Future Gravitational-Wave Detector Facilities

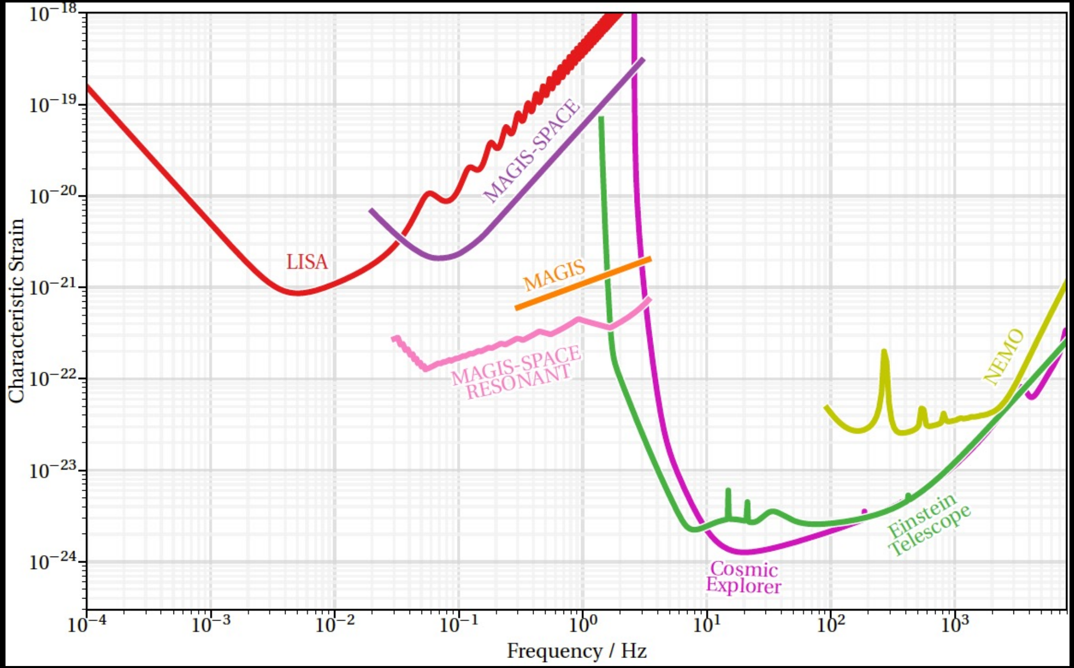
CF-7 Topical Group Meeting

Mar 10, 2022

Stefan Ballmer

White paper Status

- Contributed sections received
- Editing underway
  - Will be ~20 page document
- Currently 16 authors
- Endorsers?
- Current Draft of paper



Sensitivity comparison of future GW facilities

White paper outline

- 1) Executive Summary
- 2) Top Science Goals
  - Group by Dark Sector, Test of GR, Beyond Standard Model, Nucleosynthesis and NS physics
- 3) **Gravitational-wave new facilities and upgrades**
  - Cosmic Explorer observatory
  - Voyager design
  - International Partnerships
- 4) **Atom interferometers**
  - MAGIS / AION
- 5 Lunar-based Gravitational-Wave Detectors
- 6) Common Technologies and Research Opportunities
- 7) Outlook

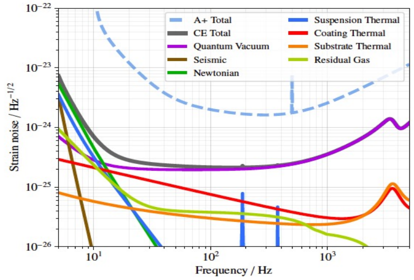


Figure 2: Estimated spectral sensitivity (solid black) of Cosmic Explorer and the known fundamental sources of noise that contribute to this total (colored curves). The design sensitivity of LIGO A+ is also shown in dashed blue. (From the Cosmic Explorer Horizon Study ?)

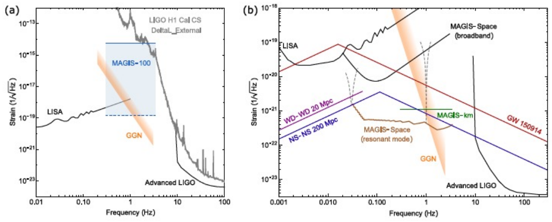


Figure 3: (a) Projected gravitational wave strain sensitivity for MAGIS-100 and follow-on detectors. The solid blue line shows initial performance using current state of the art parameters (table:futurevision, initial). The dashed line assumes parameters improved to their physical limits (table:futurevision, final). LIGO low frequency calibration data (gray) is shown as an estimate for the state-of-the-art performance in the mid-band frequency range ? . An estimate of gravity gradient noise (GGN) at the Fermilab site is shown as an orange band. (b) Estimated sensitivity of a future km-scale terrestrial detector (MAGIS-km, green) and satellite-based detector (MAGIS-Space, brown) using detector parameters from table:futurevision. The detector can be switched between both broadband (black, solid) and narrow resonant modes (black, dashed). The resonant enhancement Q can be tuned by adjusting the pulse sequence ? . Two example resonant responses are shown targeting 0.03 Hz ($8\hbar k$ atom optics, $Q = 9$) and 1 Hz ($1\hbar k$ atom optics, $Q = 300$). The brown curve is the envelope of the peak resonant responses, as could be reached by scanning the target frequency across the band. Sensitivity curves for LIGO ? and LISA ? are shown for reference. Also shown are a selection of mid-band sources including neutron star (NS) and white dwarf (WD) binaries (blue and purple) as well as a black hole binary already detected by LIGO (red). The GGN band (orange) is a rough estimate based on seismic measurements at the SURF site ? .

Key messages

- Next-Gen Gravitational Wave detectors can provide access to a wide range of fundamental physics phenomena throughout the history of the universe.
- Detector concepts at different stages of development are discussed (Laser interferometer design, Atom interferometer designs)
- Many common technology development needs where DOE has expertise
    - Vacuum system, Newtonian noise cancellation, etc,
    - Application of quantum measurement techniques

Snowmass Cross-References

- CF7 Cosmology Intertwined
- CF3 Observational Facilities to Study Dark Matter
- CF7 Advancing the Landscape of Multimessenger Science
- CF3 Dark Matter In Extreme Astrophysical Environments
- CF2 on direct dark matter searches ?

- Any other that I am not aware of ?

End

Original LOIs to be folded into this WP:

- Cosmic Explorer: The Next-Generation U.S. Gravitational-Wave Detector (CF#010)
  (Corresponding author: Stefan Ballmer, sballmer@syr.edu)
- LIGO Voyager: A Gravitational-wave Probe of Cosmology and Dark Matter (CF#063)
  (Corresponding author: Rana Adhikari, rana@caltech.edu)
- The Atom Interferometric Observatory and Network (AION) for Dark Matter and Gravity Exploration (CF#018)
  (Corresponding author: Leonardo Badurina, leonardo.badurina@kcl.ac.uk)
- Snowmass2021 Letter of Interest: The Matter wave Atomic Gradiometer Interferometric Sensor (MAGIS-100) Experiment (IF#136)
  (Corresponding author: Swapan Chattopadhyay, swapan@fnal.gov)
- Long-baseline Atomic Sensors for Fundamental Physics (CF#164)
  (Corresponding author: Jason Hogan, hogan@stanford.edu)
- Opportunities in gravitational physics (IF#134)
  (Corresponding author: Jason Hogan, hogan@stanford.edu)
- A deci-Hz Gravitational-Wave Lunar Observatory for Cosmology CF#239
  (Corresponding author: Jani Karan, karan.jani@vanderbilt.edu)

People currently engaged in writing this WP:

- **Mailing list for this WP:** dabrown@g.syr.edu, stefan.ballmer@ligo.org, swapan.chaterji@gmail.com, hogan@stanford.edu, sch.slac.stanford@gmail.com, wipf@caltech.edu, rana@caltech.edu, karan.jani@vanderbilt.edu, pf@ligo.mit.edu, b.sathyaprakash@gmail.com, tkovachy@gmail.com, blantz@stanford.edu, bram.slagmolen@anu.edu.au, josmith@fullerton.edu, dhs@mit.edu, salvatore.vitale@ligo.mit.edu, m3v4n5@mit.edu, leonardo.badurina@kcl.ac.uk, dsigg@caltech.edu

- Contact me (sballmer@syr.edu) for coordination with other white papers.