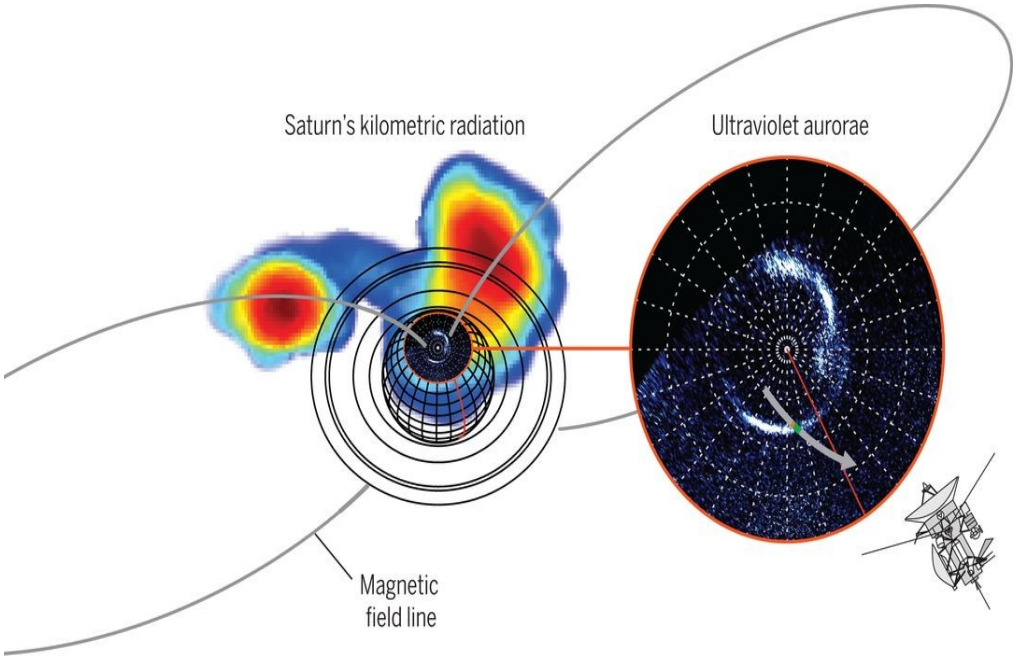
Reanalysis of SKR source crossed by Cassini: Loss cone electrons as a secondary source of free energy

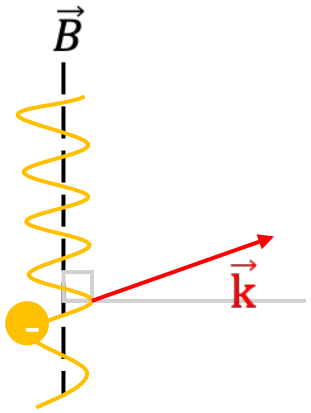
Collet B.[1], Lamy L[2,3]., Kasaba Y.[1], Andre N.[4,5]
[1]Tohoku University, Japan [2]LAM, AMU, France [3]LIRA, Obs Paris, France [4]IRAP, France [5]ISAE-Supaero, France



Lamy et al. (2018)

- Saturn Kilometric Radiation: radio auroral emission generated by the CMI
- Cassini's in situ radio and electron in a single source (2008-291)
- Fundamental mechanism in plasma physics: **wave-plasma instability**
- Saturn auroral acceleration regions
- Comparative planetology (Jupiter, Earth, Uranus, Neptune,...)

The Cyclotron Maser Instability (CMI)



Wave-plasma instability introduced at Earth amplifies waves at :

$$\omega = \frac{\omega_{ce}}{\Gamma} + k_{||} v_{||}$$

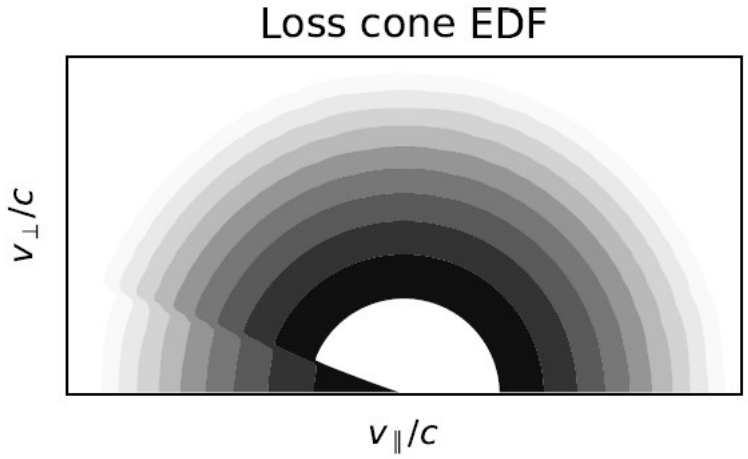
(Wu & Lee 1979)

f~fce
Quasi perpendicular to B

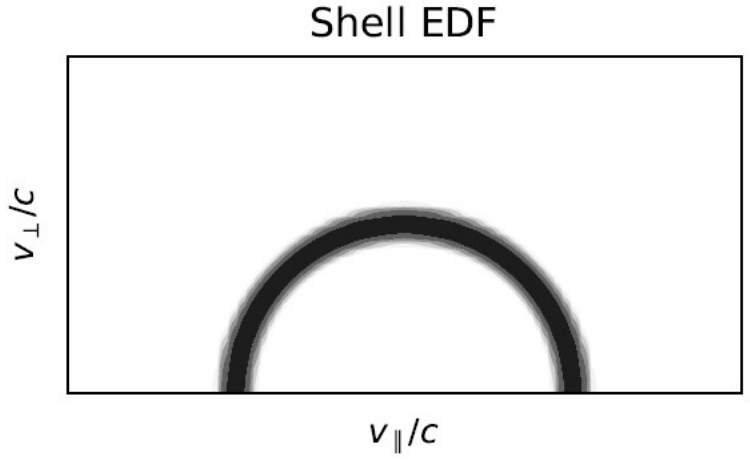
And requires:

- Depleted magnetized plasma fpe/fce<<1
- Inversion of population for electrons of few keV = diagnostic of auroral acceleration.

The Cyclotron Maser Instability (CMI)
2 main types of unstable distributions



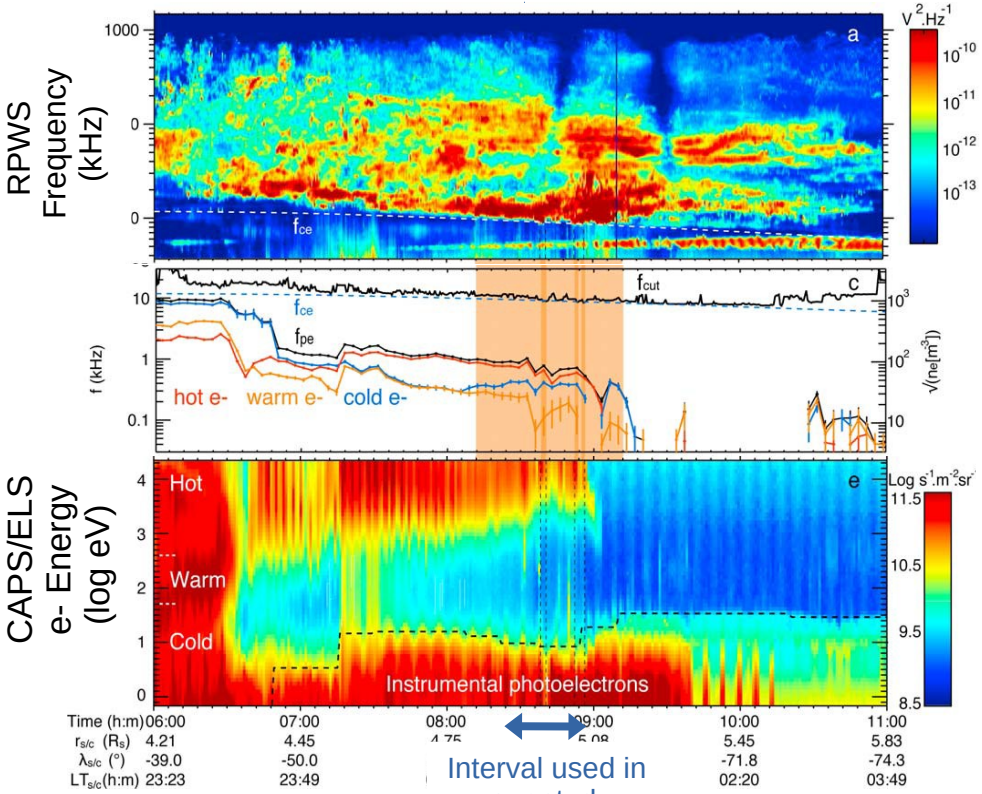
Produces emissions above fce
Quasi perpendicular to B



Produces emissions below fce
Perpendicular to B

Previous works

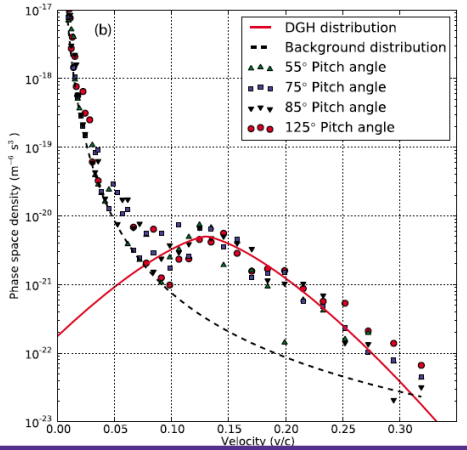
SKR source crossing on 2008-291



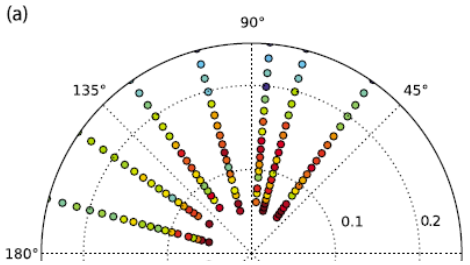
Lamy et al. (2010)

- Source identified with f<fce
- During a solar compression
- Upward field aligned current (FAC)

- Unstable distribution: 6-12 keV shell
- Far from Saturn (r ~5 R_S) => theoretical loss cone(5~10°) close to angular resolution (7.5°)

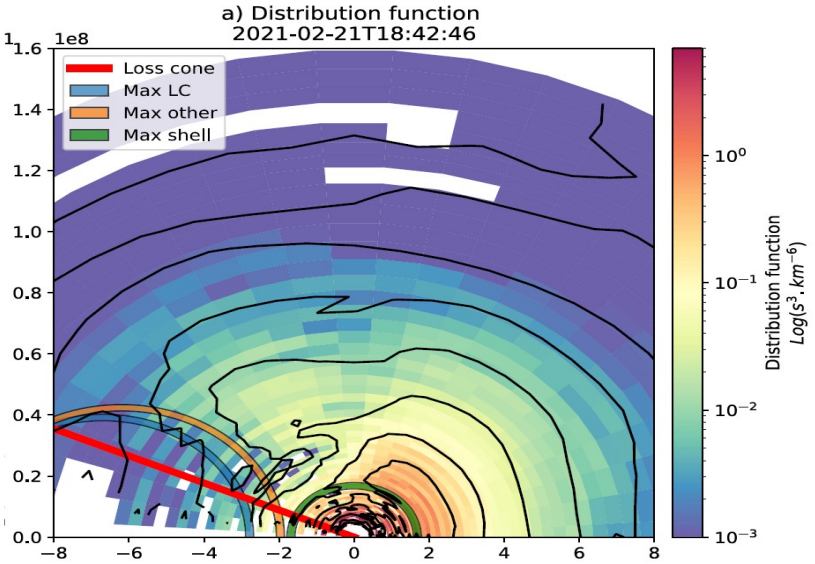


Mutel et al. (2010)



Previous works

Jovian radio source crossed by Juno

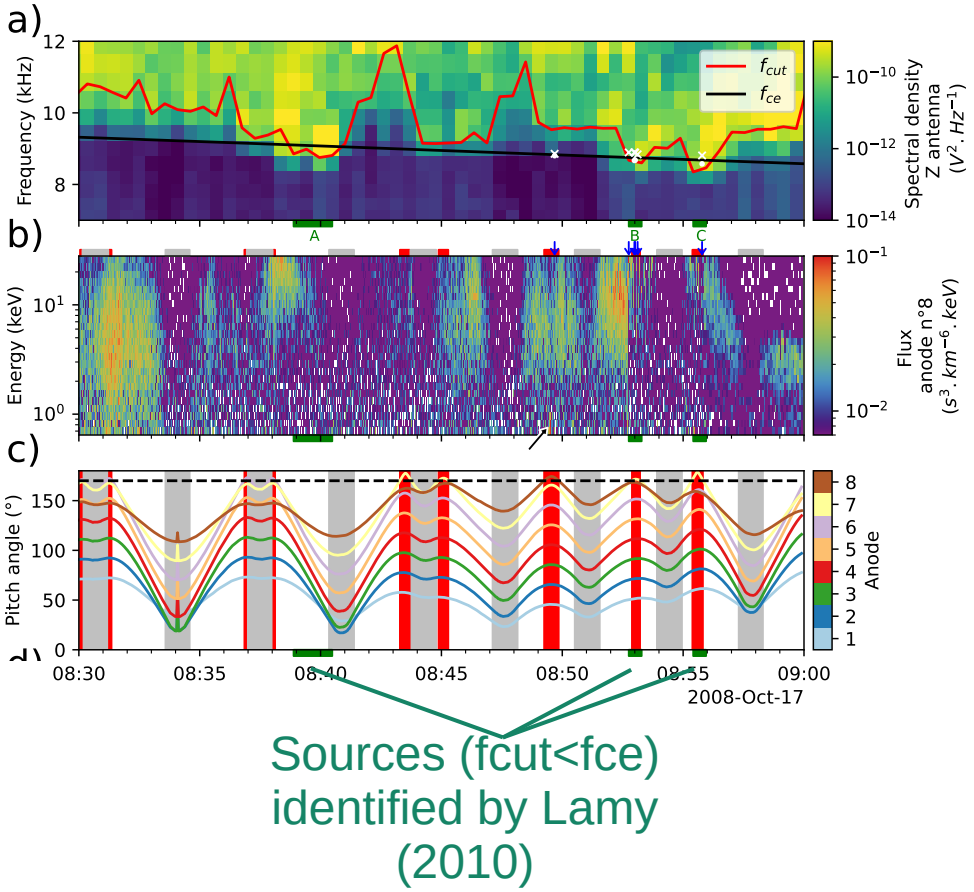


(Collet et al. 2024)

- Same generation mechanism
- Also located in upward FAC and connected to UV aurora
- Different source of free energy:
  - Mostly loss cone (Alfvenic acceleration)
  - Shell in 18% source associated with LC

Can LC be CMI unstable at Saturn too ?

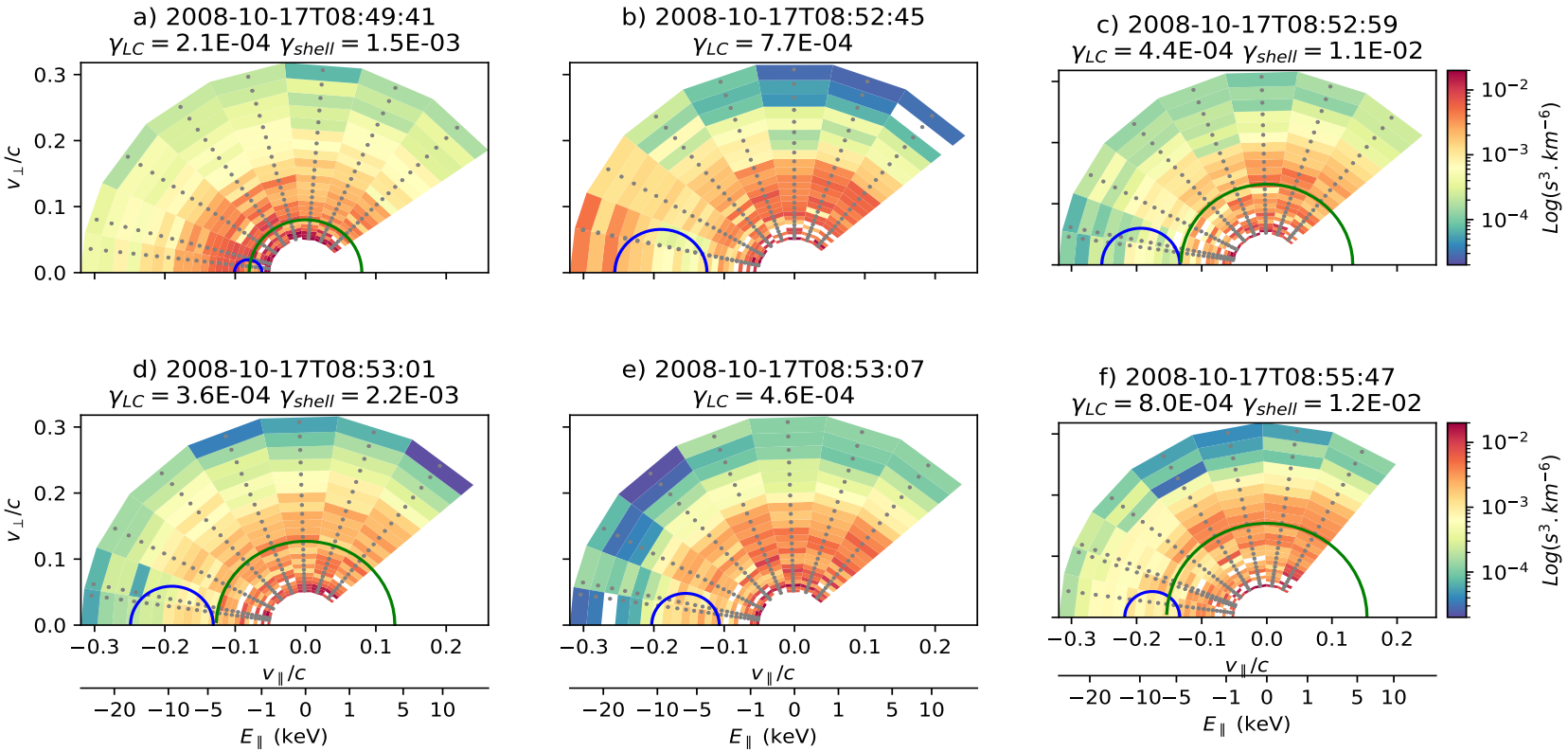
Methods



Sources (fcut<fce) identified by Lamy (2010)

- Identify regions where no instrumental shadowing and pitch angles > 170 are sampled (83 measurements)
- Identify by eye empty loss cone

Results

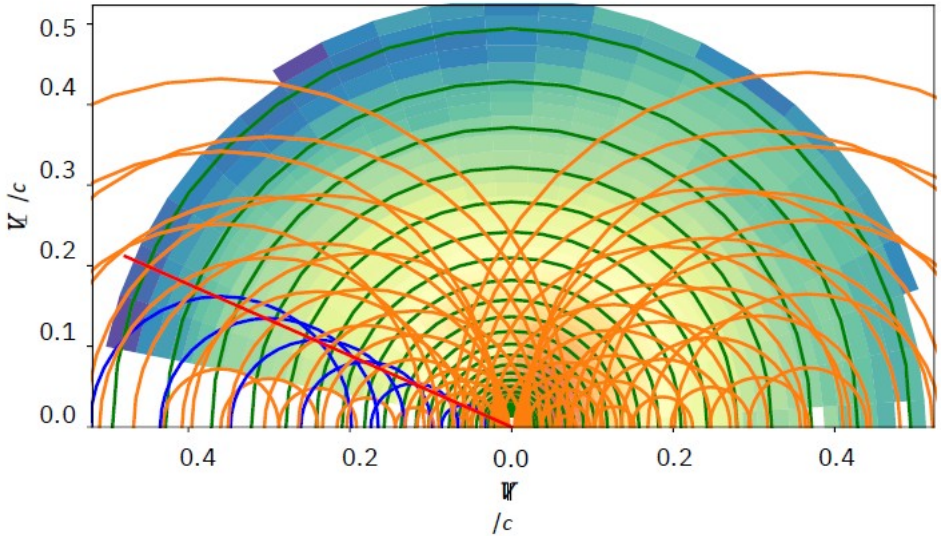


Loss cone is indeed empty !

Results

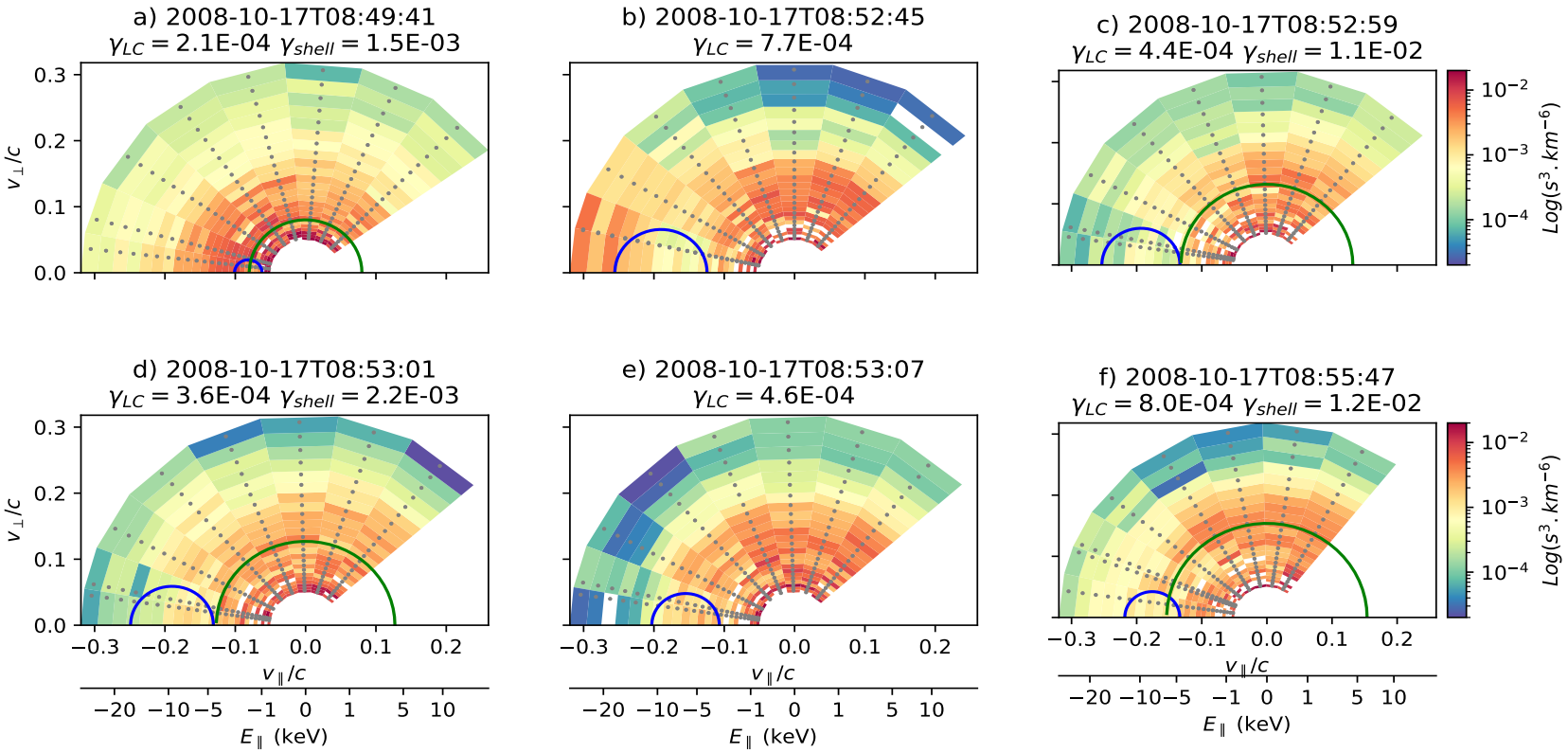
Are these distributions CMI unstable ?

CMI growth rate $$\gamma \propto \int_{circle} \frac{dF_e}{dv_\perp}$$



For each measurements we keep only the maximal growth rate

Results

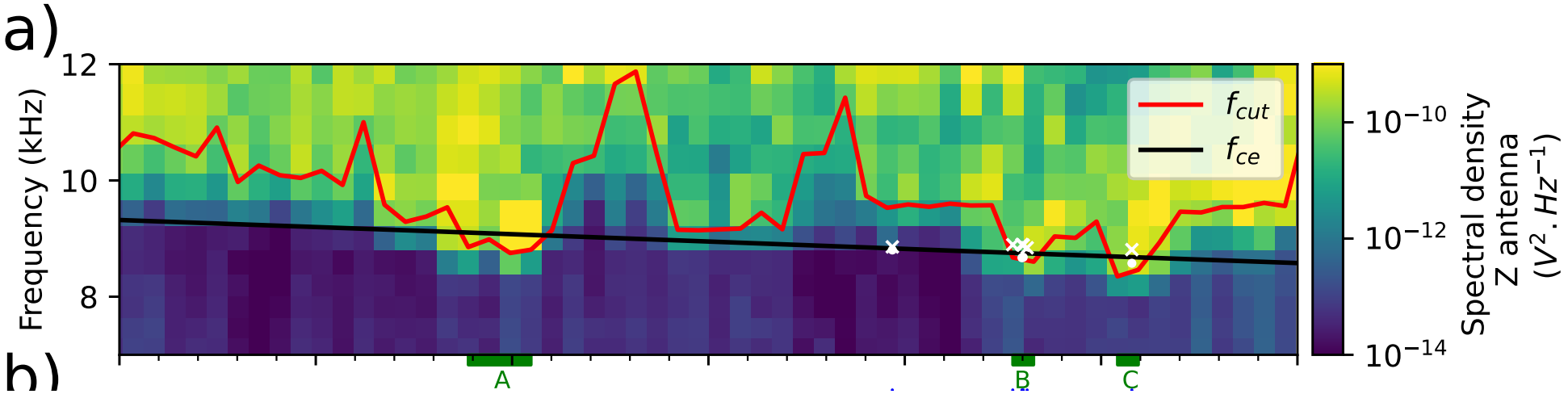


Indeed unstable!

But LC-growth rates 2 orders of magnitude less tham shell-growth rates

Results

How does it compare to radio measurements ?



Unstable LC indeed identified in source crossing
Frequency resolution is only 5%
Not enough to distinguish emissions above/below fce

Conclusions

- We looked for empty loss cone (LC) during SKR source crossing and found **6 unstable cases**.
- Positive growth rate =>LC is unstable in SKR source
- LC seen **simultaneously** with shell
- Radio instrument frequency resolution does not allow to verify simultaneous emissions
- Similar to Jovian case: Universal mechanism?
- What about High frequency SKR where LC is larger ?

Submitted to GRL

Results

Beaming ?

Shell should only produce emission at 90°

Refraction effects at the source ?
Contribution of Loss cone ?