Mars Interior Results from the InSight Mission

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Caveats

Many of the results I will be presenting today have not yet been fully peer reviewed. Some have been submitted and are in review, some have not yet been submitted. I have tried to identify this material in the presentation.

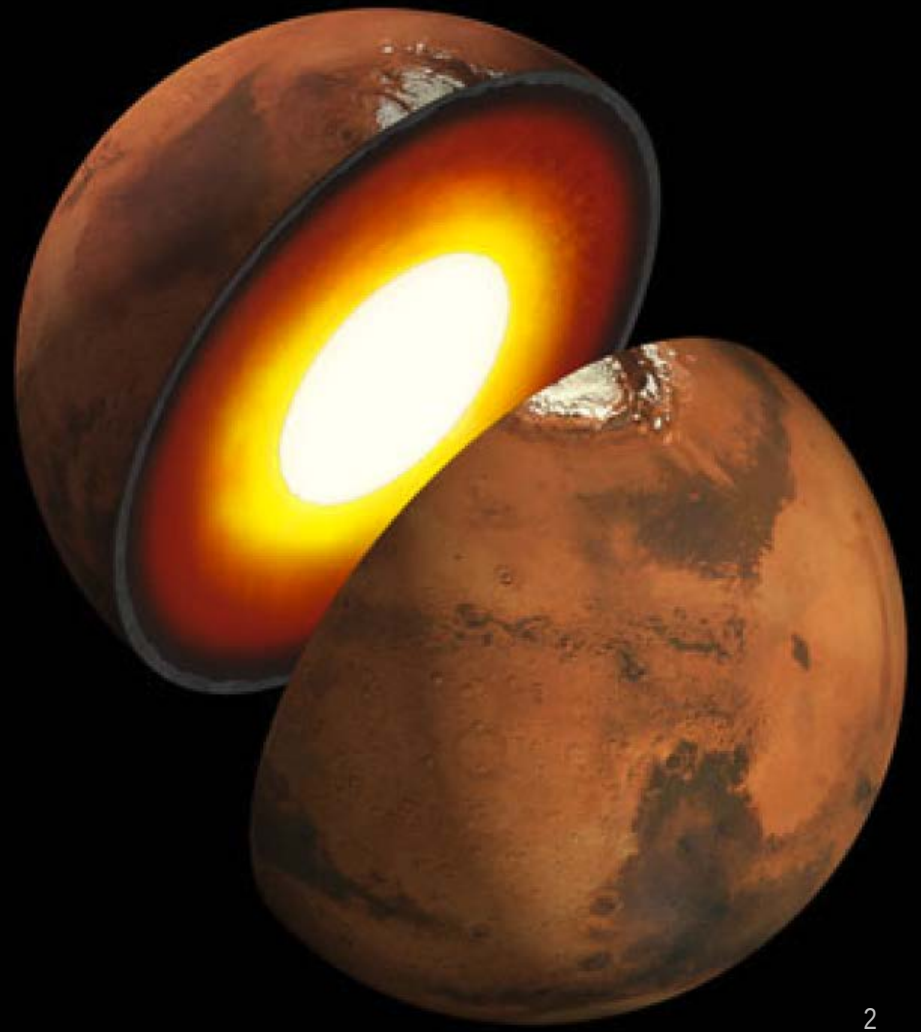
Results that have not yet been published should be considered under a “news” embargo. Discussion in a scientific context is encouraged by journal editors (most of this work has been presented at conferences), but it should not be further elaborated with the wider community.

InSight Mission Objectives

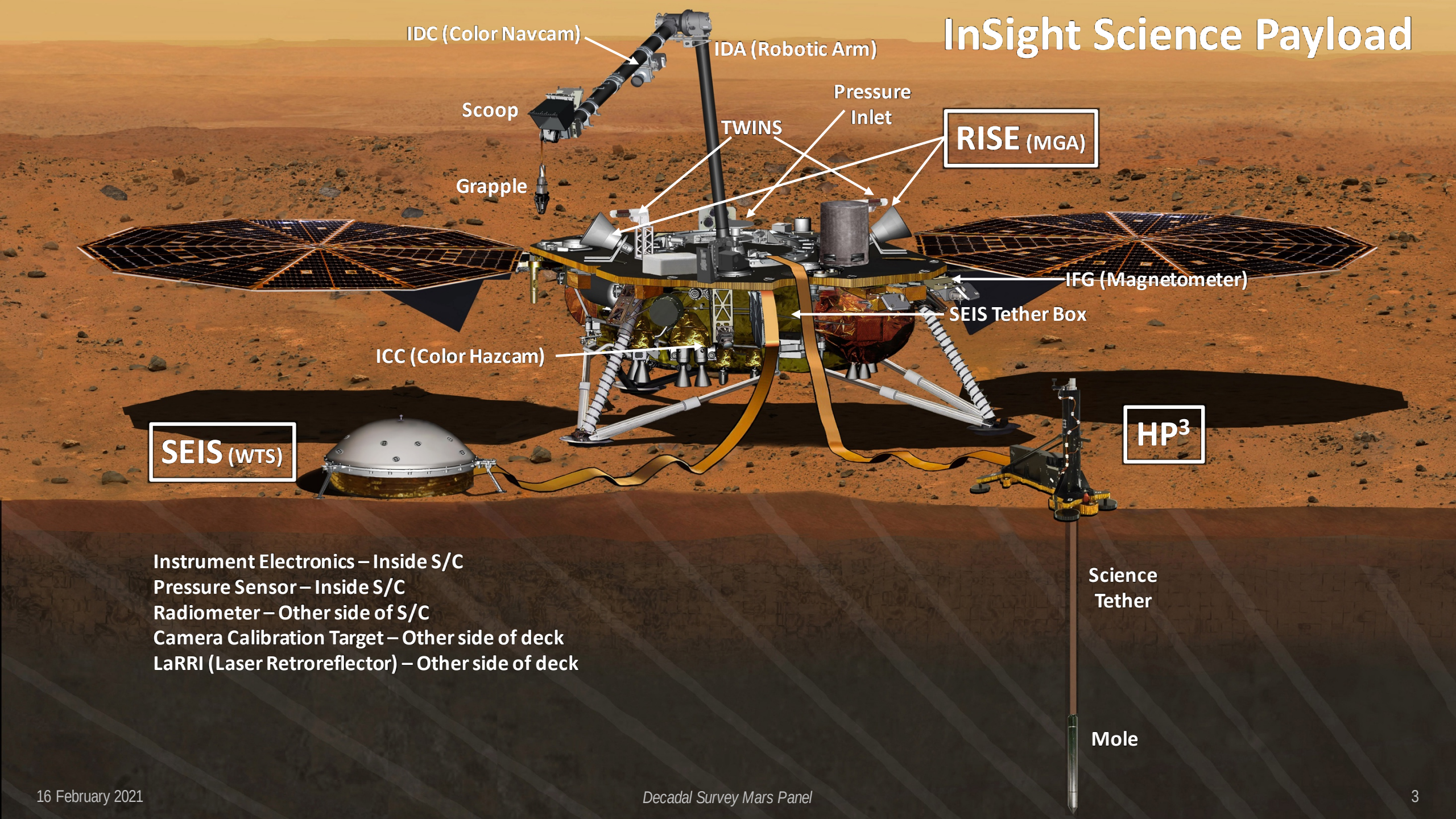
Goal: Provide constraints on the formation and early evolution processes of terrestrial planets by studying the internal structure of Mars.

In order to address this goal, InSight will determine, through geophysical measurements:

- ✓ Crustal thickness and large-scale layering
- ✓ Mantle structure
- ✓ Core size and density
- – Global heat flux
- ✓ Rate and distribution of seismic activity
- – Rate of meteorite impacts

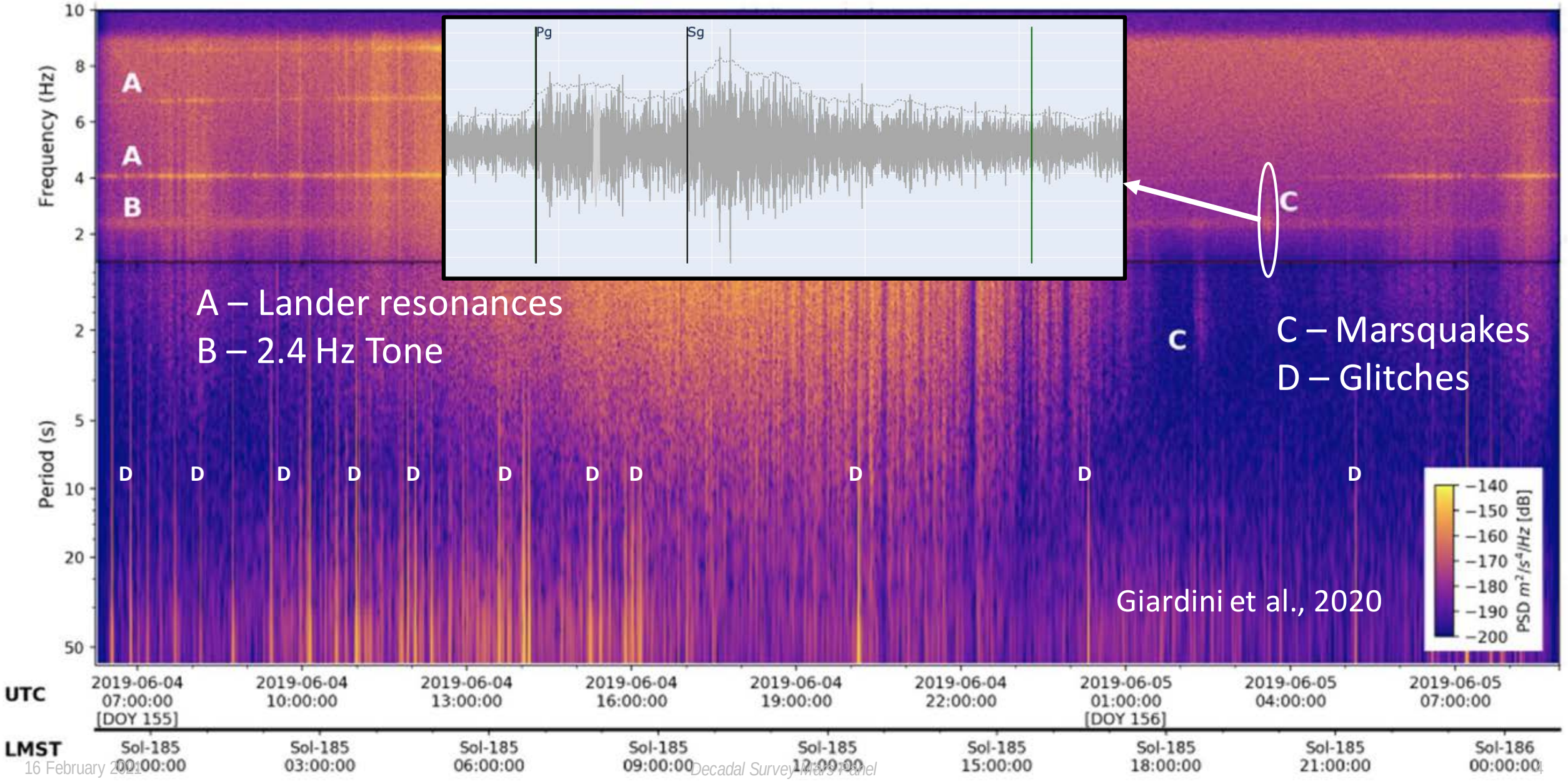


InSight Science Payload

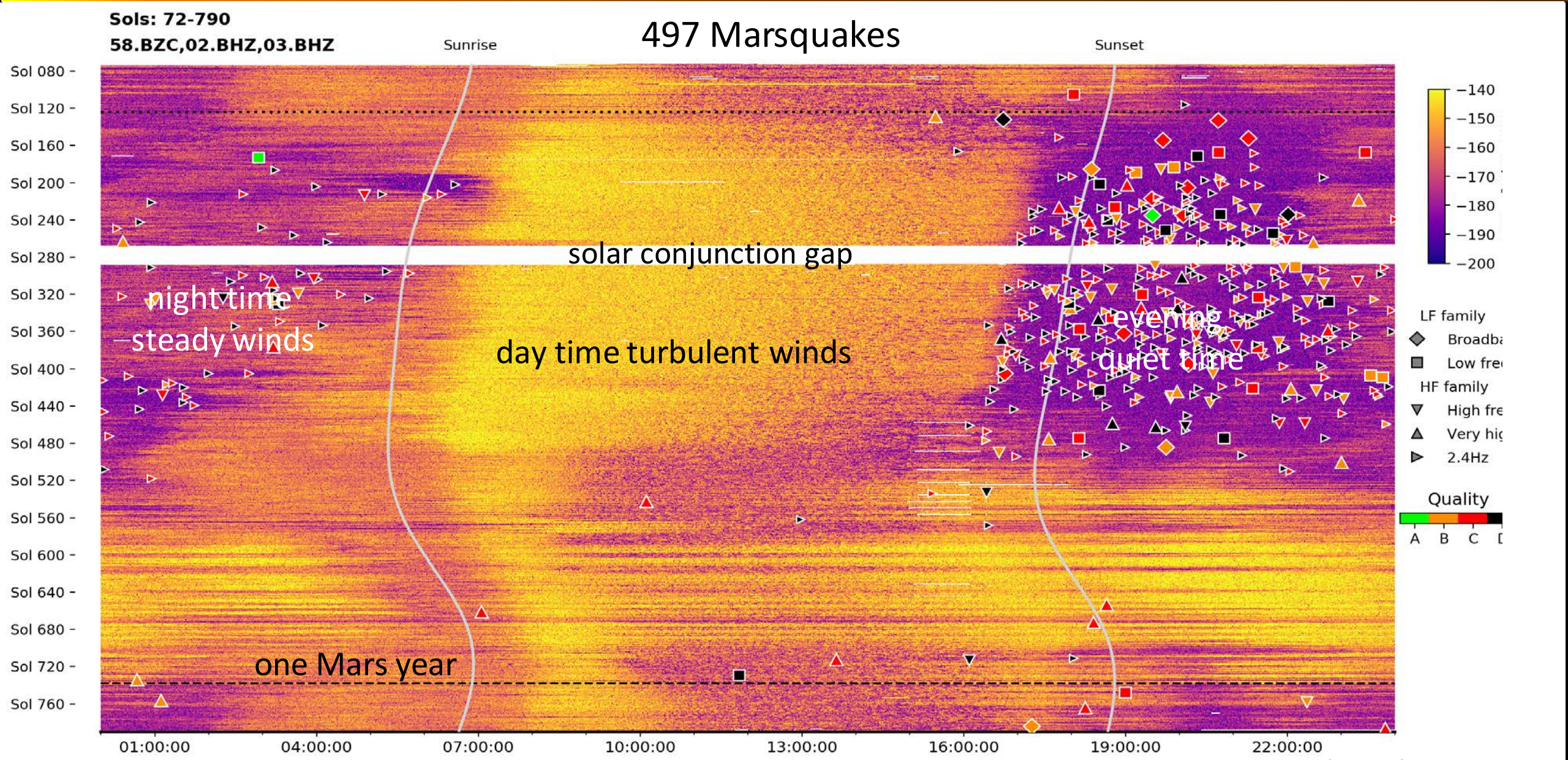


Instrument Electronics – Inside S/C
Pressure Sensor – Inside S/C
Radiometer – Other side of S/C
Camera Calibration Target – Other side of deck
LaRRI (Laser Retroreflector) – Other side of deck

Mars Seismic Data: Full-Sol Spectrogram, Sol 185



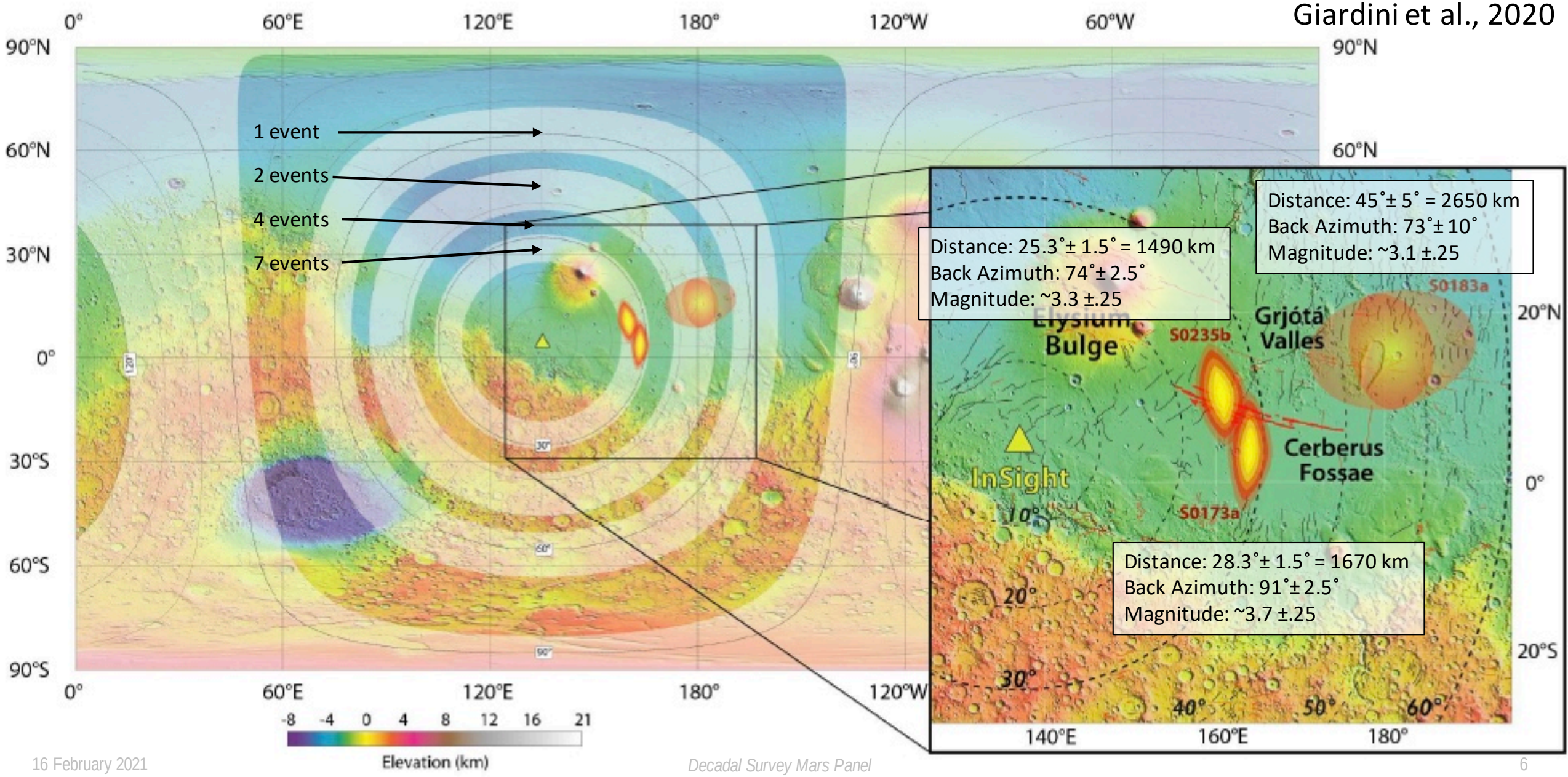
All Seismic Data as of Yesterday, Feb. 15 (sol 790)



Credit: InSight MQS

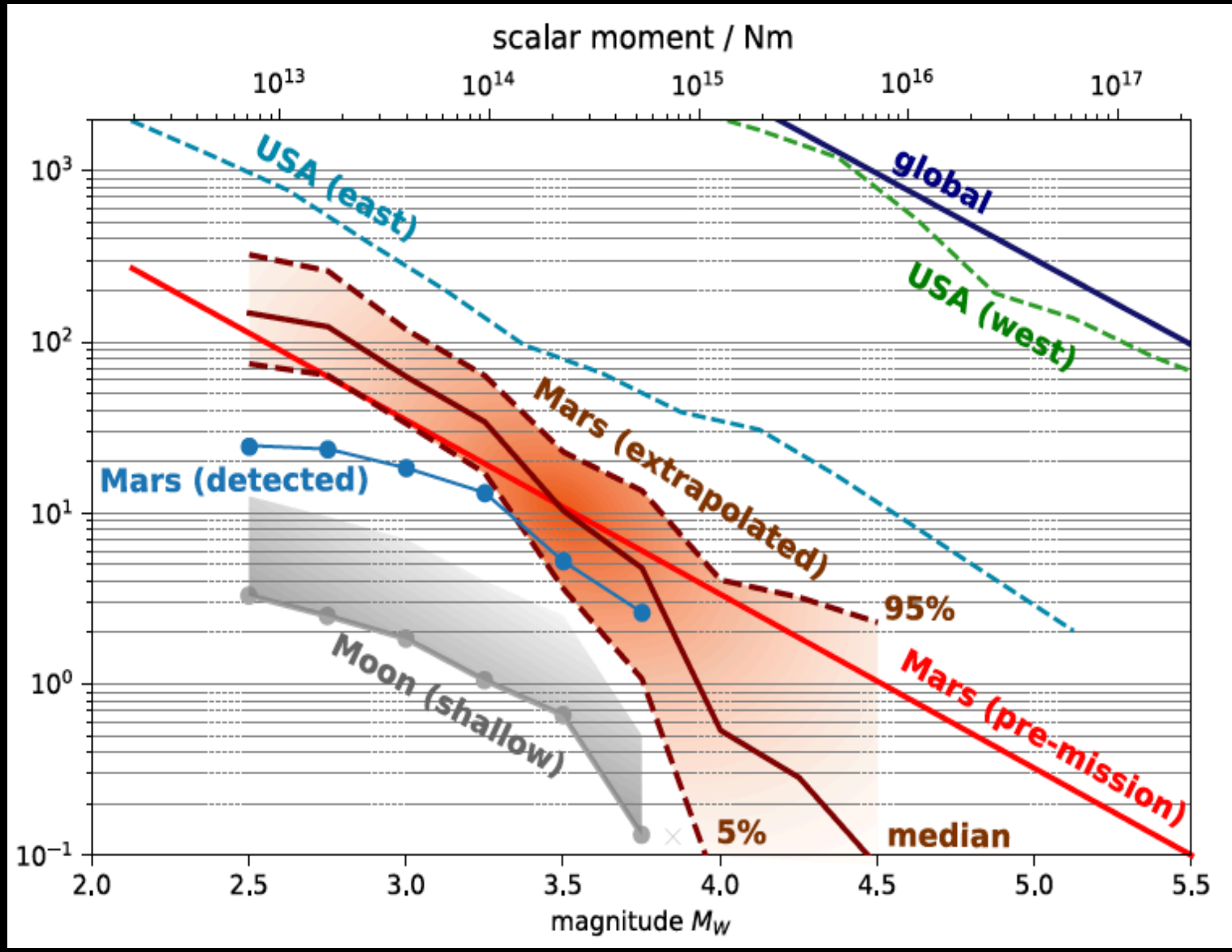
Seismicity Map for Mars – Locatable LF/BB Quakes

Giardini et al., 2020



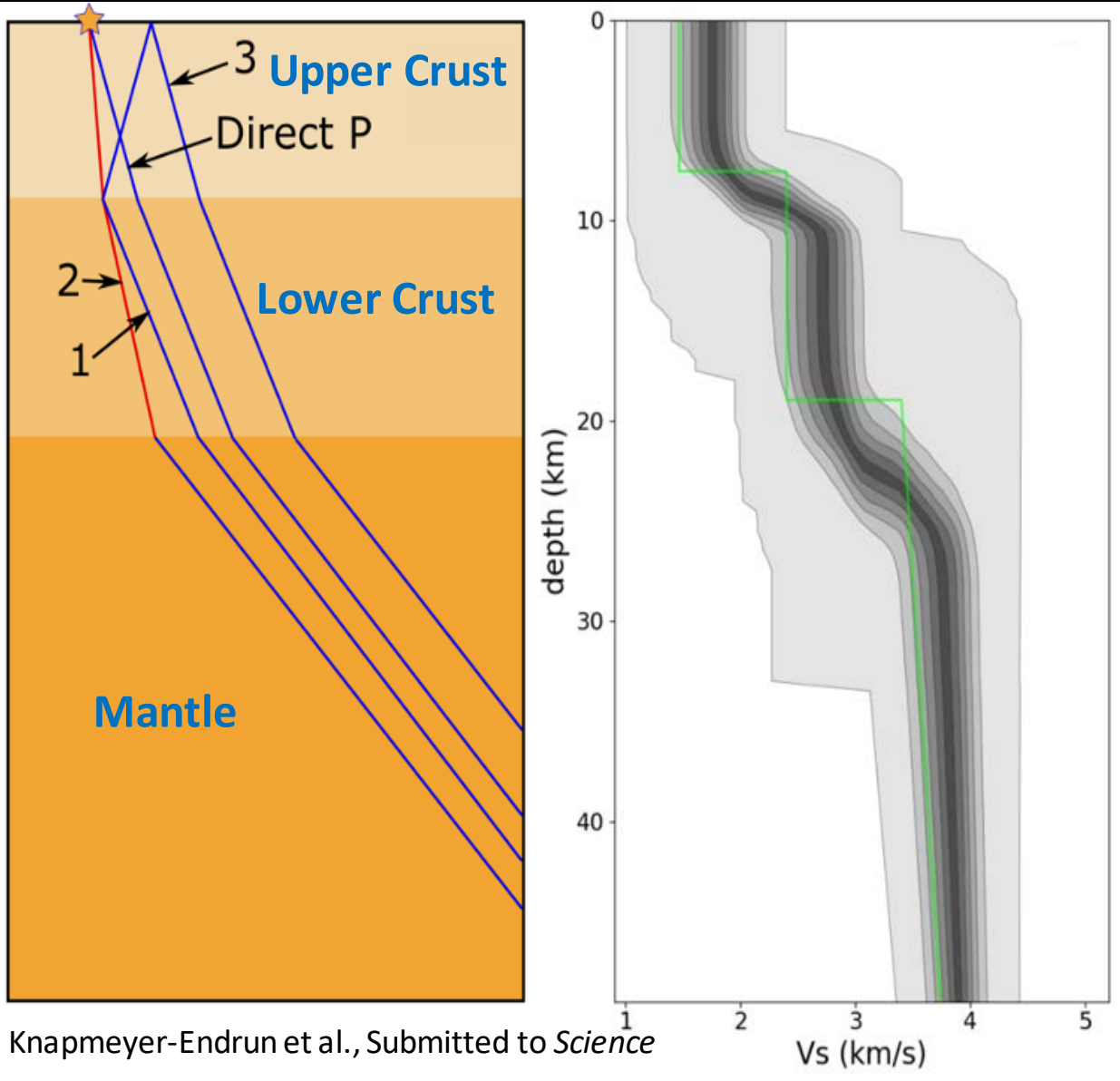
Global Seismicity

- This analysis is based on the first 14 months of data.
  - Currently re-analyzing, but no larger events have been detected.
- We find that the activity is very close to terrestrial intra-plate rates (5X less than East US).
- However, magnitudes above 3.5 are noticeably lacking.
  - Deviation from Gutenberg-Richter law (slope = 1)?
  - Marsquake size cutoff?
  - Statistical artifact?

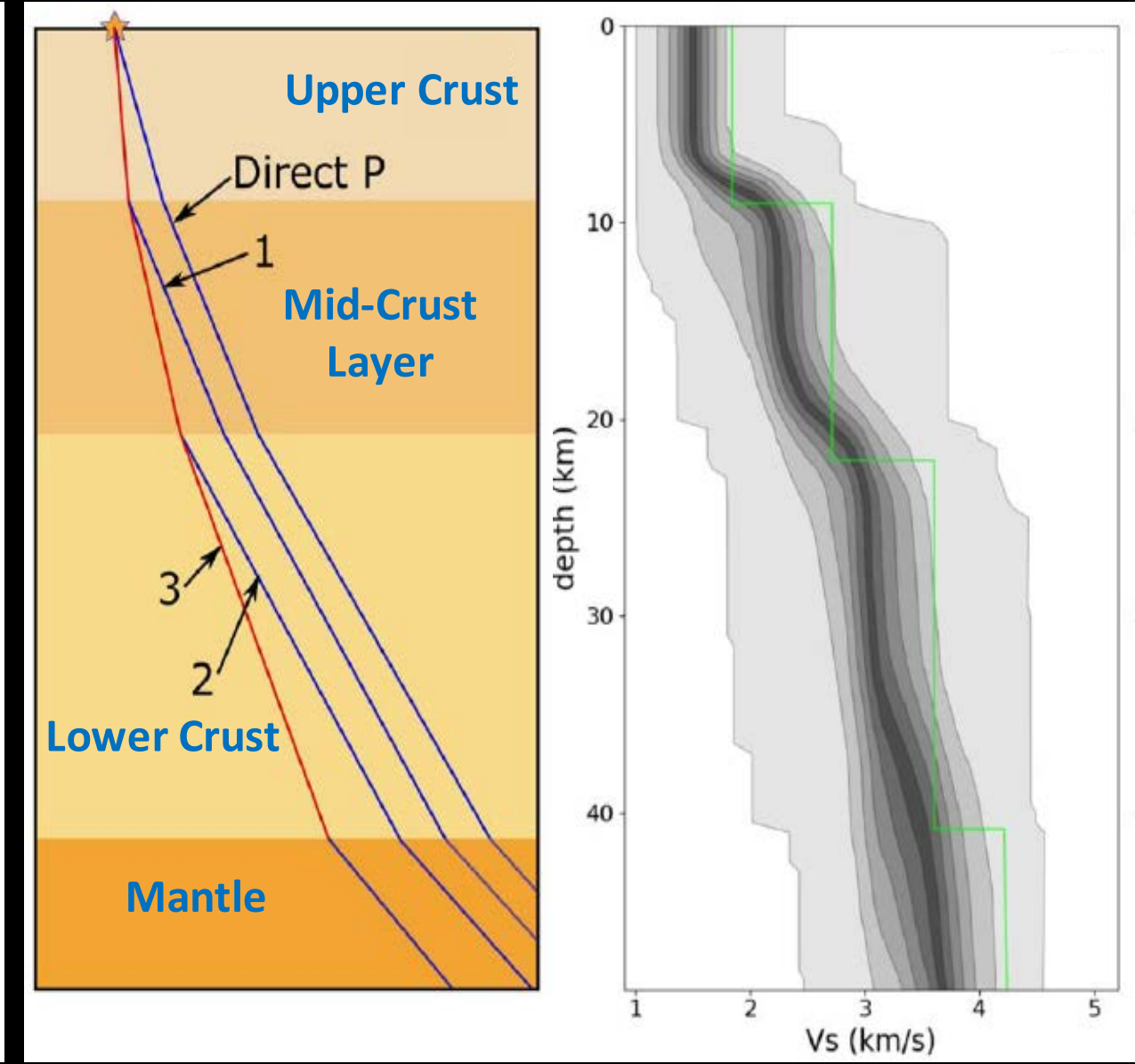


modified from Banerdt et al., 2020

Thickness of the Crust – Receiver Function Analysis

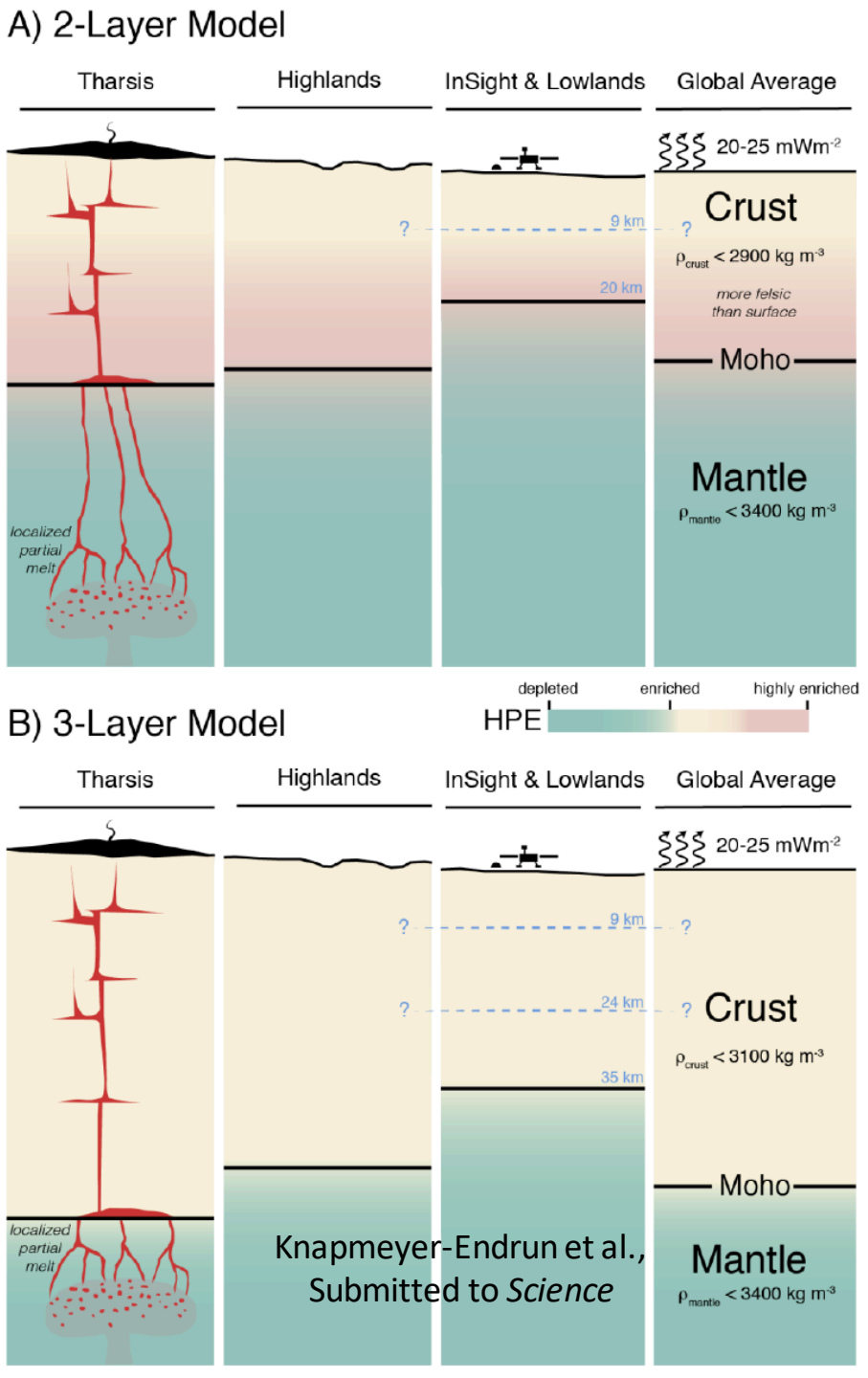


Knapmeyer-Endrun et al., Submitted to *Science*



Crust Thickness and Structure

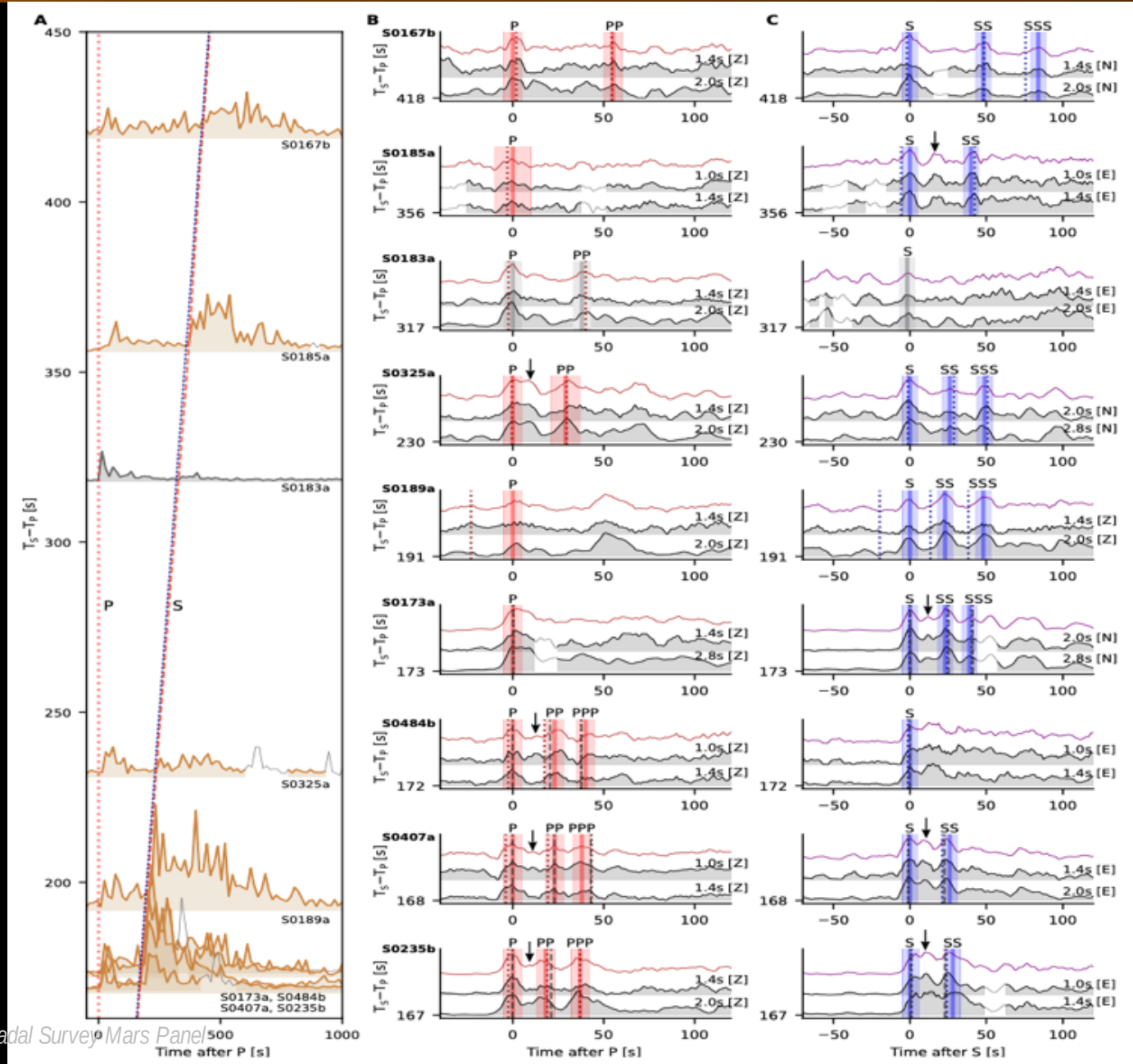
- Data on crust beneath InSight can be fit to two models:
  - Two-layer model
    - Crust thickness 20±5 km (beneath InSight); global mean is 24-40 km, depending on density
    - Crust density < 2900 kg/m^3
  - Three-layer model
    - Crust thickness 37±10 km (beneath InSight); global mean is 35-72 km, depending on density
    - Crust density < 3100 kg/m^3



Upper Mantle Structure – Multiple Phase Arrivals

- We aligned Low-Frequency/Broad Band events using P-S times.
- Arrivals of surface-reflected body waves (PP, PPP, SS, SSS) were identified using narrow-band filtered time-domain envelopes, polarization filtering and waveform matching.
- We then inverted these differential travel times for radial P- and S-wave velocity and geothermal profiles using both geophysical and seismic parameterizations.

Khan et al., Submitted to *Science*



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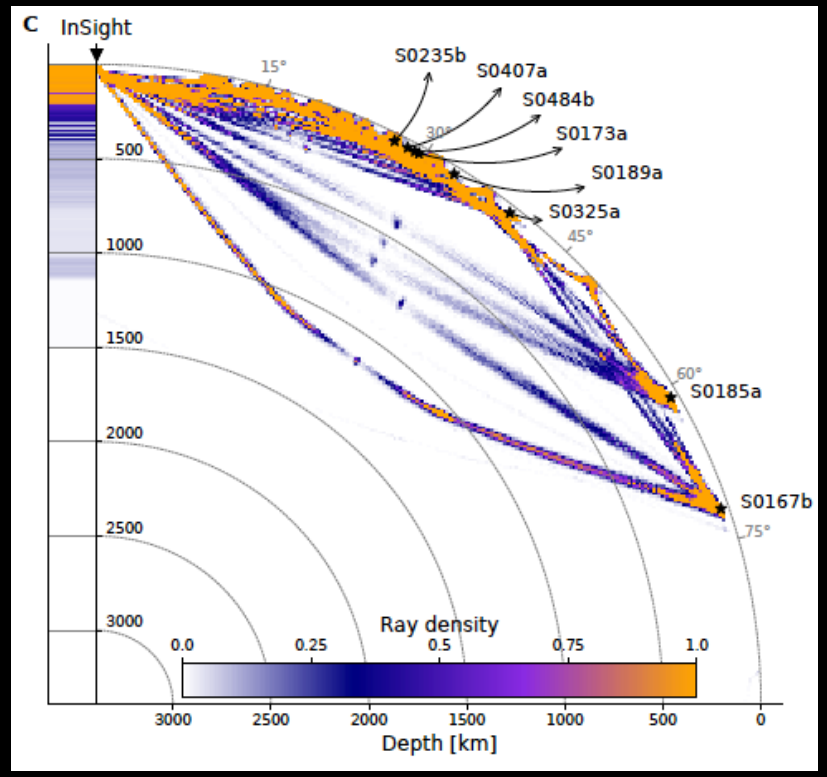
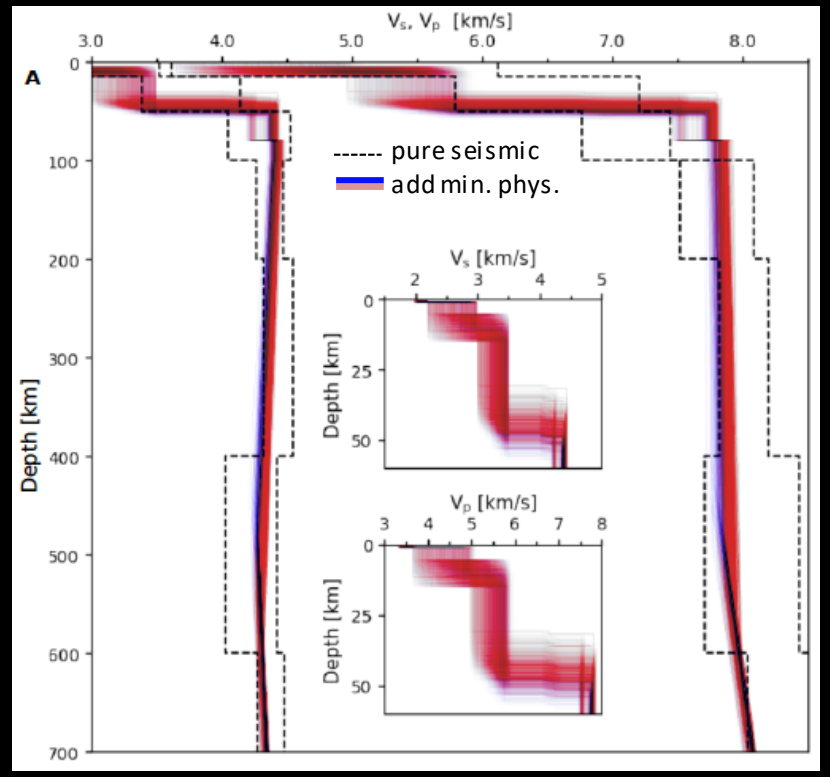
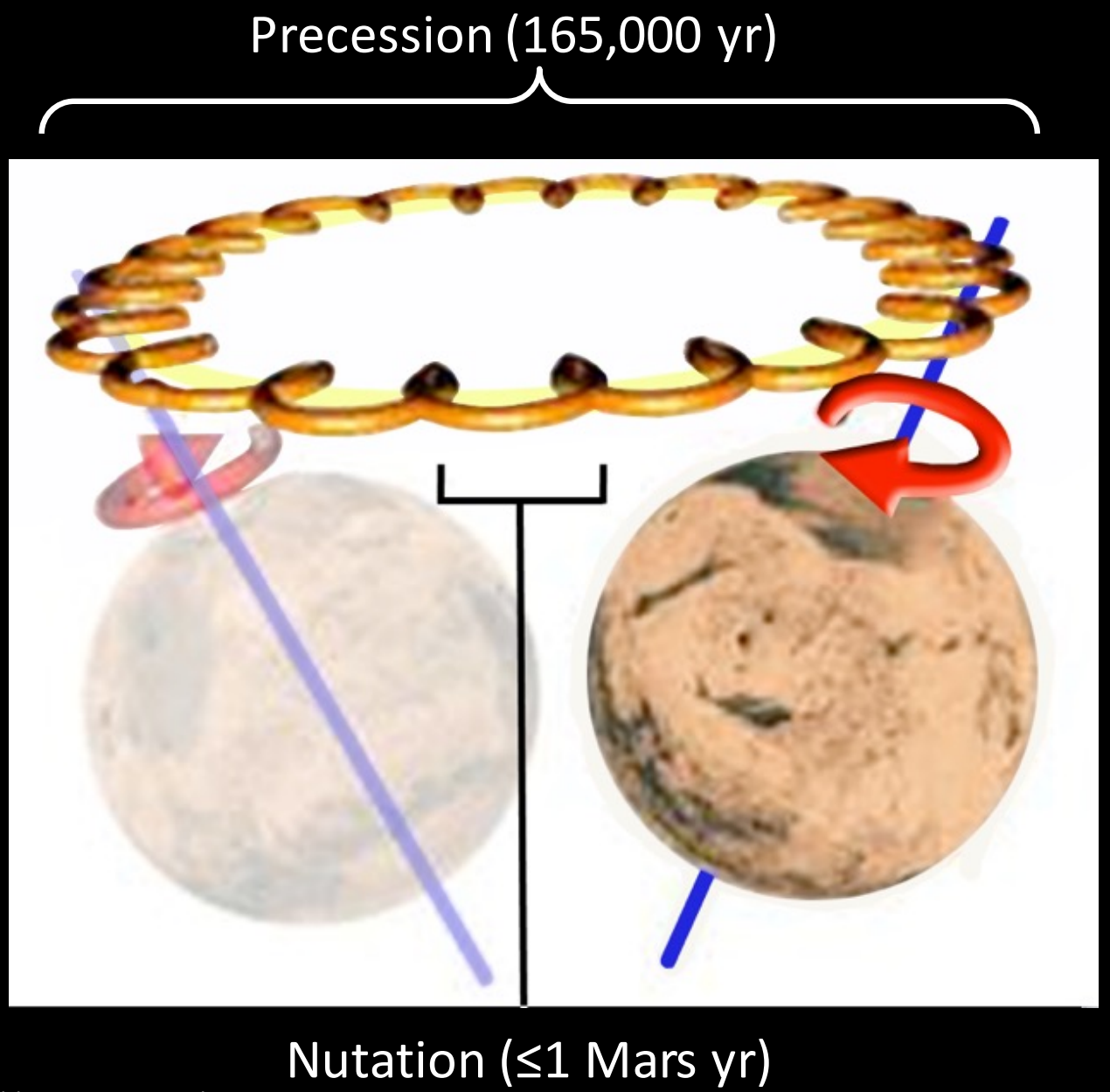




- Results show nearly constant P-wave velocities and an S-wave low velocity zone in the upper mantle (results in an S-wave shadow zone at epicentral distances of 40–60˚.
- This implies a thermal lithosphere 400-600 km thick.

Precision Radio Tracking

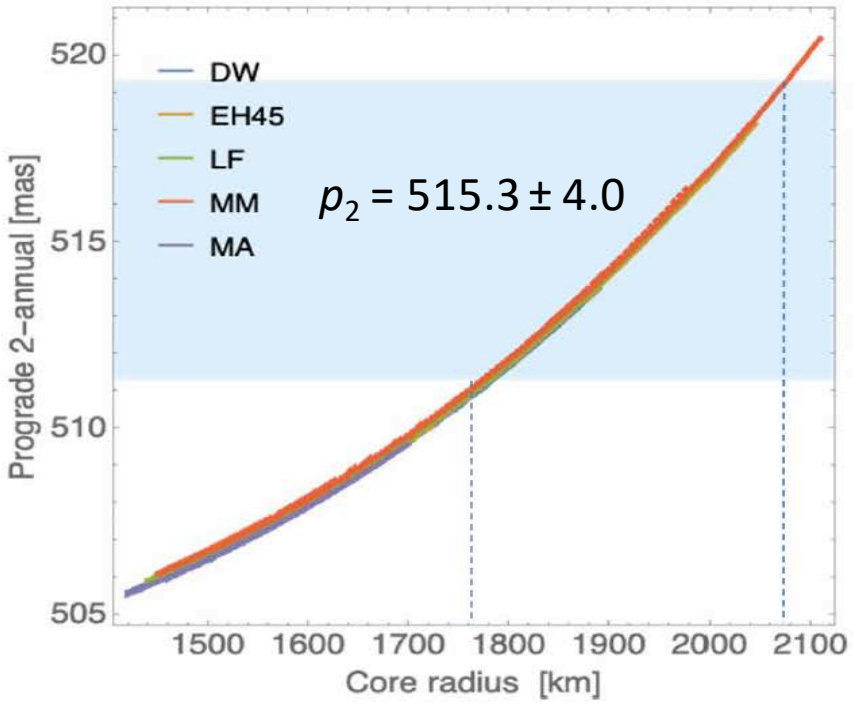
- The radio tracking investigation on InSight measures polar motion on two timescales:
  - Precession gives information about the moment of inertia; this has limited usefulness as it is impossible to separate effects of radius and density.
  - Nutation measurements, however, do allow separation of the signatures of core radius and density.

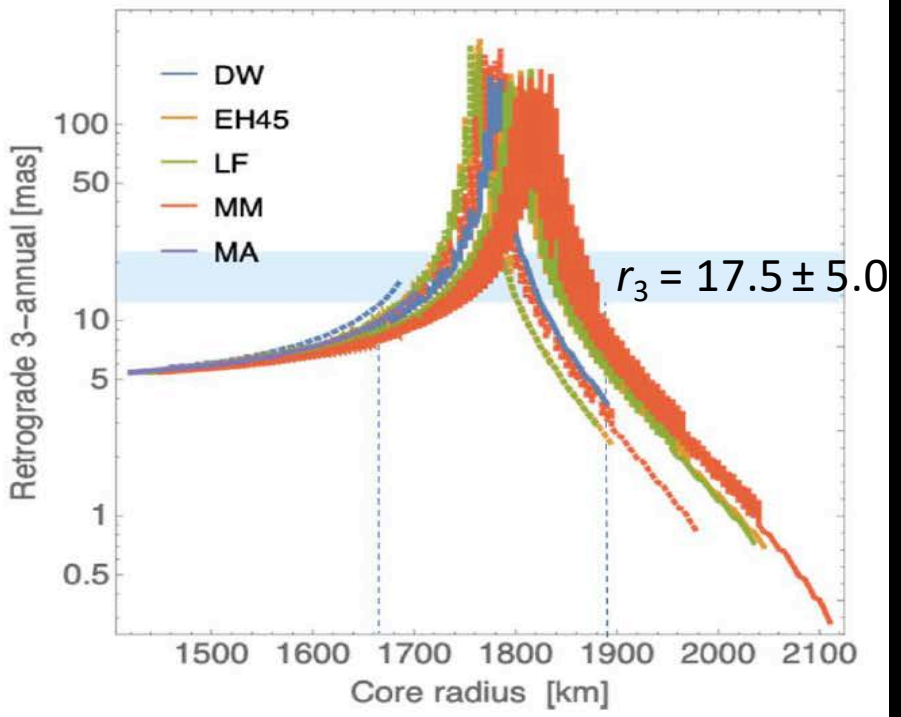


Size of the Core

- Bi- and ter-annual nutation amplitudes independently constrain core radius.
  - p_2 = 515.3 ± 4.0 mas ⇨ 1760 < R_c < 2080 km
  - r_3 = 17.5 ± 5.0 mas ⇨ 1665 < R_c < 1890 km
- Taken together, these constrain the core radius to R_c= 1825 ± 65 km
- Preliminary seismic analyses of apparent ScS core reflections give a similar radius result.

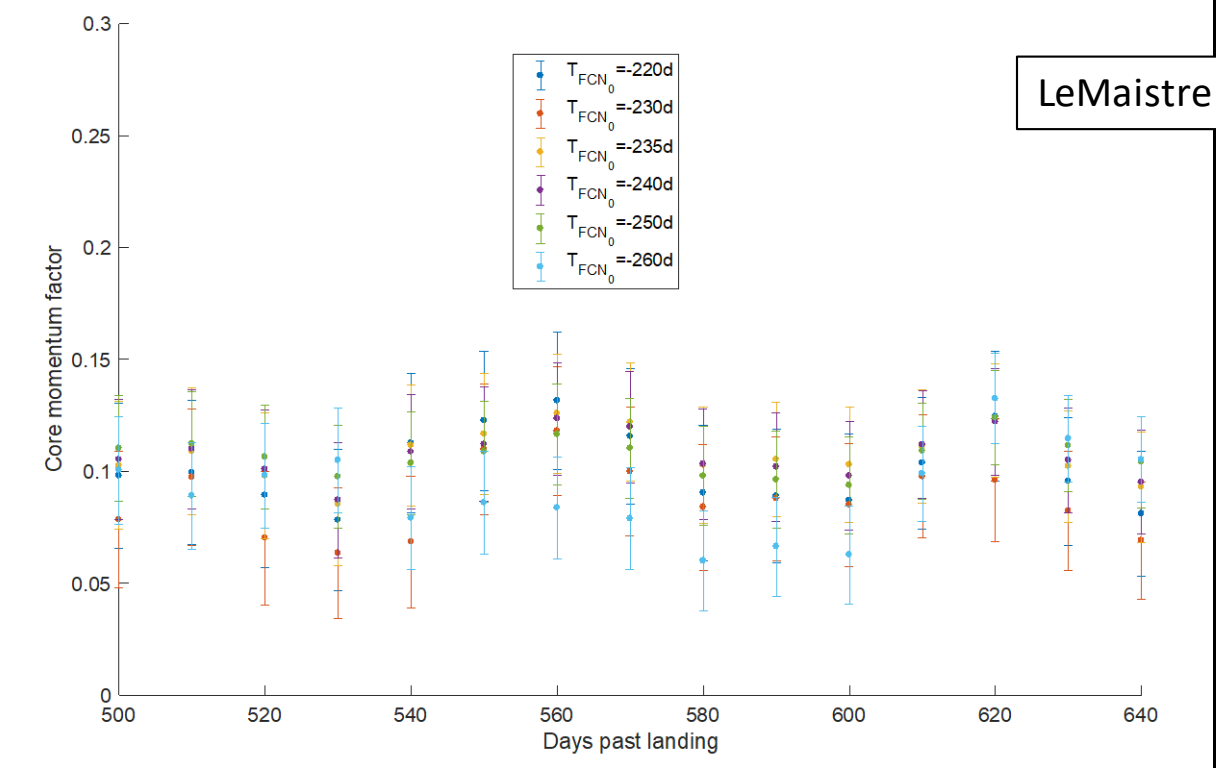
LeMaistre et al., in prep.





Core Density

- Core momentum factor is calculated from the observed amplification of the nutation amplitudes relative to those calculated for a rigid core.
  - $F = 0.09 \pm 0.025$
- This gives the core density $\rho_c = 5750 \pm 300$ kg/m^3



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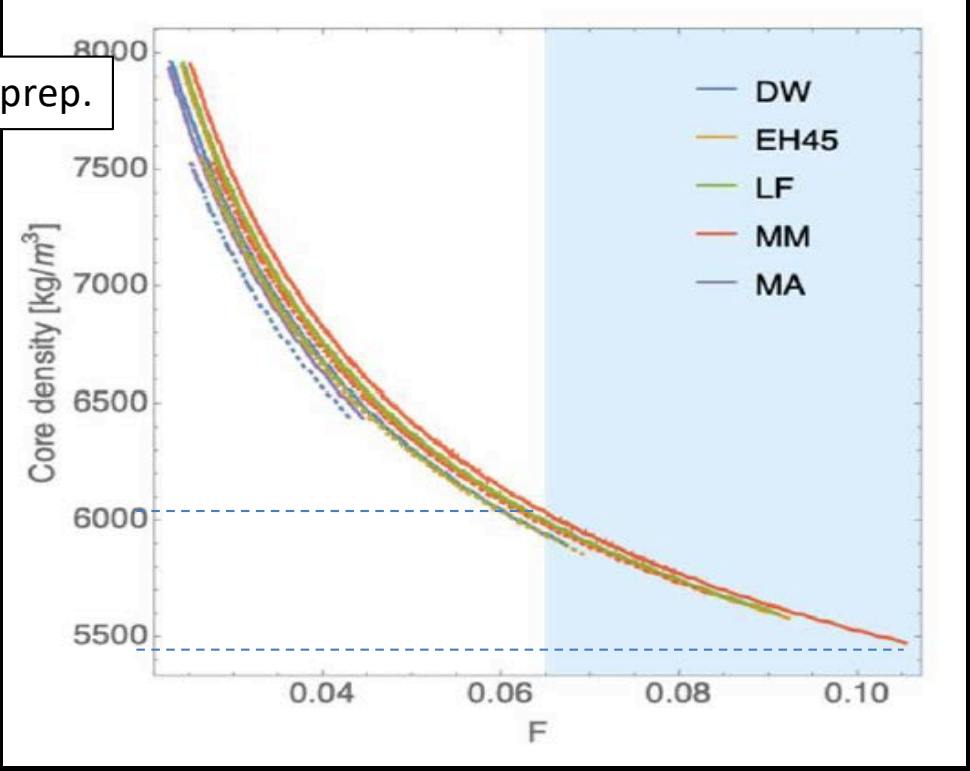
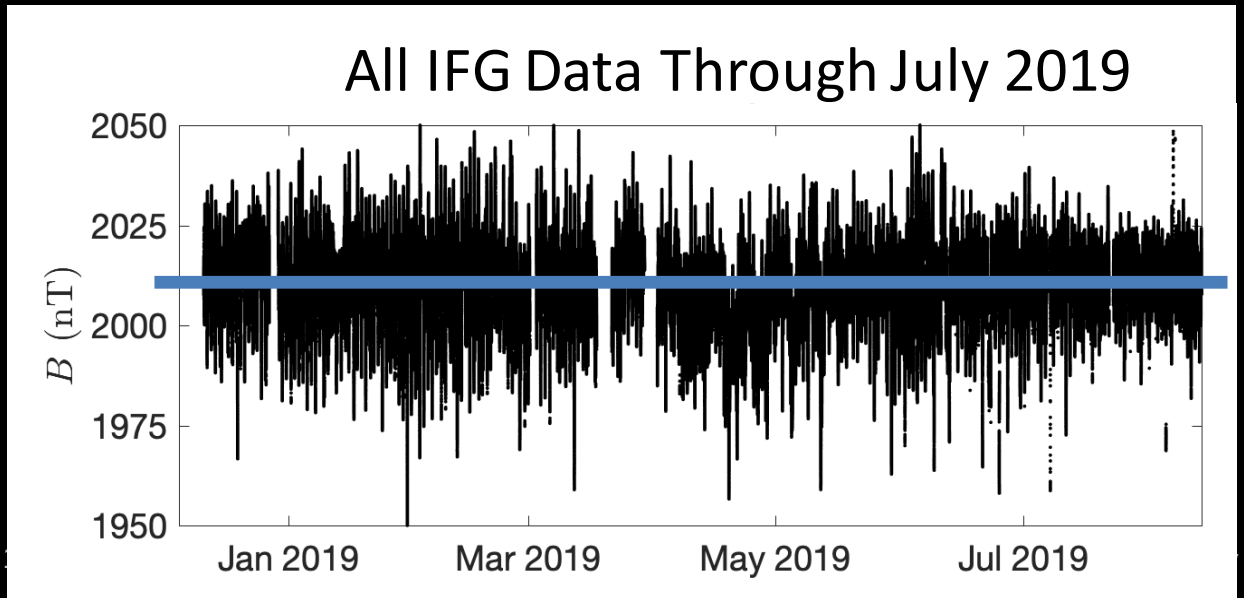


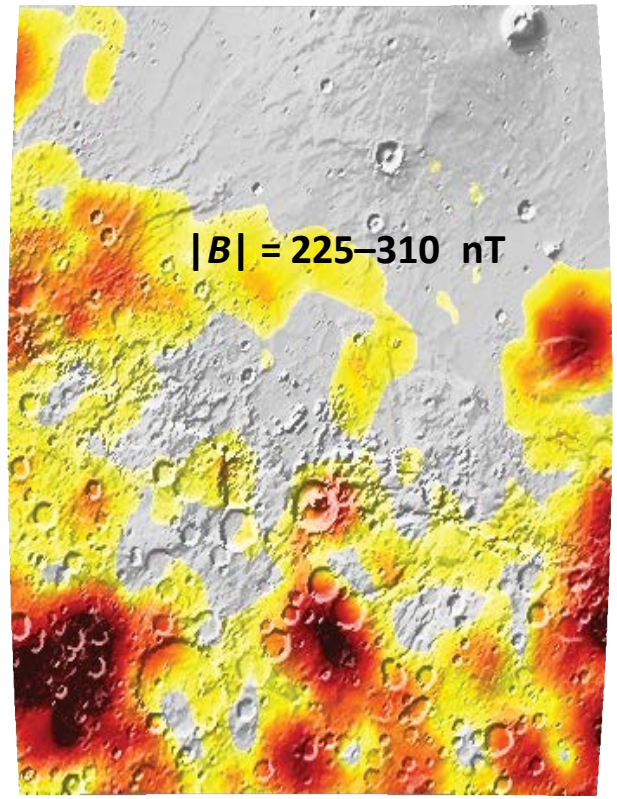
Magnetic Measurements

- InSight measured the background magnetic field at the landing site to be 2013 ± 13 nT
- This is compared to orbital measurements that predicted a surface magnetic field intensity of 225 – 310 nT, nearly a factor of 10 lower

  ⇒ Significant crustal variations at spatial scales <150 km.



Satellite Prediction



$|B_{surface}|$ MGS+MAVEN

(nT)
1250
600
300
175

Mittelholz et al., GRL, 2018

Johnson et al., 2020

Mars Structure Compared to Earth and Moon

From the Encyclopedia of the Solar System - 2014