

# Giant Planet Summary

Innovative Approaches to Planetary Seismology

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# Our Job

- Review the 8 “bullet point” conclusions Dave suggested. Are there any modifications we wish to make?
- Move towards our written report (a White Paper) by:
  - Expanding each bullet point to its own PowerPoint page with bullets.
  - Write half-page of prose that will become part of the draft report.
- Combine each bullet’s expanded presentation into a single document to present to the group tomorrow (Friday).

# Dave's Summary (Mark's Version)

- Seismic observations can provide valuable information about the atmosphere as well as the deep interior.
- There is a need for improved modeling of normal-mode excitations (including “impulsive” excitations).
- Searches for waves other than normal modes (e.g. inertial modes, interfacial modes) should be considered.
- Ground-based observations are important.
- Observations of velocity (Doppler imaging) is the most promising technique, but thought should be given to also using temperature and shape measurements.
- Saturn's rings may tell us about the interior of the planet.
- Just as when one observes in a new wavelength range for the first time, we cannot say for certain what will be seen. Serendipitous discoveries are likely.

# Seismic Observations

- Statements of fact.
  - The best technique for probing the deep interior. Earth and the Sun as examples.
  - Powerful technique for probing density structure and dynamics of the interior.
  - Complimentary to Juno.
  - Current technology is consistent with the plausible signal strength at Jupiter.
  - There is great uncertainty in the models used to predict the amplitude of seismic signals.
- Recommendations.
  - Educate our colleagues about the technique.
  - Seek partnerships with larger scientific communities whose interests are served by seismic measurements.
  - Support atmospheric and planetary modeling.
  - Support observations that can advance our ability to predict seismic behavior.
  - Support ground-based giant planet seismology.
  - Prepare and distribute a White Paper.

# Modeling of Normal-Modes & Excitations

- How can we improve the models?
  - GCM-type numerical models may provide inputs (atmospheric sources and structures) to improve normal-mode modeling.
  - Observations of structure, dynamics, composition (e.g. via impacts, gravity, magnetic field) will help.
  - Can solar models be modified for Jupiter?
  - Study the possibility of the dynamo region being an excitation source.
- Improved modeling will answer questions such as
  - Are there differences among the planets to exploit?
    - Differences in internal heat release.
    - Differences in internal density distribution (e.g. Uranus may be more uniform).
  - What is the smallest impact that is detectable and that will provide useful information?
  - What is the energy distribution across modes.
- Modeling will contribute to plausibility arguments, but only observations will provide a definitive answer.

# Searching for and Characterizing Waves other than Normal Modes

- Gravity waves, Rossby waves, etc..
- A wealth of wave features have already been observed, but the “seismological” techniques proposed will help characterize them and the atmosphere.
- Different analysis techniques may be needed for different waves.
- Supporting information (e.g. altitude) important for understanding waves (such as were seen from SL9).
- It would be useful to conduct ground-based surveys of giant planets looking for wave features and impacts as well as surveys looking for potential impactors.

# Ground-based Observations

- Current technology is consistent with plausible signal strengths. Make a statement about current observations.
- The technology for instruments exists. What is needed is support to build them, obtain (preferably large amounts of) observing time on >1.5 meter telescopes, and refine observational and analysis techniques.
- Ground-based observations will test predictions and motivate further theoretical work.

# Observing Techniques

- Doppler imaging seems most mature and well developed. Needs support to become flight qualified.
- Shape measurements by various techniques should be considered.
  - Photometry.
  - Radio occultations of spacecraft and astronomical sources as seen from the ground.
  - Occultations of astronomical sources observed from a spacecraft.
  - Gravity.
- IR temperature measurements.
- Airglow.
- Spacecraft will provide the most sensitive observations and longest time baseline.
- Pole-on observations to eliminate rotation “noise.”
- Studies of Venus may benefit from “giant planet” techniques.



# Saturn's Rings as an Interior Probe

- Saturn's rings, with broad radial extent, may have particles whose orbits resonate with internal or atmospheric waves. They might be used to constrain the amplitude of normal modes.
- Intriguing features have been observed which need explanation (Marley reference in Icarus, Hedman unpublished).