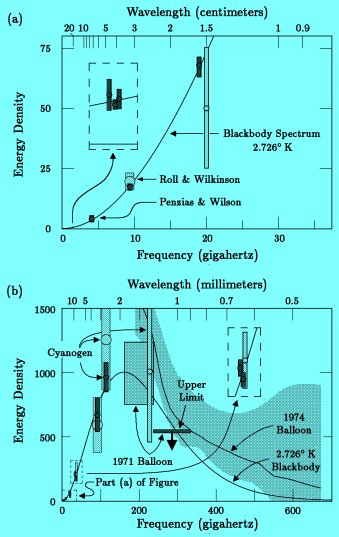
8.286 Lecture 18
November 16, 2016

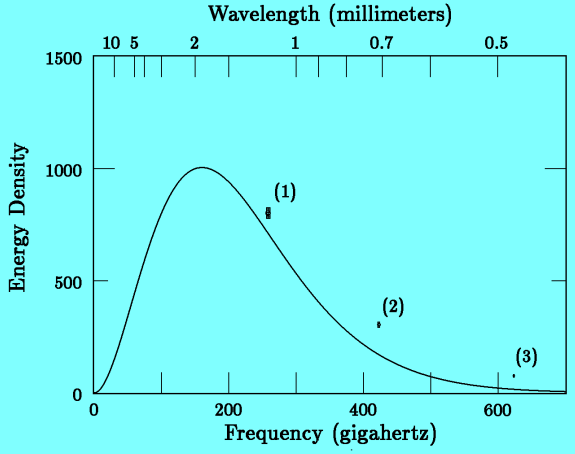
COSMIC MICROWAVE BACKGROUND
and
THE COSMOLOGICAL CONSTANT

Thermal History of the Universe

- For $0.511 \text{ MeV} \ll kT \ll 106 \text{ MeV}$, $\boxed{kT = \dfrac{0.860 \text{ MeV}}{\sqrt{t \text{ (in sec)}}}}$.
- Conservation of entropy implies that $\boxed{s \propto 1/a^3}$. When g is constant, this implies $\boxed{T \propto 1/a}$.
- At the densities found in the early universe, the hydrogen plasma becomes neutral atoms (hydrogen "recombines") at 4,000 K, and becomes transparent to photons ("photon decoupling") at 3,000 K. We estimated $T_{\text{decoupling}} \approx 380,000$ yr.



CMB Data in 1975



Data from Berkeley-Nagoya Rocket Flight, 1987

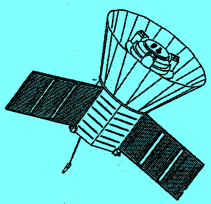
Preprint No. 90-01

GSFC

COBE PREPRINT

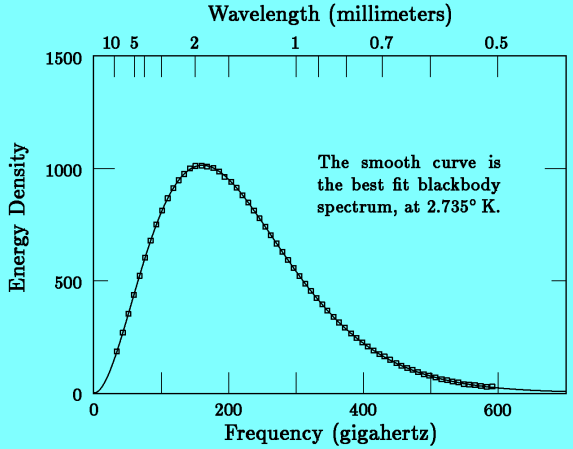
A PRELIMINARY MEASUREMENT OF THE COSMIC MICROWAVE BACKGROUND SPECTRUM BY THE COSMIC BACKGROUND EXPLORER (COBE) SATELLITE

J.C. Mather, E. S. Cheng, R. E. Eplee, R. B. Isaacman, S. S. Meyer, R. A. Shafer, R. Weiss, E. L. Wright, C. L. Bennett, N. W. Boggess, E. Dwek, S. Gulkis, M. G. Hauser, M. Janssen, T. Kelsall, P. M. Lubin, S. H. Moseley, Jr., T. L. Murdock, R. F. Silverberg, G. F. Smoot, and D. T. Wilkinson.



COSMIC BACKGROUND EXPLORER

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



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