Astro 210

Lecture 20

October 11, 2010

Announcements

- HW 6 due in class Friday
- last week for Night Observing!
  info and schedule online

Last time: Jupiter

great red spot *Q: what's that?*

composition and interior *Q: ?*

Saturn

Rings

not solid! many small icy rocks, dust

each has individual circular Keplerian orbit

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

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

aligned with equator

Cassini-Huygens: ongoing mission

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

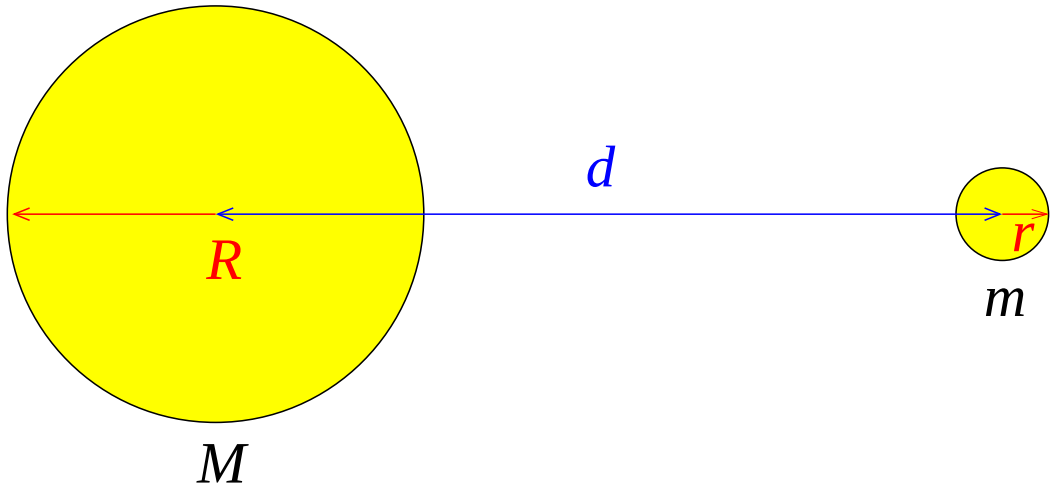
C $P_{\text{inner}} > P_{\text{mid}} > P_{\text{outer}}$

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

Tidal Forces: Roche Limit

consider object held together **by gravity alone**
"self-gravitating" mass m, size r
think: "rubble pile" held together by its own gravity
put in gravivtational 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 surface is $F_{\rm g} = Gmm_{\rm test}/r^2$

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

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

$$d^3 = 2\frac{\mathcal{M}}{m}r^3 \qquad (1)$$

if densities of similar

$$\frac{\mathcal{M}}{R^3} \approx \frac{m}{r^3} \qquad (2)$$

and so

$$d^3 = 2R^3 \quad \Rightarrow \quad d = 2^{1/3}R = 1.3R \qquad (3)$$

more detailed analysis: $d = 2.4R$
this is "Roche limit"; closer $\rightarrow$ torn apart

Saturn: rings inside Roche limit, moons outside

$\rightarrow$ rings are captured moon?

$\rightarrow$ more likely: "protomoon" that never coalesced

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?

Debris

in addition to planets

Solar system contains large amount of smller junk

- rocky debris: asteroids
- icy debris: comets

Debris I: Asteroids

Properties

"minor planets" number $\sim 10^5 - 10^6$

masses: total $\sim 10^{-5} M_{\text{Earth}}$

sizes: poorly known, but go up to ~ 300 km

composition: solid (no gasses, ices)

- 5/6 are "C-type" carbon rich
- 1/6 rea "S-type" iron rich

Q: how do we know this?

Asteroid Orbits

asteroids orbit Sun $\rightarrow$ must follow Kepler's laws (of course!)

wide variation in a, e

but average $\bar{a} \simeq 2.8$ AU

$\rightarrow$ between Mars & Jupiter

avg $e < 0.1$: nearly circular

most orbit planes close to ecliptic

`www: Inner Solar System in real time`

`www: Near-Earth objects`

if cross Earth's orbit, enter atmosphere: meteorite

`www: Leonids`

`www: fireball`

Note: meteorites on view in Geology–extraterrestrial matter!

LSST: will identify $> 90\%$ of near-Earth asteroids with $R > 140$ m

Hour Exam 1

Scores posted on Compass.

Solutions posted online.

In general: people did well, I was pleased

Recall:

- this exam worth 10% of final grade
- equivalent to 2 HW grades