CHON-Na AND EVIDENCE FOR LARGE SCALE COMPOSITIONAL HETEROGENEITY IN THE COMETARY NUCLEUS.

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Introduction: The compositional nature of cometary nuclei is still highly uncertain, due to a lack of availability of pristine cometary material. It is now well established, however, that the refractory dust components span a broad compositional range, including minerals which formed at different solar distances and some even from possible aqueous processes [1]. Samples returned by Stardust from comet Wild 2 are, unfortunately, deficient in carbonaceous material because of destruction during the hypervelocity impact into the aerogel and Al foil collectors. In this study, we revisit the data obtained by the Particle Impact Analyzer (PIA) on the Giotto mission to comet Halley, taking into account the newer results from the Stardust and Rosetta missions.

CHON Particulates: We have previously identified the organic-rich particulate population among the more populous "mixed" grains in the coma of comet Halley. Within the general nomenclature of "CHON," we have identified sub-groups with contain only the oxygen or nitrogen atoms [2]. Similar analyses have been conducted by Fomenkova et al. [3] on the PUMA instruments results. We note here in the mass spectrometer readings of the PIA instrument, the detection of CHON particles which also show evidence of a significant component in the range of 23-24 atomic mass units (AMU). A few examples are shown in Figure 1, as plots of peak intensity versus AMU.

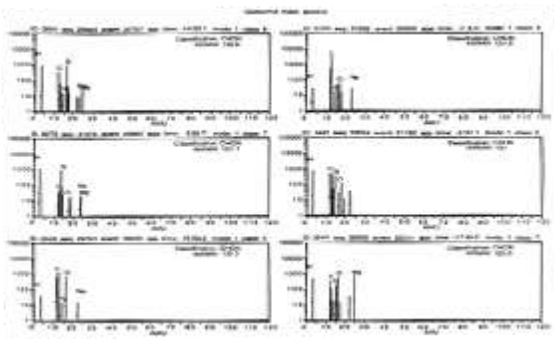

Figure 1. CHON particles with mass 23-24 line.

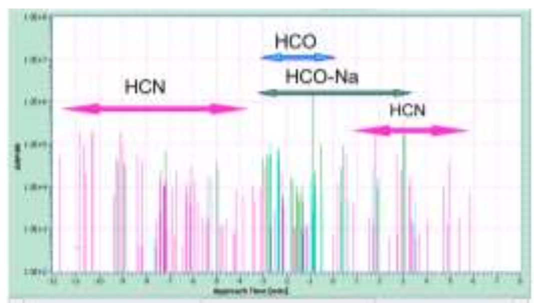

Figure 2. Heterogeneity in chemical types

The large majority of PIA mass spectra were highly compressed by an algorithm which detected peaks. This allowed far more spectra to be analyzed, but resulted in less accurate mass determination. For this reason, the peaks of the unknown constituent occur across the range of 22-26 AMU, which encompasses both Na (23) and Mg (24-26 AMU). Because Mg is much more cosmochemically common than Na, it was thought that this peak was most likely an association of Mg with CHON material, perhaps even in the form of a Mg-carbonate [4].

However, the COSIMA instrument at comet 67P/C-G found higher Na and lower abundance of Mg than in carbonaceous chondrites, plus a strong correlation of Na with C in these particles [5]. For this reason, we believe the mystery peak in Halley particulates is revealing an association of Na with organic material. We have also found that CHON's which contain N but are deficient in O do not exhibit this peak. The hierarchy seems to be (HCN)-rich particles which associate with (HCO) and (HCO-Na) particles to produce CHON-Na particles. Similarly, the PIA data imply that (FeS) particles combine with silicate particles (SiMgFeCa), and that these are more often than not also organic-rich, prosumably by containing CHON materials of various classifications.

Chemical Heterogeneity: Most importantly, the PIA and PUMA data indicate variations in coma composition during the flythrough's [2, 3]. Figure 2, above, plots the occurrence of the (HCN) and (HCO) classes as a function of the encounter time, and hence location, within the coma of comet Halley. This is but one example of the chemical heterogeneity that is apparent. Heterogeneities in organics versus silicates are also observed, for example.

Conclusions: Organic-dominated particules, and by inference the organics in "mixed" particles, have multiple components, variously including N, O, and Na atoms (unlike carbonaceous asteroids). The compositional heterogeneity on broad scales in the cometary coma must indicate chemical heterogeneity on the cometary surface, possibly reflecting accretion of cometesimals of various fractal sizes which sample different regions of the protosolar nebula.

References: [1] Brownlee, D. (2014) *Annu. Rev. Earth Planet. Sci.*. 42:179–205. [2] Clark, B.C. et al. (1987) *Astron. Astrophys.* 187: 779-794. [3] Fomenkova, M. N. et al. (1994) *Geochim. Cosmochem. Acta* 58: 4503-4512. [4] Fomenkova et al. (1992) Science 258: 266-2269. [5] Stenzel, O.J., et al., (2018) LPSC Abs. 2410.