COSMOLOGIA
(follow-up di Astrofrontiere)

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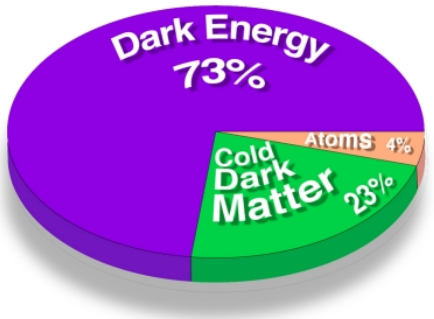
Cosa e' successo nel frattempo?

- Nuovo Presidente e nuova Presidenza
- Nuovo CdA
- Nuovo Direttore Scientifico e Direzione Scientifica
- Nuovo Consiglio Scientifico
- Nuovi Comitati di MA

High-level questions

- Nature of Dark Matter ?
- Nature of Dark Energy ?
- Behaviour of gravity at the largest scales ?
- Physics of the initial conditions (inflation) ?
- How constant are fundamental constants ?



<u>Implications for the physics beyond</u>

➔the Standard ΛCDM Cosmological Model

➔the Standard Model of fundamental interactions

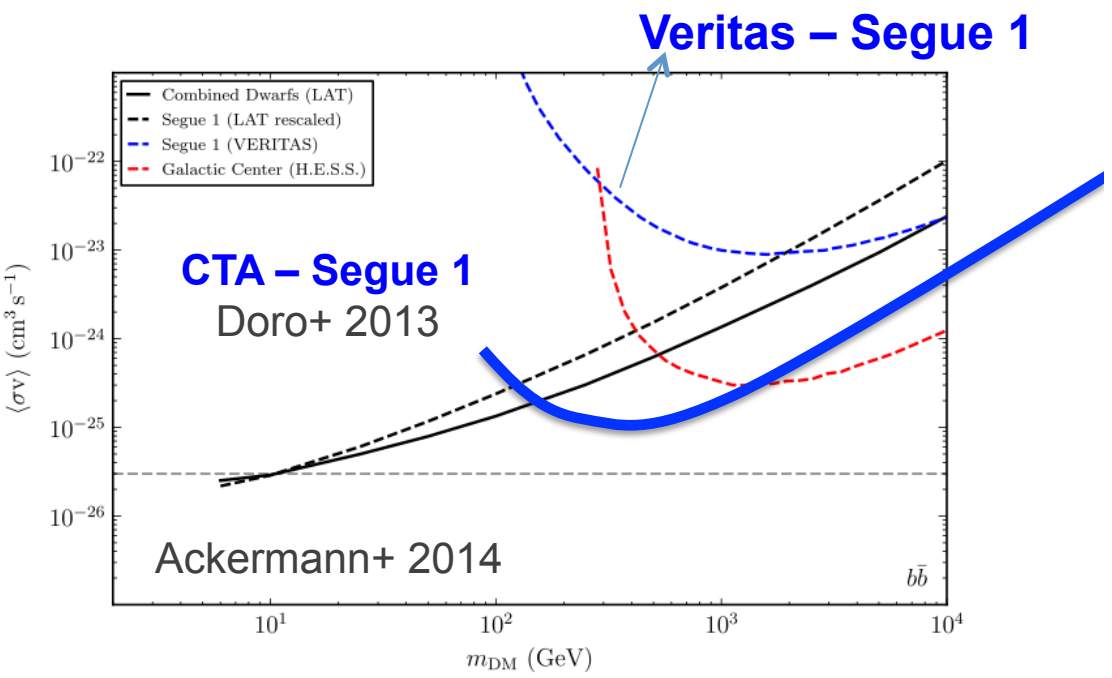
Lots of astrophysics to learn in the process!!

DM indirect detection in γ-rays

γ-ray range as the "golden channel" for ID

➔ Huge scientific success of Fermi, able to set DM strong constraints:

- **The energy spectrum of the diffuse gamma-ray background (see plot)**
- Gamma-ray flux from
  Milky Way satellites
  galaxy clusters
- Anisotropies in the diffuse gamma-ray background and extragalactic sources
- "Fermi excess" from the Galactic Center



➔ These constraints apply to DM candidates lighter than ~ 1TeV.

➔ CTA to push this limit to higher masses

Is this MA-1 science? Do we care if it isn't?

➔ Stop thinking in terms of wavelength, please!!!!!

DM nature & cosmic structure formation

➔ See sessions on surveys & clusters

Breakthrough: unveiling DM nature (pressureless? condensate? self-interacting? etc.)

➔ candidates: SUSY/WIMPS, axions or axion-like, gravitinos, sterile neutrinos, etc.

Signatures:

➔ free streaming scale

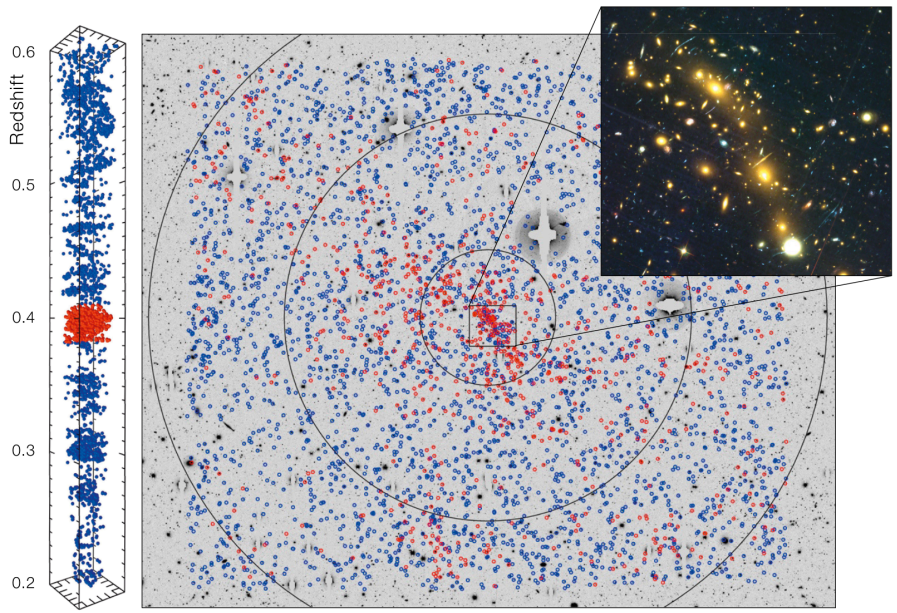
➔ effect on expansion history

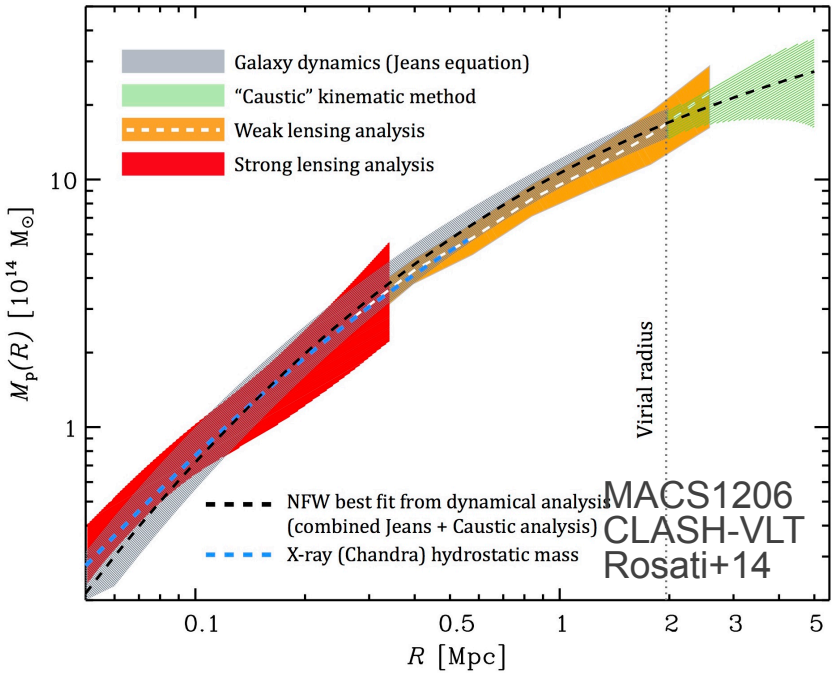
How to probe DM nature?

➔ Small-scale (<1 Mpc) observables:

- Dynamics of local galaxies (e.g. **GAIA**) and clusters (e.g. **CLASH,** MOONS)
- Strong lensing in clusters and galaxies: **CLASH**, JWST, **Euclid**, LSST, WFIRST

➔ Medium scales (10-100 Mpc): galaxy clustering, weak lensing and IGM (**Euclid**, DESI, LSST, **SKA,** WFIRST)



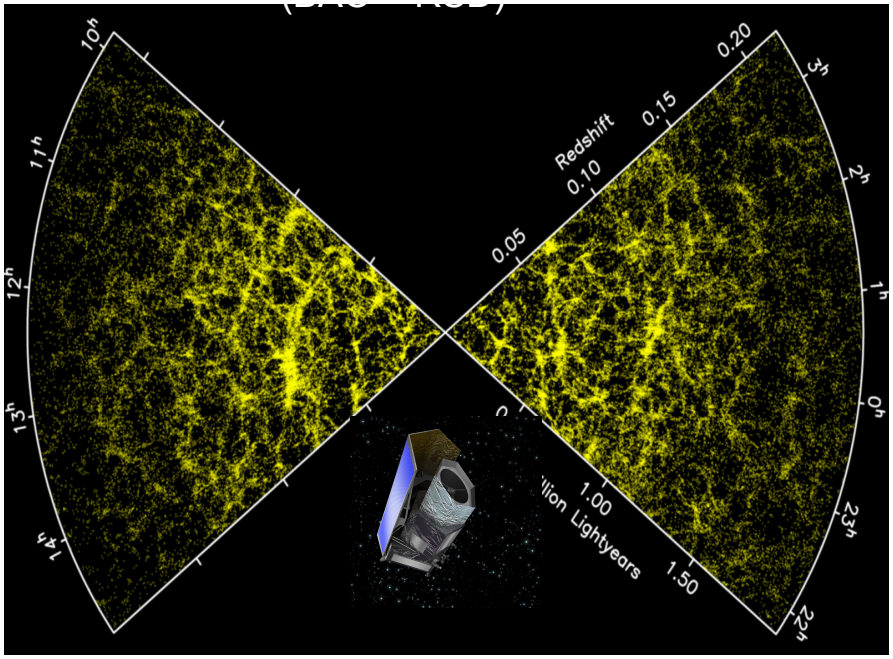


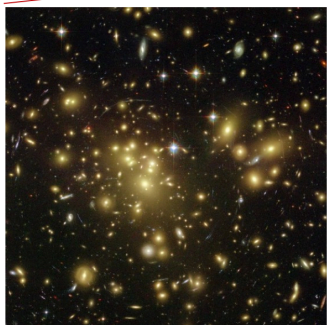
Large-scale multi-band imaging surveys

- **CFHTLS** (F): completed, 140 deg^2 in 5 bands, (e.g. CFHT-Lens project and weak-lensing shear results – basis for VIPERS)
- **Dark Energy Survey** (DES: US/UK/E + Munich LMU, ETH Zurich): started, 5000 deg^2 in 5 bands
- **VST-KIDS + VISTA-VIKING** (NL, I, D, …): started, 1500 deg^2 in 9 bands (from U to K)
- [**Pan-STARRS**? (US, UK, D, …)]: started, but unclear future developments
- **SUMIRE-PFS** (Japan + others): Subaru 8m prime focus, both imaging and spectroscopy, being defined
- **LSST** (US-led consortium): dedicated 8m telescope, 20000 deg^2 (southern sky), in 6 bands (0.3-1.1 m), with time information

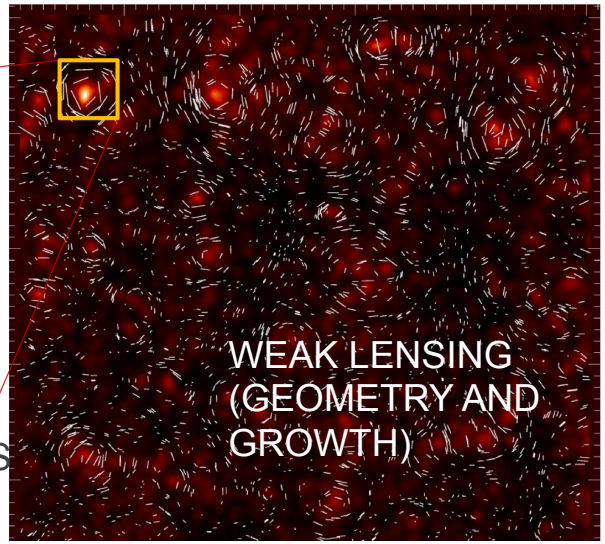
Euclid – THE cosmology experiment

➔ See sessions on surveys & clusters





GALAXY CLUSTERS (GEOMETRY AND GROWTH)



- Visible imaging (1 band)
- Infrared imaging (Y,J,H)
- Infrared slitless spectroscopy
- Launch 2020

- 15,000 deg^2 survey
- Images for 2x10^9 galaxies
- Spectra for ~5 x 10^7 galaxies (0.9<z<1.8)

Objectives:

- Build a map of dark and luminous matter over 1/3 of the sky and to z~2
- Unveil the nature of dark matter
- Trace the origin of cosmic acceleration
- Use multiple probes → max control over systematic errors

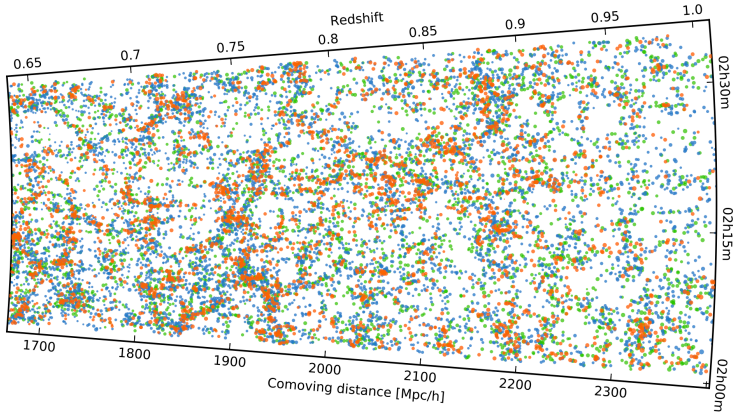
Combining imaging & spectroscopy

$$ds^2 = -a^2(\tau)\left[(1+2\Psi)\,d\tau^2 - (1-2\Phi)\,d\vec{x}^2\right]$$

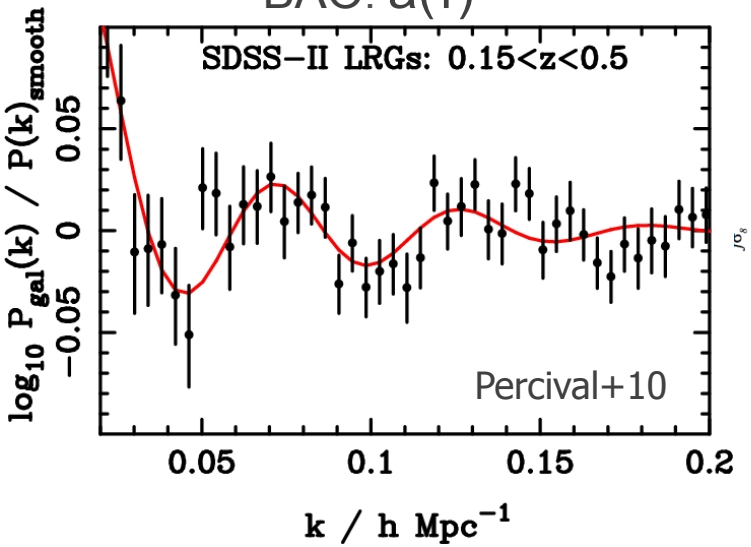
Ψ : governs motion of matter

Φ : governs motion of light

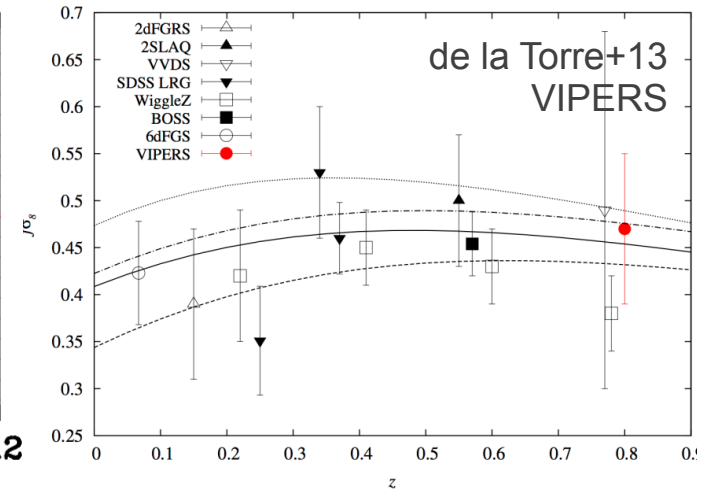
$\Phi = \Psi$ for GR



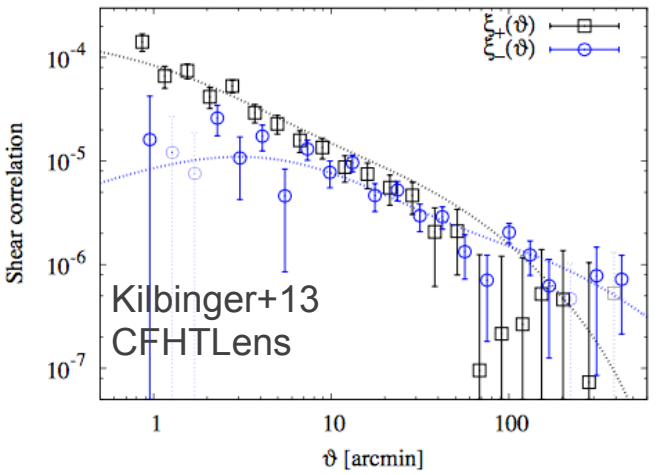
BAO: a(τ)



RSD: Ψ



Cosmic shear: $\Phi + \Psi$



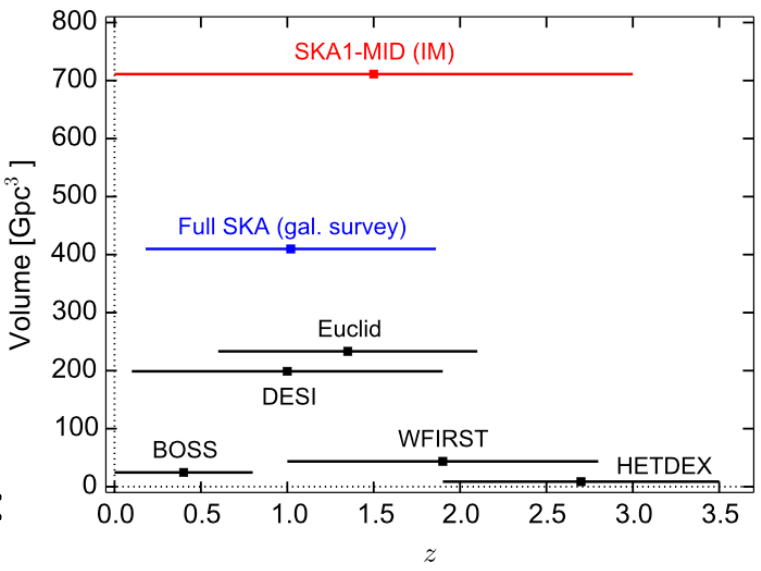
SKA – Surveys for Cosmology

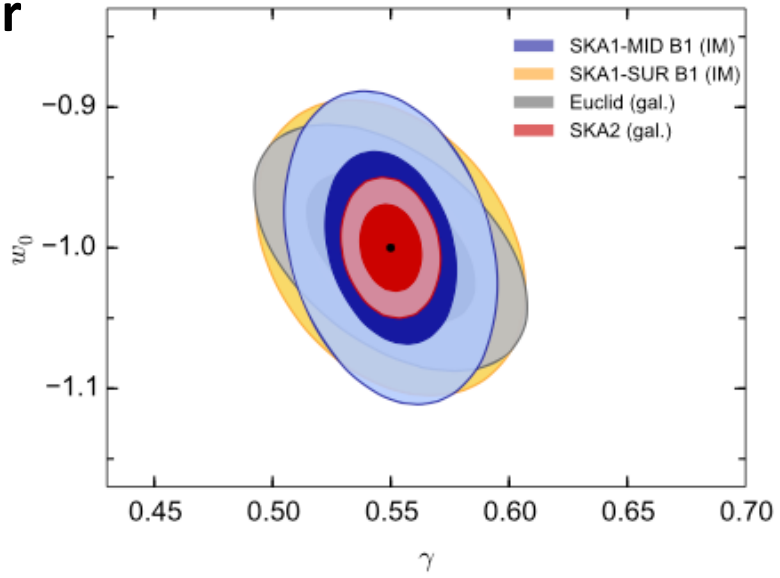
1. **HI Intensity Mapping** [BAO, super-horizon, etc.]
   All-sky (3π sr)**; low-resolution >30'**; 0<z<3

2. **HI Threshold:** galaxy redshift survey [BAO, RSD]
   SKA1: 5 10^6 gals @ z<0.5
   SKA2: ~10^9 gals @ z<2

3. **Continuum** [weak lensing, angular clustering, ISW]:
   - ➔ <u>All-Sky Survey</u> (~ 1-2" res.)
   - ➔ <u>Weak Lensing Survey</u> (0.5" res.):

   NB: Commensality with HI/Continuum surveys for galaxy evolution





<u>Euclid + SKA: huge synergies</u>
➔ Scientific: smaller volume higher res. vs large volume low-res, complementary constraints, lensing, multi-tracers, etc.
➔ Programmatics: e.g. simulations, likelihood definitions and coding, etc.

The lesson of the CMB

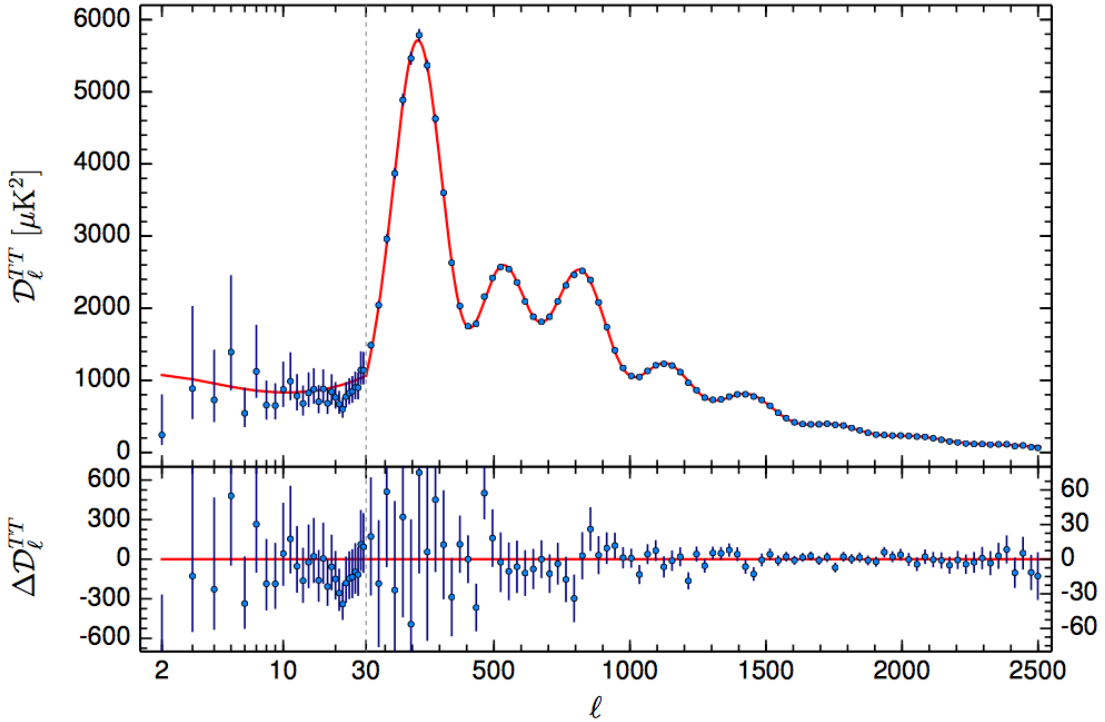
➔ See session on the CMB

Difficult measurement, BUT: ➔ Everything is linear: $\Delta T/T \sim 10^{-5}$

➔ Physics is well understood

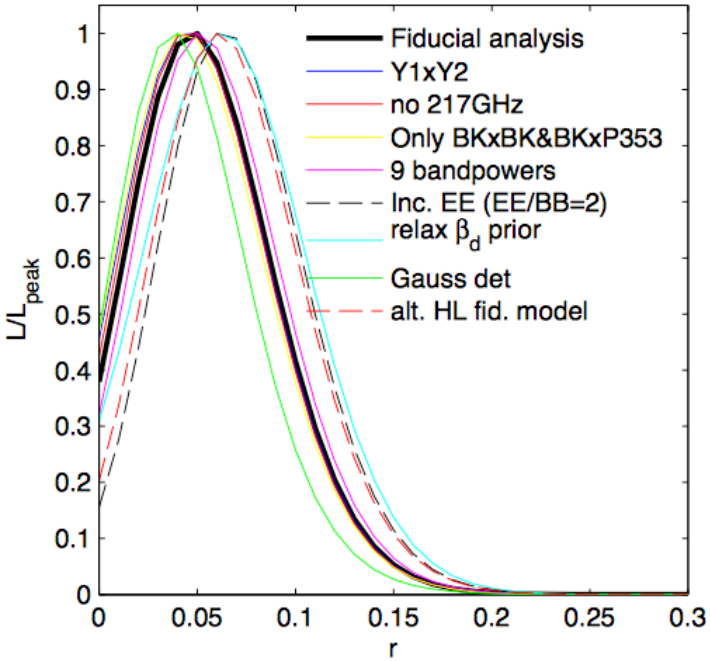
➔ Undergoing transition from precise T measurements to precise polarization measurements (and spectral distortions)

Planck 2015 – XIII: TT spectrum compared to base ΛCDM



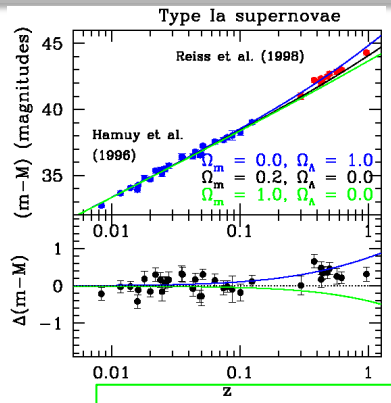
Multipole order

BICEP2/Keck+Planck joint analysis of B-mode polar.



Tensor-to-scalar ratio

SN-Ia + CMB + surveys: a single experiment



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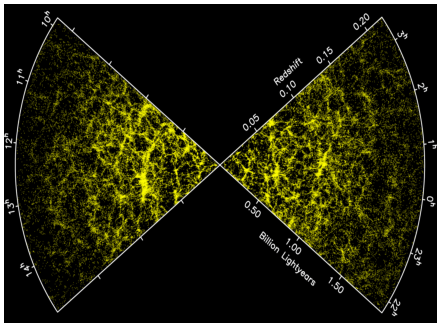

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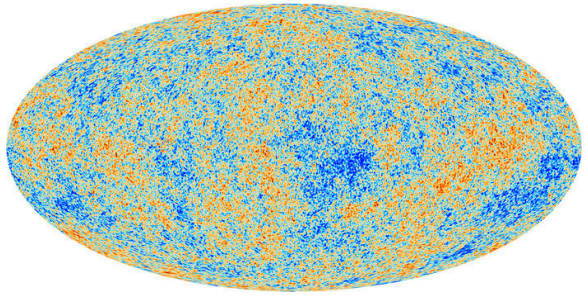
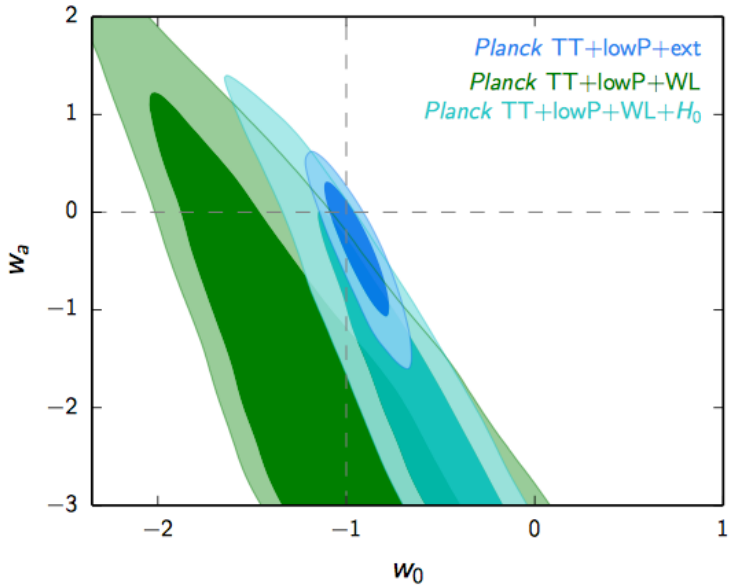
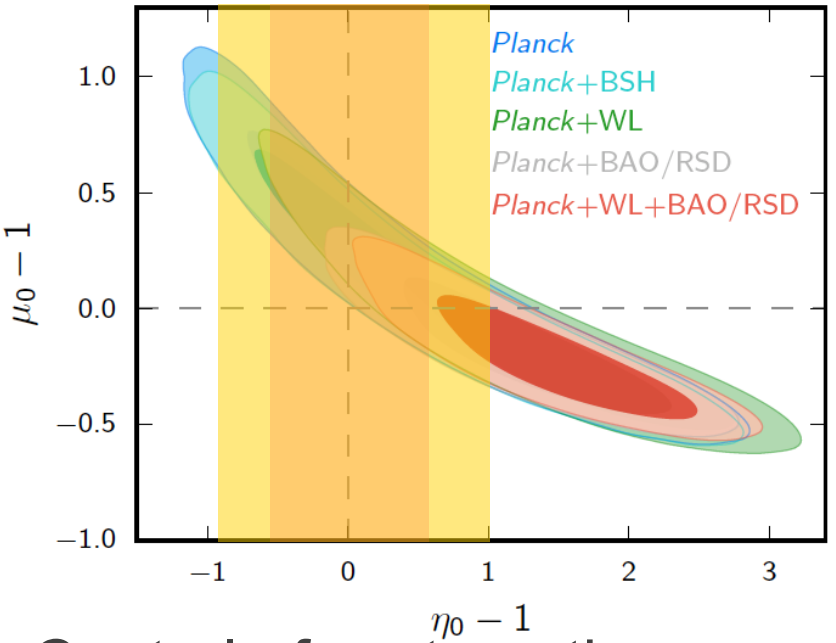


The combination is much more than the sum of the parts

Planck 2015 - XIII



Planck 2015 – XIV + CLASH



Signatures of new physics ➔ Control of systematics

Holistic approach ➔ Unique skills in the INAF community

A schematic summary

	Euclid (LSST)	SKA	E-ELT	CTA	Athena
Nature of Dark Matter					
Nature of Dark Energy					
Gravity on large scales					
Physics of initial conditions					
Fundam. constants					

Highly relevant

Possibly interesting

Not relevant

Alcuni spunti di discussione

CTA & DM: toward a collaborative effort

➔ INAF is playing a key role in CTA from the technological side.

- Expertise on DM ID well rooted in the Italian community at large
- LNGS, AMS, Pamela and Fermi have prompted a strong interest in and originated a widespread know how
- Mostly located within INFN and Universities
- Background mostly on particle physics but with strong cosmological / astrophysical expertise acquired over the years

NOTE: INAF has the expertise for all the phenomenology/model/ theory of structure formation !!

➔ How to grow the expertise in the INAF community?

➔ Compete/collaborate with INFN/University community?

➔ Attract them under the INAF umbrella instead? CTA INAF PRIN?

CMB: forthcoming activities

➔ CMB day @ ASI (30 March, 2016)

- Complete analysis of Planck data, exploiting synergies with other cosmology observables.
- Development of future experiments
  - Enabling technologies on pathfinder experiments (as EBEX, **LSPE**, **OLIMPO**,QUBIC)
  - Stage-IV
    - Array of ground based telescopes observing synergically with a total of 10^5 detectors across several atmospheric windows (< 200 GHz)
    - Exquisite sensitivity and fast mapping speed
  - Space (including balloons)
    - For large scale polarization. Proposals to be approved: PIXIE (NASA), liteBIRD (JAXA), **COrE (ESA M5)**

➔ Need to define an INAF policy for CMB

Euclid-IT

Euclid come missione strategica per INAF:

- Supporto da INAF a Euclid all'interno di una strategia di ritorno scientifico piu' generale:
  - **Salvaguardare il ritorno scientifico**
  - Partecipazione a LSST e WFIRST? A che livello?
  - Una roadmap per "survey science" che includa SKA e MOS di prossima generazione (MOONS)
- Ruolo guida di INAF per definire collaborazione con ASI, Universita' e INFN

Quale approccio al problema (se le risorse sono meno del previsto):

- Evitare la tentazione di "mantenere il proprio gruppetto"
- Monitoraggio stretto da parte di **ASI & INAF** alle attivita' supportate dai due Enti

➔ Audit delle attivita' da parte di **ASI & INAF** !

SKA-IT & Cosmology

Criticality:

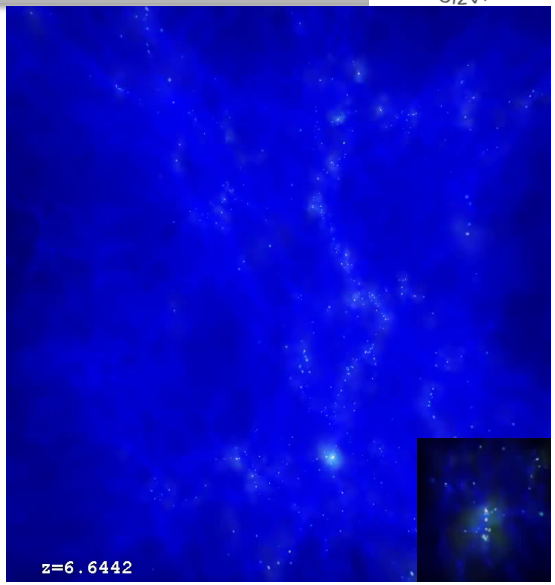
- Italian hard-core cosmologists traditionally far from radio-astronomy
- Italian hard-core radioastronomers traditionally far from cosmology
- How to get ready to make the best use of SKA?

Opportunity:

- Diffuse awareness that this gap needs to be cured
- Growing interest and interactions between these two communities
- Take advantage of the synergies with Euclid

➔ Promoting this synergy: SKA INAF PRIN?

Facilities are not only telescopes



A policy of INAF is needed (and long overdue !) for:

- High-performance computing (HPC)
- High-throughput computing (HTC)
- Ultra-wide band connectivity

Crucial for scientific exploitation
of cosmological surveys!!!!!

See also session on Galaxy Evolution

Toward defining a INAF policy on computing.....

➔ More at the Meeting in Montemario on 21-22 June, 2016

"What about computing @ INAF"

GRAZIE!