Radio occultation observations of the ionosphere of Mars

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What are radio occultations?

Radio signal sent from spacecraft to Earth such that signal passes through the environment of the target object (Titan)

Properties of the environment of the target object affect measureable properties of received radio signal

https://saturn-archive.jpl.nasa.gov/multimedia/images/artwork/images/IMG003467-br500.jpg

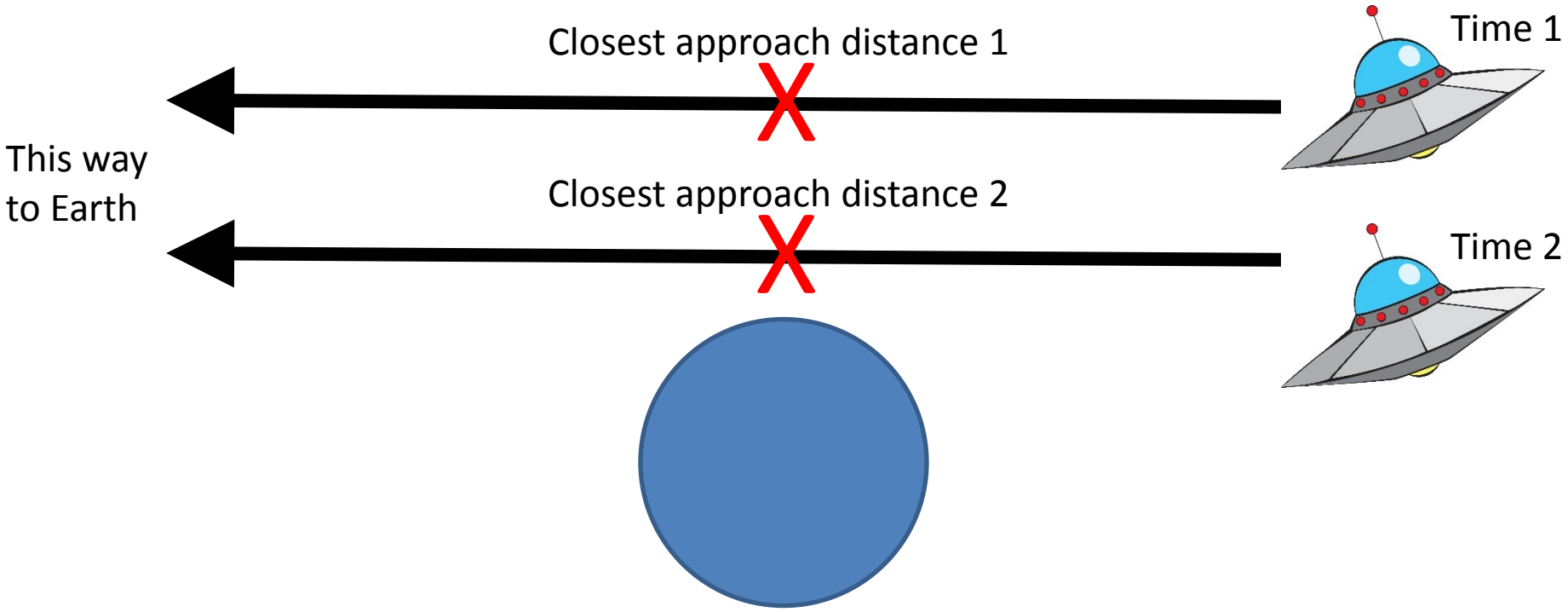
What do you get?

- Vertical profile of neutral density, pressure, and temperature
- Vertical profile of ionospheric electron density
- Vertical profile of absorbing species like NH_3, SO_2, H_2SO_4
- Information on plasma density and magnetic field in magnetosphere

How do you get them?

- Neutral and ionospheric profiles
  - Refraction bends ray path, Doppler shift affects frequency
- Absorbing species
  - Absorption affects amplitude
- Magnetospheric density and B constraints
  - Faraday rotation affects polarization

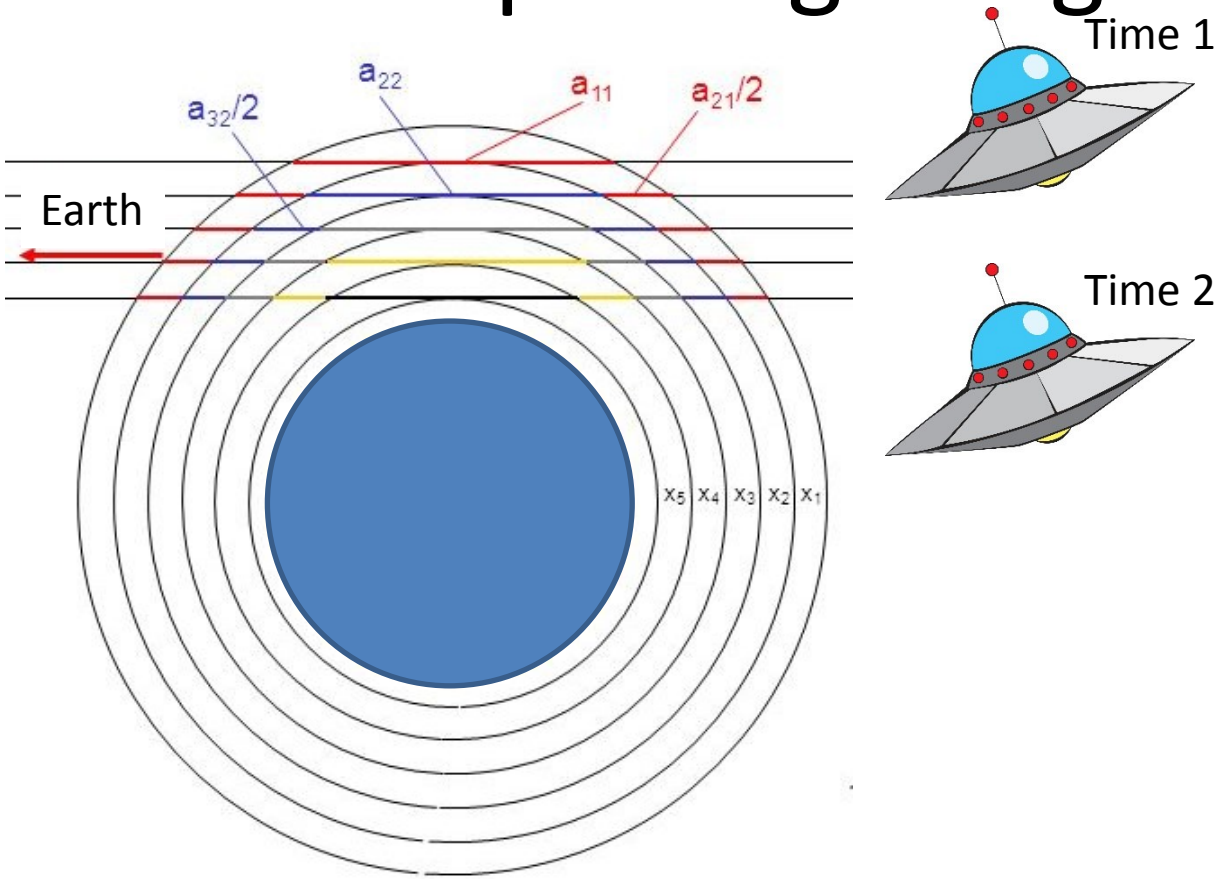
From time series to vertical profile



- Each ray path samples a different set of altitudes
- On Earth, measure time series of properties of received radio signal that is effectively a vertical profile

http://clipartbarn.com/wp-content/uploads/2017/03/Space-ship-clip-art-clipartfest.jpeg

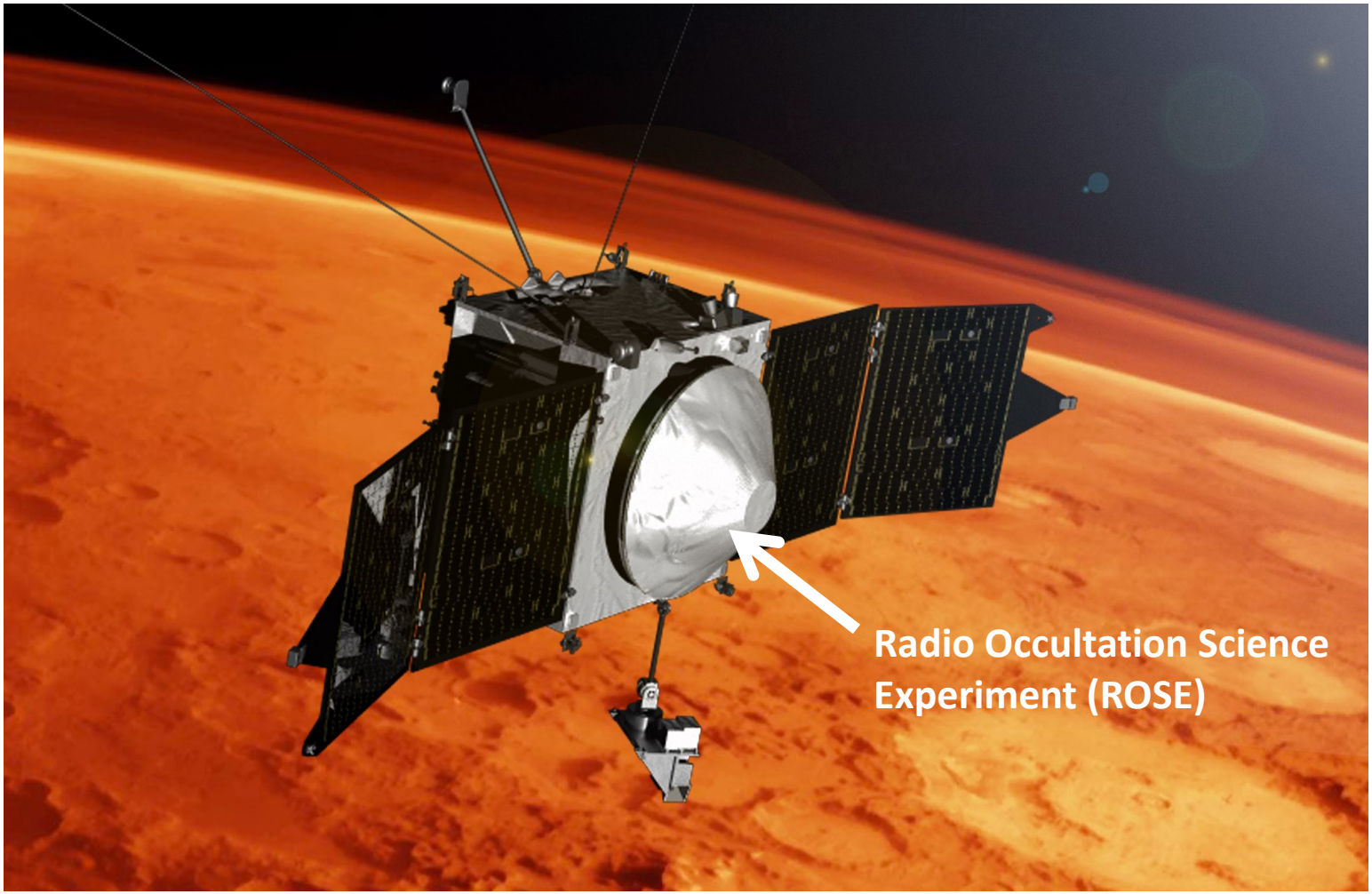
“Onion-peeling” to get profiles



- Matrix transformation from series of column-integrated properties to local properties
- Need spherical symmetry (Abel transform)

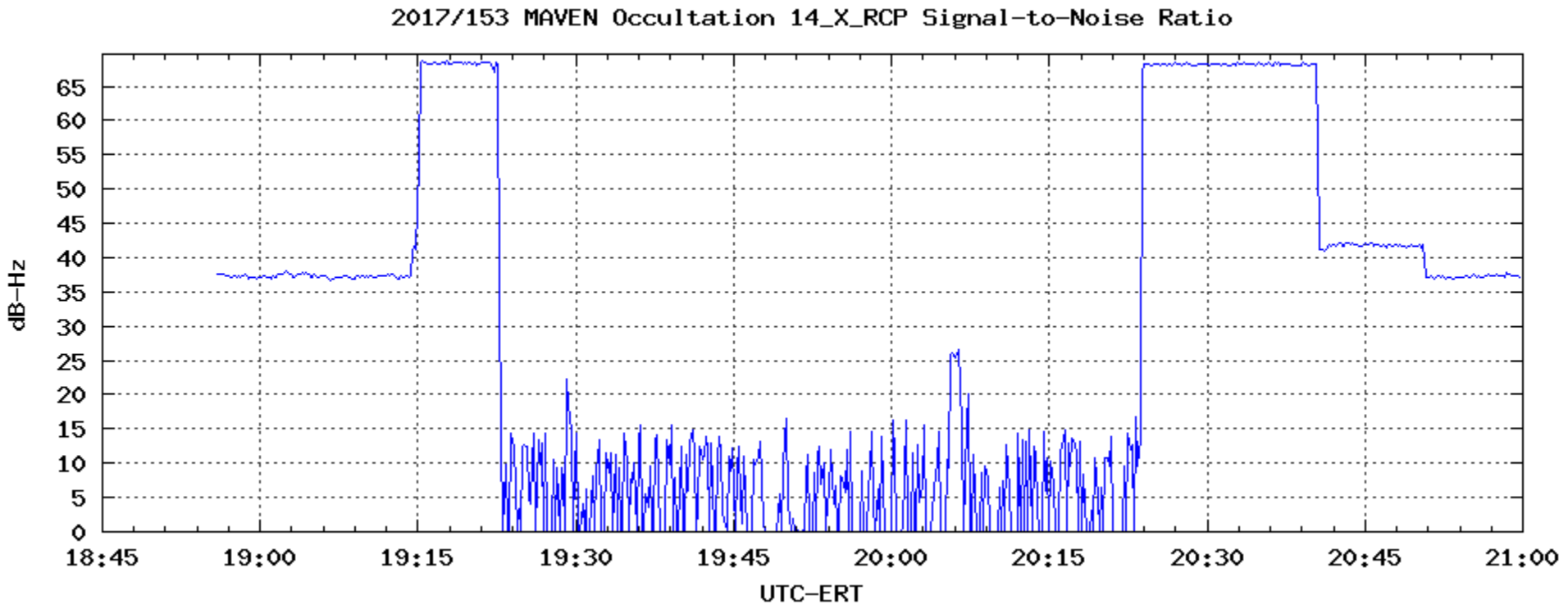
http://slideplayer.com/slide/8418417/26/images/16/Example:+Onion+peel+inversion+of+occultation+observations.jpg

MAVEN at Mars



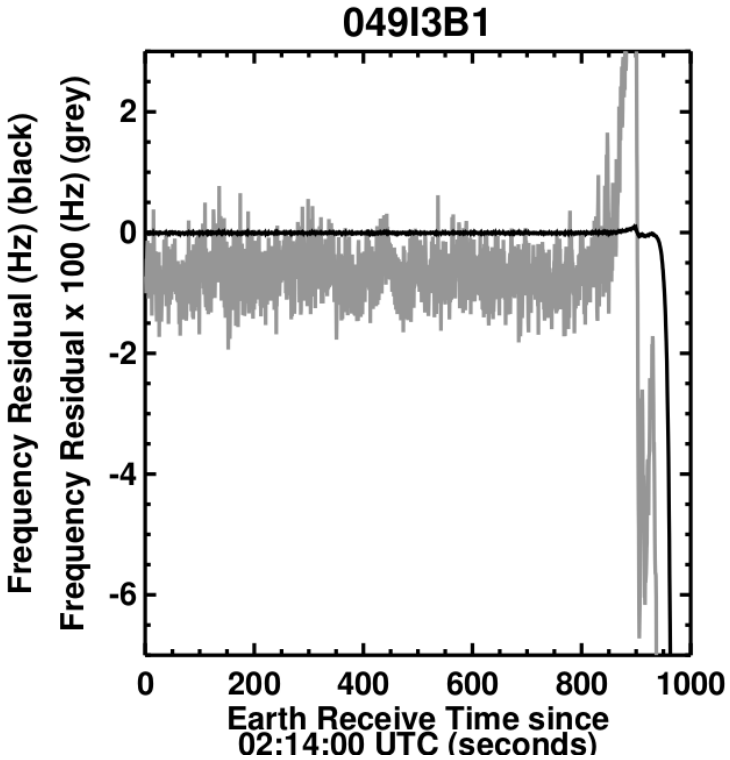
https://www.nasa.gov/feature/goddard/2017/maven-1000-days

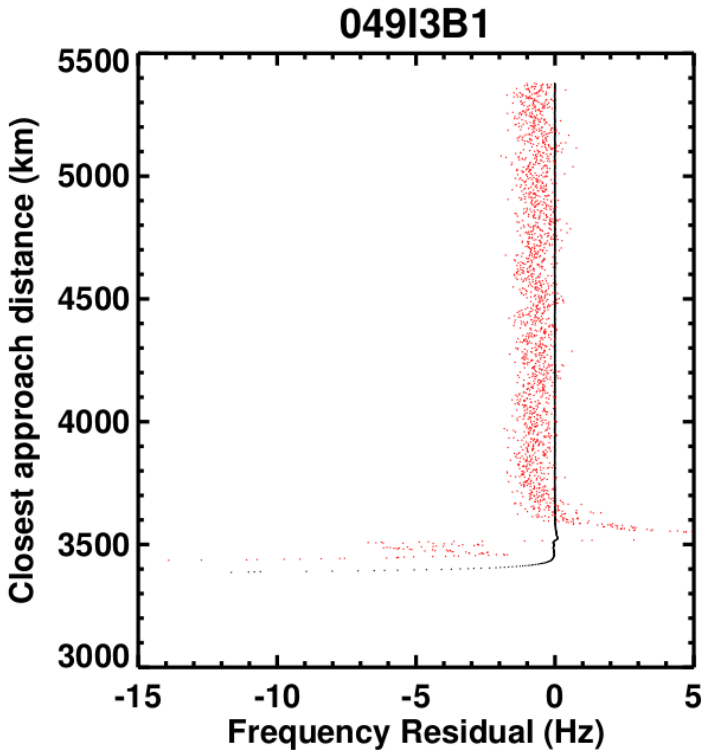
Real-time data



Time series of frequency residuals

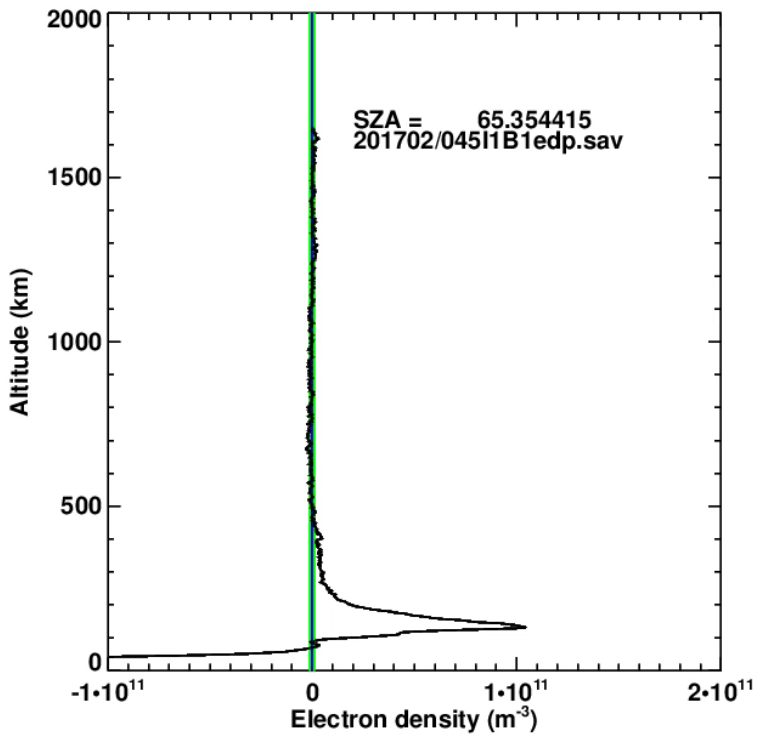
- A few weeks later…once reconstructed trajectory known

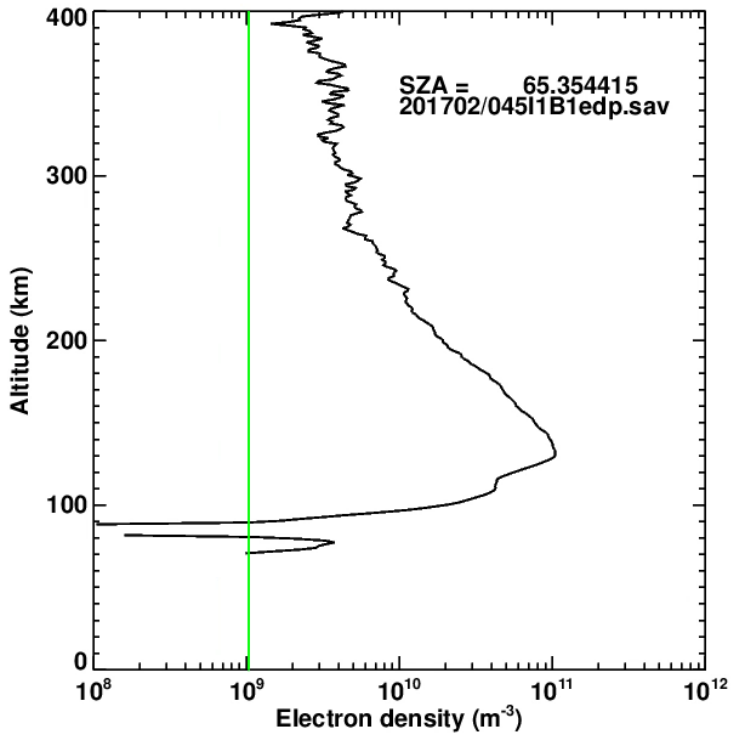




Electron density profile

- Delete/replace any bad frequency residuals
- Apply baseline correction (very sensitive)
- Trim length of data series if necessary (some geometries)
- Make electron density profile – 10 minutes <u>if all works well</u>





ROSE status

- Observations happening now, twice per week
- First data products delivered to NASA archive, will be publicly available after short review
- “First results” manuscript in preparation

- Observations will hopefully continue as long as spacecraft is alive

Radio occultations with other spacecraft

- Viking (Mars) and Pioneer Venus Orbiter
  - Data recovery effort
- Cassini
  - Generate ionospheric electron density profiles from raw data, archive
- Juno
  - Measure densities in Io plasma torus
- Mars Reconnaissance Orbiter
  - Suitable data sitting in archive, available for use
- Europa Clipper
  - NASA's next big outer solar system mission, persuade NASA that it wants radio occultations

Astrophysical radio occultations

- Theoretical concept studies
- Replace spacecraft with
  - Pulsar, AGN, maser for Jupiter observations
  - Parent star, CMB for exoplanet observations
- Potentially very promising, but ideas need further development

Opportunities for collaboration

- Scientific use of radio occultation results
- Signal processing expertise
- Knowledge of astrophysical radio sources
- Knowledge of capabilities of radio observatories