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Towards EM induction sounding of the Martian mantle

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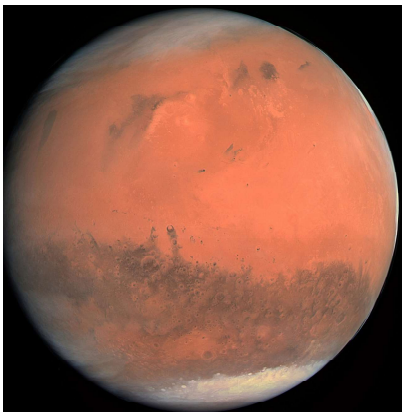
Goal of this study

- Constrain electrical structure of the Martian mantle
- What is the thickness of the crust?
- What is the mantle conductivity?
- What is the mantle water content?



By ESA - European Space Agency & Max-Planck Institute for Solar System Research for OSIRIS Team ESA/MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA

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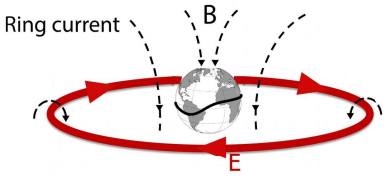
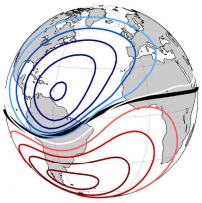
Geomagnetic environment of Earth

- On Earth several natural sources are often used:

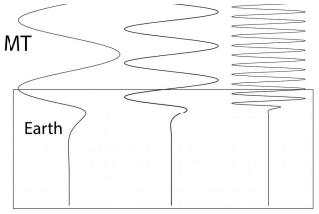


- 2 - 180 days
- 400 – 1600 km

Sq



- 4 – 24 hrs
- 150 – 500 km



- 0.001 s – 3 hrs
- 0 – 200 km

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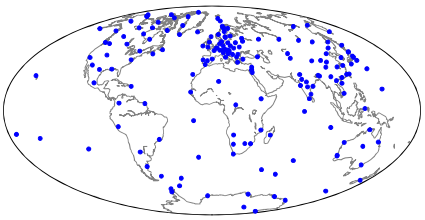
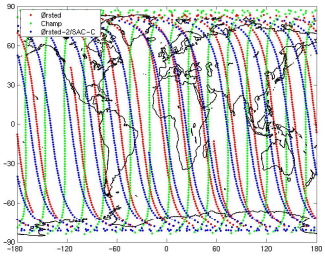
Data acquisition on Earth

- We have both ground/seafloor (temporary stations, geomagnetic observatories) and space measurements (CHAMP 2000 - 2010, CryoSat-2 2010 - present, Swarm 2013 – present).
- High quality, continuous, long-term geomagnetic observations.





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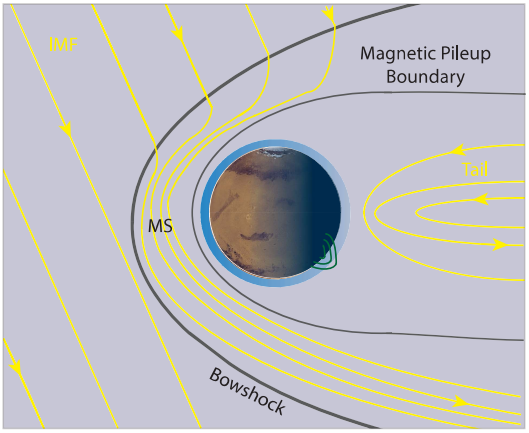
Magnetic environment of Mars

Sources of EM variations:

- Interplanetary magnetic field (Predominantly heliospheric)
- Weak ionosphere (Very different from Earth)
- Very different magnetosphere (no core field or ring current)

Challenges:

- The source mechanisms are currently poorly understood (No physical models available yet).
- As a result we have to determine the source structure from the data in time and space.



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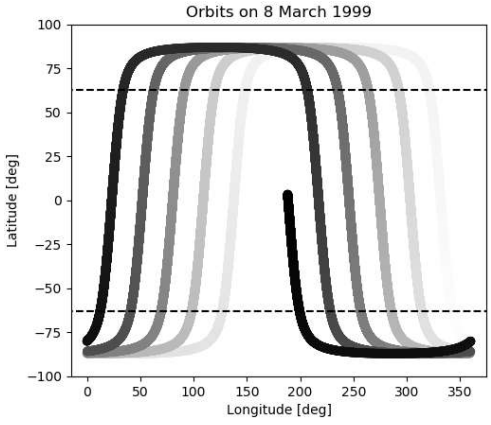
Data acquisition on Mars

- Magnetic data on Mars:

	MGS	MAVEN	InSight
Launch	1996-2006	Since 2013	Since 2018
Orbit inclination	92.0°	75°	None (lander)
Local time	02:00/ 14:00	All	All

MGS orbit tracks



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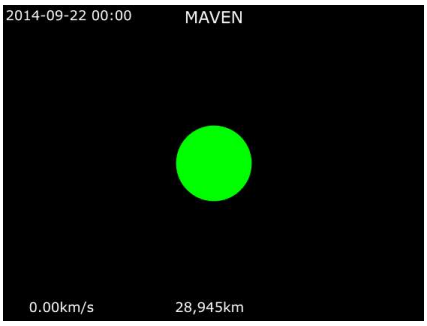
MAVEN orbit evolution



By Phoenix7777 - Own workData source: HORIZONS System, JPL, NASA, CC BY-SA 4.0

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Data acquisition on Mars

InSight landing location

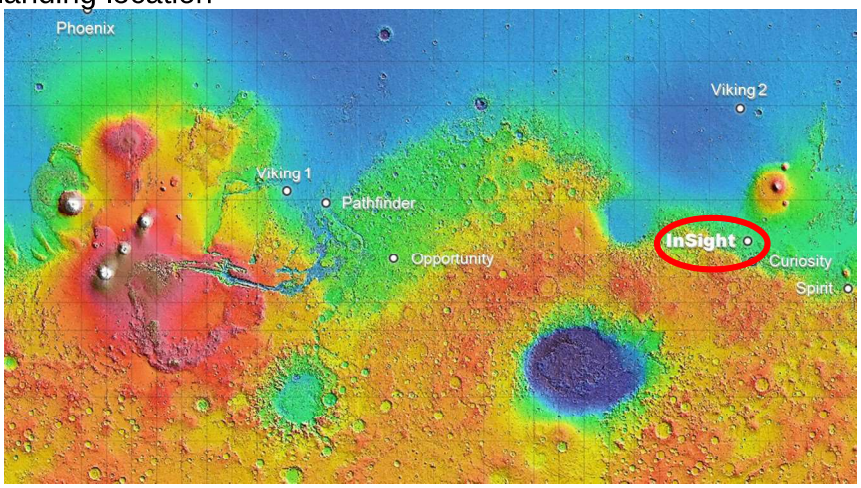

Image courtesy by NASA/JPL

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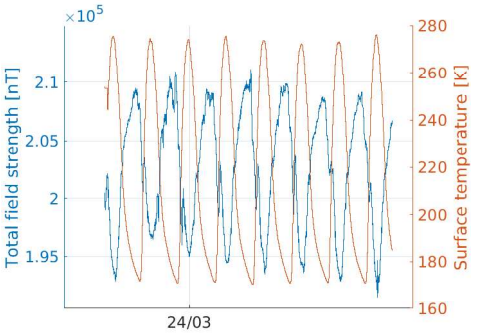
Challenges on Mars

- The sensor on InSight is not isolated, large correlation to temperature, solar panel current etc.
- MGS's orbit is fixed in local time (02:00/14:00) on the equator (longitudinal structure of external field cannot be constrained).
- MAVEN orbit is highly elliptical (not optimal for EM sounding, large revisit time).

Raw InSight magnetic scalar field (blue) and temperature (red)



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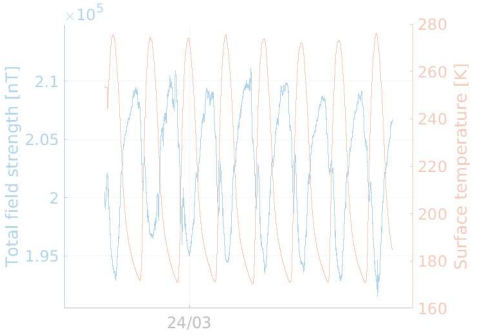

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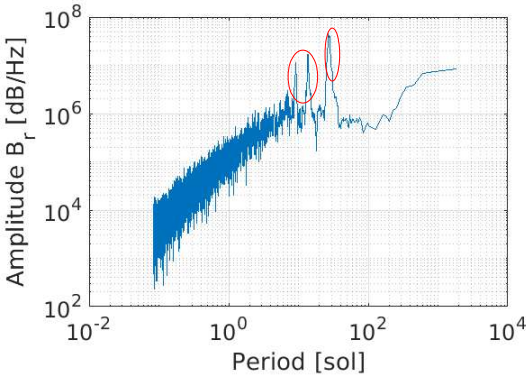
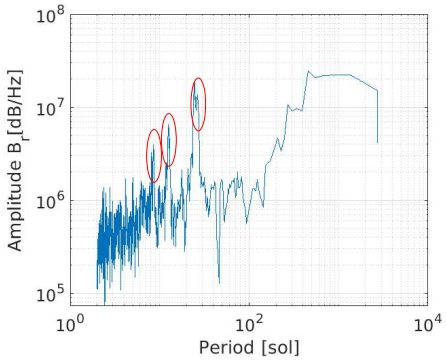
Magnetic signature of the heliospheric current sheet

- The spectrum of the radial magnetic field component as measured by ACE at L1 (left) as well as from MGS on the equator during the night time (right) show a clear 26 day periodicity.





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Source description for MGS

- We describe the source using spherical harmonics.
  - Subtract crustal field model *(Morschhauser et al. 2014)*
  - Temporal bins are 1 sol, i.e. one value per night.
  - Spatial structure is P_1^0.
- From the time-dependent spherical harmonics coefficients we determine a frequency-dependent Q-response for the Carrington rotation period plus harmonics.
- From this Q-response we get the C-response, which we can finally invert for the conductivity structure of the mantle.

$$B_r = -q_1^0(t)\cos\theta + 2g_1^0(t)\left(\frac{R_{Mars}}{r}\right)^3\cos\theta$$

$$B_\theta = +q_1^0(t)\sin\theta + g_1^0(t)\left(\frac{R_{Mars}}{r}\right)^3\sin\theta$$

$$Q_1(\omega) = \frac{g_1^0(\omega)}{q_1^0(\omega)}$$ Induced / Inducing ,

$$C_1(\omega) = \frac{R_{Mars}}{2}\,\frac{1-2Q_1(\omega)}{1+Q_1(\omega)}$$

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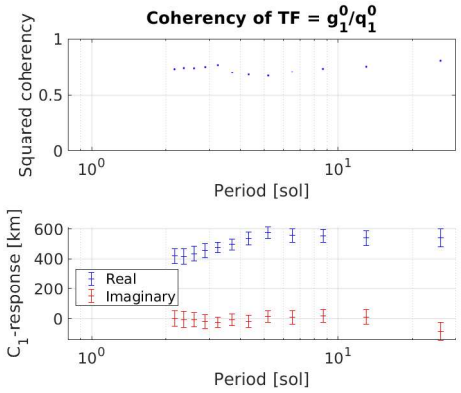
Preliminary C_1-response from MGS night time data

- Reasonable coherency
- Real part of C-response should increase monotonically with period for 1D model
- Real part is a proxy for the penetration depth
- Imaginary part is unusually small



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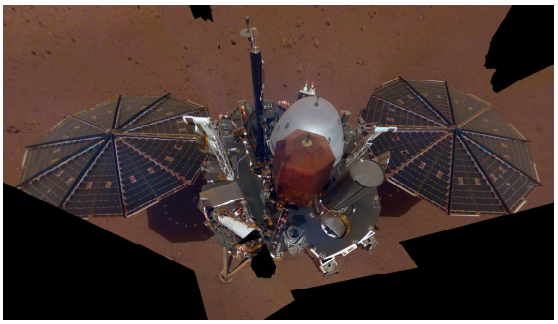
Outlook

- If we incorporate InSight night time data, we should be able to get periods up to 6 hours.
- This leaves a gap between 6 hours and 1 sols: need dayside data.
- Determining source geometry during day time is a challenge.
- MAVEN can possibly help out with this task due to its unique orbit.



- Finally: invert for a 1D conductivity profile.