Simulating a planet inside highly relativistic pulsar wind

Tanja Sara Kaister

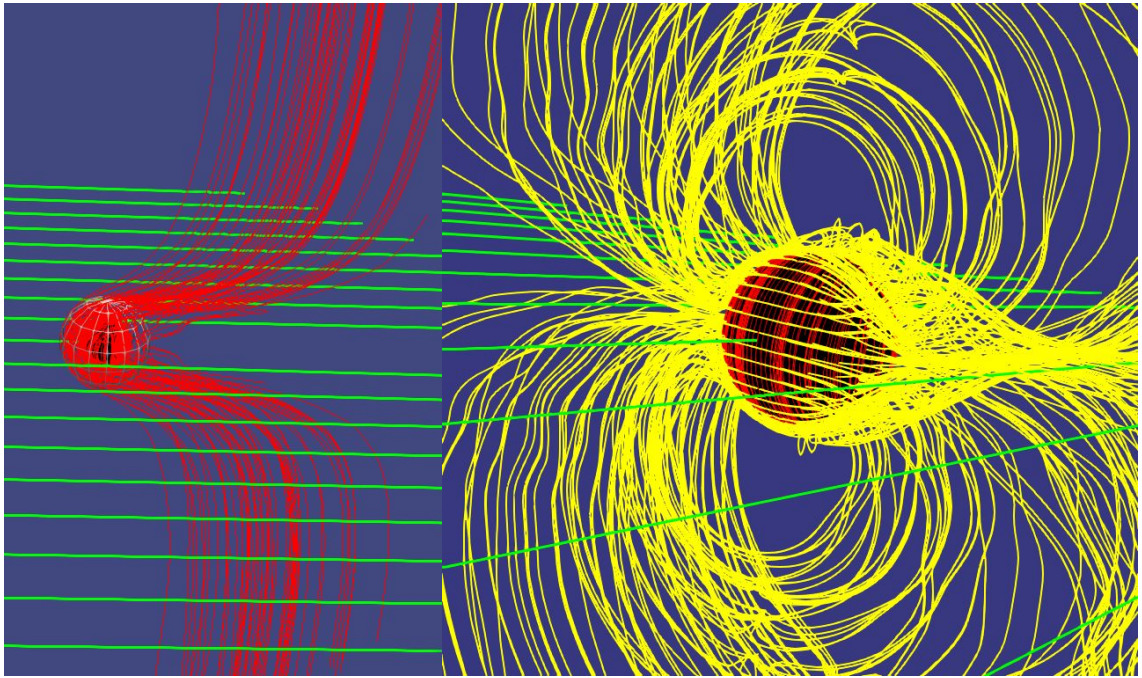
Experimental setup and parameters

- PLUTO RMHD module
- Spherical coordinates
- uniform external magnetic field in z-direction
- uniform pulsar wind in x-direction
- Simulation parameters:

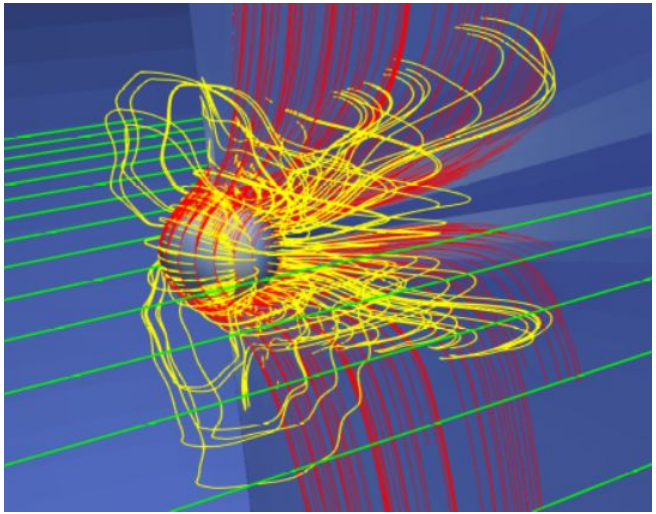
	SWSpeed [cm/s]	SWMagField [G]	SWDens [g/cm^3]	SWTemp [K]
Conductive	2.953×10^{10}	3.6	3.1×10^{-17}	5.0×10^{8}
Ferromagnetic	2.953×10^{10}	3.6	2.6×10^{-19}	5.0×10^{8}

Aim: Determine if pulsar planet emission is visible to current radiotelescopes

Conductive Planet - Electromagnetic field

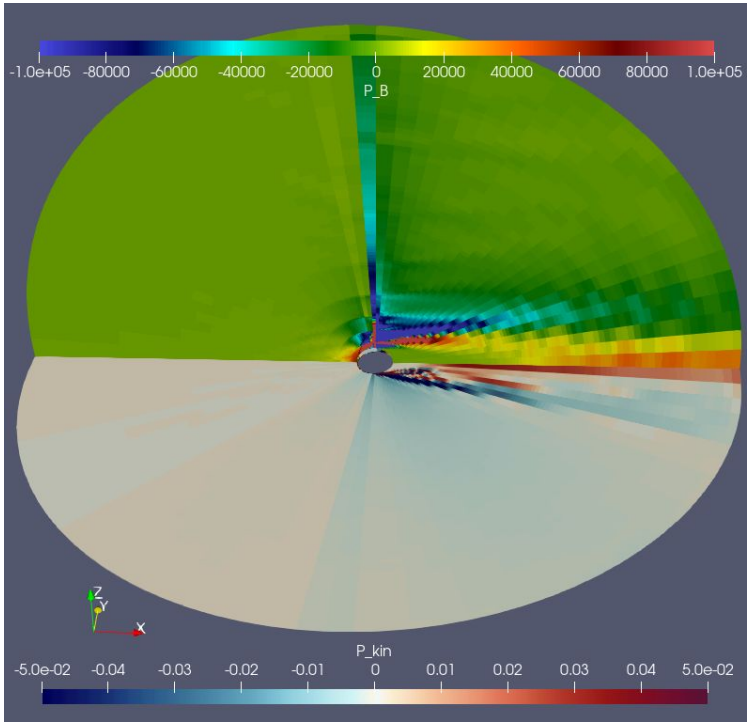


Magnetic field lines (red) and currents (yellow) at $\gamma = 5.8$



Previous results at $\gamma = 2.0$
R. Mishra et. al. (2023)

Conductive Planet - Radiation



➔ 2 power sources

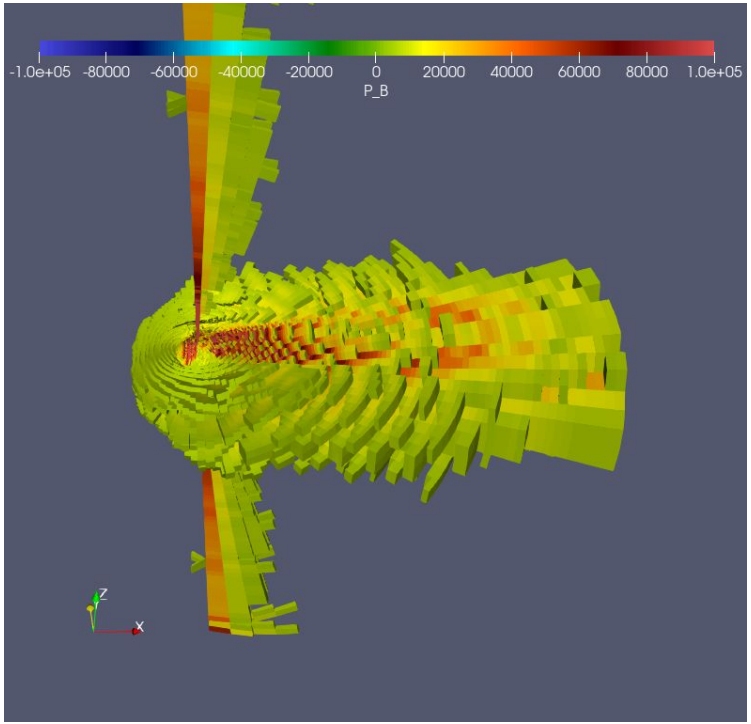
- dissipation of magnetic energy
- dissipation of kinetic energy

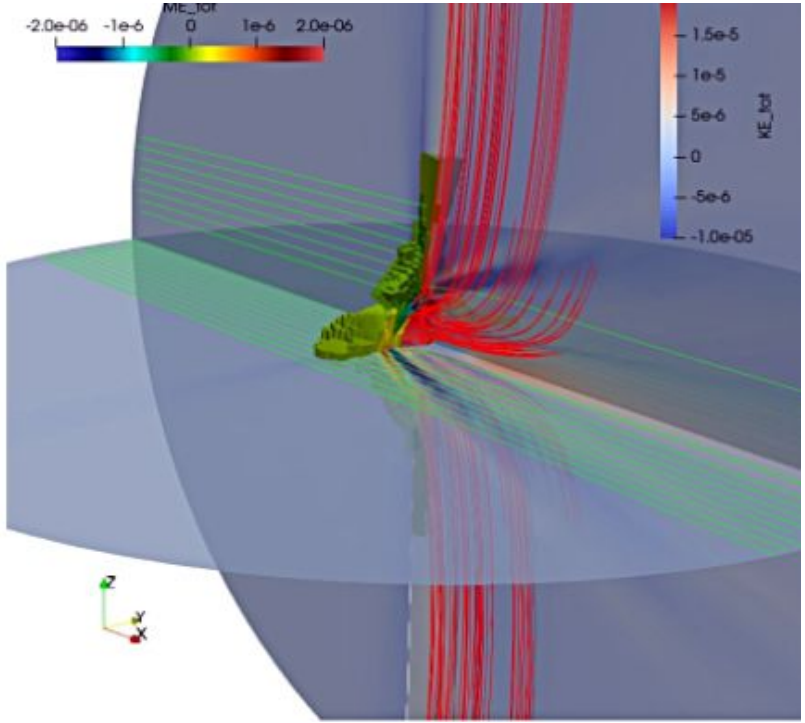
$$P_{kin} = \int_V \gamma^2 c\boldsymbol{v} \cdot \boldsymbol{\nabla}\left(\rho + \frac{p}{c^2}\right) + c\left(\rho + \frac{p}{c^2}\right)\boldsymbol{\nabla} \cdot (\gamma^2 \boldsymbol{v}) dV$$

$$P_B = \int_V \boldsymbol{\nabla} \cdot \frac{(\boldsymbol{v} \wedge \boldsymbol{B}) \wedge \boldsymbol{B}}{\mu_0} dV$$

Magnetic dissipation is 7 orders of magnitude larger

Conductive planet - Shape of emitting regions





Previous results R. Mishra et. al. (2023)

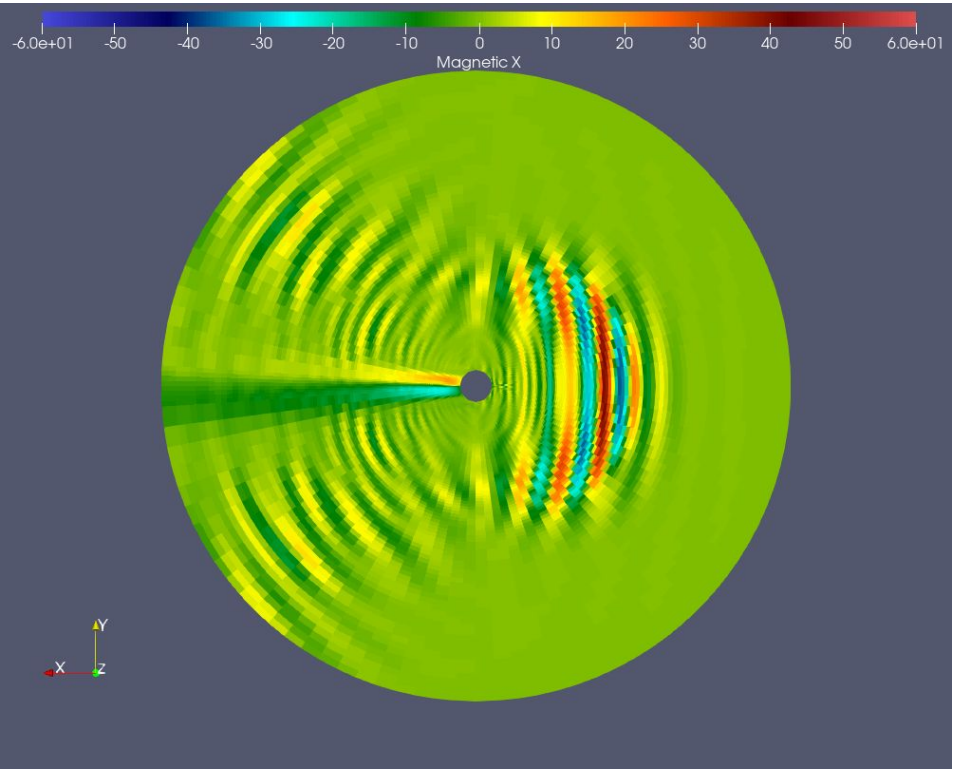
Conductive Planet – Radiation

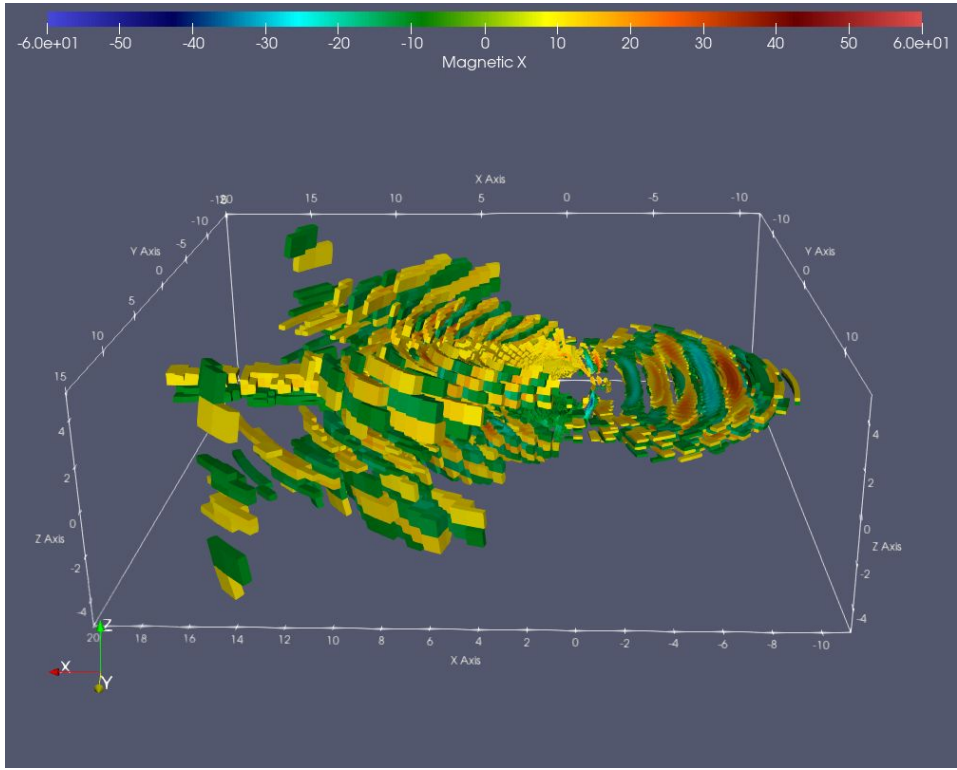
$\Phi_a(750)$ mJy	$\Phi_b(250)$ mJy	$\Phi_c(100)$ mJy	γ	P_{radio} W	$B_{p,max}$ G
$4.885 \cdot 10^3$	$4.396 \cdot 10^4$	$2.748 \cdot 10^5$	5.798	$1.05 \cdot 10^{20}$	3.6
$5.649 \cdot 10^{-2}$	$5.084 \cdot 10^{-1}$	3.177	2.0	$7.08 \cdot 10^{12}$	$2.5 \cdot 10^{-3}$

$\Delta\omega$ MHz	LOFAR (750)	MeerKAT (750)	SKA (750)
10.08	YES	YES	YES
0.007	NO	NO	NO

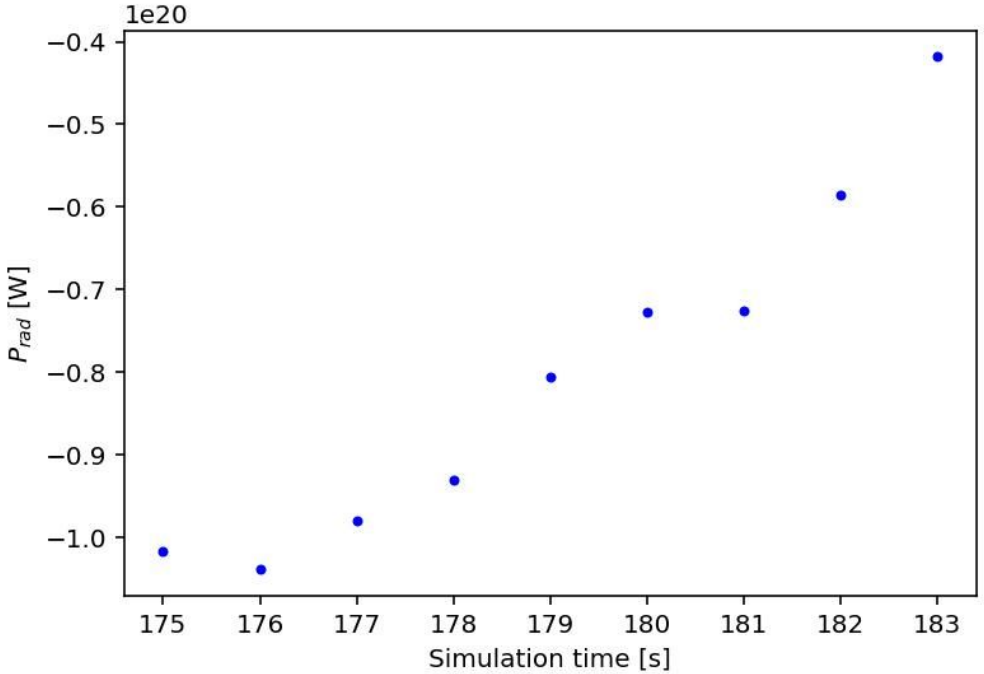
First row: New results
Second row: Results of Mishra et al. (2023) reanalyzed with new cuts

Extra slide - Ferromagnetic Planet Alfvén Wave

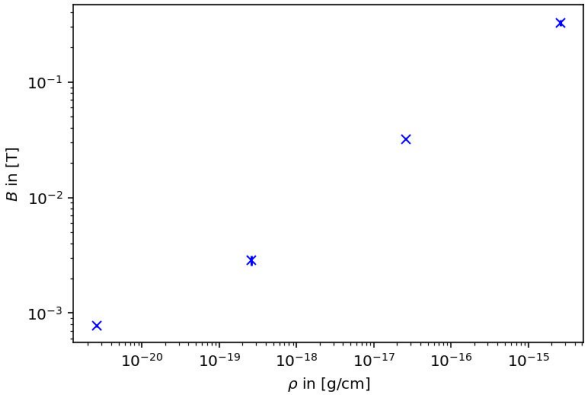


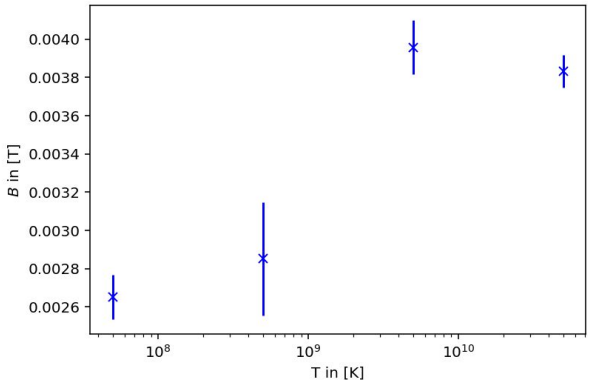


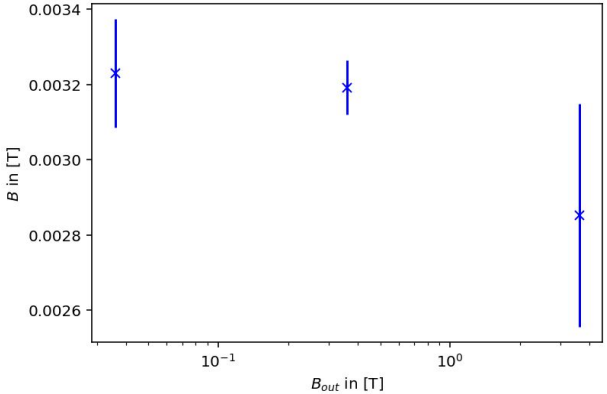
Extra slide - Ferromagnetic Planet power output



Extra slide - Wave analysis







Changes of wave amplitude when varying parameters

Extra slide - Clearer view of Alfvén wings