Transformation of standing poloidal Alfven wave to toroidal Alfven wave due to the field line curvature

Dmitri Klimushkin,
Anatoli Leonovich,
Pavel Mager,
Institute of Solar-Terrestrial Physics, Irkutsk, Russia
Oleg Cheremnykh,
Space Research Institute, Kyiv, Ukraine

Prague, June 23, 2015
In memory of Vitali Mazur (1946-2015)
Three milestones

• 1954, J. Dungey, $m=0$:
  - Toroidal Alfven modes ($B_y \gg B_x$)

• 1967, H.R. Radoski, $m \gg 1$:
  - Poloidal Alfven modes ($B_x \gg B_y$);
  - different frequencies: $\Omega_T \neq \Omega_P$

• 1974: J. Southwood, L. Chen & A. Hasegawa, H.R. Radoski:
  - Logarithmic (pole) singularity at any $m$-number;
  - $\rightarrow$ at any $m$-number the Alfven wave can be toroidal ($B_y \gg B_x$)
Graphical representation of $\Omega_T \neq \Omega_p$

Region of poloidal polarization

Region of toroidal polarization

$\Omega_p$

$\Omega_T$

$\omega$

$x_p$

$x_T$

$x$

(poloidal surface)

(toroidal surface)
Global solution

- Leonovich & Mazur, 1993:
  - Wave travels from the poloidal to the toroidal surface;
  - The wave is standing along the field lines;
  - Radial group velocity and Poynting flux appear;
  - Beyond the region between poloidal and toroidal surfaces: the mode is evanescent;
  - In the course of propagation, polarization changes from poloidal to toroidal;
  - Cause: field line curvature.
Instability due to the interaction with the energetic particles

- Klimushkin, 1998:
  - The wave is generated by some external current...
  - ... And is amplified by the particles in the course of the propagation across the magnetic shells

- Large instability, small ionospheric attenuation
- Large attenuation, small instability
RBSP-A, Oct. 23, 2012. Magnetic field:
Lei Dai et al. 2013: Poloidal Alfven wave generated by energetic particles - II

RBSP-A, Oct. 23, 2012, electric field:

![Graph showing electric field variations](image-url)
Lei Dai et al. 2013: Poloidal Alfven wave generated by energetic particles - III
A newly born (impulse-excited) wave is poloidal, but is evolves into the toroidal due to the phase mixing (because $\Omega$ depends on $L$)

- Radoski, 1974: box model
- Leonovich & Mazur, 1998: with field line curvature
- Klimushkin & Mager, 2004: with field line curvature and instability due to the wave-particle interaction

However, in this case $\Omega(L)$, but in the Lei Dai’s case $\Omega = \text{almost const} (L)$

Probably, they observed monochromatic wave...

... And transformation was in space (due to the curvatore), not in time
Related publications

Thank you!