The first billion years of galaxy formation: advances and implications

Pratika Dayal

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Maria Dziouba

Emma Giovinazzo

Jill Straat

Research students

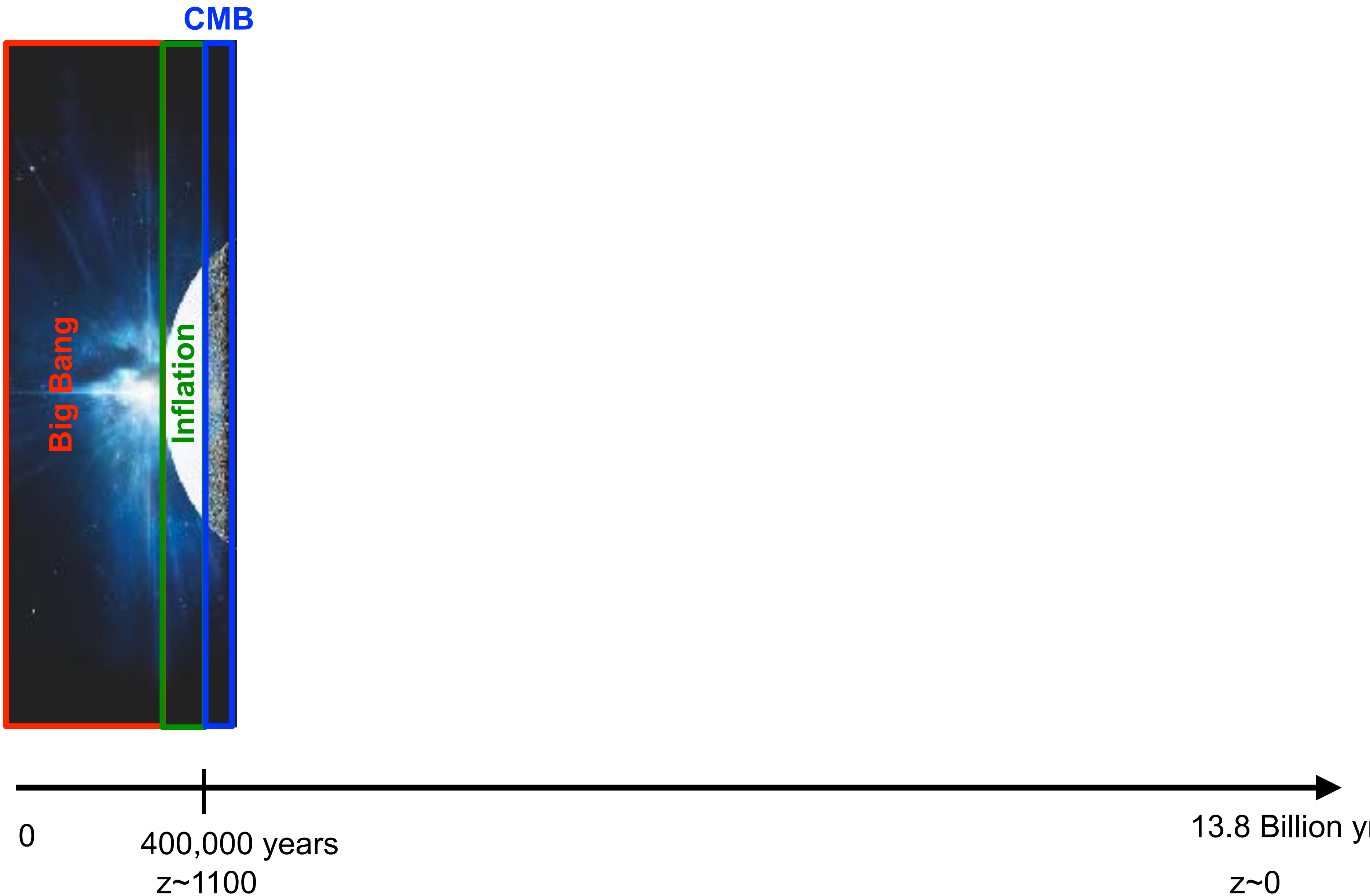
The cosmic timeline

Big Bang

0

13.8 Billion yr

The cosmic timeline



The cosmic timeline

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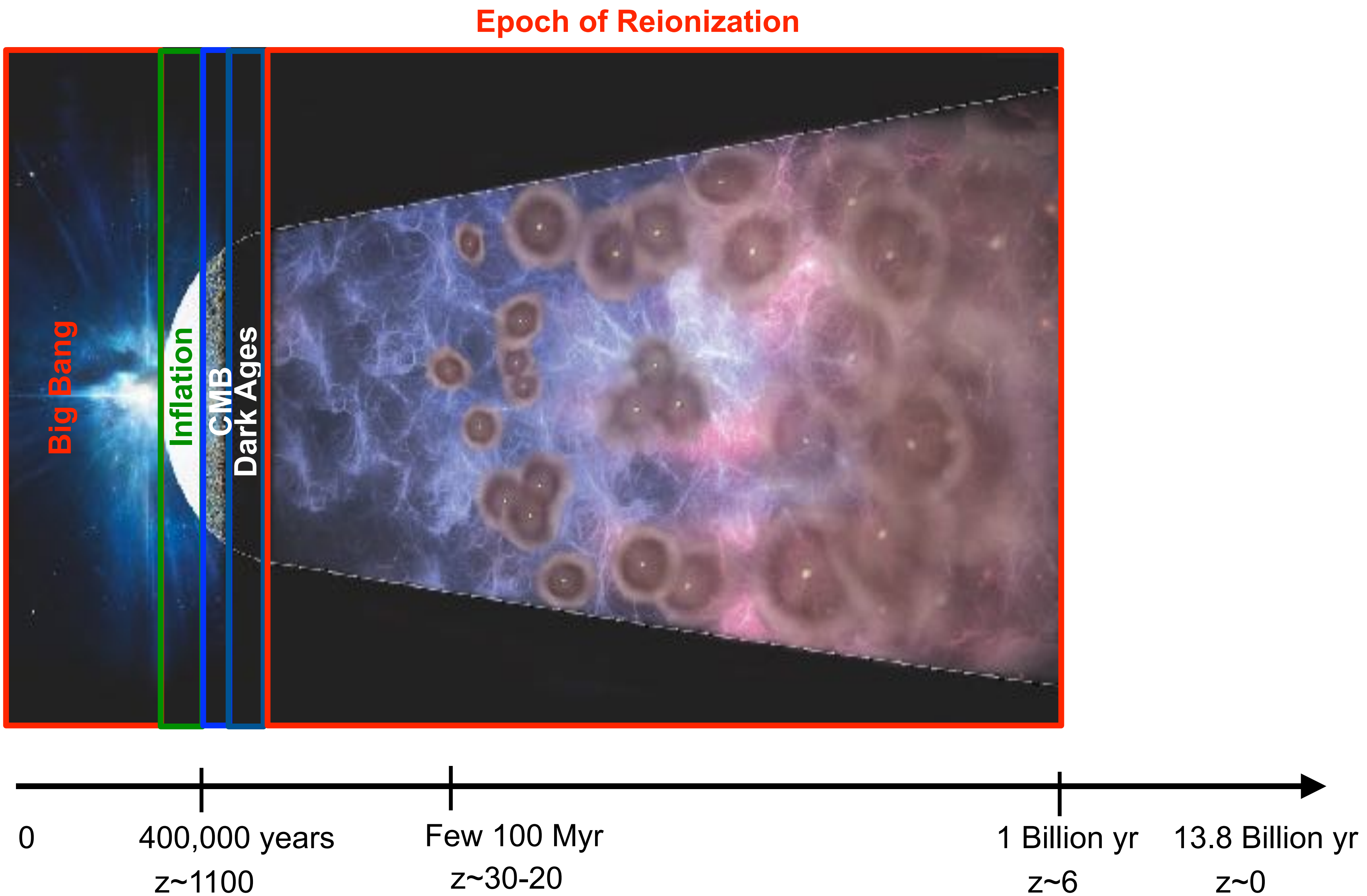

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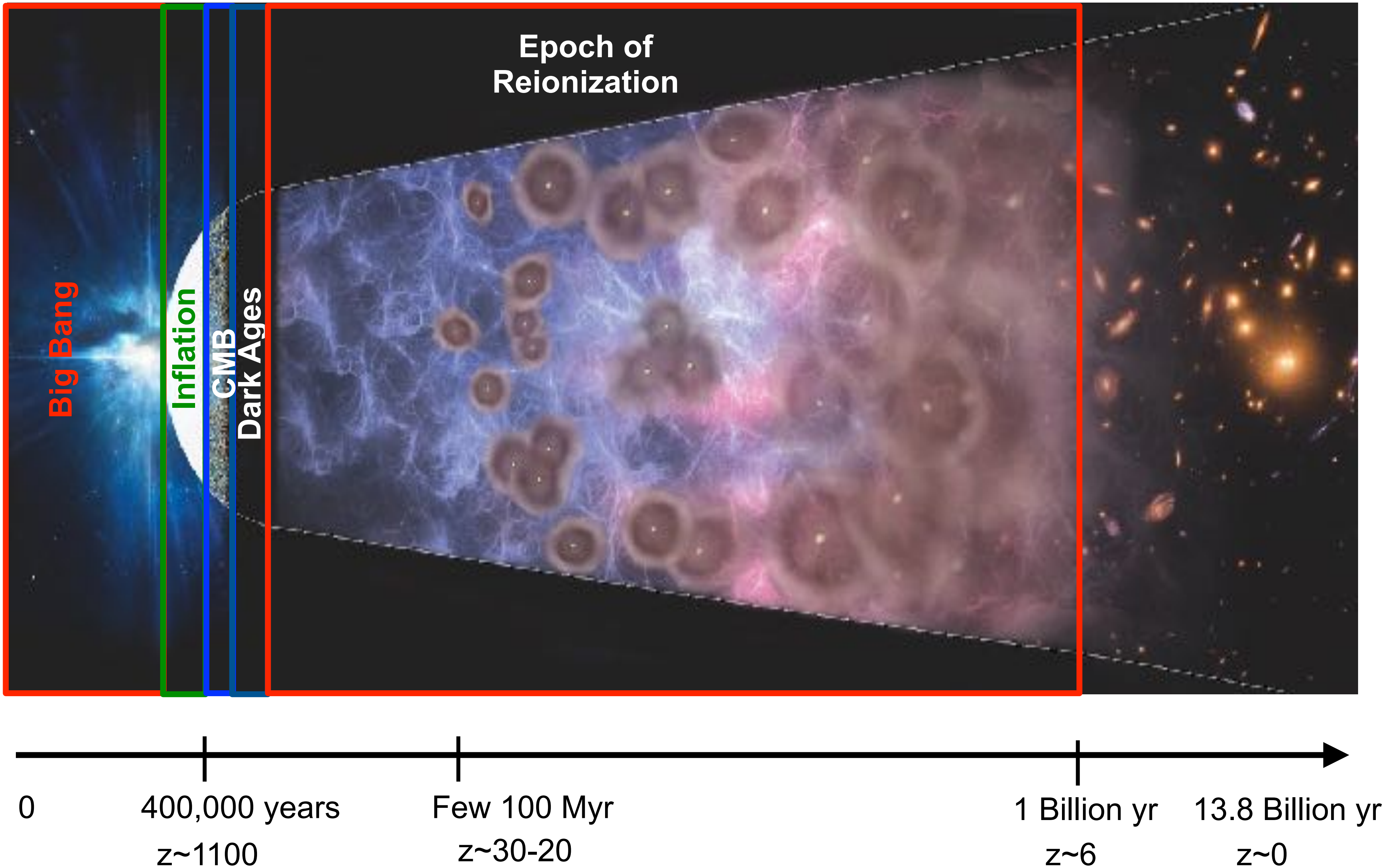
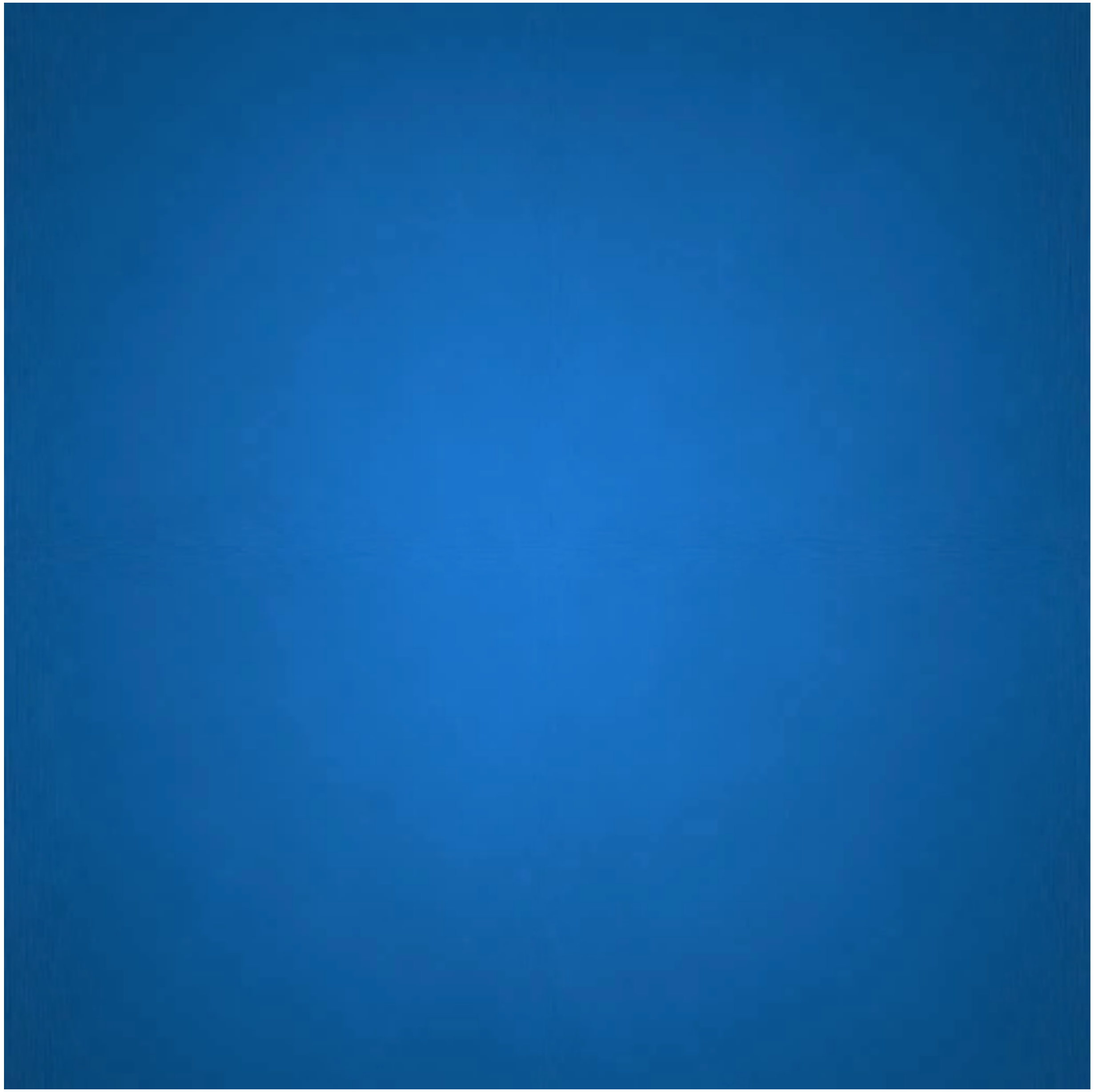


The first galaxies - seeds of all structure



http://www.clues-project.org/

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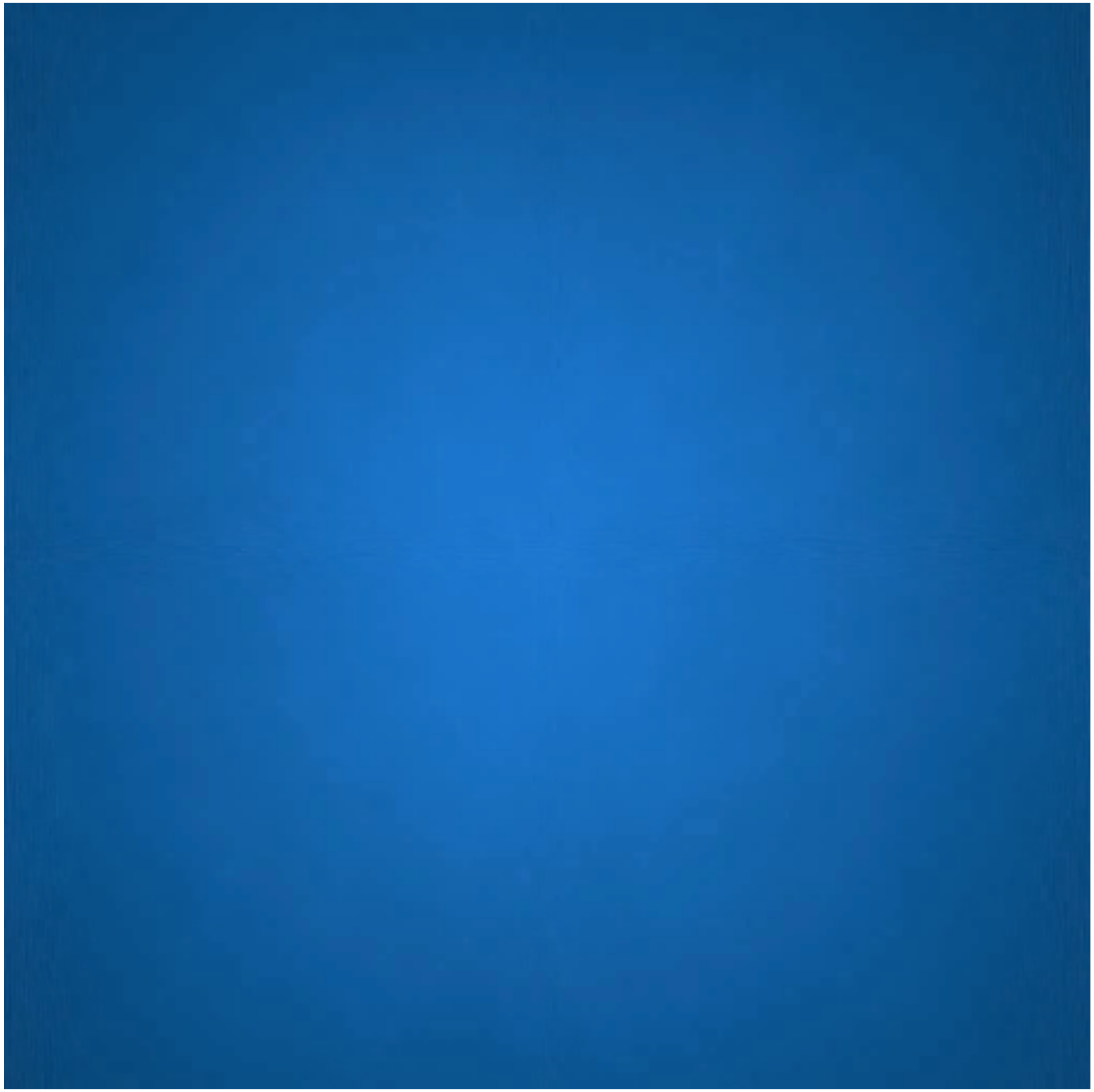

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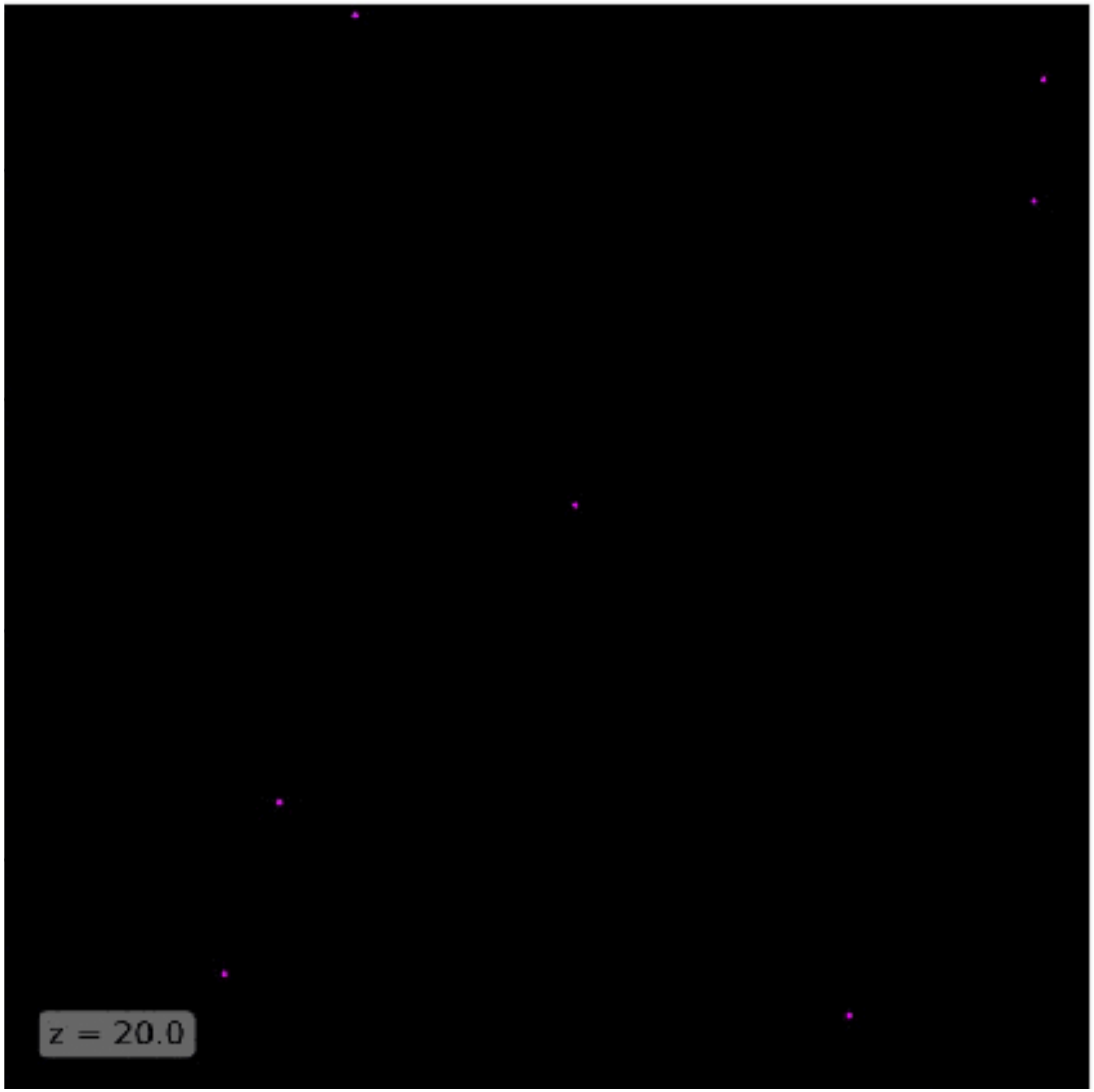
The first galaxies - the start of reionization



Galaxies

Neutral hydrogen

Ionized Hydrogen

The ASTRAEUS framework; PI:Dayal

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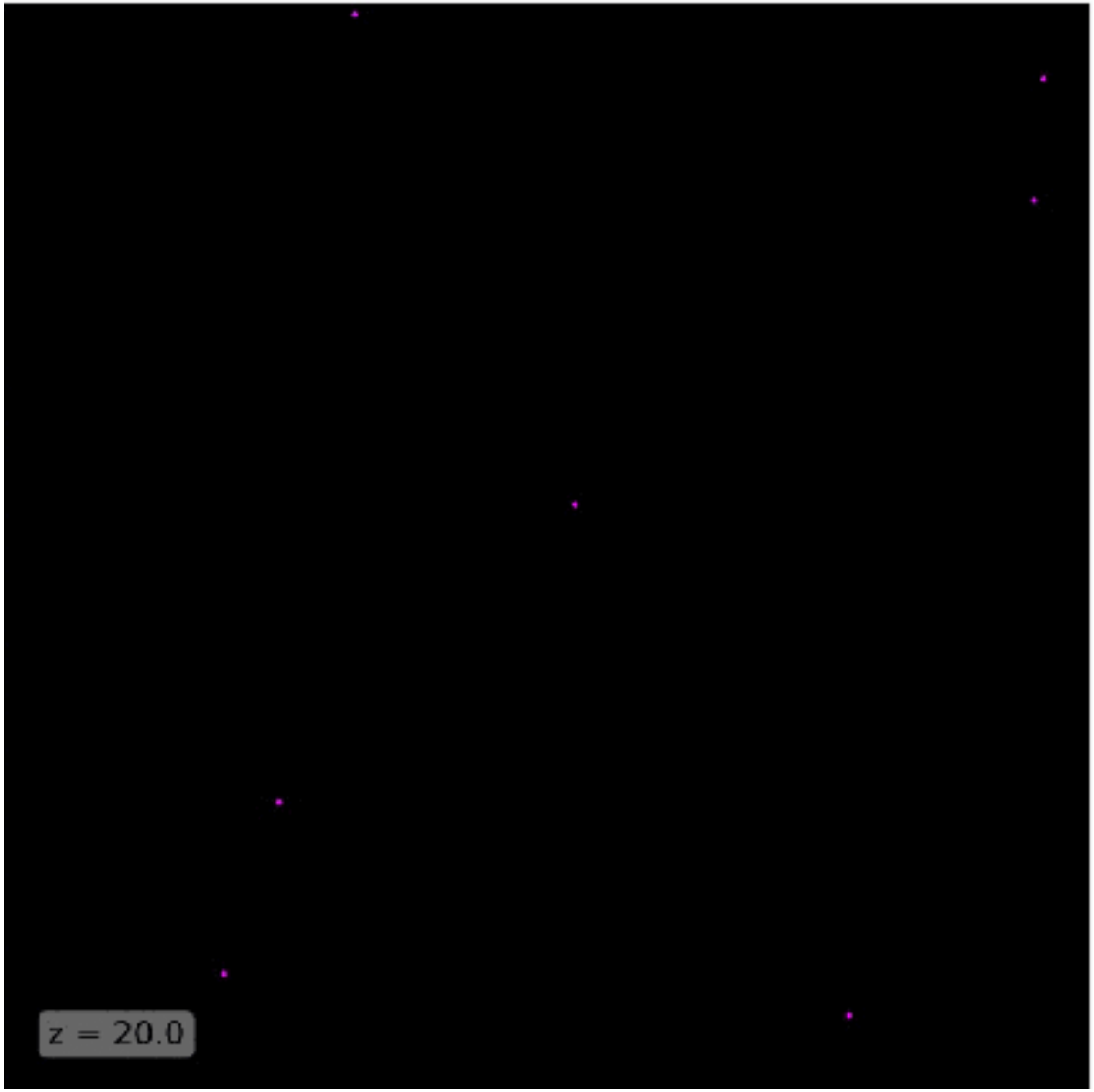

Galaxies

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DELPHI

ODIN

The ASTRAEUS framework; PI:Dayal

The golden age for observing early galaxies

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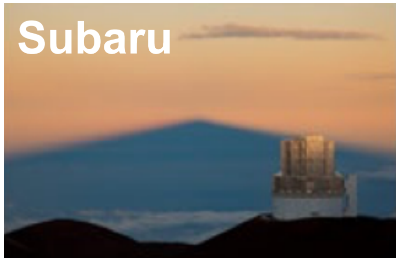

Number of galaxies of a given luminosity per unit volume as a function of cosmic time (*Luminosity function*)

Total rate of star formation per unit volume (*Star formation rate density*)

Total mass bound in stars per unit volume (*Stellar mass density*)

The dust masses of early galaxies

Sizes of early galaxies

The open questions

- What were the physical properties of early galaxies?
- How dusty and metal rich were early galaxies?
- How was early galaxy assembly dependent on the environment?
- What did early galaxies evolve into through cosmic time?
- When & how was the Universe reionized?
- What was the impact of reionization on early galaxy formation?
- What was the role of black holes in early galaxy formation & reionization?
- How many gravitational wave events do we expect from the early Universe?
- What can signals from cosmic dawn tell us about cosmology
  (e.g. galaxy formation and nature of dark matter)?

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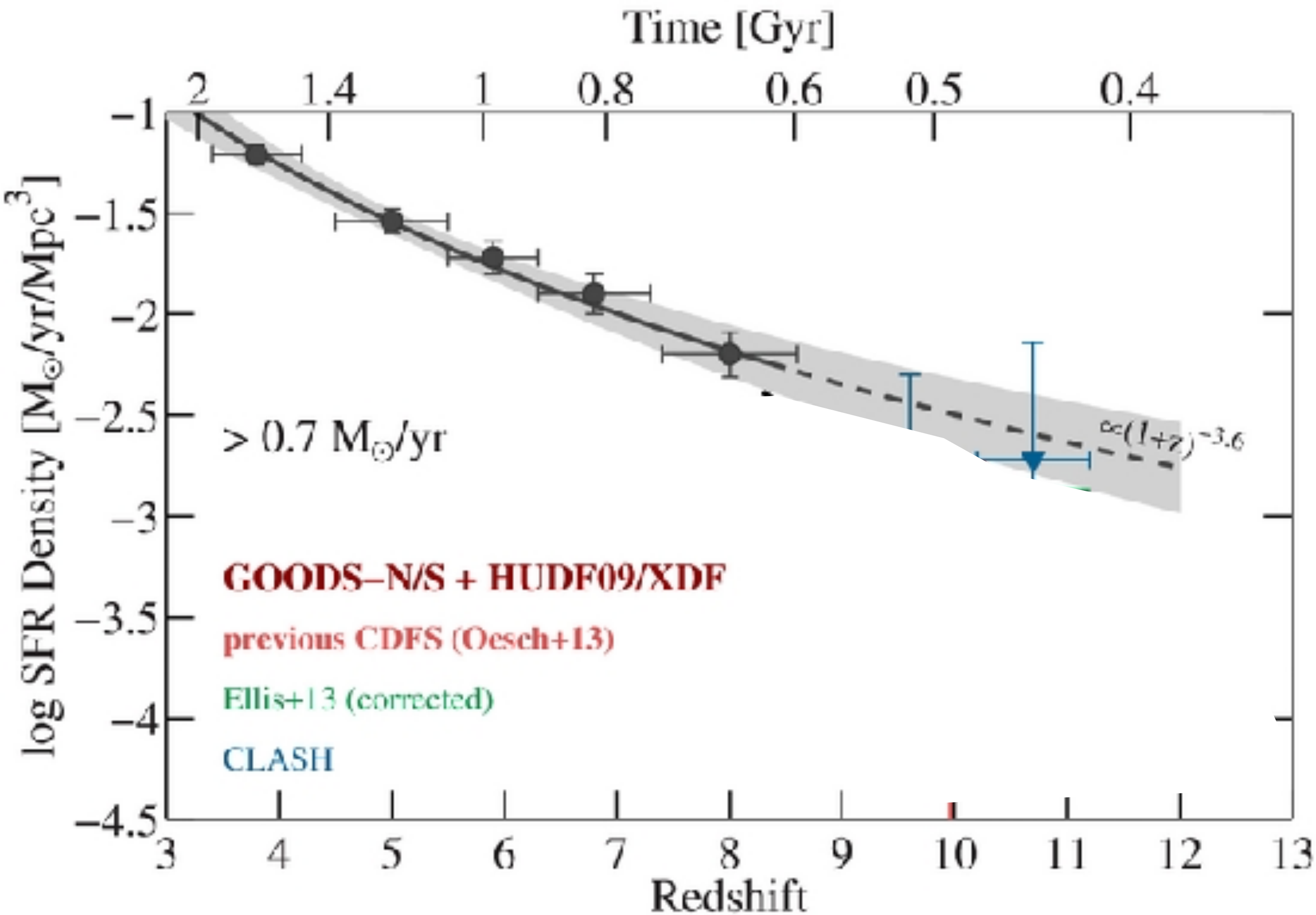
Key science highlights

Mapping out star formation through cosmic time



Oesch et al. 2013;
PD & Ferrara, 2018

SFR density extremely uncertain at z>8. *JWST will be crucial* in tightening constraints on the SFRD.

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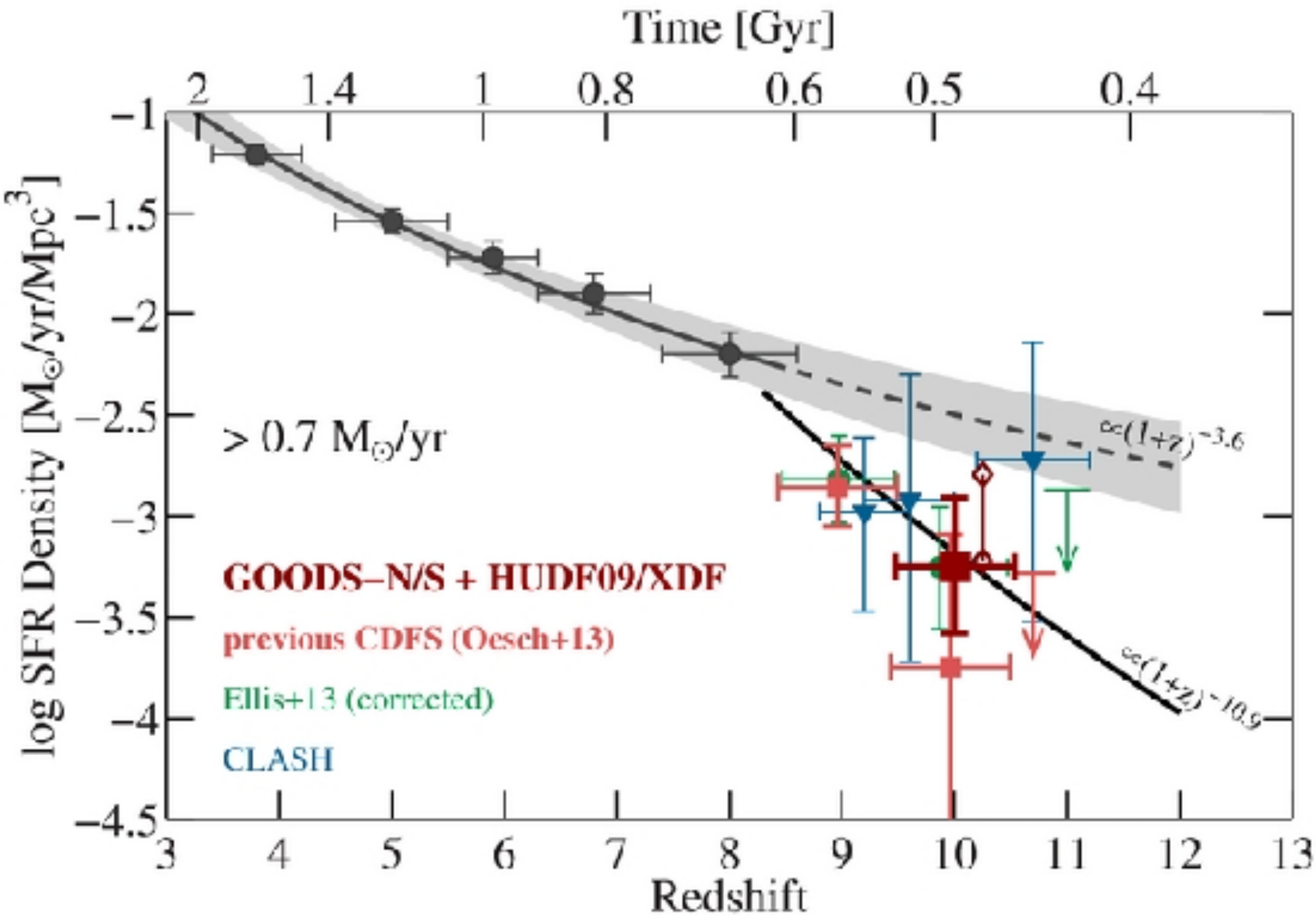

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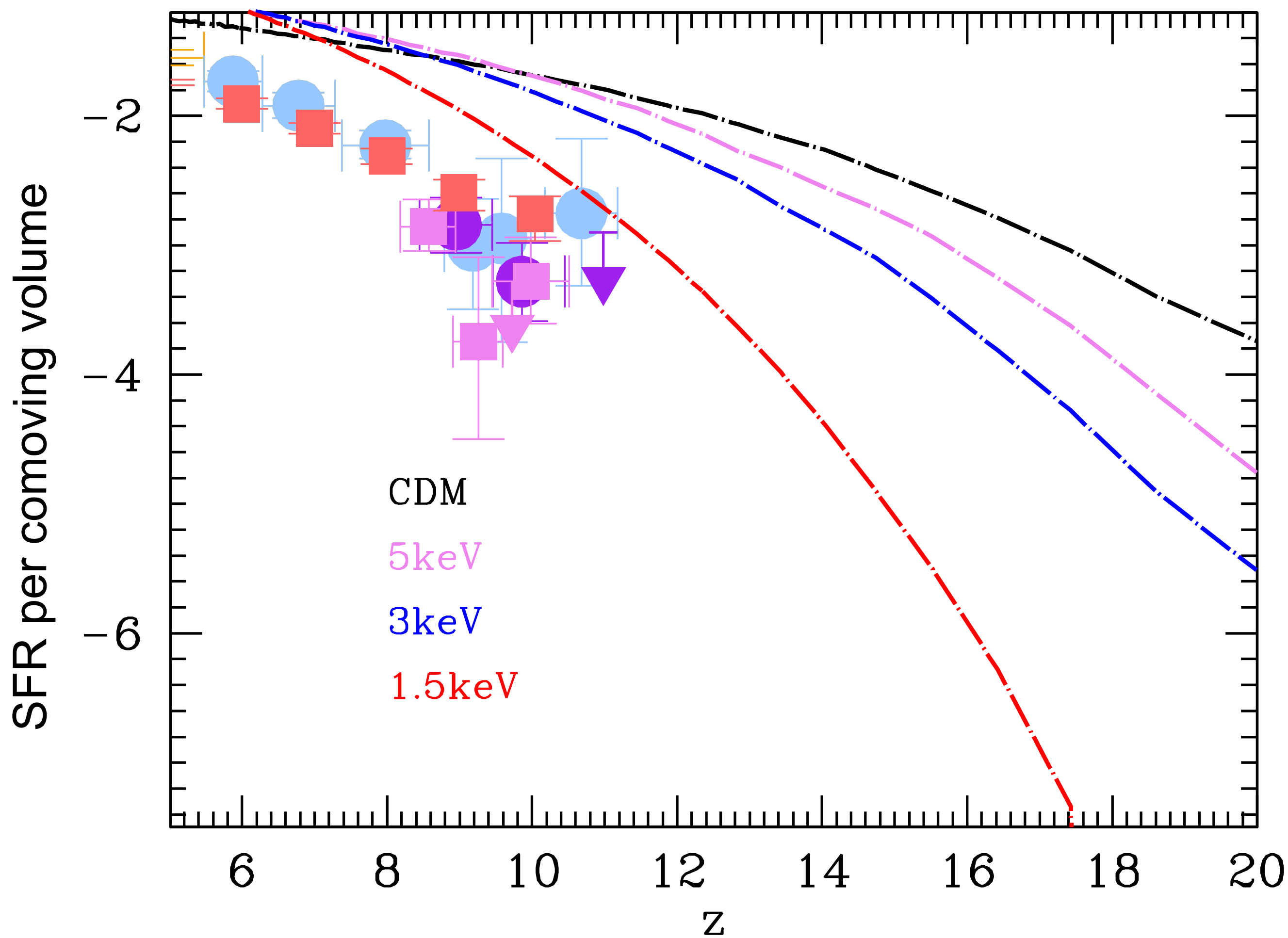
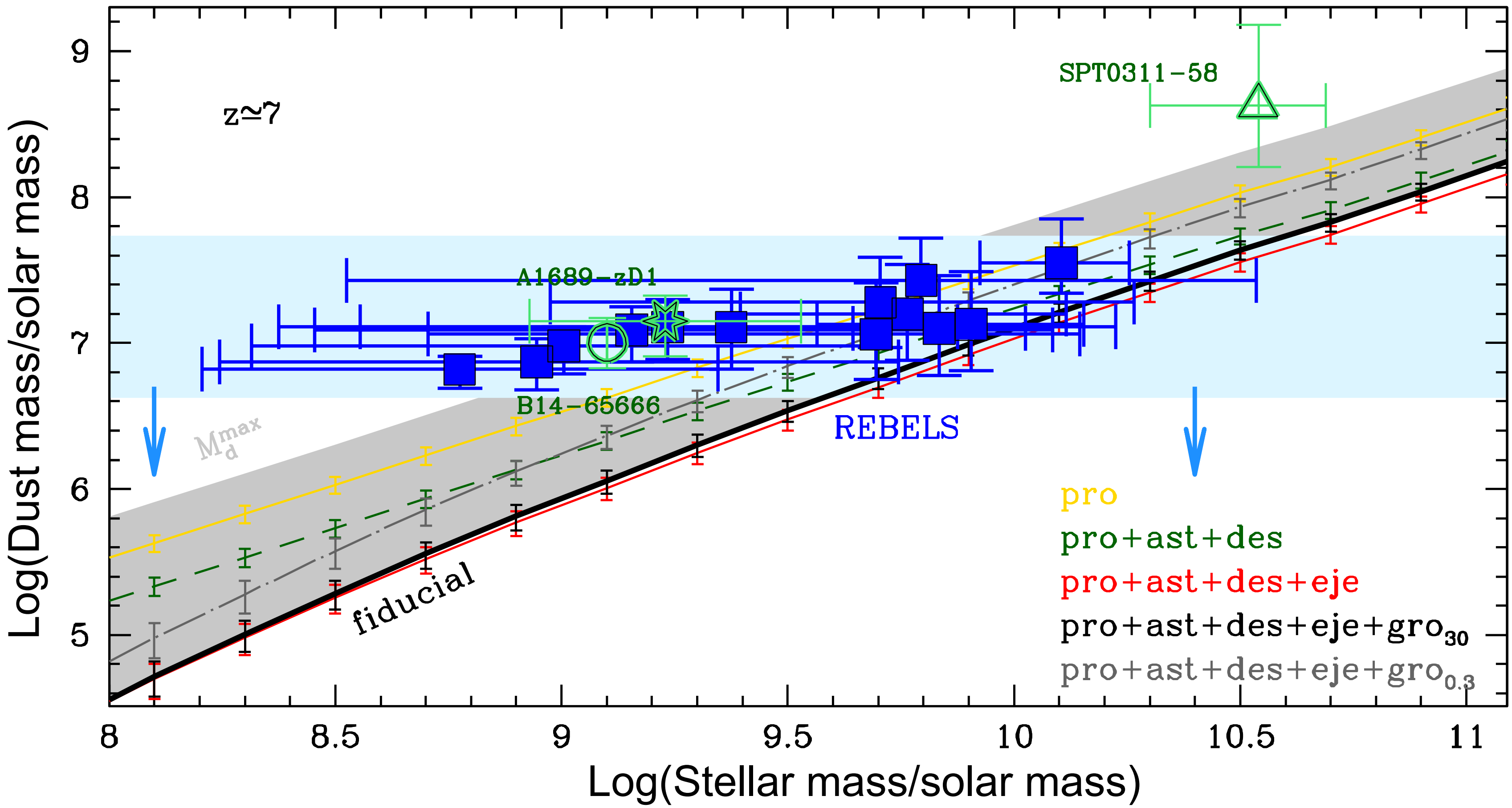
Constraints on the dark matter particle mass using galaxy data



Galaxies assemble faster in light Warm dark matter models compared to cold dark matter. This is because they start off bigger and are less feedback limited as a consequence.

PD+ 2015; PD+2017

The tantalising puzzle of dust in the first billion years



Early galaxies are much more dusty than thought (Bouwens et al. 2022; Inami et al 2022; Bethermin et al. 2020; Viero et al. 2022). Such large dust masses can not be explained by Supernovae, the standard dust factories (Dayal et al., 2022)

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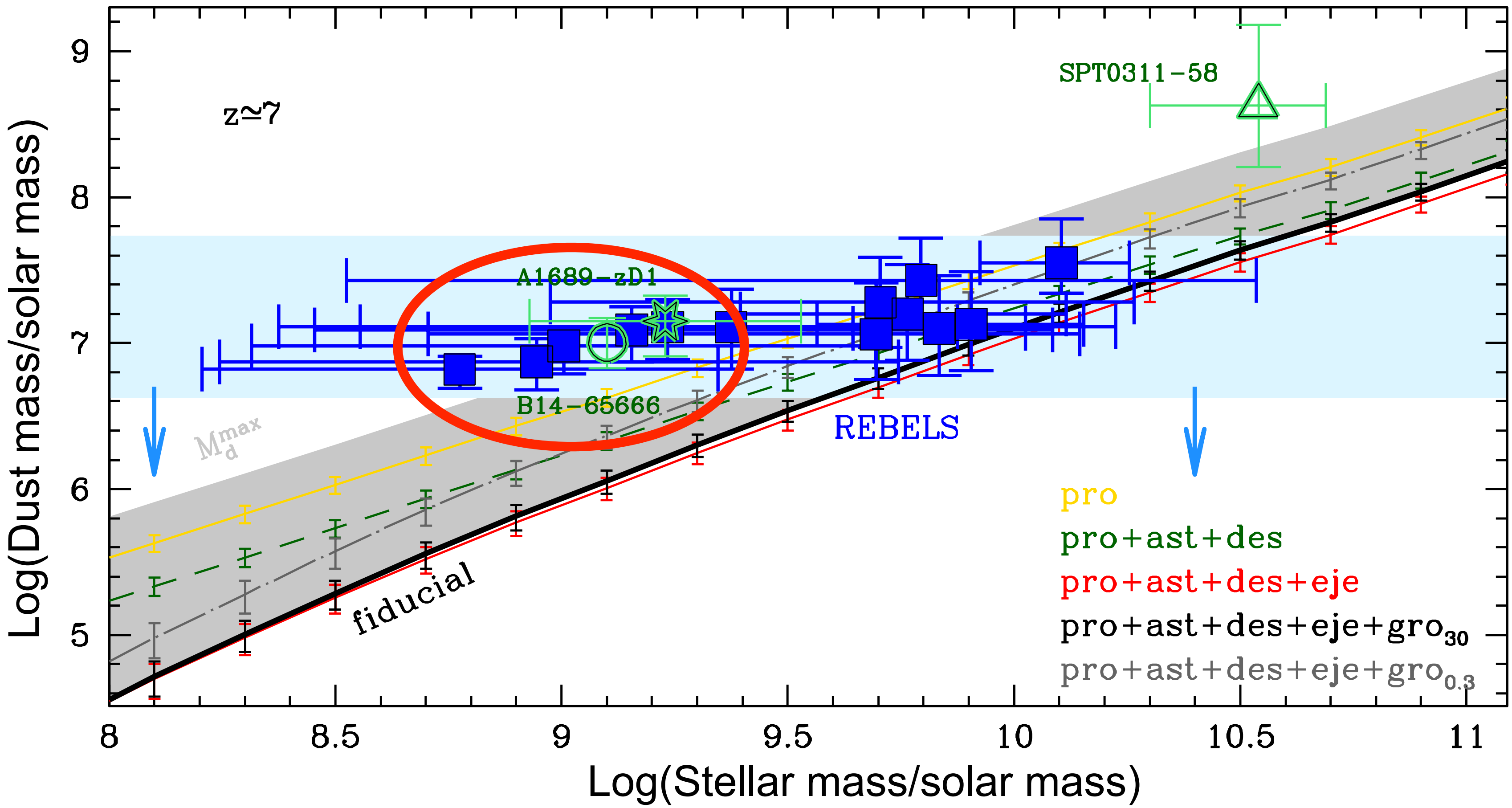

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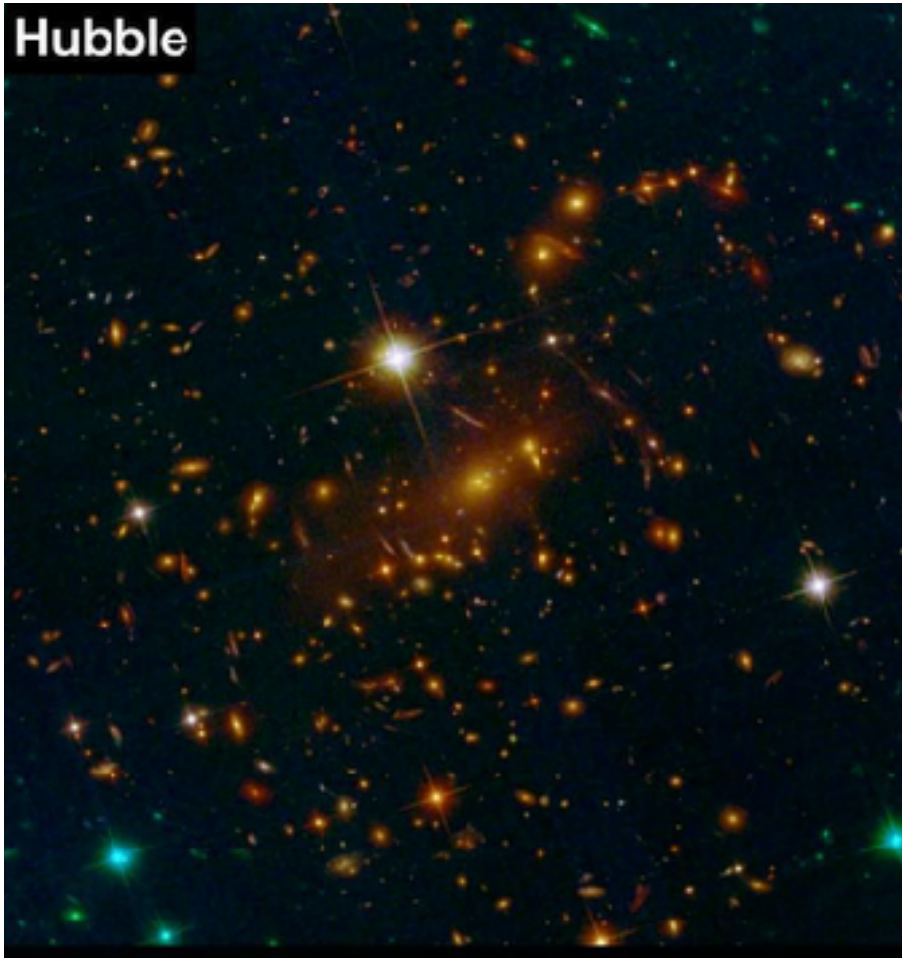
ALMA

REBELS

Reionization Era Bright Emission Line Search

First images from the JWST



webbtelescope.org/resource-gallery/images

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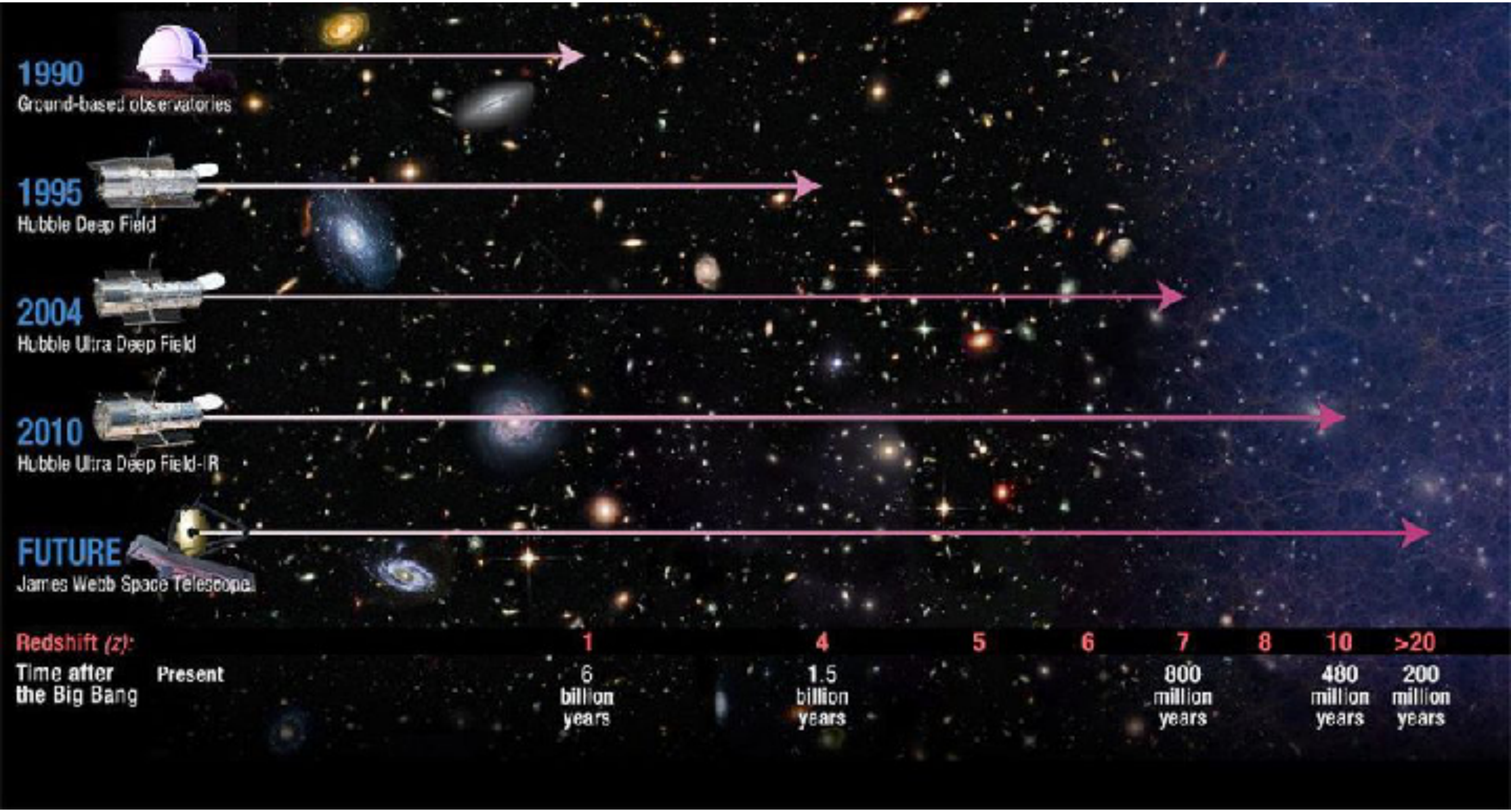
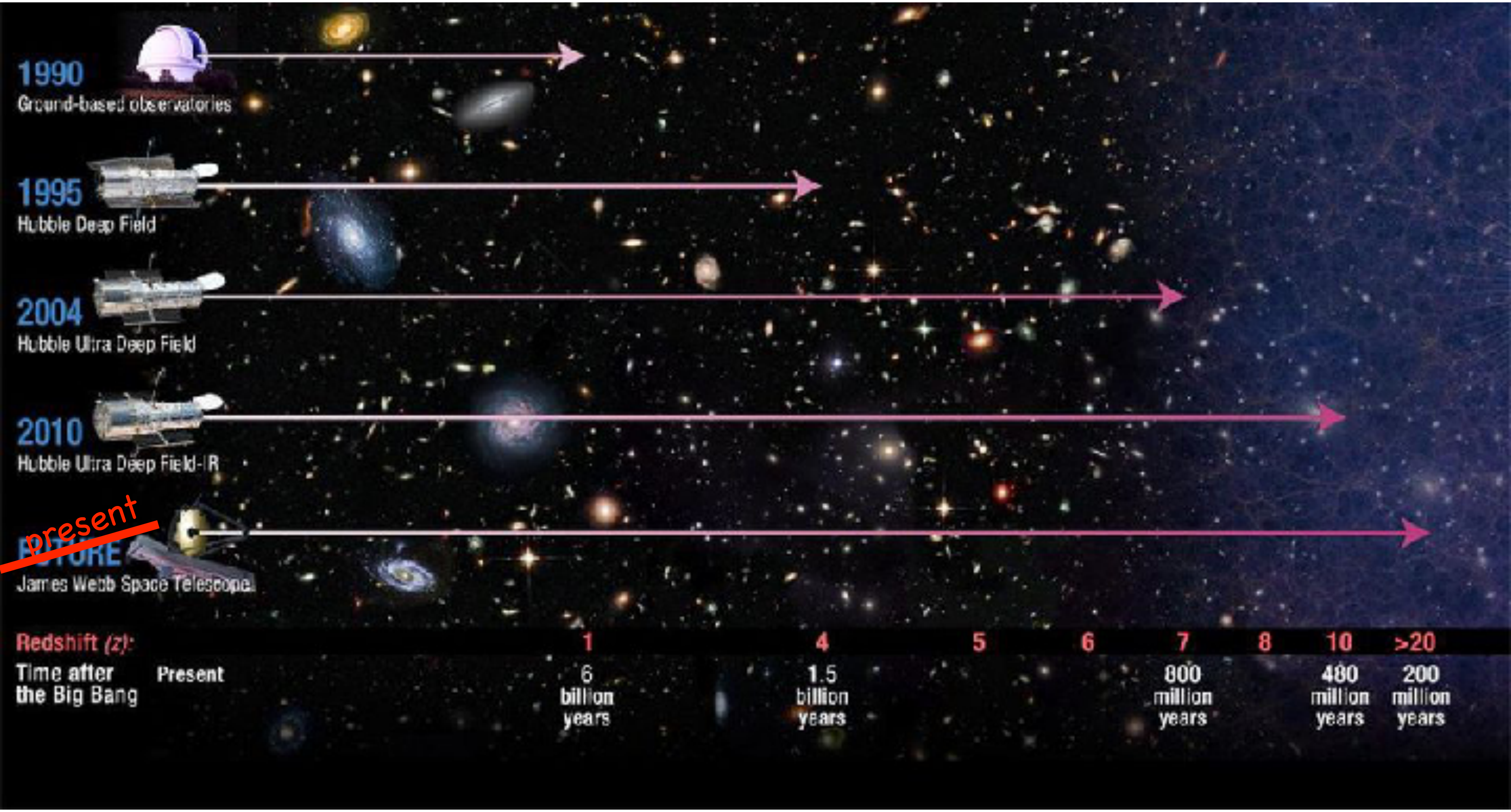
Breakthroughs in studying galaxies through cosmic time



NASA / JWST AND HST TEAMS

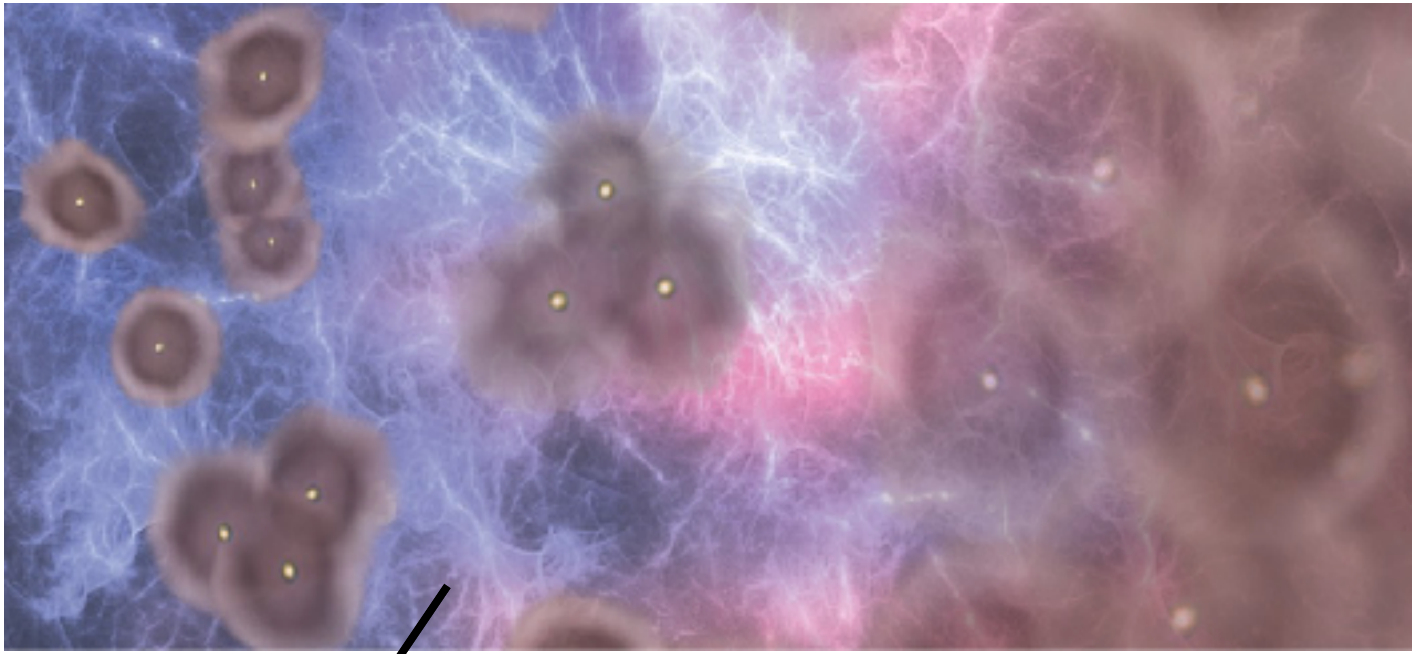
Breakthroughs in studying galaxies through cosmic time



NASA / JWST AND HST TEAMS

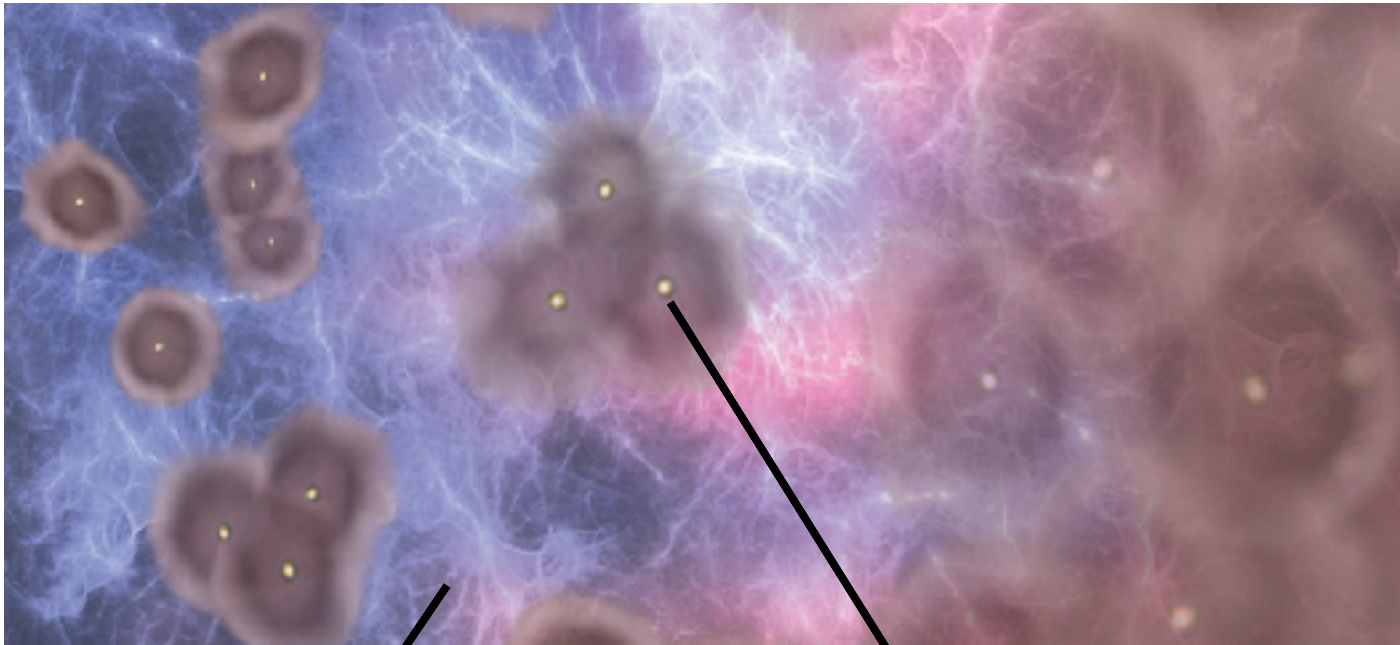
Looking towards the future

Studying the gas between galaxies



21cm emission from neutral hydrogen (SKA)

Studying the gas between galaxies



SKA EoR Synergy group

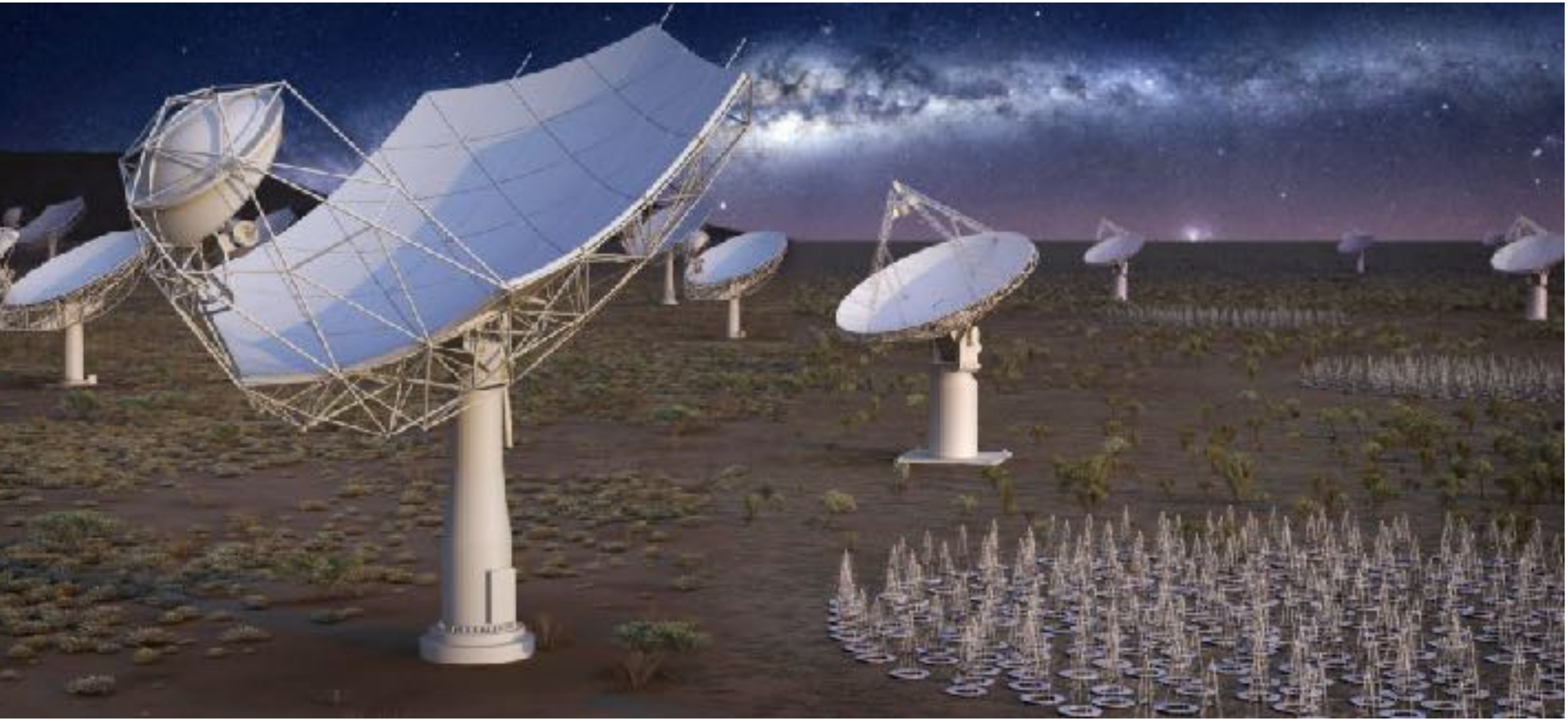
Euclid EoR group

21cm emission from neutral hydrogen (SKA)

Galaxy populations
Subaru, JWST,
NGRST, EUCLID

Neutral hydrogen produces light of a specific length corresponding to 21cm. Cross-correlating 21cm with galaxy data is one of the only ways of understanding the sources of reionziation.

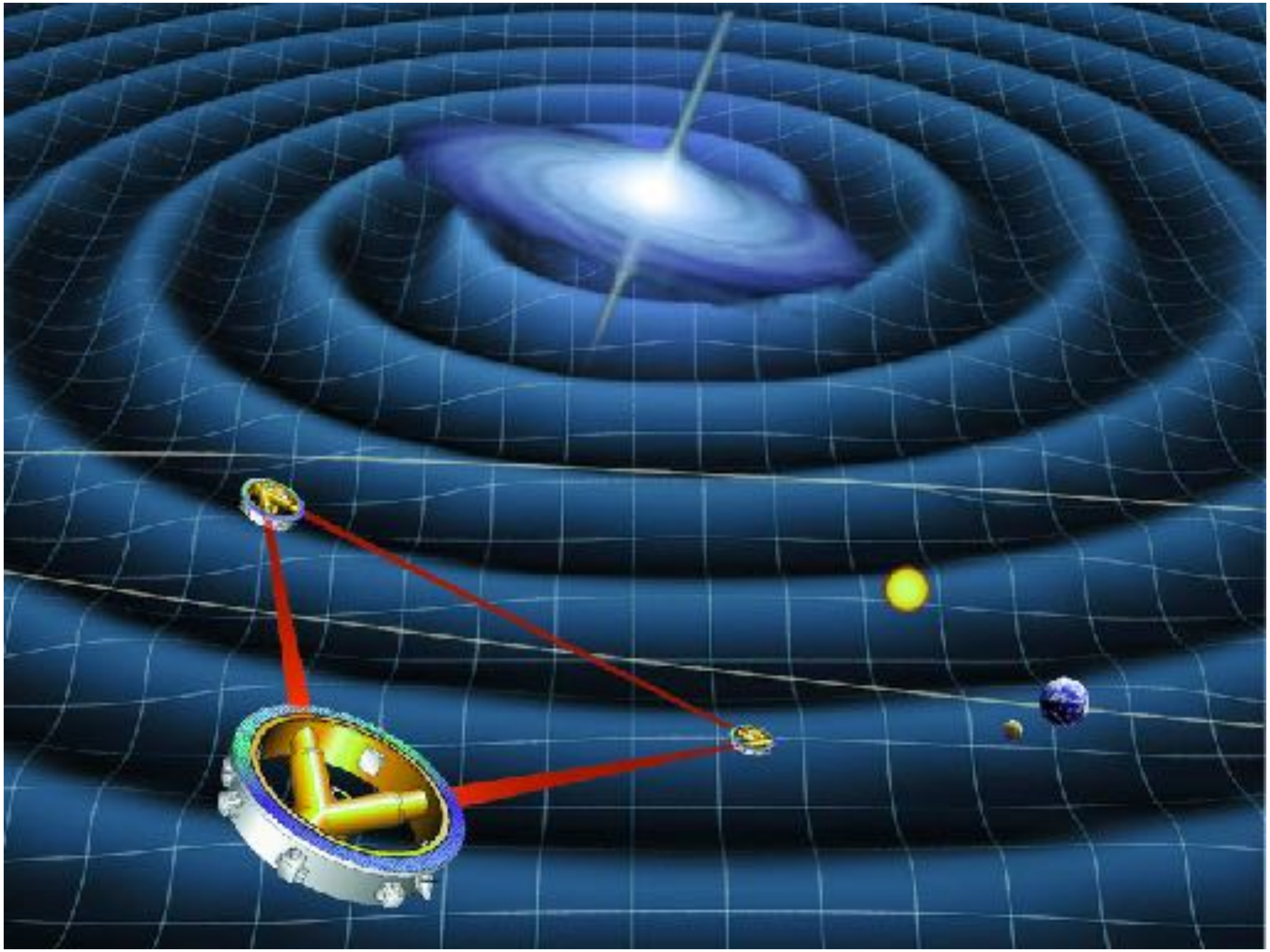
Mapping out the gas in space: the square kilometre array



The Square Kilometre Array will be “the” state of the art facility to study the evolution of neutral hydrogen through cosmic time

https://www.skatelescope.org/the-ska-project/

Looking at merging black holes through cosmic time: LISA



www.elisascience.org/

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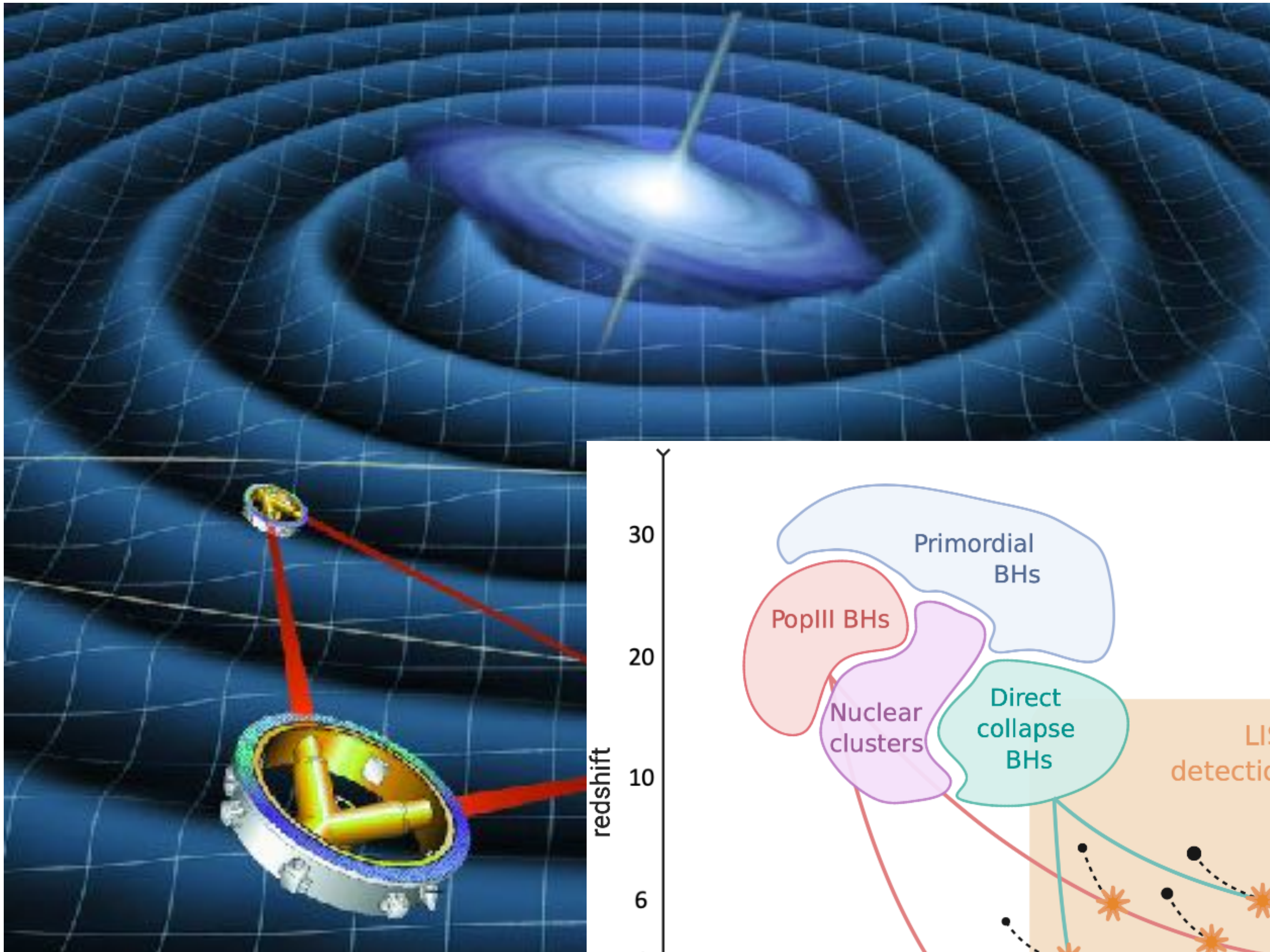

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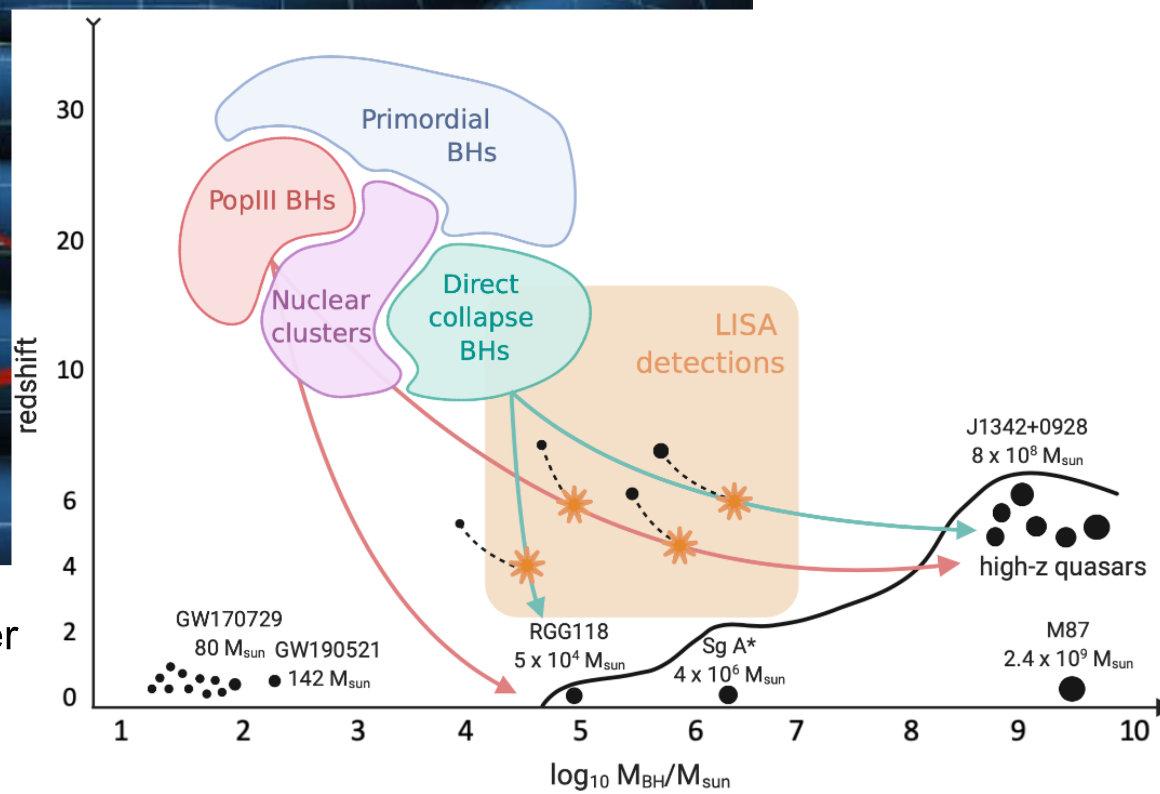
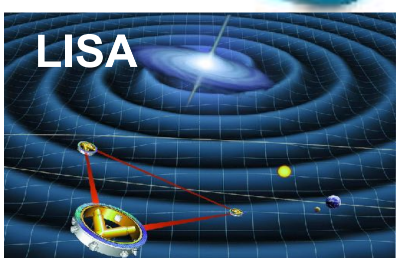


LISA astrophysics white paper
arXiv:2203.06016

Towards a panchromatic picture of galaxy formation

SKA
SQUARE KILOMETRE ARRAY



Global properties of galaxy populations
number of galaxies as a function of redshift, their star formation rates and stellar masses

Individual galaxy properties
constraints on assembly histories, dust formation mechanisms, gas masses

Cosmology
21cm constraints on topology and history of reionization; constraints on DM particle mass

Gravitational wave astronomy
constraints on black hole masses, abundances; constraints on black hole seeding and growth channels