Wet or dry? Atmospheric recycling of volatiles in pebble-accreting planets: hydrodynamic study

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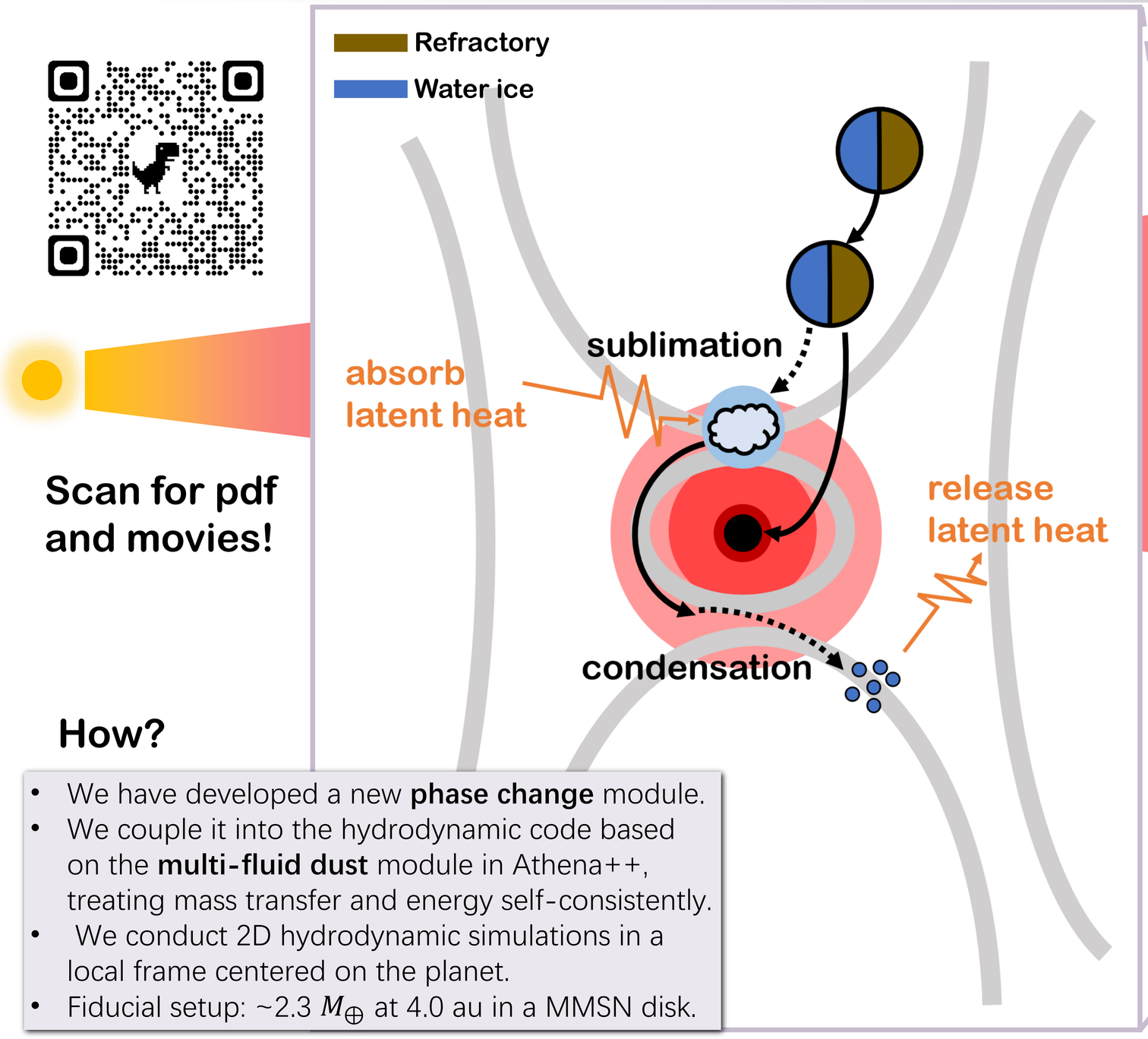
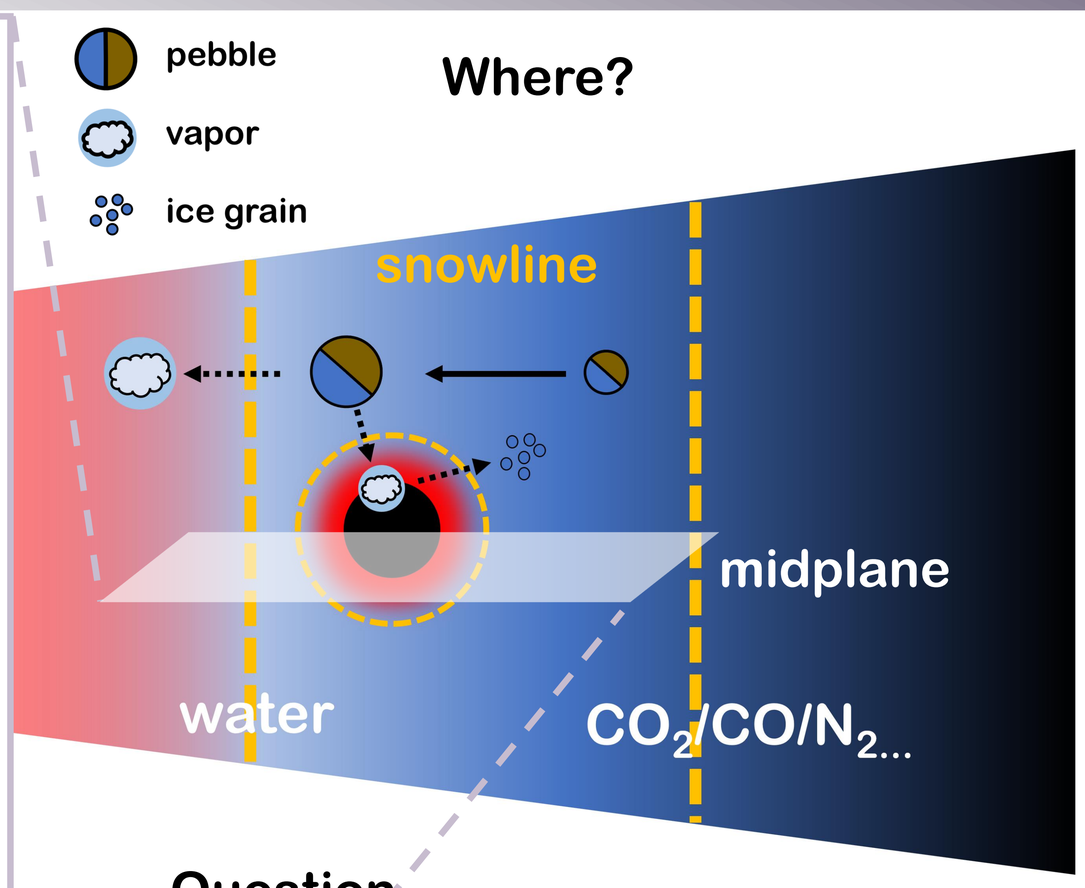




How?

- We have developed a new **phase change** module.
- We couple it into the hydrodynamic code based on the **multi-fluid dust** module in Athena++, treating mass transfer and energy self-consistently.
- We conduct 2D hydrodynamic simulations in a local frame centered on the planet.
- Fiducial setup: ~2.3 $M_\oplus$ at 4.0 au in a MMSN disk.

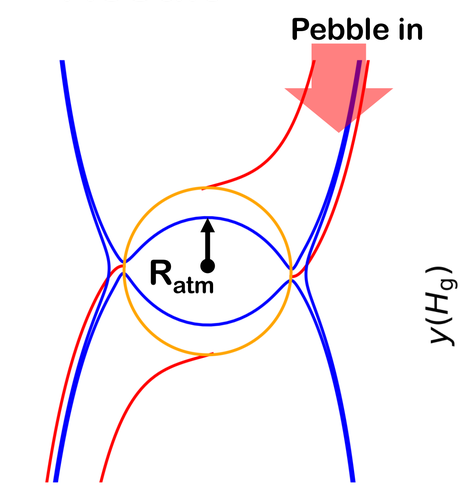
Question

- Will the volatiles contained in pebbles be recycled or remain in the atmosphere?

Why sublimation matters?

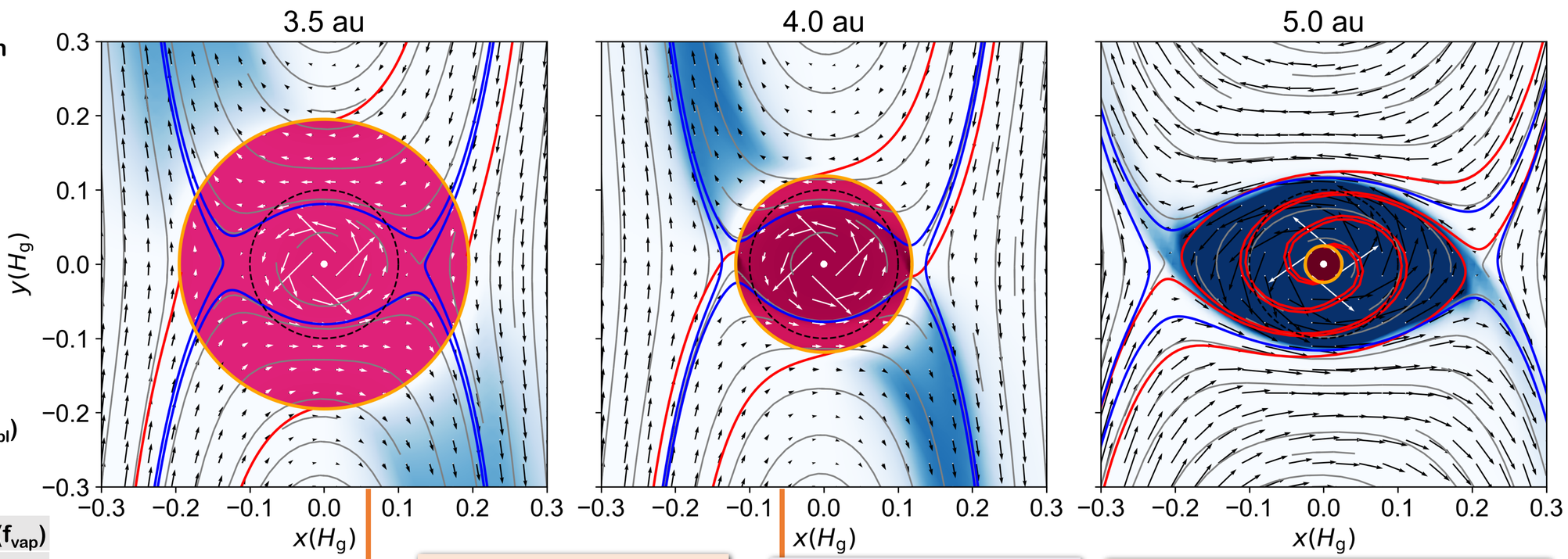
- Setting an **effective snowline** in the atmosphere by the hot planet, volatile delivery is influenced.
- Pebble sublimation alters the **thermodynamic properties** by injecting heavy elements.

Result



Inside R_{subl} :Vapor fraction (f_{vap})

Outside R_{subl} :Ice grain fraction

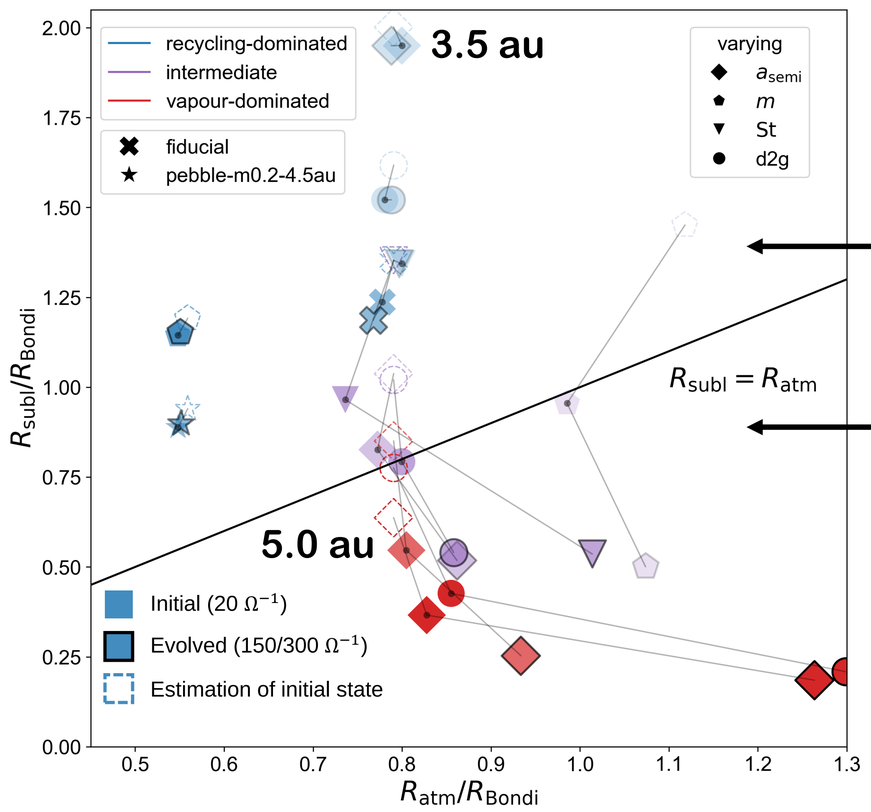


Recycling-dominated
- Steady state, f_{vap} ~1%
- $R_{atm} < R_{subl}$

Initial condition:
Pebble-to-gas ratio: 2%
50% water.

Vapor-dominated
- Non-steady, f_{vap} >30% ⬆ growing!
- $R_{atm} >> R_{subl}$

Parameter study



Findings

Relative size of **R_{atm}** and **R_{subl}** determines the recycling efficacy.

Initial values of **R_{atm}** and **R_{subl}** determine the evolutionary direction.

Vapor-dominated runs show divergence of **R_{atm}** and **R_{subl}**, which triggers vapor growth in a **positive feedback** way.

We construct an **estimator** based on initial conditions and material properties. Appling it to Earth, we find its water content is likely dry.

Apply to Earth