Preparatory Group
— Cosmology —

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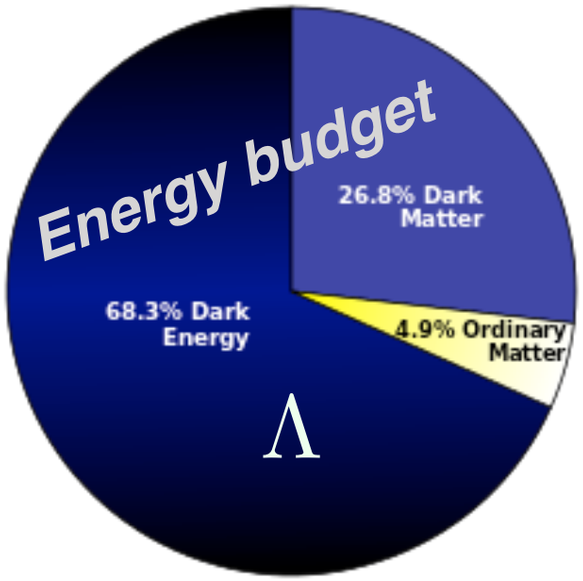
Open Symposium on Latin American Research Infraestructura in HECAP — July 8 (2020)

Main science drivers in cosmology

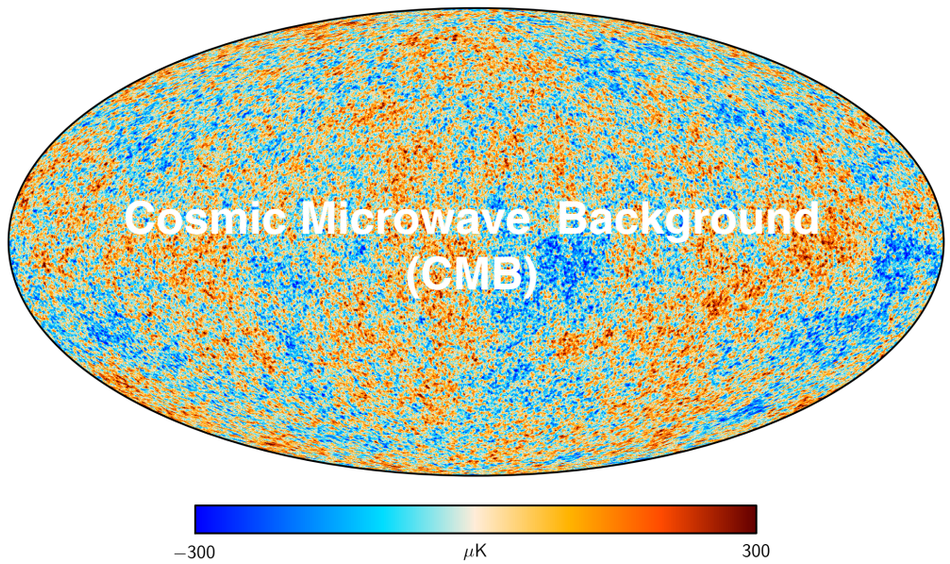
Standard cosmology

Homogeneous



Standard assumptions:
General relativity (GR),
standard physical
laws and
thermal history,
statistically isotropic
and homogeneous

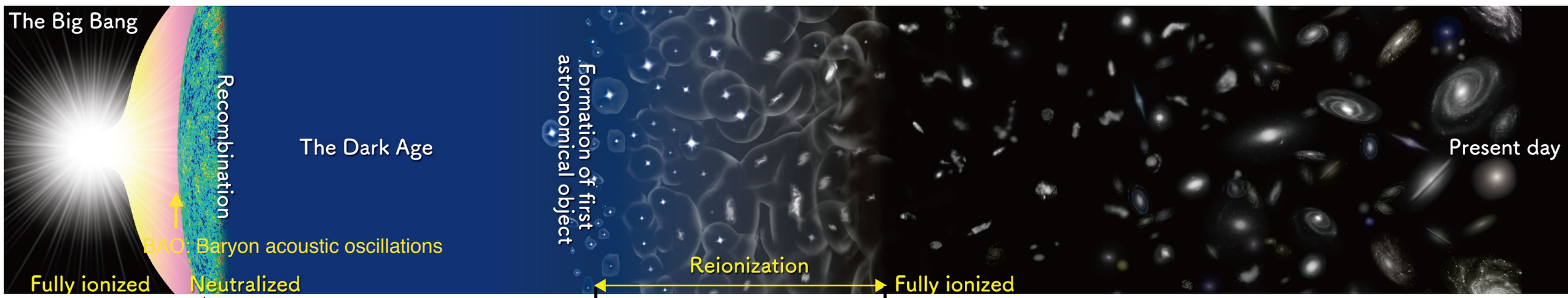
Perturbations



$h = H_0/(100\,\mathrm{km\,s^{-1}Mpc^{-1}})$ Planck Collaboration - 2018

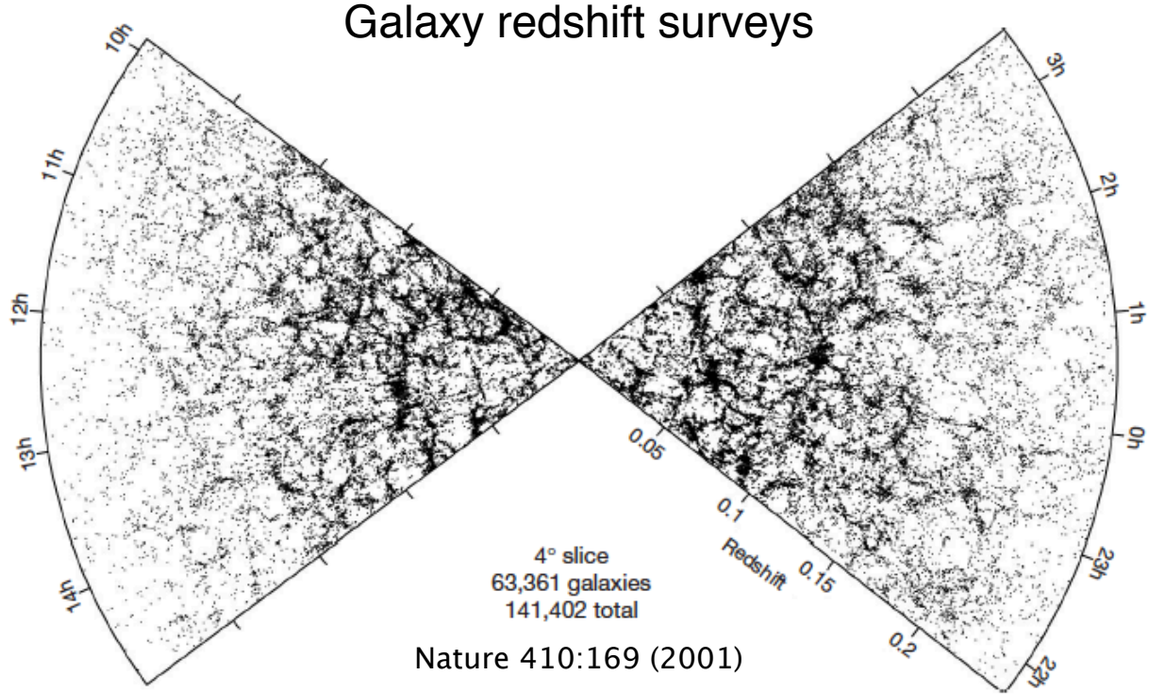
Parameter(s)	$\Omega_b h^2$	$\Omega_c h^2$	$100\theta_{MC}$	H_0 [km s^{-1}Mpc^{-1}]	n_s	$\ln(10^{10}A_s)$
Base ΛCDM	0.02237 ± 0.00015	0.1200 ± 0.0012	1.04092 ± 0.00031	67.36 ± 0.54	0.9649 ± 0.0042	3.044 ± 0.014

Evolution of initial gaussian distribution of adiabatic density perturbations



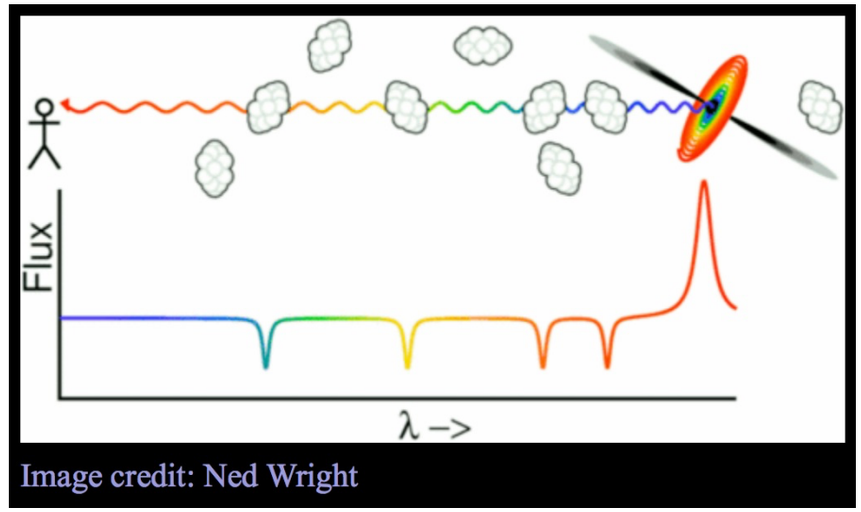
...several observables...

Galaxy redshift surveys

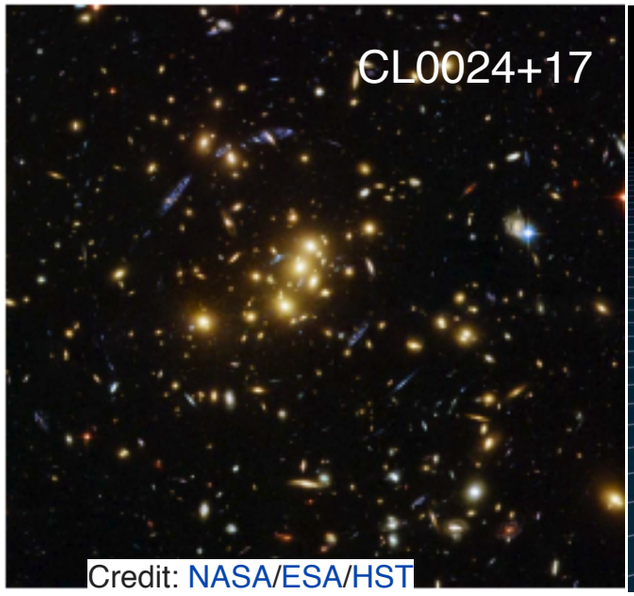


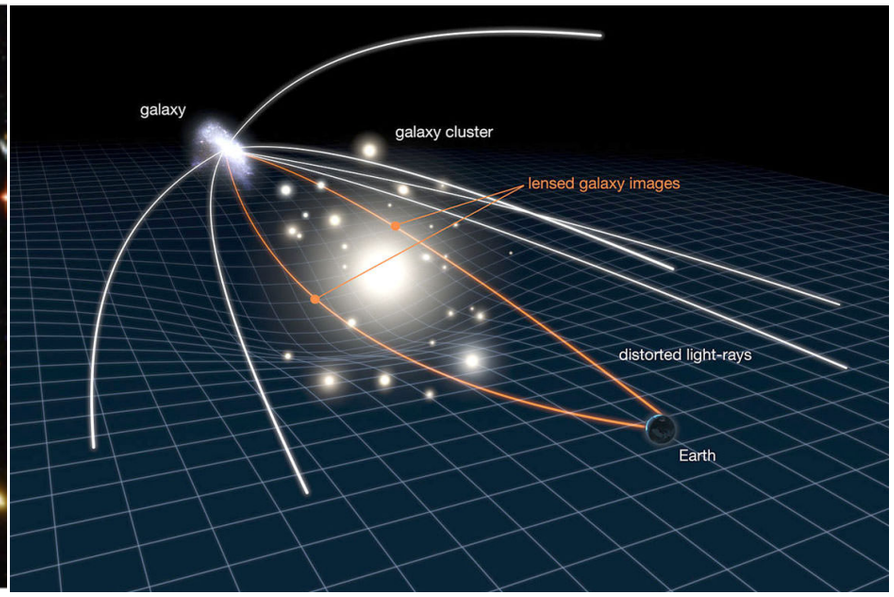
Nature 410:169 (2001)

Lyman-alpha forest



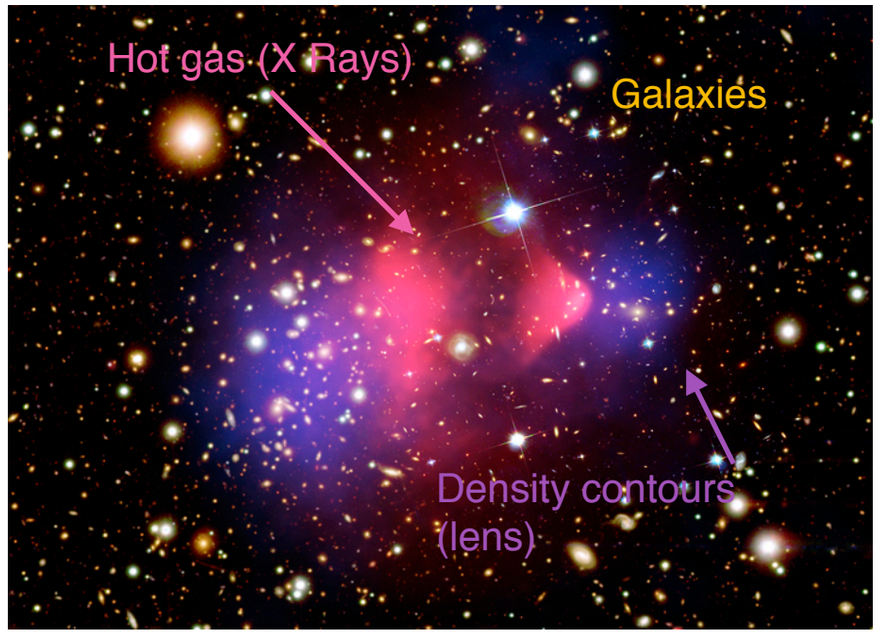
Gravitational lensing





Massey et. al., Rept. Prog. Phys. 73 (2010)

Clusters

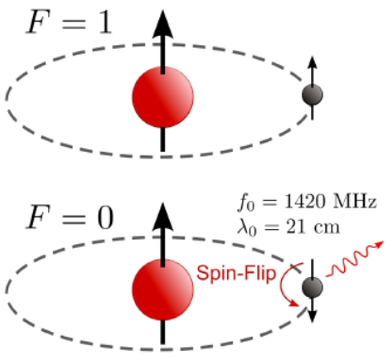


Del Popolo, Int. J. Mod. Phys. D23 (2014)

Credit: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.

… and new windows

Radio surveys

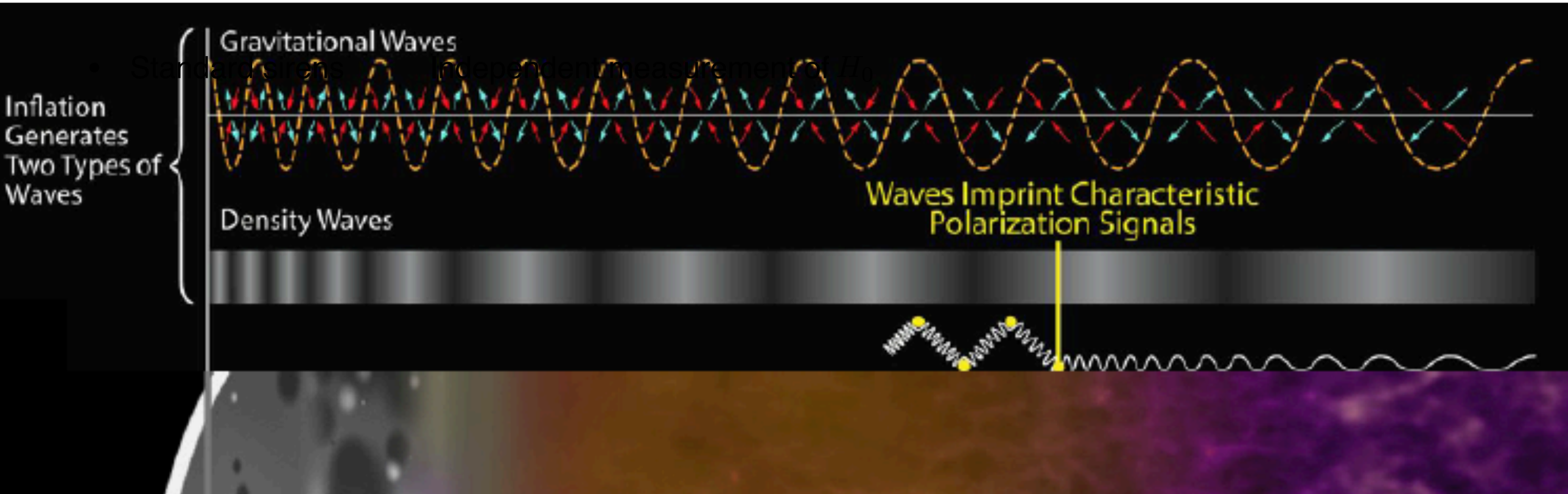


- 21 cm line emission from HI as a tracer of the 3-D LSS distribution
- Fast Radio Bursts (FRBs)

Gravitational waves and “multi-messenger” astronomy

- Detection of GW170817 and the coincident Gamma Ray Burst (GW170817A) allowed to constant the relative velocity of GW and photons: $|c_g/c - 1| \leq 5 \cdot 10^{-16}$
- Standard sirens ⟶ Independent measurement of H_0
- Black Holes: many events of coalescence of two BHs observed since GW150914

Primordial Gravitational waves



Theoretical work is needed and access to data too

- To analyze data and obtain physical quantities, test robustness
- To deepen the understanding of data and how they are analyzed
- To connect results from cosmological, astrophysical and laboratory experiments
- To study alternative theories, their consistency, robustness, connections with particle physics and with the fundamental physics laws
- To evaluate the validity of the standard assumptions
- …etc.

Human Resources and Research Infrastructure

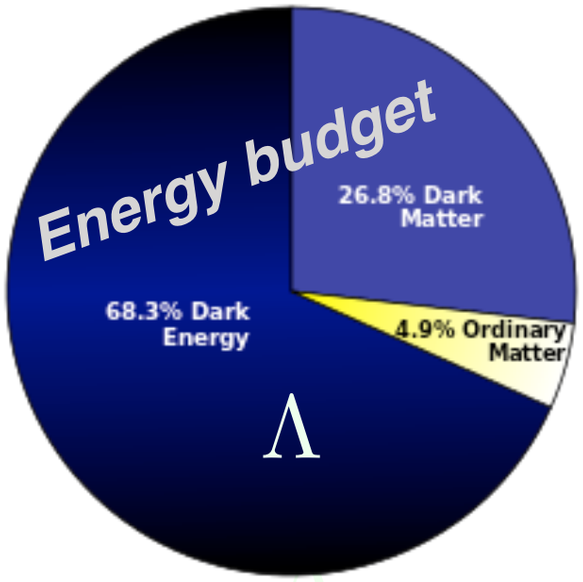
Crucial to join forces and different expertises !

Picture taken from Shutterstock

Main science drivers in cosmology

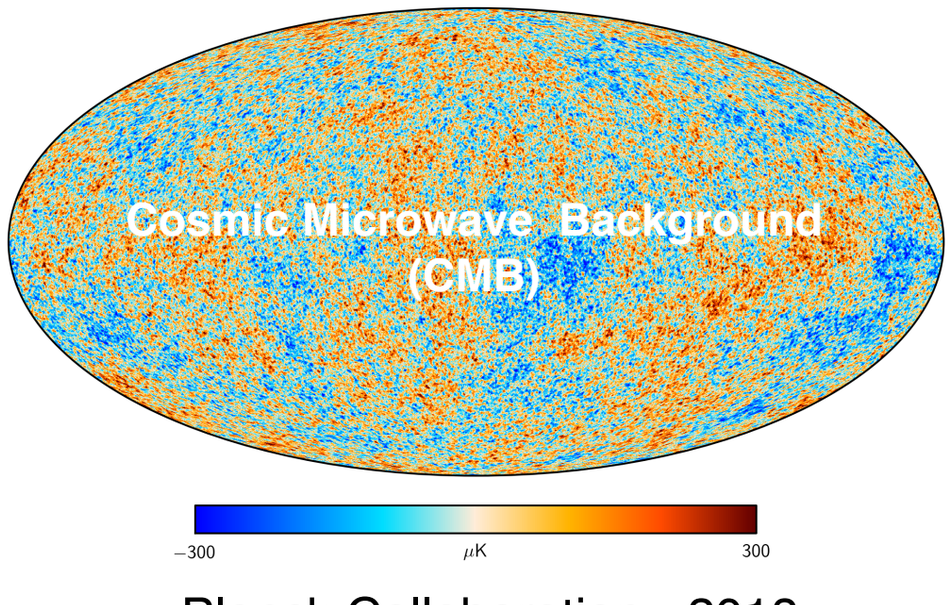
Standard cosmology

Homogeneous



Standard assumptions: General relativity (GR), standard physical laws and thermal history, statistically isotropic and homogeneous

Perturbations



Planck Collaboration - 2018

- **What are the nature, the properties and the origin of the Dark components?**
  E.g., What is Dark Matter? What is Lambda? Do they have non-gravitational interactions?
- **What is the origin of the matter-antimatter asymmetry?**
- **What are the nature and the properties of neutrinos?** E.g., What is the total mass?
- **What are the nature and the properties of Black Holes?**
- **What are the origin and the nature of the primordial perturbations?**
  E.g., Are they non-gaussian? How many degrees of freedom? Are there primordial gravitational waves?
- **Are the standard assumptions wrong?** E.g., Modification of gravity, Lorentz violation, non-standard history

Overview of the received contributions

- Large Synoptic Survey Telescope (LSST) ⟶ NSF-funded Wide-field Telescope (in Chile)

Photometric survey, billions of galaxies, 20 Terabytes of data/night!

Main science drivers: What is the nature of the Dark Sector? Are the standard assumptions wrong?

Context:

Members in Brazil: 9 PIs + 19 juniors (student and postdocs), and funding for up to 10 PIs with 40 juniors.
Institutions: LineA,MCTIC,UNESP, UFES, UFRGS,Unicamp,UdB

Methodology: Analyzing different observational quantities in a bayesian framework.

- Measurements of galaxy distribution
- Weak lensing
- Supernova
- Cluster counts

Challenges: The access to data and the big amount of data.

- Q&U Bolometric Interferometer for Cosmology (QUBIC) ⟶ To measure CMB polarization

(site in Argentina, next to LLAMA)

Unique instrument, a spectro-imager, designed to control systematics and remove foreground

International collaboration with participating laboratories in France, Italy, UK, Ireland, USA and Argentina

Main science drivers: Are there primordial gravitational waves?

Context:

r=measure the relative strength of primordial gravitational waves.

Currently, r<0.06 [Planck 2018]

Project	Frequencies (GHz)	ℓ range	Ref.	$\sigma(r)$ goal (no fg.)	$\sigma(r)$ goal (with fg.)
QUBIC	150,220	30–200		6.0×10^{-3}	1.0×10^{-2}
Bicep3/Keck	95, 150, 220	50–250	[18]	2.5×10^{-3}	1.3×10^{-2}
CLASS ⋆	38, 93, 148, 217	2–100	[20]	1.4×10^{-3}	3.0×10^{-3}
SPT-3G †	95, 148, 223	50–3000	[19]	1.7×10^{-3}	5.0×10^{-3}
AdvACT ‡	90, 150, 230	60–3000	[21]	1.3×10^{-3}	4.0×10^{-3}
Simons Array	90, 150, 220	30–3000	[22]	1.6×10^{-3}	5.0×10^{-3}
SO (SAT) ⋆⋆	27, 39, 93, 145, 225, 280	30–300	[23]	1.3×10^{-3}	3.9×10^{-3}

⋆ CLASS: Cosmology Large Angular Scale Surveyor; † SPT-3G: South Pole Telescope—3rd generation; ‡ AdvACT: Advanced Atacama Cosmology Telescope; ⋆⋆ SO (SAT=: Simons Observatory Small Aperture Telescopes.

Members in Argentina: ~22
Institutions: UNLP, ITeDA,CAB,CNEA,IAR

Methodology: Simulations and data analysis, mounting the experiment, infrastructure in site.

Timeline: Being built. First module- two frequencies- ready by 2020. Target: r ~ 0.01 in 2 years of data

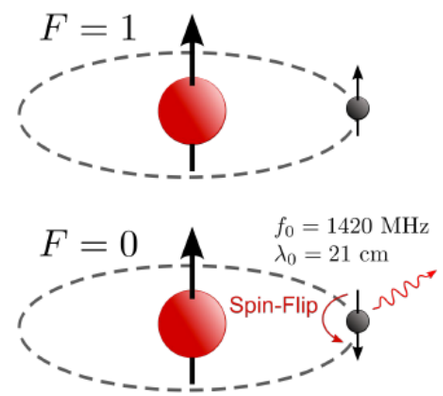
In the future, more modules at additional frequencies could be added.

- BAO from Integrated Neutral Gas Observations (BINGO) ⟶ **New radio telescope**
(to be built in Brazil)

Radio telescope designed to measure the BAO scale at 0.13 < z < 0.48

Main science drivers: What is the nature of Dark Sector? Are the standard assumptions wrong?

Context: Intensity Mapping technique (fluctuations in HI as a tracer of the 3-D LSS)



Challenge: Galactic as well as extragalactic foregrounds with intensity as large as 10^4 times the HI signal. Cross correlation with other surveys will help.

- Ground for testing different separation methods, pathfinder to the upcoming SKA telescope.
- Lower redshift than ongoing CHIME – Canadian - for BAO at z~0.8-2.5, and Tianlai - China -

Members in Brazil: 3PIs (of 5) in the steering committee and ~37 researchers (+1 in Uruguay)
Institutions in Brazil: USP,UFCG,IFPB,UFPB,UFPE,UnB. Construction and operational costs granted by FAPESP, FINEP, MCTIC and smaller fraction by non-Brazilian institutions

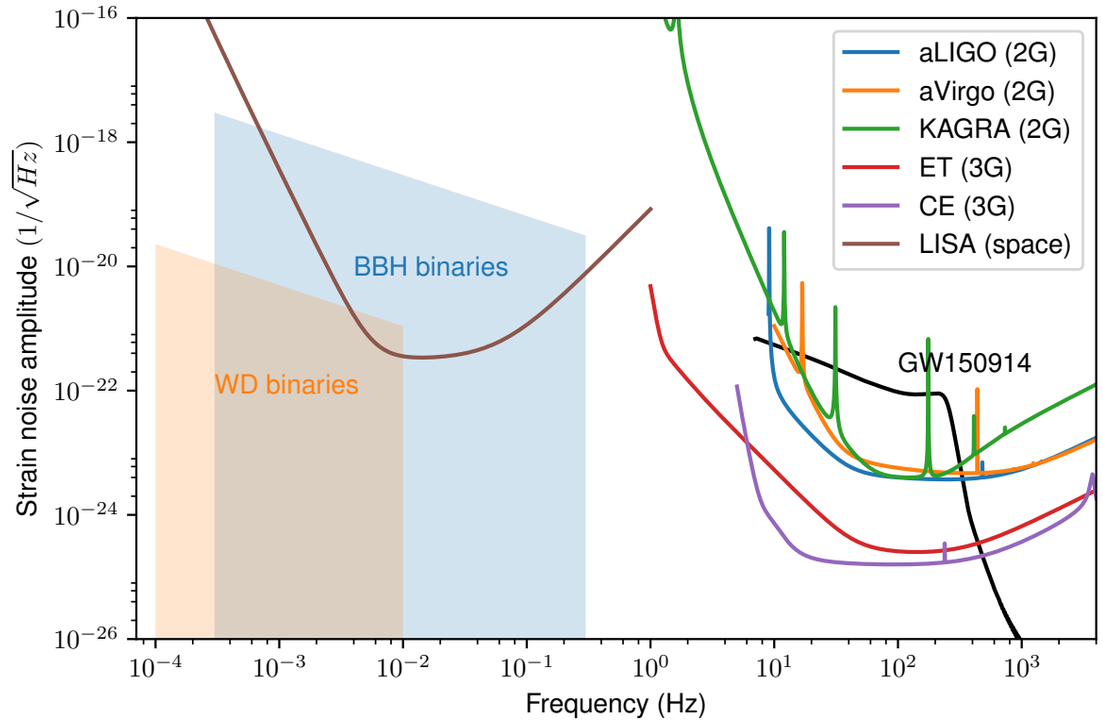
Methodology: To design and to build the radio telescope

Timeline: Under design/construction. First commissioning actions expected for 2021

- The South American Gravitational wave Observatory (SAGO) ⟶ **Final Goal** (in South America)

Main science drivers: What is the nature and properties of Black Holes, of the Dark Sector? Are the standard assumptions wrong?

[Front. Astron. Space Sci. 5:44 (2018)]



Context: Several detections of GWs from the coalescence of binary systems, since GW150914.

Methodology: step by step

First step:

- To build a local community with enough expertise in experimental activities and data analysis.
- *To involve Latin American students and post-docs in the present projects:* LIGO, Virgo, KAGRA, LIGO India, Einstein Telescope (3G), Cosmic Explorer (3G), and *attract them and foreign researchers* with knowledge on third generation detectors *to shape research groups in Latin America*.

Final goal: To construct and to operate the 3G interferometer in South America as a third partner of ET and CE in ~ 20 years

Challenge: Only a few Latin American researchers are involved in laser interferometric projects (~ 12).

- Macón Ridge Astronomical Site: the ABRAS & TOROS projects ⟶ **New site** (in Argentina)

Main science drivers: What is the nature and the properties of the Dark Sector? Modification of gravity, Lorentz violation.

Context: Gravitational waves and “multi-messenger” astronomy: Use GW as standard sirens, test Lorentz Invariance.

Methodology: To develop a new astronomical site in Macón Ridge-Salta-Argentina

First step: ABRAS & TOROS: Complementary projects dedicated to electromagnetic counterparts of GW events, in the near-infrared and optical range. Mainly BNS transient events.

***ABRAS*:** Argentinean-Brazil Astronomical Center
Main institutions: IATE, IAG. **Funding institutions:** MINCyT-Argentina- and USP -Brazil-

***TOROS*:** Transient Optical Robotic Observatory in the South
Members in LA: 13 (8-Argentina- 4-Chile-1-Mexico). **Outside LA:** 7 US-1 Poland.
Main institutions in LA: IATE, ULS,PUC, INAOE. **Funds from:** Brazil, Argentina, NSF

Timeline: TOROS is ready to start. If funding is secured, ABRAS could start in 2020.

A Latin American graduate school ⟶ **A graduate program in Astrophysics and Cosmology**

Main science drivers: All listed

Context: Theoretical work is needed and access to data is too

Picture taken from Shutterstock

Methodology:

- To increase the amount of *human resources* dedicated to theoretical aspects of Astrophysics and Cosmology, and to the use of the astronomical facilities installed in the Latin America
- To promote the *integration of the Latin American community working in Astrophysics and Cosmology*
- Use the PPGCosmo experience

Thematic areas: Dark Matter, Astroparticle Physics, Cosmology, Gravitational Waves, Dark Energy, High Energy Theory, Astronomy and Astrophysics.

Mobility: Must include an internship period in a second institution belonging to the network.

THANKS!