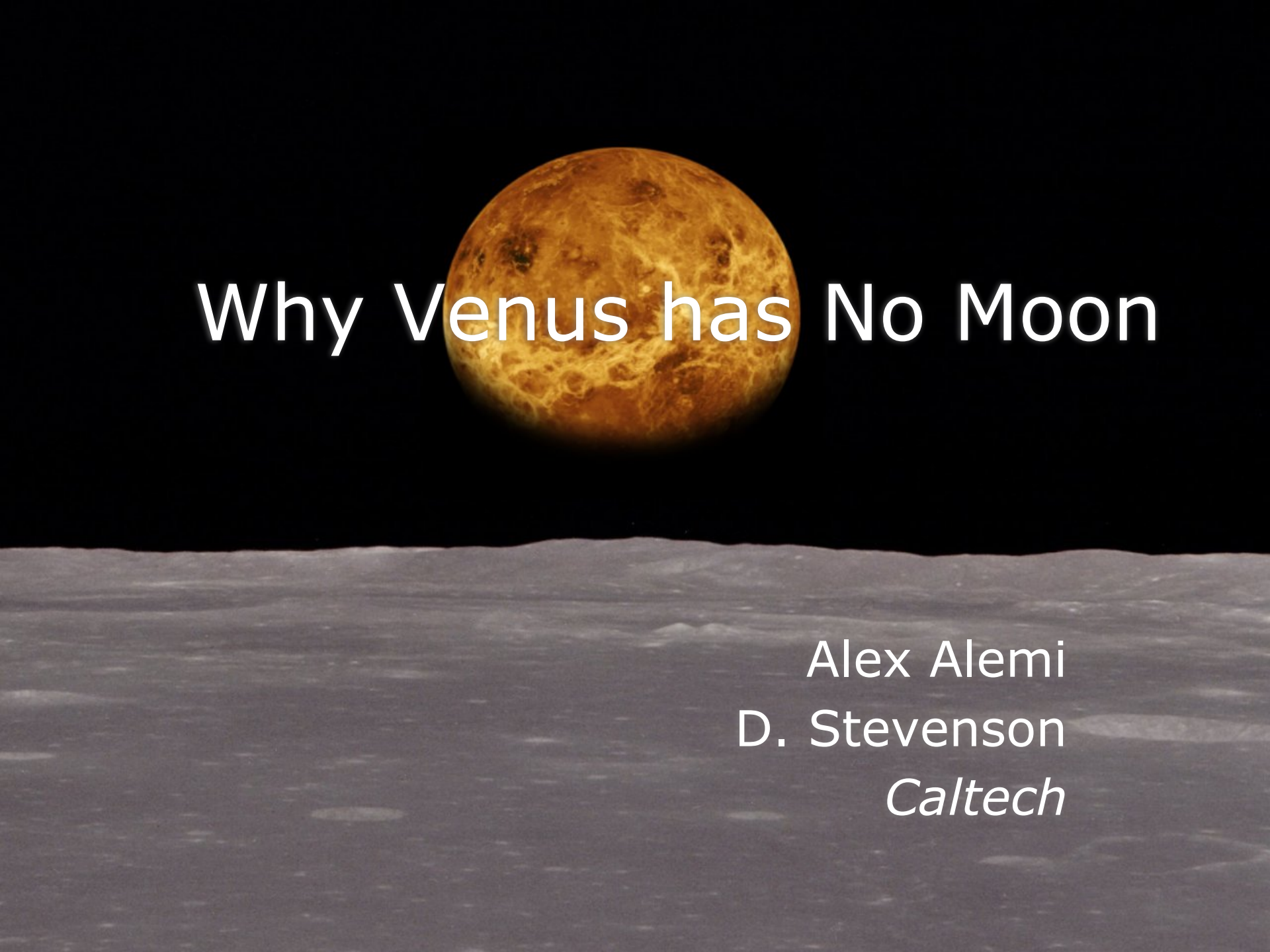


Why Venus has No Moon

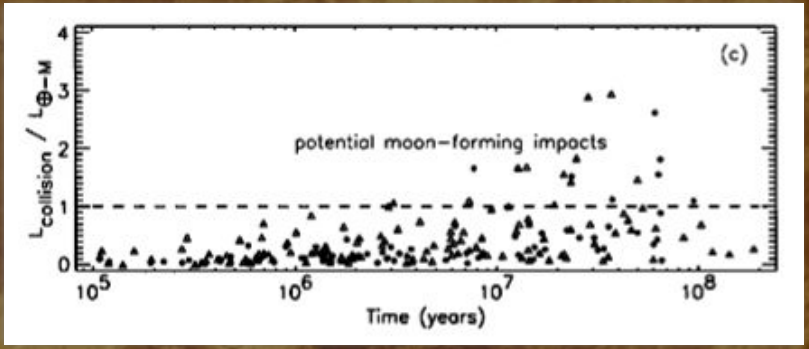
Alex Alemi
D. Stevenson
Caltech

Motivation

- Late Stage Aggregation
  - ~ Mars impactors
- Earth's moon
  - Large Impact Hypothesis
  - SPH models of Moon formation
- What was story for Venus?

Moon-forming Impacts

- J~0.6 J_{EM} required to form a moon
- LSA models involve larger Collisions (avg largest = 1.44 J_{EM})



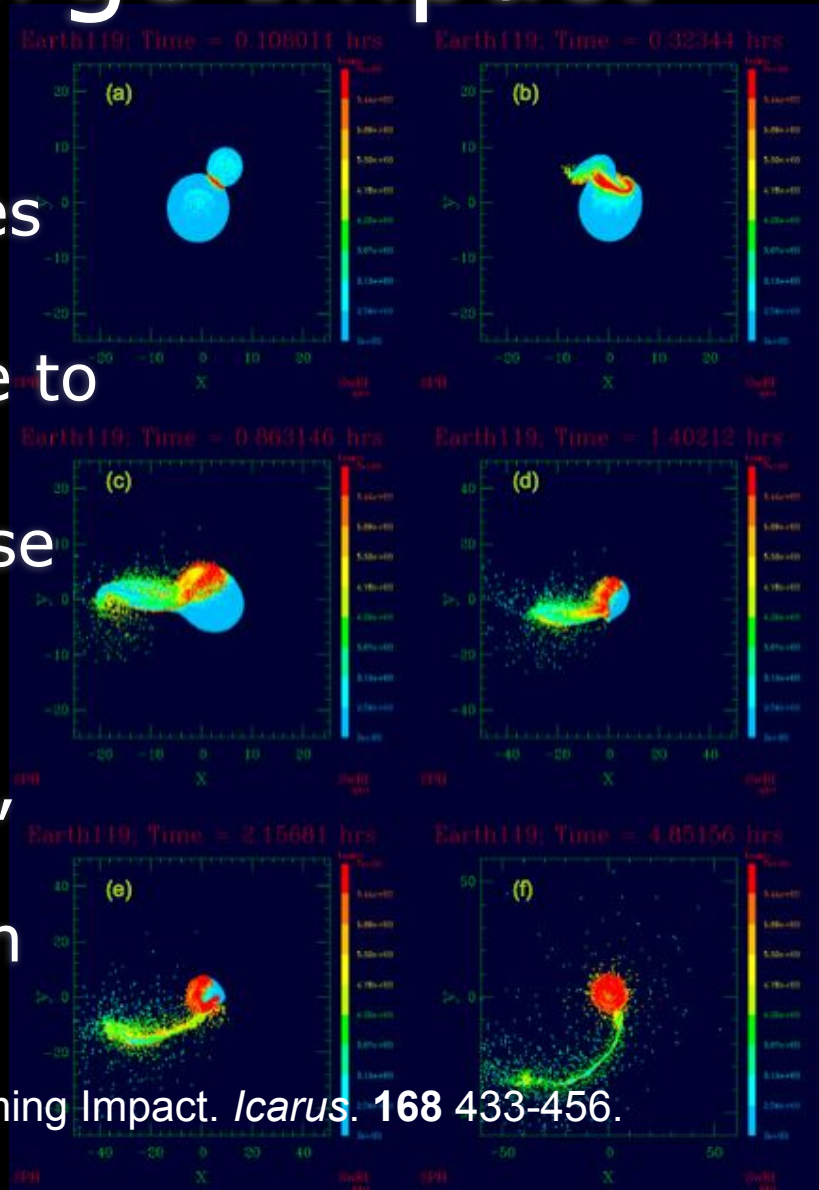
$$I\omega + (GM_V/a)^{1/2} a M_S = J$$

- I = moment of inertia of Venus = 0.34 $M_v R_v^2$
- M_v = mass of Venus
- R_v = radius of Venus
- M_s = mass of the satellite
- a =orbital distance
- w = spin of Venus
- n = $(GM_v/a^3)^{1/2}$ is the orbital mean motion of the moon

Agnor C.B., R.M. Canup, and H.F. Levison. 1999. On the Character and Consequences of Large Impacts in the Late Stage of Terrestrial Formation. *Icarus* **142**. 219-237

1 Large Impact

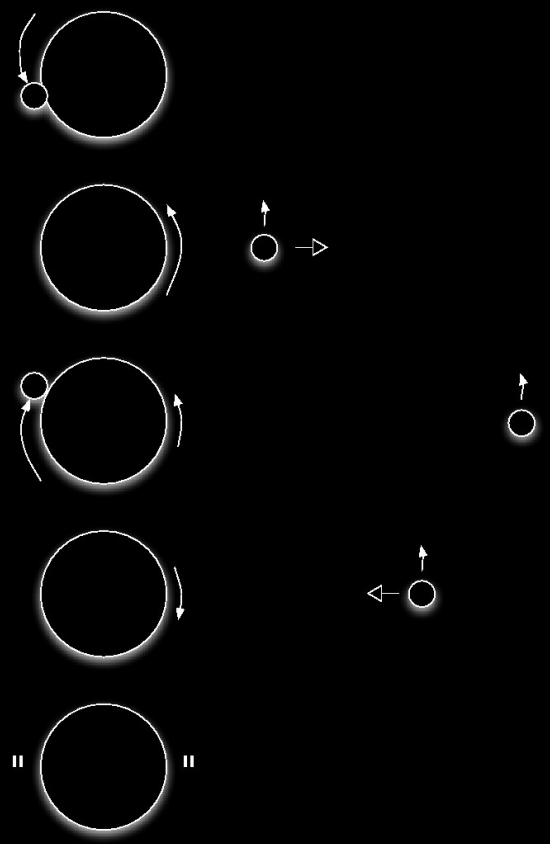
- If moon is formed, it proves difficult to get rid of.
- Venus' Hill Sphere too large to allow easy escape.
- Solar Tides too slow to cause inward evolution and coalescence
- Large impact -> Large spin, becomes difficult to explain Venus' current slow rotation



Canup R.M. 2004 Simulations of a Late Lunar Forming Impact. *Icarus*. **168** 433-456.

Two Impact Story

- Two Large impacts of opposite angular momentum
- ~25% of planets in Agnor et al underwent more than one 1 J_{EM} collision
- Causes reversal of tidal evolution -> inward coalescence
- Moon returns on 10^7 year timescales
- Results in low primordial spin



Scenarios

# of Large Impacts	
0	Unlikely according to LSA. It becomes hard to explain Venus' mass.
1	Results in large primordial spin. Difficult to get rid of moon.
2	Models suggest 2 large impacts still probable (~ 25%). Provides easy mechanism to dispose of moon. Results in low primordial spin.
>2	Becomes less probable as number of large impacts increases.

Conclusion

- Venus not having a moon is at least as interesting as Earth having a substantial one.
- Two large impacts of opposite sense can explain the missing moon and slow rotation