Bursts of narrow-band magnetospheric waves near the He^+ to H^+ cyclotron frequencies observed during MESSENGER's Mercury flybys.

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Overview

- Focus is on ULF waves with frequencies > f_{cHe+}
- IMF Bz is Northward for January 14th flyby M1.
- IMF Bz is Southward for October 6th flyby M2.
- Comparison of these waves for different conditions.
- For both M1 and M2 flybys little ULF activity was detected until just before closet approach (CA).

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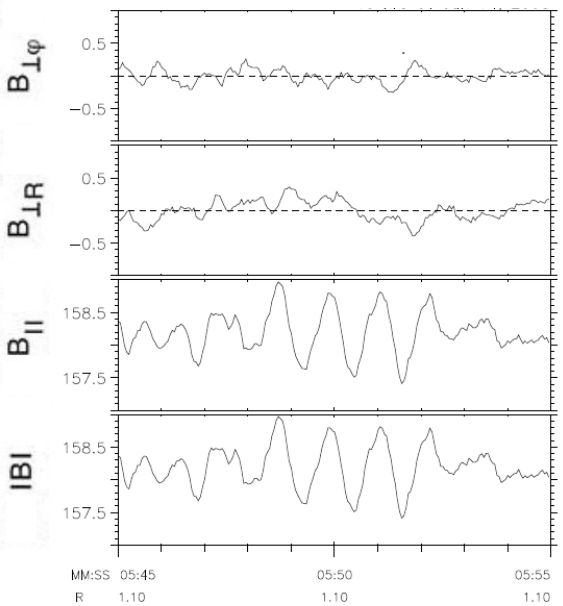
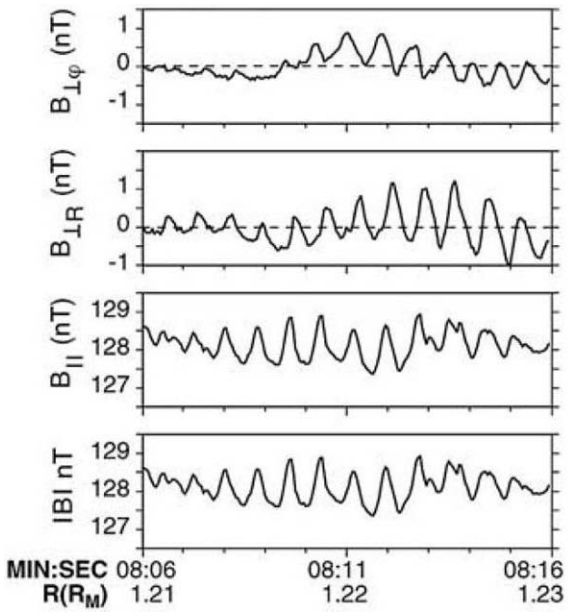
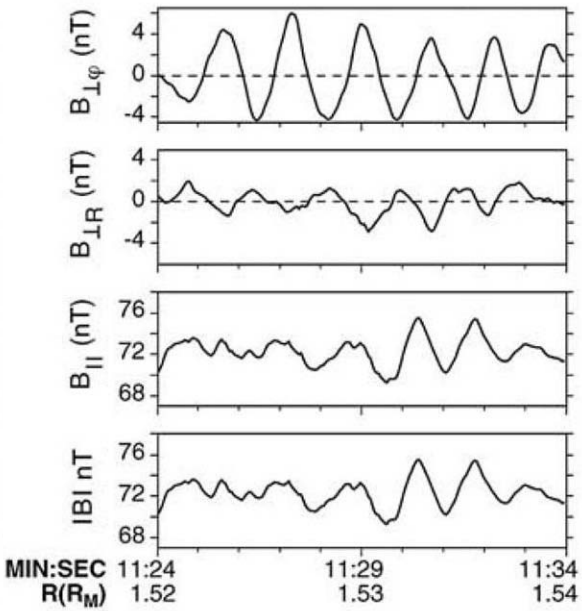
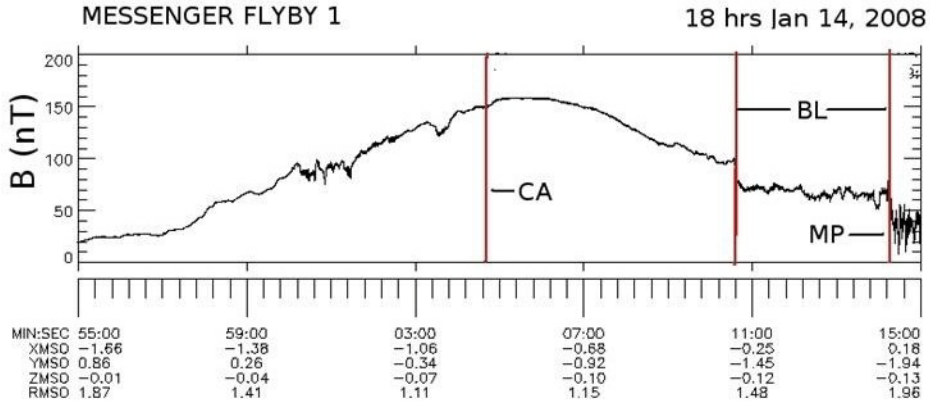
M1 Flyby









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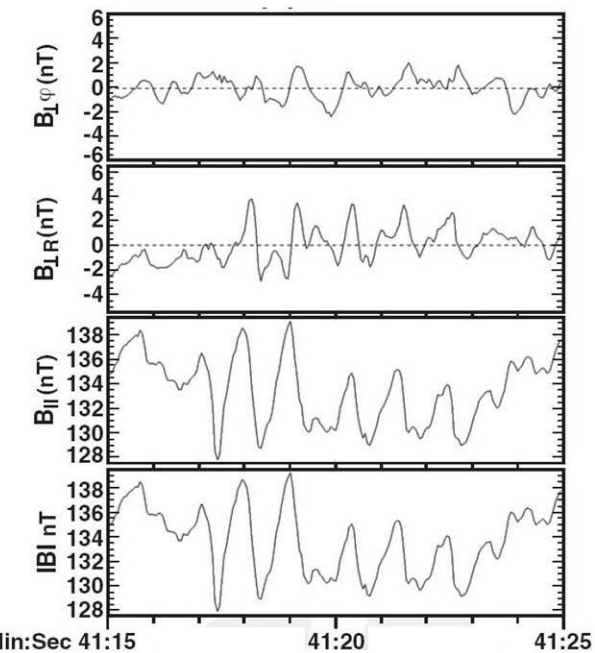
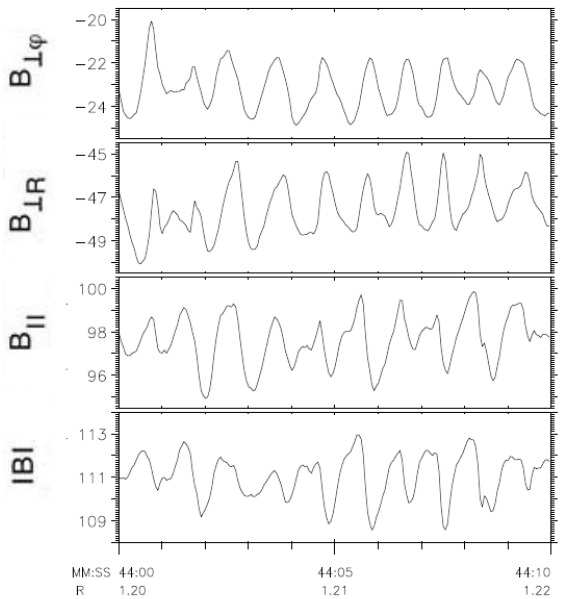
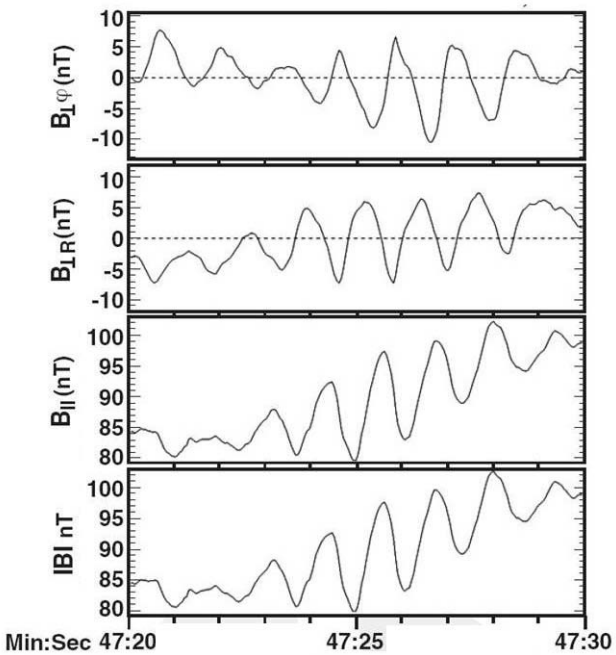
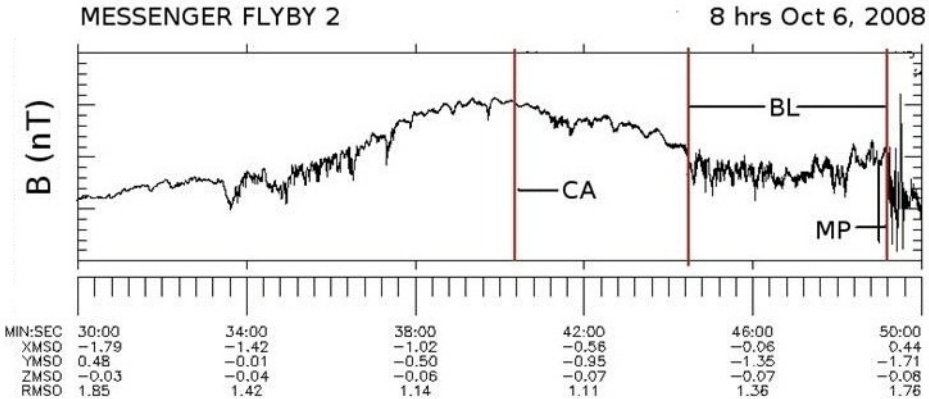
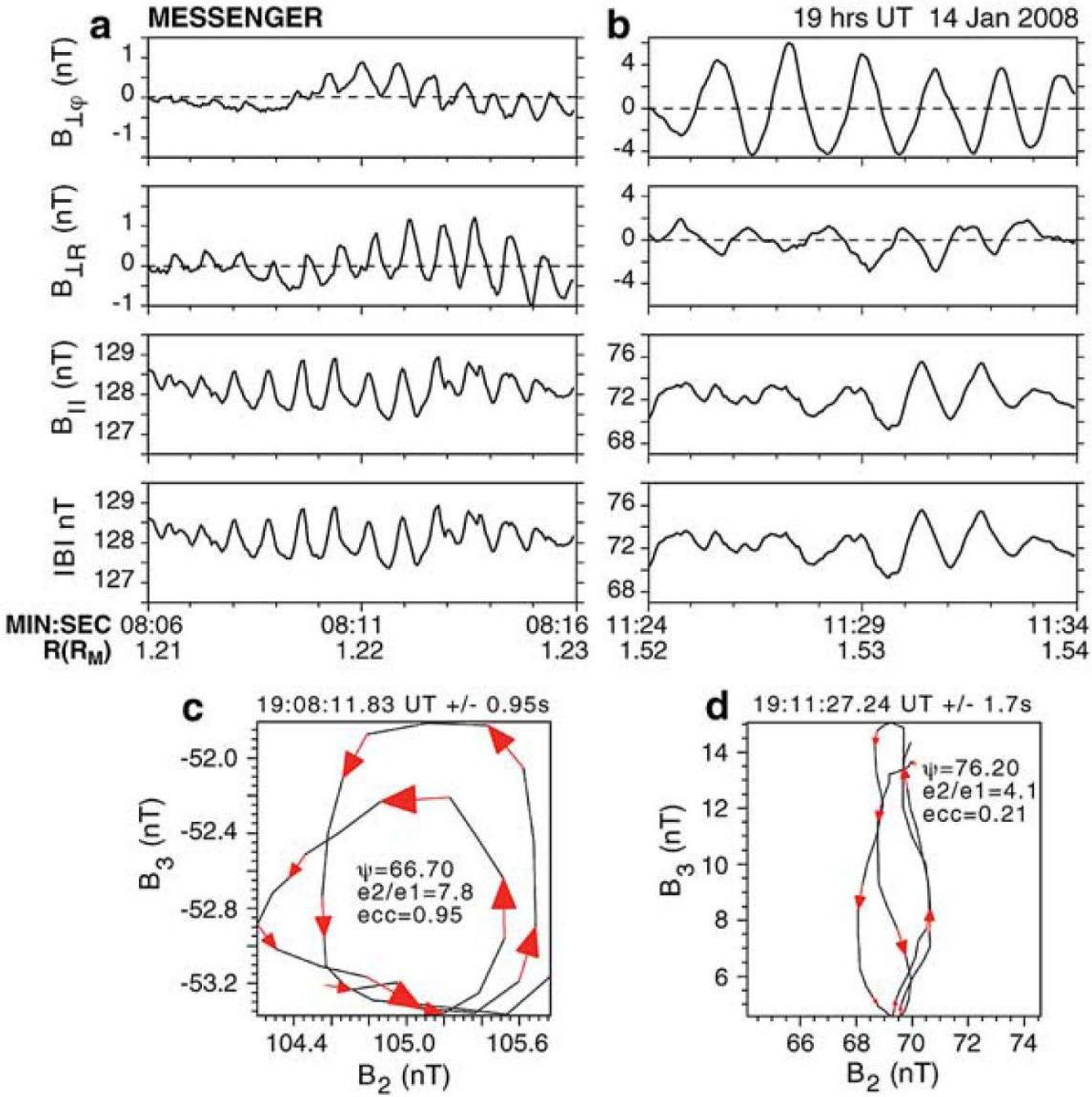
M2 Flyby

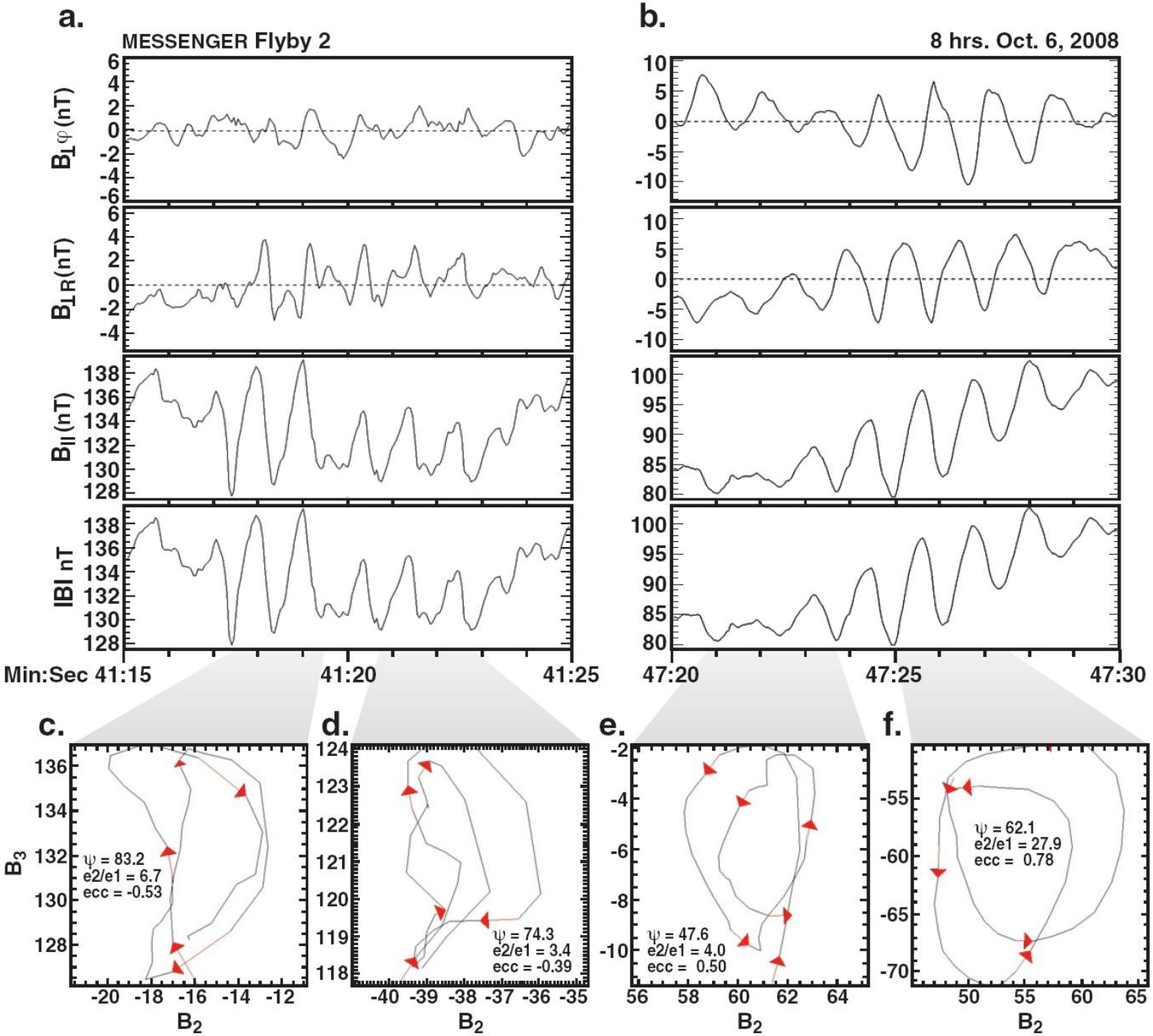




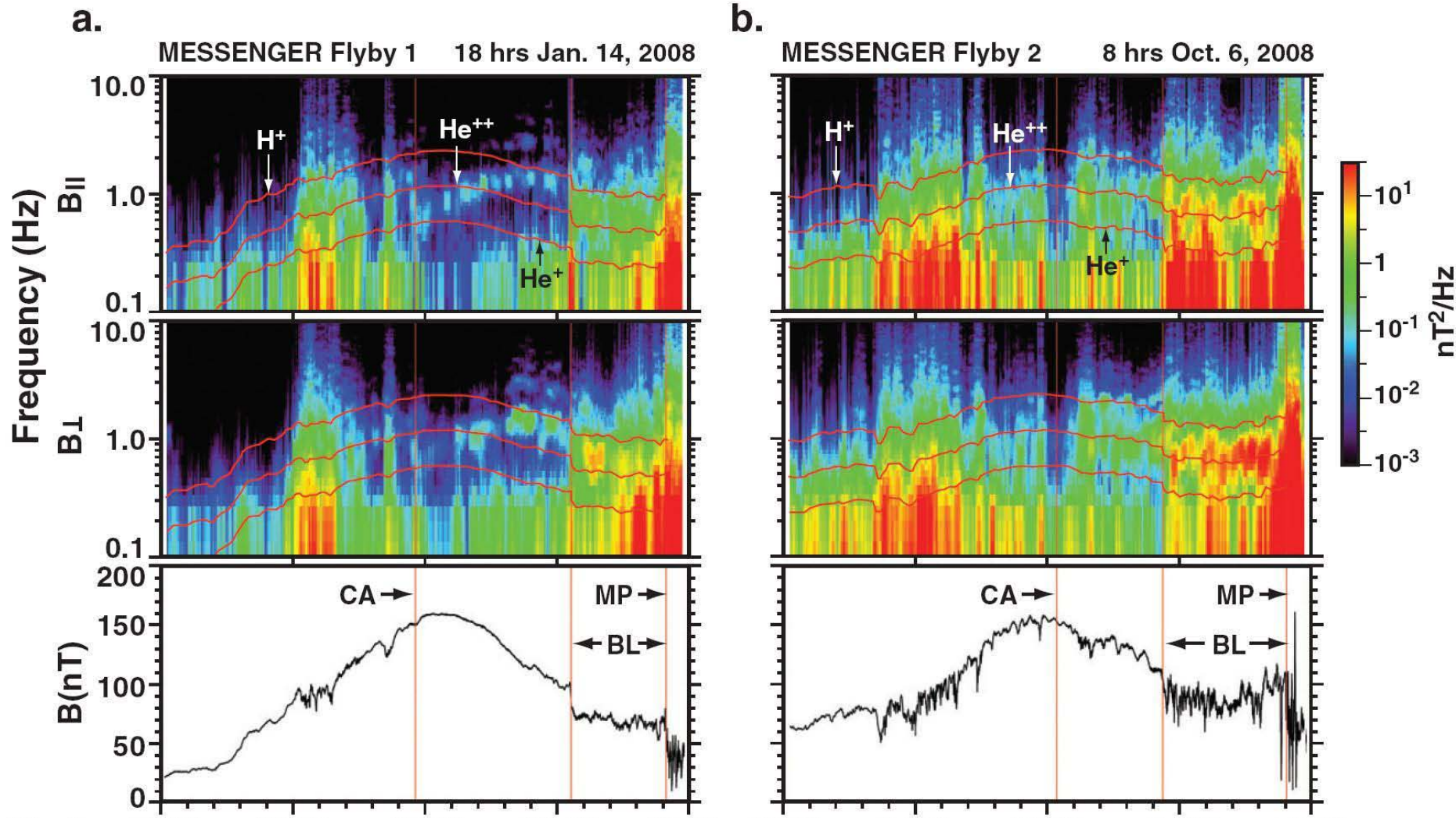





a
MESSENGER
b
19 hrs UT 14 Jan 2008
$B_{\perp\varphi}$ (nT)
$B_{\perp R}$ (nT)
$B_{\parallel}$ (nT)
IBI nT
MIN:SEC 08:06 08:11 08:16 11:24 11:29 11:34
R(R_M) 1.21 1.22 1.23 1.52 1.53 1.54
c
19:08:11.83 UT +/- 0.95s
ψ=66.70
e2/e1=7.8
ecc=0.95
B_3 (nT)
B_2 (nT)
d
19:11:27.24 UT +/- 1.7s
ψ=76.20
e2/e1=4.1
ecc=0.21
B_3 (nT)
B_2 (nT)

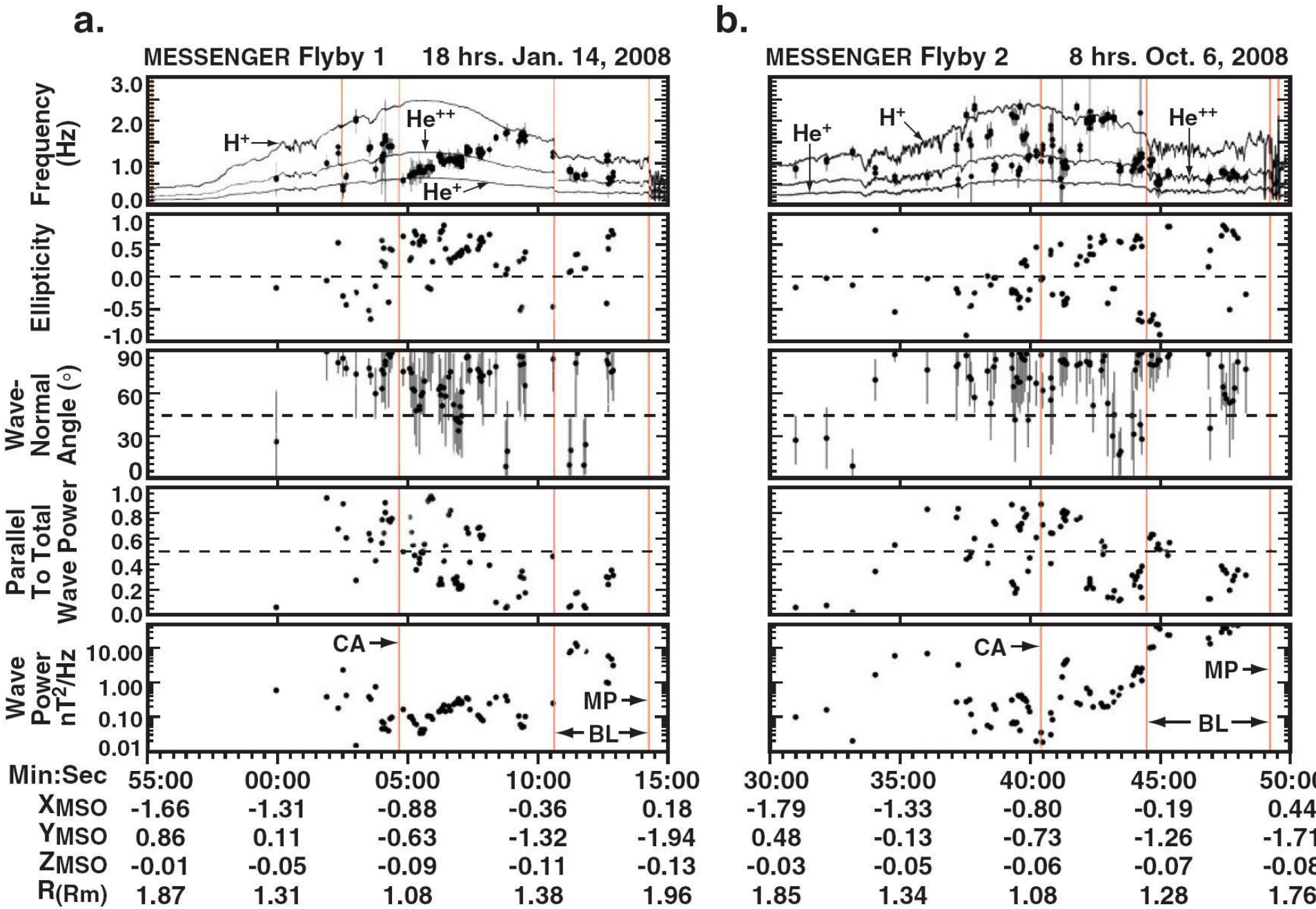

a.
MESSENGER Flyby 2
b.
8 hrs. Oct. 6, 2008
B⊥φ(nT)
B⊥R(nT)
B∥(nT)
|B| nT
Min:Sec 41:15
41:20
41:25
47:20
47:25
47:30
c.
d.
e.
f.
B3
B2
ψ = 83.2
e2/e1 = 6.7
ecc = -0.53
ψ = 74.3
e2/e1 = 3.4
ecc = -0.39
ψ = 47.6
e2/e1 = 4.0
ecc = 0.50
ψ = 62.1
e2/e1 = 27.9
ecc = 0.78

ULF Waves are observed primarily between the Helium + and H+ cyclotron frequencies

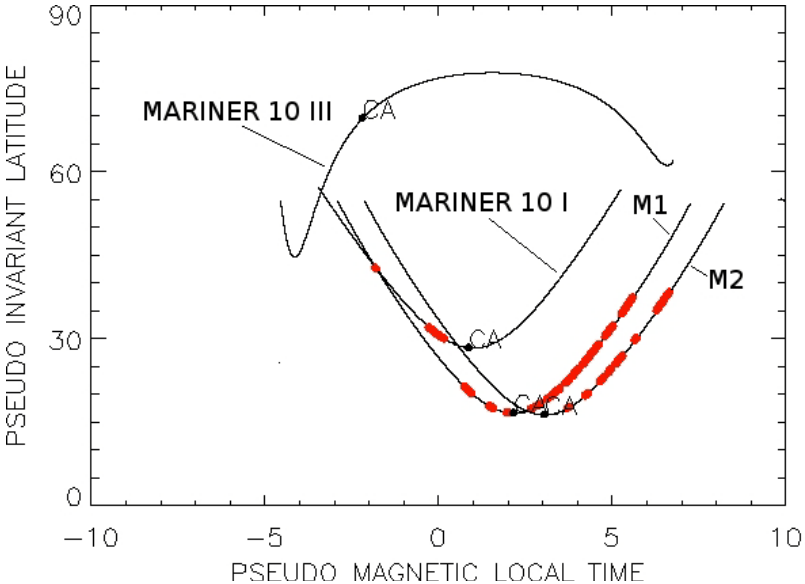


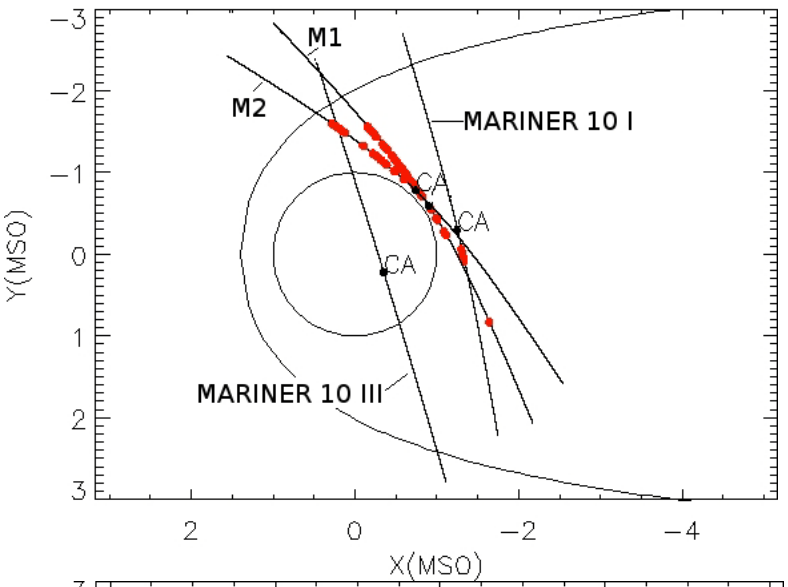
Min:Sec	55:00	00:00	05:00	10:00	15:00	30:00	35:00	40:00	45:00	50:00
X_{MSO}	-1.66	-1.31	-0.88	-0.36	0.18	-1.79	-1.33	-0.80	-0.19	0.44
Y_{MSO}	0.86	0.11	-0.63	-1.32	-1.94	0.48	-0.13	-0.73	-1.26	-1.71
Z_{MSO}	-0.01	-0.05	-0.09	-0.11	-0.13	-0.03	-0.05	-0.06	-0.07	-0.08
$R_{(Rm)}$	1.87	1.31	1.08	1.38	1.96	1.85	1.34	1.08	1.28	1.76

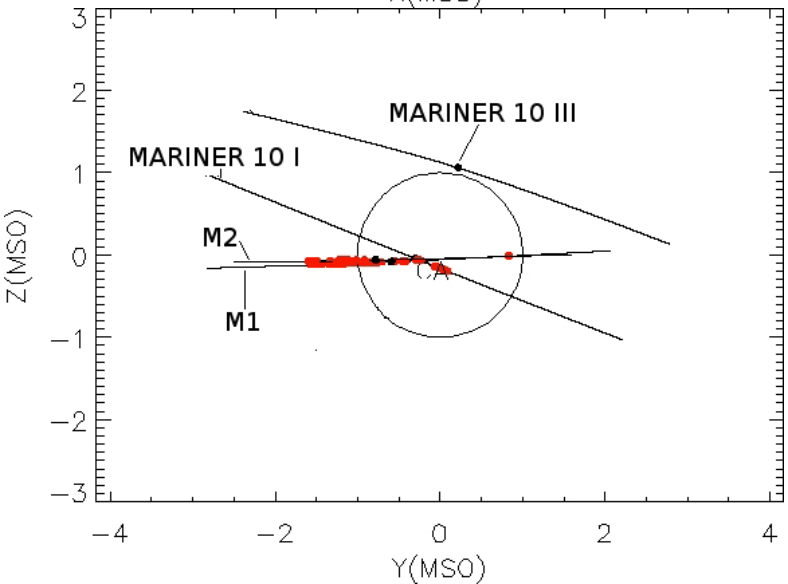
Polarization Analysis for Selected Events



LOCATION of ULF WAVES







- Red dots location of Narrow band ULF waves
- 1 Event was detected during the Mariner 10 I flyby [Russell, GRL 1989]
- No events detected during the Mariner 10 III flyby.
- MESSENGER events [Boardsen et al., 2008; Boardsen et al., 2009]

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Table 1. Comparison of ULF Wave Properties Between Mercury Flybys M1 and M2[a]

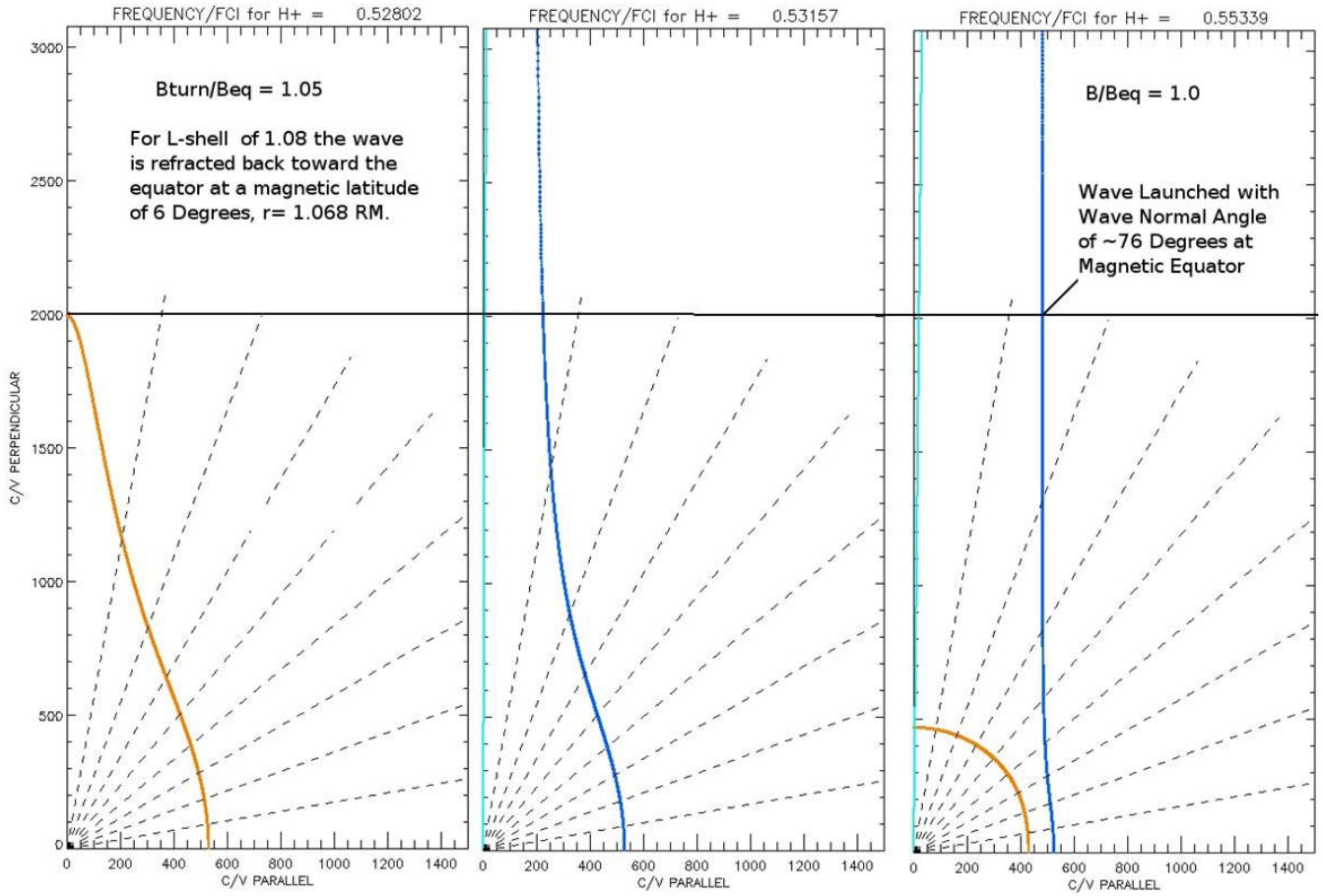
	M_1				M_2			
	ALL	<CA	CA-BL	BL	ALL	<CA	CA-BL	BL
N	81	17	53	11	86	31	36	19
f (Hz)	1.01	1.17	1.03	0.68	1.02	1.22	1.14	0.74
FWHM (Hz)	0.40	0.48	0.39	0.38	0.44	0.43	0.55	0.40
f/f_{cH+}	0.51	0.58	0.45	0.64	0.59	0.71	0.62	0.55
RIGHT HAND	65	8	47	10	39	7	21	11
$\psi > 45°$	67	16	44	7	72	26	28	18
POWER $\parallel > \perp$	34	14	20	1	39	17	15	7
nT^2/Hz	0.15	0.09	0.13	6.63	0.49	0.18	0.50	33.89
e_1/e_2	0.27	0.22	0.28	0.28	0.23	0.24	0.23	0.24

Right handed tendency, Wave Normal Angle>45° and significant compressional component suggests fast magnetosonic.

LHR and Ion-Ion resonances can quasi-trap these waves around the magnetic equator.

Why Fast Mode Waves can become Quasi-trapped by ion-ion resonances

Index of Refraction surfaces at different points along an L-shell of 1.08, assuming that the perpendicular component of the index is conserved

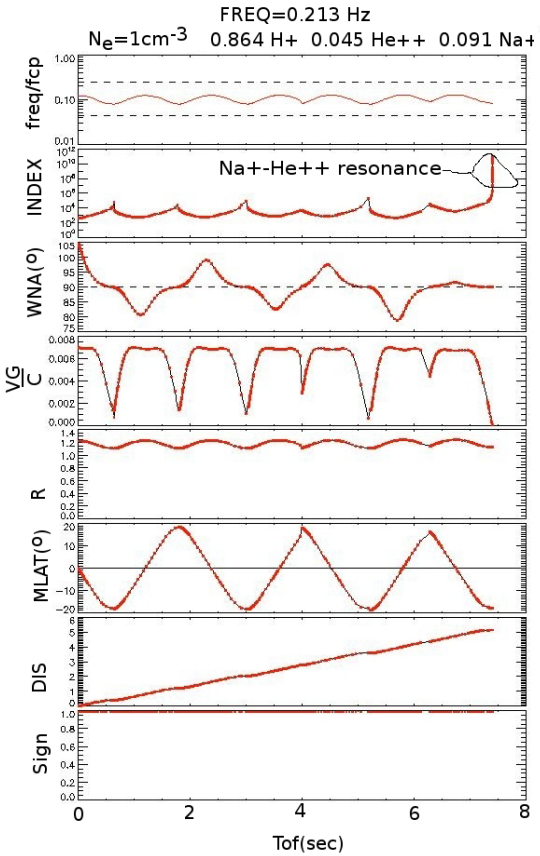


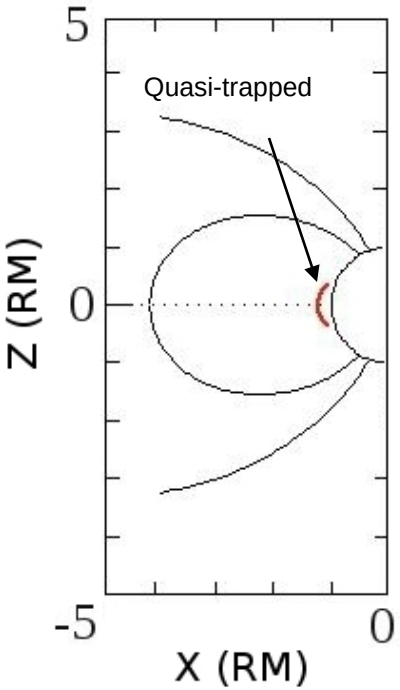
Quasi trapped Fast Mode Waves at Mercury

Plasma ray tracing example of Fast Mode waves trapped by Na+-He++ resonance.

a) wave parameters versus time of flight

b) waves plotted in MSO.

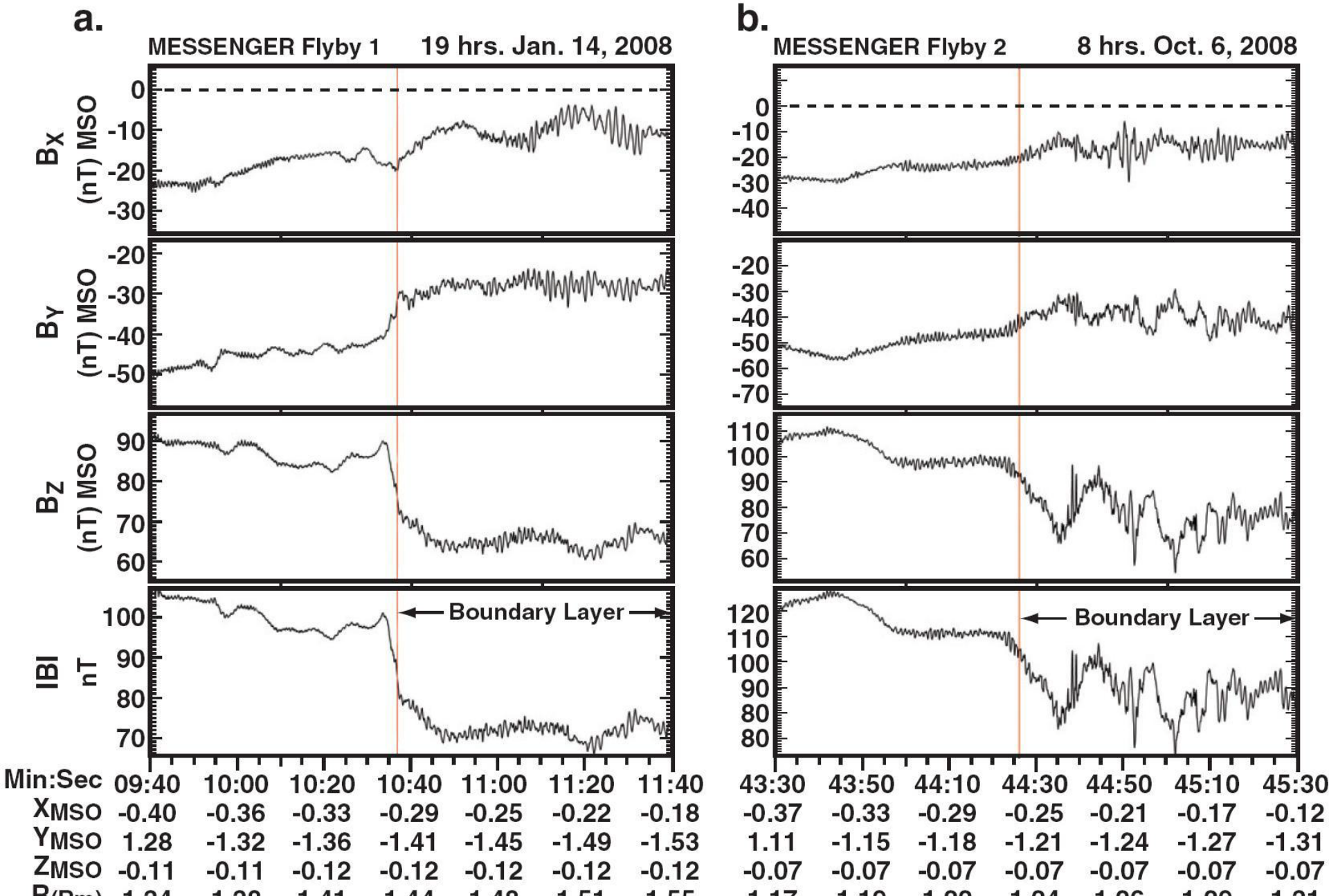




Conclusions

- During M1 and M2 narrow band ULF waves between f_{cHe+} and f_{cH+} were detected by the MESSENGER Magnetometer primarily outbound from the closet approach(CA).
- For M1 these waves increase in both frequency and amplitude from CA to the boundary layer (BL), followed by a step-like decrease in frequency across the BL with a large amplitude increase. For M2 the systematic increase between CA and the BL was not apparent in the dynamic spectra.
- Near CA the compressional component is dominant, near the outbound MP the tranverse component become dominant.
- Polarization Properties of these waves show a wide range in ellipticity and in wave vector orientation.
- The wave power in the BL is about 4 times larger for M2 compared to M1.
- The waves have a magnetosonic component.

ULF Wave examples



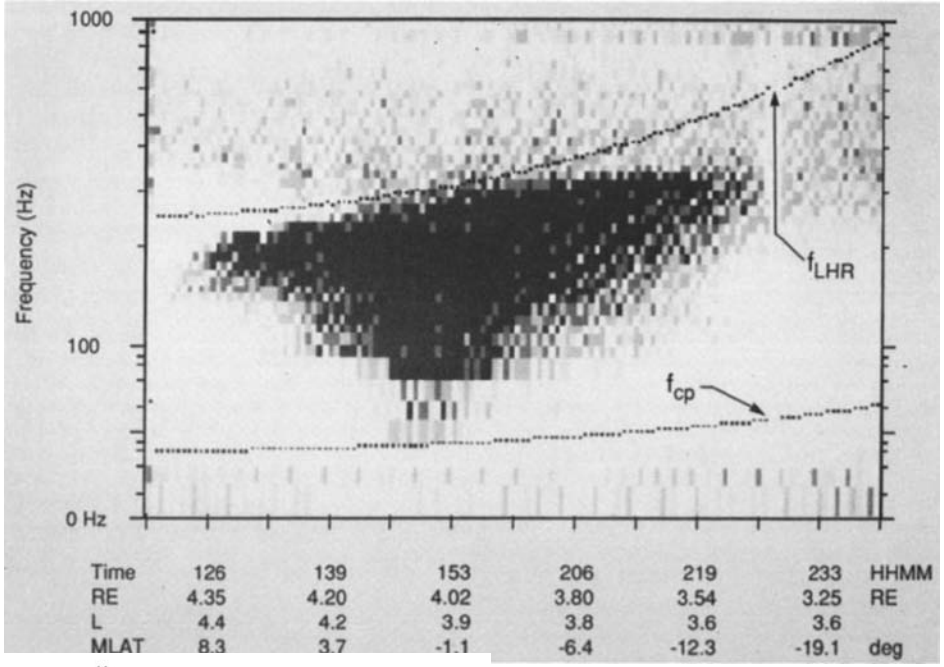
Local Source-Earth Example?

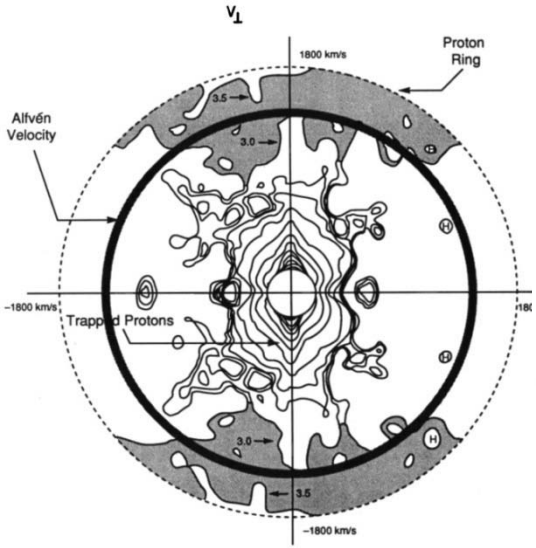
Fast magnetosonic mode waves between f_{cH+} and F_{LHR} are locally confined in latitude near the Earth's equatorial plasmapause [Boardsen, 1992].

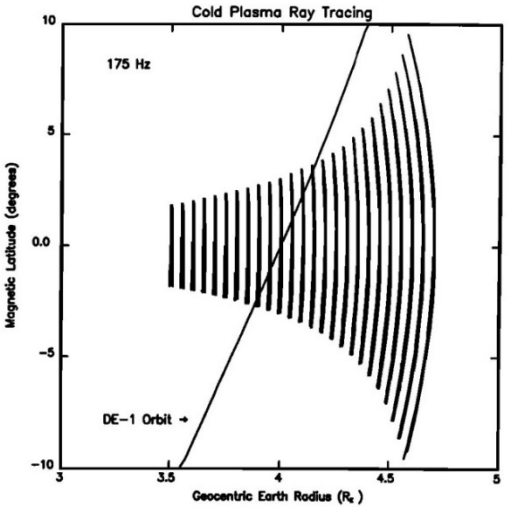
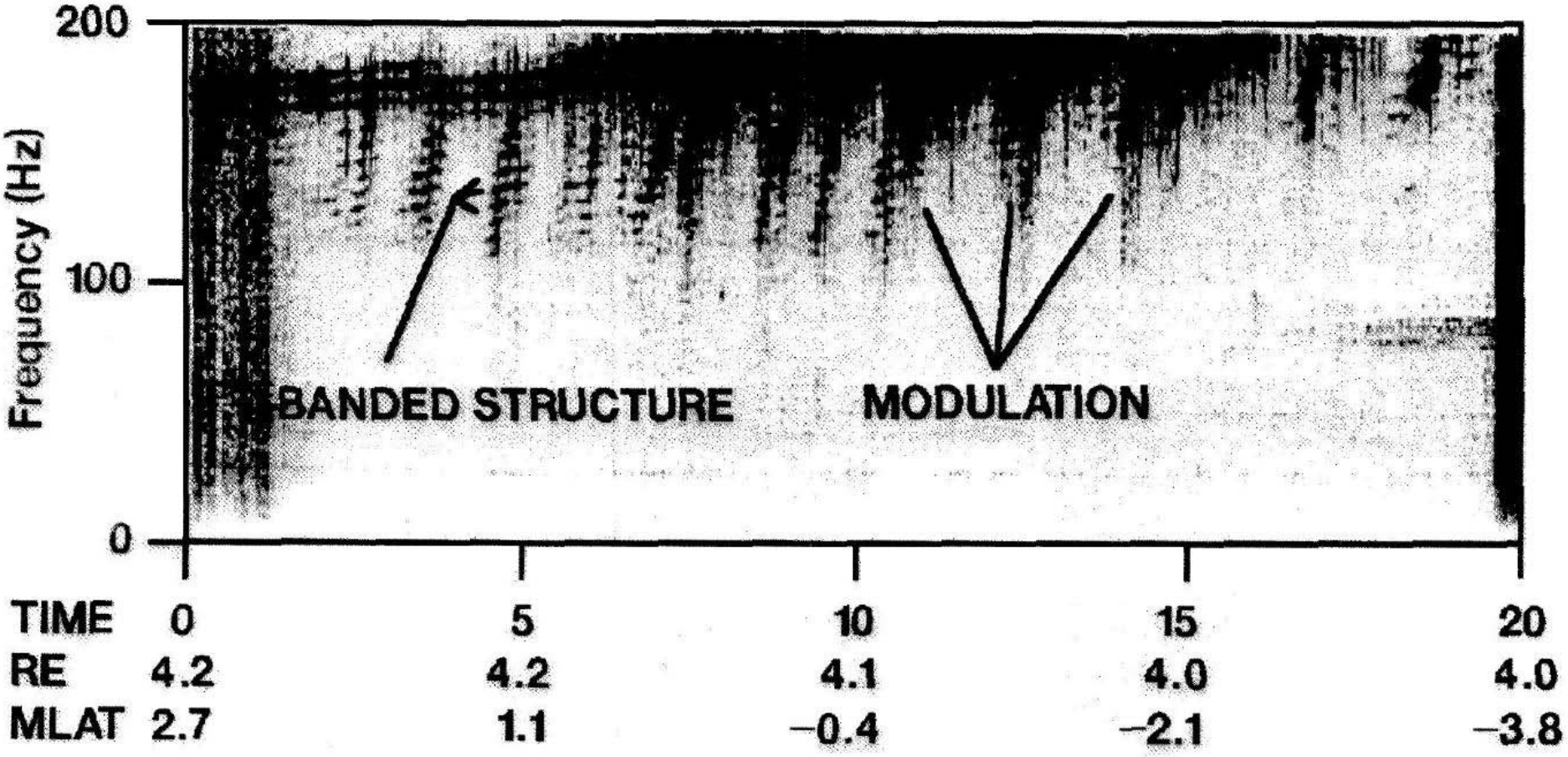
The lower hybrid resonance frequency distorts the index of refraction surface confining these waves about the magnetic equator. Their source are proton shell distributions.

At Mercury the ion-ion resonances would distort the index of refraction surface leading to their equatorial confinement. Their source would be due the the large loss cones in the inner magnetosphere of Mercury.

Problem: Can the perpendicular component be explained by this mechanism?







DE-1 Ex-Antenna Wide band data of Equatorially Trapped Fast Magnetosonic Waves at Earth