Reactive ammonia in the protoplanetary disk

D. HARRIES[1]*, P. HOPPE[2], F. LANGENHORST[1]

[1] Friedrich-Schiller-Universität, 07745 Jena, Germany. (*correspondene: dennis.harries@uni-jena.de)

[2] Max-Planck-Institut für Chemie, 55128 Mainz, Germany.

The cosmochemical origin of Earth's nitrogen is a piece to the puzzle of how habitability evolved. Earth's $^{15}N/^{14}N$ isotopic ratios fall in-between the extremes of the Sun, which is ^{14}N-rich, and comets, which are enriched in ^{15}N. The inner solar system, including asteroids, appears to constitute a third reservoir, which originated from yet poorly understood fractionation and mixing processes [1]. The study of primitive, chondritic meteorites can shed light on this [2]:

Some primitve CM2 chondrites contain assemblages of chromium nitride (carlsbergite), sulfides, magnetite, and relict grains of Cr-bearing Fe,Ni metal. The physical characteristics of the nitride suggest that it precipitated from the Cr-bearing metal. The most plausible explanation for the high nitrogen enrichments in these assemblages (~1 wt% N) is the reaction of the metal grains with a hot gas containing metastable ammonia (NH_3), water (H_2O), and hydrogen sulfide (H_2S).

We explored a model, in which NH_3- and H_2S-bearing ices are vaporized by the passages of planetesimal shock waves [3]. Thermodynamic and kinetic calculations show that the nitriding potential and the lifetime of metastable NH_3 would have been sufficent to create the nitride assemblages on time scales compatible with the shock wave transition. The source of NH_3 and H_2S can be best explained by the presence of ice particles that had a composition of volatile species similar to cometary ices.

Isotopic studies by NanoSIMS show that the nitrogen in the nitride-bearing assemblage has a $\delta^{15}N_{atm}$ of 49±15 ‰ and is similar to the bulk meteoritic isotopic composition and Earth's atmosphere, but is distinct from cometary nitrogen. Hence, the inner solar system's reservoir of moderately ^{15}N-enriched nitrogen may be traced to NH_3-bearing, compositionally comet-like, but isotopically Earth-like ices. These ices may have been brought to the inner solar system by the 'grand tack' [4], but were mostly lost after dissipation of the protosolar gas. However, some of them may be preserved in asteroids, e.g., (1) Ceres, which shows evidence for ices and ammoniated phyllosilicates [5].

[1] Füri & Marty (2015) *Nat. Geosci.* **8**, 515-522. [2] Harries et al. (2015) *Nat. Geosci.* **8**, 97-101. [3] Ciesla et al. (2003) *Science* **299**, 549-552. [4] Walsh et al. (2011) *Nature* **475**, 206-209 [5] De Sanctis et al. (2015) *Nature* **528**, 241-244.