Subaru HSC Cosmology

Hironao Miyatake
KMI, Nagoya University / Kavli IPMU

Hitoshi Fest
Dec 18, 2024 @ Kavli IPMU

How I got to know Hitoshi?

Official Supervisor

Myself (senior)

In 2006, the Aihara group watched Hitoshi's talk at KEK (?) through Polycom.

- His talk was (of course) very clear.
- Hitoshi looked different from other physicists: engaging, excited, and long hair

Big JSPS grant for HSC (2006)

広視野深宇宙探査によるダークエネルギーの研究の総括

研究領域	広視野深宇宙探査によるダークエネルギーの研究
研究課題/領域番号	18072005
研究種目	特定領域研究
配分区分	補助金
審査区分	理工系
研究機関	東京大学 (2010-2012) 国立天文台 (2006-2009)
研究代表者	**唐牛 宏** 東京大学, カブリ数物連携宇宙研究機構, 特任教授 (30221196)
研究分担者	相原 博昭 東京大学, 大学院・理学系研究科, 教授 (60167773) 杉山 直 (二間瀬 敏史) 名古屋大学, 大学院・理学研究科, 教授 (20209141) 宮崎 聡 国立天文台, 先端技術センター, 准教授 (20290885) 杉山 直 名古屋大学, 理学研究科, 教授 (70222057)
研究期間 (年度)	**2006 – 2012**

Foundation of IPMU (2007)

Director

Everything happened so fast 😳

Official Supervisor

Work with him.

I want to work on HSC!

Myself (young)

Thesis Advisor

Became one of the first (unofficial) students at IPMU

I got my Ph.D in 2012

Subaru weak-lensing mass measurement of a high-redshift SZ cluster ACT-CL J0022−0036 discovered by the Atacama Cosmology Telescope Survey

Hironao Miyatake
Department of Physics, University of Tokyo

December 2011

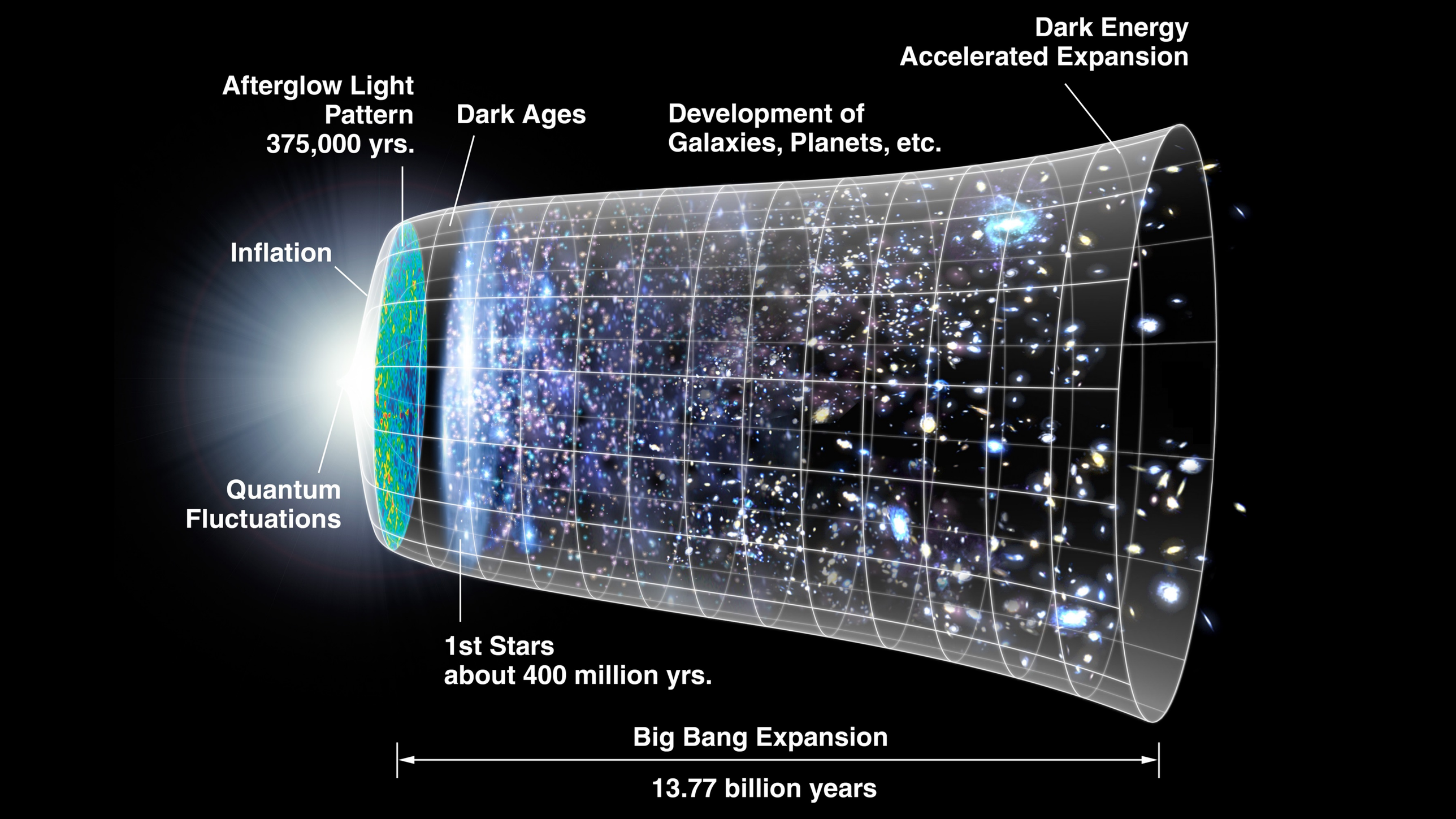
And…

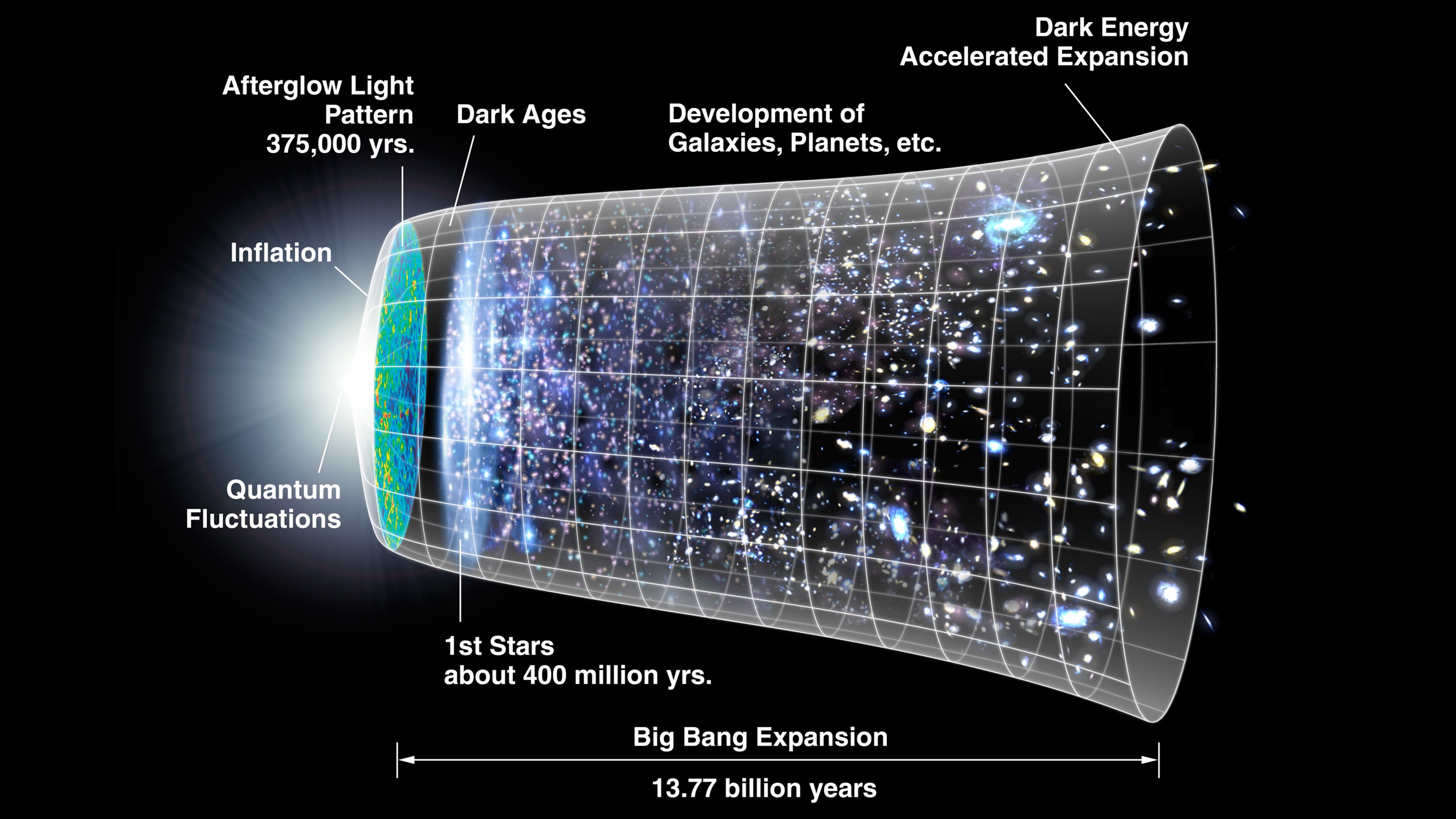
Got Married!

Myself (young) and Azusa (does’t change)

Surprise message from Hitoshi

Big applause from audience, of course


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
375,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.77 billion years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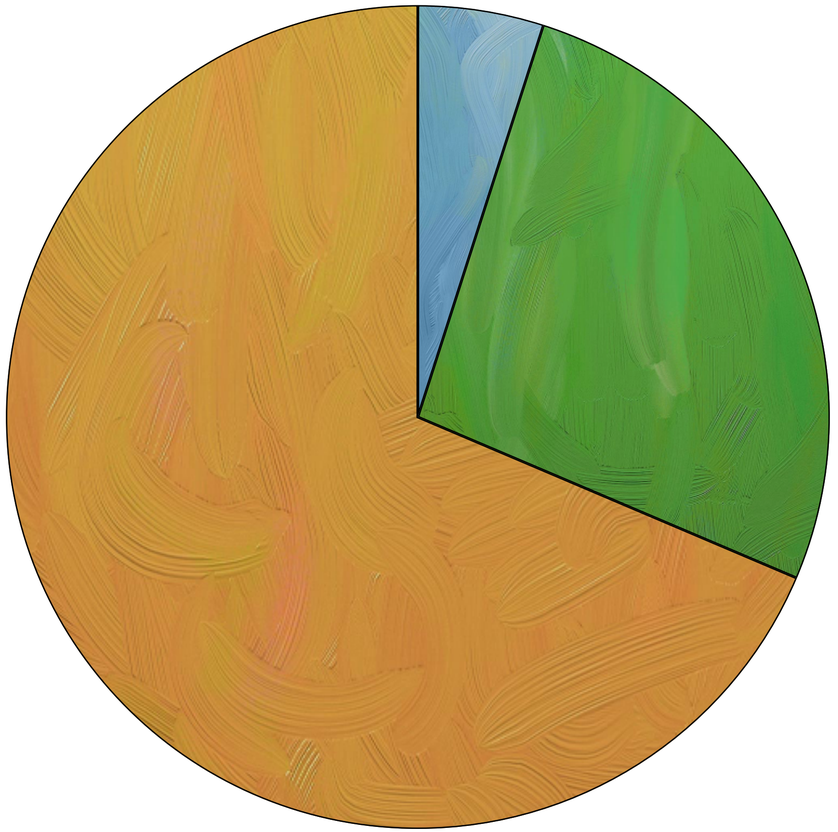
Dark Sector of the Universe

- Dark matter
  - Source of gravity to form a galaxy
  - Unknown matter, **invisible**, **new particle?**
- Dark energy
  - Source of cosmic acceleration
  - Unknown energy, **new force, breakdown of General Relativity**?



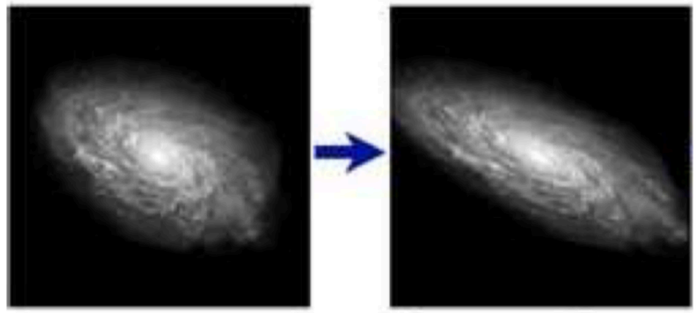
Planck Collaboration (2020)

Growth of Cosmic Structure

- Cosmic structure grows under the competition between dark matter (attractive force) and dark energy (repulsive force).
- The nature of dark matter and dark energy is embedded in large-scale structure.
- Caution: dark matter makes up ~85% of the matter in the Universe, but we cannot directly observe it.

Weak Gravitational Lensing

Credit: S. Bridle

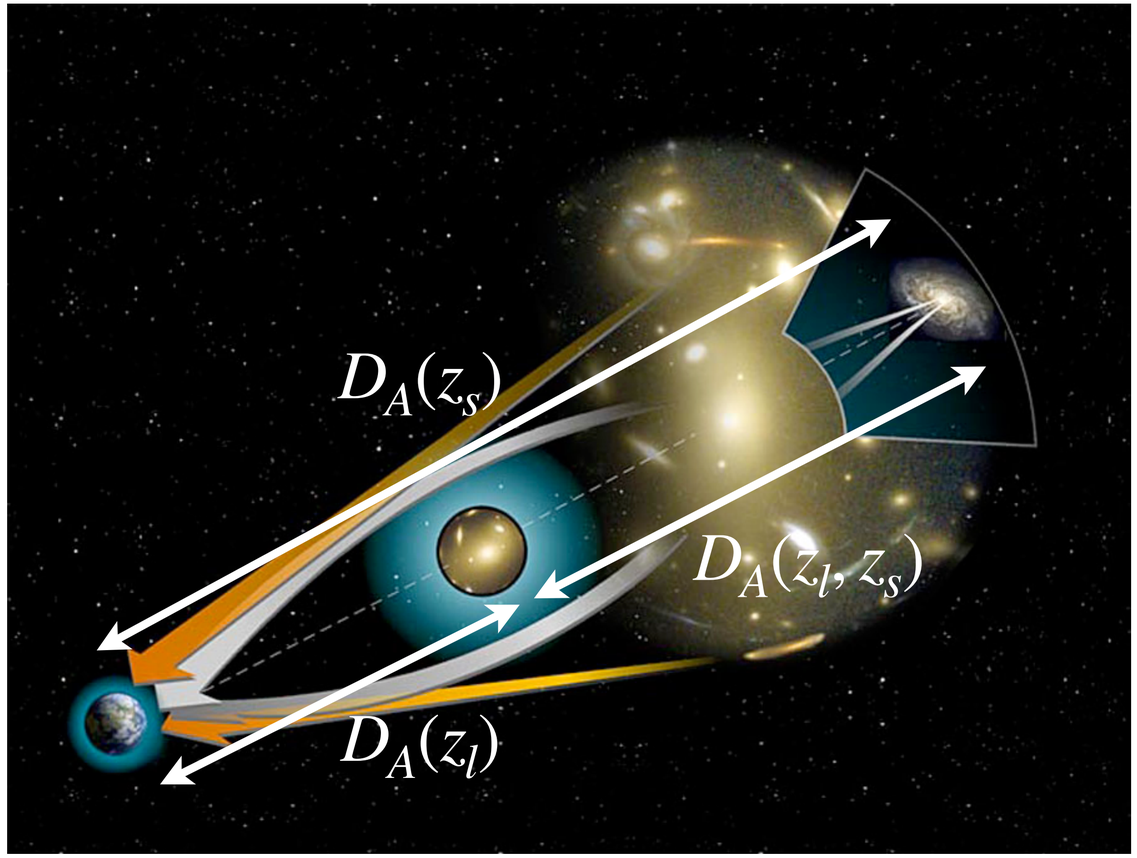


$$\gamma \sim \Omega_{\rm m} \frac{D_A(z_l, z_s) D_A(z_l)}{D_A(z_s)} \delta_{\rm m}(z_l)$$

Weak lensing shear

Geometry of the Universe

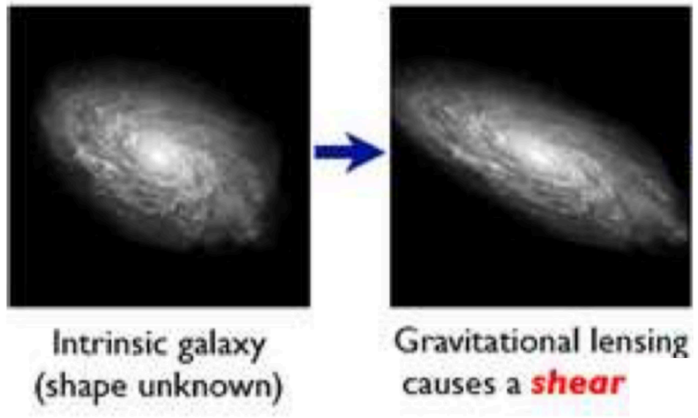
Matter density fluctuation

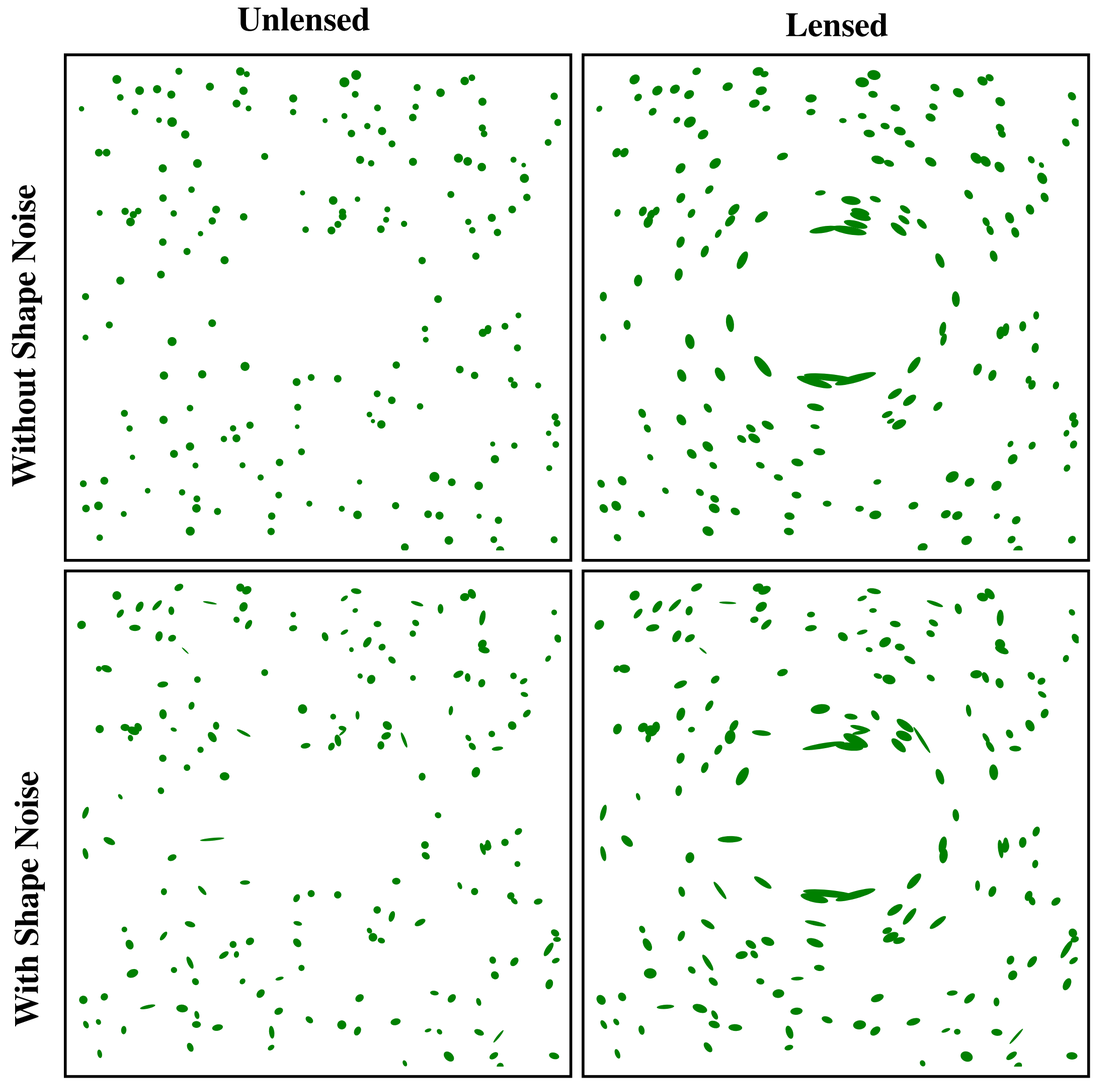


Weak lensing enables us to measure matter (incl. dark matter) distributions in the Universe.

Weak Gravitational Lensing

Credit: S. Bridle



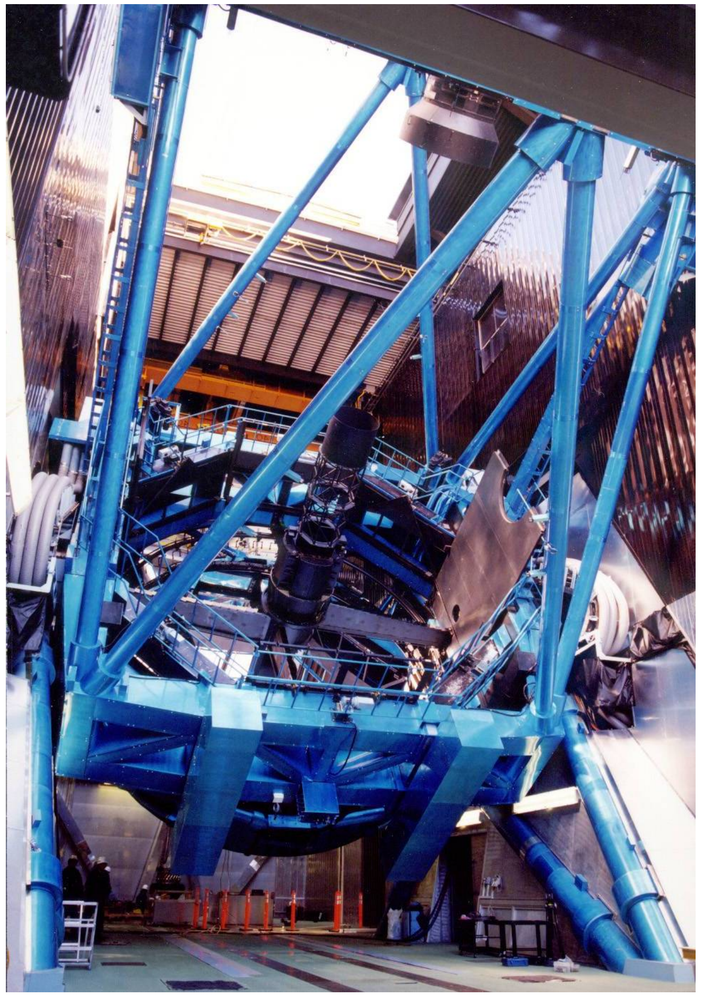


Weak lensing measurement requires

- Superb image quality
- Fide field observations
- Many faint galaxies (>>1M)

Subaru Hyper Suprime-Cam (HSC)

- Superb image quality: PSF~0.6”
  - SDSS PSF~1.0”
- Large Field-of-View: 1.5°diameter
  - ~7 x full moon
  - ~500 x Hubble Space Telescope
- 8.2 m primary mirror
  - ~11 x light collecting power of SDSS or Hubble Space Telescope



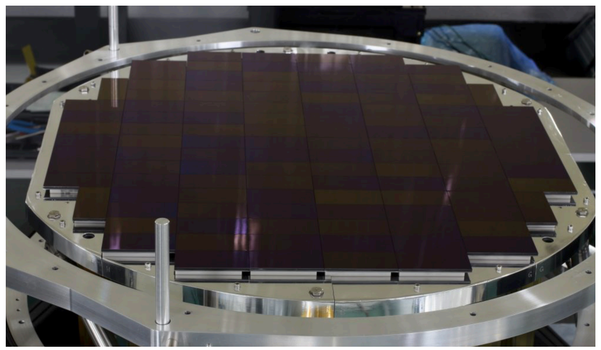
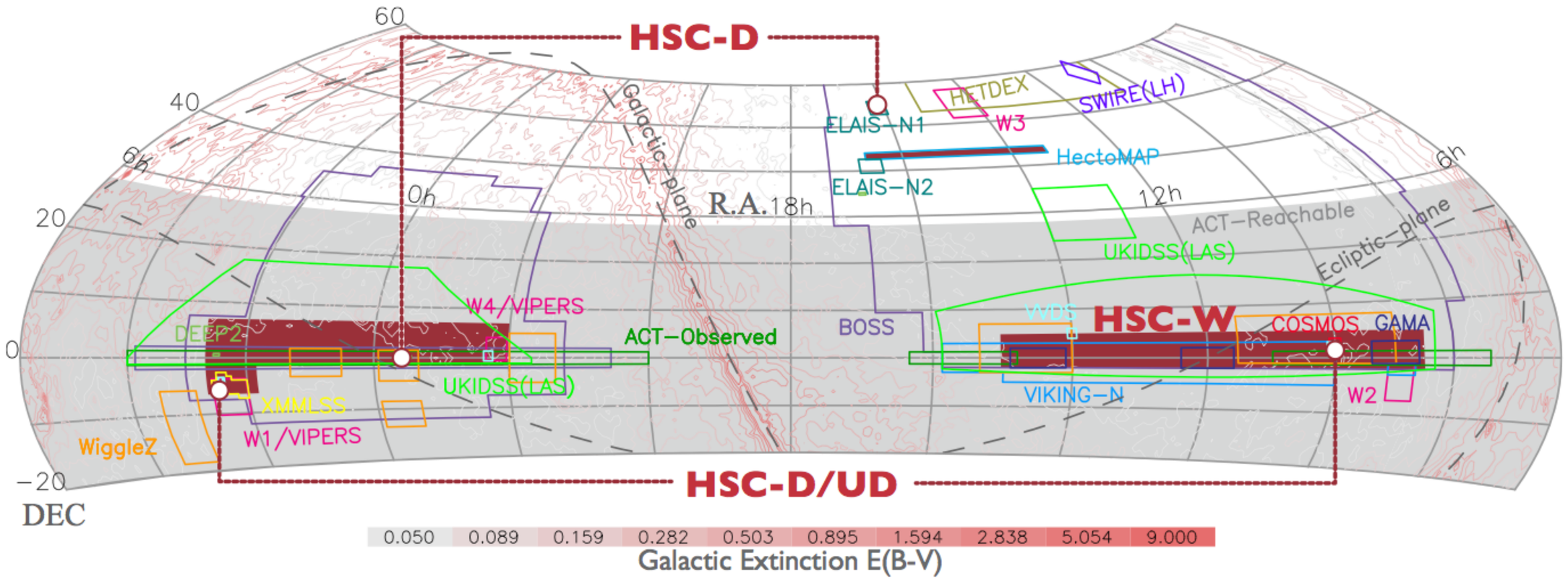
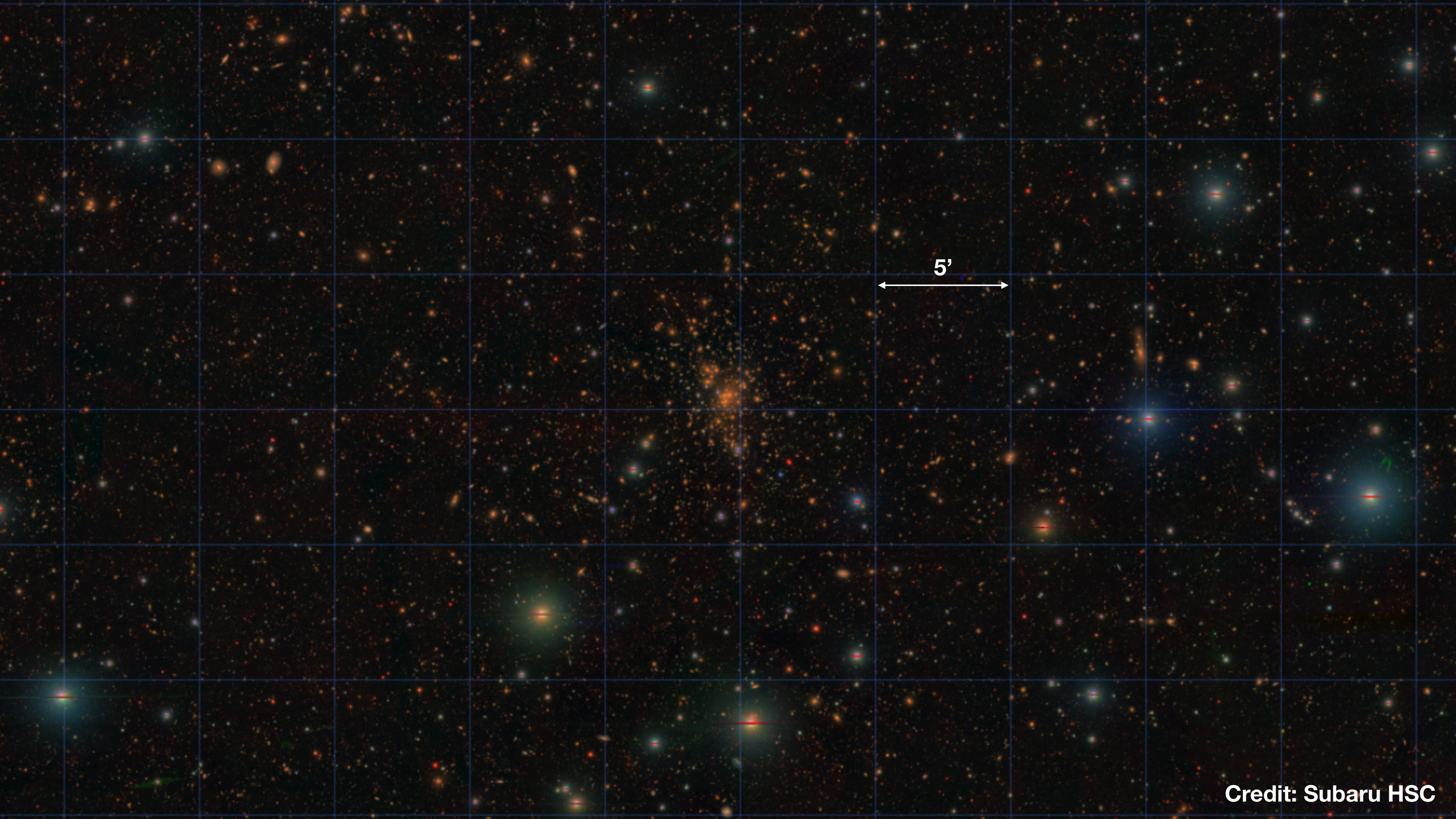


Photo credit: NAOJ, Miyazaki et al. (2018), Komiyama et al. (2018)

HSC SSP Survey



- Wide Layer (1,100 deg^2, grizy, i_{lim}~26) is designed for weak lensing cosmology (10^8 galaxies).
- Overlaps with other major surveys (SDSS/BOSS, ACT, VIKING, GAMA, VVDS, etc…).
- Survey started in 2014 and completed at the end of 2021.
- Three data releases were made.

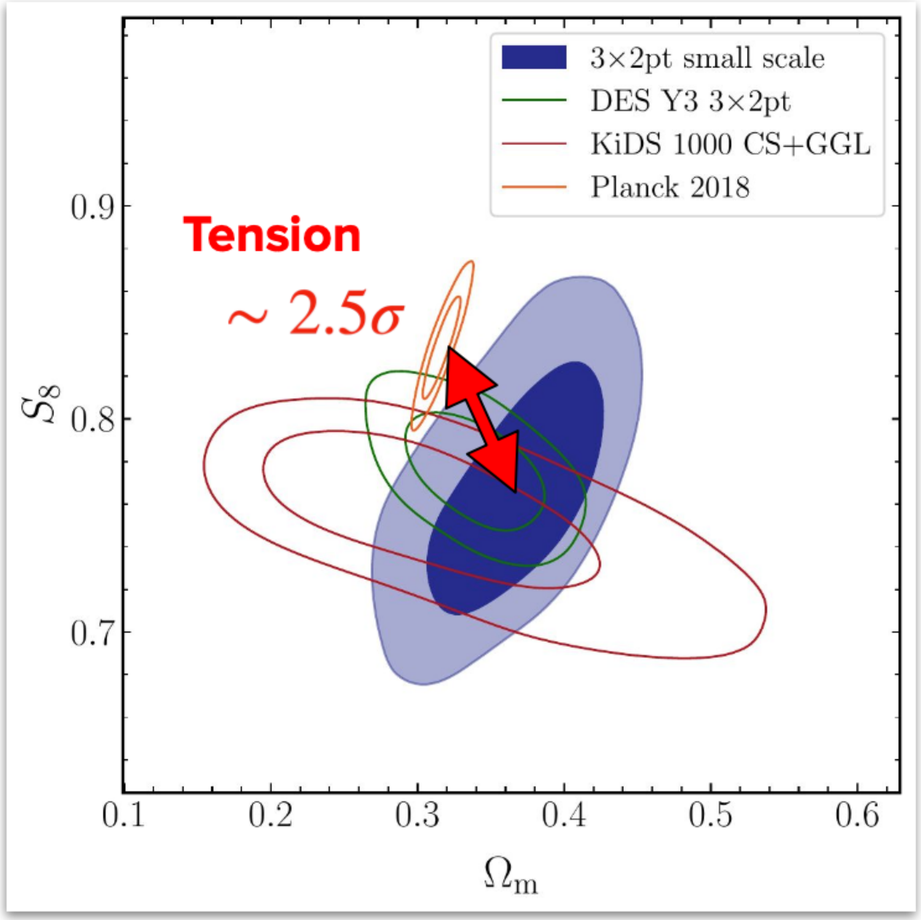

5’
Credit: Subaru HSC

Intermediate Results

$$S_8 \equiv \sigma_8 \sqrt{\Omega_m / 0.3}$$

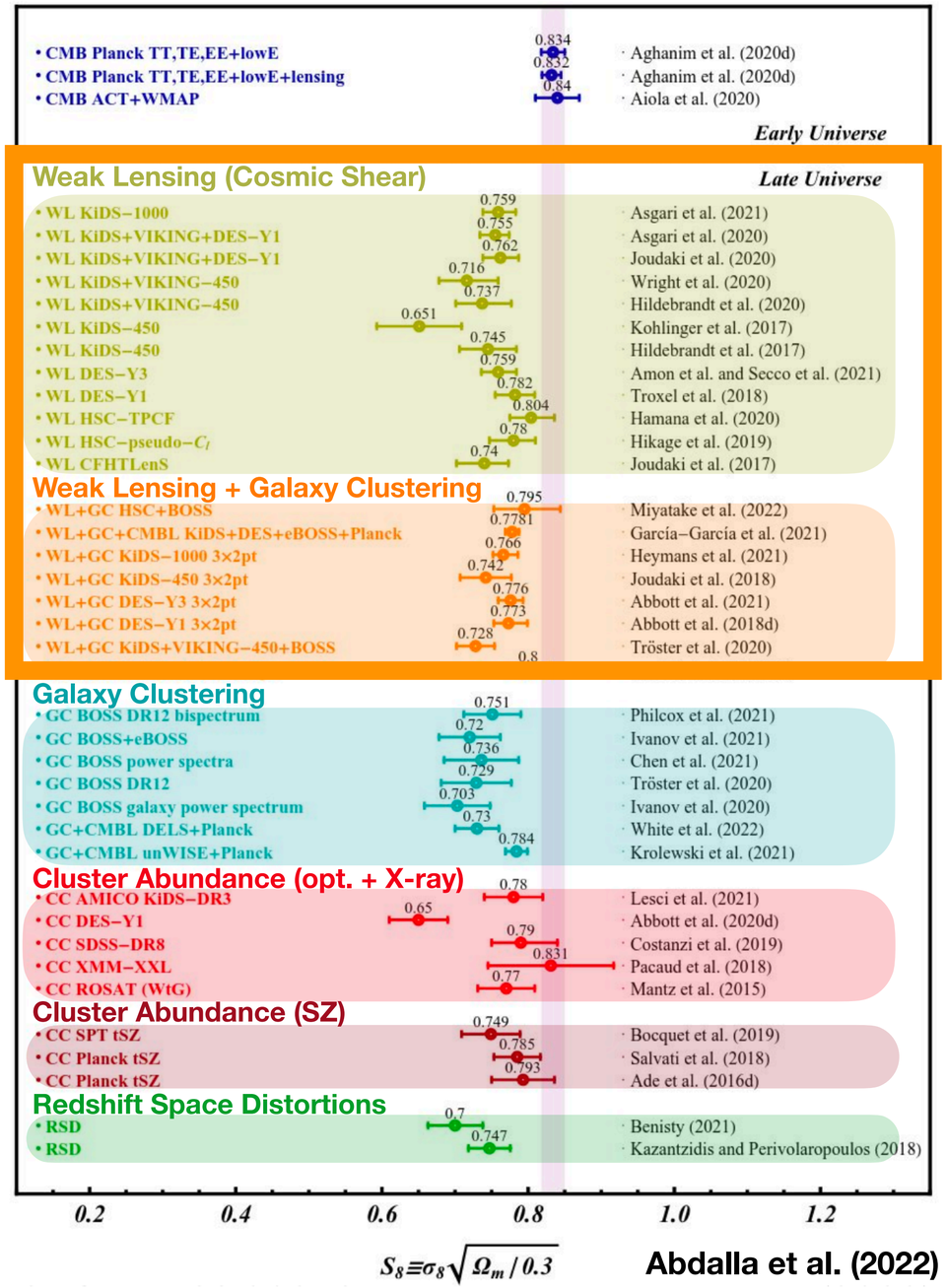
- σ_8 : Amplitude of linear power spectrum on the scale of 8 Mpc/h
- Ω_m : Energy dense of matter (incl. dark matter)

- 416 deg² (final data is 1,100 deg²)
- Combined probe (3x2pt)
  - Cosmic shear
  - Galaxy-galaxy lensing
  - Galaxy-galaxy clustering
- 2.5σ tension with Planck!



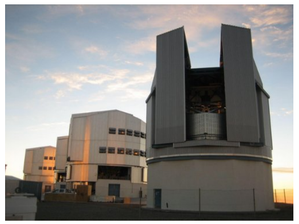
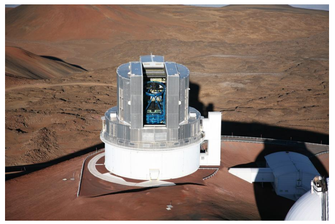
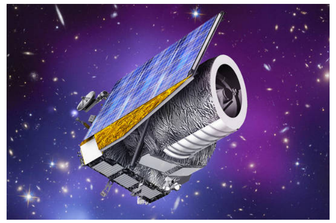
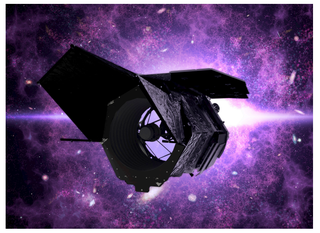
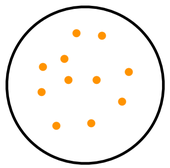
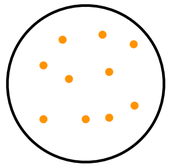
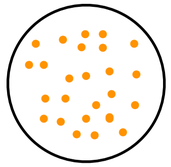
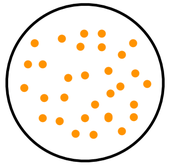
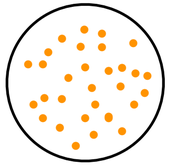
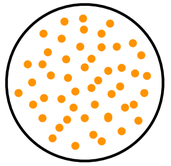
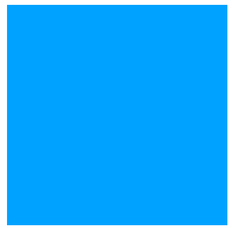
S_8 Tension

Not only weak lensing but also other large-scale structure probes may have S_8 tension!



Weak Lensing Surveys: Now and Future

Japan has access to these surveys!

	KiDS (Europe)	DES (USA)	Subaru HSC (Japan)	Euclid (Europe)	Rubin Observatory's LSST (USA)	Roman Space Telescope (USA)
						
Primary Mirror [m]	2.6	4.0	8.2	1.2	8.4	2.4
Galaxy Number Density [arcmin^{-2}]	 11	 10	 25	 30	 30	 50
Survey Area [sq. deg]	 1,500	 5,000	 1,400	 15,000	 18,000	 2,200

All sky ~41,253 [sq. deg]

2010 — 2020 — 2030

Inspired by E. Krause

Credit: ESO, Fermilab/Reidar Hahn, NAOJ, ESA/C. Carreau, Rubin Obs/NSF/AURA, NASA

Hitoshi is

- always encouraging
- always excited
- always exciting me

July 2018 ~2am. After six bottles of wine.

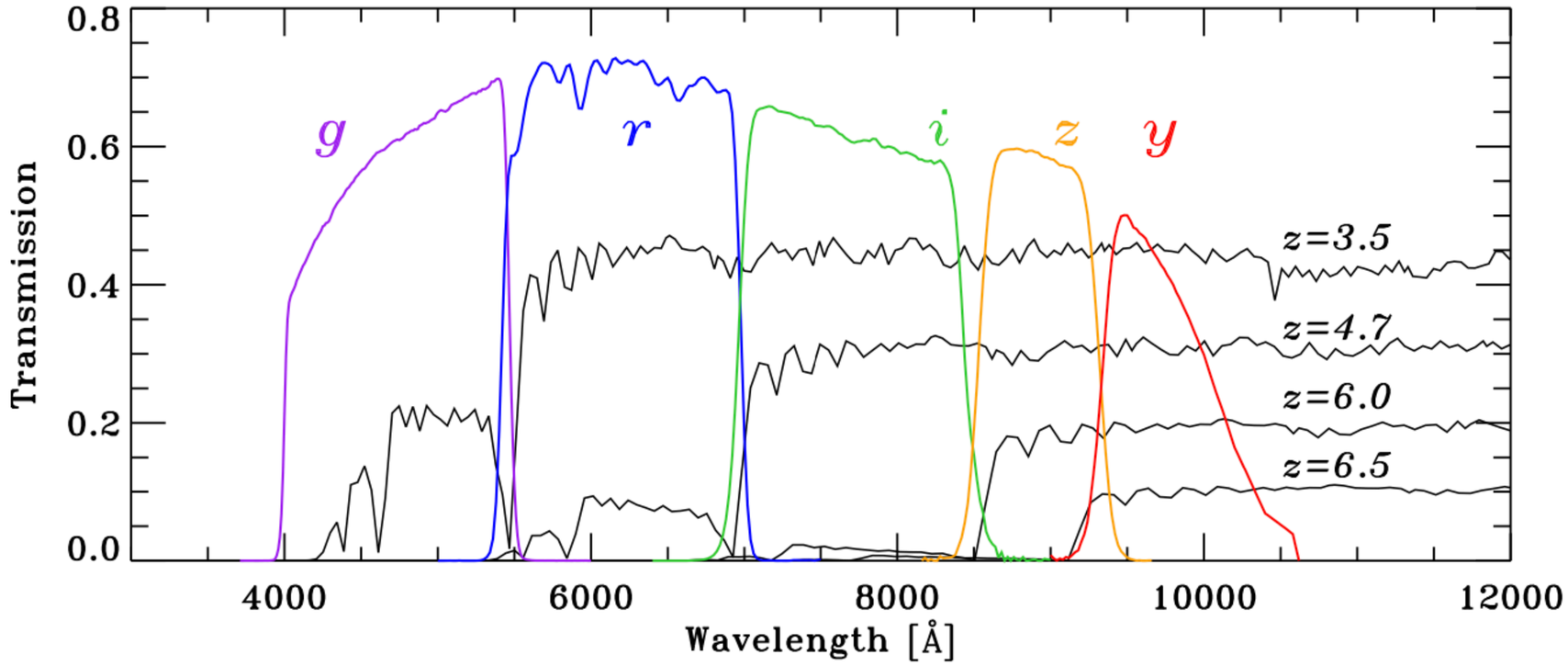
Congratulations on your 60th birthday

Looking forward to working on exciting science together!

Backup Slides

Selecting High-z Galaxies: Dropout Technique

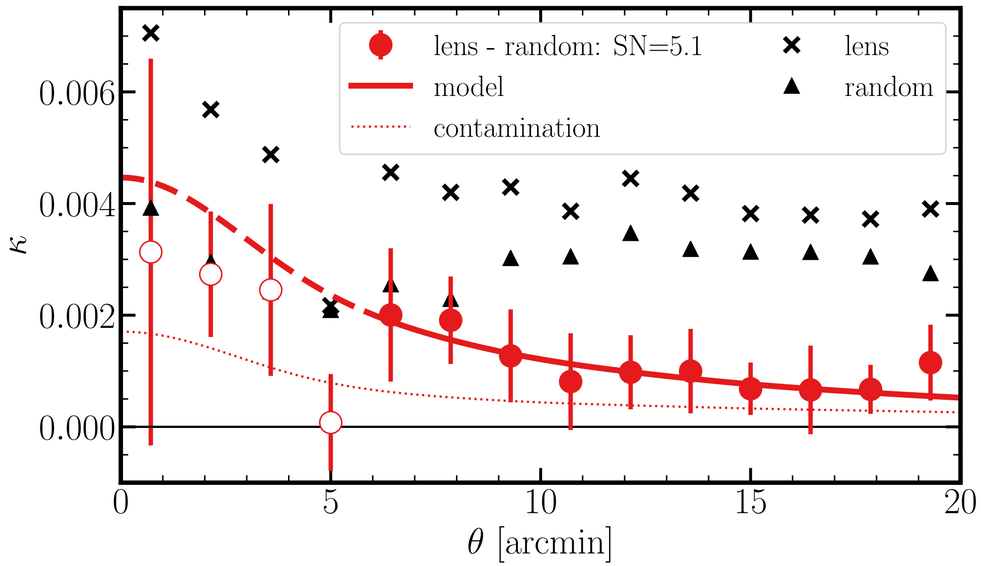
- Broadband photometry can capture the Lyman break at 912Å.
- Selecting distant galaxies with Lyman break is called dropout technique, and these galaxies are called **Lyman break galaxies (LBG)**.

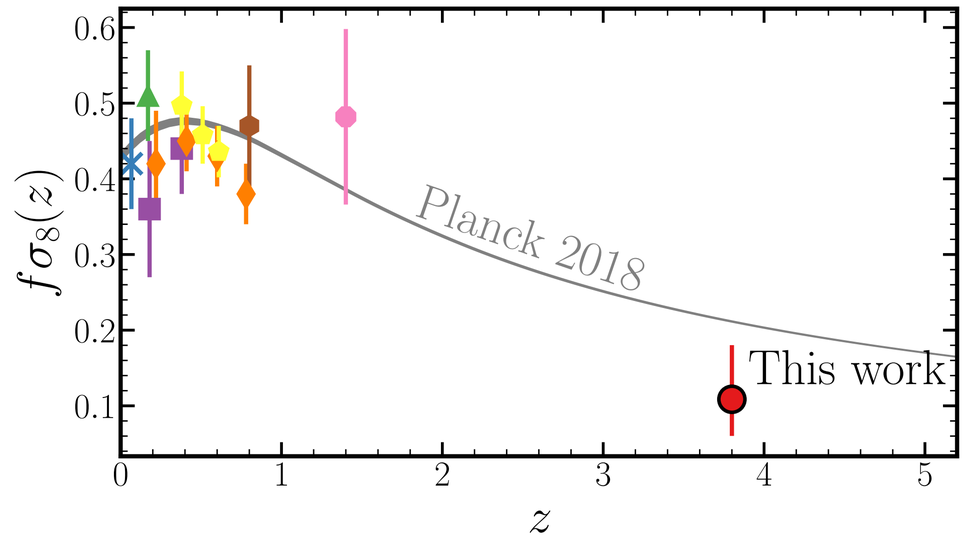


Ono et al. (2018)

LBG x Planck CMB Lensing

- ~1.5M LBG galaxies over 300 deg^2 of HSC field.
- Stacked Planck lens map behind LBGs
- Contamination from low-z galaxies is quantified by WL measurements with HSC.
- Obtained 3.5σ significance against the contamination signal.

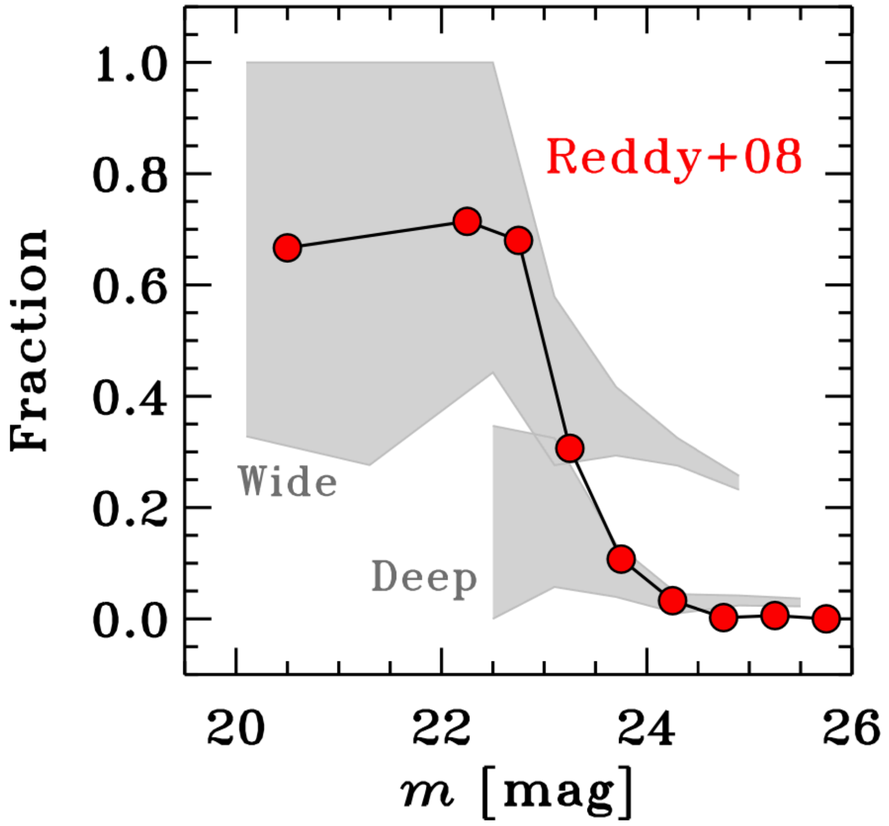




Miyatake et al. (PRL, 2022)

Contamination from Low-z Galaxies

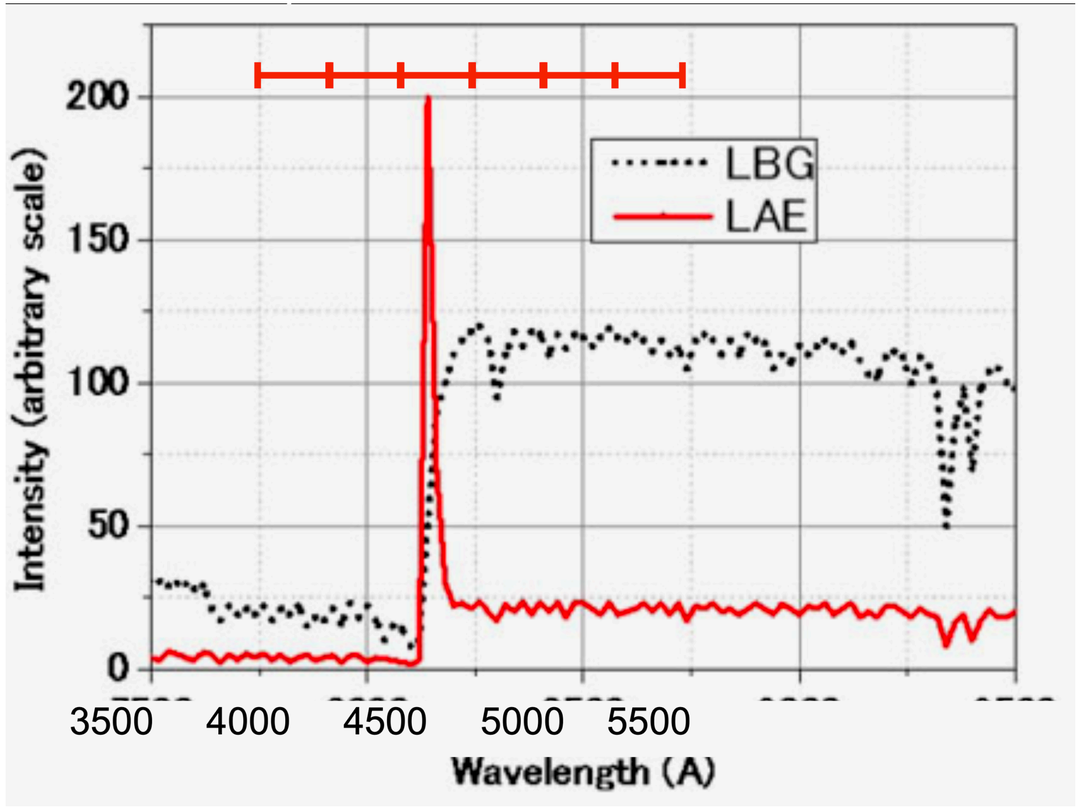
- There is a siginificant fraction of low-z galaxies in a dropout galaxy sample due to the misitification of 4000A break.
- There is more contaminations for bright galaxies: up to ~70% for i~23 galaxies.
- To carry out *precision* high-z cosmology, we need to reduce the contamination rate.



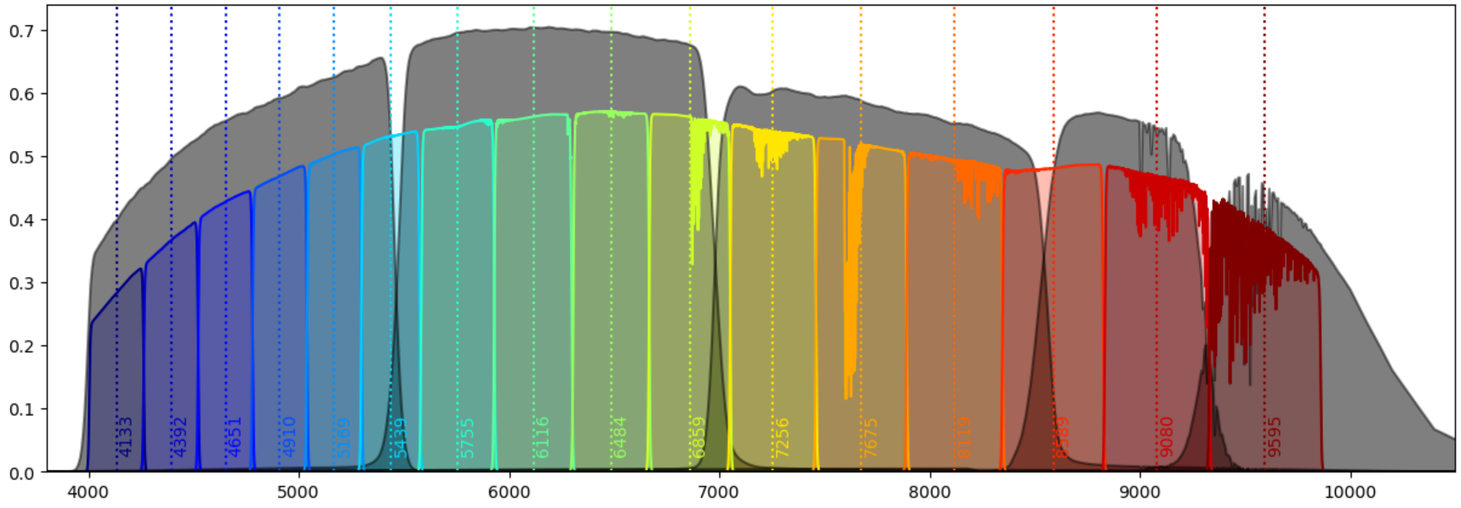
Ono et al. (2018)

LAE selection by medium-band filters

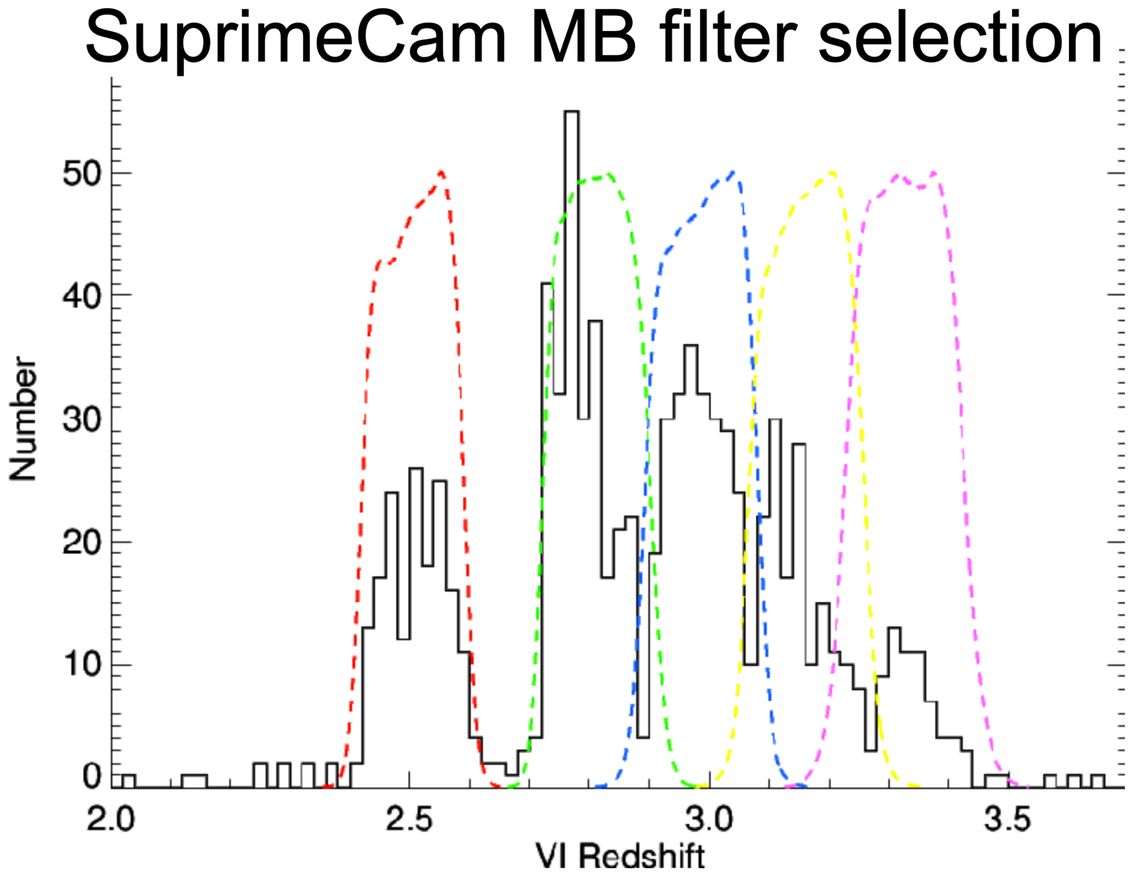
A. J. Nishizawa



Dunlop (2012)



HSC medium-band filters will be fabricated soon!



Credit: A. Dey

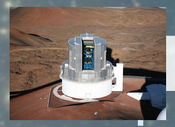
Started working on LAE selections in hydrodynamical simulations (Z. Liu, R. Kano)

High-redshift Cosmology Roadmap

2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2035 2036 2037

Galaxy Surveys

MB Imaging Surveys

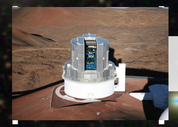


Subaru HSC (z>2.5)

DECam (z>2.5)

Study optimal combination of HSC Medium-band Survey and DECam Medium-band Survey

Spectroscopic Surveys



Subaru PFS (1,100deg^2; z<2.5)

Subaru PFS-II (3.2 < z < 4.0)

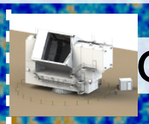
DESI (14,000deg^2; z<2.5)

DESI-2 (5,000deg^2; 2.5<z<3.2)

Spec-S5 (2.5<z<4.5)

CMB Experiments

Simons Observatory

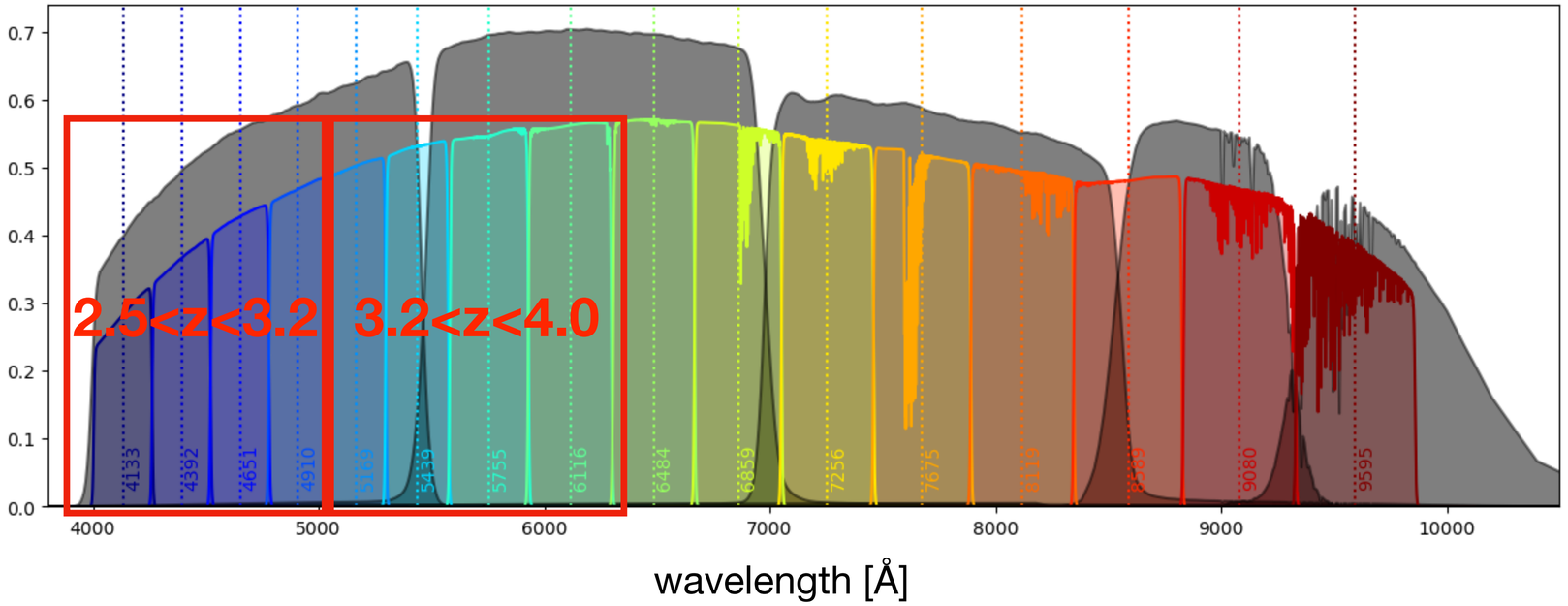


CMB-S4

LiteBIRD

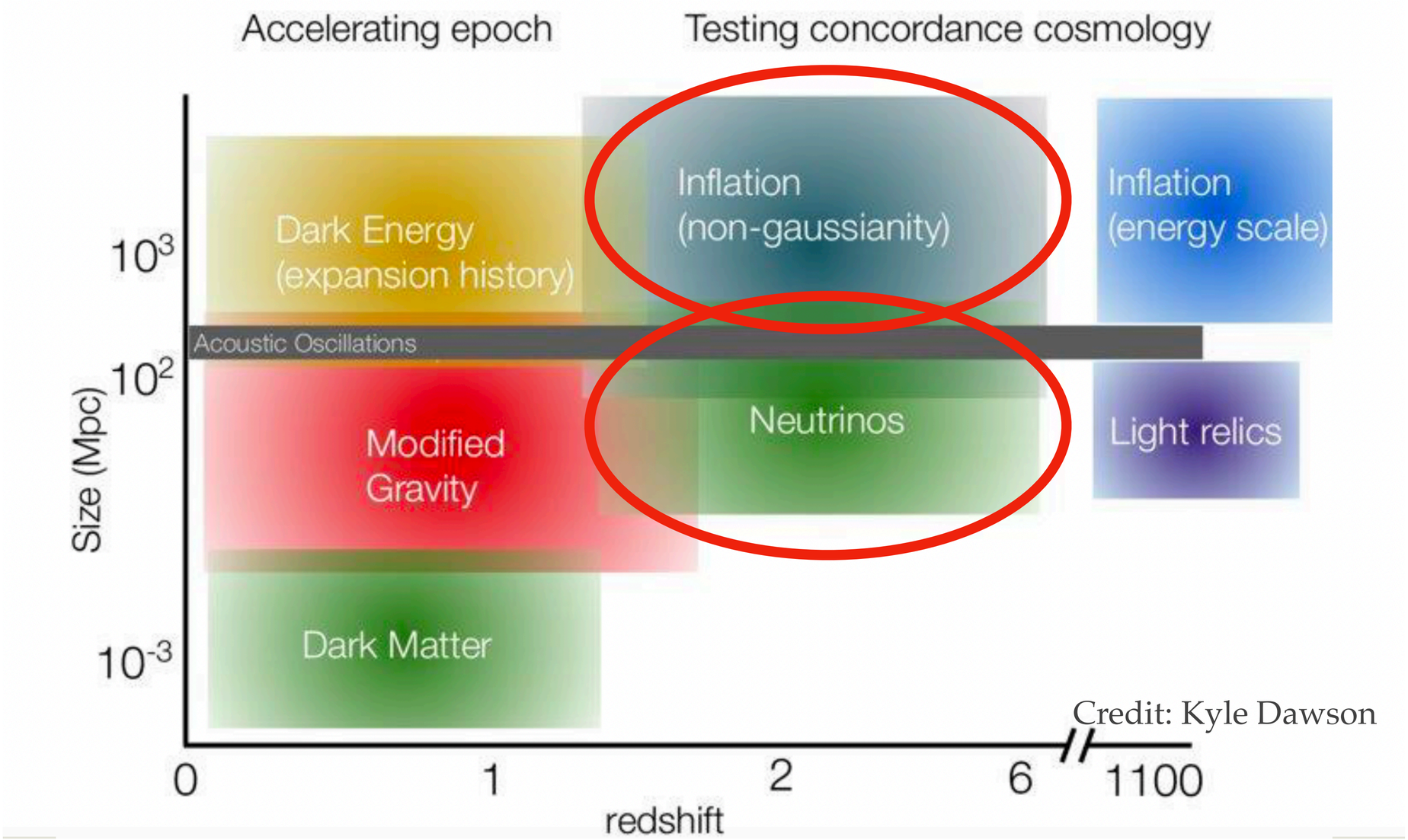
Credit: NAOJ, NOIRLab, NSF, DOE, Rubin Obs, ESA, NASA, JAXA, Schlegel et al. (2022)

Why HSC-MB+PFS-2



- HSC-MB and PFS have a larger mirror compared to DECam(4m) and DESI-2(4m)
- HSC-MB has filters covering 5000Å-6300Å ($3.2 < z < 4.0$)
- Possible options depending on results from PFS and DESI-2
  - Add depth at $2.5 < z < 3.2$
  - Go for $3.2 < z < 4.0$
- We need to complete PFS-2 before Spec-S5 (6m+4m, ~13000 fibers) which will start ~2035 if funding goes successfull.

Science cases of high-z cosmology other than S_8



Summary

- All the stage-III weak lensing surveys reported smaller S_8 compared to primary CMB.
- S_8 changes as a function of redshift?
  - LAB/LAE with CMB lensing enables us to explore S_8 at z>2!

- Message to students: you are living in the golden era of observational cosmology!