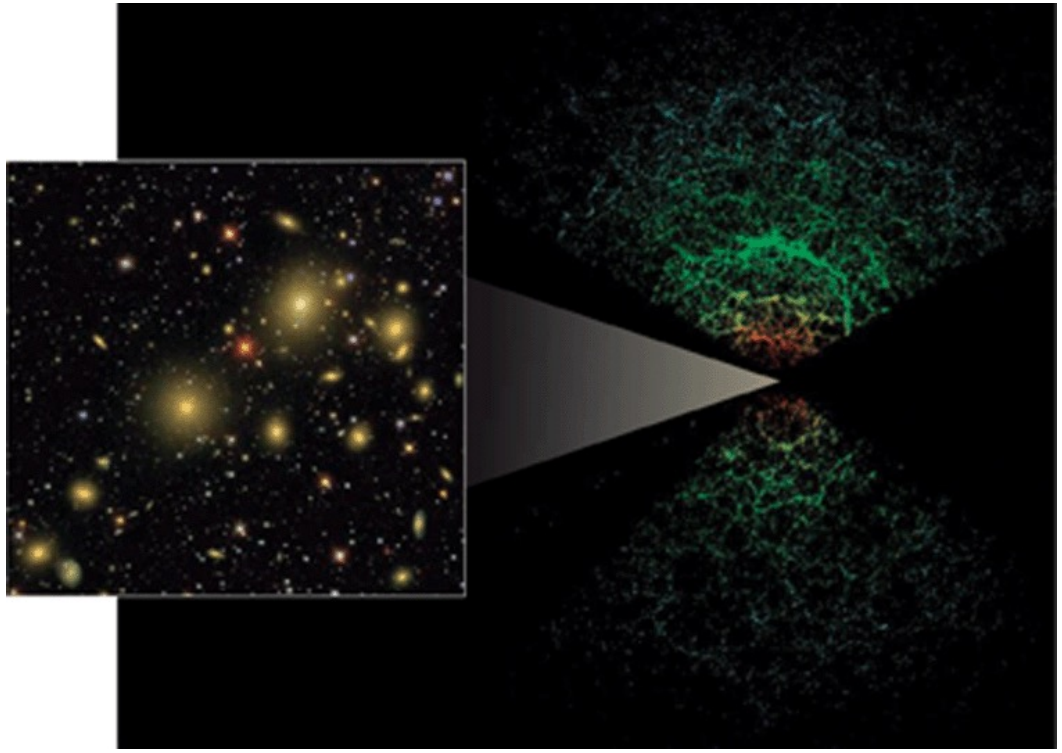
Dark matter in Large Scale Surveys

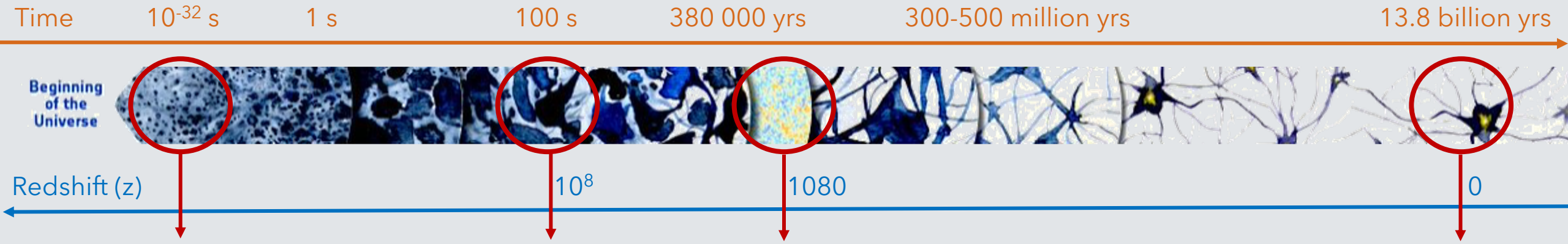
Maria Archidiacono
Università di Milano

Initiative for Dark Matter in Europe and beyond (iDMEu) kick-off meeting

10/05/2021



A short history of the Universe



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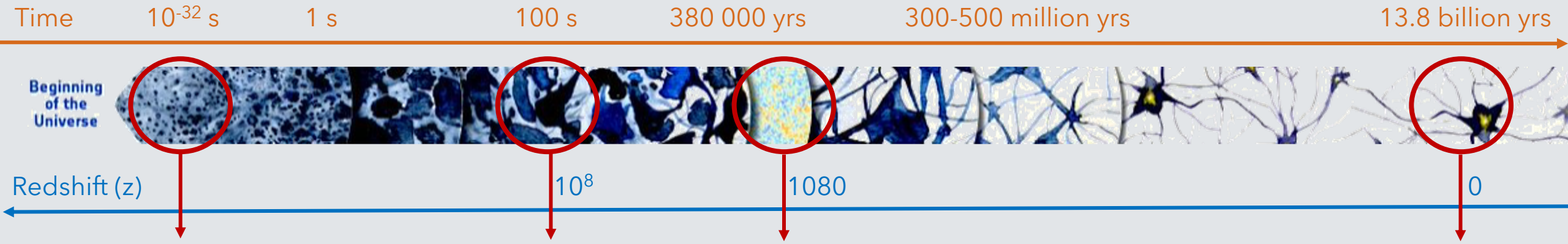
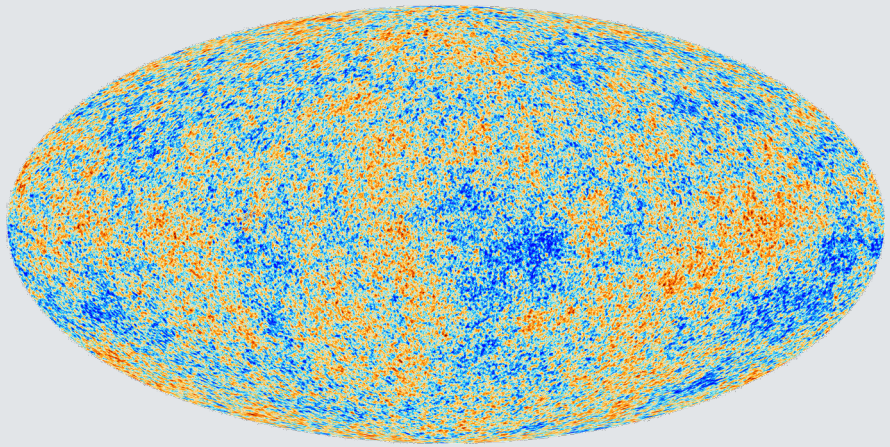


Cold Dark Matter

✓



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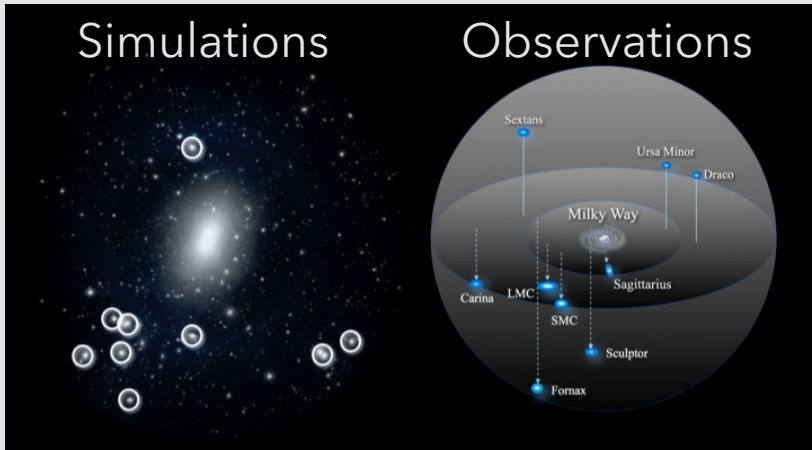
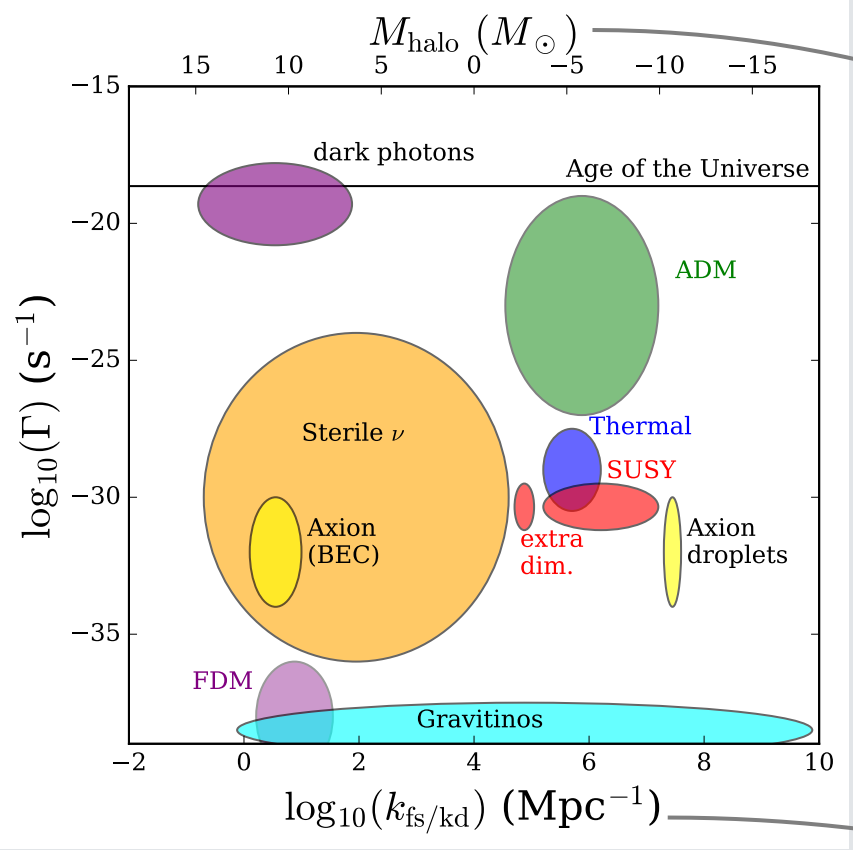
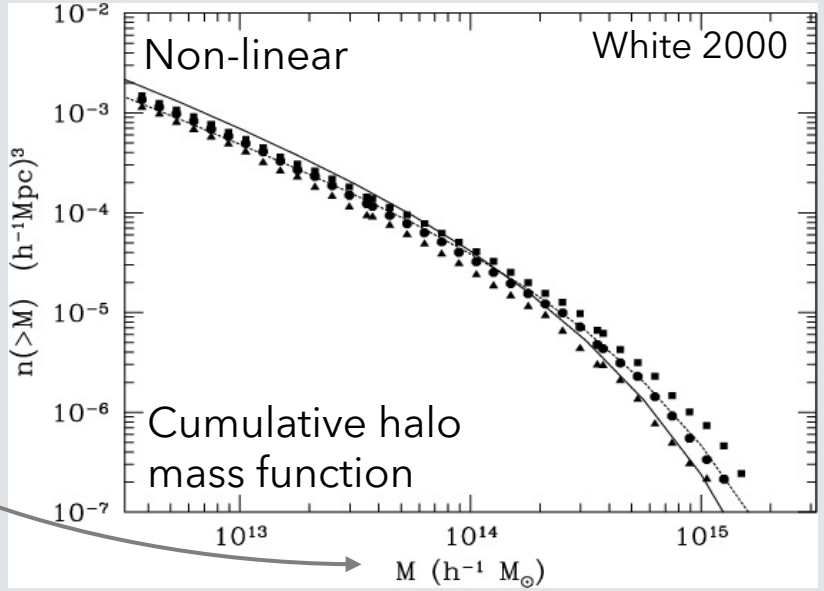


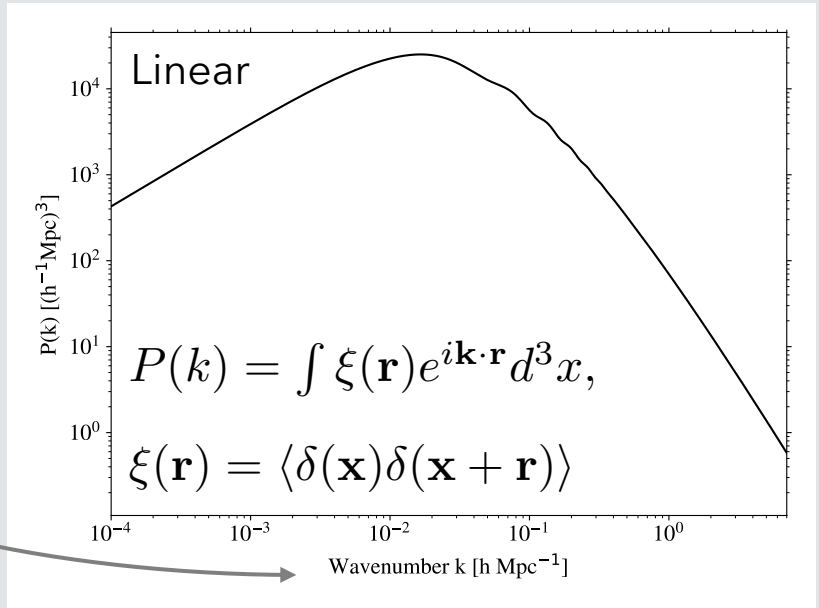
Dark Matter: models and scales

Buckley & Peter 2018



Talk by David Marsh





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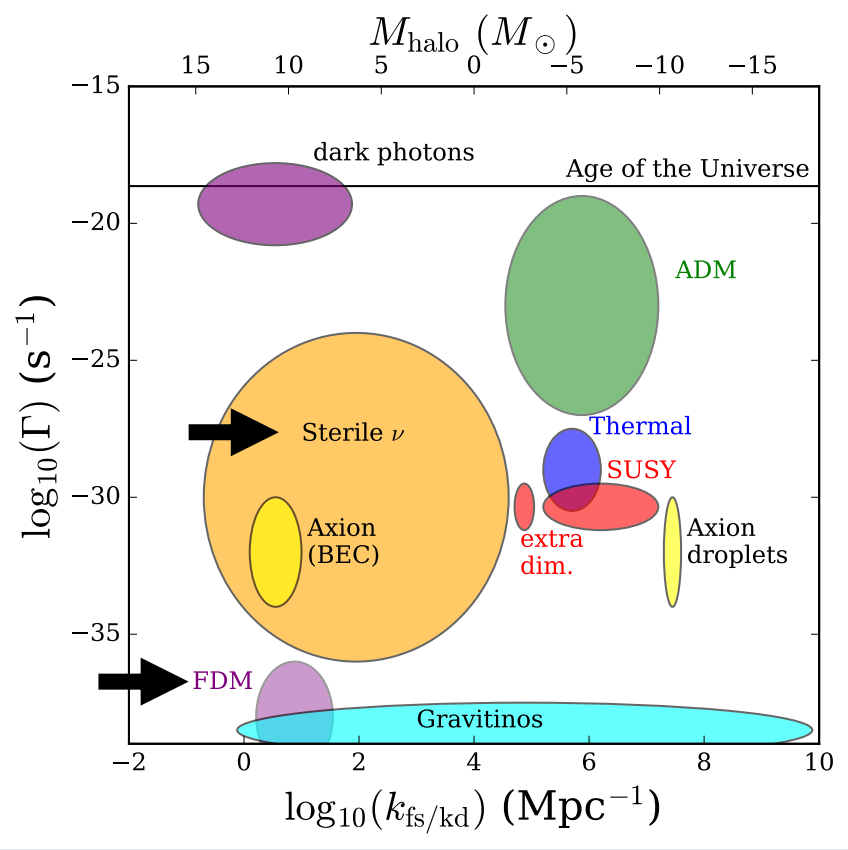
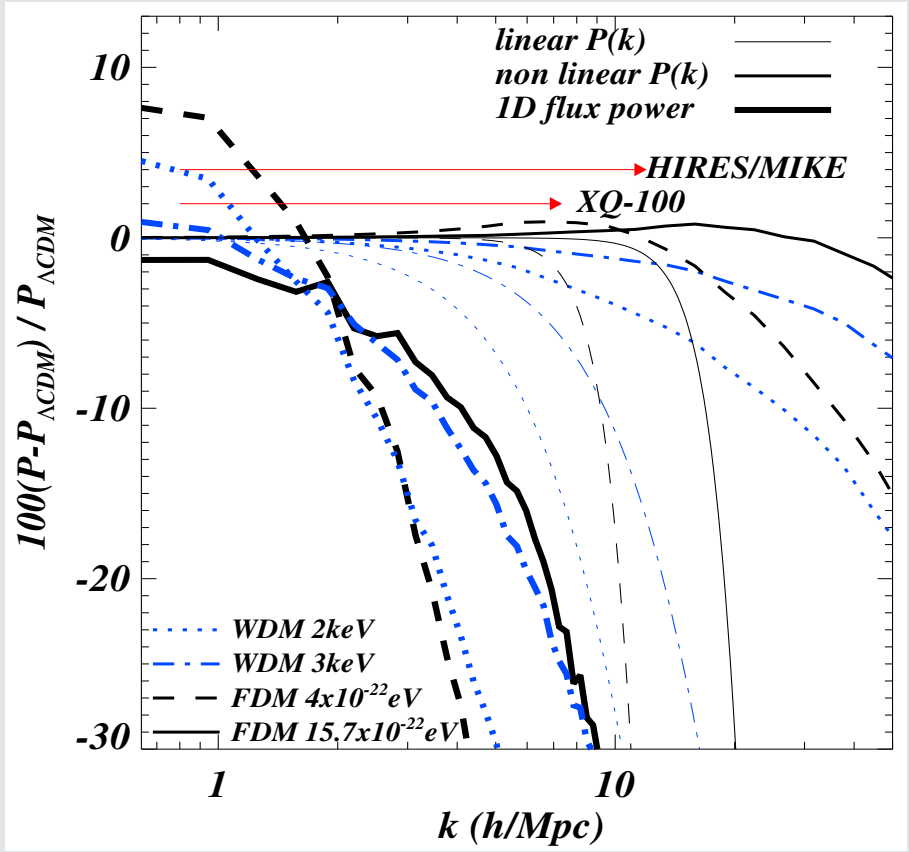


Irsic+ 2017



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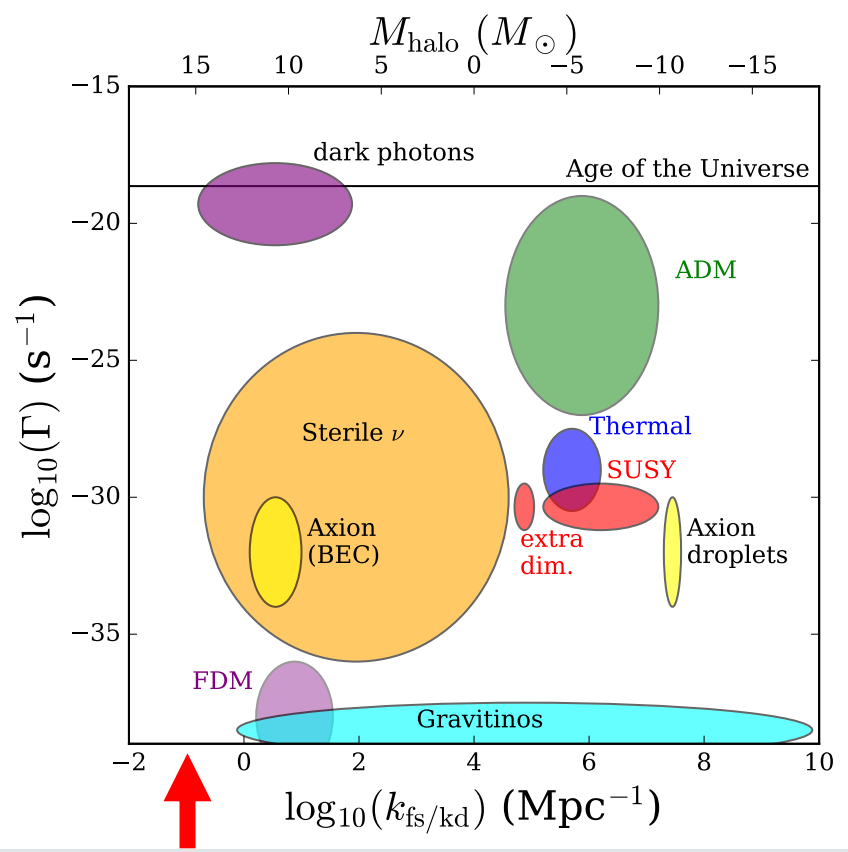
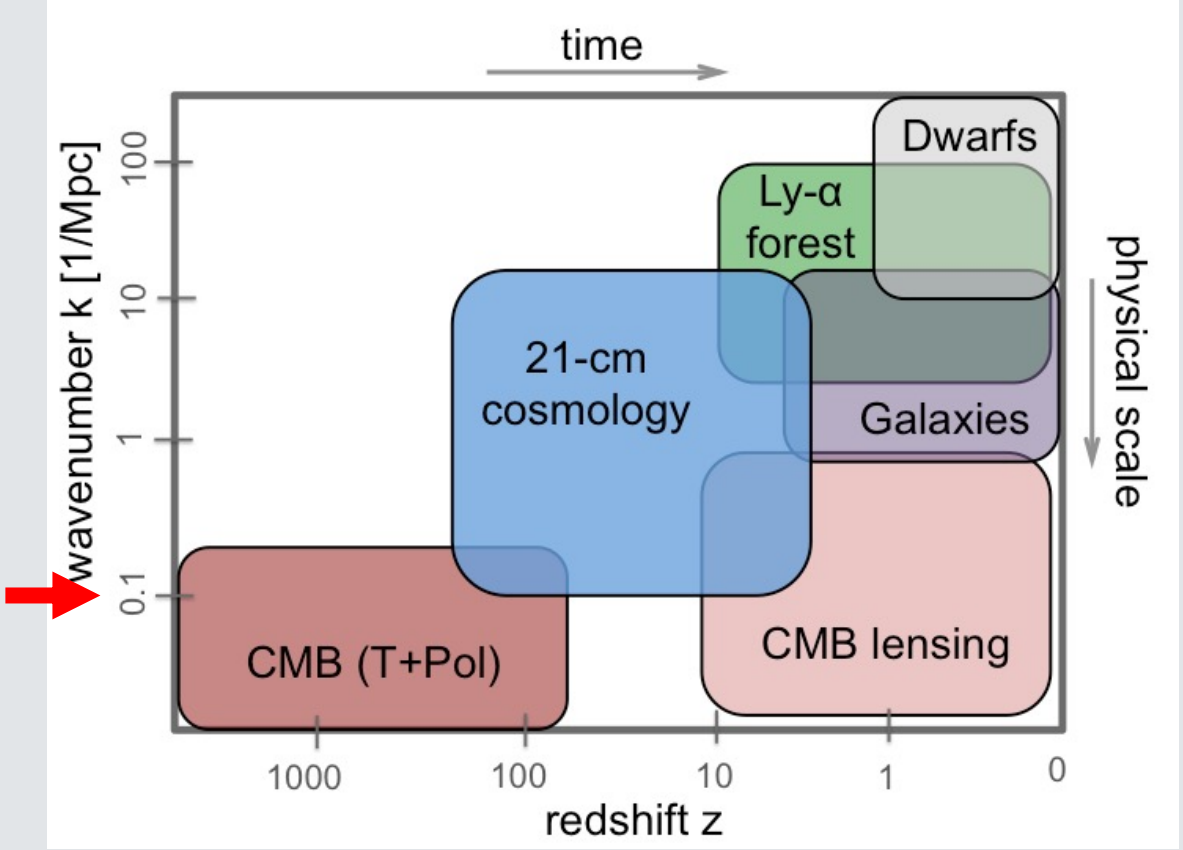


Gluscevic+ 2019



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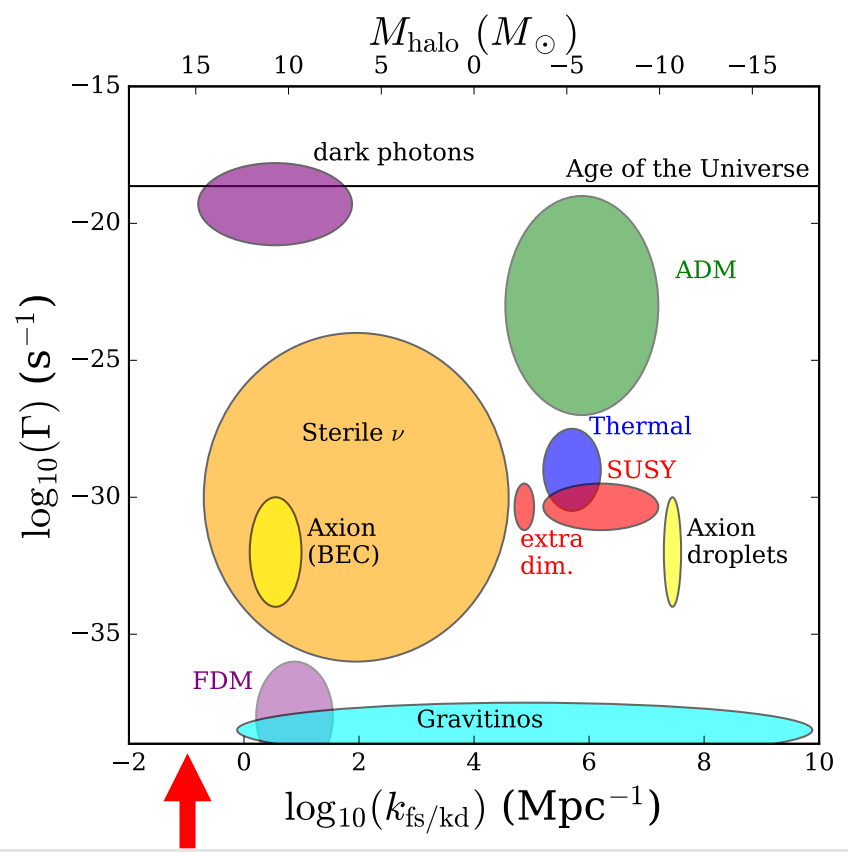
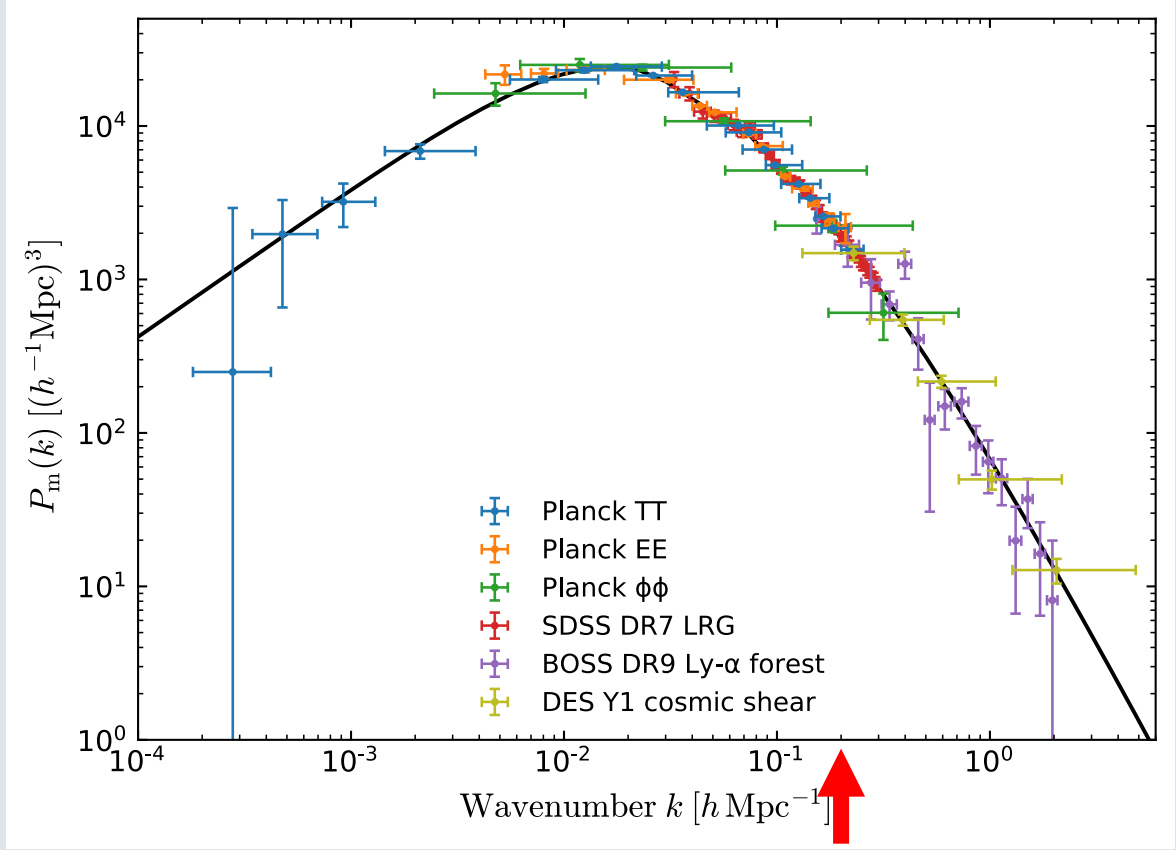
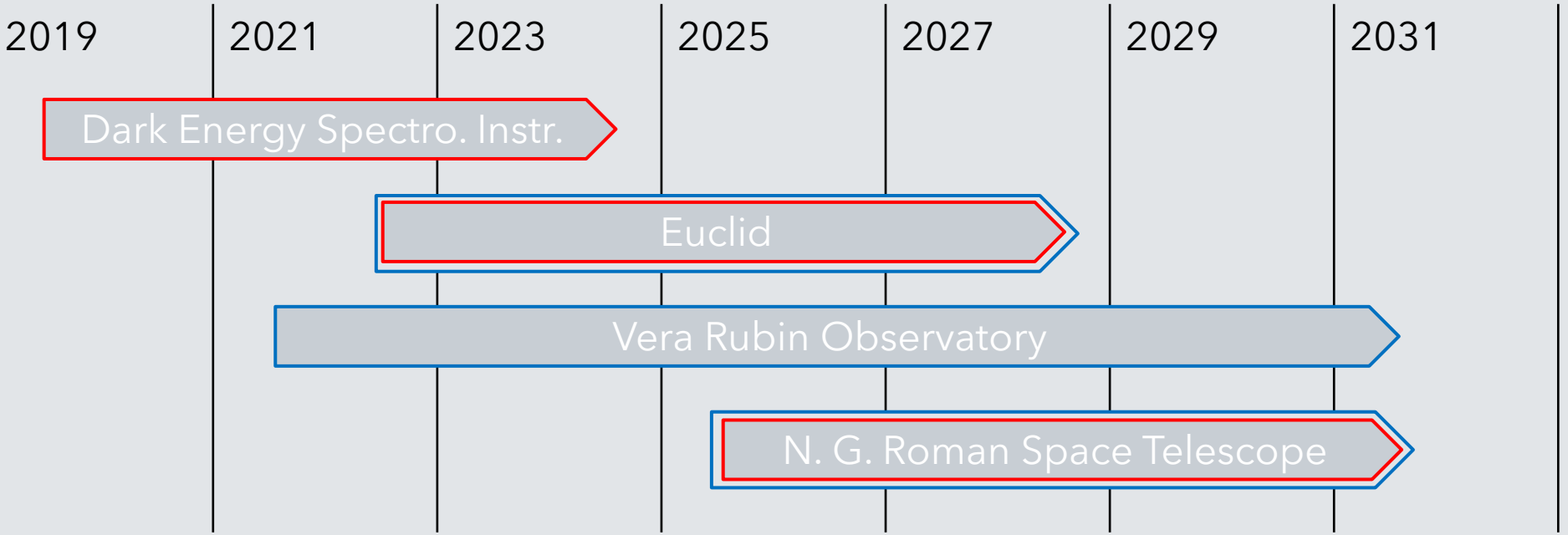


Planck 2018

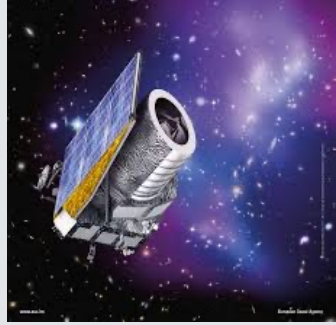


Stage IV Large Scale Surveys



Spectroscopy
Imaging

Euclid in a nutshell



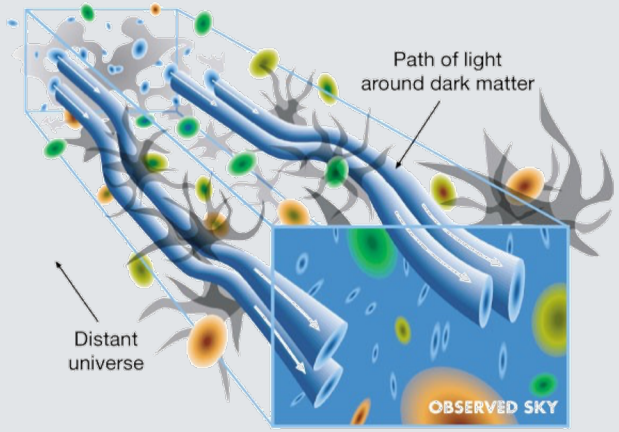
Laureijs+ 2012

- ESA M2 space mission in the framework of the Cosmic Vision program
- Launch scheduled for 2022. Duration ~6 years
- 1.2m telescope with two instruments: Visible Imager (VIS) and Near Infrared Spectrometer and Photometer (NISP)
- Wide survey (15.000 deg^2) and deep survey (40 deg^2 in 3 different fields)
- Measurements of over 1 billion images and more than 10 millions spectra of galaxies out to z>2
- Main scientific objectives: dark energy, dark matter, and General Relativity (Euclid Collaboration, Blanchard+ 2020)

Euclid probes and complementarity with other surveys

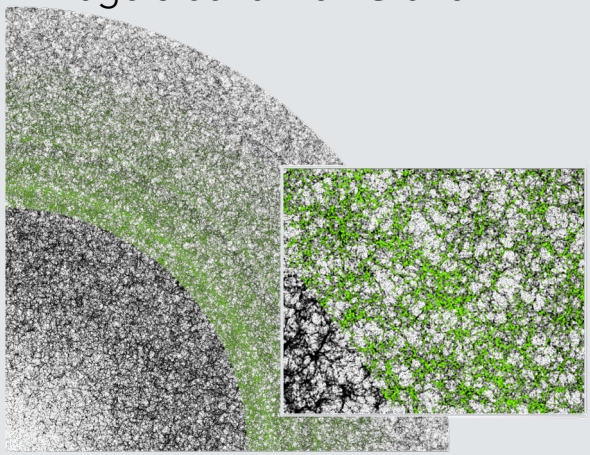
Main probes:

Weak lensing

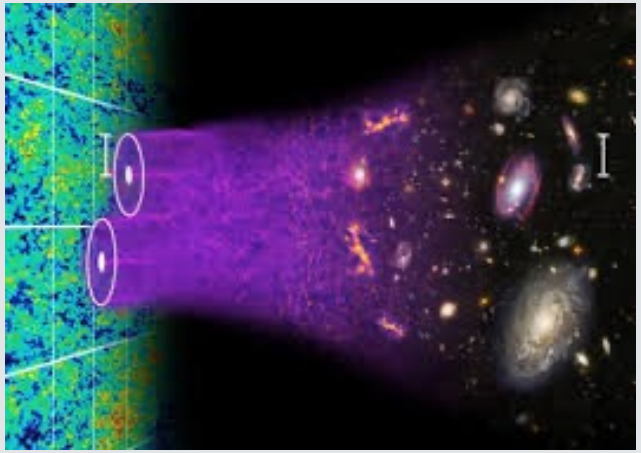


Galaxy clustering

Image credits: Ben Granett



Baryonic Acoustic Oscillations



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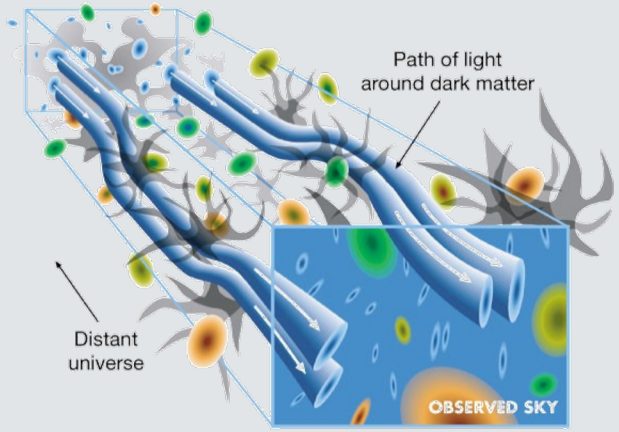

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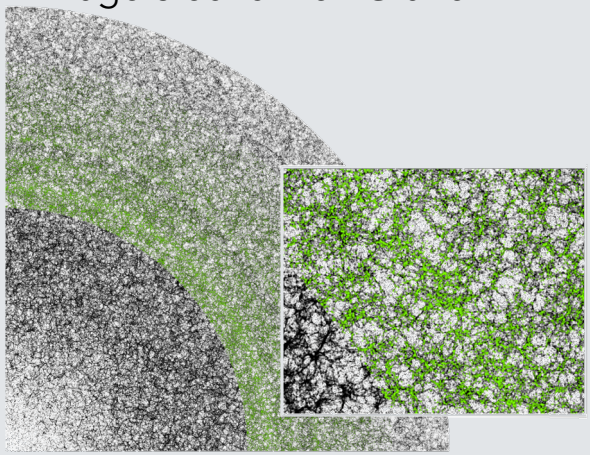

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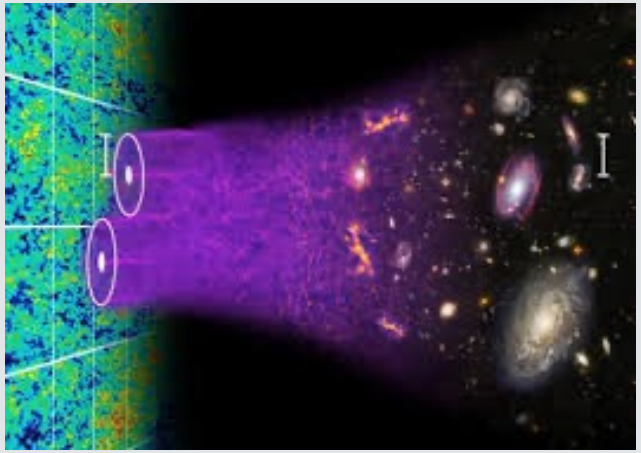

Secondary probes:

- Cluster of galaxies
- Strong lensing
- Cross-correlation CMB

Euclid probes and complementarity with other surveys

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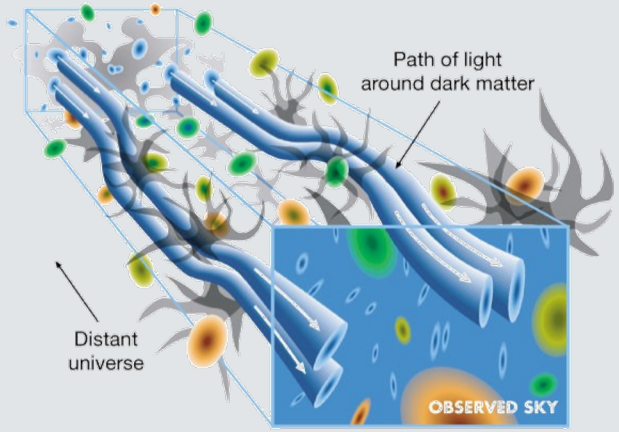
Weak lensing



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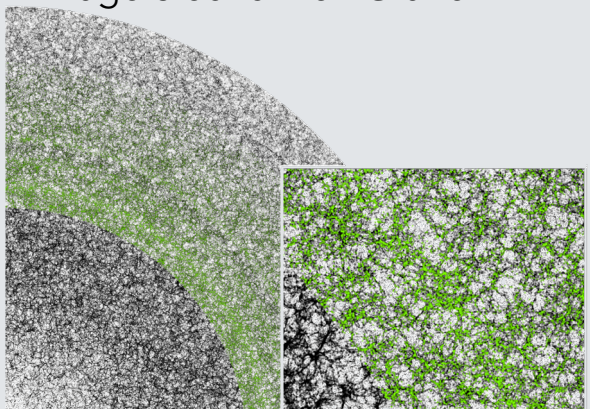

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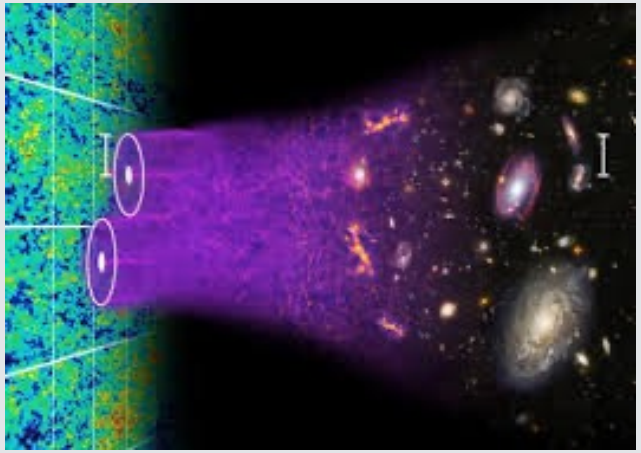

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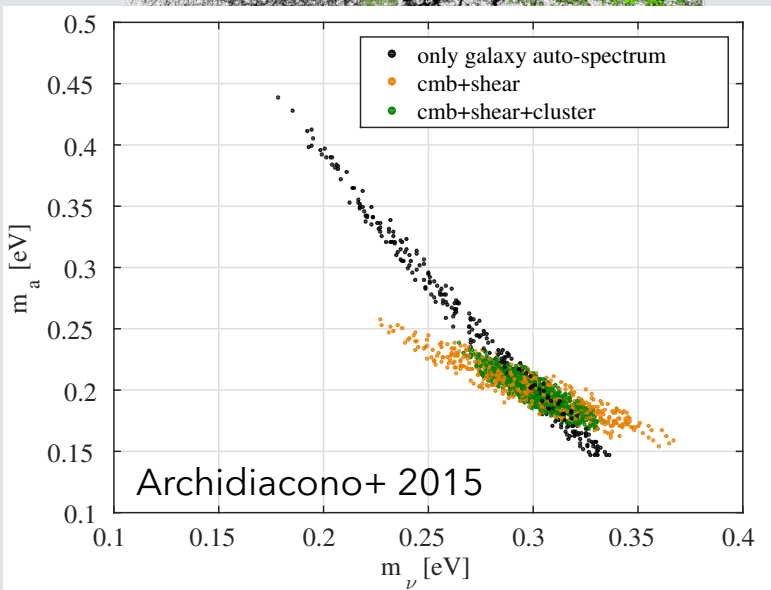

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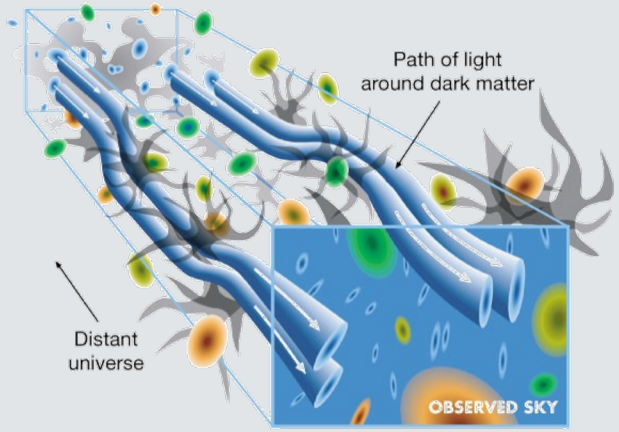

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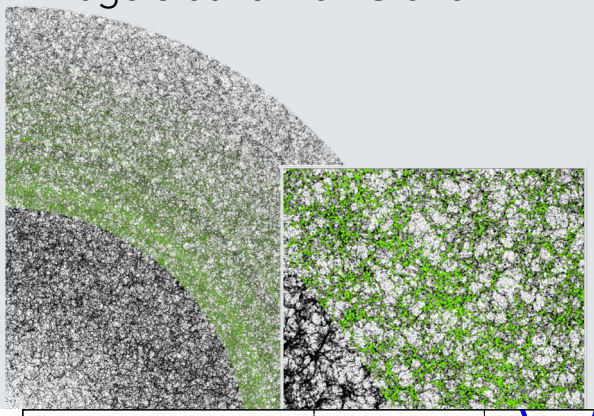

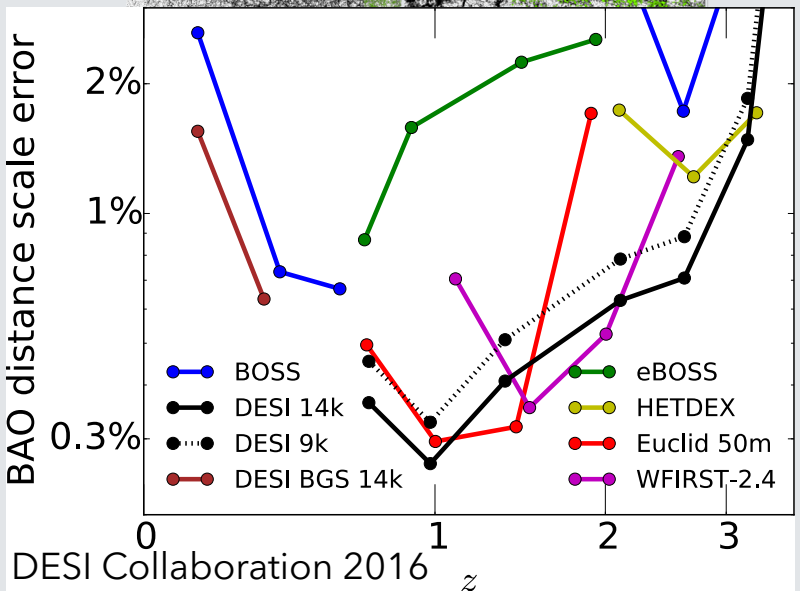

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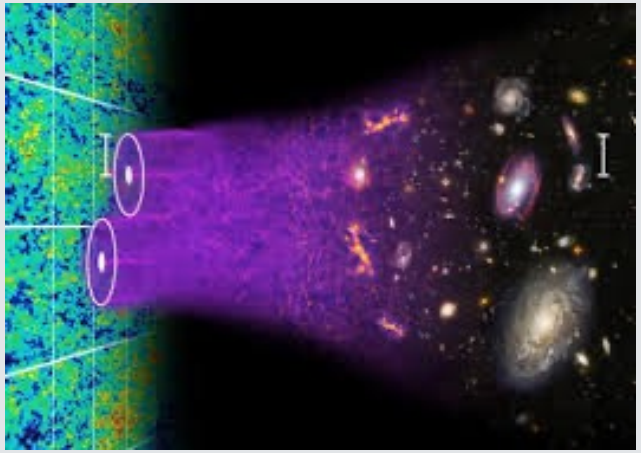

- Synergies with other surveys

Euclid probes and complementarity with other surveys

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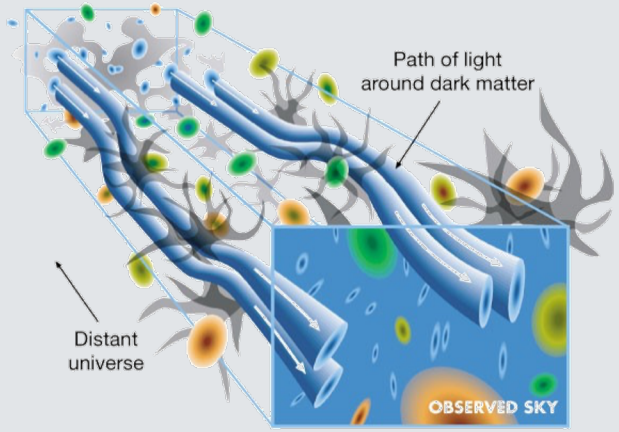

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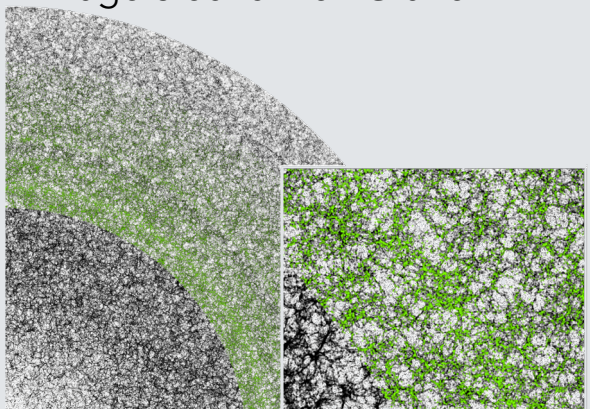

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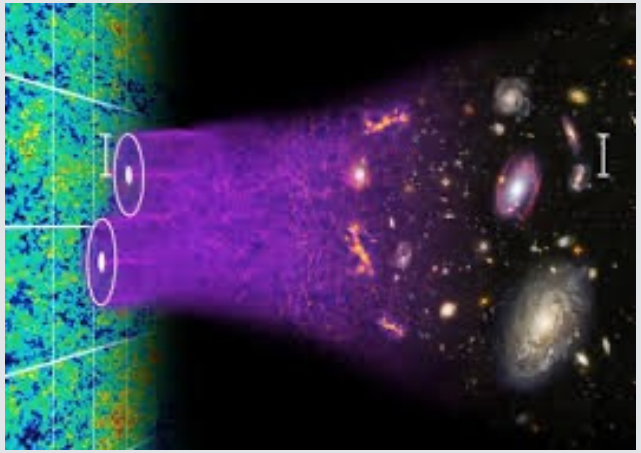
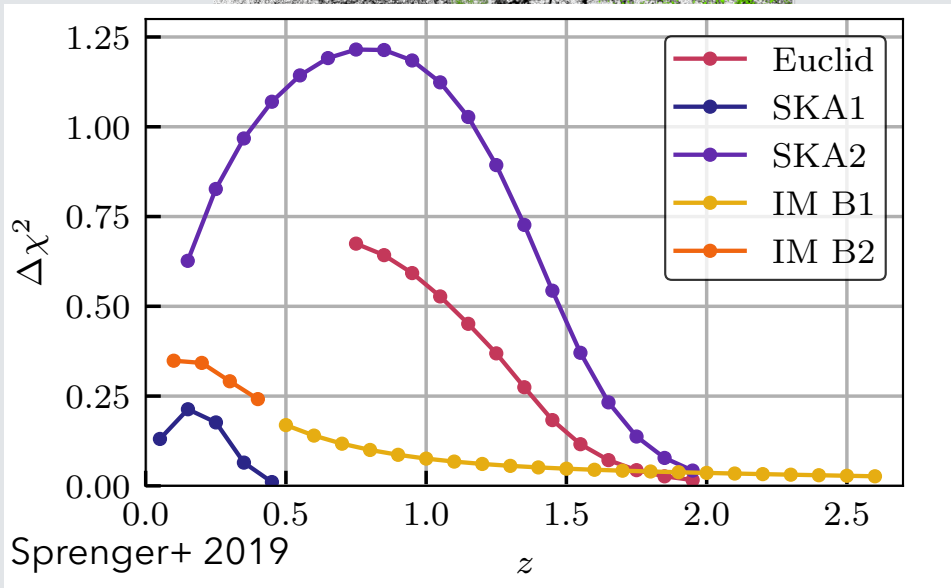


- Synergies with 21 cm surveys

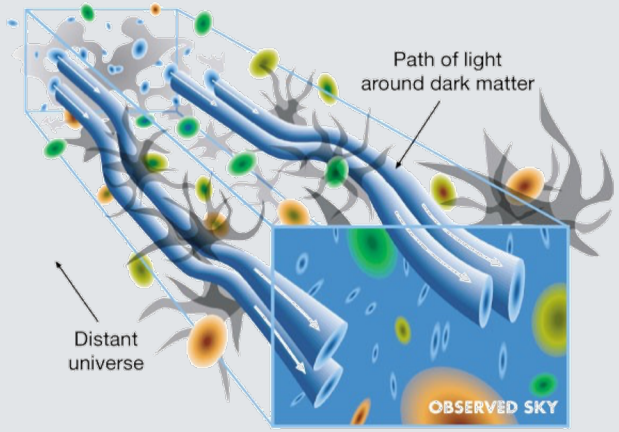


Sprenger+ 2019

Euclid probes and complementarity with other surveys

Main probes:

Weak lensing

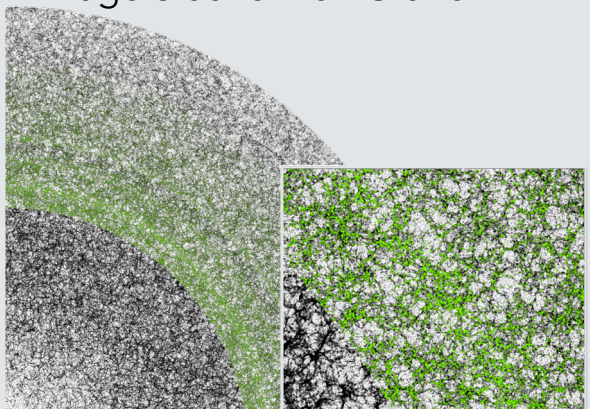


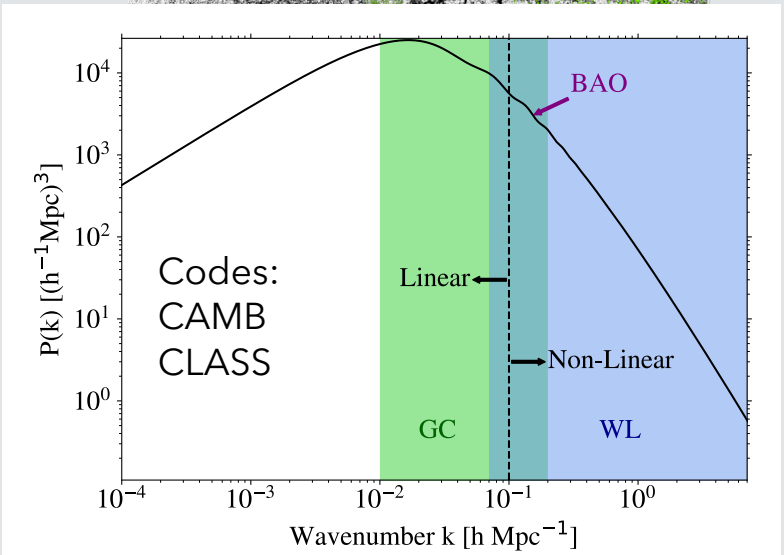
- NLO PT
- Simulations
  Codes:
  GADGET,
  Arepo

  Talk by Justin Read

Galaxy clustering

Image credits: Ben Granett





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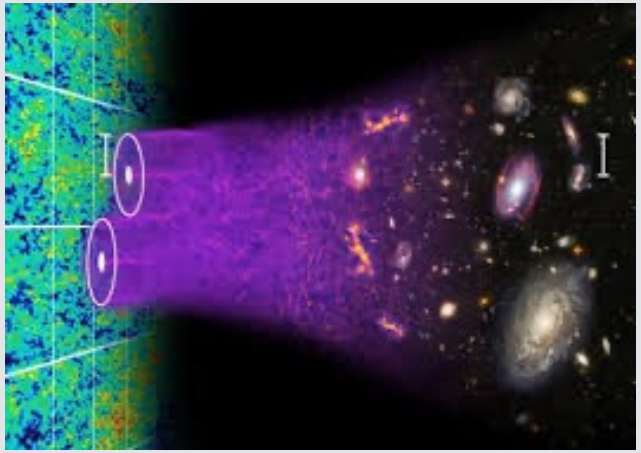


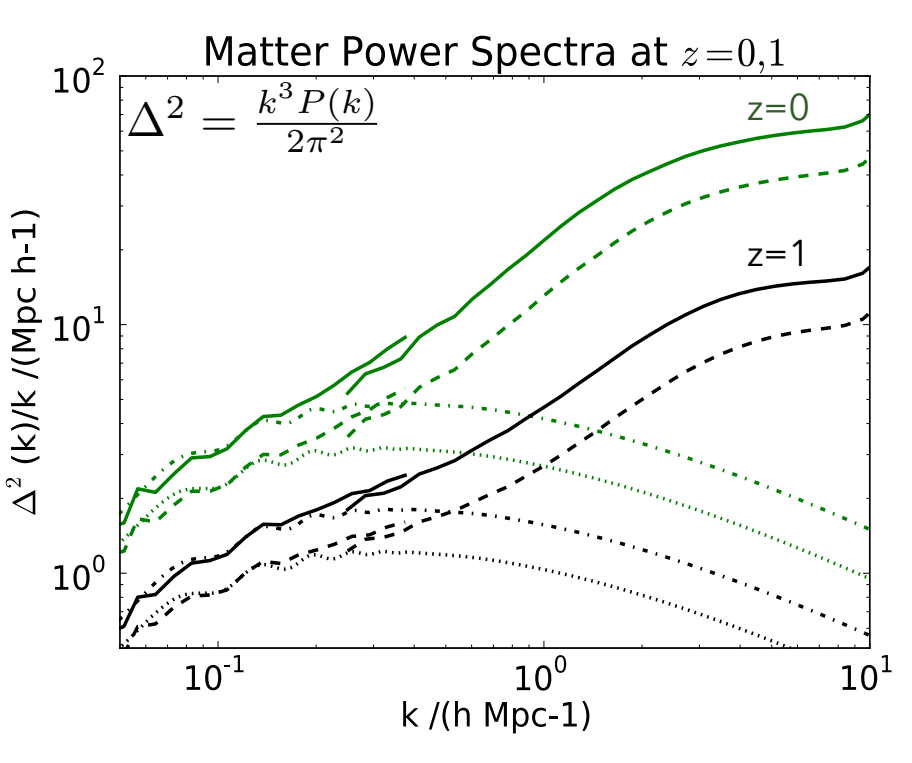
✓ High precision (~1%) measurements

✗ Equally accurate theoretical predictions

Systematics and theoretical errors

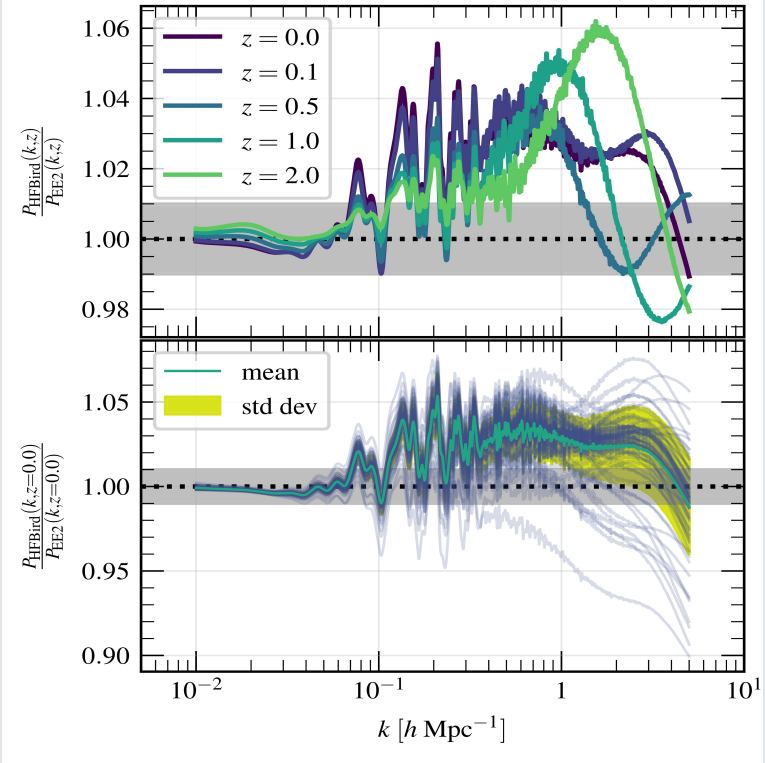
1. Non-linearities

Bird+ 2012



Matter power spectra from simulations of ΛCDM with (dashed) and without (solid) neutrinos. Dot-dashed (dotted) lines show the linear theory predictions.

Euclid Collaboration, Knabenhans+ 2020

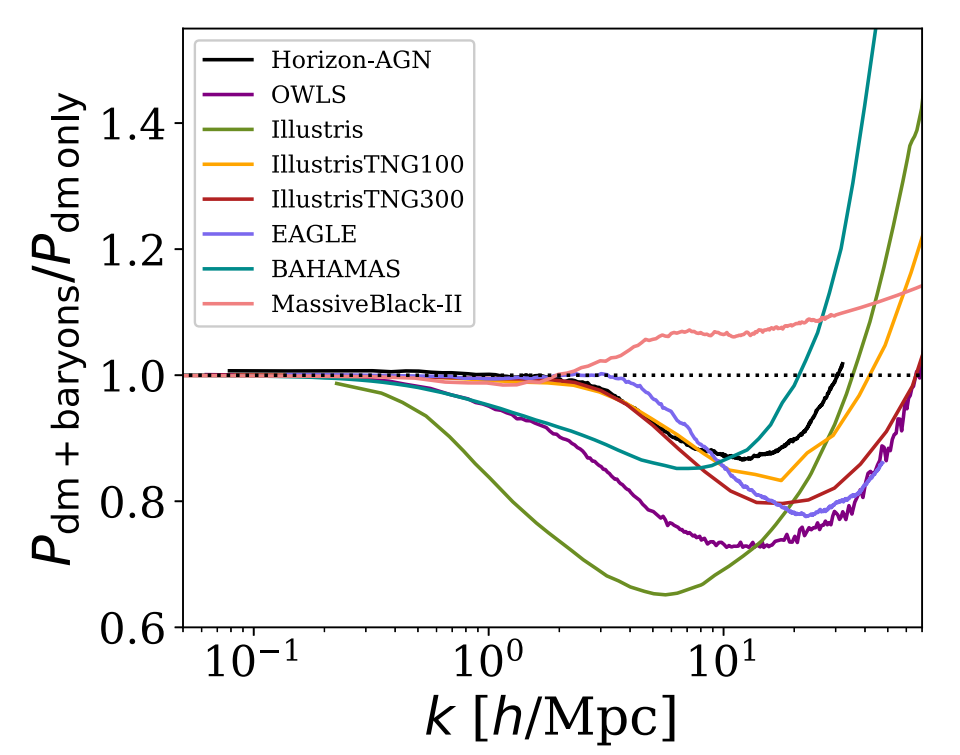


EuclidEmulator: over 250 simulations of ΛCDM + massive neutrinos + time varying dark energy with 3000 particles in a volume of 1 $(h^{-1}\ \mathrm{Gpc})^3$.

Systematics and theoretical errors

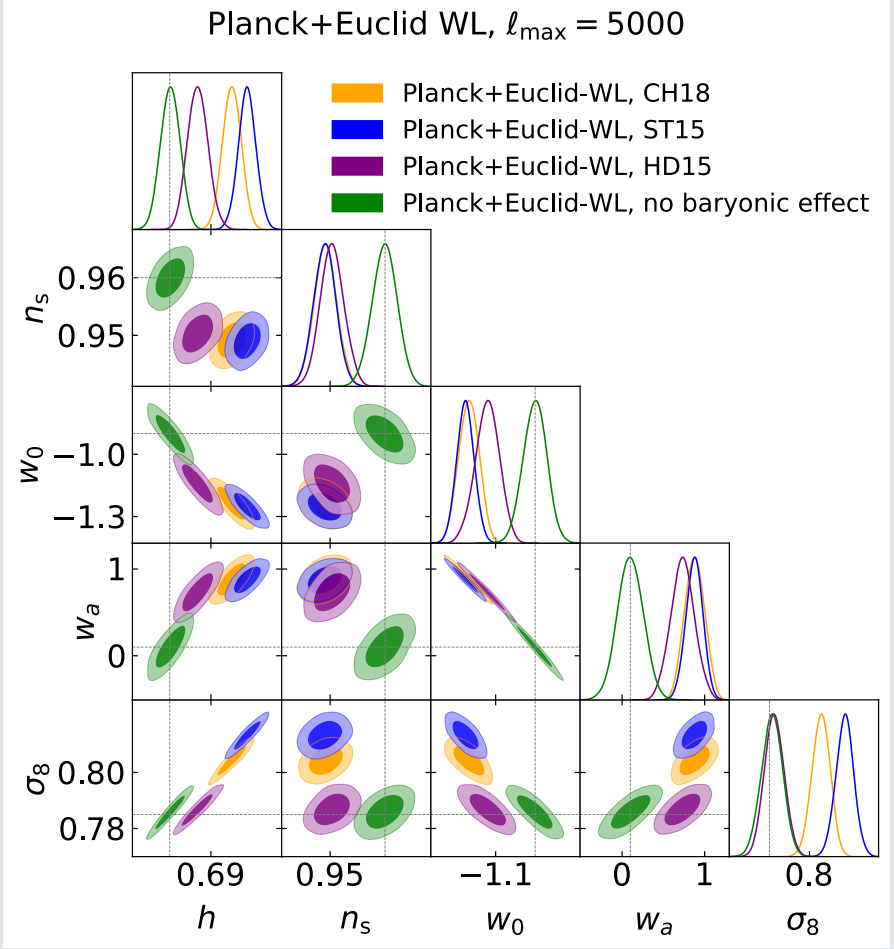
2. Baryonic feedback

Chisari+ 2019



Fractional impact of baryons on the matter power spectrum for several hydrodynamical simulations.

Euclid Collaboration: Martinelli+ 2021



Systematics and theoretical errors

3. GC bias $P_{galaxy} = b^2 P_{matter}$

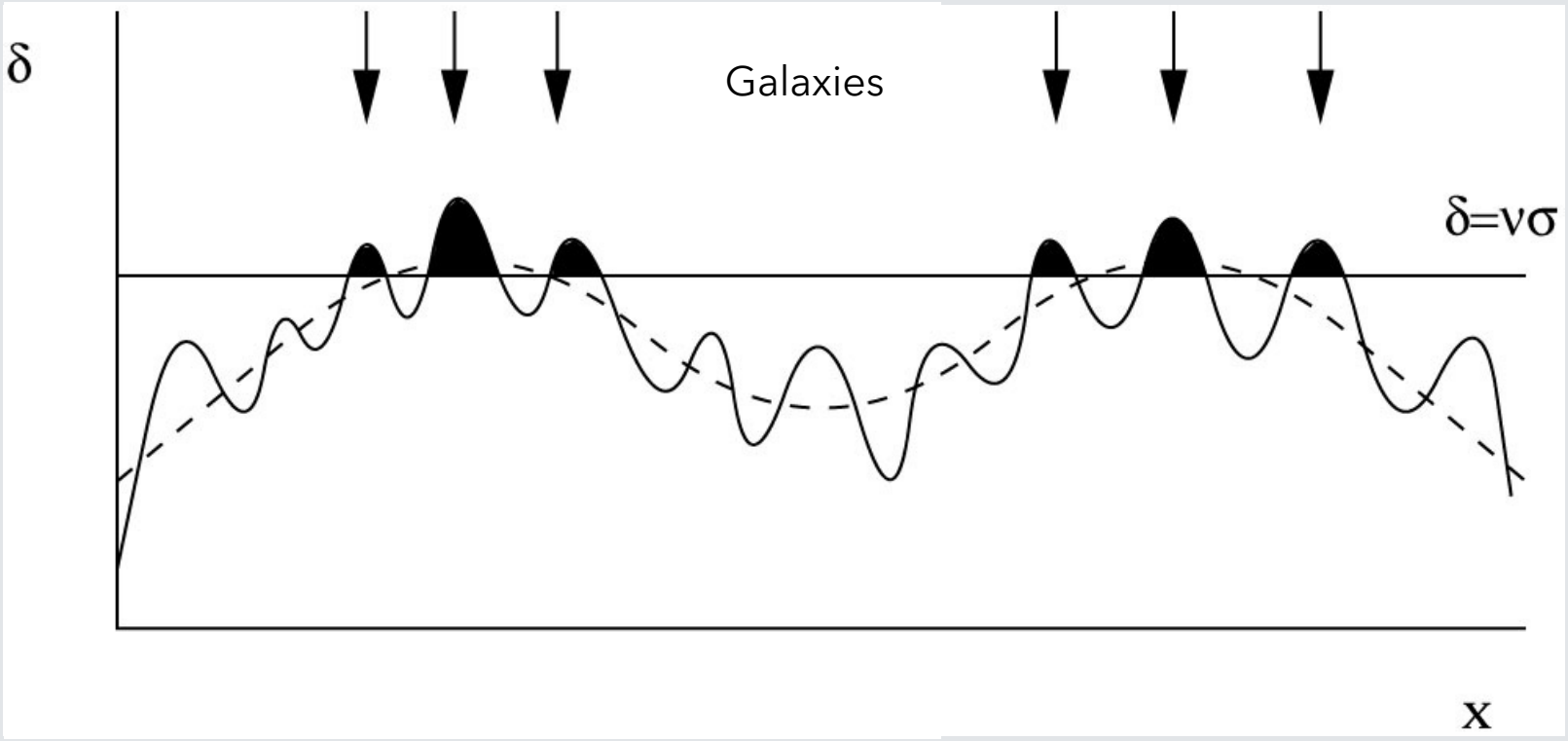


Image credits: ned.ipac.caltech.edu

Systematics and theoretical errors

What we (will) have

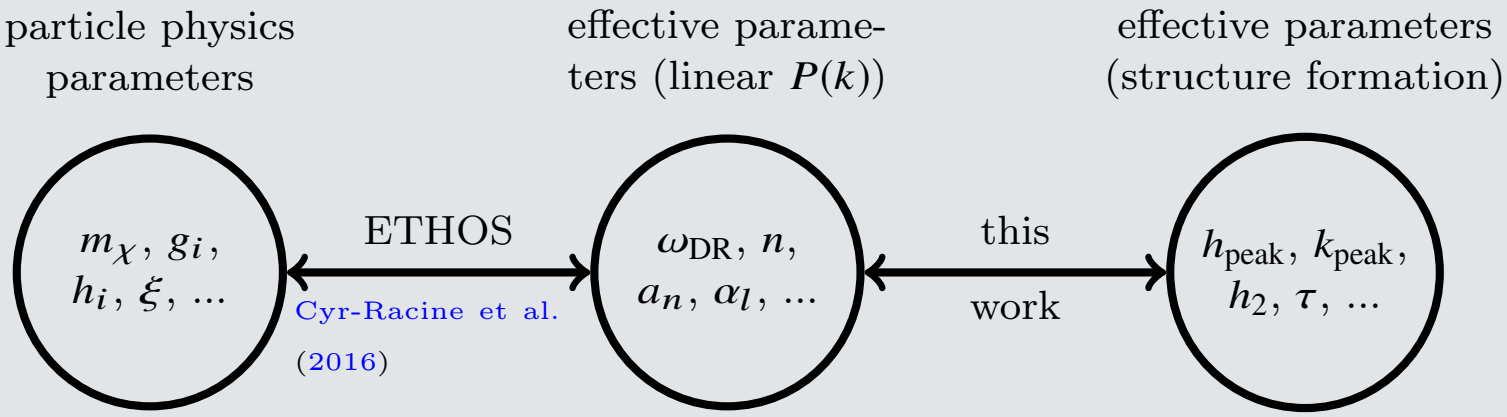
- High precision measurements in the range of scales relevant to test dark matter

What we need

- Efficient methods for theoretical predictions in the non-linear regime
- A better control of systematics
- A better understanding of the astrophysics
- …beyond CDM

Input from the Particle Physics community: parametrization

- Dark photons and self-interacting dark matter (Cyr-Racine+ 2016, Bohr+ 2020)



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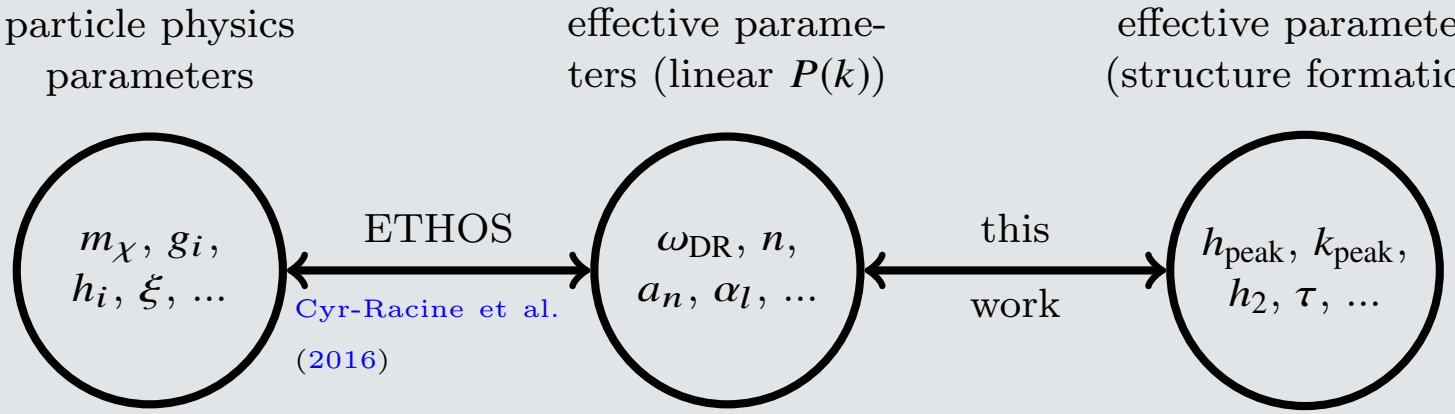
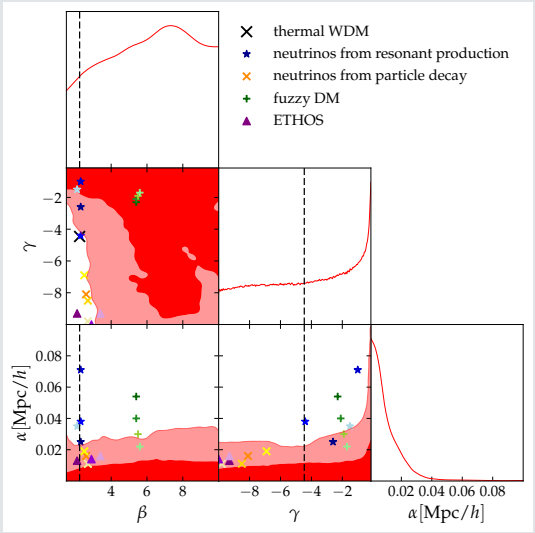
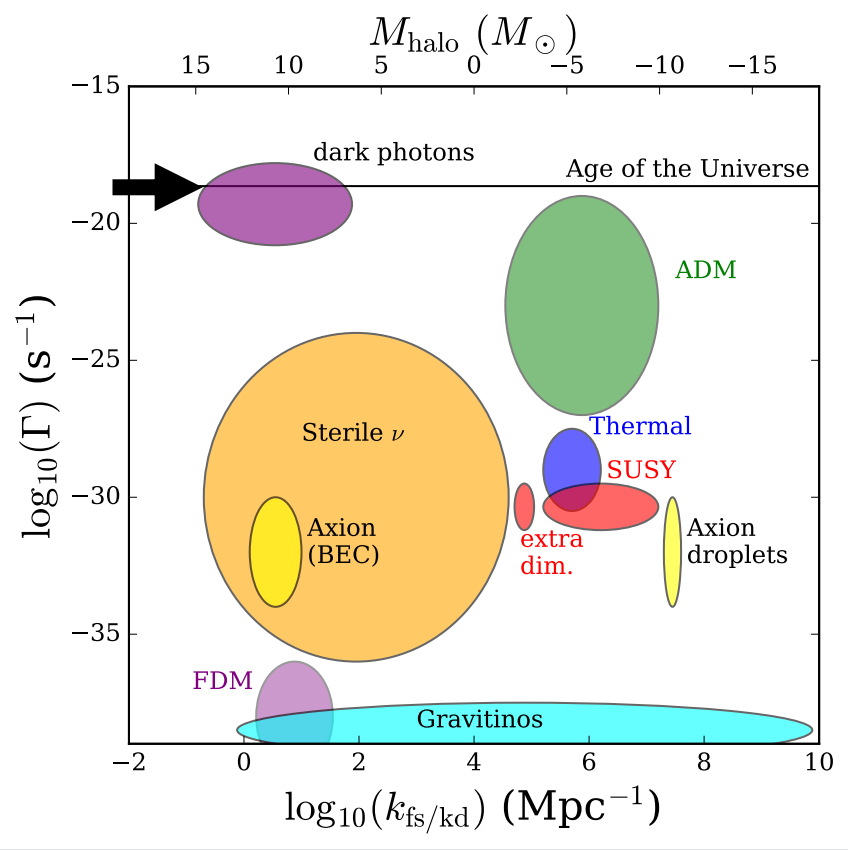


- Lyman-α constraints on non-cold dark matter models (Murgia+ 2017 & 2018)

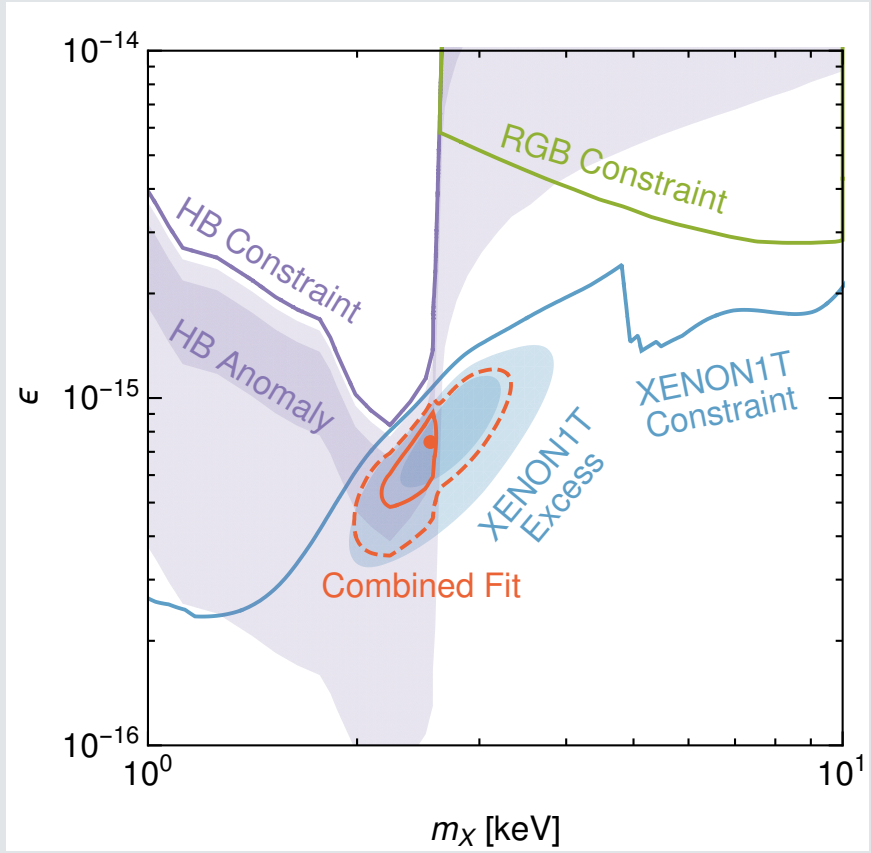


Input from the Particle Physics community: model selection

Buckley & Peter 2018



Alonso-Alvarez+ 2020



Constraints on dark photon, mass and mixing parameter.

- CosmoBit, GAMBIT Cosmology Working Group (Renk+ 2021)

Conclusions

- Future large scale surveys will probe the expansion history of the Universe and the structure formation with the best precision ever
- Future measurements are prone to several systematic effects and theoretical uncertainties
- Methodological challenge: improve the efficiency of the non-linear predictions (e.g. building emulators for several cosmologies)
- Theoretical challenge: model selection, efficient parametrization