EPSC Abstracts
Vol. 7 EPSC2012-492 2012
European Planetary Science Congress 2012

The C_2-hydrocarbon link in cometary comae

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Abstract

Comet 8P/Tuttle was the target of an ESO multi-wavelength observing campaign in 2008. Observations of the spatial distribution of C_2 and C_3 were obtained, as well as simultaneous direct detections of the C_2 parent species C_2H_2 and C_2H_6. We combine these observations to investigate the origin of cometary C_2. The observed C_2 column densities are inconsistent with a production of C_2 from C_2H_2, C_2H_6, and C_3. Based on a photochemical model, we quantitatively discuss the influence of further potential C_2 parent species. The assumption of C_4H_2 as an additional C_2 parent species in comet 8P/Tuttle provides the best explanation for the observed C_2 column densities.

1. Background

The relative abundance of the Haser model parent species of C_2 is a distinctive feature of two compositional classes of comets (A'Hearn et al. 1995). To date, the true parent species of cometary C_2 remains unknown. The progress in detecting potential C_2 parent species, such as ethane (C_2H_6) and acetylene (C_2H_2), by their infrared emissions, provides the opportunity to elucidate the mechanisms leading to the formation of C_2. Simultaneous observations of the spatial distribution of C_2 in the cometary coma, together with information on the production rates of C_2H_2 and C_2H_6, can be used to link the C_2 production with the production of parent species, and thus to interpret the C_2 abundances in comets in terms of hydrocarbon abundances.

2. Observations

Comet 8P/Tuttle was the target of an ESO multi-wavelength observing campaign in 2008 (Jehin et al. 2009). Low-resolution optical spectroscopy was employed to obtain radial column density profiles of C_2 and C_3. High-dispersion near-IR observations were performed simultaneously to detect organic parent species. Among others, both C_2H_6 and C_2H_2 were detected (Kobayashi et al. 2010). We use the spatial distribution of C_2 and C_3, together with the production of C_2H_2 and C_2H_6, as constraints for a multi-step photochemical model, employed to investigate the formation of C_2.

3. Modeling

A spherically symmetric multi-step model of the photochemistry in the cometary coma is used to compute radial column density profiles for the observed species C_2 and C_3 in comet 8P/Tuttle. Reaction rate coefficients and production rates of parent species in the model were optimized to reproduce the observations. For this purpose, use of Markov-Chain Monte-Carlo procedures was made. The optimization was performed under the additional constraint of the model parameters being as close as possible to the known rate coefficients and observed parent species production rates.

4. Summary and Conclusions

With C_2H_2, C_2H_6, and C_3 as the sources of C_2 in comet 8P/Tuttle, no reproduction of the observed C_2 column densities, being in agreement with the available observational and theoretical constraints, is possible. The observed amount of C_2 is too large to originate solely from these three sources. Among the additional potential sources of C_2 analyzed in this work, such as cyanoacetylene (HC_3N), propynal (C_3H_2O), and diacetylene (C_4H_2), only diacetylene allows for a reproduction of the observed column densities while being in agreement with the available observational and theoretical constraints.

Acknowledgements

This work was supported by the MICINN (Spanish Ministry of Science and Innovation) FEDER through grant AYA2009-14648- C02-01 and CONSOLIDER CSD2007-00050.

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