

Space Weather: From the Sun to Other Stars

T. Joseph W. Lazio

FASR2021: Solar Physics with a Next Generation Solar Radio Facility



Jet Propulsion Laboratory
California Institute of Technology

Space Weather: From the Sun to Other Stars

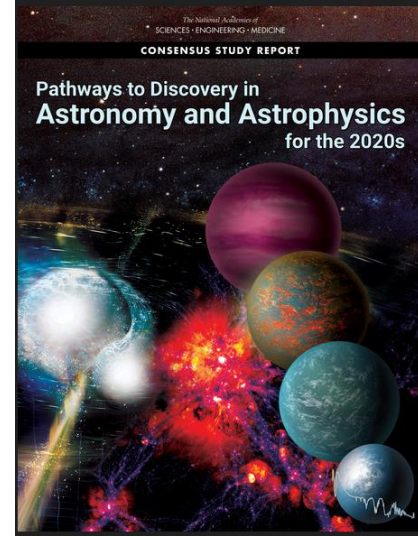
The Scientific Opportunities

- **Worlds and Suns in Context**

builds on revolutionary advances in our observations of exoplanets and stars and aims to understand their formation, evolution, and interconnected nature, and to characterize other solar systems, including potentially habitable analogs to our own.

- **New Messengers and New Physics**

- **Cosmic Ecosystems**



What Makes a Planet Habitable?

In parallel with the advances in observations, the exoplanet, Solar System, and astrobiology communities have generated a more comprehensive picture of planetary habitability. ...

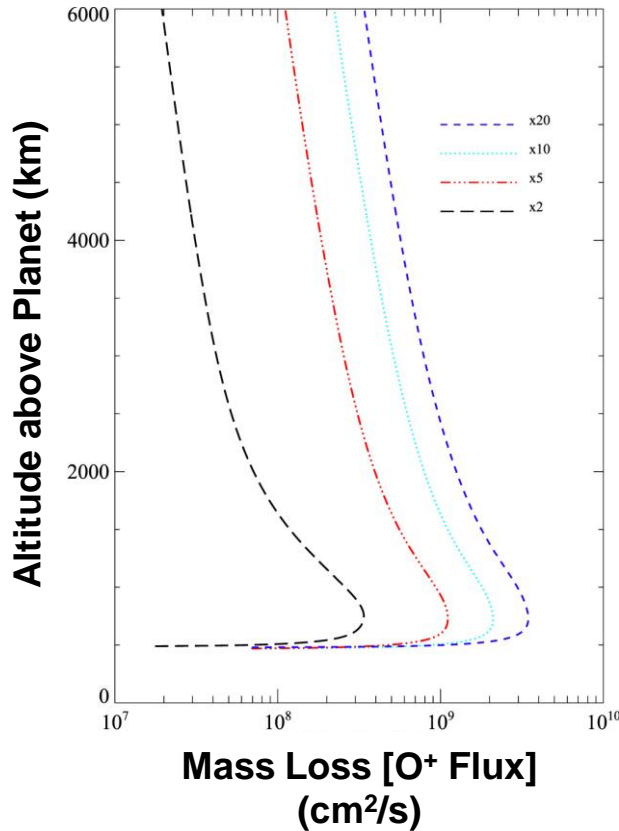
Many factors and interactions are now expected to impact planetary habitability. These include the following:

- The presence and distribution of liquid water oceans on the planetary surface
- **The presence of a stable secondary atmosphere.** ...
- The presence of tectonic or volcanic activity and weathering processes to replenish atmospheric loss (...), and buffer climate (...).
- The internal energy budget of a planet
- The presence and strength of a **global-scale magnetic field**, which depends on interior composition and thermal evolution (Driscoll and Bercovici, 2013).

There are **important feedbacks** identified between the processes listed above For example, the persistence of a secondary atmosphere over billion-year time scales requires low atmospheric loss rates, which in turn can be aided by the presence of a planetary magnetic field (Driscoll and Bercovici, 2013; Garcia-Sage et al., 2017; Dong et al., 2018).



Stable Secondary Atmosphere?



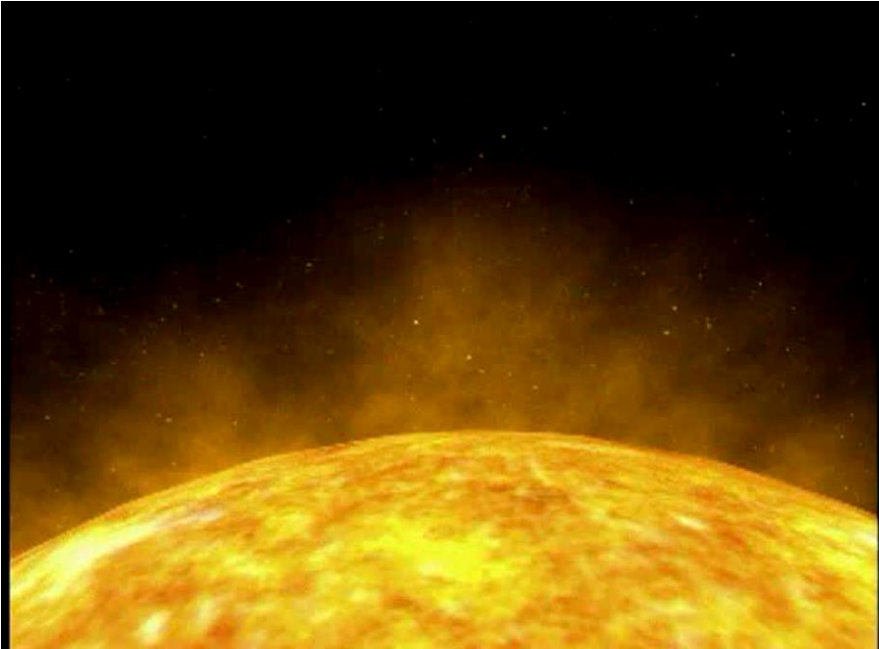
X-ray and Extreme UV (~ 20 Å–1215 Å) irradiation can

- **Change atmospheric chemistry**
- **Heat (inflate) and ionize upper regions of atmosphere, producing outflows**

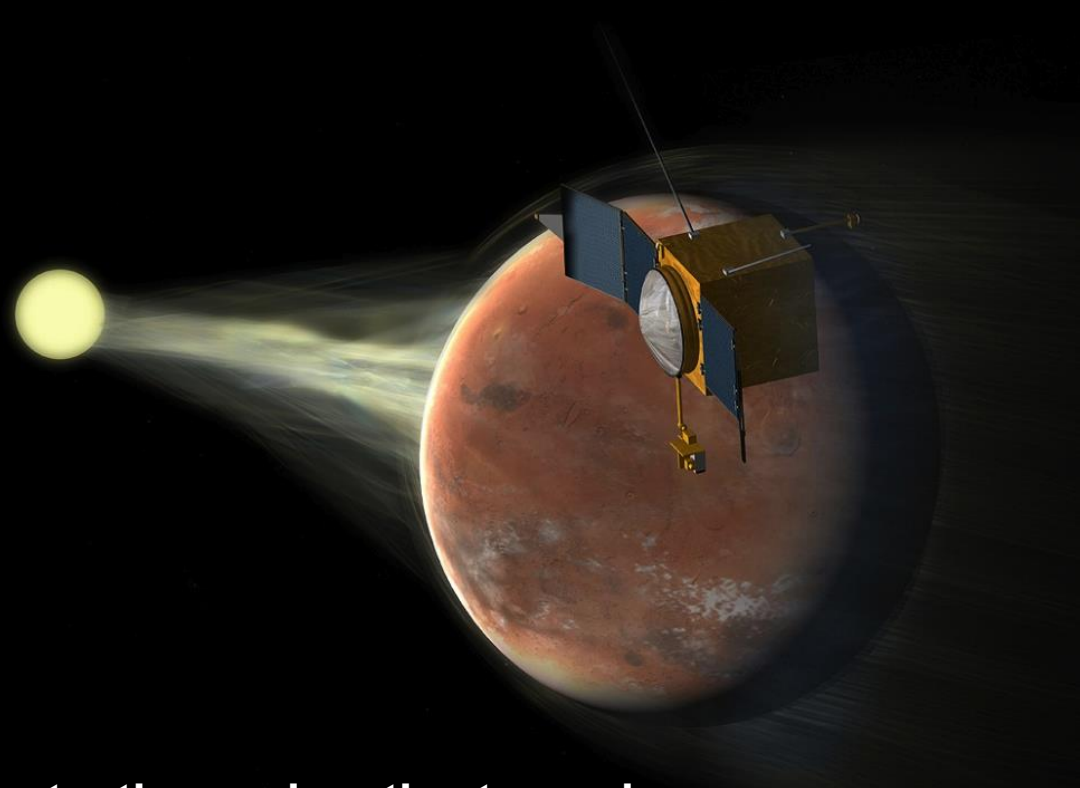
Effects could be more significant around low-mass stars



Stable Secondary Atmosphere?



Coronal mass ejections (CMEs), if they impact planet's atmosphere, can erode it



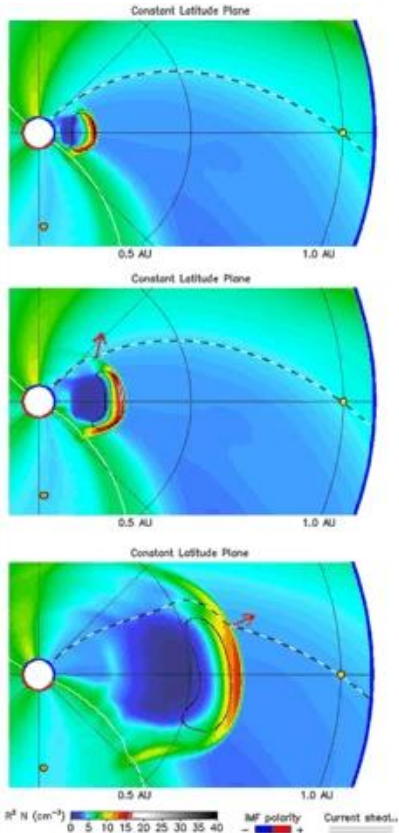
Magnetic fields are important for protecting a planet's atmosphere.

Yes?

... but atmospheric loss in solar system planets?

[From *Science* (2015 November 6).
Reprinted with permission from AAAS.]

Extrasolar Space Weather: Solar/Stellar Wind Exposure



- **Solar/stellar wind characteristics**
 - Mean ram pressure?
Kinetic vs. magnetic?
 - Variations (rms) in ram pressure?
 - Magnetic connection?
- **Solar/stellar magnetic field**
 - Strength?
“choked CMEs”?
- **Planetary orbit**
 - Velocity
 - Sub- vs. super-Alfvénic
- **Planetary magnetic field**
- ...

Multi-wavelength Space- and Ground-Based Investigations

Extrasolar Space Weather

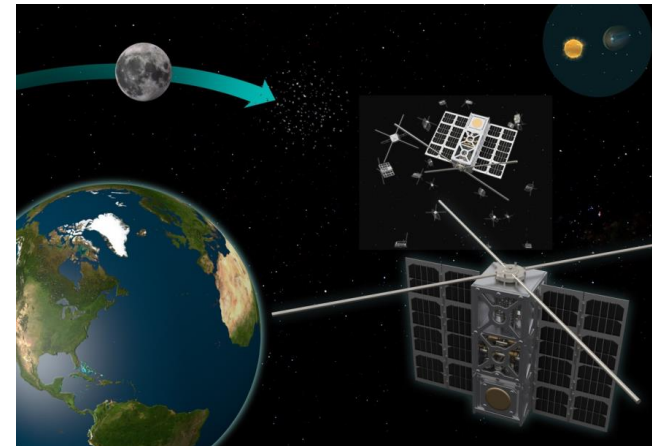
**X-ray/UV/visible
wavelength**



**Centi-/decimeter Wavelength
(FASR)**

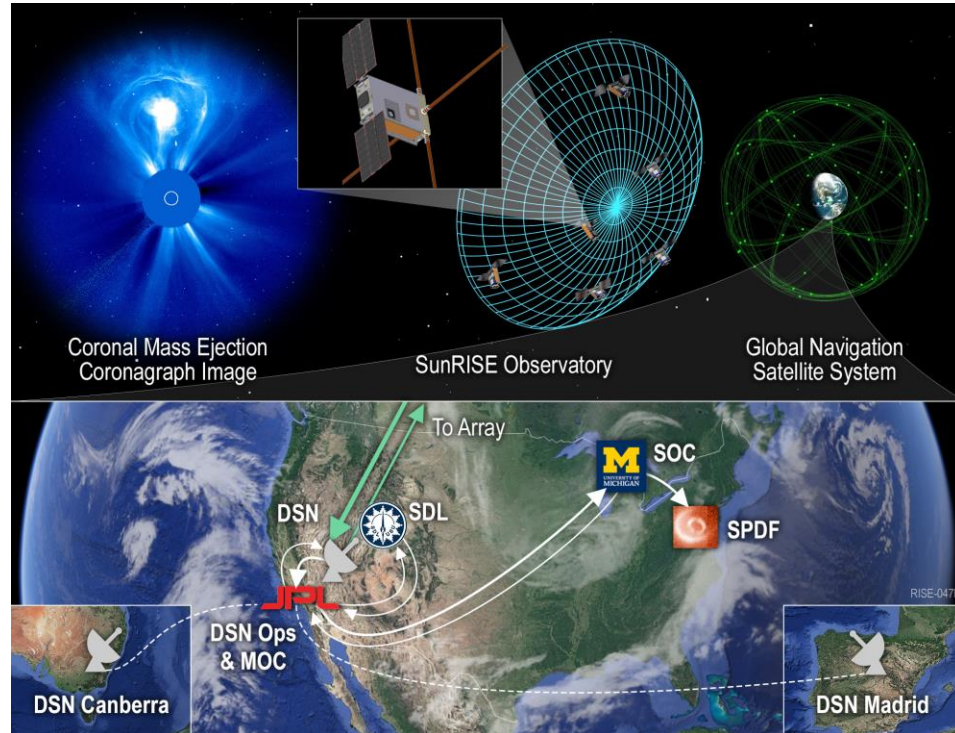
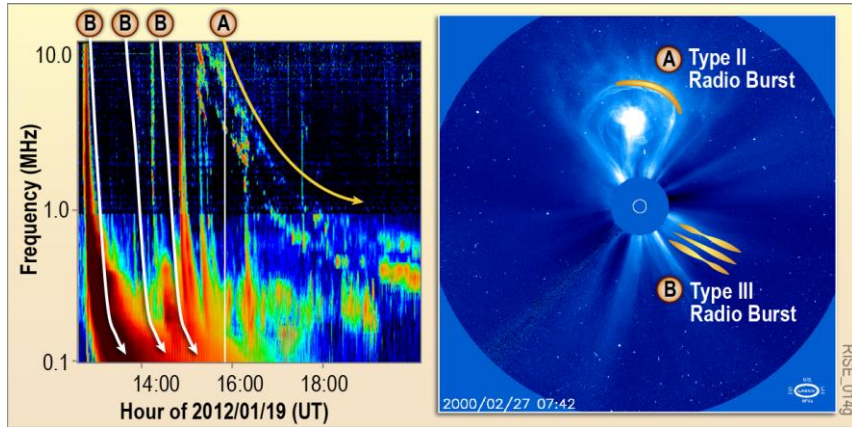


**Deca-/hectometer
Wavelength**



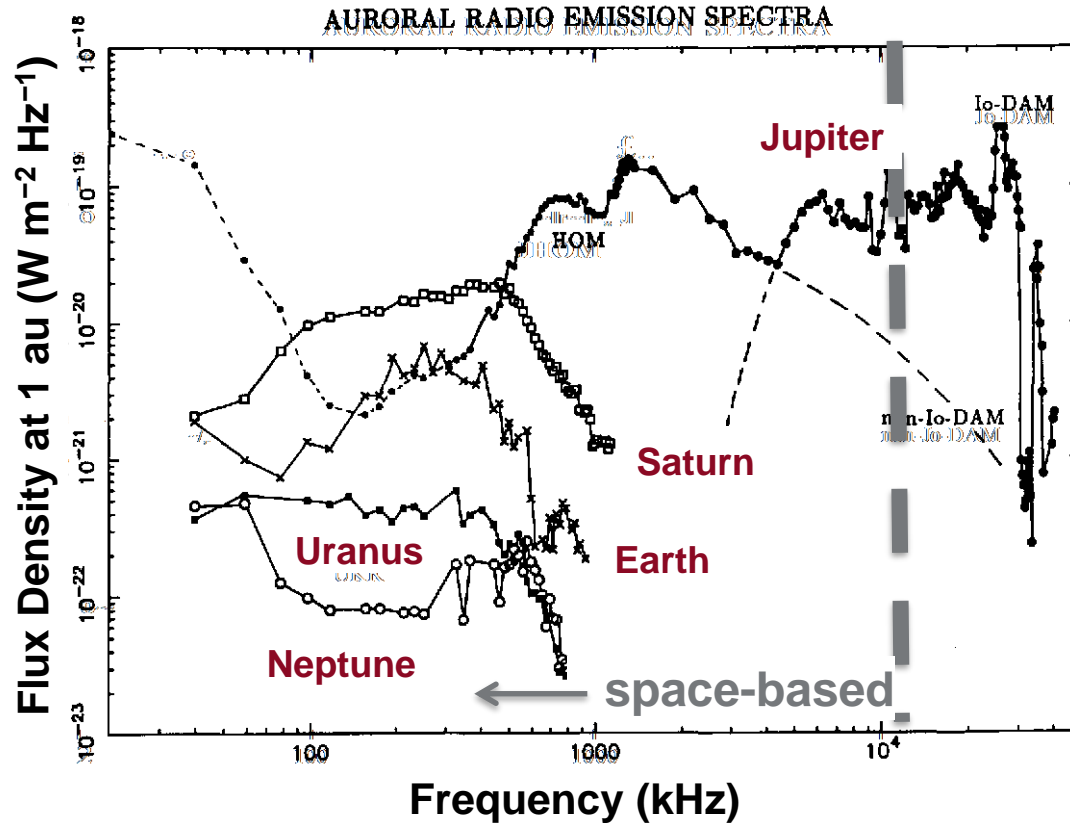
Survey techniques: “All-sky” vs. repeated visits to known stars

Extrasolar Space Weather: Deca-/hctometric Wavelengths



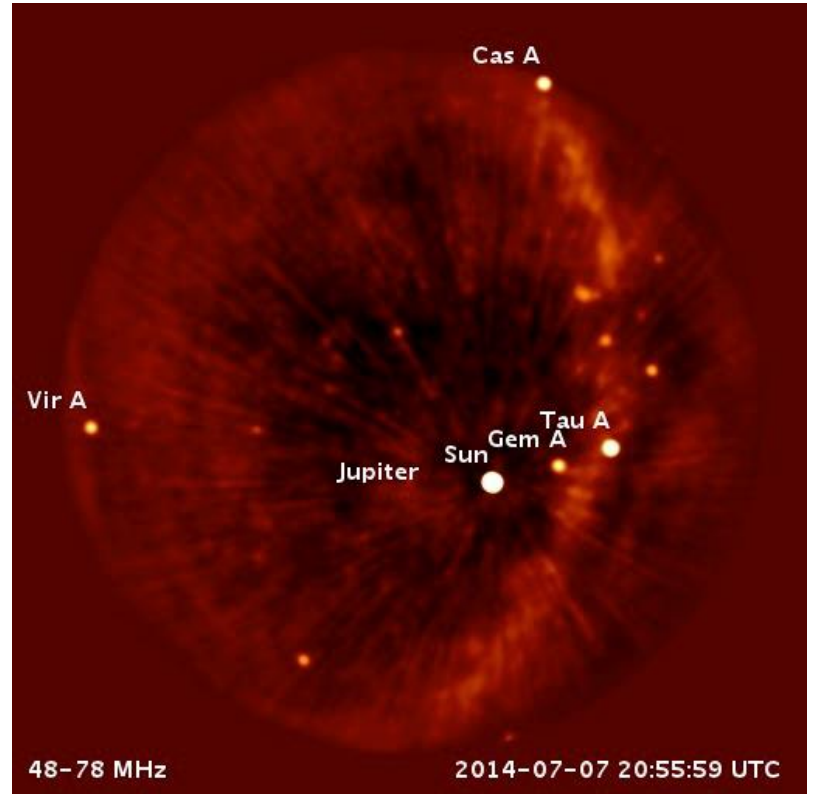
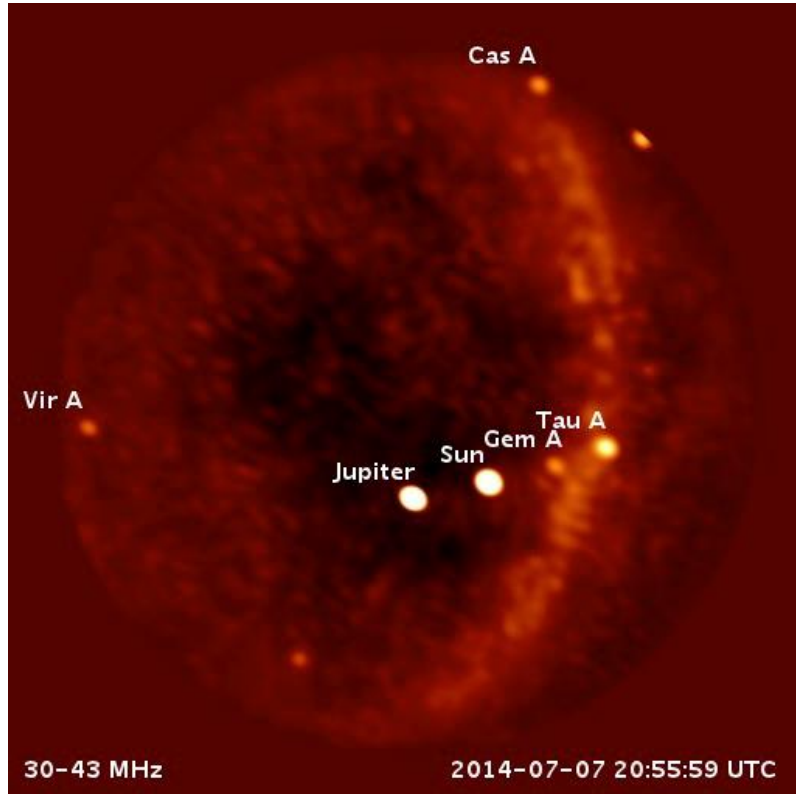
How do (solar) CMEs accelerate solar energetic particles (SEPs)?

Magnetic Emissions from Solar System Planets



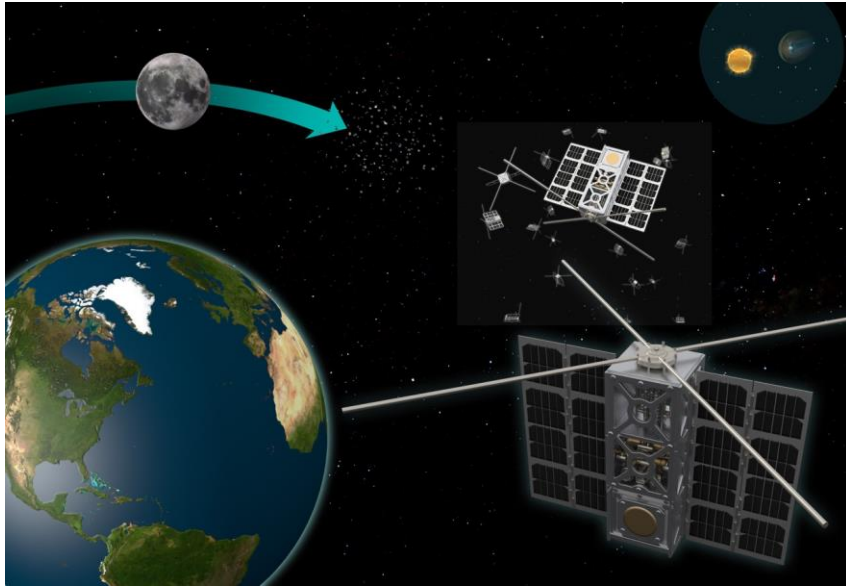
Magnetically-Generated Planetary Radio Emission

Jupiter --- and what we want to see from an extrasolar planet



Extrasolar Space Weather and Extrasolar Planetary Magnetic Fields

Beyond SunRISE



- **SunRISE insufficient for probing extrasolar space weather or extrasolar planetary magnetic fields**
 - Too few antennas (spacecraft) for sufficient sensitivity**
 - SunRISE = 6 spacecraft

Worlds and Suns in Context

Interconnected nature of stars and extrasolar planets presents rich set of questions and investigations for next 10+ years

- Solar/stellar wind characteristics
 - Mean ram pressure?
Kinetic vs. magnetic?
 - Variations (rms) in ram pressure?
 - Magnetic connection?
- Solar/stellar magnetic field
 - Strength?
“choked CMEs”?
- Planetary orbit
 - Velocity
 - Sub- vs. super-Alfvénic
- Planetary magnetic field
- ...

Multi-wavelength and ground-/space-based observations (and modeling!) will be essential

