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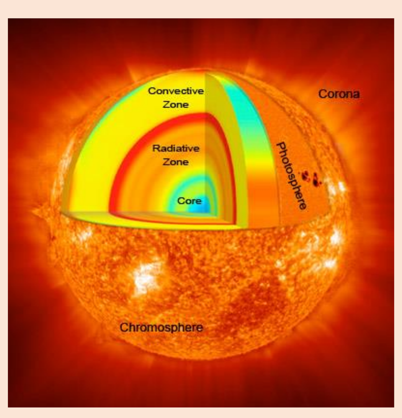
Localization of 3-D kinetic Alfven wave and turbulent spectra in the solar corona region

Garima Patel [1], R. Uma[1] and R.P. Sharma[1]

[1] Department of Energy Science and Engineering, Indian Institute of Technology Delhi, Delhi -110016, India

Abstract:- Magnetic reconnections and the Kinetic Alfven Waves (KAW) are the keys to transfer the heat from the interior of the Sun to the outer Solar atmosphere but the proper methodology to describe the heating of solar corona is still being browsed by the Solar physicist. Different magnetic structures interact with the KAW and the perturbation plays its role in the occurrence of this dramatic Corona heating. We proposed a 3D model of Kinetic Alfven wave which encounters the well-known Harris current sheet profile of the magnetic field with taking into consideration of ponderomotive effects in the solar corona. This Model equation is solved numerically using the finite difference method in time and pseudospectral in the spatial domain with the predictor-corrector method. The numerical simulation shows that the field structure feels a slow change without the nonlinearity whereas the presence of nonlinearity causes a rapid change. And approaching towards quasi-steady state, it generates a fully chaotic structure which are signals of turbulent filamentation with temporal evolution. We have also obtained the semi-analytical solution for these localized structures which shows the transverse scale size to be comparable to electron inertial length.



The Sun's corona is maintained at a temperature in excess of a million degrees. The corona lies above the solar photosphere (6000 degrees). Even only being few hundred kilometers apart. A major scientific problem in solar physics is how and why is the corona so much hotter than the photosphere.

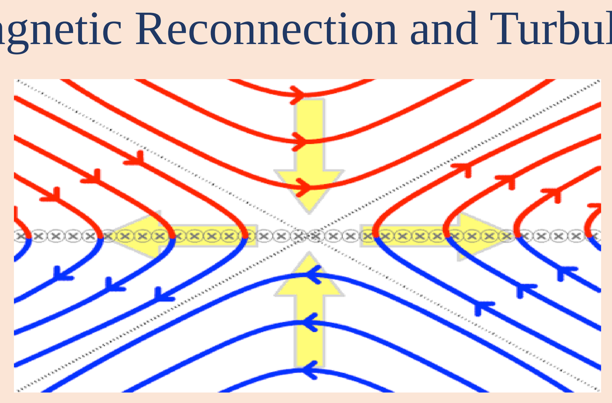
Turbulence: Kolmogorov Scenario

- Turbulent energy is injected at very long wavelengths and then cascades down toward short wavelengths along the "inertial range".
- At sufficiently short wavelengths, there is transfer of energy in the "dissipation range" where fluctuations are damped and the medium is heated.

Motivation

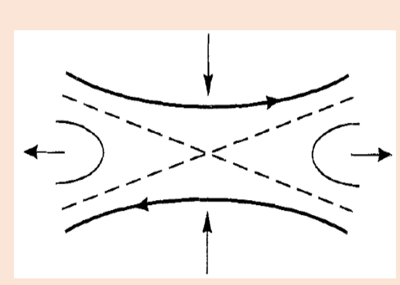
- Turbulence and magnetic reconnection have been observed to be the most important process which plays a very important role in cascading the energy to a lower scale in space plasmas.
- These two phenomena have been studied separately but their connection with each other is not fully understood.
- In inertial range Larger scale is cascaded toward smaller scales by Kolmogorov 5/3 law but the dissipation range needs a steeper slope.
- Harris current sheet profile in the vicinity of the reconnection sites and the KAW interaction is aimed to be the focus of this study.

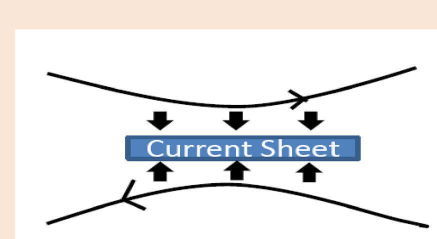
Magnetic Reconnection and Turbulence

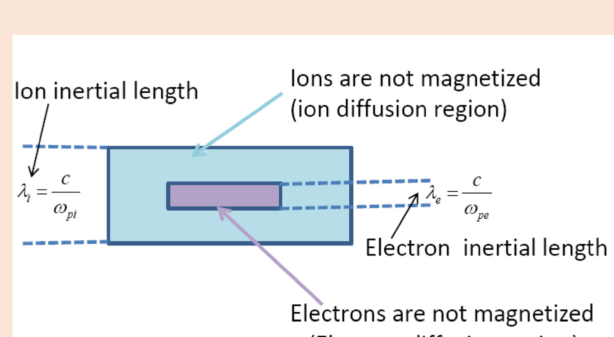


a) A magnetic null-point is a point in the reconnection site where the magnetic field is zero.
b) Magnetic null points in the solar corona are basic configurations for inducing magnetic reconnection.

Magnetic Reconnection in Plasma







Observations of Magnetic Reconnection

- The Earth's magnetosphere
  - Magnetopause
  - Magnetotail
- The Solar Atmosphere
  - Solar corona
  - Solar flares
- Laboratory plasma

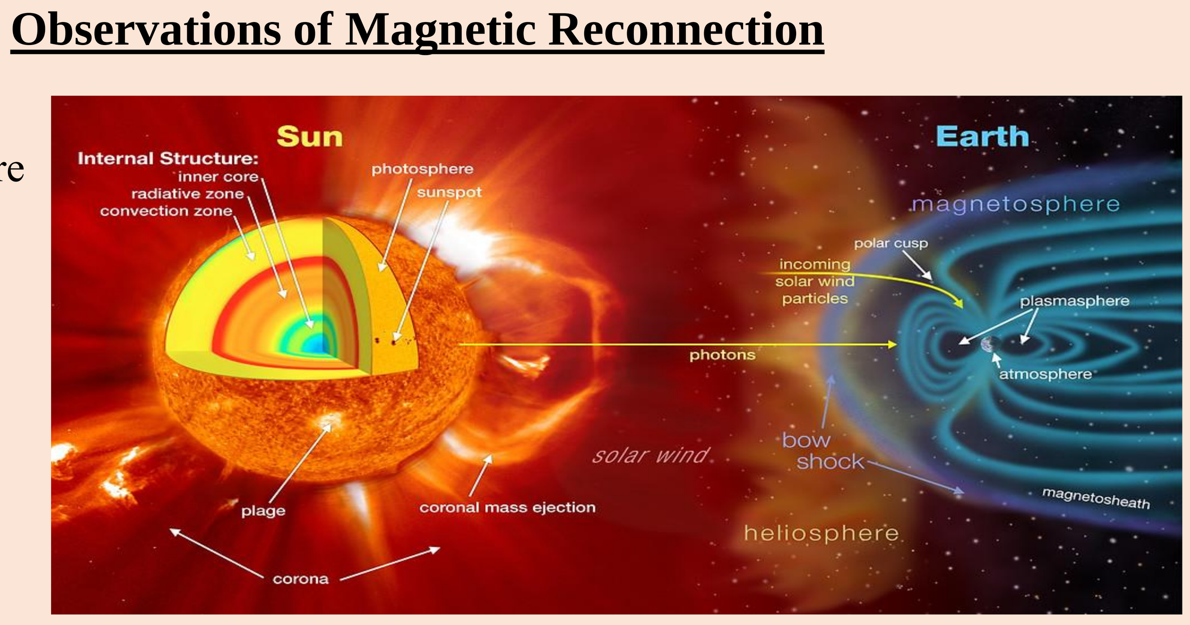


Figure: shows the solar wind interaction with the planetary magnetic field.

Characteristic of Magnetic Reconnection :-

- It generates an electric field that accelerates particles parallel to B
- It dissipates magnetic energy
- It accelerates plasma, i.e. converts magnetic energy into kinetic energy.

Modes Supported by Plasma

Unmagnetized plasma
- Electromagnetic waves
- Electron plasma waves
- Ion acoustic waves

Magnetized plasma
- Electromagnetic waves → Whistler waves, Magnetosonic waves, Alfven waves
- Electrostatic waves → Electron plasma waves, Ion acoustic waves
- Mixed mode

- In the present work, we have developed three-dimensional model using MHD model to examine the effect of 3D KAW. In this analysis, we have assumed that kinetic Alfven wave having wave vector $\vec{k} = \vec{k}_x\hat{x} + \vec{k}_y\hat{y} + \vec{k}_z\hat{z}$ is propagating in a medium with equilibrium magnetic field . $\vec{B}_0 = \vec{B}_{0z}\hat{z} + B_0\tanh\left({}^{x}/_{L}\right)\hat{y}$
- Dynamical equation have been developed using ion equation of motion.

$$(1-\lambda_e^2\nabla_\perp^2)\frac{\partial^2 A_z}{\partial t^2} - v_A^2(1-\rho_s^2\nabla_\perp^2)\left[\left(\frac{B_{0y}}{B_0}\right)^2\frac{\partial^2 A_z}{\partial y^2}\right] = 0$$

- The model equation is solved numerically for solar corona region parameters using pseudo spectral method and finite difference method.
- In numerical simulation periodic domain of $10\pi \times 10\pi \times 10\pi$ and grid point $32 \times 32 \times 32$ used.
- The typical parameters applicable in the solar corona. (Champeauxet al.,1997)

$$B_0 = 32G, n_0 = 10^8 cm^{-3}, T_e = 37eV, T_i = 235eV$$

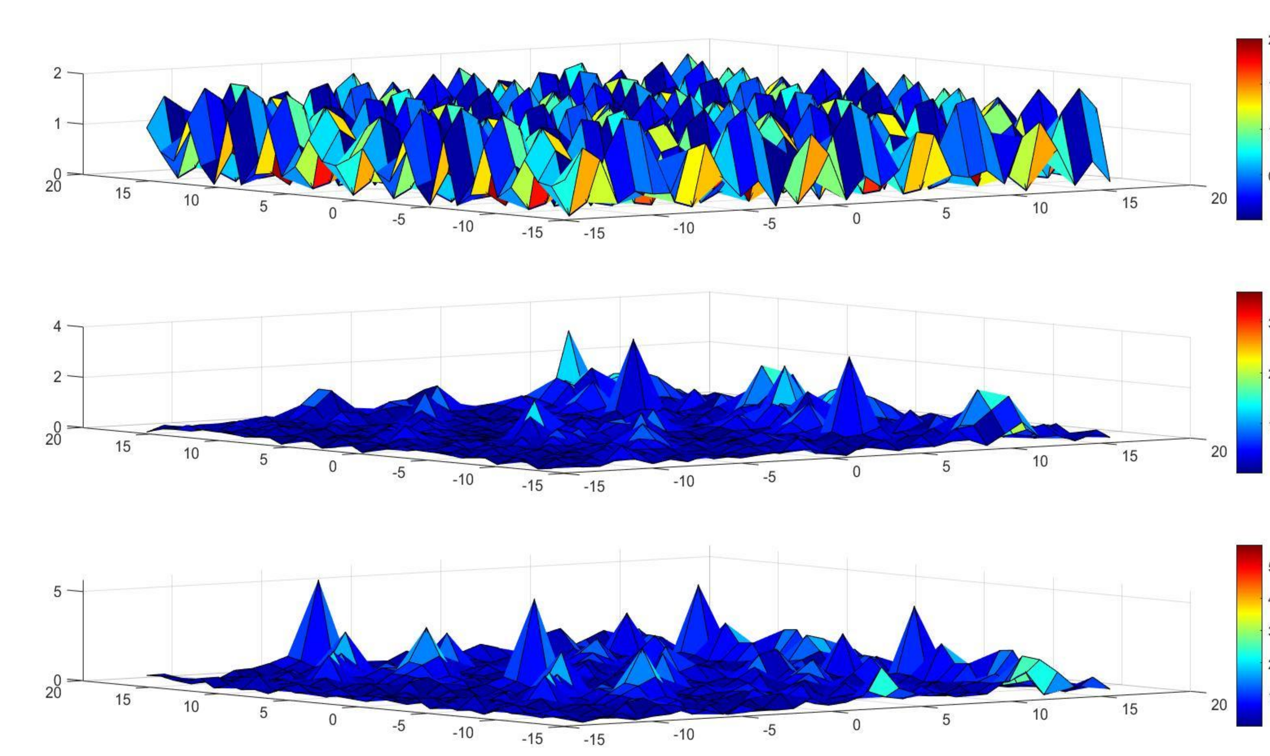


Figure : **Normalised vector potential of KAW at 1) t=0, 2) t=10 and 3) t=20**

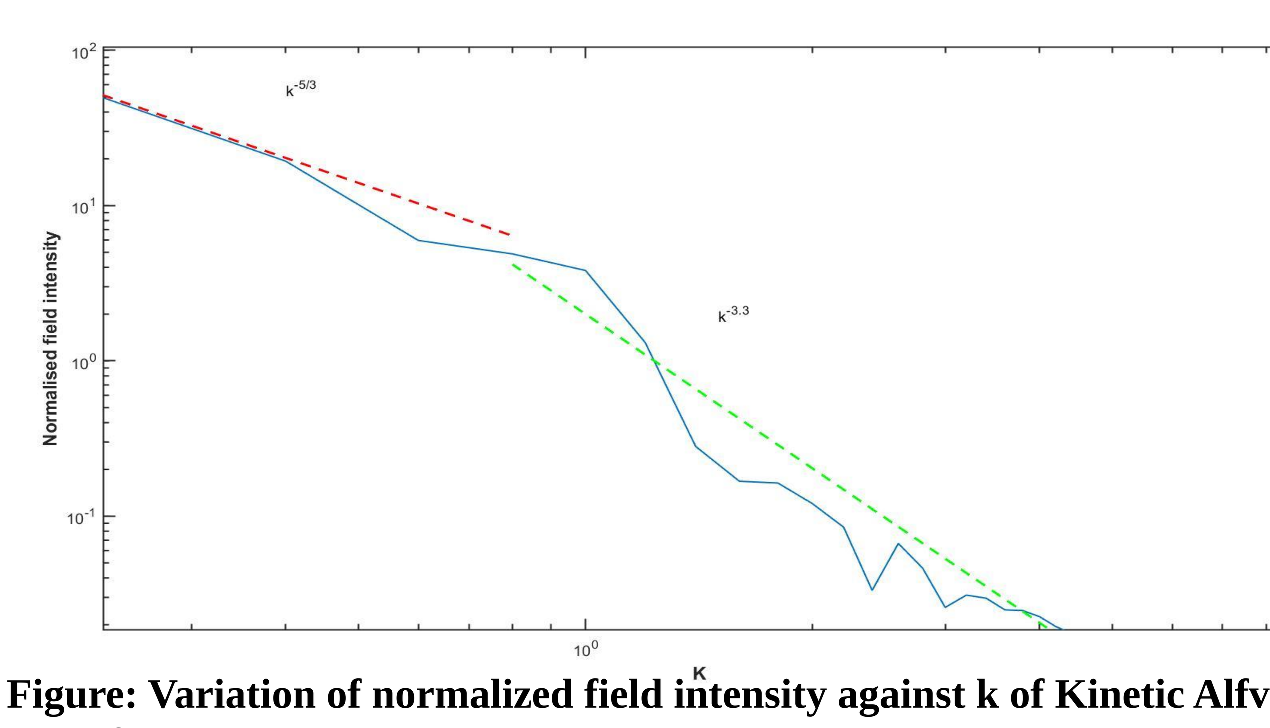


Figure: Variation of normalized field intensity against k of Kinetic Alfven wave for Solar corona region

Conclusion:-

- Simulation results represent the 3D-KAW which interact with Harish sheet through which chaotic structures formed which indicates the generation of turbulence.
- KAW breaks up into localized structures.
- In inertial range it shows $k^{-5/3}$ power law and in dissipation range it shows $k^{-3.3}$

References:-

1. S. CHAMPEAUX, T. PASSOT, and P. L. SULEM, J. Plasma Phys. **58**, 665 (1997).
2. A. A. van Ballegooijen, M. Asgari-Targhi, S. R. Cranmer, and E. E. DeLuca, Astrophys. J. **736**, 3 (2011).
3. M. Schwarzschild, Astrophys. J. **107**, 1 (1948).