The Euclid Mission

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The Euclid Mission Team Overview

14 countries + NASA, > 1400 members

- Lead: Chair (Y. Mellier - IAP France) + EC Board
- France, Italy & UK are the major contributors

Euclid Consortium

Italy in Euclid

"Euclid-Italy" Team

- **~160 members**
- Financial support from **ASI**, partly from **MIUR** (PRIN), **INFN**

- **Universities** : Bo, Mi, Na, Pd, RM1, RM2, RM3, TS, SISSA, SNS
- **INAF** : OABo, OABrera, OACt, OAA, OANa, OAPd, OARM, OATo, OATs, IASFBO, IASFMII, IAPS

- **INFN 2018 : Bologna, Lecce, Milano, Padova, Roma1**

The Cosmological "Standard Model"

Assume isotropy and homogeneity of the space components of the energy-momentum tensor in **Einstein's field equations**

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Friedmann–Lemaître–Robertson–Walker (FLRW) **metric** assume isotropy and homogeneity of the space components

Scale Factor

$$ds^2 = dt^2 - a^2(t)\left[dr^2 + S_k^2(r)(d\theta^2 + \sin^2\theta d\phi^2)\right]$$

$$S_k(r) = \begin{cases} \sin(r\sqrt{k})/\sqrt{k} & k > 0 \\ r & k = 0 \\ \sinh(r\sqrt{|k|})/\sqrt{|k|} & k < 0 \end{cases}$$

Curvature

Friedmnann equations are the solution of the Einstein's field equations given the FLRW metric and isotropy and homogeneity assumptions

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\sum_i (\rho_i + 3p_i) = -\frac{4\pi G}{3}\sum_i \rho_i (1 + 3w_i)$$

If $w_{DE} < -1/3$ acceleration is possible

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\sum_i \rho_i - \frac{k}{a^2}$$

$$\frac{H^2}{H_0^2} = \frac{\Omega_k}{a^2} + \frac{\Omega_M}{a^3} + \frac{\Omega_r}{a^4} + \Omega_{DE}\, e^{-3\int_1^a d\ln a[1+w_{DE}(a)]}$$

$H = \frac{\dot{a}}{a}$ Hubble parameter H_0 = today value

Equation of state

$p_i = w_i \rho_i$

$w_M = 0$ Cold matter

$w_r = \frac{1}{3}$ Radiation

Critical density

$$\rho_c = \frac{3H_0^2}{8\pi G}$$

Density parameters

$$\Omega_i = \frac{\rho_i}{\rho_c}$$

(The evolution of) **Perturbations** of the Einstein's equations are responsible of the structures we see today

Constraining the perturbed Einstein equations

Importance of probing effects of both potentials ψ and φ

- Small scalar perturbations:

$$ds^2 = -(1+2\psi)\,dt^2 + (1-2\phi)\,a(t)d\vec{x}^2$$

- Non relativistic particules are sensitive to: ψ
- Relativistic particules are sensitive to: $\psi + \phi$

- Standard GR + no anisotrotic stress: $\psi = \phi$

→ Poisson equation $k^2\phi = -4\pi G a^2 \sum \rho_i \Delta_i$

- Modified Gravity or Dynamical DE: $\psi = R\phi$

→ Poisson equation: $k^2\phi = -4\pi G Q a^2 \sum \rho_i \Delta_i$

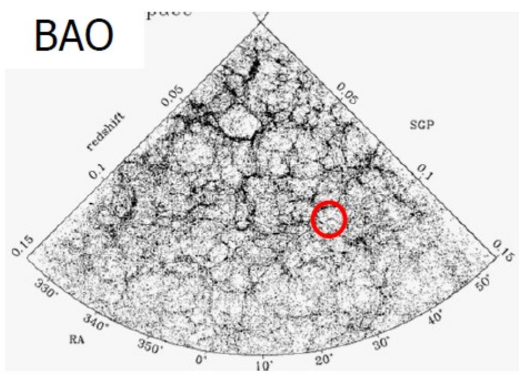
$Q(k,a)$, $R(k,a)$: imprints on clustering of DM, Gal and DE

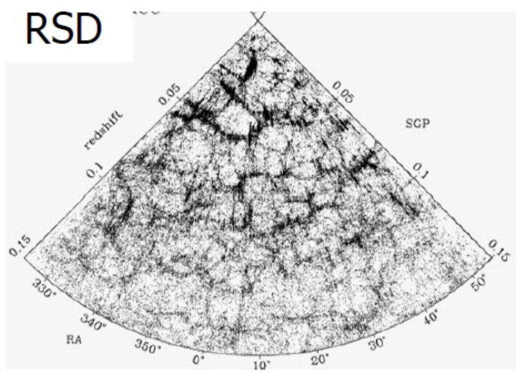
Yannick Mellier - Institut d'Astrophysique de Paris and CEA/IRFU Service d'Astrophysique Saclay

Homogenous and isotropic enough!

BAO, RSD and WL over 15,000 deg^2

50 million galaxies with redshifts

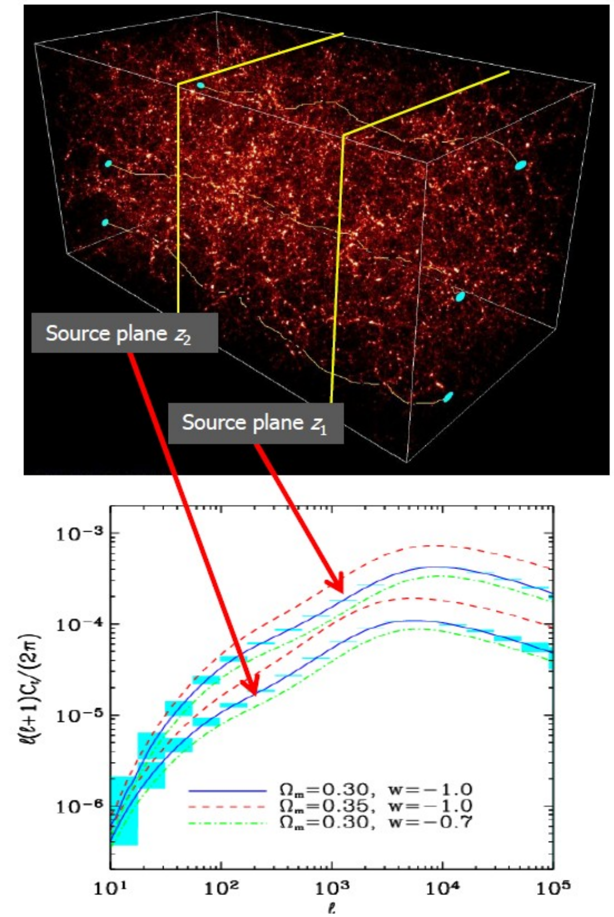




Galaxy Clustering

Euclid **NISP** Instrument

1.5 billion sources with shapes, 10 slices



Weak Lensing

Euclid **VIS** Instrument

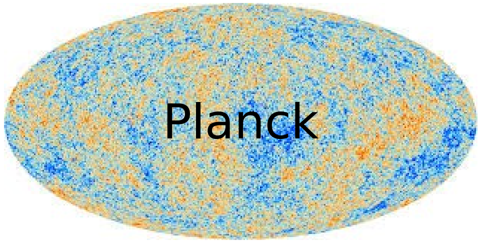
The cosmological inverse problem

We want to constraint ψ and φ

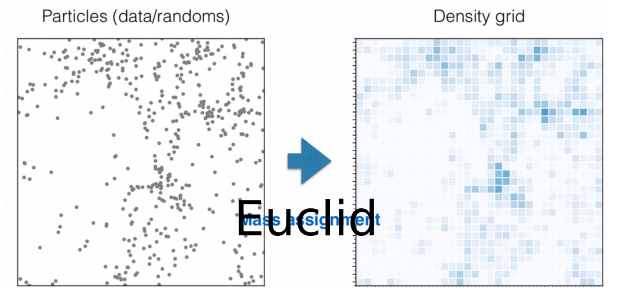
We use the Einstain's field equations
to relate ψ and φ with densities ρ

We need to study ρ, but we have no
control on the "sampling" of this fields

Temperature and polarization
of the CMB photons



Cross-Correlated



Galaxies as tracers of the
underlying densities

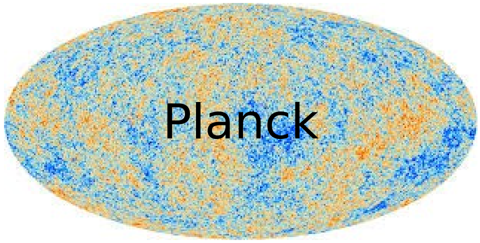
The cosmological inverse problem

We want to constraint ψ and φ

We use the Einstein's field equations

Many other different signals are used to constraint the Universe equations, CMB [with Planck] and Galaxies [with Euclid] are the most powerful tools to contraint with very high accuracy and precision multiple signals within the same experiment

Temperature and polarization of the CMB photons



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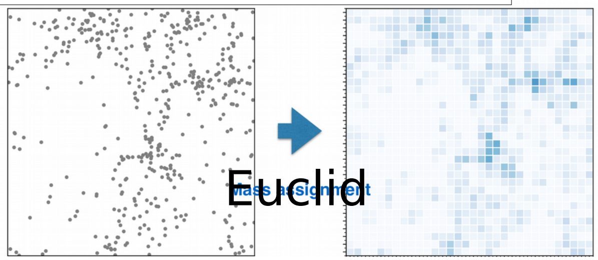
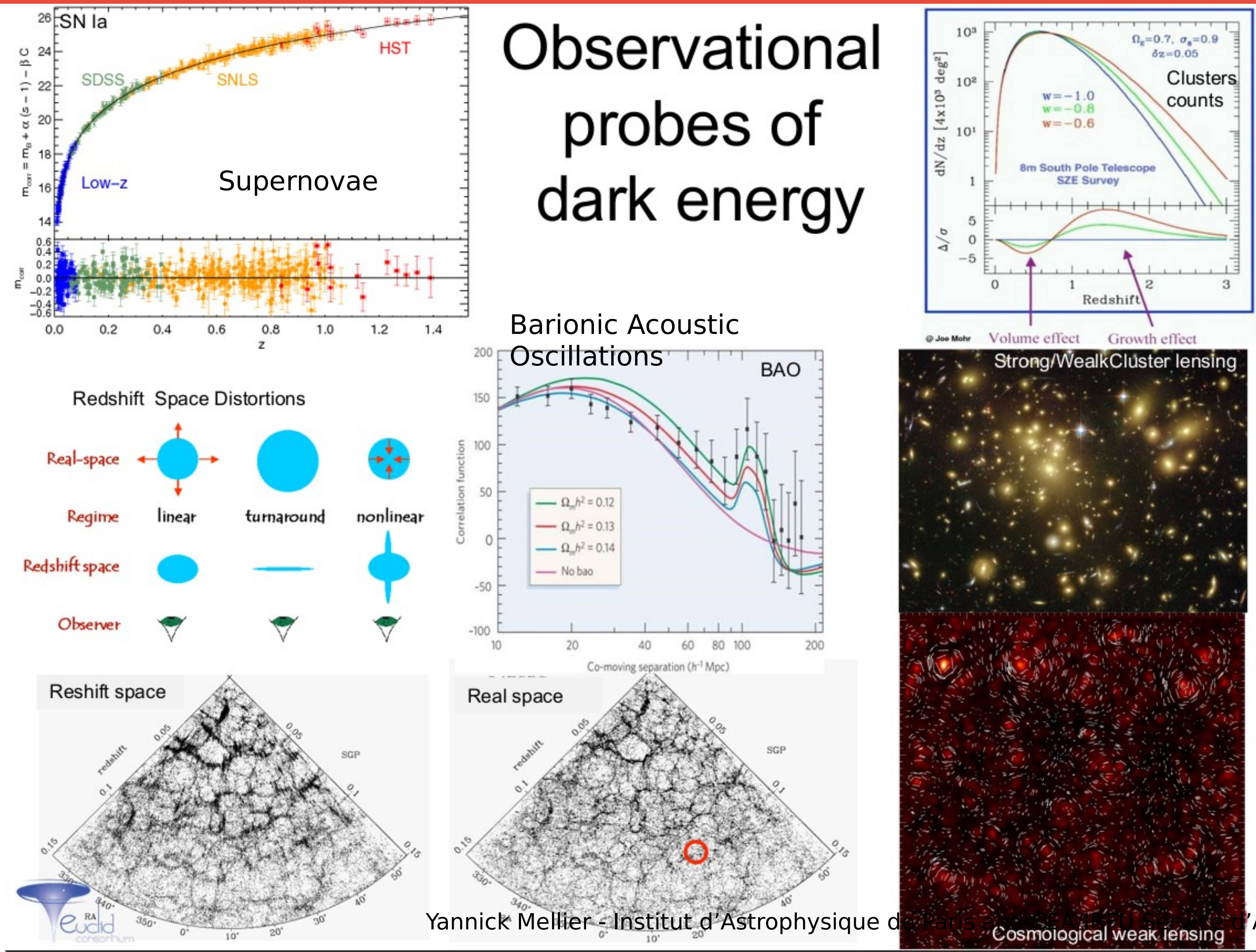


Galaxies as tracers of the underlying densities

INFN target: Dark Energy



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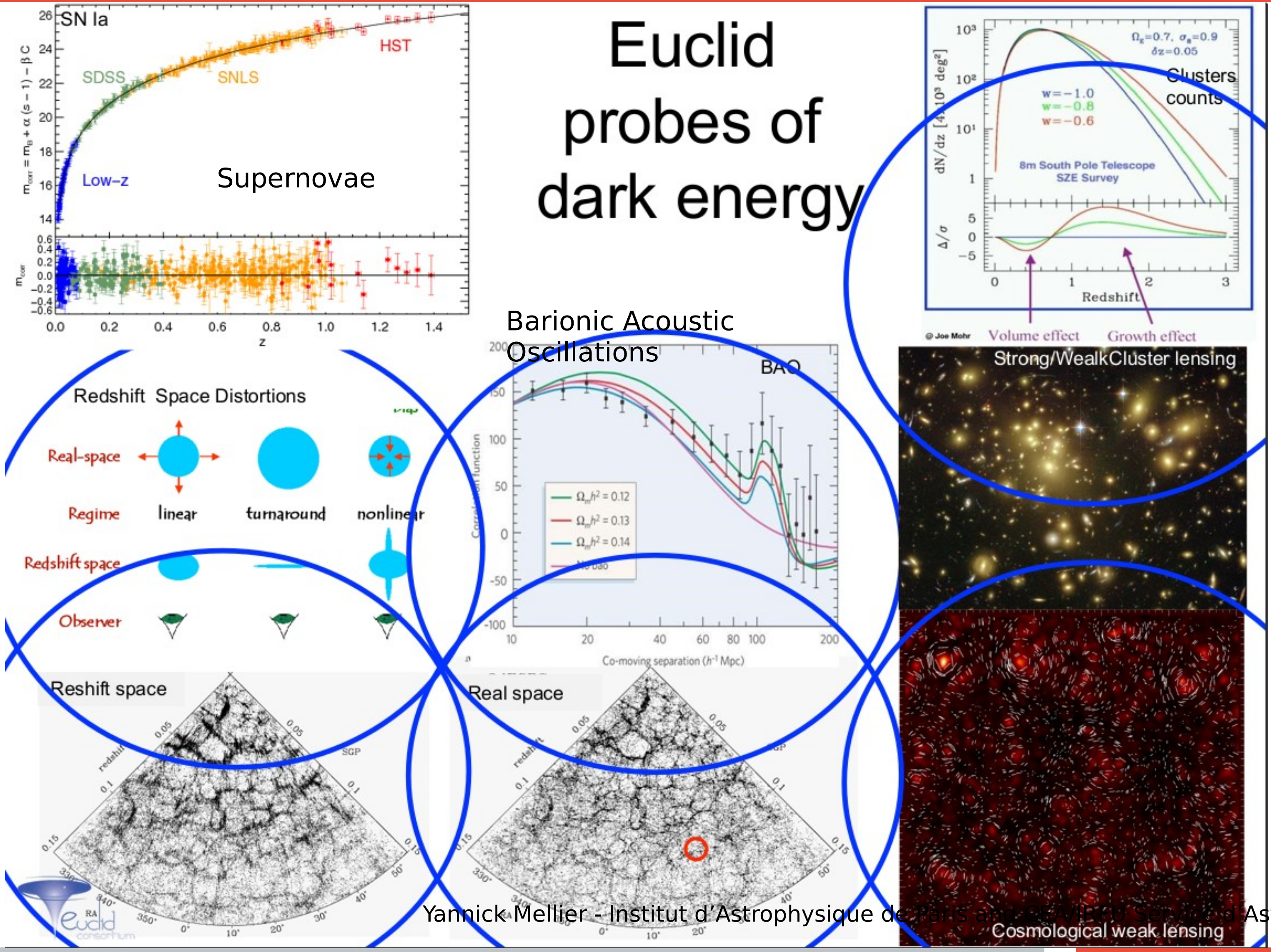

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INFN target: Dark Matter and Neutrino

- **If Σ >0.1 eV**

→ Euclid spectroscopic survey will be able to determine the neutrino mass scale independently of the model cosmology assumed.

- **If Σ <0.1 eV**

→ the sum of neutrino masses, and in particular the minimum neutrino mass required by neutrino oscillations, can be measured in the context of the Λ-CDM

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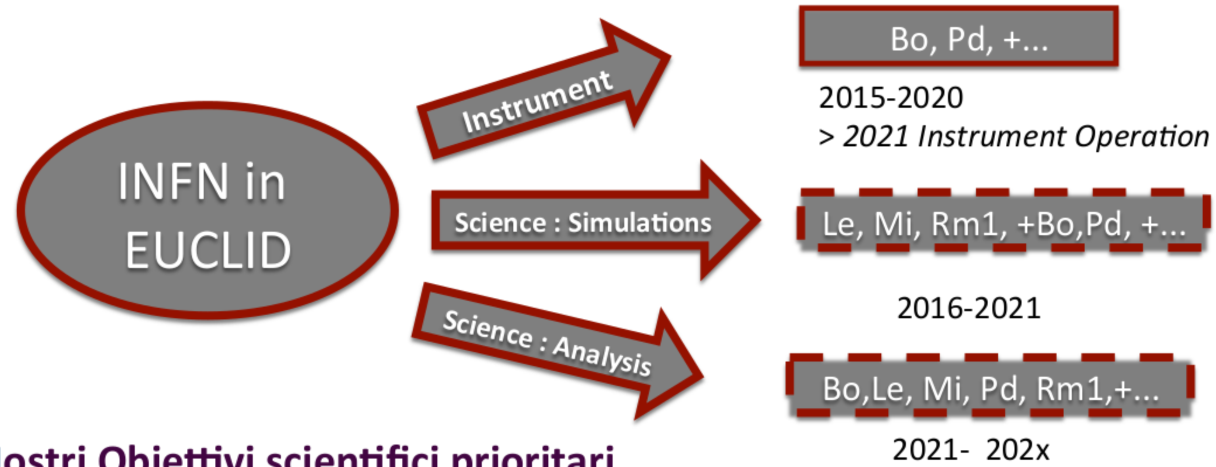
- Possible existence of sterile neutrino, Warm Dark Matter or exotic Dark Matter

INFN Involvement in Euclid



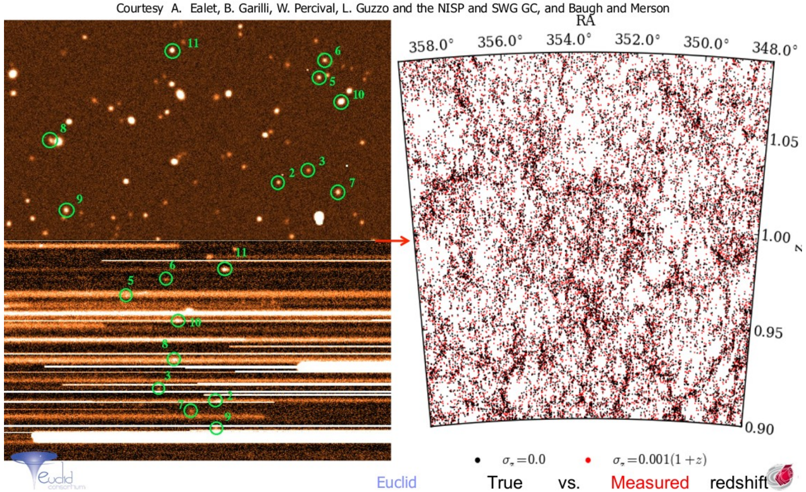
Nostri Obiettivi scientifici prioritari

- studio equazione di stato Dark Energy
- determinazione $\Sigma\, m_\nu$

Instrument: **NISP** (Near Infrared Spectrometer and Photometer)

From Euclid NISP spectral images to redshifts

Courtesy A. Ealet, B. Garilli, W. Percival, L. Guzzo and the NISP and SWG GC, and Baugh and Merson



Integrated HPC needs

	Planck (see 1603.09303)	CMB-S4 (see 1603.09303)	Euclid (see 1701.08158)
Core-Hours	~ 10-100M/year	~ 1-10G/year	~ 100M-1G/year
Storage Disk Required (Products)	~ 1PB	~ 10-100 PB	< 100 PB
Products	# MC Maps ~ 10^6 ~ 400MB/Map	#MC Maps ~ 10^8 (considering ~ 400MB/Map)	1.5G galaxies (estimated >33GB); 30M spectra (?dim)

Take-home messages

With respect to Planck satellite mission:

1 order of magnitude in CPU-hour needs
2 orders of magnitude in Disk Space needs

Scientific analysis of data will require many medium-size N-body simulations

A Euclid-like analysis example: neutrinos N-body with DEMNUni

See the paper: C. Carbone, M. Petkova, K. Dolag https://arxiv.org/abs/1605.02024

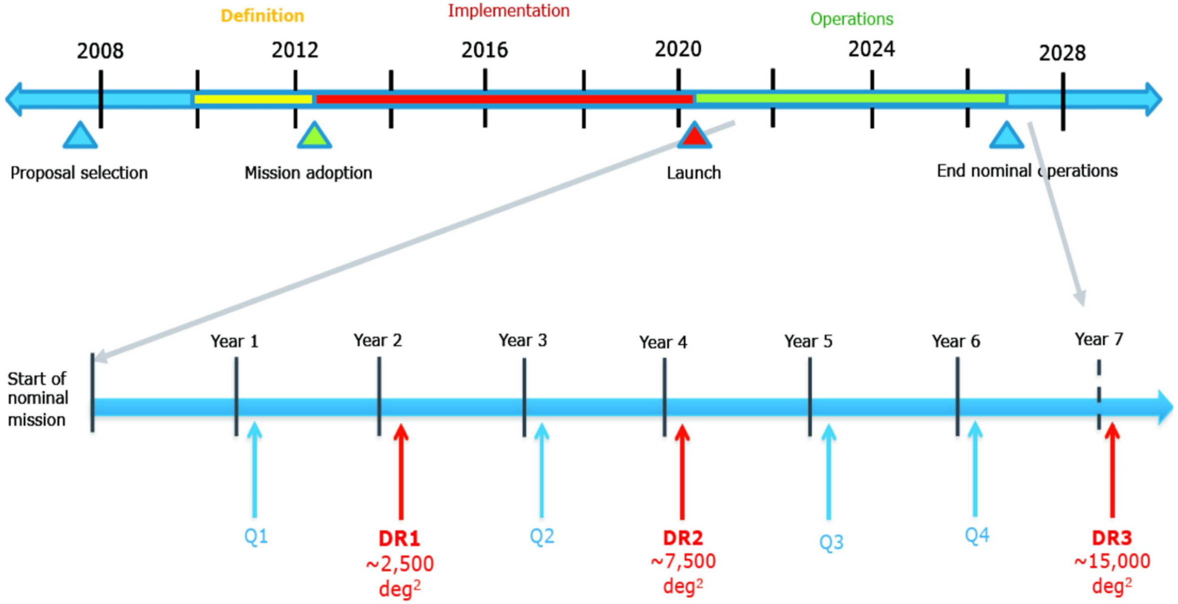
- Four different simulation with Σm_ν = (0, 0.17, 0.3, 0.53) eV
- Have been run on the Fermi supercomputer at CINECA employing ~ **1M CPU-hours per simulation**
- 62 “points” in time
- For every time point are saved snapshot of: CMD particles, neutrino particles, 3D grid of the gravitational potential, 3D grid of the derived gravitational potential [the 3D grid have dimensions: Lbox = $2h^{-1}$Gpc and a mesh of 4096^3 cells] with a total size of **~ 90 TB per simulation**

Total (only to produce the simulations):

- 4M CPU-hours
- 360 TB of space

NOTE: those are **Medium-size** simulations

Euclid timeline and HPC needs



→ Present requirement (for developing and [parzial] optimization of the data analysis codes):
Dedicated HPC/MPI with high-speed low-latency communication
1000 cores
8 GB RAM/core
~ 1 PB Storage

→ It is critical a reliable **long term large Disk Storage space**

→ High bandwidth connection with Euclid HPC facilites (only part of data are needed at a time)

→ The use of **large HPC facilities** (like CINECA) it will be soon a priority!

The End

Euclid Animal Shelter :D
https://euclidpetpals.net

Thank you for your attention