

RELEVANCE OF ROSETTA NOBLE GAS AND ISOTOPIC MEASUREMENTS TO UNDERSTANDING THE ORIGIN AND EVOLUTION OF VENUS' ATMOSPHERE

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Introduction: Understanding how the terrestrial atmospheres evolved is essential for evaluating how life formed and thrives on Earth, but not on present-day Venus or Mars. Extensive studies have been conducted for Earth [e.g. 1] and Mars [2], but the evolution of Venus is the least understood [3].

Studying the atmospheric history of Venus can determine: (1) the origin of volatiles on Venus compared to Earth and Mars; (2) the total initial abundance of volatiles; and (3) the outgassing history. Noble gas abundances and isotope ratios are particularly useful [4,5,6].

Volatile sources: Constraining atmospheric evolution requires understanding source composition. Terrestrial atmosphere noble gases likely resulted from a complex mix of gas absorbed directly from the protosolar nebula (PSN, or solar) and volatiles contributed by planetesimal and comet impacts.

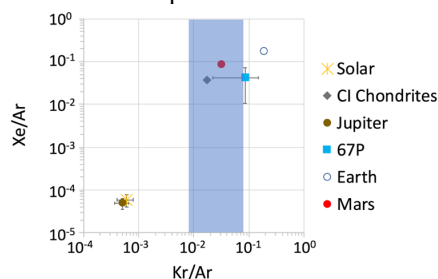


Figure 1: Relative noble gas abundances in the solar system [adapted from 6]. Venus is the shaded region [7].

Comet measurements remain limited. Ground-based observations have provided D/H, $^{12}\text{C}/^{13}\text{C}$, $^{14}\text{N}/^{15}\text{N}$, and $^{16}\text{O}/^{18}\text{O}$ in many species for several comets [8 and refs. therein], but no noble gas measurements prior to *Rosetta*. Since arrival at the comet 67P/Churyumov-Gerasimenko (67P), a Jupiter family comet, *Rosetta* mission has measured the noble gas abundances relative to water [4] as well as their isotopologues [4,9,10].

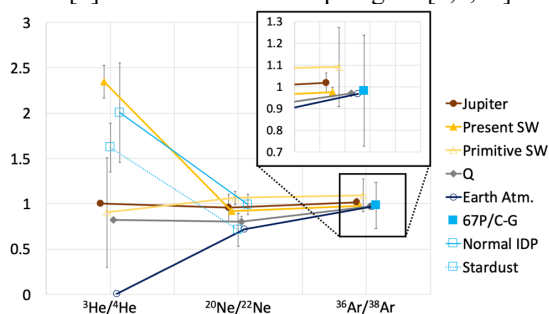


Figure 2: Isotopes of helium, neon, and argon [from 6].

Fig. 1 shows Kr/Ar compared to Kr/Xe of 67P, chondrites and other solar system bodies. Although

Kr/Xe is very similar for 67P and chondrites, the Kr/Ar ratio for chondrites is lower than the lower boundary of the 67P measurements. Fig. 2 shows He, Ne, and Ar isotopes. We find that helium isotopes provide the most diagnostic measurement for source materials because of the wide range of values throughout the solar system [6]. Finally, Fig. 3 shows Xe isotopes. If 67P is representative of cometary values, Xe isotope ratios could be diagnostic for determining the relative contribution of comets to an atmosphere.

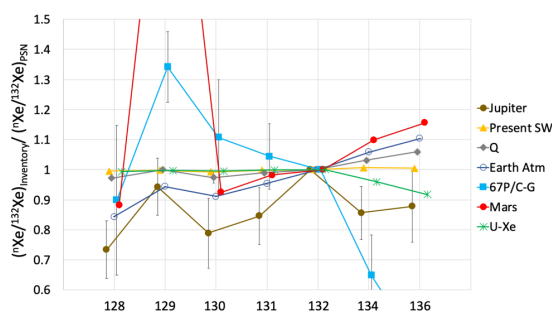


Figure 3: Xenon noble gas isotope ratios relative to solar values across the solar system [from 6].

Relevance to Venus: As shown in Fig. 1, Kr/Ar could be used to separate contributions of chondrites and comets to the atmosphere, but current error bars are too large. Venus neon and argon isotopes are limited in the diagnostic value for sources, and only an upper limit for ^3He is currently available. However, the new noble gas abundances and isotope ratios from 67P can be combined with chondrite and solar composition to provide a starting point for evaluating the origin and evolution of the Venus atmosphere. They can be used to predict how the atmosphere evolved over time for different combinations of source material, and project measurements for upcoming missions like we did this *New Horizons* prior to arrival at Pluto [11].

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