Progress of HSC-SSP Project

Satoshi MIYAZAKI

Subaru Telescope/NAOJ

Subaru UM 2023/02/01

HSC-SSP

Observing Completed Last Year

- On March, 2014, HSC-SSP started and the last observing night was 2022/01/03 (HST).

- 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.

Data Release

Slide presented last year

IDR

S16A	2016/08/04	Data used for the special issue.
S17A	2017/09/28	
S18A	2018/06/25	PDR2 on 2019/05/30. 174 nights.
S19A	2019/09/25	
S20A	2020/08/03	275 nights -> PDR3
S21A	2021/06	Possibly an incremental release (~318 nights)
S22A	2022/Summer or beyond	Final data release (330 nights). This will become PDR4

< 1 year

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.

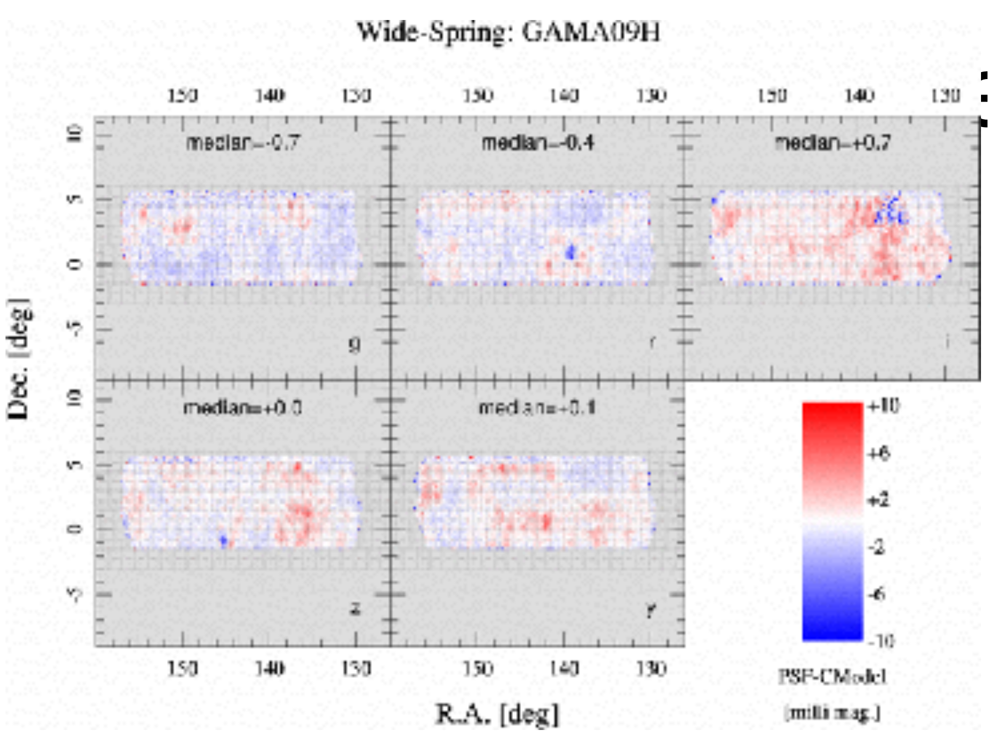
DM pipe line is experiencing big upgrade (butler gen2 -> gen3). The final data analysis must wait until the upgrade is completed. 2022/Summer is reported to be TITGHT, possibly S22B or S23A

SSP Internal Release S23A/B - Status

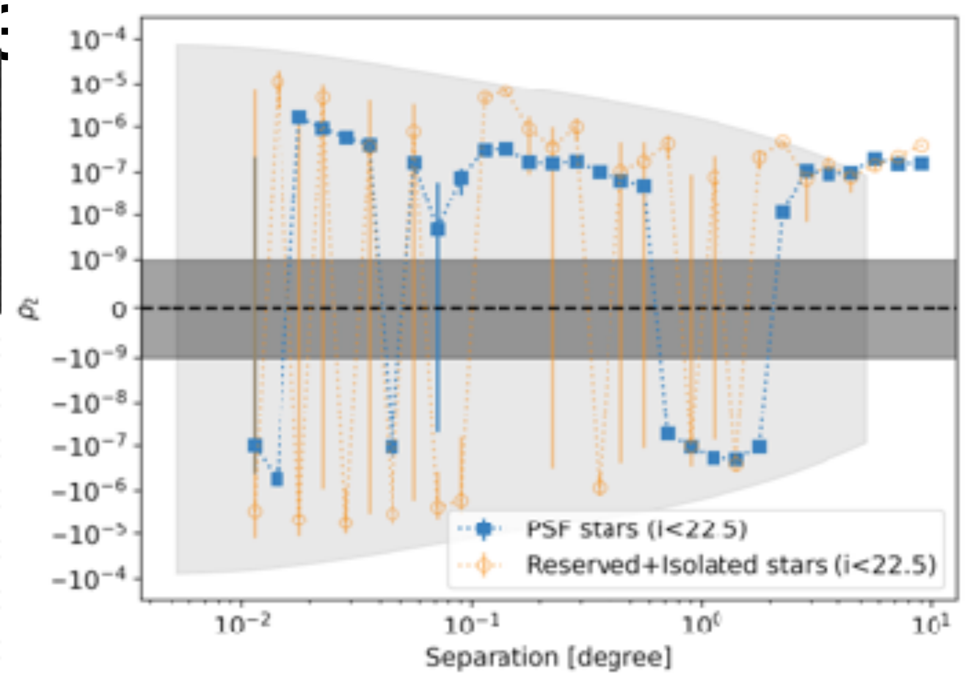
- Plan
  - Release: targeting ~2023.11 (if everything goes without any problem)
  - Reprocess all data with a new version of LSST pipeline (Gen3 framework)
- Dataset
  - All SSP data for the entire survey period 2014.4 – 2021.12
  - Wide 1,087 sq.deg (for i,z,y bands ≥ 5visits)
  - D+UD ~27 sq.deg
- Tentative Schedule
  - 2022.9-2022.11: Reviewed test products (100 sq.deg) by SSP collaboration
  - 2022.12: Determined the pipeline version
  - 2023.1(now): Production work underway
+ some additional tests behind
  - 2023.7-8: Finalizing processing
(may require additional time depending on stability of the pipeline)
  - 2023.9-10: QA, database ingestion, and documentation
  - 2023.11? Internal Release

Validation of Gen3 processing

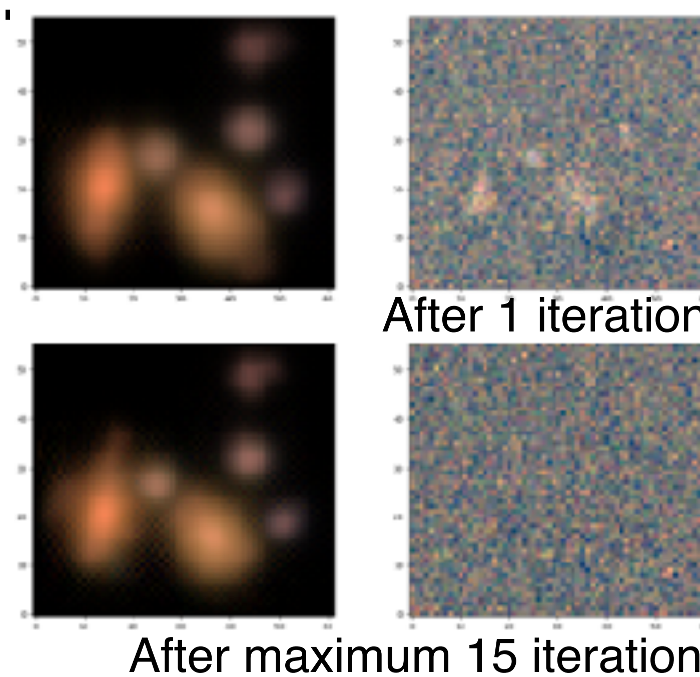
- SSP volunteers evaluated astrometry, photometry, detection/deblend, CMR/photo-z, and PSF determination (accuracy, consistency, and stability)



Photometry consistency



PSF measurement consistency

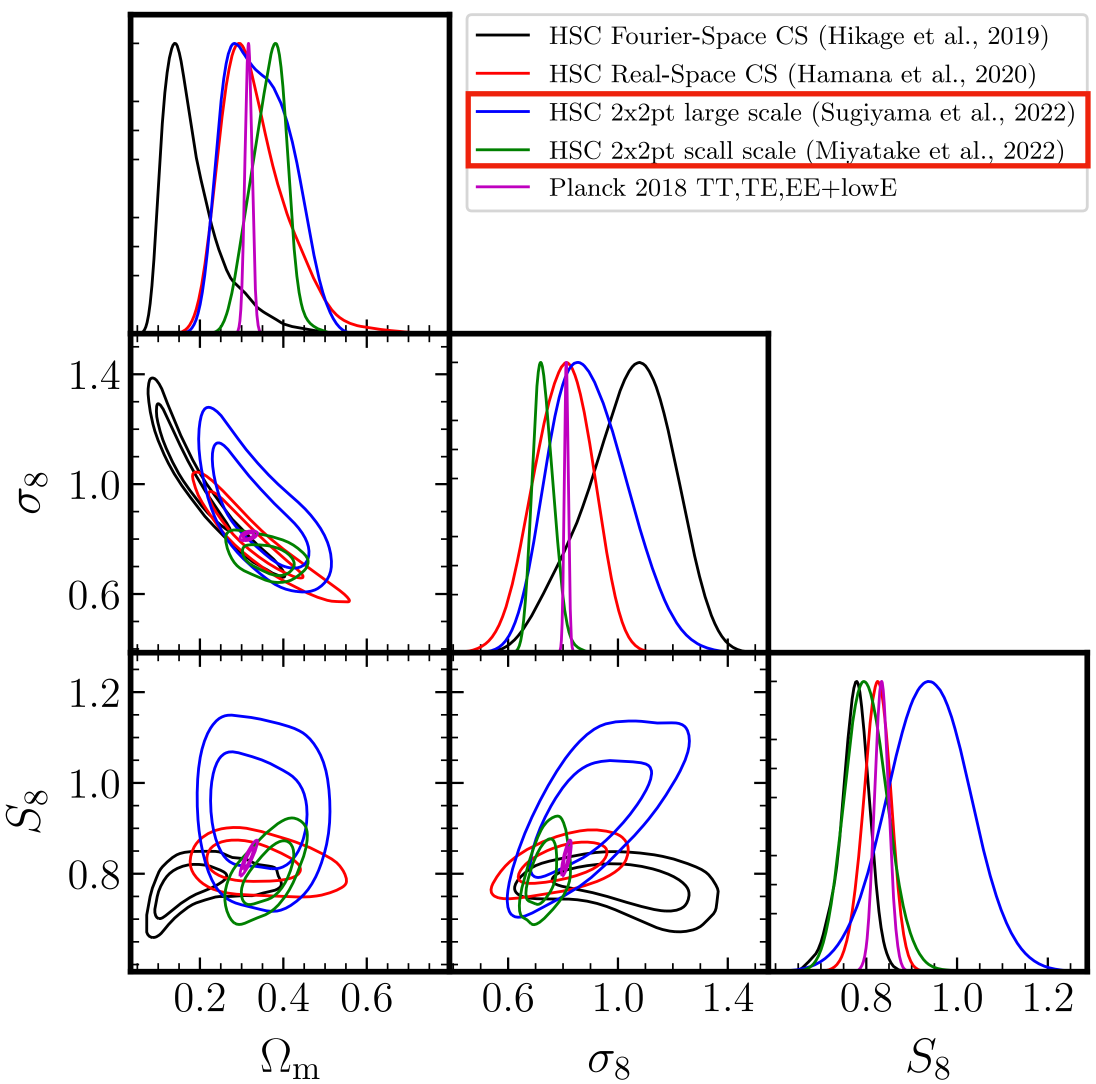


Deblender convergence

Science Highlight 2022

HSC-Y1 Cosmology Analyses Completed

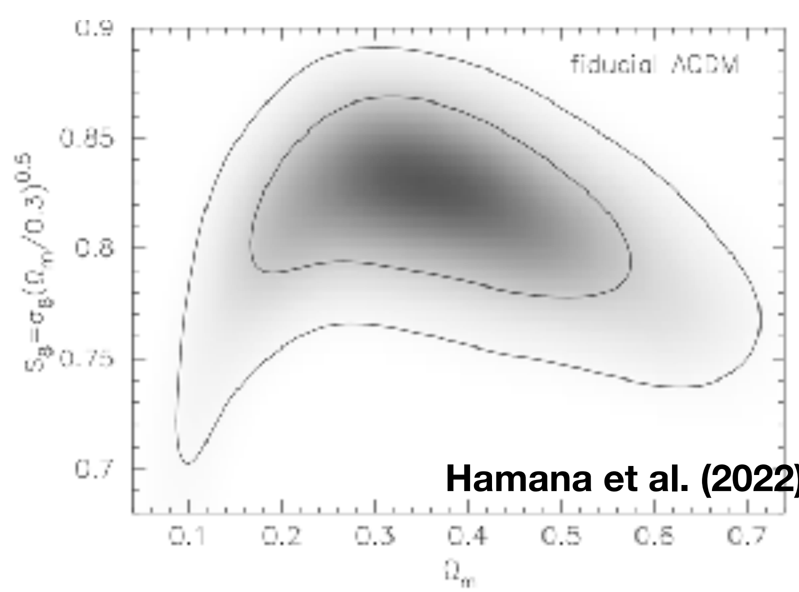
New!! 2x2pt = BOSS galaxy clustering x BOSS-HSC galaxy lensing








S. Sugiyama H. Miyatake T. Nishimichi M. Takada S. More R. Takahashi
and many others…



T. Hamana

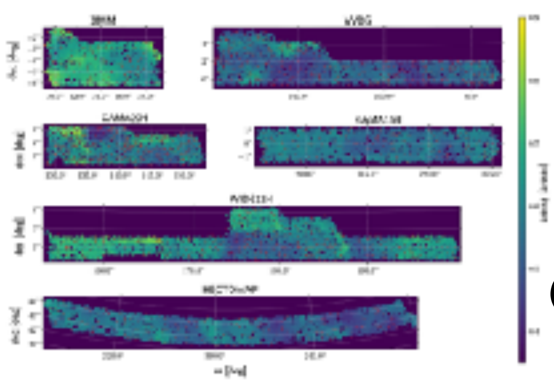
New!! Cosmic shear analysis with a new estimator COSEBIs

HSC-Y3 Cosmology Analyses Are Ongoing

(= HSC-Y1 X 3 wider)

HSC-Y3 Shear Catalog

Survey area is increased to 433 deg^2 from 137 deg^2



X. Li
(IPMU→CMU)

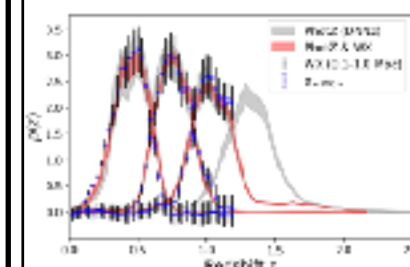
Li et al. (2022)

published

Detailed Systematics Studies

Photo-z Systematics

Tested photo-z against clustering-z
and derived combined inference

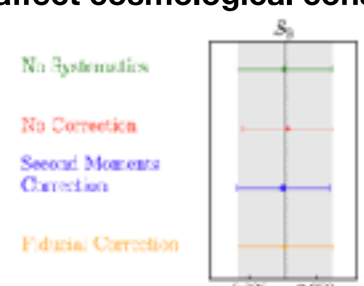


M. Rau (Argonne)

Rau et al. (2022)

PSF Systematics

Investigated how 4th order moments of PSF
affect cosmological constraint



T. Zhang (CMU)

Zhang et al. (2022)

under review or in press

Cosmology Analyses

3x2pt (2x2pt + Cosmic Shear) Analyses

Measurement
(S. More; IUCAA)

Large-scale Analysis
(S. Sugiyama; IPMU)

Small-scale Analysis
(H. Miyatake; Nagoya)

Cosmic Shear Analyses

Real-Space Analysis
(X. Li; CMU)

Fourier-Space Analysis
(R. Dalal; Princeton)

coming soon

- 4 cosmology papers (+1 measurement paper) will be out in April
- Grad. students and postdocs are leading most of the projects.

Publications Related to Weak Lensing / Cosmology

- Cosmology and related papers
    - Zhang et al., “A General Framework for Removing Point Spread Function Additive Systematics in Cosmological Weak Lensing Analysis,” arXiv:2212.03257.
    - Rau et al., “Weak Lensing Tomographic Redshift Distribution Inference for the Hyper Suprime-Cam Subaru Strategic Program three-year shape catalogue,” arXiv:2211.16516.
    - Hamana et al, “E/B mode decomposition of HSC-Y1 cosmic shear using COSEBIs: cosmological constraints and comparison with other two-point statistics,” 2022, PASJ, 74, 923.
    - Sugiyama et al., “HSC Year 1 cosmology results with minimal bias method: HSC×BOSS galaxy-galaxy weak lensing and BOSS galaxy clustering,” 2022, PhRvD, 105, 123537.
    - Miyatake et al., “Cosmological inference from emulator based halo model II: Cosmological constraintsfrom galaxy-galaxy weak lensing and galaxy clustering with HSC-Y1 and SDSS data,” 2022, PhRvD, 106, 083520.
    - Miyatake et al., “Cosmological inference from an emulator based halo model. I. Validation tests with HSC and SDSS mock catalogs,” 2022, PhRvD, 106, 083519.
    - Miyatake et al., “First Identification of a CMB Lensing Signal Produced by 1.5 Million Galaxies at $z \sim 4$: Constraints on Matter Density Fluctuations at High Redshift,” 2022, PhRvL, 129, 061301.
    - Li et al., ”The three-year shear catalog of the Subaru Hyper Suprime-Cam SSP Survey,” 2022, PASJ, 74, 421.
- Galaxy clusters and galaxies
    - Rana et al., “Splashback radius of X-ray galaxy clusters from eFEDS using galaxies from HSC survey,” arXiv:2301.03626.
    - Luo et al., “Dark matter halos of luminous AGNs from galaxy-galaxy lensing with the HSC Subaru Strategic Program,” arXiv:2204.03817.
    - Miriam et al. “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,” 2022, A&A, 661, A14.
    - Chiu et al., “The eROSITA Final Equatorial-Depth Survey (eFEDS): The X-ray Scaling Relations of Galaxy Clusters and Groups with the Weak-Lensing Mass Calibration from the Subaru Hyper Suprime-Cam Survey,” 2022, A&A, 661, A11.
    - Huang et al., “The Outer Stellar Mass of Massive Galaxies: A Simple Tracer of Halo Mass with Scatter Comparable to Richness and Reduced Projection, ” 2022, MNRAS, 515, 4722.

AGN working group

[AGN WG](#)

Yoshiki Toba

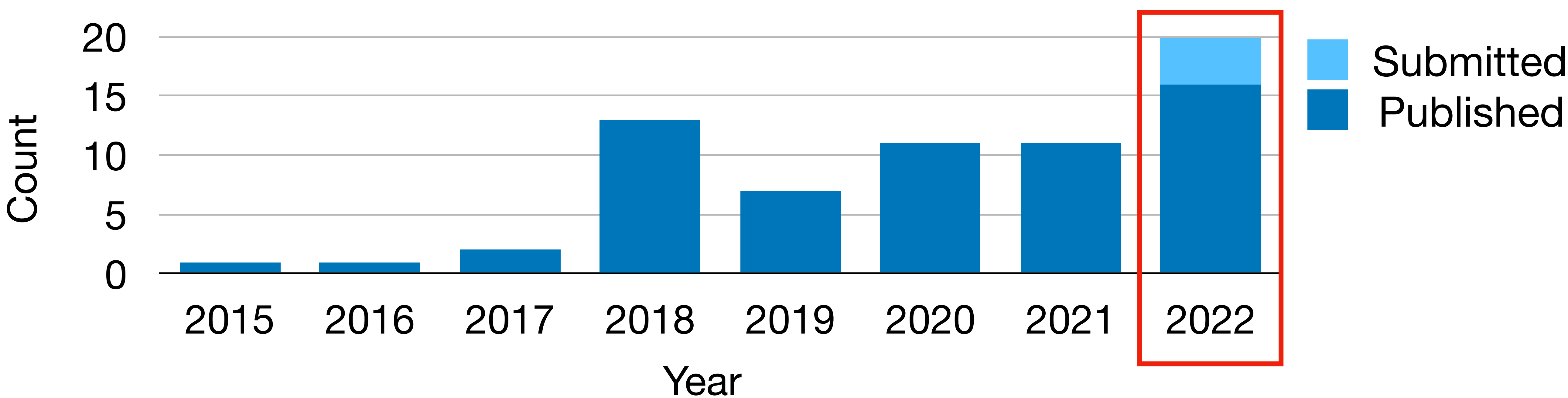
Tohru Nagao

~110 researchers belong to the AGN WG.

Number of projects (HSC Joint-Data Project)	121 (7)
Number of publications (under review)	68 (6)
Number of proposals (accpected)	~300 (~40%)

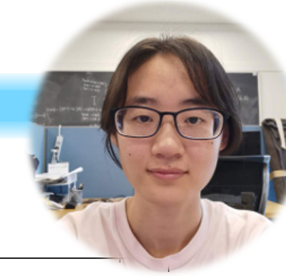
12th HSC-AGN meeting at Kagoshima U.
(Nov.30 - Dec.2, 2022)

HSC-AGN publication



HSC view of quasars

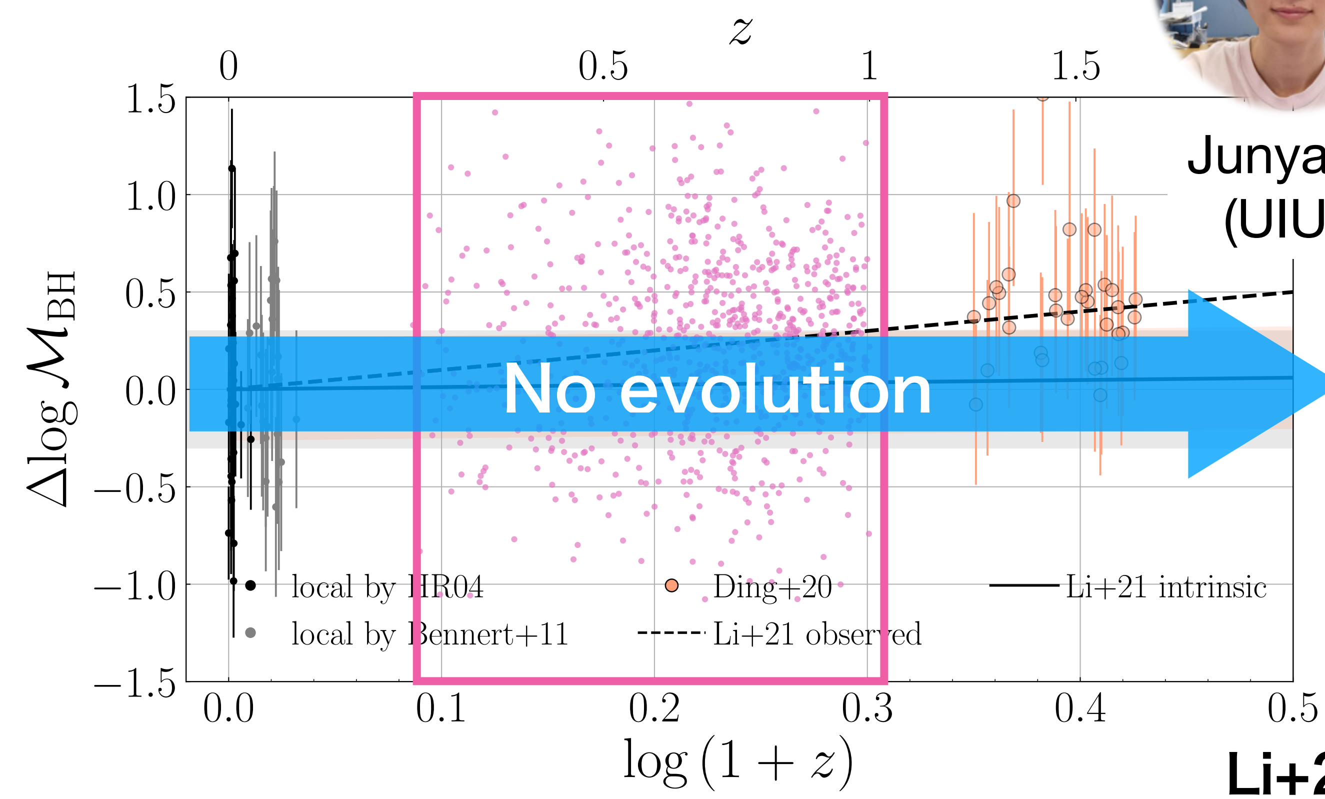
AGN WG



Junyao Li
(UIUC)

Local Universe (z < 2)

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



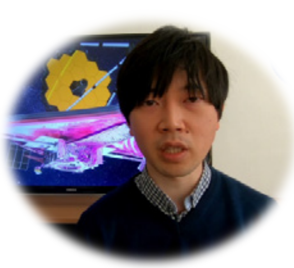
Li+21b

(See also Ding+20, Li+21a, Li+22)

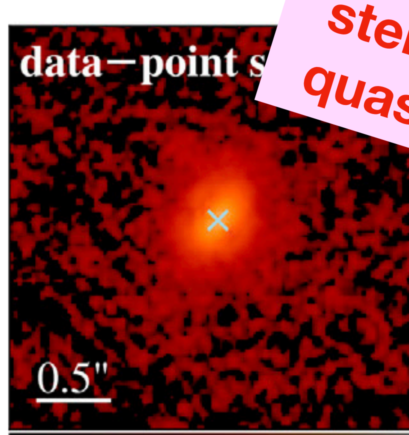
High-z Universe (z > 6)

>100 low-luminosity quasars were discovered.

Xuheng Ding
(IPMU)

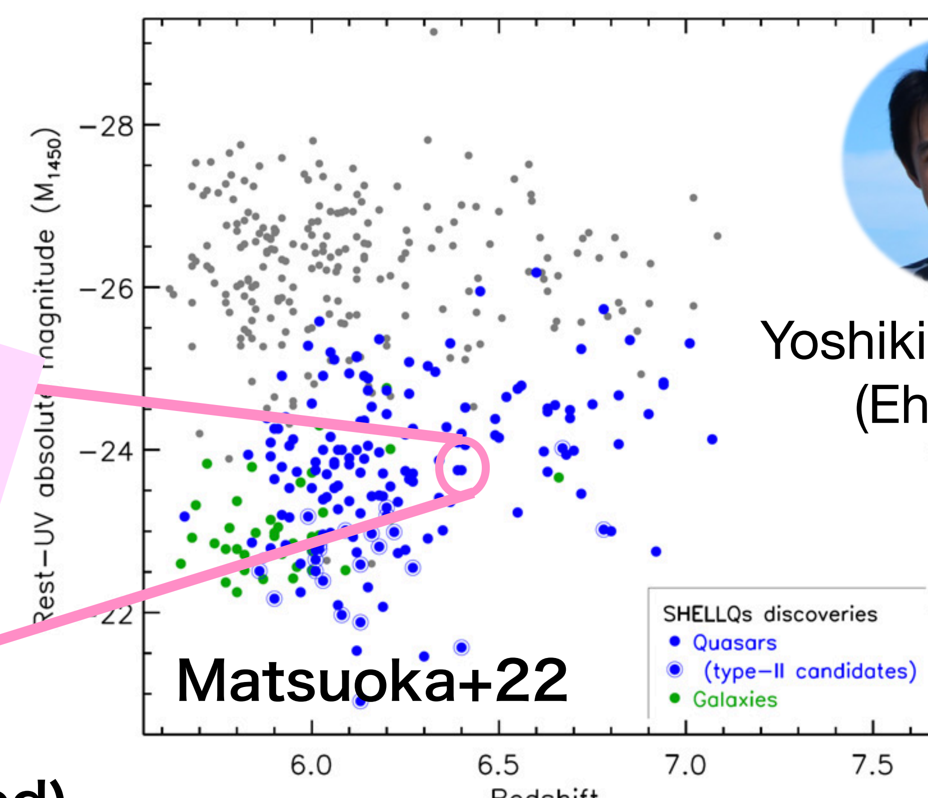


Masafusa Onoue
(KIAA/IPMU)



1st detection of stellar light from quasar by JWST!

Ding, Onoue+22 (submitted)



Yoshiki Matsuoka
(Ehime U.)

(See also Lu+22)

Multi-wavelength properties

AGN WG

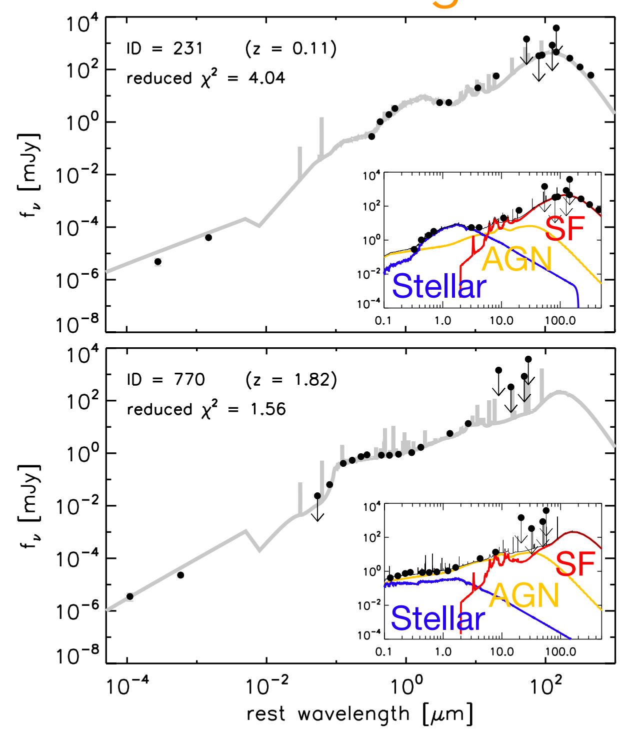
Yoshiki Toba
(NAOJ)

X-ray AGN

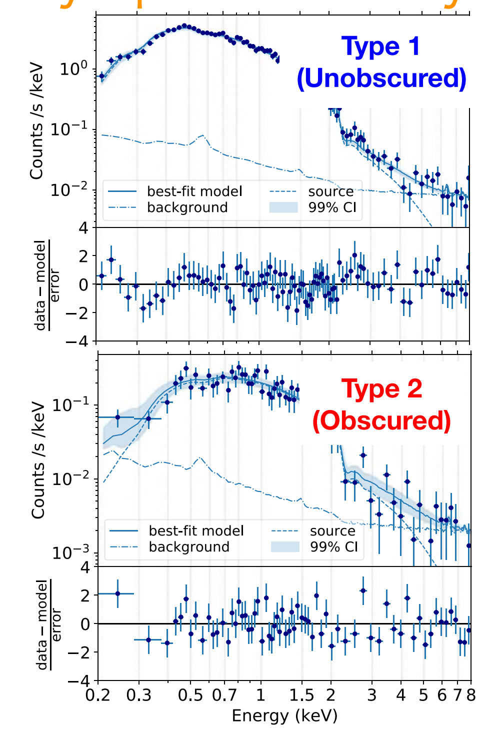
eROSITA view of WISE-selected AGNs at z < 4.

(See also Brusa+22, Liu+22, Salvato+22, Pouliasis+22, Vijarnwannaluk+22)

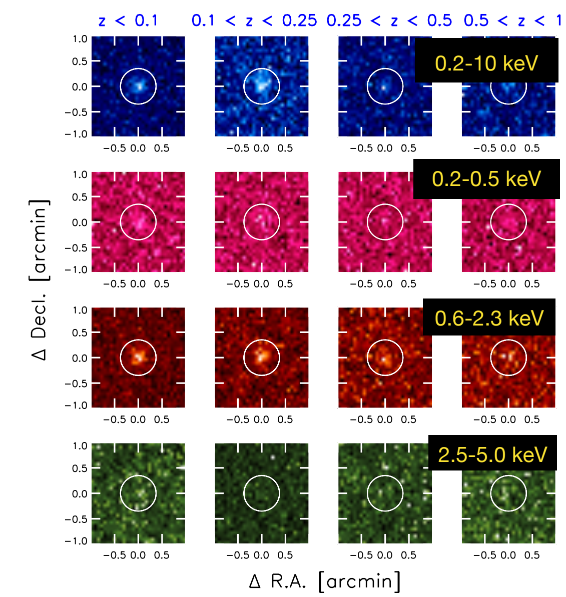
SED fitting



X-ray spectral analysis



X-ray stacking analysis

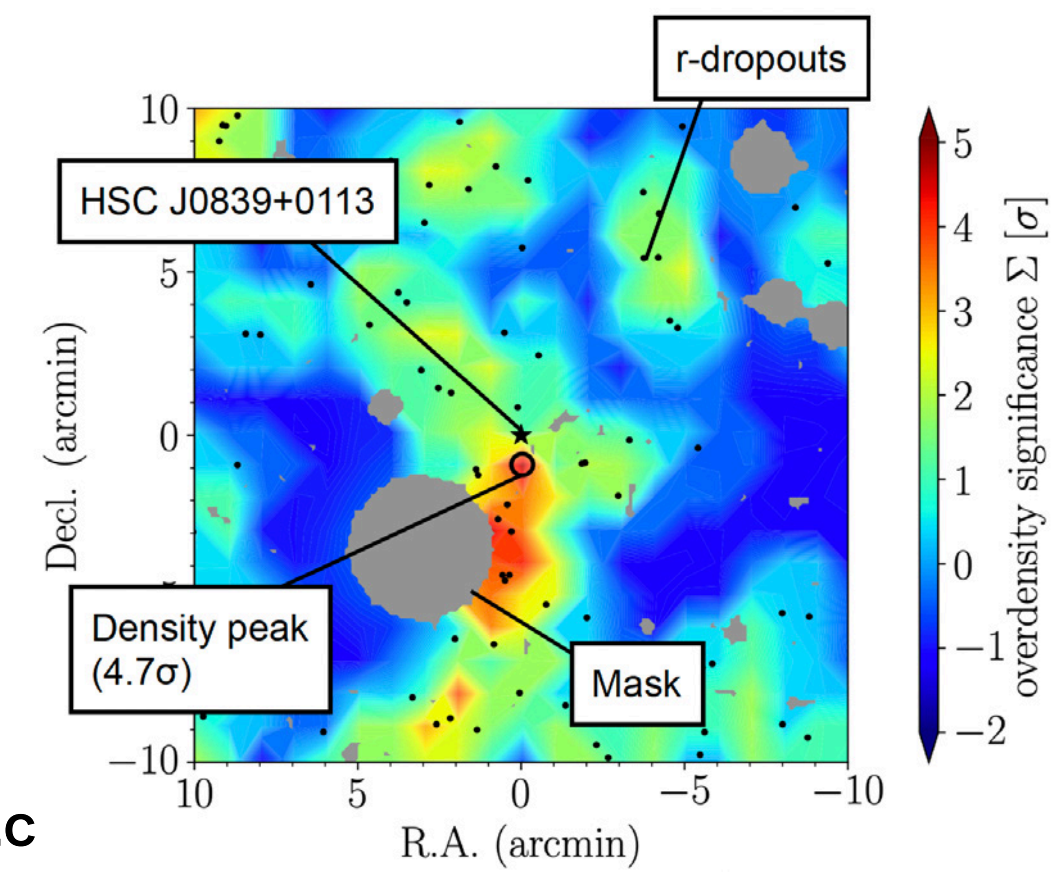


Toba+22

Radio AGN

The most overdense region at z ~ 5 inhabited by a Radio AGN.

(See also Yamashita+20, Uchiyama+22ab)



Uchiyama, Yamashita+22c

Hisakazu Uchiyama
(Ehime U.)

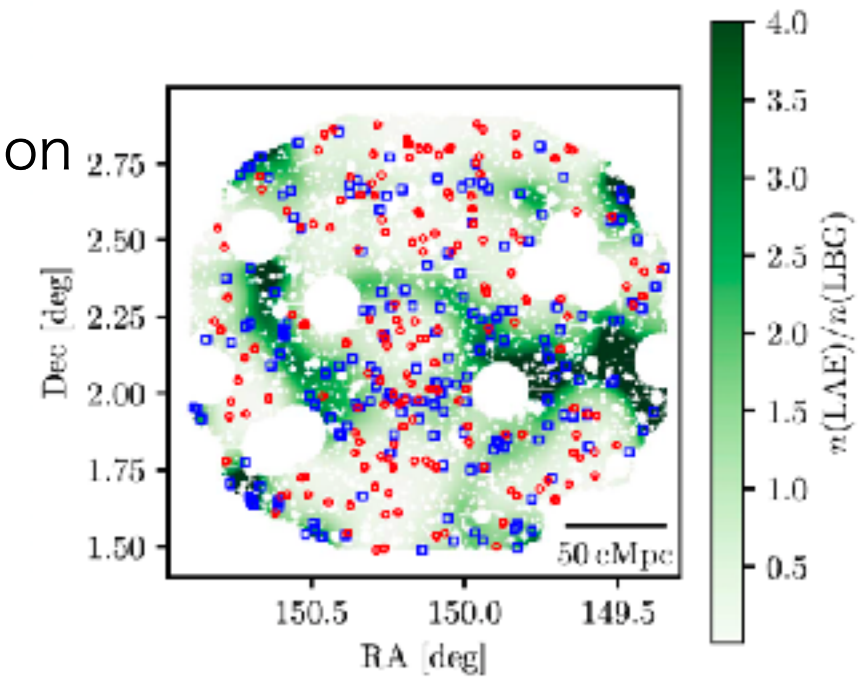
Takuji Yamashita
(NAOJ)

High-z IGM Studies with HSC

1. Yoshioka et al. 2022, ApJ, 927, 32

- NB921-selected LAEs & IB945-selected LBGs at z=6.6
- n(LAE) / n(LBG) as an estimator of neutral hydrogen fraction
- Directly map out a spatially inhomogeneous topology of reionization

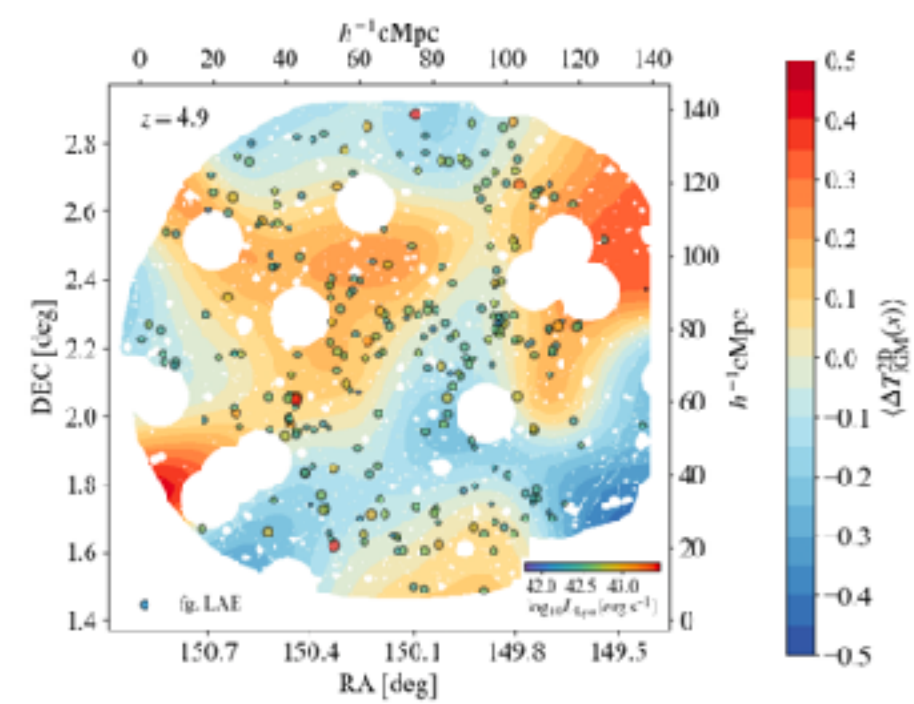
n(LAE)/n(LBG) ≒ xHI map



2. Kakiichi et al. 2023, submitted to MNRAS (arXiv:2301.00373)

- "Photometric IGM tomography" newly proposed
- novel approach to estimate Lya-forest abs using NB data
- 2D map of IGM HI at z~5

IGM HI map at z~5

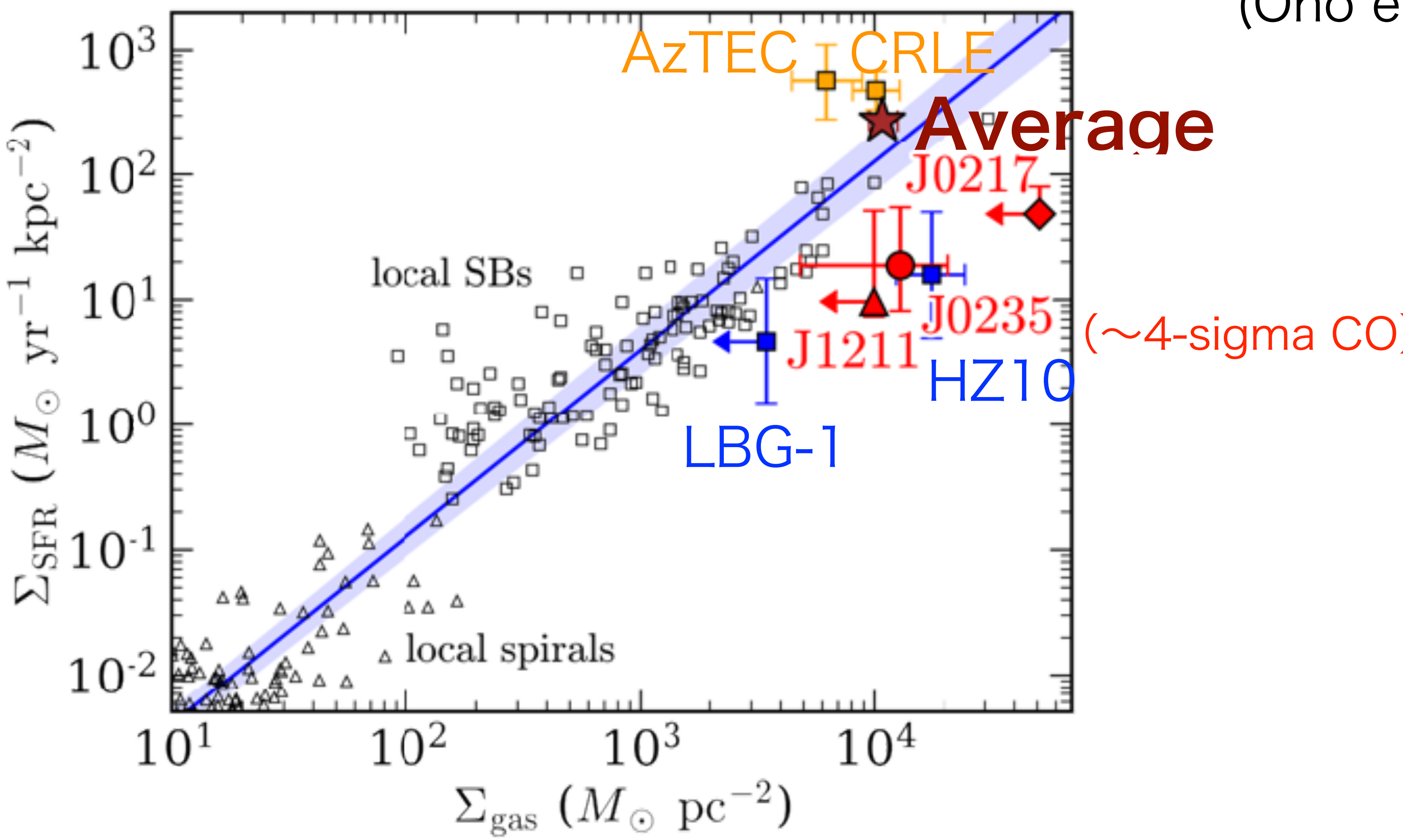


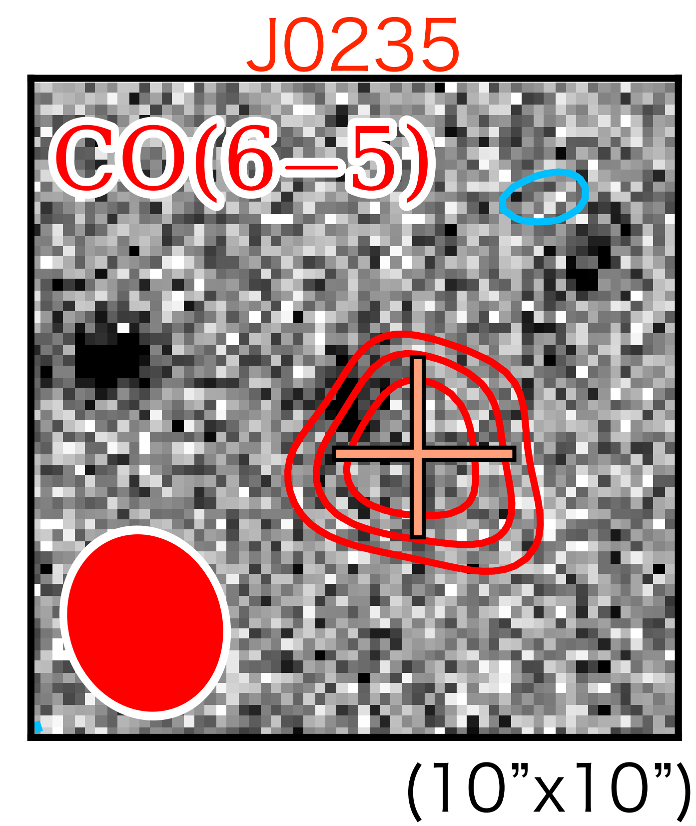
3. Mawatari et al. 2023, accepted in AJ (arXiv:2110.11977)

- Multi-band photometry and spec-z catalog for IGM - galaxy research

Deep CO Obs. for Three LBGs at z=6.0923-6.2037

(Ono et al. 2022, ApJ, 941, 74)





・marginal CO(6–5) detection from J0235. consistent with the previous UV+[OIII]+[CII] observations.

J1211 & J0217: no significant CO(6–5).

・J0235: lower $\Sigma_{\rm SFR}$ than local SBs. J1211 & J0217: consistent with local SBs.

・z=5-6 average is consistent with local SBs with possibly large scatter.

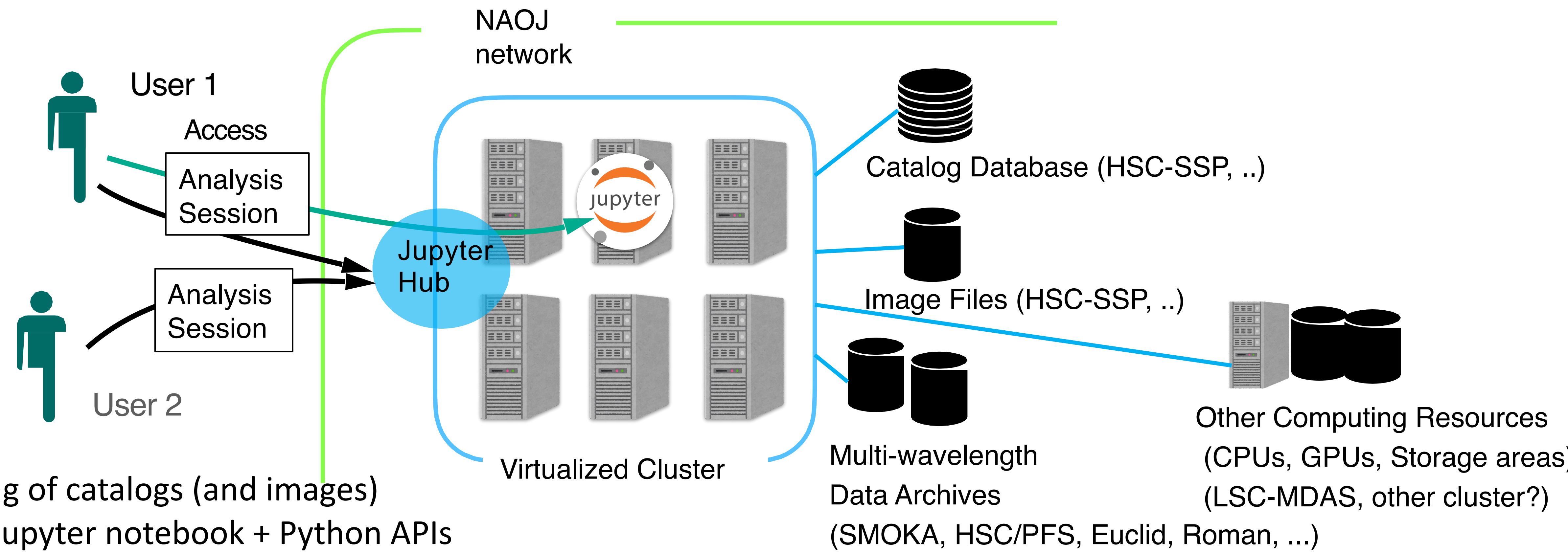
PASJ Excellent Paper Award 2022

announced last week

- Harikane et al. 2018 PASJ 70 SP1 S11
  - GOLDRUSH. II. Clustering of galaxies at z~4-6 revealed with the half-million dropouts over the 100 deg2 area corresponding to 1 Gpc3
- Matsuoka et al. 2018 PASJ 70 SP1 S35
  - ¸Subaru High-z Exploration of Low-Luminosity Quasars (SHELLQs). II. Discovery of 32 quasars and luminous galaxies at $5.7 < z \leq 6.8$

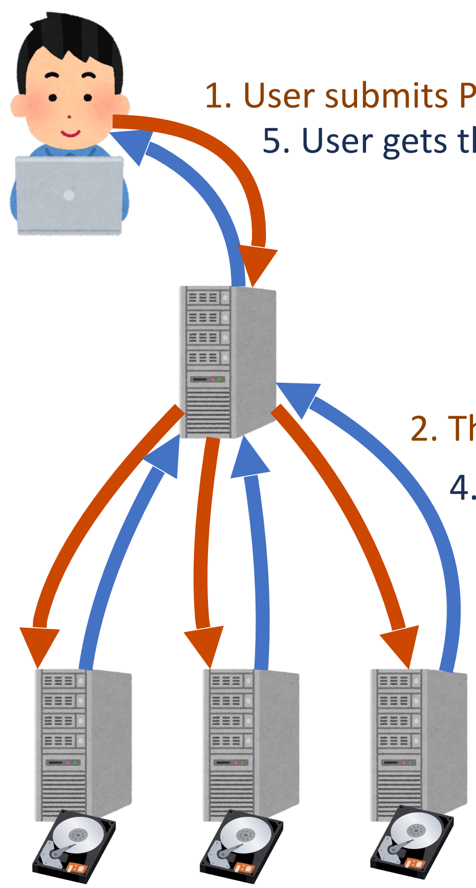
Development of Science Platform

- Designing a JupyterHub-based platform
  - to perform efficient analysis over the existing products from remote
  - to make efficient use of computing resources
- PFS involves the platform within a science archive frame work



Processing of catalogs (and images)
through Jupyter notebook + Python APIs

QuickDB



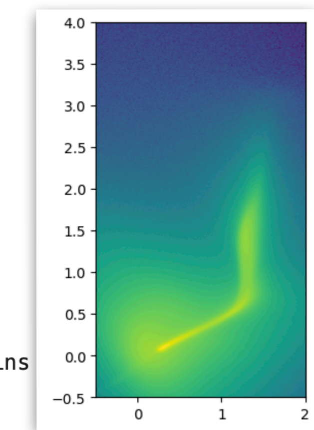
- User provides arbitrary Python codes to the system
- The codes run on distributed computers
- and run in parallel for object-catalog of each patch

Count all objects (0.3sec)

```
[11]: def map(patch):
          return patch.size

      def reduce(a, b):
          return a + b

      %time api.mapreduce(map, reduce, rerun='s20a_wide')

      [00:00<00:00]
      CPU times: user 131 ms, sys: 0 ns, total: 131 ms
      Wall time: 281 ms
[11]: 830139306
```

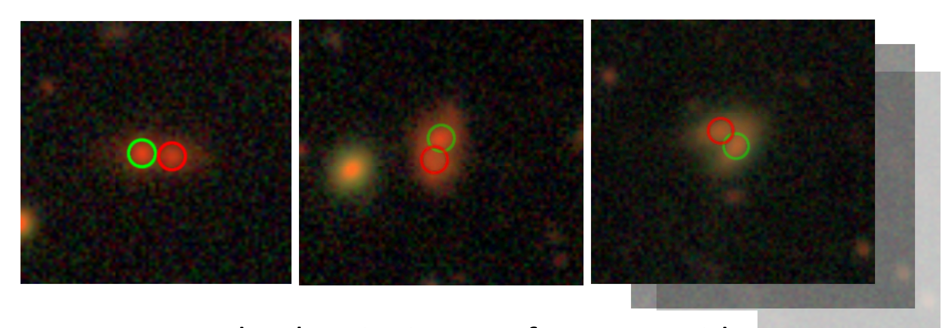
Color-Color Diagram for all objects in s20a_wide (1.2sec)

```
import numpy

def map(patch):
    where = patch('forced.i.extendedness_value') < 0.5
    patch = patch[where]
    r = patch('forced.r.psfflux_instmag')
    g = patch('forced.g.psfflux_instmag')
    i = patch('forced.i.psfflux_instmag')
    return numpy.histogram2d(
        g - r,
        r - i,
        range=((-0.5, 2), (-0.5, 4)),
        bins=(200, 400)
    )

def reduce(a, b):
    a_hist, a_xbins, a_ybins = a
    b_hist, b_xbins, b_ybinx = b
    return a_hist + b_hist, a_xbins, a_ybins

%time res = api.mapreduce(map, reduce)

hist, xedges, yedges = res
pyplot.imshow(numpy.log(1 + hist.T), origin='lower', extent=(xedges|

[00:00<00:00]
CPU times: user 220 ms, sys: 35.7 ms, total: 256 ms
Wall time: 1.12 s
```




```
[27]: import numpy
      import scipy.spatial

      from functools import reduce
      tol_mag = 0.25
      match_rad = 4 # arcsec

      columns = '''
      sdsscentroid_flag
      pixelflags_edge
      pixelflags_interpolatedcenter
      pixelflags_saturatedcenter
      pixelflags_crcenter
      pixelflags_bad
      cmodel_flag
      '''.split()

      def gen_pairs(xyz, r: float=1):
          tree = scipy.spatial.cKDTree(xyz.T)
          for i, pairs in enumerate(tree.query_ball_tree(tree, numpy.deg2rad(r / 3600.))):
              for j in pairs:
                  if i < j:
                      yield i, j

      def map(patch):
                = reduce(
               ambda a, b: a & b,
               patch(f'forced.{f}.{c}') == 0 for f in 'gri' for c in columns),
               atch('forced.isprimary') & (patch('forced.i.psfflux_instmag') < 23),
          )
          patch = patch[clean]

          if patch.size == 0:
              return
          xyz = patch('forced.coord')
          pairs = numpy.array(list(gen_pairs(xyz, match_rad)))
          if len(pairs) == 0:
              return

          a_ind, b_ind = pairs.T

          patch_a = patch[a_ind]
          patch_b = patch[b_ind]

          g_r_a = patch_a('forced.g.psfflux_instmag') - patch_a('forced.r.psfflux_instmag')
          r_i_a = patch_a('forced.r.psfflux_instmag') - patch_a('forced.i.psfflux_instmag')
          g_r_b = patch_b('forced.g.psfflux_instmag') - patch_b('forced.r.psfflux_instmag')
          r_i_b = patch_b('forced.r.psfflux_instmag') - patch_b('forced.i.psfflux_instmag')

          ok = (numpy.abs(g_r_a - g_r_b) < tol_mag) &  (numpy.abs(r_i_a - r_i_b) < tol_mag)
          ra_a = patch_a[ok]('forced.coord_ra')
          dec_a = patch_a[ok]('forced.coord_dec')
          ra_b = patch_b[ok]('forced.coord_ra')
          dec_b = patch_b[ok]('forced.coord_dec')

          return ra_a, dec_a, ra_b, dec_b

      %time coords = numpy.hstack([numpy.array(coords) for coords in api.map(map, rerun='s20a_wide')])

      [00:02<00:00]
      CPU times: user 1.06 s, sys: 139 ms, total: 1.2 s
      Wall time: 4.95 s
```

Find pairs of objects that are close and have similar colors



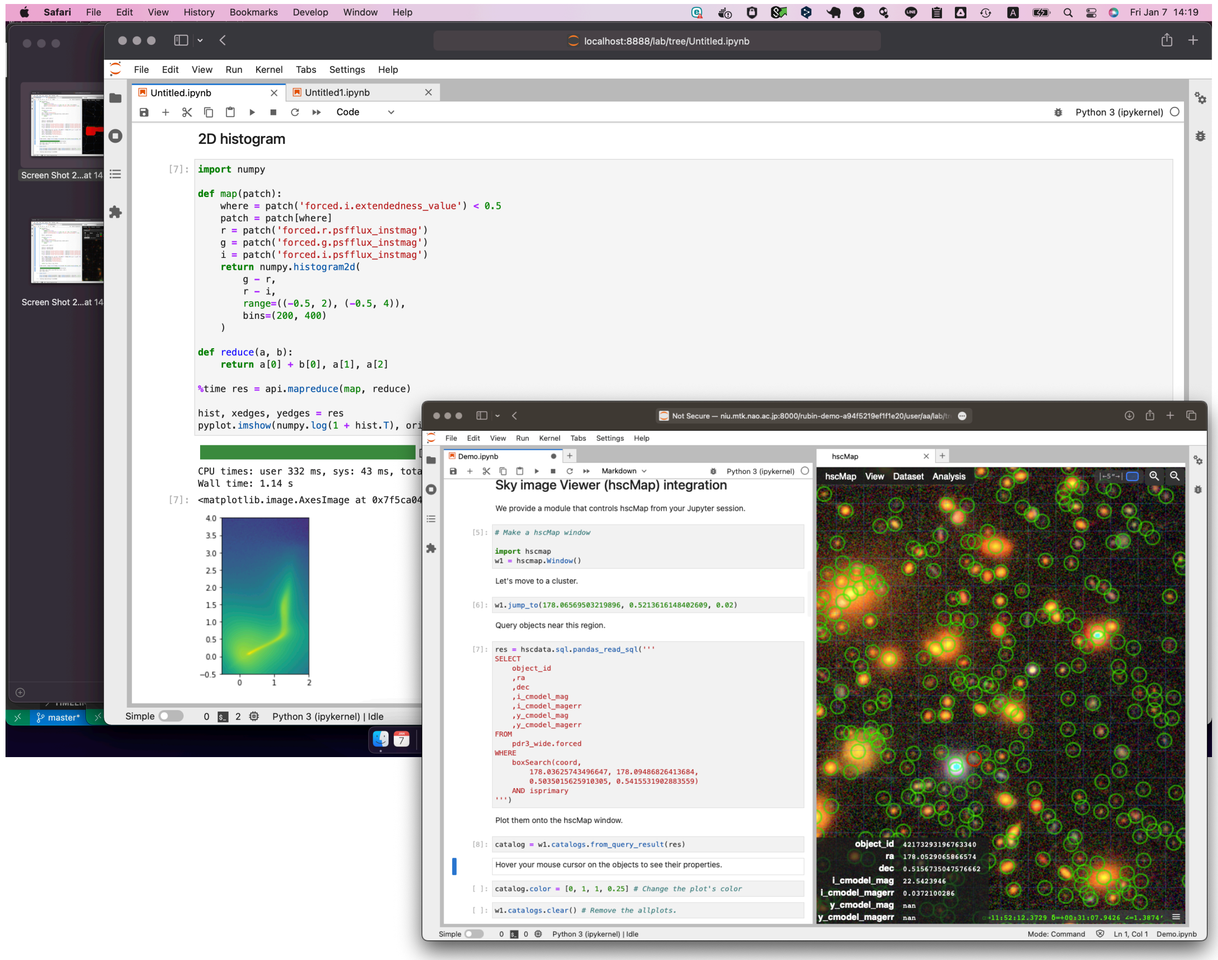
Found 87k pairs in 5sec for s20a_wide

Prototype of HSC Science Platform

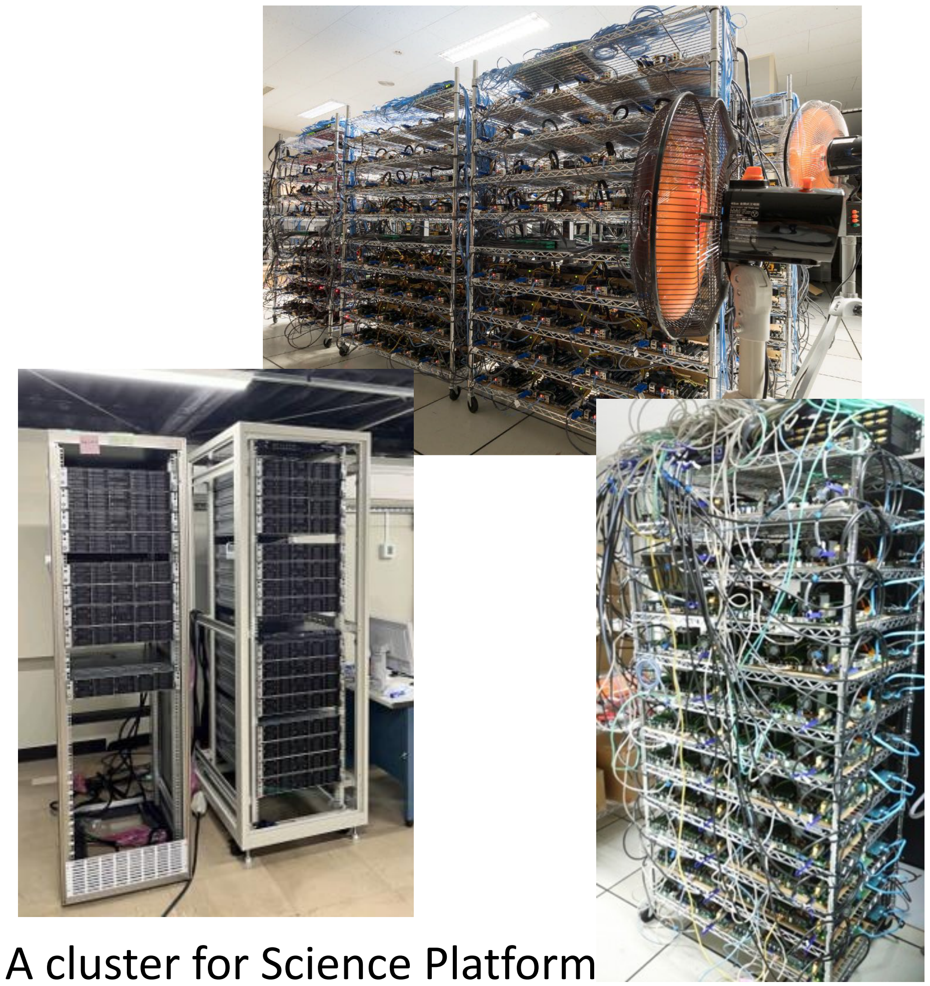
- ADC+Subaru is discussing to construct a science platform service connecting to the HSC data release PDR3

  (See a poster by Morishima et al., too)

- ADC Team Tentative target plan
  - First prototype -2023.4
  - Internal review 2023.5
  - Preview by SSP collaboration 2023.9-
  - Design for PDR (and public data) -2024.3
  - Preview for PDR 2024.4
  - Stable operation for PDR mid 2025 TBD



System Development



A cluster for Science Platform
(HSC + Rubin collaboration)
In a new computer room

QuickDB and CPUs
Hardware assisted by CfCA

System diagram for Prototype HSC Science Platform