A fully kinetic perspective of electron acceleration around a weakly outgassing comet

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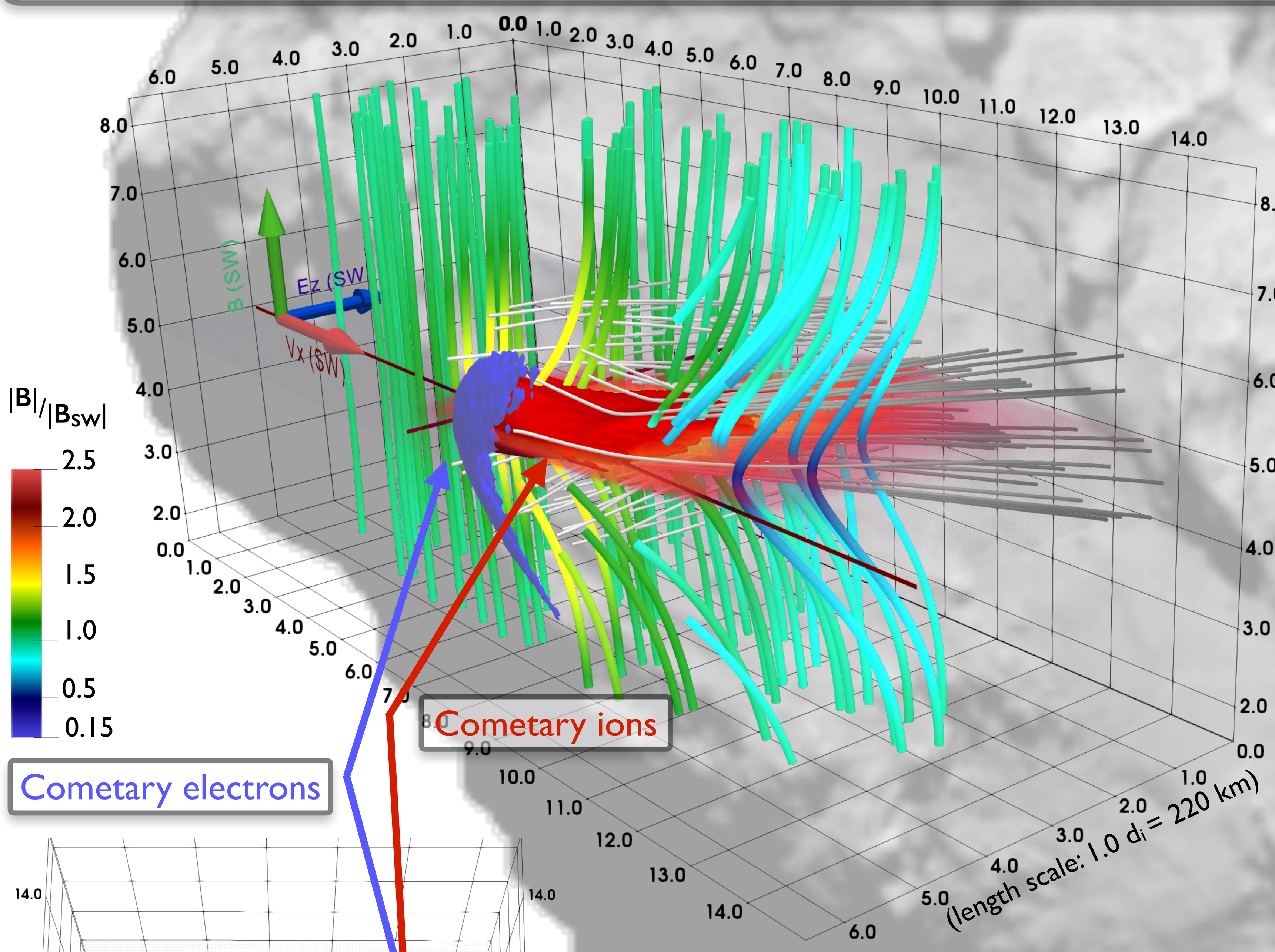
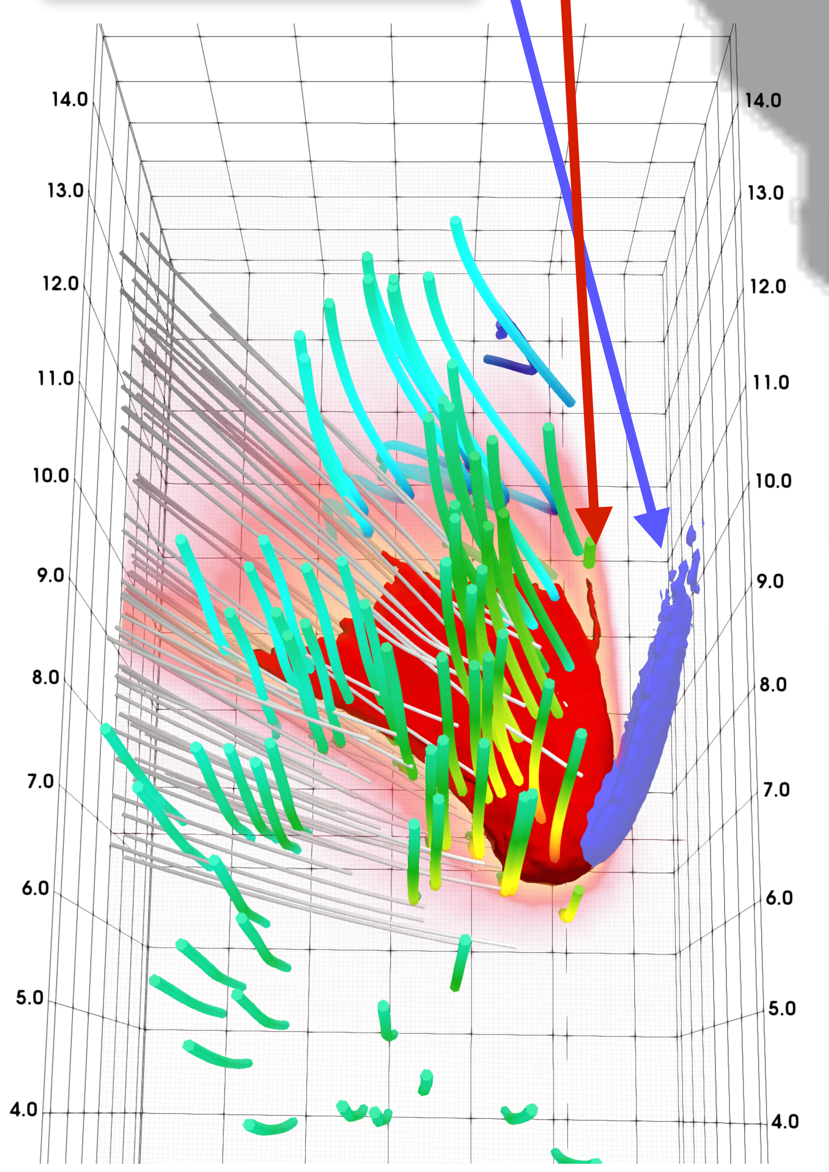
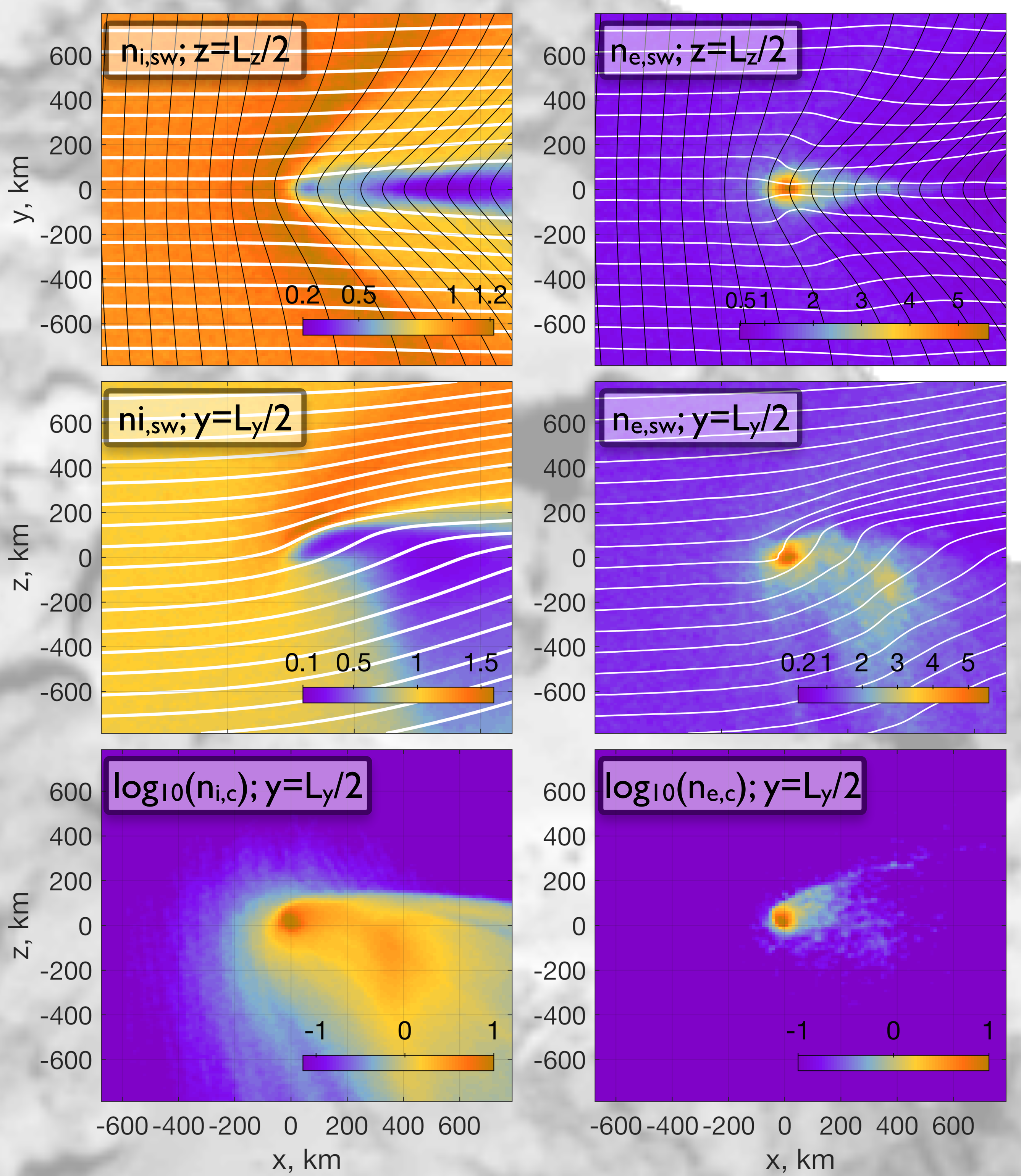
When a comet is sufficiently close to the Sun, the sublimation of ice leads to outgassing and the formation of a coma of gas and dust. Ionisation results in mass loading of the solar wind and magnetic field draping. Here we present **three-dimensional fully kinetic simulations** of the **solar wind interaction with comet 67P/Churyumov-Gerasimenko** at a very **low activity regime**, before collisions have any impact on the plasma dynamics. The interaction scales are well below the relevant ion gyroradii and **non-equlibrium electron distributions develop.** To first order, the dynamical interaction is representative of a **four-fluid coupled system** [Deca et al., PRL 2017]. We focus here on the **electron acceleration mechanisms** around the weakly outgassing comet [Divin et al., submitted].

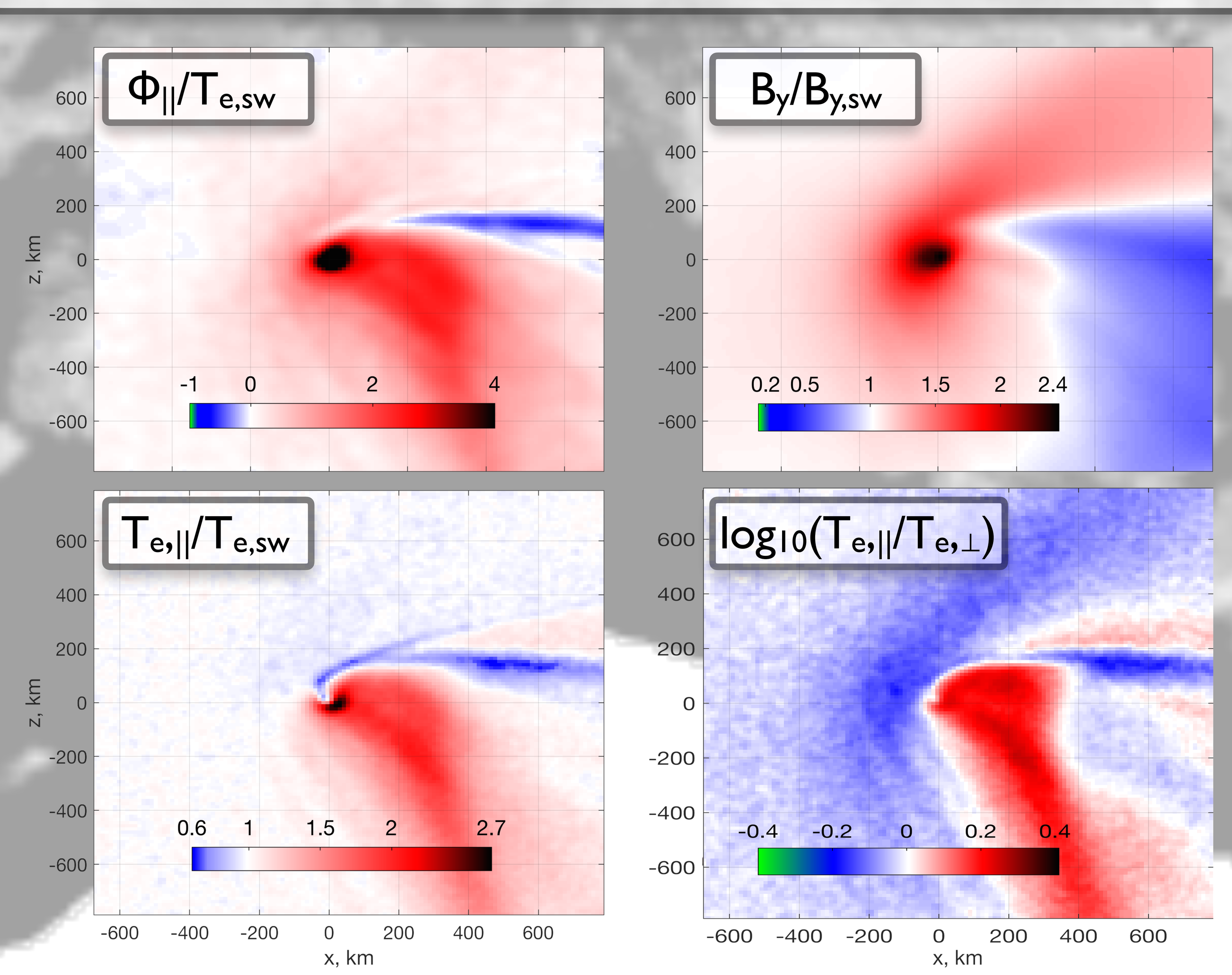




(Left and above). A 3D overview of the simulation, showing the **global morphology** of the interaction. In this low-outgassing regime no shock or diamagnetic cavity forms. The magnetic field drapes around the comet. We are in the **collisionless regime.**



(Above). Density profiles of the 4 plasma species included in the simulation, normalised to n_{sw}. Magnetic field lines are shown in black, velocity streamlines in white. Cometary ions accelerate along the convective electric field, cometary electrons are initially accelerated in the opposite direction. Solar wind **protons and electrons are decoupled** close to the nucleus and in the wake.



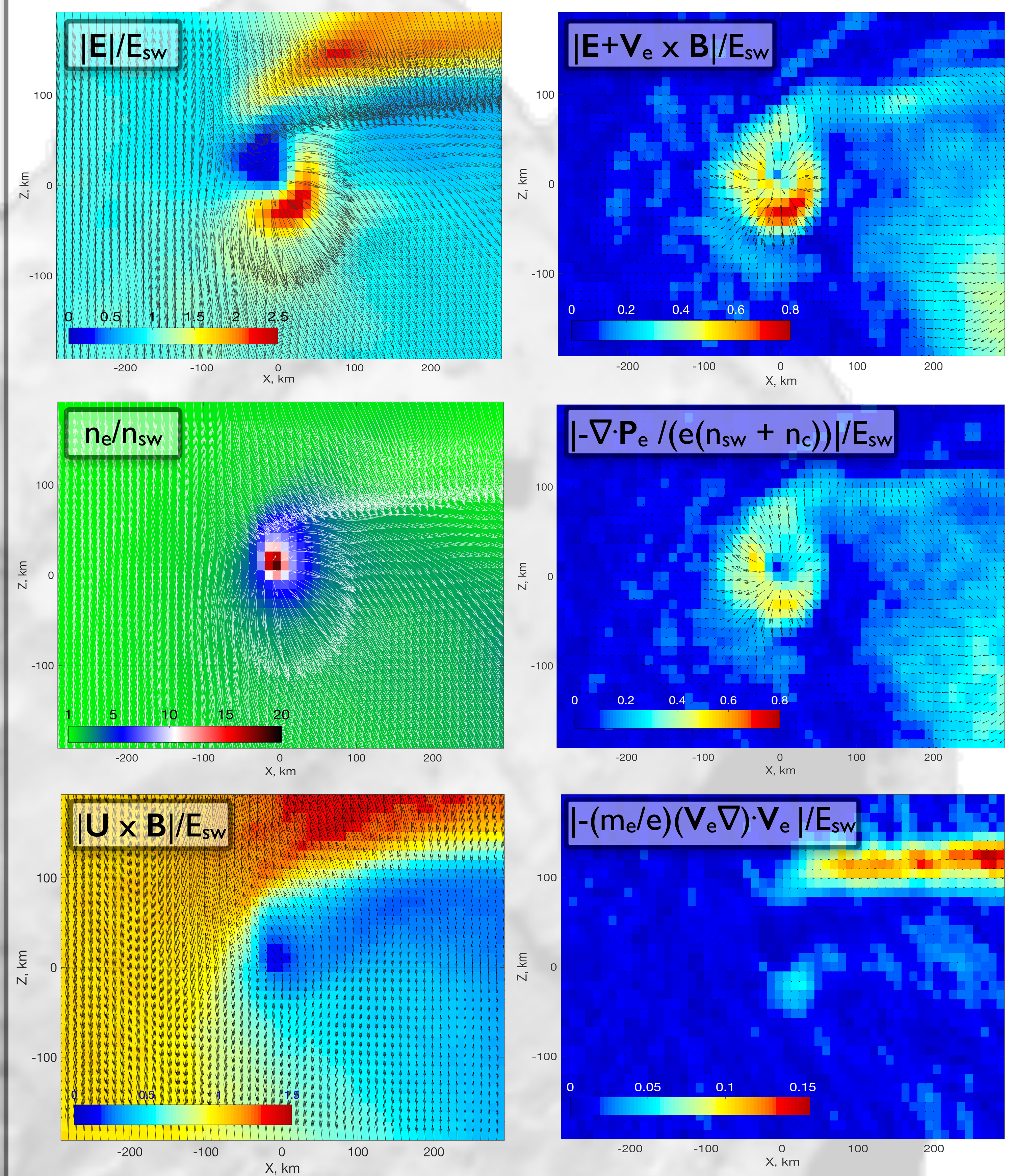
(Right). The spatial distribution of the effective acceleration potential, $\Phi_{||}$, is in good agreement with the parallel electron temperature, $T_{e,||}$, indicating a **strong acceleration** (of solar wind/ suprathermal) **electrons by the parallel** (ambipolar) **electric field.** Electrons with $T_e < T_{e,sw}$ are picked up and create a narrow region of $\Phi_{||} < 0$ at the edge of the wake. Areas where $T_{e,||}/T_{e,\perp}$ is small correspond to larger magnetic field values in the pile-up region.

Ohm's law

Ohm's law is distilled **directly from the electron dynamics in the simulation.** In the vicinity of the cometary nucleus, the balance changes between the different terms in the equation. Deciphering the **relative importance of each term allows to identify the driving physics in the various regions of the cometary plasma environment.** It shows us what happens to all ion and electron species, and why.

$$\mathbf{V_e \times B = U \times B - j \times B} / (e(n_{sw} + n_c))$$

$$\mathbf{E + U \times B = j \times B} / (e(n_{sw} + n_c)) - \nabla \cdot \mathbf{P_e} / (e(n_{sw} + n_c)) - (m_e/e)(\mathbf{V_e} \nabla) \cdot \mathbf{V_e}$$



- **Close** to the outgassing nucleus the **electron pressure gradient dominates.**
- At sub-ion scales, **the total electric field is a superposition of the solar wind convective electric field,** where electrons are frozen-in, **and the ambipolar electric field.** The latter accelerates electrons parallel to the magnetic field and is the source of/provides feedback to the electron pressure gradient that balances the Ohm's law perpendicular to the magnetic field.
- The role of **electron inertia** is **negligible** to balance the electric field.

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