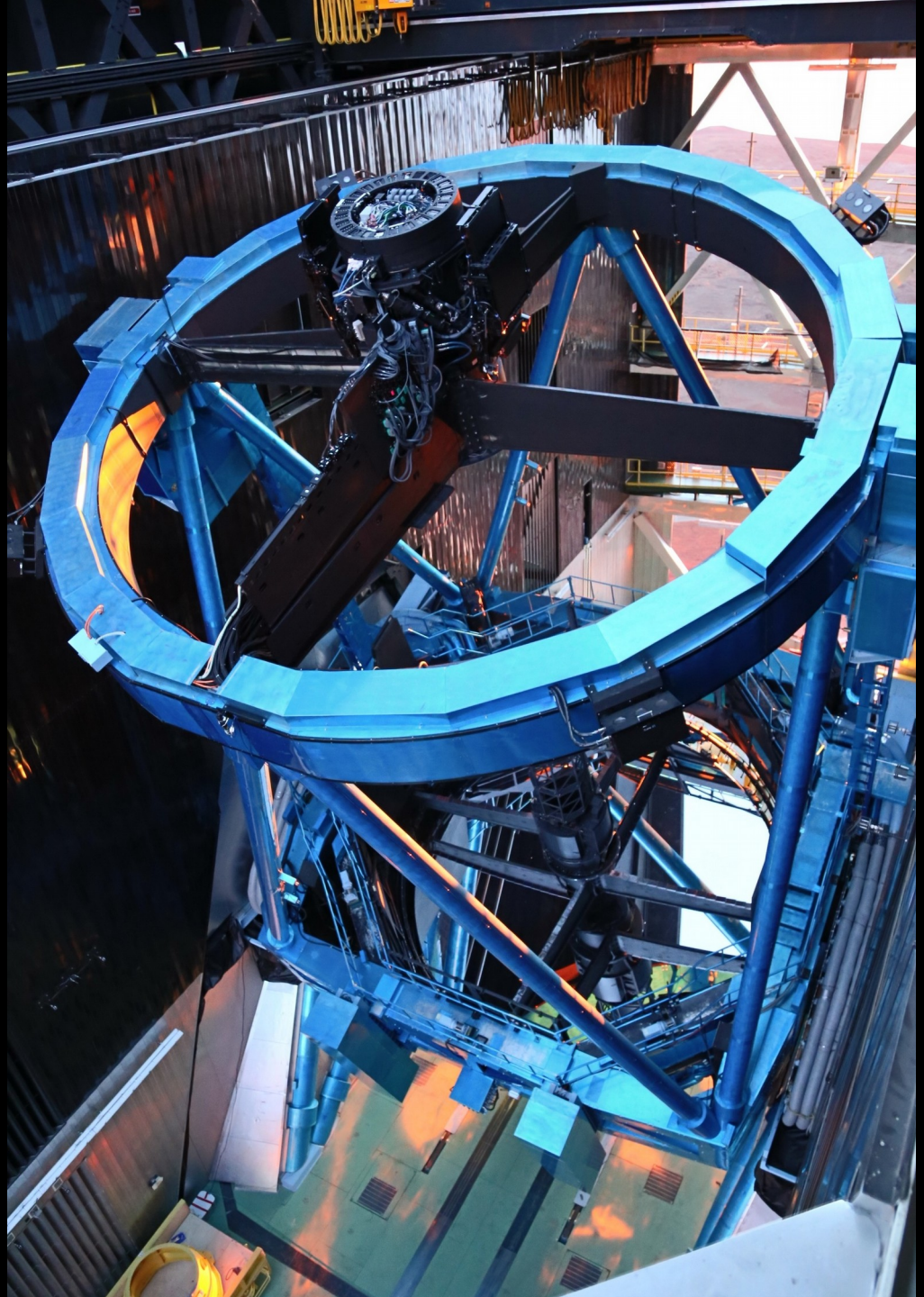
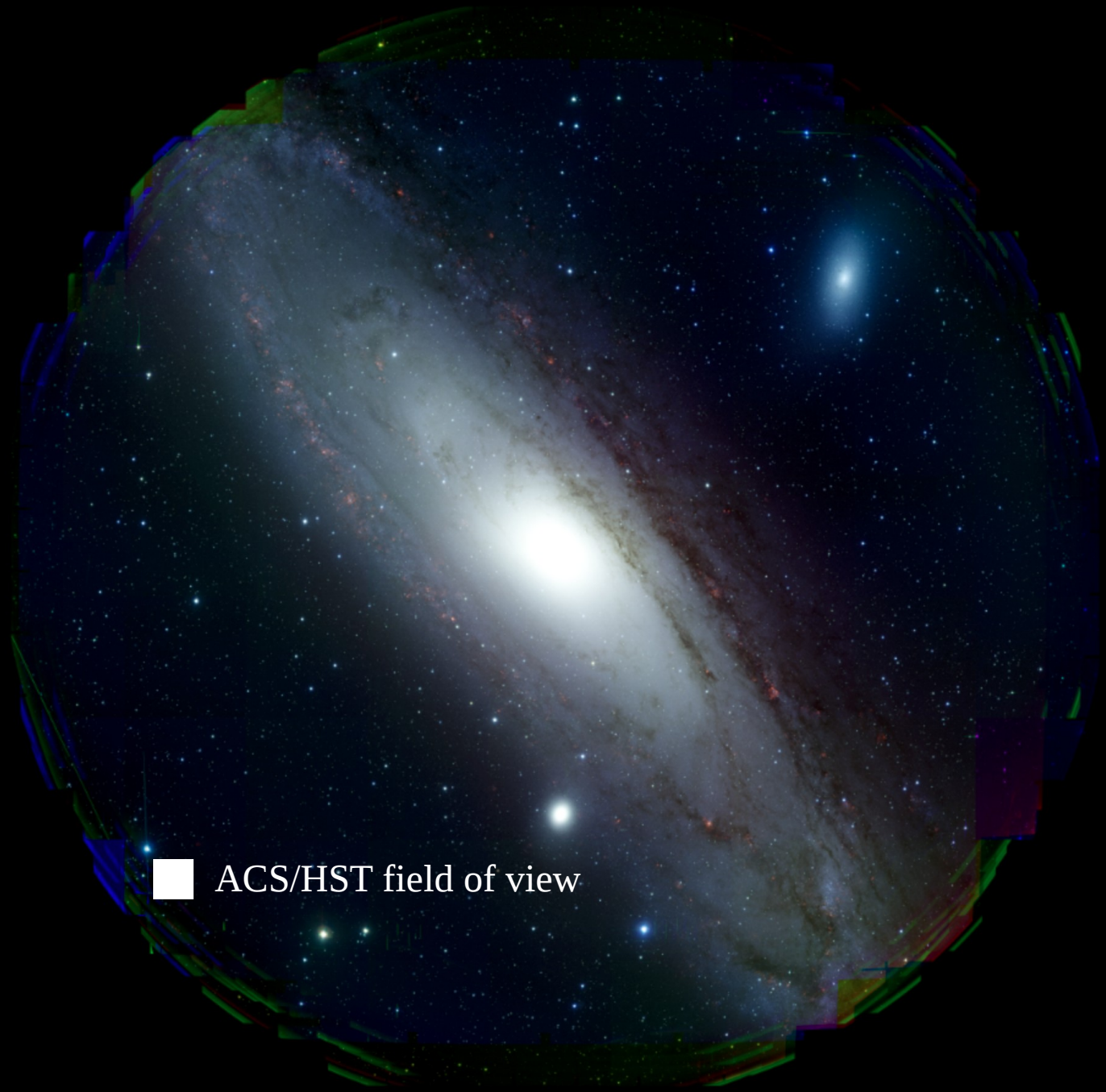
Hyper Suprime-Cam Subaru Strategic Program

Masayuki Tanaka
(National Astronomical Observatory of Japan)

Hyper Suprime-Cam

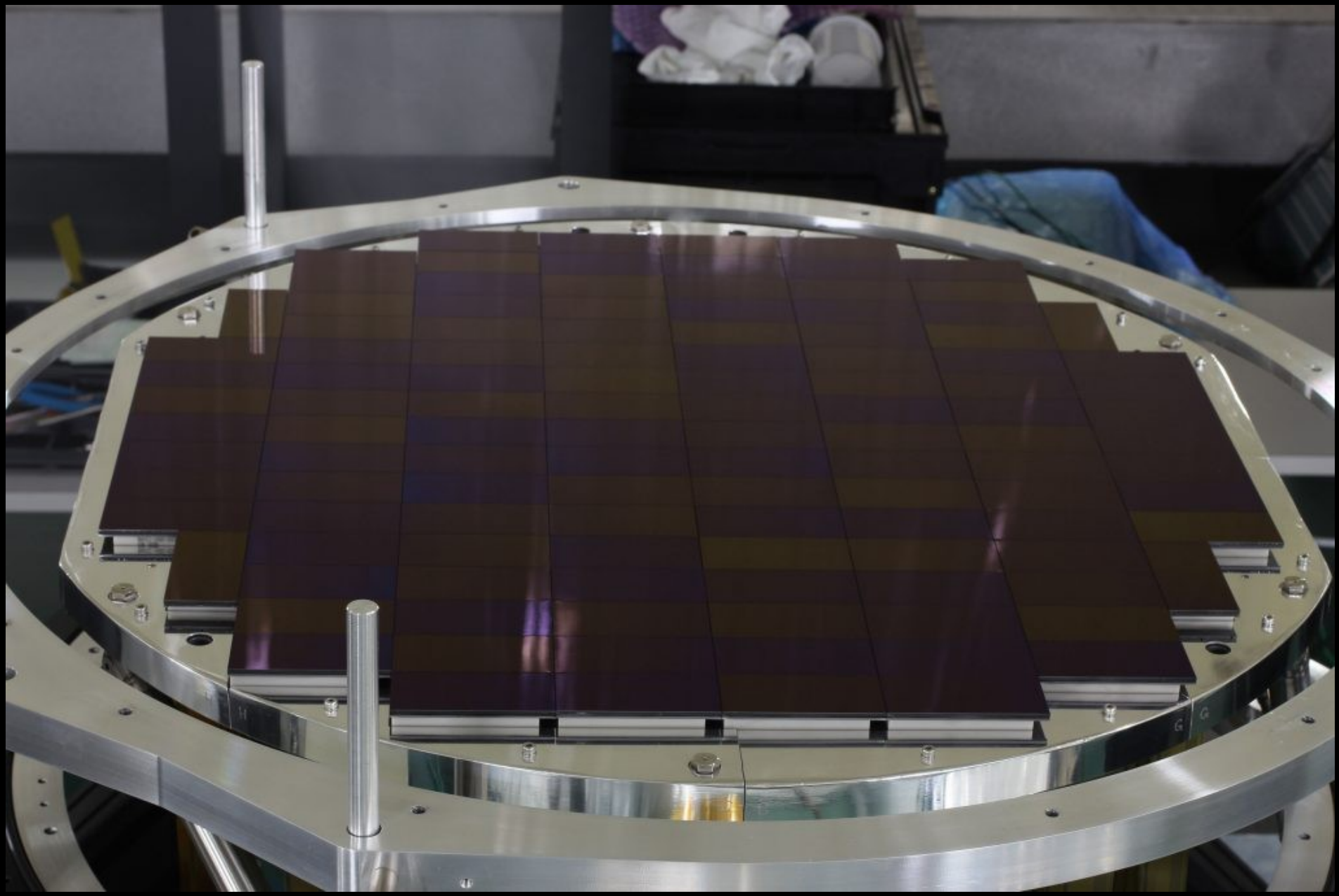



ACS/HST field of view

Camera body

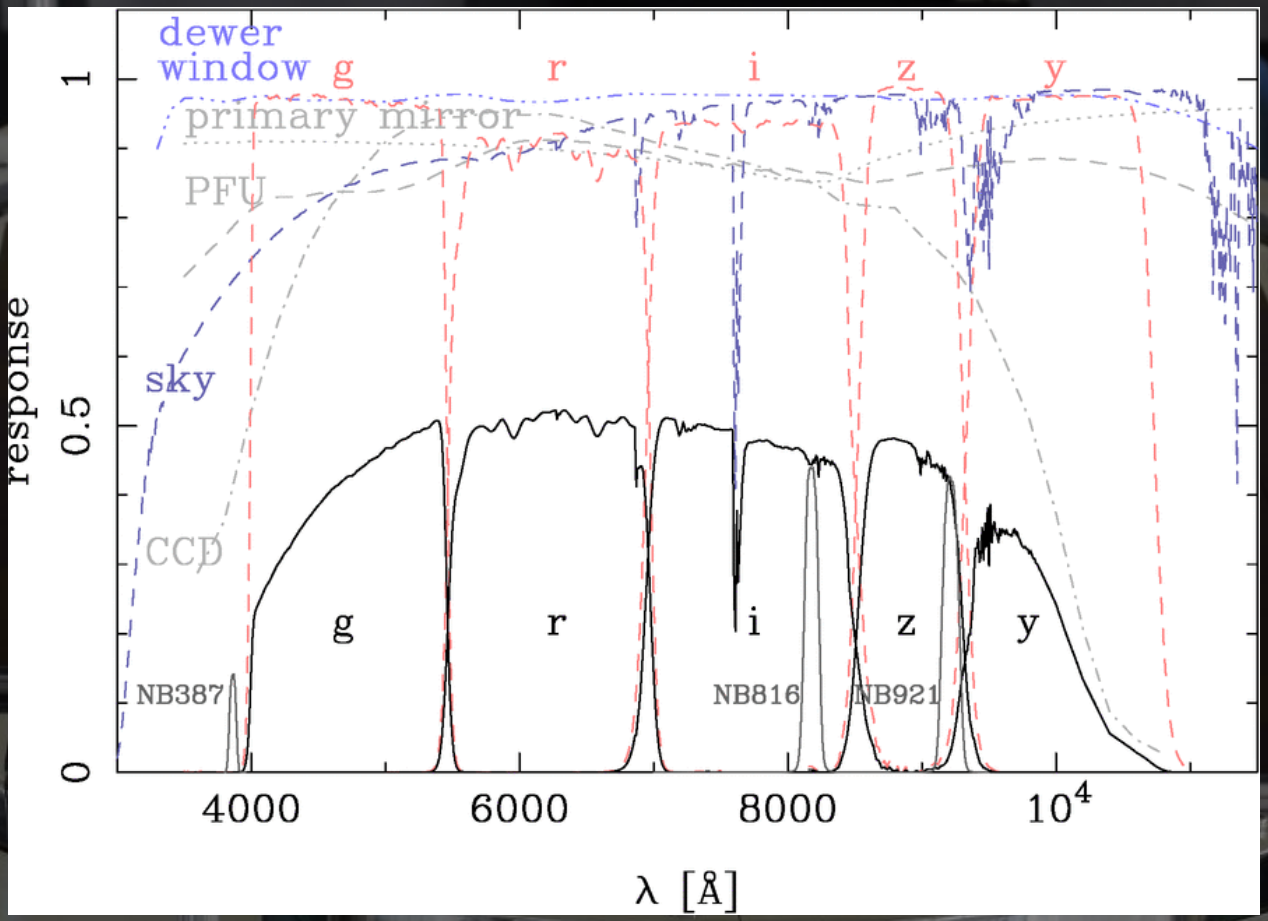
Wide-field corrector

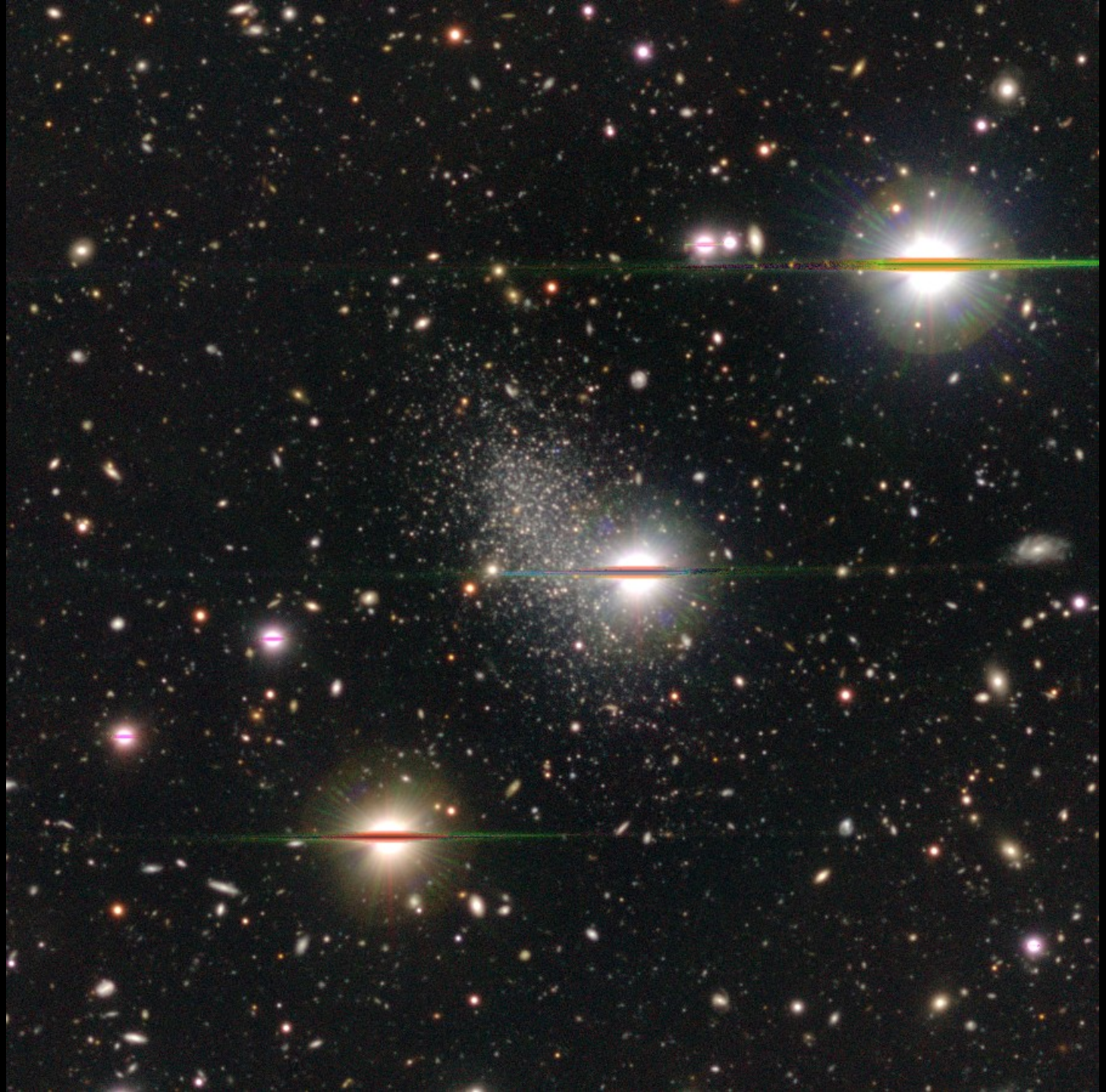
104 full depletion science CCDs. 12 CCDs for guiding and focusing.



104 full depletion science CCDs. 12 CCDs for guiding and focusing.

HSC filter system
5 broad-band filters (grizy) and several narrow-band filters.





HSC Strategic Survey

http://hsc.mtk.nao.ac.jp/

Group photo from the HSC collaboration meeting in Sendai in May

Subaru Strategic Program

International collaboration of **all Japan**, Princeton, and Taiwan.

Over 170 scientists are putting efforts in a huge observing program of 300 nights over 5-6 years. The survey started in March 2014 and it is about 50% done.

SSP proposal

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)

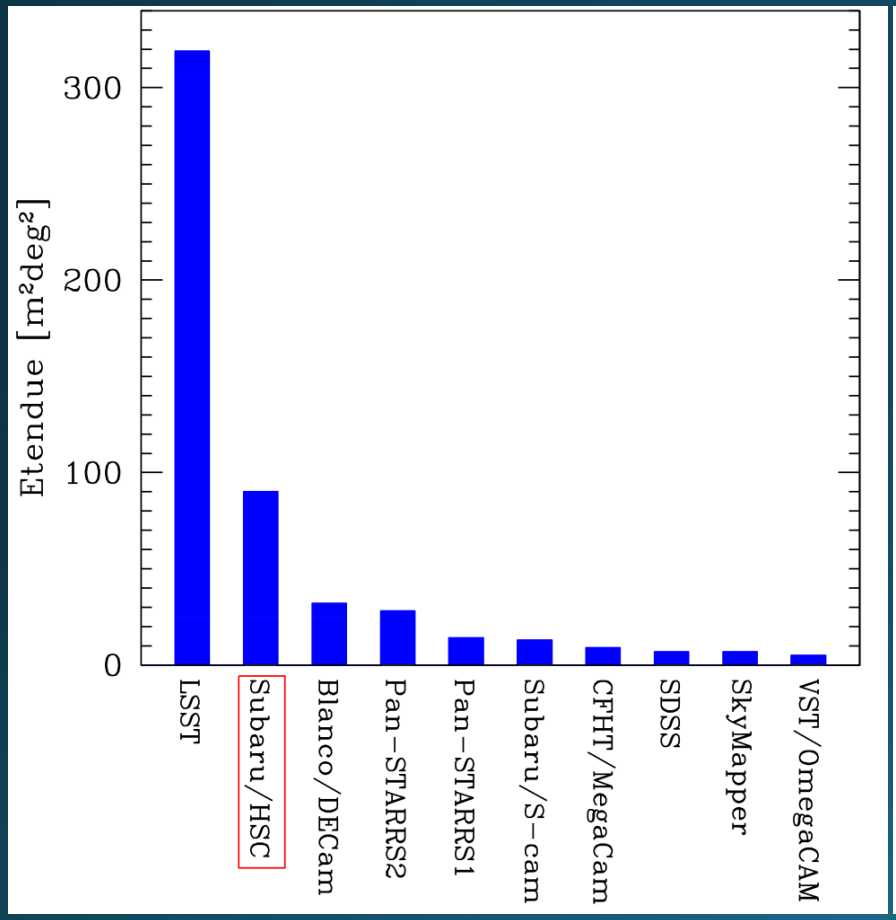
The HSC collaboration team[1]: S. Abe[(1)], H. Aihara[⋆(2),(3)], M. Akiyama[(4)], K. Aoki[(5)], N. Arimoto[⋆(5)], N. A. Bahcall[(6)], S. J. Bickerton[(3)], J. Bosch[(6)], K. Bundy[†(3)], C. W. Chen[(7)], M. Chiba[†(4)], T. Chiba[(8)], N. E. Chisari[(6)], J. Coupon[(7)], M. Doi[(2)], M. Enoki[(9)] S. 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) ISCA (28) ETH (29) Berkeley (30) CUAS (31) Hirosaki (32)

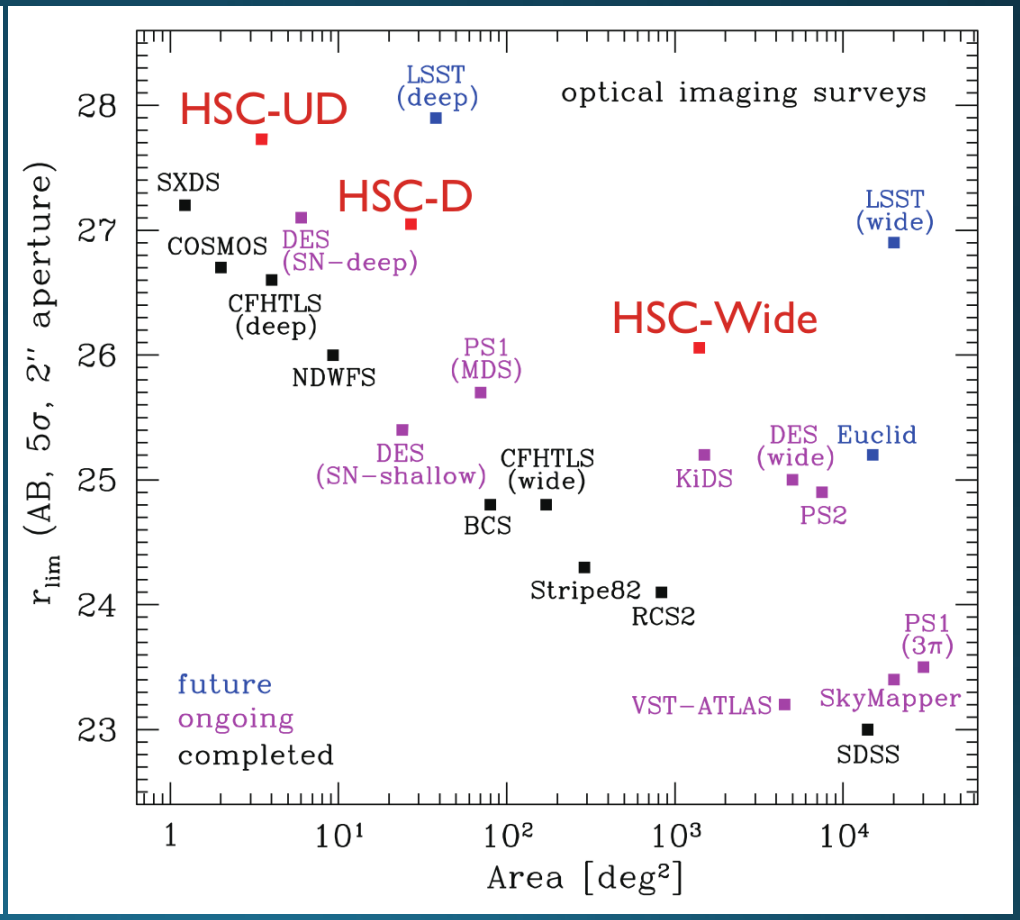
PRINCETON UNIVERSITY

ACADEMIA SINICA 1928

aboration meeting at Senday in May

Survey power

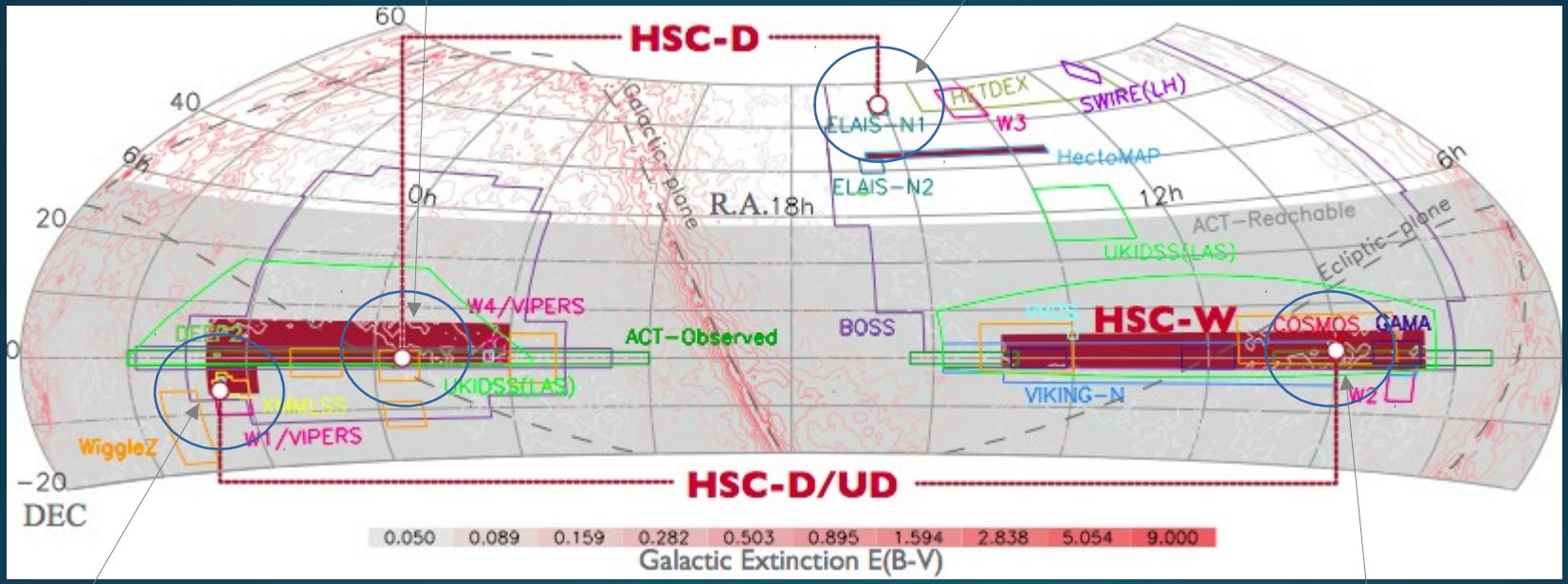




Survey fields

DEEP2-F3 (D)

ELIAS-N1 (D)



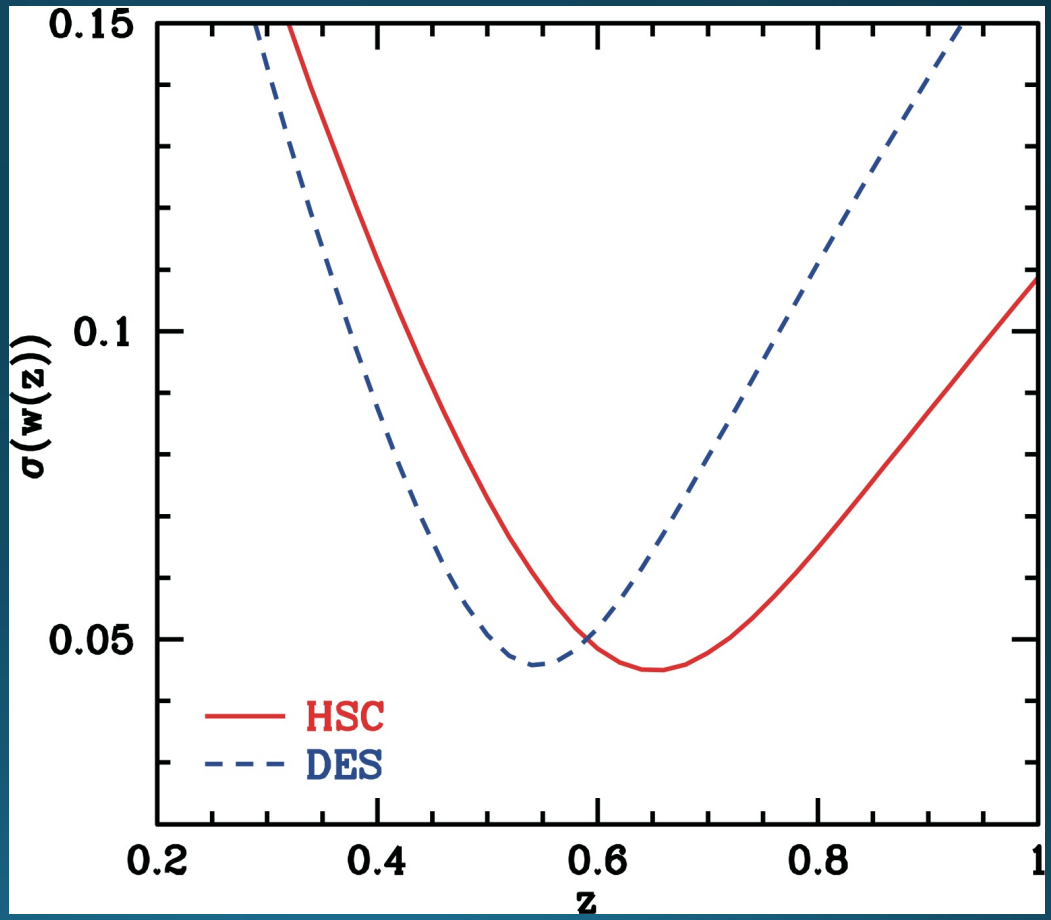
SXDS (UD)
XMMLSS (D)

- Full overlap with SDSS
- Low dust extinction
- Wide R.A. range
- Overlap with other NIR, spec, etc surveys.

COSMOS (UD)
E-COSMOS (D)

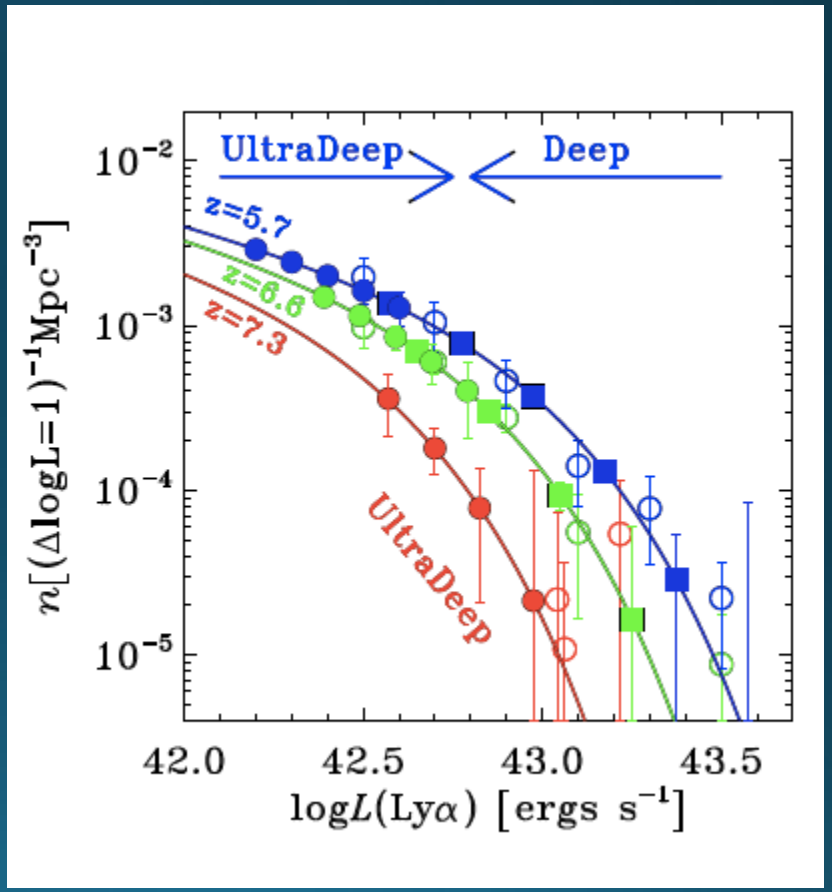
Science goals: weak-lensing cosmology

- **Weak-lensing cosmology**
- High-redshift galaxies
- Galaxy evolution
- Clusters of galaxies
- Transient objects
- Solar system bodies
- AGN/QSO
- Milky Way
- Strong lensing
- ...



Science goals: high-z galaxies

- Weak-lensing cosmology
- **High-redshift galaxies**
- Galaxy evolution
- Clusters of galaxies
- Transient objects
- Solar system bodies
- AGN/QSO
- Milky Way
- Strong lensing
- ...



Science goals: galaxy evolution

- Weak-lensing cosmology
- High-redshift galaxies
- **Galaxy evolution**
- Clusters of galaxies
- Transient objects
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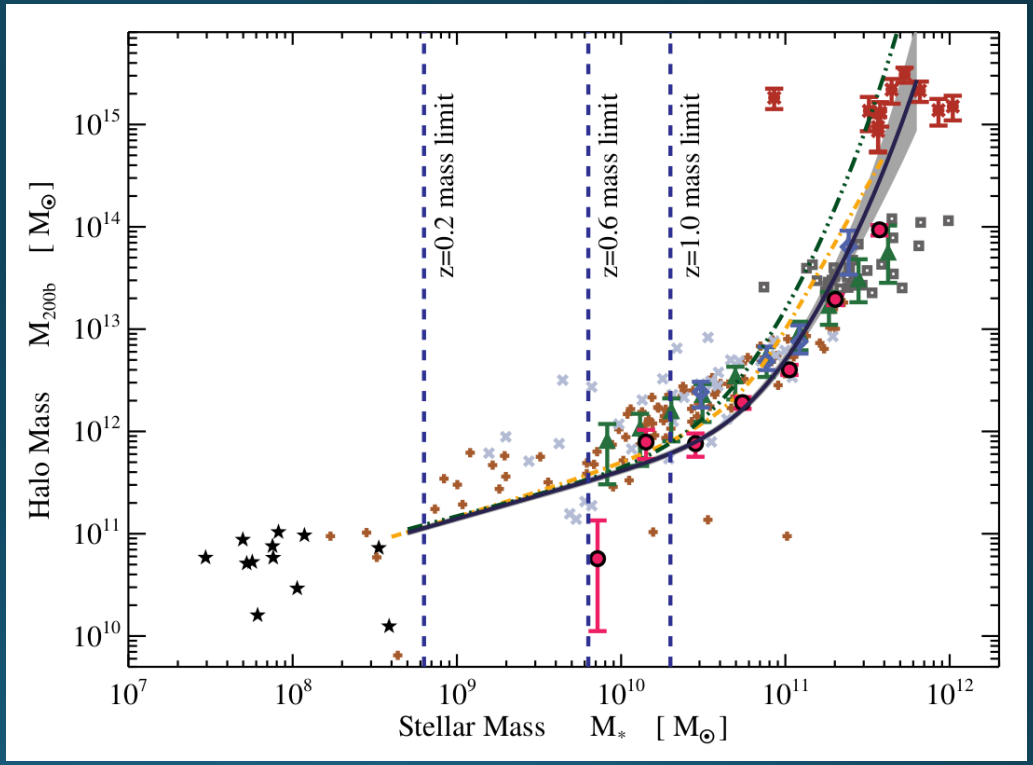
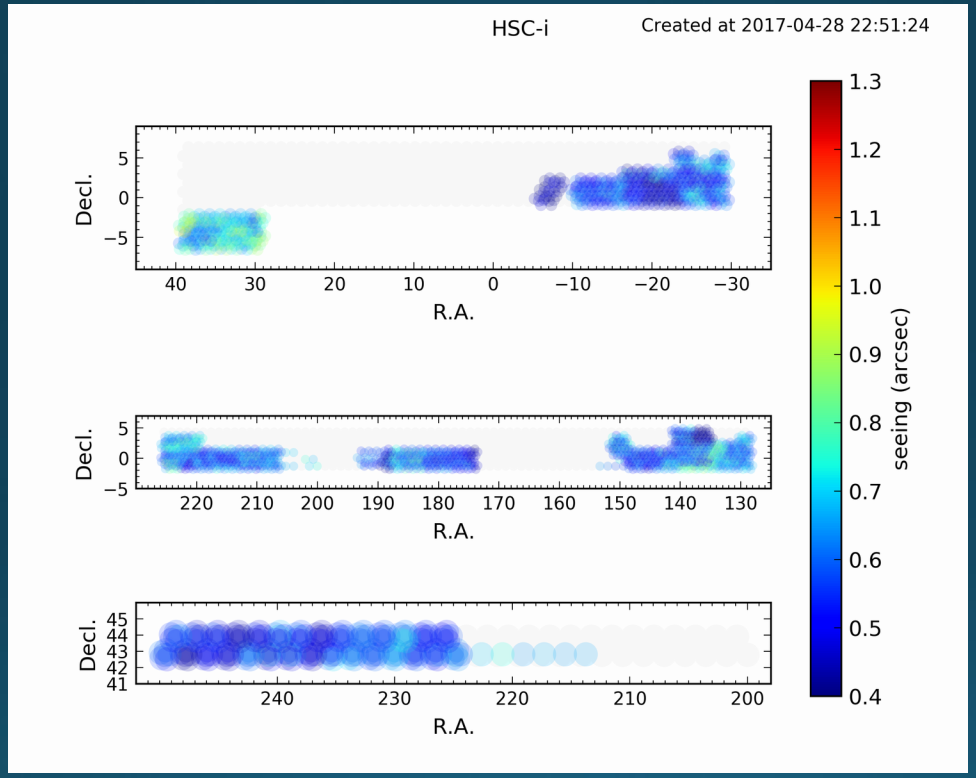
- ...

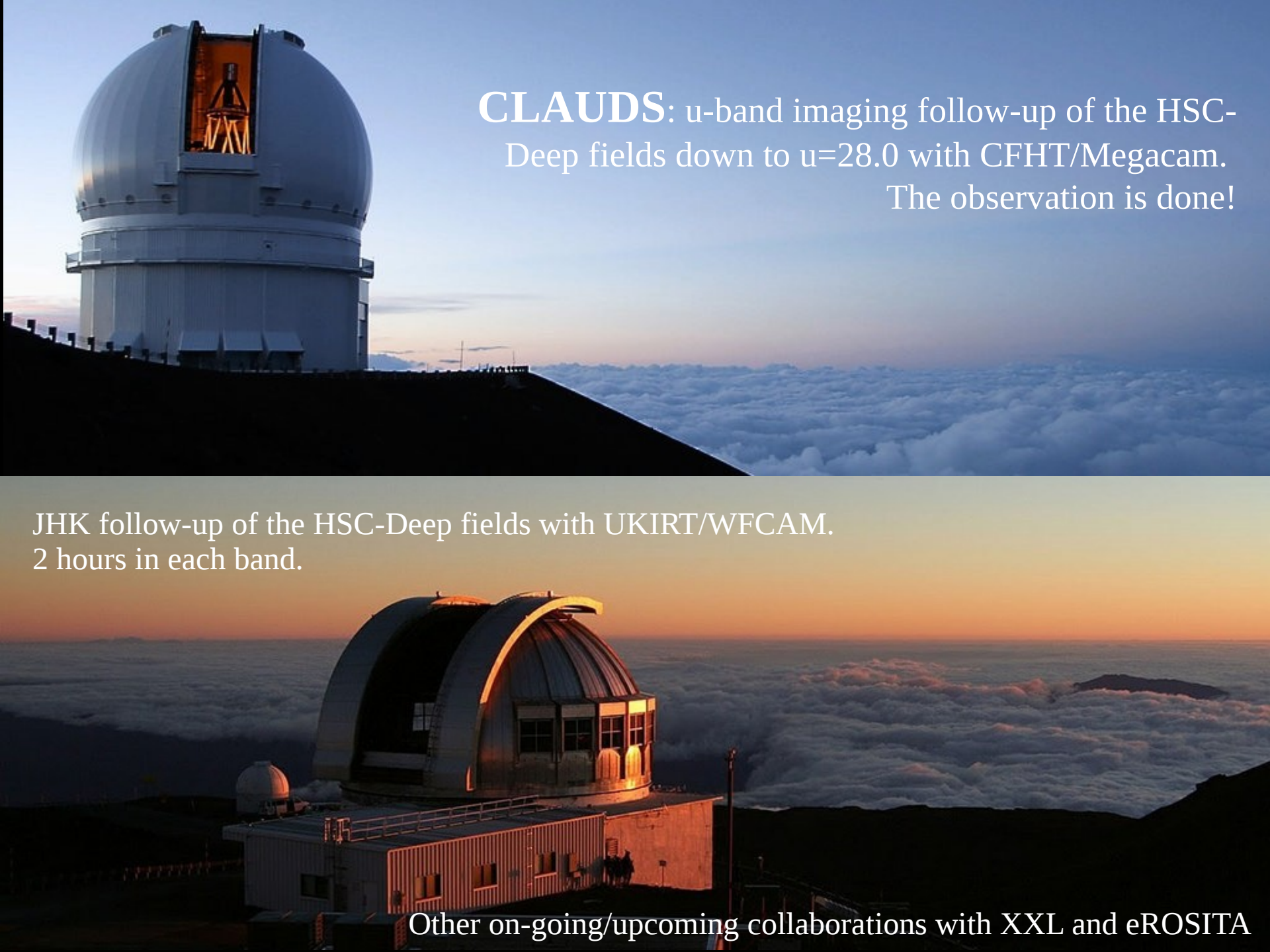


Survey progress



~300 square degrees surveyed to full-color full depth so far.
Note the excellent seeing!

Figure courtesy: Yasuda-san



CLAUDS: u-band imaging follow-up of the HSC-Deep fields down to u=28.0 with CFHT/Megacam.
The observation is done!

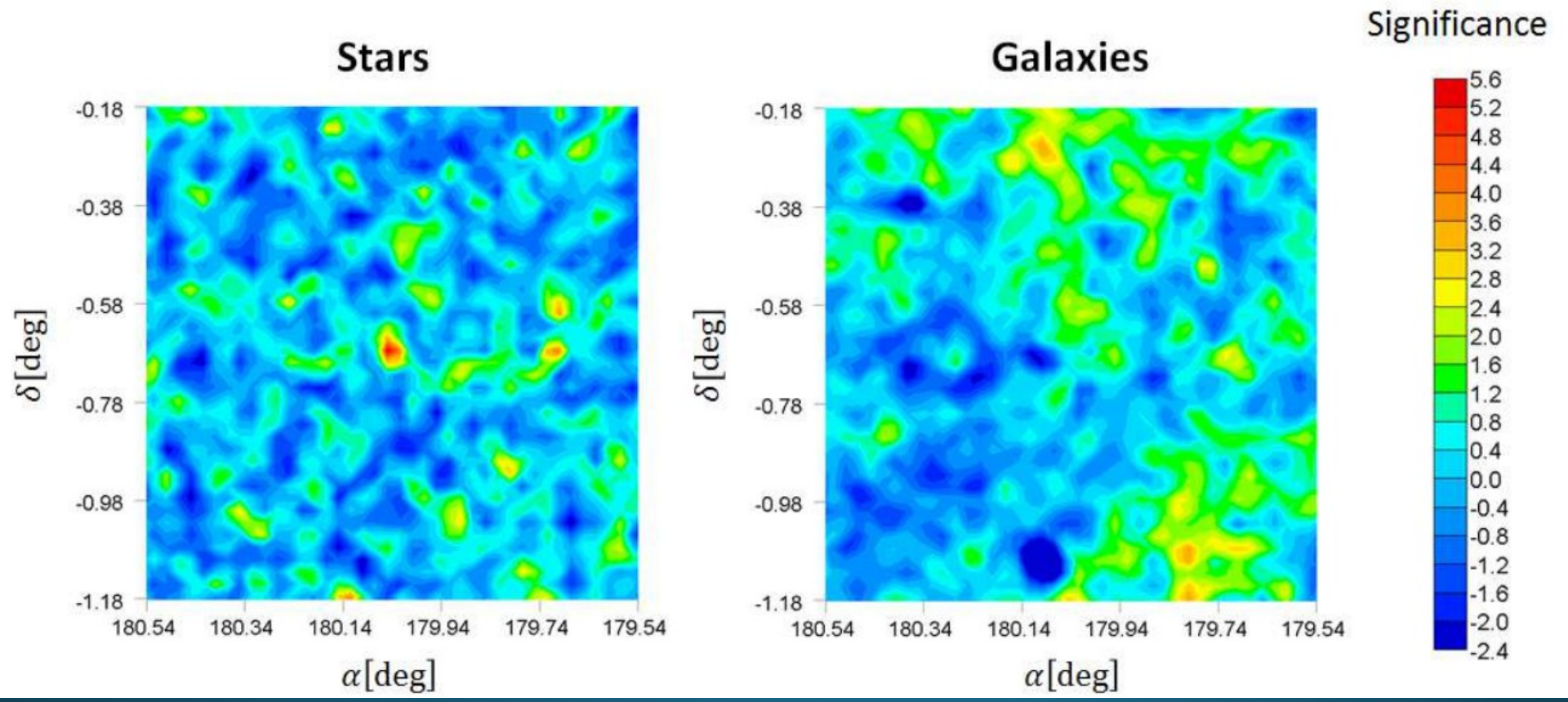
JHK follow-up of the HSC-Deep fields with UKIRT/WFCAM.
2 hours in each band.

Other on-going/upcoming collaborations with XXL and eROSITA

Early Science Results

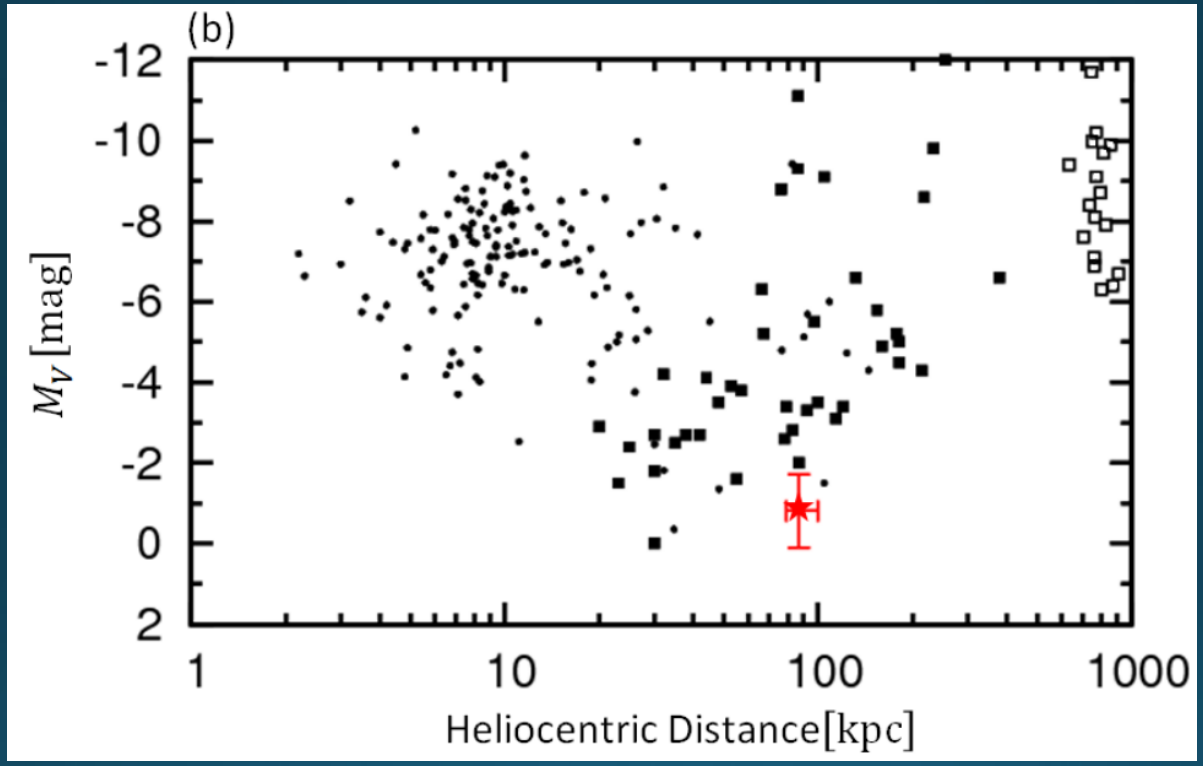
A special PASJ issue with ~30 papers is being prepared

Virgo I – a new dwarf satellite of the Milky Way



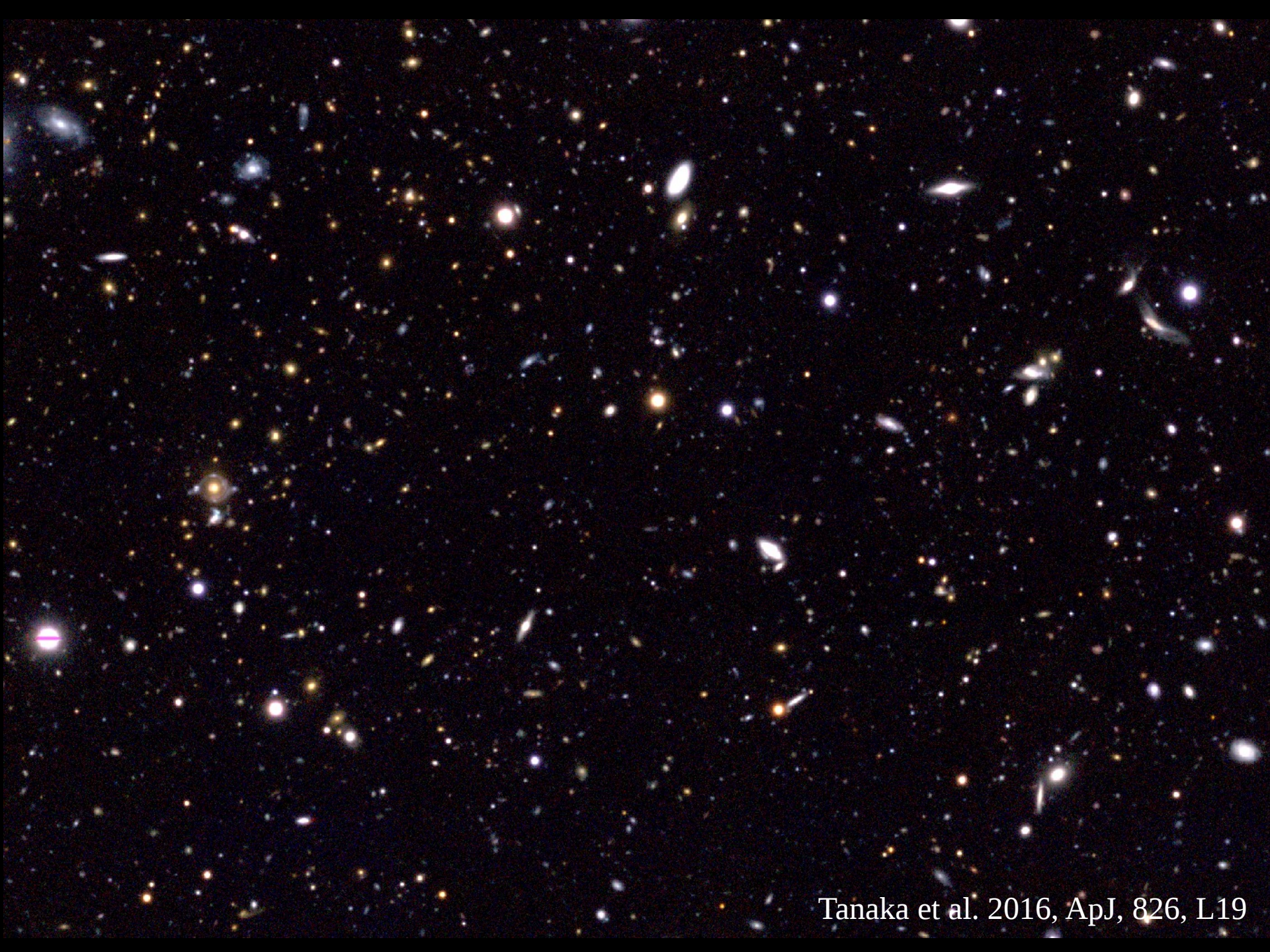
Homma et al. 2016, ApJ, 832, 21

Virgo I – a new dwarf satellite of the Milky Way

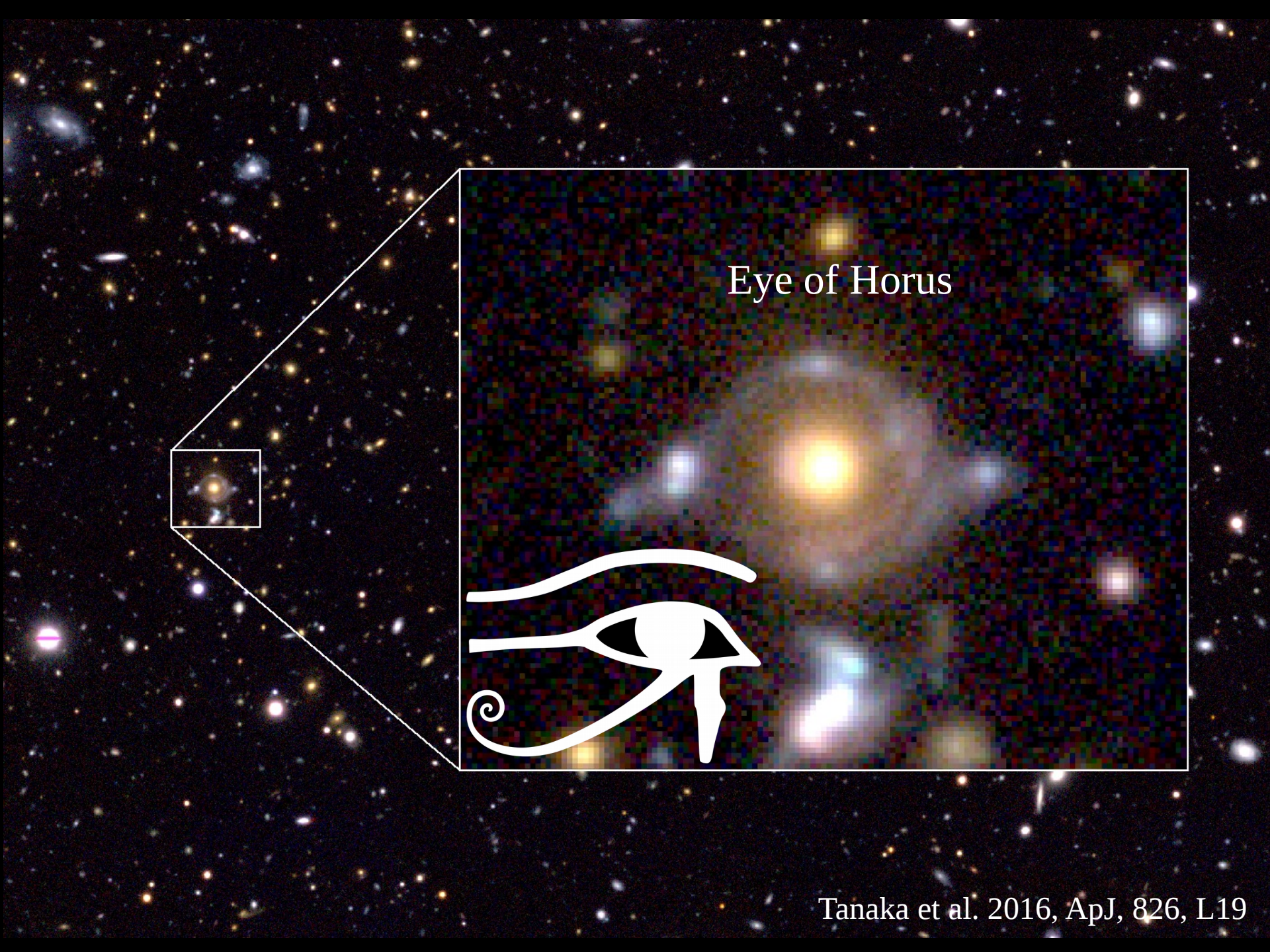


Virgo I is one of the faintest dwarf galaxy located at ~90kpc, demonstrating the power of the HSC survey.

Homma et al. 2016, ApJ, 832, 21



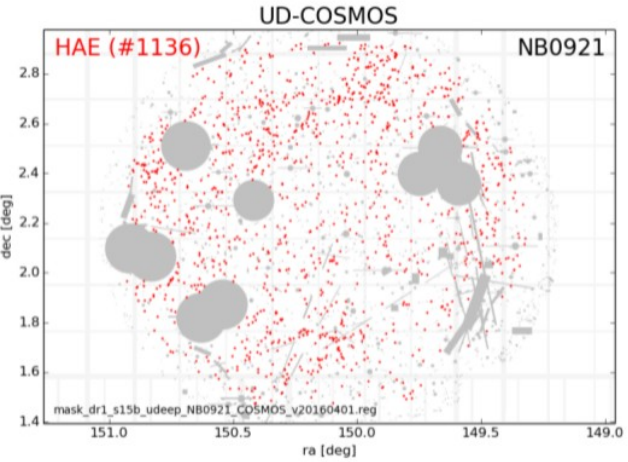
Tanaka et al. 2016, ApJ, 826, L19

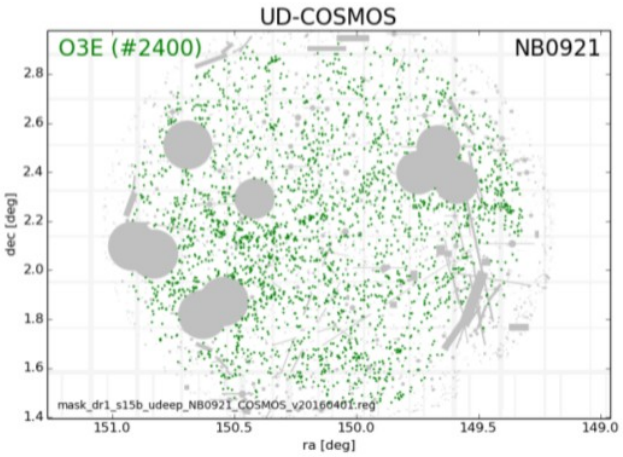


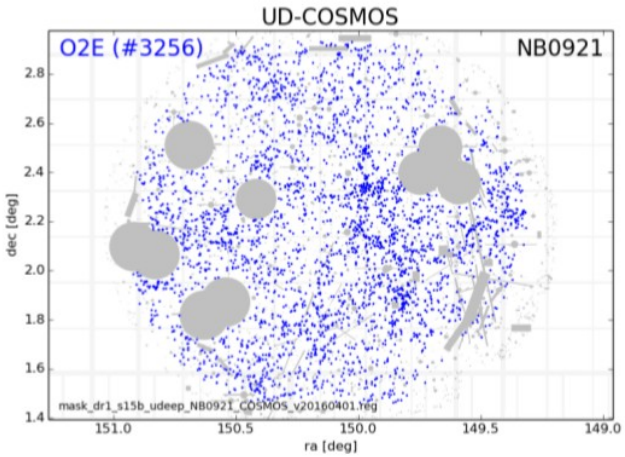
Tanaka et al. 2016, ApJ, 826, L19

Emission line objects

z~0.4 z~0.8 z~1.5



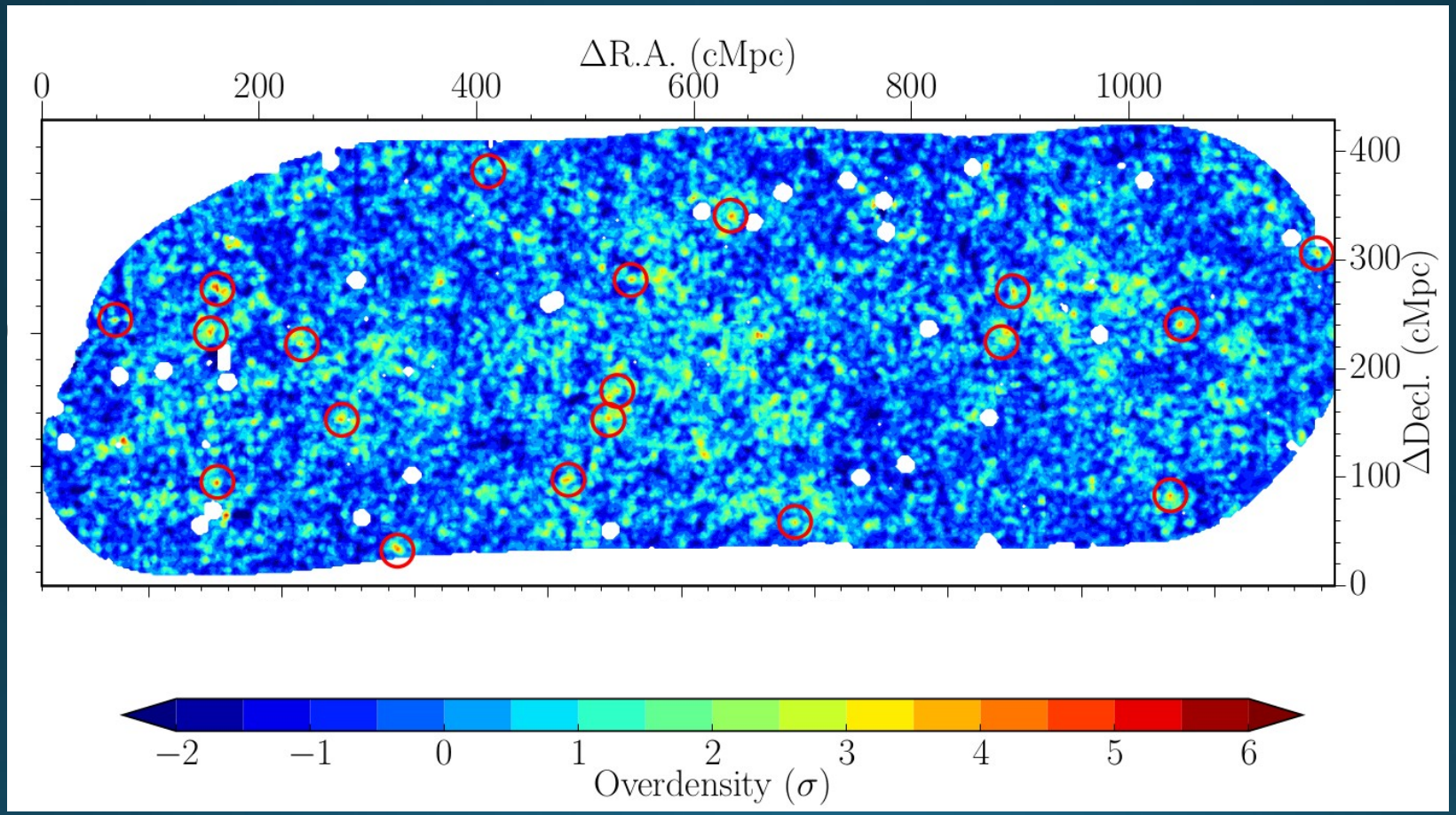




With the narrow-bands, we can detect emission line objects in narrow redshift slices to trace LSS as well as to study effects of LSS on galaxy evolution.

Hayashi, Tanaka et al. PASJ submitted (arXiv:170405978)

Proto-clusters traced by LBGs



Over 100 proto-cluster candidates so far. Number density ~ 10^-7 Mpc^-3.
A preliminary clustering analysis suggests r_0~30 Mpc.

Toshikawa et al. PASJ submitted

...and many more!

Work in progress on

- Very massive galaxies
- Ultra Diffuse Galaxies (UDGs)
- Green peas
- Very bright Lyman alpha emitters
- Very bright Lyman break galaxies
- Solar system bodies
- Dust Obscured Galaxies (DOGs)
- QSO-galaxy cross correlation
- Hosts of radio galaxies
- Galaxy-scale strong lensing
- Cluster-scale strong lensing
- Stellar tidal streams around nearby galaxies
- Blue Horizontal Branch stars to probe the MW halo
- etc, etc, etc...

The First Public Data Release

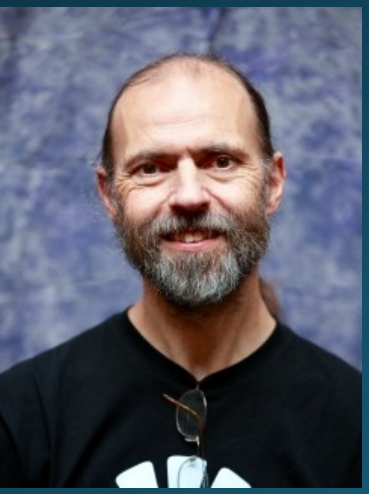
https://hsc-release.mtk.nao.ac.jp/

Data Processing

hscPipe, a version of LSST stack, has been primarily developed by the software group at Princeton, Yasuda-san at IPMU, and NAOJ.

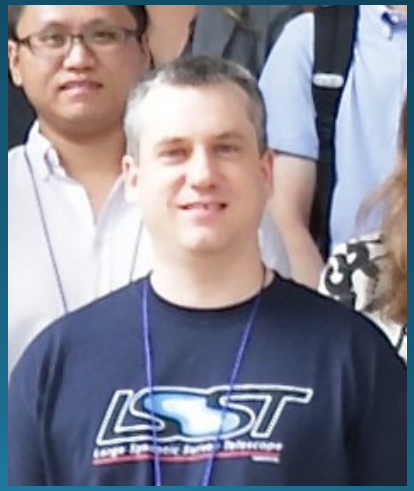
The code is getting shape:

- Internal : 1% PSF photometry, ~10mas astrometry
- Against PS1: 1-2% PSF photometry, ~40mas astrometry


Robert Lupton


Bob Armstrong


Jim Bosch


Paul Price


Naoki Yasuda

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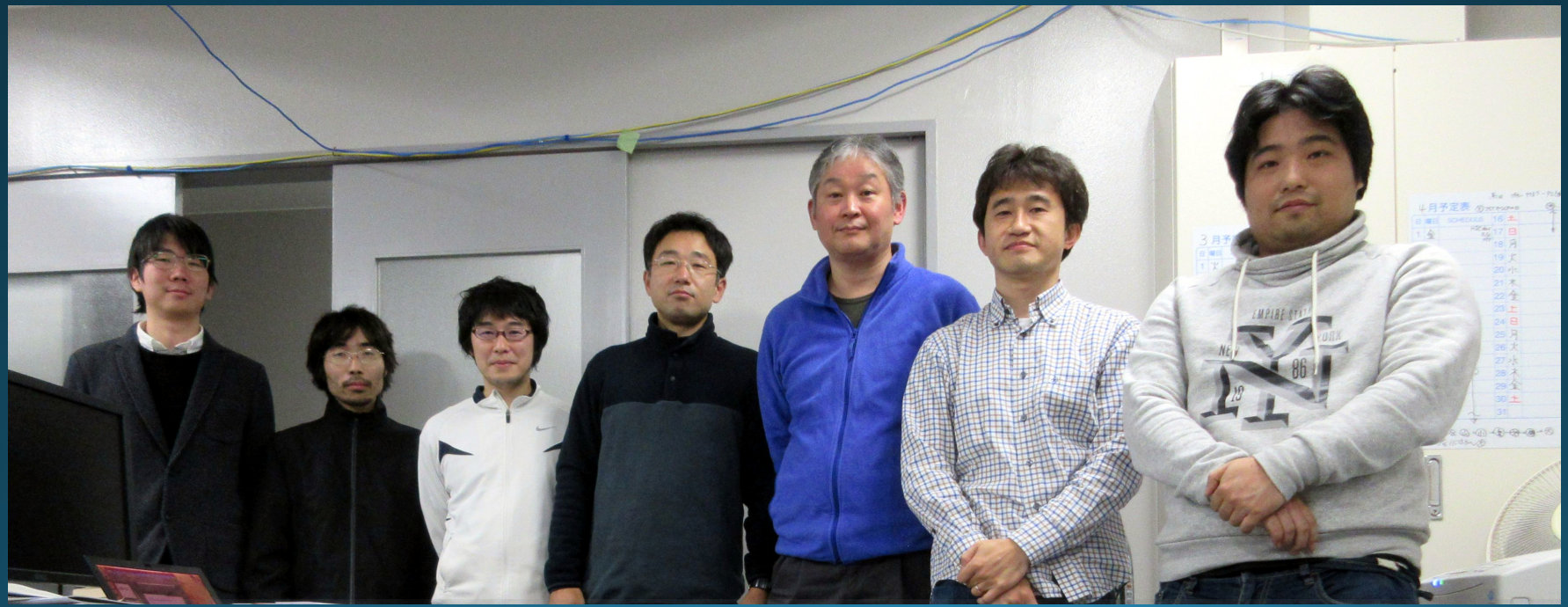
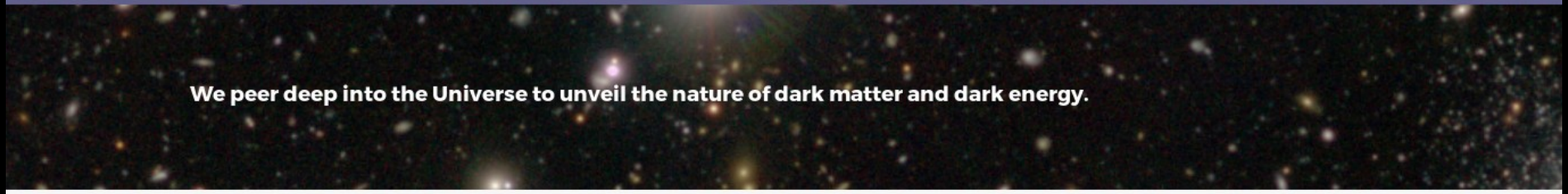


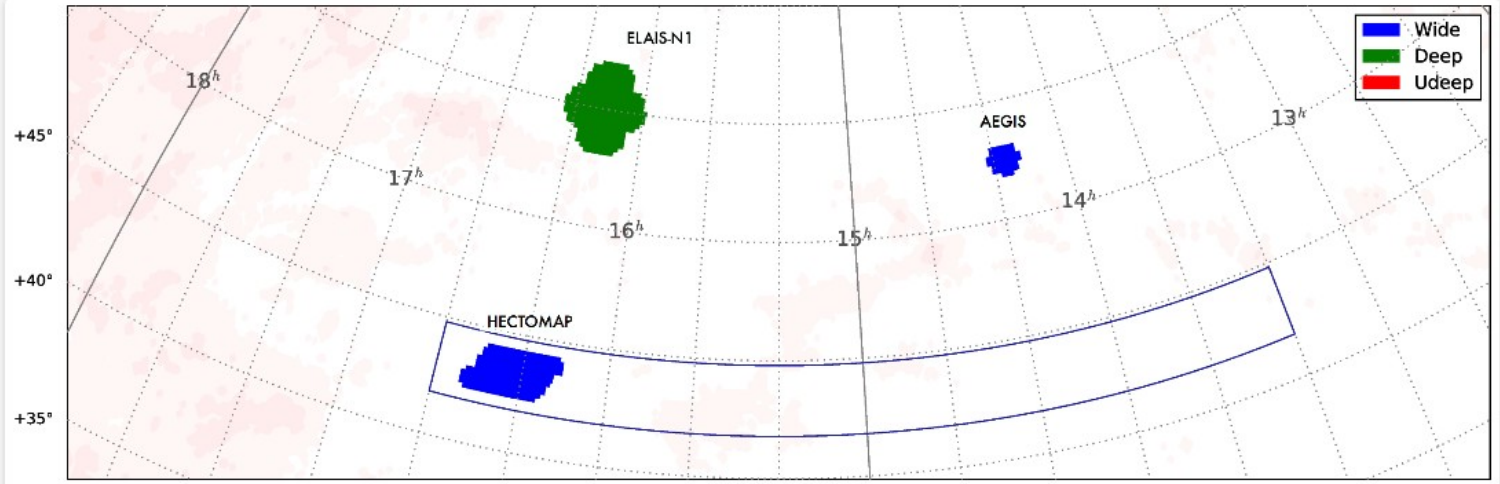
Hyper Suprime-Cam Subaru Strategic Program

Data Release 1

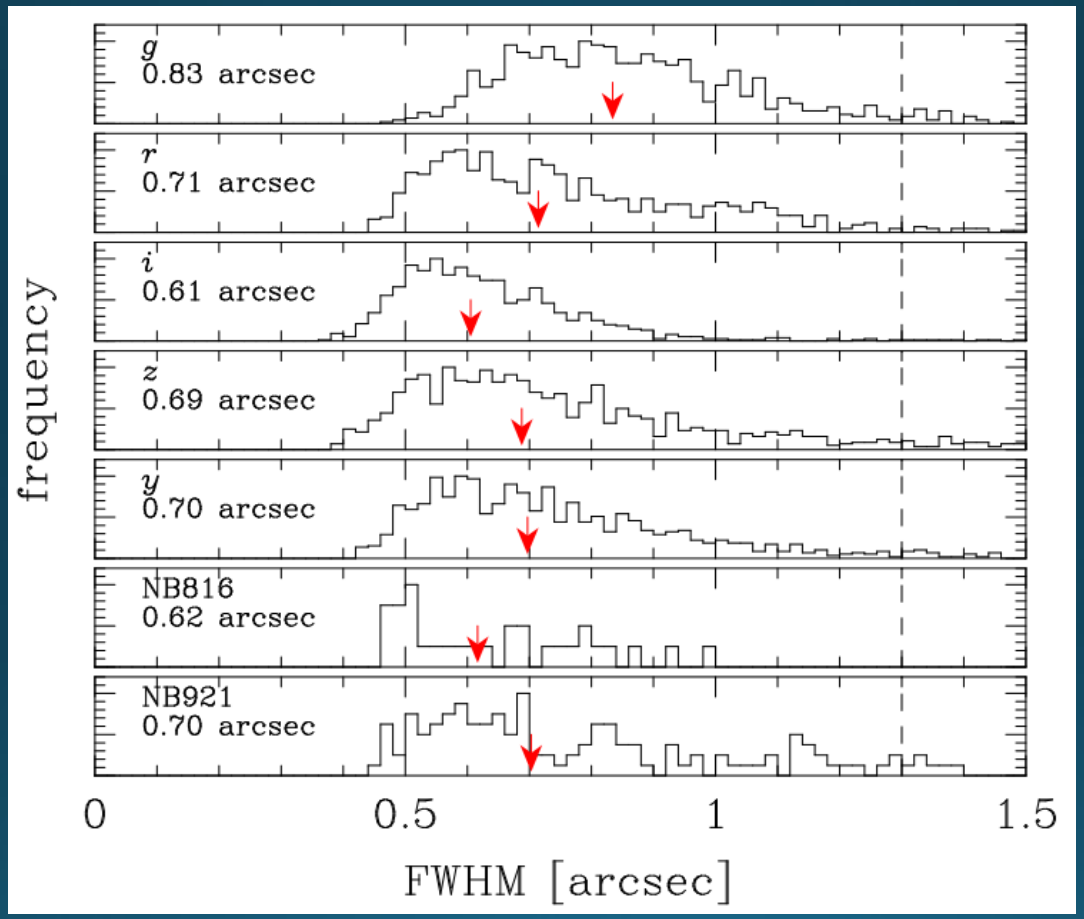


Public Data Release 1

Welcome to the Hyper Suprime-Cam Subaru Strategic Program Data Release Site!
The first public release of HSC-SSP occurred on 28 February 2017. The release includes over 100 square degrees of deep multi-color data served through dedicated databases and user interfaces. The figures below shows the area covered in this release and the table gives an overview of the data in the three survey layers. Refer to our survey website for details of the survey design.

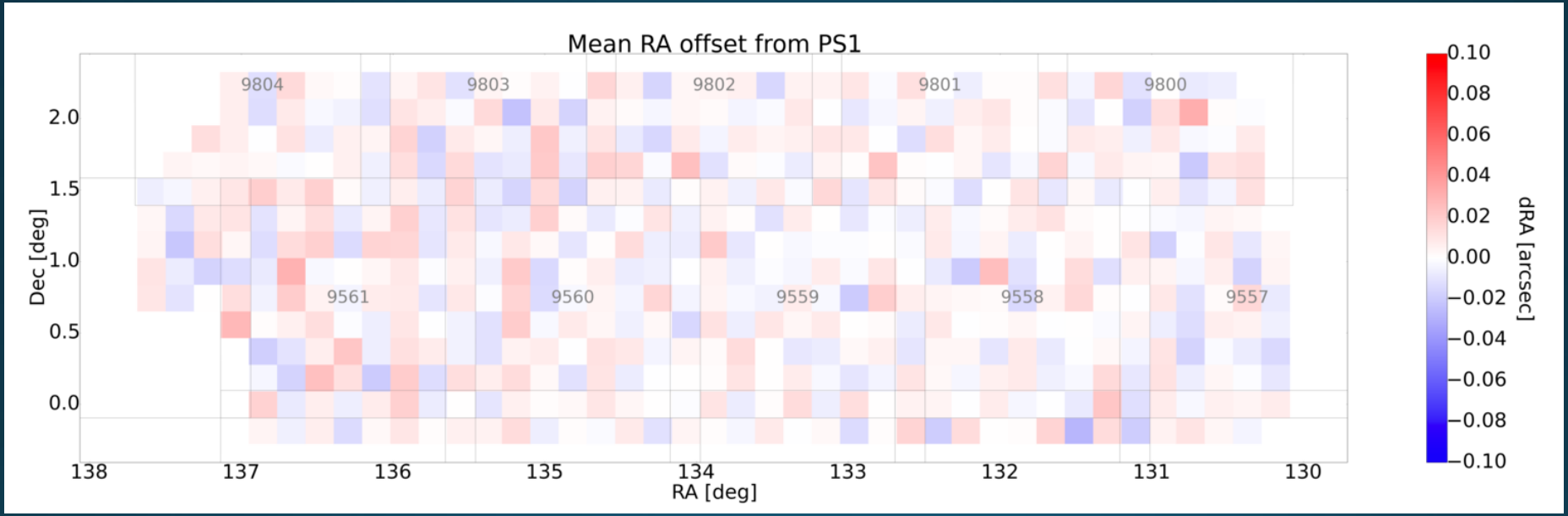


First Data Release: seeing distribution



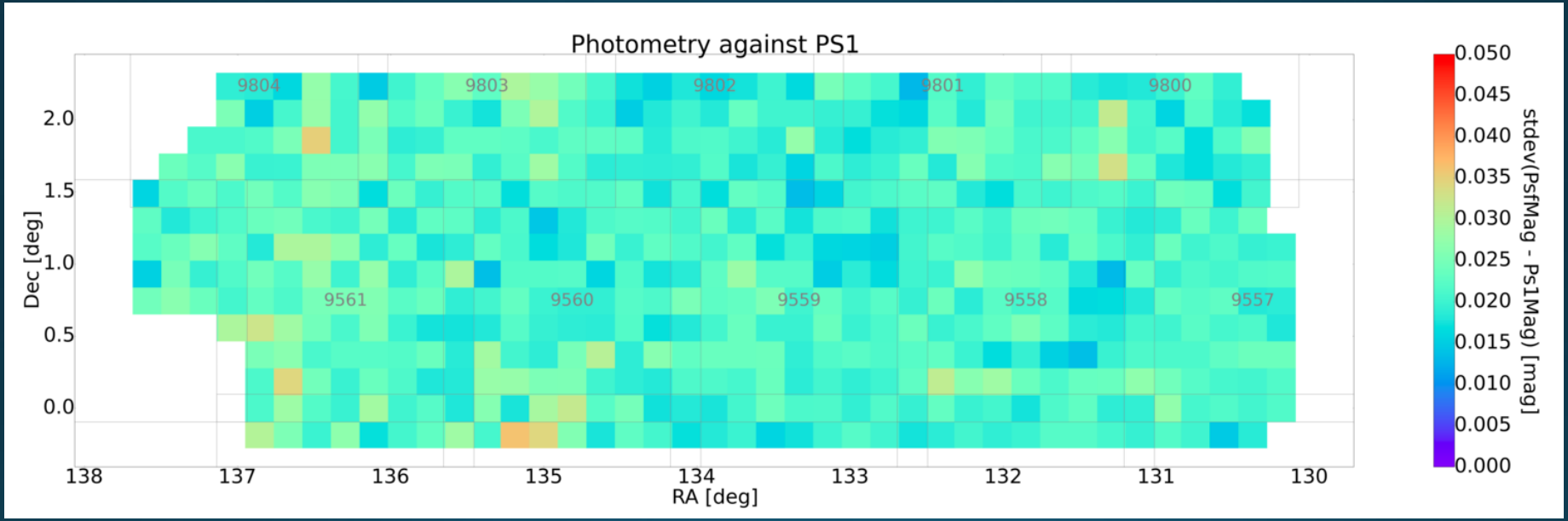
Excellent image quality – the median seeing in the i-band is 0.6 arcsec!

Data Quality: astrometry



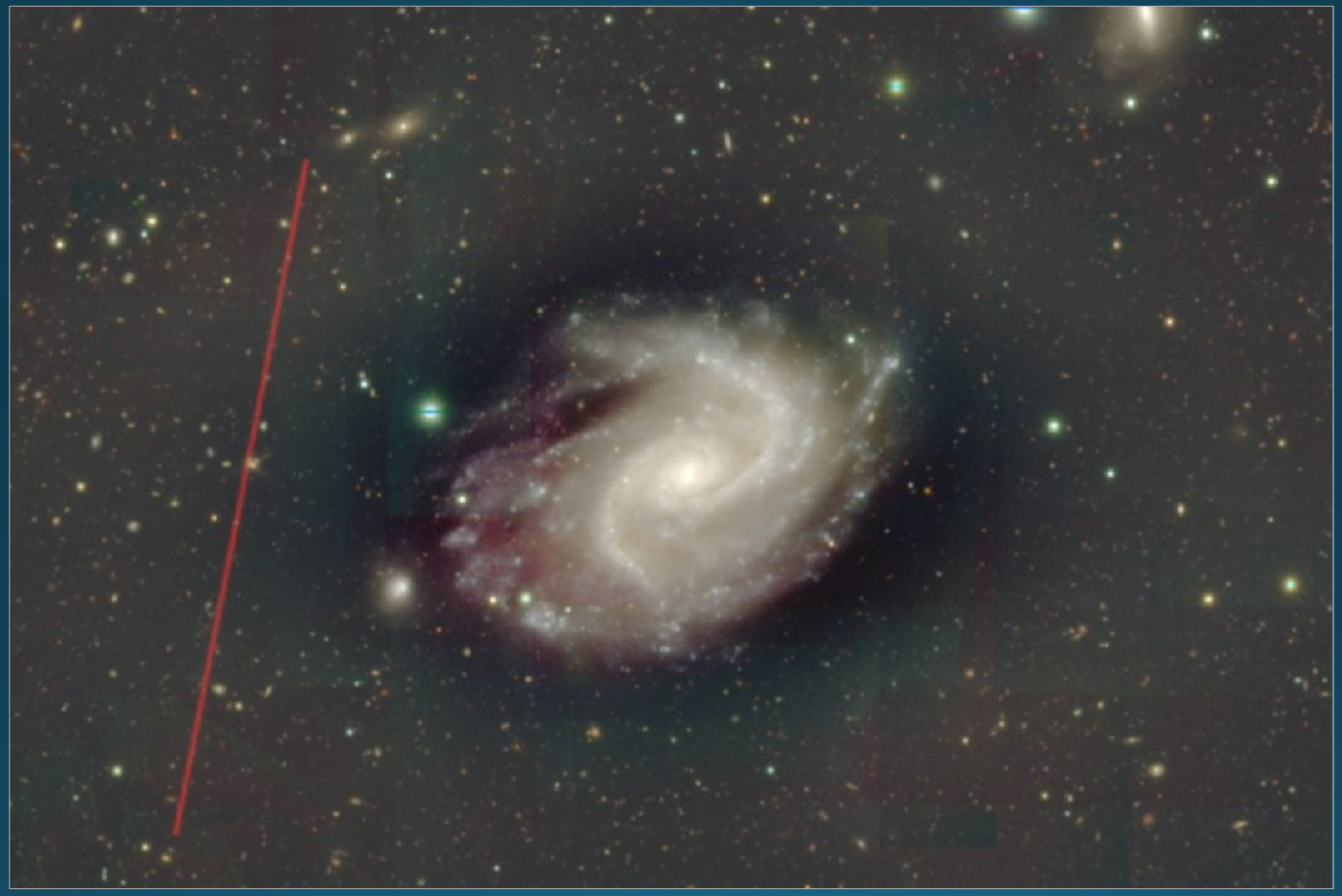
Our astrometry against an external data (PanSTARRS1) is about ~40 milli-arcsec. This is sufficient for most science cases.

Data Quality: photometry



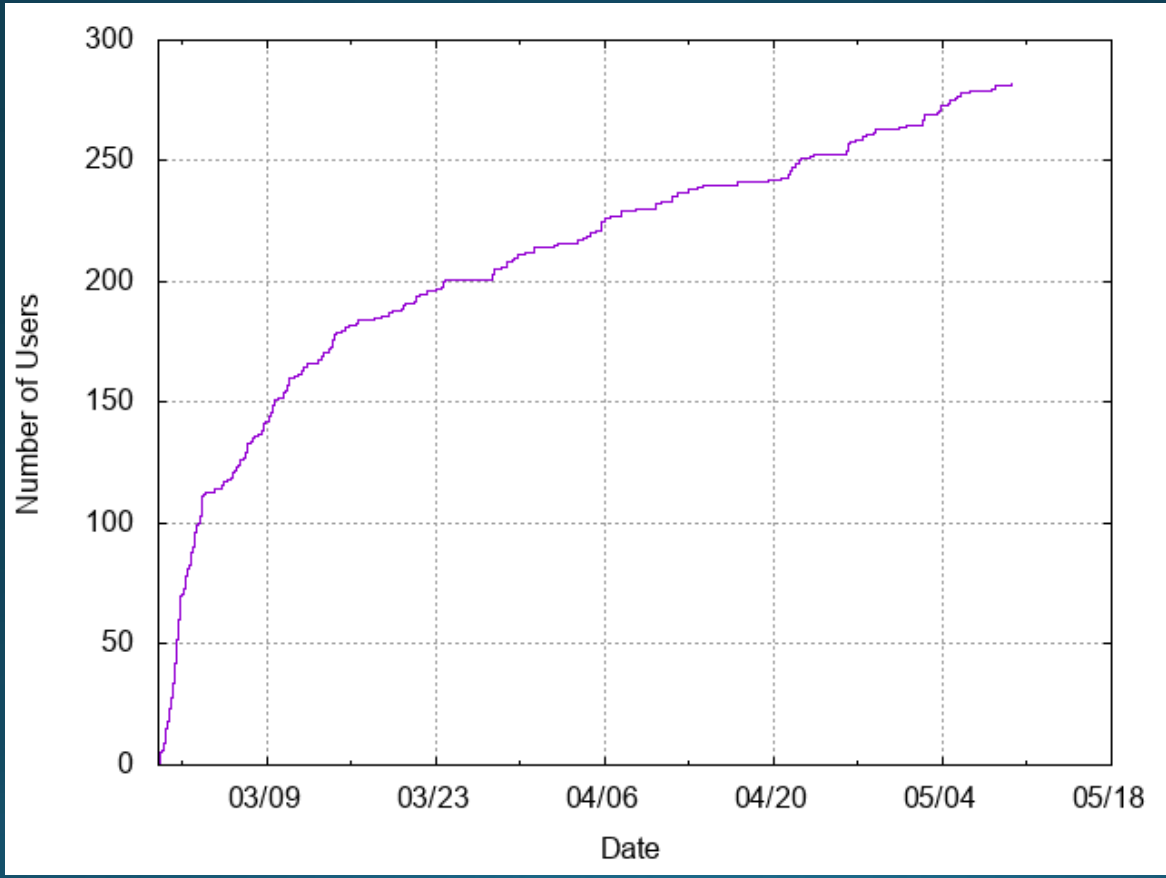
Our photometry against PanSTARRS1 is about ~0.02mag rms.
Slightly worse than the 1% goal, but we are close.

Known Problems

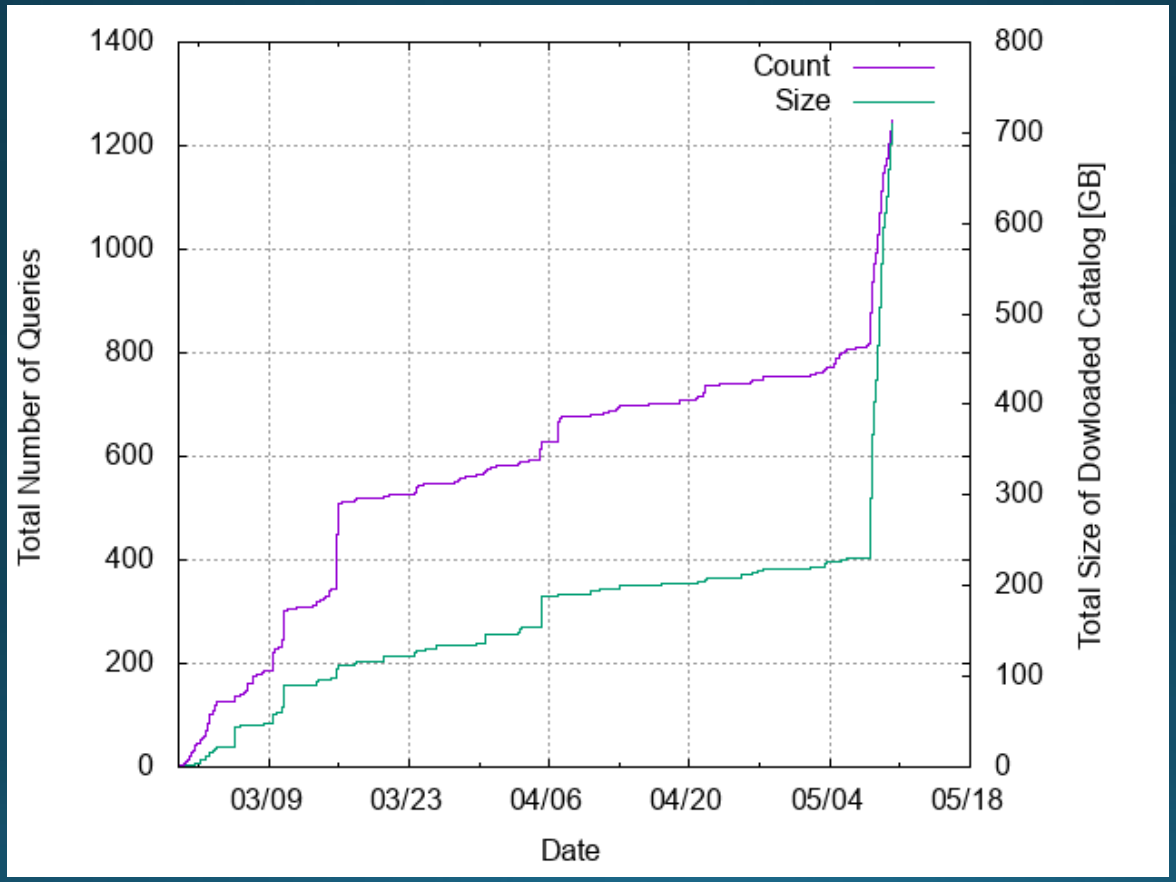


There are known problems in our data, but future improvements in the pipeline will hopefully mitigate them. An up-to-date list of known issue is available at the data release site.

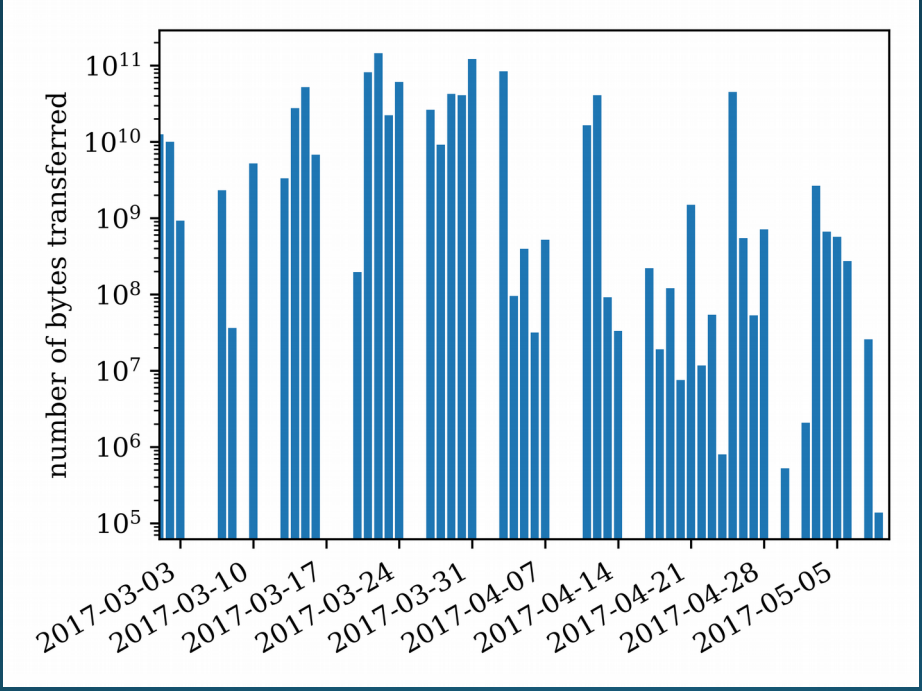
Data access statistics : registered users



Data access statistics : catalog data retrieval

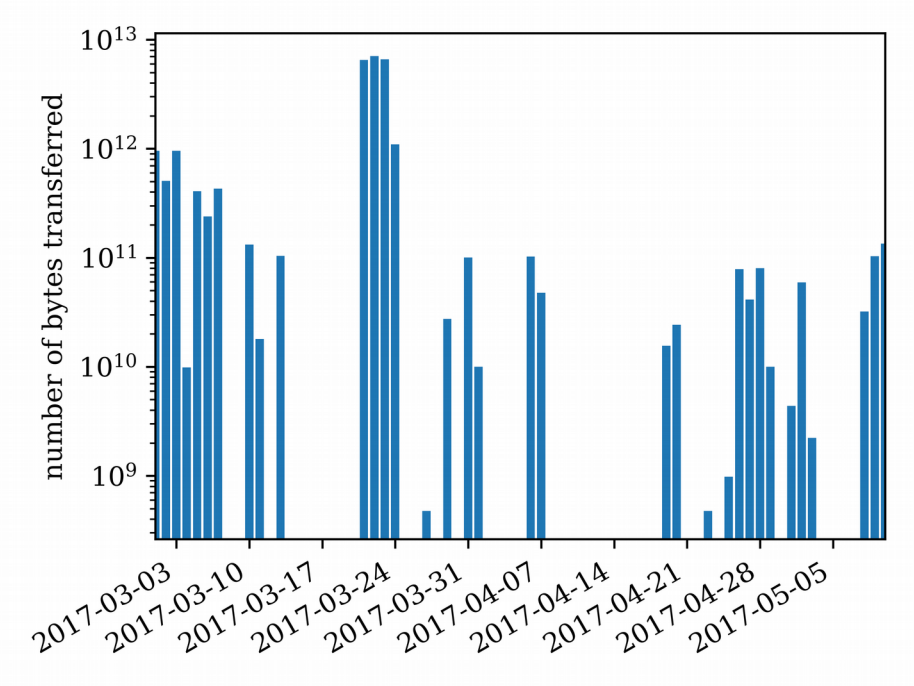


Data access statistics : Quarry (image cutouts)



Roughly constant data traffic. 867GBytes downloaded as of May 10th.

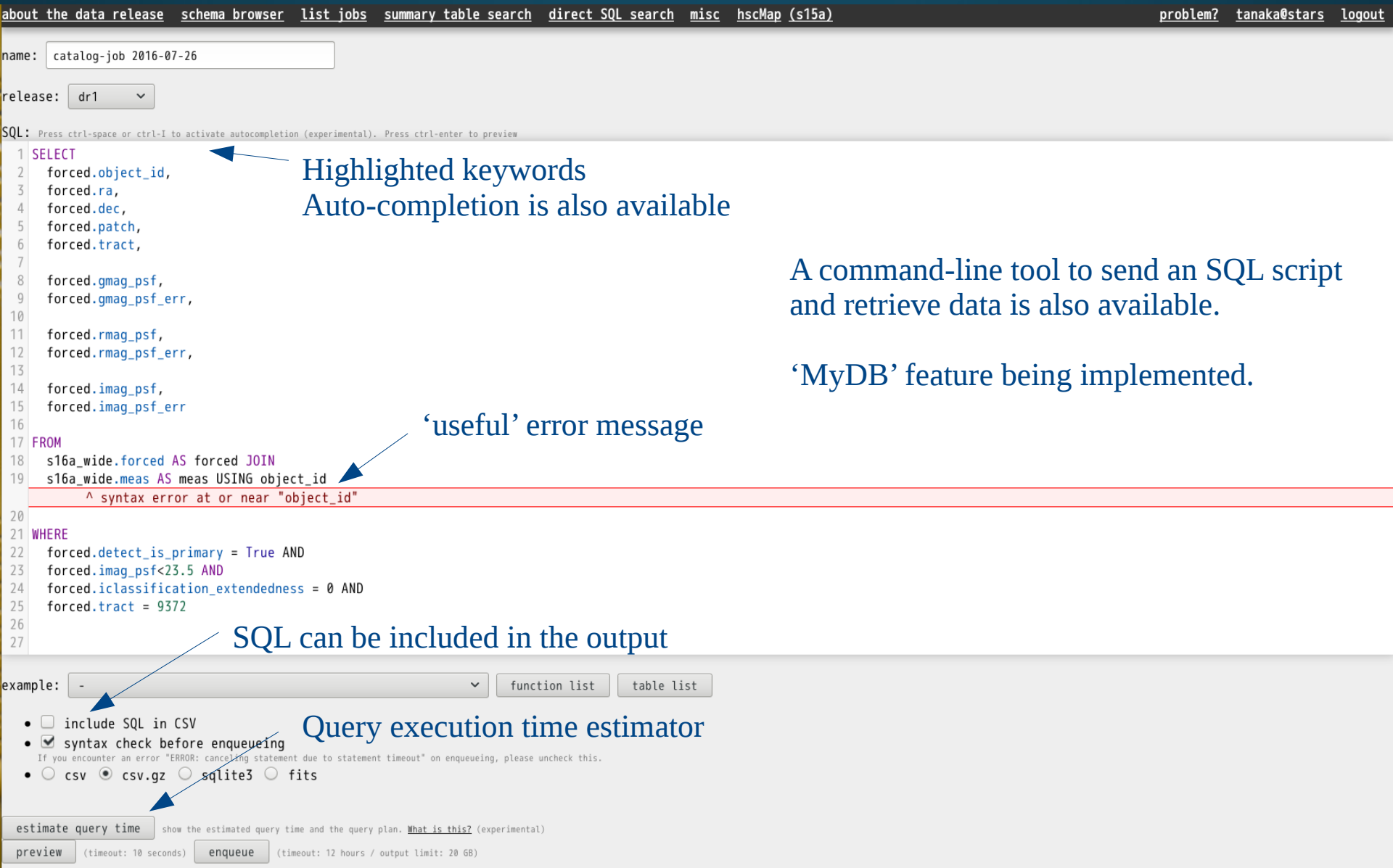
Data access statistics: binary file search



Some spikes. 25.9 TBytes downloaded.

Database and User Interfaces

Catalog Archive Server: online SQL editor



Highlighted keywords
Auto-completion is also available

A command-line tool to send an SQL script and retrieve data is also available.

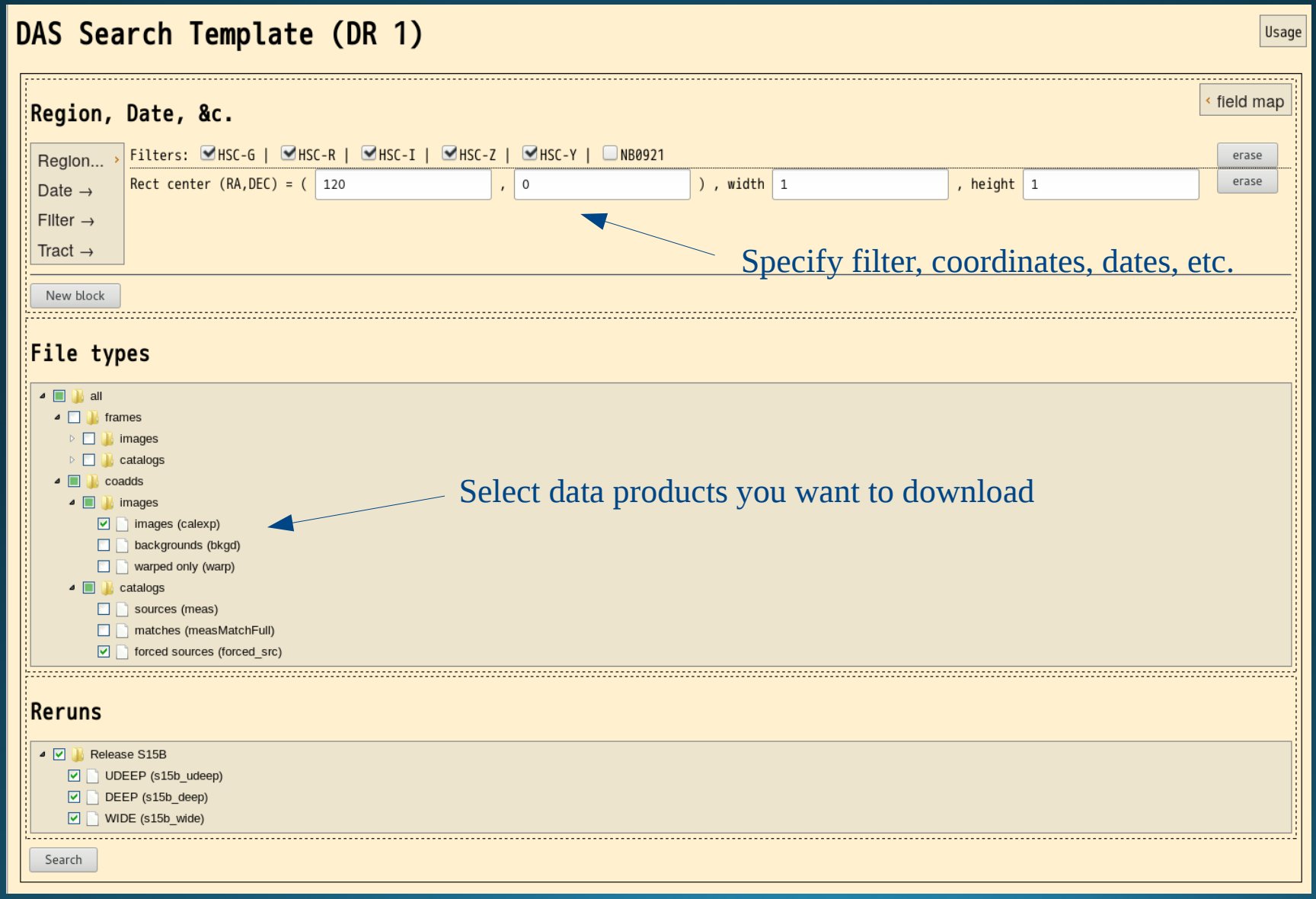
‘MyDB’ feature being implemented.

‘useful’ error message

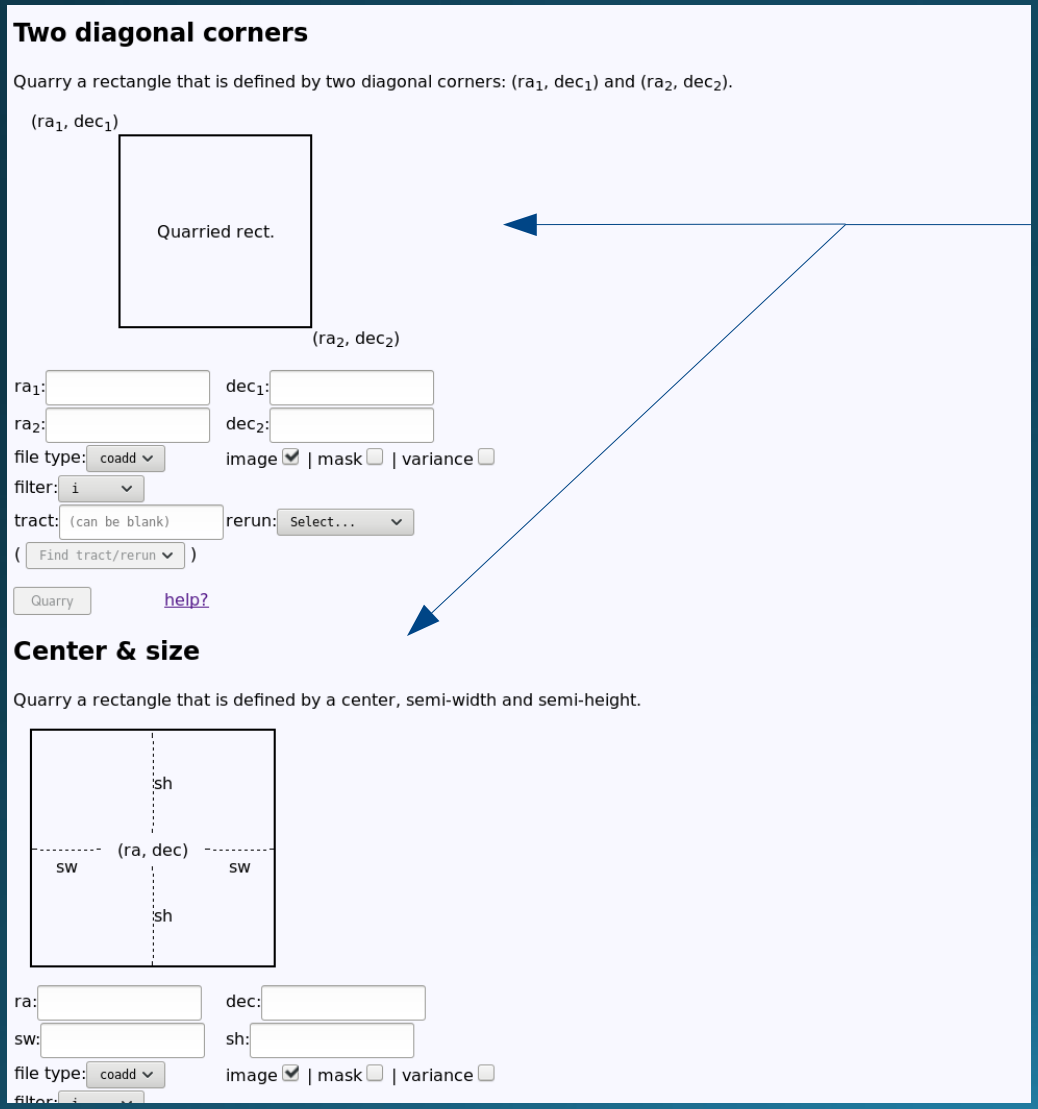
SQL can be included in the output

Query execution time estimator

Data Archive Server: data search query

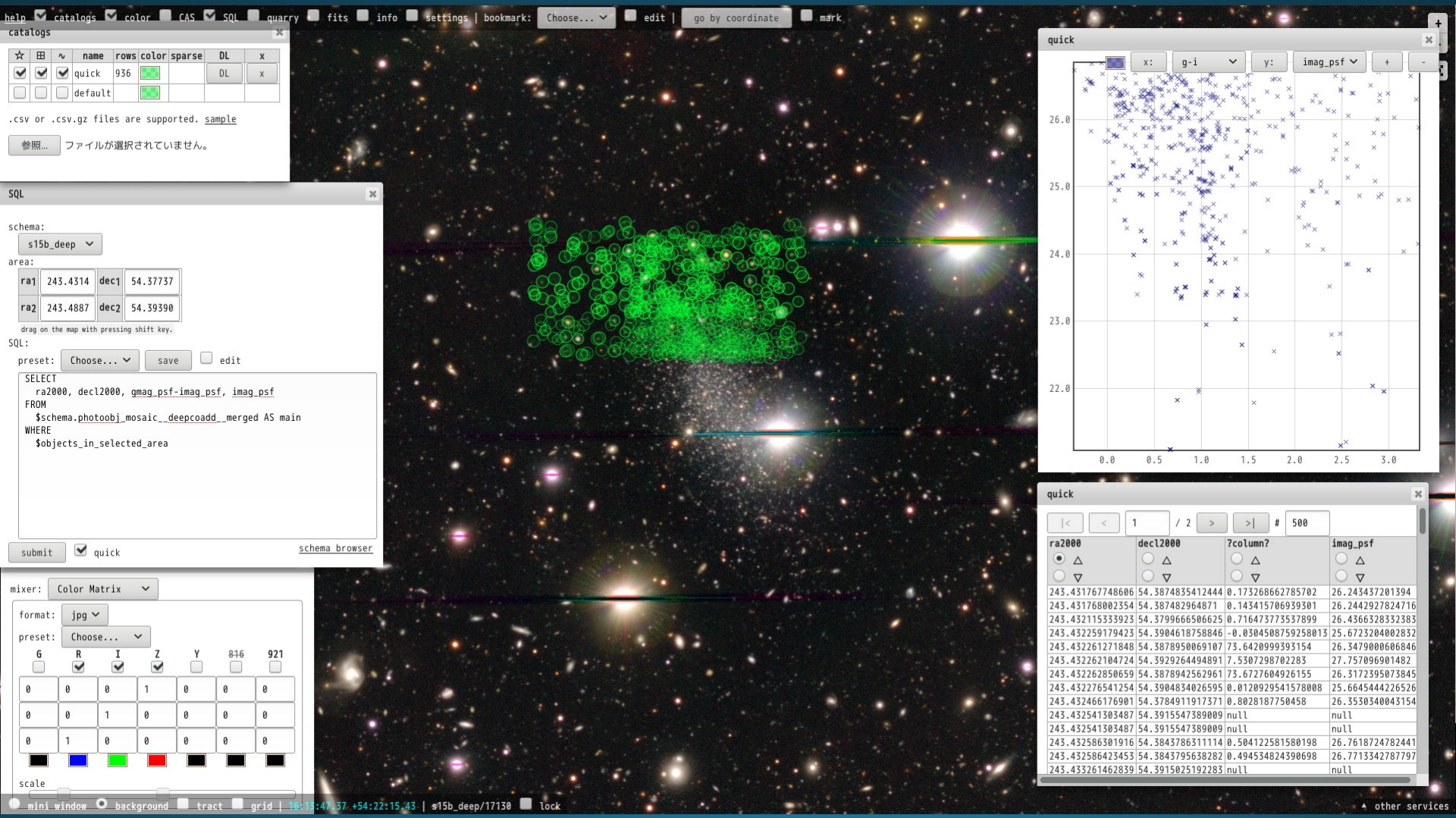


Data Archive Server: image cutouts



There are a few ways to define the coordinates and size of the cutouts. Catalog upload & batch download is also available.

hscMap: online image browser



Lots of useful features: display patch/tract borders, show individual visit images, image cutouts download, and more. Symbol shape/size can be changed. Spec. viewer is being developed.

PSF retriever

A web interface to retrieve PSF objects at given RA+Dec has been a very popular request and it is finally available (internally).

PSF picker

You can get a point spread function (PSF) at any observed positions (RA, Dec). The PSF will be delivered as a FITS image file.

RA: Dec:

filter: i rerun: select...

tract: (can be blank) patch: N/A

(Find rerun/tract/patch) type: coadd

Pick

Help?

Bulk mode

You can upload a coordinate list to get PSFs in an uncompressed tarball. For the format of the coordinate list, see the manual.

list: 参照... ファイルが選択されていません。

Upload

Fields that do not appear in your list will be supplemented with the default settings below.

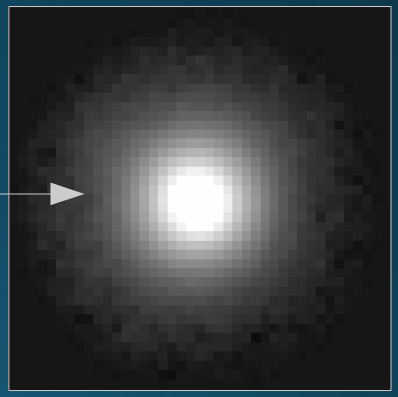
Default value settings

RA: Dec:

filter: i rerun: select...

tract: patch: N/A

type: coadd



Python data acess

```
import hscDB
# connect to the database
db = hscDB.connect('s16a_wide')
# get a list of objects from DB
hsc = db.getObjects(tract=8143, patch='4,3', imagMax=25.0)

# get unforced measurements for my objects
meas = db.getUnforcedMeasurements(hsc)
for row in meas:
  print row.object_id, row.imag_cmodel, row.imag_cmodel_err
# do the same for forced measurements
forced = db.getForcedMeasurements(hsc)

# you can get postage stamps
iStamp = db.getPostageStamp(hsc, xsize=40, ysize=40, band='HSC-I')
# PSF objects as well
iPsf = db.getPsf(hsc, band = 'HSC-I')
# save the images to disk
iStamp[0].writeFits('first_object.fits')
iPsf[0].writeFits('first_psf.fits')

# display the retrieved objects on hscMap
import hscMap
map=hscMap.init()
map.move(hsc.ra[0], hsc.dec[0], zoom=0.25)
map.markObjects(hsc, symbol='circle', size=5)
```

Summary

Summary

- The HSC survey is a 300-night survey at the Subaru Telescope. Check out our survey website at http://hsc.mtk.nao.ac.jp/
- The survey is 50% done as of today. We are making good progress!
- A PASJ special issue with ~30 papers is being prepared.
- The first public data release happened on Feb 28. Feel free to use the data!
- We have the ‘standard’ tools for database science and we are making a step forward with Python to make a unified CAS+DAS+hscMap environment for science users.