Connecting gas-phase volatile depletion to primordial planetesimal compositions

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Five Years After HL Tau
A new era in planet formation
VIRTUAL CONFERENCE
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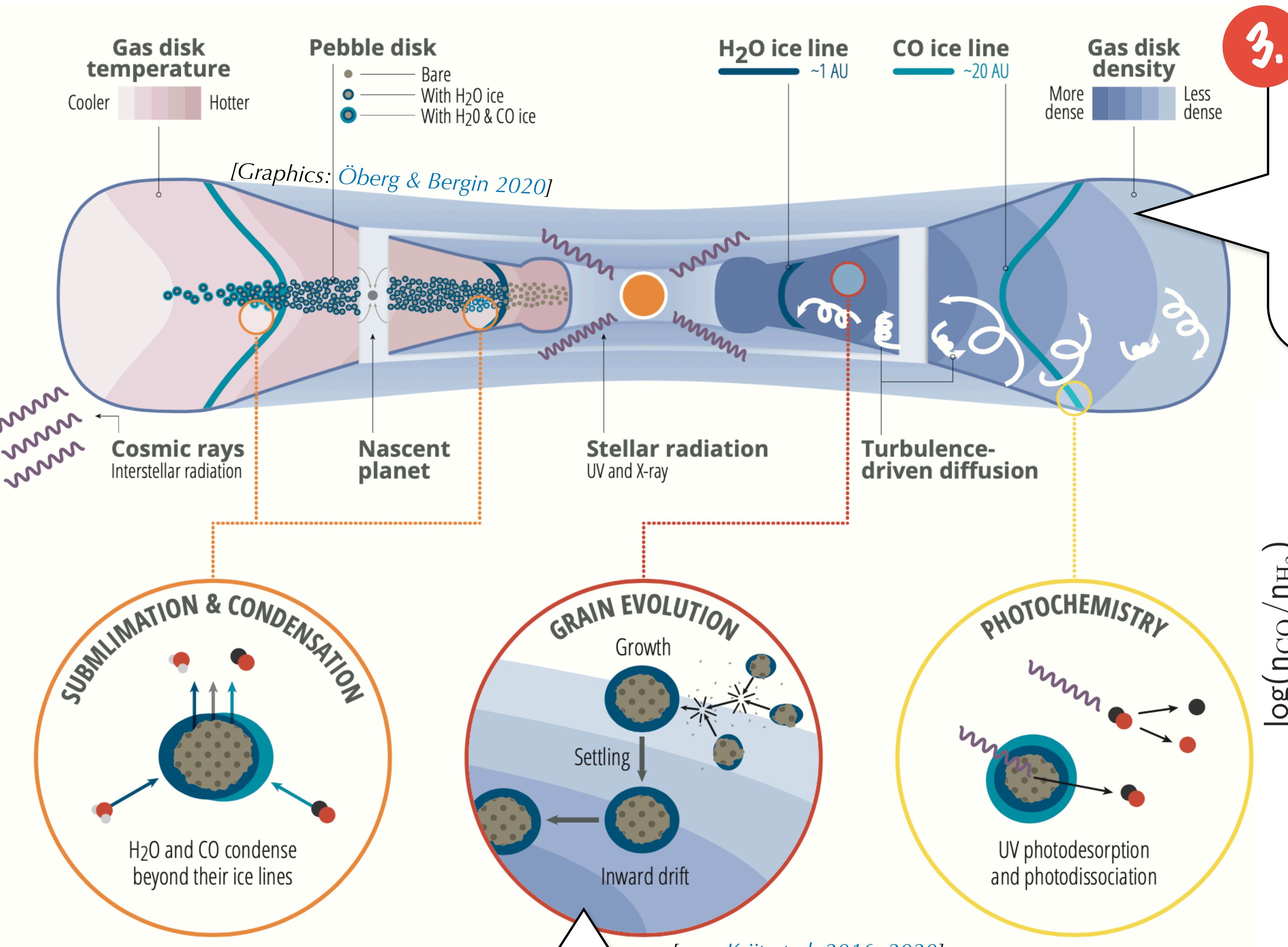
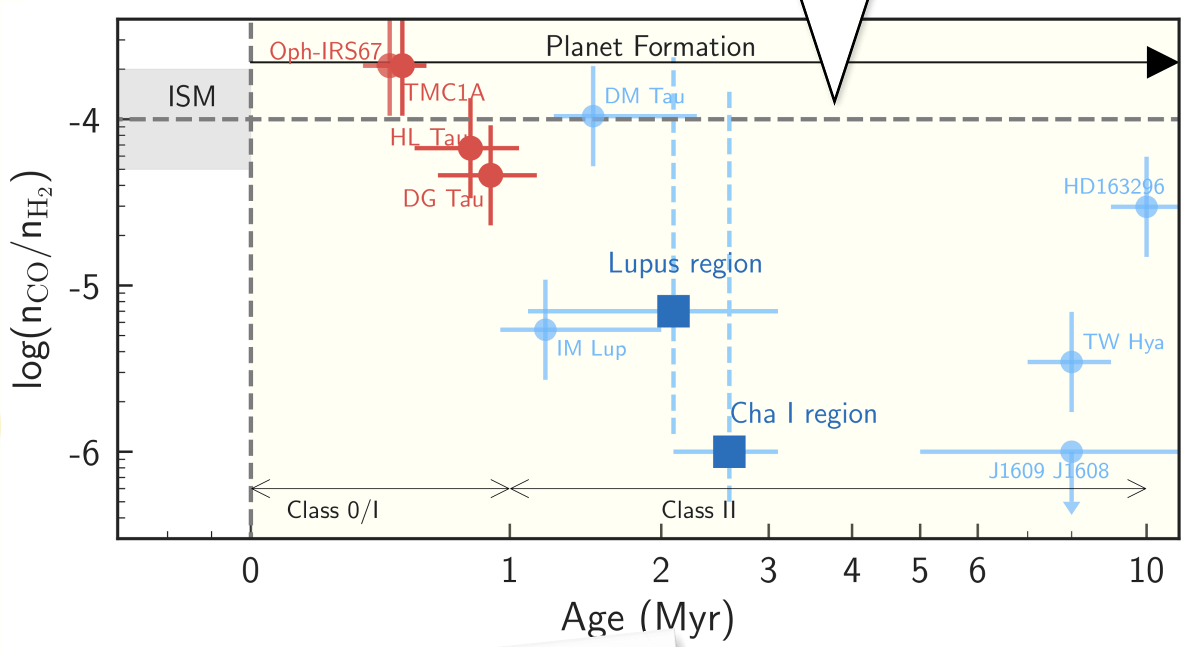


3. [e.g., Öberg & Bergin 2020]

Surprisingly, a combination of *Herschel, ALMA,* and *NOEMA* observations point to gas-phase carbon and oxygen being severely depleted in the ***surface layers*** of the outer regions of protoplanetary discs …

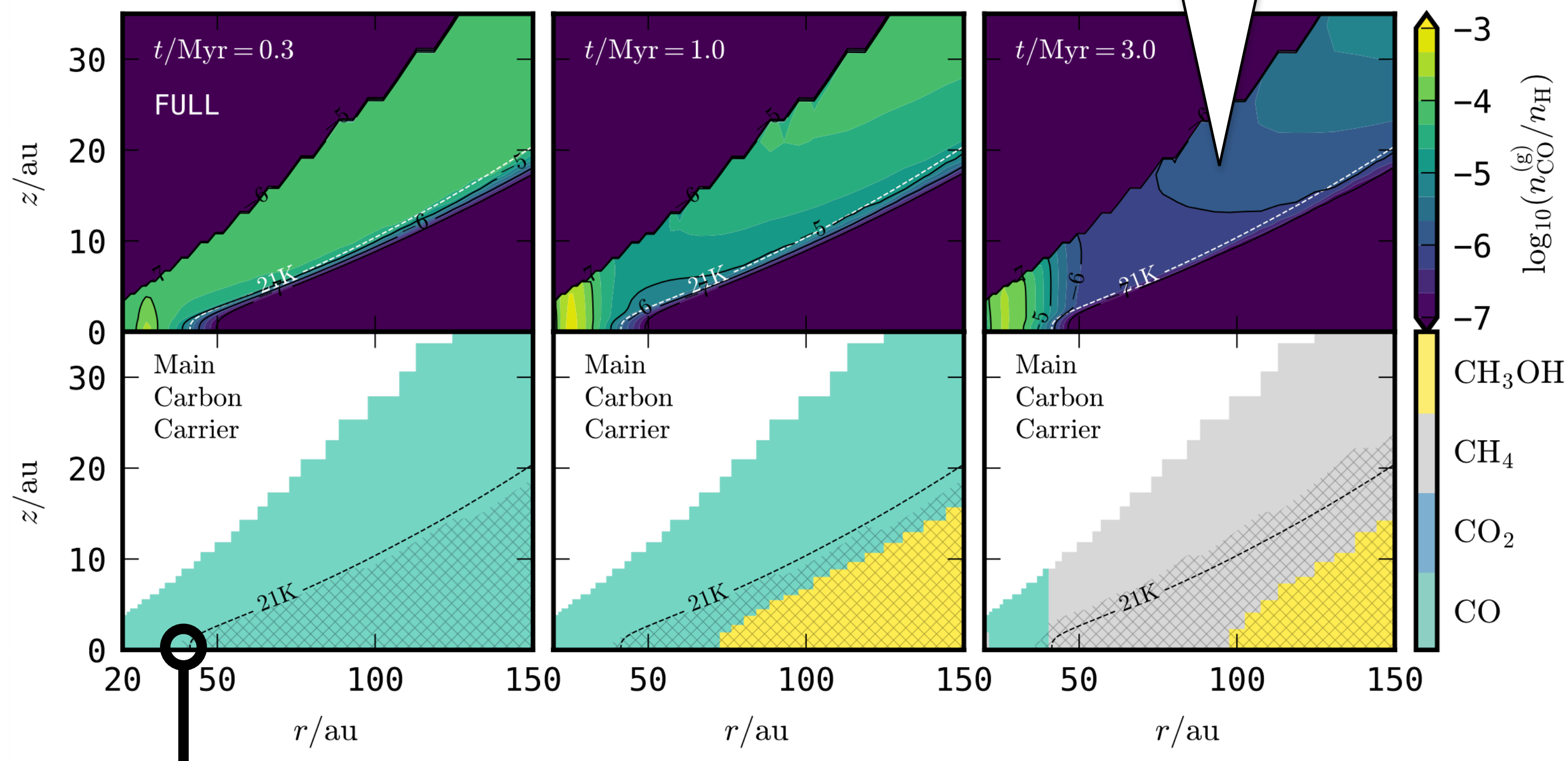
4. [Zhang et al. 2020a]

… and what's more: the magnitude of this depletion appears to increase over time. *How is this linked to planet formation?*



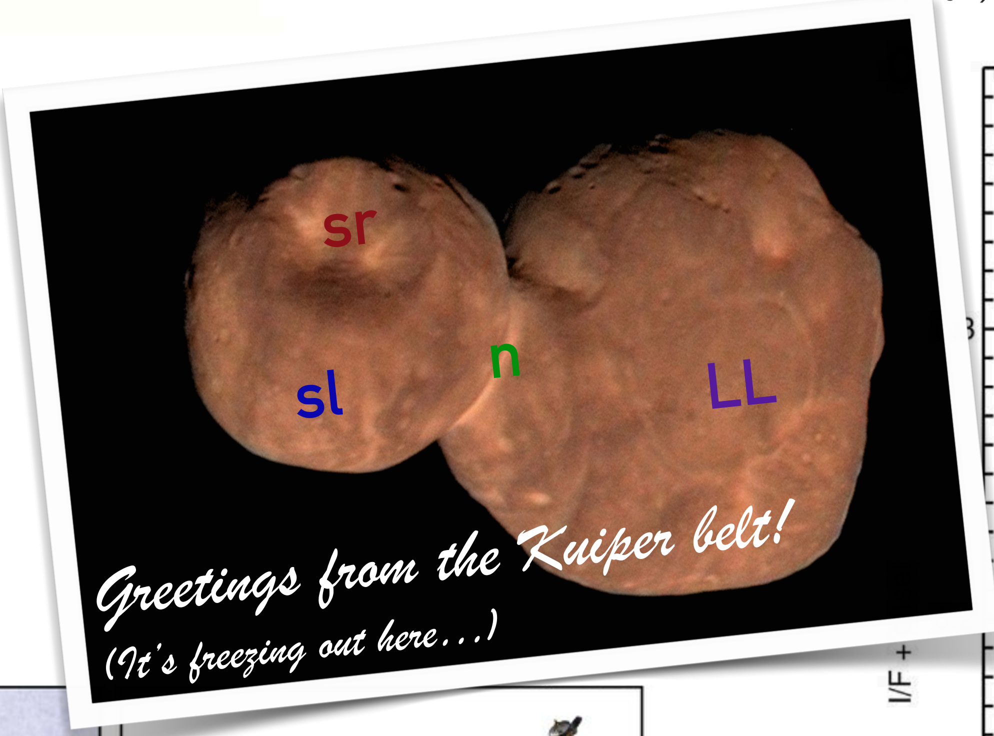
5. In *Krijt et al. (2020)*, we model dust coagulation, dust & gas dynamics, and gas + grain surface chemistry together, in an attempt to connect the observed CO depletion pattern to processes taking place near the disc midplane.

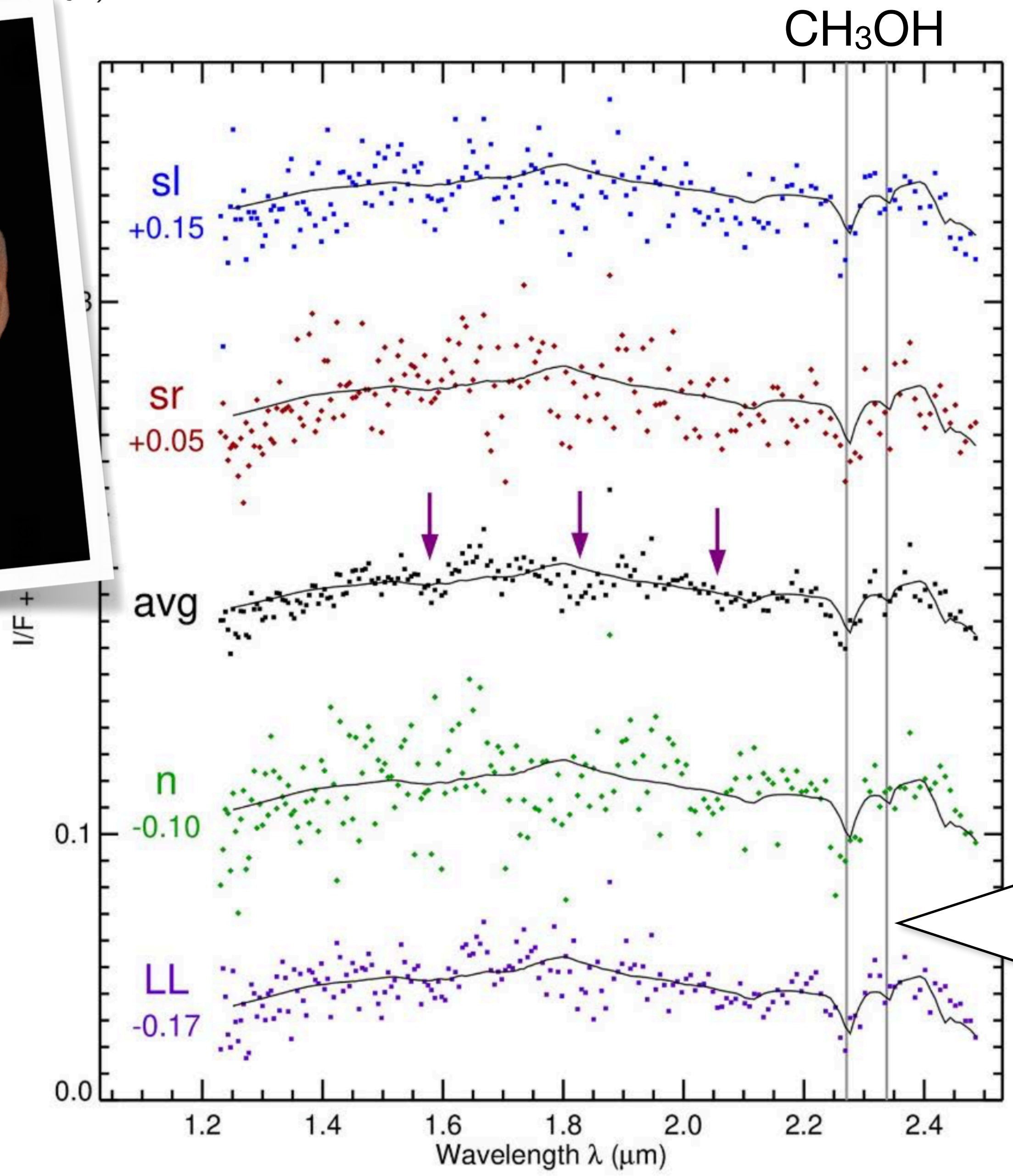
6. We find that a combination of grain surface chemistry, vertical mixing, and dust coagulation + settling can indeed deplete the upper regions in gas-phase CO. Additionally, the enhancement of CO inside its snowline can be used to constrain the local radial pebble flux (see Zhang et al. 2020b). (There are also interesting consequences for the C/O ratio in different regions, and gas disc mass estimates based on CO and/or dust emission!)

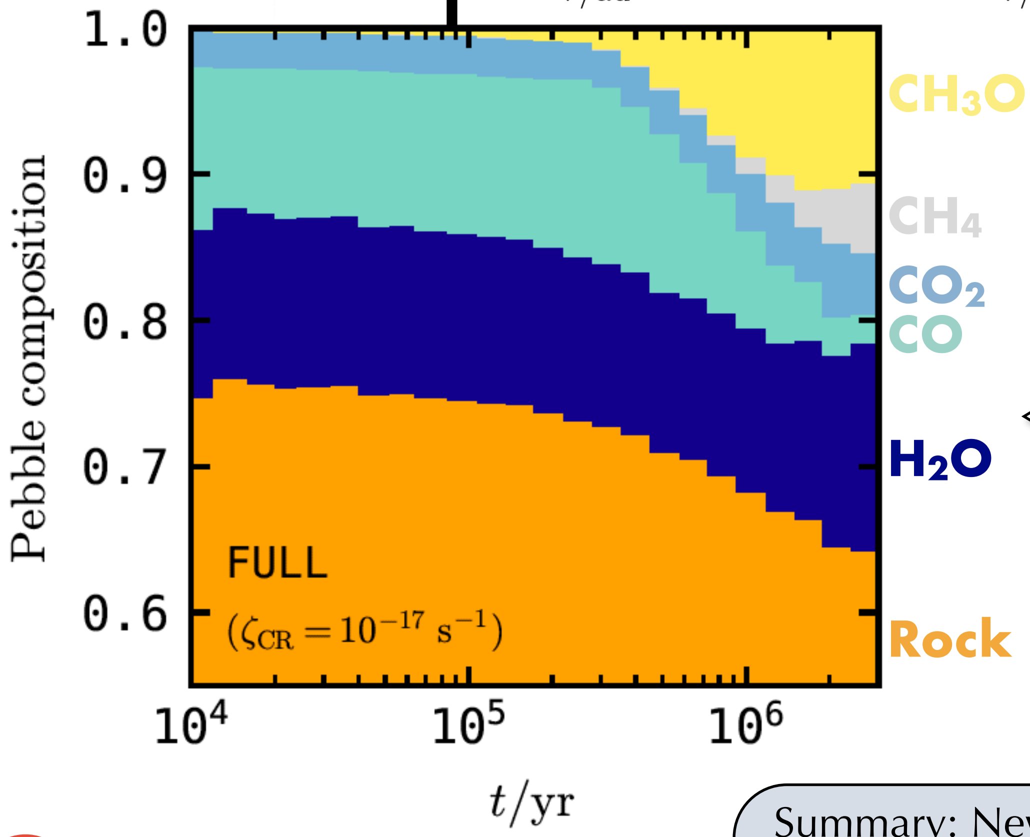


2. [e.g., Krijt et al. 2016, 2020]

Pebbles, in turn, are assembled through pair-wise coagulation of smaller dust particles, whose volatile content is set by a combination of sublimation/condensation, surface chemistry, and their dynamical history.



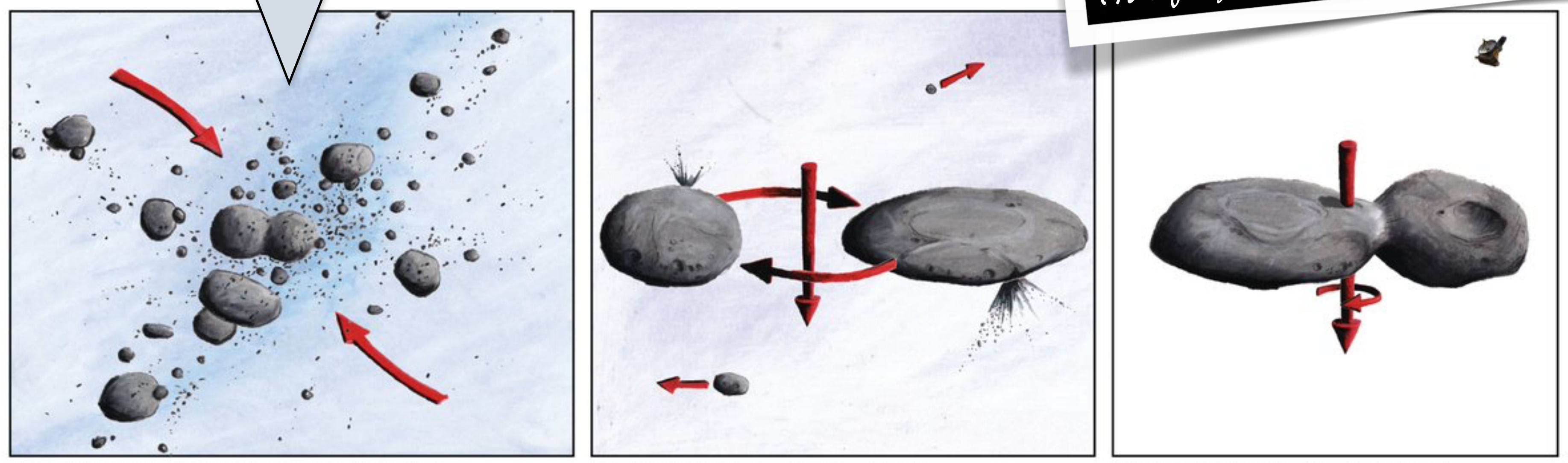




7. Focusing on the composition of pebbles in the midplane near $R \sim 45$ au (the location of the Cold Classical Kuiper belt in the solar system), we see that pebbles evolve from being rich in CO ice to being relatively poor in CO but enriched in CH_3OH & CH_4.

1. START [e.g., Johansen et al. 2015, McKinnon et al. 2020]

Planetesimals form in the slow gravitational collapse of a dense pebble cloud within a gaseous disc. The primordial composition of the planetesimal is then set by the make-up of the pebbles at the ***time*** and ***location*** where the streaming instability occurs.



A rotating cloud of small, icy bodies starts to coalesce in the outer solar system.

Eventually two larger bodies remain.

The two bodies slowly spiral closer until they touch, forming the bi-lobed object we see today.

New Horizons / NASA / JHUAPL / SwRI / James Tuttle Keane

8. [Stern et al. 2019; Grundy et al. 2020]

This is particularly interesting because NASA's *New Horizons mission to Arrokoth* (the most distant body ever to have been visited by a spacecraft!) revealed strong CH_3OH features on its surface.

9. END

Summary: New disc models designed to explain the observed depletion of C and O in the warm molecular layer lead to predictions for midplane pebble compositions. These predictions can be compared to constraints of (primordial) planetesimal compositions from the solar system or beyond, providing insights into the timing and location of formation.

Shoot me an email if you want to chat!