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

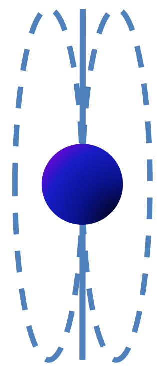
Dmitri Klimushkin,
Anatoli Leonovich,
Pavel Mager,
Institute of Solar-Terrestrial Physics, Irkutsk, Russia
Oleg Cheremnykh,
Space Research Institute, Kyiv, Ukraine

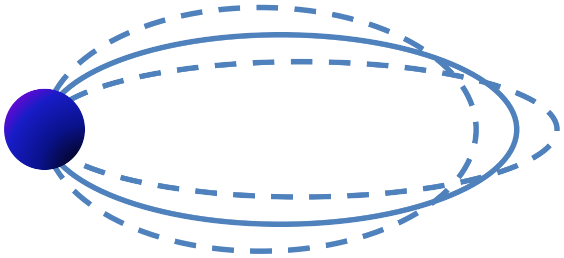
Prague, June 23, 2015

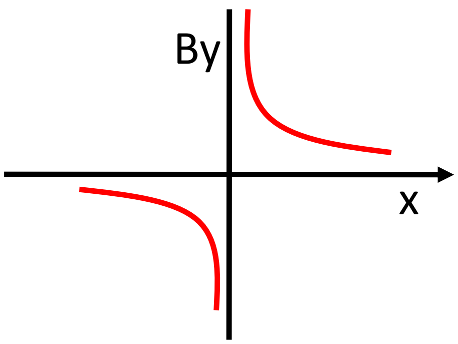
# In memory of Vitali Mazur (1946-2015)

# Three milestones

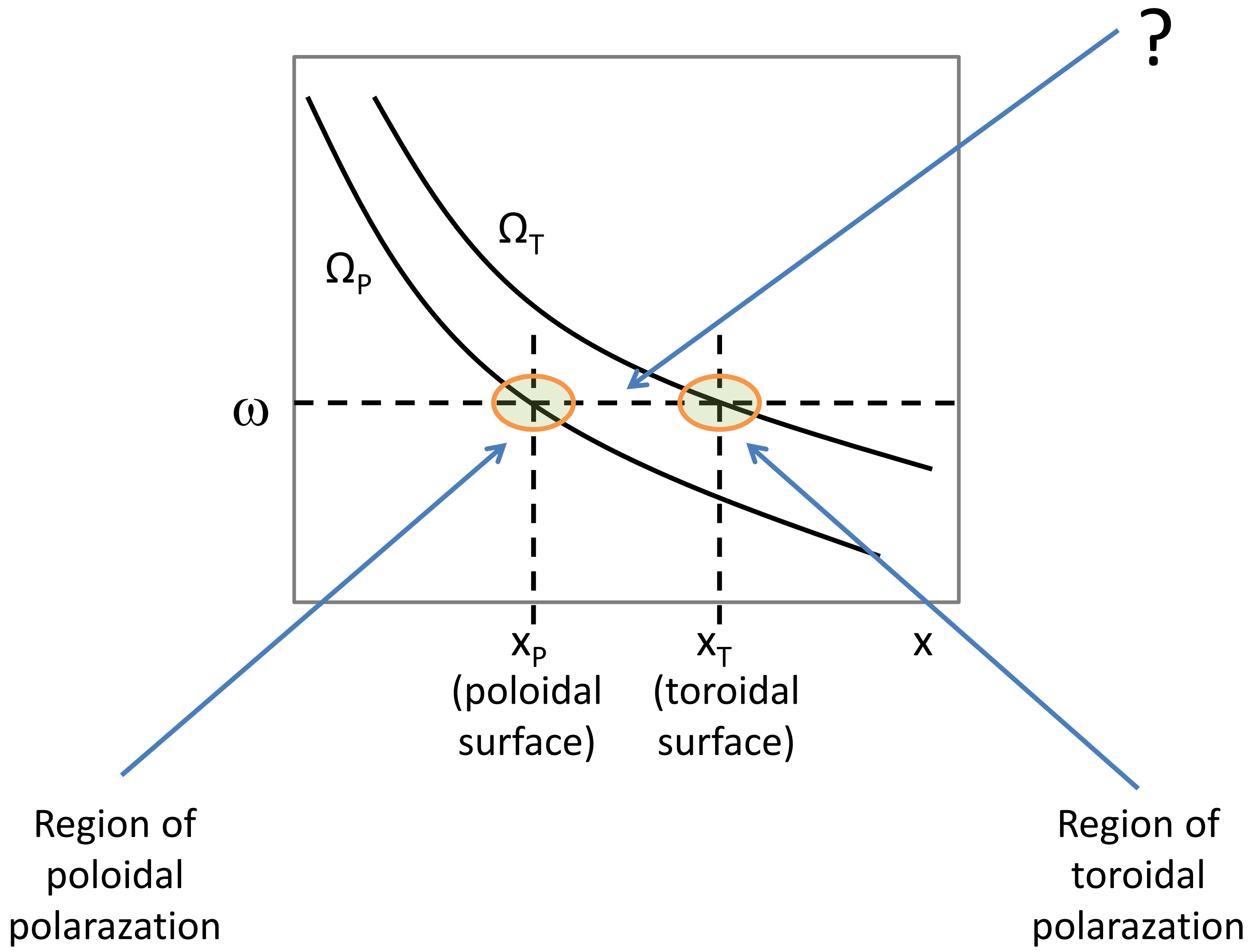
- 1954, J. Dungey, m=0:
  - Toroidal Alfven modes (By>>Bx)
- 1967, H.R. Radoski, m>>1:
  - Poloidal Alfven modes (Bx>>By);
  - different frequencies: $\Omega_T \neq \Omega_P$
- 1974: J. Southwood, L. Chen & A. Hasegawa, H.R. Radoski:
  - Logarithmic (pole) singularity at any m-number;
  - → at any m-number the Alfven wave can be toroidal (By>>Bx)





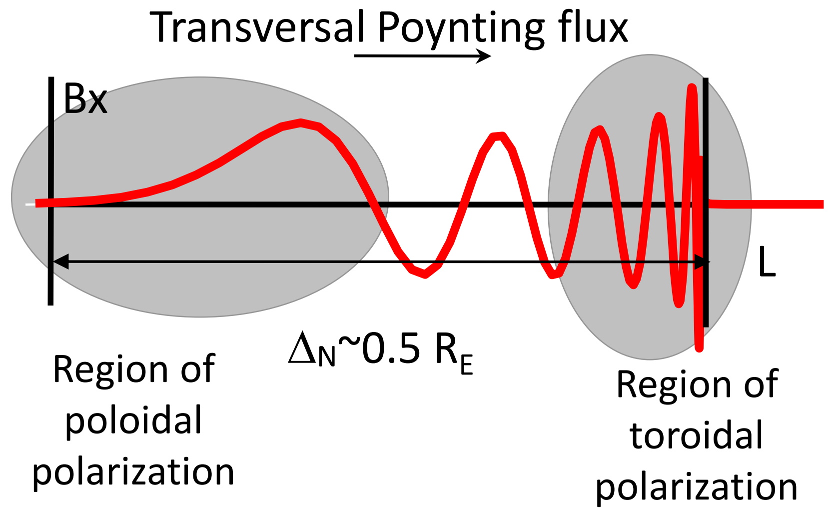


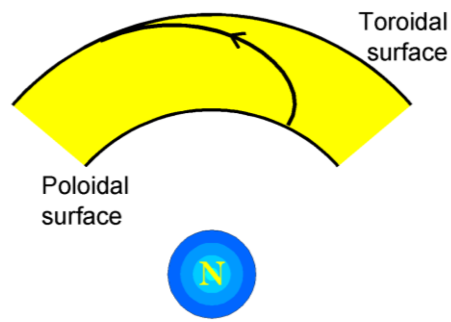
# Graphical representation of $\Omega_T \neq \Omega_P$

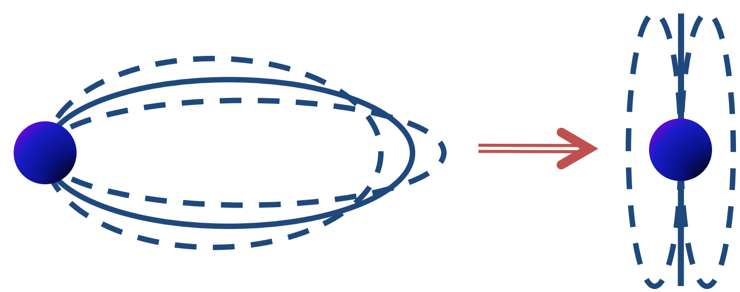


# Global solution

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

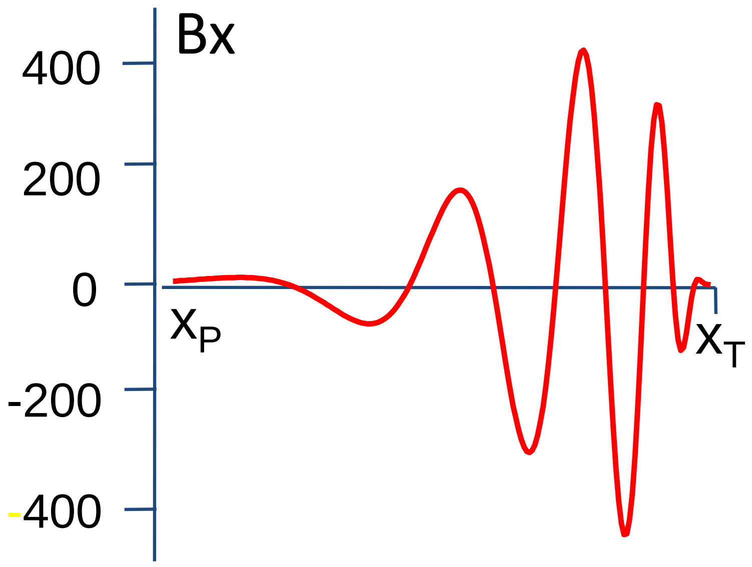


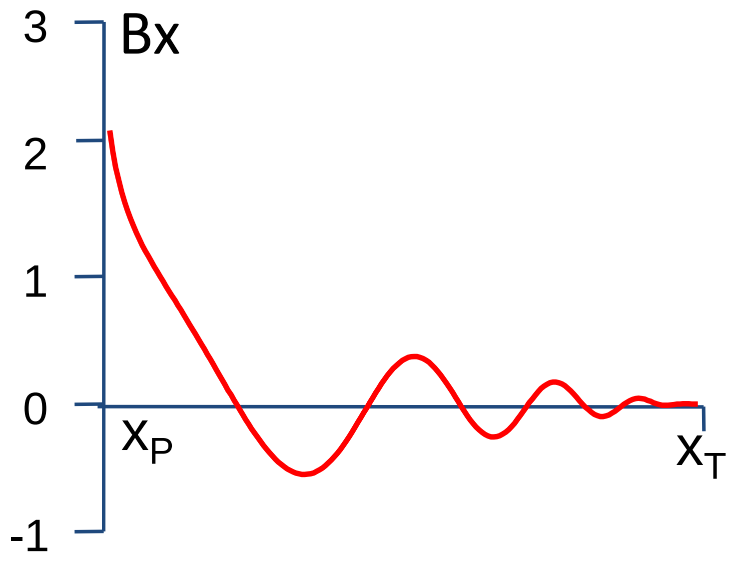



# Instability due to the interaction with the energetic particles

- 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



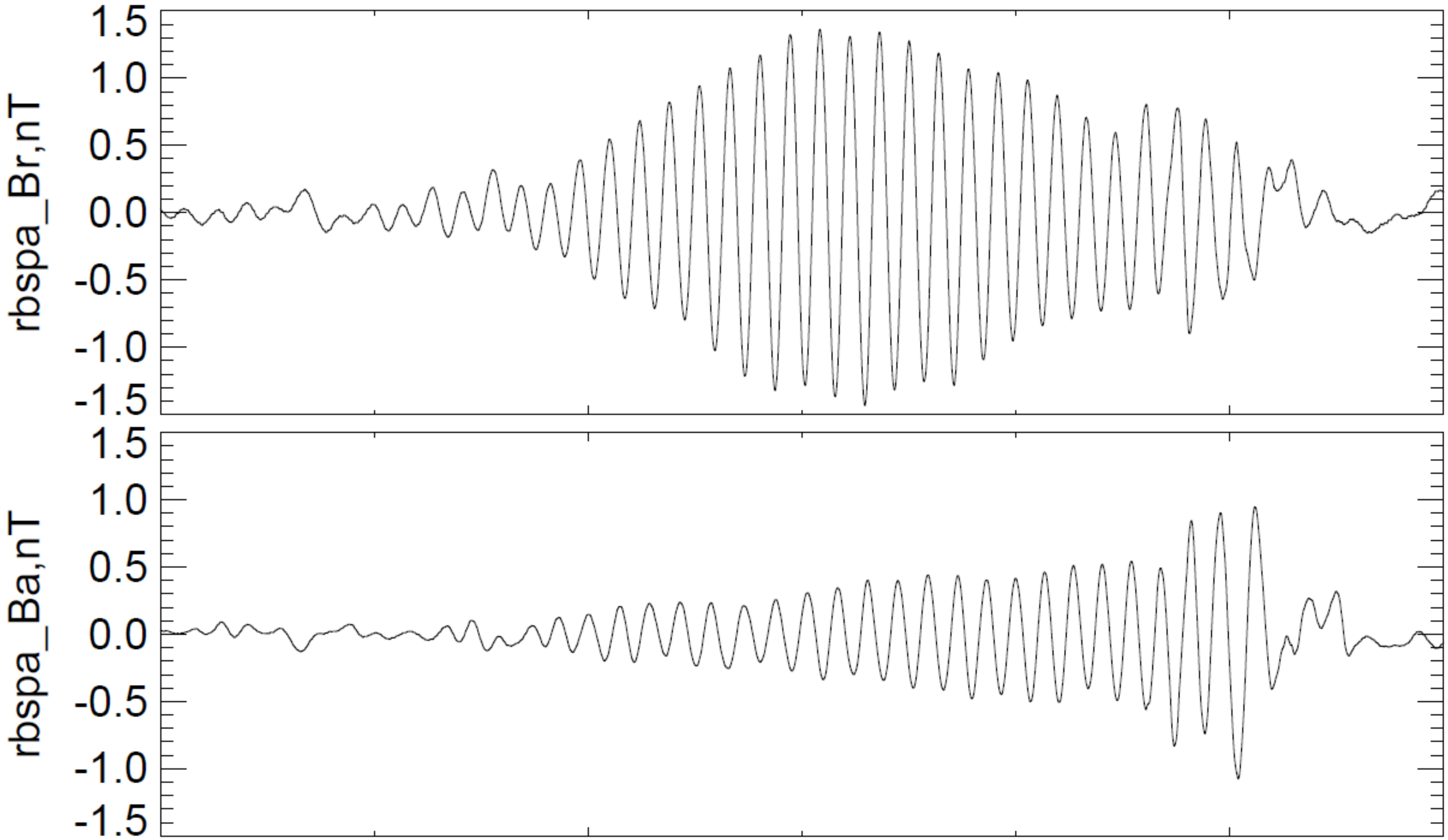

- Large instability, small ionospheric attenuation




- Large attenuation, small instability

# Lei Dai et al. 2013: Poloidal Alfven wave generated by energetic particles - I

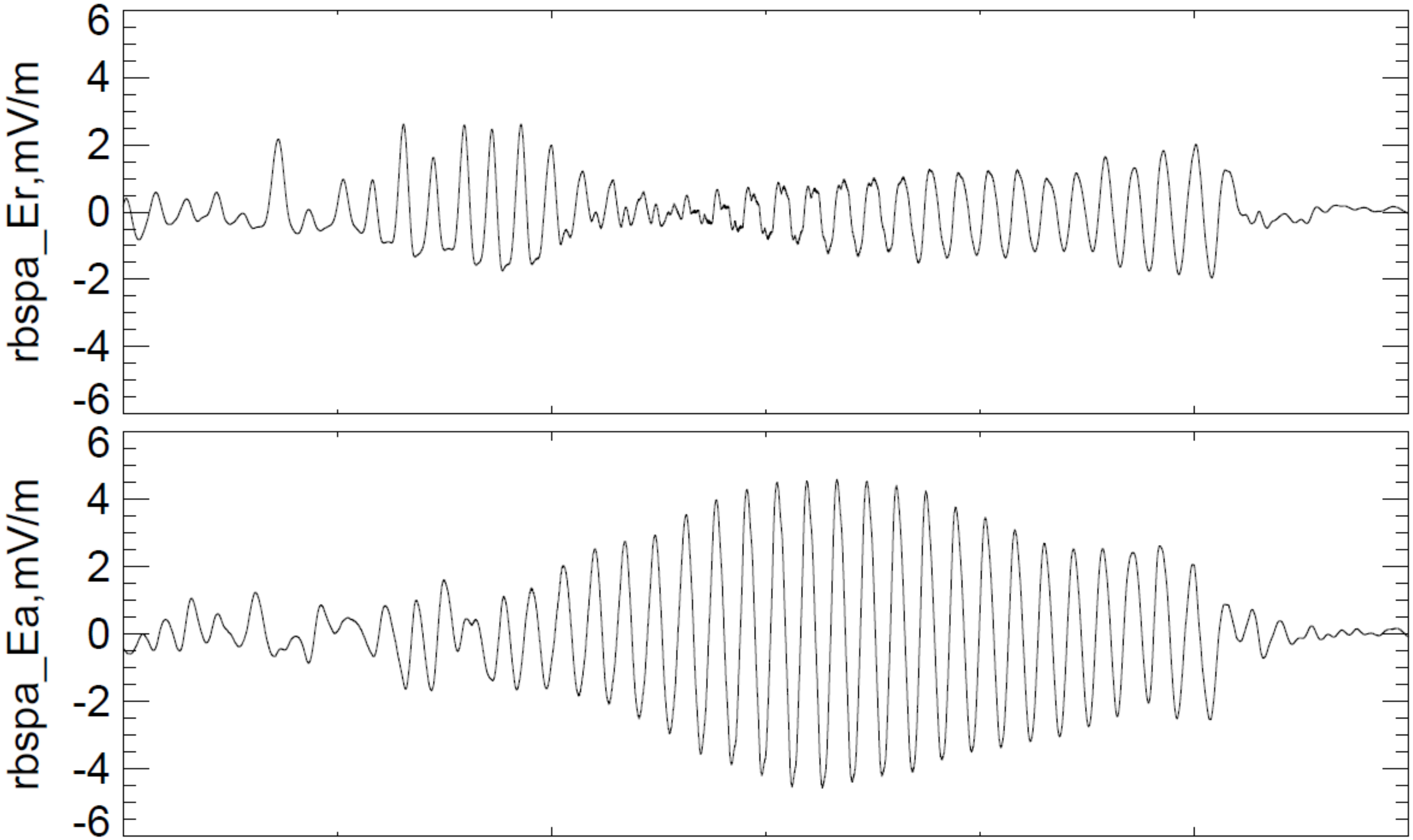
RBSP-A, Oct. 23, 2012. Magnetic field:




| | | |
|---|---|---|
| L | 5.3 | 4.7 |
| MLT | 8.2 | 8.8 |

# Lei Dai et al. 2013: Poloidal Alfven wave generated by energetic particles - II

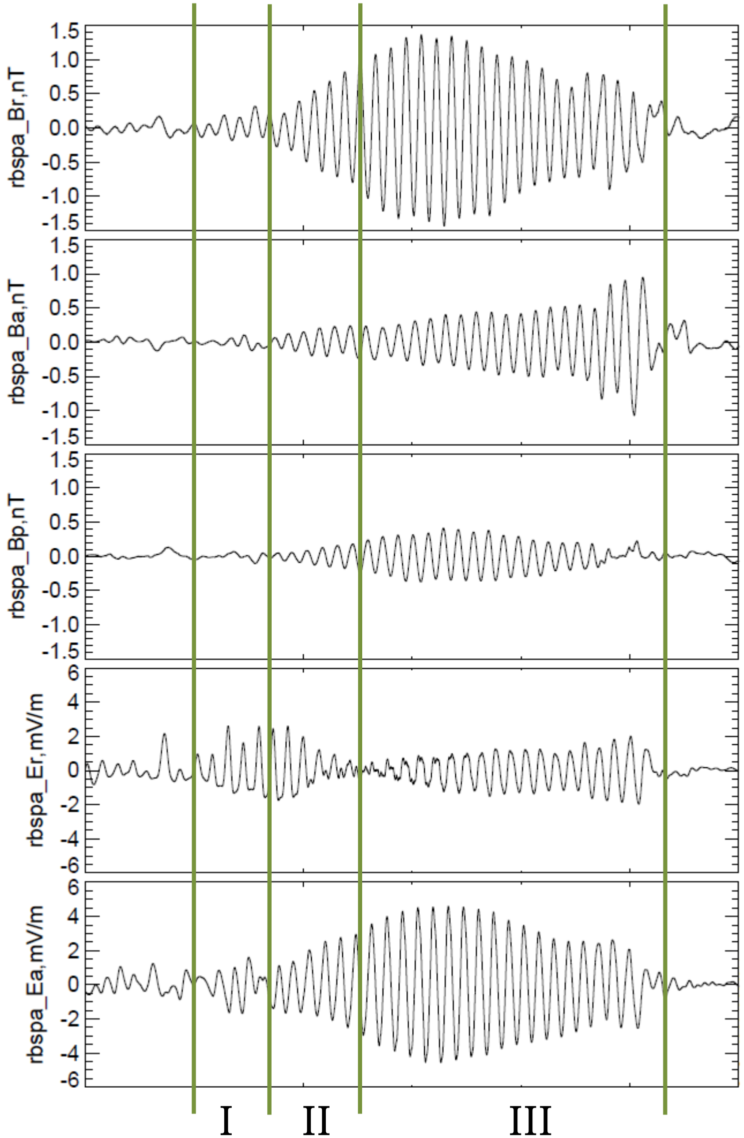
RBSP-A, Oct. 23, 2012, electric field:

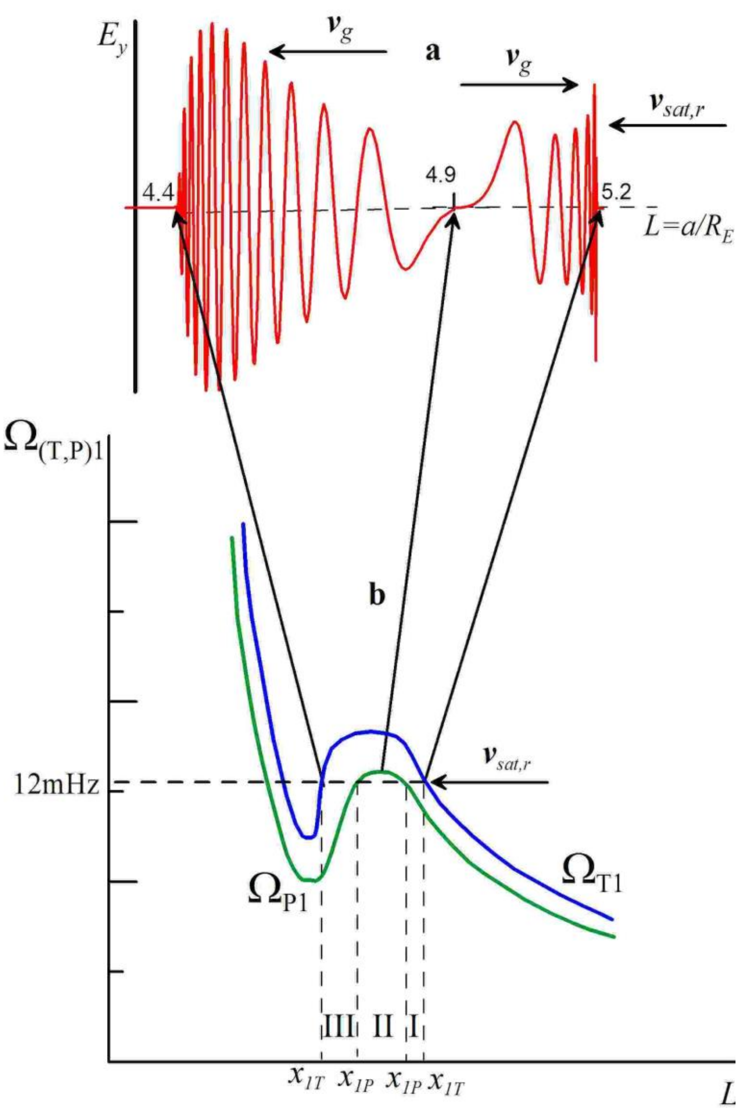



L 5.3 4.7

MLT 8.2 8.8

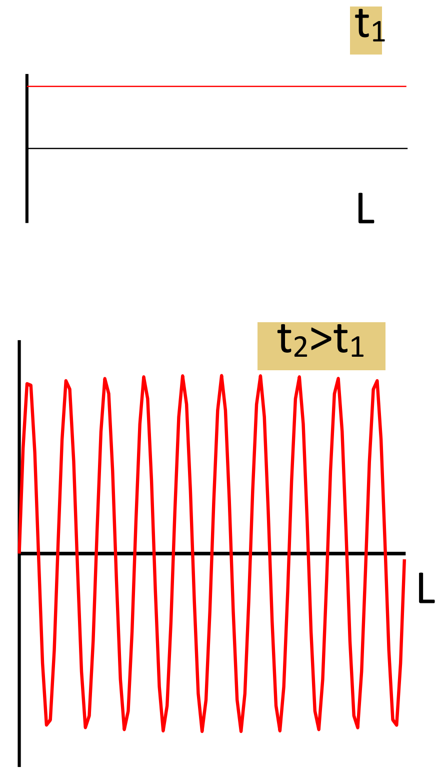
# Lei Dai et al. 2013: Poloidal Alfven wave generated by energetic particles - III



# Transformation in space – or in time?

- 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 $\Omega$ = almost const (L)
- Probably, they observed monochromatic wave…
- … And transformation was in space (due to the curvatore), not in time

# Related publications


- Leonovich A. S. and Mazur, V. A., A theory of transverse small scale standing Alfven waves in an axially symmetric magnetosphere, Planet. Space Sci., 41, 697–717, 1993.
- Klimushkin D. Yu., A.S. Leonovich, V.A. Mazur, On the propagation of transversally-small-scale standing Alfvén waves in a three-dimensionally inhomogeneous magnetosphere, J. Geophys. Res., V.100, p. 9527-9534, 1995.
- Leonovich, A. S. and Mazur, V. A., Standing Alfvén waves with m>>1 in an axisymmetric magnetosphere excited by a non-stationary source, Ann. Geophysicae, 16, 914–920, 1998.
- Klimushkin D. Yu., Structure of small-scale standing azimuthal Alfvén waves interacting with high-energy particles in the magnetosphere, Plasma Phys. Rep., V.24, p.956-964, 1998.
- Klimushkin D. Yu., P.N. Mager, K.-H. Glassmeier, Toroidal and poloidal Alfvén waves with arbitrary azimuthal wave numbers in a finite pressure plasma in the Earth's magnetosphere, Ann.Geophys., V. 22, No1, pp. 267-288, 2004.
- D. Yu. Klimushkin, P.N. Mager, The spatio-temporal structure of impulse-generated azimuthally small-scale Alfvén waves interacting with high-energy charged particles in the magnetosphere, Ann.Geophys., V. 22, pp. 1053–1060, 2004.
- Dai L., et al., Excitation of poloidal standing Alfven waves through drift resonance wave-particle interaction, Geophys. Res. Lett., 40, 4127–4132, doi:10.1002/grl.50800, 2013.
- Cheremnykh O.K., Klimushkin D., Kostarev D.V., On the structure of azimuthally small-scale ULF oscillations of hot space plasma in a curved magnetic field. Modes with continuous spectrum, Kinematics and physics of celestrial bodies. V.30, P. 209-222, 2014.
- Leonovich A. S., Klimushkin D. Yu., Mager P.N., Experimental evidence for the existence of monochromatic transverse small-scale standing Alfven waves with spatially dependent polarization, JGR (submitted).

# Thank you!