

# Gas Accretion in the Final Stage of Gas Giant Formation

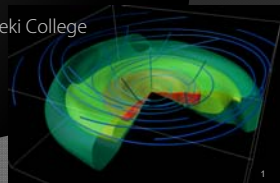
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Giant planets, such as Jupiter or Saturn, are thought to be formed by capturing protoplanetary disk gas onto well-grown solid protoplanets with about 10 earth masses. The gas-capturing growing phase occurs in the last stage of planetary system formation. The gas accretion flow is the key to understand, for example, the formation of satellites around the giant planets, budget of angular momentum of the planets, etc. In this talk, we explain the basic structure of the gas accretion flow toward the planet based mainly on our three-dimensional hydrodynamic simulation with nested grid technique, which allows us to obtain high resolution flow structure near the planet with high efficiency. We first found that the channel of the gas flow from the protoplanetary disks toward the planet is not through the disk midplane, but through the above. In the planet gravitational sphere (Hill sphere), circumplanetary disks, in which natural moons are thought to be formed, are formed as a pathway toward the planet. In the disk, gas is rotating around the planets with near Keplerian velocity, and in the hydrostatic equilibrium in the direction perpendicular to the disk midplane. The gas accretion from the above makes strong shock surface at the top of the circumplanetary disks, which would make very high temperature ( $\sim 10^4\text{K}$ ) in the post-shock thin layer. The obtained mass and angular momentum flux is approximated as a power-law function with respect to the distance from the planets, which would be the basis for the structure and formation of circumplanetary disk when we consider satellite formation processes.

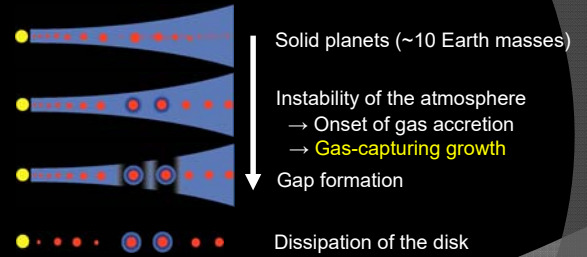
# GAS ACCRETION IN THE FINAL STAGE OF GAS GIANT FORMATION

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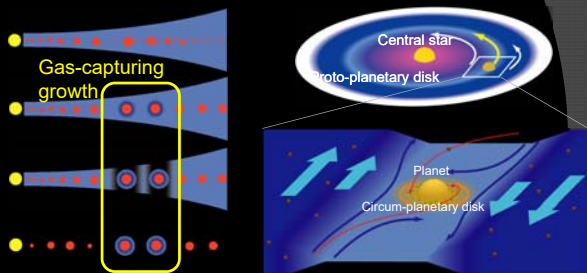
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# Formation of Giant Planets



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# Formation of Giant Planets



- Giant Planets are formed by capturing gas with Keplerian shear motion
- Disks around the planets are thought to be formed in this stage

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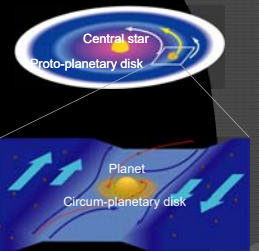
# Structure of the Accretion flow?

## Direct numerical simulations

- ⊙ Difficult to spatially resolve the accretion flow to the planet
  - $R_J \sim 1/10000 a_J$
  - → needs very high resolution

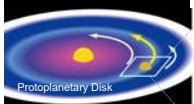
## In this study

- ⊙ Sufficiently high resolution for the flow near the planet
- ⊙ In-depth analysis of the accretion flow and the structure of the circum-planetary disk

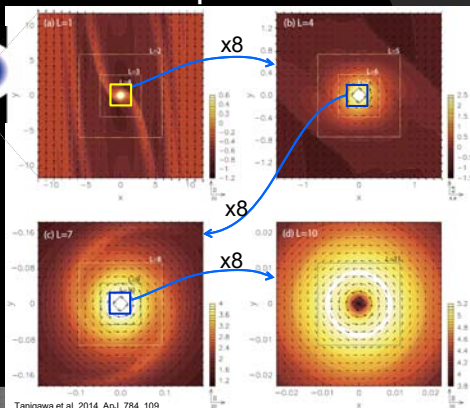


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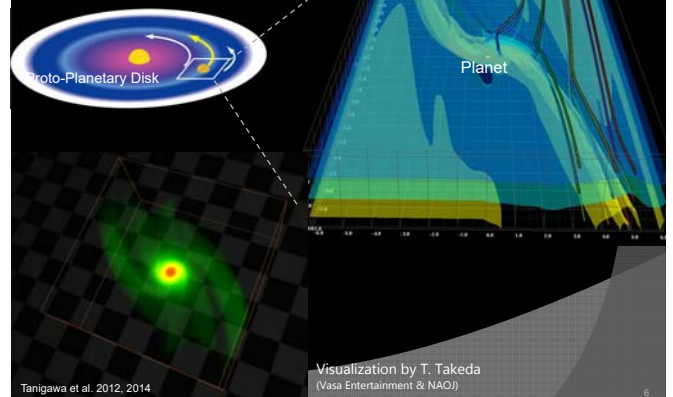
# Gas flow at the midplane



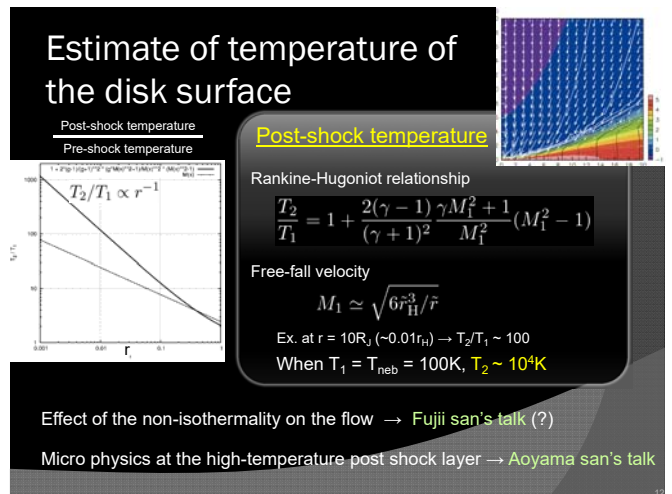
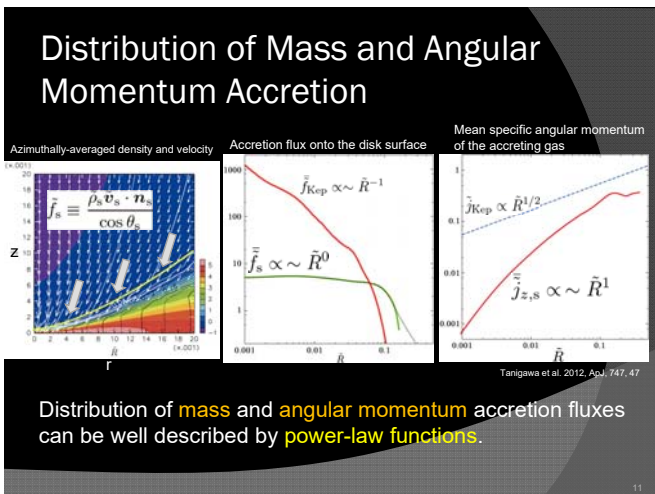
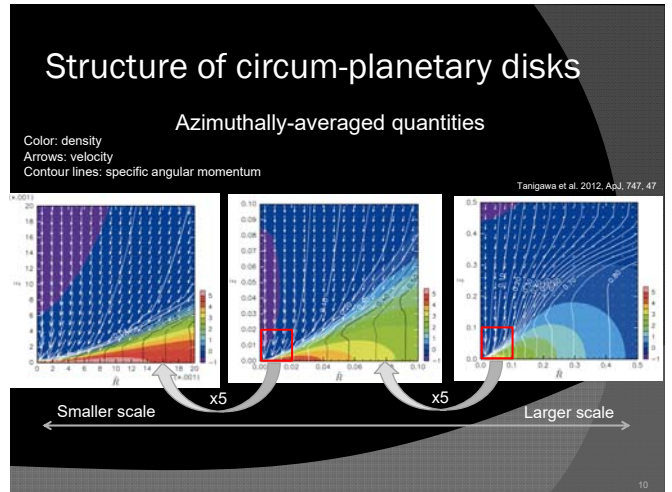
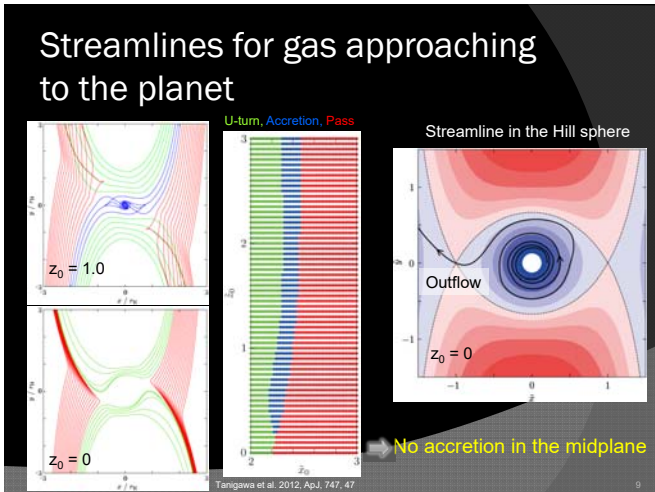
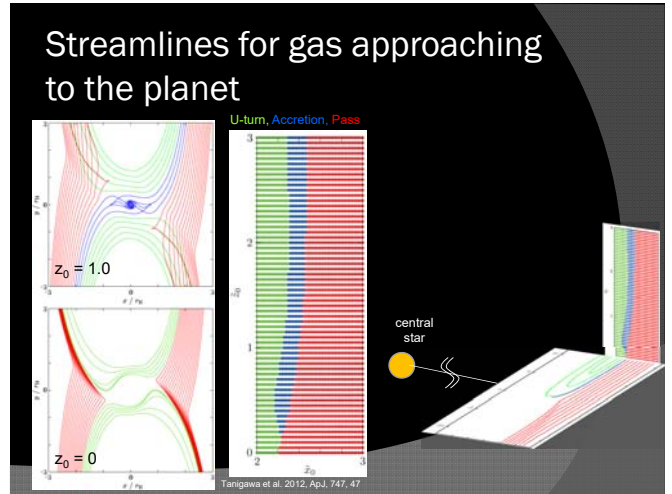
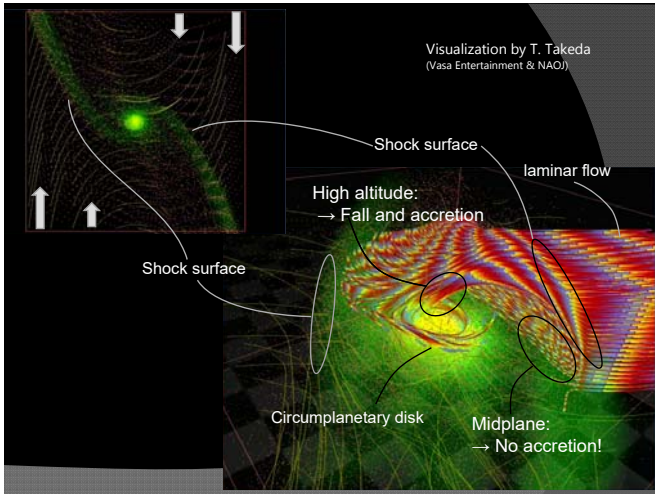
- 3D-local simulation
- Nested grid method (Matsumoto & Hanawa 2003)
  - 11 levels
- Isothermal EOS



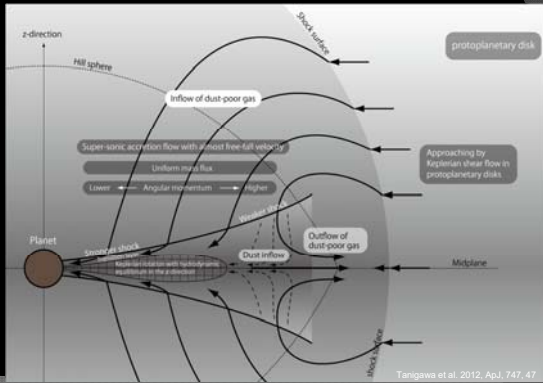
# Accretion flow structure



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## Picture of the accretion flow



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## Interaction between CPD and the planet magnetic field

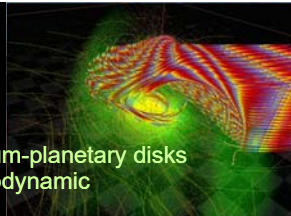
- “Despin mechanism for protogiant planets and ionization state of protogiant planetary disks”
  - Takata & Stevenson 1996
- “On the terminal rotation rates of giant planets”
  - Batygin 2018

Batygin 2018



## Summary

- Gas accretion flow onto circum-planetary disks by very high-resolution hydrodynamic simulation.
  - **Accreting gas jumps over dense circum-planetary disks and falls directly into the vicinity of planets.**
    - → Well accelerated by planet gravity
    - → Effective energy dissipation through strong shocks
  - **No accretion in the midplane and outflow from the Hill sphere**
    - → Possible mechanism to change **dust/gas ratio** of circumplanetary disks and parent planets
  - **Distribution of gas and angular momentum accretion**
    - Well described by **power-law functions**



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