Some stories told from cometary dust and IDP compositions

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This talk attempts to place extraterrestrial dust particles into their proper planetological and astrophysical proportion by illustrating examples of dust reseach.

First a short overview into the history of the "world" from the Big Bang until now is given with examples of galaxies and their dust rich star forming regions. Then it is shown how the building block of the "world", nuclei, are formed in solar type and heavier stars by high temperature nuclear fusion processes. As a special example the calculated silicon isotopic composition in the core of a 25 solar mass supernova is presented, which is characterized by a mono-isotopic overabundance of ^{28}Si of at least a factor of two. This leads to the introduction pre-solar dust particles that are identified by correlated non-solar isotopic composition of many elements. As an example the results of a TOF-SIMS analysis of a pre-solar 1.7 µm-sized SiC-type X grain extracted from the Murchison meteorite are presented. The isotopic composition of Mg – only ^{26}Mg from extinct ^{26}Al ($T_{1/2}$=720.000 y) which was incorporated into the grain with ^{26}Al/^{27}Al=0.5 – shows that the grain was formed shortly after nuclear synthetic ^{26}Al-production, which, as is clear from the factor two ^{28}Si-enrichment, occurred in a 25-solar-mass-supernova. Since the ^{28}Si overabundance is synthesized near its core and the ^{26}Al overabundance in the outer half (mass-wise) of the supernova, our result implies that during and after the SN explosion its material (ions) were not well mixed but that the inner material moved as "clumps" to the outside to condense later together with more outside-material. This interpretation is supported by the N isotopic composition (formation region same as Al) and also by astronomical evidence that Fe "clumps" stick together long after the Supernova explosion (Science 287; 203). Therefore, the study of dust particles that are supernova condensates extractable from certain meteorites allow to understand the condensation processes in supernova remnants.

This chapter is followed by the introduction of the solar system and the sizes and distances of its planets. To elucidate the history of the solar system an interlude on the science of meteorites follows because they provide input of outmost significance to our knowledge. This portion covers definitions, modern ways to collect meteorites and their significance, pre-terrestrial orbits ranging mostly into the asteroid belt, radiometric ages, classifications and their implications for parent body histories, the importance of Calcium-Aluminum-rich inclusions as the oldest solar system rocks, the onion-shell model of parent body thermal history, the oxygen isotope systematics of the solar system bodies that probably now (after the Genesis mission) indicate that CAIs were formed close to the sun and that allow to distinguish classes of meteorites by specific O isotopic compositions, and the significance of CI chondrites as representing the average chemical composition of the solar system. This portion of the talk ends with wrap-ups on lunar and

Martian meteorites and their significance followed by a short account of impact craters for dating Moon (mentioning the possible Terminal Lunar Cataclysm) and Mars.

Returning to the dust theme, Interplanetary Dust Particles (IDPs) are introduced and methods and results of their chemical analyses. The difficulties of analyzing these typically only 15 µm-sized particles are demonstrated as well the inferences of the lack of complete data sets. It is mentioned that we have shown experimentally that at least one element, Br, is prone to be largely affected by contamination in the stratosphere. A few results from the isotope analyses of dust particles collected while the Earth moved through the dust stream produced by comet Grigg-Skjellerup are presented focusing on O and Si.

The next topic is the *in-situ* chemical analysis of Halley's dust particles in 1986 in the Giotto and Vega-1/-2 missions by impact-ionization time-of-flight mass spectrometry. It is shown that Halley's dust is even more primitive that CI chondrites (= richer in volatiles), that the abundance of the CHON elements (indicating the abundance of refractory organic substances) correlates with lower density particles (compared to particles rich in rock forming elements) and that attempts to extract information on the mineralogy are difficult and resulted only on the notion that the particles are dominated by Fe-poor, Mg-rich silicates. The only element for which isotopic information could be obtained is carbon. Unequivocally, 16% of Halley's analyzed dust particles are dramatically enriched in ^{12}C (up to 50-fold!) indicating their circum-stellar origin.

20 years after the missions to comet Halley the next big step in cometary dust analysis was brought about by the STARDUST mission to comet Wild-2 that returned dust particles to Earth using aerogel as catcher medium. A few results of the many and diverse interdisciplinary studies are presented: The presence of CAIS (absent among Halley's dust), the very few pre-solar grains (identified by O isotopic composition), the notion that the bulk elemental compositions of the many different particles and their fragments are highly variable and need further study, and the presence of organic matter similar to that in IDPs and carbonaceous chondrites. A highlight of the analyses certainly was the finding of tiny (20 nm) pebbles composed of ultra-refractory metals (Fe, Ni, Ru, Pt, Os, Ir) and inclusions of TiN, an ultra- high-temperature (>1600 K) mineral. They were found in particles that by their O isotopic compositions are linked to the most refractory minerals in CAIs. If this O stems from near the forming sun (as indicated by new Genesis results), the refractory materials need to have been transported from the inner solar system to regions beyond Neptune, possibly by the X-wind process (Shu et al.), and mixed there with local (cold) organics and ices.

The talk ends with a gross comparison of the results obtained on Halley's comet, on comet Grigg-Skjellerup and comet Wild-2 emphasizing that comets appear to be very different and are true "individuals". In conclusion, more comet missions are mandatory to get close to a better understanding of these enigmatic bodies that – in any case – best witness the early history of our solar system and thus even may yield insights into the histories of other solar systems.