Detector Characterization for LCGT

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JGW-G1200777

Artificial noise encoded in GW detectors

- An interferometric GW telescope is changing its statistical behavior with short-time scale (~minute-hours).

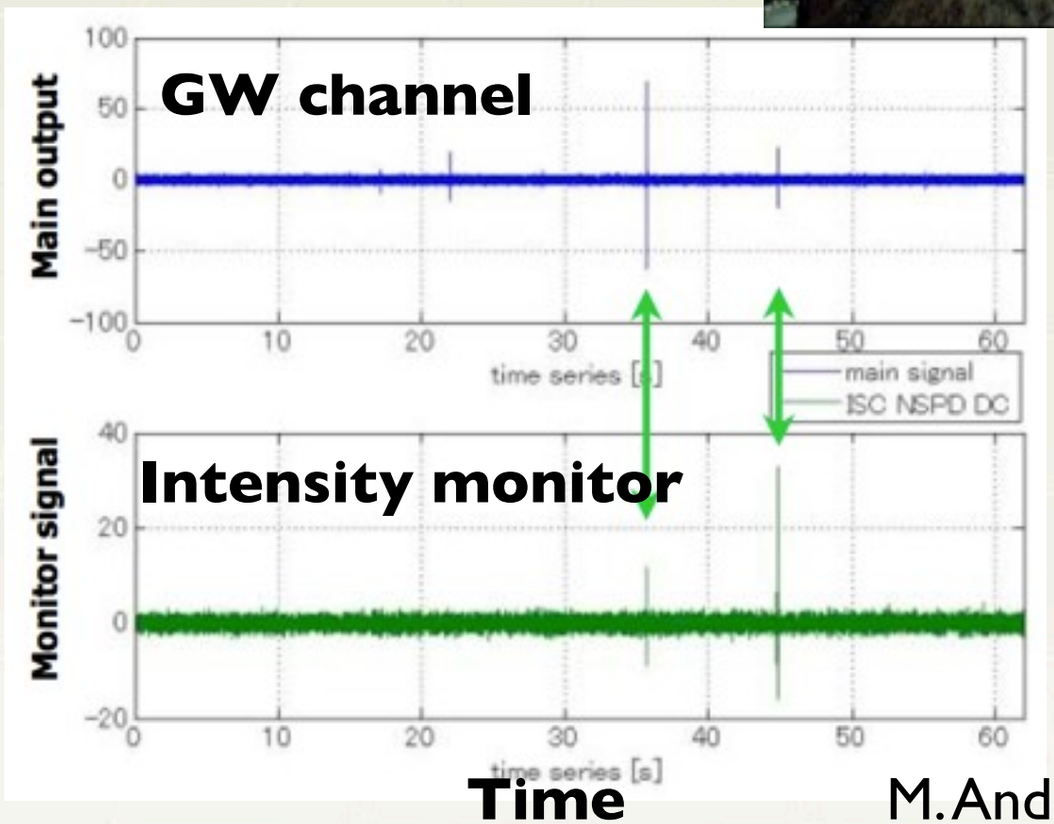
- An interferometric GW telescope is very sensitive to instruments, environmental phenomena around.

- Artificial noise is encoded into gravitational wave channel of the telescopes as well, which is sometimes very difficult to distinguish.

Intensity noise in TAMA300

- **TAMA300 located in Mitaka Tokyo, was operating during 1998-2004.**
- **We saw lots of artificial noise transients in the data.**
- **One of major one correlated with gravitational-wave channel is intensity in the power recycling cavity.**

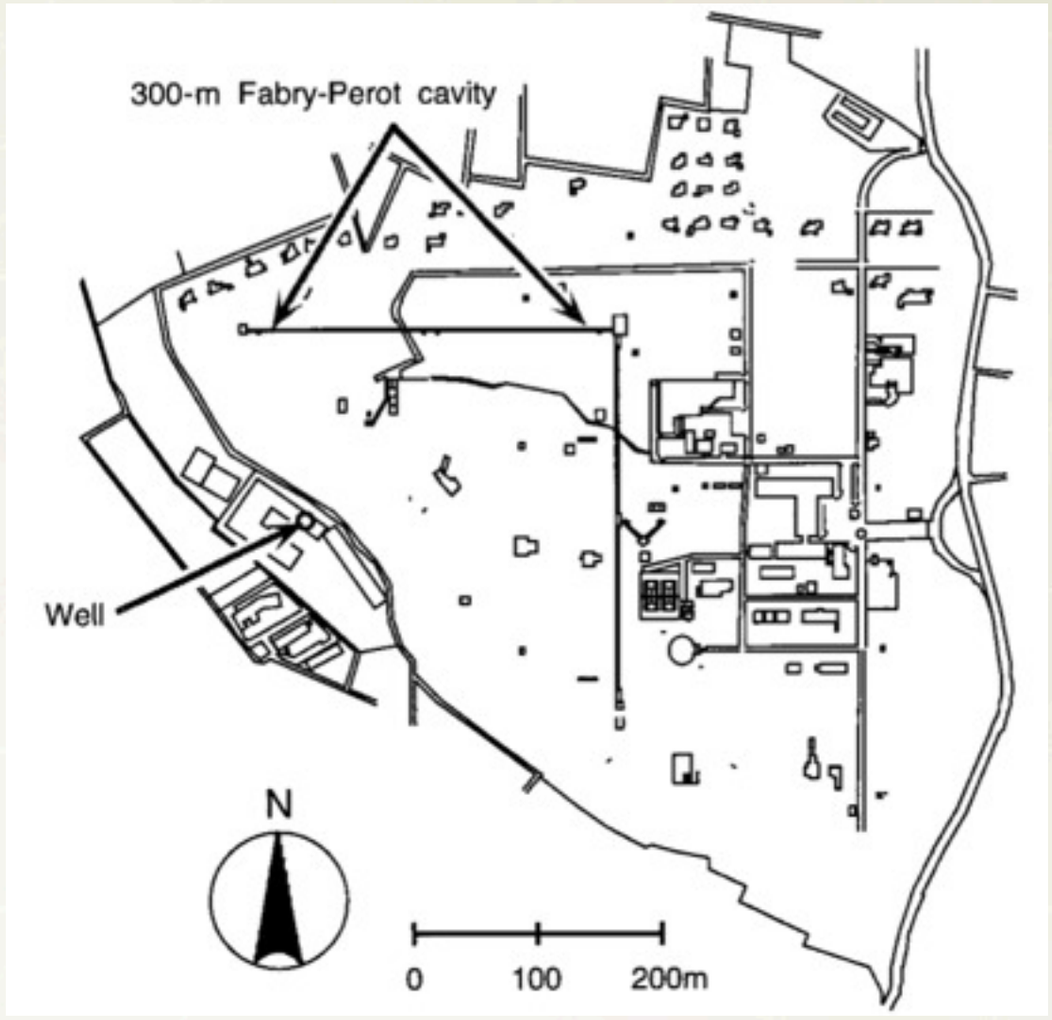
TAMA300

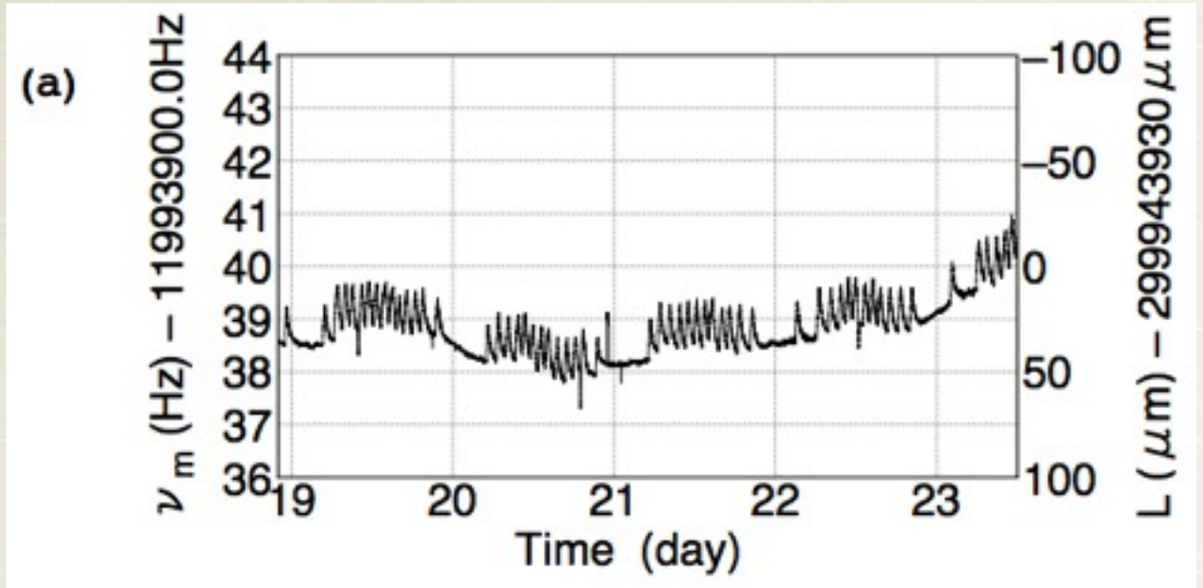


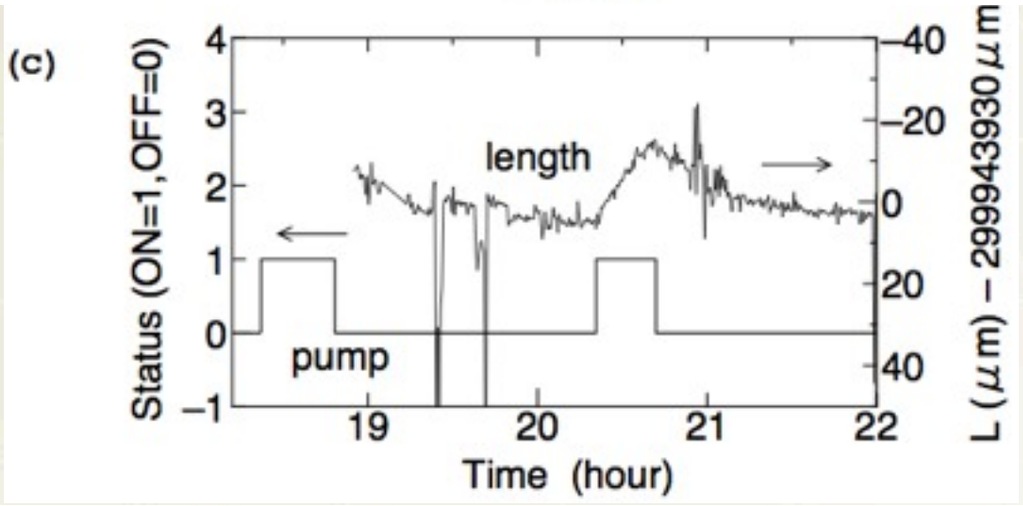
M. Ando

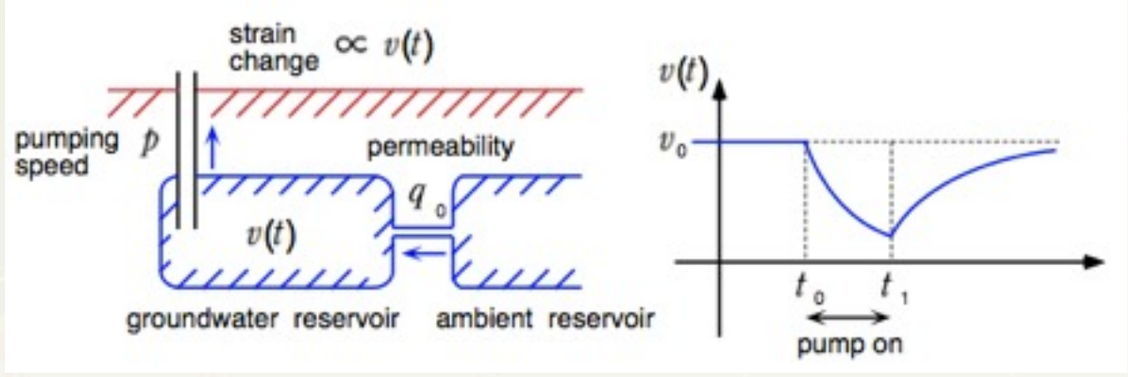
Record of pumping well in TAMA300

- **Well ~ 200m from TAMA300 influenced the lengths of the arms.**







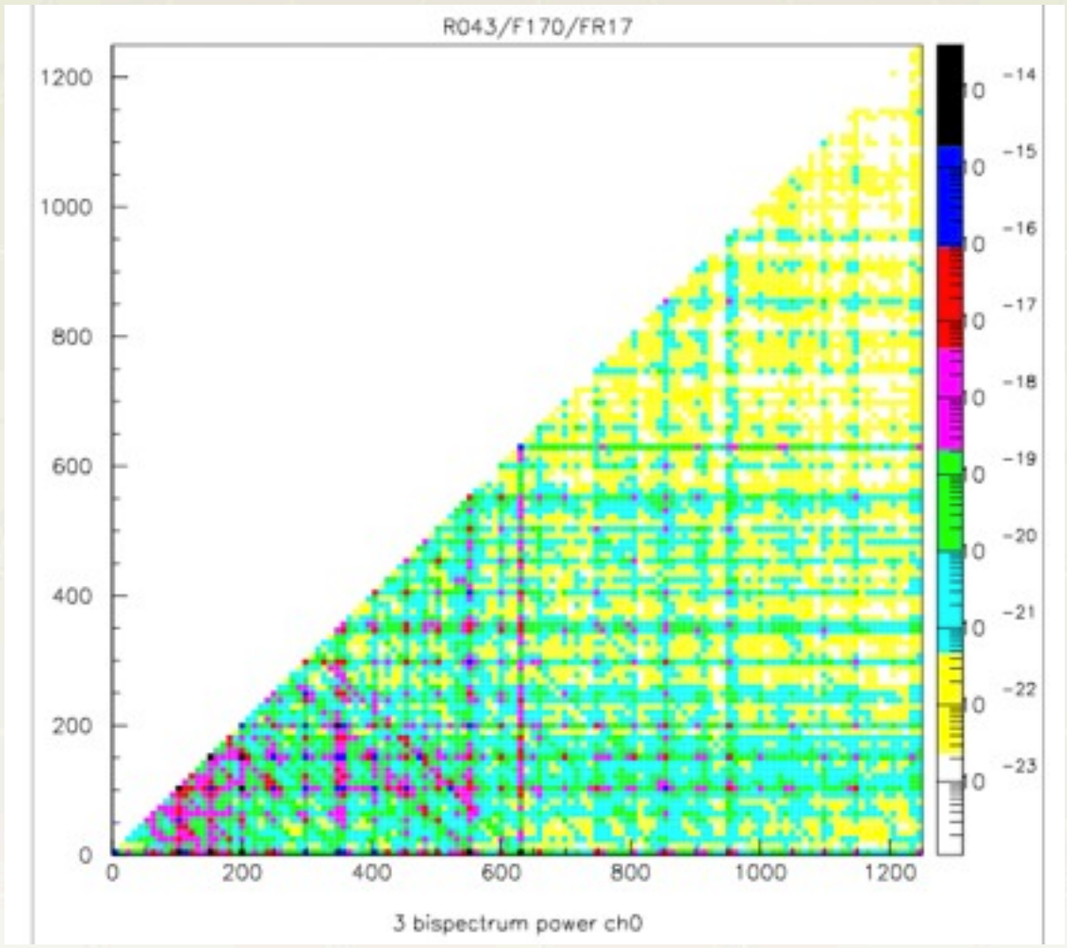


A. Araya et al. (Appl. Opt. 1999)

Bispectral analysis of TAMA300

- **Bispectral analysis is useful to identify instrumental noise correlated between frequencies.**

correlation power



frequency

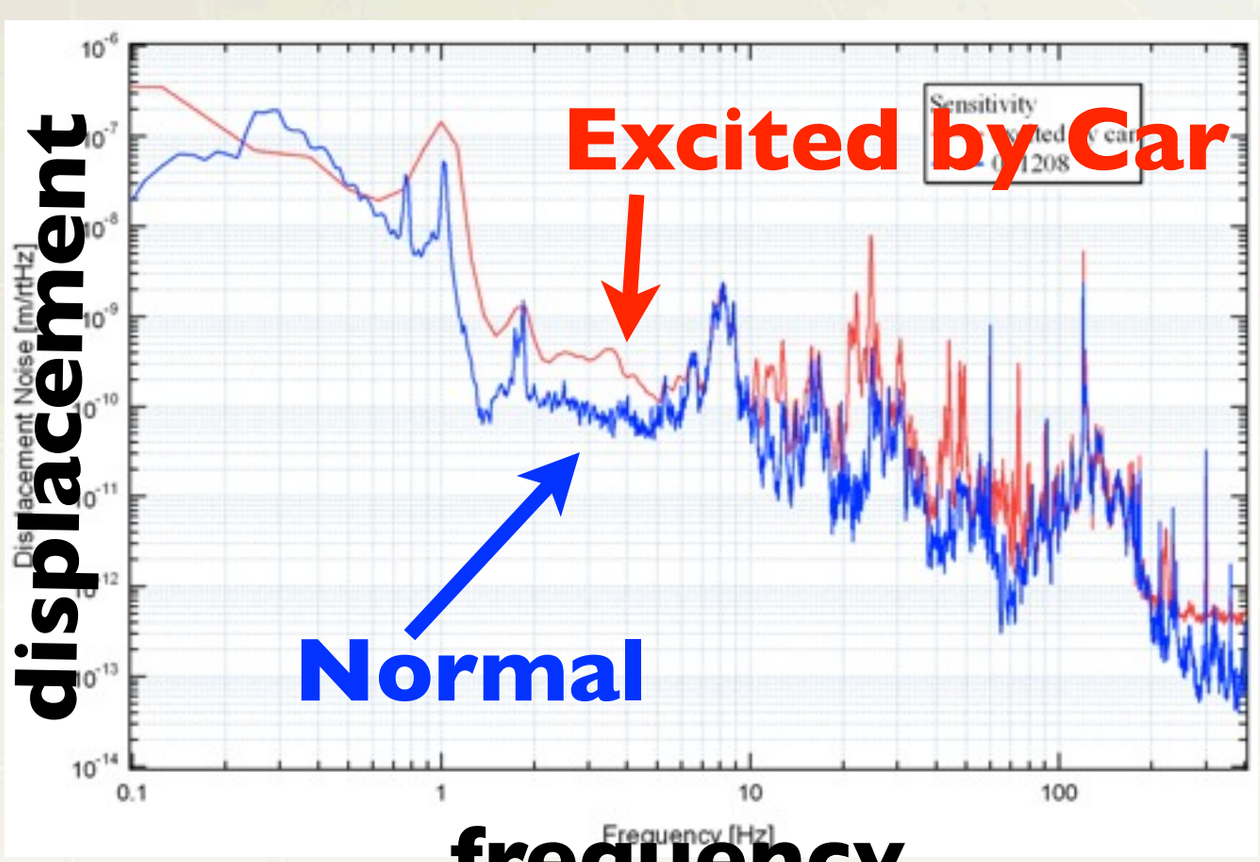
frequency

Y. Watanabe, M-thesis (2001)

Environmental noise in CLIO

- **Seismic noise :**
  A Car become a noise source.
- **Particles :**
  Smoke should show up because blasting rocks somewhere in the mine. The particles influence LCGT.
- **100 % Humidity !**

Car park in front of CLIO

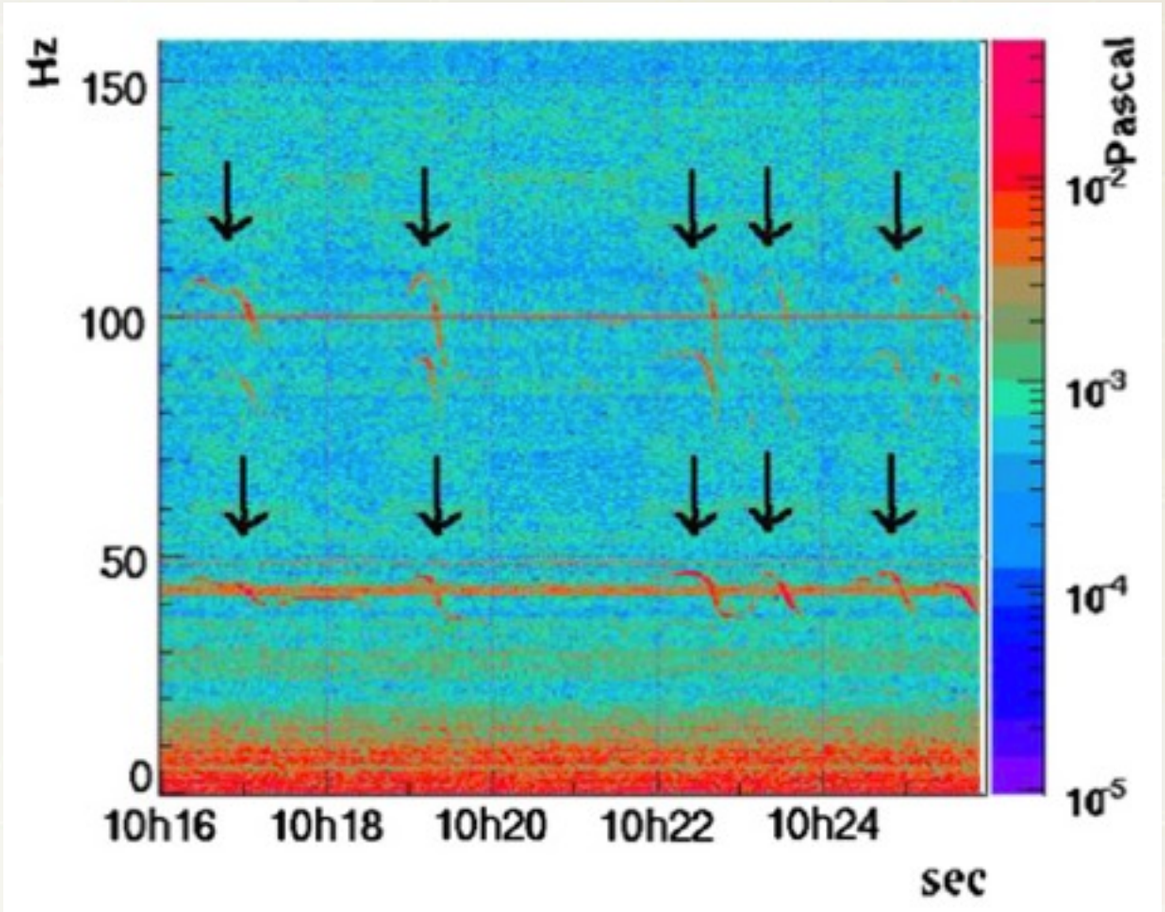


Agatsuma (2008)

Sound noise in LIGO, Virgo

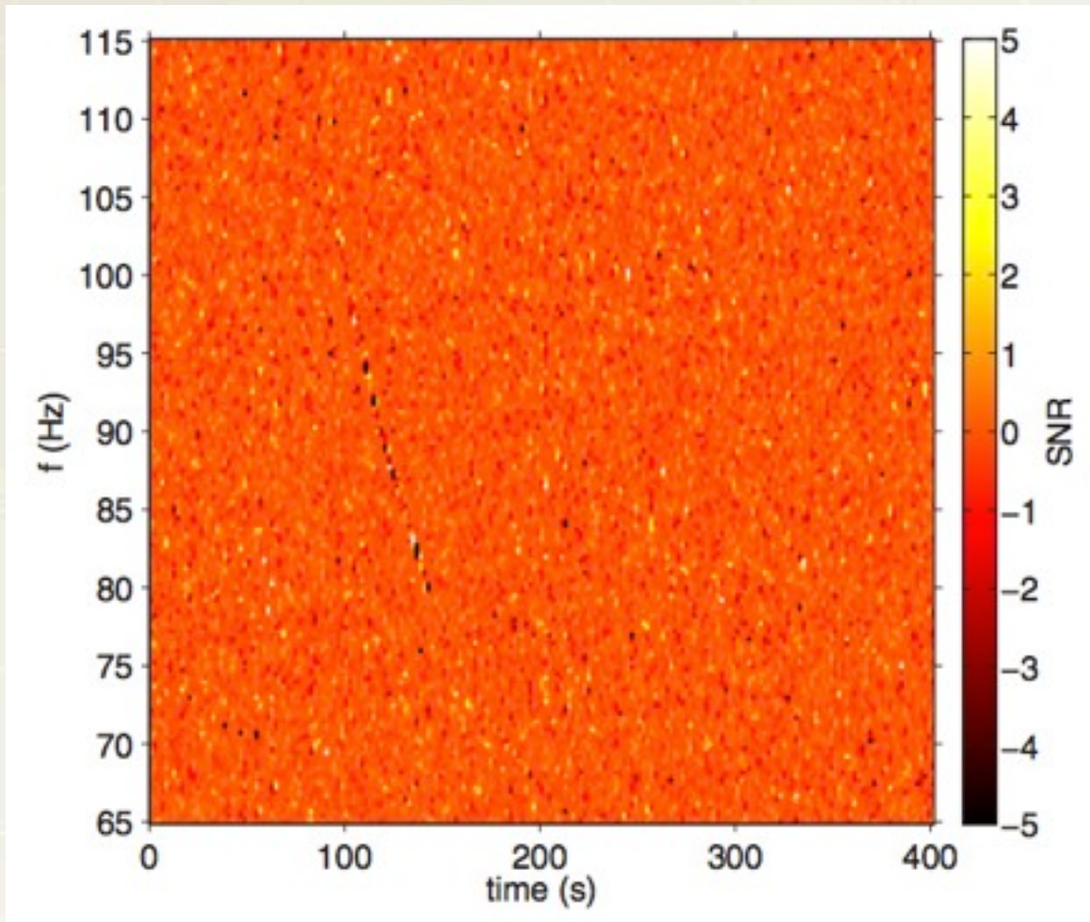
- **The sounds from helicopter, airplane etc influence data.**

helicopter



Virgo

airplane



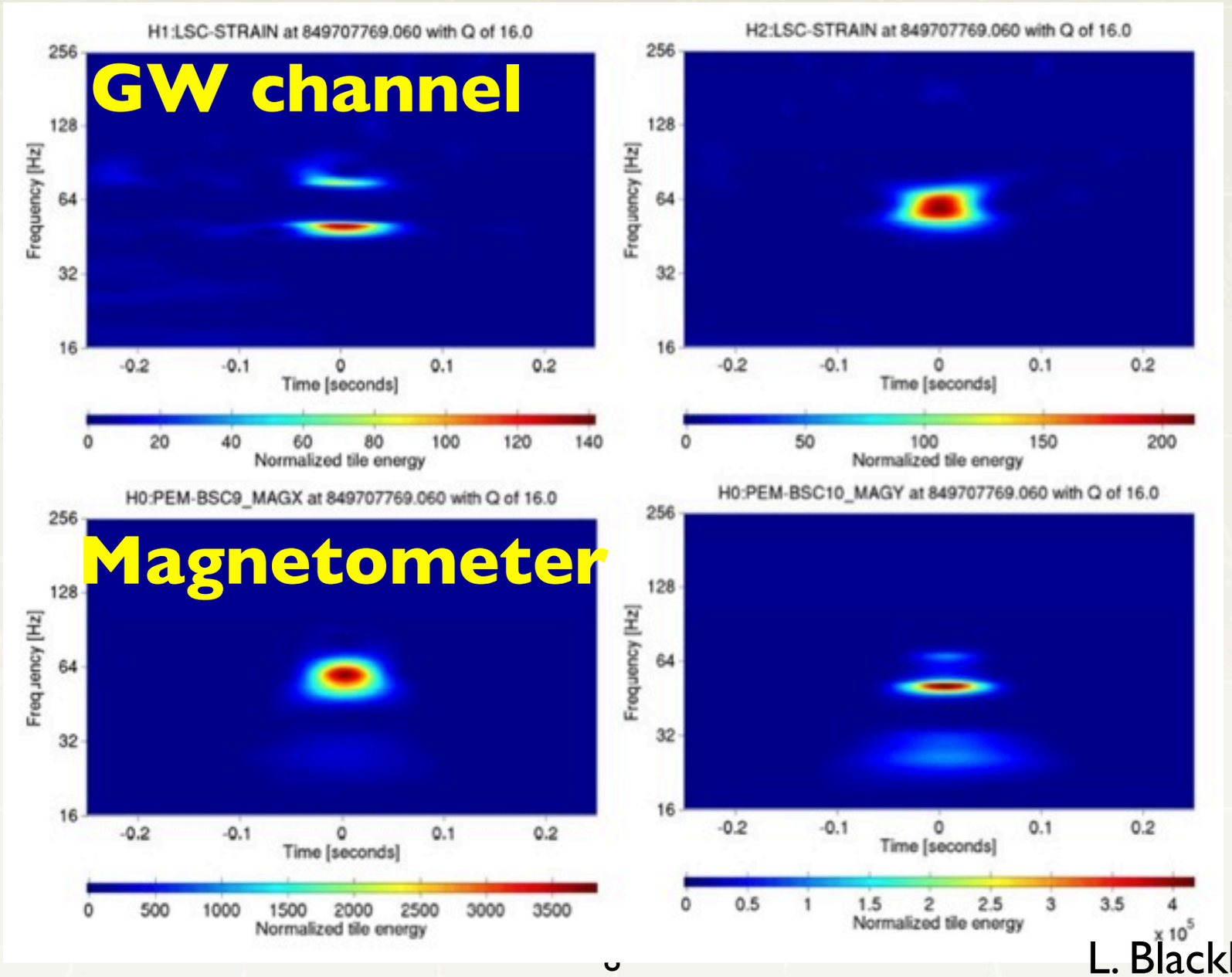
LIGO

Coughlin et al, CQG (2011)

Magnetic fields disturbances in LIGO S5

- **In LIGO S5, prominent source of noise transients were magnetically induced events caused by noise transients in the power mains. The events showed up in both GW channels and magnetometer.**

H1 **H2**



L. Blackburn, Ph.D thesis

From our experience...

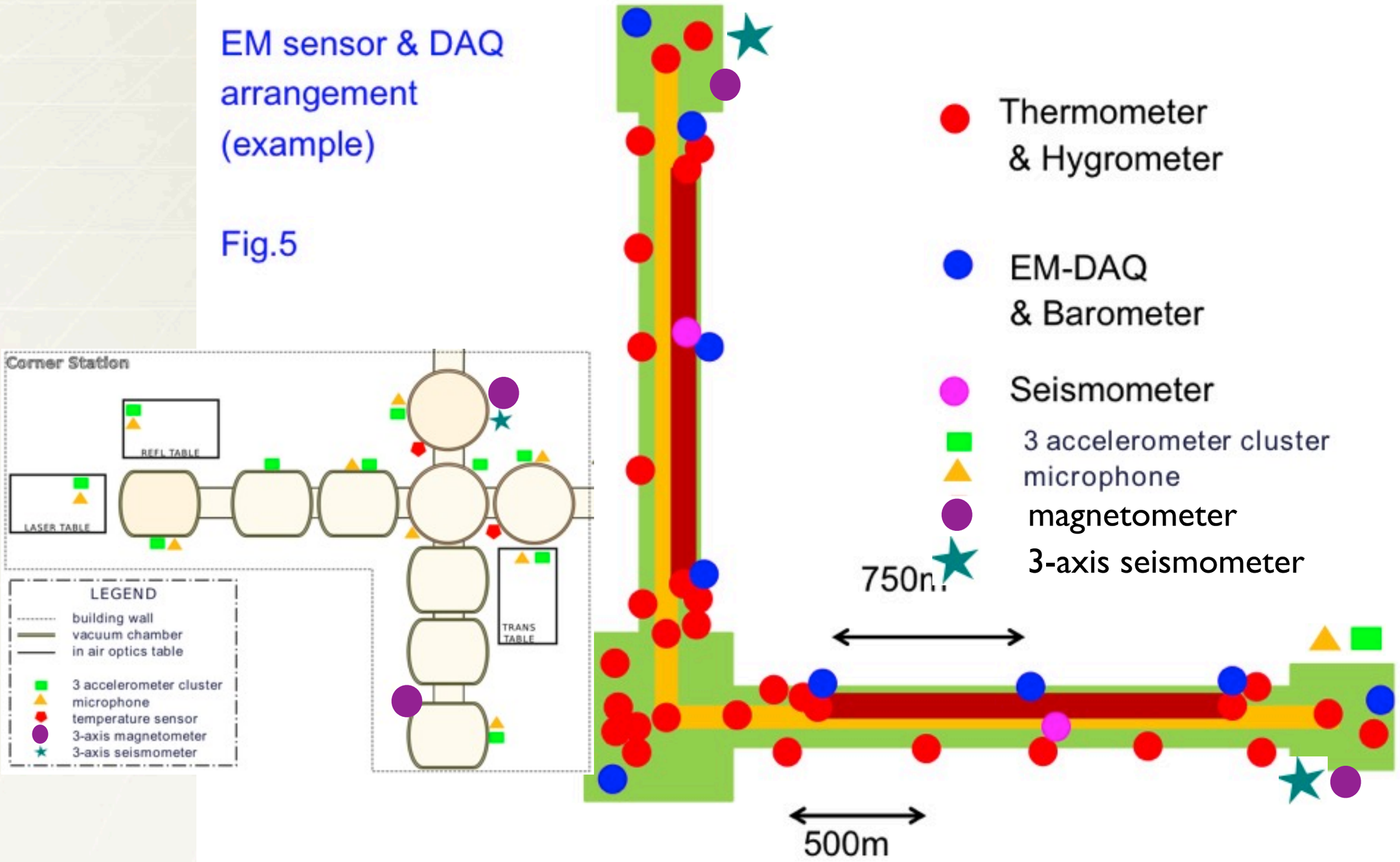
In order to monitor these noise, we need

- **Seismometer**
- **Barometer**
- **Accelerator**
- **Microphone**
- **Thermometer**
- **Particle counter**
- **Hygrometer**
- **...**

Environment monitors

EM sensor & DAQ arrangement (example)

Fig.5



Scope of detector characterization

- **Support GW detection/non-detection.**
  As shown in previous slides, there are lots of artificial noise in LCGT data. In order to claim the detection, these noise ought to be rejected.

- **Distribution of veto list to other collaborations.**

- **Killing noise sources : Improvement to LCGT data.**
  The best way is to kill noise sources before LCGT observing.

- **Accuracy of calibration.**

When ?

- **Detchar system will not be changed over *LCGT.**
- **Geophysics interferometric detector will be launched first and environment monitors start working.**
  (This year we chose sensors and decide number of them.)
- **Since the environment monitors will be shared with LCGT, we test these sensor from the point of the GW detection.**
- **During observations of iLCGT, (nearly full) detchar system will be tested. (~2015)**

How ?

- **How the detector characterization support the GW detection or non-detection?**

Next few slides shows several types of detector characterization.

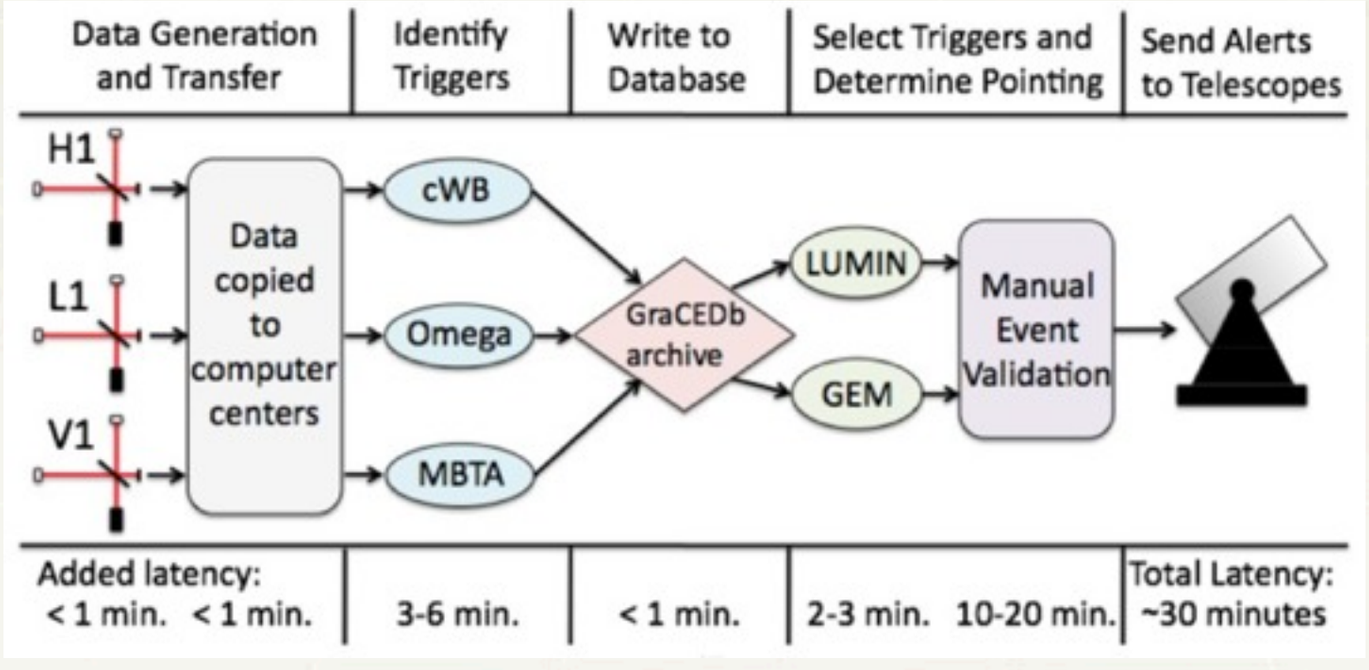
Transients, multi-messenger observations, continuous, stochastic

Transients

- Always struggling with burst-like noise (glitches). Since gravitational waveform from many sources is not or poorly modeled, distinguishment is very important.
- There are many methods to reject these noise transients developing so far.
  - Coincidence analysis between GW channel and other channels
  - Modeling noise transients and their classification
  - Multivariate statistical ways
  - Hierarchical glitch classification
  - .....
- These studies help improvement to instruments.

Multi-Messenger Observations

- Real-time distribution of data-quality information to collaboration.
  - EM waves following GWs will be emitted with short time interval.
  - To do so, all process should be automated finally.
- Rate of GW event alert should be low (not 1 event/one day)
  - Alerts with high confidence are needed, otherwise LCGT is recognized as just spammer for other collaborations.
  - For now, false alarm rate is not enough at all. One of the reason is that detector noise is not Gaussian.

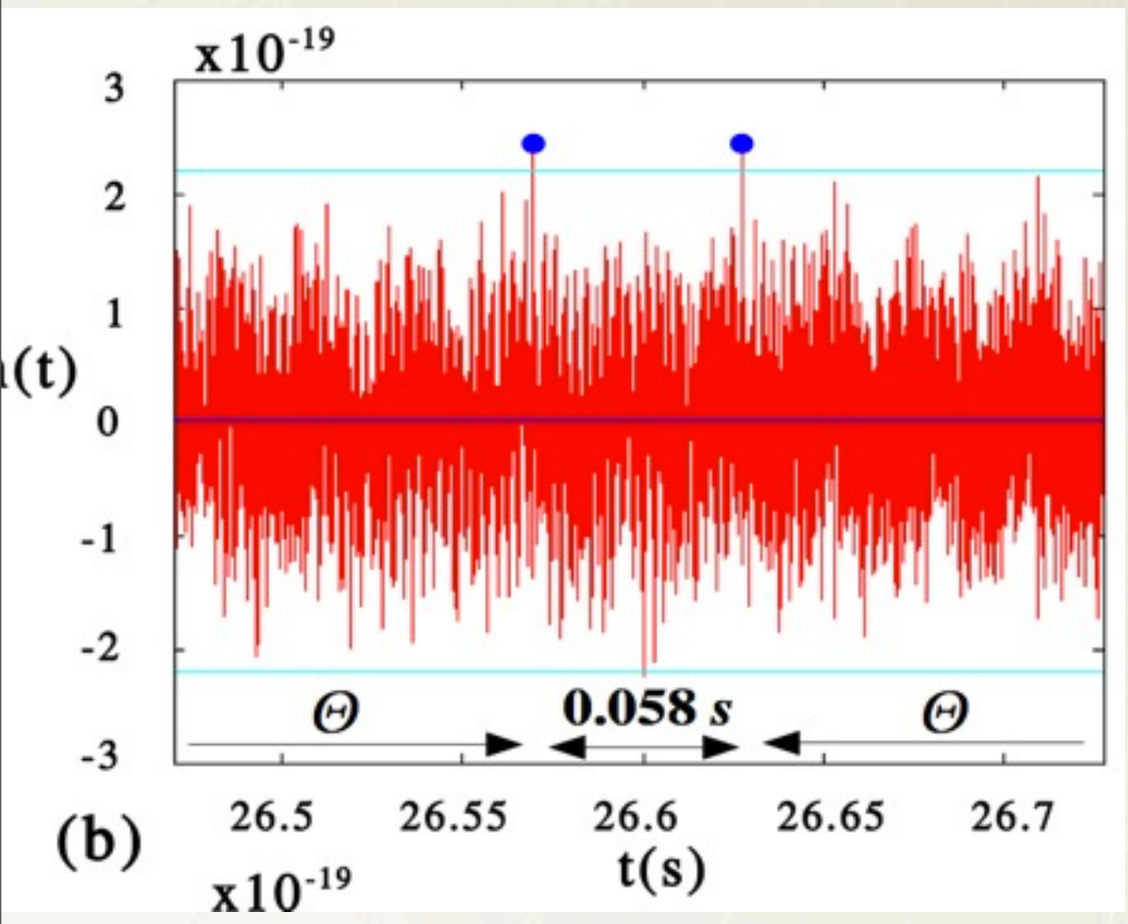


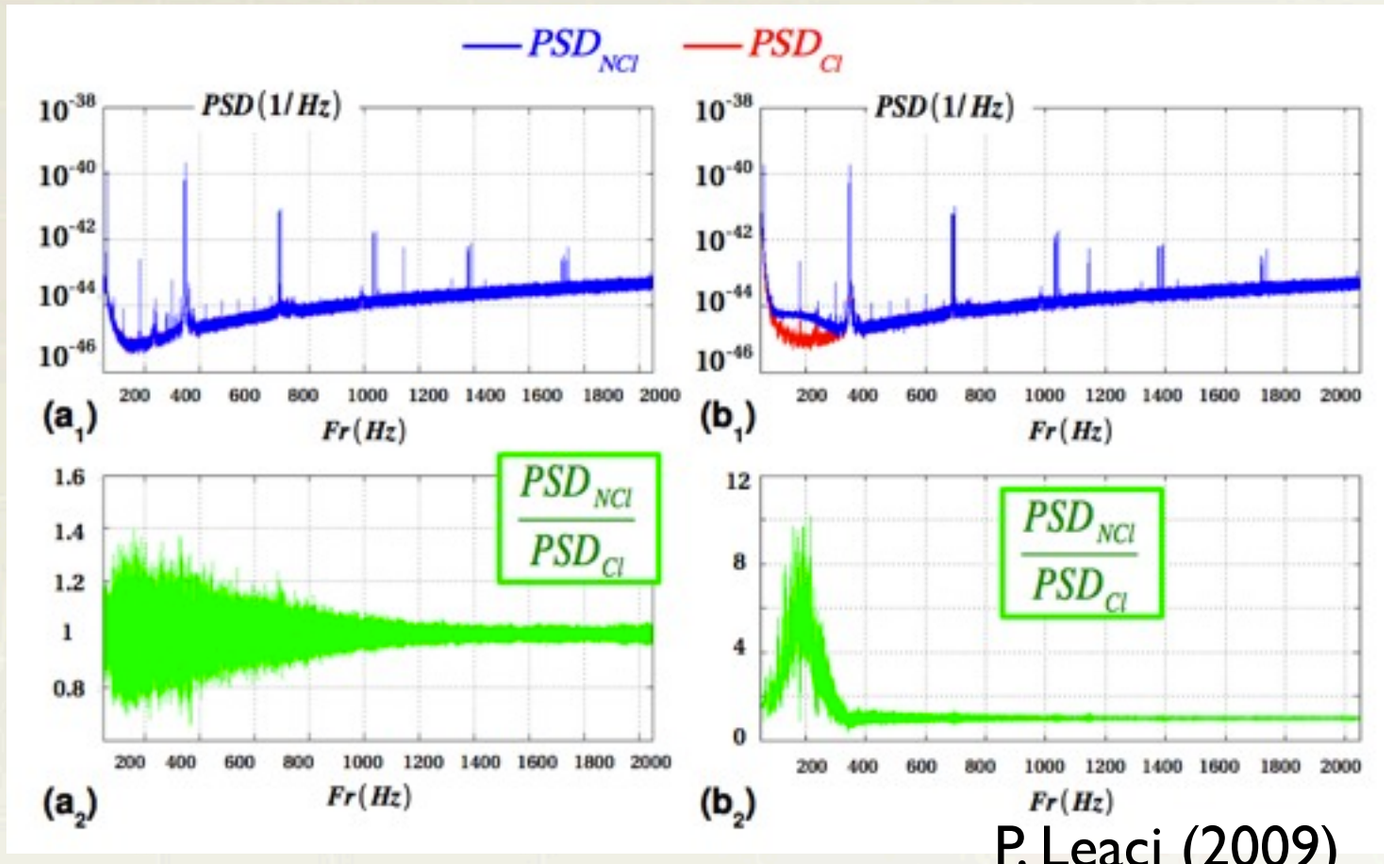
Erik in LV meeting at Orsay

Continuous, Stochastic

Continuous

- **Lots of hight frequency spike-like noise make sensitivity to continuous wave worse.**





P. Leaci (2009)

Stochastic

- **The statistical change of power spectral density crucially influences stochastic gravitational wave background.**

Distribution of detchar output

- The main output of detchar for event searches is
  - data quality information (non-stationarity(glitchy or not etc), any problem of a telescope etc, locked or not...)
  - GPS times of these segments
  - ...

- These information are essential to interpret data correctly. Because LCGT will join a world network of GW telescopes, they have to be provided to collaborators as soon as possible.
- So that external scientists who want to do science using LCGT, can focus on their science without annoying how to interpret LCGT data in the future of GW astronomy.

Detector diagnostics

Finding non-stationary components

↓

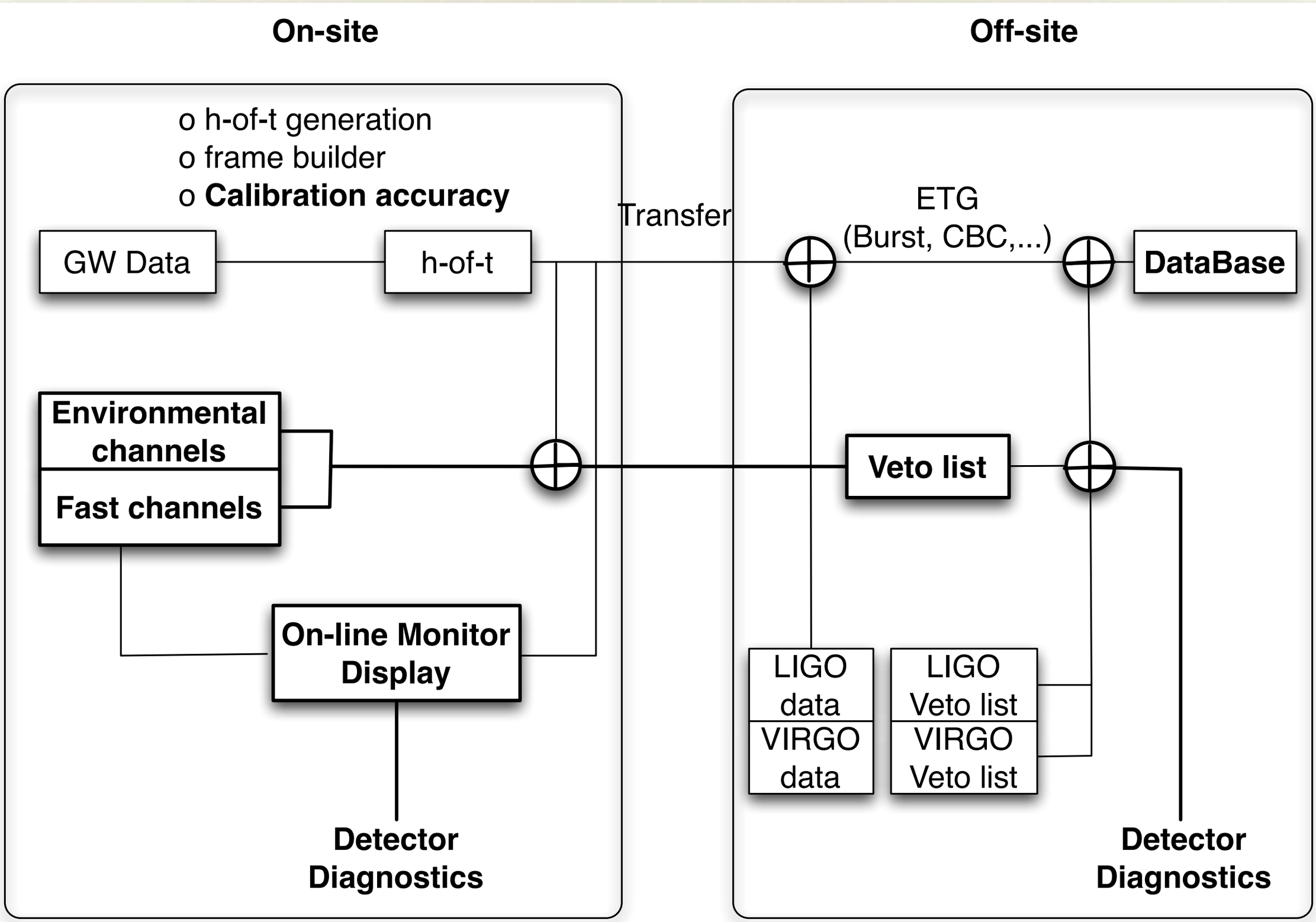
Identification of their sources and kill them

↓

Improvement to instruments

Before LCGT becomes black-box! (constructed)

DetChar Flowchart



Summary

- There are (on-going) activities of development of detchar software in LIGO, Virgo, GEO600 and TAMA300.
- Some of them should be imported. LCGT and the environment is unique, so new detchar technique must be developed.
- There are lots of room for new ideas
- Time schedule(not decided yet but) should be tight !
- Welcome to this activity !