56th Rencontres de Moriond 2022

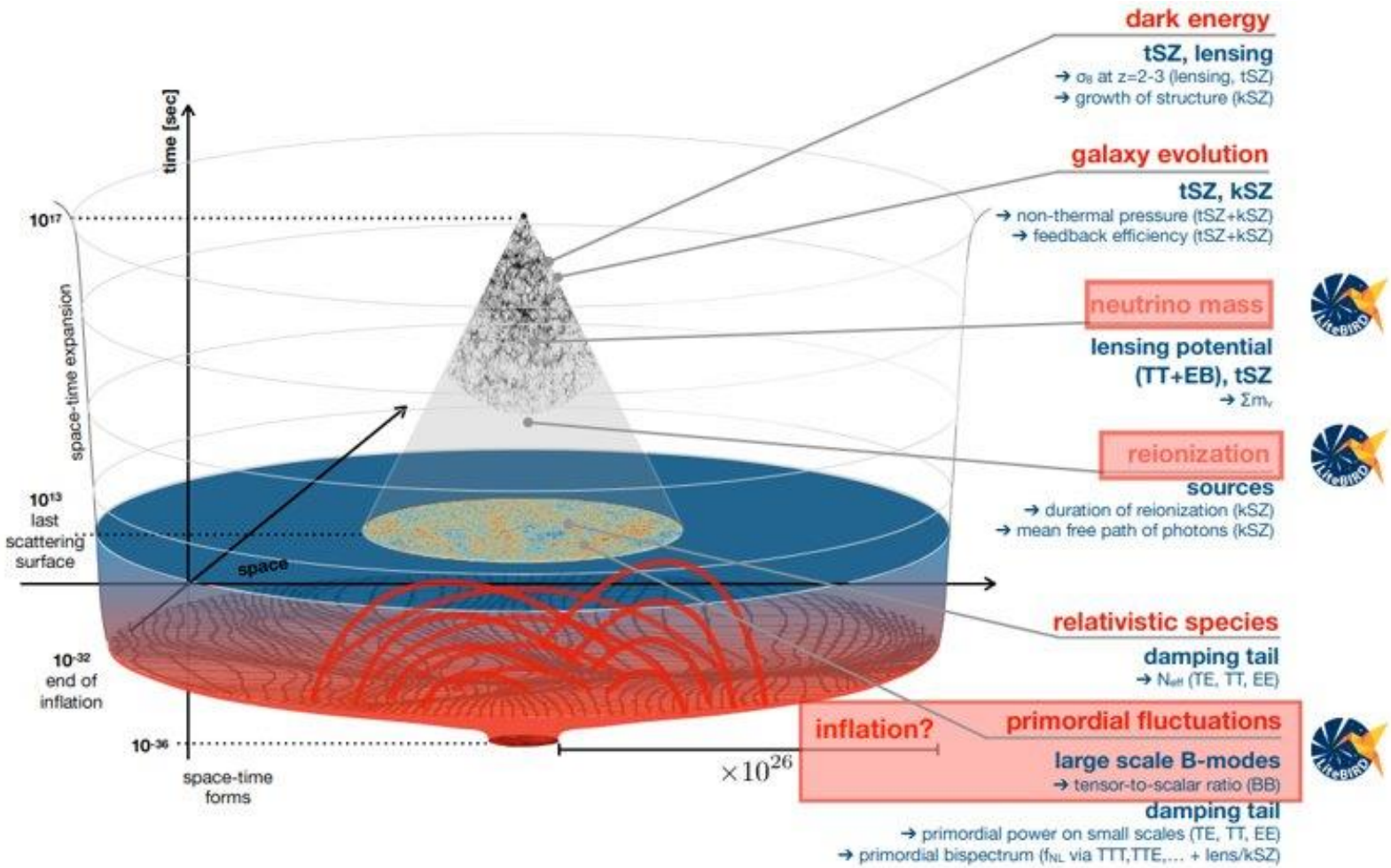
Cosmology
(January 23 – 30)

Outline

https://moriond.in2p3.fr/2022/Cosmology/Program.html

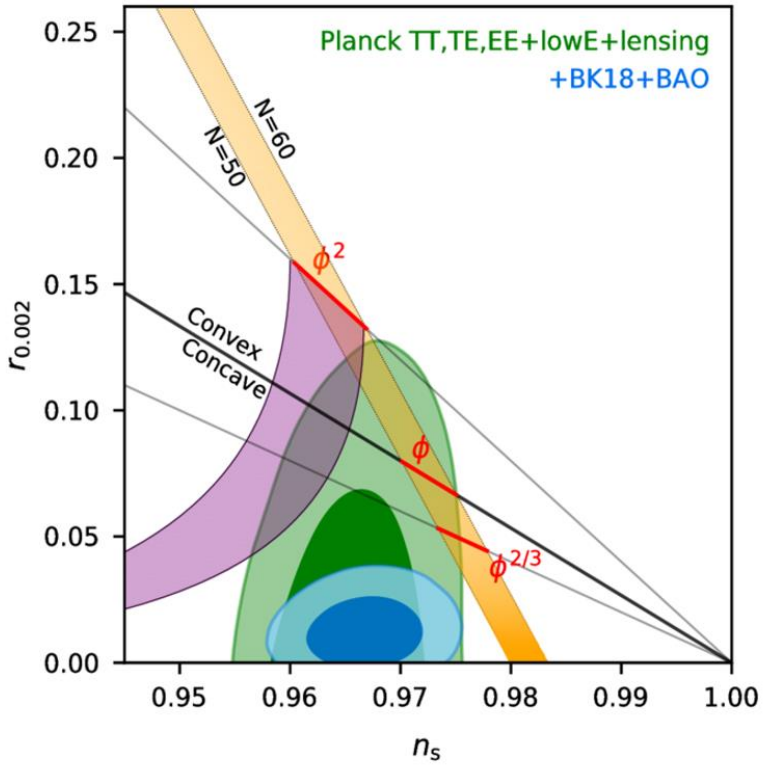
1. CMB
2. Dark matter
3. Radio cosmology
4. Clusters
5. Supernovae
6. Galaxy clustering
7. Galaxy weak lensing
8. Dark energy & controversies

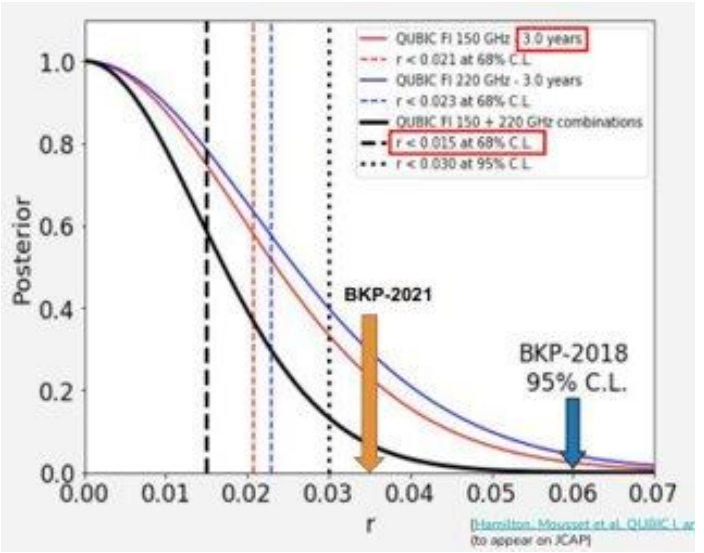
CMB


dark energy
tSZ, lensing
→ σ8 at z=2-3 (lensing, tSZ)
→ growth of structure (kSZ)
galaxy evolution
tSZ, kSZ
→ non-thermal pressure (tSZ+kSZ)
→ feedback efficiency (tSZ+kSZ)
neutrino mass
lensing potential
(TT+EB), tSZ
→ Σmν
reionization
sources
→ duration of reionization (kSZ)
→ mean free path of photons (kSZ)
relativistic species
damping tail
→ Neff (TE, TT, EE)
inflation?
primordial fluctuations
large scale B-modes
→ tensor-to-scalar ratio (BB)
damping tail
→ primordial power on small scales (TE, TT, EE)
→ primordial bispectrum (fNL via TTT,TTE,... + lens/kSZ)
time [sec]
space-time expansion
10^17
10^13
last scattering surface
10^-32
end of inflation
10^-36
space-time forms
space
×10^26

CMB – B modes

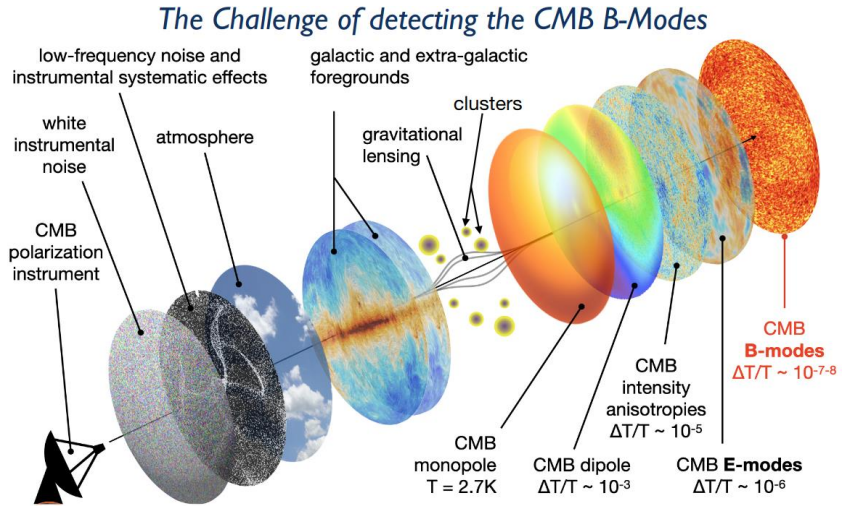
- Inflation => tensor perturbations = GW => B-modes
- The Latest Constraints on Inflationary B-modes by BICEP/Keck: 2018 observing season, lensed-ΛCDM+r+dust+synchrotron+noise, **r < 0.035** (95% CL, Planck+BAO+BK18) *(Kenny Lau, U. of Minnesota)*
- QUBIC: The Q&U Bolometric Interferometer for Cosmology APC, soon installed on the plateau de la Puna, Chile, **sigma(r) < 0.03** *(Louise Mousset, IRAP, Toulouse)*
- Simons Observatory, **sigma(r) < 0.003** *(Baptiste Jost, APC)*
- LiteBIRD: launch in late 2029: all-sky 3-year survey, L2, large frequency coverage (40–402 GHz, 15 bands), **sigma(r) < 0.001** *(Ludovic Montier, IRAP)*

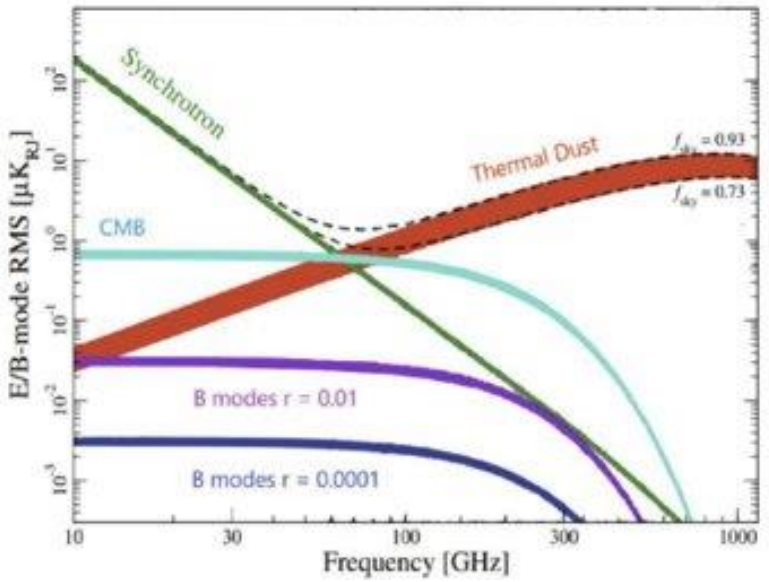




CMB – B modes – foregrounds

- **Synchrotron emission** due to Cosmic ray electrons gyrating in the Galactic magnetic field
  - Characterization of spectral and spatial spectra from Planck and WMAP *(Felice Antonio Martire, IFCA, Spain)*
  - Improved spectral model with QUIJOTE-MFI - Teide observatory, 2012 – 2018) *(Elena de la Hoz, UC-CSIC, IFCA, Spain)*
  - End-to-end posterior exploration through Gibbs Sampling *(Trygve Leithe Svalheim, U. of Oslo)*
- **Thermal dust emission**
  - expansion of around MBB spectrum in beta and T (for LiteBIRD) (Léo Vacher, IRAP)

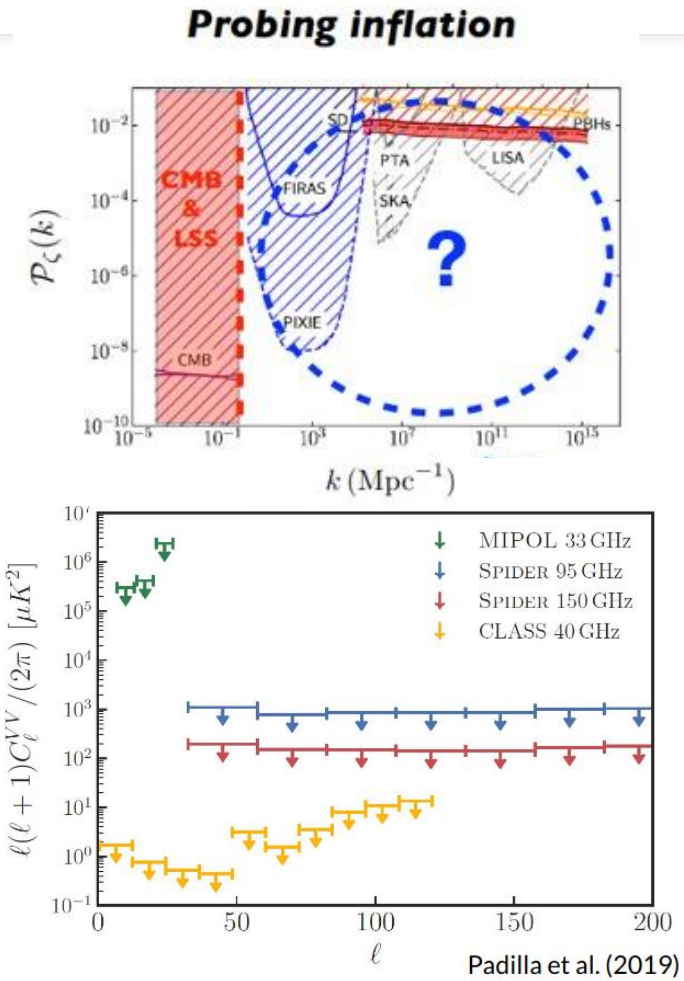




CMB – other features

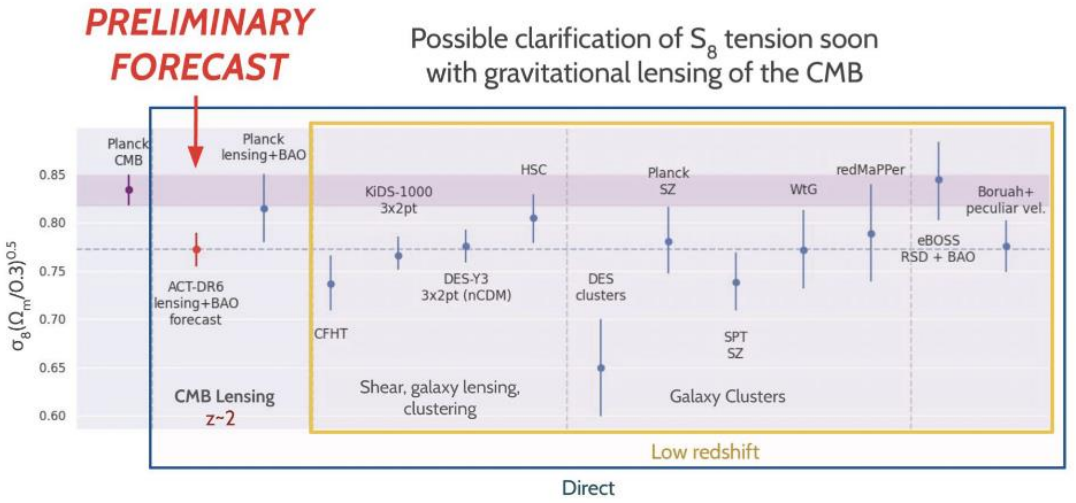
Shape ($\zeta\zeta\zeta$)	Current	SO constraint
Local	-0.9 ± 5.1	3
Equilateral	-26 ± 47	24
Orthogonal	-38 ± 23	13
Shape ($\zeta\zeta h$)	Constraint	
Local	-48 ± 28	1
Equilateral	-	8
Orthogonal	-	3

- **(n>2)pt correlators** between scalars and tensors "fNL", intrinsic bispectrum *(William Coulton, Flatiron Institute, NY)*
- Computing observables = correlators of the curvature perturbations: *Guilherme Pimentel (Leiden U.), Denis Werth (IAP)*
- GW dissipate energy in the primordial plasma => **spectral distortions** *(Thomas Kite, The U. of Manchester)*
- **Beyond slow roll-inflation**, "primordial standard clock", sharp + oscillatory features in CMB and LSS, GW background *(Matteo Braglia, UAM-CSIC, Madrid, Sébastien Renaux-Petel IAP)*
- Constraints on inflation with **primordial black holes** (Ashley Wilkins, Newcastle U.)
- Accreting primordial black holes: inhomogeneous photon injection during recombination *(Yacine Ali-Haimoud, NYU)*
- Two-year Cosmology Large Angular Scale Surveyor (CLASS) Observations: Chile, 4 frequency bands, 75% of the sky, limits on circular polarization at 40 GHz ~uK *(Ivan Padilla, Johns Hopkins U.)*



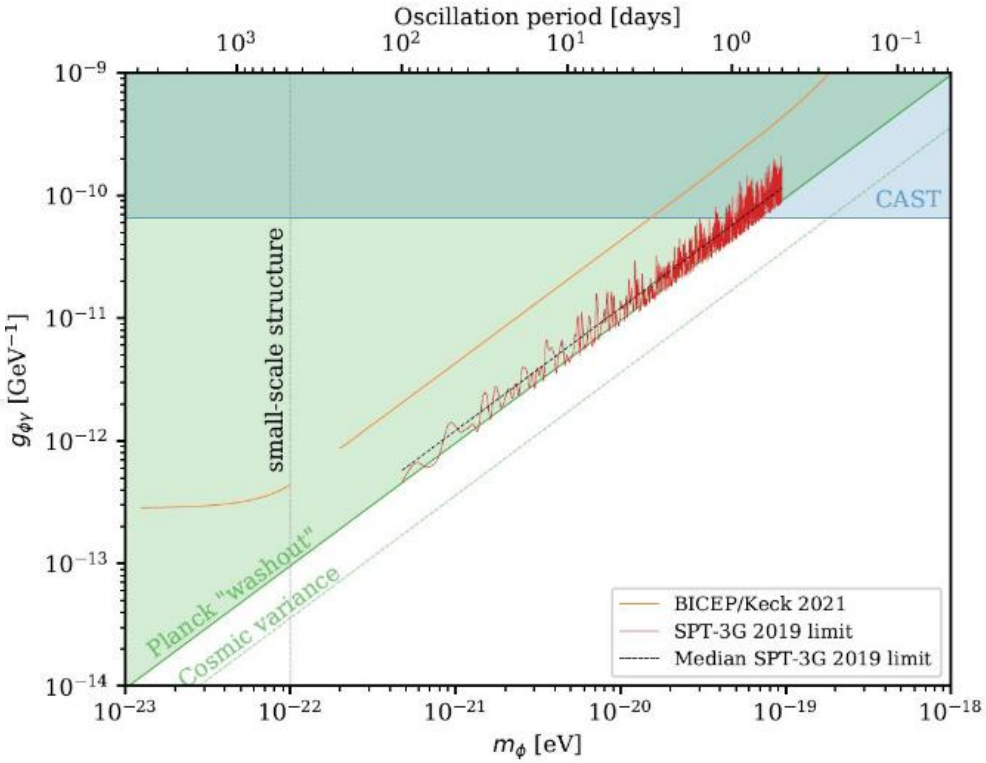
CMB as a backlight: weak lensing

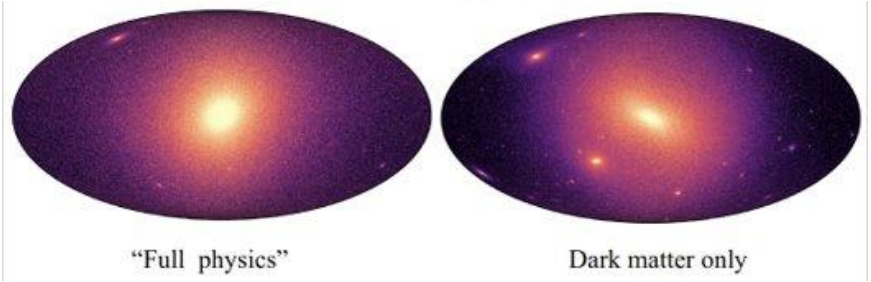
- state-of-the art S8 and mnu constraints with **ACT lensing** *(Frank Qu, U. of Cambridge)*
- **voids** found in DES Y3 imprinted in Planck lensing map, 6.6 sigmas *(Pauline Vielzeuf, CPPM)*
- extragalactic **foreground** masks correlated with lensing maps may bias lensing reconstruction *(Margherita Lembo, U. of Sussex)*

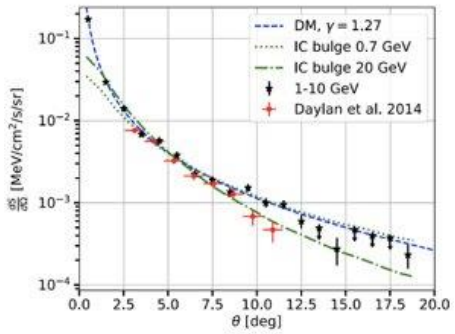


Dark matter searches

- **Birefringence:** oscillation in the axion field rotates E & B modes of the CMB:
  - In Planck DR4 *(Patricia Diego-Palazuelos, IFCA, Spain)* modelling polarized foreground emission is crucial
  - In SPT *(Kyle Ferguson, UCLA, Los Angeles)*
- **Milky Way:** baryonic effects substantially enhance and concentrate the predicted luminosity of the main Milky Way halo in annihilation radiation, reduce that of subhalos => Fermi-LAT excess
  - Hydro simulations *(Simon White, MPI, Garching)*
  - Analytical models *(Gaétan Facchinetti, U. libre de Bruxelles)*

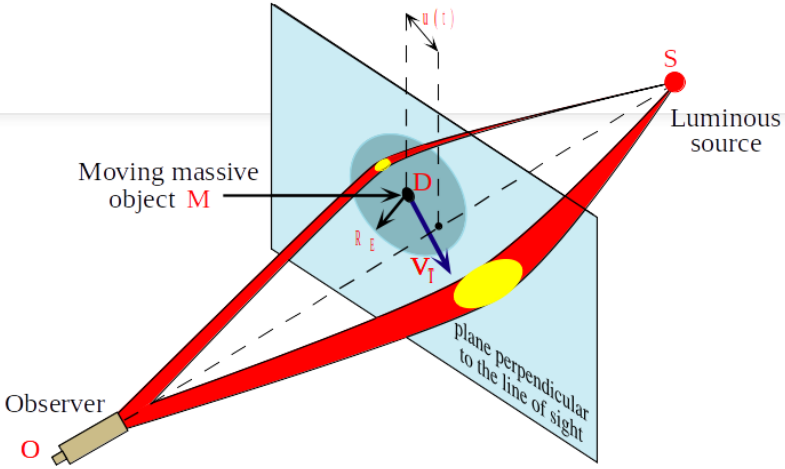


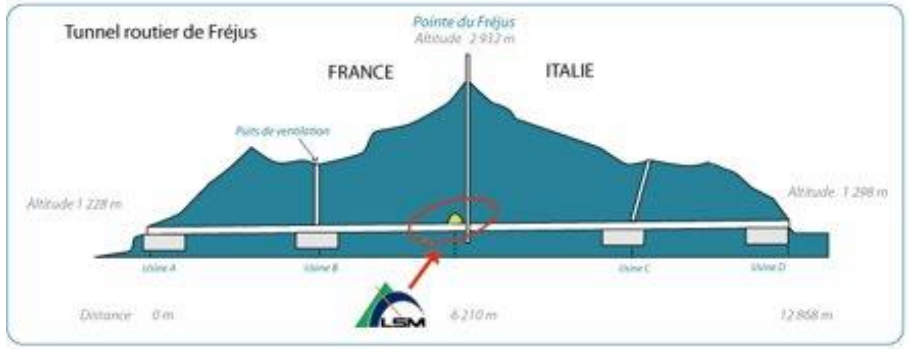




Dark matter searches

- **gravitational microlensing** by compact objects: combined EROS2 and MACHO towards LMC, objects with M < 1e3 Msol do not dominate the galactic DM halo (95% CL) *(Marc Moniez, IJCLab, Orsay)*
- **direct search** for low-mass WIMPS in dark current of DAMIC and DAMIC-M (skipper) CCDs *(Ariel Matalon, LPNHE)*

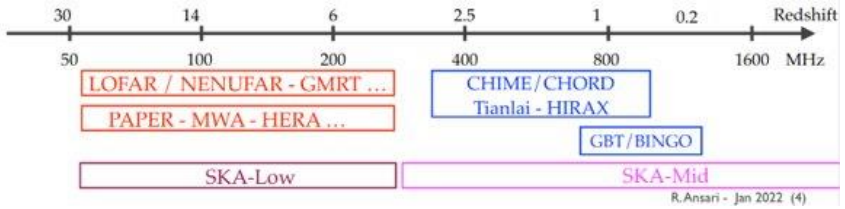




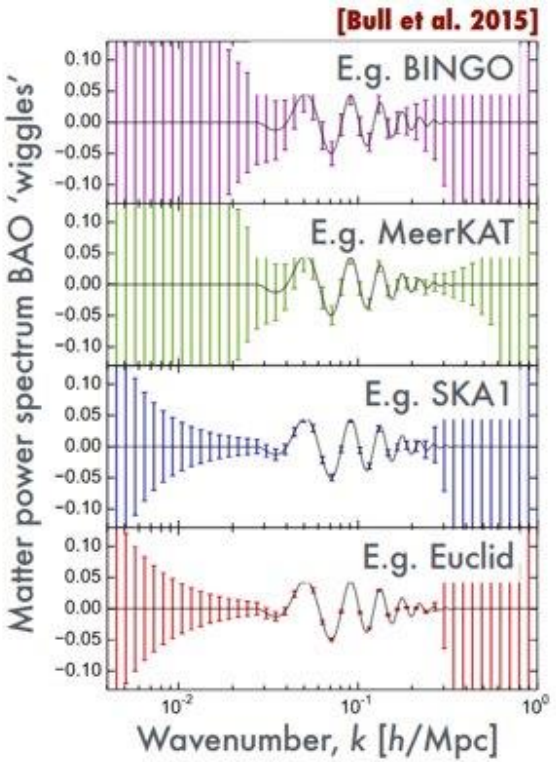
Dark matter – theory

- Breit-Wigner Enhancement in the Interactions of a Light Scalar Dark Matter: light scalar mediator *(Sreemanti Chakraborti, LAPTh, Annecy)*
- Dark Matter via Inverse Phase Transition: going beyond freeze-in with observable Gravitational Waves *(Alexander Vikman, CEICO, Prague)*
- Spin-2 ultra-light dark matter => continuous GW *(Federico Urban, CEICO, Prague)*

Radio cosmology

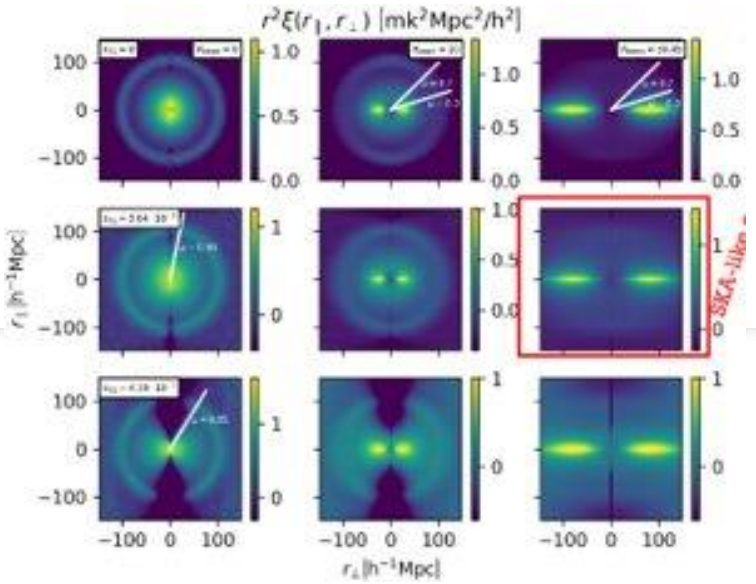


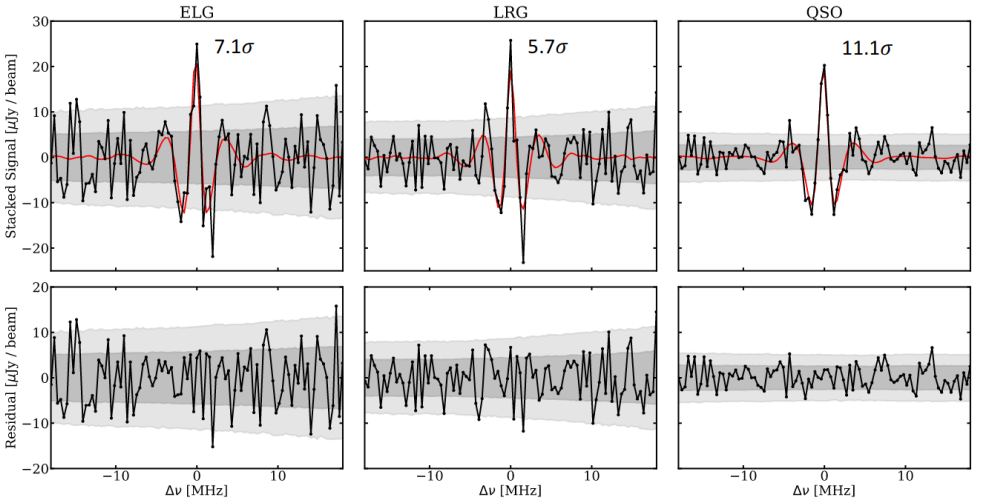
- Radio cosmology*:*
  - HI (neutral hydrogen) emission line in galaxies, redshift + luminosity => peculiar velocities few galaxies
  - Continuum, synchrotron emission, no z information => primordial non-gaussianity
  - HI intensity mapping, poor angular resolution
  - Radio weak lensing
- Current status and future of 21cm *(Reza Ansari, IJCLab)*
- SKA *(Stefano Camera, U. di Torino)*



Radio cosmology

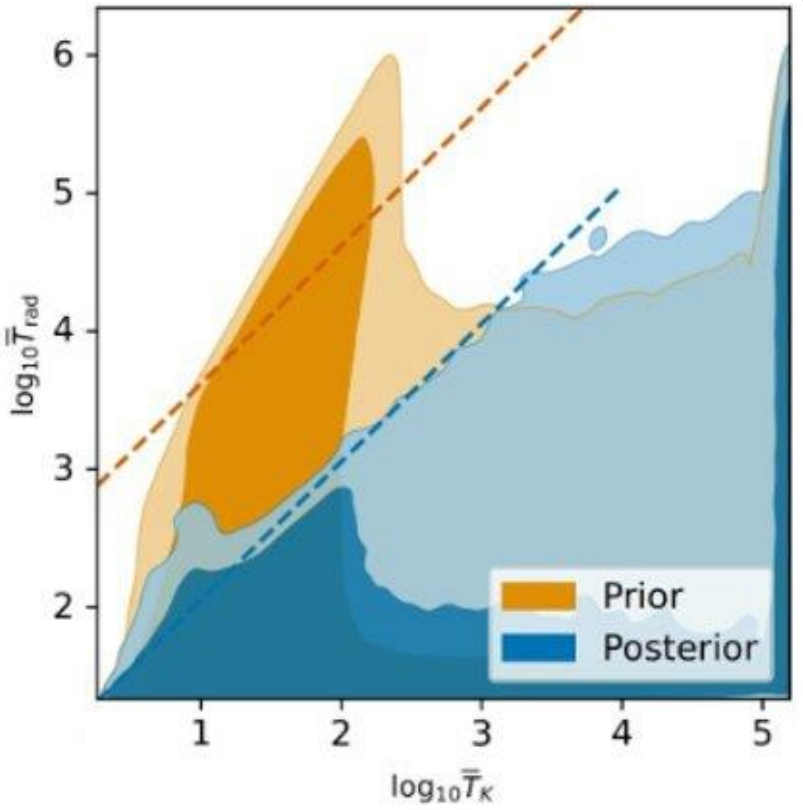
- Evolutionary Map of the Universe (**EMU**): continuum survey, angular correlation function & ISW at 2 sigmas (Jacobo Asorey, CIEMAT, Madrid)
- **MeerKAT**: setup analysis pipeline, mock challenge (foreground removal) *(Marta Spinelli, ETH)*
- Baryon Acoustic Oscillations with HI intensity Mapping *(Santiago Avila, Instituto de Física Teórica UAM-CSIC, Madrid)*
- Calibration of receiver gain with **CHIME** *(Tianyue Chen, EPFL)*





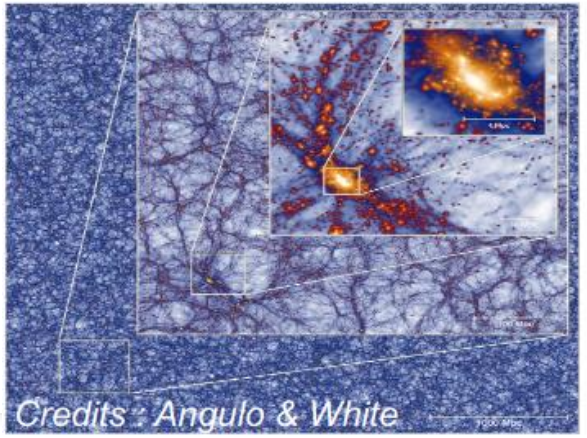
Radio cosmology – reionization

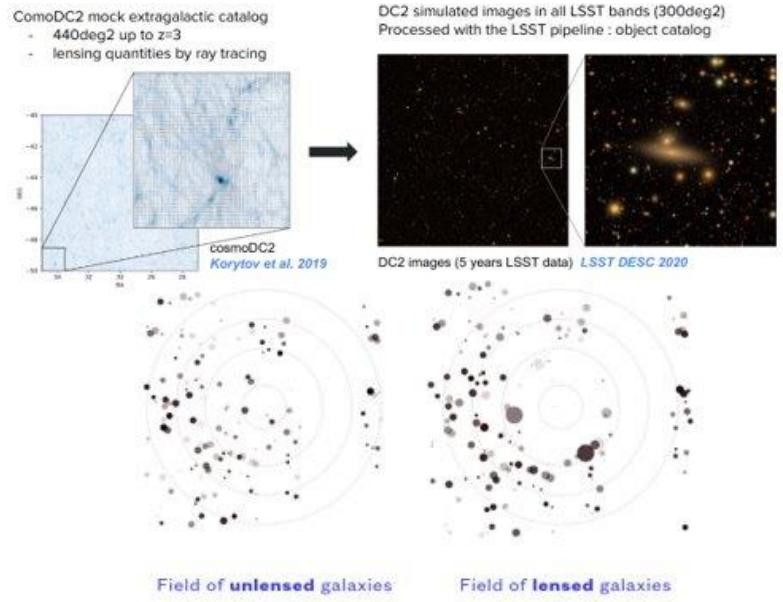
- Patchy reionization: tau - 21cm cross-correlation and CMB B-mode polarization *(Andrea Lapi, SISSA, Trieste)*
- Reionization constraints from HERA 21cm power spectrum limits *(Stefan Heimersheim, U. of Cambridge)*



Clusters

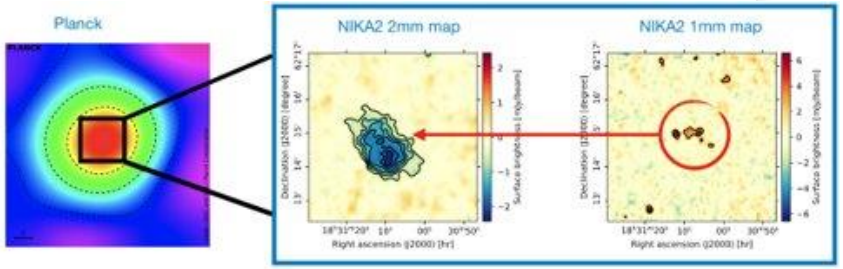
- Most **massive objects**: 10^(14-15) Msun (80% DM, 15% gas, 5% galaxies), 1Gpc
- Density of clusters vs. mass: **sensitive to cosmology** (growth of structure, DE, neutrinos)
- Seen in X-ray, SZ, lensing: **calibrate mass-observable relations**
- Review of X-ray clusters: Uhuru (1970) => XMM-XXL survey (2021) *(Marguerite Pierre, DAp)*
- Clusters with **LSST** pipeline: detection in optical/NIR + weak lensing *(Marina Ricci, LMU Munich)*
- Clusters with **Euclid** pipeline: covariance of number counts & 2PCF; FoM improved by 25% *(Alessandra Fumagalli, U. of Trieste)*
- Cluster mass estimation from magnification (using full mag distribution instead of mag cut), tested on HSC *(Calum Murray, LPSC, Grenoble)*





Clusters

- Galaxy cluster cosmology with the **NIKA2** camera: taking into account the morphology of clusters changes integrated quantities *(Emmanuel Artis, LPSC, Grenoble)*
- SZ measurements in CMB: revised temperature assumptions, hint of 2-halo term *(Aditya Rotti, Jodrell Bank Centre for Astrophysics, Manchester)*
- Planck cluster count tension: calibration issue? *(Alain Blanchard, IRAP)*
- Measuring H0 with clusters, combining X-ray from XMM-Newton and SZ from Planck DA ~ y^2 / Sx. H0 = 67.3 ± 2 km/s/Mpc *(Pasquale Mazzotta, Università di Roma "Tor Vergata")*



X-ray surface brightness

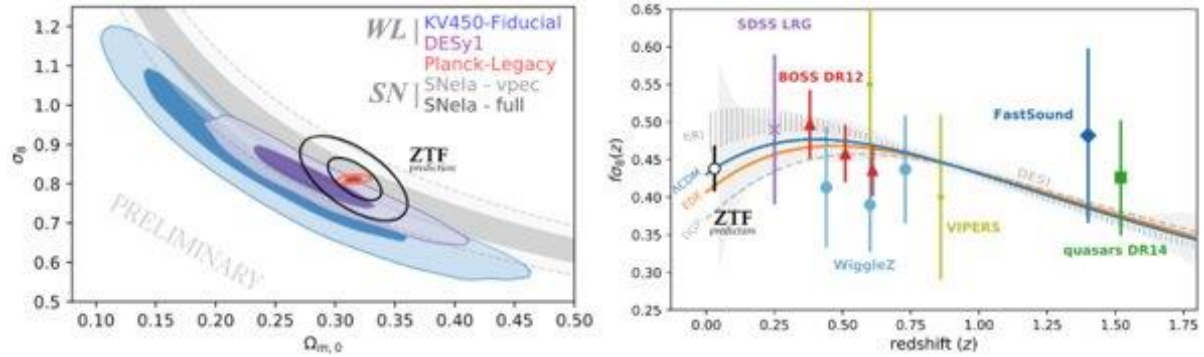
$$S_{\rm X} = \frac{1}{(1+z)^4}\int n_{\rm e}^2 {\rm d}l$$

Sunyaev-Zeldovich effect

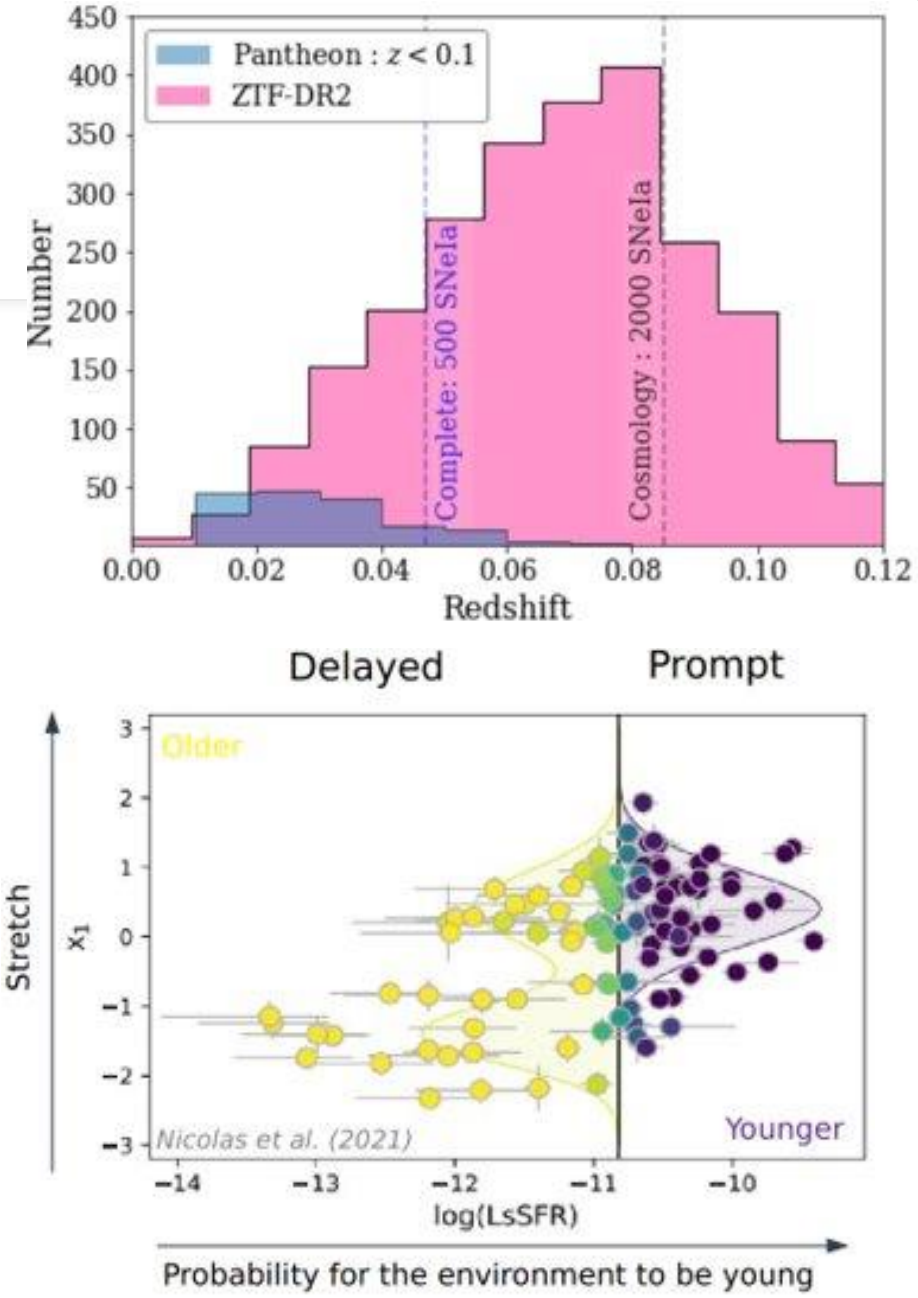
Amplitude $y = \frac{\sigma_{\rm T}}{m_{\rm e}c^2}\int P_{\rm e}{\rm d}l$

Supernovae

- **ZTF**: sigma8(z=0) with **peculiar velocities**, H0, first results this summer (Mathew Smith, IP2I Lyon)

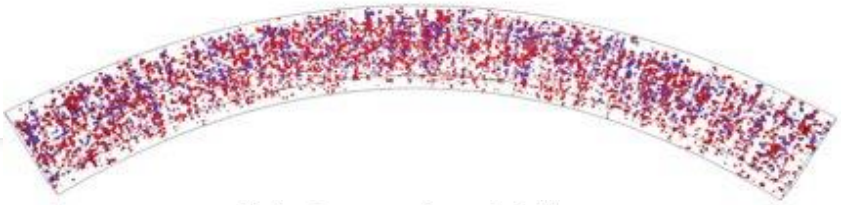


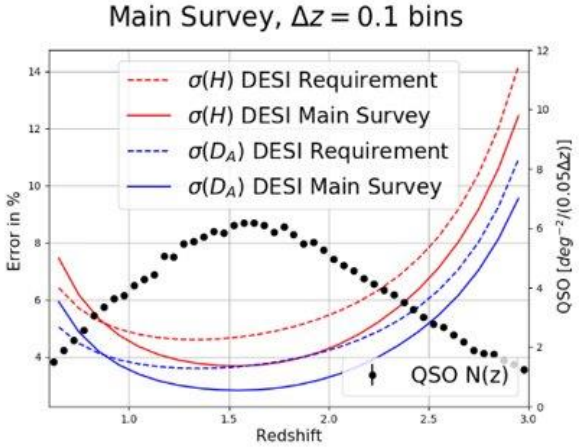
- Redshift evolution of the underlying type Ia supernova stretch distribution (Nora Nicolas, IP2I, Lyon)

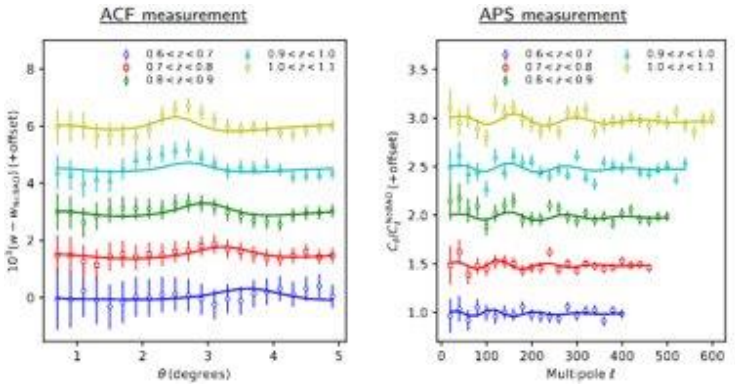


Galaxy clustering – observations

- **eBOSS** results *(Arnaud de Mattia)*
- reanalysis of **BOSS LRG and eBOSS QSO** + combination with DES *(Agne Semenaite, MPI, Garching)*
- review on **eBOSS and WEAVE-QSO** @ La Palma, higher resolution (5000 – 20000) *(Ignasi Pérez-Ràfols, IFAE Barcelona)*
- first measurement of the correlation between cosmic voids and the Lyman-alpha forest *(Corentin Ravoux)*
- status of **DESI** *(Christophe Yèche)*
- AI-assisted selection and the identification of quasars in DESI *(Edmond Chaussidon)*
- 2.7% measurement of the BAO with **DES** Y3: 5 (photometric) redshift bins, ~ 4 sigmas detection *(Juan Mena-Fernandez, CIEMAT, Madrid)*







Galaxy clustering – simulations

- Simulations to:
  - i) model **non-linear evolution under gravity**
  - ii) study tracer (galaxies, lyman-alpha, ...) relation to matter: **bias**
- Study of halo bias parameters from cosmological simulations using forward-modelling *(Titouan Lazeyras, Università degli Studi di Milano Bicocca)*

$$-2\ln\mathcal{P}\left(\delta_h|\delta_{h,\mathrm{det}}\right) = \int_{|\mathbf{k}|<\Lambda} \frac{\mathrm{d}^3\mathbf{k}}{(2\pi)^3}\left[\frac{\left|\delta_h(\mathbf{k}) - \delta_{h,\mathrm{det}}(\mathbf{k})\right|^2}{P_\epsilon(k)} + \ln\left(2\pi P_\epsilon(k)\right)\right]$$

- Hydrodynamical simulations, to study impact of massive neutrinos, dark radiation and WDM on Lyman-alpha forests *(Graziano Rossi, Sejong U.)*
- Relativistic second-order initial conditions for simulations of large-scale structure (Thomas Montandon, APC)
- Test resolution of N-body simulation (Abacus, used in DESI) using scale-free simulation (rescaling of distances <=> time) *(Sara Maleubre Molinero, LPNHE)*

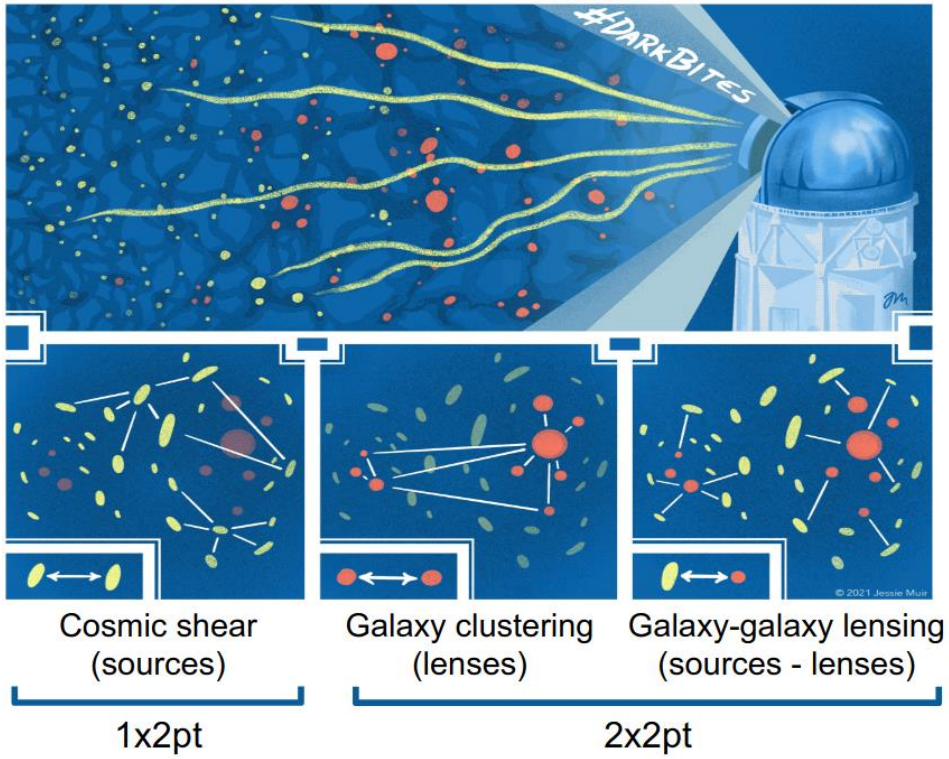
Galaxy clustering – theory

- review of **EFT of LSS**: split long distance from short distance physics, acting as non-trivial stress tensor. P(k), B(k), fnl... *(Leonardo Senatore, ETH)*
- + baryons *(Matthew Lewandowski, Northwestern U.)*
- + two-loop bispectrum of large-scale structure *(Petter Taule, TUM)*
- *… for line-intensity mapping (Azadeh Moradinezhad, Université de Genève)*
- power spectrum **emulators** relying on halo model for various dark energy and modified gravity scenarios *(Matteo Cataneo, Argelander-Institut für Astronomie, Bonn)*
- the importance of correlations in the dynamics of the large-scale structures of the Universe *(Pascal Tremblin, Maison de la simulation)*
- **forward-modelling for LSS**: lots of additional information in the phases over summary statistics like P(k) + B(k) *(Fabian Schmidt, MPI Garching)*

Galaxy weak lensing

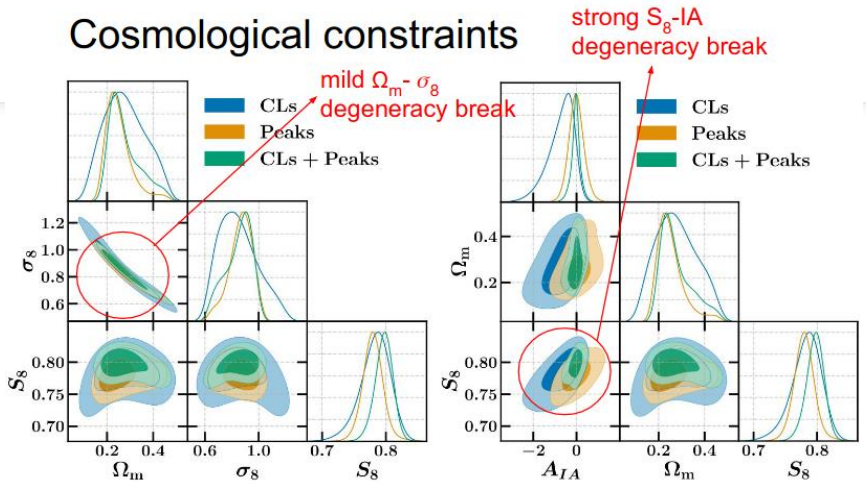
- test of **LSST-DESC** 3x3pt **analysis pipeline** with HSC *(David Sánchez Cid, CIEMAT, Madrid)*
- **metacalibration of shear bias** (deconvolving PSF, artificial shear, PSF) with **CFIS** *(Axel Guinot, APC)*
- **calibration of redshift distribution** using photoz + clustering redshifts for the **DES** Y3 lens MagLim sample *(Giulia Giannini, IFAE, Barcelona)*
- *Super-sample covariance (Sylvain Gouyou-Beauchamps, CPPM)*

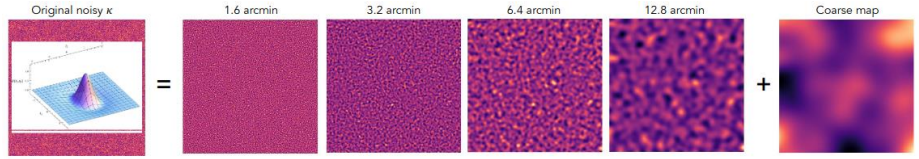
Credit: © 2021 Jessie Muir



Galaxy weak lensing – others

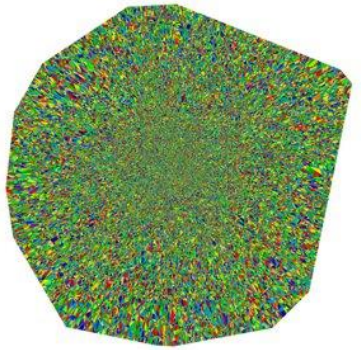
- lensing potential estimation with galaxy number counts (Viraj Nistane, U. de Genève)
- cosmology with peaks using an emulator approach for DES Y3: S8/IA degeneracy breaking *(Dominik Zürcher, ETH)*
- higher order statistics: multi-scale starlet peaks, voids & l1-norm, application to CFIS *(Virginia Ajani, ETH Zurich)*
- reconstruction of DM map *(Benjamin Remy, DAp)*



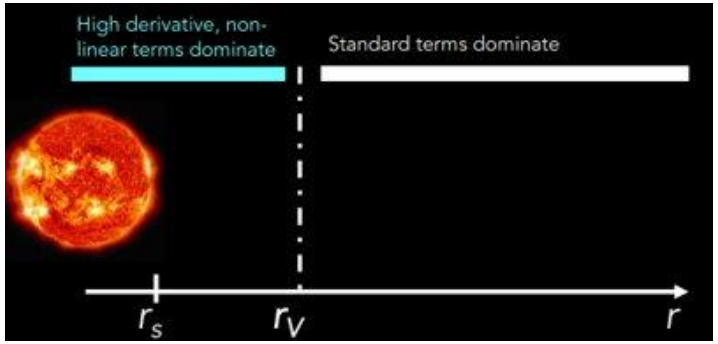


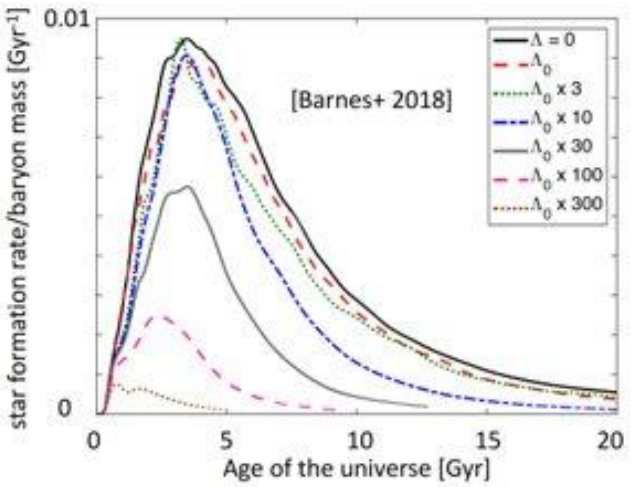
$$l_1^{j,i} = \sum_{u=1}^{\#coef(S_{j,i})} |\mathcal{S}_{j,i}[u]| = \|\mathcal{S}_{j,i}\|_1$$

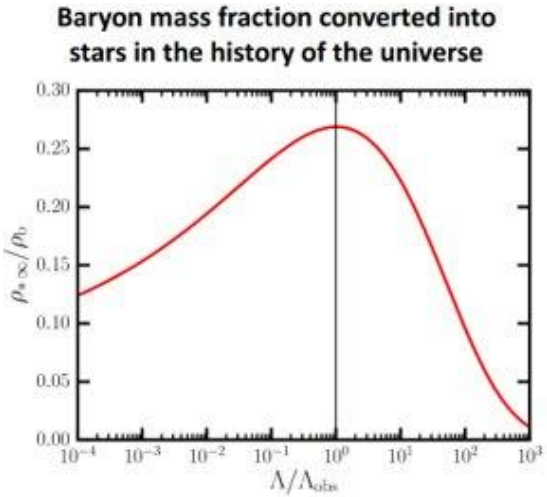
Dark energy – theory



- search for quantum gravity theories with "realistic EFTs". Reveal the **string landscape** by enumerating topological invariants of Ricci-flat six-manifolds: *Liam McAllister (Cornell U.)*
- a theory of massive Galileons against its UV completion: the IR theory Vainshtein screens, the UV theory doesn't! *(Daniela Saadeh, U. of Portsmouth)*
- we are typical observers *(Daniele Sorini, U. of Edinburgh)*
- Albrecht-Skordis quintessence model to alleviate H0 and sigma8 tensions *(Arsalan Adil, U. of California)* deviations from classicality in gravity *(Federico Piazza, CPT, Marseille)*, EFT of a massive vector field (Victor Pozsgay, Imperial College London), primordial structure from quantum cosmological bouncing models *(Jaime de Cabo Martín, National Centre for Nuclear Research, Warsaw),* EFT of DE tests with BH ringdown *(Leonardo Trombetta, CEICO, Prague)*, weak constraints on f(R) from redshift – distance relation with Einstein Telescope *(Isabela Santiago de Matos, Universidade Federal do Rio de Janeiro)*

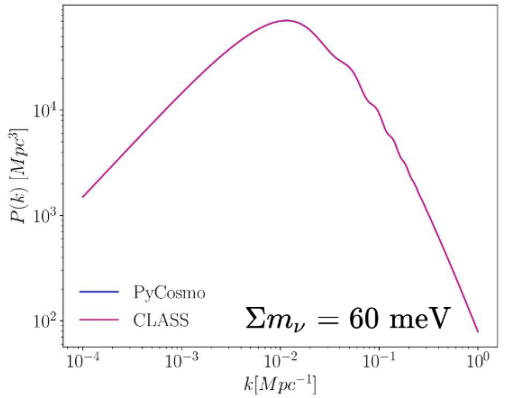


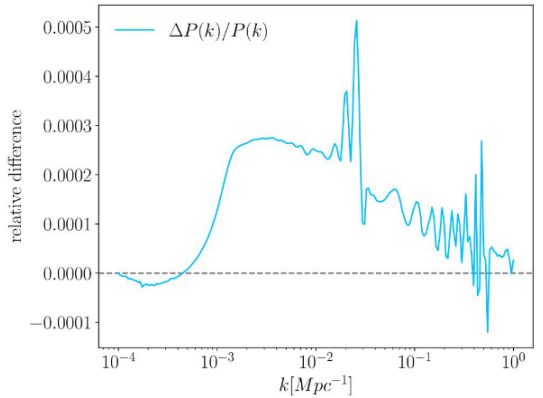




Controversies

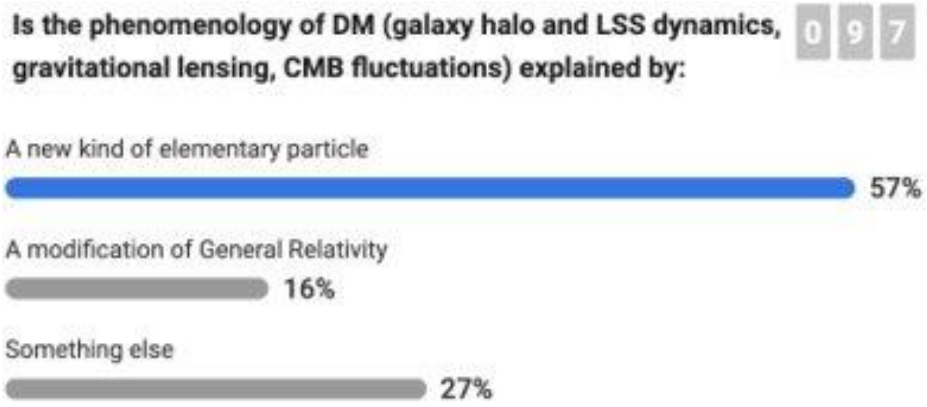
- 5-sigma H0 tension, best resolved by models modifying sound horizon, but does not solve ~ 3 sigmas "S8 tension" *(Guillermo Franco Abellán, LUPM, Montpellier)*
- A hypothetical observer during inflation was NOT likely to slow roll measure a deviation of from w=-1 *(Sveva Castello, Université de Genève)*
- Flatness problem? (Marc Holman, Utrecht U.)
- (Not a controversy): symbolic PyCosmo Boltzmann Solver (Beatrice Moser, ETH Zurich)

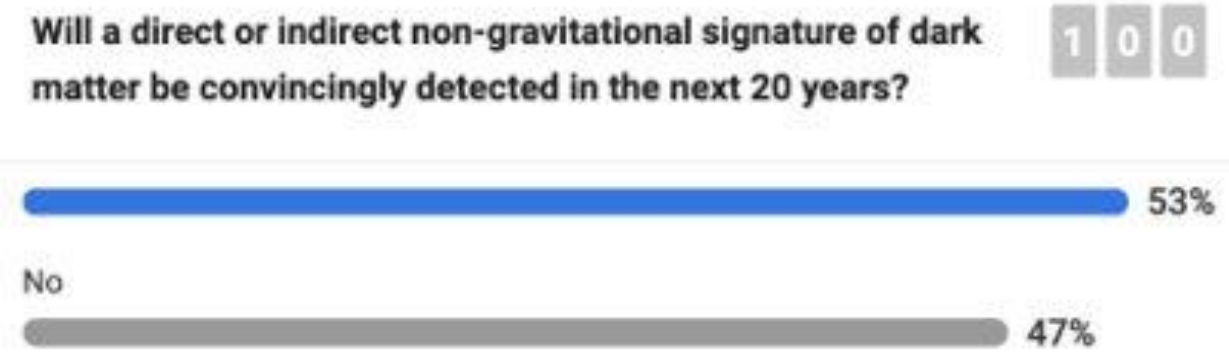


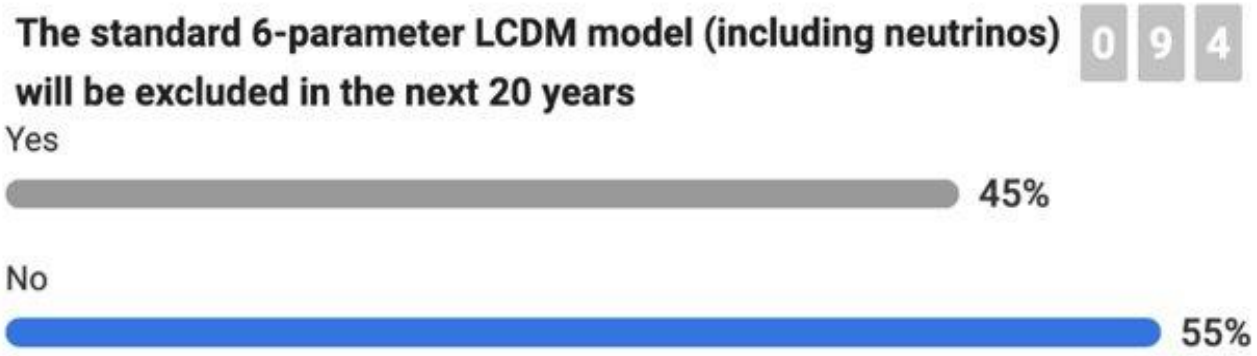


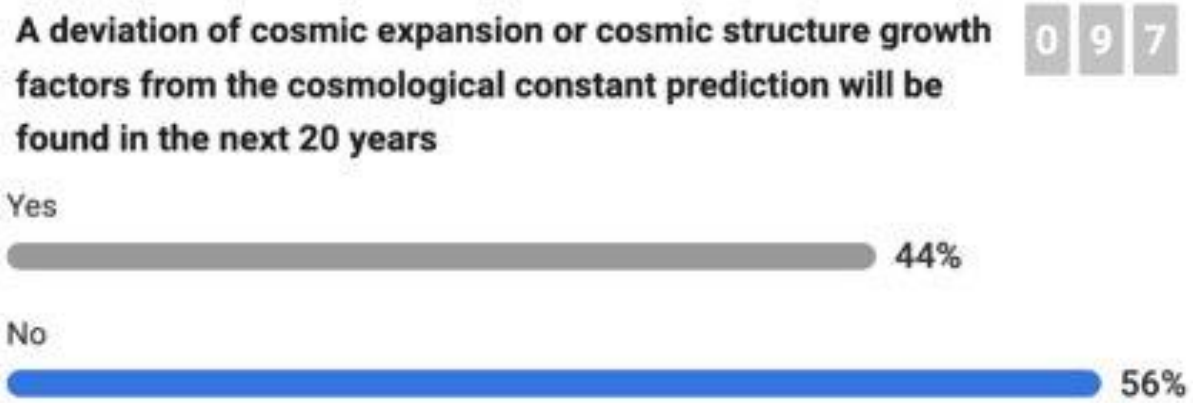
Conclusions

- Poll by Simon White (MPI, Garching)









Conclusions

- Poll by Simon White (Garching)