Robustness of N_2H^+ as tracer of the CO snowline

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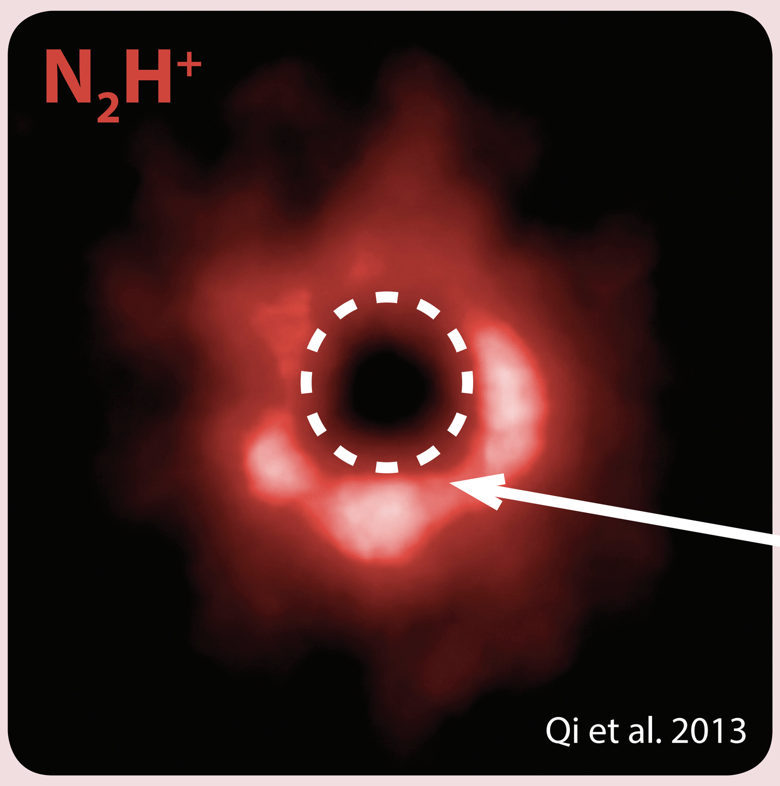
Snowline: midplane radius in a protoplanetary disk beyond which a molecular species freezes out onto dust grains.

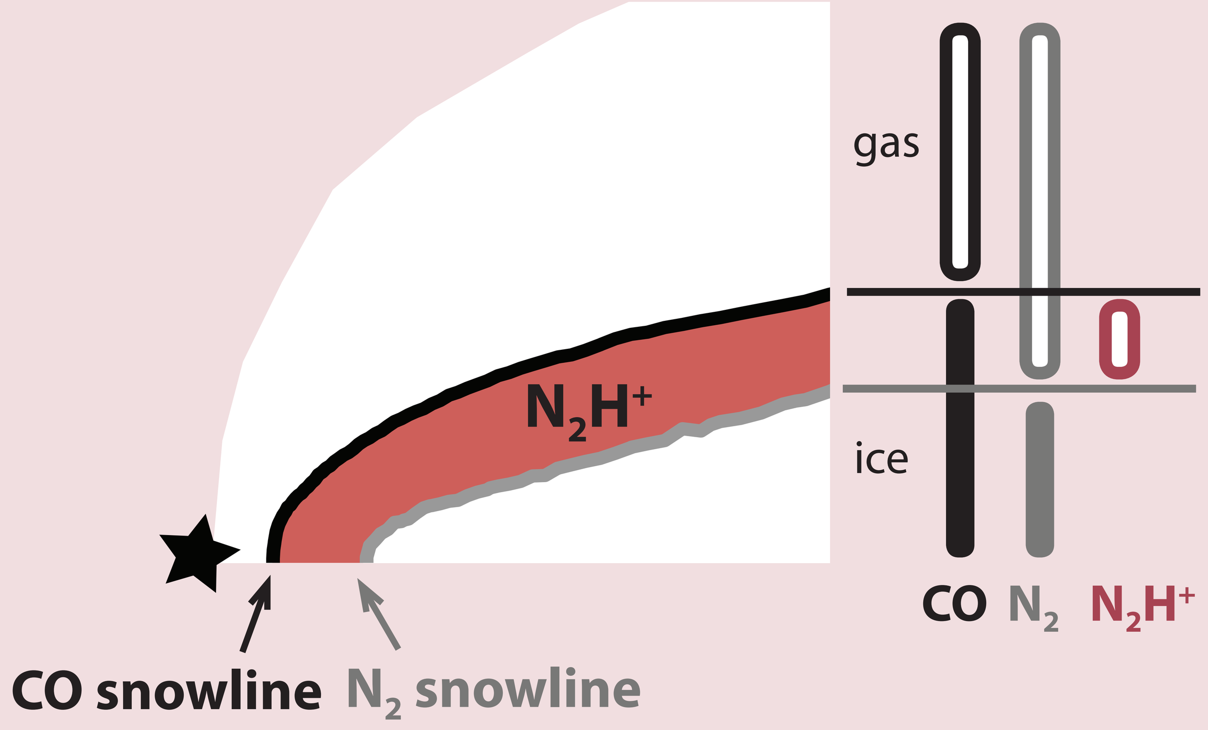
Snowlines are important for planet formation and composition.



ALMA observations of the TW Hya disk

CO snowline?

Expected N_2H^+ distribution



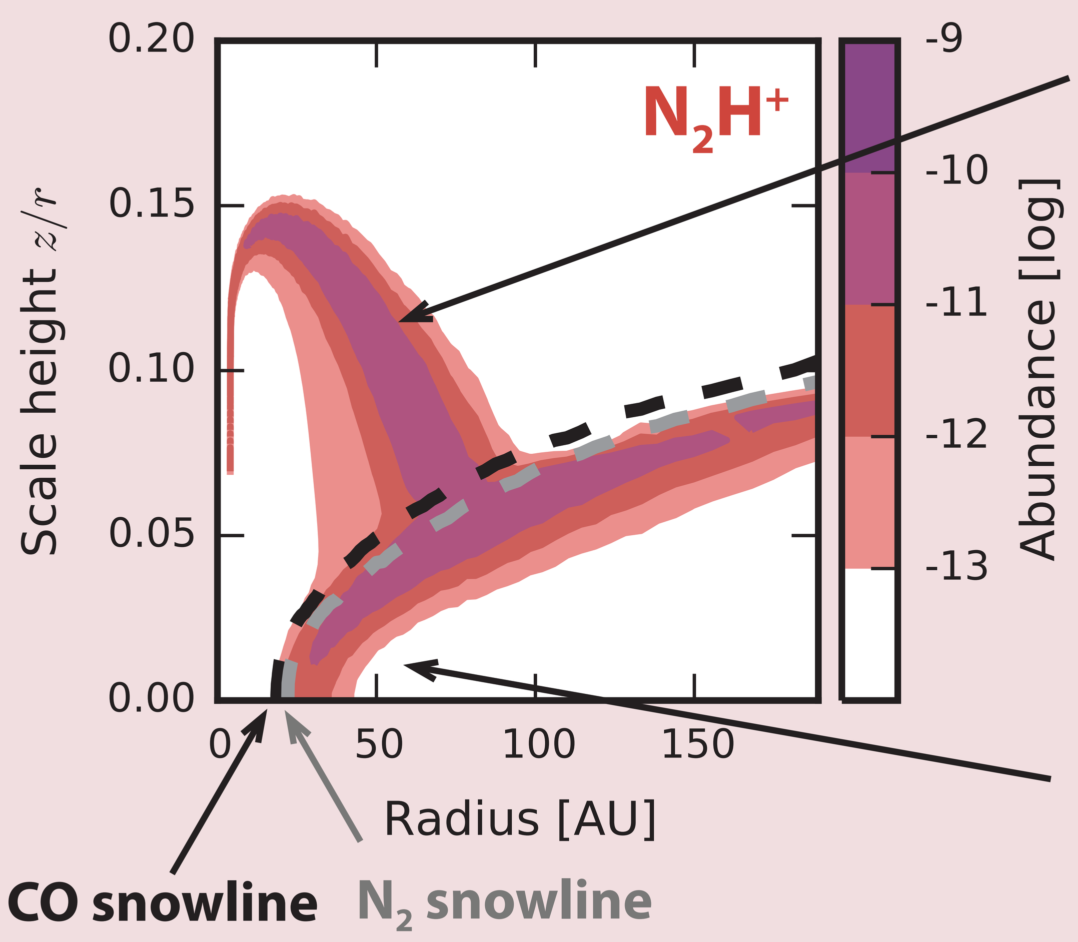
Expect N_2H^+ to be abundant between the CO and N_2 snow surfaces.

N_2H^+ is assumed to be a good tracer of the CO snowline

The CO snowline is difficult to observe directly, but can be traced with N_2H^+ [1,2], because N_2H^+ can only be abundant when CO is frozen out:

$$N_2 + H_3^+ \rightarrow N_2H^+ + H_2$$
$$CO + H_3^+ \rightarrow HCO^+ + H_2$$
$$N_2H^+ + CO \rightarrow HCO^+ + N_2$$

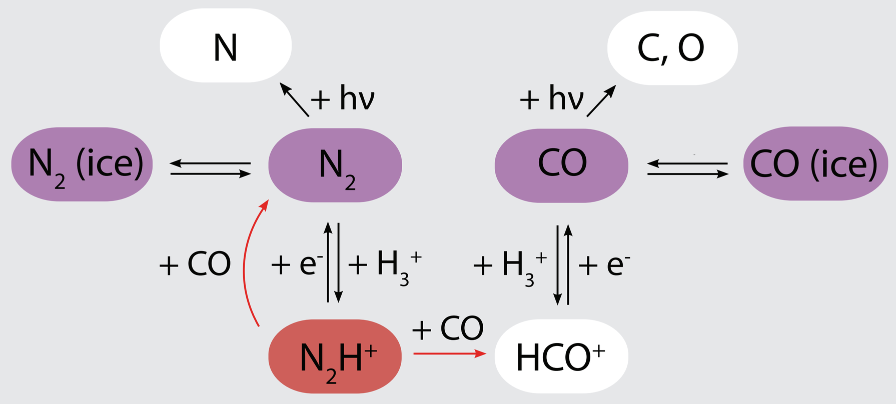
Modeled N_2H^+ distribution



N_2H^+ formed due to a faster photodissociation rate for CO compared with N_2.

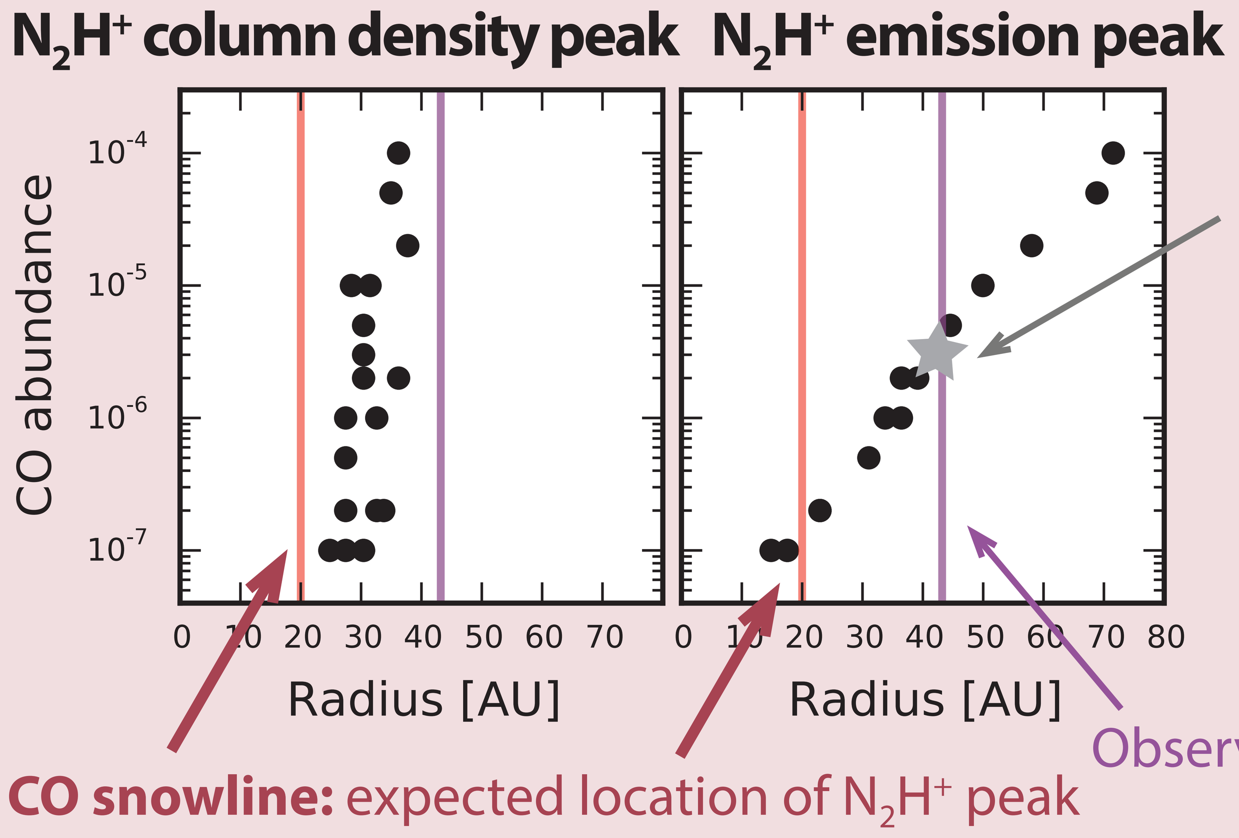
N_2H^+ does not peak at the CO snowline; the reduction of gas-phase CO at the snowline is not sufficient for N_2H^+ to reach an appreciable abundance.

Assess robustness of N_2H^+ using a small chemical network



This incorporates only the essential processes and species [3], and a physical model for TW Hya [4].

Vary CO and N_2 abundances, and determine the position of the N_2H^+ column density peak.



Best fit model has a CO abundance of 3×10^{-6}, consistent with CO depletion [4,6].

Simulate N_2H^+ $J = 4\text{-}3$ emission with the radiative transfer code LIME [5].

The N_2H^+ column density peaks at least 5 AU outside of the CO snowline.

N_2H^+ formed above the CO snow surface shifts the emission outward with respect to the CO snowline.

The relation between N_2H^+ and CO is more complicated than just CO freeze-out

Therefore, chemical modeling, as outlined in our work, rather than column density fitting, is necessary to translate N_2H^+ emission into a CO snowline location.

References

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[1] Qi, C., Öberg, K.I., Wilner, D.J. et al. 2013, Science, 341, 630. **[2]** Qi, C., Öberg, K.I., Andrews, S.M. et al. 2015, ApJ, 813, 128. **[3]** Aikawa, Y., Furuya, K., Nomura, H., & Qi, C. 2015, ApJ, 807, 120. **[4]** Kama, M., Bruderer, S., van Dishoeck, E.F. et al. 2016, A&A, 592, A83. **[5]** Brinch, C. & Hogerheijde, M.R. 2010, A&A, 523, A25. **[6]** Schwartz, K.R., Bergin, E.A., Cleeves, L.I., et al. 2016, ApJ, 823, 91.