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"Infrared Spectra of Planetary Atmospheres"
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INTRODUCTION

The primary goal of this grant has been to develop instrumentation at the longer infrared wavelengths (5μ - 20μ) with high spectral resolution and sensitivity, and with this instrumentation to examine molecular lines in planetary atmospheres in enough detail to obtain new information about these atmospheres. Such information includes (1) pressure and temperature relations in planetary atmospheres and (2) molecular and isotopic composition. Much of the initial work has been devoted to instrumental development and observational testing, but several instruments have advanced to the point where substantial new information is being obtained.

NH₃ and the Jovian Atmosphere

The attached xeroxed reprint (Ap. J. 198:L145 (1975)) of measurements and new conclusions on the atmosphere of Jupiter results primarily from work done last fall. Additional measurements of the abundance of ¹⁵N in Jupiter's atmosphere have been made from the 10μ band of NH₃. These are being analyzed, and a paper on ¹⁵NH₃ will be prepared for publication.

High Resolution 10μ and 20μ Spectrometers

The spectrometer with which the above high resolution spectra were taken is an upgraded version of an earlier spectrometer and is shown schematically in Figure 1. The spectrometer system has a sensitivity of about $1.5 \times 10^{-14}$ watts/$\sqrt{\text{Hz}}$ at 5μ wavelength and about $5 \times 10^{-14}$ watts/$\sqrt{\text{Hz}}$ at 10μ wavelength with resolution as narrow as about $\frac{1}{20}$ cm⁻¹. J. Lacy is designing a new version of such a spectrometer with a cooled Fabry-Perot interferometer to obtain even higher sensitivity in the 10μ region. Critical components have been tested, and construction of a number of parts of the system is under way.
A 20\(\mu\) spectrometer using in combination a Fabry-Perot interferometer and a cooled grating has been constructed by Greenberg and Dyal (the latter on leave of absence from NASA-Ames) and has been successfully used to obtain the first detection of the 20\(\mu\) line of S III. It has also detected 20\(\mu\) CO\(_2\) lines in the atmosphere of Venus and will be used further on \(H_2\) lines and a variety of planetary problems. Its sensitivity is \(3 \times 10^{-14}\) watts/\(\sqrt{\text{Hz}}\) and its resolution about 0.2 cm\(^{-1}\).

**Heterodyne Spectroscopy at 10\(\mu\)**

The ultimate resolution for examination of line profiles and hence determination of atmospheric characteristics of the planets will surely come from heterodyne detection. A 10\(\mu\) heterodyne detection system has been constructed, initially for a spatial interferometer, and adapted to the measurement of absorption in planetary atmospheres. Preliminary measurements on the shape of \(^{13}\text{CO}_2\) lines in the atmosphere of Mars have been made with this system, and provided a resolution of \(\frac{1}{2000}\) cm\(^{-1}\). This easily resolved the CO\(_2\) line shapes even in the thin atmosphere of Mars. A spectrum of a \(^{13}\text{CO}_2\) line in the Martian atmosphere made with such system but with resolution improved to \(\frac{1}{6000}\) cm\(^{-1}\) is represented in Figure 2. While more precise than our previous heterodyne measurement, it agrees well with the earlier results. There is a discrepancy as large as a factor of two between the intensity of this line and that expected from accepted models of the Martian atmosphere. This discrepancy could be explained by any one of the following three differences with present expectations, each of which would be surprising.

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1. The Martian atmosphere is about 25° hotter than usual models.

2. The Martian atmosphere contains substantially more CO\textsubscript{2} than present models.

3. The relative abundance of \textsuperscript{13}C is about 2.5 times as great as that on earth.

Additional measurements and analyses are being made to determine more precisely the source of this discrepancy.

**Infrared Imaging and Upconversion**

A system for converting 10\textmu m radiation into visible light while preserving a field of view has been demonstrated in the laboratory and is being designed for taking telescopic pictures of planets in this wavelength range. The system, made by Boyd and shown schematically in Figure 3, upconverts 10\textmu m photons by non-linearities in a proustite crystal excited by a laser. The upconverted light produces an image through an image converter. "Infrared photographs" of objects have been made in the laboratory and sensitivity demonstrated which will allow pictures to be made in a modest time of the 10\textmu m images of the Moon, Mars, and Venus. The images will be of a narrow frequency band of radiation, about 3 cm\textsuperscript{-1} wide, which can be varied by rotation of the crystal. Spatial resolution about twice the diffraction limit associated with the laboratory optics have been obtained, which should allow images limited in resolution only by the diffraction limit of a large telescope. It is hoped that informative IR photographs of planets can be taken during the next six months.
Figure Captions

Figure 1. High resolution tandem Fabry-Perot Interferometer for the 5μ and 10μ regions.

Figure 2. Spectral Lines of CO₂.

Figure 3. 10μ imaging upconverter for Astronomy.
5.

Publications since last report


Figure 2
10 μ IMAGING UP-CONVERTER FOR ASTRONOMY

KRYPTON ION LASER
7525 Å
0.25 W

PROUSTITE CRYSTAL

INTERFERENCE FILTERS
(Pass 7000 Å,
Reject 7525 Å)

IMAGE INTENSIFIER

CAMERA

GE BEAMSLIPPER

IMAGE