Development and validation of software to process radio occultation data: From time series of frequency residuals to vertical profiles of atmospheric and ionospheric properties

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Why care about radio occultations?

- Almost all measurements of planetary ionospheres

- Atmospheric density, pressure, and temperature profiles that are referenced to absolute altitude scale, have excellent vertical resolution, and have high accuracy near surface

- Flown on nearly every mission in history

What's the problem?

- Few US centers of excellence
  - Stanford and JPL have led every NASA experiment
- Expertise is aging
  - Next generation must be trained
- Archives contain few high-level data products
  - Limits scientific impact of experiments
 - Many partially-processed data available for exploitation

How the measurements are made

Bending angle
~0.01 degrees

**Antenna
on Earth**

MARS

Spacecraft
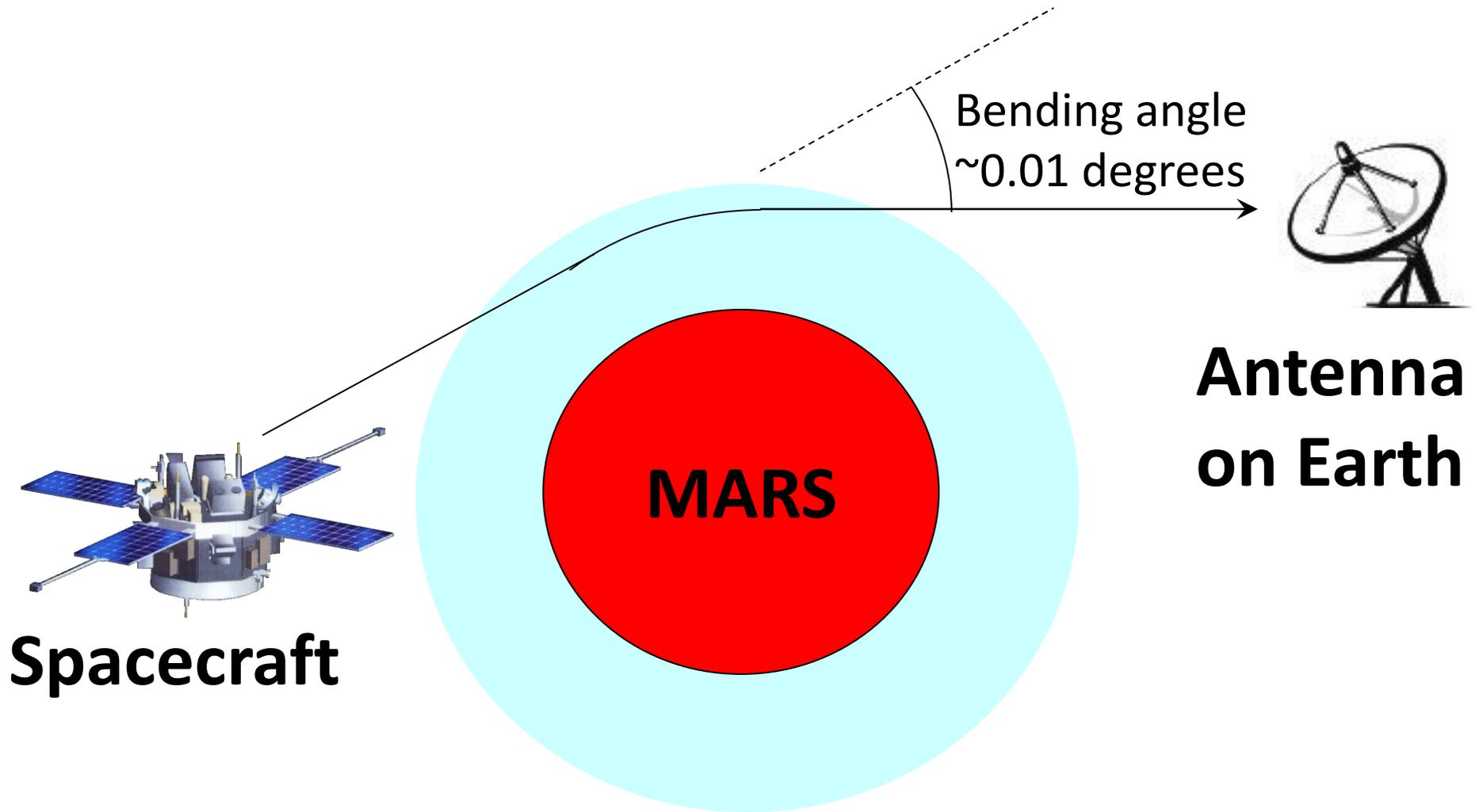
Data processing pipeline (all math omitted)

- Record $f(t)$
- Compare to expected $f(t)$, find residuals
- Get bending angles from freq. residuals
- Get atmospheric/ionospheric refractive index from bending angles
- Get electron density and neutral density from refractive index
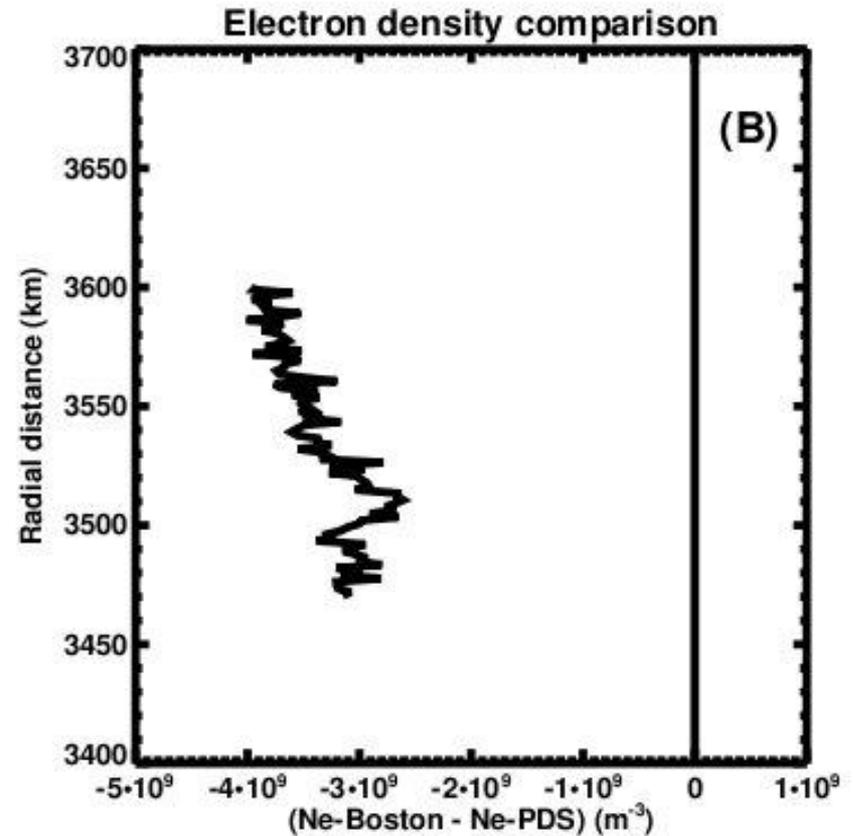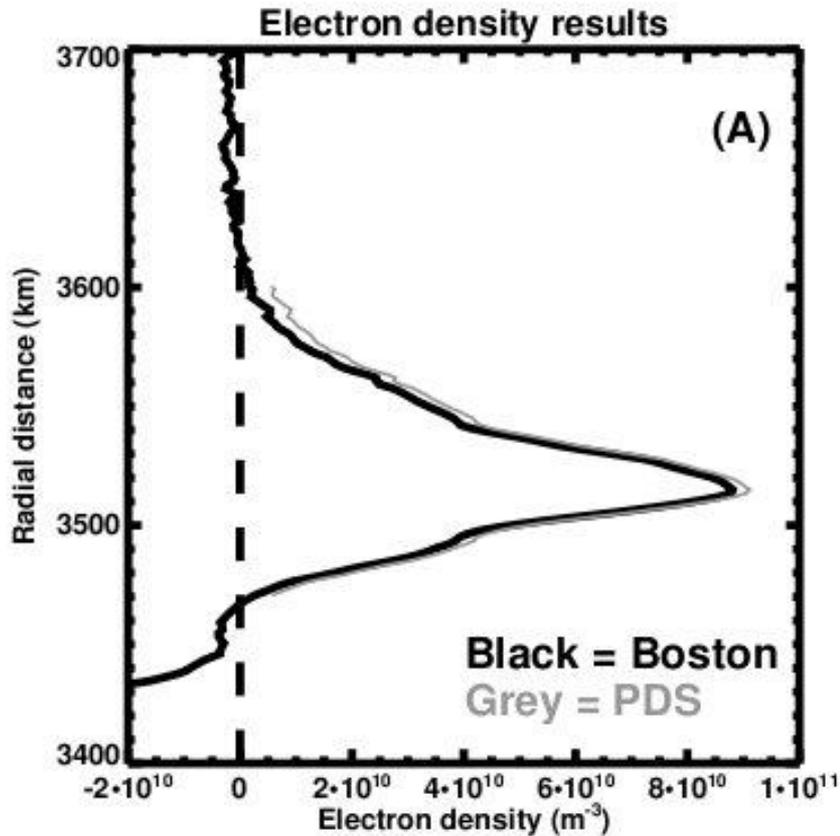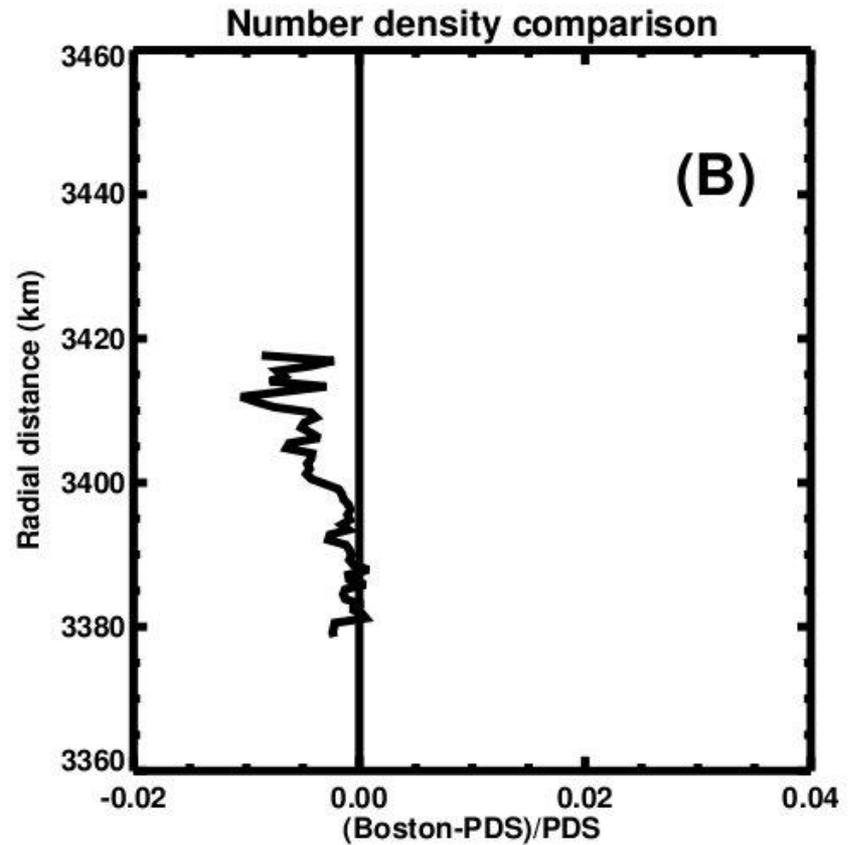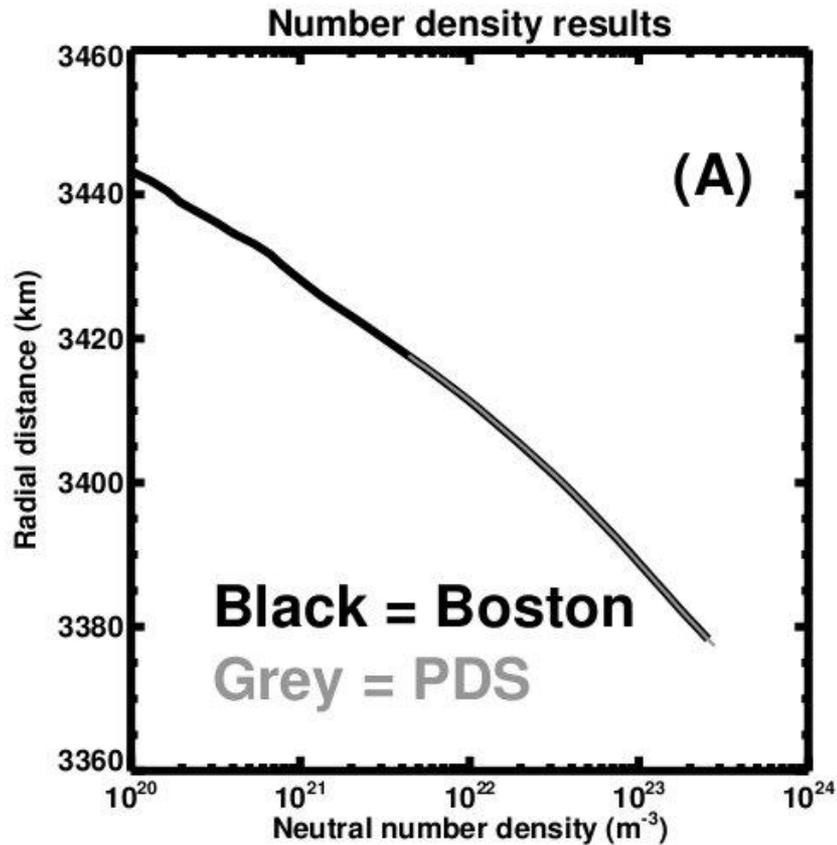- Get neutral pressure and temperature

Bending angle results
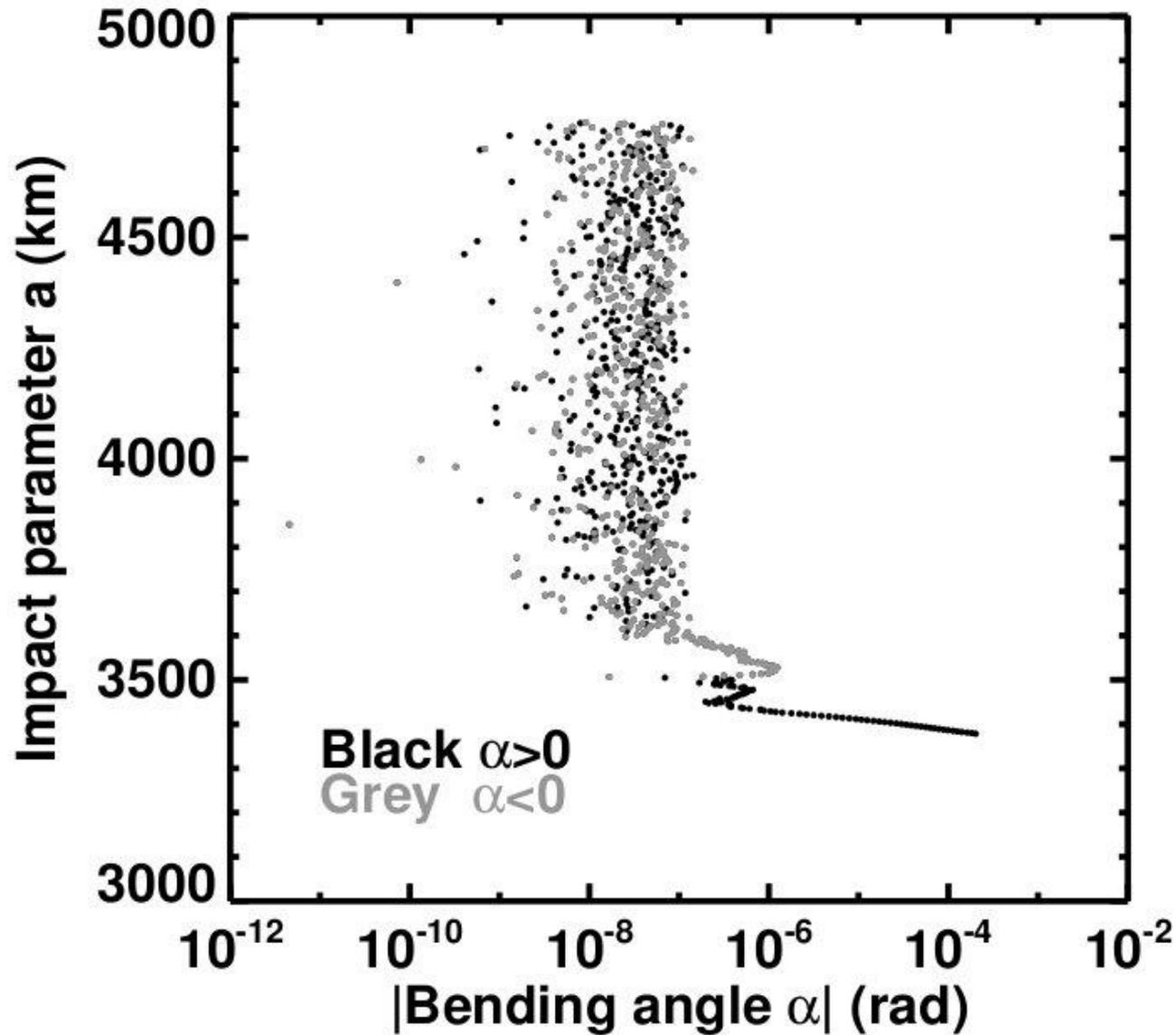
Refractive index results
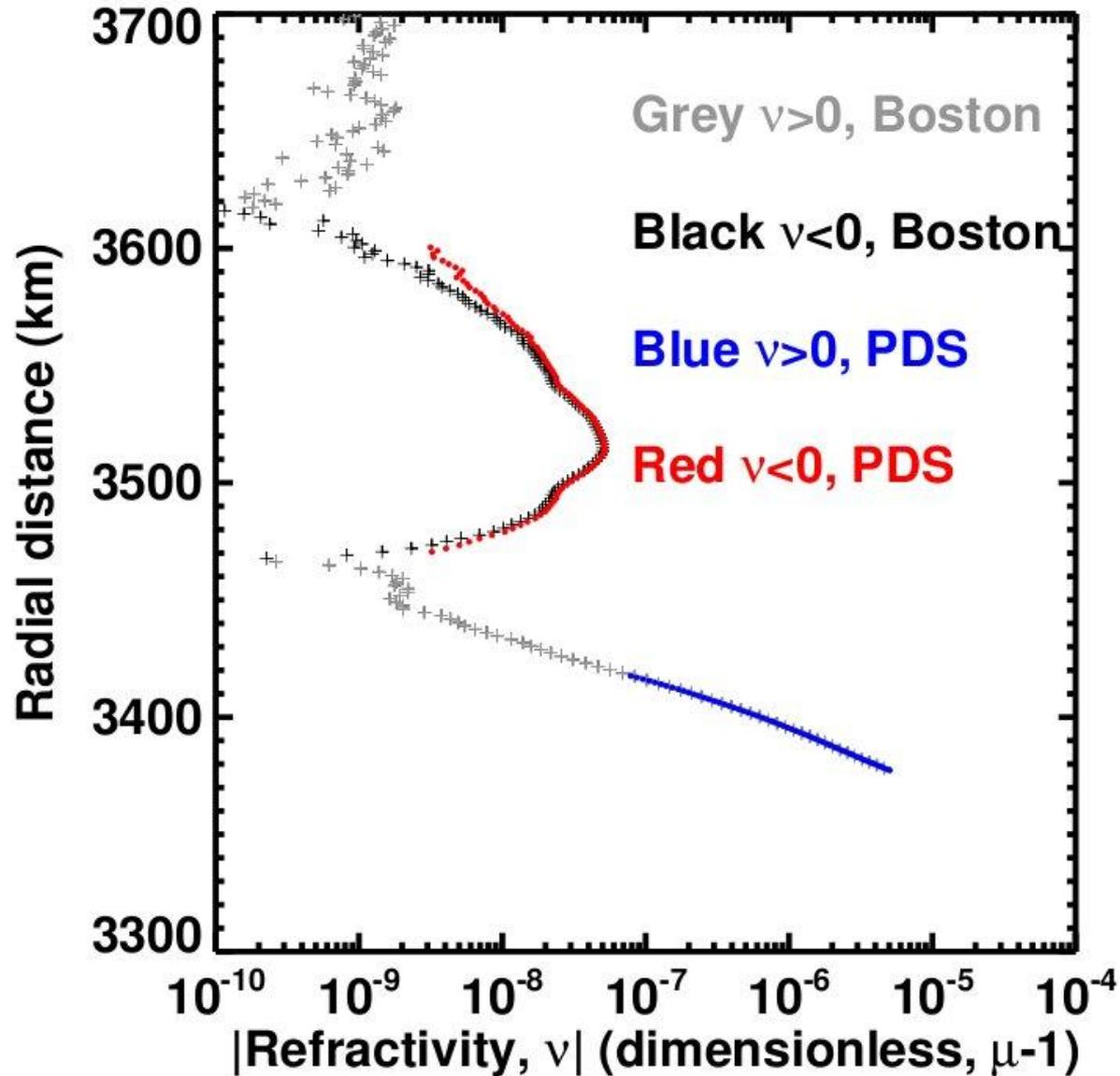
Electron density results

Neutral density results

Conclusions

- Software works adequately, not perfectly
  - Demonstration on Mars Global Surveyor example
  - Small differences with PDS results
  - Pressures and temperatures need precise gravity model
  - Some other annoying imperfections need fixing
- Will soon be able to process archived frequency residuals from other missions