南京大學
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Planet Migration

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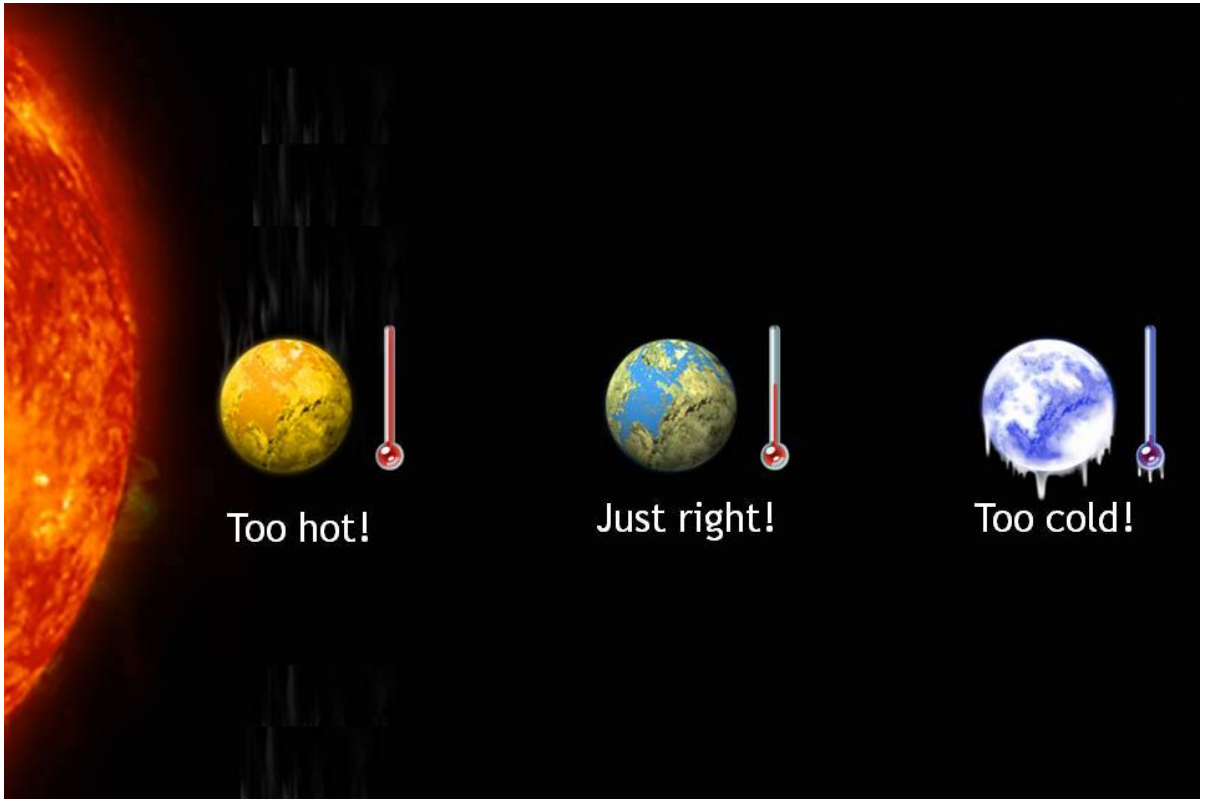
Earth 351 presentation, NU, 2017 May 24

Dynamical point of view



habitable planets

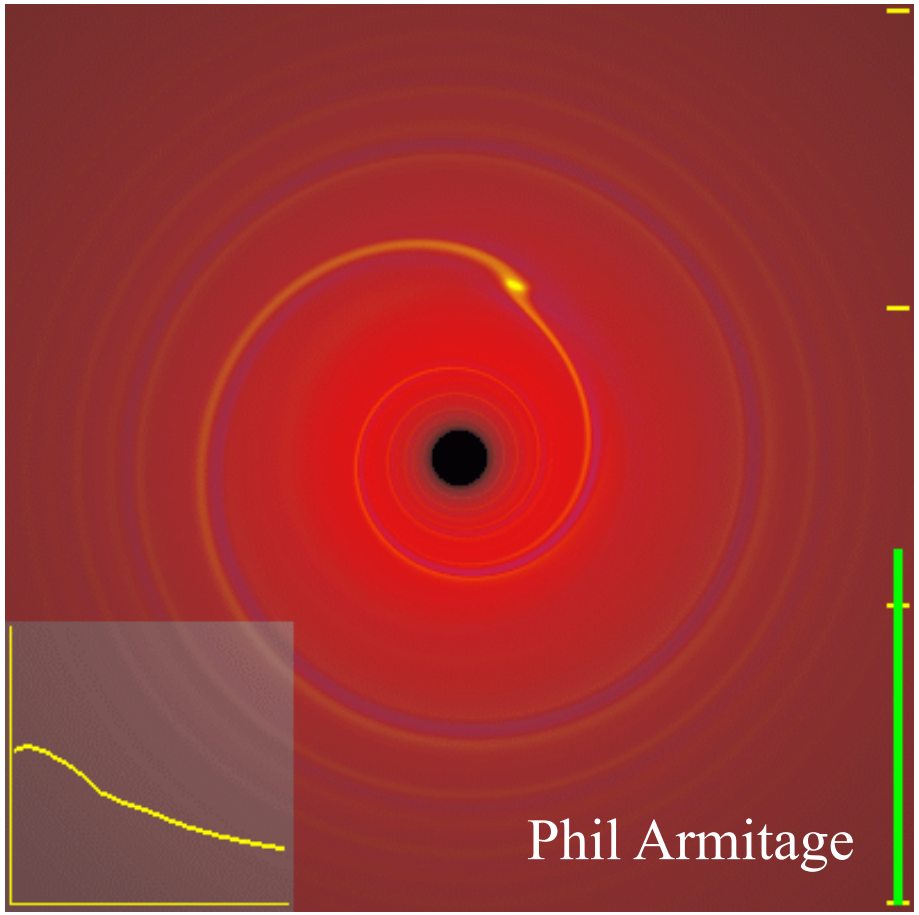
liquid water

right distance

migration

Type I migration

A *rapid* migration happens when planets are not massive enough (< $30M_{Earth}$) to perturb the disc significantly.



Disk surface density

$\Sigma \propto r^{-s}$, generally $s = 3/2$

Migration timescale

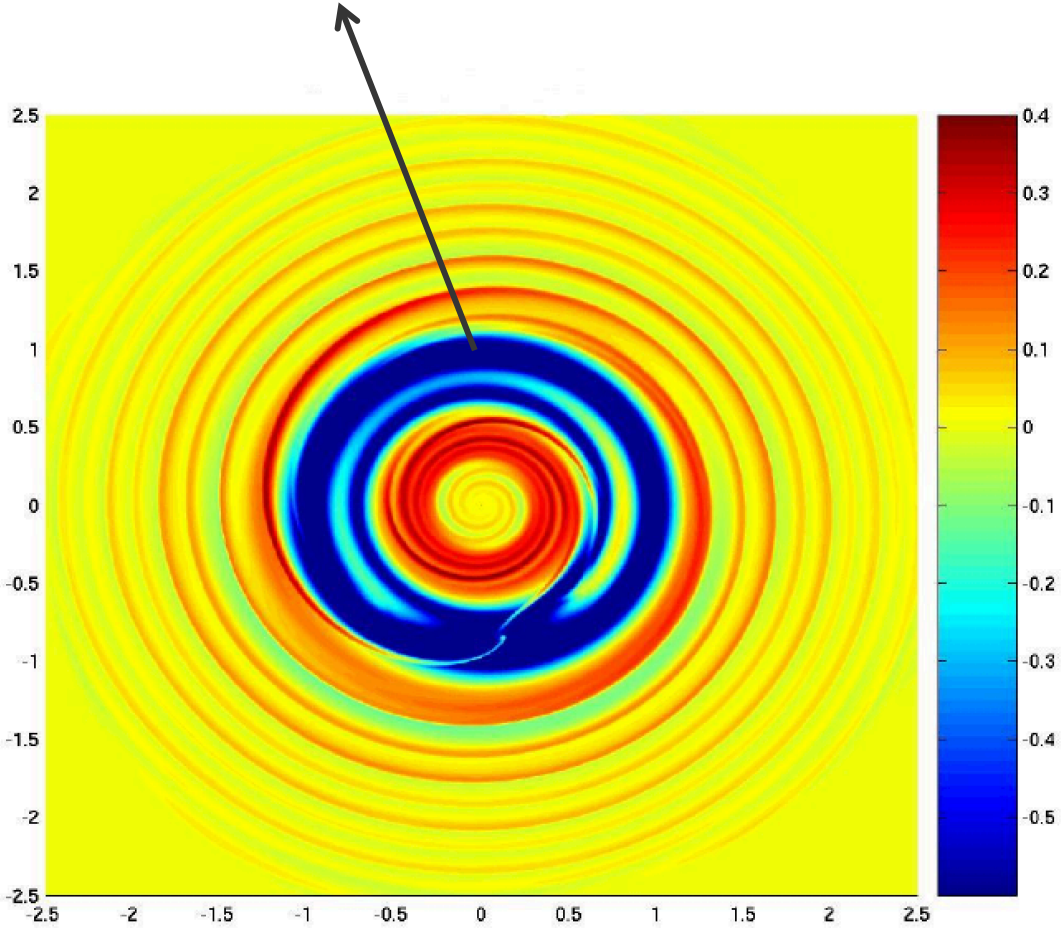
$$\tau = \frac{r_p}{\dot{r}_p} = (2.7 + 1.1s)^{-1} \frac{M_*^2}{M_p \Sigma r_p^2} \left(\frac{H}{r_p} \right)^2 \Omega_p^{-1}$$

Earth-size planet at r_p = 1AU:
$\tau \sim 0.15$ Myr

Refs:
(1) W. R. Ward, Icarus, 1997
(2) H. Tanaka et al., ApJ, 2002

Type II migration

A *relatively slow* migration happens as the planet mass grows and a GAP opens in the disc at the planet's radius.



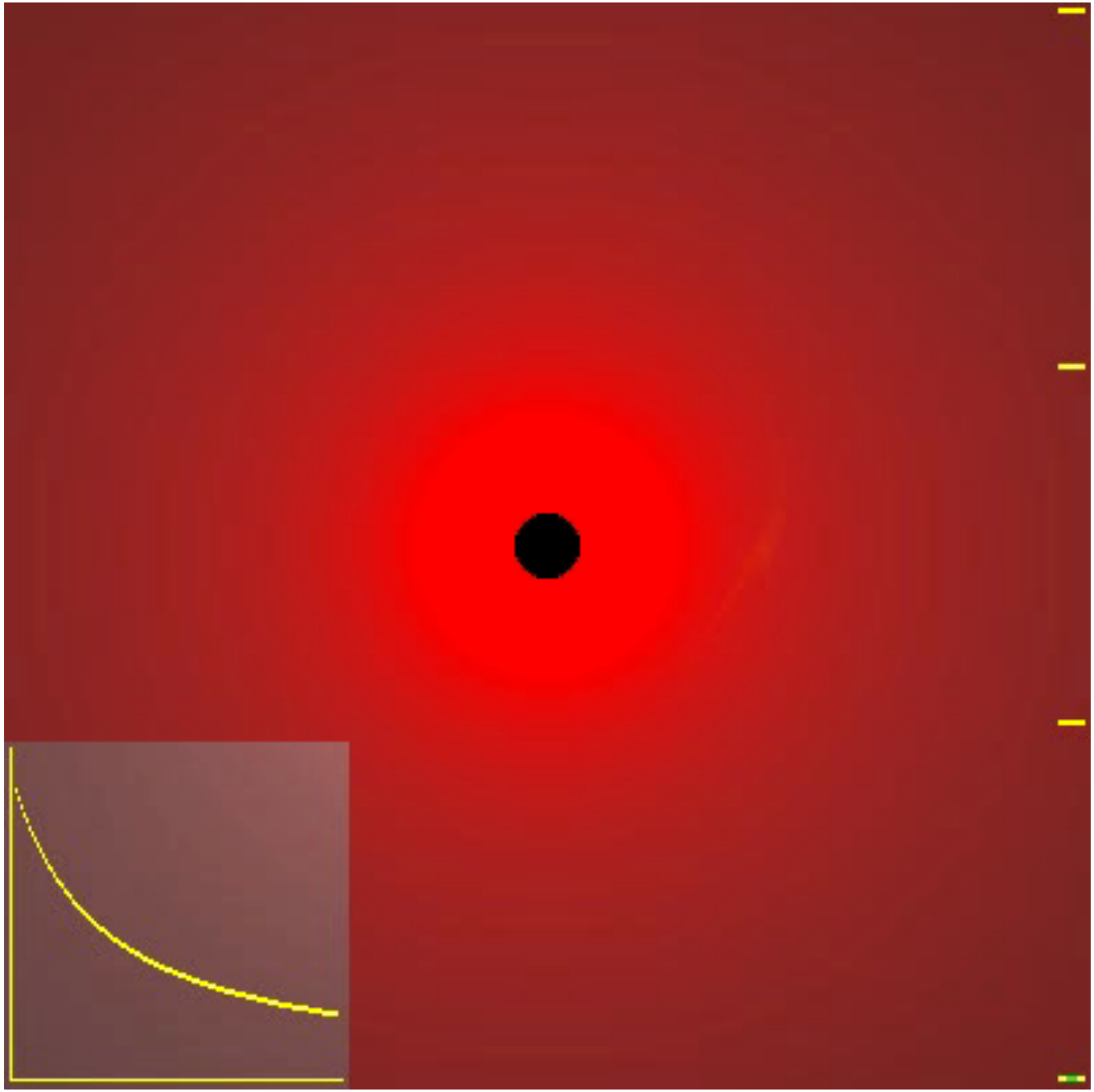
Migration timescale

$$\tau = \frac{0.05}{\alpha}\left(\frac{r_p}{H}\right)^2\left(\frac{r_p}{1\mathrm{AU}}\right)^{3/2}$$

α: disk's viscosity parameter
H: disk's half height.

Planet at r_p = 5AU: τ ~1–10 Myr

(Shakura et al. 1973 ApJ)



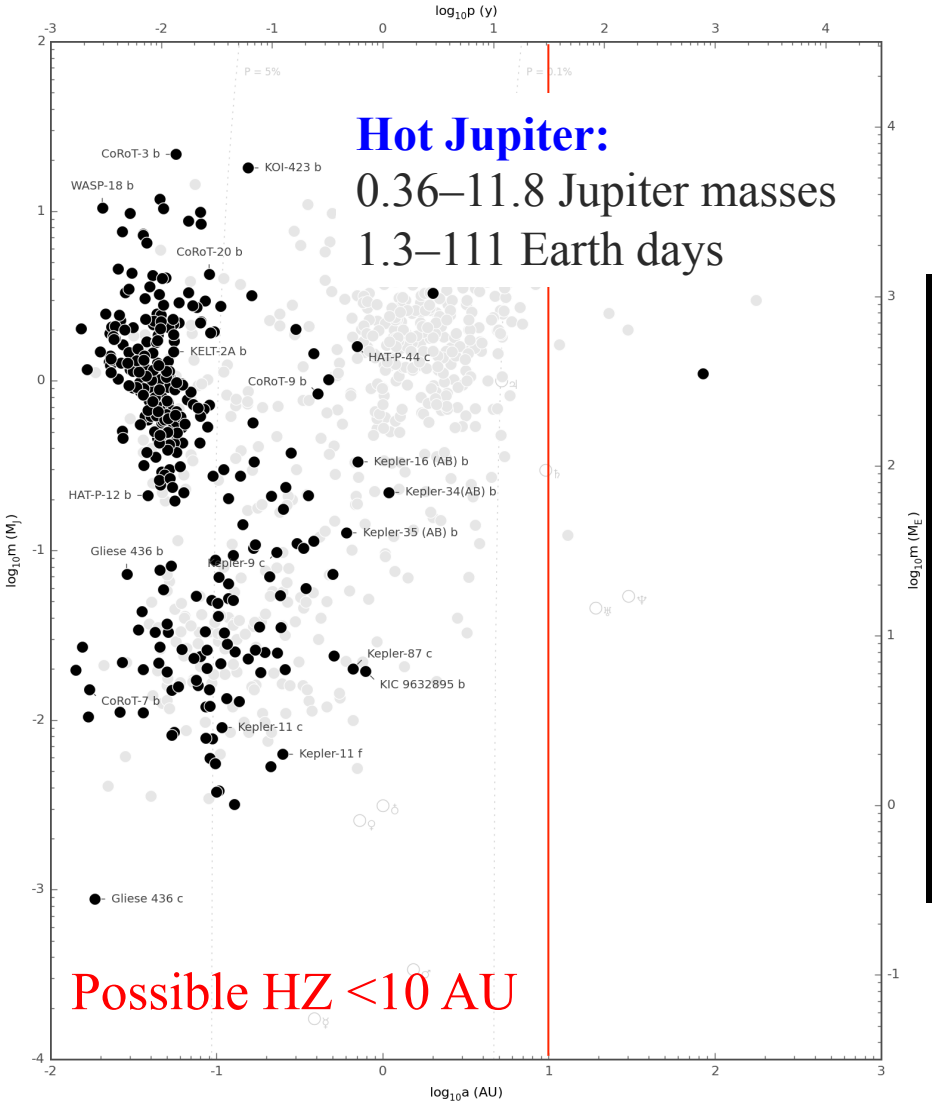
Type II migration

Gap opening

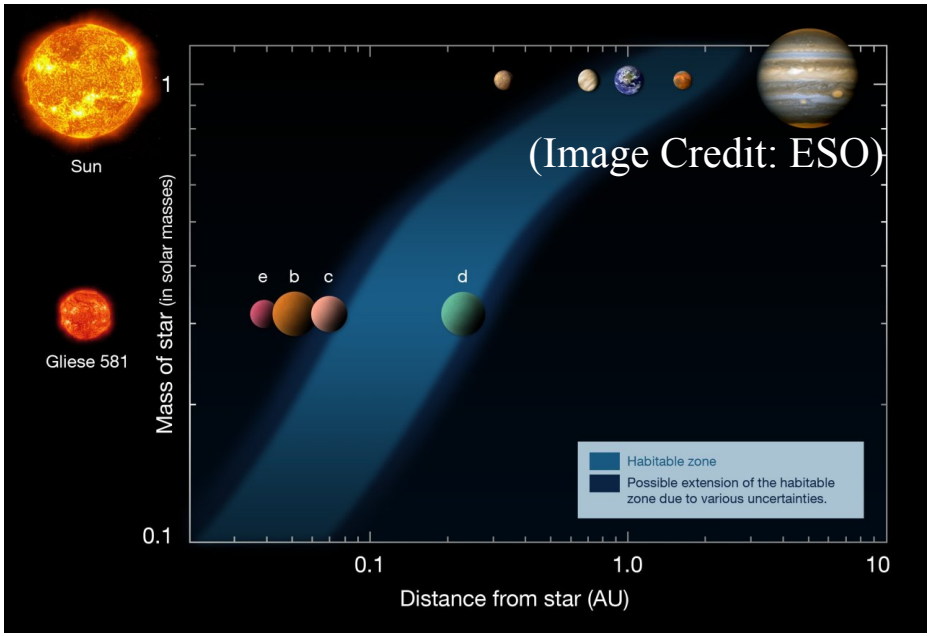
Type I migration

From: http://jila.colorado.edu/~pja/images/planet.mpg

Exosolar Systems

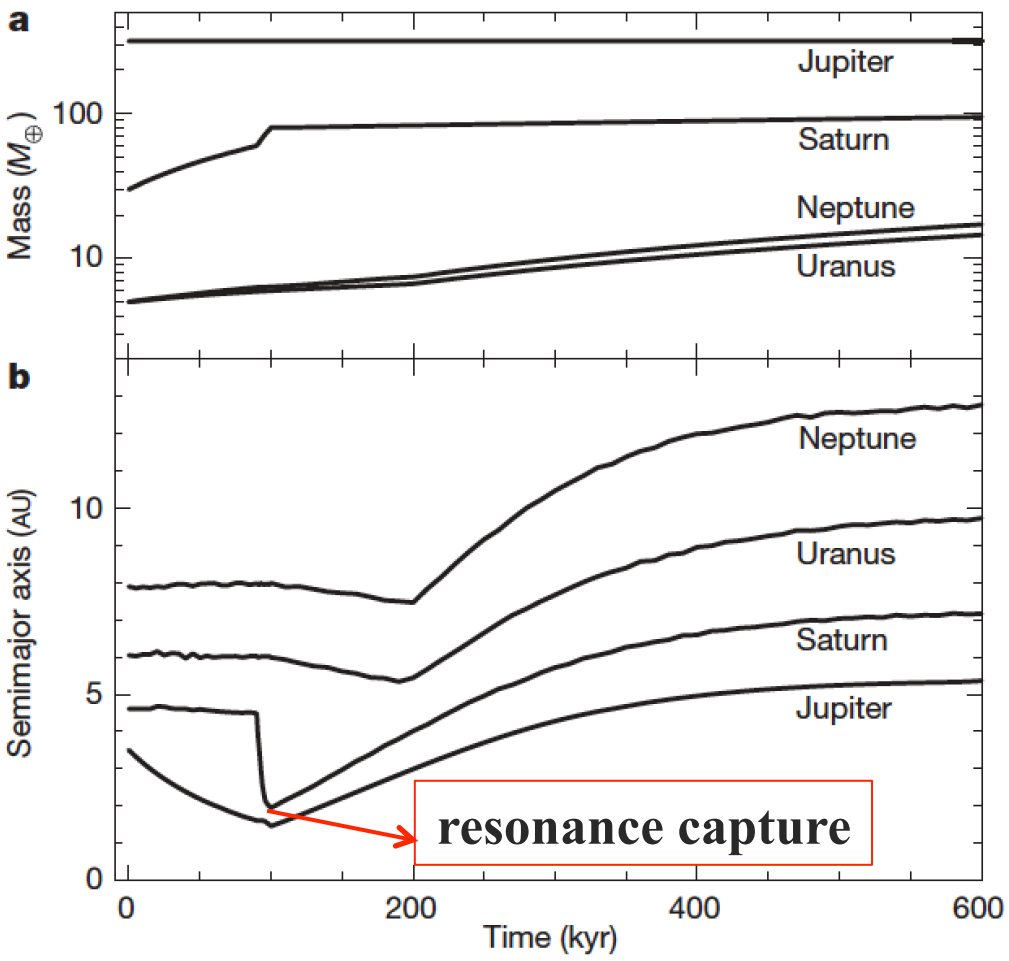


Hot Jupiter forms far from the host star (beyond the snow line), then migrates (types I and II) inward.



Could possibly habitable planets NOT be cleared away?

Solar System: why Jupiter is not hot?



(Walsh et al. 2011 Nature)

'Grand Tack' scenario:

(1) A fully-formed Jupiter starts INWARD type II migration at 3.5 AU.

(2) Saturn grows but stays at 4.5 AU as Jupiter migrates, since its type I migration is inhibited by the cooling disk (~0.1Myr).

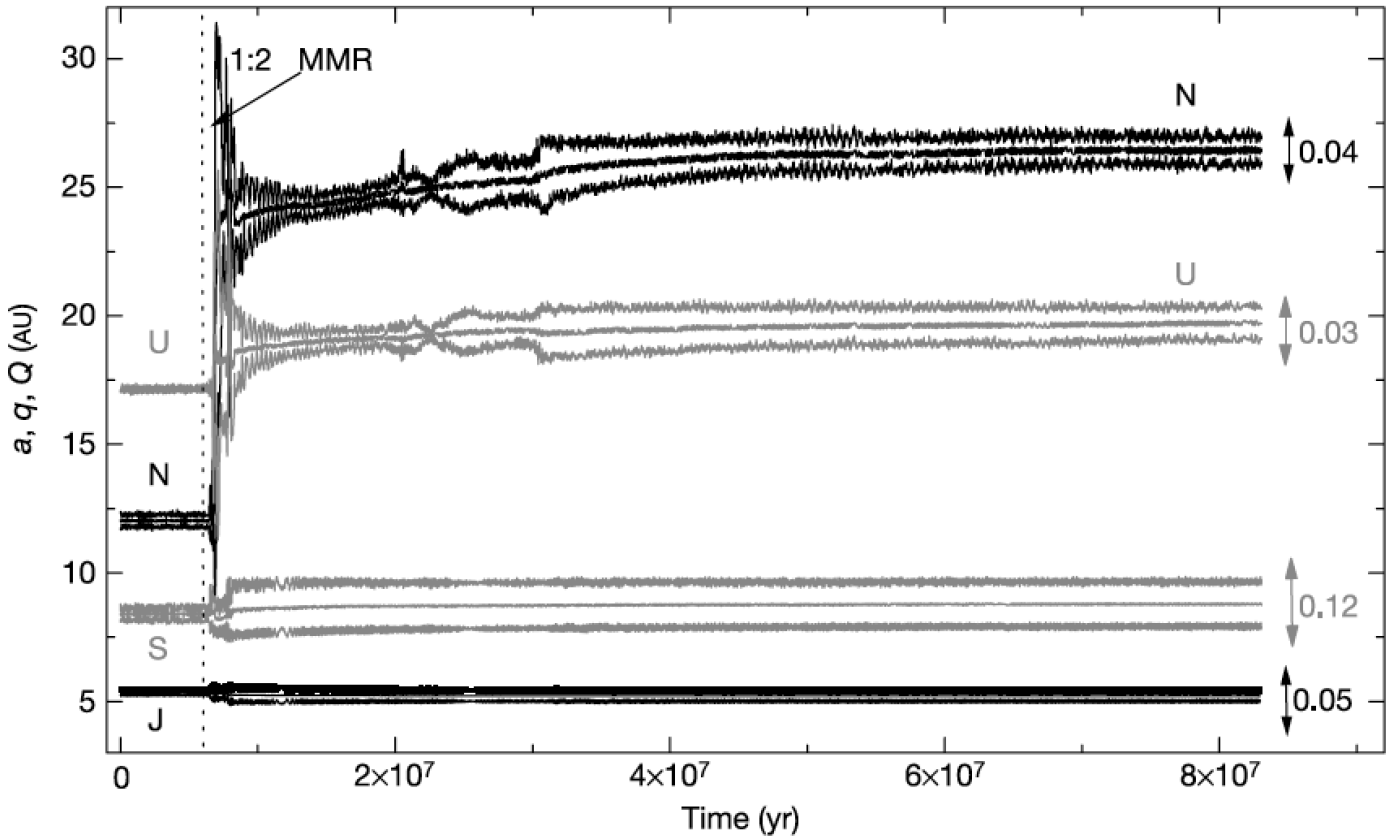
(3) Saturn reaches 60 $M_\oplus$, INWARD, faster type II migration begins.

(4) On catching Jupiter, Saturn is trapped in the 2:3 resonance.

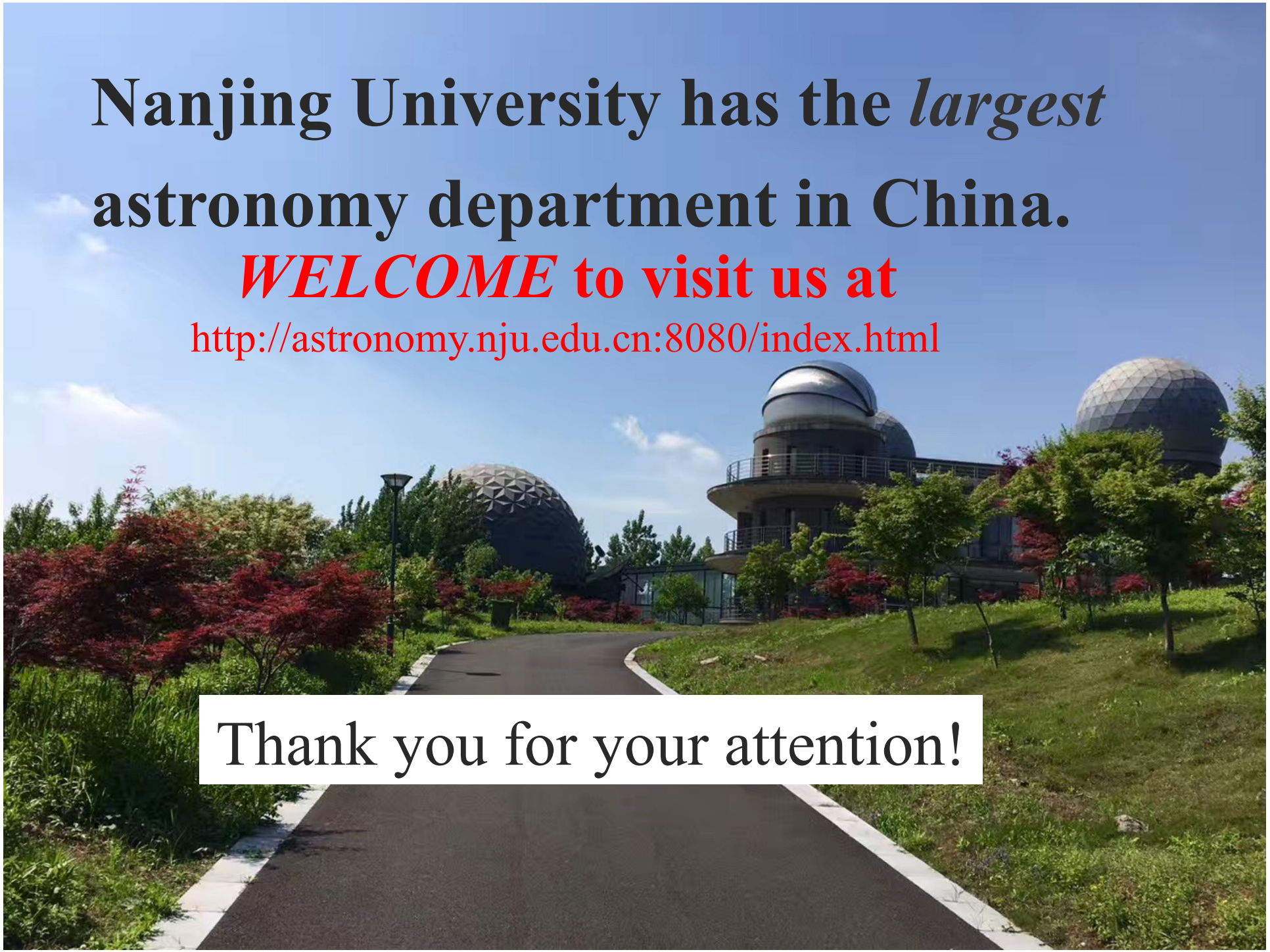
(5) The direction of migration is then reversed, becoming OUTWARD.

Migration continues…

At the end of the gas disc's lifetime, a lot of planetesimals are left behind, they continue to drive the planet migration via gravitational interaction.



Nice Model (Tsiganis et al. 2005 Nature)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