Strange things you can do with underground GW interferometers

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LIGO-G050050-00-R

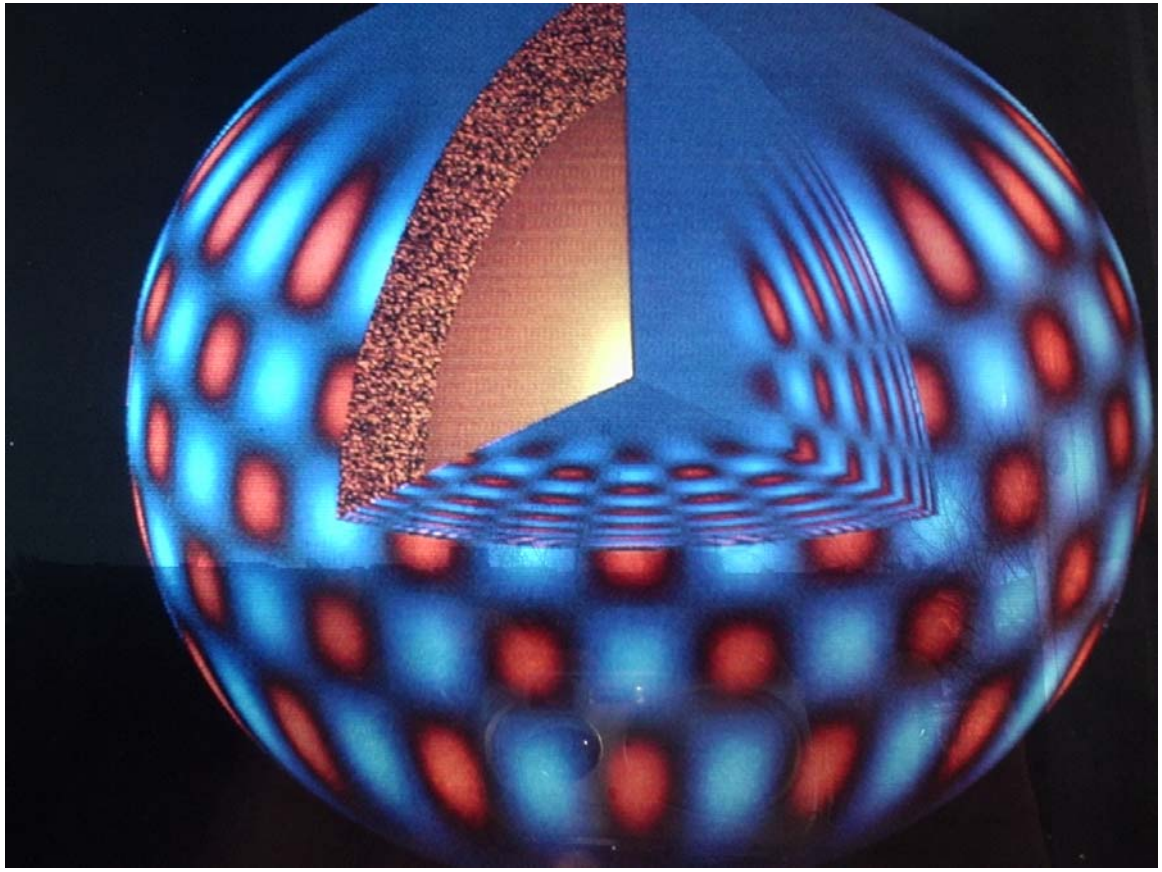
- In the next few weeks Alessandro will come to Pasadena for two months to study these things
- In a longer time scale he and his group will consider joining LSC
- They have some experience extracting signal from noise

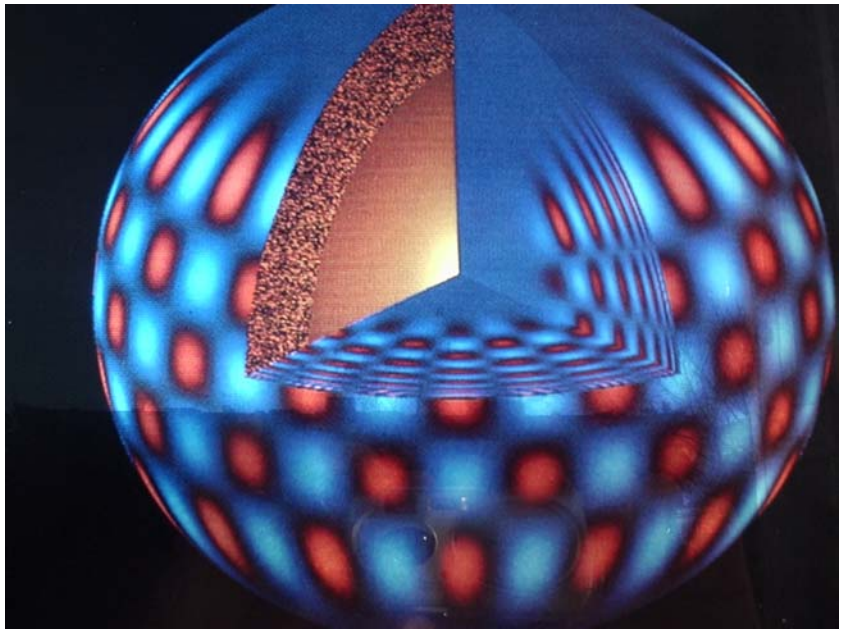
December 26 Sumatra earthquake
excited Earth in a manner similar to this

The oscillations last for many days

Could have told us many things of Earth had we been listening with many instruments

Events like this happen, happily, quite rarely

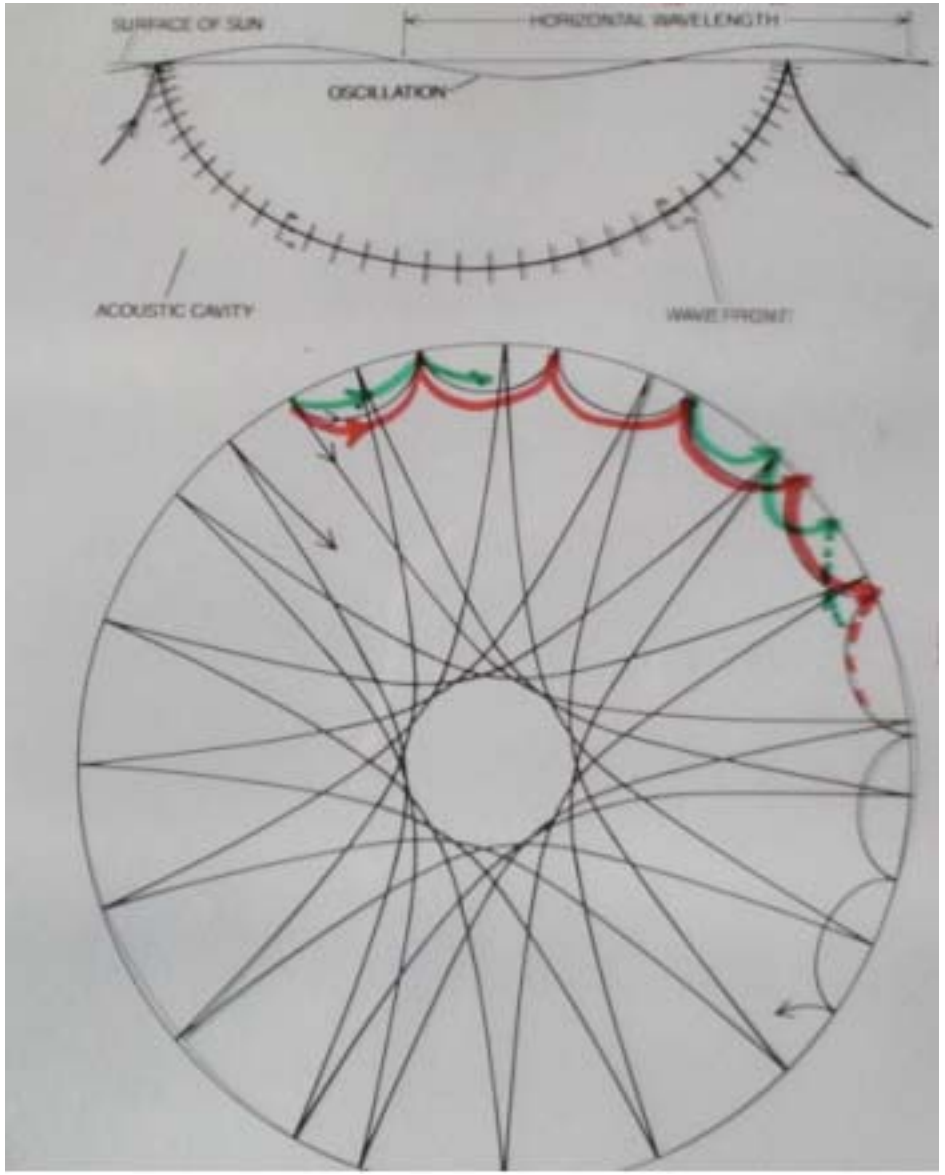




- This is actually the sun and one of its oscillation modes.
- The measurements of the surface oscillations gave us insight on the sun's core structure.
- To large extent we do not have this sort of information for Earth for lack of a sufficient network.

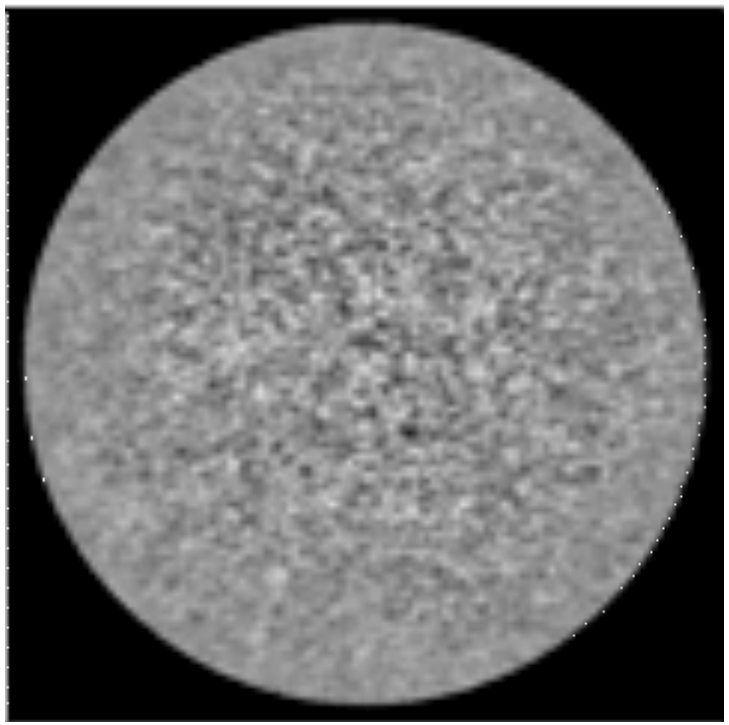
The mechanism

- Increasing density and composition variations produce dispersive seismic speed variations.
- Seismic waves of different frequencies are differently diffracted back towards the surface
- Resonances are formed at the frequencies for which surface emitted perturbations interfere constructively at the surface
- Studies of resonance structures, cross talk and lifetimes give indications of the core structure



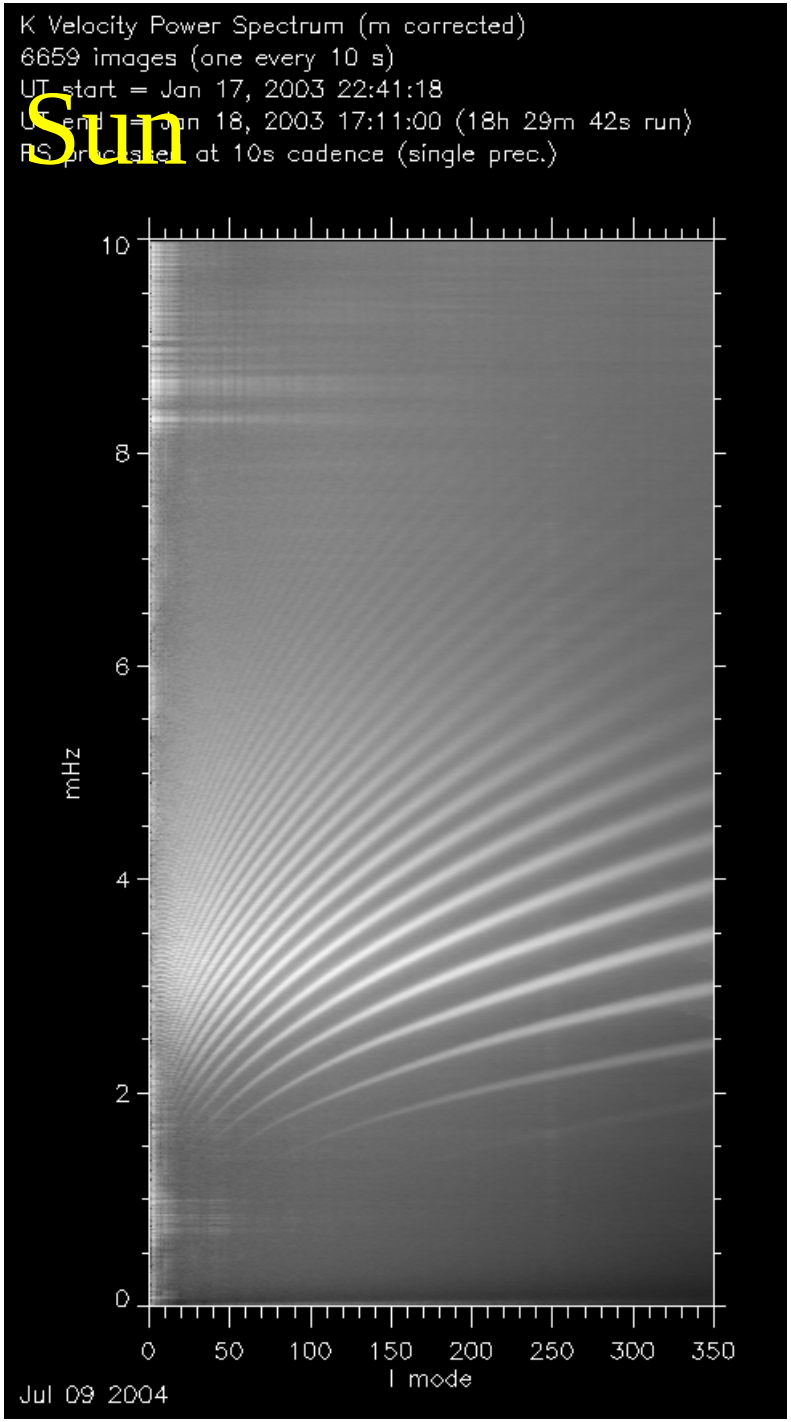
The method for the Sun

- In the Sun the seismic modes are measured from the Doppler field of its surface (above)
- Subtracting the rotation effect to generate frames (below)
- Time analysis of many frames give the seismic measurements



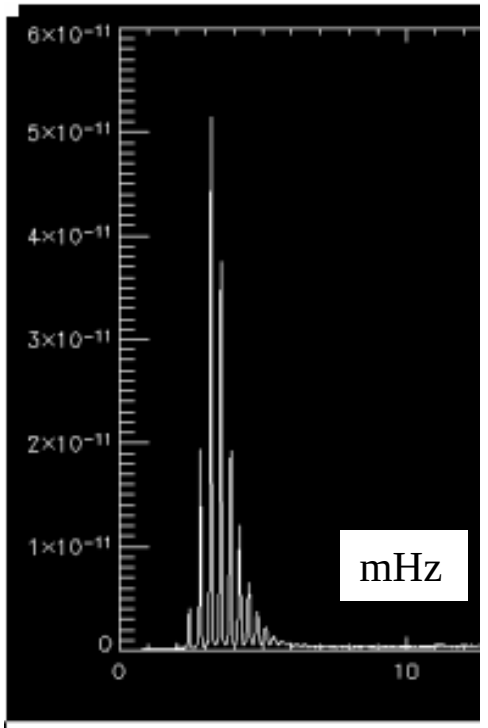
LIGO The method for the Sun

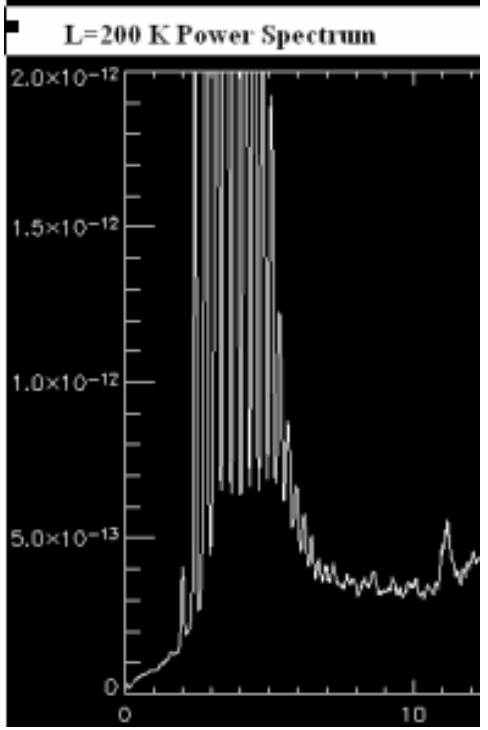
- This is the analysis of 15 hours worth of
  0.1 frames/s
- The information then yields the core shape information



The method for the Sun

- This is the analysis of the resonances of the spherical harmonic l=200 for the sun
- It happens that Earth's resonances are in the same frequency band
- This band is not easily accessible to accelerometers





How to measure Earth's din

- Underground L-shaped interferometers are being built for measuring the rock strain and reconstruct the Earth's structure.
  - (Kamioka, Gran Sasso)
- Typically 100x 100 m long instruments are used
- For the sun, measurement of the entire surface allow the separation of the spherical modes.
- Many stations will be necessary to do the same for Earth

Kamioka Earth strain measurement station

Targets

Earth's free oscillation ····· Earth's background free oscillation,
Core modes,
Outer-core resonances, etc.
(10^{-13} at 0.1~10mHz)

Iodine-stabilized Nd:YAG laser (532nm)

····· Stability : <~10^{-13} at <0.1Hz

The Sensitivity Issue

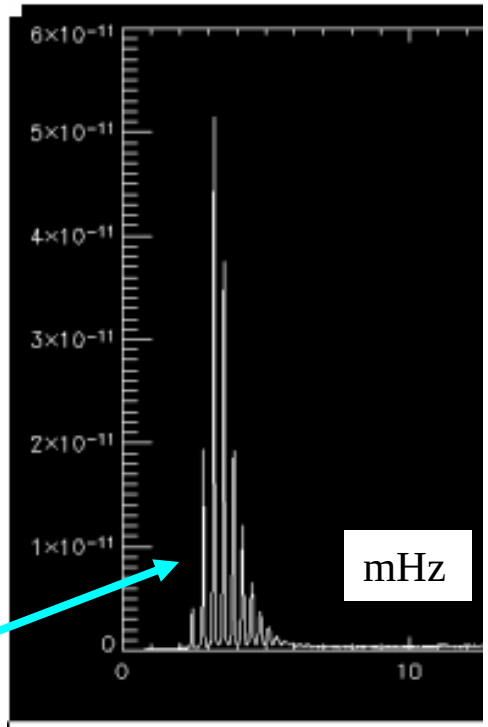
- The seismic stations have difficulties to separate the signal from noise in normal conditions
- For high resolution need to wait for exceptional events like the Sumatra earthquake to correctly measure the ring-down of these modes

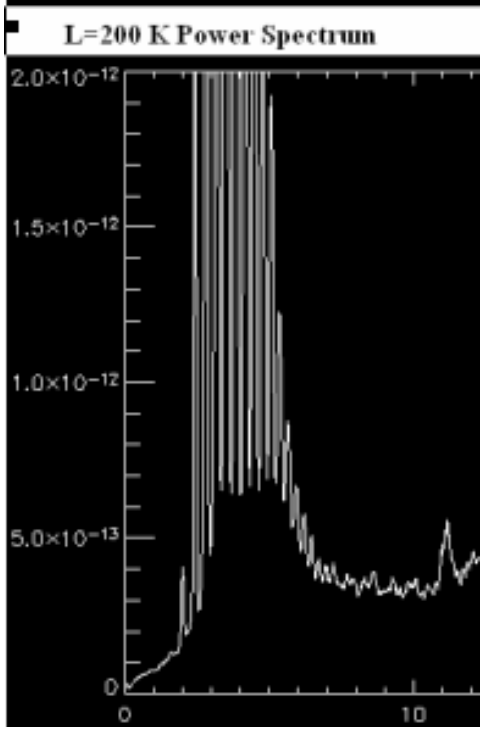
The usefulness of underground GW facilities

- GW interferometers are designed to be isolated from Earth's din.
- Have longer baseline which would entail higher sensitivity
- The signal of interest could be easily extracted by monitoring the mirror position and comparing the laser frequency with a stabilized laser (Iodine stabilized Nd laser)

The usefulness of underground GW facilities

- Although a single station is of limited interest, a Km size Earth strain interferometer would be capable to listen to Earth's din almost continuously, without requiring extremely rare catastrophic events
- Happily Earth's resonances are not as rich as Sun's resonances
- The growing network of smaller interferometers could do the job of identifying the modes and connect them to different frequencies
- The few large interferometers could provide the resolution





The usefulness of underground GW facilities

- More tantalizing….
- For unknown reasons the sodium layer at 30 Km altitude, at these low frequencies, couples to the Earth's core modes
- Sensitivity not obviously sufficient
- A few geostationary satellites monitoring the layer could identify the modal shapes while the large underground interferometer could provide the resolution

Conclusions

- Per Aspera ad Astra
  - Through adversities we will get to the stars

- Per Astra ad Terram
- Through the stars we will get to Earth