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Noble gas laser microprobe analysis of GENESIS and STARDUST material

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Abstract

We describe in this contribution 1) the techniques used to analyze and 2) the results from the analyses, of two very different extraterrestrial materials from sample return missions, "GENESIS" and "STARDUST".

1. Analytical Techniques

An entirely new extraction system was constructed in order to measure the small quantities of solar nitrogen and noble gases implanted in the high purity Au targets from the GENESIS mission. The extraction procedure for GENESIS used a 193 nm excimer laser which permitted stepwise extraction from the targets. Following extraction, the gases were purified (using Ti and Zr getters for noble gases and a Cu-CuO oxidation cycle for N_2) and analysis by static mode (pumps closed) noble gas mass spectrometry [1].

STARDUST samples of comet dust implanted in 'aerogel' were heated using an infrared CO2 (λ = 10.6 μm) laser, using the laser as a microfurnace in order to heat and eventually completely melt the 'aerogel' chips. The extracted gases were handled using the same facility as for GENESIS samples then analyzed in two fractions, He plus Ne, and then Ar, with a VG5400 Micromass© static mass spectrometer.

1.1 Blanks

It was essential that blank levels of nitrogen and the noble gases remained low for these analyses as only very small quantities of gas were contained in both GENESIS and STARDUST samples. N blanks, critical for the GENESIS analysis, were of the order 0.5 x10^{-12} mol; repeated purification of the extraction system over a 2-year period reduced these from more typical blank levels of 5x10^{-12} mol (Figure 1).

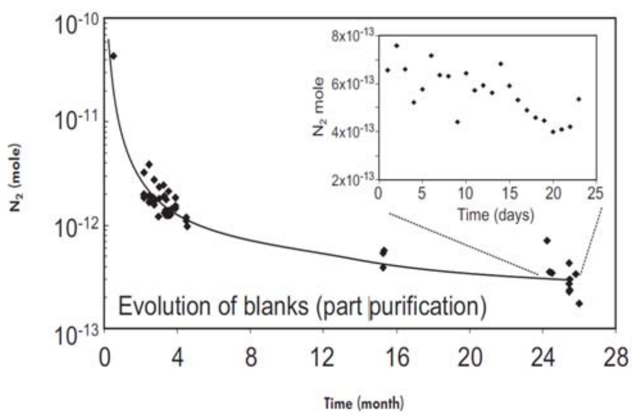

Figure 1: evolution of N blanks of the purification system over time (from [1])

Blanks for He and Ne during the STARDUST analyses were constant (at < ±10%) at 5 x10^{-15} and 8 x10^{-16} moles respectively, corresponding to 5–50% of the gases released from the samples themselves.

2. GENESIS

The GENESIS space mission recovered ions emitted by the Sun during a 27 month period. We analyzed the nitrogen and neon elemental and isotopic abundances (as well as those of He and Ar, but these are not presented here) in parts of the 'Concentrator' of the Genesis mission. Despite rigorous cleaning of the surfaces, terrestrial N was found to be a major component in all analyses. This contamination is in part intrinsic to the target material. Correcting for this contamination using correlations between Ne and N isotope ratios, it is possible to establish that the modern solar wind has a light N isotope composition, indistinguishable from that of the atmosphere of Jupiter and of lunar soil grains [2]. In contrast, planetary atmospheres are all about 400 permil enriched in ^{15}N compared to the Sun, with profound implications for the development of the solar system.

3. STARDUST

Some parts of comets are thought to have been created extremely early in the solar system and, being rich in volatiles, are ideal materials to study the processes that formed planetary atmospheres.

On 15 January 2006, the Stardust Mission returned to Earth with a cargo of particles collected from the coma of comet 81P/Wild 2. Neon isotope ratios in these particles are similar to those observed in “phase Q,” the organic material found in meteorites that is known to be a carrier of noble gases in primitive solar system components. However, helium isotope ratios (3He/4He) are double those in phase Q. The concentrations of helium and neon are high, consistent with production by ion irradiation [3]. Refractory grains are probably the carrier phases of the noble gases which were likely acquired by irradiation in a hot, nebular environment close to the young Sun.

References

[1] Zimmermann, L., P. Burnard, et al. "Laser Ablation (193 nm), Purification and Determination of Very Low Concentrations of Solar Wind Nitrogen Implanted in Targets from the GENESIS Spacecraft." Geostandards and Geoanalytical Research Vol. 33, 183-194, 2009.

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[3] Marty, B., R. Palma, et al. "Helium and Neon Abundances and Compositions in Cometary Matter." Science Vol. 319: 75-78, 2008.

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