



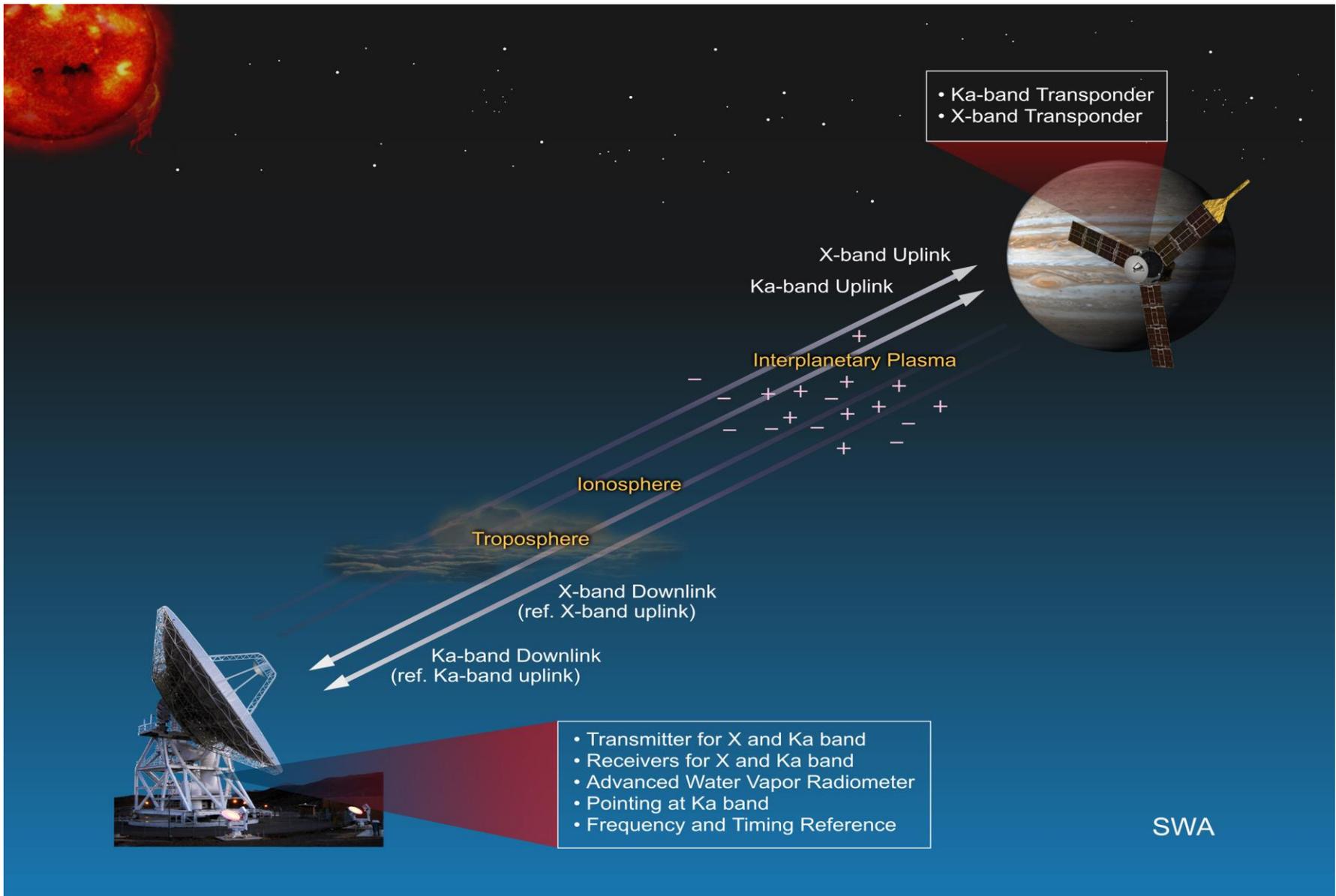
# Use of Deep Space Stations for Science And International Collaboration



**Jet Propulsion Laboratory**  
California Institute of Technology

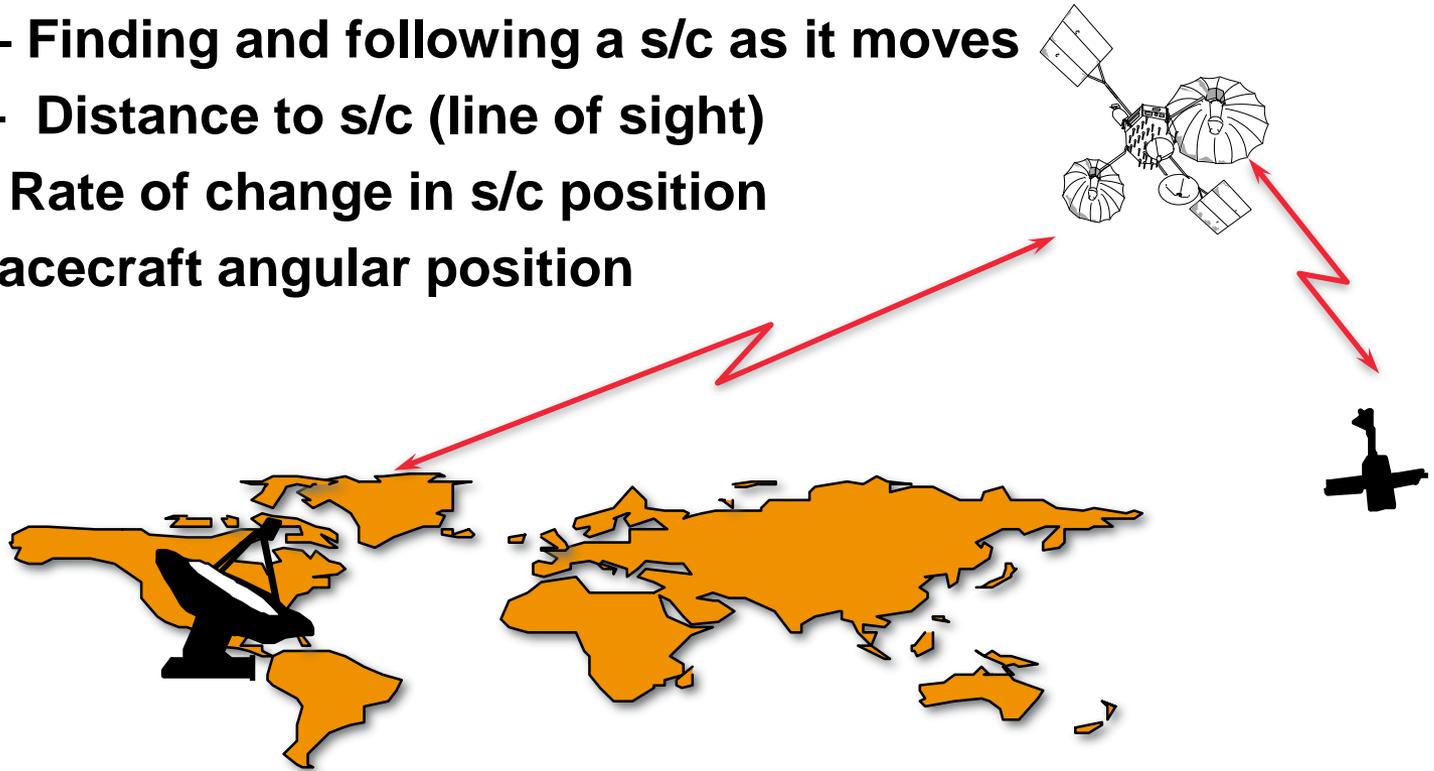
**Sami W. Asmar**

# Largest Science Instrument in Solar System



# Spacecraft Tracking Data

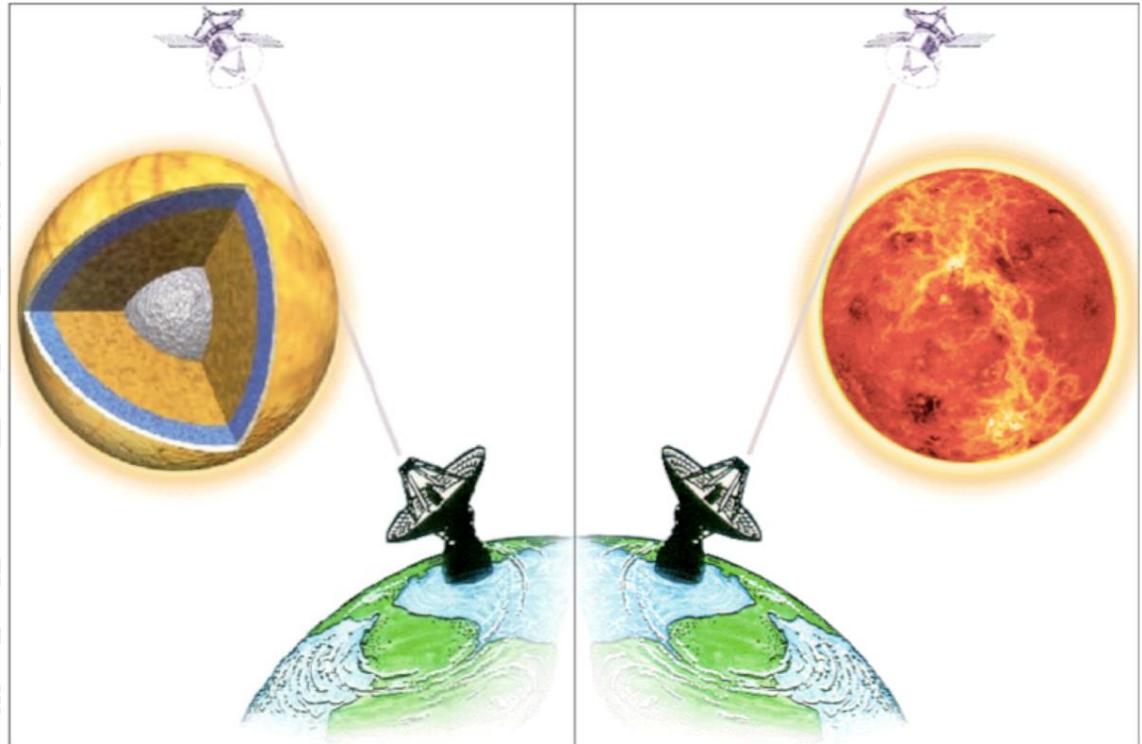
- Provide spacecraft position and velocity
  - Navigators solve current and predicts future state vector
- **Tracking** – Finding and following a s/c as it moves
- **Ranging** – Distance to s/c (line of sight)
- **Doppler** – Rate of change in s/c position
- **VLBI** – Spacecraft angular position



**Radio-metric Data:** Measurements using the radio signal and its variations.

# The Start of Radio Science

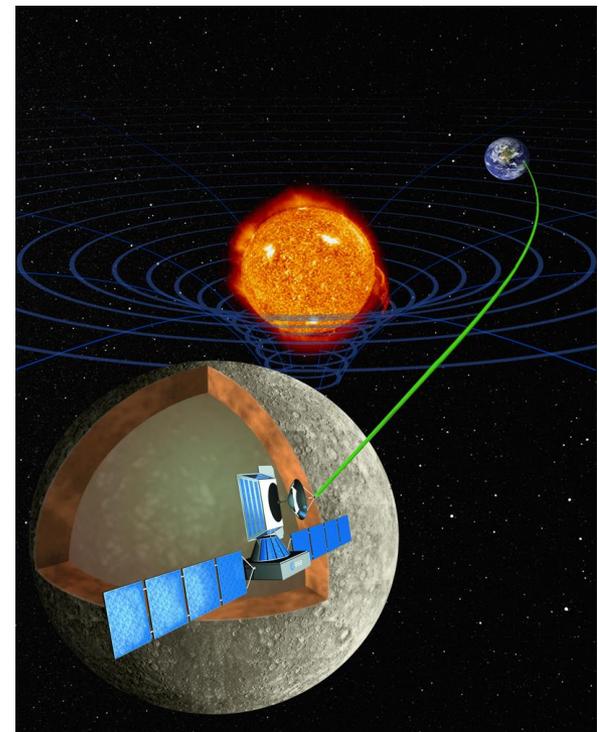
- It became apparent w  
that occultations by p  
atmospheres would a  
radio communication
- *One person's noise*
- One can study the at  
properties
  - And other aspects  
science, solar sci  
fundamental phys
- A recognized field of solar system  
exploration with instrument distributed  
between the spacecraft and the ground  
stations



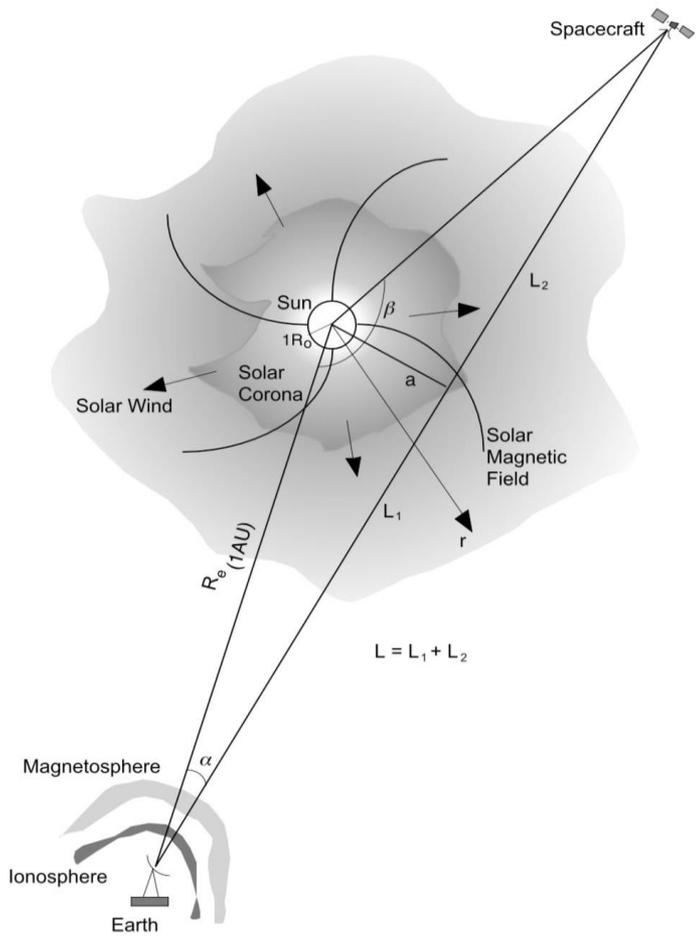
# Radio Science Investigations

Utilize the telecommunication links between spacecraft and Earth to examine changes in the phase/frequency, amplitude, and polarization of radio signals to investigate:

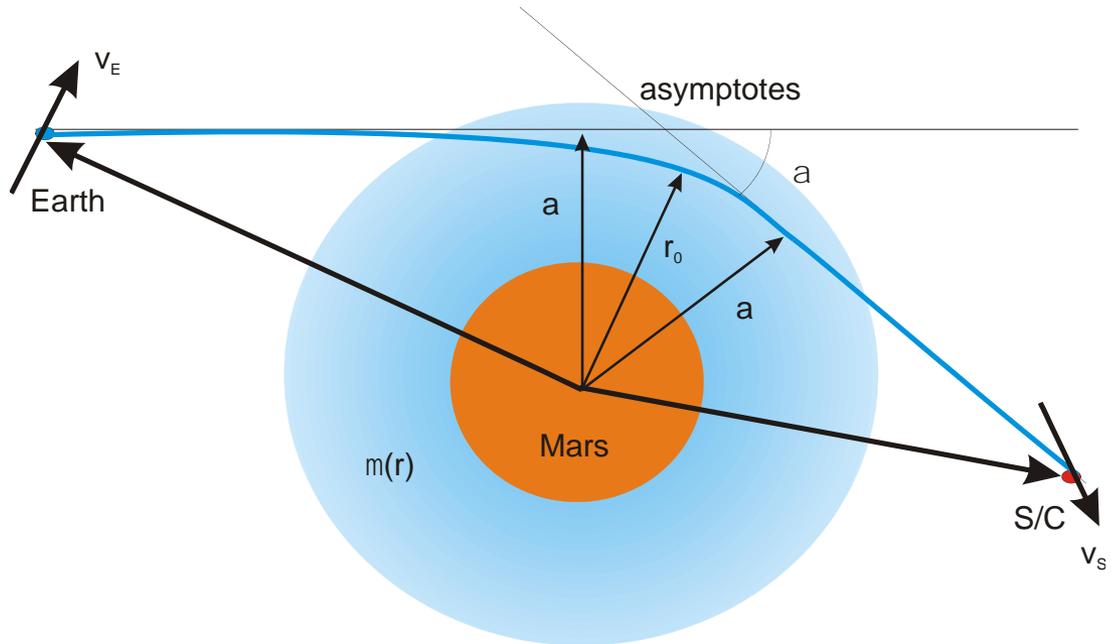
- Planetary atmospheres
- Planetary rings
- Planetary surfaces
- Planetary interiors
- Solar corona and wind
- Comet mass flux
- Fundamental Physics



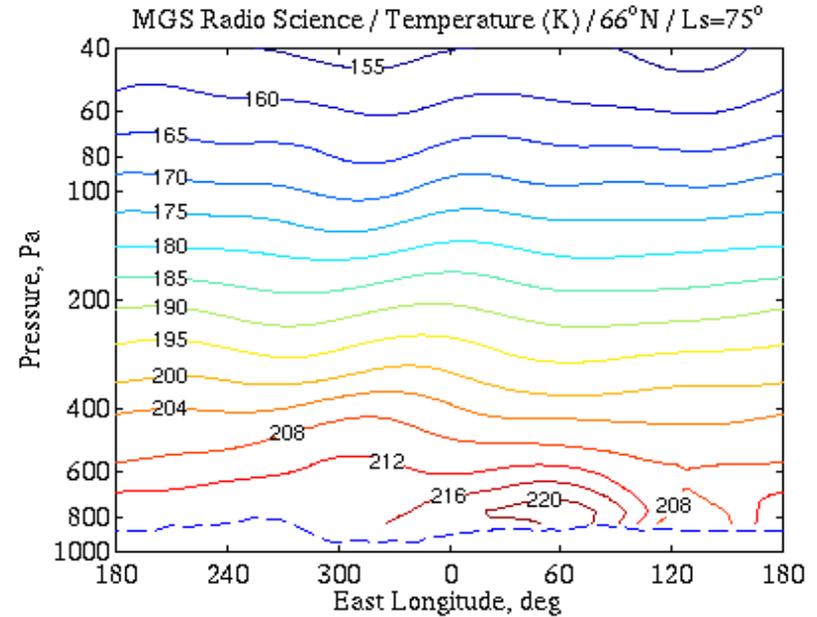
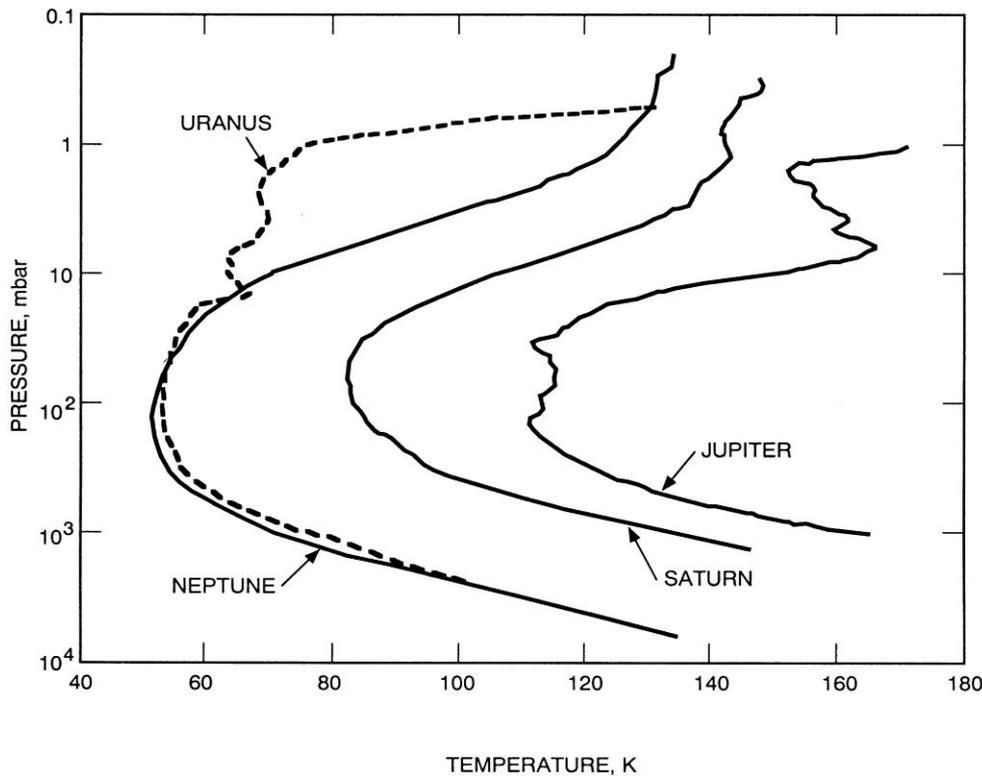
# Occultation by the atmosphere of the Sun



# Occultation by the atmosphere of Mars



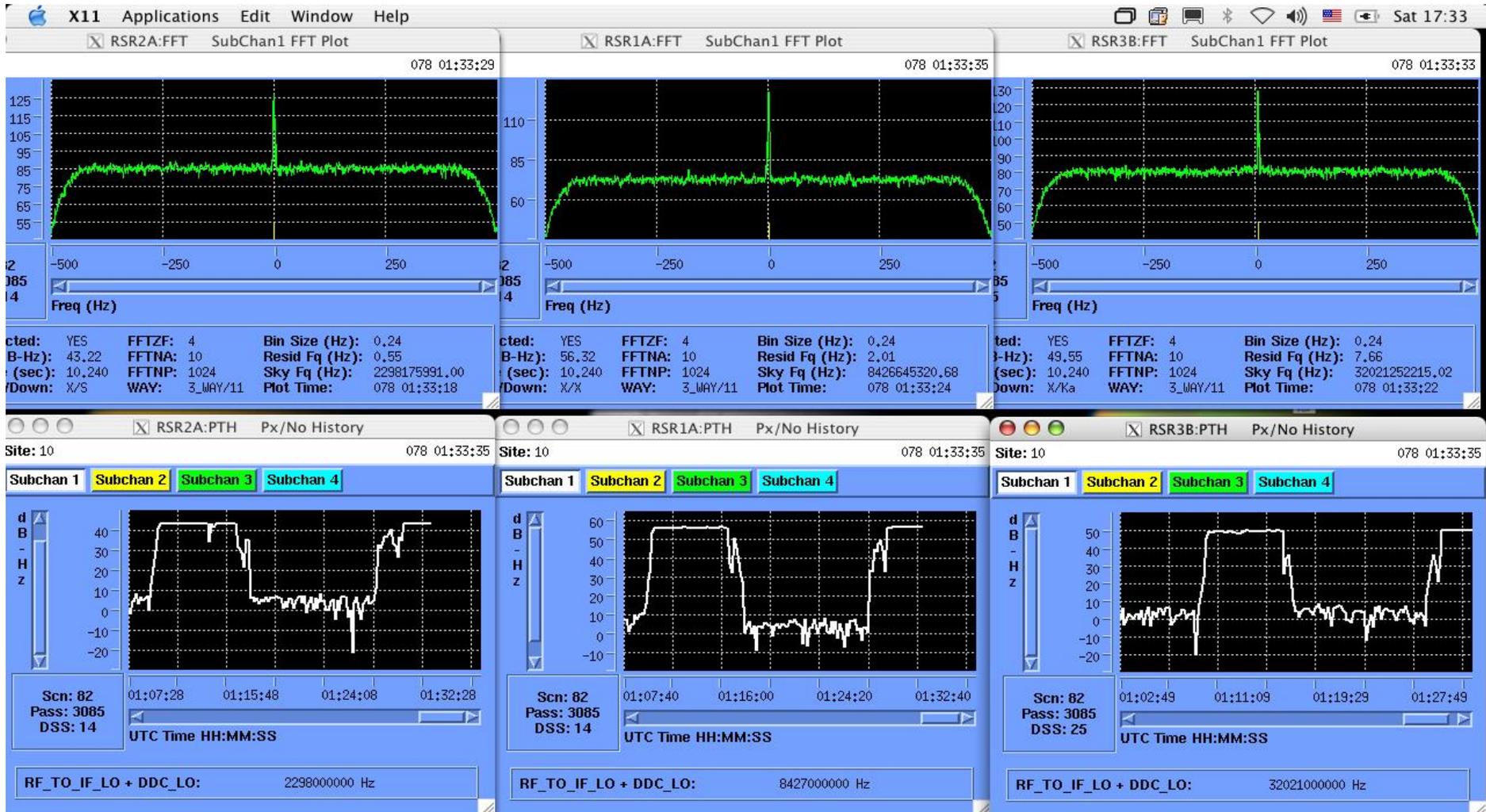
# Atmospheres of Giant Planets and Mars



Source: D. Hinson

Temperature profiles for the giant planets derived from radio occultation data acquired with the Voyager spacecraft (from Lindal, 1992)

# Three Cassini Signals Occulted by Titan



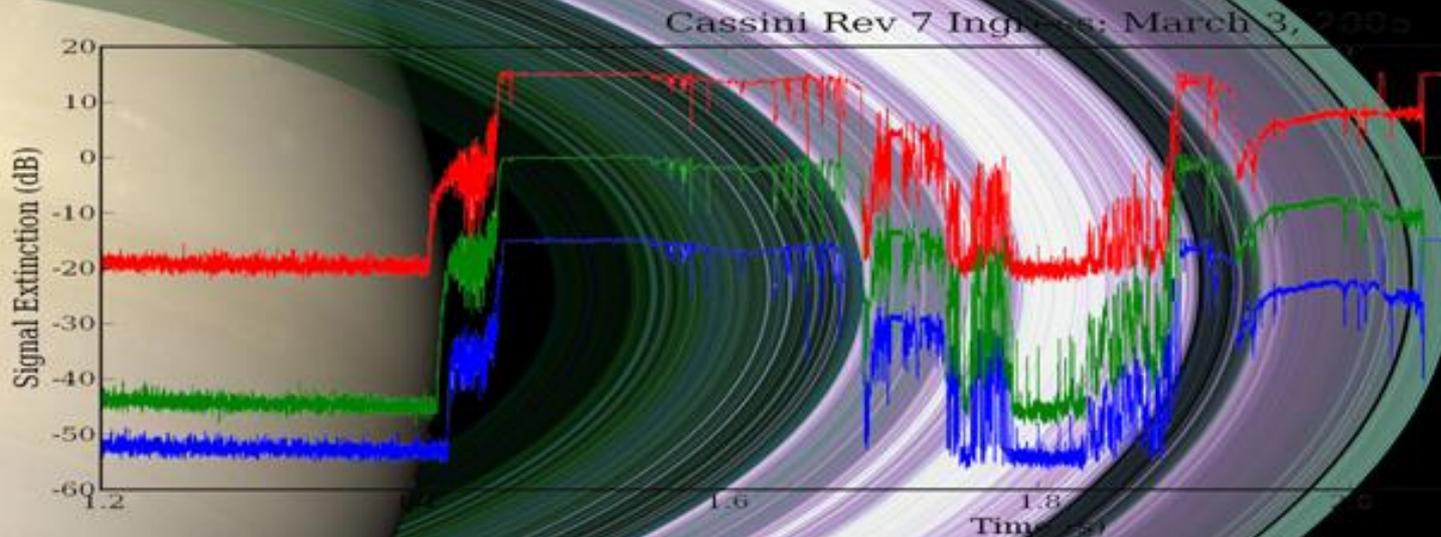
S X Ka

Picture 15

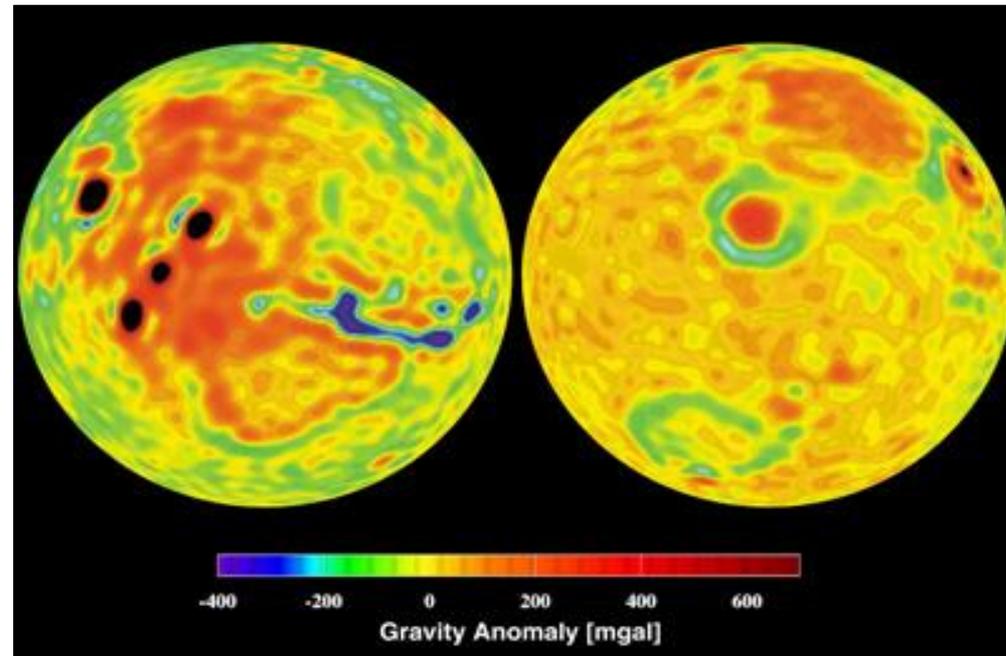
Picture 16

# Saturn's Rings In the Cassini Era

E. A. Marouf, 2007



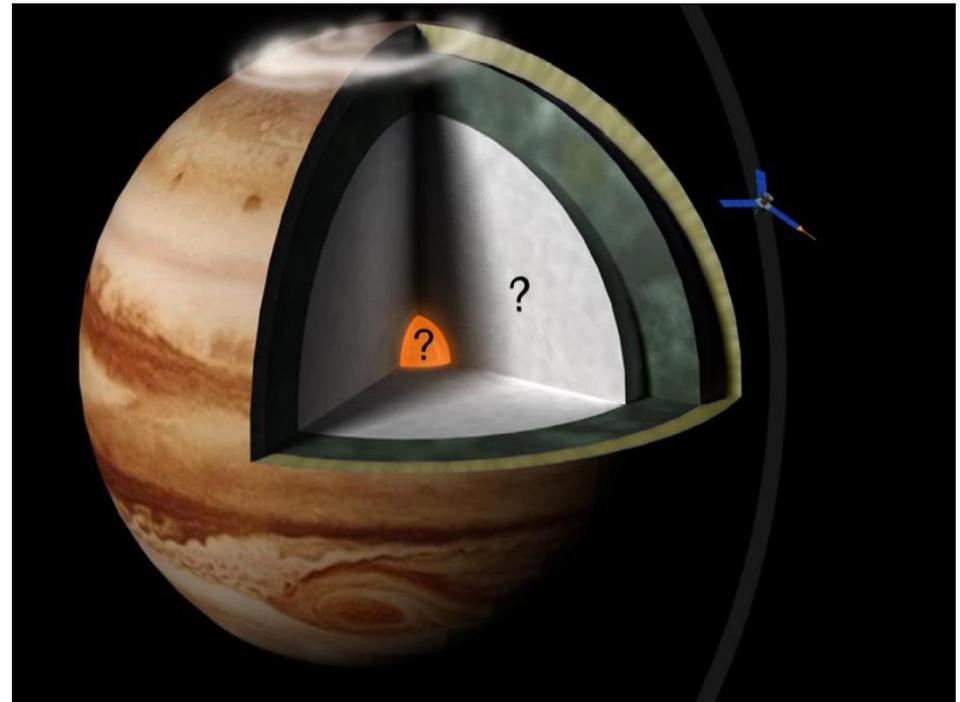
# Mars Gravity Field and Interior Models of Galilean Satellites



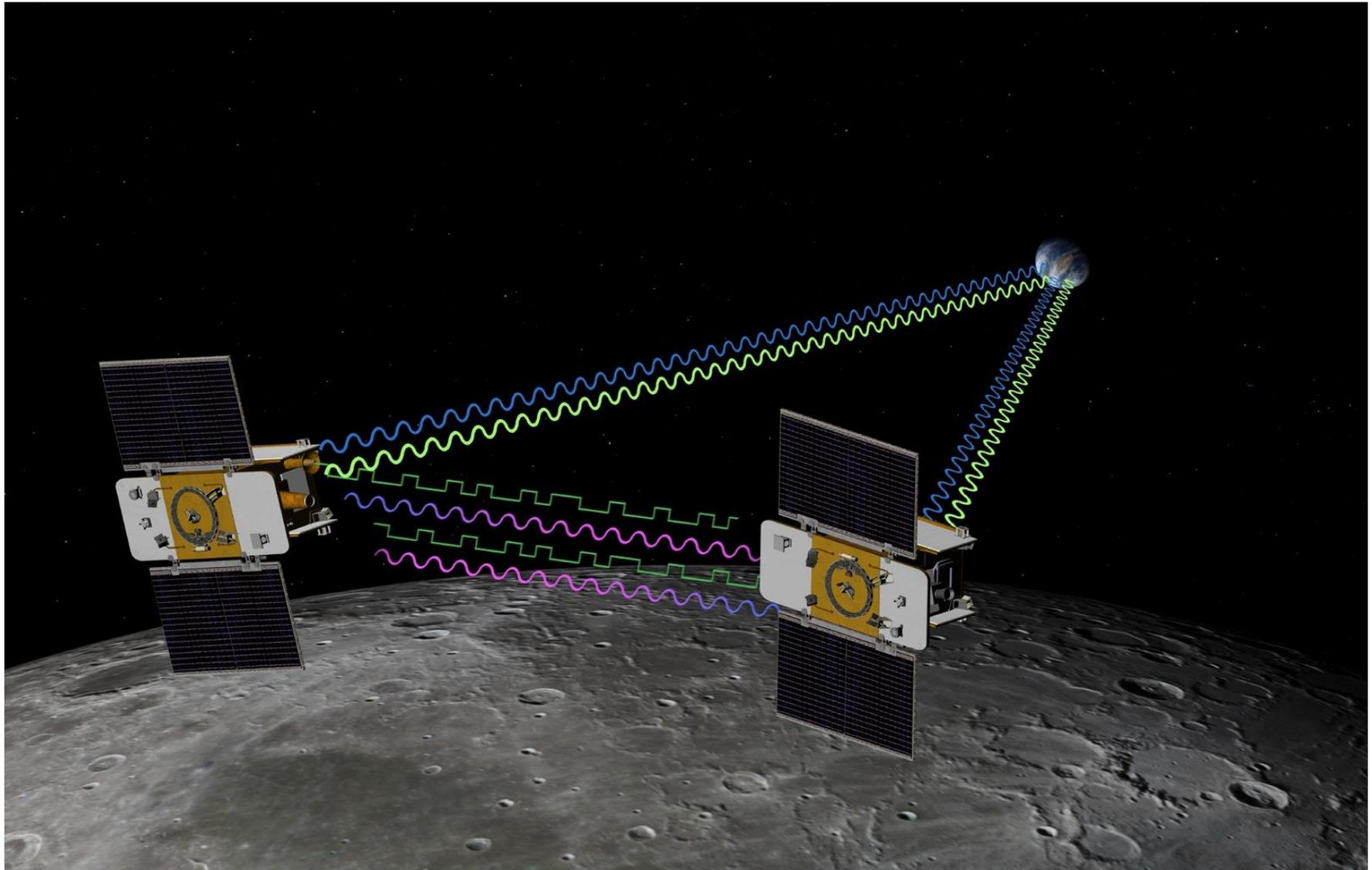
# Juno Revealing Jupiter 's Interior Structure

## Juno Gravity Science:

- Precise measurement of spacecraft motion measures gravity field
- Close-in Juno polar orbit maximizes sensitivity to gravity
- Distribution of mass reveals core and deep structure
- Higher degree harmonics reveal convective motion in deep atmosphere

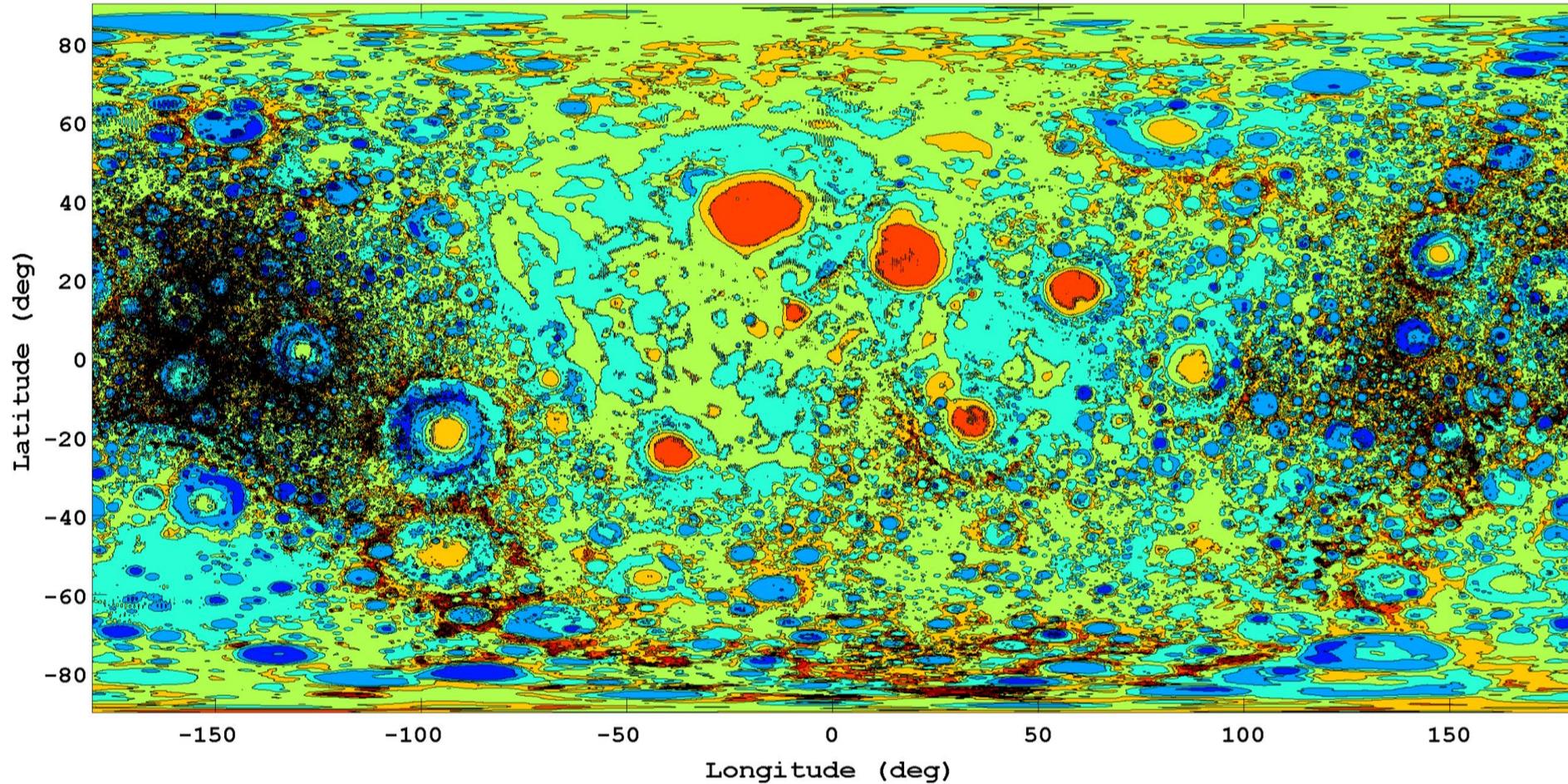


# GRAIL Reveals Lunar Interior Structure

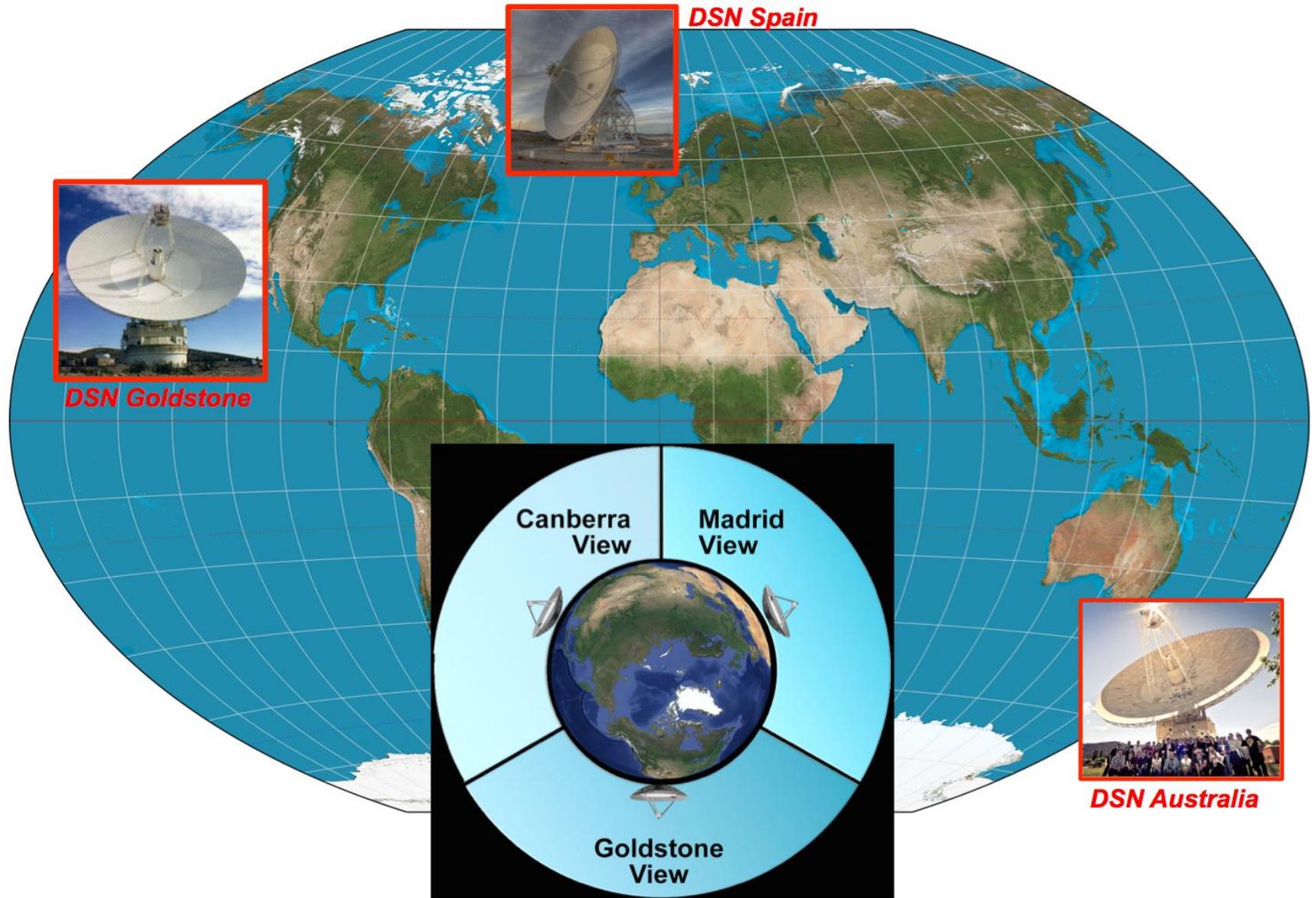


# GRAIL Results

Interiors of Moons: Earth's Moon



# In the Beginning



# Then ESA Network



**DSN Spain**



**DSN Goldstone**



**Cebreros  
ESA Spain**



**Malargue  
ESA Argentina**

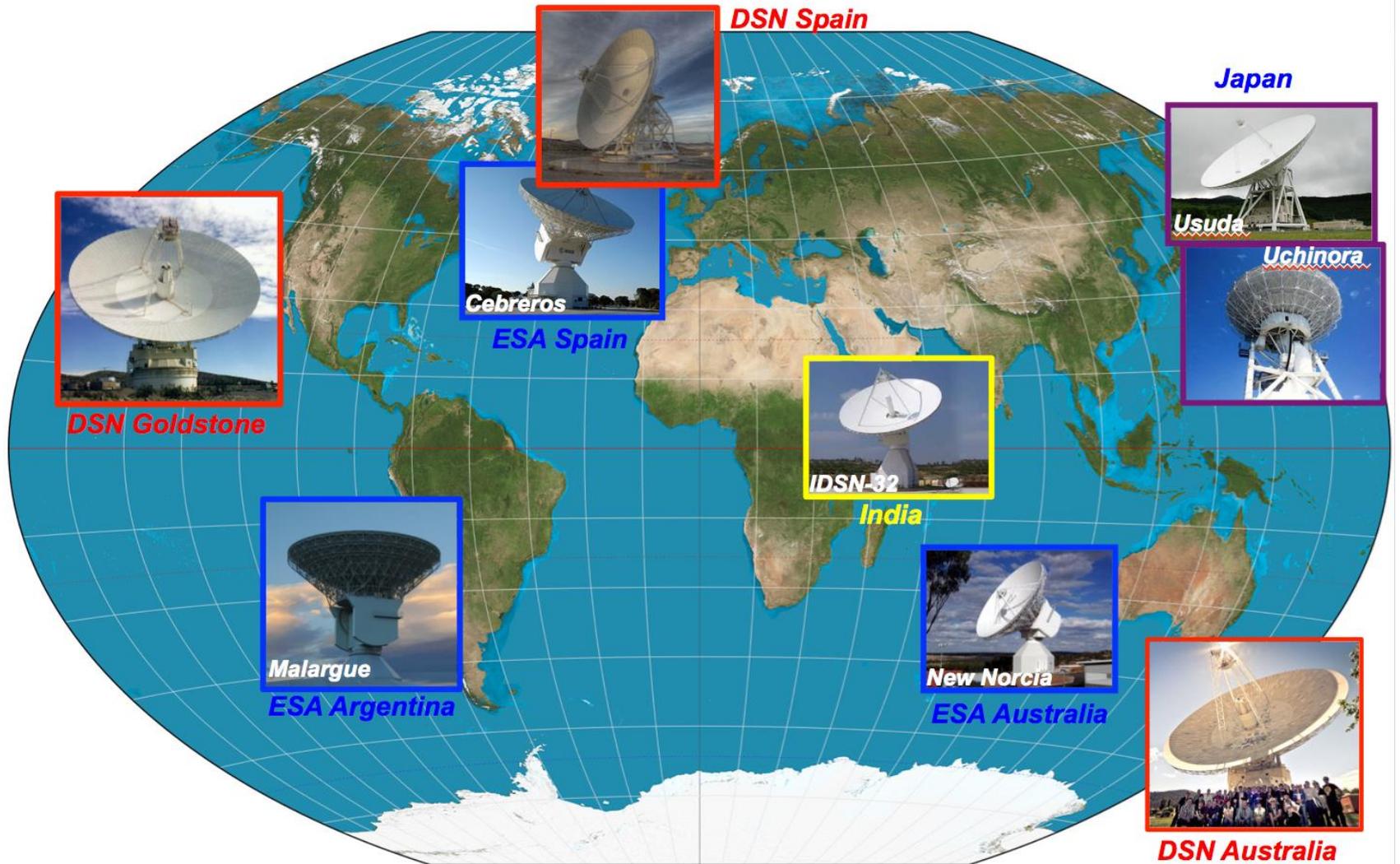


**New Norcia  
ESA Australia**

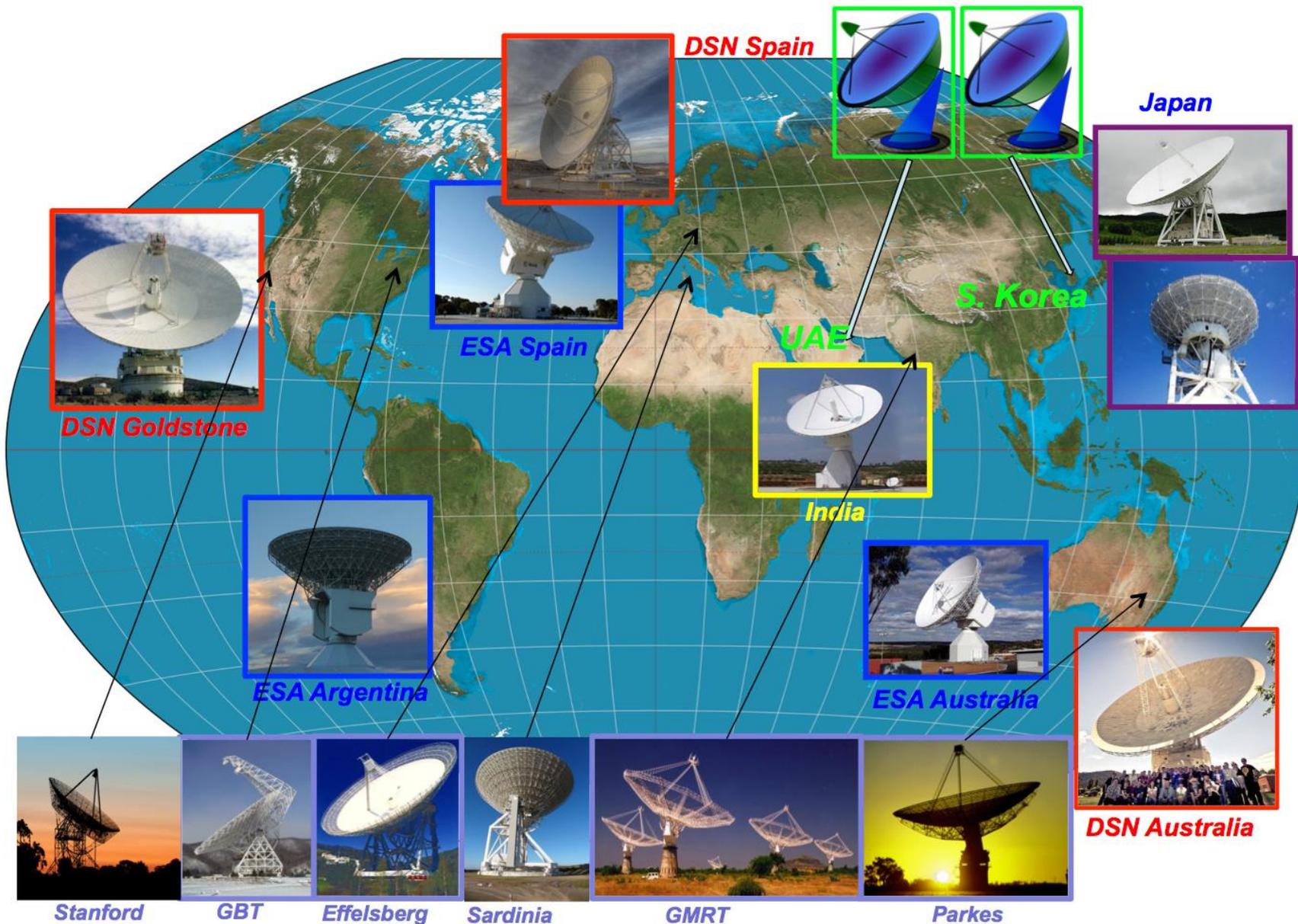


**DSN Australia**

# Then Japan & India



# Use of Radio Telescopes



# Benefits of Strategic Partnerships

- **Cost Benefits**
  - Meet redundancy requirements for critical events and navigation
  - Agencies utilize existing partner assets to balance their needs
- **Mission Benefits**
  - Quick response to reduce risks
  - Enable or enhance science
- **Collaborative Benefits**
  - Foster international collaboration to benefit agencies and science community
  - Share valuable experience and share in discoveries and excitement

