Turbulence in High Density Plasma Measured by Radar

Jonathan Yee and Sigrid Close
Stanford University
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Outline

• Plasma Turbulence
  - Motivation
  - Development

• Case Study: Meteors
  - Background
  - Diffusion of Turbulent Structures

Image Courtesy of International Business Times, 2013
Motivation

• Understand development and diffusion processes of turbulence within plasma

• Applications
  ▪ Disruption in satellite communications from structures of ionosphere plasmas
  ▪ Satellite failures and anomalies due to plasmas created from a meteoroid strike
  ▪ Electric propulsion used for satellite attitude control

Hall Thruster
Development of Turbulence

• Natural oscillations and external forces can create waves within plasmas

• As the waves grow, develop into instabilities
  ▪ Streaming
  ▪ Rayleigh-Taylor
  ▪ Universal
  ▪ Kinetic

• Instabilities rapidly become unstable and develop turbulence

Courtesy of Oppenheim et al., 2000
Formation of Meteor Trails

- Meteoroids heat up and ablate in Earth’s atmosphere
- Collisions ionize neutral air molecules
- Produces plasma regions
  - Head – region directly surrounding meteoroid
  - Trails – region left behind meteoroid
ALTAIR System

- Dual Frequency
  - VHF (160 MHz)
  - UHF (422 MHz)
- High Resolution
- Dual Circular Polarization
- Position Angles
Meteor Trail Example

UHF Detection
Jan. 6, 2007 – 5 AM

Non-Specular Trail

Head Echo

Power (dB)

Altitude (km)

Time (sec)
Ambipolar Diffusion Coefficient

From a radar signal:

\[ \tau = \frac{\lambda^2}{16 \pi^2 D_a} \]

(Greenhow et al., 1955)

Galligan Model: \( h = 4.43 \times \log(D_a) + 87.9 \)

Jones Theory: \( h = 16.7 \times \log(D_a) + 79.0 \)

Shaded areas around data signify error bars
Diffusion Shape: Results
Diffusion Shape: Results

$t = 0.0348 \text{ sec}$

$t = 0.1043 \text{ sec}$

$t = 0.2087 \text{ sec}$

$t = 0.3391 \text{ sec}$

$t = 1.0348 \text{ sec}$

LC (dB)
Parallel & Perpendicular Variation

Jan. 6, 2007 – 5 AM
Parallel Variation

Jan. 6, 2007 – 5 AM
Perpendicular Variation
Parallel & Perpendicular Variation

Weighted Slopes

Parallel to Magnetic Field Line

Perpendicular to Magnetic Field Line
Future Work

- Develop method for including both directions in calculations of the diffusion process
- Develop simulations to model and examine changing diffusion shape
- Explore the effects of polarization and frequency on plasma scattering
THANK YOU QUESTIONS?