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Selective acceleration of O+ by drift-bounce resonance in the Earth's magnetosphere: MMS observations

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Abstract

We studied O+ drift-bounce resonance using Magnetospheric Multiscale (MMS) data. A case study of an event on 17 February 2016 shows that O+ flux oscillations at ~10–30 keV occurred at MLT ~ 5 hr and L ~ 8–9 during a storm recovery phase. These flux oscillations were accompanied by a toroidal Pc5 wave and a high-speed solar wind (~550 km/s). The azimuthal wave number (m-number) of this Pc5 wave was found to be approximately –2. The O+/H+ flux ratio was enhanced at ~10–30 keV corresponding to the O+ flux oscillations without any clear variations of H+ fluxes, indicating the selective acceleration of O+ ions by the drift-bounce resonance. A search for the similar events in the time period from September 2015 to March 2017 yielded 12 events. These events were mainly observed in the dawn to the afternoon region at L ~ 7–12 when the solar wind speed is high, and all of them were simultaneously identified on the ground, indicating low m-number. Correlation analysis revealed that the O+/H+ energy density ratio has the highest correlation coefficient with peak power of the electric field in the azimuthal component (Ea). This statistical result supports the selective acceleration of O+ due to the N = 2 drift-bounce resonance.

Introduction

✦Only a few papers studied the O+ drift-bounce resonance (Yang et al., 2010; 2011, Zong et al., 2012; Ren et al., 2016).

✦Yang et al. (2011) and Zong et al. (2012) suggested the O+ acceleration due to the drift-bounce resonance.

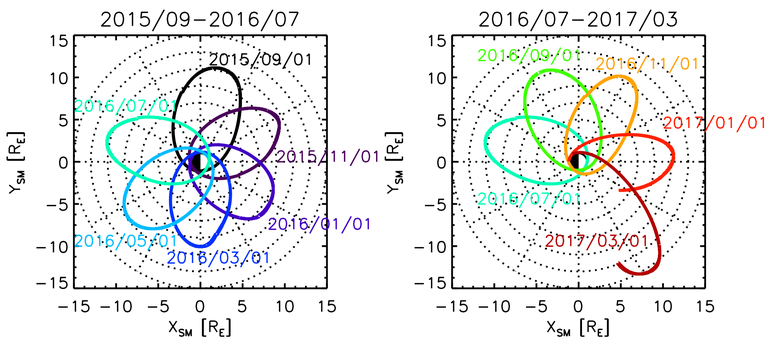
✦Oimatsu et al. (2018) simultaneously found the drift resonance (> ~50 keV) and the bounce resonance for O+ ion (< ~20 keV) for the first time. O+/H+ flux ratio shows enhancements corresponding to the O+ ion flux oscillations, which suggest the selective acceleration of O+ ions.

✦There has been no statistical and quantitative studies of the O+ drift-bounce resonance.

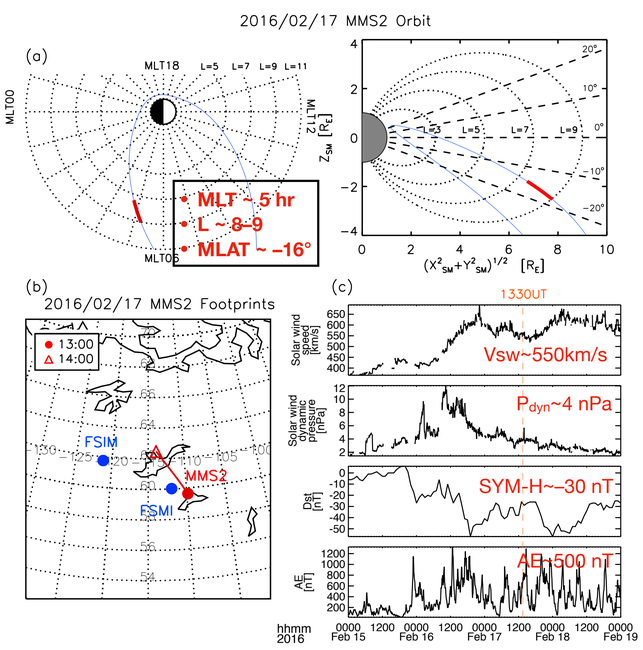
- ✦ **Whether O+ are decelerated or accelerated by the drift-bounce resonance?**
- ✦ **Does the resonance affect the storm development?**
- ✦ **Statistical and quantitative properties?**

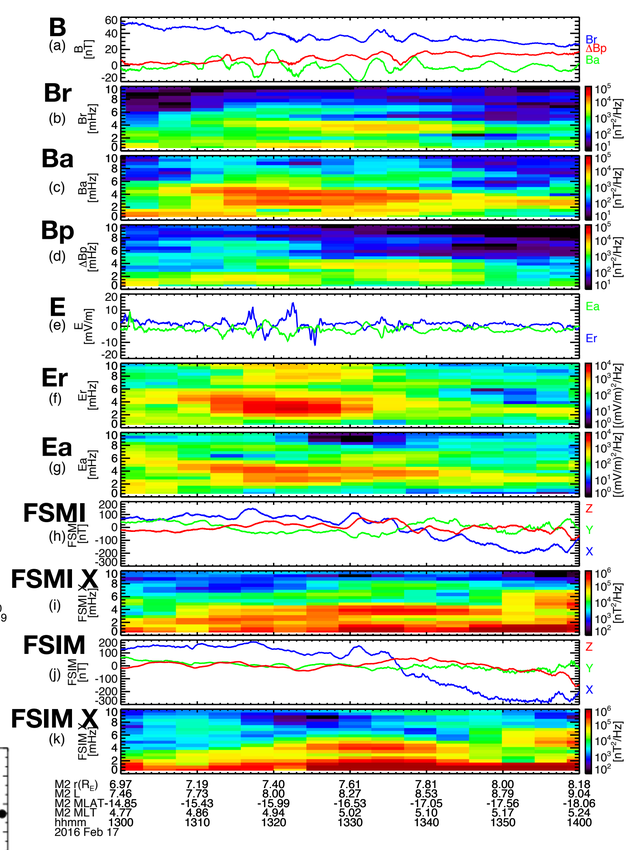
Dataset

- **HPCA**
  - Hot Plasma Composition Analyzer
  - Ion species : H+, O+, He+, He++
  - Energy: ~1 eV – 40 keV
- **FGM**
  - Magnetic fields
  - 16 or 8 Hz sampling → 1 Hz
- **EDP**
  - Electric fields
  - 16 Hz sampling → 1 Hz
- **MMS2** data
  - 2015/09~2017/03
- Solar wind parameters
- Kp and Dst indices
- Ground magnetometers (2 Hz)
  - FSIM (Fort Smith)
  - FSMI (Fort Simpson)

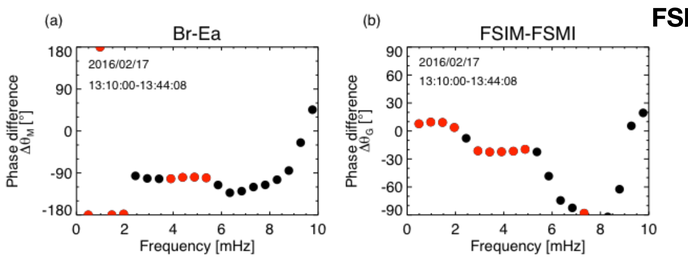


Case study of the event on February 17, 2016





Phase differences

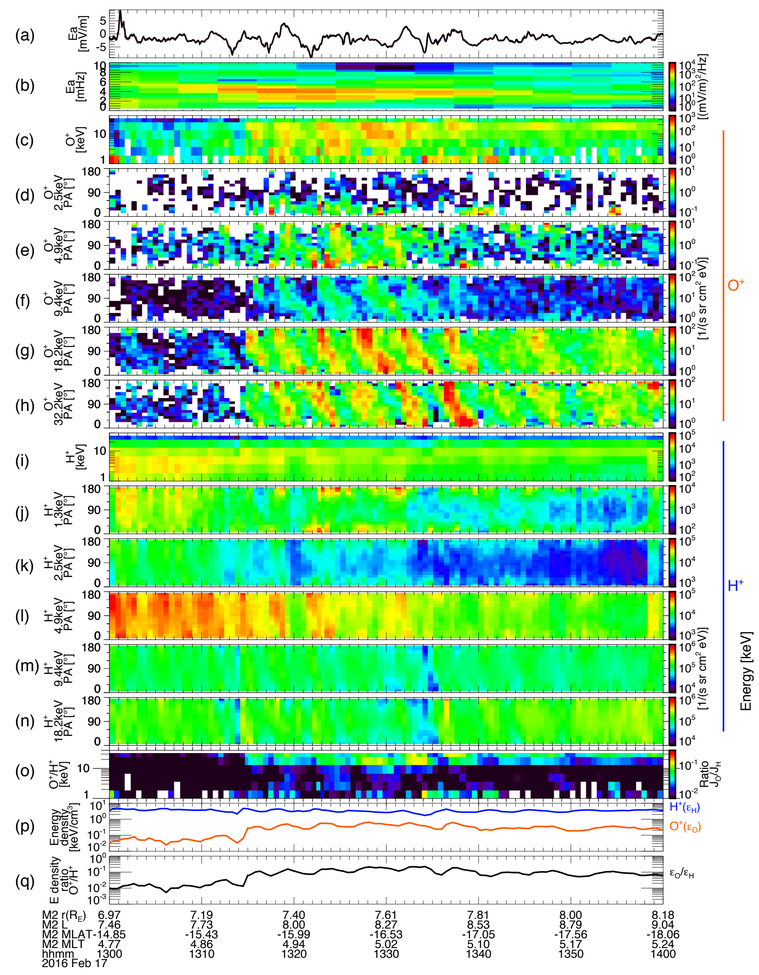


- Ea leads Br by ~90° in the southern hemisphere → Odd mode (**Fundamental mode**)
- Ground magnetic field data at FSMI and FSIM yield m-number.

$$\Delta\theta = -25^\circ,\quad \Delta\varphi = 12.64^\circ \longrightarrow m = \frac{\Delta\theta}{\Delta\varphi} \sim -2$$

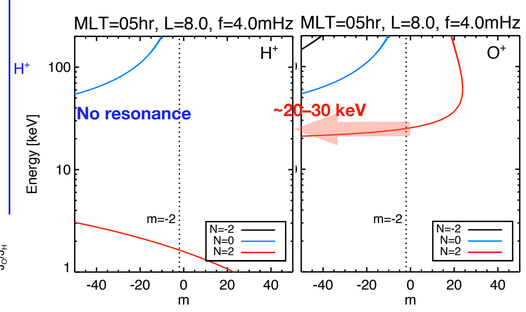
(Westward propagation)

- Pc5 wave (f ~ 4 mHz)
- Br < Ba, Er > Ea (Toroidal mode)
- Pc5 wave at FSMI and FSIM



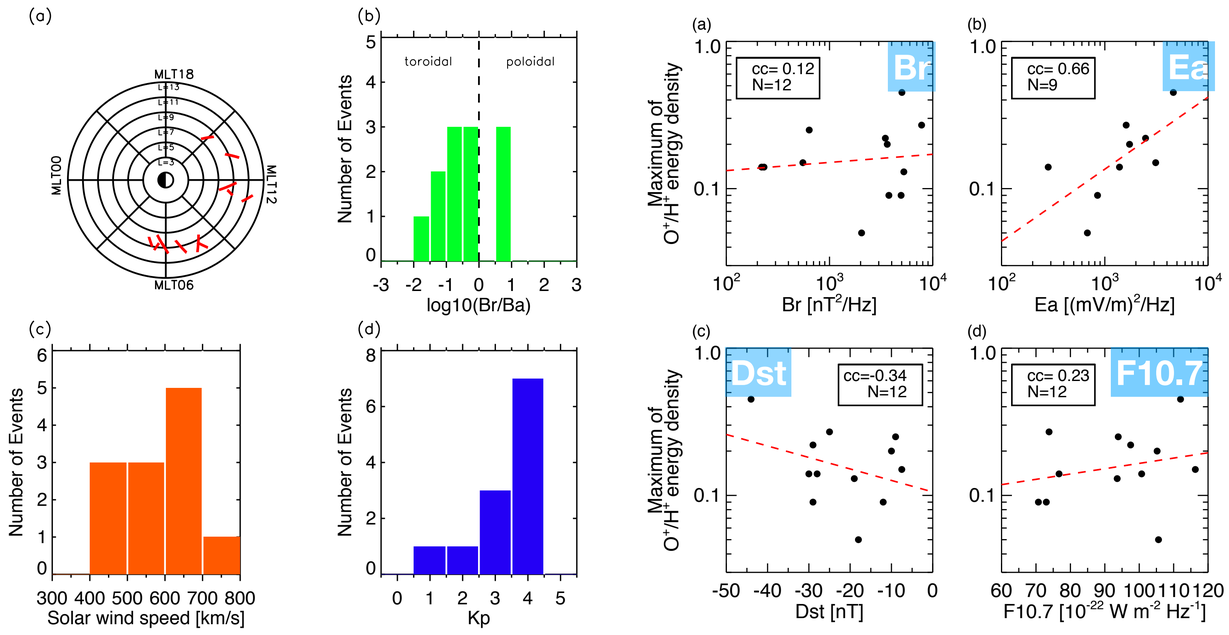
- O+ flux oscillations with the same period of a Pc5 wave
- Pitch angle and energy dispersions
- Enhancement of O+/H+ flux ratio at W = ~10–30 keV
- Enhancement of O+/H+ energy density ratio corresponds to the strong wave power (Ea)
- O+ energy density increased by ~0.5 keV/cm³

Theoretical resonance energy



- The O+ resonance energy (~20–30 keV) of N=2 corresponds to the flux oscillations → Consistent with the observation

Properties of O+ drift-bounce resonance events



- 12 O+ drift-bounce resonance events
- Toroidal mode Pc5 waves
- High-speed solar wind
- Moderately disturbed condition
- All of the waves were observed on the ground and Pc5 range → low m-number

- Low correlation with Br → Latitudinal effect? (e.g., Takahashi et al., 2011)
- High correlation with Ea → Resonance effect
- Low correlation with the storm strength (Dst) and the solar cycle variations (F10.7)

Discussion and Summary

- ☑ We conducted a case study of O+ drift-bounce resonance event on 17 February 2016 at MLT~5 hr, L~8–9 associated with the toroidal mode Pc5 wave.
- ☑ O+ fluxes at ~10–30 keV enhanced during the event. The Pc5 wave driven by high speed solar wind resonated with O+ and transported energy to the O+ ions.
- ☑ We estimated the quantitative contribution of O+ to the ring current development in the dipole volume using the Dessler-Parker-Sckopke equation, but the contribution is insignificant.
- ☑ We found twelve O+ drift-bounce resonance events using MMS data from September 2015 to March 2017.
- ☑ Correlation coefficient between O+/H+ energy density ratio and Ea peak power is high, which suggest that the selective acceleration of O+ due to the drift-bounce resonance.