PROTOPLANETARY DISCS

The wild dance of snow-lines

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A snow-line, also called ice-line, is the location where the transition between ice and gas of a volatile happens in a planetary system or a protoplanetary disk. Even though it is usually mentioned in reference to water, many volatiles sublimate and condense at temperatures found in protoplanetary disks. Snow-lines, which are mostly dependent on the temperature of the environment, play an important part in planetary formation and evolution, but they are usually modelled as fixed in time or moving outwards at geological timescales (due to the slow stellar brightening). James Owen shows that reality is probably more complex and dynamic.

Owen studies the role of thermal instabilities in the evolution of snow-lines with an analytical model. The relation between the temperature profile of the disk and the position of a snow-line is not mono-directional: the snow-line affects the temperature in turn, as it controls the formation of the solids that absorb the radiation. At moderate optical depths $\tau \approx 0.05$–2, which can be found in the outer disk regions, this mutual dependence creates an instability cycle that shifts the position of the snow-line, periodically condensing and sublimating the volatiles. A detailed case study of the CO snow-line with a numerical model shows that it can move in and out by several tens of au in relatively short timescales of 1,000–10,000 years.

Even though the water snow-line is probably not affected, as it is located in the optically thick part of the disk, many other common volatiles (such as CO, CO_2 or NH_3) can experience such instability. Owen suggests that this jumpy evolution of snow-lines can be the cause of the ring-like appearance of many protoplanetary disks observed by ALMA.

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