The Path to LIGO II

Overview

- what are the constraints?
- performance goals, astrophysical impact
- lessons from LIGO I
- strategies

Technical status

- requirements flowdown, configurations (Peter Fritschel)
- mechanical design - isolation and suspensions (Riccardo DeSalvo)
- lasers and optics (Eric Gustafson)

LIGO Laboratory view and role (Gary Sanders)

Timeline

LIGO I data run: 2002-2004

- unless detections made, instrument fully exploited after two years

LIGO II MRE support: 2002-2006

- assumes successful proposal in January 2001
- assumes ~4 year funding cycle, ramp up in 2002, ramp down in 2006

Likely data run for 'LIGO IIa': 2005-2006.5

- assumes one year for installation and shakedown of LIGO IIa configuration
- requires preparation, practice for installation
- again, unless detections made, 1-2 years observation sounds right

Likely data run for 'LIGO IIb': 2007-2009

One of the two improvements will be major, another minor

- in present planning, one upgrade will make significant changes to seismic isolation (could be IIa or IIb)
- other upgrade might take less installation/shakedown

Goals

Make a significant change in 'Physics Reach'

- significantly improved probability of detecting known sources
- significantly improved overall sensitivity

Fully exploit basic configuration

- power/signal recycled Fabry-Perot Michelson
- transmissive input optics
- pendulum suspension

Reaching some 'fundamental' limits

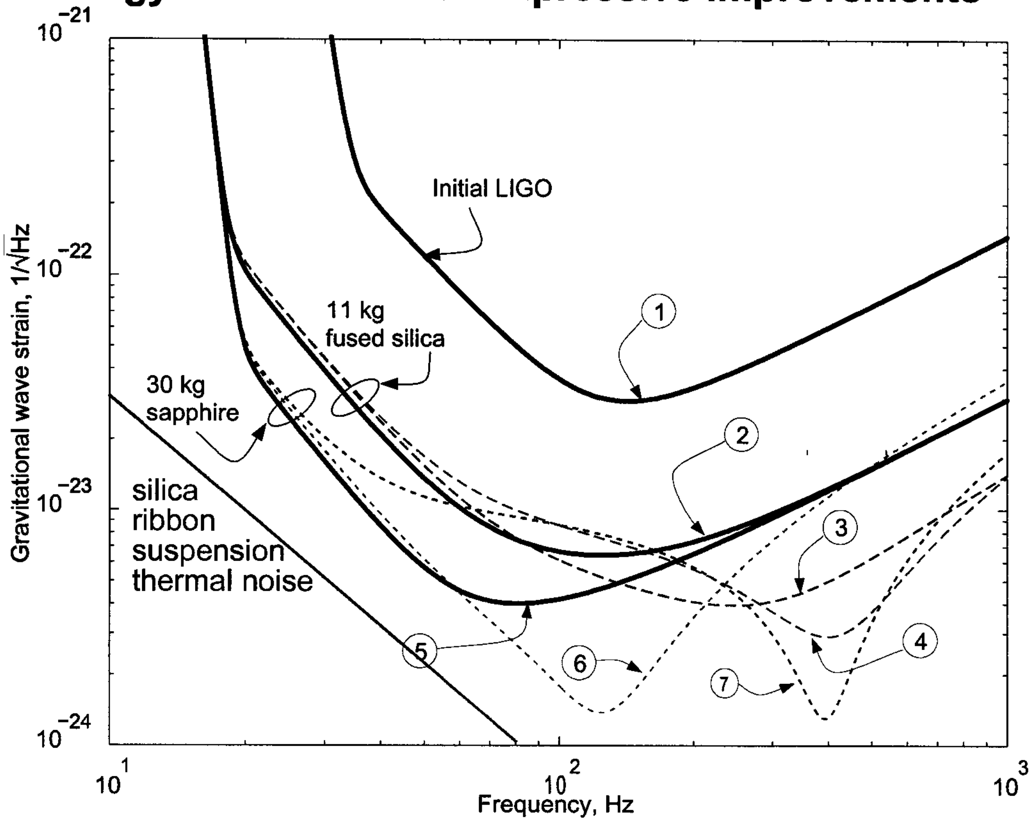
- standard quantum limit: optimize, not maximize, power
- Newtonian background

Leave exotica for LIGO III (but continue to pursue basic R&D!!!)

- cryogenic and alternative approaches to reducing thermal noise
- quantum-non-demolition techniques
- diffractive optics, other basic changes in optical configurations

Sensitivity, Technologies

Technology foreseeable for impressive improvements

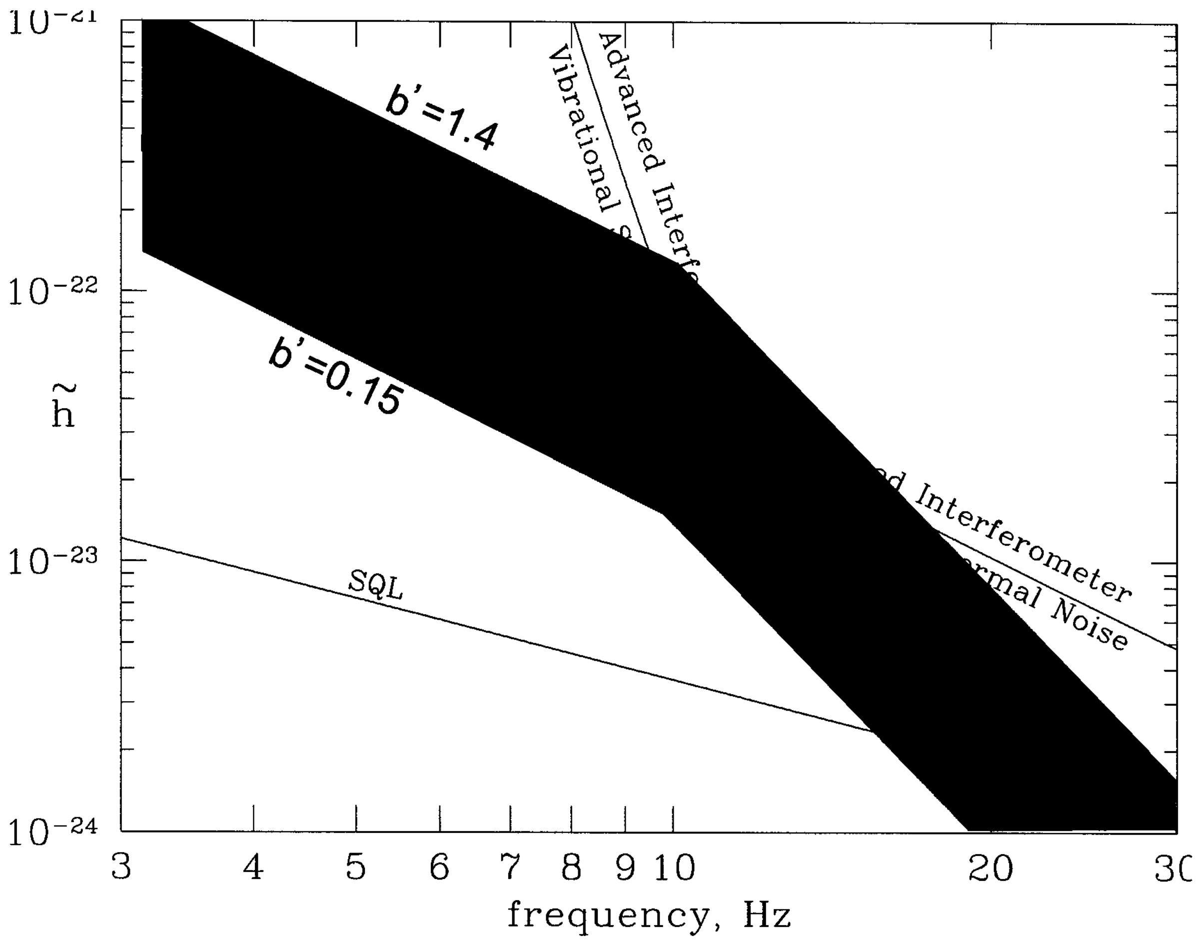


- in sensing system (~100 Hz and higher)
  - › broad-band improvement due to increase in circulating power (10 to 100 W, increased optical efficiency)
  - › addition of signal recycling (increased sensitivity in narrow band)
- in thermal noise
  - › pendulum thermal noise improvement through change to fused silica (factor 6 reduction), design of fibers (~factor 5 reduction): 30!
  - › test mass thermal noise: change to crystalline masses (factor 12)
- in seismic noise
  - › improved filtering to ~10 Hz lower 'brick wall' (touching gradients)

Newtonian Background

Hughes/Thorne

- could reach this 'advanced interferometer' low-frequency sensitivity



Physics Reach

CW sources

- possible pulsars in LF (10-30 Hz) region - strength estimates not encouraging
- Quasi-periodic sources: addressed via signal-tuned recycling in 100-1kHz range

Bursts

- much broader 'sweet spot', ~30-300 Hz, and factor 10 in sensitivity

Stochastic sources

- sensitivity to Ω varies with the low-frequency cutoff as $\sim f^{-6}$
- confusion limit of inspirals could be seen before individual events!

Binaries

- Relatively new prediction: population of 100-1000 solar mass BH
- final frequency ~ 1400 Hz/(totalmass/3M) for last 2π of phase
  - › 14 Hz for 150 solar mass; already tough; numerical/analytical upper limit during splash of 1% Mc^2
- Black Hole normal mode ringdown: damped sinus, Q=2-10
  - › frequency ~ 4 kHz/(M/3m); 40 Hz for 150 solar masses

Standard Candle 'seeing distances' for NS or solar mass BH binaries

- 6x LIGO I for 'available' technology; another 3x - 4x for all we envision for LIGO II upgrades
- altogether increase in volume over LIGO I of ~10 000

Inputs to upgrade strategies

Physics reach (as much as quickly as possible)

Some technologies close to 'available'

- fused silica pendulums, higher power lasers, thermal 'defocussing'

Some technologies challenging but require no 'breakthroughs'

- seismic attenuation, with some mix of active and passive elements
- modification of suspensions for work at low frequencies
- associated control problems

Some technologies show promise but need significant R&D

- crystalline masses/optics (industry development, millions/year)
- signal-tuned recycling (hard long lab work, multiple prototypes)

Some other important measures of improvements

- impact on observation: how much of present system to be removed? any rework of infrastructure? how much 'shakedown'?
- ability to test in advance: performance to requirements, ease of installation, reliability
- cost of new elements: R&D, design, materials
- cash flow: integral from 2002-2004 might not suffice for some large changes
- modifications of existing systems: costs, 'palatability'

Notions of costs

Magnitudes

- MRE is minimum ~$50M
- an upgrade of ~20% of original cost seems reasonable - so ~$60M

Typical funding profile

- first year, last year at ~1/2 peak yearly rate
- total duration of funding: 4-5 years

LIGO I costs:

- rough estimate, removing non-recurring costs, sharing with operations
- LIGO I detector components and labor would cost ~$60M (including contingency, management/cost/schedule, system engineering)
- LIGO I detector components alone cost ~$26M, R&D ~$6M, ~25% contingency not included (i.e., our initial best estimate of costs)
  - this was in '94; if 1.05 inflation, multiply above by 1.5
  - includes ~30 man-years of R&D, ~100 man-years of design/fab

LIGO I installation scale:

- ~18 man-years to remove then re-install LIGO I isolation/suspension
- (likely scenario is ~2/3 this mechanical installation effort)

Steps along the Path

Immediate collapsing of design options

- mid-June for Suspensions/Isolation working groups
- mid-July for Lasers/Optics, and Configurations groups

Present to LSC at July LSC meeting

- intensive working meeting with technical leaders
- presentation at plenary session for 'ratification'
- top-level requirements review
- conceptual design presentation

Costing, manpower, reality check by Lab in August

- close LSC- Lab working session
- capitalization of Lab scientific and engineering expertise

Detailed R&D plan, first draft of project plan to NSF in September

- dose of reality for LSC

Program Lab R&D efforts to closely track Project goals

- establish firm complementary plans for facilities (LASTI, 40m)
- bring other institutions into cycle of reviews (e.g., ETF)

LIGO Lab to start nucleus of LIGO II project office

- to meet September and January deadlines for information

Organization

LIGO Laboratory evidently responsible for the Observatories

- LIGO II project-oriented organization and much R&D rooted

LSC central to success for a LIGO II upgrade

- LIGO I using most Lab personnel, especially with experience in interferometer design and prototyping
- LSC has wealth of resources; also busy, but unique and numerous

Collaborators excited about significant participation

- continuing basic R&D
- directed R&D (interactions with industry, structured prototype testing)
- subsystems responsibility; fabrication/installation?

GEO playing a special role

- very strong technical partner
- also likely to contribute 'materially' - a subsystem, e.g., the Core Optics

GEO, VIRGO provide valuable technology tests

- high-sensitivity tests of real hardware
- beneficial for Lab to stay close to these projects; exchanges

Following discussions organized around LSC working groups.