Lecture 6

Galilean satellites of Jupiter-- miniature solar-system

Io, Europa, Ganymede, Callisto
Bulk density decreases with distance from Jupiter – rock and metal, to densities appropriate for rock and ice
Excluding Io, surfaces are clean ice near Jupiter – dirtier ice farther away

Synchronous rotation

Leading and trailing hemisphere

<u>Resonance between Io, Europa, Ganymede & Jupiter</u>

PEuropa/PIo = 2 PGanymede/PIo = 4

Expect tidal heating for Io (most), Europa, & Ganymede (least)– consistent with observations

Induced versus intrinsic magnetic field

Galileo results:
Io and Ganymede appear to have relatively large dipole magnetic fields – Io's may be induced, but Ganymede's appears to be intrinsic

Europa and Callisto have weak magnetic fields that are almost certainly induced- don't expect any iron core to be liquid – evidence for "salty" water in interior?

Callisto

one of the
most uniformly
cratered
objects in the solar
system
so geologically old

Jupiter &
Ganymede

the largest
planet &
the largest
moon

grooved and smooth terrains vs. dark terrain

Ganymede - **even "youngest" terrain has a fair number of craters**

Rampart craters = Ganymede (also saw on Mars)

Europa – bands and ridges – few impact craters

ridged
terrain

multiple
episodes
of ridge
formation

topography resembles mid-ocean ridges on Earth

Europa ridges

evidence
for strike-slip
faulting along
ridges– they are partly tectonic in origin

Cryovolcanism

Europa

dark patches:
eruptive material

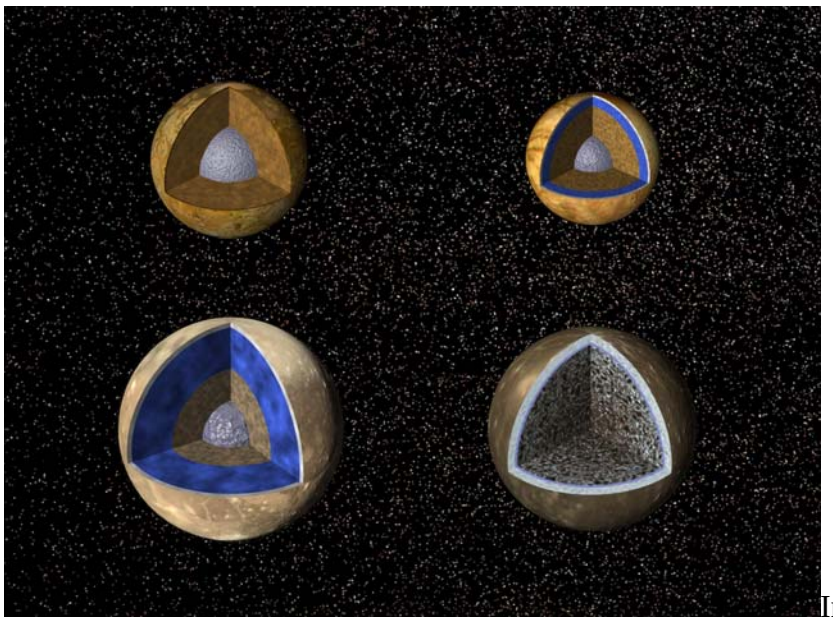
domes:
eruptive centers

rafted terrain – good evidence for “lakes’

Europa

late eruption
of less pure,
saltier water along ridges

freezing
of subsurface
ocean?

 Interior models from NASA’s Photojournal site: http://photojournal.jpl.nasa.gov/jpeg/PIA01082.jpg

Fore Europa, Ganymede, Callisto: liquid H2O
inferred based on magnetic field data

Galilean moons – recap

- **Io volcanically active; magnetic interaction with Jupiter**

- **Europa recently resurfaced; many cryovolcanic features, including "lakes"; subsurface ocean? hydrothermal vents?**

- **Ganymede locally resurfaced at earlier time; any current activity? subsurface ocean, internally generated magnetic field?**

- **Callisto very old surface covered with debris; subsurface ocean? Not differentiated?**

- **properties governed by position in Jupiter system**

<u>Titan – Moon of Saturn</u>

- bigger than Mercury – diameter 5100 km
- 2nd largest moon in solar system
- orbital period: 15.9 days (tidally locked)
- density: 1.88 g/cm3
- only moon with a significant atmosphere
- organic chemistry in atmosphere

PS = 1.5 bars, TS = 97 K

94% N2 6% CH4 0.2% H2

< 50 ppm of various hydrocarbons,
N-compounds, CO, CO2 ;
Ar maybe present

Titan's atmosphere

Voyager 1 flyby - 1980
Voyager 2 flyby - 1981
Cassini orbiter - 2004 to present

Titan—

In visible light,
orange “smog” layer
completely
obscures surface

Titan’s atmosphere:
hydrocarbons & nitriles
(Voyager 1 infrared spectral data)

Compound	**Formula**	**Concentration**
ethane	**C2H6**	**10 ppm**
acetylene	**C2H2**	**2 ppm**
propane	**C3H8**	**500 ppb**
hydrogen cyanide	**HCN**	**170 ppb**
ethylene	**C2H4**	**100 ppb**
cyanoacetylene	**HC3N**	**10 ppb**
other nitriles & H-C	**various**	**< 10 ppb**

Hemispheric hazes & global winds

Titan

haze layers--
main & detached

High hazes:
multiple layers of aerosols (find solid particles or liquid droplets)

north polar hood
especially high (500 km high) detached haze layers at north pole

polar hood aerosols thought composed partly of ethane (red areas in image)

Model: Haze particles migrate from

summer to winter hemisphere,
forming polar hood & hemispheric hazes

model predicts that hazes accumulate at cold (now northern) pole

aerosols there could potentially grow & fall towards the surface

Comparison of Earth and Titan atmosphere structure

Main component of both is nitrogen

Earth-- important role for water & oxygen

Titan-- important role for methane (CH4)

Titan's Upper Atmosphere:
exposed to sunlight
Photochemical reactions
CH4 + uv light → C-H radicals

N2 + e- → N radicals

radicals: have unpaired electrons, are reactive

C-H radicals: CH3, CH2, CH

Titan's Middle Atmosphere:
smoggy (aerosol hazes)
Haze & Tholins produced
radicals → C-N-H compounds (haze)

C-N-H compounds:
solids called "tholins",
have orange/brown coloration

Tholins produced in laboratory

- **requires H-rich atmosphere with C & N, some energy input**
- **Miller-Urey synthesis: make tholins from CH4 & NH3, sparks**
  --tholins include amino acids

Titan's Lower Atmosphere:
colder, rainy, snowy,
some methane clouds
rain predicted:
liquids, mostly ethane
& methane? ~ 1 cm/year?
snow predicted:
tholins
~ 1 cm/100,000 years?

experiments & models for Titan-like gases:
tholins should have C: N: H ~ 10: 10: 1
H mainly lost to space, C & N deposited on surface

<u>Titan</u> atmosphere lost, ~2-10x more gas earlier

Titan's surface

haze prevents viewing in visible light - probe via:

(1) IR light
- atmosphere somewhat transparent
- different surface materials radiate differently
- good: can see global context, clouds
- bad: have atmospheric blurring

(2) radar
- smooth areas dark, rough areas bright
- good: have high spatial resolution
- bad: have limited coverage, in narrow swaths only (1 per flyby pass)

2004 Cassini-Huygens (NASA/ESA)

Orbiter – radar mapper, IR mapper, UV mapper

Lander – optical camera, suite of instruments to measure properties/chemistry of atmospheric gas and aerosols, and some surface properties

**IR light emitted
from surface penetrates
haze layer**

**In IR light,
absorptions
characteristic
of different
materials occur**

Xanadu is largest of IR-bright terrains near equator;
have hydrocarbon-rich IR-dark equatorial zone

Titan surface features

Global wind patterns – huge dune fields

1. Rotation of Titan creates west to east winds
2. Tidal interaction of atmosphere with Saturn
causes surface winds to blow towards equator

Any sand becomes concentrated in
longitudinal dunes in equatorial belt

**dunes on Titan resemble longitudinal dunes on Earth
created by persistent wind from 2 different but generally not dissimilar directions;
these align sand particles into symmetric dunes that parallel main wind direction**

Dune deposits are IR-dark hydrocarbon-rich areas, concentrated in equatorial belt – sand-sized particles (tholins?)

**Dunes on Titan probably composed
of particulate hydrocarbons (tholins), not quartz-rich sand as on Earth**

Titan surface features

Evidence for flowing liquid (not water) on surface

a) channels
b) lakebeds
c) polar lakes, swamps/floodplains, seas

channels:
hydrocarbon
(methane?) rain

Dense valley networks

smooth areas with convolute, interfingering margins: probable lakebeds and former shorelines

Ontario Lacus:

Liquid ethane
± propane
± butane

(+ presumed
methane)

Existence of confirmed methane clouds at south pole suggests Ontario Lacus may have methane liquids

radar images of north polar lakes and "swamps"

radar image of large lakes & floodplains on Titan

How old are Titan's surface features?

Look for impact craters

Craters present, but crater density not high and many eroded – so surface "relatively" young

Huygens lander

- **carried piggyback on Cassini orbiter**
- **first probe to land on a moon in the outer solar system**
- **first probe of the European Space Agency (ESA) to land successfully anywhere**

Huygens sideways view – 8km altitude
Plateau (light) and lowlands (dark)

dendritic
channels:

surface
flow of
liquids

Huygens landing site contains gravel (cobbles) – but not made of silicates (rock) – water ice?

--too coarse for wind transport
--possible outwash deposits

slightly squishy surface – not just water ice

Surface: methane-bearing ices

? some water/methane ice cobbles with "tholin" sands?

Surface: ethane & cyanogen-bearing compounds
Cyanogen: the main tholin? Ethane: subsurface moisture?

Surface: not the mix of tholins we expected

Interior
Radar observations between Oct. 2005 and Mar. 2007 indicate 31 km shift in the expected location of surface features.

Evidence for decoupling between lithosphere and deep interior--best accommodated by subsurface ocean.

Many unresolved questions

1) **Much geology on Titan seems atmosphere-related. How internally active is Titan?**

2) **Titan mostly dry in equatorial regions, now. But there is evidence for past liquids there. Does Titan undergo climate change, and if so on what timescale?**

3) **Why are surface liquids mostly found at polar latitudes?**

4) **What is the composition of the liquids that fill polar lakes and seas? Methane, ethane, or other hydrocarbons?**

5) **Why and how do surface tholins (C-N compounds) on Titan differ from those expected? Are dune deposits composed of tholins?**

6) **Characteristics of the subsurface ocean? Thickness &depth? Composition?**