

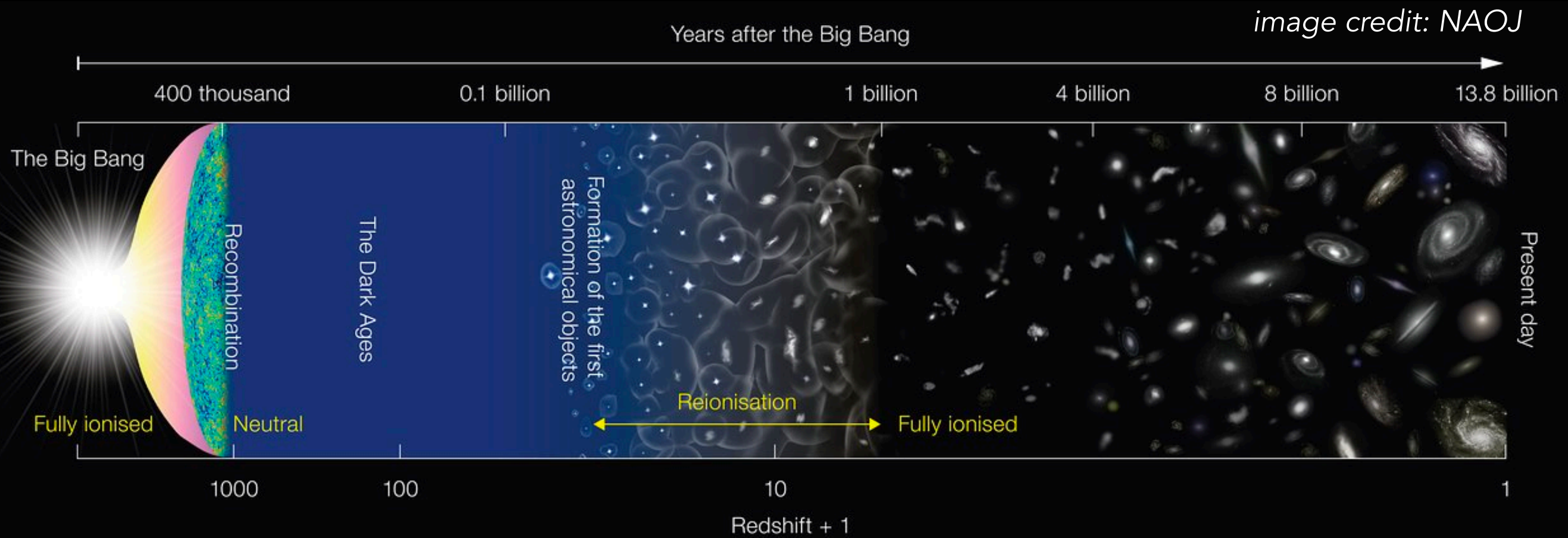
Secondary Anisotropies with CMB Probe+

A full sky millimeter/submillimeter-wave polarimetric imager and
spectrometer

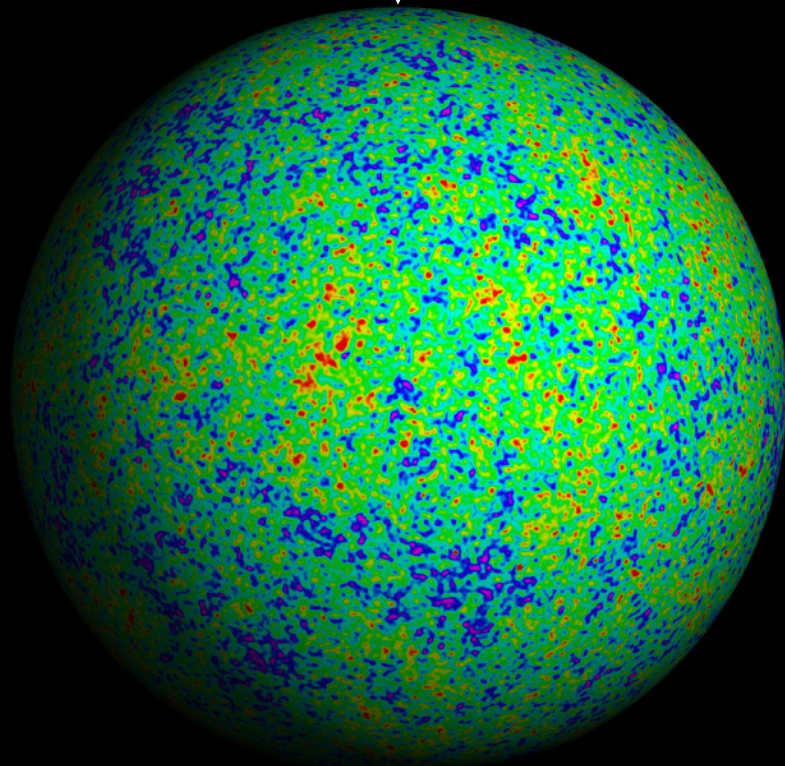
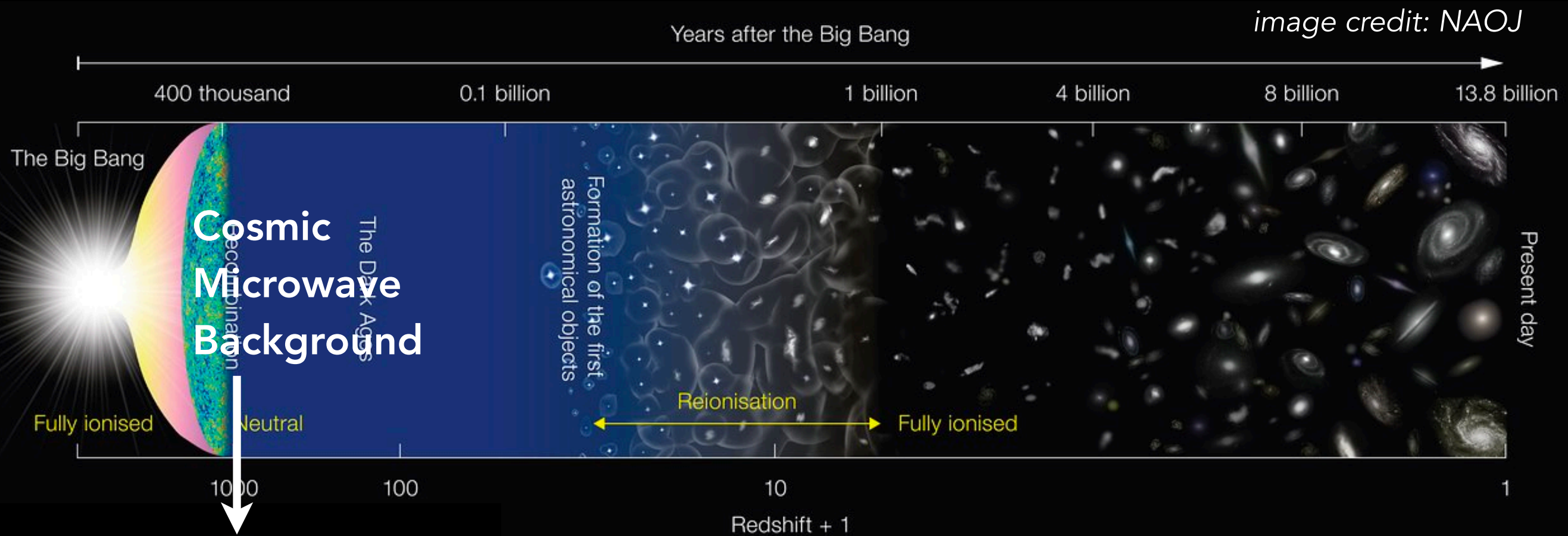
Emmanuel Schaan, in for Srinivasan Raghunathan



The Universe as a fundamental Physics laboratory



The Universe as a fundamental Physics laboratory



Tegmark, WMAP3

The Universe as a fundamental Physics laboratory

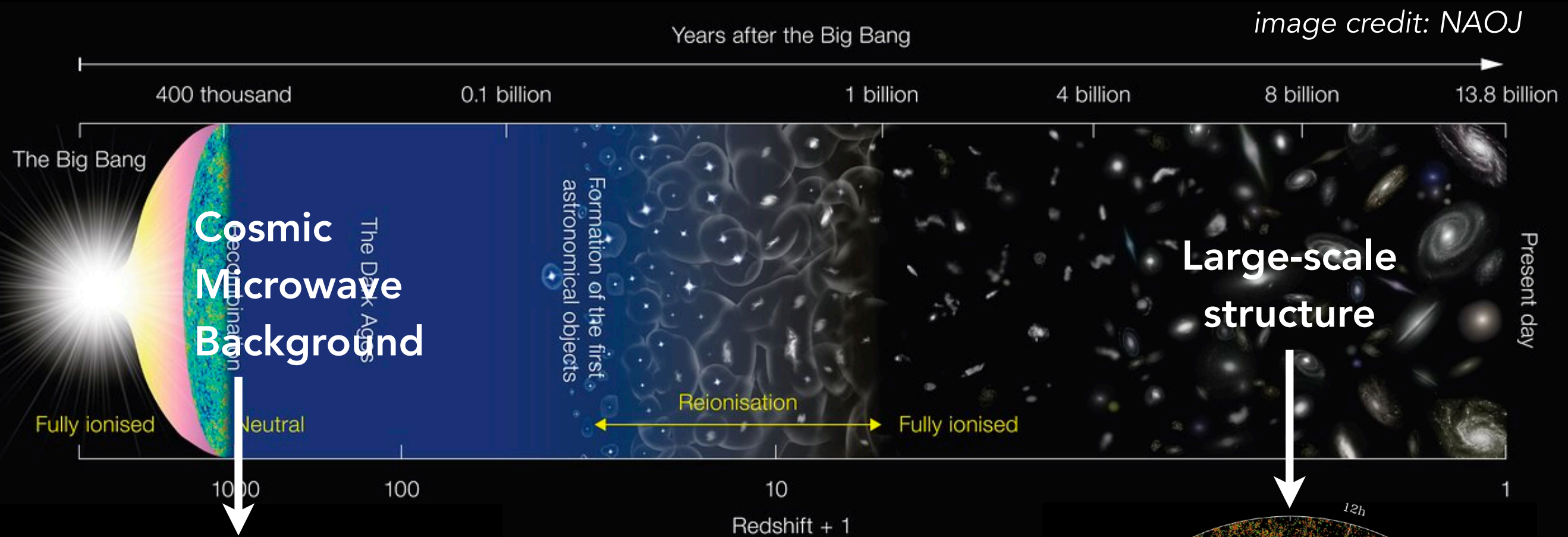
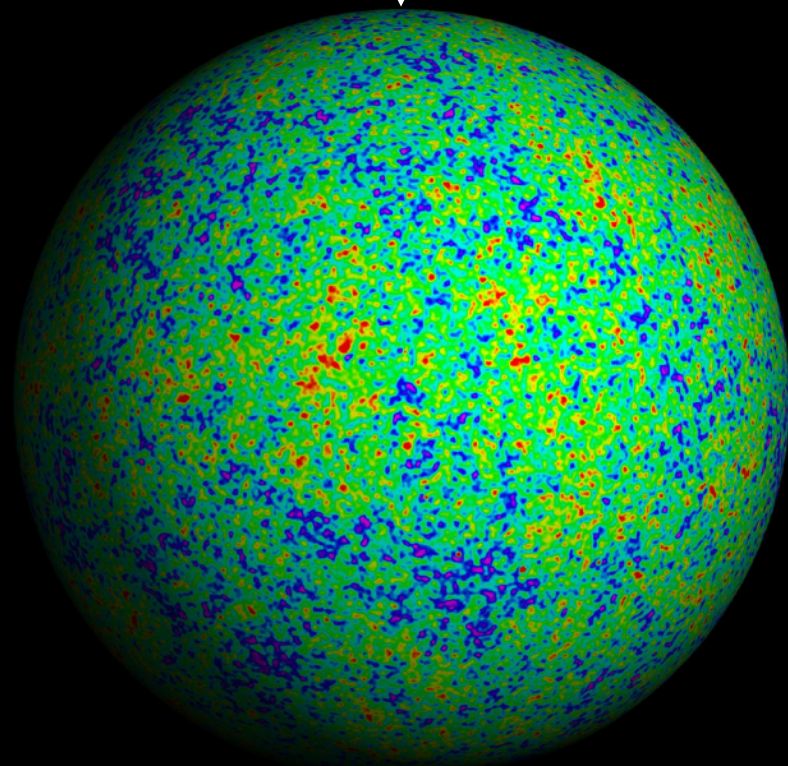
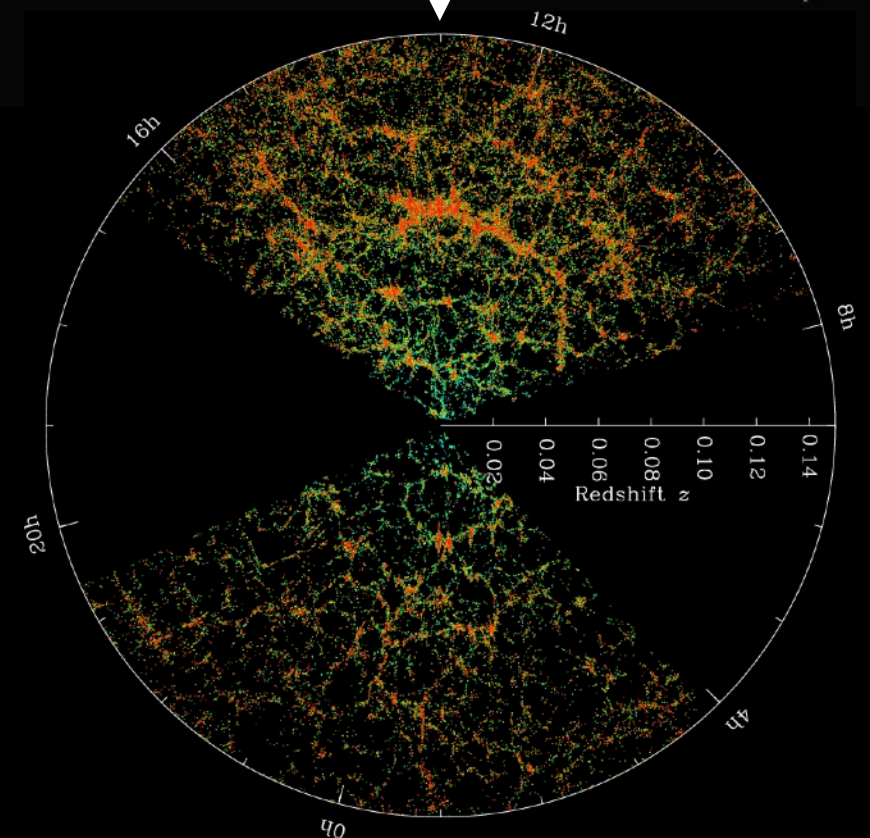


image credit: NAOJ

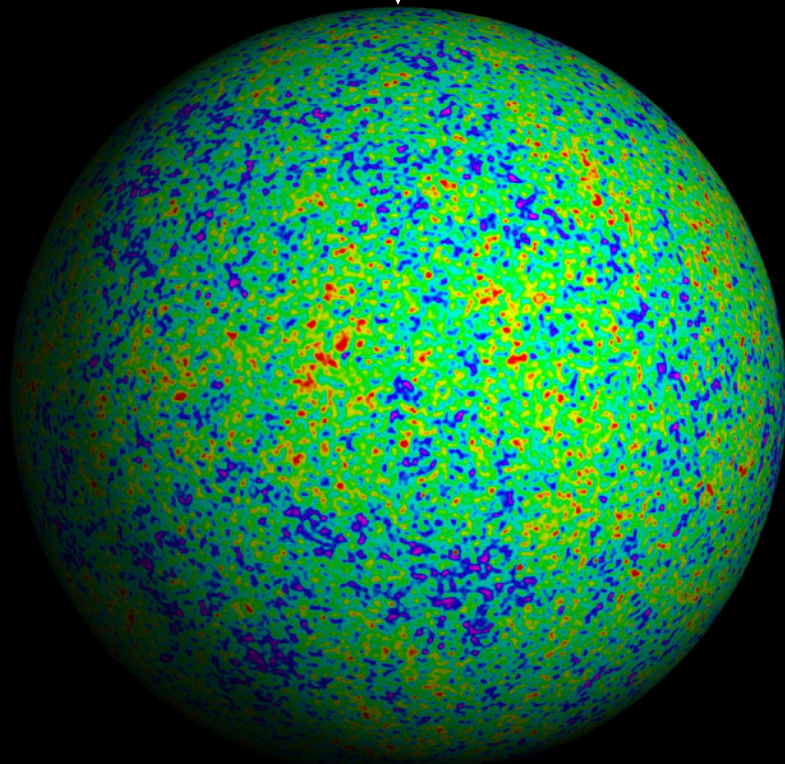
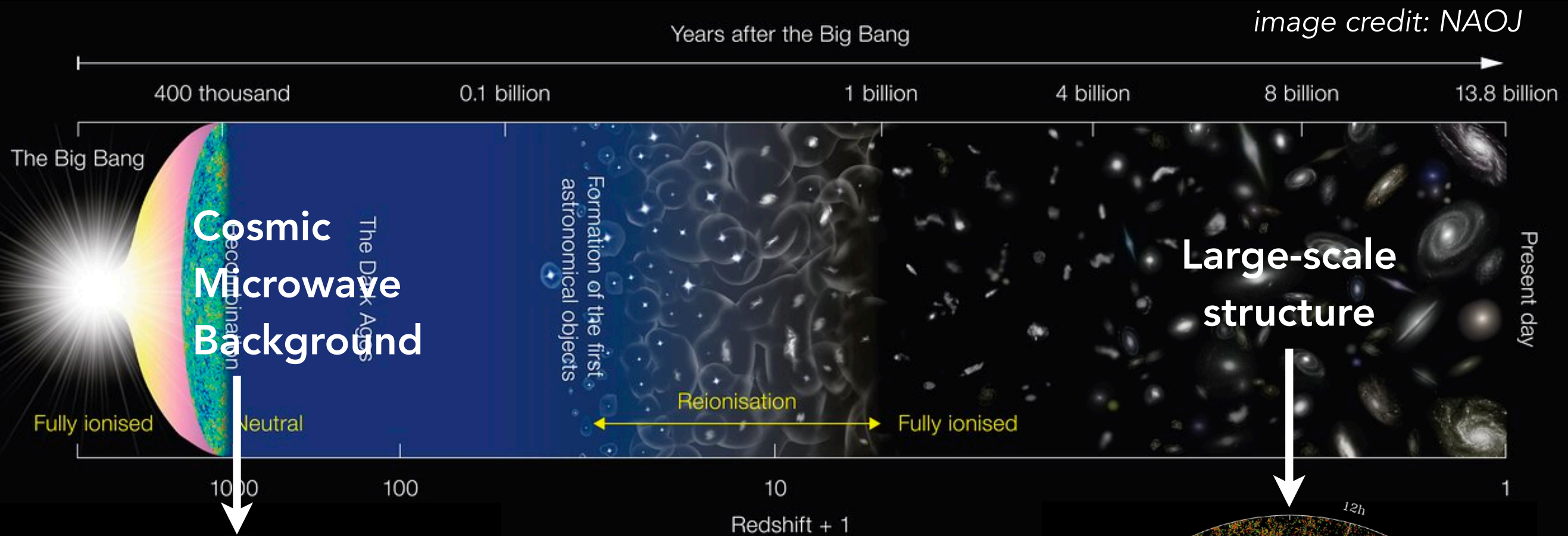


Tegmark, WMAP3



Blanton, SDSS

The Universe as a fundamental Physics laboratory



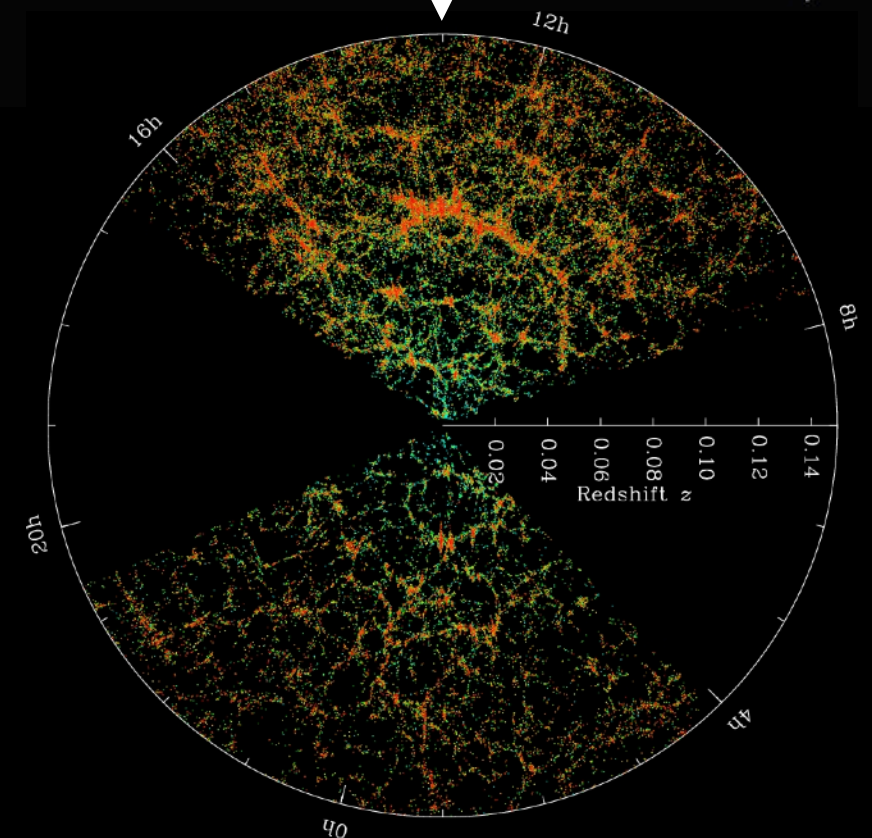
Tegmark, WMAP3

Dark energy

Dark matter

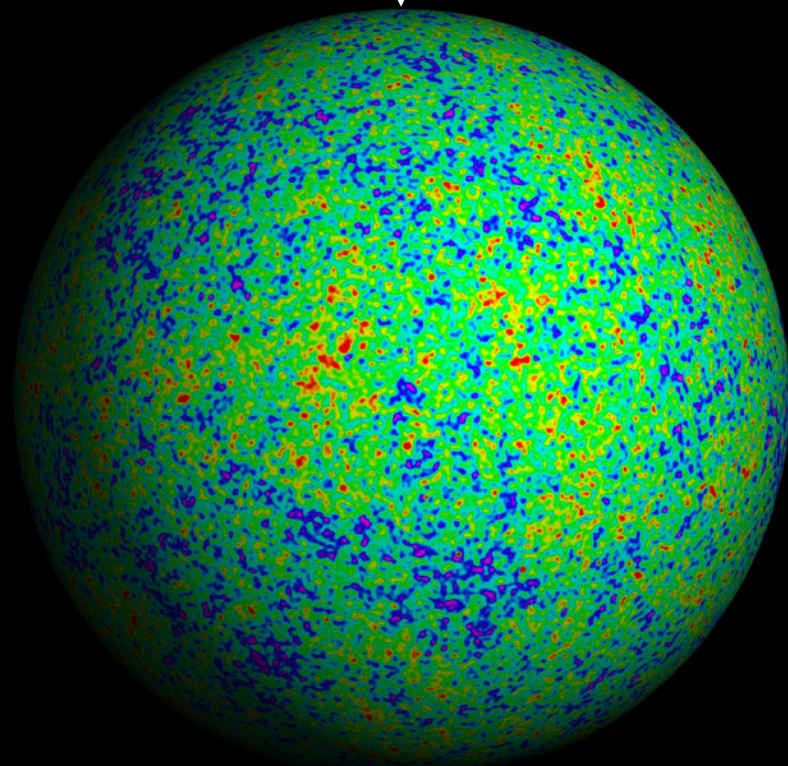
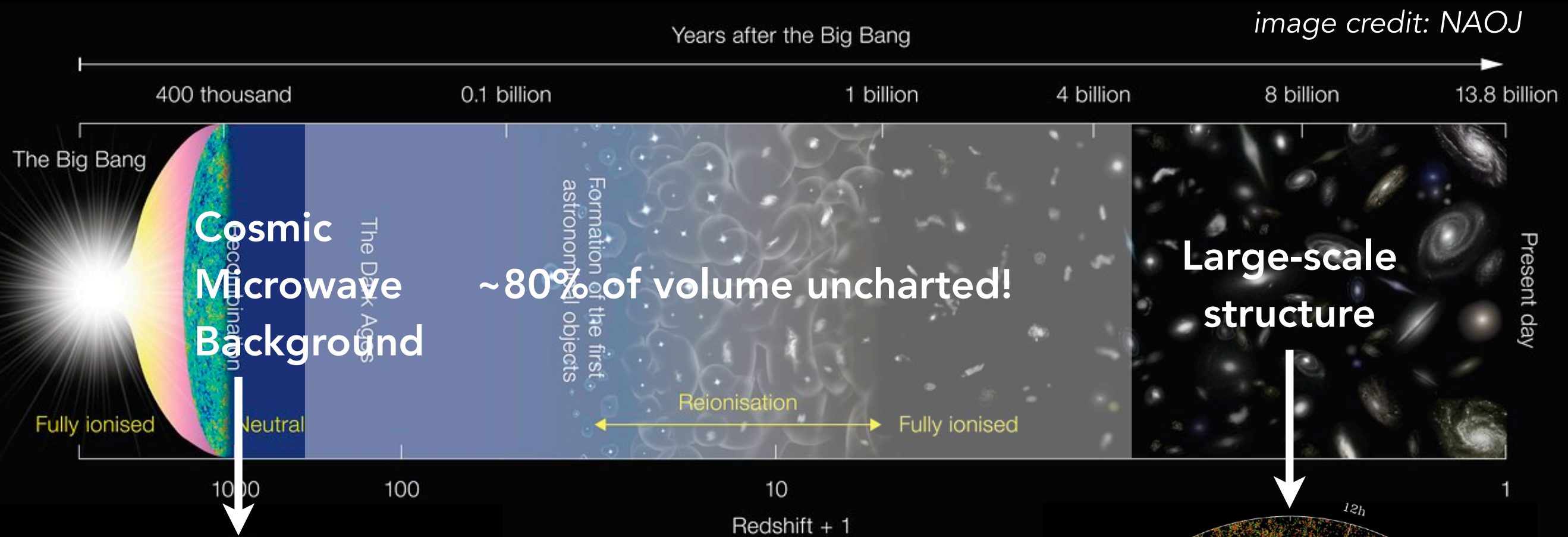
Inflation

Neutrinos



Blanton, SDSS

The Universe as a fundamental Physics laboratory



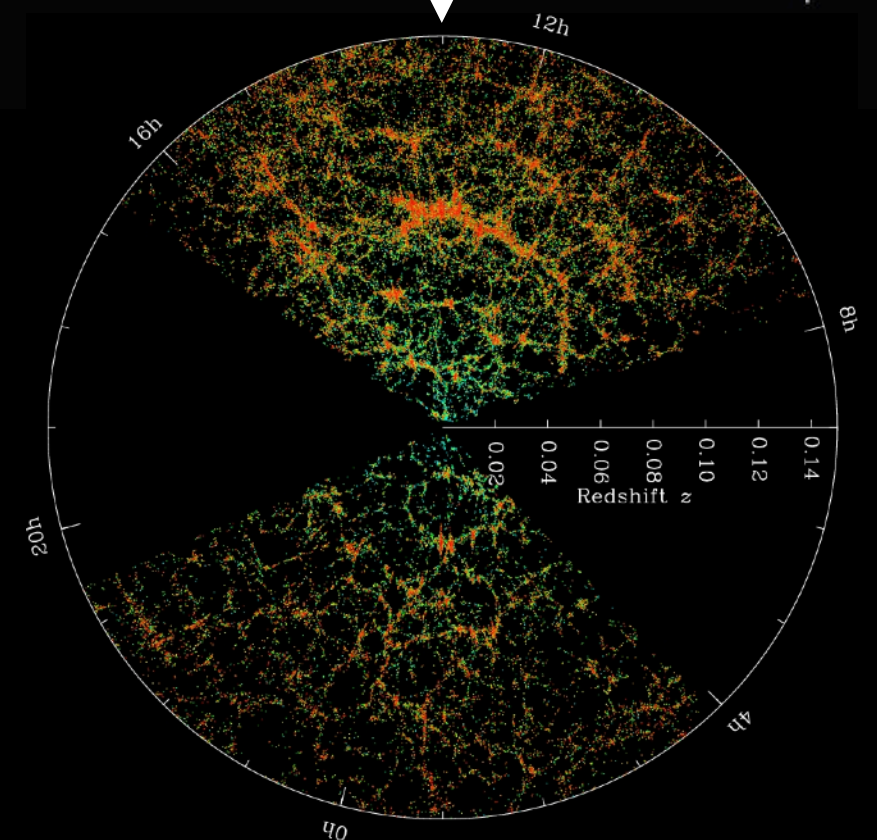
Tegmark, WMAP3

Dark energy

Dark matter

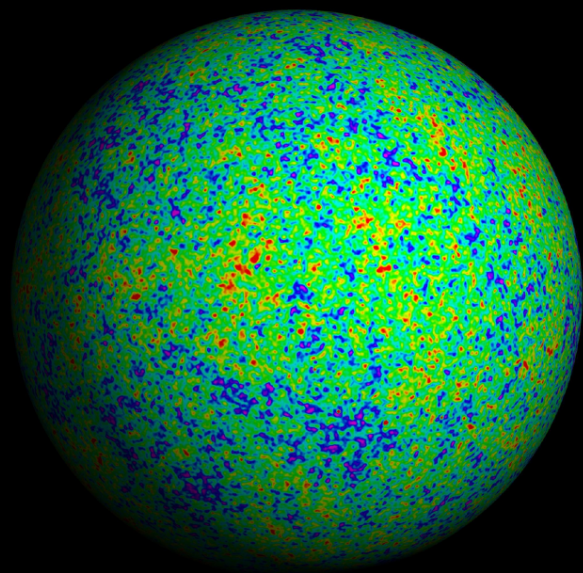
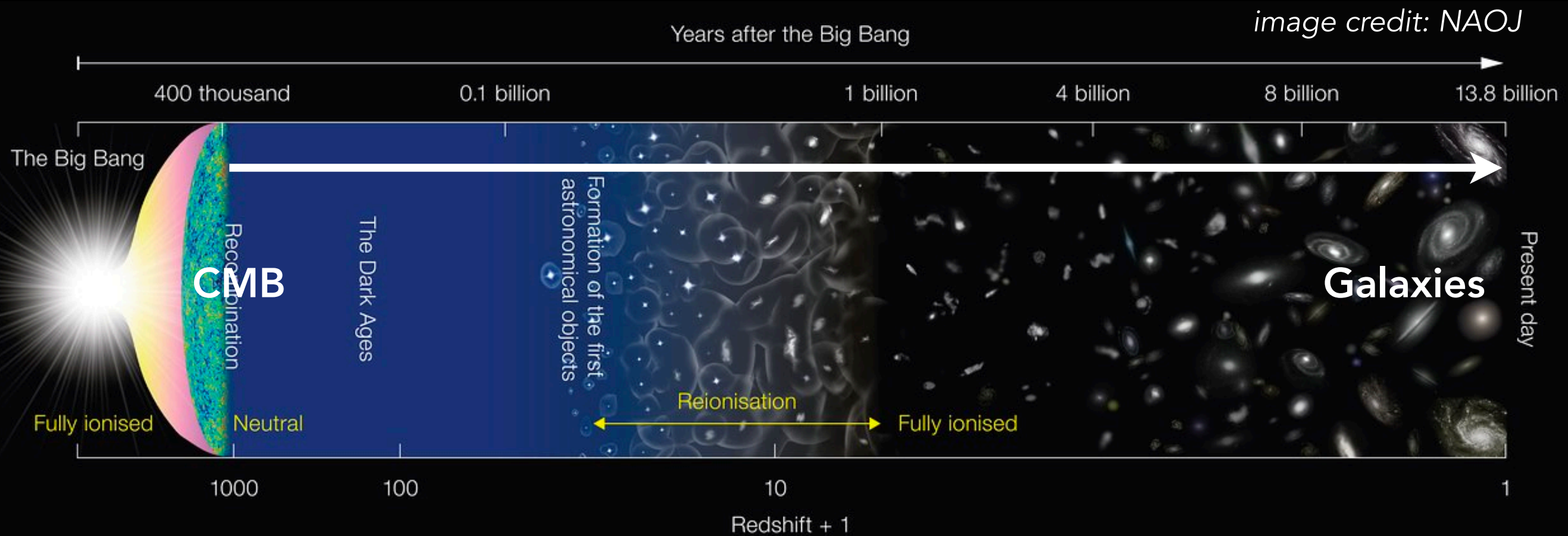
Inflation

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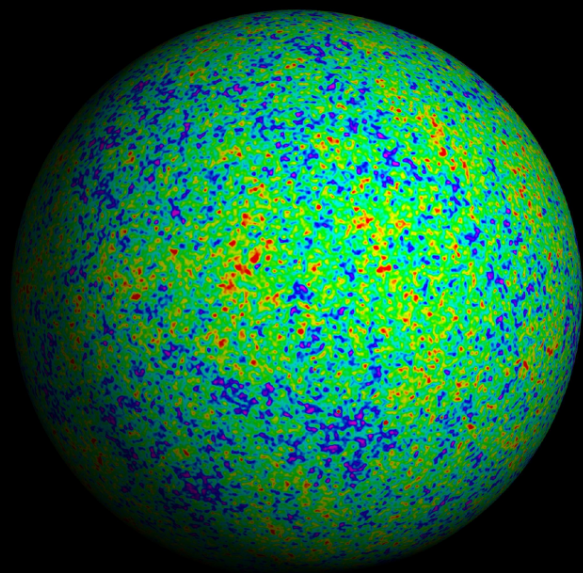
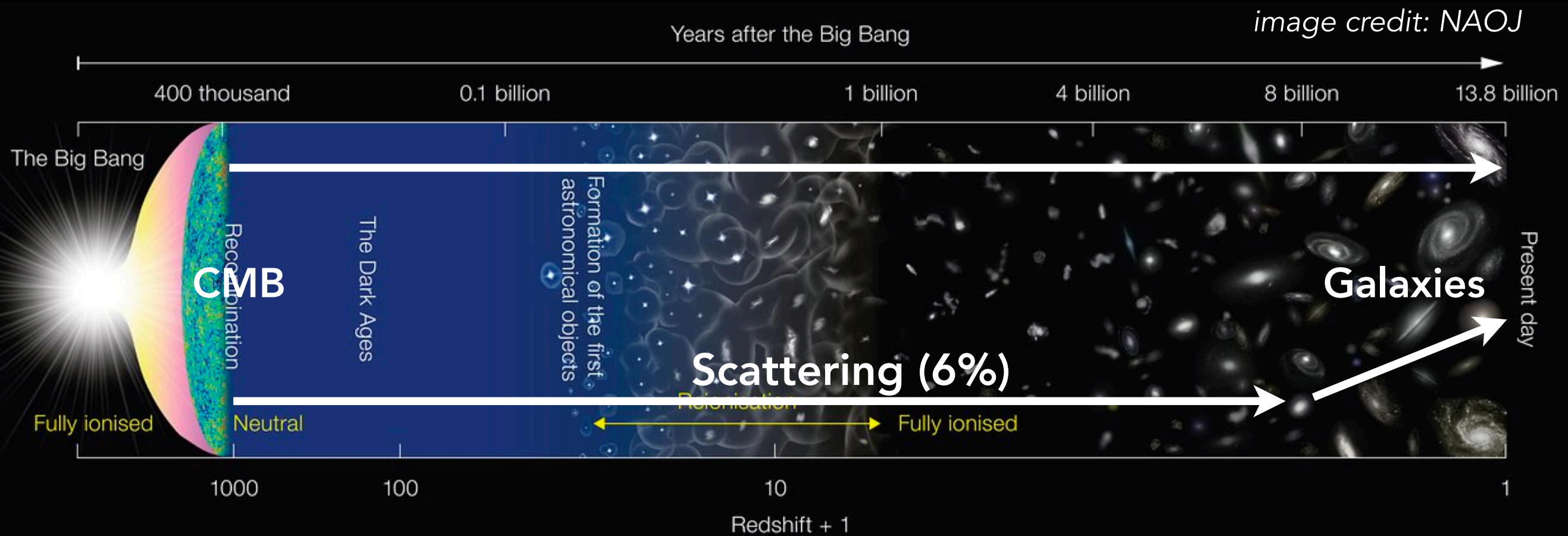
Blanton, SDSS

Backlighting the galaxies with the CMB

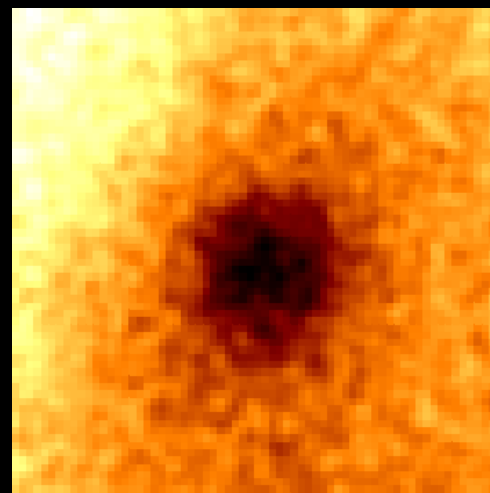


Initial conditions

Backlighting the galaxies with the CMB

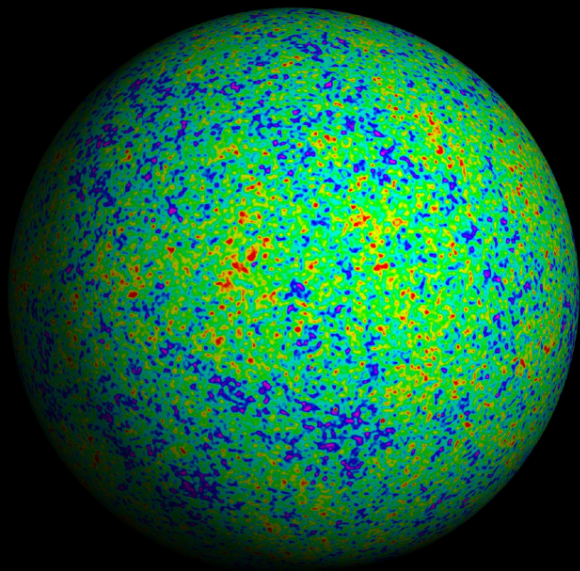
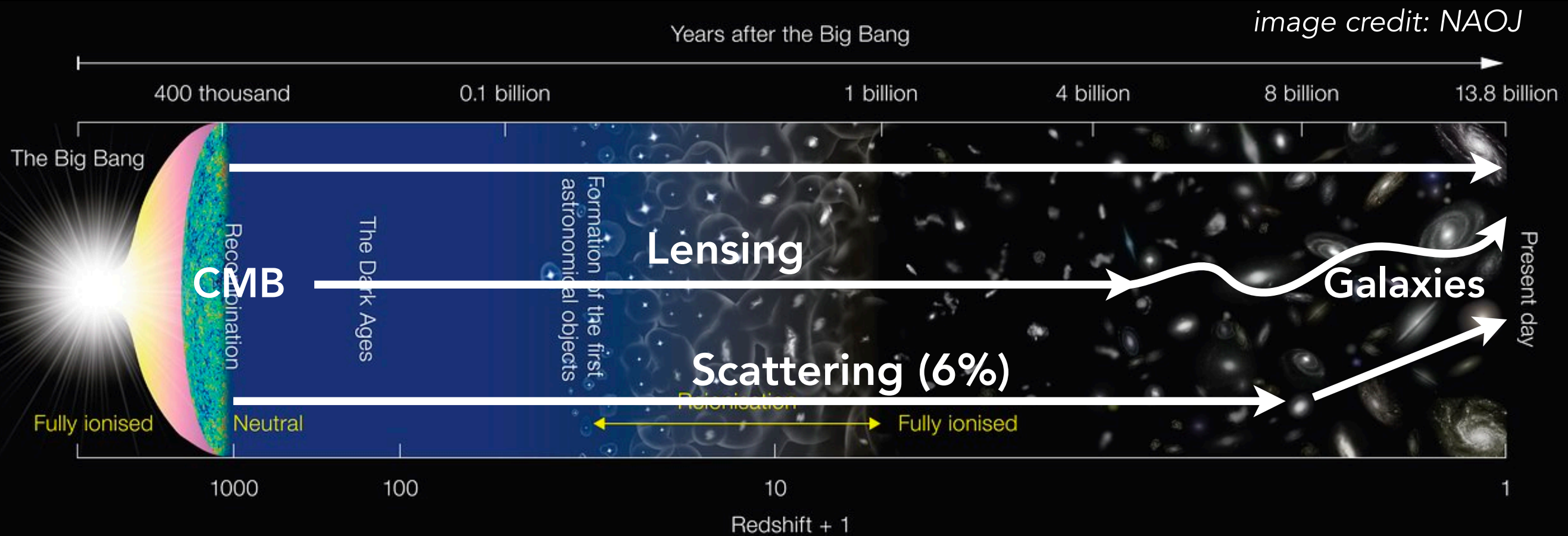


Initial conditions

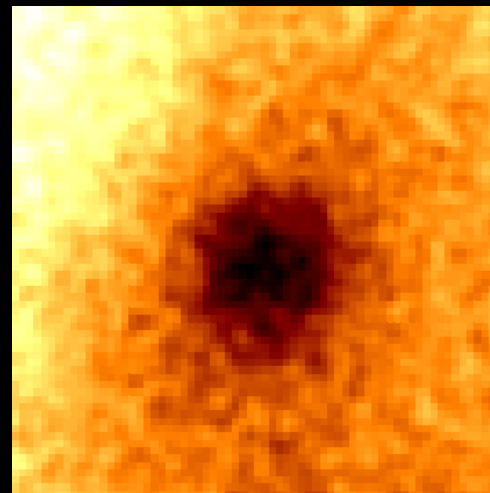


Scattering:
Gas shadows

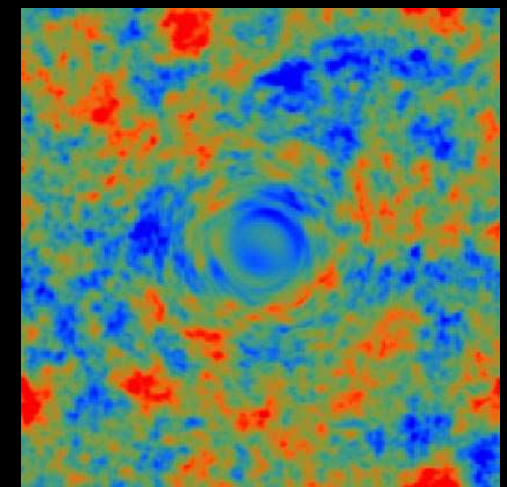
Backlighting the galaxies with the CMB



Initial conditions



Scattering:
Gas shadows



Lensing:
Mass shadows

CMB secondaries: landscape & next frontier

CMB lensing at 60σ Planck+ACT+SPT *Qu+25*

Need full-sky, foreground control, high-sensitivity, **Kimmy Wu's talk**

>10k tSZ clusters, first relativistic tSZ measurements

Need full sky, uniform selection, gas temperature, control dust & radio, high redshift

kSZ hints at large feedback in galaxy formation *Schaan+21, Hadzhiyska+24*

Need tSZ to measure non-thermal pressure, energy injection in gas

Dark energy & neutrinos call for tau re-measurements *Sailer+25, Jhaveri+25*

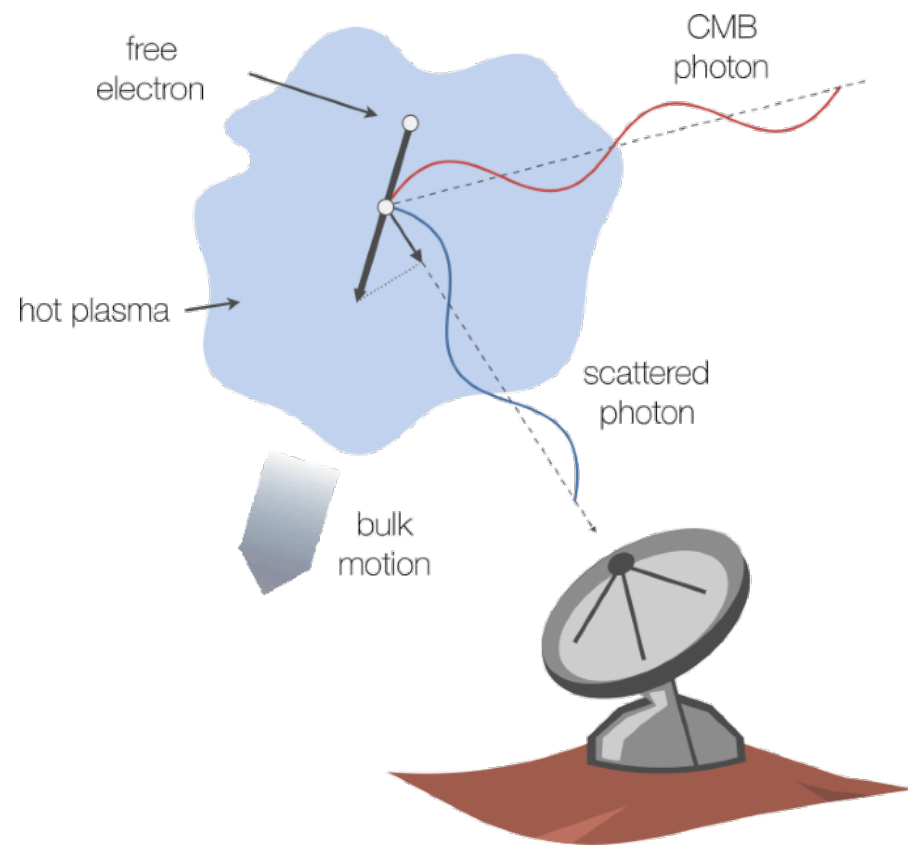
Need largest scale, L2 thermal stability, two independent handles on tau (EE & kSZ),

Daniel Green's talk

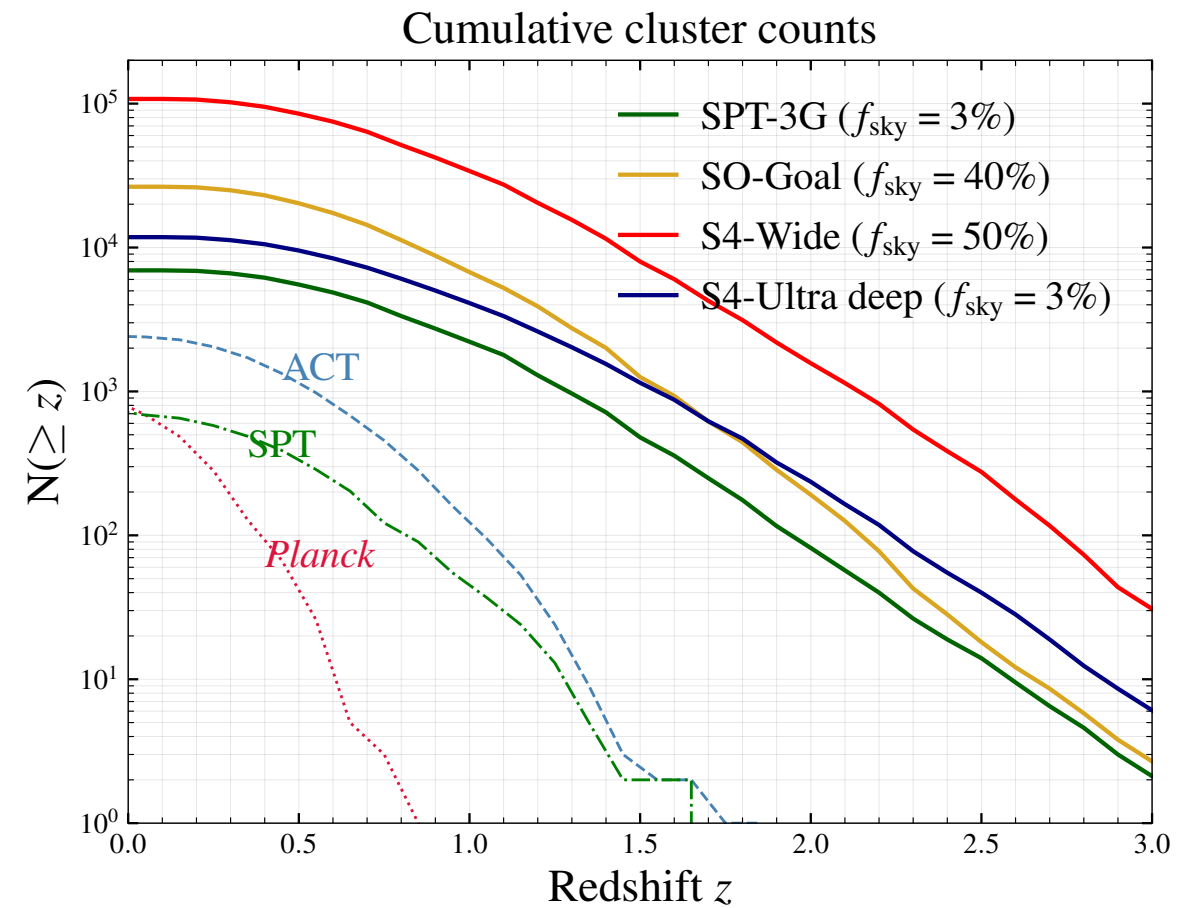
→ **Need space stability & largest scales, large frequency range**

→ **CMB Probe+**

Full-sky tSZ cluster census, with temperatures



Mroczkowski+19



Raghunathan 22, Raghunathan Alvarez Battaglia+22

CMB Probe+: 150k tSZ clusters (VS 30k for SO)

Space → Full sky, uniform selection

Frequency coverage → control dust & radio contamination

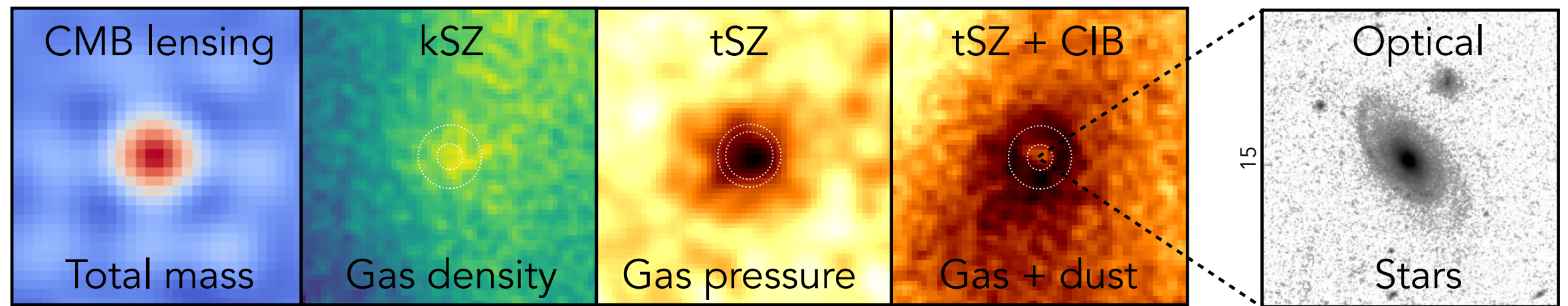
Relativistic SZ → gas temperatures

CMB lensing → internal mass calibration

Northern hemisphere → overlap with DSA2000 FRBs, DESI, Spec-S5, etc

→ σ_8 , dark energy, structure formation beyond cosmic noon, protoclusters

Feedback in galaxy formation: tSZ x everything



Schaan+21

Ground-based resolution ideal for kSZ gas density profiles

Space-based freq coverage ideal for tSZ, rSZ, dust & radio profiles

→ **Full gas thermodynamics inside halos, non-thermal pressure, energy injection**

tSZ power spectrum to 0.1% on large & small scales

→ **Cosmology & feedback**

Full sky enables overlap & tSZ x shear/CMB lensing/galaxies, function of z

→ **Break degeneracies**

Reionization beyond one integral: when, how long, high-z tail?

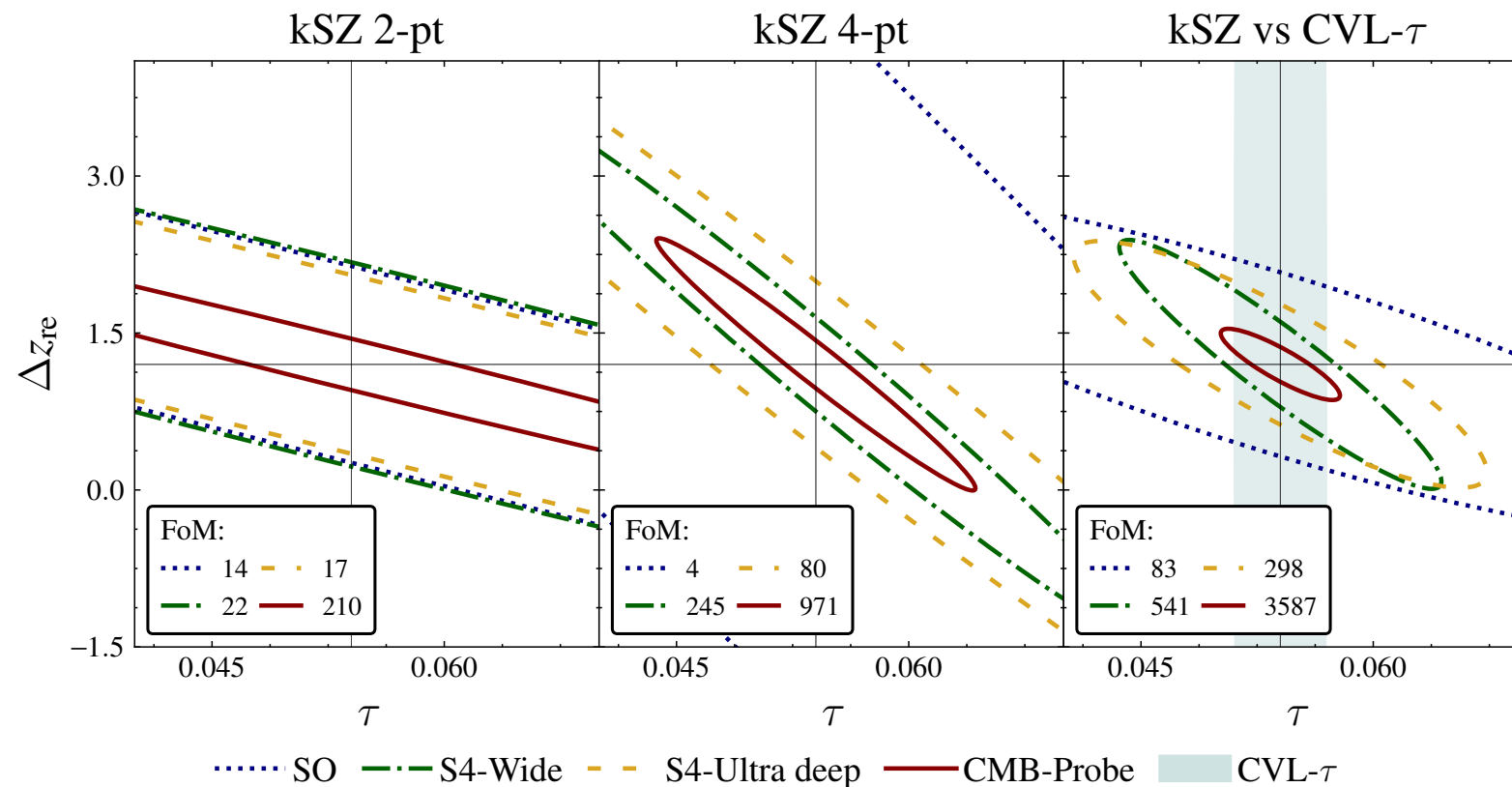


Figure: Raghunathan

τ from 2 independent channels: EE & kSZ

→ Crucial cross-checks for most challenging cosmological parameter

kSZ 2pt & 4pt provide independent integrals over ionization history

→ Time, duration, potential high-z tail

Foreground subtraction (CIB & tSZ) from multi frequencies: crucial

→ CMB Probe+ is ideal

Synergy with JWST, Roman

Conclusions: Secondaries with CMB Probe+

Full-sky CMB lensing at 600σ , foreground cleaned, from T & P

→ Delensing, tomography with Euclid, Roman, Spec-S5, 21cm

Full-sky 150k tSZ clusters with masses & temperatures, foreground cleaned

→ σ_8 , dark energy, structure formation beyond cosmic noon, protoclusters

Cosmology & galaxy formation from tSZ x everything

→ Full gas thermodynamics, non-thermal pressure, energy injection in gas

τ & reionization time, duration, high-z tail

→ Redundancy from EE VS kSZ, crucial input for dark energy, neutrinos

➡ CMB Probe+ transformative!

