Titan’s “Magic Islands”:
Transient Features in the Hydrocarbon Seas

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Outline

- Titan’s Surface Liquids and Hydrologic Cycle!
- Transient Features in Titan’s Seas!
- Waves, floating/suspended solids, or bubbles!
Atmosphere

- Titan is the only moon in the Solar System to have a significant atmosphere
- Pressure: ~ 1.5 times Earth’s
- Temperature: ~ -300° F
- Composition: ~95% nitrogen, ~5% methane
- Methane and ethane are stable liquids at Titan’s surface!

- Titan’s surface, however, is veiled by hazes
Cassini-Huygens Unveils Titan’s Surface

- Titan’s surface can be observed in infrared and microwave “atmospheric windows”

Earth’s atmospheric windows

½ scale model of Cassini spacecraft
Huygens Landing – Evidence of Liquids

Credit: NASA/ESA
Huygens Landing – Evidence of Liquids
Huygens Landing – Evidence of Liquids

Credit: NASA/ESA
Huygens Landing at 300 m Resolution

Credit: S. Birch
Lakes

• Only instance of current, stable, surface liquids in the Solar System aside from water on Earth
Lakes

- Only instance of current, stable, surface liquids in the Solar System aside from water on Earth.
Seas

- Similar in size to the Great Lakes on Earth
Distribution of Lakes and Seas

- All of the lakes and seas are poleward of 55°
- More than 99% of the liquid is in the north

Credit: A. Hayes
Depth and Composition

- Ligeia Mare is 600 feet deep and mostly methane
- A single sea has more hydrocarbons than all of the proven fossil fuel reserves on Earth

Mastrogiuseppe et al., 2014
Seasons on Titan

- Seasons are due to obliquity not eccentricity!

Saturn/Titan orbital period around the Sun is 29.5 Earth years

Credit: R. Lorenz
Seasonal Hydrologic Cycle

**Southern Summer:**
Retreat of southern lakes due to evaporation and/or infiltration
Hayes et al., 2011

**Vernal Equinox:**
Equatorial precipitation
Turtle et al., 2011
Figure 1 Cube CM_1721848119_1. Cassini Visual and Infrared Mapping Spectrometer (VIMS) cube from the T85 Titan flyby on 2012 July 24. This cube shows a bright specular reflection (sunglint) off Kivu Lacus. This interpolated color version uses 2.0 µm as blue, 2.8 µm as green, and 5.0 µm as red. The complex structure surrounding the central glint is described in Barnes et al. (2014).

This contrast inversion occurs because VIMS is seeing a specular reflection of the (somewhat) bright sky from the lake and sea surfaces. We show a practical demonstration of this effect in Figure 5.

The bright lakes and seas do not all show the same measured I/F. There are three reasons for this. The first is that at 5 µm Titan's atmosphere is optically thin. So if you were standing on the surface in a boat on one of these lakes you would see that the sky is bright, but not as bright as it appears in the image. We show a practical demonstration of this effect in Figure 5.

Figure 2 5-µm image. Here we show the 5-µm window cube CM_1721848119_1, scaled from I/F = 0.0 to I/F = 0.44. Red indicates the saturation of pixels, which occurs at the primary specular reflection off Kivu Lacus. The arrows indicate the areas of interest for this paper, which show specular reflections on Punga Mare away from the specular point that may represent wave activity.

High-phase specular reflections are isolated patches of Punga Mare: mudflats or waves.

Northern Spring

Barnes et al., 2014
Titan’s Magic Island

- 04/26/07: $\Theta_{inc} = 19^\circ$
- 07/10/13: $\Theta_{inc} = 6^\circ$
- 10/14/13: $\Theta_{inc} = 27^\circ$
- 08/21/14: $\Theta_{inc} = 11^\circ$
- 01/11/15: $\Theta_{inc} = 8^\circ$
- Not an artifact
- Not a permanent geophysical structure
- A transient feature

Titan’s “Magic Island”
Transient Hypotheses

• A new island is unlikely
  – Change in morphology
  – Not observed in most recent observation

• Sea level change that reduces absorption is unlikely
  – Ligeia Mare is nearly transparent to the radar; Mastrogiuseppe et al., 2014
  – Requires changes of > 60 m

• Sea level change that causes surface exposure is unlikely
  – Requires exposure of > 60% of the area

• Seafloor change is unlikely
  – Requires $\varepsilon_{\text{seafloor}} > 2.7$ and then reversion to $\sim 2$
Tides do not explain the Transient Features

Tides on Titan are due to its eccentric orbit around Saturn.

Tides should cause consistent presence/absence with true anomaly.

<table>
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<th>Observation</th>
<th>True Anomaly</th>
<th>Transient?</th>
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<tr>
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Bubbles are a Plausible Hypothesis

• Terrestrial Analog: La Brea Tar Pits

~ inch sized methane bubbles in tar
Credit: tarpits.org

~10 inch sized methane bubble plume in water
Credit: Feldfrei Blog
Floating or Suspended Solids are Plausible Hypotheses

Credit: Randy Kirk
Floating or Suspended Solids are Plausible Hypotheses
Waves are the *Preferred* Hypothesis

Terrestrial Analog
ERS-1 radar image of Lake Ladoga, Russia
70 by 50 km
Ivanov et al., 1997

Illustration of Waves on Titan
Credit: NASA
“Magic Island” #2

- Similar to “Magic Island” #1 on 08/21/14
- Also a transient feature that is most consistent with waves, floating or suspended solids, and bubbles
Future Observations and Exploration
Conclusions

• Titan’s Surface Liquids and Hydrologic Cycle!

• Transient features discovered and confirmed in Titan’s hydrocarbon sea, Ligeia Mare!
  – Most consistent with waves, floating or suspended solids, and bubbles

• Waves are favored as the most probable explanation because of their higher frequency in analogous terrestrial environments