Introduction to Discussion of

Prospective AION Physics Case

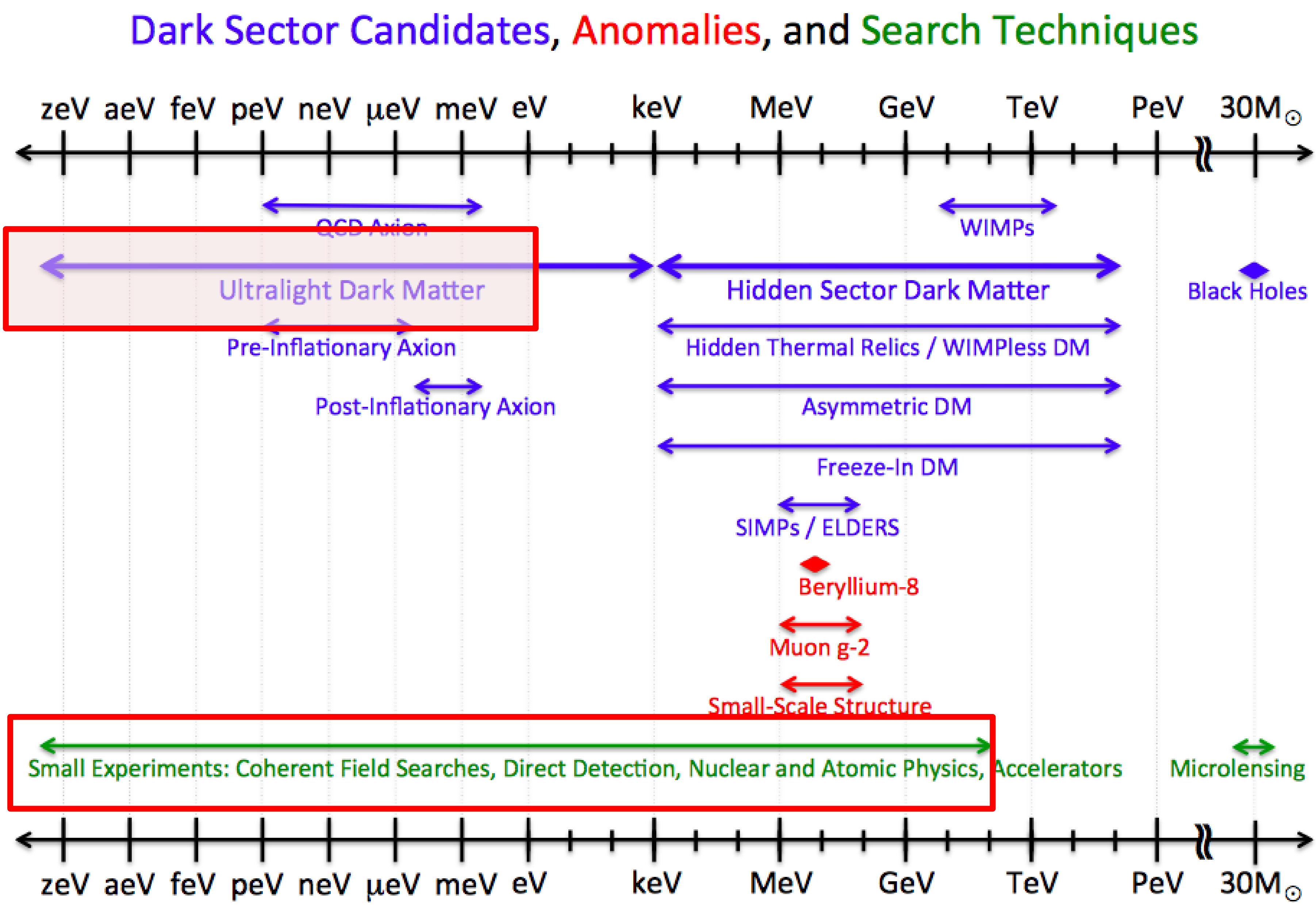
Dark Matter, Gravitational Waves, Other Topics

AION Workshop @ Imperial

March 25/26, 2019

John Ellis (King's College London)

Wide Range of Candidate Dark Matter Particles



Searches for Light Dark Matter

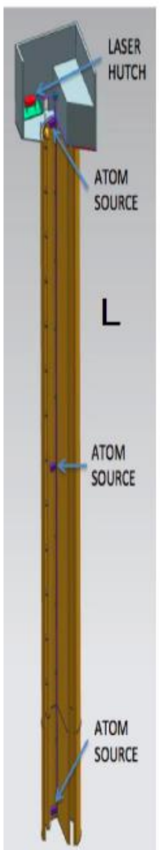
- Dark matter could be coherent waves of light bosons
  - Many detection techniques, **e.g. atom interferometers**

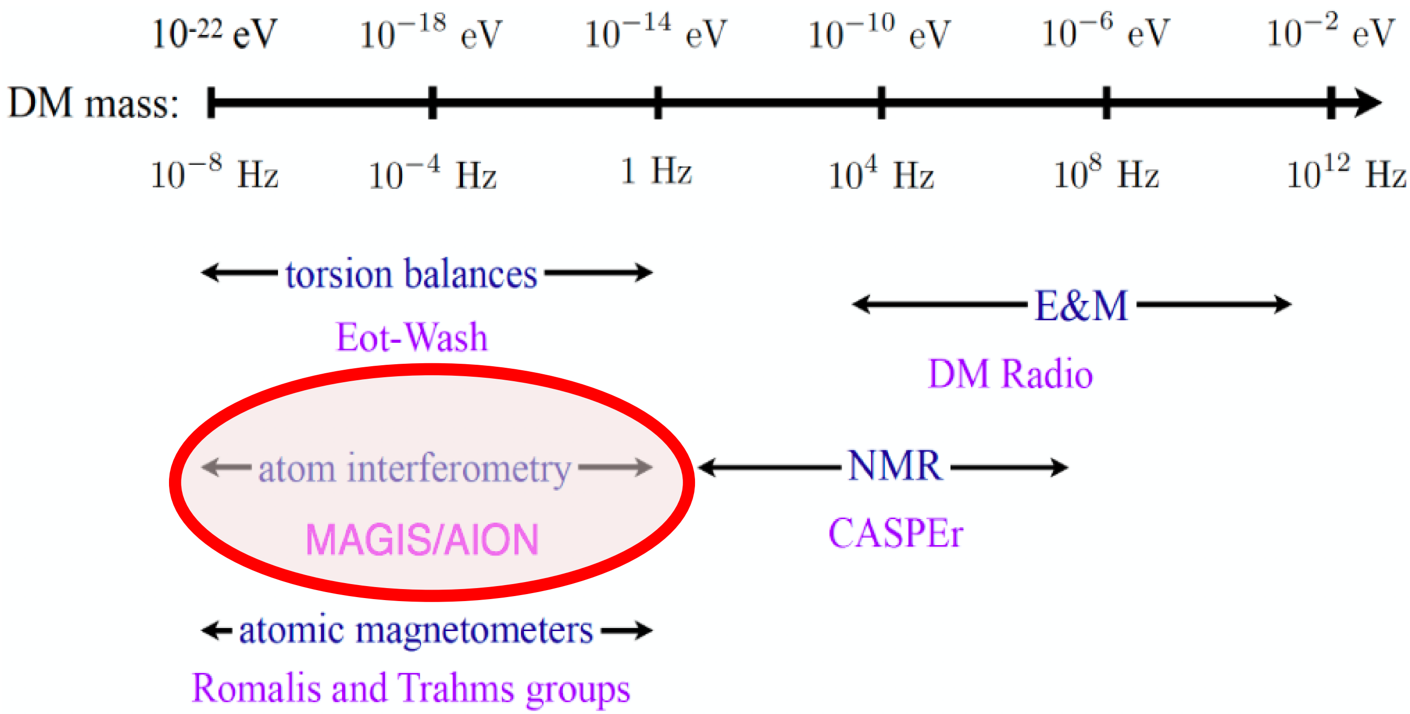
L ~ 1m to 10m

L ~ 100m

L ~ km-scale

L ~ 10^4 km





also interesting for gravitational waves

Dark Matter

Martin Bauer

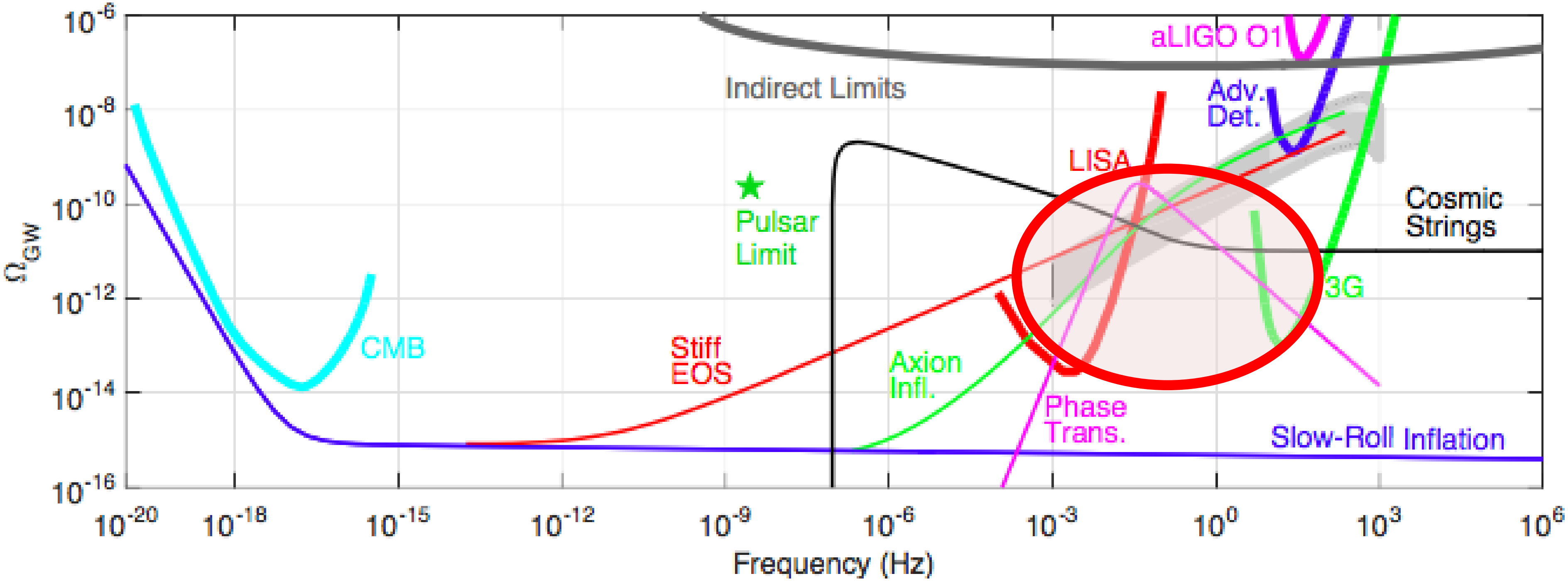
- Ultra-light bosons with masses in the range 10^{-22} to 1 eV are motivated in many extensions of the Standard Model, e.g., axion-like particles, ultra-light scalar fields such as moduli, dilatons or radions and ultra-light hidden vector bosons.
- Could have correct dark matter density and are consistent with theory of structure formation, which demands that dark matter should be ‘cold’.
- AION will be sensitive to the frequency band between 10 and 0.01 Hz, i.e., bosons in the range 10^{-16} to10^{-13} eV.
- Complementing torsion-balance, atomic co-magnetometer and atomic spectroscopy experiments.

Possible DM Theory Tasks

Horng Sheng

- Understanding the synergies between dark matter searches in this mass range and other astrophysical and cosmological observations.
- Exploring the synergies between AION and other laboratory probes of ultra-light bosonic dark matter.
- Showing how to identify unambiguously dark matter as the origin of a signal in AION, rather than a signal from, e.g., time-varying physical parameters or GWs, and extract the dark matter properties from the signal.

Gravitational Wave Spectrum



- Gap between ground-based optical interferometers @ LISA
- Electroweak phase transition? Cosmic strings?

Gravitational Waves

Marek Lewicki

- Near term: LIGO, Virgo and KAGRA @ frequencies ~ 10 Hz to KHz range.
- Longer term: LISA @ frequencies below ~ 0.01 Hz, 3ird-generation ground instruments such as Einstein Telescope @ ~ 1Hz to few kHz, on a similar timeline.
- The mid-frequency band between 10 and 0.01 Hz interesting: GWs from phase transitions in early universe; track astrophysical sources evolving from LISA range towards LIGO/Virgo/KAGRA range; new intermediate-mass BH sources.
- AION would complement MAGIS, just as Virgo complements LIGO.

Possible GW Theory Tasks

- Calculating mid-frequency GW signatures of cosmological phase transitions, e.g., at the electroweak scale, and relating them to collider signatures of possible extensions of the Standard Model.
- Sensitivity to cosmic strings.
- Understanding synergies of multiband GW astronomy combining GW searches in this frequency range with LISA, LIGO/Virgo/KAGRA & other astrophysical observations, e.g., for predicting timing, directions & distances of future merger events.
- Novel tests of the strong-gravity regime via, e.g., accurate timing of the GW phase evolution, that are not accessible with ground-based interferometers and LISA alone.
- Modelling astrophysical sources whose GWs peak in mid-frequency range, e.g., intermediate-mass BHs (seeds for supermassive BHs observed today), providing insight into their evolution and their host galaxies.

Beyond Dark Matter & GWs

- Ultra precision interferometry may also be sensitive to other phenomena beyond dark matter and GWs, and we also propose exploratory studies of such possibilities.
- Possible exploratory theoretical tasks

Clare Burrage
Ed Copeland
Diego Blas

- Probing fundamental "constants", dark energy
- Detecting the astrophysical neutrinos that traverse the Earth with high flux though very small cross-section and tiny momentum
- Precise interferometry may also be relevant for understanding long-range fifth forces – role of AION