

(Exo)Planetary Space Weather: Way forward (Perspective)



Image Source: Keck institute for space studies.

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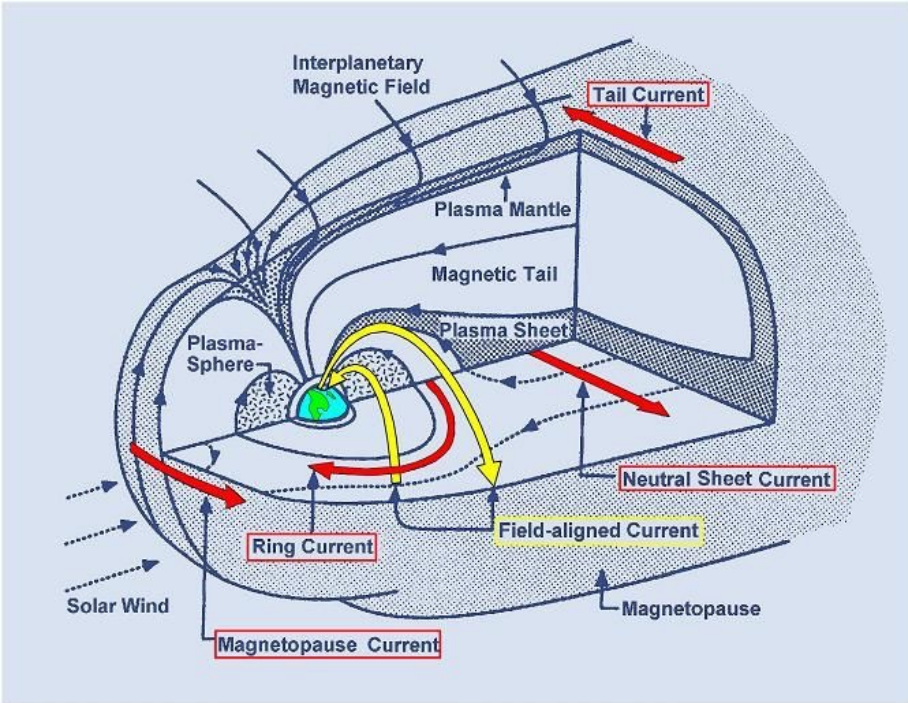
What is space weather: current understanding?

WMO task group has defined the space environment as *“the physical and phenomenological state of the natural space environment, including the Sun and the interplanetary and planetary environments”*

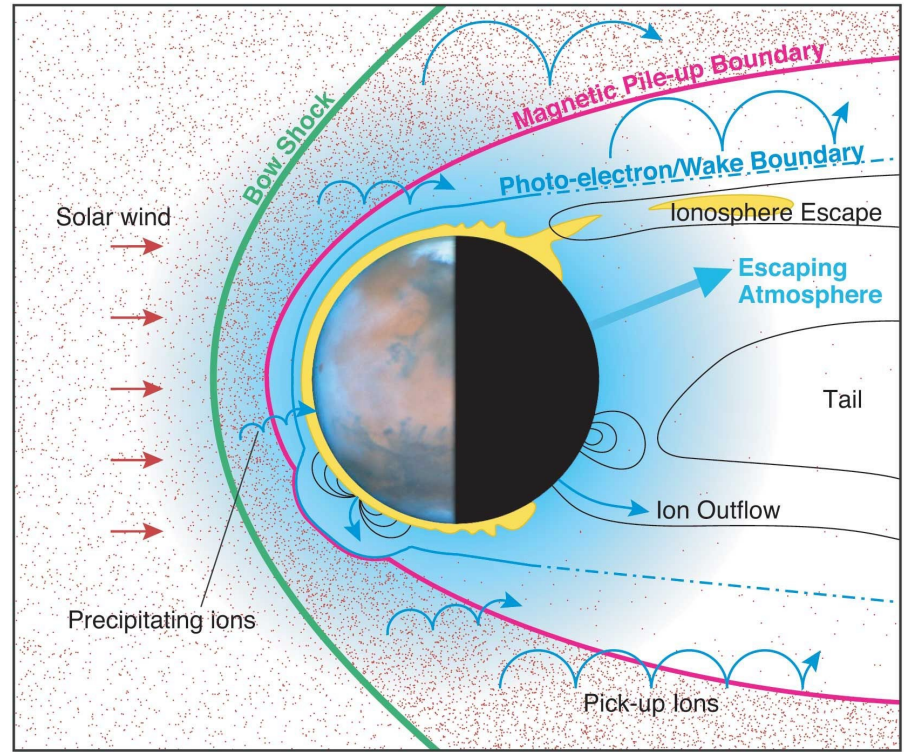
Parameters determining the Space weather around Solar system planets/objects :

- *Distance of the body from the Sun* : IMF strength and polarity, SW pressure, SEP energy and fluxes, evolution of solar wind transients
- *Presence of atmosphere*: ionosphere
- *Presence of magnetosphere* : weak or strong, intrinsic/induced, radiation belts, currents
- *Solar activity level and phase of solar cycle*: ICMEs, CIRs, X-ray, UV, GCR flux

Solar system planets: Closest laboratory for Exoplanetary space weather



(modified from Kivelson and Russel (1995))

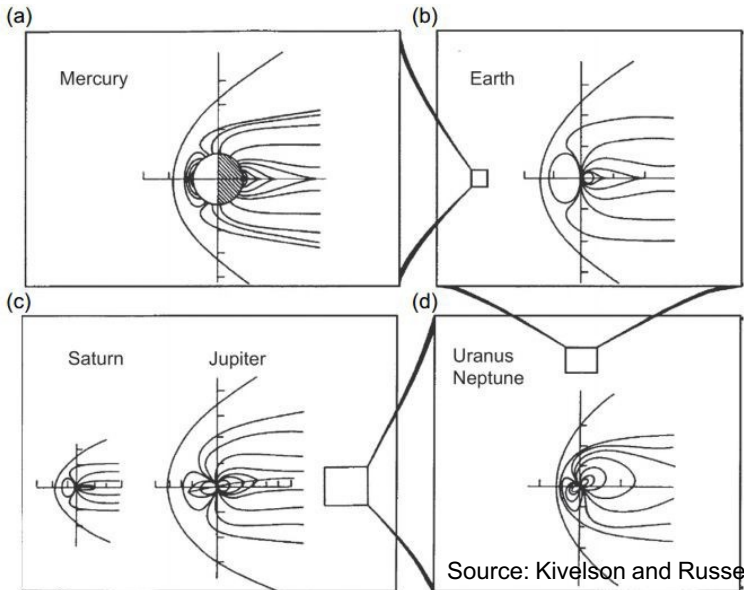


Credit: Fran Bagenal & Steve Bartlett

Solar system planets: Closest laboratory for Exoplanetary space weather

Solar system body	Distance from the Sun (in AU)	Body's radius (in km)	Rotation period (in hours)	Planets					Interplanetary magnetic field	
				Planetary space weather regions	Atmosphere major composition	Magnetic field morphology	Solar wind density (in cm^{-3})	Intensity (nT)	Inclination (in deg)	
Neptune	30.07 ¹	24,764 ¹	16.11 ¹	I, M, E	H ₂ , He, CH ₄ ¹	Dipole	0.008 ¹⁵	0.11 ²²	88.1	
Uranus	19 ¹	25,559 ¹	17.24 ¹	I, M, E	H ₂ , He, CH ₄ ¹	Multipole	0.02 ¹⁵	0.22 ²³	87.0	
Saturn	9.5 ¹	60,330 ¹	10.656 ¹	I, M, E	H ₂ , He ¹	Dipole	0.1 ¹⁵	0.2–0.8 ²⁴	83.9	
Jupiter	5.2 ¹	71,398 ¹	9.925 ¹	I, M, E	H ₂ , He ¹	Dipole	0.3 ¹⁵	0.5–1.21 ²⁵	79.0	
Mars	1.524 ¹	3,390 ¹	24.623 ¹	I, E	CO ₂ , N ₂ ¹	Crustal fields	3.5 ¹⁵	2–3 ²⁶	56.4	
Venus	0.723 ¹	6,051 ¹	5,832.6 ¹	I, E	CO ₂ , N ₂ ¹	Induced	16 ¹⁵	12 ²⁷	35.5	
Mercury	0.31–0.47 ¹	2,439 ¹	1,407.6 ¹	M, E	Exosphere: Na, K, Mg, Ca, H, He, Al ¹	Dipole	32–73 ¹⁶	15–30 ²⁸	21.1	

Source: Plainaki et al., 2016



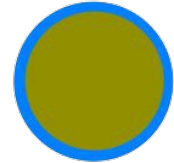
Source: Kivelson and Russell, 1995

Intrinsic and Induced magnetosphere

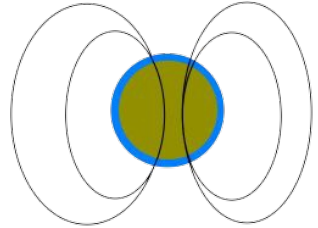
Satellites and planetary magnetosphere interaction



No mag field
No atmosphere

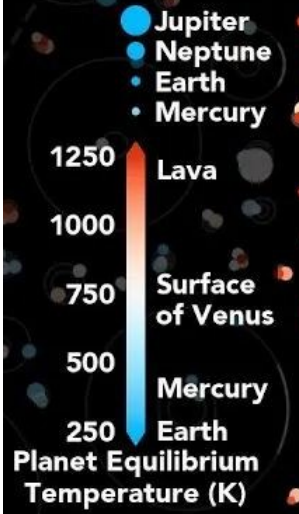


No mag field
with atmosphere

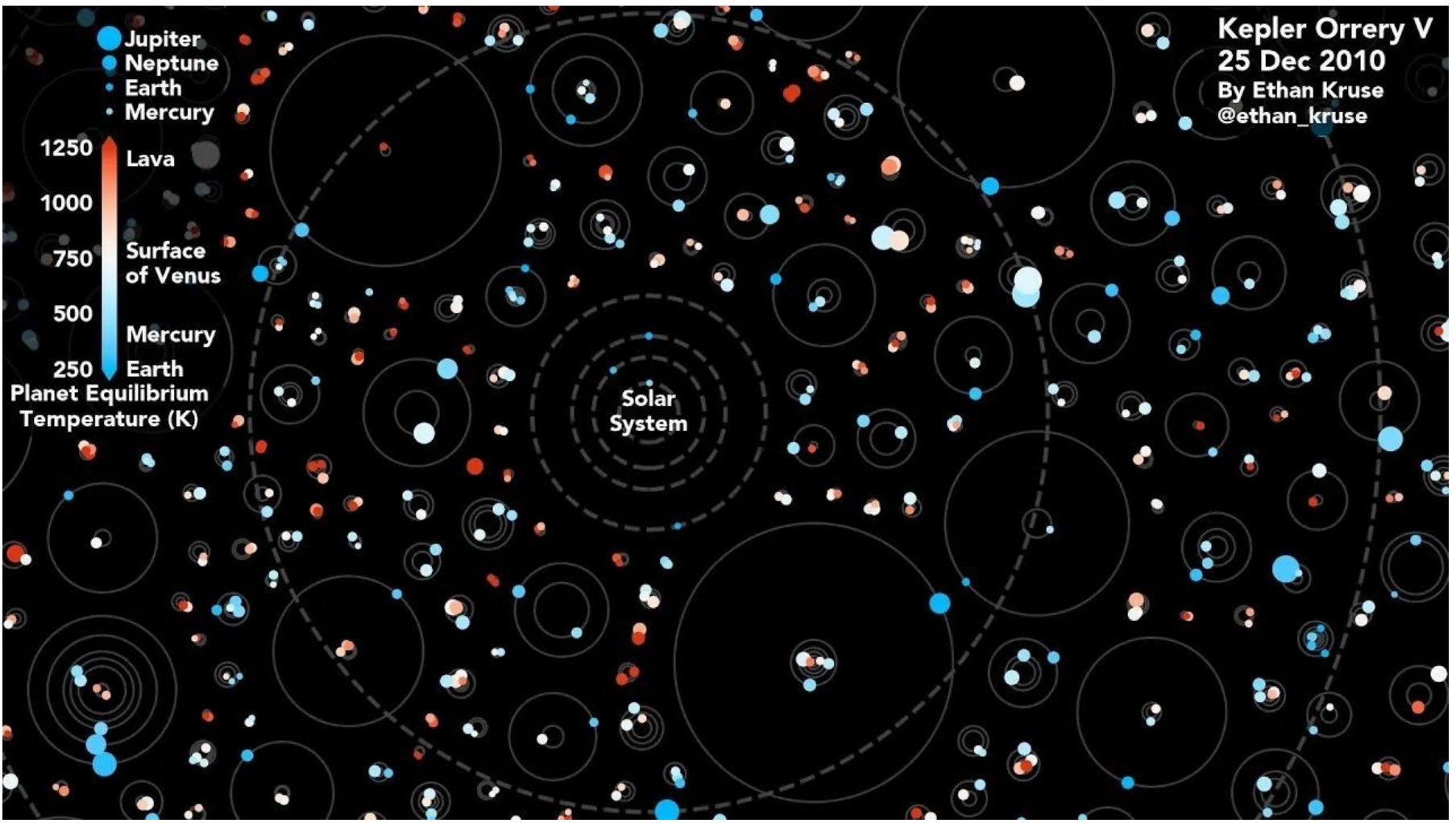


With mag field
And atmosphere

Kepler Orrery V
25 Dec 2010
By Ethan Kruse
@ethan_kruse



Solar System



Space weather Around the Earth



Planetary Space weather



Exoplanetary Space weather

What to learn about near Earth Space weather from Exoplanetary Space weather?

Ensemble: Few thousand exoplanets around,

– Stellar evolution and activity —>> space weather evolves over time around the star

Time travel

– Can act as time travel to understand past and future space weather around Earth,
evolution time scales

Diverse star-planet interaction

– Earth and solar system has limited possibilities of star-planet interaction cases

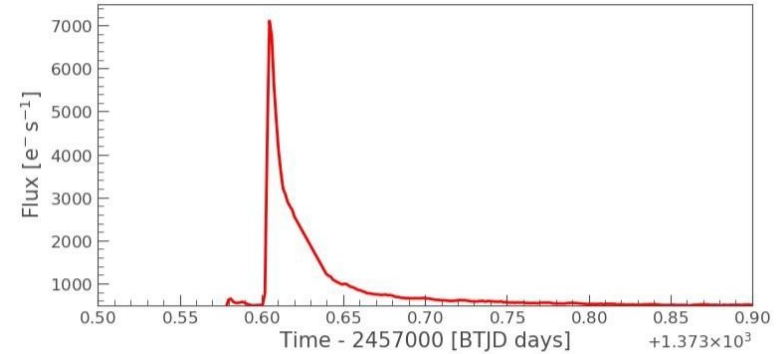
Unknown territory

– No solar system planet in subalfvenic regime of the Sun → Exoplanet could provide
such laboratories

Open problems in Space weather around the Earth:

- Estimating probability of extreme events like extreme solar flares and CME
- How does mass loss rate is controlled by solar wind for planets with induced and intrinsic magnetosphere?
- How space weather evolved around the Earth? Solar wind, SEPs, CMEs

Super flare on TIC 260506296



Open problems in Space weather of Exoplanets:

- No in situ measurements possible at present only remote sensing/modelling.
- Properties of the stellar wind around the Exoplanets.
- Space weather impact on the atmosphere of exoplanet
- Our understanding could be extrapolated to sun-type stars but to other type of stars may be very uncertain.
- Impact on habitability (e.g. Airapetian et al., 2019)

What we need to do?

- Identify key areas/questions from near-Earth space weather and Exoplanetary space weather which can complement each other.
- Create task forces with different expertise to address those in 3-5 year plans.
- Utilization of open data science and citizen involvement

Thank you !
