A new scenario for the origin of the 3/2 resonant system HD45364

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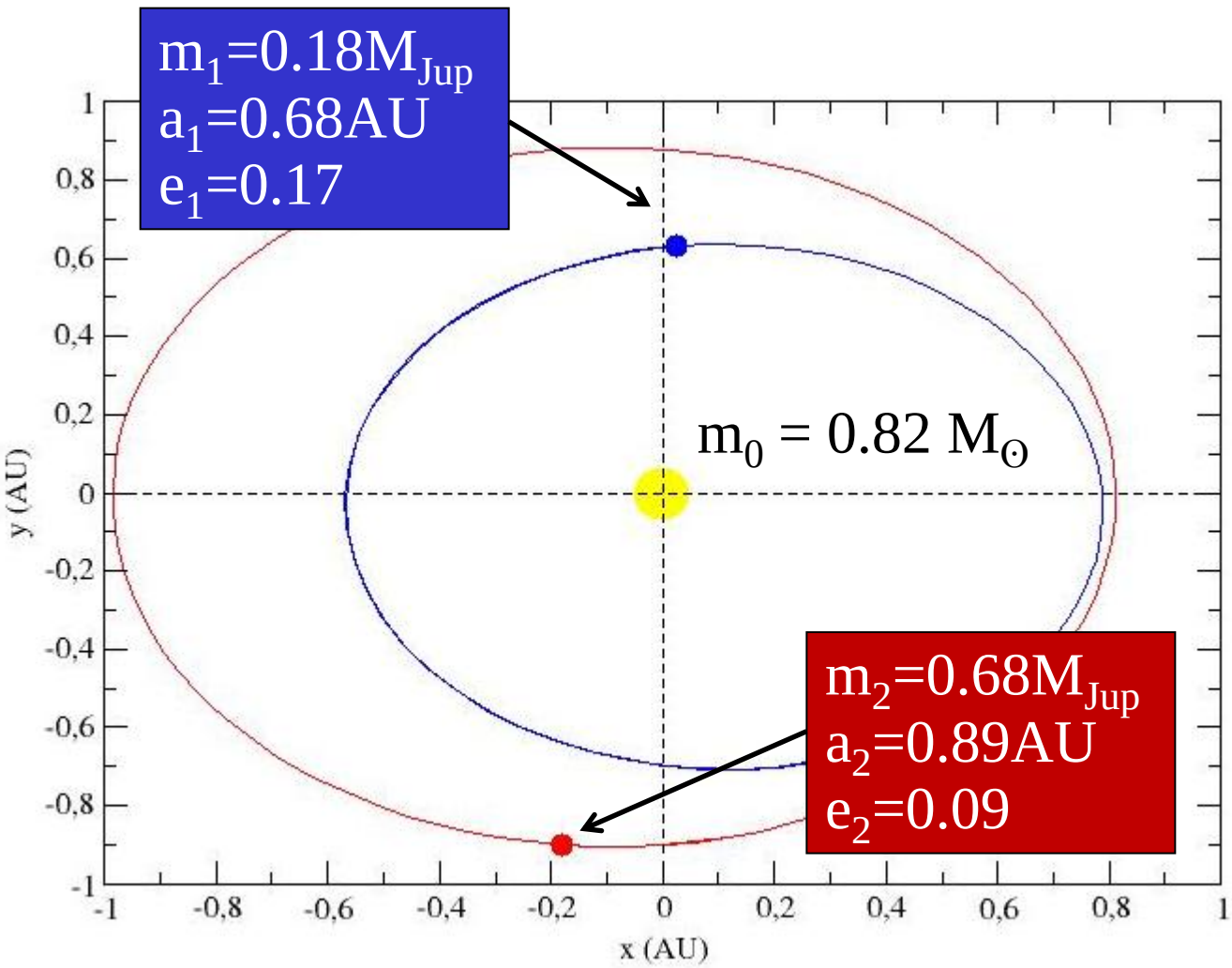
HD 45364

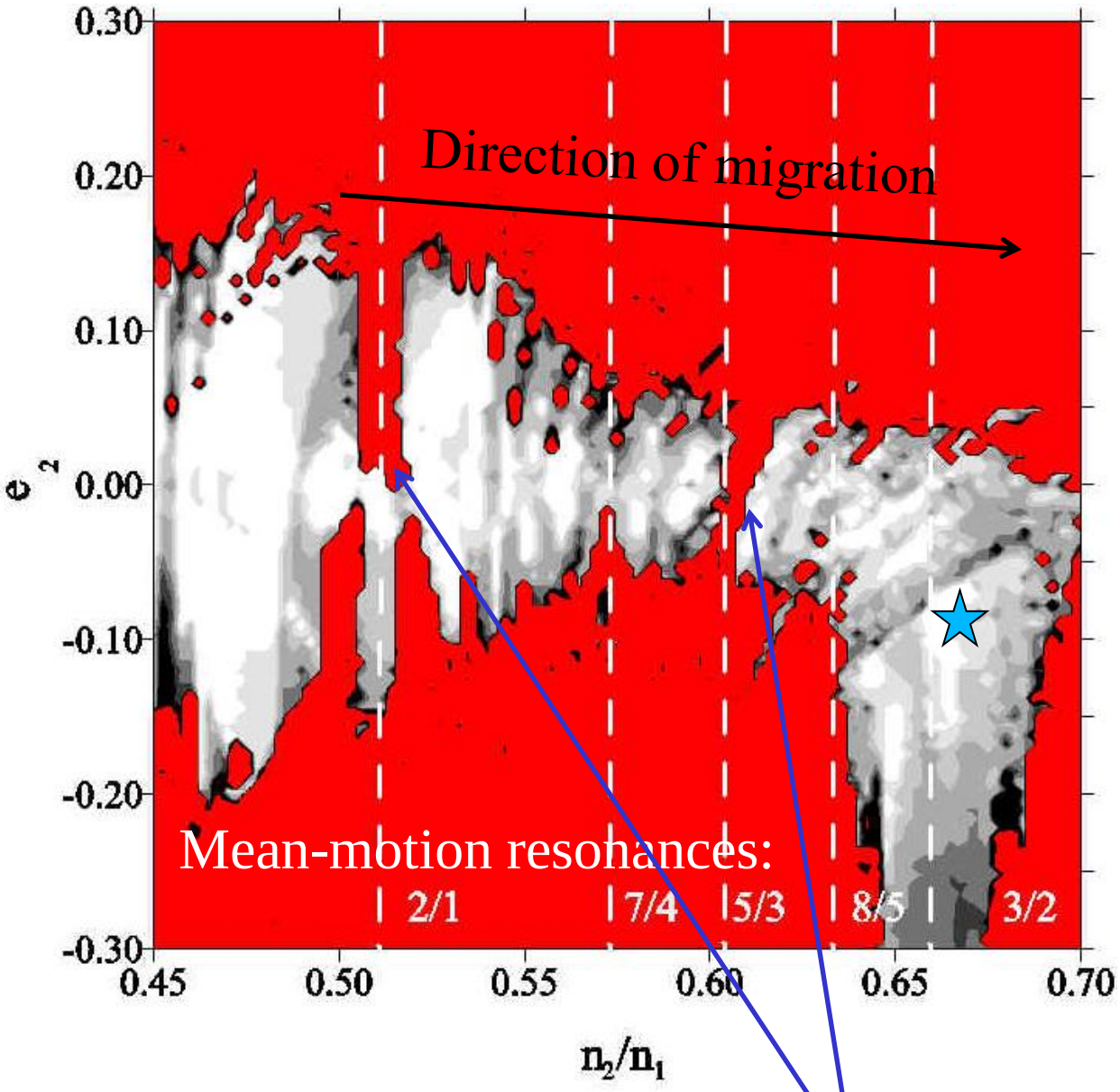
First discovered candidate with two planets evolving inside the 3/2 mean-motion resonance (Correia et al. 2009).



The long-term stability of this system was confirmed by Correia et al. (2009).

Origin of HD45364

Planetary Type II migration



Chaotic motion

Regular motion

HD45364

Strong chaotic layers (separatrix)

Origin of HD45364

Scenario I

- Traditional scenarios (e.g., Lee & Peale 2002, Beaugé & Michtchenko 2003) fail to form a compact configuration like the 3/2 resonance.

- The presence of several resonances, like 2/1 and 5/3, prevent the capture (see Figure on page 2).

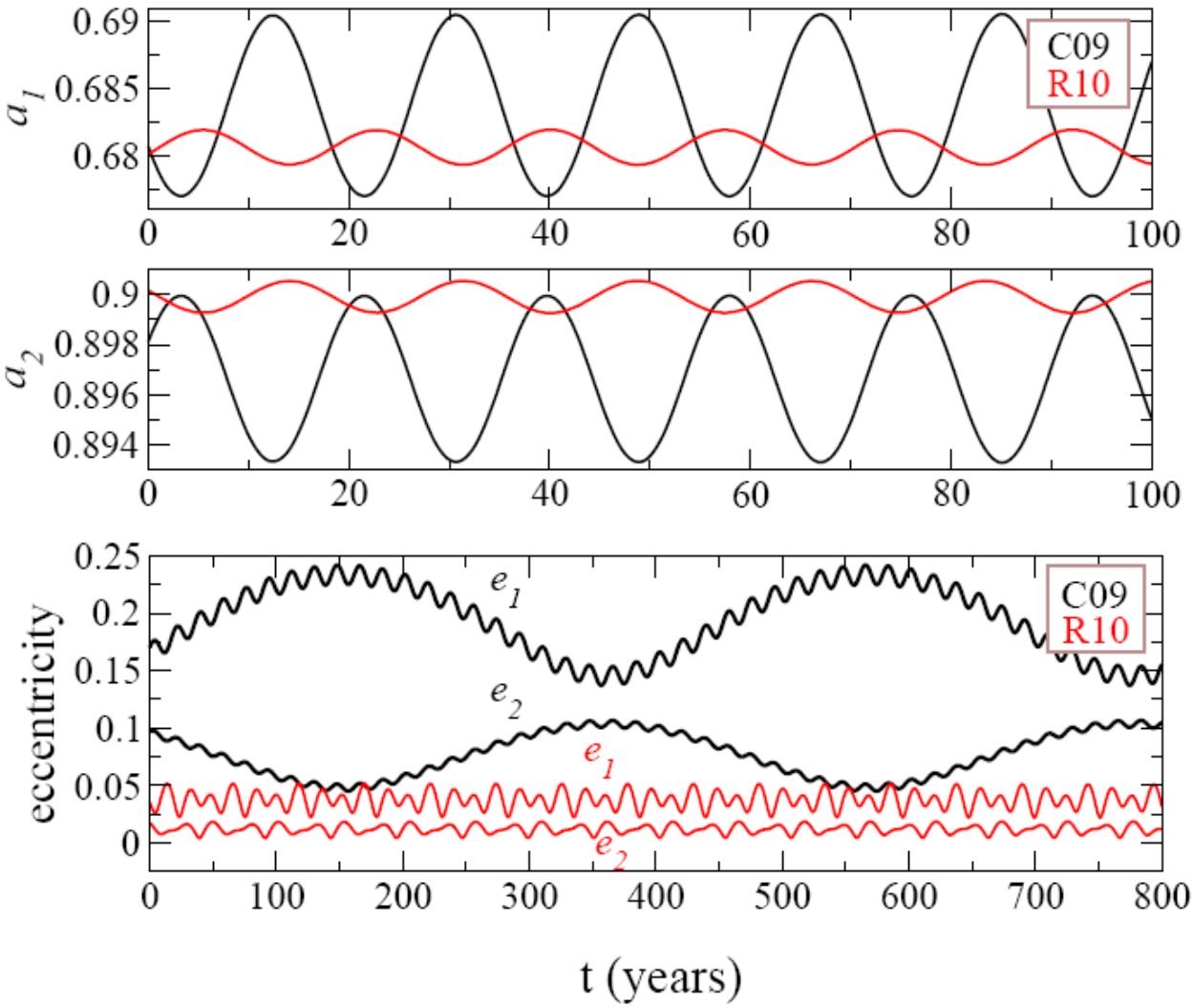
- Rein et al. (2010) have found that the Type III migration could bring the system into the 3/2 resonance.

- This fast migration is possible due to the massive protoplanetary disk.

Scenario I solution

Comparison with the best-fit of Correia et al. (2009).

— Correia et al. (2009)
— Rein et al. (2010)

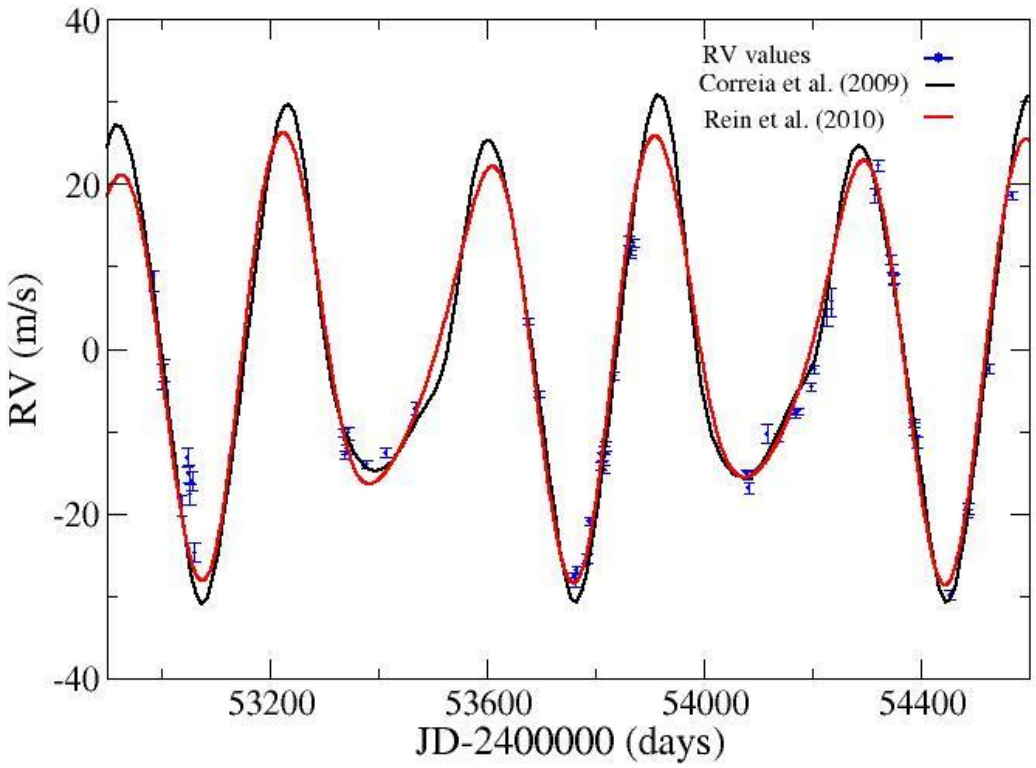


A discrepancy in the dynamical behaviour

Scenario I solution

Comparison of two solutions : statistically indistinguishable

Correia et al. (2009): χ^2=2.79
Rein et al. (2010): χ^2=3.51



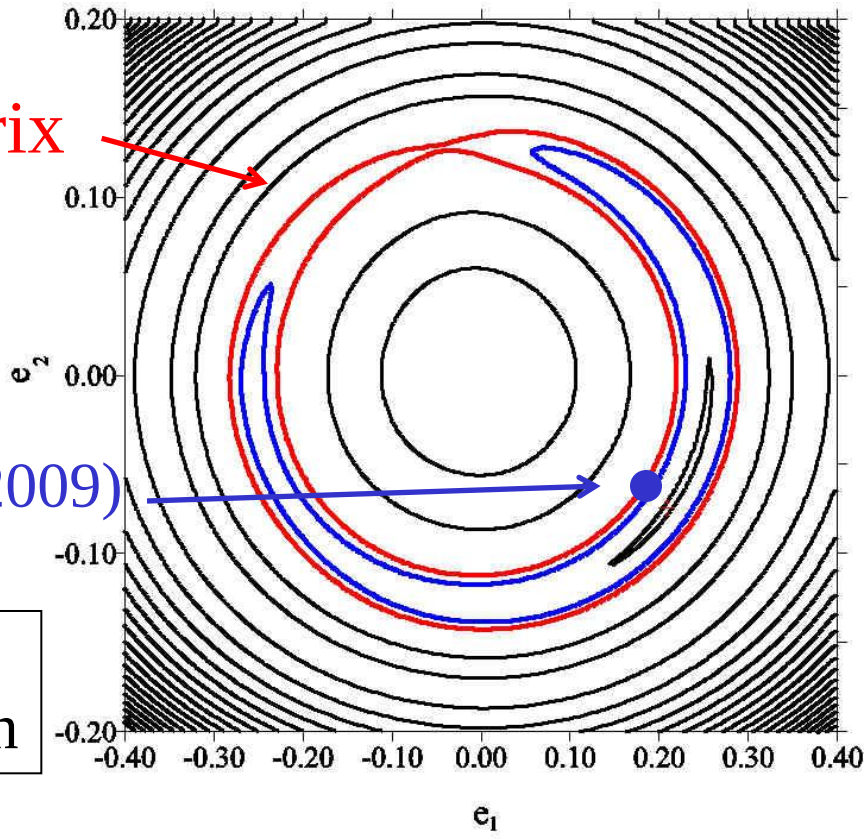
But, a detailed dynamical study shows an important difference …

Comparison of the phase spaces of two solutions

Separatrix

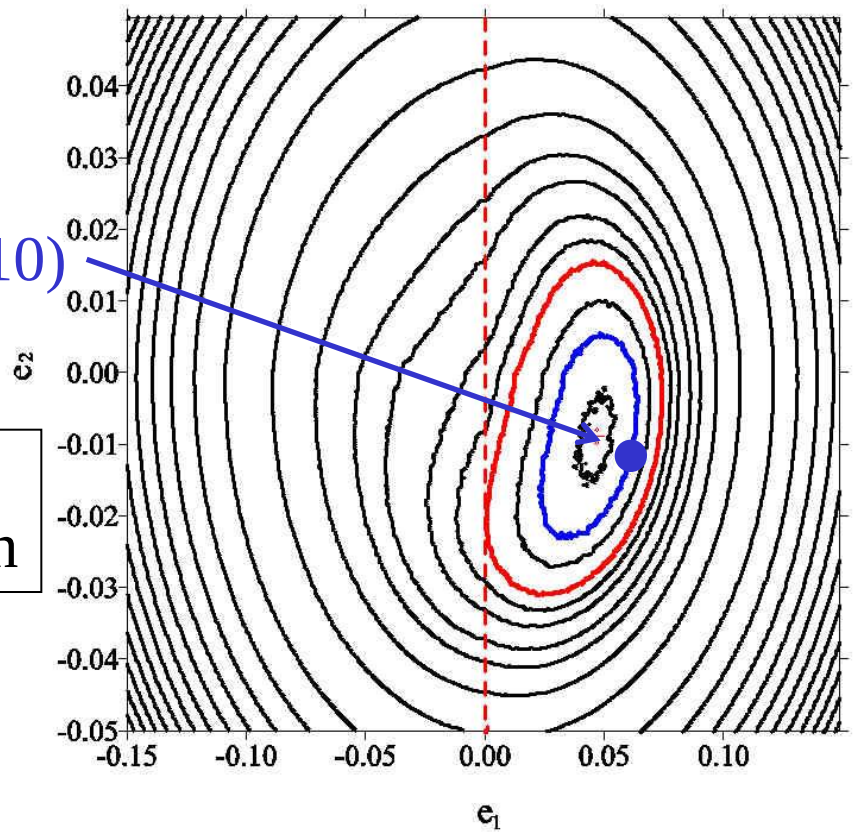
Correia et al. (2009)

Truly resonant regime of motion



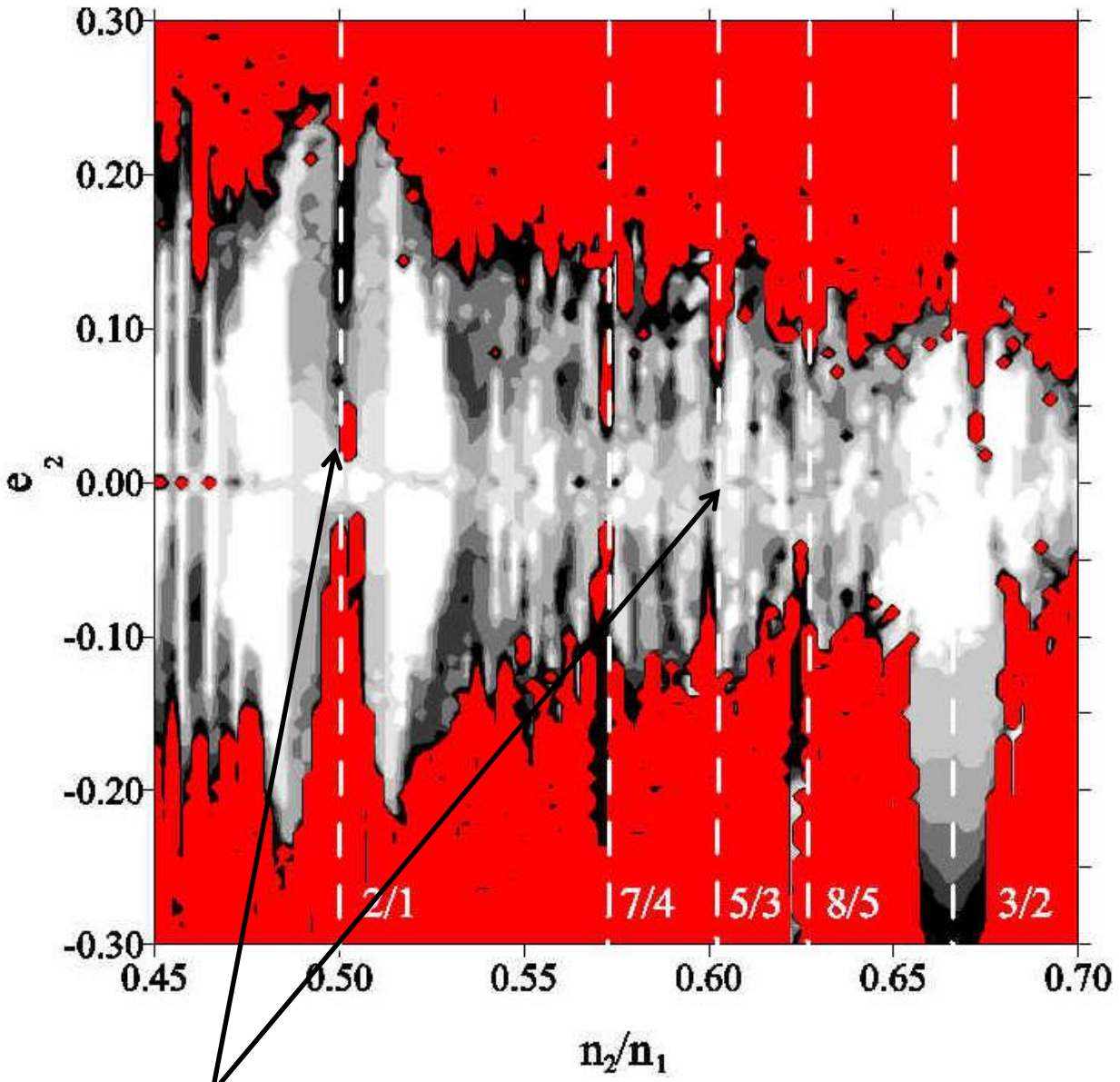
Rein et al. (2010)

Quasi-resonant regime of motion



Dynamical map with smaller planetary masses

Small planets ⟺ narrow resonance.



The chaotic layers are reduced or disappear

Chaotic motion

Regular motion

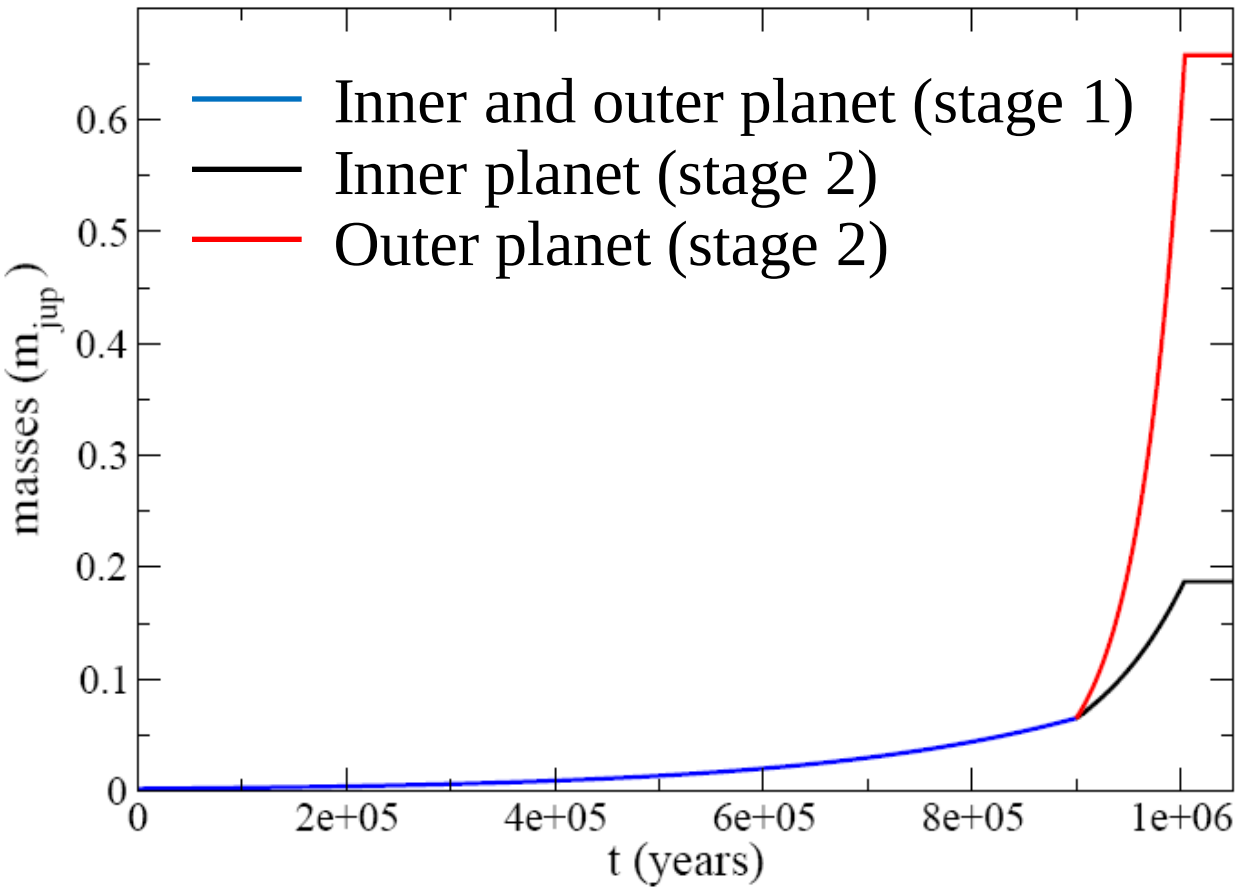
Scenario II

- We consider a scenario with simultaneous planet growth and migration (Alibert et al. 2005).

- We start with planetary embryos of 0.6 M_{Earth} and increase the masses to their actual values.

- The process of formation has two stages: 1) accretion of planetesimals and, 2) runaway gas accretion.

Planetary growth



- The planets complete the mass growth in 10^6 years.
- This time is comparable to the typical lifetimes of planetary disks.

Stage 1

Mass growth:

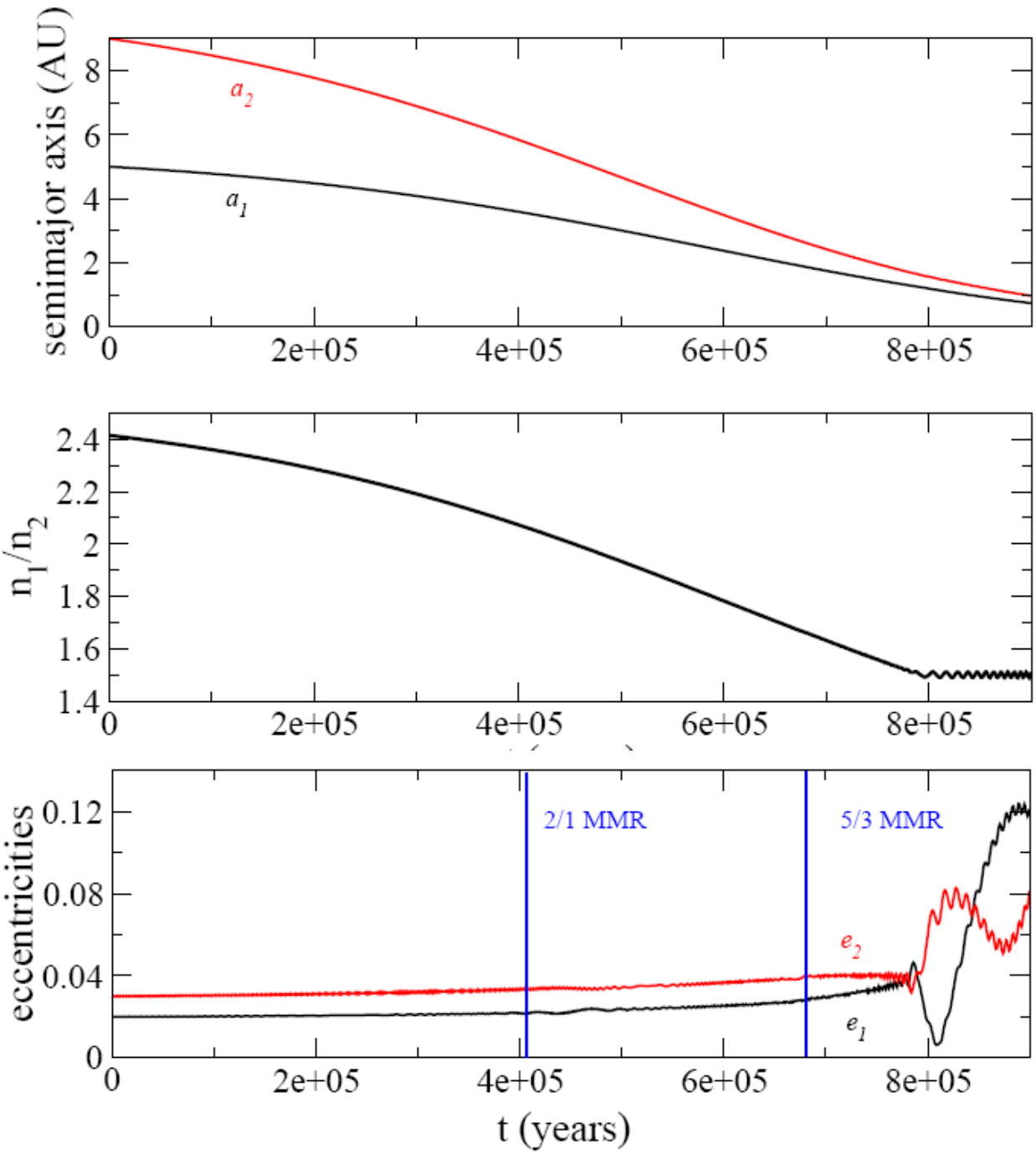
- Both planets have the same rate of growth.
- They increase their masses from 0.6 M_{earth} to 20 M_{earth} in $9x10^5$ years following an exponential law.

Migration:

- The planets are undergone the Type I migration.
- The migration is modeled according to Tanaka et al. (2002).

Stage 1

- The planets cross the 2/1 and 5/3 resonances with a small mass.
- They are captured into the 3/2 resonance with 13 M_{Earth}.



Stage 2

Mass growth:

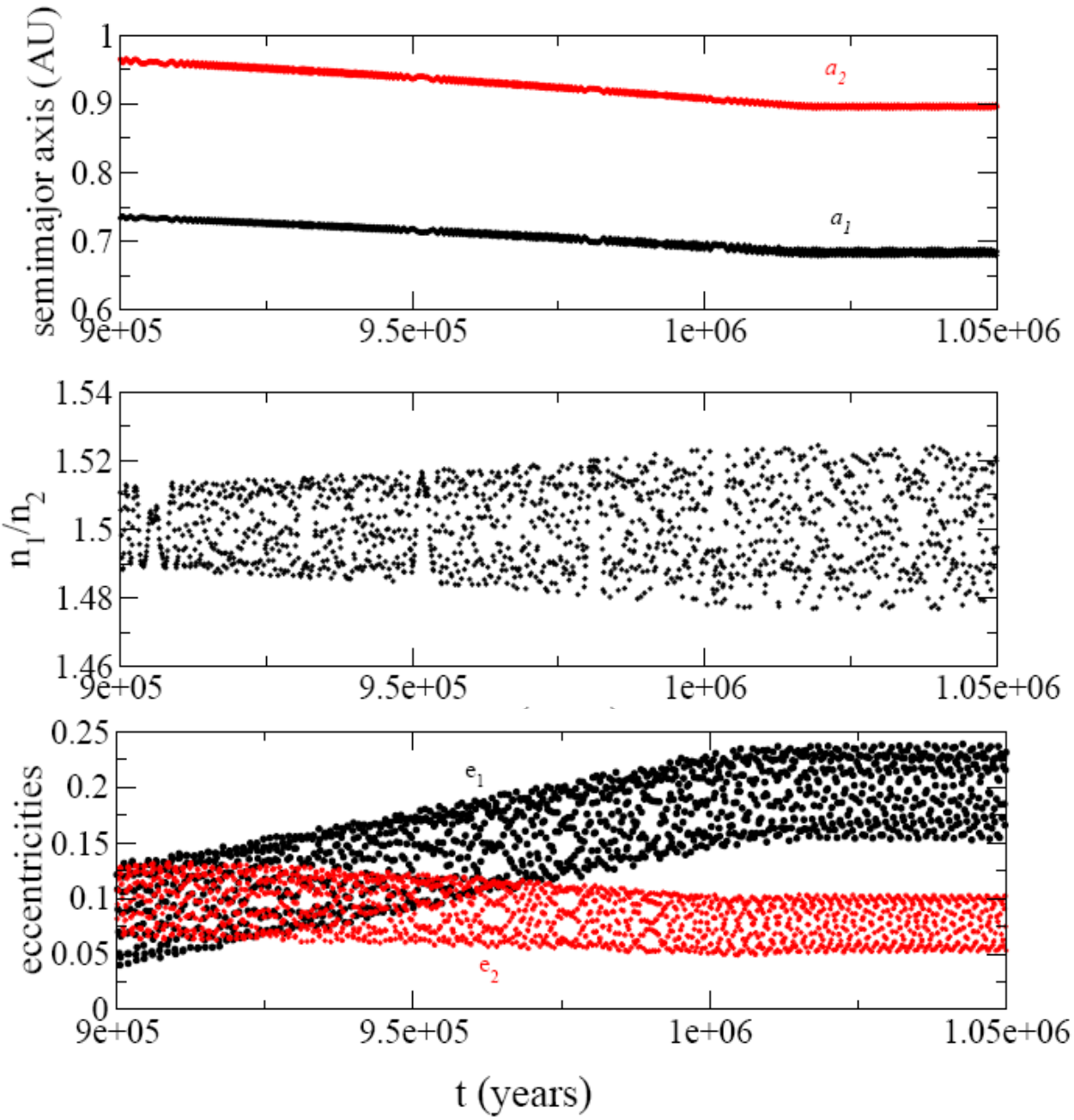
- Both planets reach their actual masses in 10^5 years following an exponential law.
- The outer planet has the mass growth rate faster than the inner planet.

Migration:

- The planets are undergone the Type II migration.
- The migration is modeled follow Beaugé et al. (2006).

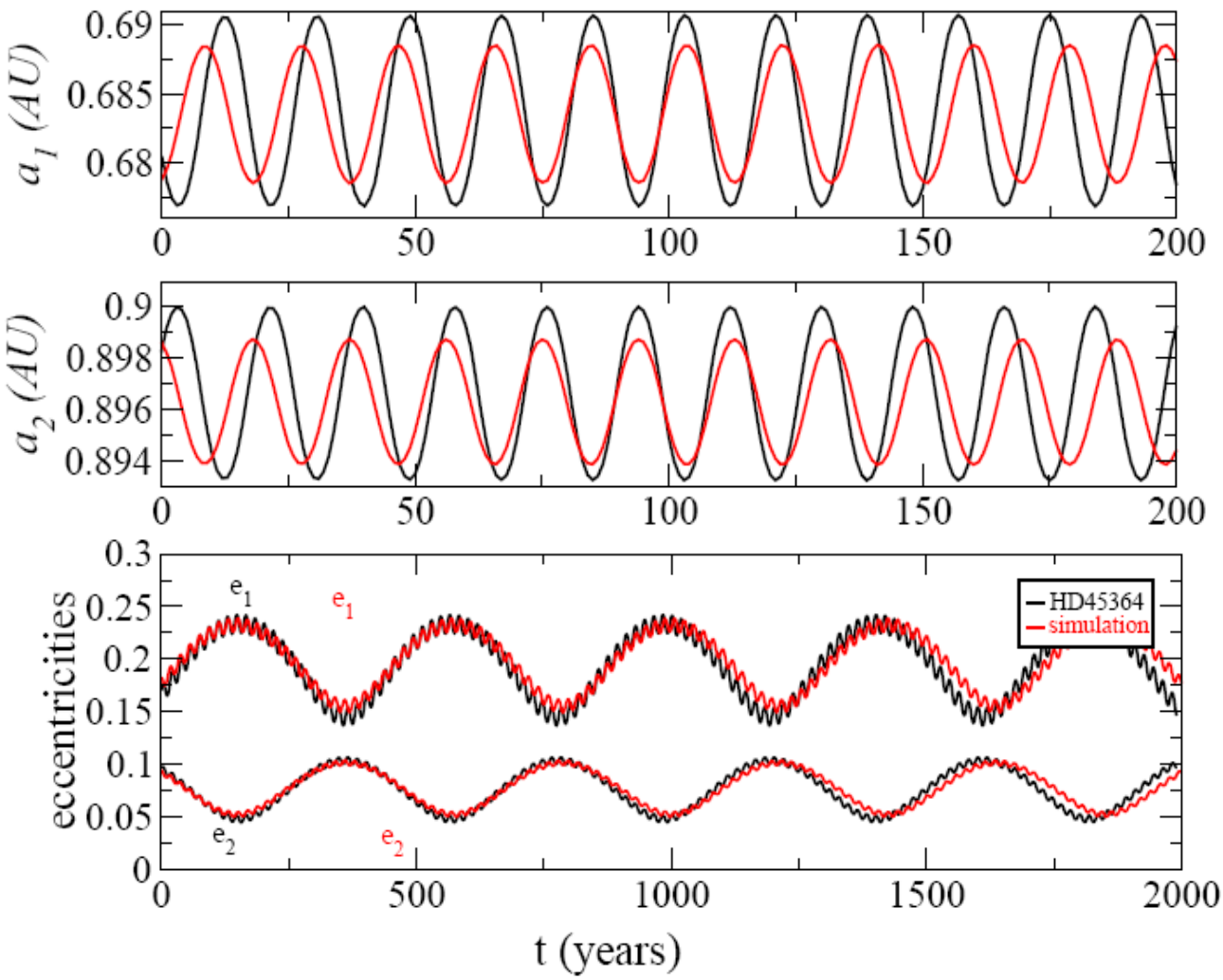
Stage 2

The resonance evolution of the planets toward their actual configuration.



Results

Our scenario is able to reproduce the resonant state of the best-fit of Correia et al. (2009).



— Correia et al. (2009)

— Our solution

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