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電離圏観測ロケット近傍のウェイクに起因するプラズマ波動

Plasma wave turbulence due to the wake of an ionospheric sounding rocket

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1. Introduction

1-1 Sounding Rocket and Plasma Wake

Speed of a rocket V_0 ; $V_{th,i} < V_0 < V_{th,e}$
→ Formation of plasma wake

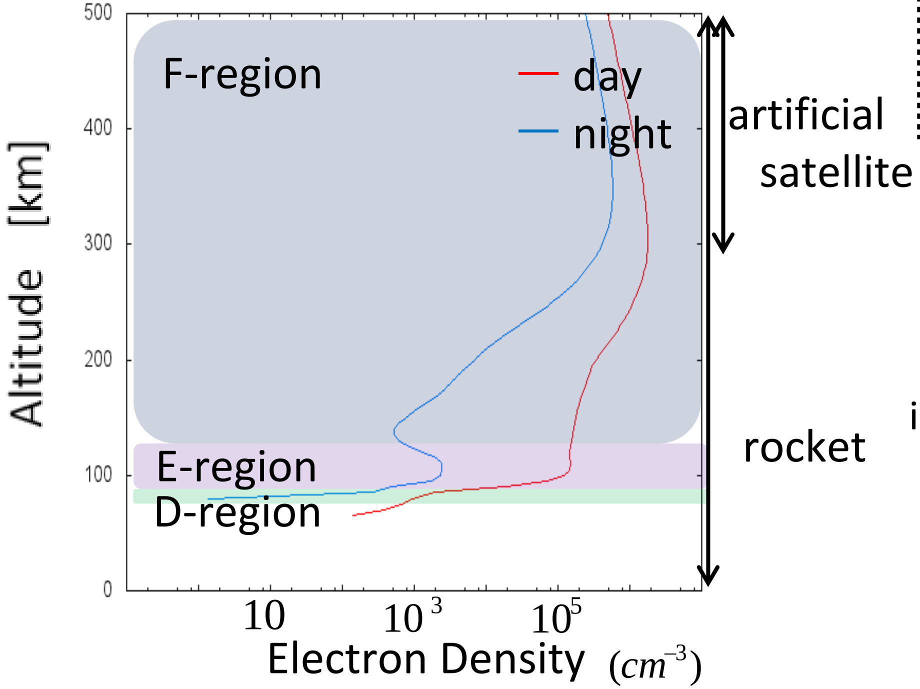


Fig. 1 Electron density profile over Japan in IRI-2007 Model. [Bilitza and Reinisch, 2008]

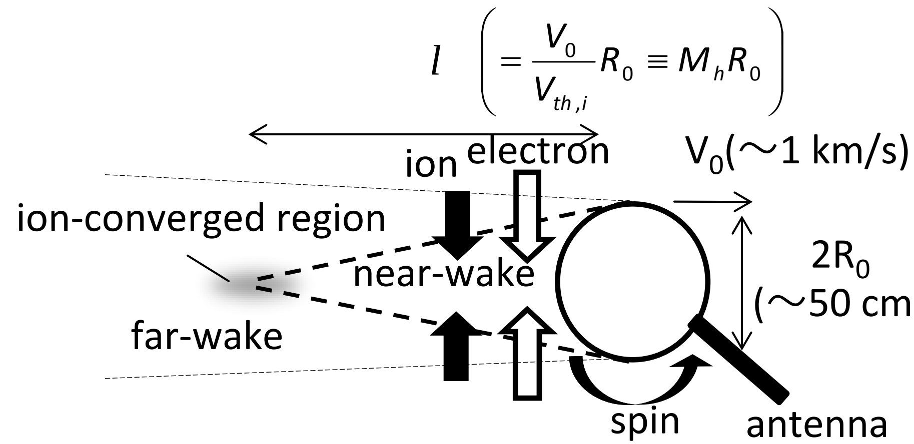


Fig. 2 Schematic picture of the wake.
(based on Stone(1981) and Yamamoto(2000))

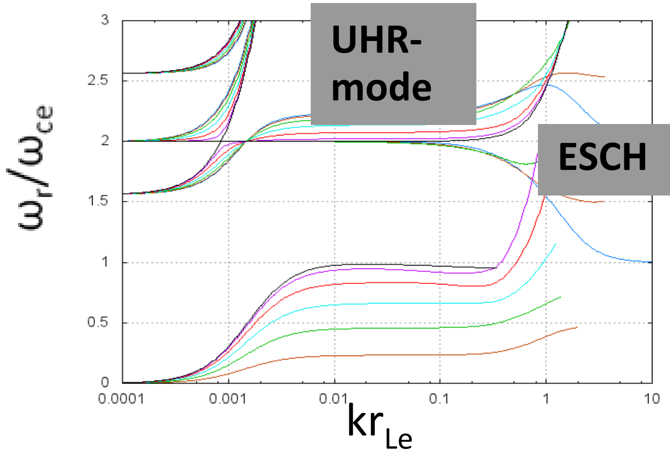
Table 1 Plasma parameters in the lower ionosphere calculated from IRI-2007 model. [Bilitza and Reinisch, 2008]

	Electron	Ion
Thermal Velocity	70～160 km/s	300～700 m/s
Larmor Radius	1～3 cm	2～4 m

It is very important to understand the wake effects.

1. Introduction

1-2. Plasma Waves around a Wake



Moon

- Langmuir wave
- Whistler-mode wave etc.

[e.g., Sibeck et al., 2012]

Artificial Satellite

- Lower hybrid wave [Keller et al., 1997]

Ionospheric Sounding Rocket

- UHR-mode wave (SS-520-1 rocket experiment) [Yamamoto, Ph. D thesis, 2000]

However, the observed wave frequencies are **not clearly coincident with the UHR-mode dispersion**.

⬇ S-520-26 Rocket Experiment in 2012

A kind of the observed waves has similar character in wave frequency.

⬇

We suggested they could be **short-wavelength electrostatic waves including ESCH waves and UHR-mode waves**.

[Endo, Master thesis, 2012]

1. Introduction

1-3. Purpose of this Presentation

Big goal of this study

To reveal generation mechanisms of plasma waves caused by the interaction between the ionosphere and a non-magnetized body.

➡ { more accurate understandings of in-situ data
general physics of interaction between plasma and bodies }

Current stage of this study

We now analyze the plasma wave data in the S-520-26 rocket experiment in detail to investigate the characteristics.

Purpose of this presentation

We show **spin-phase dependence of the plasma wave data** and discuss **difference in wave activities and unstable regions** around a moving rocket.

2. Experiment & Result

2-1 Overview of the S-520-26 Rocket Experiment

Purpose

(1) Establishment of the neutral wind measurement method with using Li gas

(2) Investigation of the momentum transfer process between the ionospheric plasma and the neutral atmosphere

Fig. 3 Li cloud observed from Uchinoura. (ISAS/JAXA Website)

Location Uchinoura in Kagoshima Prefecture

Time of Launch 2012/1/12 5:51 JST

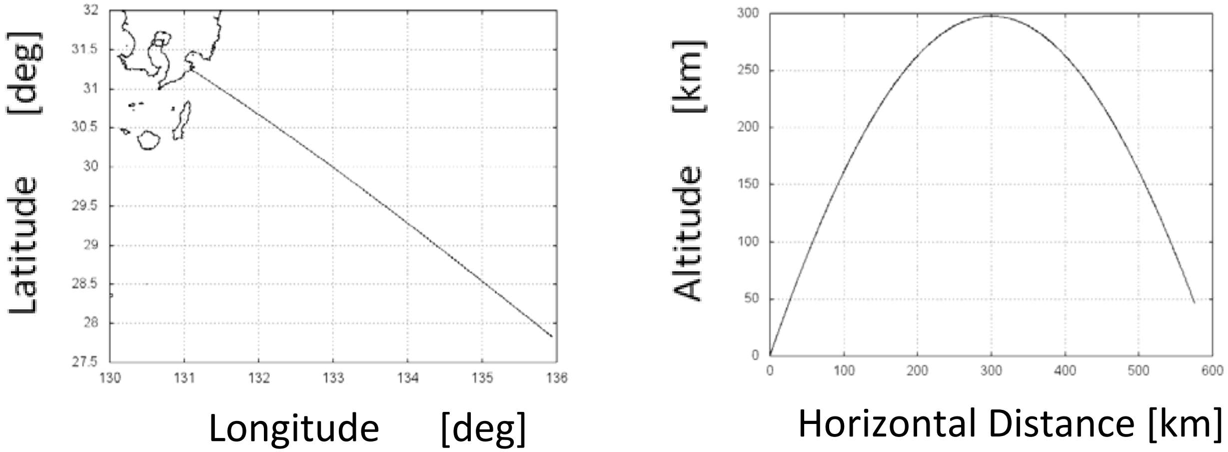


Fig. 4 Trajectory of the S-520-26 rocket.

Fig. 5 S-520-26 Rocket.

2. Experiment & Result

2-2 Instruments

--- Tohoku University Group ---

PWM ; Plasma Wave Monitor

NEI ; Number density of Electrons by Impedance probe

Other Groups

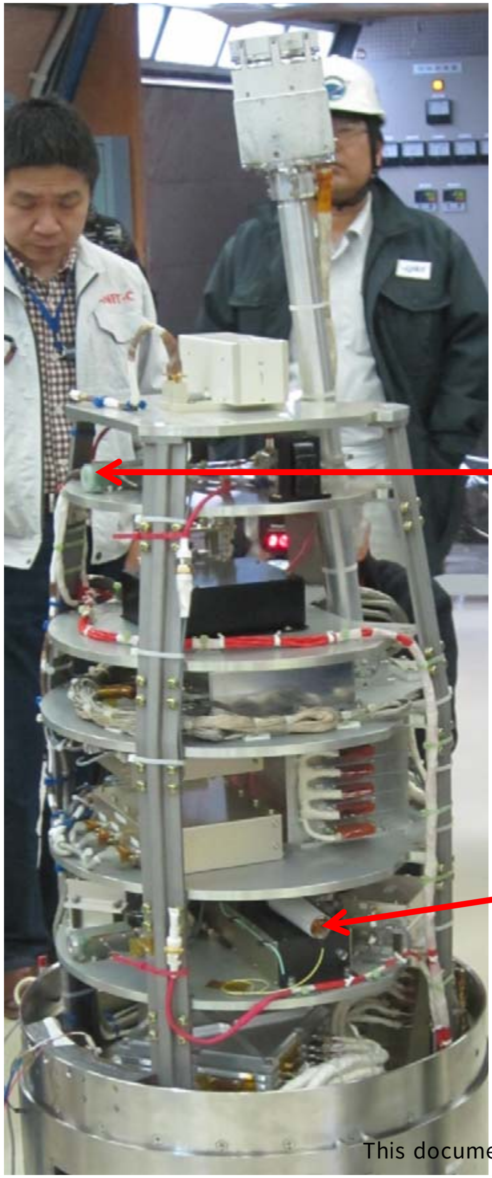
MGF ; MaGnetic Field sensor (Tokai Univ.)

SAS ; Sun Attitude Sensor (Tokai Univ.)

FLP ; Fast Langmuir Probe (ISAS/JAXA)

EFD ; Electric Field Detector (Toyama Prefecture Univ.)

IRM ; Imaging and Rapid-scanning ion Mass spectrometer (Clemson Univ.)



NEI (monopole ; 1m)

PWM (dipole ; tip-to-tip 5m)

2. Experiment & Result

2-3 Specs of NEI/PWM

Angular Resolution

PWM and NEI

Repetition Time	260 msec
Altitude ΔL	≲ 500 m
Time Δt	**39 msec (NEI), 64 msec (PWM-H)**
Angle Δθ	**12° (NEI), 20°(PWM-H)**

Spin Frequency: 0.87 Hz (private communication, Dr. Takahashi and Mr. Sugai)

Frequency Range

coverage of the UHR frequency

PWM

Mode	Frequency	Δf	Dynamic Range
PWM-L	300 Hz ～ 20.0 kHz	50 Hz	-111 ～ -8 dBm
PWM-H	20.0 kHz ～ 7.02 MHz	20 kHz	-109 ～ -12 dBm
	7.02 ～ 22.02MHz	300 kHz	-95 ～ -17 dBm

NEI

Mode	Swept Frequency	Δf	Electron Density
Ascent	0.1 ～ 13.0 MHz	10 ～ 100 kHz	10^3 ～ 2×10^6 /cc
Descent	0.1 ～ 24.8 MHz	10 ～ 200 kHz	10^3 ～ 7×10^6 /cc

2. Experiment & Result

2-4 Results of PWM measurement

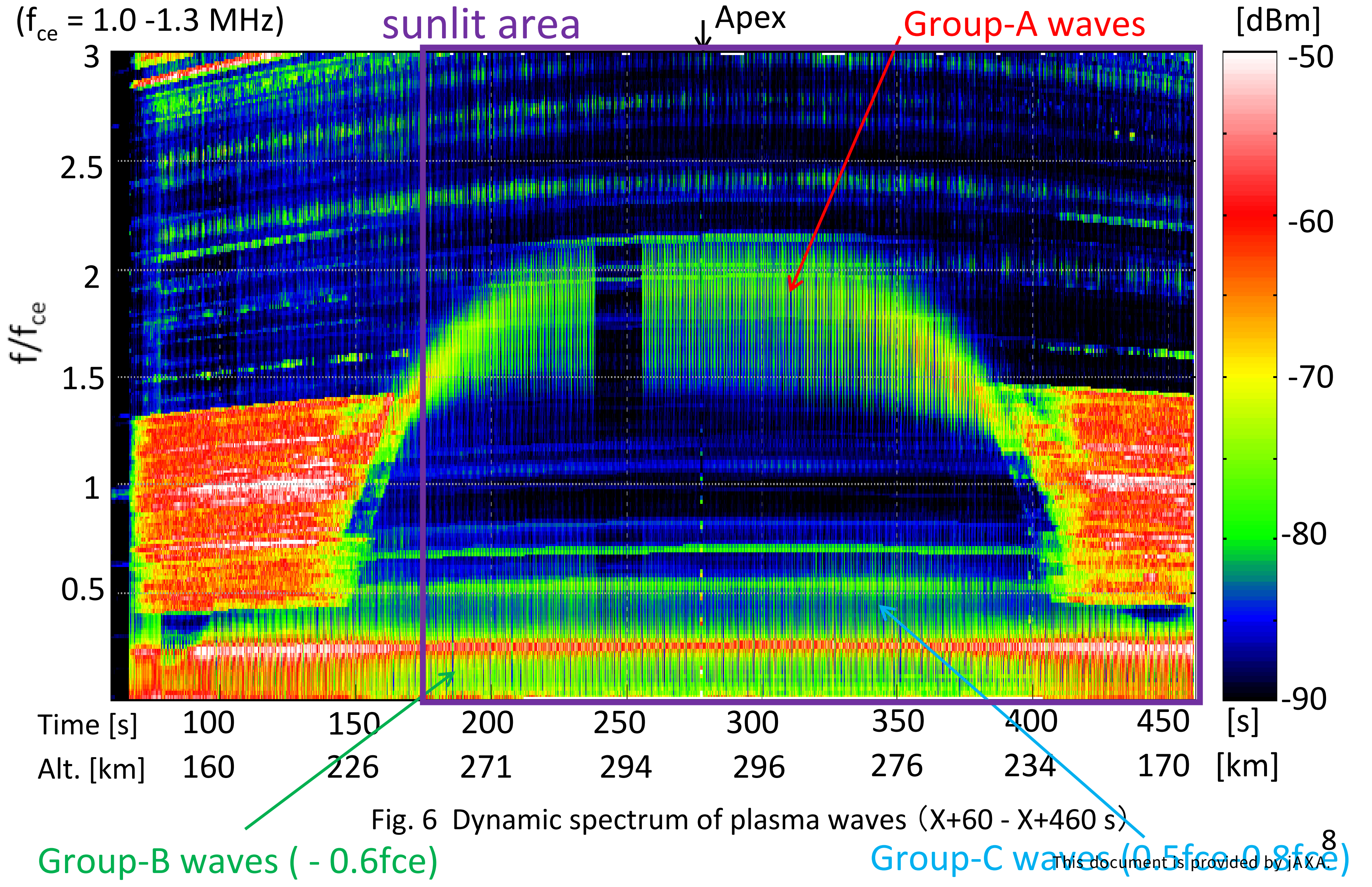


Fig. 6 Dynamic spectrum of plasma waves（X+60 - X+460 s）

3. Spin-phase Dependence

3-1 Attitude Analysis

We analyze **the rocket attitude** by using the data from MGF and SAS during from 179 sec to 462 sec and deduce **spin-phase angle**.

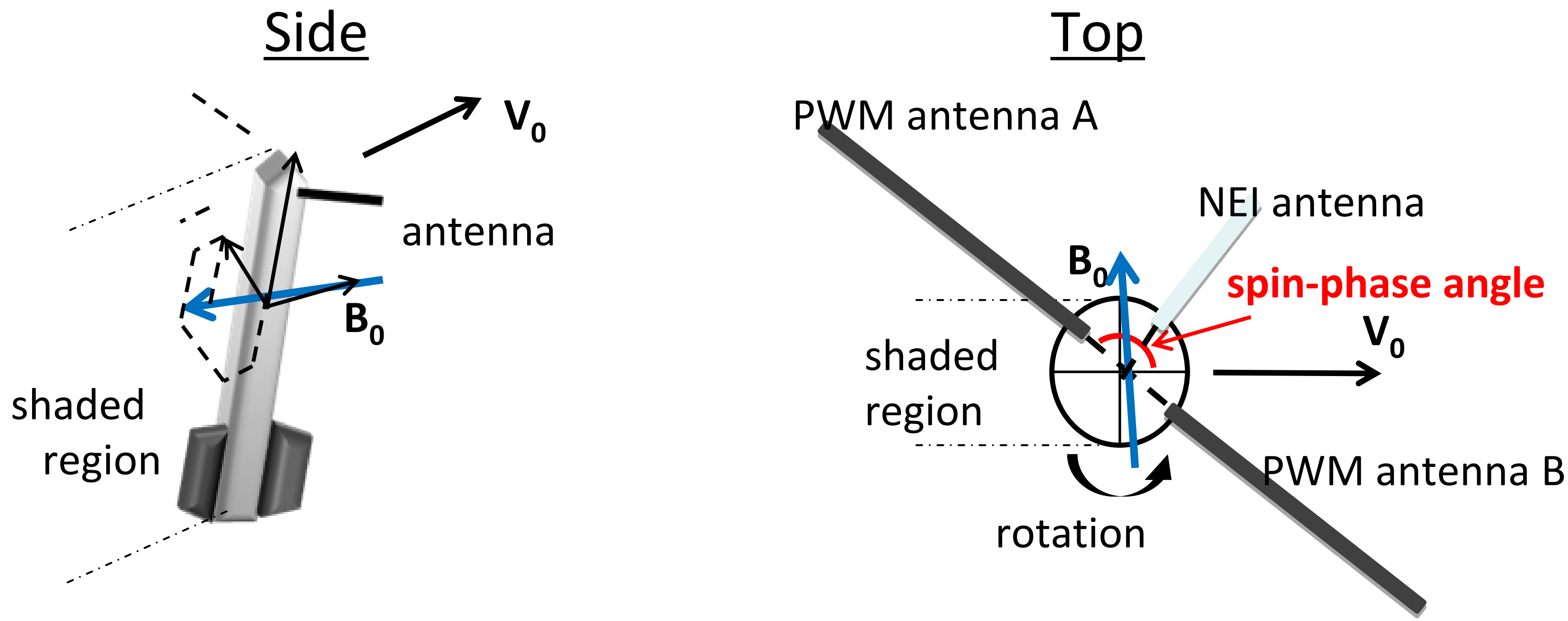
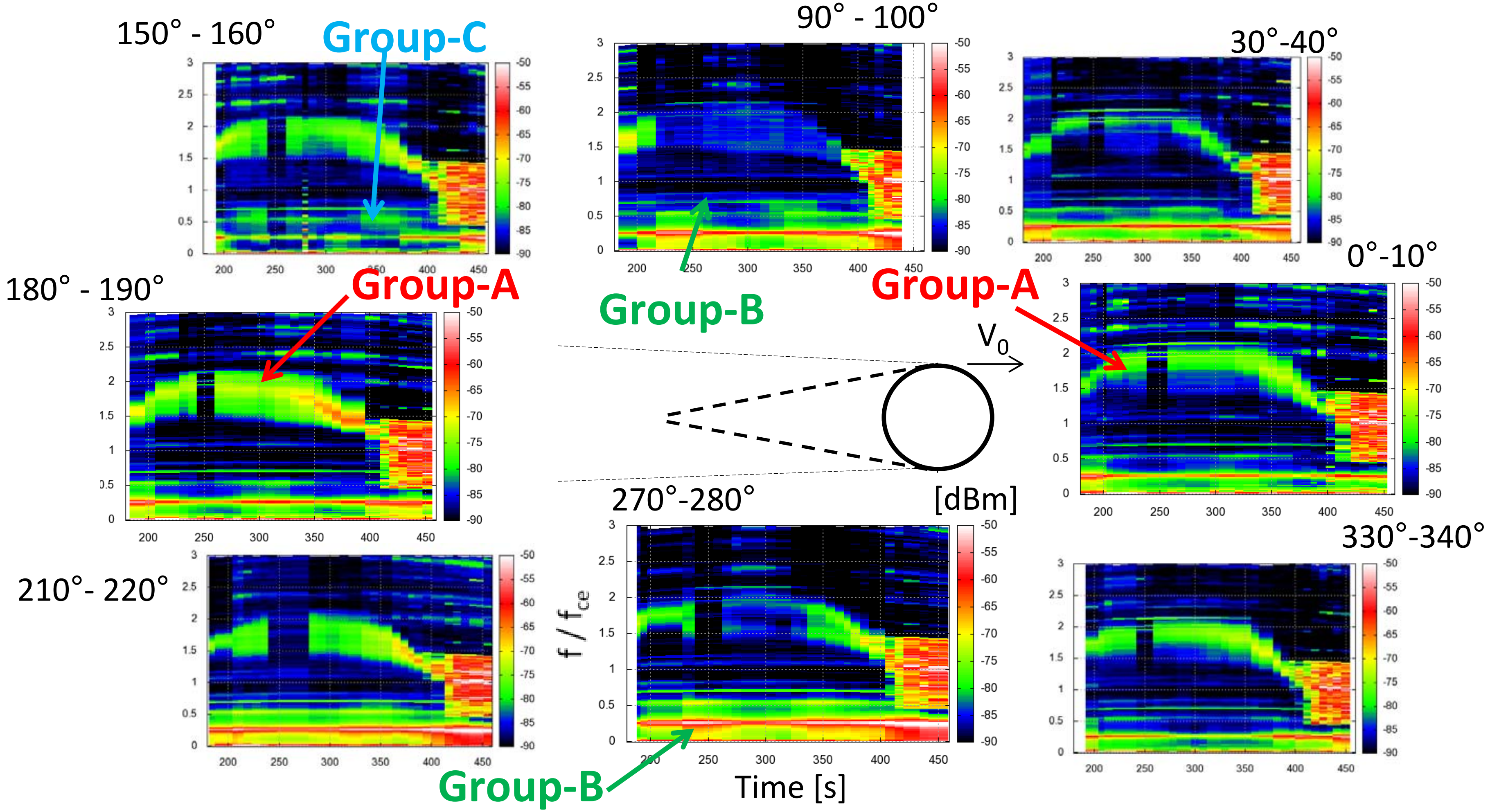


Fig. 7 Schematic side and top view of a moving rocket.

A **phase angle equal to zero** means that **PWM antenna A is in ram** and antenna B is in a shaded region.

3. Spin-phase Dependence

3-2 Spin-phase dependence of the plasma waves



The intensities in φ and φ+180° are **different.**

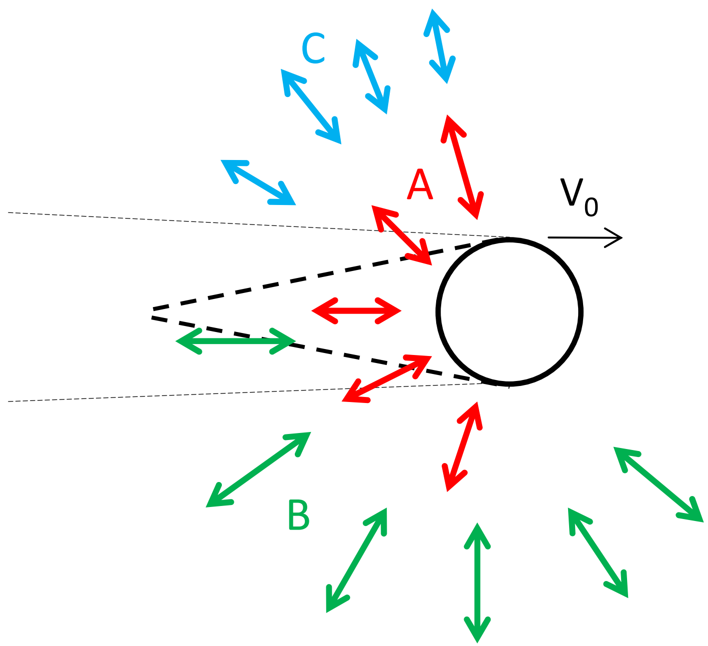
→ The antenna **was not likely to work as a dipole antenna due to some hardware trouble**.

3. Spin-phase Dependence

3-3 Difference in Wave Activity

Assumption (a)

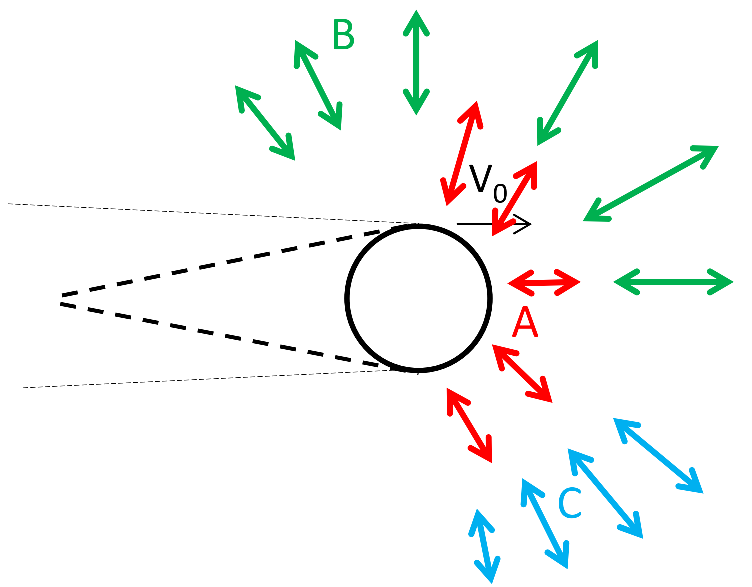
Only the antenna A receiving



Wave sources lie **the downstream** .

Assumption (b)

Only the antenna B receiving



Wave sources lie **the upstream** .

More free energy sources are expected the downstream.

4. Summary and Future Work

4-1 Summary and Future Work

Summary

- In order to investigate plasma disturbance around ionospheric rockets, we analyze the plasma wave data in the S-520-26 rocket experiment in detail.
- We reveal spin-phase dependence of the plasma wave data.
- **Asymmetry of the spin-phase dependence** indicates **inhomogeneous distribution of wave activity** as well as **asymmetric sensitivity of the two antennas**.
- The clear asymmetry might show **the plasma waves do not propagate very long distance** and **the PWM has observed waves generated near the antenna**.

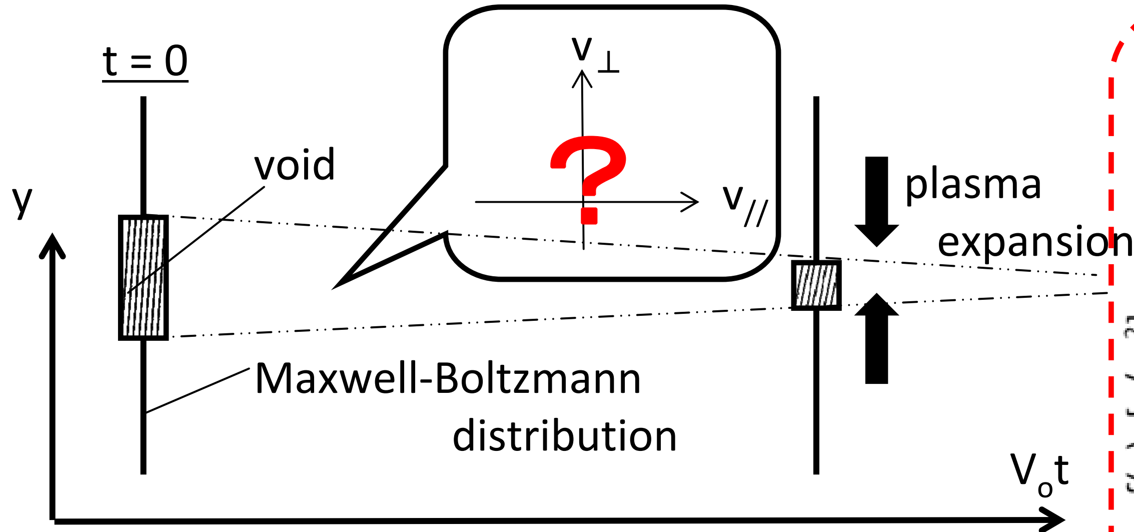
Future Work

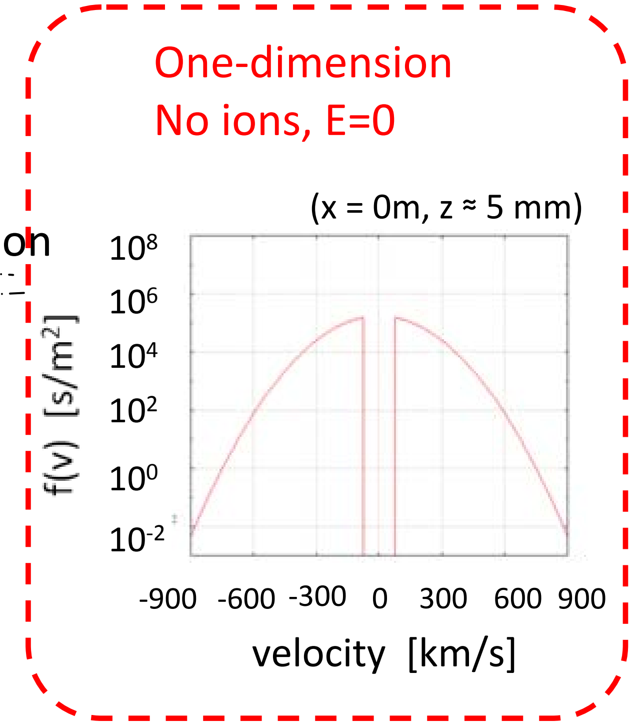
- Discussion about time variation of the spin-phase dependence of the wave data.
- Vlasov-Maxwell simulation for discussing plasma instability around a rocket.
  (→What are key parameters to generate plasma waves?)

4. Summary and Future Work

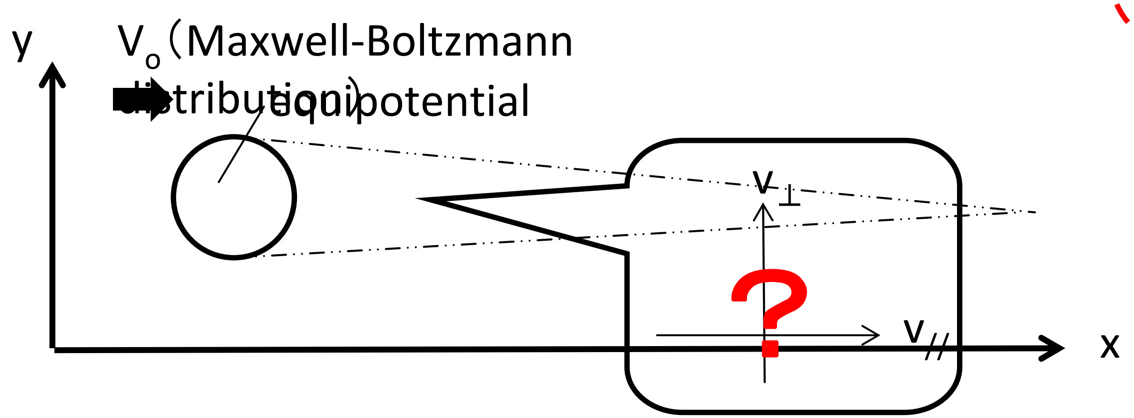
4-2 Future Work – Vlasov-Poisson Simulation

1. One-dimension model





2. Two-dimension model



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