Using an integral-field unit spectrograph to study radical species in cometary coma

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Abstract

We have observed several comets using an integral-field unit spectrograph (the George and Cynthia Mitchell Spectrograph) on the 2.7m Harlan J. Smith telescope at McDonald Observatory. Full-coma spectroscopic images were obtained for various radical species (C_2, C_3, CH, CN, NH_2). Various coma enhancements were used to identify and characterize coma morphological features. The azimuthal average profiles and the Haser model were used to determine production rates and possible parent molecules. Here, we present the work completed to date, and we compare our results to other comet taxonomic surveys.

Observations

The data were obtained using an integral-field unit (IFU) spectrograph to conduct full-coma spectroscopic imaging. This instrument, the George and Cynthia Mitchell Spectrograph (née VIRUS-P)(Hill et al. 2008), is a high-efficiency, low- to moderate- resolution fiber-optic spectrograph designed for use on the 2.7 m Harlan J. Smith Telescope. As shown in Figure 1, the 1.7 arcmin x 1.7 arcmin array contains 246-247 optical fibers, each with a diameter of 4.1 arcsec. The observations were obtained with a grating covering the passband from 3600-5800Å with a resolving power of 850.

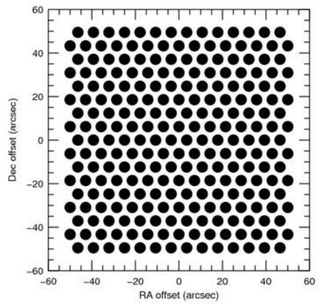

Fig. 1: The spatial distribution of fibers for the IFU spectrometer consisting of 246 fibers.

Comet	Obs. Date	R (AU)	Delta (AU)	Pre/Post Perihelion
4P/Faye	2006 Nov. 22	1.67	0.74	Post
10P/Tempel 2	2010 July 15	1.43	0.72	Post
	2010 Sept 13	1.60	0.67	Post

Drawing Out Coma Morphological Features

In general, the coma enhancement techniques used in this study will enhance features in the outer coma. Both the azimuthal and radial divisions require designating a single pixel in the image as the optocenter where the comet nucleus is positioned. For all enhancements, an azimuthal average profile is constructed. The azimuthal average profile consists of a set of points where each point is averaged with respect to position angle. Because of the hexagonal symmetry of the fiber optic array there are concentric rings of pixels that are equal distance from the optocenter. Each ring is used to compute one azimuthal average point.

Azimuthal divisions were performed by dividing each pixels' column density by its respective azimuthal average value.

Radial divisions were performed by doing a linear fit to the azimuthal average profile. Each pixels' column density is divided by the fitted function values.

The normalized azimuthal divisions uses the fitted function to account for the imprecise positioning of the optocenter which results from placing it at a particular pixel.

Coma Enhancements

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Comet Faye

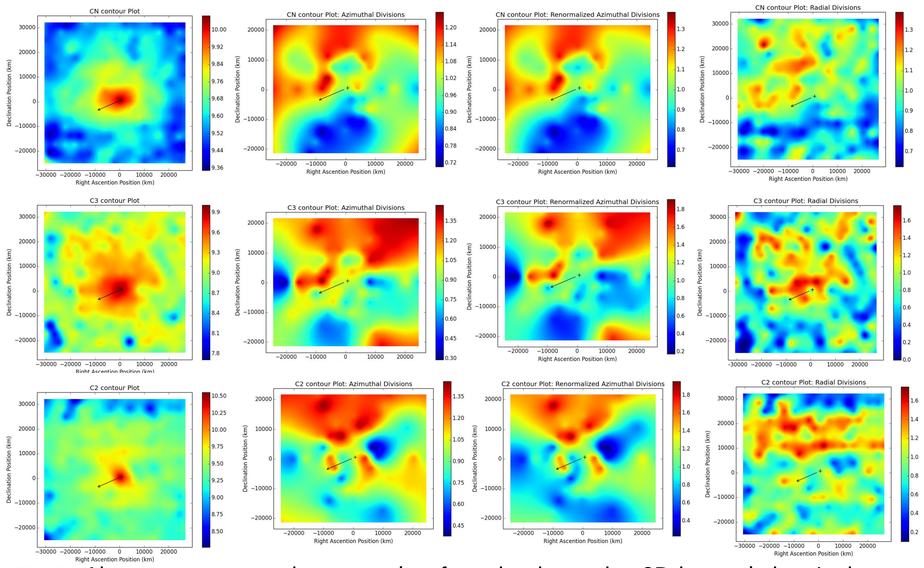


Fig. 2: Above are generated contour plots from the data using 2D-interpolation. In the first column are plots of the raw data, the second is the azimuthal divisions, the third is the normalized azimuthal divisions, and the fourth is the radial divisions. The first row is the CN data, the second is C_3, and the third is C_2.

Comet Tempel 2

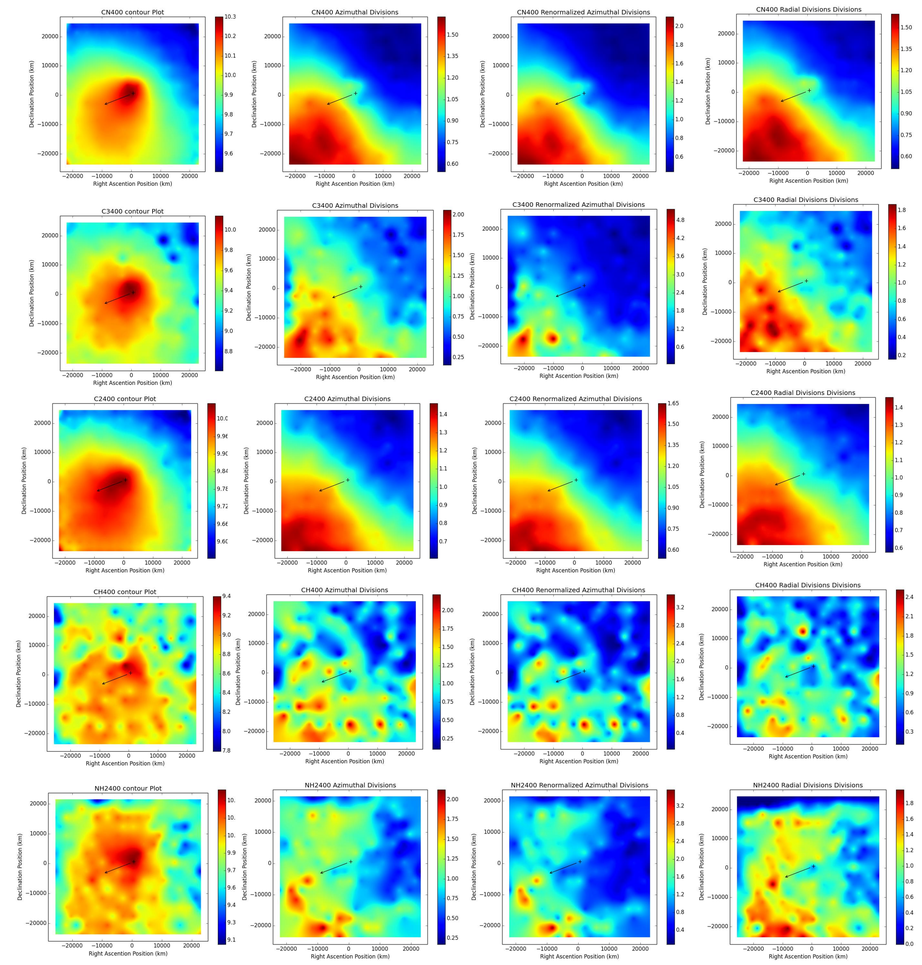
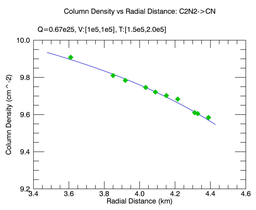


Fig. 3: Above are generated contour plots from the data using 2D-interpolation. In the first column are plots of the raw data, the second is the azimuthal divisions, the third is the normalized azimuthal divisions, and the fourth is the radial divisions. The first row is the CN data, the second is C_3, and the third is C_2, the fourth is CH, and the fifth is NH_2.

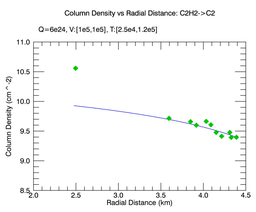
Haser Model Analysis

Notation for the parameters in the Haser Model figures are: Q=production rate, V:[parent velocity, daughter velocity], T:[parent lifetime, daughter lifetime].

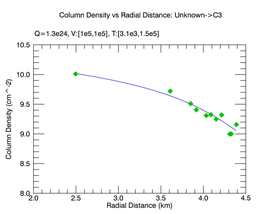
Comet Faye



For CN, the following parent lifetimes were tested; HCN, HC_3N, C_2N_2, CH_3CN. The parent **C_2N_2 provided the best fit of the model to the data** with a production rate of 0.67×10^{25} s^{-1}.

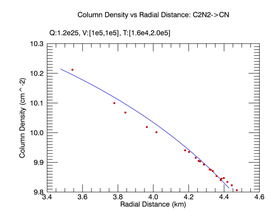


For C_2, the lifetime used was derived from a hypothetical parent scale length proposed by Cochran et al. 2012. As reported for other comets, traditional Haser modeling of C_2 yields a poor fit to the inner coma spatial profile. The production rate obtained was 6×10^{24} s^{-1}.

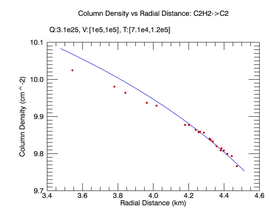


For C_3, the lifetime used was derived from a hypothetical parent scale length proposed by Cochran et al. 2012. This lifetime gave use the best fit with a production rate of 1.3×10^{24} s^{-1}.

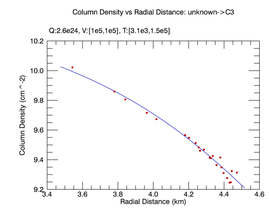
Comet Tempel 2



For CN, the following parent lifetimes were tested; HCN, HC_3N, C_2N_2, CH_3CN. The parent **C_2N_2 provided the best model to the data** with a production rate of 1.2×10^{25} s^{-1}.



For C_2, the hypothetical scale length reported in Cochran et al 2012 did not yield a good fit. The lifetime reported in Crovisier 1994 provided a good fit to the outer coma as seen in the figure to the left. The production rate obtained was 3.1×10^{25} s^{-1}.



For C_3, the lifetime used was derived from a hypothetical parent scale length proposed by Cochran et al. 2012. This lifetime provided the best fit with a production rate of 2.6×10^{24} s^{-1}.

References:

Hill, G. J., et al. 2008, Proc. SPIE, 7014, 257

Cochran, A. L., et al. 2012, Icarus, 218, 144-168

Crovisier 1994, J. Geophys. Res., 99 E2, 3777-3781

This work was funded by the National Science Foundation Graduate K-12 STEM Fellows program (Award No. DGE-0947419) and NASA's Planetary Atmospheres program (Award No. NNX14AH18G). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of NASA or the National Science Foundation. This presentation includes data taken at the McDonald Observatory of the University of Texas at Austin. We acknowledge ephemeris data from the JPL Horizons System.