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Introduction

The animations illustrate the different classes of interchange and quasi-interchange motion that plasma elements (ions and electrons) can experience in a dipole magnetic field.

André (2003) and Ferrière and André (2003) re-examined the MHD formulation of interchange motion, introduced in magnetospheric physics by Gold (1959). In this early formulation interchange was based on assumptions (i) that magnetic field lines were not curved, and (ii) that the plasma density was nearly uniform in the direction parallel to the magnetic field vectors. This original interchange has been labeled "Pure-Interchange" by Newcomb (1961) since it is implicitly based on the postulate that the wave vector component was everywhere equal to zero in the direction parallel to the local magnetic field vectors : $k_{par} = 0$ (: no node points along magnetic field lines). We use he abbreviation P-I for this mode and will sometimes call "strict interchange" since this is the mode that has been traditionally adopted within the magnetospheric community for over three decades.

Thus in the early formulations of interchange modes the dispersion relation did not take into account non-uniformities of the B-field distribution (due to the curvature of geomagnetic field lines), nor of the plasma distribution due to field aligned stratification resulting from gravity, centrifugal forces, or resulting from the breakdown of the condition $k_{par} = 0$ (i.e. for the generation situation when the MHD oscillations had a finite number of node points along magnetic field lines). These new modes of interchange for which $k_{par} \neq 0$ and $k_{per} \neq 0$, have been labeled "Quasi-Interchange" by Newcomb (1961); we will also use this original terminology and use the abbreviation: Q-I. to identify these more general interchange MHD modes. These additional effects change significantly the dispersion relations and the thresholds for which the various quasi-interchange modes become unstable (see André, 2003; Ferrière and André, 2003 for more details).

The different modes of MHD interchange modes (periodic oscillations and expansion flows, including the plasmaspheric wind flow) are displayed in five animations which are described in a separate file available here: PlasmasphericWind_Descriptions.pdf.

At initial time all plasma elements are distributed along segments of dipole magnetic field lines. Later on they oscillate with a fixed frequency both perpendicular and parallel to the local B-field directions.

Different types of strict interchange and Quasi-Interchange modes are shown.

According to Newcomb (1961)'s original terminology the Q-I modes correspond to MHD periodic oscillations which have displacements both transverse to magnetic field lines as well as parallel to them.
For the Q-I mode of type 1 the amplitude of transverse displacement is larger than the amplitude of the translational (or longitudinal) oscillation along the magnetic field lines.
For the Q-I mode of type 2 the amplitude of transverse displacement is smaller than the amplitude of the translational oscillation along the magnetic field lines.

Note that both oscillatory components are assumed to have the same period of oscillation but may have different phase angles. When the phase angles are not equal one obtains propagating MHD waves; on the other hand when the phase angles are equal one obtains stationary (non-propagating) waves.

These oscillatory components may have any number of node points transverse as well as along magnetic field lines. At nodes points the displacement is null, and plasma elements are motionless. The number of node points along the magnetic field determines the parallel wave number, $k_{//}$ of the MHD wave. The number of node points in the transversal direction is an additional free input parameter of the IDL code used. The number of nodes in the transverse direction determines the perpendicular wave number, $k_{\perp}$.

When $k_{//} \Rightarrow 0$ (i.e. when the number of field-aligned node points tends to zero) the Quasi-Interchange mode of type 1 becomes the so-called Pure-Interchange mode; this P-I mode corresponds to "the interchange motion" as originally introduced by Gold (1959) in magnetospheric physics.
When $k_{//} \Rightarrow 0$ (i.e. when the number of field aligned node points tends to zero) the Quasi-Interchange mode of type 2 becomes a periodic or non-periodic translation of plasma flow along magnetic field lines (i.e. inter-hemispheric or polar wind kind flows).

A wide spectrum of different types of MHD waves can thus be simulated with our IDL code, by changing 8 independent input parameters. Only five typical cases are shown in the five GIF files: File_1.gif ; File_2.gif ; File_3.gif ; File_4.gif ; File_5.gif. Qualitative descriptions of all five animations are given below.

Direction of use

The individual animations start automatically by “double clicking” the icon of the five different GIF files.
Each GIF file (or its icon) can also be dragged into an INTERNET EXPLORER window or into a MOZILLA FIREFOX window, where it will open automatically when released.

Bibliographical references

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Origin of the software and copyright

The following GIF files are animations which have been designed by Joseph Lemaire, IASB, Brussels, Belgium.
They have been presented, 21 Sep. 2007, for the first time at the *2007 PLASMASHERE WORKSHOP*, in Brussels, and 3 January 2008 at the USNC/URSI meeting in Boulder, Colorado.
The IDL software code has been developed by *L. Dricot, Waterloo, Belgium*.
These animations have been produced at *the Belgian Institute for Space Aeronomy (IASB)* in Brussels.

The current version of the IDL code produces output files (GIF format) showing the motion of plasma elements in 2D displays, for different input parameters.
Additional runs and animations, others than those five displayed here can be ordered from *J.F. Lemaire (jfl@astr.ucl.ac.be).*

These animations are instructive for classroom lectures, outreach talks and public presentations.
Authorisation must be requested to J.F Lemaire (jfl@astr.ucl.ac.be).
Commercial use of this material is forbidden unless written authorization by *BISA*.

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