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Mapping the Comae of Comets with an Integral Field Spectrograph at McDonald Observatory

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Abstract

The morphology of the comae of comets is determined by many factors including the shape of the nucleus, the rotation, the presence of active regions and jets and obliquity. Maps of the morphology allow us to study these underlying processes but only to the extent that we can determine departures from spherical symmetry. Photometric observations must assume symmetry. Long slit CCD spectrographic observations can probe asymmetry but only if the slit is set at different position angles and the coma is mapped sufficiently quickly that the morphology does not change. Imaging through filters allows for full mapping but is limited by the bandpass of the filters and cannot map well the weak features. We present in this paper data from a new instrument, an integral field spectrograph with a moderately large field-of-view, that allows for full mapping similar to imaging but with spectral resolution similar to long slit CCD spectrographs.

1. Introduction

The nuclei of comets are quite small and are obscured for viewing from the ground by the sublimation of the ice to form the coma. Thus, we can only obtain information about the nuclei by observing the comae and trying to interpret the morphological features observed. Processes such as rotation, shape, obliquity and active regions all contribute to the observed morphology. By studying the morphology in the emissions from various molecular features and in dust, we can attempt to understand the underlying processes. We have used a new instrument at McDonald Observatory to obtained spatially resolved spectra of cometary comae which we present here. While spherically symmetric models (e.g. Haser or vectorial models) have been sufficient for past data sets with limited spatial information, these new data require more sophisticated treatment, such as the modified vectorial model of Ihalawela *et al.* [1].

2. Observations

The observations were obtained with VIRUS-P (Visible IFU Replicable Unit Spectrograph - Prototype; Hill et al. [2]) on the 2.7m Harlan J. Smith telescope at McDonald Observatory. VIRUS-P has 246 optical fibers, each 4.1 arcsec in diameter. The array covers 1.7×1.7 arcmin on a side with a 1/3 fill factor. There are four available volume phase holographic gratings available. The comet observations were generally obtained with a grating which covered the bandpass from 3600 – 5800Å with a resolving power of 850. During 14 – 16 September 2010 we used a grating with resolving power 4500 centered on CN. This allowed for study of the Greenstein effect. Table 1 is log of the observations which have already been obtained with VIRUS-P (we anticipate obtaining observations of C/2009 P1 (Garradd) and C/2010 X1 (Elenin) during the second half of 2011).

Sky flats were obtained each night at dawn or dusk and arc lamps were observed for wavelength calibration. Standard stars and solar analogue stars were observed with a 6 position dither pattern to ensure that all of the flux from the stars was recovered. Each comet fiber was reduced separately. The relative fiber positions are well known so we were able to assign position relative to the optocenter to each fiber. Column densities were computed for the molecules of interest.

Figure 1 shows the derived column densities for CN in the coma of comet 4P/Faye. This should be contrasted with Figure 2 which shows the derived column densities for CH. The CH is much more highly confined to the center of the coma than is the CN. There is a distinctive asymmetry seen in the CN data in the lower left quadrant.

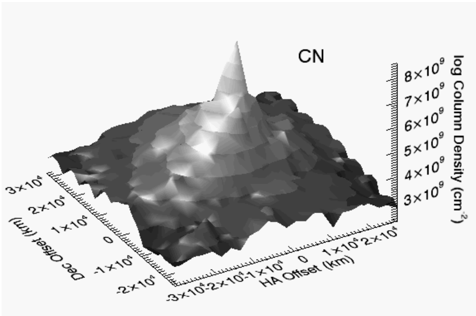

Figure 1: The derived CN column densities for 4P/Faye are shown as a function of position within the coma.

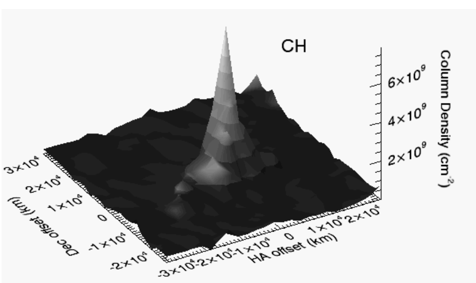

Figure 2: The derived CH column densities for 4P/Faye are shown as a function of position within the coma.

Table 1: Log of Observations

Comet	Date (UT)	R_h (AU)	Δ (AU)
4P/Faye	22 Nov 2006	1.67	0.74
67P/Churyumov-	05 Nov 2008	1.82	1.57
Gerasimenko	07 Nov 2008	1.81	1.57
103P/Hartley 2	15 Jul 2010	1.72	0.92
	13 Sep 2010	1.23	0.30
	14 Sep 2010	1.22	0.29
	15 Sep 2010	1.21	0.29
	16 Sep 2010	1.21	0.28
	14 Oct 2010	1.08	0.13
	15 Oct 2010	1.07	0.13
	09 Nov 2010	1.07	0.18
	10 Nov 2010	1.07	0.18
10P/Tempel 2	15 Jul 2010	1.43	0.72
	13 Sep 2010	1.60	0.67
	14 Sep 2010	1.60	0.67
81P/Wild 2	16 Jul 2010	2.10	1.54

3. Summary

VIRUS-P is a powerful new instrument for observing the morphology of the coma. In this poster, I will show numerous examples of how the comae change with time.

Acknowledgements

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References

[1] Ihalawela, C. A., Pierce, D. M., Dorman, G. R. and Cochran, A. L.: The Spatial Distribution of OH and CN Radicals in the Coma of Comet Encke, ApJ *in press*, 2011.

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