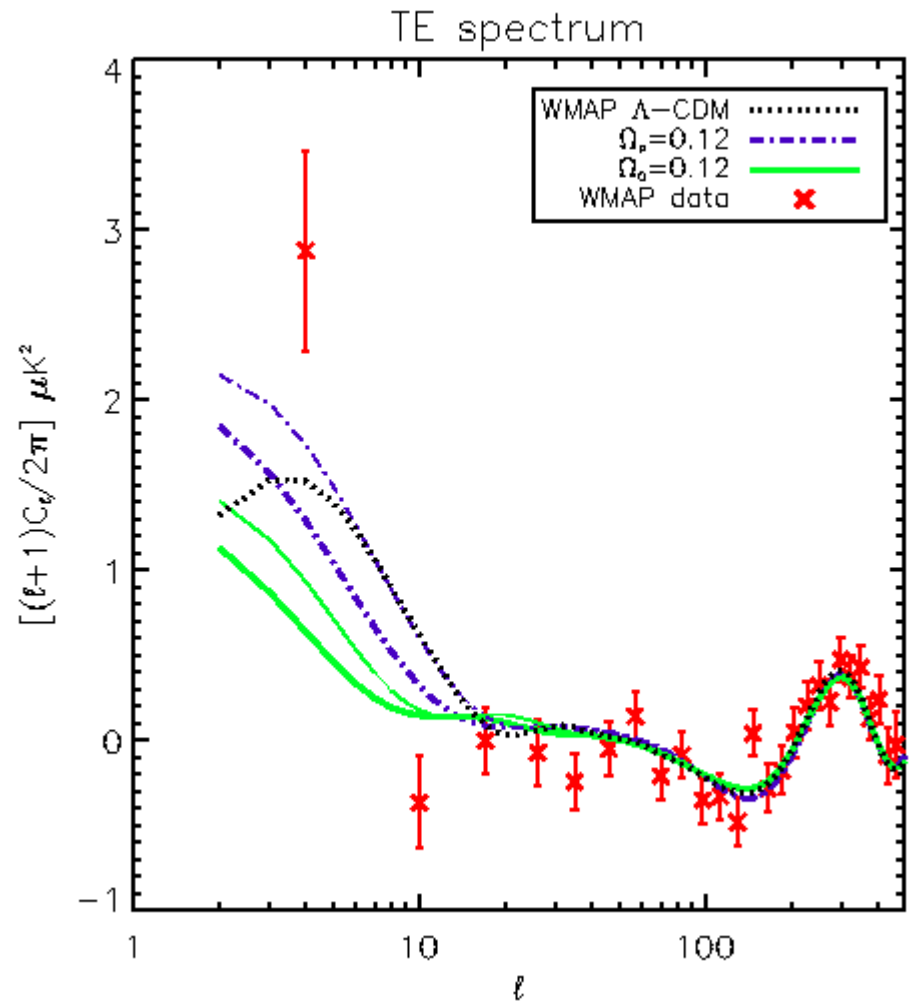
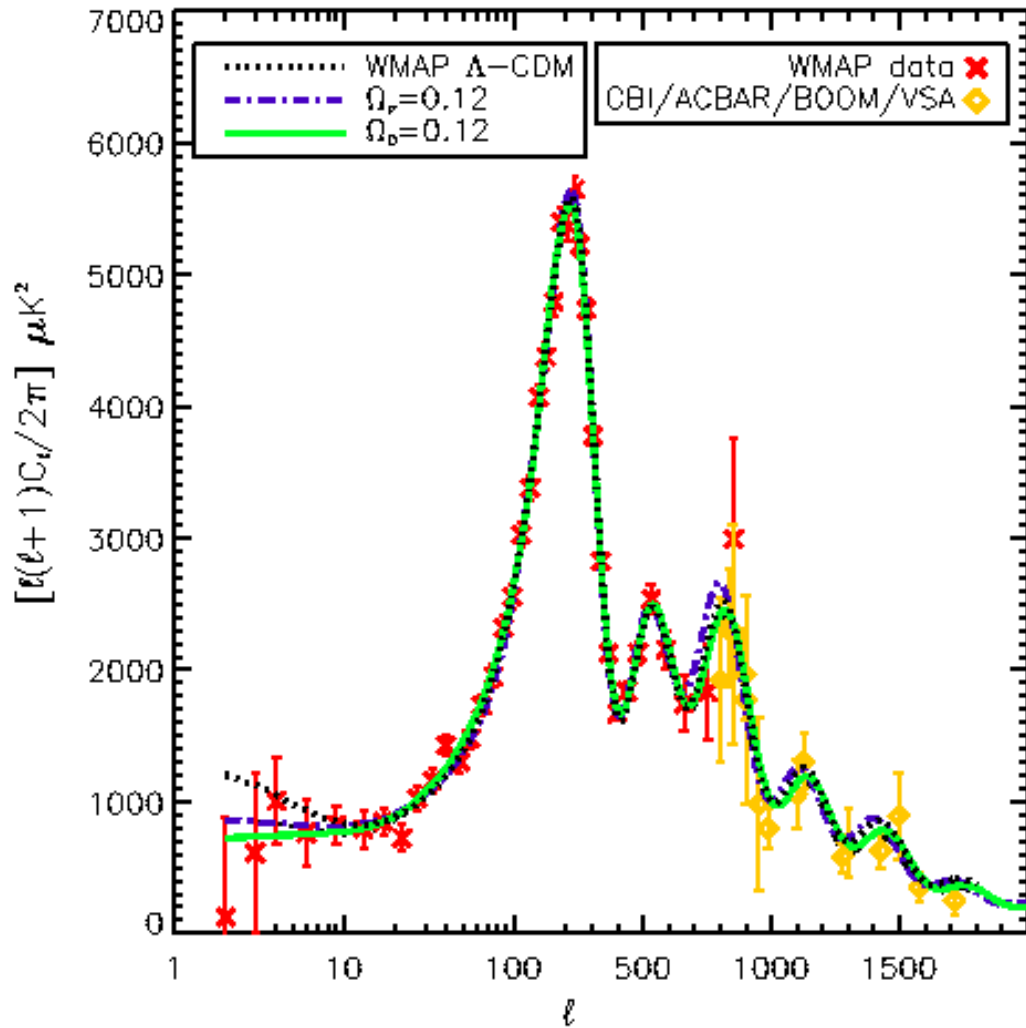




Is this sure enough to
bet a billion dollars?



Does the CMB require dark energy?



Blanchard et al 2003: Broken scale invariance model with NO dark energy
but with Ω_v and $h=0.45$

Did inflation happen?

When and why?

Will the gravity waves be measurable?
(worth betting a billion dollars?)

Are features on galaxy scales “unnatural”?

Is early element formation understood?

BBNS and the two Lithium problems

Stochasticity in early element enrichment

Anomalous C vs Fe

What is known about the first stars?

Pop III/Pop II; H_2 /HD; UV/X-ray effects;
stimulation/sterilisation; single/multiple;
remnants; clustering?

many ideas, few constraints

What about reionisation?

When and how? Once or twice? HeIII at $z=3$?

What did it? Observed populations too weak?

Size of structure at percolation?

What is known about the first stars?

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What did it? Observed populations too weak?

Size of structure at percolation?

Wait for that $z = 15$ GRB? For PAST/LOFAR/SKA?

Is galaxy formation solved?

What limits the masses of bright galaxies?

Why are there so few dwarfs?

What is responsible for down-sizing?

What establishes the SMBH/bulge relations?

How do black holes grow? Are “seeds” needed?

How are thin disks made?

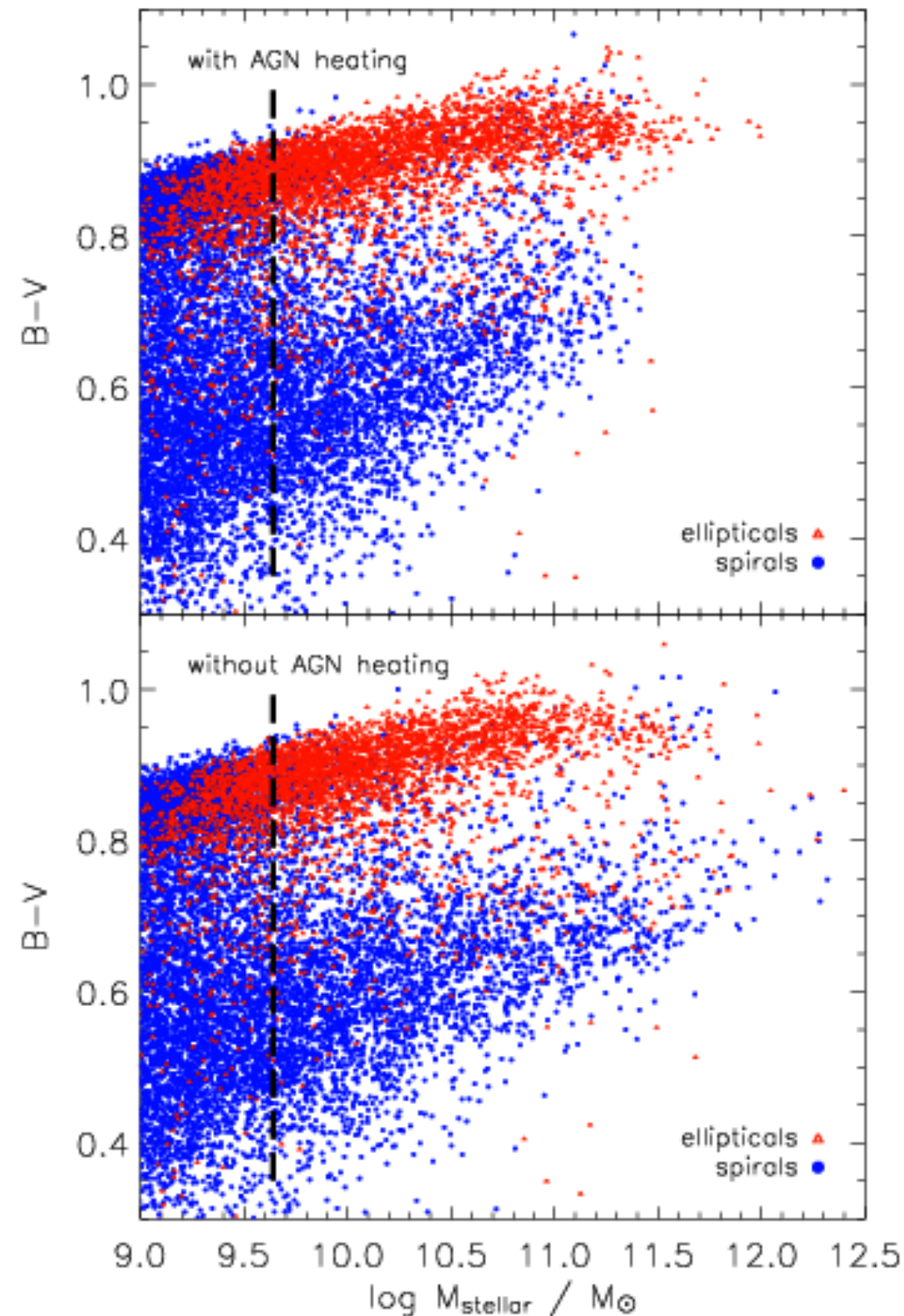
Relative importance of obscured and “visible” phases?

Is a top-heavy IMF required in bursts?

What made the backgrounds and when?

The effects of “radio mode” feedback on $z=0$ galaxies

Croton et al 2005



- In the absence of a “cure” for the cooling flow problem, the most massive galaxies are:
 - too bright
 - too blue
 - disk-dominated
- With cooling flows suppressed by “radio AGN” these galaxies are
 - less massive
 - red
 - elliptical

Structure and composition of the IGM

Where are the baryons/metals at $z = 0$?

How many metals are we missing at high z ?

Why don't we see wind bubbles?

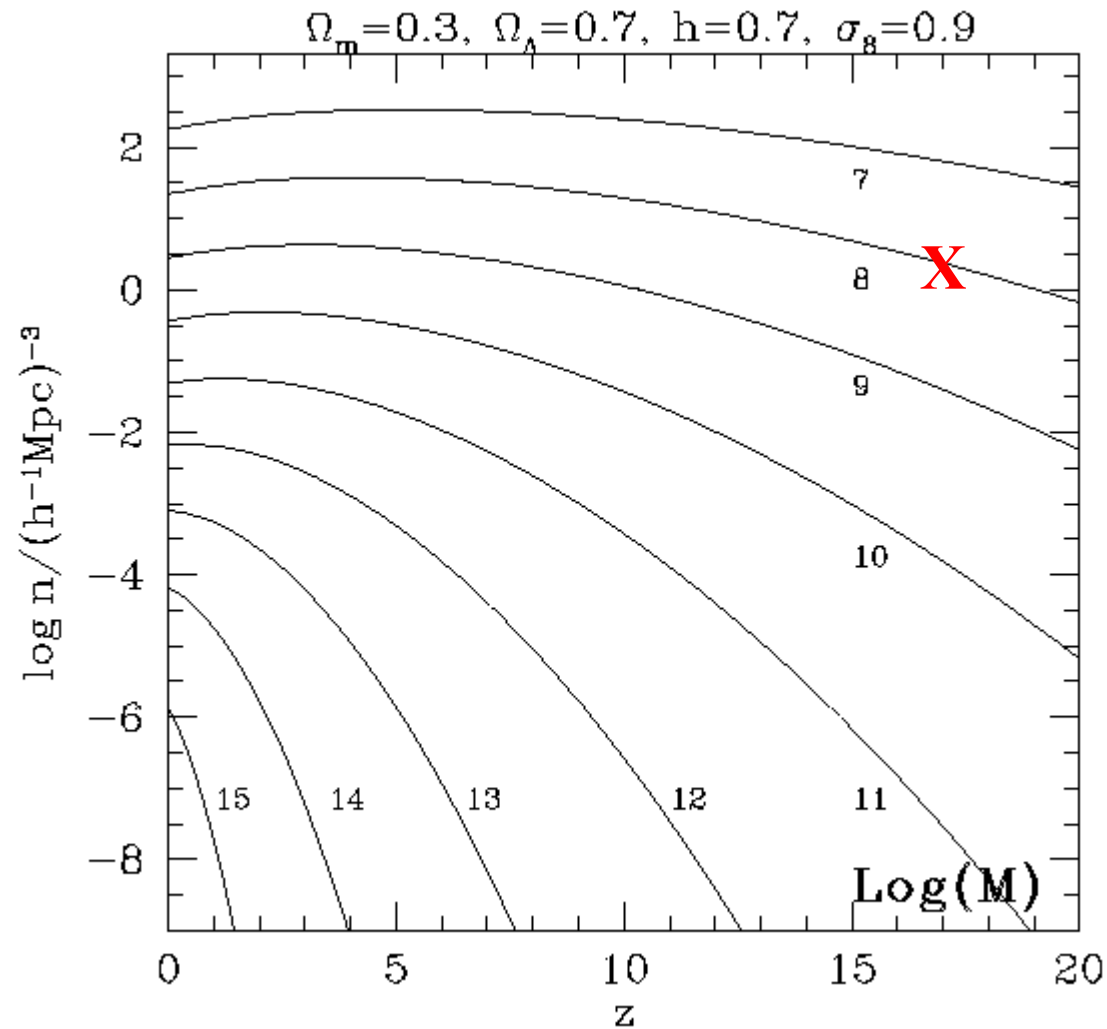
What is “galaxies”, what is IGM?

How did the observed metals get to be so uniform in low density, cool, high filling factor gas?

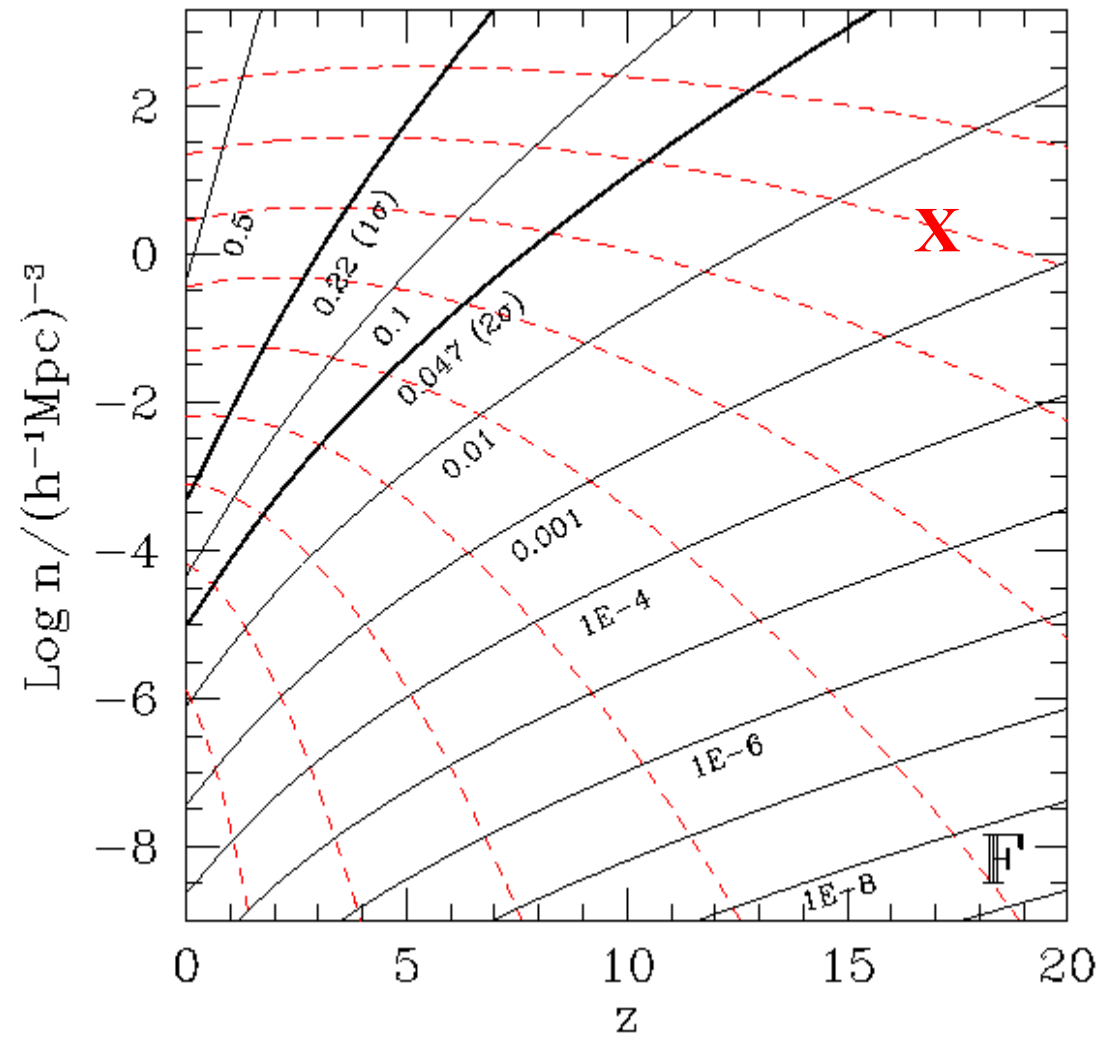
Is the lack of apparent evolution in CIV a fluke?

Do we require “early” enrichment? From what?

Does early enrichment  more uniform metals?

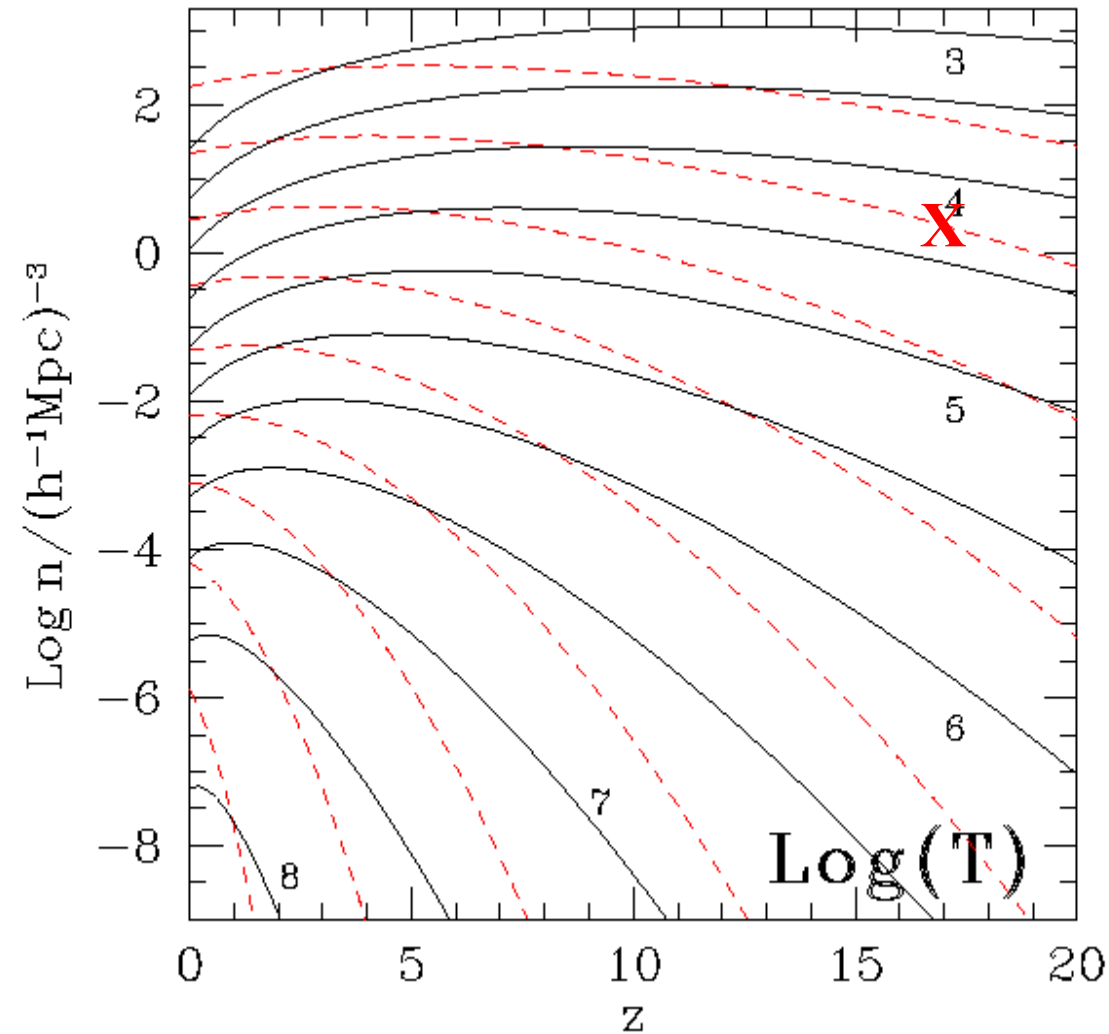


$M > 10^8 M_\odot$ halos are only 10 times less abundant at $z = 17$ than at $z = 0$

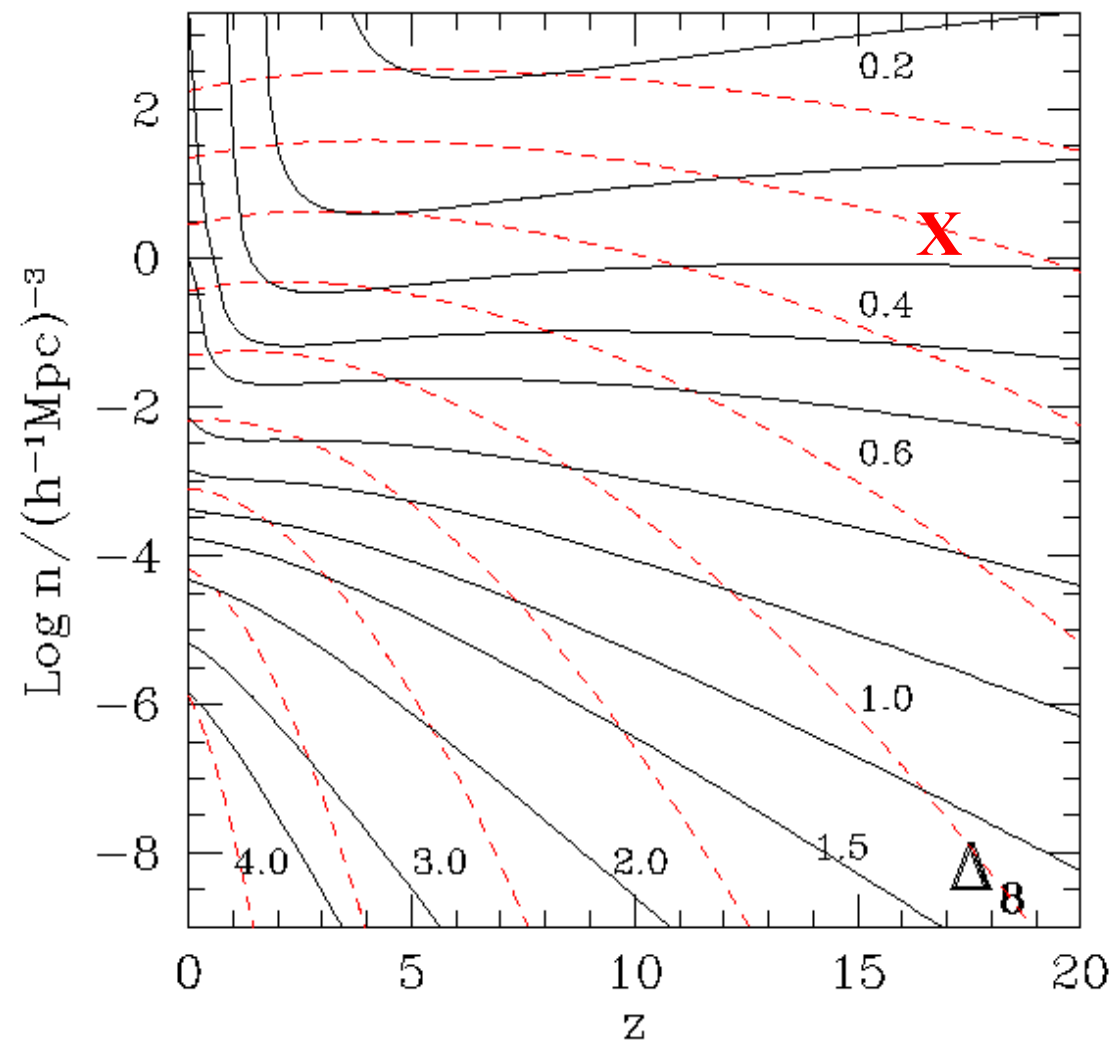


$M > 10^8 M_{\odot}$ halos at $z = 17$ contain 0.4% of all matter

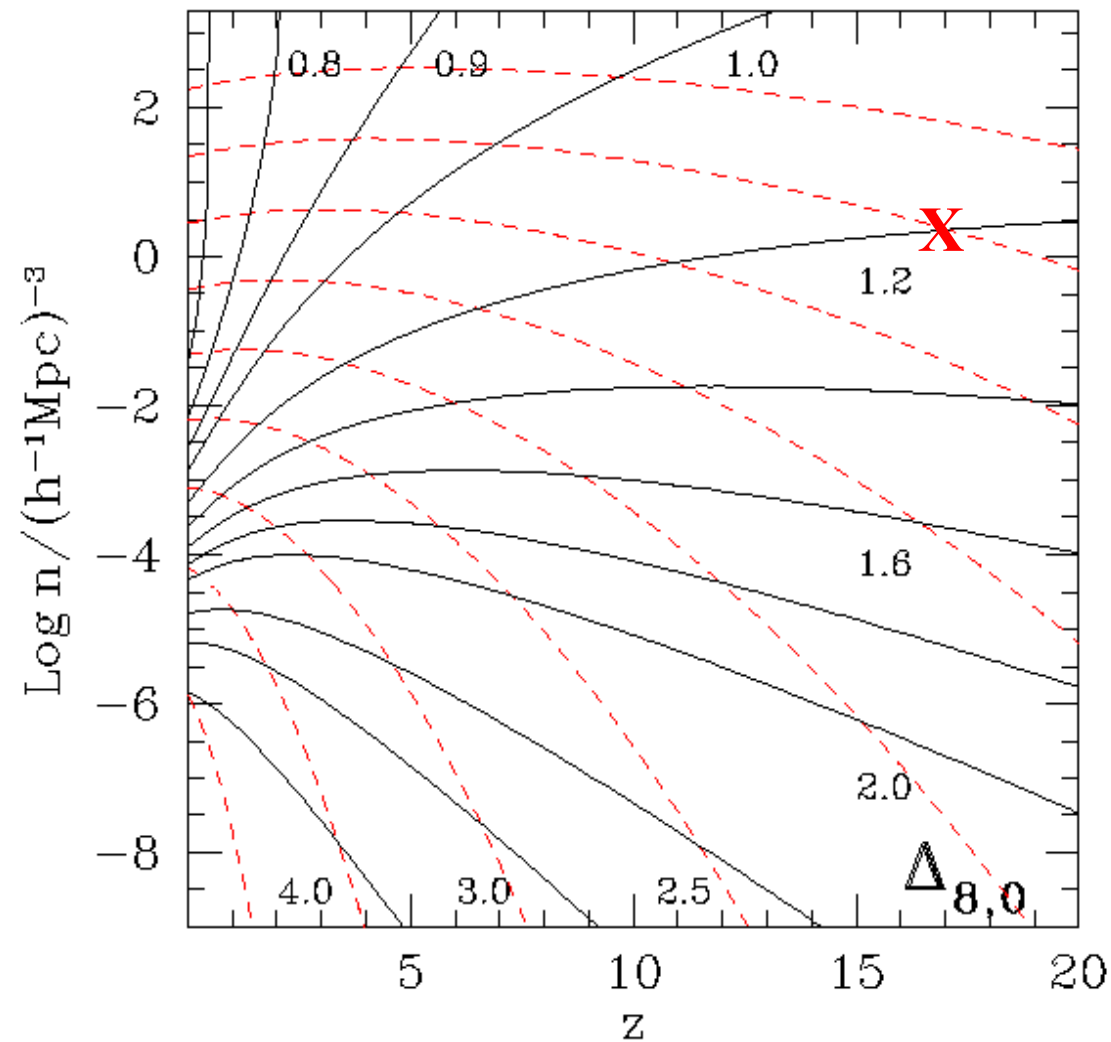
→ they could ionize the Universe



$M > 10^8 M_{\odot}$ halos at $z = 17$ have $T_{\text{vir}} > 2 \times 10^4 \text{ K}$
 → they could cool via *atomic* line processes



$M > 10^8 M_{\odot}$ halos at $z = 17$ cluster with $\sigma_8 = 0.35$ at $z = 17$



$M > 10^8 M_{\odot}$ halos at $z = 17$ produce metals which cluster with $\sigma_8 = 1.2$ at $z = 0$, and $\sigma_8 = 0.6$ at $z = 3$

CONCLUSIONS?

Very few of the important questions are “closed”

New data continually bring new insights and new questions

We still know rather little about the first billion years

