THE VOLATILE FRACTION OF COMETS AS QUANTIFIED AT INFRARED WAVELENGTHS – AN EMERGING TAXONOMY AND IMPLICATIONS FOR NATAL HERITAGE.

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Introduction: It is relatively easy to identify the reservoir from which a given comet was ejected. But dynamical models demonstrate that the main cometary reservoirs (Kuiper Belt, Oort Cloud) each contain icy bodies that formed in a range of environments in the protoplanetary disk, and the Oort Cloud may even contain bodies that formed in disks of sibling stars in the Sun's birth cluster.

The cometary nucleus contains clues to the formative region(s) of its individual components. The composition of ices and rocky grains reflect a range of processes experienced by material while on the journey from the natal interstellar cloud core to the cometary nucleus. For that reason, emphasis is placed on classifying comets according to their native ices and dust (rather than orbital dynamics). Mumma & Charnley [1] reviewed the current status of taxonomies for comets and relation to their natal heritage.

Surveys based on Product Species: Photometric and spectroscopic surveys of released gas and dust in more than 100 comets have enabled taxonomic groupings based on free radical species [2], [3], [4], [5]. These surveys demonstrate that distinct groupings do exist among comets, and generally agree on the classification of an individual comet. However, the precursors of a given product species are often unknown, or multiple, complicating the interpretation of survey results in terms of natal heritage.

Surveys based on Primary Volatiles: In recent years, compositional surveys based on primary volatiles (native to the cometary nucleus) have emerged. More than 20 primary species are now detected in moderately bright comets. At infrared wavelengths (3-5 μm), trace volatiles (primary and product) are sampled simultaneously with H_2O (the dominant primary volatile) or its direct proxy (OH prompt emission, denoted OH*), eliminating the systematic uncertainties that can occur when these species are sampled individually, and separately in space or in time.

Symmetric species (CO_2, CH_4, C_2H_2, C_2H_6, etc.) are uniquely sensed through their vibrational emissions (infrared). Their excited electronic states (UV, optical) are usually pre-dissociated, and (lacking a permanent dipole moment) they are not active in pure rotational transitions (radio, sub-mm). Using ground-based cross-dispersed infrared echelle spectrometers, ten or more primary volatiles are detected simultaneously, including H_2O, CO, H_2CO, CH_3OH, CH_4, C_2H_2, C_2H_6, HCN, NH_3, and OCS. Product volatiles (NH_2, OH*, & CN) are also detected. CO_2 is detected at IR wavelengths, but only from space. DiSanti and Mumma [6] reported survey results for 13 comets, while Dello Russo et al. [7] reported results for five JFCs. Ootsubo et al. [8] reported results for 17 comets surveyed with *Akari*. Twenty-six comets have been characterized at this writing, and we will present highlights of their comparison (see [1] for cited papers).

Nuclear spin species and Isotopologues The compositional surveys are supplemented with measurements of nuclear spin temperatures (of H_2O, NH_3, CH_4) and of isotopic ratios (e.g., HDO/H_2O, $HC^{14}N/HC^{15}N$, and $C^{14}N/C^{15}N$). Together they provide critical insights on factors affecting formation of the primary species (see [1] for cited papers).

Synopsis: The 26 comets in the IR database fall into three general groups: organics enriched, organics normal, and organics depleted. However, a freshly characterized comet often reveals some novel aspect, or changes the statistics of the sample. This demonstrates that many more comets must be quantified before the groupings will approach statistical completeness. Examples of these new insights and effects will be shown and discussed, along with overall profiles of the emerging groups.

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