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The outburst of comet 17P/Holmes at millimeter wavelengths

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Abstract

We provide the very first observations of parent molecules in comet 17P/Holmes, initiated only about two days after the onset of its remarkable outburst in October 2007. We continued monitoring the comet for one week on a daily basis, and then, on a few occasions, until March 2008. The early spectra show velocity-resolved, often high-S/N line profiles of five different molecules (HCN, CH_3OH, CS, H_2CO, and H_2S), and provide sensitive upper limits on CO. They were used to trace the evolution of the outburst, and evaluate the physical conditions in the coma. The late monitoring provides constraints on the timescale on which the comet was returning to its regular activity.

1. Introduction

On UT 2007 Oct. 23.3 [5], the Jupiter family comet 17P/Holmes underwent an event which eventually raised its optical brightness by a factor of a million, making it an easy object to see with the naked eye. It was the greatest cometary outburst ever observed. The explosion occurred nearly half a year after the perihelion passage, at the helio- and geocentric distances of 2.4 and 1.7 AU respectively. At the same time the comet was perfectly placed in the Northern hemisphere, prompting several observing campaigns.

A natural observing tool for detecting and investigating the gas environment in comets is millimeter-wavelength spectroscopy. It is sensitive to parent molecules through their rotational transitions, and offers spectral resolutions of the order of 1–10 million or even more (0.3–0.03 km s^{-1}, or better). The unique resolving power provides excellent diagnostics of the gas kinematics, which controls the spectral line profiles through the Doppler effect. By observing different lines of the same molecule we can determine the gas rotational temperature, and by observing lines of various molecules we can characterize the chemical composition of the investigated environment. All these properties make millimeter-wavelength spectroscopy an ideal technique for investigating the explosion of comet Holmes.

This project has been completed, and thus we will present our ultimate findings and conclusions. Note, that earlier stages of this work were presented elsewhere [1, 2, 3, 4].

2. Observations

We traced this astonishing event using remotely the telescopes of the Arizona Radio Observatory in USA. The campaign was divided into two main parts.

2.1 Part I

We used the 12-m telescope on Kitt Peak everyday between UT 2007 Oct. 25.5 and 31.5. The highest spectral resolution was 24.4 kHz. We detected HCN, CS, CH_3OH, H_2CO, and H_2S. We also obtained two sensitive upper limits on CO.

2.2 Part II

On UT 2007 Nov. 28, Dec. 5, Dec. 28, and UT 2008 Mar. 13–16, we monitored the HCN $J(3–2)$ transition using the Submillimeter Telescope on Mt. Graham. Because the target line was very faint, the highest useful resolution was equal to 1.0 MHz. These observations provided our last detection on UT 2007 Dec. 5.2.

3. Results

3.1 Part I

The early evolution of the outburst was traced through the $J(1–0)$ transition of HCN (Fig. 1) and the $J(3–2)$ transition of CS. We observed that the lines were initially fading rapidly, but on UT 2007 Oct. 28.4, the intensities temporarily stabilized, and the spectral profiles underwent a dramatic change. The measured relative intensities of the hyperfine components

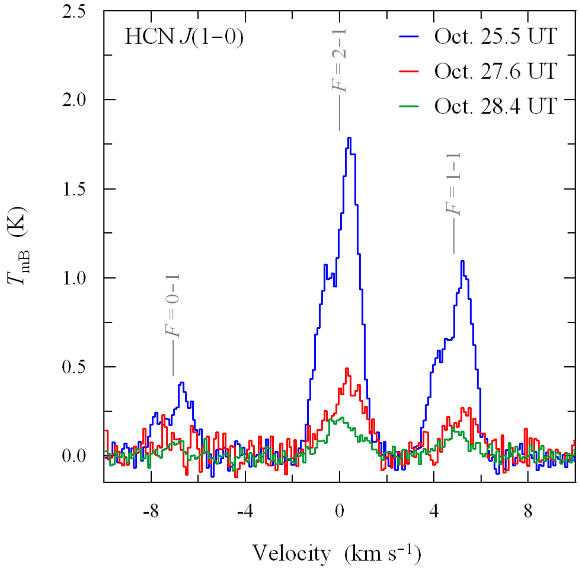

Figure 1: Evolution of the HCN J(1–0) hyperfine triplet at 88.6 GHz. The spectra from UT 2007 Oct. 30.4 and 31.5 look the same as on Oct. 28.4, thus they were omitted. The spectral resolution in this figure was reduced to 0.1 km s^{-1}.

of HCN J(1–0) are consistent with optically-thin emission, even at its brightest, which suggests that also the other (fainter) lines were optically thin. Using five lines of CH_3OH we determined the rotational temperature of 52.5 ± 6 K; however, we also measured slightly different widths of these lines, which indicates that the excitation conditions within the coma were in fact highly variable. The same conclusion arises from a comparison of the broad profile of H_2CO with the narrow one of H_2S, where both molecules have comparable lifetimes, and were observed with similar beam sizes. These results also suggest rapid acceleration of gas in the inner coma, though other explanations might be possible as well. Using our non-detections of CO, we concluded that the total content of this molecule, which might have hypothetically caused the explosion, could not have been greater than about 3×10^{32}.

3.2 Part II

The late monitoring shows that the comet was losing its excessive activity very quickly. On UT 2007 Dec. 5.2, the HCN brightness, measured through the J(3–2) transition, was below 3% of the brightness measured through J(1–0) on UT 2007 Oct. 31.5; this result accounts for the differences in intrinsic line intensity and observing geometry. Thus, HCN was not much brighter from what should be expected for a typical nucleus of that size at that heliocentric distance. If we also assume that at least a part of this late activity originated from the icy grains blown at the outburst, the scenario that the nucleus was behaving like nothing had happened in late October 2007 does not seem unrealistic.

4. Summary and Conclusions

By starting our campaign very quickly, only about two days after the onset of the outburst, we could characterize the molecular environment in the very early stages of this event. Our observations demonstrate the complexity of this environment, with several competing sources of activity. With the further follow-up observations we witnessed, however, the amazing speed at which the comet was losing this explosive activity. We avoid interpreting the observations in terms of the standard steady-state isotropic models, which are, in most aspects, irrelevant for such a complex and rapidly evolving gas environment.

Acknowledgements

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