Results from the Third Flight of the Millimeter-wave Anisotropy Experiment[a]

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INTRODUCTION

Measurements of anisotropy in the Cosmic Microwave Background (CMB) have been shown to be useful tools for constraining cosmological models.[1] Measurements on angular scales of 0.5° to several degrees are sensitive to the details of structure formation and the ionization history of the universe for $z<1000$. The Millimeter-wave Anisotropy Experiment (MAX) is designed to measure CMB anisotropy on these angular scales with spectral coverage sufficient to avoid confusion with galactic emission.

INSTRUMENT

The MAX instrument is a one-meter, Gregorian off-axis, balloon-borne, attitude-controlled telescope with a chopping secondary mirror and a multi-channel, bolometric receiver.[2,3,4] The beam size is 0.5° full width at half maximum with a 1.3° peak-to-peak sine-wave chop in the azimuthal direction at 5.8 Hz. The multi-channnel receiver simultaneously measures the brightness in three pass bands centered at 6, 9, and 12 cm^{-1}. Bolometric detectors operating at 300 mK provide high sensitivity at these frequencies. Anisotropy data are obtained by scanning the chopped beam in azimuth in order to subtract instrumental offsets.

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The MAX instrument has flown three times. The first two flights were in 1989 and 1990.[2,3] The third flight of MAX took place on June 5th, 1991 at the National Scientific Balloon Facility in Palestine, Texas. The instrument sensitivity to CMB anisotropy, determined from in-flight calibrations and noise measurements, was 533, 731, and 1940 $\mu K\sqrt{sec}$ in the 6, 9, and 12 cm^{-1} channels, respectively. The primary role of the 12 cm^{-1} channel is to measure the morphology of interstellar dust emission which is expected to be the major source of galactic confusion at these frequencies.

ANALYSIS

Anisotropy scans were performed near the stars Mu Pegasi and Gamma Ursa Minoris (GUM). After the removal of a dust component, the Mu Pegasi data set yields an upper limit to CMB anisotropy of $\Delta T/T_{CMB} \leq 2.35 \times 10^{-5}$ with an instrument sensitivity of $\Delta T/T_{CMB} \approx 1 \times 10^{-5}$. If all of the residual signal were interpreted as CMB anisotropy, a $\Delta T_{rms}/T_{CMB} \approx 1.65 \times 10^{-5}$ would be obtained.[5,6] The GUM scan produced a data set with significant correlated structure in the 6 and 9 cm^{-1} channels and little structure at 12 cm^{-1}. The measured spectrum of the structure is inconsistent with emission from interstellar dust, as shown in figure 1.

The spectrum of the structure observed at 6 and 9 cm^{-1} is consistent with CMB anisotropy, but also with free-free and synchrotron emission. These sources are not expected to be bright enough to account for the observed structure, based on scaling from maps at lower frequency. If all the structure is interpreted as CMB anisotropy, a value of $\Delta T_{rms}/T_{CMB} = 4.7 \times 10^{-5}$ was measured.[7]

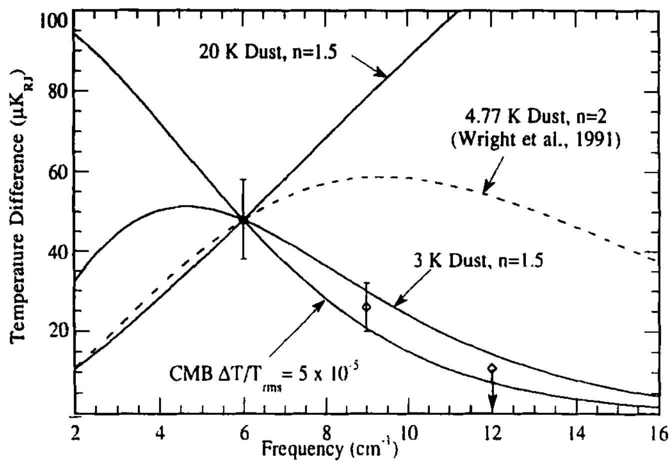

Figure 1. The measured rms anisotropy at 6, 9, and 12 cm^{-1} compared with various models of interstellar dust emission, and with CMB anisotropy. The 12 cm^{-1} is shown as an upper limit because the structure at 12 cm^{-1} is not significantly correlated with that at 6 and 9 cm^{-1}.

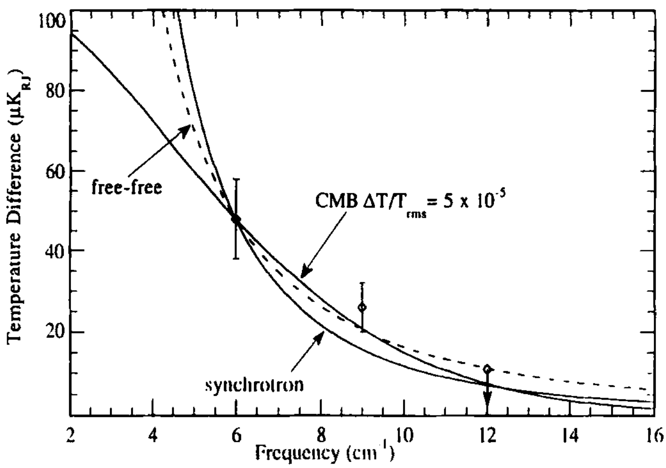

Figure 2. This figure is similar to figure 1 except that the data are compared with free-free and synchrotron spectra and with the spectrum of CMB anisotropy.

FUTURE OF MAX

The MAX experiment is evolving to answer the questions posed by each successive flight. In the spring of 1993, an 85 mK bolometric receiver is scheduled to be flown which will have 3 to 4 times greater sensitivity than the previous flight. This instrument will achieve a sensitivity of $\Delta T/T_{CMB} = 3 \times 10^{-6}$ in 1.3 hours of integration. The addition of a fourth optical channel at 3 cm^{-1} will unambiguously discriminate between synchrotron and free-free and CMB anisotropy. In conjunction with preparing this receiver, an array receiver is being developed. The array receiver will have up to 8 multi-frequency pixels, each with the same sensitivity as the 85 mK receiver. The array receiver will enable sensitive maps to be made of approximately 50 pixels per flight, allowing study of the morphology as well as the spectrum of anisotropic structure.

REFERENCES

1. Bond, J. R., Efstathiou, G., Lubin, P. M., & Meinhold, P. R. 1991, Phys. Rev Lett. **66:** 2179.
2. Fischer M., et al.. 1992. ApJ. **388:** 242.
3. Alsop, D., et al.. 1992, ApJ. **317:** 146.
4. Meinhold, P. R., Chingcuanco, A. O., Gundersen, J. O., Schuster, J. A., Lubin, P. M., Morris, D., & Villela, T. 1993a, ApJ. **406:** 230.
5. Meinhold, P, et al.. 1993. ApJ Lett. in press.
6. Devlin, M. J. et al. 1993. PNAS. in press.
7. Gundersen, J. O., et al. 1993. submitted to ApJ.