

# Occurrence characteristics of Saturn's radio burst

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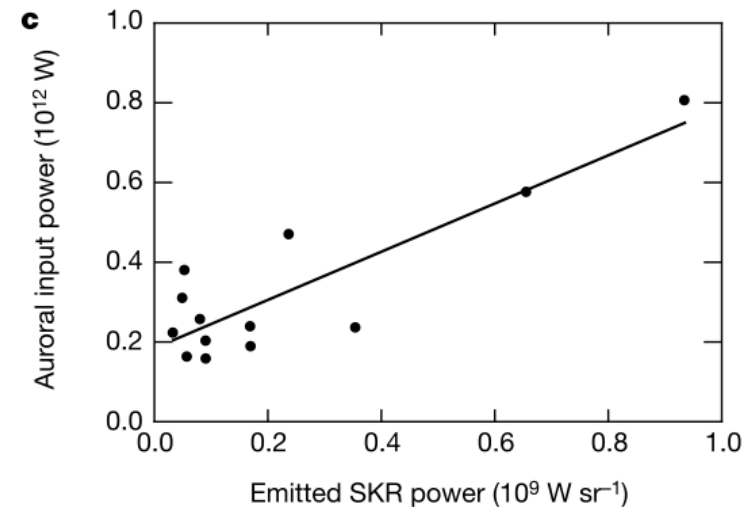
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# Introduction

## Saturn kilometric radiation (SKR)

- SKR is emitted from auroral electrons accelerated along the field lines on the polar regions.
- SKR intensity is positively correlated with auroral intensity [Kurth et al., 2005].
- The magnetic field lines on which SKR sources are located is connected to the UV main oval [Lamy et al., 2009].
- RH SKR -> from the northern hemisphere, LH SKR -> from the southern hemisphere. Here the former is called **N-SKR**, and the latter is called **S-SKR**.
- SKR frequency  $\sim$  the local electron gyro frequency at the source regions. The source altitude can be deduced with the assumption of a magnetic field model.



**FIG.** Comparison between the auroral input power and emitted radio power (derived from Observation during the month of January 2004). [Kurth et al., 2005].

**SKR**



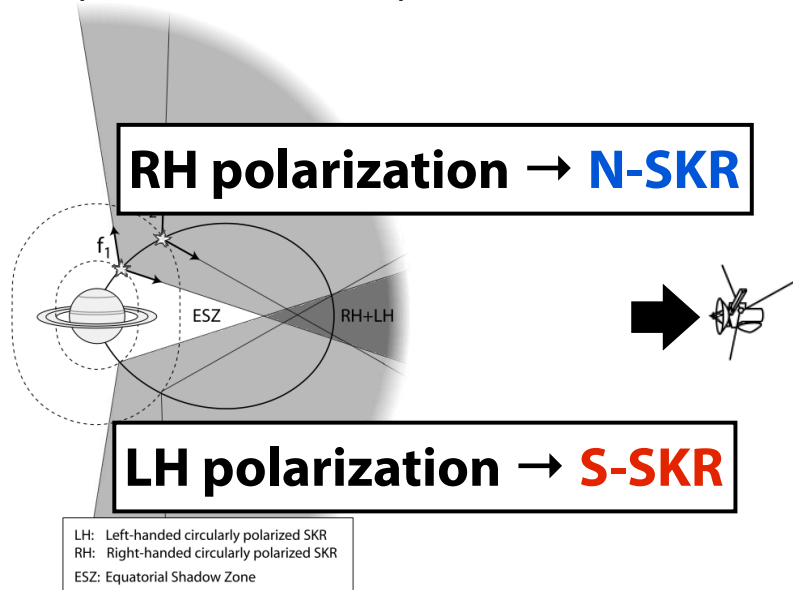
A good remote sensing tool to observe auroral activities from both polar regions

# Periodic modulations of SKR

- North-south asymmetric periodic modulations (**N-SKR: 10.6 h** , **S-SKR: 10.8 h**).  
in 2006 (Kurth et al. [2008]; Gurnett et al. [2009])
- North-south asymmetry in SKR intensity [Kimura et al., 2013]
- North-south asymmetric SKR phase systems (**N-SKR phase**, **S-SKR phase**)  
[Lamy, 2011]

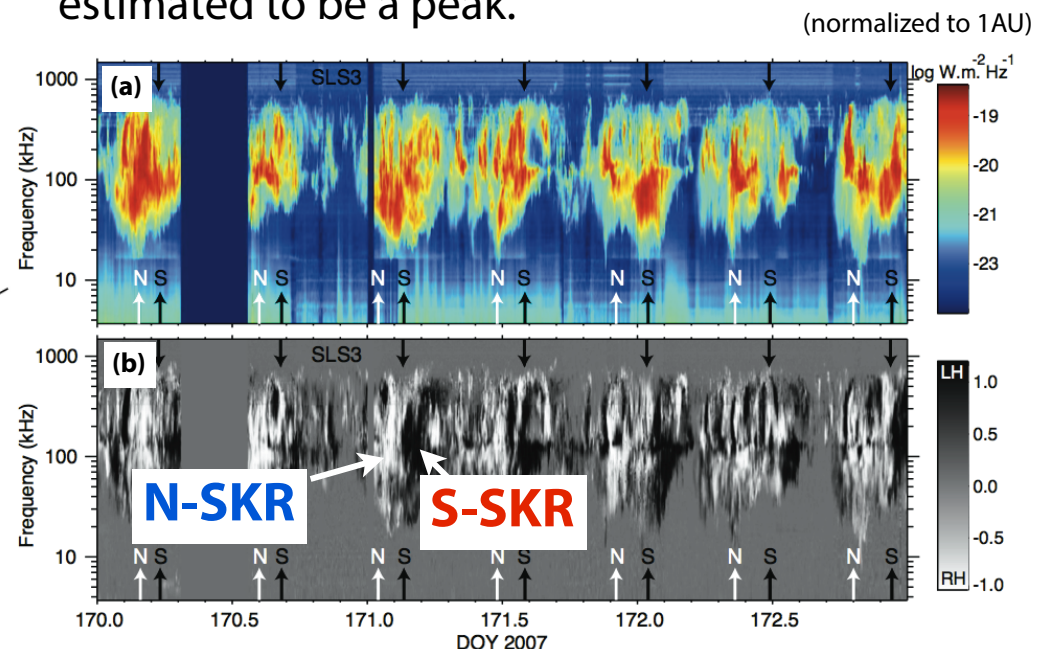
$$\Phi_{N,S}(t) = \int \frac{360}{T_{N,S}(t)} dt + \Phi_{0,N,S}, \quad (0 \sim 360^\circ)$$

Modulation periods of N, S-SKR power (40-500 kHz)。



**FIG.** Conceptual image of SKR emission pattern [Lamy, 2008].

N/S-SKR phase = 0 deg when N/S-SKR power is estimated to be a peak.



**FIG.** Dynamic spectra of SKR flux density (top) and circular polarization degree for equatorial observation in 2007 [Lamy, 2011].

# SKR burst: Main target of this study

- SKR sometimes shows **sudden enhancements** and **lower-frequency extensions**.

x 100

**"SKR burst"**

down to few kHz

- SKR bursts are reported to be associated with **magnetotail reconnections**.

SKR burst  $\leftrightarrow$  plasmoid [Jackman et al., 2009]

SKR burst  $\leftrightarrow$  ENA, aurora [e.g., Mitchell et al., 2009]

- SKR bursts and SKR modulation

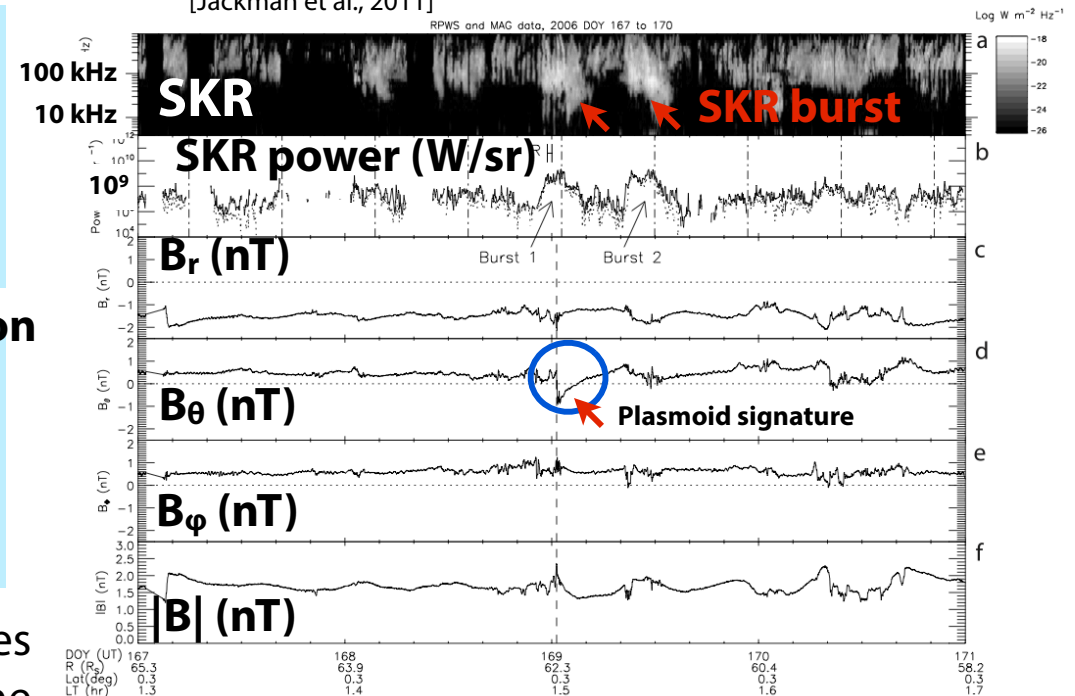
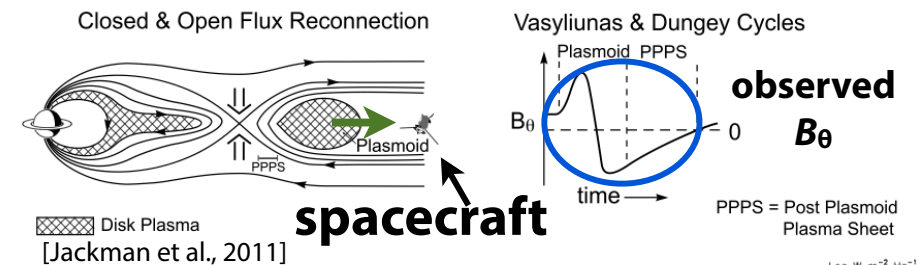
## SKR bursts in phase with SKR modulation

Reconnections under the quiet solar wind condition suggest an internally triggered driver, i.e., mass-loading [e.g., Lamy et al., 2013].

## SKR bursts independent of SKR modulation

Solar wind compressions (the external trigger) cause reconnections independent of the SKR modulation [e.g., Badman et al., 2008].

However, the occurrence timings and intensities of SKR bursts have not been examined from the viewpoint of the north-south comparison



**FIG.** SKR bursts and a reconnection event identified by the magnetic field data [Jackman et al., 2009].

# Purpose of this study

- SKR bursts : An indicator of reconnection events in Saturn's magnetotail
- The SKR phase dependence of SKR burst onsets : A hint of control factors of tail reconnections

**SKR modulations show north-south asymmetric intensities and periodicities.**



**Do SKR bursts also show the north-south asymmetry?**

**Purpose of this study :**

**To clarify characteristics of SKR bursts from the viewpoint of north-south comparisons**

Here the result of the following statistical studies are shown.

- **The north-south comparison between N- and S-SKR burst intensities**
- **The dependence of SKR burst onsets on N- and S-SKR periodicities**

# Data set

We extracted SKR burst events by using spectral data observed from the Radio and Plasma Wave Science (RPWS) instrument onboard Cassini.

**Period : 2005 DOY 250 - 2006 DOY 200**

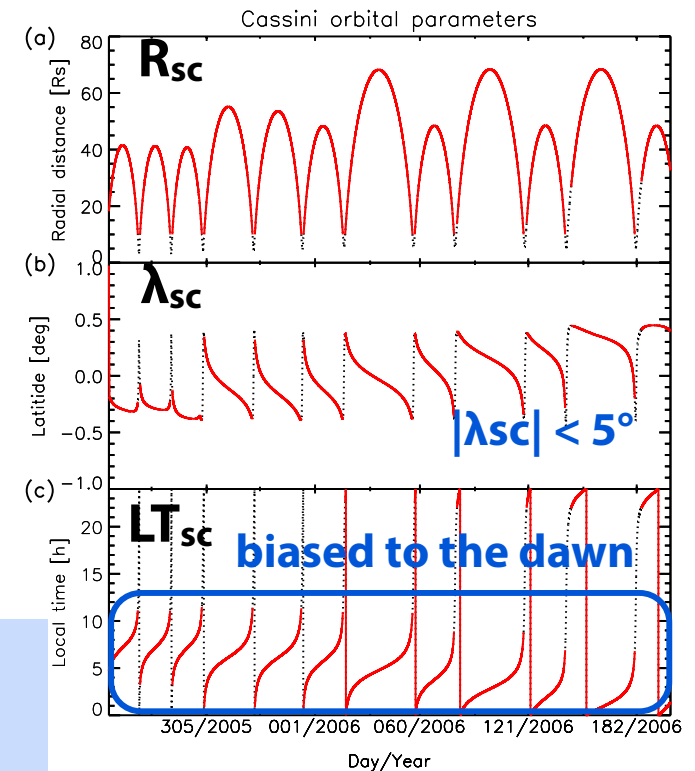
## Reduction of SKR visibility effect by the orbit criteria

The radial distance of Cassini : 10-100  $R_s$

The LT of Cassini : 22-24 and 00-14 h

## SKR spectra data [Lamy et al., 2008]

- SKR flux density (48 frequency channels) [ $W/m^2/Hz$ ], circular polarization degree, SKR power (10-1000 kHz integrated) [ $W/sr$ ]
- **Separated into N- and S-SKR components** ( $V > 0$  : S-SKR,  $V < 0$  : N-SKR)
- **Non-SKR components are reduced** ( $|V| > 0.2$ ,  $SNR > 10$  dB).
- Time resolution : 180 s
- Frequency resolution :  $\Delta f/f = 20\%$  (3.5 - 320 kHz),  $\delta f = 50$  kHz (350-1500 kHz)



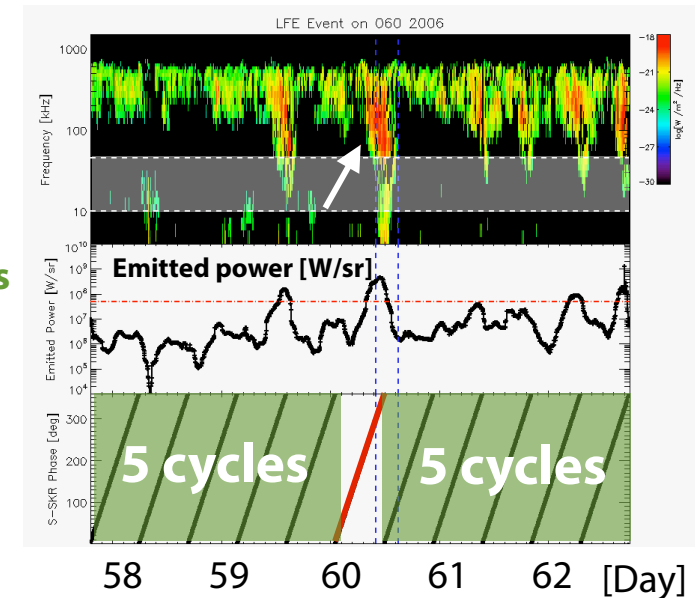
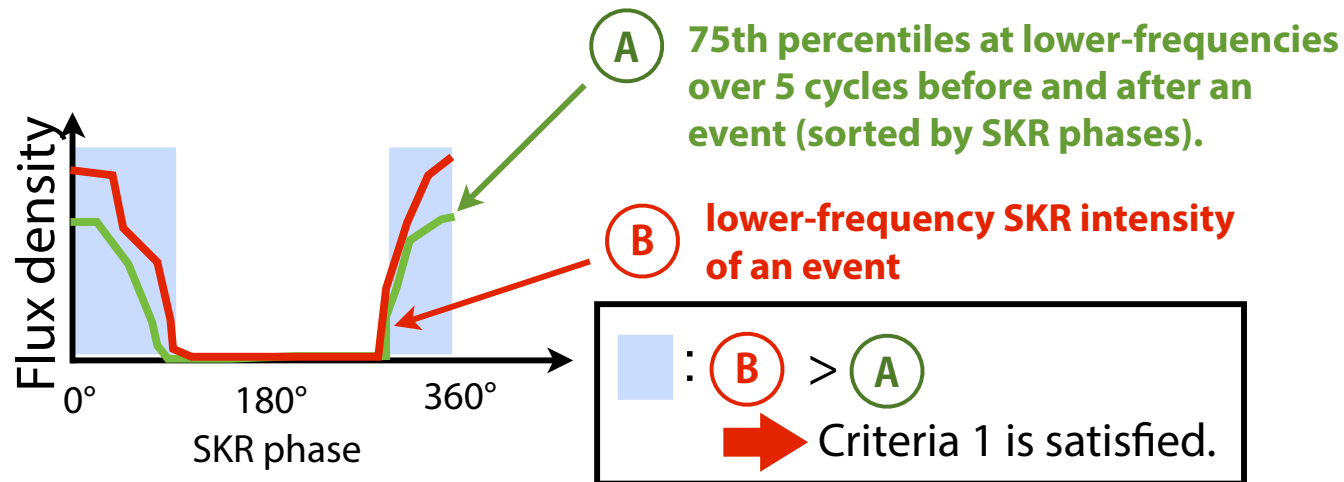
**FIG.** Cassini orbit parameters from 2005 DOY 250 to 2006 DOY 200.

# Selection of SKR burst events

## SKR burst criteria

SKR spectra varies periodically. To distinguish SKR burst events from the variations, we applied the following selection criteria for SKR bursts.

### 1. Lower-frequency extension (10-50 kHz)



**FIG.** SKR burst event on 2006 DOY 060.

### 2. Enhancement of SKR power (integrated over 10-1000 kHz)

SKR power is compared with 75th percentiles of that over 10 cycles as with the criterion 1.

### 3. No obvious gap between main band SKR(100-400 kHz) and lower-frequency SKR

This criterion is set to exclude narrowband emissions.

### 4. Duration time of an SKR burst event > 60 min

**An SKR burst event has to satisfy all 4 criteria**

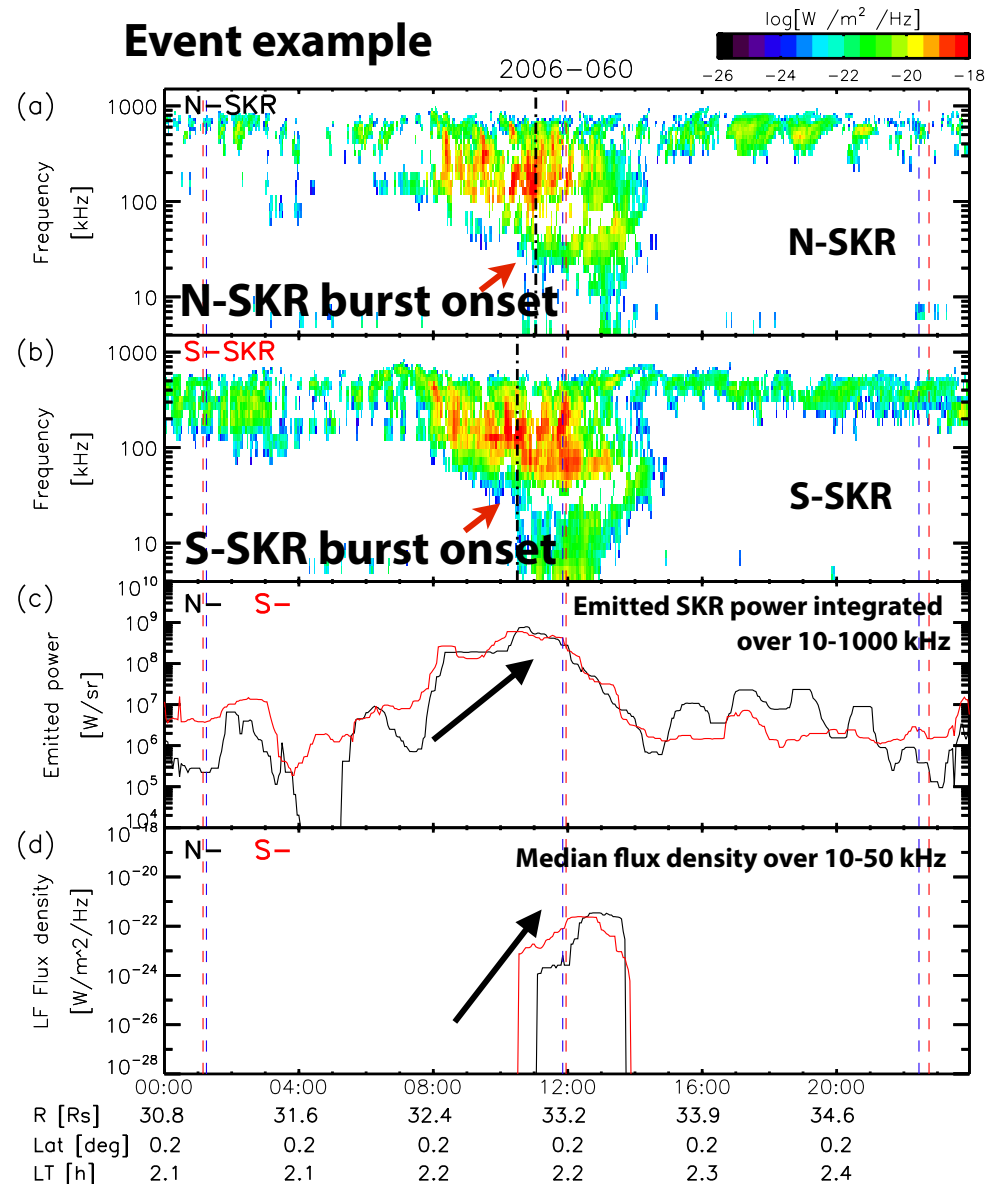
# Results: Selected SKR burst events

We selected SKR burst events from 2005 DOY 250 to 2006 DOY 200 based on the criteria in the previous page.

Selected SKR burst events :

**N-SKR burst events : 16 events**

**S-SKR burst events : 36 events**



**FIG.** An N-SKR burst event accompanied by an S-SKR burst event on 2006 DOY 060.



# Result 1 : Statistical profile of SKR frequency and source altitude

We derived median N- and S-SKR source profile from SKR spectra for 2 hours after SKR burst onsets as for all N- and S-SKR burst events, respectively.

SKR frequency has been converted into source altitude with the assumption of the magnetic field model by Dougherty et al. [2005].



► S-SKR flux density is greater than that of N-SKR by about 7 dB.

**The asymmetry in intensity between N-SKR bursts and S-SKR bursts**

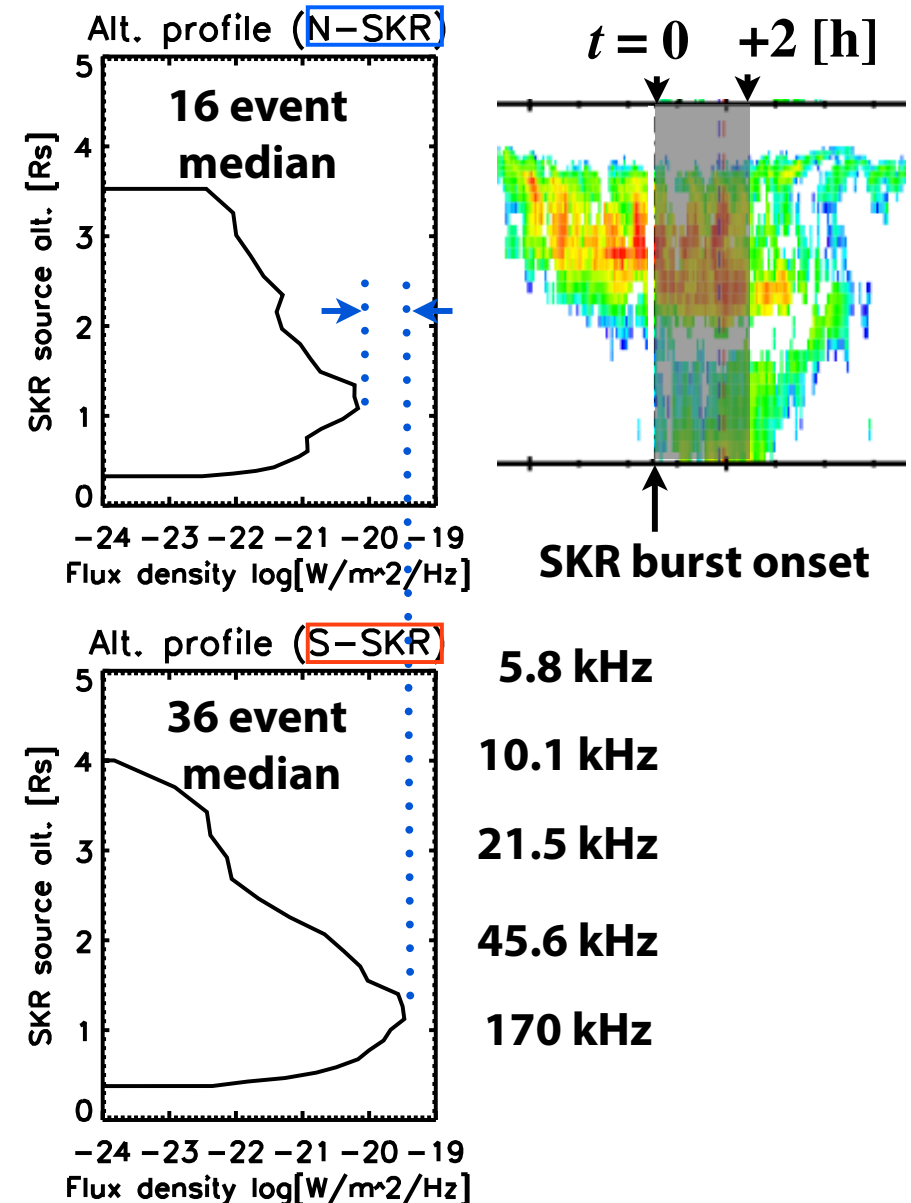


FIG. N- and S-SKR source profiles after the SKR burst onset.

# Result 2 : Dependence of SKR bursts on SKR phases

What determines the timing of SKR burst onsets?

➔ Are onset timings completely at random? Or are they controlled by SKR periodic modulations?

We examined

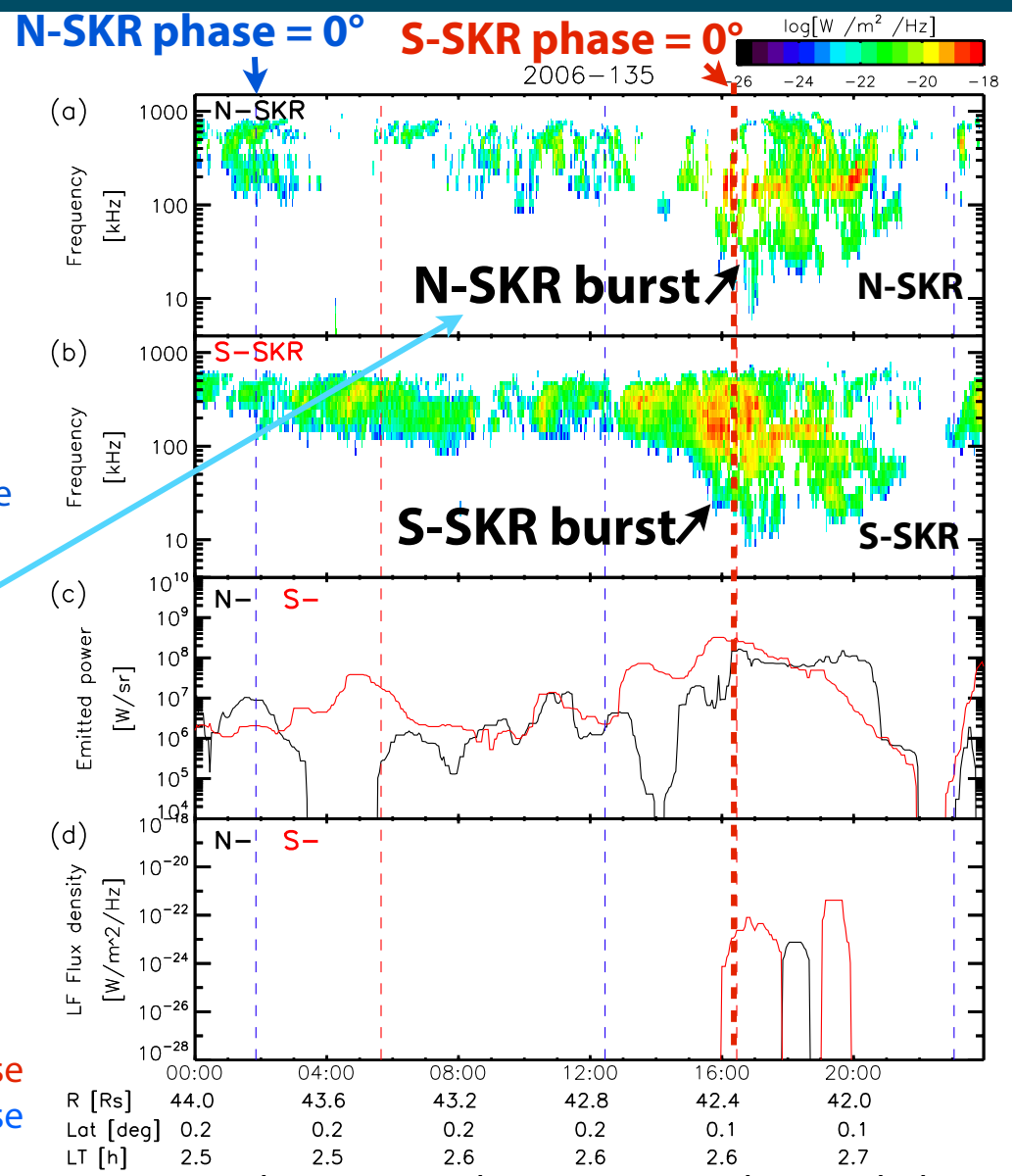
- the dependence of N-SKR bursts on the N-SKR phase
- the dependence of S-SKR bursts on the S-SKR phase

Some SKR burst events occurred in phase with the opposite SKR phase.

➔ Do SKR bursts affected by the periodic modulations on the opposite hemisphere?

We examined

- the dependence of N-SKR bursts on the S-SKR phase
- the dependence of S-SKR bursts on the N-SKR phase



**FIG.** Simultaneous SKR burst events in phase with the S-SKR phase on 2006 DOY 135.

# Result 2 : Dependence of SKR bursts onsets on SKR phases

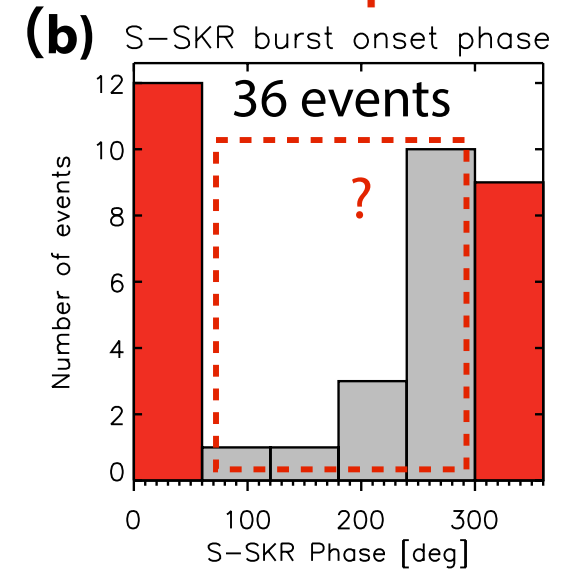
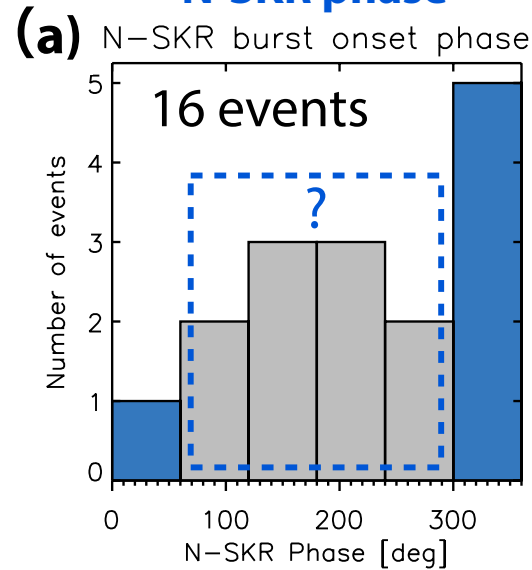
**N-SKR burst vs N-SKR phase**

**S-SKR burst vs S-SKR phase**

To examine whether SKR burst onsets are related to SKR periodic modulations, we derived the SKR phase dependence of SKR burst onsets.

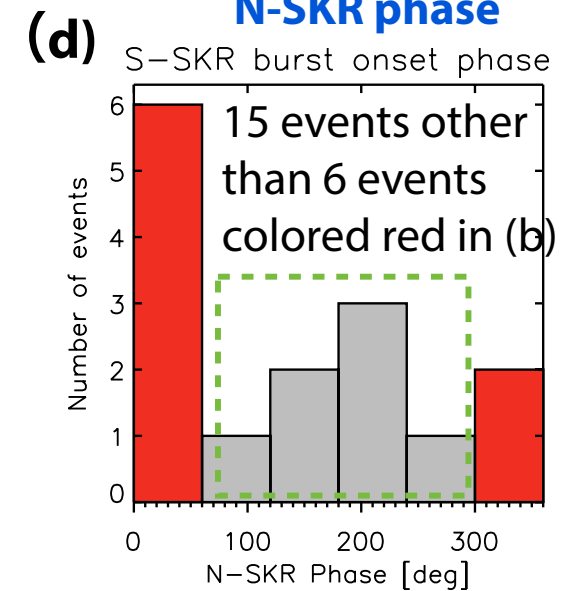
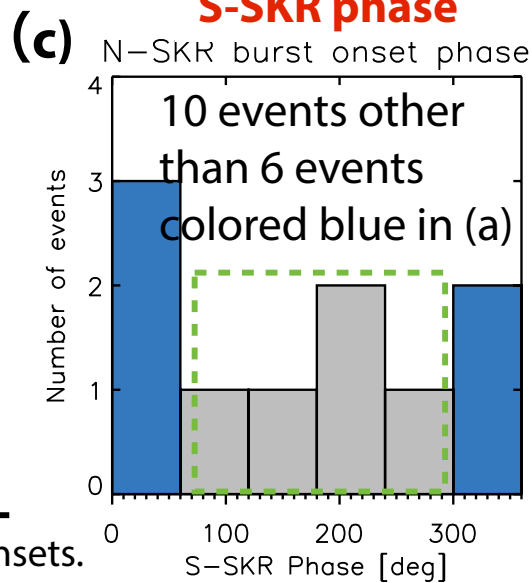


- ▶ Both SKR burst onsets showed dependence on each opposite SKR phase (In particular, S-SKR bursts showed the tendency).
- ▶ There were also SKR burst events independent of both SKR phases (In particular, N-SKR bursts showed the tendency).



**N-SKR burst vs S-SKR phase**

**S-SKR burst vs N-SKR phase**



**FIG.** N/S-SKR phase dependence of N/S-SKR burst onsets.

# Discussion: Asymmetry between N- and S-SKR bursts

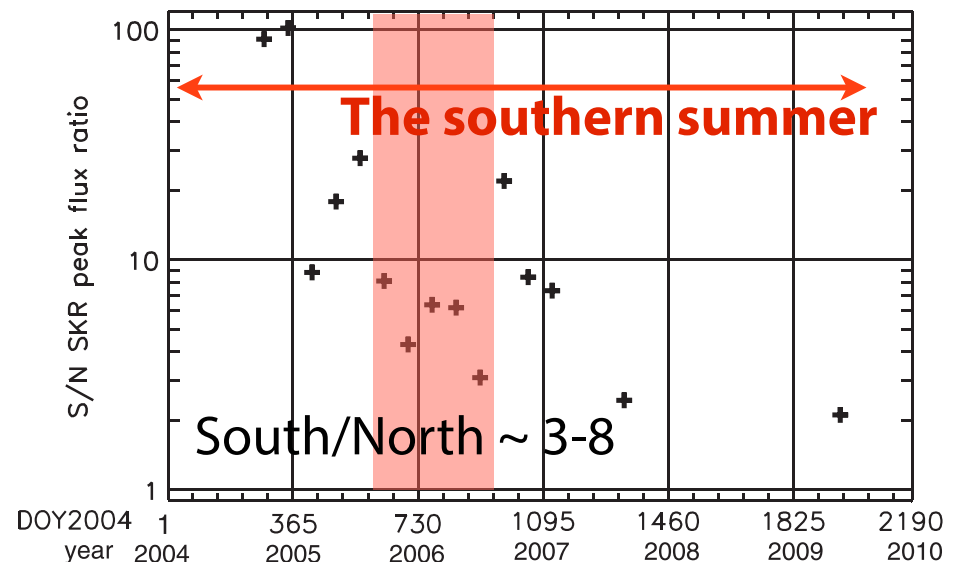
- We identified S-SKR burst events 2.3 times larger than N-SKR burst events from 2005 DOY 250 to 2006 DOY 200.
- The peak median flux density of S-SKR during S-SKR bursts was larger than that of N-SKR by about 7 dB.



## The intensity asymmetry between N-SKR bursts and S-SKR bursts

Long-term SKR analyses have reported the north-south asymmetry of SKR intensities. IR auroral main oval is also reported to show the north-south asymmetry.

[Lamy et al., 2008; Badman et al., 2011; Kimura et al., 2013]



**FIG.** The ratio of the S-SKR peak flux to the N-SKR peak flux as a function of time (from 2004 DOY 001 to 2010 DOY 193) with a time resolution of 70 days [Kimura et al., 2013].

## A candidate that cause the north-south asymmetry

**The asymmetry in the ionospheric conductivity could result in the asymmetry in the main oval region [Badman et al., 2011].**

# Discussion: Asymmetry between N- and S-SKR bursts

SKR burst evolution scenario by Jackman et al. [2009]:

The increase of the FAC intensity in the SKR source region

-> The increase of the SKR intensity and the top altitude of the SKR source region

## The asymmetry in the ionospheric conductivity



The north-south asymmetric FAC enhancement by reconnections -> The north-south asymmetry of SKR intensity and the extent of SKR source regions

### **Do the seasonal variation really result in the asymmetry of SKR bursts?**

- ▶ It is necessary to perform similar SKR burst analysis around the equinox in 2009 Sep. This analysis is possible because Cassini was flying nearly in the equatorial plane in 2010.

# Discussion: Dependence of SKR bursts on SKR phases

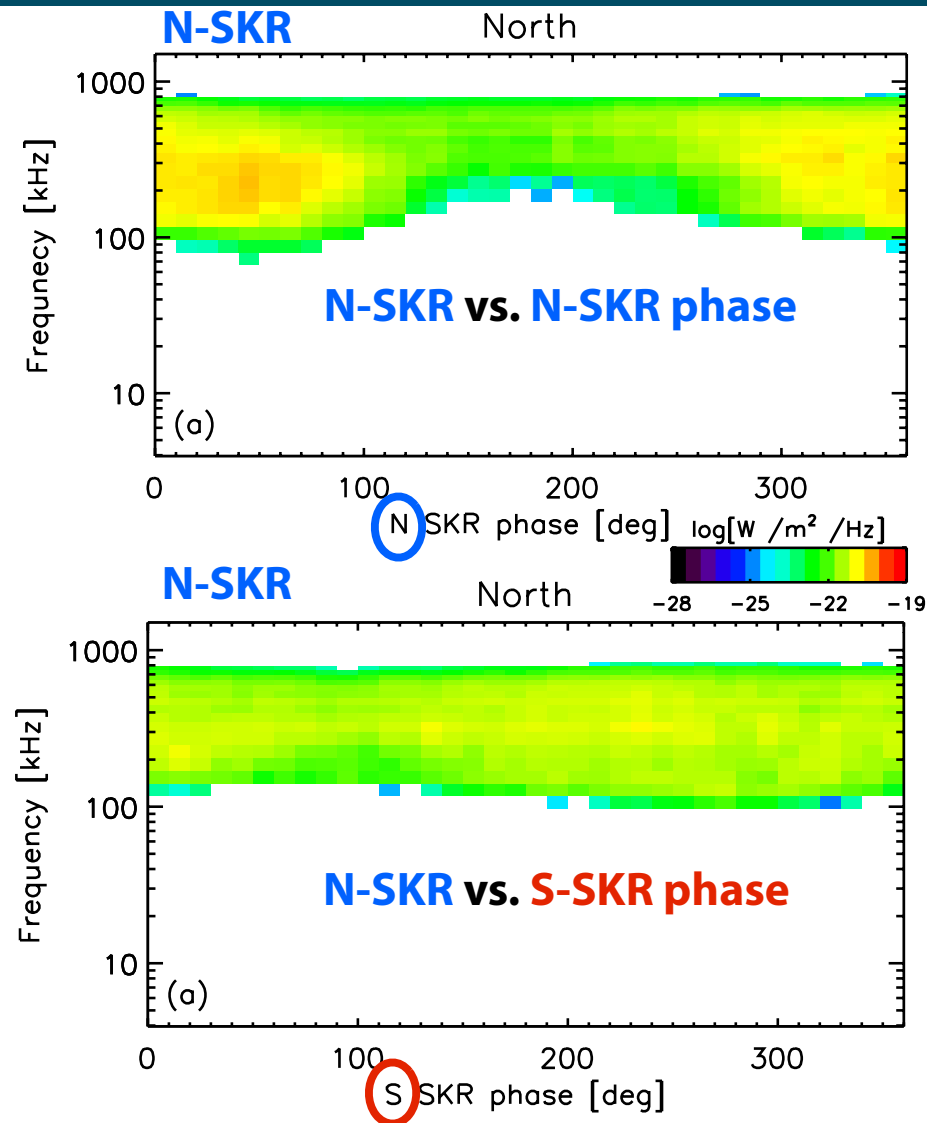
► SKR burst onsets were dependent on each opposite SKR phase.

Do ordinary SKR periodic modulations (not SKR bursts) also show the same tendency?

We examined N- and S-SKR phase dependence of SKR from 2005 DOY 250 to 2006 DOY 200 (The result of N-SKR is shown right).



**The dependence on the opposite SKR phase is the characteristic of SKR burst that is not seen in the SKR periodic modulations.**



**FIG.** The dependence of S-SKR on the S-SKR phase (top) and on the N-SKR phase (bottom). Spectra show **the 75th percentiles** overt the period from 2005 DOY 250 to 2006 DOY 200.

**The dependence of SKR bursts  
on both SKR phases**



**This suggests the relationship  
between reconnection timings and  
both northern and southern SKR  
modulations.**

**SKR bursts independent of  
both SKR phases**



**This suggests the existence of  
reconnection events independent  
of SKR modulations.**

**We confirmed the coexistence of the internal and  
external triggers for reconnections.**

**The comparison with the solar wind  
parameters is necessary to determine  
which process is the dominant trigger for  
reconnection events.**

# Summary and future perspectives

We first selected SKR burst event from 2005 DOY 250 to 2006 DOY 200 by using SKR spectral data separated into northern and southern components. As a result, 16 N-SKR burst events and 36 S-SKR burst events were extracted. Based on the statistical studies, we derived the following results.

- The number of S-SKR burst events was 2.3 times larger than that of N-SKR burst events. In addition, the peak flux density of S-SKR bursts was larger than that of N-SKR bursts by 7 dB. The analysis period is correspond to the southern summer of Saturn. We suggest that the asymmetry of SKR bursts results from the asymmetry of the ionospheric conductivity. To verify this scenario, similar analyses around the equinox is necessary.
- SKR burst onsets were dependent on both N- and S-SKR periodic modulations. This feature is a difference from SKR periodic modulations. On the other hand, there were also SKR bursts independent of both SKR modulations. These result suggests the coexistence of the internal and external trigger for reconnections. It is necessary to compare with the solar wind conditions to clarify which component is dominant.

The link between reconnections and SKR bursts is also verified in further studies.