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SUBMILLIMETER MOLECULAR LINE OBSERVATIONS OF COMET LEVY (1990c)

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ABSTRACT

We present observations of HCN and H_2CO in Comet Levy (1990c) obtained at the Caltech Submillimeter Observatory during August 1990. The HCN J=3-2 rotational line was measured at high spectral resolution (0.1 km s^{-1}) and mapped at 13 points over a region of approximately 1.5 arcmin. Analysis of the line profile and the map suggest only slight deviations from the distribution expected for isotropic outgassing of HCN from the nucleus at a velocity of 0.7 ± 0.1 km s^{-1}. Observations of the HCN J=4-3 and H_2CO 5_{15}-4_{14} transitions were obtained simultaneously on two days following the HCN J=3-2 measurements. These transitions are the first submillimeter spectral lines to be detected in a comet. Five point maps of the emission show good consistency between the J=3-2 and J=4-3 HCN observations for an HCN production rate of 2×10^{26} and a rotational temperature of approximately 30K. The map of H_2CO emission indicates that it is more extended than the prediction of models in which H_2CO originates entirely from the nucleus. We suggest that H_2CO may also originate from an extended source in the coma.

INTRODUCTION

Radio spectral line studies of comets offer an important means to study the physical state of the cometary coma and the chemical nature of the nucleus (Crovisier and Schloerb 1991). During the past year, important new molecular discoveries have been made in the millimeter wavelength band at the IRAM 30m telescope (*c.f.* Crovisier, this volume), and as the technology improves at these wavelengths, we anticipate a corresponding increase in our understanding of the nature of comets. A particularly important new area for this research will be the study of comets at submillimeter wavelengths, since many cometary transitions are intrinsically stronger in this part of the spectrum and the capabilities of submillimeter instrumentation are rapidly improving. In this paper, we report the first detection of submillimeter-wave spectral line emission from a comet and discuss some of the preliminary results derived from the observations.

OBSERVATIONS

Observations of Comet Levy (1990c) were obtained at the Caltech Submillimeter Observatory using the 10m antenna during 29 August - 1 September 1990. An SIS receiver was used for the HCN J=3-2 observations at 266 GHz; the single sideband system temperature measured on the sky by the chopper wheel method was approximately 700 K during the observations . For the HCN J=4-3 (354 GHz) and H_2CO (352 GHz) observations, the two lines were observed simultaneously by placing them in opposite receiver sidebands of the SIS receiver. The SSB system temperature of this receiver was approximately 1400K, as measured on the sky during the observations. Two Acousto-Optic Spectrometers (AOS) were used to detect the spectral lines. The AOS bandwidths were 500 MHz and 50 MHz, which yielded 0.5 MHz and 50 kHz resolution, respectively. Antenna pointing was verified on Saturn, which was relatively close to Comet Levy in the sky; the pointing uncertainties are estimated to be 3 arcsec rms. The antenna beam width is 28 arcsec at 266 GHz and 22 arcsec at 353 GHz. The beam efficiency at both frequencies is approximately 0.55.

Cometary observations pose a special problem for radio observers since typically the comet must be tracked blind. For these observations, we used orbital elements kindly supplied by D. Yeomans, JPL, at the beginning of our run to predict the position of the comet. However, subsequent improvements in the orbit, published in MPC 16841, indicated that we tracked a position about 13 arcsec NE of the actual position of the nucleus. This illustrates the need for good orbital solutions to support radio observations, and we appreciate the continuing efforts of those who provide astrometric data and ephemerides.

The HCN J=3-2 observations are illustrated in Figures 1 and 2. Figure 1 shows a high resolution (0.1 km s^{-1}) spectrum of the line and indicates the positions and relative strengths of the 6 hyperfine components of this transition. This interesting line shape is due to both the hyperfine structure and the line of sight velocity distribution of HCN in the coma, which is due primarily to the outflow morphology and speed of the coma gas. Figure 2 displays a set of low resolution spectra obtained at 13 positions on a 30 arcsec grid around the "nucleus" position that was tracked by the telescope during our observations. The map shows a significant asymmetry towards the south and west of this position in the direction of the offset between the ephemeris used for these observations and that of MPC 16841.

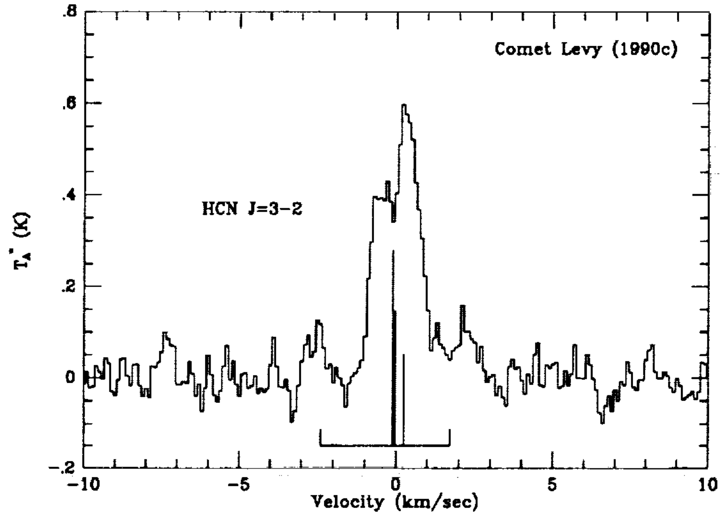

Figure 1 - HCN J=3-2 Spectrum of Comet Levy (1990c) obtained at 0.1 km s^{-1} resolution.

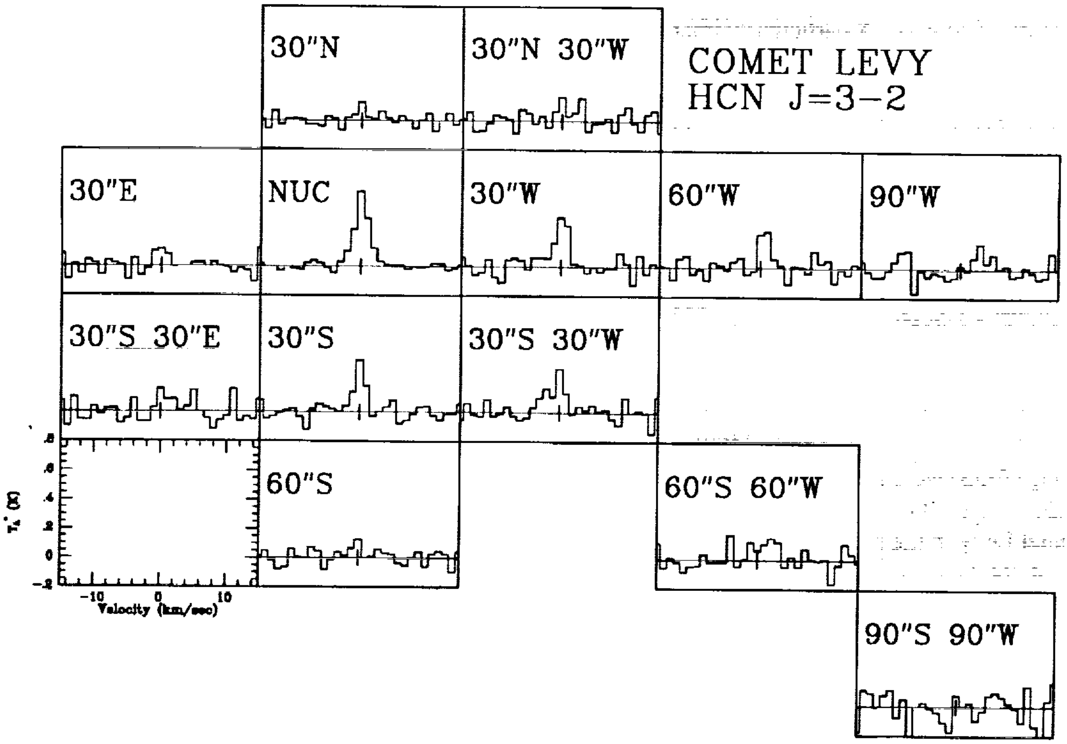

Figure 2 - HCN J=3-2 Map of Comet Levy (1990c). The spectra are sampled on a 30 arcsec grid about the "nucleus" position tracked by the telescope.

The HCN J=4-3 and H_2CO 5_{15}-4_{14} transitions at the "nucleus" position tracked during our observations are shown in Figure 3. This is the first detection of submillimeter-wave spectral line emission from a comet. In addition to observations at the nominal nucleus position, spectra were also obtained at four positions offset by 30 arcsec in the cardinal directions from the nucleus. The distribution of brightness in the HCN J=4-3 transition is consistent with that observed in the J=3-2 maps, which provides verification of the pointing of the telescope with respect to the comet during these observations and confidence in the derived results.

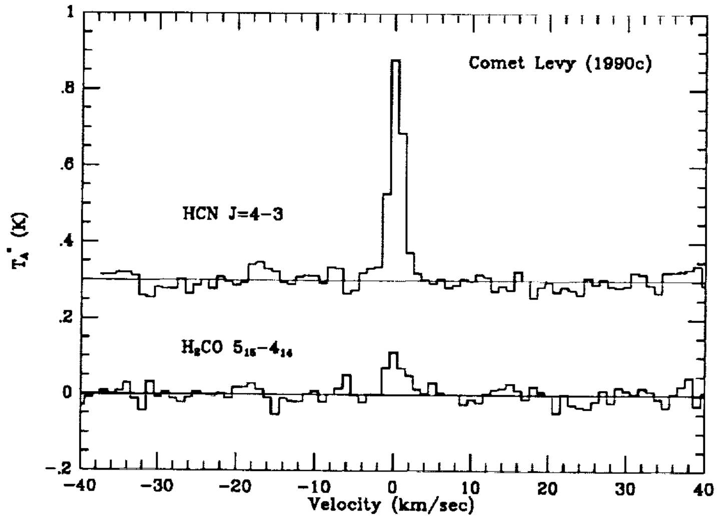

Figure 3 - HCN J=4-3 and H_2CO 5_{15}-4_{14} spectra of Comet Levy (1990c).

RESULTS

Gas Outflow Velocity

The HCN J=3-2 line profile shown in Figure 1 is reproduced reasonably well by a model of isotropic outgassing of HCN from the nucleus of the comet with a velocity of 0.7 ± 0.1 km s^{-1}. However, we also observe a slight redshift in the line position which could be due to a small deviation from isotropic gas emission from the nucleus. If the nucleus is modeled as having different production rates from its day and night sides, then the observed redshift would require that the night side emission rate is enhanced over the day side rate by approximately 20%.

HCN Distribution in the Coma

We have fit models of the radial distribution of HCN to the data displayed in Figure 2. One important parameter of the model is a possible offset between the "nucleus" position tracked during the observations and the true position of the nucleus. Assuming a nominal value for the HCN lifetime and isotropic emission of HCN from the nucleus, we find that the HCN map is fit reasonably well if the true position of the nucleus is offset 11 ± 1 arcsec West and 8 ± 1 arcsec South of the position tracked during the observations. These values compare favorably with the offsets of 10.1 arcsec West and 8.6 arcsec South that are predicted by the difference between the ephemeris we used and that of MPC 16841. Thus, we believe that the data are basically consistent with HCN emitted isotropically from the nucleus with a nominal lifetime of 8×10^4 s, normalized to a heliocentric distance of 1 AU. However, small residuals do remain in the maps, and further investigation is underway.

HCN Production Rate and Rotational Temperature

The HCN J=3-2 and J=4-3 intensities are consistent with thermal excitation of the HCN molecule with a rotational temperature of approximately 30 K. Both this simple model and a more complex excitation model which accounts for both collisional and radiative excitation of HCN in the coma yield an HCN production rate of approximately 2×10^{26} s^{-1}, which is consistent with previous estimates of the HCN abundance in comets (*c.f.* Schloerb *et al.* 1987).

H_2CO Distribution

HCN and H_2CO were mapped simultaneously at five points in the coma on two separate nights during the run. This technique makes it possible to derive accurate information on their relative intensities, and since the HCN map permits us to deduce the position of the nucleus at the time of the observations, the H_2CO map may be interpreted without many of the limitations typically imposed by antenna pointing errors and ephemeris uncertainties. The H_2CO lines in the map are intrinsically weak, and therefore, we have averaged map spectra obtained at the same radial distance from the nucleus to improve the signal-to-noise ratio. These data are summarized in Figure 4 as a plot of the integrated line intensity as a function of the radial offset from the nucleus position defined by the ephemeris in MPC 16841. Also shown in the plot are the predictions for the radial fall-off of H_2CO emission for models in which the H_2CO molecule originates isotropically from the nucleus with various lifetimes. The figure indicates that models which assume a nuclear origin for the H_2CO do not reproduce the observations, even if lifetimes much longer than the nominal value of one hour are used. Thus, we believe that the observed distribution supports previous suggestions that H_2CO is produced in an extended source in the coma (Snyder *et al.* 1989, Krankowsky 1991).

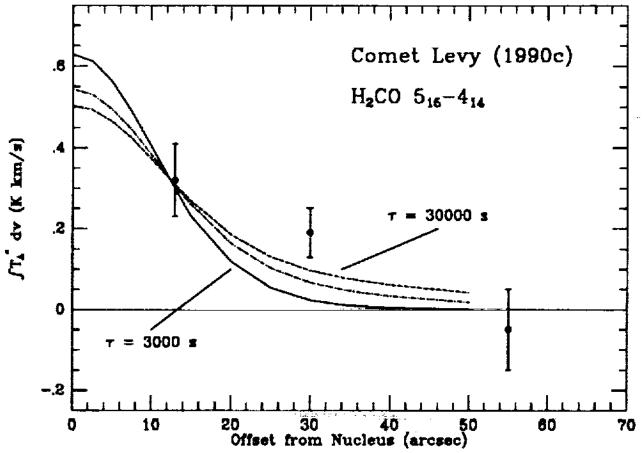

Figure 4 - Observed distribution of H_2CO emission compared to models in which H_2CO originates totally from the nucleus. The data indicate that H_2CO is more extended than the model predictions, suggesting that some H_2CO may originate from an extended source in the coma.

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