N_2/CO RATIO IN COMETS INSENSITIVE TO ORBITAL EVOLUTION. S.E. Anderson[1,3], P. Rousselot[1], B. Noyelles[1], E. Jehin[2], and O. Mousis[3,4]
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Introduction: Comets are known to be depleted in nitrogen compared to protosolar values, with a typical N_2/CO ratio of $<10^{-3}$ [1]. However, the recent discovery of comet C/2016 R2 (PanSTARRS), which is H_2O-poor and N_2-, CO-rich with an N_2/CO ratio of 0.09 [2], has prompted a re-examination of possible N_2-rich comets, where $N_2/CO > 1 \times 10^{-2}$. This sample consists of C/1908 R1 (Morehouse), C/1940 R2 (Cunningham), C/1947 S1 (Bester), C/1956 R1 (Arend-Roland), C/1957 P1 (Mrkos), C/1961 R1 (Humason), C/1969 Y1 (Bennett), C/1973 E1 (Kohoutek), C/1975 V1-A (West), C/1986 P1 (Wilson) C/1987 P1 (Bradfield), C/2001 Q4 (NEAT), C/2002 VQ94 (LINEAR), and periodic comets 1P/Halley, 29P/Schwassmann-Wachmann 1, and 67P/Churyumov-Gerasimenko (the later measured in-situ via mass spectroscopy). All long-period comets in our sample are highly eccentric and quasi-parabolic. In this study, we aim to examine the composition and dynamical history of these N_2-rich comets to identify common characteristics that may provide clues to their formation processes.

New N_2/CO ratios : Using new N_2 fluorescence factors from [3], we re-estimate the N_2/CO ratios of our sample of N_2-rich comets. These range from $N_2/CO \approx 0.01$ to 0.1. This finding is significant since [4] previously established that comets with $N_2/CO \approx 0.06$ were likely to have formed from ices that were incorporated into comets at around 50K if N_2/CO is ≈ 1 in the solar nebula. Our N_2-rich comets are consistent with the expected values for comets based on estimations of the protosolar nebula, indicating that they do not exhibit the typical nitrogen depletion found in the majority of comets.

Dynamical Evolution: We estimated the dynamical history of seven comets, including C/2016 R2, C/1908 R1, C/1947 S1, C/1961 R1, C/1987 P1, C/2001 Q4, and C/2002 VQ94, using MERCURY [5] and REBOUND [6] simulators. To generate a statistical model of potential histories, we computed the dispersion of 1000 clones with orbital elements generated using a multivariate normal distribution with the object's orbital elements as the mean. The orbital elements were provided by the *JPL Small Body Database* along with the orbital covariance matrix. The orbits of each comet and its clones perturbed by the eight planets were then simulated over a timespan of -1 Myr.

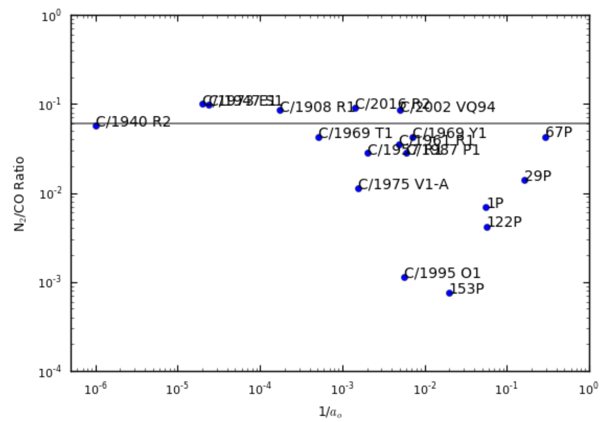

Figure 1: N_2/CO ratio as a function of the inverse semi-major axis. The horizontal line represents $N_2/CO \approx 0.06$, the value established by [4].

Results: With the exception of C/1908 R1 (dynamically new), all six comets had recent close encounters with the giant planets which erased their dynamical history. We were however able to determine how varied their histories were, all ranging from dynamically new to old. We also compared our results with the CODE catalog [8], who had computed dynamical histories for four additional N_2-rich comets, which confirmed there is no clear dynamical link between their histories, though it would appear these comets likely originated from a large heliocentric distance to retain their volatile composition.

Conclusions: This study finds no link between the N_2/CO ratio and the dynamical history of N_2-rich comets within the inner Solar System (see Fig.1). These comets do appear to preserve protosolar N_2/CO values and have undifferentiated bulk composition. The study used new N_2 fluorescence factors to re-estimate N_2/CO ratios, which align with the expected values for comets based on protosolar nebula estimations. This suggests that these comets formed in a shared region of the Solar System before being ejected to the Oort Cloud. These findings offer new insights into comet chemistry and origins, and further research is needed to expand on them.

References: [1] Cochran et al. (2000), *Icarus, 146, 583-593* [2] Anderson et al. (2022), *MNRAS, 515, 5869-5876;* [3] Rousselot et al. (2022), *A&A 661, A131*; [4] Owen & Bar-Nun (1995*), Icarus, 116, 215-226;* [5] Chambers (1999), *Icarus, 304, 793-799;* [6] Rein & Liu (2012), *A&A 537, A128.*