COMPOSITION OF A COMET NUCLEUS: PREPARING FOR ROSETTA OBSERVATIONS. T. B. McCord[1], J.-Ph. Combe[1], C. Taffin[1]. [1]Bear Fight Institute, 22 Fiddlers Rd., Winthrop WA 98862 USA. tmccord@bearfightinstitute.com

Introduction: The Rosetta spacecraft is on its way to comet 67P/Churyumov-Gerasimenko (C-G). It will rendezvous with C-G in 2014, and accompany it for at least one full comet orbit about the sun, including making the first controlled landing on the comet [1]. The nucleus composition and structure is a major topic of investigation. We have conducted a study of the state of knowledge of comet nucleus composition in preparation for planning and interpretating Rosetta observations. Here we summarize our findings.

Background: Studies of the composition of comet nuclei mostly have been made using Earth-based telescopes [2-8], until several recent spacecraft flybys. These have been hindered by coma obscuration, mostly scattering of sunlight by dust particles coming off the nucleus. This requires Earth-based observations of the nucleus to be made when the comet is far from the sun and is less active, which means that the comet is much fainter and more difficult to observe. Thus, much of the nucleus composition knowledge is inferred from comet and tail observations of ionized daughter products of nucleus molecules. One particularly helpful spacecraft flybys of a comet nucleus was Deep Impact at 9P/Tempel 1, which carried a spectrometer [9].

Summary of knowledge: Table 1 summarizes observational findings from direct observations of a comet nucleus. Figure 1 shows examples of reflectance spectra from before Deep Impact. These reflectances suggest dark, red components, spectrally featureless, except for unidentified 2.39-µm absorption. Figure 2 shows the Deep Impact reflectance spectra, showing evidence of water ice. The richest spectra resulted from the NIRSPEC/Keck telescope observations (Figure 3) [10], resulting in a number of organic molecule identifications (Tables 1 and 2). Coma observations resulted in numerous molecule identifications (Table 3), most of which are products resulting from alteration of parent molecules from the nucleus. The relatively few molecules identified on a nucleus could be identified by the Rosetta VIRTIS (Visual and IR and Thermal Imaging Spectrometer) [11].

Table 1: Molecules found from direct nucleus observation

Direct nucleus observations	Name	Molecules found	Instrument/Telescope or Missions	Articles
Short-Period Jupiter Family	124P/Mrkos 28P/Neujmin 1 19P/Borrelly 90P/Gehrels	No identification	NICS/TNG NICS/TNG MICS/Deep Space VLT	Licandro *et al.* (2002) Licandro *et al.* (2003) Nelson et al. (2004) Delahodde et al. (2002)
	9P/Tempel 1	Water ice !	HRI-IR/Deep Impact	Sunshine et al. (2006a, 2006b)
Short-Period Halley Family	C/LONEOS OG108	No identification	NASA Infrared Telescope Facility	Abell *et al.* (2003, 2005)
Long-Period Oort-Cloud	C/2001 A2 (LINEAR)	C_2H_6, C_2H_2, HCN, CH_4, CO, CH_3OH, H_2CO	NIRSPEC/W.M. Keck Observatory	Gibb et al., (2007)

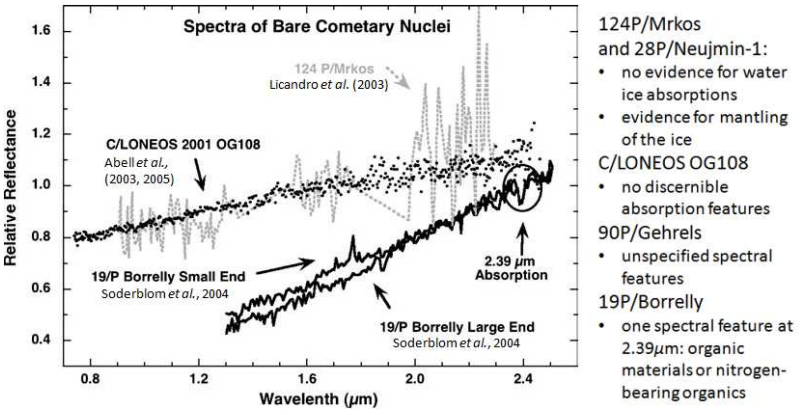

Figure 1: Examples of telescopic-based reflectance spectra from direct comet nucleus observations (adapted from Sunshine et al., 2006 [9]).

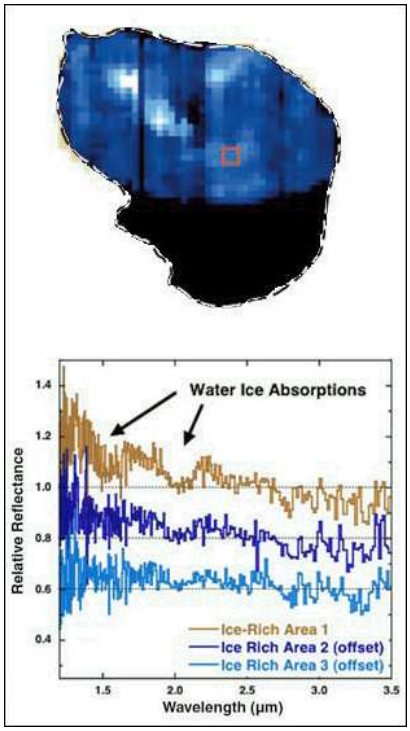

Figure 2: Spectra of ice-rich areas of the nucleus of comet Tempel 1 (adapted from Sunshine et al., 2006 [9]).

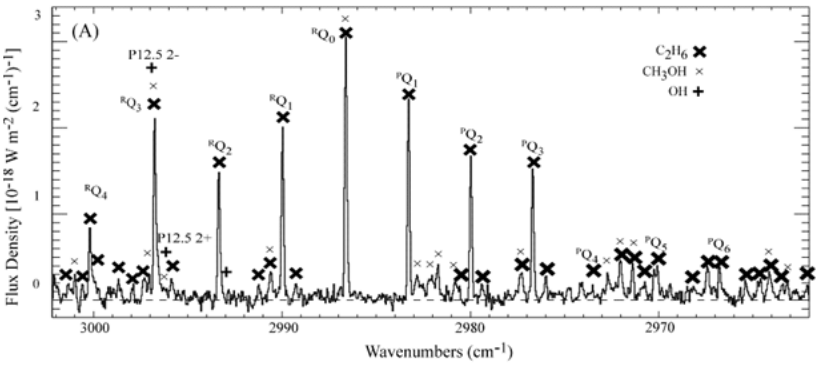

Figure 3: Selected spectral extracted from C/2001 A2 (LINEAR) acquired with NIRSPEC on the Keck 2 telescope, (Magee-Sauer et al., 2008)

Table 2: Molecules observed on comet nuclei

H_2O	Water	Several Observations	e.g. Sunshine et al. (2006a, 2006b)
CO	Carbon Monoxide	ONE observation on fresh material of **Comet C/2001 A2 (LINEAR)**.	
CH_3OH	Methanol		
H_2CO	Formaldehyde	Stable ices in the comet (at least, on one long period Oort-cloud comet)	Gibb et al., (2007) Magee-Sauer et al., (2008)
CH_4	Methane		
C_2H_6	Ethane		
C_2H_2	Ethyne (Acetylene)	=> We have **to be prepared** for this possibility on Churyumov-Gerasimenko	
HCN	Hydrogen cyanure		

Table 3: Molecules observed on comet coma.

Water	H_2O, $(H_2O)_2$, H_2O_2, HDO
Carbon	CO_2, CO, CS, OCS, H_2CS
Sulfur	SO_2, SO, H_2S, HDS, CH_3SH
Hydrocarbons	CH_4, CH_3D, CH_3OH, CH_3OD, CH_2DOH, H_2CO, HDCO, HCOOH C_2H_6, C_2H_4O, CH_3CCH, $HCOOCH_3$, CH_3COOH, CH_3OCH_3, CH_3CHO, C_2H_2, CH_2CO, CH_2OHCHO, C_2H_5OHtrans
Nitrogen bearing organics	HCN, HNC, DCN, HC_3N, HC_5N, CH_2CN, C_2H_5CN NH_2D, NH_2CHO, CH_2NH, NH_2CH_2COOH, NH_2CN, NH_2OH N_2O, HNO, HCNO, HNCO
Phosphorous	PH_3, HCP
Radicals	NS, SiC, SiO, HCO, C_2H
Ions	$HOCO^+$, H_2COH^+, $HCNH^+$, N_2H^+, H_3O^+

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References:

[1] Schulz R. et al., 2004, Astronomy & Astrophysics, 422.

[2] Licandro J. et al., 2002, Earth, Moon, and Planets, 90.

[3] Licandro J. et al., 2003, Astronomy & Astrophysics, 398.

[4] Delahodde C. E. et al., 2001, Astronomy & Astrophysics, 376

[5] Abell P, 2003, PhD thesis

[6] Abell P. et al., 2005, Icarus 179

[7] Gibb et al., 2007, Icarus 188

[8] Soderblom L. et al., 2004, Icarus 167

[9] Sunshine J. et al., 2006, Science 311

[10] Magee-Sauer K. et al., 2008, Icarus 194

[11] Coradini et al., 2011, Science 334.