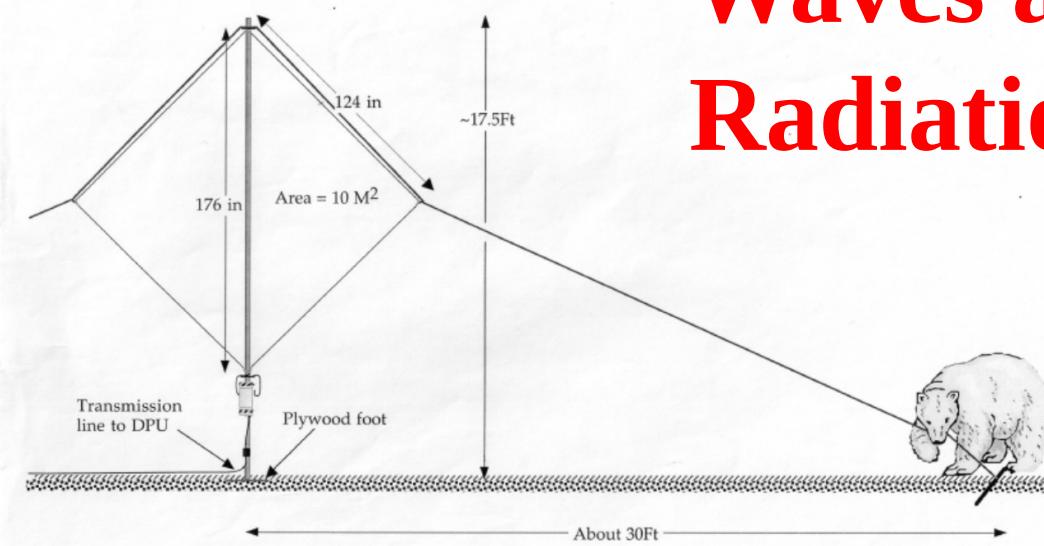


Auroral Electromagnetic Waves and Radiation



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Dartmouth College

Why study Auroral radio emissions?

Waves transport energy long distances, sometimes significant amounts

Through Wave-Particle Interactions, waves sometimes limit particle fluxes or determine boundaries between regions in geospace

Waves transport information long distances, providing methods of remotely detecting space plasma conditions and processes

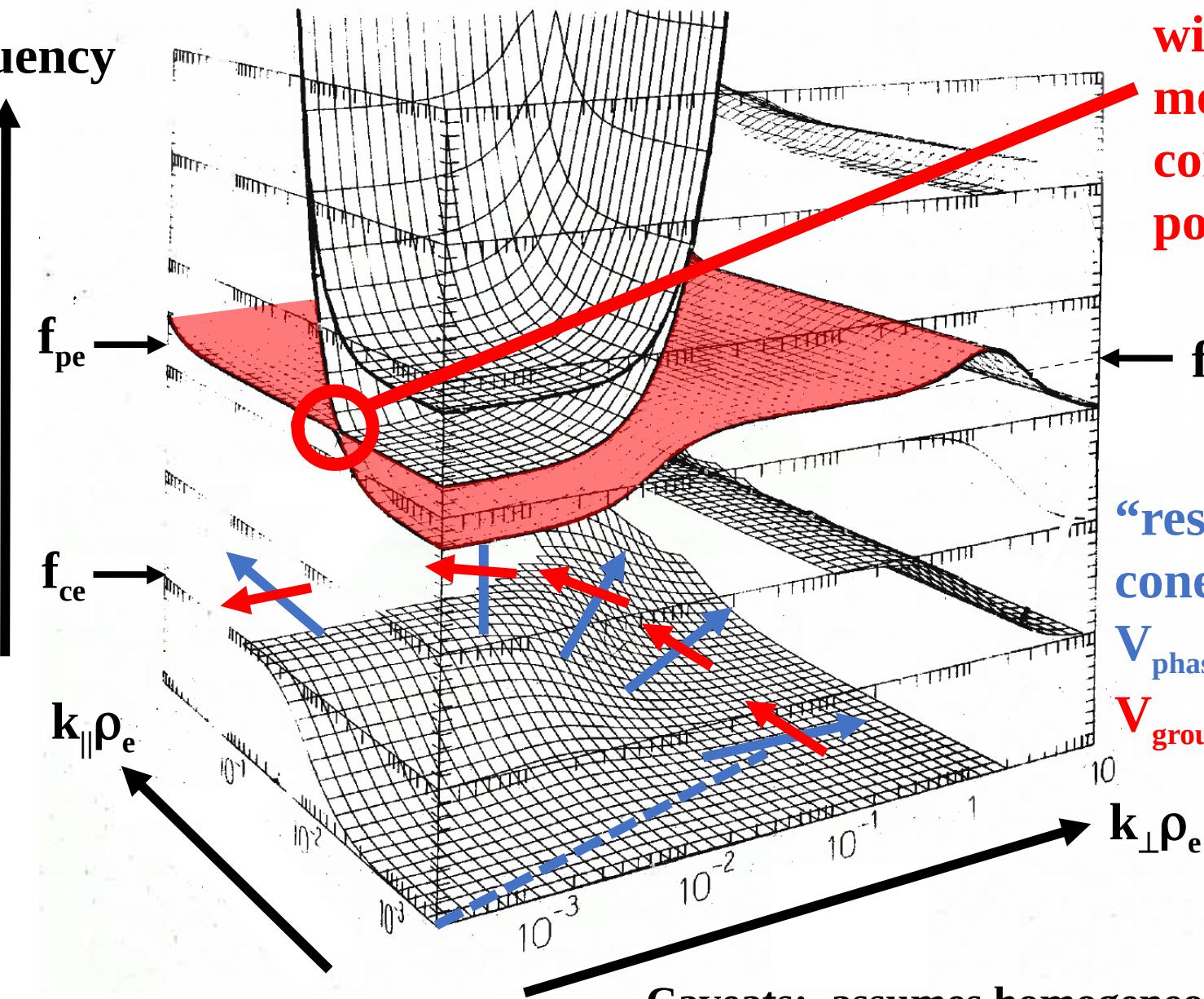
Auroral radio emission is a local laboratory for studying emissions processes that also occur in planetary and astrophysical plasmas

Auroral radio emissions are intrinsically beautiful and interesting, particularly to “wave-men” and “wave-women”

$f_{pe} > f_{ce}$ (typical of auroral ionosphere)

“Ellis window” mode conversion possible

frequency



“resonance
cone”

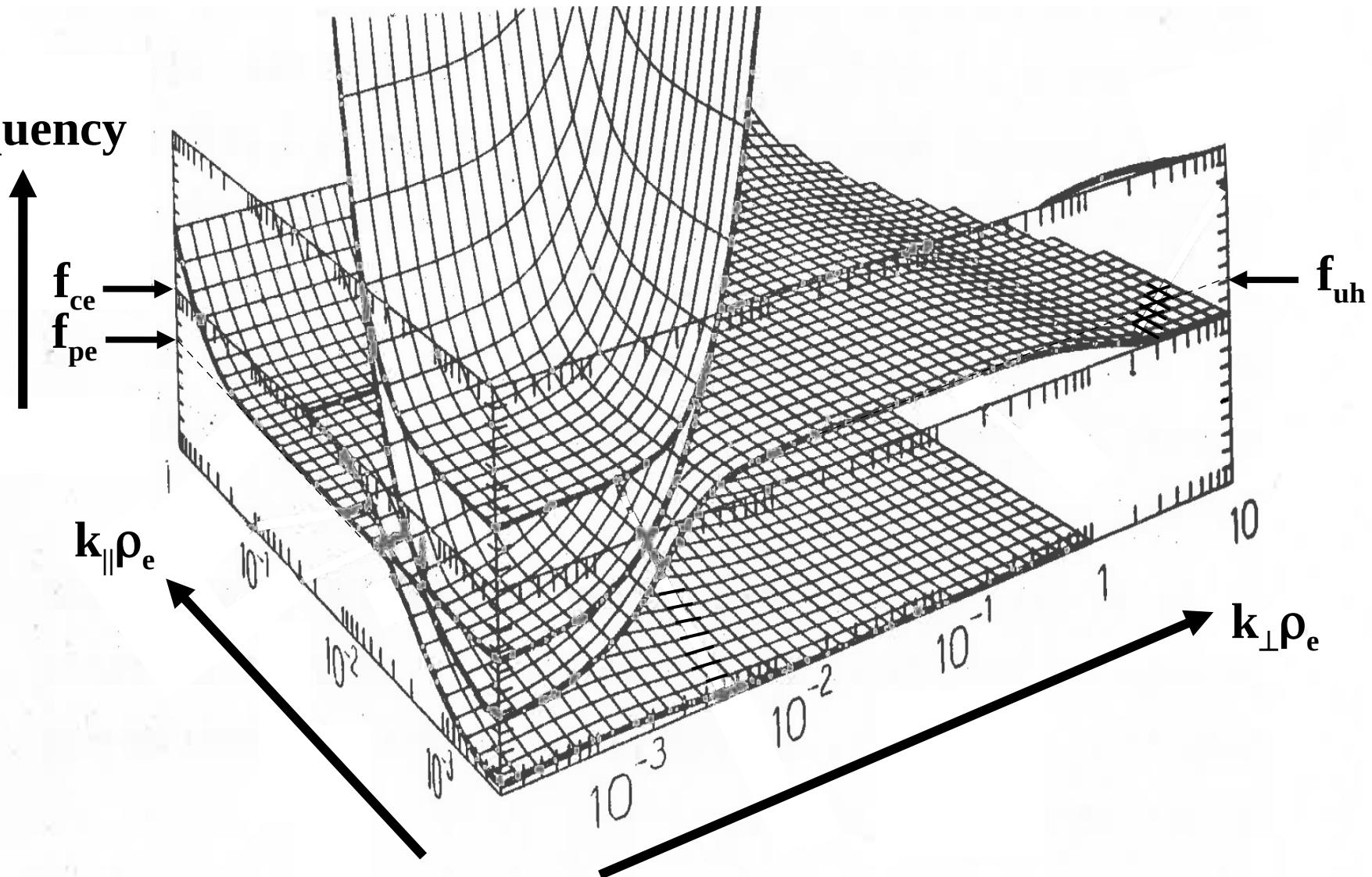
$V_{phase} \ll c$

$V_{group} \perp V_{phase}$

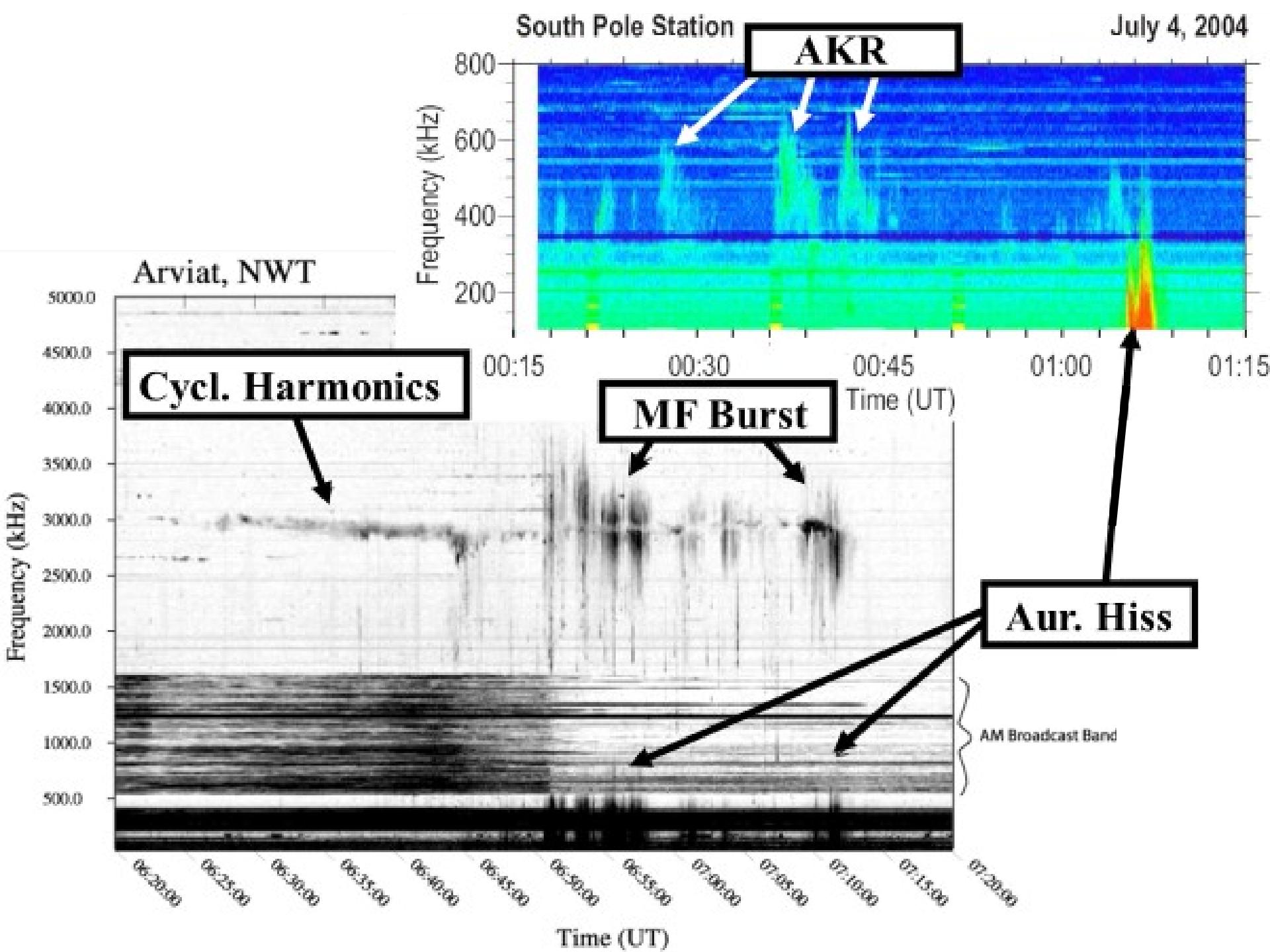
Caveats: assumes homogeneous plasma
not all wave modes shown

$f_{pe} < f_{ce}$ (typical of auroral magnetosphere)

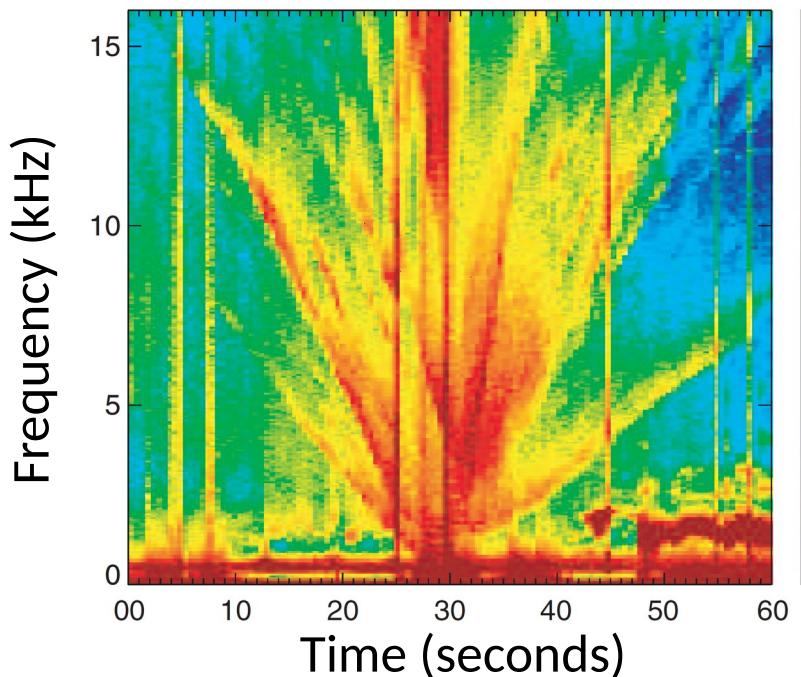
frequency



from: Andre, 1985

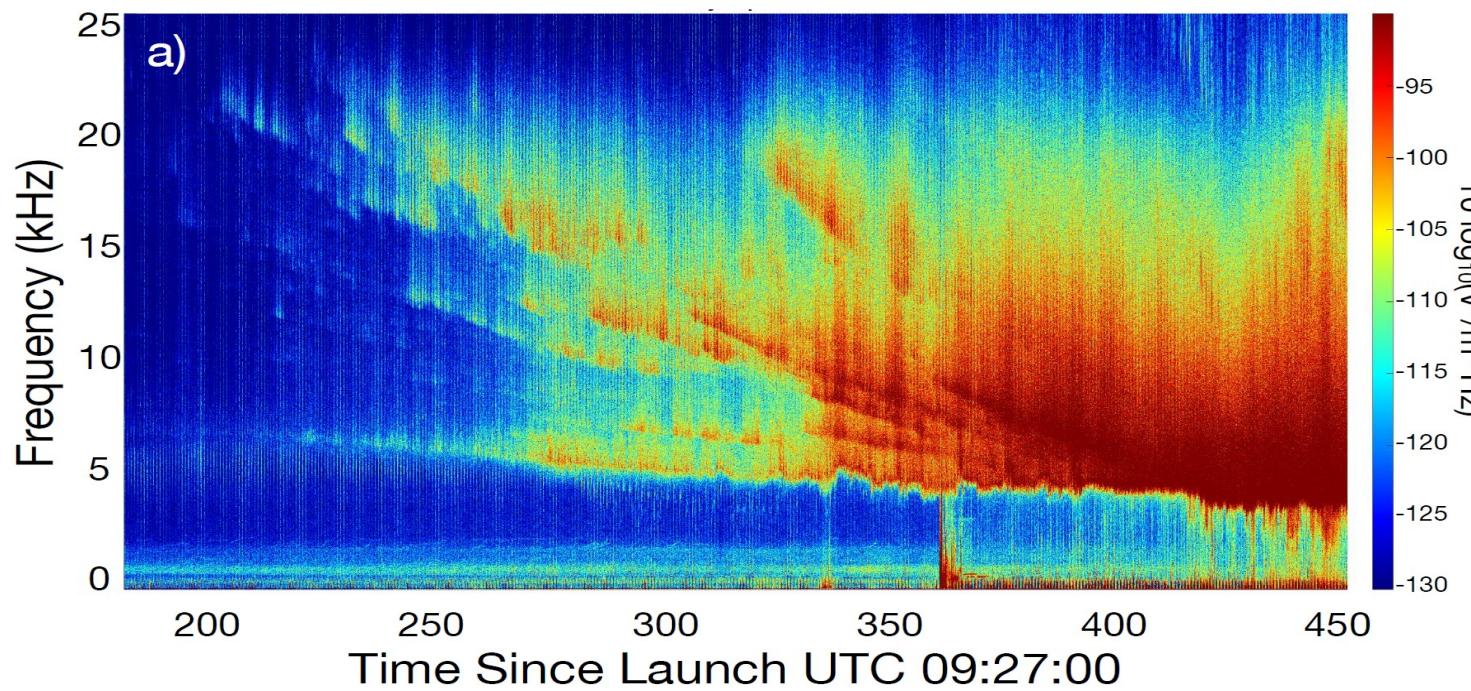


FAST ORBIT 1747

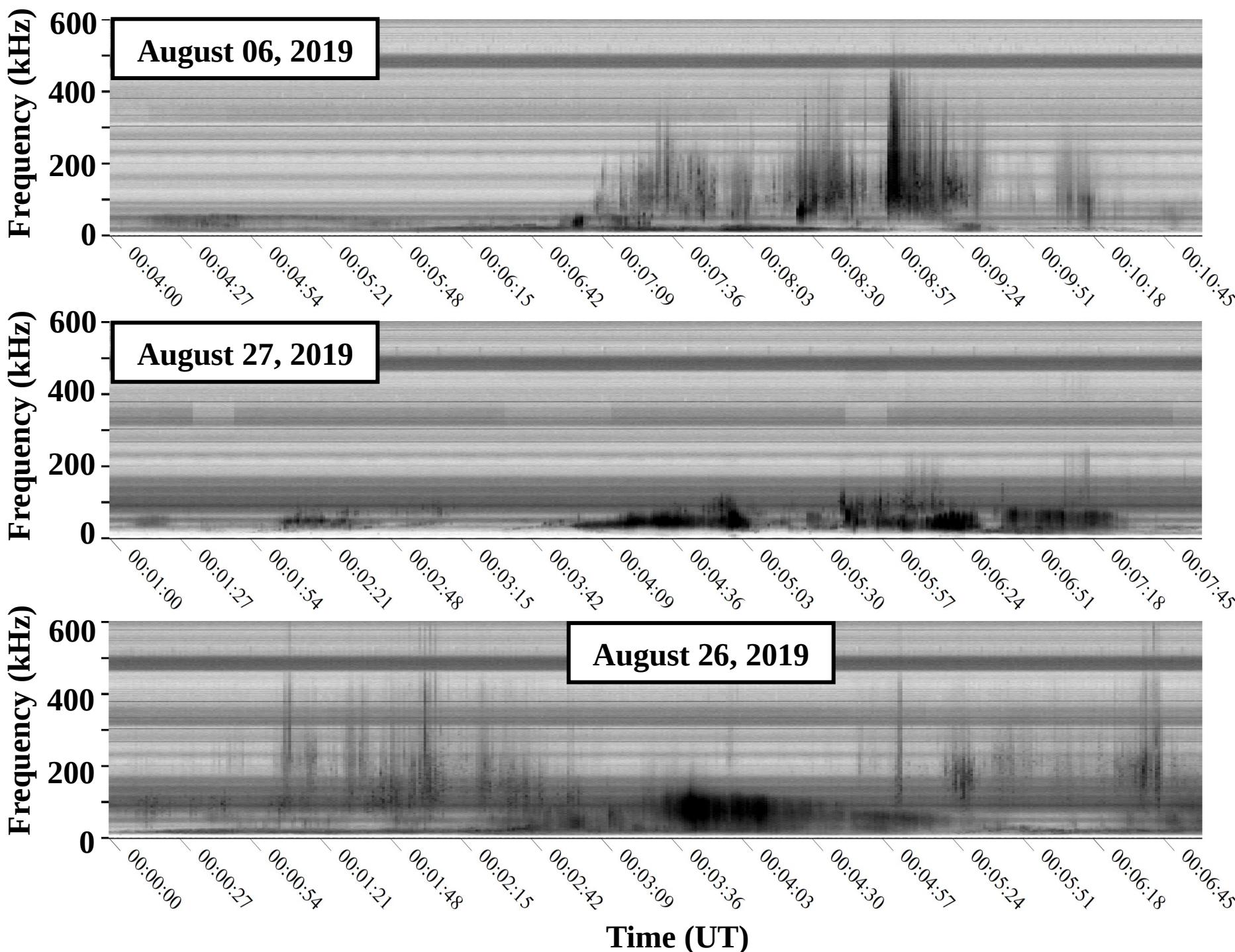


Structured Auroral Hiss: VLF Saucers

FAST satellite data
from upward electron beam
below spacecraft
[Ergun et al., 2001]

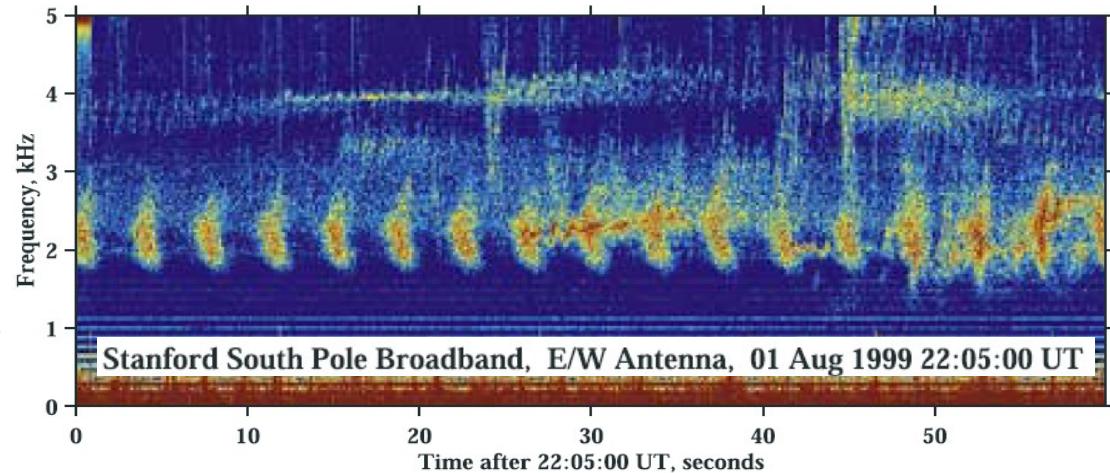


CAPER rocket
data
from downward
electron beam
4000 km above
spacecraft
(also observed
with DEMETER
spacecraft
[James et al.,
2012])

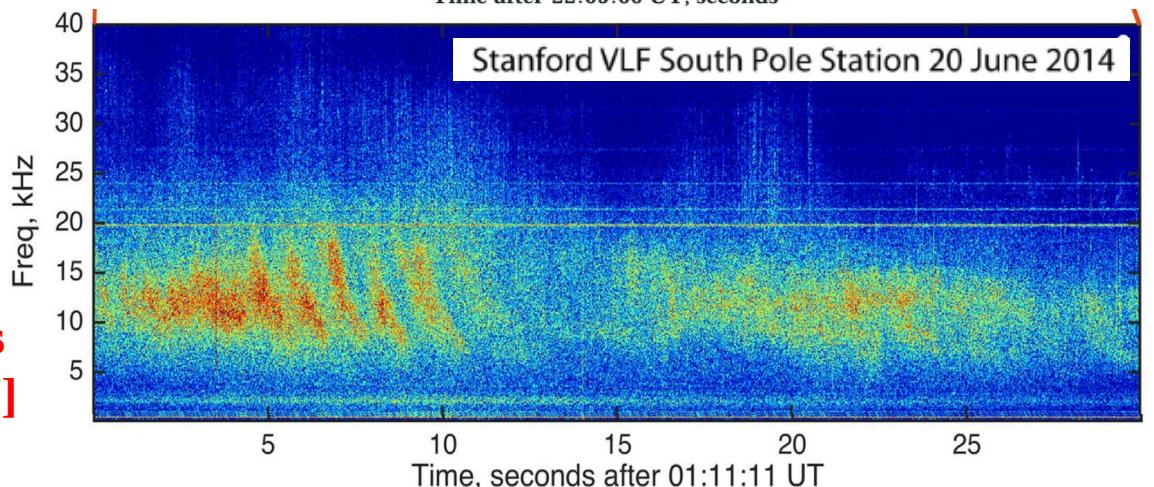


Structure in Auroral Hiss Emissions:

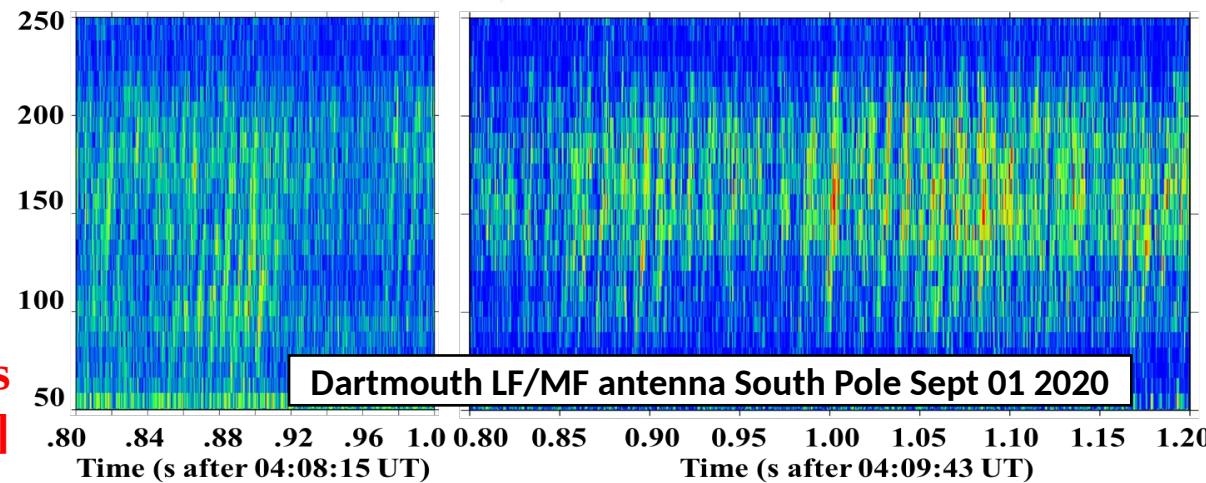
VLF “QP” emissions
[Engebretson et al., 2004]

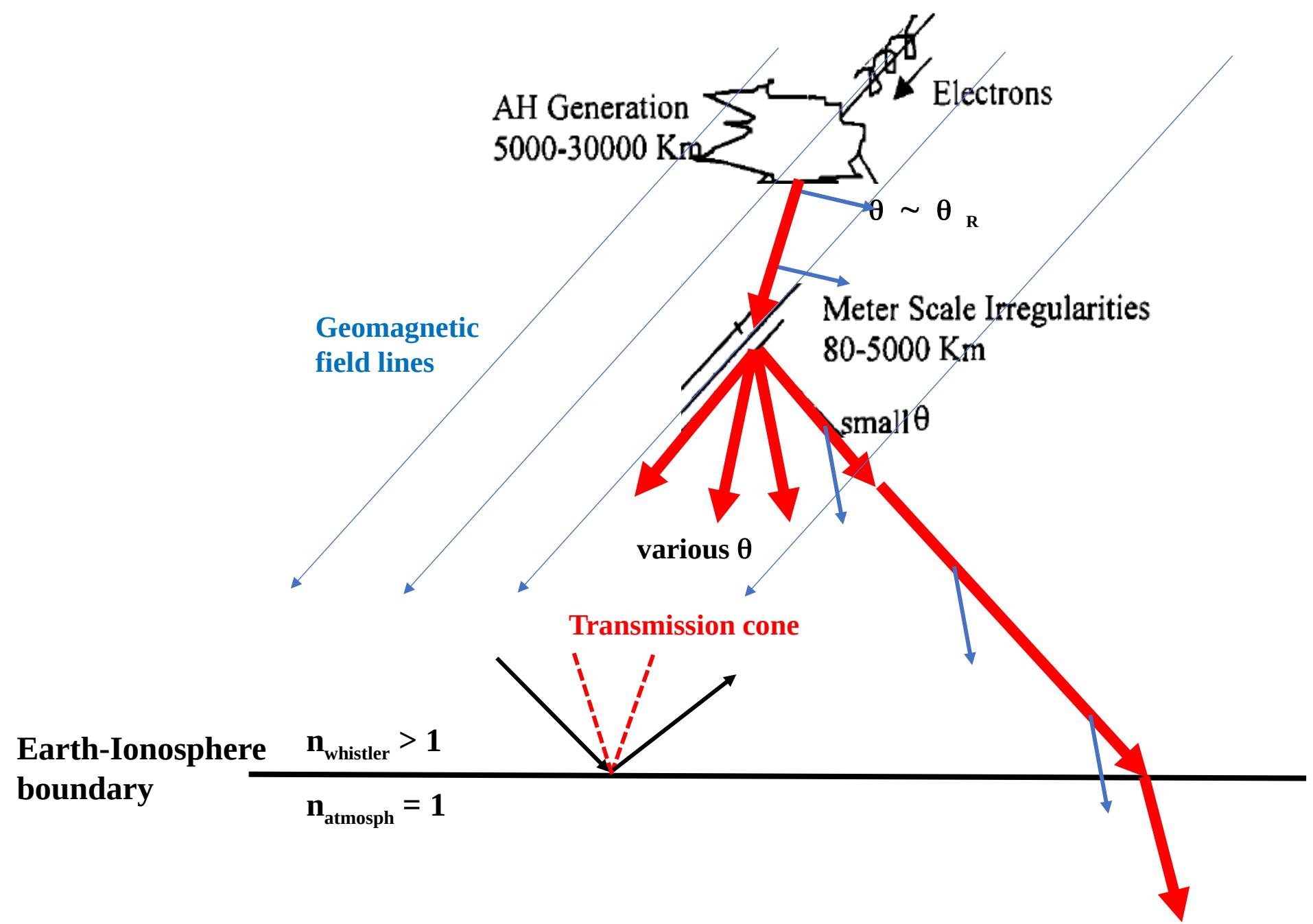


VLF “hissler” emissions
[Kim et al., 2017]



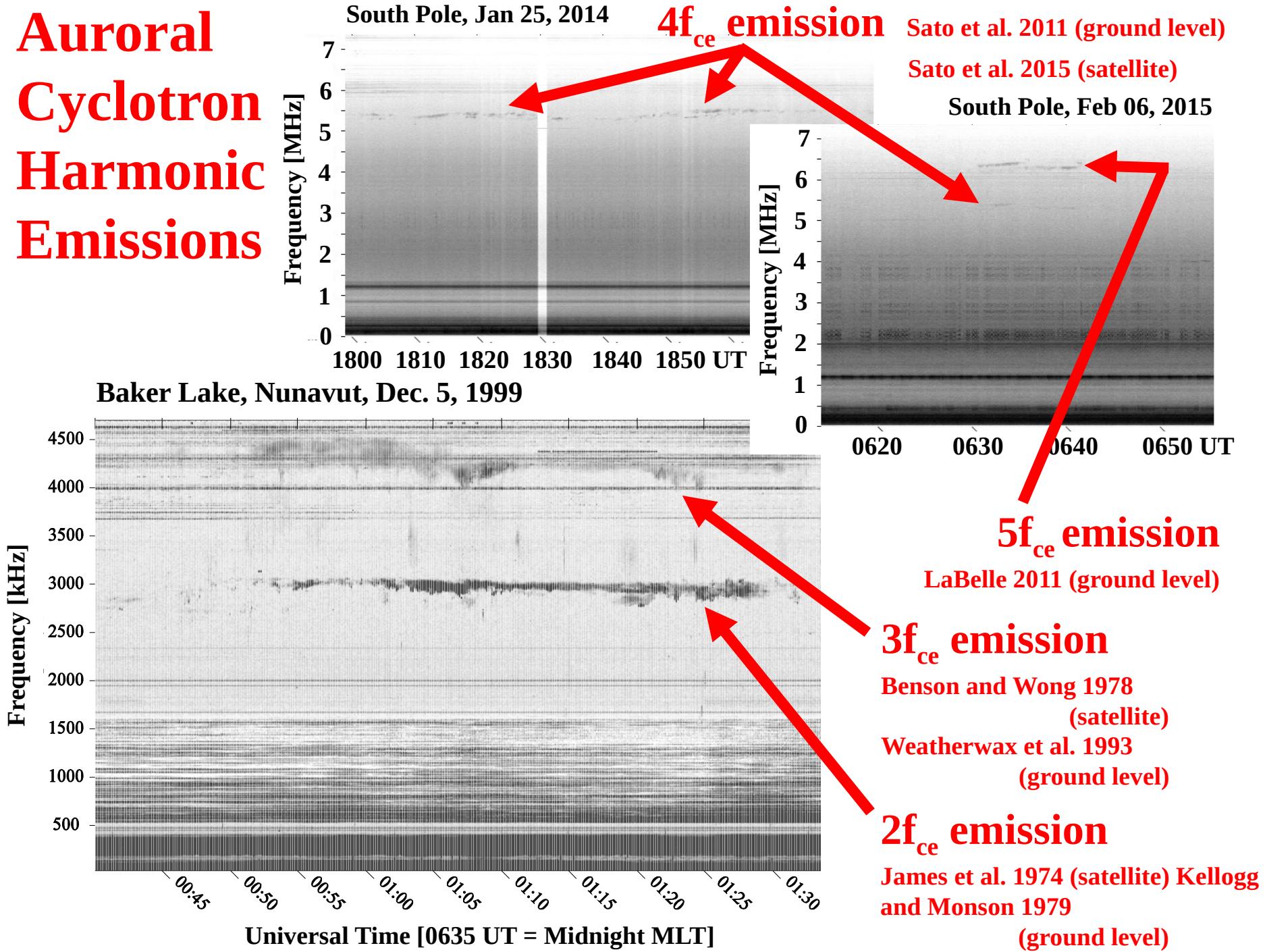
Flickering LF auroral hiss
[LaBelle, Fall 2020 AGU talk]



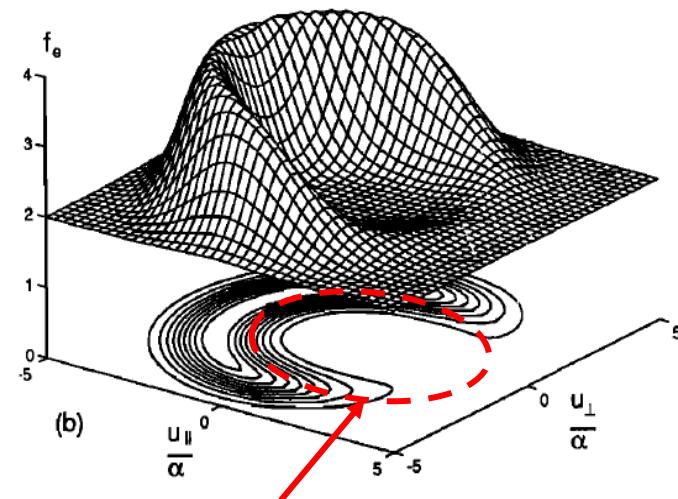


Adapted from Sonwalkar and Harikumar, 2000

Auroral Cyclotron Harmonic Emissions



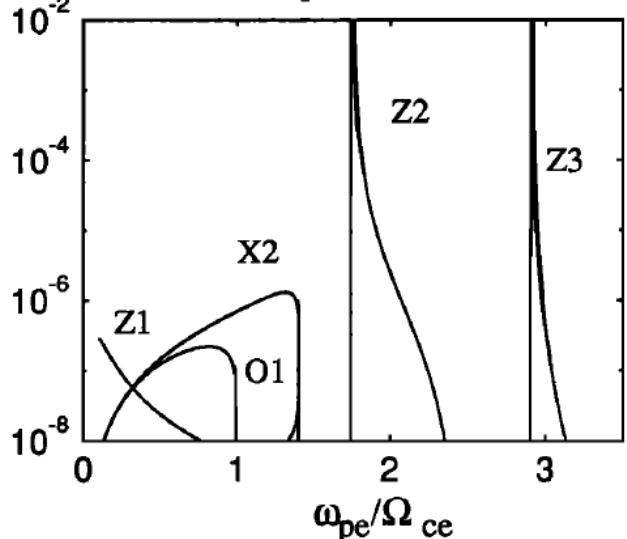
“horseshoe” electron distribution function



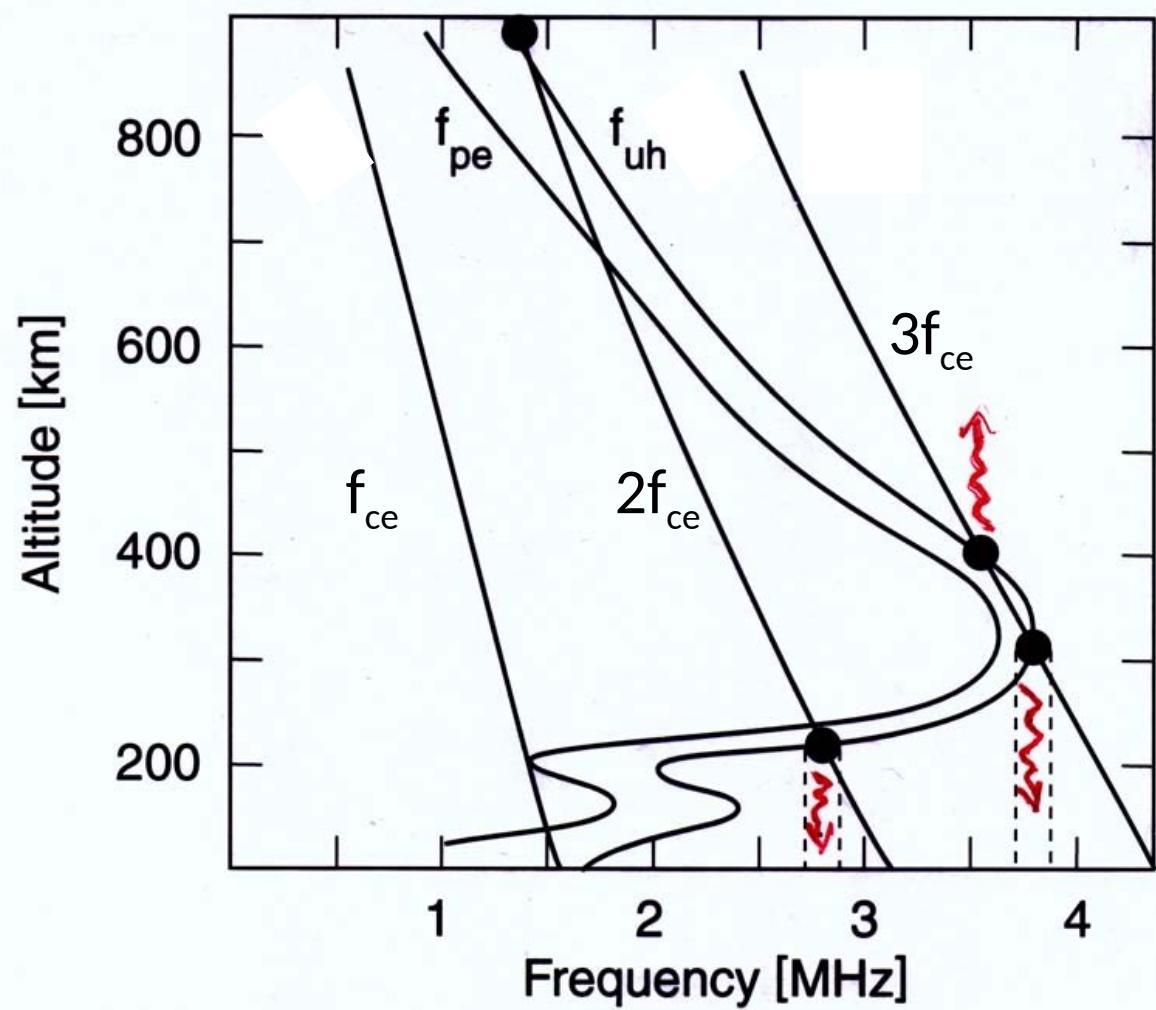
resonance condition

$$\omega - kv_{||} = s\omega_{ce}/\gamma \quad s=1,2,3,\dots$$

Maximum Spatial Growth Rates

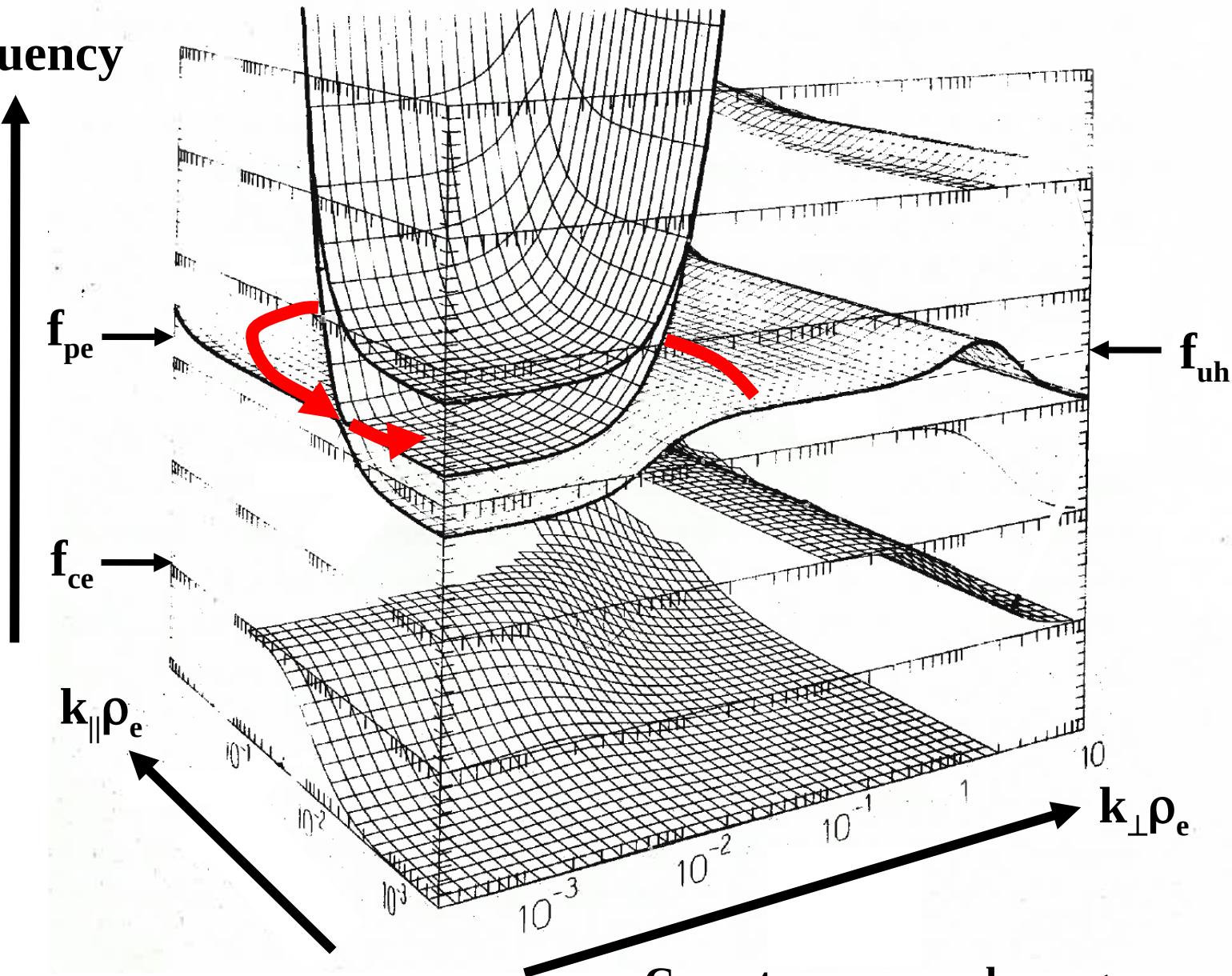


from: Yoon et al., 1998



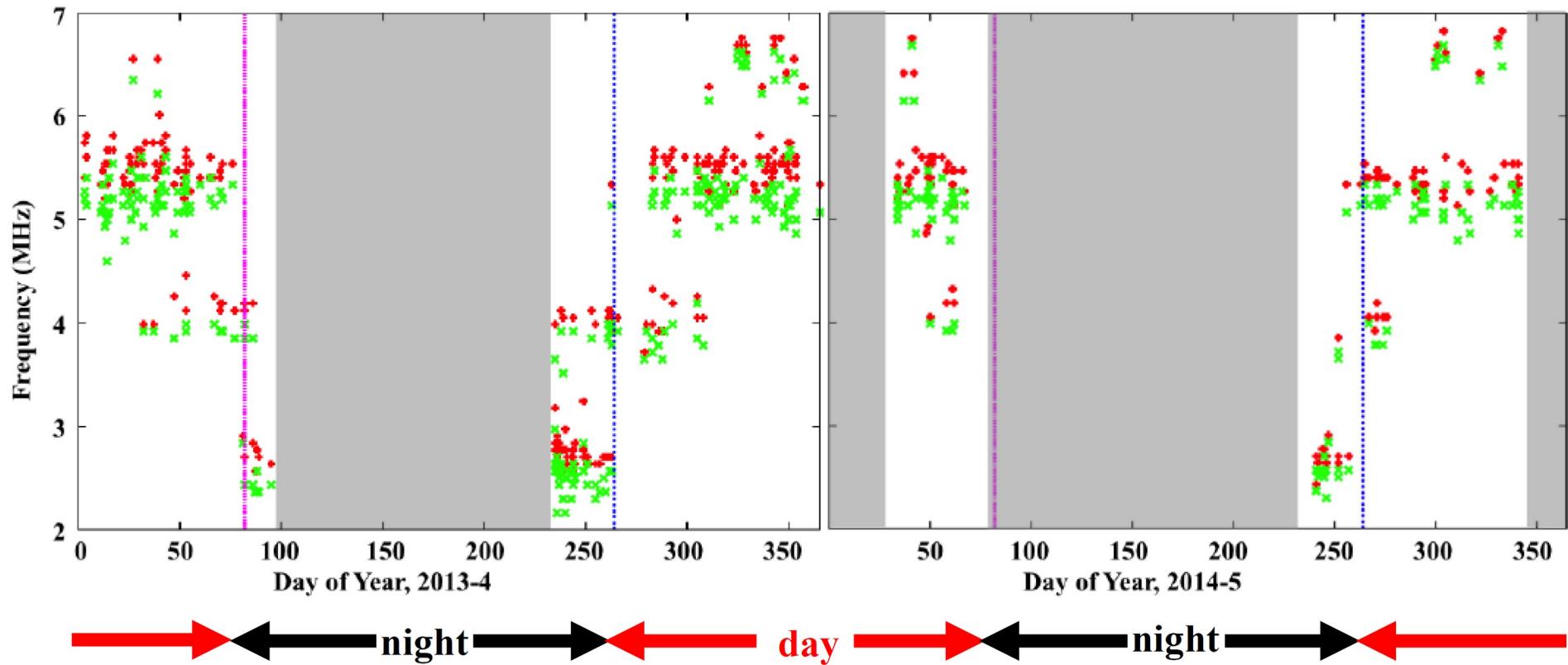
$f_{pe} > f_{ce}$ (typical of auroral ionosphere)

frequency



Caveats: assumes homogeneous plasma
not all wave modes shown

376 days of data → 347 electron cyclotron emissions on 176 days



“Stairstep” feature: higher harmonics require
higher solar zenith angles

Structure in Auroral Cyclotron Harmonic Emissions:

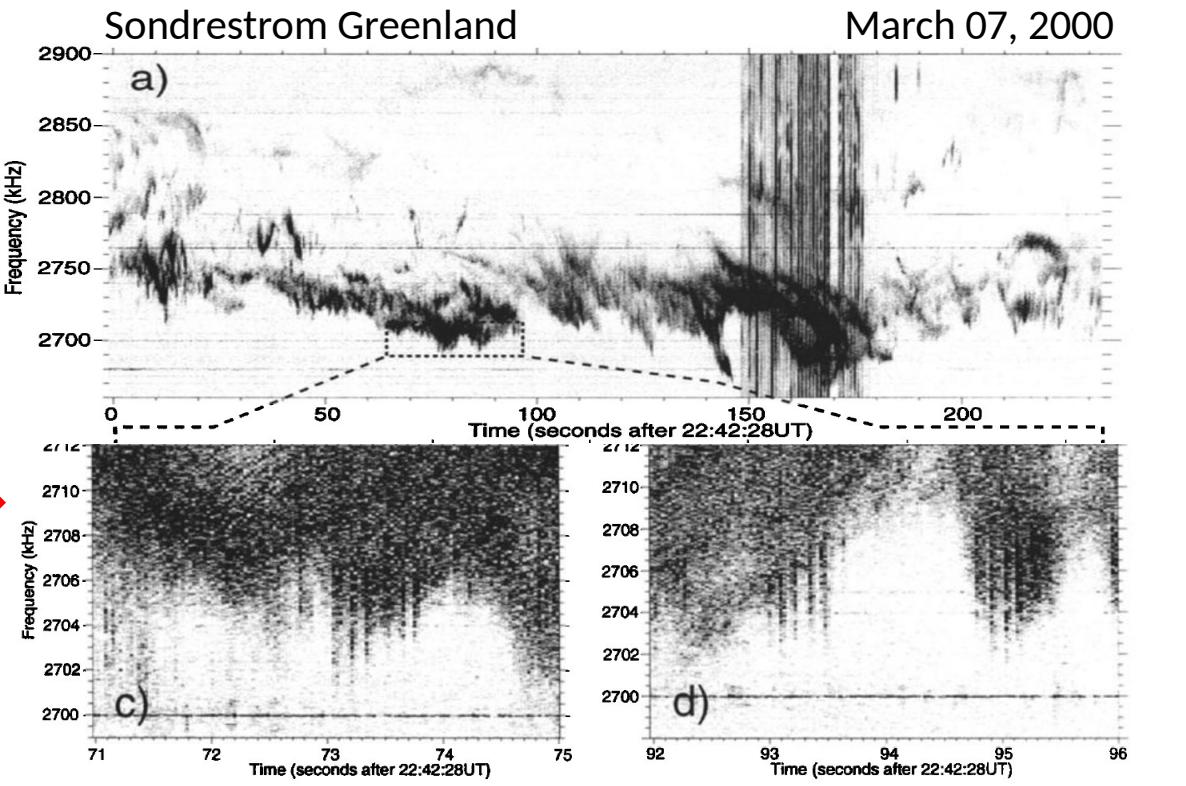
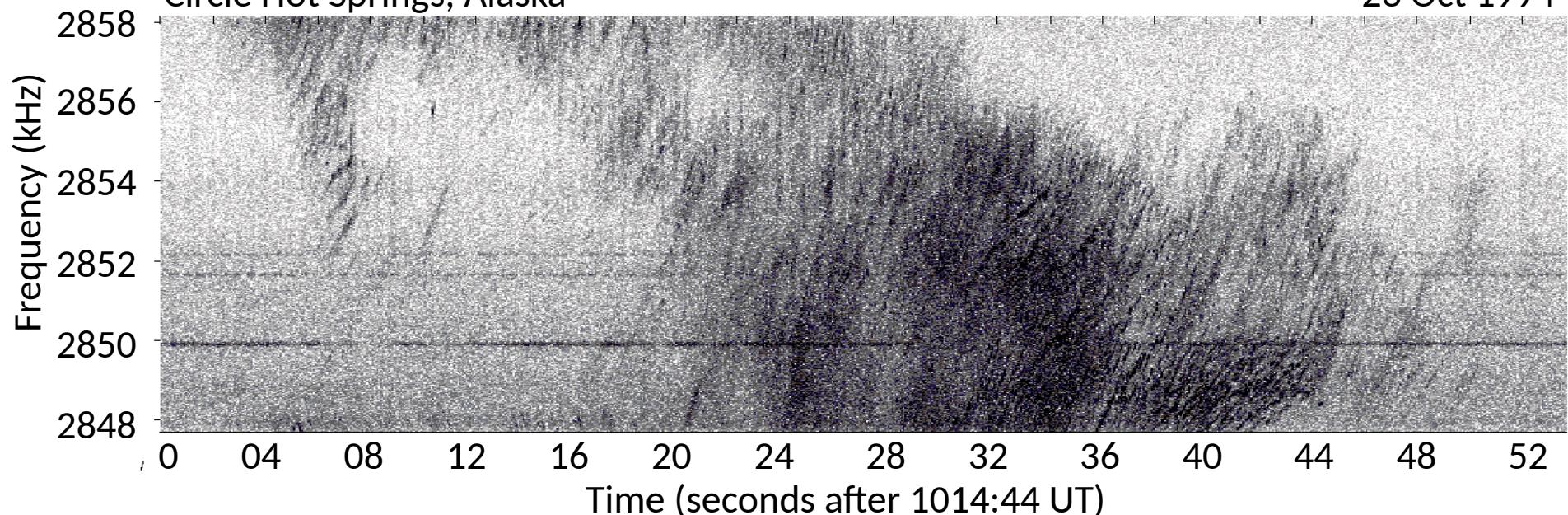
Flickering Auroral Roar
[Hughes and LaBelle, 2001]

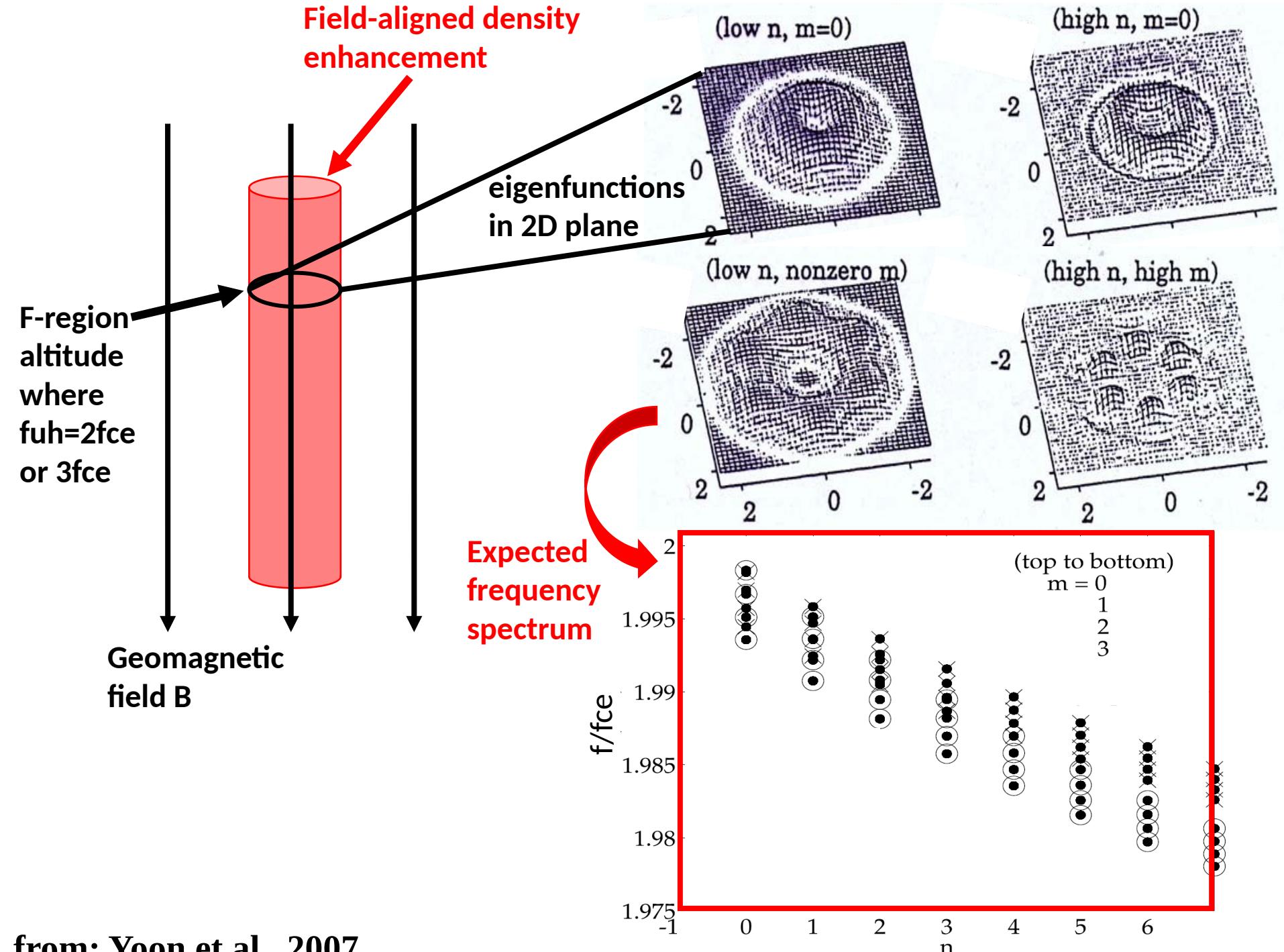


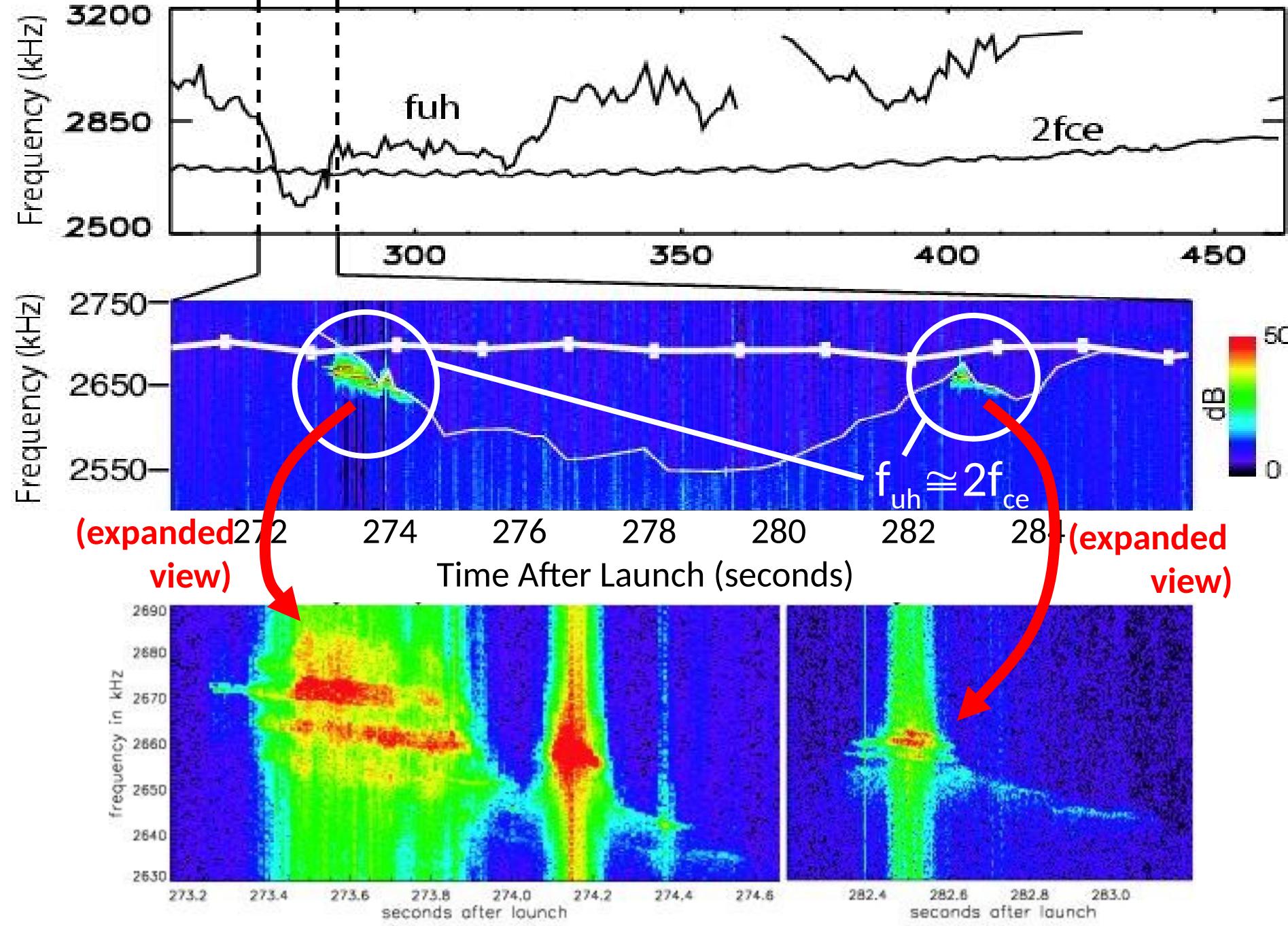
Fine frequency “multiplet” structure [LaBelle et al., 1995]



Circle Hot Springs, Alaska

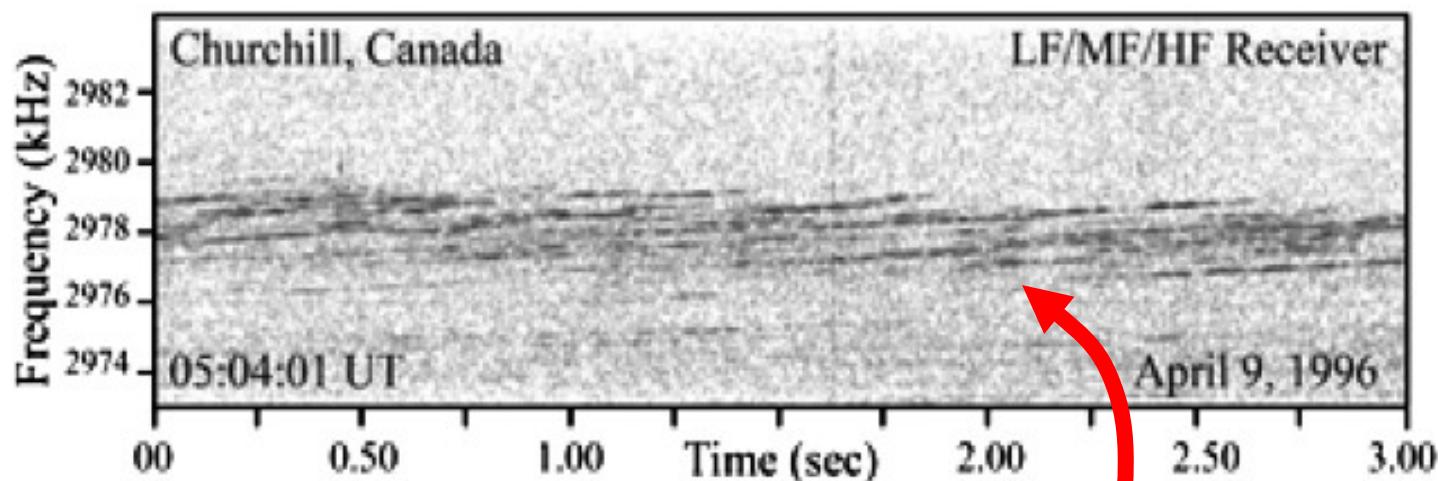
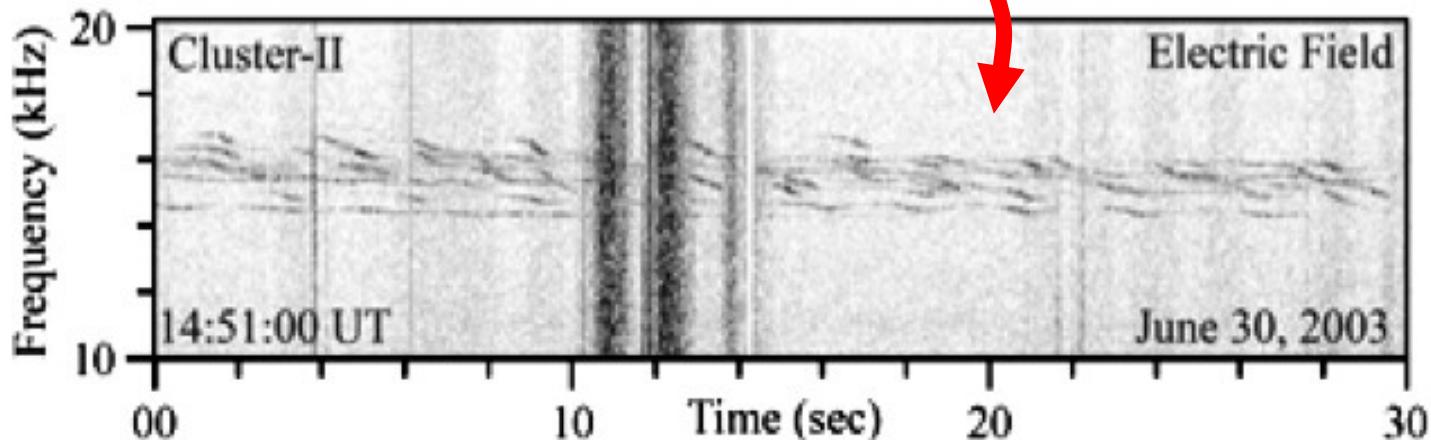






from: Samara et al., 2004

Escaping terrestrial continuum radiation (magnetosphere)



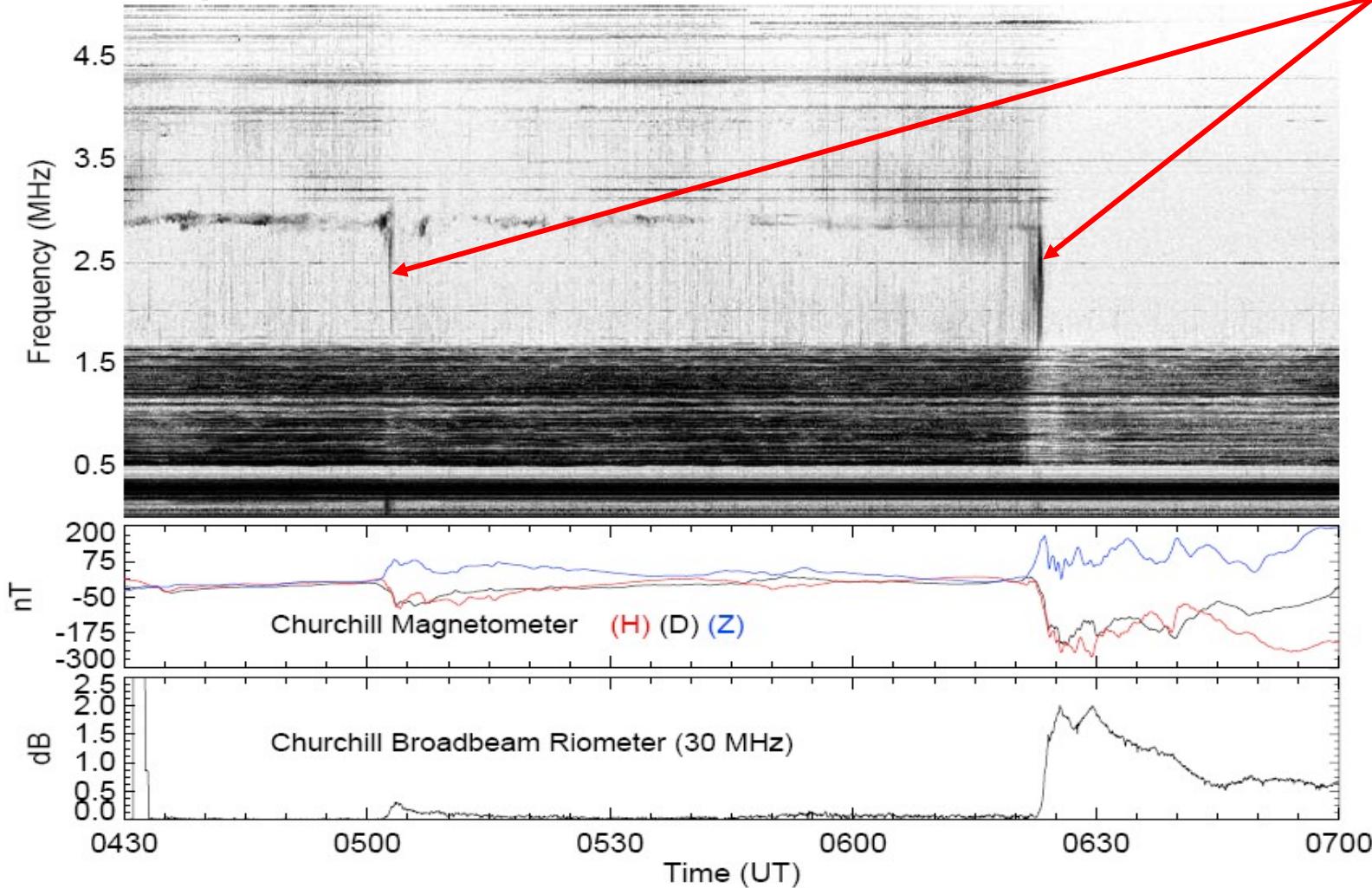
P.H. Yoon et al.: *Mode Conversion Radiation in the Terrestrial Ionosphere and Magnetosphere*,
Lect. Notes Phys. 687, 211–234 (2006)

Cyclotron harmonic radiation
(ionosphere)

April 11, 2004

Churchill, Manitoba

Auroral
MF Burst
Emission:
A signature
of substorm
onset

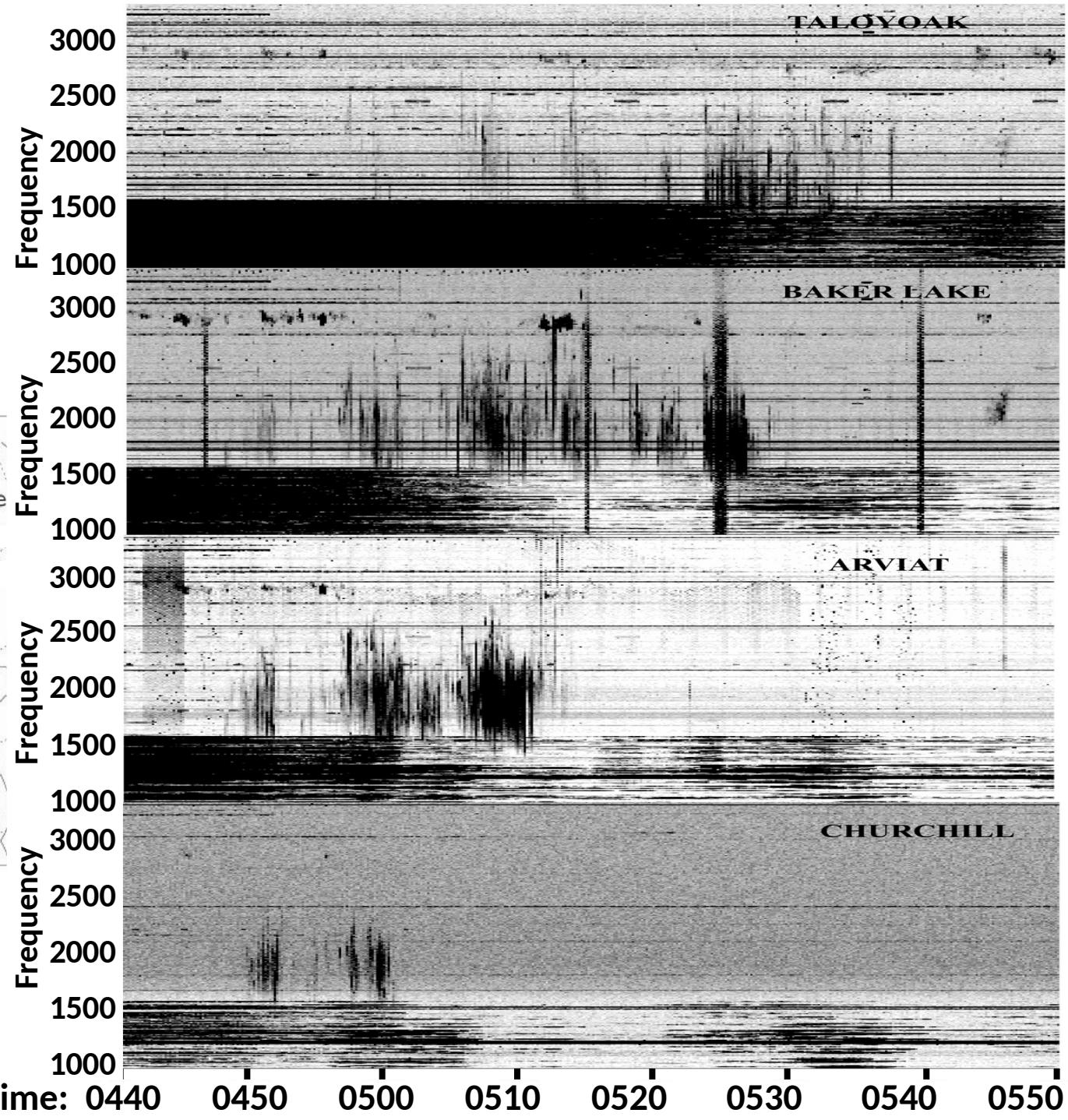


(Churchill magnetometer & riometer data courtesy of CANOPUS/CARISMA)

MF Burst Observed at multiple sites in Canada

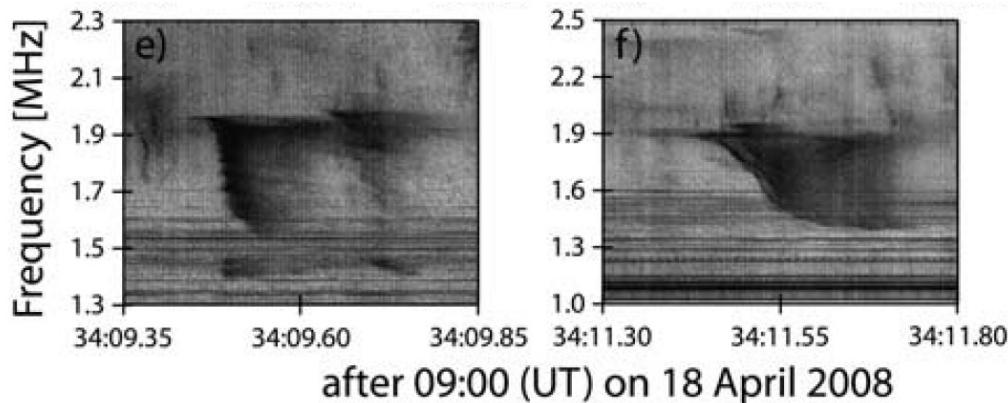


from: LaBelle et al.,
2005



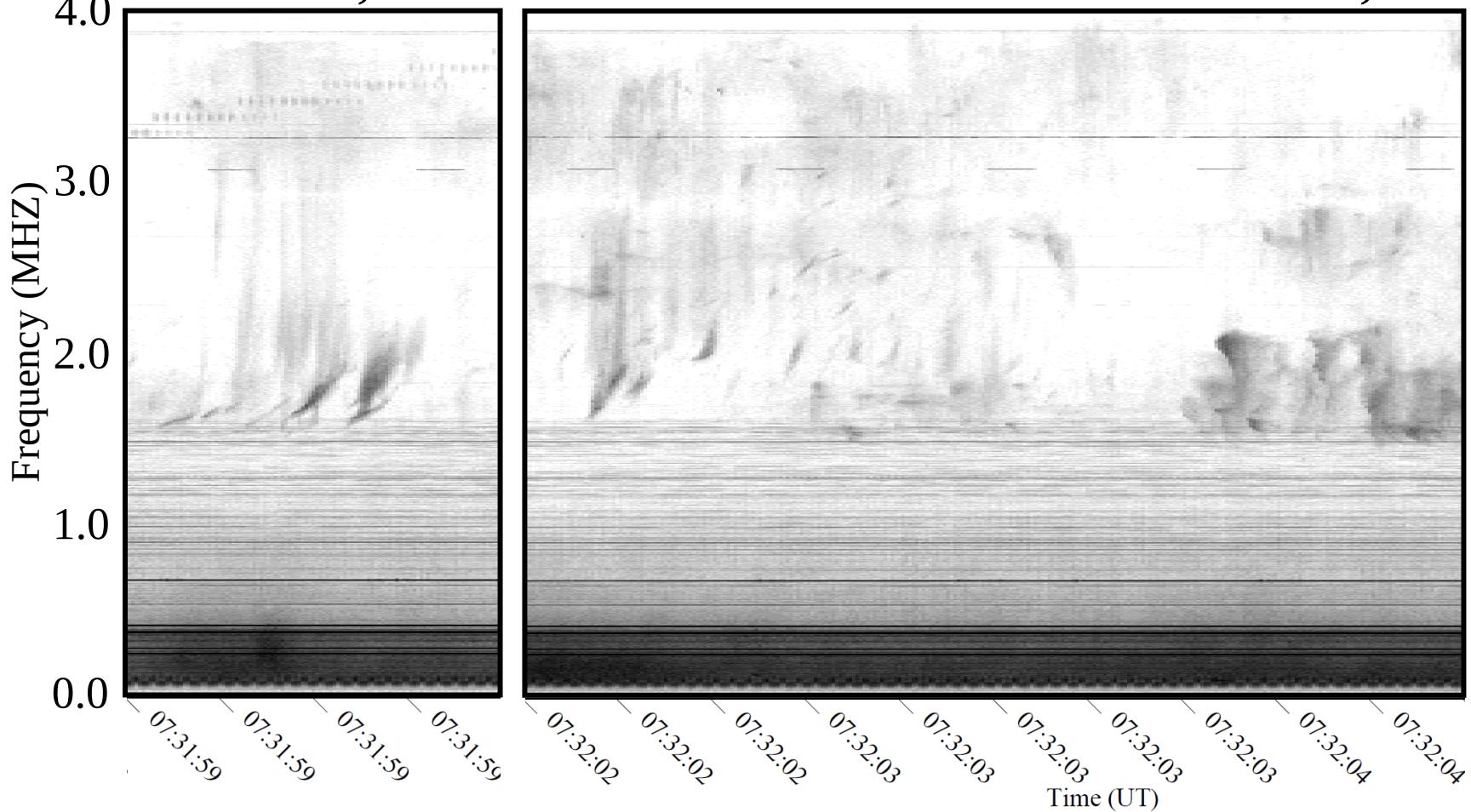
Structure in Auroral Medium Frequency Burst

Bunch and LaBelle, 2006

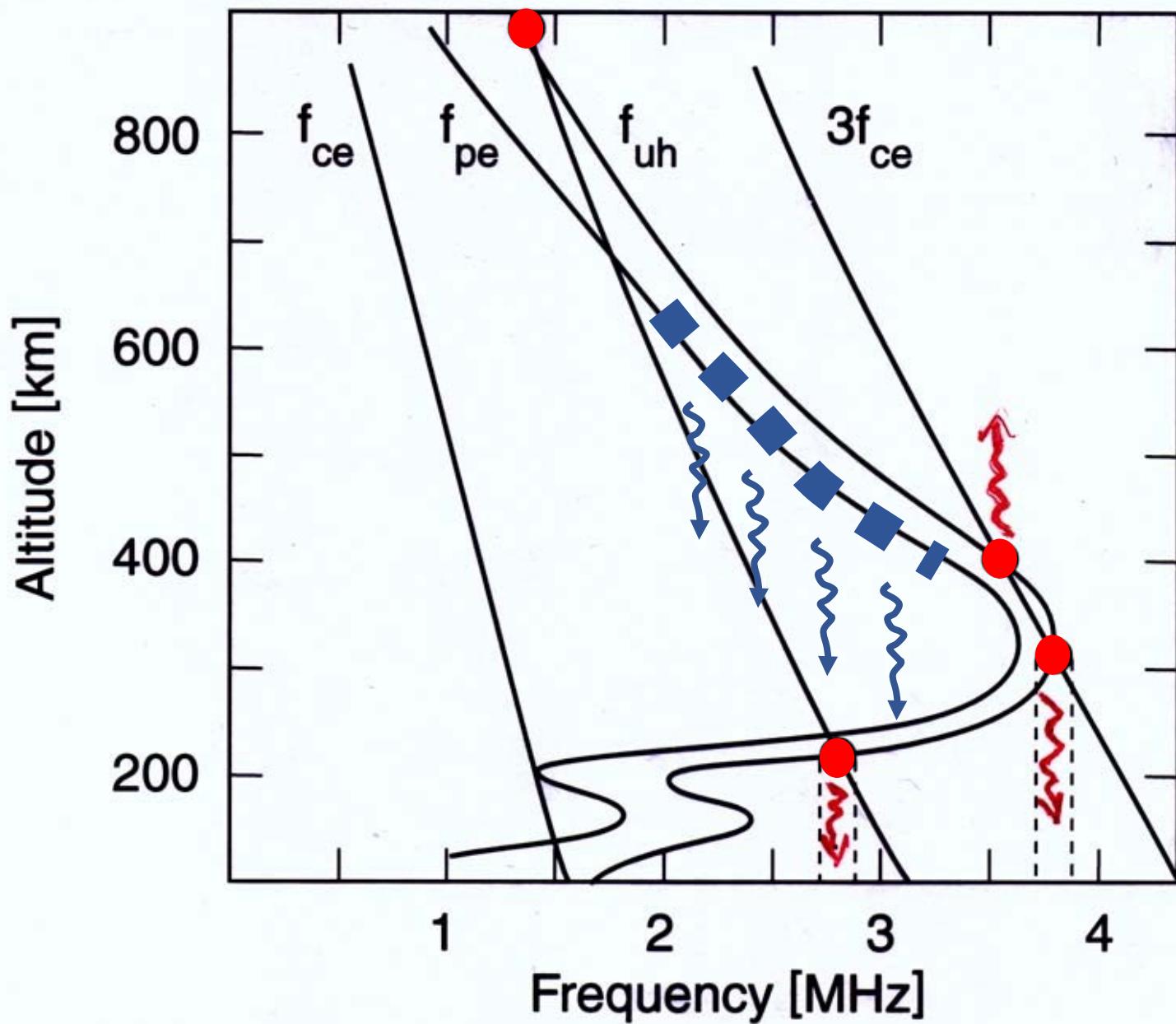


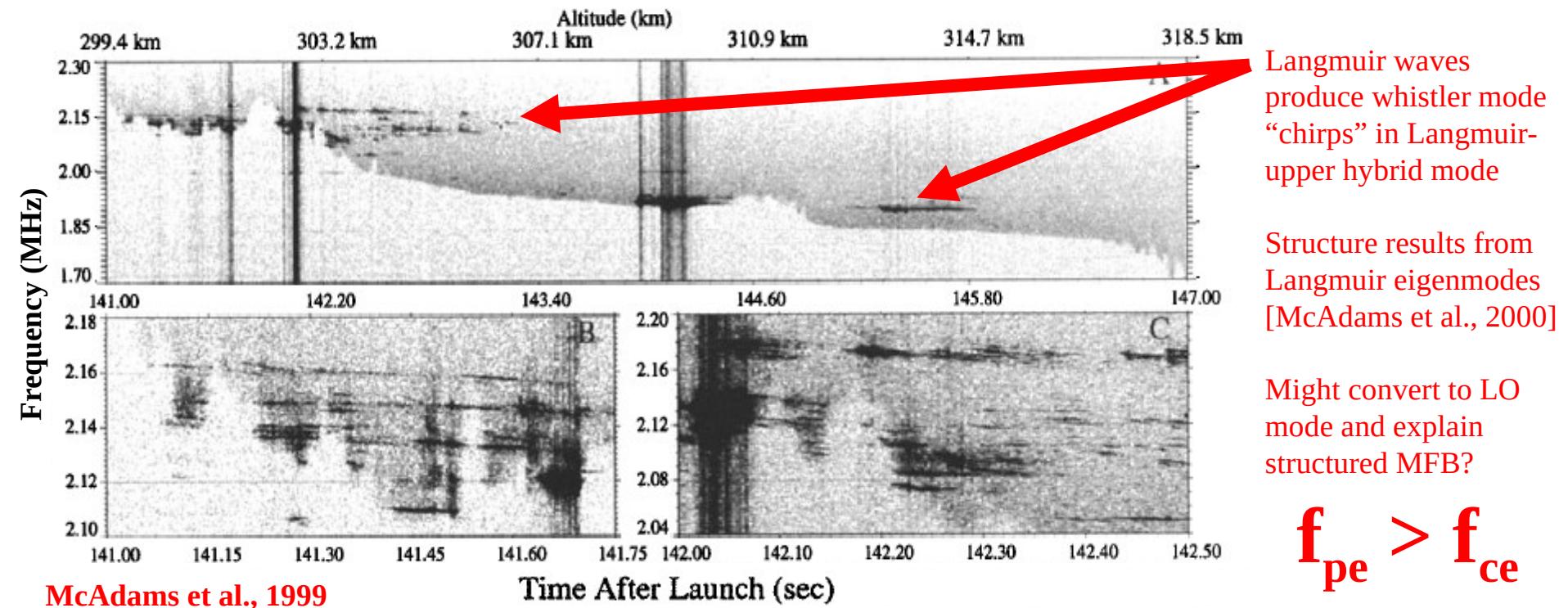
Oct 23, 2016

Toolik Lake, Alaska



Burst sources at “plasma resonance” conditions
Roar sources at “double resonance” conditions



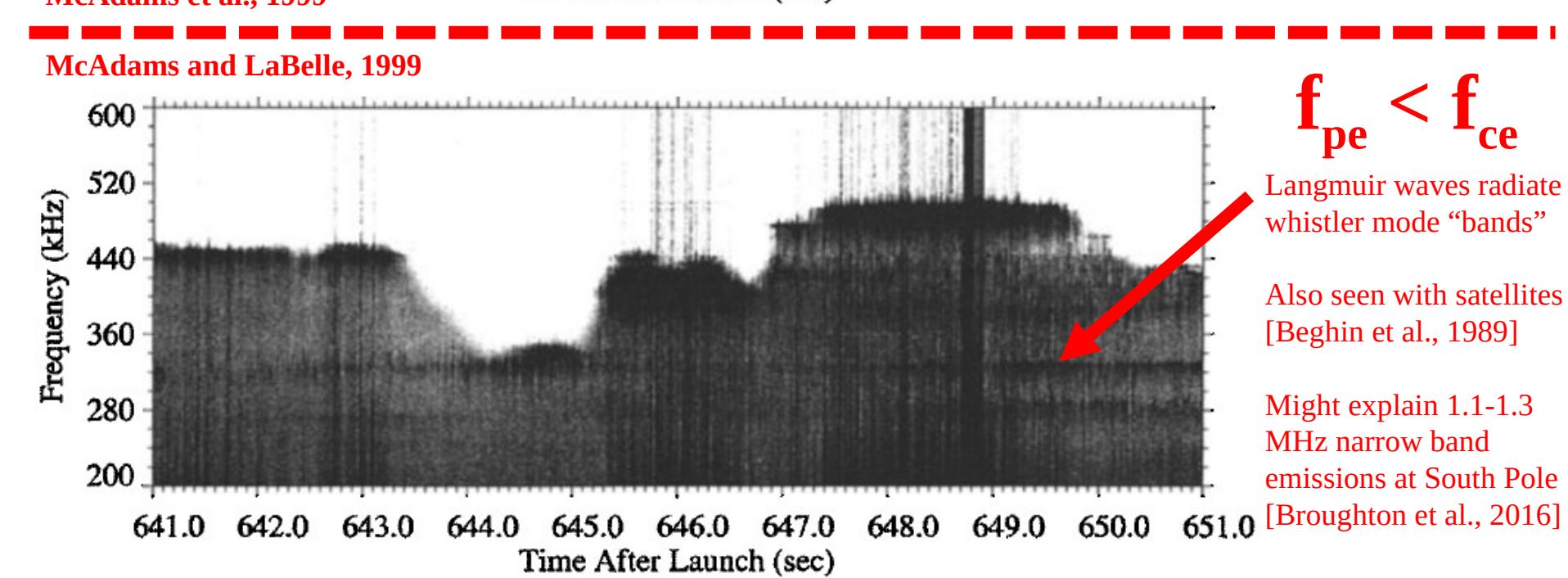


Langmuir waves produce whistler mode “chirps” in Langmuir-upper hybrid mode

Structure results from Langmuir eigenmodes [McAdams et al., 2000]

Might convert to LO mode and explain structured MFB?

$$f_{pe} > f_{ce}$$



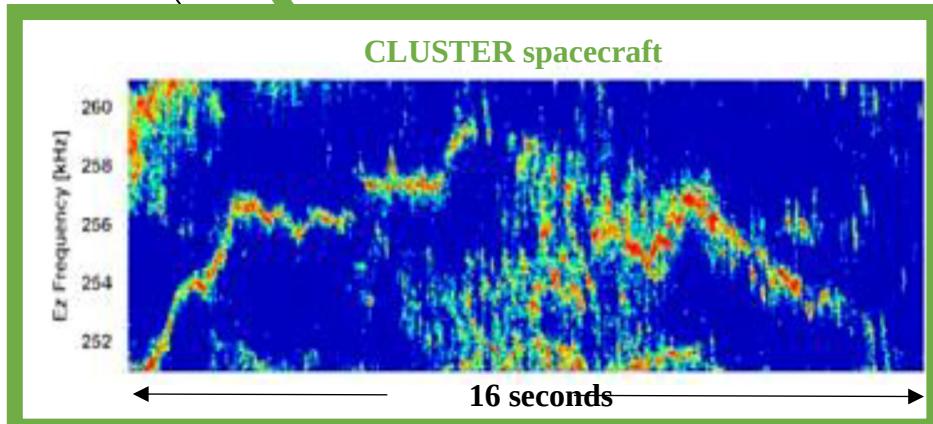
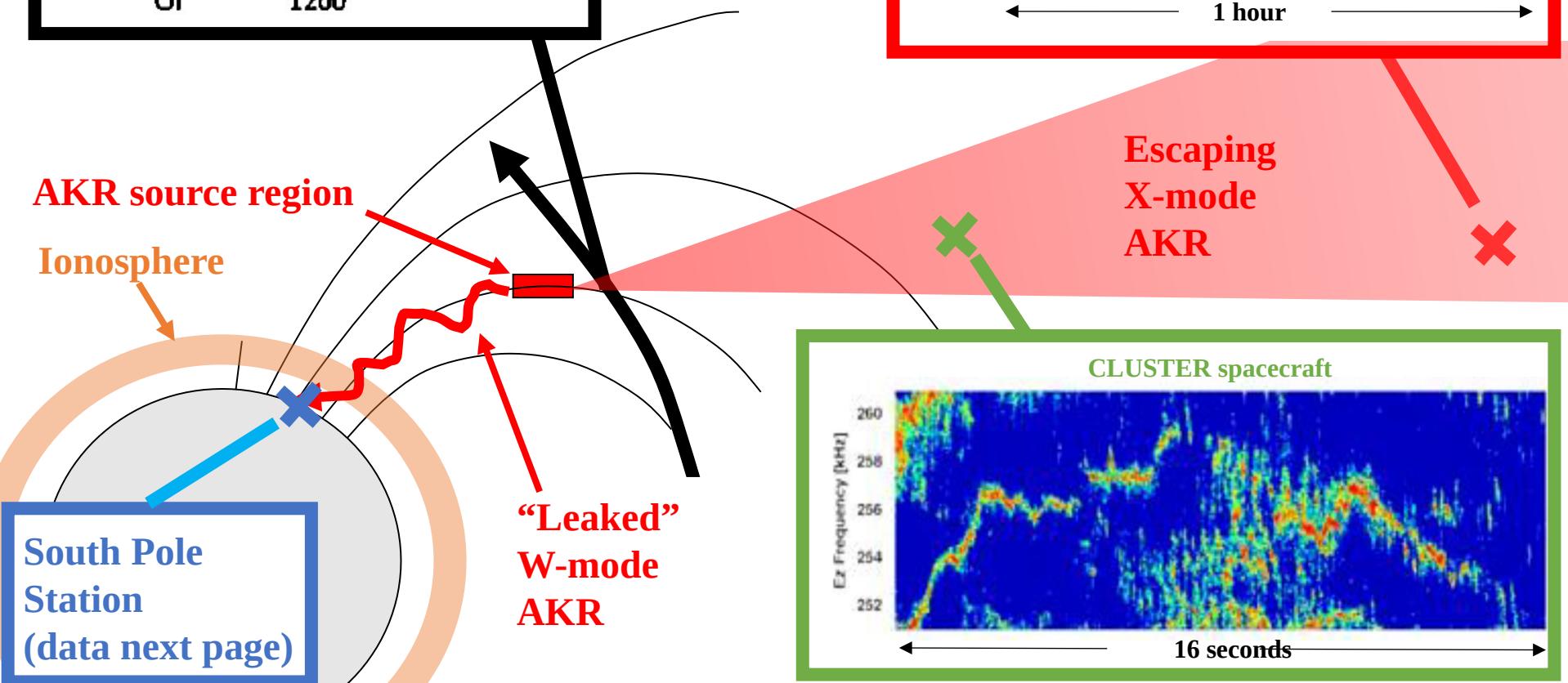
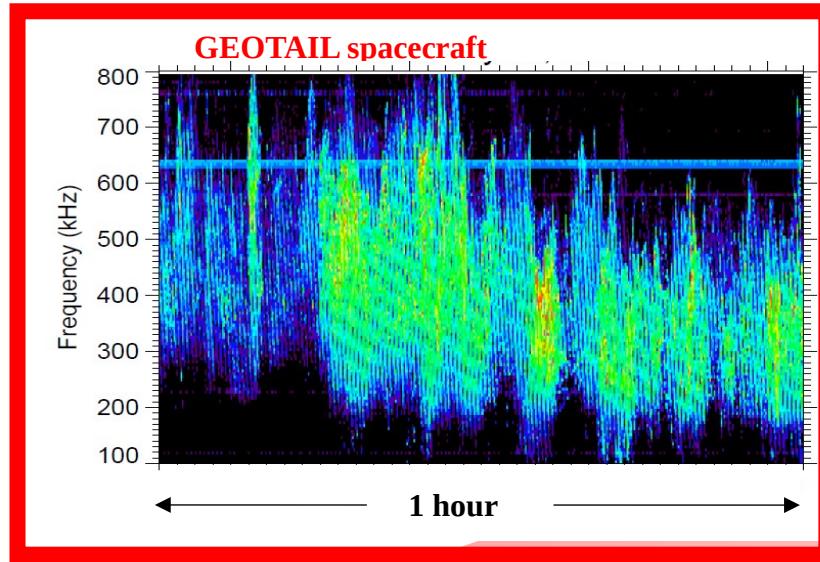
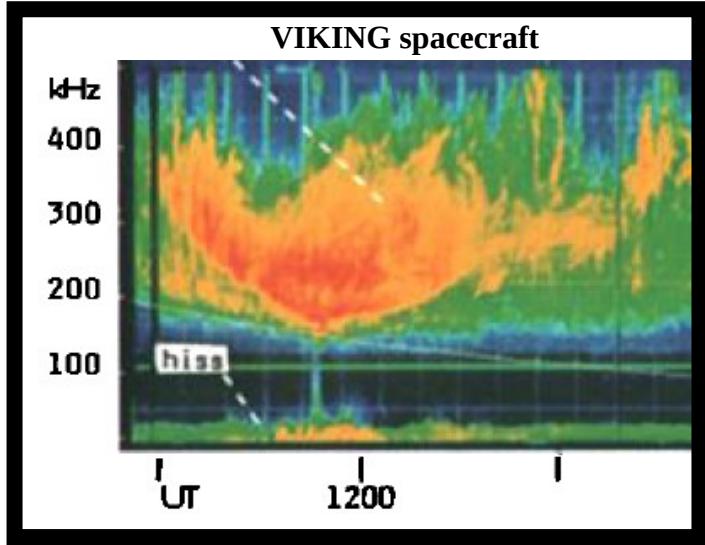
$$f_{pe} < f_{ce}$$

Langmuir waves radiate whistler mode “bands”

Also seen with satellites [Begin et al., 1989]

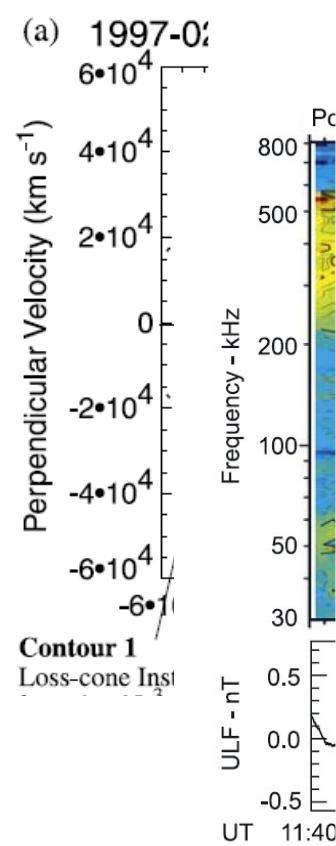
Might explain 1.1-1.3 MHz narrow band emissions at South Pole [Broughton et al., 2016]

Auroral Kilometric Radiation (AKR)



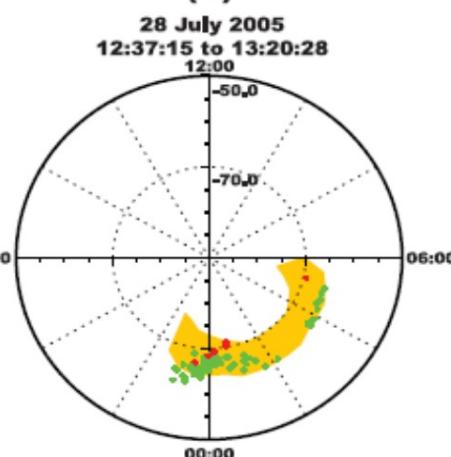
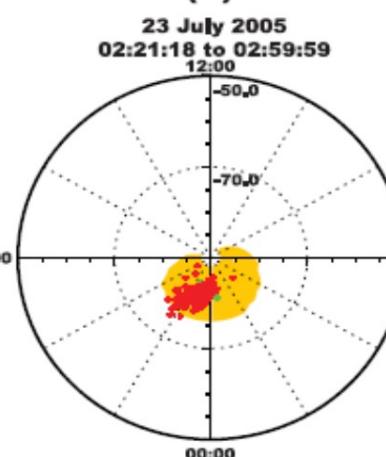
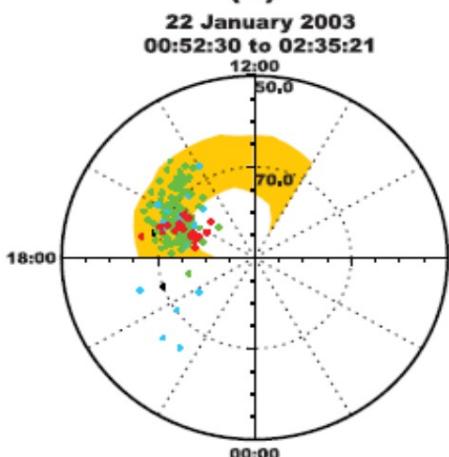
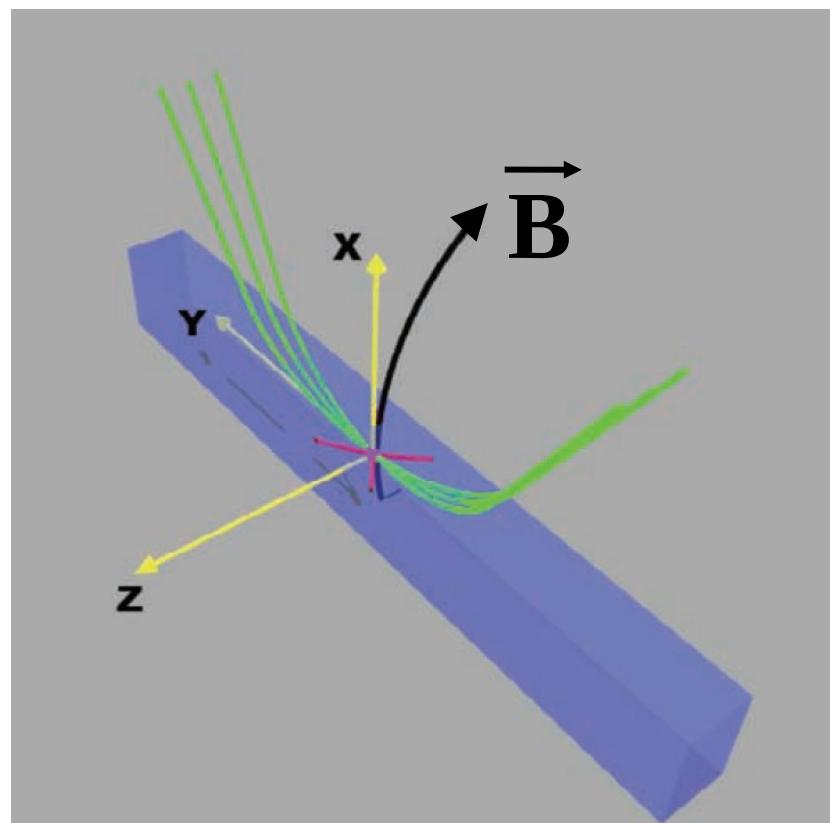
FAST satellite electron distribution

ii



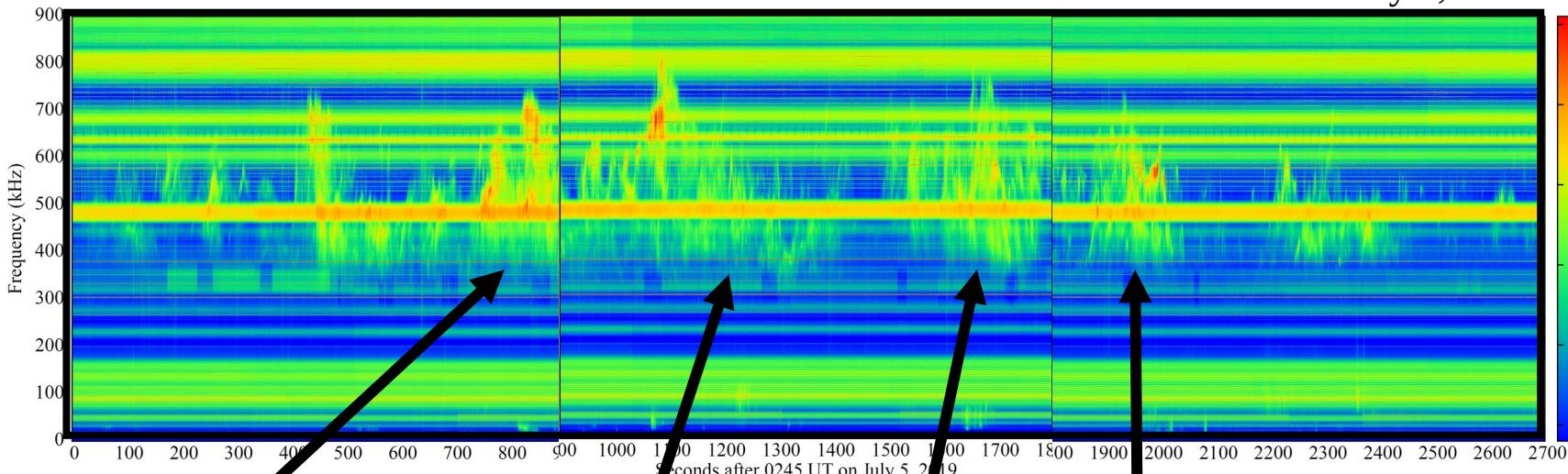
Cluster
satellites
interferometry

Mutel et al.,
2008

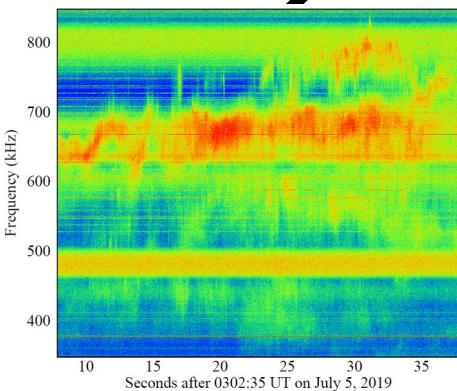


South Pole Station

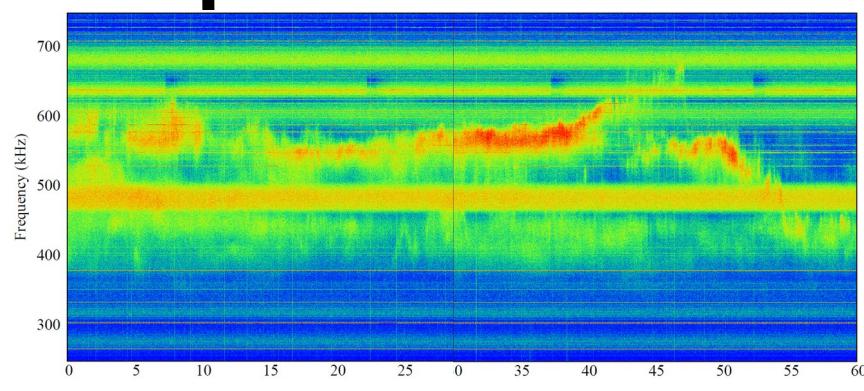
July 5, 2019



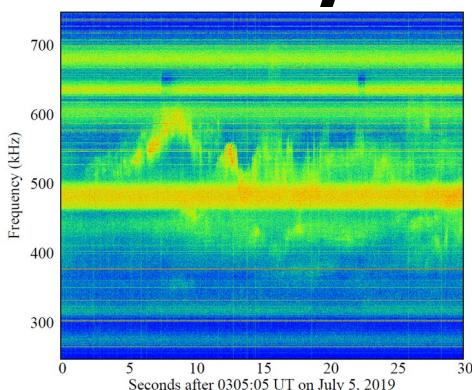
Seconds after 0245 UT on July 5, 2019



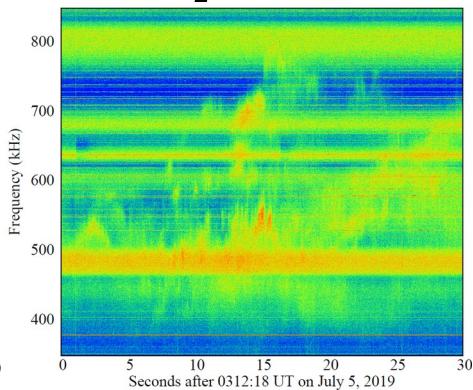
Seconds after 0302:35 UT on July 5, 2019



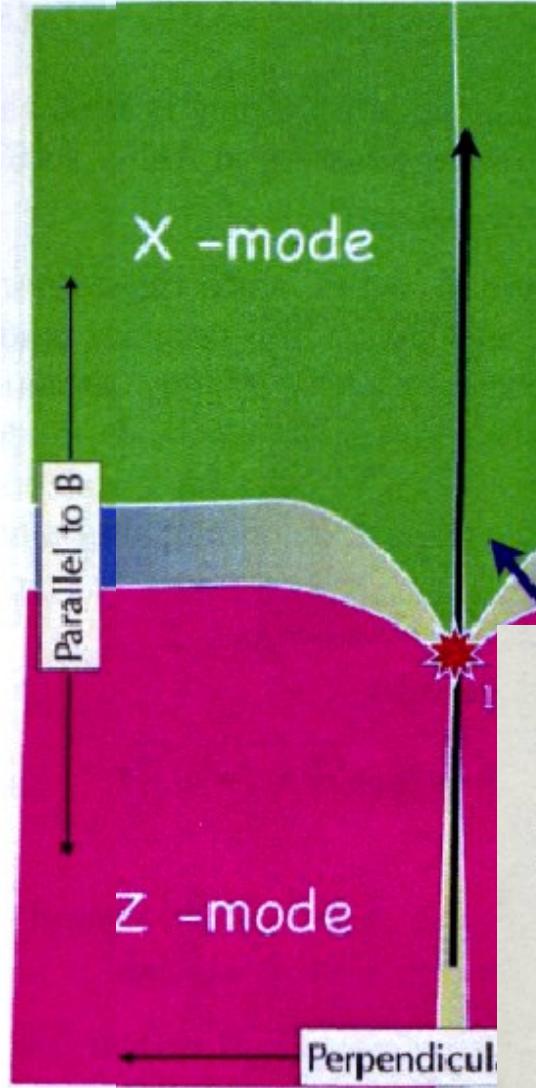
Seconds after 0317:35 UT on July 5, 2019



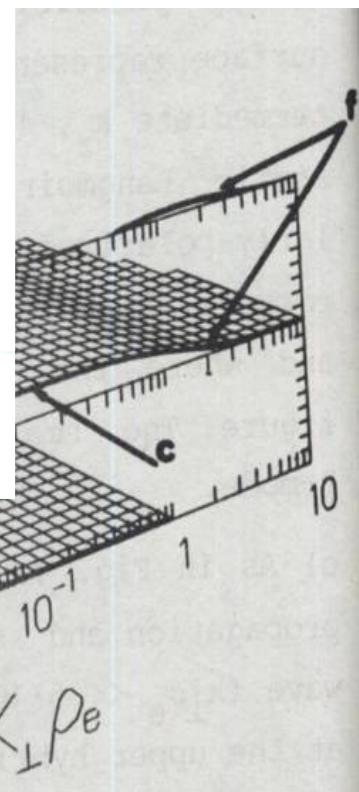
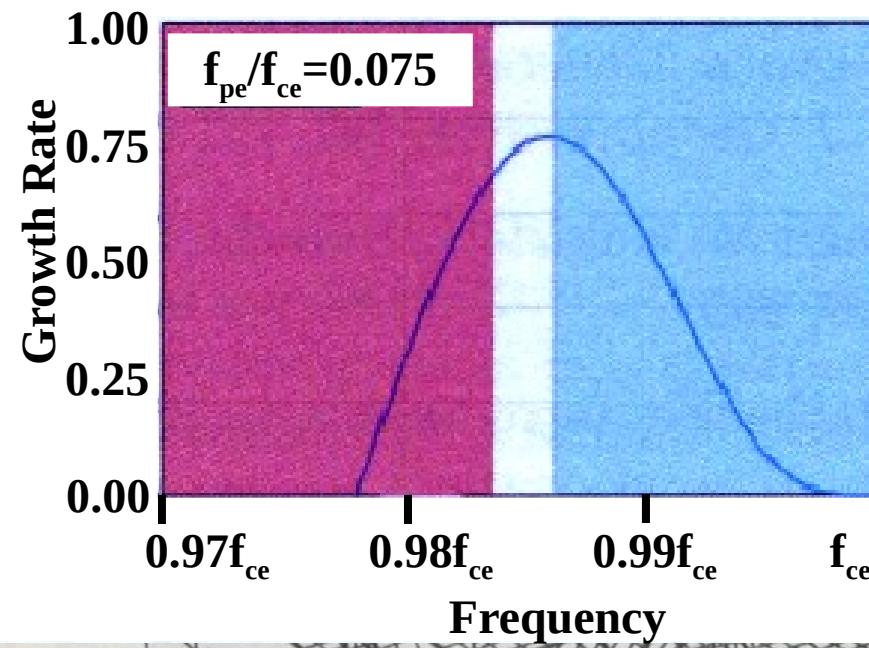
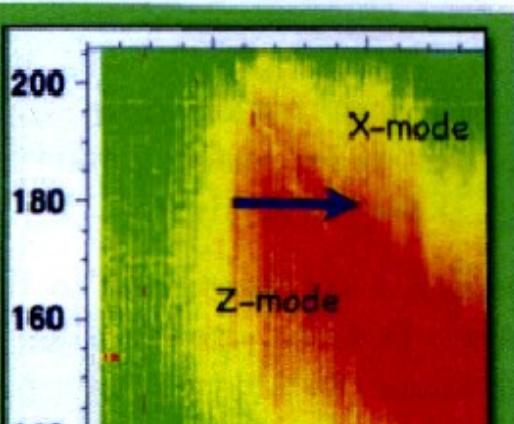
Seconds after 0305:05 UT on July 5, 2019

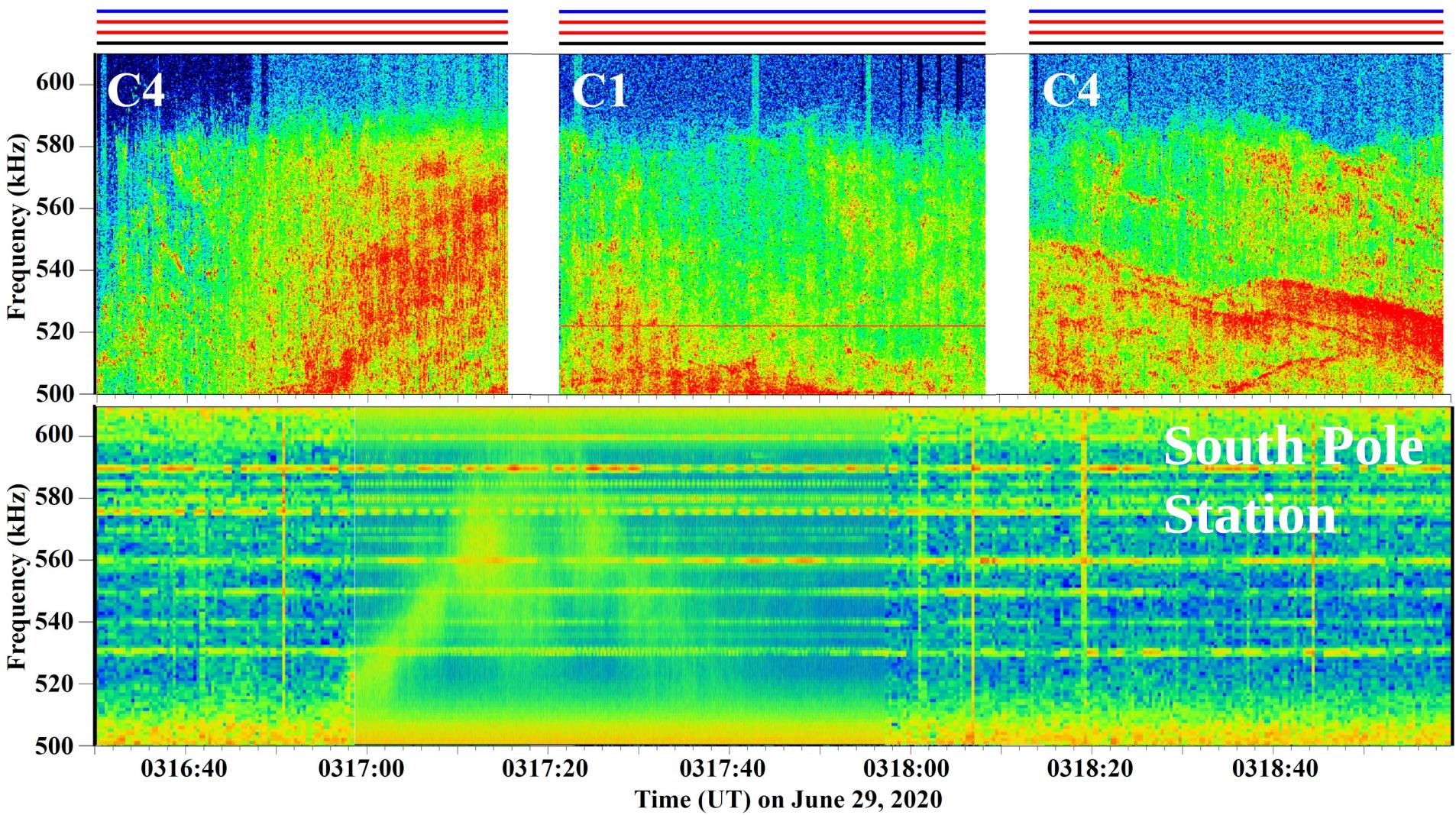


Seconds after 0312:18 UT on July 5, 2019



(from Mutel et al., in Planetary Emissions VII, Austrian Acad





Collaboration between J. LaBelle, K. Yearby, and J. Pickett

Types of Auroral radio emissions

Type	frequency	source region	mechanism
Auroral Hiss	<1 MHz (below f_{ce})	1000 km to 30000 km	Landau resonance w/auroral e-beam parallel to B
AKR	50-900 kHz (below f_{ce})	Auroral Acceleration region 2000 km to 20000 km	Cycl maser from horseshoe distr
Auroral Roar	~3,4,3,5,6,6.5 MHz (2-5 f_{ce})	Discrete altitudes in F-region 250-450 km where $f_{uh} = Nf_{ce}$	Cycl maser where $F = f_{uh} = Nf_{ce}$ mode conversion
Medium Freq Burst	1.5-4.5 MHz (above f_{ce})	Not known for sure. Thought to be Topside E- and F-region, 200-800 km	Thought to be Mode conv of Langmuir waves excited by e beam
Auroral Z-mode emissions	10's to 100's of kHz	>500 km	Mode conv of Langmir/UH excited by e-beam, loss cone