Auroral Substorms and Ionospheric Outflow

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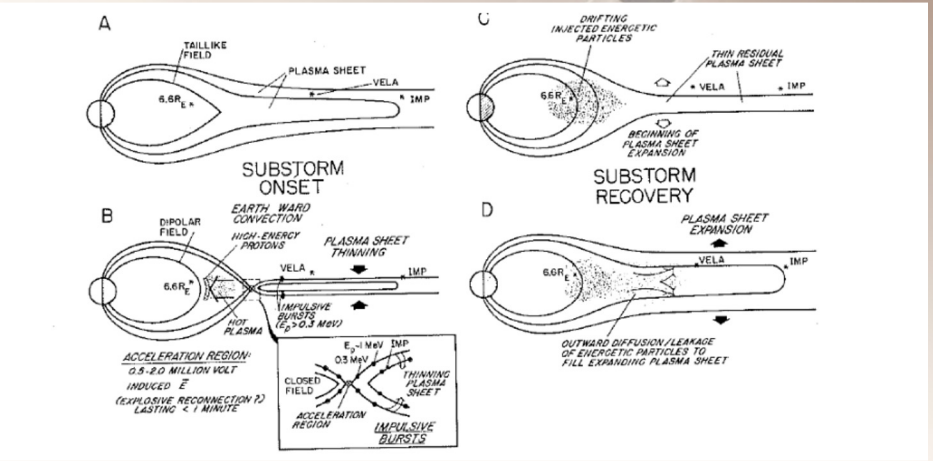
Introduction

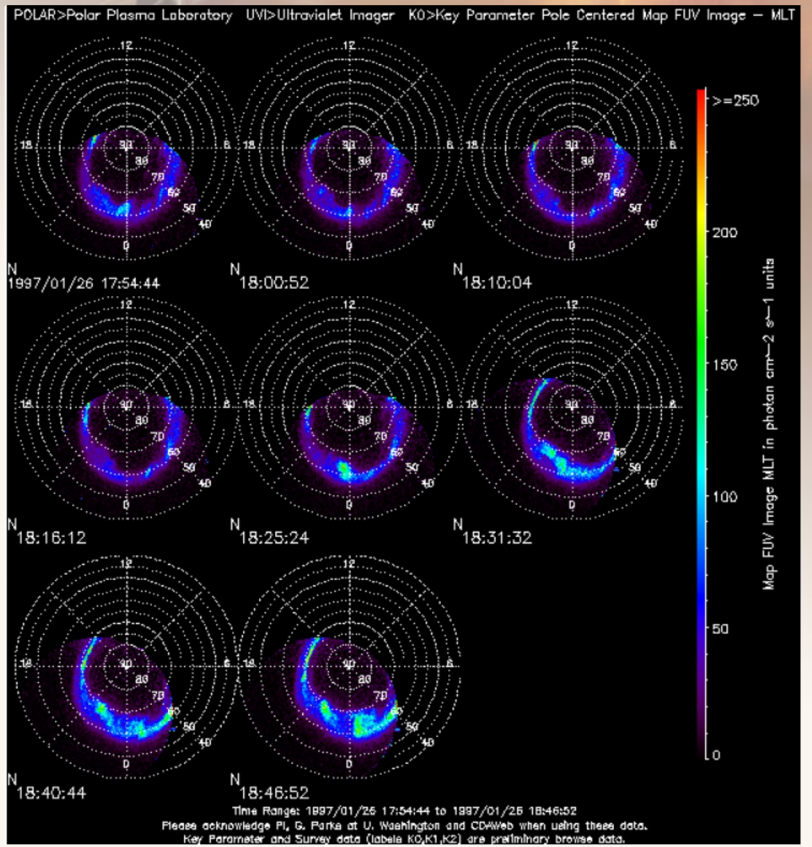
Question: How does ionospheric outflow change during auroral substorms?

- Auroral substorms: magnetic energy accumulated in the magnetotail is released through reconnection and driven into the ionosphere
- Energy drives ion outflow, so we expect it to increase during substorms
- Compare phases of the substorm and methods of substorm identification



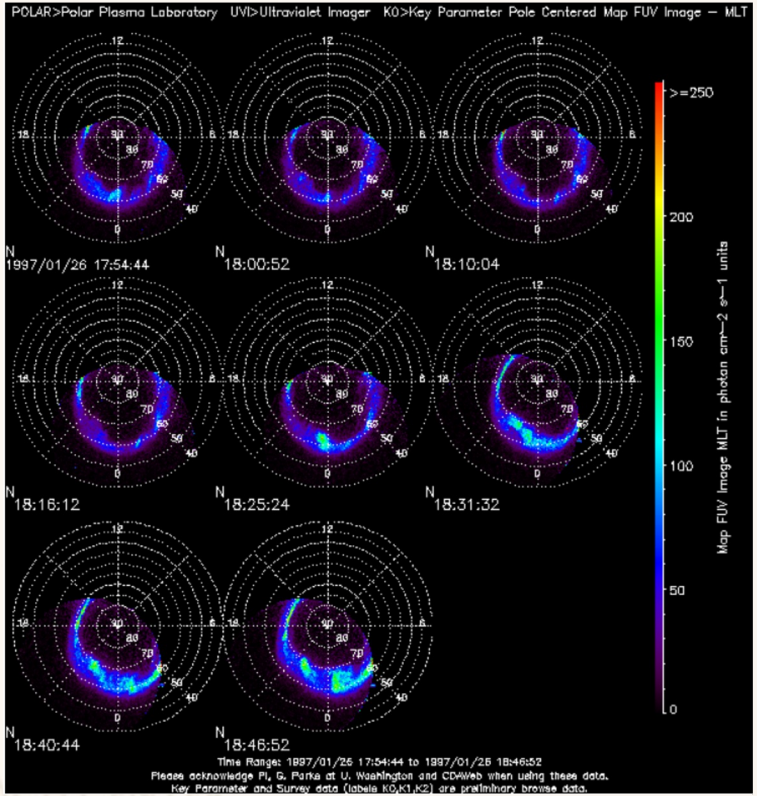
Identifying substorm onsets

- Identify the time of the initial auroral brightening using images
  - Wilson and Liou lists
- Look at the average changes in data from ground based magnetometers
  - SuperMAG lists: Forsyth, Ohtani, Newell
- Dispersionless particle injections at geosynchronous orbit
  - Not used in this study

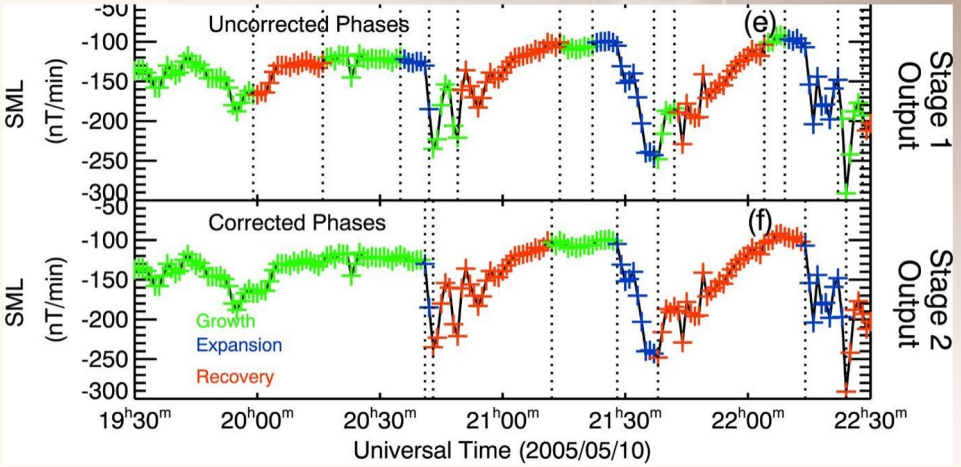


Polar UVI image of a substorm on 1997/01/26, with an onset at 18:18:00

Identifying substorm onsets



Polar UVI image of a substorm on 1997/01/26, with an onset at 18:18:00



Forsyth et al., (2015)

Methods

- Compile and compare lists of substorms that use both methods from 1996/12/01-1997/02/28
- Validate methods against Wilson et al. (2004)
- Perform a superposed epoch analysis on each list using TEAMS data from FAST Spacecraft
  - Lining up similar events at a key time, and taking the average
- Slowly expand time range

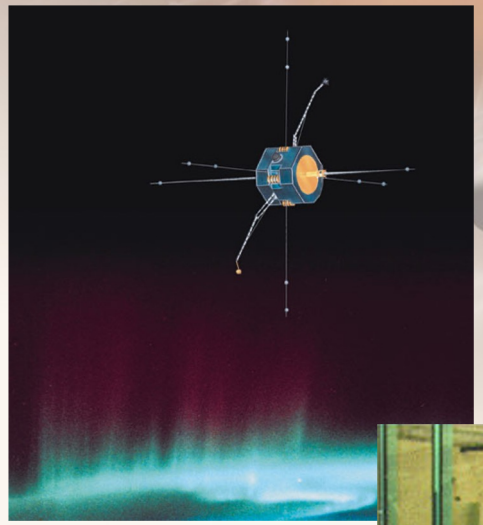


Illustration of FAST by NASA

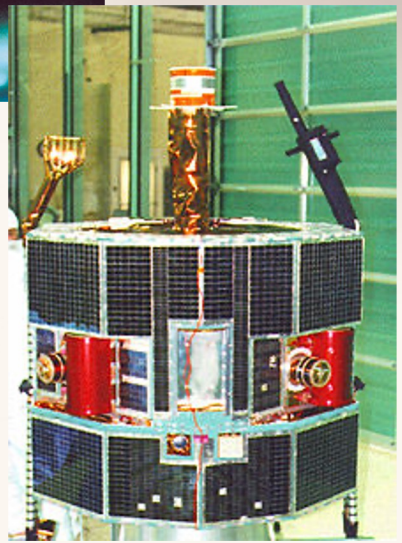
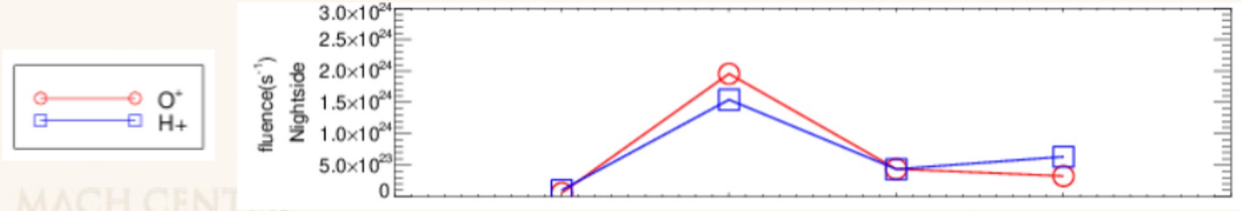


Image of FAST by NASA



Liou list -30 min 0 min +30 min +60 min

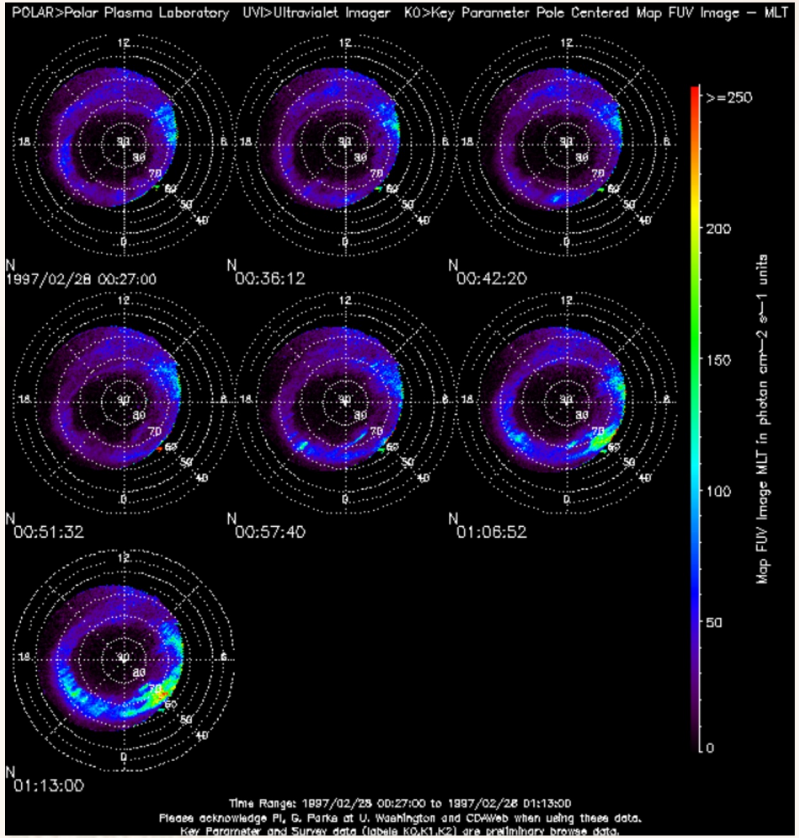
Results

- Compared Wilson substorm list to 4 other substorm lists in SuperMAG
  - Looked for matches within 5 minutes
    - Best match was 66% of onsets with Liou (2010), which is still poor since both lists used the same data
    - Best match with magnetometer data was only 20%
- Looked through Polar UVI images to discern which imager based list was more reliable
  - Did not find a pattern as to why some substorms were rejected from either list

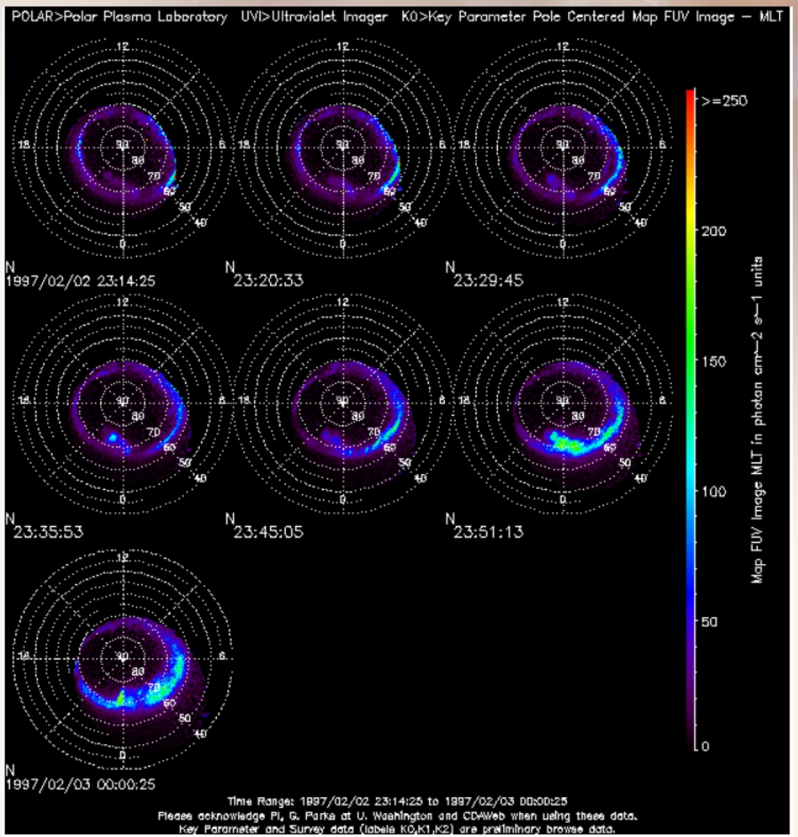
1	In order of best to worst matches to Gordon-Wilson Dataset (127 substorms using Polar UVI Images):		
2	Method:		
3	Polar UVI Images	Liou (2010)	84 matches
4	Ground Magnetometers	Forsyth et al. (2015)	25 matches
5	Ground Magnetometers	Ohtani and Gjerloev (2020)	17 matches
6	Ground Magnetometers	Newell and Gjerloev (2011)	17 matches
7			
8	Frey et al. (2004 and 2006) did not go back that far		

Results from Liou and SuperMAG list comparison

Comparing Polar UVI Images



Substorm on the Wilson list but not Liou



Substorm on the Liou list but not Wilson

Average ion outflow plots for Wilson small substorms

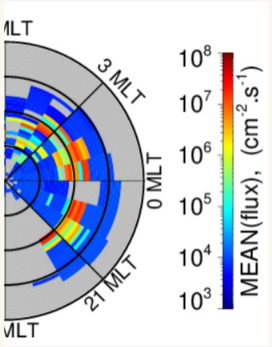
-30 min

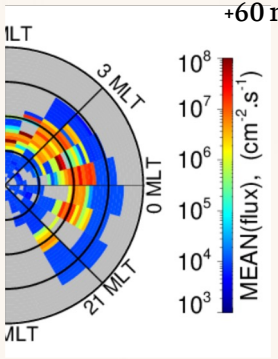
0 min

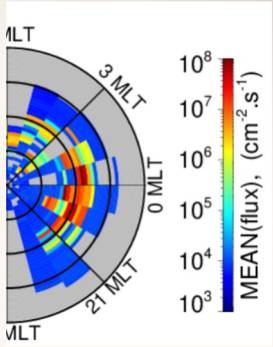
+30 min

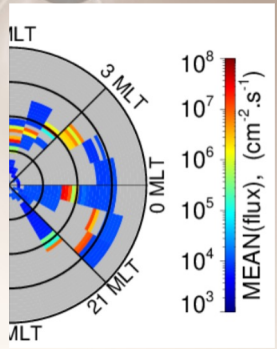
+60 min

H+

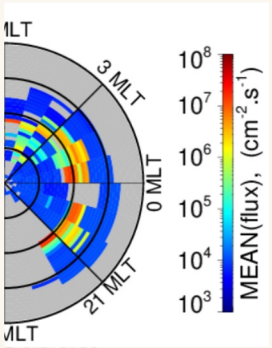


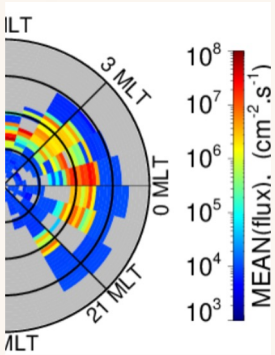


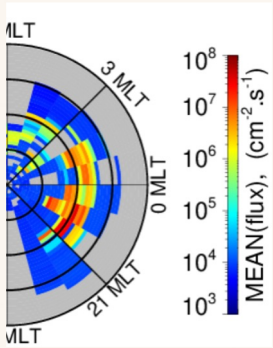


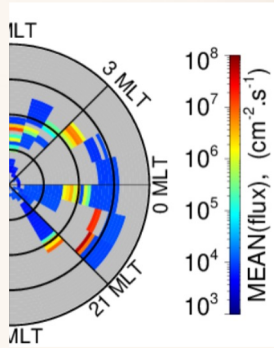


O+

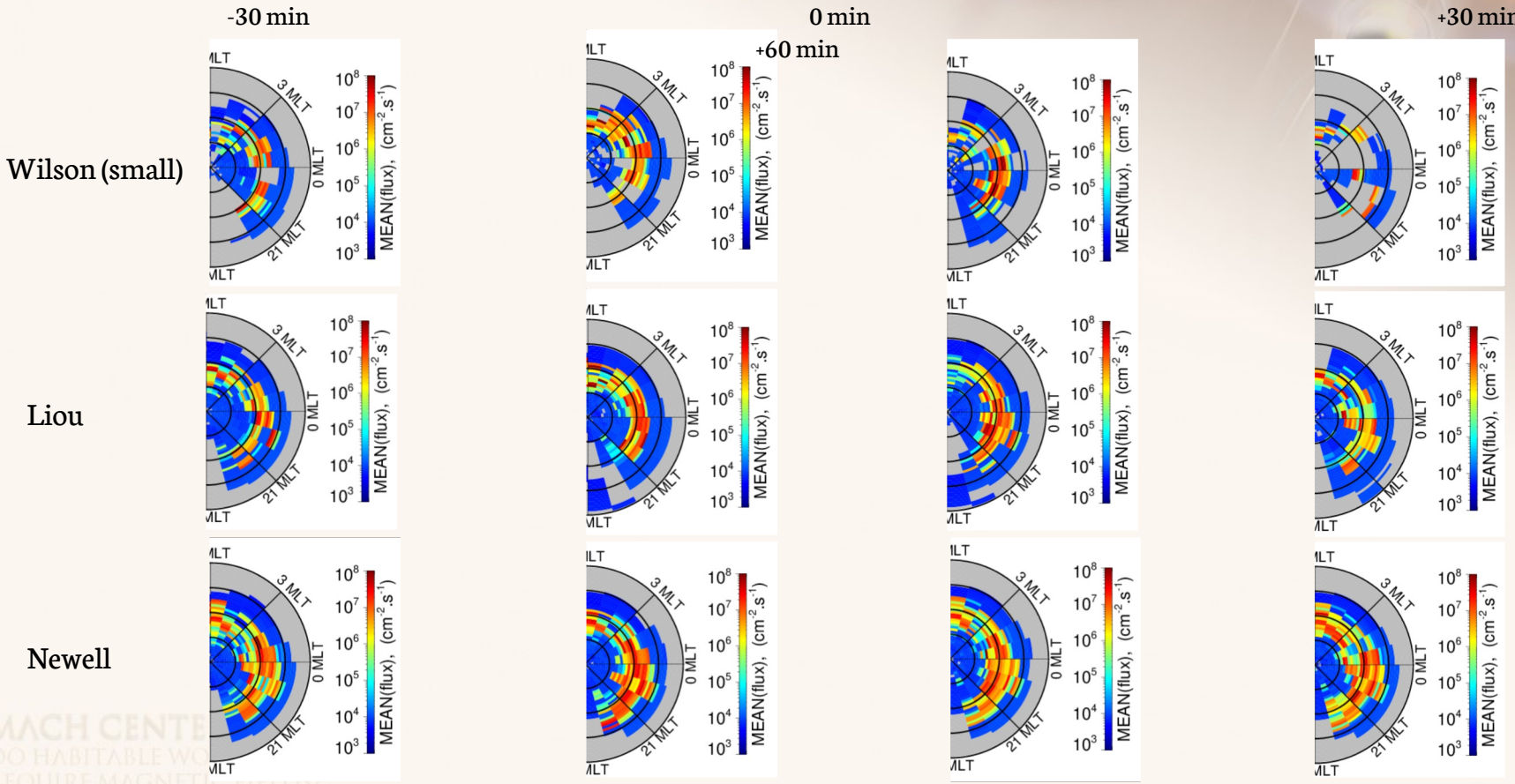








Average H+ Outflow from 1996/12/01-1997/02/28



Average O+ Outflow from 1996/12/01-1997/02/28

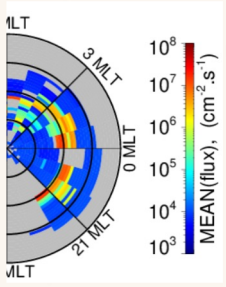
-30 min

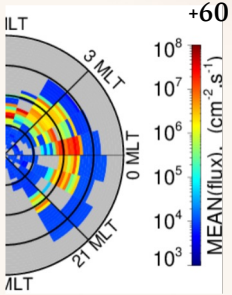
0 min

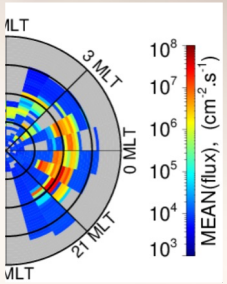
+30 min

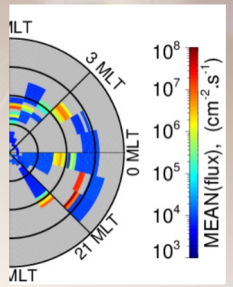
+60 min

Wilson (small)

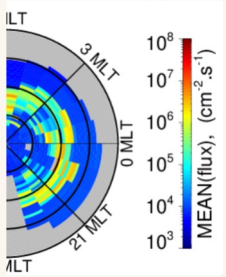


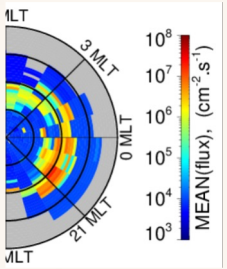


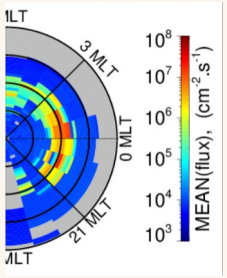


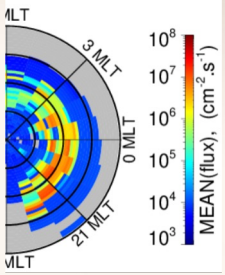


Ohtani

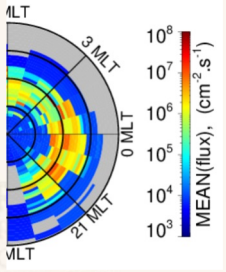


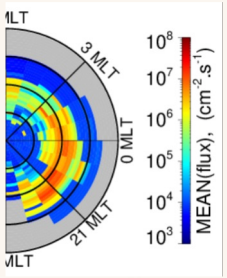


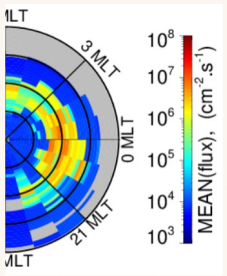


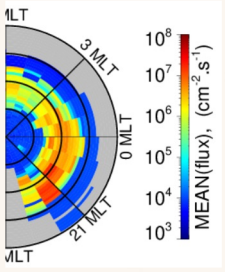


Forsyth



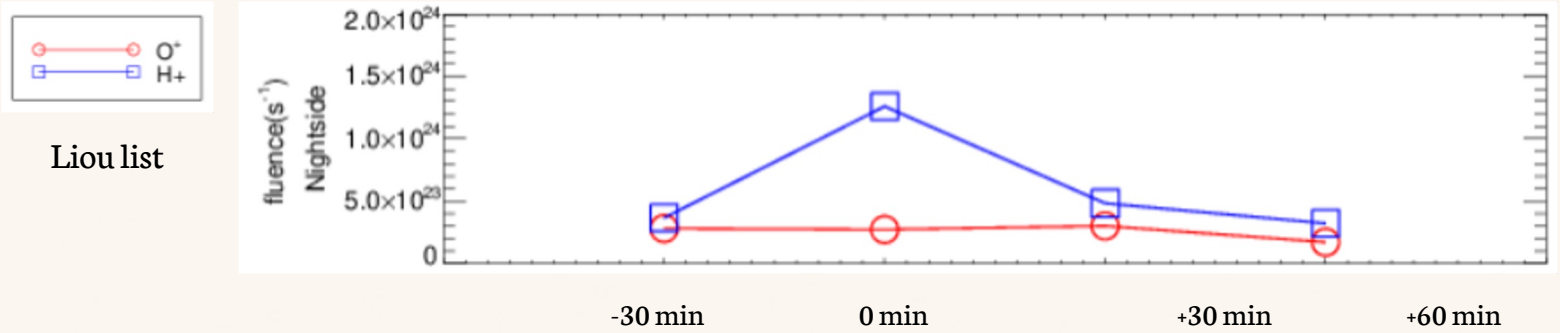






3 month conclusions

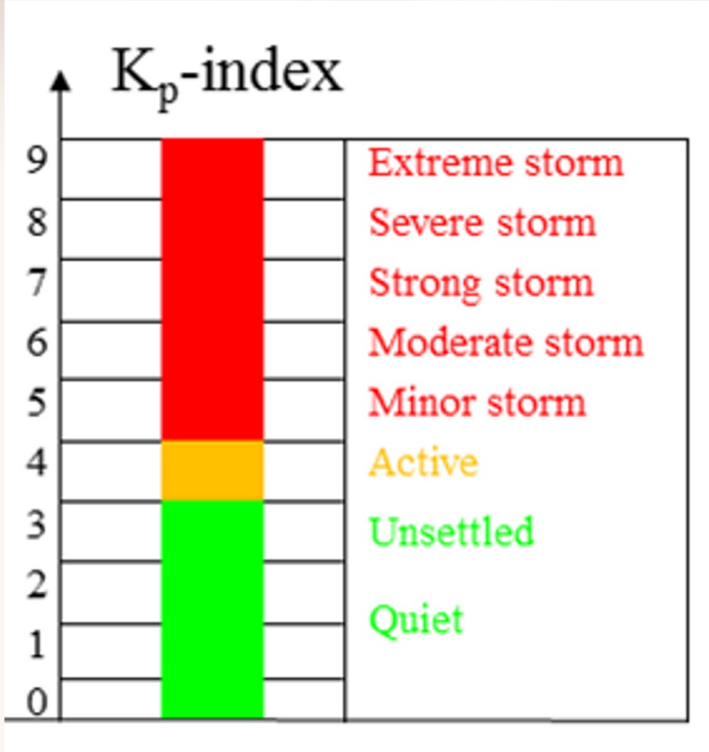
- Increased flux at onset
- Data is too sparse to calculate fluence for some lists



Liou list

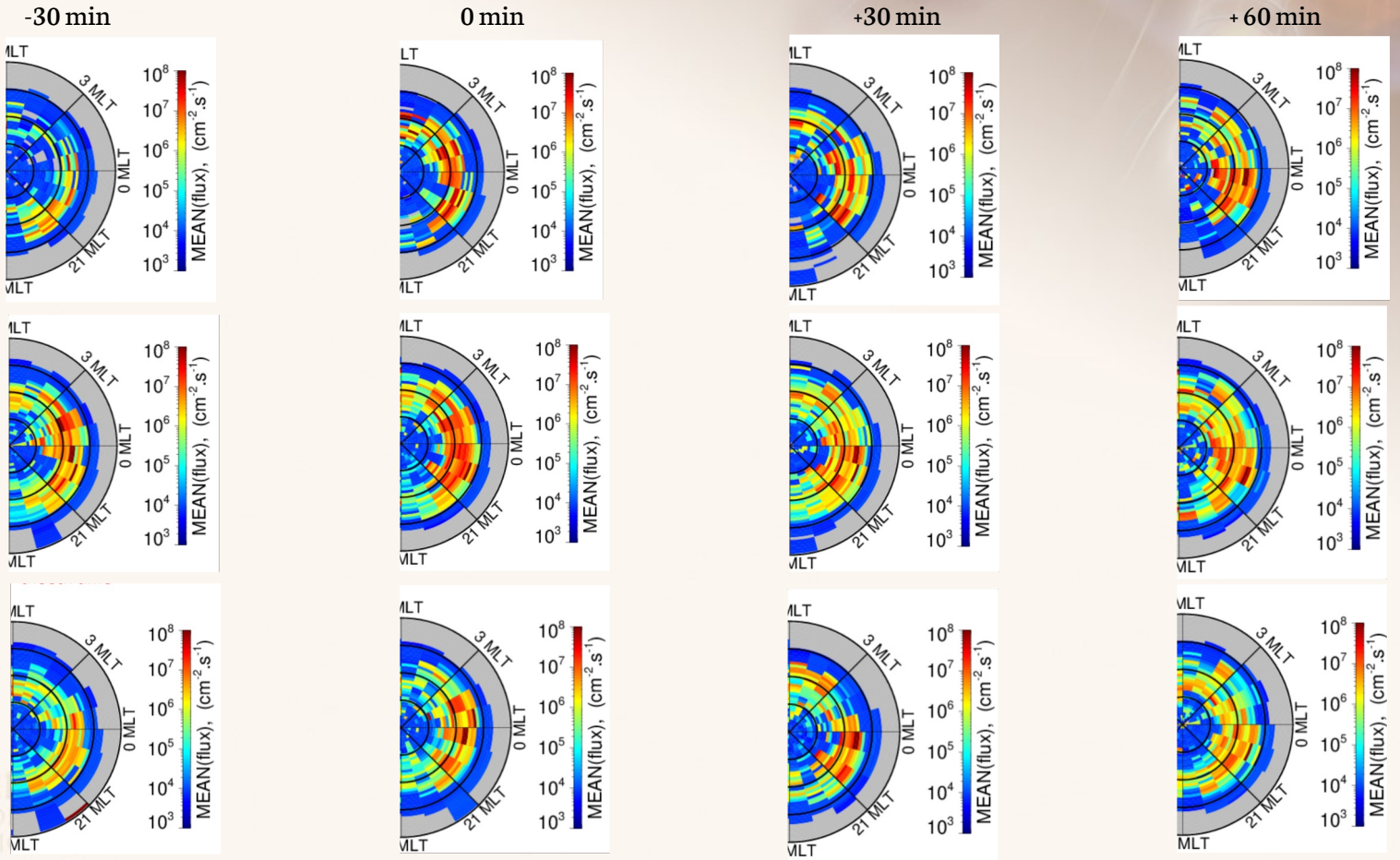
Expanding the time range

- 2 year time period
- Filter out storm time substorms using DST
- Divide into large and small substorms using Kp=2 as the cutoff

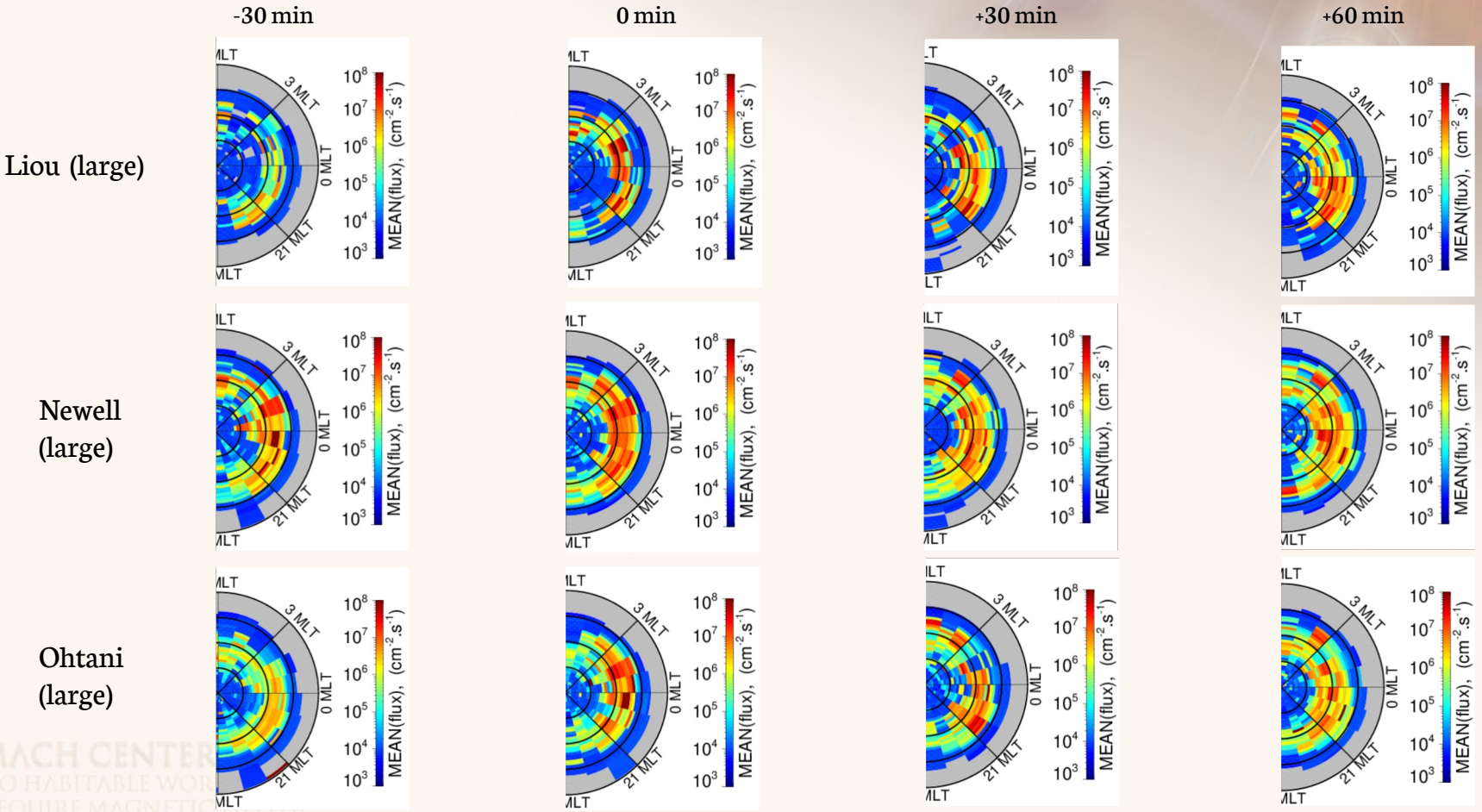


From stce.be

Average H+ Outflow from 1996/12/01-1998/11/30

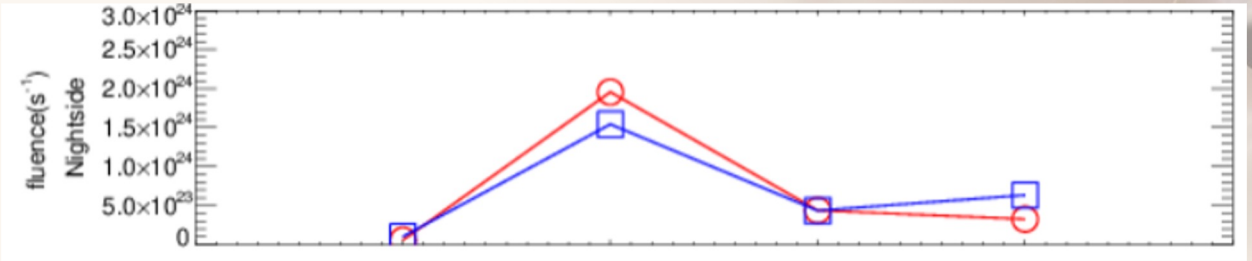


Average O+ Outflow from 1996/12/01-1998/11/30

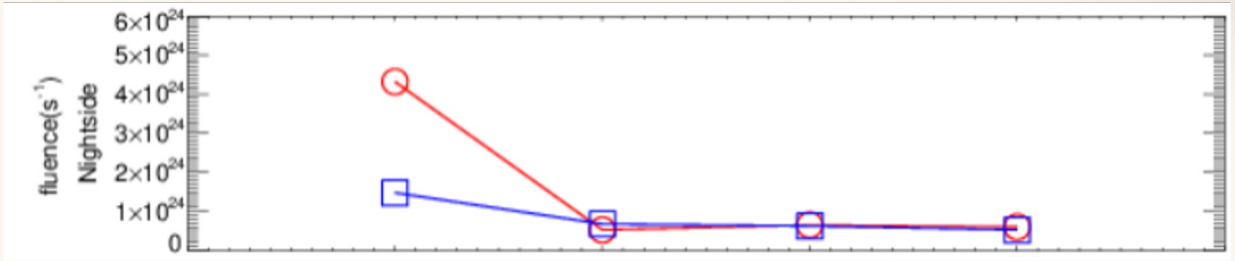


Preliminary Fluence Plots for 1996/12/01-1998/11/30

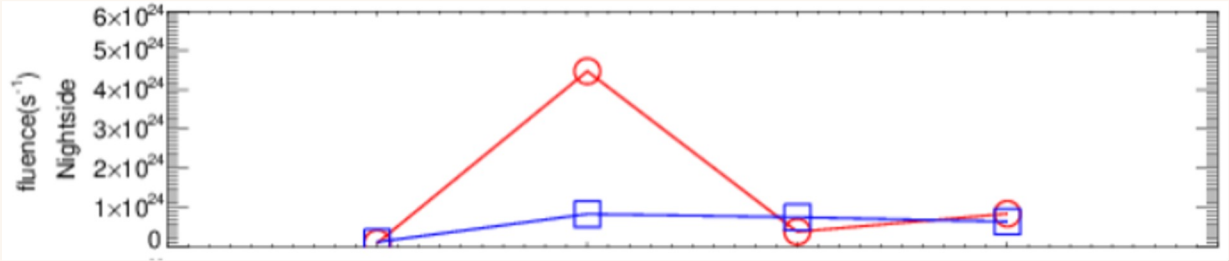
Liou (large)



Newell (large)



Ohtani (large)



-30 min 0 min +30 min +60 min

Future work

- Run superposed epoch analysis for non-storm time substorms for entire FAST mission
- Evaluate the role of solar cycle, season, and strength of solar wind-magnetosphere interactions in ion outflow during substorms

Summary

- Determining auroral onset is subjective, so different lists have different onsets for the same time period
  - Magnetometer methods do not agree with imaging methods
- Smaller timescales don't have enough data, so a longer time period is necessary for the analysis
- Ion outflow appears to increase sharply at substorm onset, isolated substorm lists show this trend better

Acknowledgments: Lynn Kistler, Niloufar Nowrouzi, Chris Mouikis, Eric Lund