Instability of electrostatic waves in an inhomogeneous plasma at Venus ionosphere

By **Alaa Ahmed Fayad**

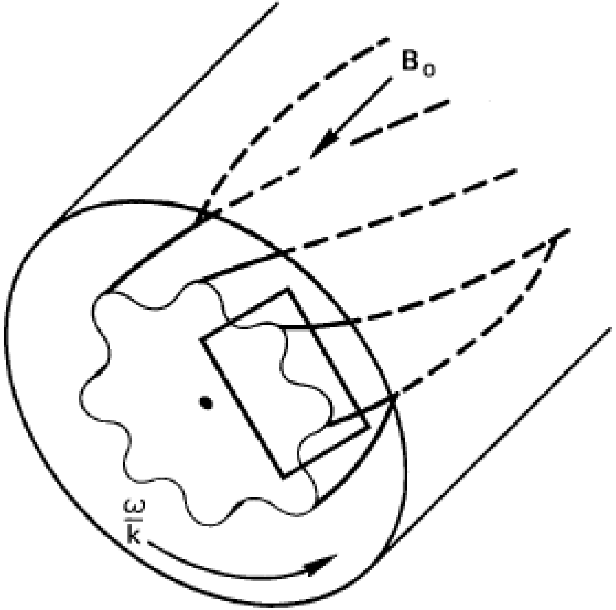
Supervisors

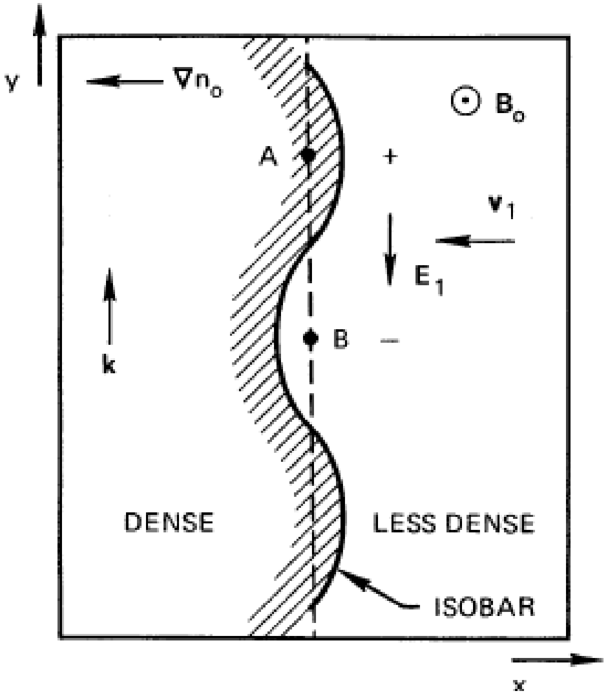
Prof. Dr. Waleed Moslem	Prof. of theoretical physics – Department of physics – Faculty of Science- Port Said University
Prof. Dr. Salah Kamel El-Labany	Prof. of theoretical physics – Department of physics – Faculty of Science- Damietta University

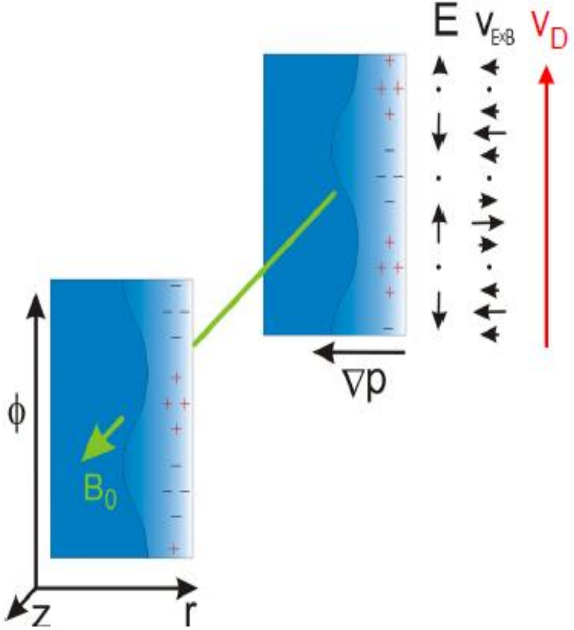
Outline

- Simple theory of drift waves
- Drift velocities
- Drift waves properties
- Introduction about Venus
- Aim of the work
- Basic equations
- Results

Simple theory of drift waves







Drift velocities

- **ExB drift**

$$\mathbf{v}_E = \frac{\mathbf{E} \times \mathbf{B}}{B^2}$$

- **Diamagnetic drift**

$$\mathbf{v}_D \equiv -\frac{\nabla p \times \mathbf{B}}{qnB^2}$$

- **∇B drift**

$$\mathbf{v}_{\nabla B} = \pm \frac{1}{2} v_\perp r_\mathrm{L} \frac{\mathbf{B} \times \nabla B}{B^2}$$

- **Curvature drift**

$$\mathbf{v}_R = \frac{m v_\parallel^2}{q} \frac{\mathbf{R}_c \times \mathbf{B}}{R_c^2 B^2}$$

- **Polarization drift**

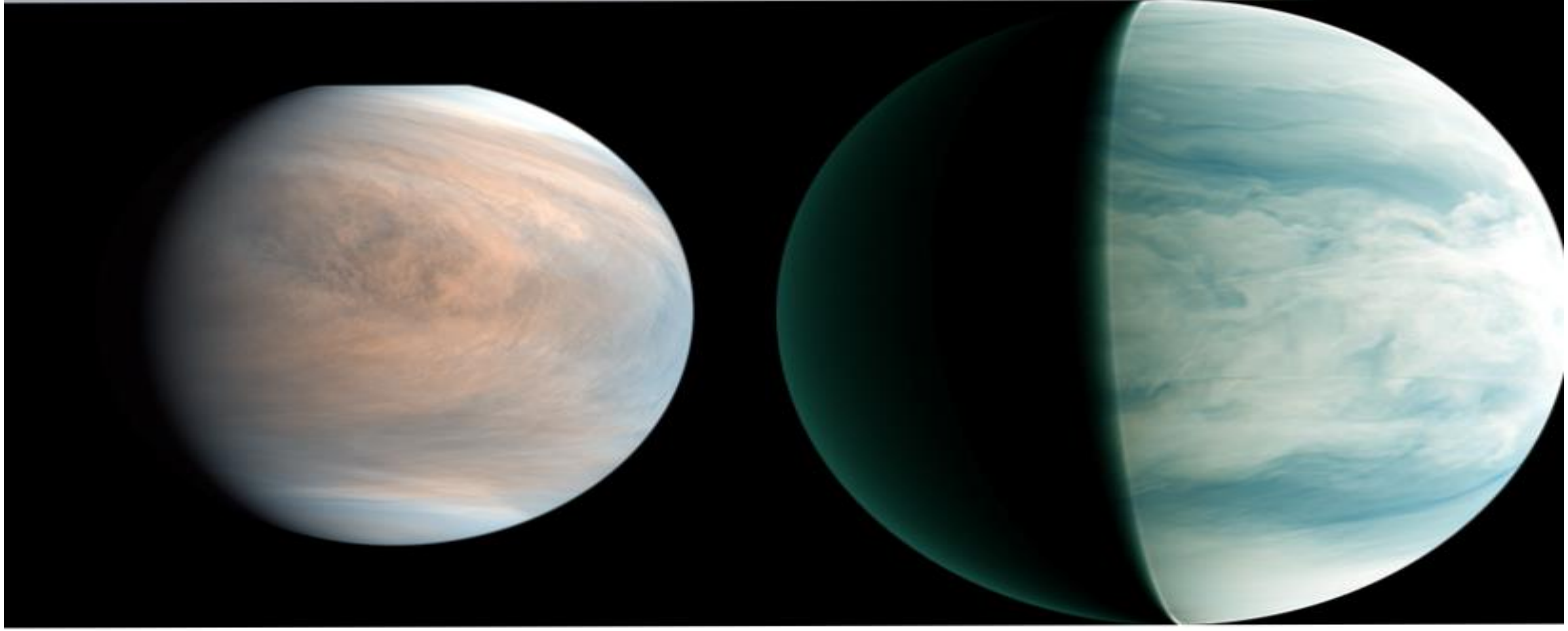
$$\mathbf{v}_p = \pm \frac{1}{\omega_c B} \frac{d\mathbf{E}}{dt}$$

- **Gravitational drift**

$$\mathbf{v}_g = \frac{m}{q} \frac{\mathbf{g} \times \mathbf{B}}{B^2}$$

Drift waves properties

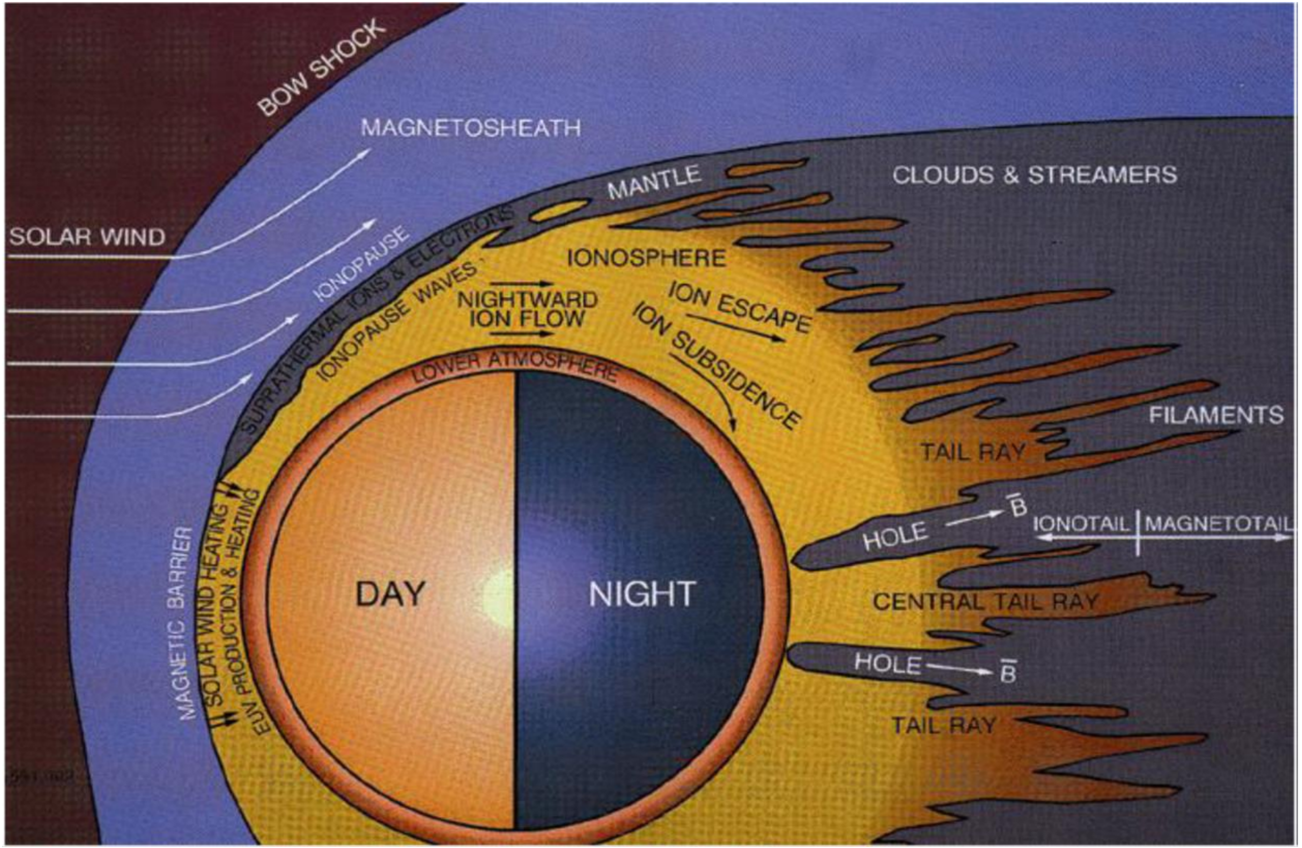
- It refers to the diamagnetic drift in magnetized plasmas with $\nabla n \neq 0$, and propagates with diamagnetic drift velocity
- „universal“ instabilities of magnetized plasmas,
- ES in low Beta plasmas EM in high Beta plasmas,
- lead to fluctuations in n, ϕ , T and B (in high β),
- have low frequency< $\omega_{ci.}$



-Venus day side synthesized false color image by UVI (2017 Sep 24).

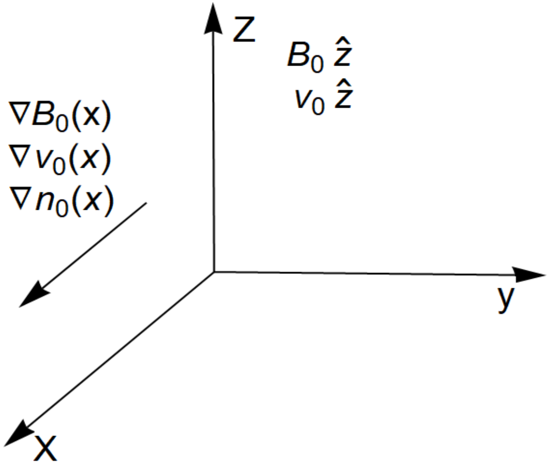
-Venus night side synthesized false color image by IR2 1.735 µm and 2.26 µm (2016 Mar 25)

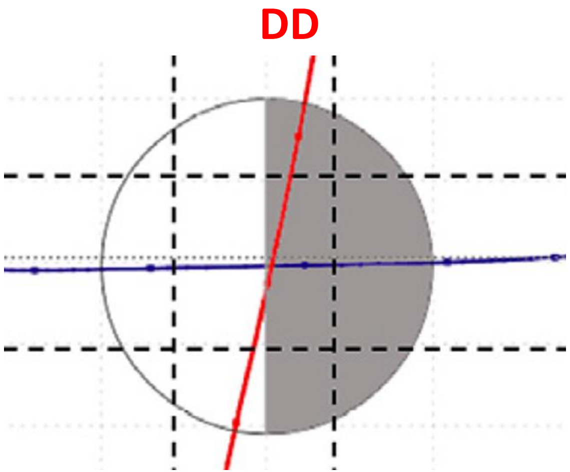
A sketch of the most important plasma boundaries and interaction regions in the environment of Venus (Brace and Kliore (1991)).



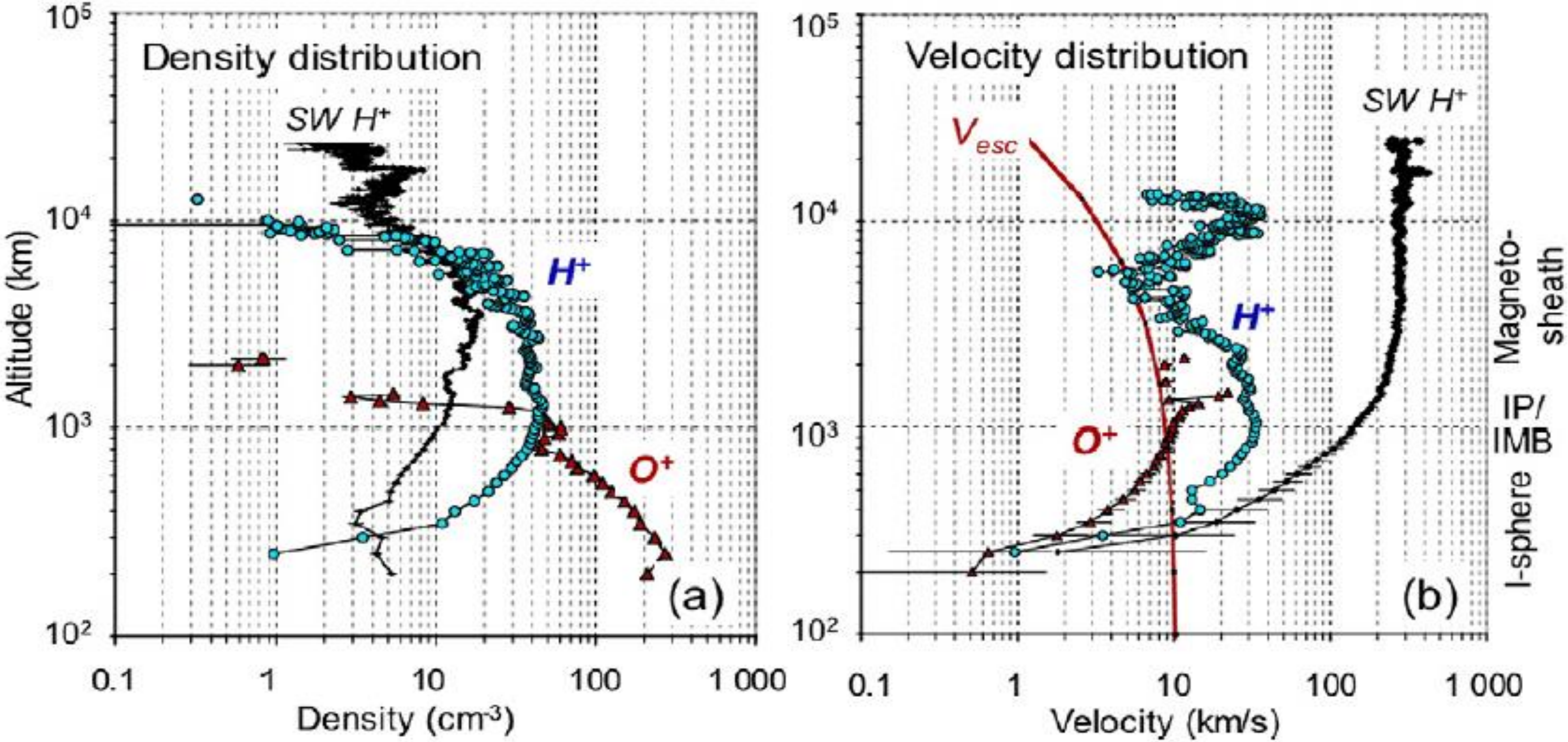
Aim of the work:

- **Studying the dispersion properties of electrostatic waves in nonuniform ionospheric plasma of Dawn-Dusk region of Venus ionosphere, and how the plasma stability affected by the inhomogeneities of the system.**





Lundin et al. (2011) Icarus, vol. 215, p. 751-758



Lundin et al. (2011) Icarus, vol. 215, p. 751-758

Plasma Parameters

$$T_o = T_H = 2 \times 10^3 \ K$$
$$T_e = 1 \times 10^4 \ K$$
$$B_0 = 1 \times 10^{-3} \ G$$
$$n_e = 1 \times 10^4 \ cm^{-3}$$
$$n_o = 100 \ cm^{-3}$$
$$n_H = 20 \ cm^{-3}$$

$$v_{e0} \approx 20 \ km/s$$
$$v_{H0} = 15 \ km/s$$
$$v_{o0} = 5 \ km/s$$
$$L_{n_e} = 10^4 \ cm$$
$$L_{n_o} = 10^6 \ cm$$
$$L_{n_H} = 10^5 \ cm$$
$$L_B = 10^7 \ cm$$

Basic Equations

-Continuity equation

$$\frac{\partial n_\alpha}{\partial t} + \bar{\nabla} \cdot (n_\alpha \vec{v}_\alpha) = 0$$

-Equation of motion

$$m_\alpha \left(\frac{\partial}{\partial t} + \vec{v}_\alpha \cdot \bar{\nabla} \right) v_\alpha = \underbrace{q \left(E \right.}_{\text{Electric force}} + \overbrace{\left. \frac{1}{c} v_\alpha \times B_0 \hat{z} \right)}^{\text{Magnetic force}} - \underbrace{\nabla P_\alpha}_{\text{Pressure gradient force}}$$

-Poisson equation

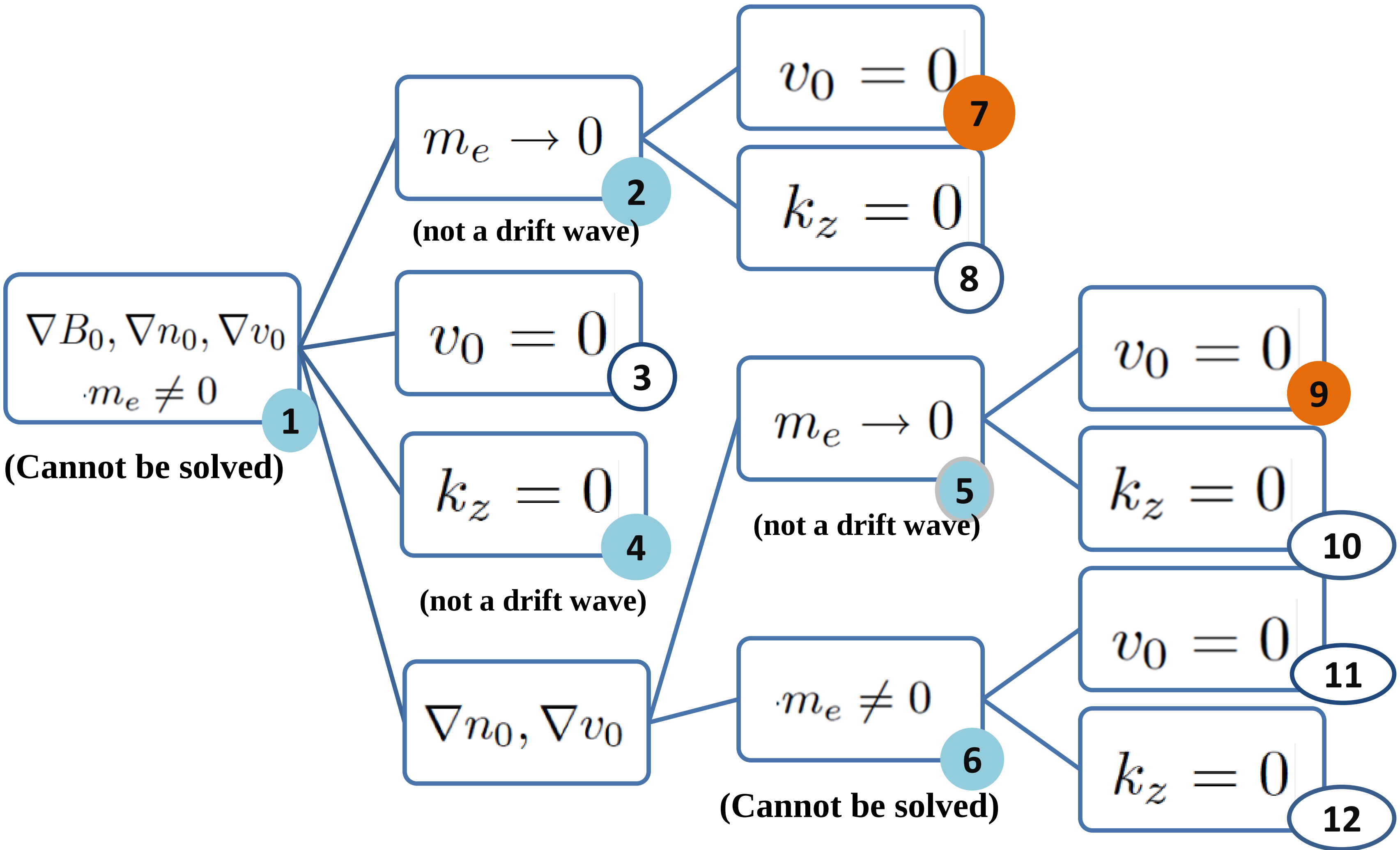
$$\nabla^2 \phi = 4\pi e (n_e - n_O - n_H)$$

Where

$$E = -\nabla \phi \qquad v_\alpha = \vec{v}_{\alpha\perp} + v_{\alpha z} \hat{z} + v_{\alpha o}(x)$$

$$\nabla P_\alpha = \gamma K_B T_\alpha \nabla n_\alpha \qquad n_\alpha = n_{\alpha 0}(x) + n_{\alpha 1}$$

α : e for electrons, O for oxygen ions, and H for Hydrogen ions.



$\nabla B_0, \nabla n_0, \nabla v_0$
$m_e \neq 0$
1
(Cannot be solved)
$m_e \to 0$
2
(not a drift wave)
$v_0 = 0$
3
$k_z = 0$
4
(not a drift wave)
$\nabla n_0, \nabla v_0$
$v_0 = 0$
7
$k_z = 0$
8
$m_e \to 0$
5
(not a drift wave)
$m_e \neq 0$
6
(Cannot be solved)
$v_0 = 0$
9
$k_z = 0$
10
$v_0 = 0$
11
$k_z = 0$
12

Drifts appeared in the system,

$$v_{\alpha_\perp} = \frac{c}{B_0}\hat{z} \times \nabla_\perp \phi + \frac{c\gamma K_B T_\alpha}{qB_0 n_{\alpha 0}}\hat{z} \times \nabla_\perp n_{\alpha 1}$$

ExB drift **Diamagnetic drift**

General case

The dispersion relation

$$-k^2\gamma_1\beta_1\alpha_1 = 4\pi e(\beta_1\alpha_1\gamma_2 + \beta_2\alpha_1\gamma_1 - \alpha_2\beta_1\gamma_1)$$

Where,

$$\alpha_1 = \left(\omega - v_\circ k_z + v_{B_e}k_y - \frac{\gamma T_e}{m_e}\frac{(k_z - S_e k_y)}{(\omega - v_\circ k_z)}k_z\right) \quad \beta_2 = \left(ck_y\kappa_{n_H B}\frac{n_{H0}}{B_0} - \frac{n_{H0}e}{m_H}\frac{(k_z - S_H k_y)}{(\omega - v_\circ k_z)}k_z\right)$$

$$\alpha_2 = \left(ck_y\kappa_{n_e B}\frac{n_{e0}}{B_0} + \frac{n_{e0}e}{m_e}\frac{(k_z - S_e k_y)}{(\omega - v_\circ k_z)}k_z\right) \quad \gamma_1 = \left(\omega - v_\circ k_z - v_{B_o}k_y - \frac{\gamma T_O}{m_O}\frac{(k_z - S_O k_y)}{(\omega - v_\circ k_z)}k_z\right)$$

$$\beta_1 = \left(\omega - v_\circ k_z - v_{B_H}k_y - \frac{\gamma T_H}{m_H}\frac{(k_z - S_H k_y)}{(\omega - v_\circ k_z)}k_z\right) \quad \gamma_2 = \left(ck_y\kappa_{n_O B}\frac{n_{O0}}{B_0} - \frac{n_{O0}e}{m_O}\frac{(k_z - S_O k_y)}{(\omega - v_\circ k_z)}k_z\right)$$

Where

$$\kappa_{n_{H,O,e}B} = \frac{B_0}{n_{H,O,e0}} \frac{d\left(\frac{n_{H,O,e0}}{B_0}\right)}{dx}$$

$$S_{H,O,e} = \frac{m_{H,O,e}c}{eB_0} v_{H,O,e\circ} \kappa_v$$

$$\kappa_v = \frac{1}{v_{H,O,e\circ}} \frac{dv_{H,O,e\circ}}{dx}$$

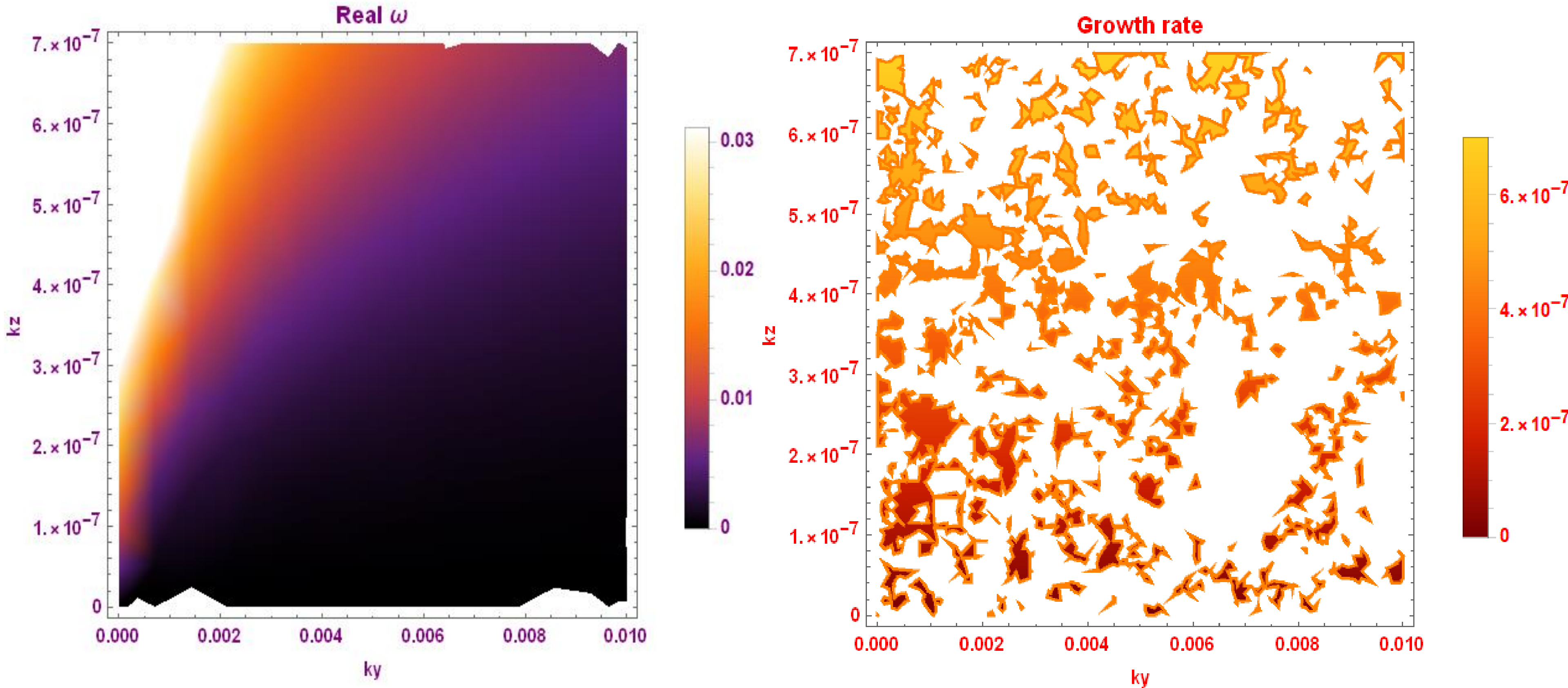
$$v_{BH,O,e} = \frac{c\gamma T_{H,O,e}}{B_0 e} \kappa_B$$

$$\kappa_B = \frac{dB_0}{B_0 dx}$$

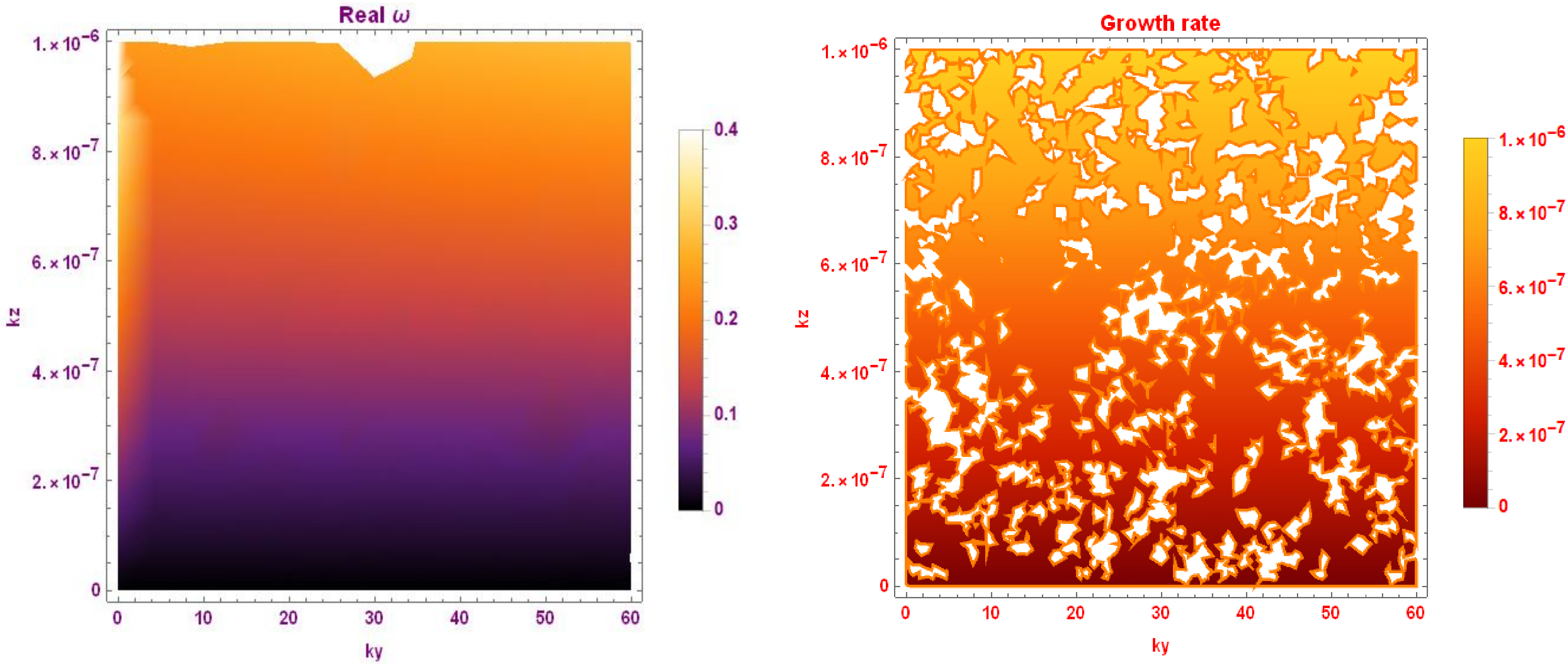
7 & 9

Flow velocity= zero
Electron inertia =zero

Case 7 ($\nabla B_0, \nabla n_0,\ v_0 = 0$, $m_e \to 0$)



Case 9 ($\nabla n_0, v_0 = 0$, $m_e \rightarrow 0$)

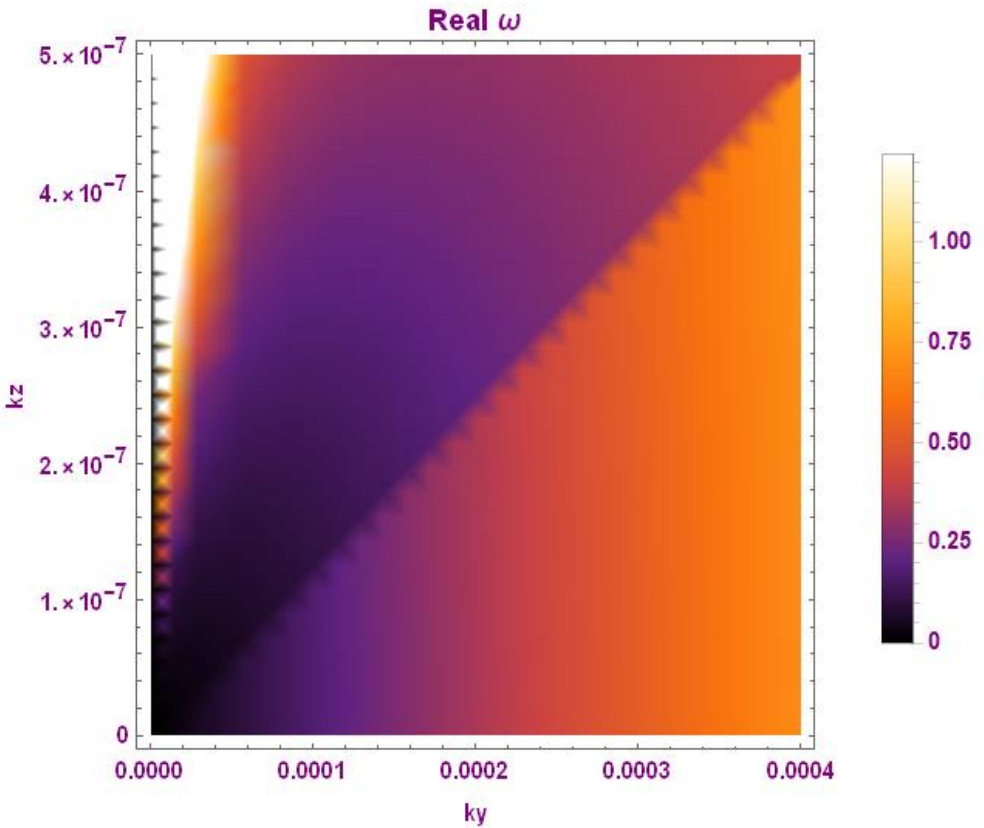


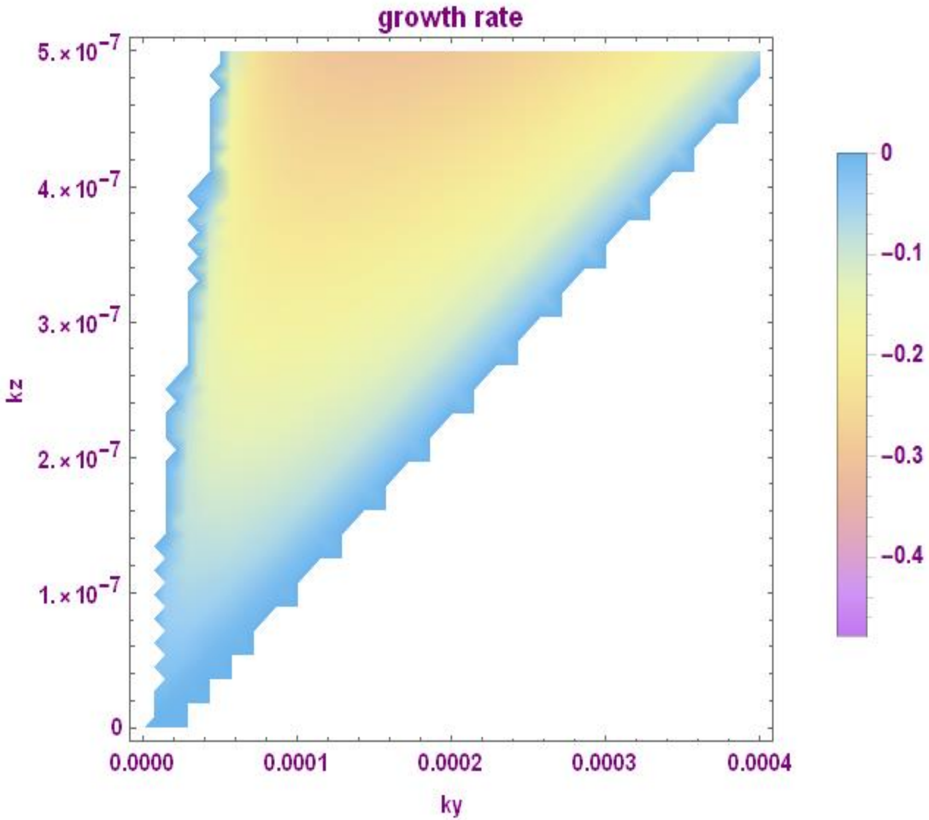
3 & 11

Flow velocity= zero

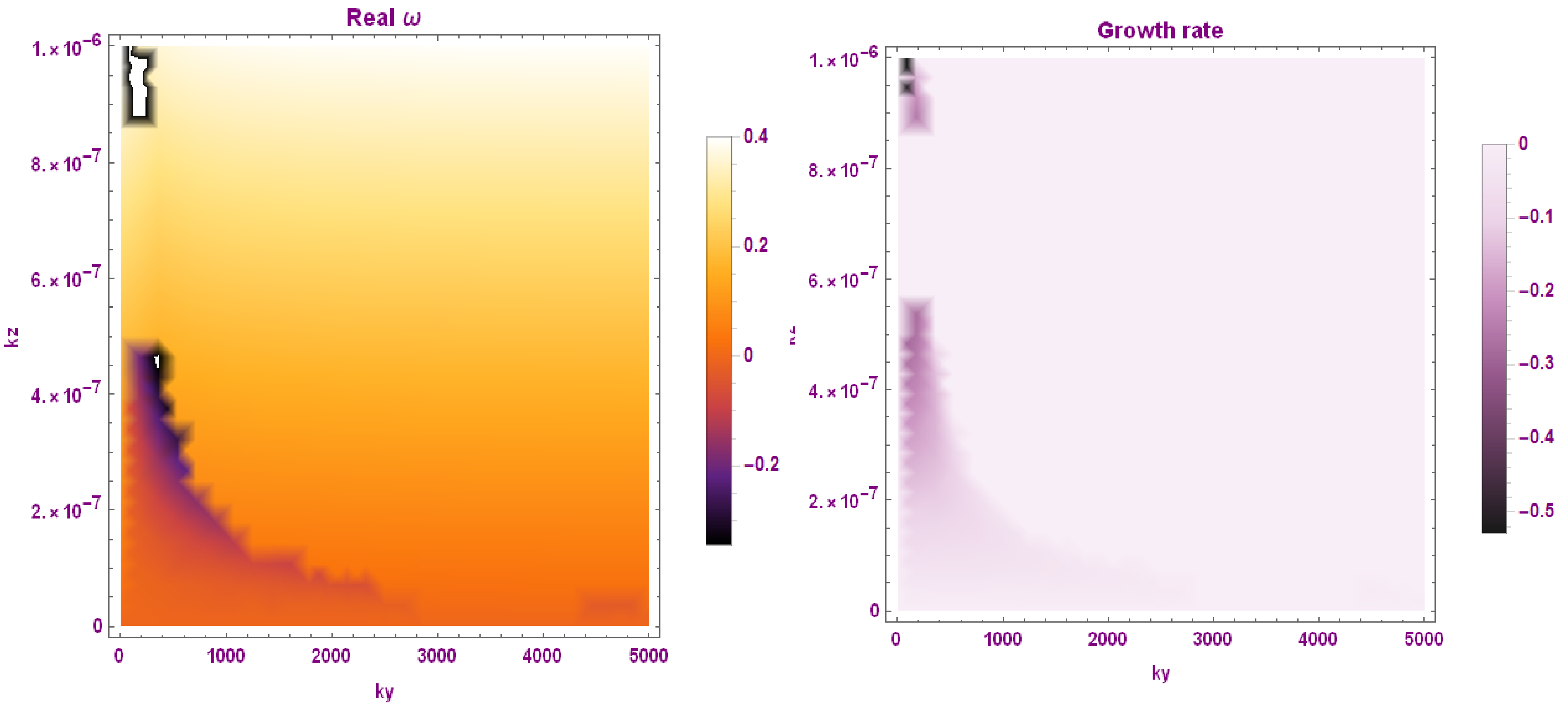
Electron inertia $\neq$ zero

Case 3 ($\nabla B_0, \nabla n_0,\ v_0 = 0, m_e \neq 0$)





Case 11 ($\nabla n_0, v_0 = 0$, $m_e \neq 0$)



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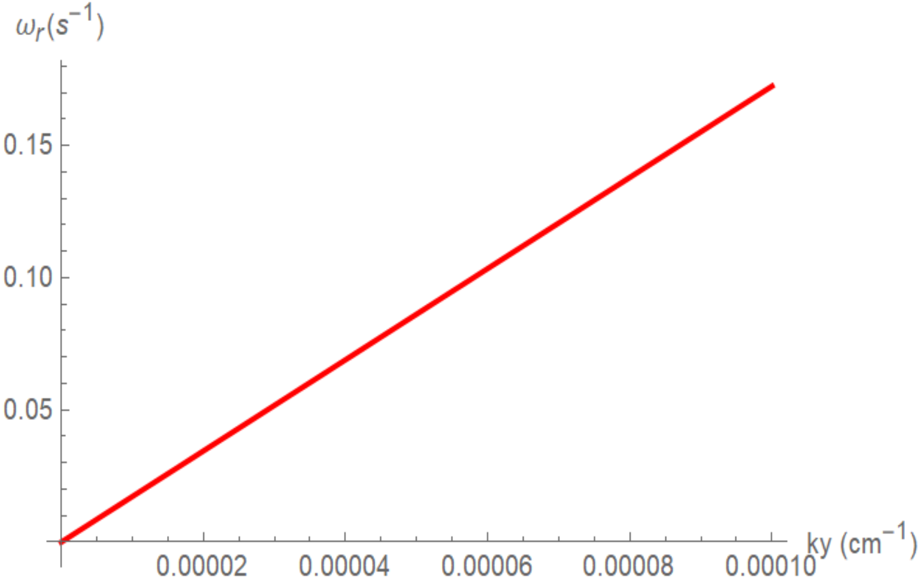
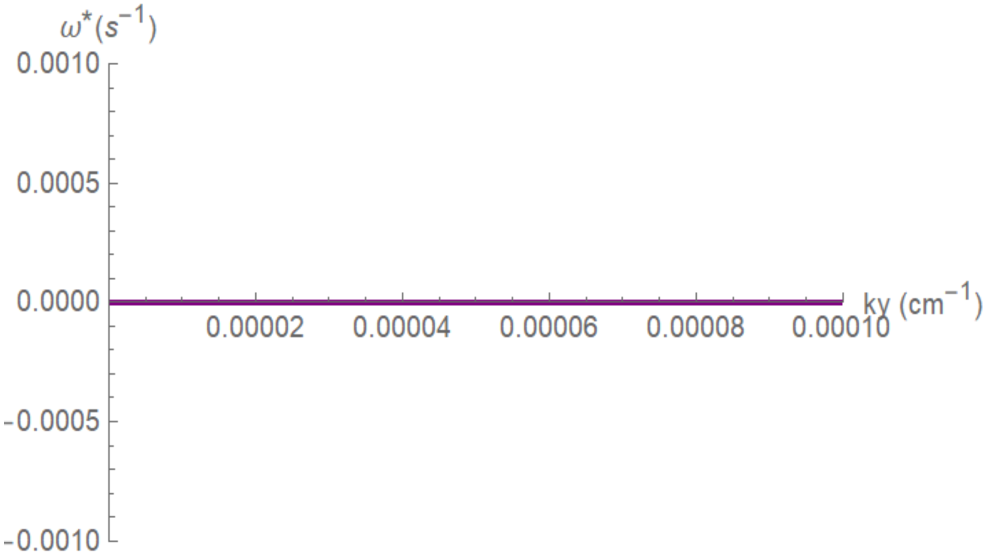
k_z = zero (Flute modes)

Case 8 ($\nabla B_0, \nabla n_0, \nabla v_0$, $m_e \neq 0$) (Periodic wave)





thank
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