EVIDENCE FOR A DOMINANT COMPONENT OF SOLAR-ENERGETIC-PARTICLE (SEP) HELIUM AND NEON IN A SUITE OF INTERPLANETARY DUST PARTICLES.

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Helium and neon measured in a suite of 12 IDPs from three stratospheric particle collectors as part of a consortium study [1] turned out to be unexpectedly rich in SEP gases. The SEP component has been identified in lunar and meteoritic regolith materials, and is attributed to implantation of solar ions with energies above those characteristic of the solar wind (SW) [2,3 and citations therein]. One thorny problem with this hypothesis is that the calculated SEP/SW abundance ratio in these materials is typically ~20-50%, several orders of magnitude above current estimates for the relative flux of solar ions at suprathermal and higher energies [3-5]. Consideration of grain-surface erosion effects reduces the required SEP abundance [6], but probably not by factors >10. Estimates from the IDP data reported here of the SEP/SW fluence ratio incident on small particles in space over the past •10^5 years are significantly lower, but still factors of perhaps 10-100 above observational estimates [3-5].

Analytic techniques and procedures used in this study were those developed previously by Nier & Schlutter [7,8] for IDP analyses. Particle sizes were typically 20-35 µm in largest dimension. Measured isotopic compositions, and abundances in ccSTP/particle, are shown in Figs. 1 and 2 for He and Ne respectively. Identifiers are JSC curation numbers; asterisks denote samples that are fragments of larger IDPs ("cluster" particles). The plotted solar wind and SEP isotope ratios were derived from acid-etch experiments on lunar ilmenites [2].

Helium. Eight of the 12 isotope ratios in Fig. 1 group closely around the composition of SEP-He. The average $^3He/^4He$ ratio for these 8 (in units of 10^{-4}) is 2.23 ± 0.12 (abundance-weighted), or 2.25 ± 0.04 ($1/\sigma^2$-weighted), compared to 2.17 ± 0.05 for SEP [2]. Of the remaining 4 particles, about 1/3 of the He in L2036*F1 appears to be SW-He, and in the 3 others, all with low ^4He contents, nominal $^3He/^4He$ ratios exceed the SW value. This kind of isotopic signature has been seen previously in low-He IDPs, notably in cluster particles from particular collectors [8-10], but here it is much more subdued.

Neon. $^{20}Ne/^{22}Ne$ ratios in the 9 particles with enough Ne for isotopic measurements all fall within error between the SEP and SW compositions, consistent with previous IDP results [11,12]. The more accurately measured ratios again cluster around the SEP value (Fig. 2). The average $^{20}Ne/^{22}Ne$ ratio of the 8 with 1σ error bars within the SEP range of 11.2 ± 0.2 [2] is 11.4 ± 1.0 (abundance-weighted) or 11.14 ± 0.34 ($1/\sigma^2$-weighted); corresponding averages of $^{21}Ne/^{22}Ne$ are 0.0313 ± 0.0034 and 0.0313 ± 0.0014 compared to 0.0295 ± 0.0005 for SEP [2].

Discussion. If these IDPs experienced space exposure to solar radiation for times governed by their Poynting-Robertson (P-R) drag lifetimes, one can roughly estimate their intercepted SEP/SW fluence ratios. The SEP fluence F_{SEP} is $\cong [^4He]_{SEP}/A$, where $[^4He]_{SEP}$ = measured atomic abundance in a grain with SEP-like isotope ratios and A = grain cross-sectional area $\cong \pi(d/2)^2$. Integration of the solar-wind ^4He flux $f_{SW} \cong 1.1 \times 10^7\ R^{-2}$ atoms $cm^{-2}sec^{-1}$ (R in AU) over the P-R lifetime of $\tau_{P\text{-}R} \cong 1.1 \times 10^{14} R^2 d$ seconds for a grain of density ~1 g/cm^3 and d > a few µm [13] yields the SW fluence F_{SW}. The resulting fluence ratio F_{SEP}/F_{SW} is $\cong 1.3 \times 10^{10}\ [^4He]_{SEP}/d^3$ for $R_{initial}$ = 3 AU, with abundances in ccSTP and d in µm. Grain "diameters" d are approximately known (K. Kehm, pers. comm.). With these the calculated SEP/SW fluence ratios of ^4He in 9 of these grains (excluding G1, I16, H1) range from ~0.2 - 10 x 10^{-4} with an average of ~3 x 10^{-4}. Corresponding calculations using the Ne data yield values that are a factor ~10 larger (range 0.2 - 8 x 10^{-3}, average ~3 x 10^{-3}); this difference occurs because the measured $(^4He/^{20}Ne)_{SEP}$ ratio from the IDP data is $\sim 75 \pm 50$, about 10% of the SW value. These SEP/SW fluence ratios are much lower than previous estimates from irradiated regolith grains. However they are still •1-2 orders of magnitude above the expected ratio of ~10^{-4}-10^{-5} for SEP particle energies >0.1 MeV/amu [3,5].

Most of the intercepted SW radiation is clearly <u>not</u> present in these IDPs. What happened to it? For the cluster particles a plausible explanation is that a single ~30 µm fragment from impact disruption of a parent IDP 2-3 times its diameter is unlikely to include much of the parent's •0.1 µm-deep surface layer where most of the SW gases are sited. But for individual IDPs, presumably collected intact, one must appeal to almost complete removal of the surficial SW gases by drag heating on atmospheric entry.

An alternative scenario would arise if these IDPs were cometary with short in-space residence times [1,10]. Here the absence of the SW component follows naturally. But now the SEP-like gases would have to be regarded as constituents of primordial cometary matter, thus posing the interesting problem of simultaneously accounting for their presence in lunar and meteoritic regolith grains.

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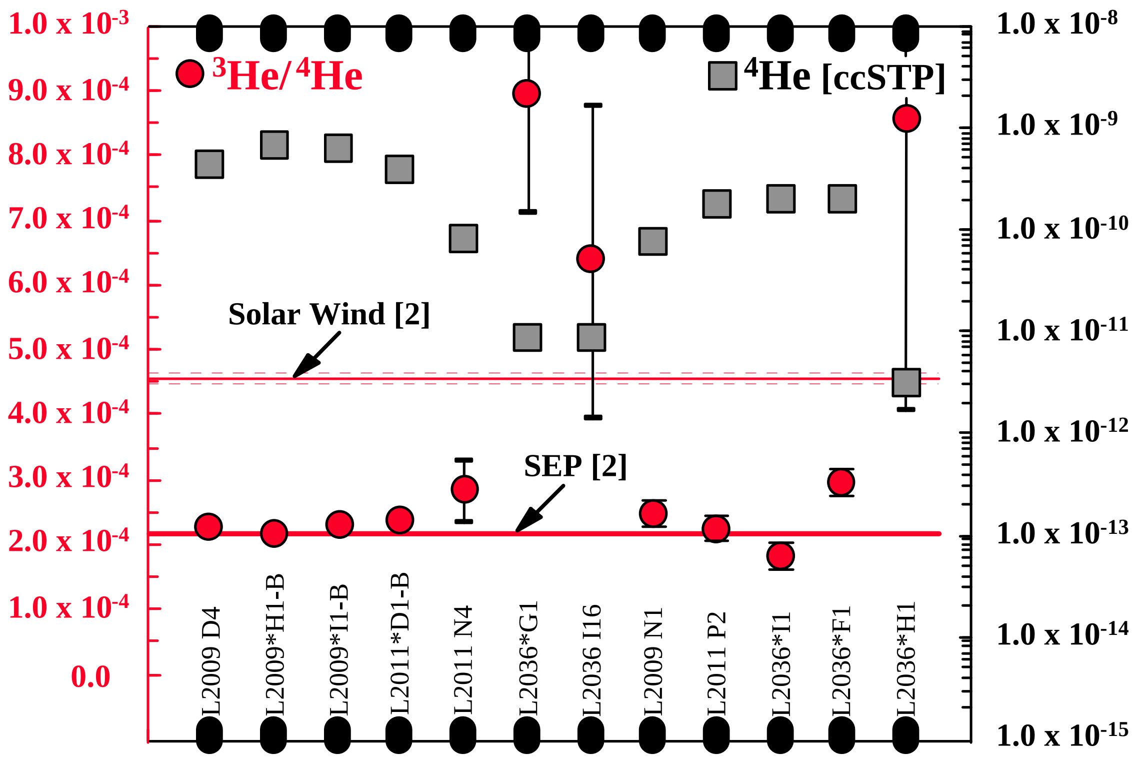

Figure 1

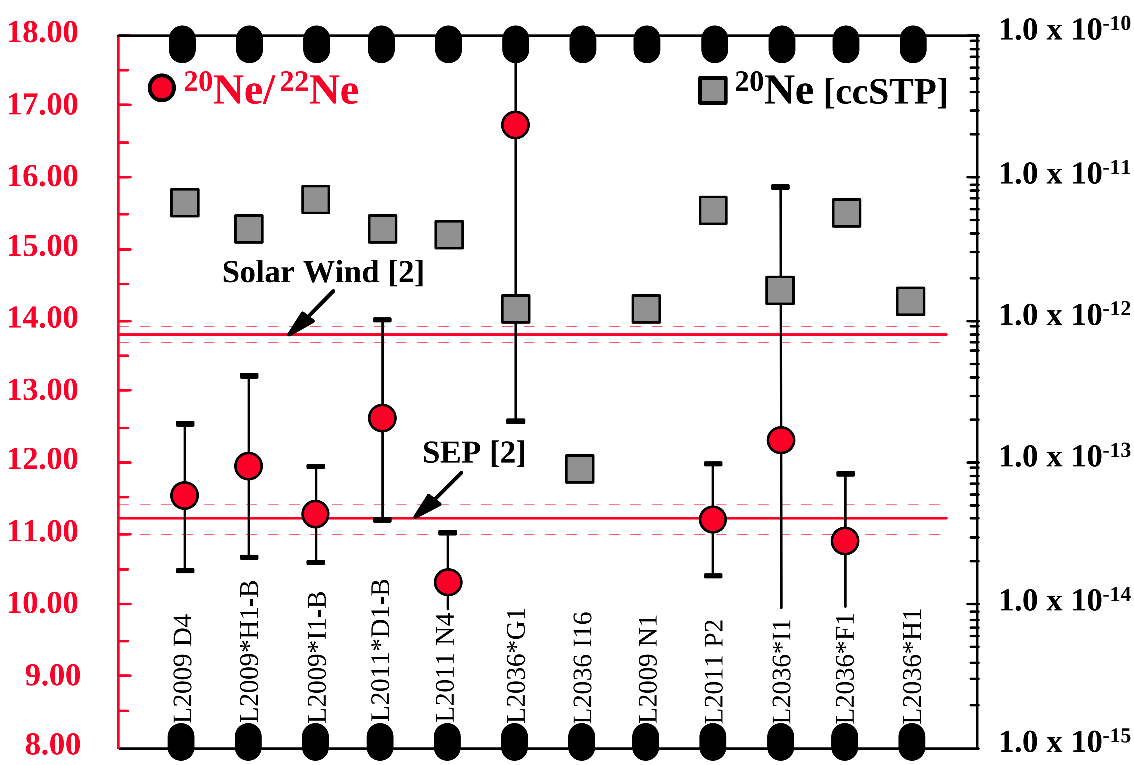

Figure 2