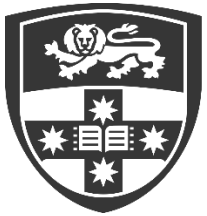
PUNCH, Shocks, and Radio Emissions

Iver Cairns

University of Sydney & CUAVA (ARC Training Centre for CubeSats, UAVs, and Their Applications))



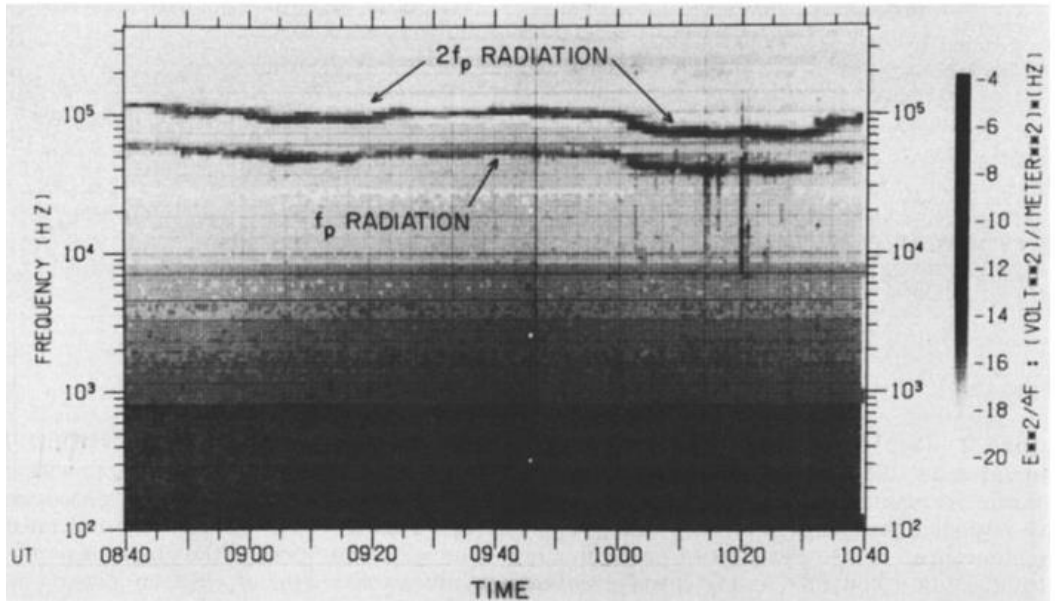
THE UNIVERSITY OF SYDNEY

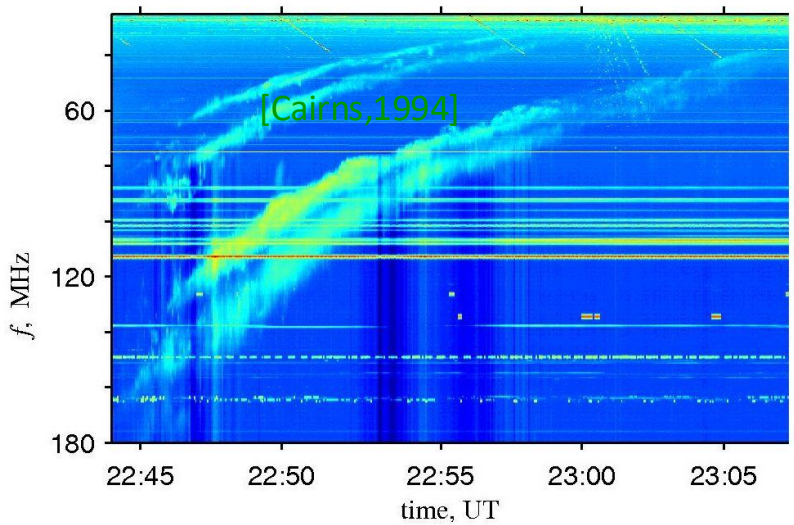
26/2/2028

Outline

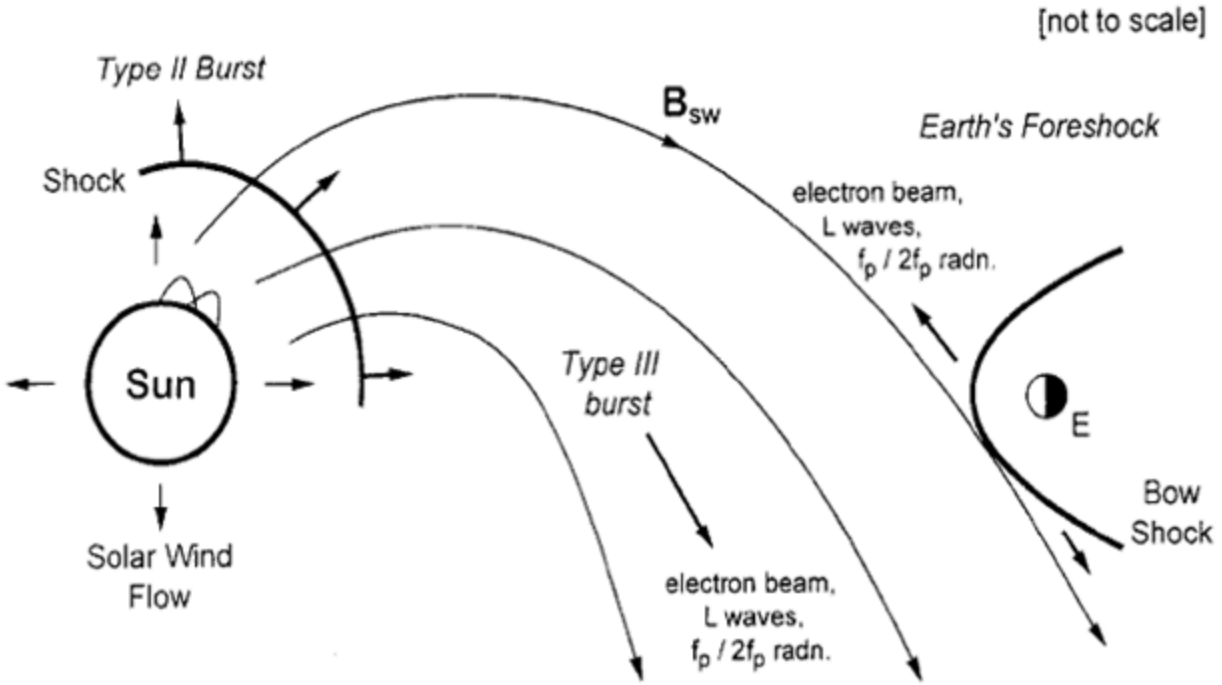
1. Context cartoon
2. Outline of the theory: shocks + plasma emission
3. Type IIs
4. Gyro-synchrotron emission from CMEs
5. CIRs
6. Earth’s foreshock radiation
7. PUNCH connections (including to Type IIIs)
8. Conclusions

1. Cartoon view: Type II bursts (coronal & interplanetary), Earth´s foreshock radiation, type IIIs



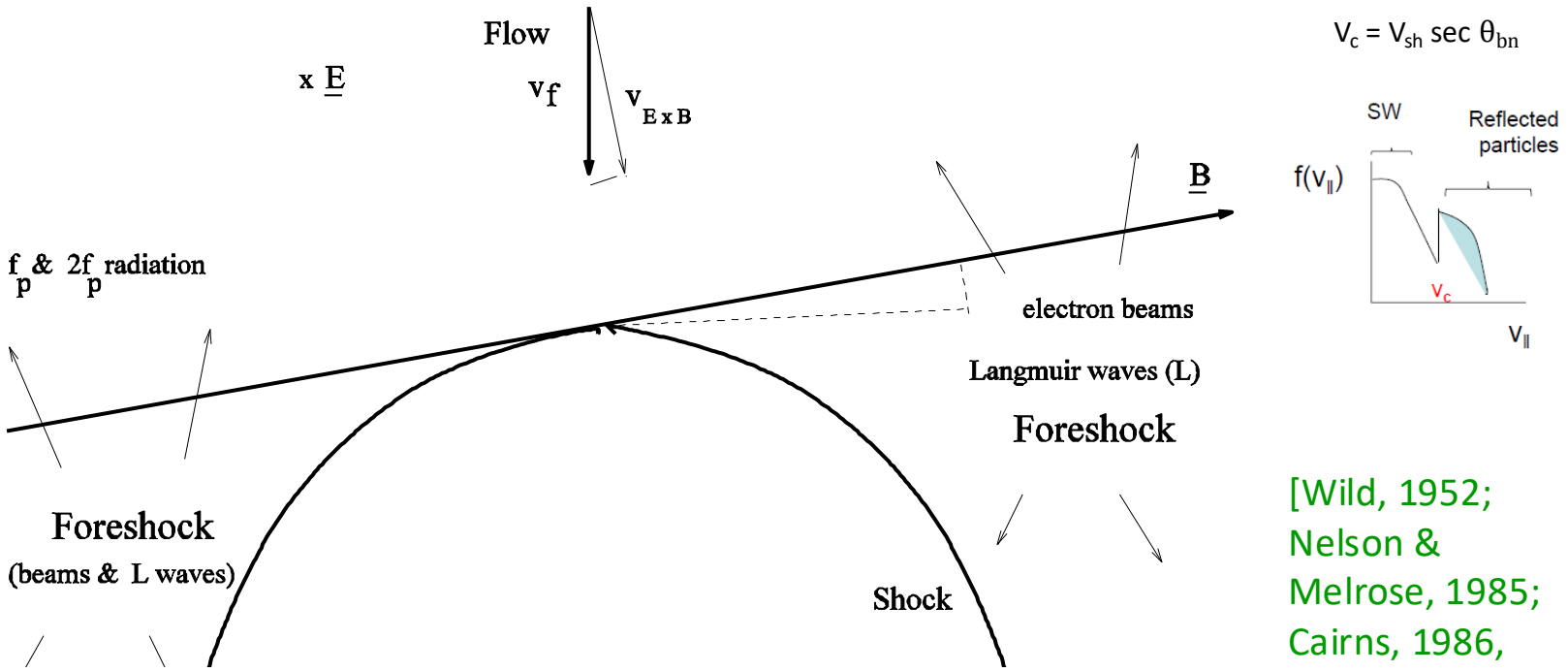


Coronal type II burst



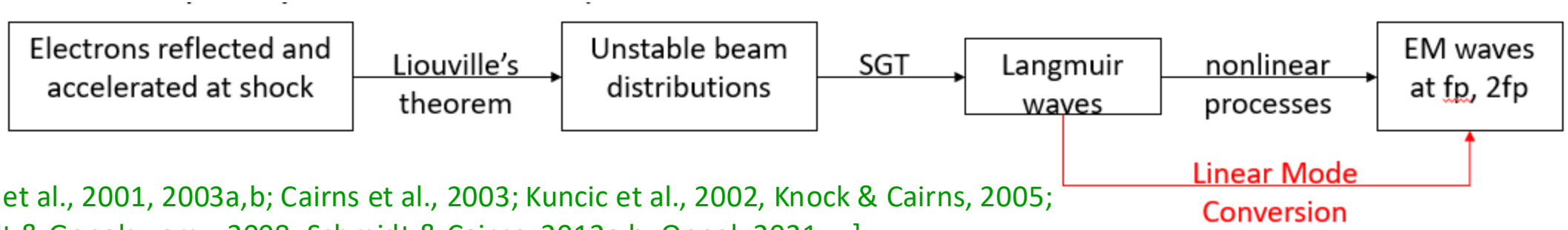
[Wild et al., 1963, …. Melrose, 1982, … Hoang et al., 1980; Cairns, 1987a,b, 1988, 1994; Burgess et al., 1988; Kasaba et al., Reiner et al., 1998; Knock et al., 2001; Cairns et al., 2003; Kuncic et al., 2002, 2004; Cairns, 2011; ….]

2. Outline of Theory: shock + “plasma emission”



[Wild, 1952; Nelson & Melrose, 1985; Cairns, 1986, 1988; …]

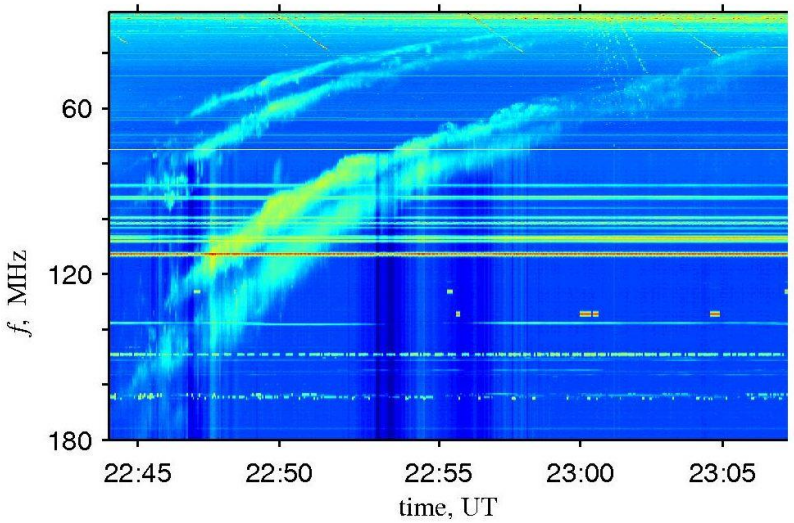
- Semi-quantitative, analytic, macroscopic theory exists:



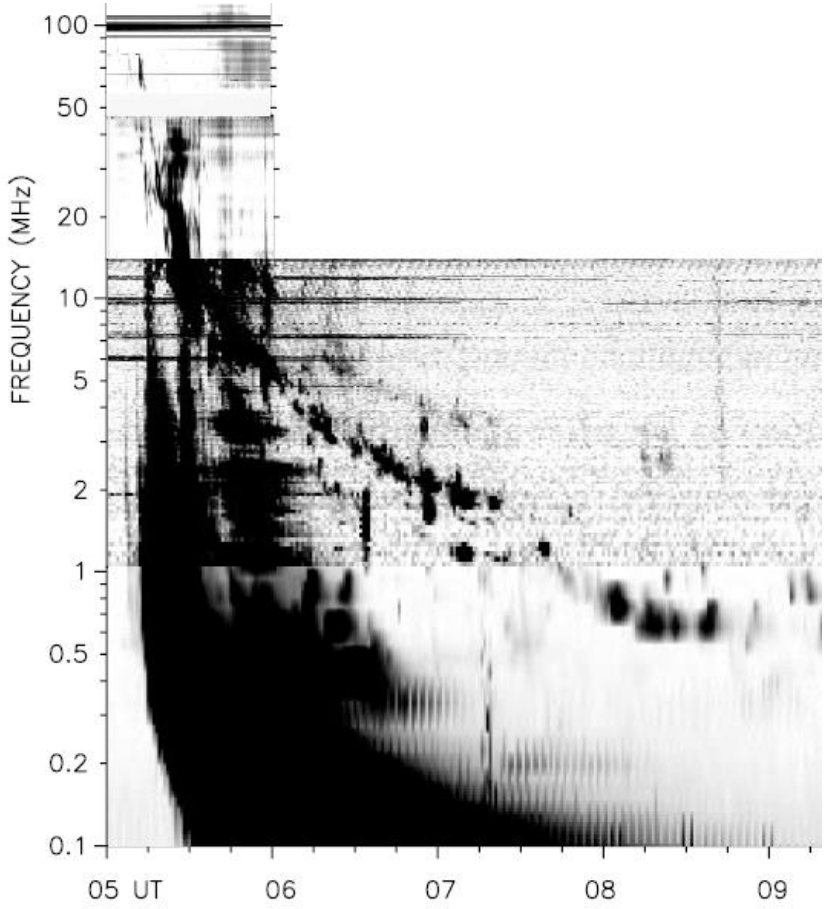
[Knock et al., 2001, 2003a,b; Cairns et al., 2003; Kuncic et al., 2002, Knock & Cairns, 2005; Schmidt & Gopalswamy, 2008; Schmidt & Cairns, 2012a,b; Oppel, 2021 …]

3. Type IIs: why blobs, split-band, & multiple lanes, what is connection between coronal & IP type IIs …?

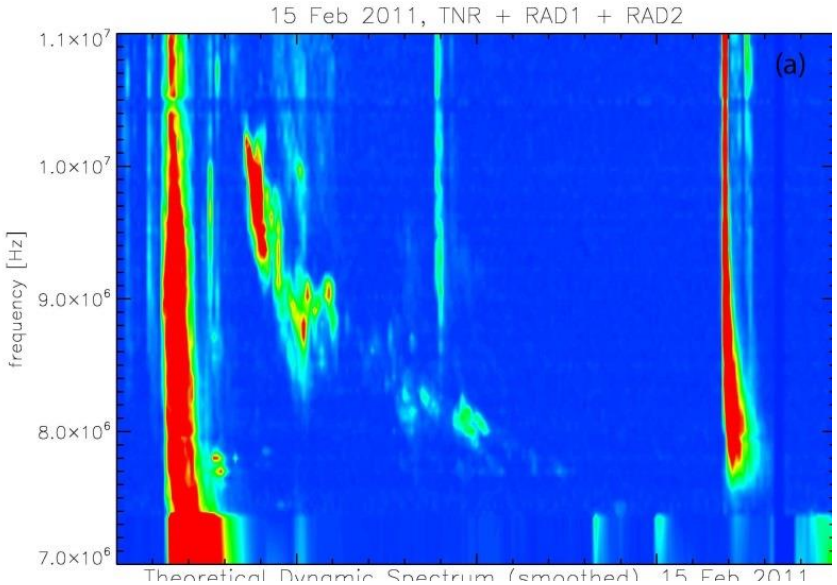
➔ special conditions for observable emission …



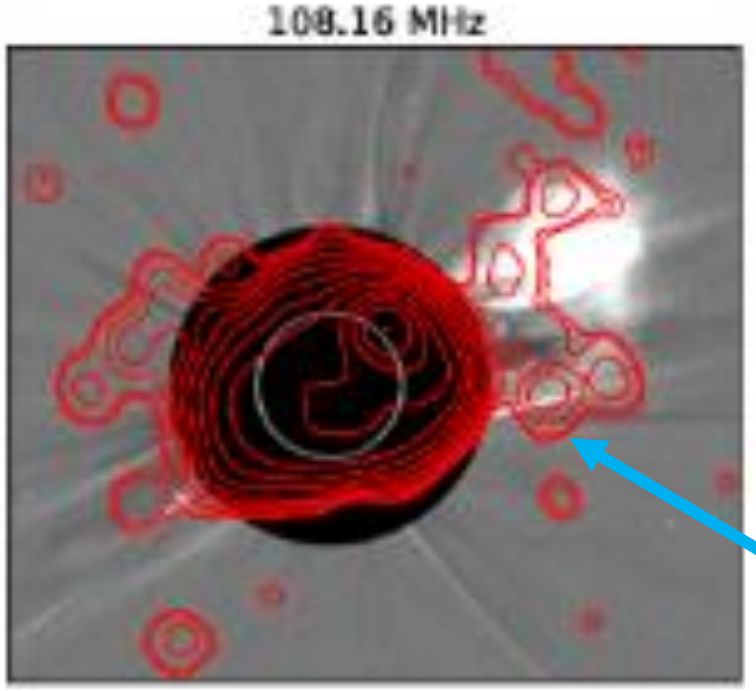
[Lobzin et al., 2008]

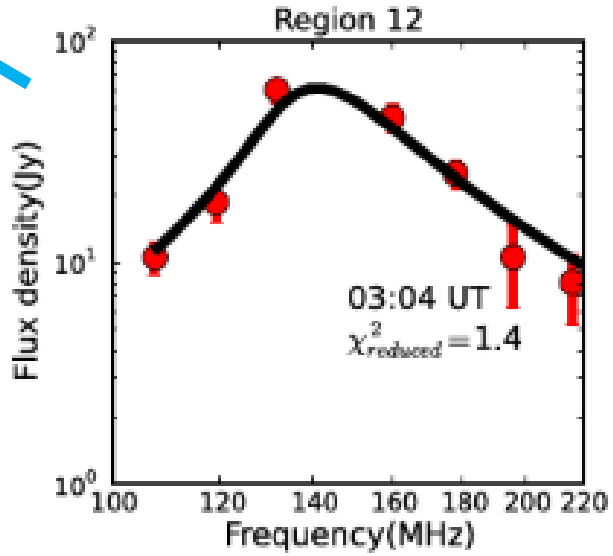


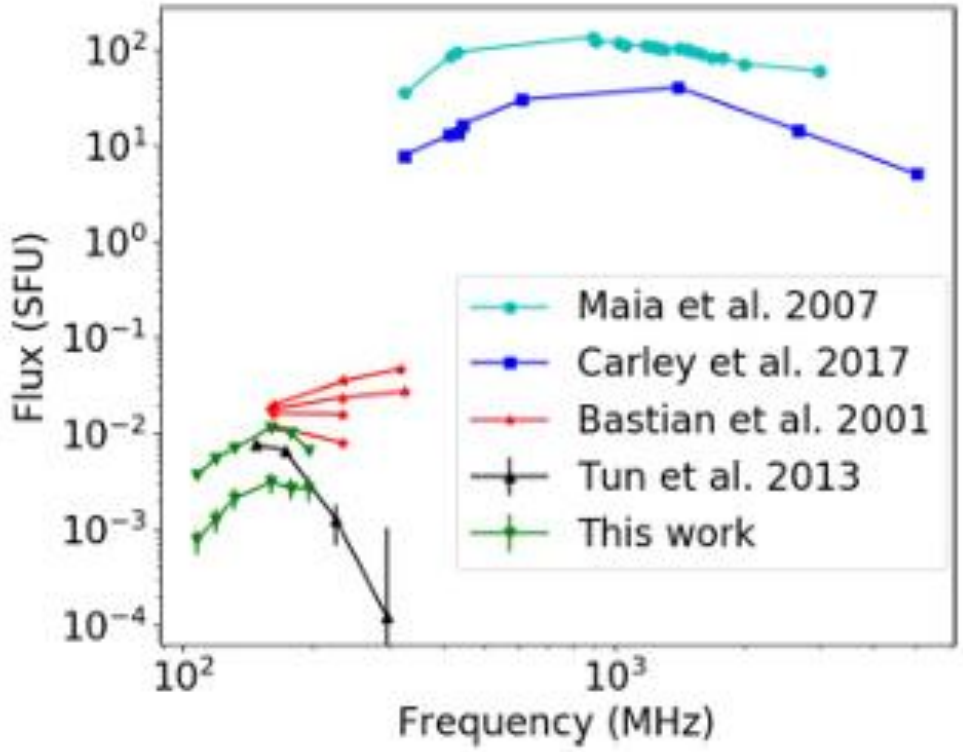
[Cane & Erickson, 2005]



4. Gyrosynchrotron emission from CMEs (e.g., Mondal et al., 2020)



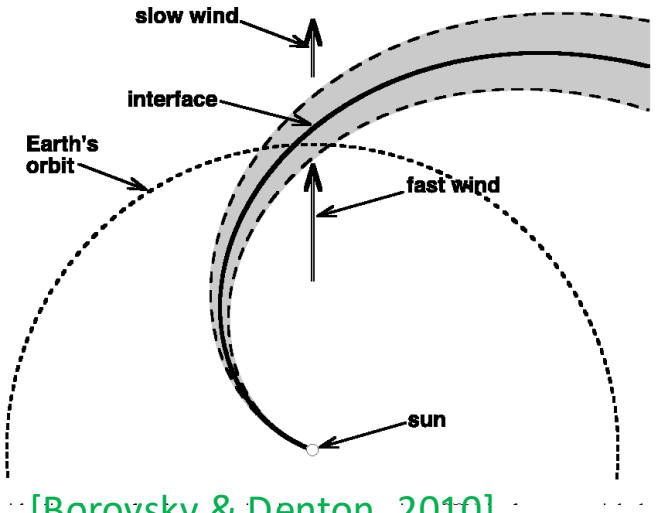




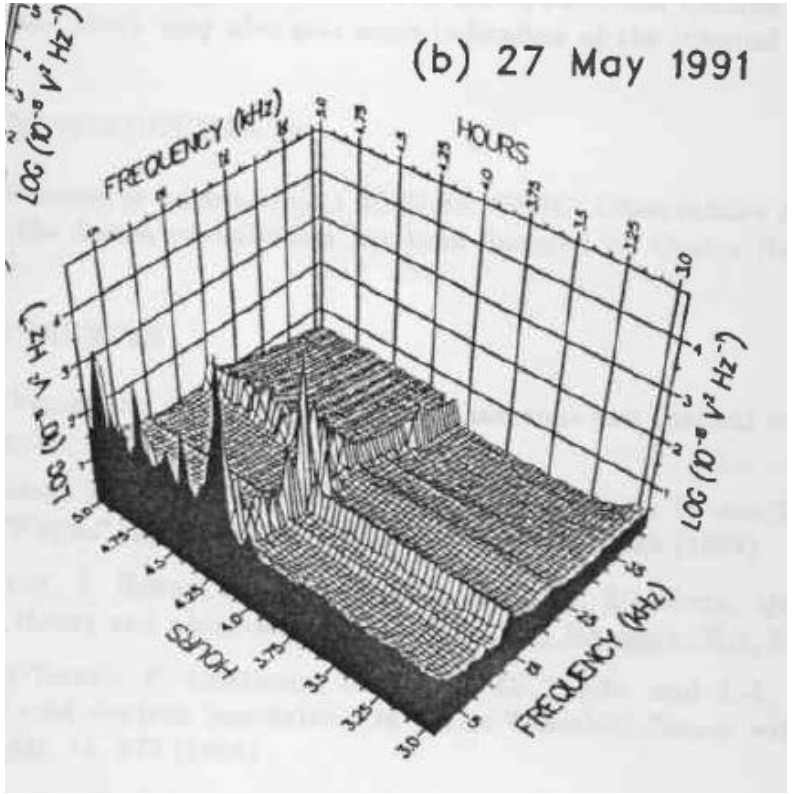
CME core, flank, or other emission?
How often?
What does this tell us?

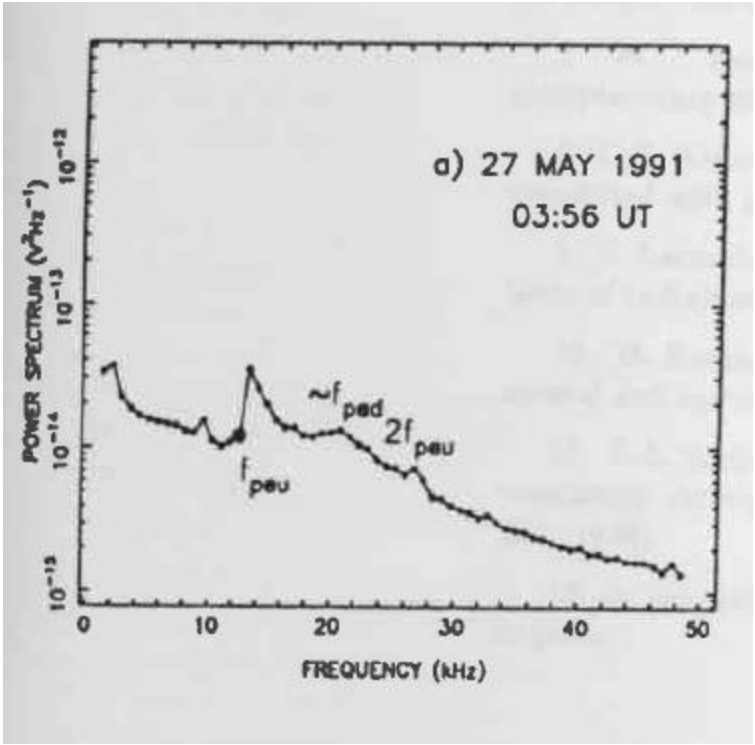
5. Hoang et al.'s CIR Emissions

[Hoang et al., 2000, Solar Wind 6.]



[Borovsky & Denton, 2010]



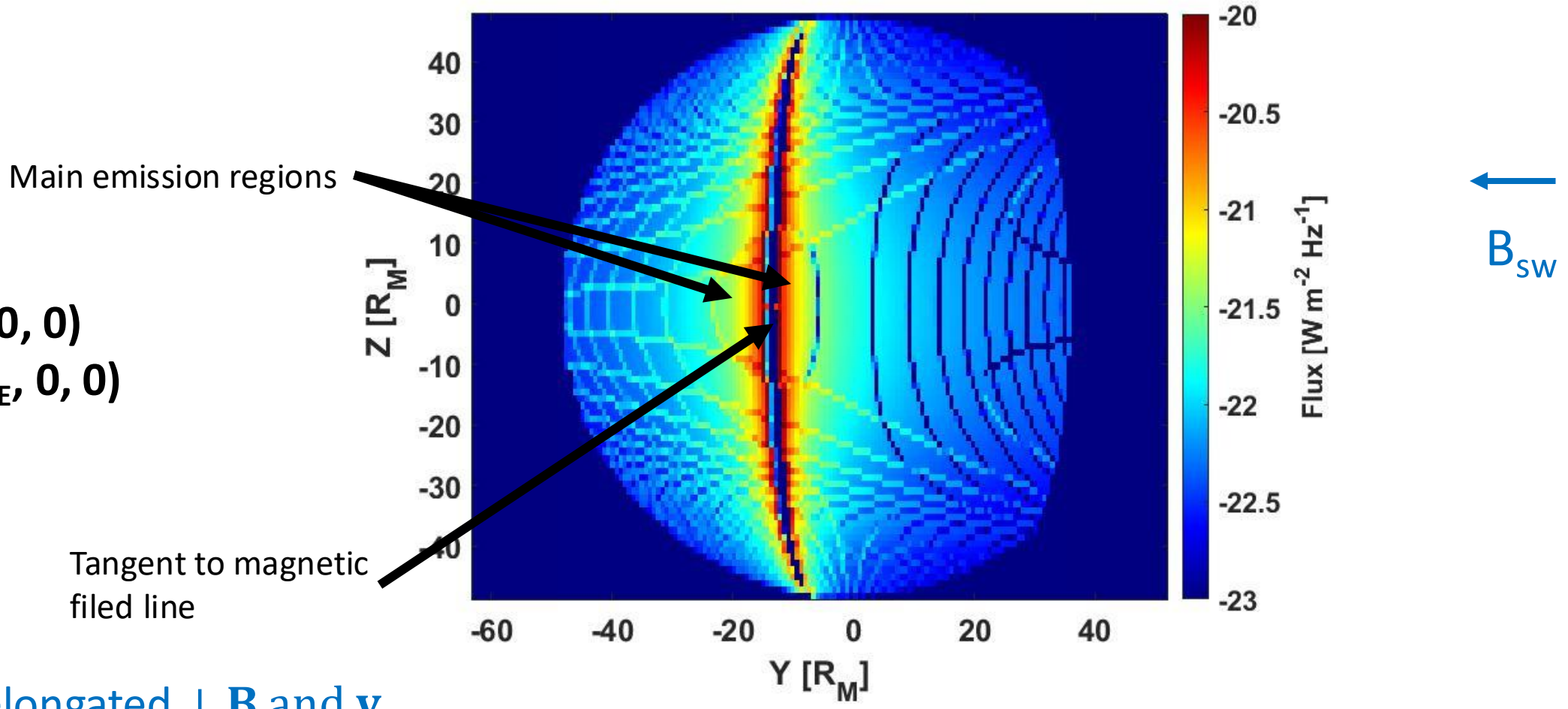


- Emission at f_p and 2 f_p of upstream plasma & apparently at f_p of downstream plasma.
- But no known source of Langmuir waves downstream
- Can PUNCH help?

6. Earth's Foreshock Source Images (L1 Observer, B in X-Y plane, $\theta_{bu} = 60°$)

[Cairns & Oppel, 2025, sub.]

Nonlinear Fundamental Emission

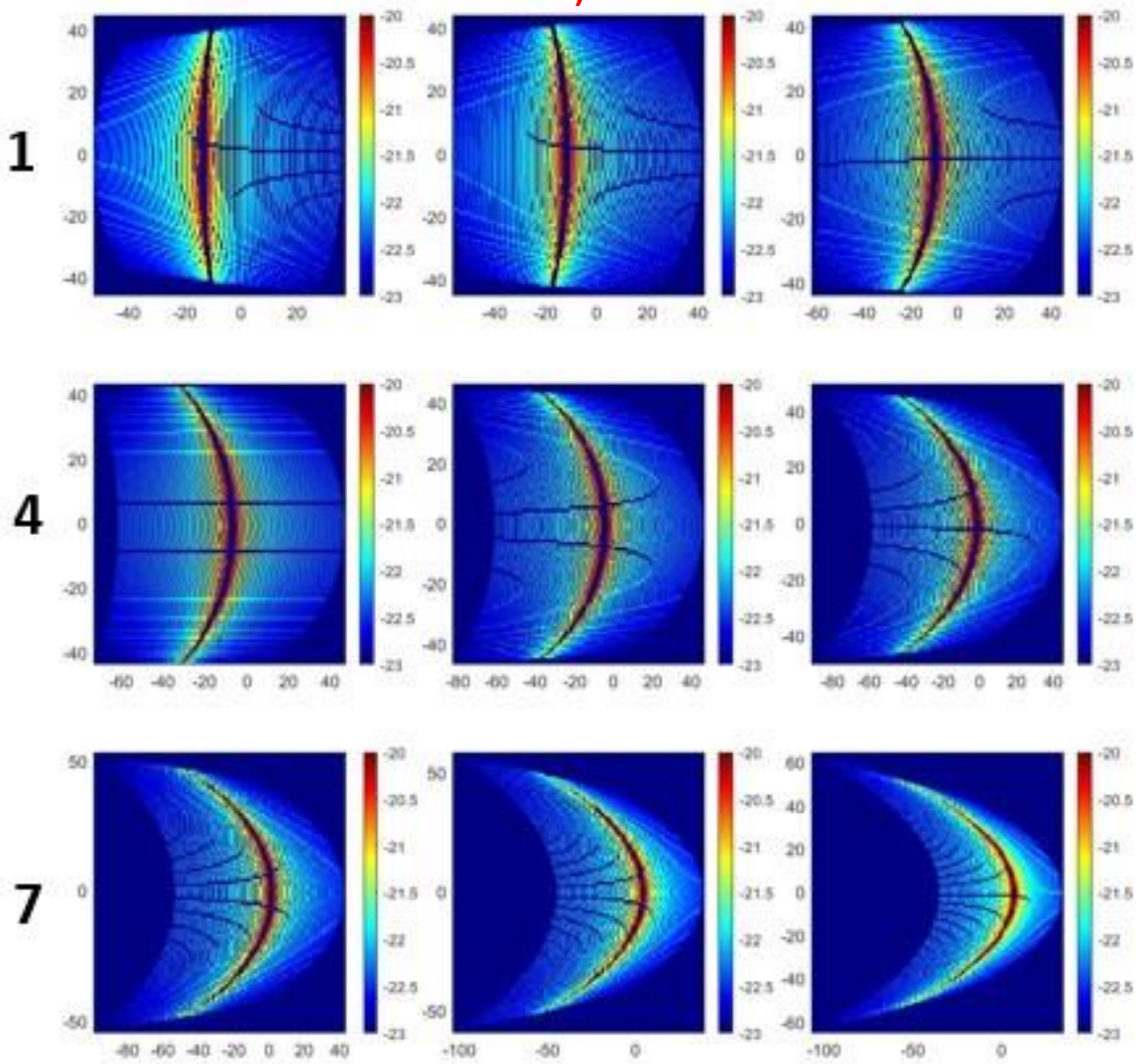


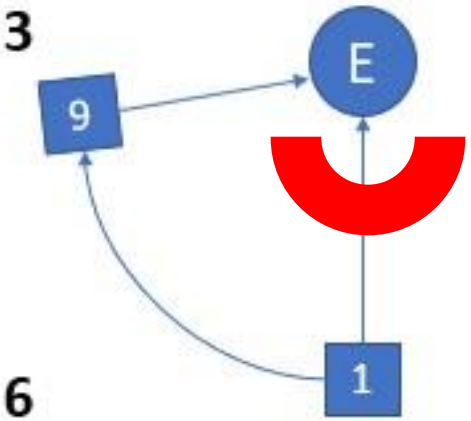
- Source elongated $\perp \mathbf{B}$ and $\mathbf{v}_{sw}$
- No emission from locus of tangent points since no electrons leave there

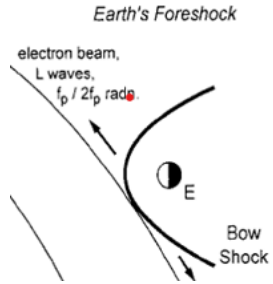
Viewing effects for different observers (B in X-Y plane, $\theta_{bu} = 60°$)

Nonlinear Fundamental Emission
(similar for harmonic & LMC)

B_{sw}







L1

[Cairns & Oppel, 2025, sub.]

Where is the 3D shock?
What is $\mathbf{B}_{sw}$?
Radio source's orientation?

7. PUNCH connections to shocks & radio sources

- Type II and gyrosynchrotron emissions?
  - 3D location & shape, velocity, rippling, & evolution of CME shocks, cores, etc
  - Density measurements (**B**?)
  - Connection to radio sources & CME simulations
- CIR radio emissions?
  - Locate 3D CIRs & compare with radio data and simulations
- Type III bursts?
  - Remotely measure densities and existence of density channels, compare to radio sources
  - Constrain turbulence & radio scattering properties (level, enhanced regions, anisotropy)
- Earth's foreshock radiation?
  - 3D location, shape, & rippling of Earth's bow shock — But PUNCH not likely to see this
  - See shock & magnetopause "breathing" as solar wind varies

8. Conclusions

- Multiple unanswered questions for solar system radio emissions and for CME and solar wind properties that PUNCH data can address uniquely.
- Type II and gyrosynchrotron emissions?
  - 3D location & shape, velocity, rippling, & evolution of CME shocks, cores, & structures
  - Density measurements (**B**?)
  - Connection to radio sources & CME simulations
- CIR radio emissions?
  - Locate 3D CIR & compare with radio data and simulations
- Type III bursts?
  - Remotely measure densities and existence of density channels, comparing to radio data …
  - Constrain turbulence & radio scattering properties (level, enhanced regions, anisotropy?)
- Earth's foreshock radiation?
  - 3D location and shape of shock
  - shock & magnetopause "breathing" as solar wind varies .. BUT PUNCH unlikely to see this.