Concluding remarks: the COSMO conferences

Leszek Roszkowski

AstroCeNT*, CAMK PAN & NCBJ, Poland

AstroCeNT: Particle Astrophysics Center for Science and Technology
@ The Nicolaus Copernicus Astronomical Centre of Polish Academy of Sciences (NCAC PAS/CAMK PAN)

NCBJ: National Centre for Nuclear Research

COSMO-97

International Workshop

on

PARTICLE PHYSICS AND THE EARLY UNIVERSE

15 - 19 September 1997

Ambleside, Lake District, England

Organised by: Lancaster University

COSMO: *annual meetings of particle physics, cosmology and astrophysics theory community*

- ’97 Ambleside UK
- ’ 98 Asilomar, CA, USA
- ’ 99 Triest, Italy
- ’ 00 Cheju, S. Korea
- ’ 01 Rovaniemi, Finland
- ’ 02 Chicago, IL, USA
- ’ 03 Ambleside, UK
- ’ 04 Toronto, Canada
- ’ 05 Bonn, Germany
- ’ 06 Lake Tahoe (UC Davis), USA
- ’ 07 Sussex, UK
- ’ 08 Madison, WI, USA
- ’ 09 CERN, CH
- ’ 10 Tokyo, Japan
- ’ 11 Porto, Portugal
- ‘12 Beijing, P.R. China
- ’13 Cambridge, UK
- ‘14 Chicago, IL, USA
- ‘15 Warsaw, Poland
- ‘16 Ann Arbor, MI, USA
- ‘17 Paris, France
- ’18 Daejeon, S. Korea
- ‘19 Aachen, Germany
- ‘20 ~~Rio de Janeiro, Brazil~~
- ‘21 Urbana, Illinois, USA (online)
- ‘22 Rio de Janeiro, Brazil

25th COSMO!

THANK YOU!!!

Local Organising Committee

- Beatriz Blanco Siffert (UFRJ)
- Felipe T. Falciano (CBPF)
- Karín Menéndez-Delmestre (UFRJ)
- Luis Raul W. Abramo (USP)
- Martin Makler (CBPF)
- Nelson Pinto-Neto (CBPF)
- Miguel Quartin (Chair – UFRJ)
- Ribamar Rondon Rezende Reis (UFRJ)
- Riccardo Sturani (IFT-UNESP)
- Thiago S. Pereira (UEL)
- Valerio Marra (UFES)

+ secretarial suport

Some numbers

- **TOTAL 153**

Latin America
- Brazil: 51
- Chile: 5
- Mexico: 5
- Colombia: 4
- Argentina: 2

North America
- USA: 8
- Canada: 2

Europe
- Spain: 8
- United Kingdom: 6
- Italy: 4
- Netherlands: 4
- Sweden: 3
- Belgium: 2
- Denmark: 2
- France: 2
- Germany: 2
- Poland: 1
- Portugal: 1
- Russia: 1
- Switzerland: 1

Asia
- India: 10
- Japan: 6
- South Korea: 3
- Cambodia: 2
- Pakistan: 2
- China: 1
- Thailand: 1

Africa
- Egypt: 1
- Ghana: 1
- South Africa: 1

Unidentified: 11

- **Male/female: ~4:1**
- **Age profile: just look around**

COSMO Steering Committee

- Vernon Barger
- Daniel Baumann
- John Beacom
- Kiwoon Choi
- John Ellis
- Kari Enqvist
- Brian Fields
- Evalyn Gates
- Ruth Gregory
- Francis Halzen
- Mark Hindmarsh
- Dragan Huterer
- Stavros Katsanevas
- Jihn E. Kim
- Edward W. (Rocky) Kolb
- Julien Lesgourgues
- Andrei Linde
- David Lyth
- Carlos Martins
- Hans-Peter Nilles
- Michael Ramsey-Musolf
- Antonio Riotto
- Matts Roos
- Leszek Roszkowski
- Goran Senjanovic
- Jun'ichi Yokoyama
- Hu Zhan

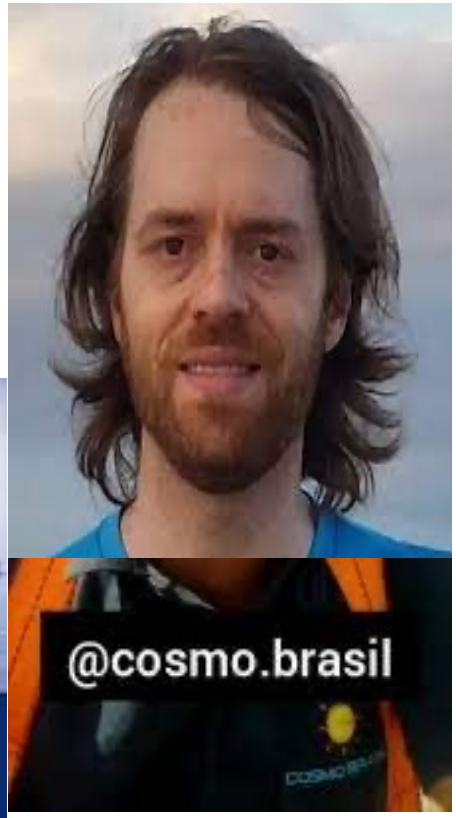
Cosmo Energy Holdings Co., Ltd.

COSMO

Japan (2010)

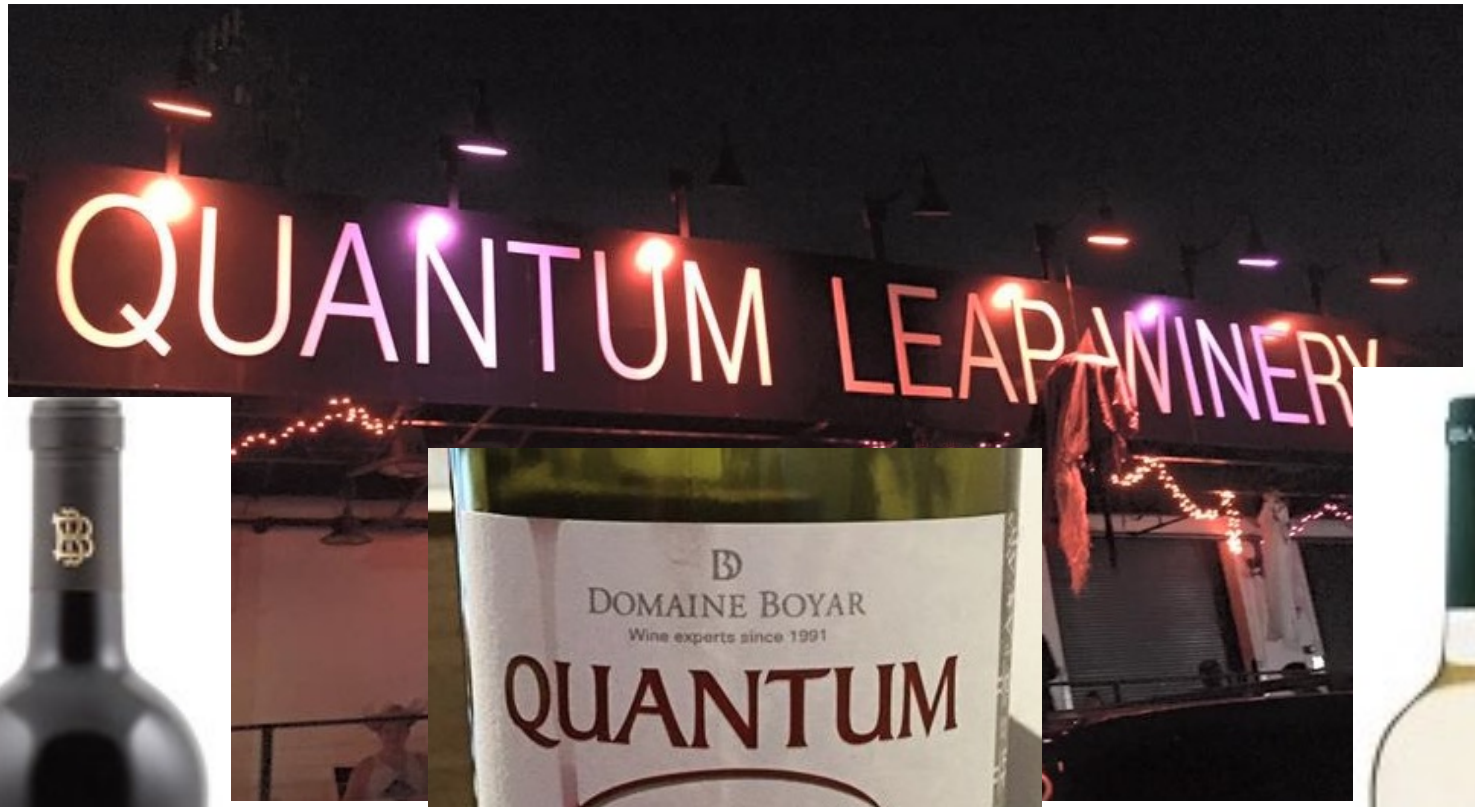
COSMO BRASIL

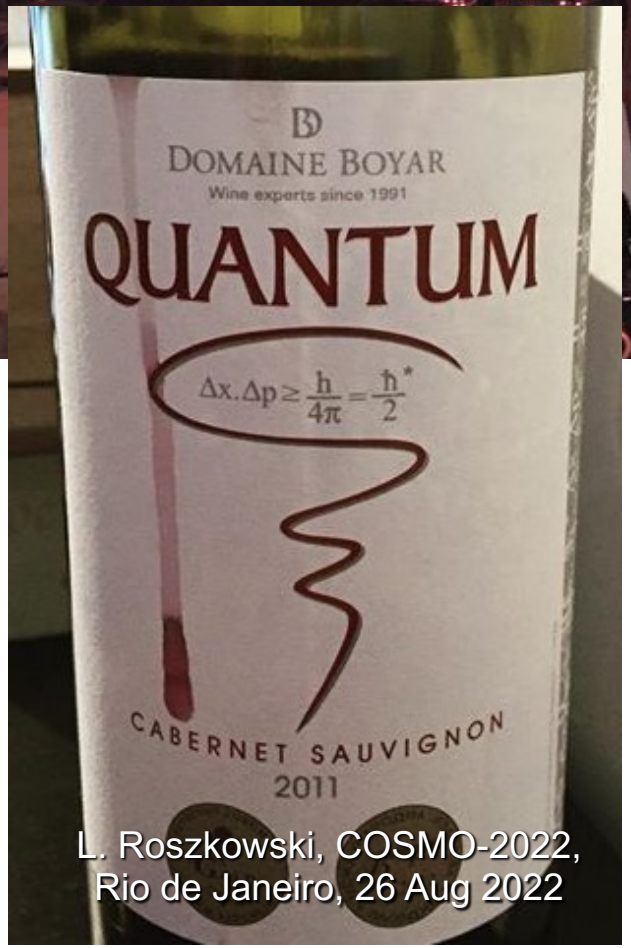
INSTALAÇÃO ELÉTRICA & SOLAR



www.cosmo-rio.com

L. Roszkowski, COSMO-2022,
Rio de Janeiro, 26 Aug 2022





L. Roszkowski, COSMO-2022,
Rio de Janeiro, 26 Aug 2022

COSMO traditions:

- (Usually) no summary talk…
- Rain!
- Each meeting is different
- Common themes
- …

Trends and perspectives…

Today's COSMO menu

- Big Bang/very early Universe
- CMB
- Power spectrum
- LSS (observations vs numerical simulations)
- Hubble constant H
- Dark energy
- DM
  - WIMP
  - Axion
  - …
- Other relics
  - Neutrinos
  - Cosmic rays
- Gravitational waves
- (Primordial) black holes
- …

- Large scale surveys
- Collider physics
- …

Big Bang/very early Universe:

- Inflation
- PBHs
- Baryo/leptogenesis
- BBN
- Particle cosmology
- String cosmology
- Quantum gravity
- Models of BB
- Holography, etc.
- …

Mid-90s COSMO menu

- Big Bang/very early Universe
- CMB
- Power spectrum
- LSS (observations vs numerical simulations)
- Hubble constant H
- ~~Dark energy~~
- DM
  - WIMP
  - Axion
  - …
- Other relics
  - Neutrinos
  - Cosmic rays
- ~~Gravitational waves~~
- ~~(Primordial) black holes~~
- …

- Large scale surveys
- Collider physics
- …

Big Bang/very early Universe:

- Inflation
- ~~PBHs~~
- Baryo/leptogenesis
- BBN
- Particle cosmology
- ~~String cosmology~~
- ~~Quantum gravity~~
- ~~Models of BB~~
- ~~Holography, etc.~~
- …

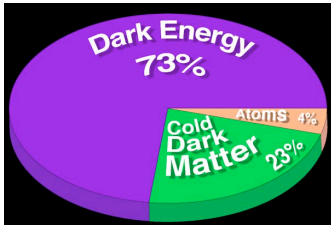
Particle physics and cosmology:

- Two nearly separate communities
- Speaking different languages
- Misunderstanding and suspicion…

Veltman: Cosmology is not science

How much progress has been made?

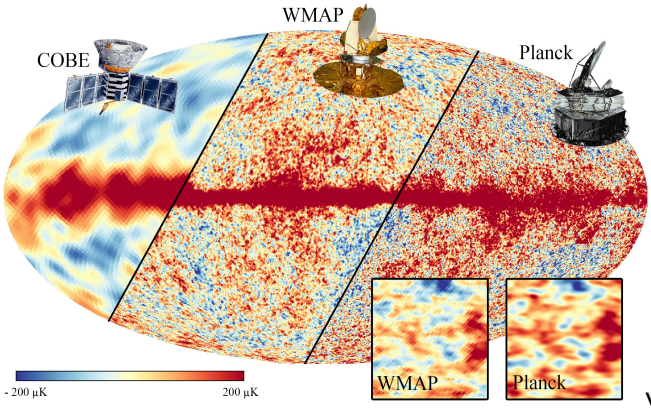
Has progress been made?



Of course!

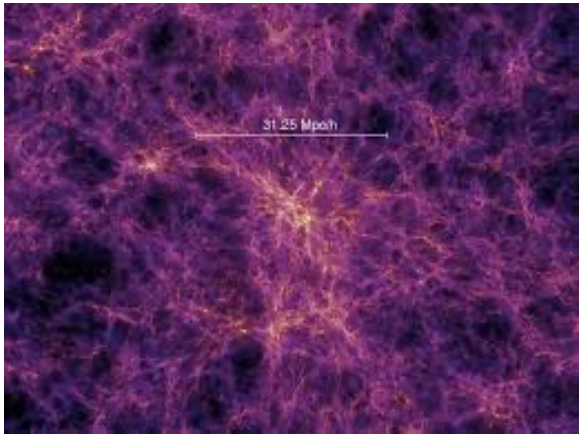
Know:

- main components of the Universe: CDM, DE
- Its geometry
- Hubble parameter
- Main cosmological parameters
- That Universe accelerates (1998)
- CMB with sub-% precision (since WMAP, ~2003)
- Universal power spectrum
- Basic mechanisms for LSS formation
- Gravitational waves
- ….



→Emergence of Standard Model of Cosmology

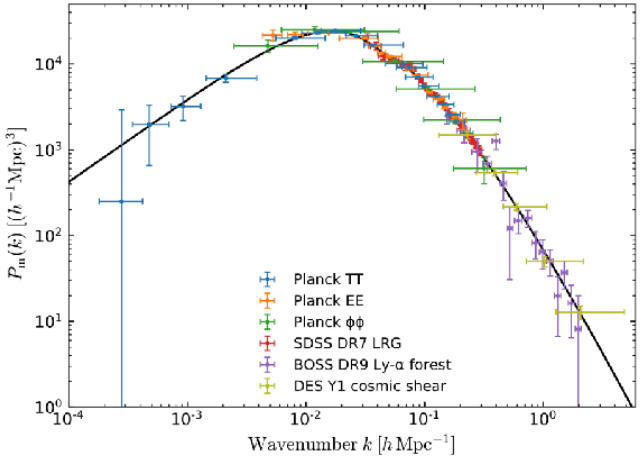
LCDM paradigm



Can describe physical evolution of the Universe:

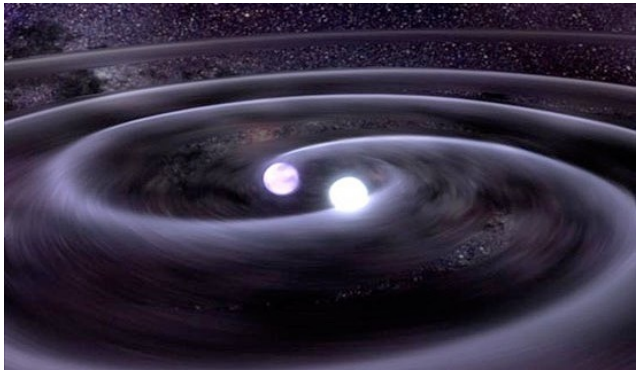
- Down to ~10^{-12}s (~100 GeV) with known physics
- Down to ~10^{-43}s (M_{Planck}) within calculable models and scenarios (BSM)

Has progress been made?



Wealth of new observations!

- New large surveys
- Large scale mapping of the sky
- New tracers
- New windows (…, GWs)

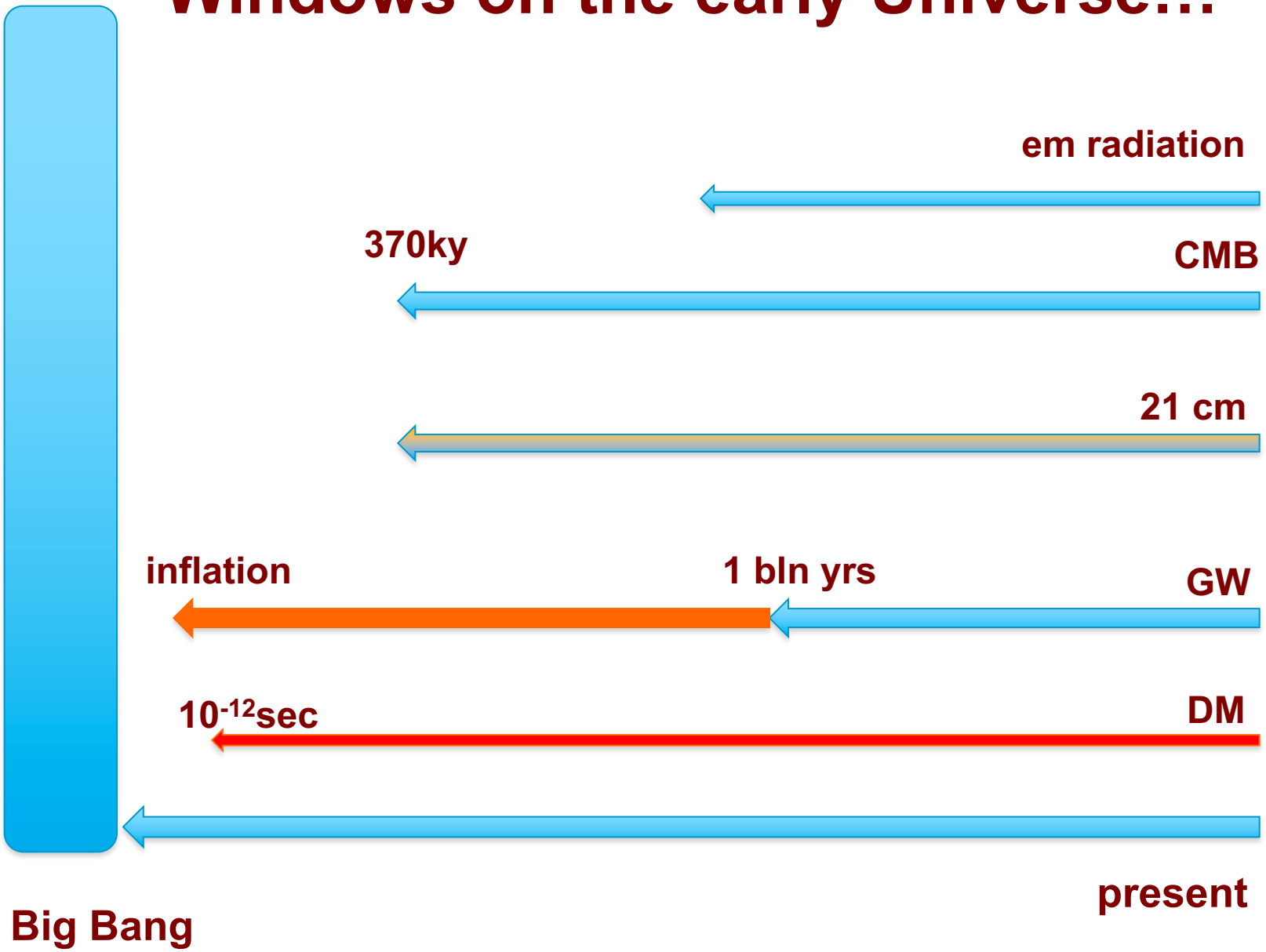


Six Nobel Prizes:

- CMB
  - 1964: Penzias & Wilson
  - 2006: Smoot (COBE)
  - 2011: Perlmutter, Schmidt and Riess
- Neutrino oscillations (2015: Kajita and McDonald)
- Gravitational Waves (2017: Thorne, Weiss and Barish)
- Physical cosmology (2019, Peebles) + astronomy…

→ Multi-messenger mapping of the Universe

Windows on the early Universe…



Longer-term perspective

100 years ago the Universe was:

- **Static**
- **Unchanging**
- **Without beginning or end**
- **Pretty boring…**

The Universe is never boring!


We now know
what the Universe is made of
and how it works…
I'm sure, darling!
But do we actually
understand it all?

We now know what the Universe is made of and *how* it works…

Do we understand *why*?

Has progress been made … on the theory side?

- Improved calculations
- New effects
- Impact of new data
- New scenarios (eg. DM, relics, inflation, …)
- New mechanisms
- New ideas (?)

Progress can be measured by learning about new viable options…

…Or by reducing them!

Less can tell you more….

Just how fresh are these insights?

Theory is still much ahead of experiment….

- What has been ruled out over the last 20 years?
- Has any paradigm been replaced by another?

Outstanding theoretical questions

- **Nature of DM:**
  Axion? WIMP? One or more?
  WIMP properties
  Broader theory framework…
- **Inflation:**
  Mechanism, type, specific model, broader BSM framework…
- **DE:**
  Is it cosmological constant?
  Or dynamical? Or both?
- …

Particle theory:

- Unification of forces
- EWSB mechanism (Higgs boson)
- Hierarchy of m_{EW} and M_{Pl}
- Number and structure of fermions
- Nature and properties of neutrinos
- Flavor and CPX
- Dark matter candidate(s)
- Baryo/leptogenesis mechanism
- Incorporation of gravity in quantum relativistic theory (Einstein or modified?)
- Vacuum (unique?)
- …

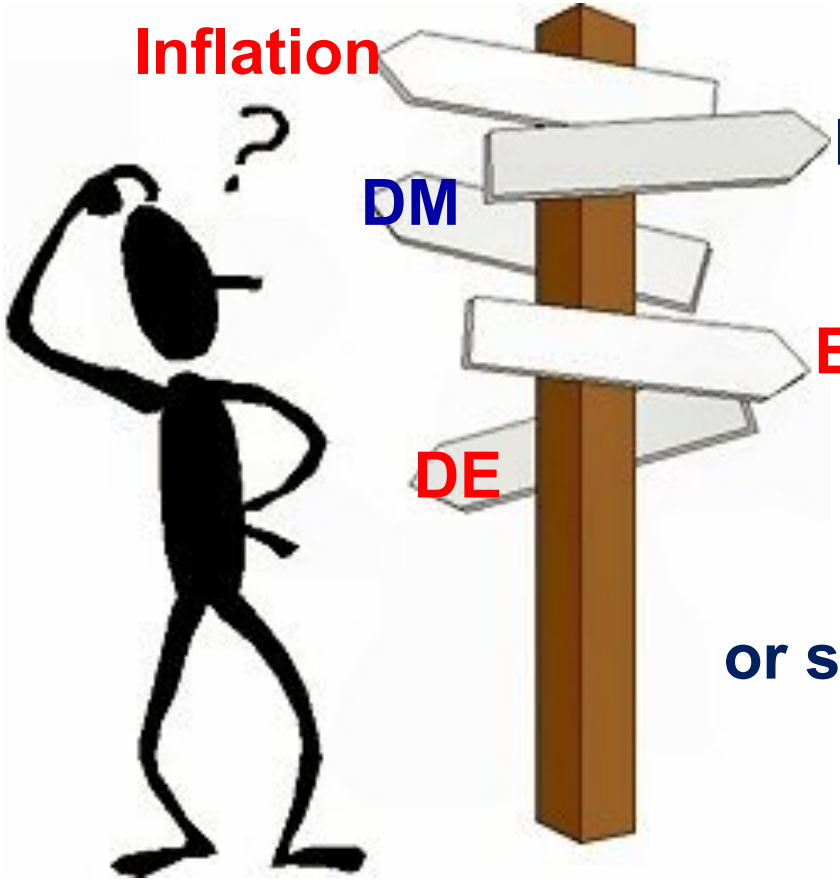
Ultimate goal: Unified fundamental theory of:

- All known particle physics (SM+)
- DM, DE
- Early Universe (Inflation, Baryogenesis, …)
- Gravity
- …

We now know what the Universe is made of and *how* it works…

Much less so in actually understanding it.

Where to expect *theoretical* breakthroughs?…. betting and hedging



Similar conclusions for:

- **DE**
- **Multiverse**
- **Landscape/swampland?**
- **Quantum gravity**
- **…**

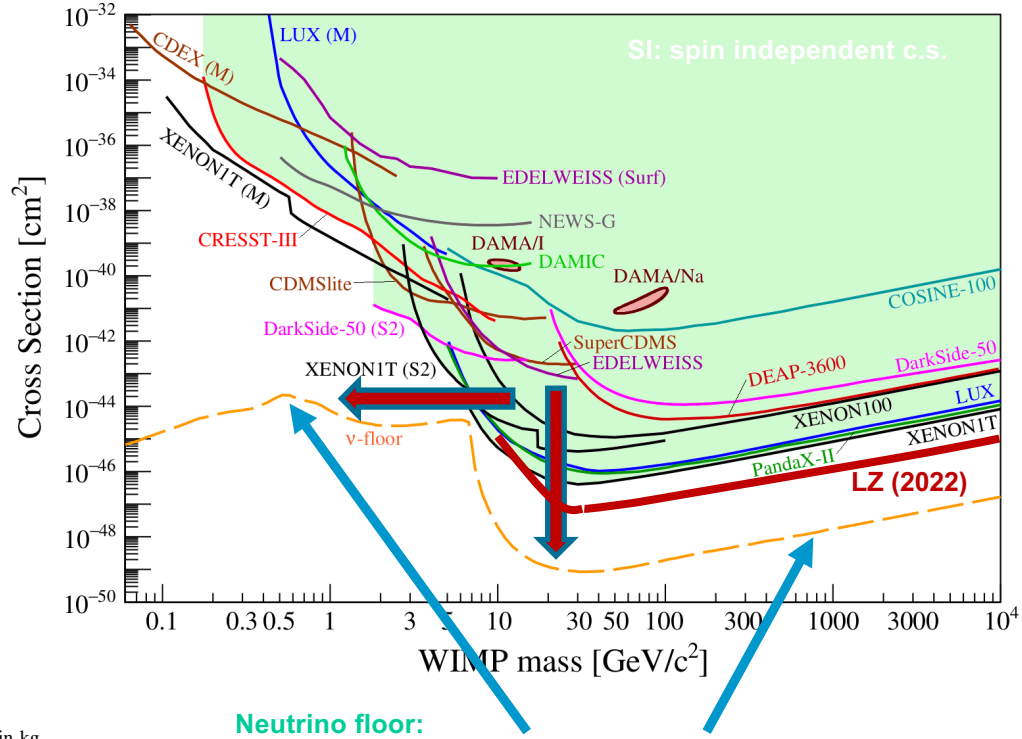
Direct detection of dark matter -- APPEC committee report

***Rept.Prog.Phys.* (2022)**
e-Print: 2104.07634

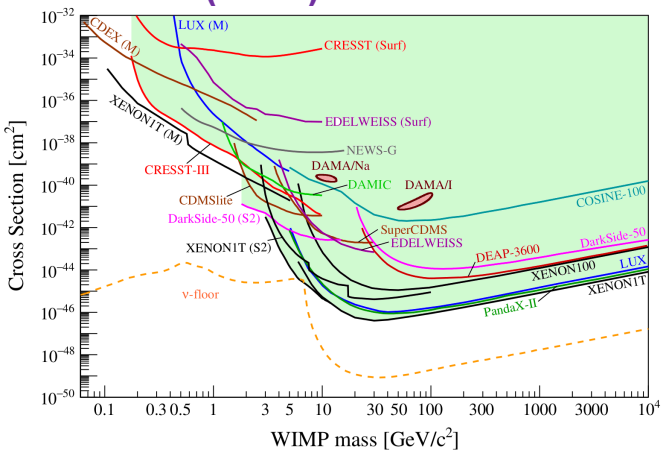
Experiment	Lab	Target	Mass [kg]	Ch	Sensitivity [cm^2@ GeV/c^2]	Exposure [t× year]	Timescale
Cryogenic bolometers (Section 4.6.1)							
EDELWEISS-subGeV	LSM	Ge	20	SI	10^{-43} @ 2	0.14	in prep.
SuperCDMS	SNOLAB	Ge, Si	24	SI	4×10^{-44} @ 2	0.11	constr.
CRESST-III	LNGS	$CaWO_4$+	2.5	SI	6×10^{-43} @ 1	3×10^{-3}	running
LXe detectors (Section 4.6.2)							
LZ	SURF	LXe	7.0 t	SI	1.5×10^{-48} @ 40	15.3	comm.
PandaX-4T	CJPL	LXe	4.0 t	SI	6×10^{-48} @ 40	5.6	constr.
XENONnT	LNGS	LXe	5.9 t	SI	1.4×10^{-48} @ 50	20	comm.
DARWIN	LNGS*	LXe	40 t	SI	2×10^{-49} @ 40	200	∼2026
LAr detectors (Section 4.6.3)							
DarkSide-50	LNGS	LAr	46.4	SI	1×10^{-44} @ 100	0.05	running
DEAP-3600	SNOLAB	LAr	3.6 t	SI	1×10^{-46} @ 100	3	running
DarkSide-20k	LNGS	LAr	40 t	SI	2×10^{-48} @ 100	200	2023
ARGO	SNOLAB	LAr	400 t	SI	3×10^{-49} @ 100	3000	TBD
NaI(Tl) scintillators (Section 4.6.4.1)							
DAMA/LIBRA	LNGS	NaI	250	AM		2.46	running
COSINE-100	Y2L	NaI	106	AM	3×10^{-42} @ 30	0.212	running
ANAIS-112	LSC	NaI	112	AM	1.6×10^{-42} @ 40	0.560	running
SABRE	LNGS	NaI	50	AM	2×10^{-42} @ 40	0.150	in prep.
COSINUS-1π	LNGS	NaI	∼1	AM	1×10^{-43} @ 40	3×10^{-4}	2022
Ionisation detectors (Section 4.6.4.2)							
DAMIC	SNOLAB	Si	0.04	SI	2×10^{-41} @ 3-10	4×10^{-5}	running
DAMIC-M	LSM	Si	∼0.7	SI	3×10^{-43} @ 3	0.001	2023
CDEX	CJPL	Ge	10	SI	2×10^{-43} @ 5	0.01	running
NEWS-G	SNOLAB	Ne,He		SI			comm.
TREX-DM	LSC	Ne	0.16	SI	2×10^{-39} @ 0.7	0.01	comm.
Bubble chambers (Section 4.6.4.3)							
PICO-40L	SNOLAB	C_3F_8	59	SD	5×10^{-42} @ 25	0.044	running
PICO-500	SNOLAB	C_3F_8	1 t	SD	$\sim 1 \times 10^{-42}$ @ 50		in prep.
Directional detectors (Section 4.6.5)							
CYGNUS	Several	He:SF_6	10^3 m^3	SD	3×10^{-43} @ 45	6 y	R&D
NEWSdm	LNGS	Ag,Br,C,...		SI	8×10^{-43} @ 200	0.1	R&D

Table 1: Current, upcoming and proposed experiments for the direct detection of WIMPs. Mass is given in kg unless explicitly specified. The experiments' main detection channel (Ch) is abbreviated as: SI (spin independent WIMP-nucleon interactions), SD (spin dependent), AM (annual modulation). The sensitivity is reported for this channel, assuming the quoted exposure. Note that many projects have several detection channels. comm. = experiment under commissioning.
*No decision yet. A CDR for LNGS is being prepared.

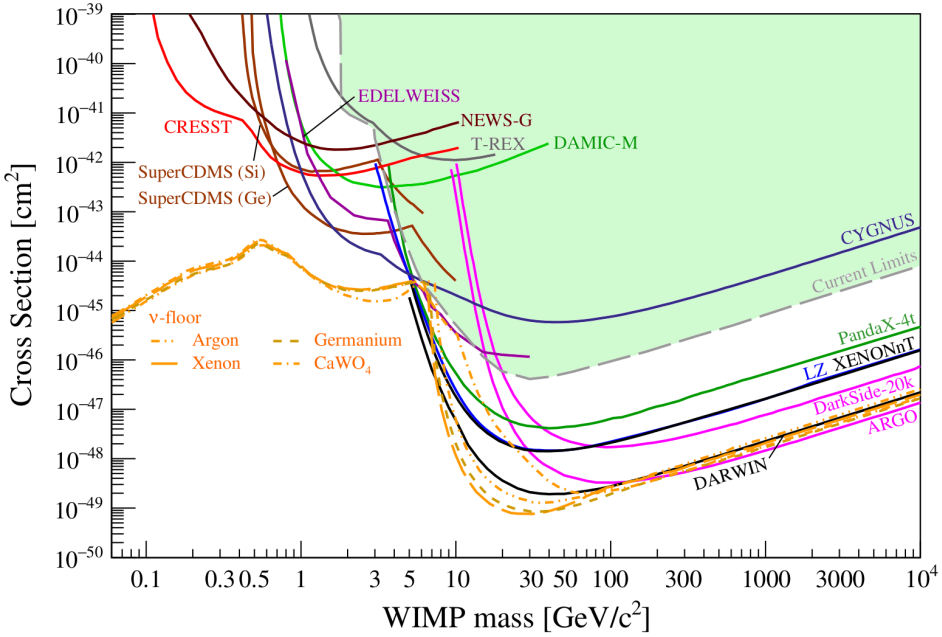
Present (2021):



Present (2021)

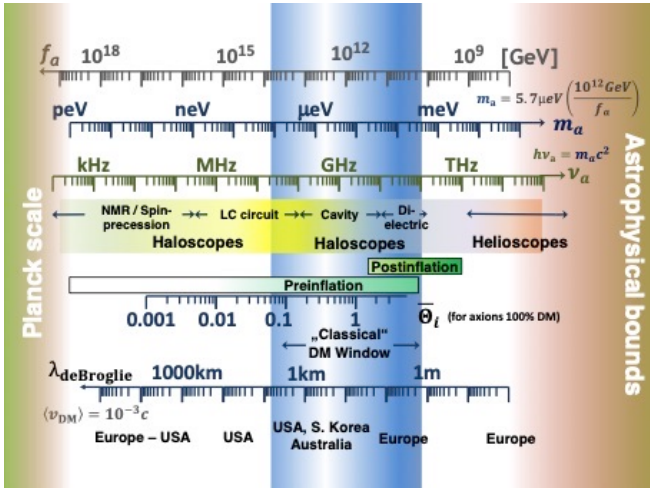


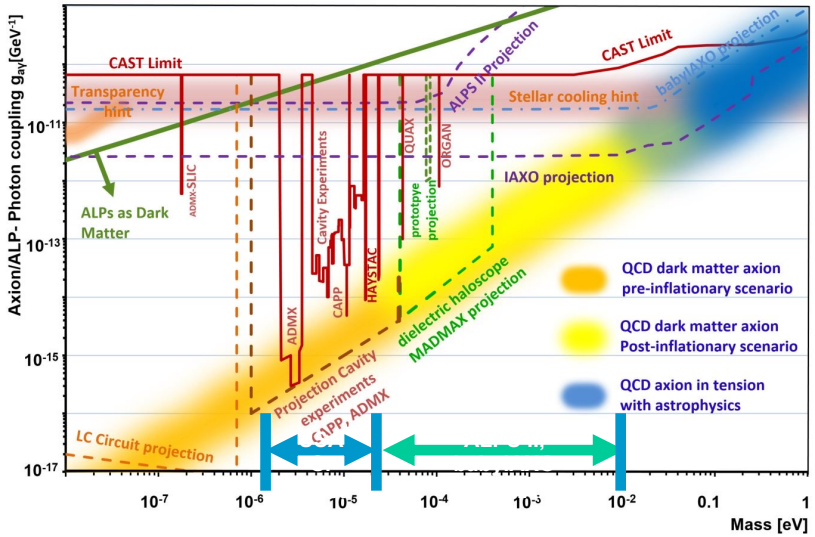
Next decade+



Recommendation 3. **The experimental underground programmes with the best sensitivity to detect signals induced by dark matter WIMPs scattering off the target should receive enhanced support to continue efforts to reach down to the so-called neutrino floor on the shortest possible timescale.**

Axion/ALP searches





Recommendation 6. **European-led efforts should focus on axion and ALPs mass ranges that are complementary to the established cavity approach and this is where European teams have a unique opportunity to secure the pioneering role in achieving sensitivities in axion/ALP mass ranges not yet explored by experiments conducted elsewhere. In parallel, R&D efforts to improve experimental sensitivity and to extend the accessible mass ranges should be supported.**

Experiment/observations:

- Programmes set for next decade+
  in key areas: DM, neutrinos, DE, surveys,
- Expect wealth of data
- Opening up new windows on the Universe (GWs,…)
- Surprises…?

Theory:

- (too) many possibilities open
- still little real understanding
- need much more data
- prepare for a long ride
- will need many more COSMO meetings

COSMO: *annual meetings of particle physics, cosmology and astrophysics theory community*

- ’97 Ambleside UK
- ’98 Asilomar, CA, USA
- ’99 Triest, Italy
- ’00 Cheju, S. Korea
- ’01 Rovaniemi, Finland
- ’02 Chicago, IL, USA
- ’03 Ambleside, UK
- ’04 Toronto, Canada
- ’05 Bonn, Germany
- ’06 Lake Tahoe (UC Davis), USA
- ’07 Sussex, UK
- ’08 Madison, WI, USA
- ’09 CERN, CH
- ’10 Tokyo, Japan
- ’11 Porto, Portugal
- ‘12 Beijing, P.R. China
- ’13 Cambridge, UK
- ‘14 Chicago, IL, USA
- ‘15 Warsaw, Poland
- ‘16 Ann Arbor, MI, USA
- ‘17 Paris, France
- ’18 Daejeon, S. Korea
- ‘19 Aachen, Germany
- ‘20 ~~Rio de Janeiro, Brazil~~
- ‘21 Urbana, Illinois, USA (online)
- ’22 Rio de Janeiro, Brazil
- **’23 Madrid, Spain**

COSMO-23, IFT-Madrid, 11th-15th Sep 2023

L. Roszkowski, COSMO-2022,
Rio de Janeiro, 26 Aug 2022

Local Organizers:

Juan Garcia-Bellido
Savvas Nesseris
David G. Cerdeño
Yashar Akrami
Sachiko Kuroyanagi
Miguel A. Sanchez Conde
Carlos Muñoz

Looking forward to seeing you in Madrid next year!