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MIRO Observation of Comet C/2002 T7 (LINEAR) Water Line Spectrum

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Abstract

Comet C/2002 T7 (LINEAR) was observed with the Microwave Instrument for Rosetta Orbiter (MIRO) on April 30, 2004, between 5 hr and 16 hr UT. The comet was 0.63AU distance from the Sun and 0.68AU distance from the MIRO telescope at the time of the observations. The water line involving the two lowest rotational levels at 556.936 GHz is observed at 557.070 GHz due to a large Doppler frequency shift. The detected water line spectrum is interpreted using a non local thermal equilibrium (Non-LTE) molecular excitation and radiative transfer model. Several synthetic spectra are calculated with various coma profiles that are plausible for the comet at the time of observations. The coma profile is modeled with three characteristic parameters: outgassing rate, a constant expansion velocity, and a constant gas temperature. The model calculation result shows that for the distant line observation where contributions from a large coma space is averaged, the combination of the outgassing rate and the gas expansion velocity determines the line shape while the gas temperature has a negligible effect. The comparison between the calculated spectra and the MIRO measured spectrum suggests that the outgassing rate of the comet is about 2.0×10^{29} molecules/second and its gas expansion velocity about 1.2 km/s at the time of the observations.

1. Introduction

Comet C/2002 T7 (LINEAR) was observed with MIRO as an engineering test to demonstrate the end-to-end capability of the submillimeter spectroscopic system [1]. The observation is the first spectroscopic, astronomical observation made with the MIRO instrument. Given that the MIRO telescope was 0.68 AU away from the comet center and the MIRO beam width is 7.5 arcmin, the field of view of the comet coma was 2.0×10^5 km. The Doppler velocity of the comet was −72.58 km/s (blue shifted). At the water line rest frequency 556.936 GHz, the Doppler frequency shift was 134.835 MHz. This Doppler shift is much larger than the design bandwidth of the water line band, which is closer to 25 MHz. As a result of the large Doppler shift, the cometary water spectral line could not be observed in the ”normal” water line band. Fortuitously, the Doppler shifted spectral line of water moved into another available band in the spectrometer. The Doppler shifted water line frequency was 557.071 GHz at the time of the observations. This placed the water line in the band reserved for methanol line at 568.566 GHz (and its lower sideband at 557.060 GHz).

2. Comet C/2002 T7 (LINEAR) water line spectrum

The spectrum observed with the MIRO instrument is shown in Figure 1. The noisy line is the spectrum integrated over 10 hours of observation. The solid line through the noisy data in Figure 1 is a Gaussian fit to the spectral line. The Gaussian fit has an amplitude of 1.14±0.11 K and a (full width half maximum – FWHM) line width of 1.78 ± 0.2 km/s.

3. Model calculated water line spectrum

In order to interpret the MIRO measurements of the water line spectrum, several synthetic spectra are calculated using a non local thermal equilibrium (Non-LTE) molecular excitation and radiative transfer model [2] with a variety of coma profiles that are plausible for Comet C/2002 T7 at the time of observations. The coma profile used in this study consists of a density profile determined by the Haser model [3], a constant gas temperature profile, and a uniform gas expansion velocity along the radial direction. The coma profile assumes isotropic outgassing and is uniquely determined by three parameters: an outgassing rate, the constant expansion velocity and gas temperature. This simple model for a coma profile is appropriate for this study because the MIRO measurement is too distant from the comet (0.68 AU) to infer a detailed spatial

distribution of the gas temperature and velocity, and is expected to be sensitive to mainly the terminal expansion velocity and temperature of the gas.

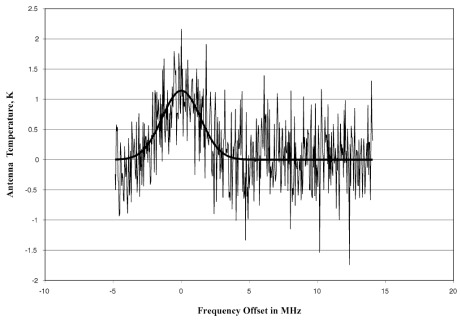

Figure 1. Comet C/2002 T7 (LINEAR) spectroscopic observation taken with the MIRO instrument on April 30, 2004, between 5 hr and 16 hr UT.

Seven coma profiles are designed to study the effect of the three coma parameters on the spectral line shape. The three parameters are listed in Table 1.

Table 1. Coma profiles used to calculate water line spectra and the resulting line shape characteristics. The coma profiles are characterized by outgassing rate (Q), expansion velocity (V), and gas temperature (T). The line shape is characterized by peak antenna temperature (Tp), full width half maximum (FWHM), and line area (LA).

Case	Q (molecules/s)	V km/s	T (K)	Tp (K)	FWHM (km/s)	LA (K km/s)
MIRO				1.1	1.8	2.1
1	$2x10^{29}$	1.2	90	1.3	1.9	2.5
2	$3x10^{29}$	1.2	90	1.9	1.9	3.6
3	$1x10^{29}$	1.2	90	0.7	2.0	1.3
4	$2x10^{29}$	1.5	90	1.1	2.5	2.7
5	$2x10^{29}$	0.9	90	1.6	1.4	2.3
6	$2x10^{29}$	1.2	120	1.4	1.9	2.6
7	$2x10^{29}$	1.2	60	1.3	1.9	2.5

Figure 2 shows the water line spectra calculated with the seven coma profiles. The outgassing rate affects the peak antenna temperature but does not affect the line width significantly. The expansion velocity changes both the peak temperature and FWHM. The change of temperature has a negligible effect on the line shape. The quantitative numbers of the peak antenna temperature, FWHM, and line area of the water spectrum are listed in Table 1. Among the coma profiles studied, Case 1 provides a line shape that is the most similar to the MIRO observed line shape.

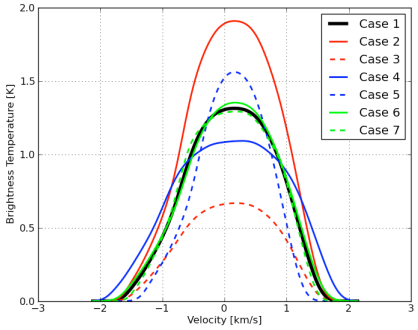

Figure 2. Synthetic MIRO water line spectra calculated with coma profiles described in Table 1.

The negligible temperature effect on the line shape can be explained by the fact that the MIRO field of view was very large and sampled mainly the region where molecules are at fluorescence equilibrium (i.e. molecule excitations are dominated by solar infrared radiation rather than molecular collisions).

4. Conclusions

For the distant, highly averaged line observation of Comet C/2002 T7 (LINEAR), the combination of the outgassing rate and the terminal gas expansion velocity determines the line shape while the gas temperature has a negligible effect on the line shape. Comparing the seven calculated line spectra with the MIRO observed line spectrum, we estimate that the outgassing rate of the comet is about $2.0x10^{29}$ molecules/second and its terminal gas expansion velocity about 1.2 km/s at the time of the MIRO measurements. This result is similar to what was estimated from the Odin measurements [4].

References

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