A tool to diagnose magnetosphere under northward IMF conditions: Simultaneous detections of TPA and omega-band aurora

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Abstract

In this study, we try to explore the feasibility on whether or not the magnetospheric processes under northward Interplanetary Magnetic Field (IMF) conditions can be diagnosed using two different auroral phenomena; transpolar arc (TPA) and omega-band aurora. Both TPA and omega-band aurora can occur during the northward IMF intervals, and their appearances are closely related with the nightside magnetospheric processes. TPA can be formed and grown by the field-aligned currents induced by the plasma flow shear or the plasma vortex structures between the fast plasma flows generated by magnetotail magnetic reconnection and slower background magnetospheric flows, and the convection of the reconnection-formed closed magnetic fluxes, which cause in the nightside plasma sheet. On the other hand, the omega-band aurora can be attributed to the Kelvin-Helmholtz instabilities triggered by the flow shear between the plasma flows of the nightside magnetospheric boundary layer such as low-latitude boundary layer (LLBL) and background magnetospheric (plasma sheet) flows. If both auroral phenomena can simultaneously be observed, we might remotely investigate (diagnose) how the plasma and its energy are transported in the nightside magnetosphere and at the magnetospheric boundary region under northward IMF conditions. We will discuss the feasibility of this magnetospheric diagnosis, giving the observational example(s) of simultaneous observations of two different auroral phenomena, that is, TPA and omega-band aurora, and in-situ magnetospheric observation(s). Keyword: 1. Transpolar arc and omega band aurora 2. Solar wind-magnetotail-ionosphere coupling 3. Magnetospheric diagnosis 4. Magnetospheric dynamics under northward IMF conditions

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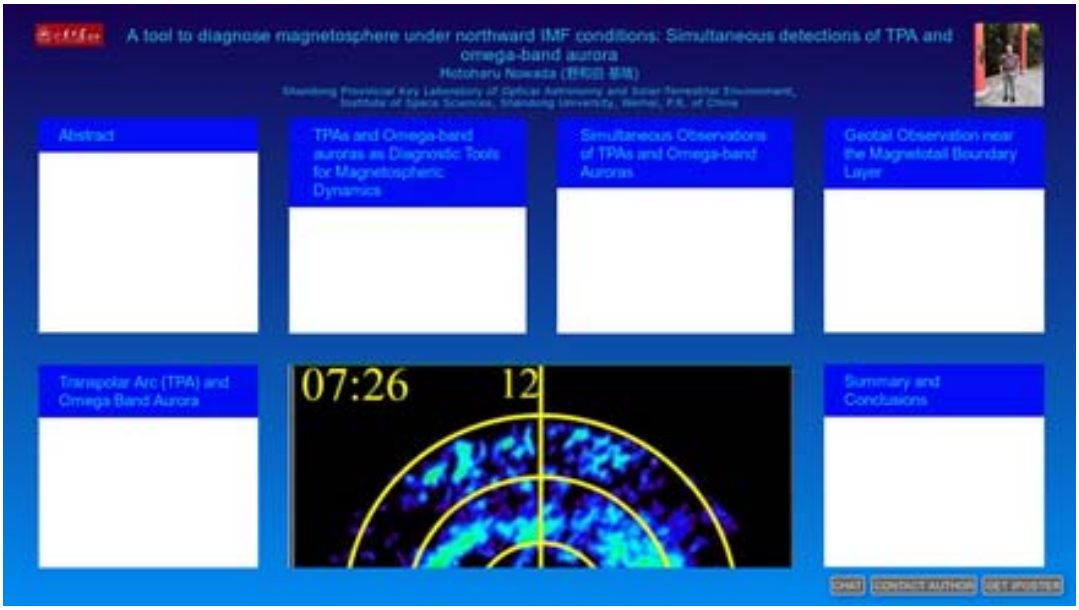

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ABSTRACT

In this study, we try to explore the feasibility on whether or not the magnetospheric processes under northward Interplanetary Magnetic Field (IMF) conditions can be diagnosed using two different auroral phenomena; transpolar arc (TPA) and omega-band aurora. Both TPA and omega-band aurora can occur during the northward IMF intervals, and their appearances are closely related with the nightside magnetospheric processes. TPA can be formed and grown by the field-aligned currents induced by the plasma flow shear or the plasm vortex structures between the fast plasma flows generated by magnetotail magnetic reconnection and slower background magnetospheric flows, and the convection of the reconnection-formed closed magnetic fluxes, which cause in the nightside plasma sheet. On the other hand, the omega-band aurora can be attributed to the Kelvin-Helmholtz instabilities triggered by the flow shear between the plasma flows of the nightside magnetospheric boundary layer such as low-latitude boundary layer (LLBL) and background magnetospheric (plasma sheet) flows. If both auroral phenomena can simultaneously be observed, we might remotely investigate (diagnose) how the plasma and its energy are transported in the nightside magnetosphere and at the magnetospheric boundary region under northward IMF conditions. We will discuss the feasibility of this magnetospheric diagnosis, giving the observational example(s) of simultaneous observations of two different auroral phenomena, that is, TPA and omega-band aurora, and in-situ magnetospheric observation(s).

TPAS AND OMEGA-BAND AURORAS AS DIAGNOSTIC TOOLS FOR MAGNETOSPHERIC DYNAMICS

TPAs and Omega band auroras can be used as "diagnostic tool" for dynamics of magnetosphere under northward IMF conditions.

To effectively diagnose the whole magnetosphere during the northward IMF interval, simultaneous obervations of ionosphere (e.g., ionospheric plasma flow patterns and auroral imaging) by low-latitude orbiters and radars/magnetic observatory arrays and magnetosphere (magnetotail) based on fleets of satellites are required.

For example…

TPA case:

Please see the iPoster presentation PEM13-20.

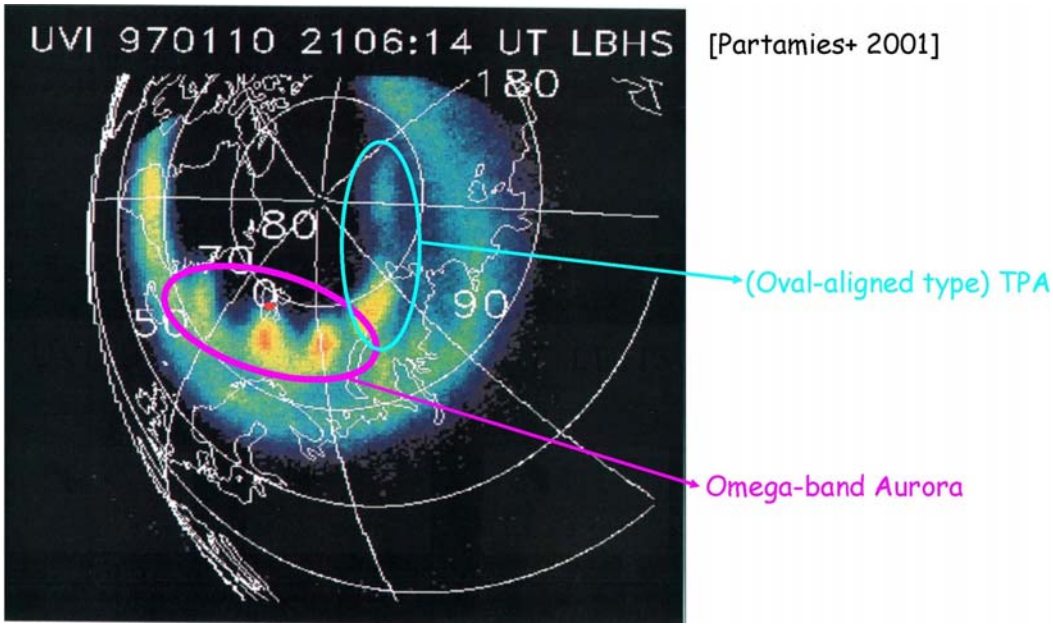
Omega-band Aurora case:

Partamies+ 2017

Both observations: ??

SIMULTANEOUS OBSERVATIONS OF TPAS AND OMEGA-BAND AURORAS

Partamies+ 2001 showed an example of simultaneous observations of TPAs along the dawnside main auroral oval (oval-aligned type TPA) and Omega-band auroras.

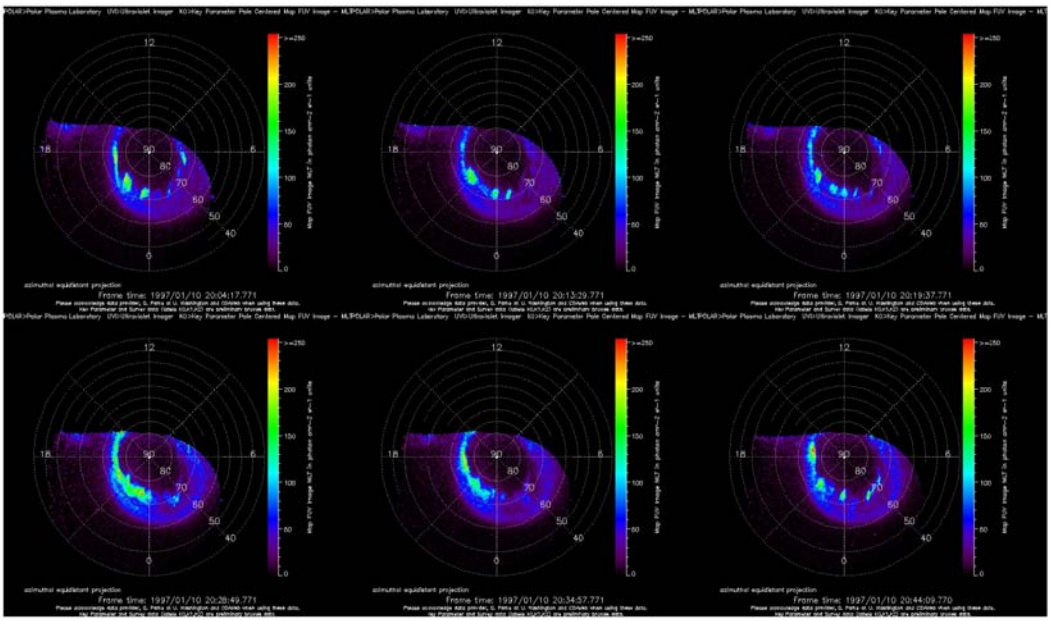


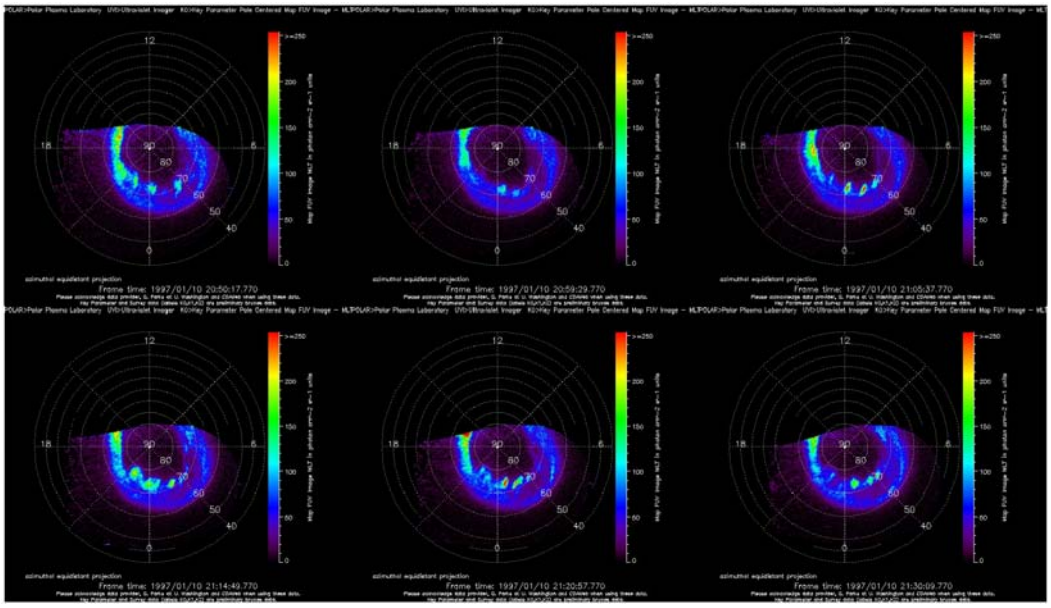
The temporal variations of the TPA and Omega-band aurora can be seen by a following movie.

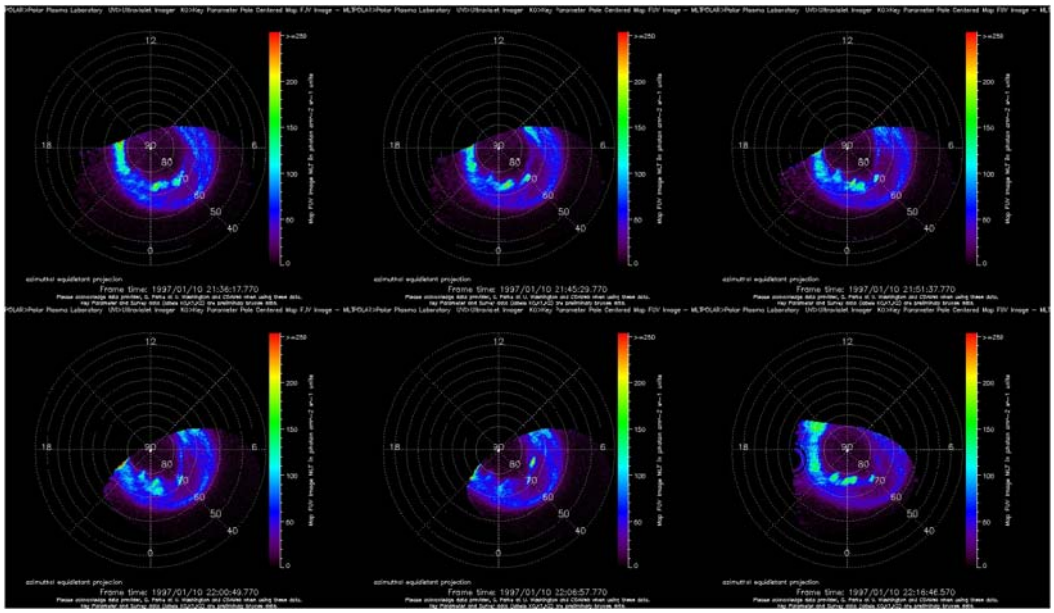
[VIDEO] https://player.vimeo.com/video/432412622?app_id=122963

This case was detected by ultraviolet (UVI) instrumental onboard Polar on January 10th 1997.

The detailed snapshots are shown as follows.







- Before 20:59 UT, Omega-band auroras can dominantly be found at the poleward of the main auroral oval, and their wavy (curved) forms evolved eastward. TPA started to grow from the poleward edge of the postmidnight main auroral oval, and aligned to the dawnside main auroral oval after 20:59 UT.

- This reslt suggests that siginificant plasma flow shears caused not only around the magnetospheric boundary layer but also in the magnetotail plasma sheet and/or plasma sheet boundary layer.

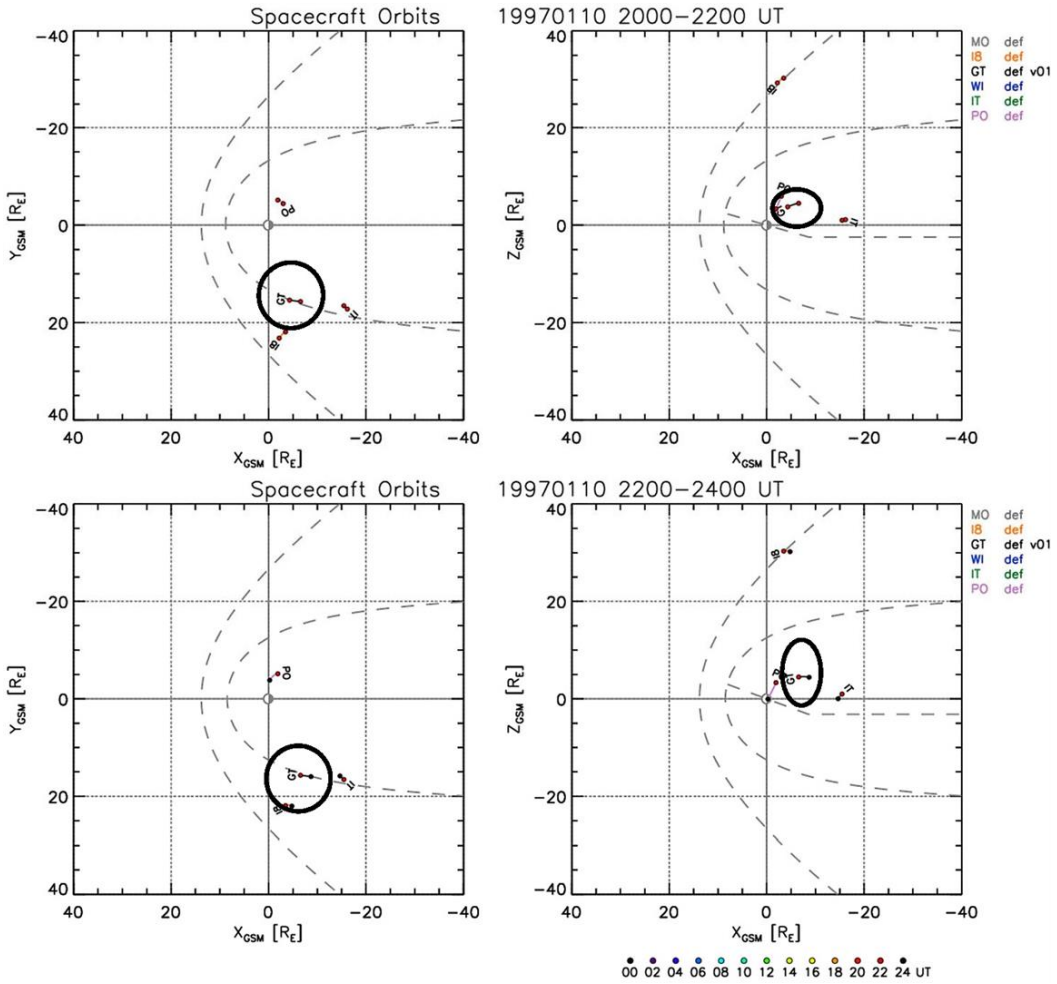
- In case of the TPA occurrence, magnetotail magnetic reconnection might occur. This is because the plasma flow shear during the TPA interval can be driven between the fast plasma flows due to nightside reconnection and background slower plasma sheet flows (see the detail in the paper of PEM13-20).

- Although we had no *in-situ* magnetotail plasma sheet/plasma sheet boundary layer observations during the TPA interval, the plasma flow patterns obtained from the SuperDARN radar arrays and geomagnetic field variations from the ground magnetic observatory networks can be elucidated 1) whether or not magnetotail reconnection occurred, and 2) TPA (Omega-band)-associated plasma flows and geomagnetic field variations (future works).

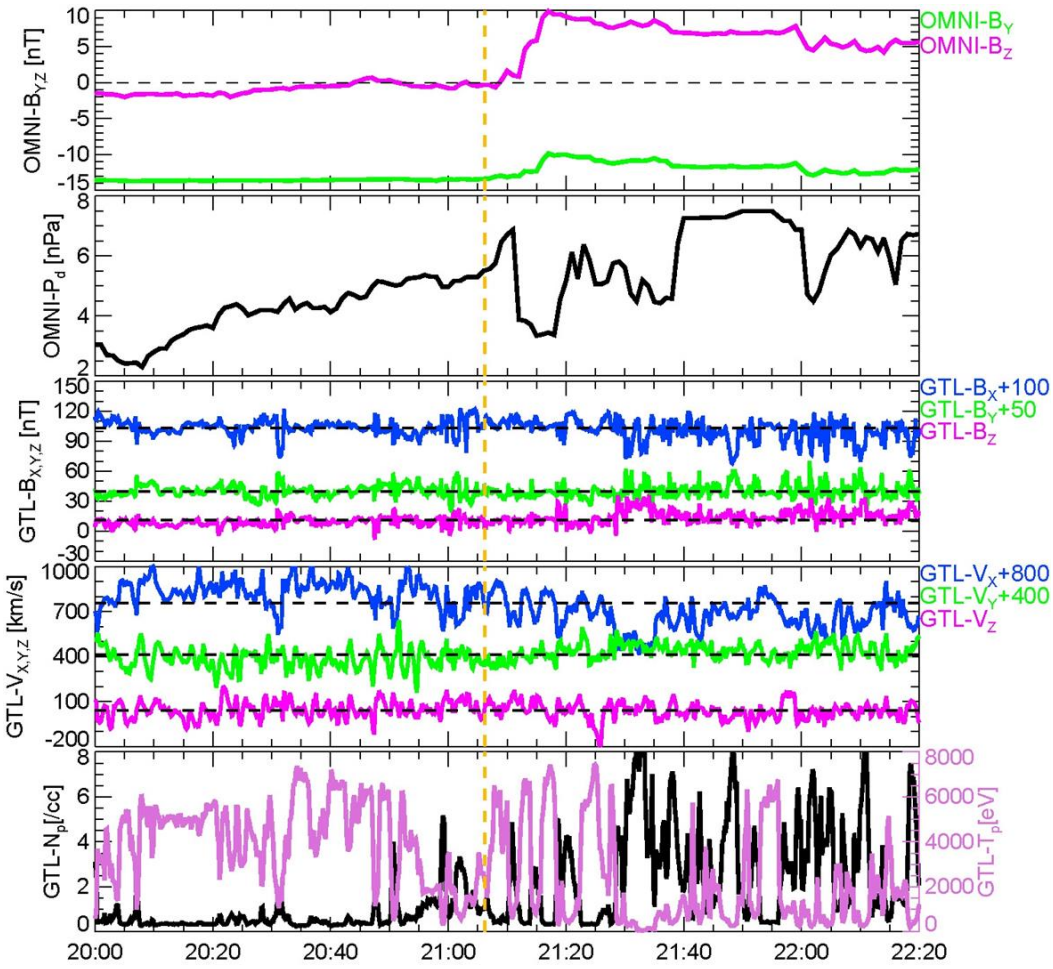
GEOTAIL OBSERVATION NEAR THE MAGNETOTAIL BOUNDARY LAYER

Geotail observed the magnetotail boundary layer in the duskside when the Omega-band aurora was seen.

The Geotail orbit and locations between 20:00 UT and 24:00 UT are highlighted with black ovals.



The summary plots of the IMF, solar wind dynamic pressure, the Geotail magnetic and plasma data are shown as follows.



From top to bottom panels; The IMF-By (green) and -Bz (violet) obtained from the OMNI database, solar wind dynamic pressure, three components of the magnetic field and plasma velocity in GSM measured by Geotail, and ion number density/temparature from the Geotail observations are displayed, respectively. The present time interval is 1 hour 20 minutes from 20:00 UT to 22:20 UT, including the time intervals when the TPA and Omega-band aurora were simultaneously observed. A gold vertical broken line indicates on 21:06 UT.

I. Before 21:08 UT, the IMF-Bz intensity was weak, and its polarity was chageable between negative and positive.

II. The Bz intenstity abruptly increased after 21:08 UT, and nothward component became dominant.

III. Comparing the IMF-Bz polarity with the TPA/Omega-band auroral acitivty, TPA appeared after 21:30 UT, and persisted until ~22:10 UT. The TPA was found in the dawn sector in the polar cap, which is consistent with the relationship between the TPA location and the IMF-By polarity. The omega-band aurora activity, that is, eastward evolutions associated with the wavy motions, also were clearly found after 20:59 UT.

IV. This result suggests that the appearance and activity of these auroras well-reflect the magnetospheric dynamics under the northward IMF condtions, if the time lag between the OMNI-IMF data and the signatures seen in the ionosphere is 20 - 30 minutes.

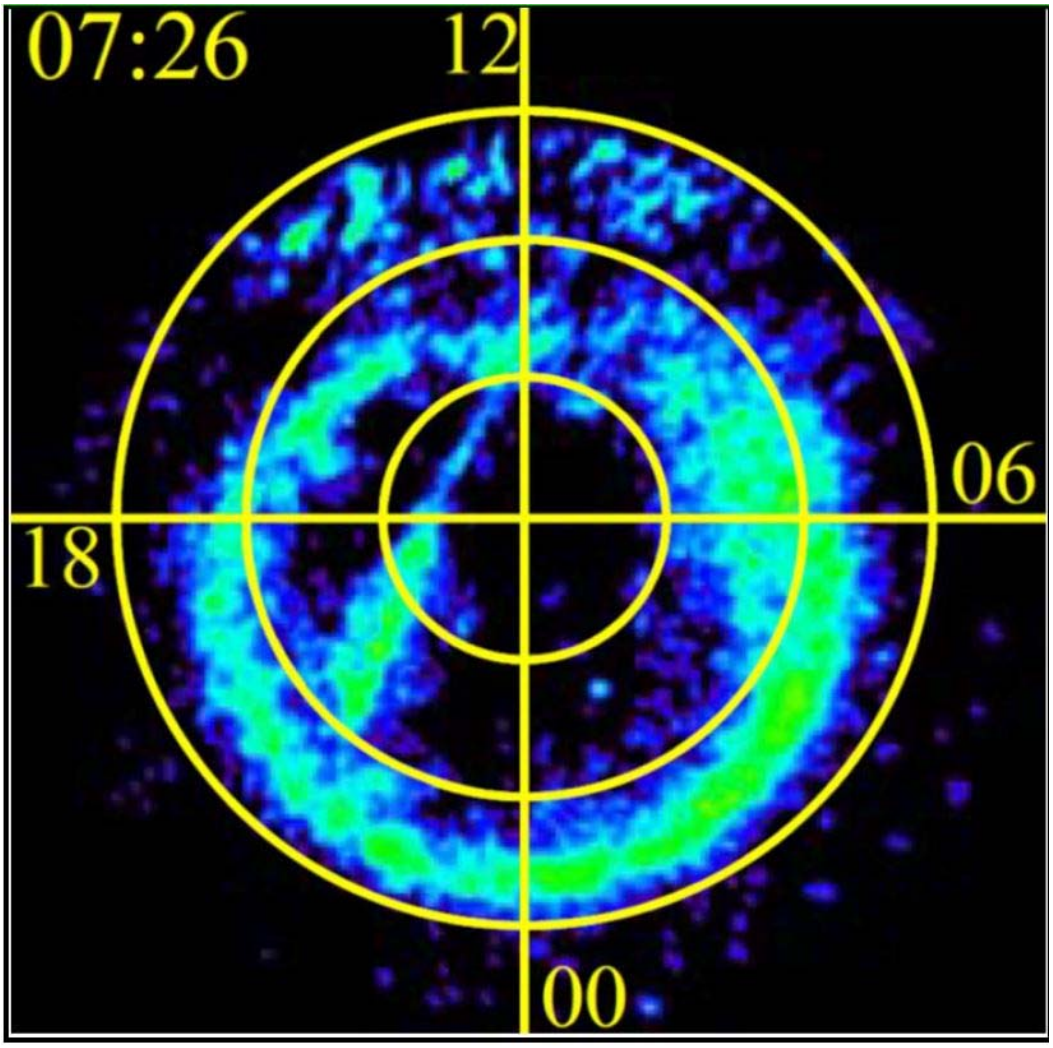
V. During this time interval, the magnetic field and plasma had wavy structures. In particular, after 20:43 UT, when the IMF-Bz component became northward, the plasma density and temperature had higher fluctuations. If these fluctuations were driven by the flow shear at the magnetospheric boundary layer, the omega-band aurora might be triggered by these fluctuations.

TRANSPOLAR ARC (TPA) AND OMEGA BAND AURORA

Sometimes, when the IMF-Bz is northward, Transpolar arcs (TPA) and Omega-band aurora are simultaneously observed.

I. What is Transpolar Arcs (TPAs) ?

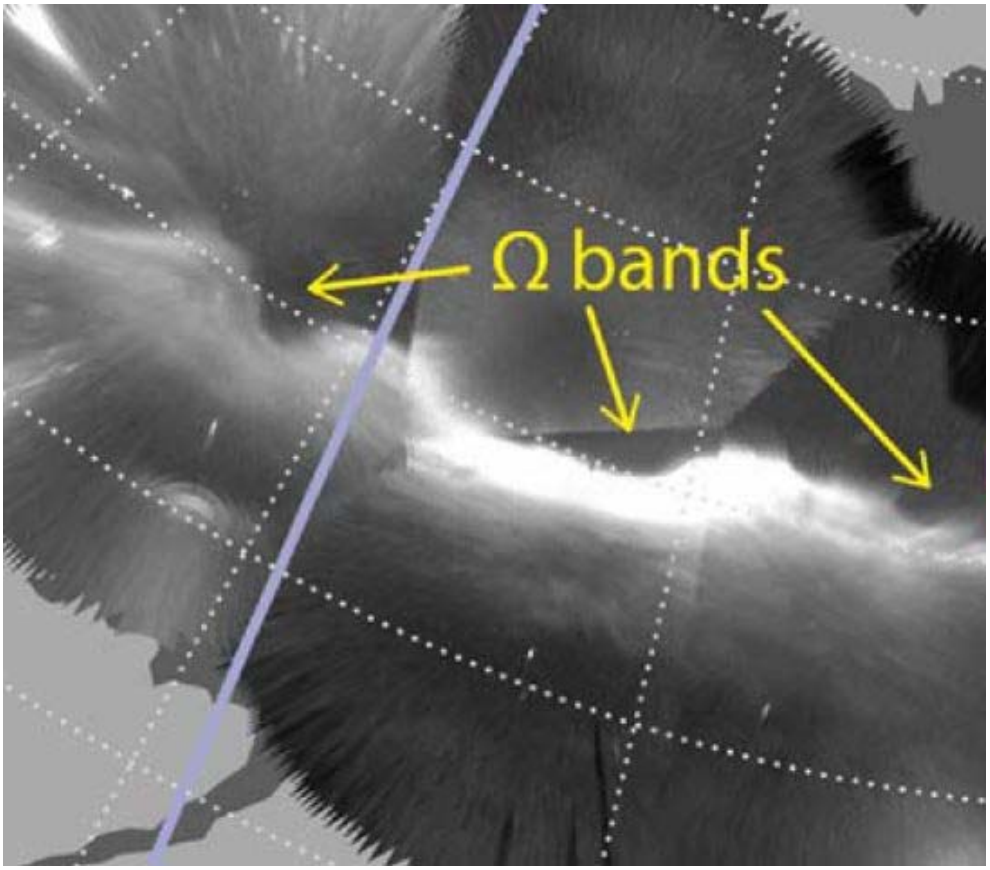
- Transpolar Arcs can be identified as the “cross bar” type emissive part of aurora whose shape is a letter of "theta" (so-called "theta aurora) within the polar cap. TPA is extended from the poleward edges of the nightside auroral oval toward the dayside region.



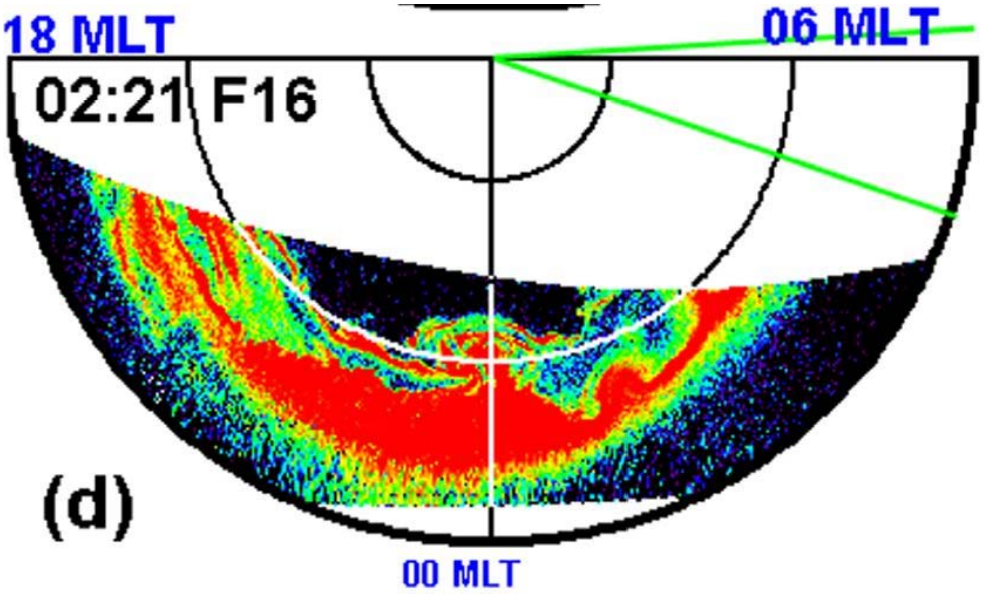
II. What is Omega Band Aurora ?

- Omega band aurora is curved (wavy) aurora forms that evolve from a quiet arc located along the poleward edge of a diffuse auroral band within the midnight to morningside auroral oval.

[Ground-based Observation]



[Satellite Observation]



The Common Characteristics

1. Two auroral phenomena (TPA and Omega-band aurora) are expected to occur under the northward IMF conditions.

2. Their formation mechanisms are directly reflected to dynamics in magneototail and magnetospheric boundary layer.

- TPA formation is closely related with magneototail reconnection and magnetospheric convection

- Omega band aurora formation is closely related with Kelvin-Helmholtz instability driven by a shear between the plasma sheet slow flows and the magnetospheric boundary flows (e.g., magnetopause and Low-Latitude Boundary Layer).

SUMMARY AND CONCLUSIONS

1. We found a case where the TPA and the Omega-band auroras simultaneously observed.

2. Based on the TPA and the Omega-band aurora appearance and activity, the magnetospheric process during the northward IMF intervals can be diagnosed.

3. TPAs and Omega-band auroras can be used as a diagnostic tool for the dynamics of the magnetosphere under the northward IMF conditions.

AUTHOR INFORMATION

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If you had any questions on this presentation, please E-mail to a corresponding author (Motoharu Nowada).

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Slack (Please write down freely your message, questions, comments, suggestions, and so on, if you missed my chat time):

https://app.slack.com/client/T017B3BQZ6V/C016HMZ68G7/user_profile/U016RNAG094 (https://app.slack.com/client/T017B3BQZ6V/C016HMZ68G7/user_profile/U016RNAG094)

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