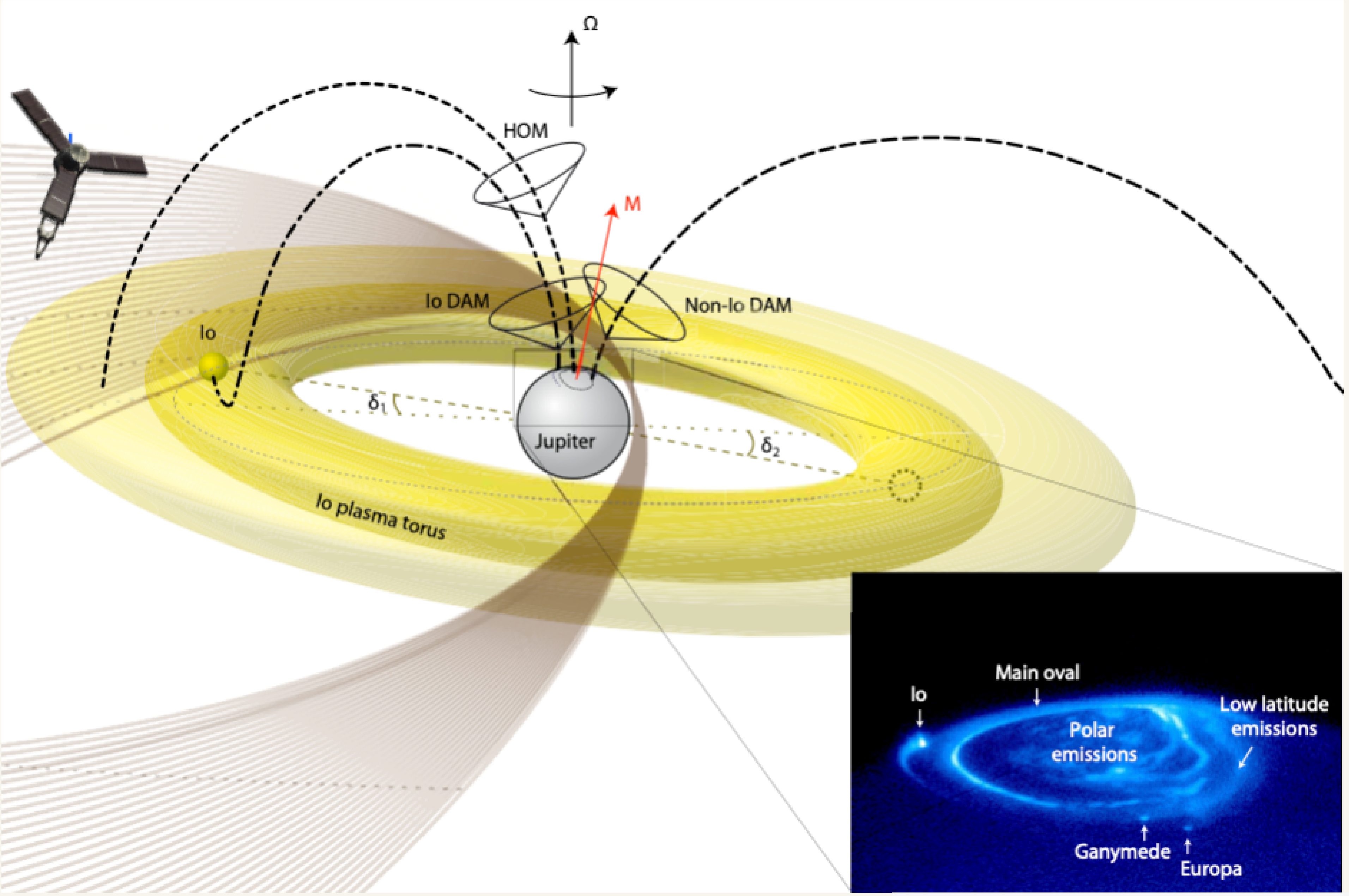
Radio auroral emissions generated by electron beams

B. Collet, L. Lamy, C.K. Louis, P. Zarka, R. Prangé, P. Louarn, W.S. Kurth, F. Allegrini

- **Fundamental** mechanism in plasma physics (**wave-plasma instability**)
- **Jupiter auroral** acceleration region
- **In situ** electron and radio measurements
- **Newly** identified source at Jupiter



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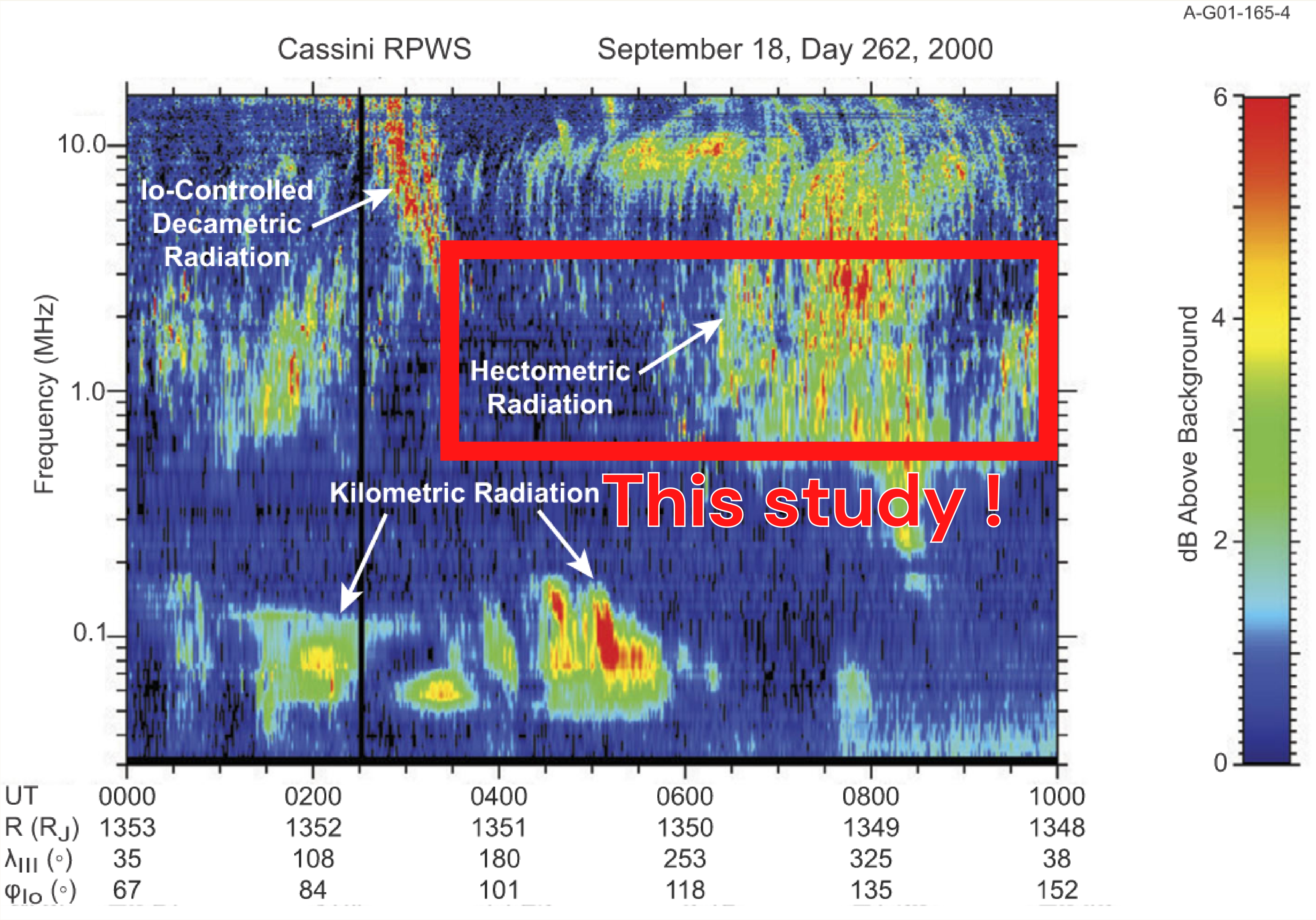

Credit: Kurth+ (2017)

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

$$\frac{f_{pe}}{f_{ce}} \ll 1$$

$$\frac{\partial f}{\partial v_{\perp}} > 0$$ Population inversion

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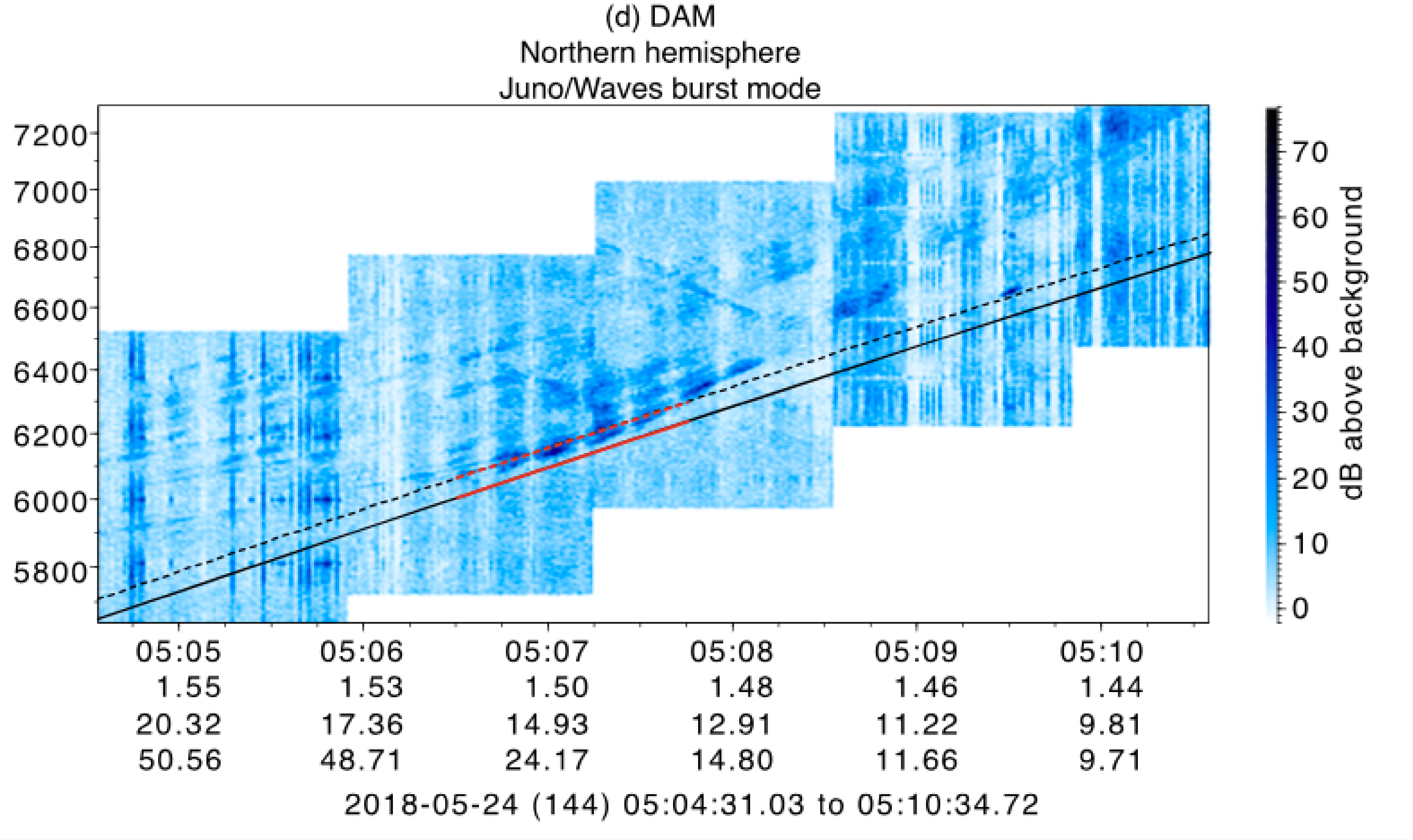
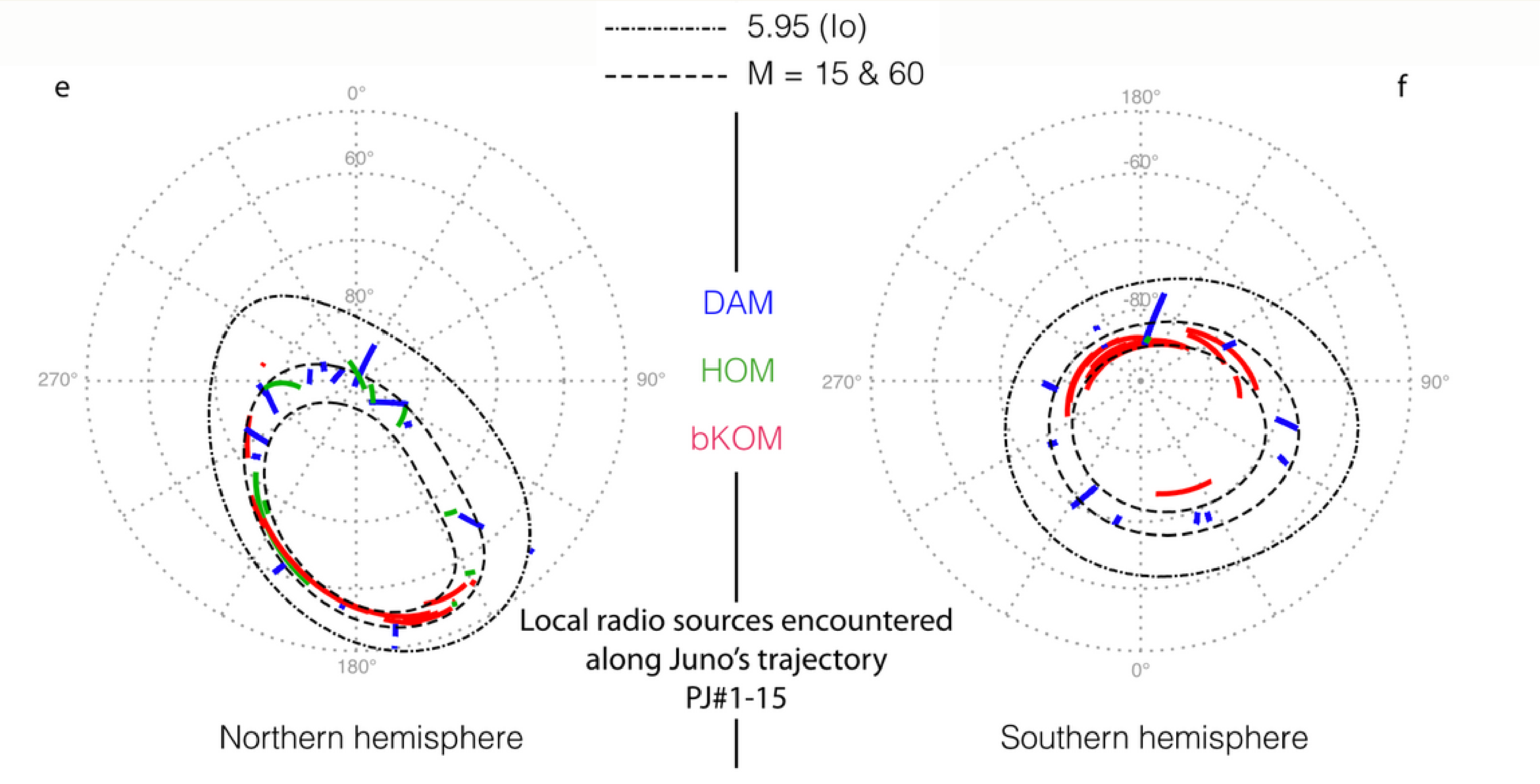
Radio sources



Louis+(2019)

Juno/Waves



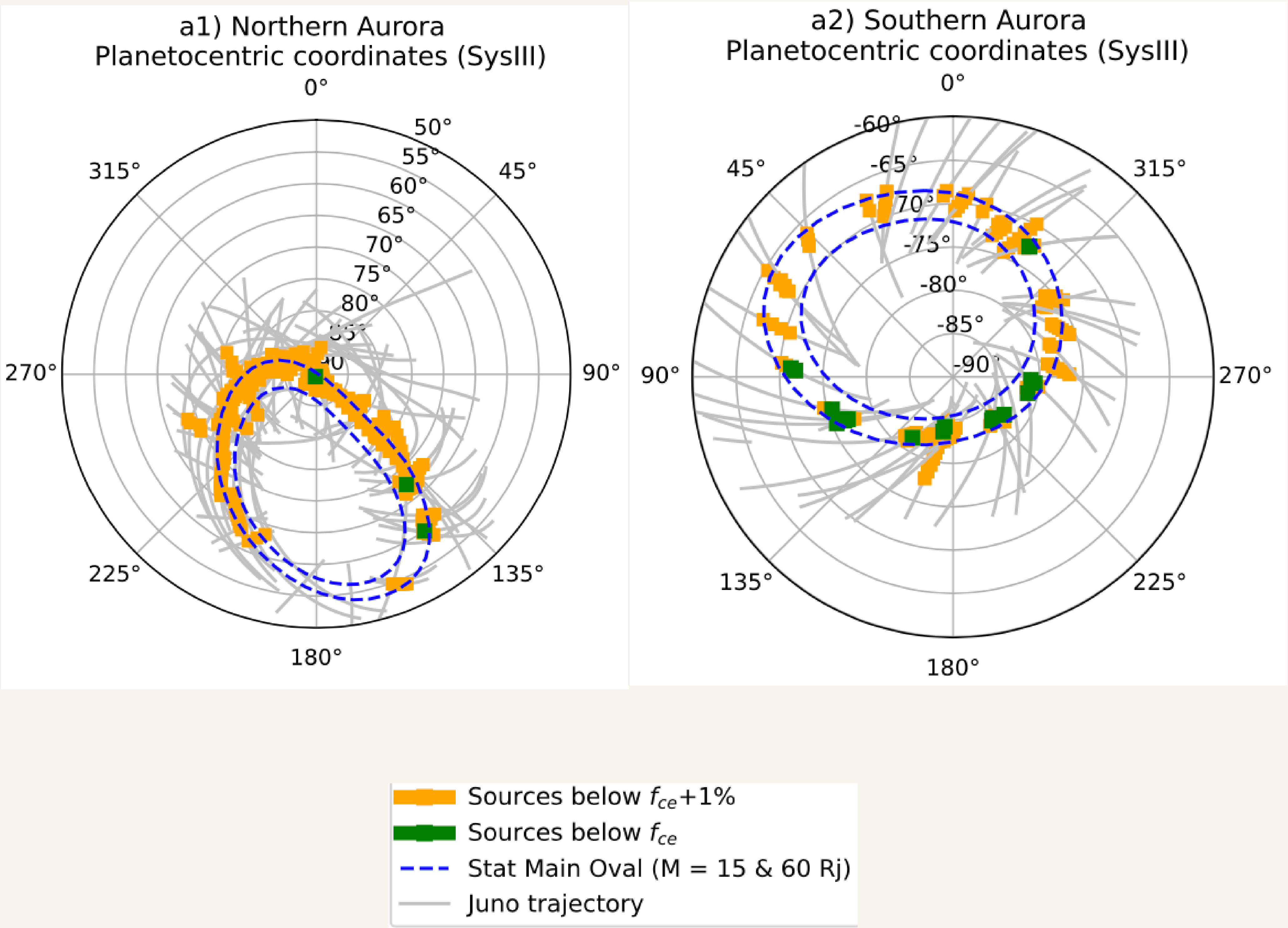
Louis+(2019)

15 first perijoves

Source crossings
identified with f<fce+1%

f<fce ?

Radio auroral emissions generated by electron beams
Radio survey



<u>Out of the 45 Juno perijoves</u>

- 15 HOM **f<fce** sources
- ~90 HOM/DAM **fce<f<fce+1%** sources

Associated with:

- Dawn side
- Hot plasma
- fpe/fce~10^−3
- Depletion of electrons (but no cavity)
- Upward FAC current (Bphi)
- Not systematically connected with brightest UV

Generation ?

Radio auroral emissions generated by electron beams
Cyclotron Maser Instability

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

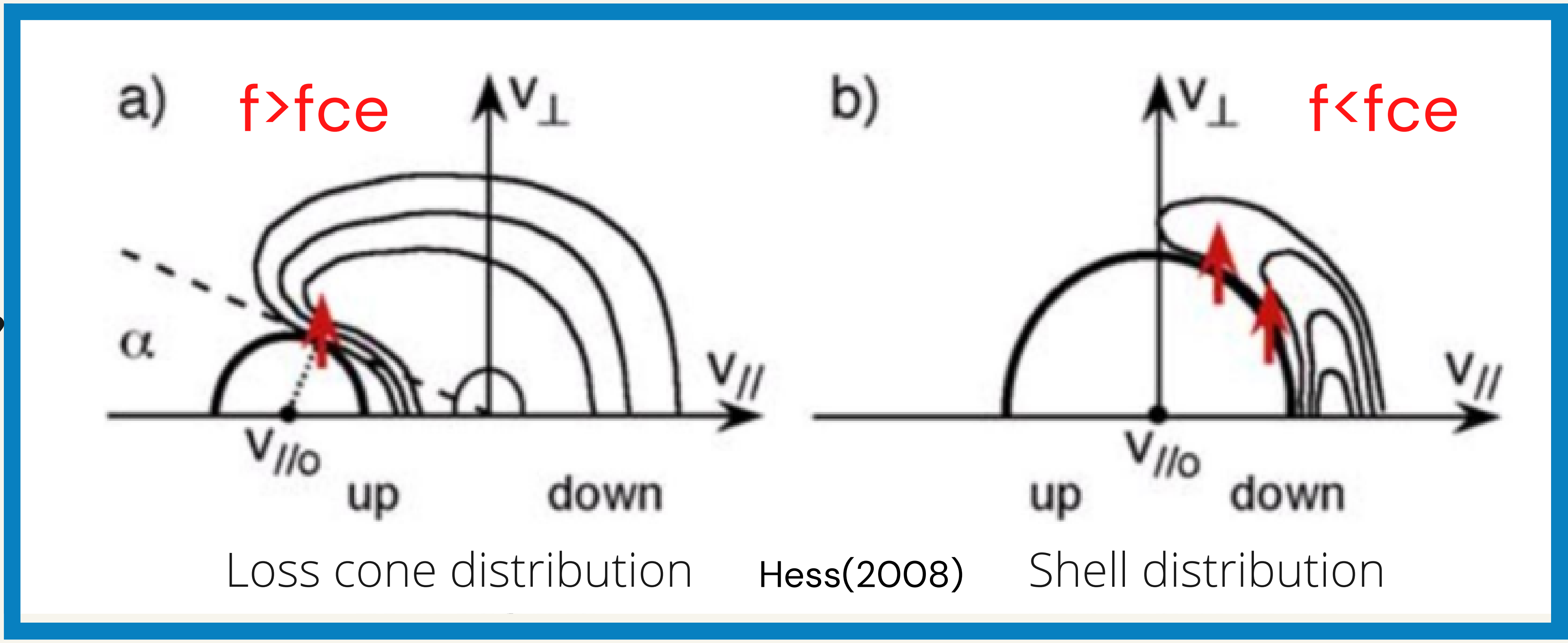
$$\frac{f_{pe}}{f_{ce}} \ll 1 \quad \frac{\partial f}{\partial v_\perp} > 0$$

$$v_\perp^2 + (v_{||} - v_0)^2 = v_r^2$$

Direction of propagation

Frequency

Wu&Lee (1979)



Identified at Jupiter (Louarn+ 2017)

Main source at Earth

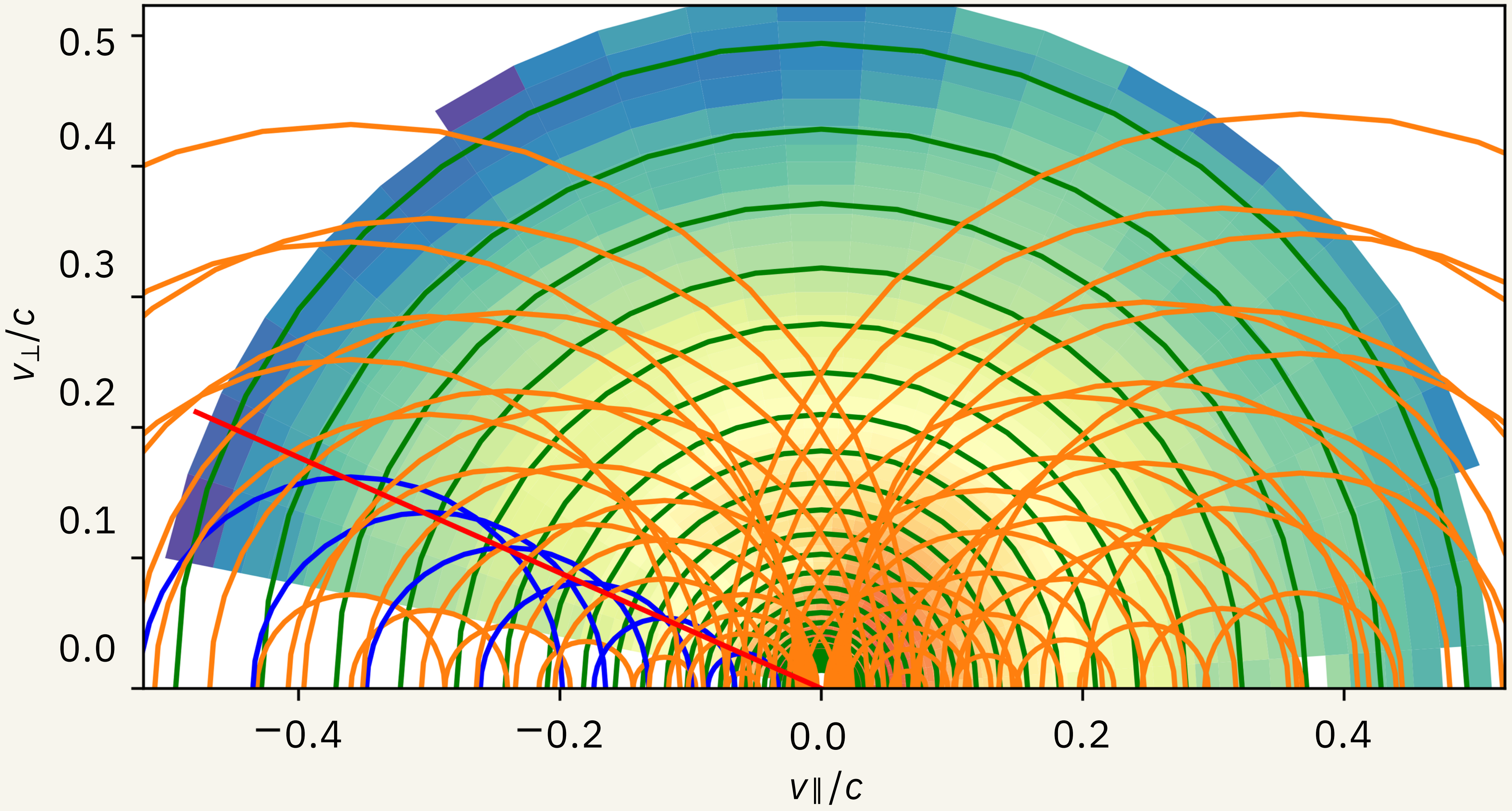
Newly identified at Jupiter

Radio auroral emissions generated by electron beams
Electron measurements

$$\omega_i \propto \oint_{C(v_0, v_r)} \frac{\partial f}{\partial v_\perp}$$

3 types of unstable circles :

- Centered on 0 : **shell** — **f<fce**
- Near the **loss cone** — f>fce
- **Other** (conics, etc...) — f>fce



Radio auroral emissions generated by electron beams
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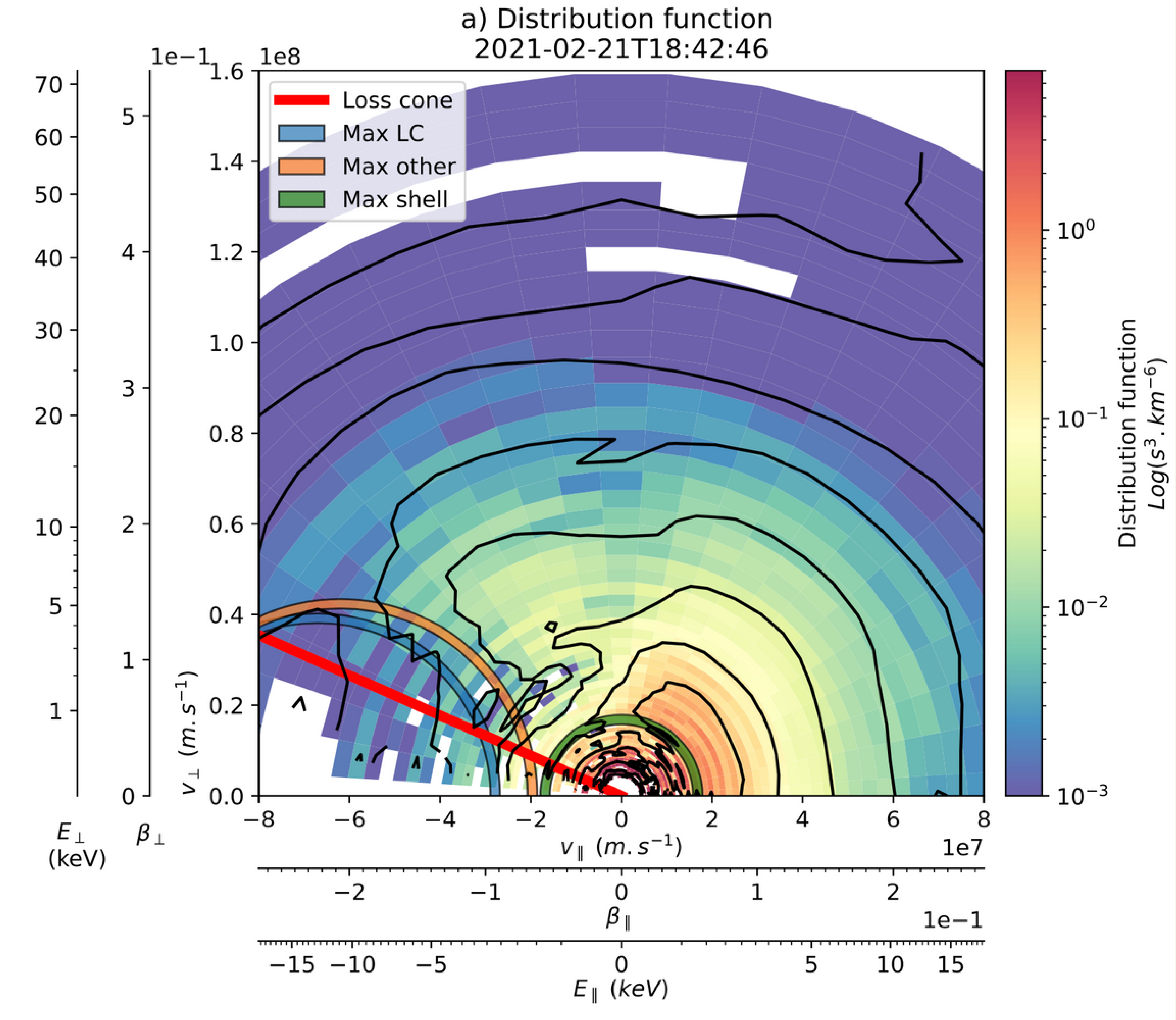


Juno/JADE-E

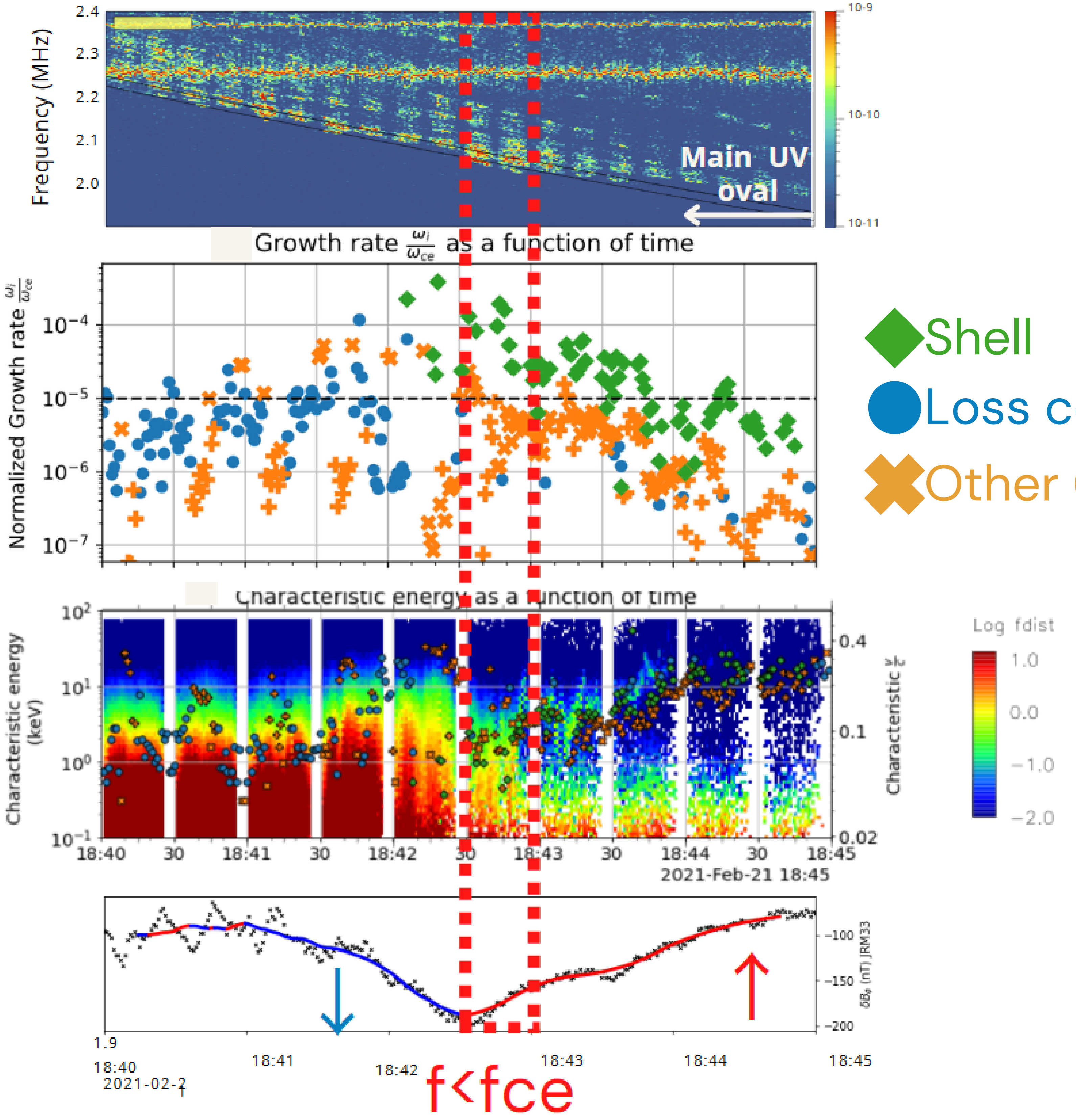
Radio auroral emissions generated by electron beams
Case study PJ32S

Waves spectra

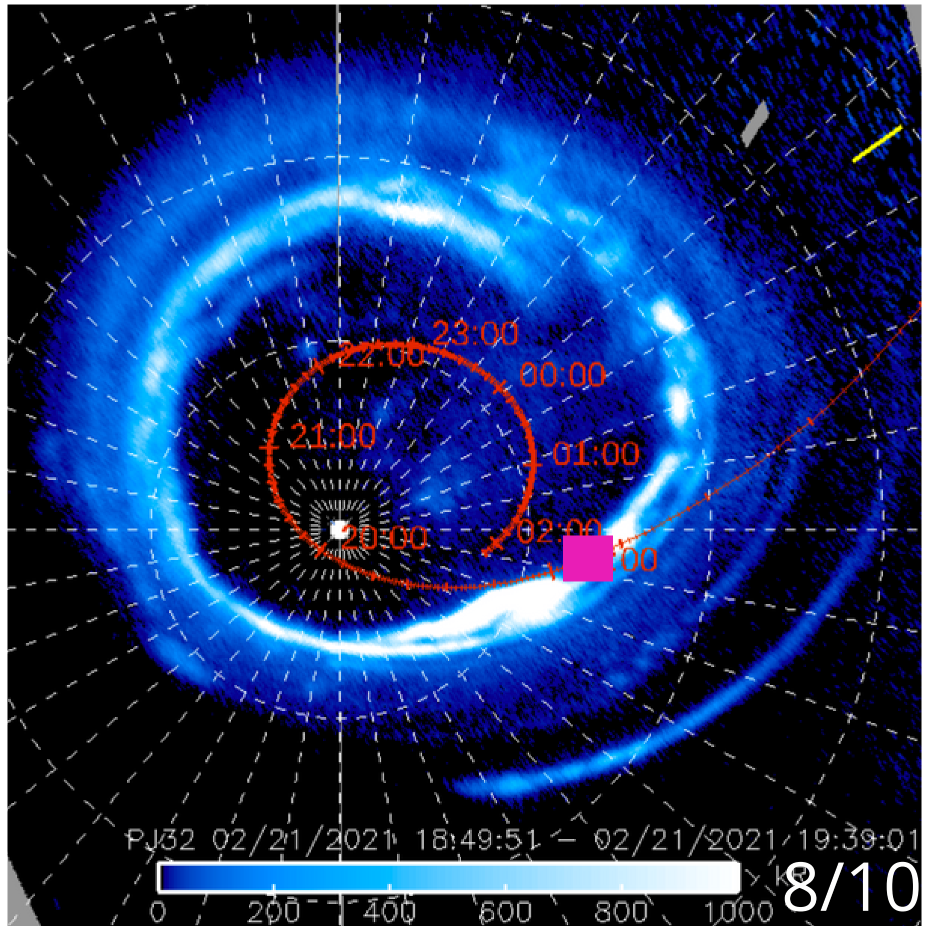
CMI Growth rate

JADE-E ↓ (1-30 keV)

FAC from Bphi

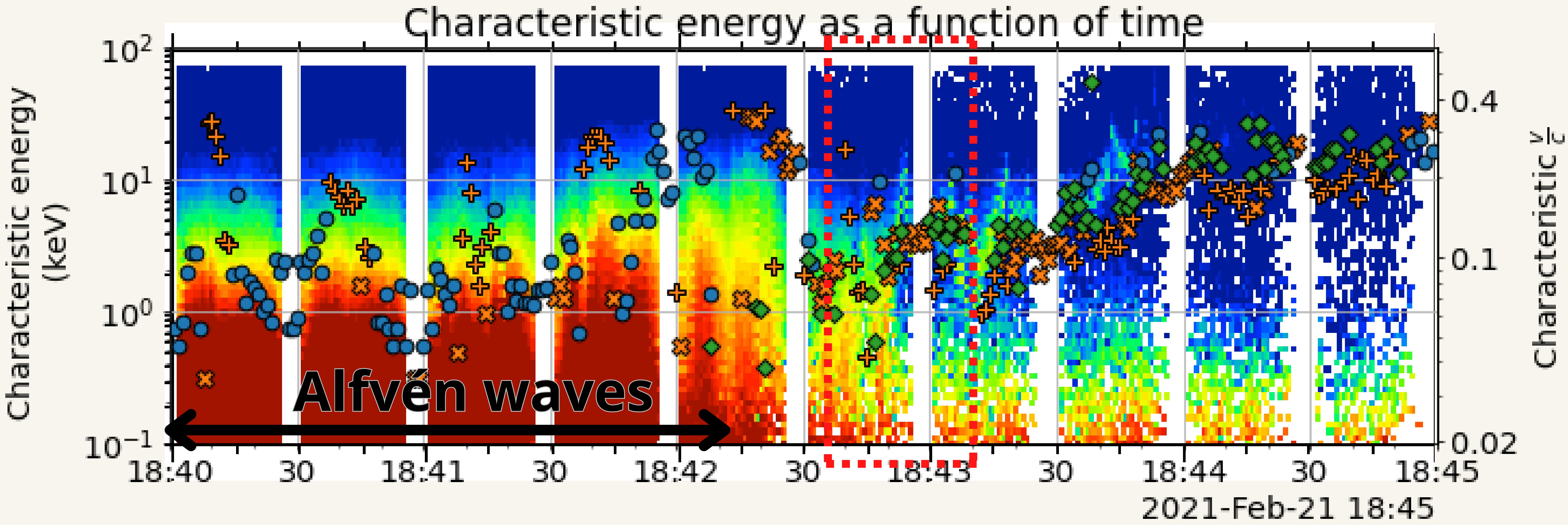


Shell
Loss cone
Other (conics or ...)

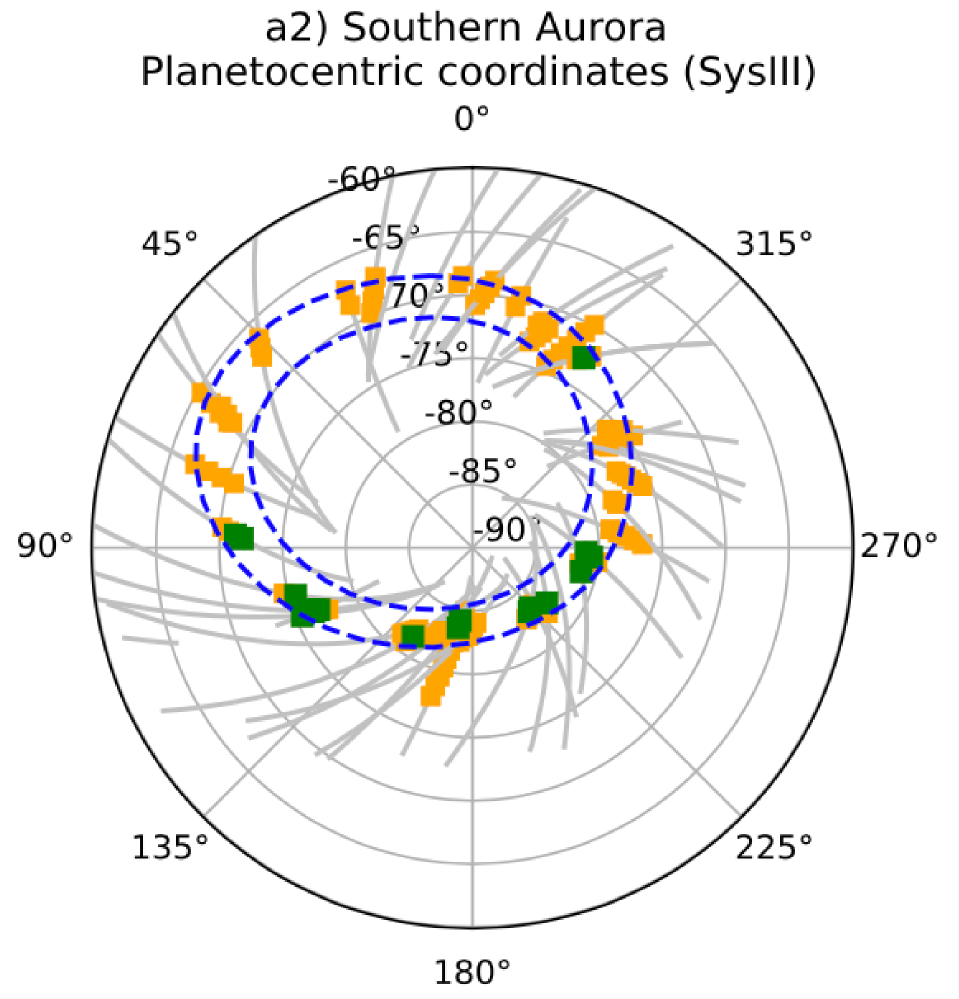


Radio auroral emissions generated by electron beams

Case study PJ32S



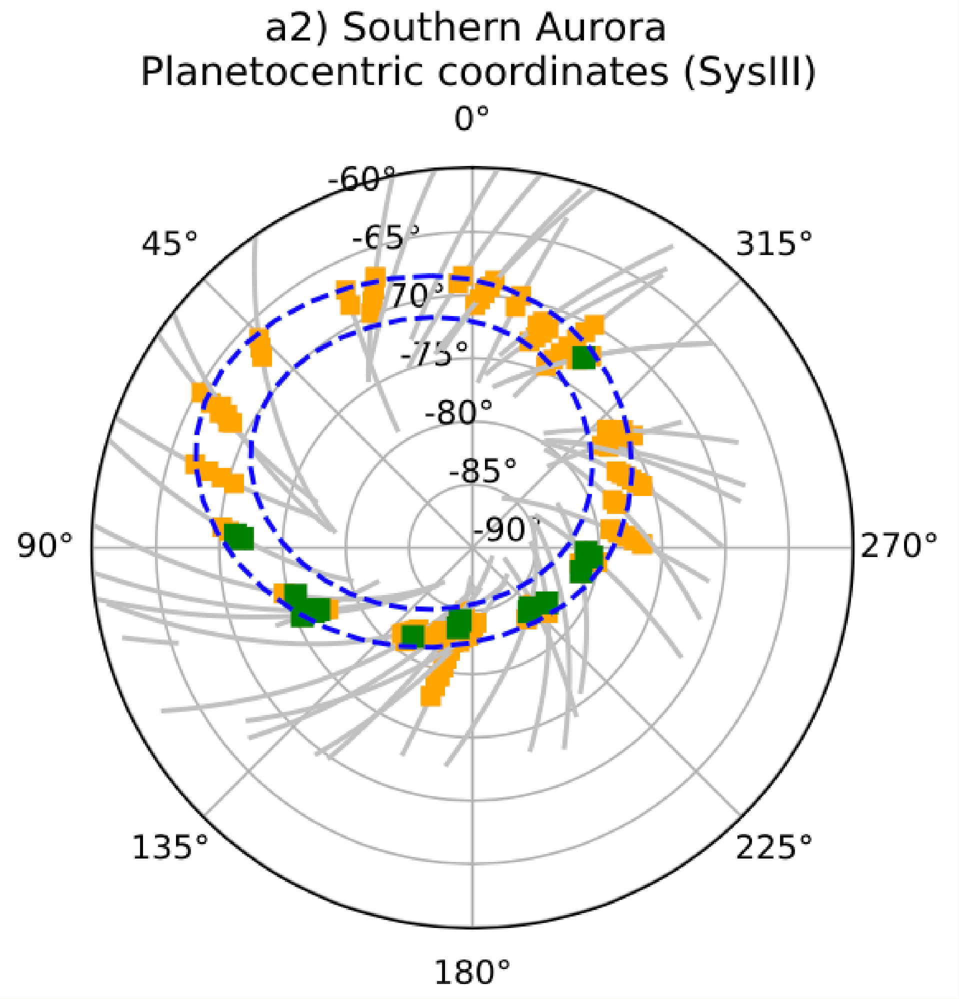
Radio auroral emissions generated by electron beams
Results and conclusions



15 HOM f<fce candidate sources
=>Associated with unstable shell EDF

- Energy lower than at Earth and Saturn (0.2 – 5 keV)
- Mono energetic signatures (inverted V)
- Associated with enlargement of LC (unstable with same energy !)

Radio auroral emissions generated by electron beams
Results and conclusions



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Radio survey

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Associated with: Hot plasma ;

- fpe/fce~10^-3
- Depletion of electrons (but no cavity)
- Upward FAC current
- Dawn side

CONCLUSION

- New source of free energy for HOM in a peculiar plasma environment
- Identification of mono energetic structures with radio

Collet et al.(2024) submitted JGR

What about :-bKOM ?-High energy electrons ?

PJ	Interval	f (MHz)	$\frac{f-f_{ce}}{f_{ce}}$	$\frac{f_{pe}}{f_{ce}}$	UV aurorae	Mono energetic signature	$\frac{n_h}{n}$	FAC direction	Alfvén waves	Shell energy	Enlargement of LC	Normalized growth rate (x10^{-4})	Size (10^3km)	Estimated intensity ($W.m^{-2}.Hz^{-1}$)
1S	2016-08-27 13:29:29-30:51	5	-0.6 %	4×10^{-3}	Poleward.		0.5	↑	X	0.2	X	0.3-0.8	0.25	7.9×10^{-10}
6S	2017-05-19 06:51:45-52:27	3	-0.2%	10^{-3}	Diffuse	X	0.8	↑		0.5-3	X	$0.2-2$	2	8.02×10^{-12}
11N	2018-02-07 12:57:24-36	2.5	-0.3%	2×10^{-3}	Main Oval		0.8	↑	X	1	X	$0.5-1$	0.6	1.85×10^{-11}
11S	2018-02-07 14:44:54-45:19	2.8	-0.25%	3×10^{-3}	Main Oval		0.8	↑	X	2	X	$0.5-3$	1.25	2.56×10^{-11}
21N	2019-07-21 03:08:05-29	2.6	-0.25%	2×10^{-3}	Diffuse	X	0.7	↓		3	X	$0.2-2$	1.25	1.20×10^{-11}
24S	2019-12-26 19:04:04-54	1	-0.3%	3×10^{-3}	Diffuse	X	0.15	↑		1	X	$0.2-0.8$	2.5	2.69×10^{-11}
25S	2020-02-17 19:11:43-57	1.2	-0.2%	3×10^{-3}	Poleward		0.5	↑		0.2-0.7	X	2-3	0.75	4.13×10^{-11}
28S	2020-07-25 07:14:06-51	2.2	-0.3%	2×10^{-3}	Main Oval	X	0.5	↑		2	X	0.5	1.5	4.00×10^{-12}
31S	2020-12-30 23:08:24-09:20	1.1	-0.25%	2×10^{-3}	Main Oval	X	0.6	↑↓		2-3	X	$0.3-3$	2.75	8.27×10^{-12}
32S	2021-02-21 18:42:13-43	2.2	-0.55%	10^{-3}	Diffuse	X	0.7	↑	X	1.5	X	$0.1-1$	2	1.01×10^{-11}
35N	2021-07-21 7:27:30-40	4.0	-0.2 %	2×10^{-3}	Diffuse		0.7	*	*	0.2	X	0.25	1-10	6×10^{-10}
37S	2021-10-16 18:22:33-25:39	1.6	-0.4%	3×10^{-3}	Main Oval		0.4	↓		3	X	$2-20$	(1+)3	1.29×10^{-11}
38S	2021-11-29 15:34:35-36:34	1.1	-0.4%	2×10^{-3}	Diffuse		0.5	↑		4	X	$1-20$	(0.5+)1.5	8.27×10^{-12}
41S	2022-04-09 17:05:40-06:35	1.3	-0.3%	5×10^{-3}	Diffuse		0.6	↑		5	X	$2-10$	2.75	3.50×10^{-11}
44S	2022-08-17 16:17:14-34	0.9	-0.8%	4×10^{-3}	Diffuse	X	0.5	↑		5	X	$0.2-1$	1	2.69×10^{-10}

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

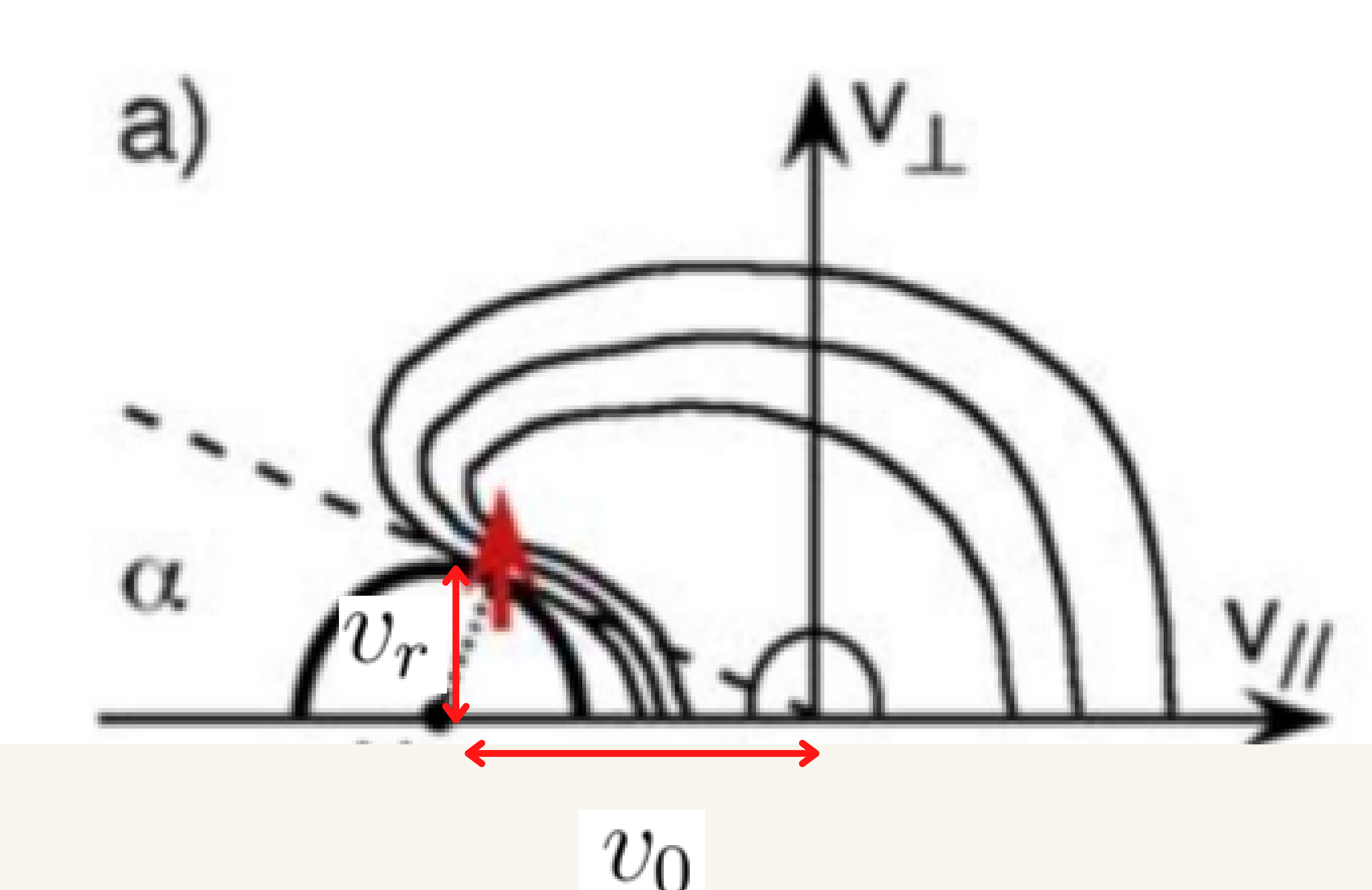
Semi relativitic electrons

$$v_{\perp}^2 + (v_{\parallel} - v_0)^2 = v_r^2$$

$$v_0 = \frac{k_{\parallel} c^2}{\omega_{ce}} \qquad v_r = (v_0^2 - 2c^2 \Delta\omega)^{\frac{1}{2}}$$

$$\Delta\omega = \frac{\omega - \omega_{ce}}{\omega_{ce}}$$

- Wave-electron resonance near fce (Wu & Lee 1979)
- Conditions : $\frac{f_{pe}}{f_{ce}} \ll 1 \quad \frac{\partial f}{\partial v_{\perp}} > 0$



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- Wave-electron resonance near fce (Wu & Lee 1979)
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$$\frac{\omega_i}{\omega_{ce}} = \frac{\left(\frac{\pi\epsilon_h}{2}\right)^2}{1 + \left(\frac{\epsilon_c}{2\Delta\omega}\right)^2} c^2 \int_0^\pi d\theta v_r^2 \sin^2(\theta) \frac{\partial f_h}{\partial v_\perp}$$

Lien entre Louarn (2017) et Mutel(2007)

Integral resonance circle