THE D/H AND $^{18}O/^{16}O$ ISOTOPIC RATIOS IN COMET HALLEY.

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On March 14, 1986, the Giotto spacecraft of the European Space Agency flew past comet Halley at a distance of 605 km. The neutral gas mass spectrometer (NMS) [1] measured both the gas and ion composition in the coma from 900'000 km to within 1000 km from the nucleus.

Water is the dominant volatile constituent. Its production rate was $5.5 \cdot 10^{29}$ molecules/s [2]. The relative abundance of CO with respect to water was within 5 to 15% [3]. A substantial fraction of the CO was not released from the nucleus but was released from dust grains at distances of up to 15'000 km. The relative abundance of N_2 and CO_2 were < 10% and ≦ 3.5% respectively.

The light elements hydrogen, carbon, oxygen, etc. show substantial isotopic variations in meteorites, planetary atmospheres, interstellar matter and stars. A determination of their isotopic composition in cometary matter is thus of particular cosmochemical interest. The in situ mass spectrometric measurement is however difficult, as the low abundance isotopes (D, ^{13}C, ^{18}O, etc.) are always heavier than the major isotopes and can be masked by hydrides (H_2, ^{12}CH, $H_2{}^{16}O$, etc.). Only for the ion H_3O^+ is the interference for the isotopic H_2DO^+ (mass 20^+) and $H_3{}^{18}O^+$ (mass 21^+) limited to a few species, cf. [4]. The mass resolution and dynamic range of the NMS was sufficiently high to allow a measurement of these two low abundance mass peaks (cf. Fig. 1). The preliminary evaluation of the data obtained within the contact surface gave for the D/H ratio in water from comet Halley

$$0.6 \cdot 10^{-4} \leq D/H \leq 4.8 \cdot 10^{-4}$$

and for the ^{18}O abundance

$$^{18}O/^{16}O = 0.0023 \pm 0.0006.$$

The $^{18}O/^{16}O$ agrees within the error limits with the average solar system value of 0.00205. The uncertainty in the cometary D/H is still substantial, partially because no assumption on the mixing ratio of H_2O^+/NH_4^+ on mass 18^+ was made (for more details cf. [4]) and partially because of the preliminary nature of the data evaluation. Our upper limit for the D abundance is essentially in agreement with the upper limit obtained by IUE observations [5].

Figure 2 gives an overview over the deuterium abundance in different solar system and galactic reservoirs. The very high D enrichments observed in molecules from interstellar clouds are due to fractionation in ion-molecule reactions [6]. Deuterium should thus be enriched in icy interstellar grains or in the proposed volatile-rich mantles of the grains [7]. Ion-molecule or low temperature chemical reactions in the protosolar nebula might be an additional source for D enrichment (cf. [8]). Solar system hydrogen which was in isotopic equilibrium with interstellar volatile molecules should thus be enriched in D compared with hydrogen derived from H_2.

From Fig. 2 some conclusions are quite evident:

- The water ice of Halley is enriched by at least a factor of 3 in deuterium compared with protosolar H_2 and with hydrogen accreted in gaseous form from protosolar H_2 (i.e. Jupiter and Saturn).
- The D/H in Halley water ice is compatible with the ratio observed for other solar system hydrogen that was accreted as part of volatile molecules, e.g. as H_2O-, CH_4-ices (i.e. Titan, Earth, Meteorites).

- Comet Halley, Titan, the Meteorites and the Earth could have acquired their hydrogen from the same region of the protosolar nebula, i.e. they could have formed in the same heliocentric distance range.
- The D/H in Halley water ice is in agreement with models proposing that the earth and other terrestrial planets acquired their volatiles from a veneer of volatile rich materials of e.g. cometary origin [9].
- A cometary origin of carbonaceous meteorites and of interplanetary dust particles is not excluded by the measured D/H ratio.

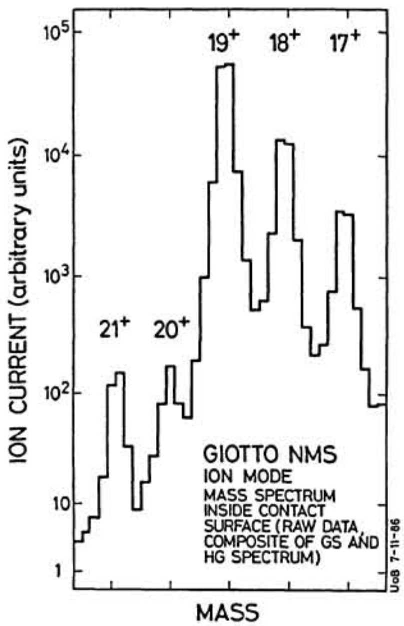

Fig. 1: Ion mass spectrum obtained with the M-Analyzer of the NMS inside the contact surface. The figure shows raw data.

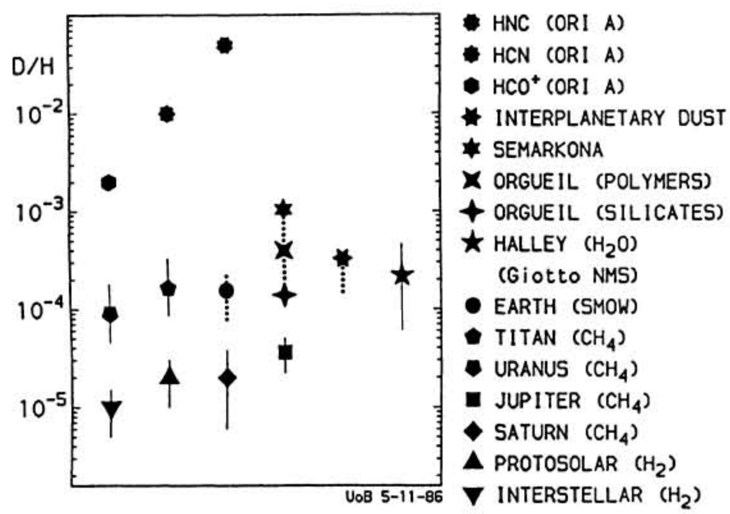

Fig. 2: Deuterium abundances in different solar system and galactic reservoirs. The dotted lines give the range of D/H ratios observed on the earth, in meteorites and in interplanetary dust particles. For source of data cf. [4].

Acknowledgement: This research was supported by the Swiss National Science Foundation (grants 2.034-0.81 - 2.825.85); the German Bundesminister für Forschung und Technologie (grants 010F0519, 010F0628 and 010F85120); CNES (grants 81, 82/244 - 83/211 - 84, 85/1211); and NASA headquarters (contract NASW-3576).

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