

THE ETERNAL SILENCE OF
THESE INFINITE SPACES
TERRIFIES ME

THE FUTURE OF THE COSMOS

MARK WYMAN

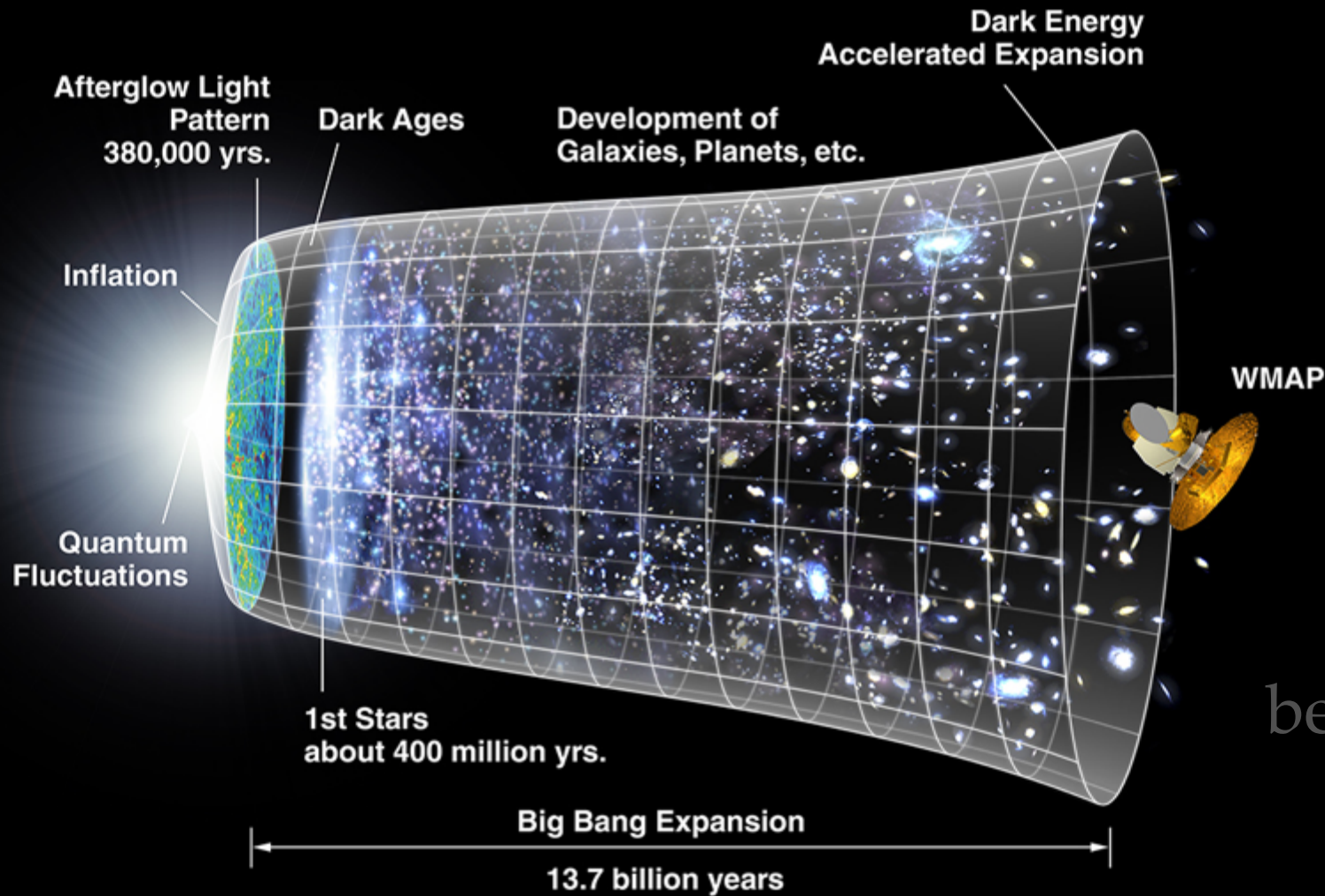
74TH COMPTON LECTURE SERIES



“Le silence éternel
de ces espaces
infinis m'effraie.”

- Blaise Pascal

(The eternal silence
of these infinite
spaces terrifies me)



and
beyond

...

WHAT COMES NEXT?

Heat Death

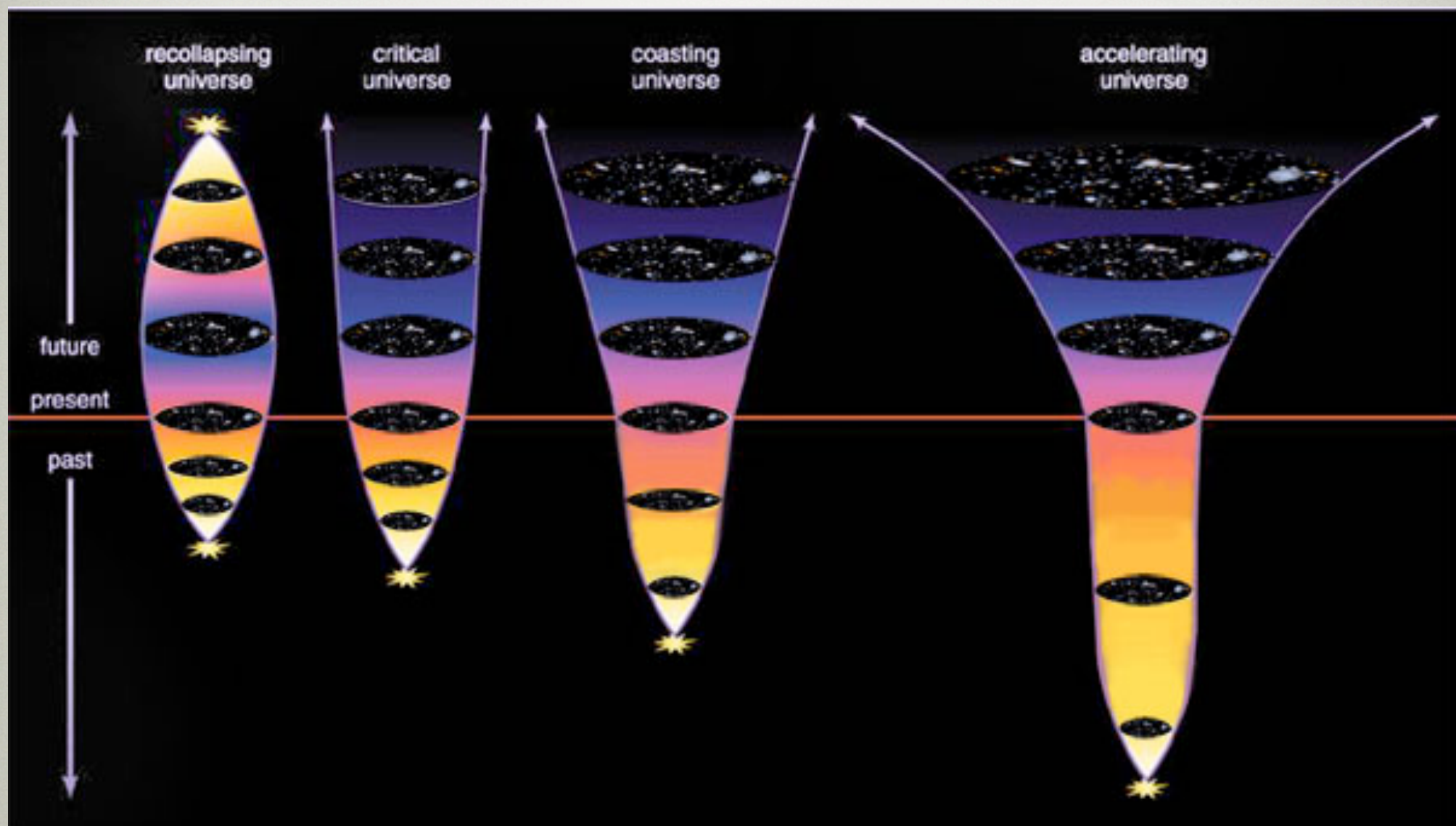
Big Crunch

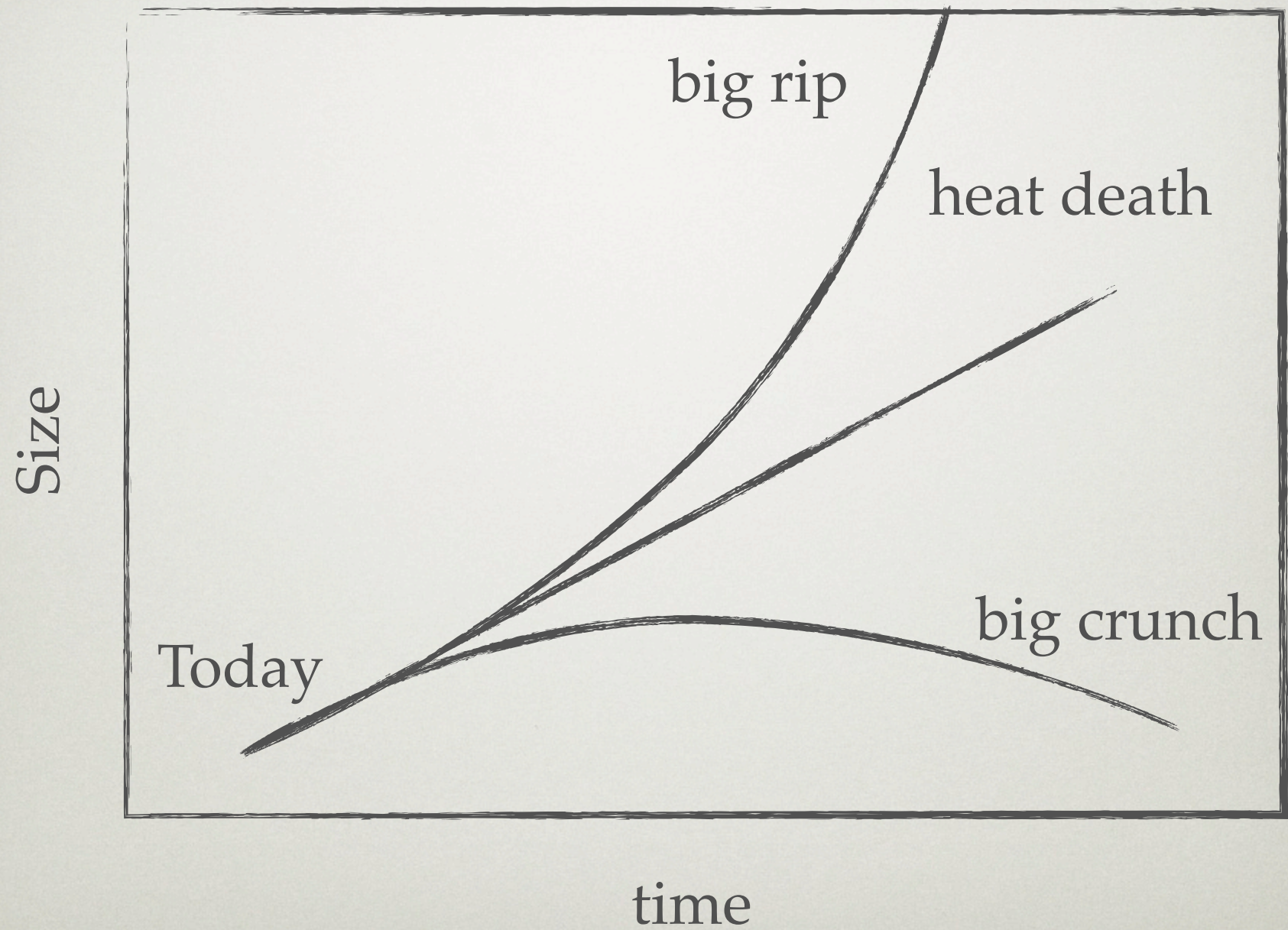
?

Cyclic Rebirth

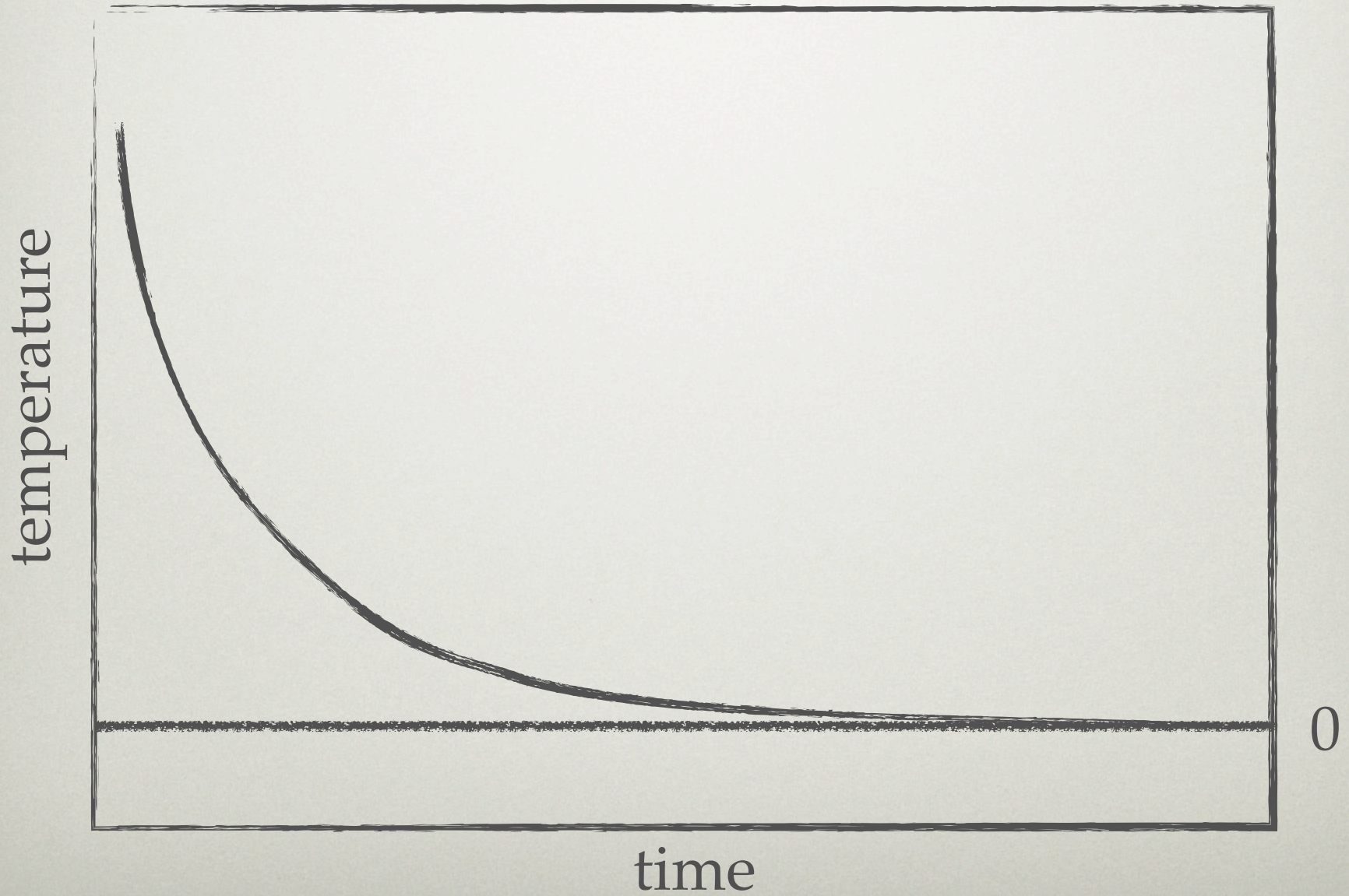
Big Rip

STANDARD (SMOOTH) POSSIBILITIES





HEAT DEATH



IT'LL TAKE A WHILE...

5 billion years: our Sun becomes a red giant

2 trillion years: dark energy makes all non-nearby galaxies disappear

100 trillion years: all stars go out

100^{100} years: all black holes have evaporated

DARK ENERGY AND FINITE INFORMATION

WHAT IS INFORMATION?

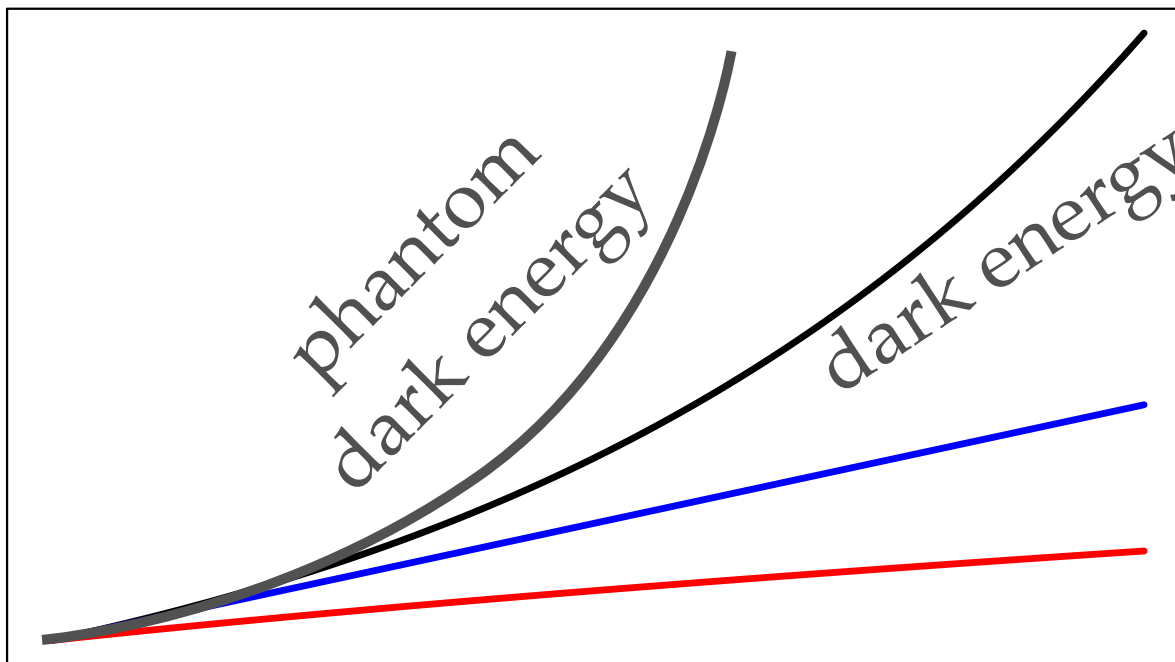


**IN A DARK ENERGY UNIVERSE,
ENTROPY IS FINITE (BUT BIG)**

$$S = \text{Entropy} = \frac{M_p^4}{\Lambda} \simeq 10^{121}$$

alternate statement of heat death

BIG RIP?



BIG RIP?

A few billion years from now: Milky Way galaxy
would be ripped apart

60 million years later: solar system disrupted

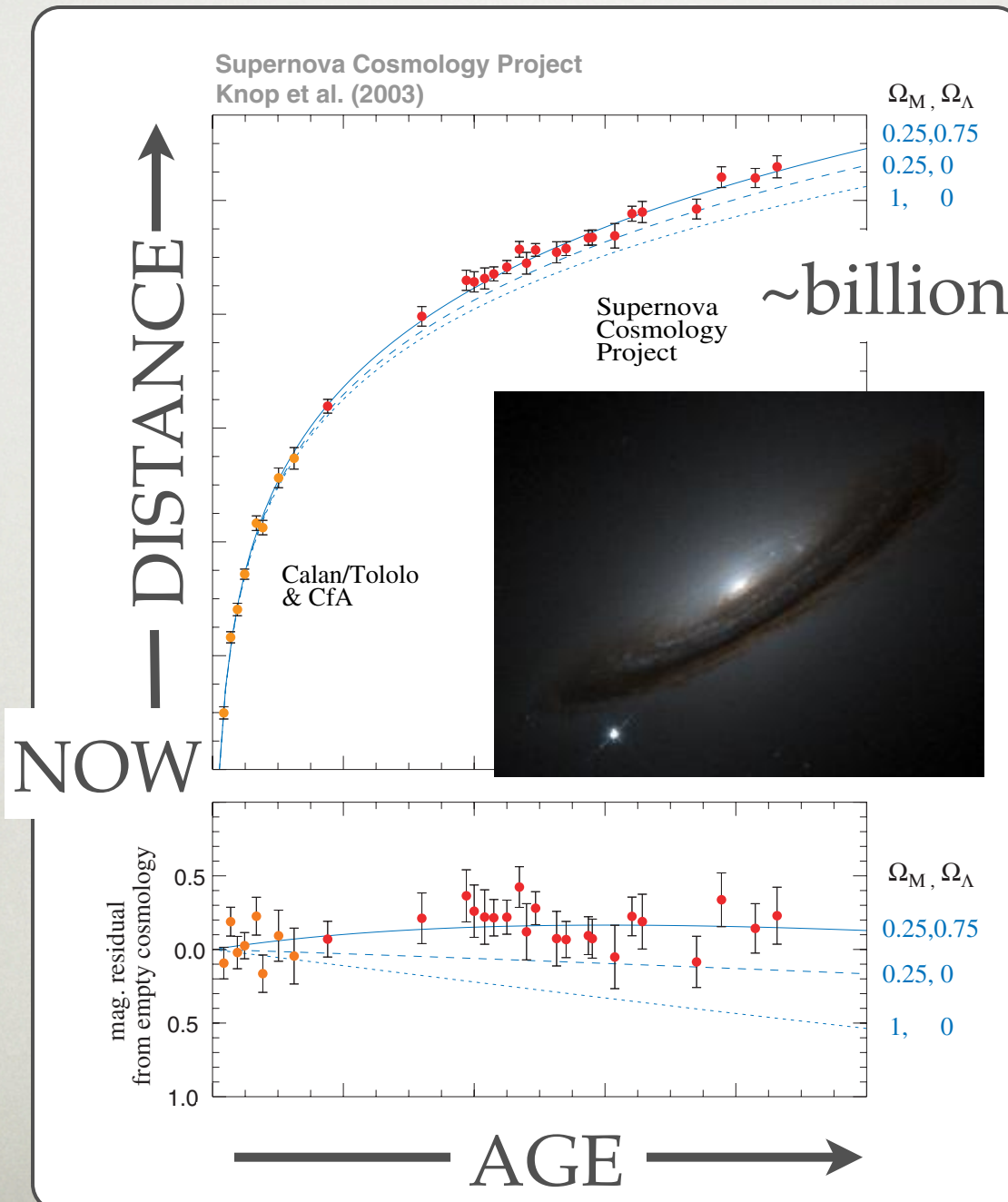
3 months later: stars and planets would be destroyed

within minutes: atoms would be ripped apart

BIG CRUNCH

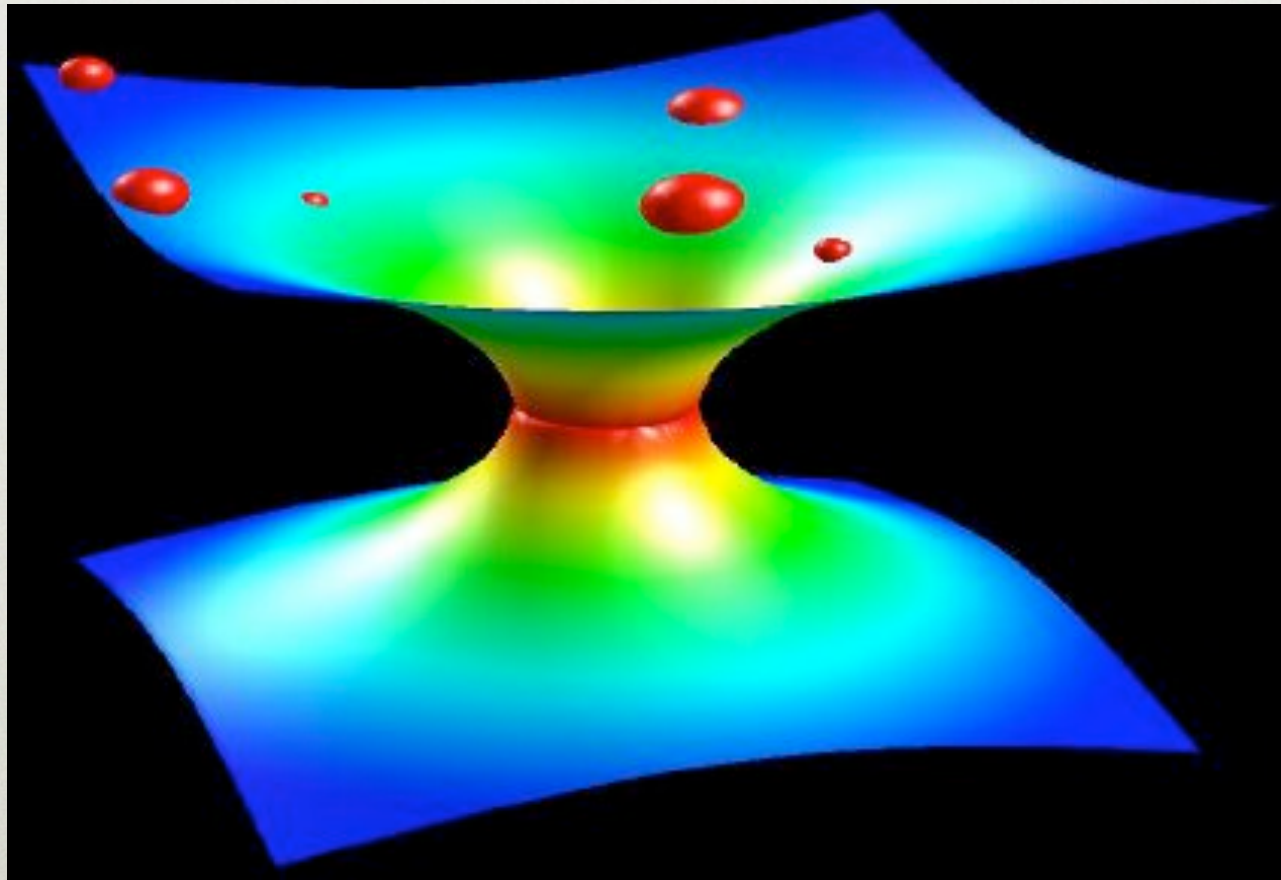
(largely) out of fashion

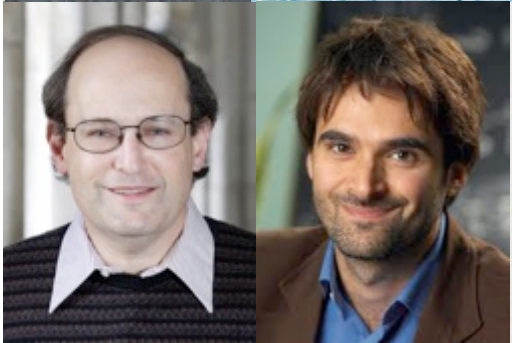
WHY: EXPANSION RATE IS ACCELERATING!



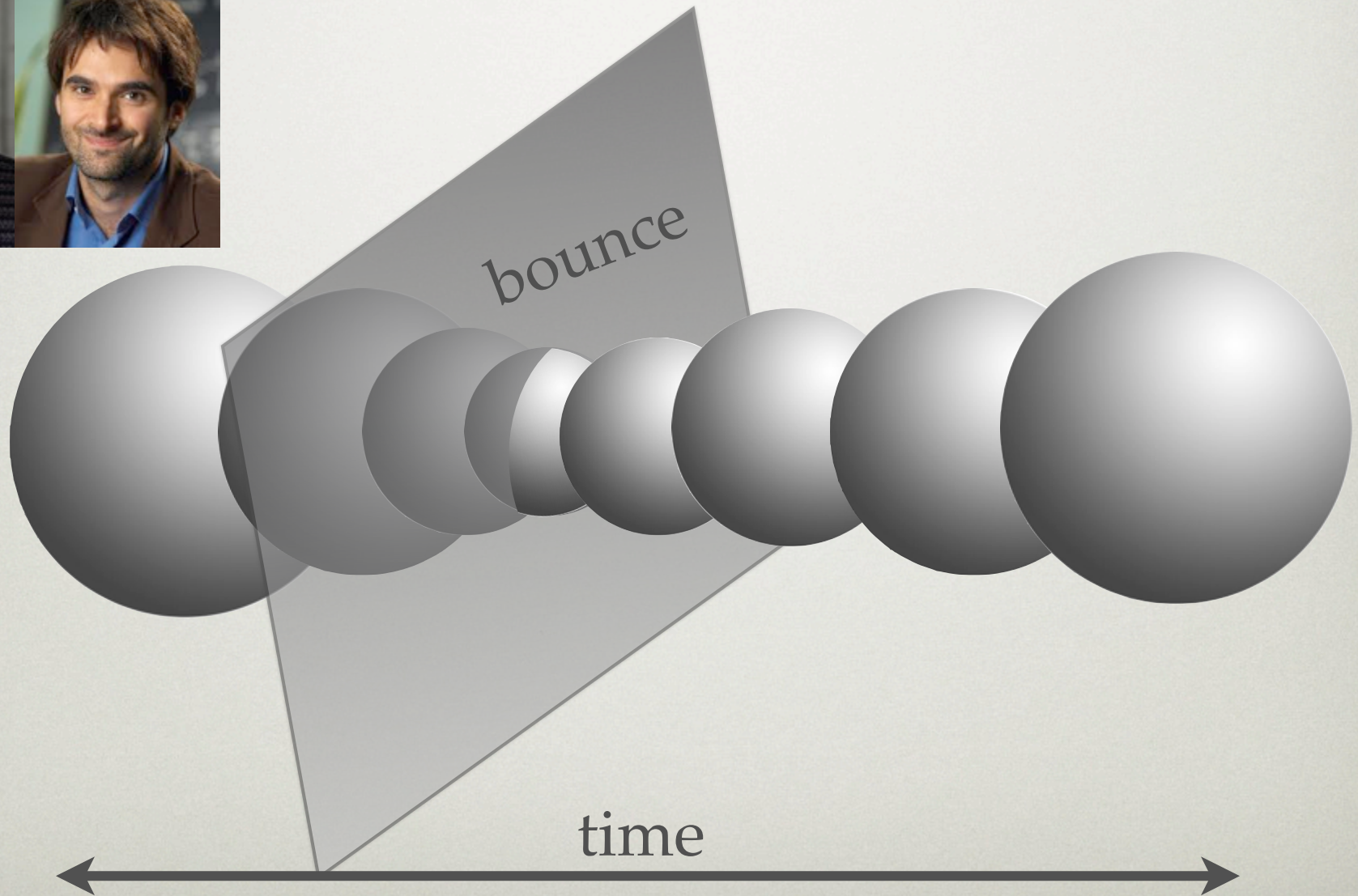
~2000

CYCLIC REBIRTH?





CYCLIC CONTRACTION

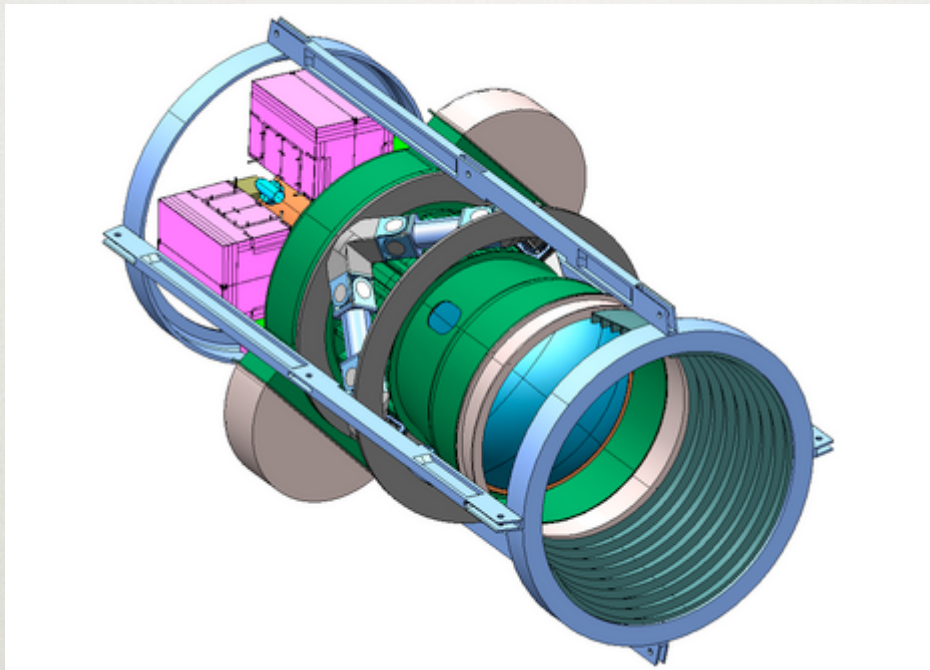


PENROSE'S “CONFORMAL INFINITY” CONJECTURE



CAN WE TELL WHICH FATE IS OURS?

maybe.



Dark Energy Survey
(run by Fermilab / UChicago)

IS DARK ENERGY A COSMOLOGICAL CONSTANT?

$$\frac{\text{Dark Energy Pressure}}{\text{Dark Energy Density}} = w = -1?$$

IS DARK ENERGY CHANGING IN TIME?

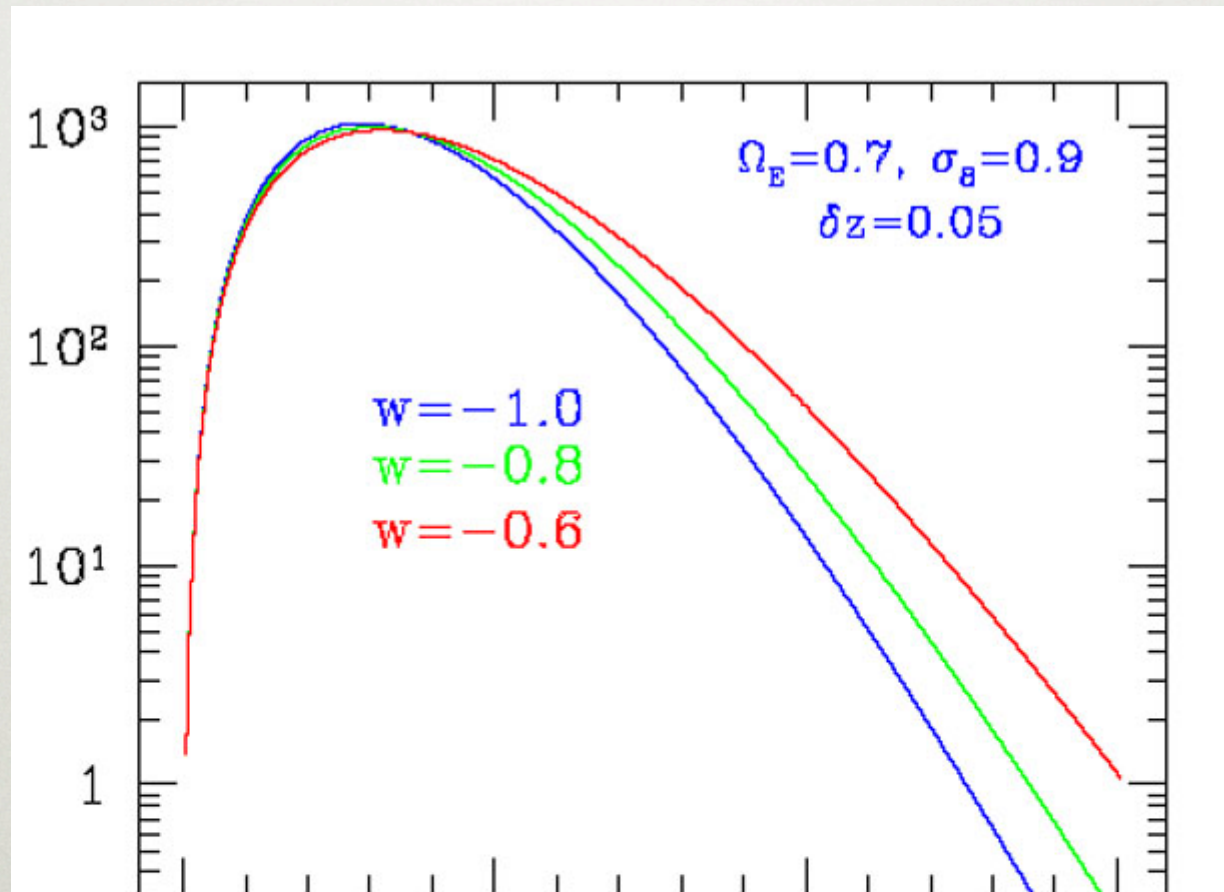
$$\frac{d}{dt} \left(\frac{\text{Dark Energy Pressure}}{\text{Dark Energy Density}} \right) = 0?$$

4 MEASUREMENTS

count clusters	weak lensing
supernovae observations	galaxy color measurements

CLUSTER COUNTING

number of visible clusters

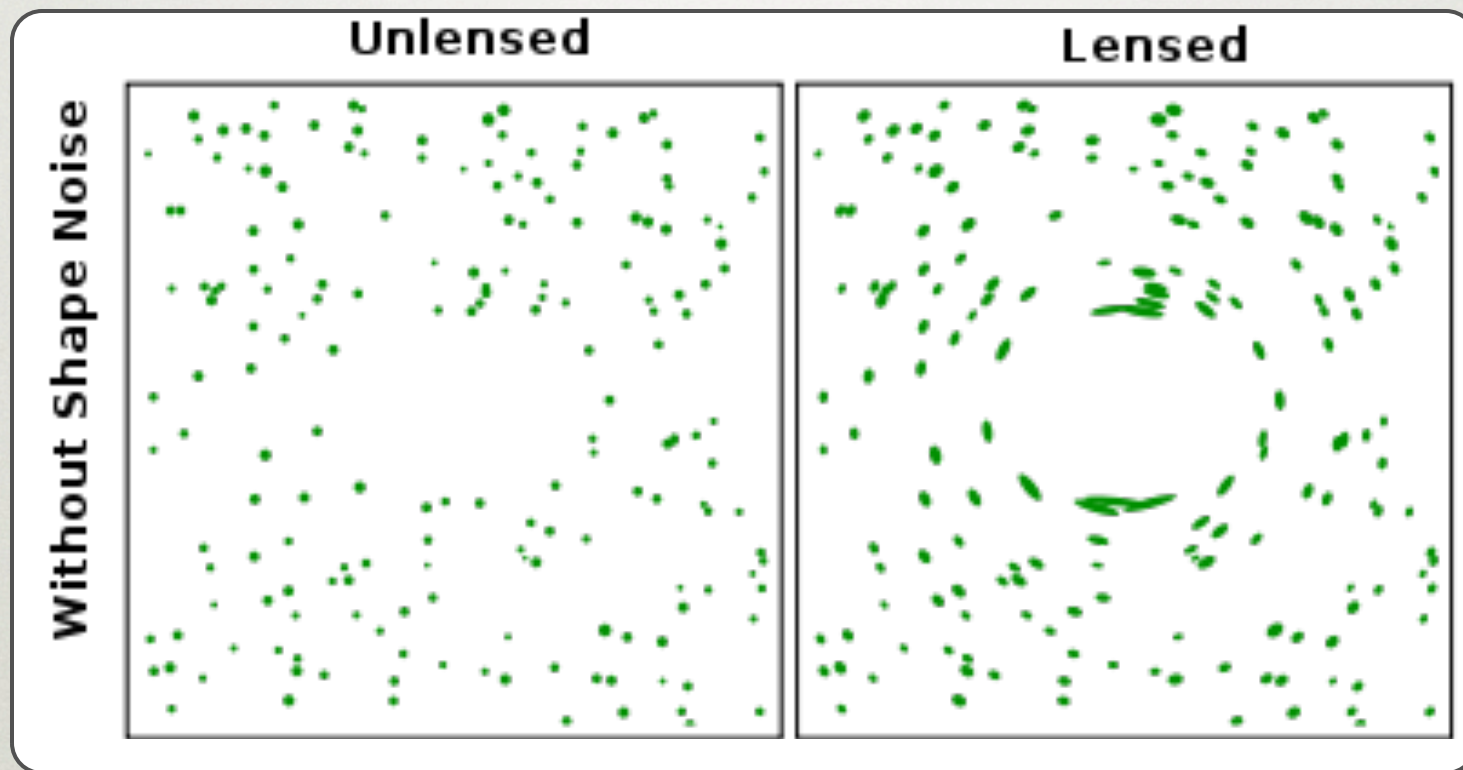


today

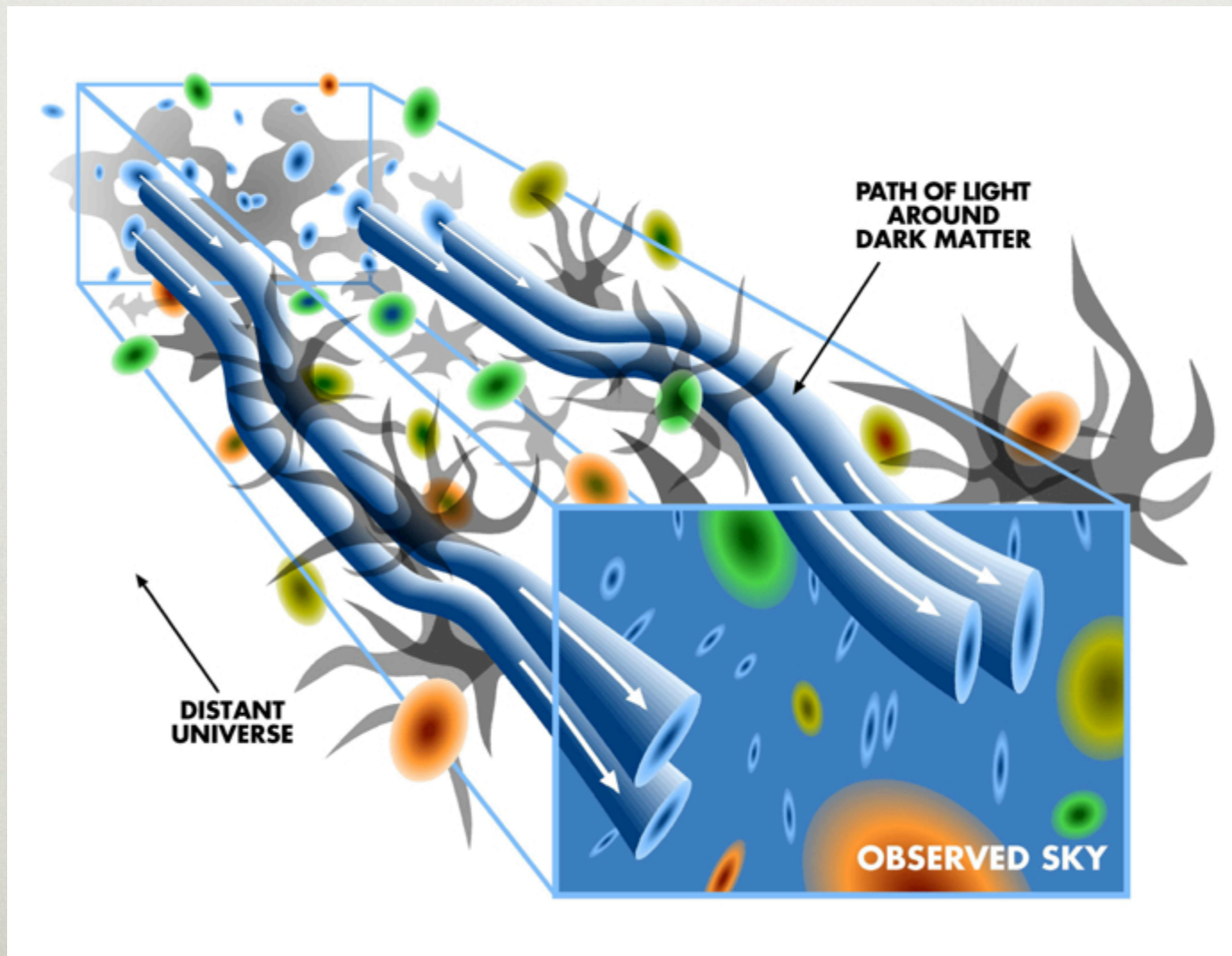
time

10 billion years ago

WEAK LENSING



WEAK LENSING

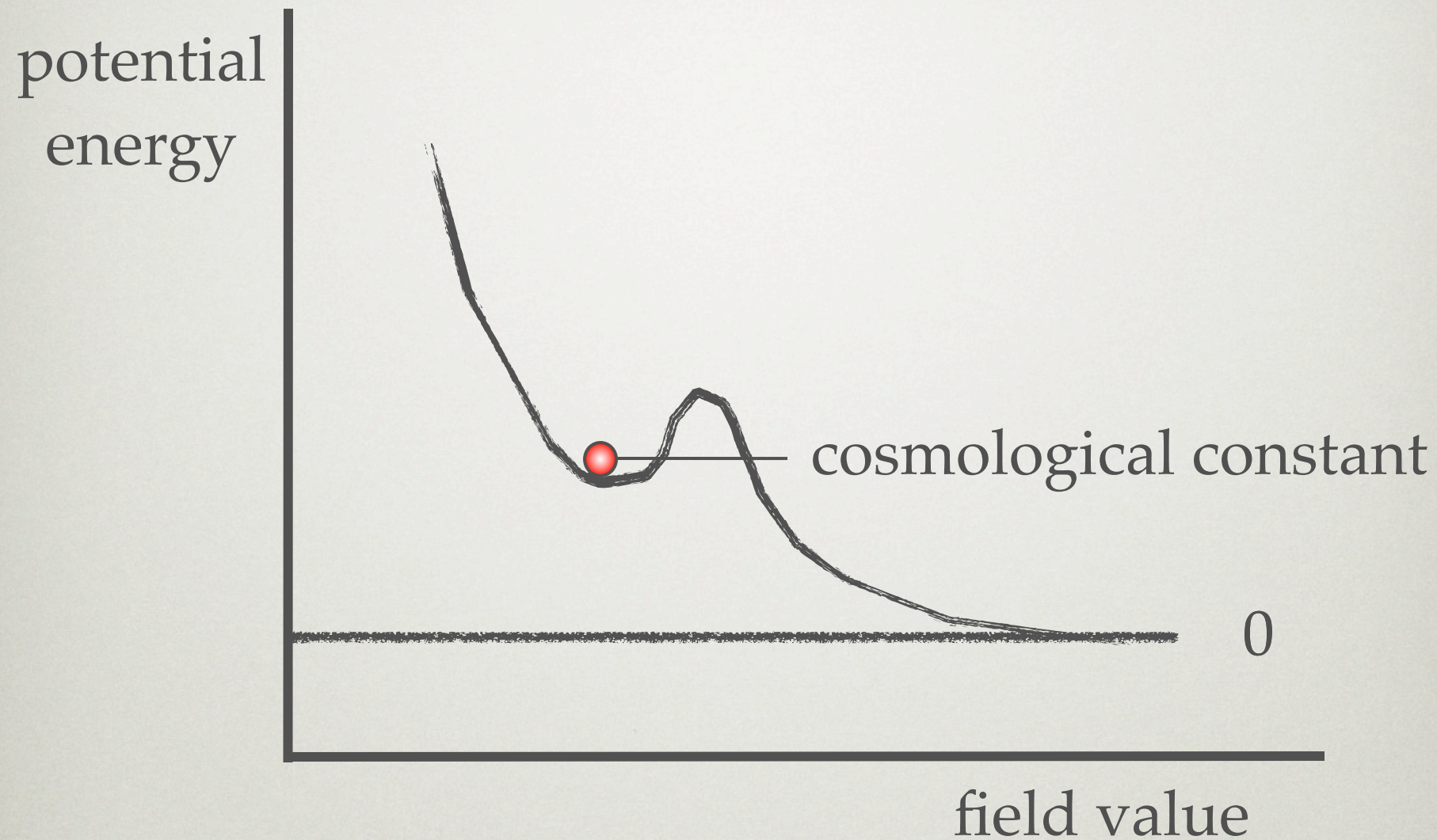


EXOTIC POSSIBILITIES (QUANTUM / NONLINEAR)

VACUUM DECAY

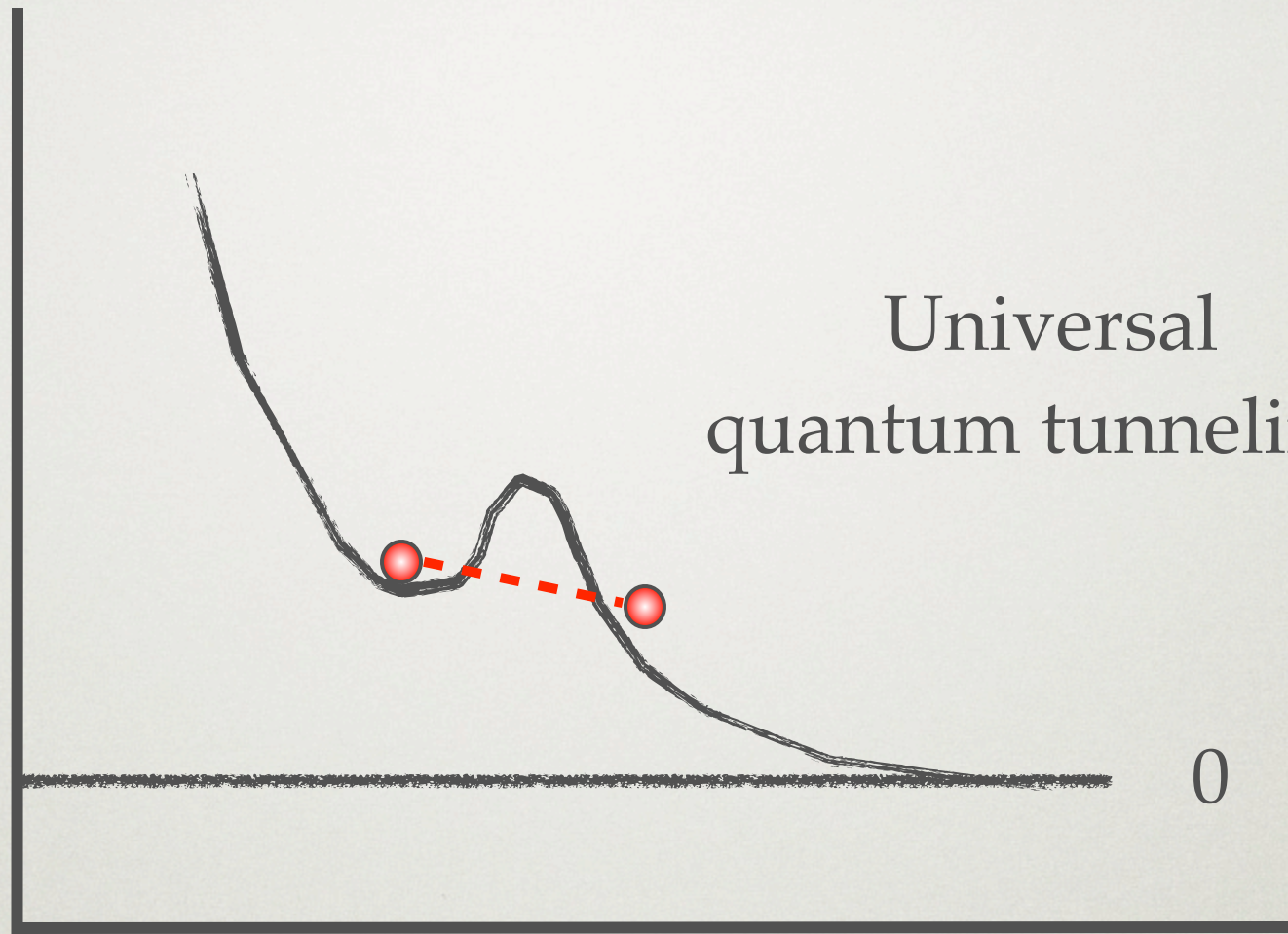
"Vacuum decay is the ultimate ecological catastrophe; in the new vacuum there are new constants of nature; after vacuum decay, not only is life as we know it impossible, so is chemistry as we know it. However, one could always draw stoic comfort from the possibility that perhaps in the course of time the new vacuum would sustain, if not life as we know it, at least some structures capable of knowing joy. This possibility has now been eliminated." - S. Coleman





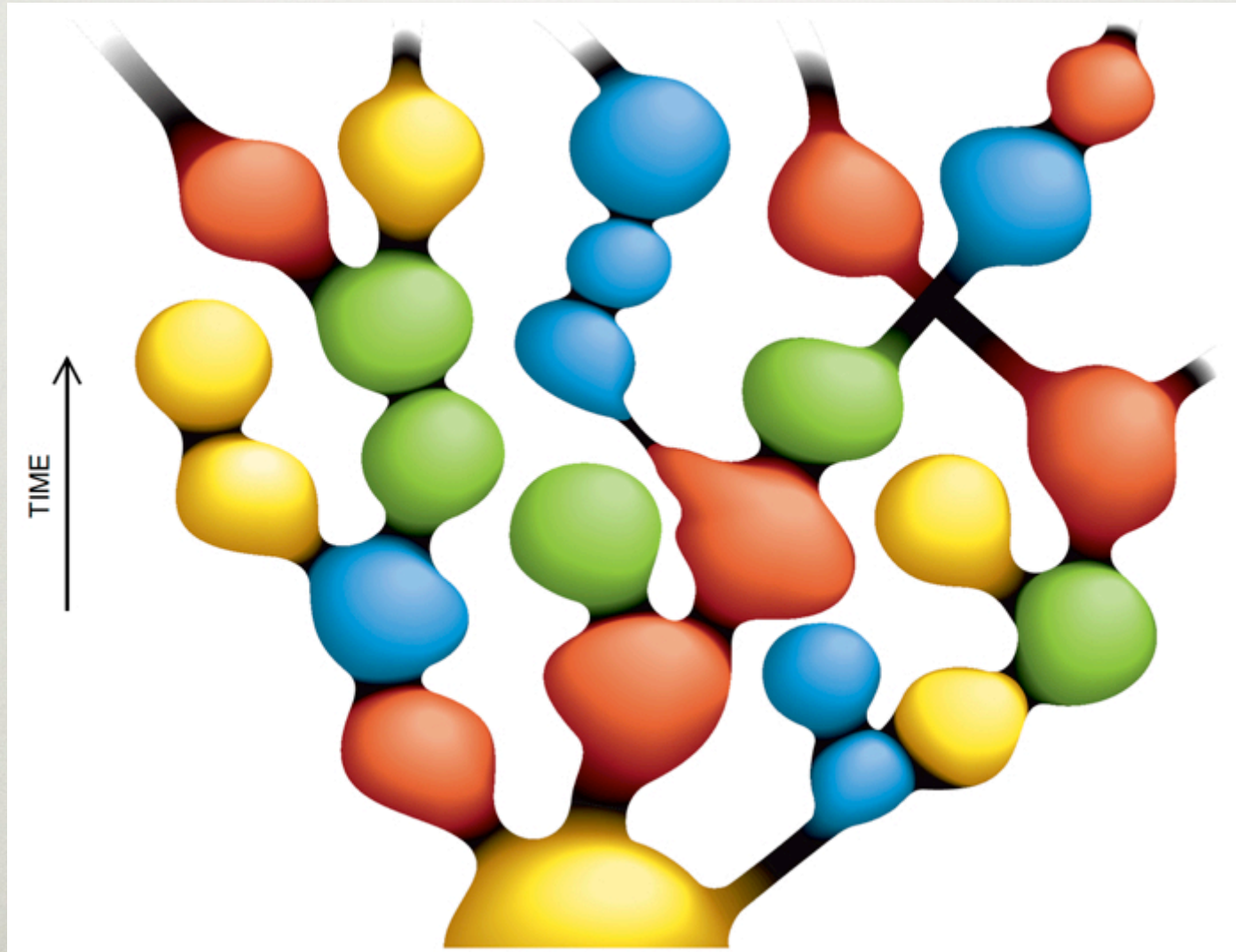
potential
energy

Universal
quantum tunneling!



field value

ETERNAL INFLATION ENDS TIME?



SOME SAY SO:

PHYSICAL REVIEW D **83**, 023525 (2011)

Eternal inflation predicts that time will end

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Present treatments of eternal inflation regulate infinities by imposing a geometric cutoff. We point out that some matter systems reach the cutoff in finite time. This implies a nonzero probability for a novel type of catastrophe. According to the most successful measure proposals, our galaxy is likely to encounter the cutoff within the next 5×10^9 years.

DOI: 10.1103/PhysRevD.83.023525

PACS numbers: 98.80.Jk, 04.20.Gz, 98.80.Qc

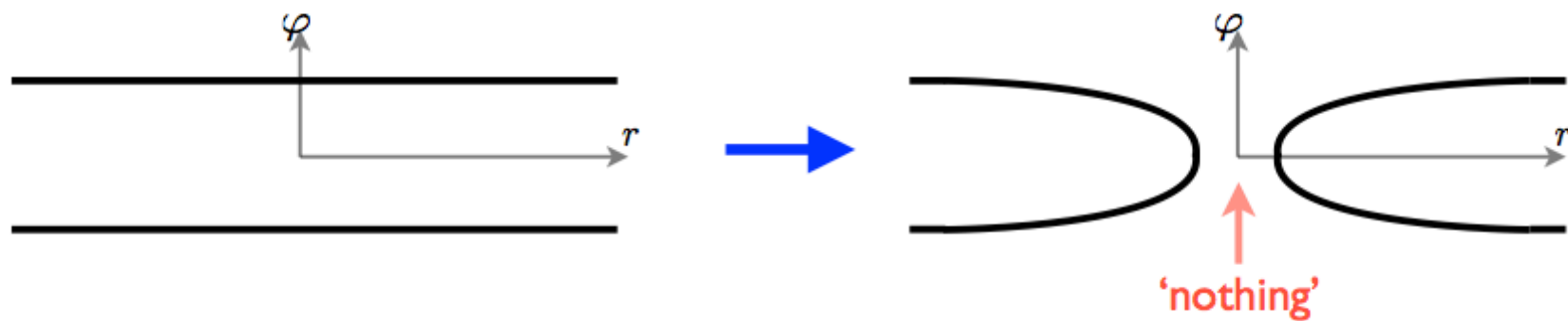
I. INTRODUCTION: TIME WILL END

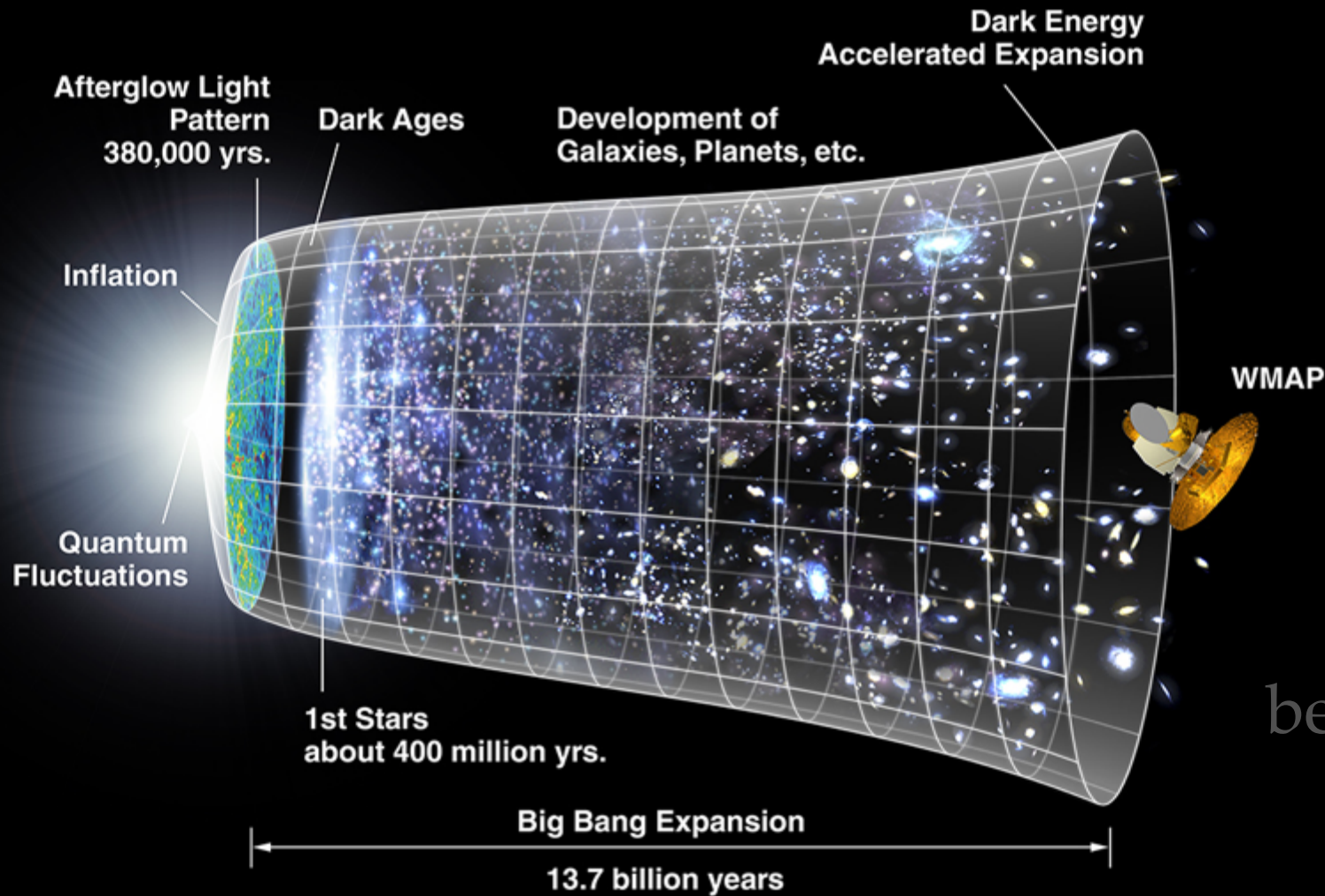
A sufficiently large region of space with positive vacuum energy will expand at an exponential rate. If the vacuum is stable, this expansion will be eternal. If it is metastable, then the vacuum can decay by the nonperturbative formation of bubbles of lower vacuum energy. Vacuum decay is

on geometric cutoffs, which discard all but a finite portion of the eternally inflating spacetime. The relative probability of two types of events, 1 and 2, is then defined by

$$\frac{p_1}{p_2} = \frac{\langle N_1 \rangle}{\langle N_2 \rangle}, \quad (1.1)$$

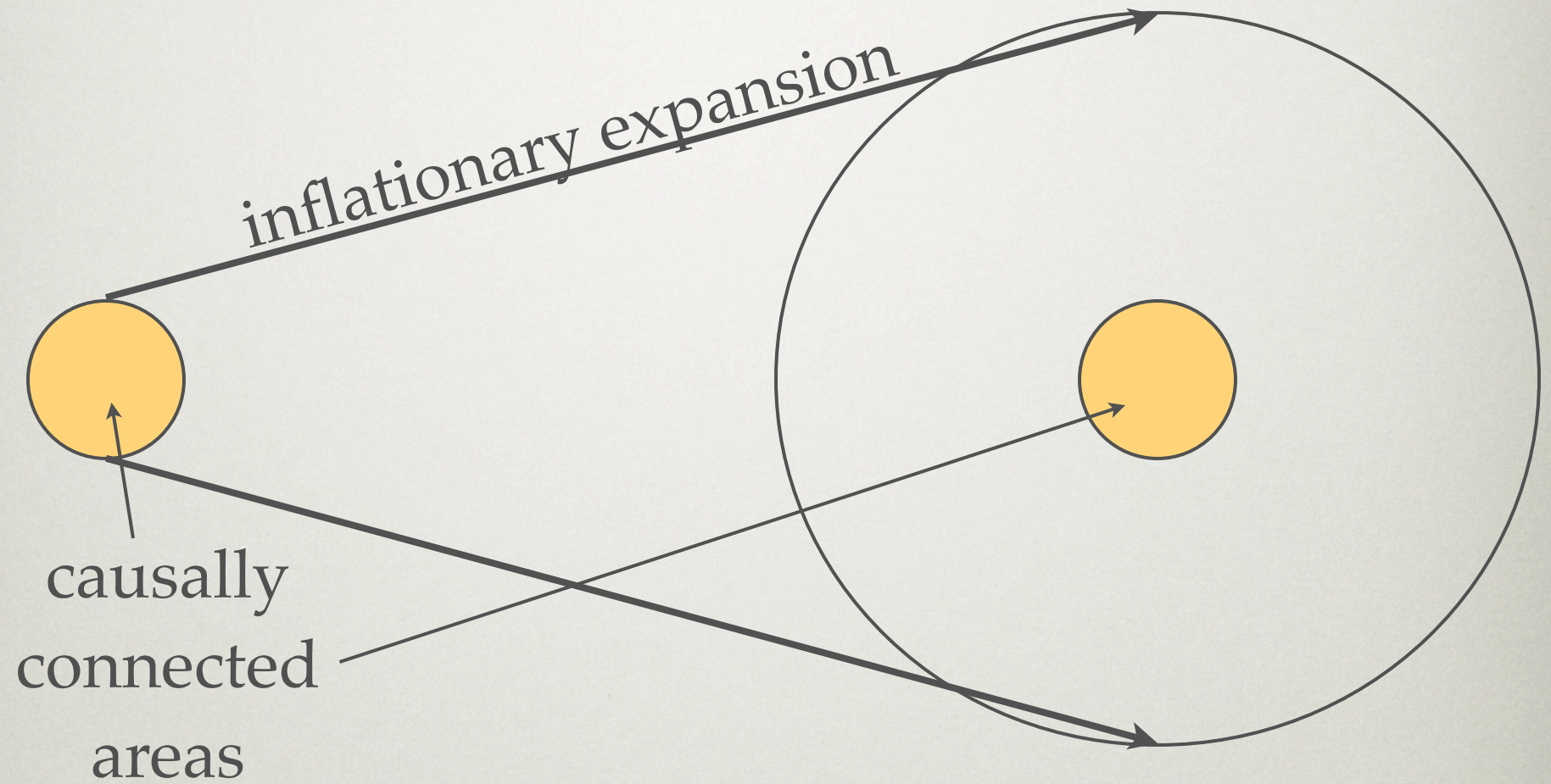
BUBBLES OF NOTHING



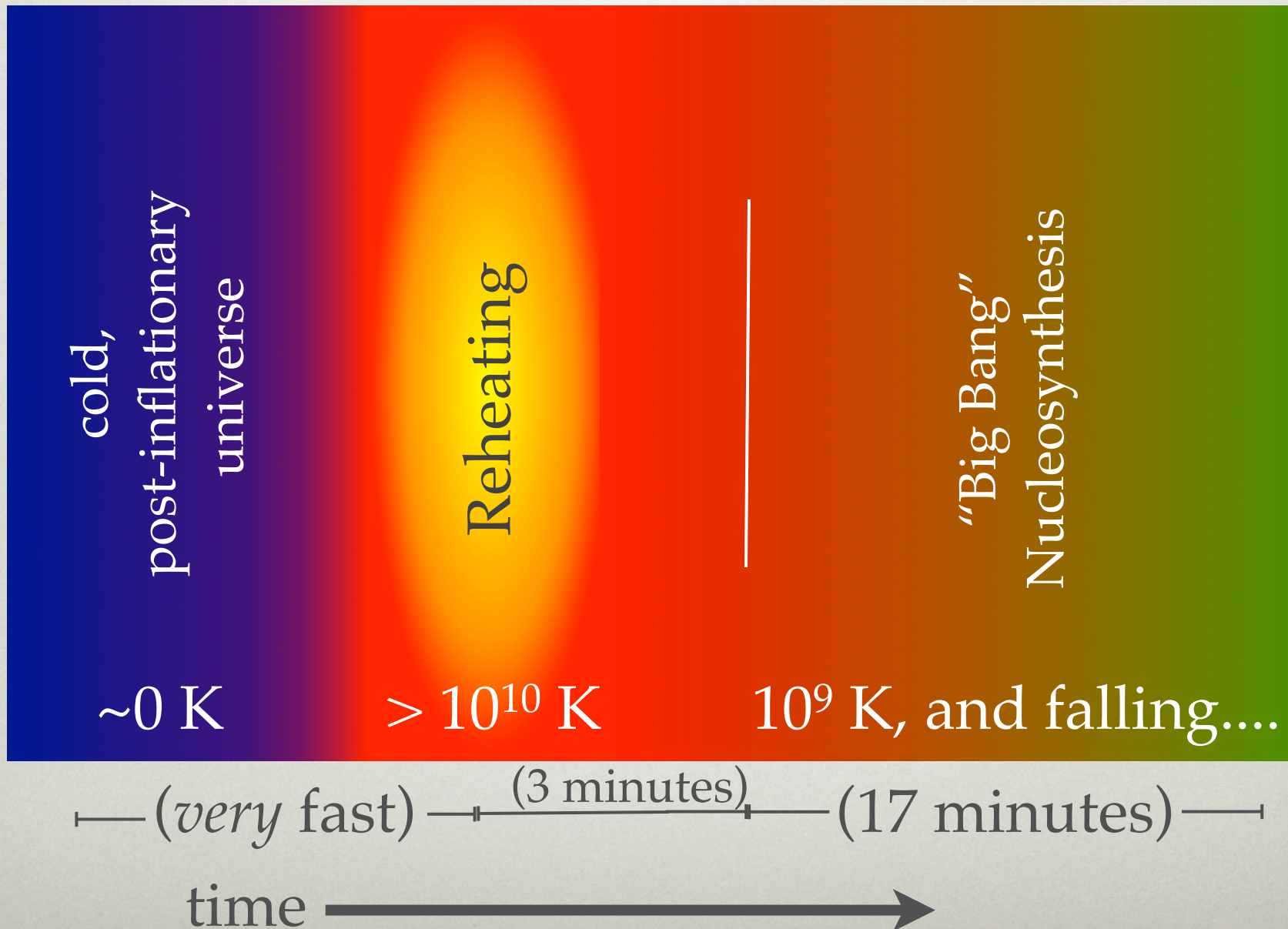


and
beyond

...

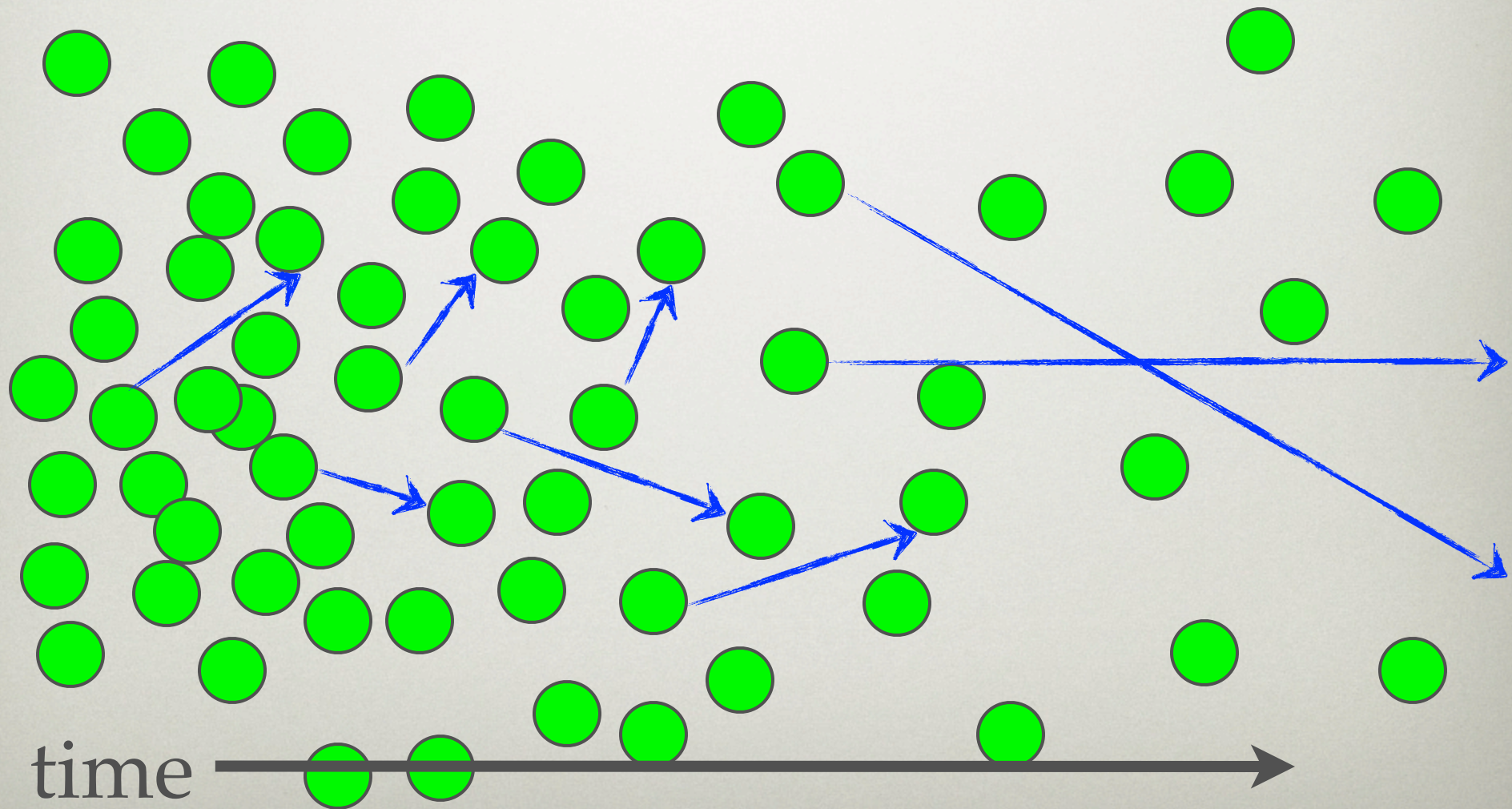


THE BIG BANG

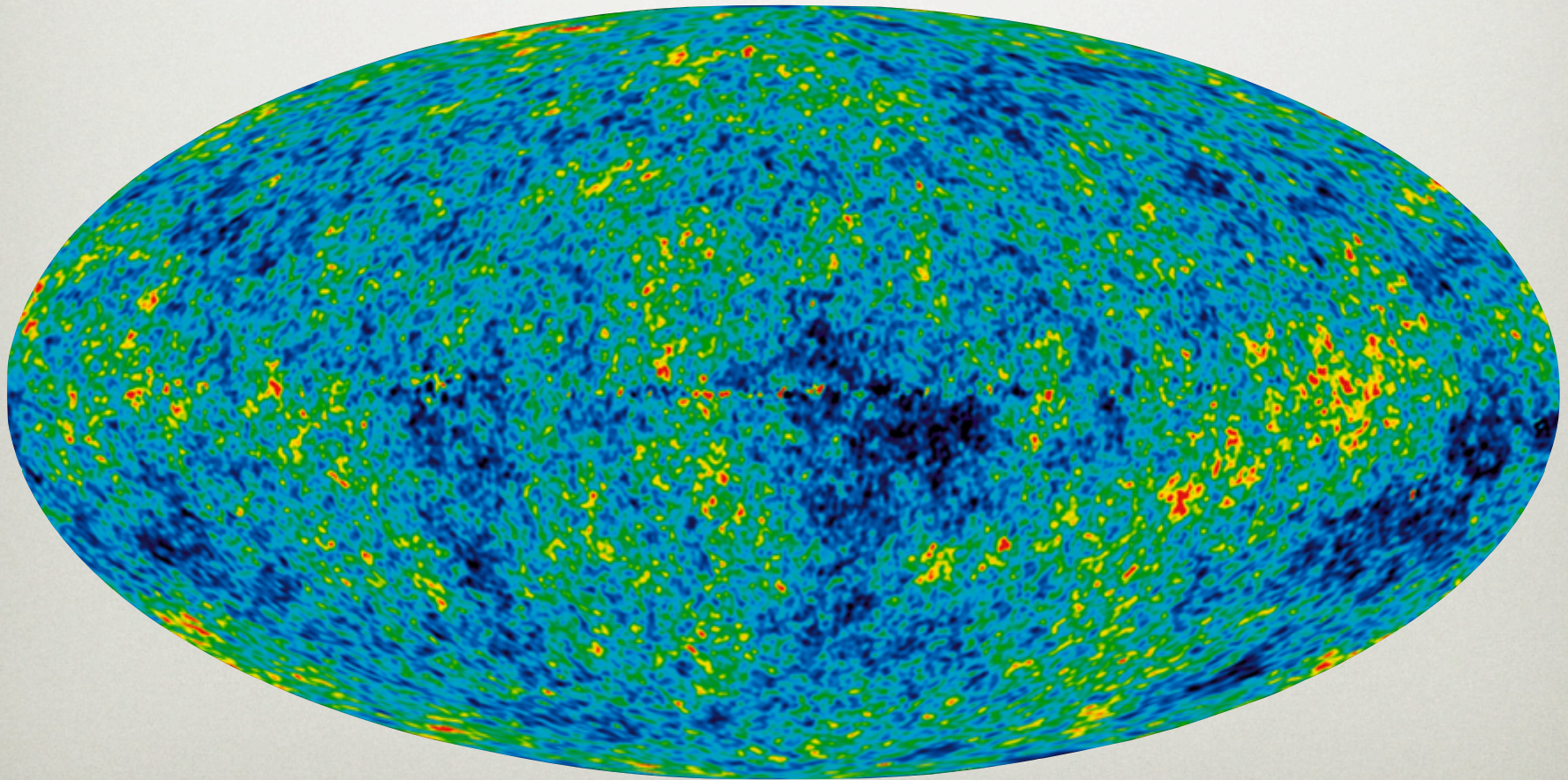


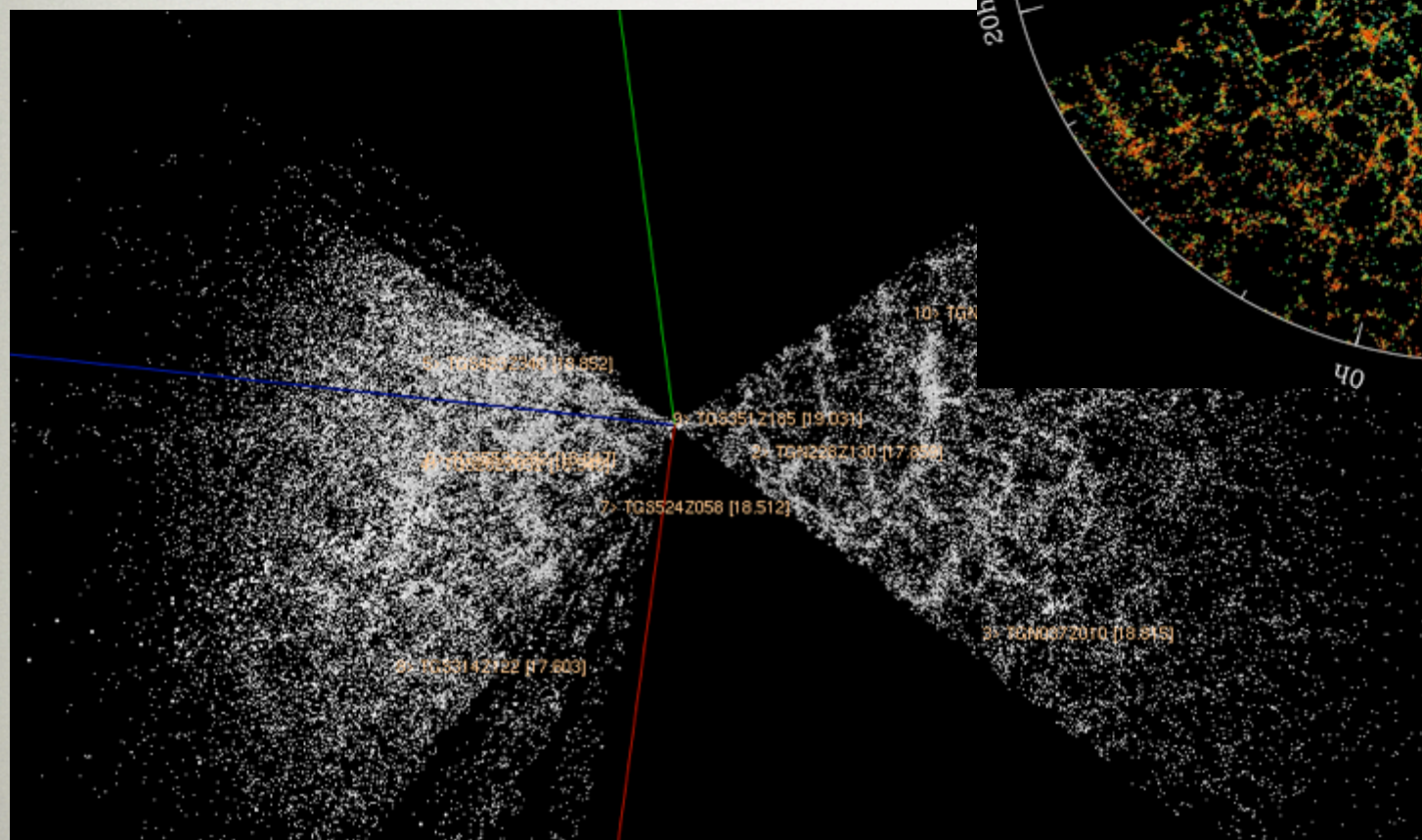
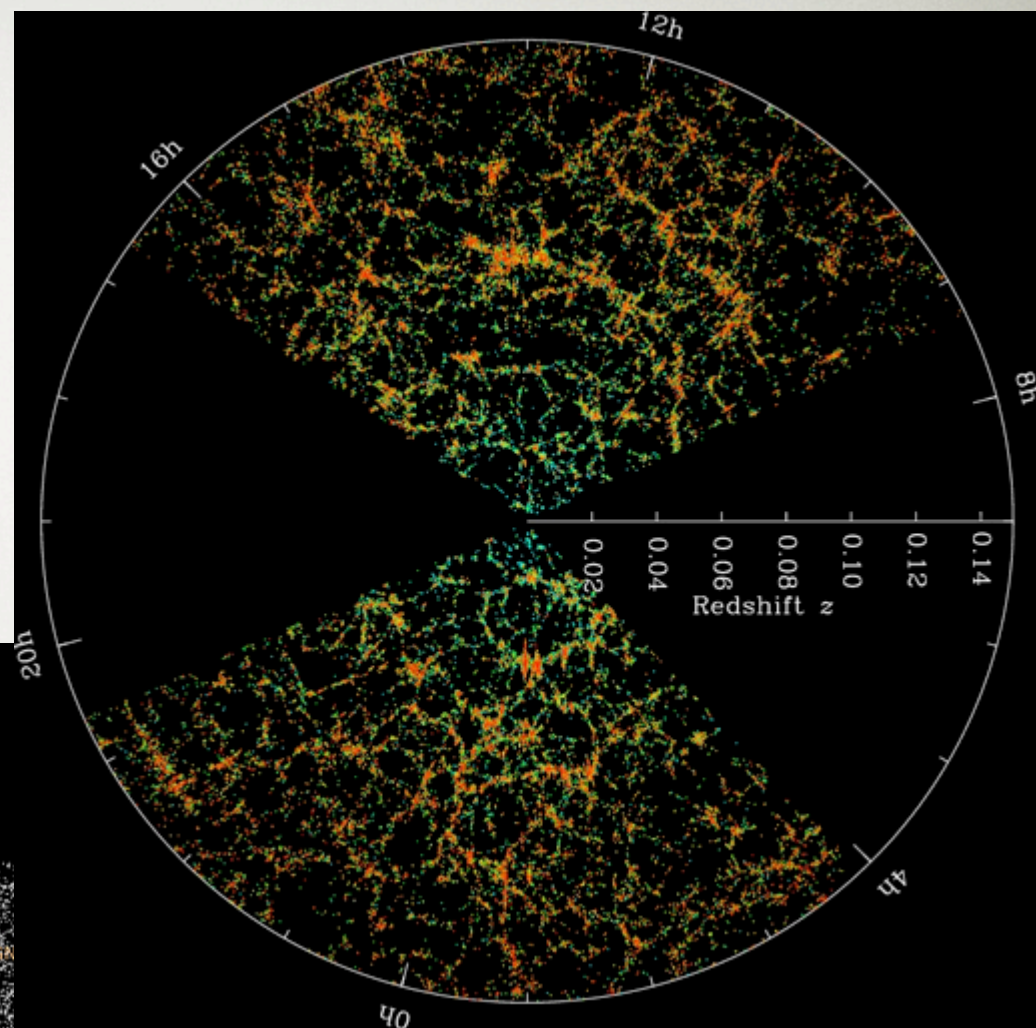
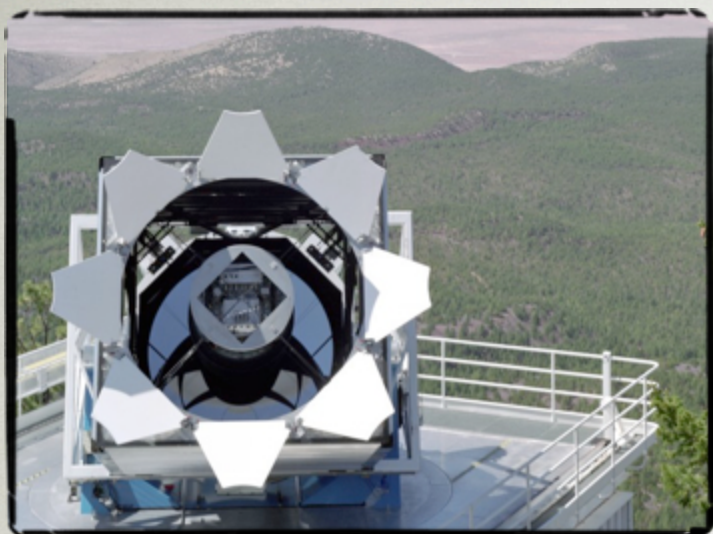
TRANSPARENCY!

aka Last Scattering

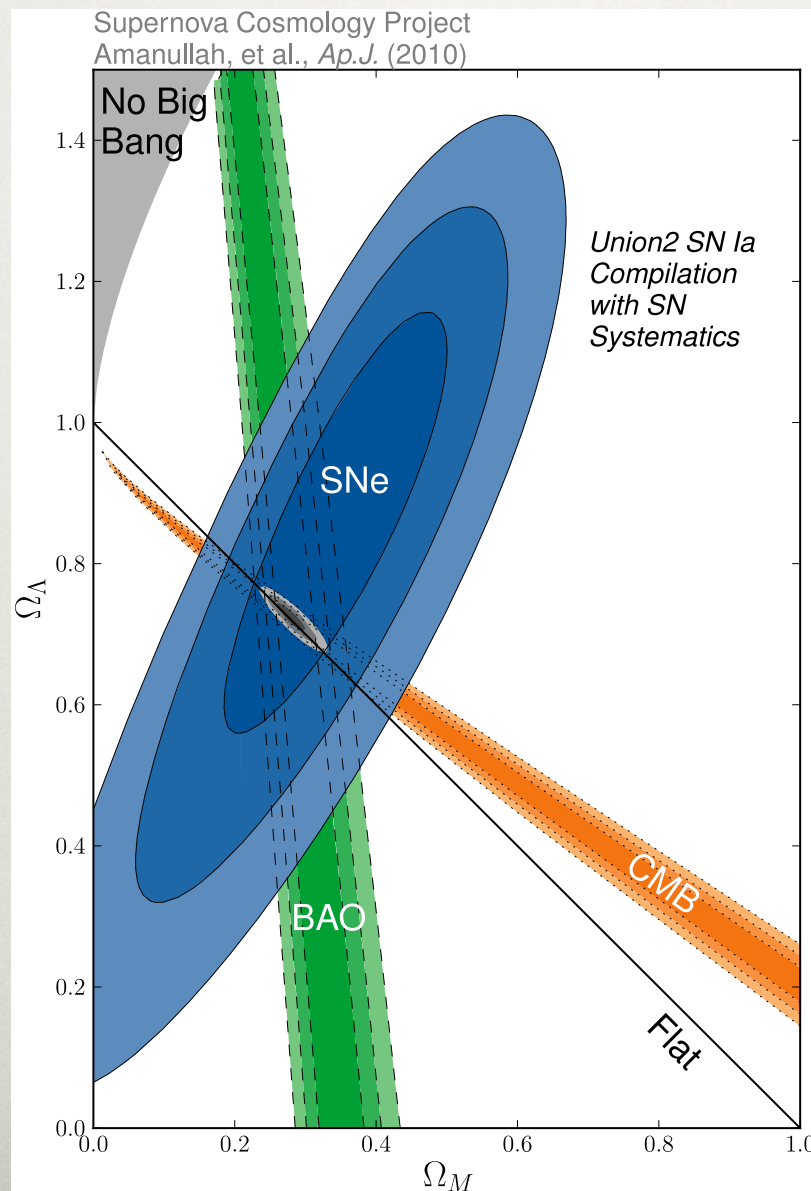


THE CLEANED WMAP SKY





DARK ENERGY OBSERVATIONS



from the Supernova
Cosmology Project
(Perlmutter et al)

Heat Death

Big Crunch

?

Vacuum decay

Big Rip

THANKS,
AND FAREWELL,
Y'ALL!