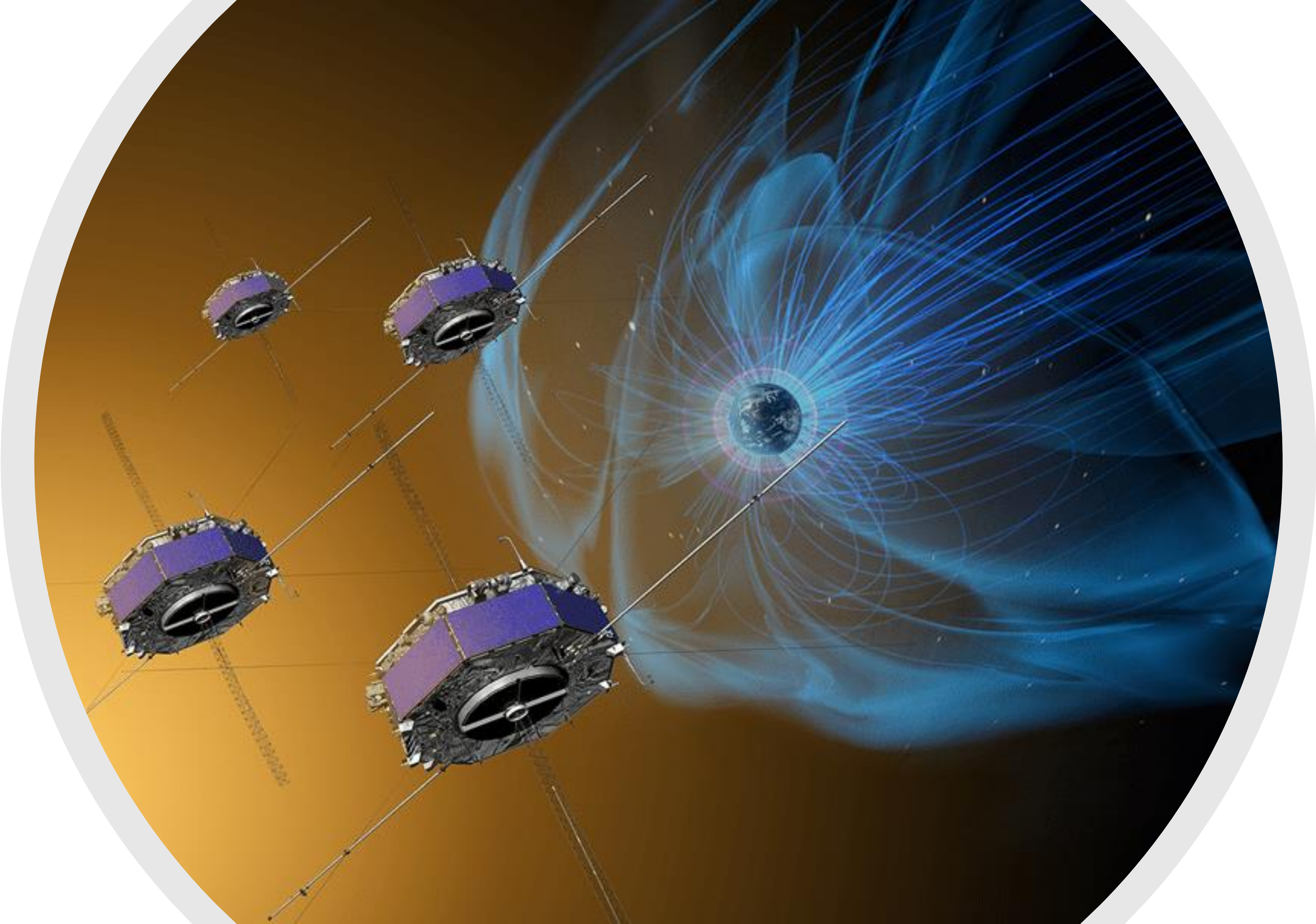


Linear Analysis of Electrostatic Waves in the Earth's Magnetopause

Presented by

Atef Bassyouni

Supervisors

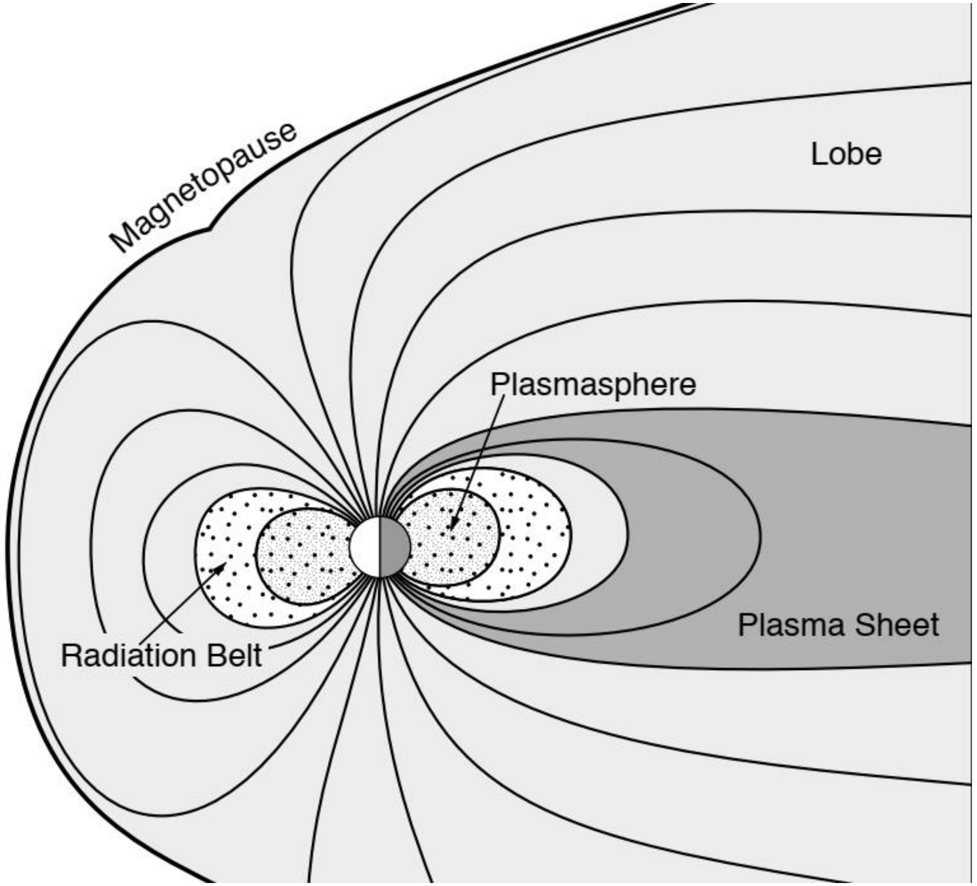
Prof. Dr. W. Moslem

Prof. Dr. M. Ali Hassouba

Dr. M. Saad Afify

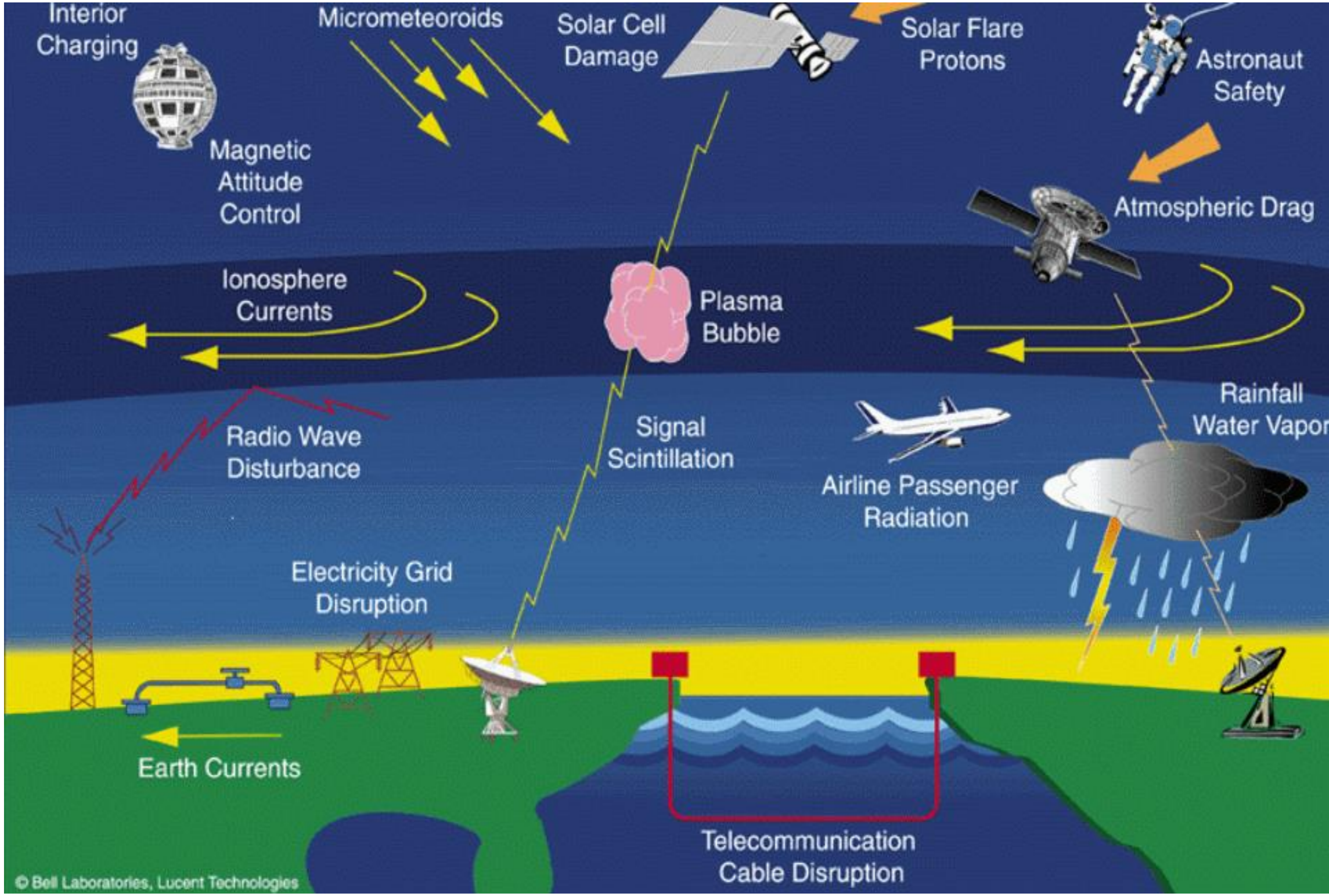
Plasma inside the magnetosphere

- **The radiation belt (dilute and hot) [Van Allen and Frank, 1959]** It consists of energetic electrons and ions which move along the field lines and oscillate back and forth between the two hemispheres.
- **plasma sheet (hot plasma)** most of the magnetotail plasma.
- **magnetotail lobe (dilute plasma)**: The outer part of the magnetotail.
- **Plasmasphere (dense cold plasma)**



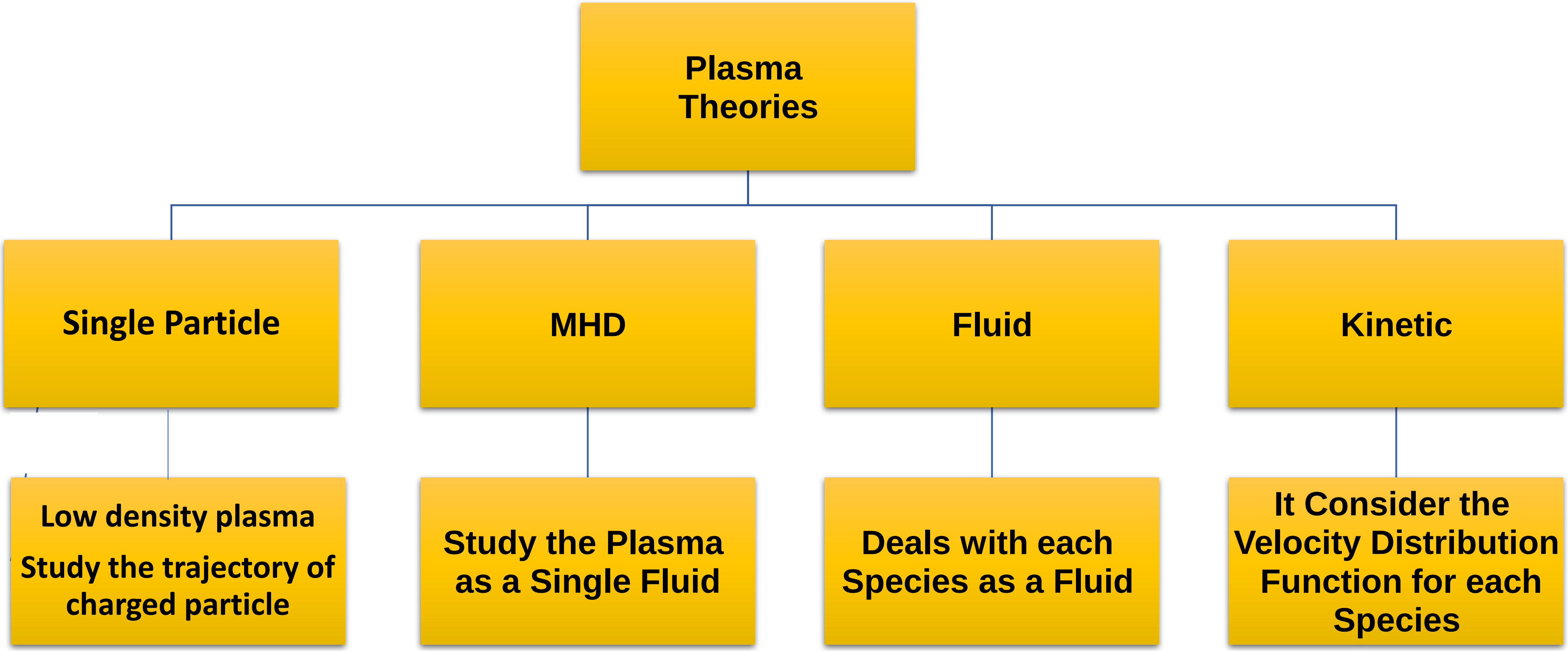
The role of plasma in space weather

- **Has a significant impact on many things inside the Earth.**
- **Examples: air navigation, power plants, communications, and others.**



Waves as diagnostic tools

- **Instability is accompanied by waves.**
- **Waves is considered as fingerprints of plasma.**
- **Plasma waves can be used to determine the composition through detection of characteristic frequencies.**
- **Wave observations made remote-sensing of the heliopause possible before other means of investigation were available.**


Plasma Theories
Single Particle
MHD
Fluid
Kinetic
Low density plasma
Study the trajectory of charged particle
Study the Plasma as a Single Fluid
Deals with each Species as a Fluid
It Consider the Velocity Distribution Function for each Species

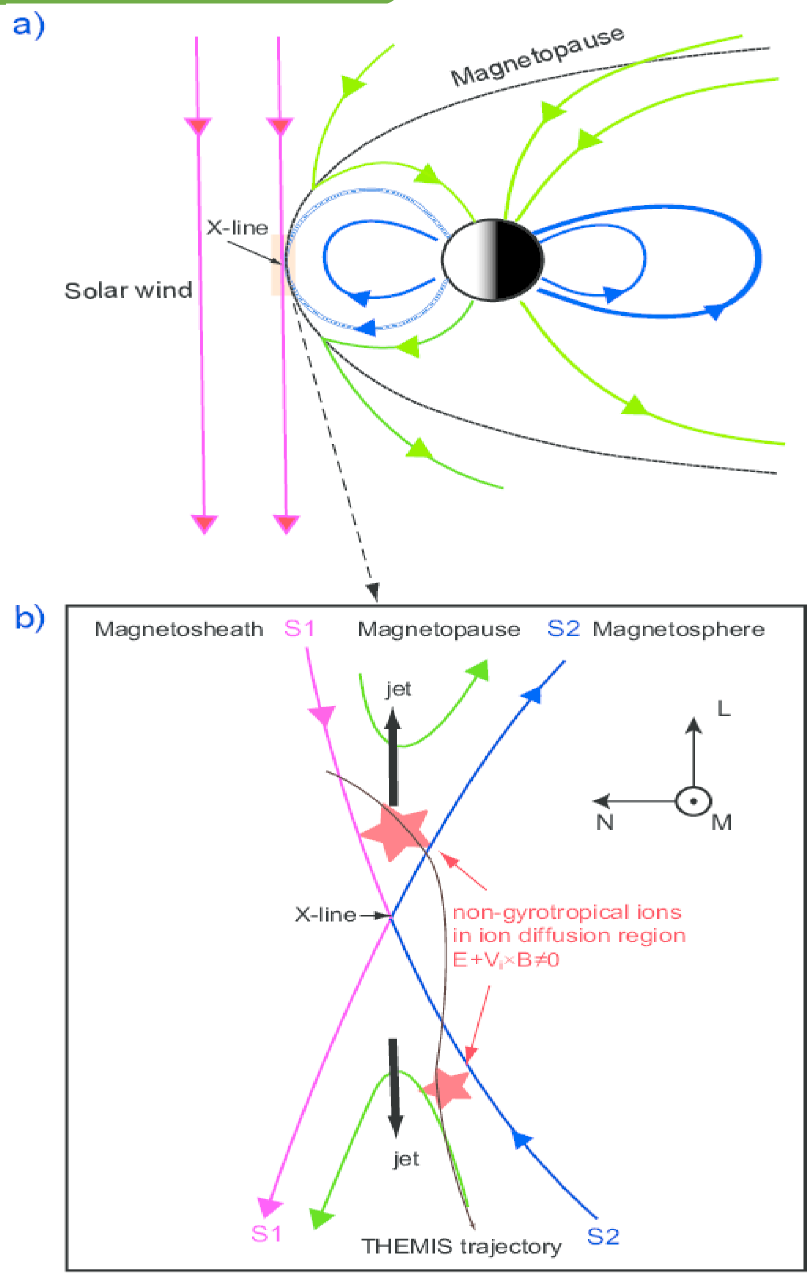
Our model

Solar wind:

1. Solar ions beam.
2. Solar electrons.

Magnetopause:

1. Hot ions.
2. Cold ions.
3. Background electrons.



Basic Equations

Fluid Equations

$$\frac{\partial n_j}{\partial t} + \frac{\partial}{\partial x}.\left(n_j . u_j\right) = 0, \qquad (1)$$

$$m_j n_j \left(\frac{\partial}{\partial t} + u_j . \frac{\partial}{\partial x}\right) u_j = -e\frac{\partial \emptyset}{\partial x} - \frac{\partial P_j}{\partial x} \qquad (2)$$

$$P_j = P_0 n_0^{-\gamma} \frac{\partial n^{\gamma}}{\partial x}, \qquad P_0 = n_0 K_B T$$

Maxiwell distribution

$$n_j = n_{j0}\, exp\left(\frac{e\emptyset}{K_B T_j}\right) \qquad (3)$$

Linearization

$$n = n_0 + n_1$$
$$u = u_0 + u_1$$
$$\emptyset = \emptyset_0 + \emptyset_1$$

Fourier Transform

$$n_1(x,t) = n_1 \exp[i(kx - \omega t)]$$
$$u_1(x,t) = u_1 \exp[i(kx - \omega t)]$$
$$\emptyset_1(x,t) = \emptyset_1 \exp[i(kx - \omega t)]$$

Dispersion Relation

$$1 + \frac{e^2\, n_{es0}}{\epsilon_0\, K_B\, T_{es}\, k^2} + \frac{e^2\, n_{e0}}{\epsilon_0\, K_B\, T_e\, k^2} - \frac{e^2\, n_{ic0}}{\epsilon_0\, m_{ic}\, \omega^2} - \frac{e^2\, n_{is0}}{\epsilon_0\, m_{is}[(\omega - k\, U_{iso})^2 - 3\, \epsilon_0\, K_B\, T_{is}\, k^2]} - \frac{e^2\, n_{ih0}}{\epsilon_0\, m_{ih}[\omega^2 - 3K_B\, T_{ih}\, k^2]} = 0$$

Normalization of Dispersion Relation:

Frequencies are normalized by proton plasma frequency $\omega_{pi} = \sqrt{\frac{e^2\, n_{ic0}}{\epsilon_0\, m_i}}$.

Velocities are normalized by ion acoustic waves $C_s = \sqrt{\frac{K_B\, T_e}{m_i}}$.

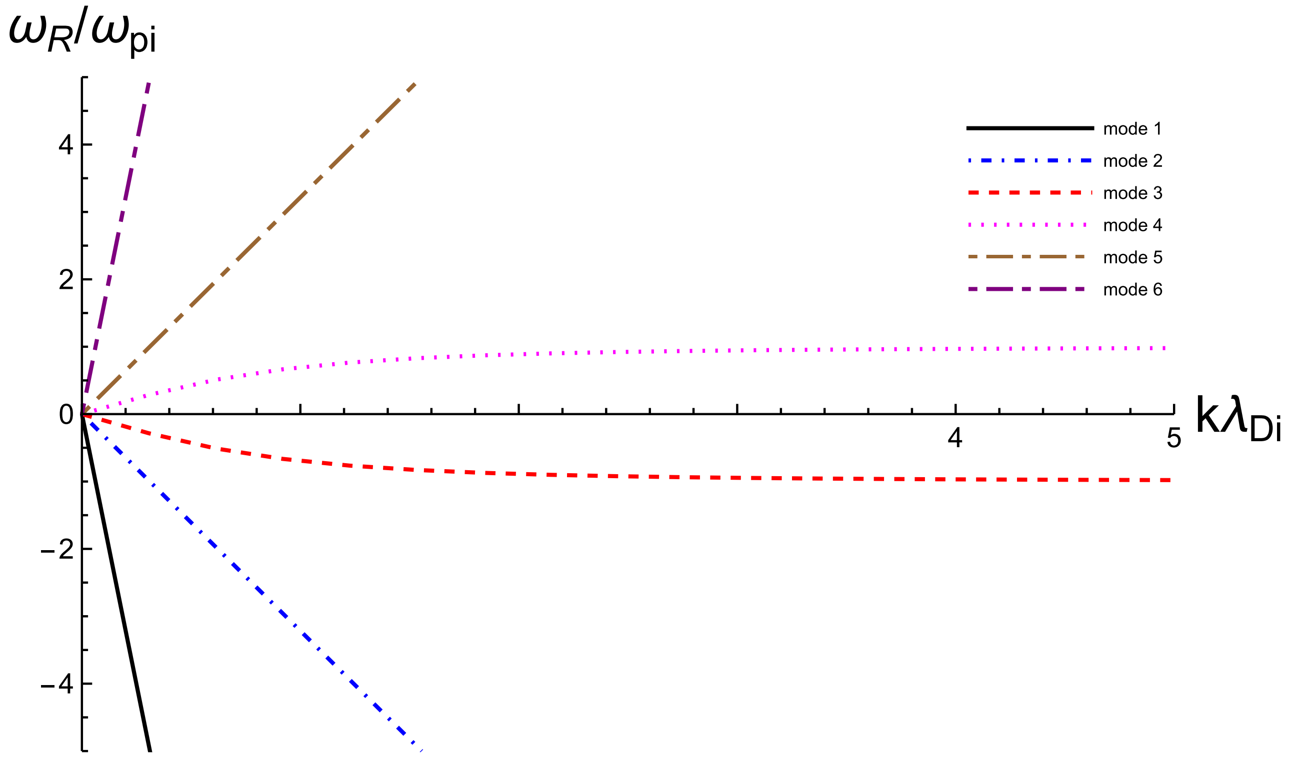
Wave number (k) normalized by proton Debye length $\lambda_{Di} = \sqrt{\frac{\epsilon_0 K_B\, T_e}{e^2\, n_{ic0}}}$.

$$1+\frac{\delta_1}{\lambda_{Di}^2\,k^2\,\sigma_1}+\frac{\delta_2}{\lambda_{Di}^2\,k^2}-\frac{\delta_3}{(x-\lambda_{Di}\,k\,v)^2-3\lambda_{Di}^2\,k^2\,\sigma_2}-\frac{1}{x^2}-\frac{\delta_4}{x^2-3\lambda_{Di}^2\,k^2\,\sigma_3}=0$$

$$\delta_1=\frac{n_{es0}}{n_{ic0}},\quad \delta_2=\frac{n_{e0}}{n_{ic0}},\quad \delta_3=\frac{n_{is0}}{n_{ic0}},\quad \delta_4=\frac{n_{ih0}}{n_{ic0}}$$

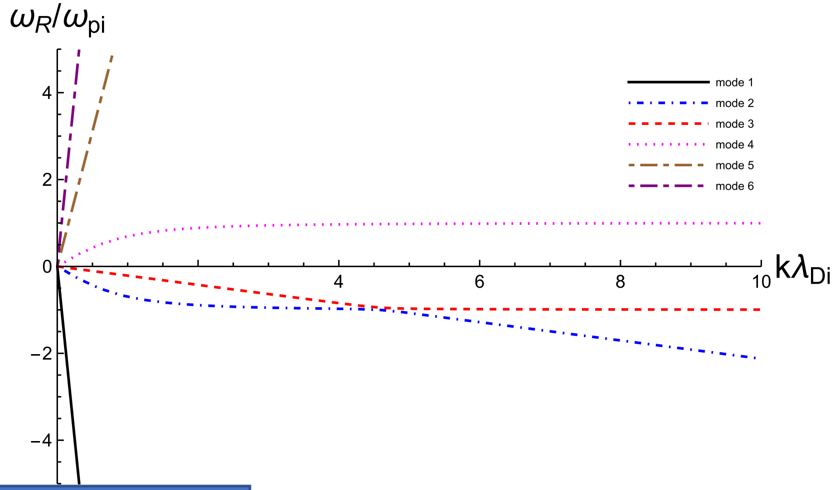
$$\sigma_1=\frac{T_{es}}{T_e},\quad \sigma_2=\frac{T_{is}}{T_e},\quad \sigma_3=\frac{T_{eh}}{T_e}$$

$$x=\frac{\omega}{\omega_{pi}},\ v=\frac{U_{is0}}{C_s}$$

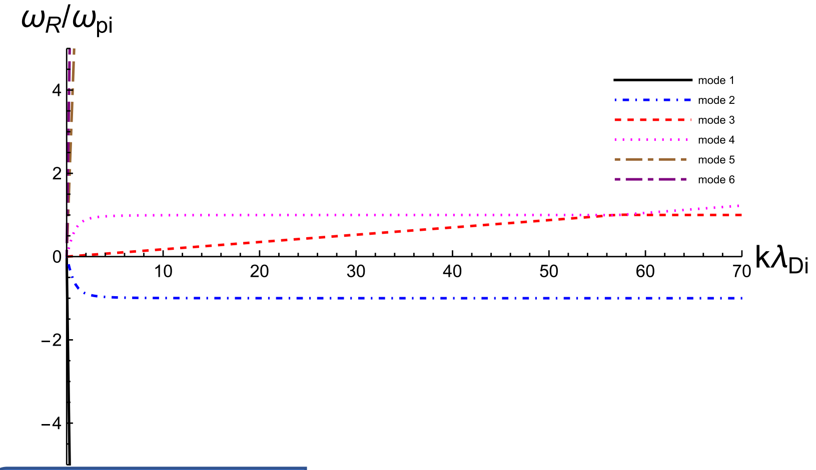


Influence of solar ion beam velocity

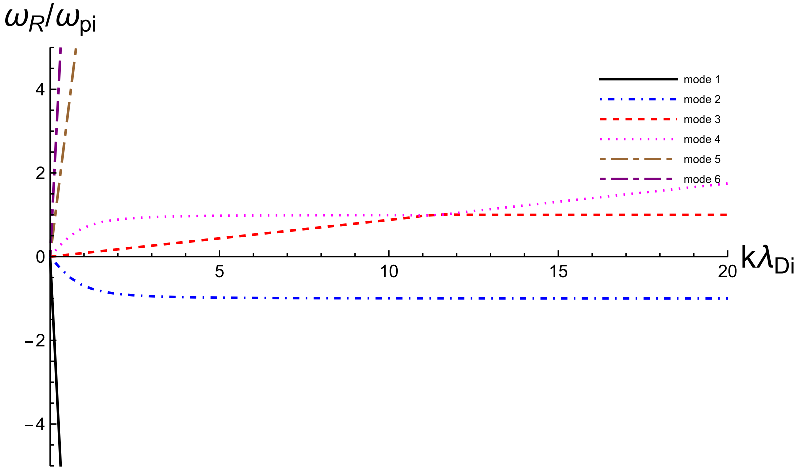
v=3



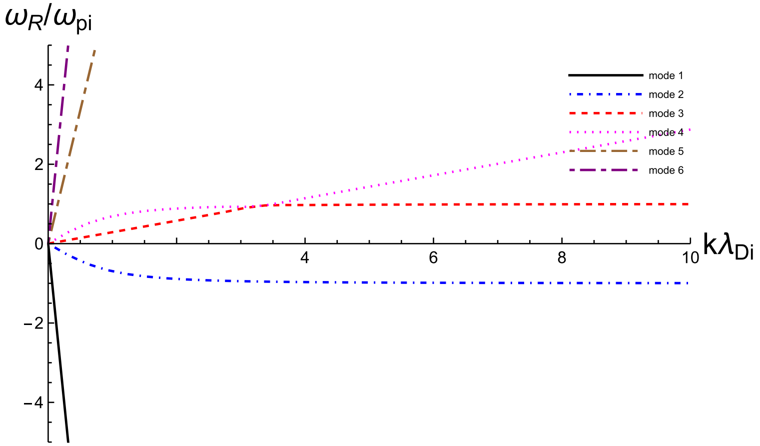
v=3.23



v=3.3

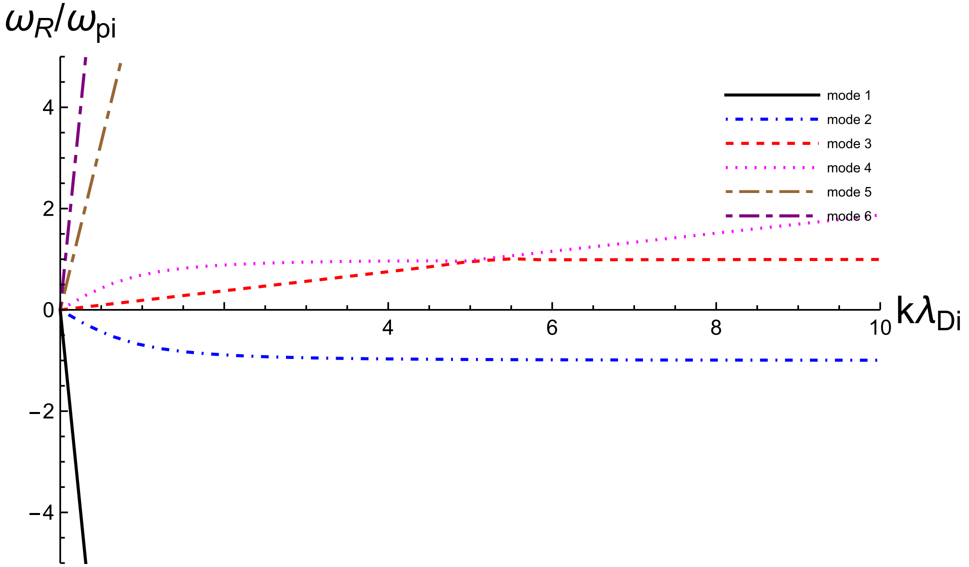


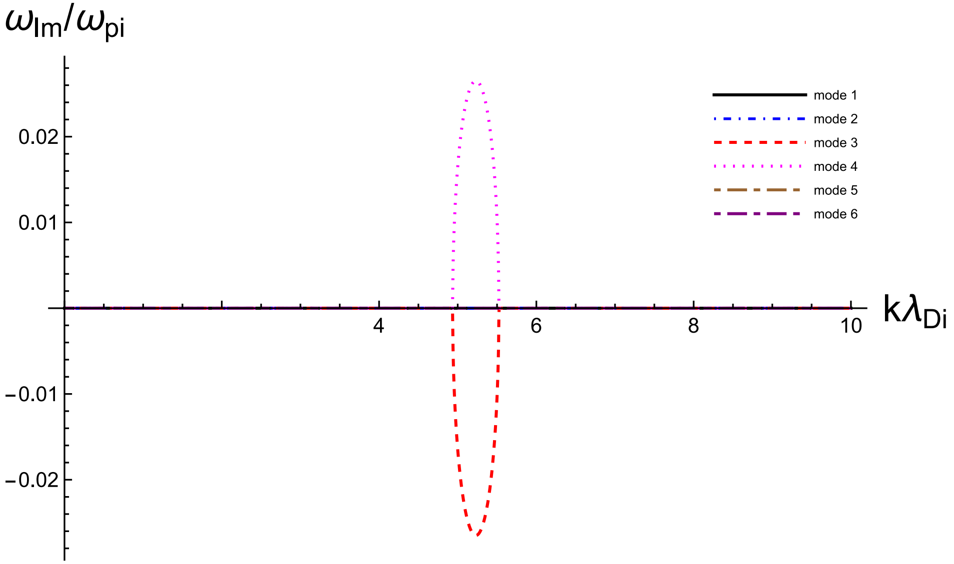
v=3.5



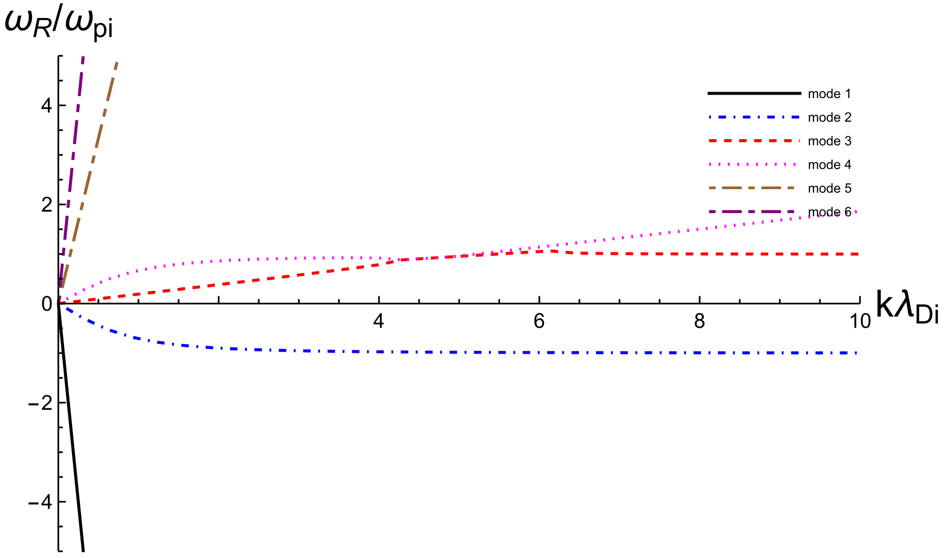
Influence of density of solar ions

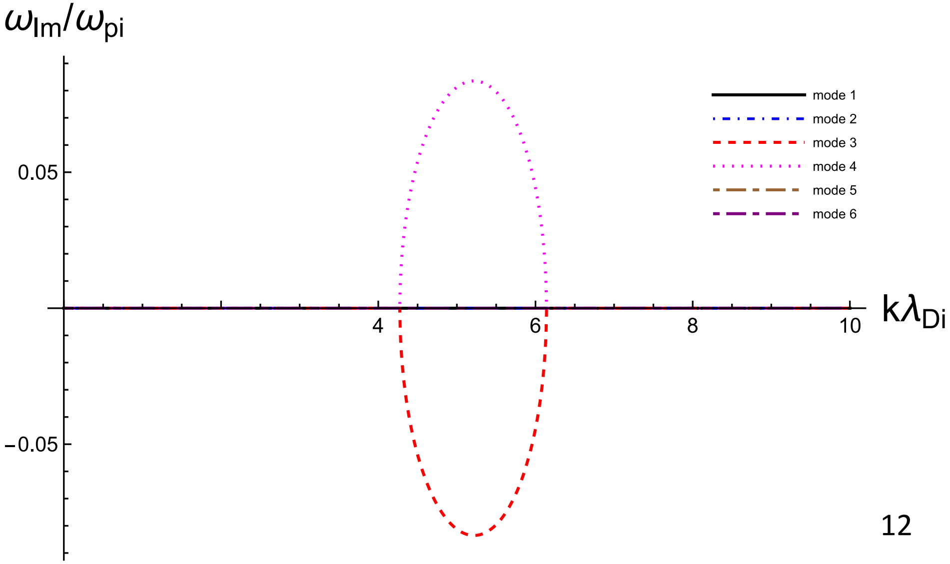
$n_{is0}/n_{ic0} = 0.05$





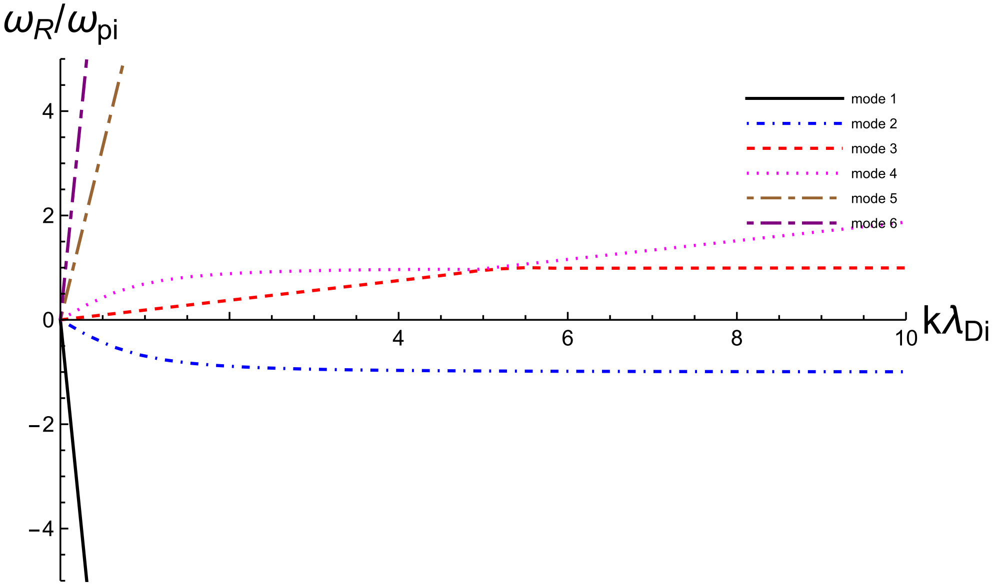
$n_{is0}/n_{ic0} = 0.5$

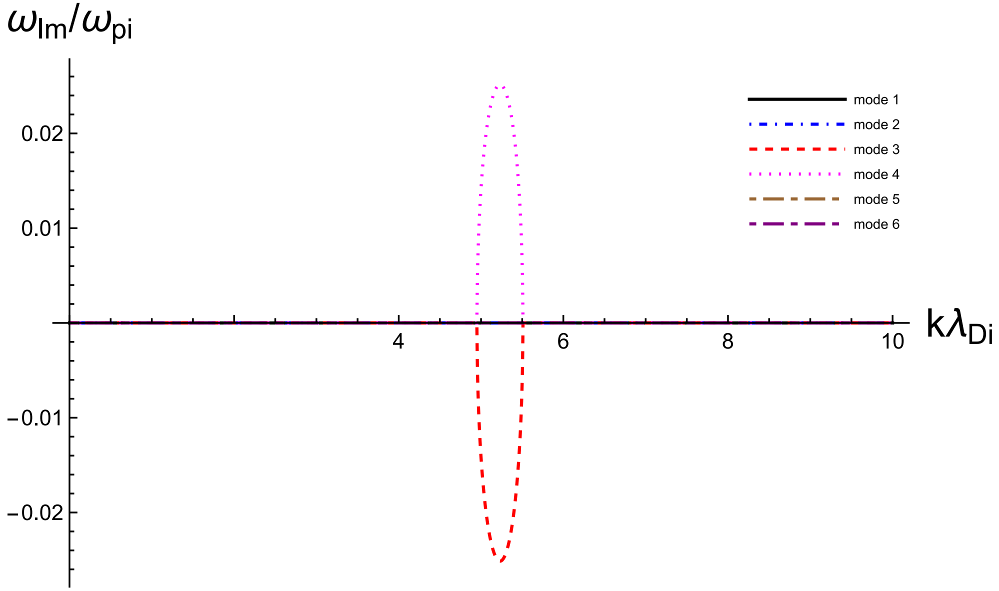




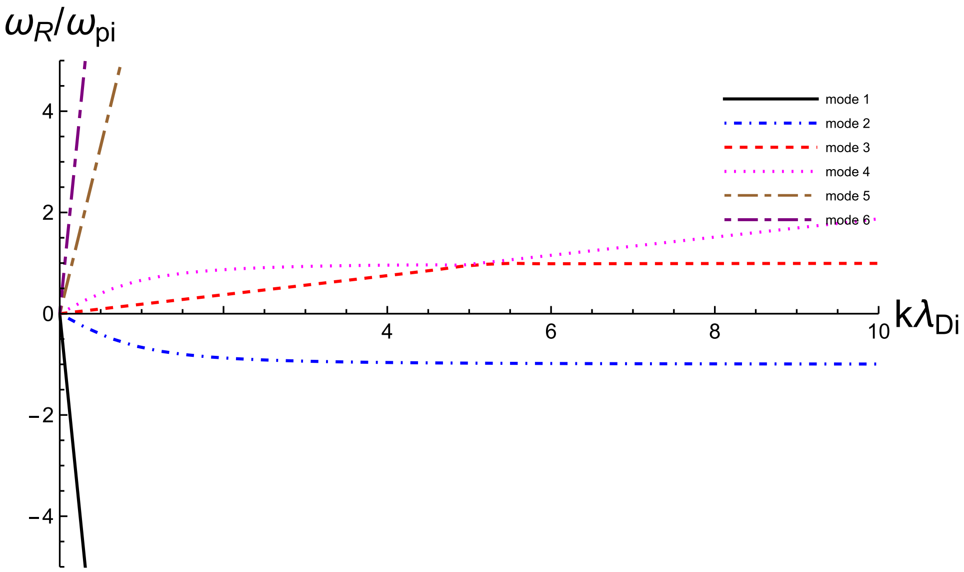
Influence of density of solar electrons

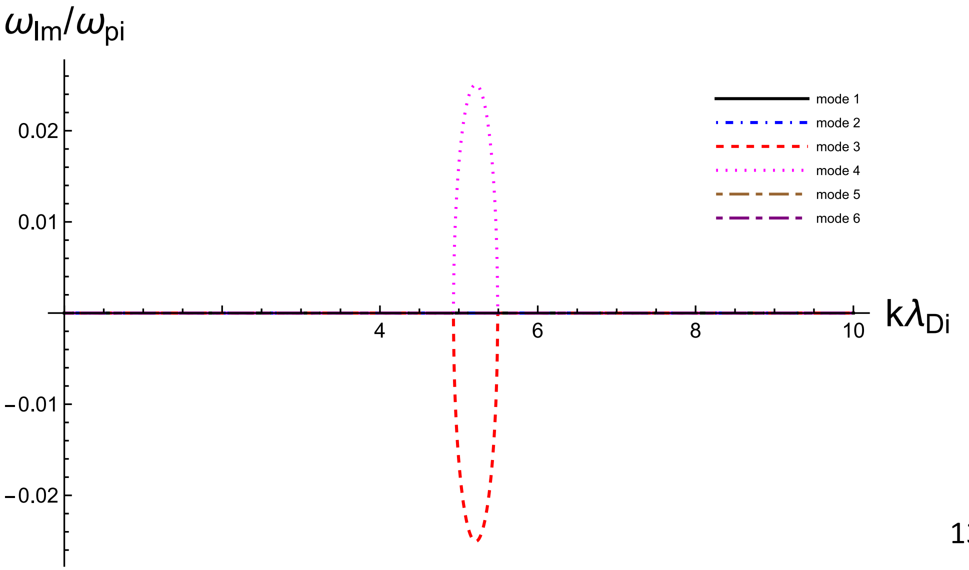
$n_{es0}/n_{ic0} = 0.01$





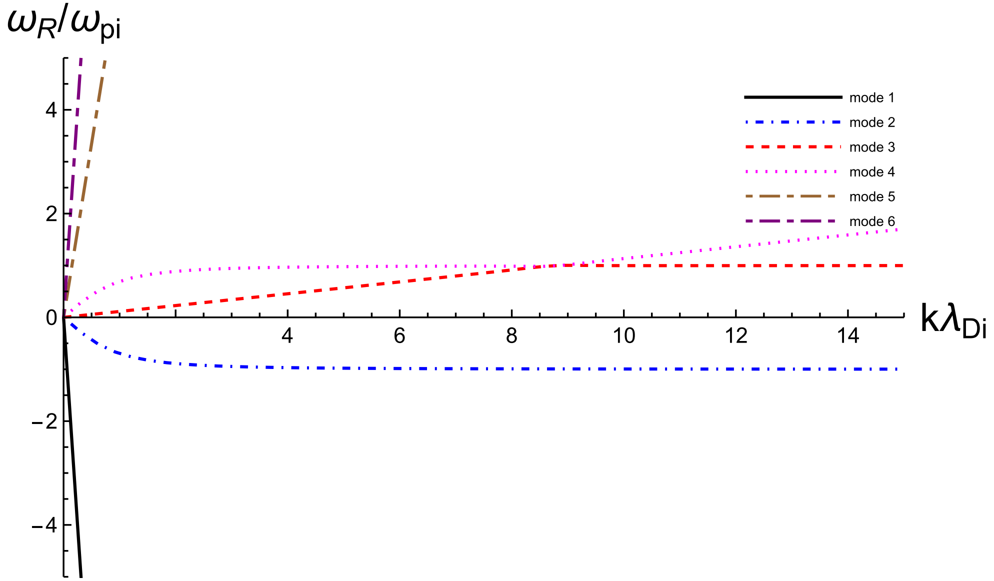
$n_{es0}/n_{ic0} = 0.1$

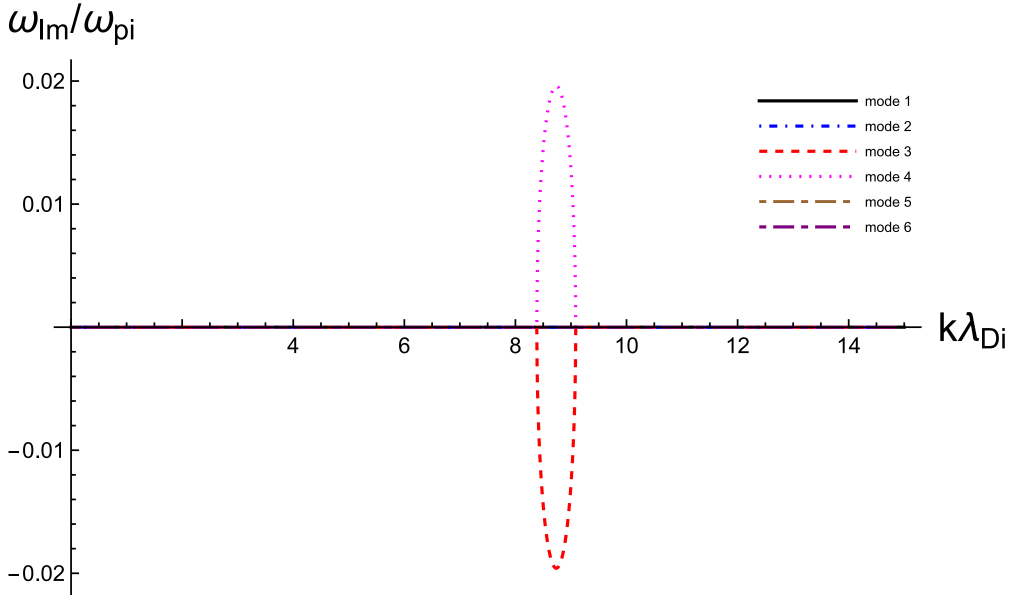




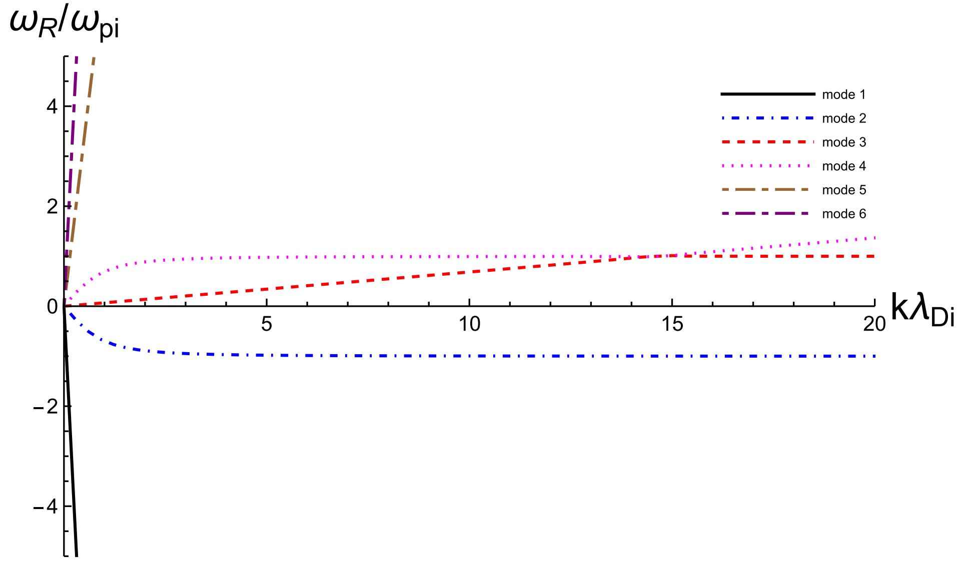
Influence of temperature of solar ions

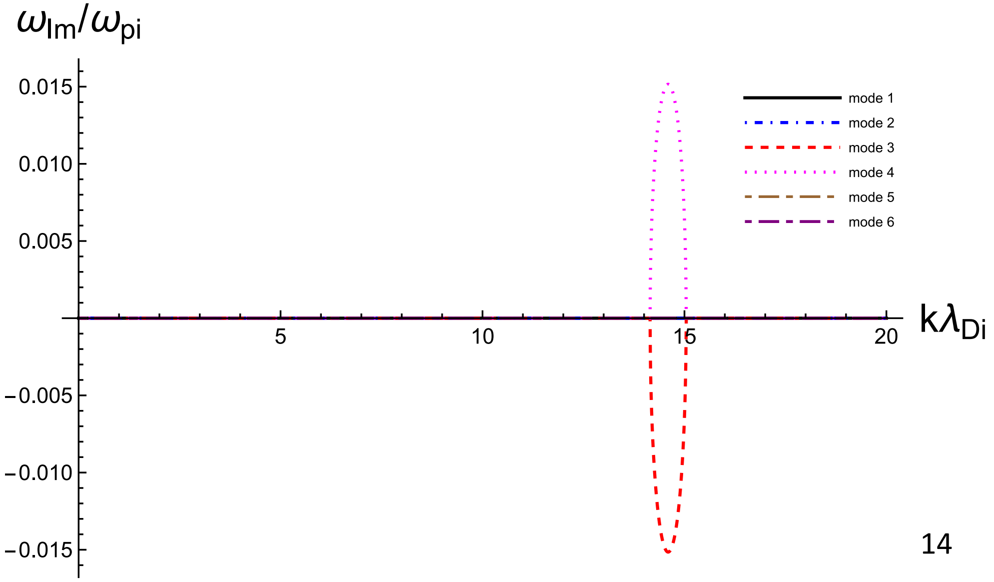
$T_{is}/T_e = 3.6$





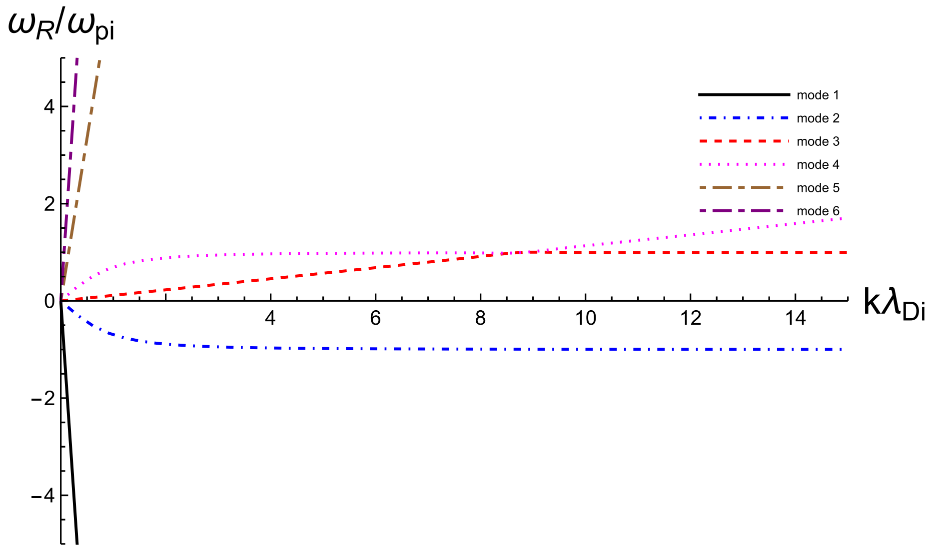
$T_{is}/T_e = 3.7$

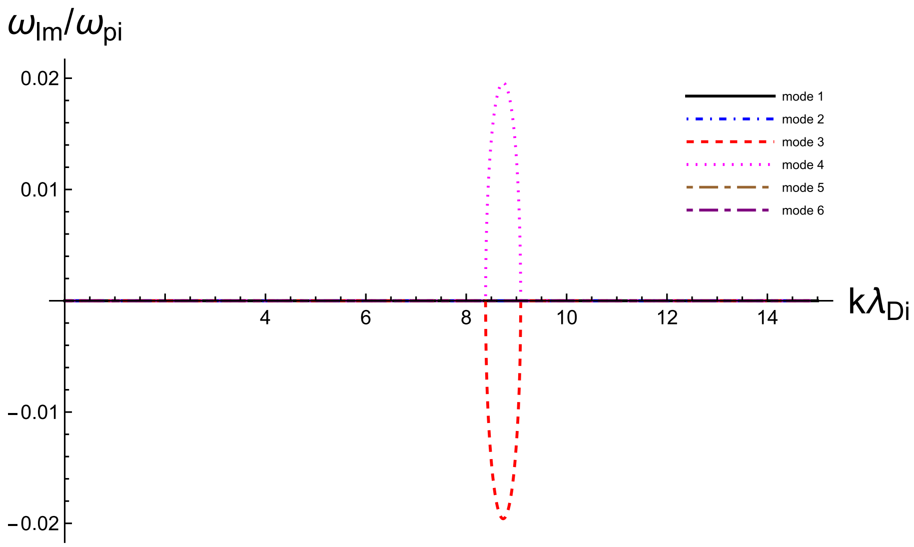




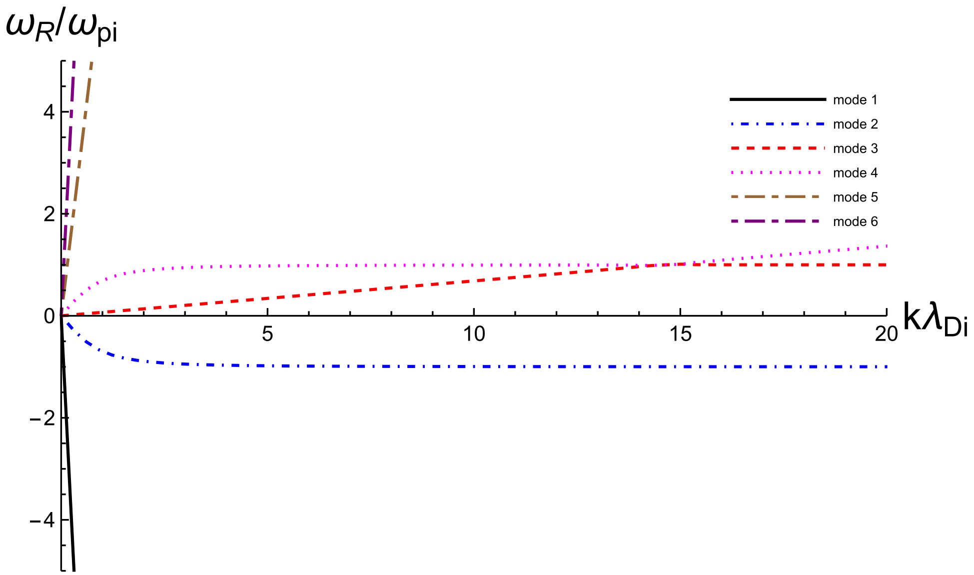
Influence of temperature of hot ions

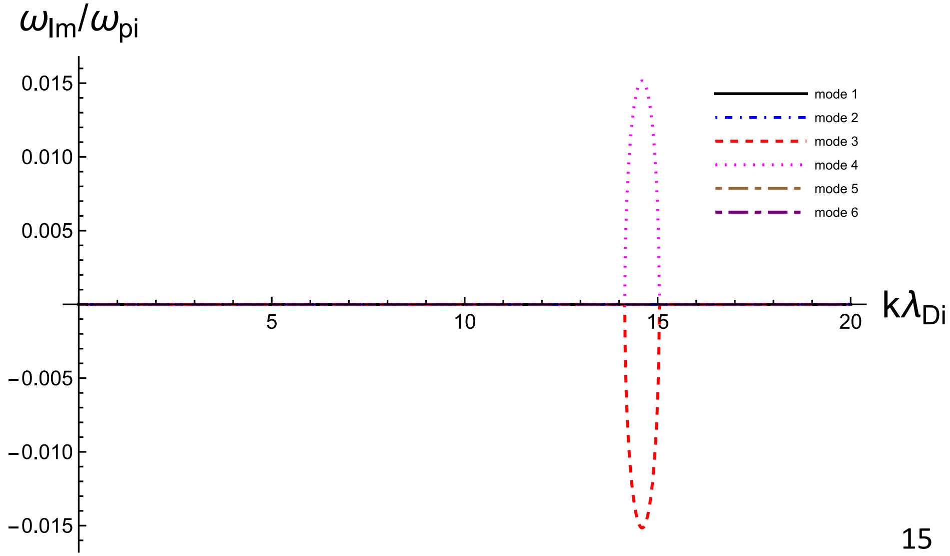
$T_{ih}/T_e = 3.6$





$T_{ih}/T_e = 3.7$





Summary

- We had done a linear analysis of properties of electrostatic waves in a system of plasma.
- Plasma consisted of 5 components as solar ions beam, solar electrons, hot ions, cold ions and background electrons.
- Dispersion relation was obtained by solving fluid model equations. Six roots were gotten as two for solar ions, two for hot ions and two for cold ions.
- It is observed that by increasing solar ion beam velocity, phase velocity of mode 5 increased. At $\frac{U_{is0}}{C_s} = 3$ mode 2 begin to merge with mode 3 to form an unstable region. Merging occurred at low wave number. As $\frac{U_{is0}}{C_s}$ increased merging region shifted to high wave number. Also, frequency increased. Continuously increasing ion beam velocity mode 3 started to merge with mode 4 at $\frac{U_{is0}}{C_s} = 3.22$ at high wave number. The merged region was almost fixed and frequency increased. Also, it is observed unstable region shift to low wave number as ion beam velocity increased until disappeared at $\frac{U_{is0}}{C_s} = 4.3$.

Summary

- ❑ The effect of different spices density was investigated:
- ▪ For increasing density of solar ions beam, the merged region between modes 3 and 4 increased and frequency also increased.
- ▪ The effect of density of solar electrons is not noted.
- ❑ The effect of temperature of different spices was studied as:
- ▪ Increasing solar ions beam temperature, the instability region between modes 3 and 4 was almost fixed and shifted to high wave number. However, frequency of wave decreased.
- ▪ Same behavior for temperature of hot ions, where increasing temperature leaded to instability region shifted to high wave number and decreasing in frequency of wave.


THANKS!