NTNU – Trondheim
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High frequency signals from airguns

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Main peak created when the bubble

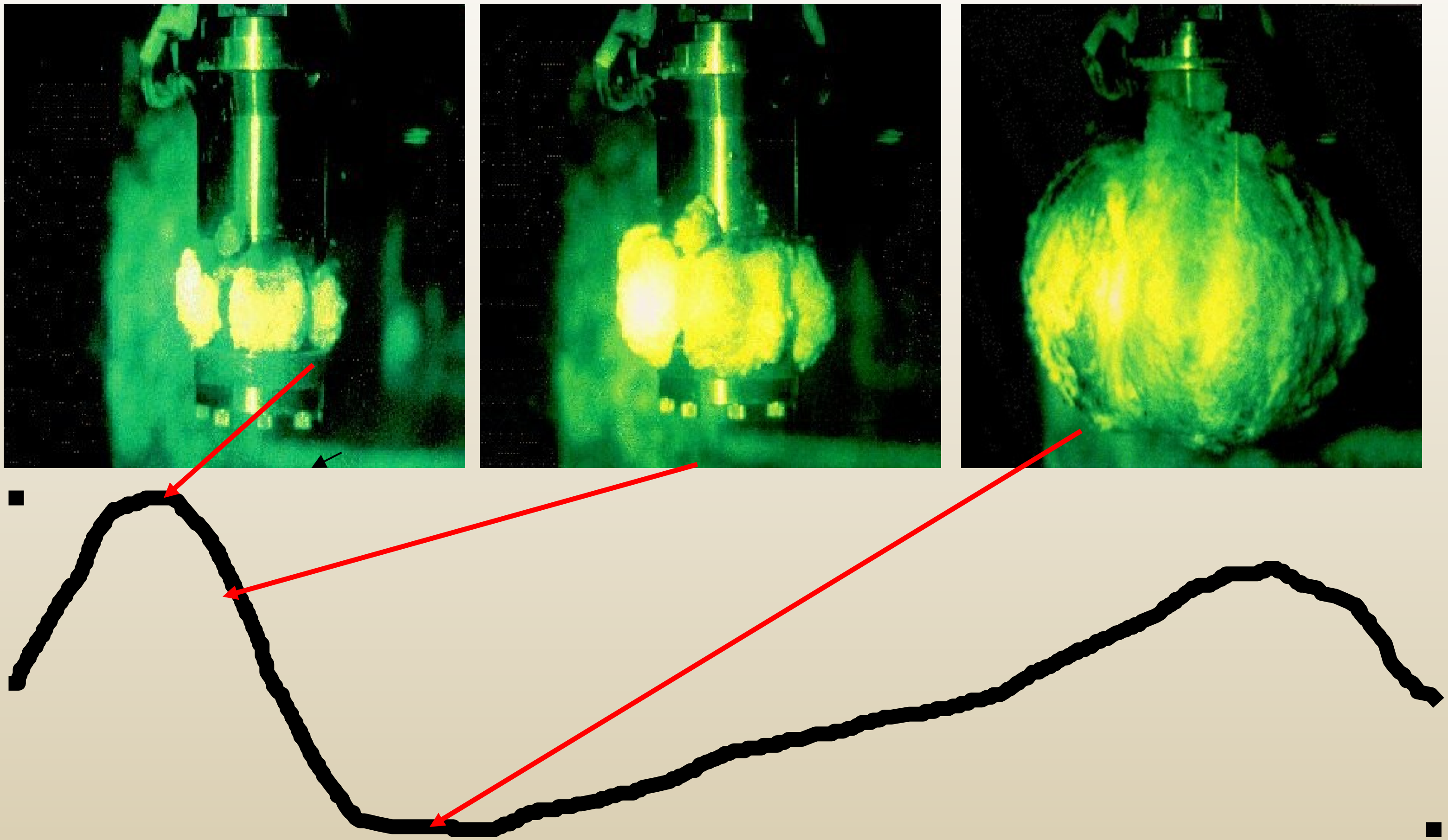


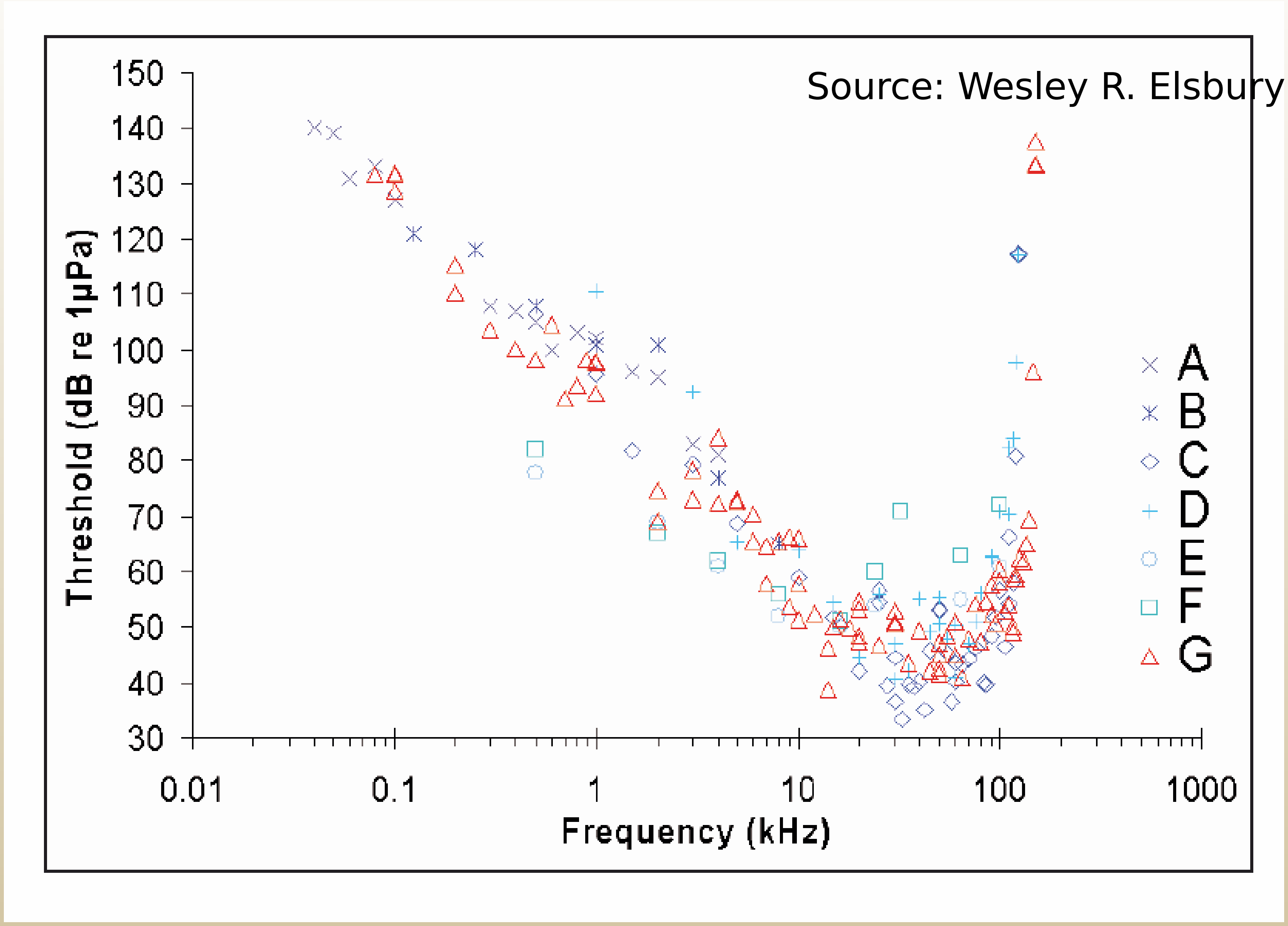
Photo: Jan Langhammer's PhD the

Why study high frequency signals of air gu

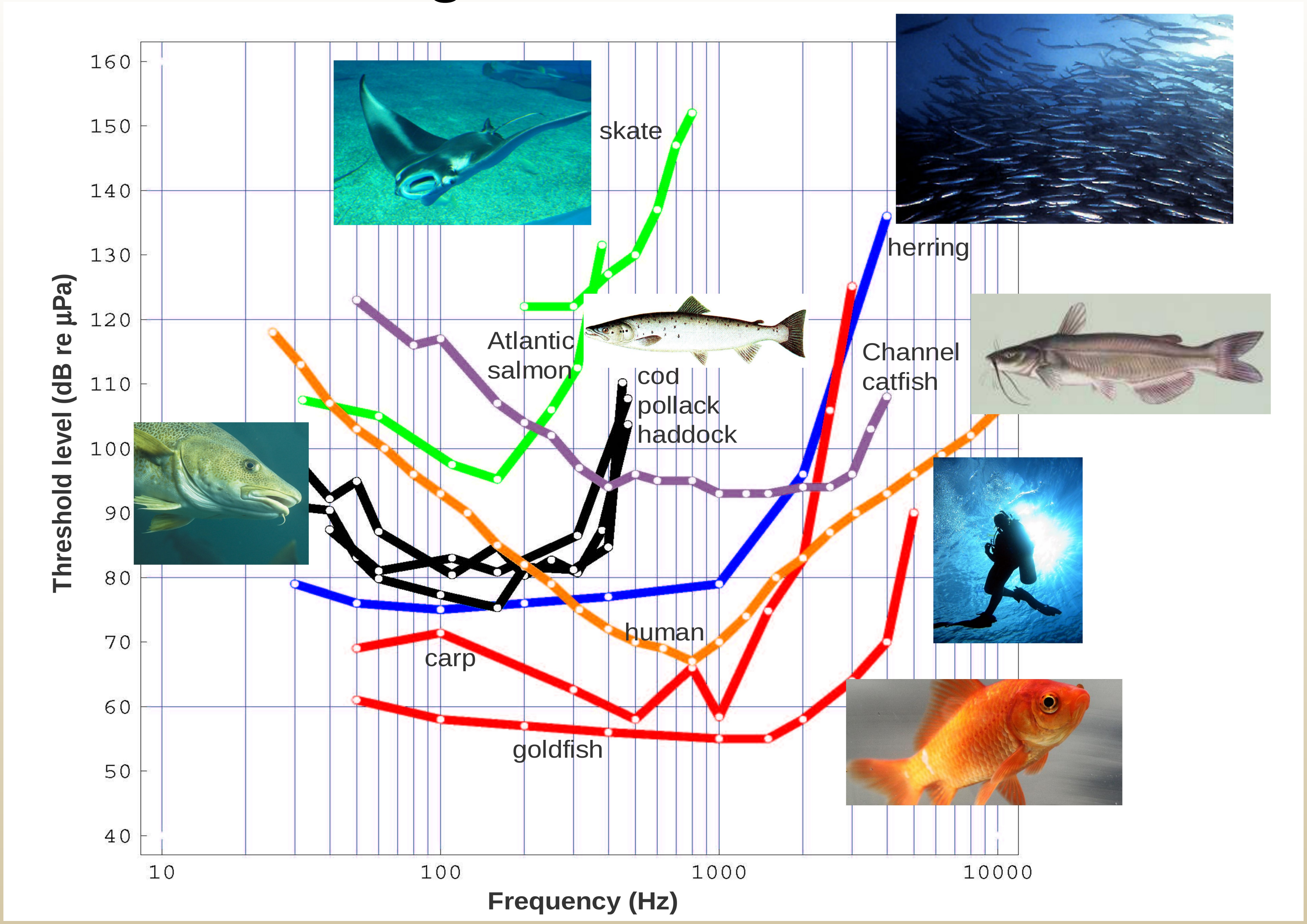
Animal	Frequency (Hz)	
	Low	High
Humans	20	20,000
Cats	100	32,000
Dogs	40	46,000
Horses	31	40,000
Elephants	16	12,000
Grasshoppers	100	50,000
Mice	1,000	90,000
Bats	2,000	110,000
Whales	5	200,000
Seals and sea lions	200	55,000

Frequency range of hearing for humans and selected animals. Bats are the land animal with the broadest hearing span (see *GEO ExPro* Vol. 7, No. 4). The squeaks that we can hear a mouse make are in the low frequency end and are used to make long distance calls, as low frequency sounds travel further than high frequency ones. Mice can alert other mice of danger without also alerting a predator like a cat to their presence, if the predator can not hear their high-frequency distress call. Marine mammals have a mammalian ear that through adaptation to the marine environment has developed broader hearing ranges than those common to land mammals. As a group they have functional hearing ranges from 5 Hz to 200 kHz.

Hearing curve for white whales

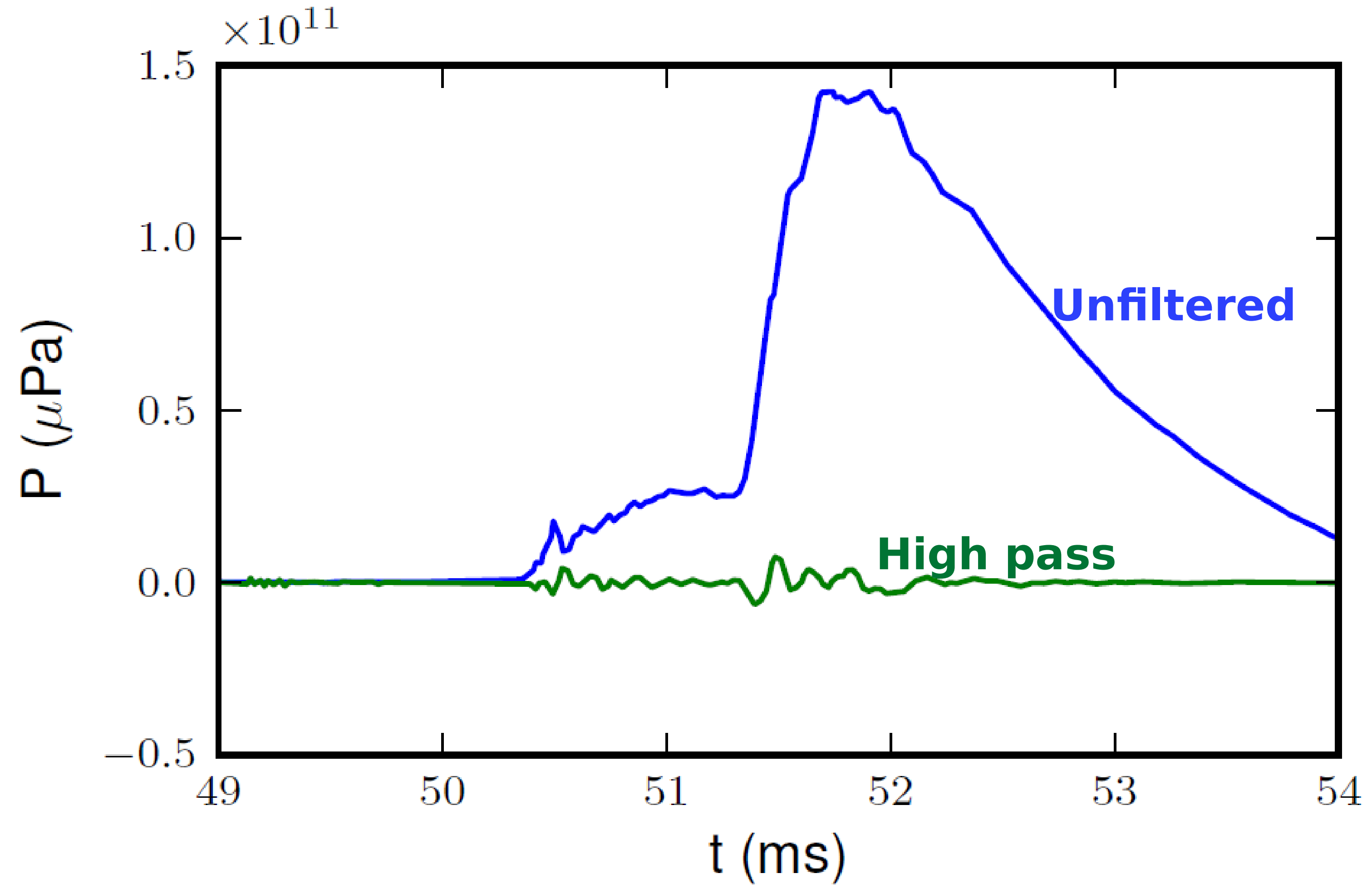


Hearing curves for fish



More info: Amundsen and Landrø: Recent advances**, GeoExpro**

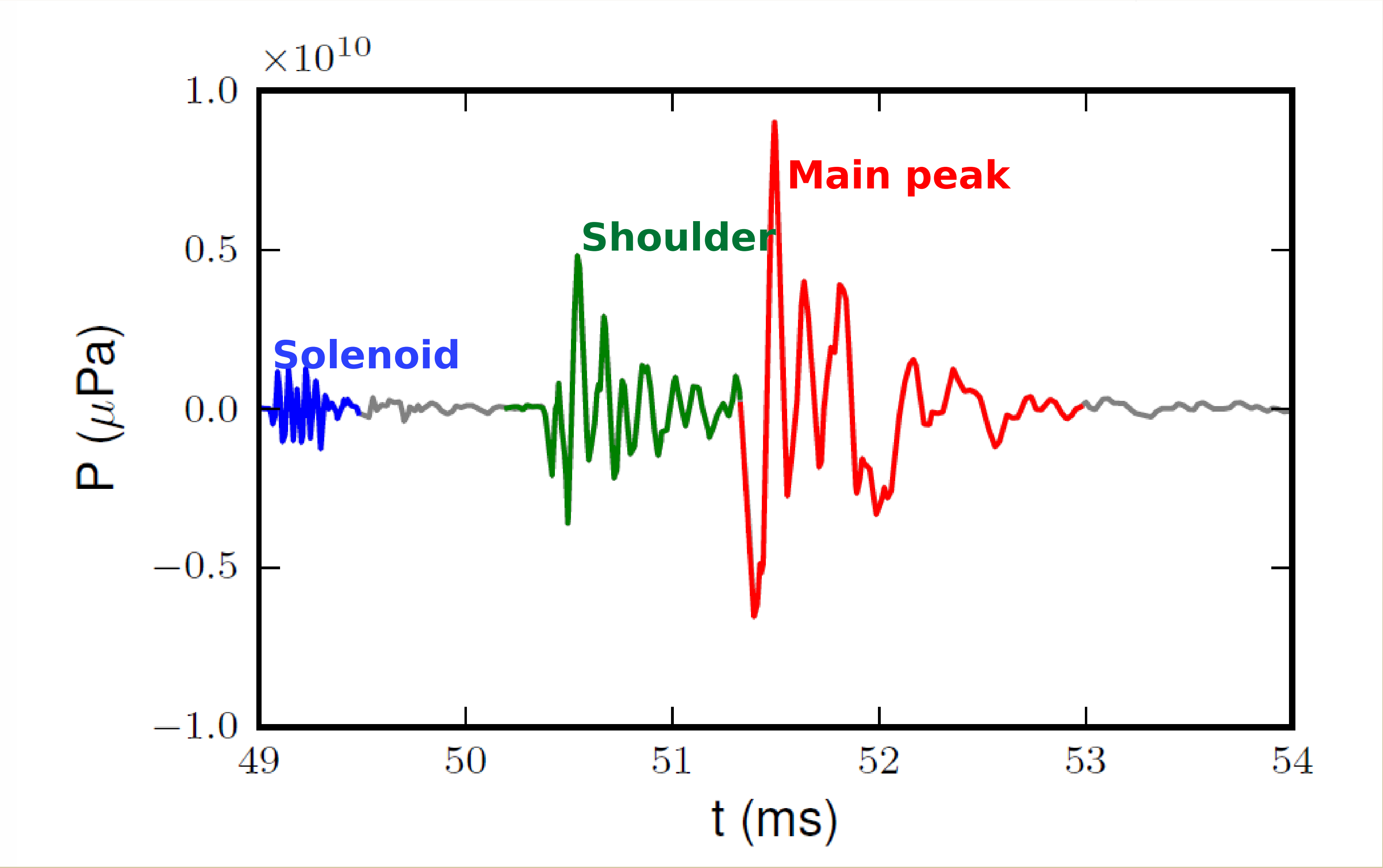
Single air gun (10 cubic inch)



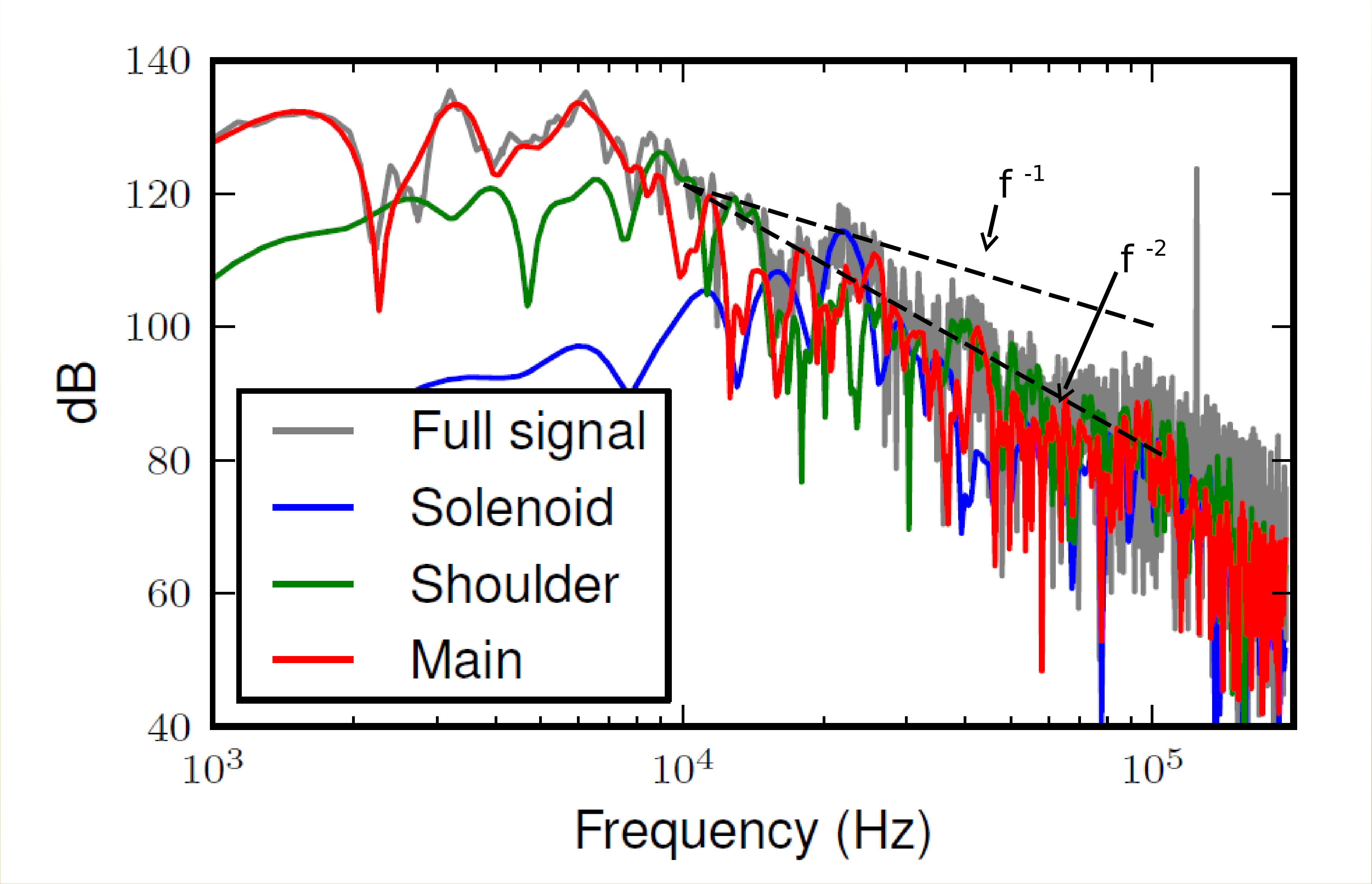
Mechanical and electrical noise

- The solenoid creates high frequency noise prior to the main signal
- The sudden of the piston inside the air gun might cause a high frequency signal
- Air gun jumping will cause mechanical noise

High pass filtered signal – single air

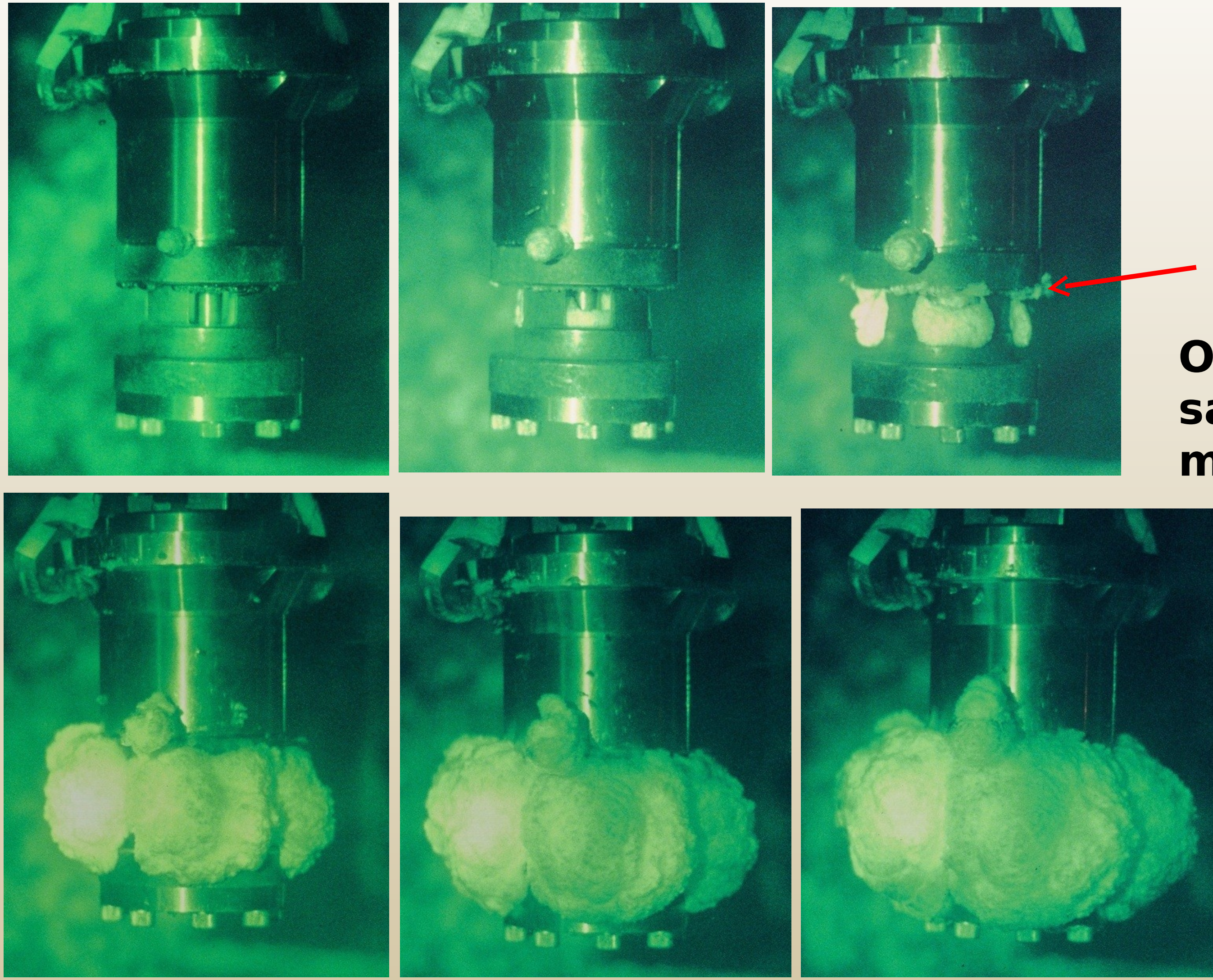


Single air gun – frequency spectr



Typical cavitation noise has f^{-1} attenuation, (Brennen, 1995) => most of this noise is not cavitation? Solenoid noise ~$f^{-2.5}$

High speed photography of a small air gun



Cavitation?

Occuring at the same time as the maximum peak

From Jan Langhammer’s PhD work in 19

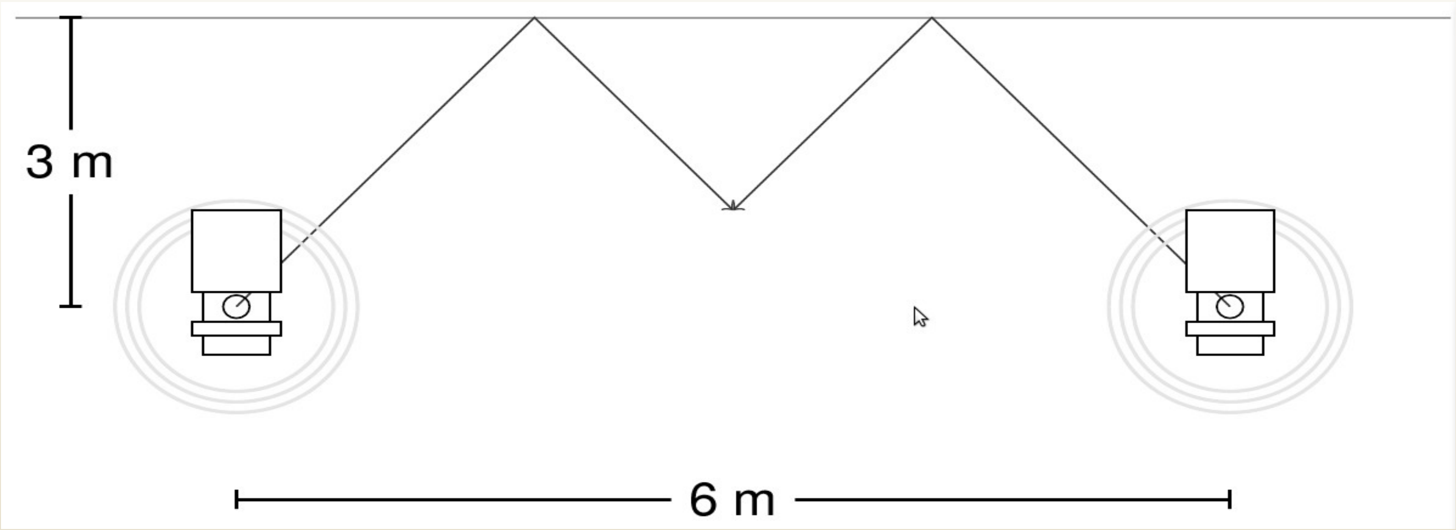
Cavitation

Cavitations are vapor bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapor pressure. When cavities collapse, they create high-frequency signal. Rayleigh (1917) calculated the collapse time of a cavitation is approximately

$$\tau = 0.91468\,R_0\sqrt{\frac{\rho}{P_{hyd}}}$$

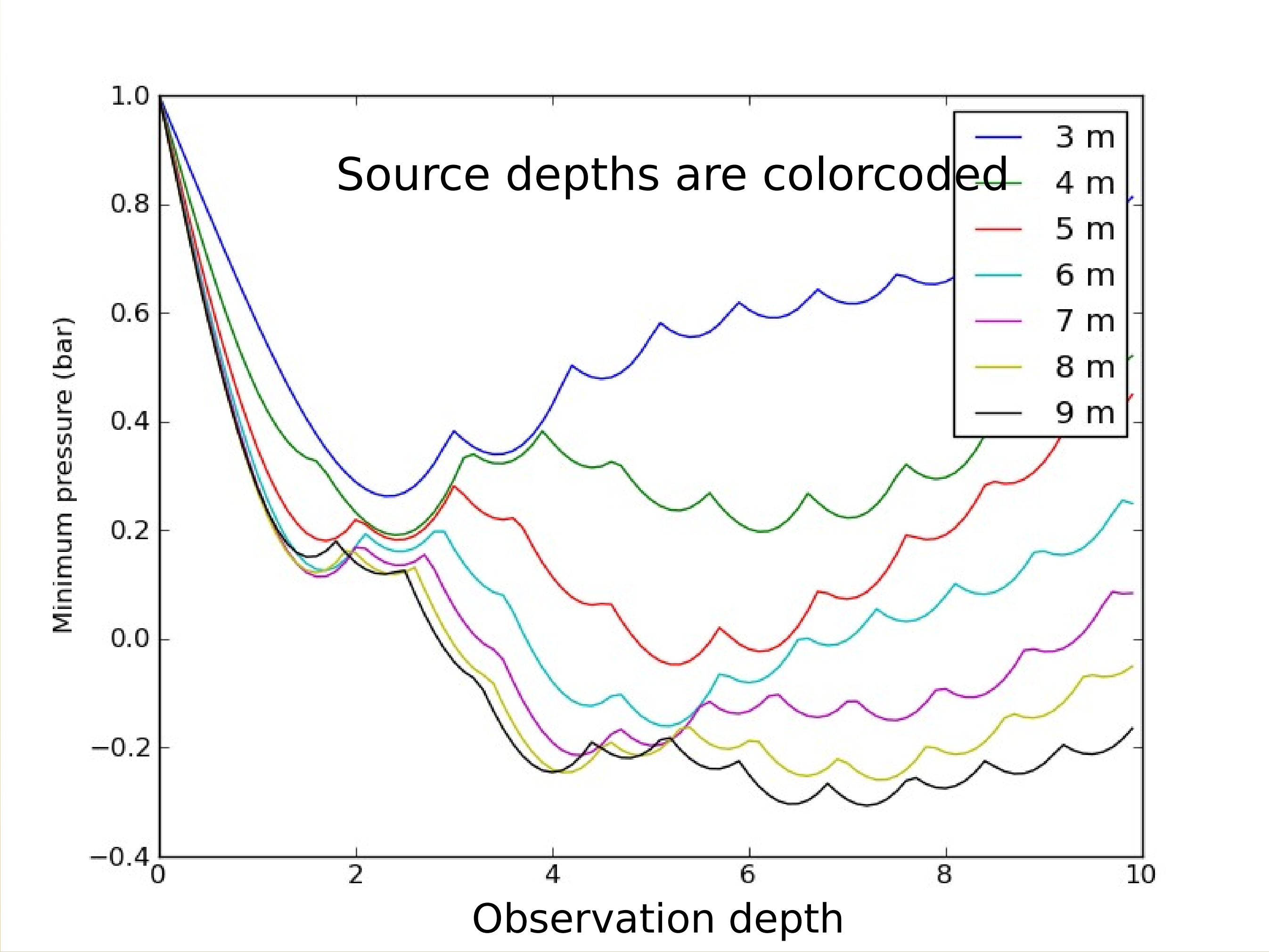
A cavity with radius 1 mm at 5 m depth, will collapse in 0.075 ms, and a cavity with 10 cm will collapse in 7.5 ms

Ghost cavitation

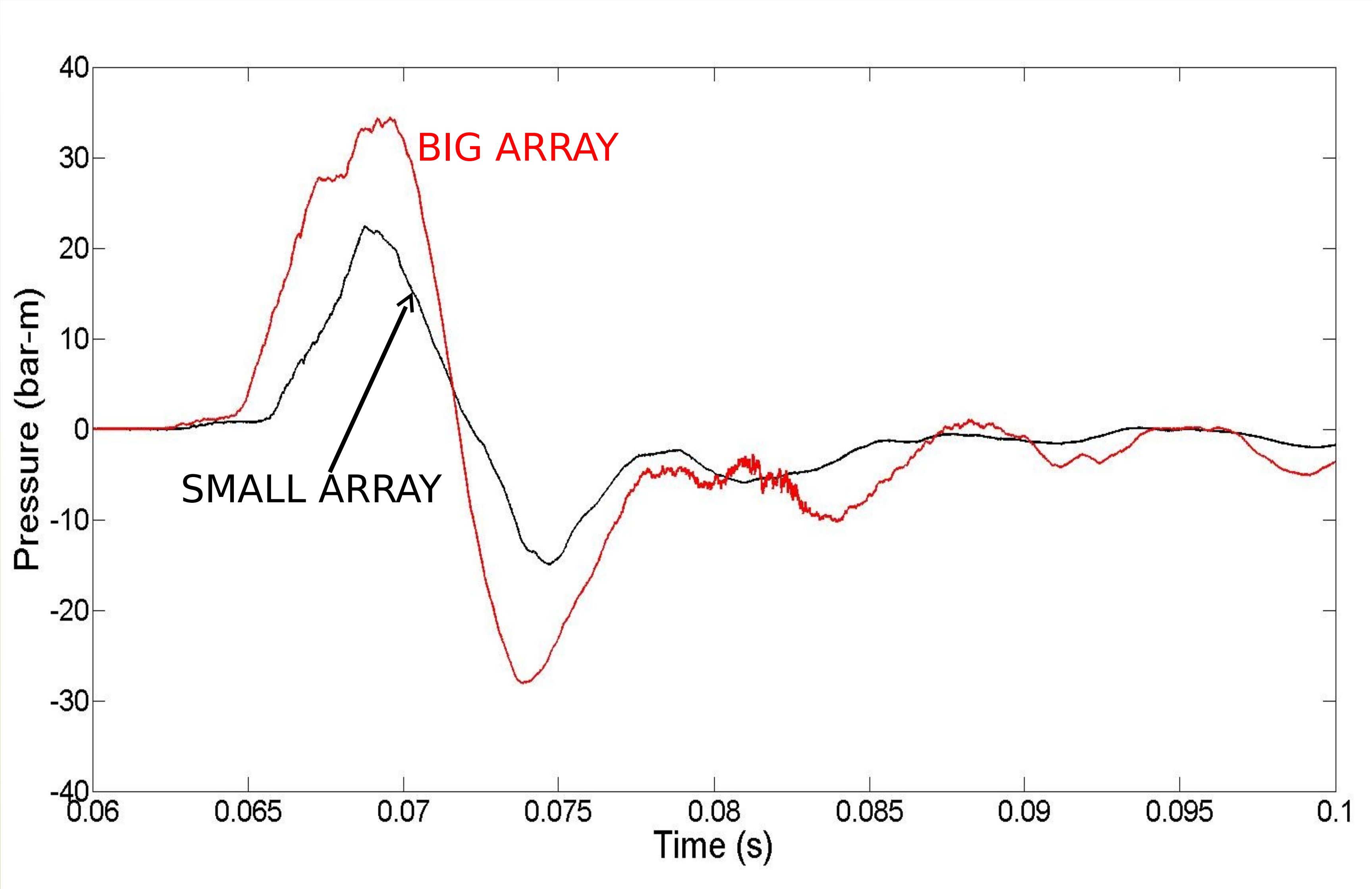


Assuming two guns producing 4 bar-m signal each => -1.3 bar at 2 m depth corresponding to the unphysical value of -0.1 bar in pressure. Linear theory is not valid, however, it clearly shows the potential for ghost cavitation, especially for compact air gun arrays.

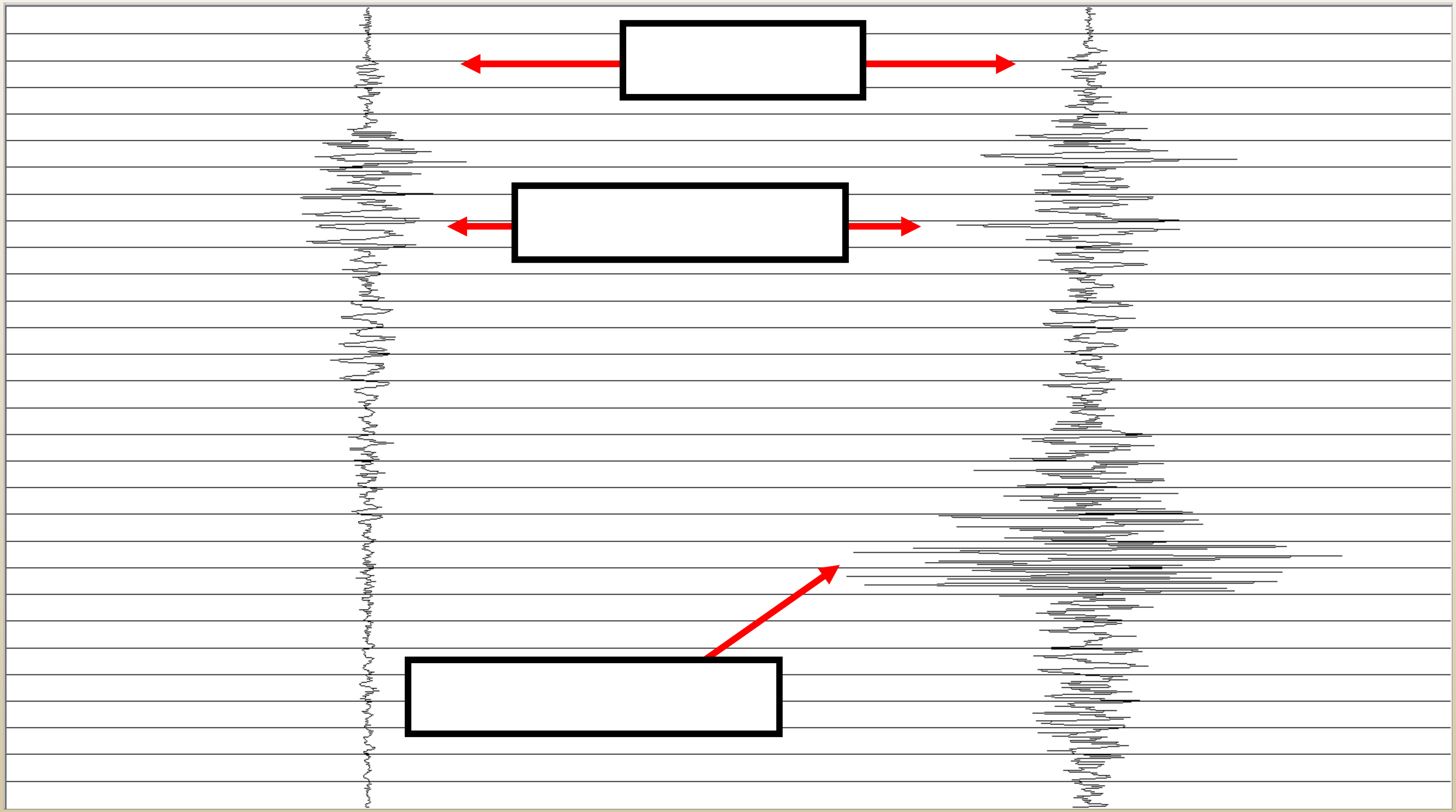
Air gun modeling and depth dependency of ghost cavitation



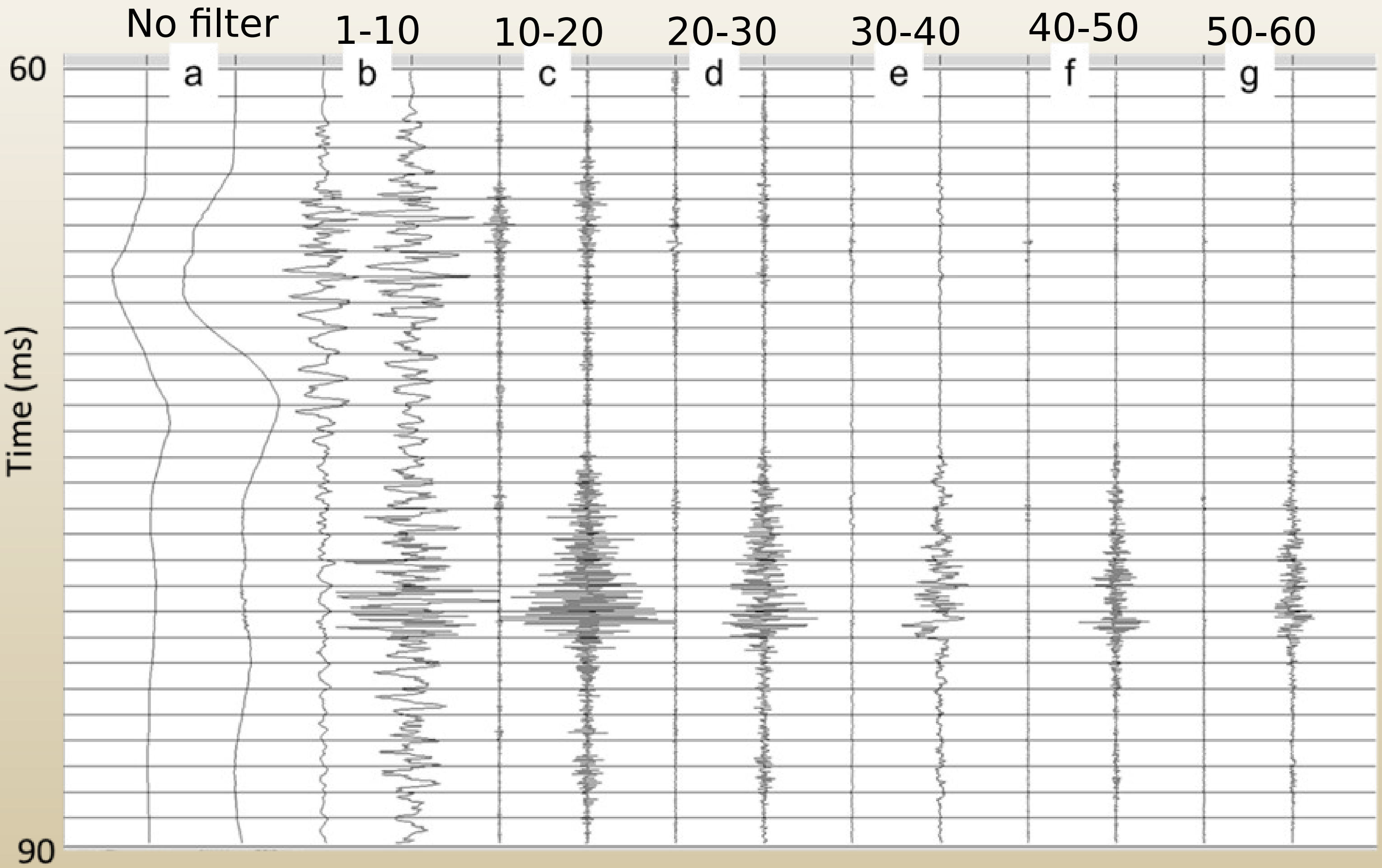
Far field data of a small and big a



1 kHz high pass filtered data

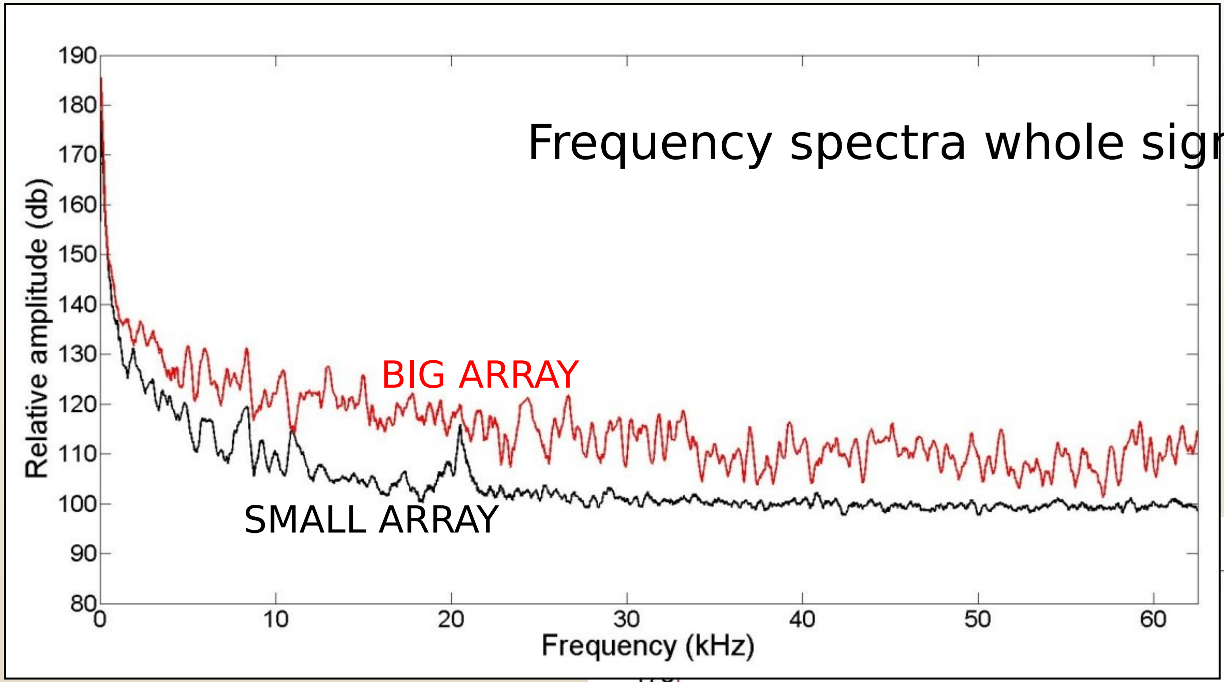


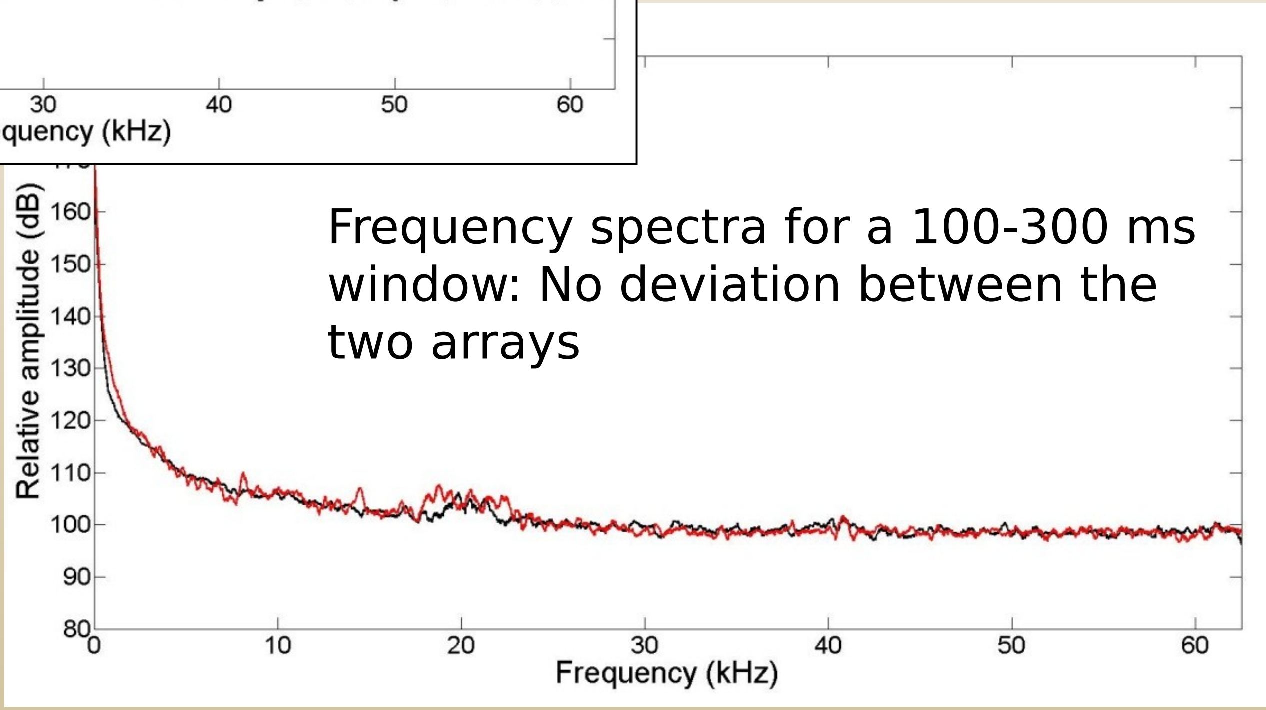
Pairs of small and big arrays for various band pass filters (kHz)



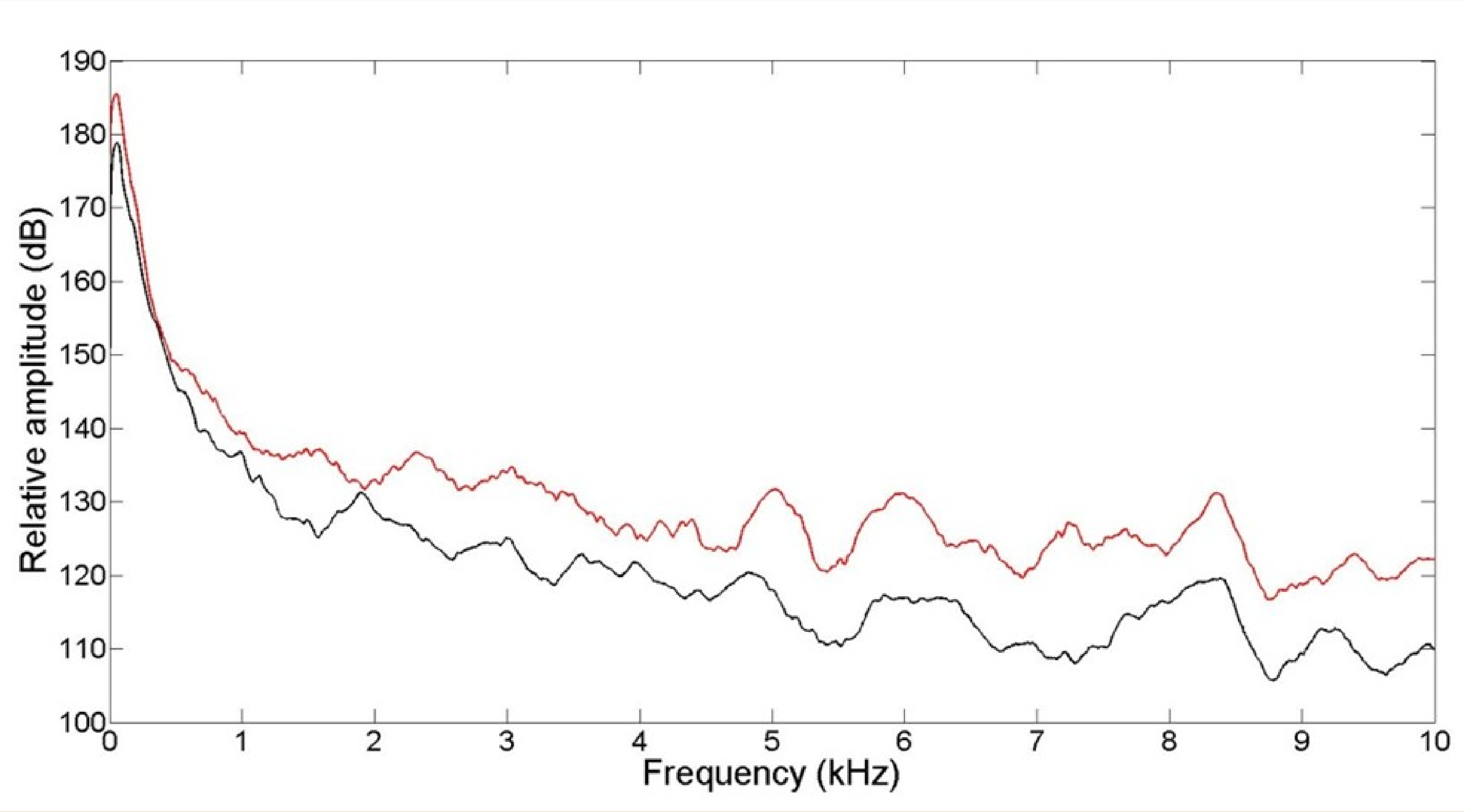
Significant difference between small and big array for ghost cavitation

Spectral analysis

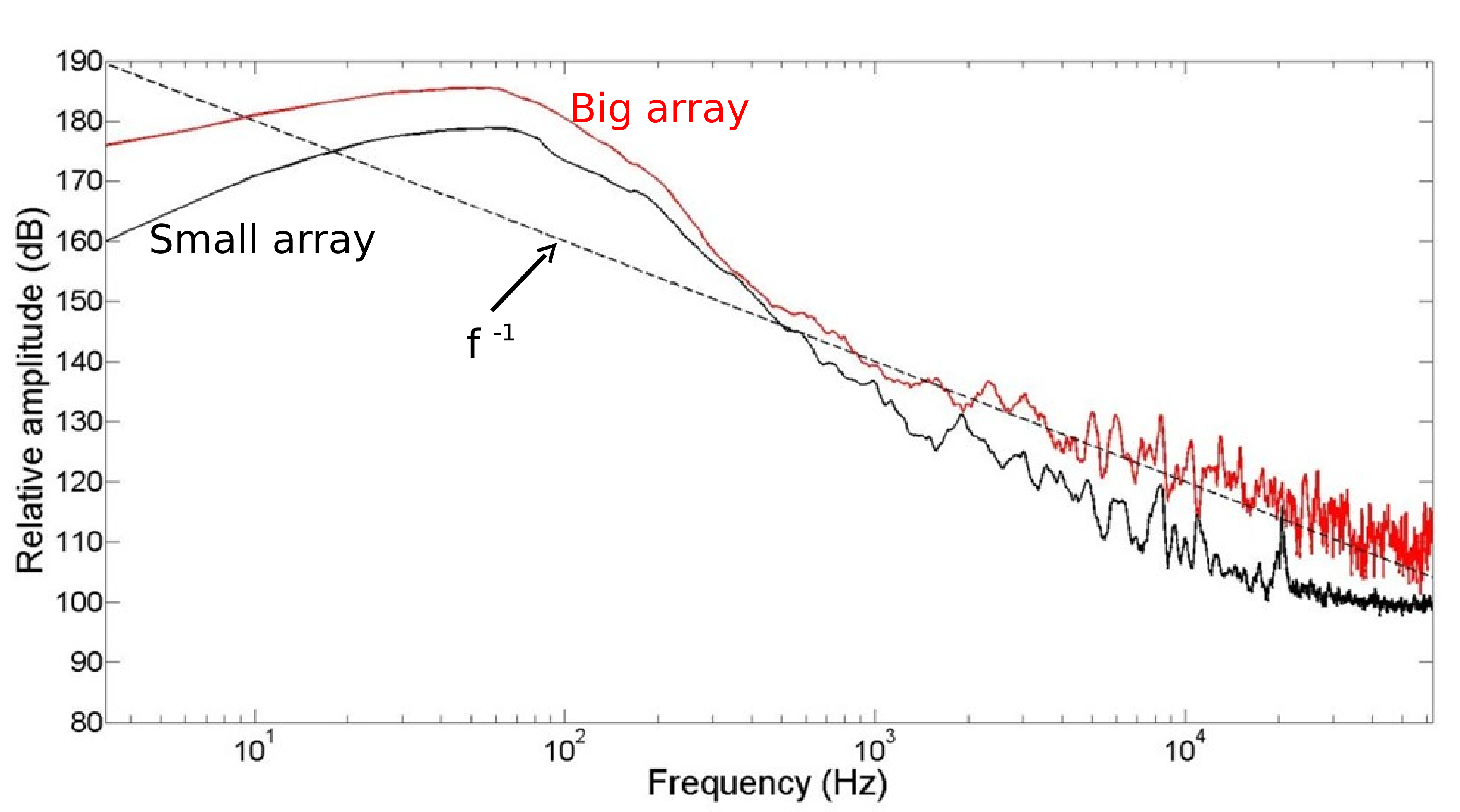




Similarities between small and big array



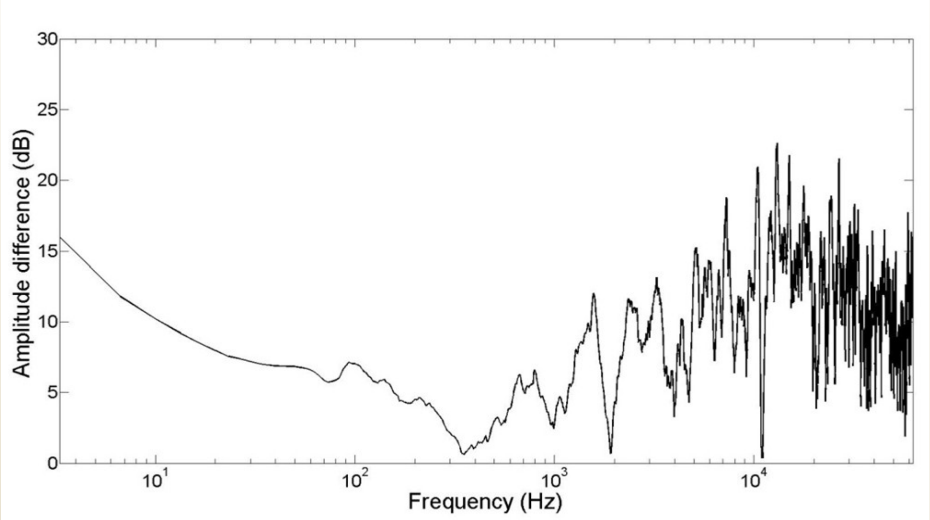
Spectral analysis



Big array is close to f $^{-1}$ attenuation => more cavitation nois

In contrast to the f $^{-2}$ attenuation observed for single ai

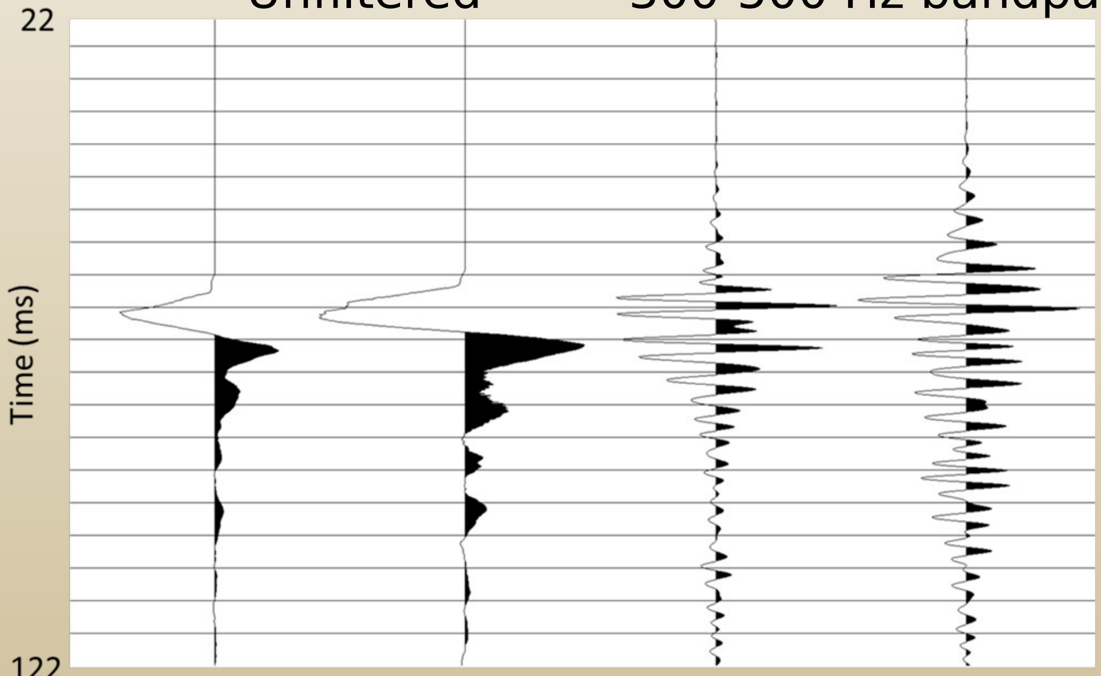
Spectral difference between small - big array



Notice the low difference around 350

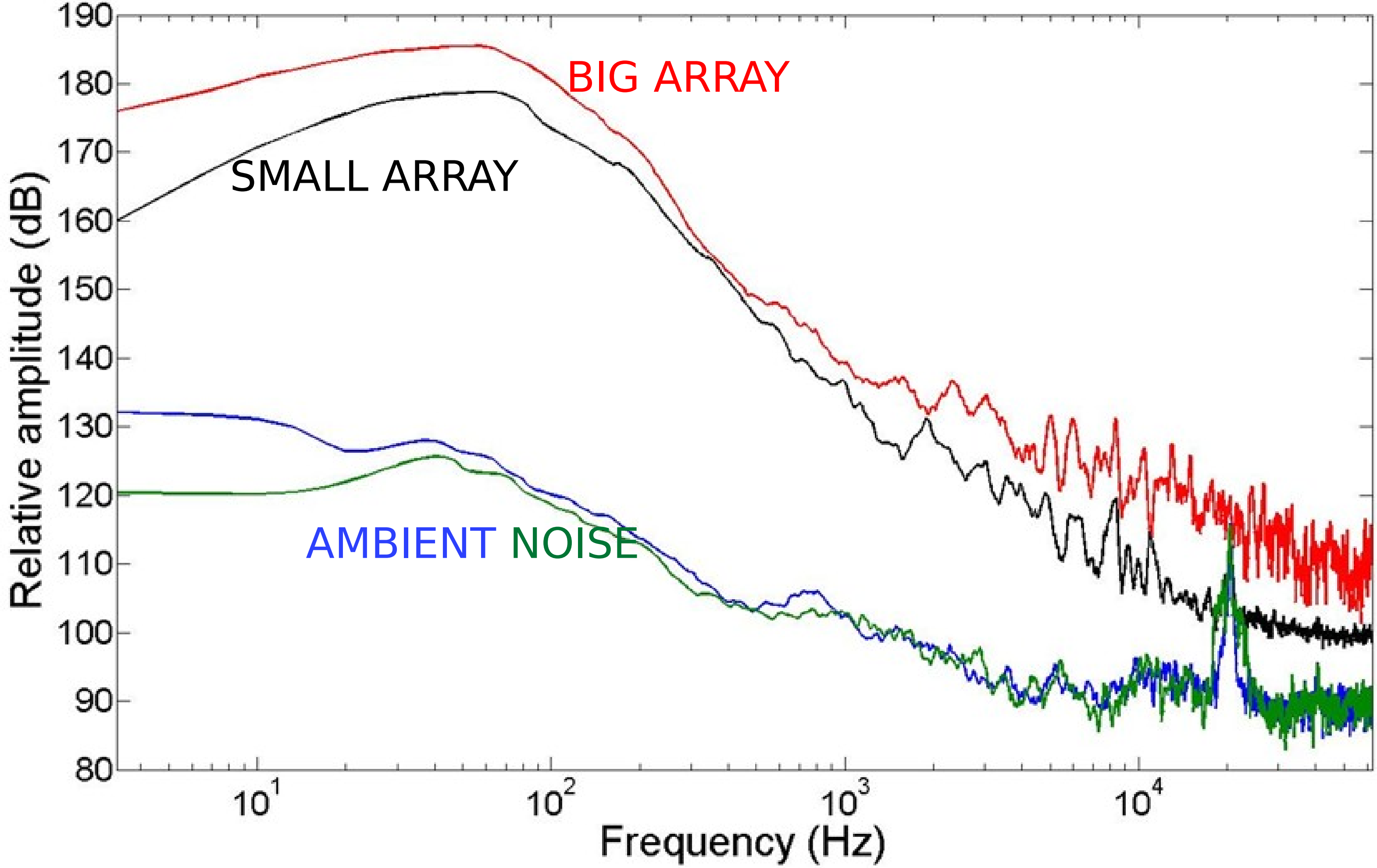
Unfiltered

300-500 Hz bandpass



Comparison of un-filtered and filtered traces for small and big array

Comparison to ambient noise



Conclusions

- **Multicausal high frequencies:**
  - **Mechanical**
  - **Solenoid**
  - **Cavitation close to gun**
  - **Ghost cavitation (?)**
- **Ghost cavitation (?) shows 1/f attenuation, single air gun shows stronger attenuation**
- **Need more measurements to demonstrate that ghost cavitaion is the dominant effect**
- **IF so – this noise might be avoided by increasing the distance between guns**

References

Brennen, C. [1995] Cavitation and bubble dynamics. Oxford University press.

Rayleigh, O. [1917] On the pressure developed in a liquid during the collapse of a spherical cavity. Philosophical Magazine, 34,94–98.

Landrø, M., Amundsen, L. and Barker, D, 2011, High frequency signal from air gun arrays, paper accepted for publication in Geophysics

Acknowledgements

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