

## The Importance of the Moon for Life on Earth



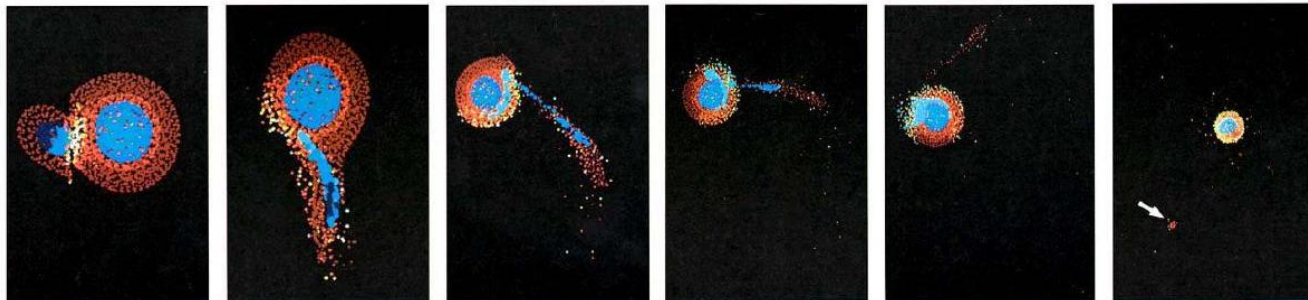
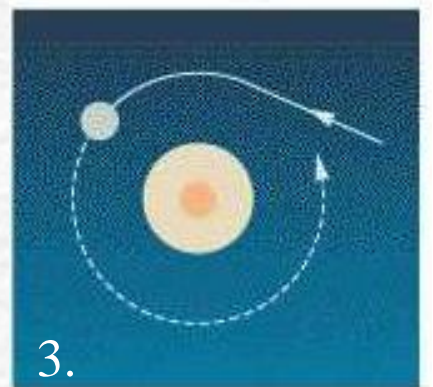
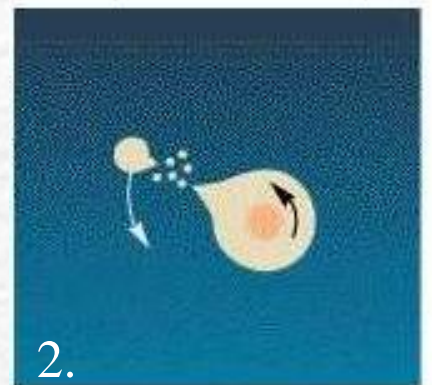
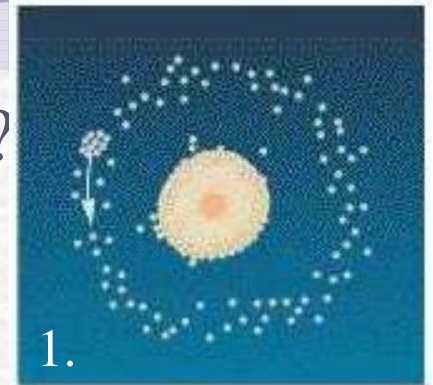
### Unusual features of Earth's Moon:

1. Largest Moon relative to planet by 50x
2. Largest angular momentum rel. to planet mass
3. Low density, lack of iron and volatiles

(NASA Photo from Messenger Spacecraft on journey to Mercury)

# Origin of the Moon

1. Co-accretion Theory (Laplace-1800) Sister?  
High angular momentum, low density?
2. Fission Theory (George Darwin -1898)  
Daughter? Insufficient angular momentum
3. Capture Theory (Urey-1952, Fisher-1968)  
Wife? Braking to near circular orbit?
4. Large-impact Theory/Grazing Collision  
(Hartmann & Davis-1976, Kona-1984)





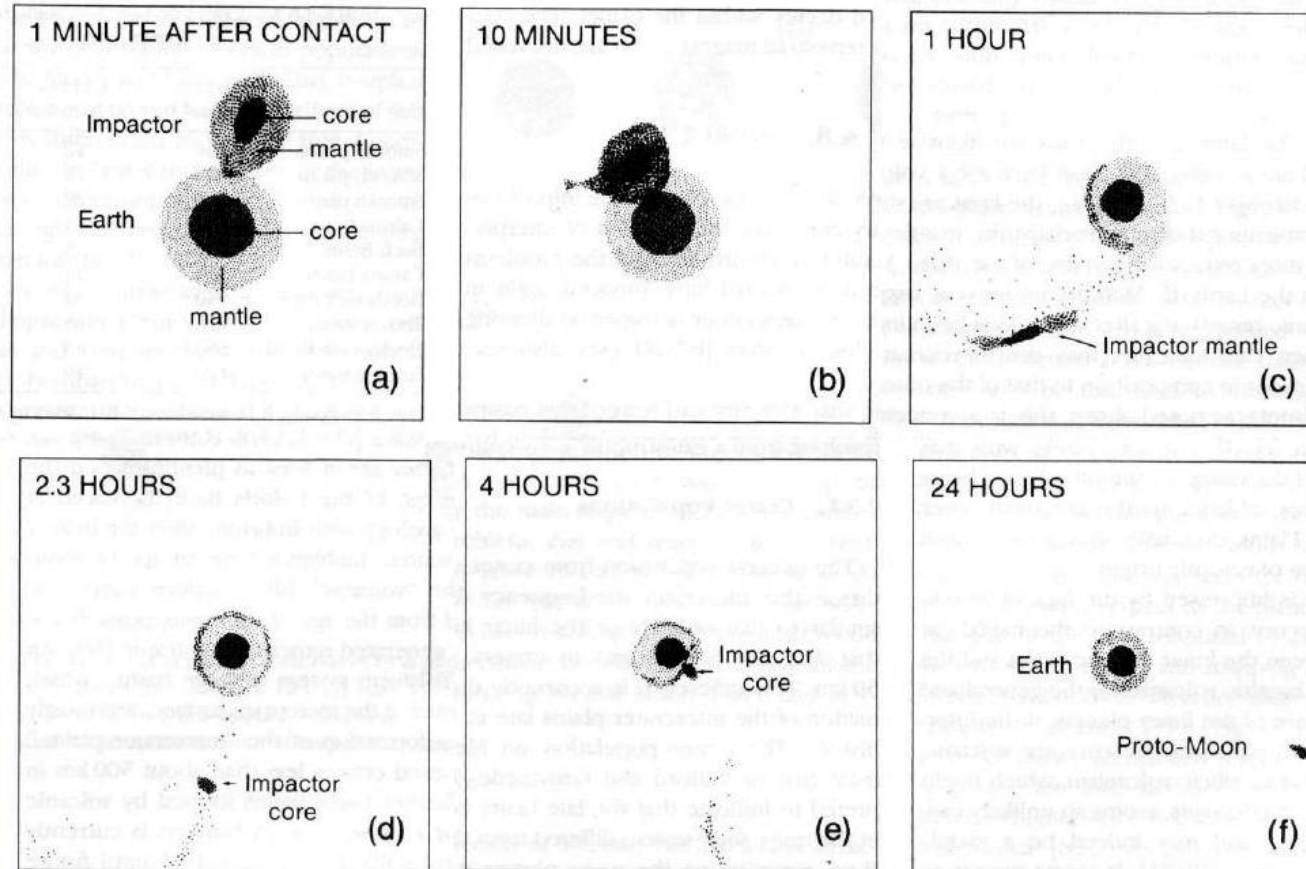
# Large-Impact Theory/Grazing Collision

Simulation requires - Mars-size object ( $> 0.1M_e$  at  $\sim 5$  km/sec)

(Benz and Cameron-1985, Robin Canup/single impact-2003)

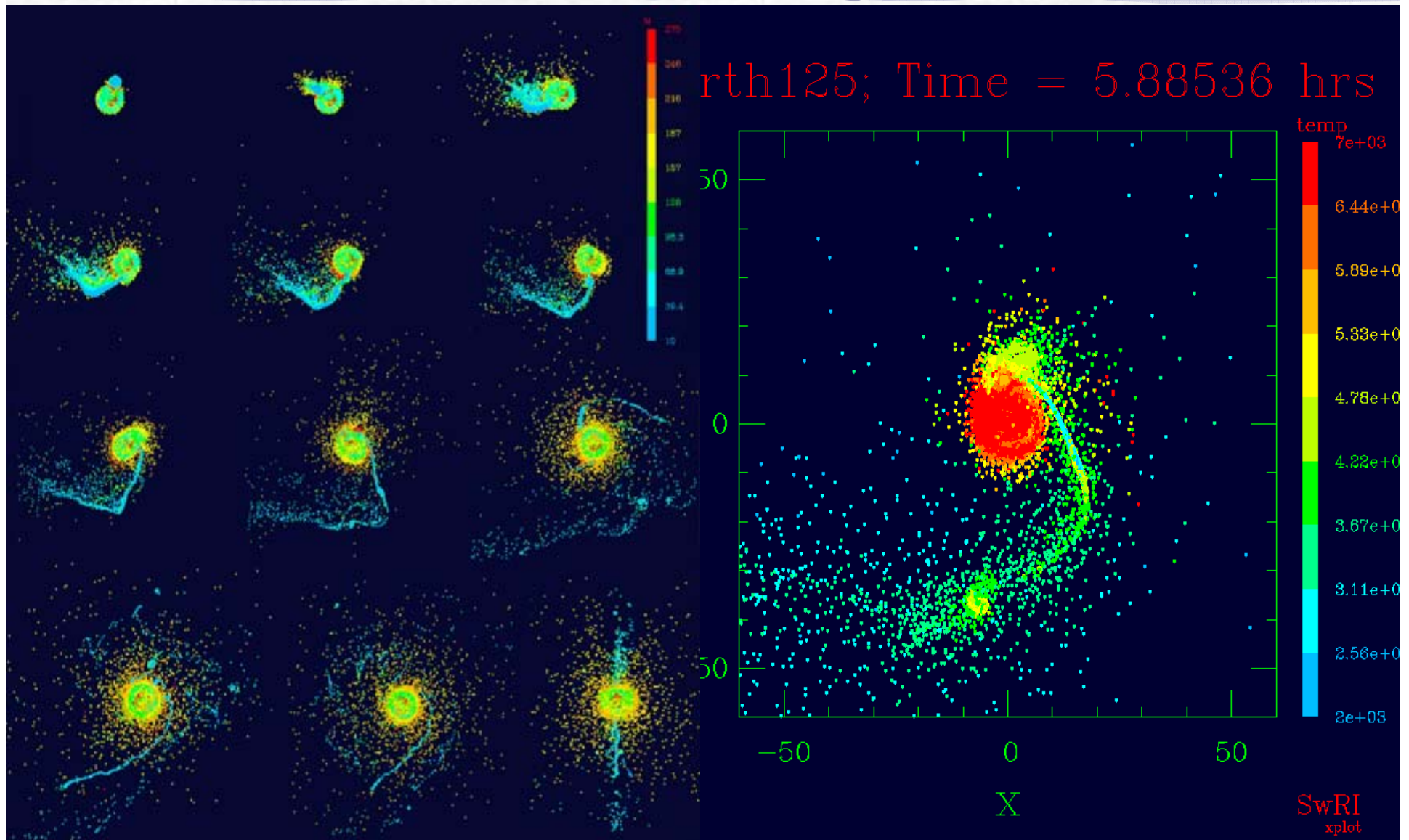
Rare (Spitzer) - right size, time, location, direction, speed, spin

(S. Jaki, Probabilities:  $0.001 \times 0.1 \times 0.2 \times 0.03 \times 0.01 \sim 10^{-8}$ )



(A.G.W. Cameron and W. Benz, Smithsonian Astrophysics Institute)

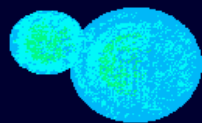
# Giant-Impact Simulations (Southwest Research Inst.)



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# Glancing Collision Simulation



Southwest Research Institute



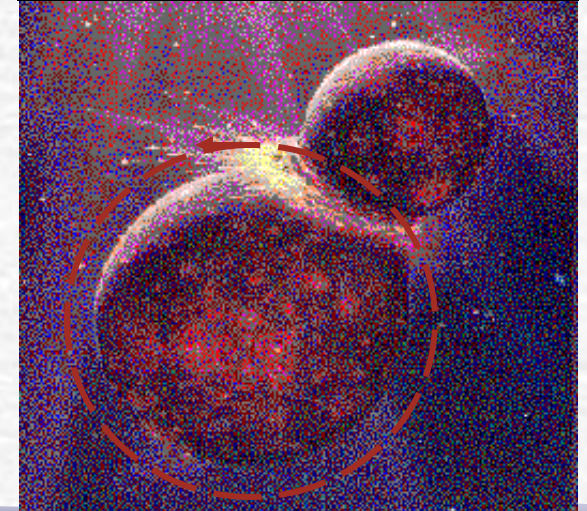
# Ten Results of Glancing Collision

3-4 in *What if the Moon Didn't Exist?* N. Comins

4-5 in *Rare Earth*, Brownlee & Ward

5-6 in *Privileged Planet*, Gonzalez & Richards

1. Greenhouse gases removed: Venus atmosphere 90 x more pressure than Earth. Thins atmosphere enough to allow photosynthesis for oxygen.
2. Glancing collision increased rotation rate to ~ 6 hours and gave optimal axial tilt for ideal temperature range. Mercury with 59-day rotation and no axial tilt has long 700K days and 100K nights.



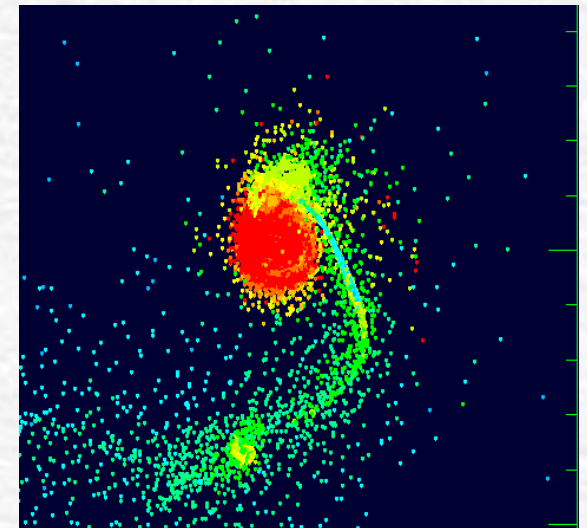
# Further Results from Glancing Collision

3. Strong magnetic field from faster rotation and larger molten iron core, deflecting solar wind that would strip atmosphere and threaten life. Observed by ESA's Mars Express and Venus Express in 2008.



4. Stronger gravity from more massive Earth holds water vapor longer before condensing to form oceans.

5. Surface minerals fall back from impact debris to form a “late veneer” of heavier elements needed for life.





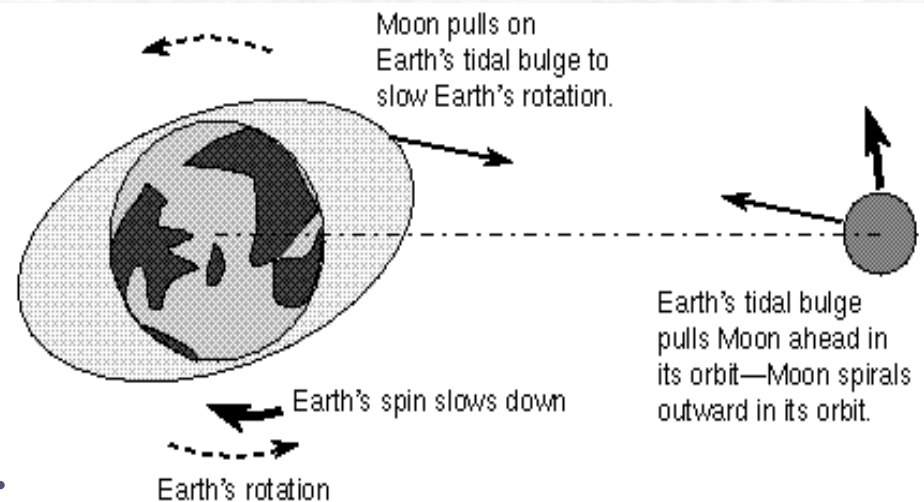
# Importance of a Large Moon

6. Plate tectonics (unique to Earth) result from thinner crust and more heat. Forms continents and controls climate by carbon-cycle.

7. Oceans enriched with minerals by huge tides from early nearby Moon and fast rotation of Earth.

8. Moon slows Earth rotation, reducing super-hurricane winds and optimizing climate.

Diagram removed for copyright protection





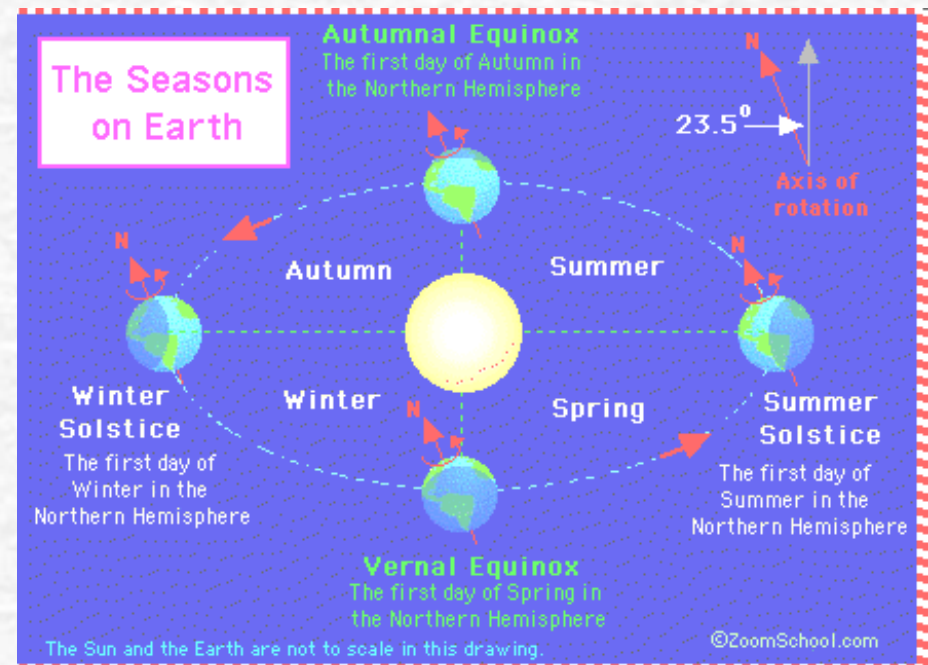
# Importance of a Large Moon for Life on Earth

9. Tides drive ocean currents to moderate global climate; cleanse and oxygenate oceans; tidal pools concentrate nutrients for early life forms.

10. Tilt of Earth's axis is stabilized ( $22.1^{\circ}$ - $24.5^{\circ}$ ) by the Moon, giving stable seasons. Wide variations in tilt of Mars give chaotic climate changes.

## Conclusion:

The giant impact theory of the Moon's origin accounts best for its properties and appears to have had just the right conditions and effects to make life on Earth possible.

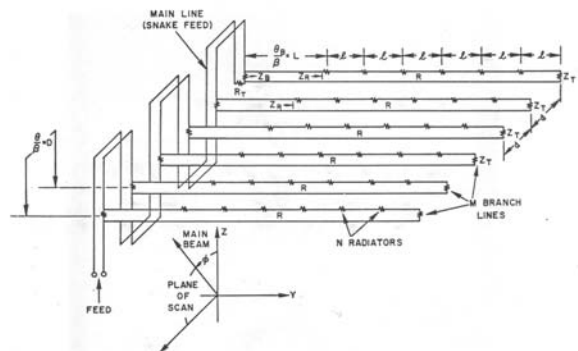


# Ten Life-sustaining results of Large Impact

1. Greenhouse gases removed: transparent atmosphere
2. Increased rotation & tilt of axis: less temperature variation
3. Strong magnetic field formed: deflects solar wind
4. Stronger gravity from larger iron core: holds water vapor
5. Essential metals fall back from debris: late mineral veneer
6. Thinned crust and more heat for plate tectonics: continents
7. Huge tides from early Moon: enrich oceans with minerals
8. Moon slows Earth rotation: reduces hurricane winds
9. Tides drive ocean currents: tidal pools concentrate nutrients
10. Tilt of Earth's axis stabilized by Moon: stable weather



# Phased Array Antennas



## Messenger Space Craft Orbiting Mercury

