Long-period G-ring laser observations:
How far can we go?

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HUMDAY Munich, 12th September 2014

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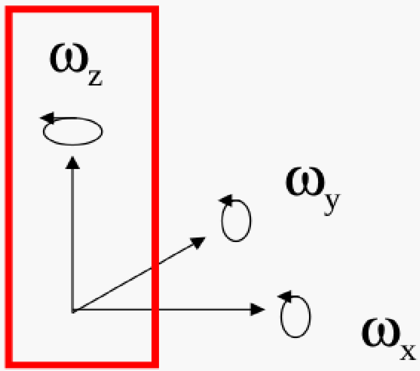
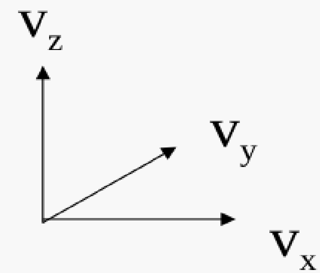
Rotational Motions

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



Rotation rate

Rotation sensor



Ground velocity

Seismometer

Transversely polarized plane wave propagating in x-direction

$$u_y(x,t) = F(kx - \omega t) \qquad c = \frac{w}{k}:$$

Acceleration : $$a_y = \ddot{u}_y = \omega^2 F''(kx - \omega t)$$

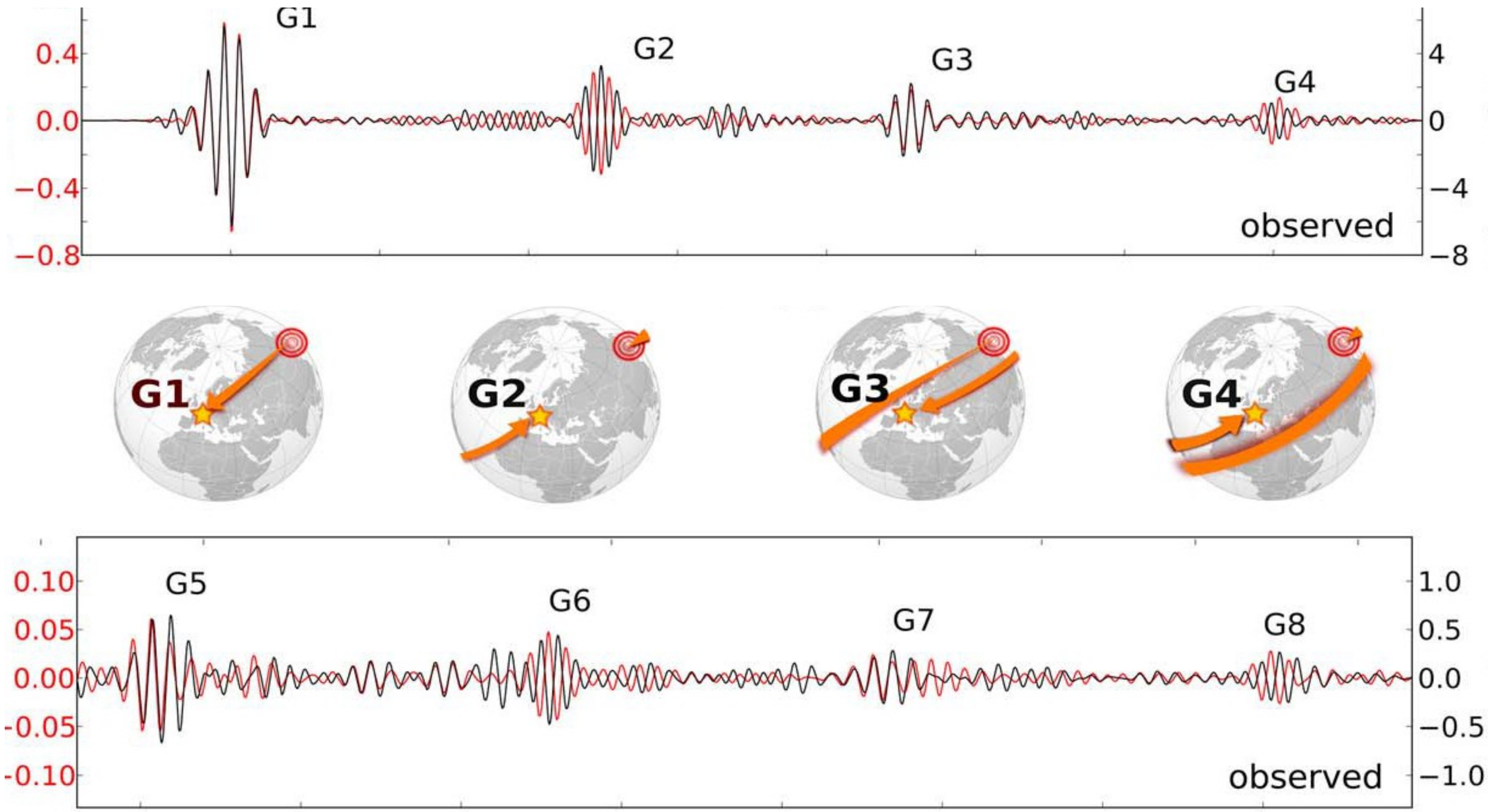
Rotation rate: $$\dot{\Omega} = \frac{1}{2}\nabla \times \dot{u}_y = -\frac{1}{2}k\omega F''$$

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

Rotation rate and acceleration are **in phase** and
the amplitudes scaled by two times the horizontal phase velocity.

Tohoku-Oki M9 Earthquake

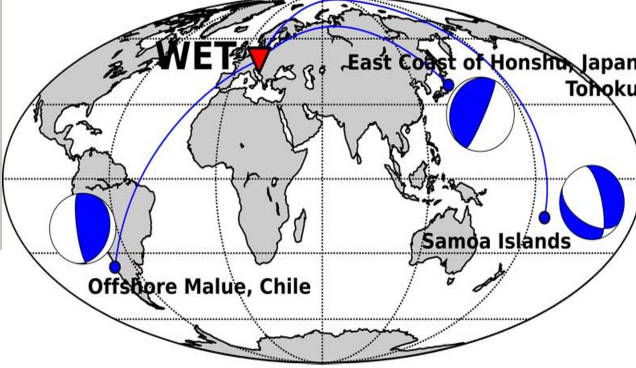
Love waves GX traveling around the Earth



Black – seismometer
Red – ring laser

Igel et al., GRL, 2011
Nader et al. JOSE, 2012

Tohoku-Oki M9 Earthquake



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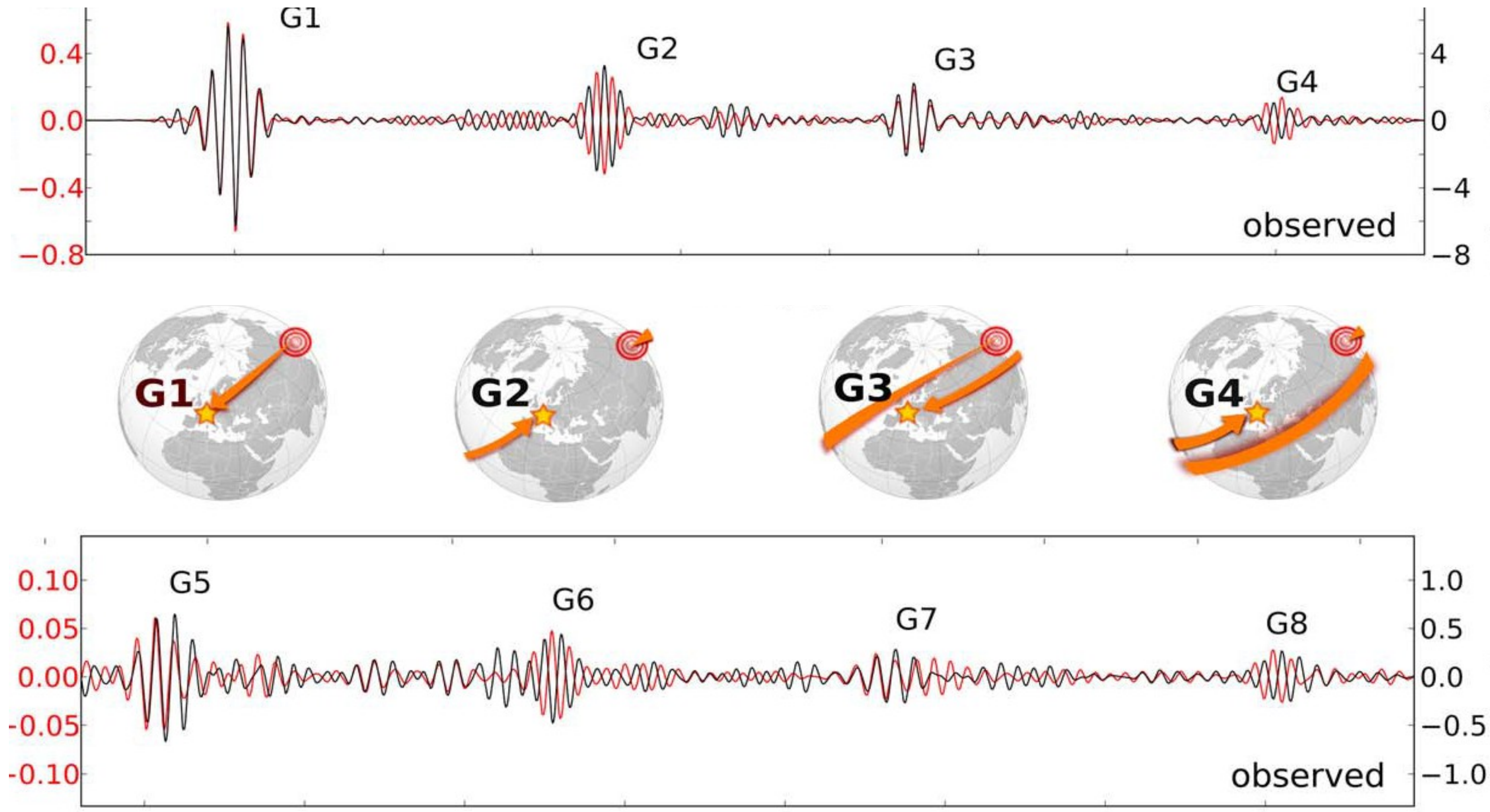

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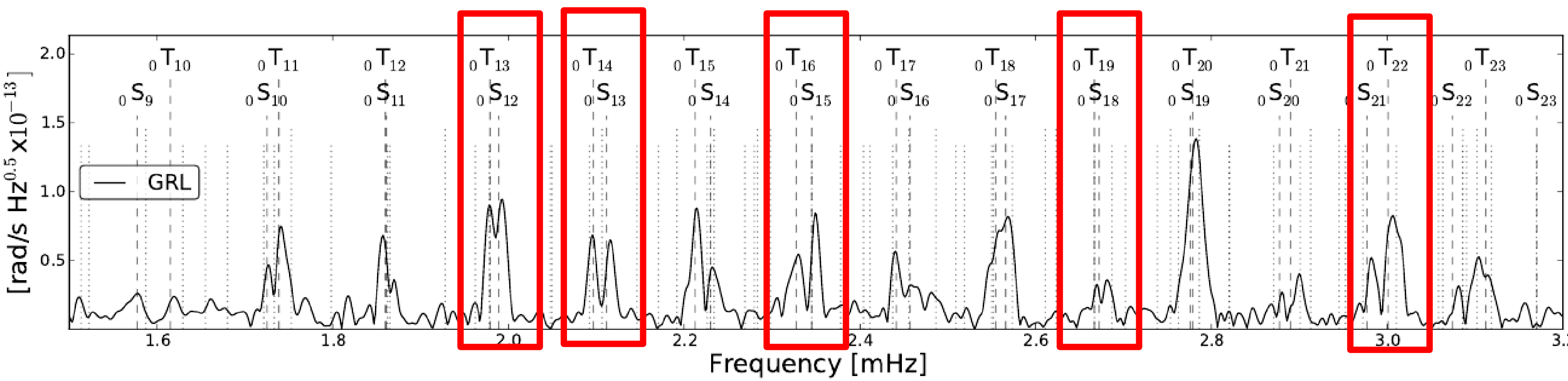
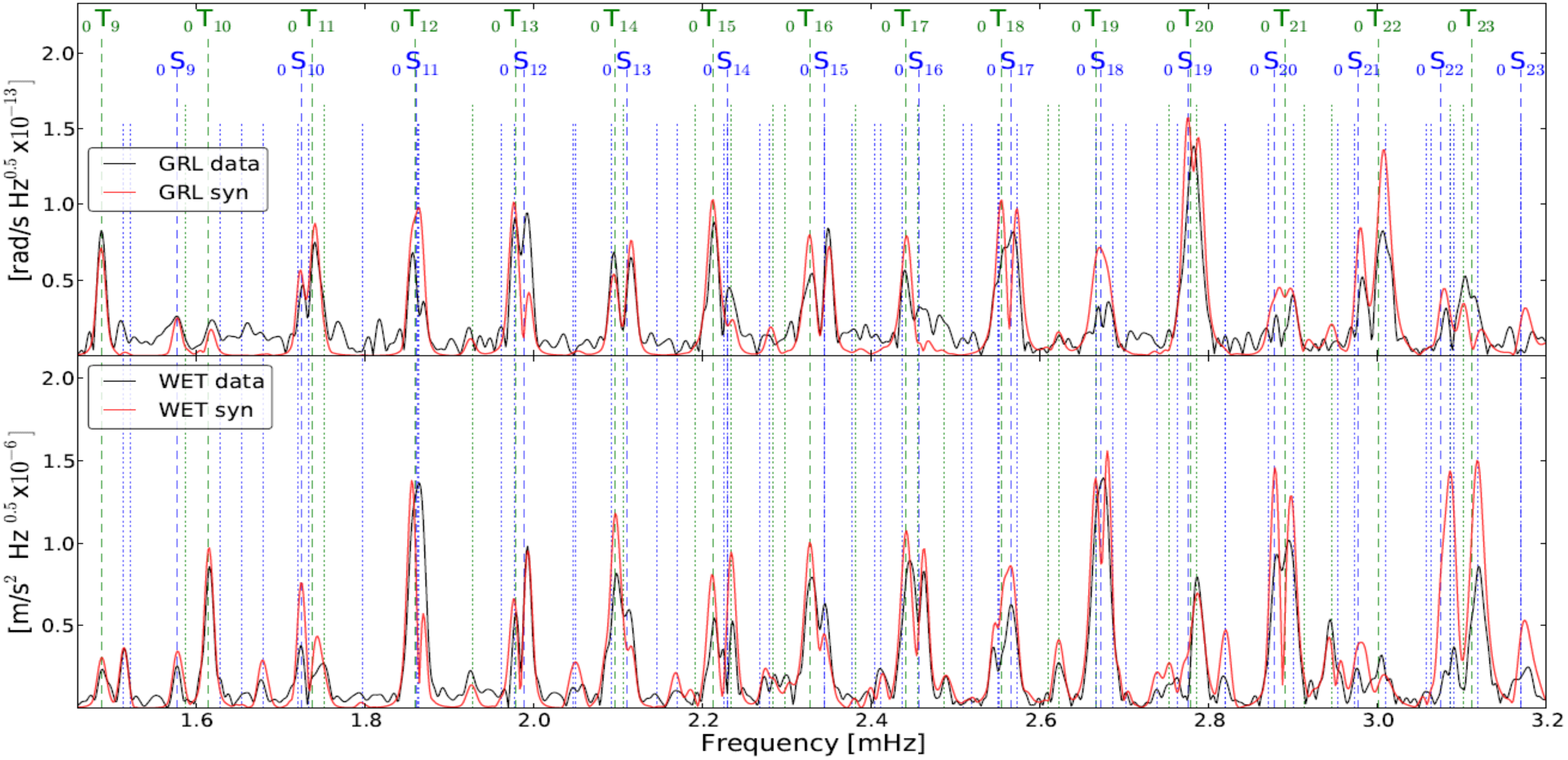


Amplitude spectrum of 48 hour-long time series of the z-component rotations after the Mw 9.0 Tohoku-Oki earthquake (2011) recorded at Wettzell, Germany by the G-ring laser (GRL).

Dashed vertical line are the toroidal and spheroidal eigenfrequencies

Tohoku-Oki M9 Earthquake



The relative percentage difference of the observed-synthetic correlation between the observables is 3.2% for the frequency band target of our study.

Can we detect a signature of permanent excitation of Earth's Free oscillations in the G-Ring laser data?

Rotational motions in an SNREI Earth

The ground displacement associated with a given mode of vibration (Dahlen & Tromp 1998):

$$S_i(x) =_n \mathcal{D}_\ell(r\theta\phi)Y_{lm}(\theta,\phi)$$

Where:

$$\mathcal{D} = U\hat{r} + \hat{\Theta}k^{-1}[V\partial_\Theta + W(\sin\Theta)^{-1}\partial_\Phi] + \hat{\Phi}k^{-1}[V(\sin\Theta)^{-1}\partial_\Phi - W\partial_\Theta]$$

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Rotational motions are the curl of the wave field:

$$[\nabla \times \mathcal{D}]_{\hat{r}} = \frac{\hat{r}}{r\sin\Theta}k^{-1}[\partial^2_\Theta(-W\sin\Theta) + \partial^2_\Phi(W\sin\Theta^{-1})]$$

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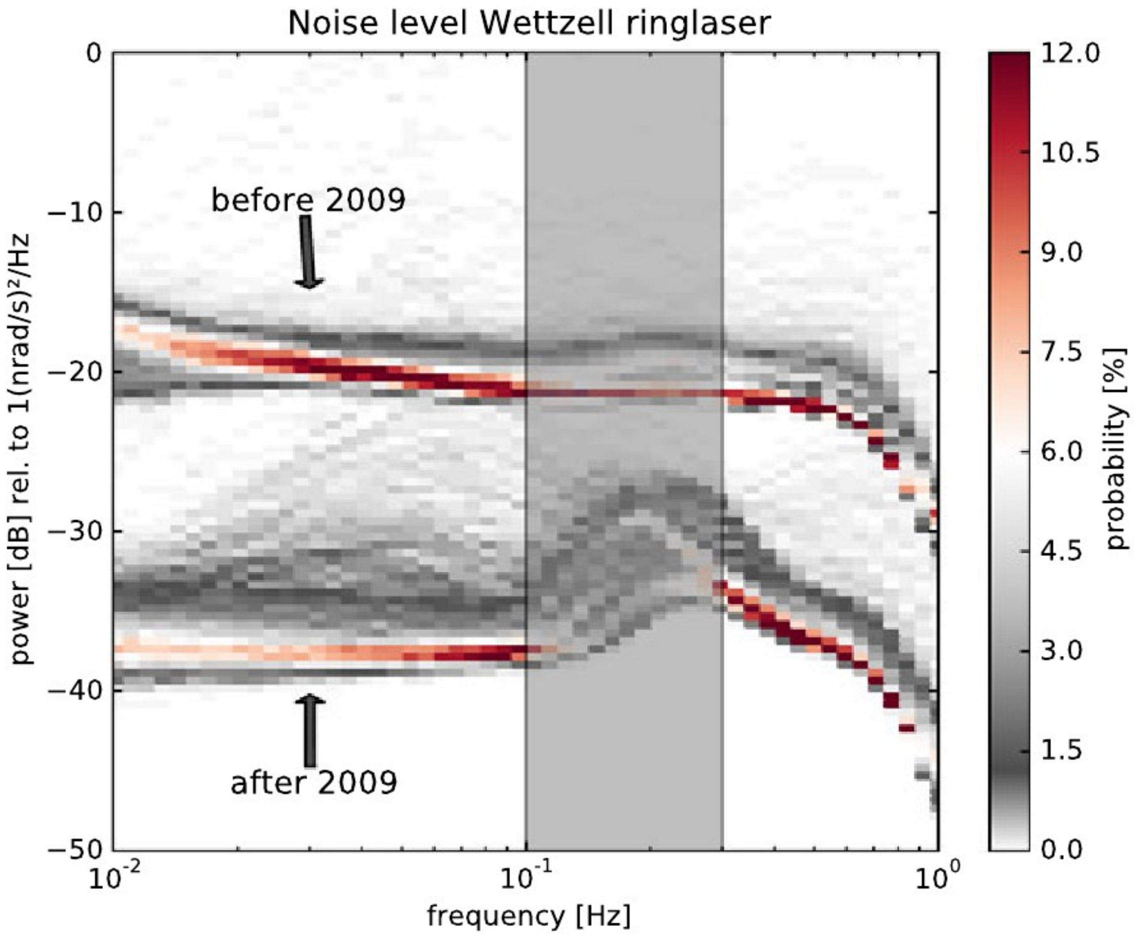
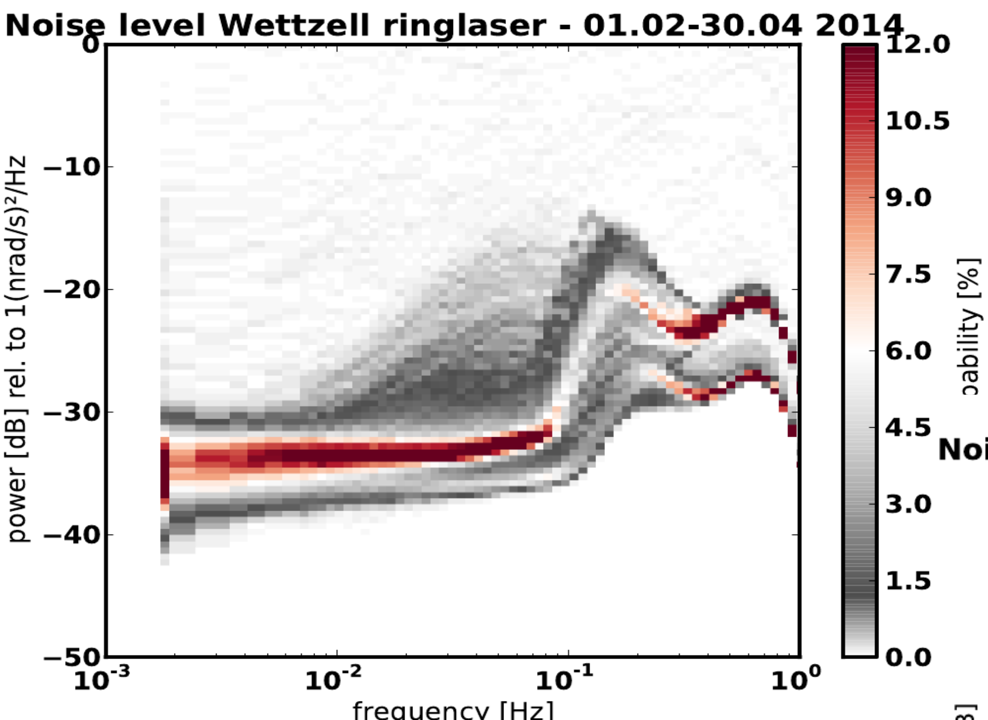
Noise level G-ring laser

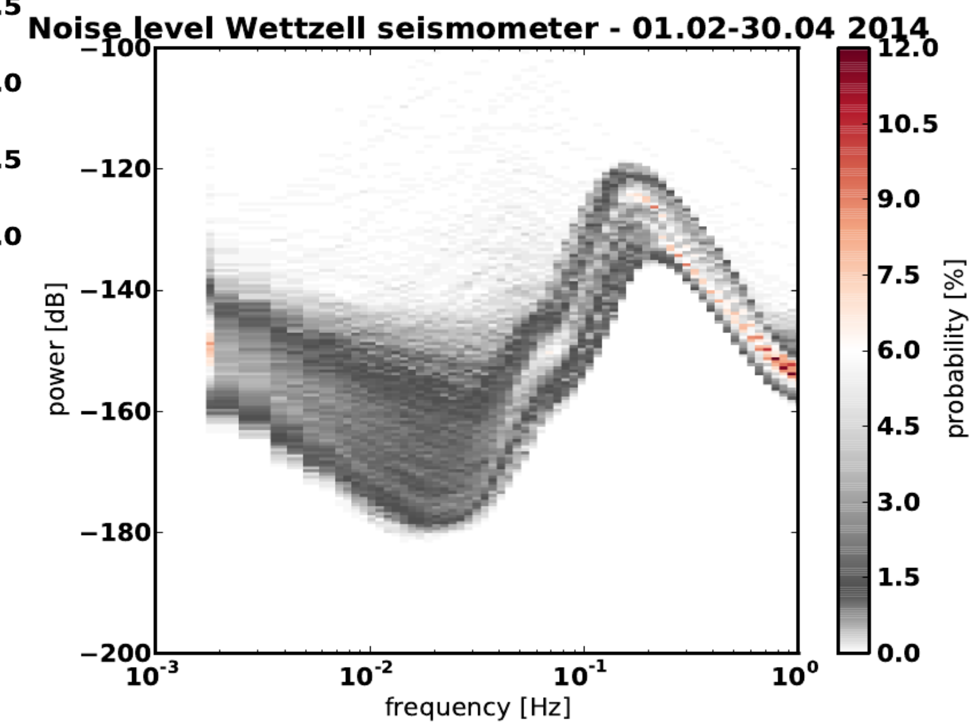


Hadziioannou et al. 2012



G-Ring laser

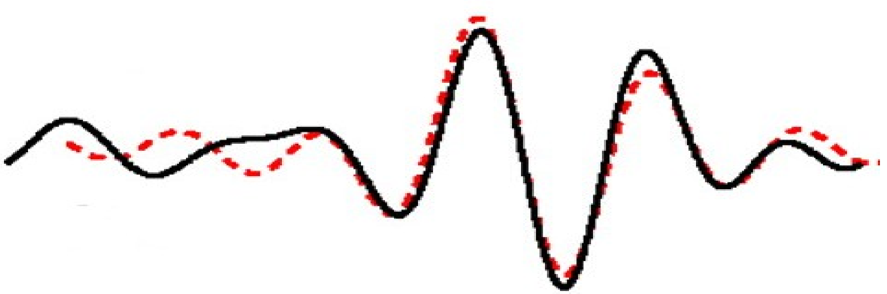
STS-2 seismometer
N-S component



Love waves detection in noise

Can we observe Love waves in the ring laser noise?

Black – Transv. acc
Red – rotational rate

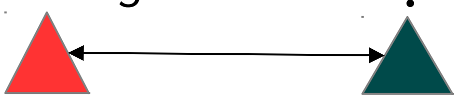


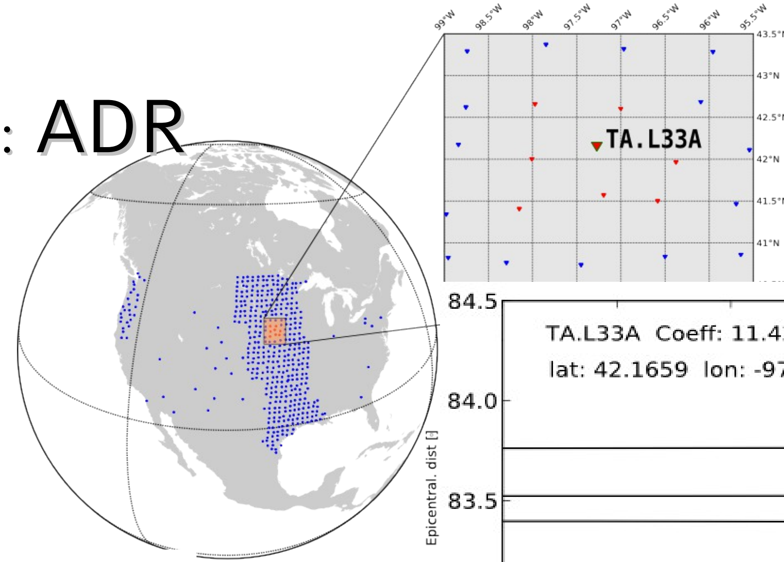
Rotational rate and transverse Acceleration are in phase.

Array Derived Rotations

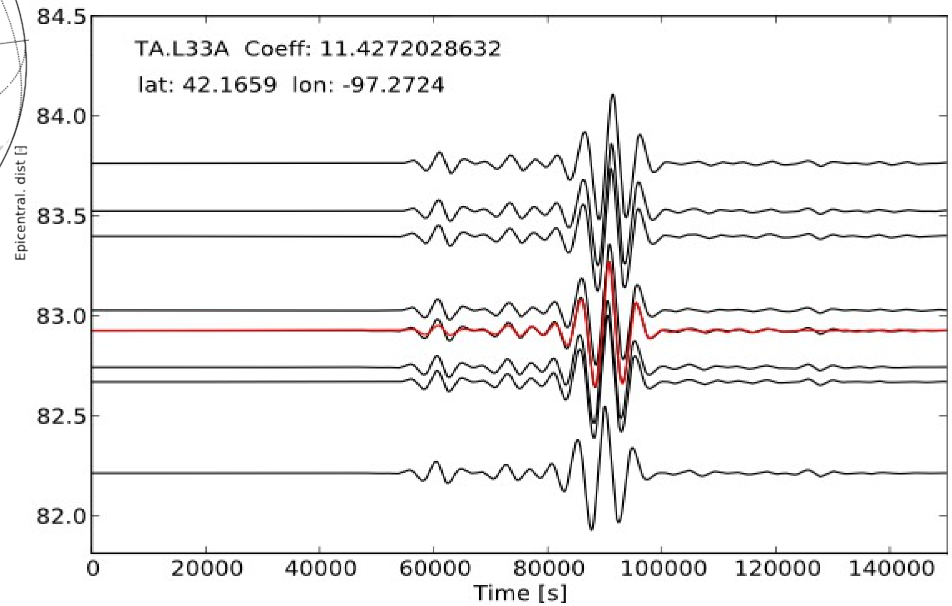
Alternative: ADR

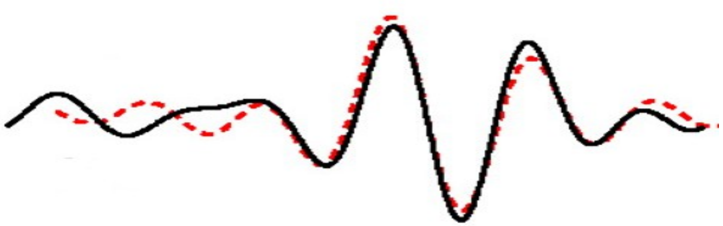
G-ring ?





Tohoku-Oki M9





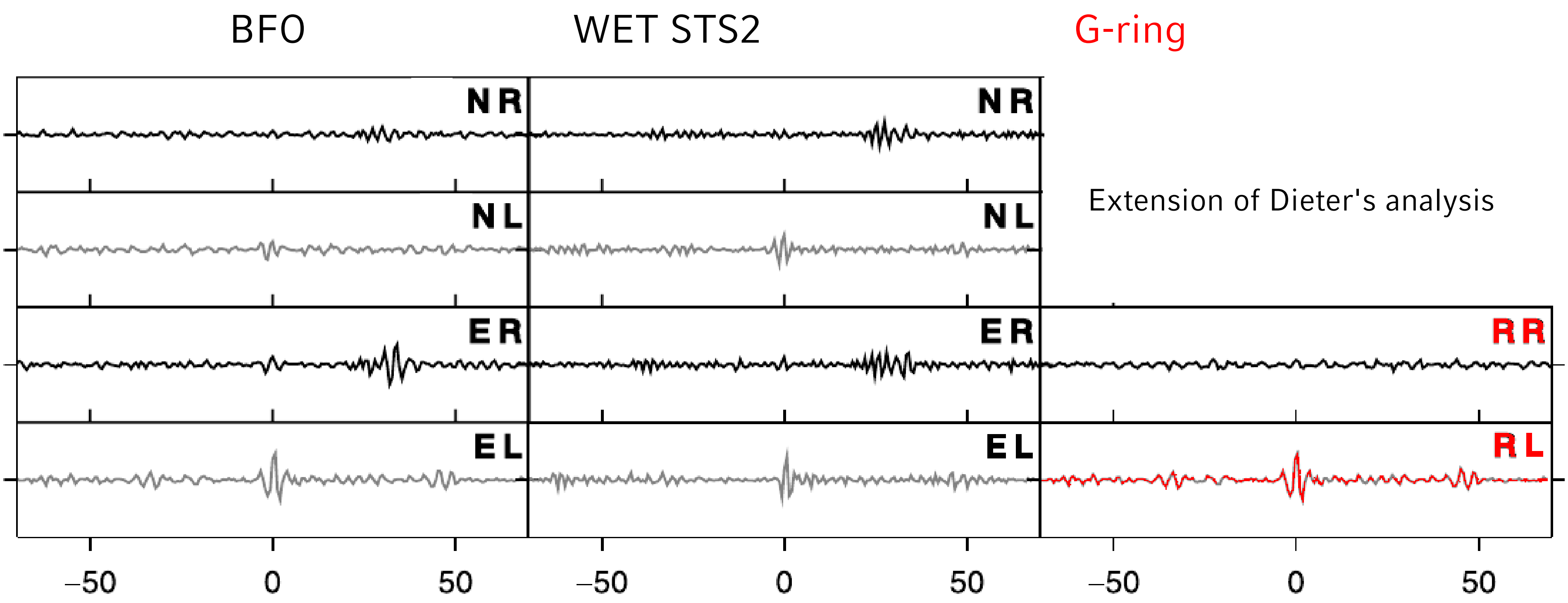
Black – Transv. acc

Red – rotational rate

Can we detect Earth's background oscillations?

Method : Time domain analysis of Earth's long-period background (Ekstroem, 2001)

Standing Love waves (200-400s)
Based on autocorrelation functions and the great circle operator
Transforms G_n --> G_{n+2} correlating of an original seismogram with a copy to which the operator was applied



THE GOAL!

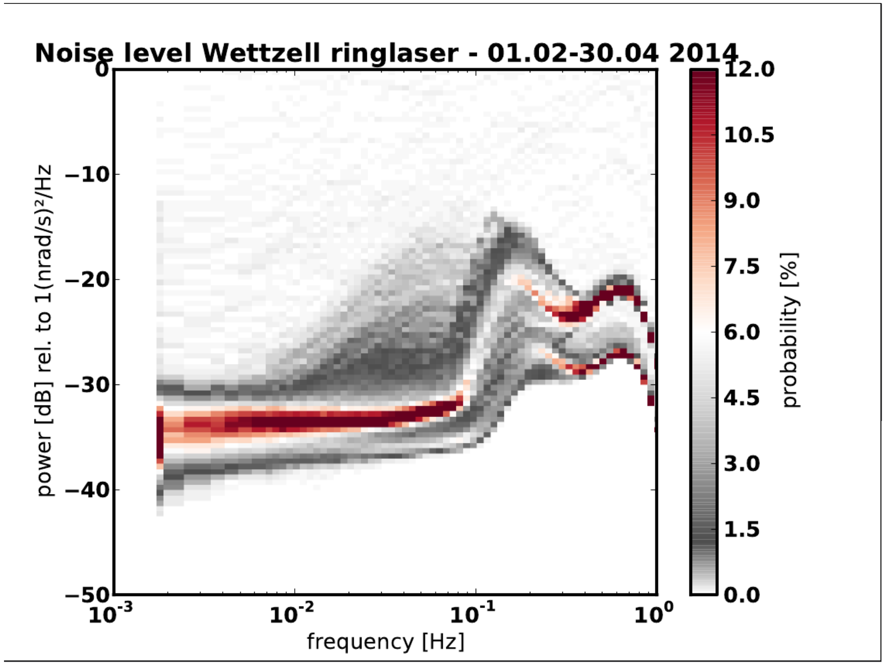
Searching for sings of continuously exited normal modes in the G-ring laser noise.

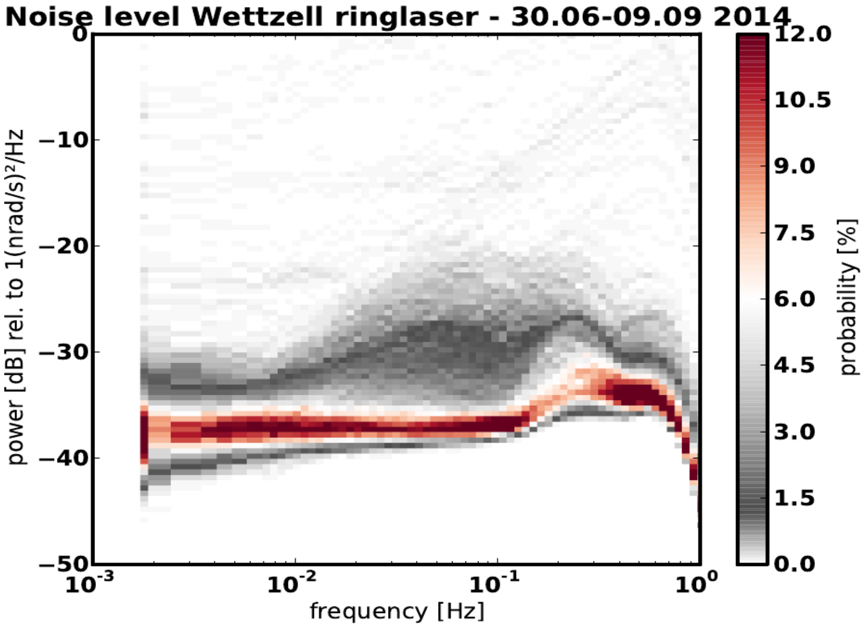
Can we detect permanent excitation of normal modes in the Ring lase data?

And if so …

Does an answer to this question can give us more insights about the mechanism that generates the horizontal global Hum?

Recent improvement ?





Strain Rotation coupling:

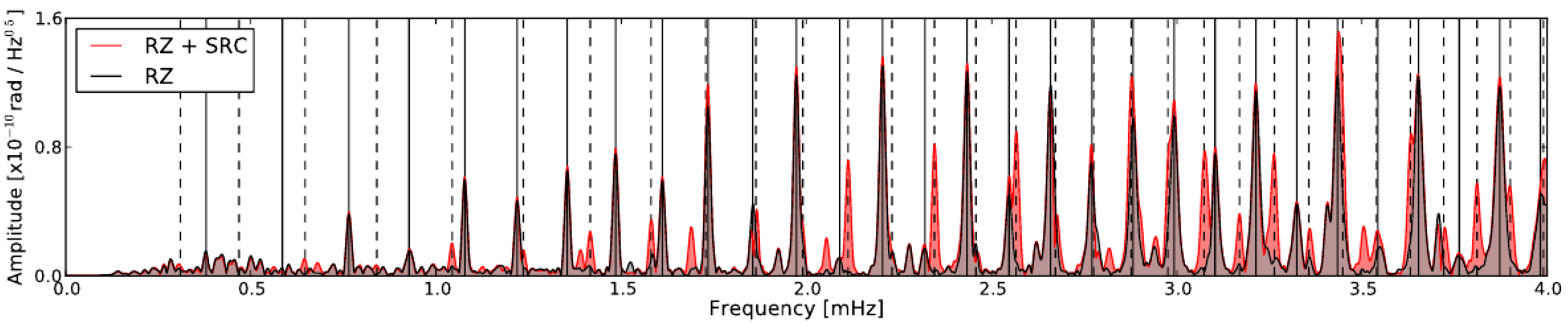
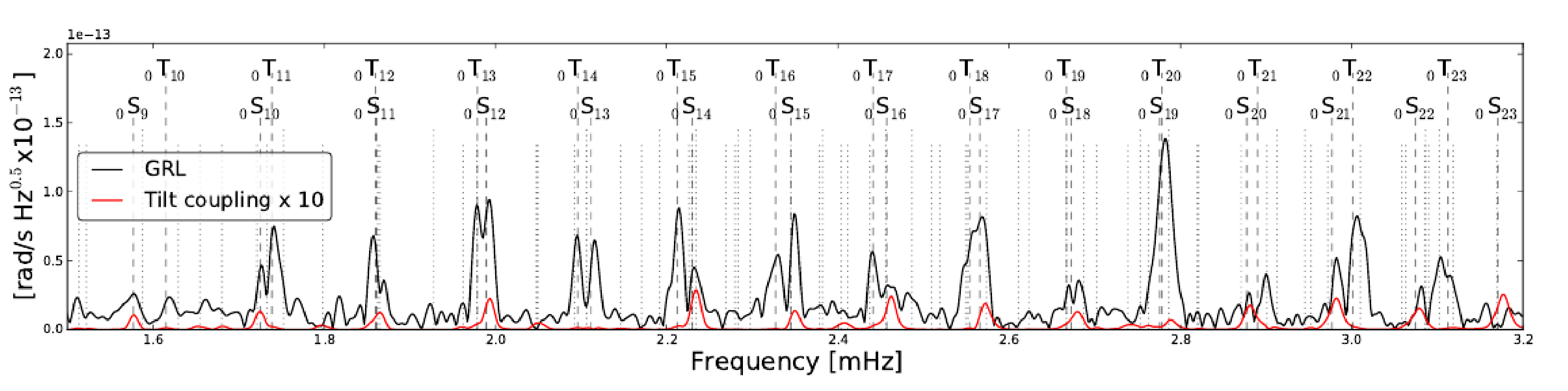


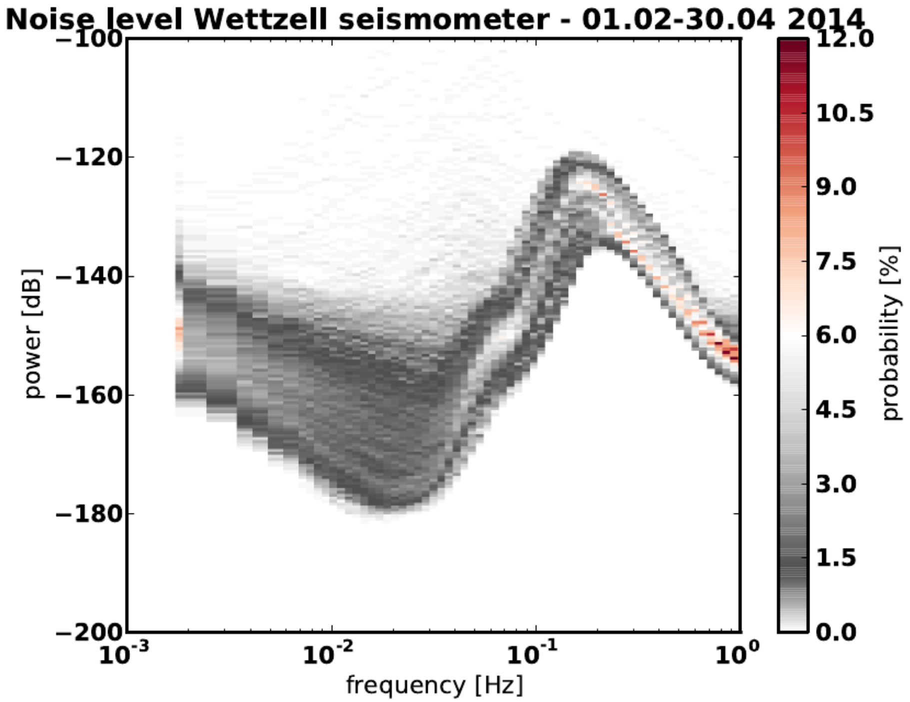
Fig. 9 Amplitude spectrum for rotation around *z*-axis for 36 h of synthetic data for the *M*9.0 Tohoku, Japan, earthquake recorded in Wettzell, Germany. Pure rotation with main peaks at toroidal modes (*vertical lines* mark 0Ti modes); strain rotation coupling (here constants are chosen $c_{NZ} = c_{EZ} = -c_{SZ} = 0.2$) can cause additional peaks at spheroidal modes (*dashed lines* mark 0Si modes)

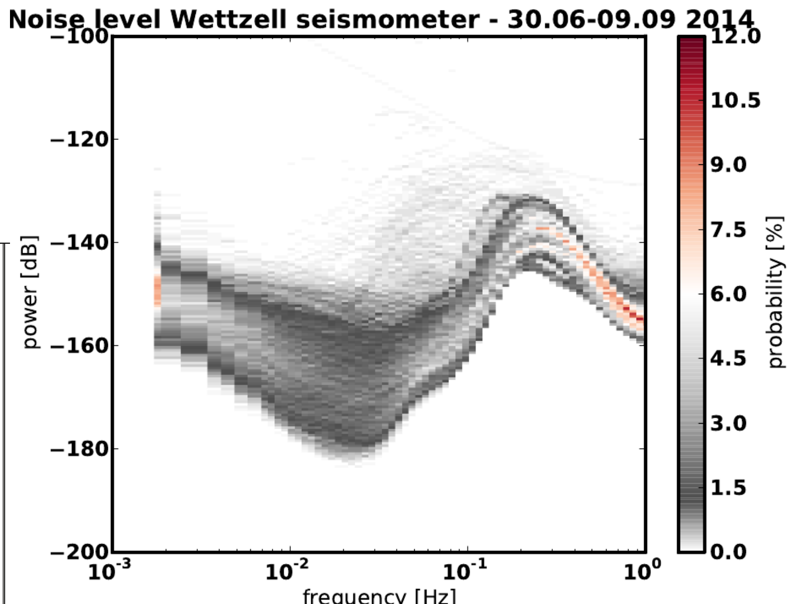
Van Driel et al. JGR 2003

Tilt-Ring Laser Coupling

$$\dot{\Omega}_{tilt} = -\dot{\Omega}_P \Omega_E \cos\left(\Lambda - \frac{\Omega_E}{2}\right)$$




Noise level Wettzell seismometer - 01.02-30.04 2014
−100
−120
−140
−160
−180
−200
power [dB]
10^-3
10^-2
10^-1
10^0
frequency [Hz]
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0
probability [%]


Noise level Wettzell seismometer - 30.06-09.09 2014
−100
−120
−140
−160
−180
−200
power [dB]
10^-3
10^-2
10^-1
10^0
frequency [Hz]
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0
probability [%]