

# **[Instead of] Summary and Concluding Remarks**

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Poland**

**New Research Center in Poland:**

**AstroCeNT -- Particle Astrophysics Centre 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 Steering Committee

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- **Goran Senjanovic**
- **Jun'ichi Yokoyama**
- **Hu Zhan**

## **COSMO traditions:**

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

**New tradition?: childcare support**

# 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**
- ...
  
- Large scale surveys
- Collider physics
- ...

## Big Bang/very early Universe:

- Inflation
- PBHs
- Baryo/lepto-genesis
- BBN
- Particle cosmology
- String cosmology
- Quantum gravity
- Models of BB (bouncing, etc)
- Holography, etc.
- ...

# Mid-90s COSMO menu

- **CMB**
- **LSS (observations, numerical simulations)**
- **Hubble constant H**
- ~~Dark energy~~
- **DM**
  - **WIMP**
  - **Axion**
  - ...
- **Other relics**
  - **Neutrinos**
  - **Cosmic rays**
- ...
- ~~Large scale surveys~~
- **Collider physics**
- ~~Gravitational waves~~
- ...

## Big Bang/Early Universe:

- **Inflation**
- ~~PBHs~~
- **Baryo/lepto-genesis**
- **BBN**
- ~~Quantum gravity~~
- **Particle cosmology**
- ~~String cosmology~~
- ~~Models of BB (bouncing, etc)~~
- ~~Holography, etc.~~
- ...

## Particle physics and cosmology:

- **Two nearly separate communities**
- **Speaking different languages**
- **Misunderstanding and suspicion...**

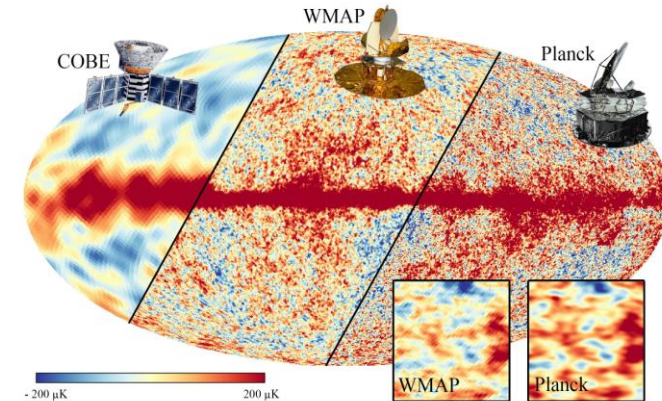
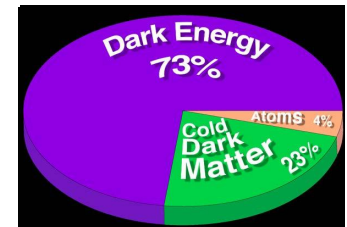
**Cosmology is not science (Veltman)**

# 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
- ....

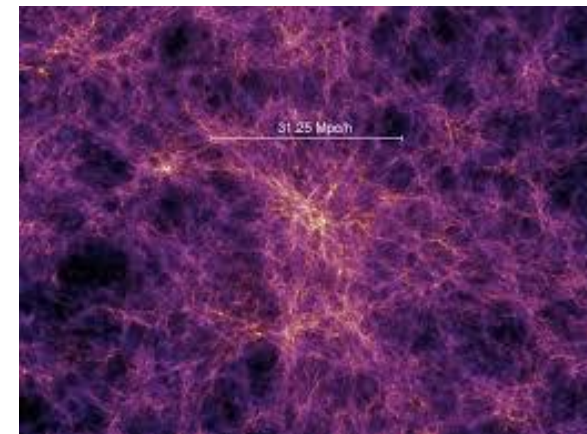


## → Emergence of Standard Model of Cosmology

ΛCDM paradigm

Can describe physical evolution of the Universe:

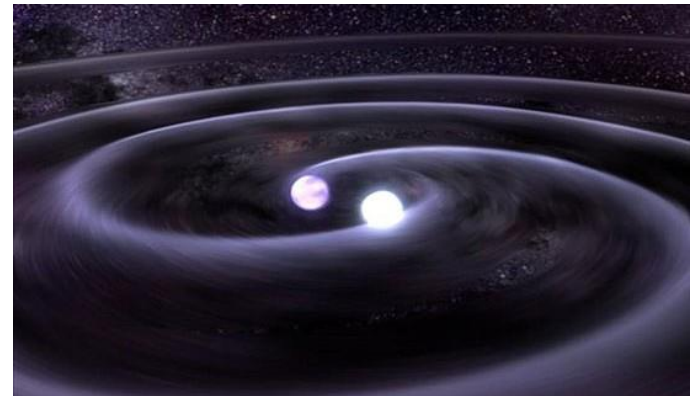
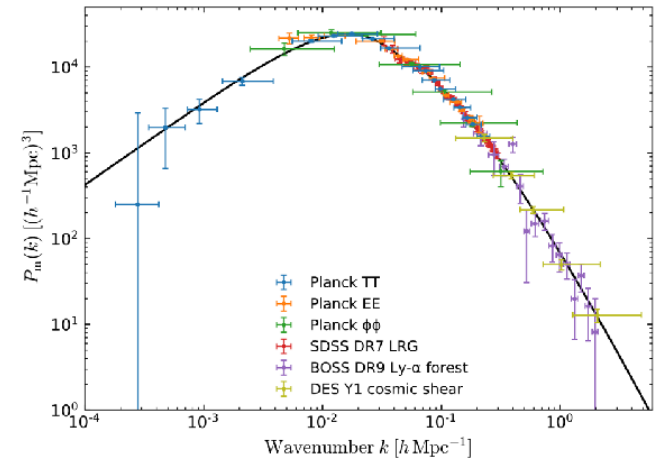
- Down to  $\sim 10^{-12}\text{s}$  ( $\sim 100\text{ GeV}$ ) with known physics
- Down to  $\sim 10^{-43}\text{s}$  ( $M_{\text{Planck}}$ ) within calculable models and scenarios (BSM)



# Has progress been made?

## Wealth of new observations!

- New large surveys
- Large scale mapping of the sky
- New tracers
- New windows

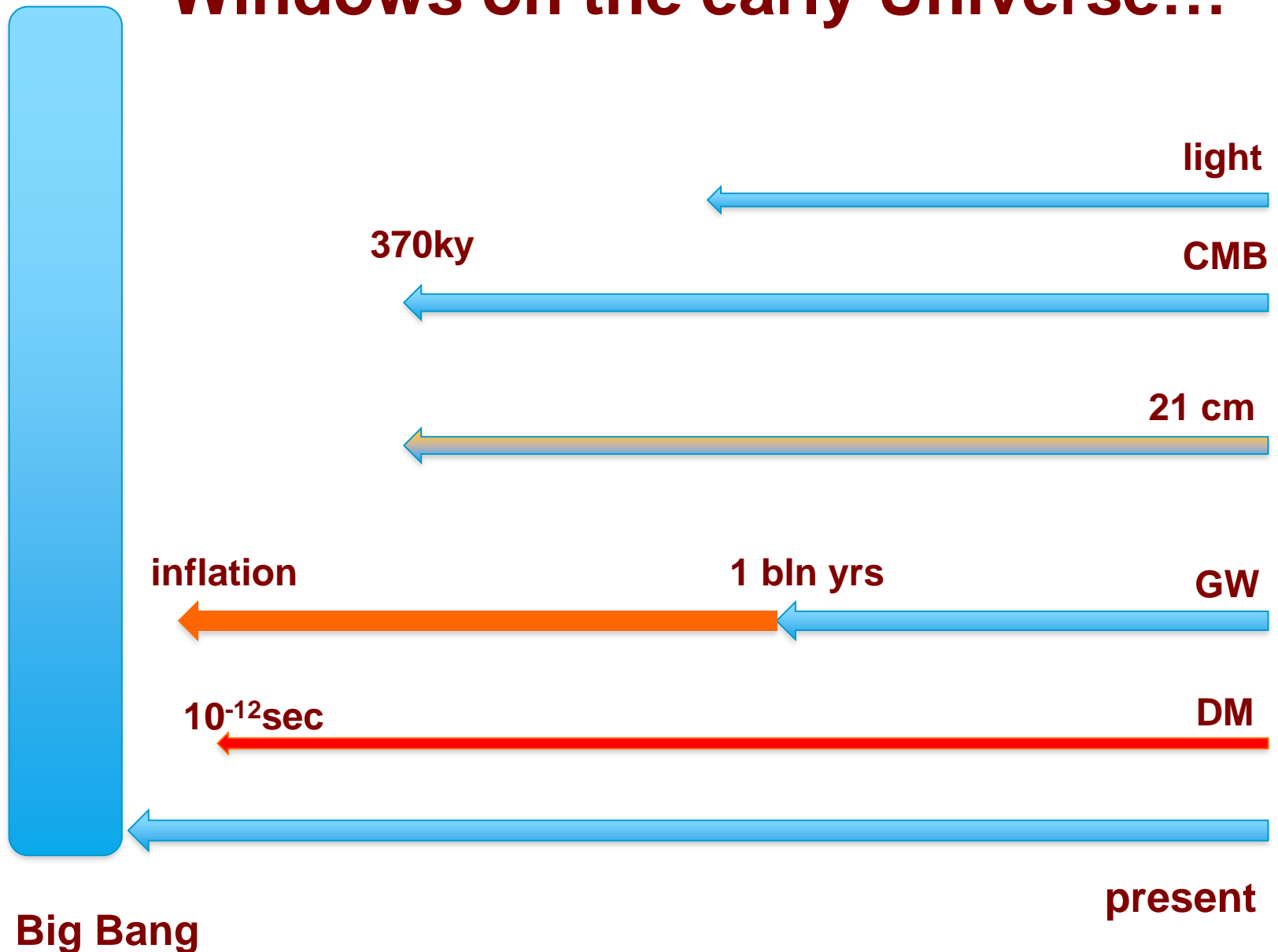


## Five Nobel Prizes:

- 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)

→ Multi-messenger mapping of the Universe

# Windows on the early Universe...



**Much progress has been made in learning  
about our Universe.**

**Much less so in actually understanding it.**



## **Conclusions (theory):**

- **Need much more data**
- **Prepare for a long ride**
- **Will need many more COSMO meetings**

# COSMO

## *Particle Physics and the Early Universe*

*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

# COSMO'19



# COSMO'19

## Some numbers

- TOTAL 277**

Germany	53
United Kingdom	35
Spain	22
Netherlands	13
Switzerland	12
France	11
Italy	10
Belgium	9
Poland	6
Finland	4
Portugal	3
Sweden	3
Denmark	2
Czech Republic	1
Estonia	1
Norway	1
Russia	1

Japan	34
S. Korea	4
India	2
Israel	2
China	1
Thailand	1

Europe	187
Asia	44
North America	36
South America	7
Australia	2

USA	26
Canada	6
Mexico	4

Chile	4
Argentina	1
Brazil	1
Colombia	1

- Age distribution: just look around!**

# COSMO'19

## ➤ Local Organising Committee

**Christian Fidler**  
**Deanna C. Hooper**  
**Felix Kahlhoefer**  
**Michael Krämer**  
**Julien Lesgourgues (Chair)**  
**Philipp Mertsch**  
**Jesus Torrado**



## ➤ Secretarial support

## ➤ Help from many students

# COSMO

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- '17 Paris, France
- '18 Daejeon, S. Korea
- '19 Aachen, Germany
- **COSMO is going down...**

An aerial photograph of Rio de Janeiro, Brazil, taken during sunset. The sun is low on the horizon, casting a golden glow over the city and the surrounding mountains. The city is densely packed with buildings, and the ocean is visible in the foreground with waves crashing against the shore. The sky is filled with soft, colorful clouds.

**COSMO is going down...**

**24-28/Aug/2020**

**Rio de Janeiro**

*To the sound of samba...  
& the taste of caipirinhas...*

**Save the date!**