Jet Propulsion Laboratory
California Institute of Technology

Weather-Related Service Management Working Group

Mars Reconnaissance Orbiter

Ka-Band Radio Science Experiments

And the Effect of the Troposphere

Sami Asmar
David Morabito

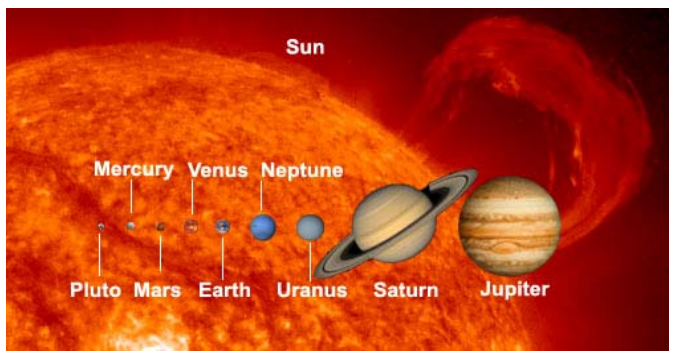
Jet Propulsion Laboratory
California Institute of Technology

29 March 2006
GSAW 2006
Manhattan Beach, CA

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 and particle distribution
- Fundamental Physics and Relativity



Limits On Sensitivity

- Frequency stability
  - Typically measured in Allan deviation
- Amplitude stability
  - Typically 0.1 dB over few minutes
- Signal to noise ratio
  - Places thermal noise limits
- Spacecraft pointing stability
  - Reaction wheels versus thrusters
- Non-gravitational forces
  - Momentum dumping, fuel sloshing, etc.
- Trajectory accuracy
- Intervening media
  - Interplanetary plasma
  - Ionosphere
  - Troposphere

Planetary Interiors from Gravity Observations

- Determine the mass and mass distribution
  - GM of body or system (planet + satellites)
  - Mean density and quadrupole moments
  - Gravity field: higher order expansion of mass distribution
  - Constrain models of internal structure
    - Differentiation of Galilean satellites, ocean on Titan
  - Improve orbits and ephemeredes
- Observables:
  - Doppler and range: precise measurement of relative motion
    - Doppler accuracy has improved to 0.01mm/s at X-band
    - Ranging accuracy to ~ 1 meter at X-band

Goals & Products of Mars Gravity Science

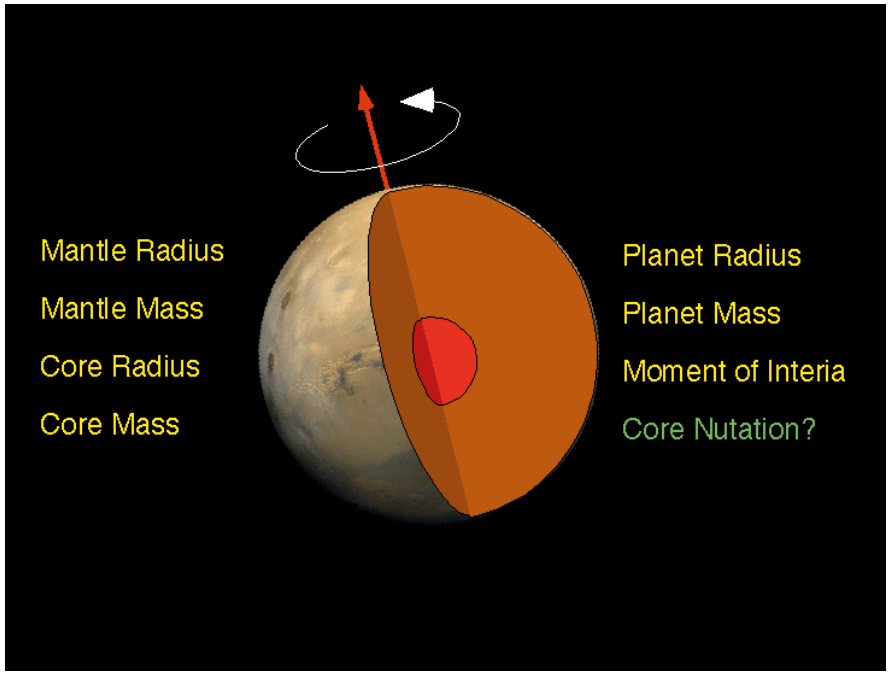


Figure source: W. Folkner

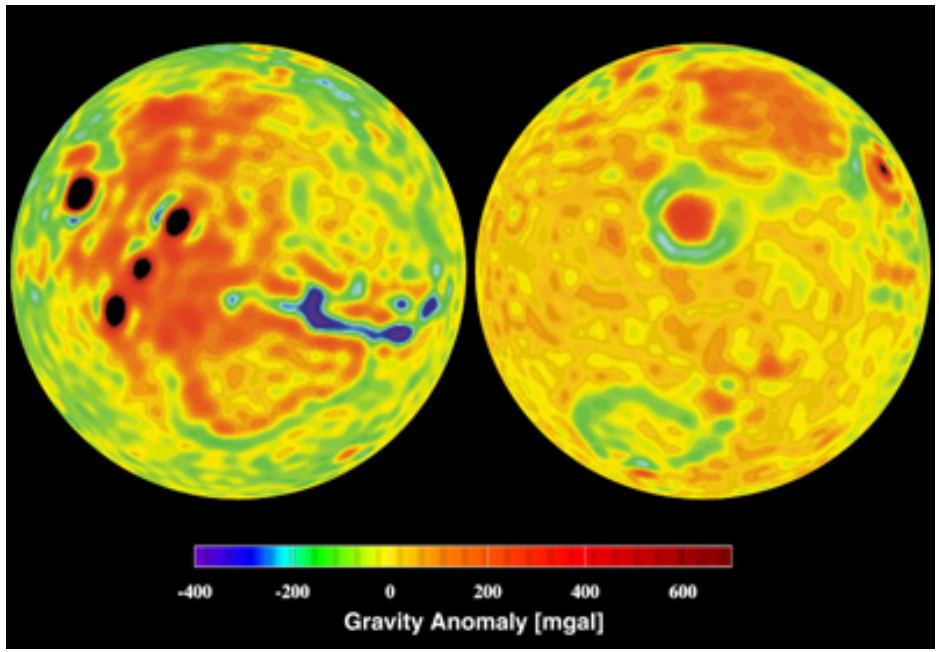


Figure source: A. Konopliv

Typical Data Processing

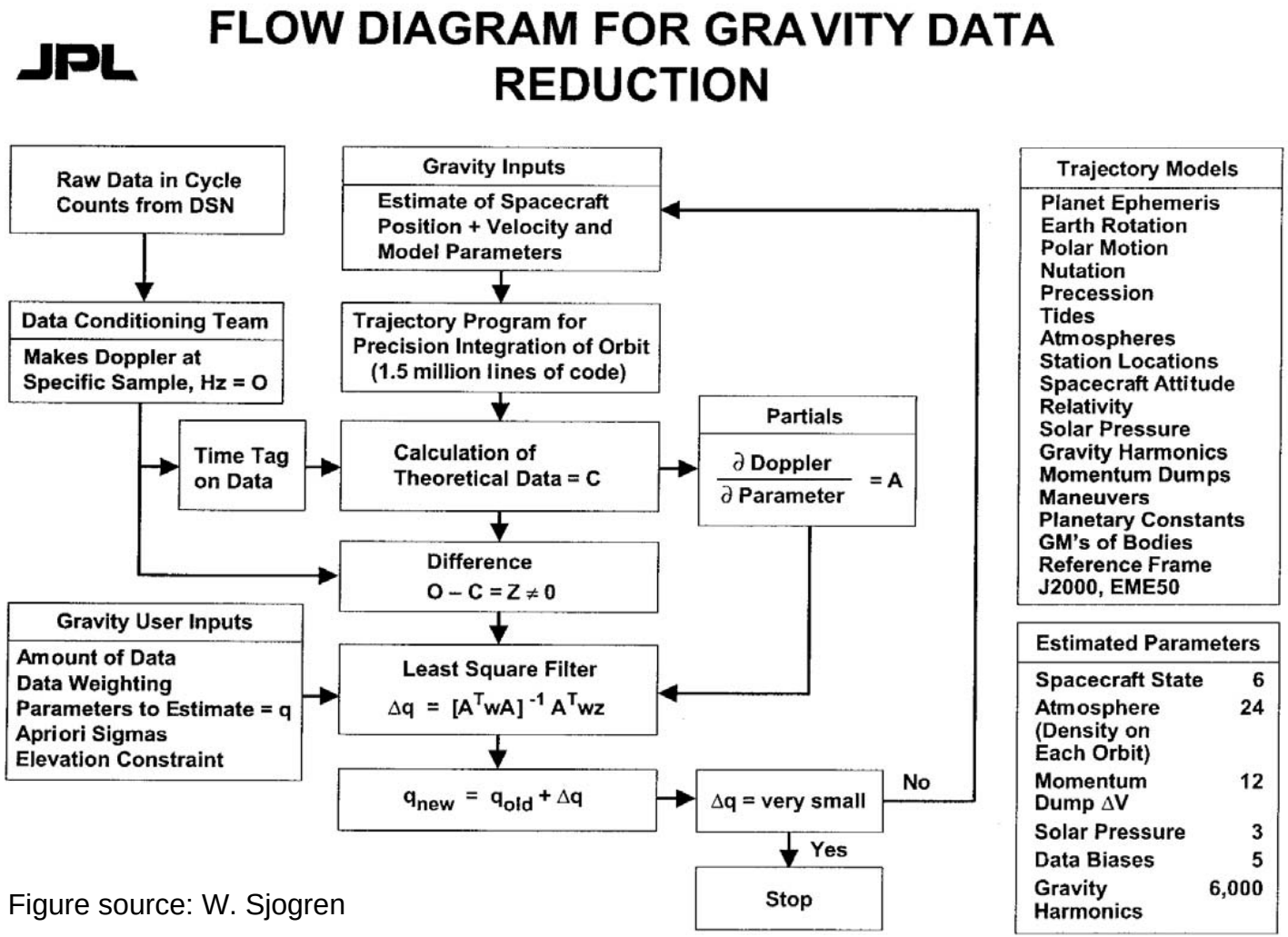
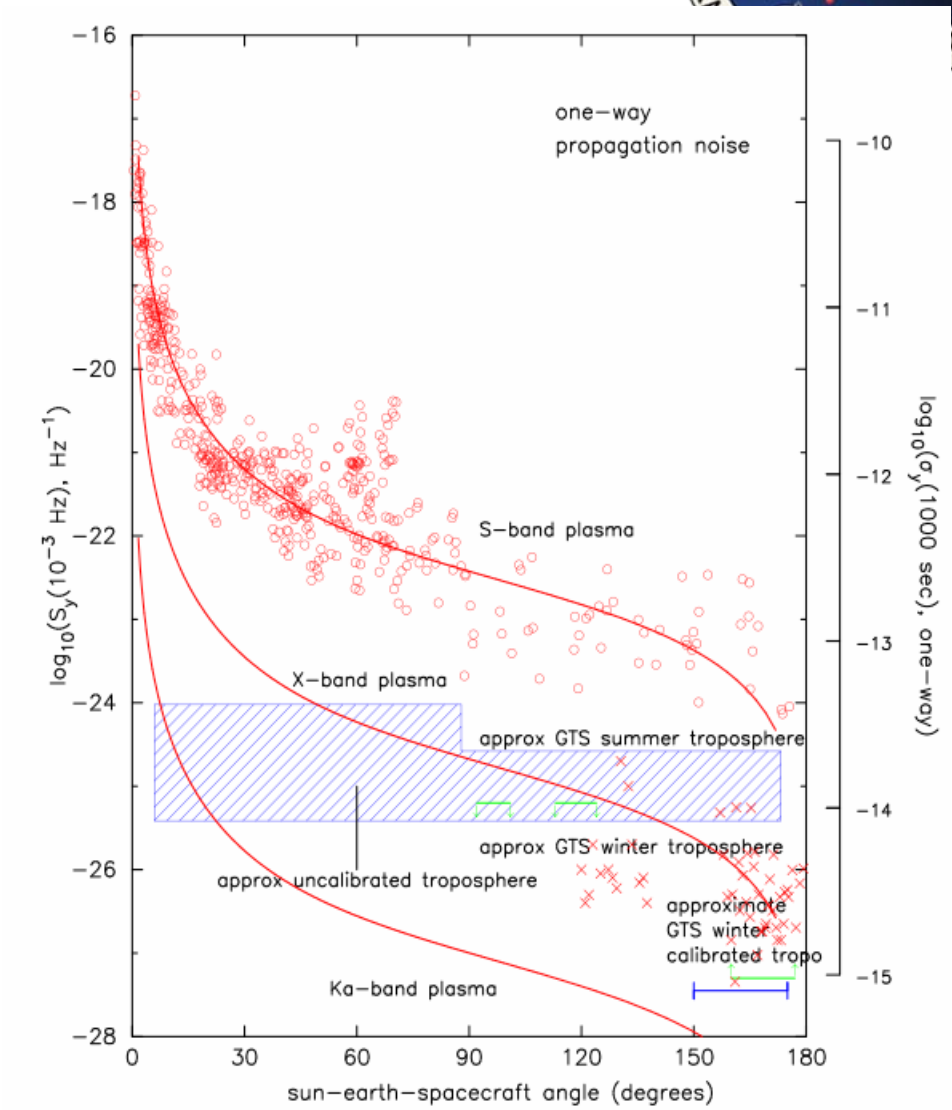


Figure source: W. Sjogren

Solar Contribution to Noise

- Noise in one-way propagation at S-, X-, and Ka-bands as function of angular distance from the Sun
- Also shows troposphere
- Particularly useful for planning future missions or experiments

- Ref: Asmar et al., 2005

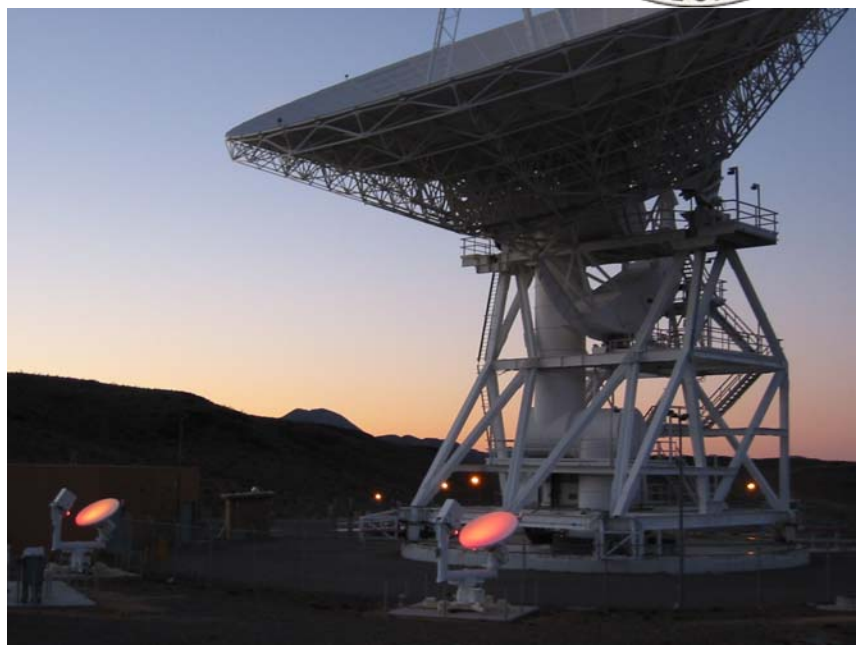


Ka-band for Radio Science

- The MRO mission utilizes X-band coherent (uplink and downlink) carrier Doppler and range for its gravity investigation
- Gravity team will also take advantage of Ka-band downlink signal
- Tropospheric calibration data from Advanced Water Vapor Radiometer (AWVR) will be used
  - Developed for Cassini precision Radio Science experiments
  - Only two units (currently one at Goldstone and in Madrid)
  - Not “delivered” to DSN; operated remotely by Radio Science Group
- Learn from Cassini experience of tropospheric calibration of Doppler data
  - Cassini had Ka-band uplink and downlink

Advanced Media Calibration

- Advanced Water Vapor Radiometer and related meteorological systems
- Measures path delay due to Earth troposphere
- Critical to supporting precision experiments at Ka-band
- Adjacent to DSN station
- Remotely operated by *Radio Science Systems Group*



Cassini Data Before and After Tropo. Cal.

- Contribution of tropospheric scintillation up to 30E-15
- Calibrated down to better than 3E-15
- Example below from Cassini show magnitude of improvement
  - Red prior to tropo correction, green after tropo correction

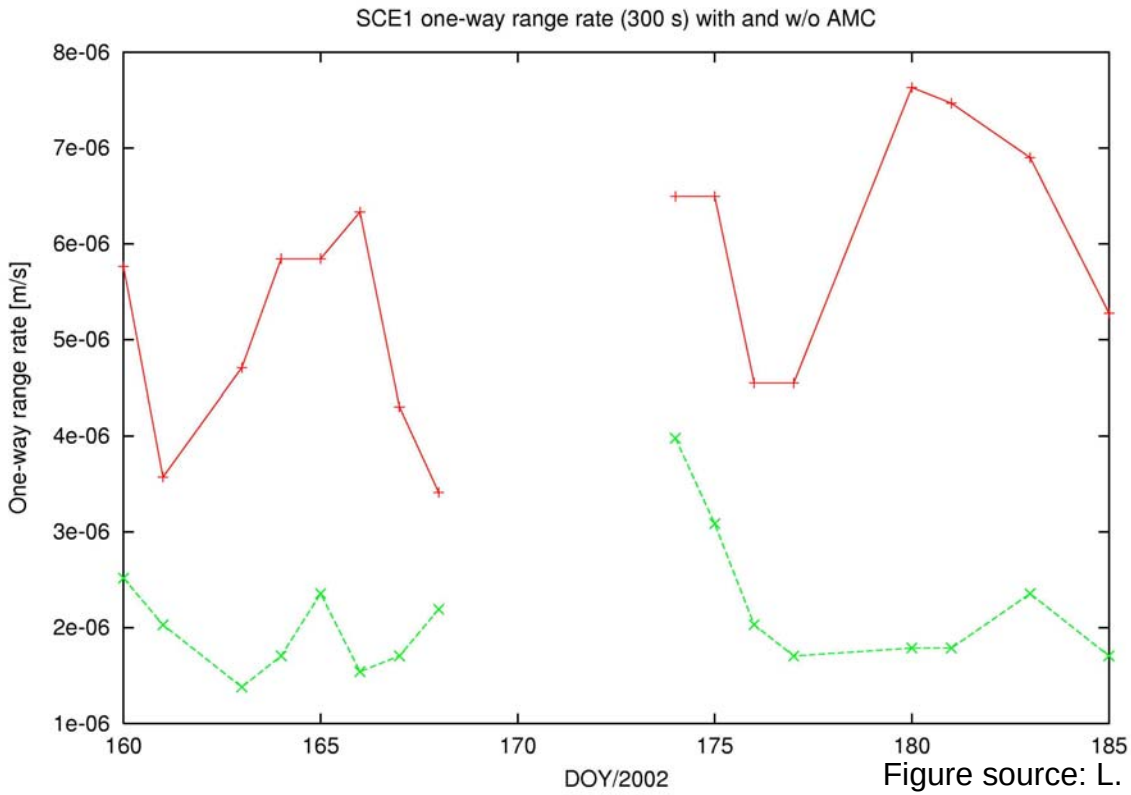


Figure source: L. less

Ka-band for Radio Science

- Study by Keihm et al., (2004) of Cassini AWVR data
  - One and one-half years of near continuous measurements of the troposphere induced path delay at Goldstone analyzed to
  - Characterize the troposphere-delay fluctuations statistically
  - Evaluate the path-delay calibration performance of the system
  - Both wet and dry components of delay are considered
- Similar work will be applied to Mars Reconnaissance Orbiter
- Future reports will announce results