Realistic models of star-planet magnetic interactions in close-in exoplanets : implications for Ohmic heating

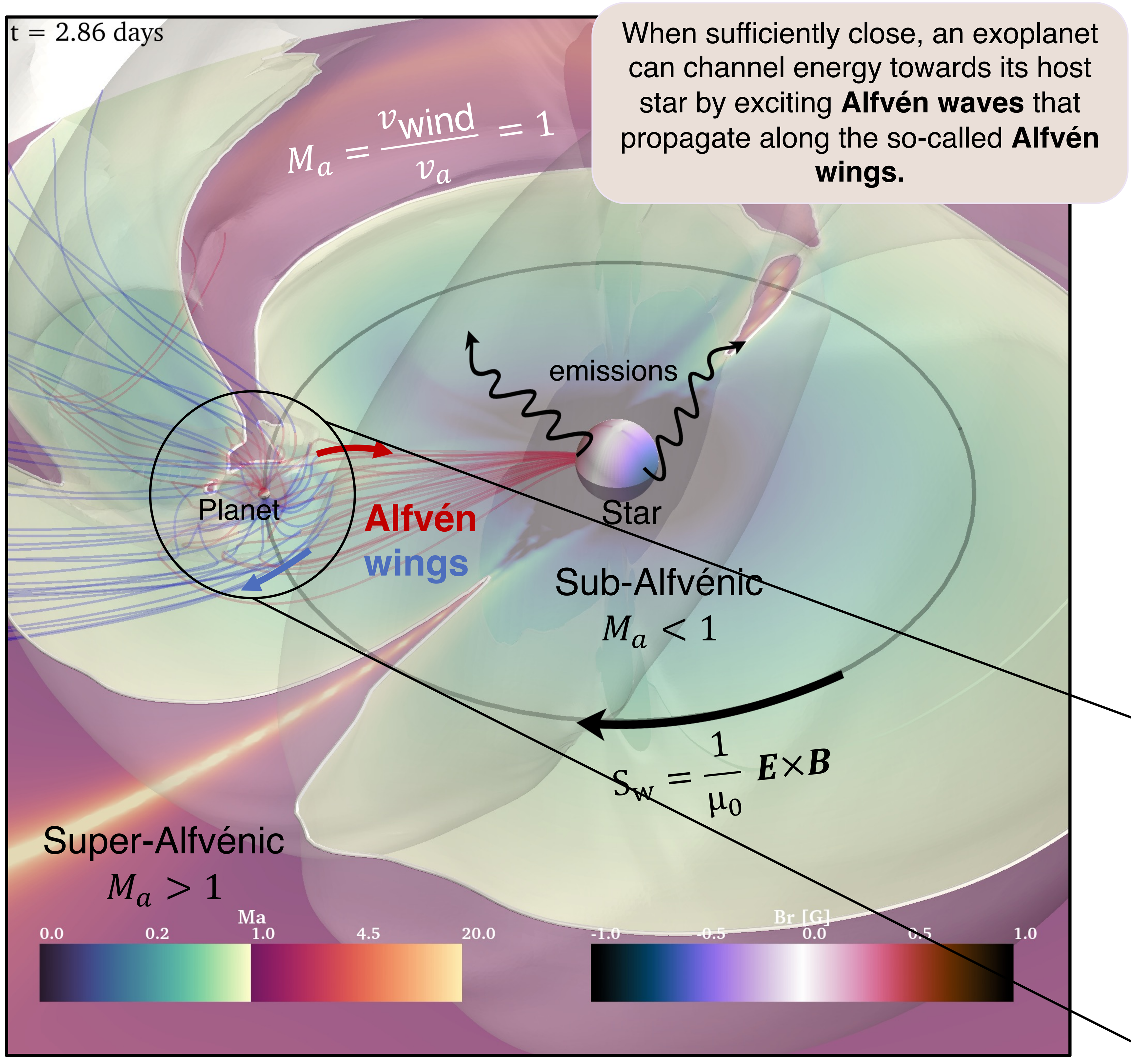
Clémence Gourvès, Antoine Strugarek & Arghyadeep Paul

AIM Paris-Saclay, CEA/IRFU Université Paris-Cité, CNRS/INSU, Gif-sur-Yvette, France

Context

Despite playing a crucial role in assessing dynamo theories and atmospheric retention, not a single **exoplanetary magnetic field** has been unambiguously characterised at the moment. Several promising investigations have focused on **star–planet magnetic interactions**, which provide a unique probe of the coupled magnetic properties of stars and their close-in exoplanets.

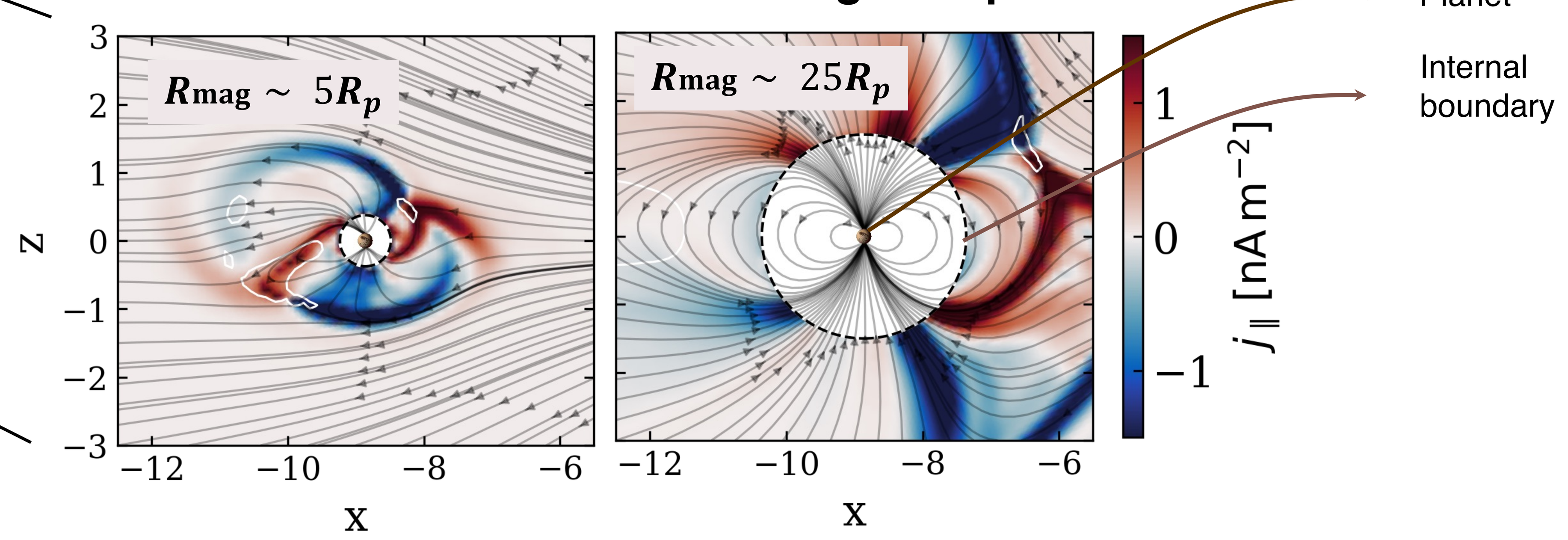
➢ We **model stellar winds of a close-in exoplanet system** to investigate conditions for star-planet magnetic interactions and their potential as an indirect probe of exoplanetary magnetic fields. As a first step toward assessing the consequences of these interactions for the planetary environment, we also present preliminary **estimates of Ohmic heating in the ionosphere**.



Modelling star-planet magnetic interactions

- **3D non-axisymmetric MHD model** of the stellar wind of a cool star : use of PLUTO[1] to resolve MHD equations in order to characterise stellar winds.
- WindPredict[2] model including the **planet self-consistently** and an implementation of the **rotating frame,** allowing the planet and the star to be fixed in the grid while properly solving for the orbital motion and stellar rotation.
- The **magnetosphere** of the planet is modelled as a simple dipole. Inside the internal boundary, the MHD equations don't evolve with time.

We are now capable of modelling 3D star-planet environment for different sizes of magnetospheres



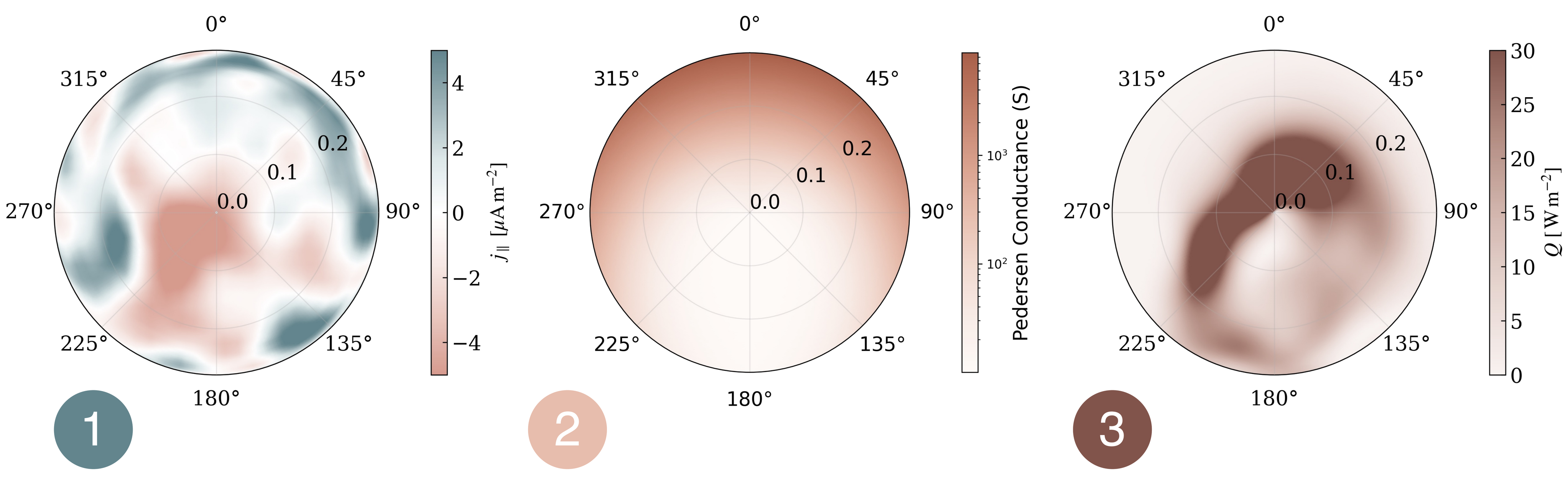
Parallel currents for two size of magnetosphere

In our models, we do not resolve the planetary atmosphere itself, but we can still **solve a 2D electrodynamic problem in the upper atmosphere.**

Ohmic heating of the ionosphere

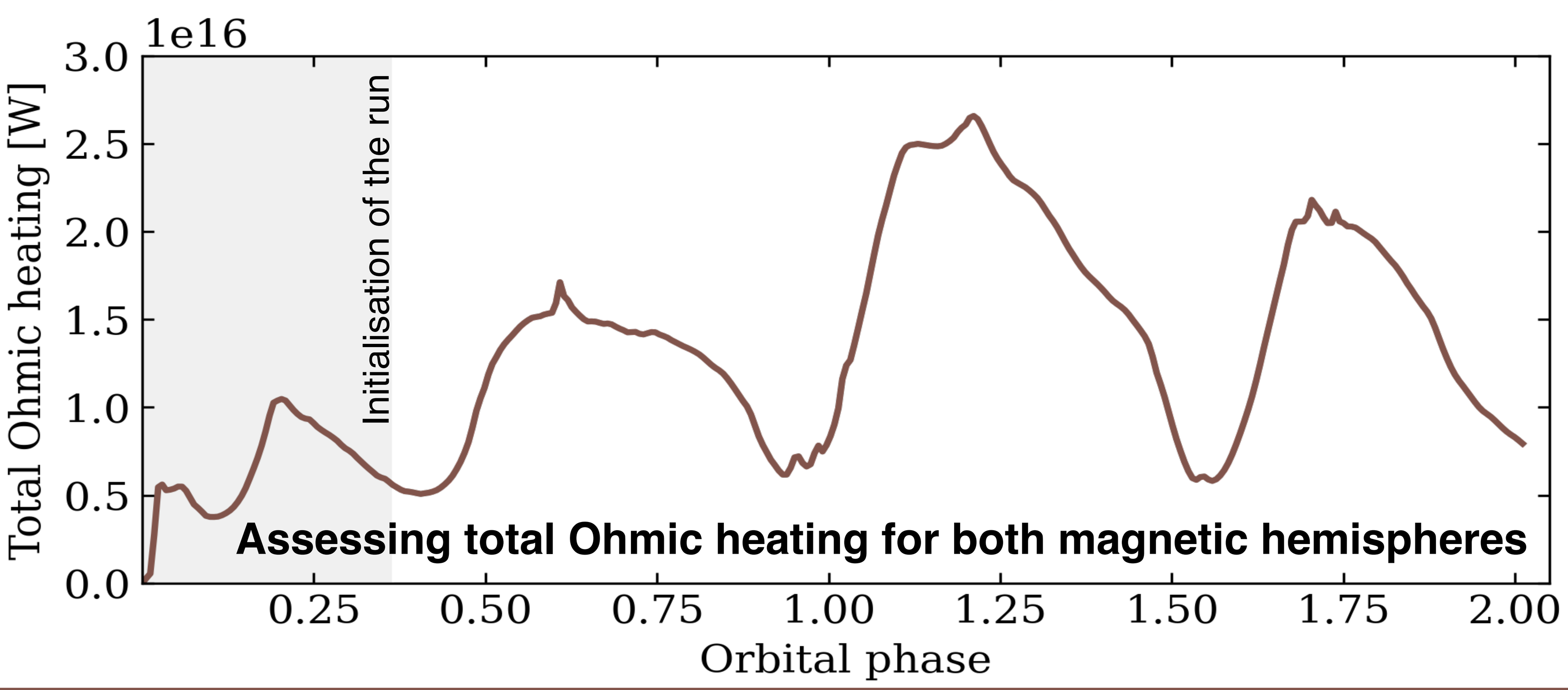
1. **Currents** on each magnetic pole of the planet, $j_\parallel = \boldsymbol{J} \cdot \frac{\boldsymbol{B}}{|\boldsymbol{B}|}$
2. We need to solve the general Ohm's law $\mathbf{J} = \bar{\bar{\sigma}}\,\mathbf{E}$, use of **non-uniform Pedersen conductivity** modelled with a Gaussian (from photoionization), maximum value of ~10^4 Simens[3]
3. **Leads to assessing Ohmic heating,** $\mathbf{Q} = \mathbf{J} \cdot \mathbf{E}$ **for each magnetic pole.**

Southern hemisphere



SH 3D movie

NH 3D movie



Conclusion

✓ We modelled the **stellar environment of a close-in exoplanet and its magnetosphere**. Novel rotating-frame approach: the astrosphere evolves while the planet remains fixed in the grid.

✓ We are now capable of modelling **different sizes of magnetosphere**

✓ We present preliminary estimates of the **total Ohmic heat** deposited into the ionosphere of the close-in exoplanet, considering day/night conductivity asymmetry

✓ The connectivity is modulated by the complex **magnetic topology** of the star as well as the intensity of the exoplanet's magnetosphere and present a **temporal and spatial variability**

Future Directions

❑ Parametric study to come in *Gourvès et al. (in prep)*

❑ Compare the model with observations of SPMI[4,5,6] by accounting for ZDI map of specific system

→Contact at clemence.gourves@cea.fr

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