LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Obervations of long-period rotational ground motions: from ambient noise to Earth's free oscillations

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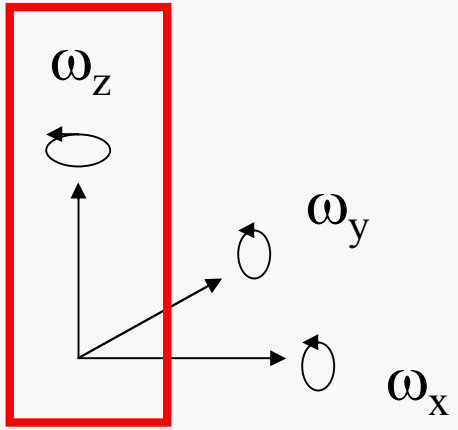
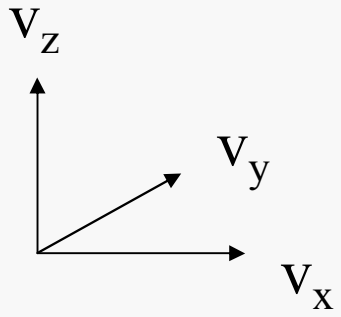
$$\begin{pmatrix} \omega_x \\ \omega_y \\ \omega_z \end{pmatrix} = \frac{1}{2} \nabla \times \underline{\mathbf{v}} = \frac{1}{2} \begin{pmatrix} \partial_y v_z - \partial_z v_y \\ \partial_z v_x - \partial_x v_z \\ \partial_x v_y - \partial_y v_x \end{pmatrix}$$



Rotation rate

Rotation sensor



Ground velocity

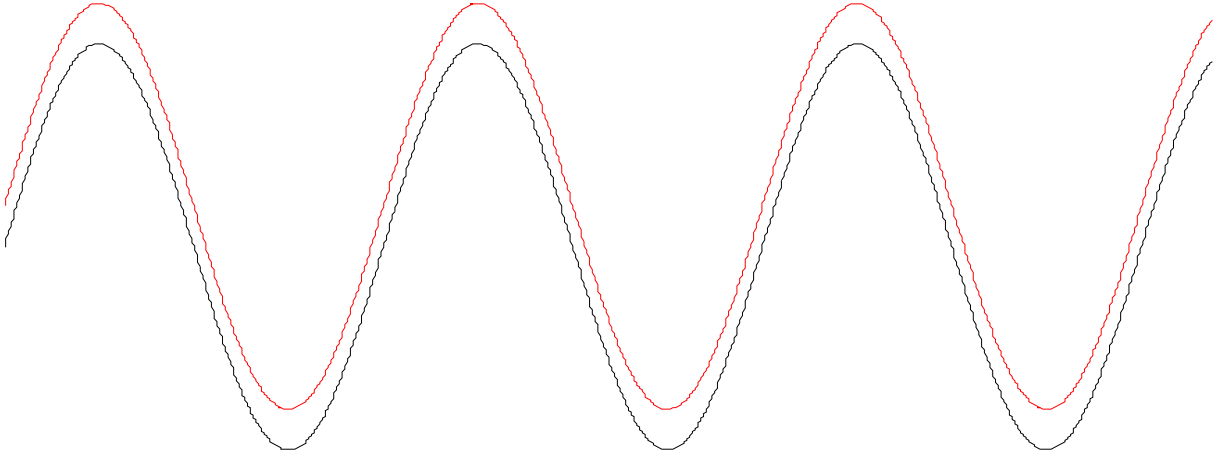
Seismometer

Plane shear waves

Theory

Plane transversely polarized wave propagating in x-direction with phase velocity c

rotation rate – transverse acceleration

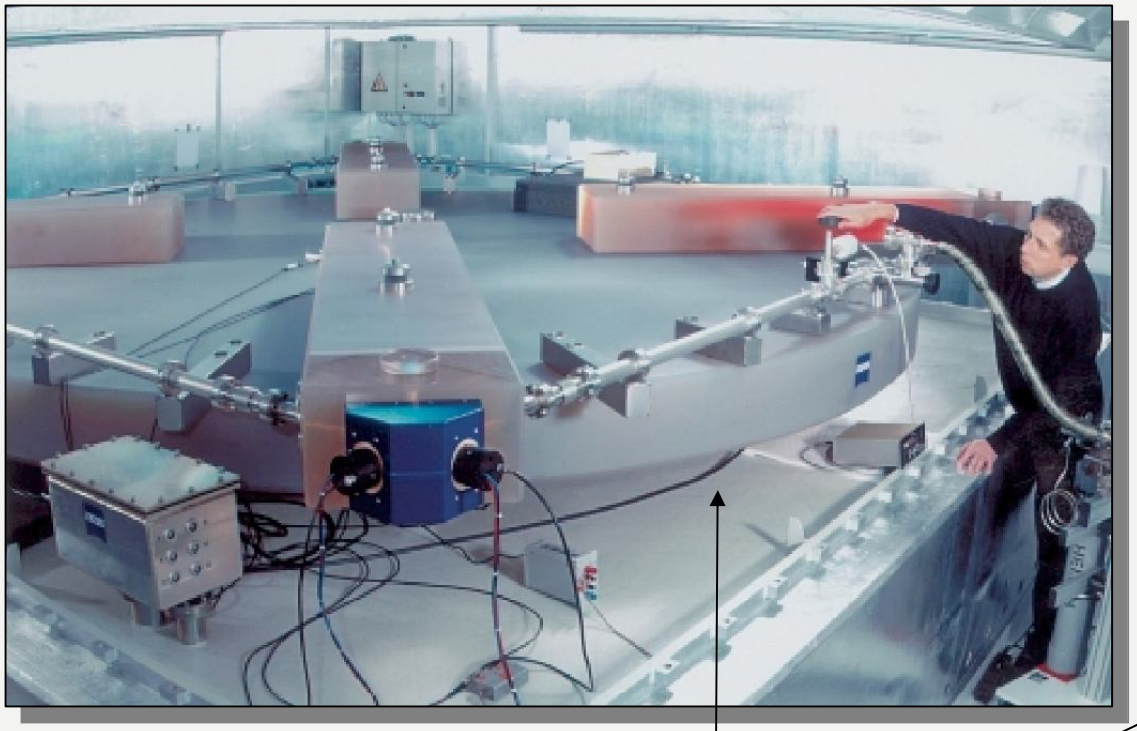


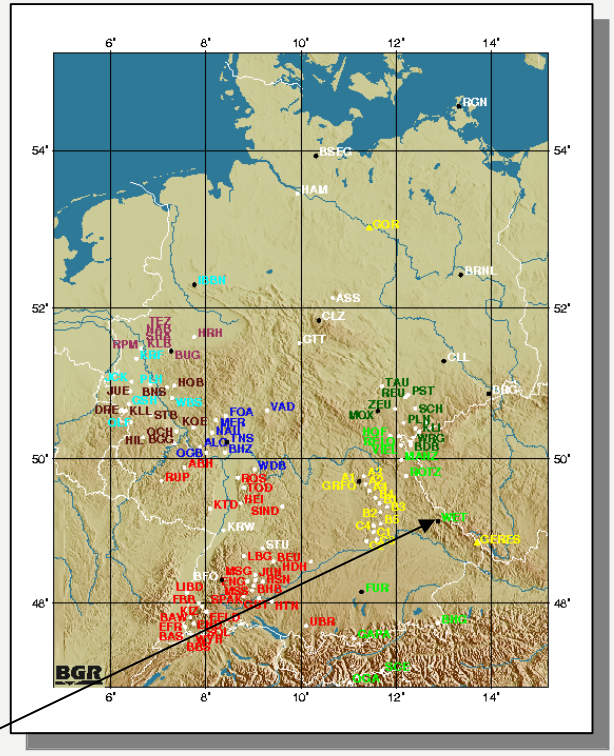
$$a(x,t)/\dot{\Omega}(x,t) = -2c$$

Rotation rate and acceleration should be in phase and the amplitudes scaled by two times the horizontal phase velocity

Ring Laser Rotation Sensor

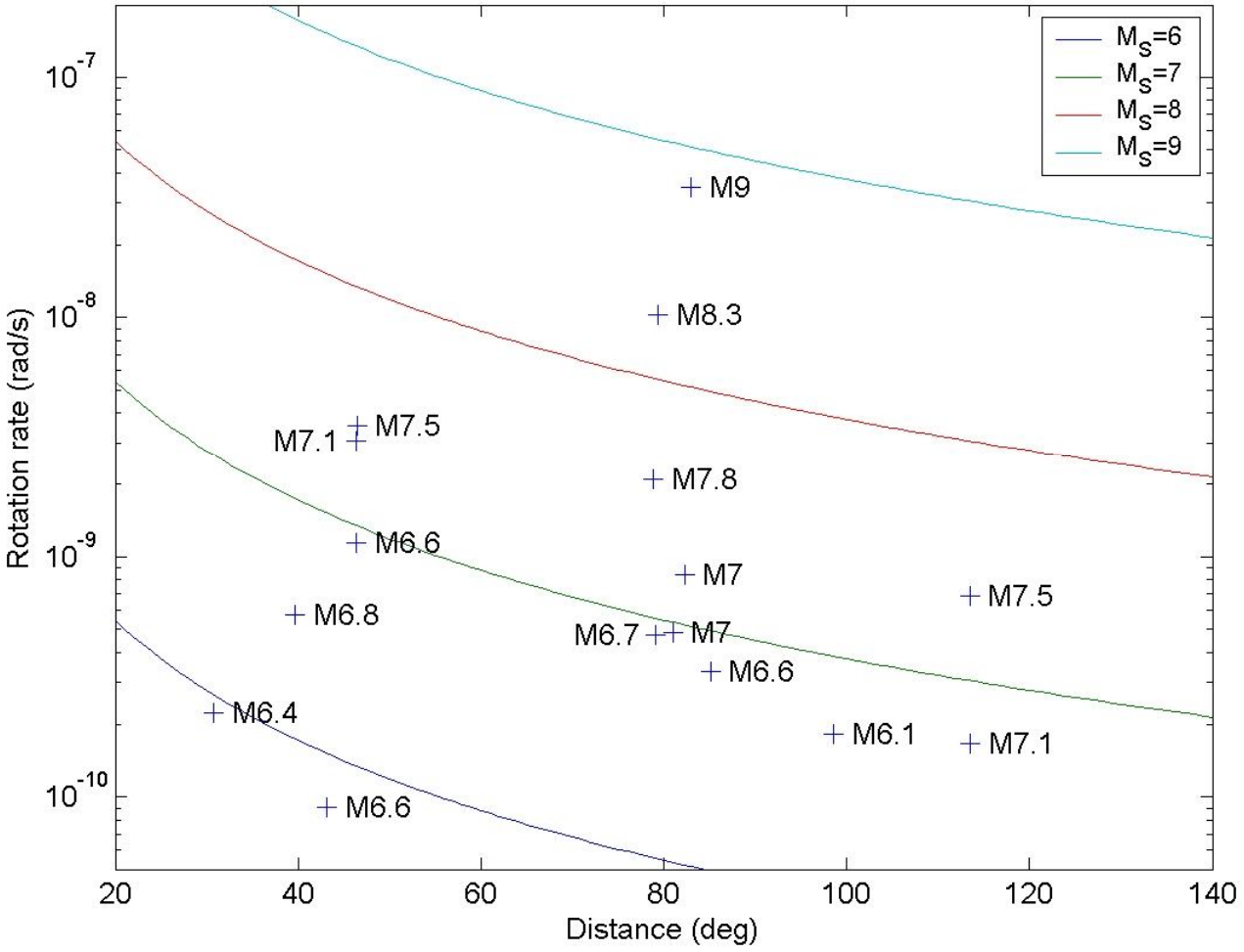
Instrument principle described in Schreiber et al., BSSA, 2009, special issue.





Ring Laser

Rotation rate amplitudes: what to expect?



M=9

M=8

M=7

Earthquake-induced rotations

Observations

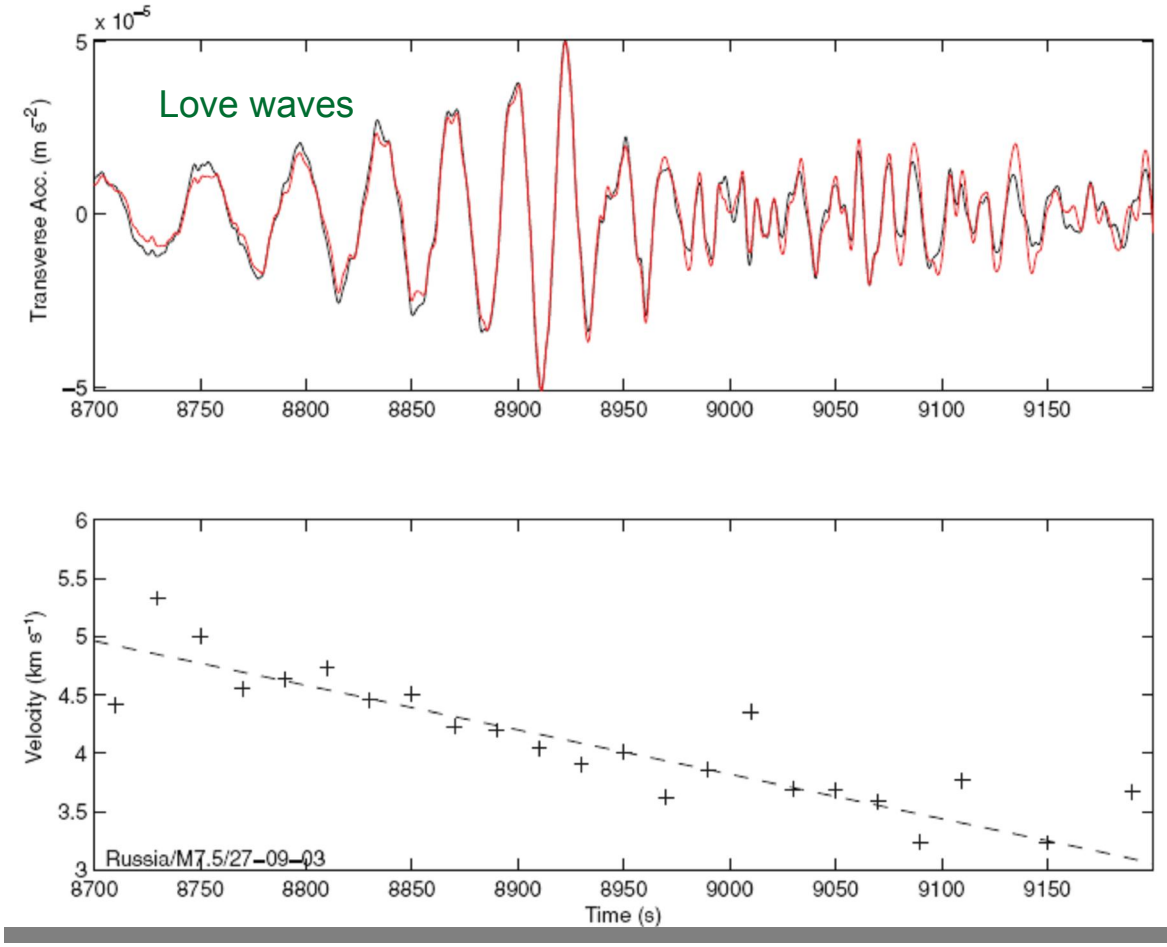
Plane wave analysis tells us:

- Waveforms (transverse acceleration and rotation rate) should be in phase
- The ratio between acceleration and rotation rate is proportional to phase velocity
- This can be used for **seismic tomography without travel times**

References (e.g.):

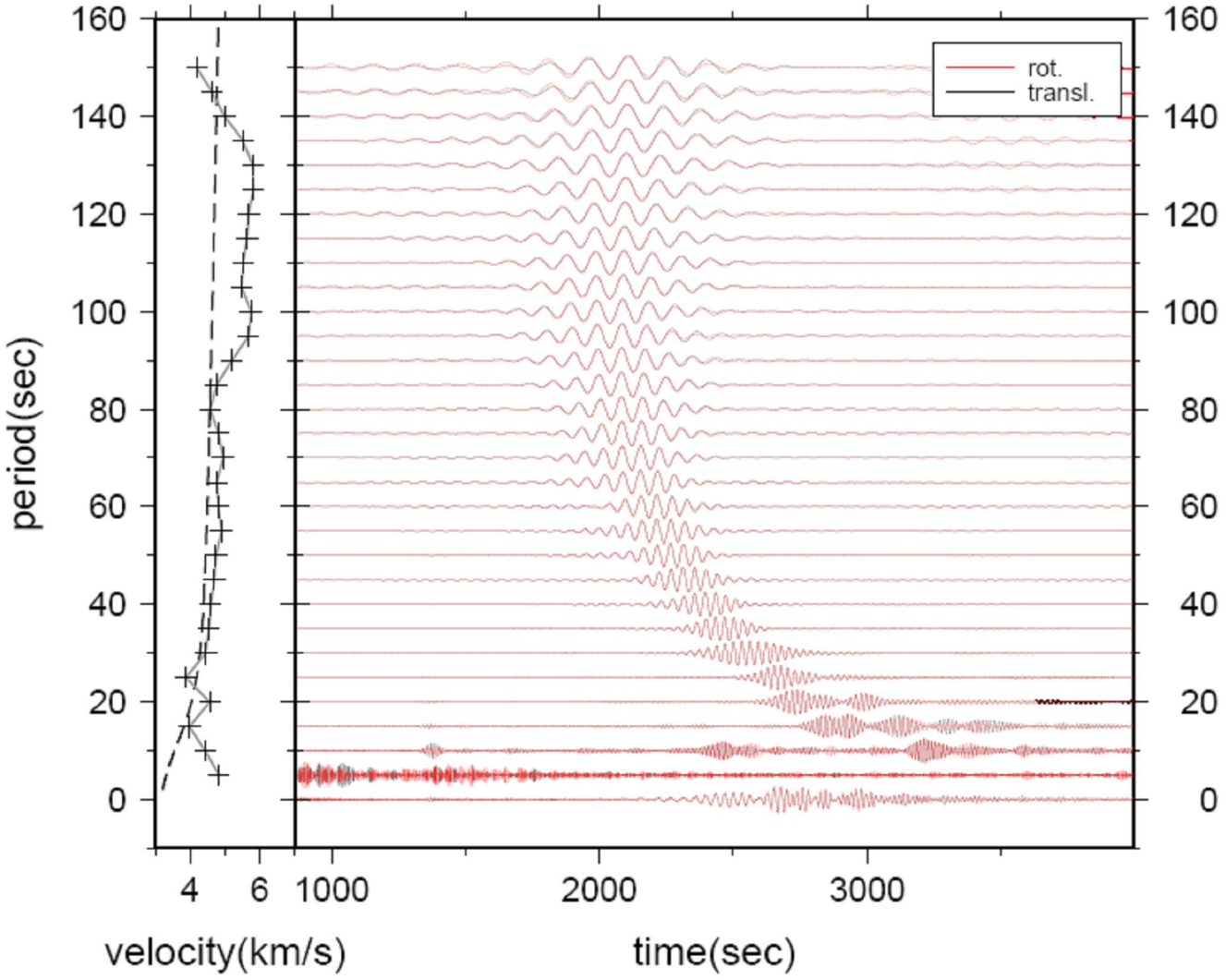
Pancha et al., GRL, 2000
Igel et al., GJI 2007
Ferreira and Igel, BSSA, 2009
Kurrle et al., GRL, 2010
Fichtner et al., BSSA, 2009
Bernauer et al., Geophysics, 2009

rotation rate – **transverse acceleration**



Love wave dispersion

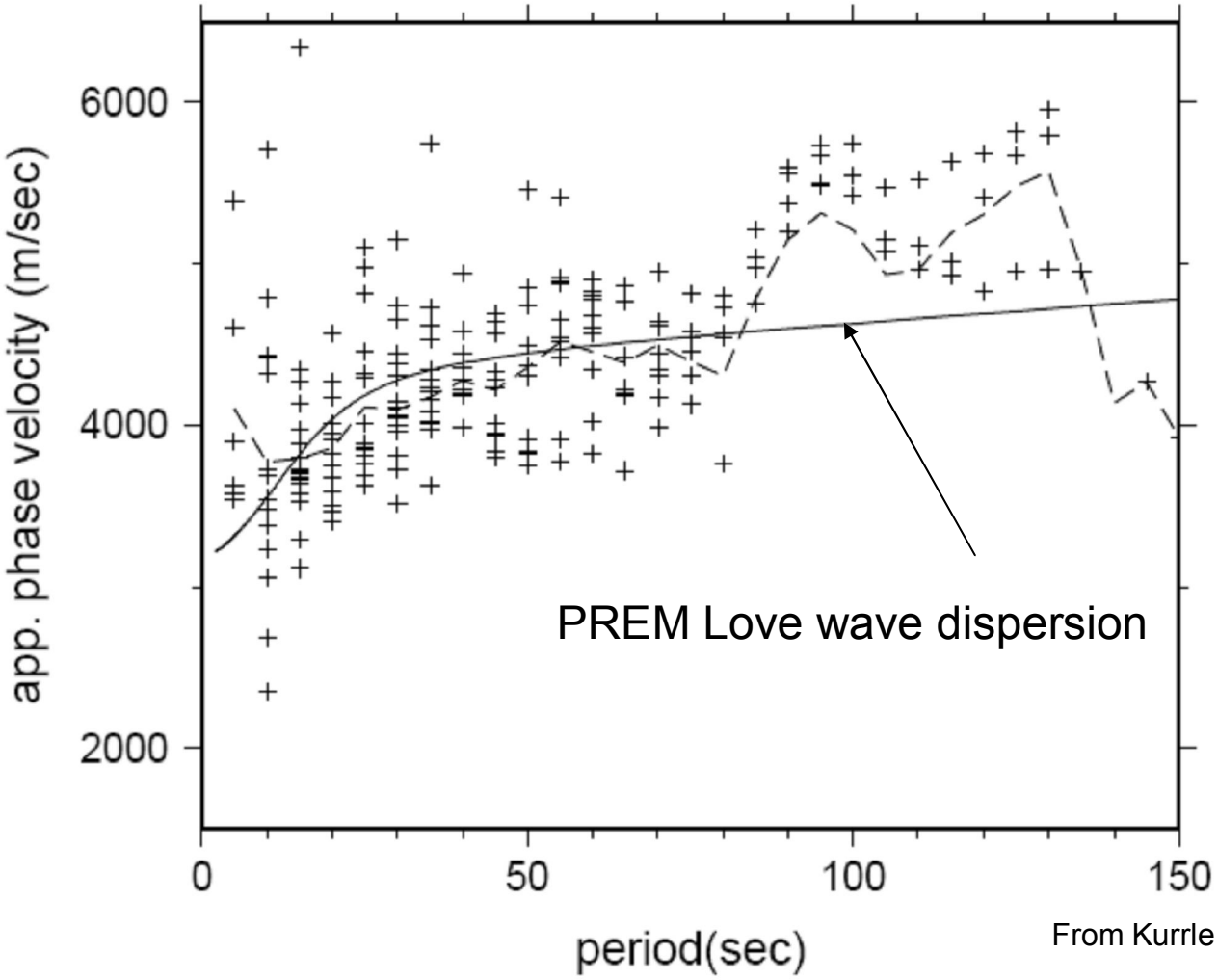
Observations



Mw = 7.4 Kuriles earthquake on Jan 15, 2009

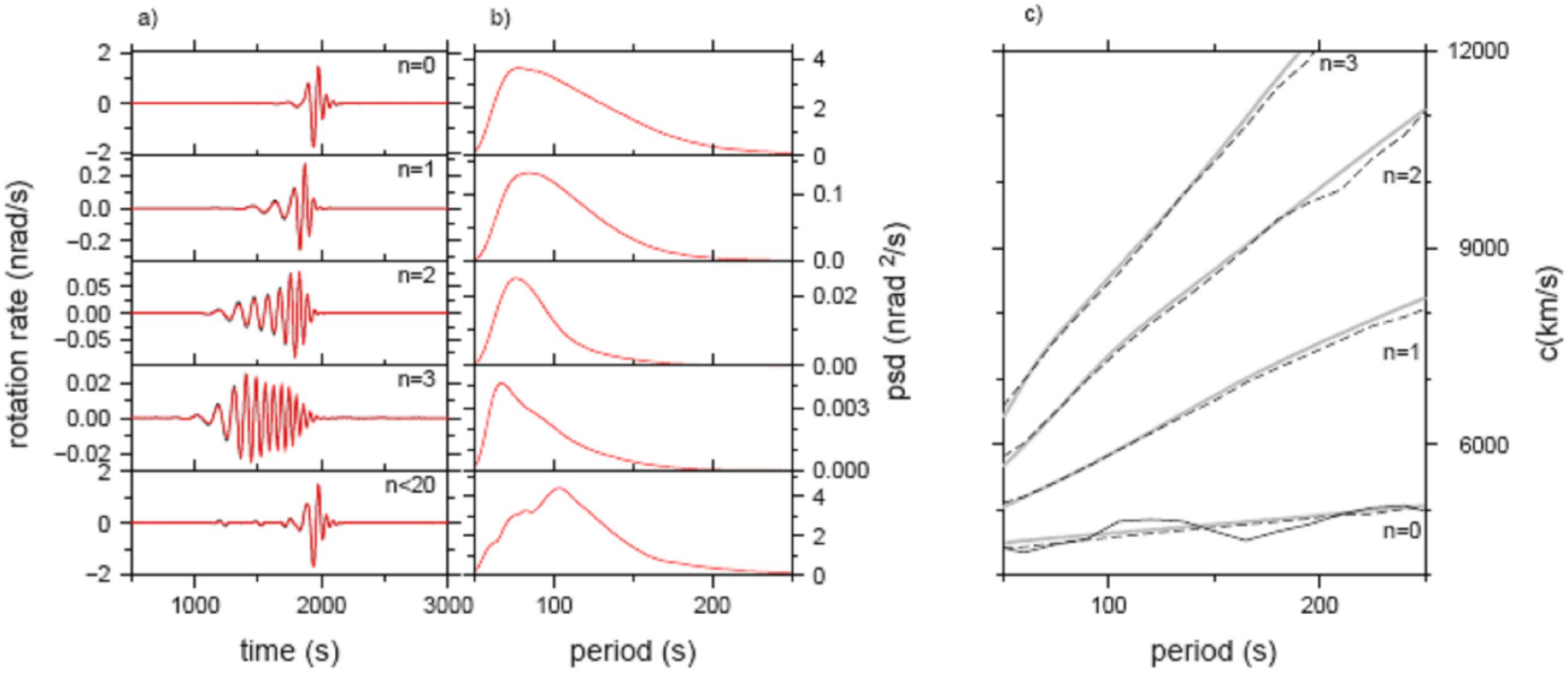
Love wave dispersion

Observations



From Kurrle et al., GRL, 2010

Why is it so difficult?



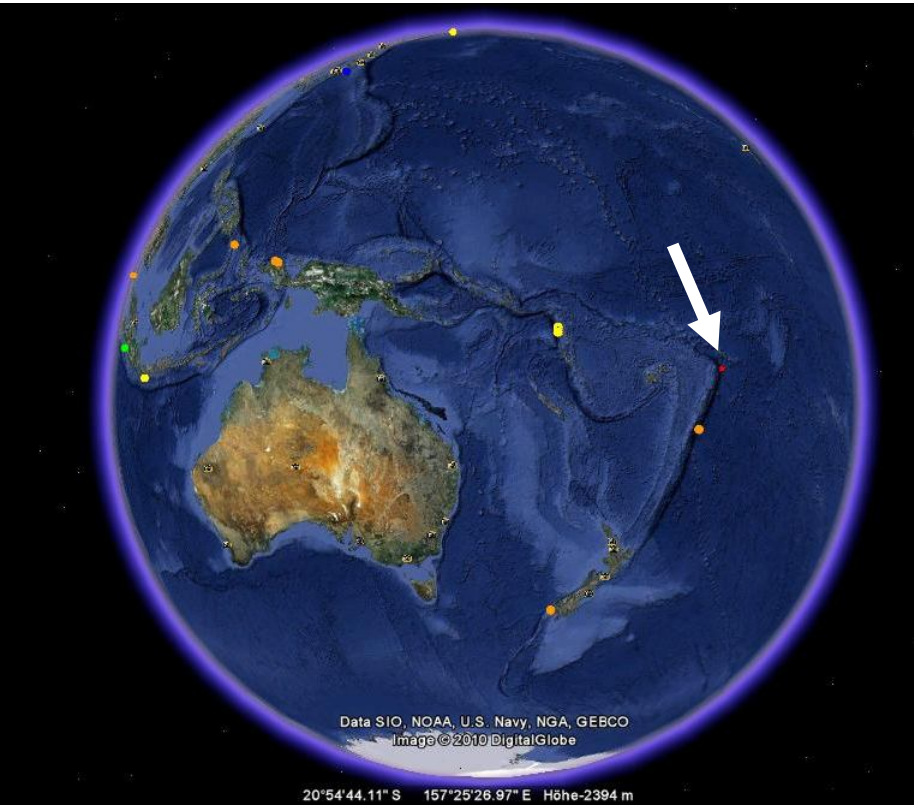
… higher mode Love wave contributions can spoil it!

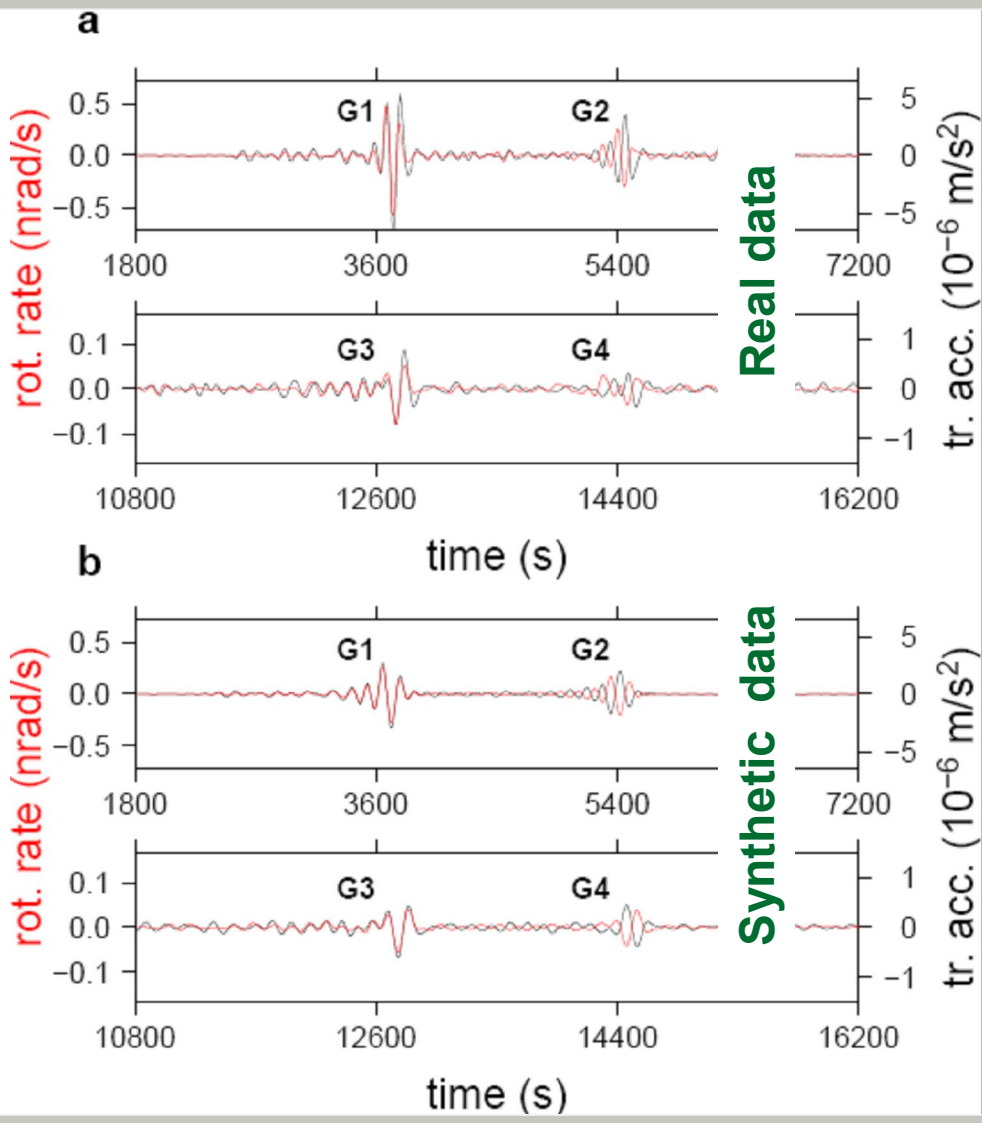
Free Oscillations?

Because at low frequencies ($f < 5$ mHz) horizontal seismometers are limited by tilt noise, there exists the possibility for obtaining superior torsional mode spectra with ring lasers provided that their self noise is further reduced.

Widmer et al., BSSA, 2009

Magnitude 8.1 - SAMOA ISLANDS REGION
2009 September 29 17:48:10 UTC

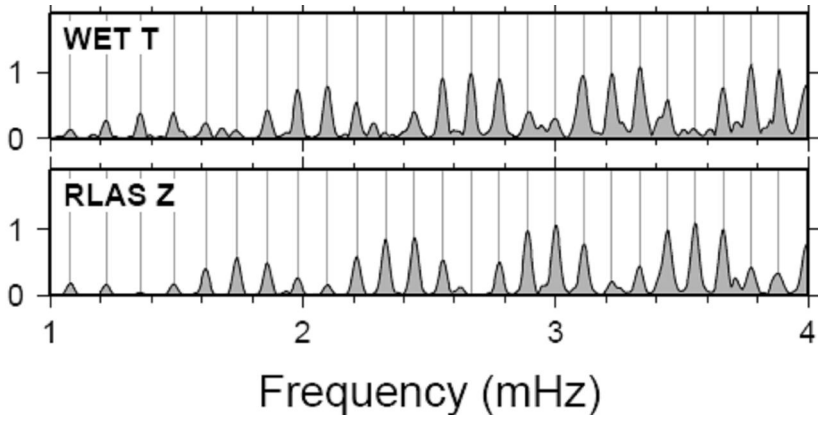




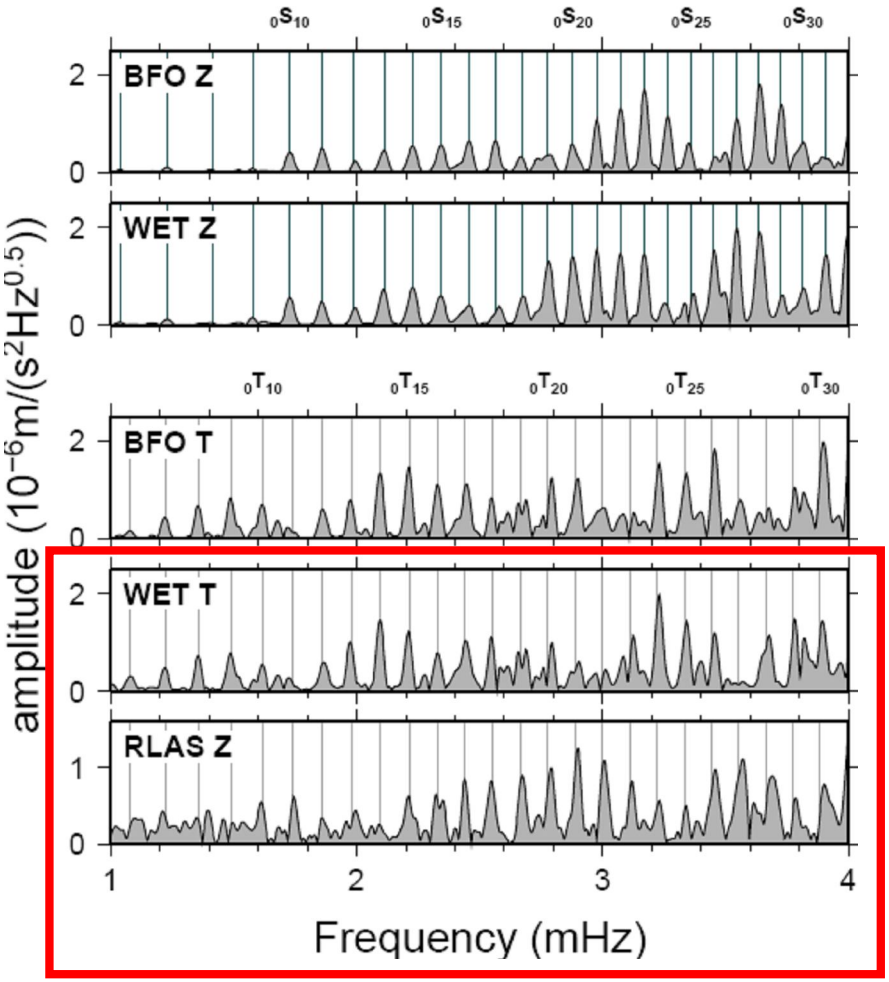
Spectra: M8.1 Samoa

- 16 hr time window
- Comparison with BFO
- Hanning taper

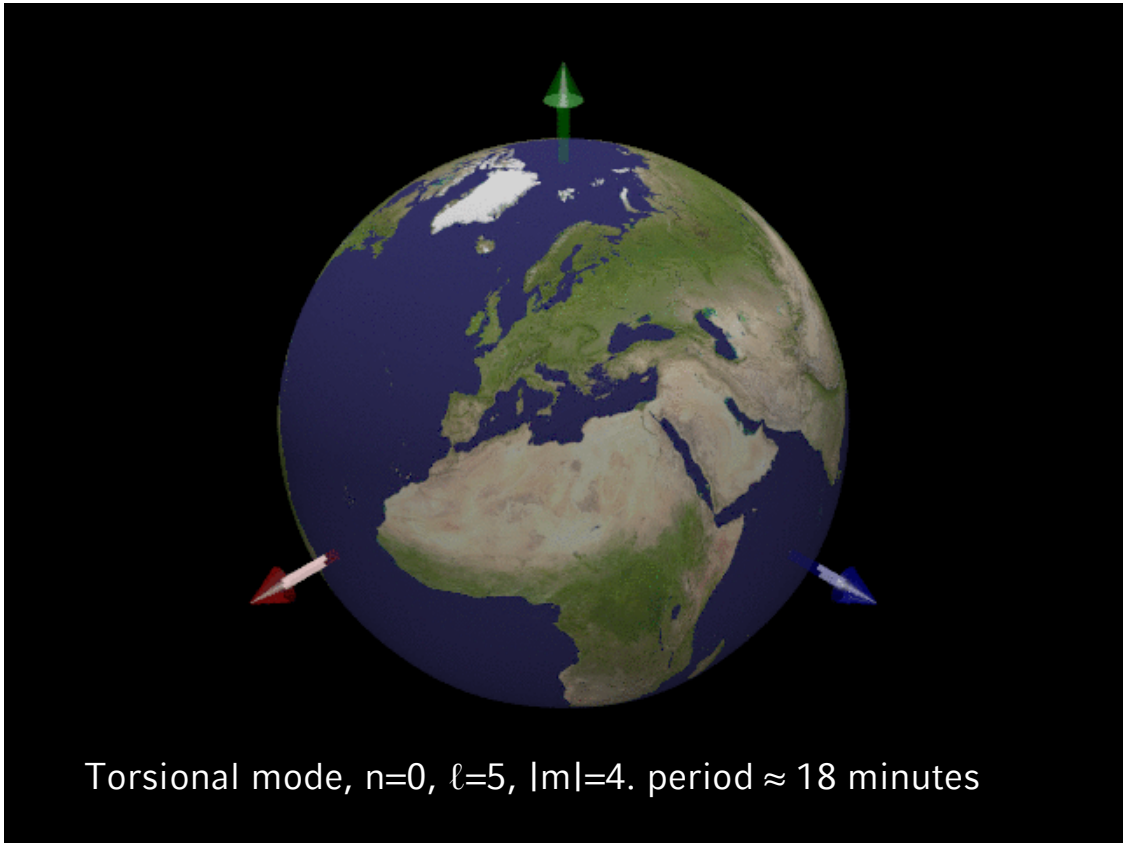
Synthetic spectra (normal modes)



Observations



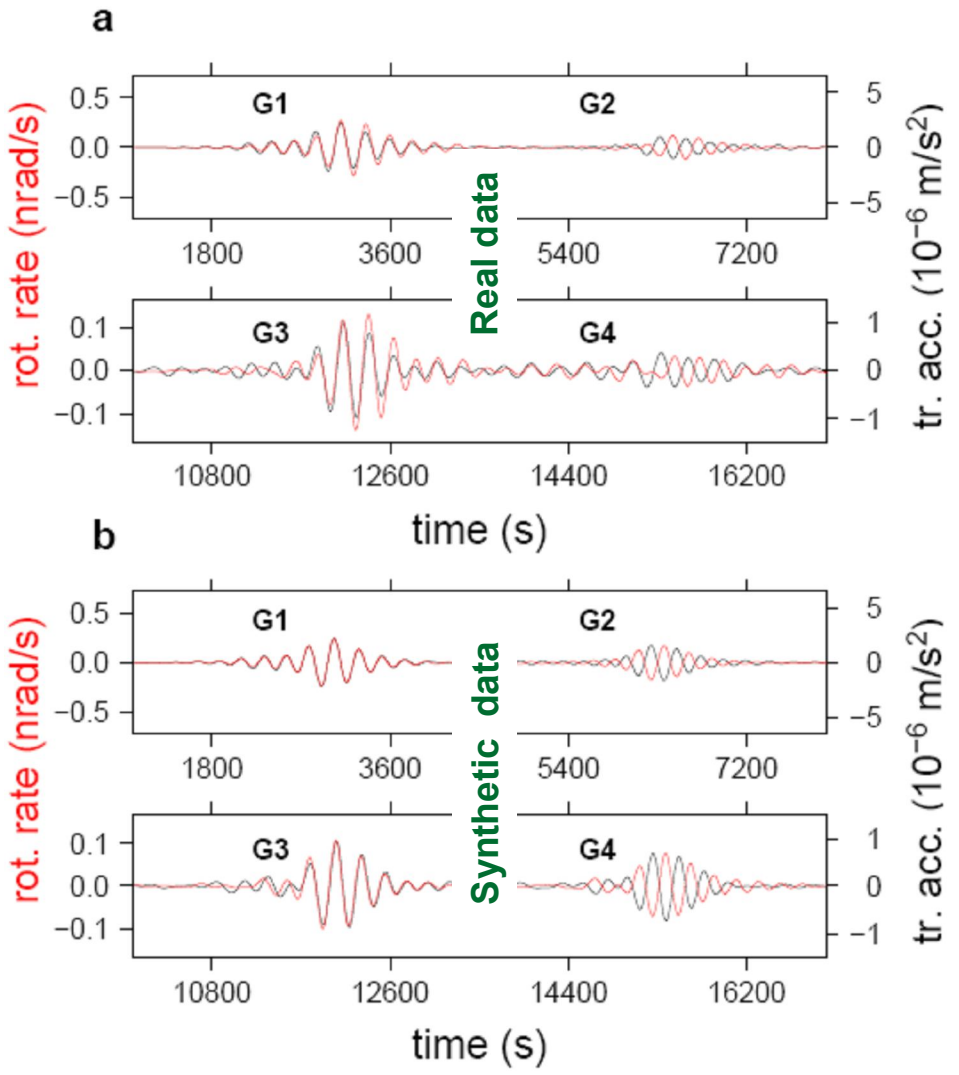
Earth‘s free oscillations



Source: http://icb.u-bourgogne.fr/nano/MANAPI/saviot/terre/index.en.html

Magnitude 8.8 – OFFSHORE MAULE, CHILE

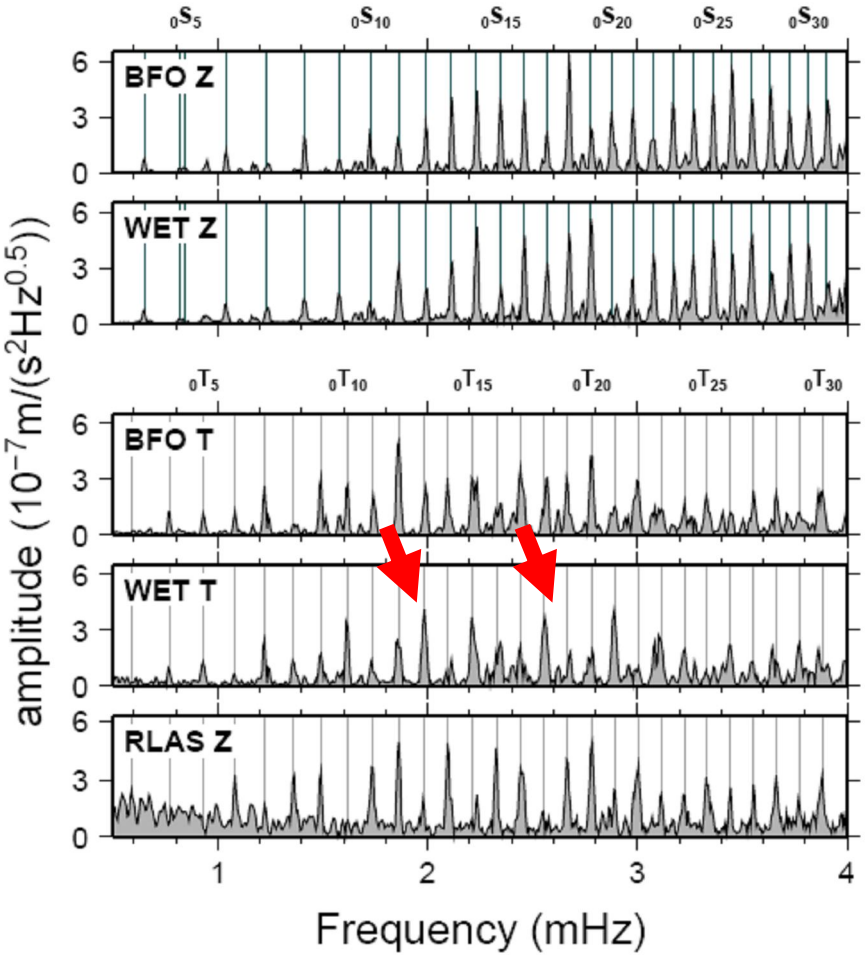
2010 February 27 06:34:14 UTC



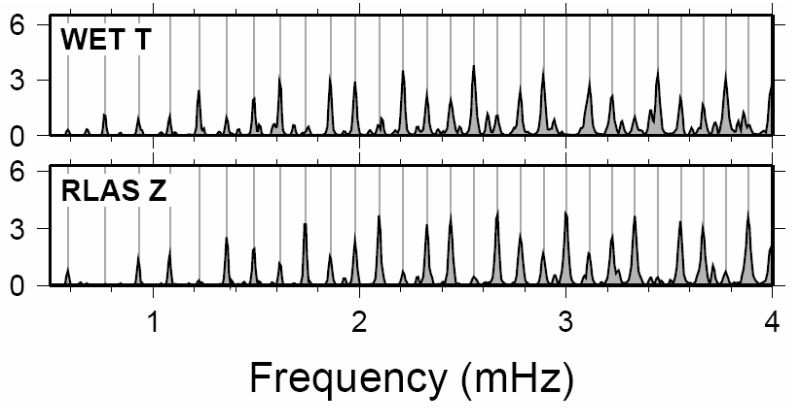
Spectra: M8.8 Chile

- 36 hr time window
- Comparison with BFO

Observations

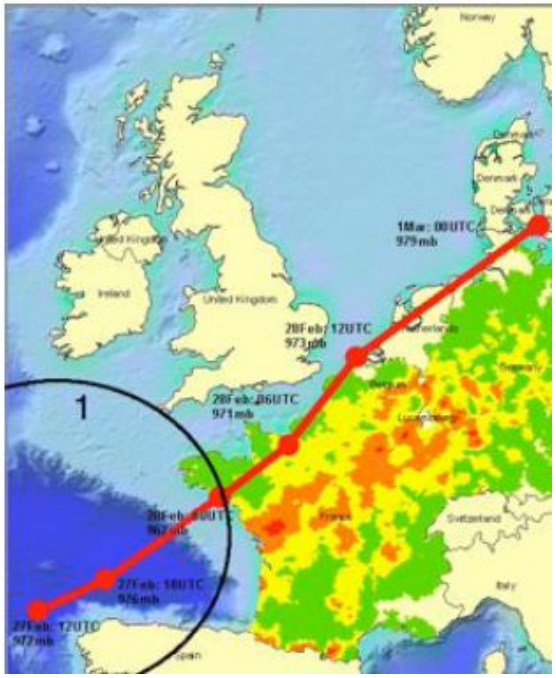


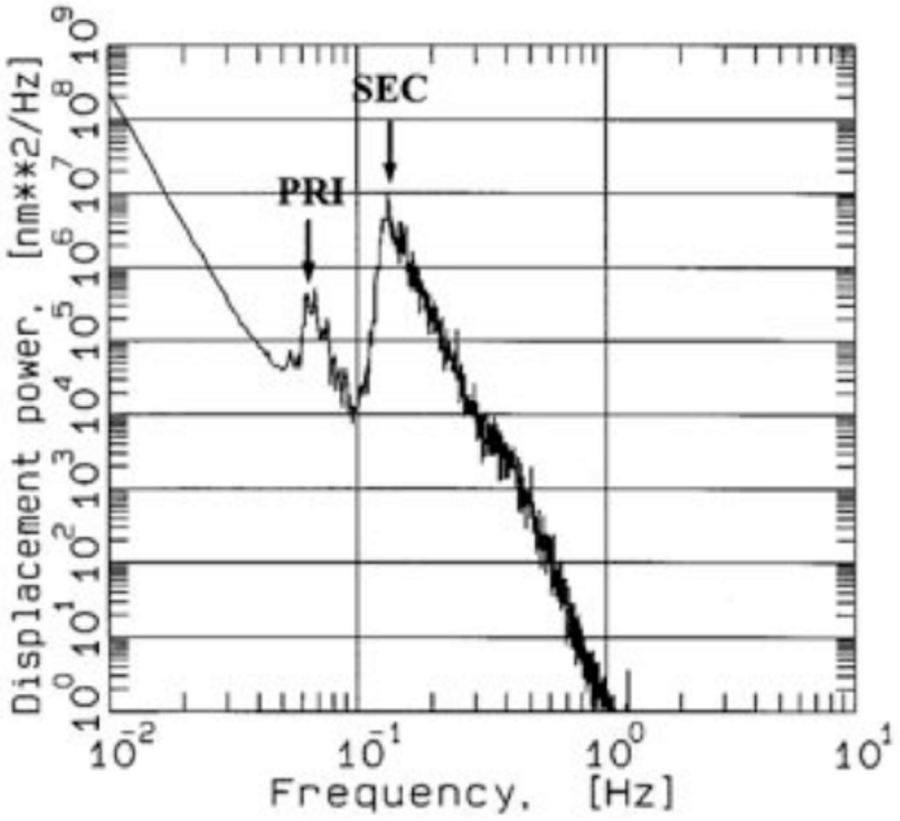
Synthetic spectra (normal modes)



Ocean generated noise

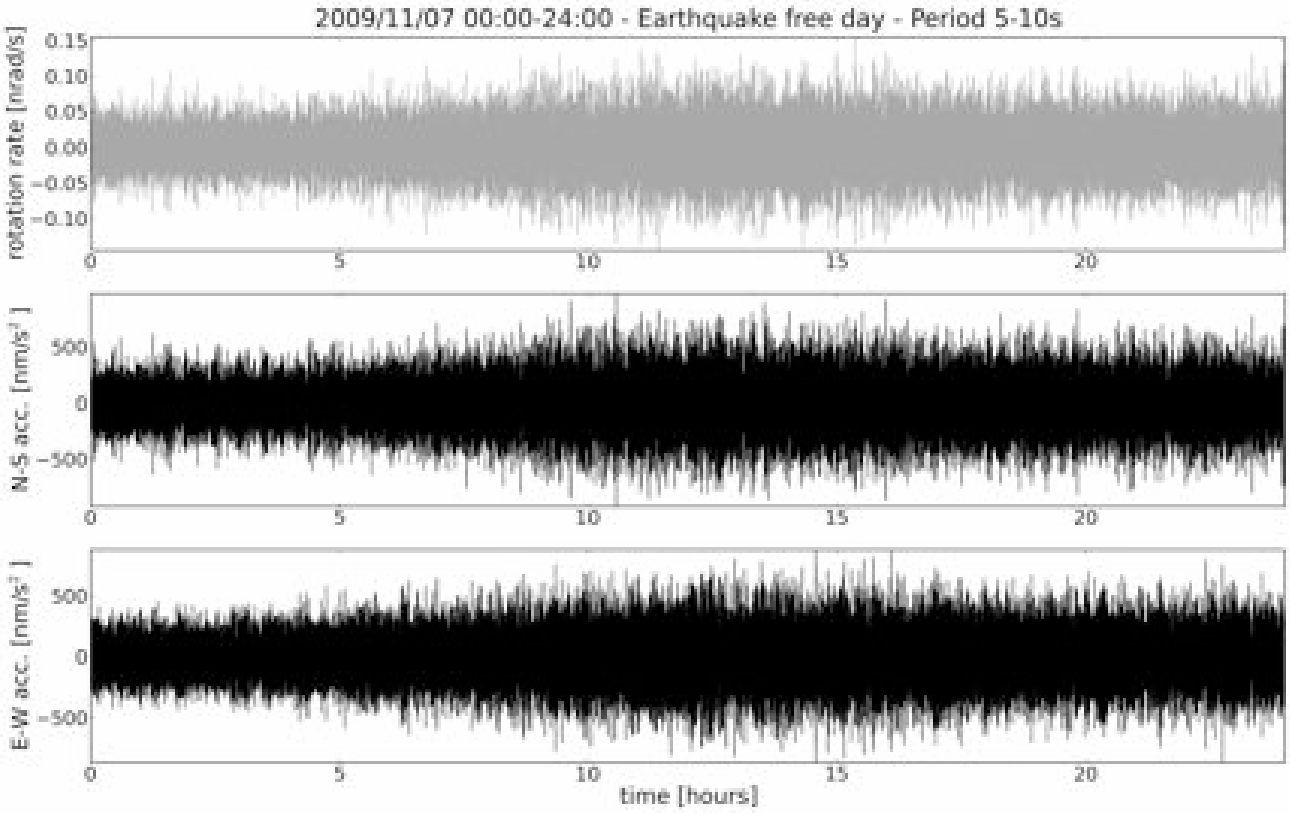
Observations





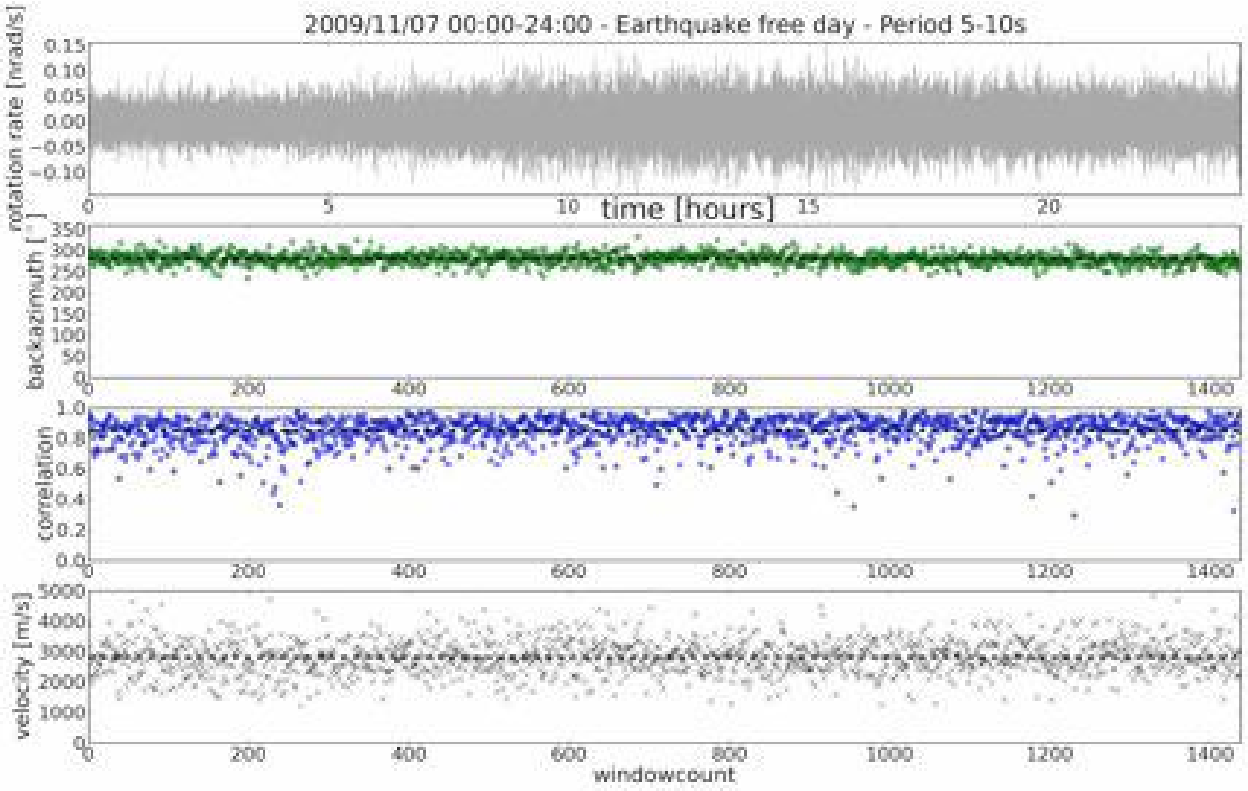
Ambient Noise

Observations



Ambient Noise

Observations



Rotation rate

Back azimuth

Correlation coefficient

Phase velocity

Total length 24 hours, window length 1 minute

Conclusions

- Observations of Earth‘s free oscillations (torsional modes) are complementary (to standard observations), we would like to go 3C with rotational measurements
- The detection of Love waves in ambient noise might open new possibilities for correlation type techniques
- Pure broadband tilt (uncontaminated by transverse acceleratios) has never been observed! (more precise seismometer recordings, gravitation wave detection, displacement histories, health of buildings, etc.)