DI43A-1944
Interior Structure and Evolution of the Terrestrial Planets II

# Signal Strength and Bandwidth for Magnetotelluric Sounding of the Interior of the Moon

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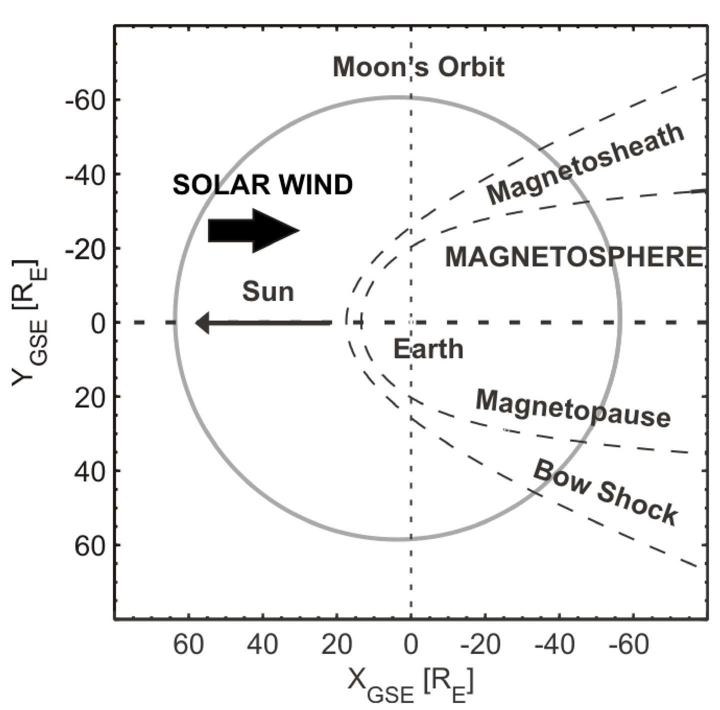
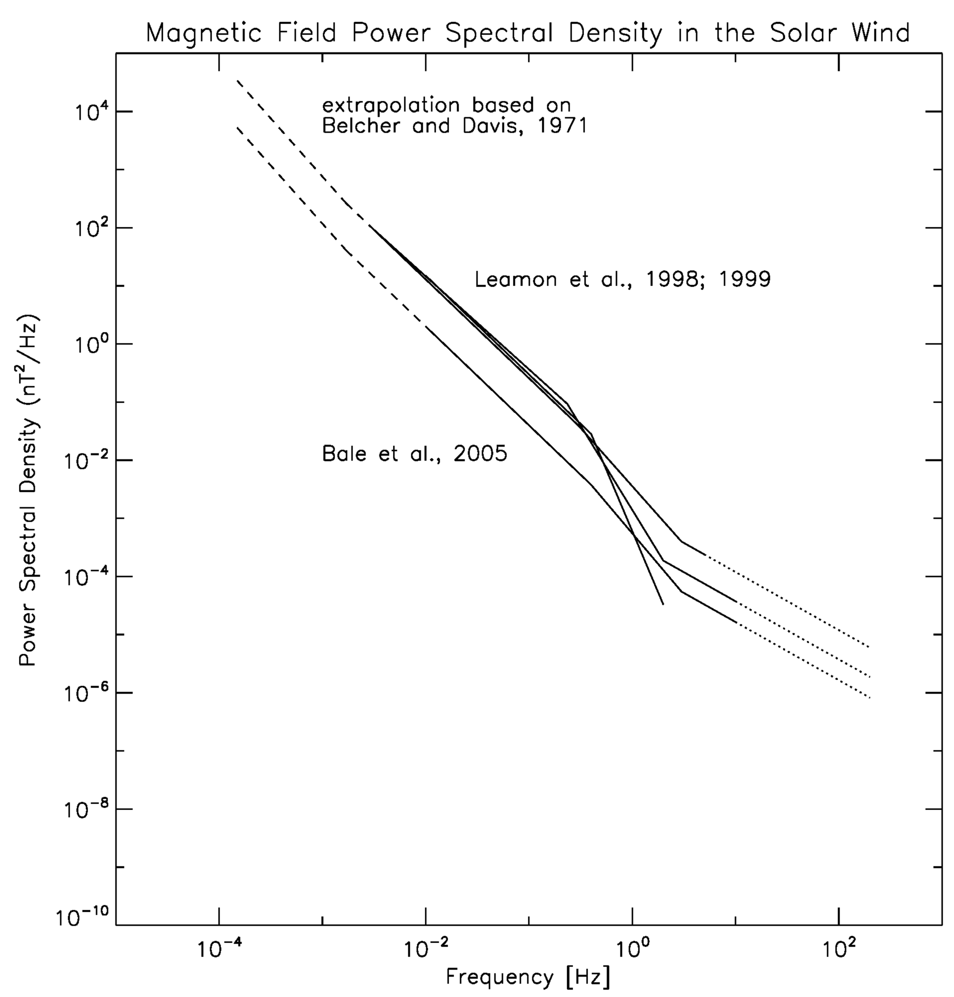
## Introduction

- Electromagnetic (EM) sounding is a group of geophysical methods used to characterize the interiors of planetary bodies from 1 m to > 1000 km
  - Previous EM soundings of the Moon performed during the Apollo Era utilized a transfer function method requiring both orbiting and surface magnetometers
- In the magnetotelluric (MT) method, the orthogonal components of the horizontal electric and magnetic fields on the surface are used to discern the conductivity structure
  - Sensor suites commonly used in space physics (electrometers and magneto-meters) can make measurements for EM sounding on the surface of the Moon
- The Moon encounters a wide variety plasma regimes and EM source signals over a broad range of frequencies (below and right)
- Here, our goal is to consolidate previous observations to develop a catalog of EM disturbances at the Moon that will be useful for surface MT measurements.




## Source Signals

- On the terrestrial planets, electromagnetic discharges (lightning) or magnetic field variations due to interactions with the solar wind can provide MT source signals.
- On airless bodies such as the Moon, solar wind turbulence and other plasma waves can create source signals.




Target layers, depths, and EM frequency ranges necessary for MT sounding of the Moon:

| Target | Depth | Frequency |
|---|---|---|
| Crust | 0 - 60 km | > 1 Hz |
| Mantle | 60 - 1500 km | $10^{-3}$ - 1 Hz |
| Core | > 1500 km | < $10^{-3}$ Hz |

The Moon spends ¾ of its orbit in the solar wind

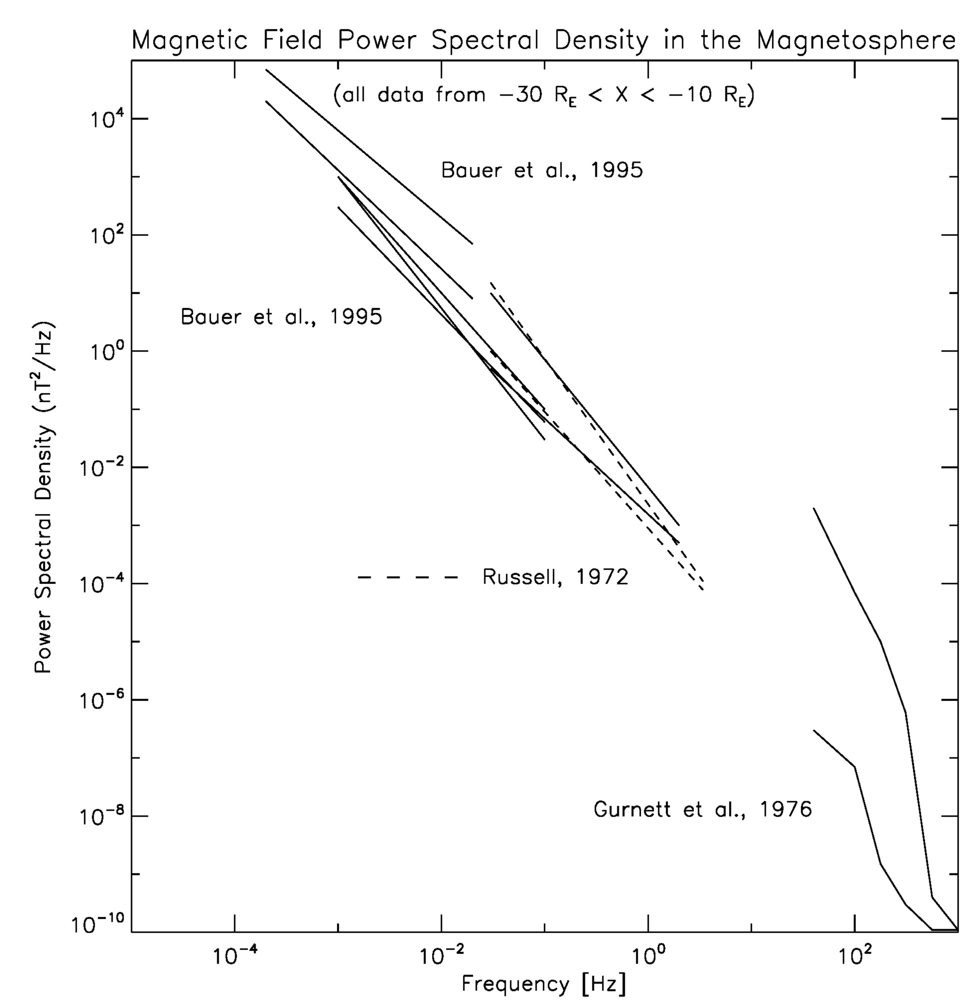
Observations show that solar wind turbulence can provide a robust source of electromagnetic fluctuations spanning frequencies from < $10^{-4}$ Hz to > $10^{2}$ Hz

[Above and left: Power spectral density as a function of frequency for magnetic fluctuations in the solar wind and Earth's magnetosphere]

The Moon spends the remaining ¼ of its orbit in Earth's magnetosphere

Waves in Earth's magnetosphere also provide a robust source of electromagnetic fluctuations from $10^{-4}$ Hz < $f$ < $10^{2}$ Hz

At the highest frequencies, source signal strengths appear slightly lower in the magnetosphere than in the solar wind




## Analysis Methodology

- In MT, assuming a simple planar geometry, the *apparent resistivity* as a function of frequency, $\rho_a$, is determined from E & B (1), with each wave penetrating the subsurface according to its *skin depth*, $\delta$ (2)

$$\rho_a = \frac{1}{5f}\frac{E_y^2(uV/m)}{B_x^2(nT)} \text{ ohm-m} \qquad (1)$$

$$\delta = \frac{1}{\sqrt{\pi f \mu \sigma}} \sim 500\sqrt{\frac{\rho}{f}} \text{ m} \qquad (2)$$

- Using (1) and (2), standard inversion procedures convert apparent resistivity, $\rho_a$, to true resistivity as a function of depth, $\rho(z)$
- This result can be generalized to apply to spherical geometries at longer wavelengths using a response function, $c(\omega)$, as outlined by *Weidelt* [1972]:

$$c(\omega) = E(r_M,\omega)/i\omega B(r_M,\omega) \quad \rightarrow \quad \rho_a = \omega\mu\left|c(\omega)\right|^2$$

Again, the apparent resistivity, $\rho_a$, can be inverted to find conductivity vs. depth

## Missions/ Instrumentation

- E & B sensor suite on *Lunette* lunar lander (see Neal et al., poster DI43A-1939, this session)