LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
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Technical Note **LIGO-T1200307-v4** 2012/08/14

Early aLIGO configurations: example scenarios toward design sensitivity

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Abstract

In this note we present a set of detector sensitivities as plausible representations of commissioning progress in the early phase of Advanced LIGO.

1 Introduction

Several aLIGO operational parameters can in principle be chosen to maximize different figures of merit: NS-NS range, BH-BH range, high frequency performance [1].

The **nominal aLIGO sensitivity** (183 Mpc NS-NS range) is based on the following parameters choices:

- **input power**: **125 W**, corresponding to about 770 kW in the arm cavities;
- **SRM transmission**: **T=20%**;
- **Homodyne phase**: the nominal value of the homodyne phase (which can in principle be tuned by changing the Michelson dark fringe offset) is 26° away from the natural value of 90°;
- **Signal Recycling Cavity (SRC) phase**: the phase of the carrier light inside the SRC is **0** in the nominal case (**zero-detuning**). Other tuning phases have been investigated to optimize a particular frequency range.

The experience with commissioning initial and enhanced LIGO is that design sensitivity is reached by a series of incremental improvements. We anticipate a similar progression for Advanced LIGO, and so here we establish a set of mock scenarios where design sensitivity is approached through increases in laser power and reductions in low frequency noise. To improve the sensitivity for low power operation, a higher transmission of the signal recycling mirror (SRM) will be adopted in the early days of aLIGO: $\mathbf{T = 35\%}$, instead of the nominal 20% [2]. In this case, a NS-NS range higher than 150 Mpc can be achieved with only 25 W of input power.

2 Plausible Scenarios

We imagine the commissioning sequence defined by target input powers of 12.5 W and 25 W, which can be considered as "low power" modes of operation, as they should require minimal thermal compensation [3]. To simulate excess low frequency noise, we add a $\sim 1/f^2$ noise term, with an amplitude that increases the low frequency noise by a factor of 3 or 10. This is a purely hypothetical noise; its purpose is to provide examples of excess noise spectra, based loosely on experience with first generation detectors.

We envision three plausible steps in the commissioning phase, with corresponding curves shown in figure 1:

- **Early**: 12.5 W input power, x10 noise at low frequency (55 Mpc NS-NS)
- **Mid**: 25 W input power, x3 noise at low frequency (110 Mpc NS-NS)
- **Near Final**: 25 W input power, target noise at low frequency (160 Mpc NS-NS)

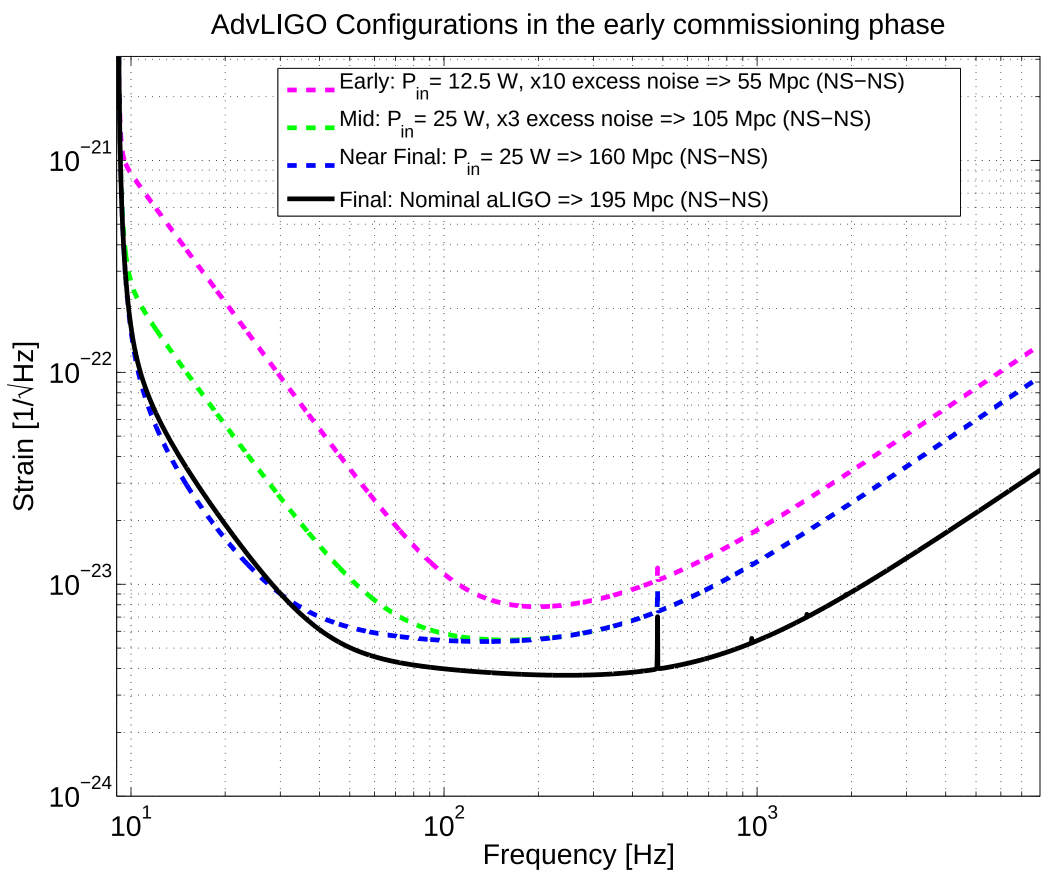

Figure 1: Plausible sensitivity curves in the early phase of the aLIGO commissioning. For reference, the light gray curve shows the sensitivity achieved in S6 (Enhanced LIGO).

A better representation of the uncertainty associated with these target curves is shown in figure 2.

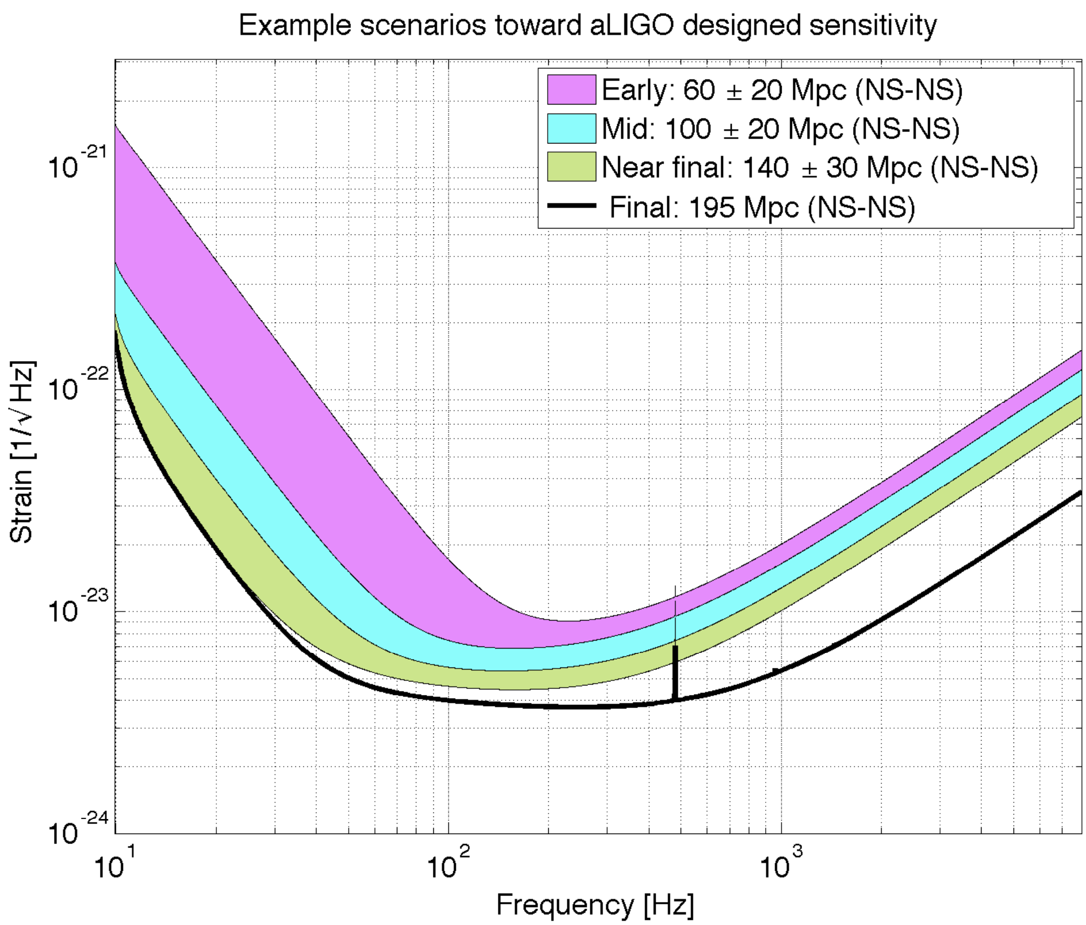

Figure 2: Plausible sensitivity curves for aLIGO. For reference, the light gray curve shows the sensitivity achieved in S6 (Enhanced LIGO).

Target dates for the three scenarios are the following:

- **Early**: 2015-2016
- **Mid**: 2016-2017
- **Near final**: 2017-2018

3 Detection expectations

Given the "realistic" rate estimate [4] for gravitational wave detection of :

$$R_{re} = \frac{1}{Mpc^3 Myr}$$

and assuming to have two interferometers running, one can estimate the number of gravitational wave detection events N_{events} as function of the average range Range_{IFO}, for different duration of observational runs:

$$\mathrm{N}_{events} = \frac{1}{Mpc^3 Myr} \times \frac{4\pi}{3} \times \left(\sqrt{2}\ \mathrm{Range}_{IFO}\right)^3 \times \mathrm{Time}_{Obs}$$

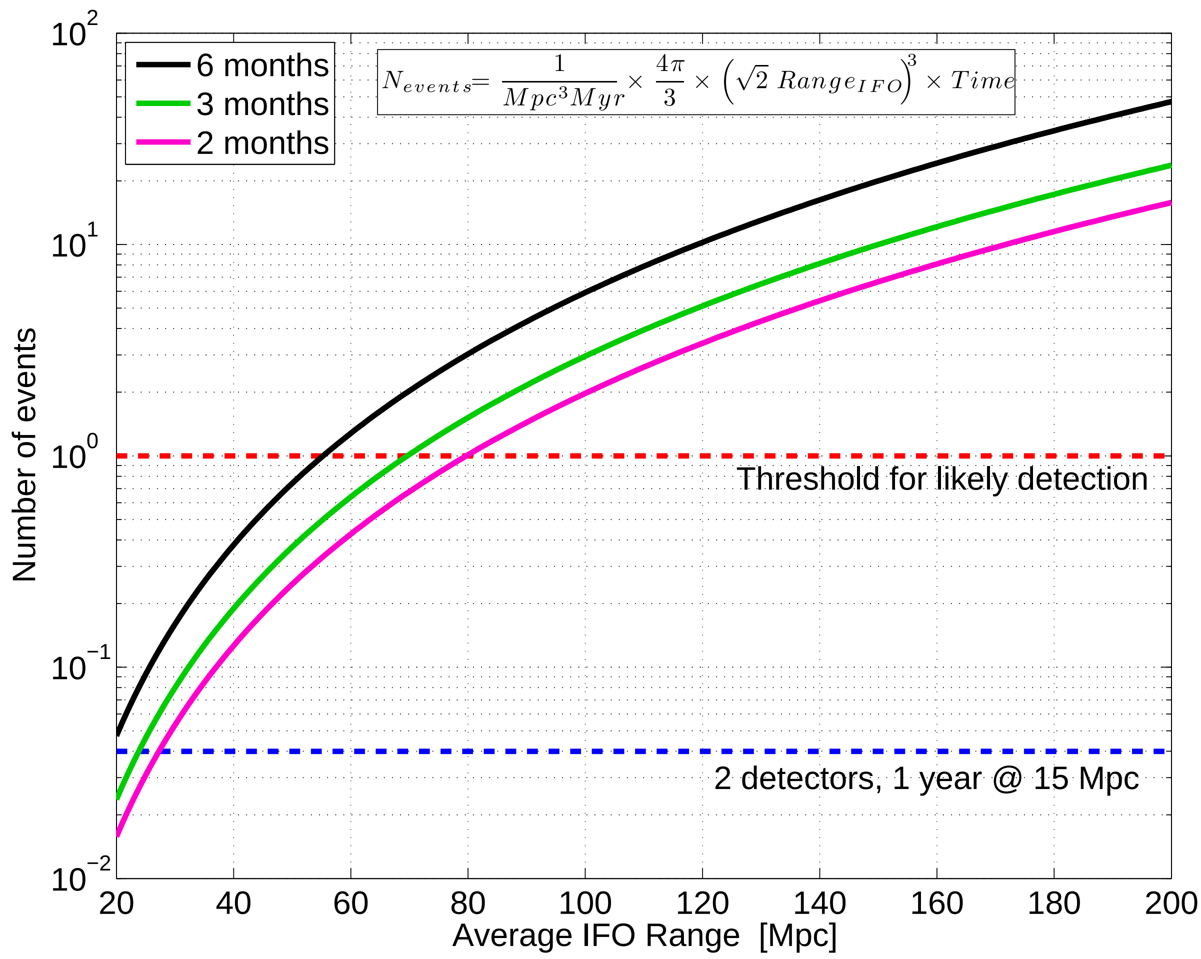

Figure 3: Number of events for two interferometers, each running at an average range Range_{IFO}, for different duration of observational runs.

Figure 3 shows a prediction of the number of events for hypothetical science runs of different duration: 2, 3 and 6 months. From this plot, some considerations can be made:

- a 2 month long science run in the "Early" scenario gives a probability of detection significantly higher than during S5 (simplified as 2 detectors running at 15 Mpc for 1 year);
- a 3 to 6 months science run in the "Mid" scenario (100 ± 20 Mpc) has a good chance of detection;
- a 6 months science run in the "Near Final" scenario has a good chance of detection even if the rate estimate is a factor 10 lower than the "realistic" estimate.

References

[1] P. Fritschel et al, *AdvLIGO Interferometer Sensing and Control Conceptual Design*, LIGO-T070247-01-I

[2] L. Barsotti et al, *aLIGO ISC design study for low power operation*, LIGO-T1200128

[3] M. A. Arain and G. Mueller, *Optical Layout and Parameters for the Advanced LIGO Cavities* LIGO-T0900043-10

[4] J. Abadie et al., *Predictions for the Rates of Compact Binary Coalescences Observable by Ground-based Gravitational-wave Detectors* Class. Quantum Grav. 27 (2010) 173001