Composition and Analysis of Thermal Emission Data from Saturn

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Topics we’ll visit...

• Saturn in context
• The search for waves. Why do we care?
• Mapmaking concepts and approach
• Preliminary Results
• Next steps
Saturn in Context

- Approx. 95 Earth masses and 4.5 Earth diameters in radius, makes it the least dense planet with a surface gravity close to Earth’s.

- High rotational speed – approx. 10 hour day gives rise to an oblate spheroid shape.

- Composed of primarily H, He, with traces of CH₄, C₂H₆, and NH₃.

- Located approx. 10 AU from the sun with a mean temp. of -139 °C near 1 atm.

- 4 missions have visited: Pioneer 11, Voyager I & II, and Cassini/Huygens.
Thermal Waves

• Waves may be sensed as displacements from the mean temperature

• Emitted light at different wavelengths trace different species at different atmospheric heights
  - Ethane at 12.2 µm – 12.5 µm probes stratosphere
  - Molecular Hydrogen at 17.2 µm – 18 µm probes troposphere

• Observations give rise to empirical models of wave dynamics. These may inform models of Saturn atmosphere, and may be applied to the dynamics of extra-solar gas giants

• We seek to develop methods to exploit ground-based observations of waves.

One way: Corroborate Cassini CIRS observations
Mapmaking Concepts

• What is required to build a map?
  • Observations!
  • Data-reduction
  • Creating planet-wide composites

August 15th, 2014. Remotely observing Saturn using the MIRSI instrument at NASA’s IRTF
Map-making Concepts: Data Reduction

- Cylindrical Map
- Subtraction
- Bad Pixel Mask
- Registration
- Co-adding
Mapmaking Concepts: Creating Composites

- Collecting component maps

- Emission-angle correction

- Residual production

- Averaging boundary regions

*Cosine of the emission angle between line of sight and planetary surface normal*
Approach: Limb-Effect Modeling With Ramp

- Used power fit with ramp, applied latitude-by-latitude to model radiance dependence on $\mu$:

$$r_{\downarrow l} = A \ast \mu_{\downarrow l}^k + B \ast \left[ 1, 2, \ldots, i \right]$$

$r_{\downarrow l} =$
Approach: Sigmoid Stitching to Average Boundaries

- Uses a sigmoid function to weight the blending of the left and right side of the map
Now for the Science…

• Maps were compiled between 2003 and 2013

• Instruments used:
  • NASA IRTF’s MIRSI (8 - 26 µm)
  • NAOJ Subaru COMICS (7.25 - 25 µm)
  • ESO’s VLT VISIR (8 - 13µm and 16.5 - 24.5 µm)

• Maps were analyzed using a Lomb-Scargle periodogram code
  • Computes “power” of each temperature fluctuation’s spatial frequency
  • Allows for analysis of non-uniformly sampled data
Some Initial Results

December 2003, MIRSI – 12.20 μm

December 2003, MIRSI – 17.90 μm
October 2004, MIRSI – 17.90 µm
December 2004, MIRSI – 12.20 µm

December 2004, MIRSI – 17.90 µm
May 2008, VISIR – 12.27 μm

May 2008, VISIR – 17.65 μm
May 2013, COMICS – 12.50 μm

May 2013, COMICS – 17.65 μm
A look back…

• Where we get our planetary data
• How we reduce it to a calibrated, cylindrical map
• How we produce global composites
• Producing a survey of results
• Analysis revealing interesting trends
Immediate Impacts of Work

• Generally concluded that artificially induced waves are generally much more sensitive to fitting approach
• Has helped identify wave epochs for further scrutiny

Next Steps

• Analyze more maps
• Identify breaks in data continuity, and fill them in
• Correct artifact issues with sigmoid stitching
• Re-process many input images to produce improve maps
• Possibly merge functionality into a tool
Thank You!

Special thanks to:
• Oregon Space Grant Consortium
• NASA, Caltech and JPL
• Glenn Orton
• My fellow interns
• Erik Sanchez