

Energetics of Star Planet Magnetic Interactions:

*Novel Insights from 3D
Modelling*



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The Observational Premise

EVIDENCE FOR PLANET-INDUCED CHROMOSPHERIC ACTIVITY ON HD 179949

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HOT JUPITERS AND HOT SPOTS: THE SHORT- AND LONG-TERM CHROMOSPHERIC ACTIVITY ON STARS WITH GIANT PLANETS¹

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Evidence of Magnetic Star–Planet Interactions in the HD 189733 System from Orbitally Phased Ca II K Variations

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Planet-Induced Emission Enhancements in HD 179949: Results from McDonald Observations

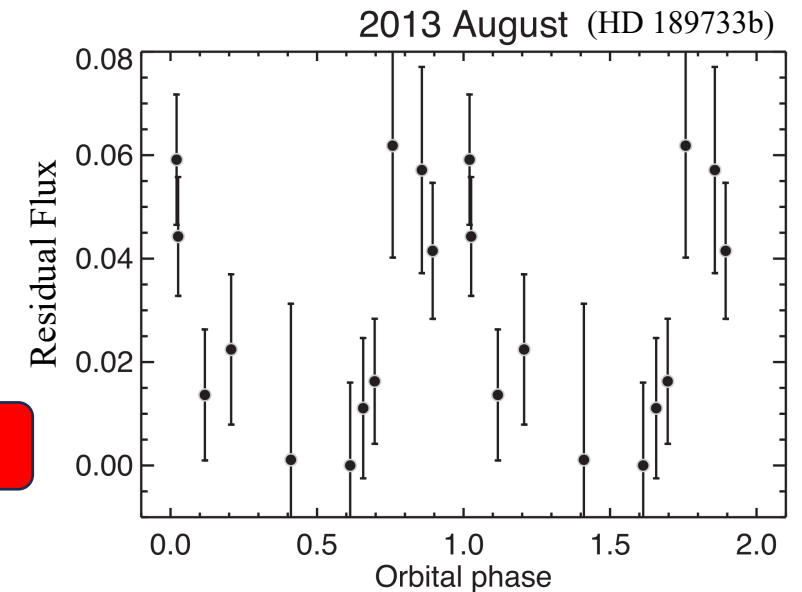
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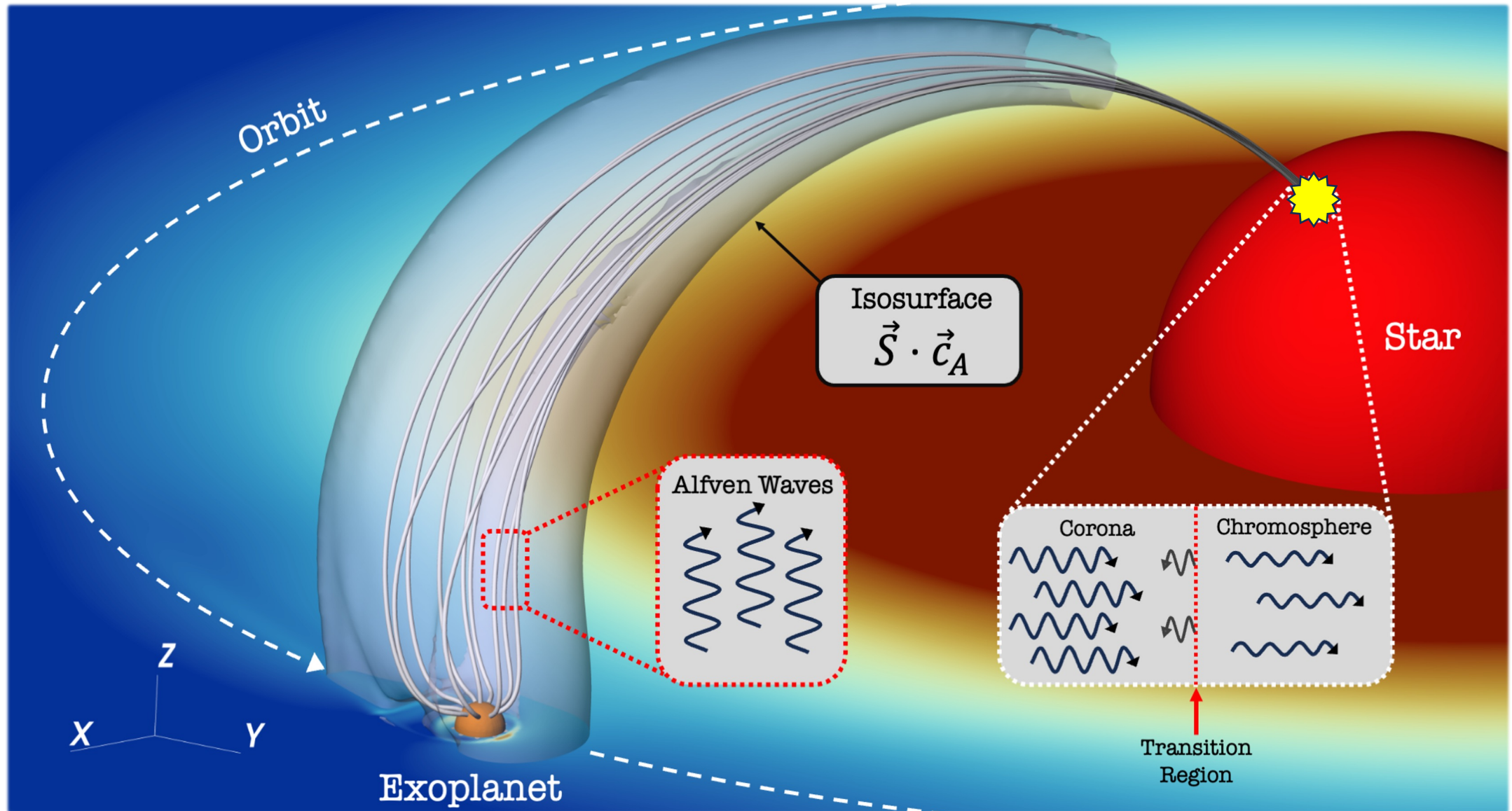
^CCorresponding author. Email: cuntz@uta.edu

Close-in planets inside the Alfvén surface

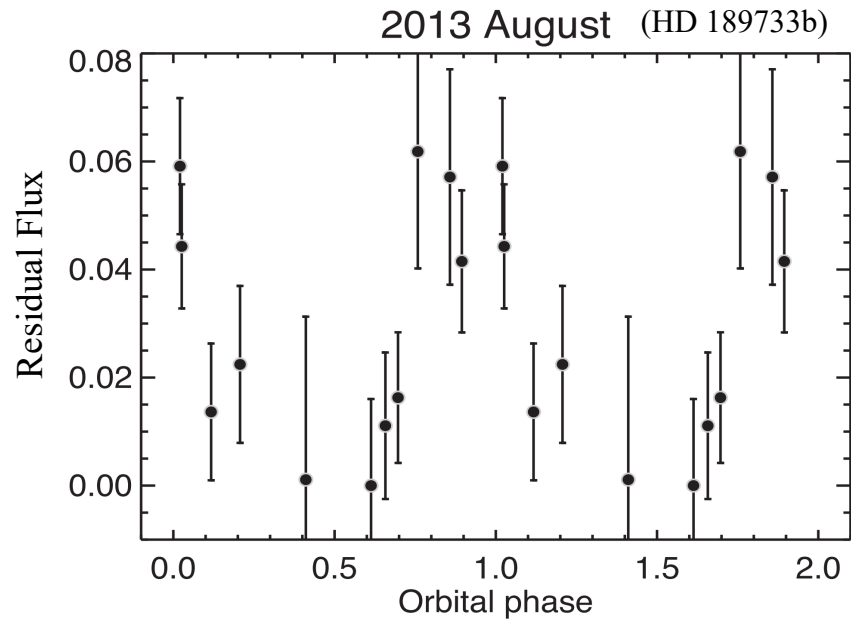


Cauley et al. 2018

Star Planet Magnetic Interactions : SPMI



SPMI: Tentative Observations



Cauley et al. 2018

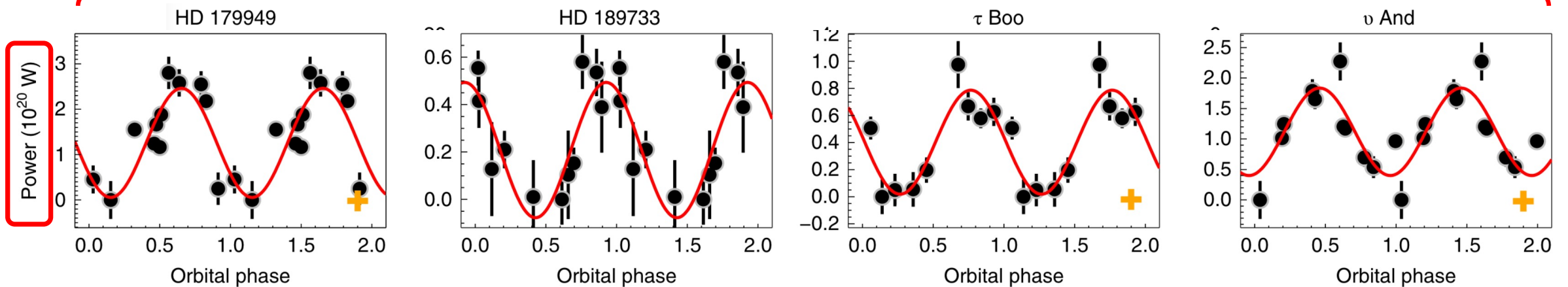
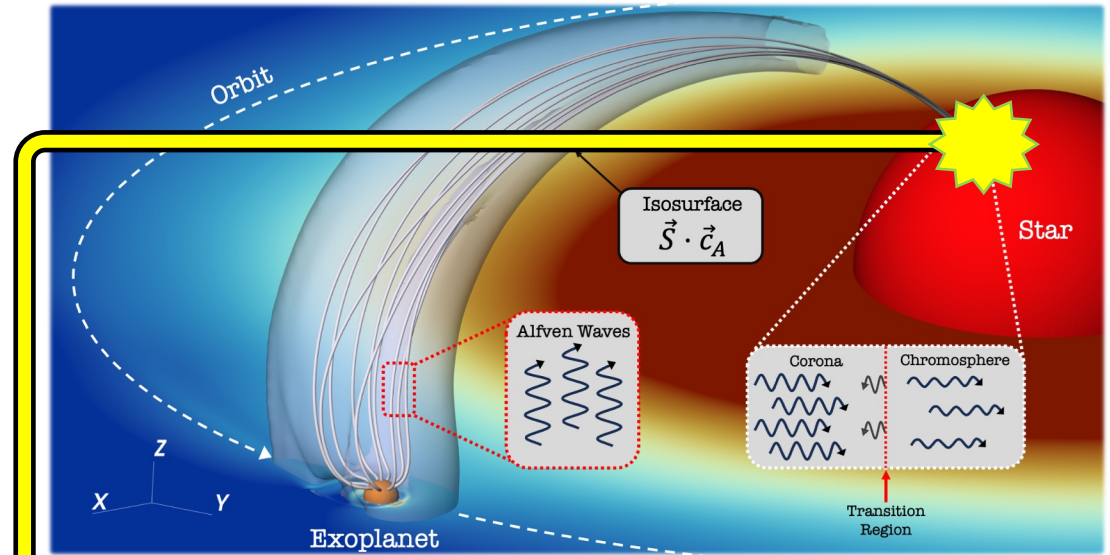


Fig: Observations of excess power in stellar chromospheric hotspots found to be in phase with the orbital period of the exoplanet (Cauley et. al 2019).

SPMI : Analytical Power @ Planet?

Magnetic Reconnection

- SPMI power is provided by magnetic reconnection between the stellar wind field lines and the planetary magnetic field lines.
- Analytical result for typical SPMI: **10^{17-18} Watts**

Kivelson et al. 1997, Zarka 2007

Alfven-Wings

- SPMI power is generated by field perturbation in the vicinity of the planet acting as an obstacle stellar wind flow.
- Analytical result for typical SPMI: **10^{18-19} Watts**

Zarka 2007, Saur et. al. 2004, 2013

Stretch & Break

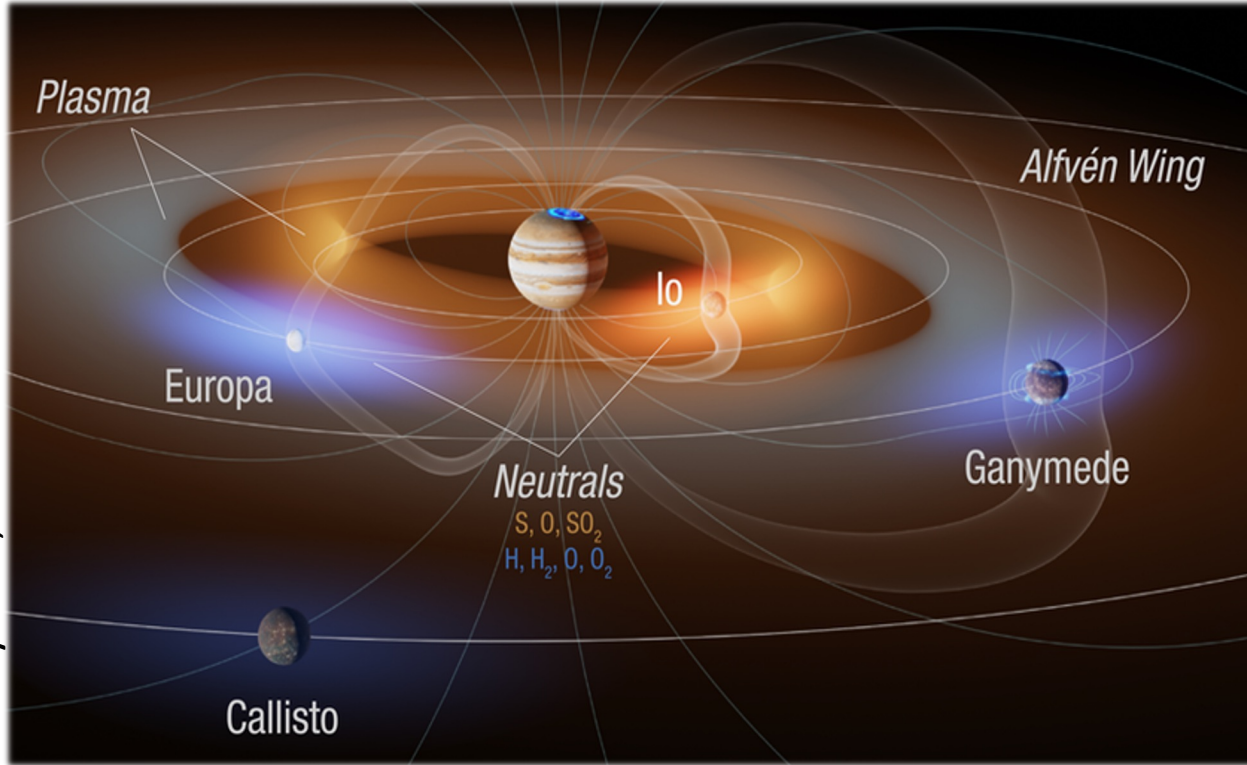
- SPMI power is generated by magnetic stresses conveyed to the stellar surface due to the orbital motion of the planet.
- Analytical result for typical SPMI: **10^{20-21} Watts**

A. F. Lanza 2013

❖ Major discrepancy in literature on the magnitude of SPMI power generated by the planet.

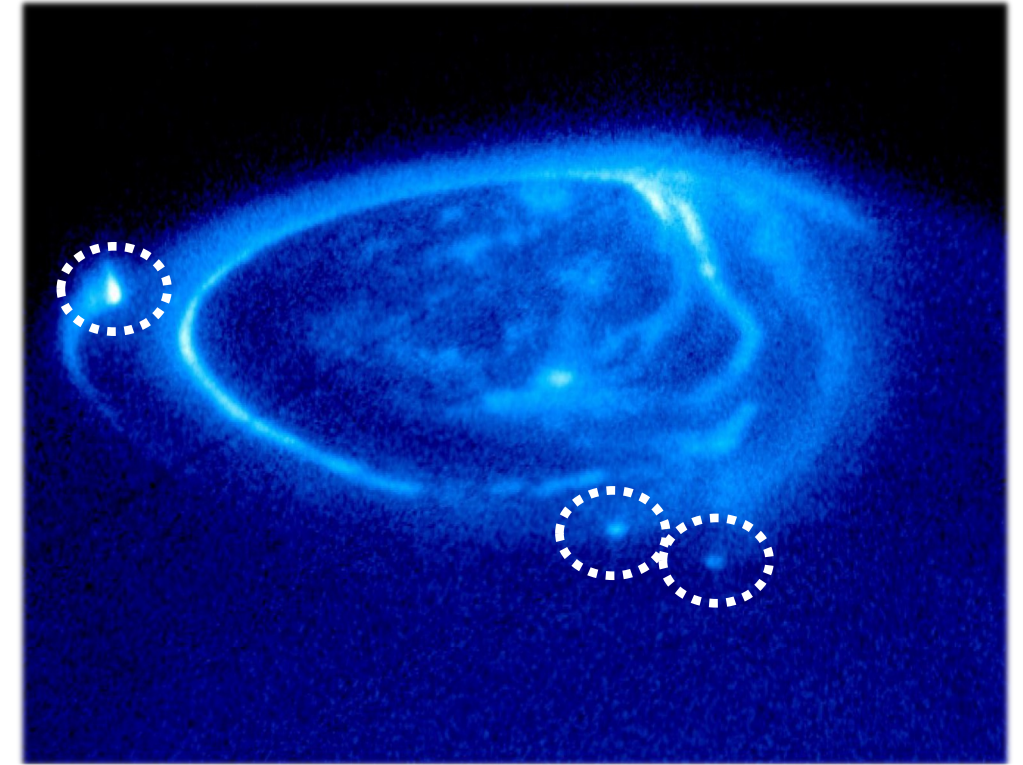
SPMI : Analytical Power Estimates

Szalay et al, 2022



Satellite	P_d (W/hem.)	$P_{Radio}(W)$	$P_{UV}(W)$
Io	$(1.8-4.1) \times 10^{12}$	$0.3-3 \times 10^{10}$	$(2-10) \times 10^{10}$
Europe	$(1.0-2.3) \times 10^{11}$?	$(1-10) \times 10^9$
Ganymede	$(0.9-6.2) \times 10^{11}$	$\sim 10^9$	$(1-10) \times 10^9$
Callisto	$(0.1-15.) \times 10^9$	$\leq 8.5 \times 10^8$?

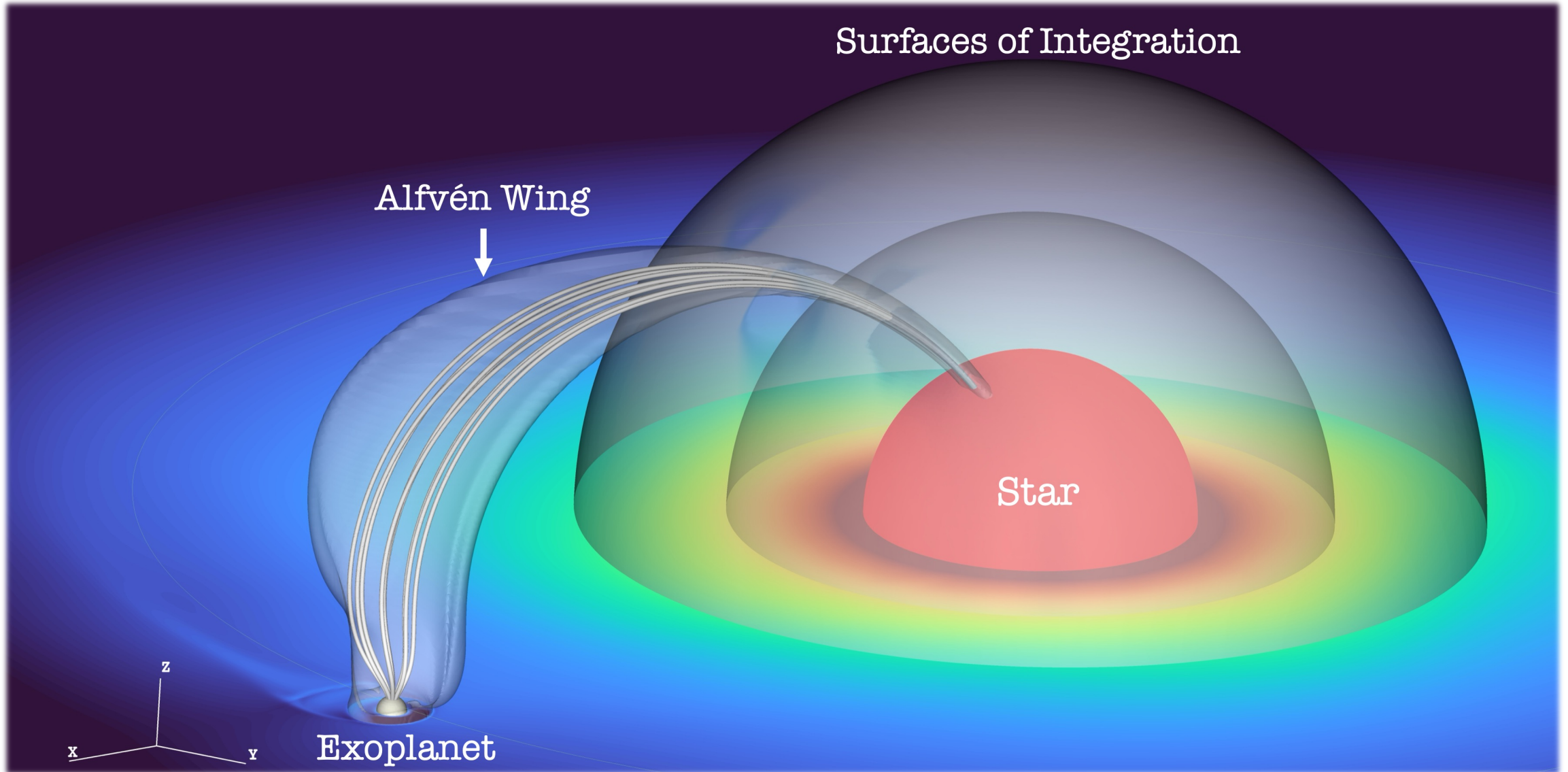
Philippe Zarka (2007)



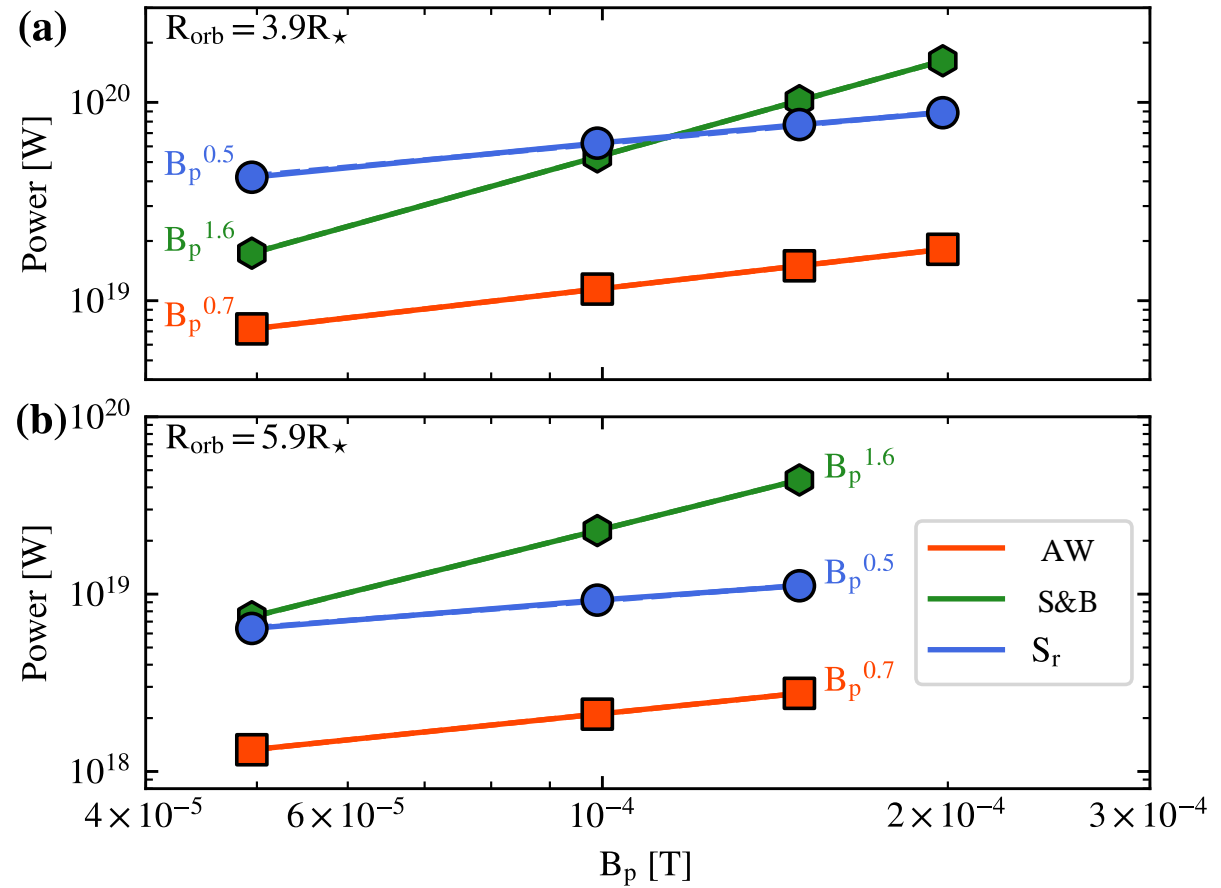
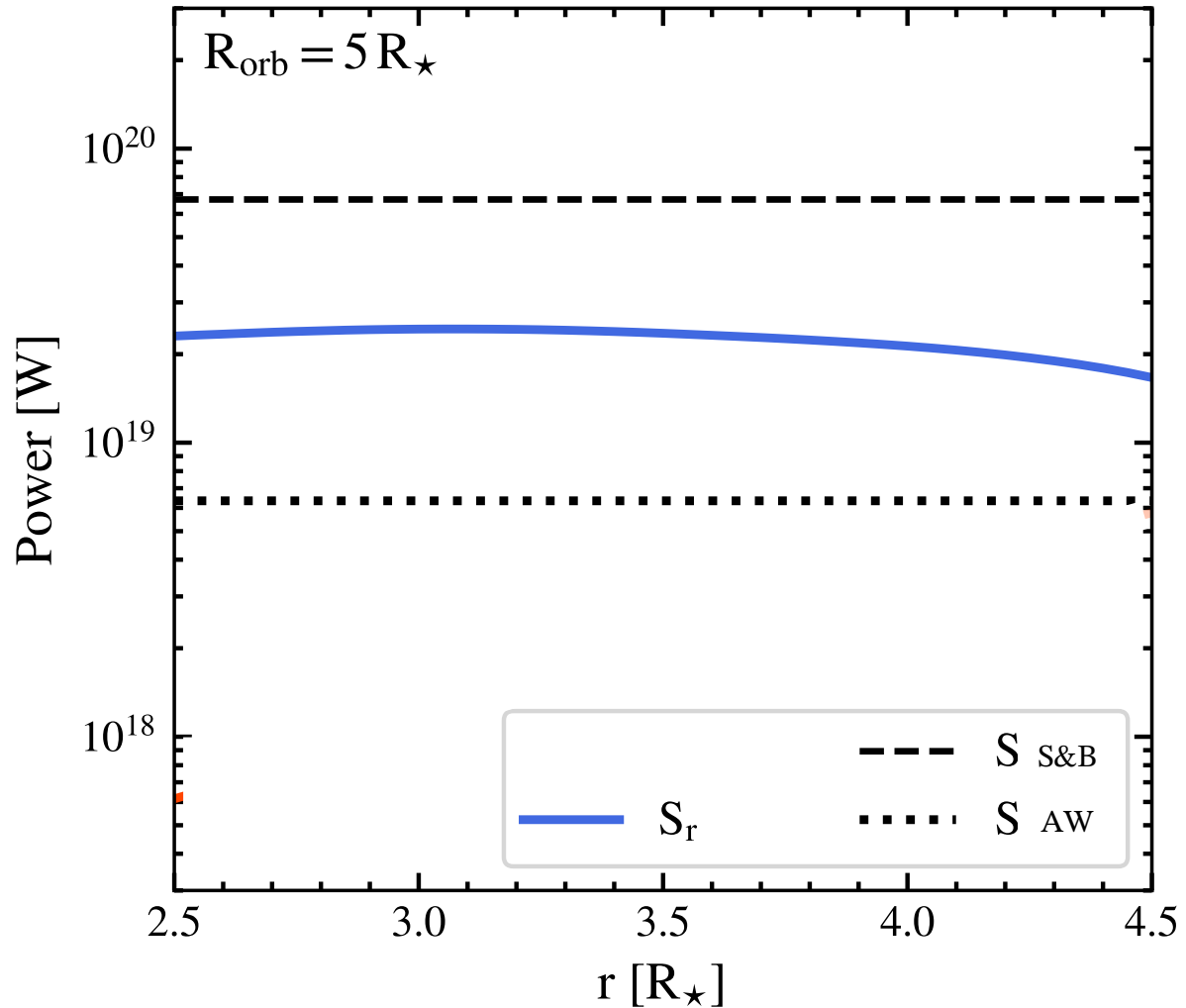
Satellite	S_{obs}	S_{theo}
	10^9 W	10^9 W
Io ^{a,c}	4-300	288-1660
Europa ^{a,c}	0.1-8	0.1-71
Ganymede ^{a,c}	0.1-15	1-149

Joachim Saur et al. (2013)

SPMI : Numerical Power Estimates

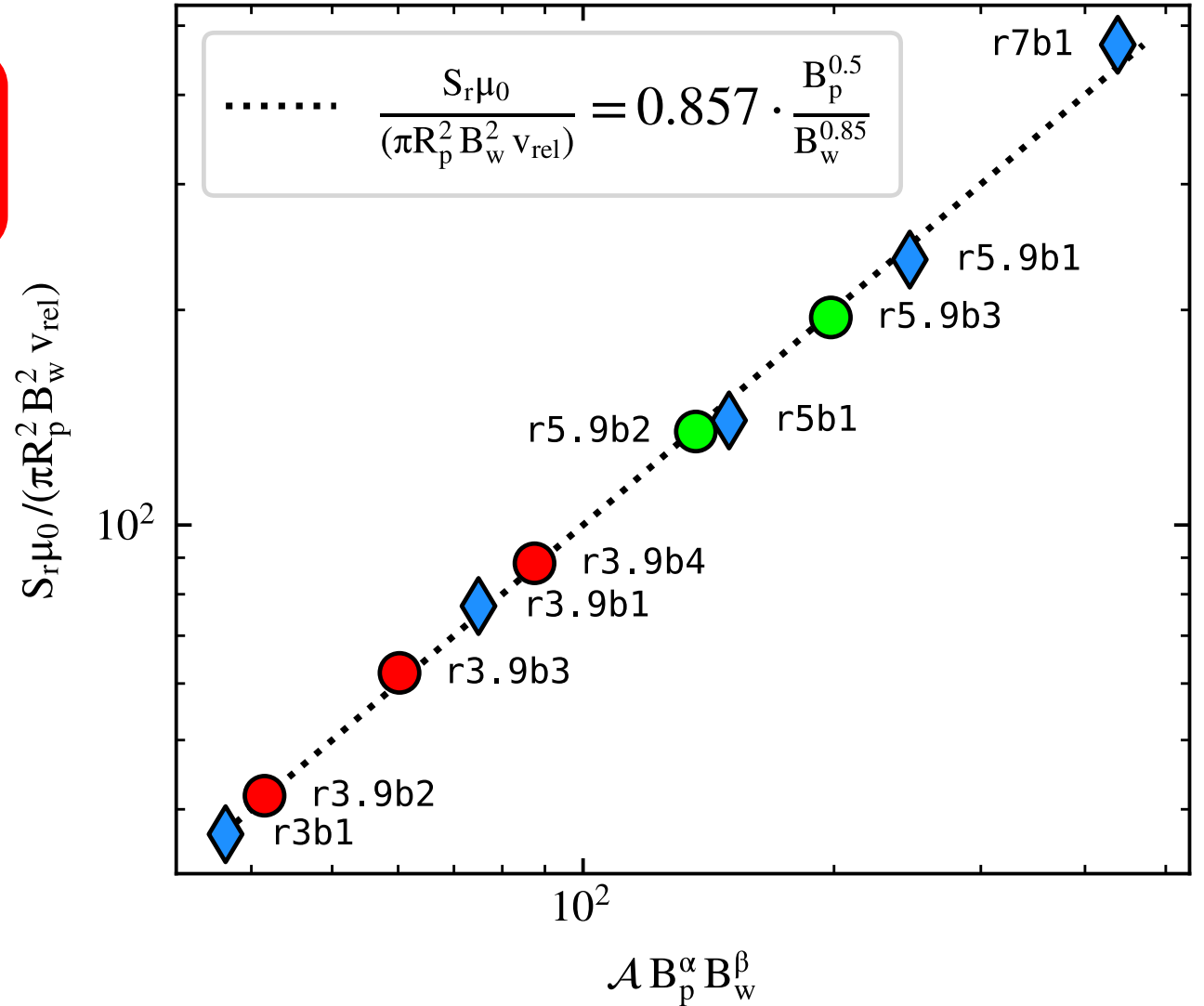
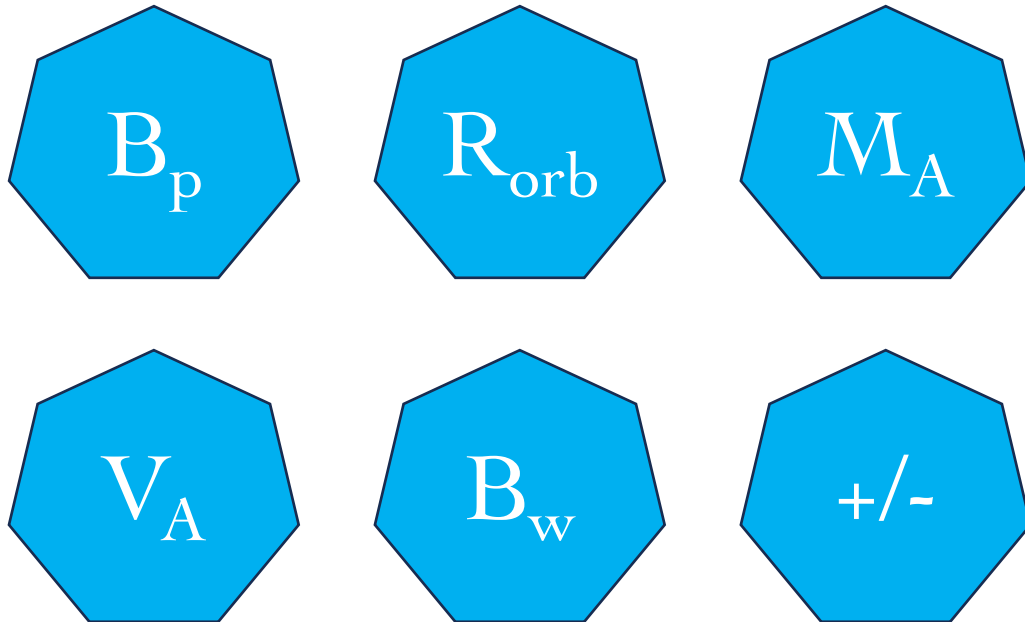


SPMI : Numerical Power Estimates



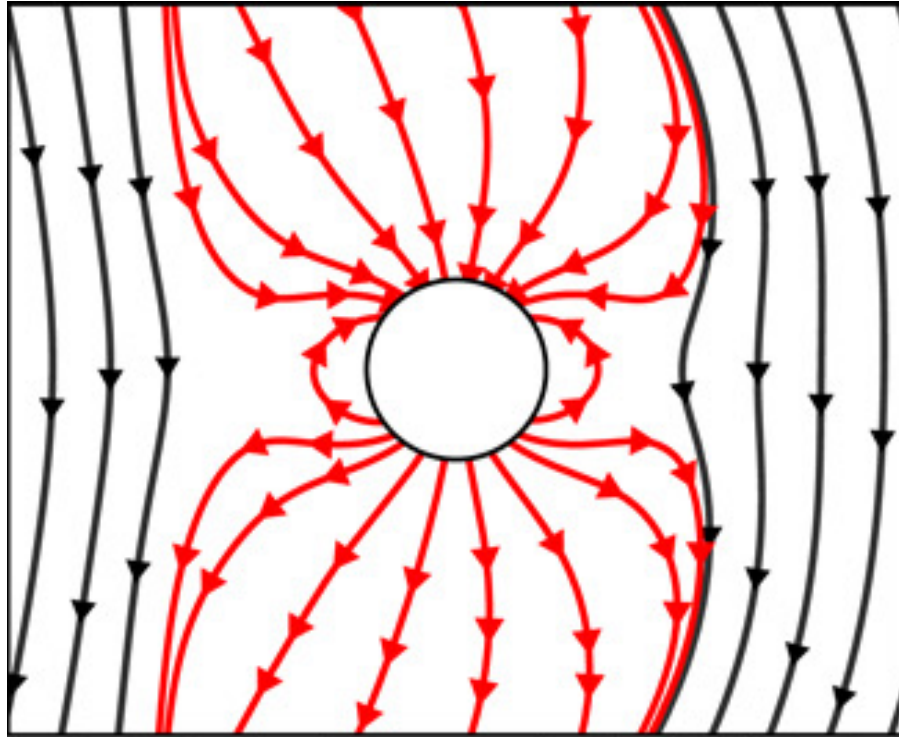
SPMI : A New Scaling Law

$$S_{\text{SPMI}} = 0.857 \left(\frac{\pi R_p^2 B_w^2 v_{\text{rel}}}{\mu_0} \right) \left[\frac{B_p}{1\text{T}} \right]^{0.5} \left[\frac{1\text{T}}{B_w} \right]^{0.85} \quad [\text{Watts}]$$

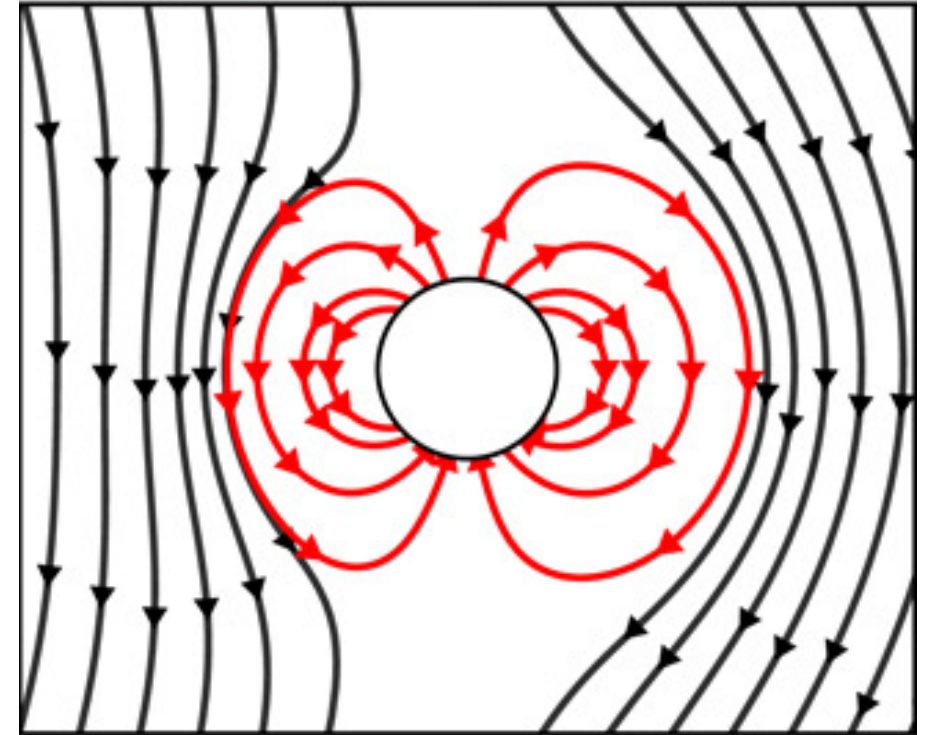


SPMI : A New Scaling Law

Open Magnetosphere



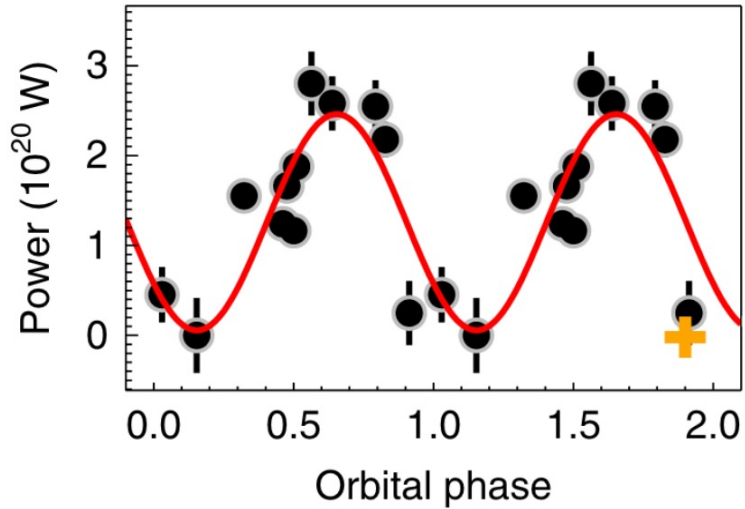
Closed Magnetosphere



$$S_{\text{SPMI}} = 0.857 \left(\frac{\pi R_p^2 B_w^2 v_{\text{rel}}}{\mu_0} \right) \left[\frac{B_p}{1\text{T}} \right]^{0.5} \left[\frac{1\text{T}}{B_w} \right]^{0.85} \quad [\text{Watts}]$$

$$S_{\text{closed}} \approx \frac{S_{\text{open}}}{5}$$

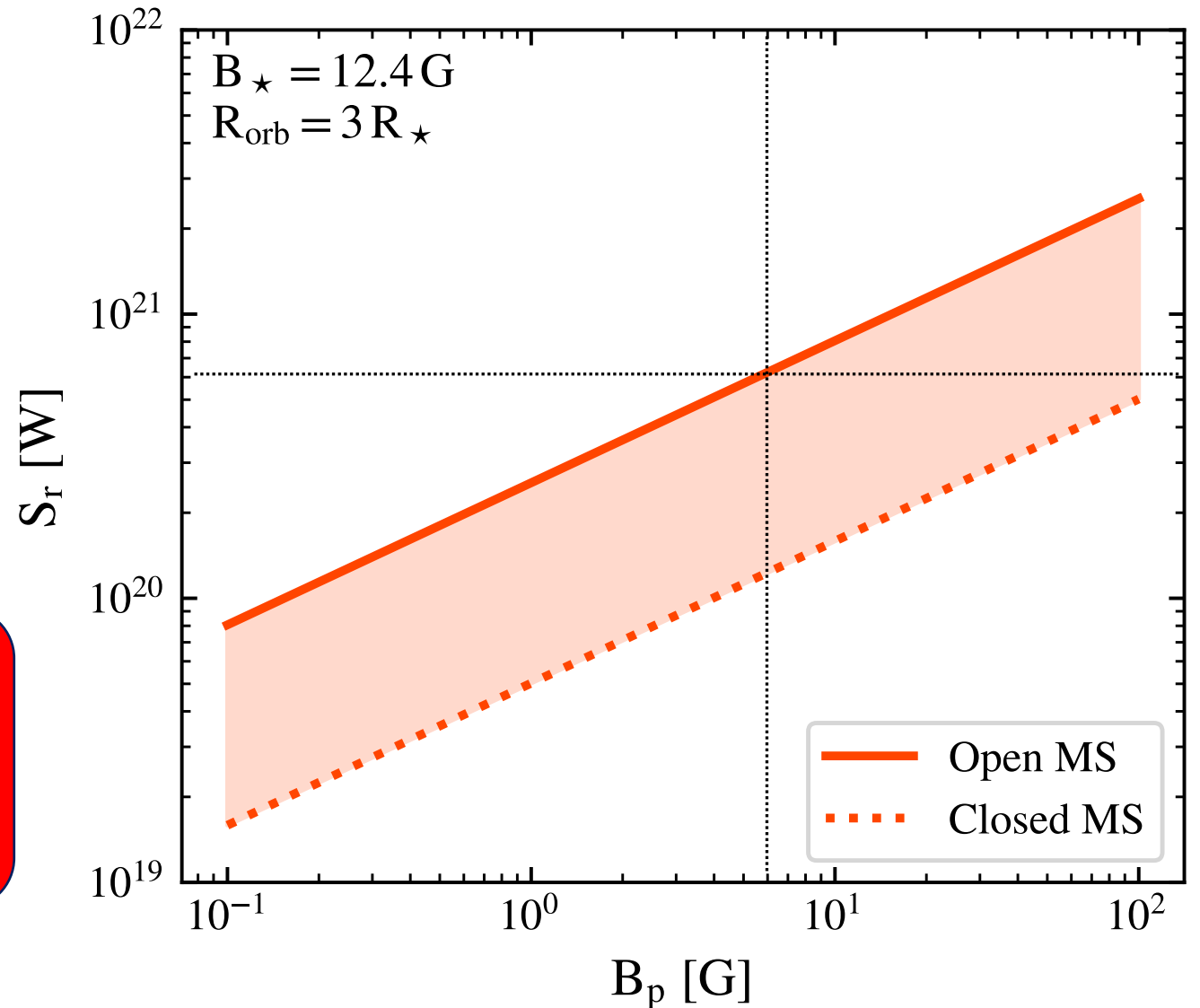
SPMI : A New Scaling Law



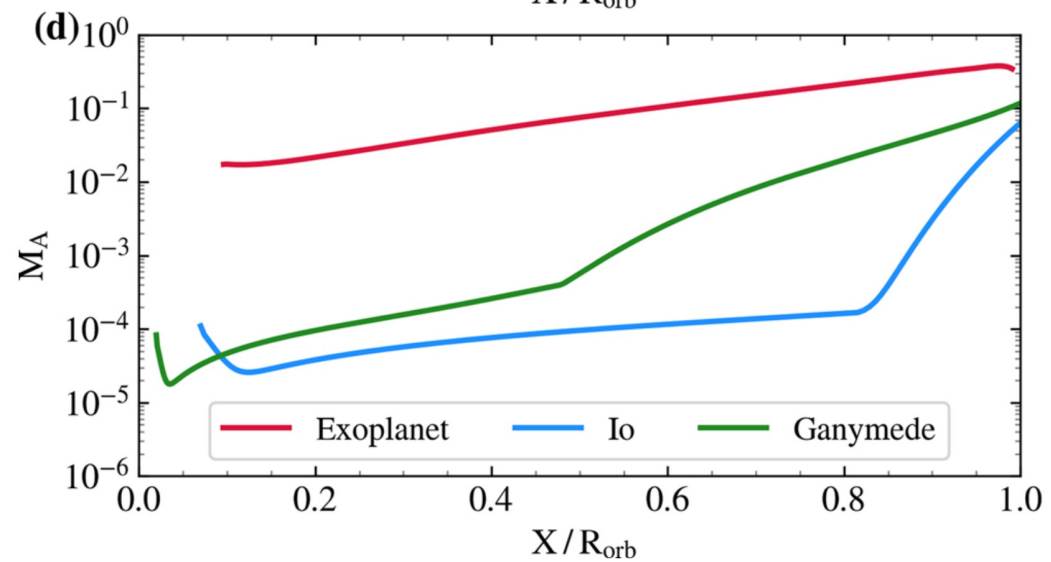
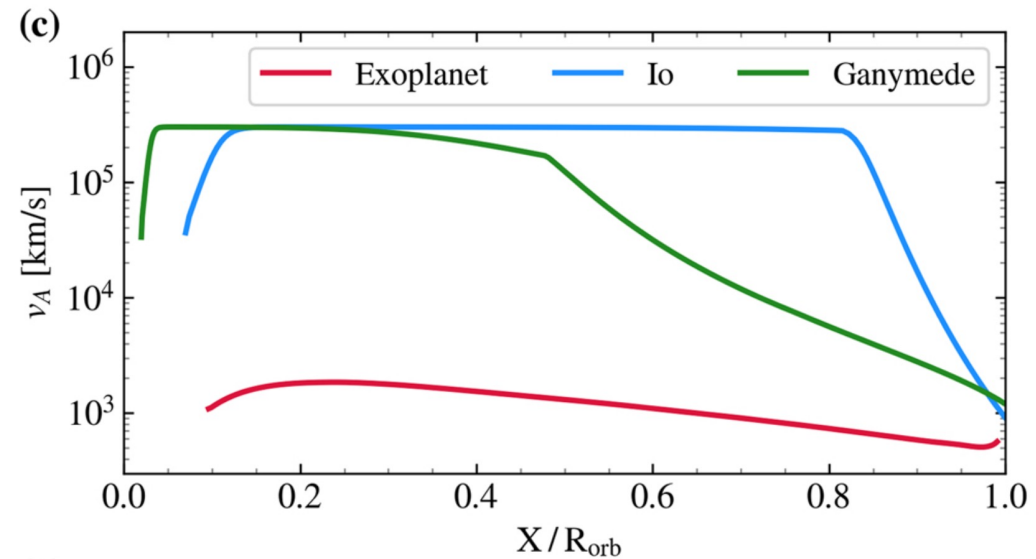
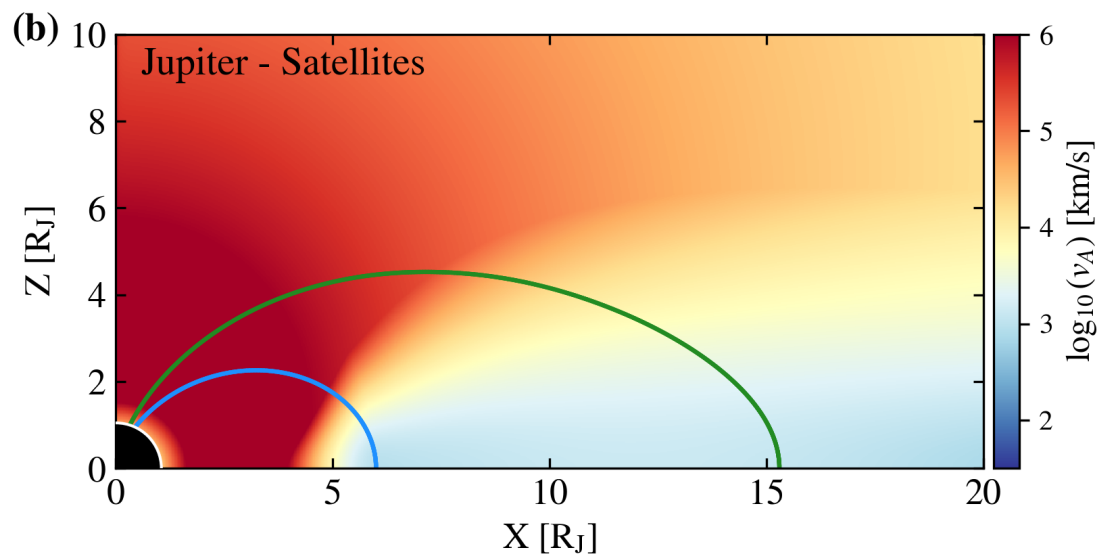
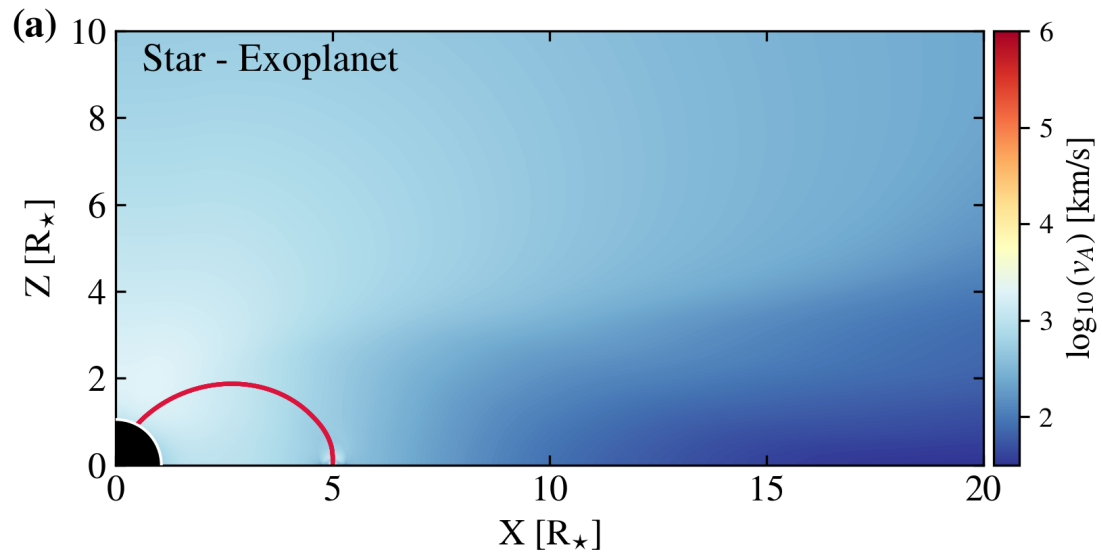
❖ Sun-like star.

❖ Jupiter like planet.

□ Solves the discrepancy on the magnitude of SPMI & the debate on the analytical models.



SPMI : A Word of Caution



That's all folks



