Ray Tracing Study of Rising Tone EMIC-triggered Emissions

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INTRODUCTION

- Electromagnetic ion cyclotron (EMIC) triggered emissions have similar properties to whistler-mode chorus emissions
- Characteristics: highly coherent, frequency range from 0.5 Hz to 2 Hz (below the helium or proton gyrofrequency), rising tone, mostly at the onset of geomagnetic storms
- We perform ray tracing simulations and compare resulting polarizations, dispersions and wave vector angles w. r. t. magnetic field (θ_k) with Cluster spacecraft data
- We show that source locations are close to the equator and in high density gradients of the plasmapause or plasmaspheric plumes (modelled as field aligned ducts)
- Basic properties of the cyclotron and Landau damping for the Maxwellian distribution are presented

DATA SET

- We studied three EMIC events observed by the Cluster spacecraft in years 2004-2006
- Wave analysis was done on STAFF-SC and FGM low frequency measurements with PRASSADCO code [1]

METHODS

- Ray tracing in cold plasma with continuous WKB condition control and computation of Landau and cyclotron damping in weak growth approximation for parallel propagation
- Radial profile of electron density obtained from EFW data calibrated by WHISPER instrument data ($80\ cm^{-3}$ e^- density upper limit) , ion composition estimate based on crossover frequencies
- Forward tracing from the equator with assumed left polarization and initial $\theta_k = 0°$ or backward tracing with measured properties and mirrored wave vector

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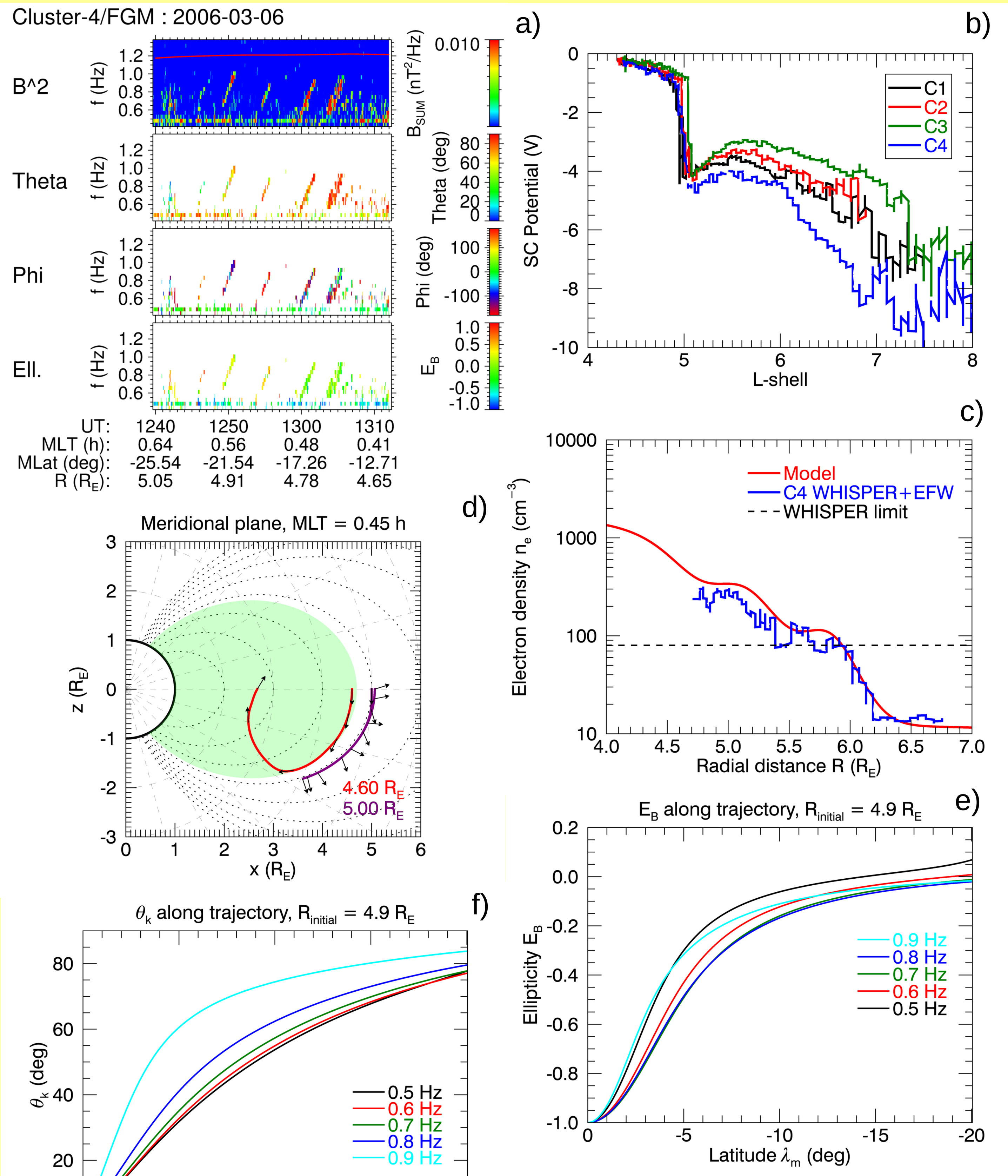
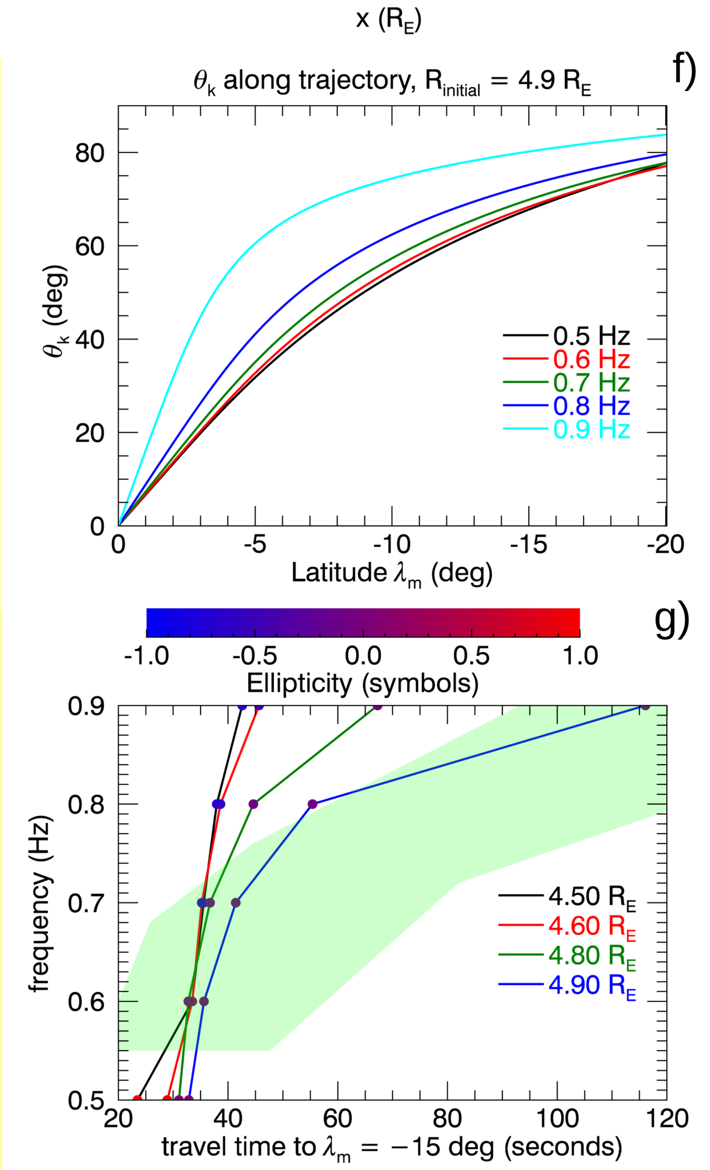
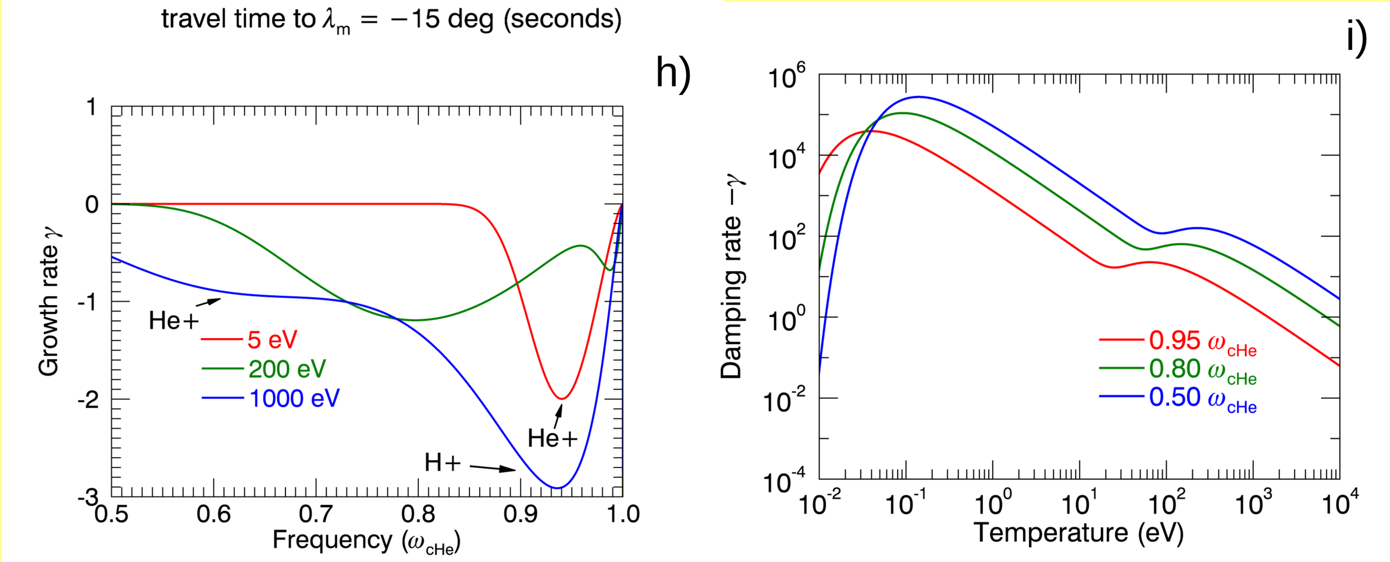
- Quasiperiodic risers with linear dispersion in the midnight MLT sector, below helium gyrofrequency, measured by the spacecraft C4
- Forward ray tracing successfully explains only the last tone for $\phi = 0°$; no fitting propagation scheme found for other elements (backward tracing)





a) From the top: PSD of magnetic fluctuations, wave vector polar angle, azimuthal angle, ellipticity of polarization
b) Spacecraft potential C1-4, EFW data
c) Electron density obtained from WHISPER and EFW data, fitted on C4
d) Forward ray tracing, stopped at the equator; wave frequency 0.6 Hz
e) Ellipticity, propagation from the equator
f) Angle θ_k, propagation from the equator
g) Dispersion during propagation from the equator to λ_m = -15°. Green polygon corresponds to last tone in spectrogram a). Final values of ellipticity are the color coded symbols.



h) Ion cyclotron damping at the equator for different temperatures; isotropic Maxwellian distribution. At higher temperatures (200 eV and 1 keV) the damping is also influenced by protons, as shown by the H+ arrow.
i) Landau damping for different frequencies; isotropic Maxwellian distribution. Except for the regions below approx. 10 meV and above 10 keV, the damping is extremely large.

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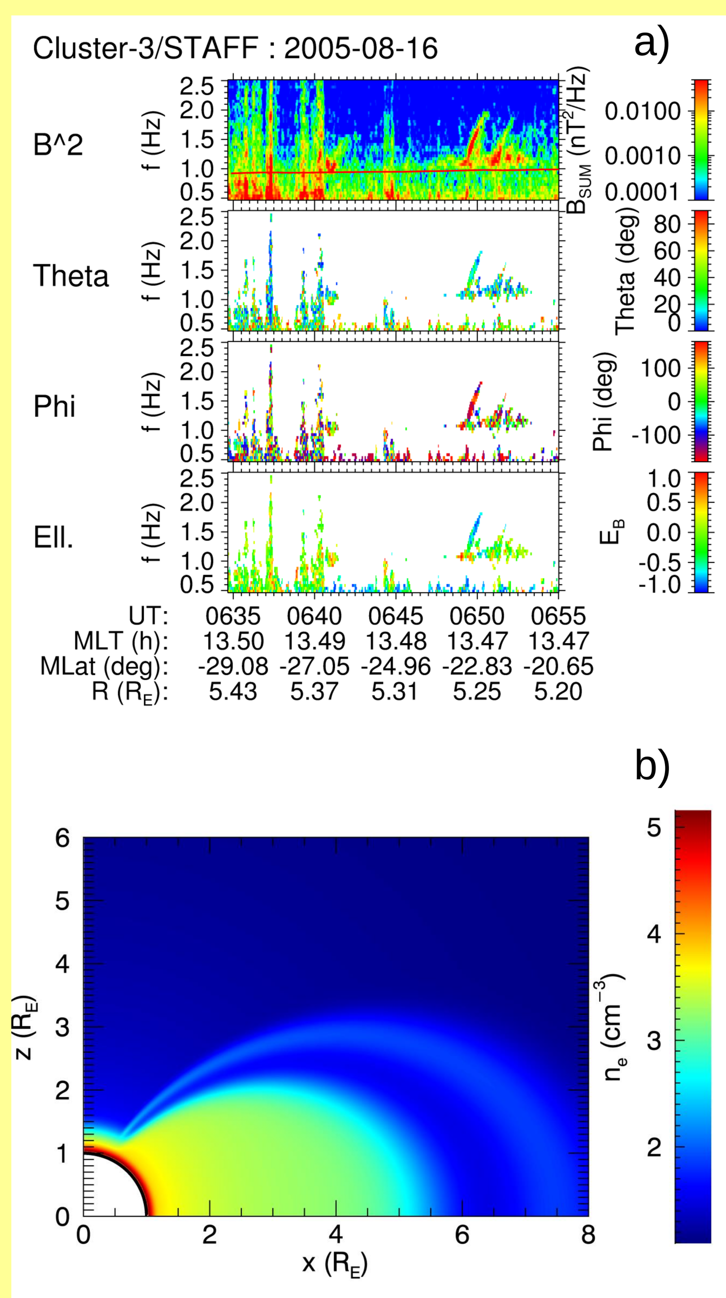
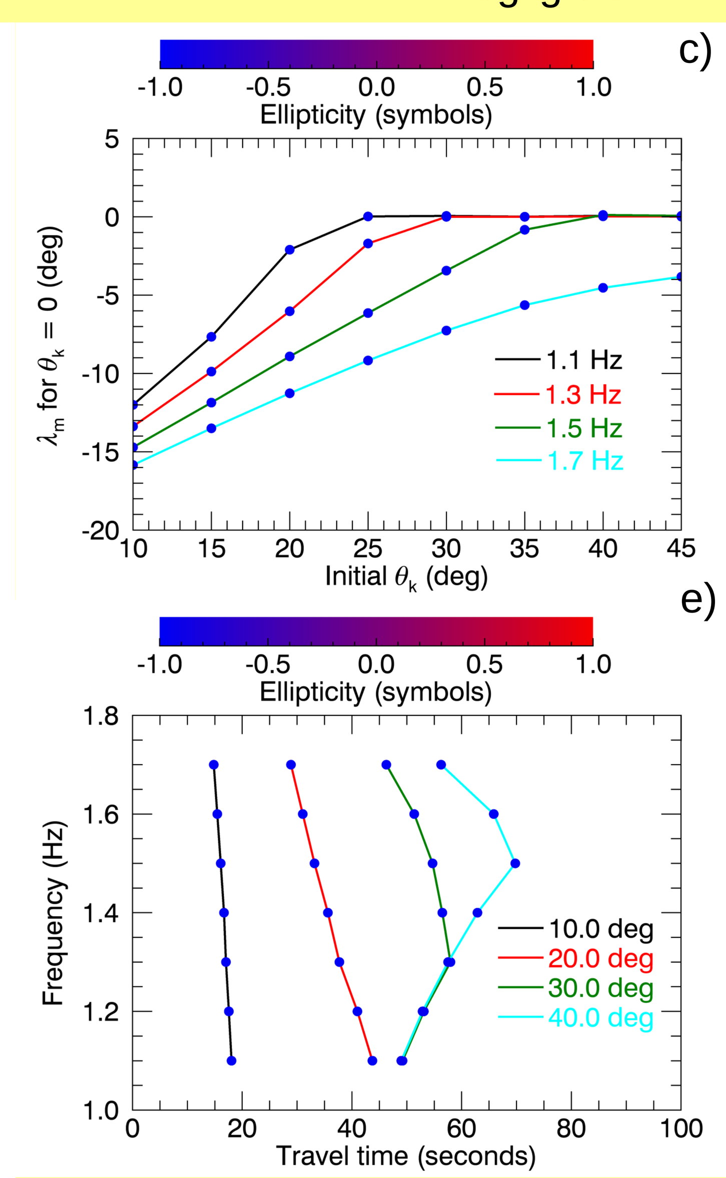
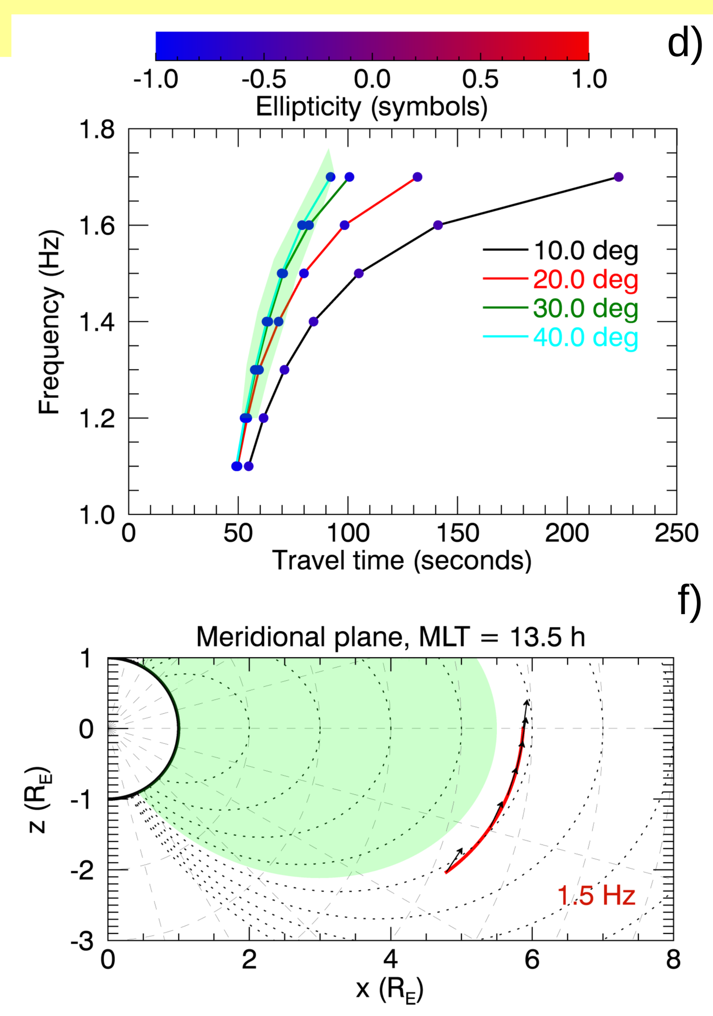
- Two successive rising-tone emissions; only the first, more intense tone is studied
- Spacecraft C4, in the afternoon sector, propagating southwards, risers above helium gyrofrequency
- Helium and oxygen concentration assumed to be negligible



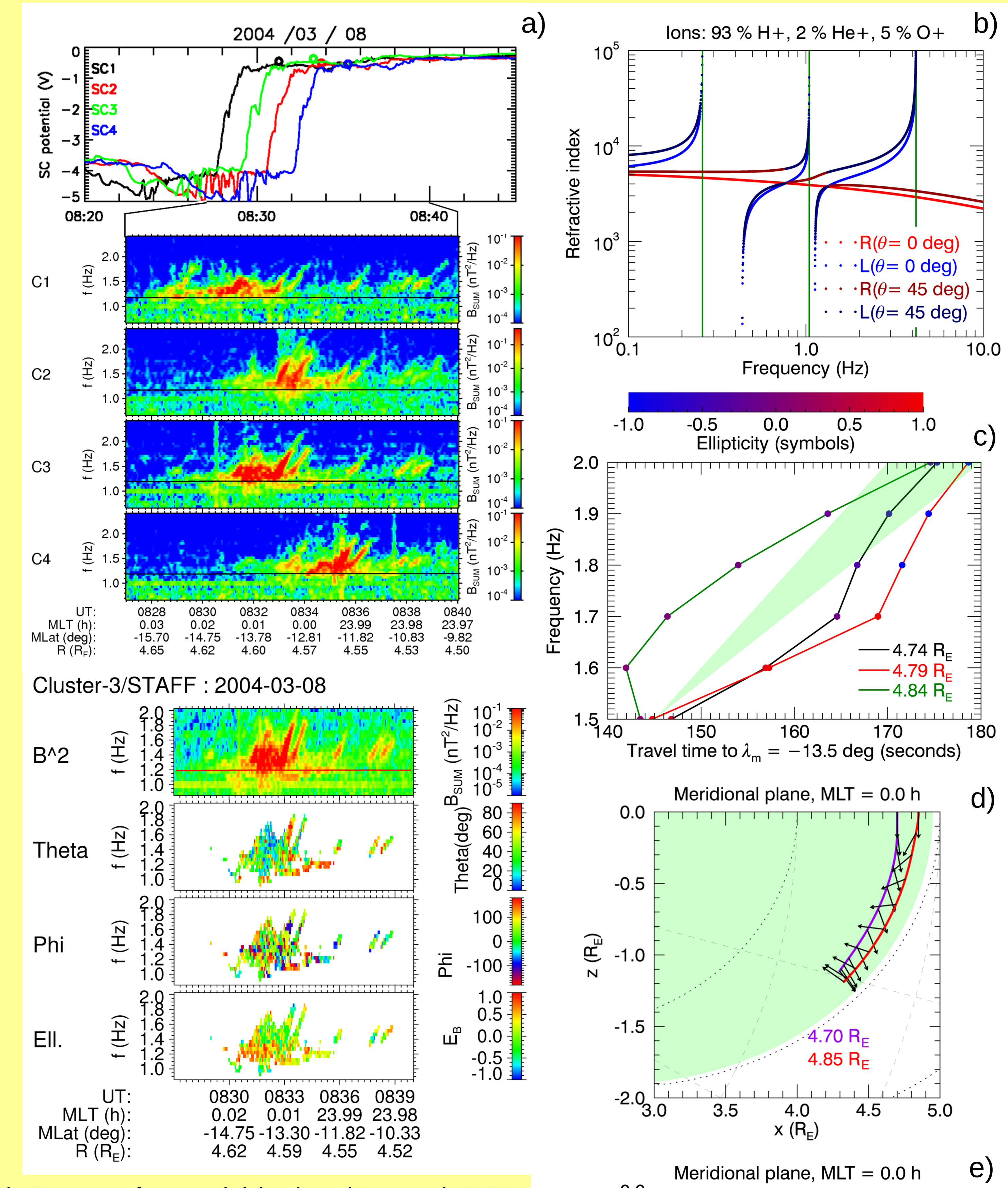




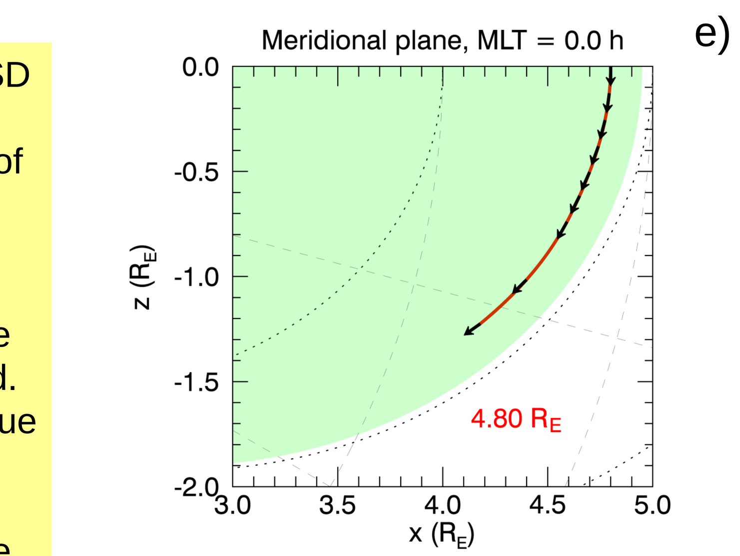
a) From the top: PSD of magnetic fluctuations, wave vector polar angle, azimuthal angle and ellipticity of polarization. Thick red line represents helium gyrofrequency.
b) Electron density. Plasmapause profile at L = 6.5 based on WHISPER data.
c) Backward propagation. Showing latitude where wave vector becomes parallel with magnetic field.
d) Dispersion, ray terminates at the equator
e) Dispersion, ray terminates at θ = 0°. In disagreement with measurements.
f) Example of propagation back to equator

2004-03-08

- Two emissions above the helium gyrofrequency, midnight MLT sector, seen by all four spacecraft. The first, more intense rising tone was studied.



a) Spacecraft potential (top) and magnetic PSD (middle) for the four Cluster spacecraft. Circles on potential plots indicate the time of the most intense triggered emissions [3]. Wave properties for C3 (bottom).
b) Typical dispersion relation for two different angles θ_k. Modes corresponding to the blue lines are left polarized, red = right polarized.
c) Dispersion, ellipticity represented by red-blue circles. Green polygon represents average dispersion from all four satellites.
d) Ray tracing starting from the equator. Wave vector of the more distant ray turns in the earthward direction – opposite behaviour is observed for the other source.



e) Small variation in the source distance gives rise to large variety of θ_k values at the latitude of interest.

CONCLUSIONS

- We explained the variation in θ_k and ellipticity in the 2004 case and obtained reasonable agreement in θ_k, dispersion and ellipticity for all cases
- Good knowledge of density profile and ion composition is crucial for obtaining correct results. All simulations gave best results when source location was on outer or inner boundary of plasmapause.
- Ray tracing without time variation of the environment cannot fully explain observations due to low group velocity of EMICs. Evolution of density structures can be estimated from different spacecraft of the Cluster fleet.
- Maxwellian distribution is insufficient for study of wave growth in EMICs [2].

References: [1] Santolík, O., M. Parrot, and F. Lefeuvre (2003), Radio Sci., 38, 1010
[2] Chen, L. et al. (2010), J. Geophys. Res., 115, A07209
[3] Grison, B. et al. (2013), J. Geophys. Res. Space Physics, 118, 1159–1169

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