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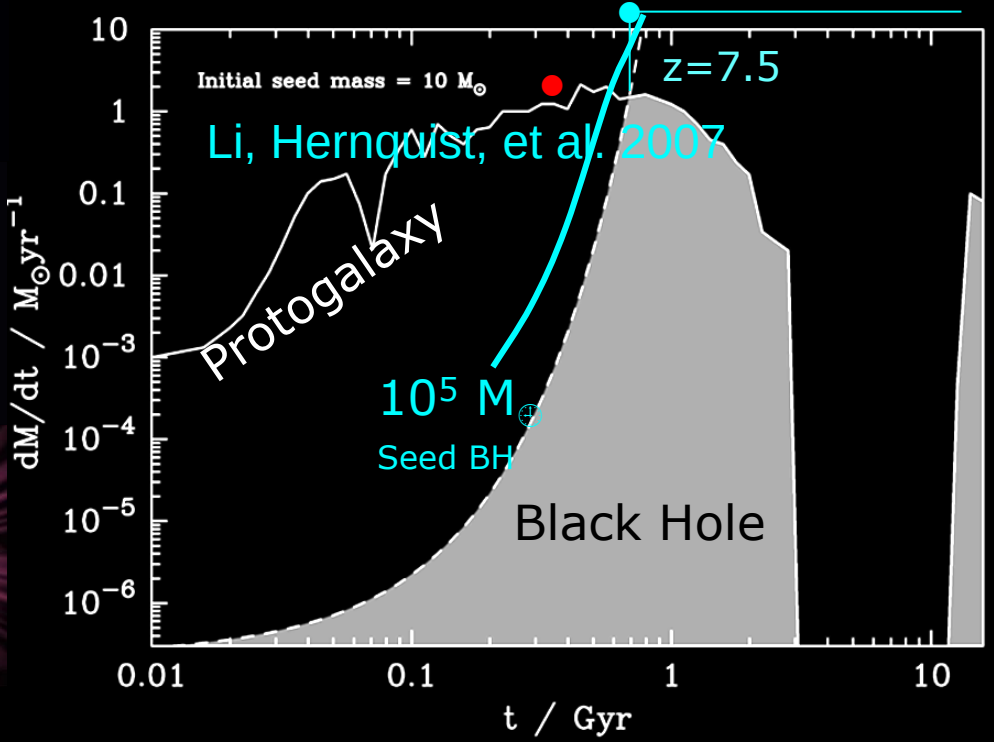
Is Dark Matter made of Primordial Black Holes?

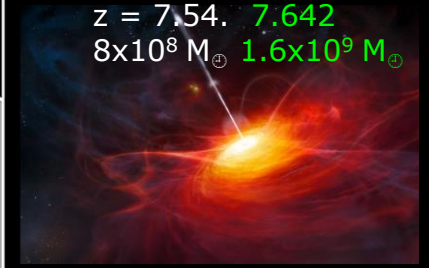
Günther Hasinger

NICOLAUS COPERNICUS WORLD CONGRESS

Torun, Poland, 21. February 2023

How to produce the first proto-quasars





ULAS J1342+0928
(Bañados et al. 2018)

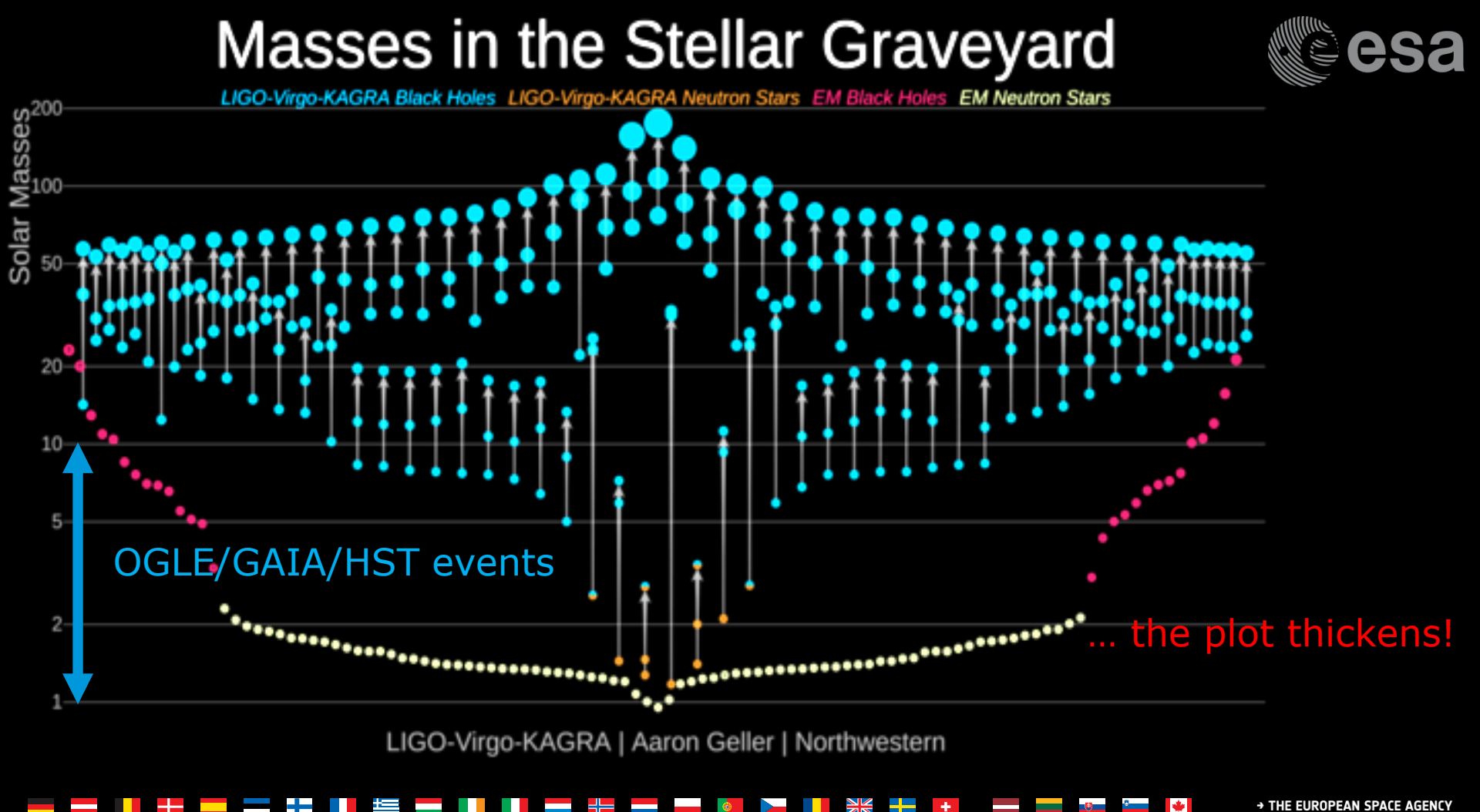
J0313-1806
(Wang et al. 2021)

See also Pacucci et al. 2022 for putative z~13 QSOs at 10^8 $M_\odot$

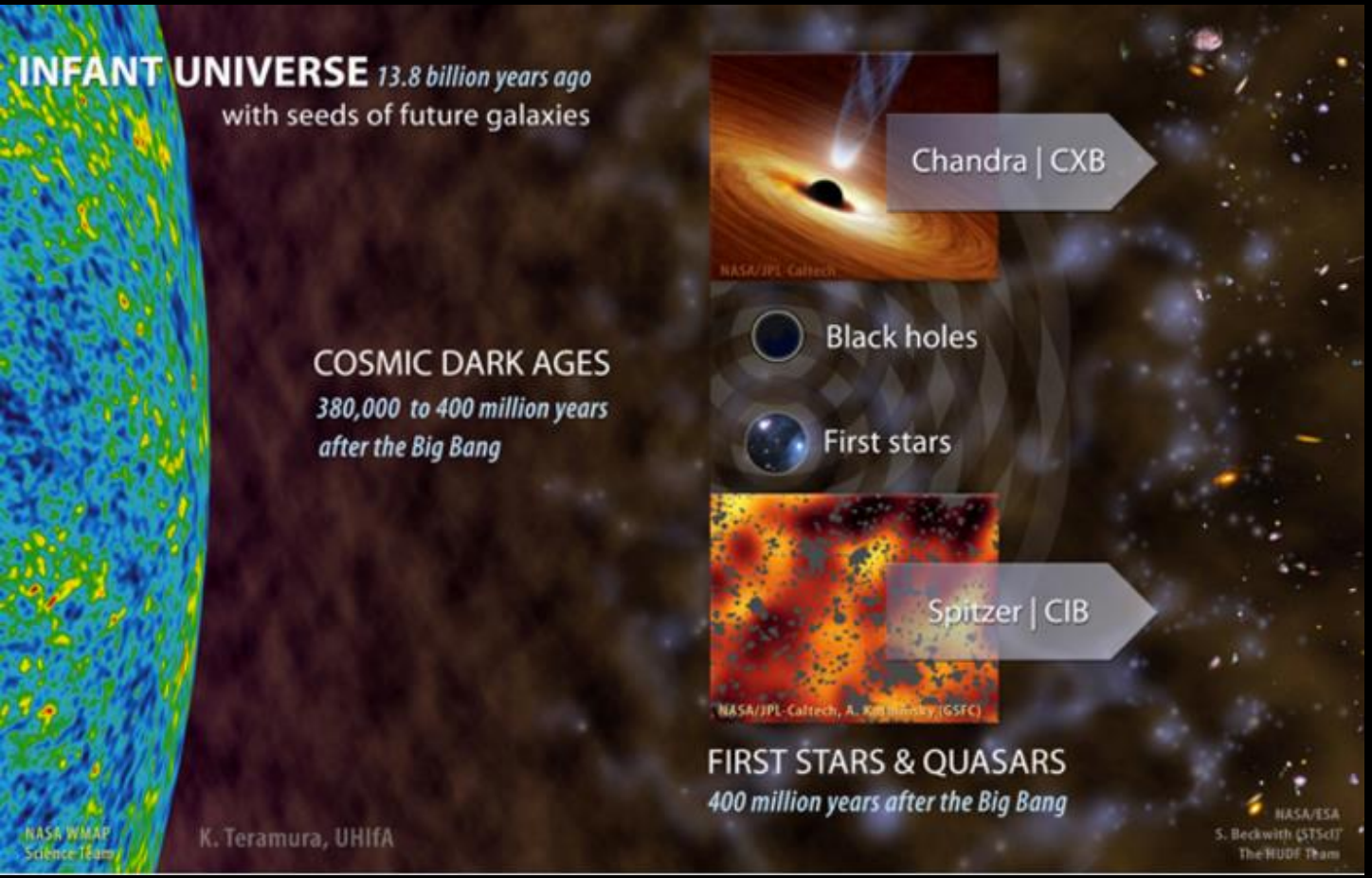
Archibald et al., 2001

Need massive ($10^{5\text{-}7}$ $M_\odot$) seed Black Holes early in the Universe !

Masses in the Stellar Graveyard



CIB x CXB fluctuations indicate high-z BH population



Significant cosmic background fluctuations have been found both in the NIR and in X-rays.

The strong CIB/CXB cross-correlation signal indicates a substantial contribution of Black Holes to the signal.

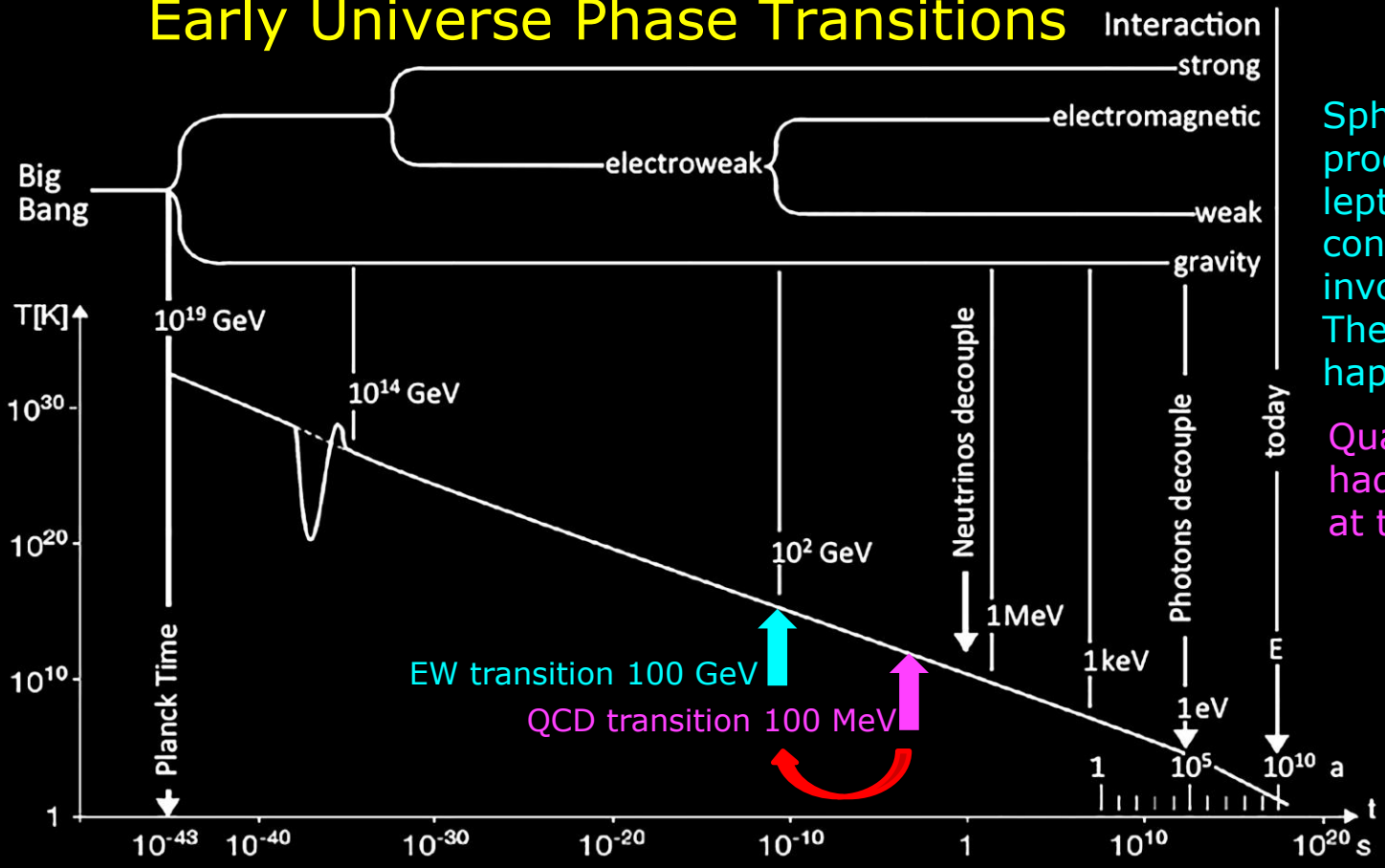
There is no correlation with fluctuations in the deepest HST images, therefore the signal likely comes from redshifts z>13.

Large angular scale also points to high-z origin.

Could these be primordial?

Cappelluti et al., 2013

Early Universe Phase Transitions

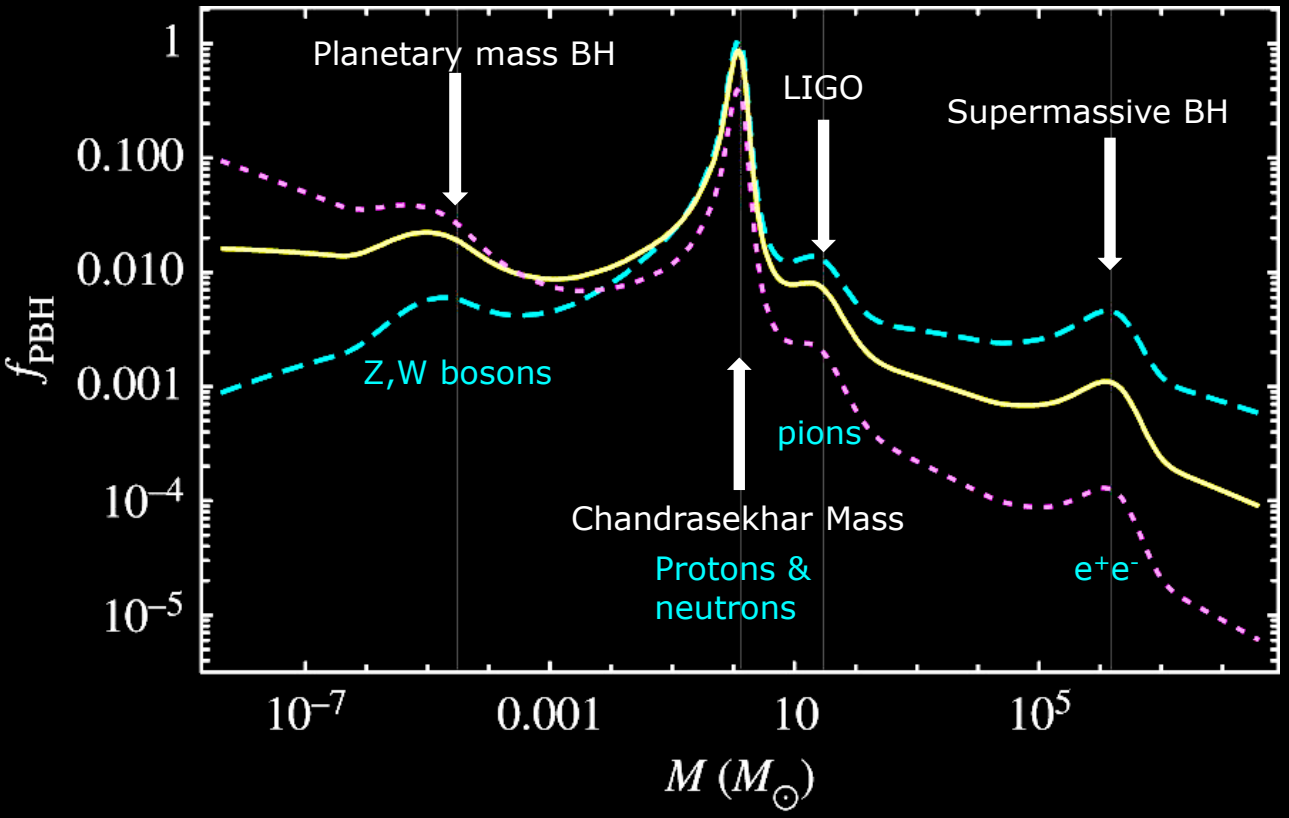


Sphaleron transitions are processes violating the lepton and baryon number conservation and are invoked for baryogenesis. They are expected to happen at the EW scale.

Quarks freeze out to form hadrons (baryons, pions) at the QCD transition.

PBH collapse locally re-heats hot spots to the EW scale & create baryon asymmetry

PBH Mass Spectrum



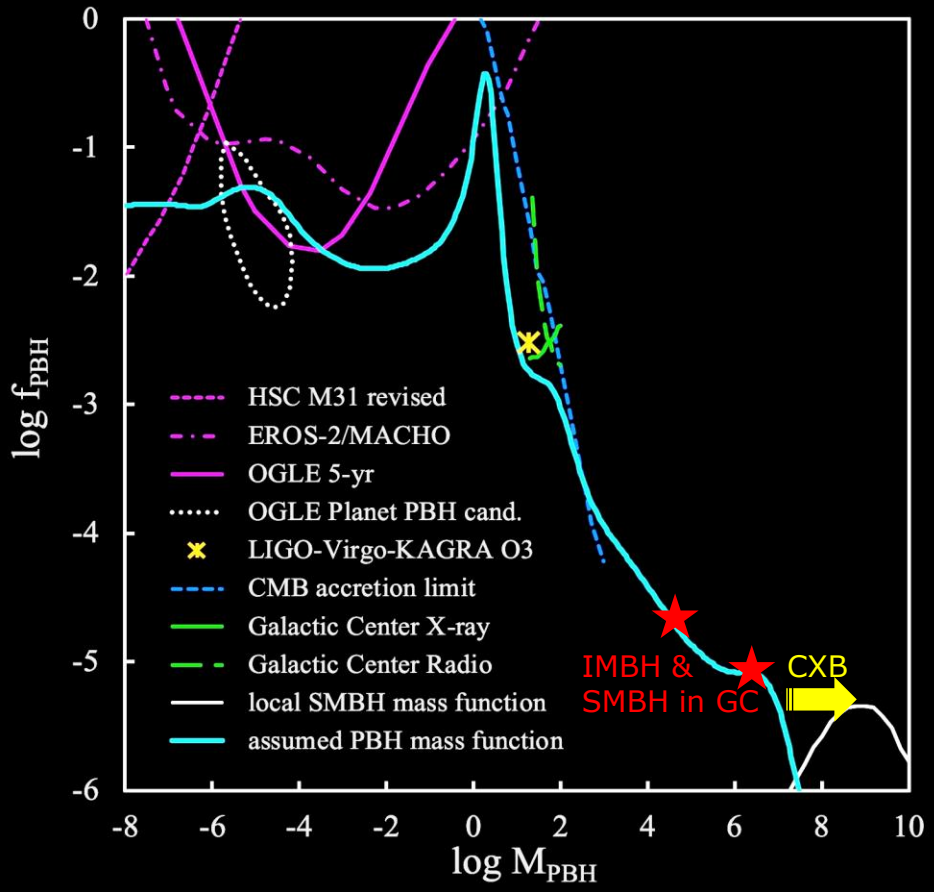
Different peaks correspond to different particles created at the QCD phase transition and e^+e^- annihilation and the corresponding reduction in the sound velocity.

BH mass corresponds to the horizon size at each time.

Only requirement is enough fluctuation power in a volume fraction of 10^{-9} of the early Universe.

Carr, Clesse, García-Bellido 2019

PBH mass spectrum assumed for this work



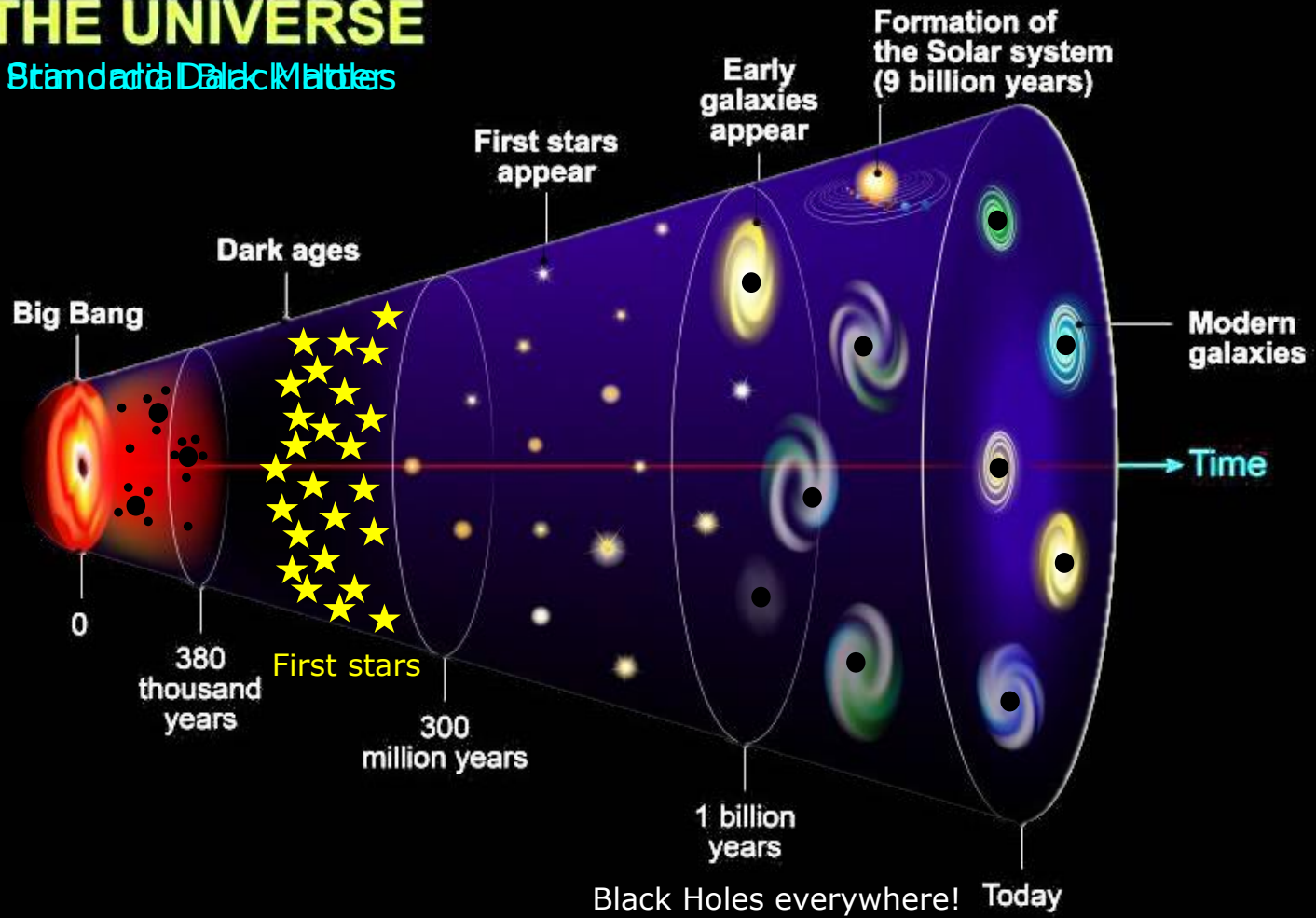
Bernard Carr, Juan García-Bellido et al. are working on a new version of their PBH mass spectrum, which assumes a rolling index of the primordial power spectrum and thus has a steeper decline at large PBH masses. This is now fully consistent with all observational constraints.

This is, what we use to estimate the PBH contribution to the extragalactic backgrounds.

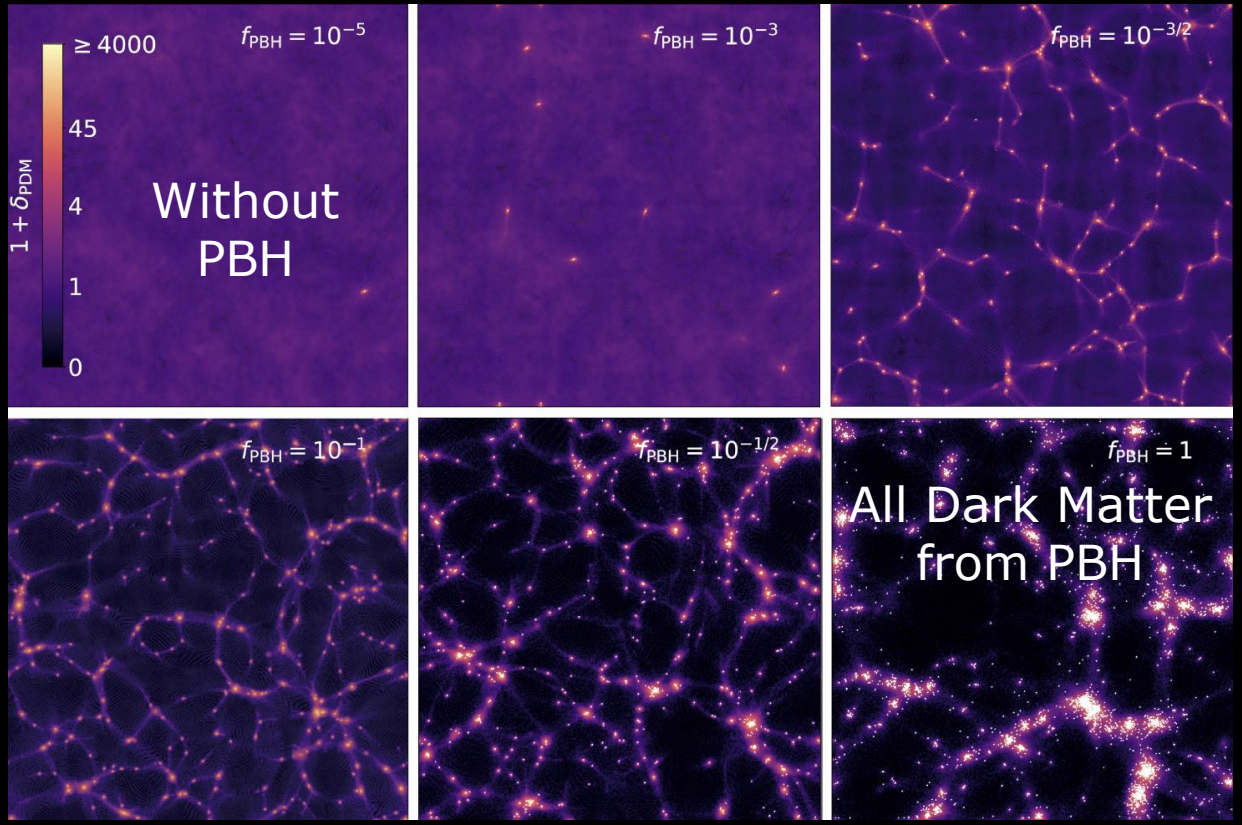
Hasinger 2020

EVOLUTION OF THE UNIVERSE

Standard Dark Matter



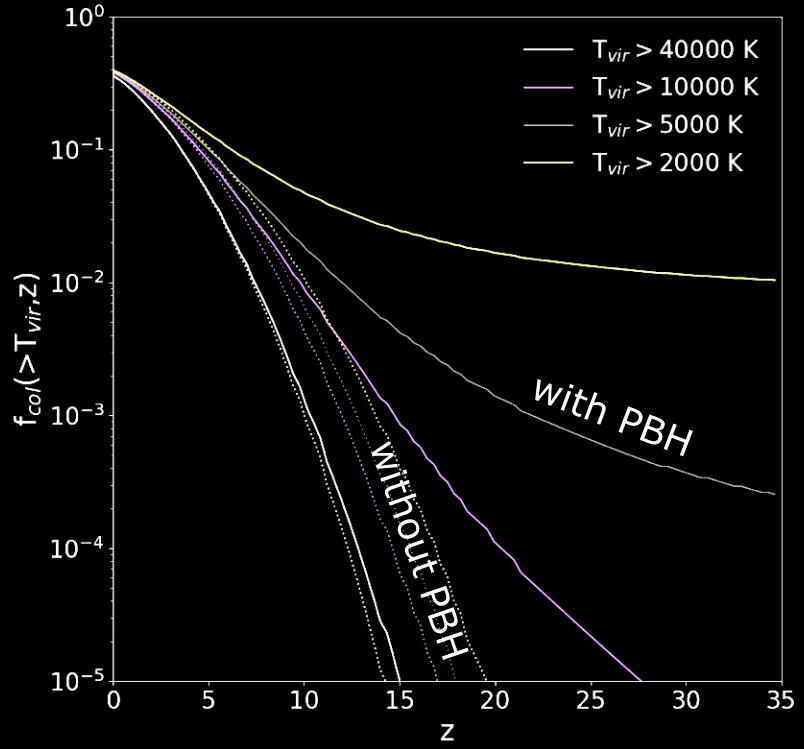
Growth of Large-Scale Structure at z=10



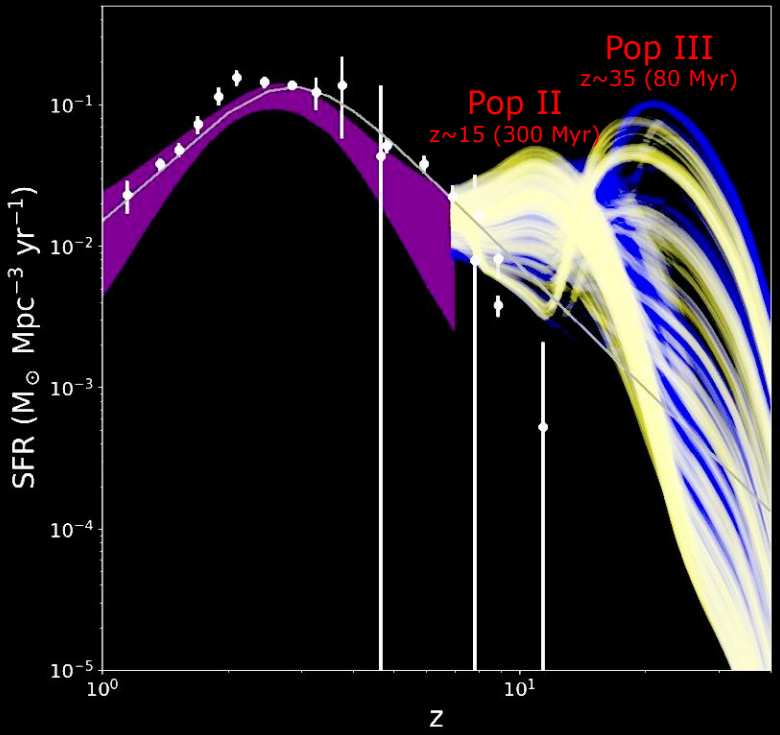
D. Inman and Y. Ali-Haımoud, Early structure formation in primordial black hole cosmologies, Phys. Rev. D 100, 083528 (2019), arXiv:1907.08129

PBH add small DM haloes and early star formation

Dark Matter Halo Growth

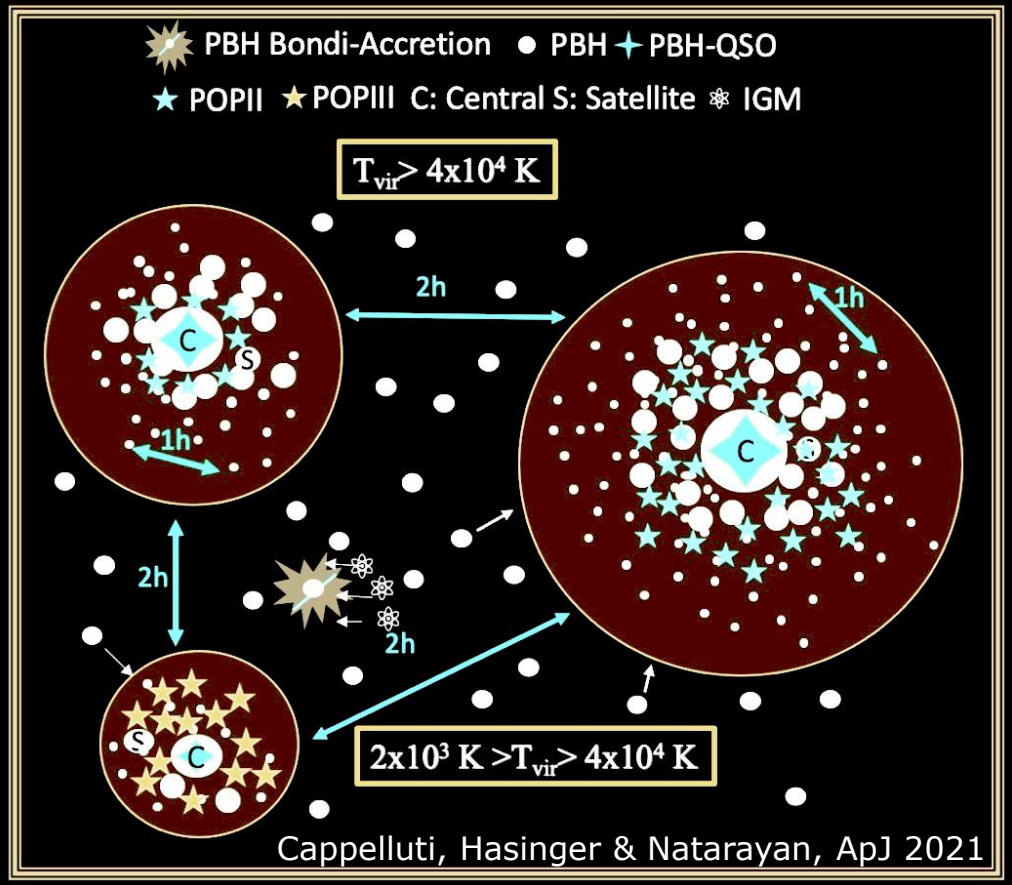


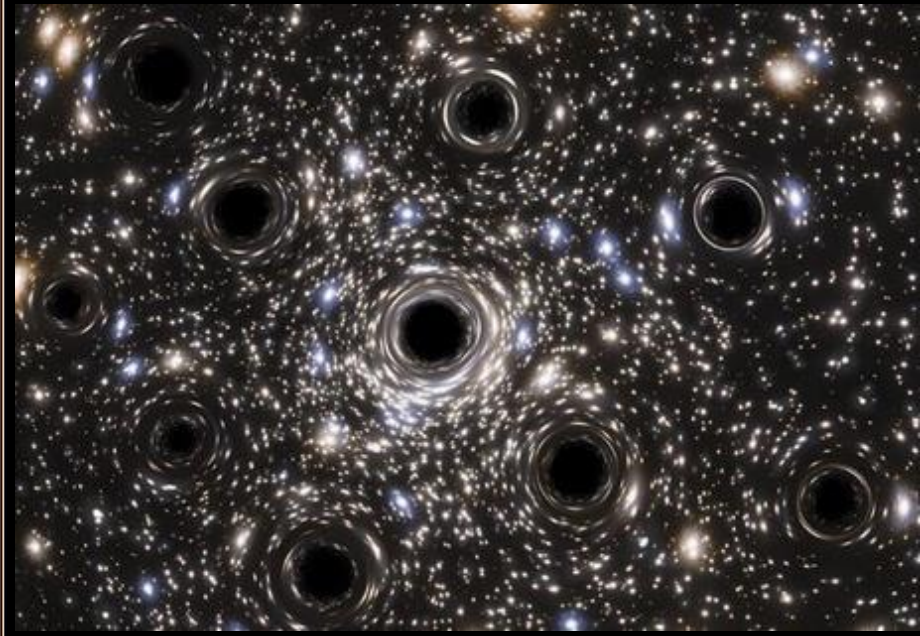
Star Formation History



Cappelluti, Hasinger, Natarajan, 2022, ApJ

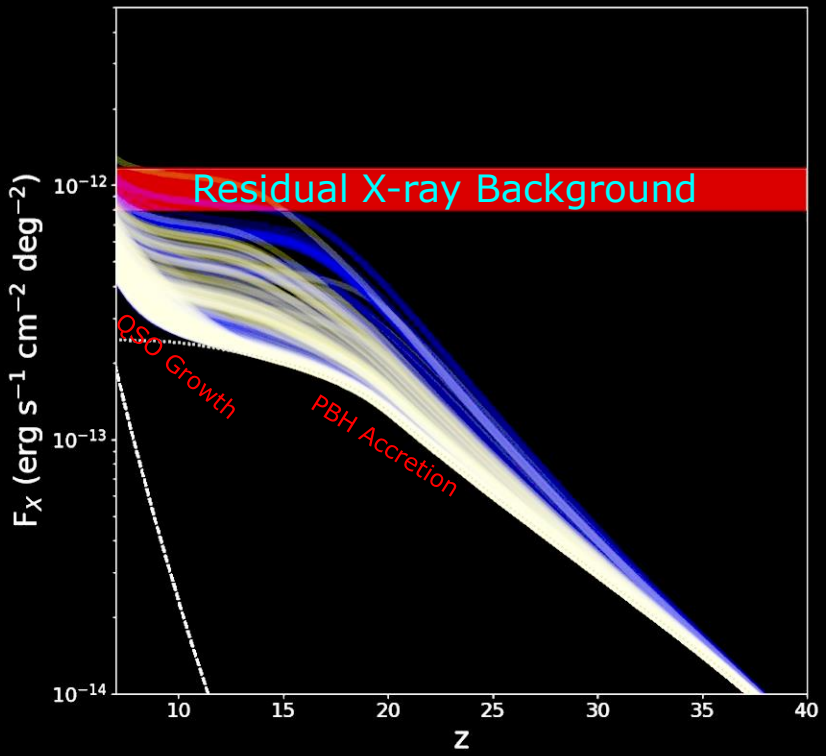
Primordial Black Hole Dark Matter Scheme

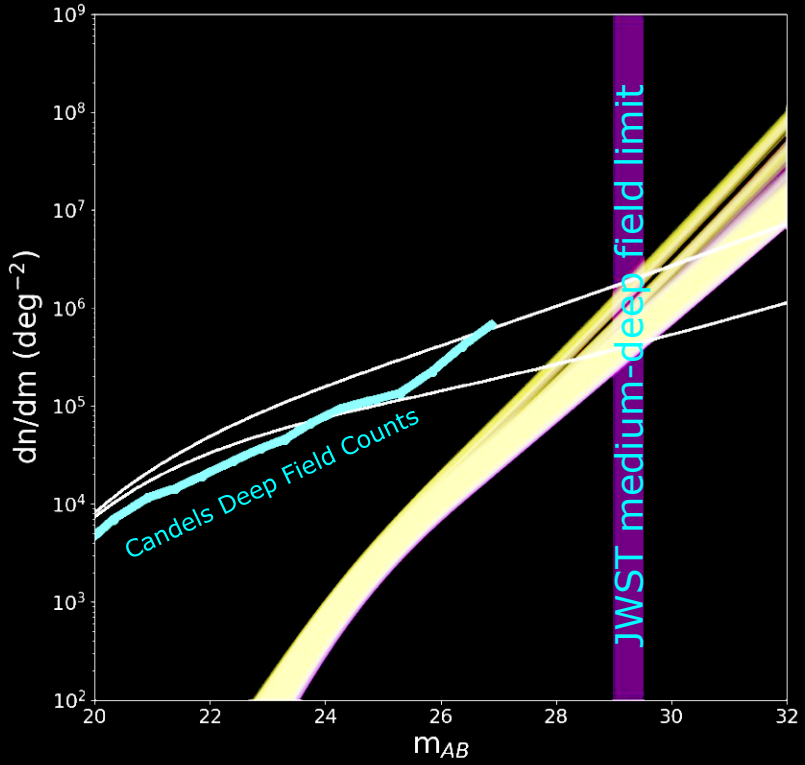




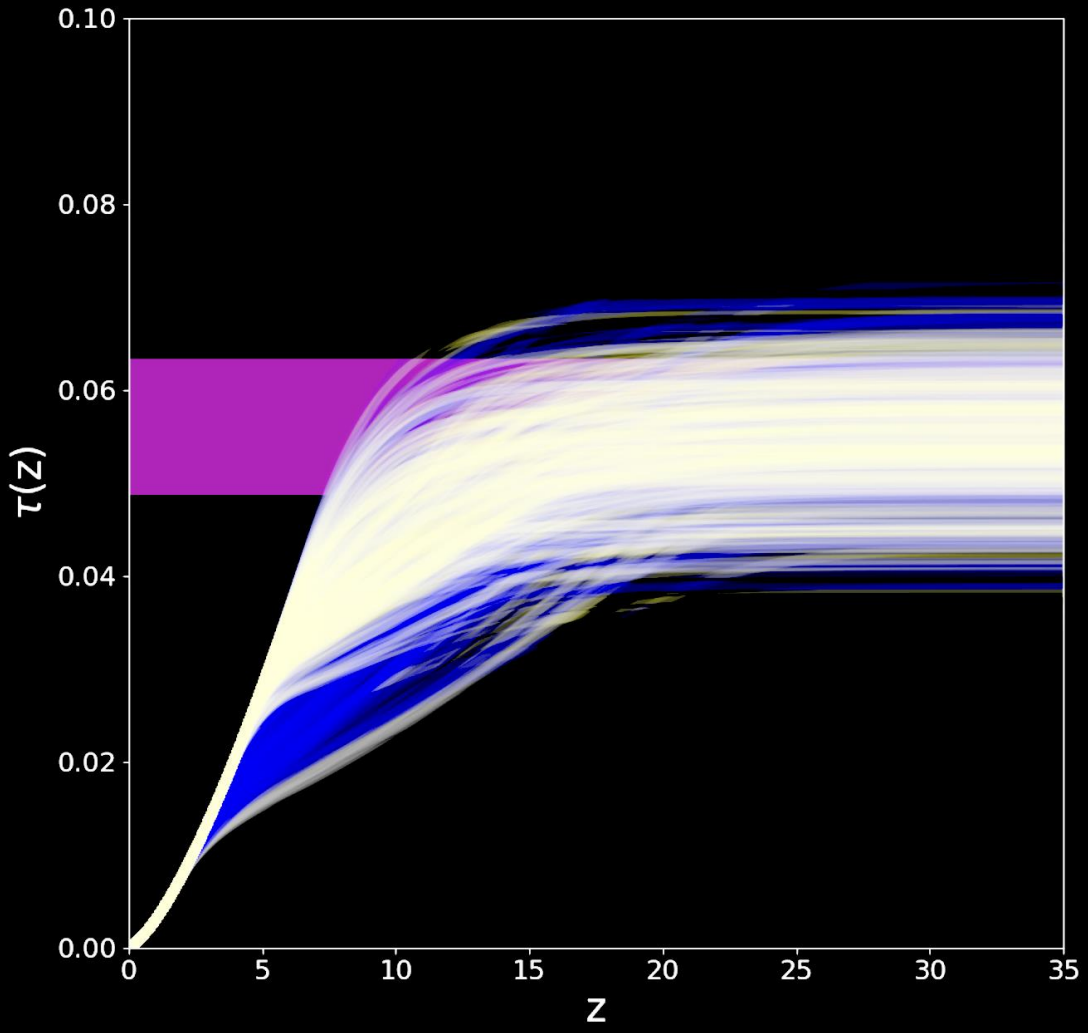
Vitral, E. et al., 2022, MNRAS: Clusters of ~1000 compact objects (WD?, BH?, PBH?) detected in Globular Clusters NGC 3201 and NGC 6397 with GAIA and HST.

X-ray flux and NIR counts from early BH and stars





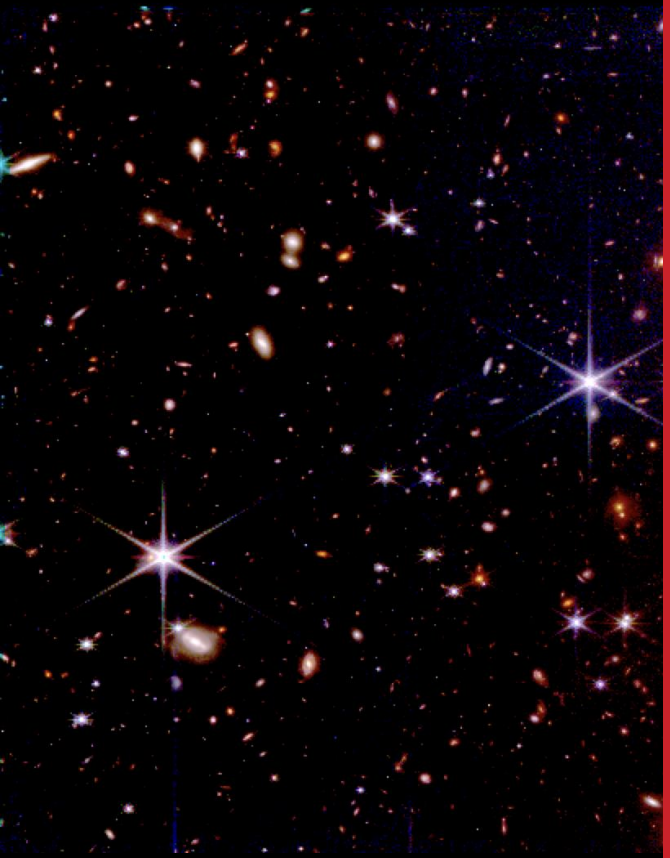
Significant steepening of NIR source counts predicted in JWST Deep Fields!



Planck re-ionisation limits

No problem with re-ionization. Actually, this model gives a better fit to the reionisation parameter, than the classical model, taking into account recent determinations of low Ly-α escape fractions.

The first JWST Deep Image revealed by President Biden!



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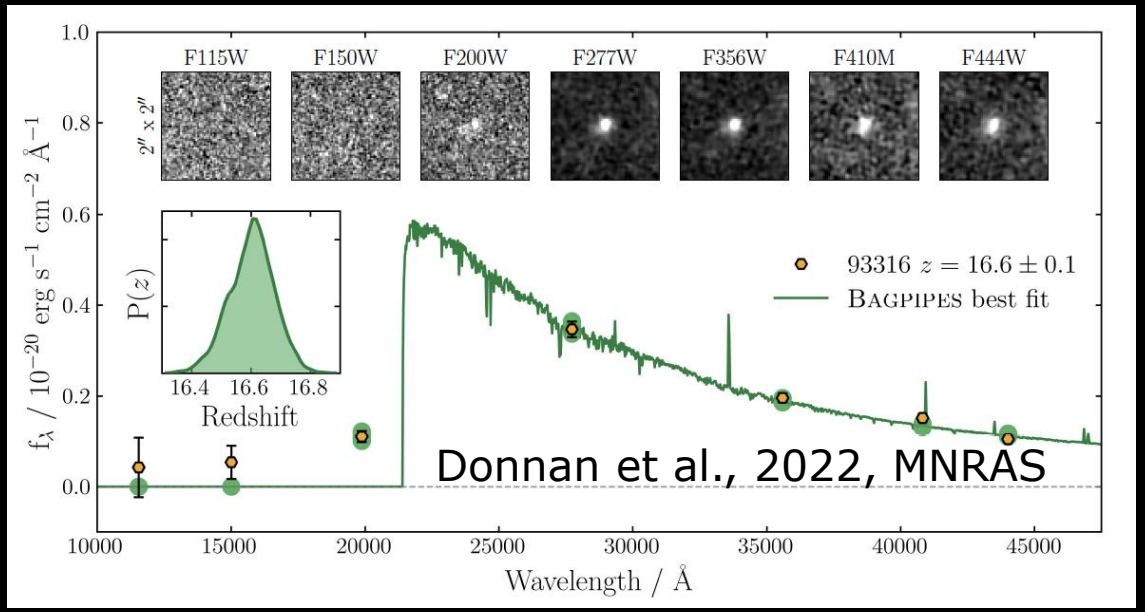
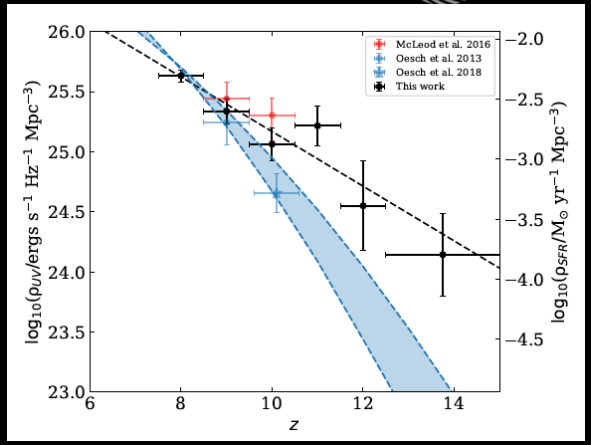
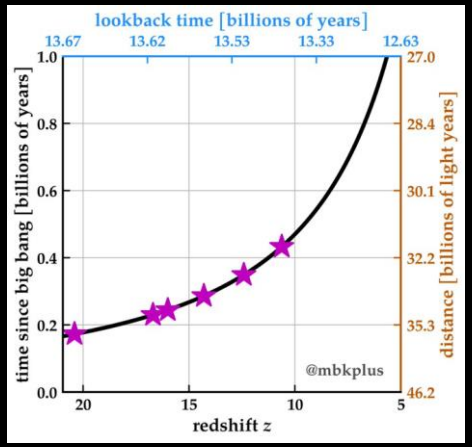
arXiv: JWST high-z papers: z>16!



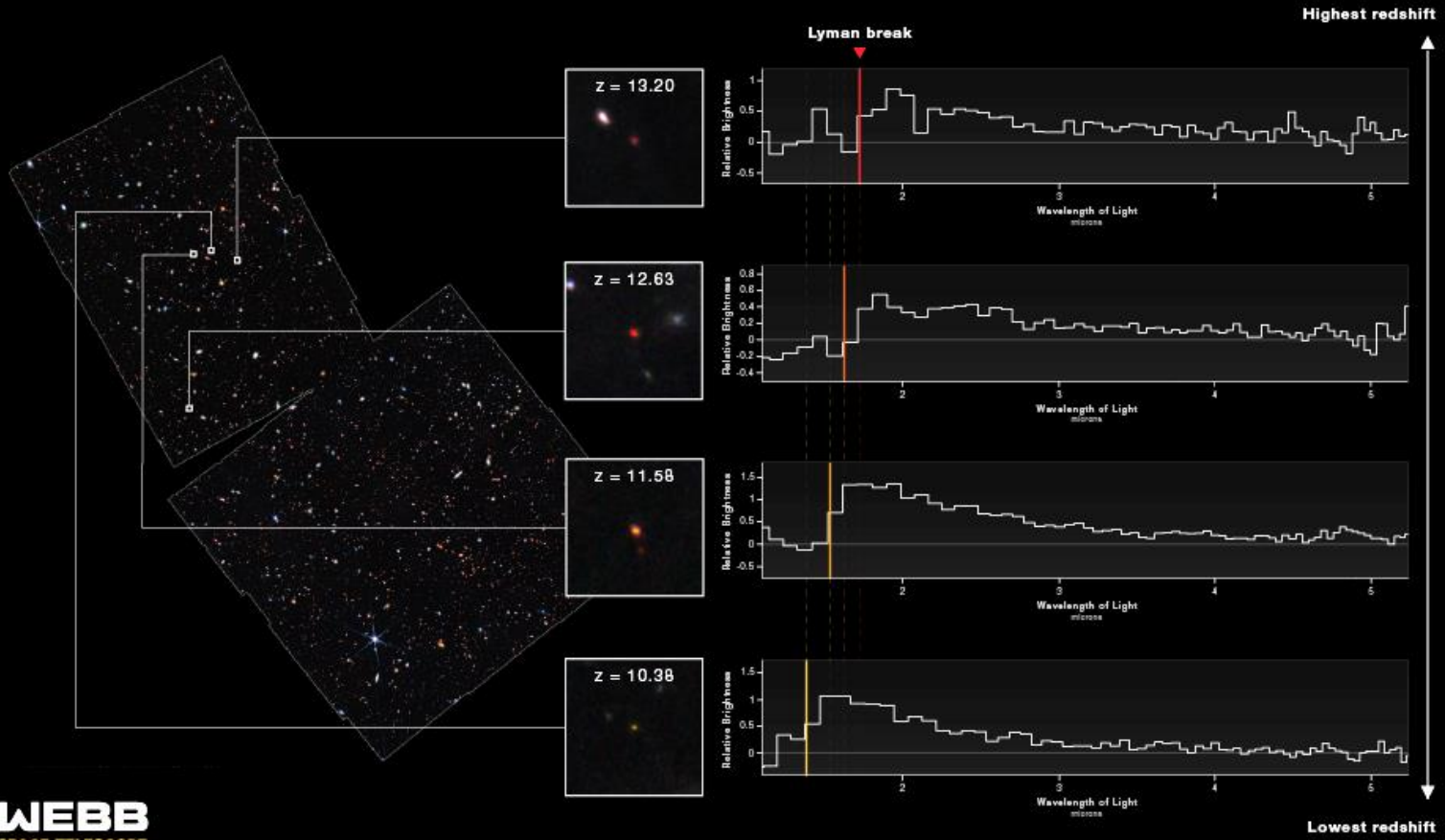




We have a total of 88 such candidates spreading over the two fields, some of which could be at redshifts as high as 20. Neither the high number of such objects found nor the high redshifts they reside at are expected from the previously favored predictions.

Yan et al., 2022, Nature

JWST: new distance records!



325 Myr

346 Myr

390 Myr

454 Myr

after Big Bang

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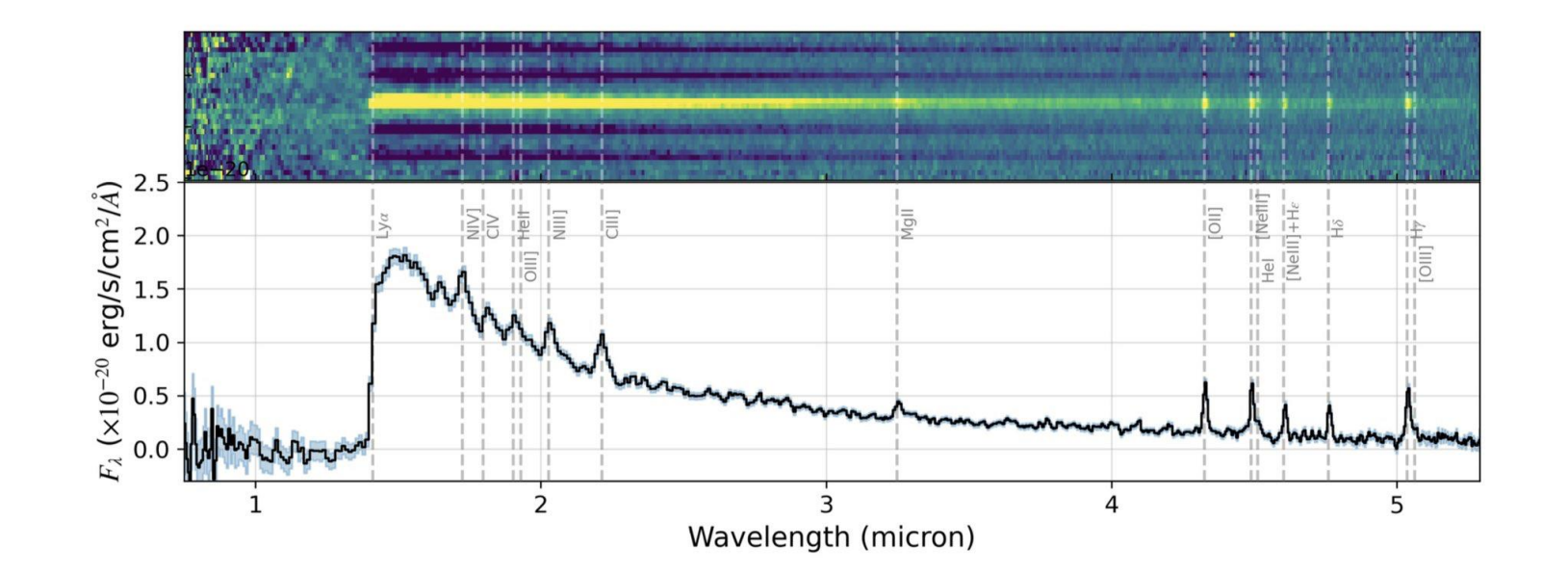
JWST NIRSpec Observation of GN-z11



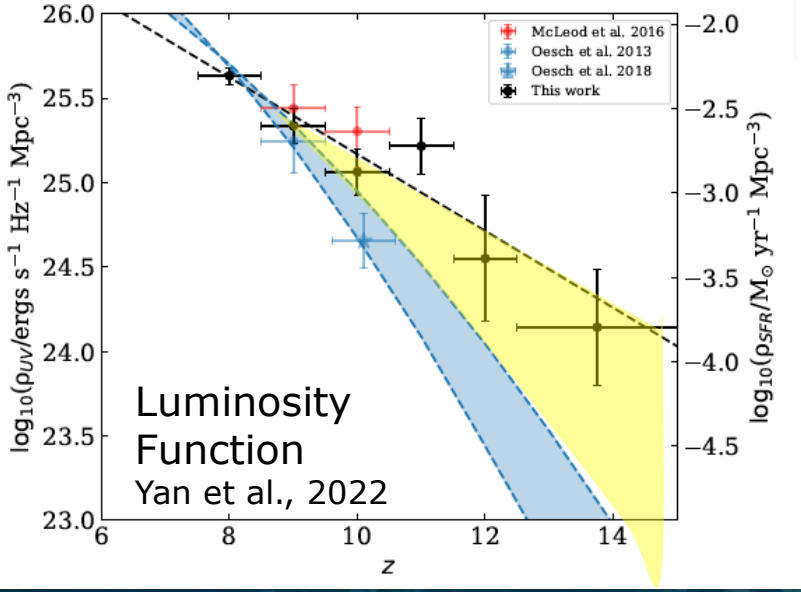
Star Formation Rate ~24 $M_\odot$/yr and stellar mass ~10^9 $M_\odot$ at z=10.6 !

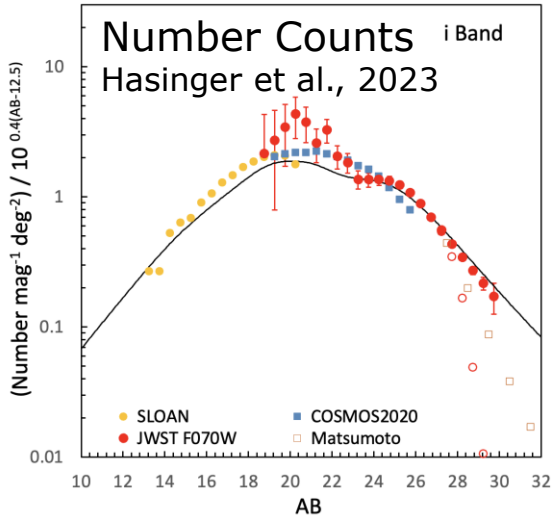
Bunker et al., 2023, arXiv:2302.07256v1

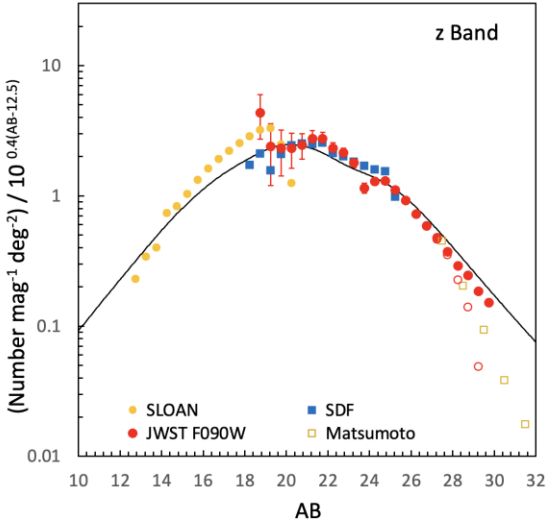
Number of Galaxies
in JWST Medium-Deep Fields

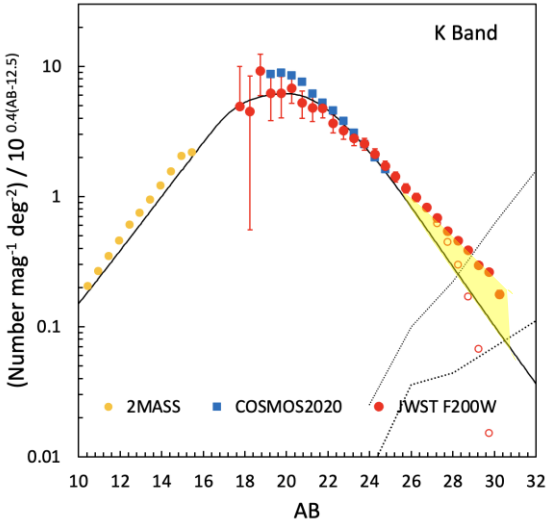
First hints for a new population of early galaxies.

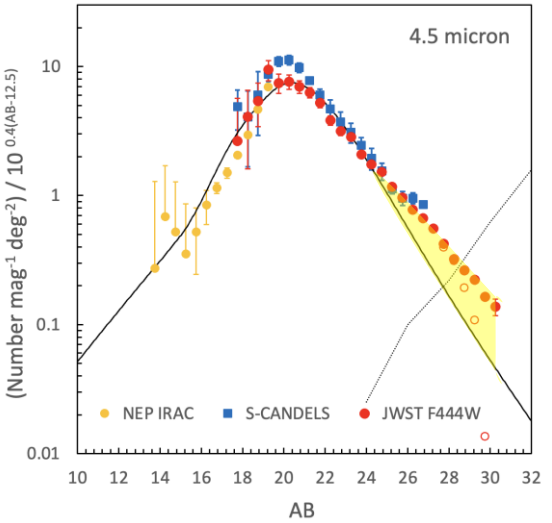
This has been predicted by the primordial black hole dark matter model!

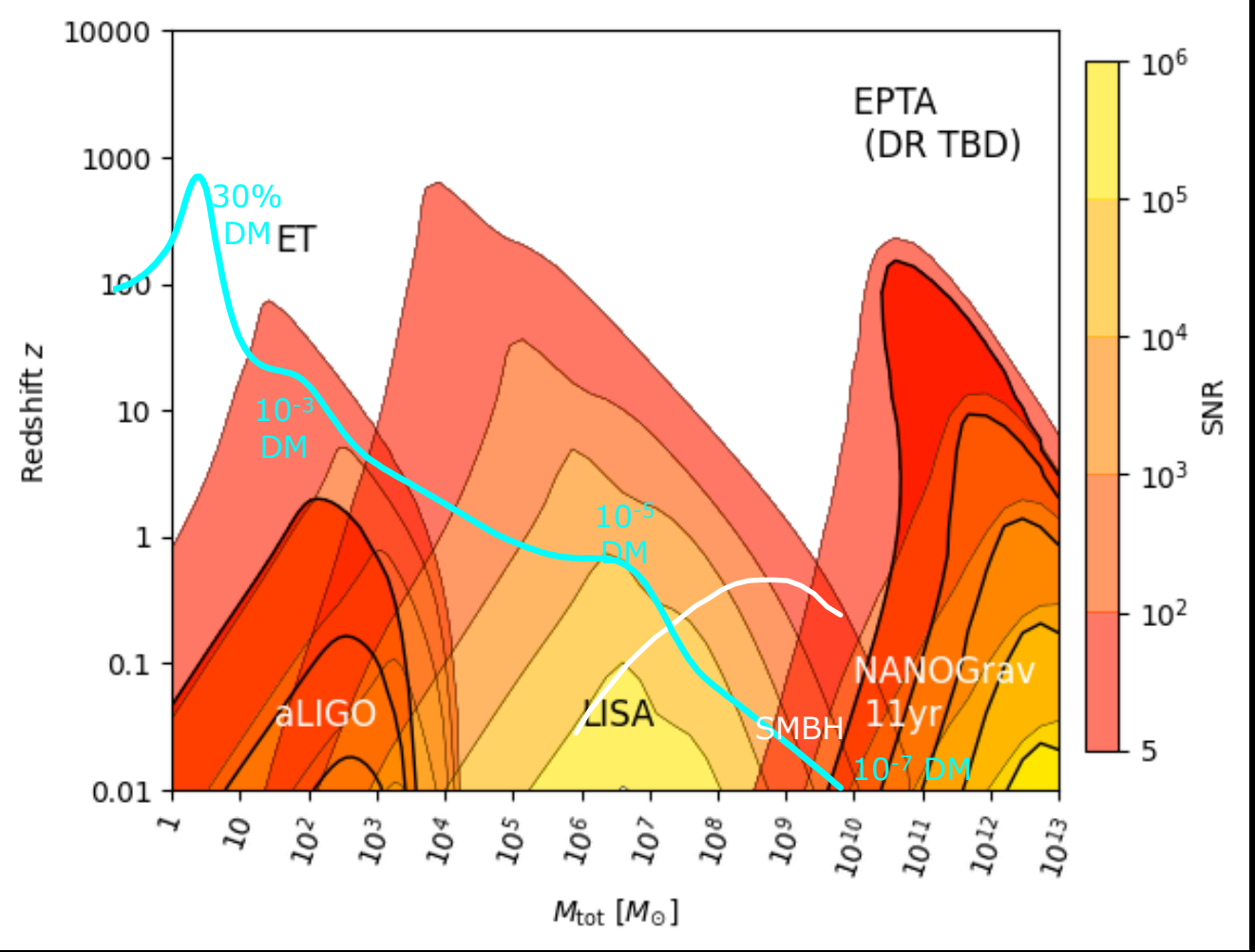












Sensitivity to BH-BH Mergers

So far, all of these "fingerprints" are tantalizing, but only circumstantial evidence.

However, future Gravitational Wave observations can uniquely discriminate between astrophysical and primordial black holes!


Thank you
very much!
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