A 10 MICRON HETERODYNE RECEIVER FOR ULTRA HIGH RESOLUTION ASTRONOMICAL SPECTROSCOPY

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Infrared heterodyne spectroscopy is extremely useful in determining by precise measurements of atomic and molecular infrared line spectra the molecular abundances, velocity structure, and excitation conditions of the interstellar medium, and the temperature- and pressure-profiles of planetary atmospheres (cf. Kostiuk et al. 1977, Betz et al. 1976, 1977, Abbas et al. 1978).

Heterodyne detection is achieved by combining infrared source radiation with a coherent laser local oscillator output at a non-linear detector - e.g. HgCdTe photo-mixer. The difference frequency or intermediate-frequency (IF) recovers the spectral characteristics of the source radiation and may be measured by radio frequency techniques to an arbitrarily high resolving power.

Our present CO_2 laser heterodyne spectrometer (Fig. 1) includes several improvements over our first generation system described by Mumma et al. 1978 and Kostiuk et al. 1977: the present system uses reflective optics to eliminate re-focusing at different wavelengths, and the local oscillator is a line-center-stabilized isotopic CO_2 laser built at GSFC. Easy and rapid selection of over 50 transitions per isotope of CO_2 is made possible by a tunable diffraction grating. A GSFC built visible and infrared star-tracker can be used for automatic guiding on astrononomical sources. The IF (0-1.6 GHz) from the HgCdTe photomixer is analysed by a 128-channel filter bank. A tunable bank of 64 5-MHz filters and a fixed set of 64 25-MHz RF filters provide resolving powers of $\sim 10^6$-10^7 and velocity resolution of 50-250 m/sec. The output of the 128 filters is synchronously detected, integrated, multiplexed and stored as signal (S) and reference (R) in a buffer memory for the desired integration period. The result is presented as (S-R)/R, and stored on floppy disks for subsequent data reduction. A CRT graphics terminal provides on-line display with the printer and hard-copy unit providing more permanent records (Fig. 2).

The observations were taken on the main telescope of the McMath Solar Observatory at Kitt Peak National Observatory in June 1979. Line

B. H. Andrew (ed.), Interstellar Molecules, 633–636.

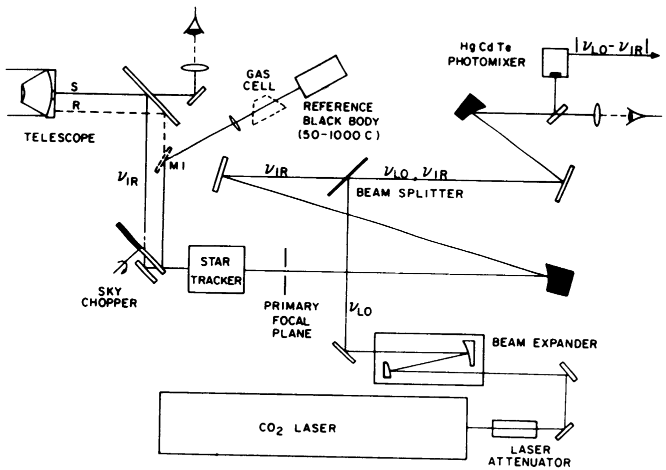

Fig. 1. The GSFC 10 micron heterodyne receiver with completely reflective optics, a line center stabilized CO_2 laser LO, and an infrared star-tracker.

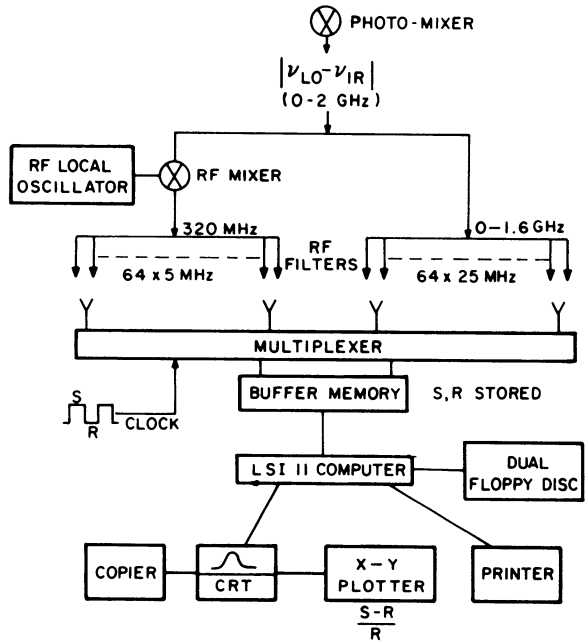

Fig. 2. The receiver IF(0-2 GHz) is analysed by 128 filters in sets of 64 25-MHz-wide and a tunable set of 64 5-MHz-wide banks. The RF signals are digitized and stored in signal (S) and reference (R) memories in a digital multiplexor. The output of the multiplexor is read out to a LSI-11 microcomputer system where (S-R)/R is calculated, stored on floppy disks, and displayed.

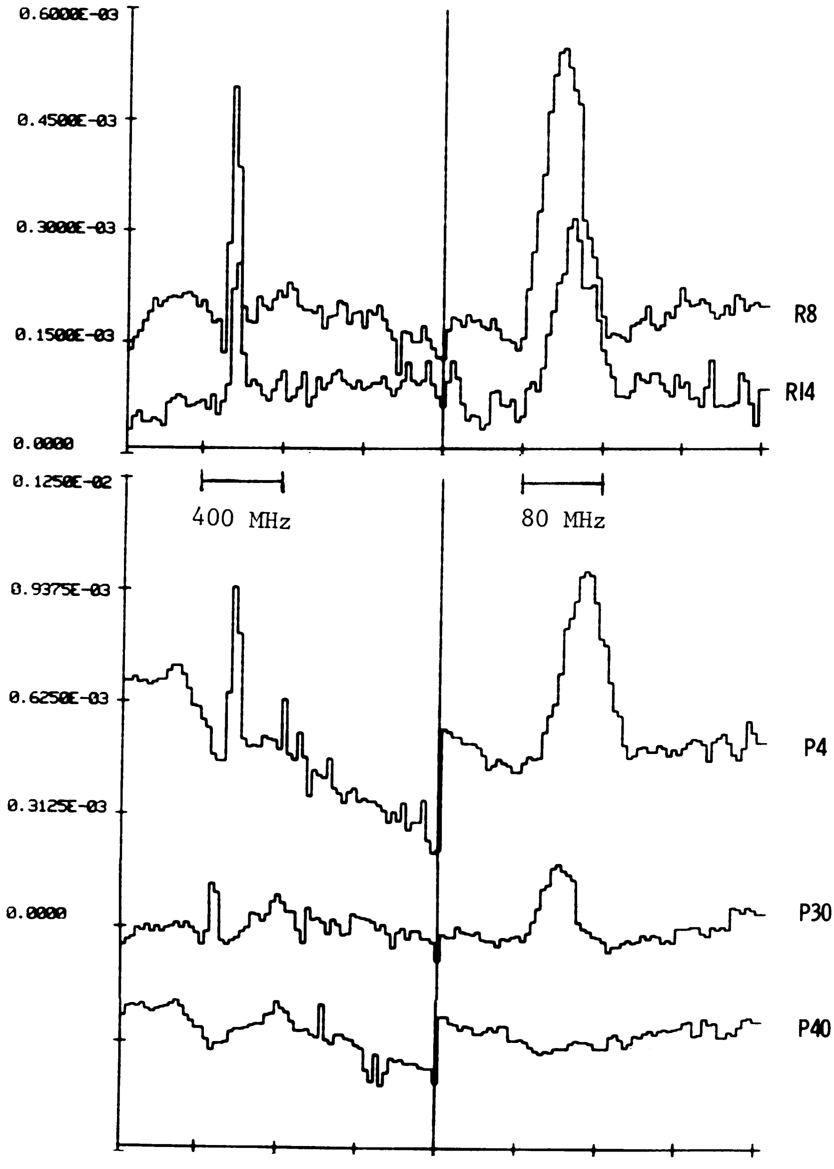

Fig. 3. Observations of CO_2 on Venus. These preliminary results with the GSFC 10 micron heterodyne system show that the central core CO_2 emission varies with J values. The lower Venusian atmosphere can be sampled in scans with an absence of core emission while scans with core emission may be used to fit the temperature and pressure of the Venusian mesosphere and upper atmosphere.

profiles from the R8, R14, and P4 through P44 transitions of CO_2 were observed from the Venusian atmosphere. Fig. 3 shows several of the observed spectra. These scans are uncorrected for atmospheric attenuation or Doppler shifts of individual unstacked data. Solar scans at each observed Venusian line were also made as a measure of the amount of telluric attenuation. We see that higher J transitions in the P branch in Venus have weaker or negligible emission cores and may be used to deconvolve the pressure- and temperature-profiles of the lower atmosphere Lower J transitions in the P branch have sizeable emission cores and are probes of the mesosphere and upper atmosphere (Betz et al. 1976). The R8 and R14 transitions show evidence of a non-thermal spike above a thermal plateau. This thermal pedestal would imply the existence of a mesospheric temperature inversion in the Venusian atmosphere.

The NH_3 transitions in near coincidence with the 626 and 636 laser were searched for in α Sco, R Cas, and α Her. However there was a sizeable continuum (S/N $\sim$ 10) and no spectral features were observed above the noise. Expected modifications will increase the sensitivity ten-fold at 1.5 GHz.

These Kitt Peak observations with the GSFC infrared heterodyne receiver show the wide spectral coverage, wide mixer and electronics bandwidth and high sensitivity of our system. The manifold of P- and R- branch transitions on Venus will allow us to make theoretical models of the lower, mesospheric, and upper levels of the atmosphere after the data have been corrected for telluric attenuation and Doppler shifts. Improvements underway at GSFC include the development of a (0 - 2.5 GHz) photo-mixer with an increased bandwidth response, a cooled matched low-noise preamplifier and back-end filter, the development of a tunable diode laser local oscillator heterodyne front-end, and the extension of operating wavelengths to 30 μm.

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