

# Concluding Remarks

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February 19, 2020 Kavli IPMU

*Send your slides  
to Masahiro*





# Phases of cosmic expansion

3 pillars of science

A03

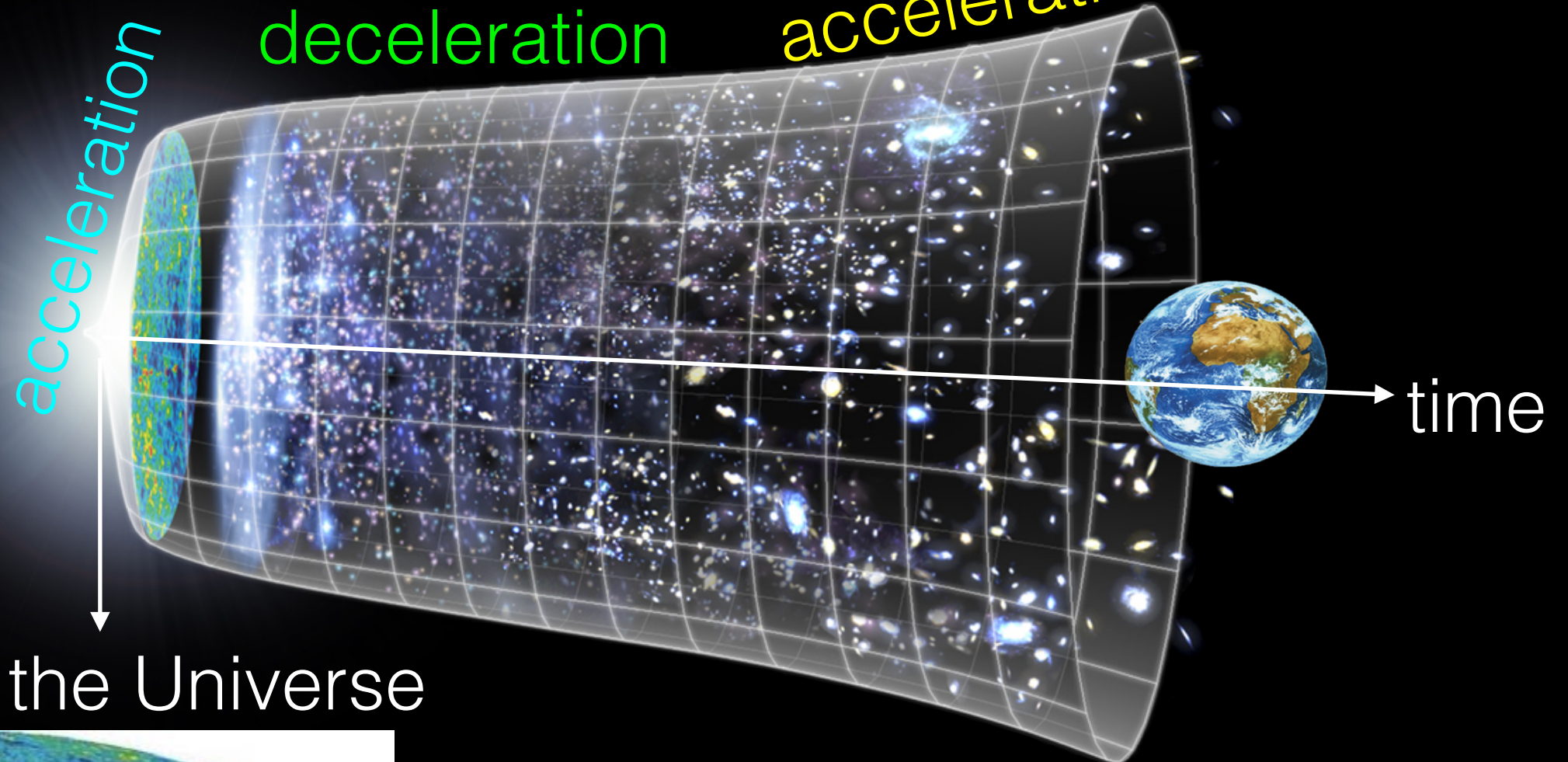
dark energy

acceleration

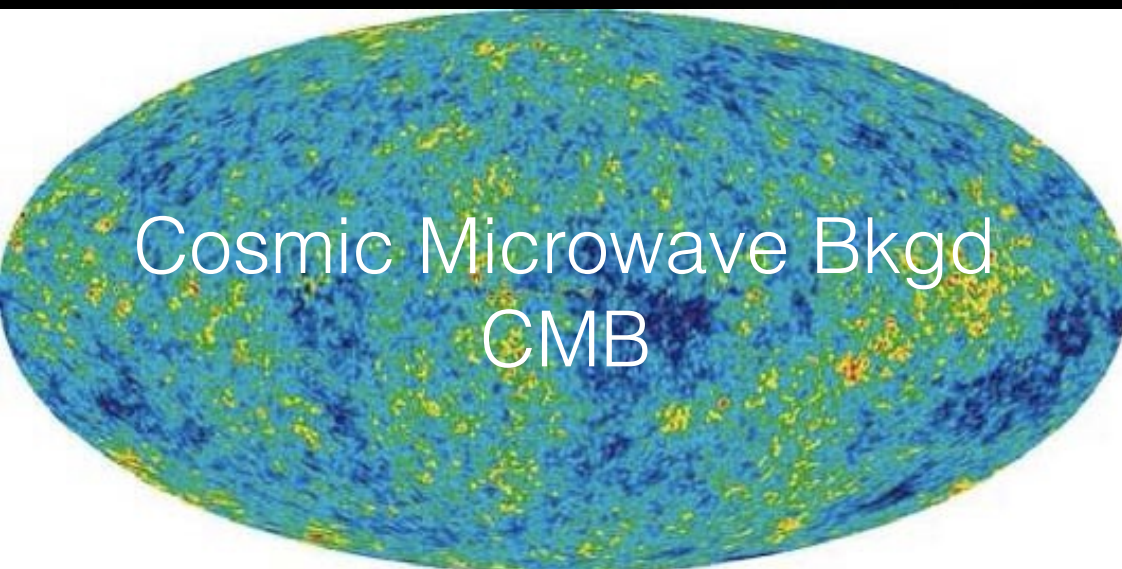
A02 dark matter  
deceleration

A01  
Inflation

acceleration



size of the Universe



Cosmic Microwave Bkgd  
CMB

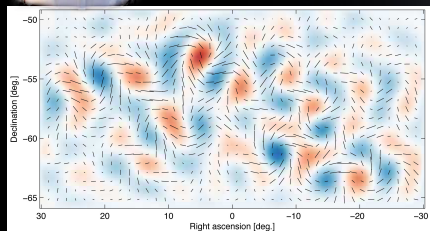
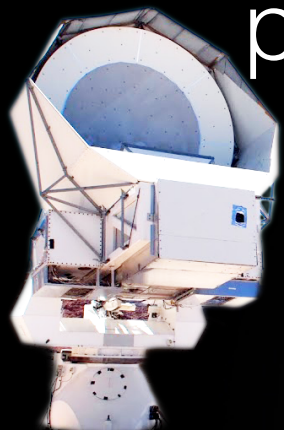
2011 Nobel Prize in Physics



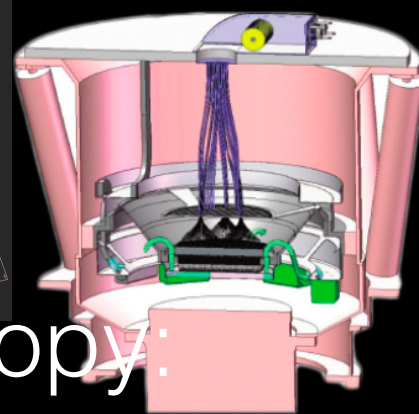
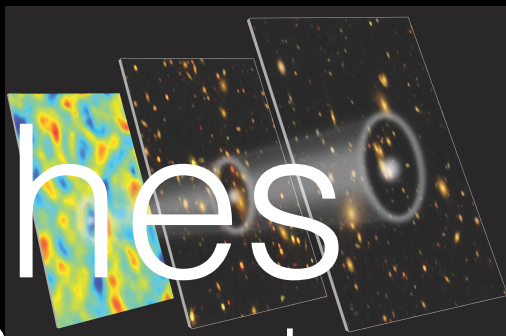


# 4 Approaches

B01: CMB  
polarization



B03: spectroscopy:  
3D

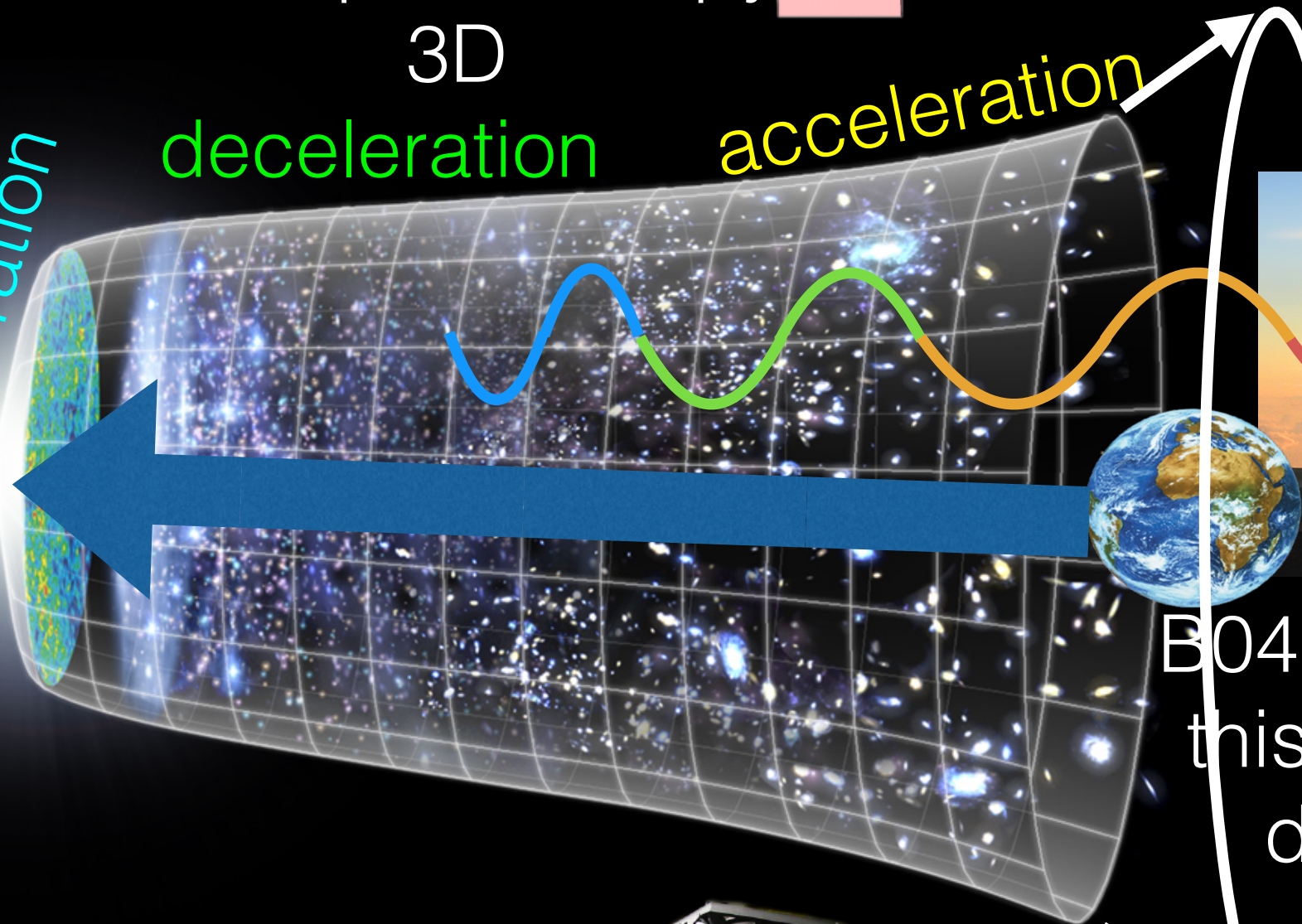


10 yrs later

acceleration

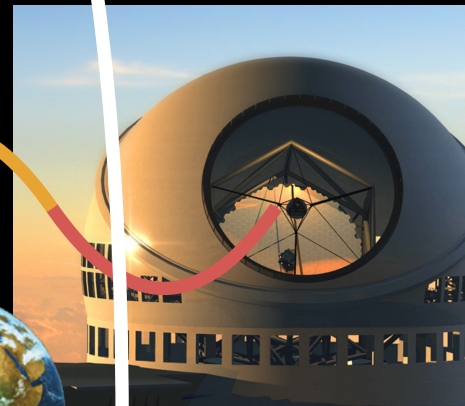
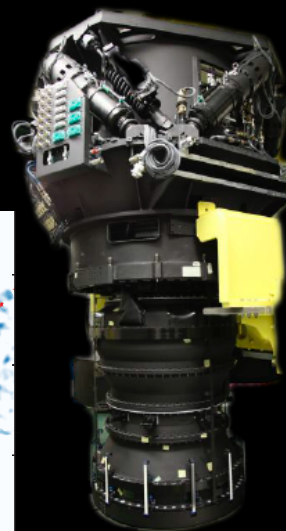
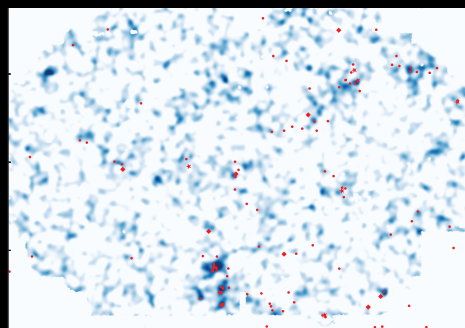
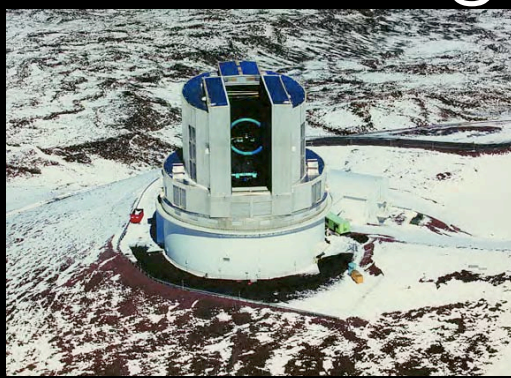
deceleration

acceleration



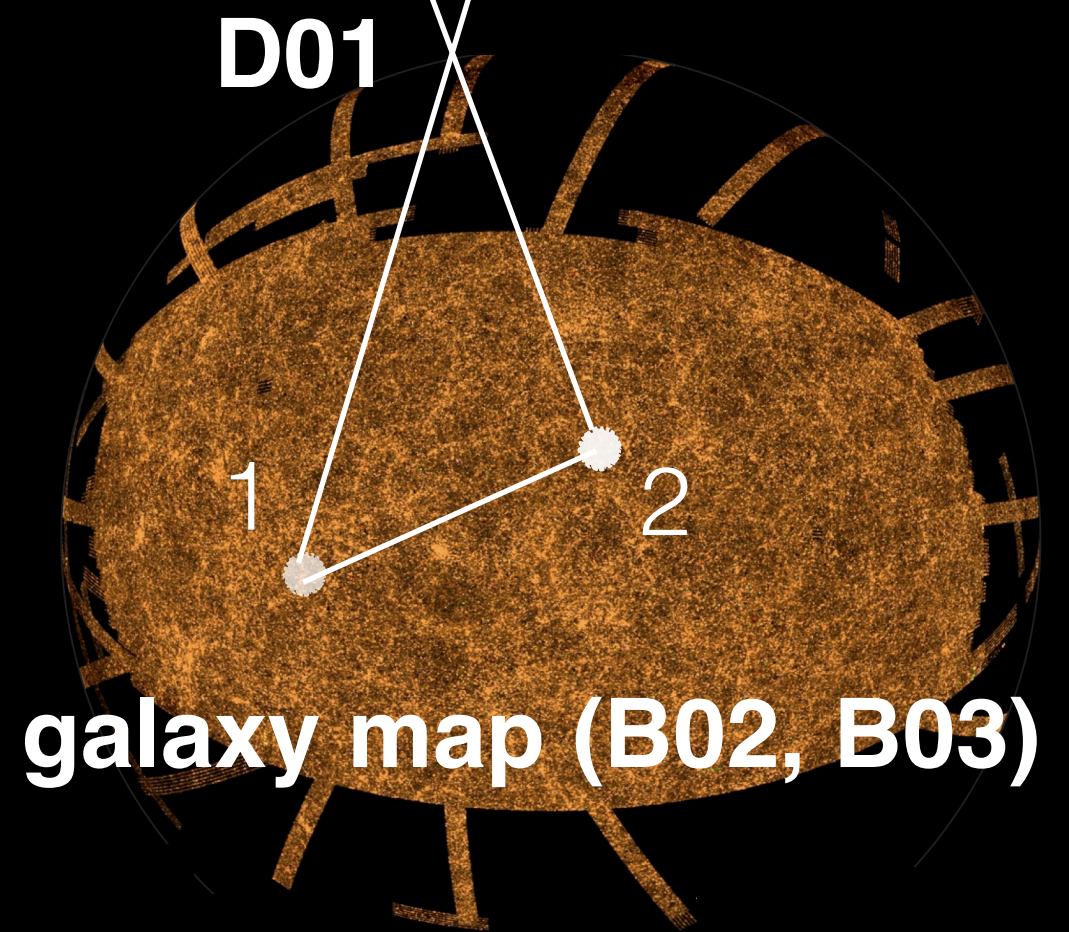
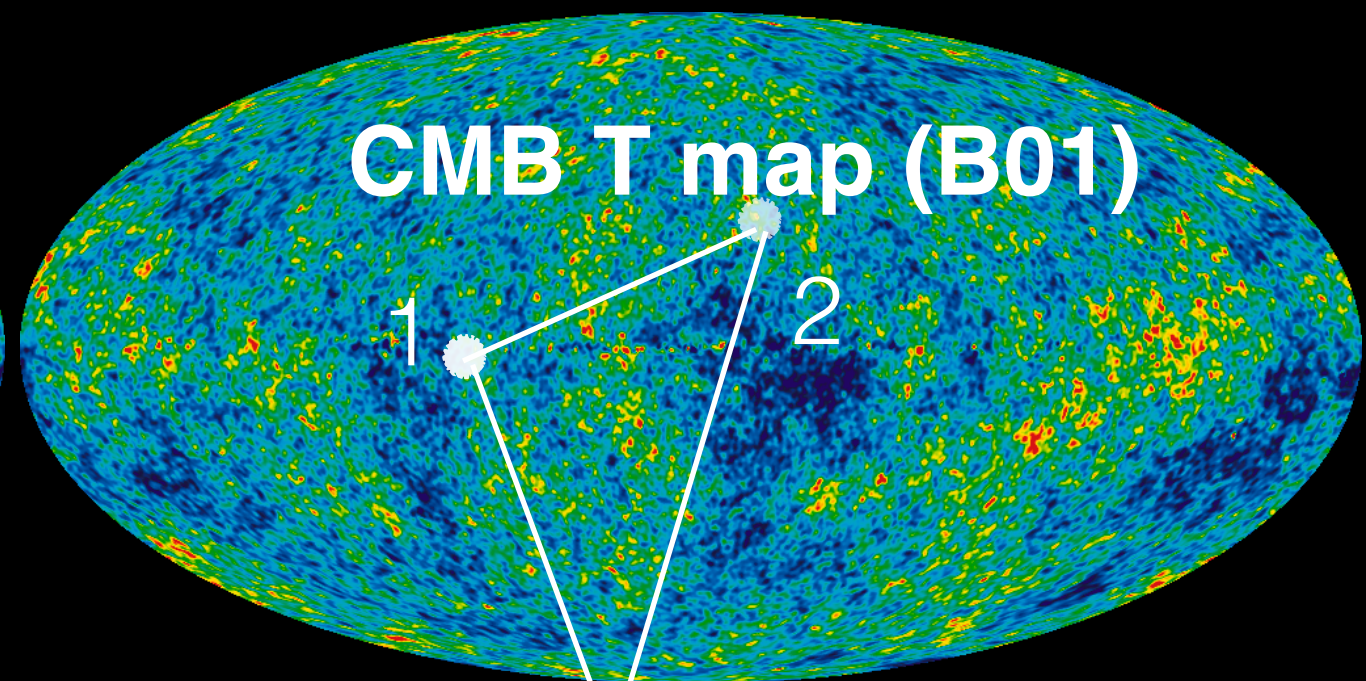
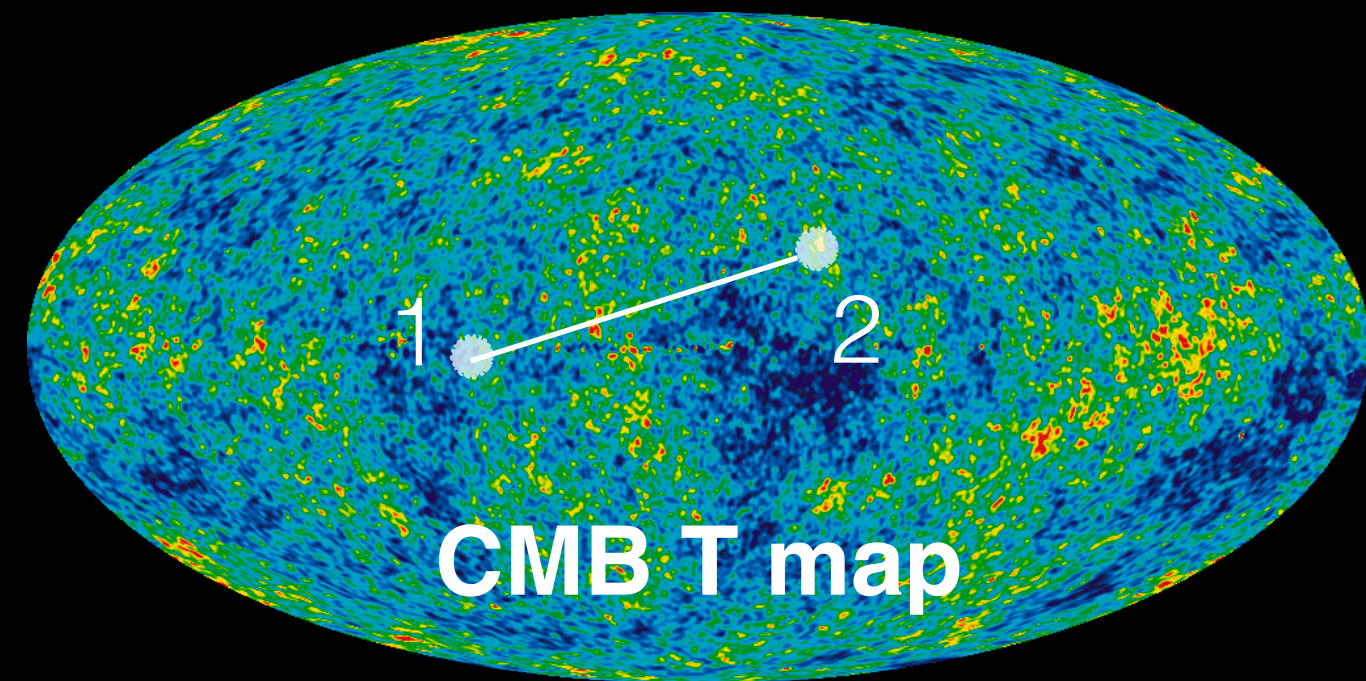
B04: measure  
this change  
directly

B02: imaging : 2D





# D01: combination $\Rightarrow$ synergy





	PBH as a consequence [A01] Inflation Sasaki (Kyoto)	new candidates detection method [A02] ident. & struct. Takahashi (Tohoku)	GW170817 mod grav unlikely [A03] Dark Energy Sugiyama (Nagoya)
hardware R&D LiteBIRD	Simons Array completed	limits on PBH, axion, light DM	$\tau$ vs $w$ $H_0$ tension? $\sigma_8$ tension?
many many HSC papers	PBH limits	dark matter map splash back	HSC cosmic shear
IR detector science case	non- Gaussianity	PFS galactic archaeology	PFS construction
successful R&D	sensitivity study	ultralight dark matter	feasibility demonstration

***PFS construction at full steam with 2022 start!***

***LiteBIRD approved by JAX for 2027 launch!***

important observables at each intersection



# C01: ultimate theory Ooguri(Caltech)

Universe before inflation?

Birth of time?

quantum gravity? string?

other dims? end of Universe?

Multiverse?

swampland  
de Sitter  
conjecture

[A01]インフレーション  
松本(京都大)

[A02]揺らぎと構造  
高橋(東北大)

[A03]ダークエネルギー  
杉山(名古屋大)

[B01] CMB偏光  
羽生(KEK)

$\zeta, r, n_s$   
直接検出

CMB lensing  
isocurv.  
 $m_\nu, N_\nu$

cosmo. params  
CMB lensing

[B02] すばる銀河  
イメージング  
宮崎(NAOJ)

Lensing  $\rightarrow b(k)$   
 $\rightarrow P_{\text{primod}}(k)$

weak lensing  
 $m_\nu$   
non-std. DM

weak lensing  
SNe,  $\gamma$

[B03] 銀河分光  
高田(KIPMU)

primord. NG  
 $\Omega_K, n_s, \alpha_s$

isocurv.  
DM in dSph gals.  
 $P(k), m_\nu$

BAO, RSD  
 $\Omega_{\text{de}}(z), \gamma$

[B04] TMT  
Eihei(NAOJ)

微細構造定数( $\alpha$ )  
空間・時間変化

Lyman- $\alpha$  forests  
IGM

宇宙加速膨張  
の直接検出

science cases  
log normal analyses  
cross correlation  
earth acceleration

X00: organization  
Murayama (IPMU)

D01: ultimate intensity maps Komatsu(MPA)





# Why accelerate?

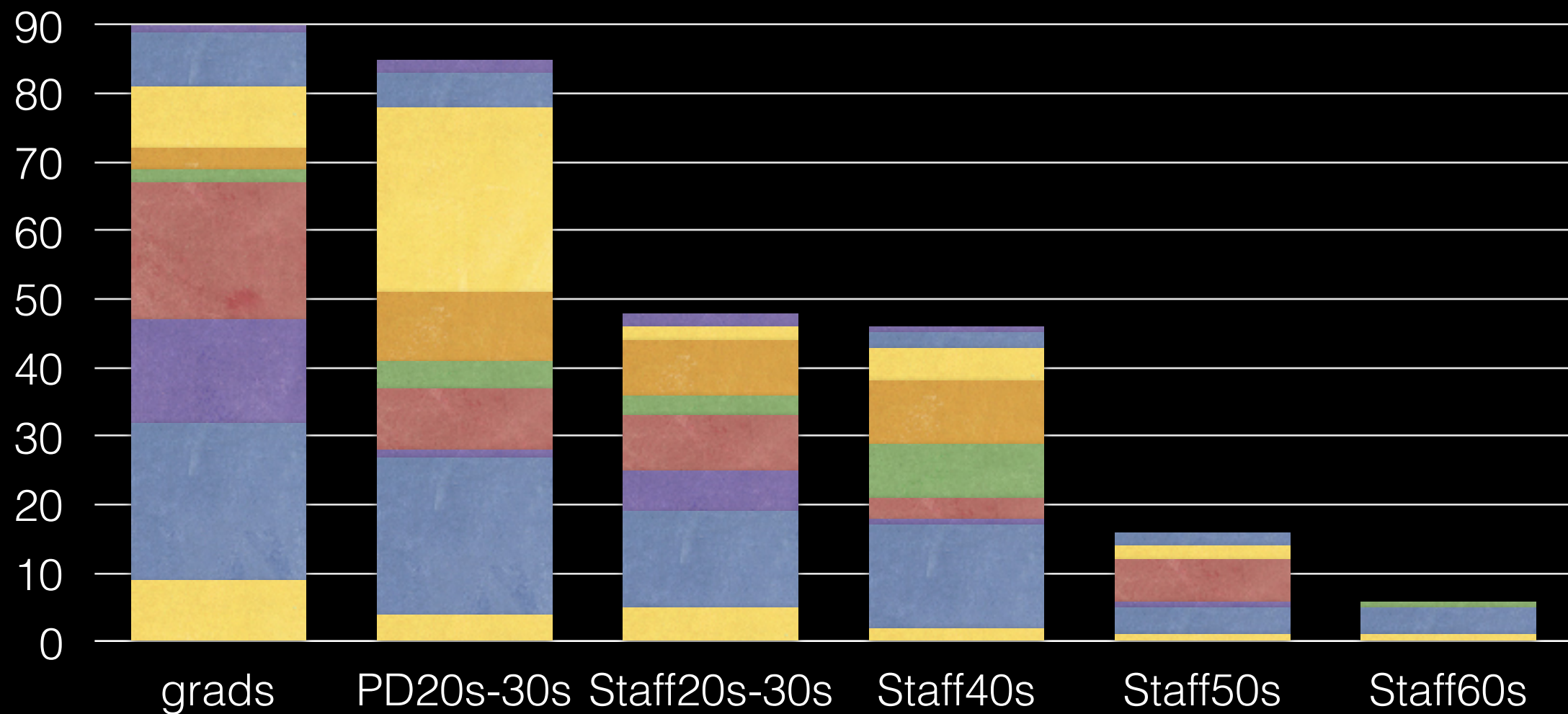
- From GW170817, modified gravity unlikely to explain current acceleration
- swampland hypothesis suggests  $w > -1$ : quintessence
- if cosmological constant, can test multiverse with curvature measurement  $\Omega_k > 0$ , fluctuation in  $\Omega_k$  with PFS
- inflation, dark matter, quintessence may have common origin (PBH, axion, supergravity)



# All Star Team

Team	Name	Affiliation	Expertise
PI, organization	Murayama	Tokyo/Berkeley	particle theory
administration	Katayama	Tokyo	particle expt
A01	Sasaki	Kyoto	relativity
A02	Takahashi	Tohoku	particle theory
A03	Sugiyama	Nagoya	cosmology
B01	Hazumi	KEK	particle expt
B02	Miyazaki	NAOJ	observation, instrument
B03	Takada	Tokyo	cosmology
B04	Usuda	NAOJ	observation, instrument
C01	Ooguri	Tokyo/Caltech	particle
D01	Komatsu	Tokyo/MPA	cosmology

# Age population



research led by grad students and researchers in 30s-40s





*Thank you!!!!*



# Finale

A night sky filled with colorful fireworks. Large bursts of yellow, red, and green light explode against the dark background. Smaller, vertical streaks of light are visible near the bottom of the frame.

***Have a safe trip home!***

***But there is exciting science ahead!***