

Reanalysis of SKR source crossed by Cassini:

Loss cone electrons as a secondary source of free energy

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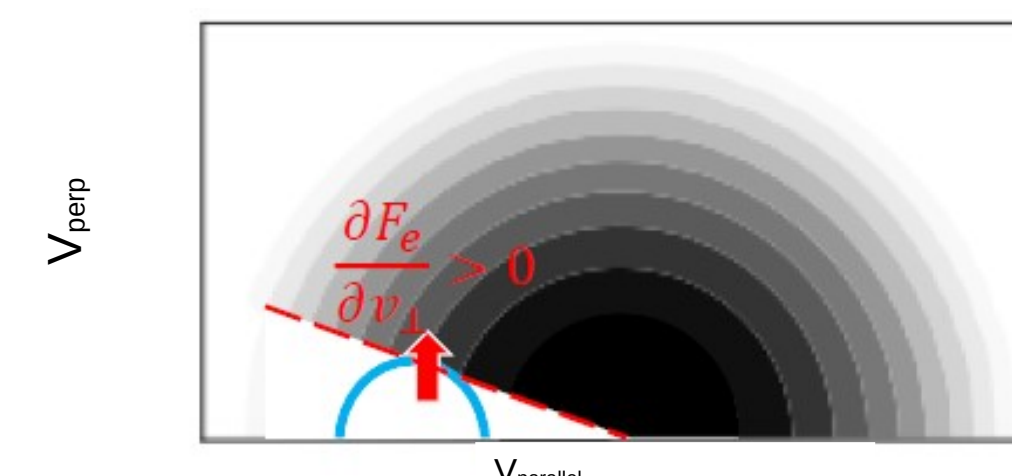
Introduction

The **Cyclotron Maser Instability**: Wave-plasma instability introduced at Earth amplifies freely propagating waves at

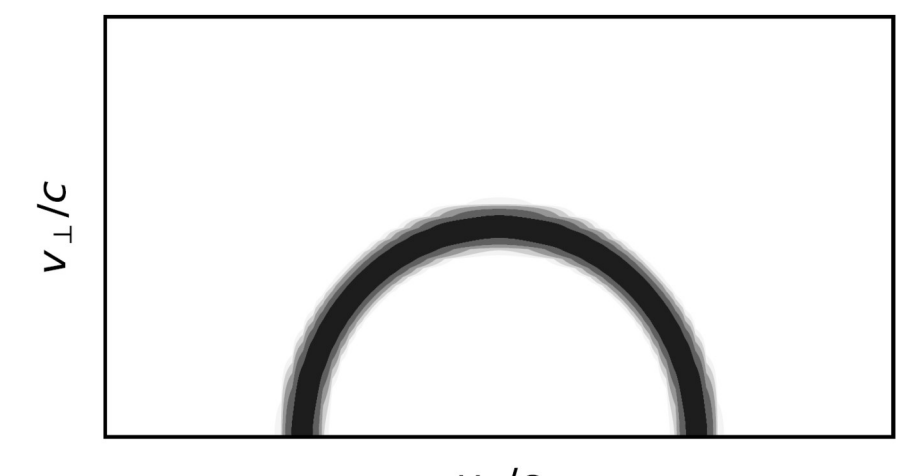
$$\omega = \frac{\omega_{ce}}{\Gamma} + k_{\parallel} v_{\parallel} \quad \text{f-fce} \quad \text{Quasi perpendicular to B} \quad \text{Wu et al. (1979)}$$

Requires:

- Depleted magnetized plasma fce/fpe << 1
- Inversion of population for electrons of few keV = **diagnostic of auroral acceleration**
- 2 main distribution types:



Loss cone => oblique emissions f > fce
E- loss by collision with atmosphere
Main source at Jupiter (Louarn+ 2017)

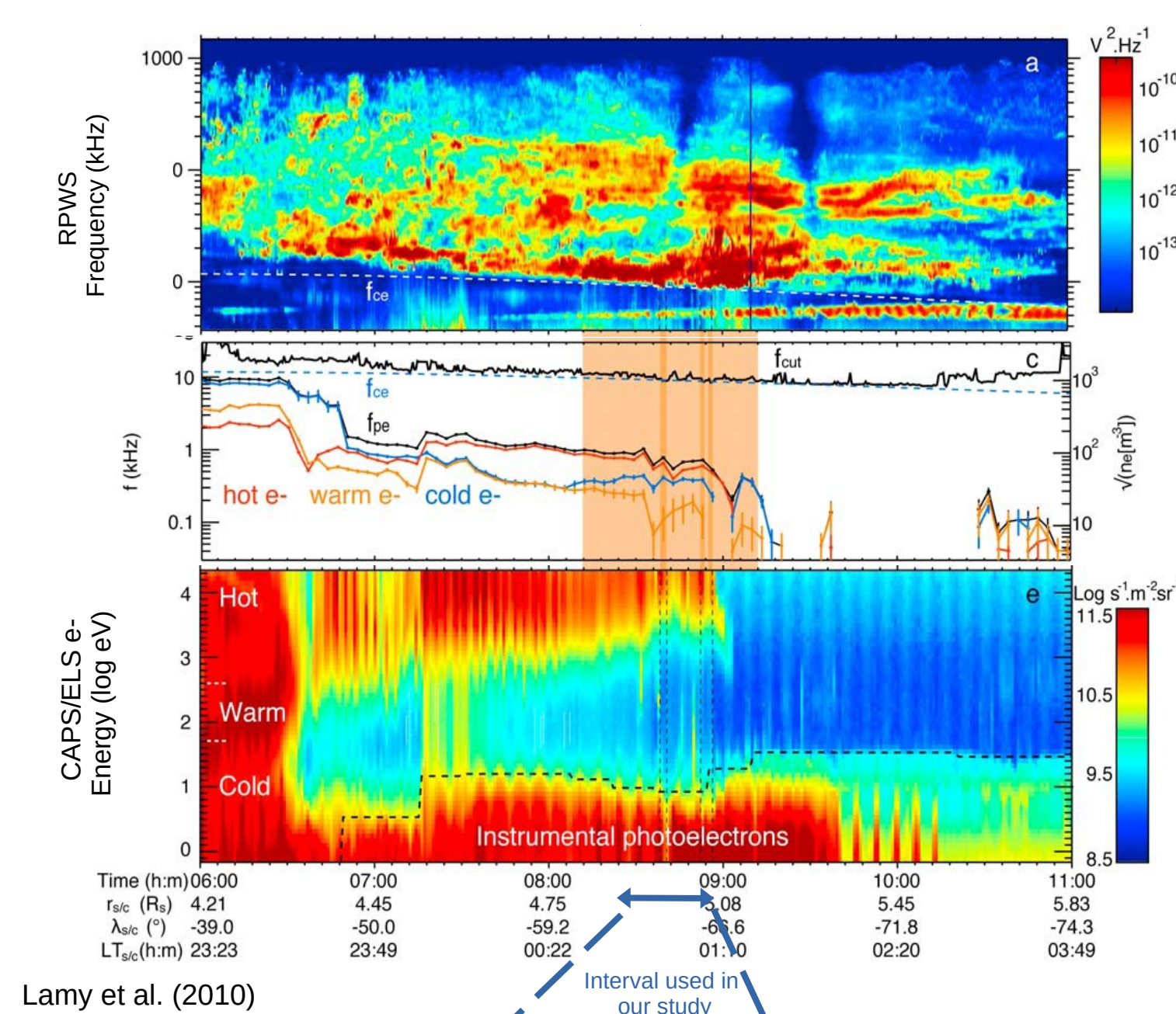


Shell => perpendicular emissions f < fce
Generated by monoenergetic accelerations
Source at Earth & Saturn

- 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**
- Connected to Saturn auroral acceleration regions
- Comparative planetology (Jupiter, Earth, Uranus, Neptune,...)

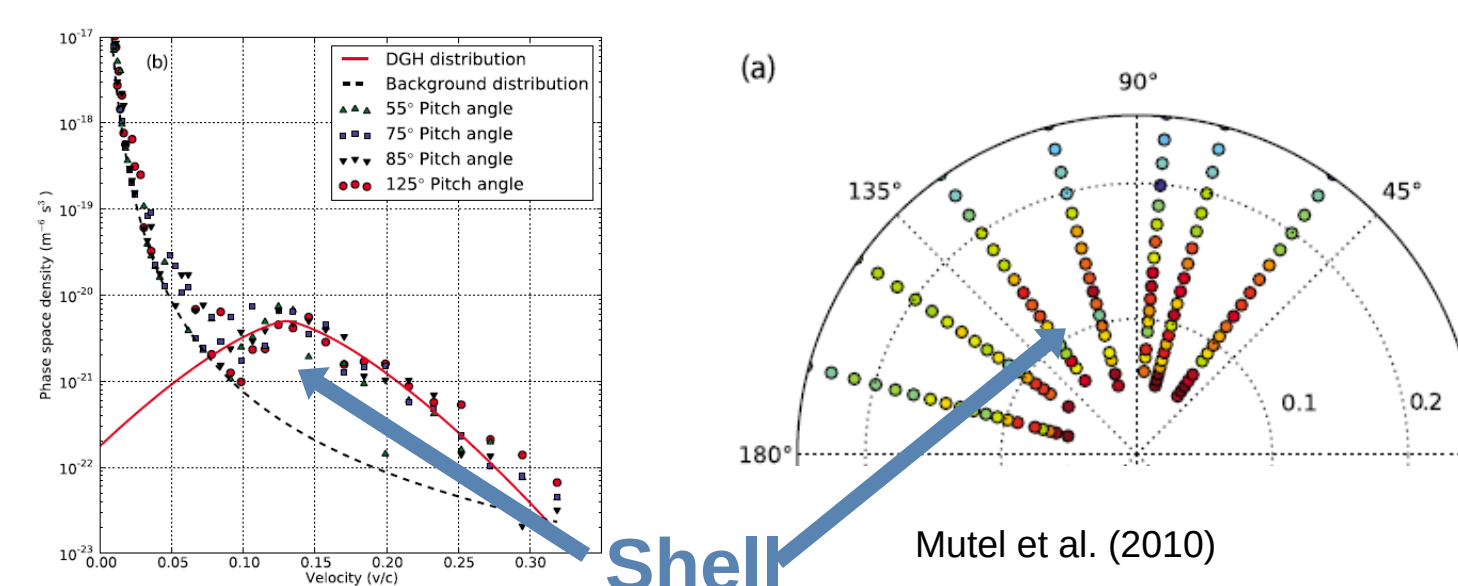
Previous works

SKR source crossed by Cassini on 2008-291

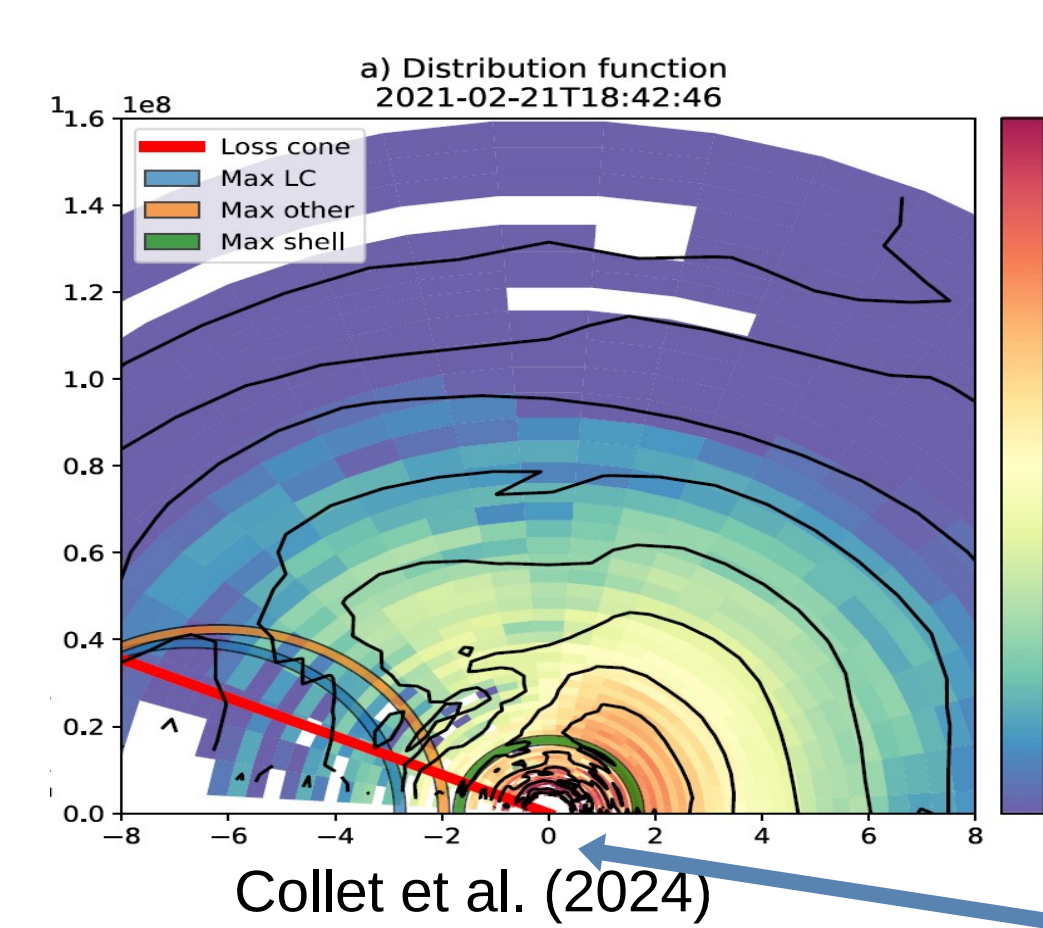


- Source identified with **f < fce**
- During a solar compression
- Upward field aligned current (FAC)

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



Jovian radio source crossed by Juno

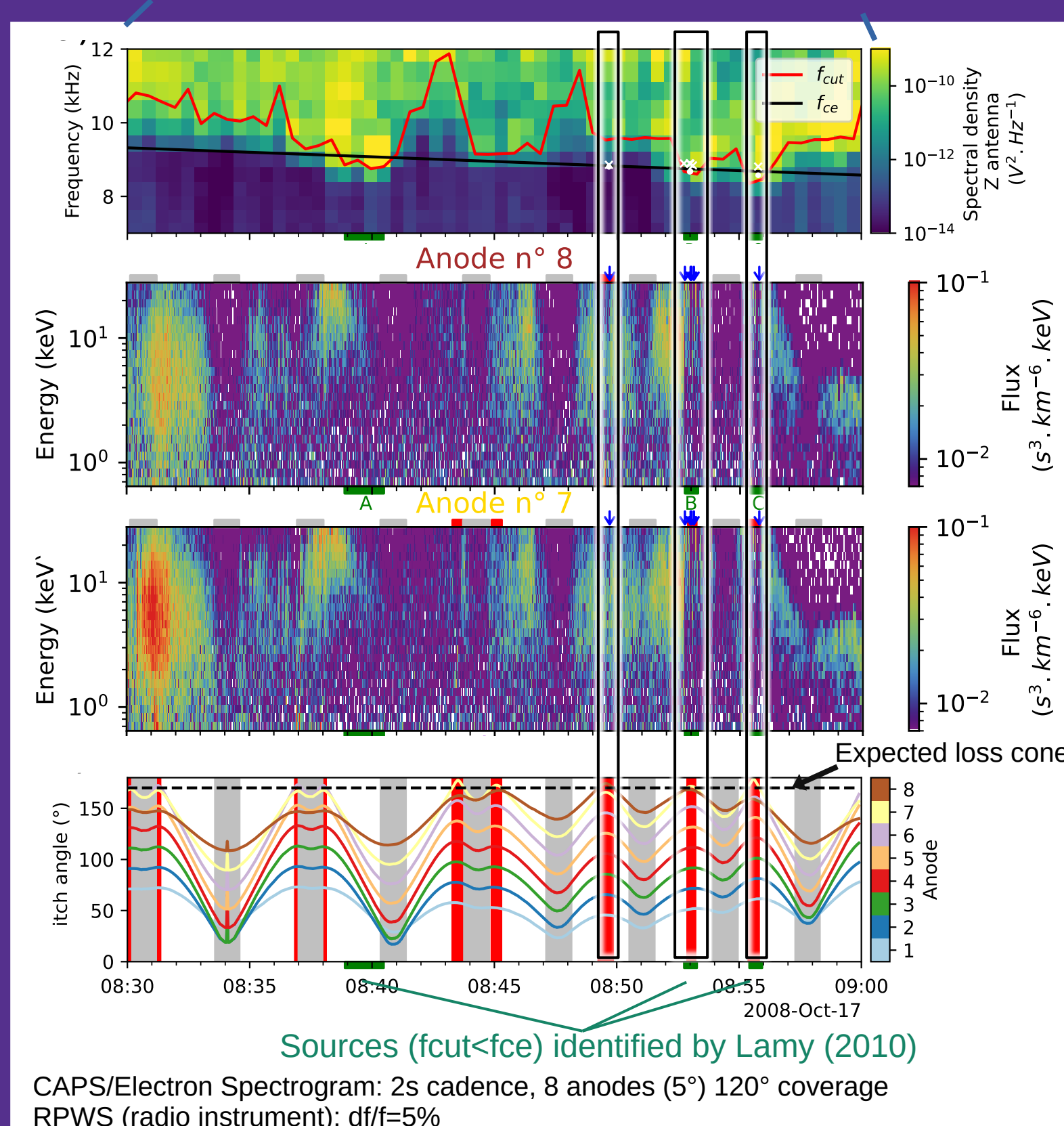


- Same generation mechanism (CMI)
- Also located in upward FAC and connected to UV aurora
- Different source of free energy:
- Mostly loss cone** (Alfvénic acceleration)
- Shell** in 18% source associated with **LC**

Here both **shell** and enlarged **loss cone**

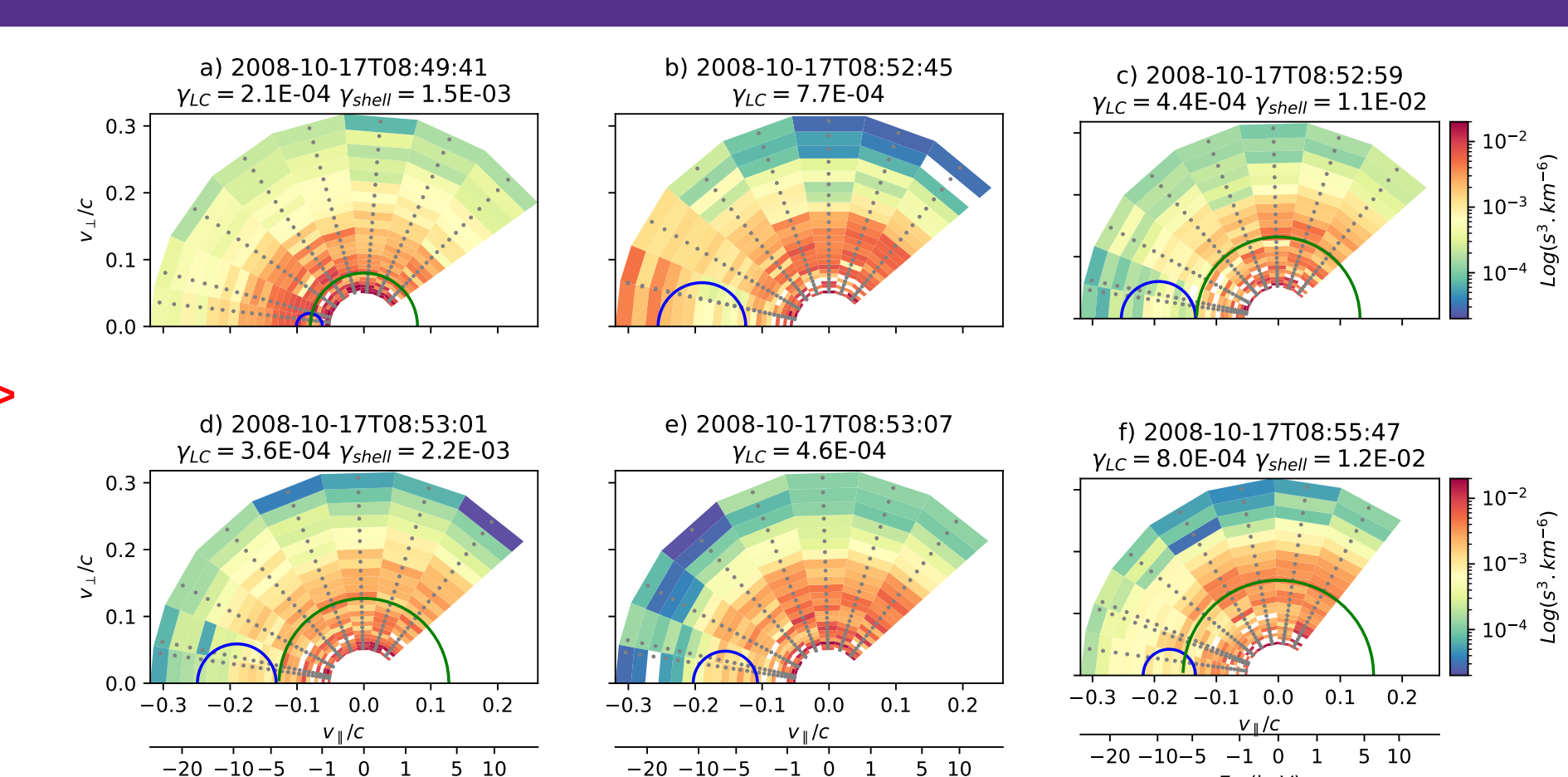
Can LC be CMI unstable at Saturn too ?

Methods & Results



- Identify regions where no instrumental shadowing and pitch angles > 170° are sampled (83 measurements)
- Identify by eye empty loss cone (6 measurements)
- Compute the CMI growth rate using Collet et al. (2023)'s method

Unstable 0.3-8 keV loss cones seen on 6 occasions
Associated with unstable 0.3-8 keV **shell** on 4 out of 6 cases
Loss cone growth rate **1 order of magnitude lower** than shell



Time	Depletion Aperture (±2.5°)	Depletion Factor	γ_{LC} (×10 ⁻⁴)	γ_{shell} (×10 ⁻³)	E_{LC} (keV)	E_{shell} (keV)	$\Delta\omega_{LC}$ (%)	$\Delta\omega_{shell}$ (%)	Beaming angle LC (°)
a) 2008-10-17 08:49:41	6.7	6	2.1	1.5	1.6	1.6	0.3	-0.3	85
b) 2008-10-17 08:52:45	12.3	3	7.7		8.3		1.6		79
c) 2008-10-17 08:52:59	11.5	5	4.4	11	8.9	4.5	1.7	-0.9	79
d) 2008-10-17 08:53:01	11.7	5	3.6	2.2	8.5	4.2	1.6	-0.8	79
e) 2008-10-17 08:53:07	11.1	3	4.6		5.6		1.1		81
f) 2008-10-17 08:55:47	8.0	2	8.0	12	7.6	6.2	1.5	-1.2	80

Conclusion

- We surveyed for empty **loss cone** (LC) during **SKR** source crossing and found 6 unstable cases.
- Positive growth rate => **LC is unstable** in SKR source. **Shell** remains **main source**
=> enough to produce emissions ? Maybe, compare with Jovian case Collet et al. (2024), Yoon et al. (2025)
- LC seen simultaneously with unstable shell
- Radio instrument frequency resolution does not allow to verify simultaneous emissions
- Similar to Jovian cases: **Universal mechanism**? What about **Earth**? Broadband distributions reported in Wu et al (2026)
- What about **High frequency SKR** where LC should be larger ? Is it unstable? More extended temporally and spatially?
- Submitted to GRL late May

References

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