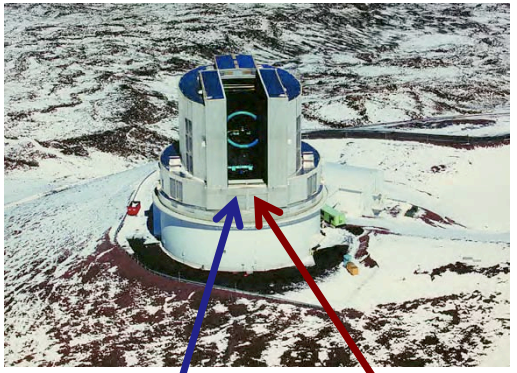
Subaru large surveys

Masahiro Takada (Kavli IPMU)
on behalf of HSC and PFS collaborations

Subaru WS @ NAOJ, March 2017

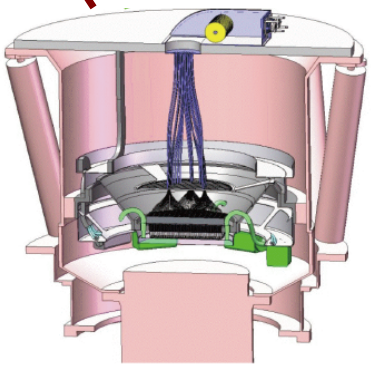
Imaging and spectroscopic surveys with Subaru

- Build wide-field camera (Hyper Suprime-Cam) and wide-field multi-object spectrograph (Prime Focus Spectrograph) for the Subaru Telescope (8.2m)
- HSC imaging survey since 2014
- PFS survey will start around 2020
- Keep the Subaru Telescope a world-leading telescope in the TMT era
- Precise images of 1B galaxies
- Measure distances of ~4M galaxies

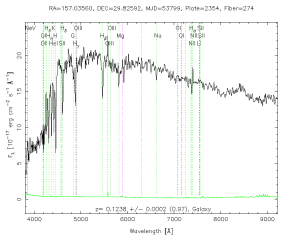


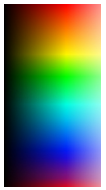
Subaru (NAOJ)

HSC



PFS





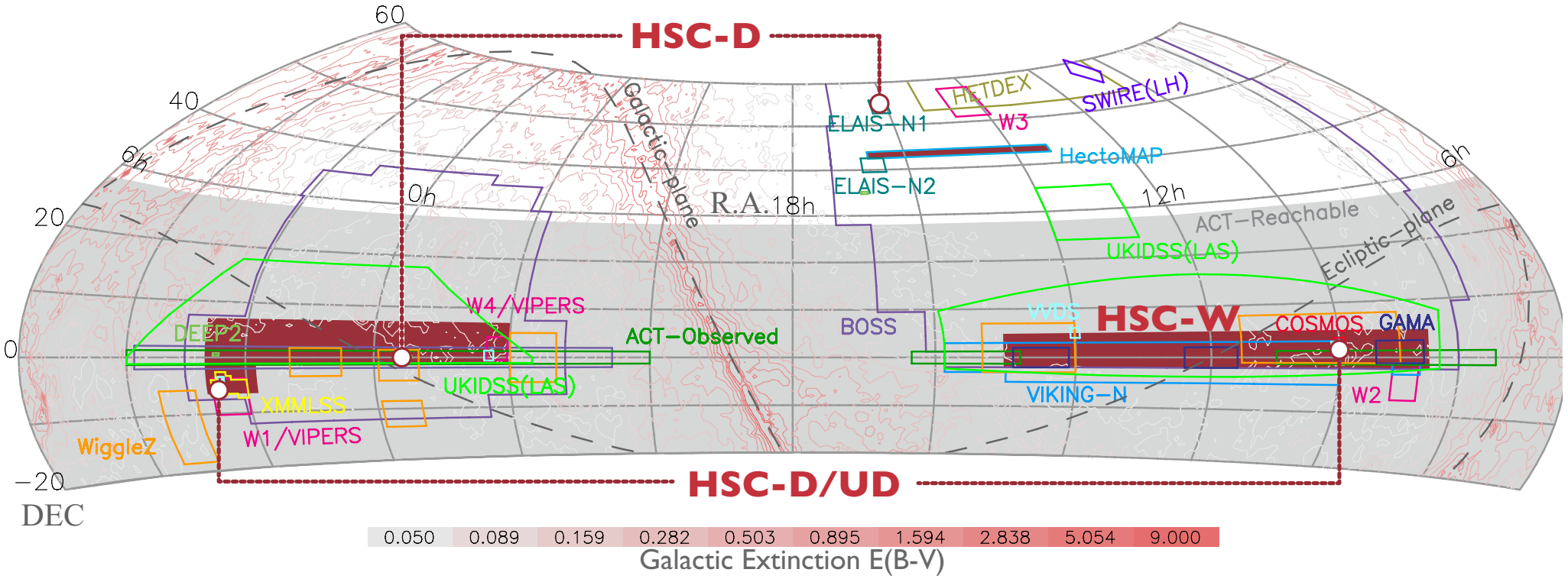
HSC SSP survey since 2014

PI: S. Miyazaki
(NAOJ)

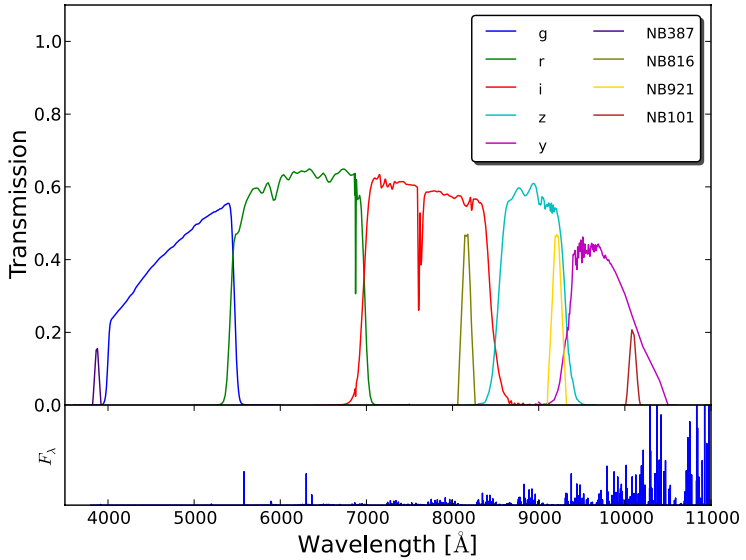
International collaboration (Japan, Taiwan, Princeton U.)

Subaru 300 nights already granted

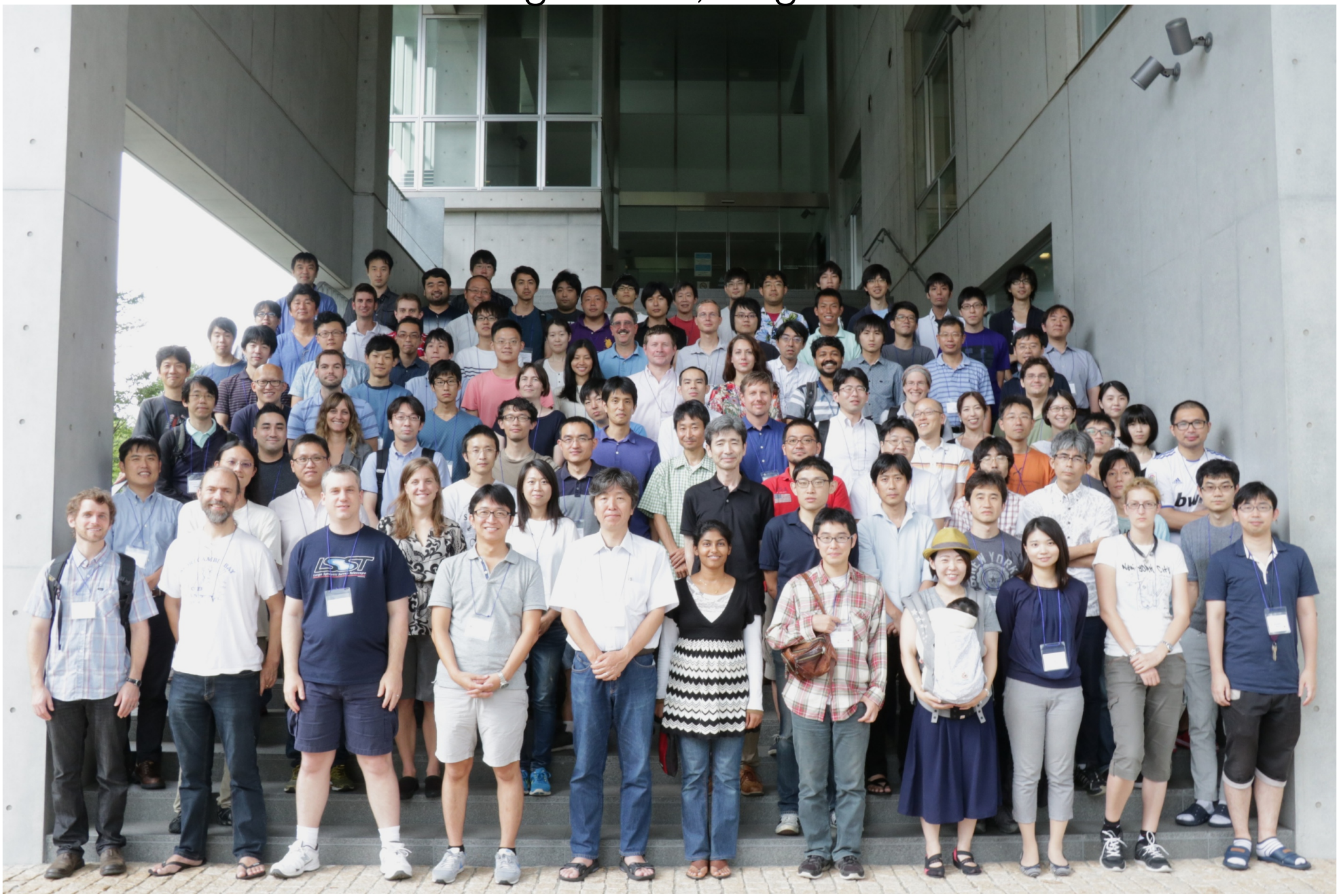
HSC SSP Survey Fields



- Three-layer survey
  - Wide:1400 sq. deg, grizy (i~26)
  - Deep: 26 sq. deg, grizy (i~27)+3NBs
  - UltraDeep: 3.5 sq. deg., grizy (i~28)+3NBs



HSC collaboration meeting@IPMU, Aug 2016 ~300 Cols



First Data Release (DR1) of HSC SSP
28 Feb, 2017

~60 Subaru nights, ~100 sq. deg., ~10^8 objects ≃10yrs SDSS

A series of science papers will come out this April

First Public Data Release by the Hyper Suprime-Cam Subaru Strategic Program

February 28, 2017 | Topics

Publ. Astron. Soc. Japan (2014) 00(0), 1
doi: 10.1093/pasj/xxx

Masayuki Tanaka
(NAOJ)

First Data Release of the Hyper Suprime-Cam Subaru Strategic Program

Hiroaki Aihara[1], Robert Armstrong[2], Steven Bickerton[3], James Bosch[2], Jean Coupon[4], Hisanori Furusawa[5], Yusuke Hayashi[5], Hiroyuki Ikeda[5], Yukiko Kamata[5], Hiroshi Karoji[6,2], Satoshi Kawanomoto[5], Michitaro Koike[5], Yutaka Komiyama[5,7], Robert H. Lupton[2], Sogo Mineo[5], Hironao Miyatake[8,9], Satoshi Miyazaki[5,7], Tomoki Morokuma[10,9], Yoshiyuki Obuchi[5], Yukie Oishi[5], Yuki Okura[11,12], Paul A. Price[2], Tadafumi Takata[5,7], Manobu M. Tanaka[13], Masayuki Tanaka[5,*], Yoko Tanaka[14], Tomohisa Uchida[13], Fumihiro Uraguchi[5], Yousuke Utsumi[15], Shiang-Yu Wang[16], Yoshihiko Yamada[5], Hitomi Yamanoi[5], Naoki Yasuda[9], Nobuo Arimoto[14,7], Masashi Chiba[17], Francois Finet[14], Hiroki Fujimori[18], Seiji Fujimoto[19], Junko Furusawa[5], Tomotsugu Goto[20], Andy Goulding[2], James E. Gunn[2], Yuichi Harikane[19,21], Takashi Hattori[14], Masao Hayashi[5], Krzysztof G. Hełminiak[22], Ryo Higuchi[19], Chiaki Hikage[9], Paul T.P. Ho[16,23], Bau-Ching Hsieh[16], Kuiyun Huang[24], Song Huang[25,9], Masatoshi Imanishi[5,7], Ikuru Iwata[14,7], Anton T. Jaelani[17], Hung-Yu Jian[16], Nobunari Kashikawa[5,7], Nobuhiko Katayama[9], Takashi Kojima[19,21], Akira Konno[19], Shintaro Koshida[14], Alexie Leauthaud[25], C.-H. Lee[14], Lihwai Lin[16], Yen-Ting Lin[16],

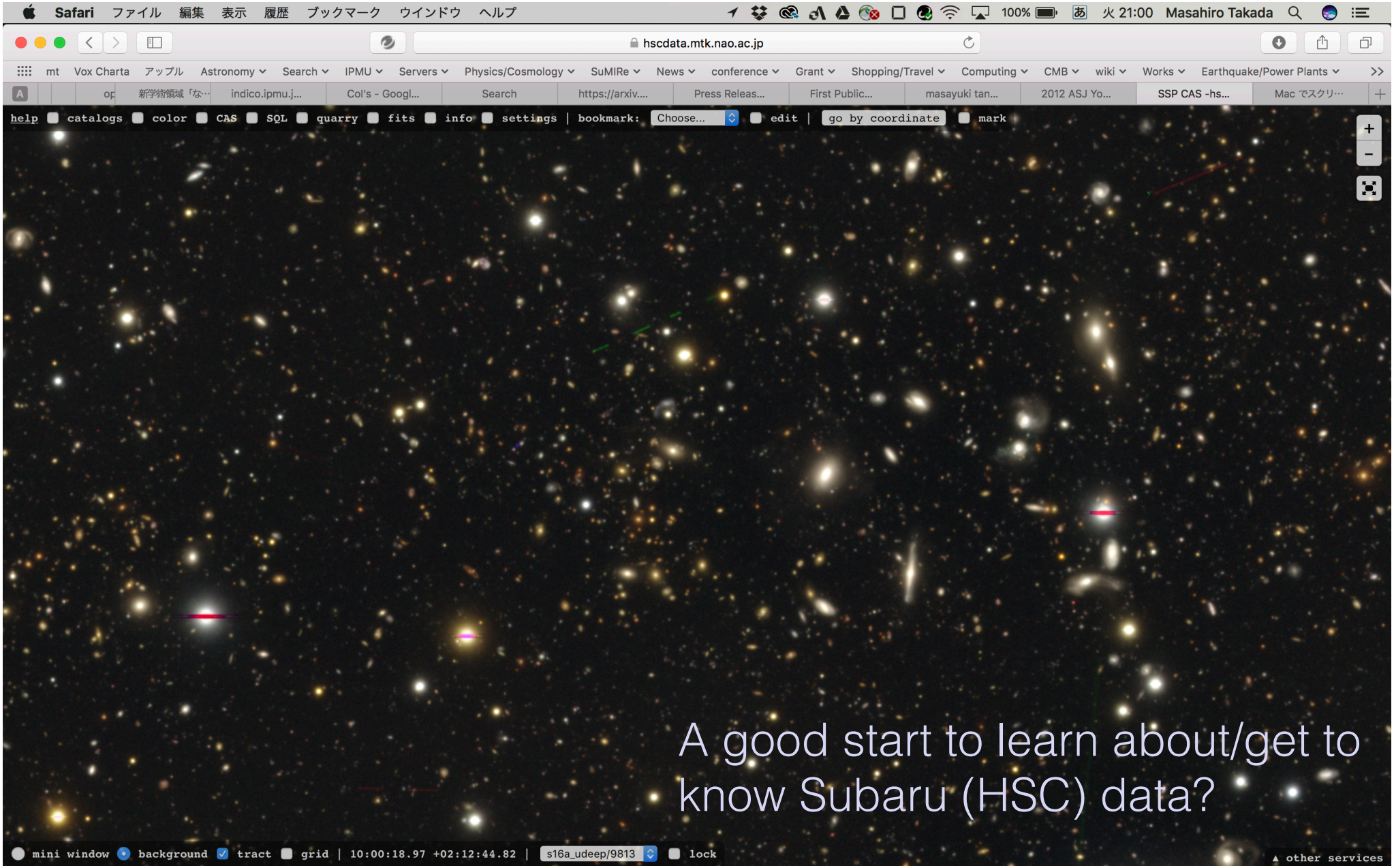
v1 [astro-ph.IM] 27 Feb 2017

Release	Date	Layer	N filter	Area (deg^2)	Files (TBytes)	N object	Version hscPipe
Public Data Release 1	2017-02-28	UltraDeep	7	4	8.6	3,225,285	4.0.1
		Deep	7	26	16.6	15,959,257	4.0.1
		Wide	5	108 (100)	57.1	52,658,163	4.0.1
S14A0	2014-09-04	UltraDeep	5	2	2.2	880,792	2.12.4a
		Wide	2	24	2.6	10,548,142	2.12.4a
S14A0b	2015-02-10	UltraDeep	5	4	6.4	2,183,707	2.12.4d
		Wide	5	94 (23)	18.6	63,954,672	3.4.1
S15A	2015-09-01	UltraDeep	6	4	7.2	2,973,579	3.8.5
		Deep	6	24	17.7	14,747,568	3.8.5
		Wide	5	203 (82)	40.7	64,073,662	3.8.5
S15B	2016-01-29	UltraDeep	7	4	8.6	3,225,285	4.0.1
		Deep	7	26	16.6	15,959,257	4.0.1
		Wide	5	413 (111)	145.2	157,423,778	4.0.1
S16A	2016-08-04	UltraDeep	7	4	7.5	3,208,918	4.0.2
		Deep	7	28	8.0	16,269,129	4.0.2
		Wide	5	456 (178)	245.0	183,391,488	4.0.2

Table 3. Summary of this public release and previous internal data releases. The area is estimated by using HEALPix index system ($N_{side} = 2^{11}$) and mosaicking information from the pipeline processing. The 5th column gives the survey area in square degrees. The full-color full-depth area in the Wide survey is shown in the parenthesis. Only the full-color full-depth Wide area is included in this release, but the area in the brackets in the top row is smaller than the total area. This is primarily because the release area is determined on a patch by patch basis, but a fraction of the area in the patches on the field borders actually do not reach the full depth. The 7th column shows the number of objects; since the deblender became functional in the S15A release, the numbers for the subsequent releases are for primary objects (`detect_is_primary`=True; see Section 4.3).

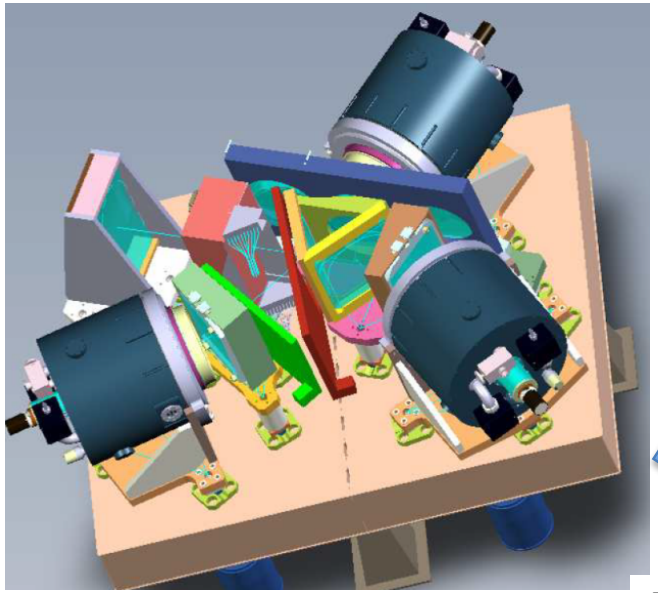
http://hsc.mtk.nao.ac.jp

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

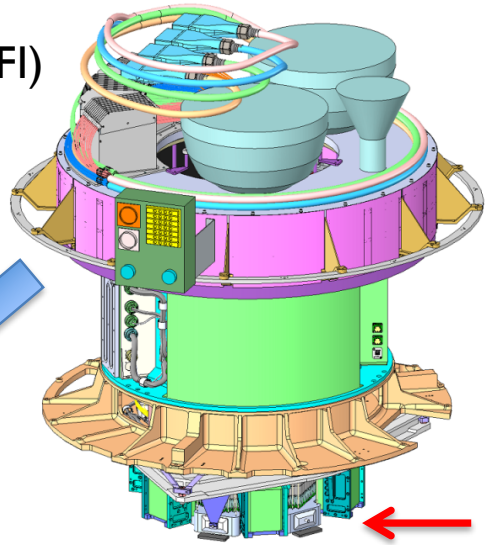


Subaru Prime Focus Spectrograph (PFS)

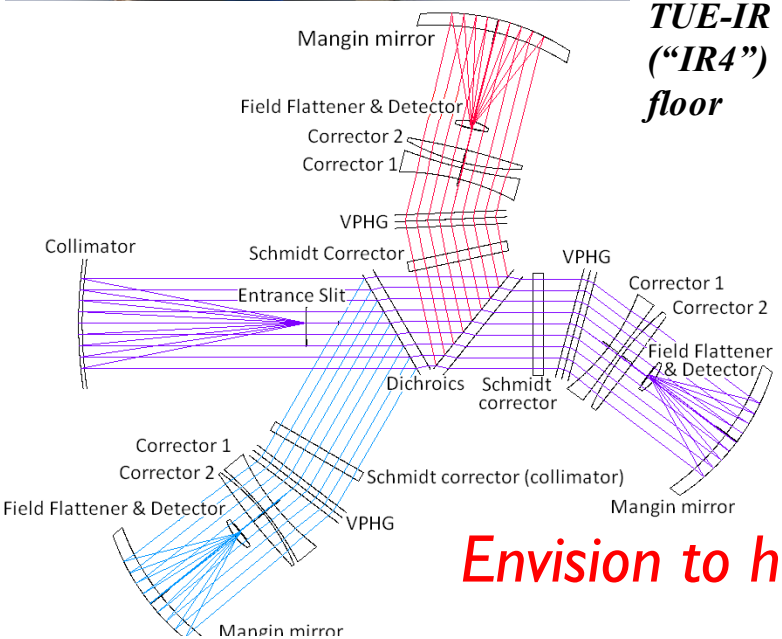
Spectrograph System (SpS)



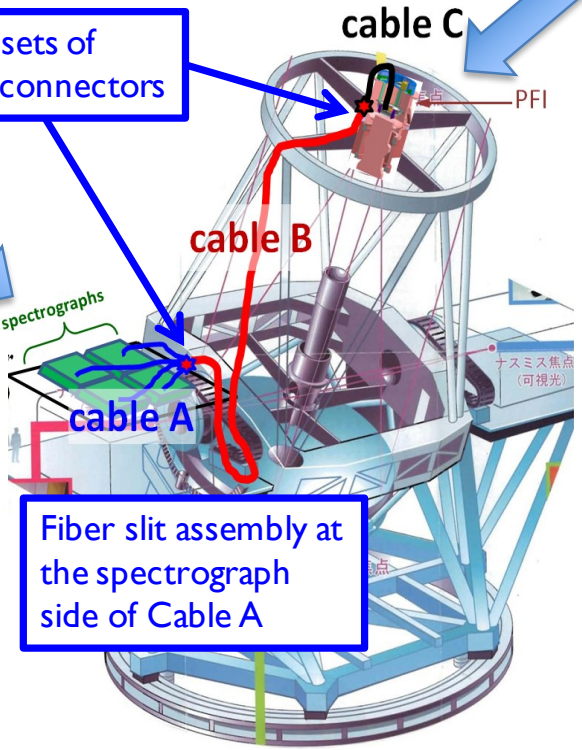
Prime Focus Instrument (PFI)

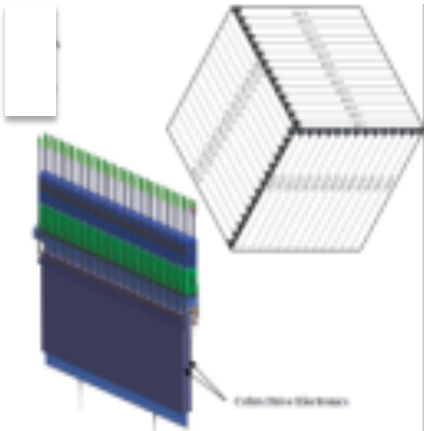


Subaru prime focus

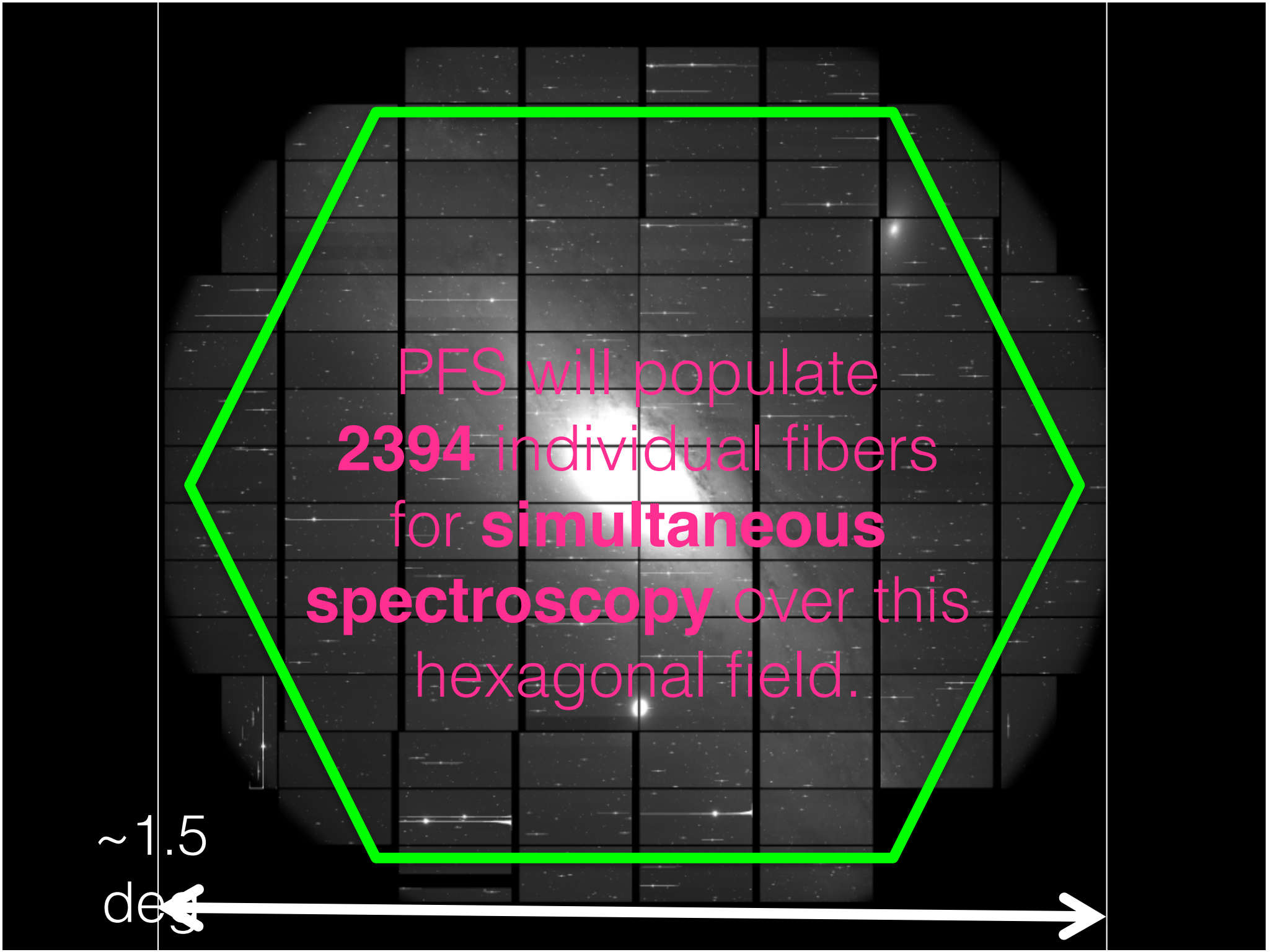


TUE-IR ("IR4") floor





Envision to have the first light in 2018


PFS will populate
2394 individual fibers
for **simultaneous**
spectroscopy over this
hexagonal field.
~1.5
deg

H. Murayama (PI)

PFS Collaboration

N. Tamura (PM)

Kavli IPMU is *leading* this international collaboration

LAM
LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE

国立天文台 NAOJ

CALIFORNIA INSTITUTE OF TECHNOLOGY 1891 Caltech

中央研究院 ACADEMIA SINICA 1928

PRINCETON UNIVERSITY

NASA JPL

JOHNS HOPKINS UNIVERSITY

Max-Planck-Institut für Astrophysik

KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

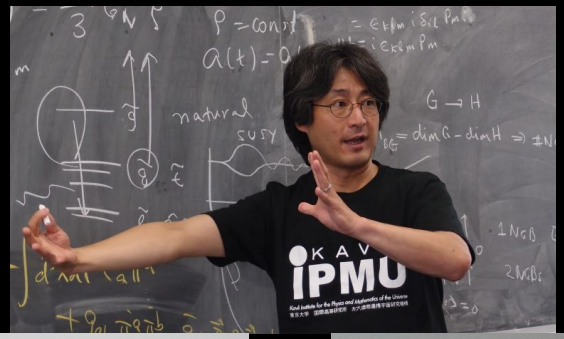
LNA LABORATÓRIO NACIONAL DE ASTROFÍSICA

OBSERVATÓRIO DE SÃO PAULO SANCTI PAVLI CÆLVM AGER MEVS

PFS collaboration meeting @JHU, Dec 2016

PFS Science Team Organization

Naoyuki Tamura
[Kavli IPMU, Project Manager]



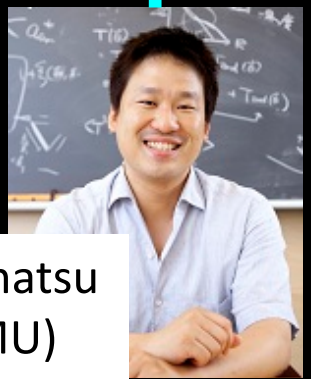
Hitoshi Murayama
[IPMU director, PFS PI]

Masahiro Takada
[Kavli IPMU]

Richard Ellis
[UCL/ESO]

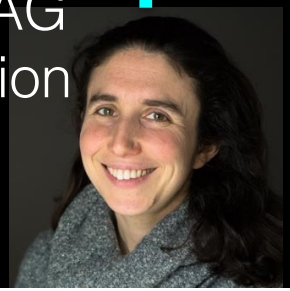
Science working group co-chairs

Cosmology



Eiichiro Komatsu
(MPA/IPMU)

Galaxy/AG
N evolution



Jenny Greene (Princeton)

Galactic Archaeology

Masashi Chiba
(Tohoku U.)

PFS Science White Paper

Takada, Ellis et al. 2014

Publ. Astron. Soc. Jpn (2014) 66 (1), R1 (1–51)
doi: 10.1093/pasj/pst019
Advance Access Publication Date: 2014 February 17
Review

Review

Extragalactic science, cosmology, and Galactic archaeology with the Subaru Prime Focus Spectrograph

Masahiro Takada,[1,*] Richard S. Ellis,[2] Masashi Chiba,[3] Jenny E. Greene,[4] Hiroaki Aihara,[1,5] Nobuo Arimoto,[6] Kevin Bundy,[1] Judith Cohen,[2] Olivier Doré,[2,7] Genevieve Graves,[4] James E. Gunn,[4] Timothy Heckman,[8] Christopher M. Hirata,[2] Paul Ho,[9] Jean-Paul Kneib,[10] Olivier Le Fèvre,[10] Lihwai Lin,[9] Surhud More,[1] Hitoshi Murayama,[1,11] Tohru Nagao,[12] Masami Ouchi,[13] Michael Seiffert,[2,7] John D. Silverman,[1] Laerte Sodré, Jr.,[14] David N. Spergel,[1,4] Michael A. Strauss,[4] Hajime Sugai,[1] Yasushi Suto,[5] Hideki Takami,[6] and Rosemary Wyse[8]

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[3]Astronomical Institute, Tohoku University, Aramaki, Aoba-ku, Sendai 980-8578

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Science Objectives: Three Pillars

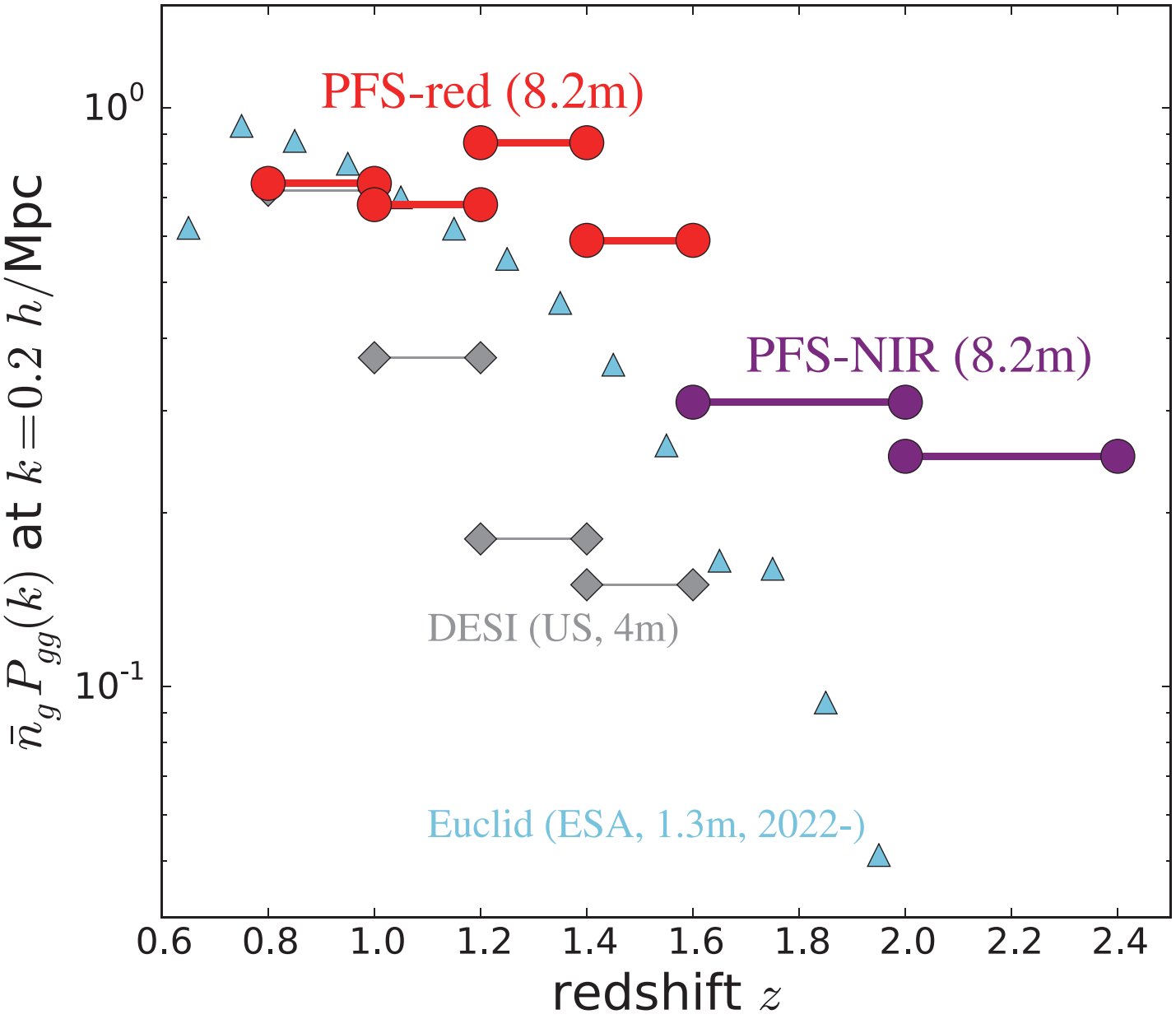
All science cases are based on a spectroscopic follow-up of objects taken from the HSC imaging data

- Cosmology (~100 nights)
  - ~4M redshifts of emission-line galaxies
  - BAO at each of 6 redshift bins over 0.8<z<2.4
  - Cosmology with the joint experiment of WL and galaxy clustering (HSC/PFS)
- Galaxy evolution studies (~100 nights)
  - A unique sample of galaxies (~1M) up to z~2, with the aid of the NIR arm
  - Dense sampling of faint galaxies (also many pairs of foreground/background gals)
  - Studying cosmic reionization with a sample of LAEs, LBGs and QSOs
- Galactic Archaeology (~100 nights)
  - ~1M star spectra for measuring their radial velocities
  - Use the 6D phase-space structure, in combination with GAIA in order to study the origin of Milky Way (also use the M31 survey)
  - Use a medium-resolution-mode survey of ~0.1M stars to study the chemo-dynamical evolution of stars in Milky Way

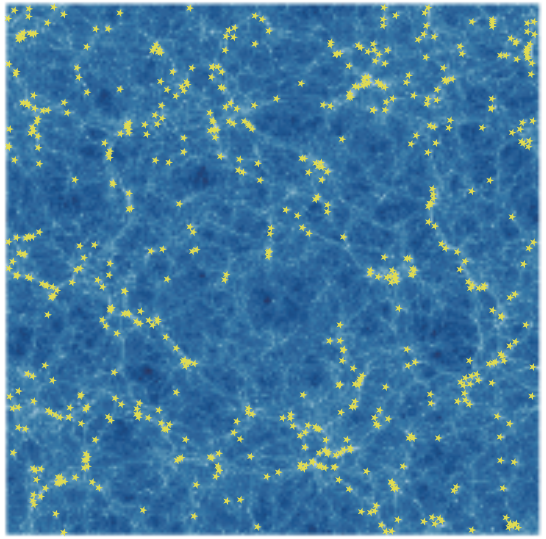
Power of PFS

Takada et al. 2014

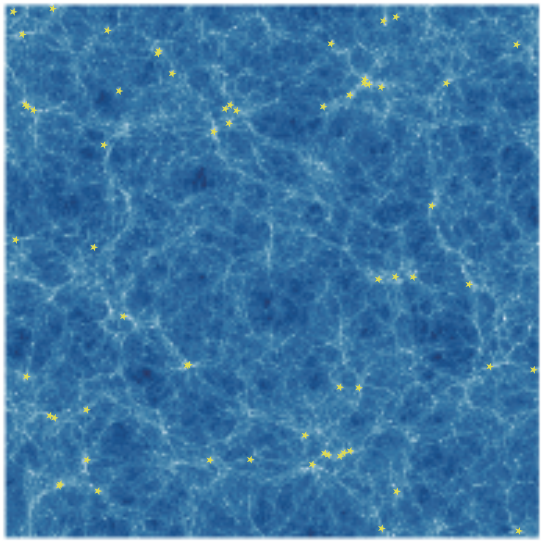
Densest galaxy sample at z>1… before WFIRST (NASA: 2025-)



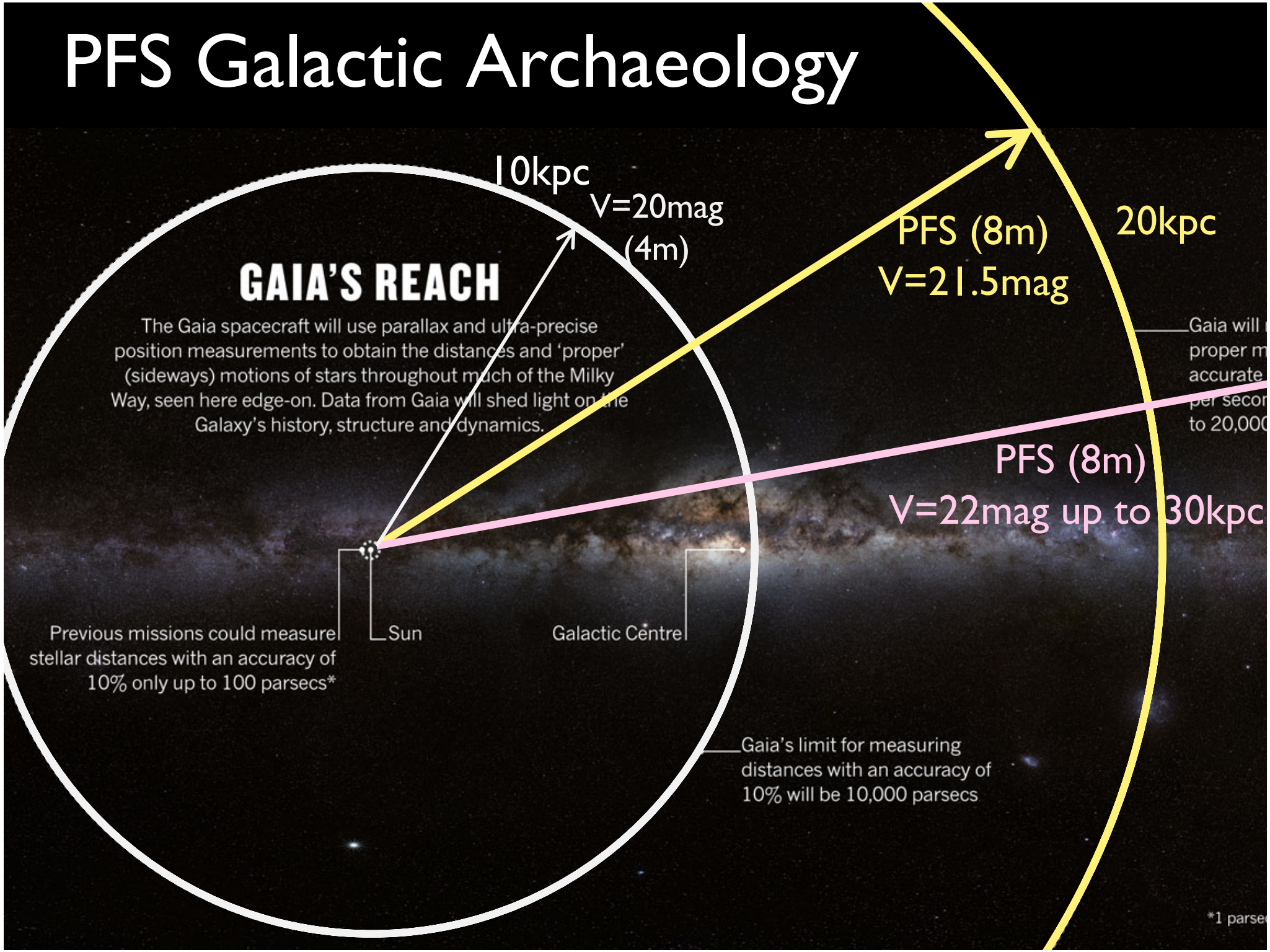
PFS (8.2m) for z~1.5 slice

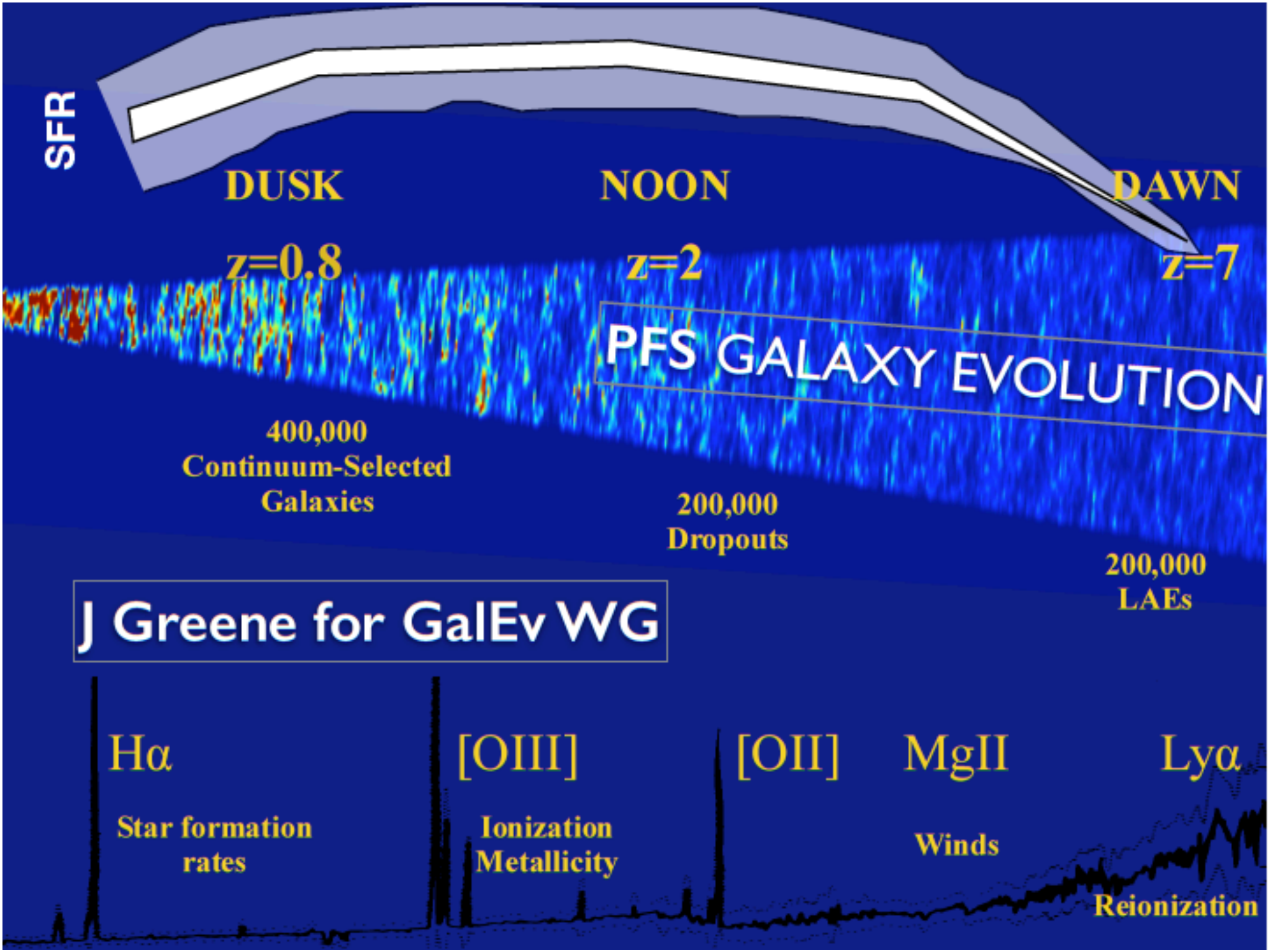


4m-class tel.



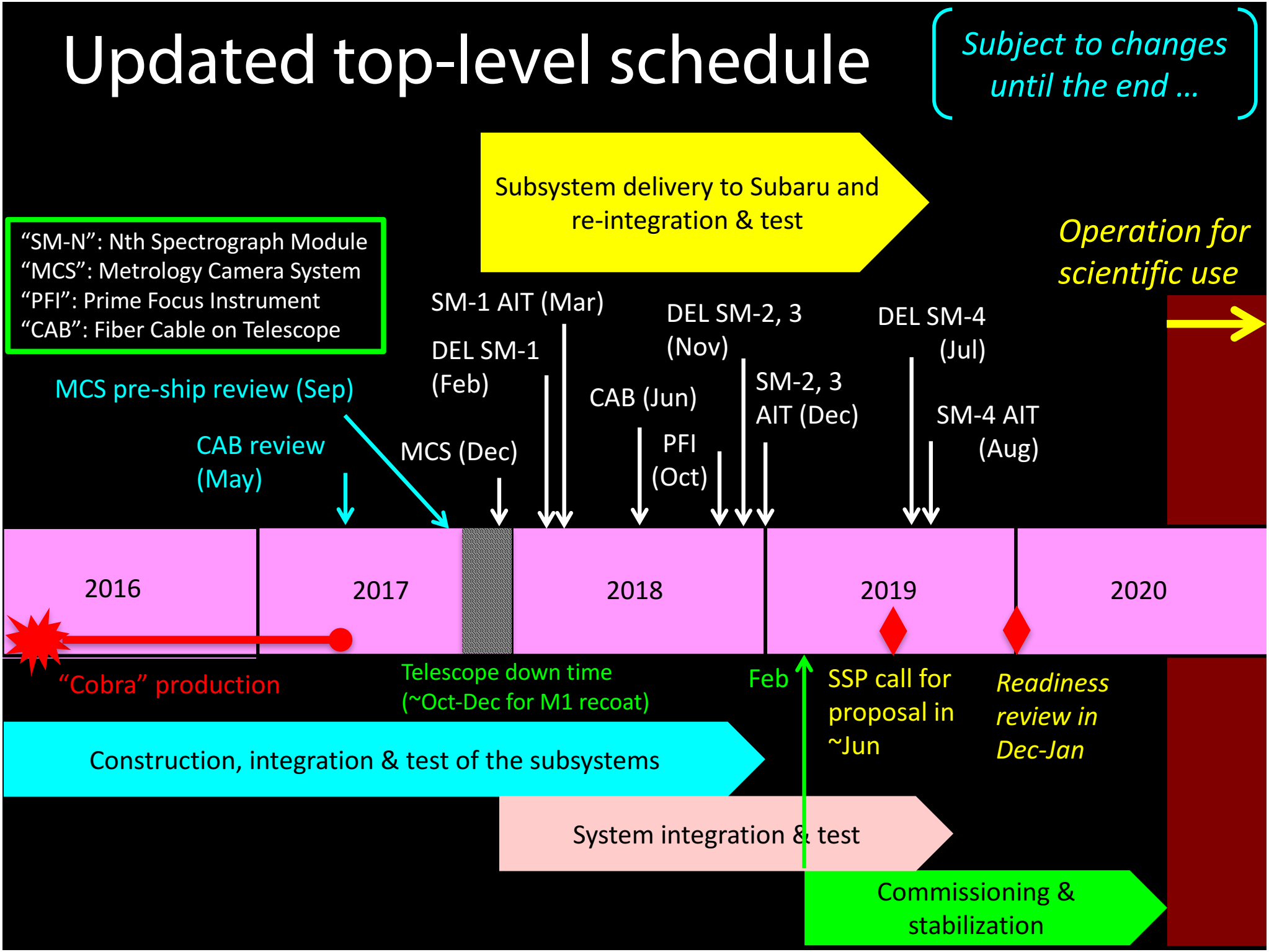
PFS Galactic Archaeology




SFR
DUSK
NOON
DAWN
z=0.8
z=2
z=7
PFS GALAXY EVOLUTION
400,000
Continuum-Selected
Galaxies
200,000
Dropouts
200,000
LAEs
J Greene for GalEv WG
Hα
[OIII]
[OII]
MgII
Lyα
Star formation
rates
Ionization
Metallicity
Winds
Reionization

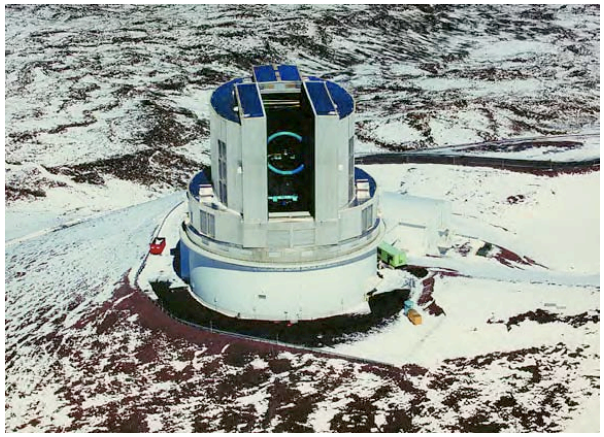
Updated top-level schedule

Subject to changes until the end …

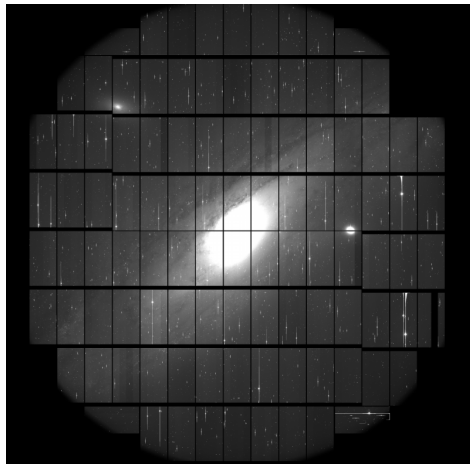


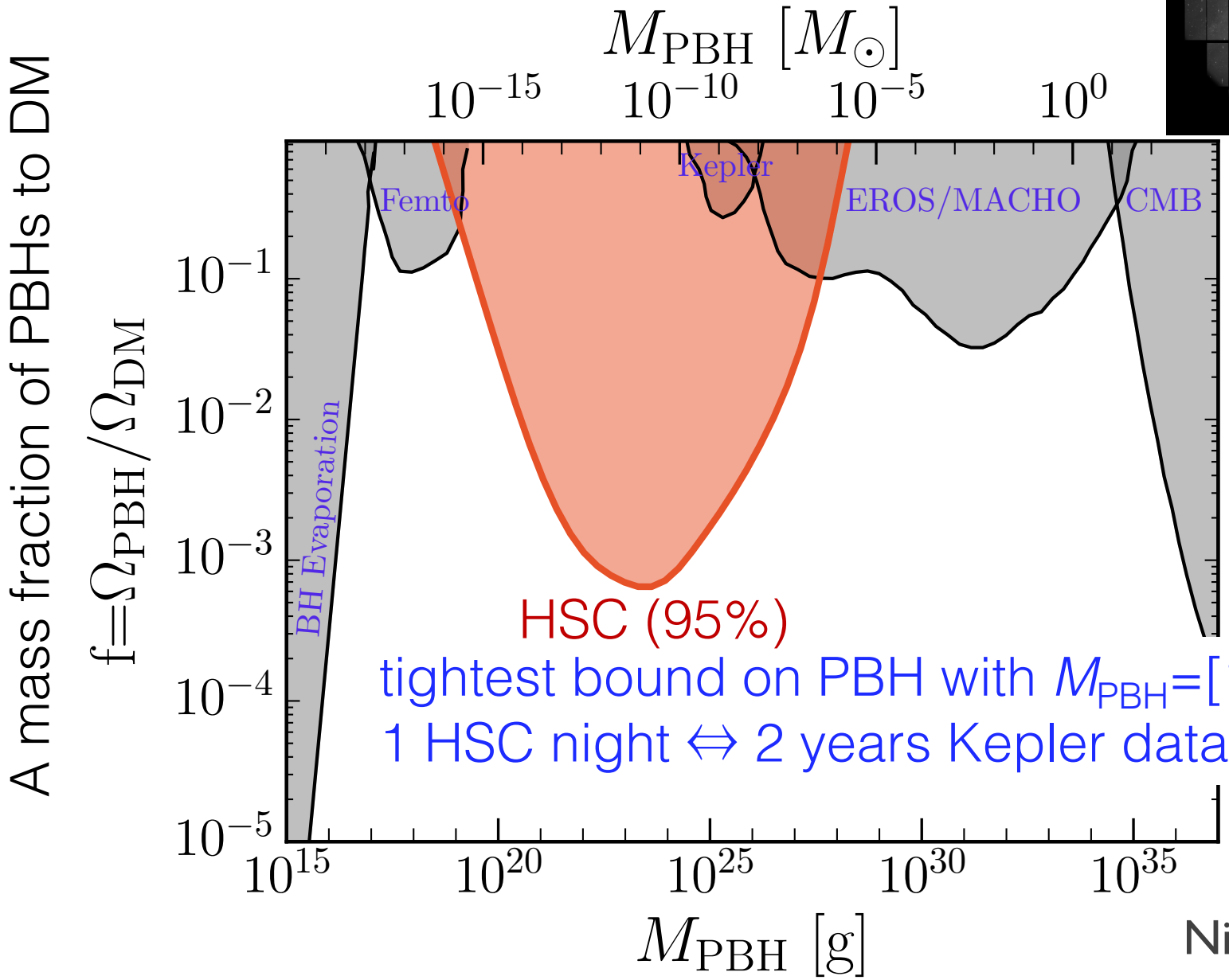
Subaru Strategy with the Future

- HSC & PFS allow for making Subaru Tel. a unique facility in 2020era: target obs ⇒ survey telescope
- HSC, PFS, GLAO major instruments in 2020era
- Various synergies
  - GAIA (2013)
  - Euclid (2019)
  - LSST (2020? -)
  - WFIRST (2025?)
  - TMT& E-ELT (202?)



HSC microlensing constrain on PBH abundance





dense (2min) cadence data of M31

HSC (95%)

tightest bound on PBH with $M_{\rm PBH}$=[10^{20},10^{28}]g

1 HSC night ⇔ 2 years Kepler data

Niikura, MT, + 17

Summary

- **The wide-field capability of Subaru** is so unique, and very powerful for survey-oriented astronomy/cosmology
- **Hyper Suprime-Cam (HSC)** = Wide-field imager
  - HSC SSP survey: 2014 – 2019(20)
  - **First public data release (28 Feb, 2016)**
- **Prime Focus Spectrograph (PFS)** = Wide-field, multi-object spectrograph
  - Envision PFS SSP survey: 2020 –
  - Cosmology, Galaxy Evolution, Galactic Archaeology
  - Currently working of designing survey/science programs