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Dark Matter Detection with Laser Interferometers

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GWDAW

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Dark Matter

- Dark matter contributes 22% to the total energy density
- Clumps into galaxies. At the location of the Solar System the DM density is ~10^5 of the average
- Nonrelativistic, pressureless fluid
- The best candidate for dark matter are weakly interacting massive particles (WIMP) that arise in models with supersymmetry (SUSY)
- Direct searches for WIMPs with masses O(1-10^3 GeV) already ruled out a significant part of the SUSY models phase space (most stringent experimental result D. S. Akerib et al. [LUX Collaboration], arXiv:1310.8214)
- LHC discovered Higgs – but no evidence for SUSY so far.

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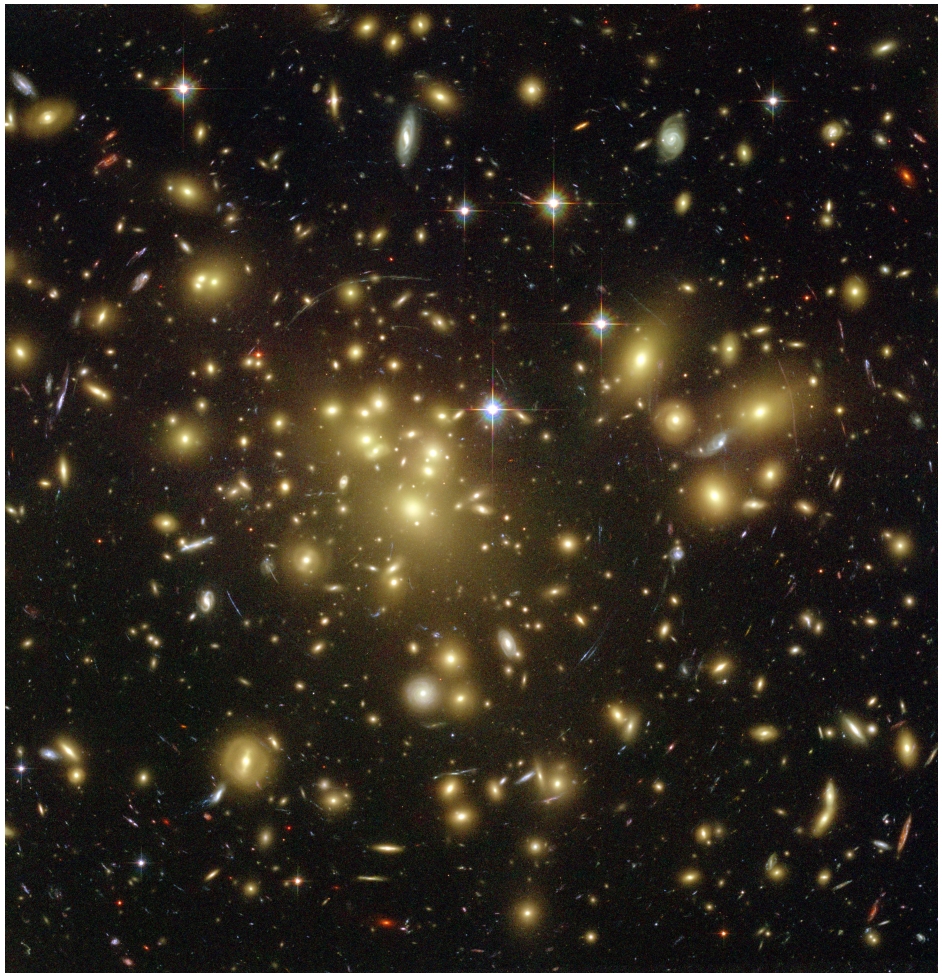

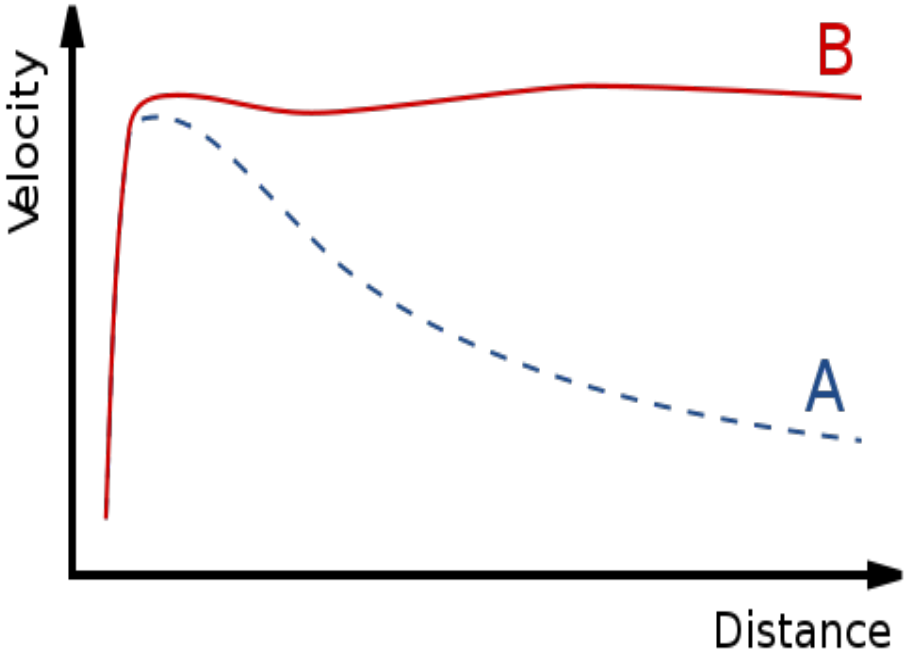

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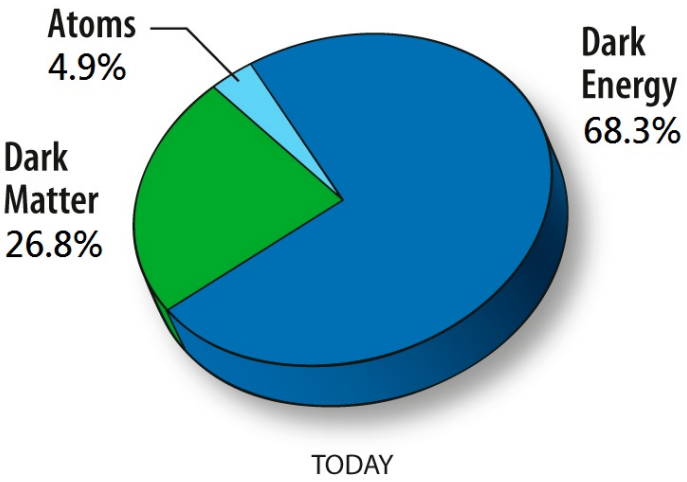
Atoms
4.9%
Dark
Energy
68.3%
Dark
Matter
26.8%
TODAY
Neutrinos
10%
Dark
Matter
63%
Photons
15%
Atoms
12%
13.7 BILLION YEARS AGO
(Universe 380,000 years old)

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What if no WIMP

- If there are no WIMPs, consider alternatives e.g.:
  - Conglomerates of DM particles (dust) held together by gravity or by *new force* and protected from annihilation by *new symmetry*
  - Topological defects – vacuum field assumes different values at different space points (classical example ferromagnet magnetization below T_c): monopoles (*strings, domain walls not p-less)* (A.Derevianko, M.Pospelov arXiv:1311.1244 proposal for search with atomic clocks)
- In this talk we discuss signals in LIGO/ET/LISA from:
  - Point-like DM clumps
  - Extended objects – walls (TDs are not good DM candidates but we make the estimates assuming this density distribution anyway)

Encounters with DM Clumps

Signal is due to Newtonian force - no GW involved

Choose clump mass M as a parameter
Number density can be obtained:

$$\rho_{DM} = nM$$

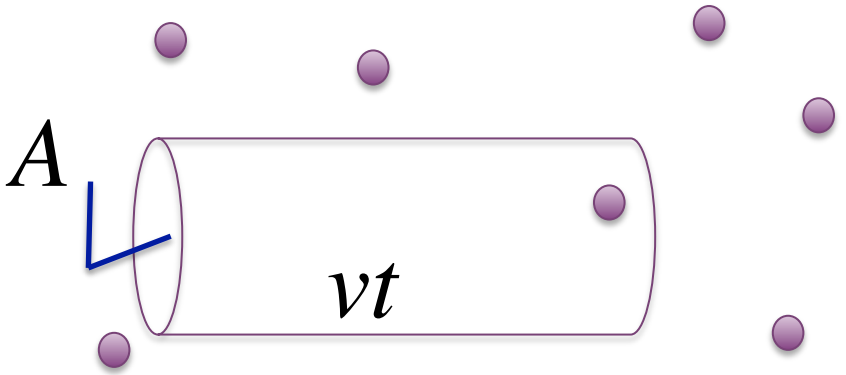
t - time between encounters
A - cross section
v = 230 km/s velocity w.r.t galactic rest frame

$$vt = \frac{1}{An}$$

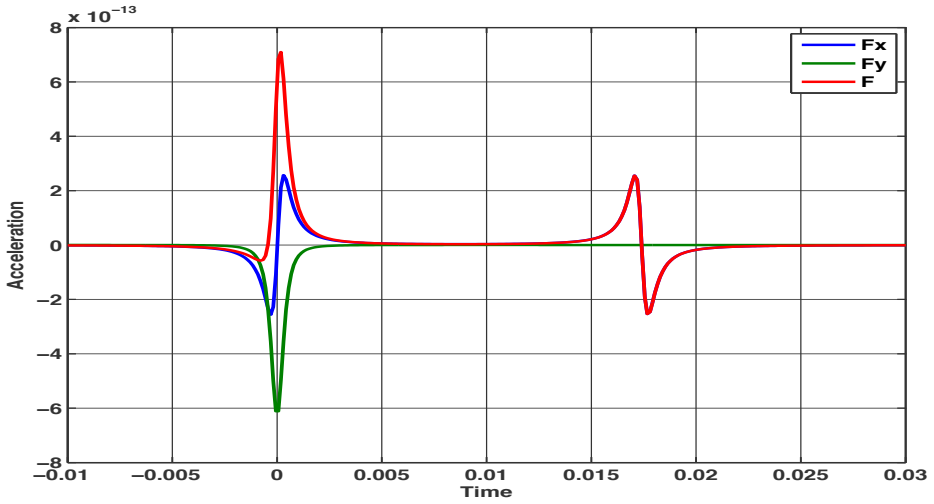
Characteristic area(distance):

$$A = \frac{M}{\rho_{DM} vt}$$

Clump size < d, L_{arm}



Signal from a clump moving along X arm



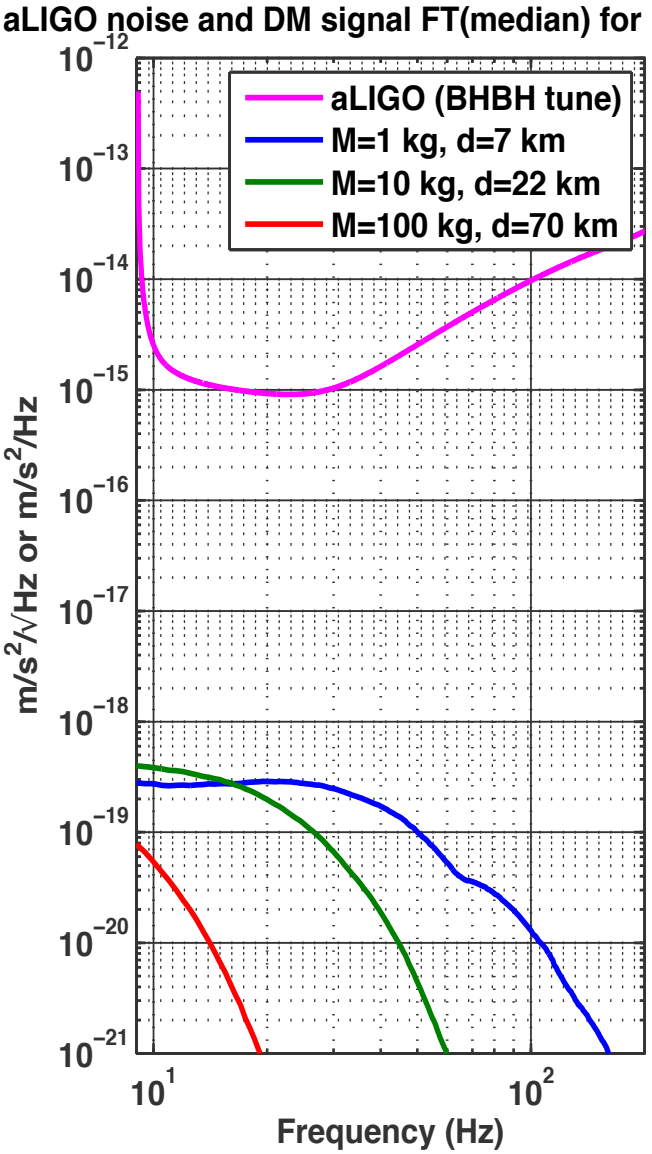
Signal in aLIGO

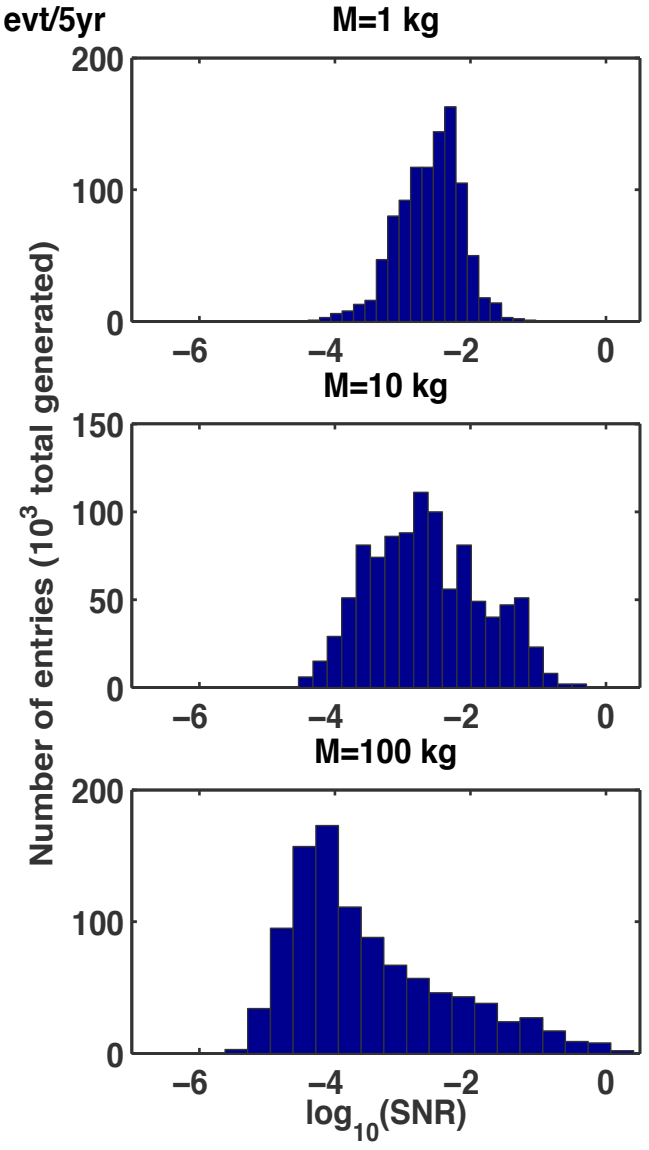
Random angle and position

Signal from gravitational interaction is small but DM may have long range non-minimal interaction - lot of room for model building and testing

SNR was obtained by integration. Searches should be done using templates.

No coincidences between non-colocated interferometers due to solid angle





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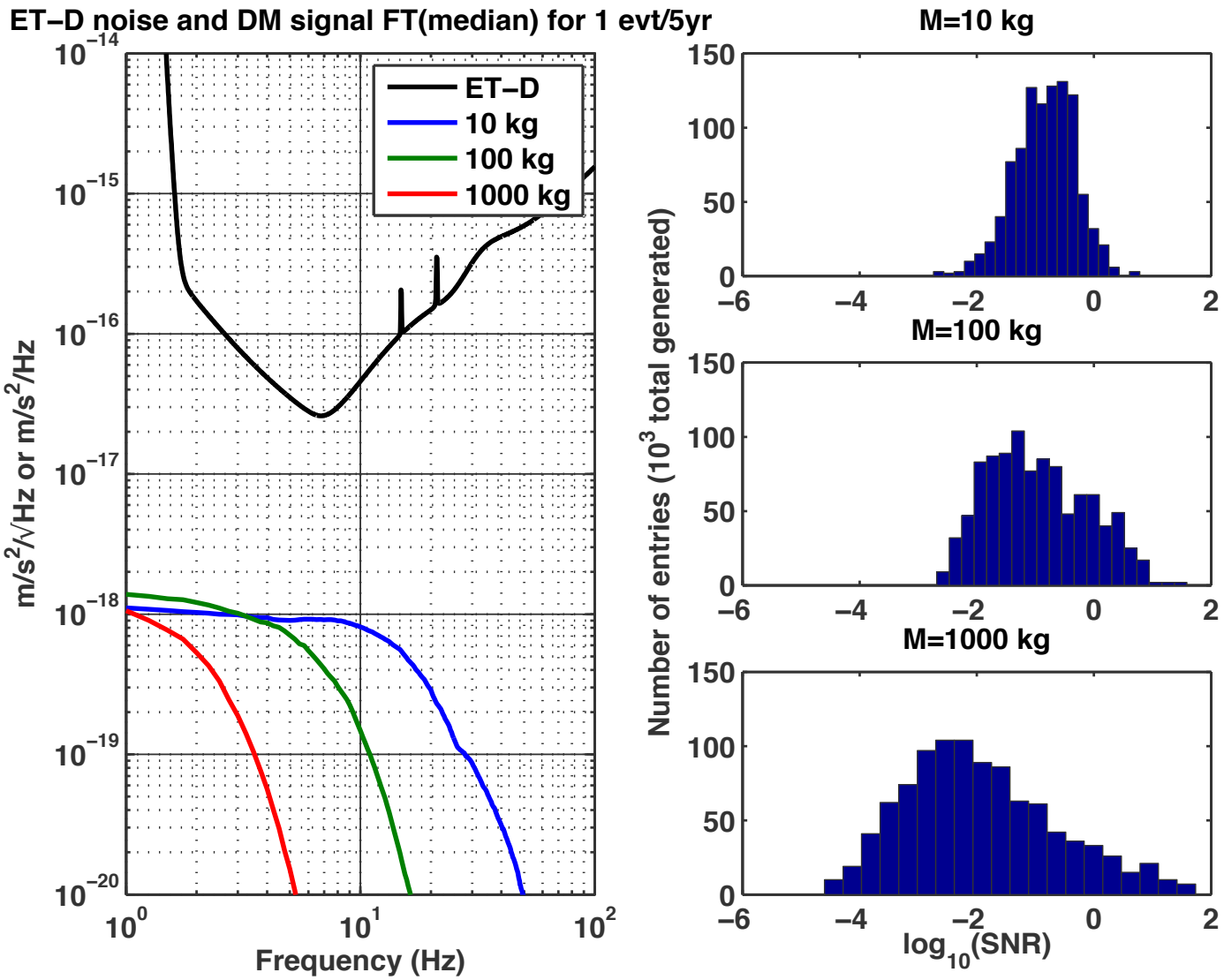
Signal in ET

Three interferometers are co-located. Coincidence and wave form analysis allows background rejection.



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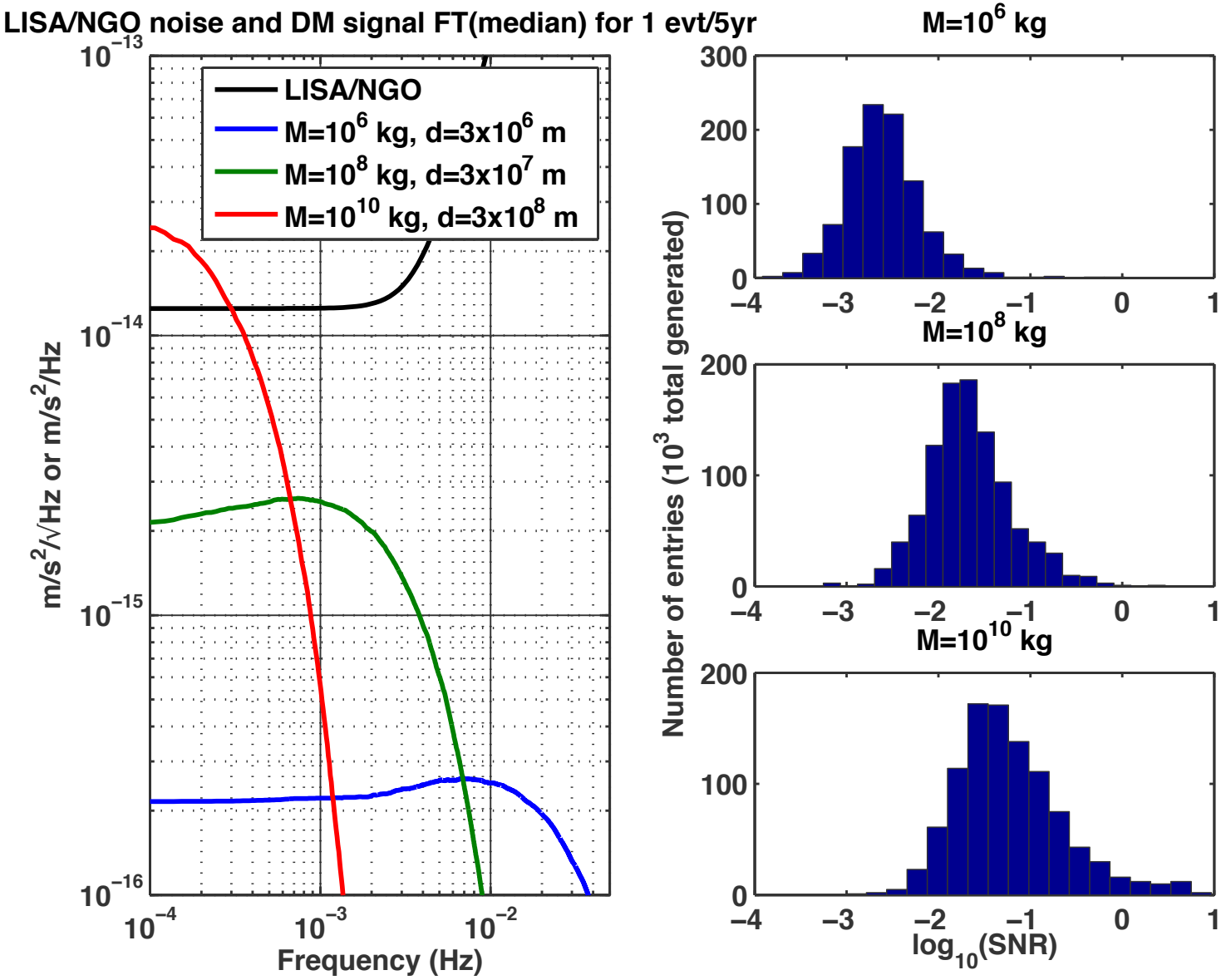
Signal in LISA

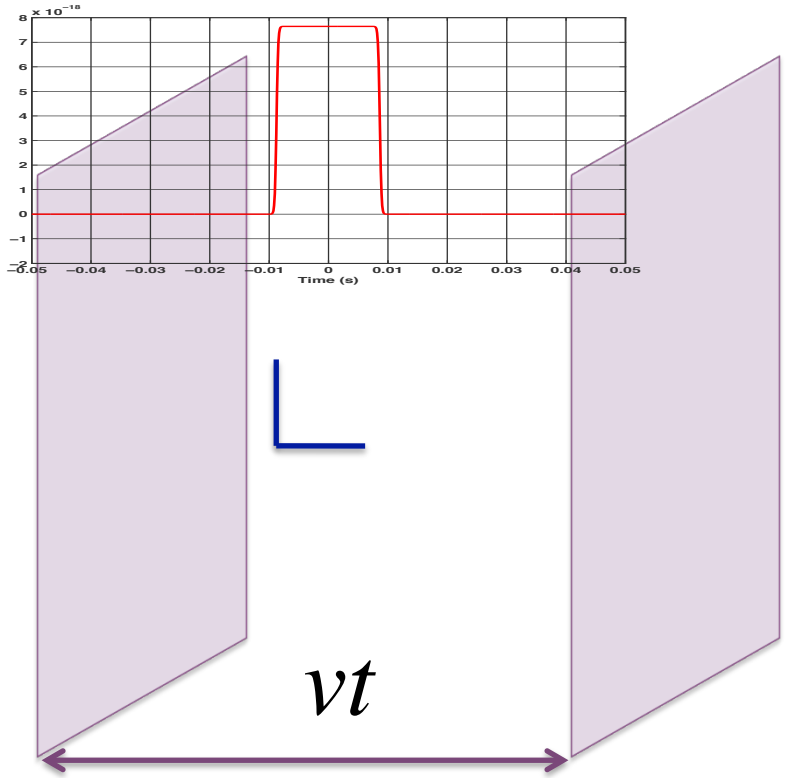


Encounters with Walls

Wall surface density:

$$\sigma_{wall} = \rho_{DM} vt / 3$$

t - time between encounters
v = 230 km/s velocity w.r.t galactic rest frame
L=vt – characteristic distance between walls in the network



Wall thickness d < L_{arm}

- Coincidence between L1/H1 with ~15 sec max delay
- Correlation with motion through galactic rest frame

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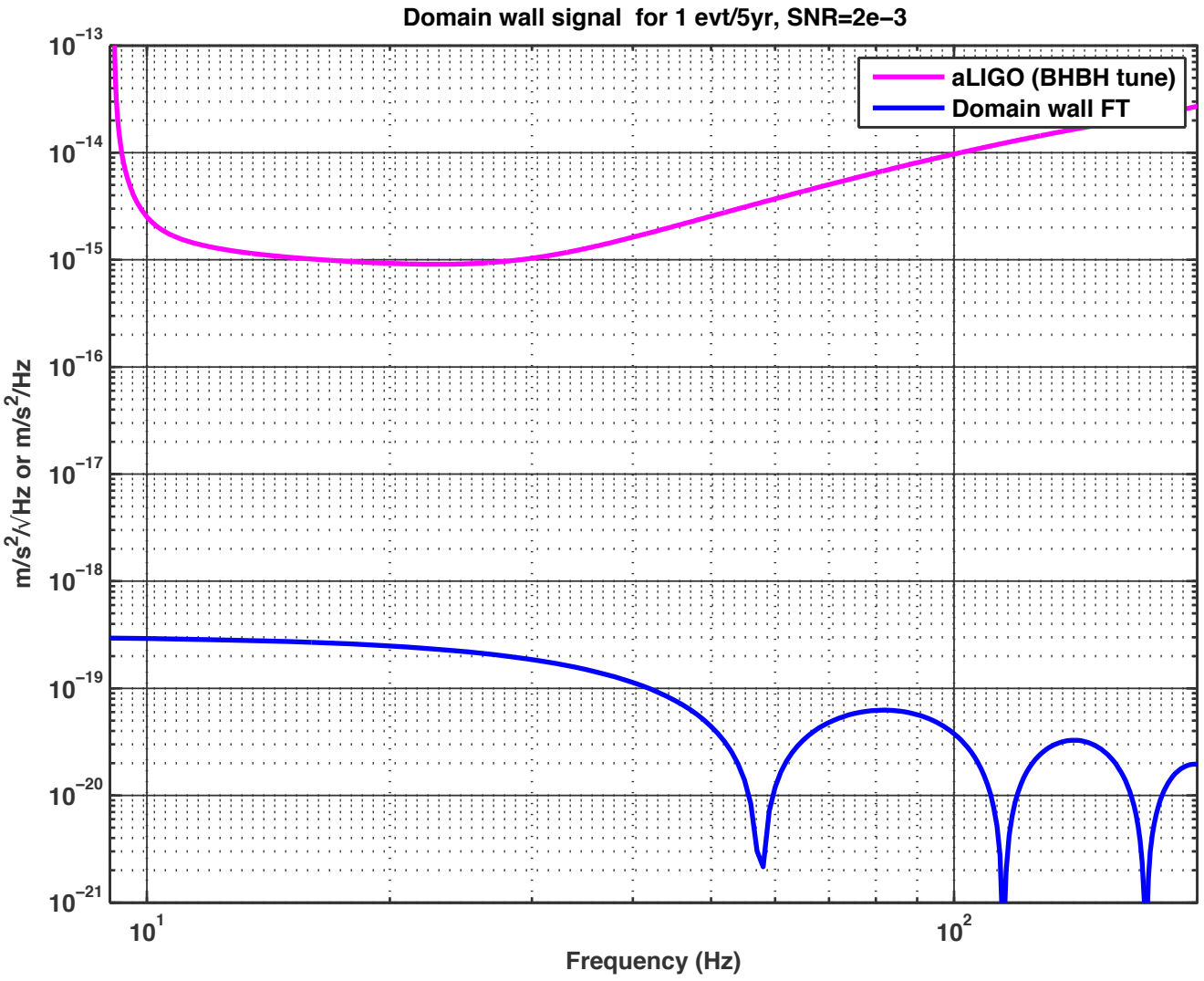
Signal in aLIGO



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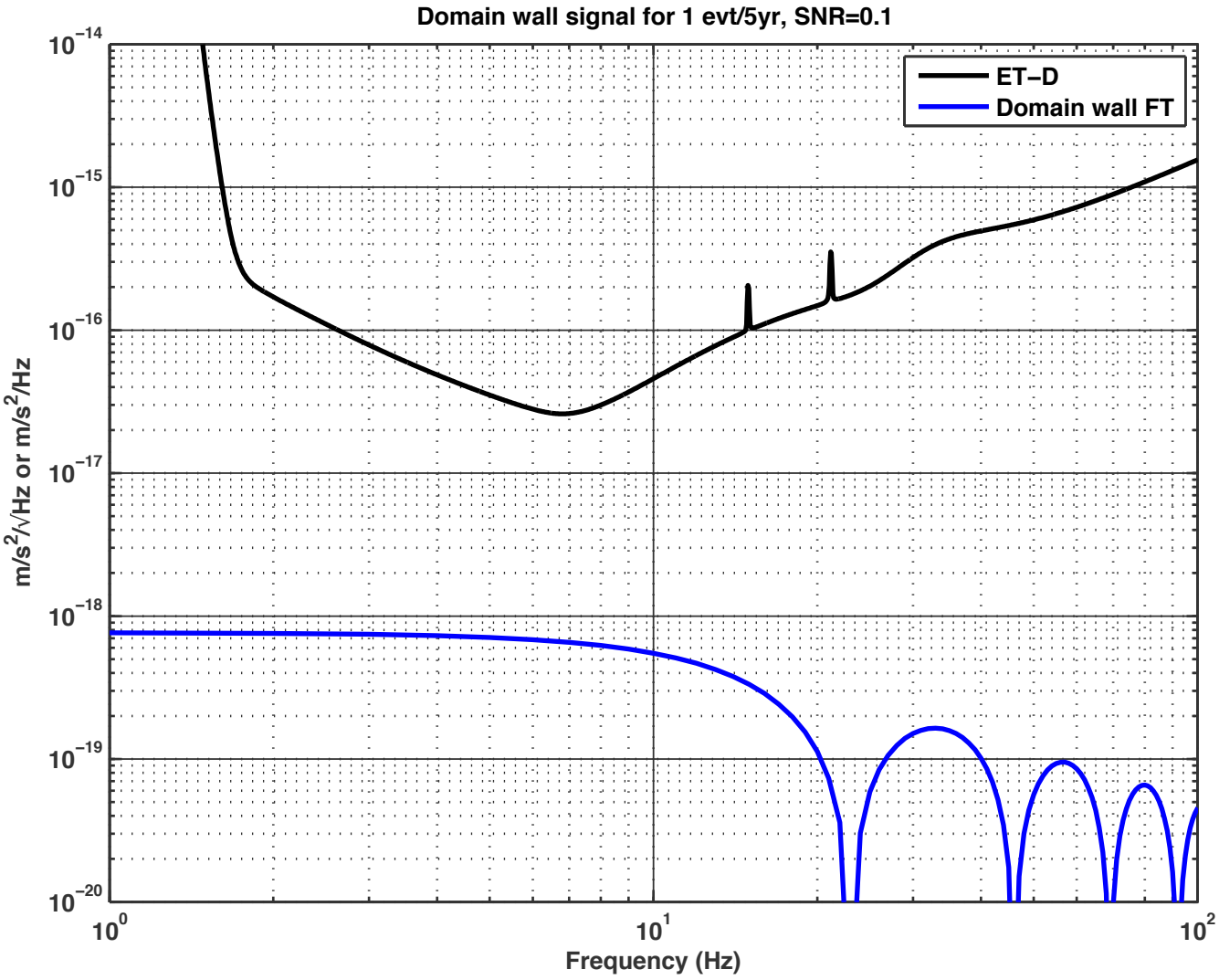
Signal in ET



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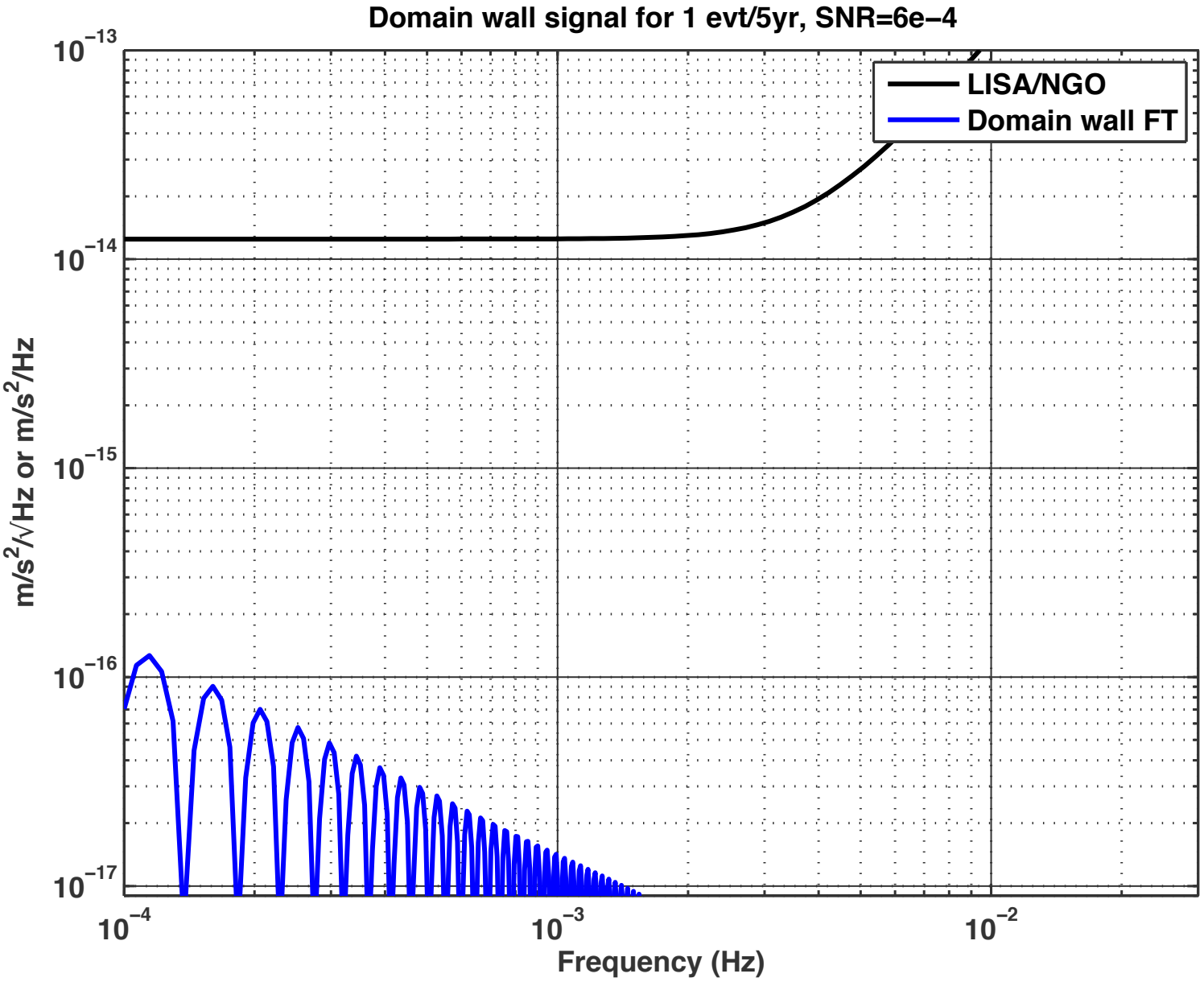
Signal in LISA



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Summary

- If no SUSY and WIMPs are found – look for alternative DM
- Laser interferometers can be used as gravimeters to search and place limits on non-standard DM