天文学正在发现

Bin HU

bhu@bnu.edu.cn

Astro@BNU

Office: 京师大厦9907

outline

1. 膨胀宇宙的发现

2. 暗物质的发现

3. 暗能量的发现

4. 宇宙微波背景辐射的发现

5. 中微子的发现

6. 引力波的发现

7. 脉冲星的发现

8. 宇宙第一缕曙光的“发现”

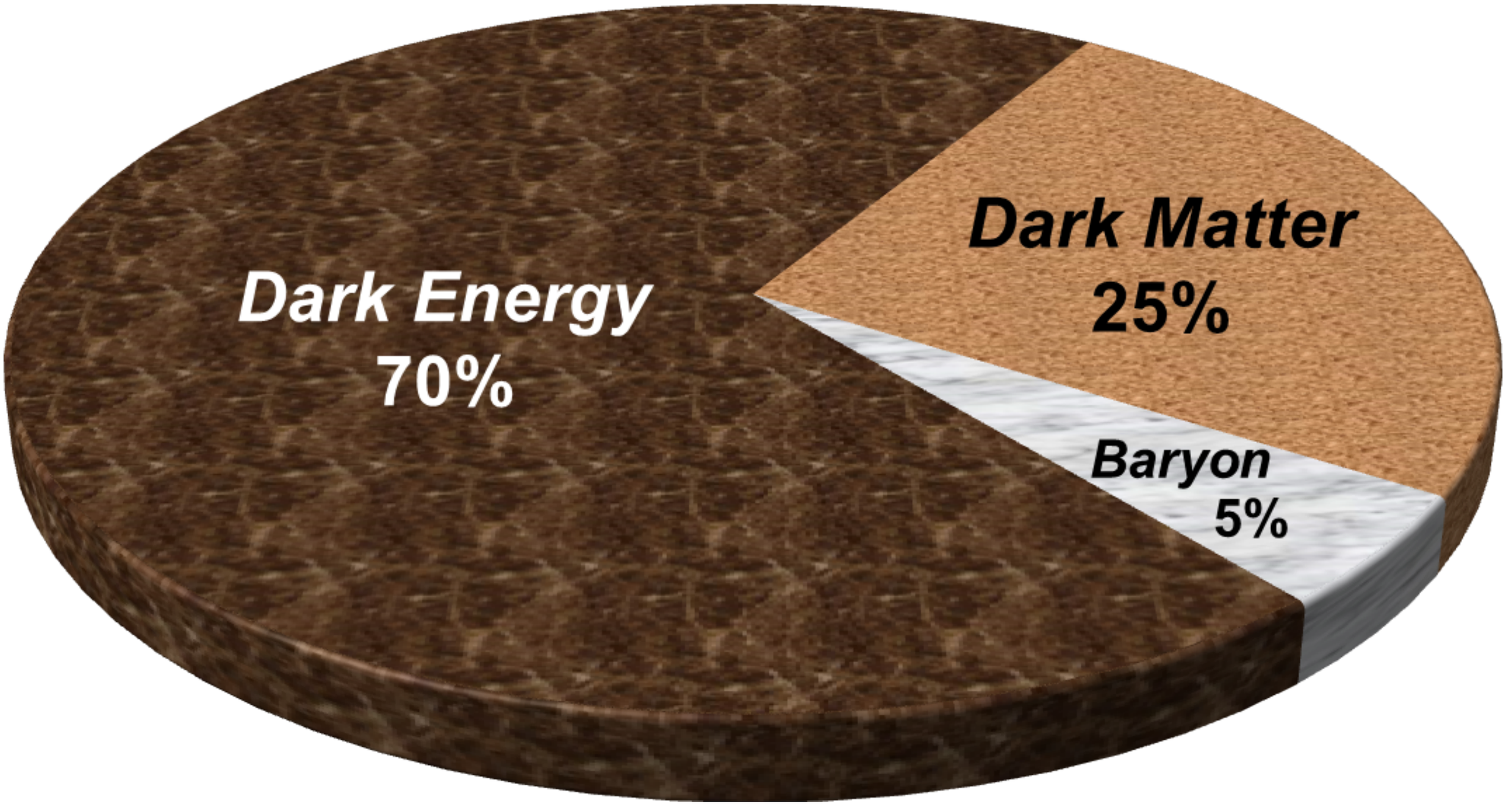

Dark Energy
70%
Dark Matter
25%
Baryon
5%

Photo: Lawrence Berkeley National Lab

Saul Perlmutter

Photo: Belinda Pratten, Australian National University

Brian P. Schmidt

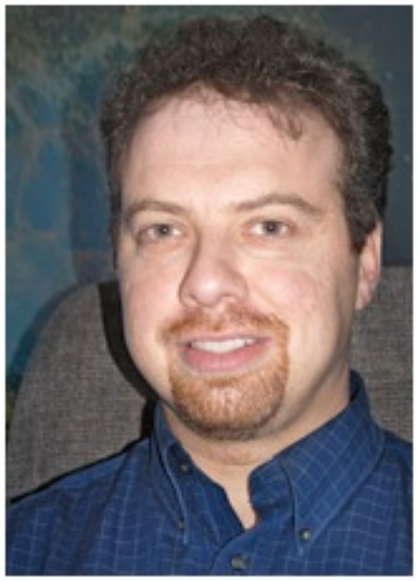
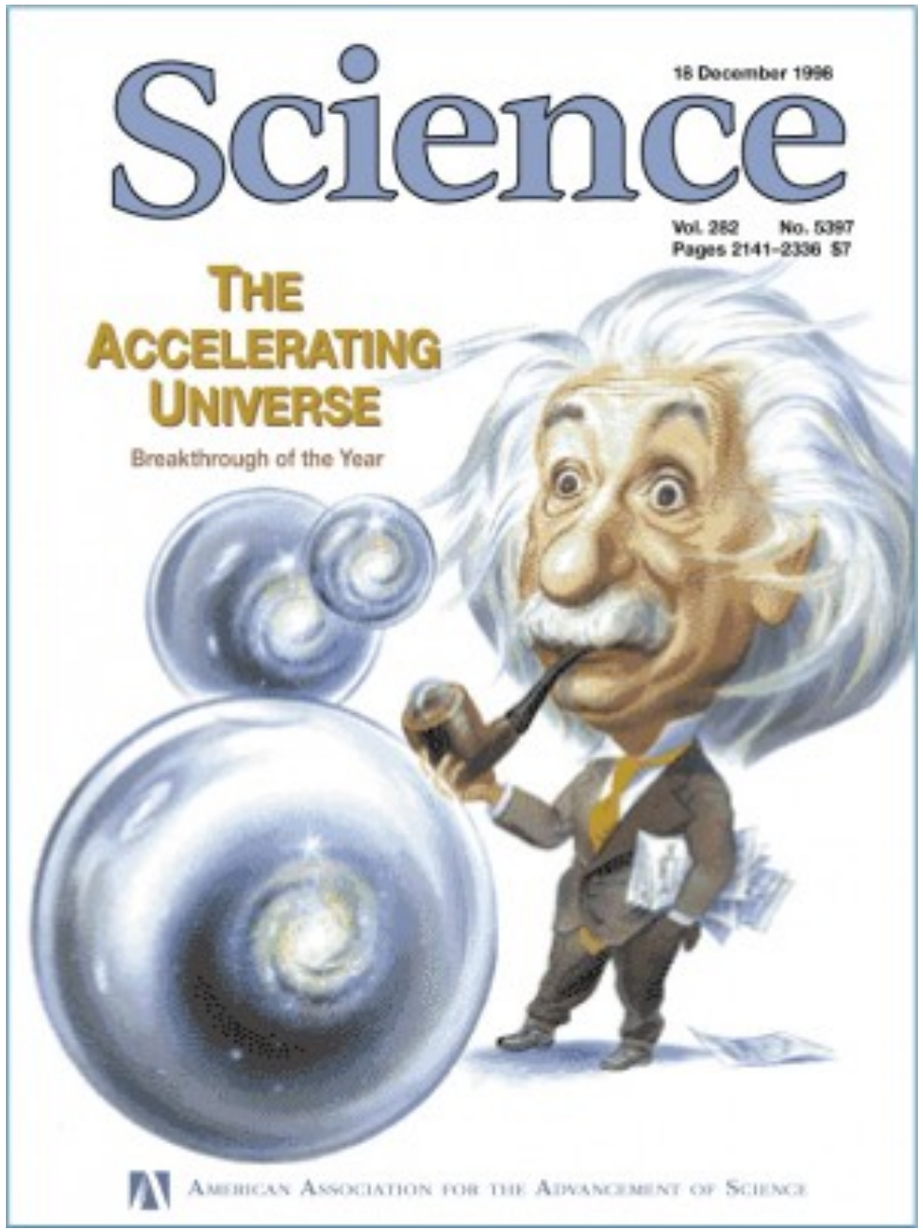


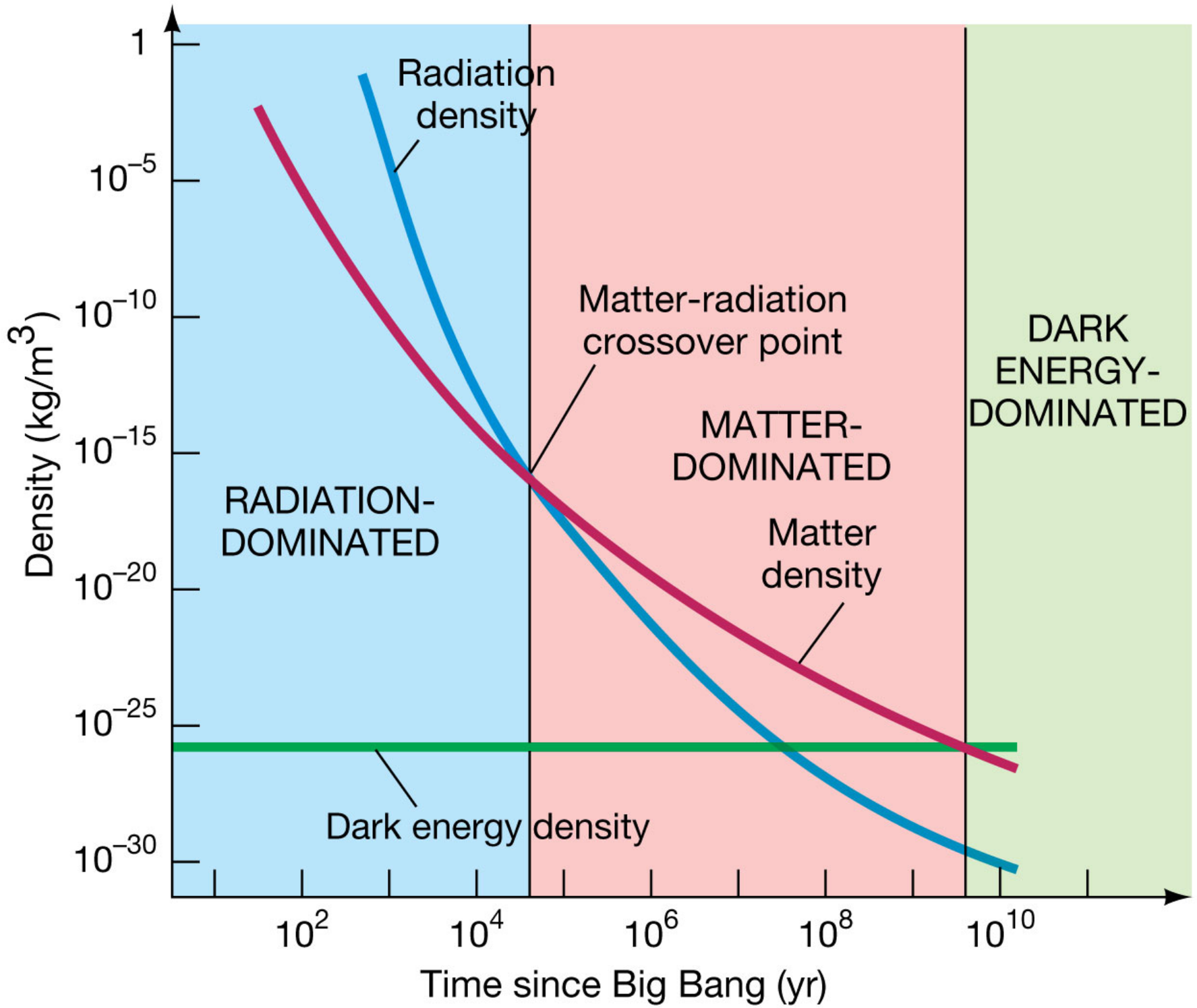
Photo: Scanpix/AFP

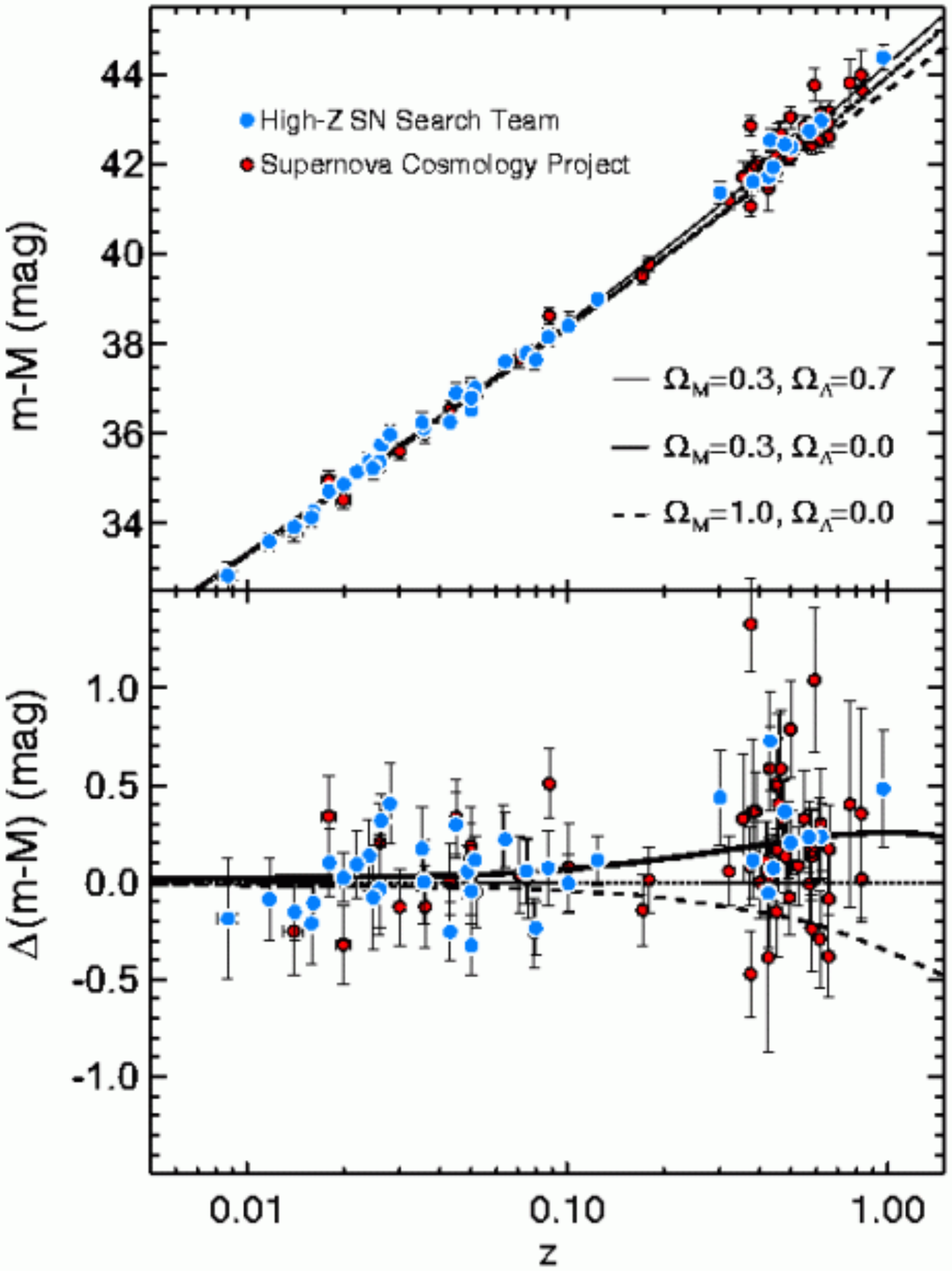
Adam G. Riess

The Nobel Prize in Physics 2011 was awarded *"for the discovery of the accelerating expansion of the Universe through observations of distant supernovae"* with one half to Saul Perlmutter and the other half jointly to Brian P. Schmidt and Adam G. Riess.



1998




High-Z SN Search Team
Supernova Cosmology Project
Ω_M=0.3, Ω_Λ=0.7
Ω_M=0.3, Ω_Λ=0.0
Ω_M=1.0, Ω_Λ=0.0
m-M (mag)
Δ(m-M) (mag)
z
44
42
40
38
36
34
1.0
0.5
0.0
-0.5
-1.0
0.01
0.10
1.00

citation: 16000+

Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant

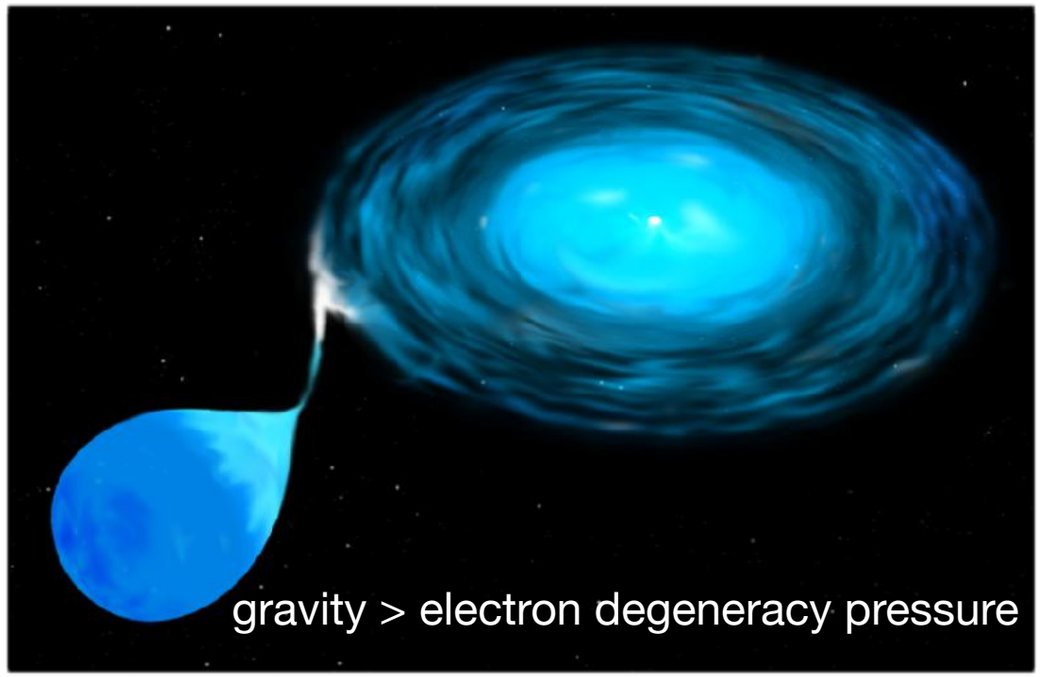
To Appear in the Astronomical Journal

Adam G. Riess[1], Alexei V. Filippenko[1], Peter Challis[2], Alejandro Clocchiatti[3], Alan Diercks[4], Peter M. Garnavich[2], Ron L. Gilliland[5], Craig J. Hogan[4], Saurabh Jha[2], Robert P. Kirshner[2], B. Leibundgut[6], M. M. Phillips[7], David Reiss[4], Brian P. Schmidt[8 9], Robert A. Schommer[7], R. Chris Smith[7 10], J. Spyromilio[6], Christopher Stubbs[4], Nicholas B. Suntzeff[7], John Tonry[11]

ABSTRACT

A Universe closed by ordinary matter (i.e., $\Omega_M = 1$) is formally ruled out at the 7σ to 8σ confidence level

5. Standard candle



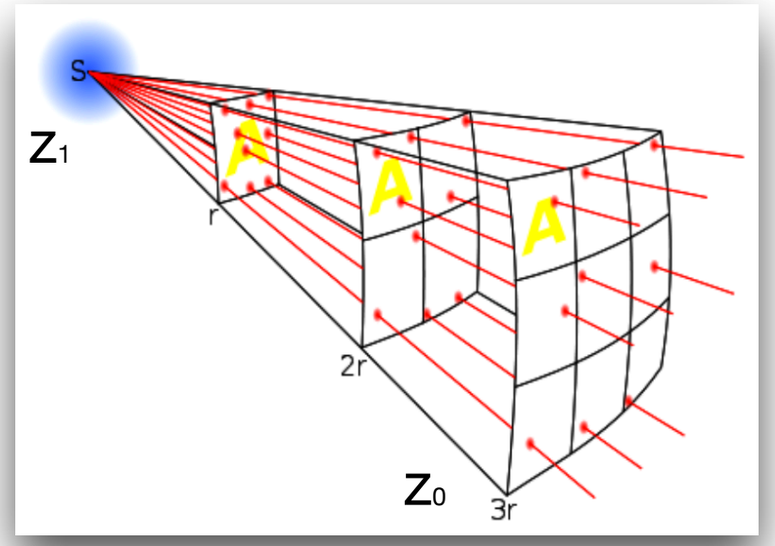
SN Ia explode from a binary star system, typically one white dwarf, one giant star

$$M_{WD} > 1.44 M_{\odot}$$

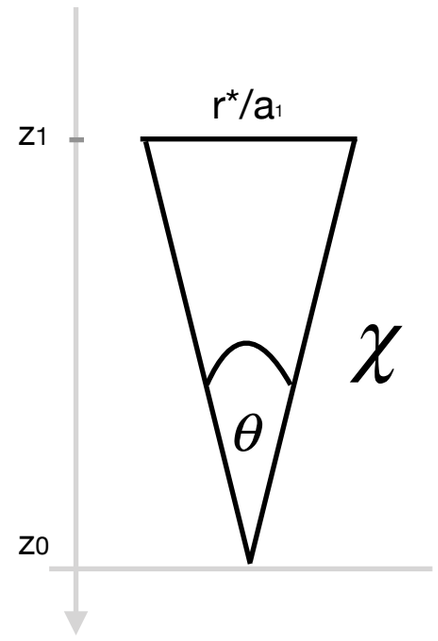
(Chandrasekhar limit)

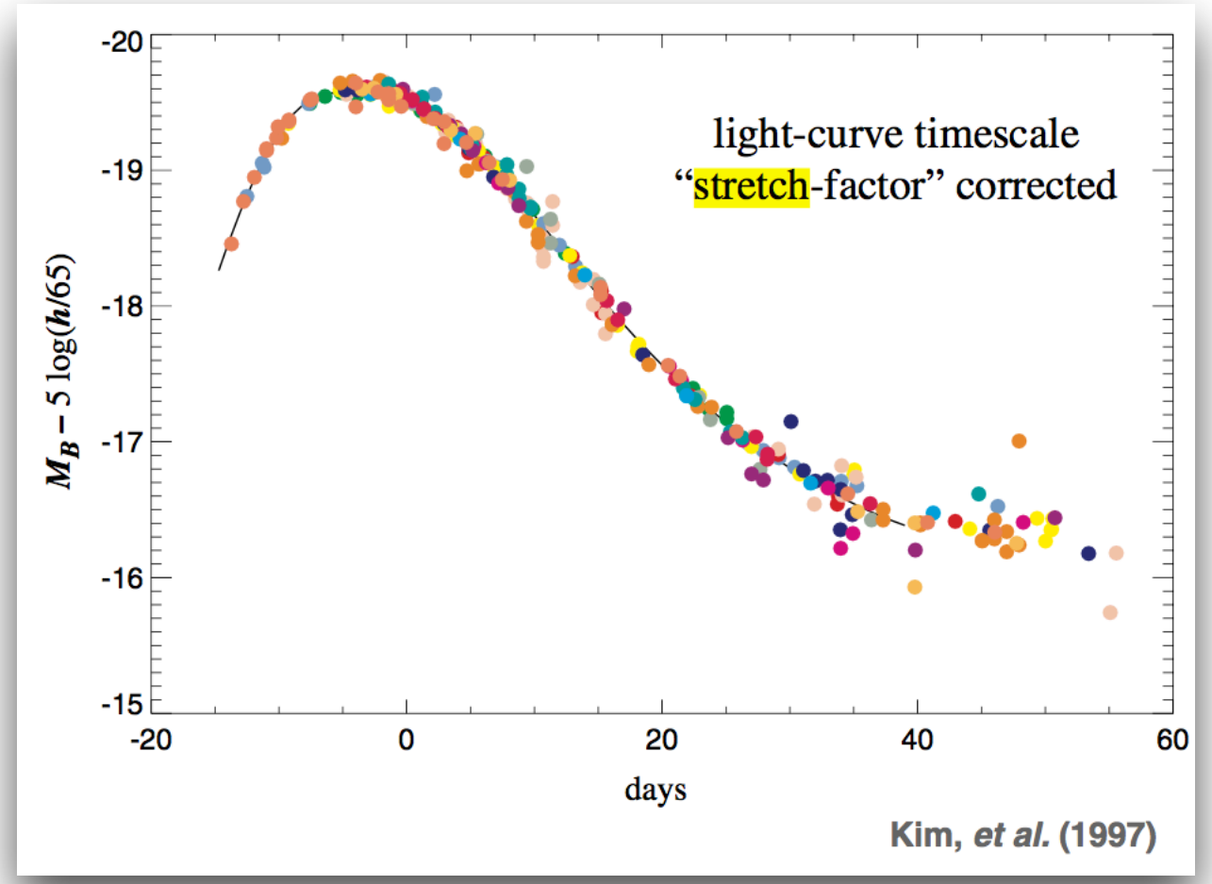
$$F_{obs}(z_0) = \frac{L_{ABS}(z_1)}{4\pi * {D_L}^2}$$

$$L_{ABS}^{SN} \sim 10^{10} L_{M\odot}$$

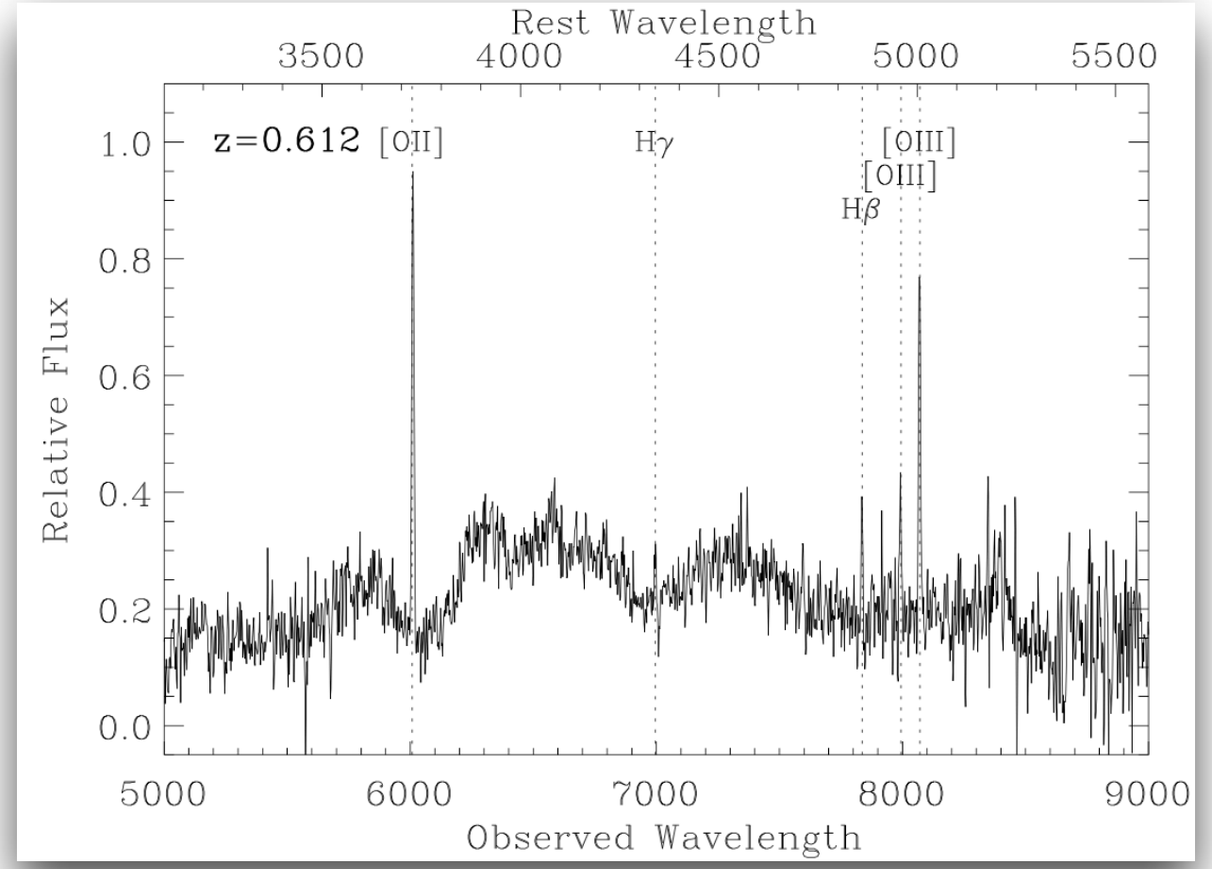


$$D_L = (1+z)\chi$$

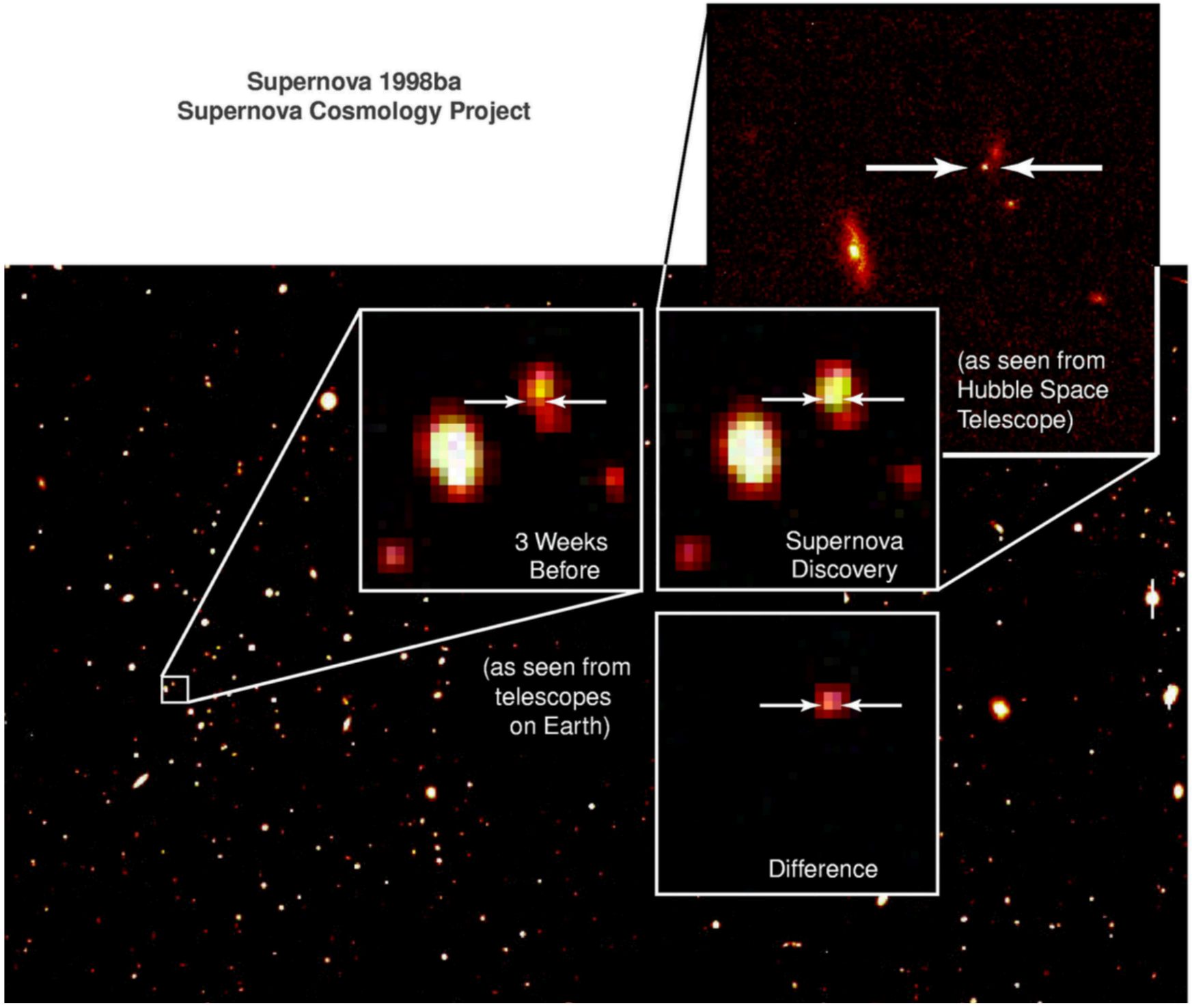




$\lambda_0 \sim 3700\,\mathring{A}$



z~6000/3700-1~0.6



年龄：10岁

学校：合肥市安庆路三小五年级学生

事件：2015年9月12日，廖家铭发现两亿光年外疑似超新星，或成为全球发现超新星年纪最小的人之一。


You know nothing, Jon Snow.

$$\frac{H^2}{H_0^2} = \Omega_r a^{-4} + \Omega_m a^{-3} + \Omega_k a^{-2} + \Omega_\Lambda$$

e.g. Equation of State $w = P / \rho$

$$H^2 = \frac{8\pi G}{3}\rho - \frac{k}{a^2} \qquad V \sim a^{-3}$$

$$\rho \propto a^{-3(1+w)} ,$$

$$\rho \propto \begin{cases} a^{-3} & \text{matter} \\ a^{-4} & \text{radiation} \\ a^{0} & \text{vacuum} \end{cases}$$

$$\rho_{\text{crit},0} = \frac{3H_0^2}{8\pi G} = 1.9 \times 10^{-29}\, h^2\, \text{grams}\, \text{cm}^{-3}$$
$$= 2.8 \times 10^{11}\, h^2\, M_\odot\, \text{Mpc}^{-3}$$
$$= 1.1 \times 10^{-5}\, h^2\, \text{protons}\, \text{cm}^{-3}$$

$$\Omega_{I,0} \equiv \frac{\rho_{I,0}}{\rho_{\text{crit},0}}$$

- for non-relativistic particle, E is conserved
- for relativistic photon, E is **NOT** conserved!

$$E(\nu_a) > E(\nu_b)$$

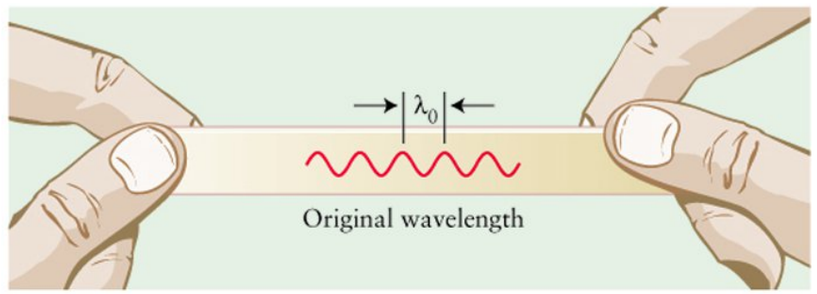
- for vacuum energy,
  E is **NOT** conserved!

$$dU = -PdV$$

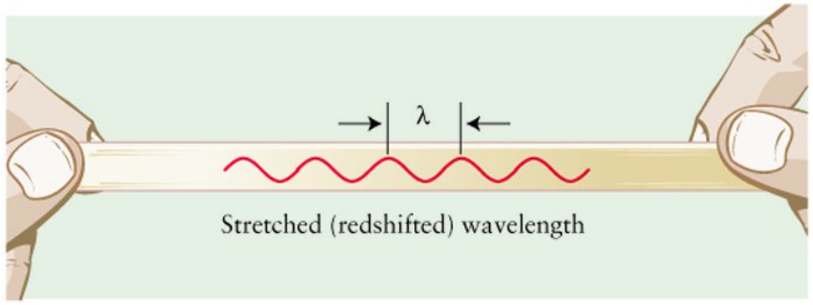
vacuum energy:
where there is space, there it is

$$dU = \rho dV$$

A negative EoS means, after a system work to the environment,
its internal energy is **increased** instead of decreased.

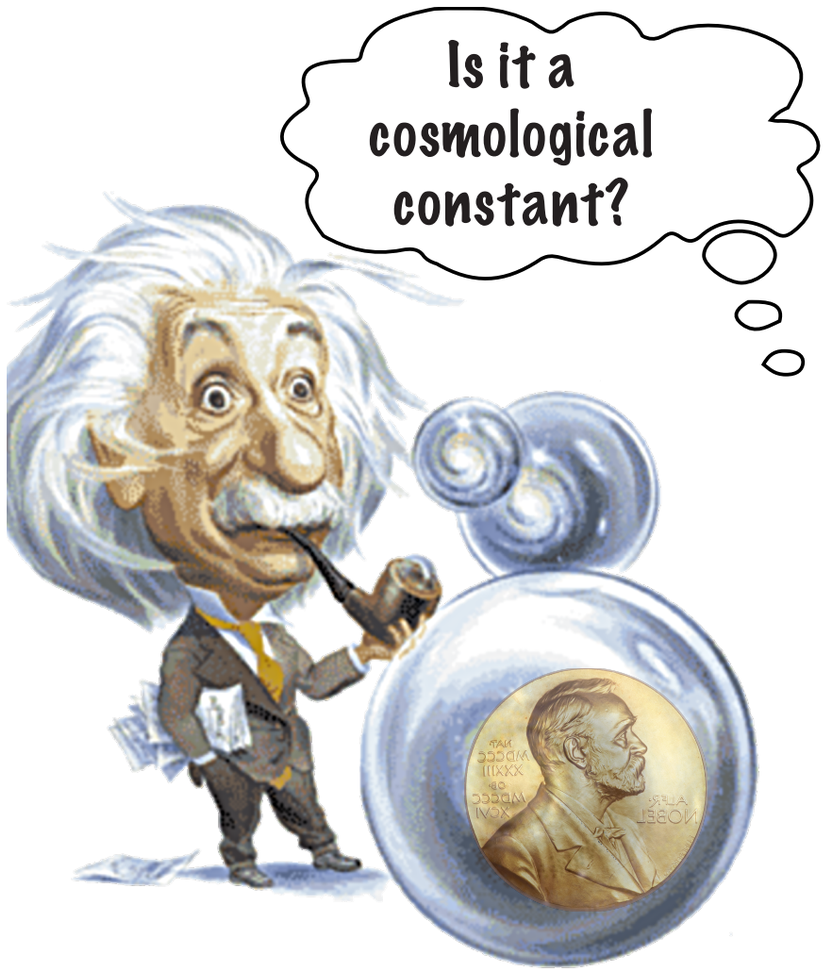


(a) A wave drawn on a rubber band ...



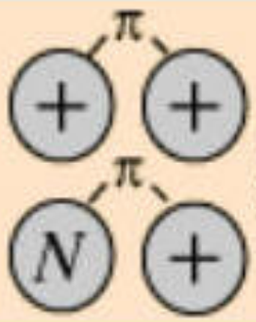
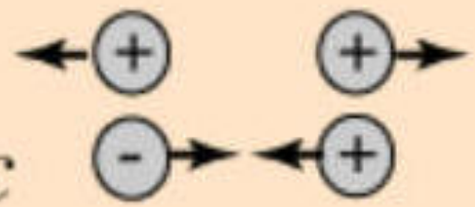
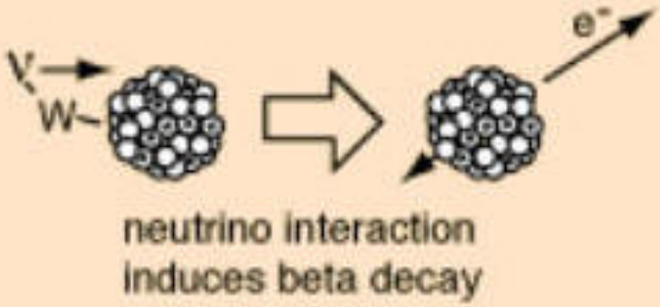
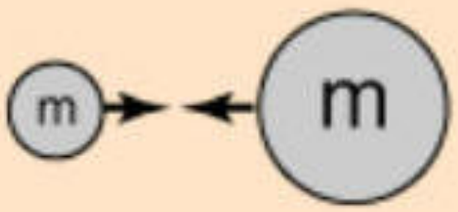
(b) ... increases in wavelength as the rubber band is stretched.

对宇宙学常数的最自然的解释
是量子场论的**真空能**(Planck Mass)



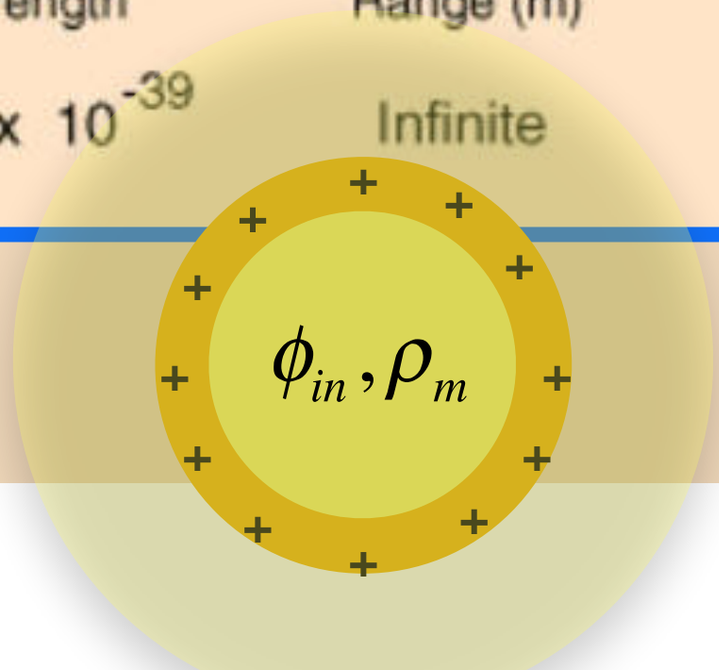
理论计算结果竟
然比观测结果
整整高出了
10^{120} 倍!

我们对真空能在引力系统中的动力学认知
还**远远不够**

		Strength	Range (m)	Particle
Strong	 Force which holds nucleus togeher	1	10^{-15} (diameter of a medium sized nucleus)	gluons, π(nucleons)
Electro-magnetic		$\frac{1}{137}$	Infinite	photon mass = 0 spin = 1
Weak	 neutrino interaction induces beta decay	10^{-6}	10^{-18} (0.1% of the diameter of a proton)	Intermediate vector bosons W^+, W^-, Z_0, mass > 80 GeV spin =1
Gravity		6×10^{-39}	Infinite	graviton ? mass = 0 spin = 2

5th force?

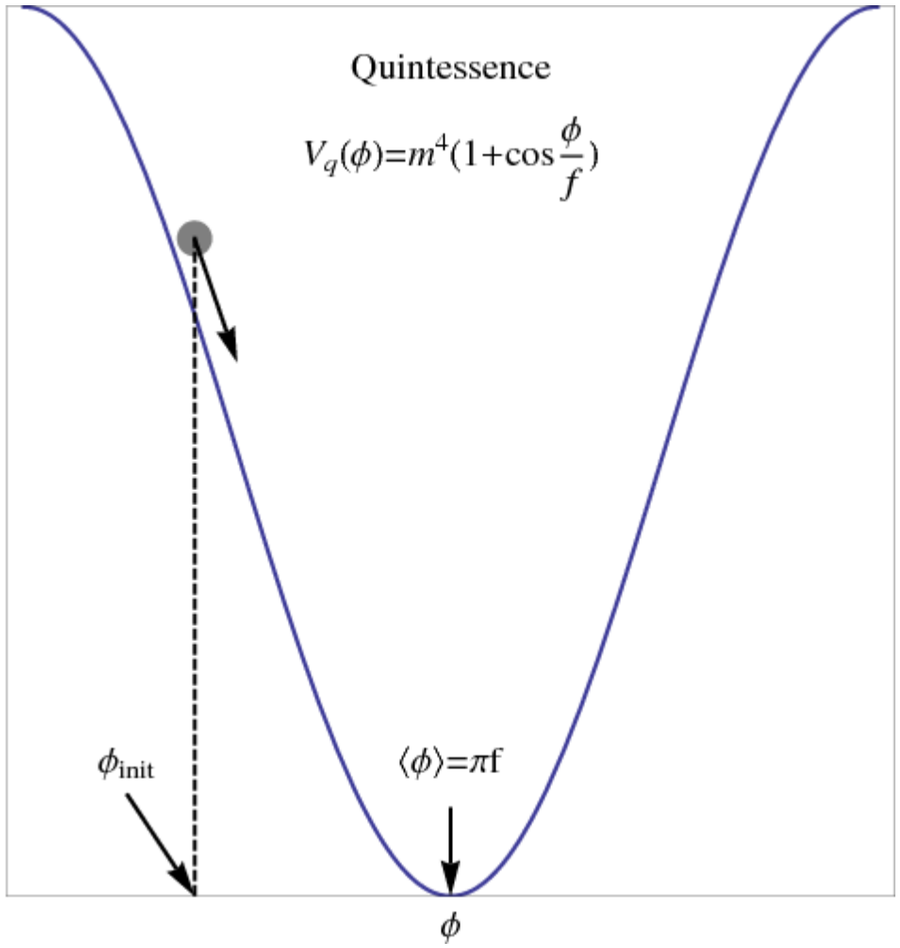
Dark Energy

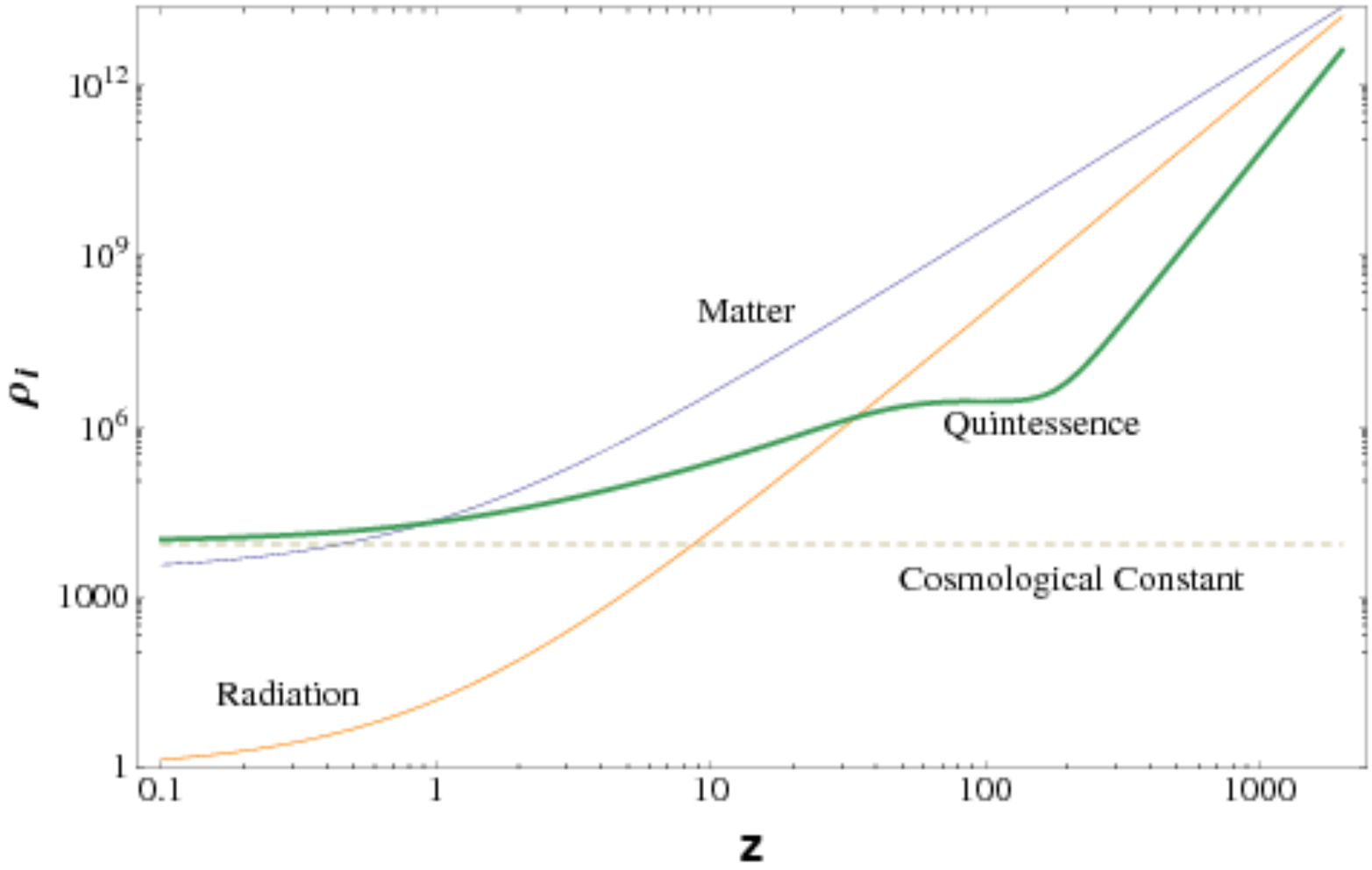


quintessence

精质

fifth ⟵ quinto



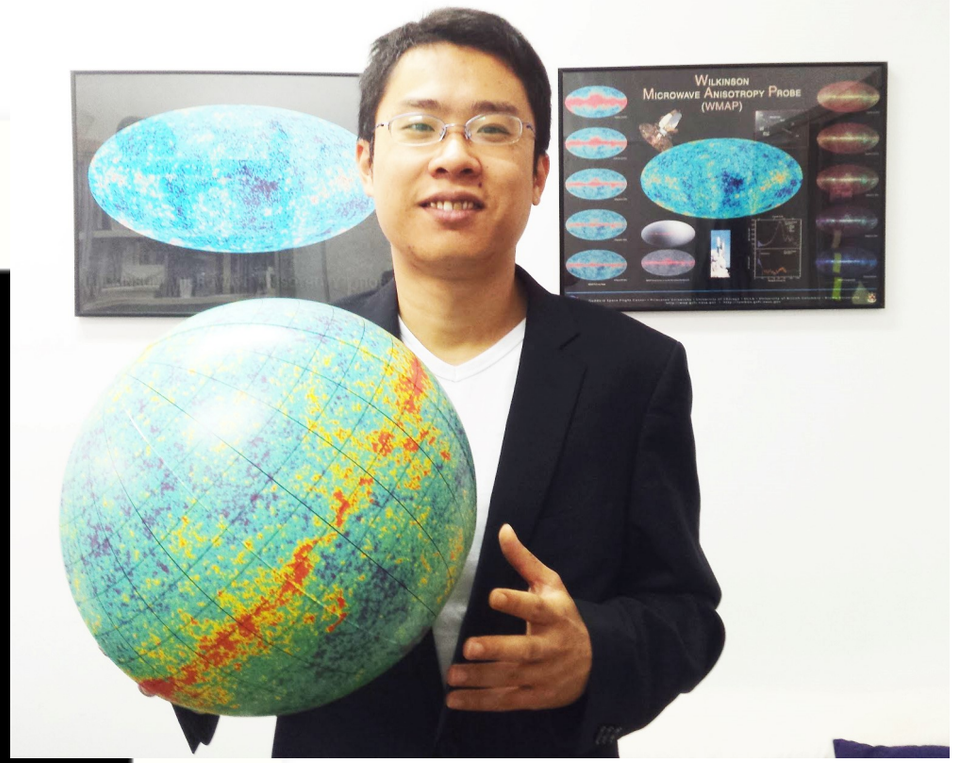


problem-5: Can u propose a new method to detect dark energy?

problem-6:


MAY THE
FORCE
BE WITH
YOU


5th
MAY THE
FORCE
BE WITH
YOU


Wilkinson
Microwave Anisotropy Probe
(WMAP)