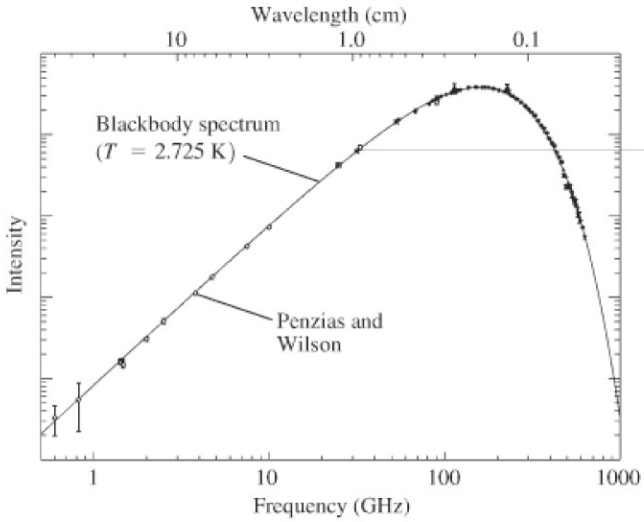

FIGURE 33–22 Spectrum of cosmic microwave background radiation, showing blackbody curve and experimental measurements including that of Penzias and Wilson. (Thanks to G. F. Smoot and D. Scott. The vertical bars represent the experimental uncertainty in a measurement.)

The intensity of this cosmic microwave background radiation as measured at $\lambda = 7.35\,\text{cm}$ corresponds to blackbody radiation (see Section 27–2) at a temperature of about 3 K. When radiation at other wavelengths was measured, the intensities were found to fall on a blackbody curve as shown in Fig. 33–22, corresponding to a temperature of 2.725 K.

The remarkable uniformity of the cosmic microwave background radiation was in accordance with the cosmological principle. But theorists felt that there needed to be some small inhomogeneities, or "anisotropies," in the CMB that would have provided "seeds" around which galaxy formation could have started. Small areas of slightly higher density and temperature, which could have contracted under gravity to form stars and galaxies, were indeed found. These tiny inhomogeneities were detected first by the COBE (Cosmic Background Explorer) satellite experiment (1992) and by subsequent experiments with greater detail, culminating in 2003 with the WMAP (Wilkinson Microwave Anisotropy Probe) results. See Fig. 33–23. WMAP gives the CMB temperature as 2.725 ± 0.002 K.

Importance of CMB: the Big Bang

The CMB provides strong evidence in support of the Big Bang, and gives us information about conditions in the very early universe. In fact, in the late 1940s, George Gamow and his collaborators calculated that a Big Bang origin of the universe should have generated just such a microwave background radiation.

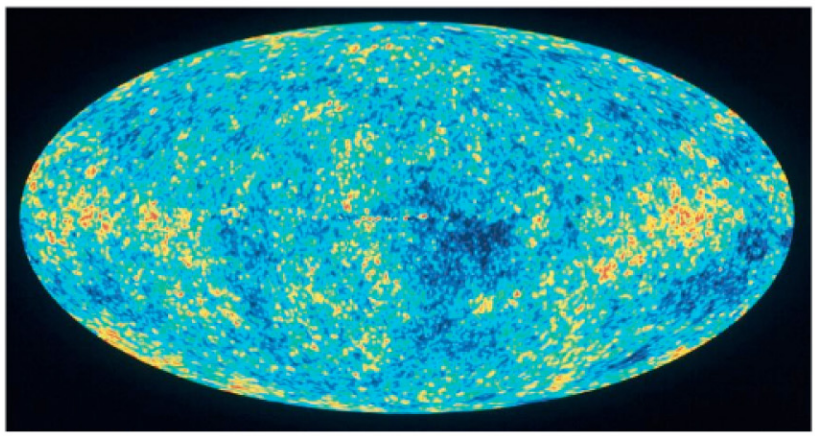

FIGURE 33–23 The cosmic microwave background radiation over the entire sky, color-coded to represent differences in temperature from the average 2.725 K: the color scale ranges from $+200\,\mu$K (red) to $-200\,\mu$K (dark blue), representing slightly hotter and colder spots (and also variations in density). Results are from the WMAP satellite in 2003: the angular resolution is 0.2°. The larger version of WMAP at the start of this Chapter was done at a specific frequency band and includes our Galaxy in the foreground (red stripe) which here has been subtracted out.