Composition and Analysis of Thermal Emission Data from Saturn

Dave Coulter
Department of Physics, Portland State University
Glenn S. Orton
Earth and Planetary Atmospheres, Jet Propulsion Laboratory

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

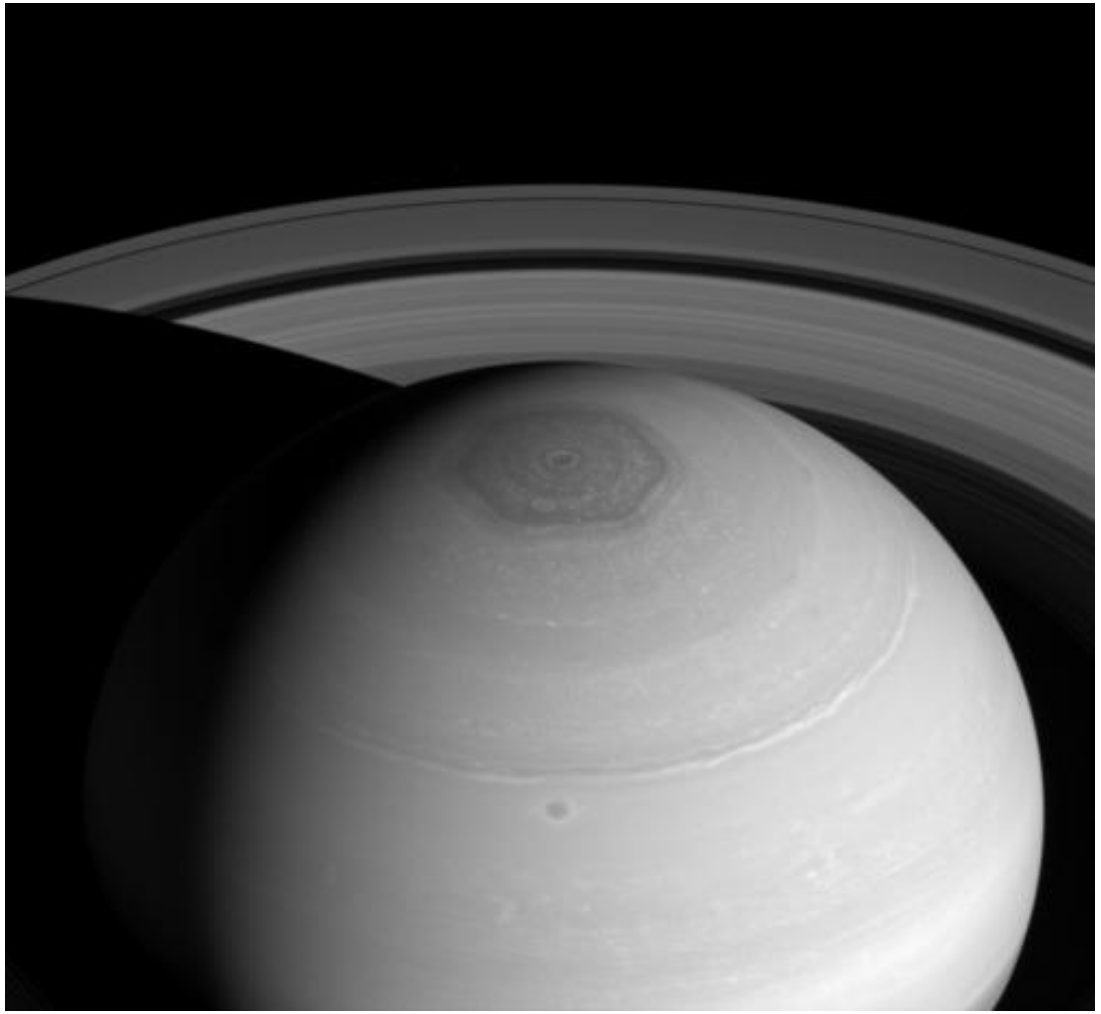
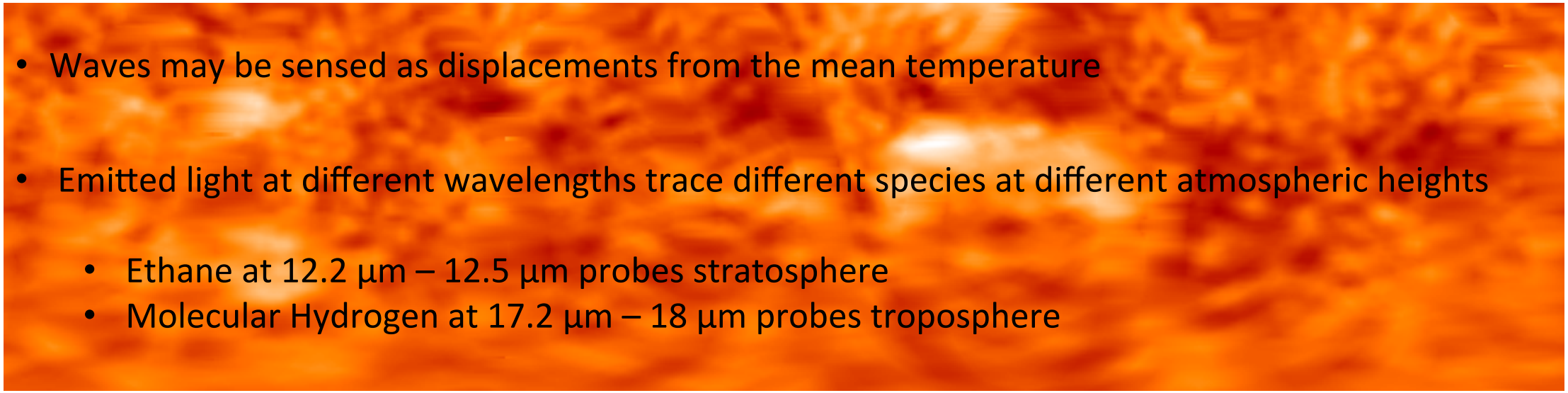


Image Credit: NASA/JPL-Caltech/Space Science Institute

- 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 CH_4, C_2H_6, and NH_3
- 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

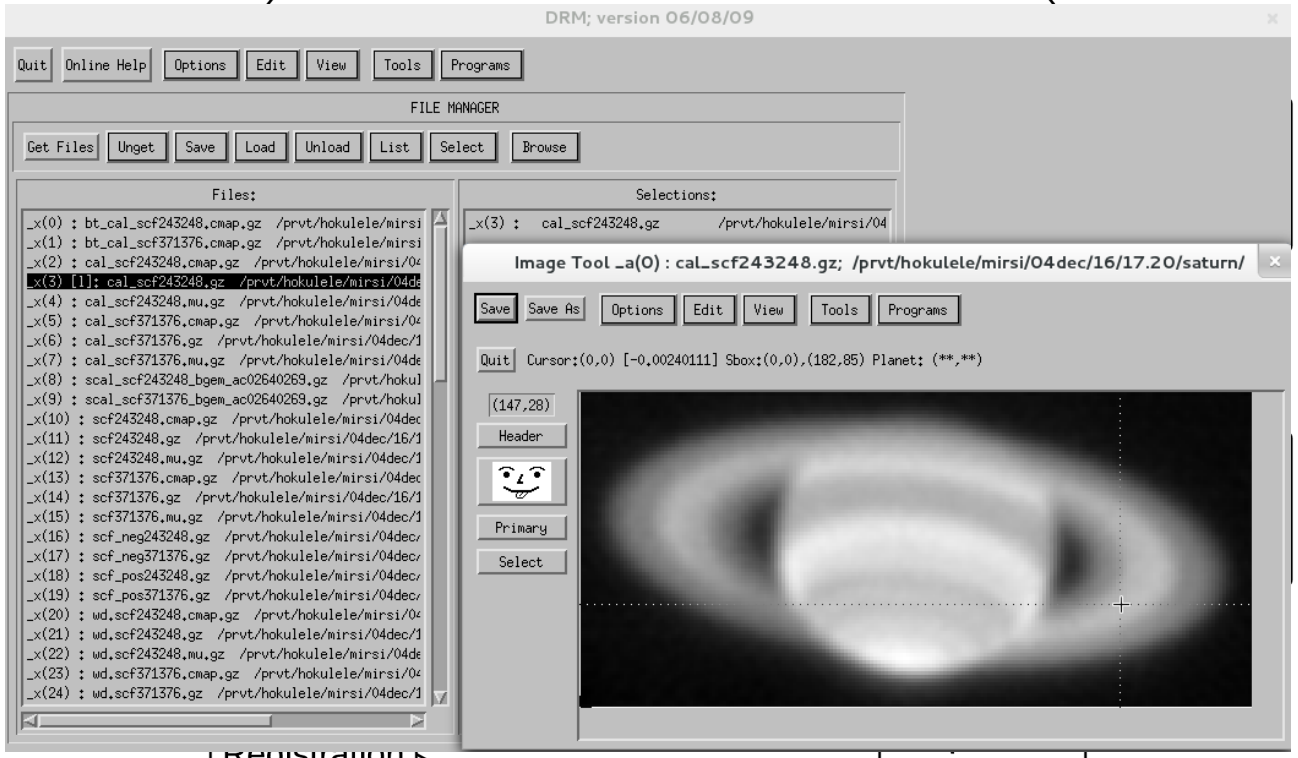
August 15th, 2014. Remotely observing Saturn using the MIRSI instrument at NASA's IRTF

Map-making Concepts: Data Reduction

ABAB Subtraction

Cylindrical Map

Bad Pixel Mask



Registration

Co-adding

Mapmaking Concepts: Creating Composites

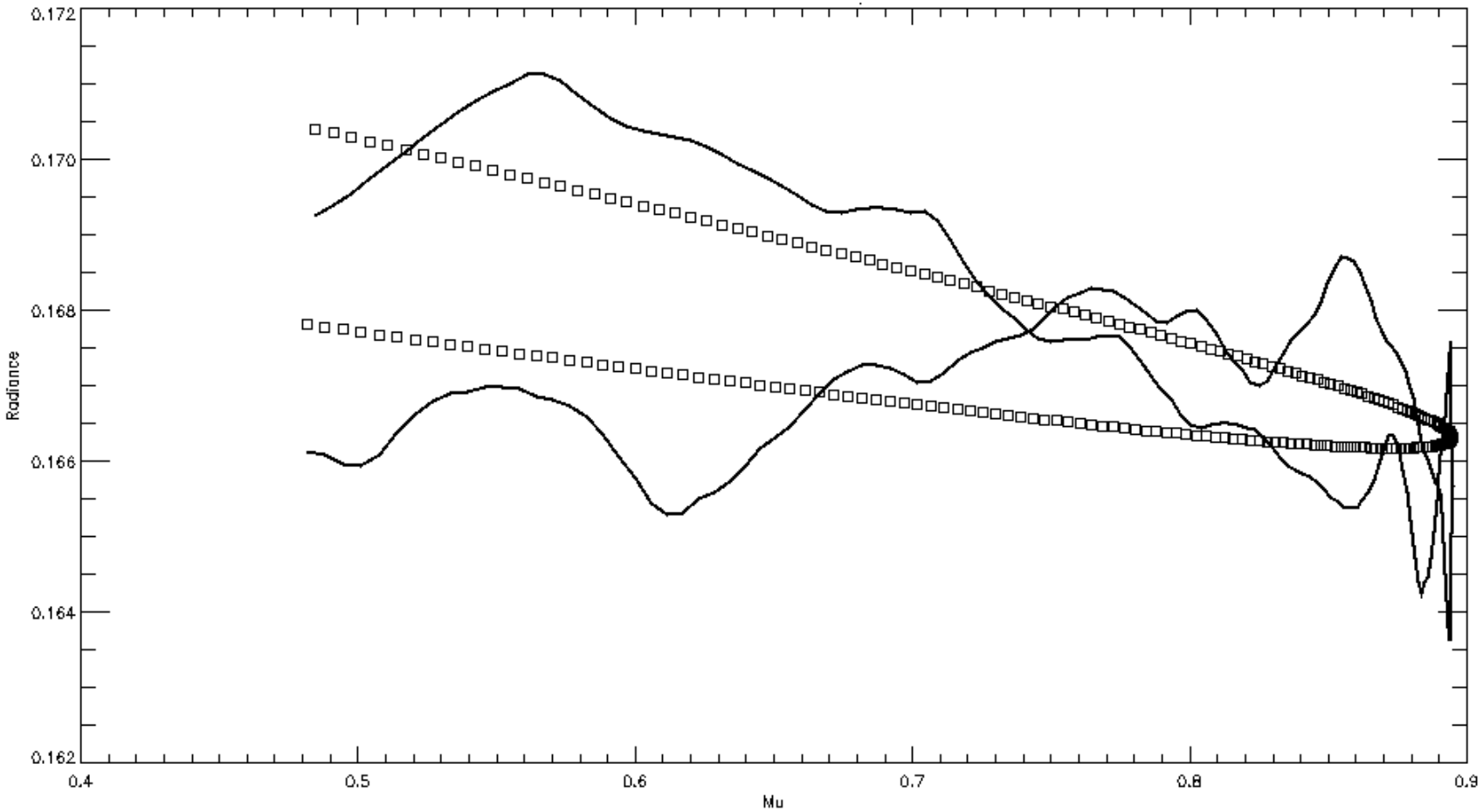
- Collecting component maps
- Emission-angle correction
- Residual production
- Averaging boundary regions

*Cosine of the emission angle between line of sight and planetary surface normal

Approach: Limb-Effect Modeling With Ramp

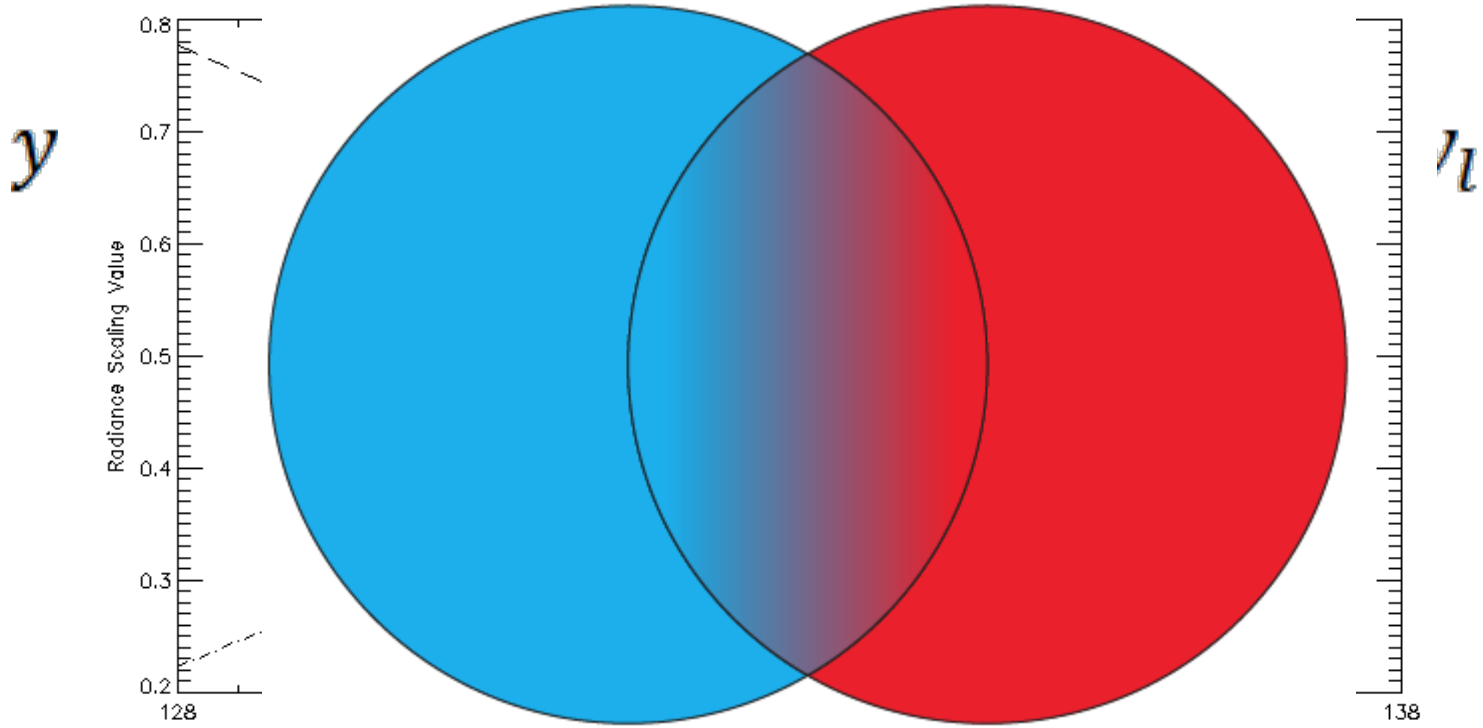
- Used el radiar

$r\downarrow i =$



Approach: Sigmoid Stitching to Average Boundaries

- Uses a sigmoid function to weight the blending of the left and right side of the map



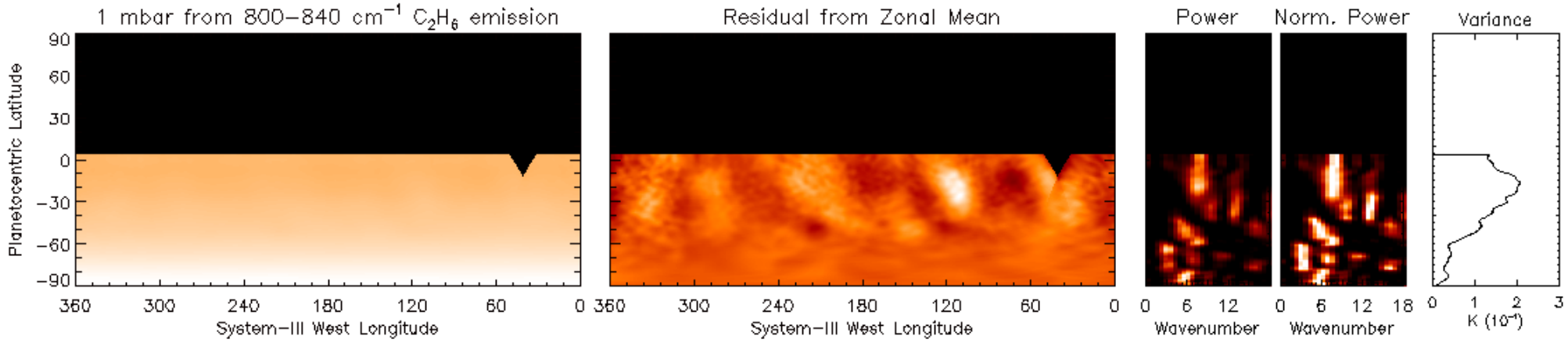
Now for the Science…

- Maps were compiled between 2003 and 2013

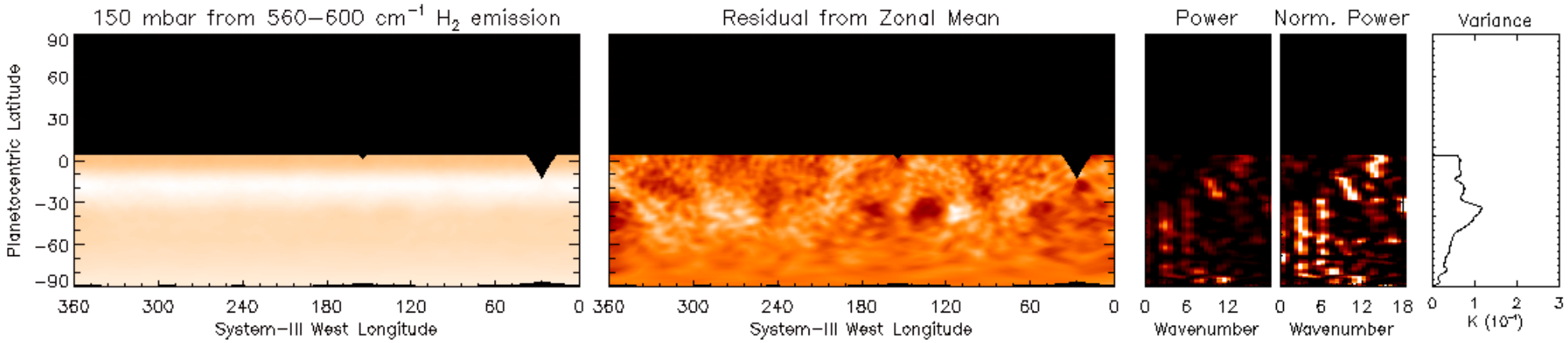
- Instruments used:
  - NASA IRTF's MIRSI (8 - 26 μm)
  - NAOJ Subaru COMICS (7.25 - 25 μm)
  - ESO's VLT VISIR (8 - 13μm and 16.5 - 24.5 μm)

- 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

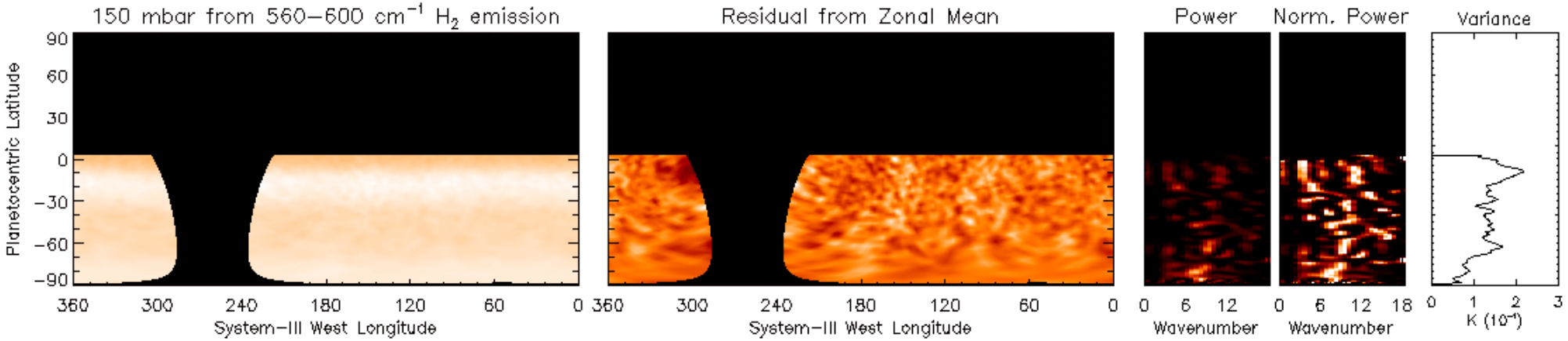
December 2003, MIRSI – 12.20 μm



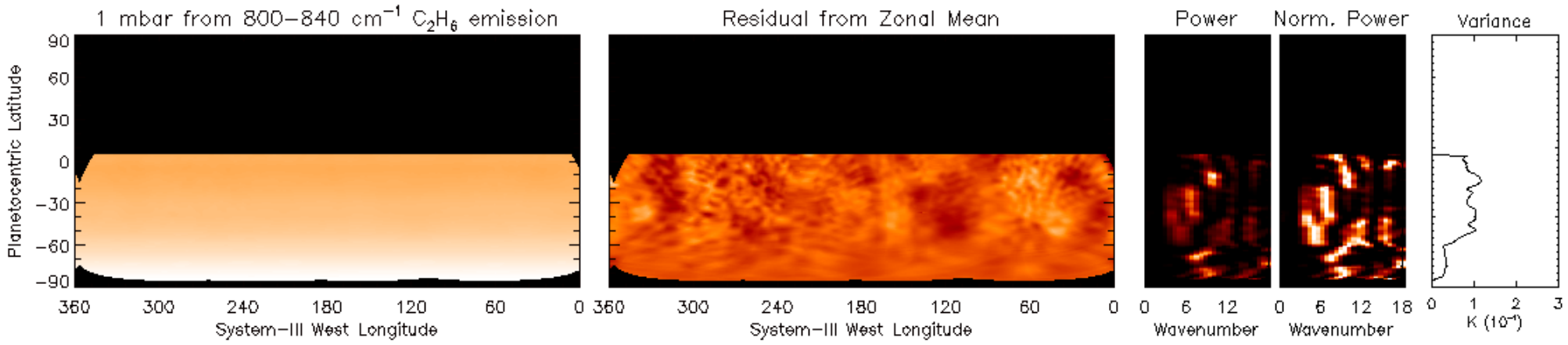
December 2003, MIRSI – 17.90 μm



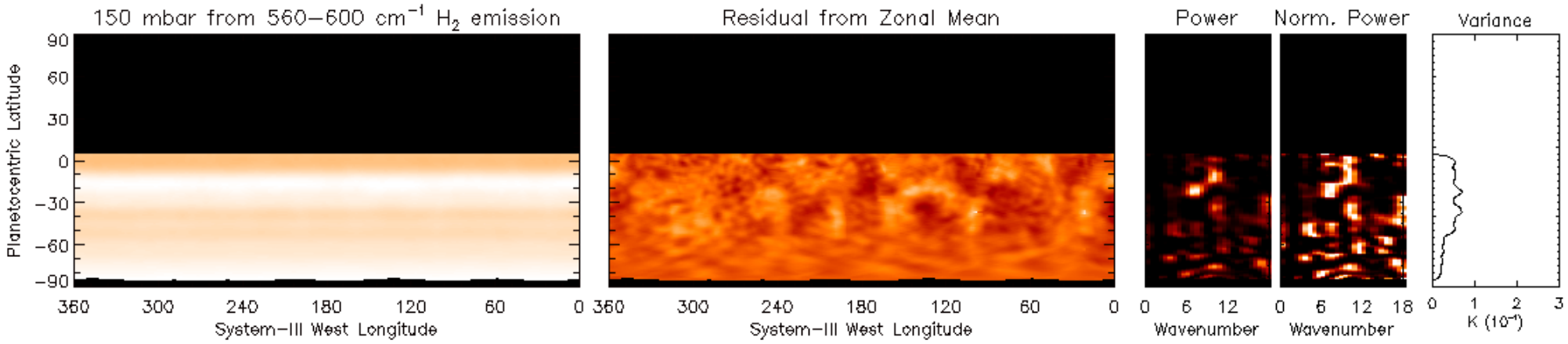
October 2004, MIRSI – 17.90 μm



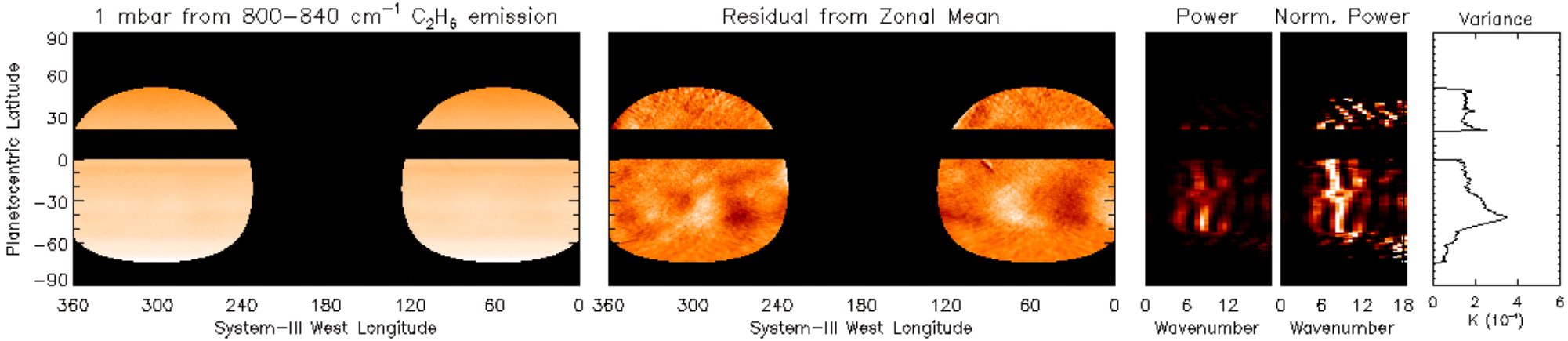
December 2004, MIRSI – 12.20 μm



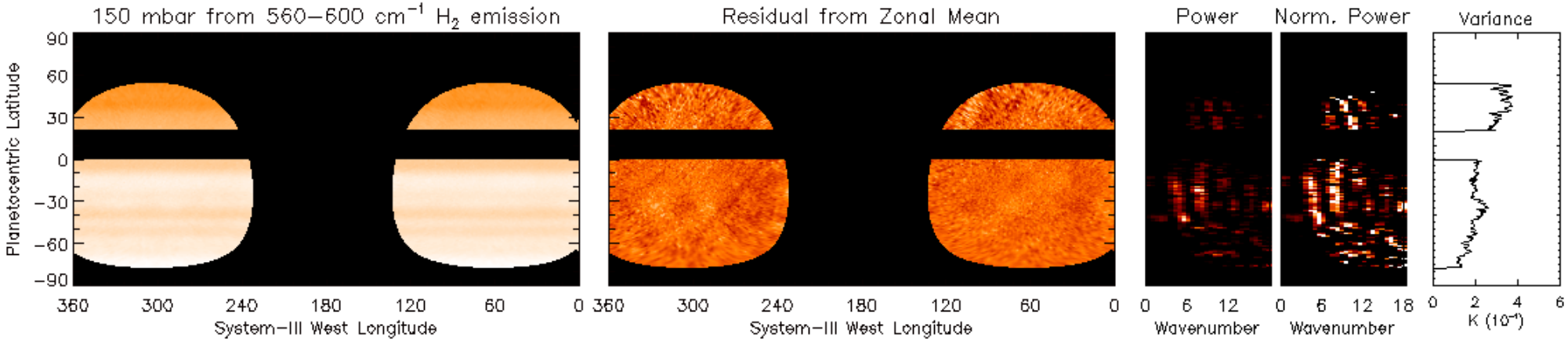
December 2004, MIRSI – 17.90 μm



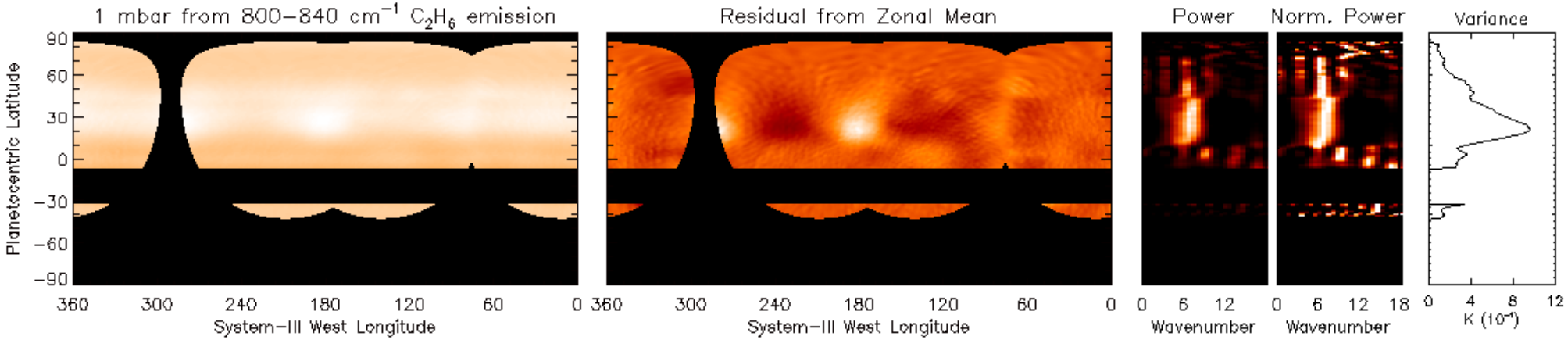
May 2008, VISIR – 12.27 μm



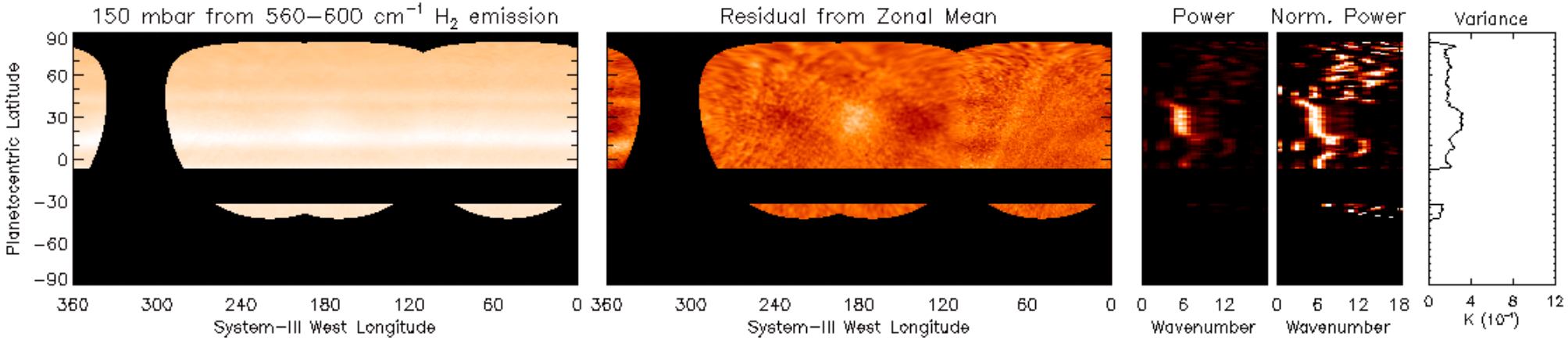
May 2008, VISIR – 17.65 μm



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