

WG2: Sub-eV Dark Matter

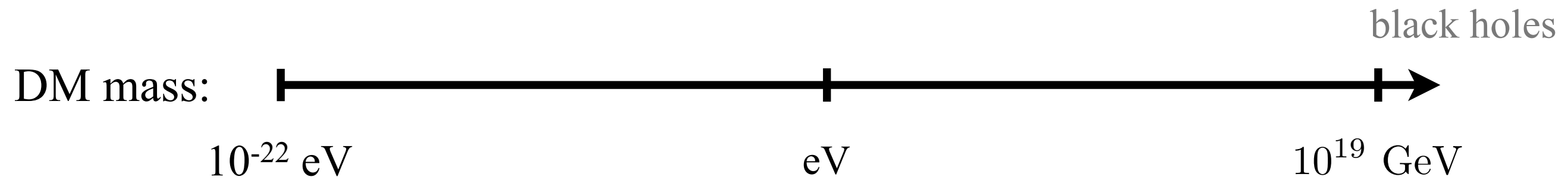
Conveners

Aaron Chou

Peter Graham

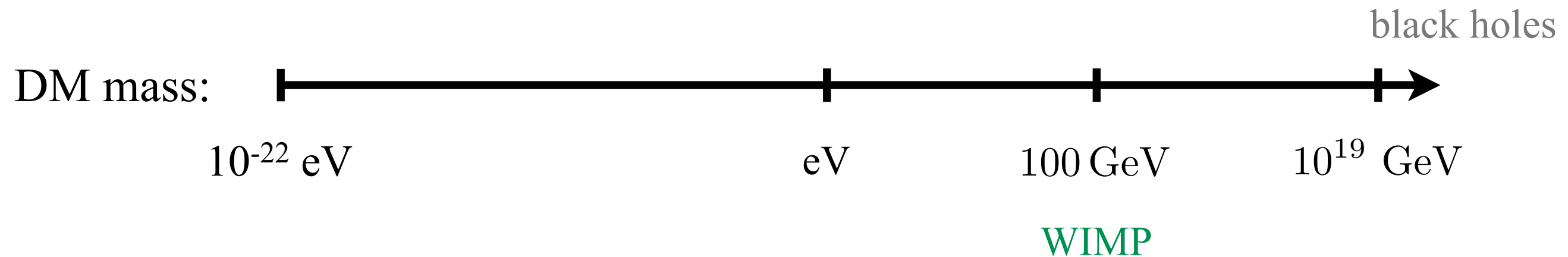
Dark Matter Candidates

DM has a broad parameter space



Dark Matter Candidates

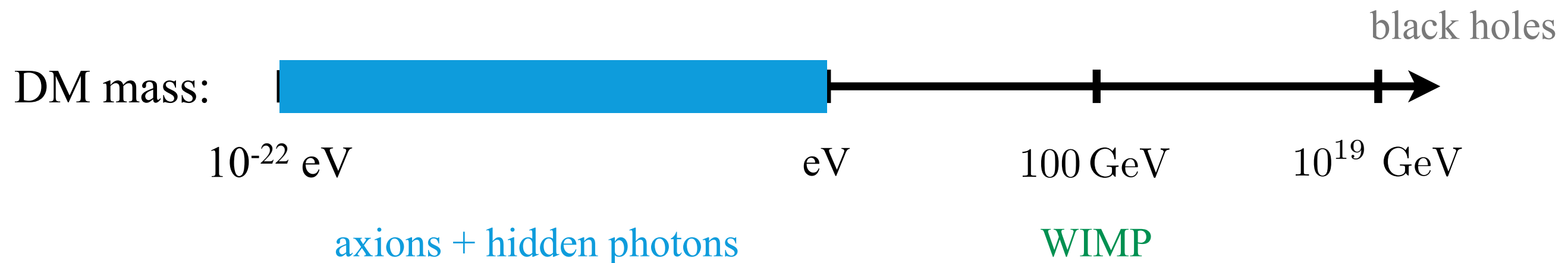
DM has a broad parameter space



WIMP is well-motivated, significant direct detection effort focused on WIMPs

Dark Matter Candidates

DM has a broad parameter space

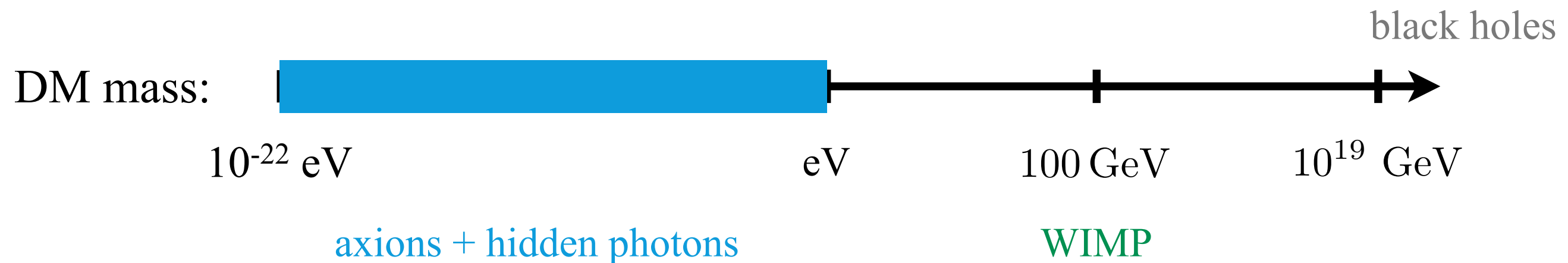


WIMP is well-motivated, significant direct detection effort focused on WIMPs

Axion is other best-motivated candidate, only a small fraction of parameter space covered

Dark Matter Candidates

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WIMP is well-motivated, significant direct detection effort focused on WIMPs

Axion is other best-motivated candidate, only a small fraction of parameter space covered

Huge DM parameter space currently unexplored!

Science Case

- Two best-motivated DM candidates: WIMPs and QCD axions
 - motivated as solutions to major problems (hierarchy problem, strong CP)
- general axions, dark photons, etc., well motivated DM candidates

Important to cover:

1. QCD axion mass range (for strong CP solution) \sim kHz - 100 GHz (& sharp coupling prediction)
 2. General candidates over full mass range $\sim 10^{-22}$ eV - 1 eV
- Four possible DM couplings can be used (E&M, QCD, spin, scalar)
 - Recent major growth of interest in this area

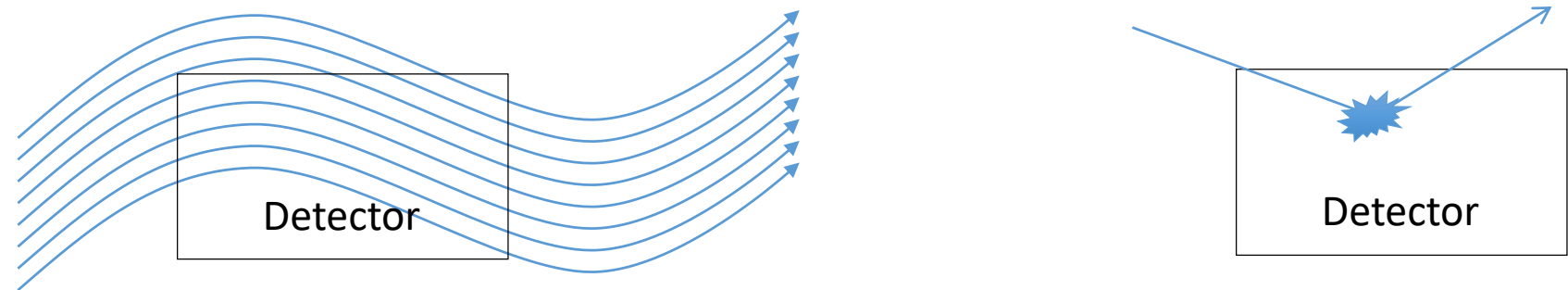
Many promising, unexplored directions

Science Motivation

- can solve strong CP problem
- can solve hierarchy problem
- a natural DM candidate (inflationary production mechanisms)
- search for light scale particles probes very high energy physics (up to Planck scale)
- arise naturally from UV theories e.g. string theory models
- a detection could probe inflation

New Techniques

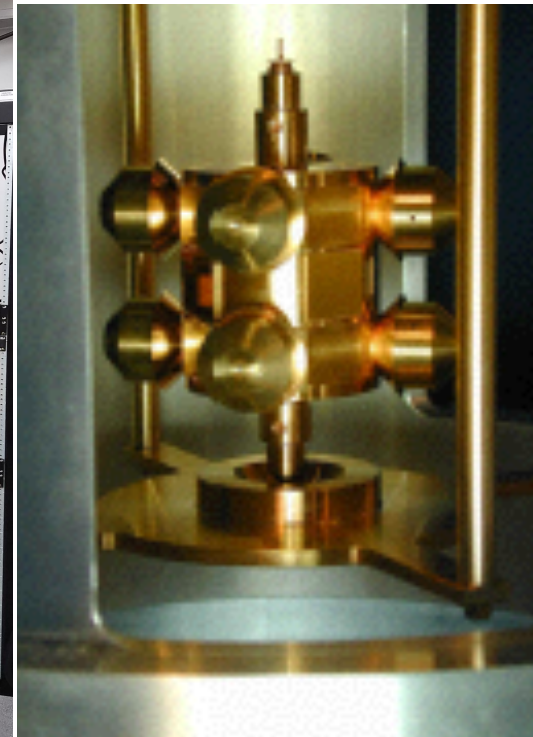
Oscillating signal at DM frequency (field-like) vs WIMP signal (particle-like)



- Very few experiments currently probe sub-eV dark matter
 - large parts of well-motivated parameter space currently unexplored
- Recently many new experimental techniques just proposed/begun
- Driven by high precision technology from other areas of physics
- Wide range of techniques: EM resonators, atomic clocks/interferometry, NMR, high-precision magnetometry, laser interferometry...

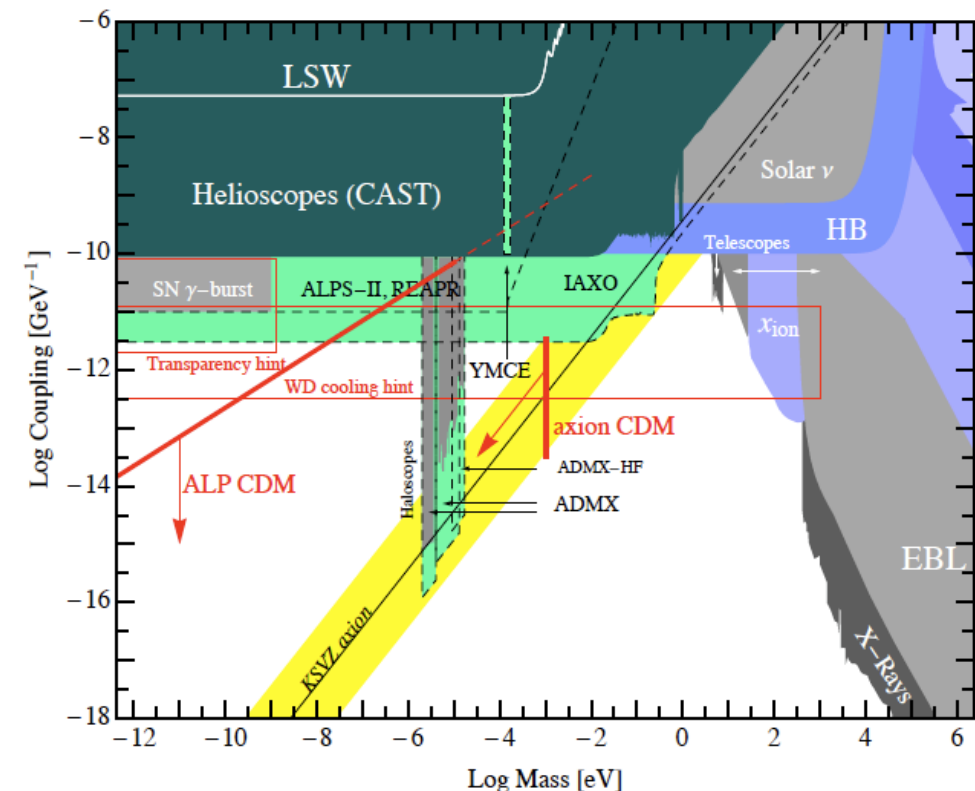
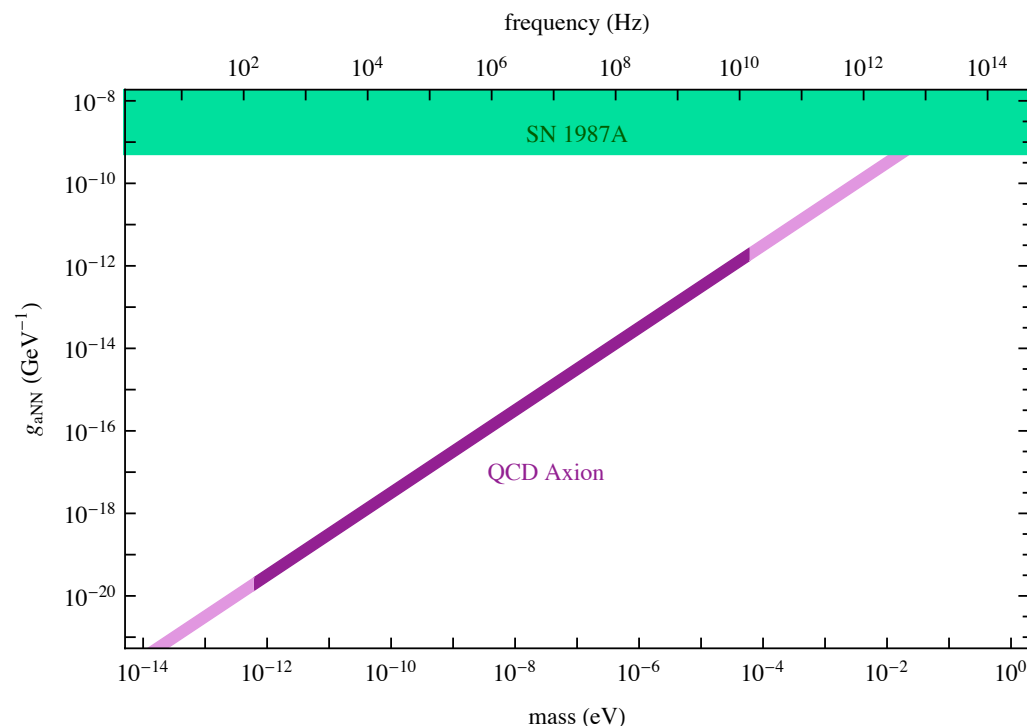
Experiments

- Several (~10) specific experimental proposals have significant promise for covering this area, essentially all under \$10M
- These projects are ready to start now (technology exists)
- Timeline for most of these experiments ~ few years



Reach

- Excitingly, most of QCD axion parameter space (mass \sim kHz - 100 GHz) can be covered with a combination of these experiments (NMR, EM Resonators)
- Indeed most of general ultralight DM mass range can be probed
- Experiments probe all types of couplings (E&M, QCD, spin, scalar)
- Covers very large parts of parameter space for axions and hidden photons



Extra science beyond DM

Many of these experiments can also do other science, e.g.

- torsion balances search for new forces, equivalence principle violation,...
- atom interferometry searches for gravitational waves, EP violation,...
- may have practical applications (geological mapping,...)

these high precision technologies have application to quantum information
(e.g. EM resonators, NMR, ultracold atoms)

Experiments

Direct detection projects “ready to go”: few million \$, much technology already demonstrated

1. ADMX*
2. HAYSTAC
3. LC Circuit
4. DM Radio
5. ABRACADABRA
6. CASPEr
7. Eot-Wash
8. Atom Interferometry

New particle search projects which can cover DM space “ready to go”

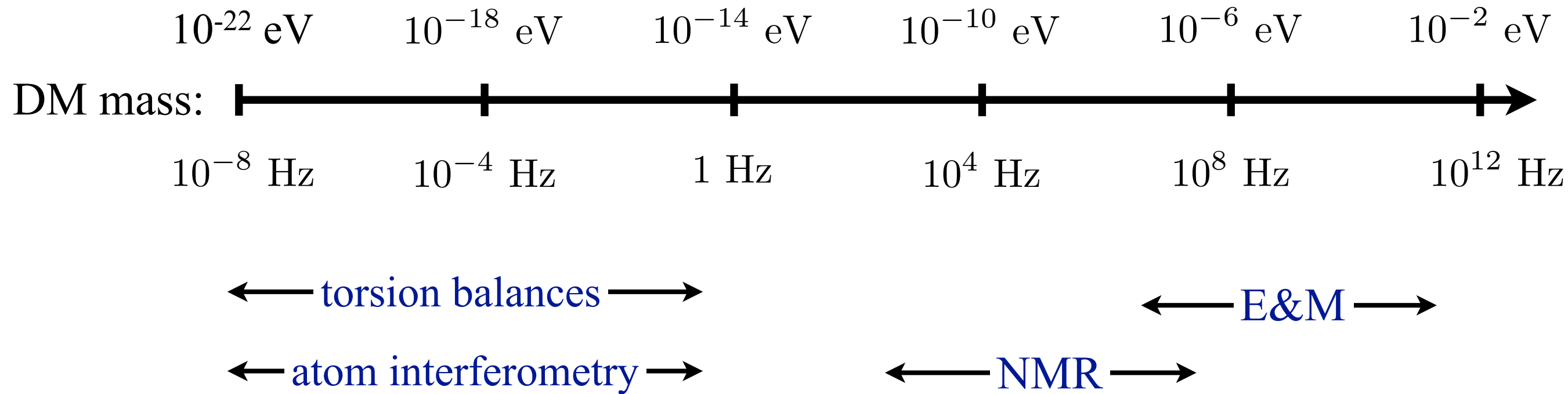
1. mini-IAXO
2. ARIADNE

R&D work which would enable significant future experiments

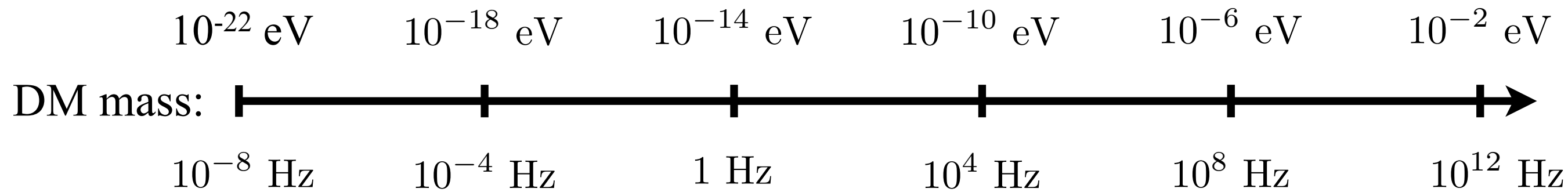
1. high frequency EM resonators (open resonators, qubit sensors...) - future experiment ~ \$10M
2. high field magnet development
3. IAXO (large-scale ~ 10's of million \$)

*upgrades to G2 project

DM Direct Detection



DM Direct Detection



← torsion balances →

← atom interferometry →

← E&M →

← NMR →

Coupling:

E&M

QCD

Spin

Scalar

Eot-Wash (spin)

Eot-Wash (scalar)

Atom Interferometry (spin)

Atom Interferometry (scalar)

CASPER-Electric

CASPER-Wind

ADMX

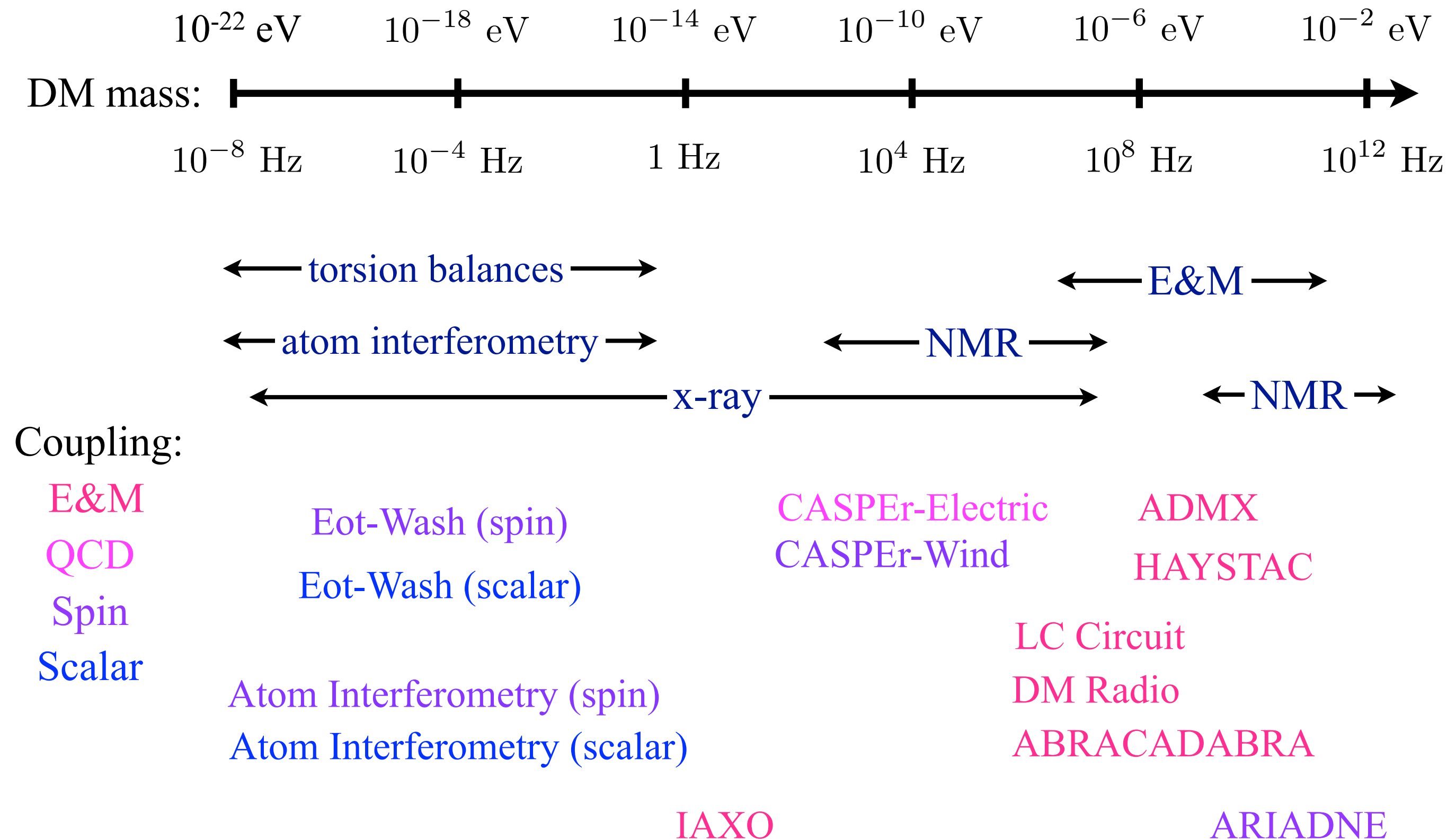
HAYSTAC

LC Circuit

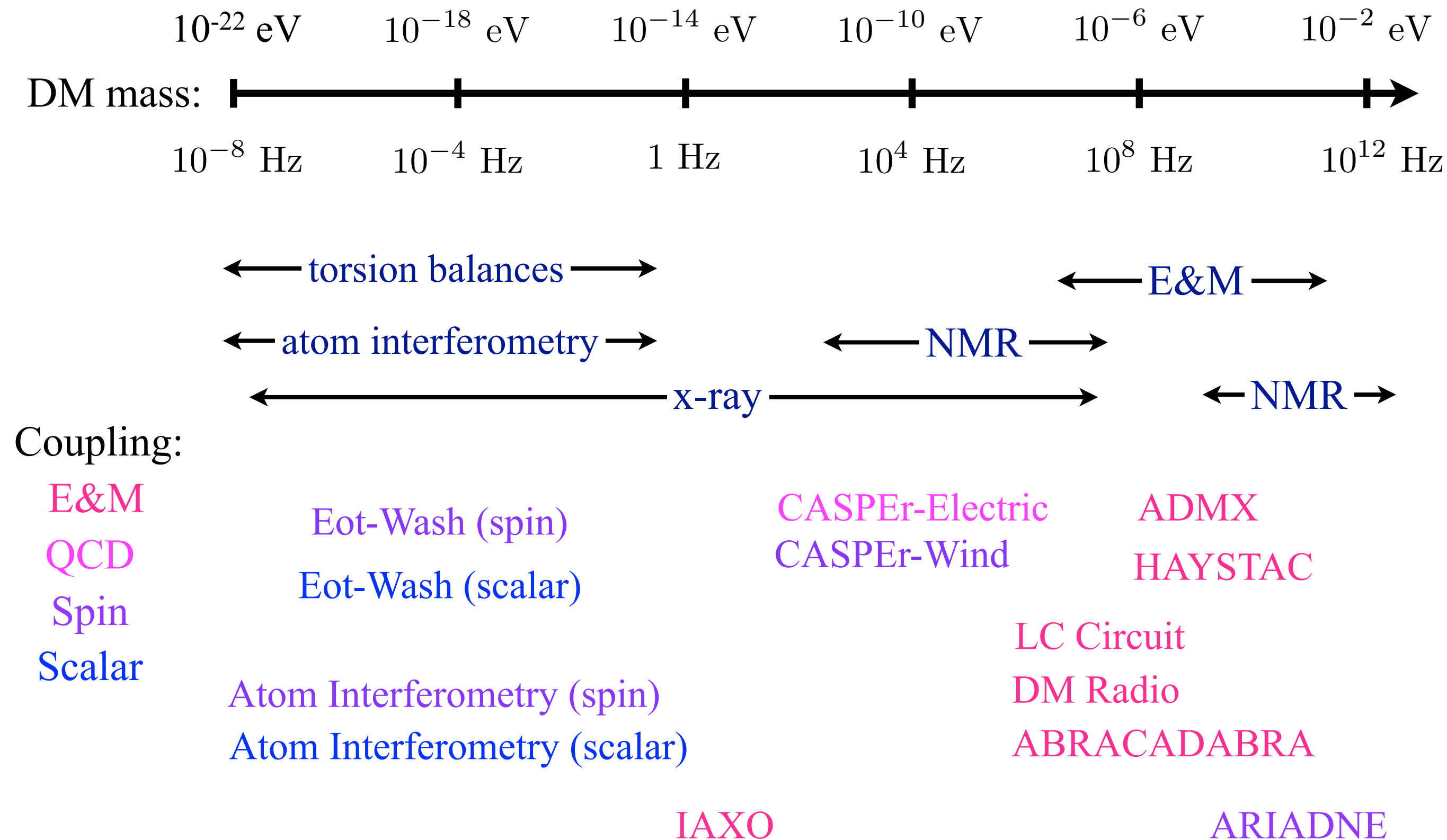
DM Radio

ABRACADABRA

Axion/Hidden Photon Mass Range



Axion/Hidden Photon Mass Range



Complementary experiments cover axion and hidden photon mass range!

Conclusions

We do not know what DM is

Full DM parameter space is broad $\sim 10^{-22}$ eV - 10^{27} eV (and beyond)

Experiments can cover huge range of DM masses (~ 20 orders of magnitude)

Includes the very-well motivated QCD axion target
and general axions/hidden photons