*Geophysical Research Letters*

Supporting Information for

**Kinetic Generation of Whistler Waves in the Turbulent Magnetosheath**

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## Additional Supporting Information (Files uploaded separately)

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## Introduction

Figures S1-S27 show overviews of the events where whistler waves were observed together with the electron butterfly distribution. The figures have the same format as Fig. 2 in the main text, except that the pitch-angle distribution is shown in four energy ranges instead of three and has been normalized to the maximum value in each time step.

Figure S28 shows the beam distribution observed at ~11:29:13 in Fig. 2 in the main text. A model distribution, which mimics the measured distribution, consisting of a core and a beam population, is also shown. The model distribution is used as input in WHAMP (Rönnmark, 1982). The output from WHAMP is shown in Figure S29. The whistler growth rate $\gamma$ (Figure S29a) is zero or negative for all wave vectors; indicating that this beam distribution is not associated with whistler wave generation. This result was insensitive to changes in the parameters (e.g., doubling the beam density or varying its speed between $2 \times 10^3$ km/s and $8 \times 10^3$ km/s). Table S1 gives the parameters used to model the beam distribution in WHAMP.
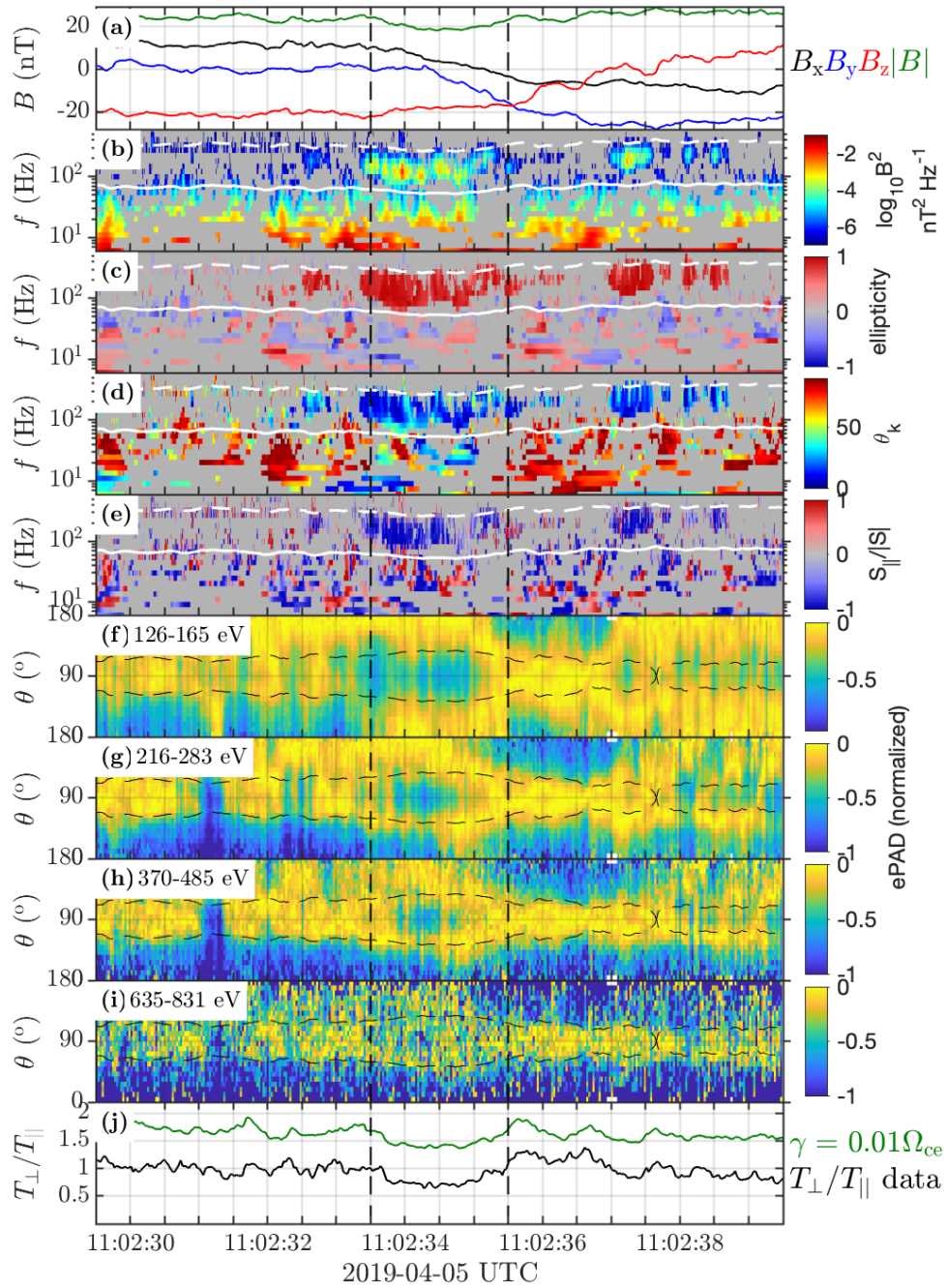
**Figure S1**. (a) Magnetic field vector and magnitude. (b)-(e) Magnetic field wavelet spectra: (b) power, (c) ellipticity, (d) wave normal angle, (e) Poynting flux direction. (f)-(i) Electron pitch-angle evolution in four different energy ranges, normalized to the maximum value in each time step. (j) Electron temperature anisotropy (black), whistler instability threshold (green). Vertical dashed lines mark approximate start/end times of the events. In (b)-(e), the white curves are $0.1f_{ce}$ (solid) and $0.5f_{ce}$ (dashed). Dashed curves in (f)-(i) show the trapping angle $\theta_{tr}$ and $180 - \theta_{tr}$.
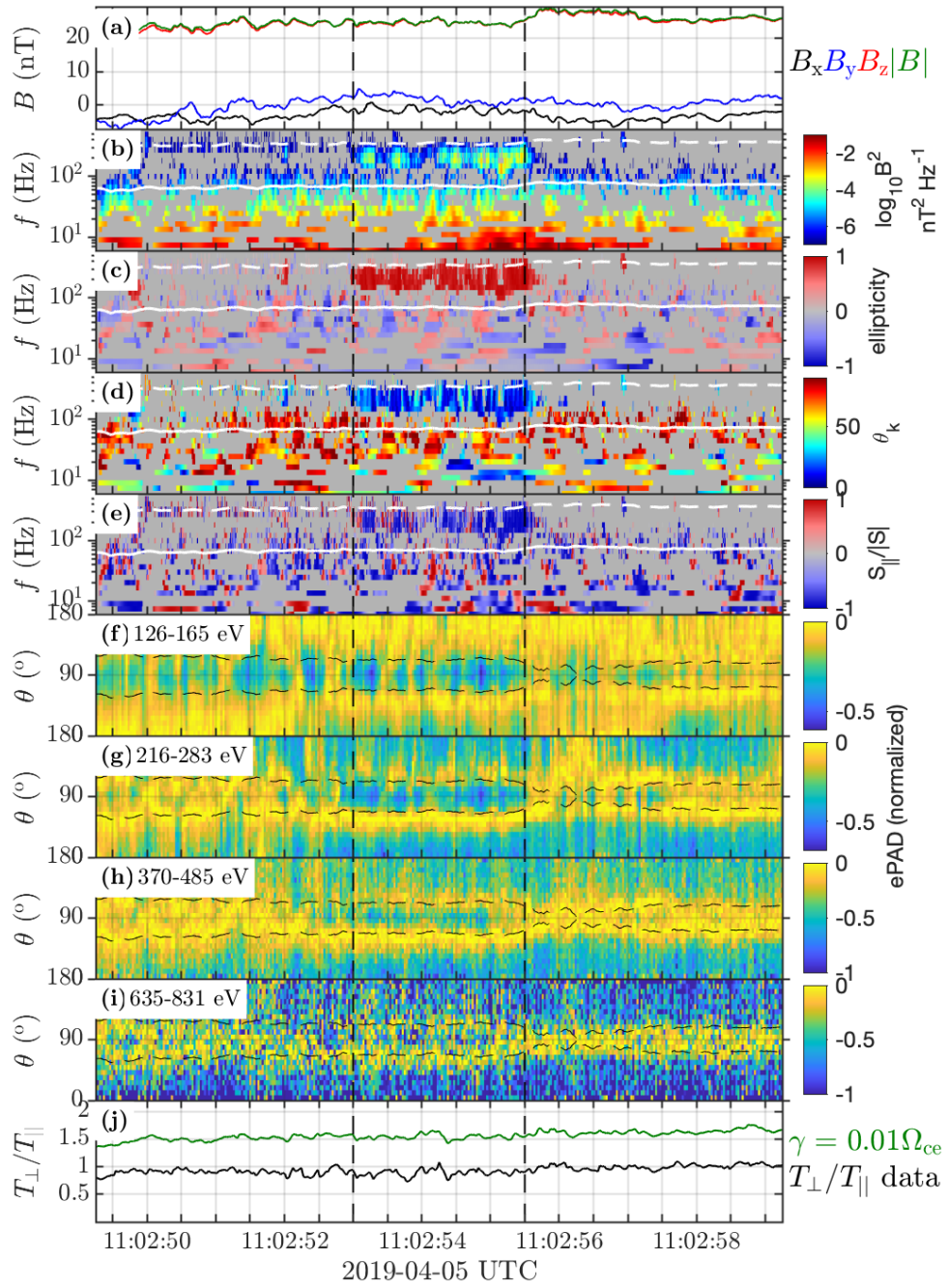
**Figure S2**. Same format as in Figure S1.
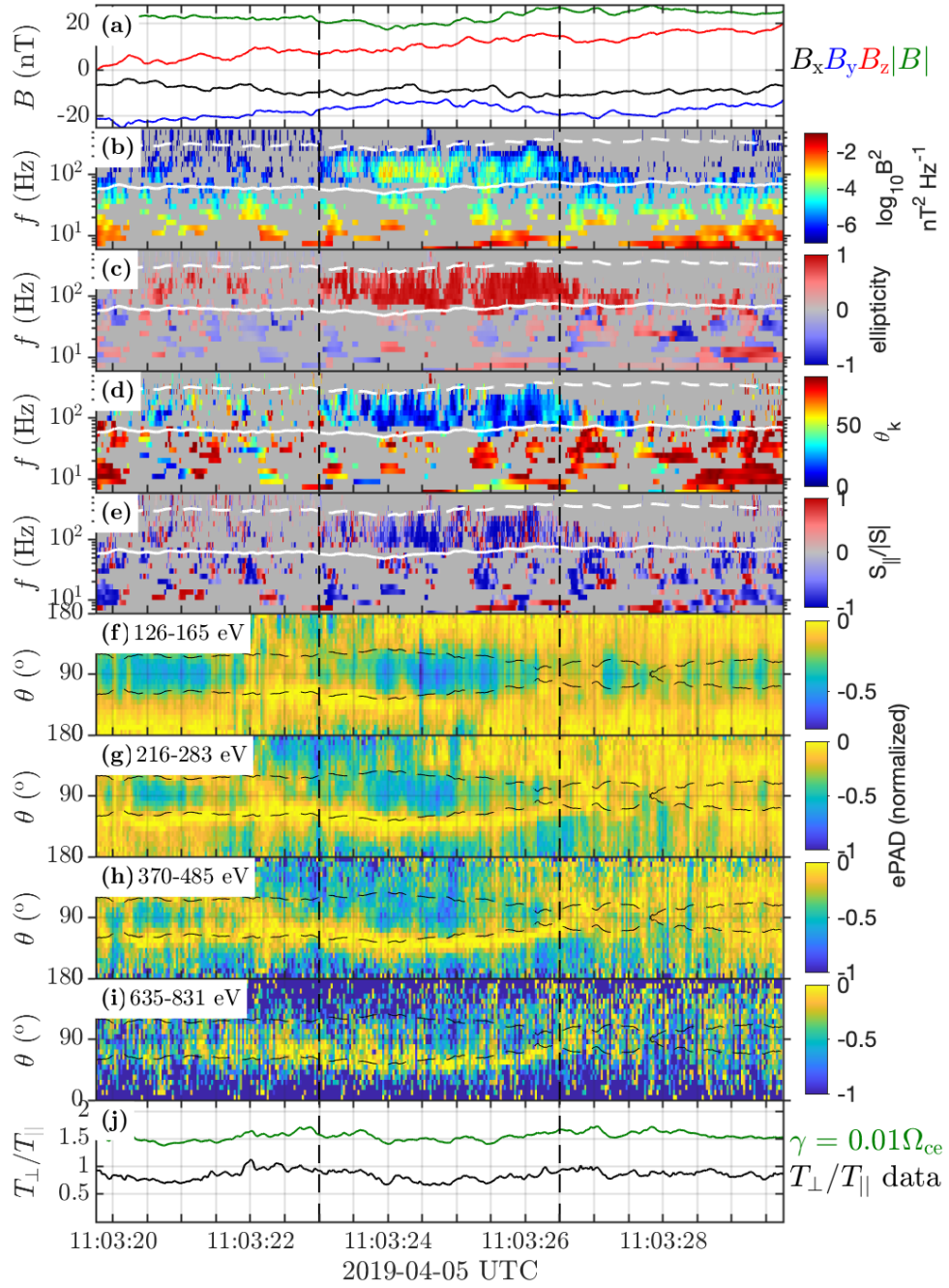
**Figure S3**. Same format as in Figure S1.

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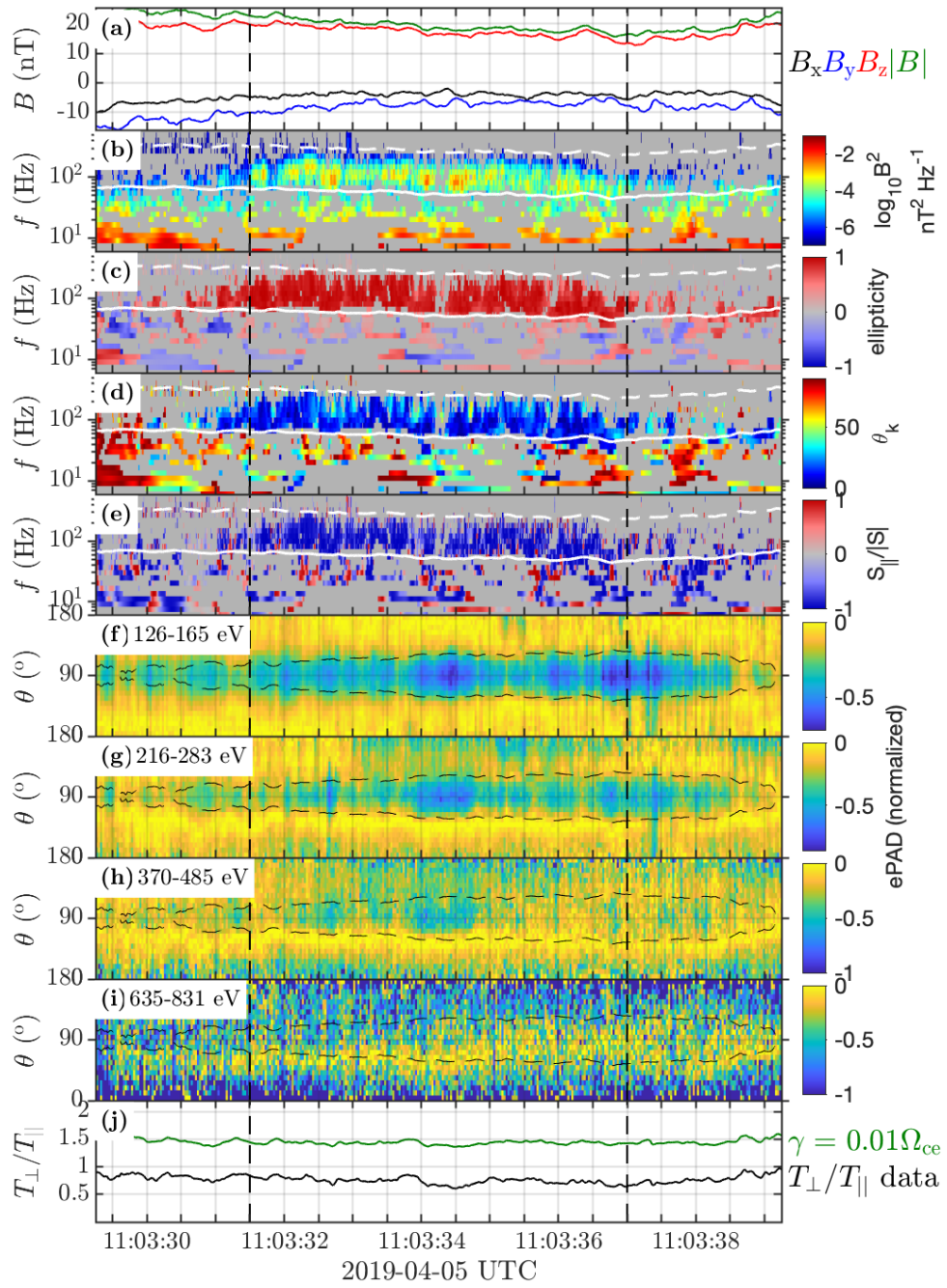
**Figure S4**. Same format as in Figure S1.
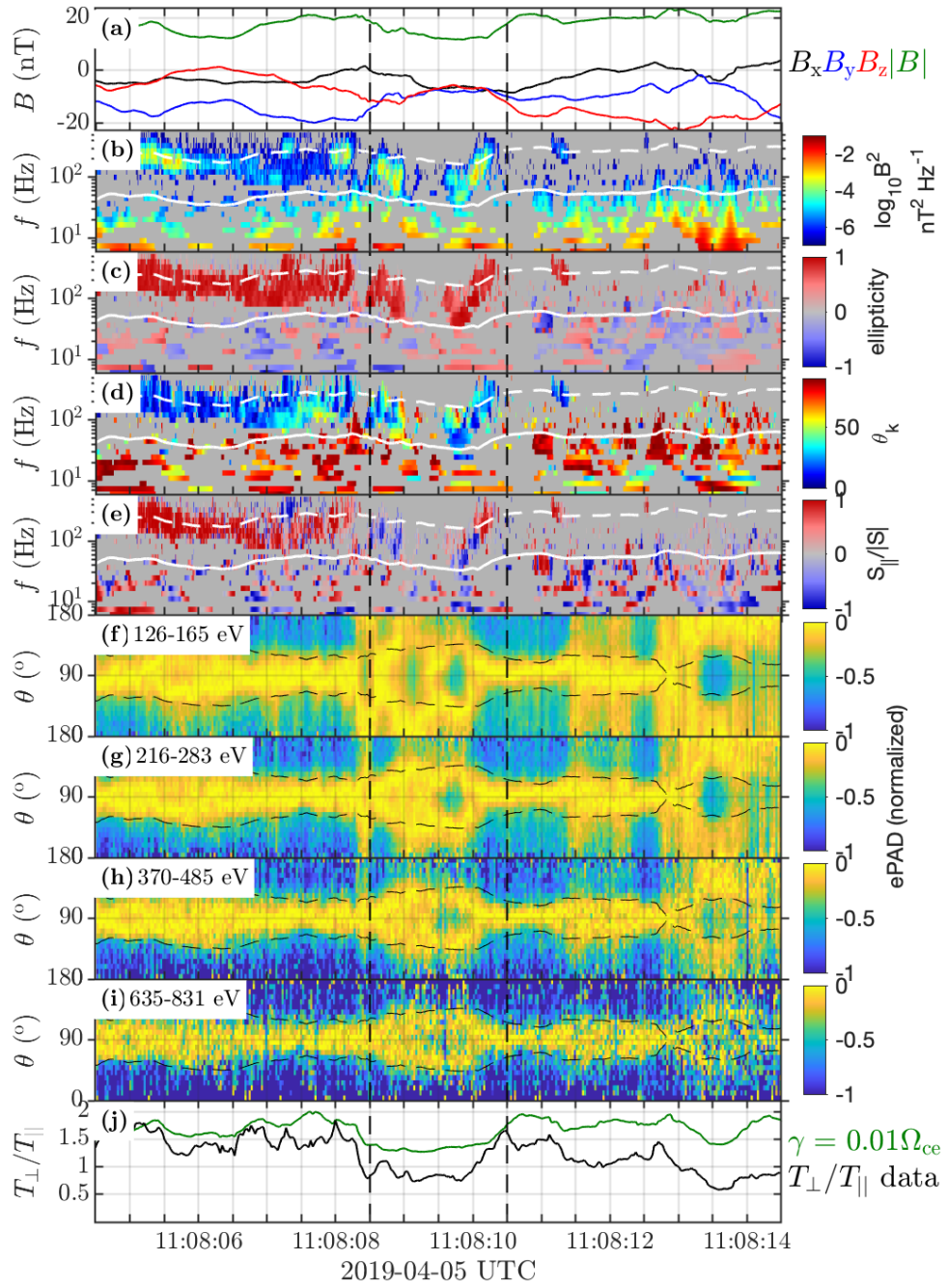
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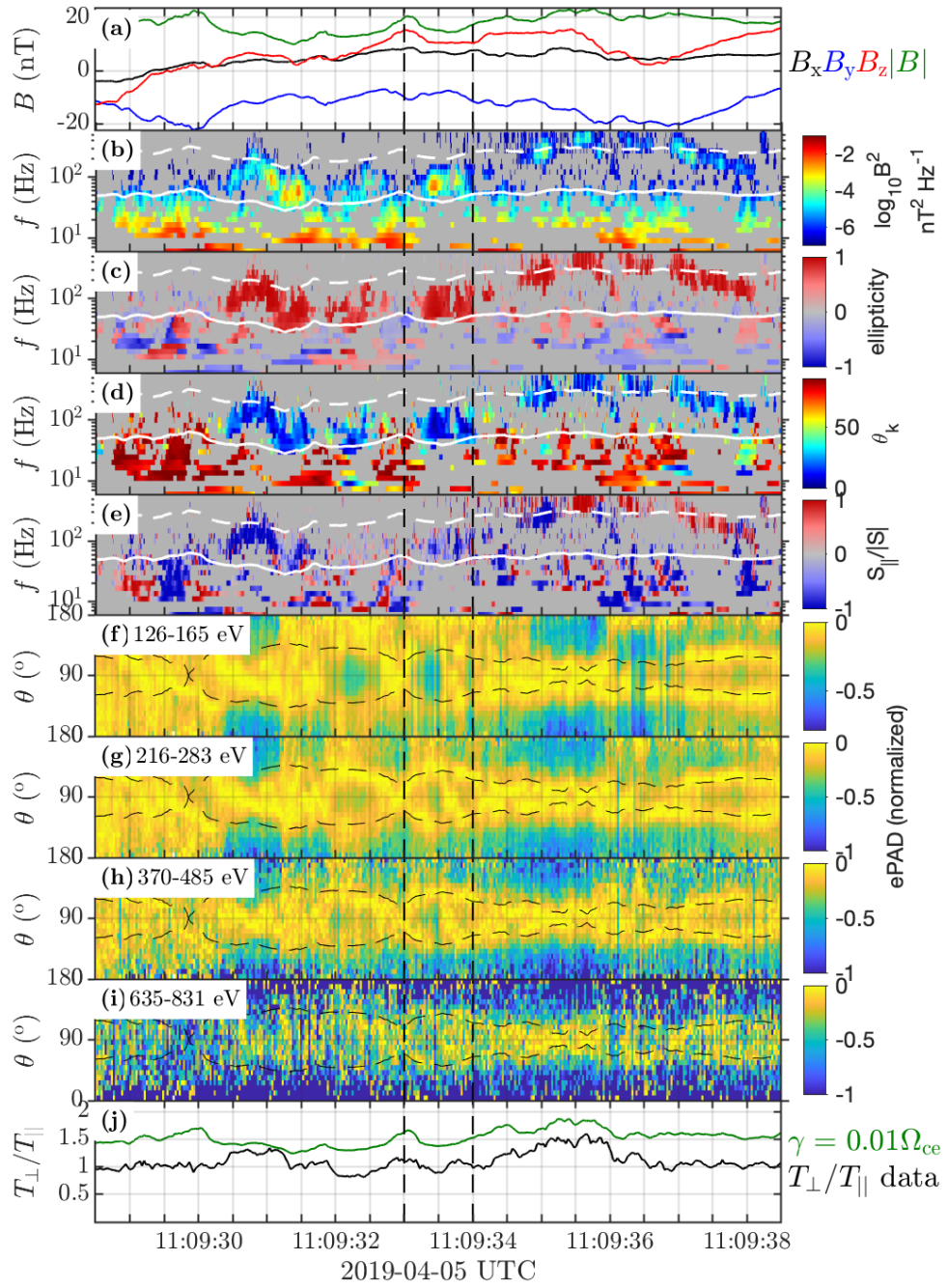
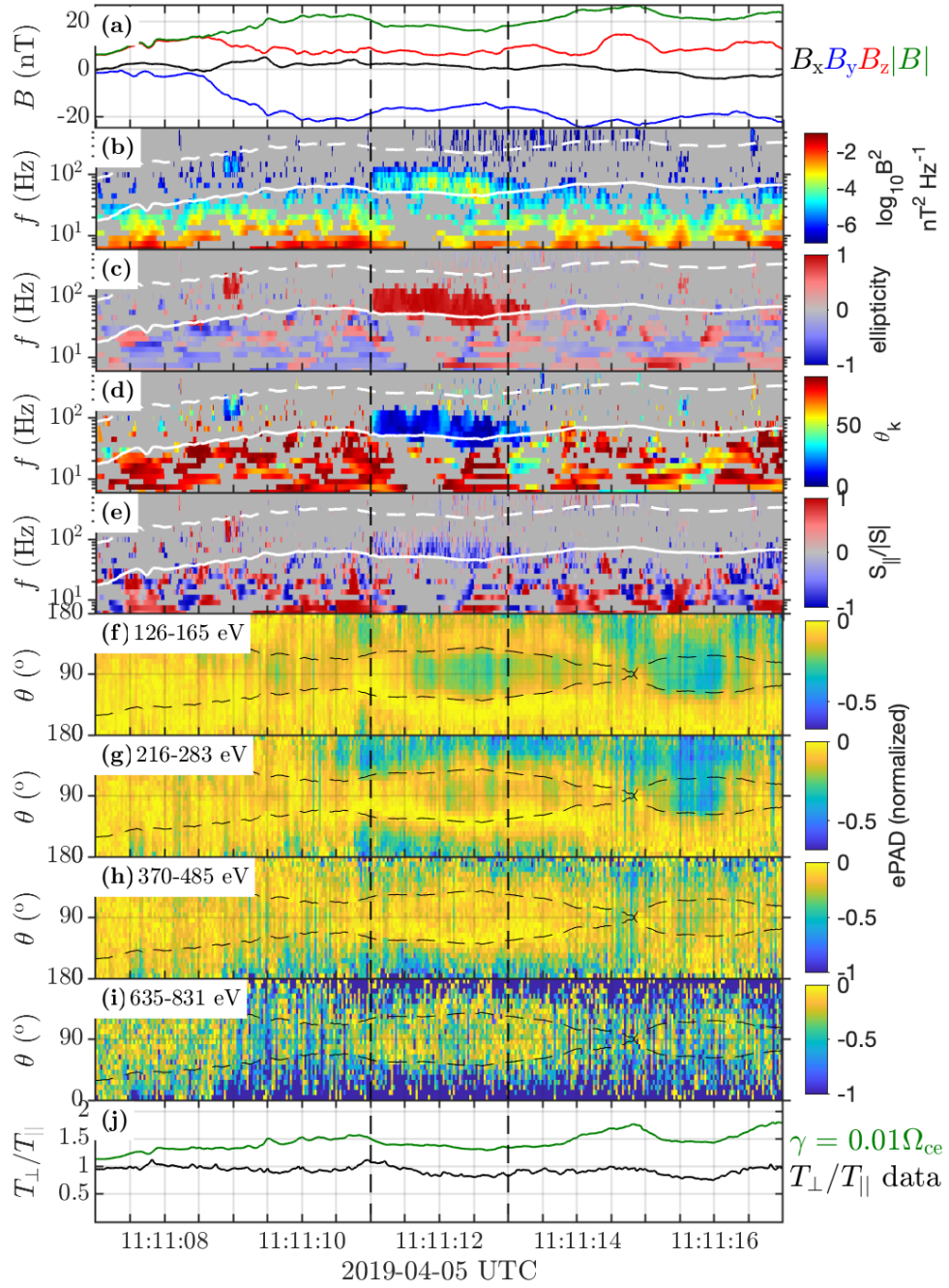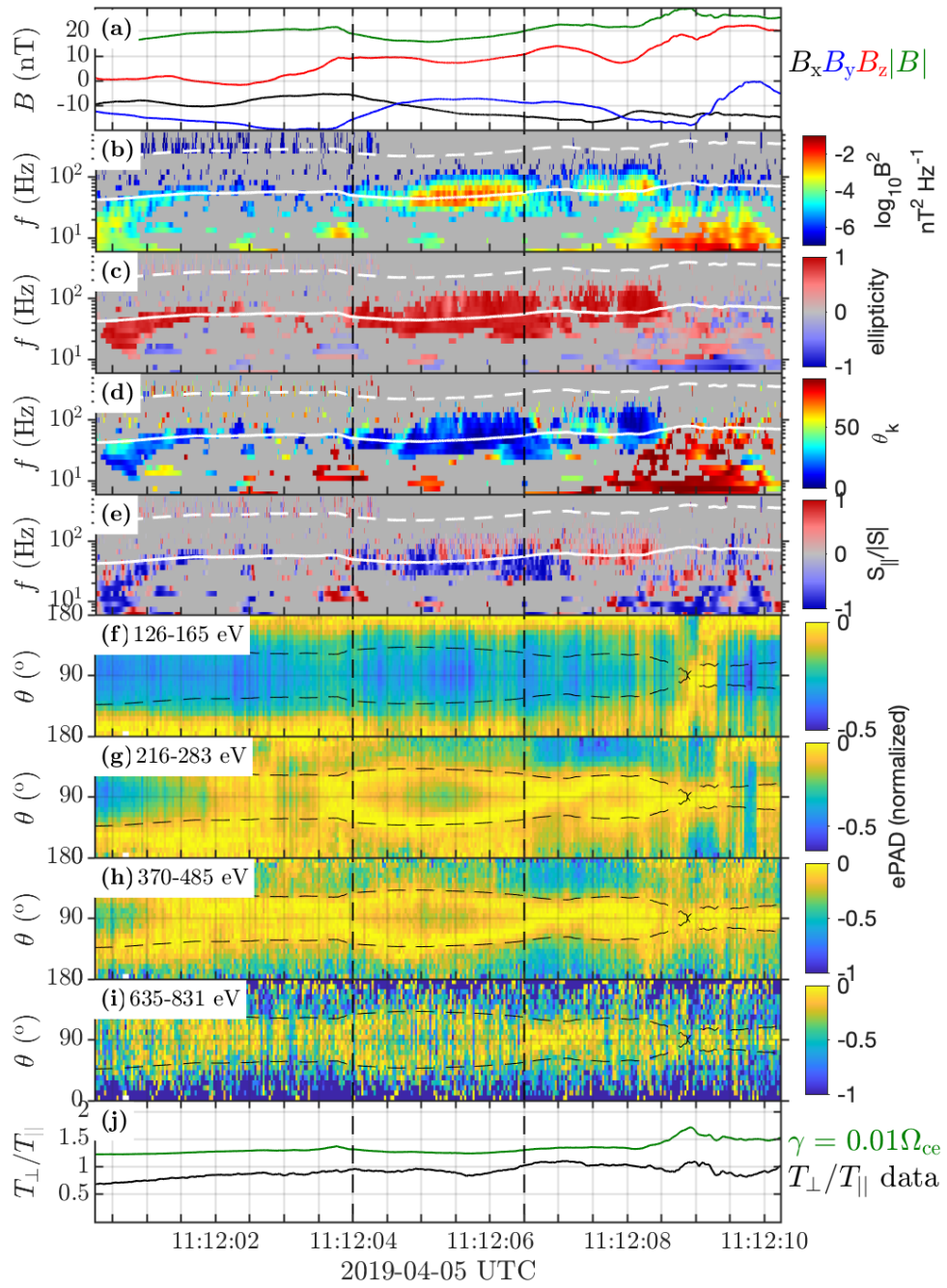**Figure S6**. Same format as in Figure S1.

**Figure S7**. Same format as in Figure S1.

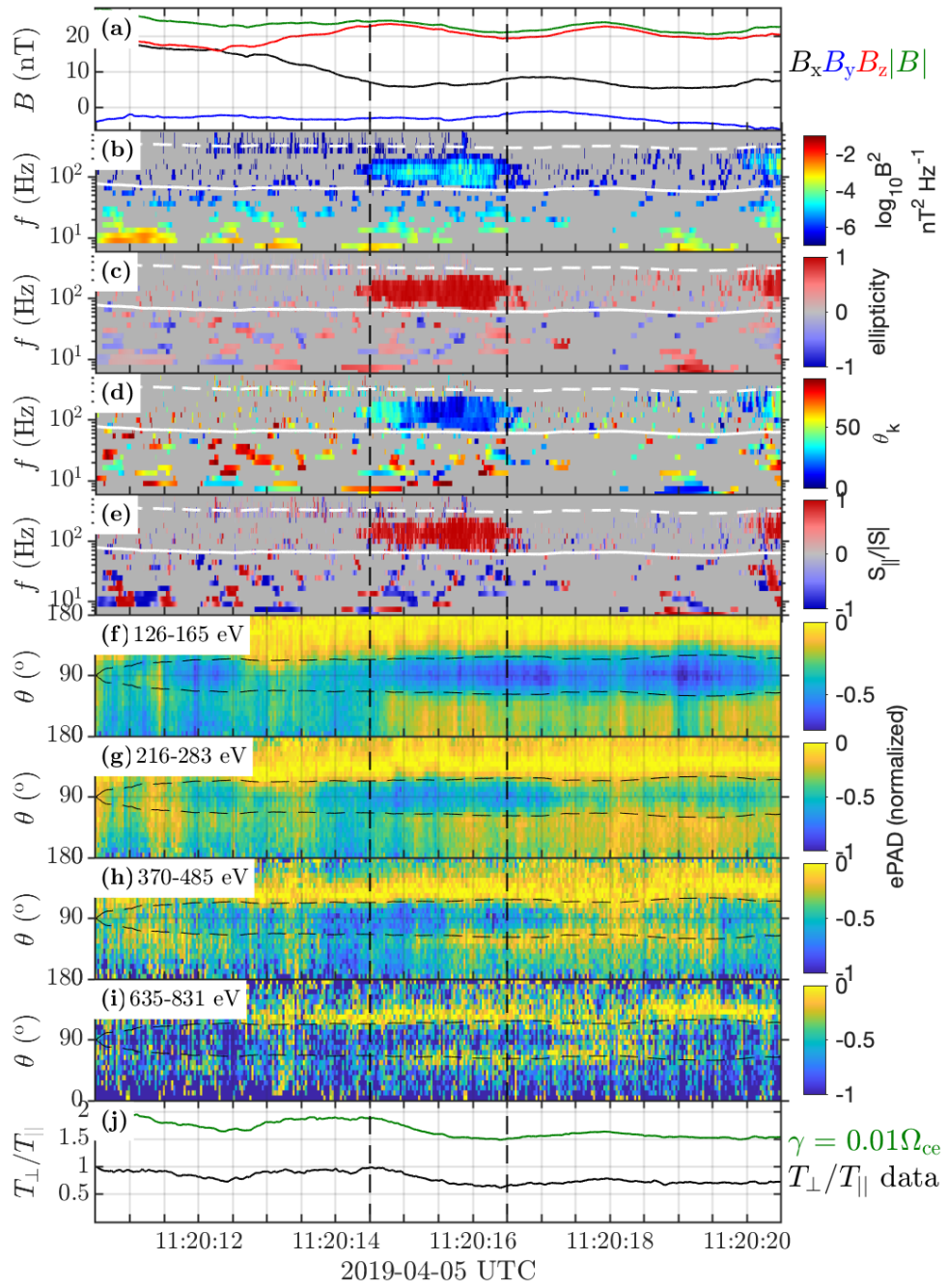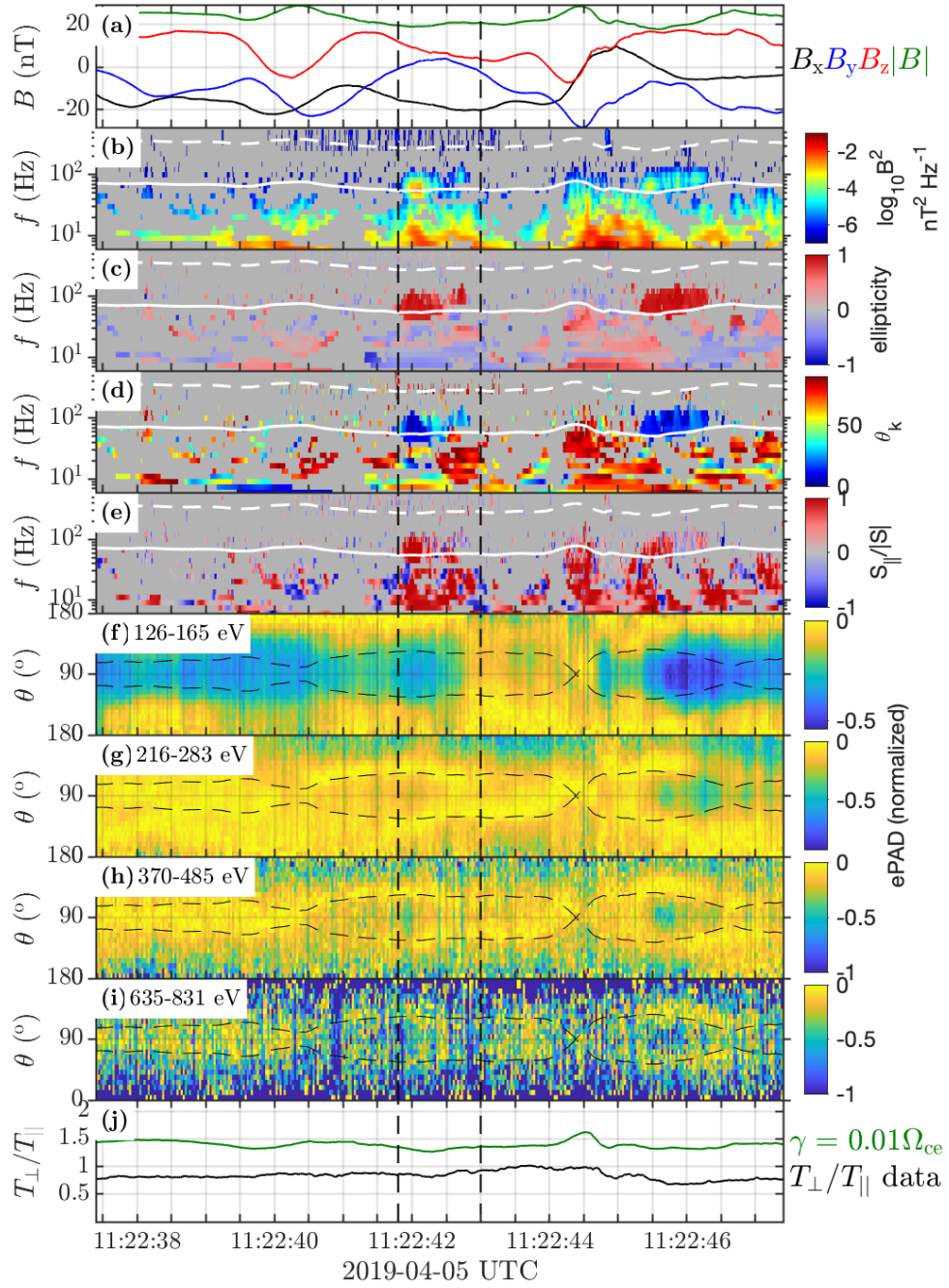**Figure S8**. Same format as in Figure S1.

**Figure S9**. Same format as in Figure S1.
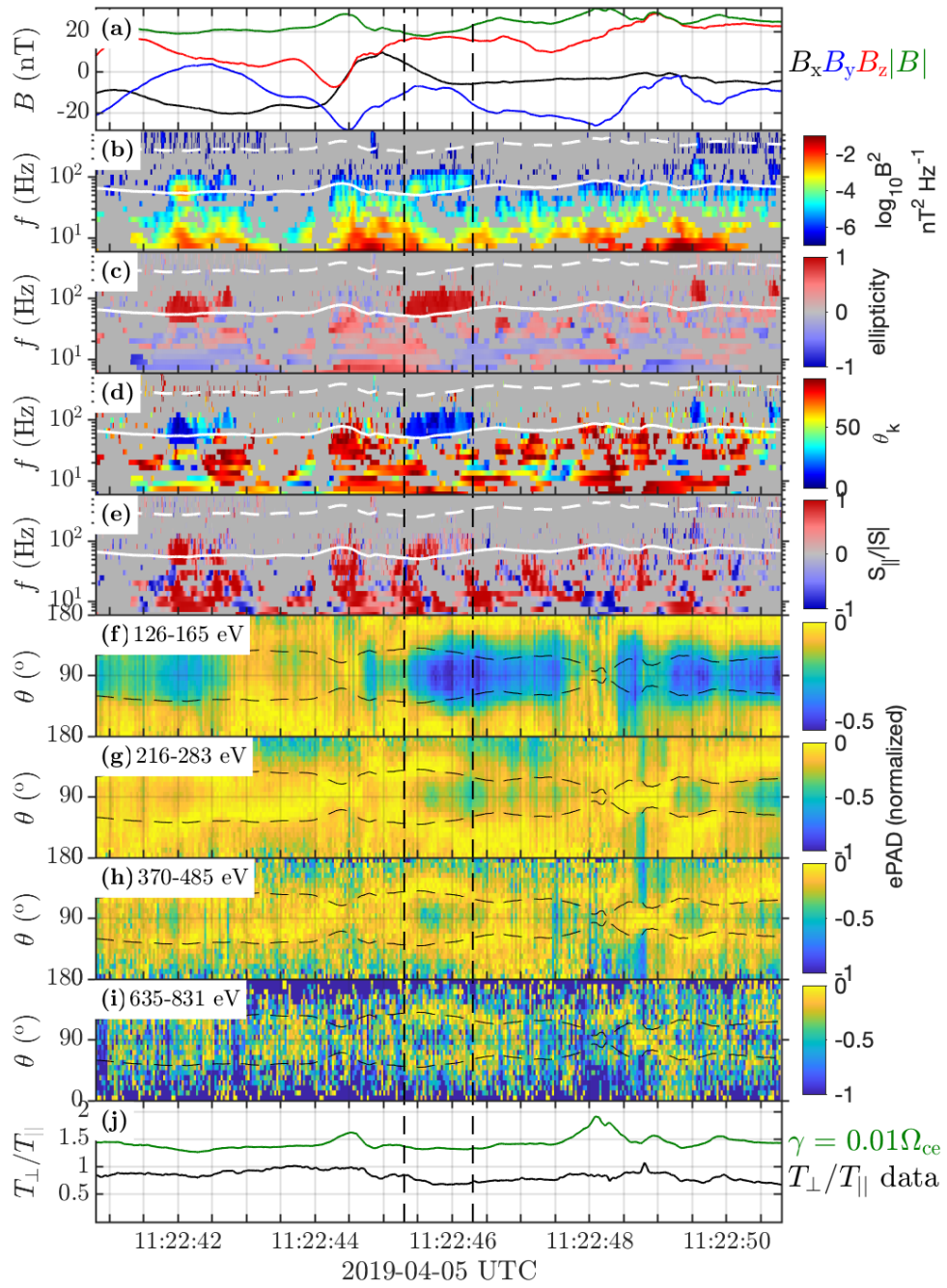
**Figure S10**. Same format as in Figure S1.
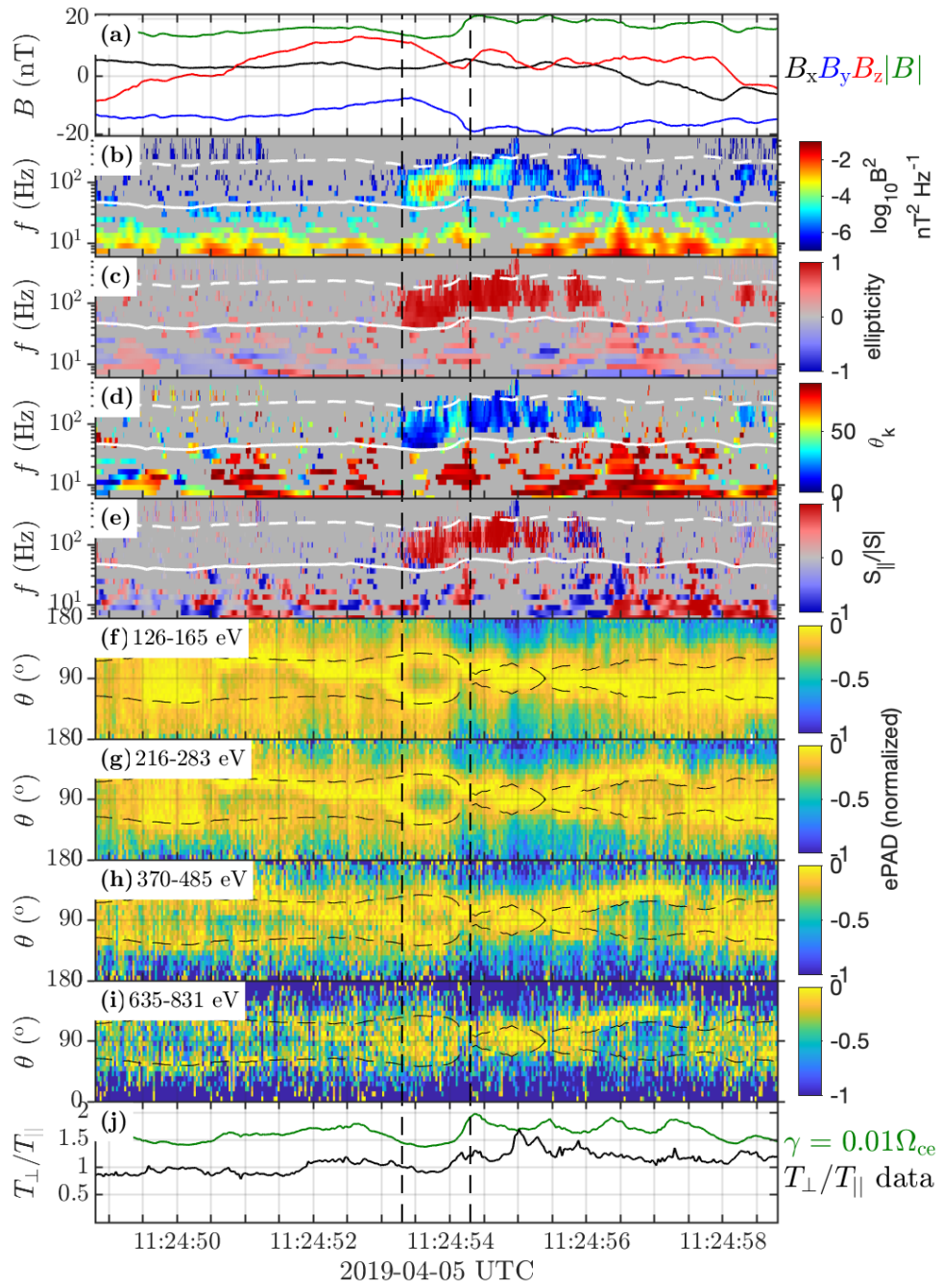
**Figure S11**. Same format as in Figure S1.

**Figure S12**. Same format as in Figure S1.

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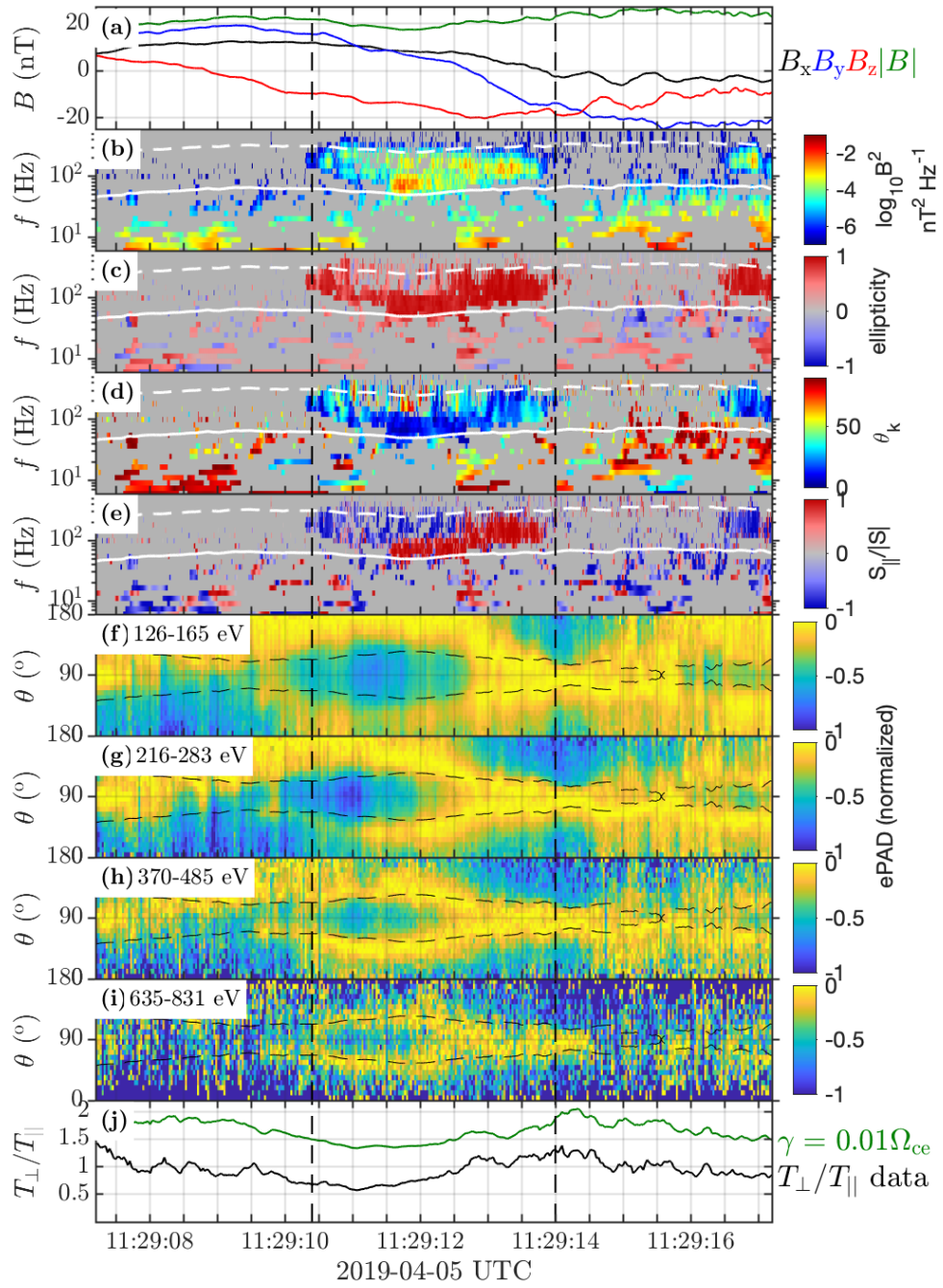
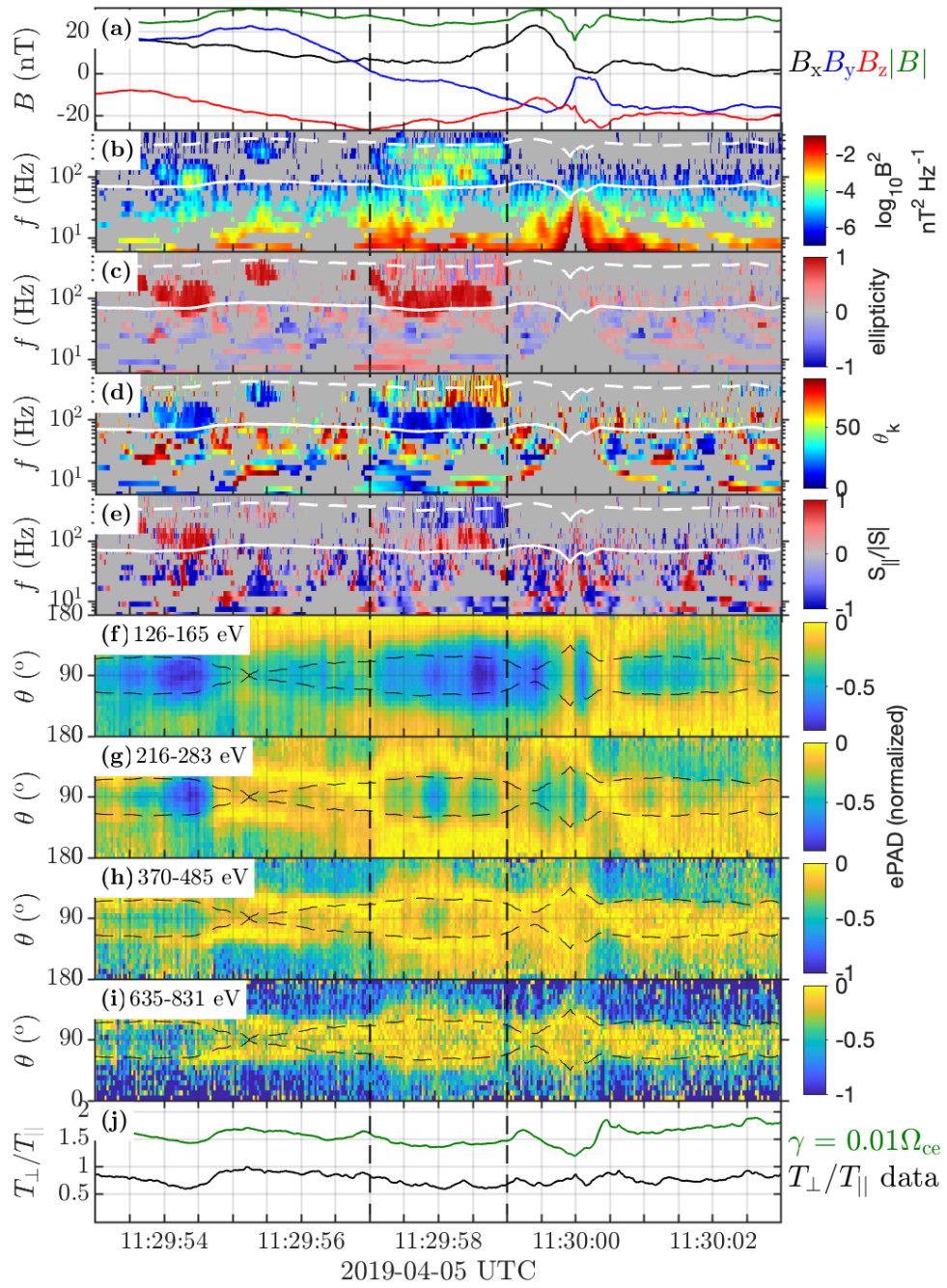**Figure S13**. The example in Fig. 2 in the main text. Same format as in Figure S1.
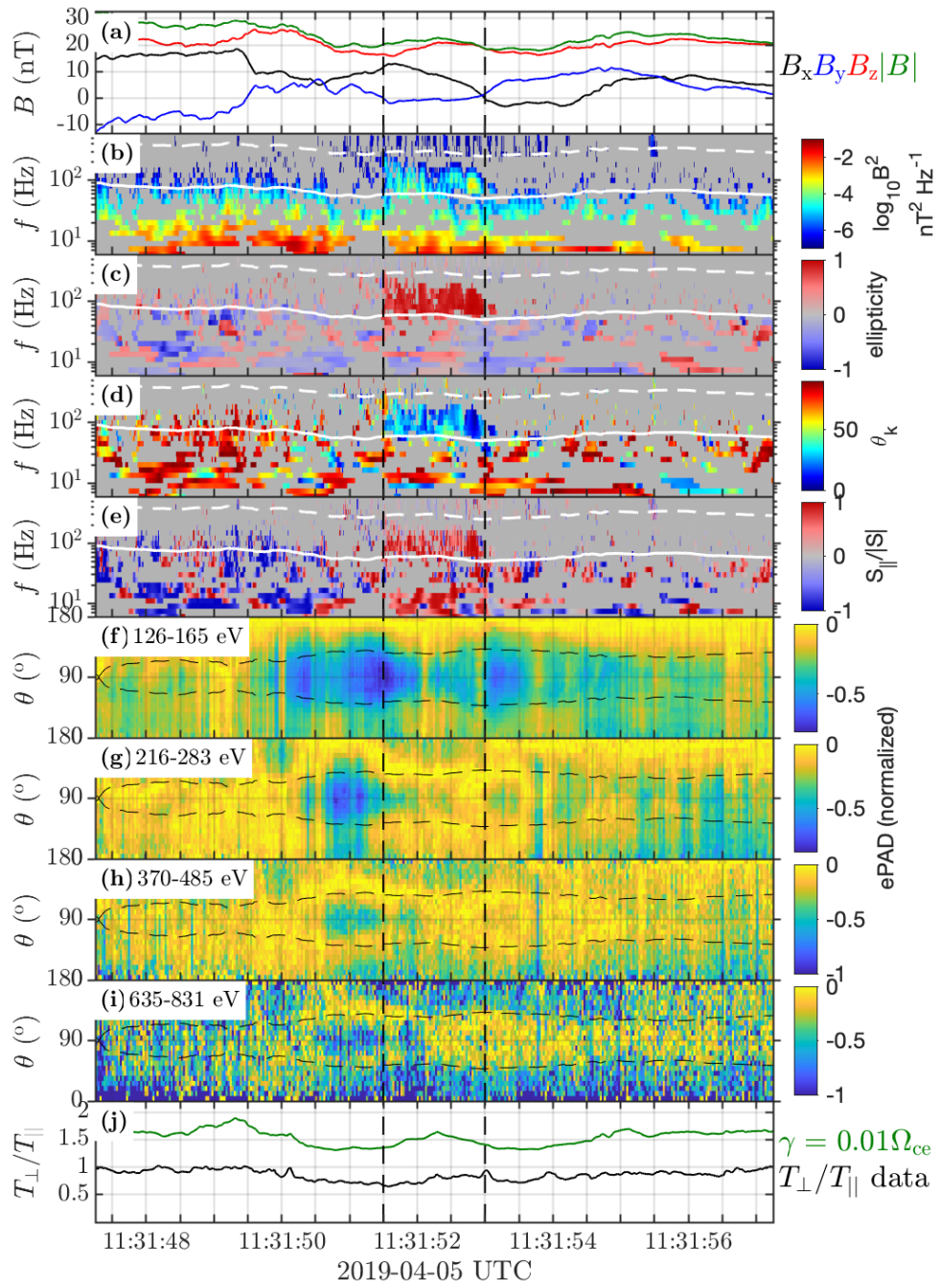
**Figure S14**. Same format as in Figure S1.

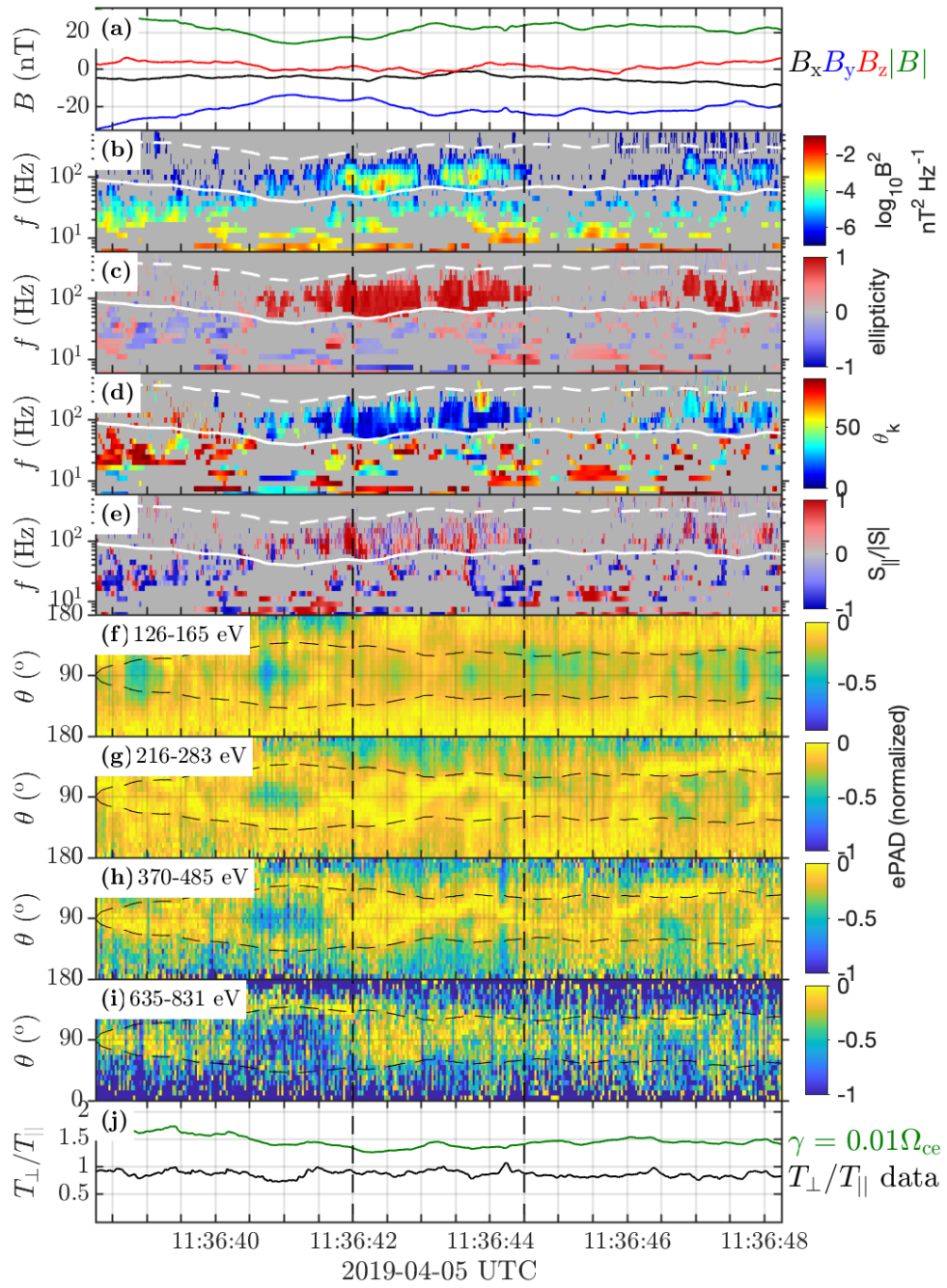**Figure S15**. Same format as in Figure S1.

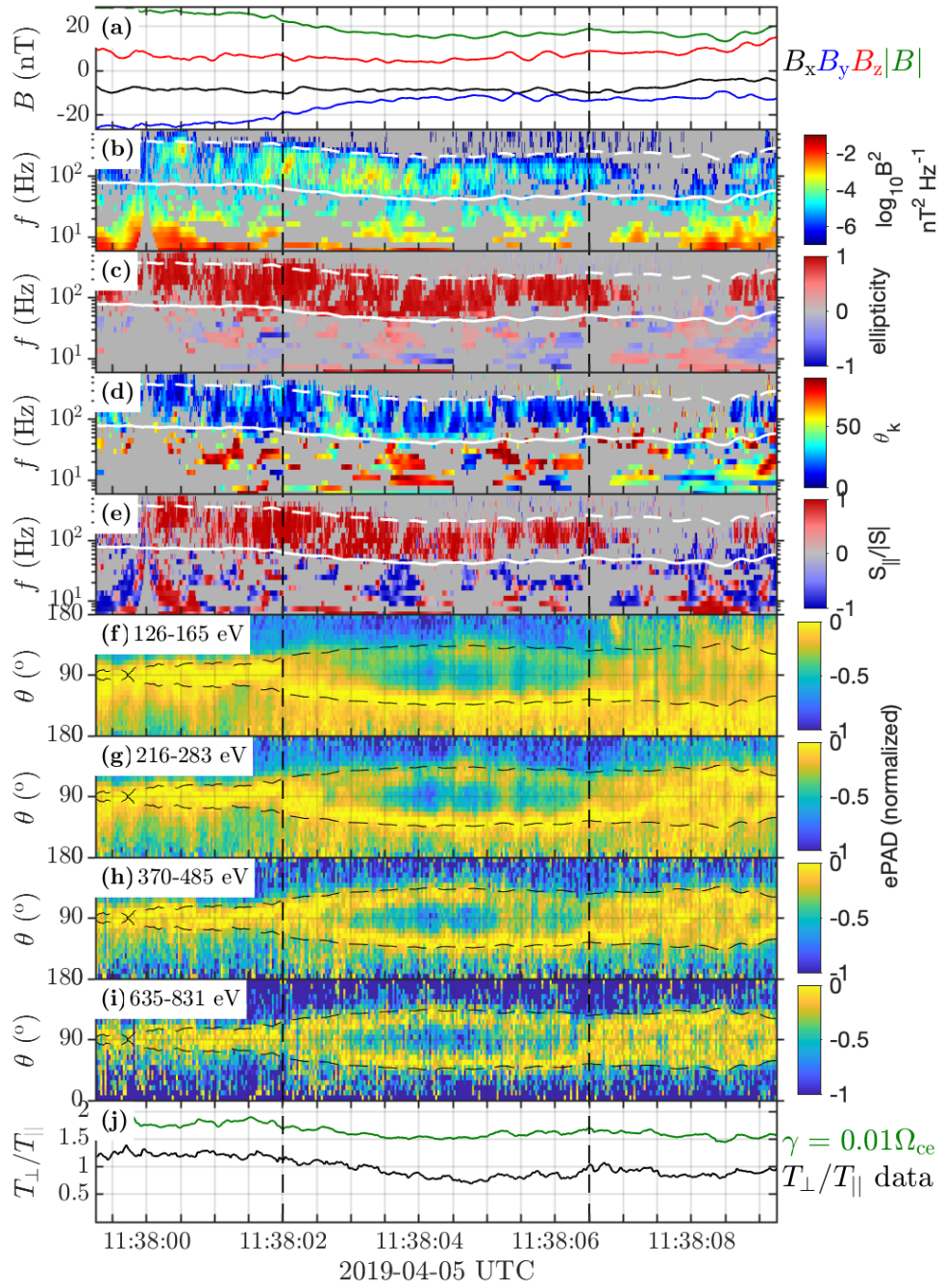**Figure S16**. Same format as in Figure S1.

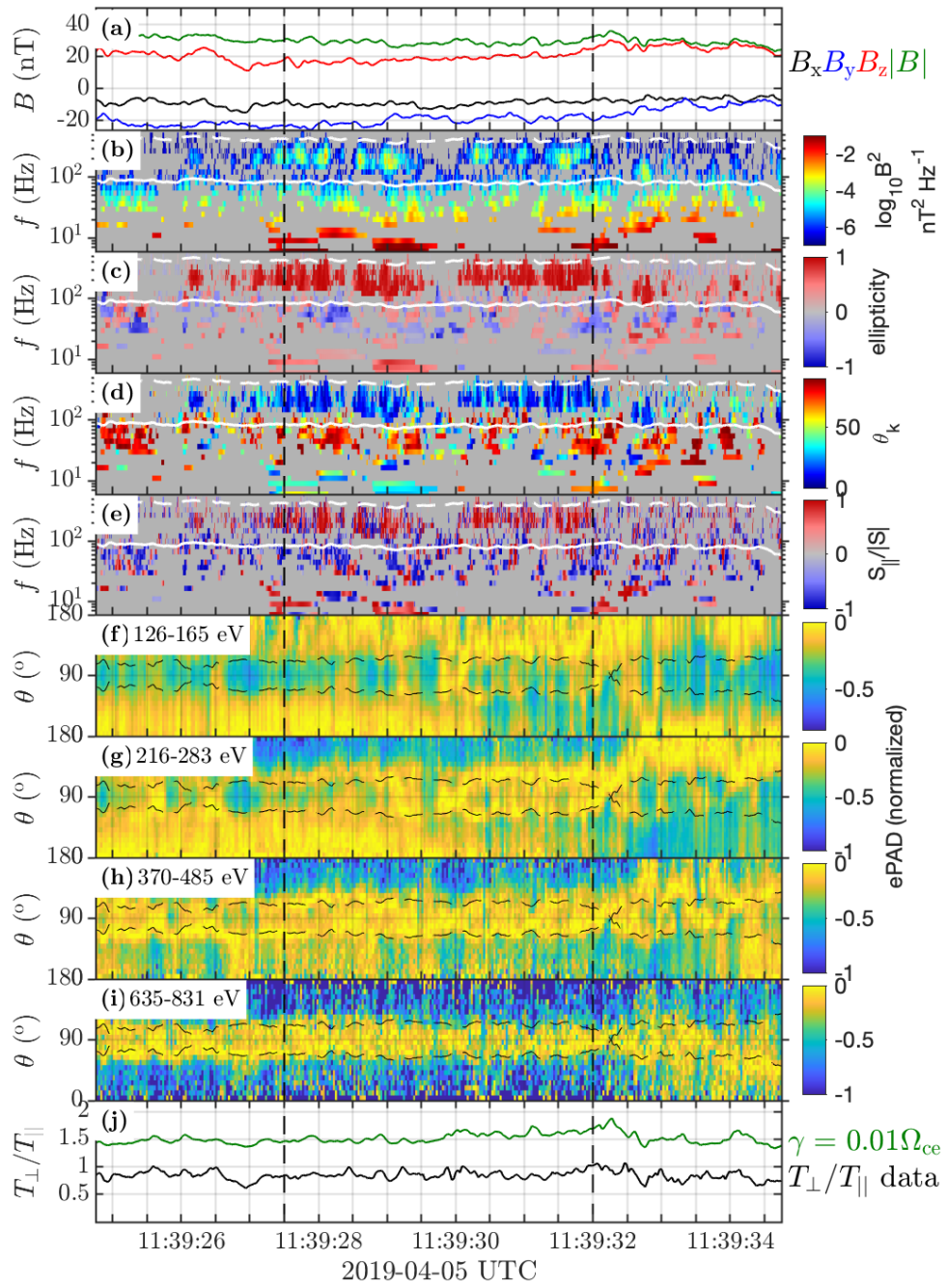**Figure S17**. Same format as in Figure S1.

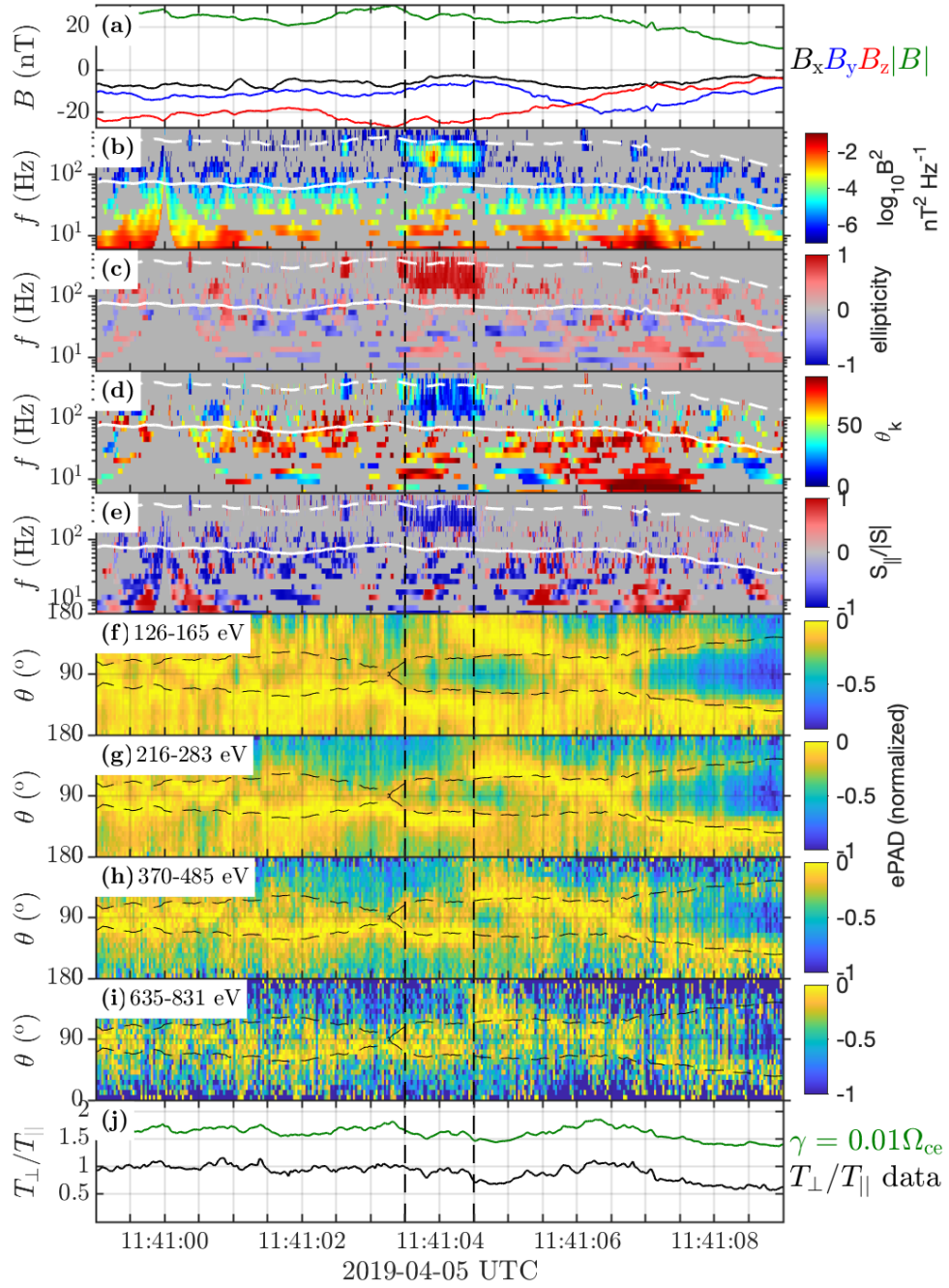**Figure S18**. Same format as in Figure S1.

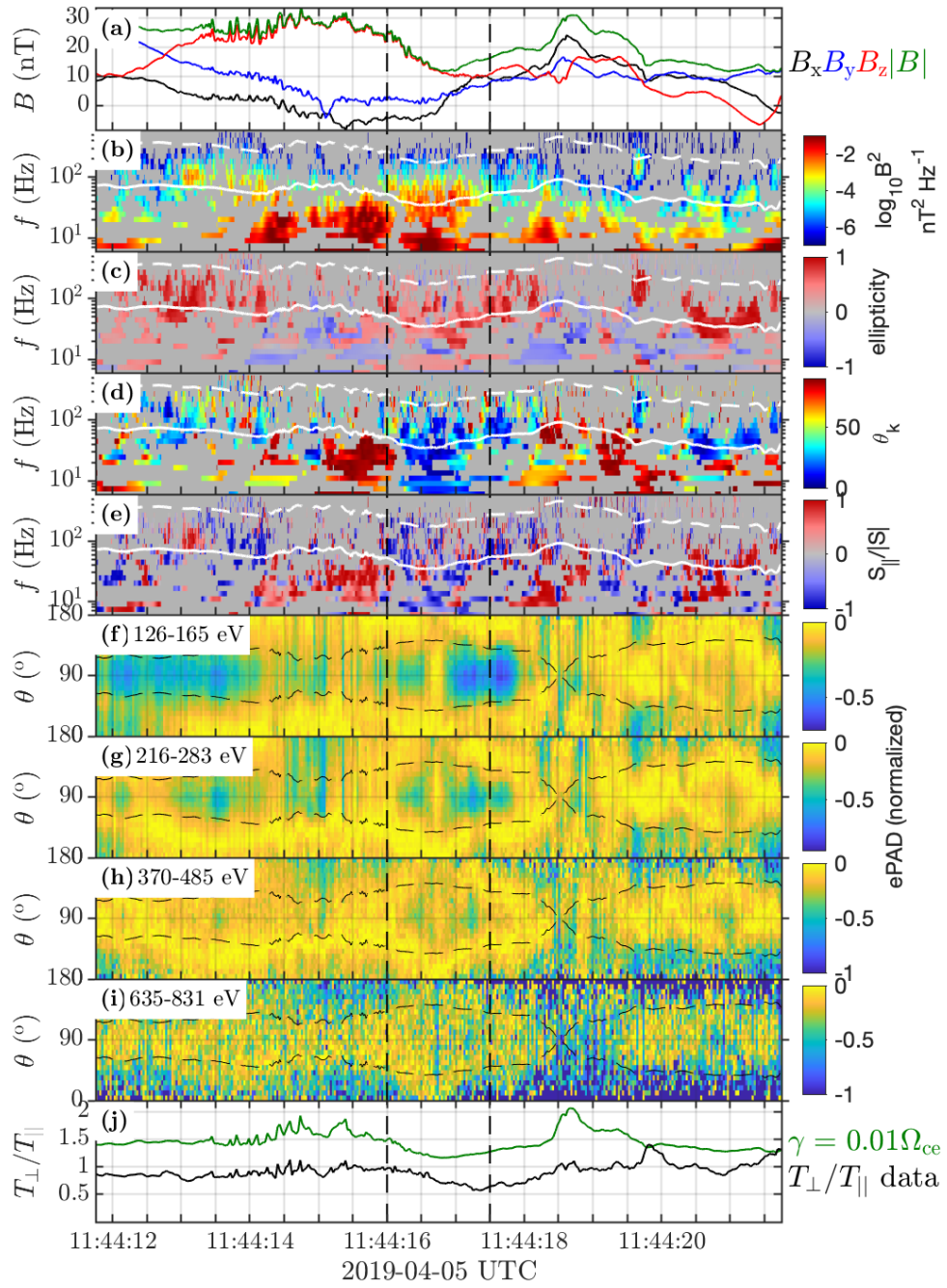**Figure S19**. Same format as in Figure S1.

**Figure S20**. Same format as in Figure S1.

**Figure S21**. Same format as in Figure S1.

**Figure S22**. Same format as in Figure S1.

**Figure S23**. Same format as in Figure S1.

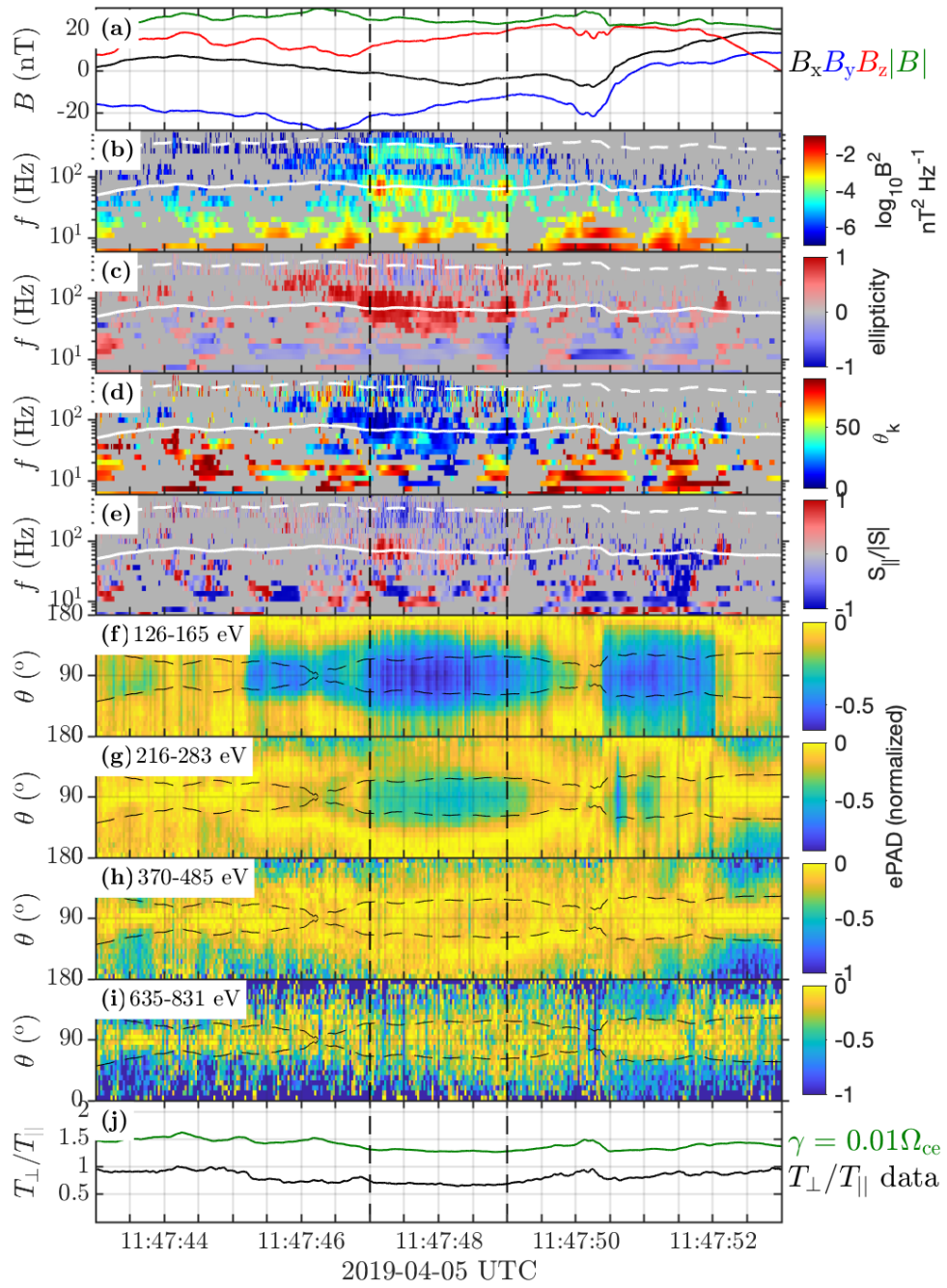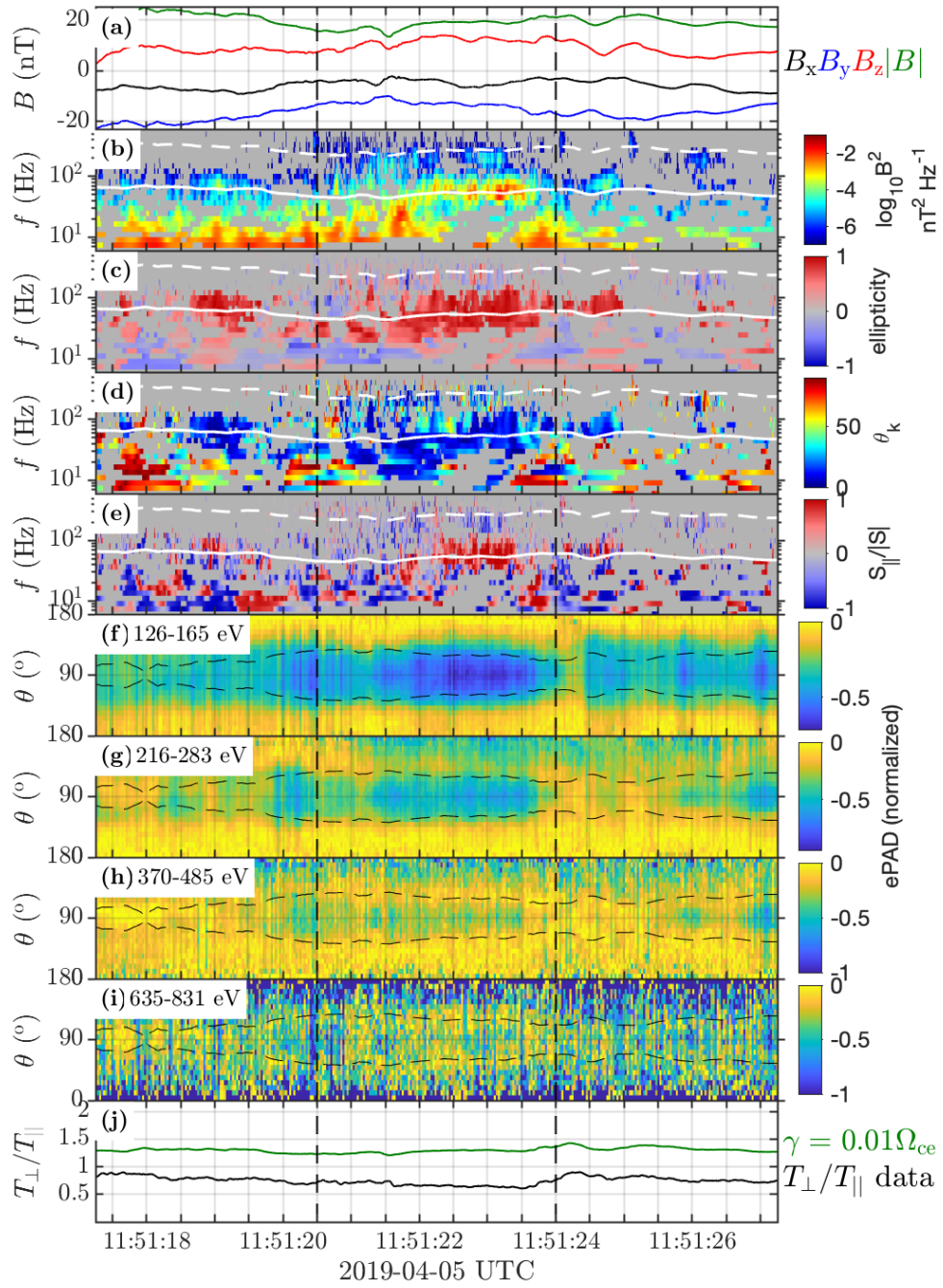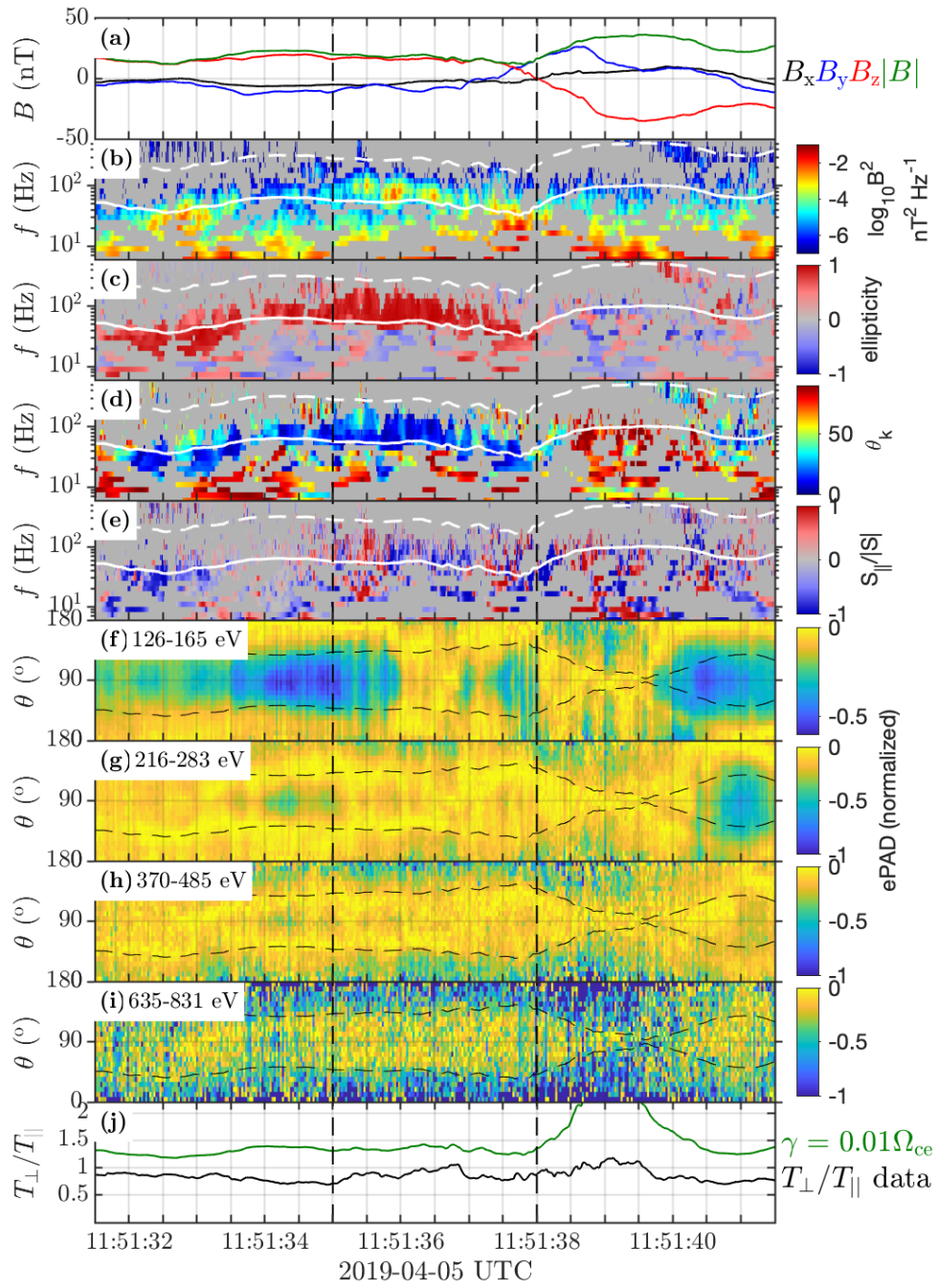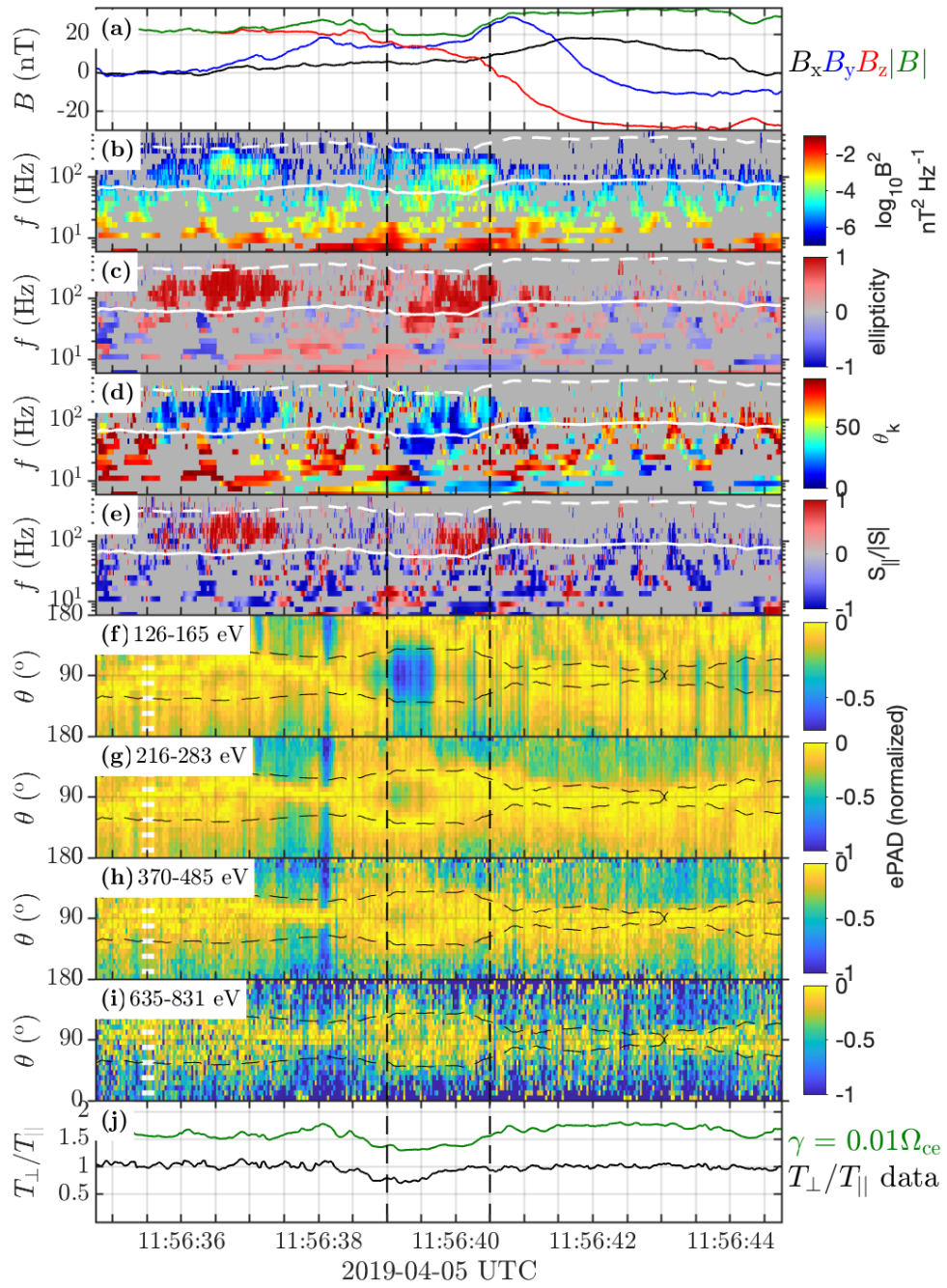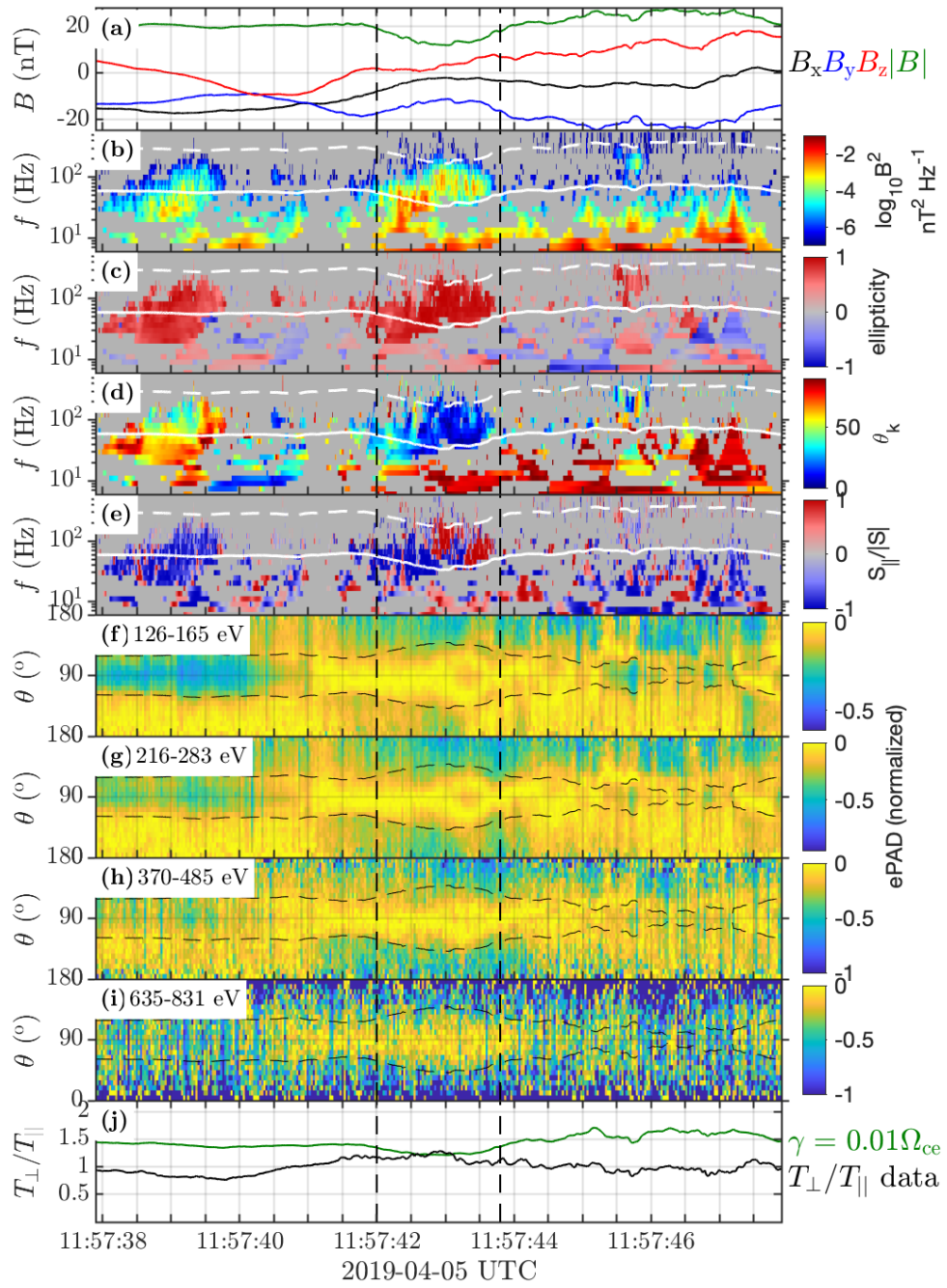**Figure S24**. Same format as in Figure S1.

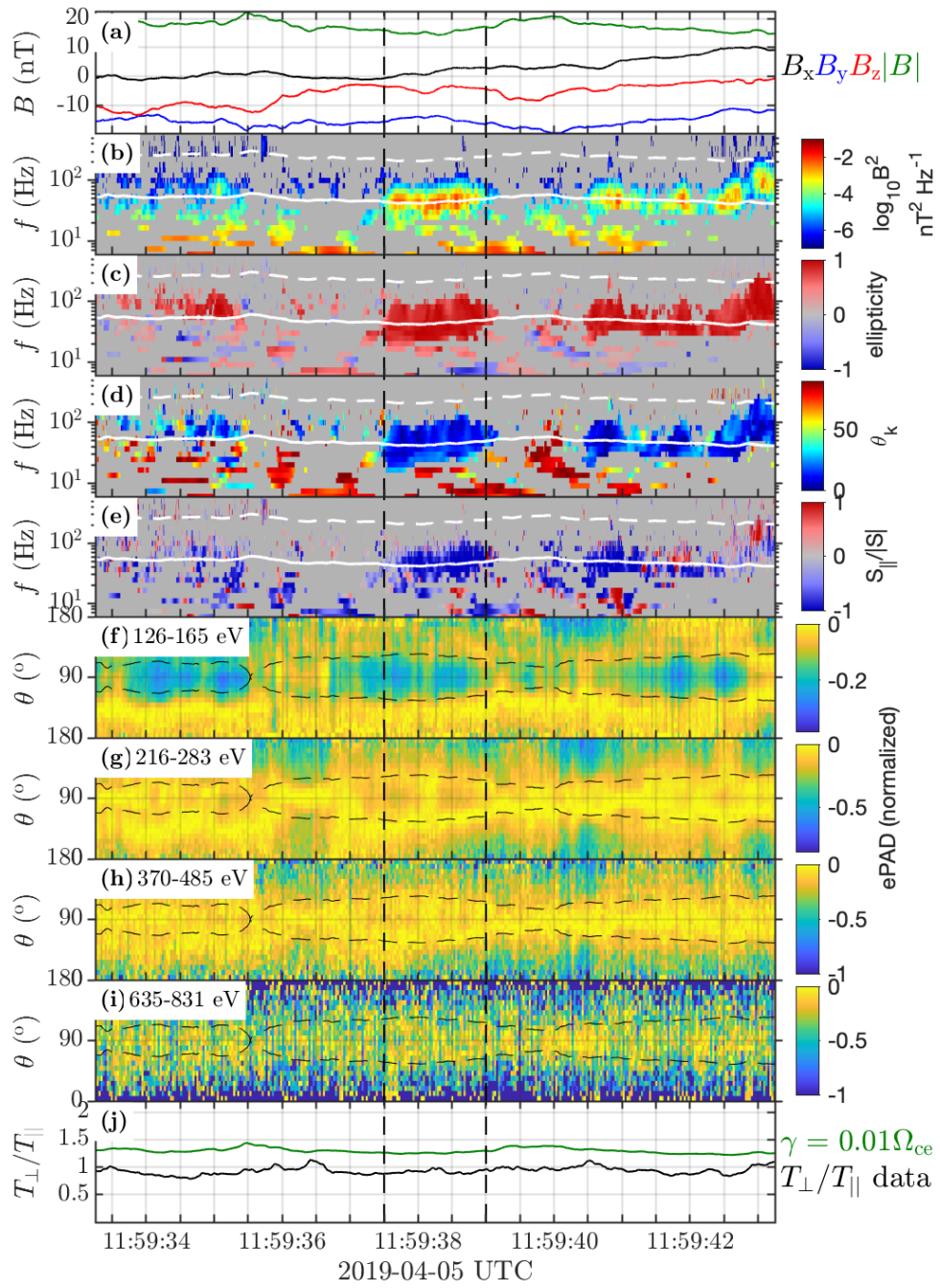**Figure S25**. Same format as in Figure S1.
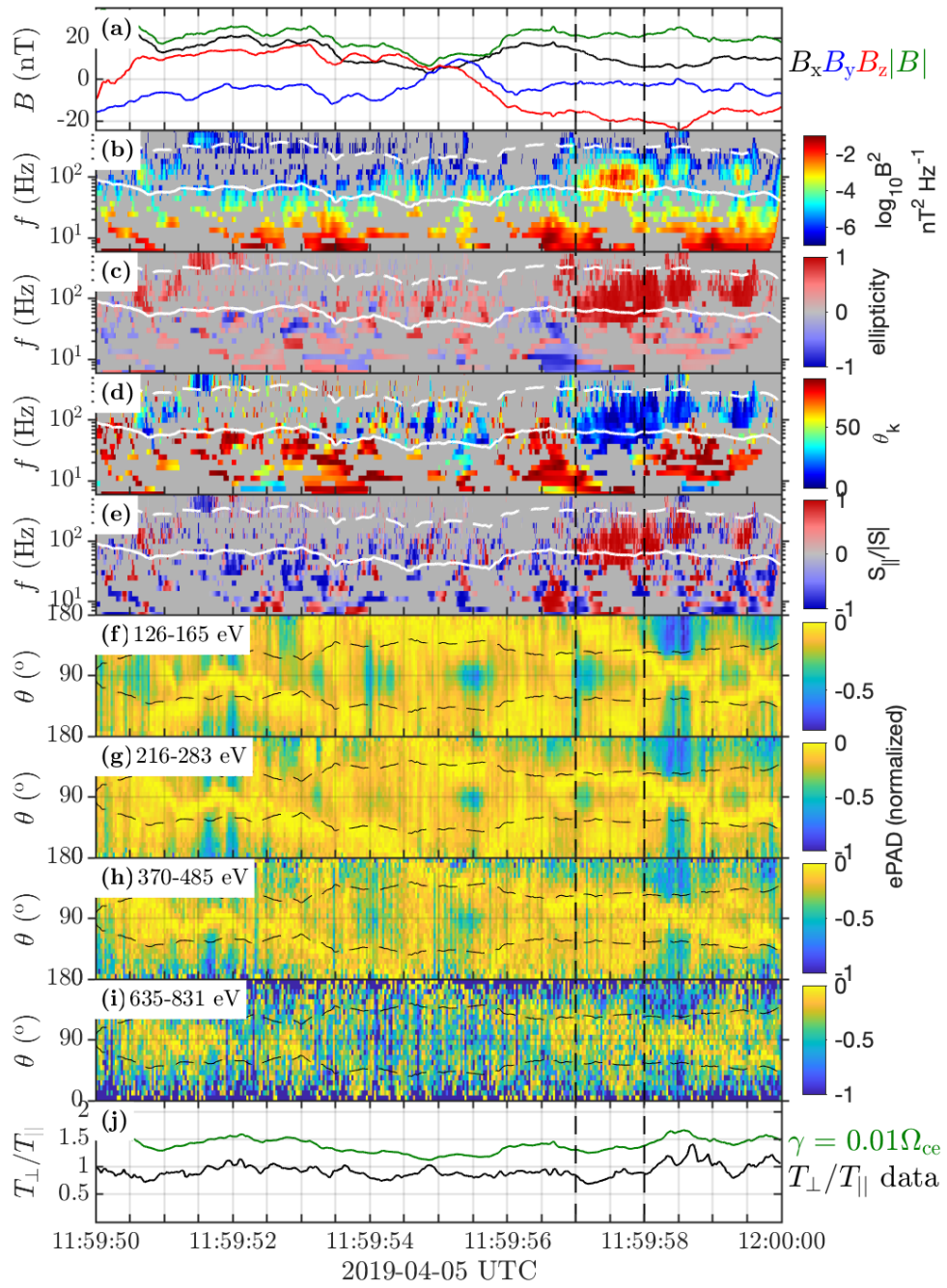
**Figure S26**. Same format as in Figure S1.

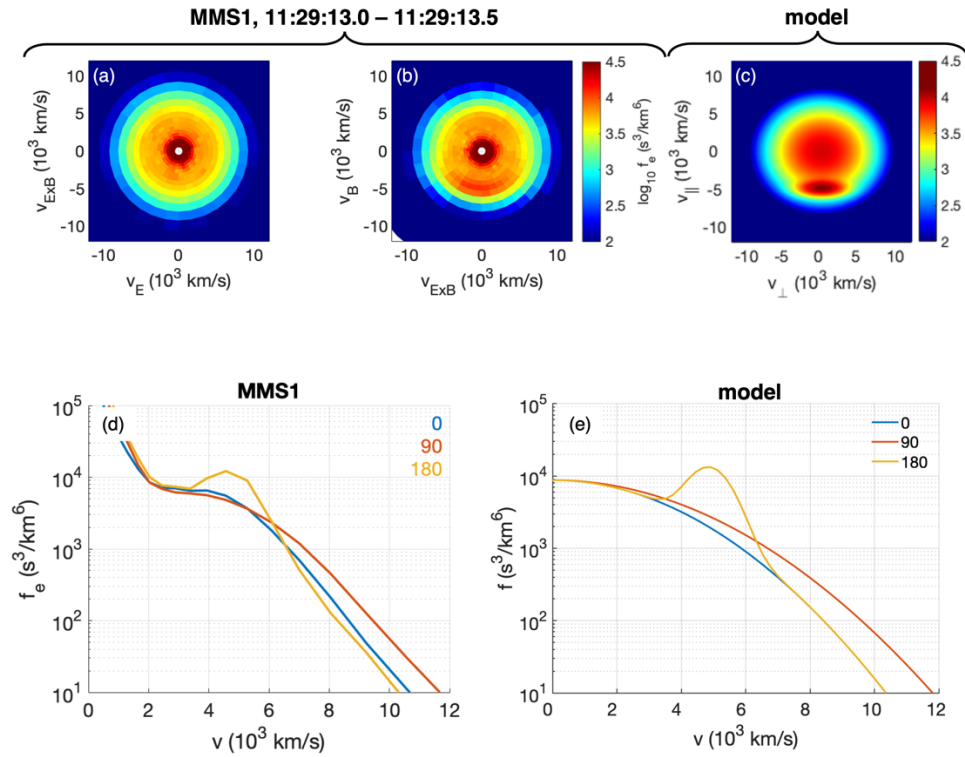**Figure S27**. Same format as in Figure S1.

**Figure S28**. Modeling the beam observed in Fig. 2 in the main text. (a), (b) Polar plots of the electron velocity measured by MMS, averaged during the interval 11:29:13.0-11:29:13.5. (c) Model distribution used in WHAMP, $\mathbf{v}_\parallel$ and $\mathbf{v}_\perp$ denoting velocity parallel and perpendicular to $\mathbf{B}$, respectively. (d), (e) Cuts at pitch-angles 0°, 90°, and 180° of (d) the measured and (e) the model distribution. The parameters used for the model distribution are given in Table S1.
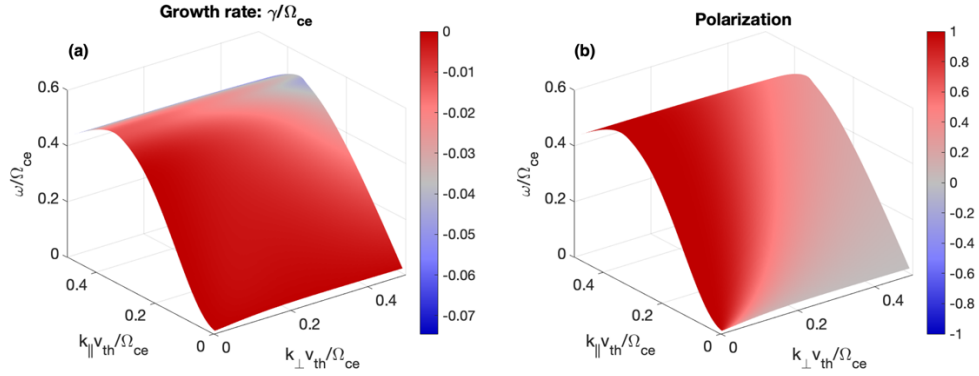
**Figure S29.** Dispersion surfaces calculated by WHAMP using the model distribution shown in Figure S28c,e. The angular frequency $\omega$ of the whistler mode is shown as function of the 2-dimensional wave vector $(k_\parallel, k_\perp)$. The color scales show (a) growth rate $\gamma$, (b) polarization.

**Table S1.** Parameters used to model the beam distribution shown in Figure S28; the sum of the core and beam populations are used in WHAMP.

|      | $n_e$ [cm$^{-3}$] | $T_{e\parallel}$ [eV] | $T_{e\perp}/T_{e\parallel}$ | $v_{\parallel \text{drift}}$ [$10^3$ km/s] |
|------|------|------|------|------|
| core | 4    | 45   | 1.3  | 0    |
| beam | 0.3  | 2    | 8    | -4.9 |