Current Status of Advanced LIGO

Kiwamu Izumi
for LSC

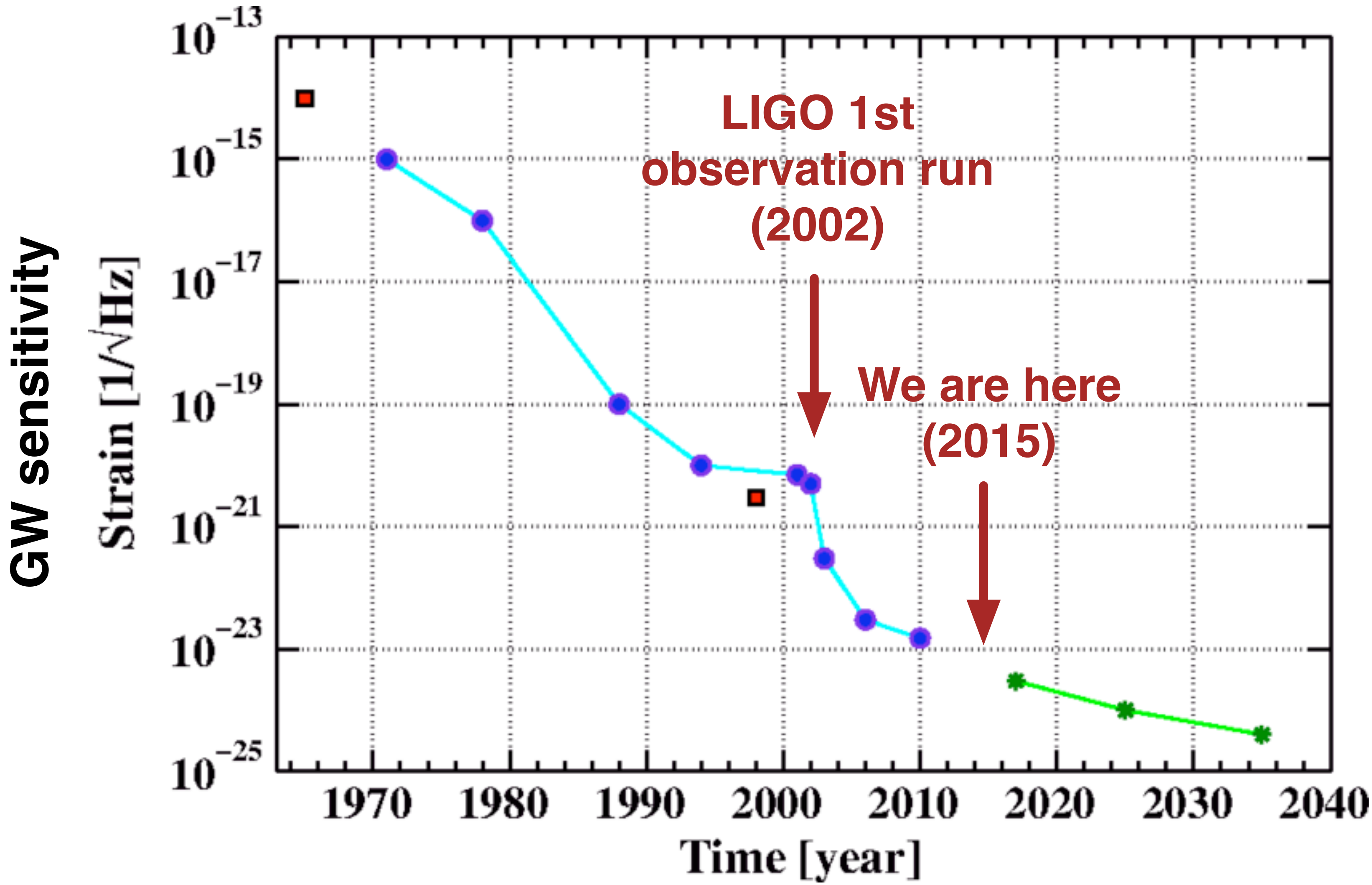
LIGO-G1500170-v2
31st PCGM University of Oregon (14/Mar/2015)

Contents

Evolution in 40 yrs

and beyond

Almost 9 orders of magnitude improvement



R.X.Adhikari, Rev. Mod. Phys.86, 121 (2014)

LIGO

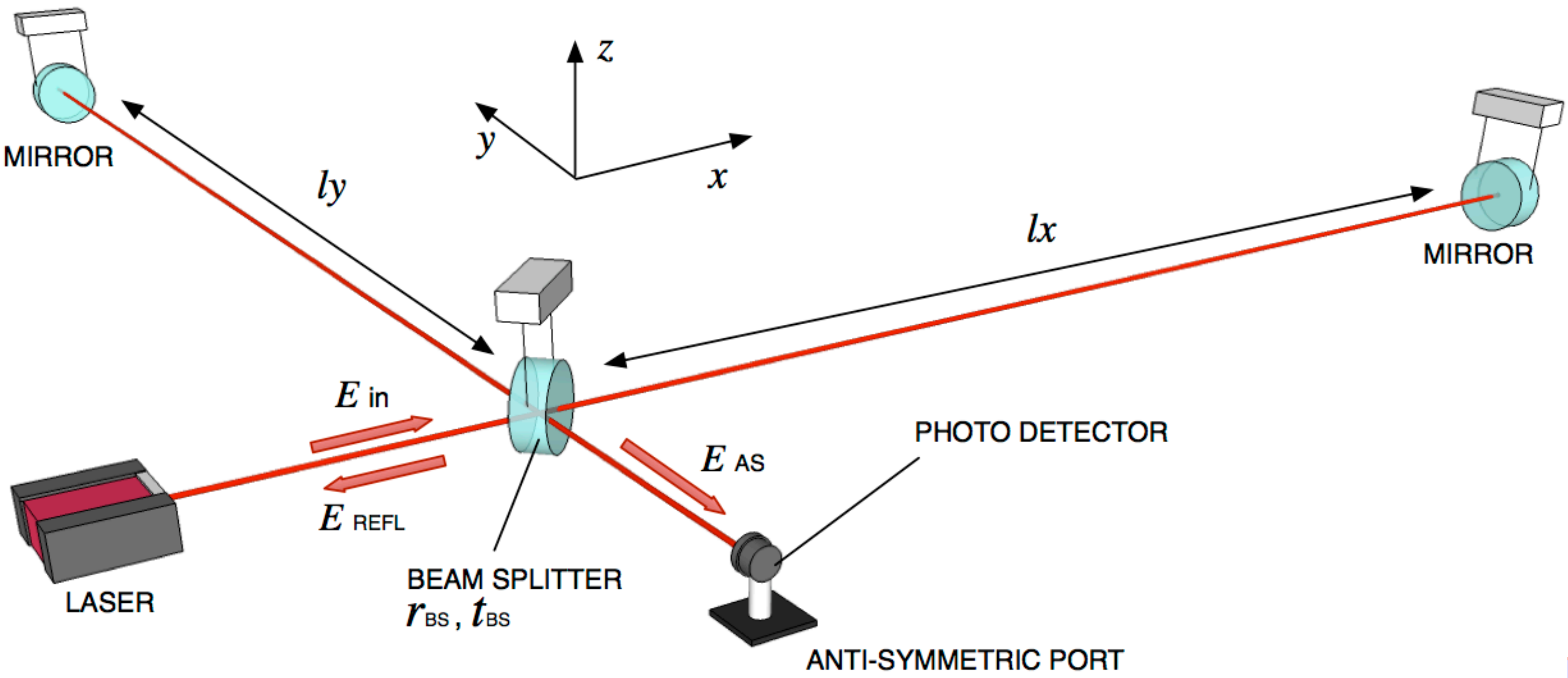
- LIGO = Laser Interferometer
  Gravitational wave Observatory
- Joint project between Caltech and MIT funded by NSF
- Collaboration with ~ 90 institutes all over the world

- The detectors have been upgraded to Advanced LIGO (aLIGO)

Science, 256, 5055, 325-333

Working principle

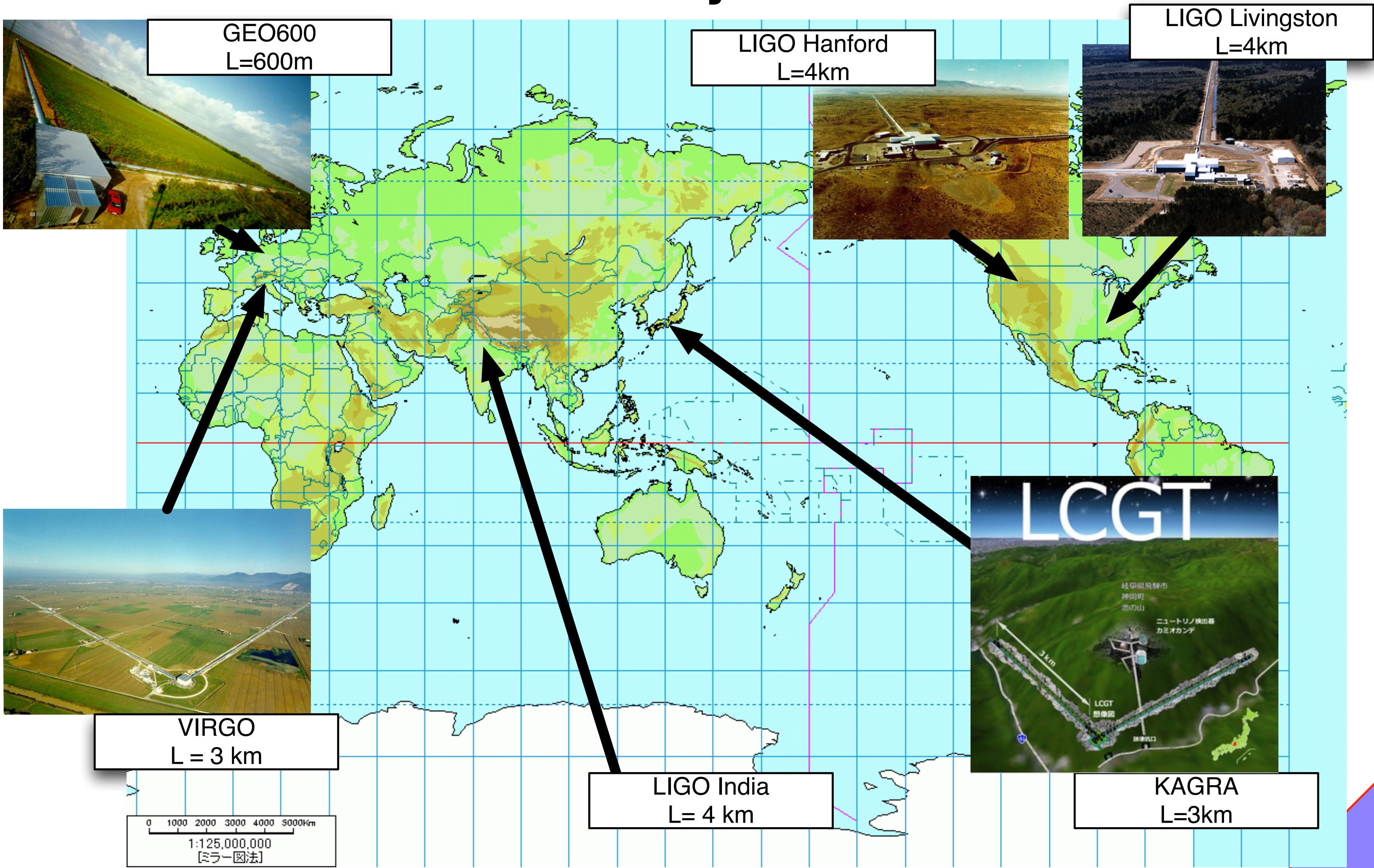
Sensitive in 10 to several kHz band



Two LIGO observatories

Wold Wide Network

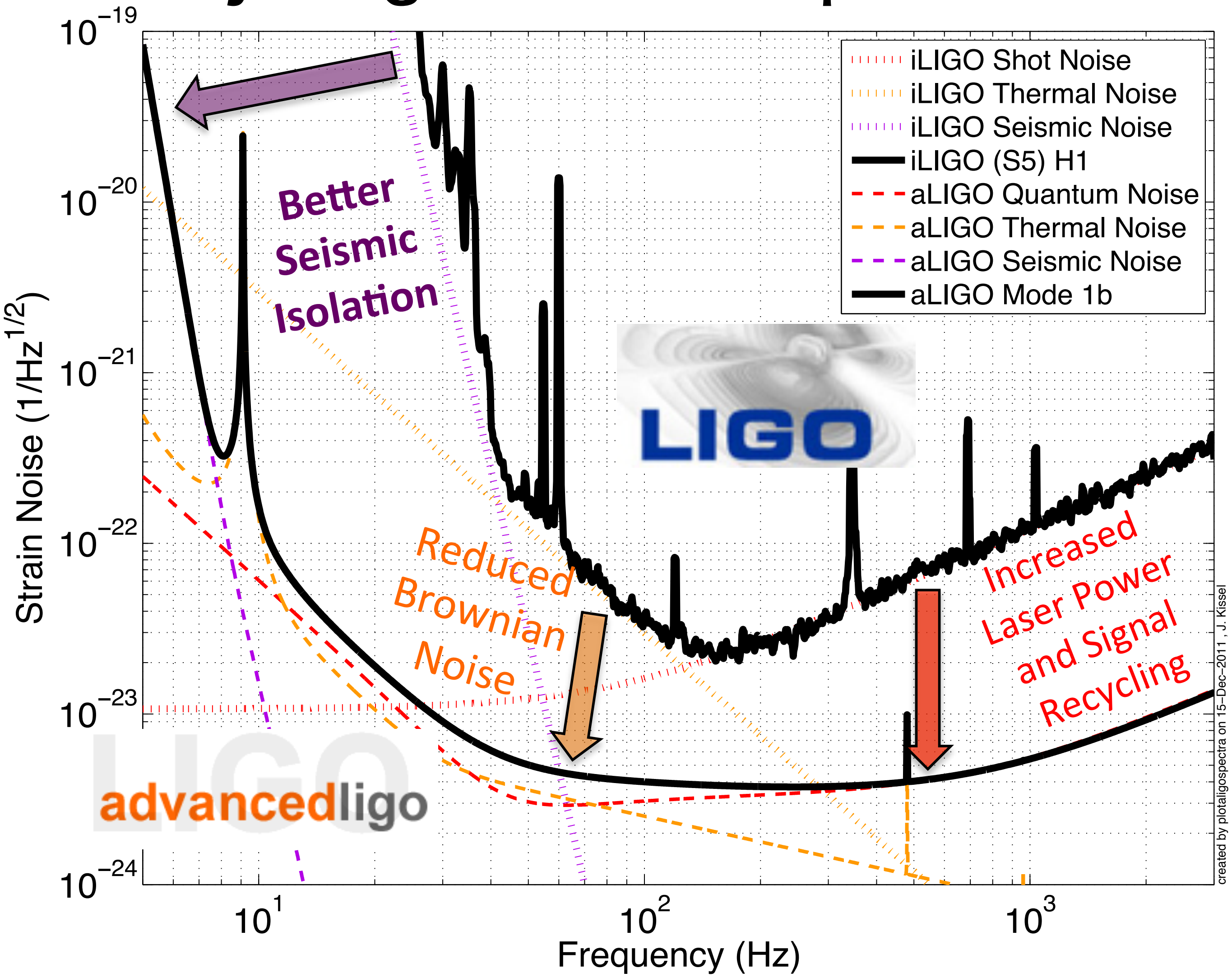
Allows for sky localization



Contents

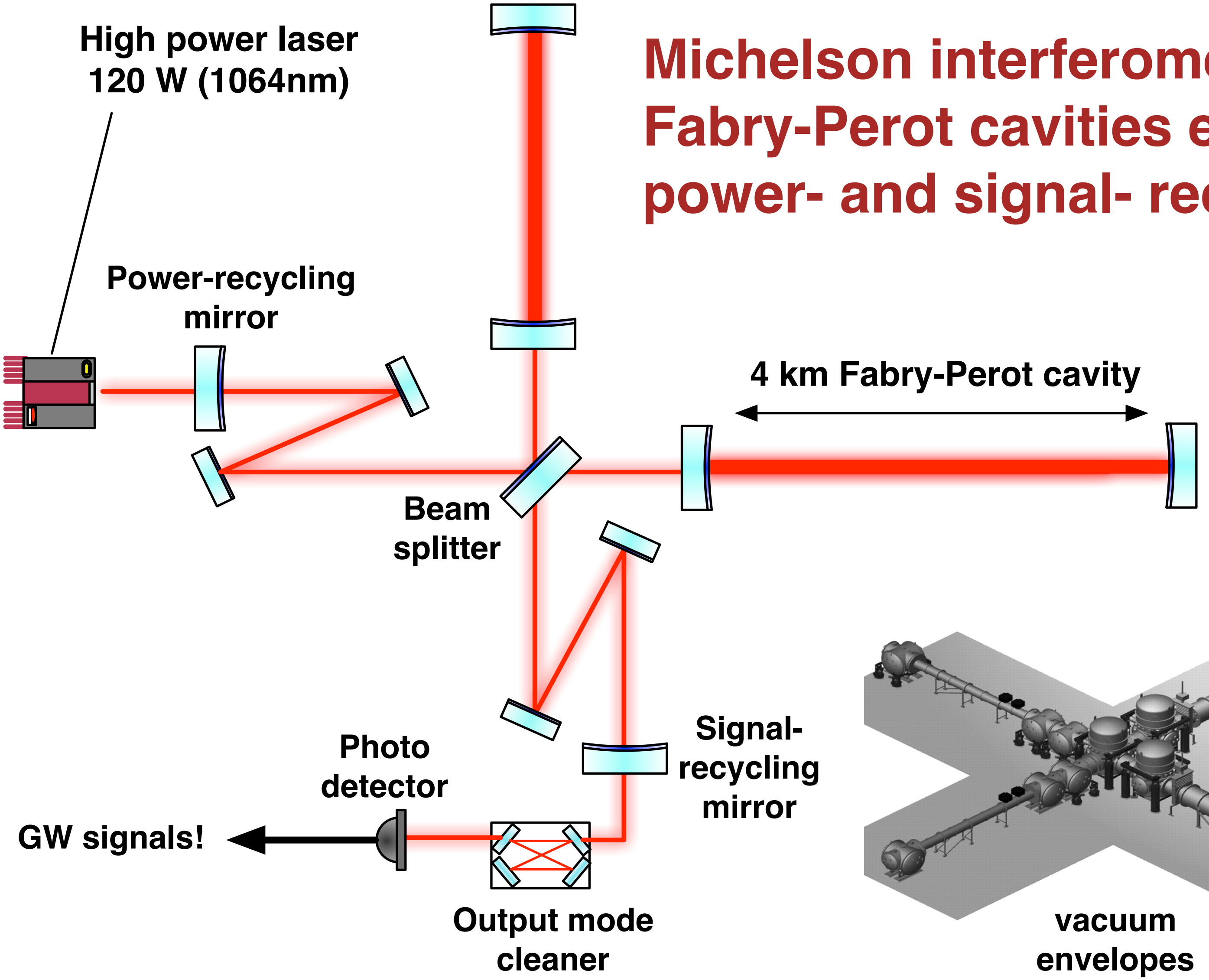
Advanced LIGO

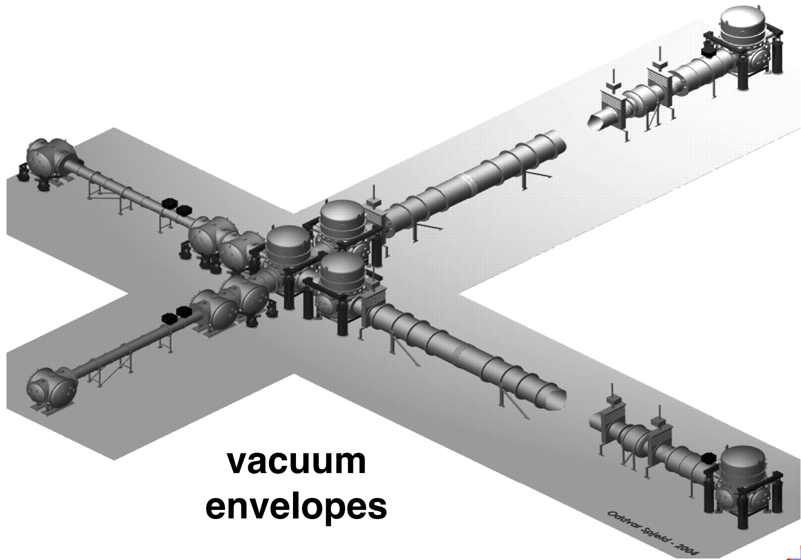
- Aims to increase the sensitivity by a factor of ~10
- NS-NS binary range of ~ 200 Mpc



Advanced LIGO

Michelson interferometer with Fabry-Perot cavities enhanced by power- and signal- recycling cavities

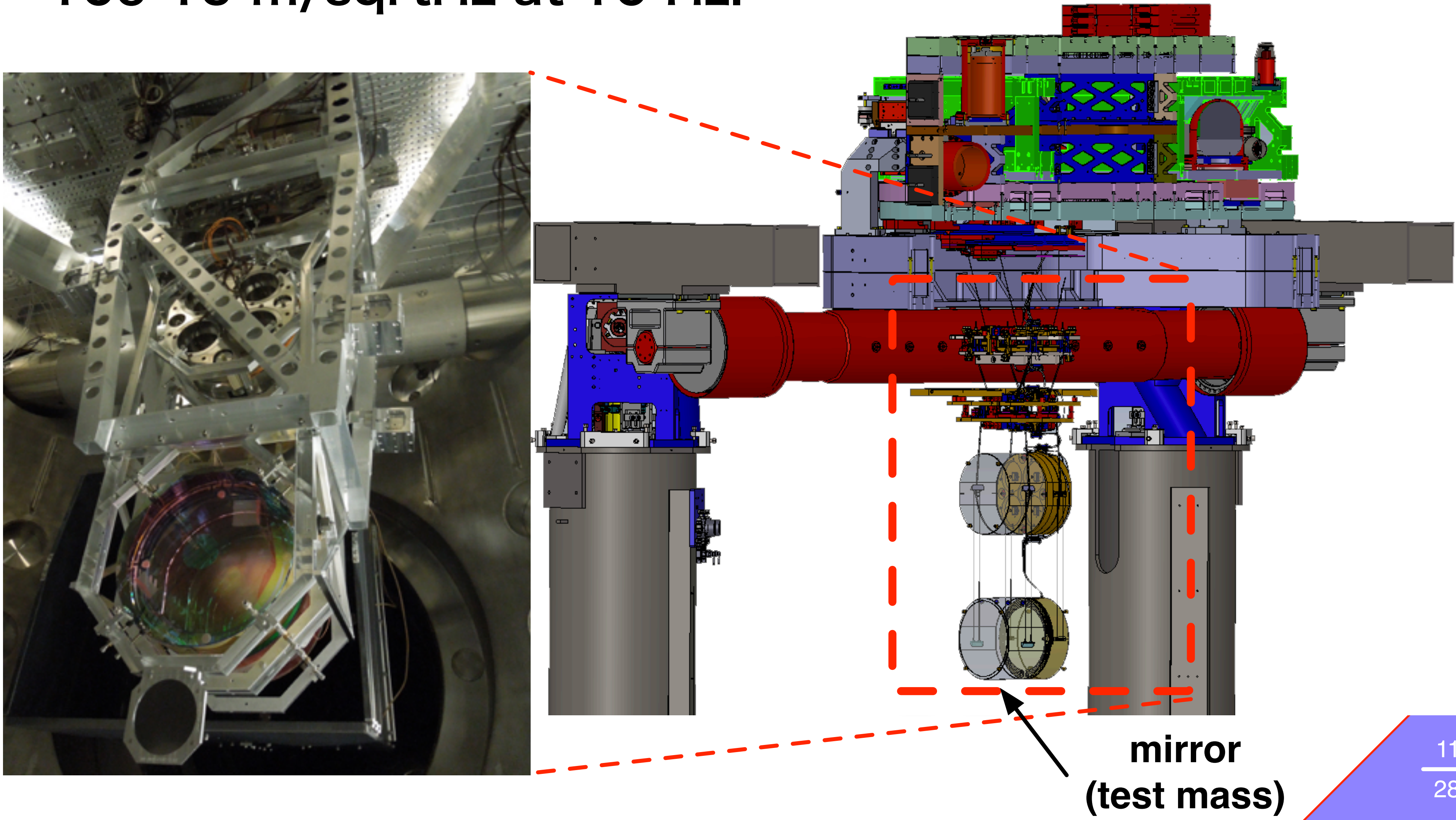




vacuum envelopes

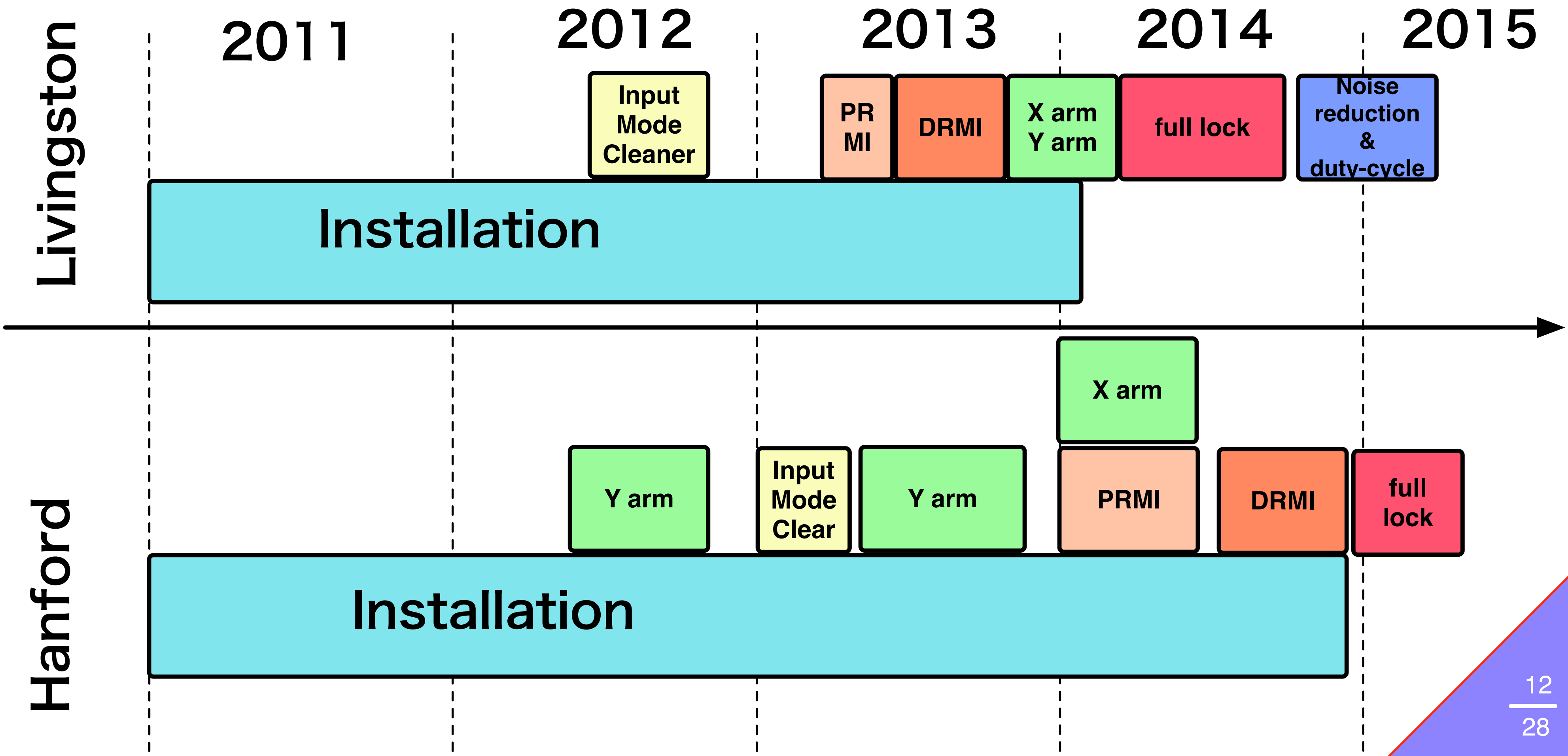
Vibration Isolation

- Multiple isolation stages to provide seismic level of 10e-19 m/sqrtHz at 10 Hz.



Installation and integration tests

We performed several integration tests
as the hardware was installed and became ready for testing



Current Status

Goals for the installation are acheived

Goals: we provide

- Fully locked interferometer.
- Stable operation for 2 hours.

We are preparing for observation runs

- Noise hunting
- Duty-Cycle improvement

with a low laser power (10-25 W)

Livingston achieved 60 Mpc binary range

Contents

What are difficulties ?

- More complicated interferometer control
  - Large number of active control loops to handle
  - Signal-recycling optical cavity is newly implemented
  - Weaker test mass position actuators

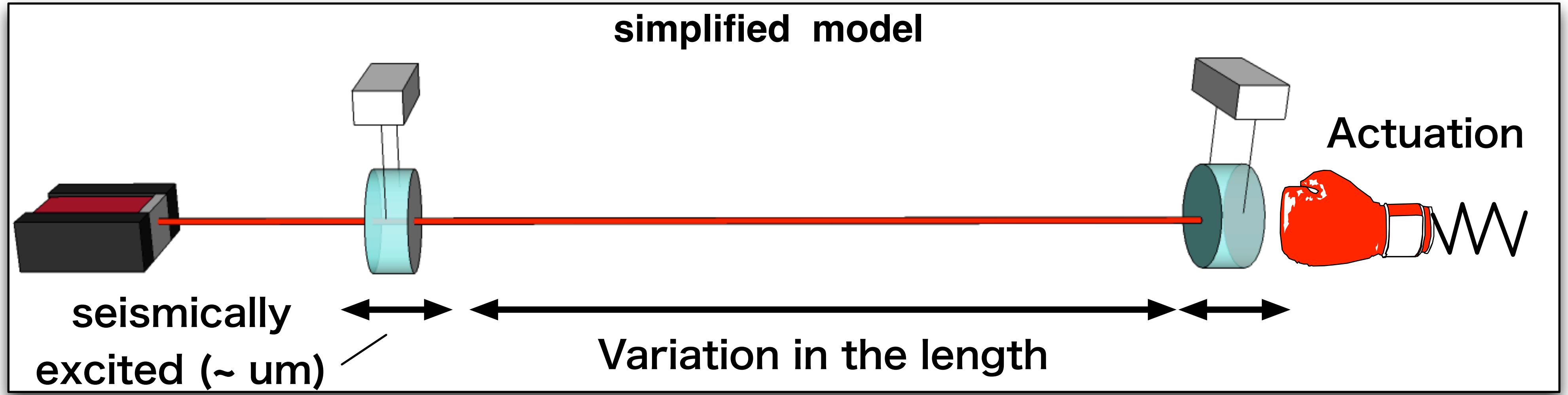
- Use of high power laser
  - Opto-mechanical couplings
  - Thermal deformations of mirror substrates

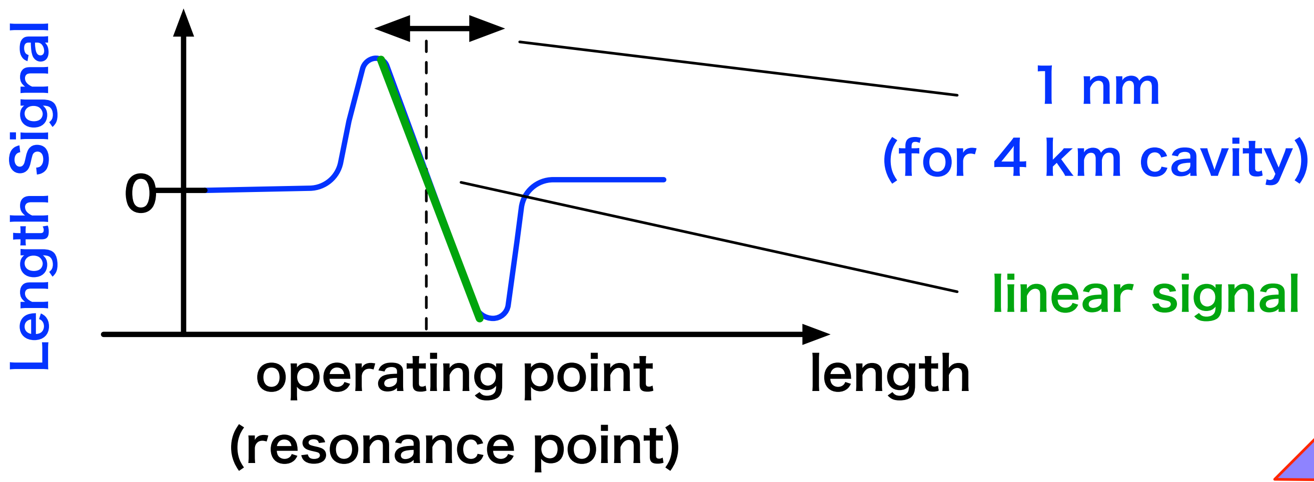
- Noise Hunting
  - Source identification

- And more

Interferometer Control

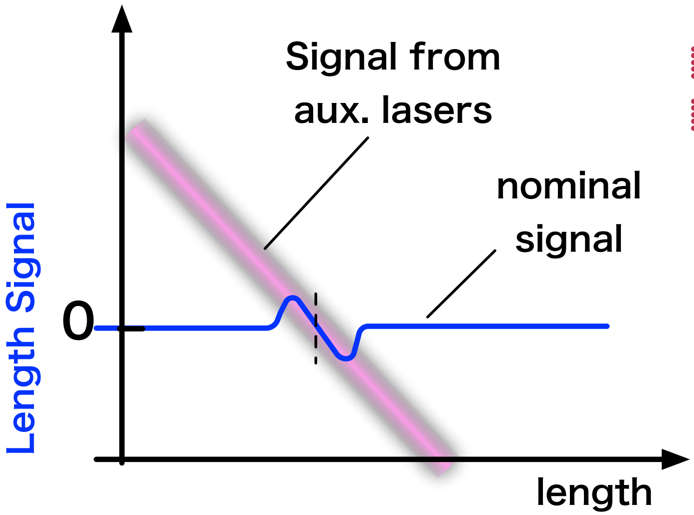
Signal can be obtained
only when the cavity is in the vicinity of operating point

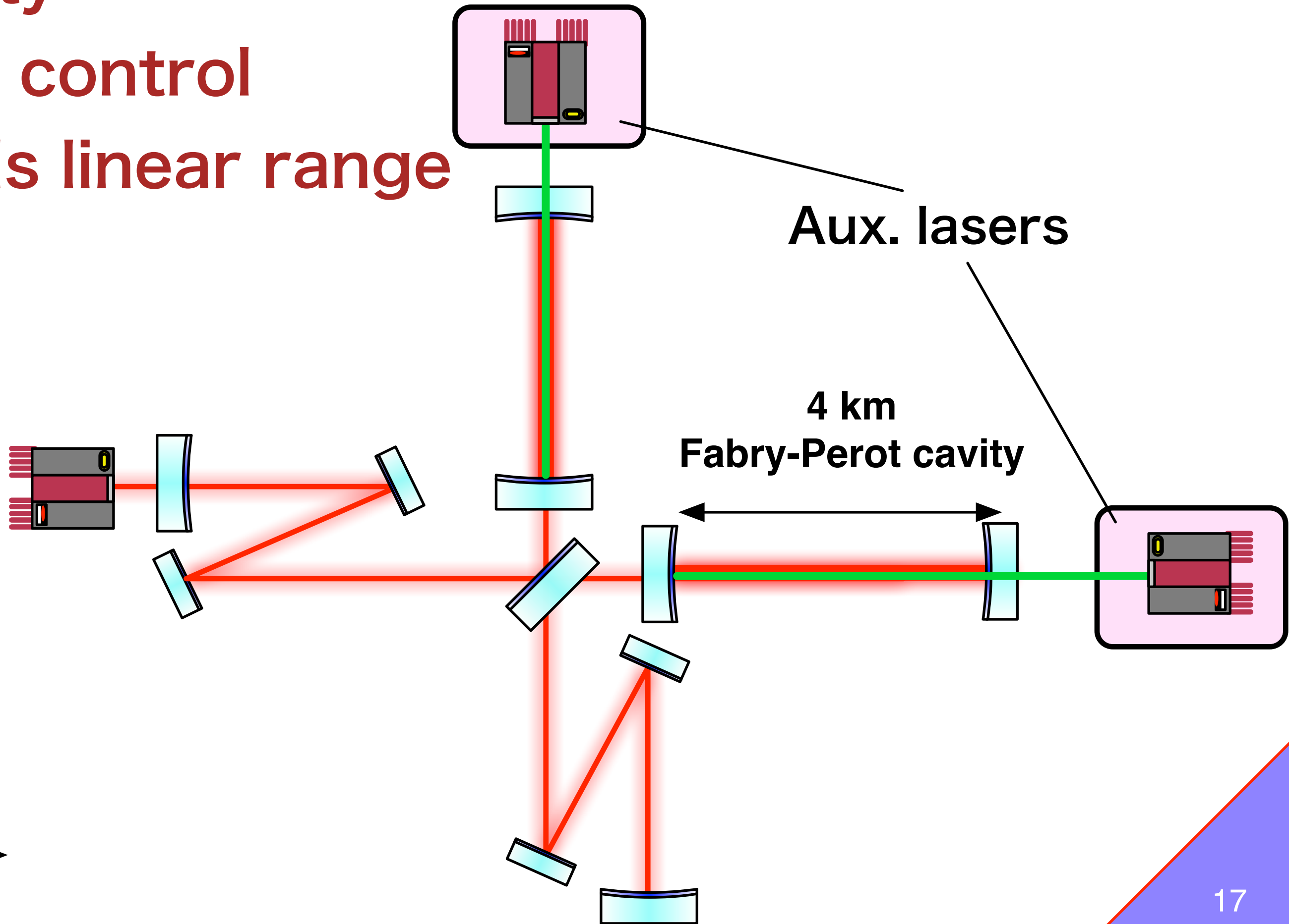




Arm Length Stabilisation (ALS)

- Uses auxiliary lasers (532 nm, visible)
- Senses the arm lengths independently
- Reduces complexity of interferometer control
- Effectively expands linear range but noisier

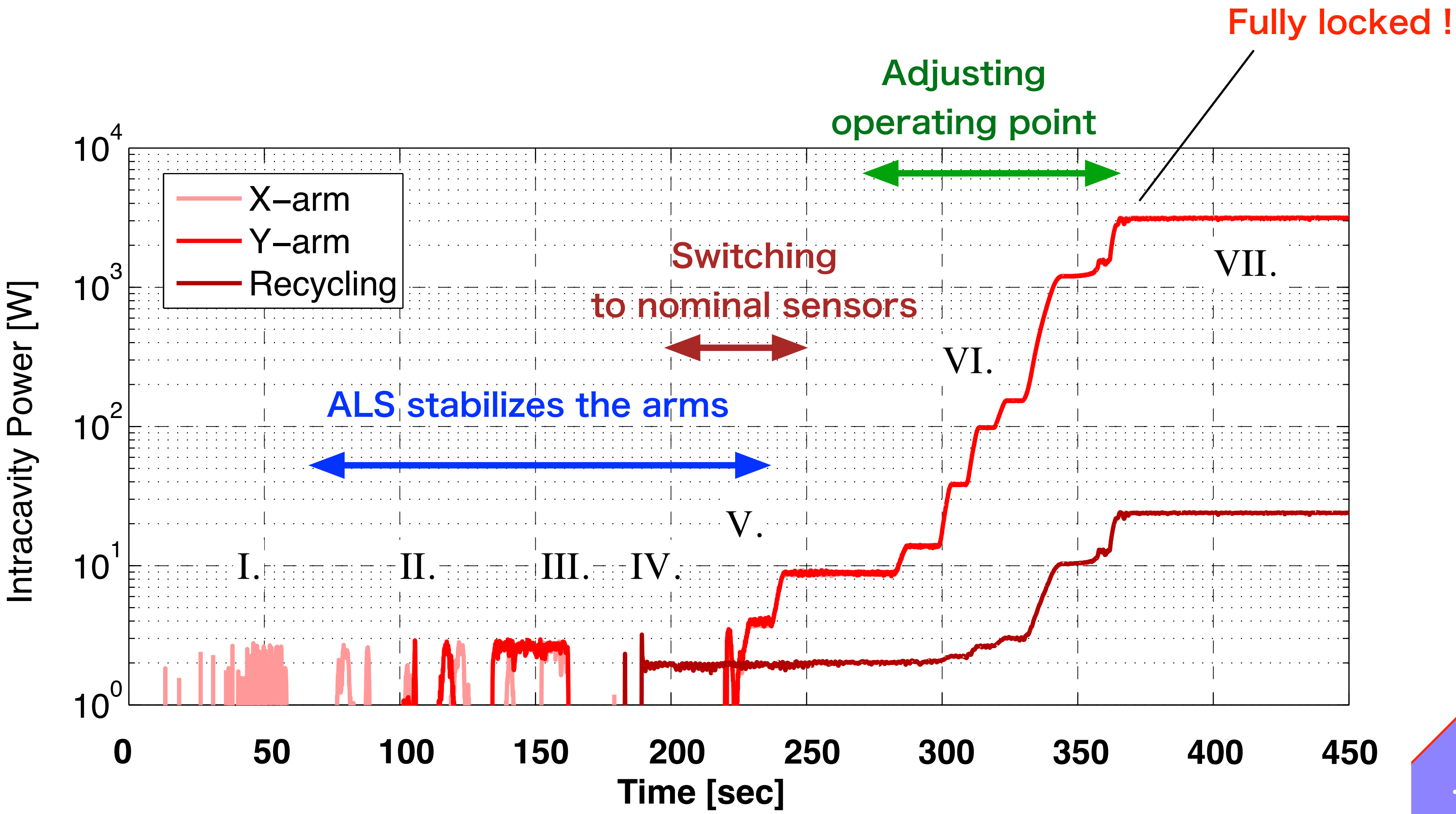




Details:[1] A.Mullavey et al., Opt. Express, 20, 1, 81 (2012)
[2] KI et al., J.Opt.Soc.Am.A, 29,10,2092 (2012)

Full lock achieved

- Achieved at Livingston in May 2014
- Achieved at Hanford in Feb. 2015



A.Staley et al., Class. Quantum Grav. 31,24 (2014)

Challenges with high power

- To achieve better quantum noise, laser power will be increased
- However high power laser is known to cause a number of issues

- Thermal deformation of the mirror substrates
- Radiation pressure will be large enough to cause opto-mechanical couplings

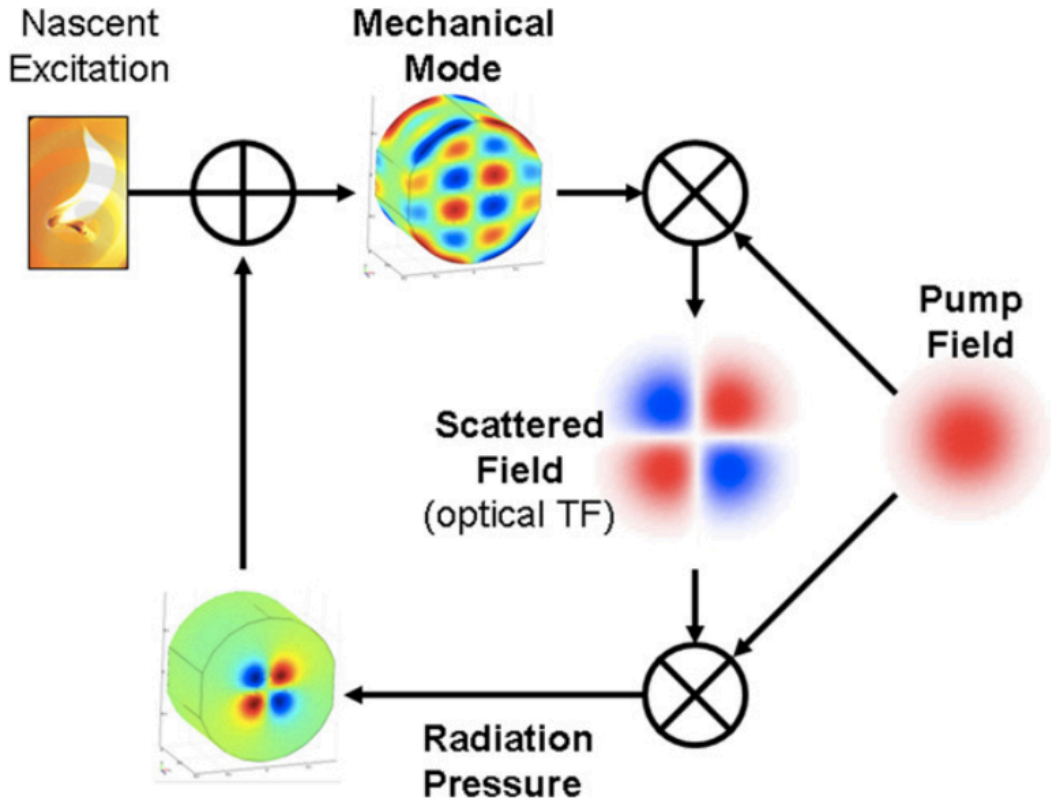
=> Parametric instabilities

=> Radiation pressure angular instability

=> we started experiencing these issues

Parametric Instabilities

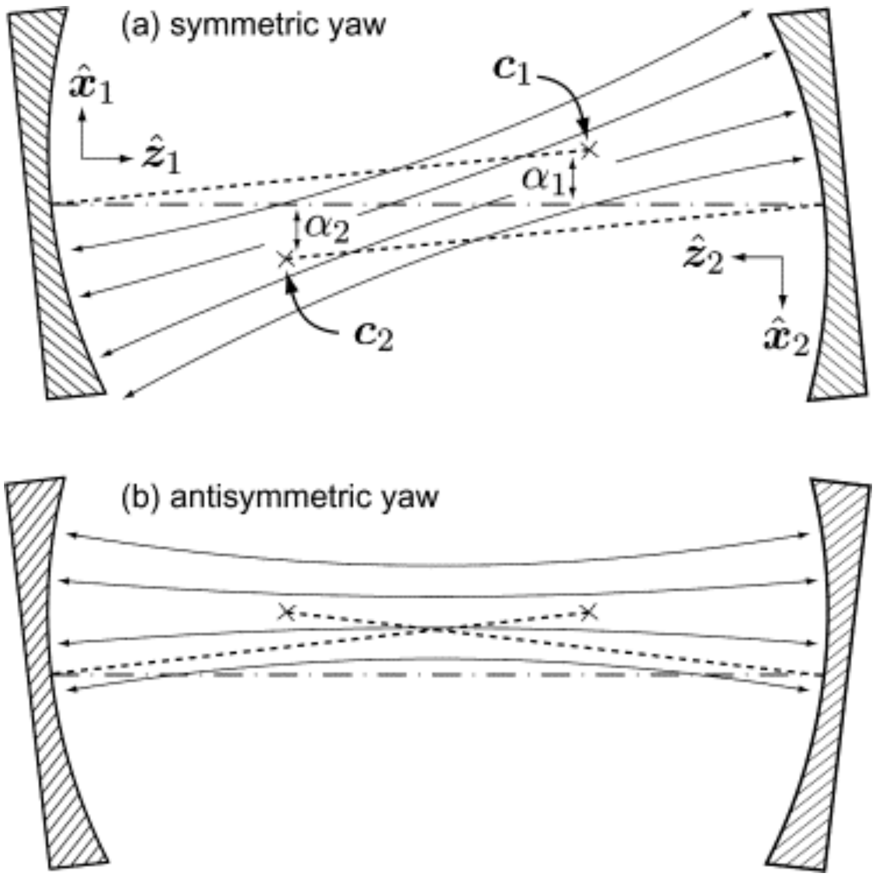
- Mechanical modes of the test masses couple to particular spatial mode of the laser field [1]
- Some modes can be unstable (it grows forever)
- Livingston started seeing an unstable mode at 25 W [2]



- An active damping technique will be applied [3].

[1] M.Evans et al.,Phys.Letters A, 374 665 (2010)
[2] M.Evans et al., arXiv:1502.06058 (2015)
[3] J.Miller et al., Phys.Letters A, 375 3 788 (2010)

Radiation Pressure Torque

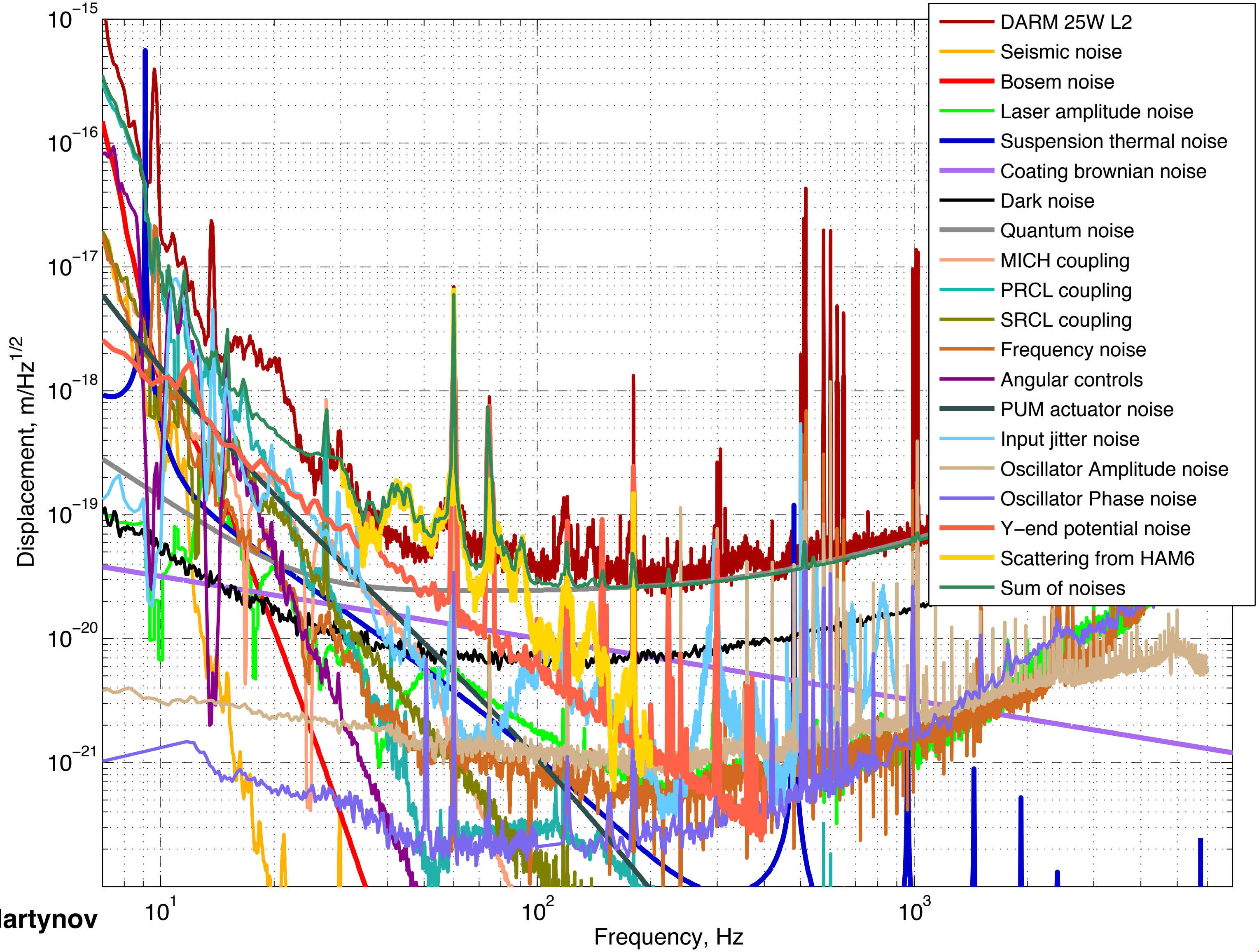


- Radiation pressure links two test masses [1]
- This leads to a unstable mechanical mode
- Experienced in initial LIGO and mitigated by active alignment control [2][3]
- We will enter the unstable regime

[1] J.A.Sidles and D.Sigg, Phys. Letters A, 354,3,167 (2006)
[2] K.Dooley et al., JOSA A, 30 12 2618 (2013)
[3] E.Hirose et al., Applied Optics, 49 18 3474 (2010)

Noise hunting (identification)

- Continuous effort to identify sources and reduce noise



plot by D.Martynov

Contents

Observation plans

- **O1 (nominally Sep.- Dec. 2015)**

  3 months

  40 - 80 Mpc range

- **O2 (2016 - 2017 ?)**

  6 months

  80 - 120 Mpc range

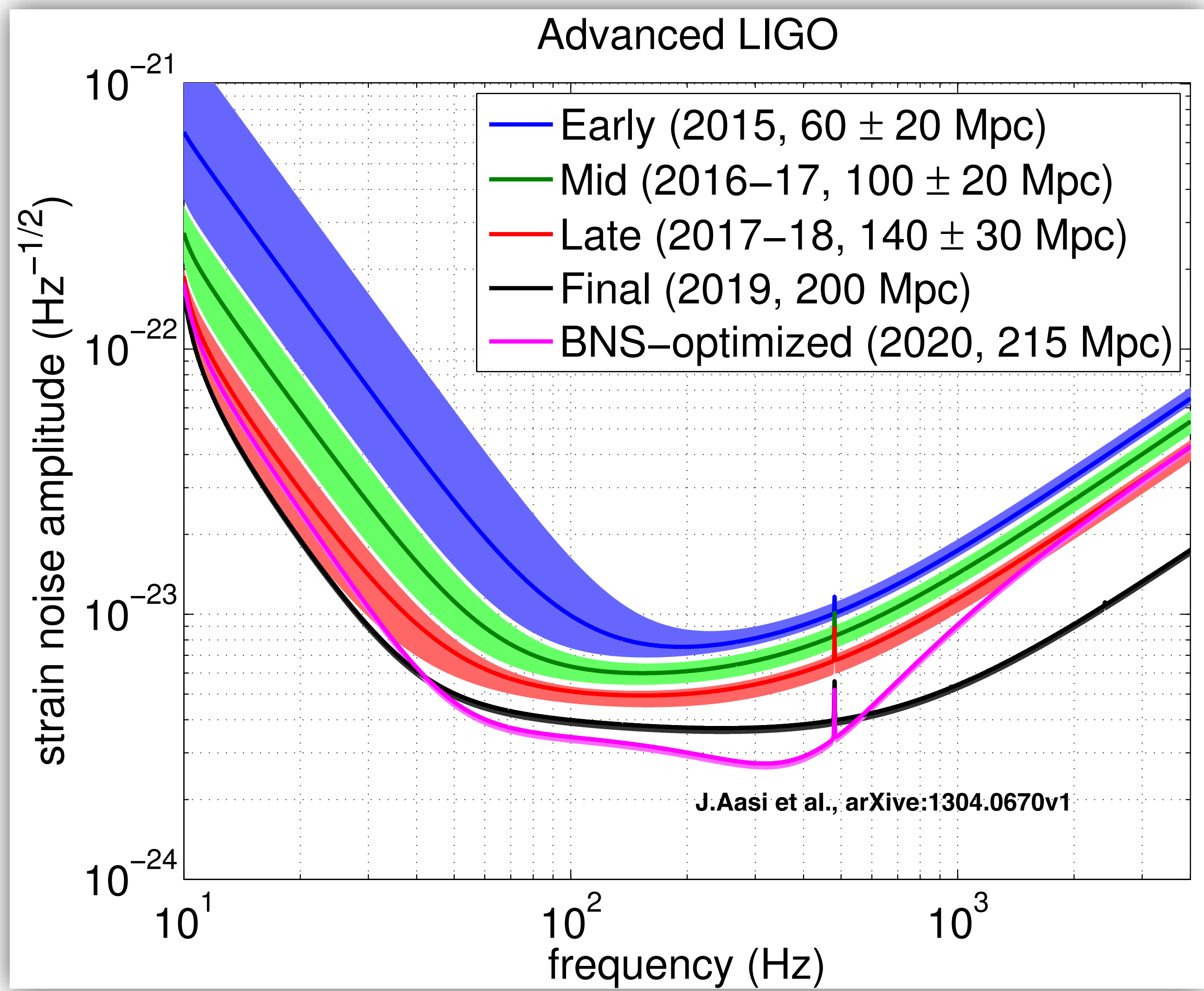
- **O3 (2017 - 2018 ?)**

  9 months

  110 - 170 Mpc range

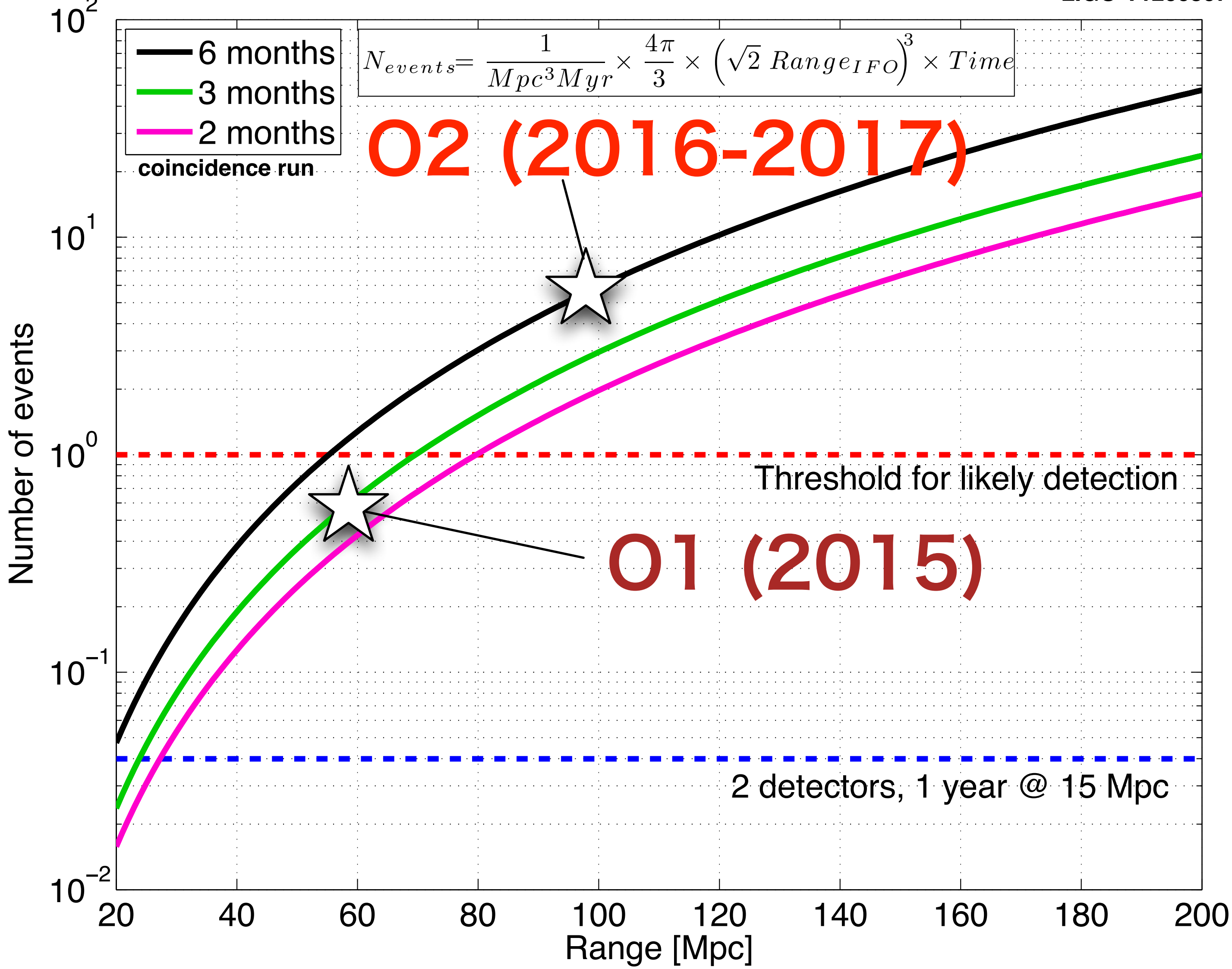
*** Strongly depend on how the commissioning activities go**

Example Noise Progression



Detection Rate

plot from L.Barsotti and P.Fritschel, LIGO-T1200307-v4



Contents

Conclusions

- Installation completed at both observatories
- Both observatories achieved full lock and demonstrated stable operation
- Currently in a low power state to improve noise and duty-cycle
- The planned 1st observation run starts Sep. 2015 with 40-80 Mpc sensitivity.