LIGO

Initial LIGO Upgrades

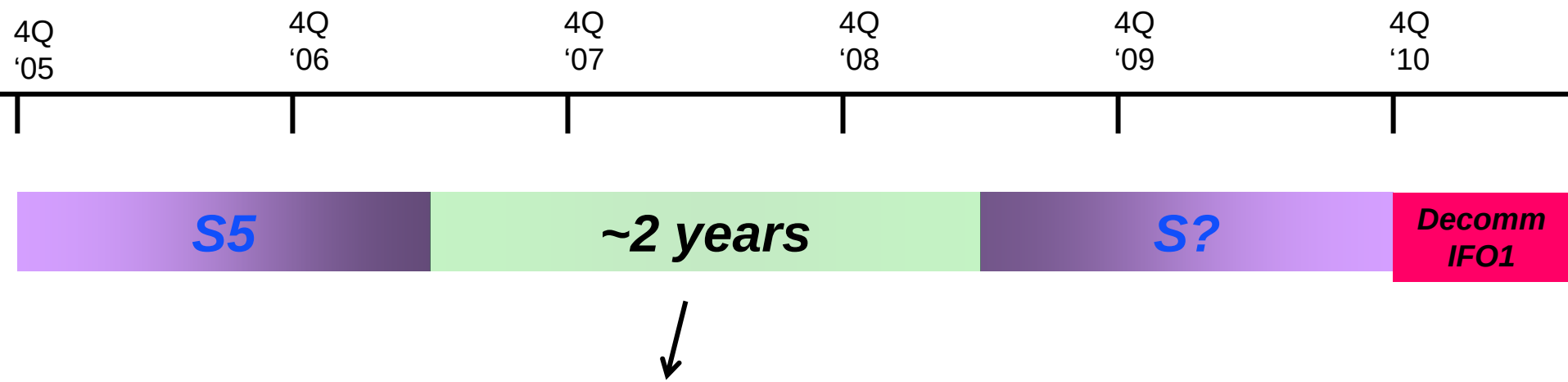
P Fritschel

LSC Meeting

LLO, 22 March 2005

G050109-00-D

The Next 5-6 Years



- Certainly enough time for one significant upgrade
- Possibly time for 2 upgrade steps, with a short run in-between
- Or limit to 1 step, and increase run time

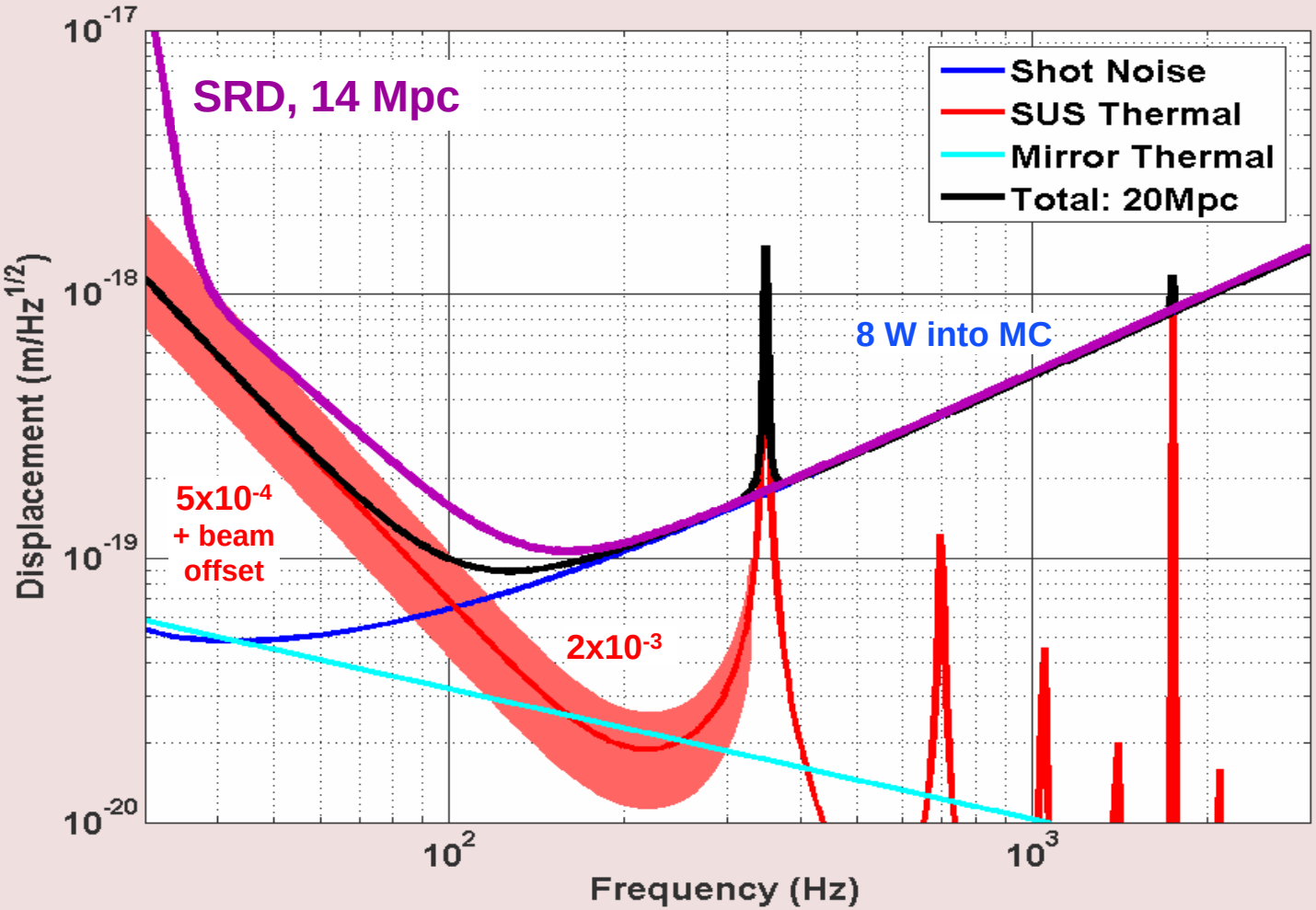
General considerations

- Any upgrade must account for time to install and fully commission it, plus time for running!
- Plan should favor technologies, techniques, subsystems that are part of Advanced LIGO
- Plan should consider contingency options for potential AdLIGO delays
- Initial LIGO components/features that are not candidates for upgrade
  - Core Optics (except possible spare replacements)
  - Isolation stacks
  - IFO beam path (e.g., no suspension change that moves the optic)

Resource constraints

- Equipment funds
  - Budget has tightened up
  - Stan: maybe $1-1.5M, over a couple of years, available for Detector upgrades
  - Ideas for other sources of $$ are welcome!
- Schedule
  - Plan must not delay Advanced LIGO implementation
- Manpower
  - AdLIGO development program must not be short-changed
  - Unclear (to me, at least) what this means for available upgrade manpower

Initial LIGO fundamental noises

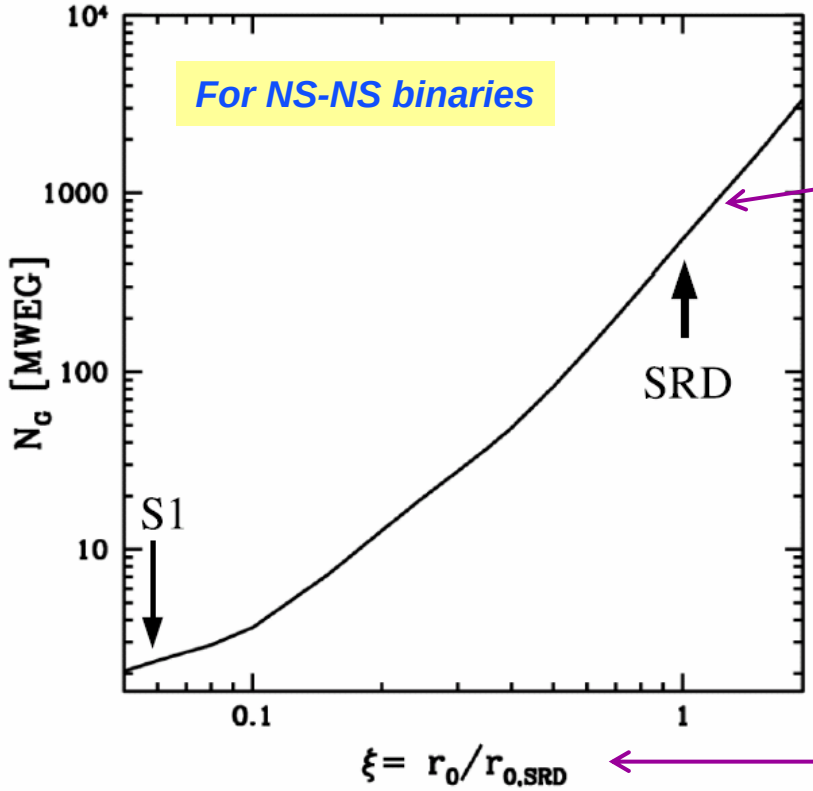


See also Rana Adhikari's thesis

Where to set the upgrade goal? Astrophysical impact

- How does the number of surveyed galaxies increase as the sensitivity is improved?

From astro-ph/0402091, Nutzman et al., "Gravitational Waves from Extragalactic Inspiraling Binaries: Selection Effects and Expected Detection Rates"



Power law: 2.7

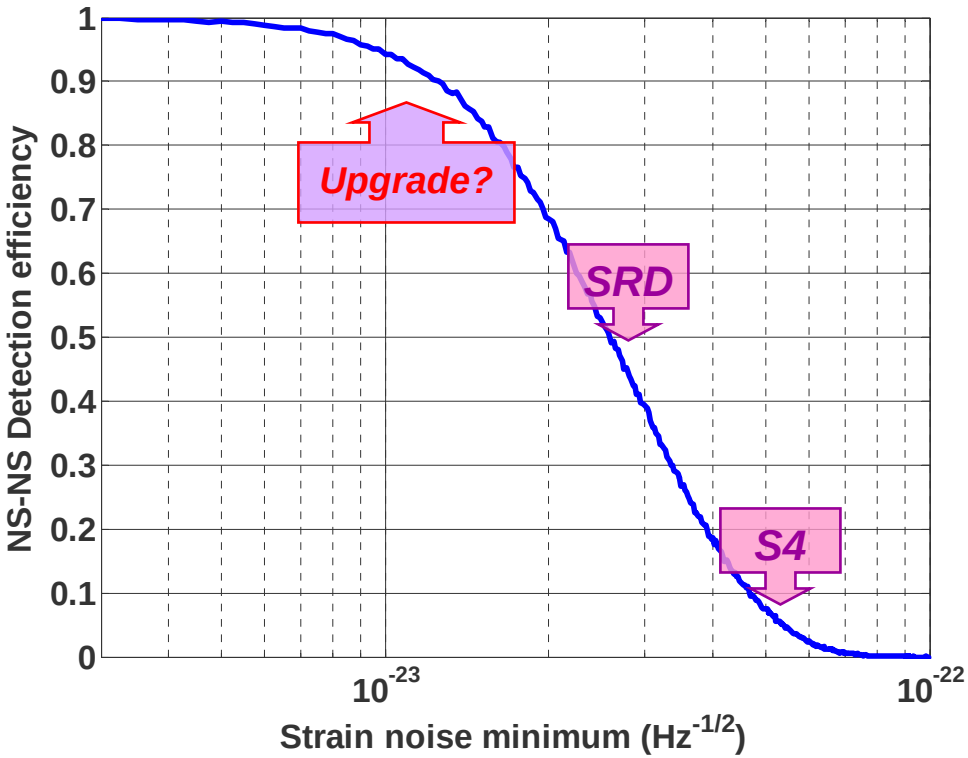
Factor of 2-2.5 reduction in strain noise,

⇨factor of 6.5-12 increase in MWEG

Prop. to inspiral range

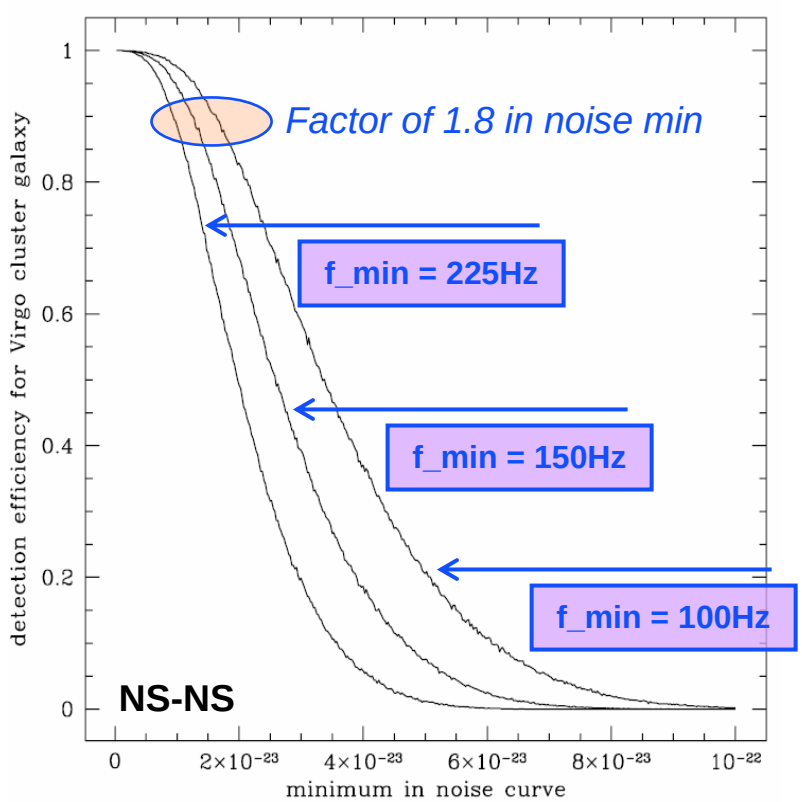
Sensitivity to Virgo cluster

Effect of reducing noise floor:



(same shape as SRD)

Effect of reducing min freq:



Data courtesy of Philip Nutzman

Detection rate estimates

Assuming factor of 10 increase in surveyed volume:

Source	***Initial LIGO***	***Upgrade***
NS-NS	~1 / 3000 yrs to **~1 / 3 yrs**	~1 / 300 yrs to **~3 / yr**
NS-BH	~1 / 5000 yrs to **~1 / 3 yrs**	~1 / 500 yrs to **~3 / yr**
BH-BH	~1 / 250 yrs to **~2 / yr**	~1 / 25 yrs to **~20 / yr**

Suspension options

- Find that current wire suspensions operate at wire-loss limit
  - Optimize with beam position shift (1 cm down from center)
- Find that current wire suspensions have excess loss
  - Design new clamping systems for the ends

Factor of 2-3 lower noise than SRD at 100 Hz

Beyond current wire suspensions: more than 3x below SRD

- Two wire loops
- Low-loss flexures
- Cradle for optic, suspended by silica fibers
  - See G020241 & G020242

***Research needed**: In-vacuum test suspension, to investigate violin mode Q's of current wire suspension, and potential variants*

Power increase: 4-5x more laser power

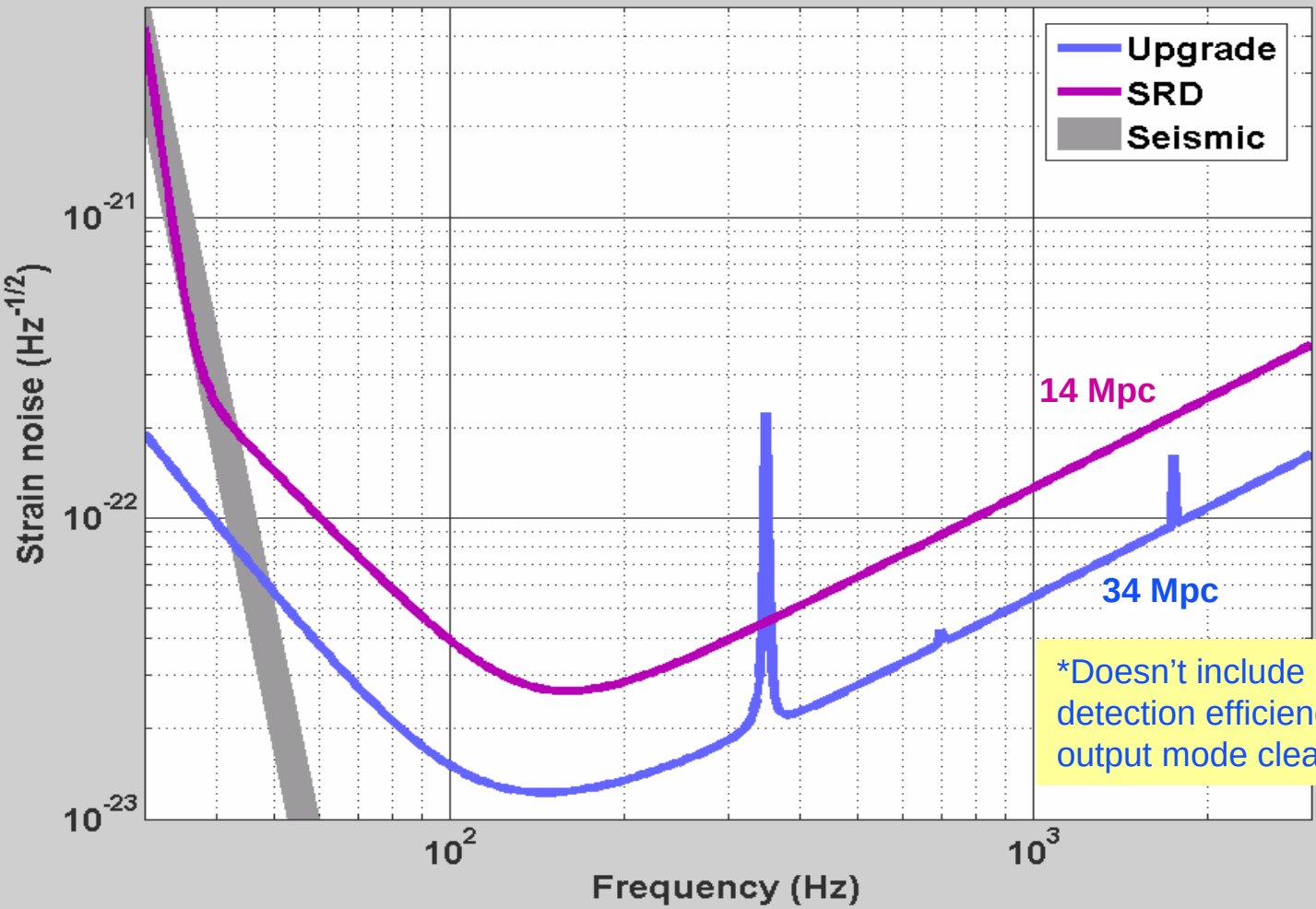
- Higher power laser
  - Amplify current LWE laser (being pursued, see T040063)
  - 50W laser from LZH, a la AdLIGO: Lutz Winkelmann talk
- Input Optics to handle it at the input
  - Dave Reitze talk
- Output mode cleaner to handle it at the output
  - Talks by Daniel and Rana
- Thermal compensation to handle it inside
  - Current system compensates 100 mW of absorbed power (H1)
  - If optics absorb at their expected level:

$$0.1\,\mathrm{W} = (P_{bs}/2)(4\,\mathrm{ppm/cm} \times 20\mathrm{cm} + 0.6\,\mathrm{ppm} \times 130)$$

$$\Rightarrow P_{bs} = 1.3\,\mathrm{kW}$$

  - Initial LIGO estimate: P_bs = 8W*0.65*40 = 200 W: *factor of 6 headroom*
  - Opportunity to try ring heater?

5x more power* & good wire suspensions + beam offset



*Doesn't include increased detection efficiency due to output mode cleaner

Other possibilities

- Add PEPI to the LHO test masses
  - Sensors (large part of cost) would be useable in AdLIGO
- Dealing with wind noise (both sites)
  - Adding good tilt sensing to HEPI
- Miscellaneous
  - Lower noise ADCs
  - Active beam stabilization for detection tables
  - Detection table seismic isolation
  - Acoustic mitigation at LHO
- Test mass double suspension ?
- Signal recycling ?

Next steps

- Power upgrade
  - Ingredients are clear, many are components of AdLIGO
  - Budget and implementation schedule needs to be fleshed out
- Suspension upgrade
  - Establish a suspension test setup to research what we have and potential modifications
  - More interferometer *in-situ* tests ?
- Produce a white paper on initial LIGO upgrades
  - Input from LSC is hereby solicited
  - Time scale, ~6 months