

X. INFRARED INSTRUMENTATION AND ASTRONOMY

Academic and Research Staff

Prof. Dirk J. Muehlner
Prof. Rainer Weiss
Richard L. Benford

Graduate Students

Patricia Downey
Margaret A. Frerking

Mark Halpern
David H. Shoemaker

1. INFRARED HETERODYNE DETECTION

Joint Services Electronics Program (Contract DAAB07-76-C-1400)

Dirk J. Muehlner, Richard L. Benford, Margaret A. Frerking

A continuously tunable infrared heterodyne receiver was developed with the original intention of using it for very high spectral resolution astronomical observations. The complete detector, including a PbSnSe diode laser local oscillator, a HgCdTe photodiode mixer and associated optical components, was assembled in a small dewar. The dewar and additional transfer opticals made a compact package which could be mounted as a unit on even a small astronomical telescope.

The technology of tunable diode lasers for the mid infrared is new and we encountered considerable difficulties due to deterioration of the early lasers when they were cycled between room and liquid helium temperatures. Late in 1976 we obtained (from Laser Analytics, Inc.) a diode laser which operated at liquid nitrogen temperature, making it practical to store the instrument cold. This longest-lasting of our diode lasers was used in late 1976 to make heterodyne measurements of absorption of solar radiation by ozone in the earth's atmosphere near 1010 cm^{-1} . Preliminary results on this project were described in RLE Progress Report No. 119 (p. 31). The work was published¹ in essentially the same form, except that a better match of a calculated spectrum to the observed one was obtained by using the latest available line parameters² for ozone. The most complete description of the work, including results of high resolution laboratory absorption spectra of ozone, appears in the Ph.D. thesis³ of Margaret Frerking.

No further experimental work was done after the ozone measurements were completed, and the project came to an end, after having demonstrated the potential of the compact heterodyne receiver, with the completion of Ms. Frerking's thesis.

References

1. Applied Optics 16, 526 (1977).

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2. A. Barbe, C. Secroun, P. Jouve, N. Monnanteuil, J. C. Depannemaeker, B. Duterage, J. Bellet, and P. Pinson, *J. Mol. Spectrosc.* 64, 343-364 (1977).
3. Margaret A. Frerking, "Heterodyne Detection of Infrared Molecular Lines," Ph. D. Thesis, Department of Physics, M.I. T., August 1977.

2. MEASUREMENTS OF THE LARGE-SCALE ANGULAR DISTRIBUTION
OF THE COSMIC BACKGROUND RADIATION AT MILLIMETER
AND SUBMILLIMETER WAVELENGTHS

National Aeronautics and Space Administration (Grant NGR 22-009-526)

Rainer Weiss, Dirk J. Muehlner, Richard L. Benford

For several years we have been making balloon flights with a dual-channel differential radiometer to measure the anisotropy in the angular distribution of the 3°K cosmic background radiation on angular scales of 17°. The radiometer has passbands of 3-10 cm⁻¹ and 10-25 cm⁻¹. We have established that the radiation is isotropic to a few parts in a thousand over one half of the sky. At this level of sensitivity we are observing anisotropies caused by interstellar dust clouds which exhibit a steeply increasing spectrum with frequency. The galactic plane is a major source of nonuniform width, temperature, and emissivity. Other sources have been discovered, in particular, a diffuse and extended region in the northern sky in the vicinity of W1. The analysis of the cosmic component has been complicated by these sources. Further progress requires the addition of more spectral channels in the radiometer in order to characterize the sources and allow their removal in the background measurement.

Even though isotropy measurements at smaller frequencies are less troubled by these sources and may have succeeded in measuring the anisotropy caused by the motion of the Earth against the primeval plasma, isotropy measurements must be carried out at several wavelengths so that spectra of the anisotropy can reveal the true source of the anisotropy.

This program is active and is now being administered by the Department of Physics.

3. SKY SURVEY AT MILLIMETER AND SUBMILLIMETER
WAVELENGTHS

National Aeronautics and Space Administration (Grant NGR 22-009-526)

Rainer Weiss, Dirk J. Muehlner, Richard L. Benford

In an effort to understand the results of the isotropy experiments, we have been carrying out a sky survey from balloons in the 3-10 cm⁻¹ and 10-25 cm⁻¹ bands with an

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angular resolution of 1.5° . Two flights have been made which have mapped the galactic plane $-2^\circ < l_{II} < 120^\circ$. The maps reveal that the galactic plane is a strong source in the $10\text{-}25\text{ cm}^{-1}$ band, the galactic center is about $1/300$ as bright as the moon in the same beam size. The galactic plane is not uniform in width but varies from a size as small as the beam size to over 8° . The spectral index varies more steeply than the frequency to the third power.

More survey flights will be made in the next year using new bolometers and two more spectral channels.

This program has been transferred to the Department of Physics.

4. INTEGRATED SILICON BOLOMETER

National Aeronautics and Space Administration (Grant NSG-7328)

Rainer Weiss, Patricia Downey

Broadband composite bolometers constructed entirely of silicon have been tested. The technique of manufacture is the following. A resistance thermometer is ion-implanted in a high-purity single-crystal wafer of silicon. The wafer, after masking, is etched leaving a central square 5 millimeters on a side supported by a silicon spider that makes thermal contact to a large silicon frame thermally connected to the heat bath. The central square is coated with a thin film of conductor that is the radiation absorbing surface.

At present, the best detector has had a 5-ms time constant and a radiation NEP of $3 \times 10^{-14}\text{ W/Hz}^{1/2}$ at 1.5°K . The observed performance is within a factor 1.2 of the calculated performance of the specific device. We expect with further refinement of present techniques to construct detectors with a NEP of a few $10^{-15}\text{ W/Hz}^{1/2}$ and time constants in the 10 's of milliseconds.

Difficulties have been encountered in maintaining reasonable yields due to nonuniformity in the ion implants. Until this problem is solved, the initial concept of manufacturing detector arrays is unpromising. Future work will be directed toward constructing bolometers operable at 0.3°K using He_3 cryogen. Detectors of this style do not exhibit Kapitza resistance and should have NEP's that vary as $T^{-5/2}$.

This project has been transferred to the Department of Physics.

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5. COSMIC BACKGROUND EXPLORER SATELLITE (COBE)

National Aeronautics and Space Administration (Contract NAS5-24096)

Rainer Weiss, Mark Halpern, David H. Shoemaker

We are participating in the phase B study of a satellite mission to be flown in 1983 to measure the spectrum and the large-scale angular distribution of the cosmic background radiation in four bands, as well as the diffuse infrared background between 2 and 300 micron wavelengths. Rainer Weiss is team leader of the study and coinvestigator on the instrument to measure the spectrum of the radiation. The phase B study will culminate in the definition, costing, and specifications of the Fourier transform spectrometer designed to measure the spectrum of the cosmic background radiation with a signal-to-noise exceeding 1000/1 at the blackbody peak in angular resolution elements between 3° and 5° . The spectral resolution of the instrument will be better than $.5 \text{ cm}^{-1}$ at frequencies less than 20 cm^{-1} . The spectral range of the instrument extends to 100 cm^{-1} .

The coordinated observations of the mission should provide the most definitive measurements of the properties of the background radiation limited only by the "noise" due to the local astrophysical environment.

This project has been transferred to the Department of Physics.