Vers une calibration de précision des détecteurs d'OG

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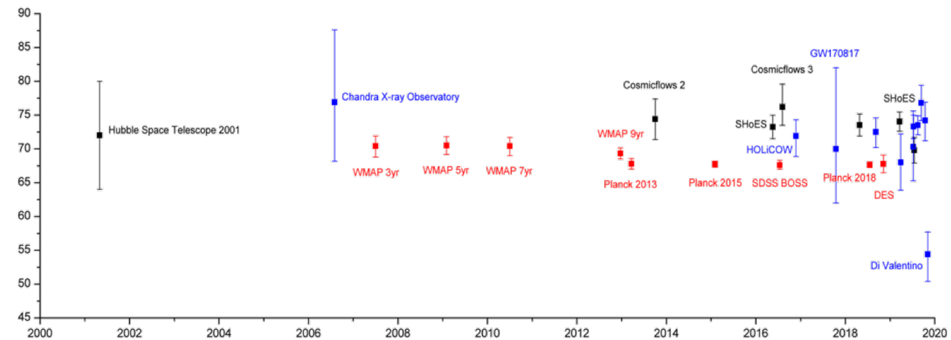
Why an accurate calibration for GW: Hubble constant

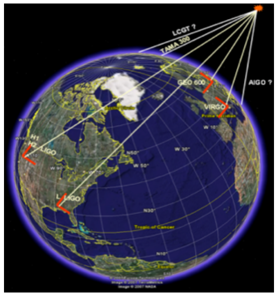
- Measuring the Hubble Constant:
  - Measurements with distance ladder
    - around 73 km/s/Mpc
  - CMB/BAO measurements
    - around 67 km/s/Mpc

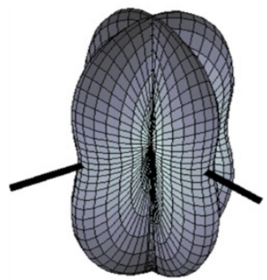


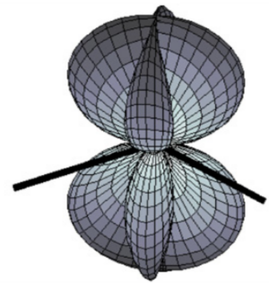
  - One GW event (GW170817): $H_0 = 72.4^{+7.9}_{-7.3}\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$ (7.6%.)
- Error on absolute h(t) calibration directly translate to H_0 error
  - The event rate is expected to increasing by a factor 3 at each run
    - Need to target sub-percent sensitivity for O5
    - Event more challenging for Einstein Telescope

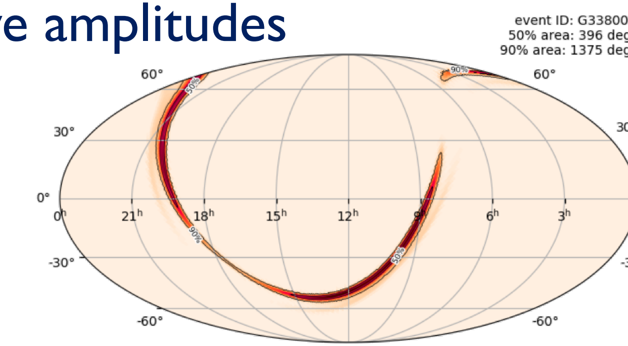
Why an accurate calibration for GW: sky maps

- Sky maps built using times of flight and relative amplitudes





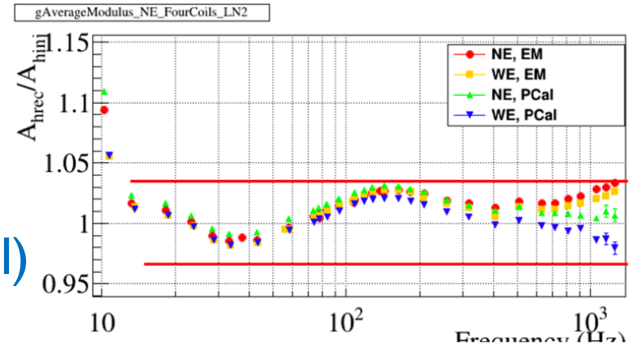




- Need a reconstructed h(t) accurately calibrated in:
  - Amplitude
    - Current SNR up to 20-30
    - Could expect SNR close to 100 within few years and much more with ET
    - → require sub-percent accuracy
  - Time/phase over the full frequency spectrum (need to target less than 10 us)
  - + Cross calibration between detectors

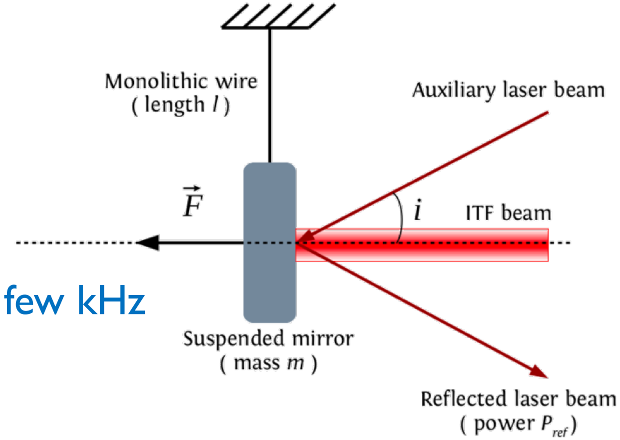
Calibration basic

- Principle: inject a know mirror displacement and validate/correct h(t).
  - Checks with a set of frequencies (runs) or large freq. band (dedicated studies)

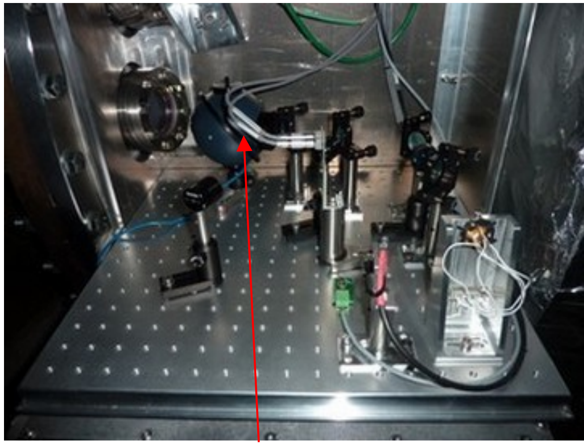


- Three techniques to move the mirrors:
  - Radiation pressure using an auxiliary laser (PCal)
  - Newtonian force using moving masses (Ncal)
  - Electromagnetic actuators (not the most accurate in the long run)
- Common challenges:
  - Do not introduce additional noise beside the injected calibration signals
  - Cross calibration with LIGO and KAGRA
  - Stringer requirements as the sensitivity improves

Photon Calibrator (PCal)

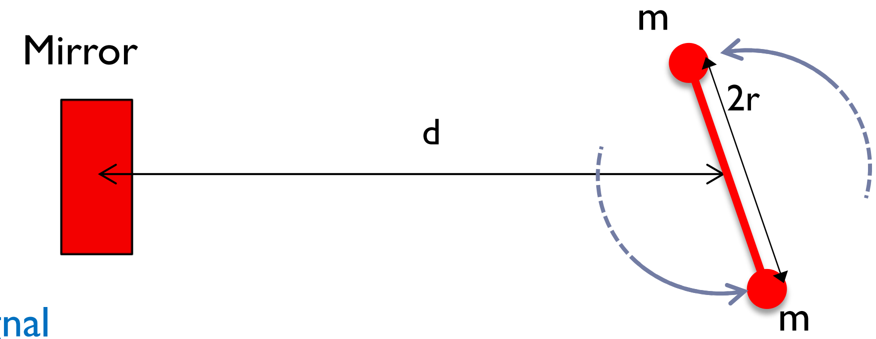


- Modulate the power of an auxiliary laser beam
- Benefits:
  - Versatile system: easy to produce complex waveforms, up to few kHz
  - Simple optical system, but….
- Challenges
  - Difficult to calibrate the absolute power reflected on the in vacuum mirror
    - Parameters of the optics, polarization…
  - Absolute calibration is based on calorimetry (power-meter),
    - Difficult to reach sub-percent level
    - Discrepancy of few percent's between national institutes
  - System stability (environment, alignment, cleanliness, ageing…)
  - Reduction of the laser power noise
  - Mirror mechanical response
- R&D plan:
  - Reach sub-percent absolute calibration
  - Install the system in (light) vacuum?



NIST-calibrated integrating sphere

Newtonian Calibrator (NCal)



- Basic model: rotor made of two masses
  - The non linear Newtonian force creates the signal
  - Signal at twice the rotor frequency; $1/d^4$ effect
- Expected benefits
  - Signal depends mostly on the rotor geometry and position
    - Mirror mass cancels out
  - No aging effect of the signal
  - Simple interface with the ITF: could be moved from one to another
- Challenges
  - Able to rotate at few hundred 100 Hz (10k-20k RPM), for years
    - "Without" mechanical vibration or electromagnetic noise
  - Well known geometry and mass
  - Be able to be install at different location with different orientation → support
  - Safety: no dislocation + protection in case of dislocation
- R&D plan: build (incrementally) prototypes that could reach a 0.1 % absolute calibration
  - Involve high precision mechanic, metrology, instrumentation,…