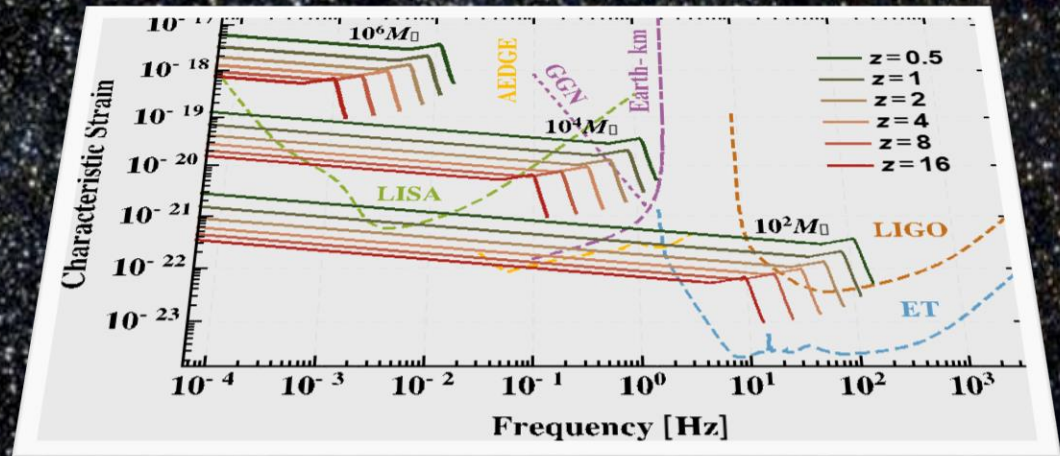
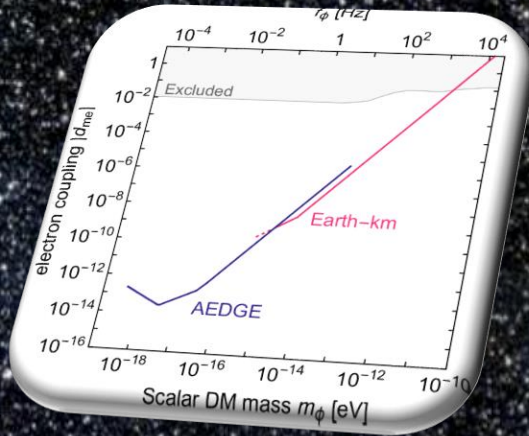


AEDGE: Atomic Experiment for Dark Matter and Gravity Exploration



Informal Workshop
CERN, July 22/23 2019

Organizers:

Kai Bongs(CA), Philippe Bouyer(CA), Oliver Buchmueller(PP),
Albert De Roeck(PP), John Ellis(PP, Theory), Peter Graham (CA, Theory),
Jason Hogan (CA), Wolf von Klitzing(CA), Guglielmo Tino(CA), and AtomQT
PP=Particle Physics
CA=Cold Atoms

White Paper: Physics Case

- The White paper would focus on the physics opportunities and how to connect the fundamental research areas of particle physics and gravitational wave physics using technologies based on cold atom expertise.
- It should emphasis "Cold Atoms" as technology scheme, possibly giving examples of technology options, but its focus will be on the physics opportunities:
 - *Mid-frequency band GW physics and its synergies with LISA and ET/AdvancedLigo – i.e. its not in competition with other future GW projects, but rather an opportunity to cover the full frequency spectrum, which will be crucial for GW physics in general.*
 - *Exploration of Ultra-Light Dark Matter focusing on scalar particles but also highlighting opportunities for pseudo-scalar (xions) and vector dark matter*
 - *Other fundamental physics*

The above outlined case spans several science areas ranging fundamental particle physics over astrophysics & cosmology to cold atoms and, thus, connects these communities.

Current WP Outline

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White Paper Call

Voyage 2050 CALL

<https://www.cosmos.esa.int/web/voyage-2050>

White Paper Description

[https://www.cosmos.esa.int/documents/1866264/1866292/Call for Voyage 2050 White Papers.pdf](https://www.cosmos.esa.int/documents/1866264/1866292/Call+for+Voyage+2050+White+Papers.pdf)

Basic Outline:

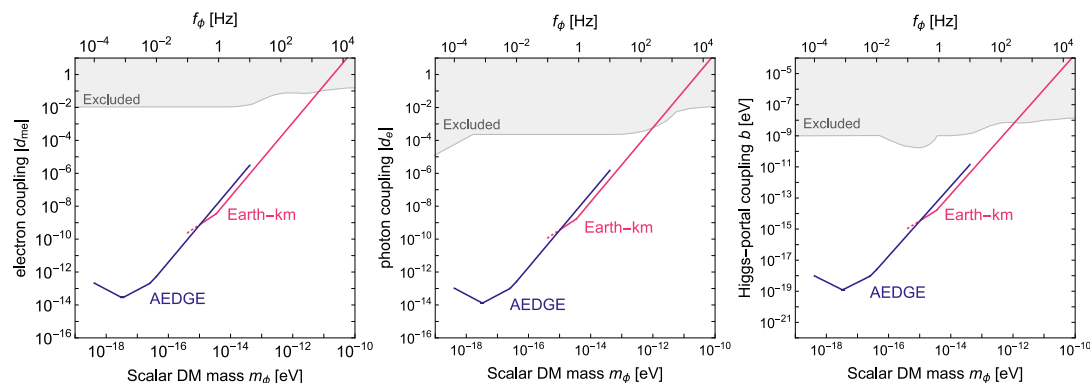
- By means of the present Call for White Papers, the Agency is soliciting ideas from the scientific community for the science themes that should be covered during the Voyage 2050 planning cycle.
- White Papers are not proposals for specific missions; they should rather argue why a specific scientific theme should have priority in the Voyage 2050 planning cycle. At the same time, and to ensure realism in the resulting Programme, applicants should briefly illustrate possible mission profiles.
- Any scientist or science team can submit a White Paper, with no limitation in terms of residence or nationality. White Paper lead scientists cannot be members of the Topical Teams. The author list is restricted to a maximum of 30 authors

White Paper Call – more details

- Describe clearly the proposed science question(s) that you propose to be addressed by the future Science Programme of the Agency. The proposal should place the proposed science question(s) in the broad context of contemporary science, and in the context of the foreseen advancement of scientific knowledge at large and of the specific field in particular.
- Briefly describe how a space mission would address these scientific questions. Proposers are welcome to discuss whether the proposed science is effectively addressed through an L mission, an M mission, or with smaller mission profiles. Should proposers feel that the science goals require an L mission, they are encouraged to discuss if and what fraction of the science might be addressed with a smaller mission profile.
- Proposers are encouraged to explain how the science mission that would address the proposed science goal would fit in a worldwide context of space (and, if applicable, ground- based) science.
- Proposers should explicitly address any technology challenges that they believe would be enabling for addressing the science questions discussed in the White Paper.

EXAMPLE OF AEDGE CAPABILITIES

Atomic Experiment for Dark Matter and Gravity Exploration -- AEDGE



Currently preparing a White Paper for the
ESA Voyager 2050 call:

<https://www.cosmos.esa.int/web/voyage-2050>

[Deadline August 5]

Focus on physics case!

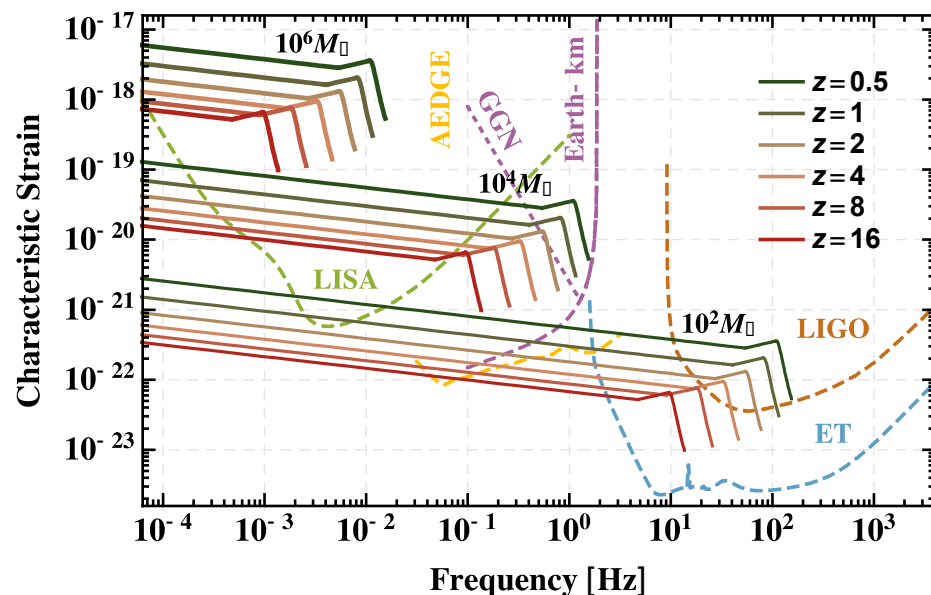
AEDGE Main Physics Goals:

➤ Search for Ultra-Light Dark Mater

- Complement and expand parameter space for DM searches
- Main focus on scalar DM, but pseudoscalar and vector DM might be possible too.

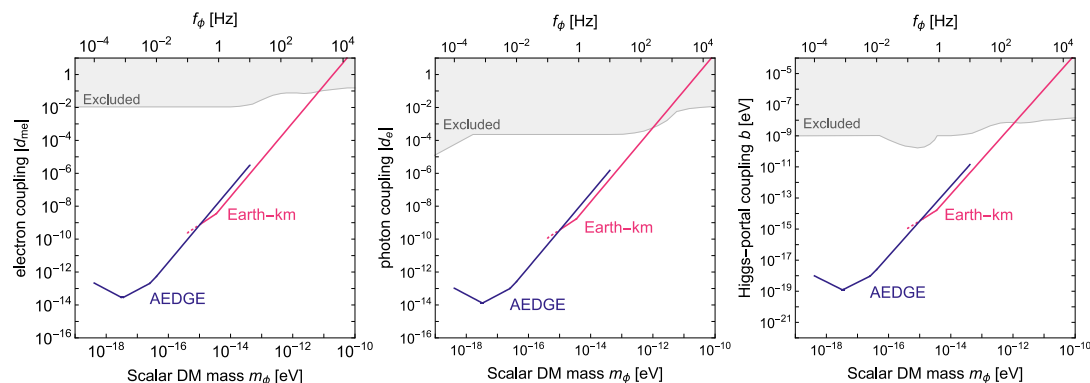
➤ Measurement of GW signals in mid-frequency band

- Measure GW in the frequency range between the most sensitive ranges of LISA and the LIGO/Virgo, KAGRA and Einstein Telescope experiments.



Atomic Experiment for Dark Matter and Gravity Exploration -- AEDGE

O. Buchmueller Workshop Introduction & Welcome



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ESA Voyager 2050 call:

<https://www.cosmos.esa.int/web/voyage-2050>

[Deadline August 5]

Focus on physics case!

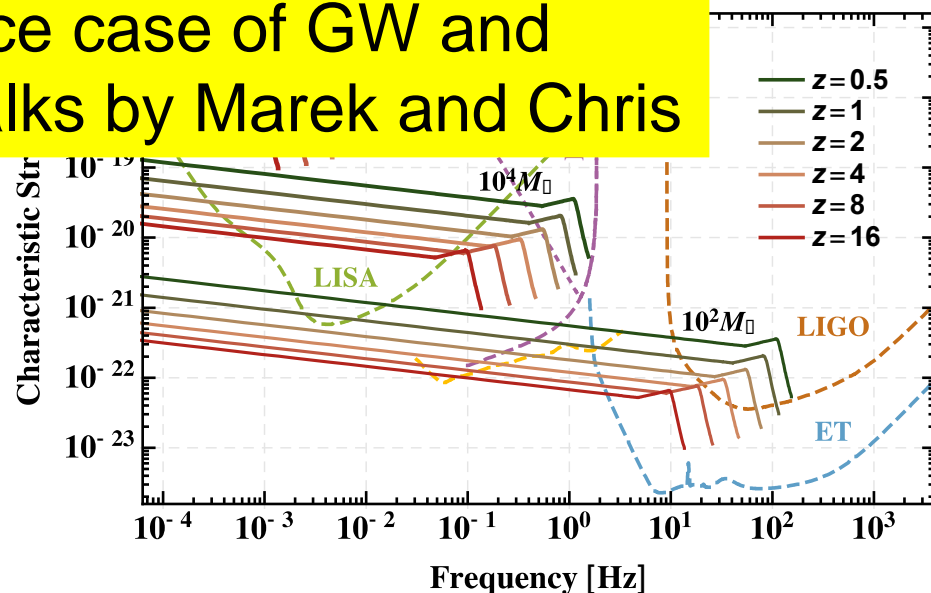
**More about the science case of GW and
AEDGE DM in the following two talks by Marek and Chris**

➤ Search for Ultra-Light Dark Matter

- Complement and expand parameter space for DM searches
- Main focus on scalar DM, but pseudoscalar and vector DM might be possible too.

➤ Measurement of GW signals in mid-frequency band

- Measure GW in the frequency range between the most sensitive ranges of LISA and the LIGO/Virgo, KAGRA and Einstein Telescope experiments.

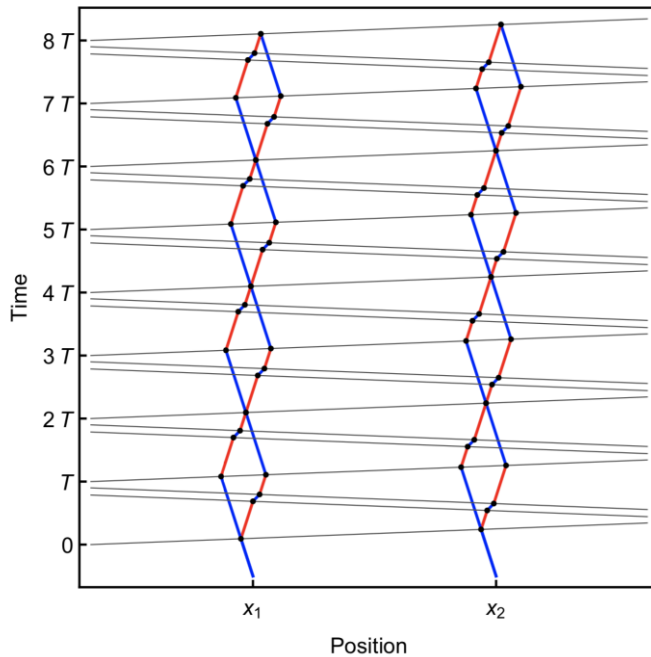
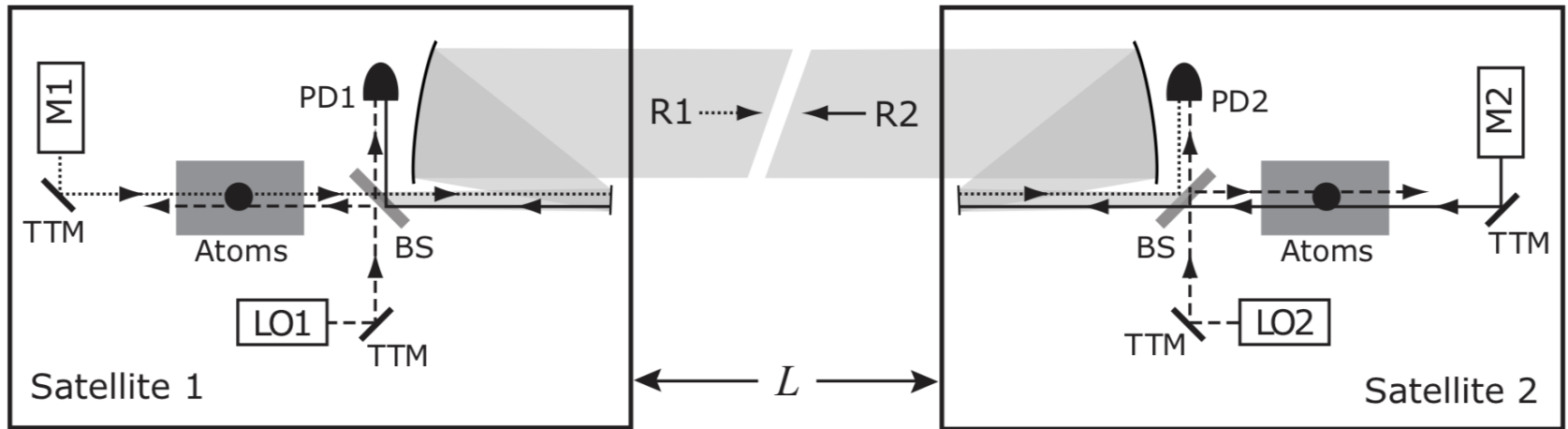


POSSIBLE EXPERIMENTAL CONCEPT

Mission Outline Example

- As we discussed in the previous sessions, here are several cold atom projects based on various technologies that are currently under construction, planned or proposed, any of which could be considered as a concept for a mission proposal.
- To keep things simple, we chose one EXAMPLE to outline a possible high-level mission profile.
 - We will use the mission outlined in detail in:
<https://arxiv.org/pdf/1711.02225.pdf>
 - Was already part of the SAGE proposal
- We emphasize that this is just one of several options to design a space mission based on cold atom technology that could meet these science goals, and other possible technologies are discussed in the section of “Technology Readiness”.

Mission Outline Example



	Parameter	Constraint	Notes
Spacecraft	Satellite longitudinal acceleration noise	$10^{-9} \frac{\text{m/s}^2}{\sqrt{\text{Hz}}} \left(\frac{f}{0.03 \text{ Hz}} \right)^4$	Residual gravity gradient $T_{zz} < 10 \text{ E}$
	Satellite transverse acceleration noise	$3 \times 10^{-10} \frac{\text{m/s}^2}{\sqrt{\text{Hz}}} \left(\frac{f}{0.03 \text{ Hz}} \right)^2$	$\lambda/100$ wavefront at $\Lambda = 1 \text{ cm}$
	Satellite pointing stability	$1 \mu\text{rad}/\sqrt{\text{Hz}}$	
Payload	Telescope aperture	30 cm	$\lambda/100$ wavefront aberration
	Laser pointing stability	$10 \text{ nrad}/\sqrt{\text{Hz}}$	Tip-tilt mirror servo; atom positioning $\Delta x < 1 \mu\text{m}$
	Laser power	2 W	Primary interferometry laser; one per spacecraft
	Interrogation region length	1 m	Length of UHV vacuum chamber
Atom Interferometry	Maximum interferometer duration	$2TQ < 300 \text{ s}$	Limited by vacuum, spontaneous emission
	Maximum atom optics pulses	$n_p < 10^3$	Includes all LMT and resonant enhancement
	Maximum wavepacket separation	$\frac{n\hbar k}{m} T < 1 \text{ m}$	
	AI readout noise	$10^{-4} \text{ rad}/\sqrt{\text{Hz}}$	Requires flux of 10^8 atoms/sec

WHITE PAPER, WORKSHOP WRITE-UP AND AUTHORSHIP

White Paper & Workshop Write-up

- ESA limits the authors allowed to sign the White Paper to 30 max. We will have to be strategic about it to maximize the impact of the WP.
- However, we are planning to use the White Paper as foundation for the write-up planned for the workshop, which will go to arXiv and possibly even be published in a journal (tbd).
- The author list for the arXiv paper will be open to Workshop participants and, in the interest of community building and supporting the science case, we can open it up to everyone having an interest in the science goals of AEDGE.

Subscribe as Author for Workshop Write-up

After the Workshop we will circulate a call to sign up as author for the Workshop Write-up

Personal Data

Fill the description

Title *

First Name *

Last Name *

Email Address *

Affiliation *
This affiliation will be used on the author list and thus should represent your main affiliation typically used for publications.

Disabled fields ?

Position

Address *
IMPORTANT: This address will be used on the author list and thus should represent the address of the institution you belong (and typically used for publications)

Country *

Phone Number

Main Research Interest & Community

Fill the description

Main Research Interest in AEDGE * ☐ CA ☐ GW ☐ DM ☐ Others

Please specify your main research interests. You have to tick at least one of the boxes.
Legend: CA = Cold Atoms, GW=Gravitational Waves, DM=Dark Matter, O=Others