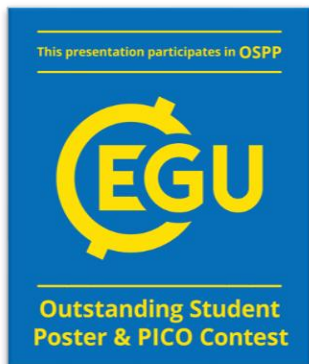


# Statistical Study of Oxygen Ion Cyclotron Harmonic Waves Observed by Van Allen Probes

**Yan Wang<sup>1</sup>** ([11930877@mail.sustech.edu.cn](mailto:11930877@mail.sustech.edu.cn)), Kaijun Liu<sup>1</sup>, Kyungguk Min<sup>2</sup>, Fei Yao<sup>1</sup>, Ying Xiong<sup>1</sup>, Kun Cheng<sup>1</sup>, Yuqi Liu<sup>1</sup>, Xianming Zheng<sup>1</sup>, and Jingyi Zhou<sup>1</sup>

<sup>1</sup>Department of Earth and Space Sciences, Southern University of Science and Technology, Shenzhen, China,

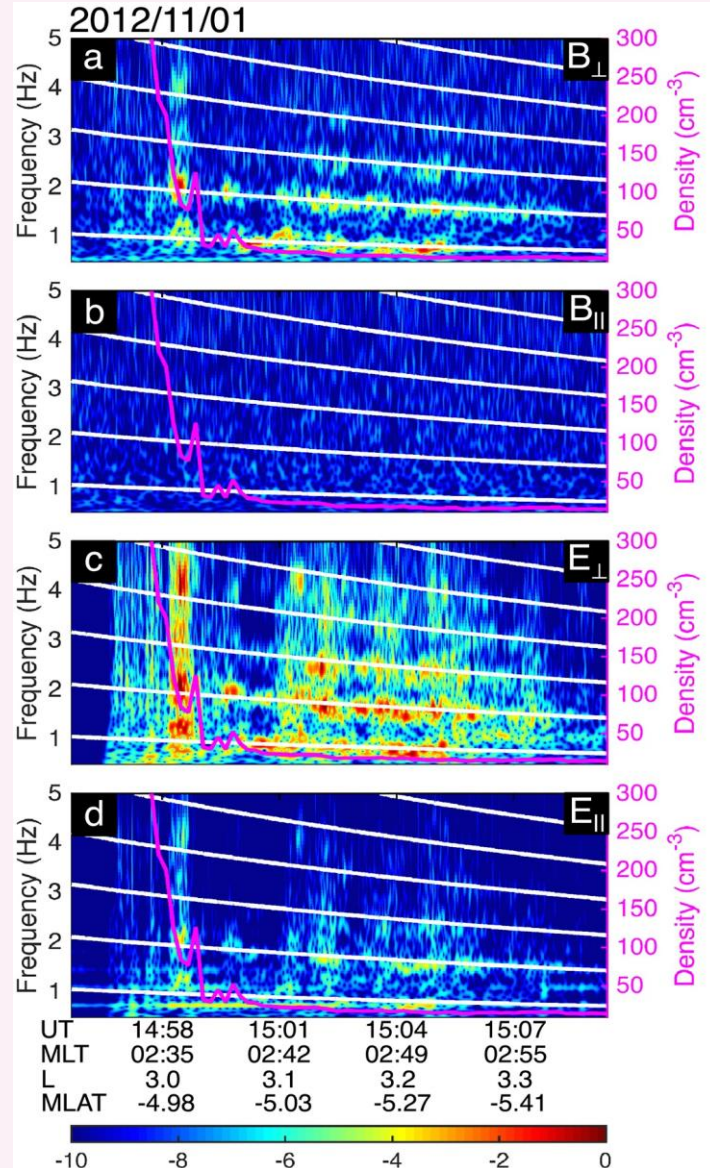
<sup>2</sup>Department of Astronomy and Space Science, Chungnam National University, Daejeon, South Korea



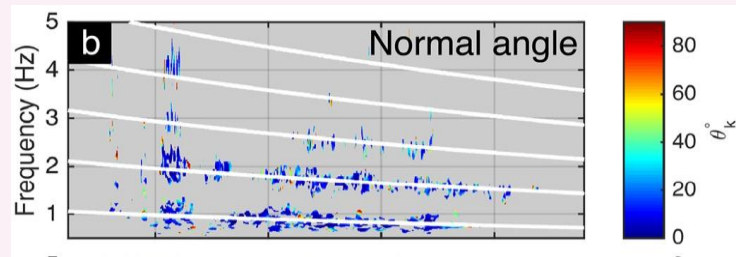
# Introduction:

## What Are the Oxygen Ion Cyclotron Harmonic Waves?

### ◆ Observation



$\text{WNA} \approx 0$  (SVD)

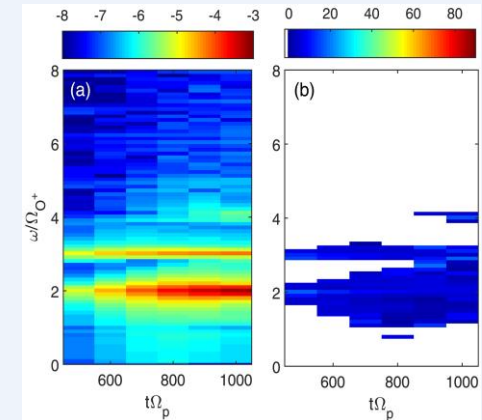
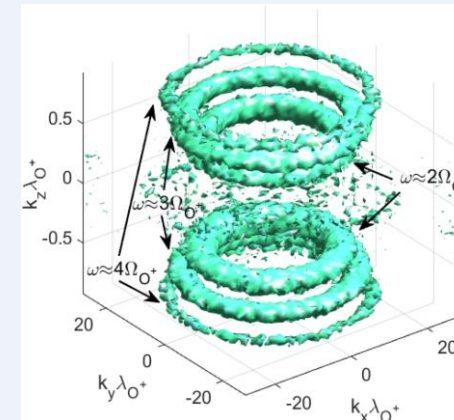


Usanova et al., GRL, 2016

### ◆ Simulation

Peaks at  $n\Omega_{O^+}$   
Electromagnetic  
Transverse  
Mixed ellipticity

$\text{WNA} \approx 90 \longleftrightarrow \text{WNA} \approx 0$  (SVD)

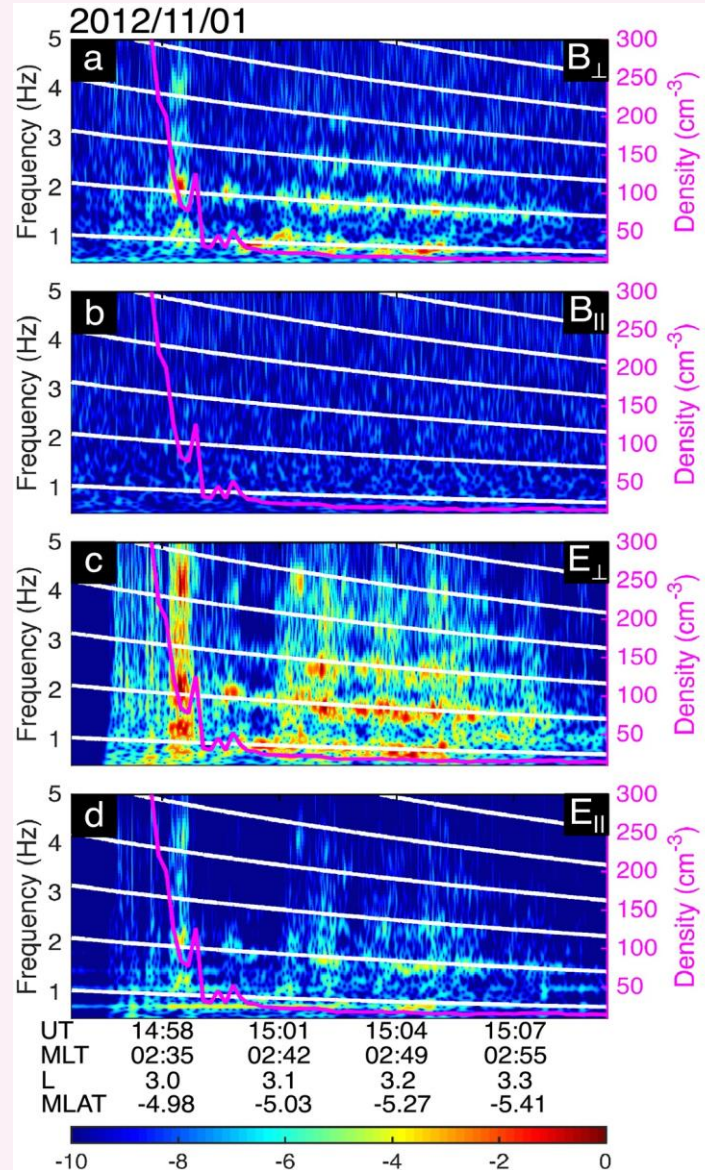


Liu et al., GRL, 2020

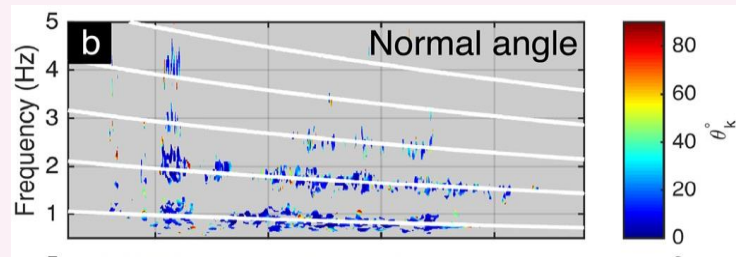
# Introduction:

## What Are the Oxygen Ion Cyclotron Harmonic Waves?

### ◆ Observation



$\text{WNA} \approx 0$  (SVD)



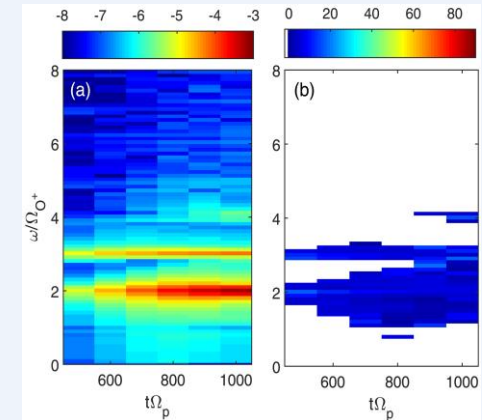
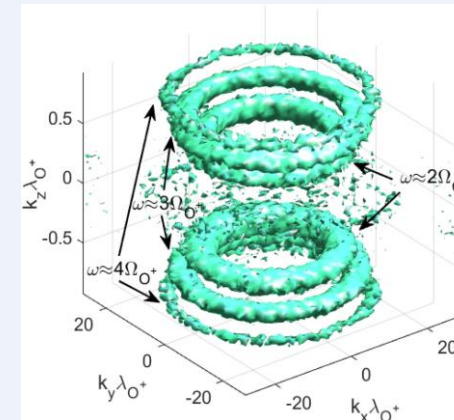
Usanova et al., GRL, 2016

### ◆ Simulation

Peaks at  $n\Omega_{O^+}$   
Electromagnetic  
Transverse  
Mixed ellipticity

**Because of the superposition**

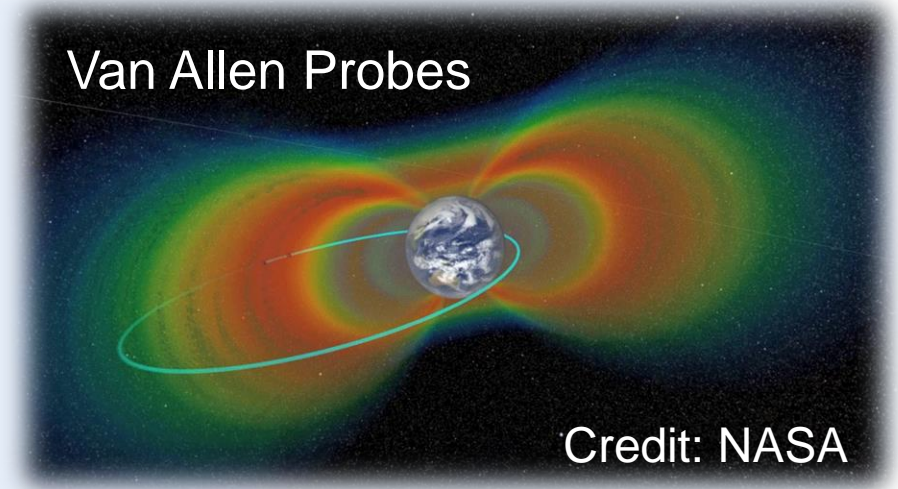
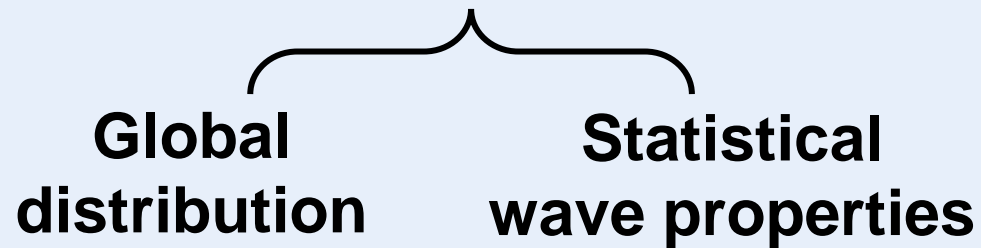
$\text{WNA} \approx 90 \longleftrightarrow \text{WNA} \approx 0$  (SVD)



Liu et al., GRL, 2020

# Our Objective:

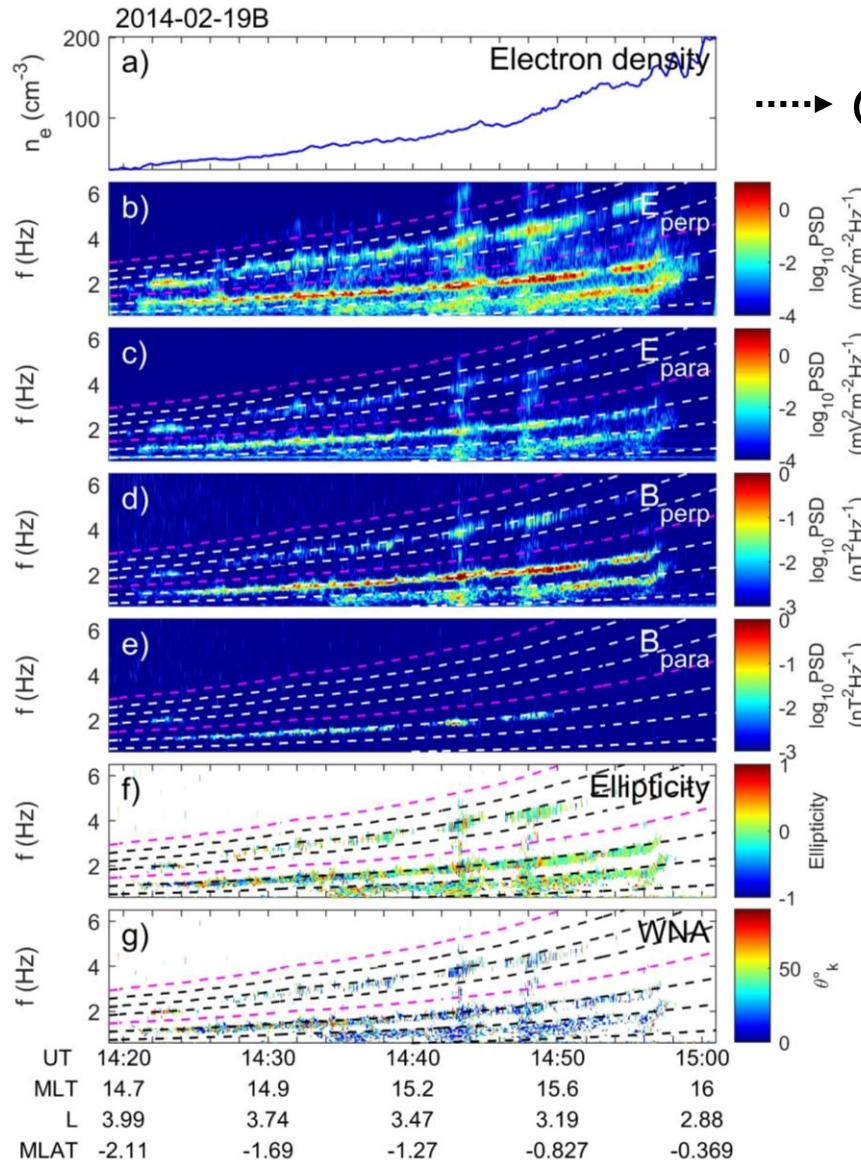
**Oxygen ion Cyclotron  
Harmonic waves (OCH)**



## Criteria of OCH waves:

- The frequency of the first harmonic is to be between  $0.1\Omega_{O^+}$  and  $4\Omega_{O^+}(=\Omega_{He^+})$
- At least 2 obvious harmonics of both electric and magnetic components
- At least one of the electric or magnetic components has higher harmonics
- Minimum power threshold of  $0.01 \text{ nT}^2/\text{Hz}$

# Example Event of Oxygen Ion Cyclotron Harmonic Waves



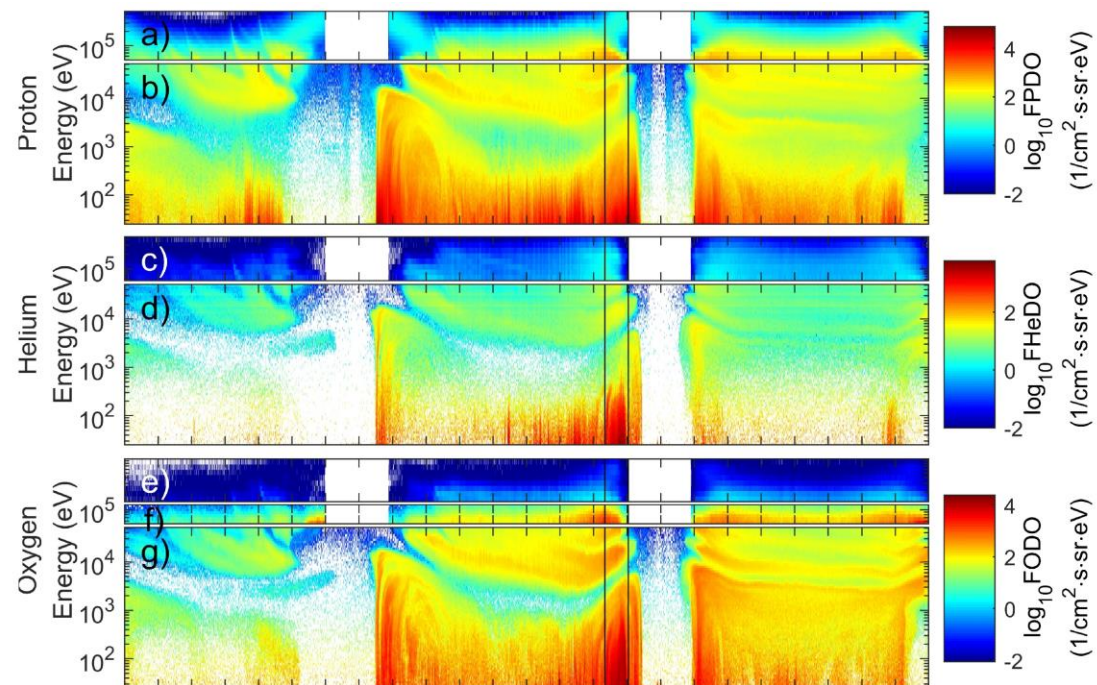
.....► Outside the plasmasphere

- Electromagnetic
- Transverse
- Locally generated

.....► Mixed ellipticity

.....► Parallel propagating (SVD)

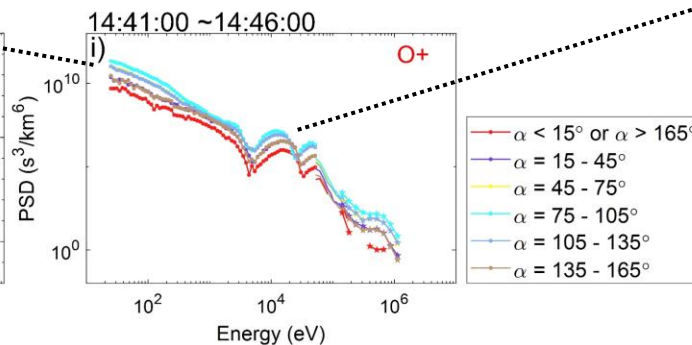
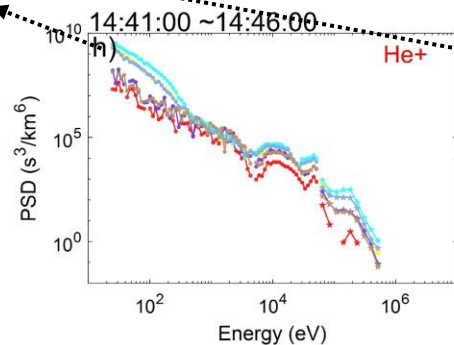
# Example Event of Oxygen Ion Cyclotron Harmonic Waves



UT	03:00	06:00	09:00	12:00	15:00	18:00	21:00
MLT	12.6	16.1	10.3	12.6	16	10.3	12.5
L	6.23	2.86	4.76	5.88	2.88	4.53	5.77
MLAT	-15.5	-6.56	-10.6	-6.99	-0.369	-2.77	-1.92

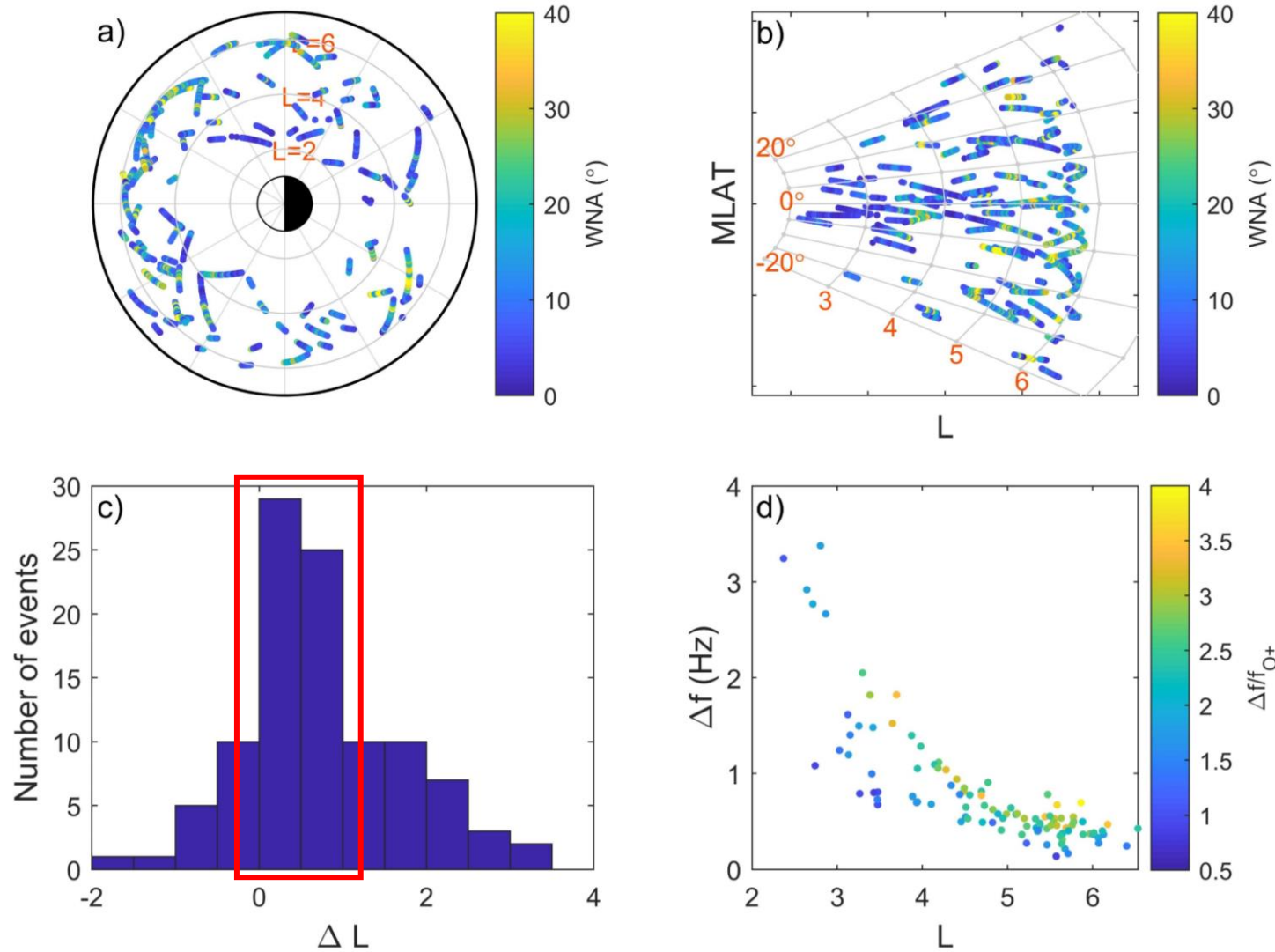
Ring current O<sup>+</sup> increased

Transversely heated



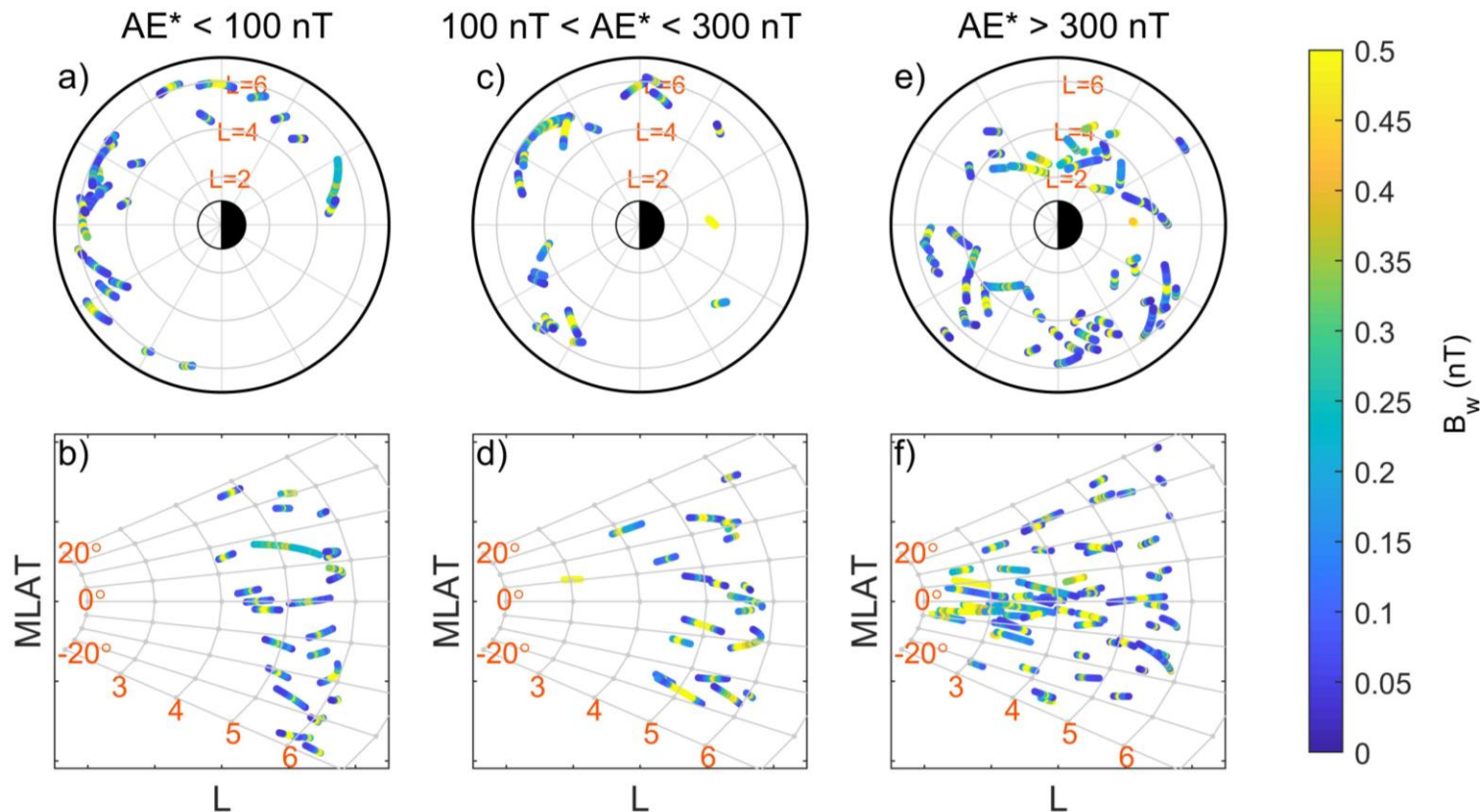
Ring-like partial shell distribution

# Statistical Results



- A total of 104 events
- Wide L range ( $2 < L < 6$ )
- Across all MLT
- The wave normal angle given by the SVD method tends to be larger at larger L on average
- More than 50% of the events are just outside the plasmopause
- Some waves have likely propagated radially outward for some distance

# Statistical Results



- Left: Quiet geomagnetic conditions
- Middle: Moderate geomagnetic conditions
- Right: Active geomagnetic conditions
- Wave amplitudes vary between  $\sim 0.1$  and several nT
- Wave amplitude tends to increase with decreasing L value

# Summary

We present the first statistical survey of the oxygen ion cyclotron harmonic waves in the inner magnetosphere detected by Van Allen Probes throughout the mission from November 2012 to July 2019:

- We found a total of 104 events. Waves occurred in a wide L range ( $2 < L < 6$ ) and across all MLT.
- **Over 50%** of the events were observed **just outside the plasmopause**.
- $\Delta f/f_{o+}$  is larger than 1 for most events, especially the ones observed at  $L > 5$ .
- The wave amplitude varies from  $\sim 0.1$  to several nT.
- The spatial distribution of wave events varies under different levels of geomagnetic activity.

Wang, Y., Liu, K., Min, K., Yao, F., Xiong, Y., Cheng, K., ... & Zhou, J. (2022). Van Allen Probes Observations of Oxygen Ion Cyclotron Harmonic Waves: Statistical Study. *Geophysical Research Letters*, 49(4), e2021GL096825. doi: 10.1029/2021GL096825

