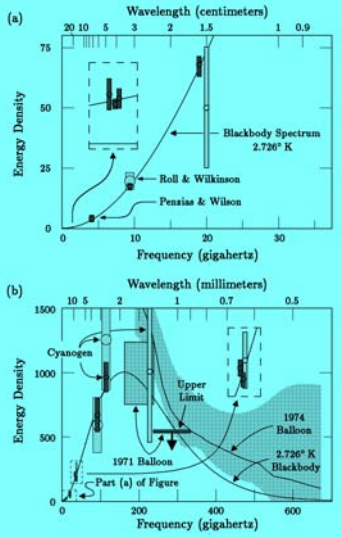
8.286 Lecture 19
November 19, 2013

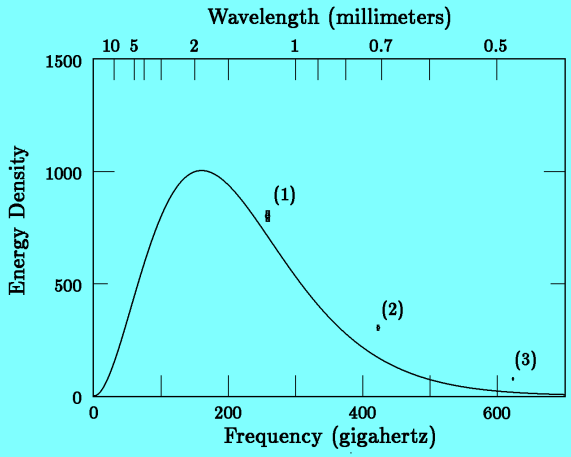
THE COSMOLOGICAL CONSTANT

Summary of Lecture 18



CMB Data in 1975

Summary of Lecture 18



Data from Berkeley-Nagoya Rocket Flight, 1987

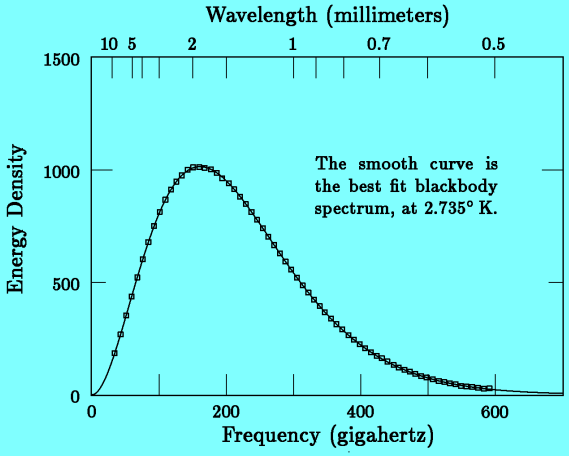
Summary of Lecture 18

A Preliminary Measurement of the Cosmic Microwave Background Spectrum by the Cosmic Background Explorer (COBE) Satellite

J. C. Mather, E. S. Cheng, et al.

Cover Page of Original Preprint of the COBE Measurement of the CMB Spectrum, 1990

Summary of Lecture 18



Original COBE Measurement of the CMB Spectrum, Jan 1990. Energy density is in units of electron volts per cubic meter per gigahertz.

Summary of Lecture 18:
Gravitational Effect of Pressure

$$\frac{d^2a}{dt^2} = -\frac{4\pi}{3}G\left(\rho + \frac{3p}{c^2}\right)a \ .$$

Vacuum Energy and the Cosmological Constant:

$$u_{\rm vac} = \rho_{\rm vac}c^2 = \frac{\Lambda c^4}{8\pi G} \ .$$

$$\dot\rho_{\rm vac} = 0 \quad \Longrightarrow \quad p_{\rm vac} = -\rho_{\rm vac}c^2 = -\frac{\Lambda c^4}{8\pi G} \ .$$

Summary of Lecture 18

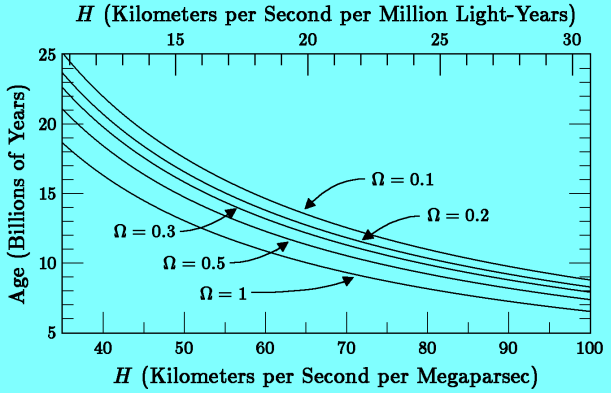
Defining $\rho = \rho_n + \rho_{\rm vac}$ and $p = p_n + p_{\rm vac}$,

$$\frac{d^2a}{dt^2} = -\frac{4\pi}{3}G\left(\rho_n + \frac{3p_n}{c^2} - 2\rho_{\rm vac}\right)a \ .$$

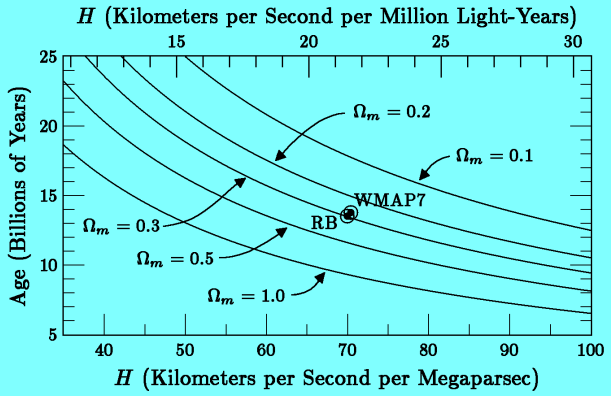
$$\left(\frac{\dot a}{a}\right)^2 = \frac{8\pi}{3}G(\rho_n + \rho_{\rm vac}) - \frac{kc^2}{a^2} \ .$$

Dominance of vacuum energy at late time implies

$$H \to H_{\rm vac} = \sqrt{\frac{8\pi}{3}G\rho_{\rm vac}} \ ,$$
$$a(t) \propto e^{H_{\rm vac}t} \ .$$



The age of an open ($\Omega < 1$), closed ($\Omega > 1$), or flat ($\Omega = 1$) universe containing only nonrelativistic matter.



The age of a flat universe containing nonrelativistic matter and vacuum energy.

8.286 The Early Universe

Fall 2013