Drawing Atmosphere–Interior Connections
MANTLE RESISTIVITY AND ATMOSPHERE ESCAPE

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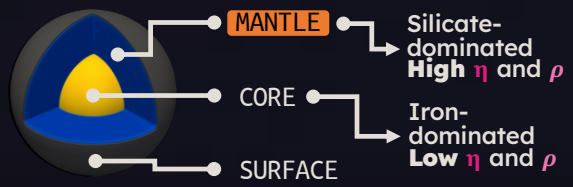
1 Planetary interiors contain layers with different resistivity.

electrical resistivity $\rho = \frac{1}{\sigma} = \mu_0 \eta$ magnetic diffusivity

electrical conductivity

Interior properties such as composition, temperature, and pressure determine resistivity. Overall, the core is conducting and the mantle is resistive.



Magnetic field lines diffuse quickly through material with high η.

length scale of region $t_D = \frac{L^2}{\eta}$ magnetic diffusion timescale

In the solar system, mantle η $[m^2/s]$ varies by orders of magnitude.

Earth: $\eta \sim 10^8 - 10^{10}$

Mercury: $\eta \sim 10^{13}$

2 How can η alter magnetic field line transport in exoplanets?

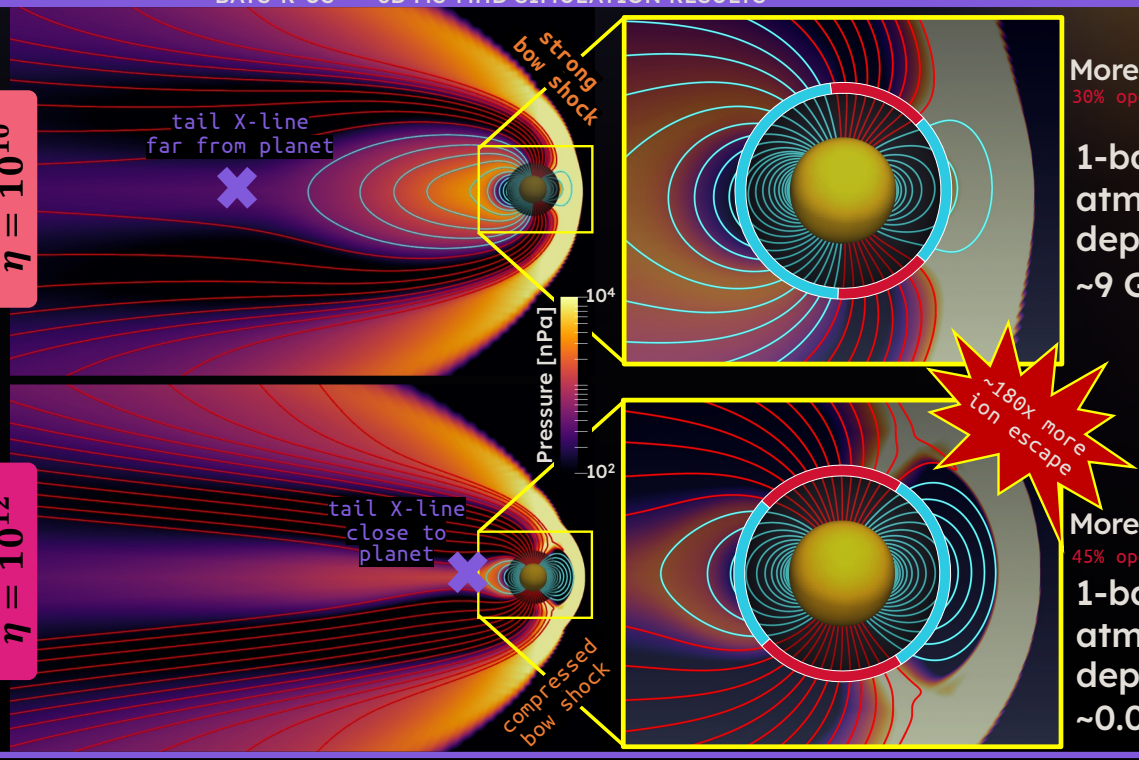
Will η impact atmospheric ion escape?

3 BATS-R-US[1,2] 3D MS-MHD SIMULATION RESULTS

Under extreme stellar conditions:
SW $P_{dyn} \sim 10^4$ nPa
Ex: near M-dwarf host

1. Planet $\vec{B}$ lines reconnect with $\vec{B}_{SW}$ on dayside [right]
2. Low η mantle impedes $\vec{B}$ transport to nightside [left]
3. $\vec{B}$ lines pile up in polar regions, bolstering bow shock

Magnetosphere topology:
- Tail X-line is located farther away
- Nightside bubble of closed field lines remains larger
- Fewer open $\vec{B}$ lines in poles
- $\vec{B}$ lines take longer to return to dayside, so dayside bubble is smaller



4 Conclusions:

1. Strong link between interior resistivity, stellar wind-magnetosphere interaction, and atmospheric ion escape
2. Planet with low mantle resistivity retains 1-bar atmosphere over full history of our solar system; high-η planet loses it ~100 times over

[1] Tóth, G., van der Holst, B. Sokolov, I.V., et al. 2012, JCP, 231(3), 870-903
[2] Ma, Y.J., Nagy, A.F., Russell, C.T., et al. 2013, JGR: Space Physics, 118, 321

The Space Weather Modeling Framework (SWMF) that comprises BATS-R-US is publicly available: https://github.com/SWMFsoftware/BATSRUS