Vortices in the magnetic tail of Uranus* (PS2.3 EGU24-18135)

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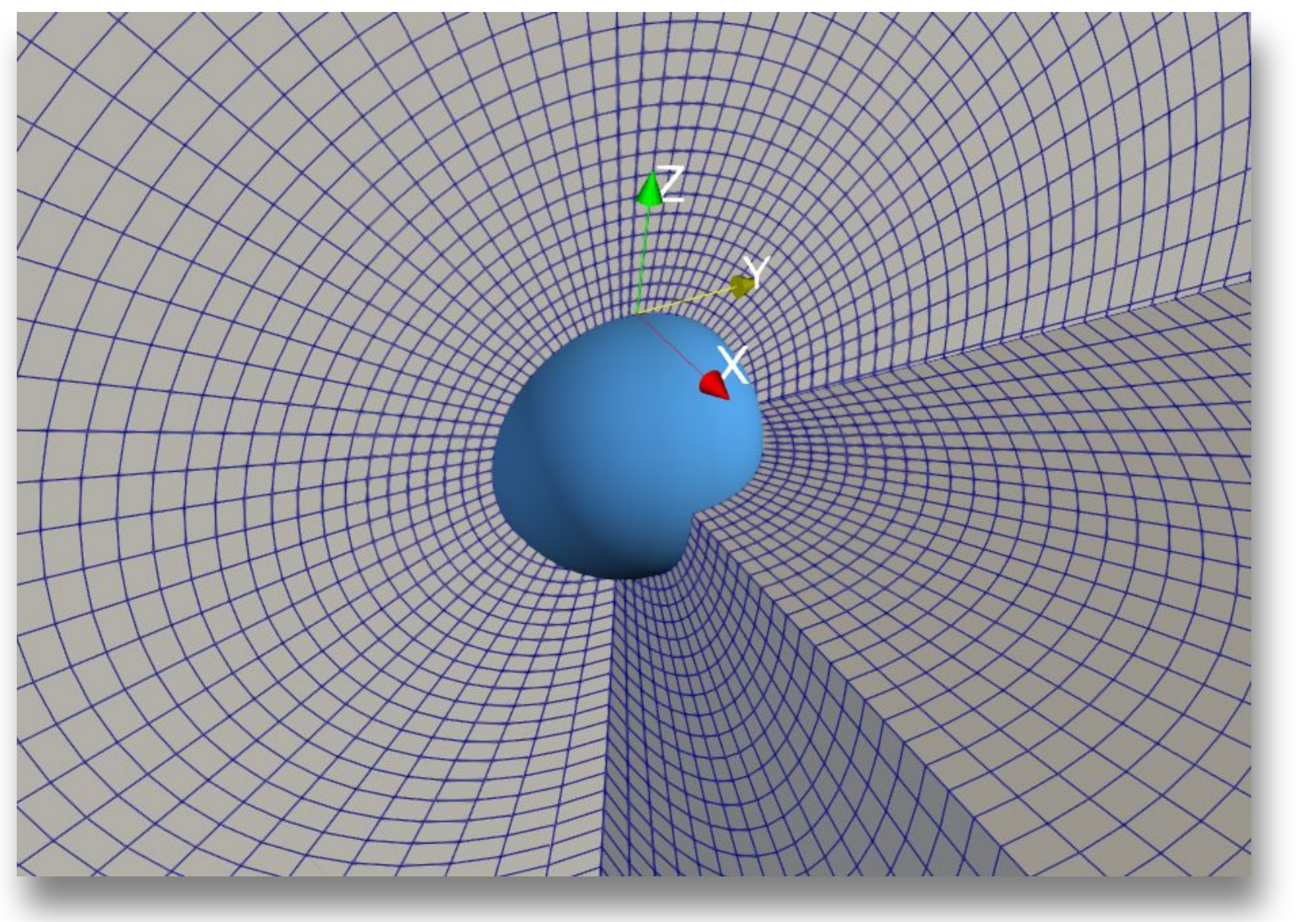
* NB: poster content differs with respect to the submitted title and abstract

Introduction: We present MHD simulations of the interaction of a magnetized solar wind with the magnetosphere of Uranus at solstice time with particular emphasis on the temporal evolution of the distant magnetic during a full planetary rotation. The structuring role of the interplanetary magnetic field (assumed to be oriented perpendicularly to the solar wind flow) appears to be much more crucial than previously assumed.



MHD simulations: We use the MPI-AMRVAC code to solve the ideal MHD equations (see Griton et al 2018 for details).
The simulation domain is delimited by two spherical surfaces at $10R_U$ and $1200R_U$ from the center of the planet. The numerical grid is a spherical one with resolution $(N_r,N_\theta,N_\phi)=(96,36,80)$ uniformly stretched in r and θ as shown in the figure (only innermost region shown).

Solar wind parameters:

We adopt relatively standard values near Uranus, with the interplanetary magnetic field $\mathbf{B}_{IMF}$ oriented perpendicularly to the Sun-Uranus axis (z-axis).

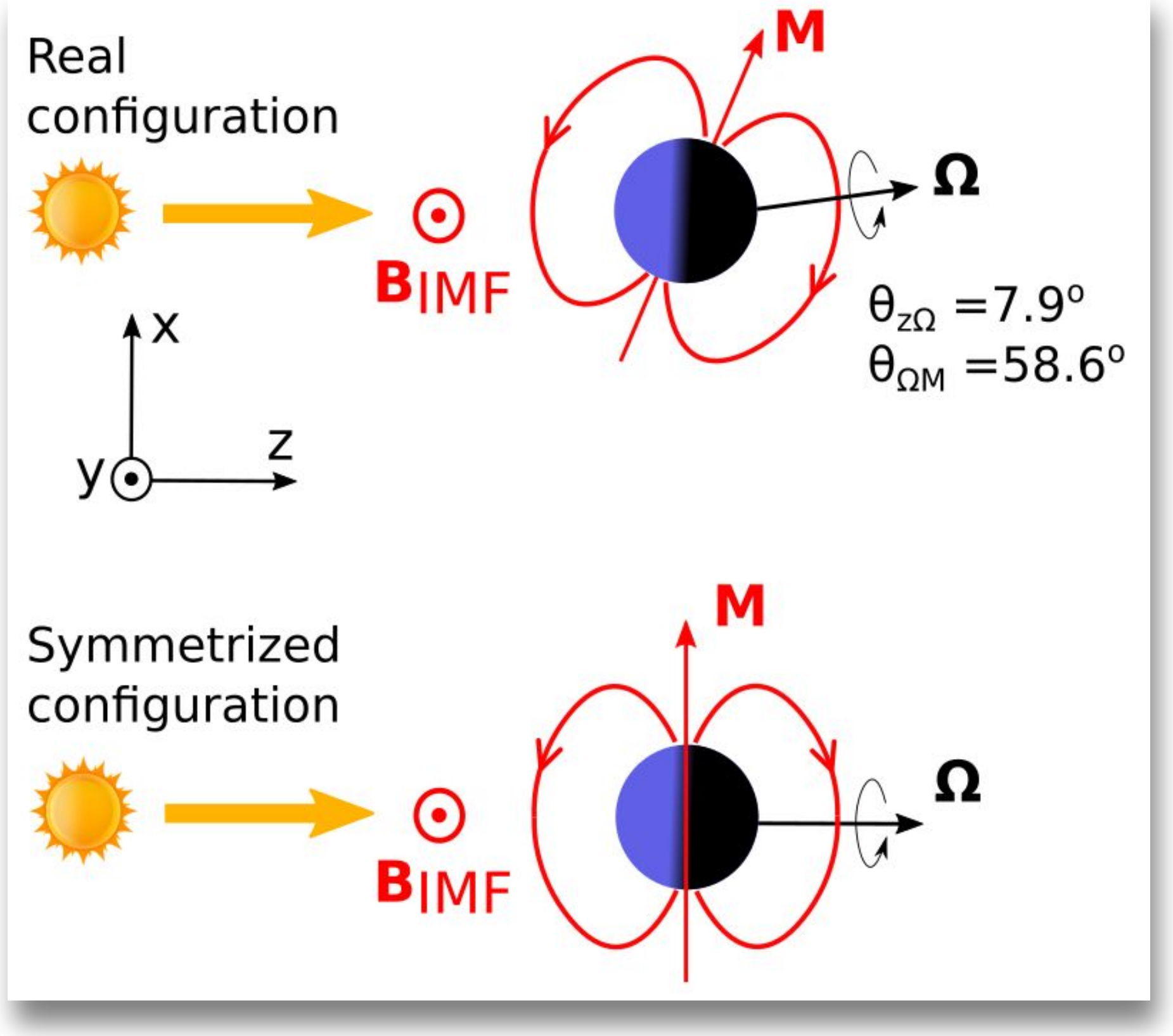
Wind speed (directed along $+z$ axis)	430 km/s
Magnetic field $B_{\rm IMF}$ (along $+y$ axis)	0.19 nT
Sound speed $c_s = \sqrt{\gamma p/\varrho}$ (with $\gamma = 5/3$)	12.6 km/s
Alfvén speed $c_A = B_{\rm IMF}/\sqrt{\mu_0 \varrho}$	18.5 km/s
$\beta = (2/\gamma)\, c_s^2/c_A^2$	0.56
Sonic Mach number M_s	34.1
Alfvénic Mach number M_A	23.2

Uranus data and orientation:

The planet's rotation period is 17.25h. The planetary field is a centered dipole of strength $M = 22.8\mu T\, R_U^3$ where R_U=25559 km is the planet's radius. Besides the "real" configuration at solstice time (top panel), we consider a symmetrized configuration (bottom panel).

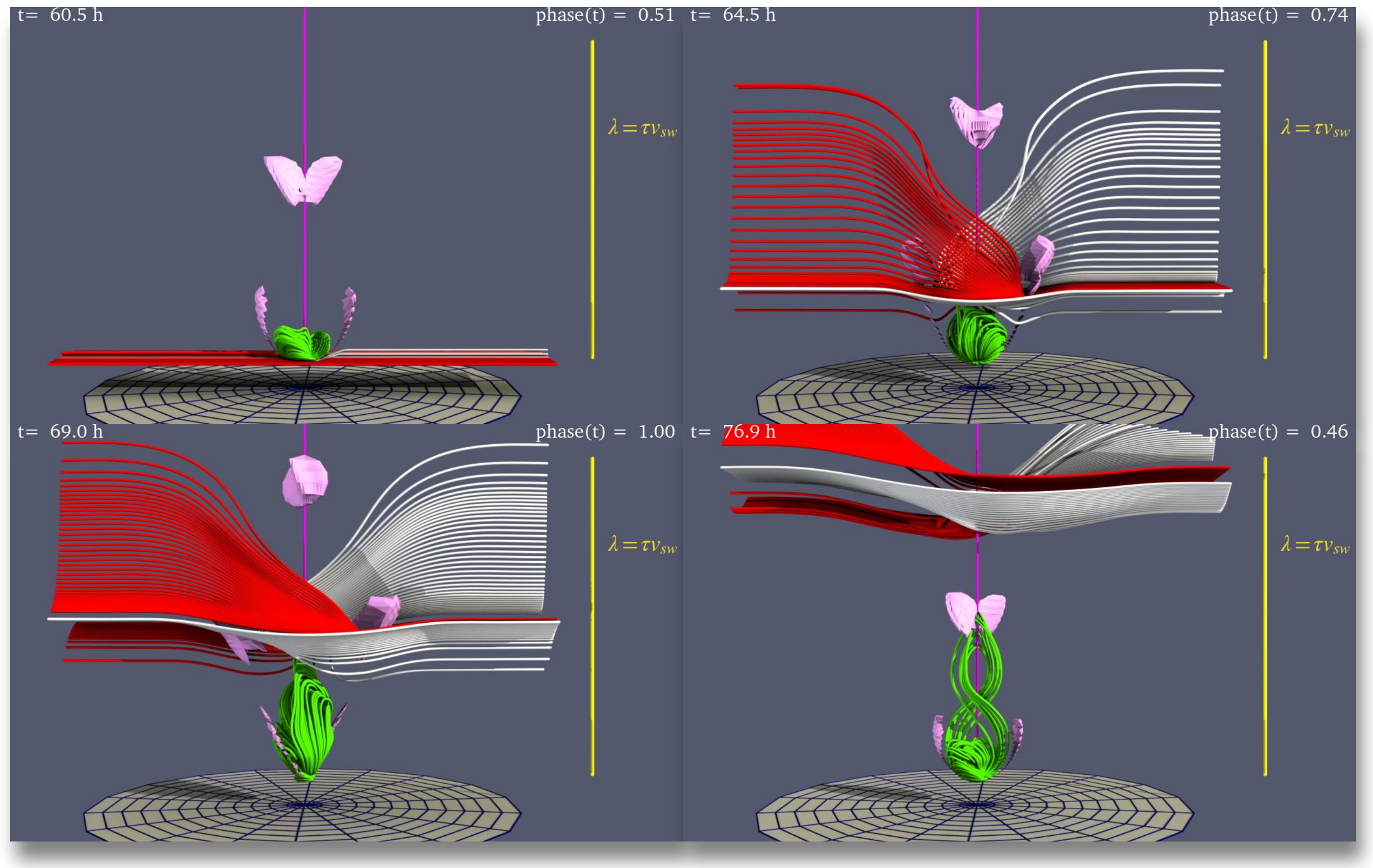
NB : With the above wind parameter, the distance covered by the solar wind during one rotation period is $\tau v_{sw} = 1044\ R_U$.

The orientations of **M** as shown in the figure correspond to a phase=0.25. As a reference, in the symmetrized configuration, **M** is parallel to $\mathbf{B}_{IMF}$ for phase=0.5, and antiparallel for phase=0 or 1.

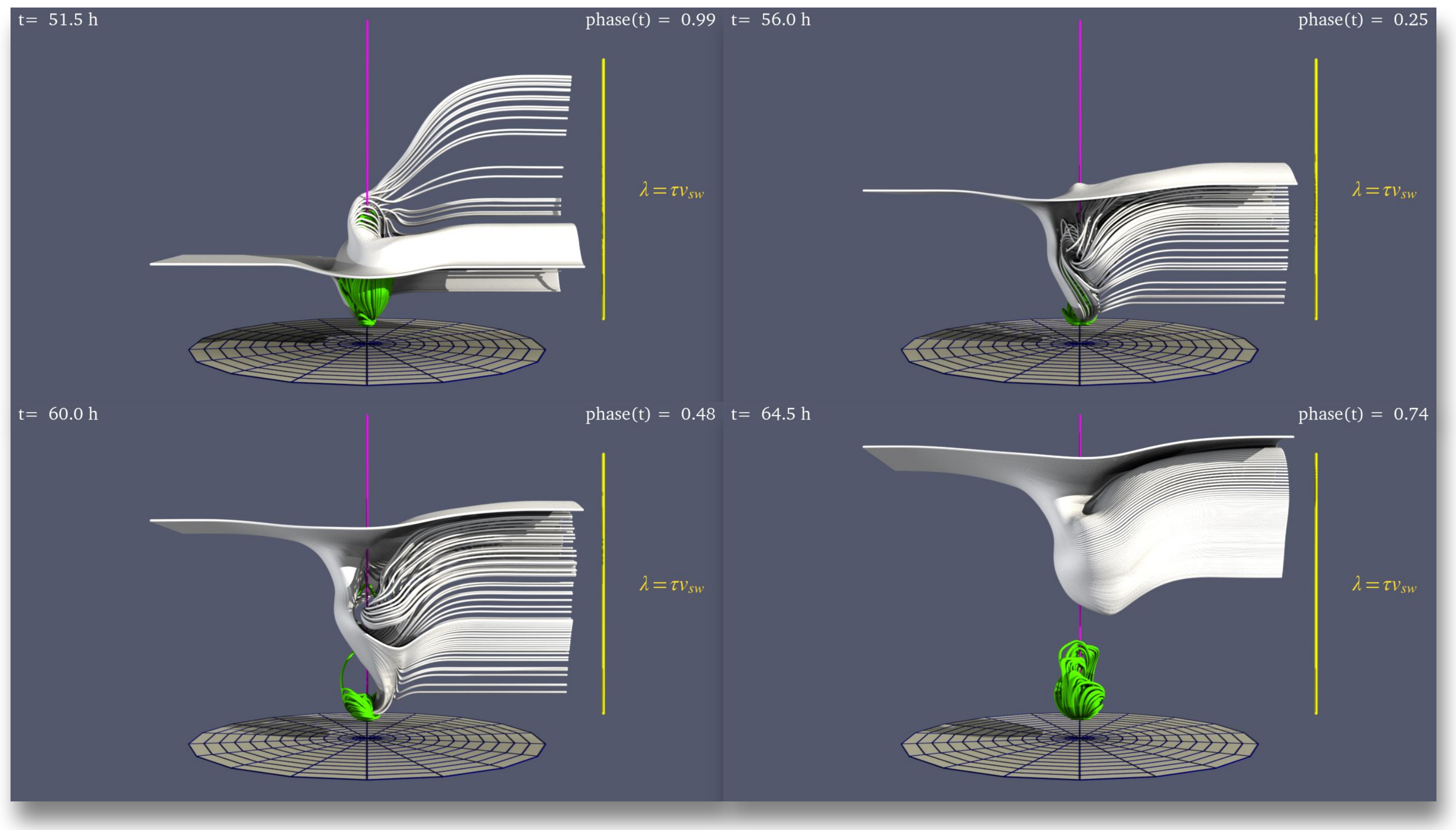


NB: For better visibility, transverse dimensions (with respect to z axis) are scales by a factor 2 in all figures.

Symmetrized configuration: Evolution of the closed planetary field lines (in green) during a planetary rotation period $\tau=2\pi/\Omega$. Their tailward extension increases gradually after phase=0.5 with the most strongly twisted lines reaching an extension of the order $\frac{1}{2}\tau v_{sw} = 522$ RU before being disrupted by reconnection.



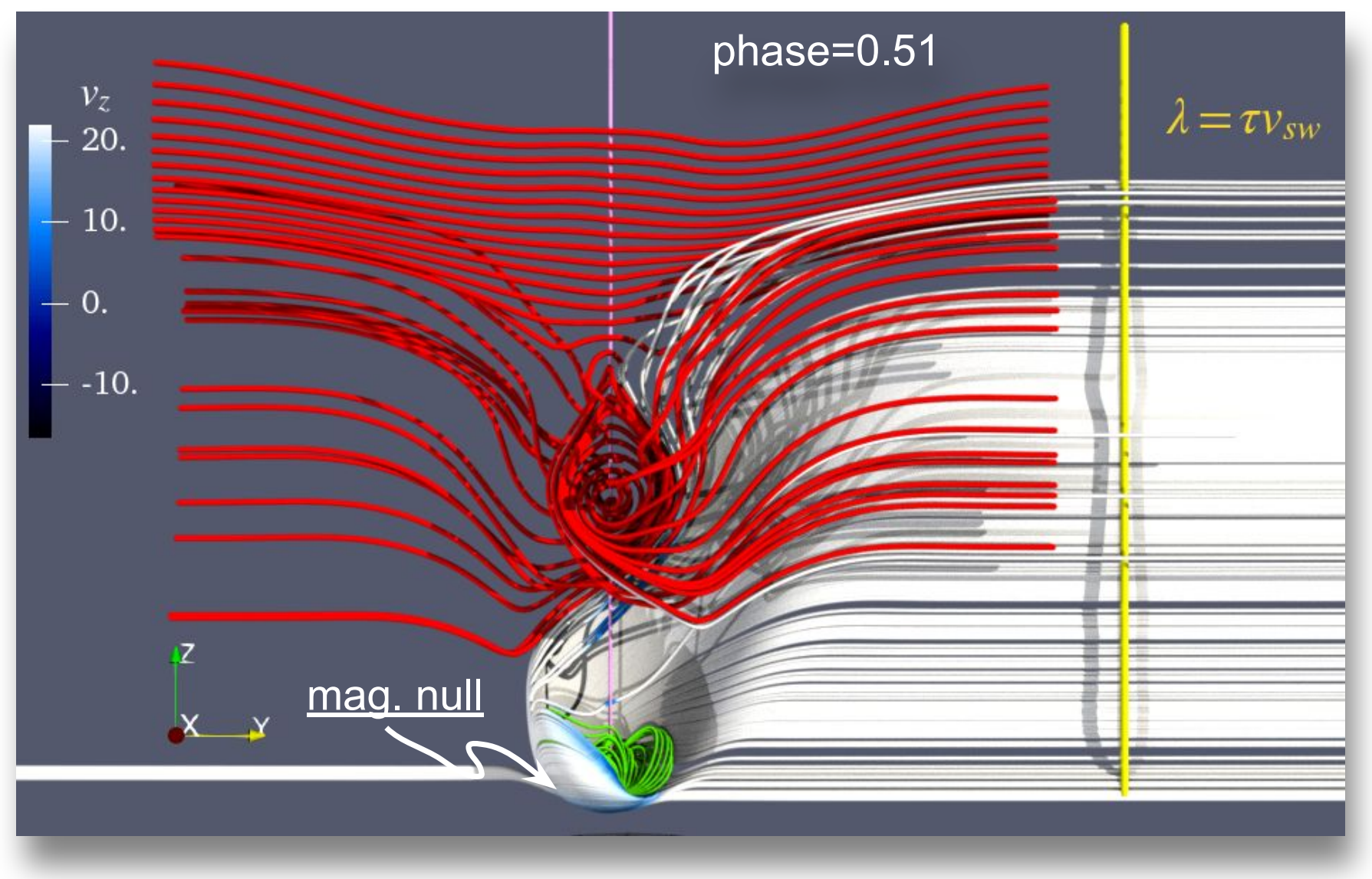
Small Alfvén speed regions are in pink, corresponding to null point regions and diffusive regions. White and red field lines are anchored in the solar wind (where ideal MHD applies) on the left and the right, respectively. They all reach the planet at phase=0.5 but, once disconnected from the planet (after phase=1), the opposing ends of the lines are sometimes advanced or retarded due to no-ideal effects.



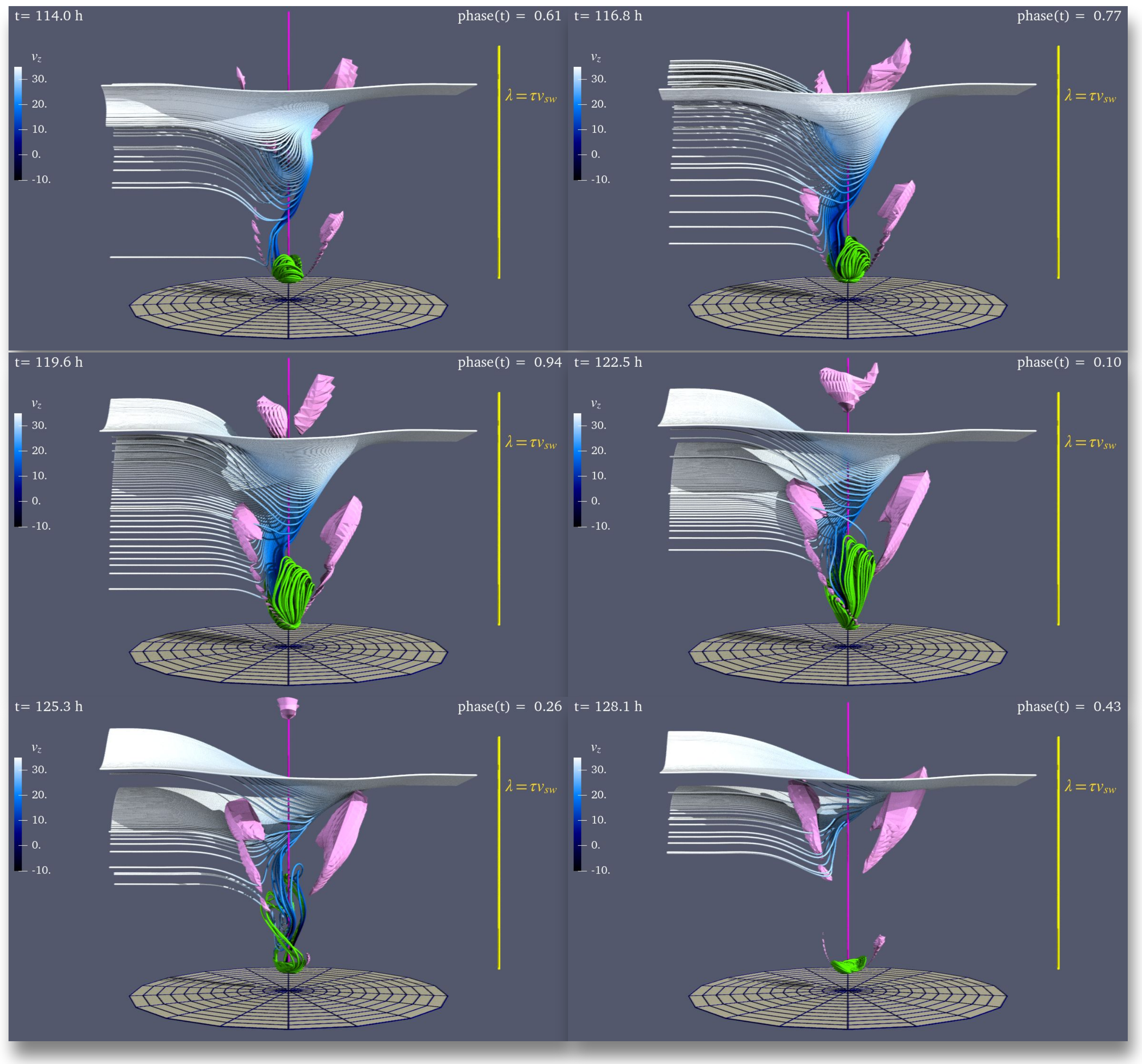
Field lines anchored in the solar wind evolve differently depending on phase at impact. For example, the lines in the above figure reach the planet at phase=0.75 and remain connected during $\sim\frac{3}{4}\tau$

NB1: Field lines detaching from the planet at particular times form magnetic loops.

NB2: The white lines emanate from near the external spine of a magnetic null.



Real configuration: Field lines start from fixed positions in the solar wind, 900 R_U downstream of the planet. The behavior is qualitatively the same as in the symmetrized configuration: (1) closed field lines are stretched tailward no more than $\frac{1}{2}\tau v_{sw}$ and (2) IMF field lines remain connected to the planet no longer than $\sim\frac{3}{4}\tau$.



Conclusions:

- Contrary to results from earlier works with no IMF (Toth et al (2004)) or a 10 times faster rotating planet (Griton et al (2018)), planetary field lines do not extend beyond $\sim\tau v_{sw}$ downstream of the planet.
- Planetary magnetic flux is stripped from the planet in a non-continuous way. Closed planetary field lines are gradually stretched after phase=0.5 with the most elongated (and twisted) ones becoming "detached" from the planet just before the next occurrence of phase=0.5.
- Large scale magnetic structures (of the size $\sim\tau v_{sw}$) including open magnetic loops are periodically released tailwards of the planet.
- Magnetic vortices, as described by Pantellini (2020), are ephemeral structures reaching a maximum tailwards extension $\sim \frac{1}{2}\tau v_{sw}$ just before phase=0.5.
- We conclude by noting that magnetic reconnection and strong non-ideal field line motions (namely in the vicinity of the pink regions) are central (see e.g. Li et al (2021)). In our simulations, they are due to numerical diffusion, which is possibly overefficient with respect to the real case.

References:

G. Toth et al, JGR Space Physics, 109, A11210, 2004.
L. Griton et al, JGR Space Physics , 123, 2018.
T. Li et al, Proc of the Royal Society A, Vol 477, 2021.
F. Pantellini, A&A 643, A144, 2020