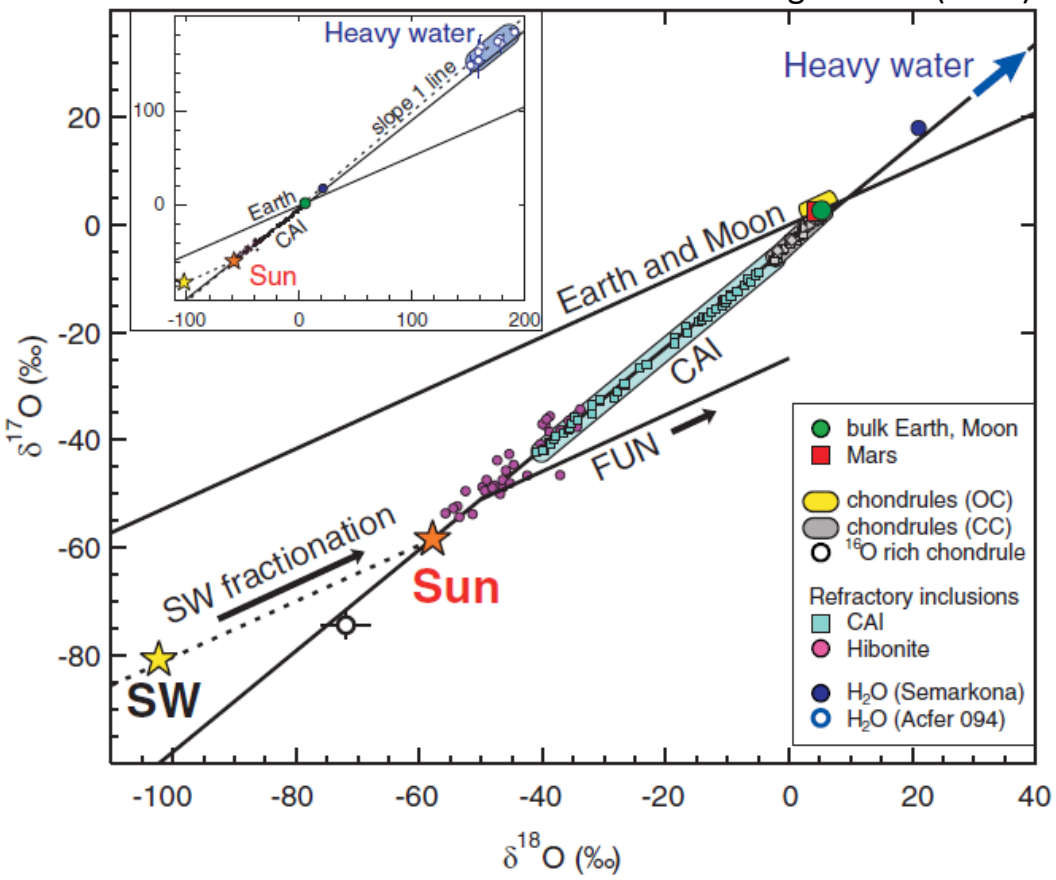
1. What are the isotopic compositions for key elements in comets, specifically D/H, $^{15}N/^{14}N$, and $^{18}O/^{17}O/^{16}O$ in various species? In particular, what are the oxygen isotopic compositions of comet dust and ice? Is the dust ^{16}O-rich like the Sun? Is the H_2O ^{16}O-poor as predicted by self-shielding models?

McKeegan et al. (2011)



2. Interstellar amorphous silicates were a major building block of our Solar System.

- What is the abundance, nature, and origin of amorphous silicates in comets and primitive asteroids?
- Are these amorphous silicates circumstellar grains, interstellar dust grains, or nebular condensates?
- Are there comets that are truly pristine aggregates of interstellar materials?
- What is the oxidation state of Fe in comets and primitive asteroids? When and where do Fe-sulfides form (lifecycle of S)?

For amorphous silicate grains, which in situ techniques allow you to discriminate between a high temperature melt (glass), crystalline material amorphized by ionizing irradiation or shock, non-equilibrium condensates, and silicate gels? All with sub-micrometer grain sizes…

3. When, where and how did the crystalline silicates in comets form?

- How were the crystalline silicates mixed in the protoplanetary disk (bipolar outflows? turbulent mixing? etc.)?

- How does the proportion of crystalline to amorphous silicate material vary with heliocentric distance? Direct condensation of crystalline silicates vs. annealing?

- Amorphous silicates are known to be highly reactive - are hydrated minerals present in comets?

4. What is the diversity and complexity of organic materials in comets and primitive asteroids?

- Which organic materials are primordial, which have been altered by parent body processes (aqueous alteration, thermal metamorphism), and which have been modified by interactions with the space environment (space weathering)?

Important in situ measurements:

1. The oxygen isotopic composition of cometary water (JFC).

2. Analyses of organic material as a function of depth (esp. for an asteroid regolith).

3. Fe oxidation state and mineralogy in primitive materials.

How do you make these measurements in microgravity in a dusty regolith?