LIFE BASED ON METHANE ON SATURN'S MOON TITAN?

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Talk scheme:

Introduction: what do we knew about TITAN?

Titan after CASSINI and HUYGHENS

Methane-based methabolism?

Future perspectives
What do we knew about Titan?

Christiaan Huyghens discovered Titan in 1655

Typical ground-based pictures of Titan in the pre-CASSINI era.
Titan as seen by CASSINI

CASSINI spacecraft

EXOATMO Nice, Oct 2015
Huyghen's probe (~1.30 m across)
GCMS → surface wet with $\text{CH}_4$ that evaporated after being heated by the warmer probe.
**HUYGHENS** result # 2

**GCMS** $\rightarrow$ Surface rich in organic compounds (ethane, cyanogen...)$\equiv$ complex chemistry

$^{12}\text{C}/^{13}\text{C}$ measured in $\text{CH}_4$ $\rightarrow$ continuous/periodic replenishment of $\text{CH}_4$

$\rightarrow$ no evidences of active bio systems
Huyghen's Descent Imager/Spectral Radiometer

EXOATMO Nice, Oct 2015
What do we know about Titan?

Saturn's largest moon and 2\textsuperscript{nd} biggest one in the solar System (> than Mercury)

**Mass** $\sim 0.024 \, M_{\text{Earth}}$  
**Radius** $\sim 0.4 \, R_{\text{Earth}}$

**Mean Density** $\sim 1.9 \, g/cm^3$  
(Earth's $\sim 5.5 \, g/cm^3$)

**Orbital period:** 16 days  
**Inclination:** 0.3°  
→ Saturn's equator

**Eccentricity:** 0.03  
Tidally locked

The only moon in the solar system with a dense atmosphere

$P_{\text{Titan}} \sim 1.45 \, P_{\text{Earth}}$
Titan's ID after CASSINI and Huyghens

113 close flybys (as for 24 Sep 2015):

Atmosphere: 98% $N_2$ 2% $CH_4$ + hydrocarbons (traces)

◊ surface temperature -180 ºC (liquid methane)

◊ surface humidity 50% 5% methane abundance

◊ lakes of ethane (76%), methane (10%) and propane (8%)

◊ cryovolcanoes expelling $H_2O$ ice (?)

◊ subsurface mixtures of liquid amonia & water ?

◊ subsurface ocean
Permanent liquid hydrocarbon lakes (near north pole)
Ligeia mare (NASA - GSFC)
Weird life on the surface of Titan?

Methanogenic archea could live on Titan using a number of metabolic pathways, where terrestrial $O_2$ is changed by $H_2$.

Such organisms would inhale $H_2$ in place of $O_2$, metabolize it with acetylene instead of glucose, and exhale methane instead of carbon dioxide

(e.g. Abbas & Schulze-Makuch 2002; McKay & Smith 2005)

\[
\text{Acetylene } \rightarrow C_2H_2 + 3H_2 \rightarrow 2CH_4
\]

\[
\text{Acetate } \rightarrow CH_3COO^- + H^+ \rightarrow CH_4 + CO_2
\]

\[ \rightarrow \text{Methanogenic archea on Earth can survive on the energy levels released by these reactions} \]
BUT:

If microorganisms are consuming Hydrogen and Acetylene on Titan's surface, the abundances of them should be measurably lower than otherwise expected (McKay & Smith 2005).

Indeed, Strobel (2010) found a greater abundance of $H_2$ in the upper atmospheric layers of Titan compared to the lower layers and Clark et al. (2010) fail to find Acetylene on the surface of Titan from CASSINI's VIMS data. Other explanations are possible → →

→ → Must wait for more flybys
February 2015:
Stevenson et al., Sci Adv 2015, 1:

As liquid bylayer membrane NOT possible without liquid water.

**ALTERNATIVE:** Molecular simulations

New type of membrane, composed of small organic nitrogen compounds, capable of forming and functioning in liquid methane at cryogenic temperatures.

The “azotosome” has properties similar to lipidic membranes.

It can be formed from compounds observed in Titan's atmosphere.
Acrylonitrile azotosomes and final vesicule

(CH2CHCN)
THANK YOU!