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research highlights

PROTOPLANETARY DISKS

Snow lines not so simple

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One of the key constraints in theories of planet formation is provided by the location of snow lines in protoplanetary disks — condensation fronts that form the radial demarcation between gaseous molecules and solid ices. Solid ices frosting the surface of dust grains may provide enough stickiness for hydrogen to accrete and dust grains to coagulate, allowing the cores of giant planets to form. Dust grains without ices are unlikely to form gas giant planets. Snow lines depend not only on the sublimation temperature of the molecule concerned (H_2O, CO and so on), but also on the temperature profile of the protoplanetary disk. Snow lines can be modelled and they can be estimated from observations. However, CO, one of the most abundant molecules in protoplanetary disks, is optically thick and thus difficult to observe directly. A recent paper by Qi *et al.* (*Science* **341,** 630–632; 2013) proposed to use N_2H^+ as a proxy for CO. The idea is simple: when CO is in the gas phase, it destroys N_2H^+. When CO is frozen to grains, N_2H^+ flourishes. Outside a certain disk radius, both species become frozen. So when observed, one should see a ring of N_2H^+ emission surrounding a central hole, the size of which would give the extent of the CO snow line.

Merel van 't Hoff and collaborators have pointed out that it is not quite that easy. Snow lines are not just a ring in the disk midplane; snow lines are in fact snow surfaces, and one should take into account the vertical extent. Modelling the distribution of N_2H^+ shows that the N_2H^+ peak column density and the emission peak can be offset from the CO snow line by at least 5 au and as much as 53 au. For the disk of TW Hydrae observed by Qi and colleagues, they determined a snow line for CO at the midplane of 19 au — much smaller than the 30 au inferred from the N_2H^+ observations. Moreover, they find that some N_2H^+ traces a surface layer in the disk, and therefore may not faithfully trace the CO in the midplane of the disk. The N_2H^+ abundance is also found to depend on the chemical environment of the disk, particularly the N_2/CO ratio and the cosmic-ray flux. Overall, the picture is that the N_2H^+ distribution provides a more complicated indicator of the CO snow line than initially thought. A combination of high-resolution observations and disk models are needed to make robust interpretations, although the chemical networks used in the models need not be extensive.

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