A Dynamical Study on the Origin of the Moon

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Formation of the Moon

Most likely the Moon formed from a debris disk produced by a late giant impact of a Mars-sized body (Theia) onto early Earth (70-120 Myrs after formation of the terrestrial planets). Our Questions:

• Where did Theia come from?



- **Collision angle, impact velocity?**
- What happened during and after the collision?
- How did the Moon form out of the fragments?



Some collisions happen after 70 Myrs – <u>good</u> candidates for Moon-forming impact.



Most collisions happen before 50 Myrs Fig. 1. Results of n-body integrations after 5 million years using initial conditions following the Grand Tack model. An additional body is produced in the inner Solar System. This body may have crashed into the proto-Earth and formed the debris disk, from which the Moon condensed.

Collision statistics:

Opynamics simulations by own nbody code

Collision angles and velocities determine fragmentation

• Water transport between colliding bodies depends on fragmentation scenario

Fig. 2. N-body simulations: 100 Myrs with inner Solar System, **Jupiter, Saturn and additional** Mars-sized planet. Mean anomaly **for** *Theia*: 0 – 360° (equally distributed).

How can the Moon condense from the fragments remaining after the crash between the proto-Earth and "Theia"?

 Detailed collision simulations with own smooth(ed) particle hydrodynamics (SPH) code

 First results on larger fragments

and impact angle $\sim 50^{\circ}$. (Burger 2015)





happen with $\alpha \sim 45^\circ$ and $v \sim v_{esc}$.

Subsequently reaccreted fragment

again to form the Moon?



Fig. 4. Collisions (red) and ejections (green) for three different massive objects started at 1.065 AU. The "stability region" narrows for the lower mass additional planet.





-150 -100 -50 *x* (10³ km)

References: Burger, 2015, unpublished | Maindl, T. I., Dvorak, R., Schäfer, C., Speith, R., 2014, IAUS, 310, 138. | Dvorak, R., Maindl, T. I., Süli, Á., Schäfer, C., Speith, R., Burger, C., 2015a | Dvorak, R., Loibnegger, B., Maindl, T. I., 2015b, in prep. | Dvorak, R., Burger, C., Maindl, T. I., 2015c, in prep.









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