Kinetic Simulations of High-Field Fusion Plasmas

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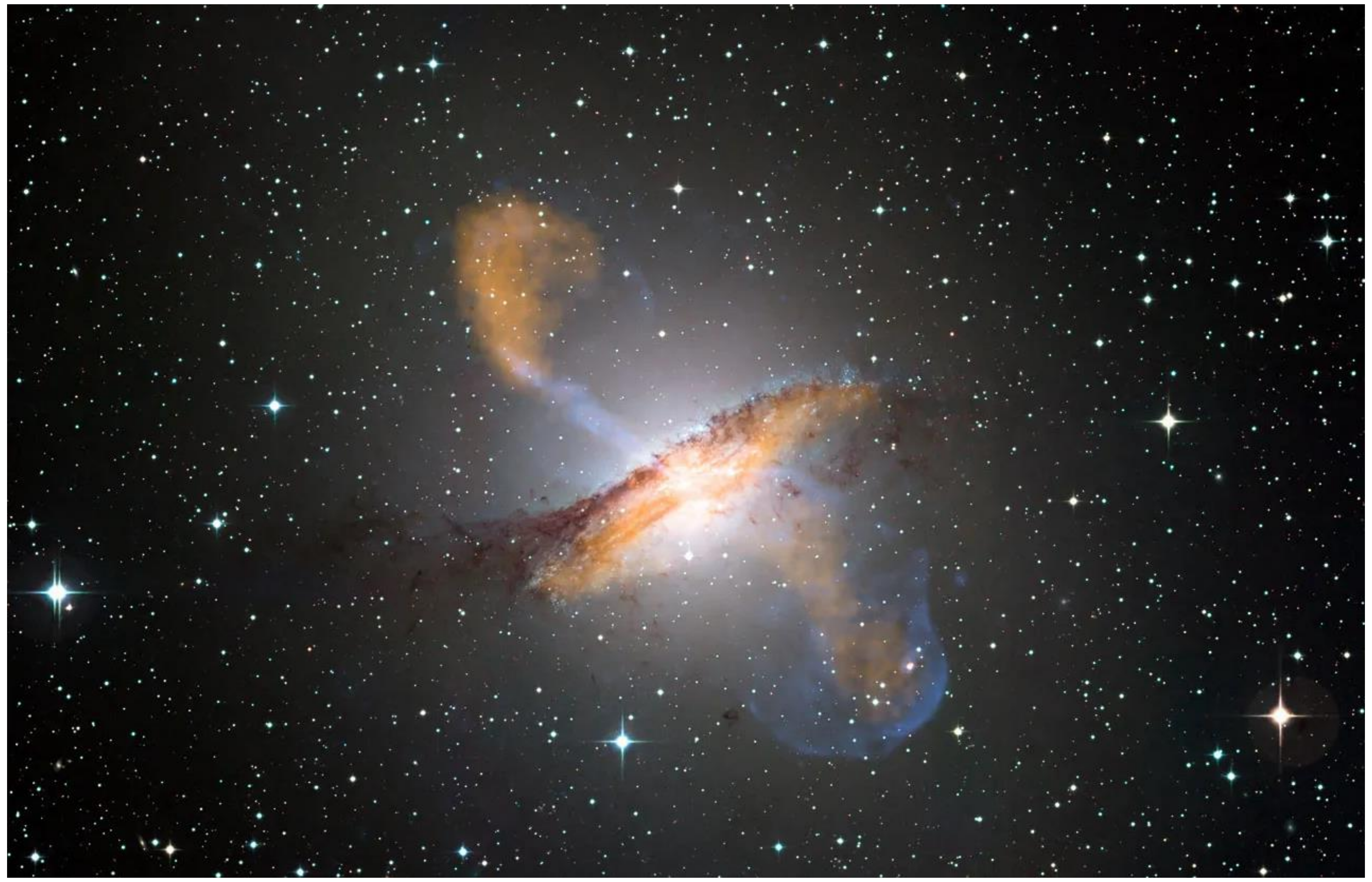
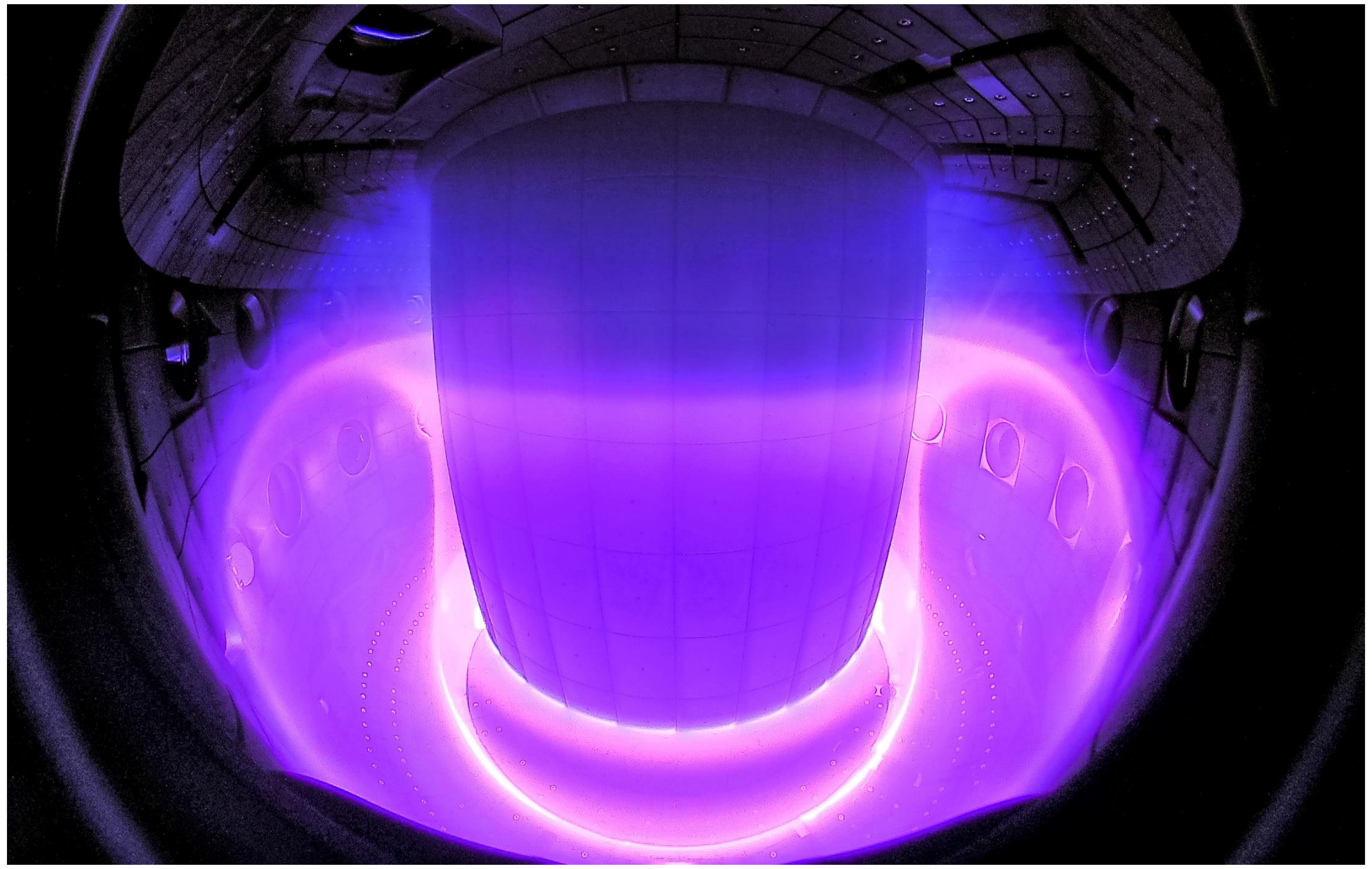
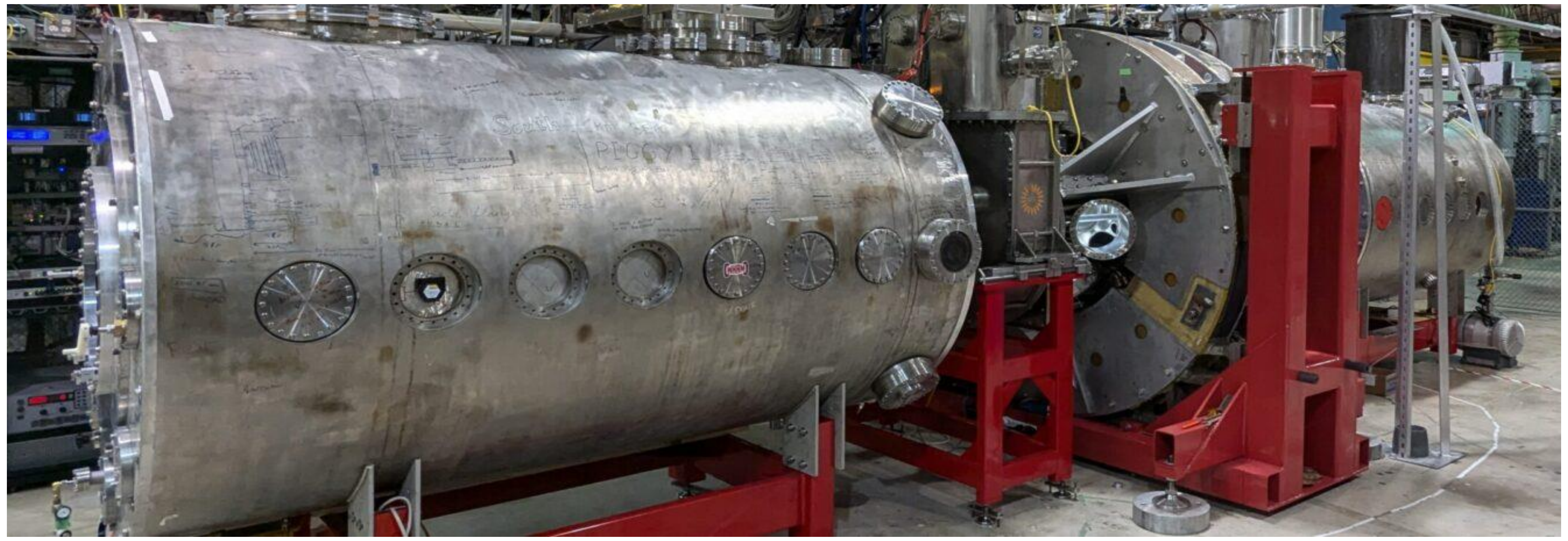
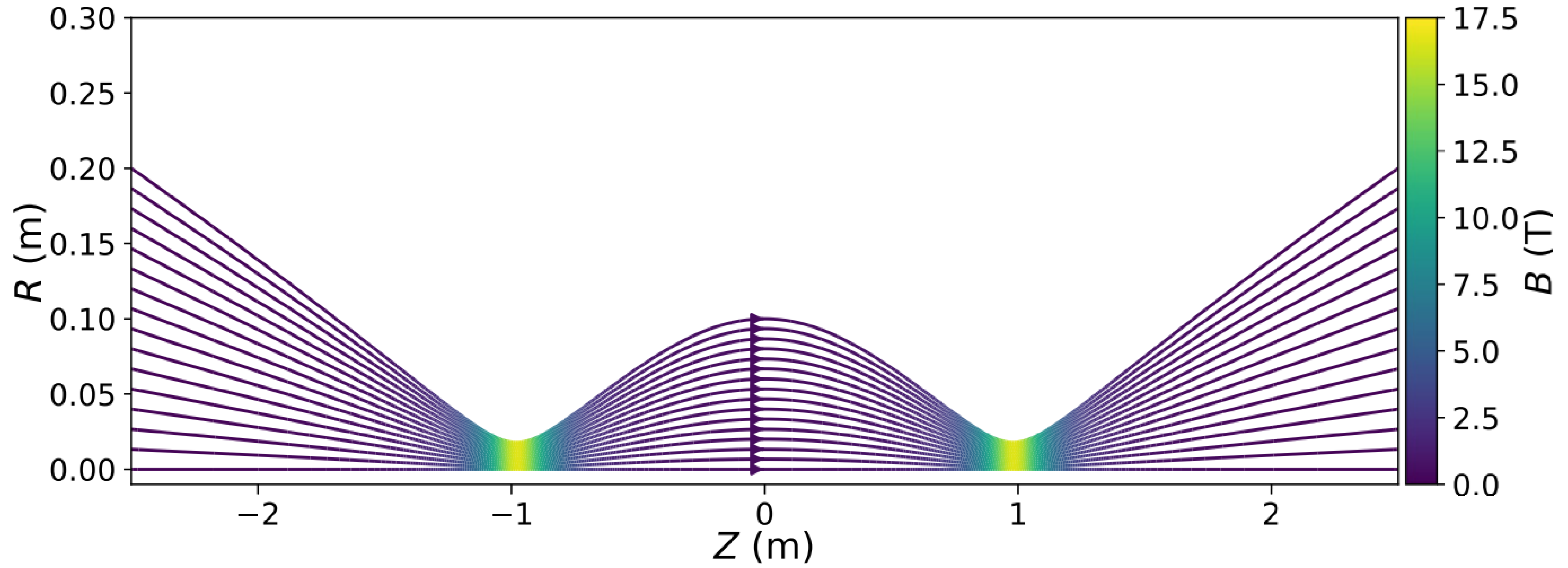
Why study highly magnetized plasmas?

Astrophysical plasmas	Fusion plasmas
	

High-field plasmas offer fusion potential, but vast-scale separations pose challenges

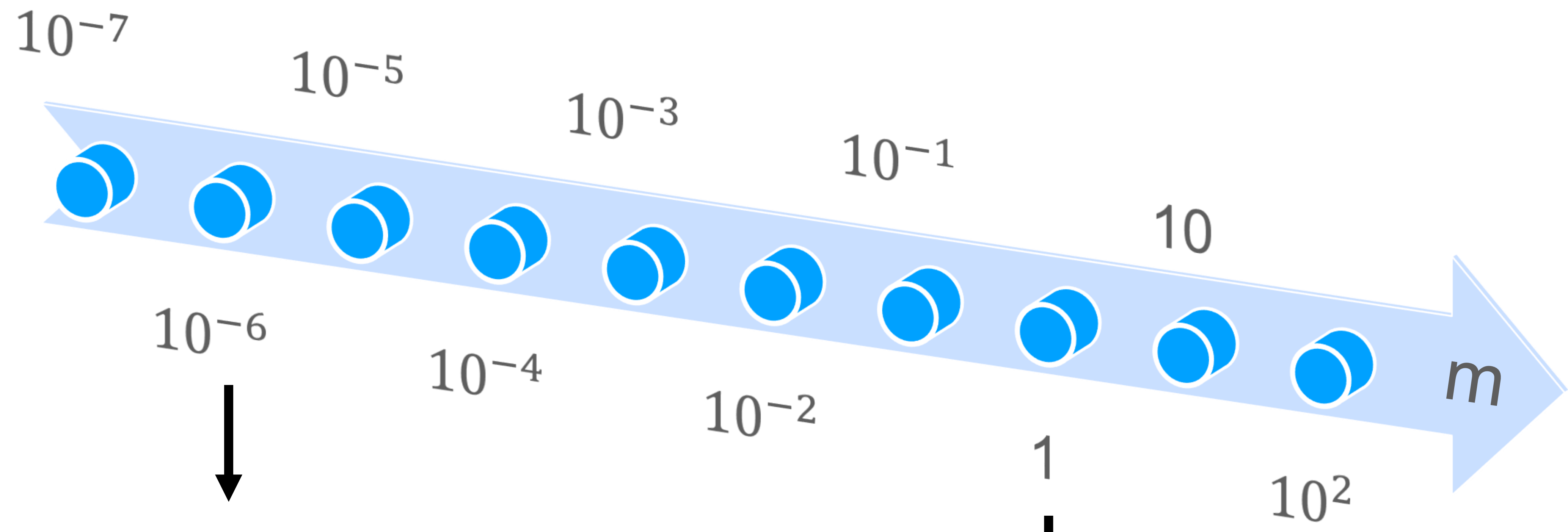
WHAM, a high-field magnetic mirror for fusion



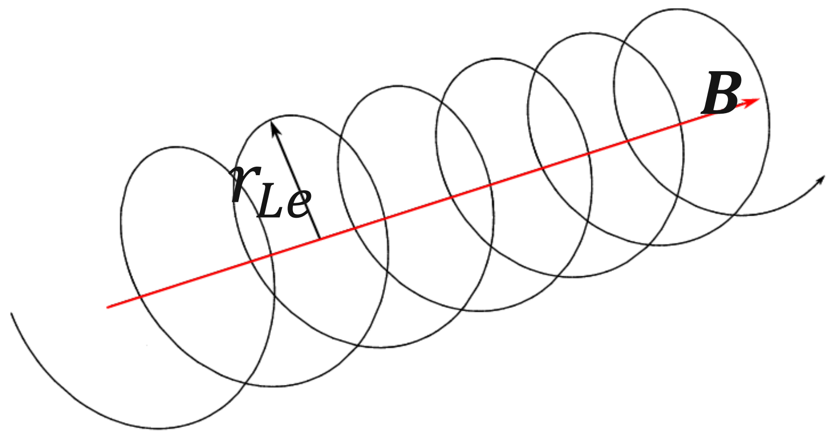


High-field fusion relies on kinetic simulations. However…

Challenges:
Complexity
Non-linearity
Interplay across vast scales



WHAM - Larmor radius r_{LE}

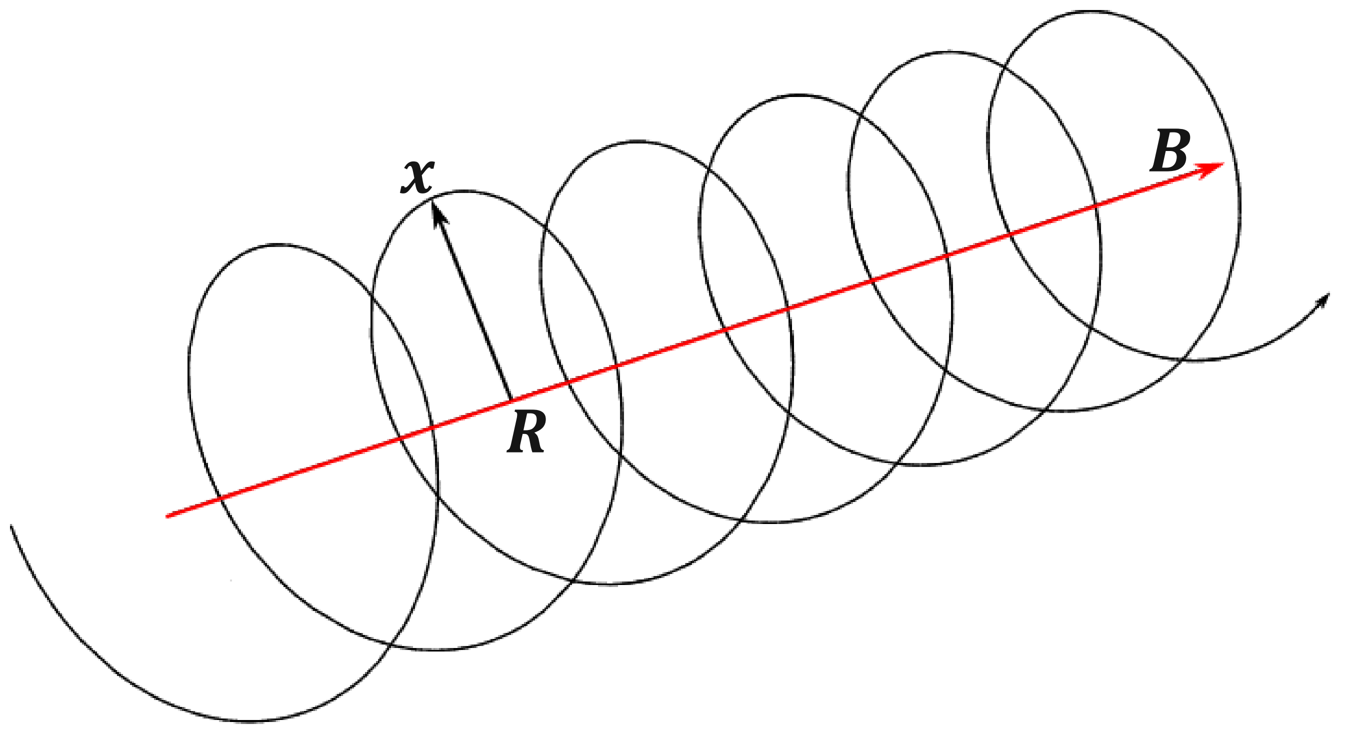


WHAM - distance between coils L

We'll develop efficient high-field kinetic simulations based on the GCA

TÉCNICO LISBOA

Average out Ω with the Guiding Centre Approximation (GCA)



$$\frac{d\boldsymbol{R}}{dt} = \frac{\boldsymbol{u}_\parallel}{\Gamma} + \boldsymbol{v}_E + \boldsymbol{v}_c,$$

$$\frac{du_\parallel}{dt} = \frac{q}{m}E_\parallel + u_\parallel \boldsymbol{v}_E \cdot (\boldsymbol{b}\cdot\nabla)\boldsymbol{b} + \Gamma\boldsymbol{v}_E \cdot (\boldsymbol{v}_E \cdot \nabla)\boldsymbol{b},$$

$$\frac{d\mu}{dt} = 0,$$

Avoiding resolving Ω, leads to a computational gain

WHAM – important scales

	Magnetic Field [T]	Gyro- -frequency [s/rad]	Plasma Frequency [s/rad]
Formula	B	$\frac{1}{\Omega} = \frac{m_e c}{eB}$	$\frac{1}{\omega_{pe}} = \sqrt{\frac{m_e}{4\pi n_e e^2}}$
Centre z=0m	0.86	7e-12	3e-12
Coils z=±1m	17	3e-13 →	6e-12

20^{D+1} times speed up