Final Report of HSC-SSP

Satoshi MIYAZAKI

Subaru Telescope/NAOJ

Subaru UM 2025/01/30

SSP Observing Proposal

- 300 nights
- 166 Collaborators
- 2012/10 Submitted

2013/05 accepted

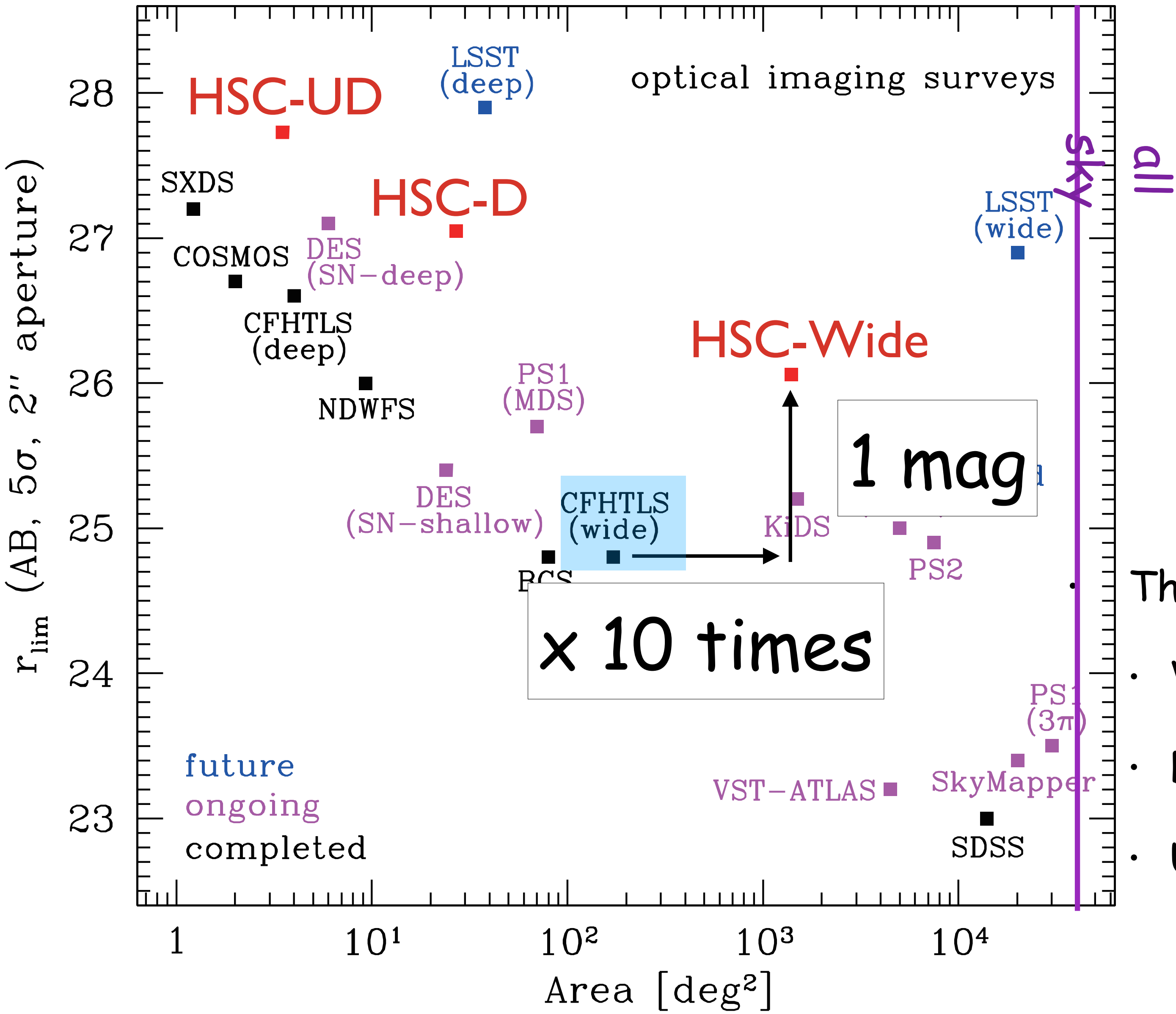
Wide-field imaging with Hyper Suprime-Cam: Cosmology and Galaxy Evolution

A Strategic Survey Proposal for the Subaru Telescope

PI: Satoshi Miyazaki (NAOJ)
Co-PI: Ikuru Iwata (NAOJ)

The HSC collaboration team[1]: S. Abe[1], H. Aihara[*2,3], M. Akiyama[4], K. Aoki[5], N. Arimoto[*5], N. A. Bahcall[6], S. J. Bickerton[3], J. Bosch[6], K. Bundy[†3], C. W. Chen[7], M. Chiba[†4], T. Chiba[8], N. E. Chisari[6], J. Coupon[7], M. Doi[2], M. Enoki[9] S. Foucaud[10], M. Fukugita[3], H. Furusawa[†5], T. Futamase[4], R. Goto[2], T. Goto[11], J. E. Greene[6], J. E. Gunn[†6], T. Hamana[†5], T. Hashimoto[2], M. Hayashi[5], Y. Higuchi[2,5], C. Hikage[12], J. C. Hill[6], P. T. P. Ho[*7], B. C. Hsieh[7], K. Y. Huang[†7], H. Ikeda[13], M. Imanishi[5], N. Inada[14], A. K. Inoue[15], W.-H. Ip[1], T. Ito[5], K. Iwasawa[16], M. Iye[5], H. Y. Jian[17], Y. Kakazu[18], H. Karoji[3], N. Kashikawa[5], N. Katayama[3], T. Kawaguchi[19], S. Kawanomoto[5], I. Kayo[20], T. Kitayama[20], G. R. Knapp[6], T. Kodama[5], K. Kohno[2], M. Koike[5], E. Kokubo[5], M. Kokubo[2], Y. Komiyama[5], A. Konno[2], Y. Koyama[5], C. N. Lackner[3], D. Lang[6], A. Leauthaud[†3], M. J. Lehner[7], K.-Y. Lin[7], L. Lin[7], Y.-T. Lin[†7], C. P. Loomis[6], R. H. Lupton[†6], P. S. Lykawka[21], K. Maeda[3], R. Mandelbaum[†22], Y. Matsuda[5], K. Matsuoka[13,23], Y. Matsuoka[12], S. Mineo[2], T. Minezaki[2], H. Miyatake[6], R. Momose[2], A. More[3], S. More[3], T. J. Moriya[3], T. Morokuma[†2], H. Murayama[*3], K. Nagamine[24], T. Nagao[†23], S. Nagataki[23], Y. Naito[2], K. Nakajima[2], F. Nakata[5], H. Nakaya[5], T. Namikawa[2], C.-C. Ngeow[1], T. Nishimichi[3], H. Nishioka[7], A. J. Nishizawa[†3], K. Nomoto[3], M. Oguri[†3], A. Oka[2], N. Okabe[7], S. Okamoto[25], S. Okamura[26], J. Okumura[23], S. Okumura[27], Y. Okura[5], Y. Ono[2] M. Onodera[28], K. Ota[23], M. Ouchi[†2], S. Oyabu[12], P. A. Price[6], R. Quimby[3], C. E. Rusu[2,5], S. Saito[29], T. Saito[3], Y. Saitou[30], M. Sato[12], T. Shibuya[5], K. Shimasaku[†2], A. Shimono[3], S. Shinogi[2], M. Shirasaki[2], J. D. Silverman[3], D. N. Spergel[*6,3], M. A. Strauss[†6], H. Sugai[3], N. Sugiyama[12,3], D. Suto[2], Y. Suto[*2], K. Tadaki[2], M. Takada[†3], R. Takahashi[31], S. Takahashi[5], T. Takata[5], T. T. Takeuchi[12], N. Tamura[3], M. Tanaka[5], M. Tanaka[†3], M. Tanaka[4], Y. Taniguchi[13], A. Taruya[2], T. Terai[5], Y. Terashima[13], N. Tominaga[32], J. Toshikawa[30], T. Totani[23], M. Tsai[1], E. L. Turner[*6], Y. Ueda[23], K. Umetsu[7], Y. Urata[†1], Y. Utsumi[5], B. Vulcani[3], K. Wada[33], S.-Y. Wang[7], W.-H. Wang[7], T. Yamada[4], Y. Yamada[5], K. Yamamoto[34], H. Yamanoi[5], C.-H. Yan[7], N. Yasuda[†3], A. Yonehara[35], F. Yoshida[†5], N. Yoshida[2], M. Yoshikawa[36], S. Yuma[2] (1) NCU, Taiwan (2) Tokyo (3) Kavli IPMU (4) Tohoku (5) NAOJ (6) Princeton (7) ASIAA (8) Nihon (9) Tokyo Keizai (10) NTNU, Taiwan (11) DARK, Copenhagen (12) Nagoya (13) Ehime (14) NNCT (15) Osaka Sangyo (16) Barcelona (17) NTU, Taiwan (18) Chicago (19) Tsukuba (20) Toho (21) Kinki (22) CMU (23) Kyoto (24) Las Vegas (25) KIAA, China (26) Hosei (27) JSGA (28) ETH (29) Berkeley (30) GUAS (31) Hirosaki (32) Konan (33) Kagoshima (34) Hiroshima (35) Kyoto Sangyo (36) JAXA

HSC SSP Survey: Three layers



Three-tier survey

- Wide: 1400 sq. degs, i~26
- Deep: 28 sq. degs, i~27
- UltraDeep: 3 sq. degs, i~27.7

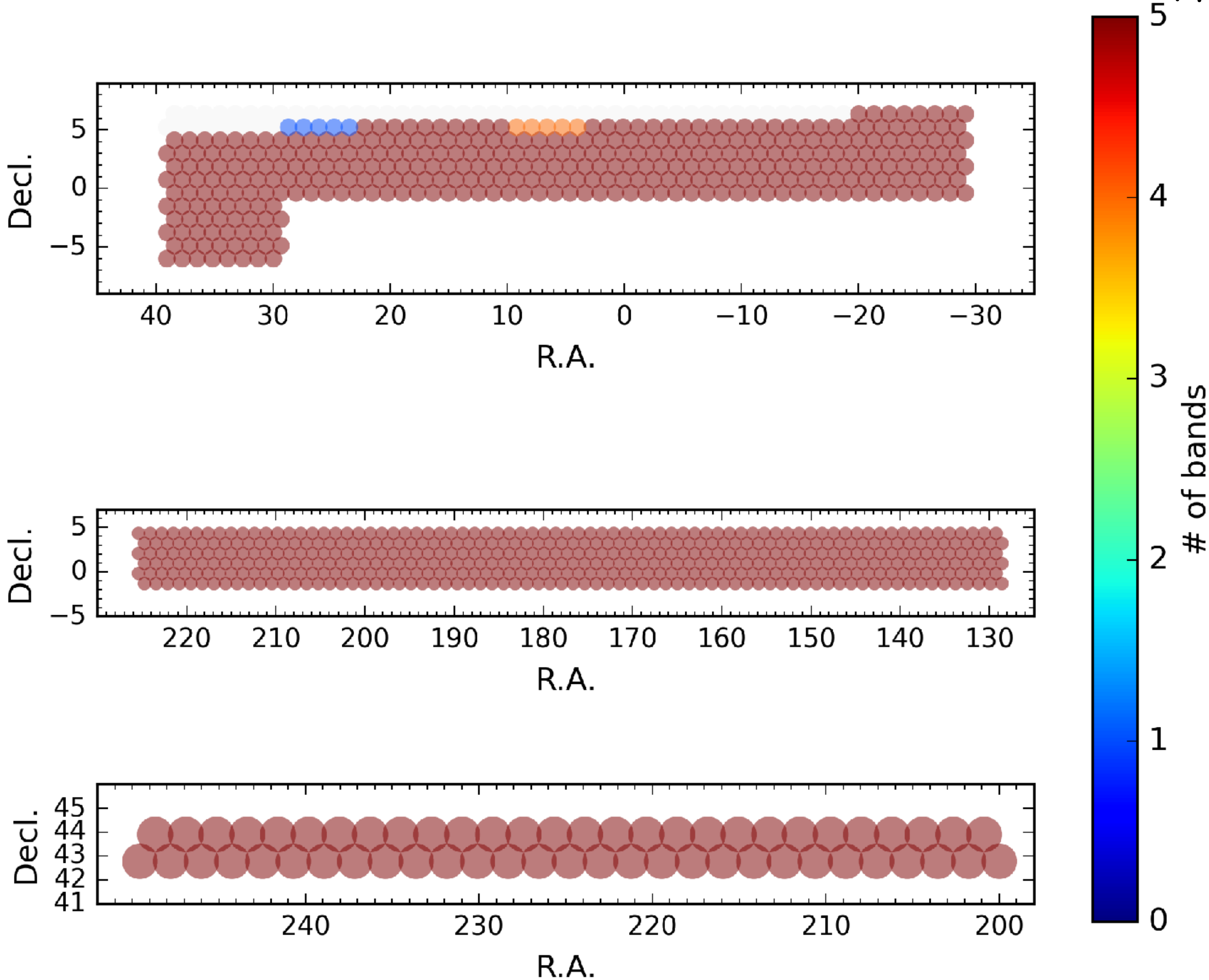
HSC-SSP Observation

- On March, 2014 (HST), HSC-SSP observation started
- We asked Japanese astronomy community to allocate 30 more nights at Subaru UM in 2019, and it was approved.
- The last observing night was January 3rd, 2022.

Field Coverage (Wide)

Full depth area (5) Created at 2021-12-09 21:28:29

Prof. Yasuda

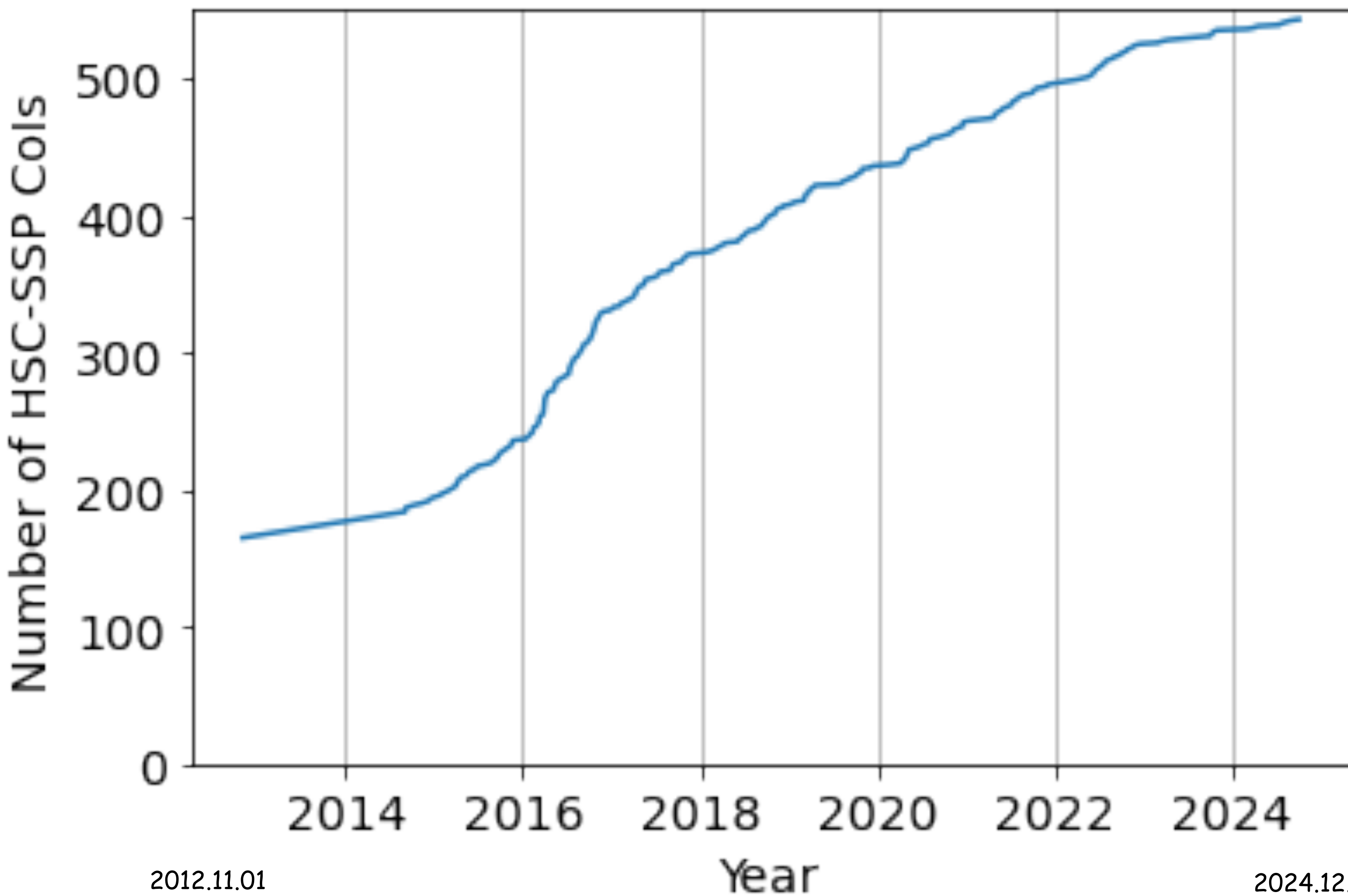


full-depth full-color 1086.8 deg2

Deep:27 deg^2
UD: 3.5 deg^2

Number of CoIs

Thank you Oguri-san and Tom Winegar
for processing the registrations for 11 years.



2012.11.01

2024.12.24

HSC SSP Science Working Groups

Working Group	Co-Chairs	as of Jan.2025	
AGN	Toba	A. Takahashi	
Weak Lensing	Sugiyama	Sunayama	X. Li
Strong Lensing	K. Wong	Oguri	
Galactic Structure	M. Tanaka	Koyama	
High-Z galaxies	Mawatari	Ono	
Low-Z galaxies	A. Goulding		
Clusters	Okabe	Koyama	
Photo-Z	Nishizawa		
Transient	Moriya	Kokubo	
Supernova	Yasuda	Urata	
Solar System	F. Yoshida		

AGN Working Group

AGN working group

Chair | **Vice-chair**

Yoshiki Toba

~2024.10

Tohru Nagao

Ayumi Takahashi

~110 researchers belong to the AGN WG.

HSC-AGN publications

https://hscsurvey.pbworks.com/w/page/148058889/HSC-AGN%20publication%20list

~80 papers👏

14th HSC-AGN meeting at Hokkaido Information U.
(Aug.26 -28, 2024)

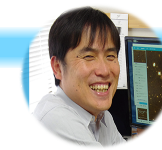
Key sciences

1. **Evolution of supermassive black holes (e.g., luminosity function).**
2. **Clustering properties and environments of quasars.**
3. **Relationship of AGN to their host galaxies**

(see Section 5.3 in the SSP proposal)

① Evolution of supermassive black holes


Y.Matsuoka

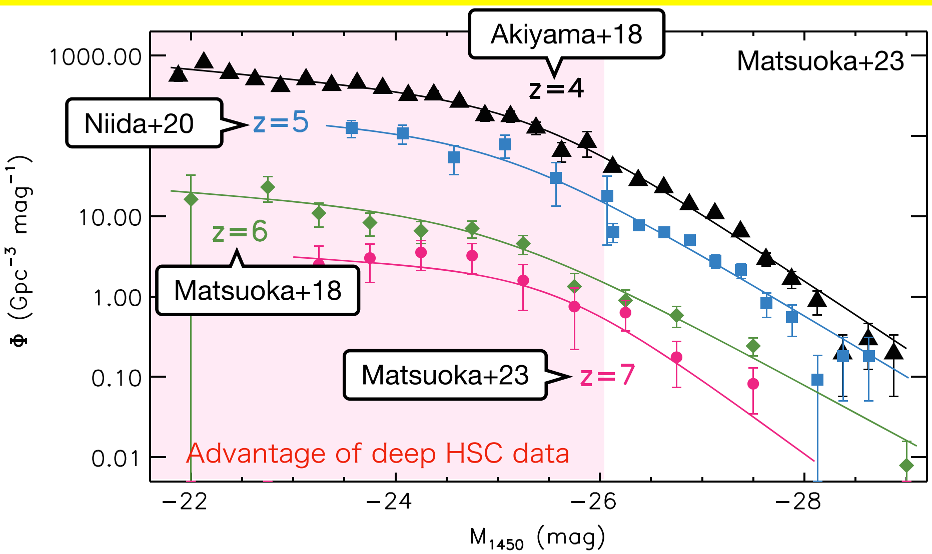

M.Akiyama

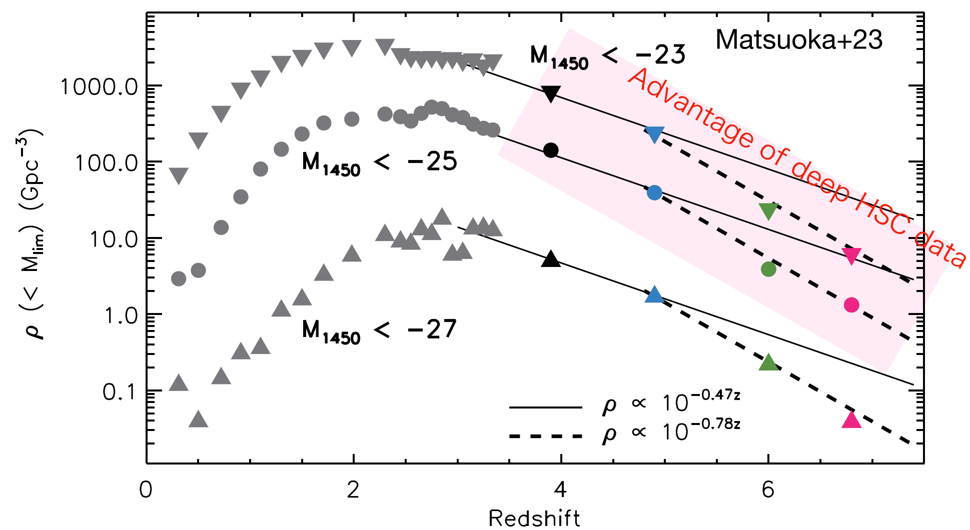
Luminosity Function of quasars at 4 < z < 7

For example, Subaru High-z Exploration of Low-Luminosity Quasars (SHELLQs),
~180 quasars at z > 6 were discovered, which is consistent with what was expected in the SSP proposal!

The faint-end slope of LFs for quasars at 4 < z < 7 is successfully determined!

The cosmic evolution of quasar number density is revealed!





See also, Toba+15; Series of SHELLQs paper (15 papers); Onoue+17; Pouliasis+22ab; He+24; Pouliasis+24

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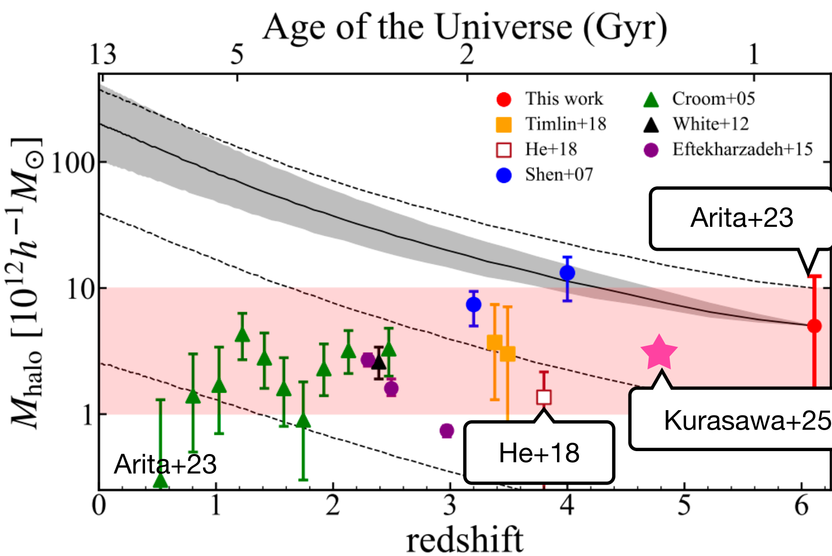
②③ Clustering/evniroment and AGN host

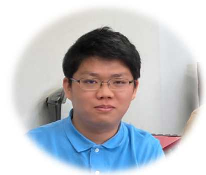
AGN WG

Clustering

See also, Toba+17; Shirasaki+18; Córdova Rosado+24

Mhalo for less-luminous quasars at 4 < z < 6 is constrained!



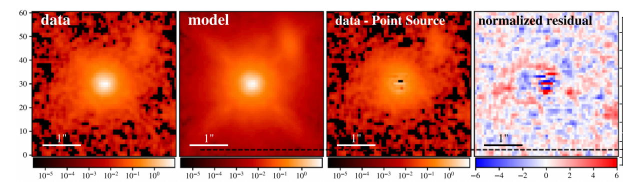


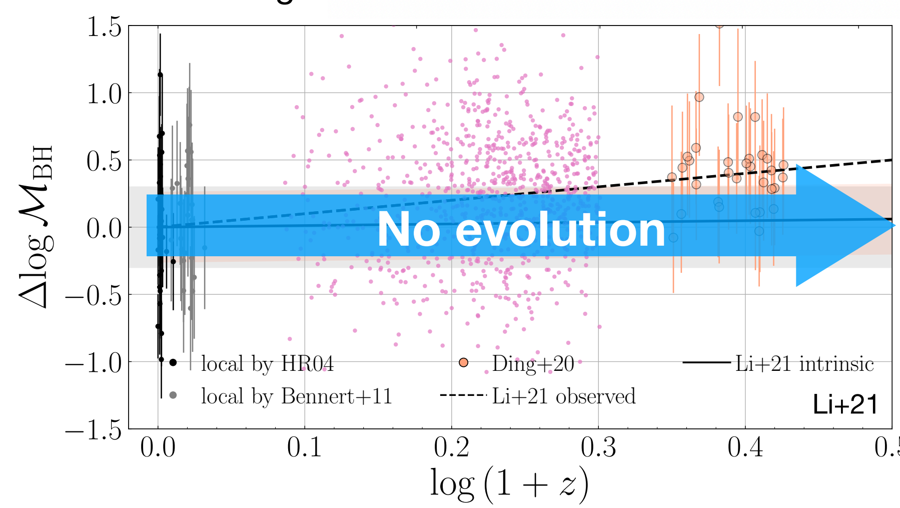
AGN environment

E.g., Onoue+18, Uhiyama+18,22ab; Shirasaki+20; Hashiguchi +23; Suzuki+24

AGN host properties

No significant evolution of M_{BH}-M_* relation up to z~2.





3

See also, Goulding+18; Series of WERGS paper (8 papers); Ishino+20; Chang+21; Brusa+22; Toba+22; Tang+23; Nagele+23; Li+24

Exploring clustering in the high redshift regime

HSC sharp image enables subtraction of AGN cores and characterization of host galaxies

Weak Lensing Working Group

Weak Lensing Working Group

- HSC Survey design (width) is driven mostly by WL. The proposal needs to be verified.

$\sigma(\Omega_m)$

Data	$\sigma(\Omega_{\rm de})$	$\sigma(w_{\rm const})$	$\sigma(w_0)$	$\sigma(w_a)$	FoM	$\sigma(f_{\rm NL})$
HSC	0.026	0.070	0.26	0.69	20.6	16.5
HSC+BOSS	0.019	0.046	0.20	0.52	41.1	16.1

Proposal

Table 9.1.: Expected marginalized errors (68% C.L.) on dark energy parameters and the primordial non-Gaussianity parameter $f_{\rm NL}$ for the HSC Survey, assuming the survey area of 1,400 deg^2. The details can be found from Oguri & Takada (2011). As the observables we included the cluster counts, the cluster correlation function and the stacked weak lensing signals of each cluster redshift slices, as shown in Figures 9.8 and 8.12. We also assumed the CMB priors on cosmological parameters expected from the Planck satellite mission, which give tight constraints on other cosmological parameters besides those shown here. In total we included 34 parameters: cosmological parameters plus nuisance parameters to model various systematic uncertainties (the source redshift uncertainty, the halo off-centering effect and the mass-observable relation, the multiplicative shear error). Note that we did *not* assume any prior on the nuisance parameters, and therefore the marginalized errors shown above are as a result of the self-calibration of the systematic uncertainties (see Figure 9.6).

Expected precision shown on the HSC White Paper (appendix of the HSC-SSP proposal)

Result based on 430 deg^2 data

$$\Omega_{\rm m} = 0.382^{+0.031}_{-0.047}(0.401)\,,$$
$$\sigma_8 = 0.685^{+0.035}_{-0.026}(0.696)\,,$$
$$S_8 = 0.763^{+0.040}_{-0.036}(0.805)\,,$$
$$\Delta z_{\rm ph} = -0.05 \pm 0.09,$$

Miyatake et al. 2023

The precision expected from the final data set (1100 deg^2) wil be:

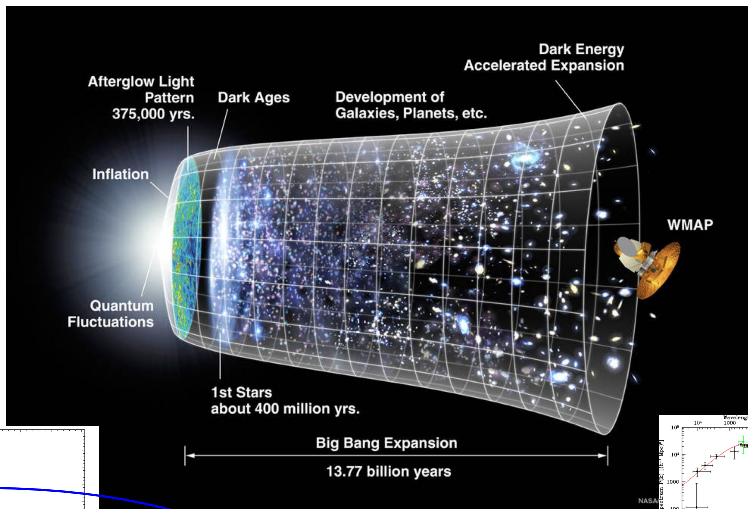
$$\sigma(\Omega_m) \sim 0.04 * \sqrt{430/1100} = 0.025$$

Weak Lensing Working Group

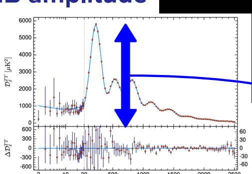
Testing ΛCDM with S_8 tension

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

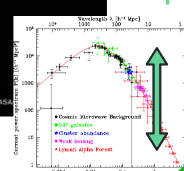
Most of **large-scale structure (LSS) probes** (weak lensing, galaxy clustering, galaxy clusters, etc…) prefer smaller S_8 compared to **CMB**, if we assume ΛCDM is correct.



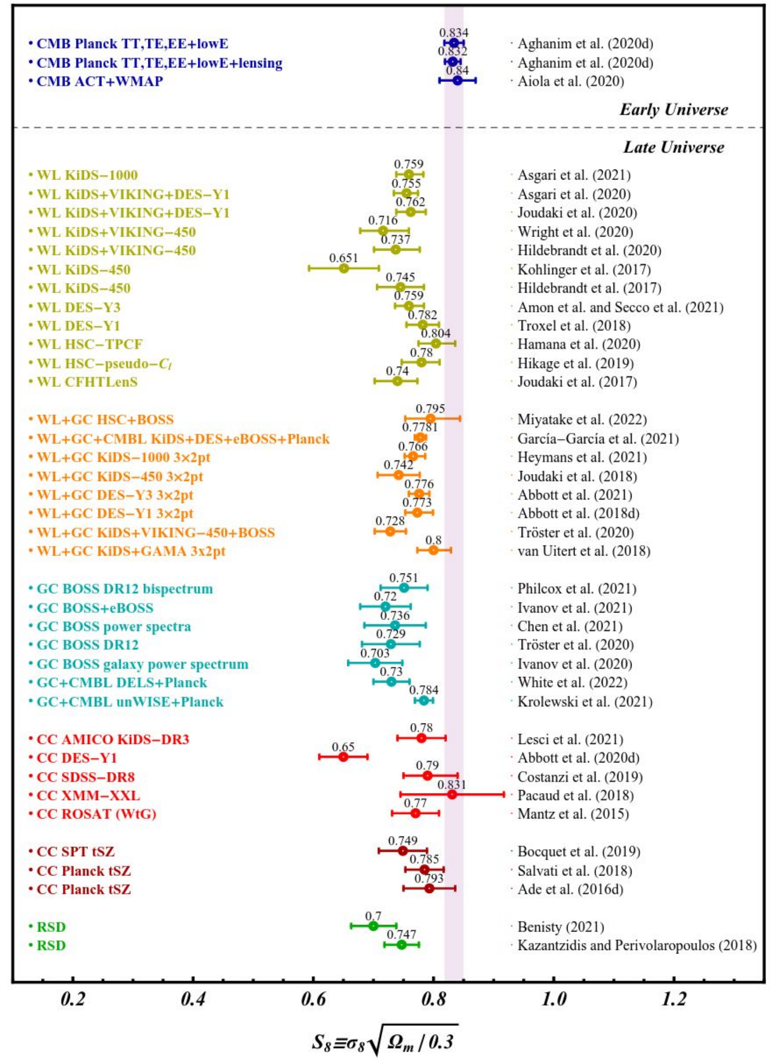
CMB amplitude



LSS probes



Predicting Growth in ΛCDM → S_8 S_8



CMB

Large Scale Structure (LSS)

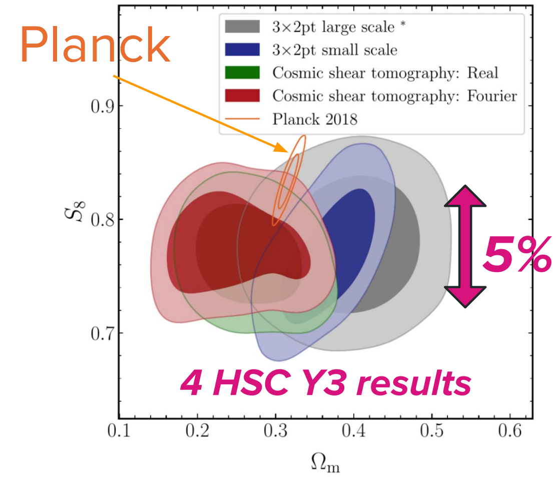
SNOWMASS 2021 Summer study: Abdalla et al. (2022)

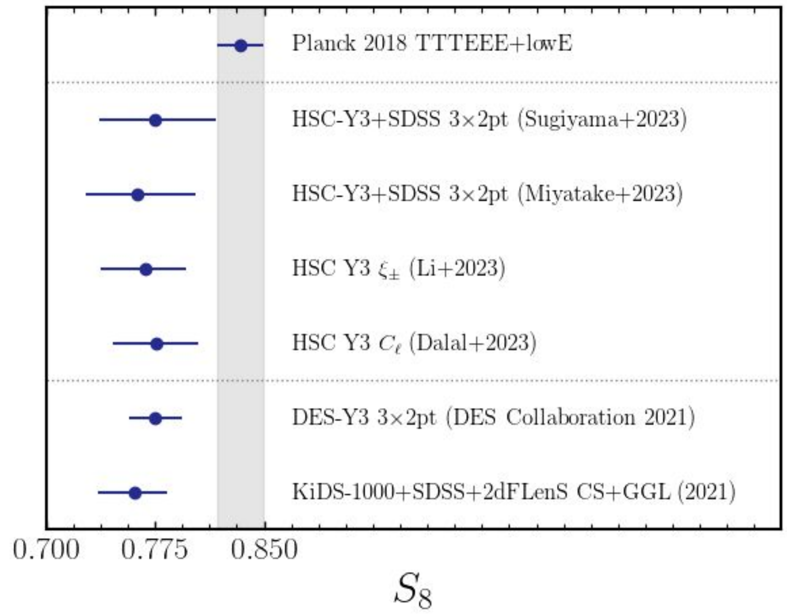
Weak Lensing Working Group

HSC-Y3 Cosmology key papers

$$\gamma \sim \frac{3H_0^2\Omega_{\rm m}}{2c^2}\int_0^{\chi_s} {\rm d}\chi' \frac{\chi'(\chi_s-\chi')}{\chi_s a(\chi')}\delta_m(\chi'\theta,\chi') \sim S_8$$

- ❑ Catalog papers (sky coverage 416 deg^2 from S19A)
  - ❑ Shape catalog (Li+2022)
  - ❑ Photometric calibration (Rau+2023)
  - ❑ PSF systematics (Zhang+2023)
- ❑ Cosmology papers
  - ❑ 3x2pt analyses (Miyatake+, Sugiyama+, More+2023)
  - ❑ Cosmic shear Real/Harmonic spaces (Li+, Dalal+2023)
- ❑ We determined S_8 at ***5%*** accuracy
  → indicating ***2σ tension*** with Planck CMB prediction
- ❑ We advertise our results at HSC-Y3 result
  https://hsc-release.mtk.nao.ac.jp/doc/index.php/wly3/

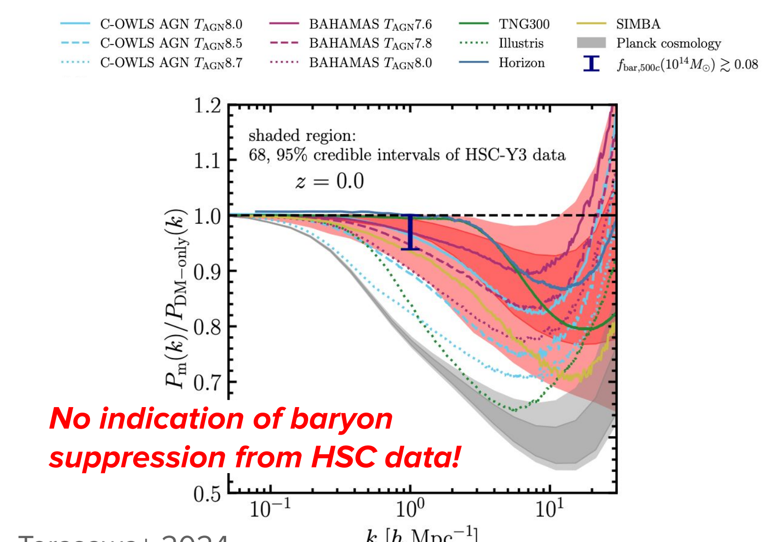




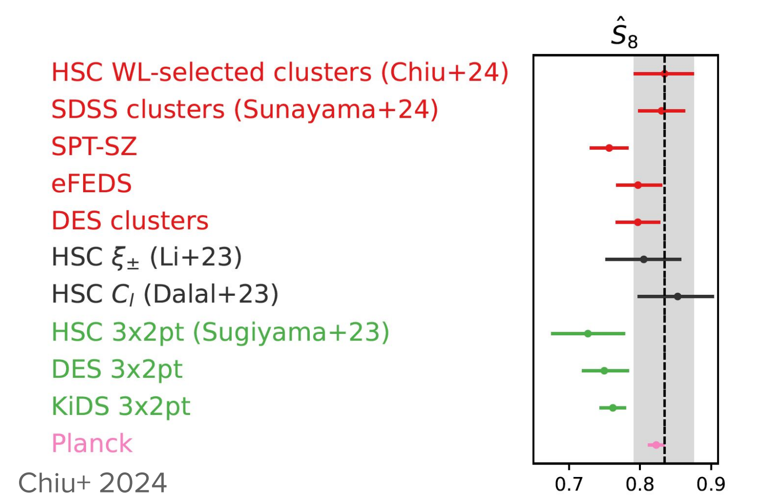
Weak Lensing Working Group

Extended model and analysis

- ❑ Extended HSC-Y3 analyses
  - ❑ Checked that S8 tension is not due to the astrophysical systematics (baryon suppression) in HSC data (Terasawa+2024)
  - ❑ Shear ratio test for the photometric calibration based on the ratio of 2PCF (Rana+ in prep)
  - ❑ Tomography 3x2pt (Zhang+ in prep), wCDM model (More+ in prep), etc.
- ❑ Cluster Cosmology using HSC Y3 data
  - ❑ SDSS redMaPPer clusters (Sunayama+2024)
  - ❑ Shear-selected clusters (Chiu+, Feng+ 2025)
  - ❑ Both studies are consistent with CMB and HSC Y3 cosmic shear analyses
- ❑ HSC final-year (on going)
  - ❑ Now working on the catalog production

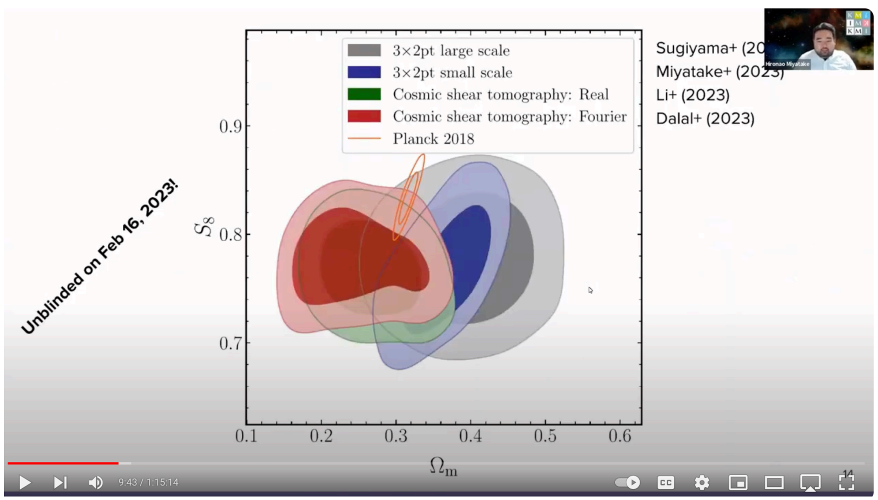


Terasawa+ 2024

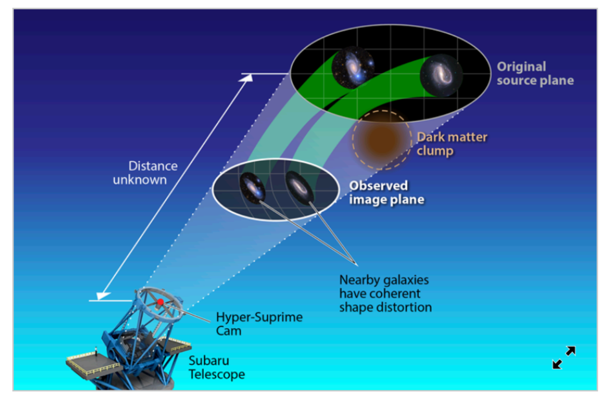


Chiu+ 2024

Weak Lensing Working Group



Webinar was held in Apr 2023, when papers were published in arXiv. About 280 scientists joined the webinar.



HSC-SSP; NOAJ; APS/Alan Stonebraker

Five cosmology papers were published in PRD in Dec 2023, and appeared in Physics Viewpoint. Only 0.5% of accepted papers are covered by Viewpoint.

Strong Lensing Working Group

HSC SSP Strong Lensing Working Group

Overall goals:

- discover a statistical sample of strong lenses at all scales (galaxy/group/cluster) across a range of redshifts (particularly at $z_L > 0.7$)
- develop lens search methodologies that can be applied to future datasets (e.g., LSST)
- discovery of lensed quasar candidates for cosmology
- study of galaxy/group/cluster structure and dark matter profiles
- characterization of lens environments/line-of-sight structure

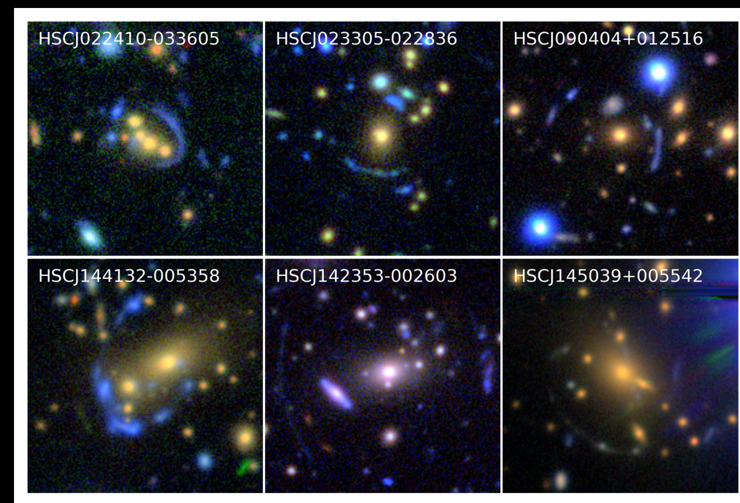
HSC SSP is ideal for lens search due to wide area, depth, image quality

Synergy with upcoming PFS SSP - ancillary target fibers will measure redshifts for > 1000 HSC lenses for “free” as part of the survey

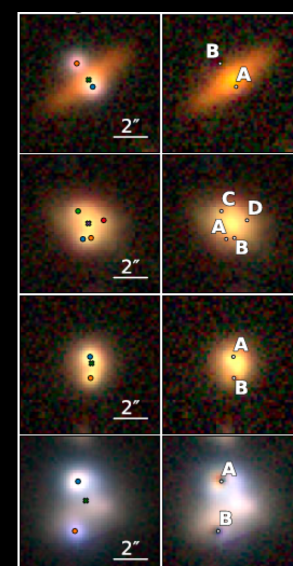
Survey of Gravitationally-lensed Objects in HSC Imaging (SuGOHI)

catalog available here: https://www-utap.phys.s.u-tokyo.ac.jp/~oguri/hsc/stronglens/

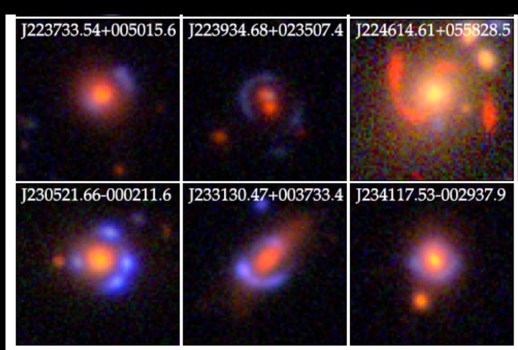
- lens-finding methods
  - automated algorithms (Chan+2015; Sonnenfeld+2018)
  - spectroscopic search method (Shu+2016)
  - variability search method (Chao+2020)
  - citizen science (Sonnenfeld+2020)
  - machine learning (Jaelani+2024; Ishida+2024)
- supplementary searches in PDR by collaborators (e.g., HOLISMOKES)
- grade A/B lens candidates discovered to date
  - > 1000 galaxy-scale lenses
  - > 300 group/cluster-scale lenses
  - > 30 lensed quasar candidates



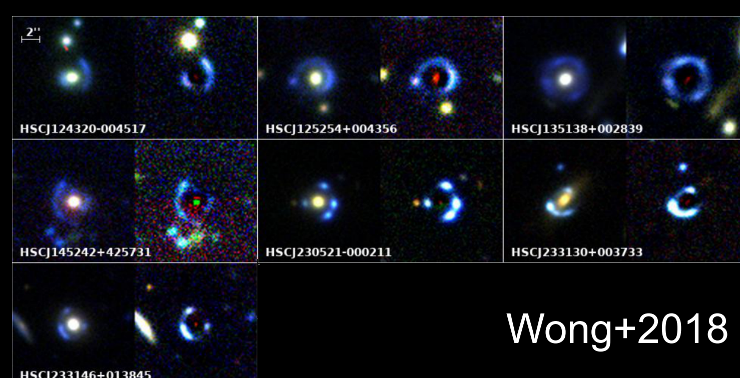
Jaelani+2020



Chan+2024



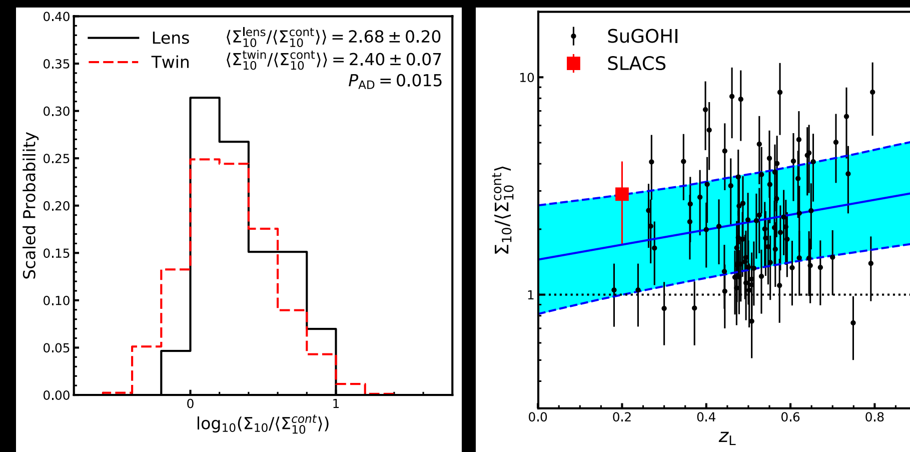
Jaelani+2024



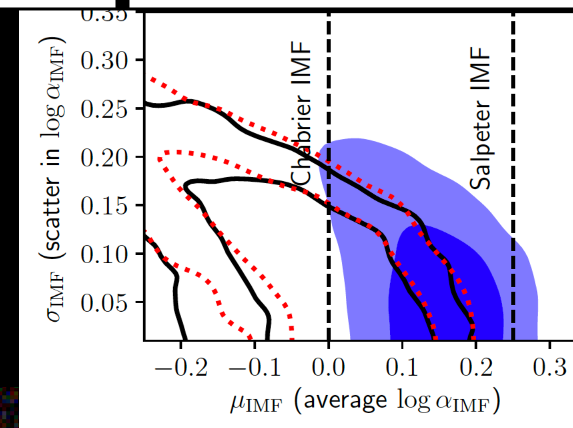
Wong+2018

Strong Lensing Science Results

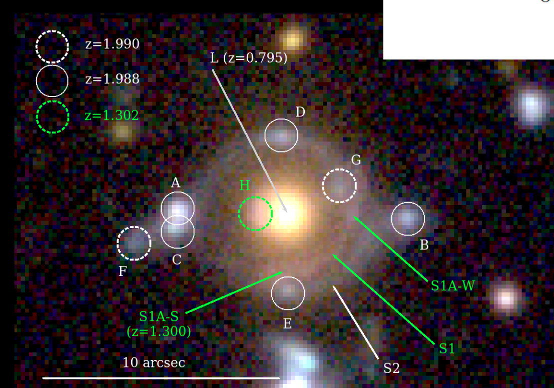
- Environments of lens galaxies (Wong+2018)
  - lens galaxies lie in similar environments/lines of sight to non-lens galaxies of similar mass/redshift
  - no evidence for redshift evolution of lens environment
- Constraints on stellar IMF (Sonnenfeld+2019) - elliptical lens galaxies more consistent w/ Chabrier IMF than Salpeter
- Double source plane lens "Eye of Horus" (Tanaka+2016)
  - first spectroscopically confirmed DSP lens
  - mass/cosmology constraints from detailed lens modeling (Jaelani+ in prep.)
- Comparison of ML-based lens search methods
  - evaluation of multiple lens search networks using common test sample (More+2024)
  - combining neural networks w/ lens light subtraction (Ishida+2024)



Wong+2018



Sonnenfeld+2019



Tanaka+2016

Cluster Working Group

1.Constructing galaxy cluster catalogs

- optical CAMIRA clusters (Oguri+18a, Oguri+ in prep.)

  Using the final photometric data

  29035 clusters/groups over ~1089 deg^2 for WIDE

  655 clusters/groups over ~32 deg^2 for Deep+UD

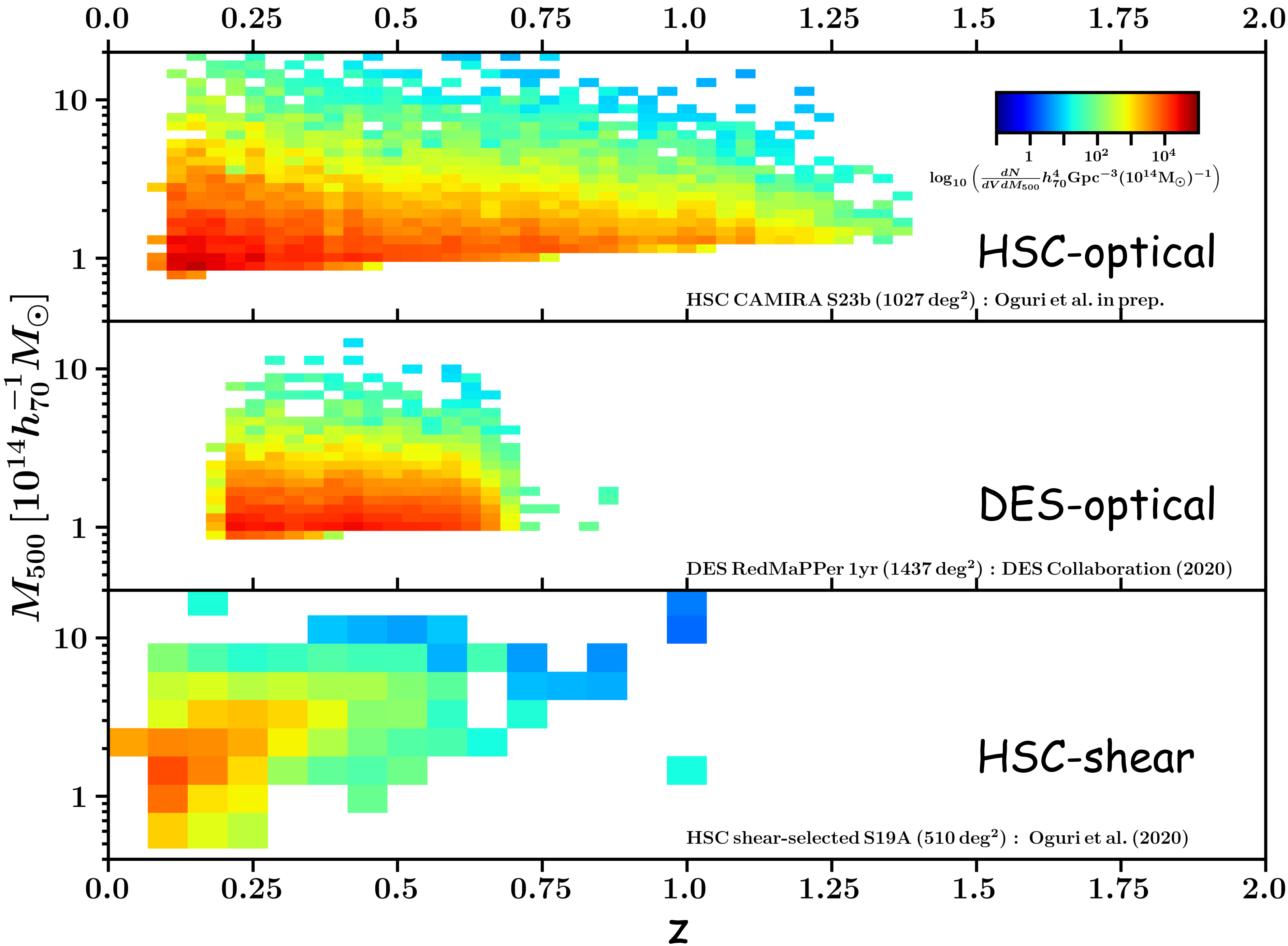
- shear-selected clusters : (Miyazaki+18, Oguri+18b, Oguri+21)

  187 clusters over ~517 deg^2 with S19A-shape catalog

- superclusters (Simakawa+22, Chen+24)

  King Ghidorah Supercluster (400 comoving Mpc @ z~0.55)

  673 superclusters over ~1027 deg2 at z~0.5-1.0

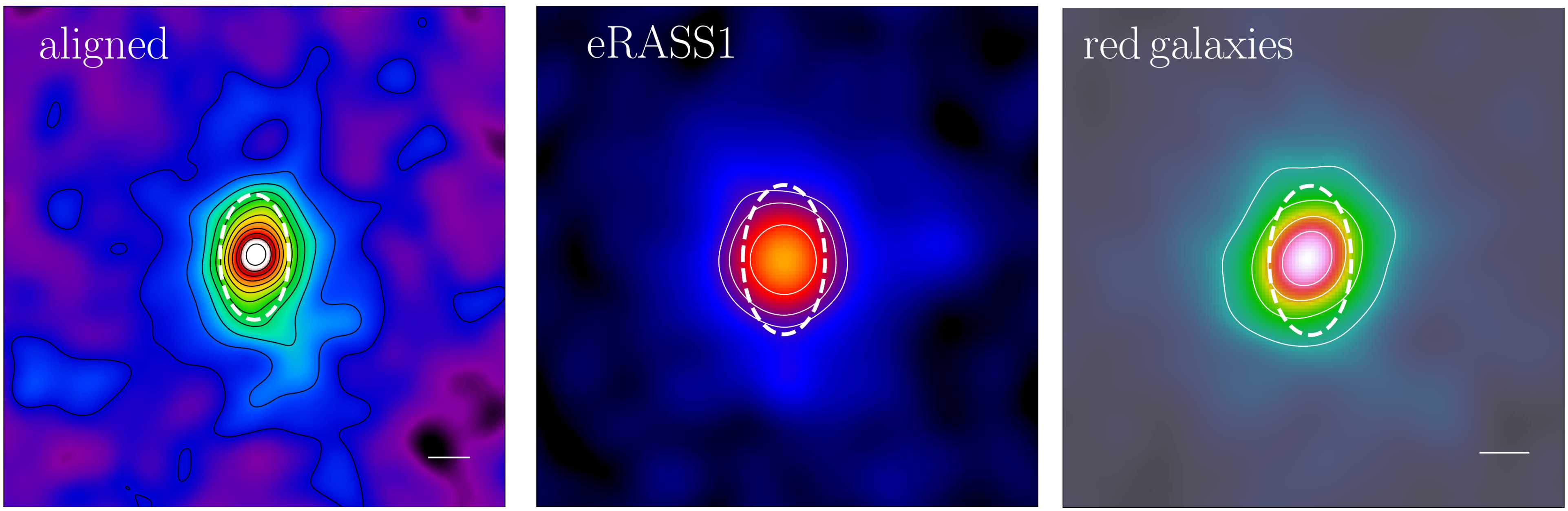


HSC-optical
HSC CAMIRA S23b (1027 deg^2) : Oguri et al. in prep.
DES-optical
DES RedMaPPer 1yr (1437 deg^2) : DES Collaboration (2020)
HSC-shear
HSC shear-selected S19A (510 deg^2) : Oguri et al. (2020)
$\log_{10}\left(\frac{dN}{dV\,dM_{500}} h_{70}^4 \mathrm{Gpc}^{-3} (10^{14} \mathrm{M}_\odot)^{-1}\right)$
1
10^2
10^4
$M_{500}\,[10^{14} h_{70}^{-1} M_\odot]$
z
0.0
0.25
0.5
0.75
1.0
1.25
1.5
1.75
2.0
1
10

2.Measuring internal mass structures (Okabe+18, Umetsu+20, Okabe+sub.)

Halo Ellipticity (Okabe+ sub.)

Mass | X-ray | Galaxies

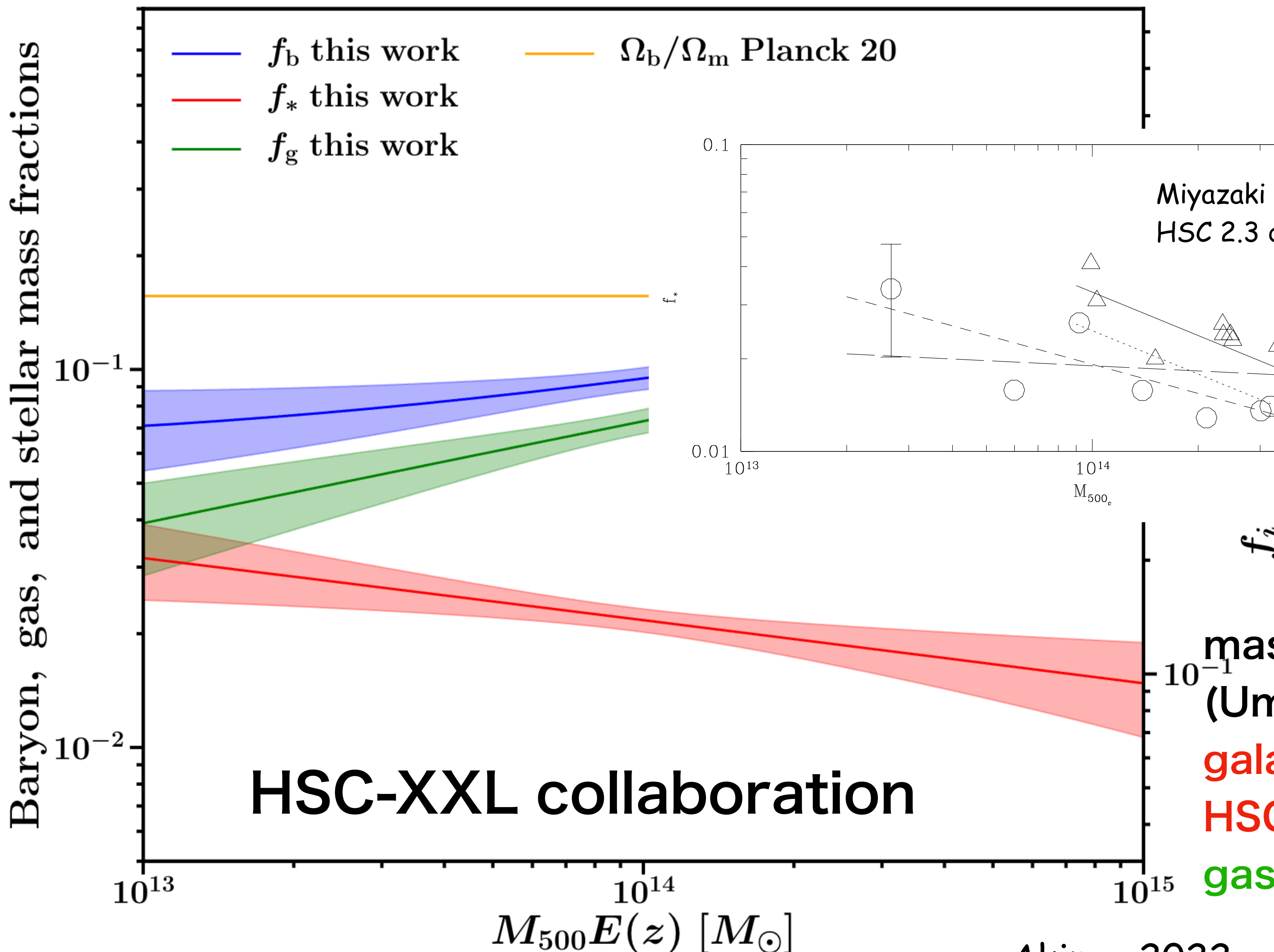


$\langle \varepsilon \rangle \sim 0.5$ | $\langle \varepsilon \rangle \sim 0.1$ | $\langle \varepsilon \rangle \sim 0.2$

3. Understanding an interplay between the intracluster medium and dark matter through multi-wavelength analyses or external collaborations.

- XMM-Newton (Miyaoka+18, Ota+20)
- XXL (Akino+22; other 5 papers)
- eROSITA (Ota+21; other 13 papers)
- ACT-Pol (Miyatake+19, Ding+25)
- ALMA (Kitayama+23) and MUSTANG-2 (Okabe+21

Baryon fraction in the range of two-order magnitude of mass



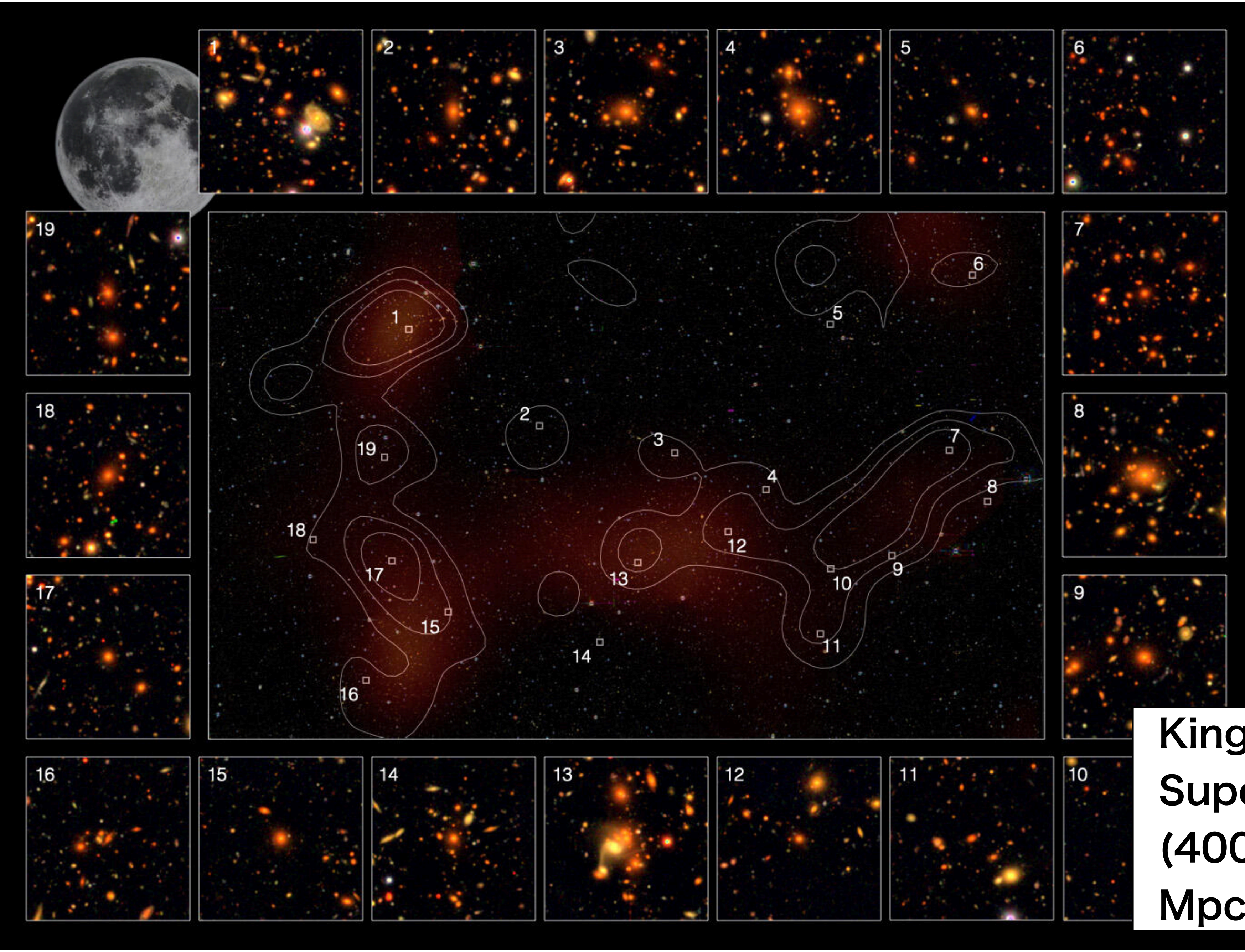
mass = HSC WL (Umetsu+20)

galaxies = HSC galaxies

gas = XXL X-ray

Akino+ 2022

4. Understanding galaxy evolution in extreme environments (Koyama+18, Shimakawa+22)



King Ghidorah Supercluster (400 comoving Mpc @ z~0.55)

HSC - eROISITA Collaboration

- Formal MoU in 2017/07 and the collaboration established
- Cluster WG and AGN WG
  - Project announcements from individual and the chairs of WGs made arrangement if necessary.
  - Collaboration Board was formed to resolve issues if conflict occurs but no such report.
  - No direct proprietary data exchange

Memorandum of Understanding

Between

The HSC-SSP Collaboration

and the

German eROSITA Consortium

Dated:

Peter Predehl, Principal Investigator, eROSITA Telescope Date

Satoshi Miyazaki, Principal Investigaor, HSC-SSP Date

Late Yasuo Tanaka (MPE) bonded us together …

HSC - eROISITA Collaboration

- 140 deg^2 eFEDS Field (Commissioning Field)
- > 15 papers have been published on A&A Special Issue

1 2021arXiv211009544B 2021/10
The eROSITA Final Equatorial-Depth Survey (eFEDS): Galaxy Clusters and Groups in Disguise
Bulbul, Esra; Liu, Ang; Pasini, Thomas *and 21 more*

2 2021arXiv211009534B 2021/10
The eROSITA Final Equatorial-Depth Survey (eFEDS): X-ray Properties and Scaling Relations of Galaxy Clusters and Groups
Bahar, Y. Emre; Bulbul, Esra; Clerc, Nicolas *and 16 more*

3 2021arXiv210907836R 2021/09
The eROSITA Final Equatorial-Depth Survey (eFEDS): A complete census of X-ray properties of Subaru Hyper Suprime-Cam weak lensing shear-selected clusters in the eFEDS footprint
Ramos-Ceja, Miriam E.; Oguri, M.; Miyazaki, S. *and 23 more*

4 2021arXiv210705652C 2021/07 cited: 9
The eROSITA Final Equatorial-Depth Survey (eFEDS): X-ray Observable-to-Mass-and-Redshift Relations of Galaxy Clusters and Groups with Weak-Lensing Mass Calibration from the Hyper Suprime-Cam Subaru Strategic Program Survey
Chiu, I-Non; Ghirardini, Vittorio; Liu, Ang *and 18 more*

5 2021arXiv210615086G 2021/06 cited: 4
The eROSITA Final Equatorial-Depth Survey (eFEDS): Characterization of Morphological Properties of Galaxy Groups and Clusters
Ghirardini, V.; Bahar, E.; Bulbul, E. *and 16 more*

6 2021arXiv210614527T 2021/06 cited: 2
The eROSITA Final Equatorial-Depth Survey (eFEDS): A multiwavelength view of WISE mid-infrared galaxies/active galactic nuclei
Toba, Yoshiki; Liu, Teng; Urrutia, Tanya *and 21 more*

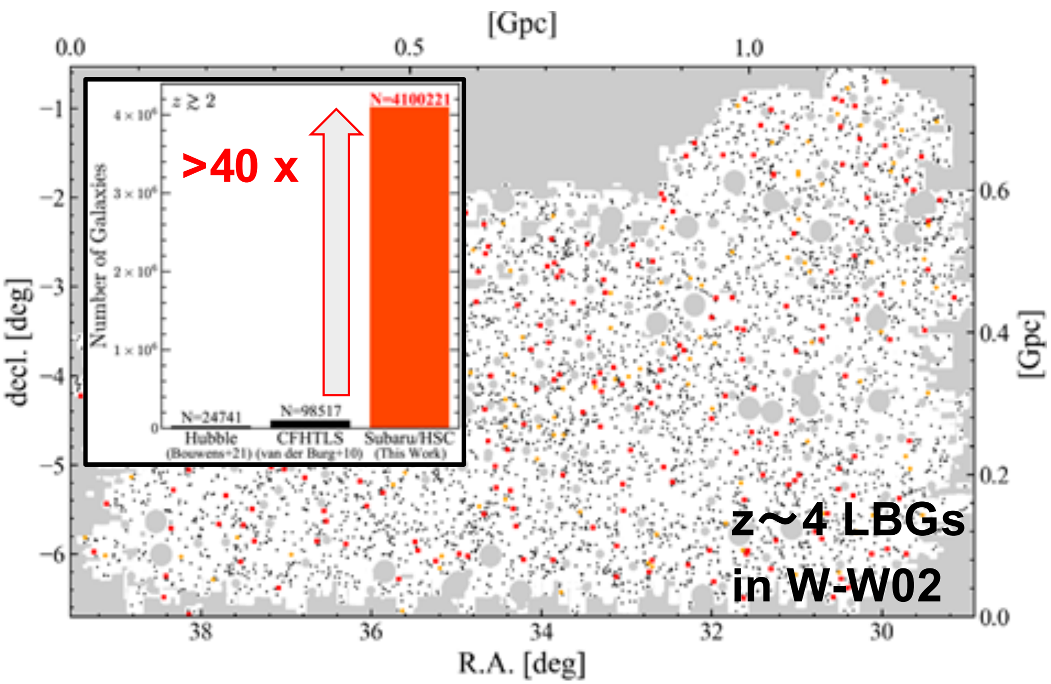
7 2021arXiv210614526V 2021/06
The eROSITA Final Equatorial-Depth Survey (eFEDS): Presenting The

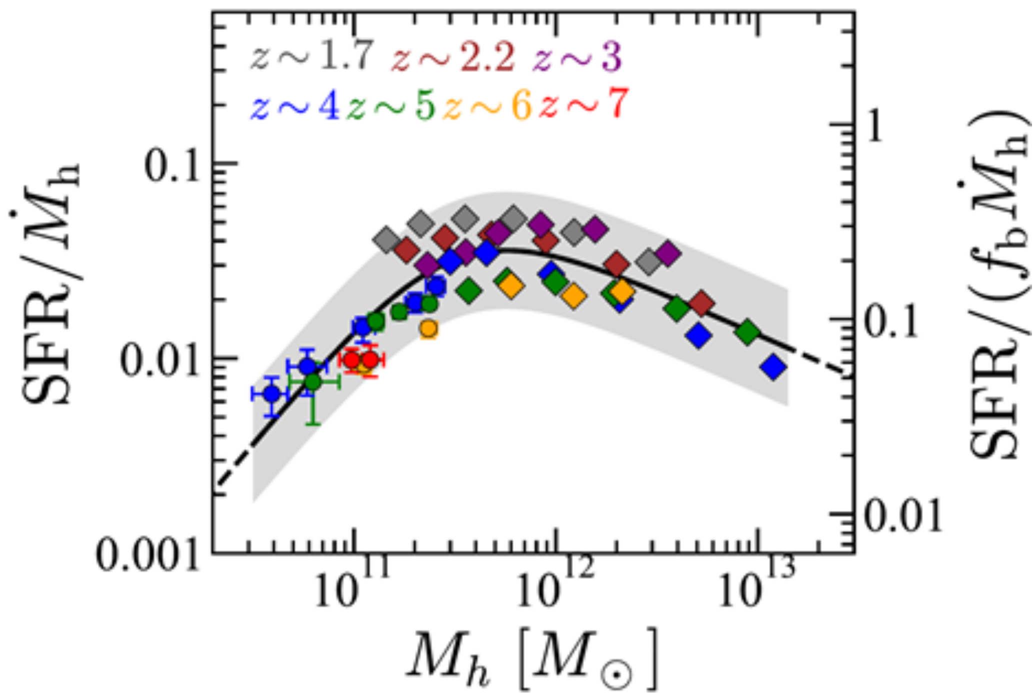
High-z galaxy Working Group

LBG

Clustering Analysis of >4,000,000 Galaxies at z=2−7

(Harikane et al. 2022, ApJS, 259, 20)

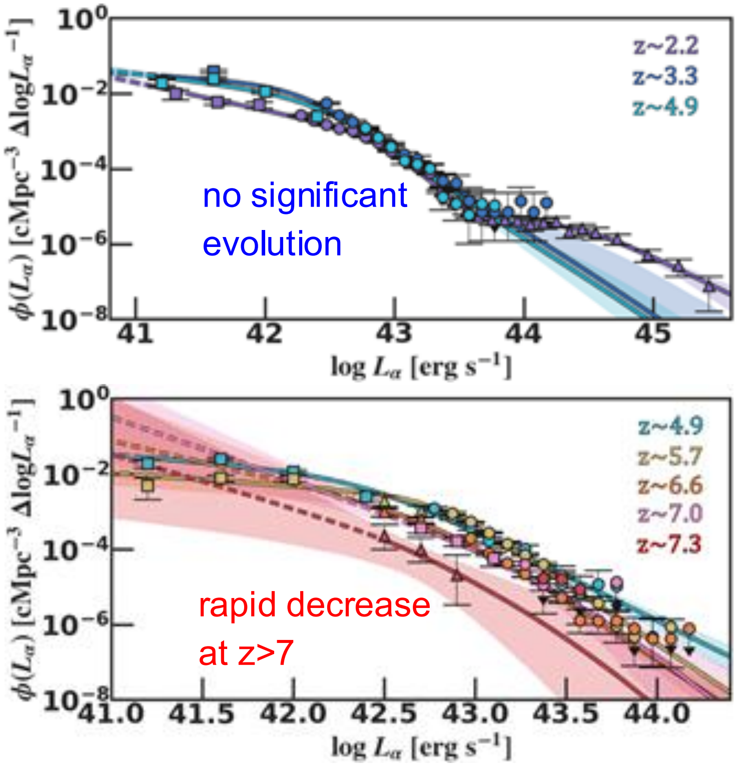


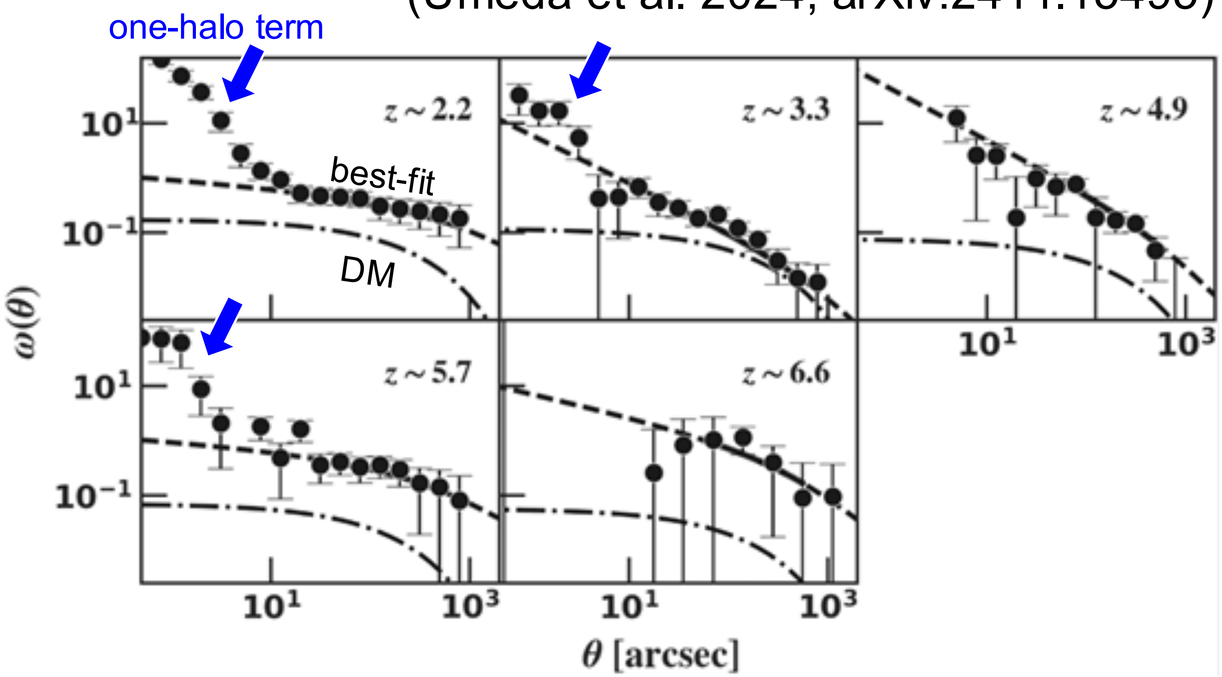


- The large survey volume of HSC SSP enables the unprecedentedly large sample, allowing high-z galaxies' halo mass constraints across a broad halo mass range.
- $\mathrm{SFR}/\dot{M}_\mathrm{h}$ almost constant at z~6−7 to z~4, then increases with decreasing redshift, remarkably well reproducing the evolution of the cosmic SFR density.

Lya LFs and ACFs from ~20,000 Lya Emitters at z=2.2−7.3

(Umeda et al. 2024, arXiv:2411.15495)





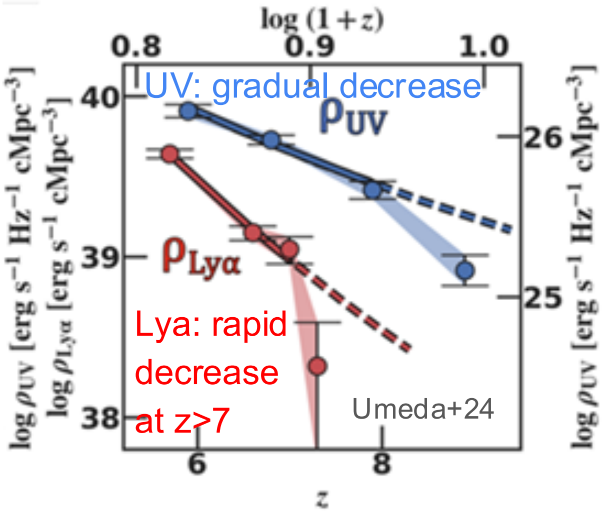
- Based on the HSC SSP and CHORUS data, Lya LFs show no significant evolution at z=2.2-5.7, start to decrease from z=5.7, and sharply decline at z>7
- Clustering Analysis yields halo mass estimates of ~1e+11 Msun for LAEs across all redshifts.

(See also, Goto et al. 2021, ApJ, 923, 229)

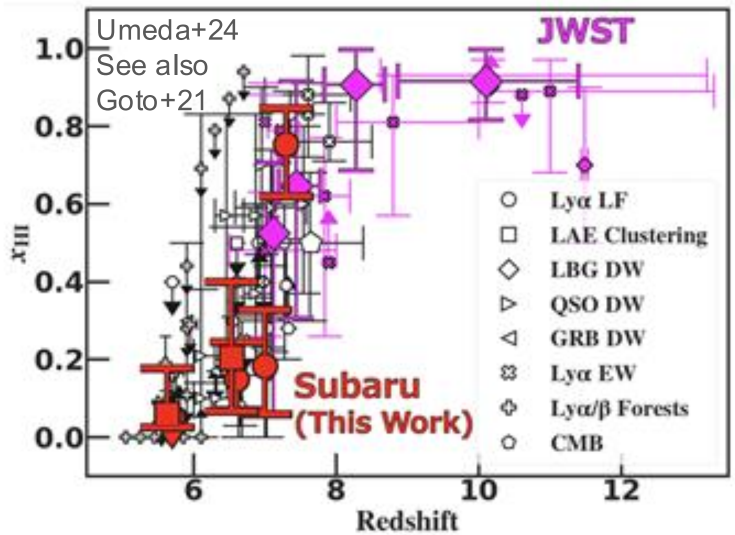
based on the largest Lya emitter samples

IGM neutral hydrogen fraction during the reionization

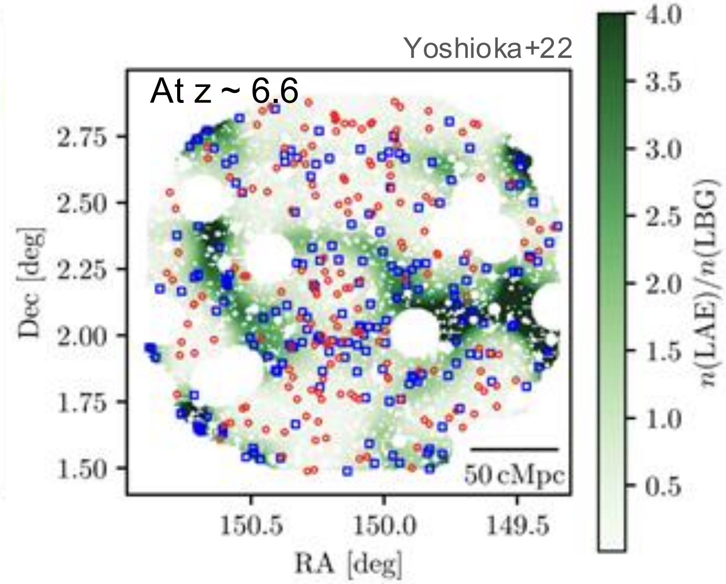
(Umeda et al. 2024, arXiv:2411.15495; Goto et al. 2021, ApJ, 923, 229; Yoshioka et al. 2022, ApJ, 927,32)



Luminosity density



neutral hydrogen fraction



- Lya luminosity density rapidly decreases at z ~7 compared to UV luminosity density, indicating rapid increase of neutral hydrogen fraction (x_HI) around z ~7.
- The observed number density ratio of LAEs to LBGs, n(LAE)/n(LBG), at z ~ 6.6 shows the significant spatial variation. This potentially reflects the x_HI inhomogeneous topology, as well as difference between inherent distributions of LAEs and LBGs.

green contour: n(LAE)/n(LBG)
quite imhomogeneous

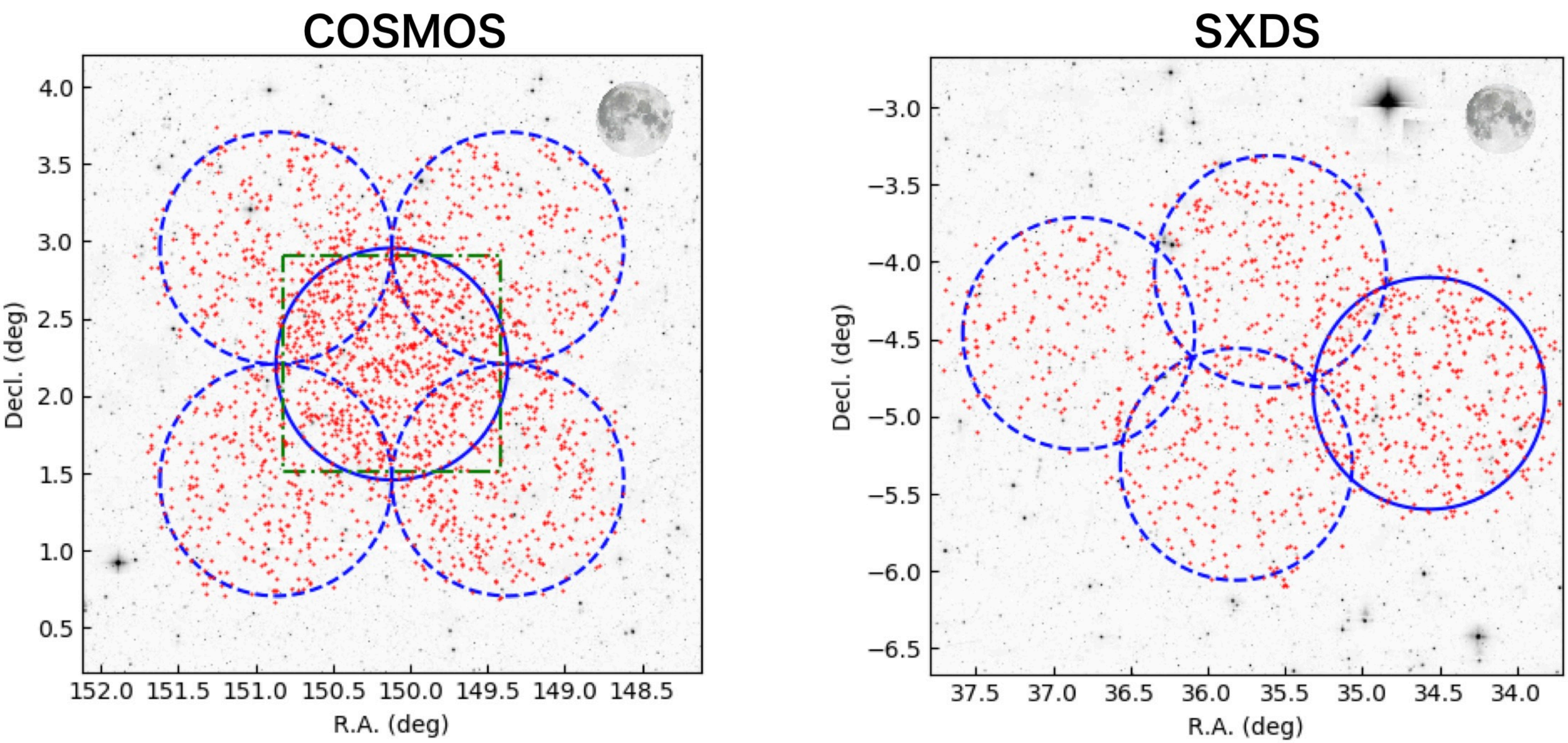
Supernova / Transient Working Group

Transient Surveys in the HSC SSP Deep/UDeep fields

Supernova/Transient Working Group

Key science goal:

- constraining the dark energy parameters with ~120 type Ia supernovae up to z ~ 1.4
- discovering significant numbers of core-collapse supernovae up to z ~ 4



red points: locations of SN candidates

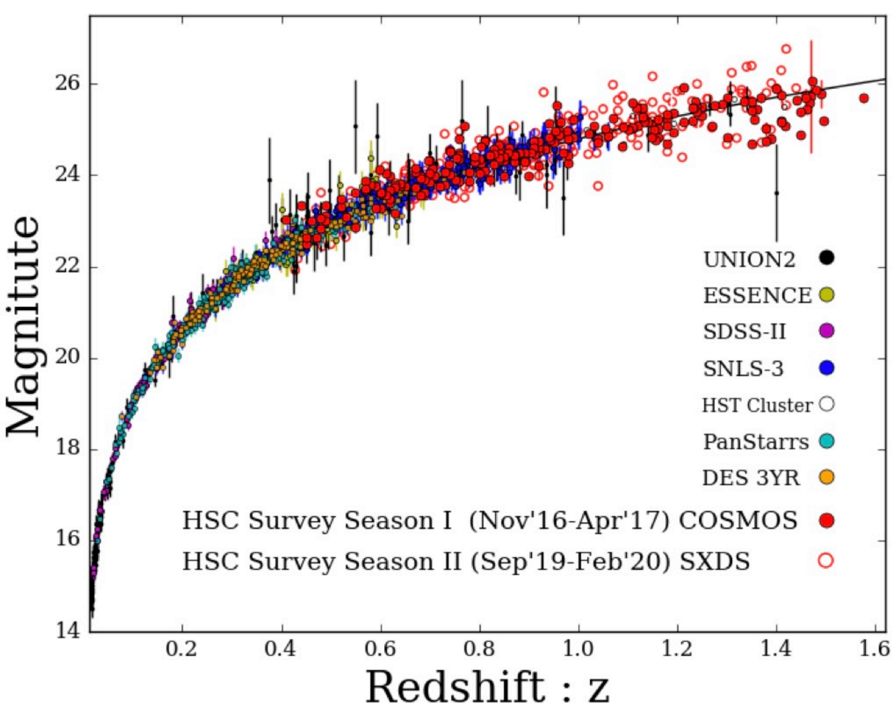
Type Ia supernova cosmology

- 165 Type Ia SNe at z > 1!
- Getting close to achieve the most precise measurement of dark energy.
- Ongoing effort of Spec-z follow-up and Calibration

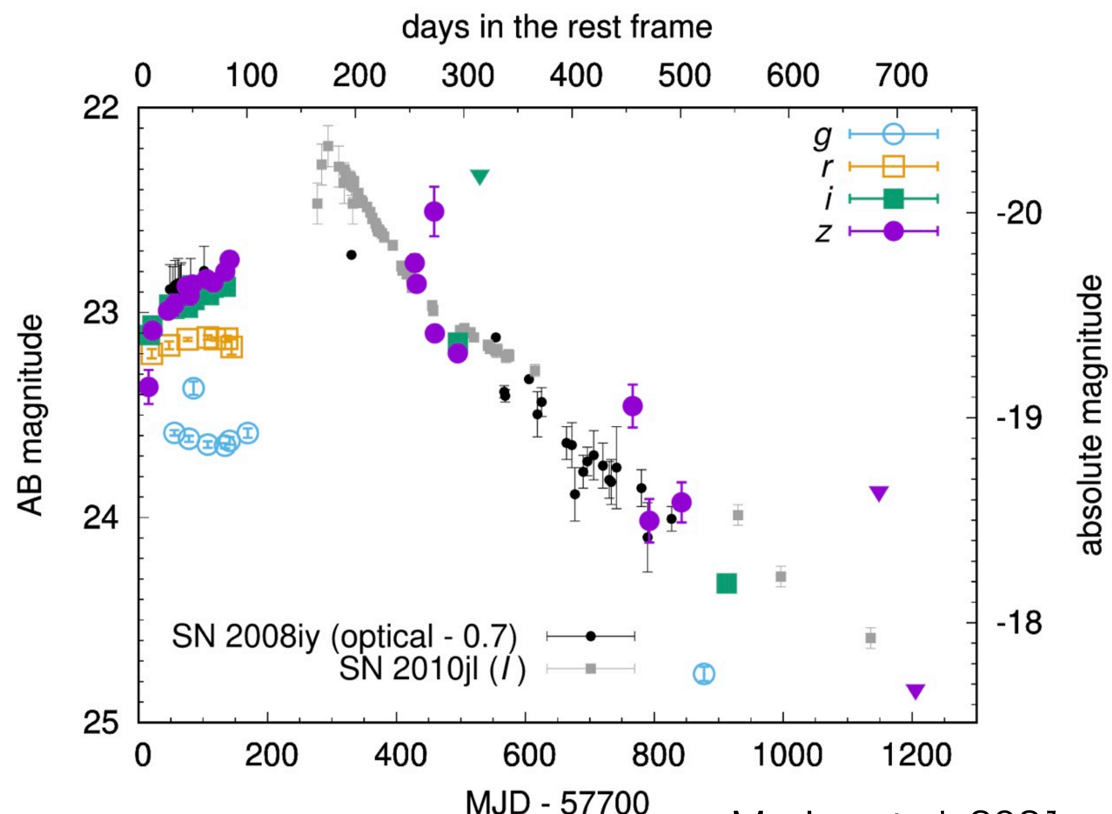
Core-collapse supernova

- Rare long-lasting SNe were discovered, and event rate for long-lasting SNe is constrained (Moriya et al. 2019, 2021)
- 14 rapid transients up to z~2 were discovered, including two candidates of superluminous SNe (Toshikage et al. 2024)

SN Ia Hubble diagram



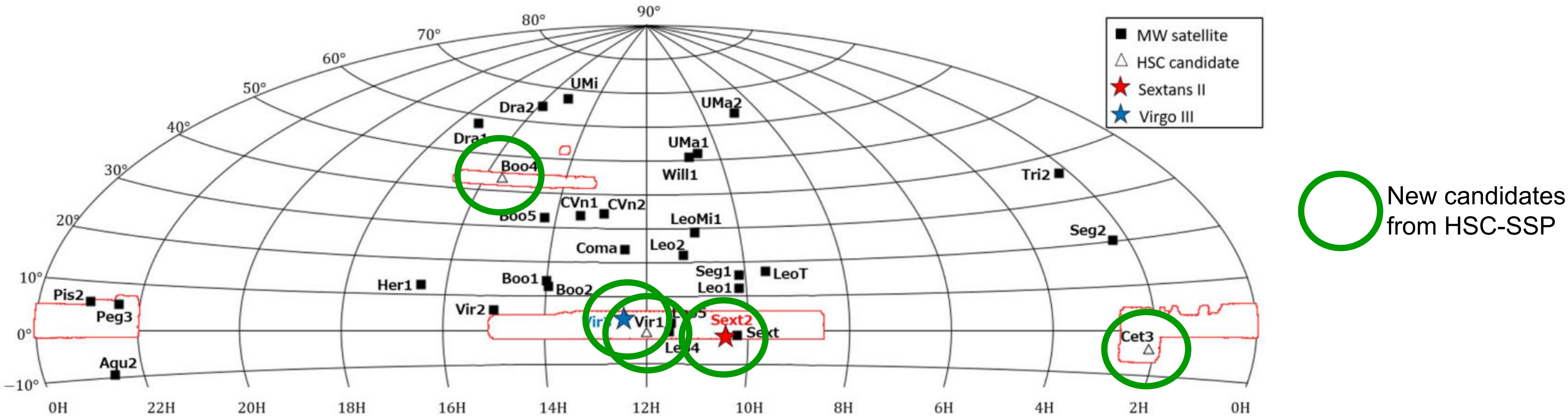
Suzuki et al. in prep.

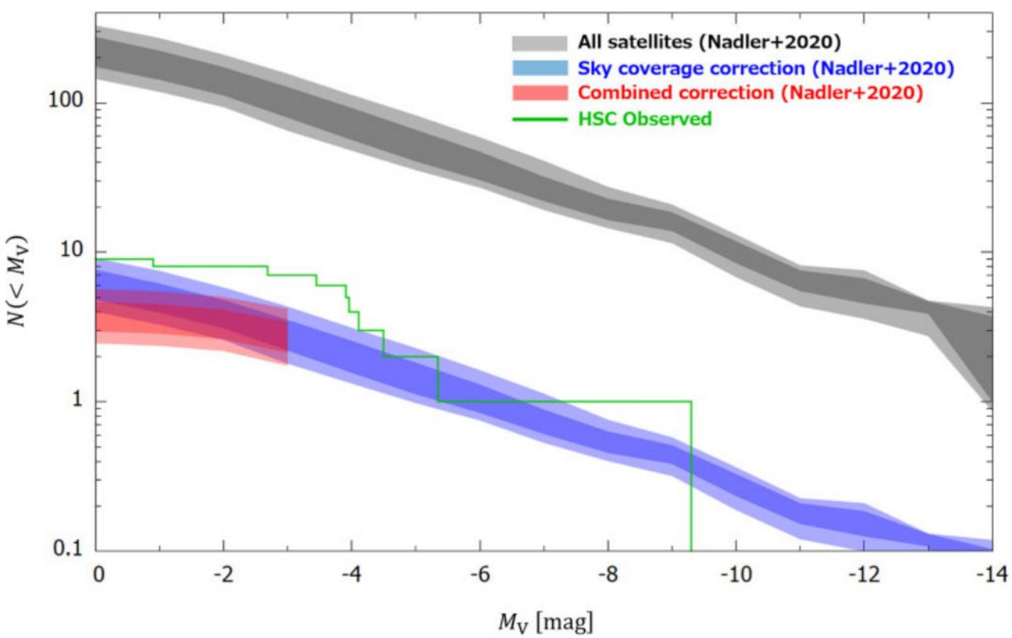


Moriya et al. 2021

Low-z galaxy / archaeology Working Group

Ultra faint satellites of the Milky Way Galaxy

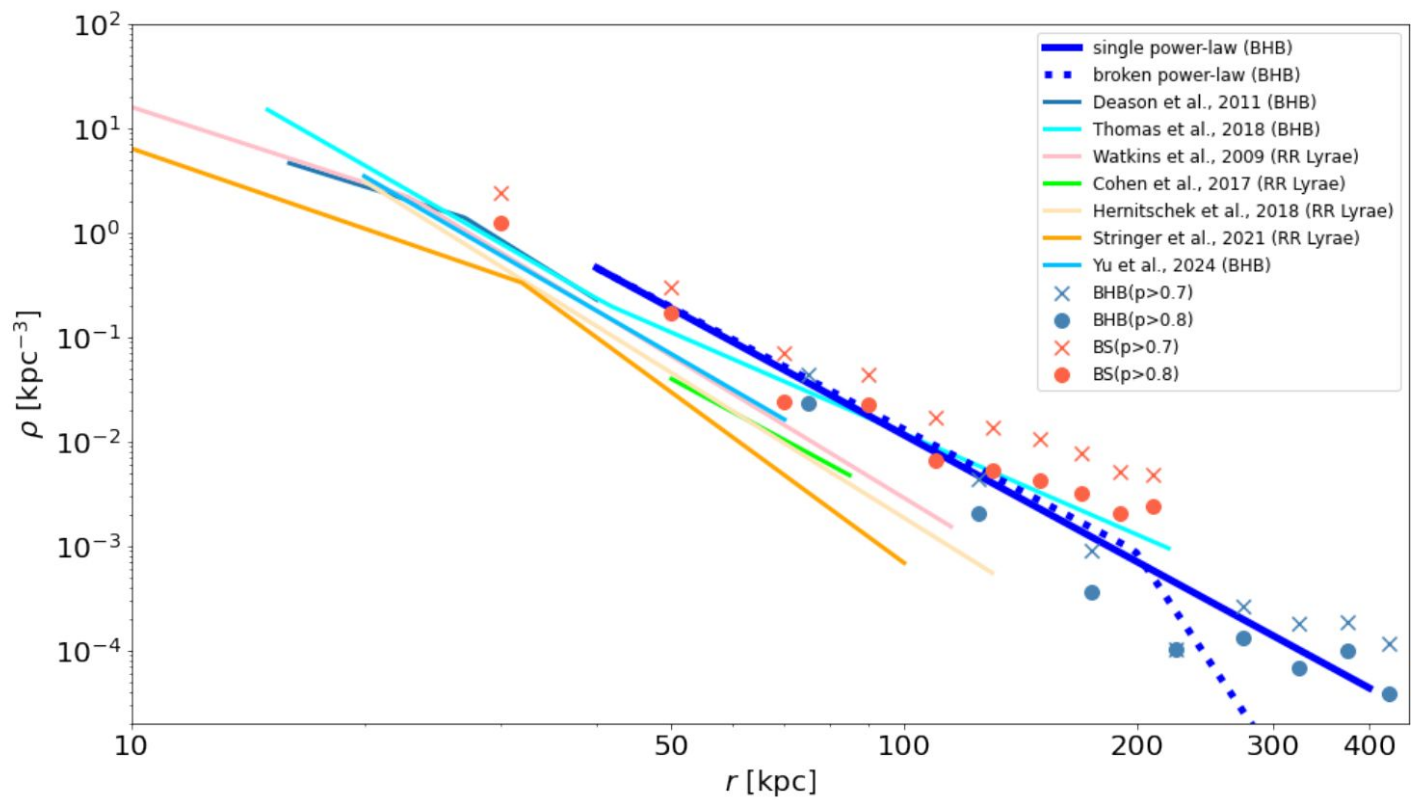




We have identified 5 new ultra-faint dwarf satellite candidates around the MW from HSC-SSP. Follow-up spectroscopic campaigns are being made. The candidates indicate an over-abundance of satellite galaxies compared to recent simulations, i.e., "too many satellites problem", instead of missing satellites problem in ΛCDM theory.

Homma et al. 2024, PASJ

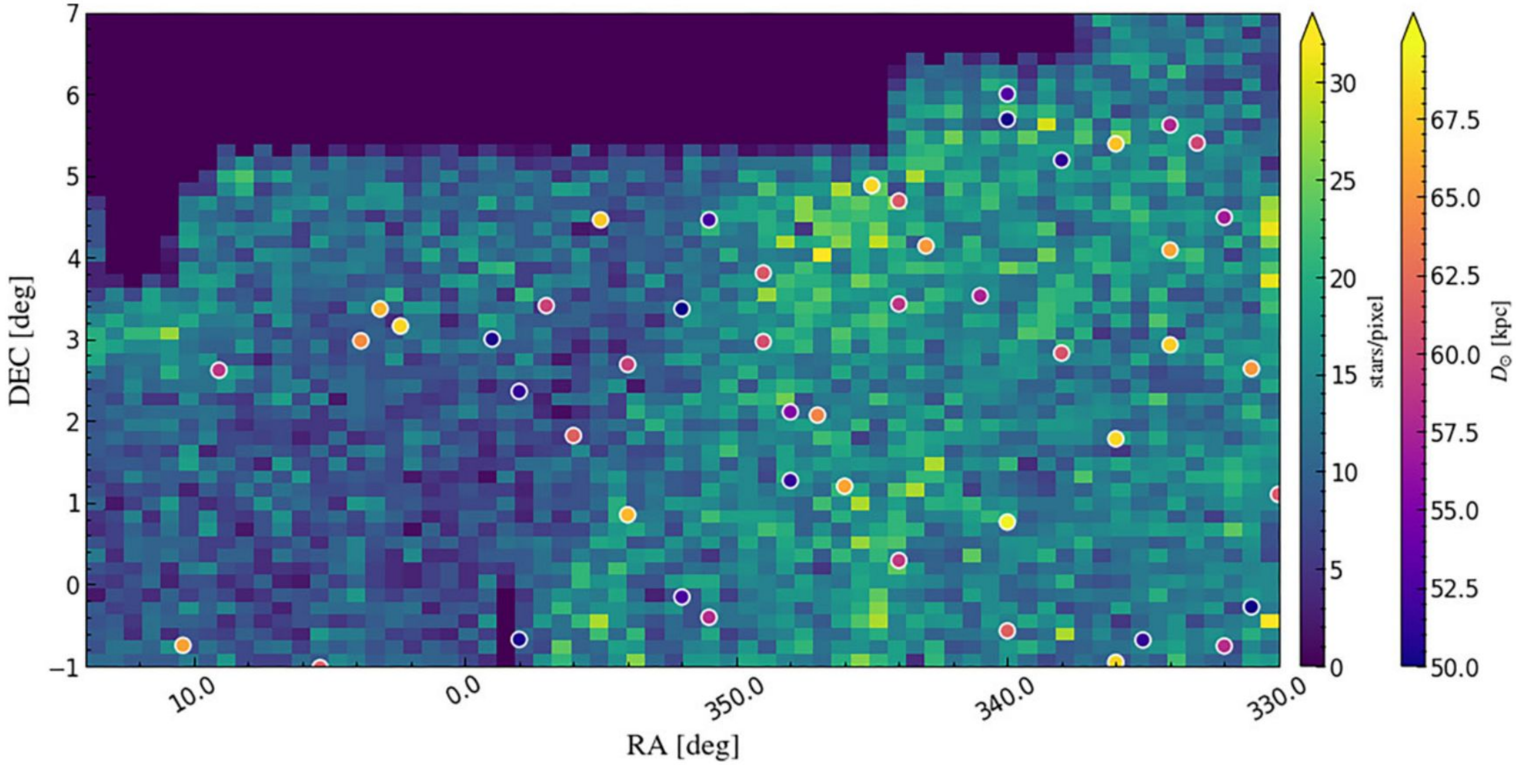
Mapping the halo of the Milky Way Galaxy



By carefully selecting Blue Horizontal Branch stars (BHBs) using the multi-color information from HSC-SSP, we have constructed a map of the Galaxy halo using BHBs as halo tracers, reaching out to the edge of the Galaxy. The outer profile of the halo can be fitted by a |broken / single| power-law. Rubin is going to firmly establish the outer profile.

Fukushima et al. 2025, PASJ

New stellar stream candidates



By applying an isochrone filter to the halo stars, we have identified a new stellar stream candidate at ~66 kpc. The points here are blue stragglers with distances color-coded. There is a rough correspondence between the candidate stream and the location and distance of the blue stragglers.

Suzuki et al. 2024, PASJ

HSC photo-z working group

Atsushi J. Nishizawa (Gifu-Shotoku), Masayuki Tanaka (NAOJ), Bau-Ching Hsieh (ASIAA),
Sogo Mineo(NAOJ), Jean Coupon, Joshua Speagle(Tronto), and HSC photo-z WG

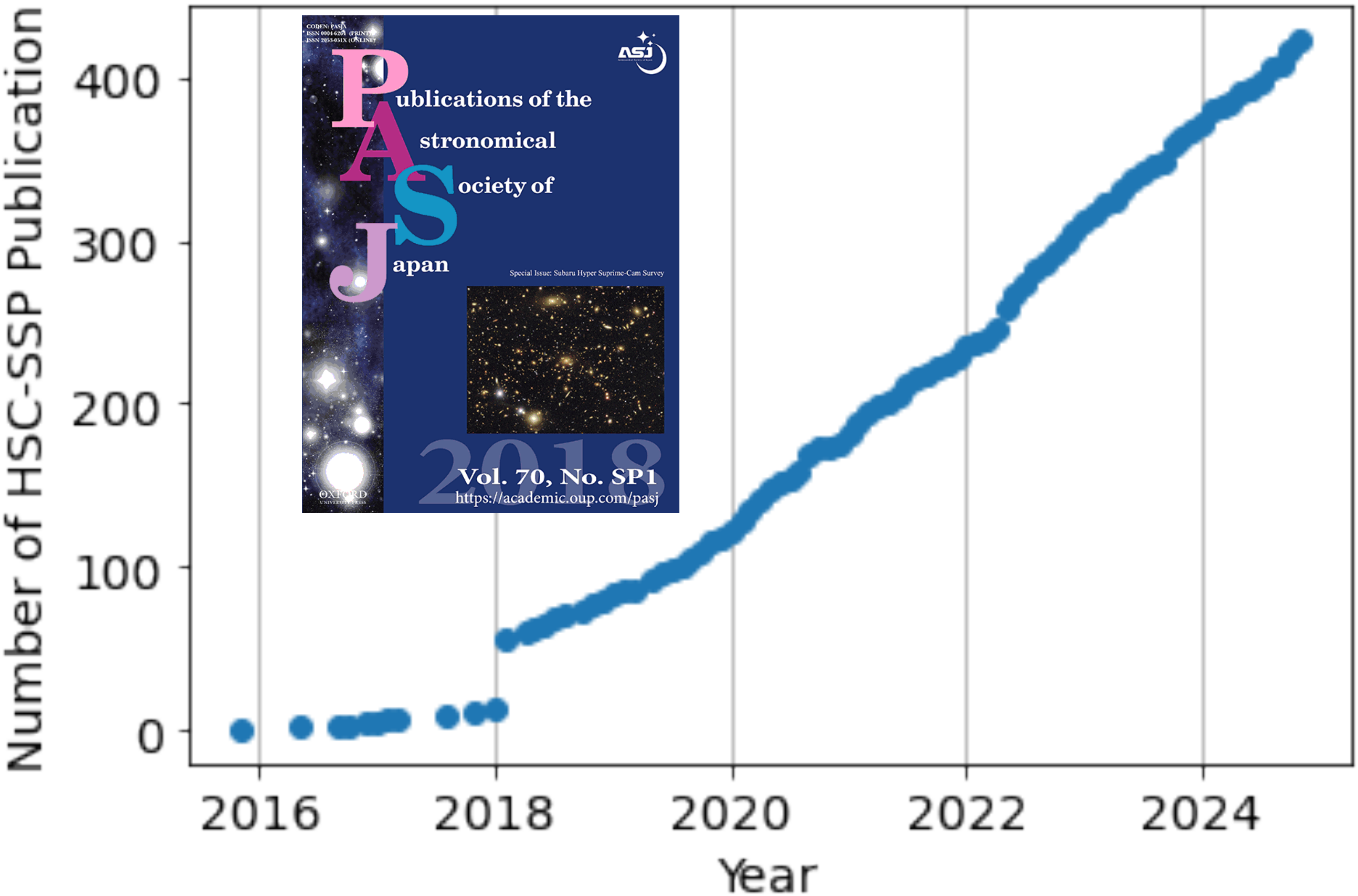
semester/code	Mizuki	DEmP	NNPZ	SOMz	Ephor	Ephor_cm	FrankenZ	dNNz
S15B	o	o	o	o			o	
S16A (PDR1)	o	o	o	o	o	o	o	
S17A	o	o						
S18A (PDR2)	o	o						
S19A	o	o						o
S20A (PDR3)	o	o						o
S21A	o	o						o
S23B (PDR4)	△	△						△

We have provided a set of photo-z and spec-z catalogs at every data release

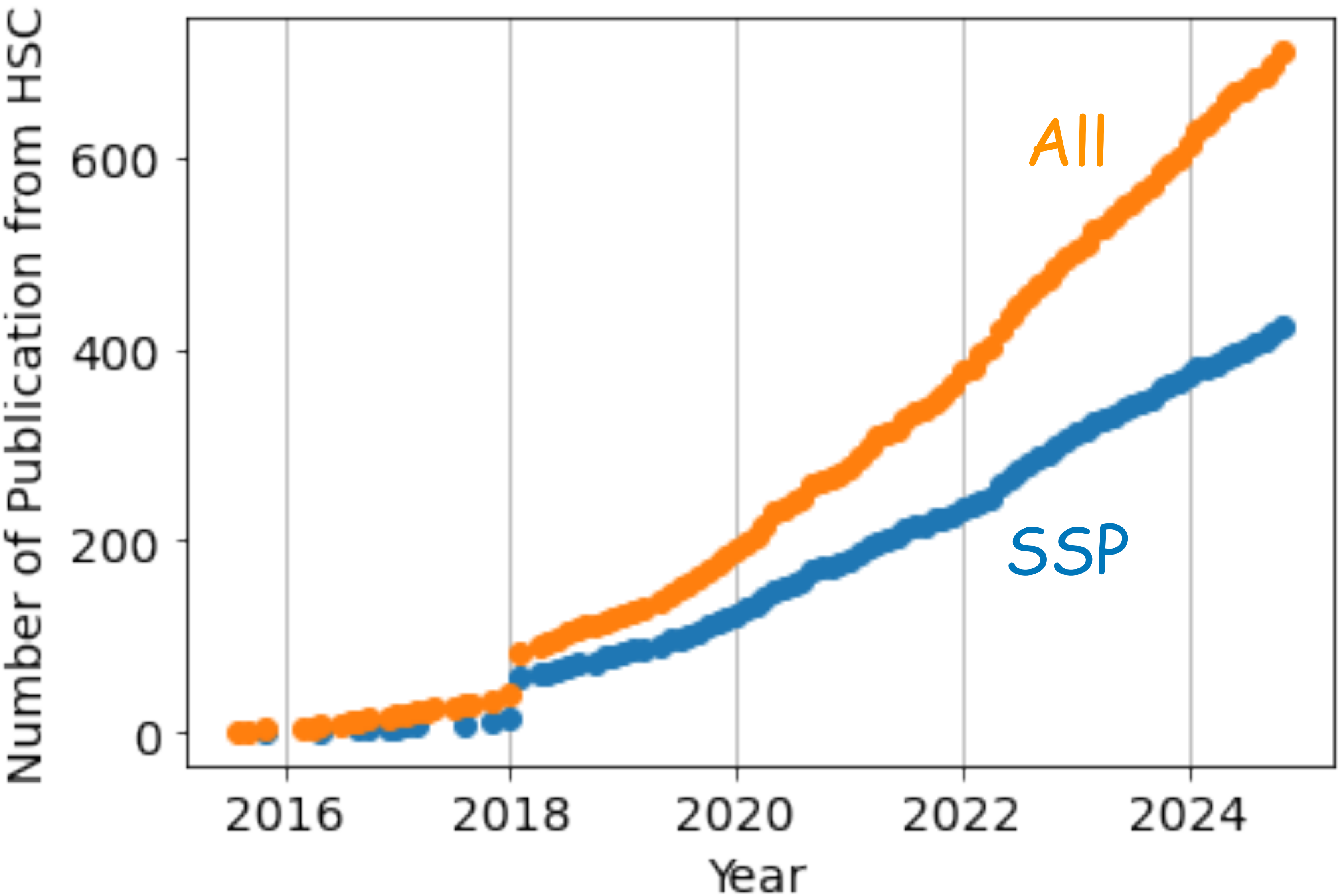
- photo-z catalog
  - photo-z blind test by splitting the reference data into training/test samples and test samples are blinded
  - provide full PDFs for either 100 or 700 binning over the range of 0<z<7
- spec-z catalog
  - compilation of ~20 publicly available catalog (as homogeneous as possible on the redshift quality)
- publications
  - DR1 paper : Tanaka et al. 2018 (1704.05988) -> **274** citations
  - DR2 paper : Nishizawa et al. 2020 (2003.01511) -> **70** citations
  - photo-z/spec-z catalogs are used in various science cases inside/outside HSC collaboration

o	already available
△	under construction

HSC-SSP Publication



Publication based on HSC data



Data Release

Wide [deg^2]

IDR

			Wide [deg^2]
S16A	2016/08/04	Data used for the special issue.	178
S17A	2017/09/28		
S18A	2018/06/25	PDR2 on 2019/05/30. 174 nights.	
S19A	2019/09/25	WL Year 3	420
S20A	2020/08/03	275 nights -> PDR3	670
S21A	2021/06	Possibly an incremental release (~318 nights)	
S23B	2024/07 -> 2025/03E	al data release (330 nights). This will become PDR	1100

(Deep area under reprocessing for fixing deblending problem)

PDR

PDR1	2017/02/28	FCFD area only. 61.5 nights
PDR2	2019/05/30	174 nights
PDR3	2021/08	S20A Data release to public
PDR4	TBD	All data. Final data release. 330 nights.

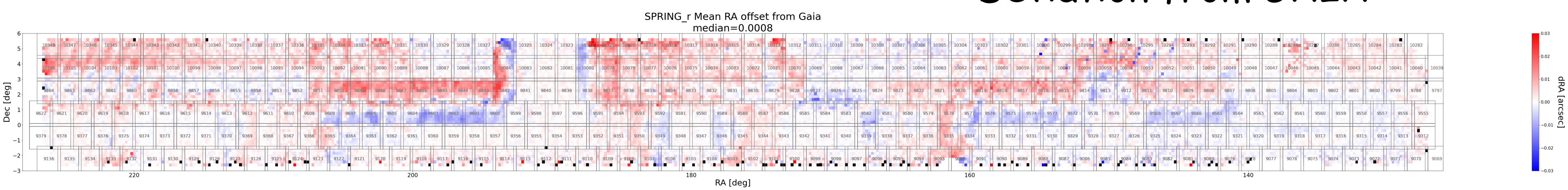
1 year

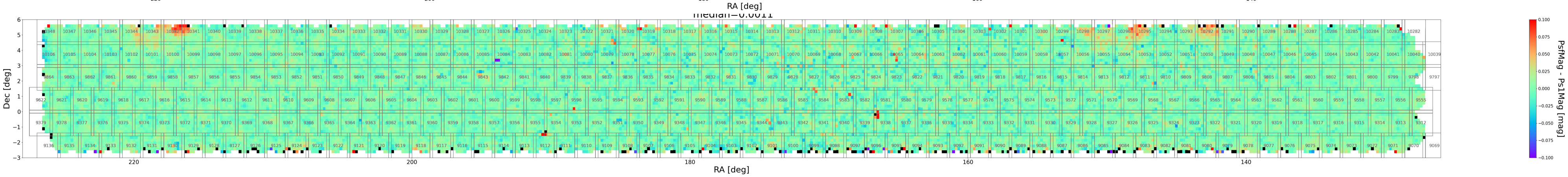
DM pipe line had a big upgrade (butler gen2 -> gen3) from S21A (hscPipe 8).
S23B has come out in 2024.7, but it turned to have a severe deblending problem in Deep-layer.
The corrected release is expected to be available some time in 2025.2.

SSP Internal Release S23B - Status

- Plan
  - Release: targeting ~2025.3E (reprocessing ends, Photo-Z, WL after that)
    - To fix deblending problem on Deep layer
- Dataset
  - All SSP data for the entire survey period 2014.3 – 2022.1
  - Wide   1,087 sq.deg (for i,z,y bands ≥ 5visits)
  - D+UD   ~27 sq.deg
- Quality Evaluation (Final)
  - Quality metrics show good enough astrometry & photometry calibration
  - Astrometry ~ 10 milliarcsec scale (stdev) or better against GAIA-DR2 in many areas
  - Photometry is as good as about 0.01-0.02 mag (stdev) in many areas

Deviation from GAIA

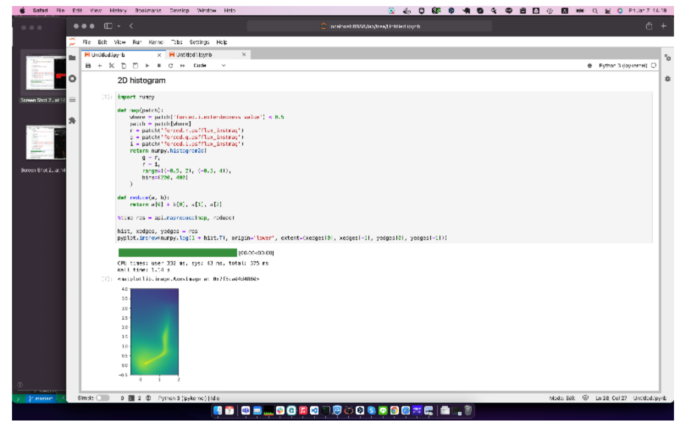


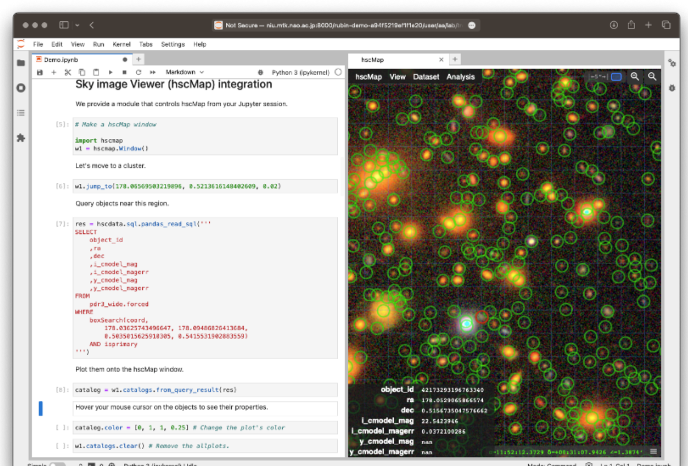


Deviation from Pan-STARRS

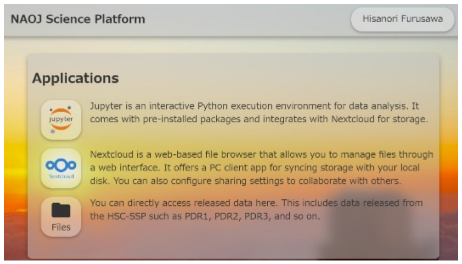
Prototype of HSC Science Platform

- Prototyping SP on the HSC data release PDR3
- This is made possible mostly by ADC.
  - Internal review by a few experts is being delayed -- continued
  - Preview by SSP collaboration by 2025 Summer
  - Design for PDR (and public data) this year

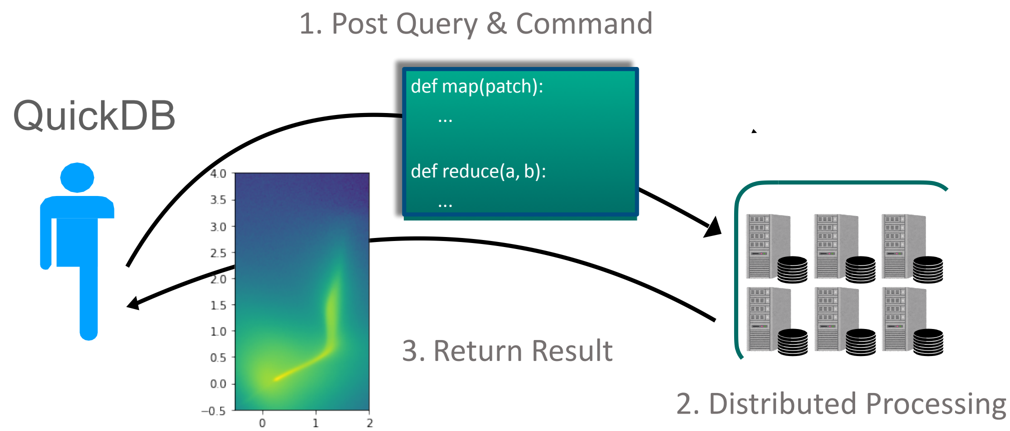




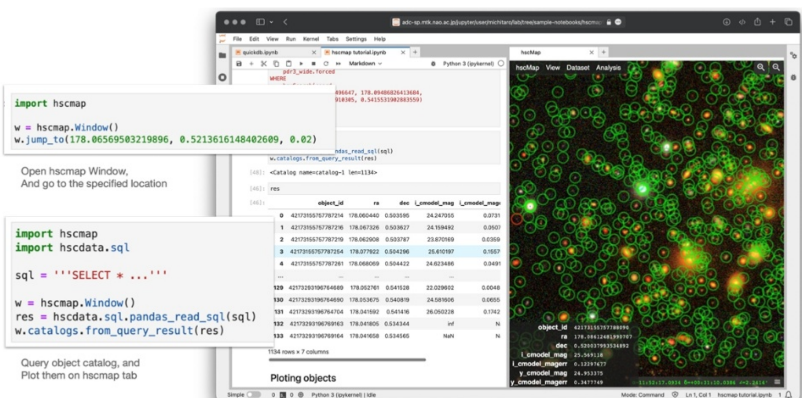
Snapshots From the Ongoing HSC-SP Development



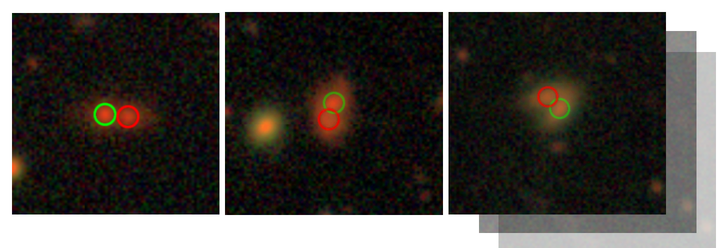
HSC-SP provides 1) computing resources in ADC,
2) Jupyter-notebook I/F for data query & processing,
3) Efficient file sharing mechanisms: Inter-operation w/ various archives (PFS, Rubin, SMOKA...) in the plan



QuickDB a columnar federated database, capable of fast search (<2.5sec for 800M rows) and MapReduce-driven complex query



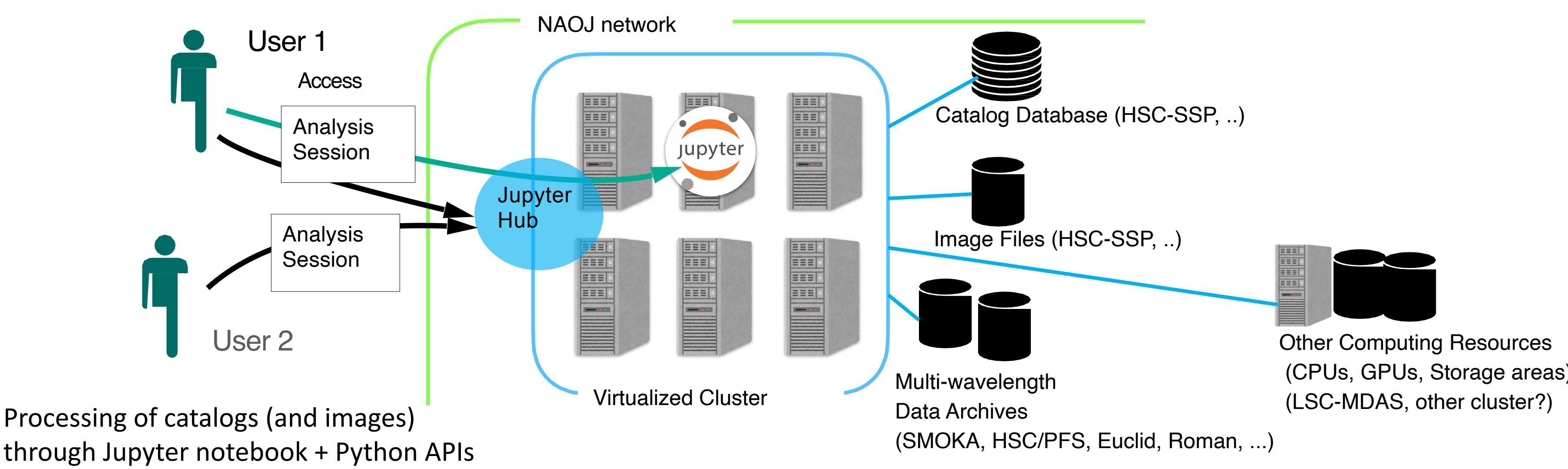
Jupyter I/F offers easy access/analysis of cat & image with Python APIs and interactive HIPS viewer hscMap.



A Science Application to find close pairs with similar colors by a QuickDB query, obtaining 87k pairs in 5sec for 500M rows. Optimal tools for various science cases to be developed.

Science Platform

- Developing a JupyterHub-based data analysis platform
  - efficient analysis over the existing products from remote
  - efficient use of computing resources
- ADC+Subaru coworking to implement services to HSC and PFS sharing the software design
- SP will also be applied to Rubin Japanese data access center, & Euclid, etc..



Acknowledgements

Long-long 300 + 30 nights observations have been successfully completed thanks to the tremendous efforts made by observatory's scientists and staff members. We really appreciate their continuous collaboration.