RECENT RESULTS FROM THE *COBE* DIFFERENTIAL MICROWAVE RADIOMETER

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The scientific objective of the *COBE** Differential Microwave Radiometer (DMR) investigation is to use the cosmic microwave background (CMB) radiation as a probe of cosmology. Stringent limits can be set on the amplitude of fluctuations of the potential energy at the surface of last scattering of the CMB photons. Large angular scale (>1°) fluctuations in the gravitational potential energy are directly related to temperature anisotropies in the CMB by the Sachs-Wolfe Effect (Sachs & Wolfe 1967), which describes the gravitational redshift of photons as they are last scattered at a gravitational potential energy per unit mass, ϕ, giving $\delta\phi/c^2 = 3\delta T/T$. The DMR instrument was described by Smoot et al. (1990), recent scientific results by Smoot et al. (1991a,b), and calibration by Bennett et al. (1991). The DMR consists of two independent radiometers at each of three frequencies: 31.5, 53, and 90 GHz. Each radiometer measures the difference in temperature between two 7° FWHM beams separated by 60°. The scanning pattern of the instrument causes all 60° separation pixel-pairs to be observed thousands of times.

The only temperature differences detected to date attributable to the sky are: emission from the Moon; a dipole temperature distribution from the well-known Doppler effect of the CMB photons due to the Solar System's peculiar motion; and synchrotron, free-free, and dust emission arising in our galaxy. Emission from our galaxy is strongest in the galactic plane but there is significant emission off of the plane, as expected. The minimum of the galactic signal is between 53 and 90 GHz.

We find a best-fit dipole amplitude of 3.3±0.2 K in the direction $(\alpha,\delta) = (11^{h}.2 \pm 0^{h}.2, -7^\circ \pm 2^\circ)$ or $(l,b) = (265^\circ \pm 2^\circ, 48^\circ \pm 2^\circ)$ for the motion of our solar system. This corresponds to a solar system speed of 365 km s^{-1}, or a galactic speed of 547±17 km s^{-1} toward $(l,b) = (266^\circ \pm 2^\circ, 29^\circ \pm 2^\circ)$. The dipole, if due to our peculiar motion, should have a thermal spectrum and a precise cosine distribution from pole to pole. The pole to pole distribution is well fit by a pure cosine law and the spectrum is thermal across the three DMR frequencies and through the *COBE*-FIRAS (Far-Infrared Absolute Spectrophotometer) frequency of 600 GHz.

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Other than the dipole and galactic emission there is no evidence for any other features in the DMR sky maps. We place a limit of $\Delta T/T<3x10^{-5}$ (95% C.L.) on any rms quadrupole and $\Delta T/T<4x10^{-5}$ (95% C.L.) on any rms multipole, Y_{lm}, with l<21 (using T=2.735 K). We place a limit on the corresponding correlation function of $C(\alpha)<0.01$ mK^2 (95% C.L.). The amplitude of 7° beam-size fluctuations in the DMR maps are $<1.5x10^{-4}$ (95% C.L.).

Standard cold dark matter models estimate the amplitude of potential fluctuations to be $(1-3)x10^{-5}$ on large angular scales (see e.g. Bond & Efstathiou 1984). Recent measurements of the large angular scale galaxy correlation function imply the current models underestimate the amplitude of large scale power in the universe (Efstathiou, Sutherland, & Maddox 1990; Maddox, Efstathiou, Sutherland, & Loveday 1990) while the DMR results show the amplitude to be $\Delta\phi/c^2 = 3\Delta T/T < 9x10^{-5}$ at 95% C.L. While not in contradiction with current estimates of the amplitude of gravitational potential energy fluctuations at the surface of last scattering, these preliminary results indicate that the fluctuations are small and we expect future analyses of the data to directly confront current models. The DMR anisotropy limits also imply that the energy density in long-wavelength (λ_{GW}>400 Mpc) gravity waves relative to the critical energy density of the universe is given by $\Omega_{GW} < 10^{-7}$ $(h\ \lambda_{GW}/1000\ \mathrm{Mpc})^{-2}$ where $h=H_o/100$ km s^{-1} Mpc^{-1} and H_o is the current value of the Hubble constant. The DMR quadrupole limit rules out all of the models of a rotating universe considered by Collins & Hawking (1973) for rotation frequencies $\omega/H_o<10^{-6}$. where w is the rotational frequency.

The COBE-DMR instrument continues to operate and preliminary analyses indicate that the noise continues to average down with time. Current DMR anisotropy upper limits are determined by our ability to quantify, or place limits on, *potential* systematic effects and are not at the limit of the instrument noise. Careful analyses of potential systematic errors continue. Corrections will be applied for known systematic errors and improved limits are expected for other potential systematic errors. Improved cosmological anisotropy limits will result.

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