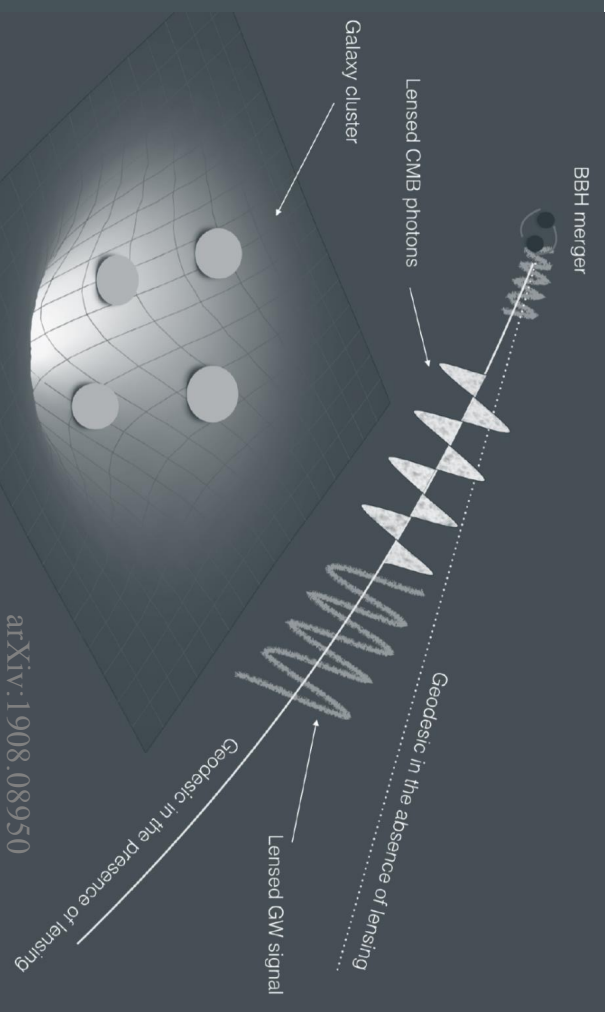


LSS-GW-CMB CROSS-CORRELATIONS

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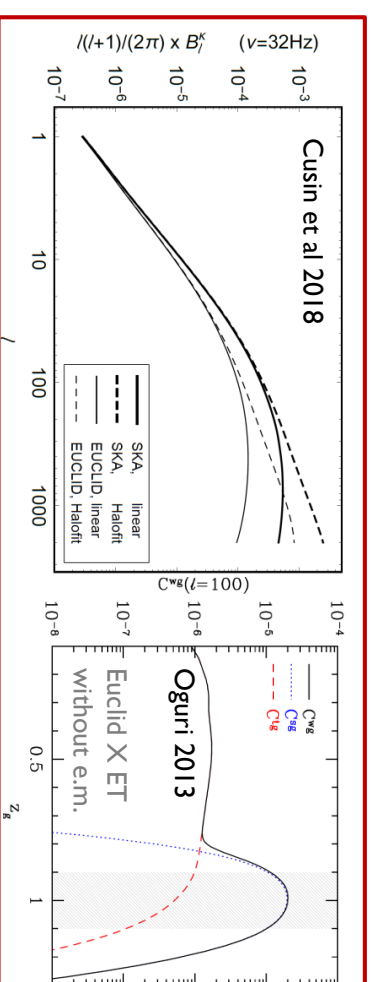
CROSS-CORRELATING GWs WITH LSS & CMB

Multimessenger cosmology probes the evolution and structure formation:

- ❑ LSS: galaxy-clustering (GC) and weak-lensing (WL) [eg, DESI(2019), Euclid(2022+), LSST(2022+), SKA(2027+)]
- ❑ GWs: single events from astrophysical sources, as well as astrophysical and cosmological SGWBs [eg, Ligo/Virgo/Kagra, INDIGO, LISA, BBO, DECIGO, Cosmic Explorer, ET...]

The GW-LSS cross correlation:

- ❑ provides new GR tests and cosmological probes:
 - XC between GW-magnification and WL (eg Congedo, Camera, Wandelt)
 - XC between GWs and GC (eg Oguri, Scelfo, Wandelt)
 - XC between SWGB and WL & GC (eg Cusin, Sakellariadu)
 - XC between SWGB and CMB (eg Wandelt, Tasinato)
- ❑ helps determining the **redshift of BBH mergers via statistical approaches** (eg, Menard, Oguri, DES/LIGO/Virgo collaboration)
- ❑ helps reducing errors on cosmological parameters (eg H_0) by **subtraction of peculiar velocities** of host galaxies (Palmese et al 2019)
- ❑ helps **GW delensing** and better estimation of the GW luminosity distance (and cosmological parameters)



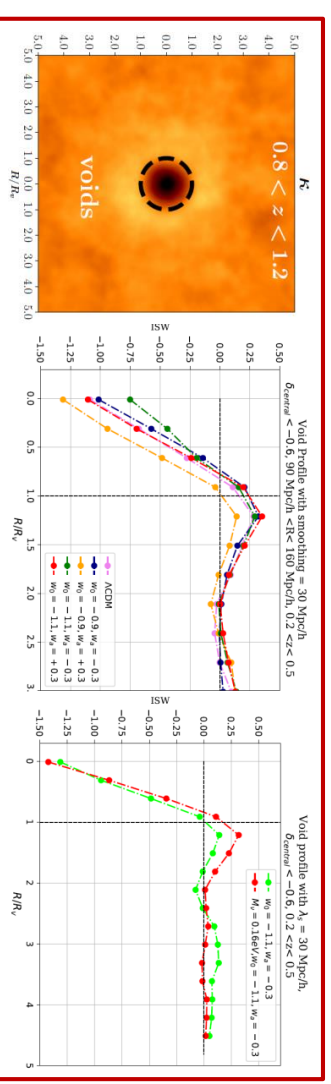
CROSS-CORRELATING CMB WITH LSS

Multiprobe cosmology (eg LSS X CMB) breaks degeneracies and increases performance

- ❑ LSS: galaxy-clustering (GC) and weak-lensing (WL) [eg, DESI, Euclid, LSST, SKA]
- ❑ CMB: secondary anisotropies in temperature and polarization [eg Planck, SO(2022+), LiteBIRD(2028+), CMB-S4(2028+)]

CMB-LSS cross correlation accounts for:

- a. Galaxy X CMBlensing → galaxy redshift distribution, galaxy bias, structure growth, neutrino mass, DE, halo profiles
- b. Shear X CMBlensing → cosmological distance ratios
- c. a+b → lensing ratios, systematics, low-z/high-z tension
- d. Galaxy-velocity X CMBlensing → deviations from GR
- e. **Void X ISW** → DE & neutrino mass
- f. **Void X CMBlensing** → neutrino mass
- g. Galaxy X ISW → fnl, DE, neutrino mass



STATE OF ART IN THE ITALIAN COSMOLOGICAL COMMUNITY

GWS-XC

- ❑ PD (Uni): SGWB, GC X GWs (LISA node, ET, SKA, Euclid)
- ❑ TS (SISSA) : SGWB, GC X GWs (LISA node, ET?, SKA, Euclid)
- ❑ TO (Uni): GW lensing (SKA, Euclid)
- ❑ MI (Uni) : tepidly involved in GW-cosmology (LISA node)
- ❑ MI (IASF): starting, especially on SGWB secondary anisotropies, polarization, and XC with LSS (LISA node, ET, Euclid, SKA)

**Submitted Euclid Key Project on LSSxGWs
(involved MI, TO, OARM, PD, AO)**

CMB-XC (Euclid-SWG lead)

- ❑ AO (INAF-agreement): CMB simulations
- ❑ TS (INAF+SISSA): CMB simulations (ASI-WP lead)
- ❑ PD (INFN+Uni): Theory & Estimators
- ❑ BO (INAF, INFN+Uni): Estimators, Nbody, CMB simulations & Theory (Euclid SWG-WP & ASI-WP lead);
- ❑ FE: (INFN+UNI) Estimators & Likelihood (Euclid SWG-WP & ASI-WP lead)
- ❑ RM (Uni RM-II): Estimators and CMB simulations
- ❑ MI (INAF+INFN+Uni): Nbody, CMB simulations & Likelihood (SWG-WP lead)

**Several submitted Euclid Key Projects on
LSSxCMB**

ACTIONS

GWS-XC: do not miss the boat in multimessenger cosmology

- ❑ Several LISA nodes: **coordination needed**
- ❑ **Exploit existing expertise in galaxy-clustering and weak-lensing**, on the observational (eg clustering redshifts, peculiar velocities, lensing), theoretical, data analysis and simulation levels
- ❑ Allocate dedicated funds for PhD and postdocs
- ❑ Focussed Italian meetings & workshops to motivate the cosmological community

CMB-XC: excellent expertise in place

- ❑ Planck heritage, **Euclid WP leads and KPs**
- ❑ Get stable link with CMB probes
- ❑ Consolidation and coordination
- ❑ Allocate dedicated funds for PhD, postdocs and facilities, particularly in the fields of:
 - **CMBLensing X LSS, estimator & likelihood**
 - Non-linear effects in CMB X LSS: **lensing reconstruction**, simulations, storage, computational time