Quick User Guide to PKUES

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1. Introduction:

PKUES is a tool package programmed in Matlab language, and stands for "Plasma Kinetics Unified Eigenmodes' Solution". It mainly consist of three parts. (1) It solves and displays the dispersion relation of all possible eigenmodes at one time by transforming the dispersion relation to a standard matrix eigenvalue problem of an equivalent linear system. This part is mainly based on the tool of PDRK (Plasma Dispersion Relation Kinetics) (Xie & Xiao, Plasma Science and Technology, 18(2), 97., 2016). (2) It calculates and displays wavenumber dependence of the polarization relationship, transport ratio, compressibility and magnetic helicity, providing a reference for users to choose the appropriate wave mode they want. Besides the wave electromagnetic field vectors, the fluctuations of number density and bulk velocity of different particle species are also calculated. (3) It also calculates and display the disturbed velocity distribution (phase space density) of different particle species main according to the textbook of "Wave in Plasmas" (Stix, 1992). The function of the third part is similar to the second part of the NHDS tool programmed in Fortran language (Verscharen et al., Astrophys J 831:128, 2016; Verscharen & Chandran, Arixv, 1804.10096, 2018).

2. Setup of background magnetized plasma conditions & wavenumber domain of interest:

(1) set the file: /input/input.m for the plasma parameters
(The same as the package of pdrk)
Set parameters of different components:
charge, qs, unit: elementary charge;
mass, ms, unit: proton mass;
number density, ns, unit: m^{-3};
Parallel temperature, Tzs, unit: eV;
Perpendicular temperature, Tps, unit: eV;
Parameter in VDF, alpha;
Parameter in VDF, Deltas;
Drift parallel to the background magnetic field, vds, unit: light speed;

Example:

qs(e)	ms(mp)	ns(m^-3)	Tzs(eV)	Tps(eV)	alphas	Deltas	vds/c
1	1	1.1e6	2383.3	4340.6	1.0	1.0	0.0
-1	5.447e-4	1.1e6	348.0	458.3	1.0	1.0	0.0

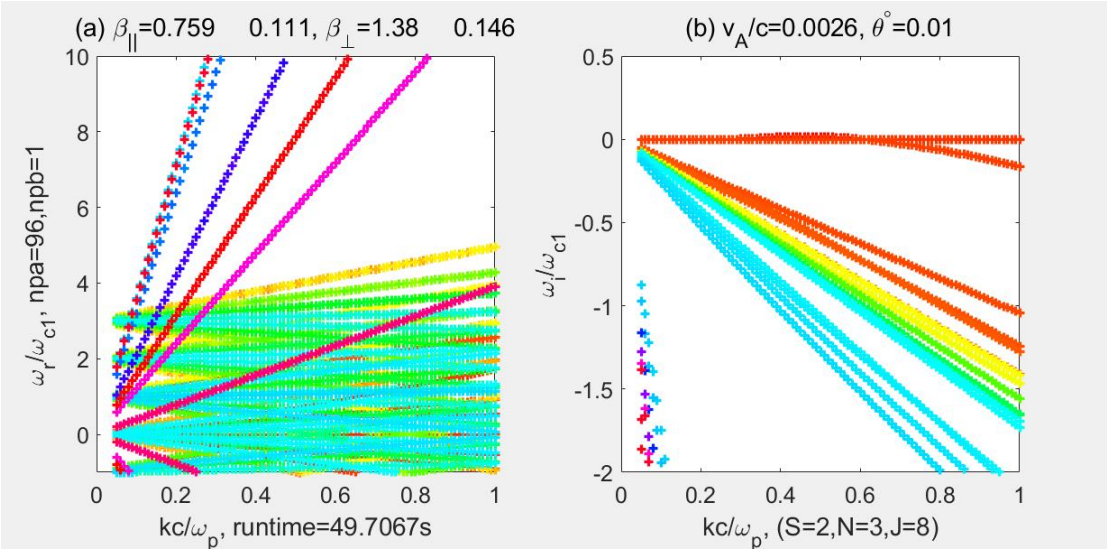
(2) Set the file: /input/pkues_setup.m for background magnetic field, k start, k end, k

step
magnetic field: B0=37.3E-9; % magnetic field (Tesla)
k: pa1=0.05; pa2=1; dpa=0.01

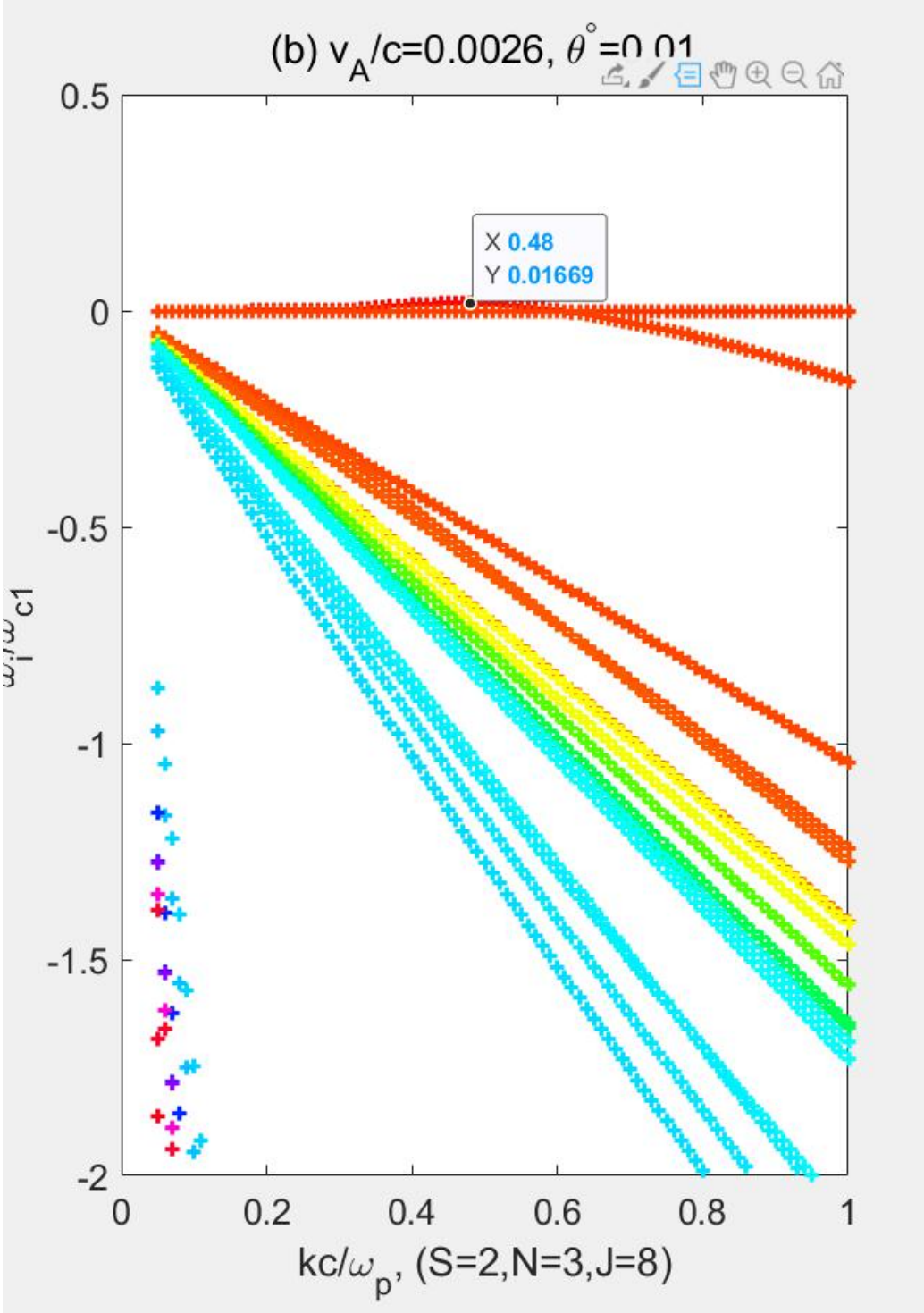
Note: We have modified "pdrk_setup.m" by adding the following three aspects of content.
(a) If idf=1, calculate the disturbed velocity distribution functions (VDFs) of the eigenmode. If if=0, skip calculating the disturbed velocity distributions.
(b) Determine at which point in the parameter space to calculate the VDFs.
jpa_df: point in the first parameter space.
jpb_df: point in the second parameter space.
s_df: determine which species to calculate disturbed VDFs.
(c) Set the calculation ranges (vxrange, vyrange, vzrange) and number of points (vxsteps, vysteps, vzsteps) in velocity space, and amplitude of the fluctuations (ampl).

3. Run to calculate the dispersion relations of all wave modes and select the target wave mode:

(1)Run the file: pdrk_main_modified.m
(2)You will get the plots of all the dispersion relations (output from pkues_plot_all.m):



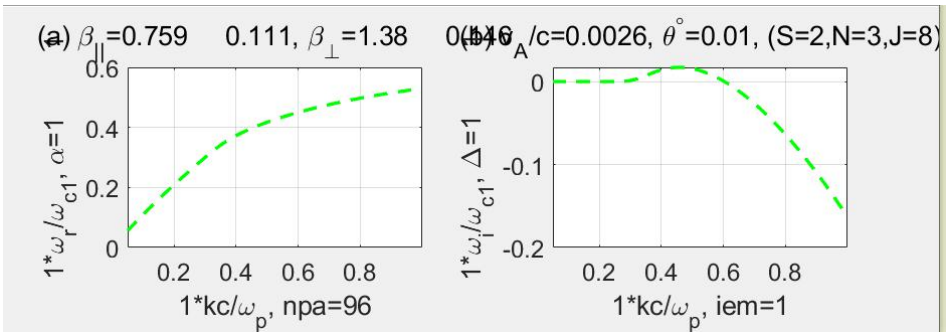
(3) Using data tips to select a branch of the waves:



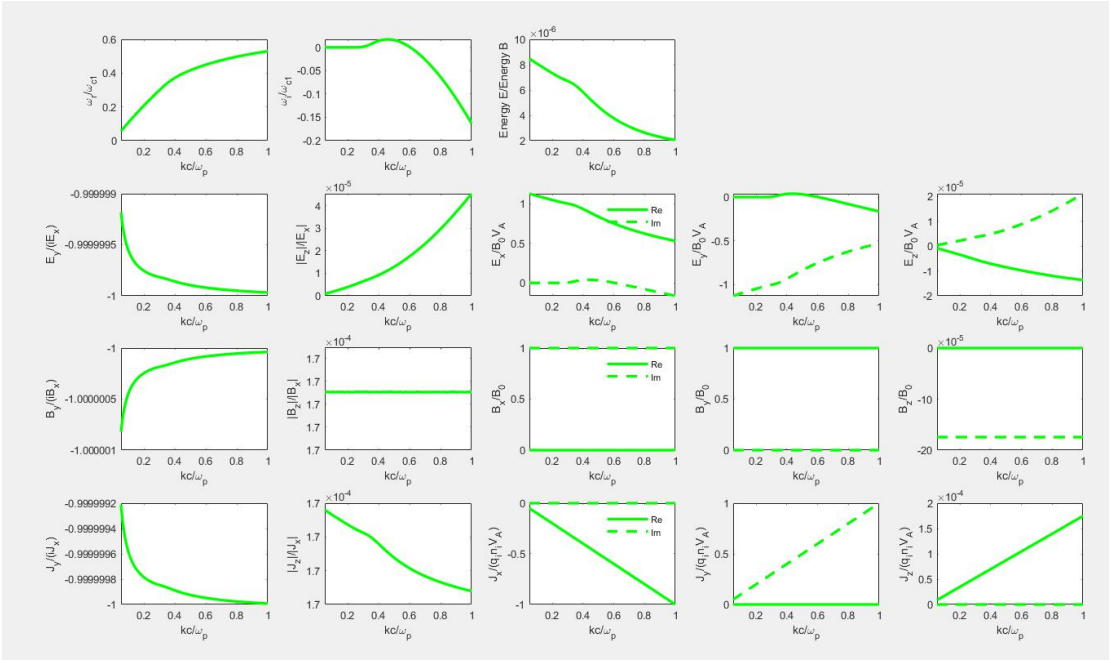
Input 1 (for real frequency) or 2 (for imaginary frequency) in the console to confirm.

4. Get and visualize results of the target wave mode:
Below illustrate some examples.

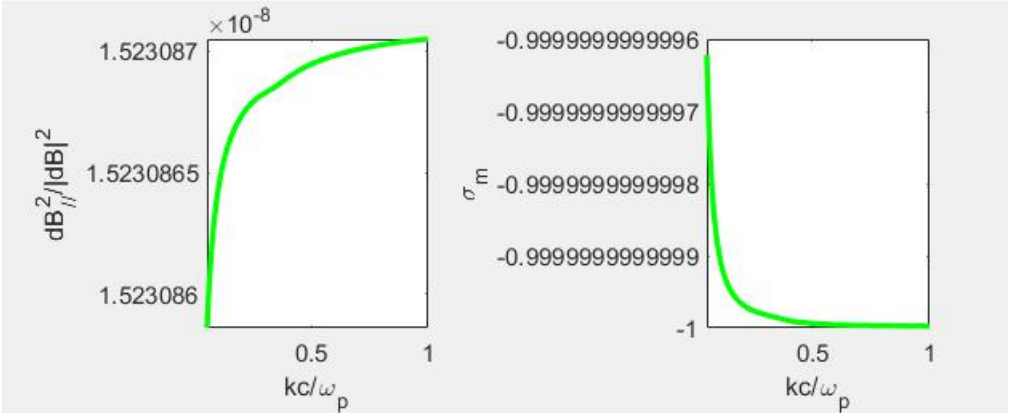
Frequencies (real and imaginary parts) as a function of wavenumber (↓):



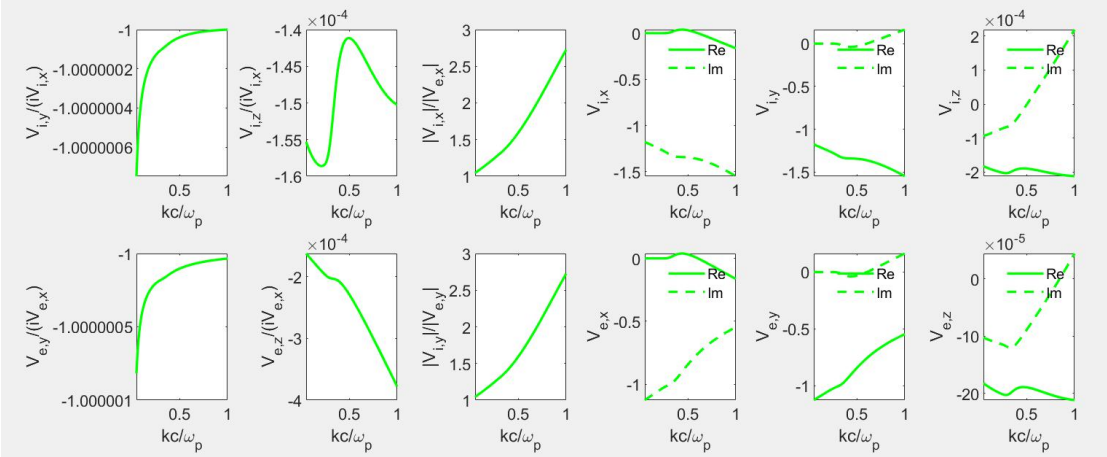
General polarization and transport ratio as a function of wavenumber (output from pkues_output.m) (↓):



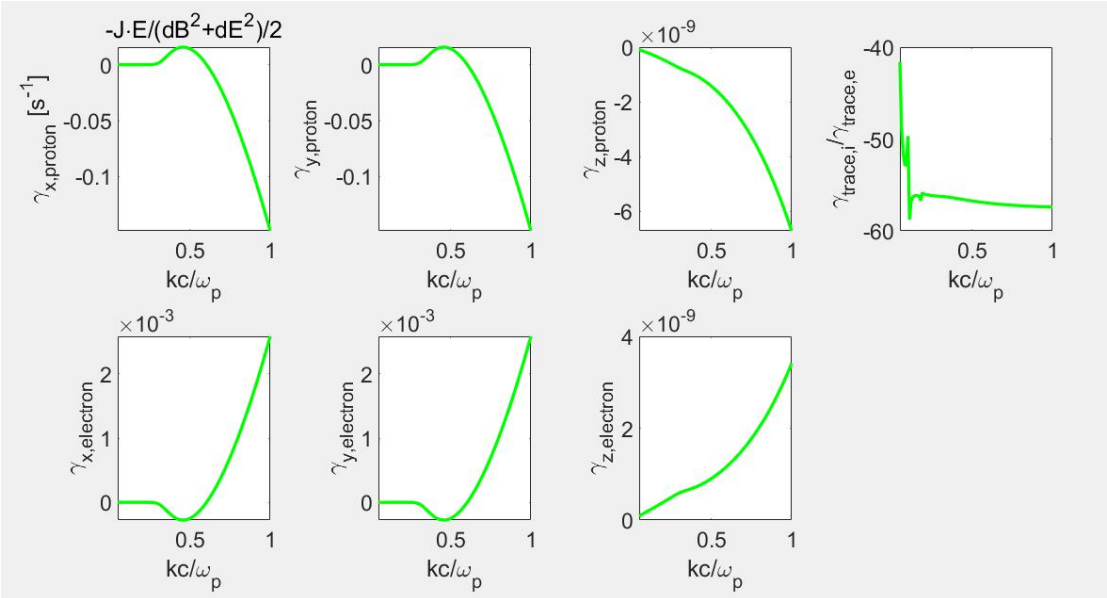
Magnetic compressibility and magnetic helicity (-1 for Left-handed and 1 for Right-handed when ωr>0, and vice versa when ωr<0) (output from pkues_output.m) (↓):



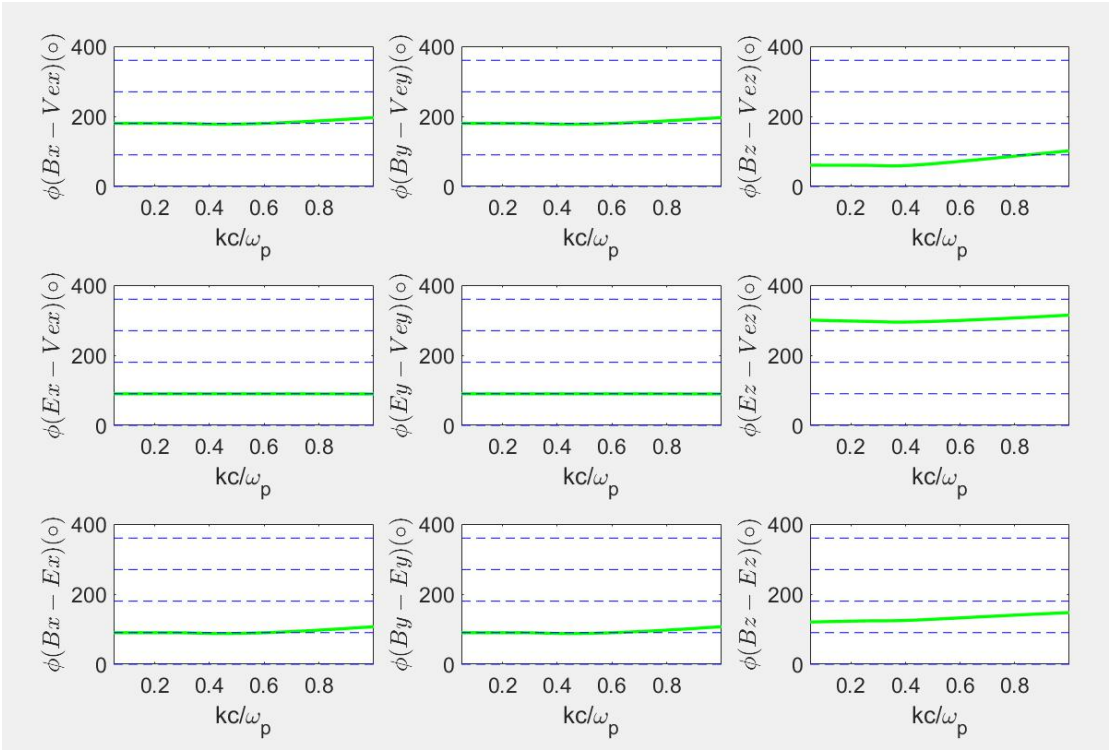
Velocities perturbations and polarizations (output from pkues_plot_comp_velocity.m) (↓):

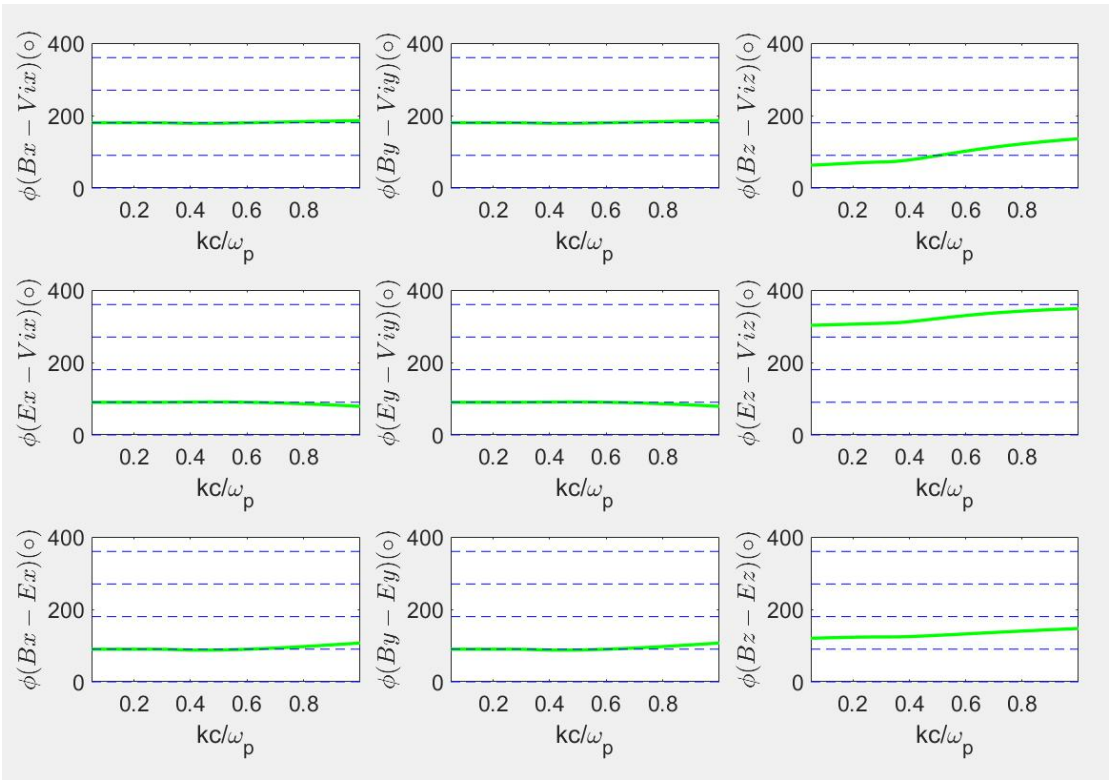


Pseudo energy transfer rate between field and particles (output from pkues_plot_growing_rate.m) (↓): (see He et al. ApJ, 880, 121, 2019, Duan et al. ApJ, 896, 47, 2020)



Phase difference between disturbed electromagnetic fields and disturbed proton/electron fluid velocities (↓):





5. Calculate disturbed VDFs and ouput vtk files for visualization:

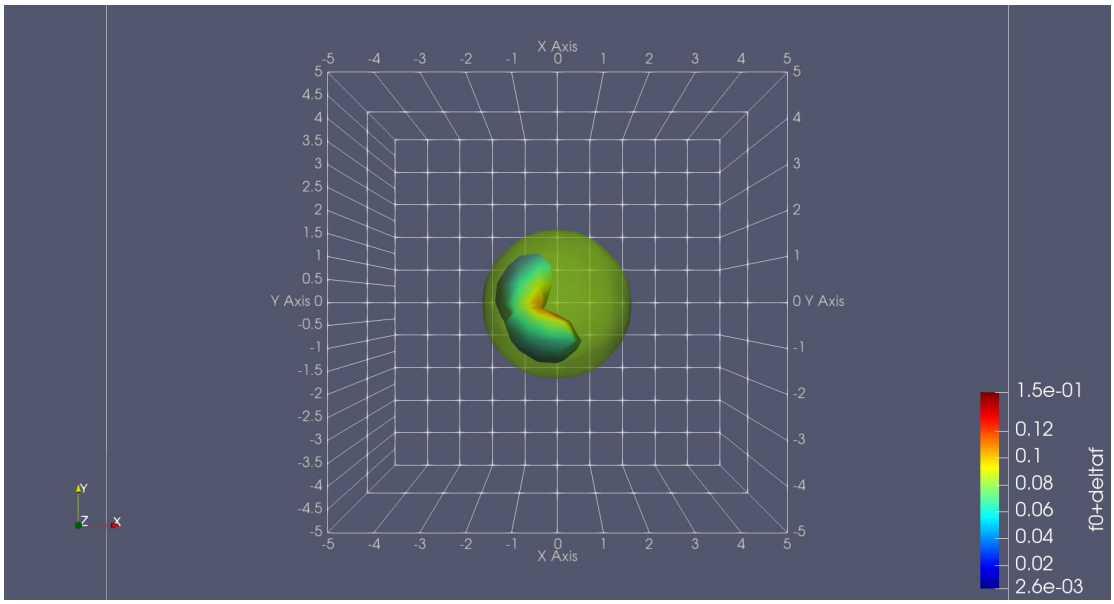
Program file: pkues_write_f_SI_unit.m

(refer to Chapter 10 in Stix (1992), similar to NHDS)

This is the program that calculates the VDFs of species in SI unit.

This code can output the data file in vtk format to be loaded by “ParaView”. (You can change the output file format in this program)

An example illustrating the disturbed and total (disturbed plus background) VDFs associated with an ion cyclotron wave mode through Paraview:



6. Calculate plasma kinetics in terms of the conductivity matrix:

Program file: pkues_velocity.m

Calculate the velocity fluctuations of different species at different points in parametric space.

dV: velocity fluctuations in SI unit.

dVnorm: normalized velocity fluctuations, dV/VA.

JE: growing/damping rates of different species.

Xinorm: normalized density fluctuations.