Relating Intracochlear Pressure to Emissions

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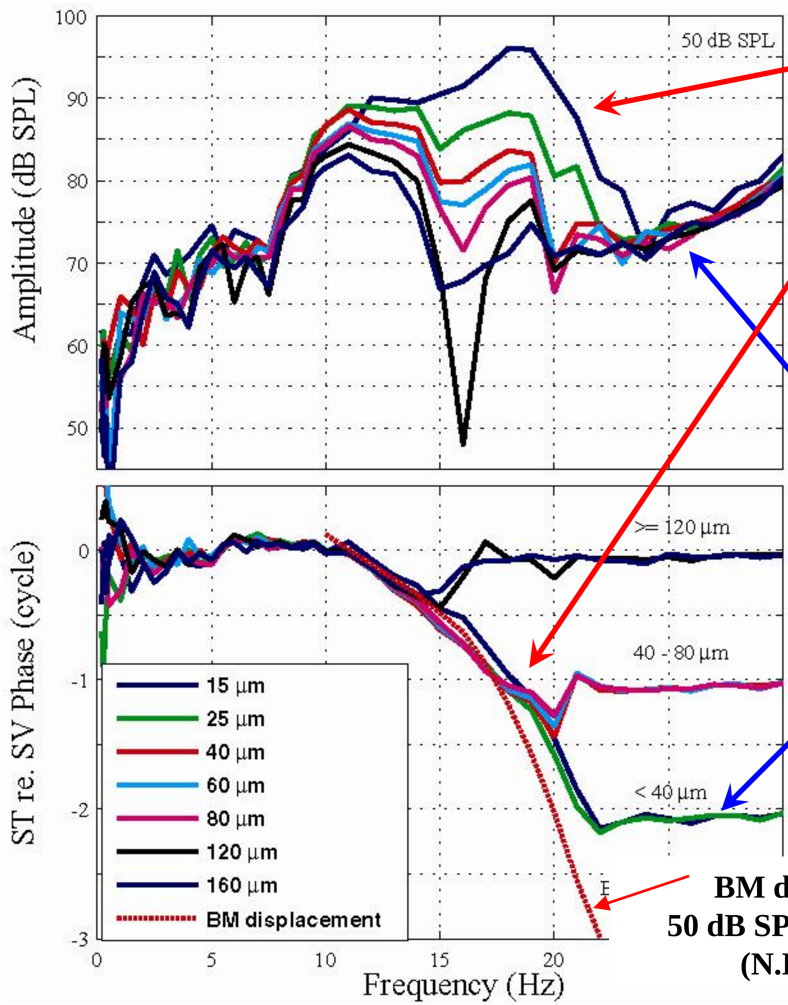
Cochlear wave in forward direction

Traveling + compression waves

Pressure versus distance – 50 dB



Traveling wave

Travels along cochlear partition
Peaks at its BF place
Changes rapidly in space around BF
Phase is delayed up to several cycles

Compression / fast wave

Travels at speed of sound in water ~ 1500 m/s
Changes little with space
Fills up the cochlea instantaneously
Phase is nearly constant

BM displacement
50 dB SPL, BF = 19 kHz
(N.P. Cooper)

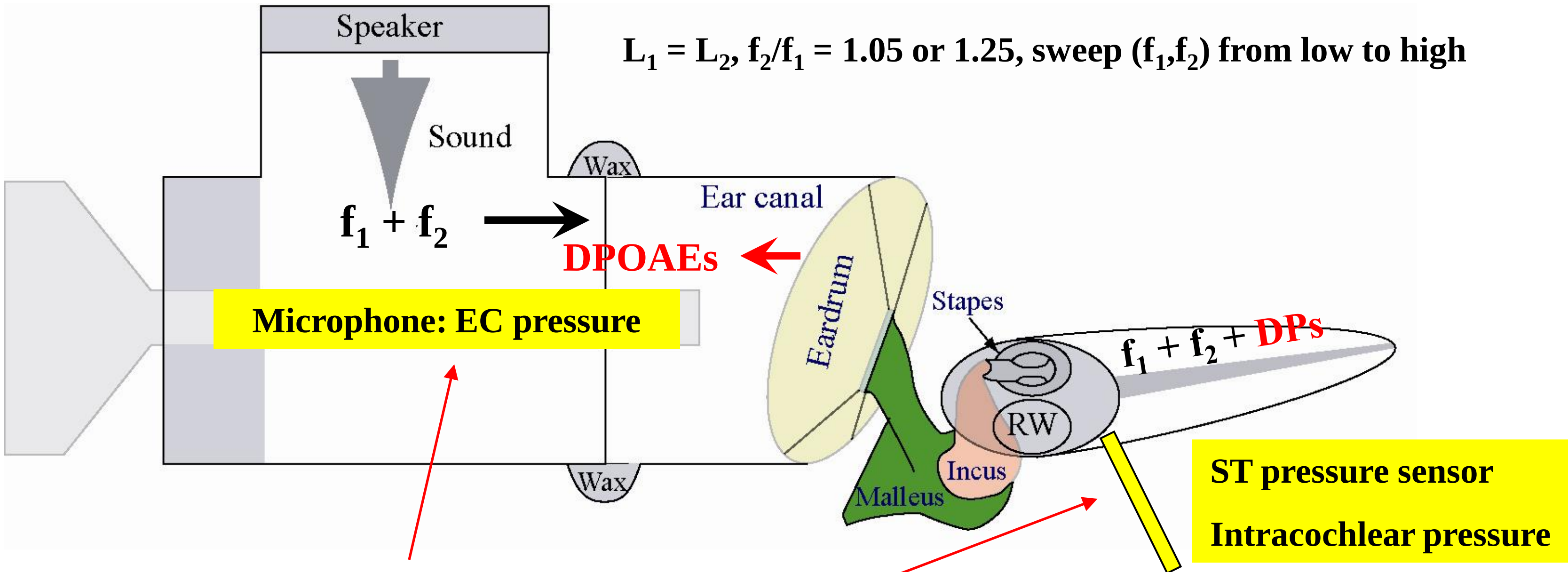
Wg45

Dong & Olson, JASA, 117, 2005

Method

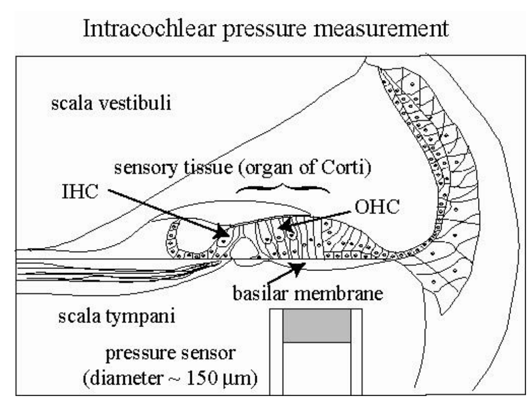
Simultaneous recording of DP and DPOAE

$L_1 = L_2$, $f_2/f_1 = 1.05$ or 1.25, sweep (f_1,f_2) from low to high



Forward: phase ST – EC (f_1 & f_2 frequency)

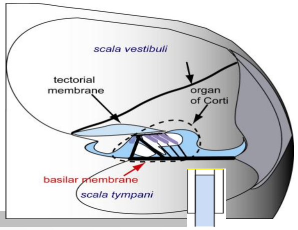
Reverse: phase DPOAE – DP (DP frequency)



Adult gerbil (50 – 70 g)

Basal cochlear turn BF ~ 20 kHz

DP *local and remote generation*



At fs ~ BF

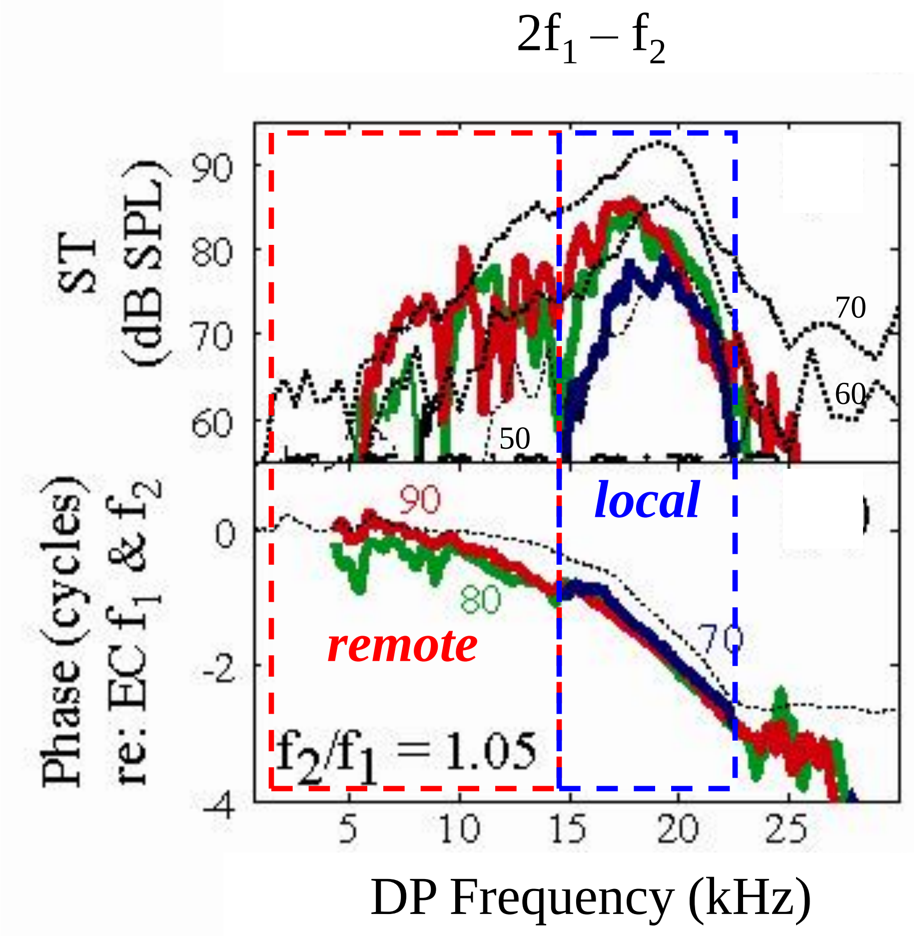
Tuned similarly to single-tone with similar traveling group delay

Cochlear filtering shapes DP amplitude
DPs appear to be locally generated

At fs << BF

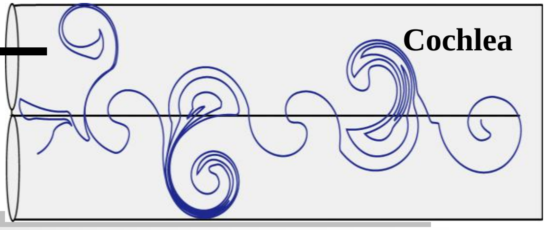
Fine structure in amplitude
Phase is relatively steep with wiggles

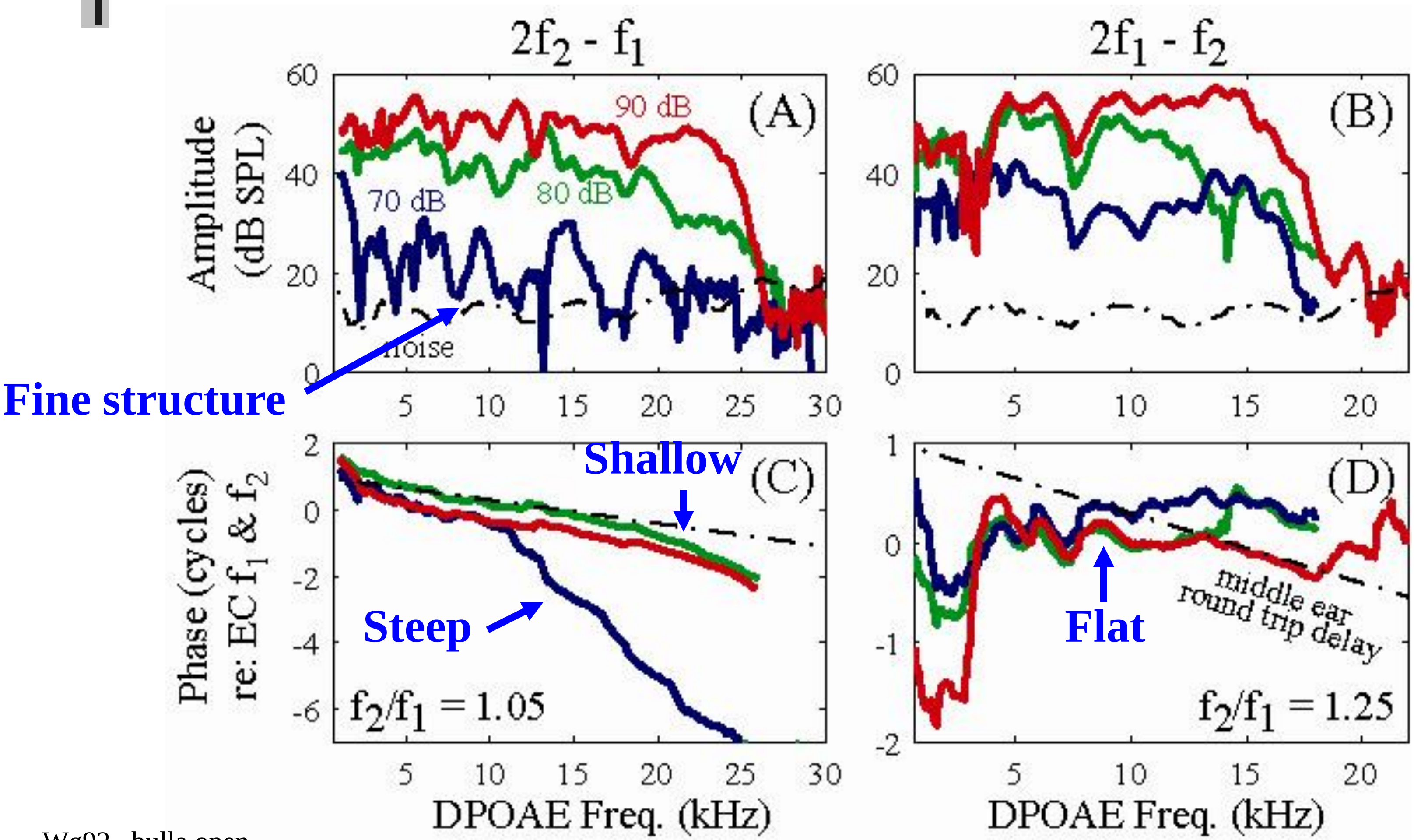
DPs appear to be remotely generated



Wg93, sensor positioned 10 μm from the BM
$L_1 = L_2$ = 70, 80 & 90 dB SPL
$f_2/f_1 = 1.05$
f_2 = [1 : 0.2 : 35] kHz

DPOAE *complex*





Wg92, bulla open

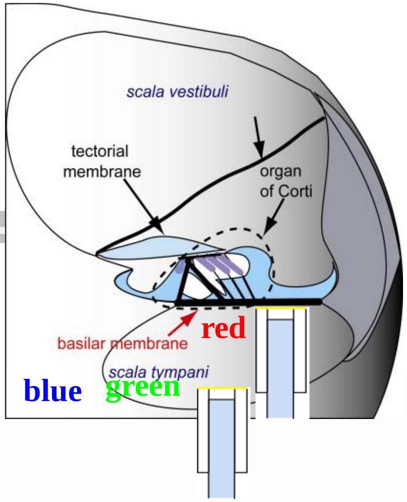
$L_1 = L_2 = 70$, 80 & 90 dB SPL

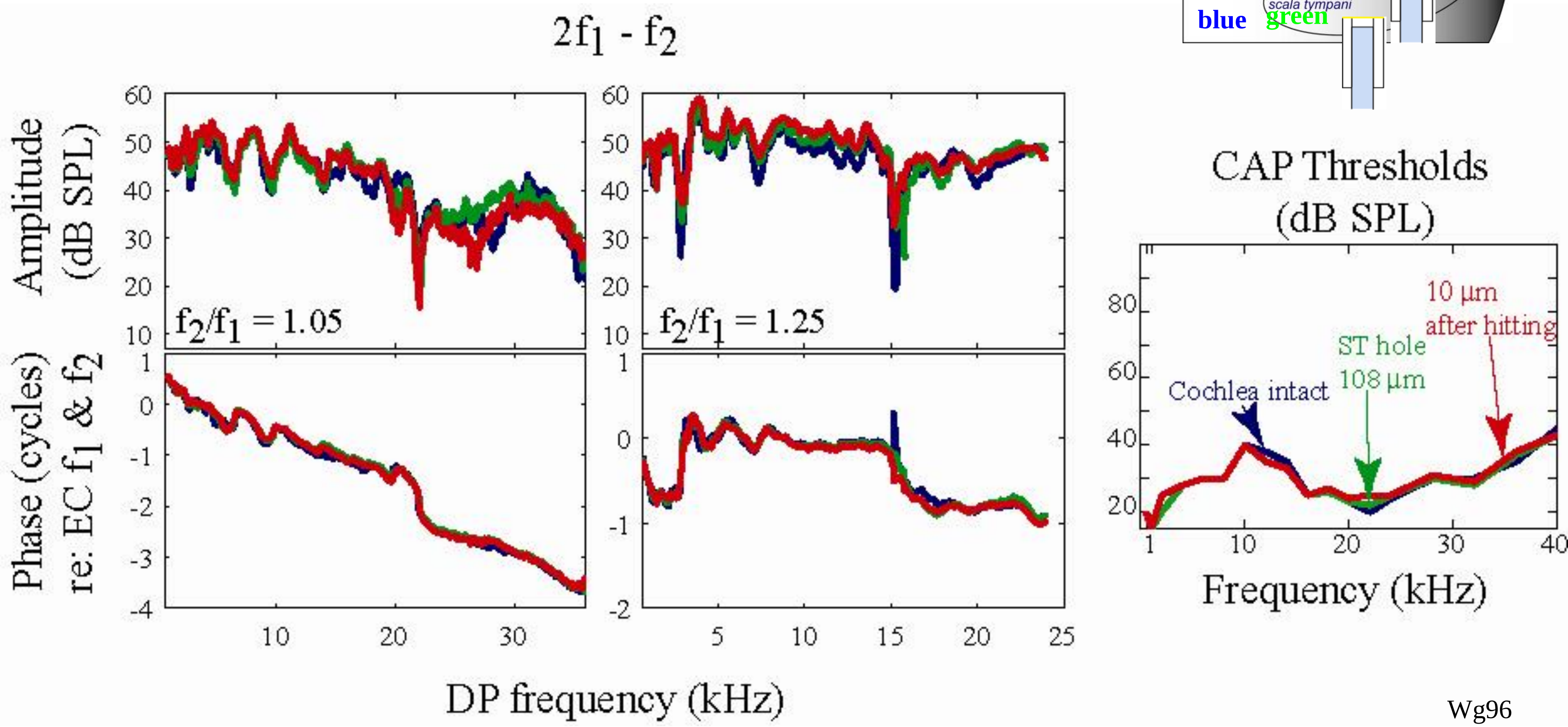
$f_2/f_1 = 1.05$ or 1.25

$f_2 = [1 : 0.2 : 30]$ kHz

Lack of sensor perturbation

Little change in DPOAE and CAP





Wg96

$L_1 = L_2 = 80$ dB SPL

$f_2/f_1 = 1.05$ or 1.25

$f_2 = [1000:100:40000]$Hz

Questions

Is there clear similarity between DP and DPOAE?

IF YES

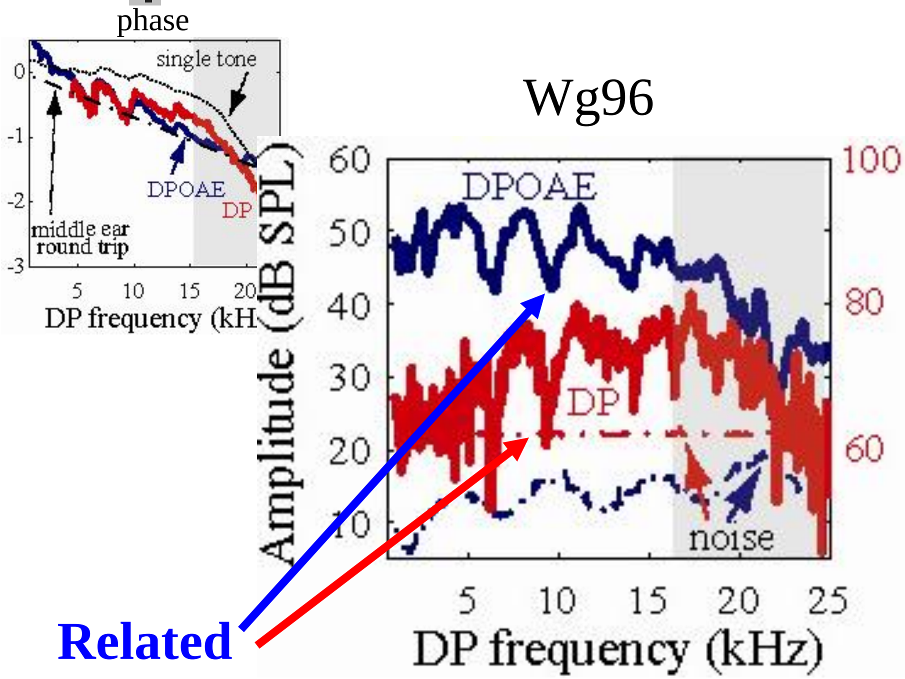
How will DPs travel out of the cochlea?

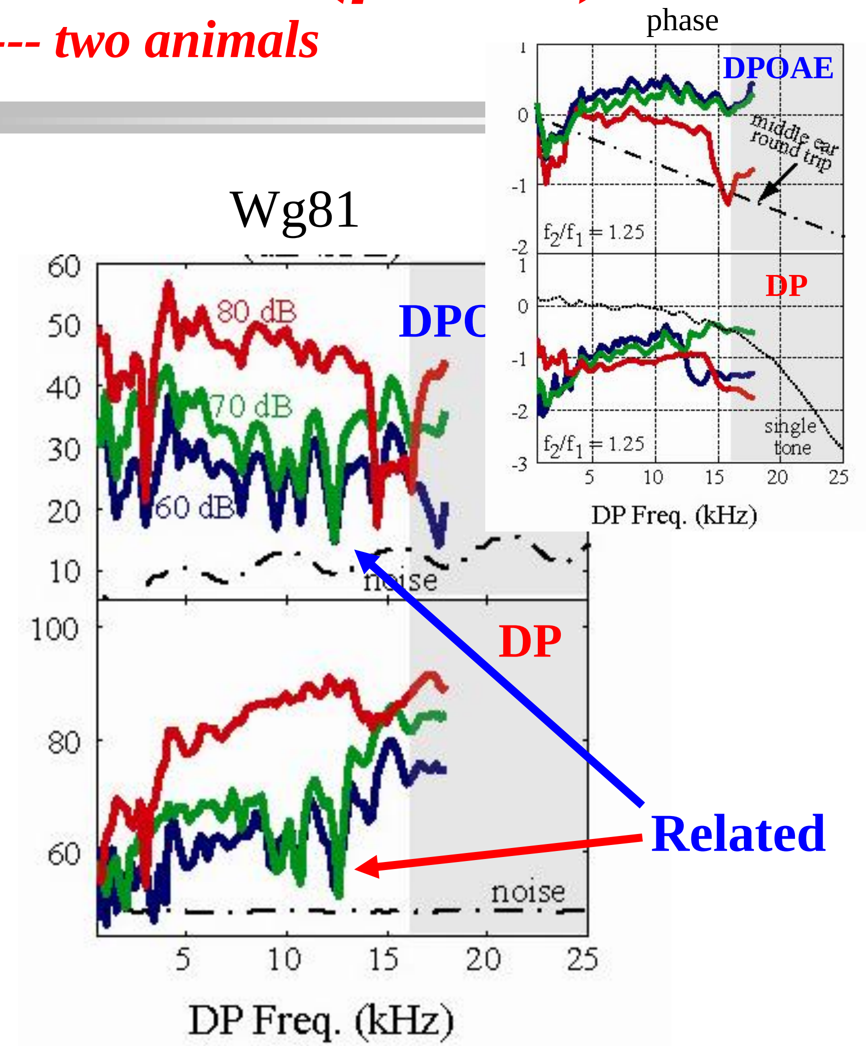
Propagating via BM reverse traveling wave?
Or directly through fluid via compression wave?

Evidence should be in the phase:
Reverse traveling wave phase delay ≈ forward traveling wave phase delay
Compression wave phase ≈ middle ear reverse delay

DP directly related to DPOAE *(f < BF)*

$2f_1 - f_2$: similar fine structure -------- two animals



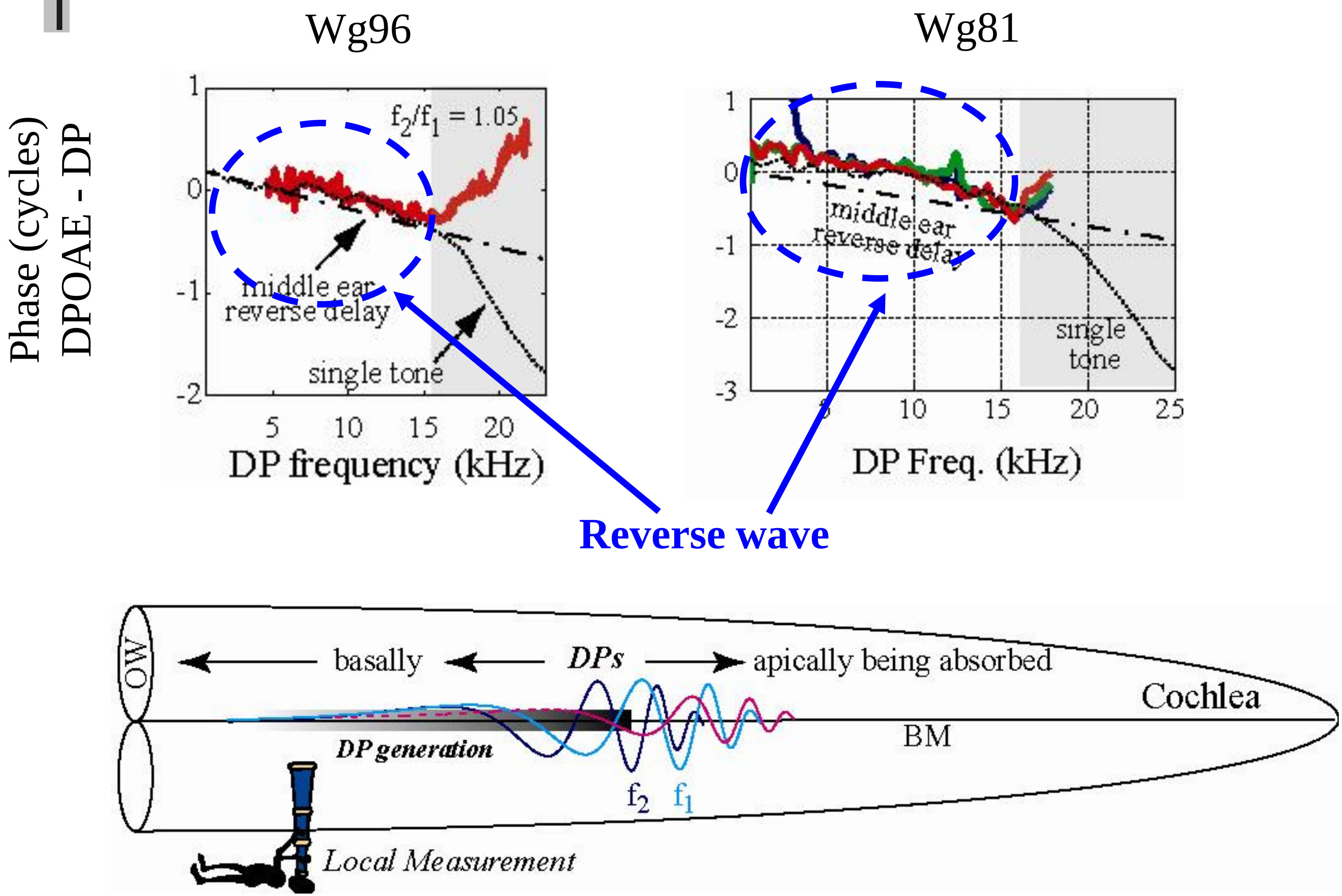


Sensor positioned 28 µm from the BM, before hitting
$L_1 = L_2 = 80$ dB SPL
$f_2/f_1 = 1.05$
$f_2 = [1 : 0.1 : 40]$ kHz

Sensor positioned 20 µm from the BM, after hitting
$L_1 = L_2 = 60, 70$ & 80 dB SPL
$f_2/f_1 = 1.25$
$f_2 = [1 : 0.4 : 30]$ kHz

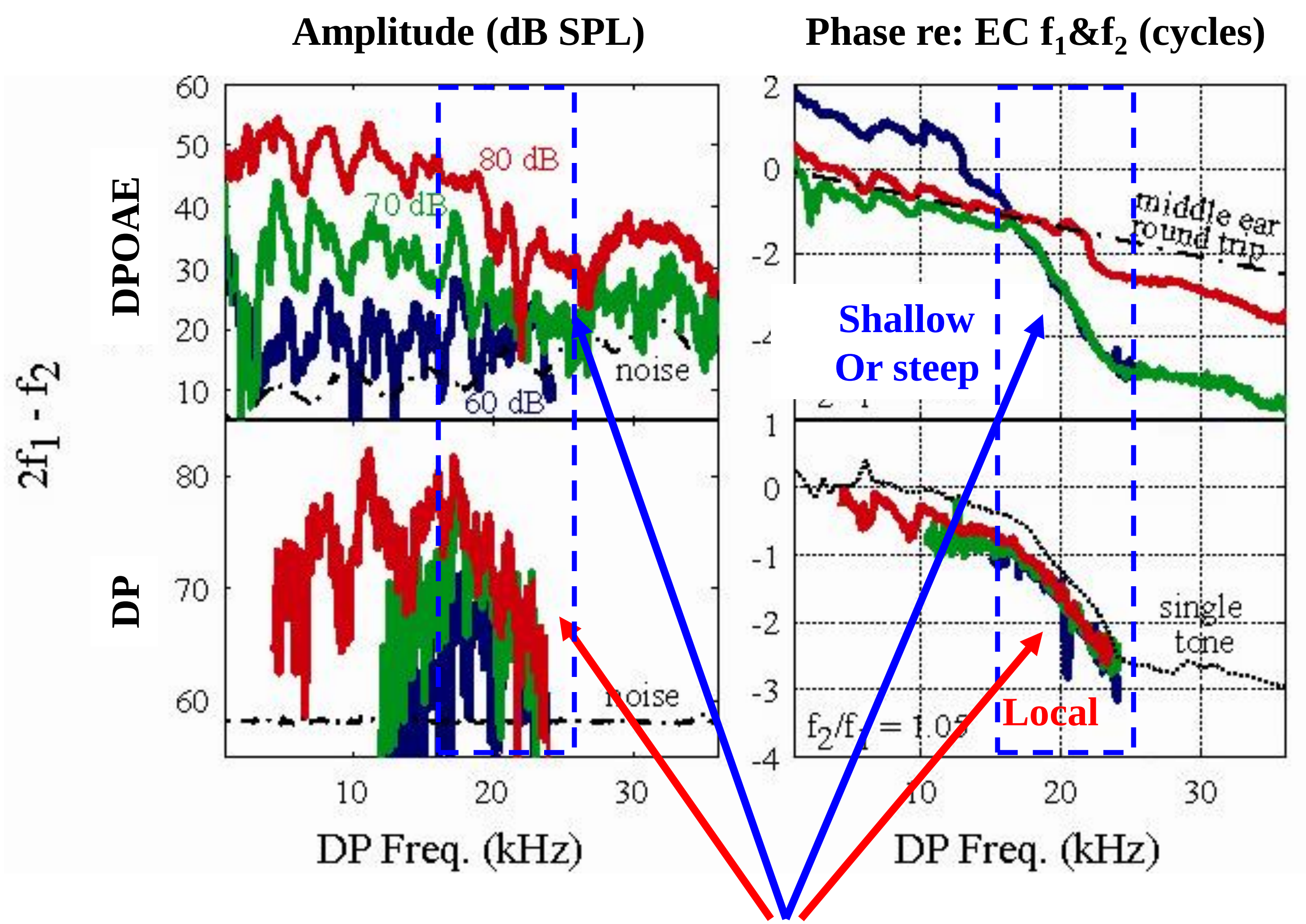
DP directly related to DPOAE *(f < BF)*

$2f_1 - f_2$: Phase DPOAE-DP favors reverse wave



DP directly related to DPOAE *(f ~ BF)*

$2f_1 - f_2$: no similar fine structure (wg96)

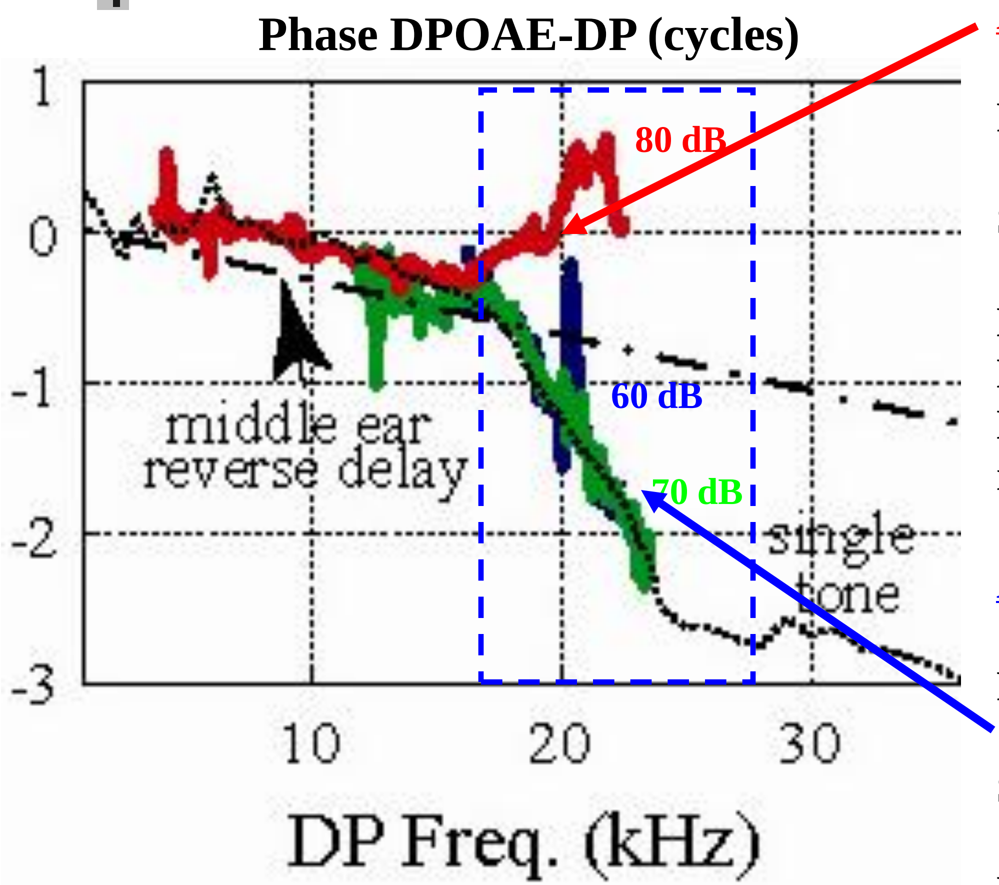


DPOAE and DP not similar, yet we do expect the BF DPOAE to have substantial contribution from BF region. Can we get a quantitative relationship?

f_2 = [1 : 0.1 : 30] kHz

DP directly related to DPOAE *(f ~ BF)*

$2f_1 - f_2$: phase DPOAE-DP (wg96)



At 80 dB SPL

Phase leads instead of lags:

Supports compression wave hypothesis
OR
Due to:
DP phase – forward traveling
DPOAE phase – shallow, has no phase information about traveling in and out

At 60&70 dB SPL

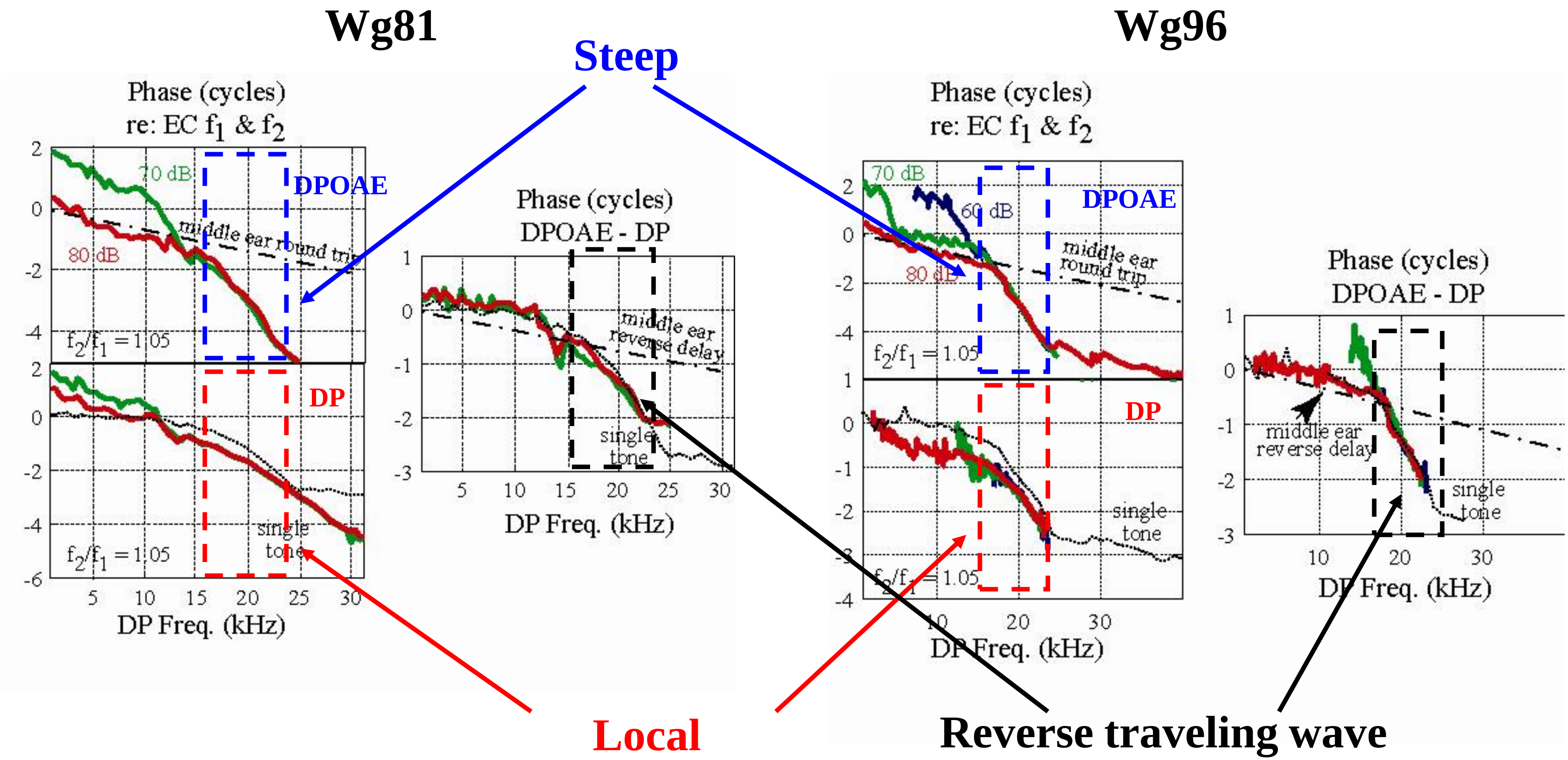
Phase lags:

Supports reverse traveling wave
AND
Due to:
DP phase – forward traveling

DPOAE phase – steep, contains phase information about traveling in and out

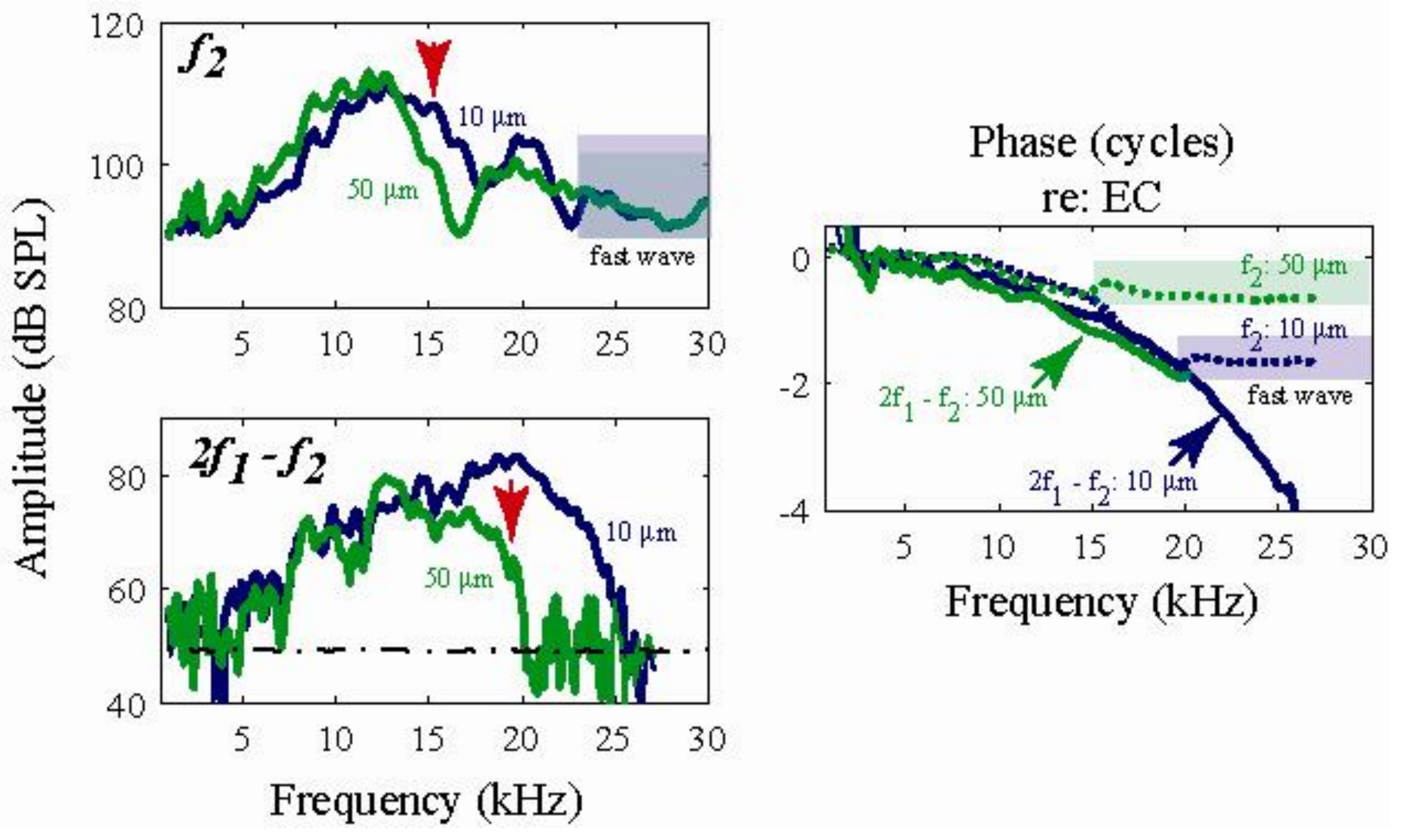
More reverse wave like phase

$2f_2 - f_1$: phase DPOAE-DP favors reverse traveling wave ($f_2/f_1 = 1.05$)



DP compression wave is not in evidence due to spatial variation of DP pressure

Pressure versus distance



DPs change rapidly in space, were not dominated by a compression wave (which would be spatially unvarying)

Summary

- At fs ~ BF, comparisons of DPs and DPOAEs need to be interpreted with caution. The phase DPOAE – DP can only be expected to have meaning when the DPOAE phase is steep. In those cases, DPOAE – DP phase is consistent with the reverse traveling wave.
- At fs < BF, comparison of DPs and DPOAEs routinely show a direct relationship, that DPs travel back to the EC via a reverse traveling wave.
- In addition, DP spatial variation indicates that the DP close to the BM is not dominated by a compression wave.

The end

Thank You