Astro 210

Lecture 20

March 5, 2018

Announcements

- **HW6 due online in PDF, Friday 5:00 pm**
- **Night Observing this week**

  Campus Observatory. Mon, Tue, Thur 7–9pm

  bring **report form** available on Moodle

  take and submit **selfie** while there
- **Distinguished Lecture & Extra Credit Opportunity**

  Prof. Sara Seager, MIT,

  "Exoplanets and the Search for Habitable Worlds"

  7-8 pm, Wed March 7, Lincoln Hall Theater

  Selfie+online report = *bonus points* ("extra credit")

  Tech alternative: Astro Colloquium 3:45pm Tue Mar 6, NCSA Auditorium

Water on Mars

today: ice–polar caps, permafrost in soil

but much evidence for liquid water in past!

`www: outwash ‘‘river delta’’`

- "arroyos" – river-like channels (run downhill, show sandbars!)
- Martian meteorites: were wet when made
- Mars Global Surveyor: flat basin in N. hemisphere w/ "coast-line" features
  channels stop here → ancient ocean?
- gullies–small but uneroded → recent
  2005–new gully created – confirms active flows
- Mars Phoenix Lander 2008: excavation exposed white material
  gone in 1 day: timescale for water ice → vapor (sublimation)

Life on Mars?

Water → maybe life?
No clear evidence

But: ancient Mars meteorite (discovered on Earth)
Q: how did it get here? how know it's Martian?
claimed to have fossil bacteria
`www:  microscopic image--bacteria-like figures?`
→ perhaps life long ago?

Q: even if Mars had bacterial life–why is this a Big Deal?

Jupiter

prototype for Jovian planets

mass: $M = 1.9 \times 10^{27}$ kg $= 0.1\% M_\odot \simeq$ sum of rest of planets

radius: about 10 R_{Earth}

$\rho_{\text{avg}} \simeq 1,300\ \text{kg/m}^3 \ll \rho_{\text{rock}}$ for sure isn't rocky!

composition: H 79%, He 20%, 1% other $\rightarrow$ very similar to sun

color: ammonia clouds

spin: rapid, 9hr 50min $\rightarrow$ oblate ("M&M shape") $\rightarrow$ atmospheric circulation!

`www: Jupiter`

high pressure regions: zones

low pressure regions: belts

Great Red Spot: long-lived storm

`www: Red Spot`

`www: red spot animation`

Jupiter Interior

`www: Giant planet interiors`
no solid surface!

gaseous atmosphere becomes increasingly dense
until compressed liquid H_2 (hi pressure)
then liquid H metal, probably rocky core
(differentiation of heavy elements)

Saturn

Rings

not solid! many small icy rocks, dust

each has individual circular Keplerian orbit

$\longrightarrow$ rings have different periods, speeds depending on distance

$\sim$ few $\times$ 100 m thick: razor-thin!

aligned with equator

Cassini-Huygens: at Saturn 2004–2017

spectacular views of rings

detailed data on ring structure, interaction with moons

`www: Cassini images, movies`

iClicker Poll: Saturn's Rings

Saturn's rings made of orbiting particles

What is pattern of orbit periods, from innermost to outermost?

A $P_{\text{inner}} < P_{\text{mid}} < P_{\text{outer}}$

B $P_{\text{inner}} = P_{\text{mid}} = P_{\text{outer}}$

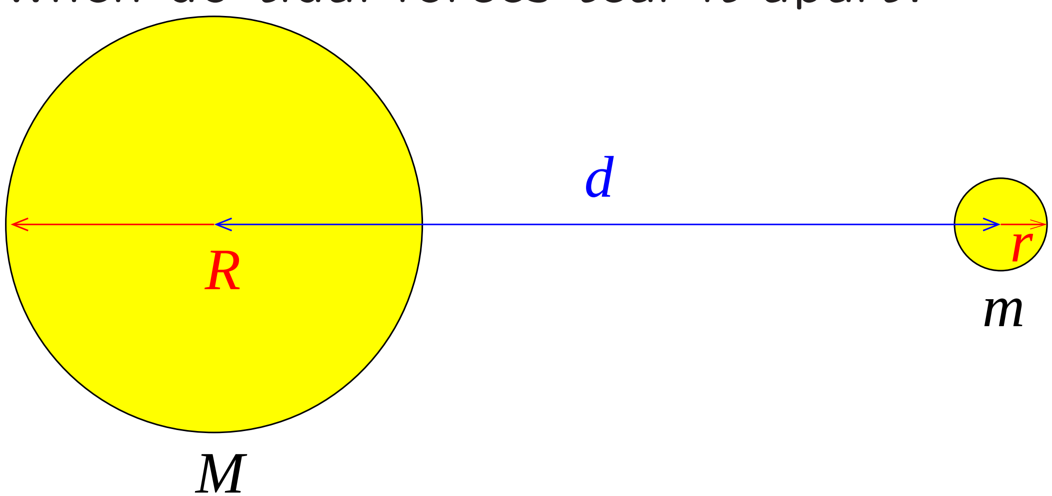
C $P_{\text{inner}} > P_{\text{mid}} > P_{\text{outer}}$

So: why does Saturn have rings?
what gives them their structure?

Tidal Forces: Roche Limit

consider "orbiter" object held together **by gravity alone**
"self-gravitating" mass m, size r
think: "rubble pile" held together by its own gravity
put in gravitational field of larger object M

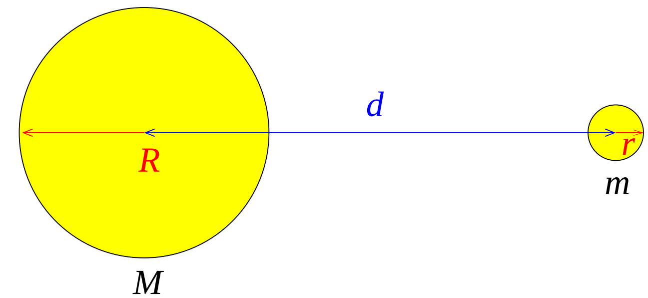
tidal forces of M in competition with self-gravity *Q: why?*
when do tidal forces tear it apart?



how close is too close?

competition:

inward self-gravity vs. *outward tides*



•grav. force on test particle at orbiter surface r is
$F_{\mathrm{g}} = G m m_{\mathrm{test}}/r^2$

•large body of mass $\mathcal{M}$ at d exerts tidal force
$F_{\mathrm{t}} = 2 G \mathcal{M} m_{\mathrm{test}} r/d^3$

Ratio of inward orbiter gravity to outward tides:

$$\frac{F_{\mathrm{g}}}{F_{\mathrm{t}}} = \frac{1}{2}\,\frac{m}{\mathcal{M}}\left(\frac{d}{r}\right)^3$$

for fixed m and $\mathcal{M}$:

Q: behavior for large separation $d \gg r$? for $d \ll r$?

Q: critical distance?

Roche Limit

tides and gravity equal when $Gmm_{\text{test}}/r^2 = 2G\mathcal{M}m_{\text{test}}r/d^3$, or

$$d = d_{\text{Roche}} = \left(2\frac{\mathcal{M}}{m}\right)^{1/3} r \tag{1}$$

and in terms of average densities, e.g., $\rho_M = 4\pi\mathcal{M}/3R^3$

$$d_{\text{Roche}} = \left(2\,\frac{\rho_M}{\rho_m}\right)^{1/3} R \tag{2}$$

if densities of similar, so that $\rho_m \approx \rho_D Mm$, then

$$d_{\text{Roche}}^3 \approx 2R^3 \quad \Rightarrow \quad d \approx 2^{1/3} R = 1.3R \tag{3}$$

more detailed analysis (fluid orbiter): $d_{\text{Roche}} = 2.4R$

this is "**Roche limit**":

- for $d > d_{\text{Roche}}$: orbiter bound by self-gravity
- for $d < d_{\text{Roche}}$: orbiter torn apart by tides

Q: implications for rings?

Roche Limit and Rings

Saturn: rings lie inside Roche limit, moons lie outside
$\longrightarrow$ are rings "protomoon" that never coalesced?
$\longrightarrow$ more likely: captured moon

note: **all** Jovian planets have rings!
`www: Jupiter rings (Voyager, IR)`

note: we are inside the Roche limit for Earth!
Q: why don't we get ripped apart?