Title: The classification of universes

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Abstract:

BJORKEN
FEB '04

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WARNING !!

THE FOLLOWING MATERIAL IS RATED

TO

ITS CONTENTS INCLUDE SOCIALLY UNACCEPTABLE WORDS SUCH AS:

MULTIVERSE

ANTHROPIC PRINCIPLE

DIGESTION OF THIS MATERIAL MAY LEAD TO FUTURE UNHEALTHY EMPLOYMENT

J. BJORKEN (2)
JAN-FEB 2004

THE CLASSIFICATION OF UNIVERSES

I. EXPOSITION

MULTIVERSES
ANTHROPICS
OUR UNIVERSE
THE LOCAL ENSEMBLE
A MORE DISTANT ENSEMBLE?
BJORKEN (RE)SCALING
HIERARCHY PROBLEMS "SOLVED"

II. DEVELOPMENT

QCD AND DARK ENERGY
TWO UNIVERSES ??
THE BEGINNING OF INFLATION

III. (RE)CAPITULATION

LESSONS LEARNED ?
IS THIS SCIENCE ?

I. EXPOSITION

MULTIVERSES:

MARTIN REES — "OUR COSMIC HABITAT"
"JUST SIX NUMBERS"

ANTHROPICS:

JOHN BARROW
FRANK TIPLER — "THE ANTHROPIC COSMOLOGICAL PRINCIPLE"

FINE TUNING:

FRED HOYLE ET. AL.

$\alpha + \alpha \rightarrow Be^8$
$\alpha + Be^8 \rightarrow C^*$
$\alpha + C^* \not\rightarrow O^*$

$\alpha + Be^8$ — 7.367 MeV
C^* — 7.656 MeV

$\alpha + C$ — 7.162 MeV
O^* — 7.119 MeV

"FACTS" ABOUT OUR UNIVERSE:

- DARK ENERGY (time independent?)
- SPATIALLY FLAT ("criticality")
- WE SEE ONLY A TINY PIECE OF THE COSMOS.

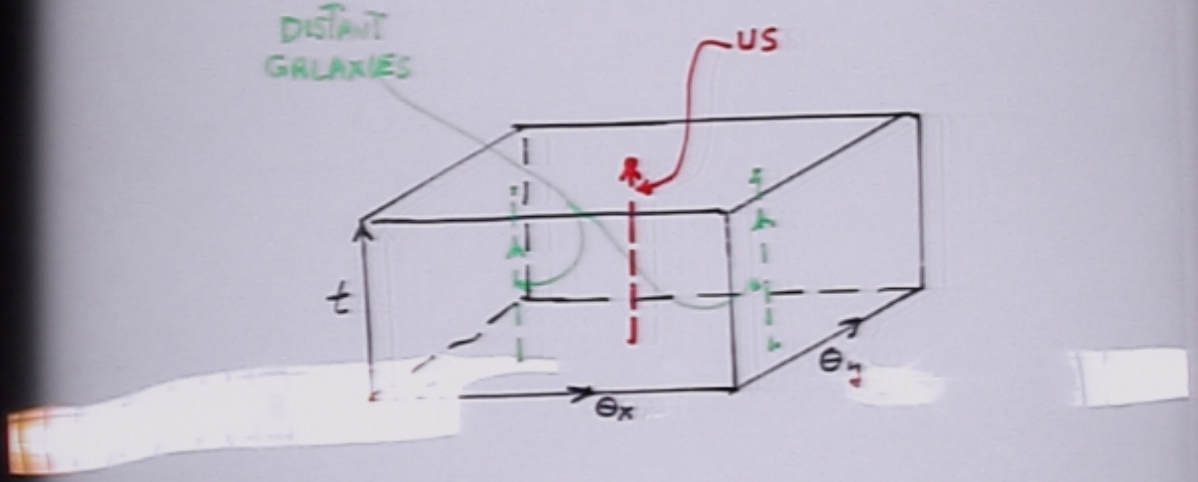
NO THEORY EXISTS FOR

- THE BEGINNING OF TIME
- THE END OF TIME
- THE BOUNDARY OF (FLAT) SPACE

THERE ARE PLENTY OF SPECULATIONS

DEFINE A UNIVERSE AS THE INTERIOR OF A (COMOVING) SPACETIME BOX

THE SPACETIME BOX



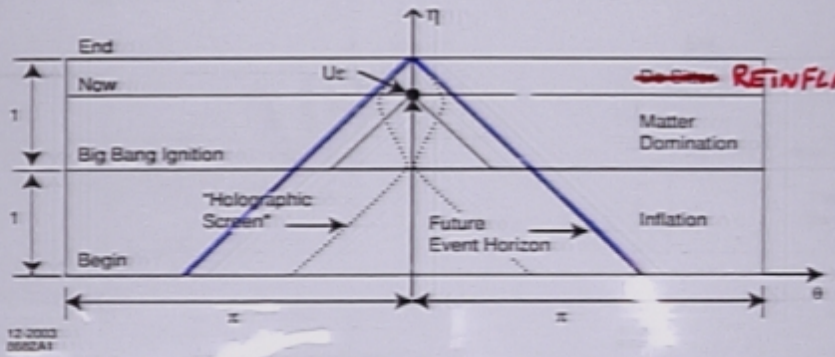
FRIEDMANN - ROBERTSON - WALKER METRIC

$$ds^2 = dt^2 - a^2(t)\left(d\theta_x^2 + d\theta_y^2 + d\theta_z^2\right)$$

$$H_{FRW}^2 \equiv \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi}{3M_{pl}^2}\rho(t)$$

THE SPACETIME BOX IN CONFORMAL COORDINATES

$$\eta = -\int_t^\infty \frac{dt'}{a(t')}$$



$$ds^2 = a^2(\eta)\left(d\eta^2 - d\theta_x^2 - d\theta_y^2 - d\theta_z^2\right)$$

EQUATION FOR "HOLOGRAPHIC SCREEN":

RADIUS $R(\eta) = a(\eta)|\eta| = H(\eta)^{-1}$

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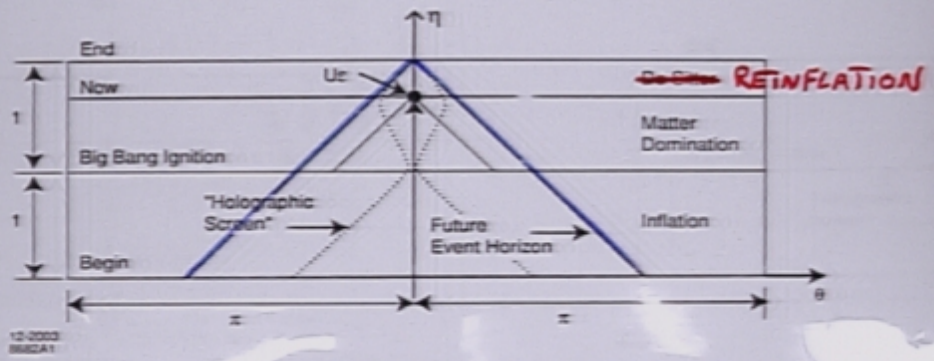

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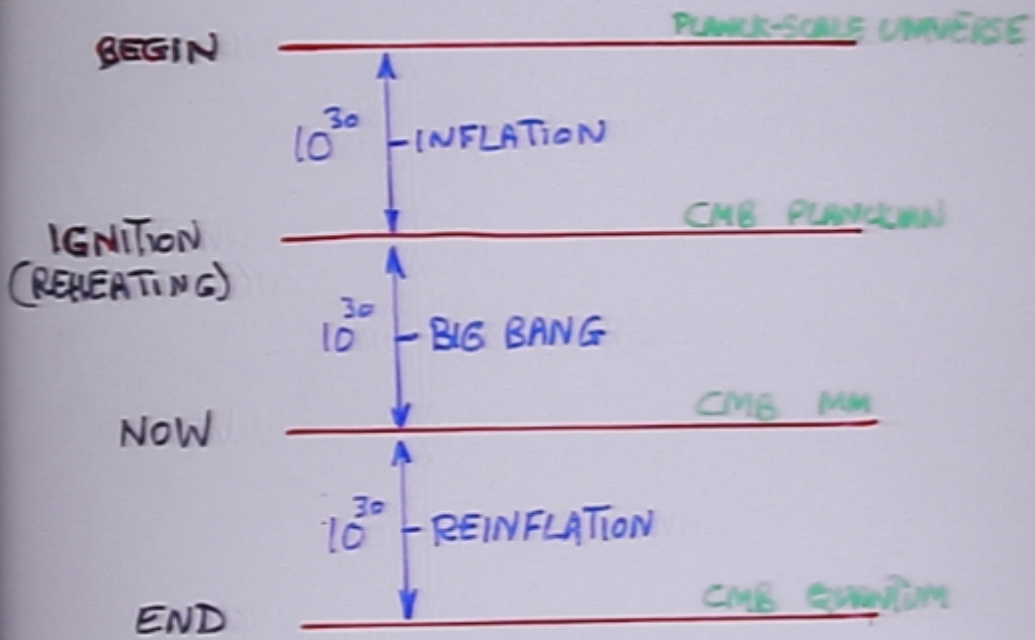
THE UNIVERSE FOR DUMMIES

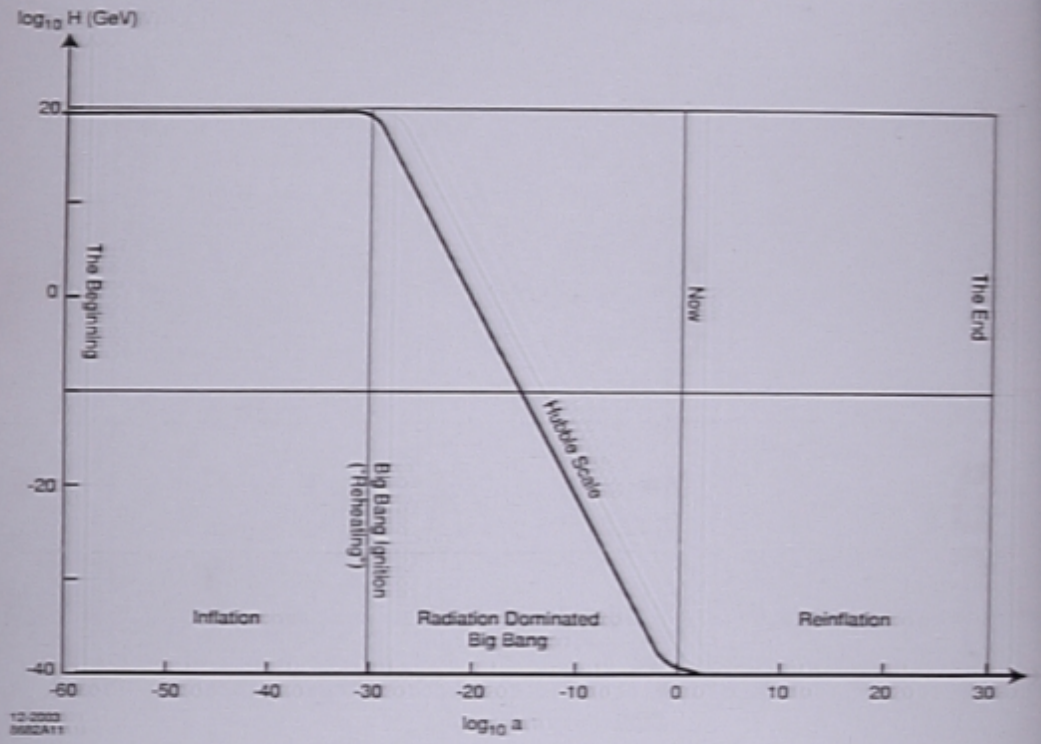
OMIT ORDINARY MATTER

OMIT DARK MATTER

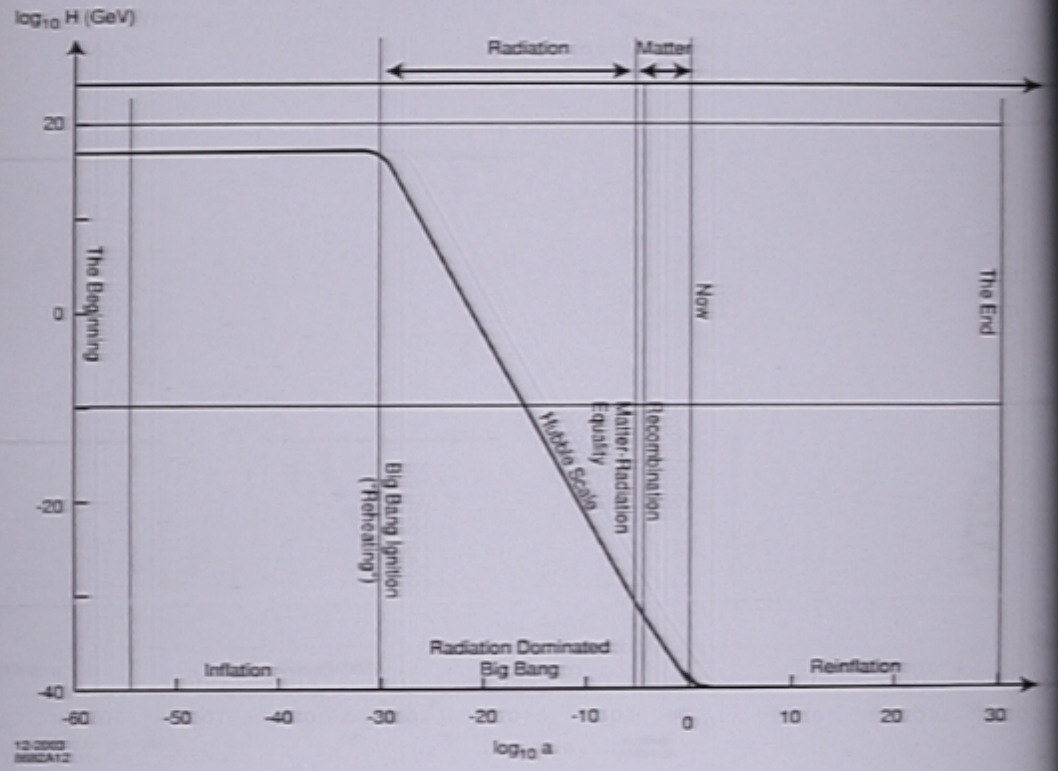
INFLATION SCALE ≈ PLANCK SCALE



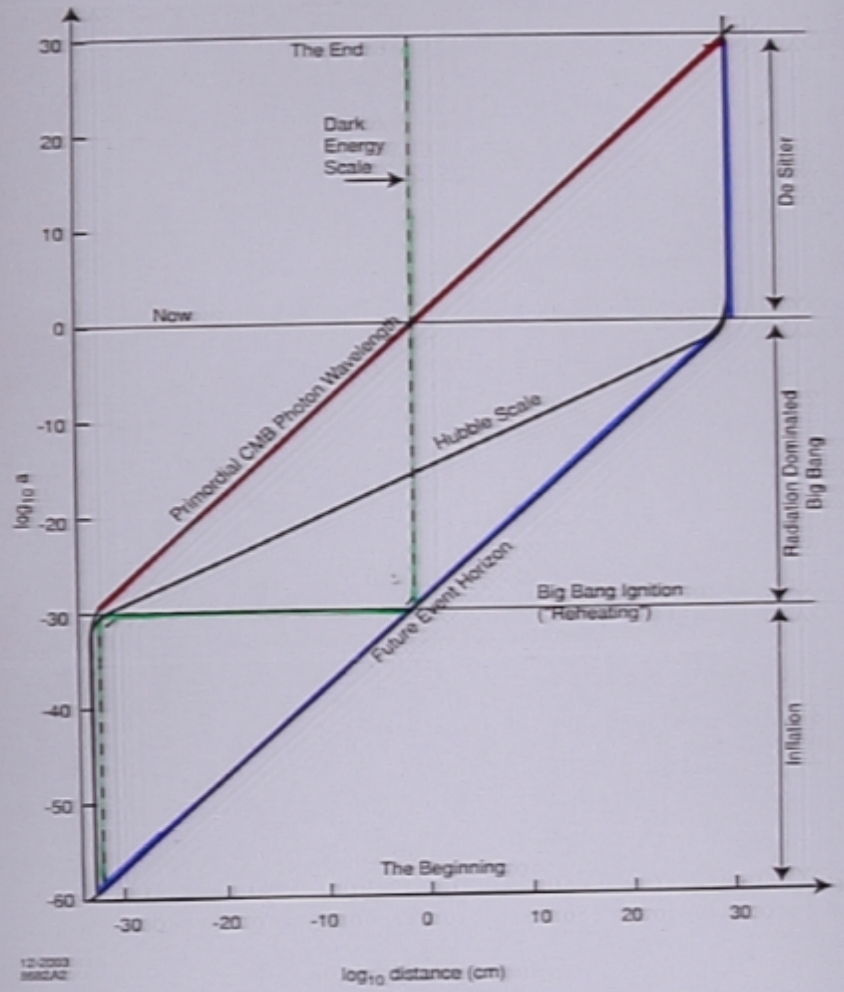
THE UNIVERSE FOR DUMMIES



OUR UNIVERSE



DISTANCE SCALES IN THE UNIVERSE FOR DUMMIES



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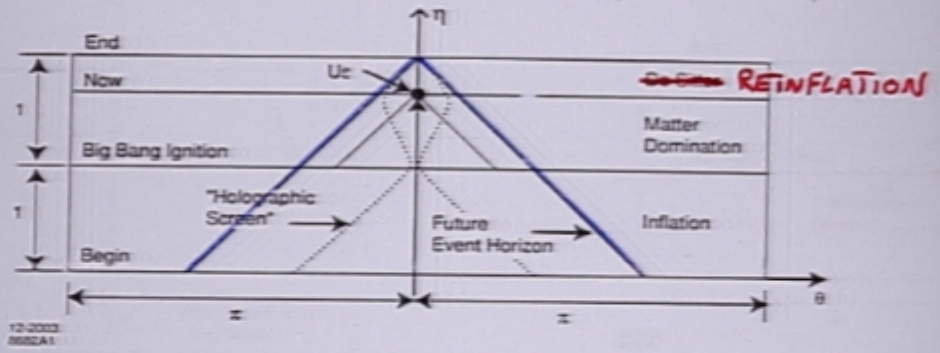

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EQUATION FOR "HOLOGRAPHIC SCREEN":

RADIUS $R(\eta) = a(\eta)|\eta| = H(\eta)^{-1}$

- FACTOR 10^{30} APPEARS EVERYWHERE

- IT IS RATIO OF DARK ENERGY SCALE μ TO PLANCK SCALE M_{pl}.

- DARK ENERGY DENSITY $\mu^4 \sim \frac{meV}{(mm)^3}$

- DEFINE SIZE OF UNIVERSE IN TERMS OF DARK ENERGY SCALE:

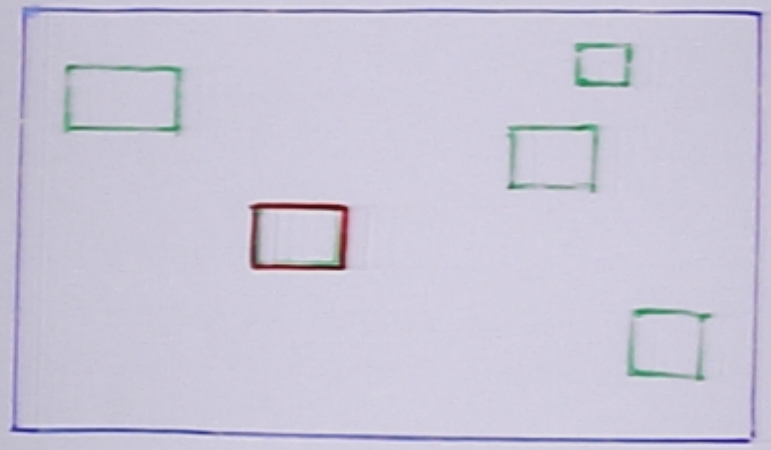
FRW: $H^2 = \left(\frac{\dot{a}}{a}\right)^2 \rightarrow \frac{8\pi}{3M_{pl}^2}\mu^4$

$$H \sim \frac{\mu^2}{M_{pl}}$$

$$\text{"SIZE"} = H^{-1} \sim \frac{M_{pl}}{\mu^2}$$

NOMENCLATURE:

- COSMOS: ALL OF SPACETIME
- UNIVERSE: OUR SPACETIME BOX
- MULTIVERSE: ENSEMBLE OF SIMILAR BOXES



(DATA-DRIVEN) ASSUMPTION:

COSMOS $\gg$ UNIVERSE

ENSEMBLES OF UNIVERSES:

LOCAL:
- IDENTICAL (?) COPIES
- MAYBE SOME VACUUM CONDENSATES DIFFER A BIT (e.g. AXIONS) WILCZEK

MORE DISTANT:

SELECTION CRITERIA:
- SIMILAR HISTORY
- NONVANISHING DARK ENERGY AT LATE TIMES
- SPATIALLY FLAT
- SAME STANDARD-MODEL LAWS
- DIFFERENT STANDARD-MODEL (AND COSMOLOGICAL) PARAMETERS

BJORKEN (RE)SCALING:

- IN THE MORE-DISTANT ENSEMBLE THE VALUES OF ~~MOST~~ STANDARD MODEL PARAMETERS ARE CORRELATED WITH THE VALUE OF THE DARK ENERGY ("SIZE")

(• IF A "THEORY OF EVERYTHING" EXISTS, THIS HAS TO BE TRUE.)

- A SPECIFIC HYPOTHESIS ON THE NATURE OF THE CORRELATION IS PROPOSED

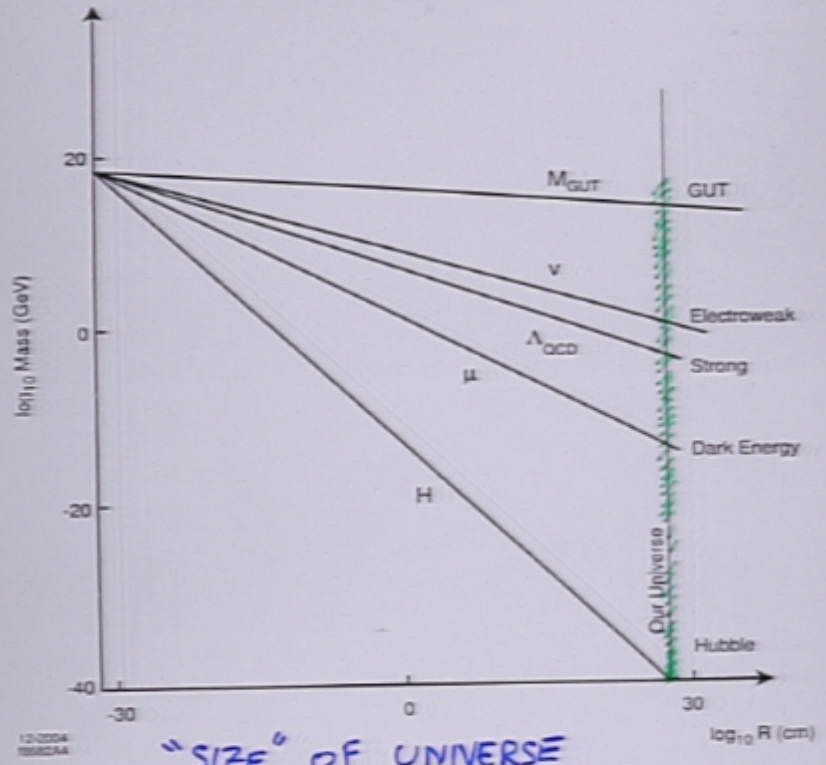
  SIMPLE

  MINIMAL

  NOT MOTIVATED BY UNDERLYING THEORY

- SMALL UNIVERSES ARE STRONGLY INTERACTING
- THE INFINITE UNIVERSE CONTAINS NO STANDARD MODEL INTERACTIONS
- HIERARCHY PROBLEMS ARE "SOLVED",

BJORKEN (RE)SCALING



"SIZE" OF UNIVERSE

- IN THE MORE-DISTANT ENSEMBLE THE VALUES OF MOST STANDARD MODEL PARAMETERS ARE CORRELATED WITH THE VALUE OF THE DARK ENERGY ("SIZE")
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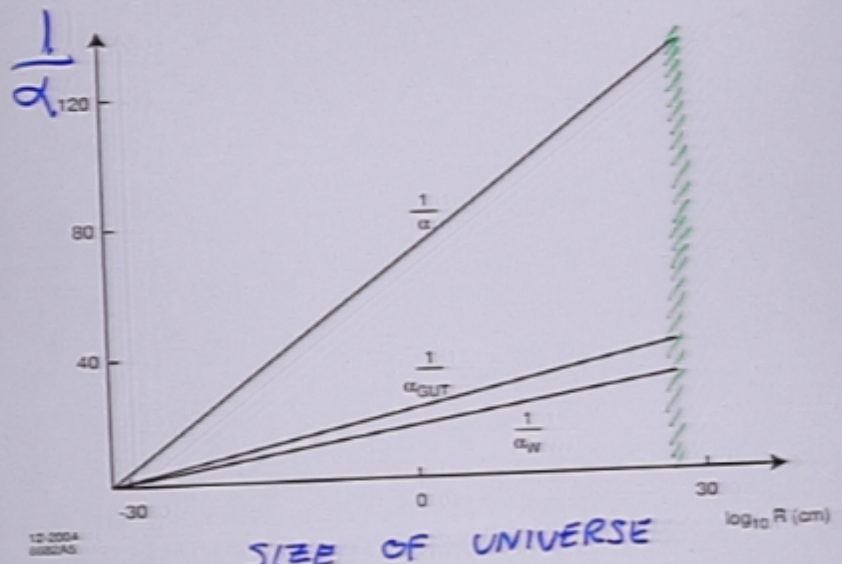
COUPLING CONSTANT SCALING



SIZE OF UNIVERSE

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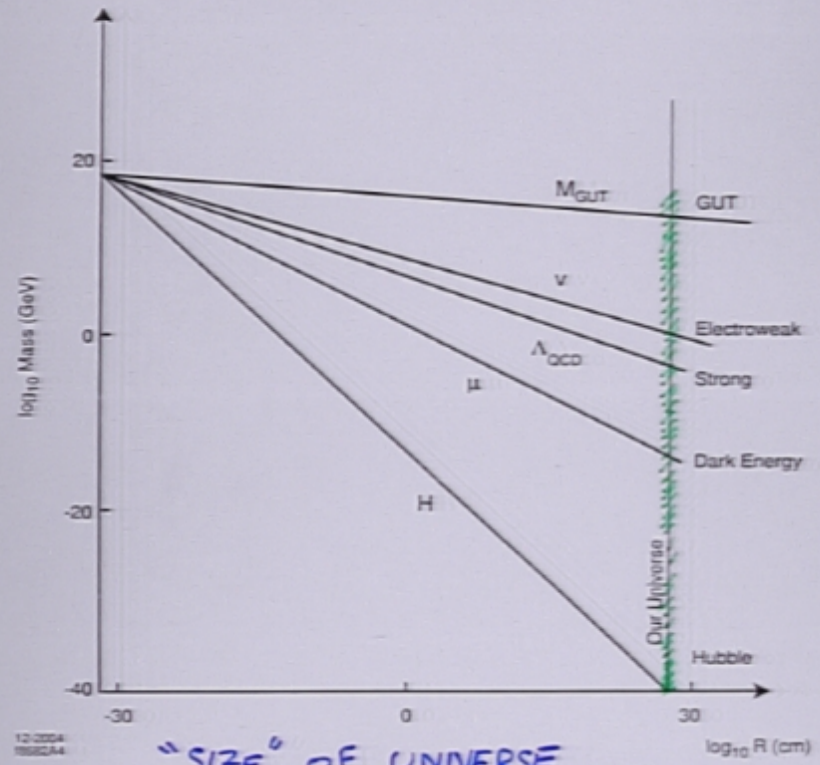
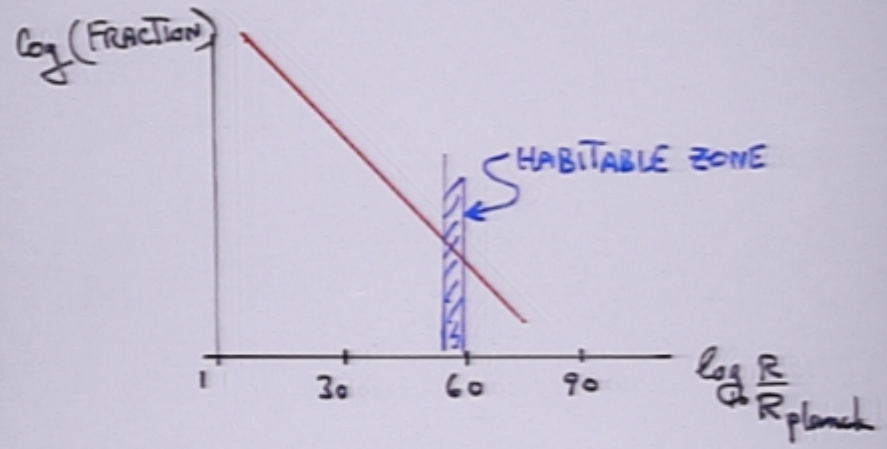


"SIZE" OF UNIVERSE

GUESS THE SIZE DISTRIBUTION OF UNIVERSES IS POWER-LAW:

$$R \frac{dN}{dR} \sim R^{-p}$$

$$\left\{ \begin{array}{l} \text{FRACTION OF UNIVERSES} \\ \text{WITH SIZE} > R \end{array} \right\} \sim \left(\frac{R_{min}}{R} \right)^{p} \gtrsim 10^{60p}$$



THE MAIN MESSAGES

- ALL "HIERARCHY PROBLEMS" SOLVED
- A NEW AND DIFFERENT PROBLEM REPLACES THEM:
  - × EXPLAIN THE "RESCALING" EXPONENTS
- ARE THERE MORE "ANTHROPIC" PARAMETERS?
  - × SMALL QUARK/LEPTON MASSES
  - × CKM MIXINGS
  - × DARK [redacted] MATTER
  - × CMB AMPLITUDE
  - ⋮

II. DEVELOPMENT

A. QCD AND DARK ENERGY: WHY IS THE RESCALING EXPONENT 1/3 ??

ZELDOVICH '67
NOVELLO et al '0
SCHUTZHOLD '0
CARNEIRO '0

- REINFLATING UNIVERSE HAS A HORIZON (BLACK HOLE INSIDE-OUT)
- HORIZON RADIUS $R_H = H^{-1} \approx 1.4 \times 10^{28}$ cm.
- BEKENSTEIN-HAWKING ENTROPY ON HORIZON $\sim 10^{122}$
- PADMANABHAN CONNECTS THIS ENTROPY WITH EINSTEIN-HILBERT LAGRANGIAN

II. DEVELOPMENT

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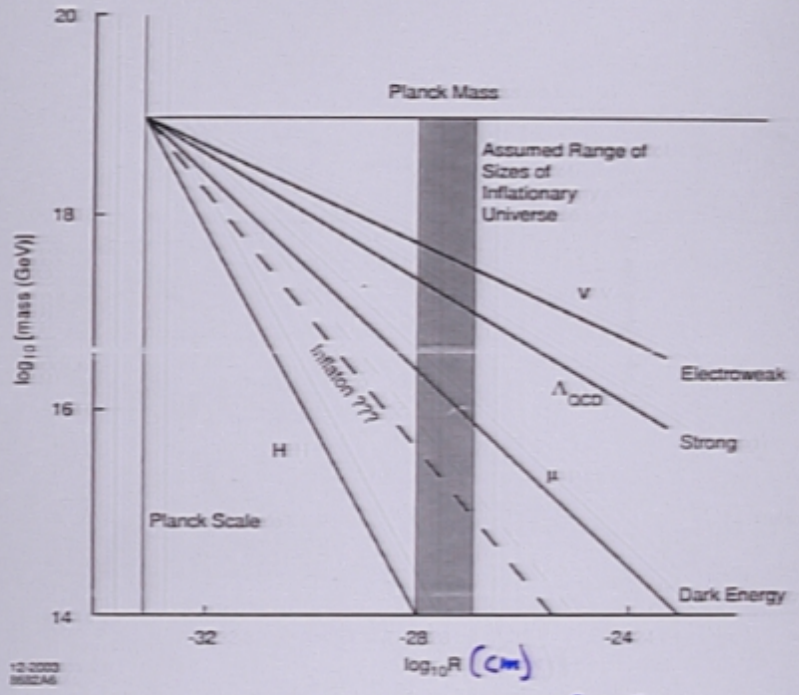
B. IS THE INFLATIONARY UNIVERSE A SEPARATE UNIVERSE?

- HUGE DARK ENERGY
- DARK ENERGY SCALE IS COMPARABLE TO QCD AND ELECTROWEAK SCALES (UNIFICATION??)
- INFLATON ENERGY SCALE MAY BE SMALLER
- WITH TWO UNIVERSES IN CAUSAL CONTACT, MIGHT NOT $\hbar$, c, & M_{pl} CHANGE DURING BIG BANG IGNITION??

BOTTOM LINE: UNDERSTAND BIG-BANG IGNITION

STANDARD MODEL PARAMETERS IN THE INFLATIONARY UNIVERSE



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III. RECAPITULATION

- LOCAL MULTIVERSE : DATA - DRIVEN
- EXTENDED MULTIVERSE : DATA - DRIVEN
- COSMOLOGICAL CONSTANT IS ANTHROPIC PARAMETER
- WHERE DOES ANTHROPIC REASONING STOP? (IF AT ALL)
- BJORKEN RESCALING
- DOES IT DELIVER?
- IS IT SCIENCE?