

Plasma Waves Near the Electron Cyclotron Frequency in the Near Sun Solar Wind: Wave Mode Identification and Driving Instabilities

2021 EGU meeting ST1.4 - Latest results from Parker Solar Probe

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> > This work is under review in Astronomy & Astrophysics





Between Switchbacks

Switchbacks

- localized reversals of radial **B**
- Perhaps the most unexpected large-scale solar wind feature < 55 Rs ?

In this talk, I will do something extremely controversial with regard to switchbacks:



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Fig. 3. Switchback example. a MAG magnetic field data, b Proton velocity, c Trace Spectrogram from the SCM waveform, d Proton density, e Proton temperature. Leading and trailing edges, respectively, are located between the first and second pairs of vertical lines.



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I will not talk about them!



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Quiescent wind regions show:

- ~10x lower turbulent amplitudes (Dudok de Wit+ 2020)
- Lower-frequency turbulent break point (Dudok de Wit+ 2020)
- Magnetic field closely aligned with the Parker Spiral (Malaspina+ 2020)
- Stronger / narrower electron strahl (e- that escape the corona)

Quiescent wind regions contain:

- The solar wind least evolved from coronal conditions
- Intense plasma wave activity near _ electron cyclotron frequency (fce)





Malaspina+ 2020





Near-fce Waves in the Quiescent Near-Sun Solar Wind

Malaspina+ 2020





Burst Mode Observations





Three wave types

e-Bernstein waves (ECH) Non-integer near-fce harmonics (only prior obs. in solar wind w/ s/c Barium release or at shocks)

Type B

Near-fce very narrow band df ~ 130 Hz df / f ~ 3%

Type C

Near-fce/2 narrow band df ~ 360 Hz df / f ~ 12%

What wave modes are types B and C? How do they interact with solar wind e-?











Burst Mode Observations - Wave Vector





Type B Wave character:

0 < f < fce (likely ~fce) 0.15 < |k| (1/m) < 0.3 $\theta_{k,B} \sim 110^{\circ} \text{ or } 70^{\circ}$

If Landau Resonant

 $\omega_{\text{real}} = \mathbf{v} \cdot \mathbf{k}$

 $v_{\parallel} = \omega_{real} / k \cos(\theta_{k,B})$ $v_{\perp} = \omega_{real} / k \sin(\theta_{k,B})$

 $(0.19 \text{ eV}) < v_{\parallel} < (0.75 \text{ eV})$ $(0.0025 \text{ eV}) < v_{\perp} < (0.10 \text{ eV})$ Instability exists in cold e- core Te ~ 35 eV

Possible if strong strahl current offsets sunward e- core (?)

If Cyclotron Resonant $(f_{real} \sim 0.98 fce)$

 $v_{\parallel} = (\omega_{real} - N \omega_{ce}) / k_{\parallel}$ $v_{\parallel} = (\omega_{real} - N \omega_{ce}) / |k| \cos (\theta_{k,B})$

N = +1
$$7x10^{-5}$$
 $< v_{\parallel}$ $3x10^{-4}$ N = +2 $0.2 eV$ $< v_{\parallel}$ $0.8 eV$ N = -1 $0.74 eV$ $< v_{\parallel}$ $3.0 eV$ N = -2 $1.7 eV$ $< v_{\parallel}$ $6.7 eV$

Instability still in cold e- core Te ~ 35 eV

Anomalous cyclotron resonance with sunward e-?

Possible if strong strahl current offsets sunward and antisunward e- core







(so component of k and Vsw align: $(\mathbf{k} \cdot \mathbf{V}sw) > 0$)



What if high amplitude e- Bernstein (Type A) region is a source region?

Source region ~cylindrical for Doppler shifts to be consistent







Identified three wave modes near fce for near-Sun quiescent solar wind:

Type A: e- Bernstein (ECH) waves

Type B: Extremely narrowband, near fce (df/f ~3%)

- Doppler analysis:
 - f ~fce, $|\mathbf{k}| \sim 0.15$ (1/m), $\theta_{\mathbf{k},\mathbf{B}} \sim 70^{\circ}$
 - Resonant energies in cold e- core
 - Anomalous cyclotron possible
- Polarization Analysis
 - $E \perp B$ (approximately)
 - Right-hand elliptically polarized

Type C: Moderately narrowband, near fce /2 (df/f ~ 12%)

- Doppler analysis:
- k opposes Type B k
- f ~fce, $|\mathbf{k}| \sim 0.08$ (1/m), $\theta_{\mathbf{k},\mathbf{B}} \sim 85^{\circ}$
- Resonant energies in cold e- core
- Polarization Analysis
 - $E \perp B$ (approximately)
 - Left-hand elliptically polarized

All three: Source regions at broadband bursts (?)

- Type A strongest
- Type B, C k 'radiate' from source regions (?)
- Elongated source regions (?)



[1] The quiescent solar wind may give us our best look at the properties of the solar wind close to the corona.

[2] The quiescent solar wind has lots of interesting physics!

- plasma waves, turbulence
- current sheets, energetic particles
- [3] Focused here on near-fce waves
 - interact with cold plasma
 - possibly related to strahl-driven e- core drift

[4] Open questions:

- What mode are Type B, Type C waves?
- What instability drives them?
- How do they evolve solar wind e- distributions?
- Are the e- Bernstein waves independent?
 - or a consequence of the near-fce waves?

[5] Publications:

Statistical analysis of near-fce waves: Malaspina+ 2020 ApJ doi: <u>https://doi.org/10.3847/1538-4365/ab4c3b</u>

Burst analysis of near-fce waves: Malaspina+ 2021 A&A (under review)

[6] Pursuing new lines of inquiry

- (bicoherence + secondary cold plasma instabilities)

