VLASOVIA, Strasbourg, Thursday, July 25th

Interplay between Kelvin-Helmholtz and Lower Hybrid Drift instabilities

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This project AIDA receives funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 776262.

Interplay between Kelvin-Helmholtz and Lower Hybrid Drift instabilities

Instabilities along a current sheet:

- Velocity shear —> Kelvin-Helmholtz
- Density gradient —> Lower-Hybrid drift instability

Interplay between Kelvin-Helmholtz and Lower Hybrid Drift instabilities

Instabilities along a current sheet:

- Velocity shear —> Kelvin-Helmholtz —> fluid scales
- Density gradient —> Lower-Hybrid drift instability —> kinetic scales

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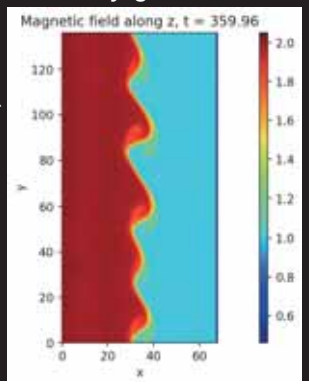

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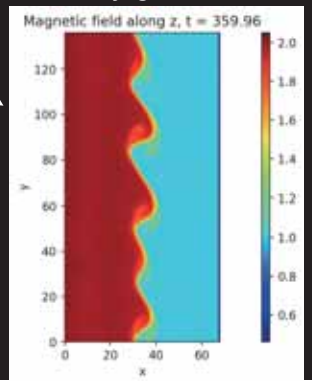
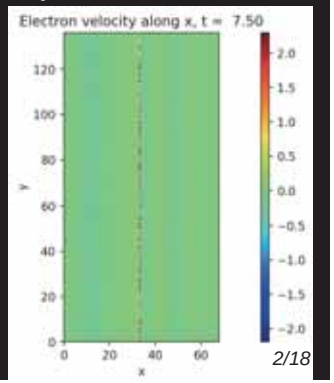
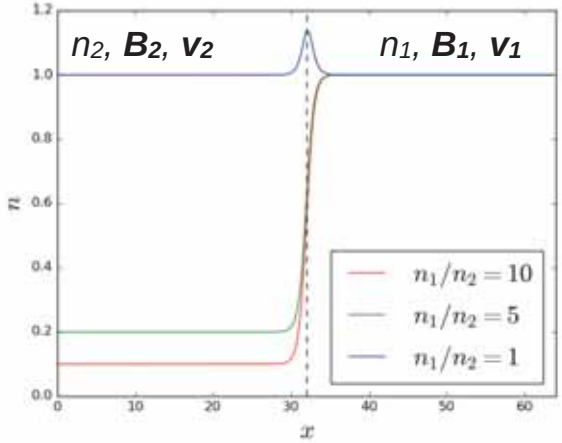




Simulations: initial setup



$m_i/m_e = 25$ $B_1/B_2 = 0.5$

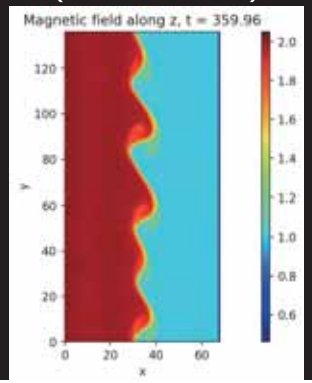
- full PIC simulations
- 4 simulations:

  3 different density profiles
  +
  1 simulation without velocity shear (n_1/n_2=10)

Simulations: initial setup

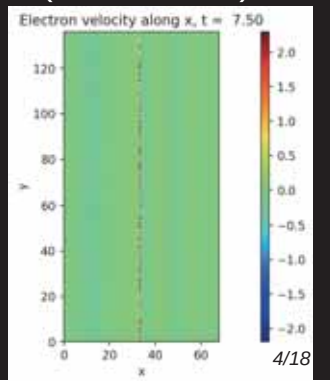
KHI= Kelvin-Helmholtz instability
LHDI = Lower-Hybrid Drift instability

1 **pure KHI** simulation (simulation 4)

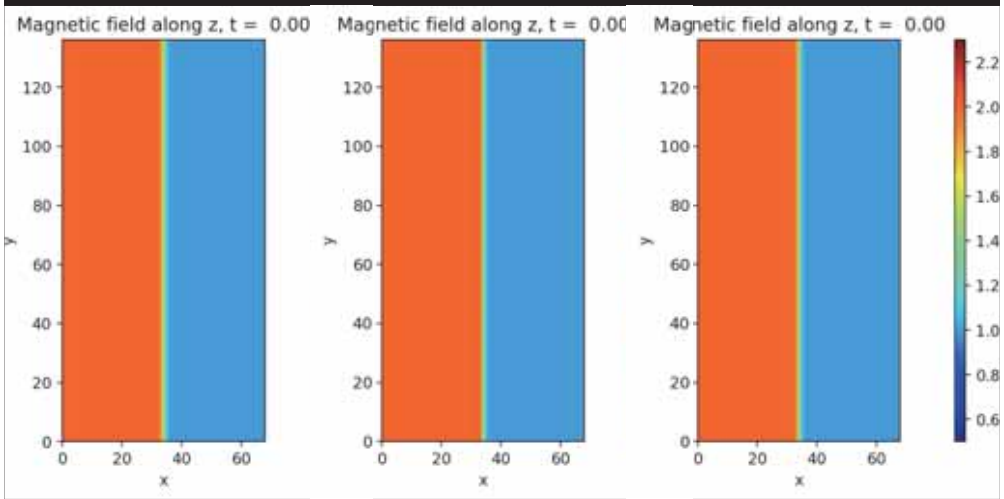


2 **hybrid KHI + LHDI** simulations (simulations 2 and 3)

1 **pure LHDI** simulation (simulation 1)



Overview of simulations



Simulation 2 n_1/n_2=10

Simulation 3 n_1/n_2=5

Simulation 4 n_1/n_2=1

Evolution of the simulation

- The simulations are characterized by **3 main phases**:

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  1. The **linear phase of LHDI**

Evolution of the simulation

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  1. The **linear phase of LHDI**
  2. The **nonlinear phase of LHDI**

Evolution of the simulation

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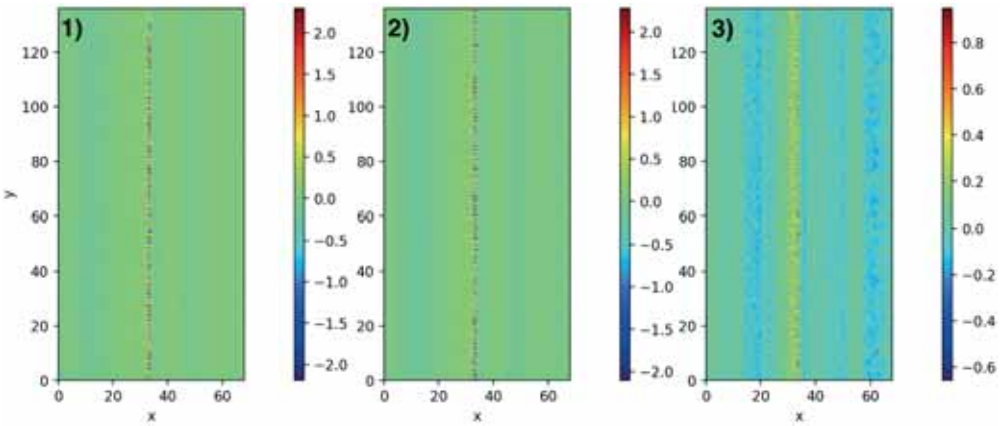
  1. The **linear phase of LHDI**
  2. The **nonlinear phase of LHDI**
  3. The **linear phase of KHI**

The linear phase of LHDI

V_{ex}, t=7.5

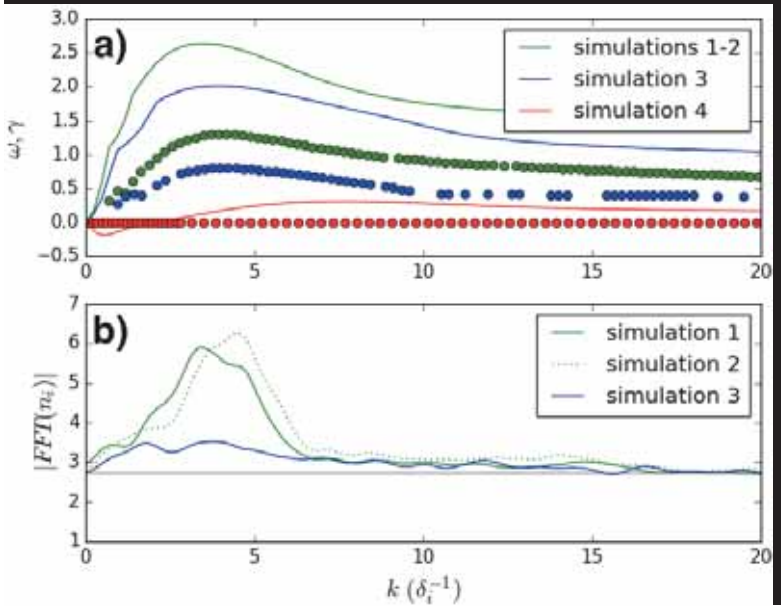


Simulation 1
n_1/n_2=10

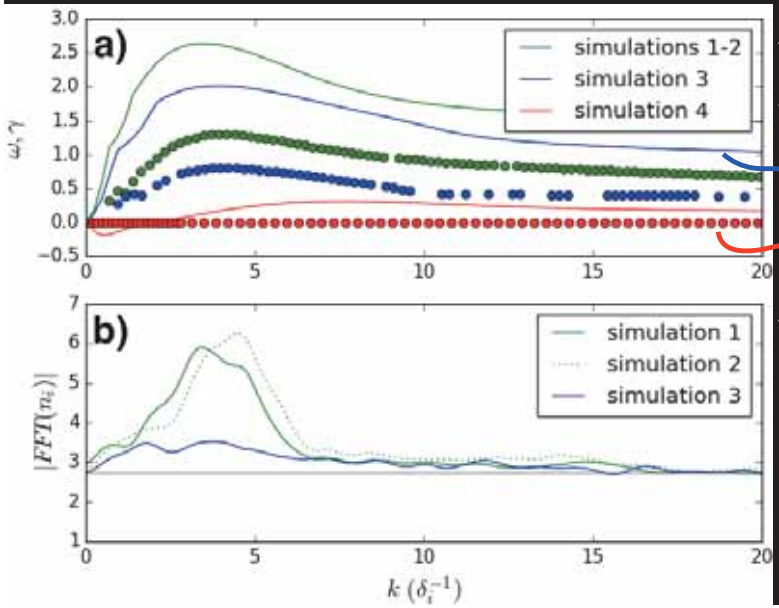
Simulation 2
n_1/n_2=10

Simulation 3
n_1/n_2=5

The linear phase of LHDI



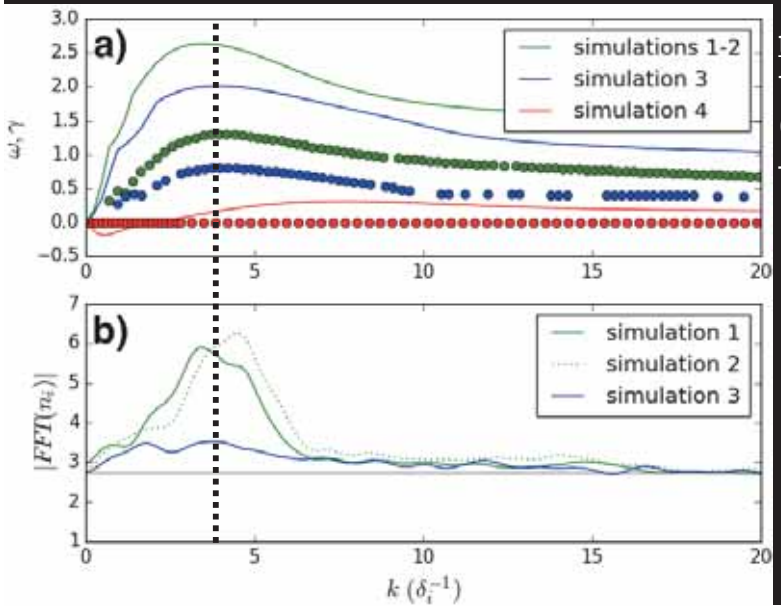
The linear phase of LHDI



straight lines:
Lower-Hybrid frequency

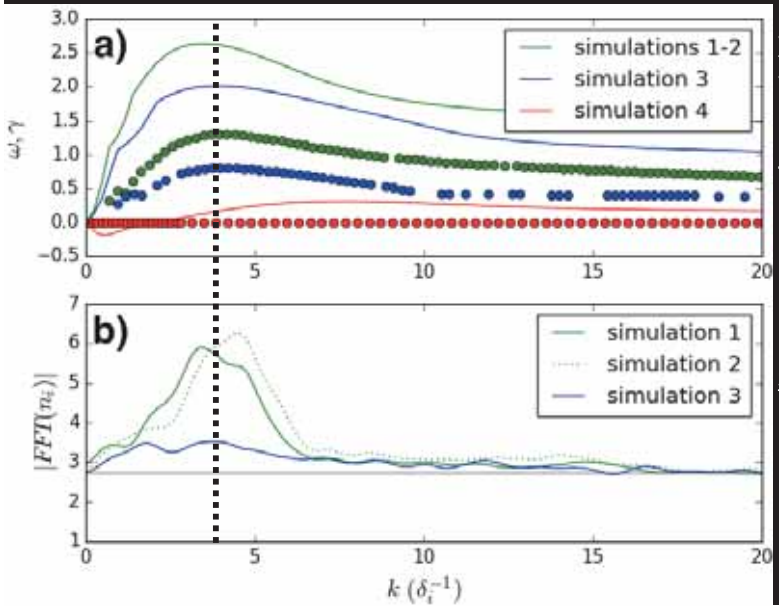
dotted lines:
LHDI growth rate

The linear phase of LHDI



theory:
fastest growing mode
—> **k~4**

The linear phase of LHDI

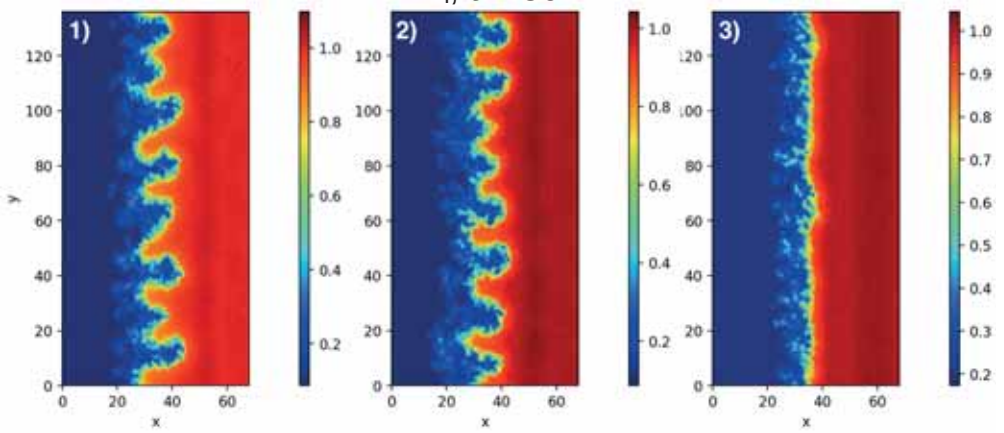


theory:
fastest growing mode —> **k~4**

simulations:
idem (t=5)

The nonlinear phase of LHDI

N_i, t=150



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Simulation 2
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Simulation 3
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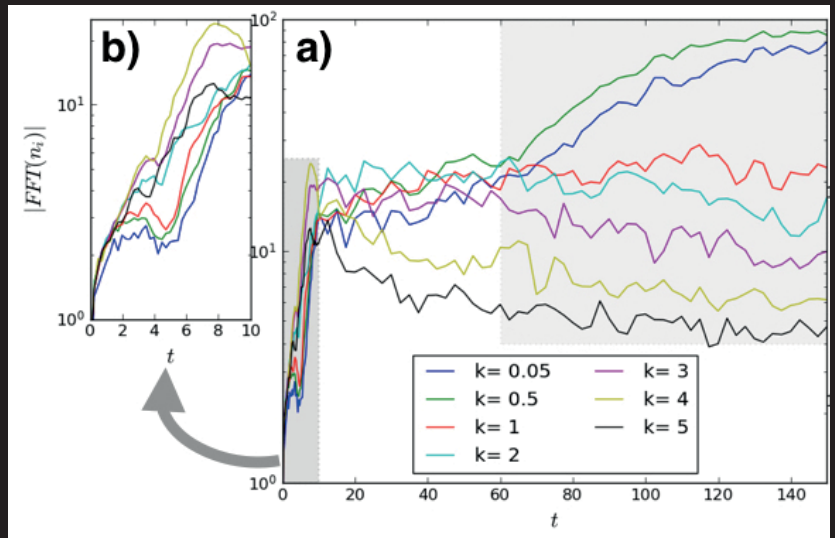
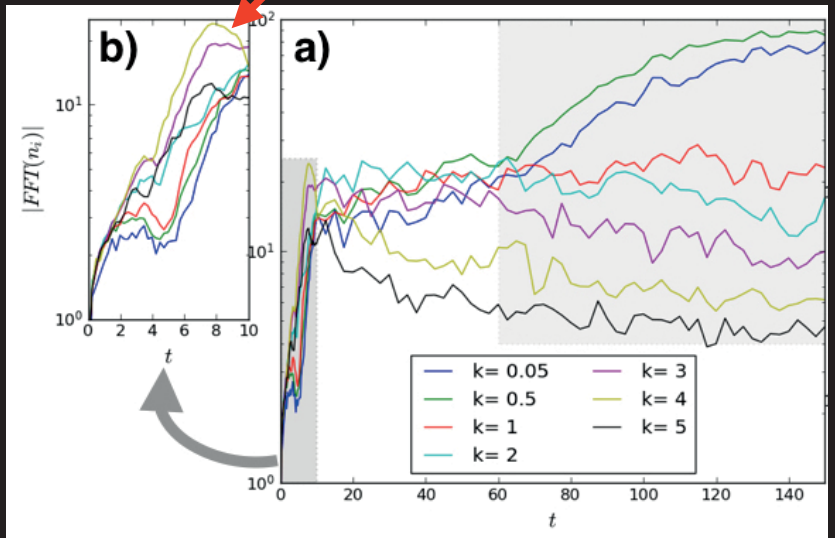
The nonlinear phase of LHDI



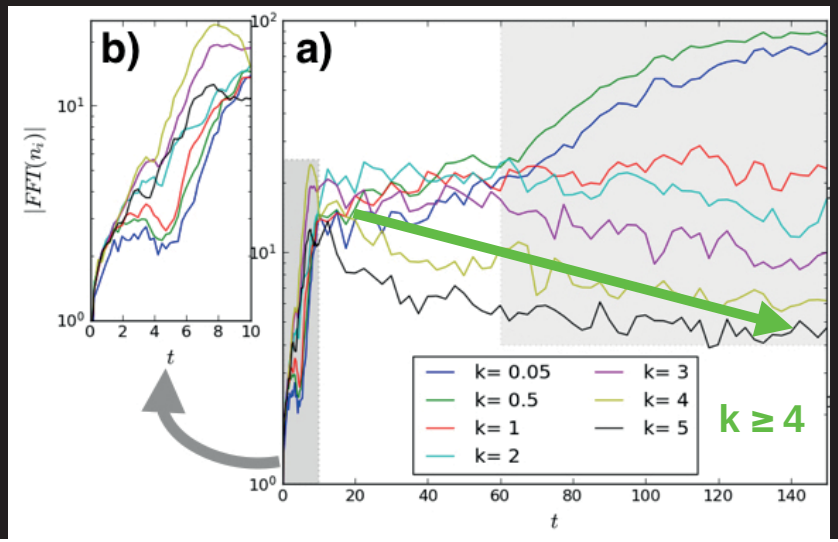
The nonlinear phase of LHDI

linear LHDI —> fastest growing mode **k~4**



The nonlinear phase of LHDI

nonlinear LHDI —> inverse cascade towards **k<1**



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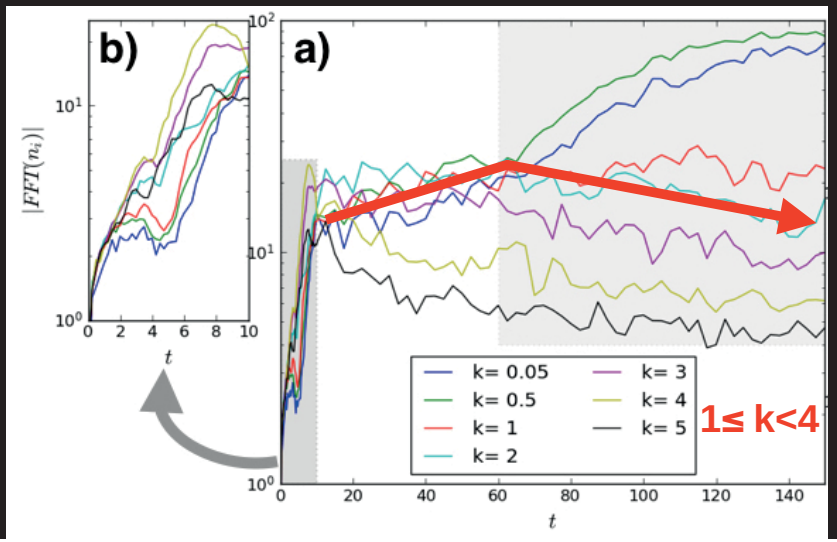

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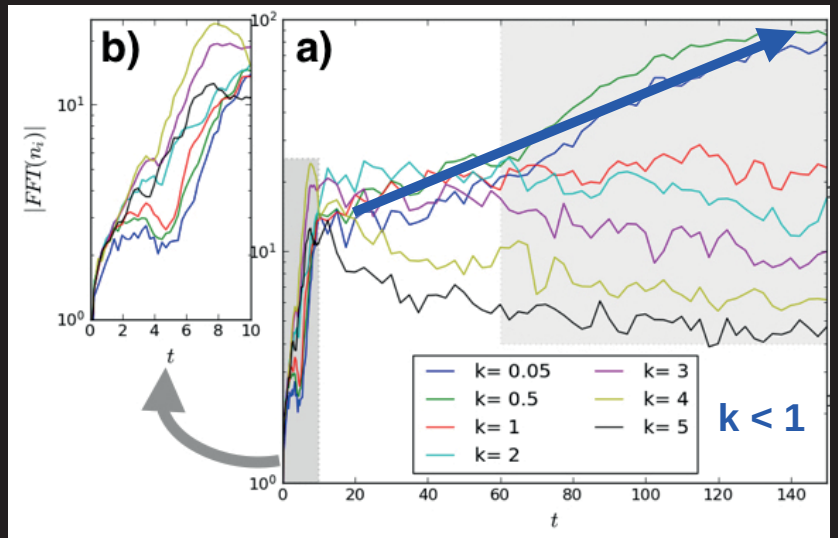

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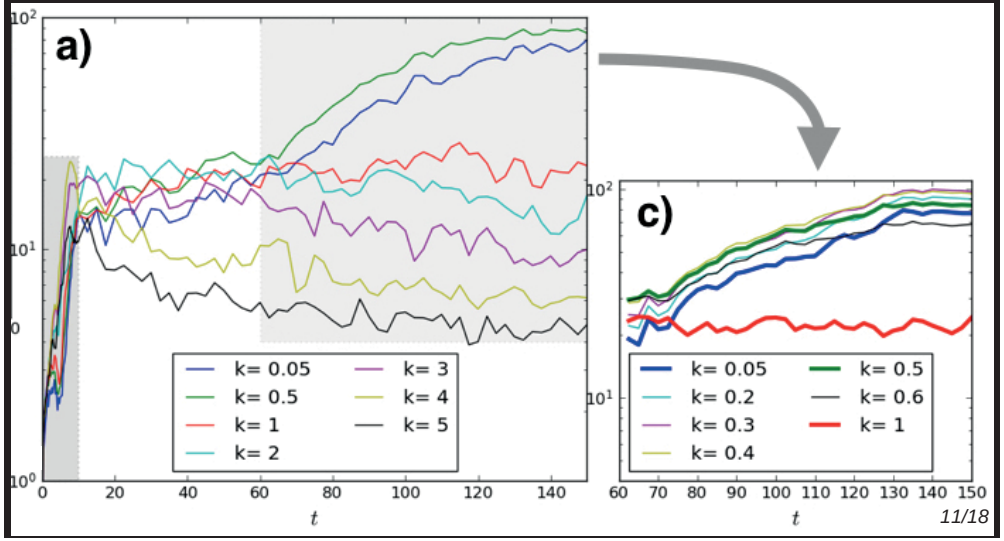

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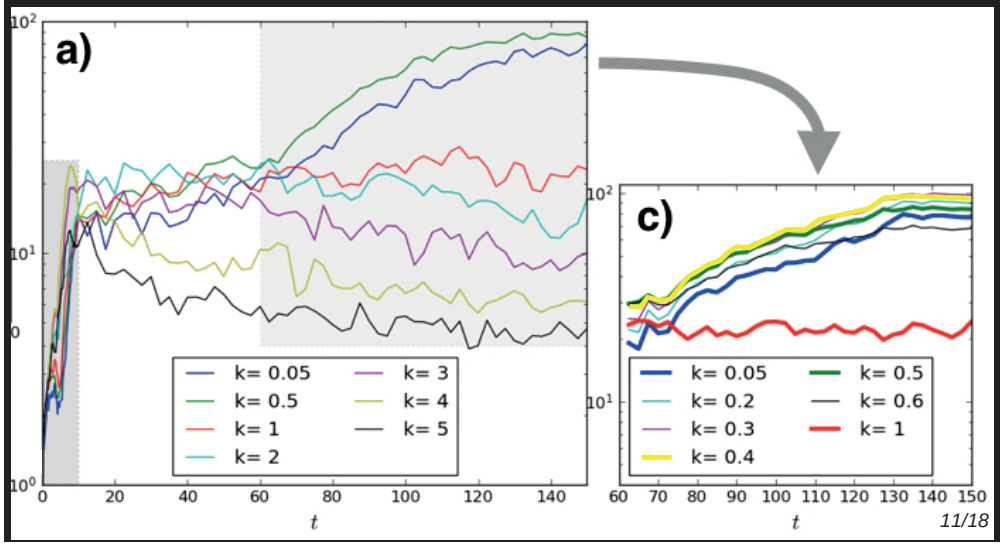

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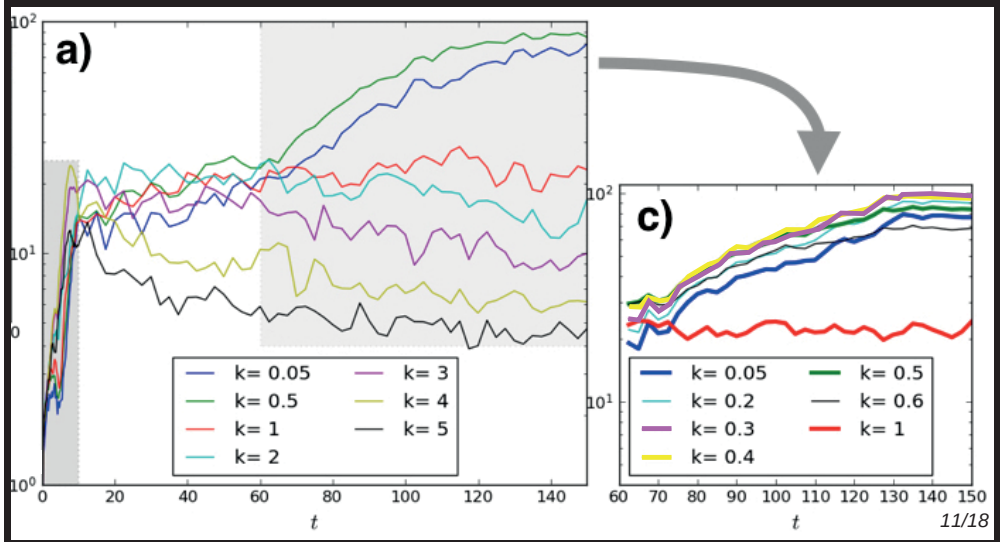
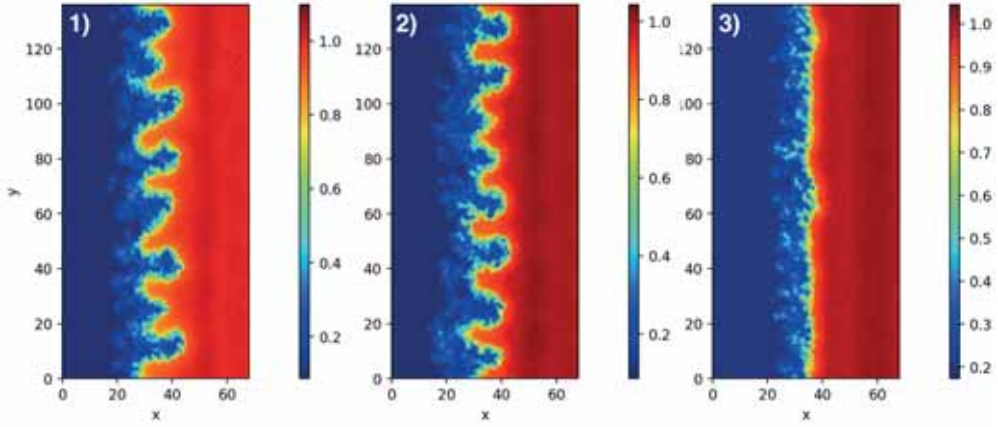


The nonlinear phase of LHDI

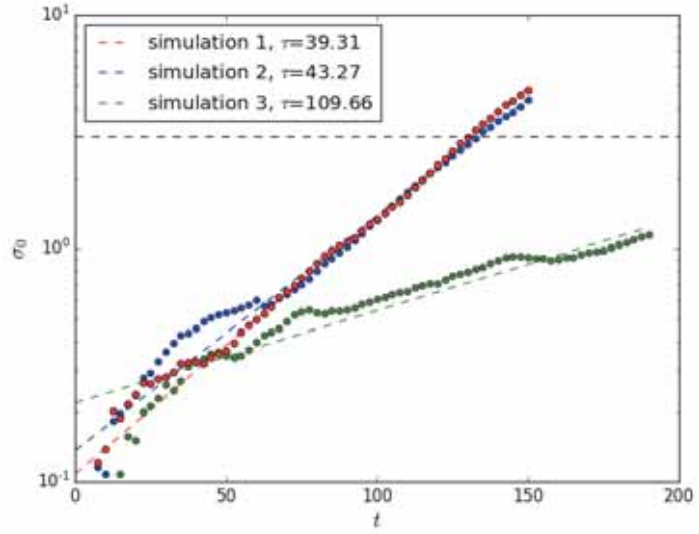
N_i, t=150



Simulation 1	Simulation 2	Simulation 3
$n_1/n_2=10$	$n_1/n_2=10$	$n_1/n_2=5$

The nonlinear phase of LHDI

Standard deviation of the layer's position



$$\sigma_0 = \sqrt{< x_0^2 >_y}$$

The nonlinear phase of LHDI

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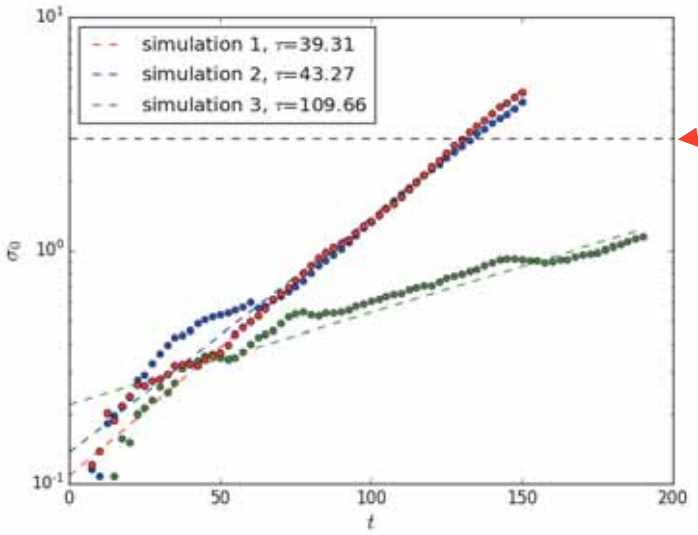

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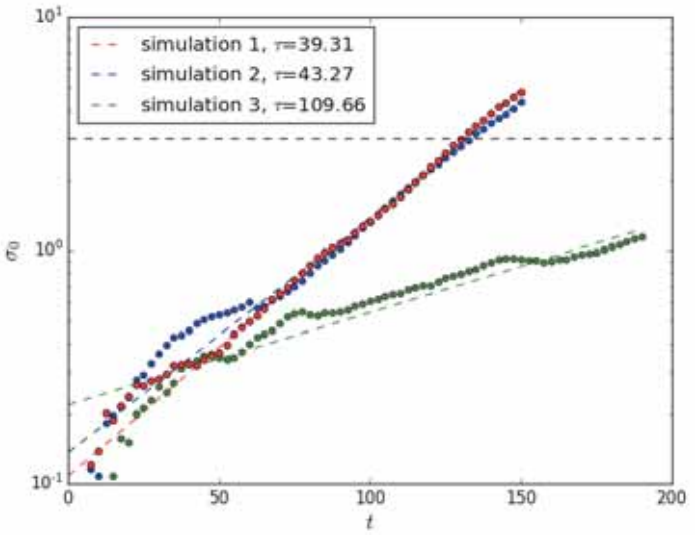
Typical size of KH vortices

The nonlinear phase of LHDI

Standard deviation of the layer's position



$\sigma_0 = \sqrt{< x_0^2 >_y}$

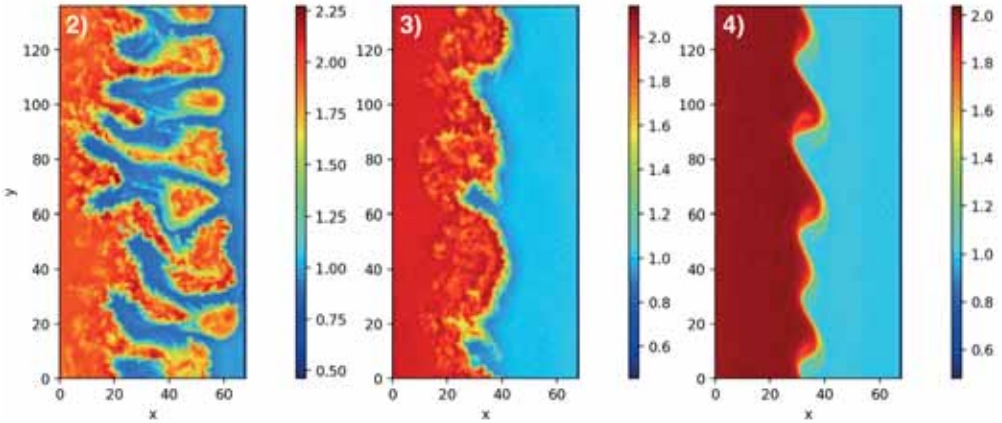
Exponential fit:

$Ae^{t/\tau_{NL}}$

We obtain a characteristic time τ_{NL}

The linear phase of KHI

B_z, t=350



Simulation 2
n_1/n_2=10

Simulation 3
n_1/n_2=5

Simulation 4
n_1/n_2=1

The linear phase of KHI

- Theoretically, we have:
  - Hyperbolic tangent for the velocity profile [Michalke 1964]:

$$\gamma_{KH} = 0.095\Delta u/L$$

  - Inhomogeneous density [Chandrasekhar 1961]:

$$\gamma_{KH} \propto \frac{\sqrt{n_1/n_2}}{1 + n_1/n_2}$$

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Simulation	2	3	4
$\tau_{KH} = 1/\gamma_{KH}$	77	57	42

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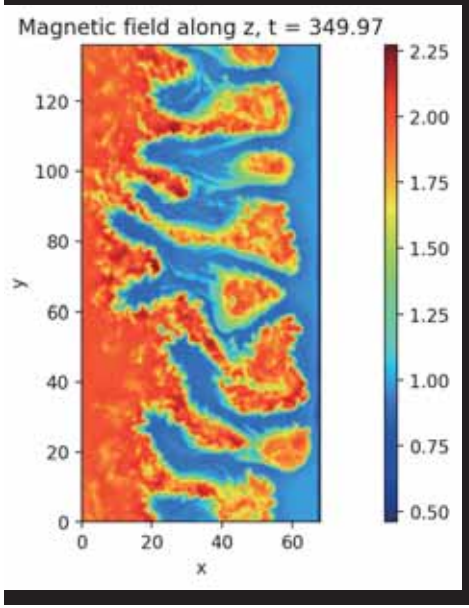
Simulation	2	3	4
$\tau_{KH} = 1/\gamma_{KH}$	77	57	**42**

Comparison with the exponential fit method for simulation 4

$\tau_{KH} = 49$

The linear phase of KHI



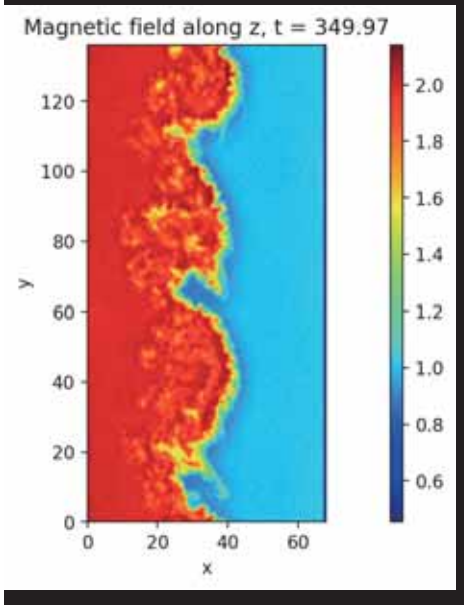
- Case 1: Simulation 2

τ_{KH}	τ_{NL}
77	43

$$\tau_{KH} > \tau_{NL}$$

The nonlinear LHDI dominates
The KHI is unable to develop

The linear phase of KHI



- Case 2: Simulation 3

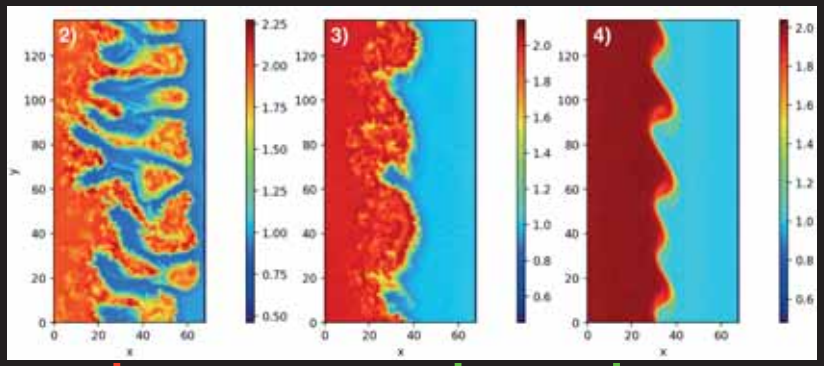
τ_{KH}	τ_{NL}
57	110

$$\tau_{KH} < \tau_{NL}$$

The KHI dominates

Conclusion

Depending on the **density asymmetry**, the **layer width** and the **velocity shear**:



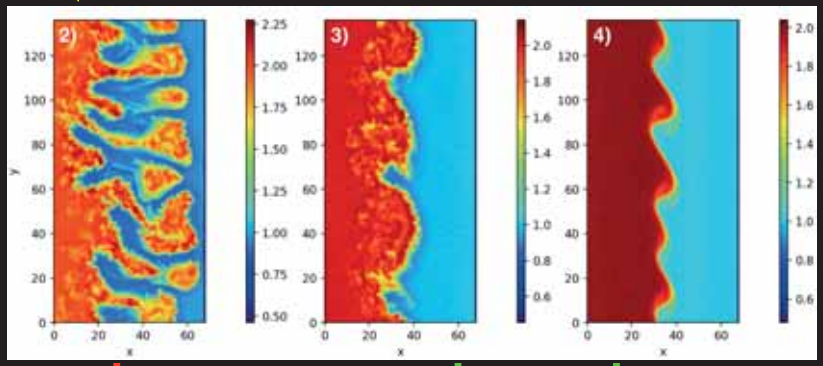
LHDI dominates

KHI dominates

Conclusion

Depending on the **density asymmetry**, the **layer width** and the **velocity shear**:

Mercury-like magnetopause



LHDI dominates

KHI dominates