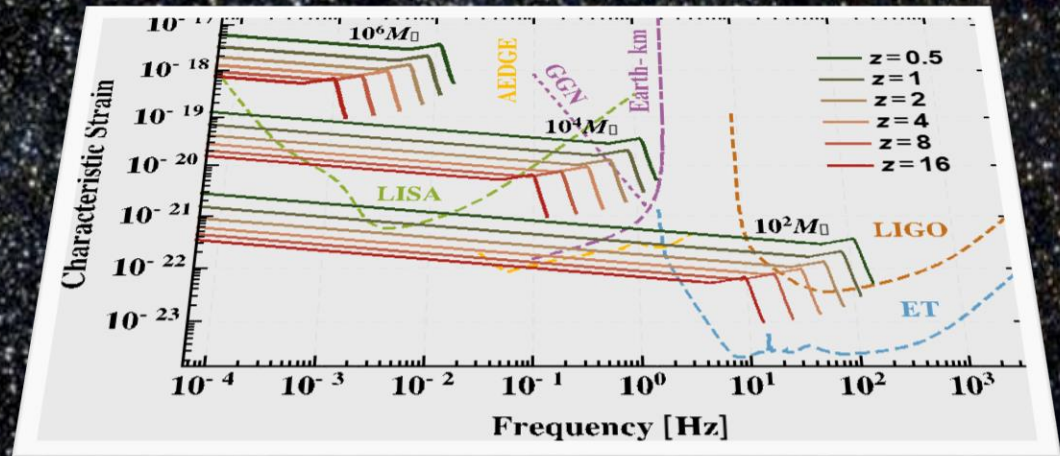
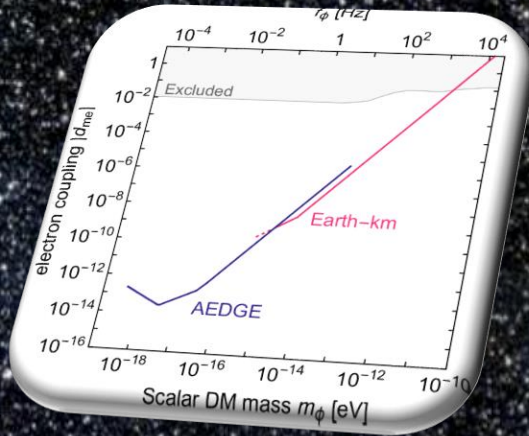


AEDGE: Atomic Experiment for Dark Matter and Gravity Exploration



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

Workshop Outline and Goals

- The purpose of this informal workshop is to review the landscape of cold atom technologies being developed to explore dark sector physics, gravitational effects, and searches for new fundamental interactions - which offer several options for ground-breaking discoveries.
- The Workshop will focus on the physics opportunities and connections between the fundamental research areas of particle physics and gravitational physics using technologies based on cold atom expertise.
- This Workshop will be an opportunity to bring together representatives of the cold atom, particle physics and gravitational communities in Europe (and world wide), to work towards a strong science case that will build the foundation for future space-based as well as terrestrial projects.

An important goal of the workshop will be to assemble a White Paper outlining the physics case for a future space-based cold atom detector in response to the ESA Voyage 2050 call (deadline August 5th).

ESA White Paper: Why now?

- We believe that the time is ripe to propose the use of a space-based cold atom technology to explore gravitational waves in the mid-frequency band, enabling also the exploration of properties of dark sector physics, especially light dark matter, as well as searches for new fundamental interactions, with several options for ground-breaking discoveries.
- We believe that this White Paper effort would be an excellent opportunity to bring together the different communities in Europe and to work towards a strong science case that will build the foundation for future space-based, possibly also terrestrial, projects.
- The ESA White Papers are supposed to focus on the physics case, which has the advantage that we can easily include several different technology scenarios without having to choose, or even favour, any of them.

White Paper: Physics Case

- The White paper will 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 will emphasis "Cold Atoms" as a technology scheme, 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 AdvancedLigo/ET – i.e., it is 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 (axions) and Vector Dark Matter*
 - *Other fundamental physics*

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

CERN: founded in 1954: 12 European States

“Science for Peace”

Today: 23 Member States

~ 2500 staff

~ 1800 other paid personnel

~ 13000 scientific users

Budget (2018) ~ 1150 MCHF

Member States: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Spain, Sweden, Switzerland and United Kingdom, Serbia

Associate Members in the Pre-Stage to Membership: Cyprus, Slovenia

Associate Member States: India, Lithuania, Pakistan, Turkey, Ukraine

Applications for Membership or Associate Membership:

Brazil, Croatia

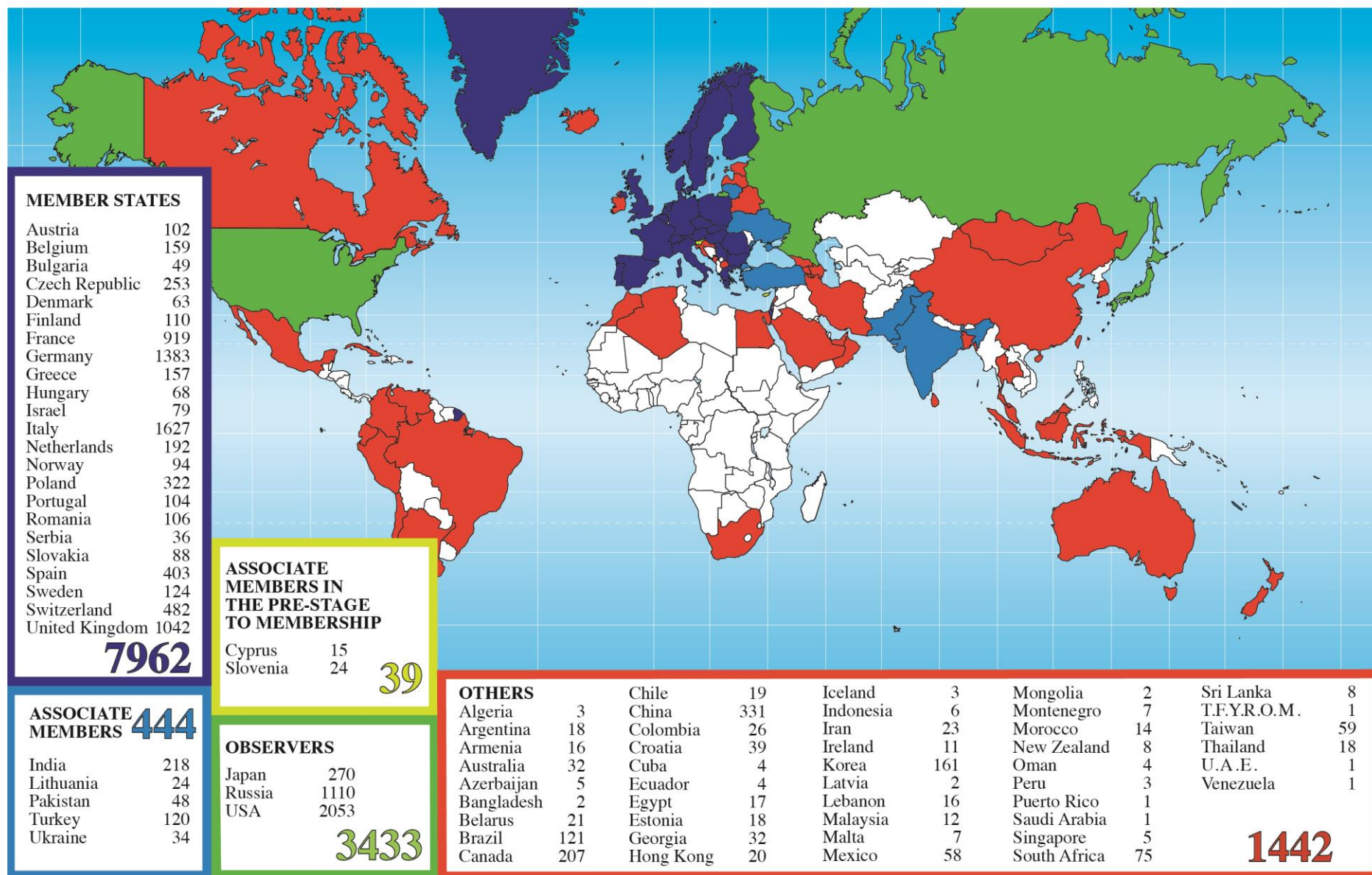
Observers to Council: Japan, Russia, United States of America;

European Union, JINR and UNESCO



Distribution of All CERN Users by Location of Institute on 28 January 2019

O. Buchmueller Workshop Introduction & Welcome



Distribution of All CERN Users by Nationality on 28 January 2019

MEMBER STATES

7918

Austria	112
Belgium	119
Bulgaria	87
Czech Republic	233
Denmark	64
Finland	95
France	850
Germany	1319
Greece	240
Hungary	75
Israel	65
Italy	2050
Netherlands	179
Norway	68
Poland	351
Portugal	116
Romania	133
Serbia	52
Slovakia	138
Spain	458
Sweden	92
Switzerland	219
United Kingdom	793

OBSERVERS

2689

Japan	304
Russia	1187
USA	1198

ASSOCIATE MEMBERS

India	376	757
Lithuania	37	
Pakistan	77	
Turkey	154	
Ukraine	113	

ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP

56

Cyprus	23
Slovenia	33

OTHERS

1930

Bosnia & Herzegovina	3	El Salvador	1	Jordan	2	Montenegro	11	Saint Kitts and Nevis	1	T.F.Y.R.O.M.	3
Brazil	126	Estonia	15	Kazakhstan	10	Morocco	22	Tunisia	3		
Burundi	1	Georgia	49	Kenya	1	Myanmar	2	San Marino	1	Uruguay	1
Cameroon	1	Ghana	1	Korea	174	Nepal	7	Saudi Arabia	4	Uzbekistan	3
Canada	168	Guatemala	1	Latvia	3	New Zealand	5	Senegal	1	Venezuela	10
Chile	21	Hong Kong	1	Lebanon	24	Nigeria	3	Singapore	5	Viet Nam	12
China	557	Honduras	1	Luxembourg	4	North Korea	3	South Africa	48	Zambia	1
Colombia	42	Iceland	4	Madagascar	1	Oman	3	Sri Lanka	10	Zimbabwe	2
Croatia	49	Indonesia	11	Malaysia	20	Palestine	7	Sudan	1		
Cuba	16	Iran	51	Malta	8	Paraguay	1	Syria	1		
Ecuador	8	Iraq	1	Mexico	86	Peru	6	Taiwan	56		
Egypt	24	Ireland	14	Mongolia	2	Philippines	3	Thailand	26		

Workshop Agenda: Day 1

10:30 → 11:00	Welcome Coffee	30m	222/R-001
11:00 → 11:15	Welcome and Introduction	15m	222/R-001
	Workshop Introduction	10m	
	Speaker: Oliver Buchmueller (Imperial College (GB))		
11:15 → 12:30	Towards Space: Review of Terrestrial Projects		222/R-001
11:15	The ZAIGA Experiment	30m	
	The Zhao Shan long-baseline Atom Interferometer Gravitation Antenna (ZAIGA) is an underground laser-linked interferometer facility under construction near Wuhan, China. It has an equilateral triangle configuration with two 1-km-apart atom interferometers in each arm, a 300-meter vertical tunnel equipped with an atom fountain and atomic clocks, and 1-km-arm-length optical clocks linked by locked lasers. It is designed for experimental research on gravitation and related problems including gravitational wave detection and high-precision tests of the equivalence principle. https://arxiv.org/pdf/1903.09288.pdf		
	Speaker: Prof. Mingsheng Zhan (Wuhan Institute of Physics and Mathematics)		
11:50	The MIGA Experiment:	30m	
	The Matter-wave laser Interferometric Gravitation Antenna (MIGA) Experiment aims at demonstrating precision measurements of gravity with cold atom sensors in a large-scale instrument and at studying associated applications in geosciences and fundamental physics. In particular, it will assess future potential applications of atom interferometry to gravitational wave detection in the mid-frequency band between 0.1 and 10 Hz, intermediate between LISA and LIGO/Virgo/KAGRA/INDIGO/ET. http://miga-project.org/ .		
	Speaker: Dr Dylan O Sabulsky (Institut d'Optique d'Aquitaine)		
12:30 → 13:30	Lunch	1h	

Morning

Day 1

Review of large scale
terrestrial projects:

ZIGRA, MIGA, MAGIA-Advanced,
MAGIS, AION, ELGRA

Space:
SAGE

Early afternoon

13:30 → 15:15	Towards Space: Review of Terrestrial Projects		222/R-001
13:30	The MAGIA-Advanced Experiment	30m	
	The MAGIA-Advanced Experiment is a project funded by the Italian Ministry for Research and Istituto Nazionale Fisica Nucleare for a large scale atom interferometer based on ultracold Rb and Sr atoms. In addition to lab R&D activity, the team is investigating the possibility of a 100-300 m atom interferometer to be installed in a vertical shaft on Sardinia island. Main goals are GW observation and search for DM.		
	Speaker: Guglielmo Maria Tino (INFN - National Institute for Nuclear Physics)		
14:05	The MAGIS Project	30m	
	The Matter-wave Atomic Gradiometer Interferometric Sensor (MAGIS) project in the US plans a series of interferometers using cold atoms with progressively increasing baselines of 10m, 100m, and 1km. The first step is funded and under construction at Stanford, the second step is being prepared at Fermilab, and the third step is planned for the Sanford Underground Research Facility. https://arxiv.org/pdf/1812.00482.pdf		
	Speaker: Jonathon Coleman (Physics Dept, University of Liverpool)		
14:40	The AION Project	30m	
	The UK Atom Interferometry Observatory and Network (AION) project in the UK proposes a series of atom interferometers with baselines of 10m, 100m, and 1km, similar to MAGIS. The first stage would be located in Oxford, with sites for the subsequent steps awaiting study. http://www.hep.ph.ic.ac.uk/AION-Project/		
	Speaker: Oliver Buchmueller (Imperial College (GB))		
15:15 → 15:45	Coffee Break	30m	222/R-001

Late afternoon

15:45 → 17:25	Towards Space: Review of Terrestrial Projects		222/R-001
15:45	The ELGAR Project	30m	
	ELGAR is a European initiative to build a terrestrial infrastructure for cold atoms for gravitational wave detection with potential applications also for dark matter. Configurations similar to MAGIS/AION are included in the proposal, and a White Paper about this infrastructure is being prepared [https://indico.obspm.fr/event/58/contributions/214/attachments/88/98/Slides-bouyer2018_06_21_MIGA_GDR.pdf]		
	Speaker: Dr Benjamin Canuel (Institut d'Optique d'Aquitaine)		
16:15	Start of Space Mission Review -- continues on Day 2	5m	
16:20	The SAGE Mission	30m	
	The Space Atomic Gravity Explorer (SAGE) mission was proposed to the European Space Agency in 2016 in response to a Call for "New Ideas" (https://www.cosmos.esa.int/web/new-scientific-ideas). It has the scientific objective to investigate Gravitational Waves, Dark Matter, and other fundamental aspects of gravity as well as the connection between gravitational physics and quantum physics combining quantum sensing and quantum communication based on recent impressive advances in quantum technologies for atom interferometers, optical clocks, microwave and optical links.		
	Speaker: Guglielmo Maria Tino (INFN - National Institute for Nuclear Physics)		
16:55	Discussion and Preparation for Day 2	30m	

Workshop Agenda: Day 2

Day 2

Review of large scale
space projects:

Optical Clocks,
BECCAP, STE-QUEST

AEDGE Physics

GW and DARK Matter

Closed Session:

Discuss WP Draft

Morning

09:15 → 11:30	Towards the White Paper: Other Relevant Space Missions	40/S2-B01 - Salle Bohr	
09:15	Morning Coffee	30m	
09:45	Space Optical Clock mission Speaker: Stephan Schiller (Heinrich-Heine-Universität Düsseldorf)	30m	
10:20	The BECCAL Project The Bose-Einstein Condensate and Cold Atom Laboratory (BECCAL) is a bilateral project of NASA and DLR for a multi-purpose facility on the international space station, based in the heritage of drop tower (QUANTUS) and sounding rocket experiments (MAIUS). It will enable a variety of experiments in atom optics and atom interferometry to cover a broad spectrum ranging from fundamental physics to studies for applications in earth observation. It is intended as a pathfinder for future space missions: Speaker: Dr Christian Schubert (Leibniz Universität Hannover)	30m	
10:55	The STE-QUEST Mission Speaker: Dr Aurelien Hees (SYRTE - Paris Observatory)	30m	
11:30 → 12:35	White Paper: The Physics Case of AEDGE	40/S2-B01 - Salle Bohr	Join 40/S2-B01
11:30	Introduction to AEDGE White Paper Physics Case Speaker: Oliver Buchmuller (Imperial College (GB))	15m	
11:50	AEDGE: Gravitational Waves Speaker: Marek Lewicki (Kings College London)	20m	
12:15	AEDGE: Dark Matter Speaker: Dr Christopher McCabe (King's College London)	20m	
12:35 → 12:50	Open Session - Closing Convener: Jonathan R. Ellis (University of London (GB))	40-S2-B01	
12:50 → 13:30	Lunch	40m	

Afternoon

13:30 → 15:30	White Paper Authors Meeting (closed session)	60/6-015 - Room Georges Cha...	Join 60/6-015
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Workshop Venue Map

