On the Diversity of Satellite Systems formed form Roche-interior Particle Disks

(Hyodo et al. 2015, ApJ 799 40, arXiv: 1411.4336)

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Introduction

● <u>Single Satellite System：</u>

-Earth-Moon (M_s/M_c~0.012)
-Mass ratio to the host planet M_s/M_c is relatively high
(M_s: satellite mass, M_c: mass of the central planet)

image courtesy of NASA

Introduction

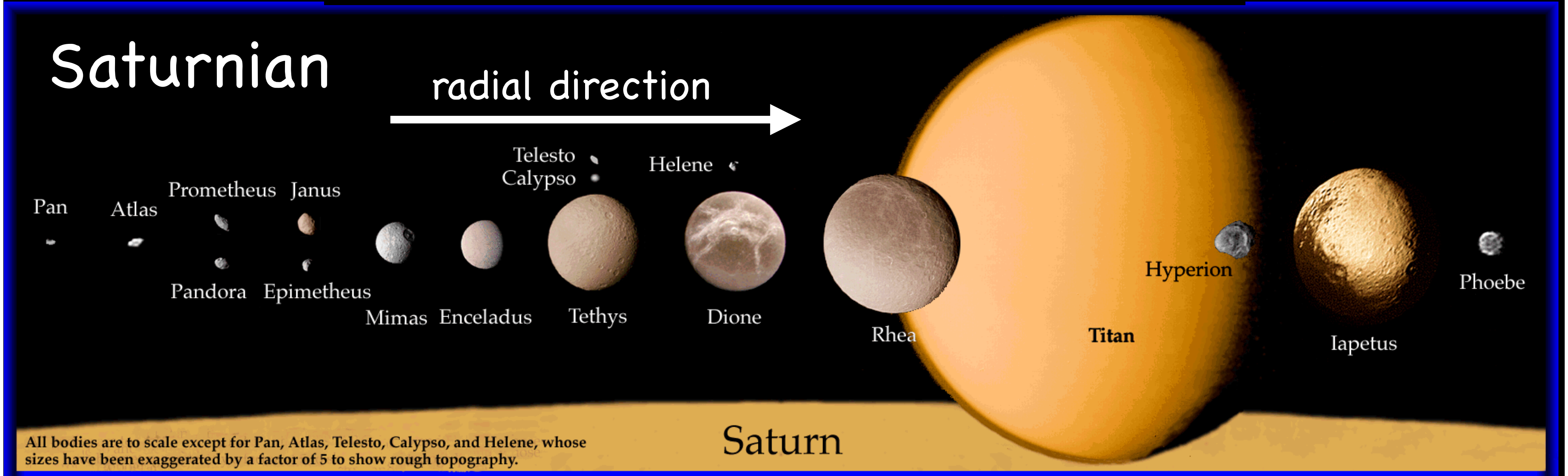


image courtesy of NASA

- Multiple Satellite System :

-inner major satellites: nearly circular, coplanar orbits

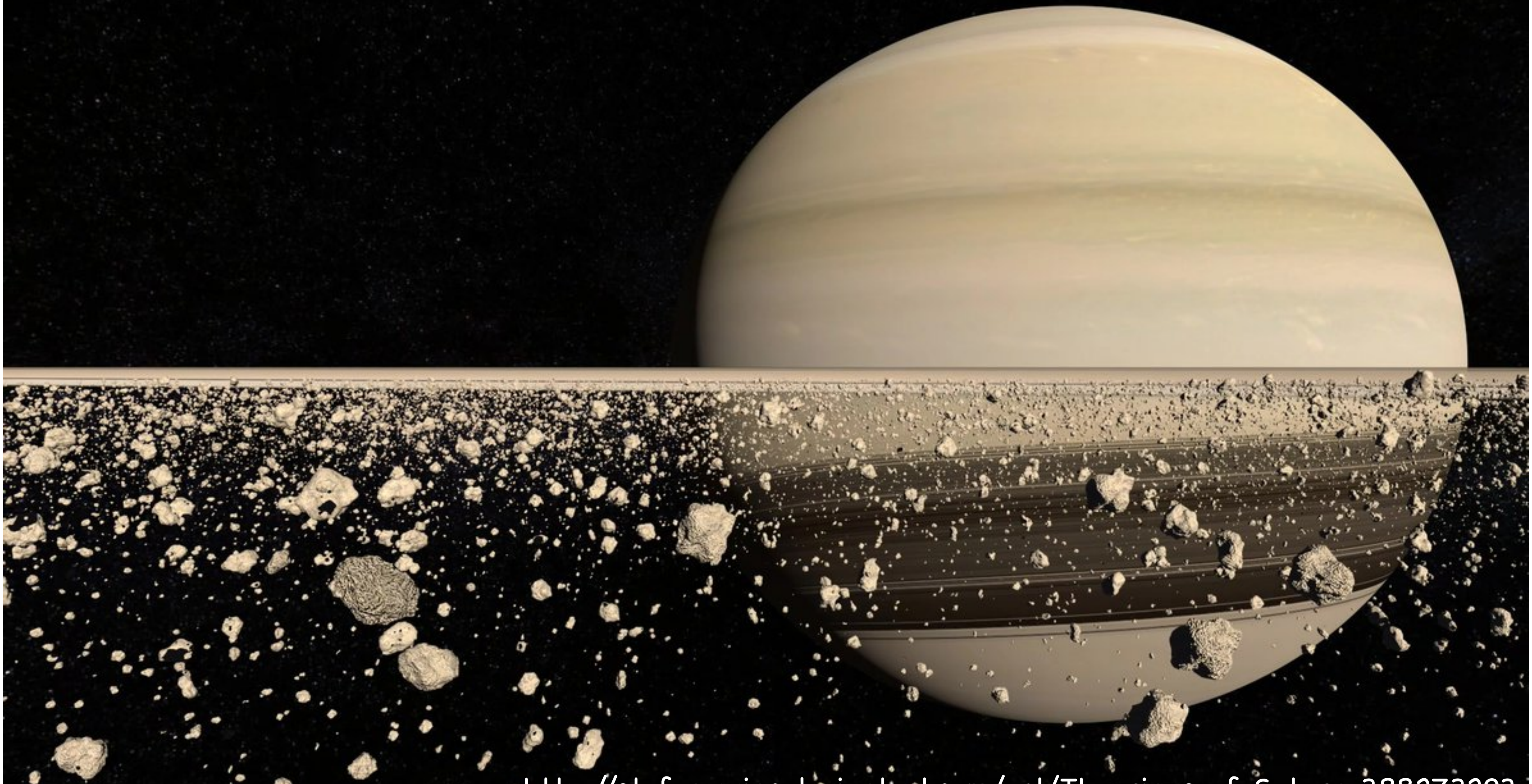
-located just outside the Roche limit

-small mass ratio to the host planet ($M_s/M_c \sim 10^{-4}$)

-increasing mass with increasing radial distance

-the existence of co-orbital satellites

From Particle Disks (or Rings) to Satellite Systems??



http://stefanpwinc.deviantart.com/art/The-rings-of-Saturn-388273293

Investigate Disk Evolution

(Hyodo et al. 2015, ApJ)

-Equal sized particles (N=50,000)

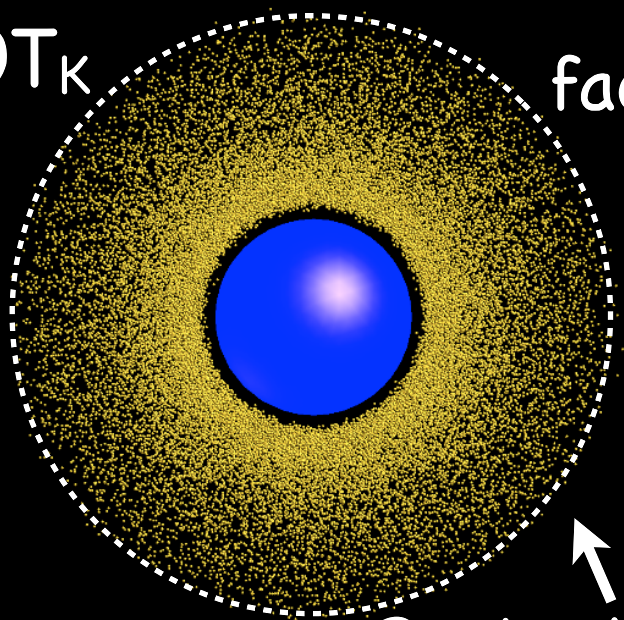
-Radial distribution : 0.4-1.0a_R (a_R : Roche limit)

-"massive disk" : $M_{disk,init} = 0.045M_c$

-"less massive disk" : $M_{disk,init} = 0.0235M_c$

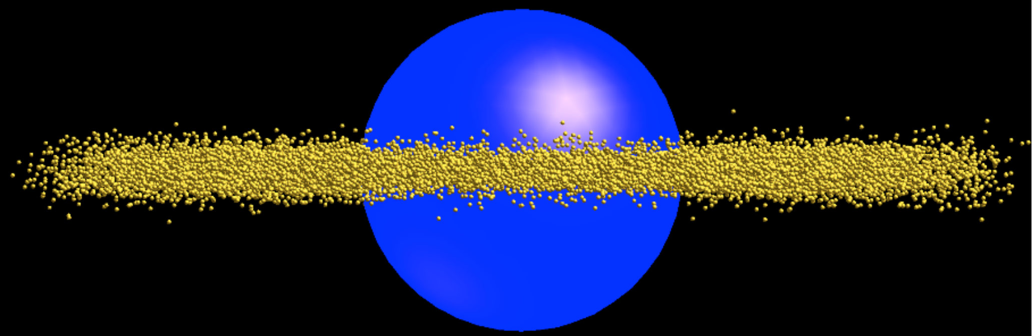
t=0T_K

face-on view



Roche limit a_R

edge-on view



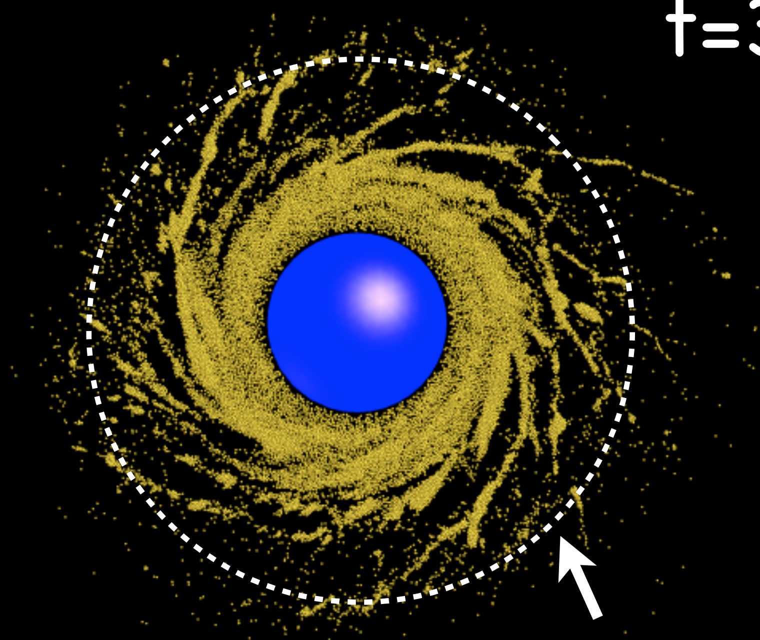
T_K: orbital period @ a_R

Case of Massive Disk

Case of Massive Disk

($M_{disk,init}$=0.045M_c)

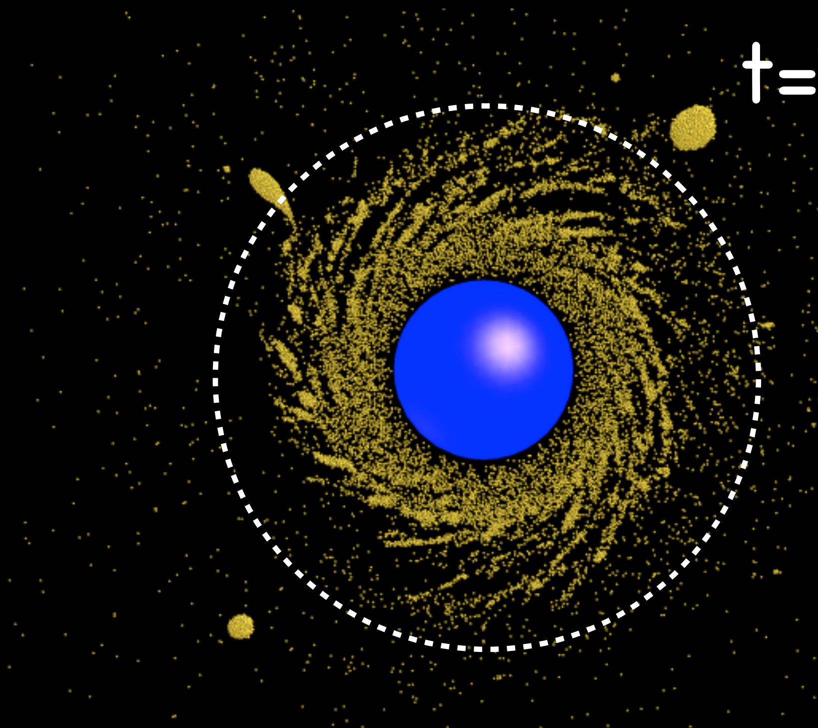
$t=3T_K$



Roche limit a_R

- Disk material is transferred outside the Roche limit.
- Outside the Roche limit, particles start to form gravitationally bound aggregates.

$t=22T_K$

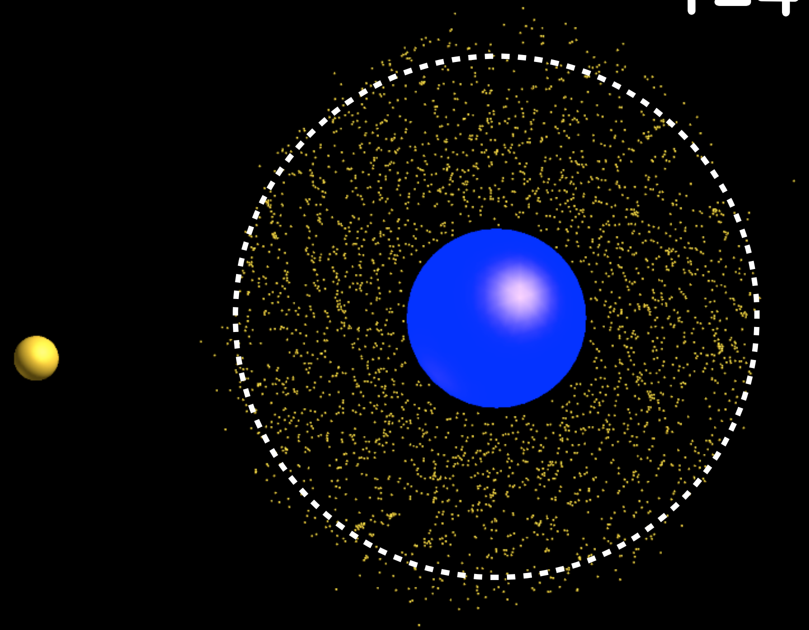


- Some aggregates re-enter the Roche limit and are disrupted.
- Aggregates grow through collisions with other aggregates or disk particles.

Case of Massive Disk

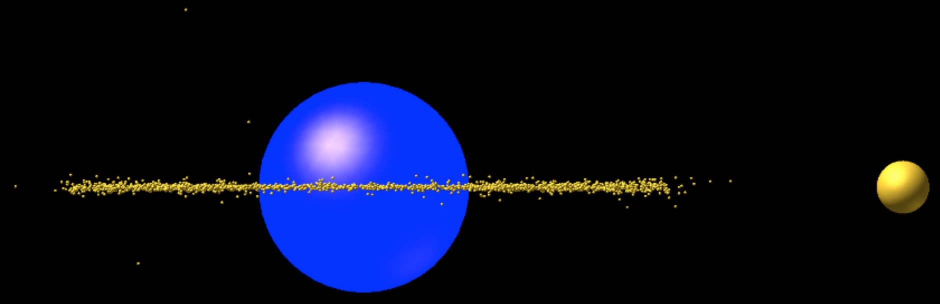
($M_{disk,init}$=0.045M_c)

t=434T_K



- The satellite and the disk repelled each other due to gravitational interaction
- A large amount of disk material has fall into the central plant

t=434T_K



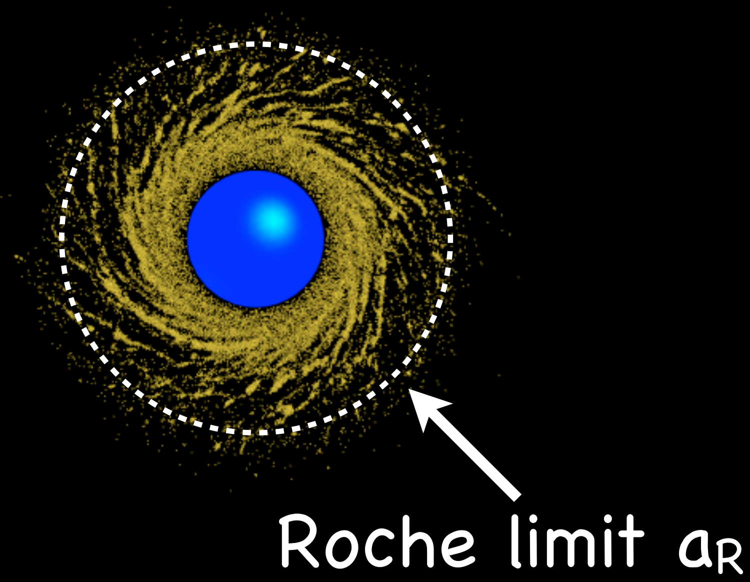
- A single relatively large satellite is formed and only a very small fraction of the disk material remain (e.g. Ida et al. 1997)
- The formed satellite is on nearly circular orbit with low inclination

Case of Less Massive Disk

Case of Less Massive Disk

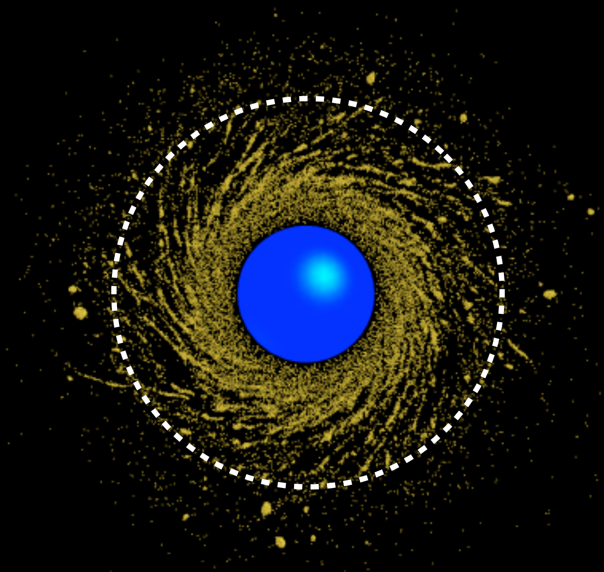
($M_{disk,init}$=0.0235M_c)

t=5T_K



- Spirals extend radially outward and disk material is transferred outside the Roche limit.

t=20T_K

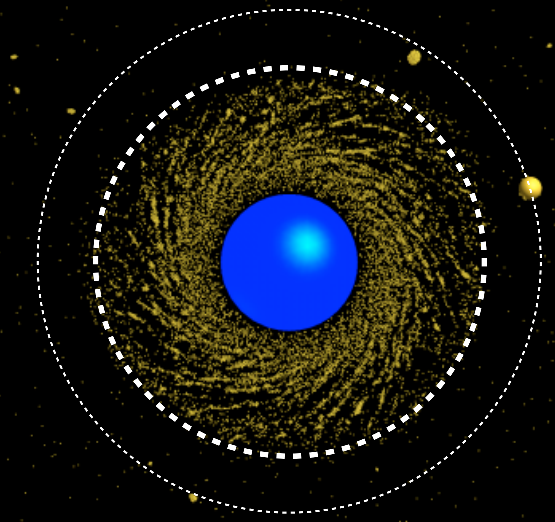


- The timescale of the disk evolution is longer and mass transfer rate is smaller compared to relatively massive disk.

Case of Less Massive Disk

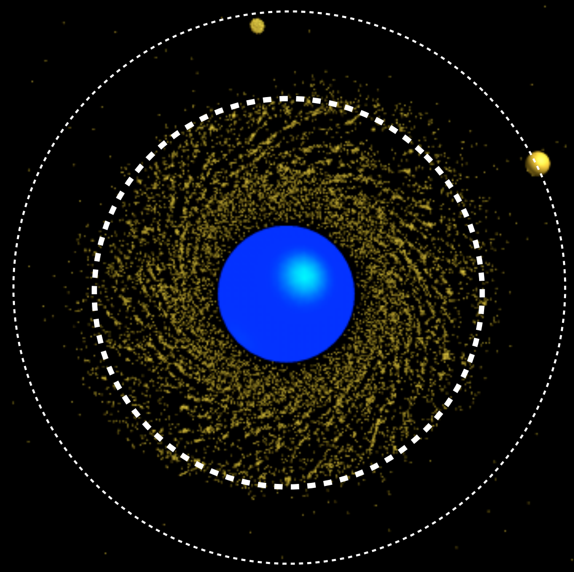
($M_{disk,init}$=0.0235M_c)

t=50T_K



- 1st satellite is smaller compared to the "massive disk" case
- There still remain a large amount of disk material
- A small companion is formed with the 1st satellite

t=100T_K

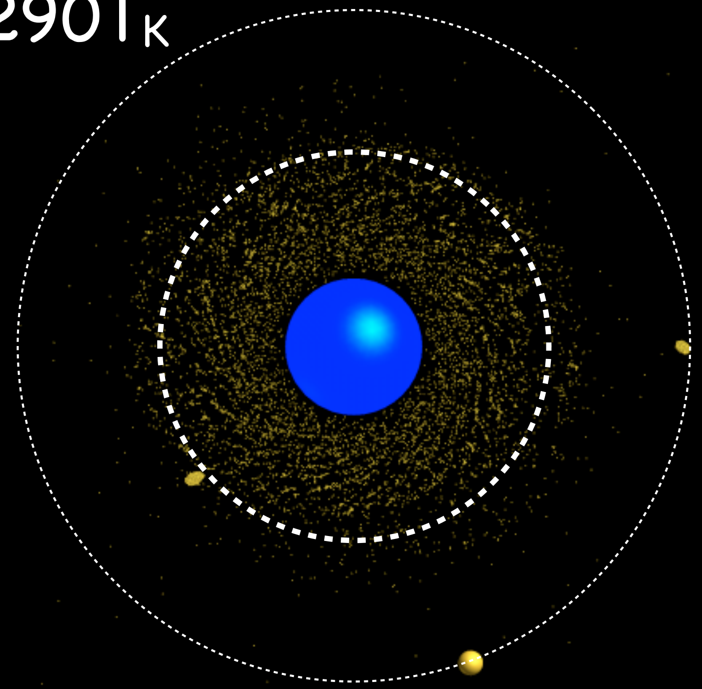


- Even thought the satellite migrates outward and the disk move inward due to gravitational interaction, not huge amount of disk particles fall into the central planet
- The 1st satellite migrates further outward

Case of Less Massive Disk

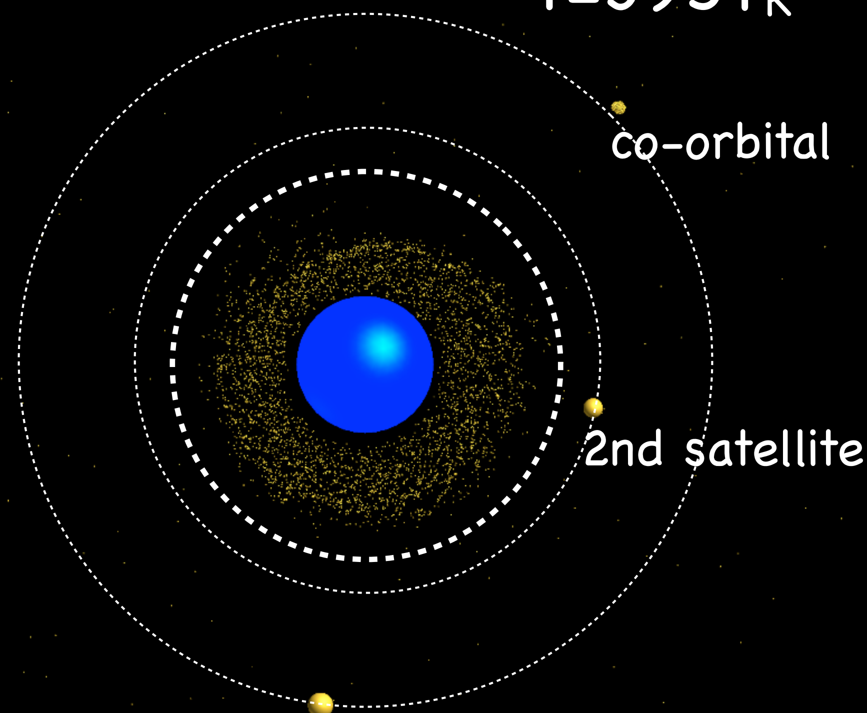
($M_{disk,init}$=0.0235M_c)

t=290T_K



- 1st satellite migrates sufficiently outward and the location of its 2:1 mean motion resonance (MMR) moves just outside the Roche limit, where disk particles are piled up.

t=395T_K



- 2nd satellite is formed from particles piled up at the 2:1 MMR and is locked around the resonance.

Take-home messages

(Hyodo et al. 2015, ApJ)