The Cosmos

Planets & Life

PHYS 214

Dr Rob Thacker

Dept of Physics (308A)

thacker@astro.queensu.ca

Please start all class related emails with "214:"

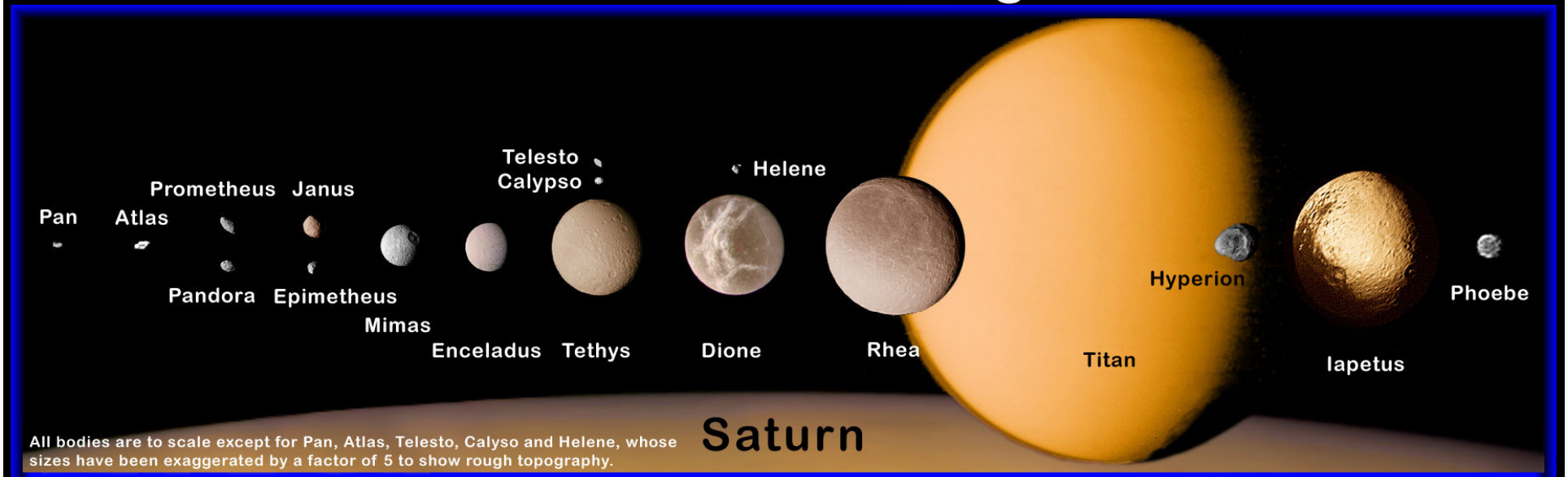
Admin

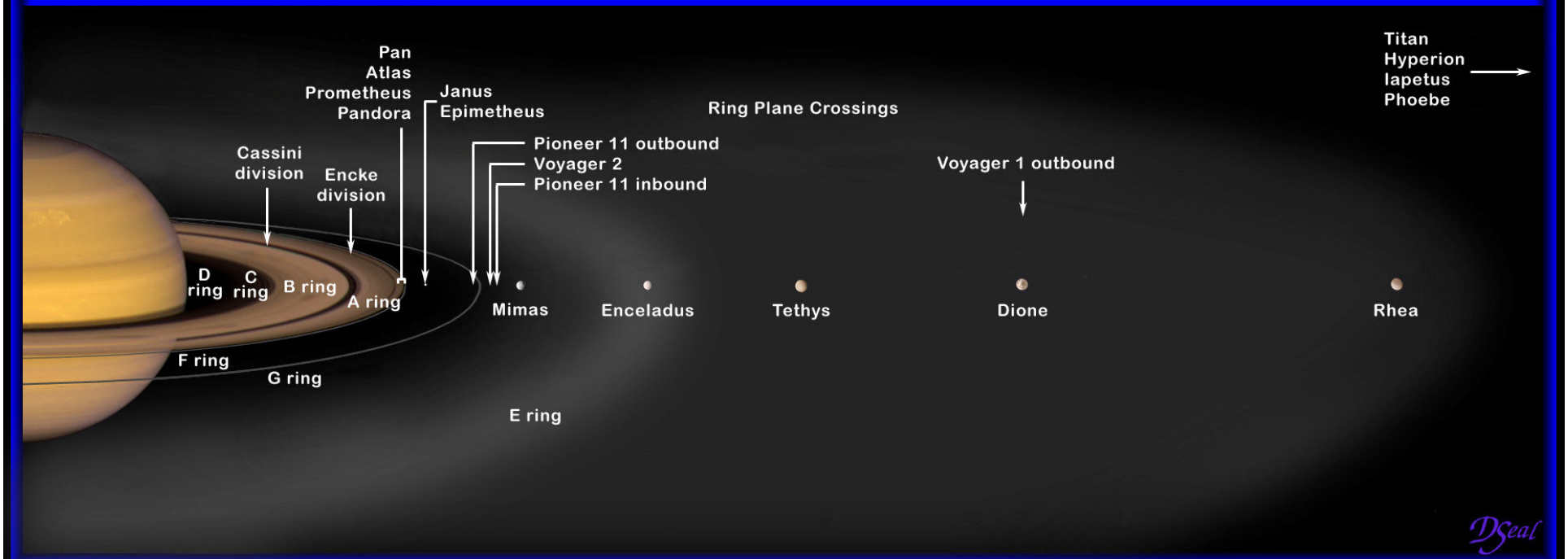
- Assignment 4 to be posted tonight
- Due on last official class on Wednesday 4th April (*two* weeks this time)
- I will run a purely voluntary *review* lecture (no new material) on April 6th since term ends on April 5th
- USATs Friday? – need volunteer to pick them up from the physics main office and drop them off
- Final exam April 24th, 2pm (2 hours)
  - I'll give more information on the exam structure when I've finalized and written it

Today's Lecture

- Titan
  - Lecture derived from a presentations by Dr Conor A Nixon (University of Maryland), Dr Jonathan Lunine (Arizona)
    - Gilmour & Sephton is out-of-date relative to the Cassini-Huygen mission
  - Saturn system summary
  - Titan history
  - Space probes (Voyager 1 and Cassini-Huygens)
  - Atmosphere
  - Geography
  - Life?

Saturn's Satellites and Ring Structure

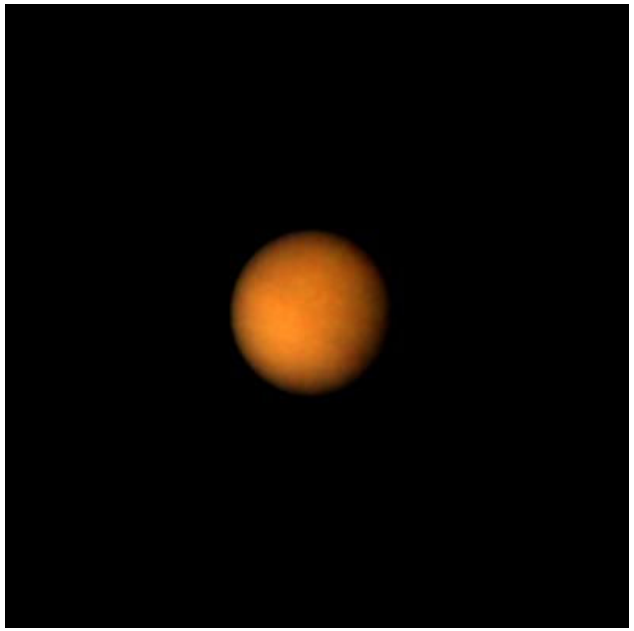




The Giant Moon

- Titan was the sixth moon ever to be discovered, in 1655 by Dutch astronomer Christian Huygens.

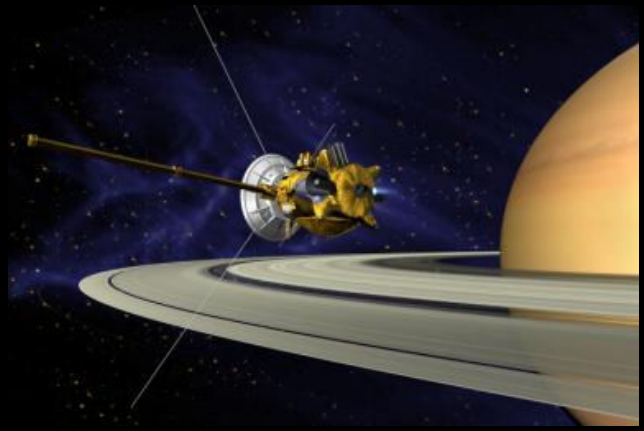
- Named due to its massive size, Titan was originally thought to be the solar system's largest moon.
  - That title goes to Ganymede (Jupiter)
- Through a large telescope, Titan appears as a pale orange ball. Even Voyager 1 saw little detail.



Value of space missions

- Voyager 1
  - Extremely little known about Titan prior to Voyager 1
  - Provided enormous amount of information about Titan's atmospheric composition
  - Also provided estimates of atmospheric structure and temperature

- Cassini-Huygens (NASA-ESA)
  - Utilized the information learnt from Voyager to include
    - Imaging spectrometer to see through the haze (VIMS)
    - GCMS on Huygens to look at atmosphere composition during descent
    - SSP surface science packages



http://saturn.jpl.nasa.gov/home/index.cfm

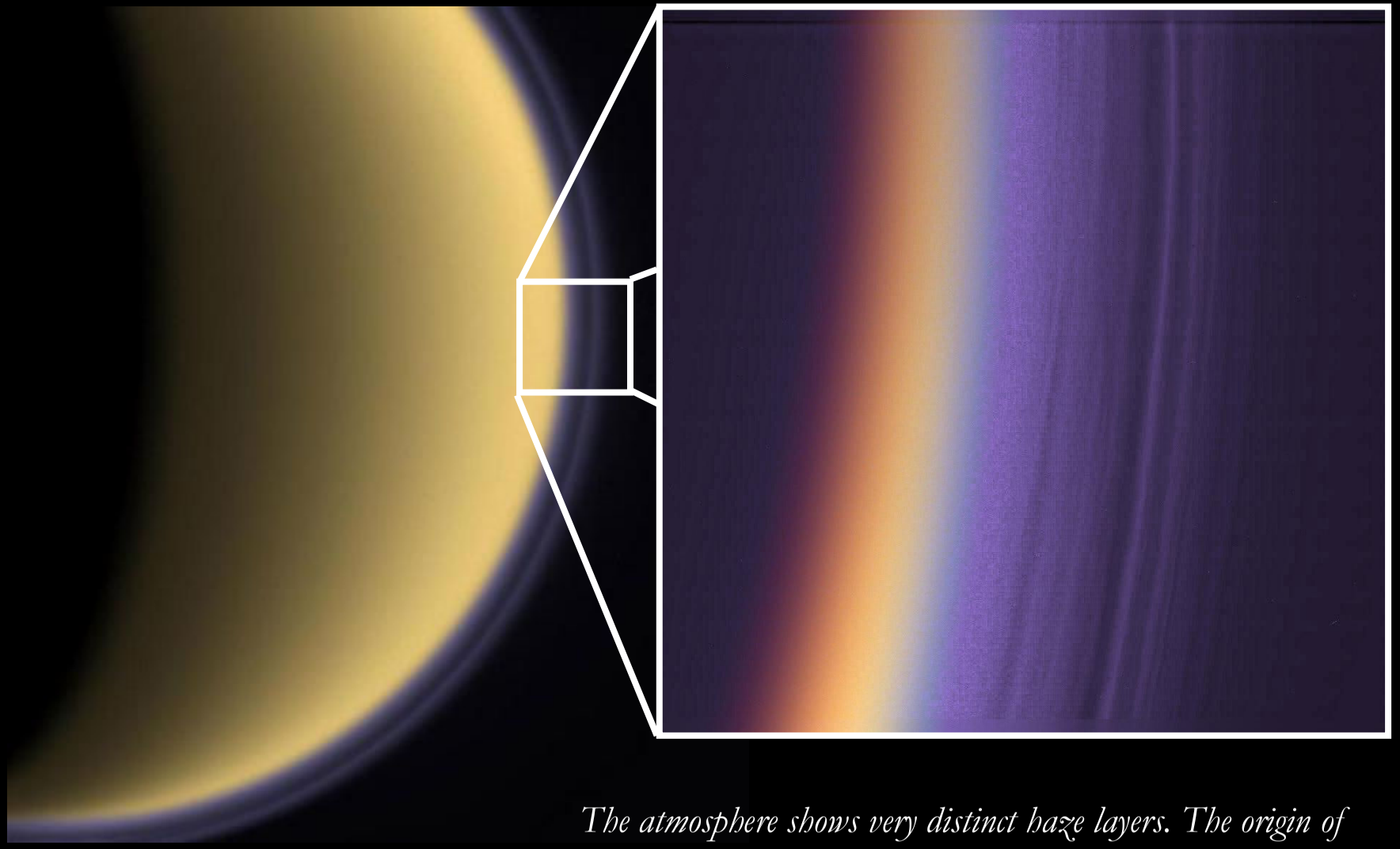
Useful facts about Titan

- Titan's diameter of 5150 km is larger than Mercury but smaller than Mars
- Titan rotates very slowly – one Titan Day corresponds to about 16 Earth days
- Titan is tidally locked around Saturn just like our own Moon
  - Same face always points toward Saturn
  - Orbital period must also be 16 Earth days
- With Saturn's orbital period being 29.5 Earth years, a year on Titan contains about 673 Titan Days
- Inclined at 26.7° to the Sun (cf Earth's ~23°) => Titan experiences seasons
- Without being able to take soundings we know very little about its internal structure

Titan's surface is obscured by clouds

- Titan's size was originally over-estimated: we are looking at dense, thick layers of **opaque haze**, not the surface.
- Voyager 1 snapshots of the planet's edge (1980) showed that the haze was *multi-layered*.

- Voyager 1 was crucial in determining the size of Titan - used radio waves to penetrate the haze

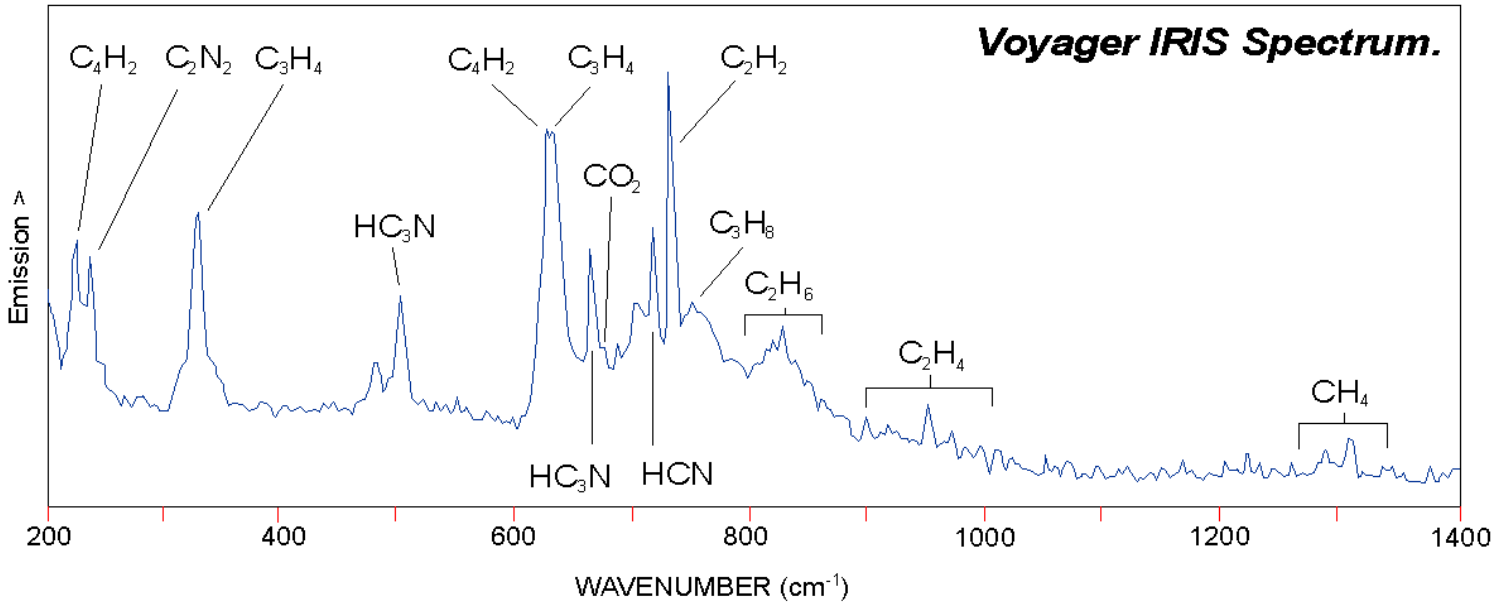


The atmosphere shows very distinct haze layers. The origin of these layers is not yet understood (possibly related to a wave-type phenomenon in the atmosphere).

Atmospheric Composition

- We now know that the atmosphere is largely composed of nitrogen. Sound familiar?

- In addition, the atmosphere contains several percent of methane, and many compounds of H,C,N: but no free O_2.



Relative abundances in Titan's atmosphere

Molecule	Relative abundance on Titan (Earth)
N_2	0.97 (0.78)
CH_4	3×10^{-2} (1.75×10^{-6})
H_2	2×10^{-3} (5.5×10^{-7})
CO_2	6×10^{-5} (3.84×10^{-4})
C_2H_6	2×10^{-5} (1.75×10^{-6})
C_2H_4	4×10^{-6}

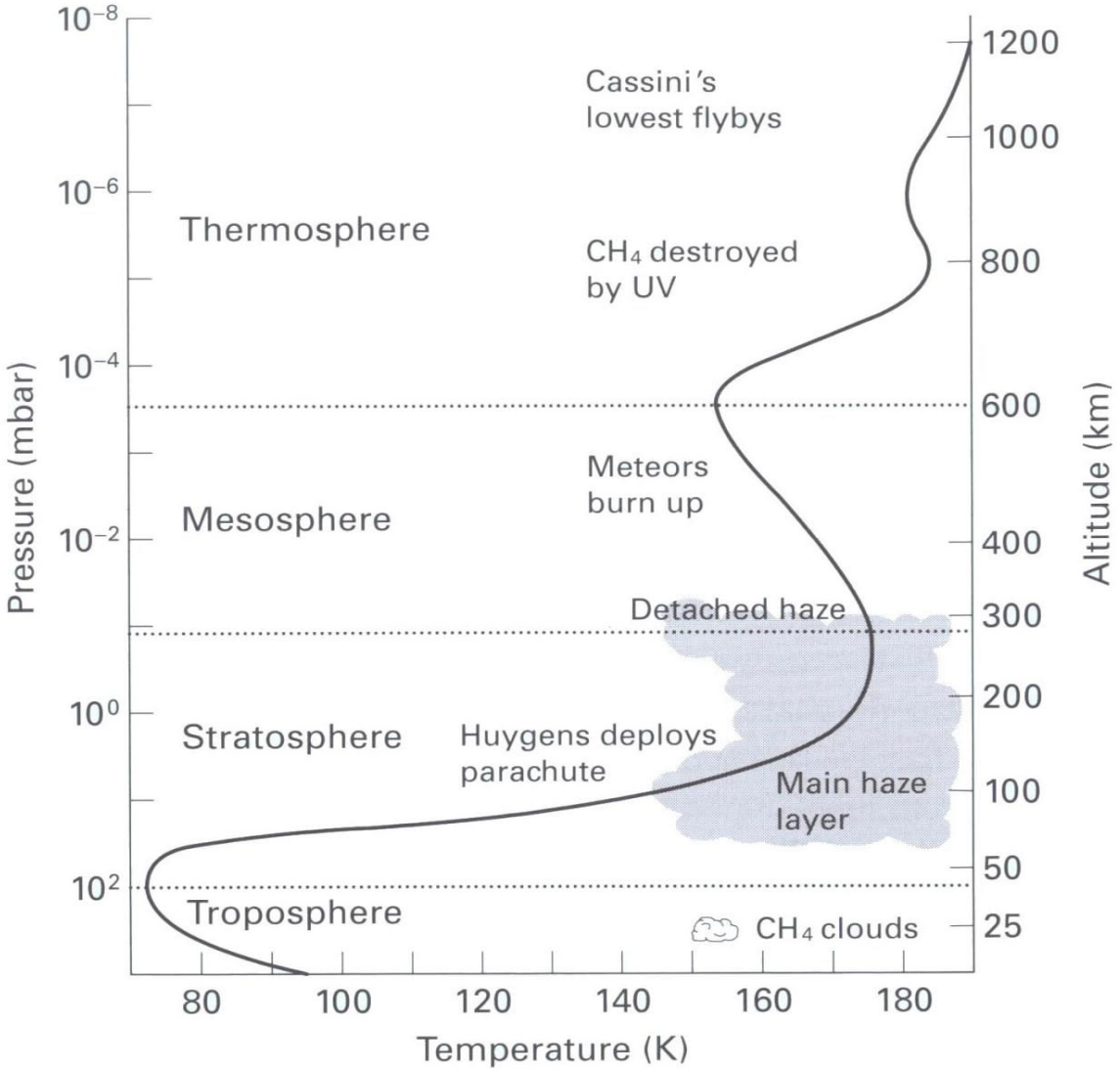
Temperature of Titan

- Naively applying the radiation balance model to Titan we find the estimate for it's temperature is

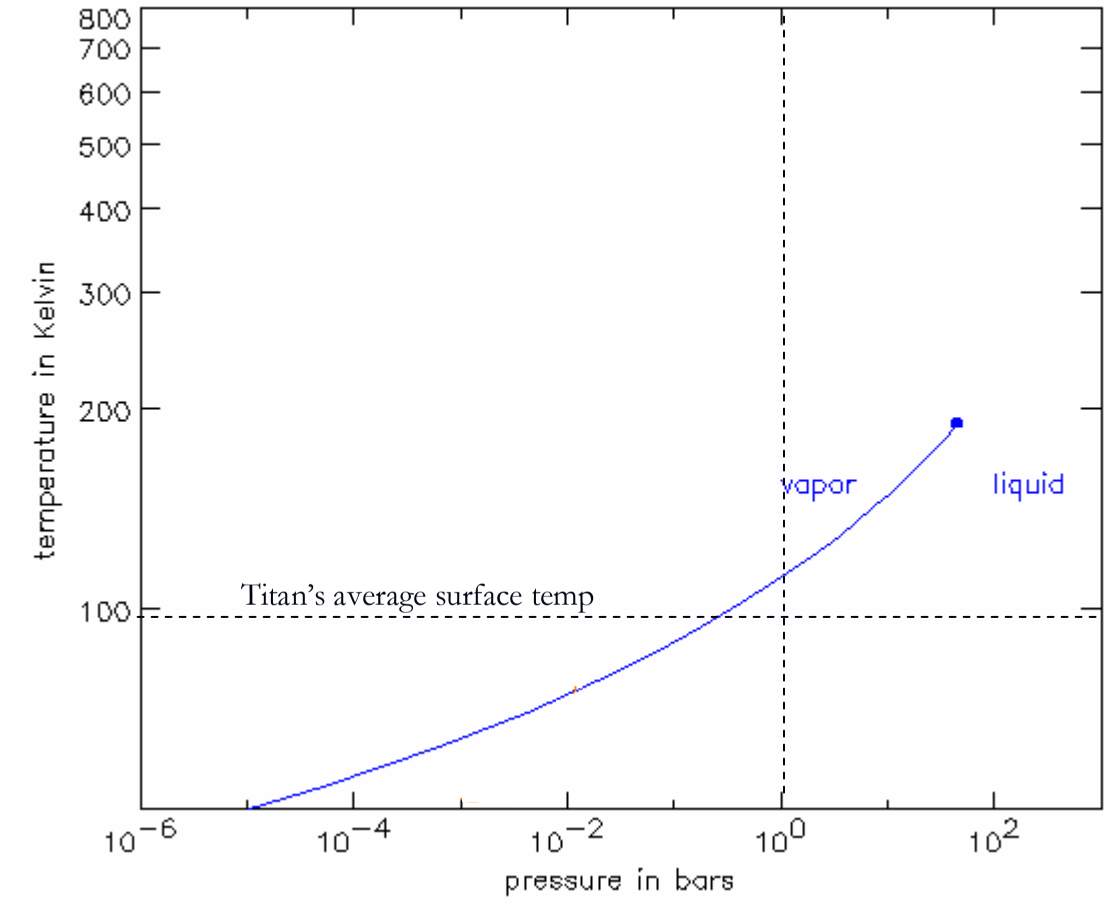
$$T_p = \frac{278}{\sqrt{d_{p\text{ in AU}}}}\,\mathrm{K} = \frac{278}{\sqrt{9.5}}\,\mathrm{K} \cong 90\,\mathrm{K}$$

- This is actually very close to the found answer
- Haze created in Titan's atmosphere serves to increase albedo – compensating for any greenhouse effect that might occur
  - Sometimes called an "anti-greenhouse effect" but is equivalent to the scenario involved in a "nuclear winter"

Temperature in the atmosphere



Phase diagram for methane



One bar is about 1 atm

Pressure at surface of Titan is about 1.5 bar

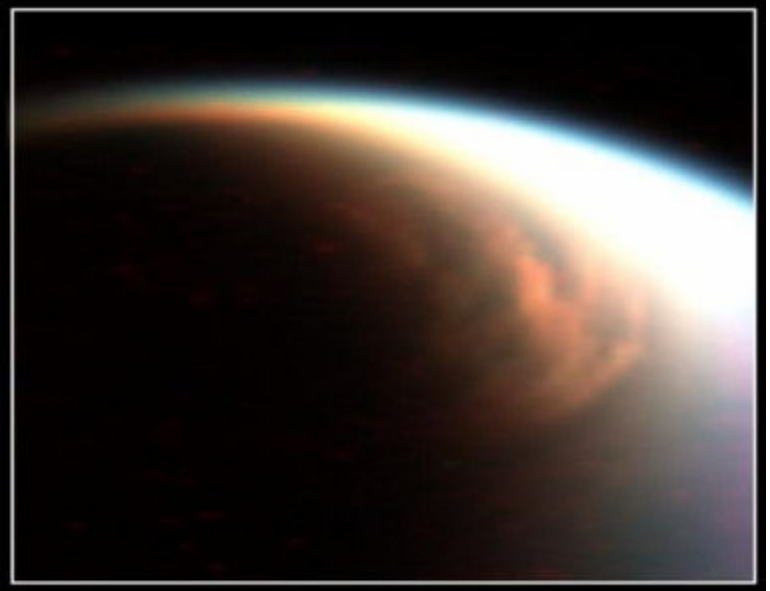
Expect to find both liquid and gaseous forms of methane

Atmospheric chemistry…

- Titan's atmosphere is a giant chemistry lab: UV light from the distant Sun splits up some of the native methane and nitrogen molecules, *e.g.*
  - CH_4 + photon → CH_2 + H + H
  - CH_4 + photon → CH + H + H_2
- The highly reactive radicals will then bond together in new ways, forming heavier chemicals which are expected to condense and rain out
  - Comparatively straightforward to form very long chain hydrocarbons through reactions with CH radicals (see G&S 180)
- Over billions of years, huge lakes of liquid hydrocarbons *should* have accumulated on the surface…

Titan's "Climate"

- At -94 K water will not evaporate so there is virtually essentially no water vapour in the atmosphere
- Clouds are composed of methane/ethane and other simple organic molecules
- Precipitation of the clouds should also result in liquid methane & ethane rain!
  - Will help form the proposed lakes and seas of hydrocarbons



Polar cloud formation


Lakes of hydrocarbons…. an artist's impression

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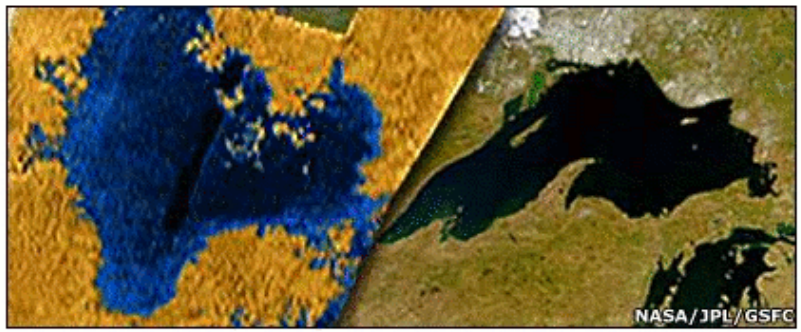
Probe reveals seas on Saturn moon

By Paul Rincon
Science reporter, BBC News, Houston



The Cassini radar image (left) shows one of Titan's seas is larger than Lake Superior (right)

Nasa's Cassini probe has found evidence for seas, probably filled with liquid hydrocarbons, at the high northern latitudes of Saturn's moon Titan.

The dark features, detected by Cassini's radar, are much bigger than any lakes already detected on Titan.

The largest is some 100,000 sq km (39,000 sq miles) - greater in extent than North America's Lake Superior.

It covers a greater fraction of Titan than the proportion of Earth covered by the Black Sea.

The Black Sea is the Earth's largest inland sea and covers about 0.085% of our planet's surface.

The newly observed body on Titan covers at least 0.12% of that world's surface. Cassini team members argue that this gives them reason to

CASSINI MISSION TO SATURN

ANIMATED GUIDE

Destination Saturn
Watch how the Cassini mission to the ringed planet takes place

LATEST NEWS
- New Saturn ring discovered
- 'Ethane cloud' seen on Titan moon
- 'Great lakes' seen on Titan moon
- Saturn's moon 'best bet for life'

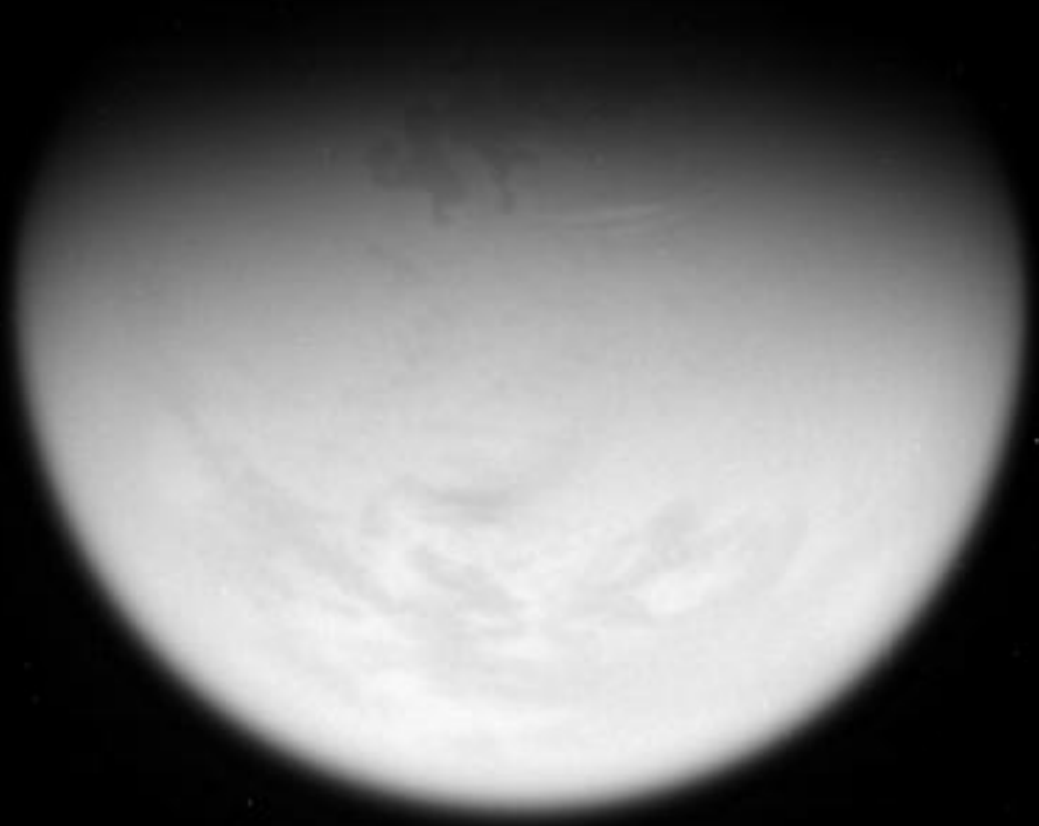
PLANET AND RINGS
- Saturn rings have atmosphere
- Cassini makes detailed ring map
- Saturn ring particles 'fluffy'
- Cassini sees lightning on Saturn

MOON VISITS
- Cassini's super scenes on Saturn
- Saturn moon 'may have ocean'
- Icy Dione captured in close-up
- Cassini pictures spongy Hyperion

TITAN TARGET
- 'Ice volcano' found on Titan moon
- A return to the orangey world
- Titan probe's pebble 'bash-down'
- Huygens probe lands on Titan

RELATED INTERNET LINKS
- Cassini-Huygens, JPL
- Cassini-Huygens, European Space

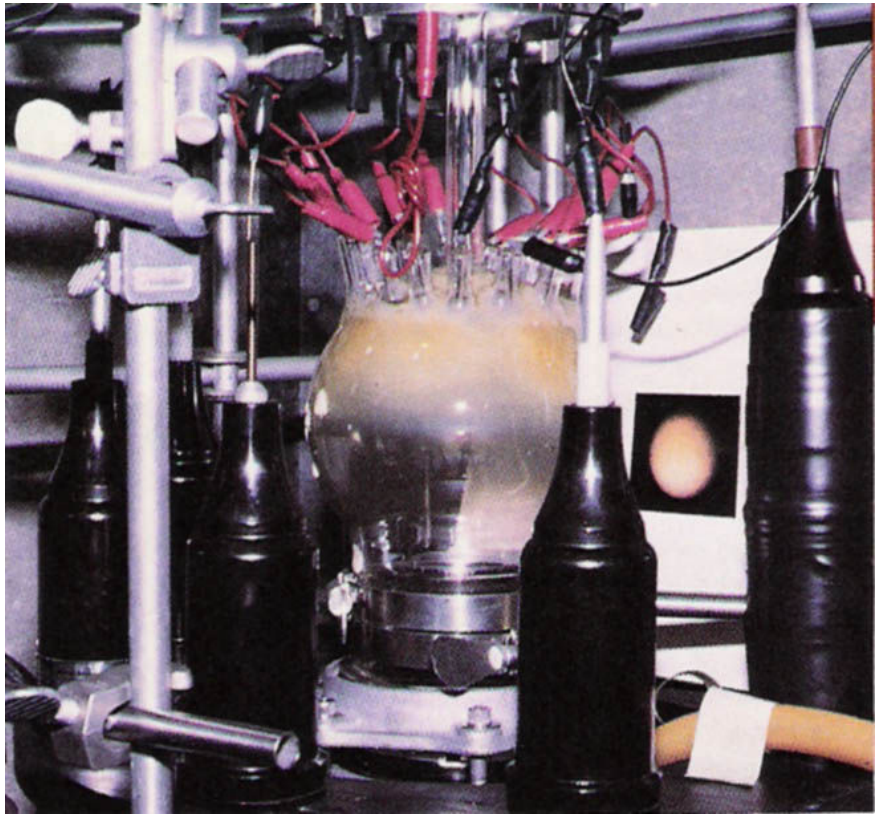
This view of Titan taken on Feb. 25, 2007, reveals a giant lake-like feature in Titan's North Polar Region. It is approximately 1,100 kilometers (680 miles) long and has a surface area slightly smaller than that of Earth's largest lake, the Caspian Sea.



Organics to pre-biotics?

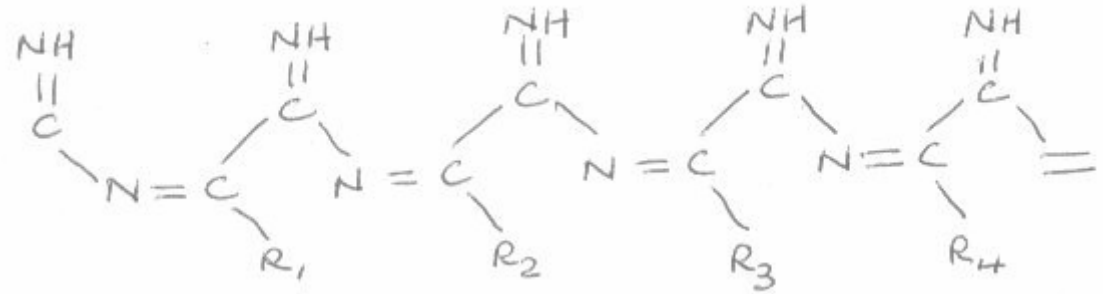
- The presence of simple organic molecules on Titan led scientists to speculate whether any more complex, pre-biotic molecules may have formed too

- Khare, Sagan and colleagues experimented by passing a DC current though a reaction vessel containing 90% N_2 and 10% CH_4 to simulate Titan's atmosphere
  - Same idea as Miller-Urey



Tholins

- This experiment produced a tarry, reddish-brown goo which formed on the walls of the reaction vessel.
- This was named '*tholin*', after the Greek word for mud!
- Tholins have been intensively studied in the lab as possible analogs for Titan and Triton hazes
- It has also been hypothesized that large deposits of tholin could be visible as dark regions on Titan
- Khare et al also found that by the simple addition of HCl, 16 *amino acids* were produced.



Possible structure of tholins on Titan

Water on Titan

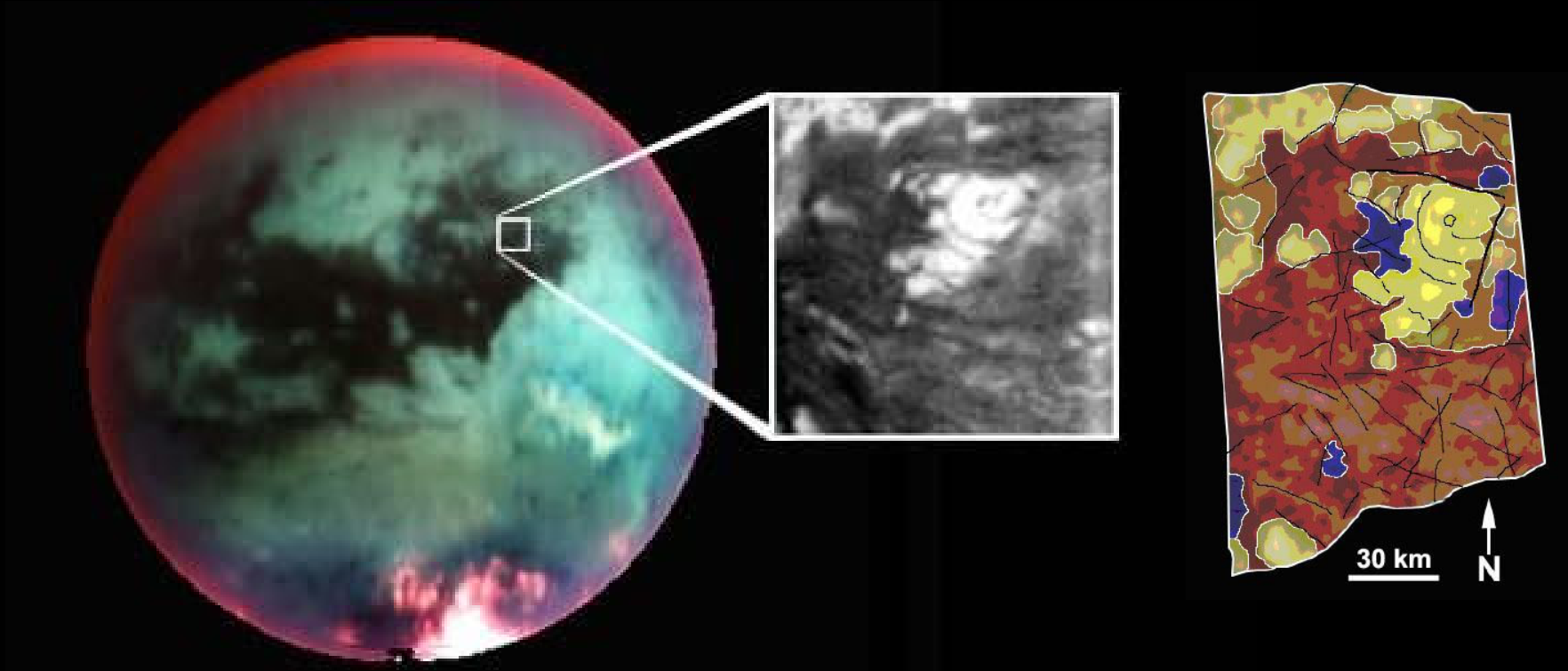
- Titan is much too cold for surface liquid water, with a temperature of 95 K (-178°C)
- LAWKI cannot survive without liquid water
- However, it has been proposed that water could exist temporarily in melt pools produced by impacts
  - There may also be liquid water under the ice-like surface
- Large melt pools hundreds of meters deep might take *centuries* or even *millenia* (if mixed with ammonia) to freeze completely.

Liquid assets

- *If* liquid water could survive for hundreds of years, that is long enough for interesting chemistry
- Chemical reactions in surface melts could add oxygen from water to the N, C, H in the tholin to make carboxylic acids, purines and pyramidines (forms base found in nucleic acids)
- As mentioned, Titan may well have a sub-surface ocean like Europa
  - This is needed in many models to allow methane to escape from the interior, and replace the methane lost in the atmosphere by chemistry

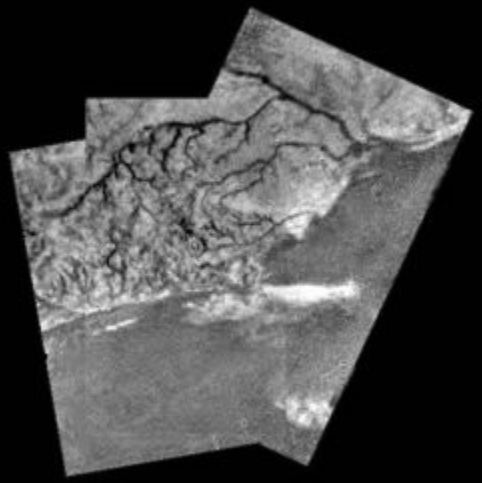
Titan *Cryovolcano*?

- Huygens team produced this picture of a *possible volcano*, with two outflowing 'arms'
- Rather than spewing lava it is believed to spew a slurry of methane, ammonia and water ice



Titan Geography

- Huygen's gave us some incredible pictures of smaller scale features
  - Hills
  - Drainage features
  - Mud flats?

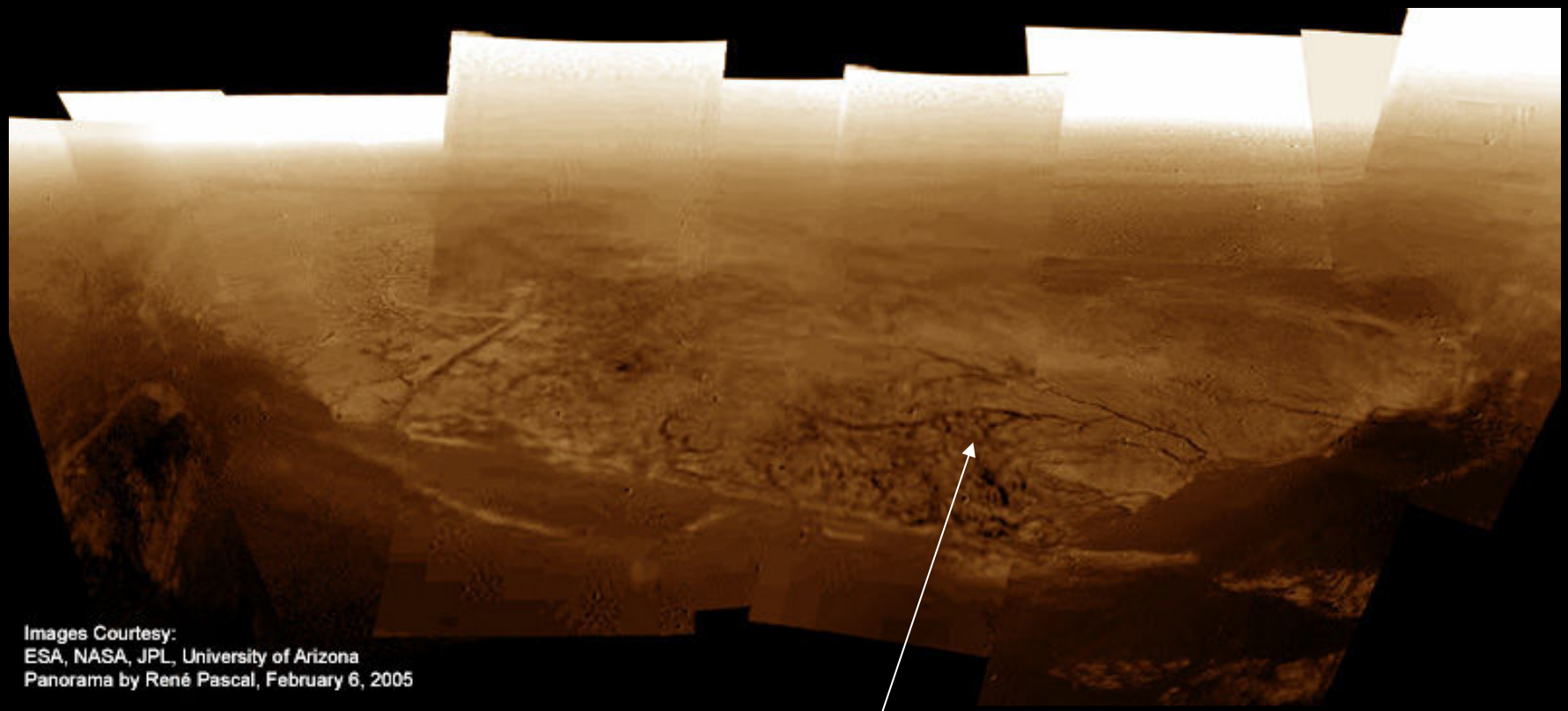


- Note the camera stopped working before touchdown so there are no detailed images from right above the landing site

The descent…

NASA movie

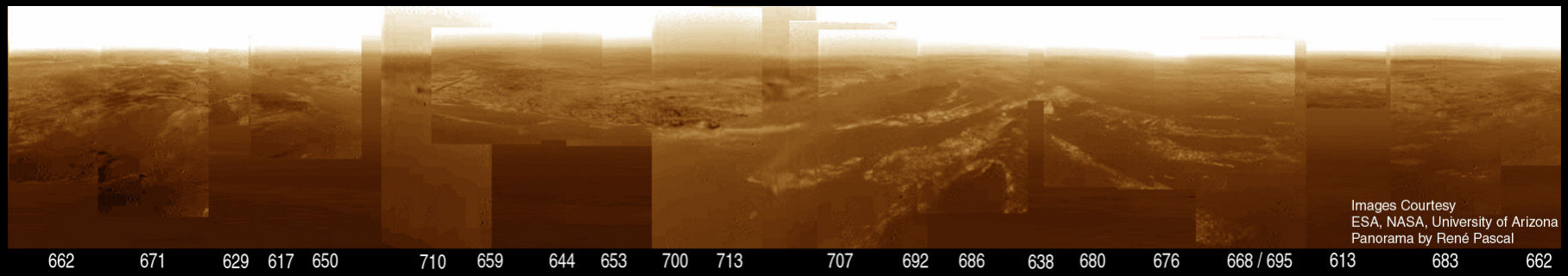
Panorama of Huygens images

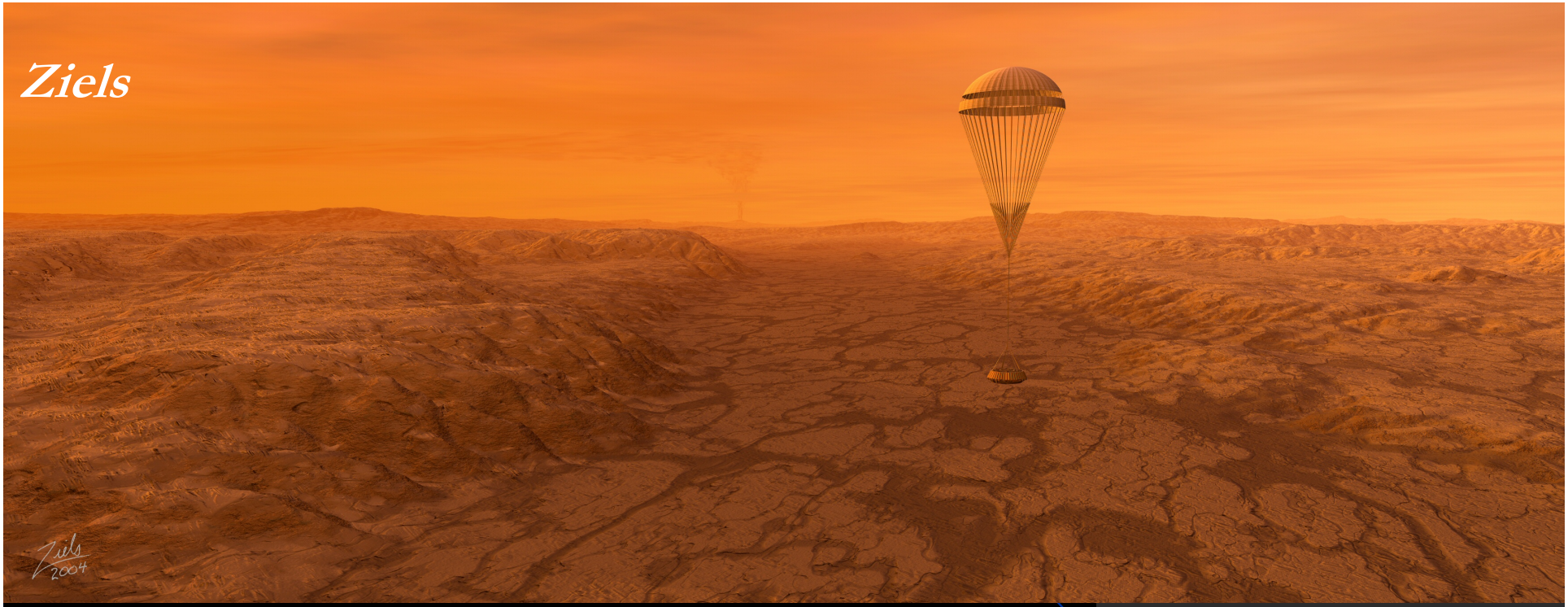


Drainage features

Pictures taken while probe will still several km above surface

Full 360º view

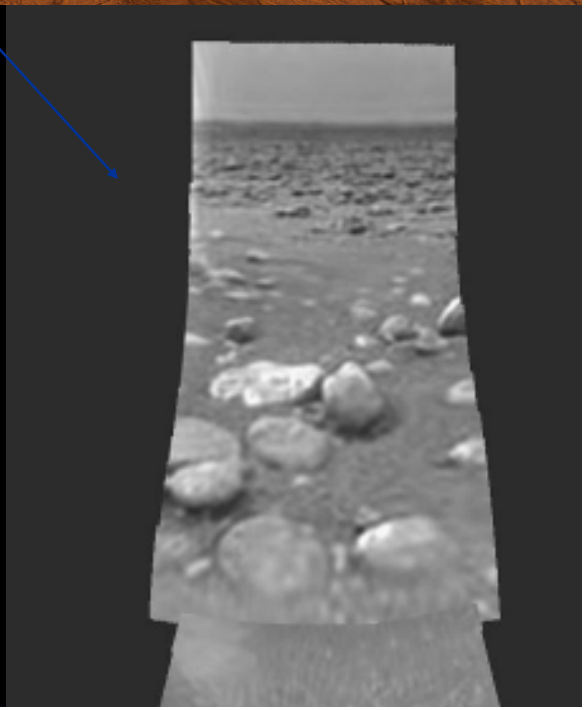




The dark plain is pebbly, and cut by channels.

It is also wet with methane and ethane….

View from the landing site



Oceanography on Titan?

- Finding another body with liquid content presents the opportunity to hypothesize about the behaviour of those liquids
- Scientists have modelled the expected wind-driven wave heights for hydrocarbon seas

	Titan	Earth
Significant wave height / m	4.5	0.6
Wave speed / m s^{-1}	5.5	5.5
Wavelength / m	105	11
Period /s	11.5	3.5

- Anyone for surfing on Titan?

Life on Titan?

- As we might expect, the possibility seems very remote
- If there is life it would probably be imbedded in a water layer embedded under ice
  - Little oxygen though, and the low temperatures make this possibility even less probable
- *Possibly* earlier in its life Titan was sufficiently warm (following its formation)
- Alternatively, when the Sun becomes a supergiant Titan's temperature is expected to rise to (a balmy!) 170 K
  - Still a long way from freezing point of water though…

Summary of lecture 25

- Titan shows many incredible features
  - Only liquid bodies observed in the solar other than Earth
    - Huge seas of hydrocarbons
  - Only moon with a thick atmosphere
    - Similar to Earth in that it is dominated by nitrogen
  - Surface features consistent with erosion
- However, it seems highly doubtful it is a good candidate for life

Next lecture

- Icy bodies in the solar system