GINGER AND GINGERINO

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Gyroscopes IN GEneral Relativity

Lense Thirring effect, on Earth, 1% precision

Ring laser measures absolute angular velocity (Sagnac Effect)

- *Large frame ring lasers are top sensitivity devices to measure absolute angular velocity*
- *Routinely they measure at the pico-rad/s scale and below, present record 10^{-13} rad/s in 1 day*

- *Very low frequency measurements are of primary importance for geophysics and geodesy*

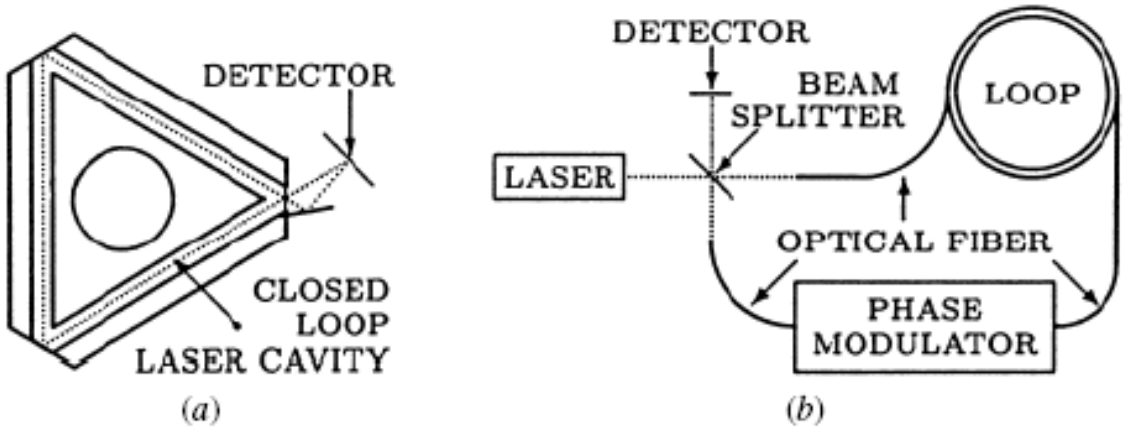
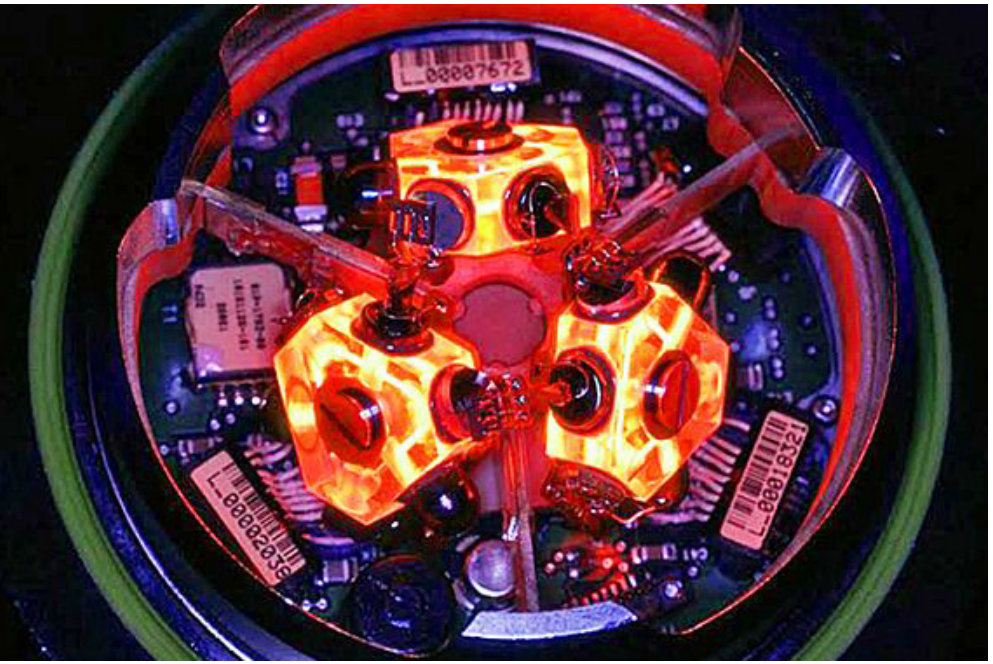
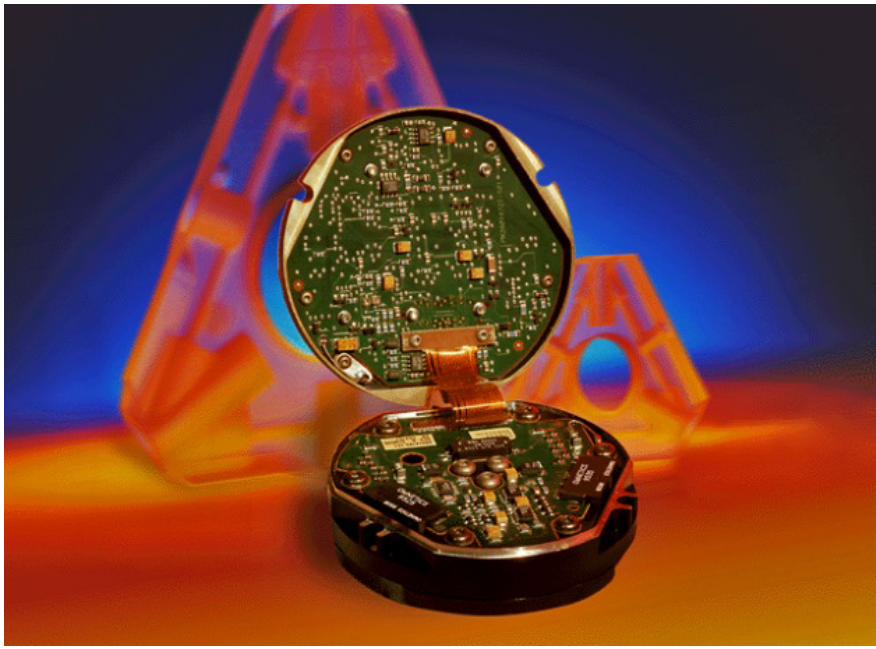


Fig. 9.10 Laser gyroscopes: (*a*) ring laser gyro (RLG); (*b*) fiberoptic gyro.

Industry is active in developing RL since more than 50 years, especially for navigation, submarines and drones





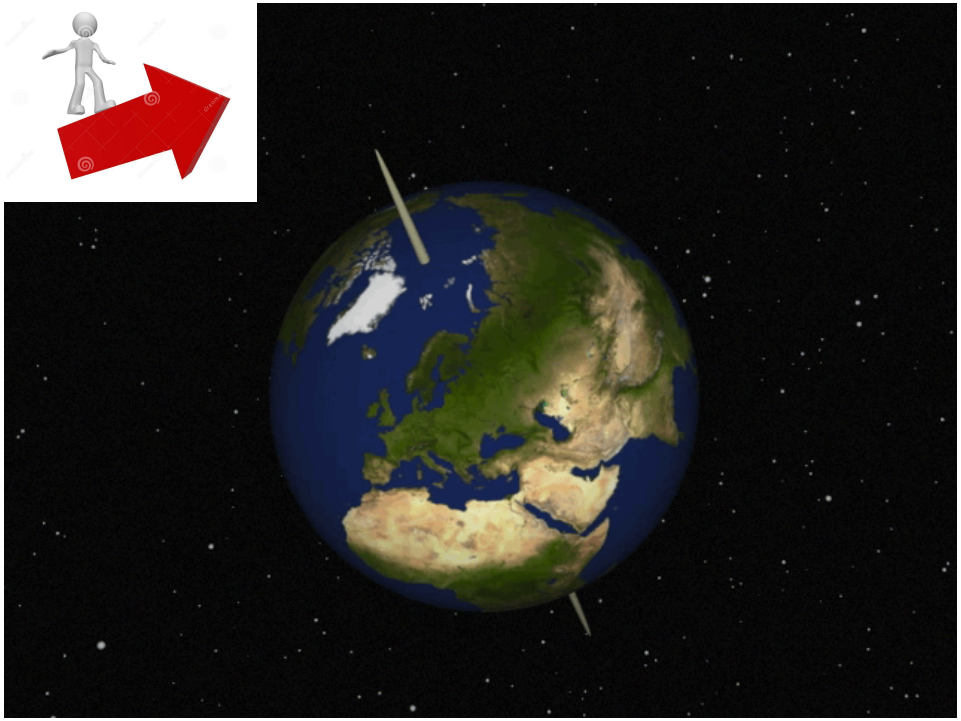
https://www.youtube.com/watch?v=-HzmxW3Jll8

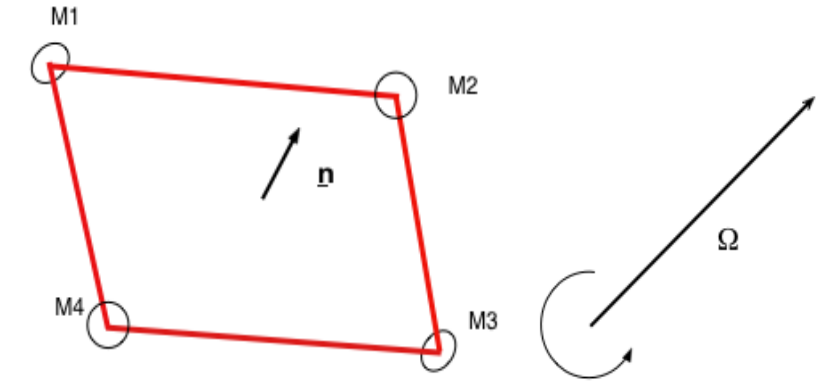
EXISTING LARGE FRAME RING LASERS IN EUROPE

- ***Gross Ring G*** *at the geodetic observatory of Wettzell, perimeter 16m* ***geodesy***
- ***GINGERINO*** *at LNGS, 14.4m perimeter,* ***Fundamental Physics***
- ***ROMY*** *array under commissioning, 4 ring lasers 36m perimeter each (ERC project),* ***seismology***

- *a bunch of devices in NewZealand, not working after the Christchurch earthquake, but some of them will be back soon*
- *project exists in China*

The probe is a vector which can be oriented at will
The quantity to measure is the angular rotation vector
The output is the scalar product between the two vectors





the ringlaser gyroscope is described by
n and its scale factor **S**

S geometrical scale factor

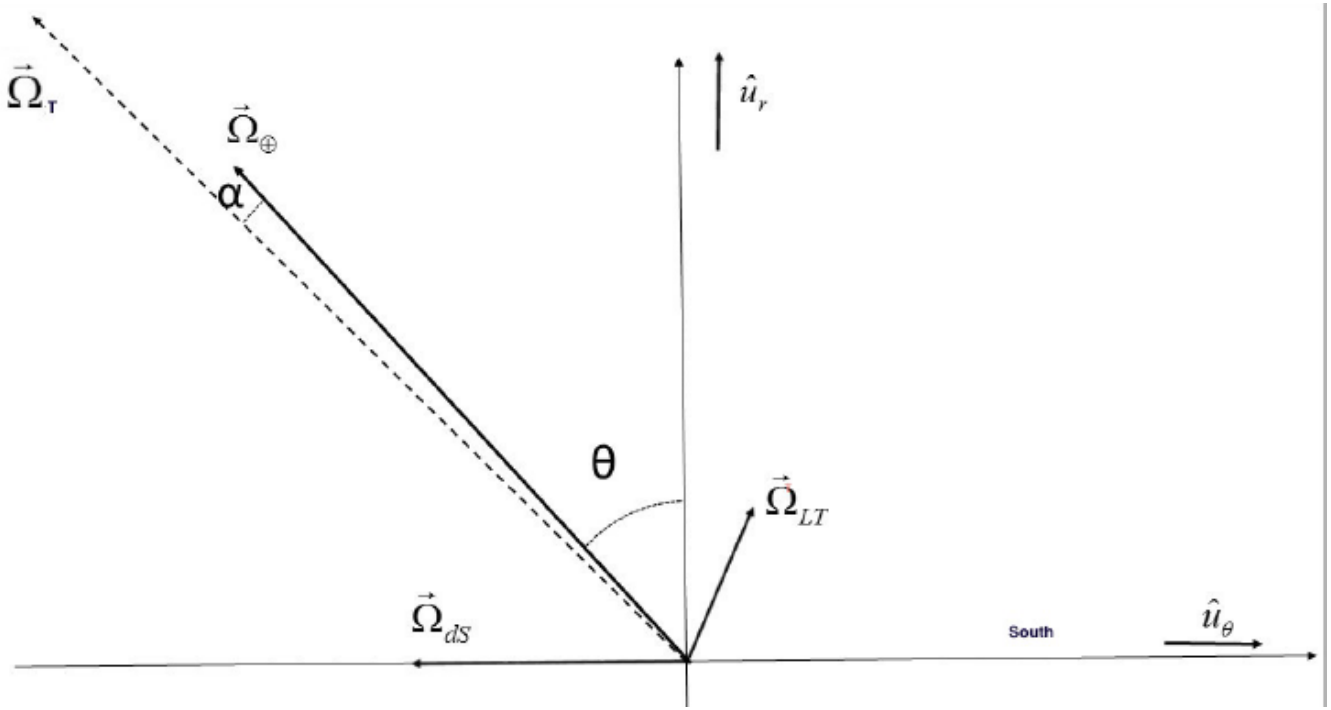
n area versor

Beat frequency Scalar product $\mathbf{n} \cdot \boldsymbol{\Omega}$

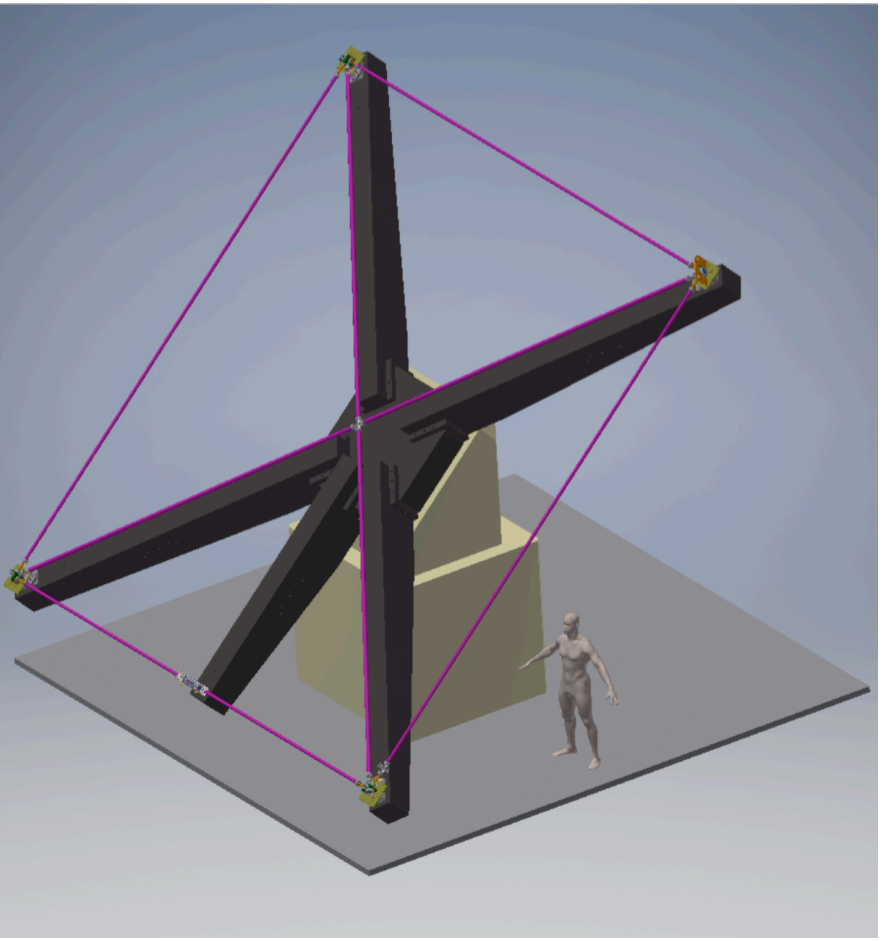
THE GR TERMS

$$f = \frac{4A}{\lambda P}\left[\Omega_{\oplus} - 2\frac{m}{r}\Omega_{\oplus}\sin\theta\hat{u}_{\theta} + G\frac{I\Omega_{\oplus}}{c^2 r^3}\left(2\cos\theta\hat{u}_r + \sin\theta\hat{u}_{\theta}\right)\right]\cdot\hat{u}_n = S\left(\Omega_{\oplus} + \Omega_{dS} + \Omega_{LT}\right)\cdot\hat{u}_n.$$

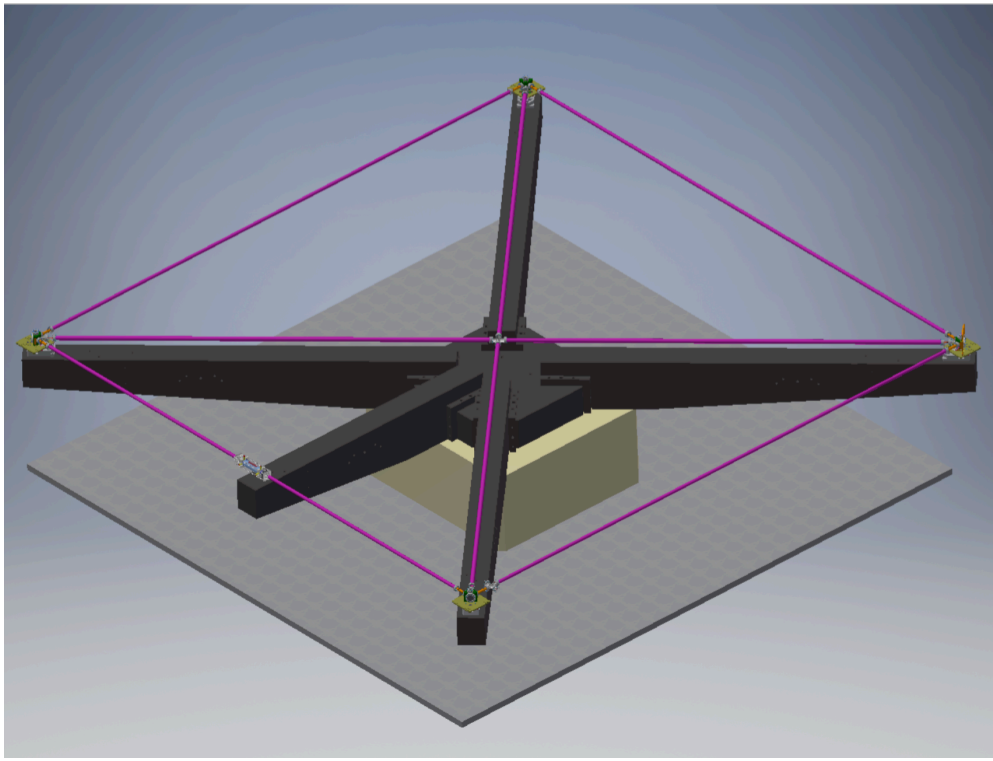
A. Tartaglia, A. Di Virgilio et al. Eur. Phys. J. Plus (2017) 132: 73



The deSitter and LenseThirring terms are equivalent to an extra rotation 9-12 orders of magnitude below the Earth rotation rate



2D apparatus, 3D adding one more ring

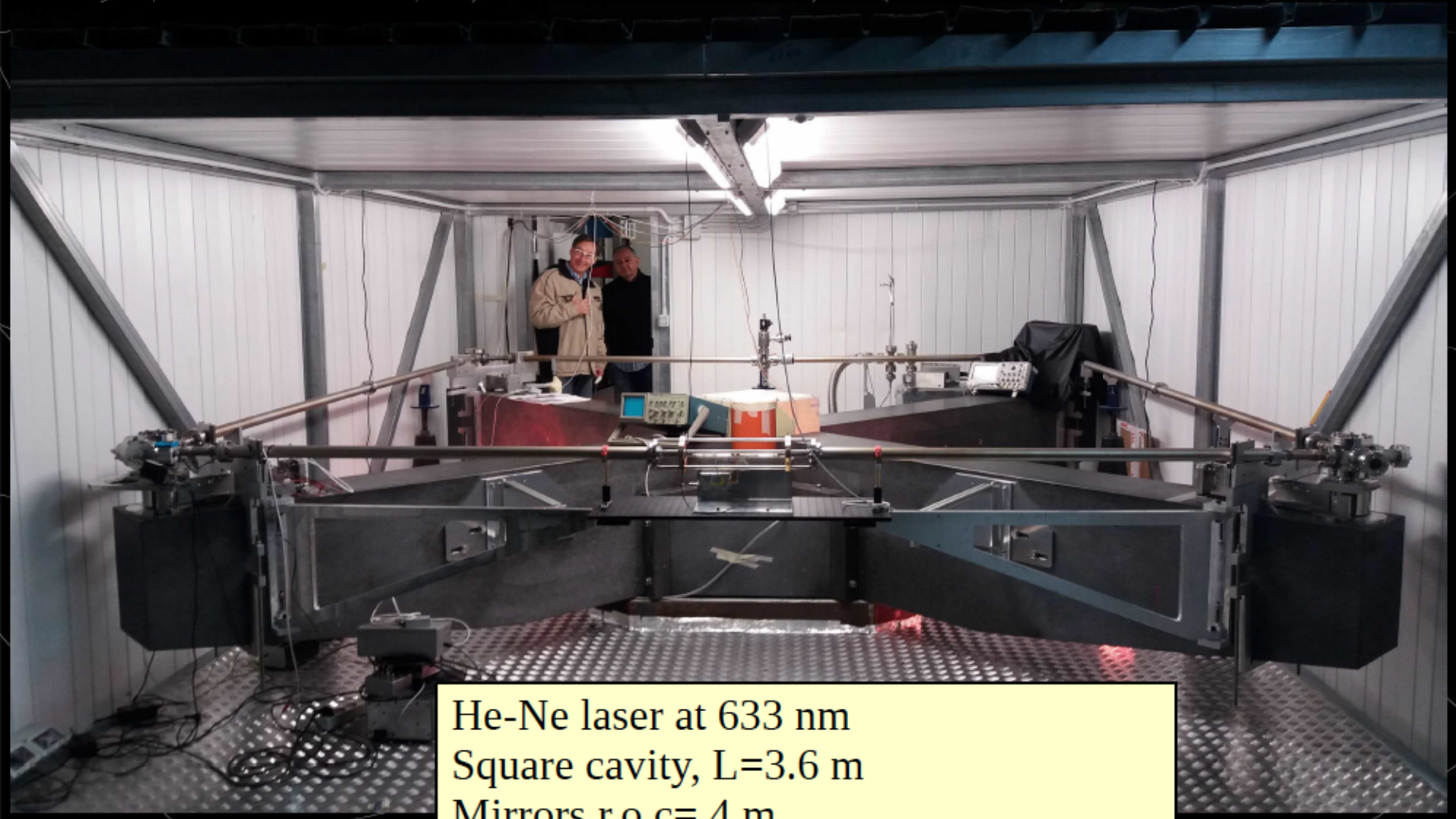


A. Di Virgilio et al: GINGER: a feasibility study

Eur. Phys. J. Plus (2017) **132**: 157
DOI 10.1140/epjp/i2017-11452-6

GINGERino: deep underground ring laser

GINGER-ino (INFN-LNGS)+ Seismometers (INGV)

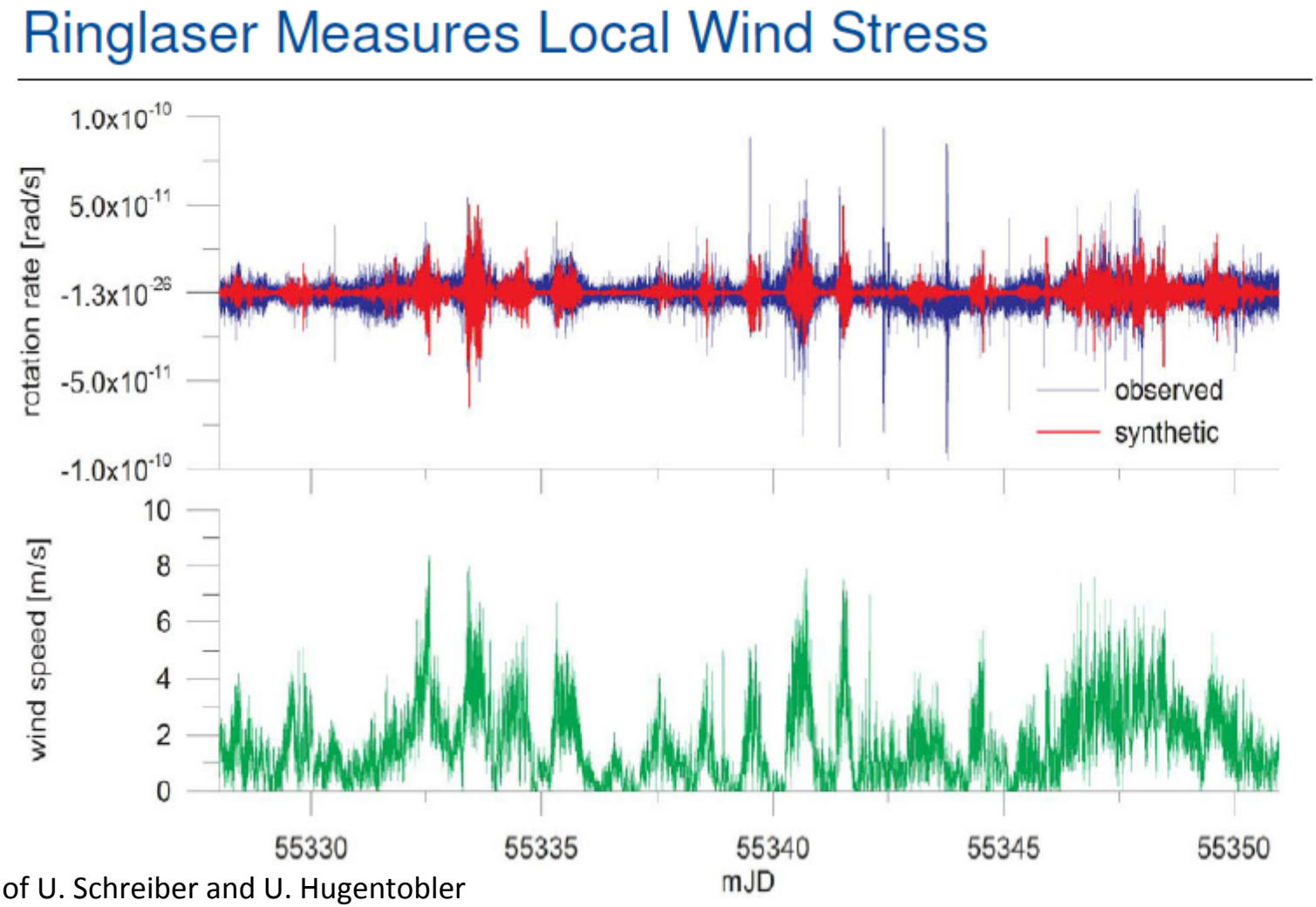


He-Ne laser at 633 nm
Square cavity, L=3.6 m
Mirrors r.o.c= 4 m
Earth rotation Sagnac bias: **fs=280.4 Hz**

- *GINGERINO has bee built to verify whether LNGS is qualified for the GR test*
- *It has already proved that underground laboratories provides very high thermal stability and quiet environment*

- *It is now working in a continuous basis to provide data to geophysics*

PERTURBATION ON THE EARTH SURFACE(G DATA)



Courtesy of U. Schreiber and U. Hugentobler

GINGERINO TYPICAL SENSITIVITY

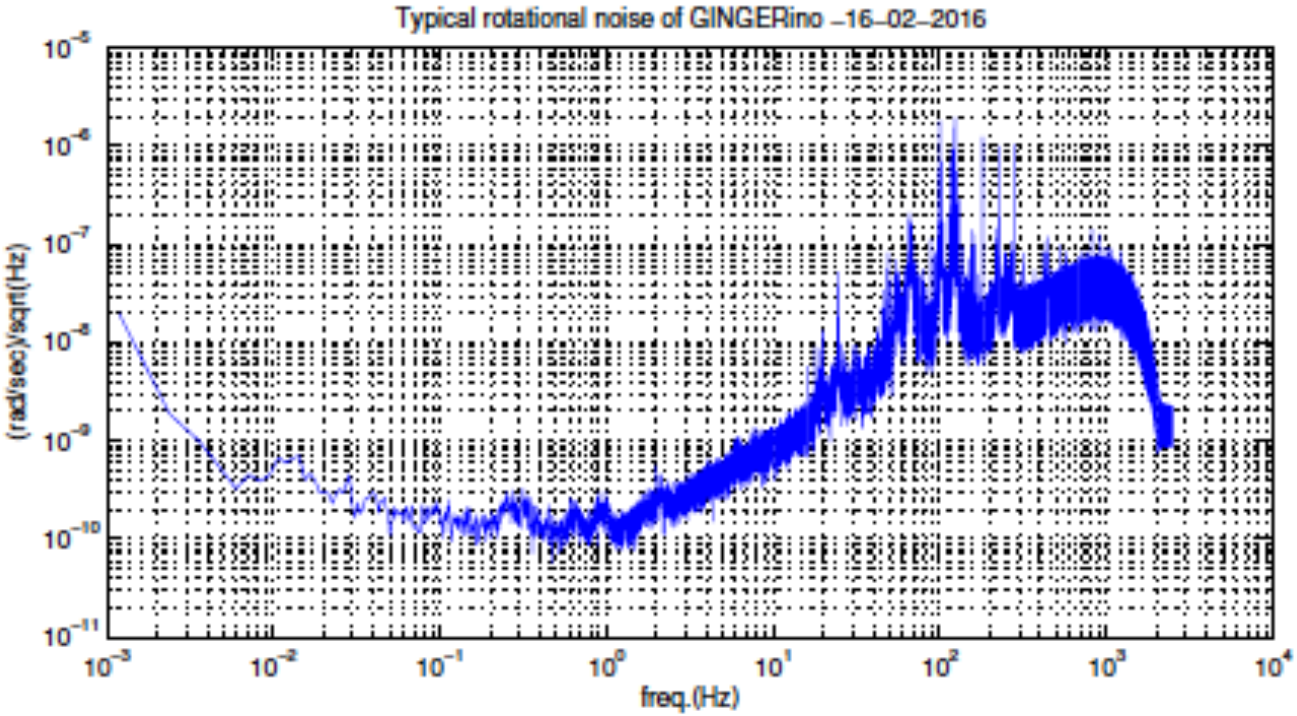
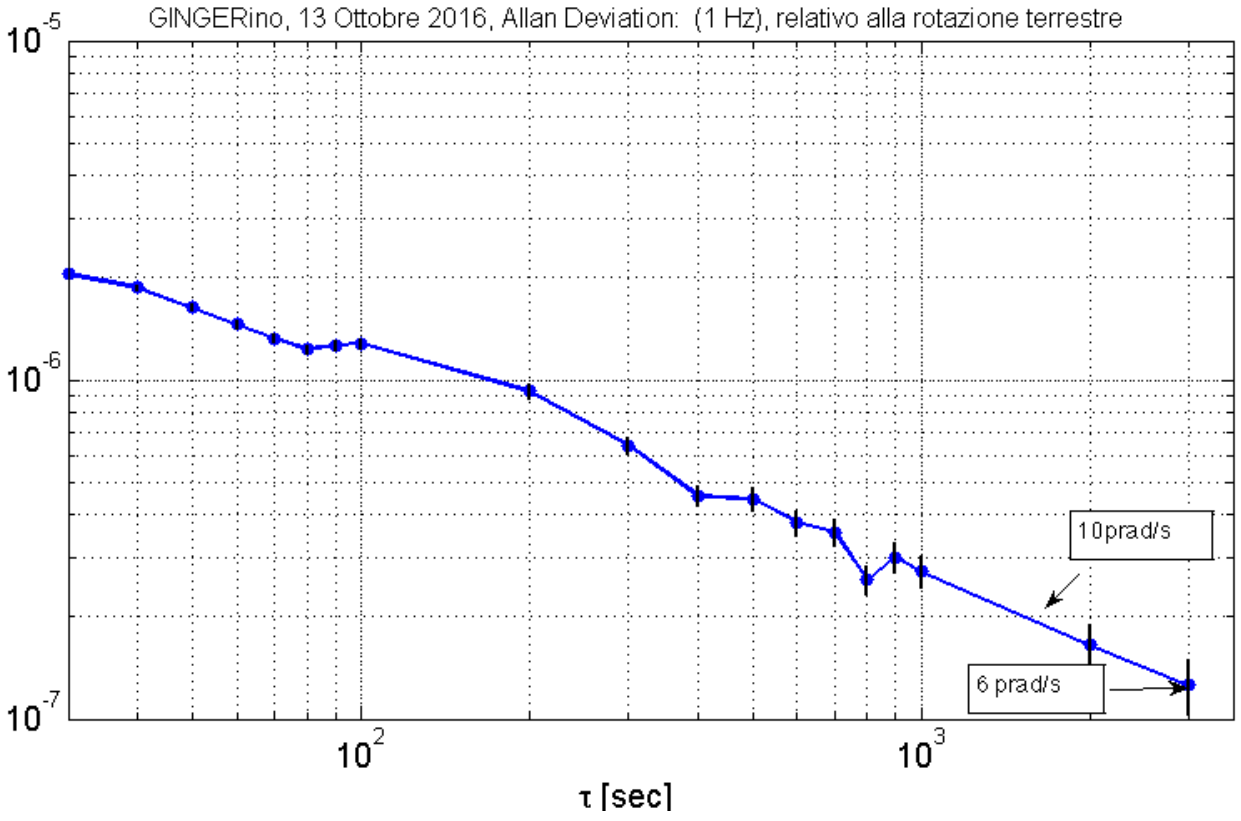


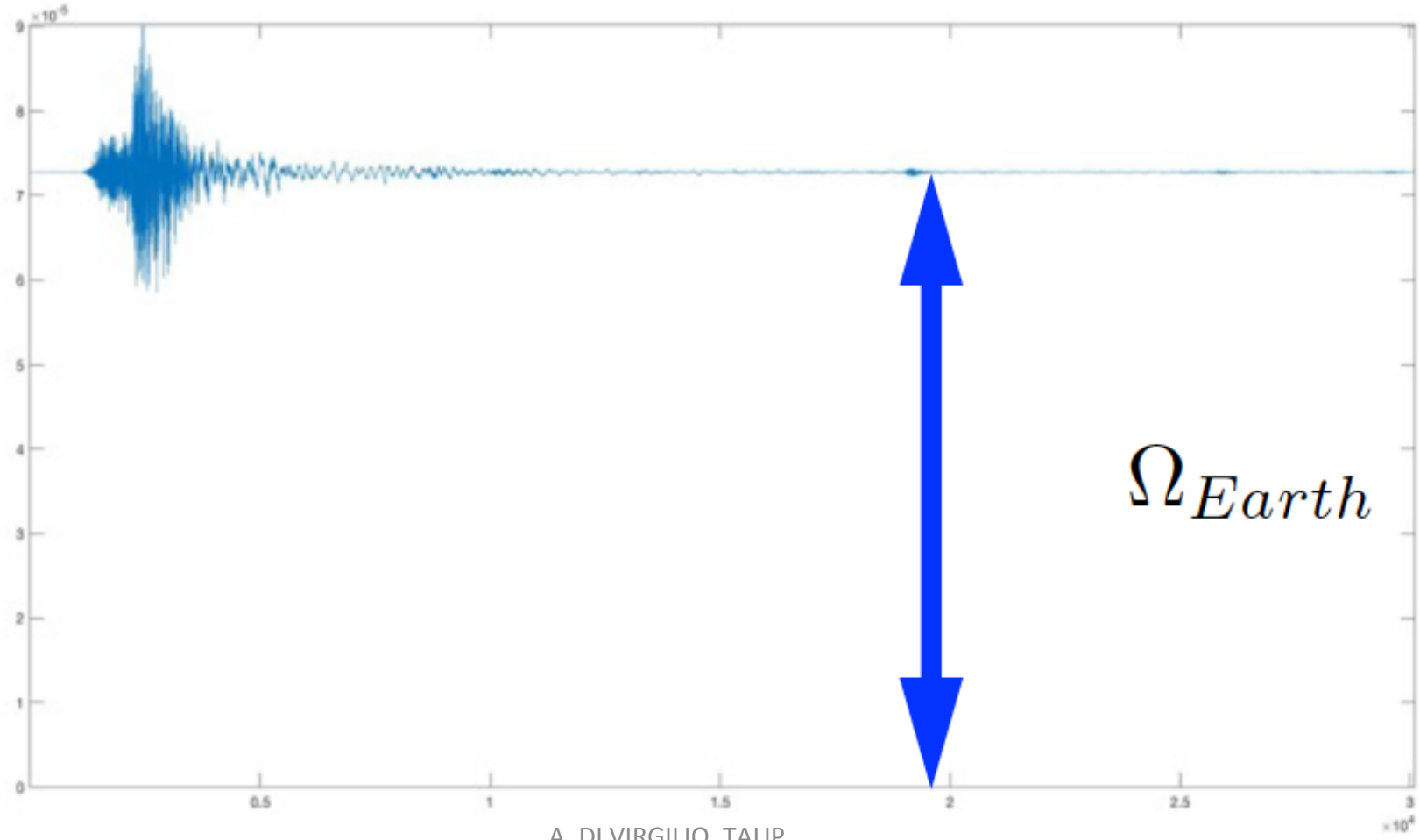
Figure 3. Angular velocity linear spectral density of GINGERino during the February 2016 run. Power spectral density is estimated from the raw data interferogram.

BEST ALLAN, WITH PARTICULAR CARE IN SELECTING DATA

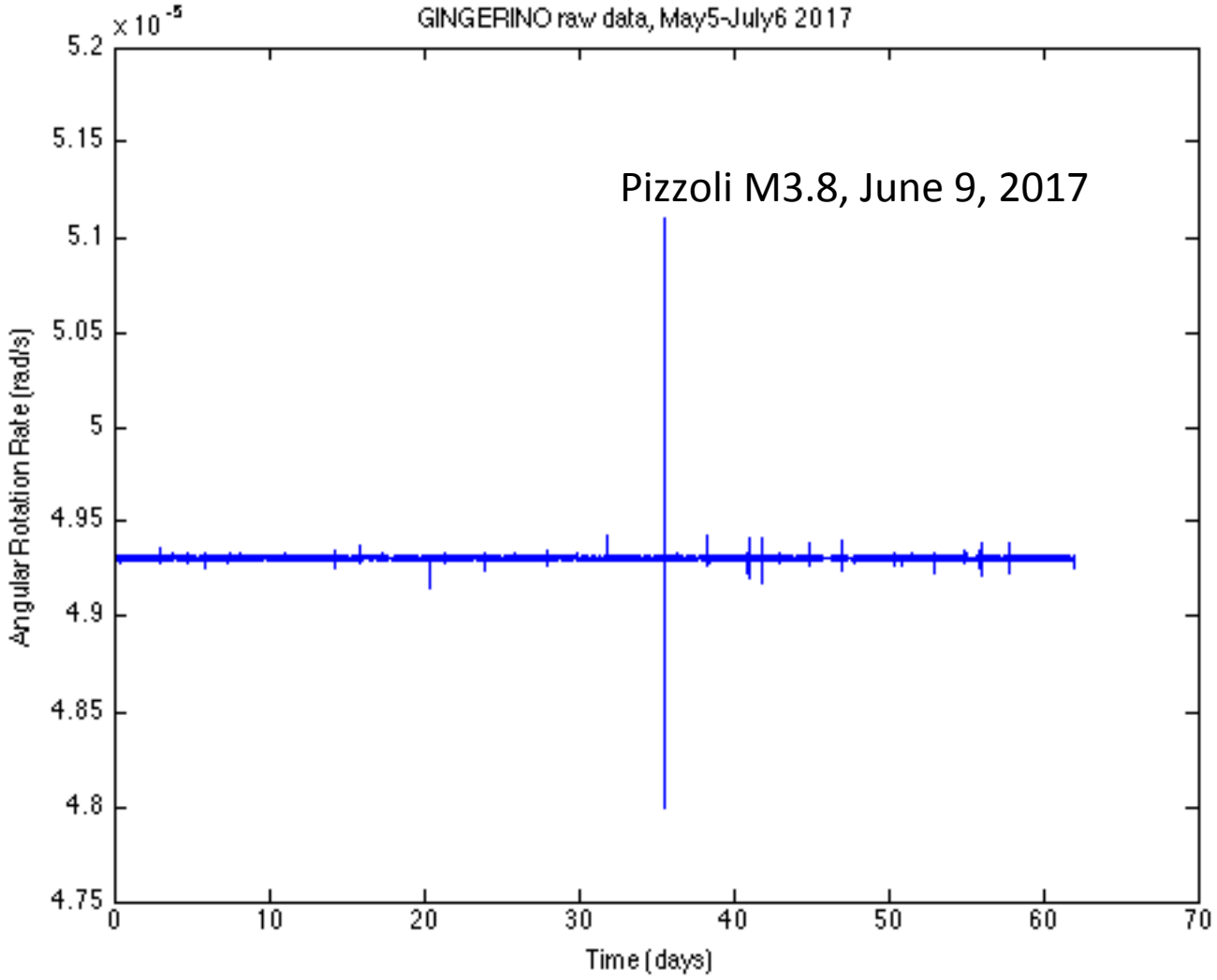


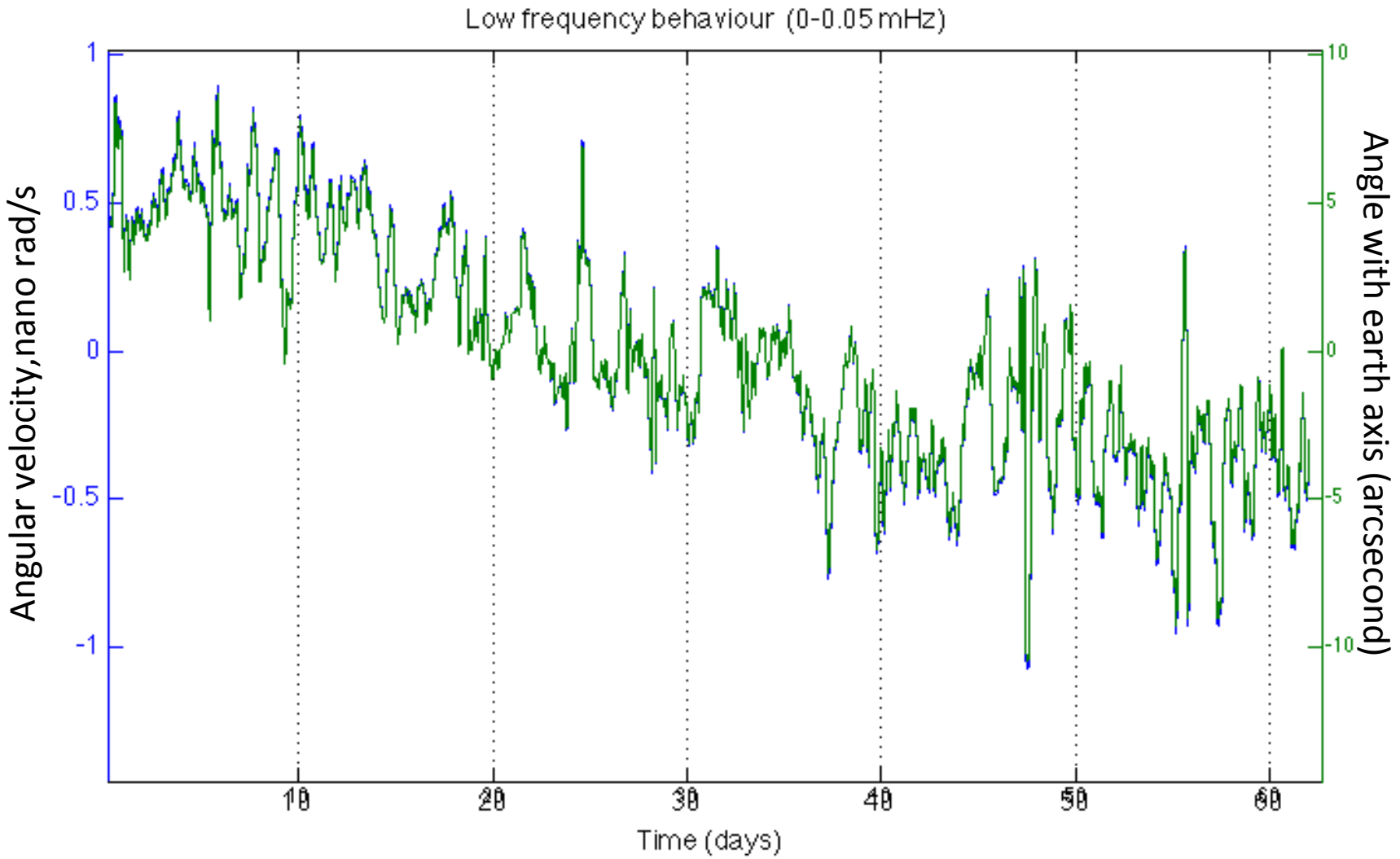
GINGERINO CAN DETECT VERY HIGH ANGULAR ROTATION SIGNALS

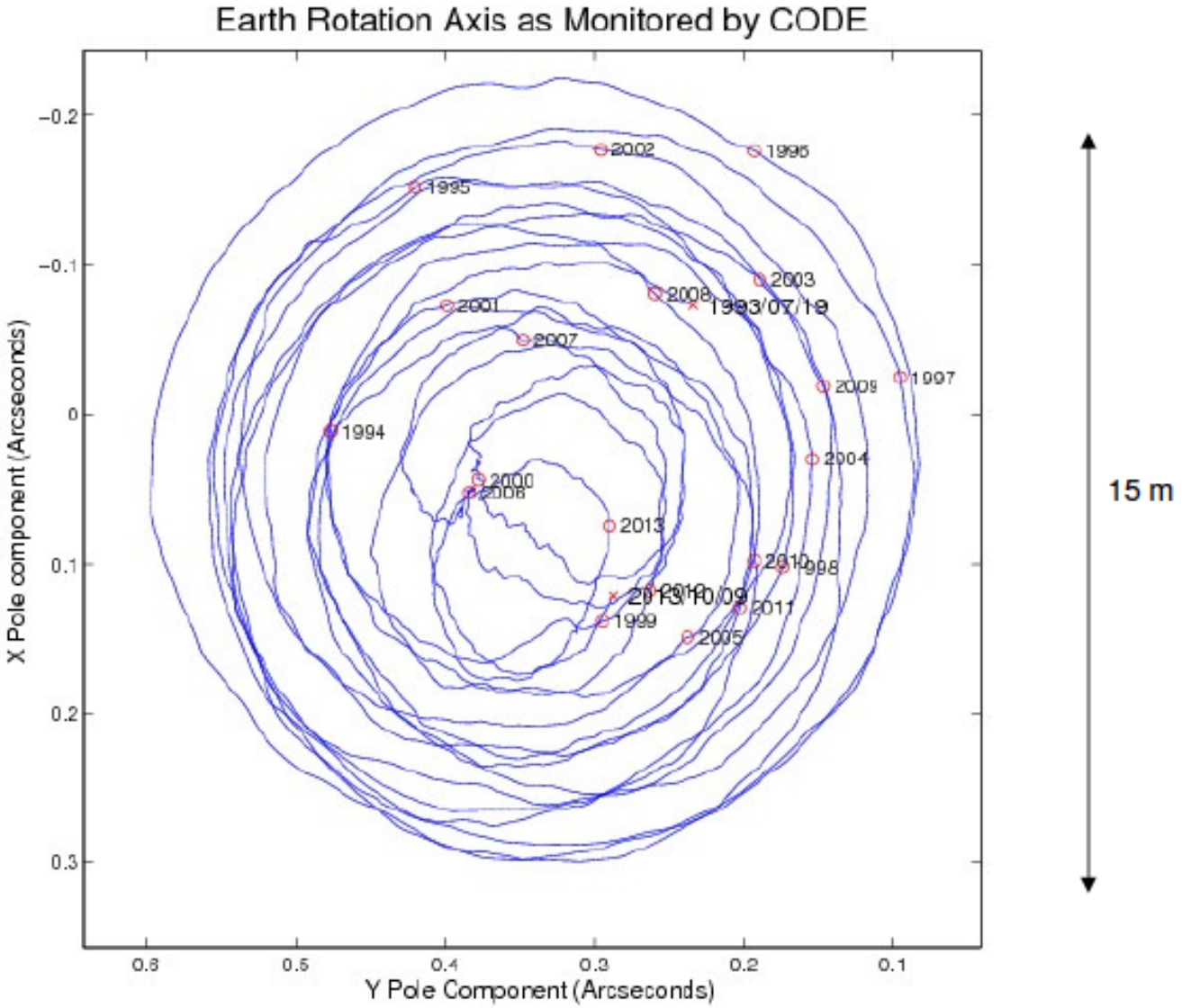
The Visso M 5.9 earthquake, probably the largest seismic rotational signal ever recoded



CONTINUOUS DATA TAKING
SINCE MAY 3 2017, DUTY CYCLE > 97%




Low frequency behaviour (0-0.05 mHz)
Angular velocity,nano rad/s
Angle with earth axis (arcsecond)
Time (days)
1
0.5
0
-0.5
-1
10
5
0
-5
-10
10
20
30
40
50
60

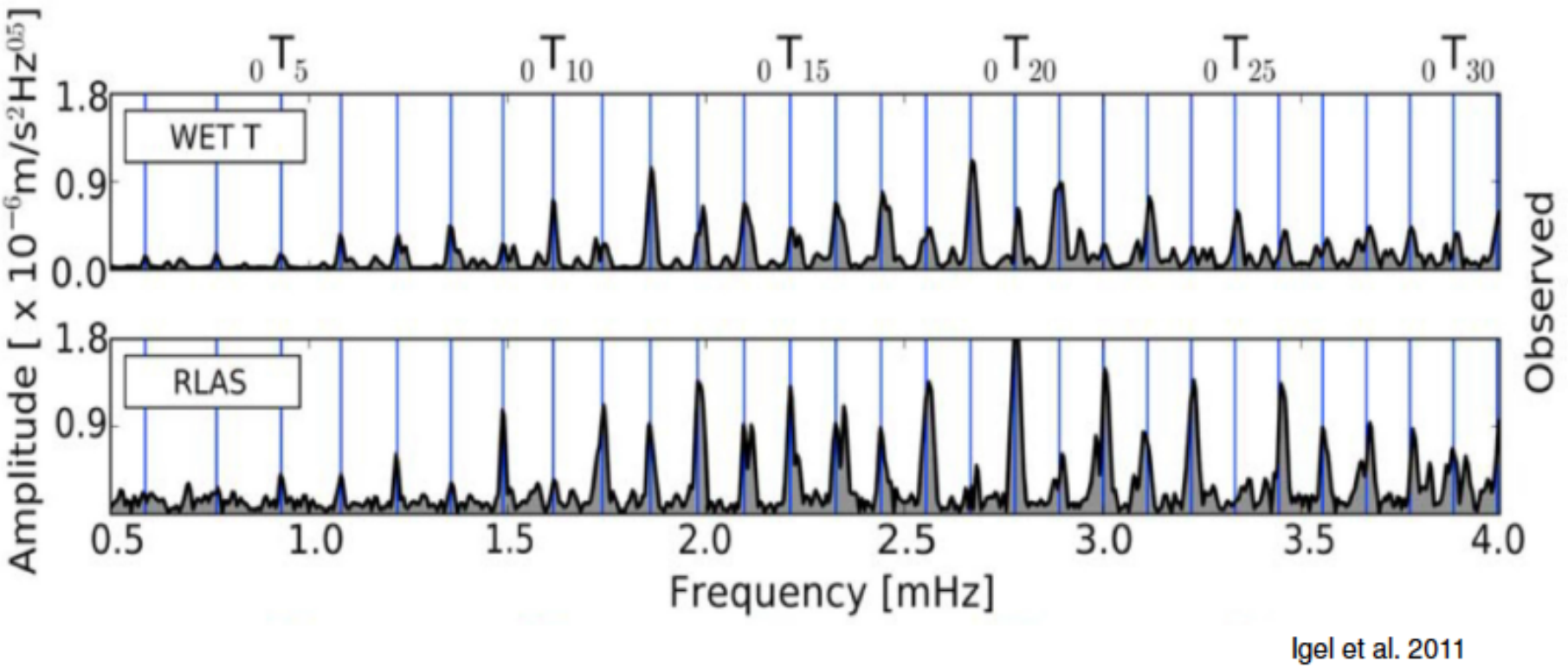

Earth Rotation Axis as Monitored by CODE
X Pole component (Arcseconds)
Y Pole Component (Arcseconds)
−0.2
−0.1
0
0.1
0.2
0.3
0.6
0.5
0.4
0.3
0.2
0.1
2002
1996
1995
2003
2008
1993/07/19
2001
2007
1997
2009
1994
2004
2000
2006
2013
2010
1998
2013/10/09
2011
1999
2005
15 m

RING LASER AND GEODESY

- *The top sensitivity ring is the Gross Ring G at the geodetic station of Wettzell*
- *The main purposes for geodesy are the daily and sub-daily variations of the length of day (LOD) and the earth axis variations, key points for geodesy*

Ringlaser Measures Eigenmodes of Earth

- Observed eigenmodes of the ringing Earth, stroked by the Tohoku-Oki earthquake



Gross ring G Wettzell

Courtesy of U. Schreiber and U. Hugentobler

CONCLUSIONS

- *Large frame ring lasers are based on a mature technique*
- *high sensitivity and long term stability make RL able to investigate the very low part of the spectrum, providing remarkable measurements for general relativity, geodesy and geophysics*
- *They can measure locally global quantity*
- *G, ROMY and GINGERINO are already providing data for seismology*
  http://ec2-52-59-201-108.eu-central-1.compute.amazonaws.com:8000
- ***GINGER?***

sensitivity & stability
key points to access very low frequency signals
Underground-Stability