Formation of Phobos and Deimos by a Giant Collision

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Capture Theory

- Composition closely matches carbonaceous chondrites [1]
- Low densities with Phobos at 1.860 ± 0.060 g/cm^3 and Deimos at 1.650 ± 0.3 g/cm^3 [1]
- Unlikely scenario due to:
  - Mostly circular orbits of Martian moons
  - Orbit plane close to Mars's equatorial plane

Giant Collision Theory

- First proposed by Singer 1996
- Evidence:
  - Larger angular momentum then can be easily described by ordered accretion[1,3]
  - Surface features
    - Large craters hold impact history
    - Oblique craters on surface from moonlets scraping Mars' surface

Increased Angular Momentum

- Define *r* as a relation between the planets mass and hill sphere [1,2]

$$r = \frac{R_P}{R_H} = \frac{R_P}{(GM_p/\Omega^2)^{1/3}}$$

- Number of rotations per revolution[1,2]

$$\mathcal{R} = \frac{3<I_z>}{2\Omega R_p^2}$$

- In ordered accretion $-2.2 < Rr < 0.3$ [3]
- For Mars $R = 670$ and $r = 0.002$ meaning that $Rr = 1.5$

Impactor Mass

- In stochastic accretion, we can define S_m as the ratio between the effective mass of the impactor to the planet defined
  - S_m is related to the excess spin by [1]

$$|\mathcal{R}| \approx \frac{S_m}{r^{3/2}} \approx \frac{m_1}{M_P} r^{-3/2}$$

- Can determine the mass of the impactor using previously calculated values of R and r

$$m_1 = 7.23 \times 10^{22} \mathrm{kg}$$

- Leads to a size of 1795.7 km (assuming a density of 3 g/cm^3)

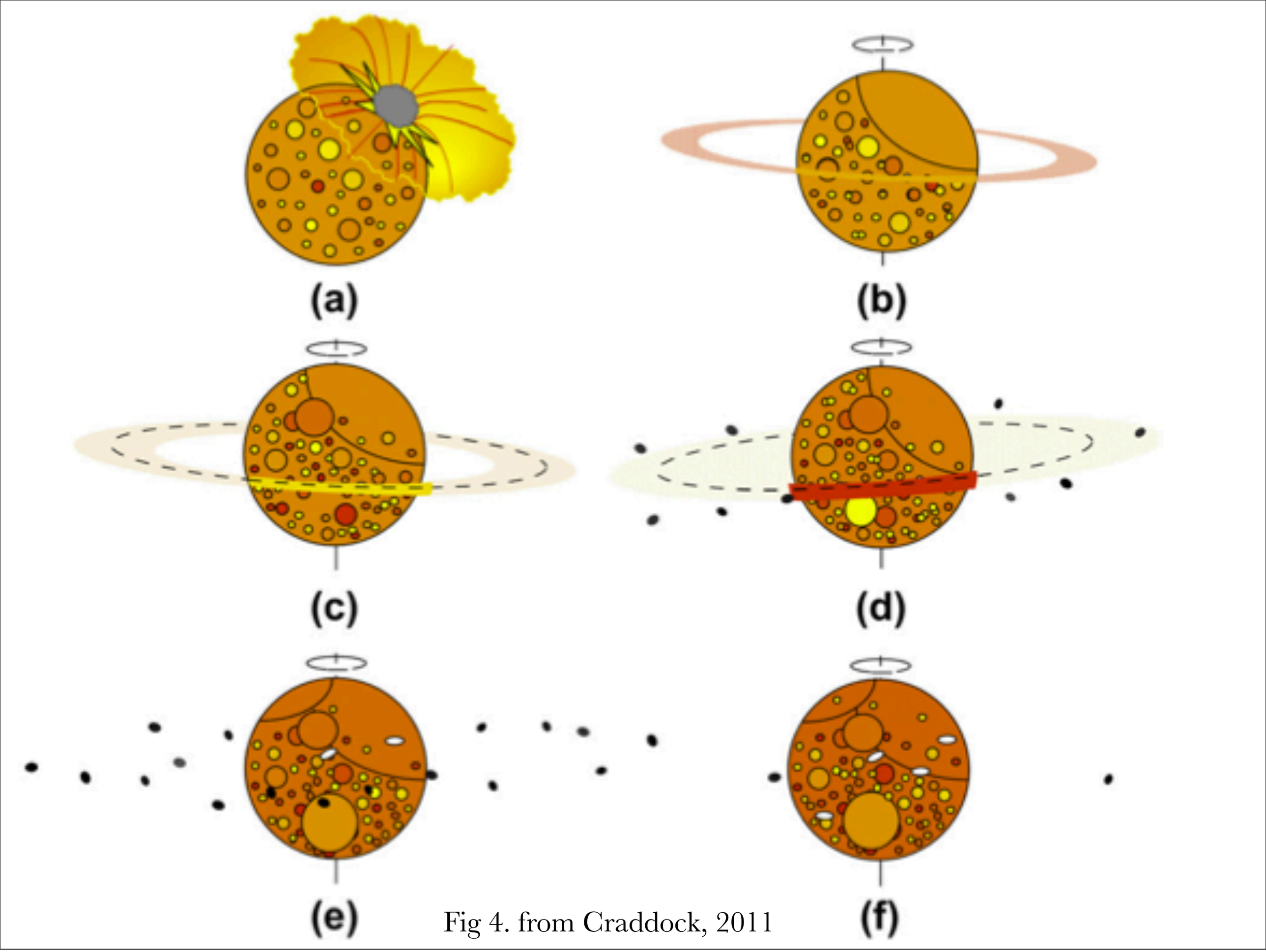


Fig 4. from Craddock, 2011

Large Craters

- Scaling relation for sizes of impact craters[1]

$$D = 1.8\ \rho_i^{0.11}\ \rho_t^{-1/3}\ g^{-0.22}\ L^{0.13}\ W^{0.22}$$

- We can use this to determine the energy impacted to the surface.
  - Get the impact velocity and the object and check against accretion theories to see if the speed is feasible
  - Values of 5 - 10 km/s are applicable [1]

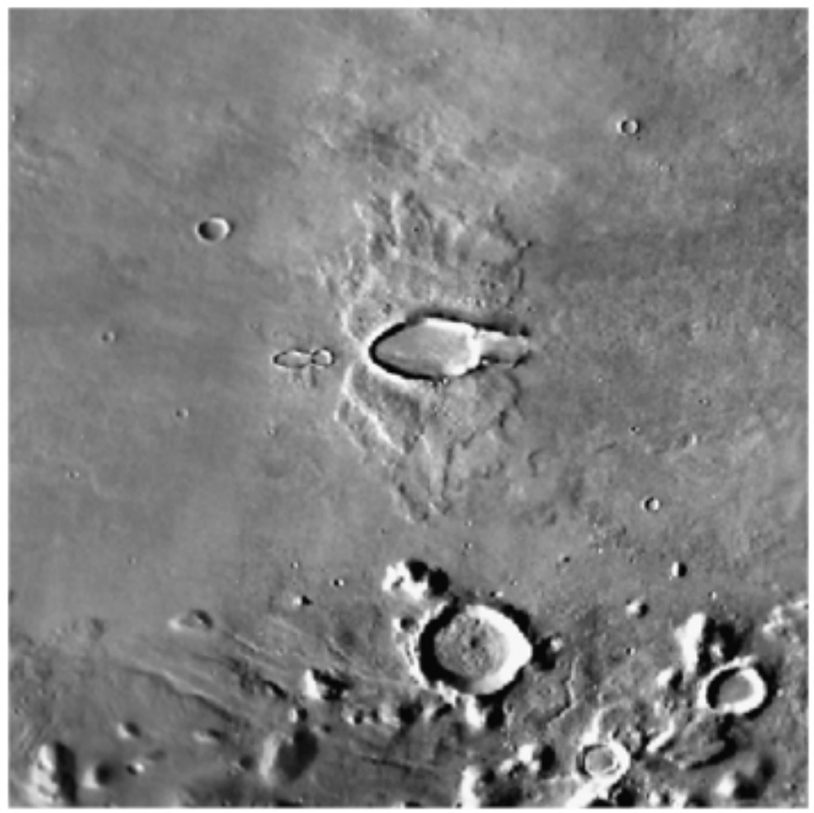
Crater	Diameter (km)	Energy ($10^3$6 W)	Impact Velocity (km/s)
Boreallis A	9550	79.79	15.37
Boreallis B	7700	29.98	9.42
Elysium	4970	4.09	3.48
Daedalia	4500	2.61	2.78
Utopia	3300	0.646	1.37

Oblique Craters

- Potentially many moonlets were in orbit around Mars at one time and fell back down to the surface due to tidal effects

- A double, oblique impact crater located at 40.5°N, 222.5°E

- Best explained by the impact of a former Mars-orbiting moonlet.



Chappelow and Herrick (2008)

Summary

- Phobos and Deimos were likely formed in a giant impact scenario - much like our moon
- Mars has too much angular momentum to have been formed with ordered accretion
- We can determine impactor mass from excess spin
- Then we can compare impactor mass to craters on Martian surface

References

[1] R. A. Craddock. Are Phobos and Deimos the result of a giant impact? *Icarus*, 211:1150–1161, February 2011.

[2] L. Dones and S. Tremaine. On the origin of planetary spins. *Icarus*, 103:67–92, May 1993.

[3] L. Dones and S. Tremaine. Why does the earth spin forward? *Science*, 259:350–354, January 1993.