# Study of solid accretion in mean motion resonances with gas giants via N-body simulations: Toward understanding the formation of Uranus and Neptune

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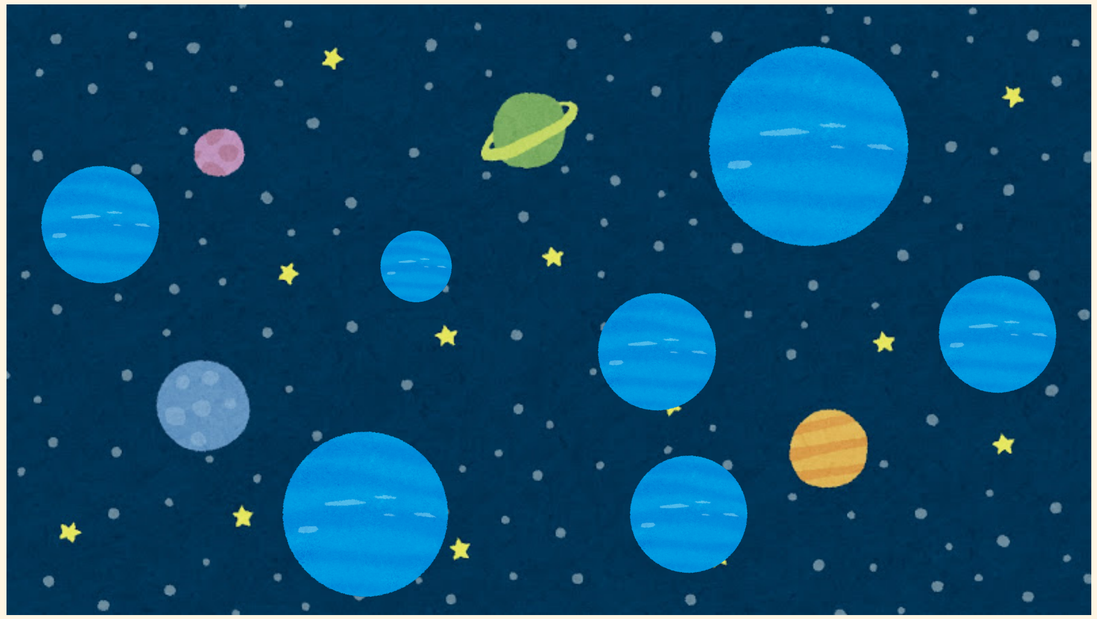
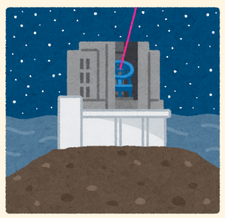
# The current picture of the formation of Uranus and Neptune

## In exoplanets systems





Many Neptune-like planets beyond the snow line

## In Solar system

**Uranus**

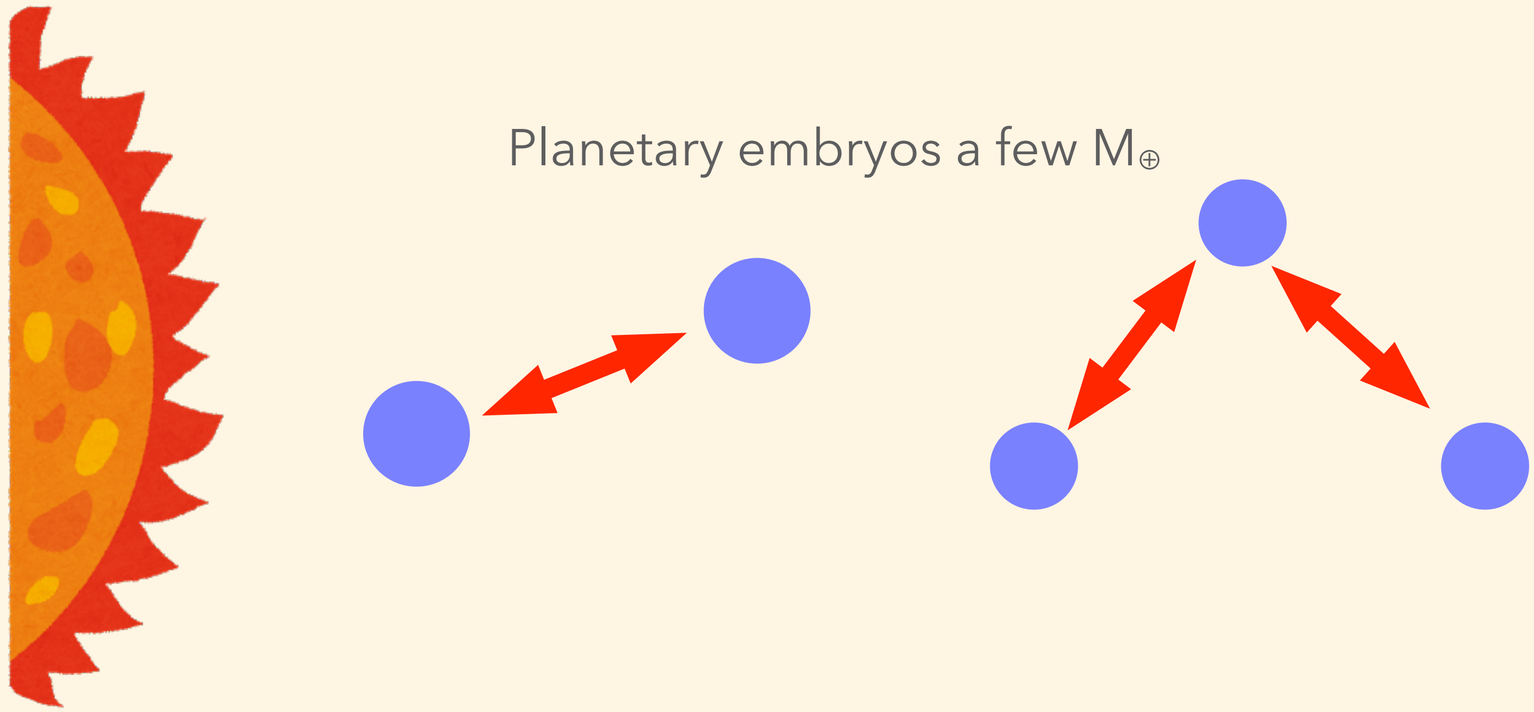
**Neptune**

**Mass: 14.5 $M_\oplus$ 17.1 $M_\oplus$**
(NASA Planetary Fact Sheet)

**The formation process of Uranus and Neptune is important for understanding the origin of such exoplanets.**

In a promising formation scenario of Uranus and Neptune…

**Giant collision between planetary embryos**




**How did such embryos accrete in the early Solar system?**

# A possible model

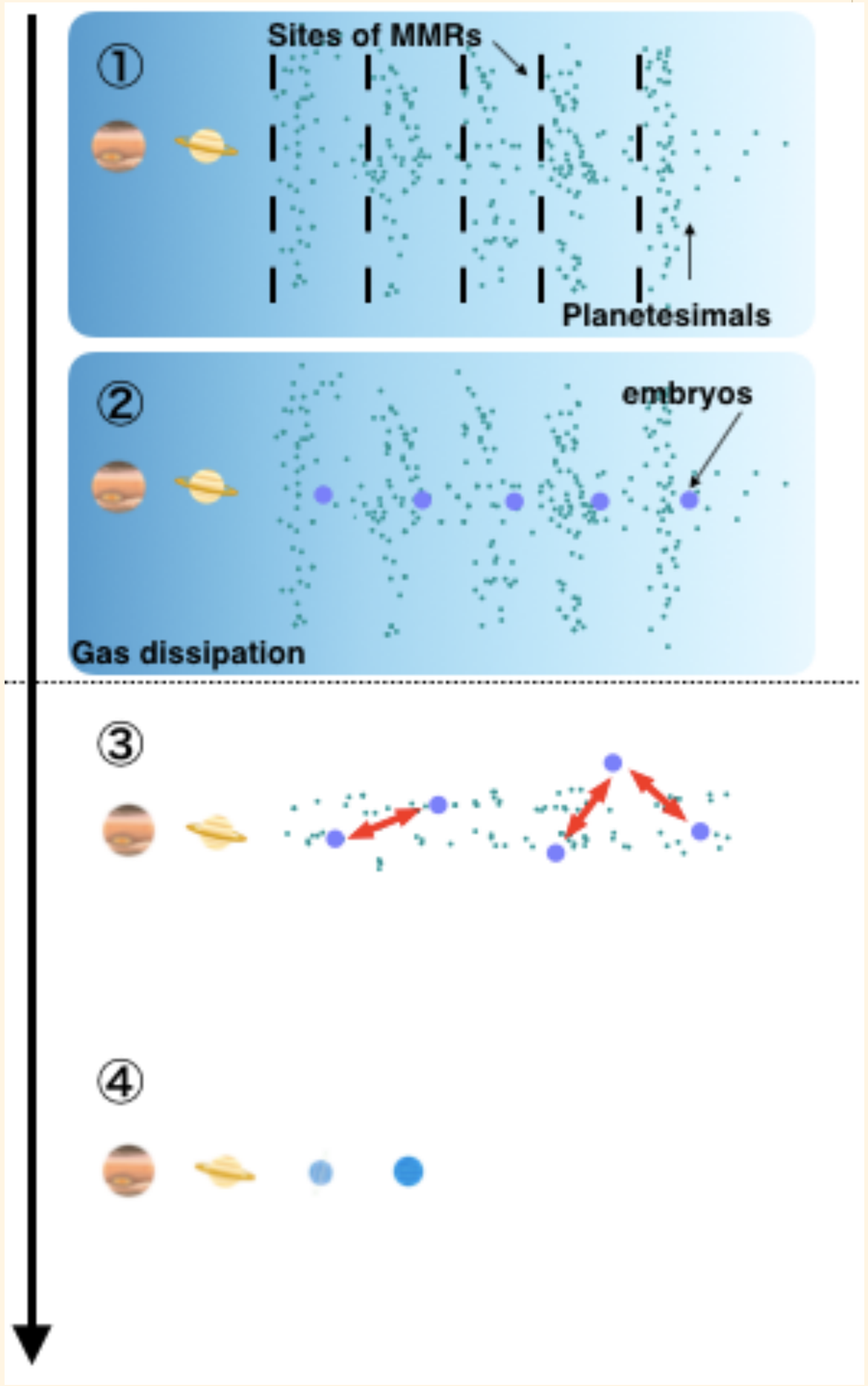
①The accretion of planetesimals trapped in **mean motion resonances (MMRs)** with inner giant planets

②The formation of Embryos near MMRs

③Giant collisions of embryos **after gas dissipation**

- **After disk gas dissipation, the proto-embryo system becomes dynamically unstable, leading to collisions of embryos.**

④The formation of core of Uranus and Neptune



## Objective & Method

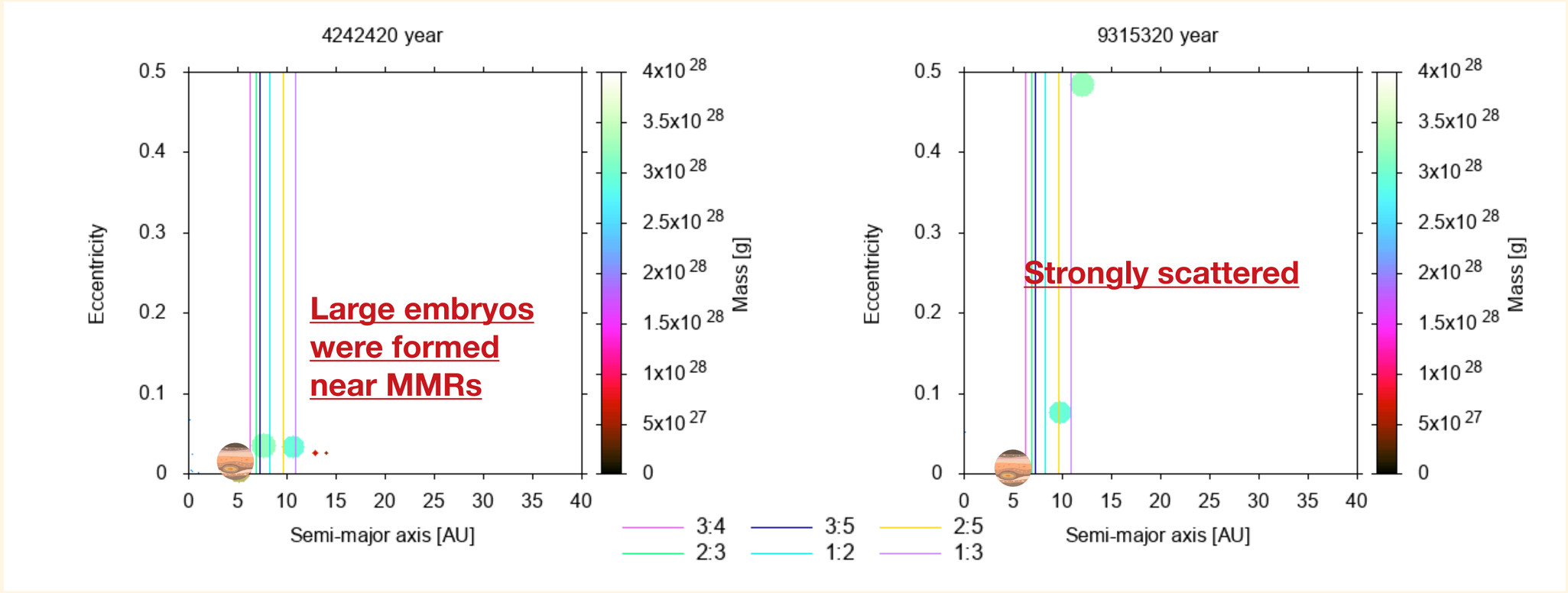
- To investigate
  - **The effect of MMRs with inner giant planets on planetary accretion**
  - **The dynamics of embryos in MMRs in the presence of disk gas**

**Initial condition**


- 2D *N*-body simulation.
- Planetesimals (N=1000, $m_0 \sim 9.0 \times 10^{25}$ g) are distributed in a 2D ring (6.5 – 15 AU) with Jupiter.
- In accordance with Beaugé et al. (1994), the following interactions are considered:
  - Mutual gravitation between planetesimals
  - Gravity of Jupiter and Sun
  - Gas drag (which we have enhanced for saving the computational time)

# Results & Comparison with Beaugé et al. (1994)

## Snapshot in my simulation




- Large embryos (~ $10^{28}$g) are formed through accretion of planetesimals near the MMRs.
- In my result, instead of giant collisions, **embryos undergo mutual gravitational scattering.**
- In Beaugé et al. (1994), **giant collisions of the embryos occurred in the presence of the disk gas**.

**We conclude that before gas dissipation,**
**giant collisions of large embryos near MMRs do NOT always occur.**