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: Venus
- similar to Earth in size, mass, composition
  probably very simliar at birth
- but now: hellishly hot
- $T_{\text{surface}} \gg T(a_{\text{Venus}}) \approx 230$ K from our master equation

$\rightarrow$ i.e., much hotter than expected equilibrium avg
but our calculation only used energy conservation
and properties of thermal radiation

Q: Why so hot?

Greenhouse Effect

basic idea: atmosphere traps thermal energy
surface region at different T than top of atmosphere
in HW6 you work this out in detail
note: important for Earth and Mars too

Consider radiative energy flows
incoming: sunlight–visible wavelengths, atm transparent
  Venus surface not dark!
outgoing: surface thermal (BB) emission: IR
  but CO_2 in atm blocks IR, absorbs energy
$\Rightarrow$ atmosphere acts like blanket

iClicker Poll: CO_2 and Surface Temperature

Imagine Sun's radiation and Venus orbit fixed
but more CO_2 added to Venus' atmosphere

What would be the effect on Venus' surface temperature T_s?

A T_s stays the same

B T_s increases

C T_s decreases

Venus: probably initially cooler, had liquid water(?)
  note–early Sun was 30% dimmer!

if so, CO_2 dissolved in oceans, rocks
  note: CO_2 in Earth rocks, oceans is enough
  for 70 atm! ...just like Venus!

Now imagine: watery Venus heated a bit
Q: What is effect of heating on atmosphere? on temperature?

if early water-bearing Venus heated, positive feedback loop:
Heat $\rightarrow$ surface $T \uparrow$
$\rightarrow$ H_20 evap, atm $\rightarrow$ CO_2 released as well
$\rightarrow$ repeat until all H_2O evaporated!

also: H_2O molecules lighter than CO_2
$\rightarrow$ all H_2O evaporated
$\rightarrow$ go to upper atm
$\gamma + H_2O \rightarrow H + OH$, H escapes
$\Rightarrow$ water lost! – warming irreversible
$\rightarrow$ **runaway greenhouse effect**

Mars

Vital Statistics:
$R \simeq 1/2\ R_{\text{Earth}}$
$M \simeq 10\%\ M_{\text{Earth}}$
$\rho_{\text{avg}} = 3900\ \text{kg/m}^3\ <$ Earth $\rightarrow$ smaller core

atmosphere thin: $P_0 \sim 1/200$ Earth atm
$\rightarrow$ liquid water cannot exist! sublimates, freezes
composition: heavy species–95% CO_2, $\sim 2\%$ N_2, Ar
- smaller mass $\rightarrow$ more escape
- no ocean to absorb CO_2

surface temperature: $T \sim$ 190–240 K
polar caps: frozen water, CO_2; cap sizes vary: seasons!

soil – iron rich (red color $\rightarrow$ iron oxide=rust)

Water on Mars

today: ice–polar caps, permafrost in soil

`www: nuclear reaction cartoon`

`www: epithermal neutron map of Mars`

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/ "coastline" features

  channels stop here → ancient ocean?
- gullies–small but uneroded → recent

  2005–new gully created – confirms active flows
- Mars Phoenix Lander 2008: excavated trench exposed white material

  gone after 1 day–right timescale for water ice → vapor (sublimiation)

Life on Mars?

Water $\rightarrow$ 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?`
$\rightarrow$ 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}
$\rho_{\text{avg}} \simeq 1,300$ 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

transp: Jupiter cutaway
no solid surface!

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