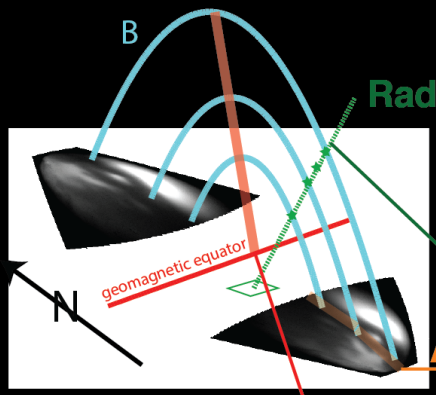
Characteristics and Onset Conditions of Spread *F* Inferred from a Long-Term Transequatorial HF Radio Experiment

Ethan S. Miller

11 May 2017

APL JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

A brief tour of Spread *F* effects

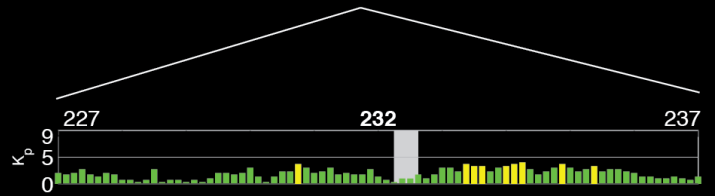


Radar Beam

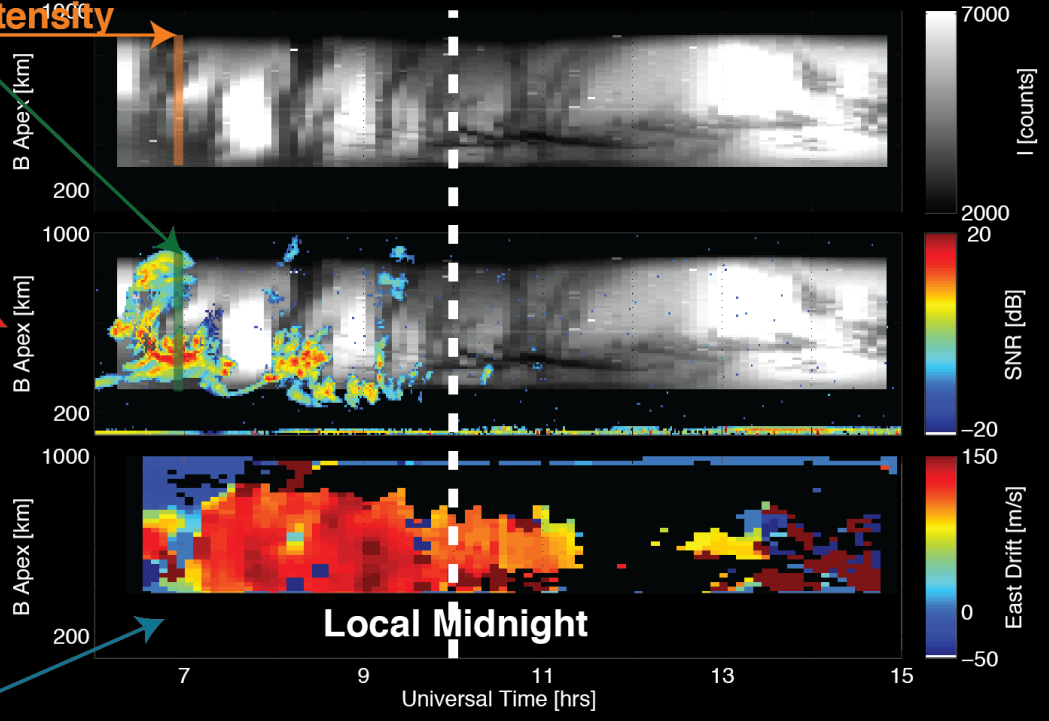
Site/Date

19 August
(232) 2004
CXI / CNFI

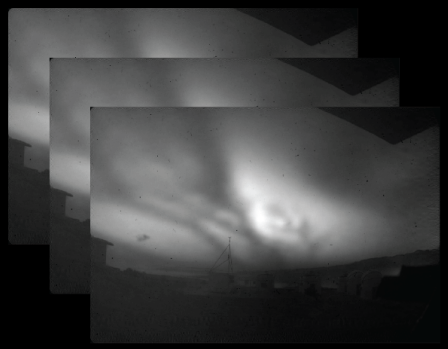
Geophysical Activity



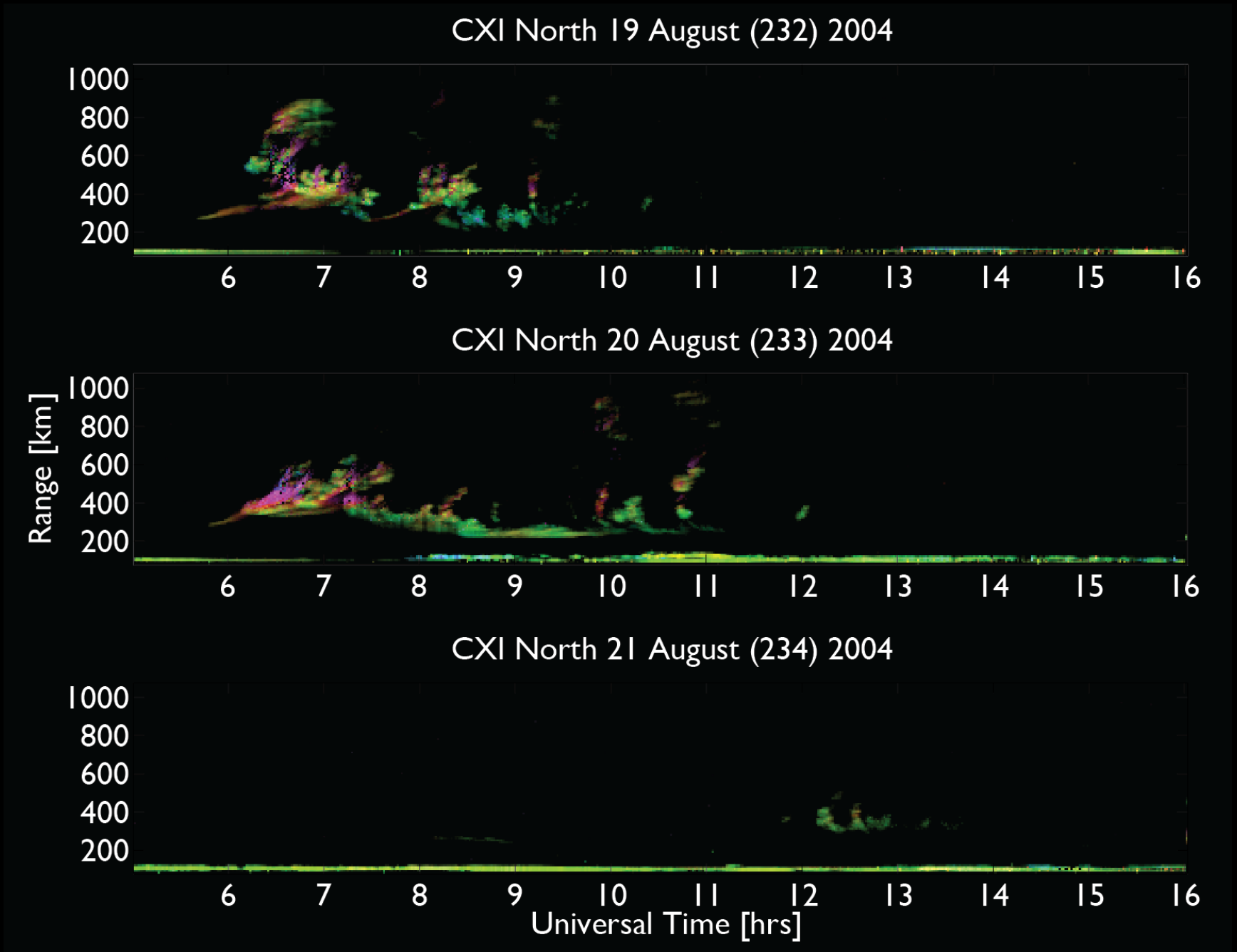
Airglow Intensity



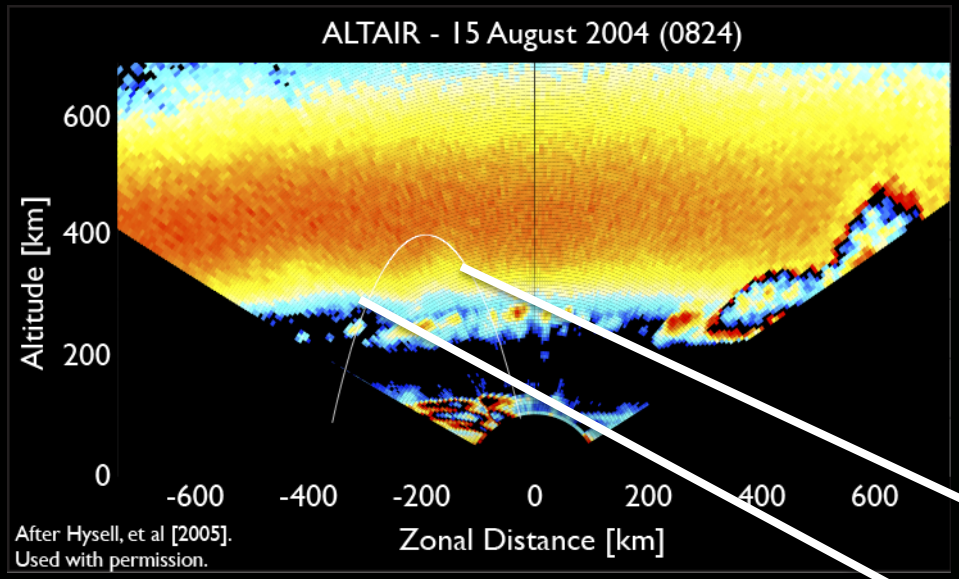
Field-Line Apex Altitudes

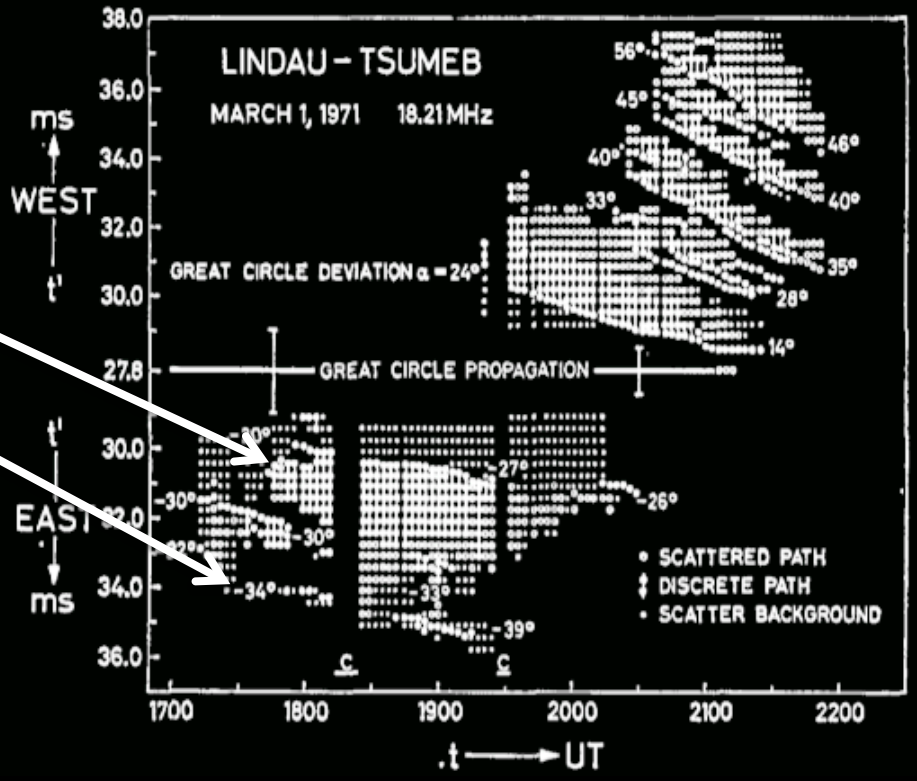


Frame-to-Frame Correlation
yields feature velocity.


CXI North 19 August (232) 2004
CXI North 20 August (233) 2004
CXI North 21 August (234) 2004
Range [km]
1000
800
600
400
200
6
7
8
9
10
11
12
13
14
15
16
Universal Time [hrs]

Zonal Structure Around Sunset

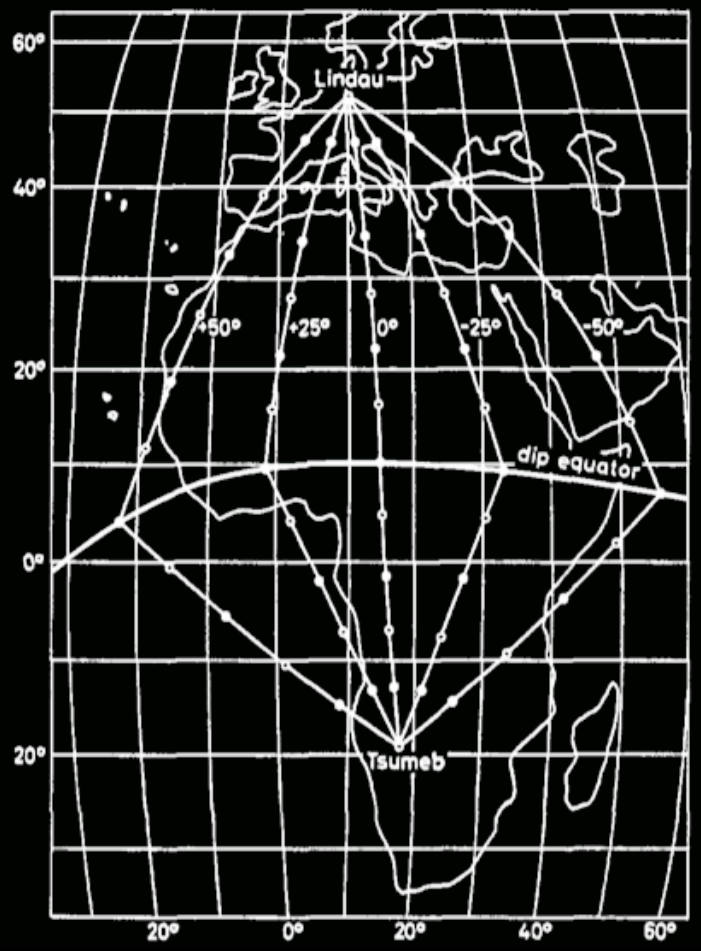


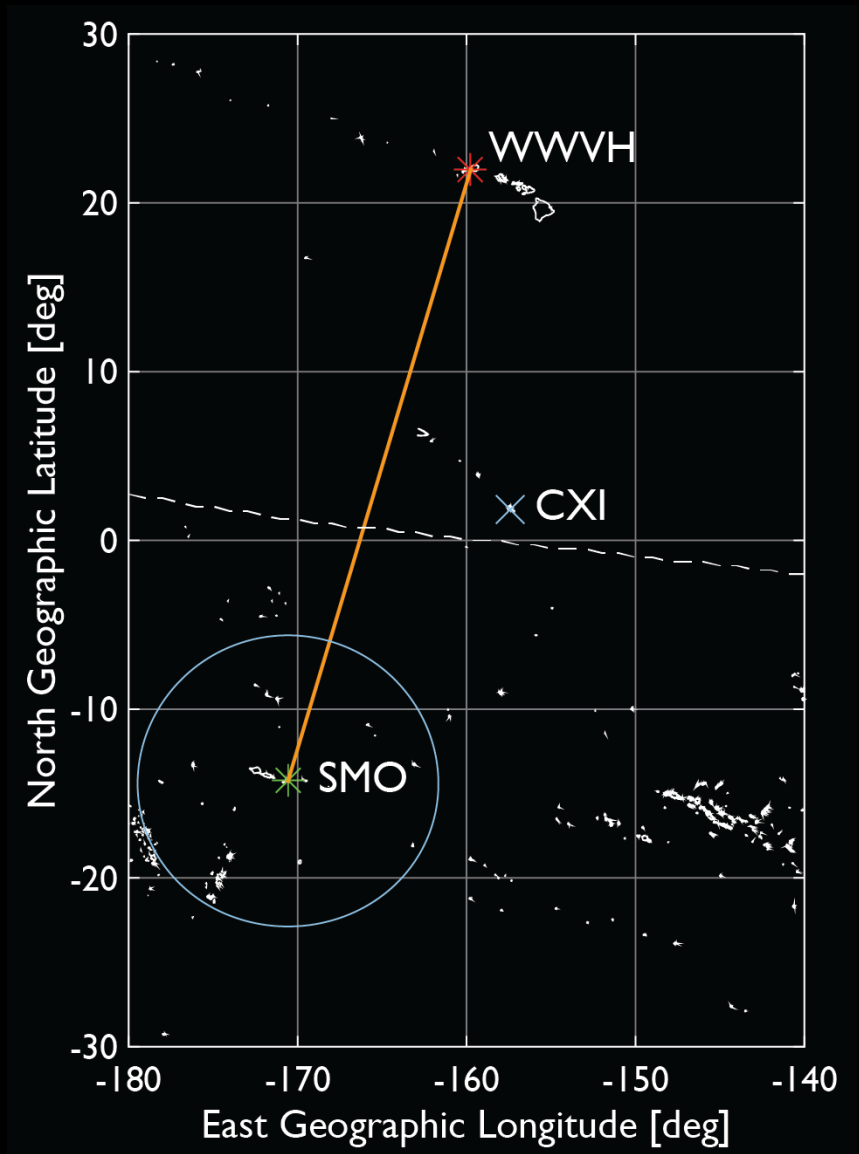


Röttger [1973] (right) showed corrugated structuring on a transequatorial path and theorized that atmospheric gravity waves might be responsible for ESF.

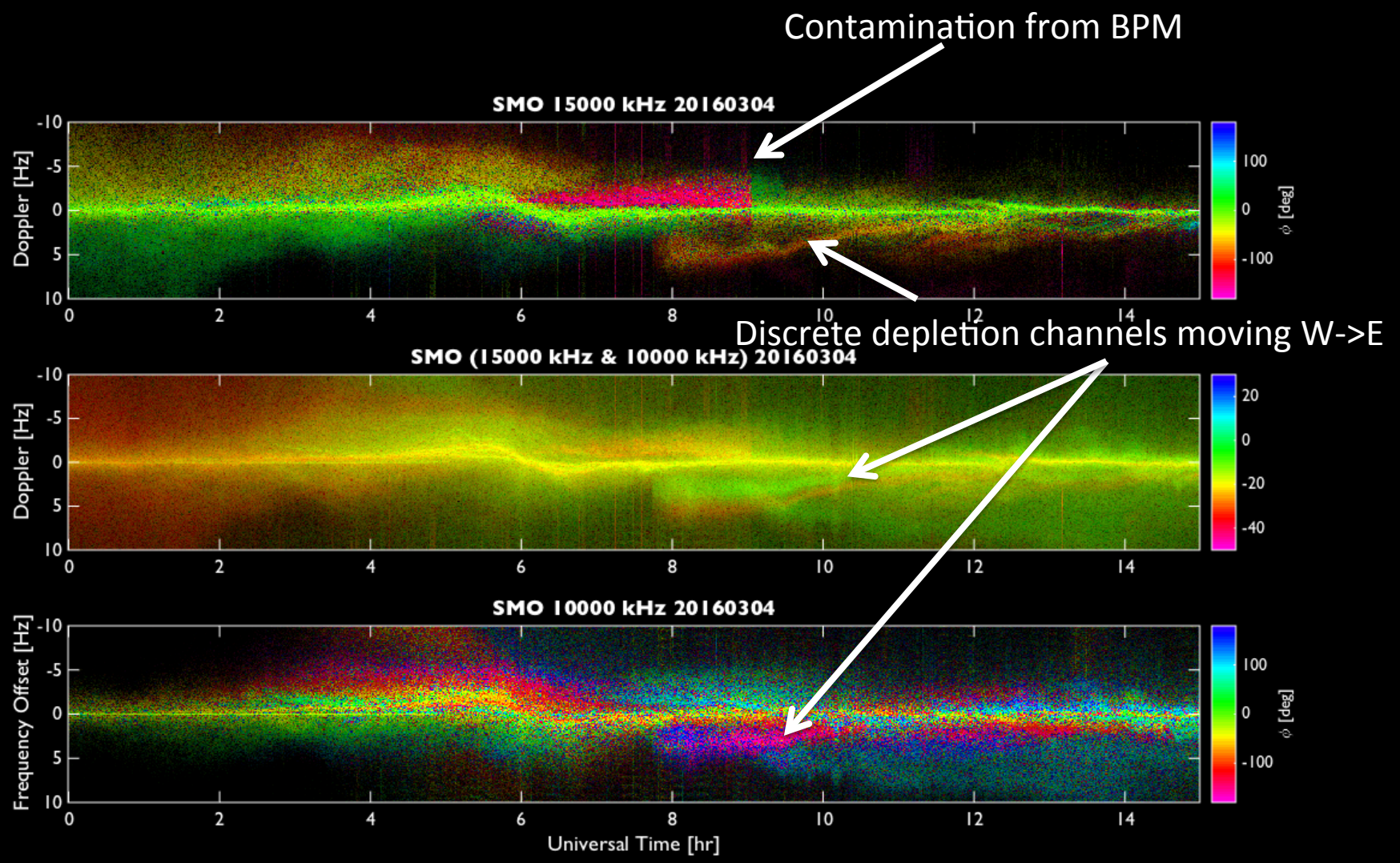
Tsunoda and White [1981] recognized standing wave structures in ALTAIR ISR scans (above, after *Hysell*, et al [2005]).

Modern Röttger Experiment



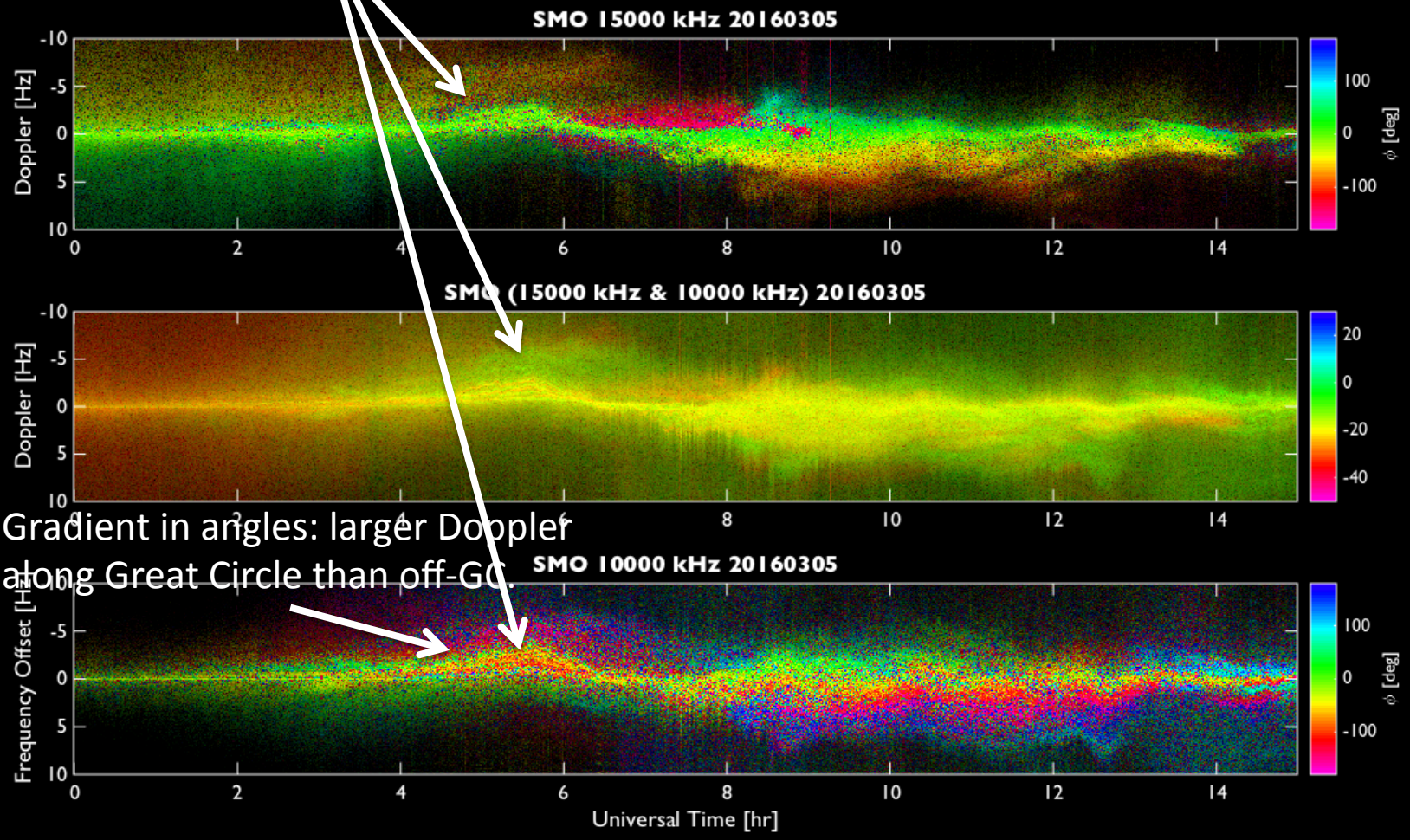


WitL – Week in the Life



WitL – Week in the Life

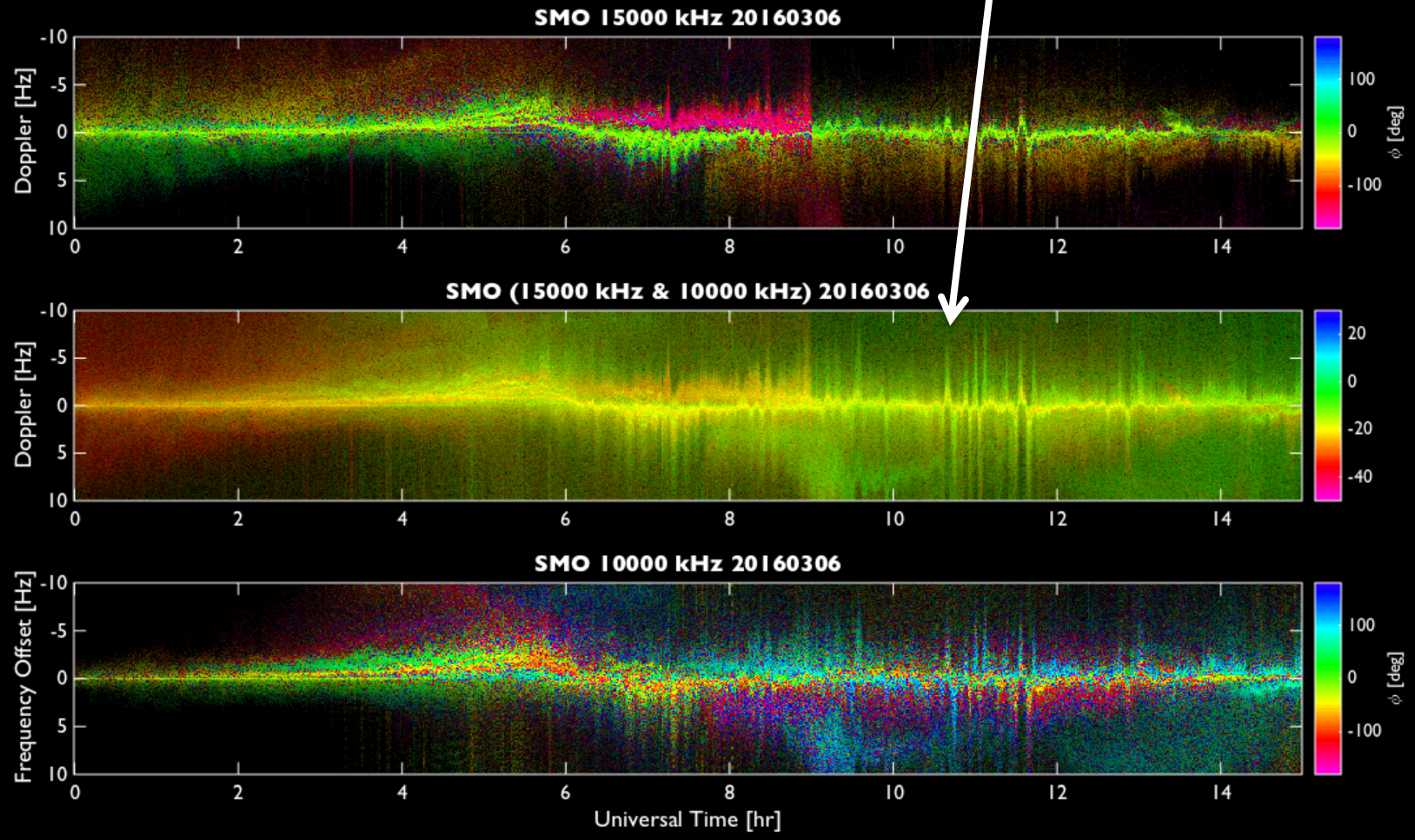
Pre-reversal enhancement of vertical drift



Gradient in angles: larger Doppler along Great Circle than off-GC

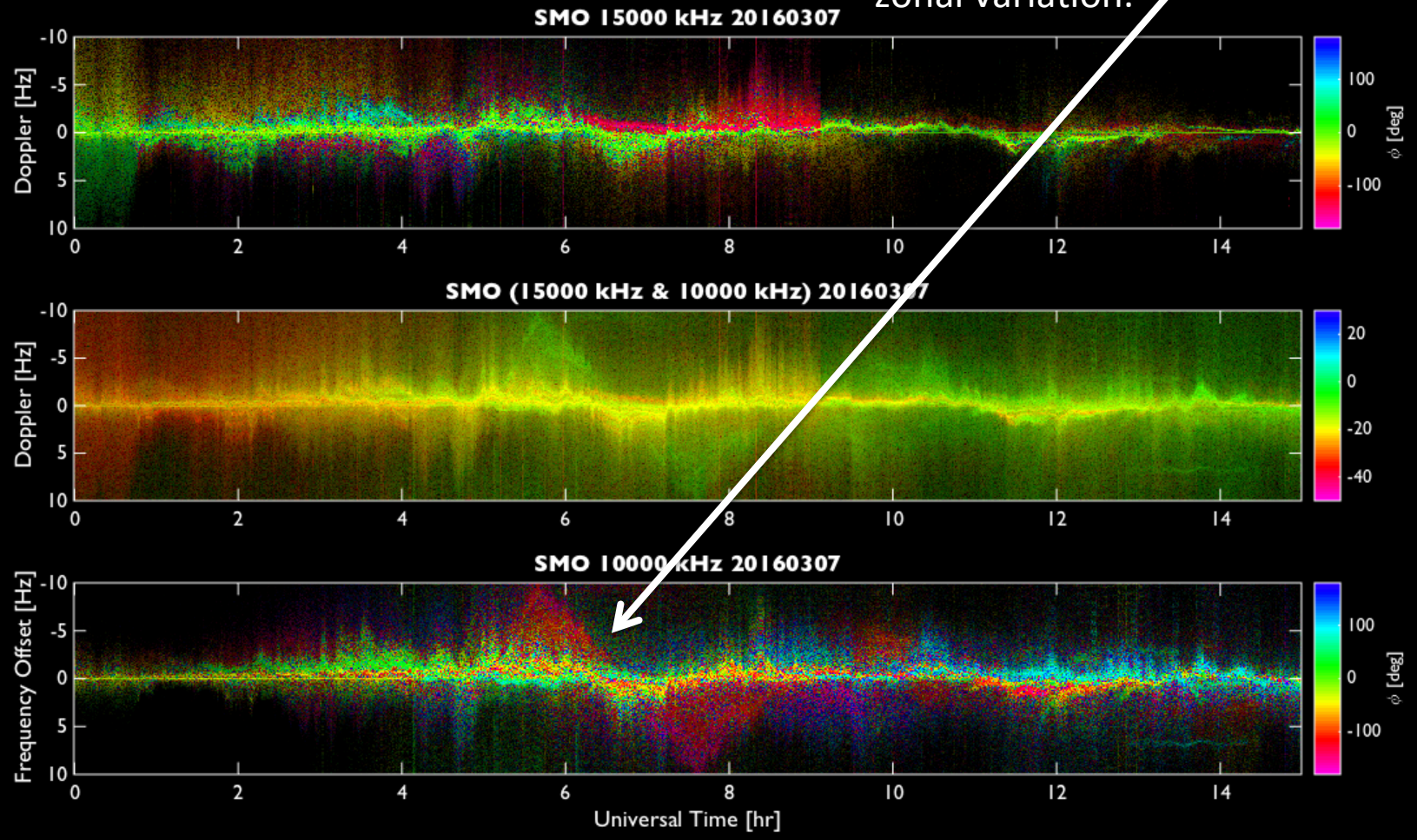
WitL – Week in the Life

What are these spikes? Commonly observed during ESF-quiet times.

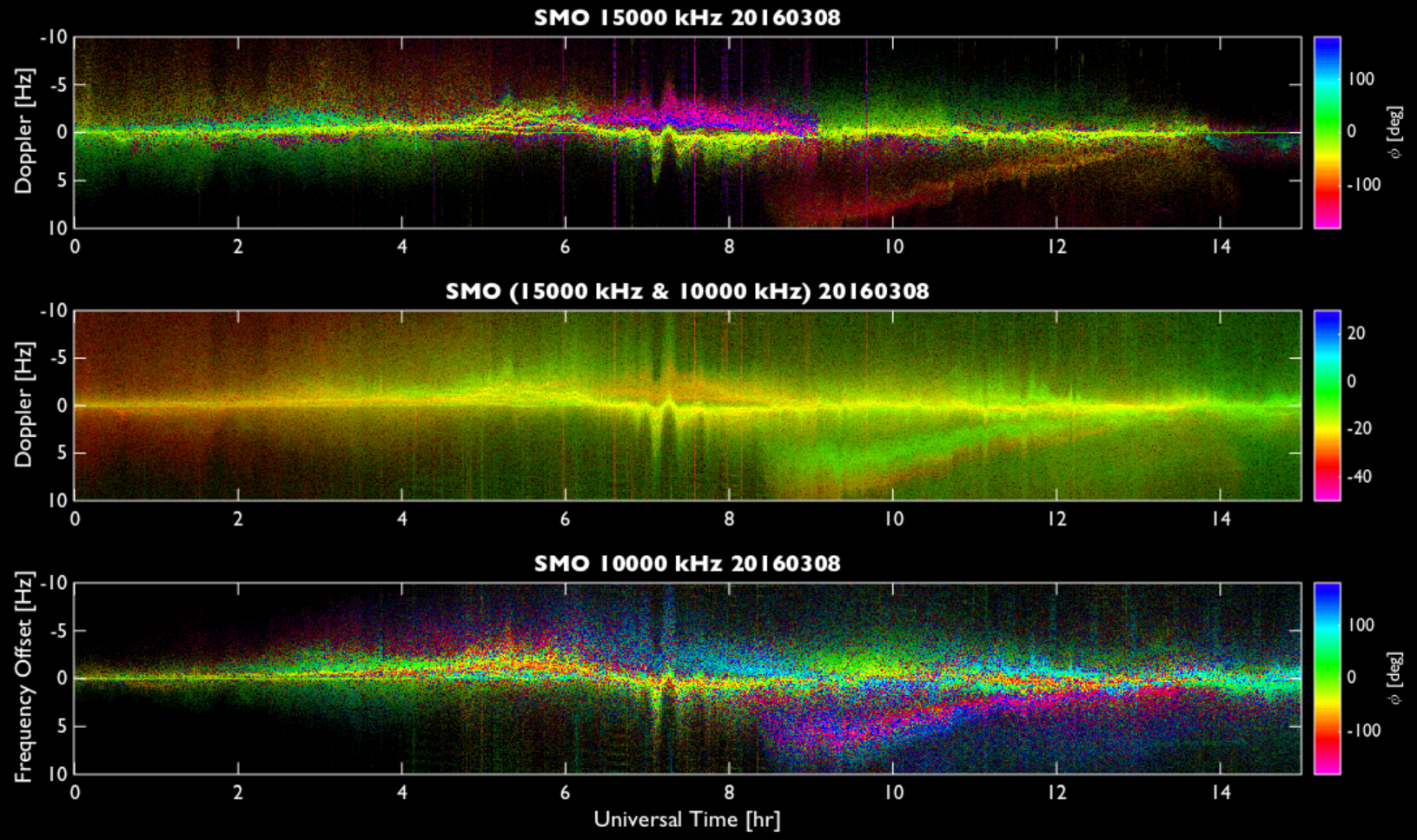


WitL – Week in the Life

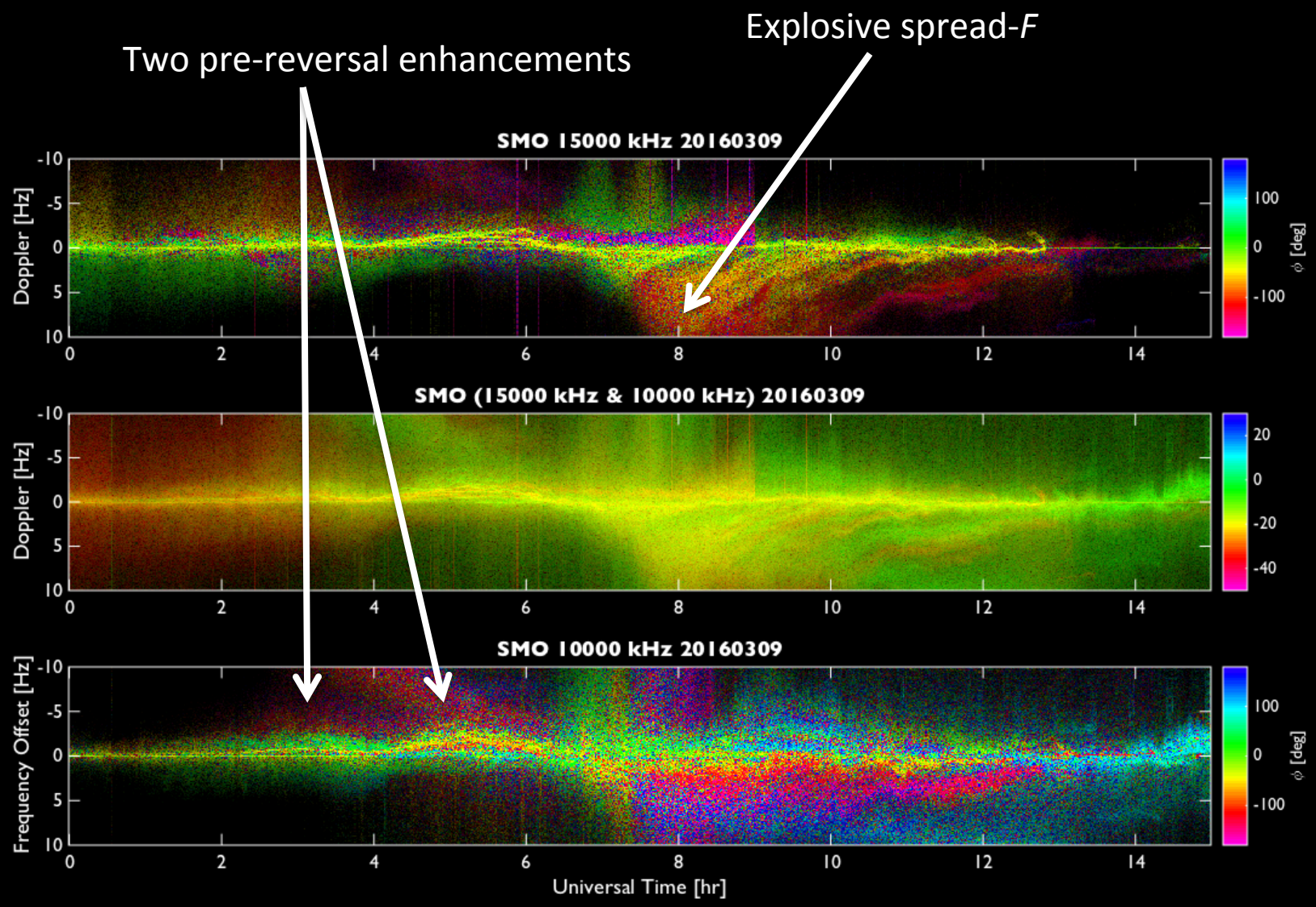
BIG vertical drifts to the west but not along Great Circle. Considerable zonal variation.



WitL – Week in the Life

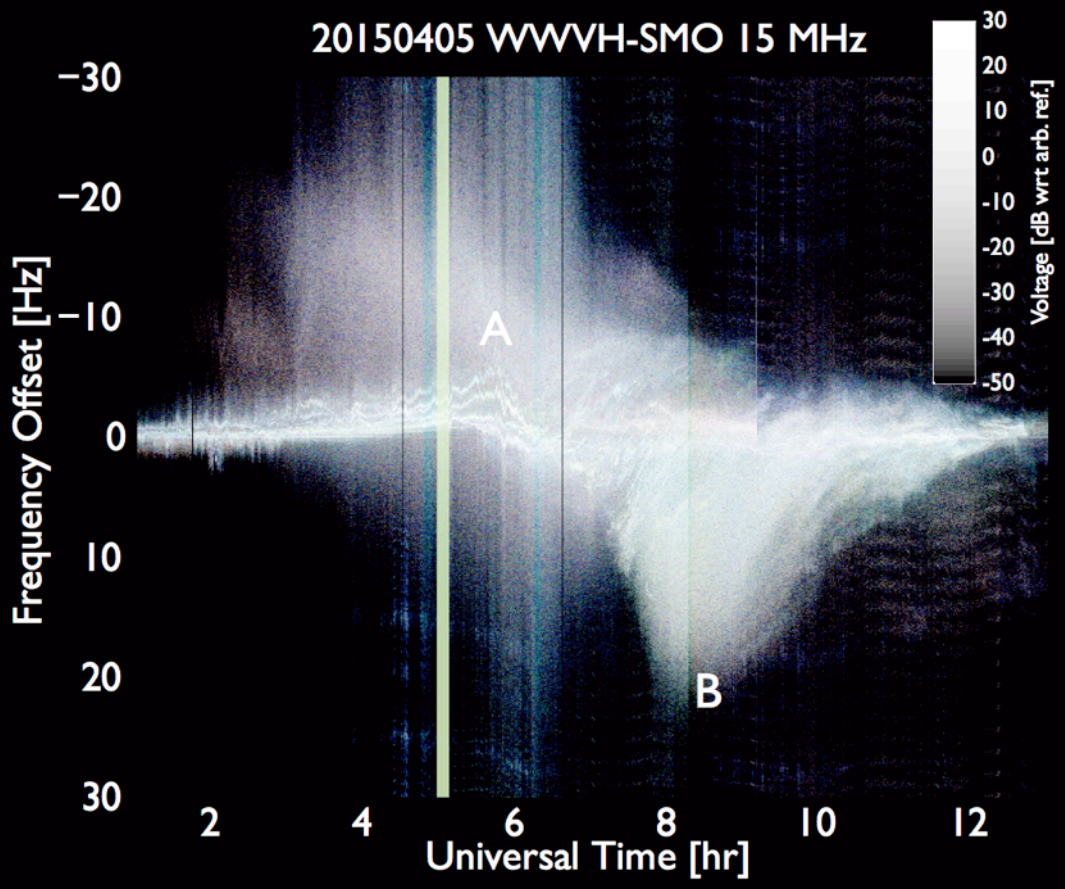


WitL – Week in the Life

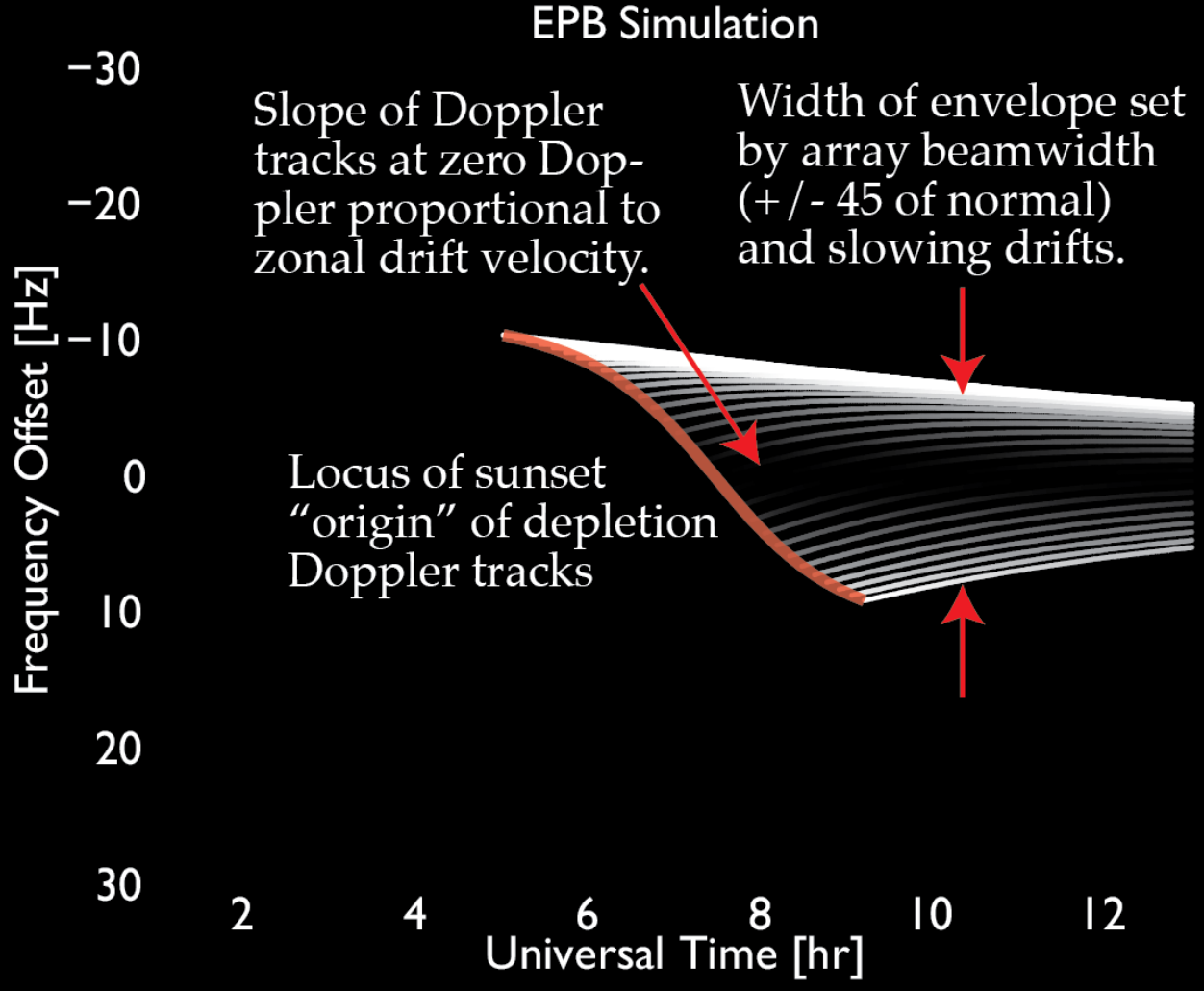


Doppler Shift Regimes

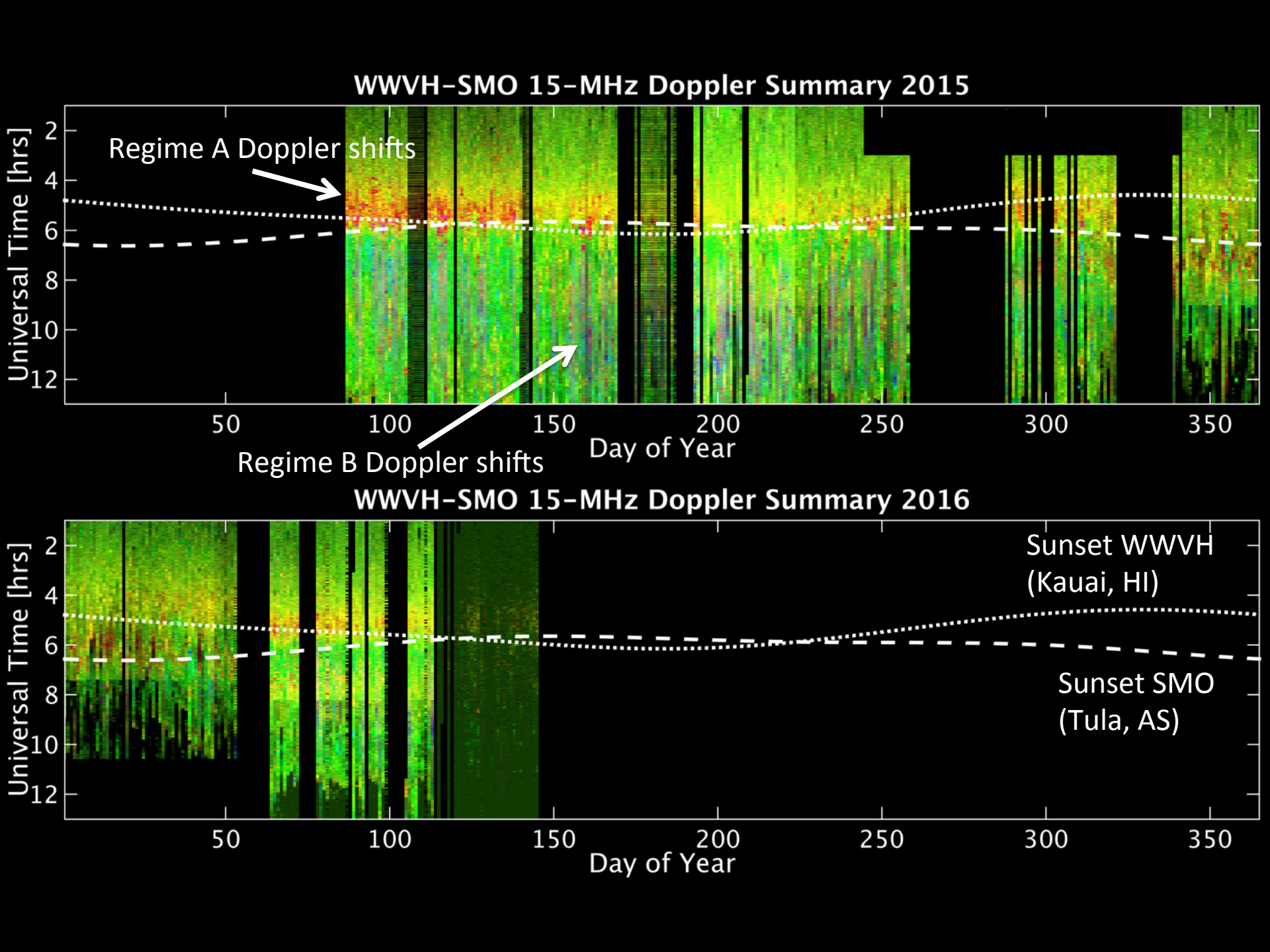
- Regime A: vertical drift dominated
  - Captures PRE.
  - Captures explosive ESF growth.
- Regime B: zonal drift dominated
  - Captures E x B drift of depletion structures.



Doppler Regime B Simulation

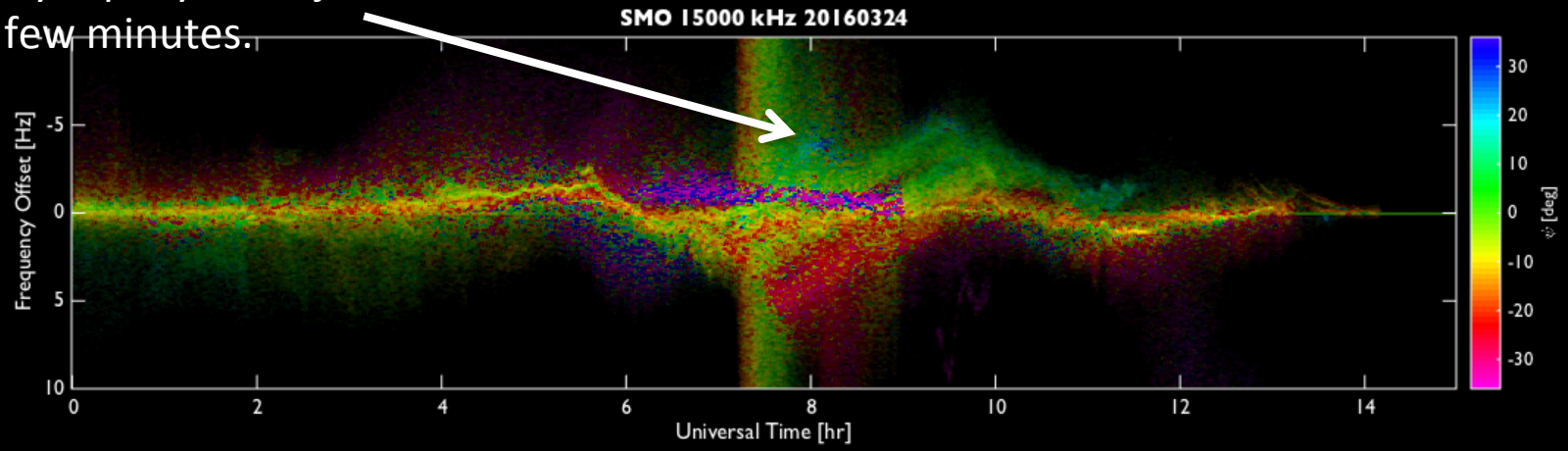


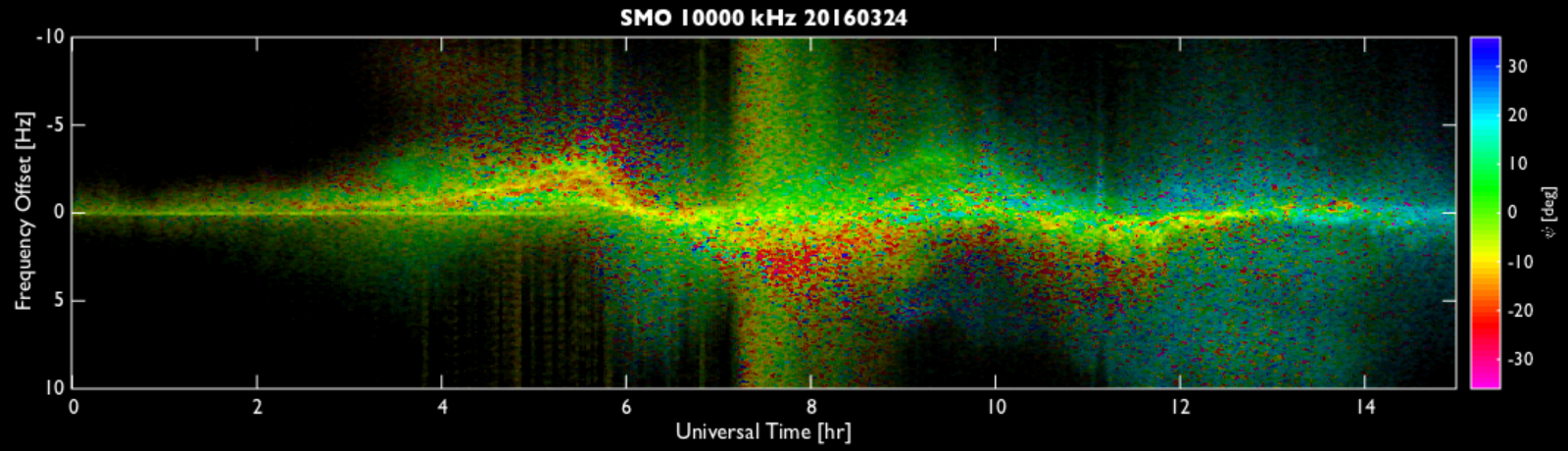
$$\Delta f = -\frac{f}{c_0}\frac{dR_\phi}{dt}$$


WWVH-SMO 15-MHz Doppler Summary 2015
Regime A Doppler shifts
Regime B Doppler shifts
Universal Time [hrs]
Day of Year
WWVH-SMO 15-MHz Doppler Summary 2016
Sunset WWVH
(Kauai, HI)
Sunset SMO
(Tula, AS)
Universal Time [hrs]
Day of Year

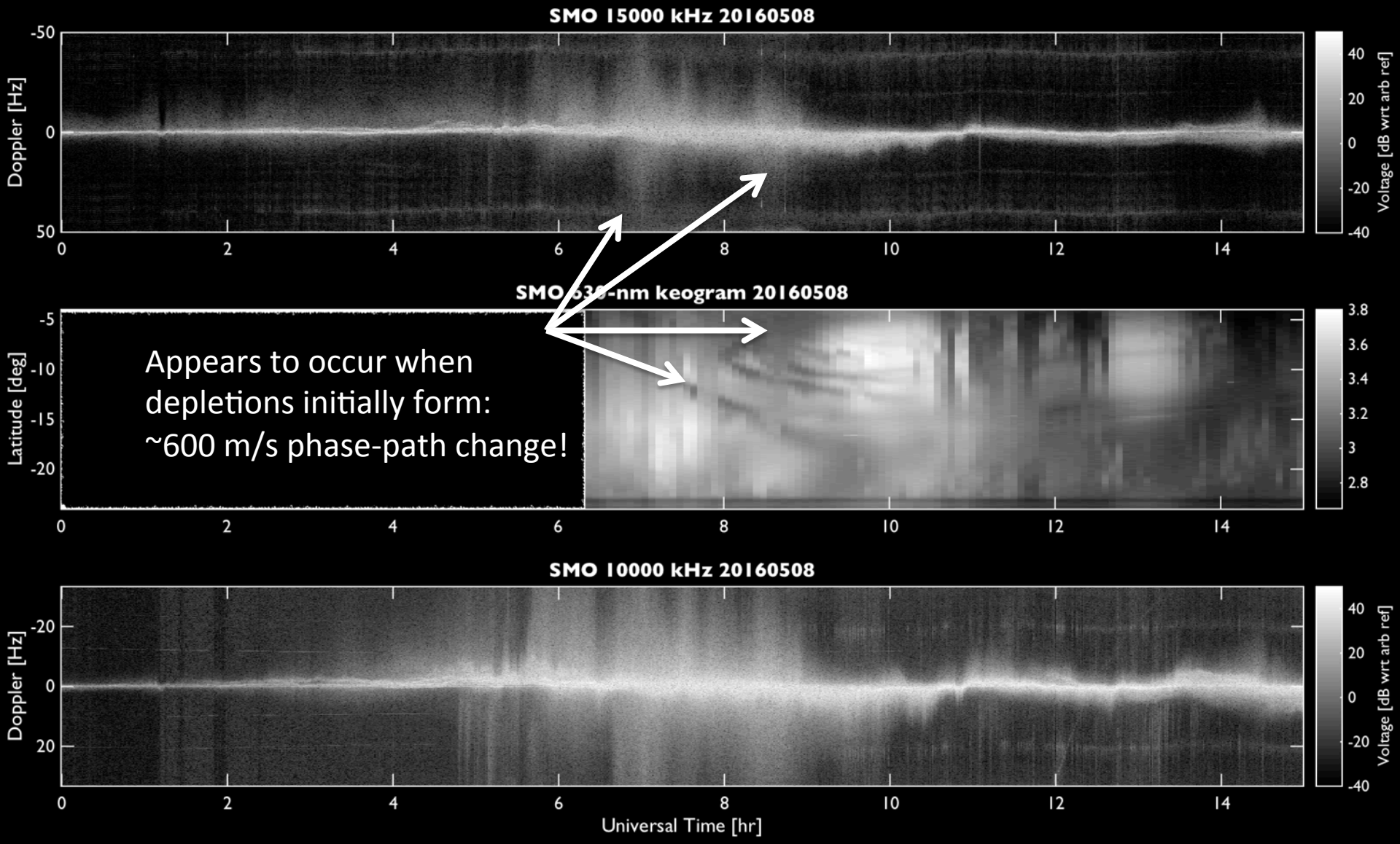
Explosive Spread *F*

These plumes extend to +/- 60 Hz or so and grow very rapidly: over just a few minutes.





Explosive Spread *F*

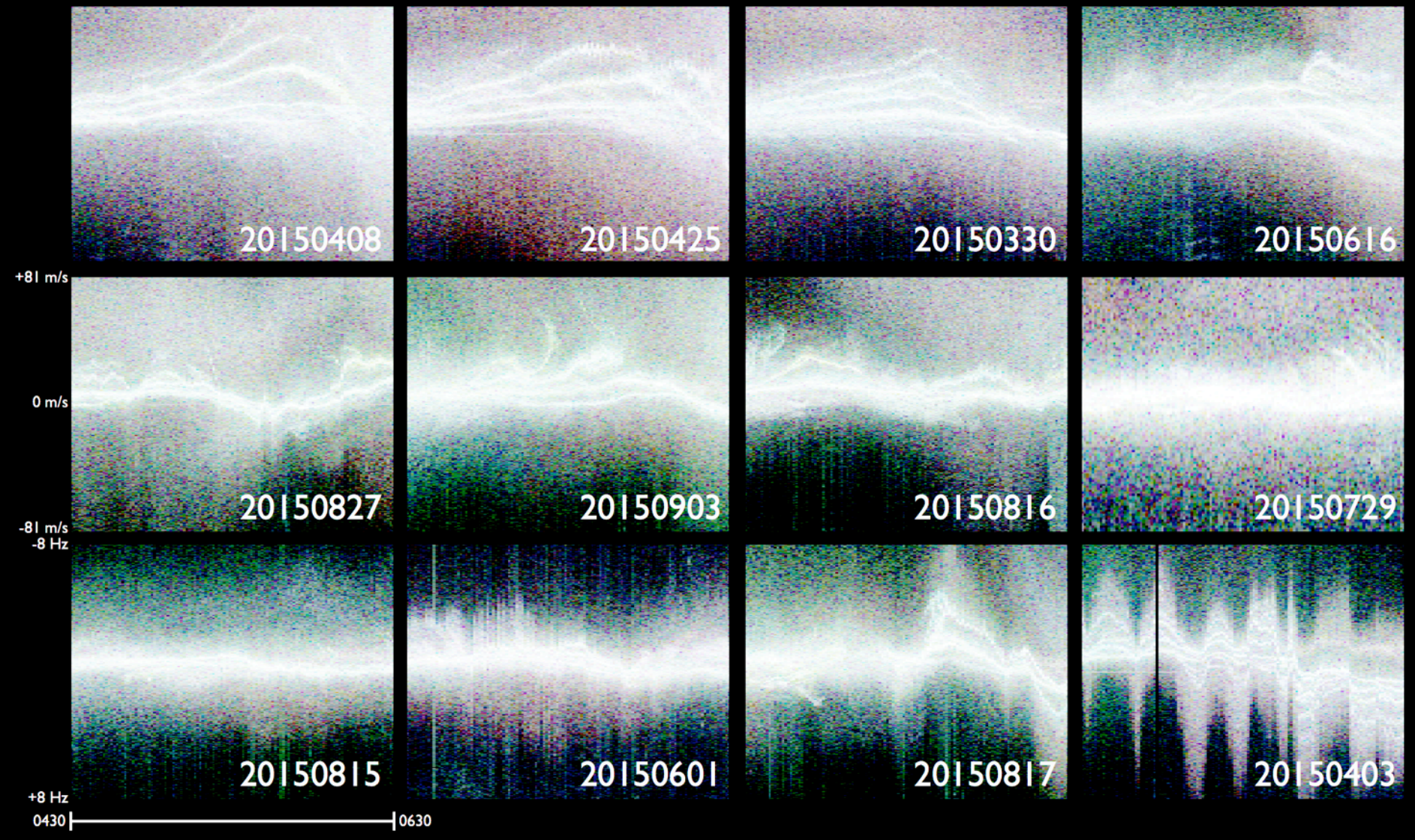


Conclusion

- Observed Doppler and angle over 1+ years on transequatorial circuit
  - 10 MHz better than 15 MHz for bottom side, even over very long path (4200 km, at limit of 1F2).
  - Most data are at 15 MHz
- Still working on drivers of day-to-day variability.
  - Vertical drifts match Fejer-Scherleiss (shown in AGU poster 2015).
  - Unable to unambiguously detangle and match wave crests to depletions with present signal structure.
  - Will need to consider the entire flux tube.
- Acknowledgement: This work was supported by AFOSR FA9550-14-1-0278.

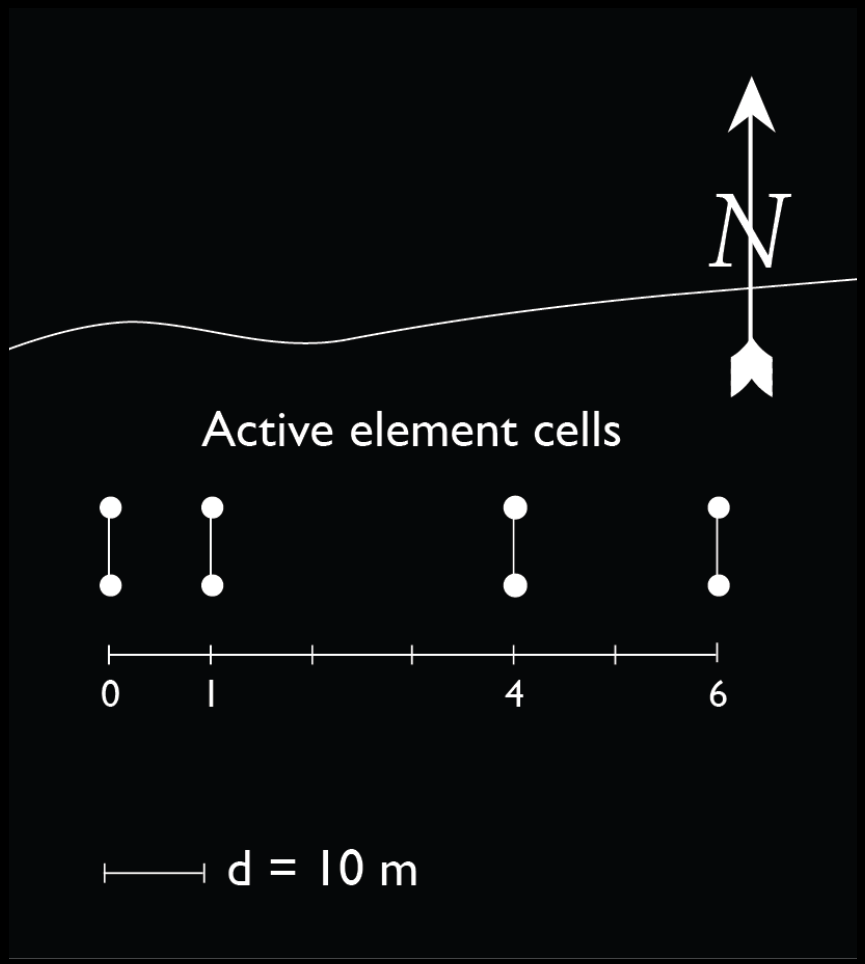
APL JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

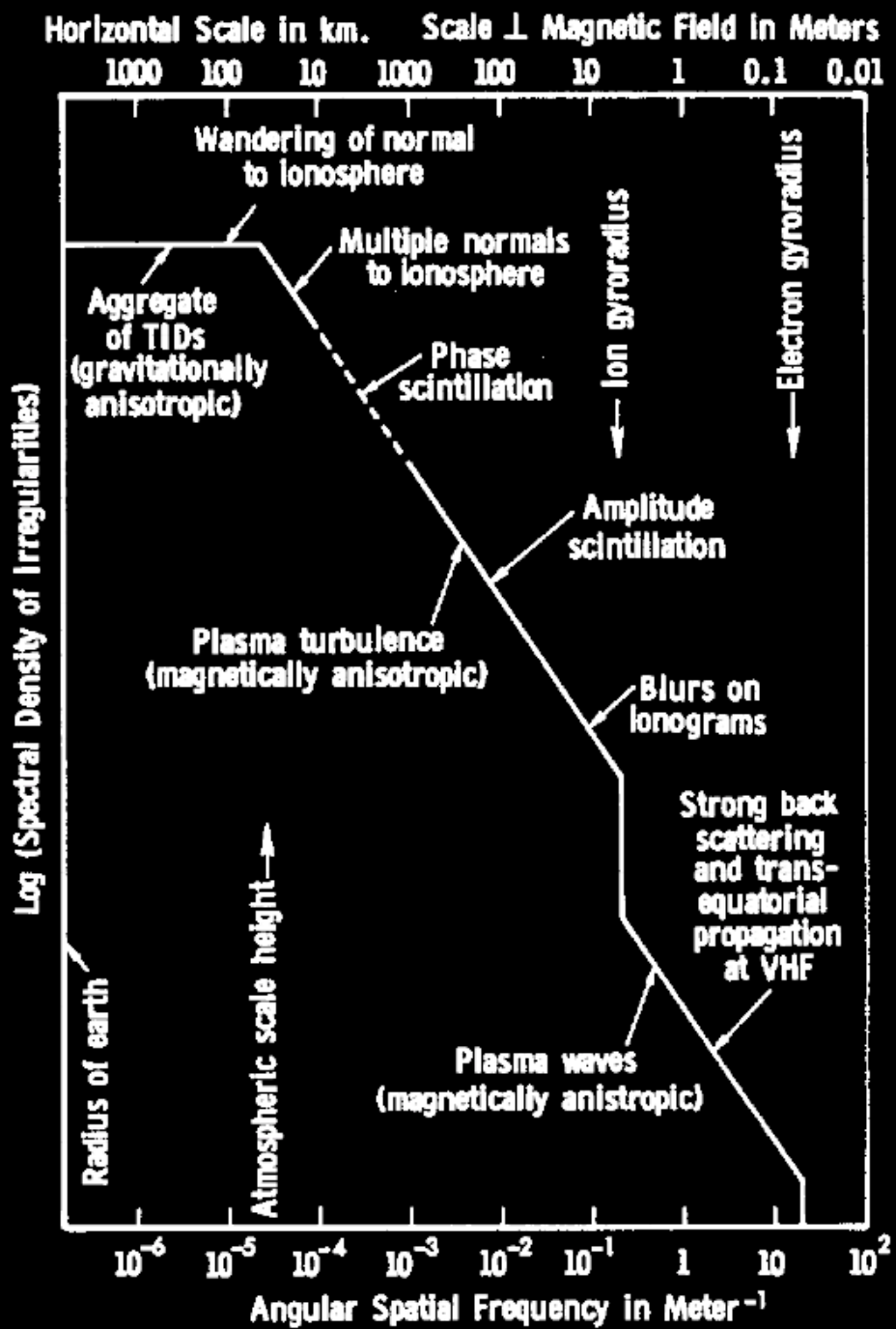
WWVH (Kauai, HI) to SMO (American Samoa) 15.000 MHz Doppler



Experimental Setup

- COTS hardware
- Ettus Research USRP N200 x2 w/ GPSDO
- DX Engineering ARAV3 1.8-meter receive whips (modified)
- Cells 0 and 6 used for 10-MHz observations
- Cells 1 and 4 used for 15-MHz observations





After *Booker*, 1979.