PFS SSP survey: Cosmology & Galaxy/AGN Evolution

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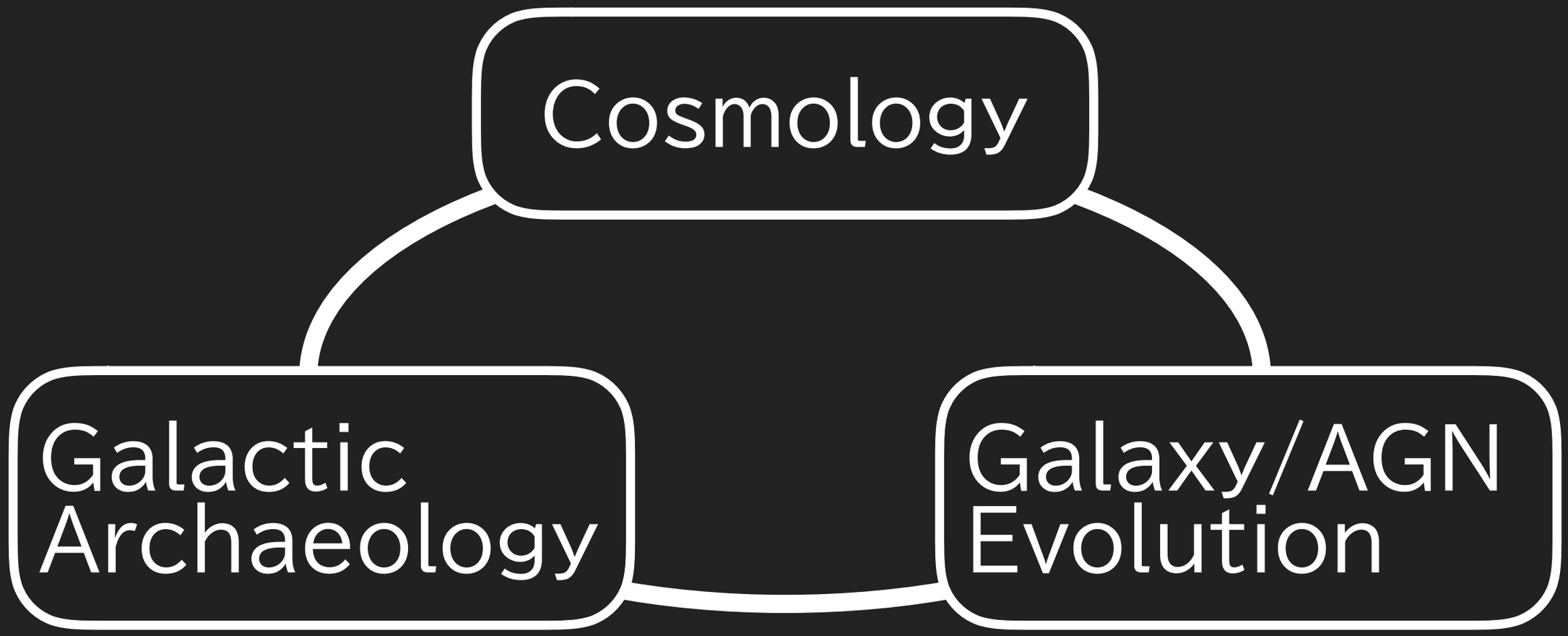
(PFS project office, Kavli IPMU)

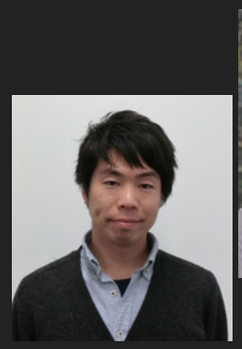
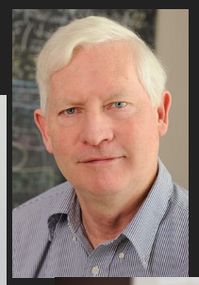
PFS SSP survey:

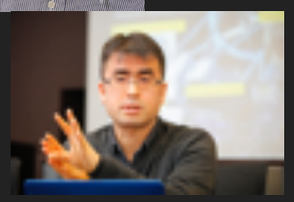
- Subaru Strategic Program (SSP): ~300 nights over ~5 years
  - HSC SSP has been started since 2014 and continues until ~2020?
  - PFS SSP is going to start after the HSC SSP is finished
    - ✓ Expected to start from early 2022
    - ✓ A proposal is currently in preparation
    - ✓ A survey program with three big science topics



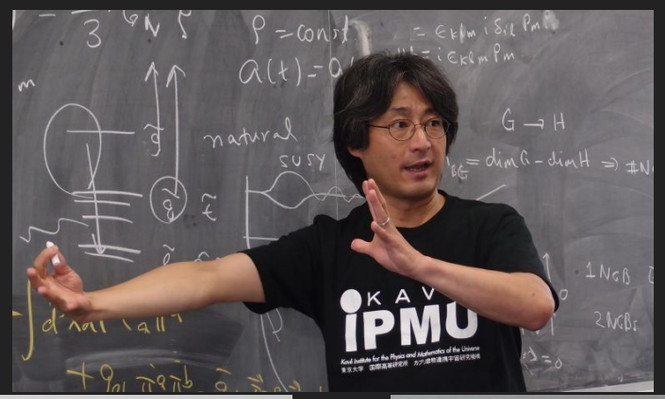
”Comprehensive Challenge on Standard Model of the Universe and Beyond”

PFS SSP survey:



Masahiro Takada
[Kavli IPMU]



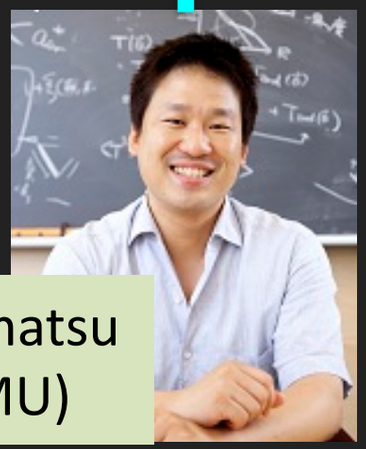
Hitoshi Murayama
[PI of PFS project]

Survey integration team


Richard Ellis
[UCL]

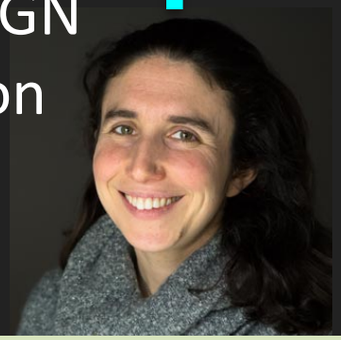
Science working group co-chairs

Cosmology



Eiichiro Komatsu
(MPA/IPMU)

Galaxy/AGN evolution



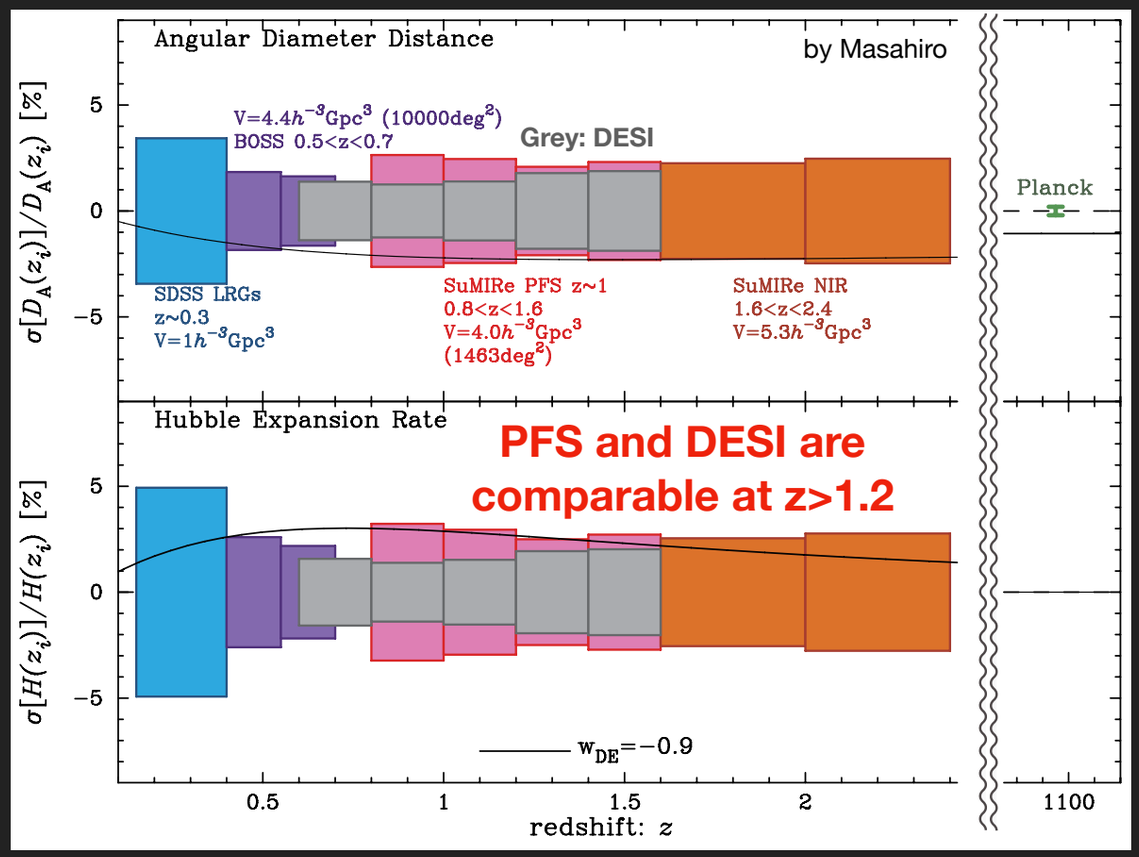
Jenny Greene (Princeton)

Galactic Archaeology

Masashi Chiba
(Tohoku U.)

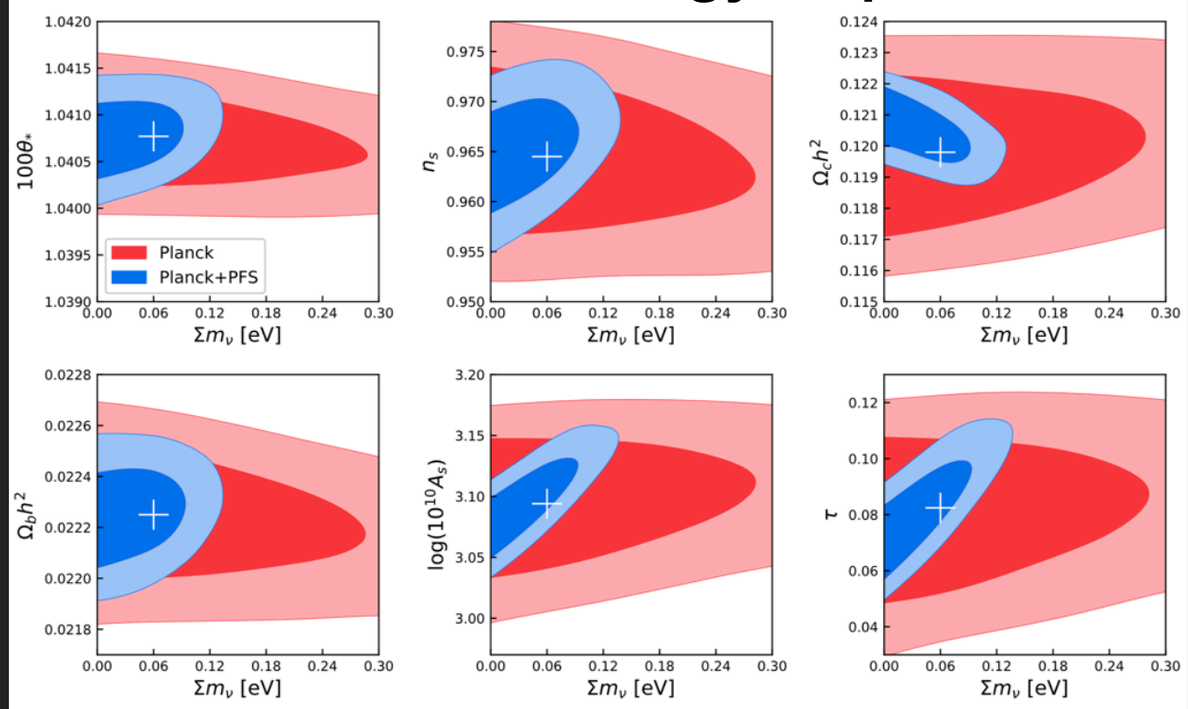
PFS SSP survey: Cosmology

- Scientific goals:
  - Precise measurement of cosmological parameters
  - Constraint on the neutrino mass hierarchy
- Front loading survey because of other competitors?
- Neutrino science and the higher redshift would be unique



Measurements of cosmological parameter as a function of redshift

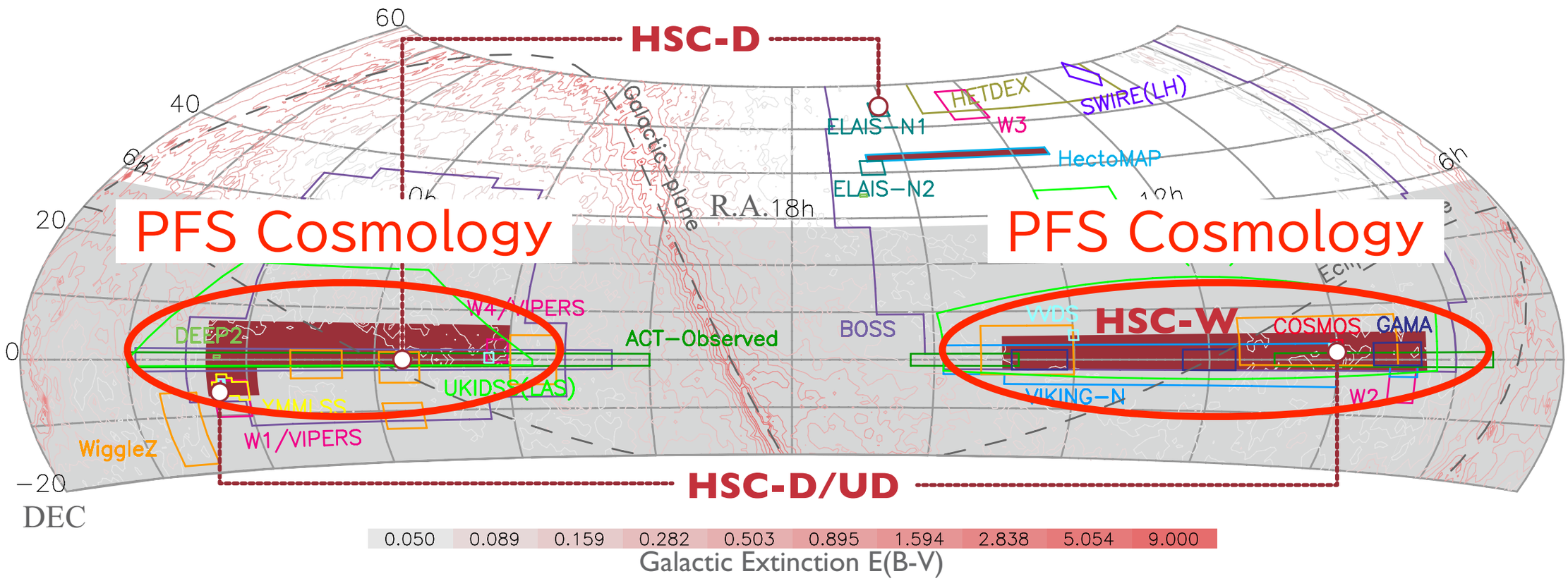
[One of the] Expected Main Plot in the Cosmology Paper! by R. Makiya



Constraint on Σm_ν from measurements of power spectrum with high precision

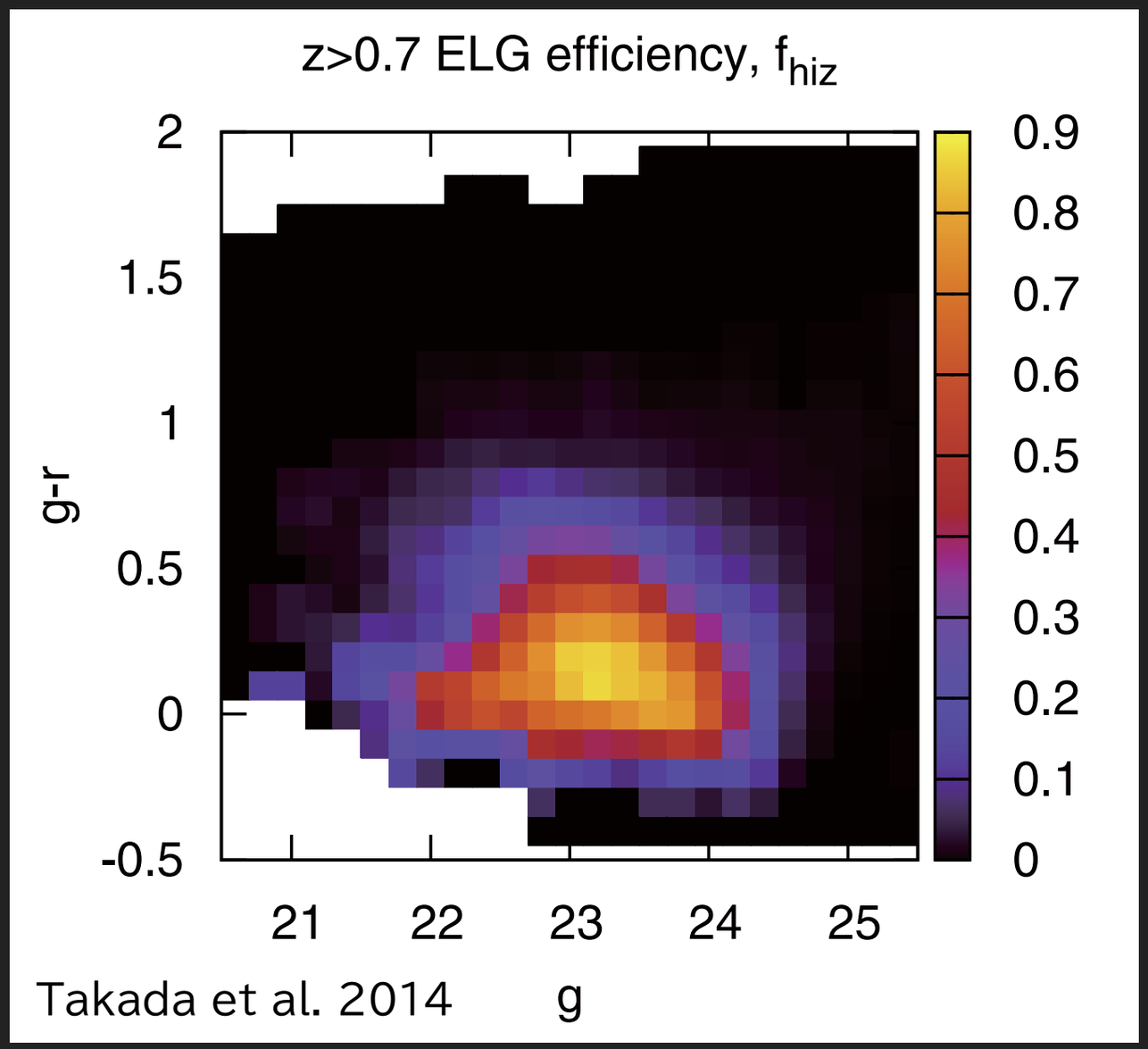
PFS SSP survey: Cosmology

- Target fields:
  - ~1400 deg² of HSC-wide fields
  - cf. eBOSS=~6000 deg², DESI=~14000 deg²
- Targets:
  - Emission line ([OII] emitters) galaxies at 0.6 < z < 2.4
  - Various AGNs (BL AGNs at z>4, MIR/radio AGNs, time variable AGNs, QSO absorption, and so on...) are also included



PFS SSP survey: Cosmology

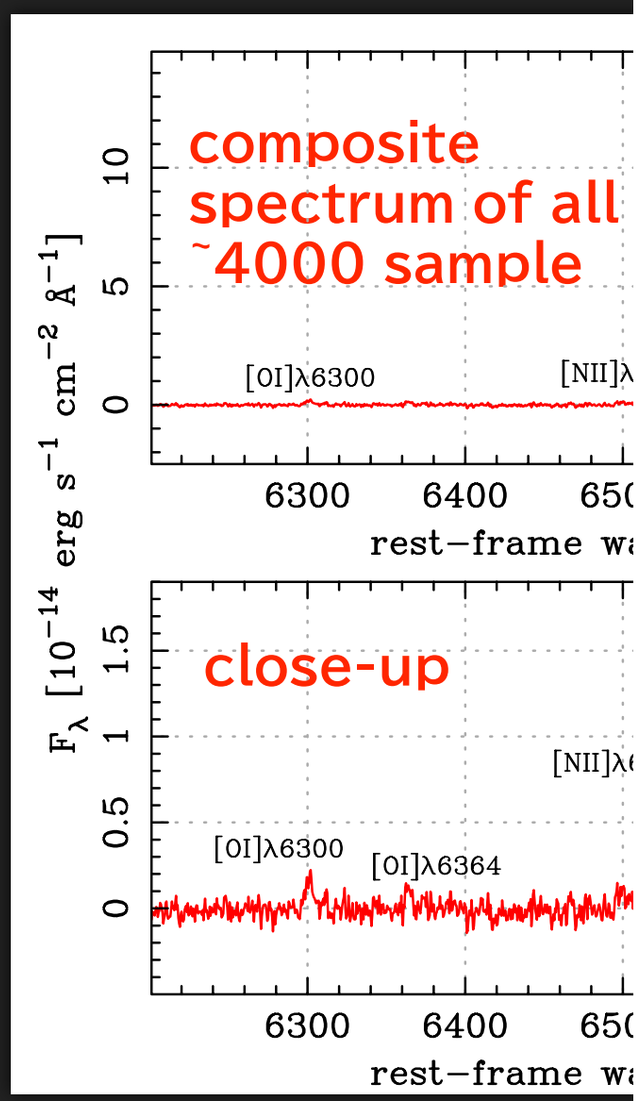
- Target selection for emission line galaxies
  - Basically, color selected sample
  - Improvement of the color selection is on-going
- 4M emission line galaxies will be detected in total



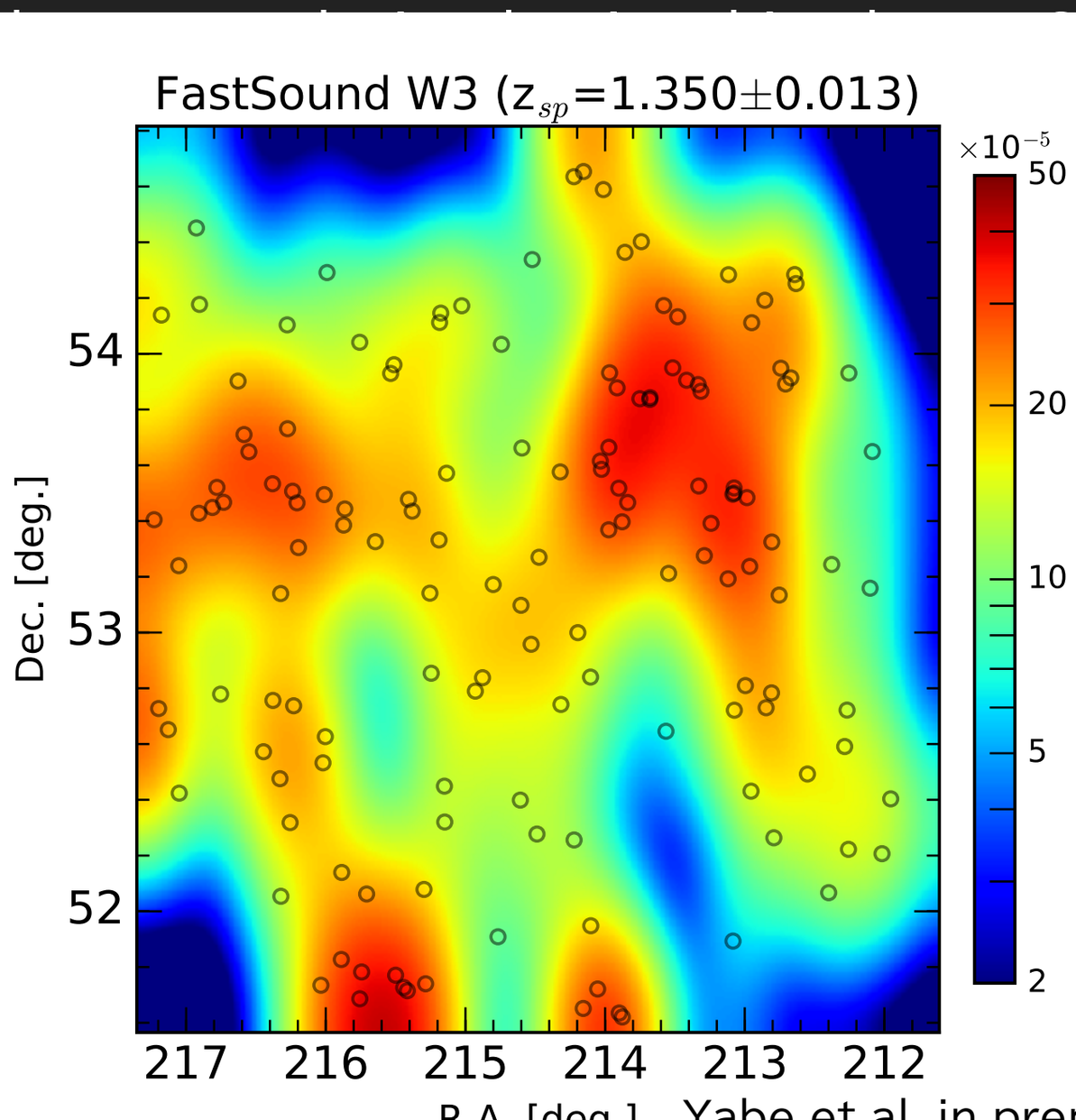
- Survey strategy
  - 2 visits for the same field
  - 15 min. (450 sec. × 2) in each visit
  - Strategy of the tiling of FoVs is currently under discussion

Too shallow for galaxy science?

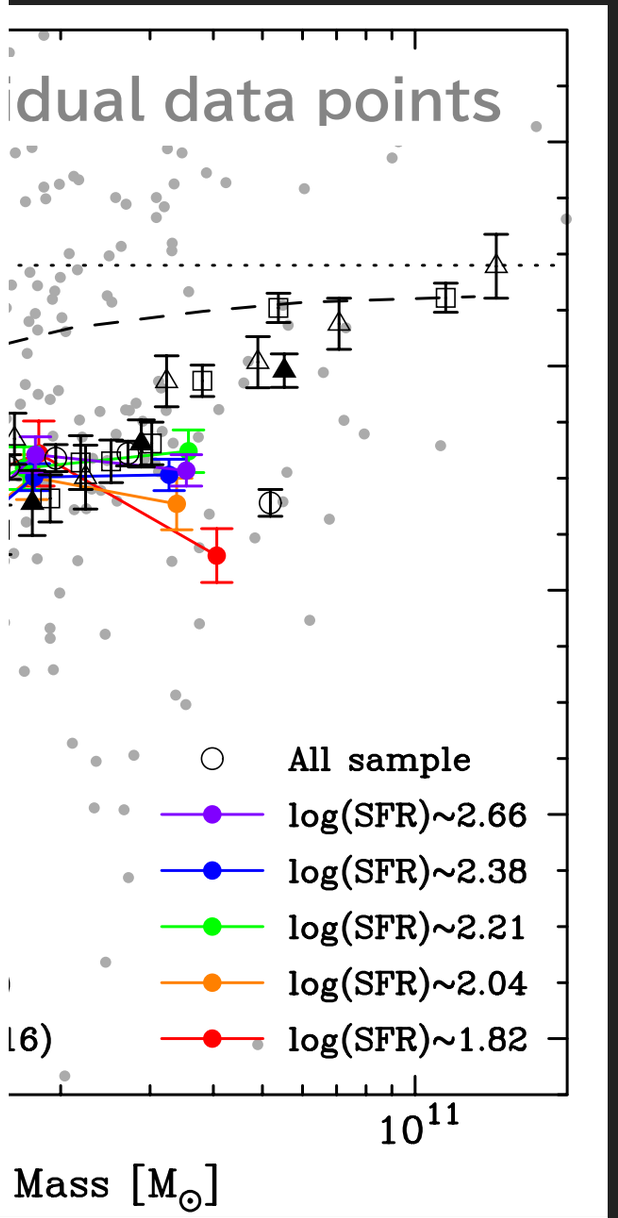
- Probably, NO
- We (at least I) have experience of Fastsound (FMOS SSP)
  - On-source exp. time is ~30 min.
  - We wrote (and will) science papers on galaxy science
- Much larger ga[illegible]urvey



Yabe et al. 2015

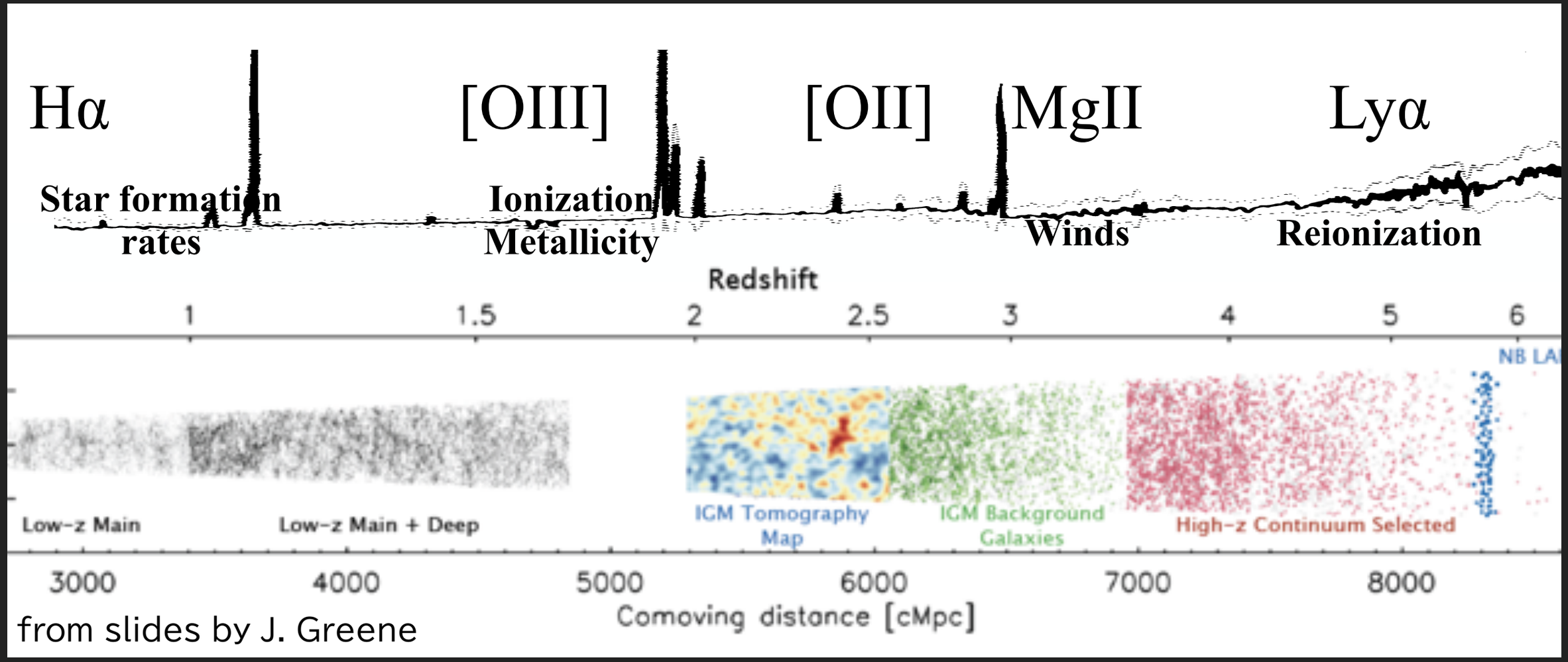


Yabe et al. in prep.



PFS SSP survey: Galaxy/AGN Evolution

- Scientific goals:
  - Charting mass assembly within the cosmic web (from z∼7 to z∼1)
- Targets:
  - ∼Magnitude limit sample at 0.7<z<2
  - Galaxies at z=2-2.5 for IGM tomography
  - Galaxies at z>3 and LAEs@z=2.2, 5.7, 6.6
  - All in ∼15 deg² of HSC-D with U-band and NIR/Spitzer coverage



from slides by J. Greene

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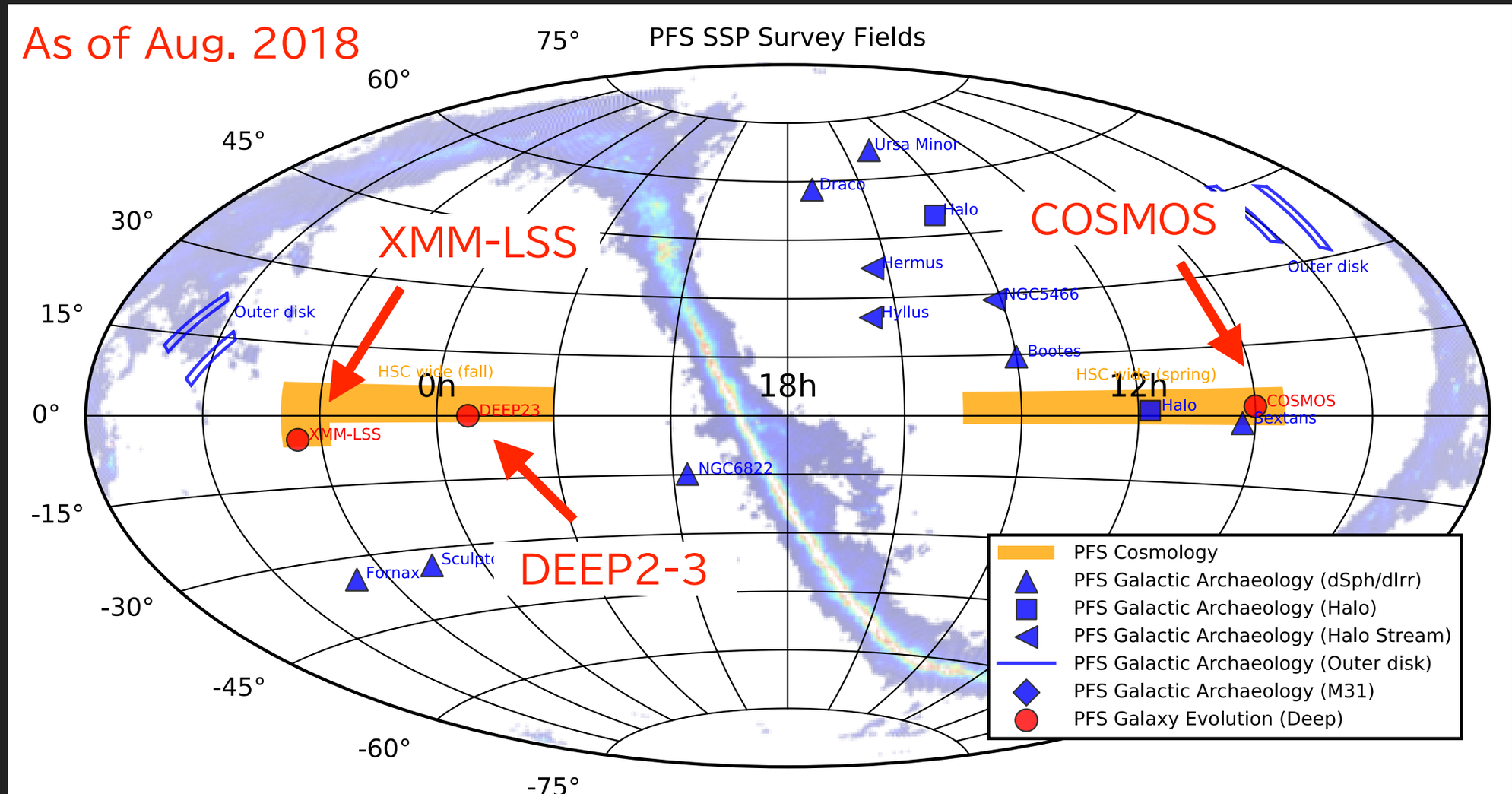


PFS SSP survey: Galaxy/AGN Evolution

"Current" plan of target sample

Total area: 14.5 deg^2

sample	redshift	mag / flux limit	exp. time (hours)	number	description
low-z (main)	0.7<z<2	J~23	2	~230,000	main compoent
low-z (deep)	0.7<z<2	J~22.5	12	~14,000	deep component
high-z (IGM)	2.1<z<3.5	g~25, y~24	6-12	~44,000	IGM tomography
very high-z	3.5<z<7.0	y~24.5	6	~22,000	very high-z
LAE	z=2.2, 5.7, 6.6	L(Lya) ~ 3-5×10^{42}	3-12	~15,000	LAEs
AGN	various	various	various	~10,000	AGN

- The total observing time is 70 nights (including weather factor)
- A single pointing is observed in 40-50 hours

PFS SSP survey: Galaxy/AGN Evolution

“ISM properties”

Metallicity

Ionization diagnostics

PFS SSP survey: Galaxy/AGN Evolution

Build-up of “red sequence”

- Velocity dispersion

- Number density of post-star burst galaxies

PFS SSP survey: Galaxy/AGN Evolution

Outflow velocity as a function of SFR

SFR vs. Environment

All these properties as a function of “environment”

PFS SSP survey: Galaxy/AGN Evolution

Tomographic reconstruction of 3D gas distribution using Lyα forest (Lee et al. 2014)

HI 21 cm cross-correlation to LAEs at z>6

PFS SSP survey: Galaxy/AGN Evolution

AGN science

TABLE 1
TARGET SELECTION AND OBSERVING STRATEGY IN THE GE SURVEY FIELD

Target (1)	Selection (2)	$N_{\rm AGN}^{\rm total}$ (3)	$N_{\rm AGN}$ (4)	$N_{\rm fiber}$ (5)	$T_{\rm exp}$ (6)	$N_{\rm fiber}T_{\rm exp}$ (7)
BL/X-ray AGNs	CLAUDS/HSC/UKIRT/X-ray					
$0.5 < z < 2.0$	$i_{\rm AB} < 22.5$	2,000	500	1,000 (0.5)	1	
	$22.5 < i_{\rm AB} < 23.3$	1,000	500	1,000 (0.5)	2	7,000
	$23.3 < i_{\rm AB} < 24.0$	1,000	500	1,000 (0.5)	4	
$2.0 \leq z < 4.0$	$i_{\rm AB} < 22.5$	600	600	1,200 (0.5)	1	
	$22.5 < i_{\rm AB} < 23.3$	500	500	1,000 (0.5)	2	8,000
	$23.3 < i_{\rm AB} < 24.0$	600	600	1,200 (0.5)	4	
$4.0 \leq z < 6.0$	$i_{\rm AB} < 24.0$	400	400	800 (0.5)	4	3,200
$6.0 \leq z$	$z_{\rm AB} < 25.0$	10	10	100 (0.1)	5	500
SMGs	HSC/SCUBA-2 $f_{850\mu{\rm m}} > 8$ mJy	100	100	500 (0.2)	4	2,000
Radio AGNs	HSC/FIRST detection	2,000	200	250 (0.9)	3	750
XMP AGNs	HSC NB excess	···	a few	1,000 (0.001)	2	2,000
IMBHs	HSC variability	30	30	300 (0.1)	2	600
RM project	COSMOS/VVDS variability	···	300	300 (1.0)	0.5×30	4,500
Total						28,550

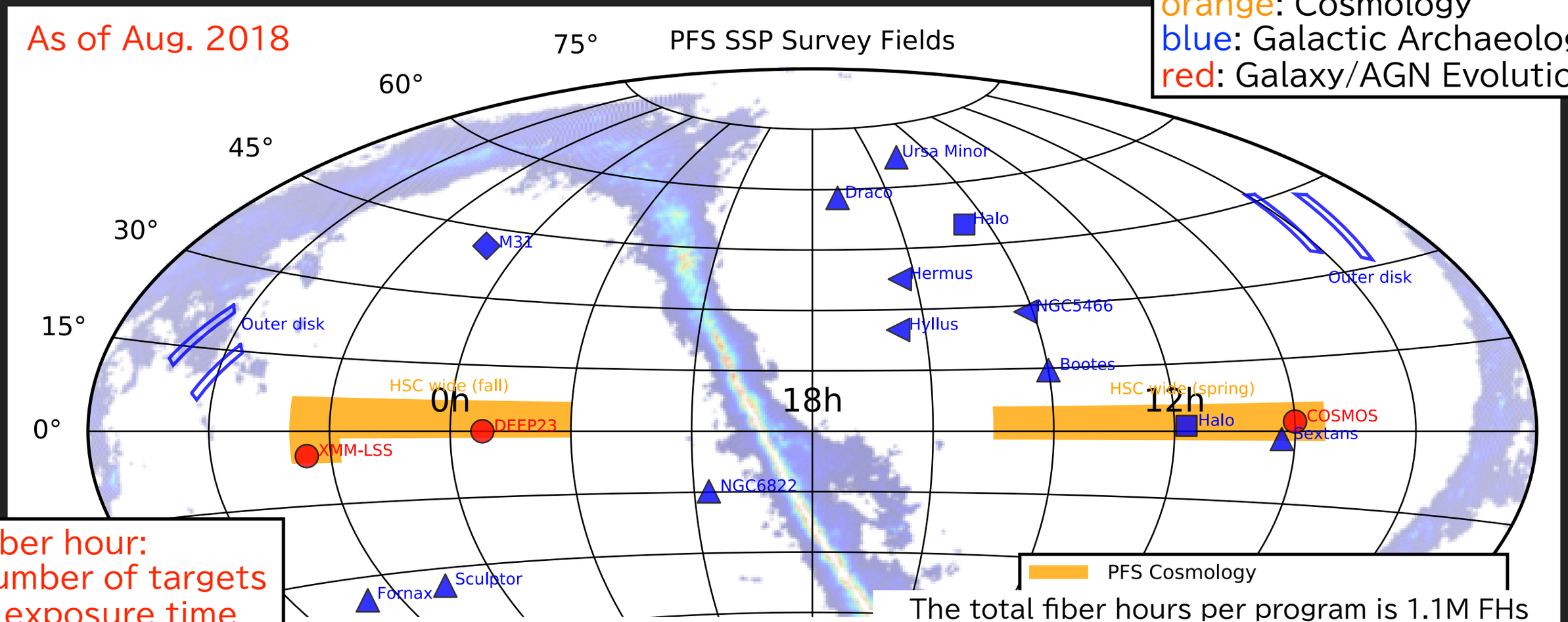
NOTE. — Columns (1) target; (2) selection method; (3) total number of AGNs expected in 15 deg^2; (4) number of AGNs we aim to observe; (5) number of requested fibers (the number in parenthesis represents the expected success rate of AGN identification, i.e., $N_{\rm AGN}/N_{\rm fiber}$); (6) exposure time (hr); (7) fiber hours.

PFS SSP survey: Galaxy/AGN Evolution

- The current plan does not necessarily include everything...
  - Low-mass emission line galaxies such as Hα/[OIII] emitters at low redshift
  - Clusters are not target so much (cf. we expect >30 clusters@z=1-2 with $M_{halo} > 10^{14}\ M_{sun}$)
  - Time domain science
- We are welcome to include additional sample if it makes the proposal stronger

PFS survey planning and simulations

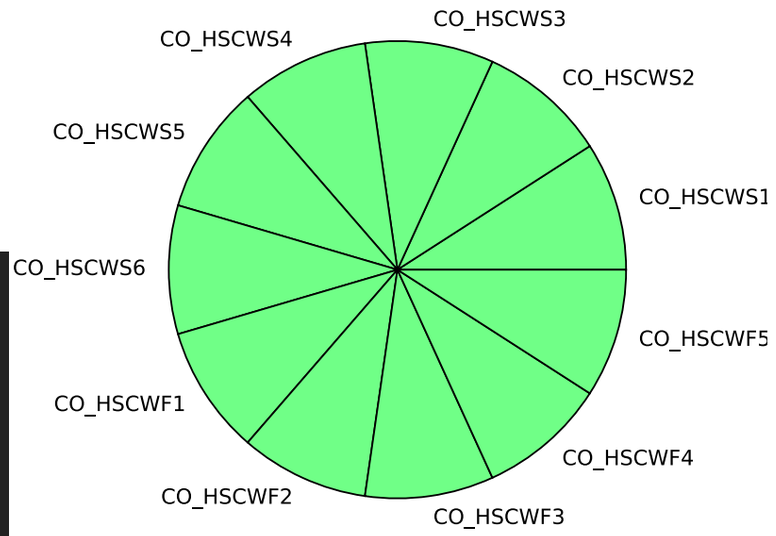
orange: Cosmology
blue: Galactic Archaeology
red: Galaxy/AGN Evolution



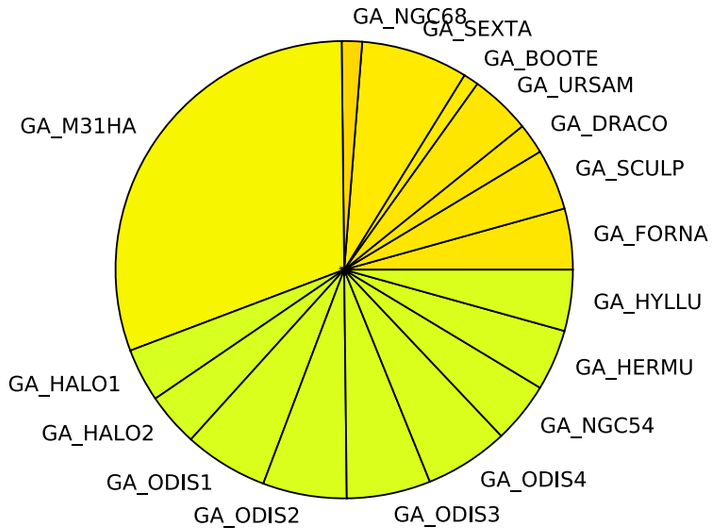
Fiber hour:
number of targets
× exposure time

The total fiber hours per program is 1.1M FHs

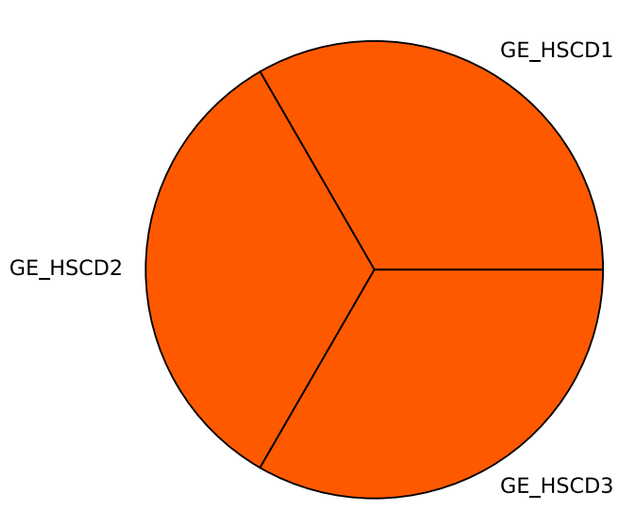
Cosmology



Archaeology



Evolution

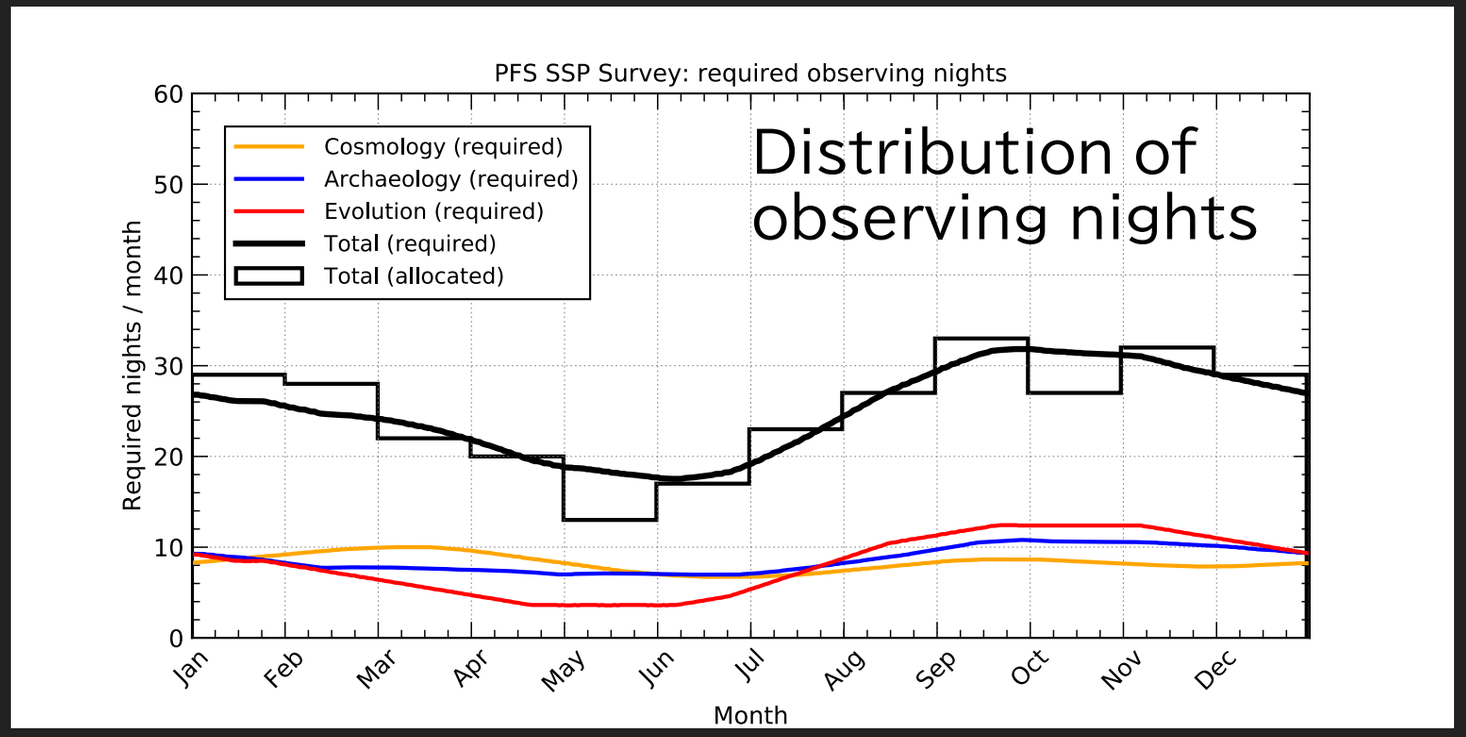


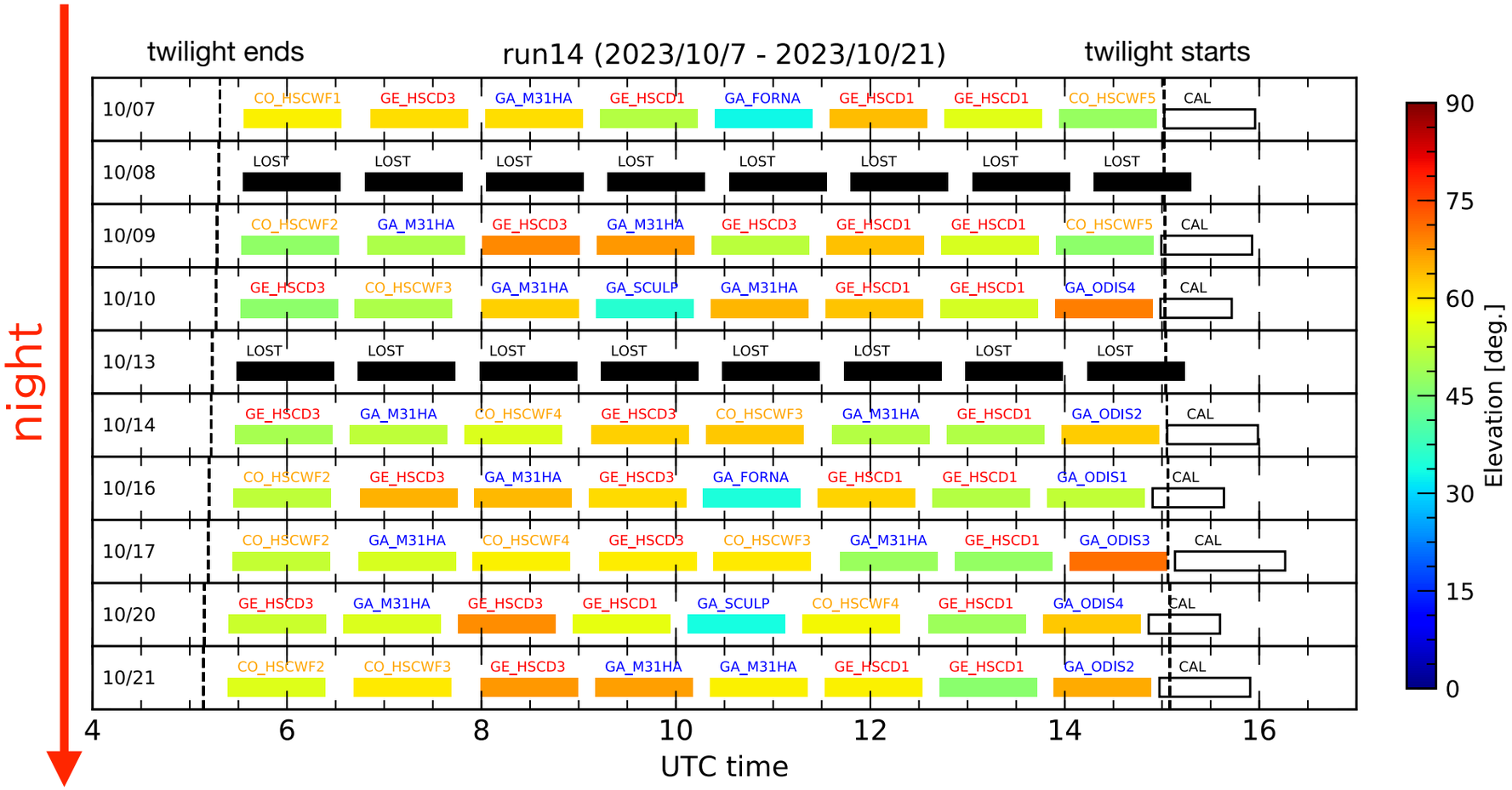
For simplicity, the Cosmology field is divided into 11 sub regions

* Cosmology and Evolution include AGN targets

PFS survey planning and simulations

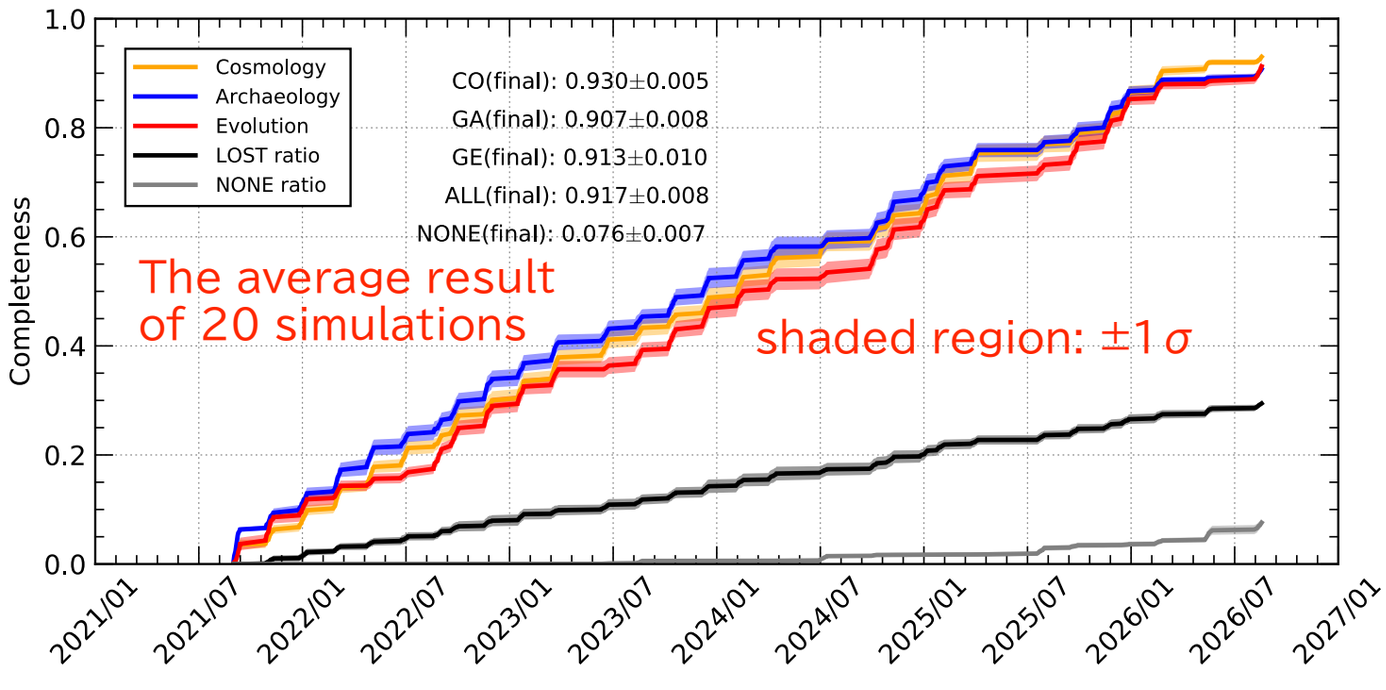
- For an ideal case of night allocation, we simulates the actual observing nights
  - Sep. 2021 - Sep. 2026
  - 1 PFS run = 10 dark/gray nights
  - 30 runs in total (=300 nights)
  - Weather factor = 0.7

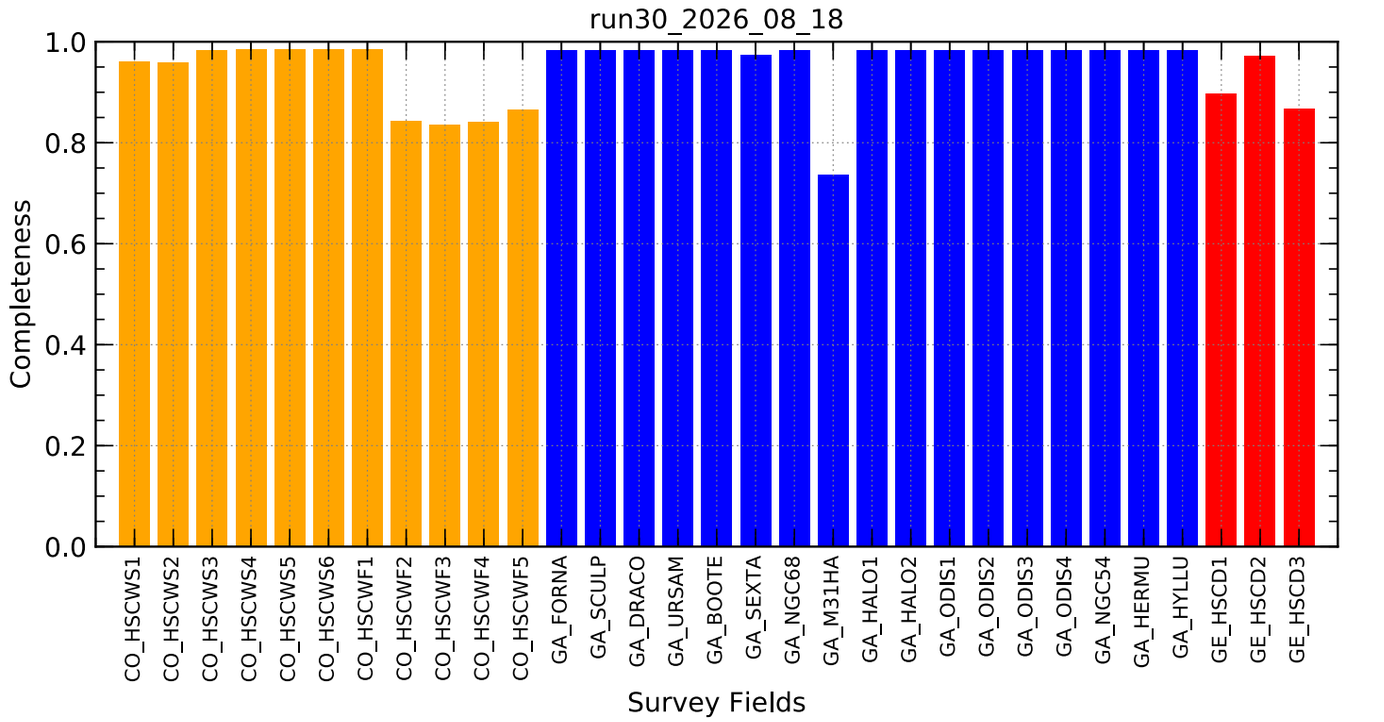




- 1-hour obs. blocks
- An observable target field assigned to each observing block is selected by ”score”:
  - Remaining fiber hours
  - Visibility
  - WG progress

PFS survey planning and simulations





Running 20 simulations by changing nights lost due to bad weather

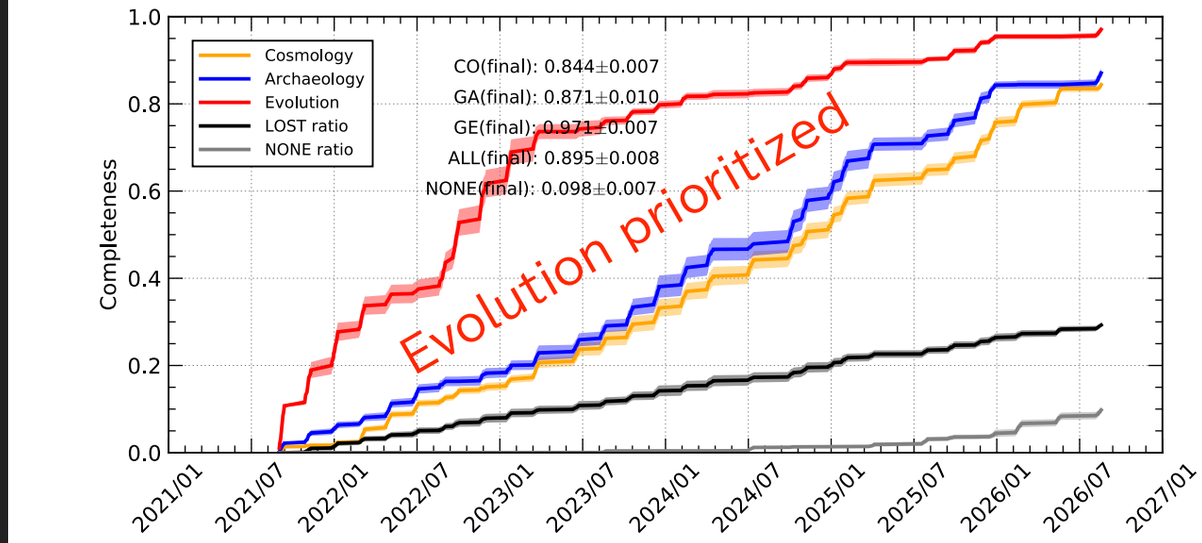
We can achieve >90% completeness for each science WG

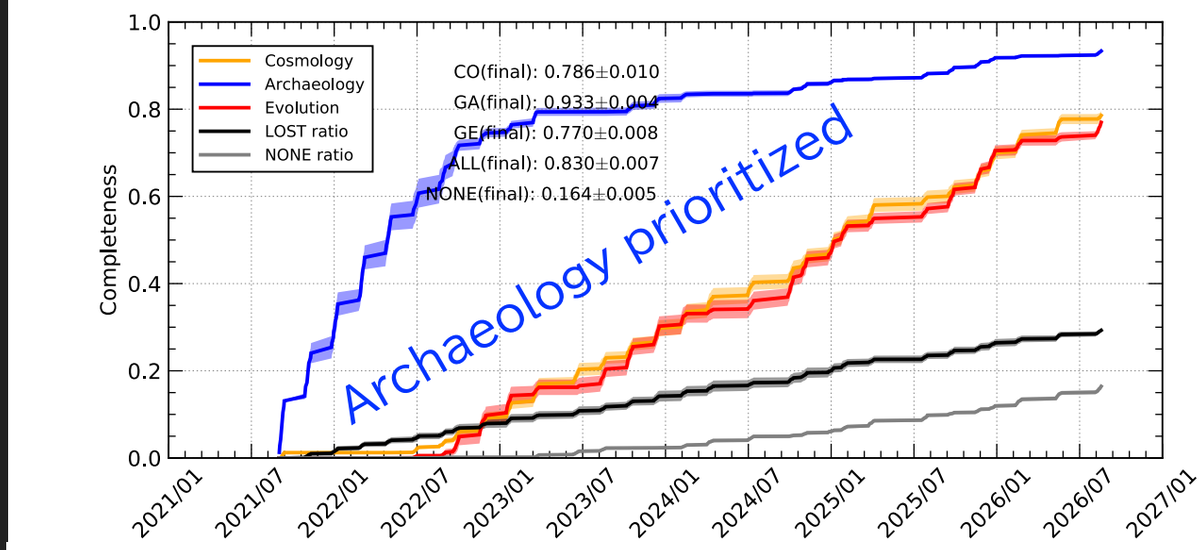
Low completeness in a part of ”CO fall fields”, ”GA M31”, ”GE XMM-LSS and DEEP23” because they are in crowded R.A.

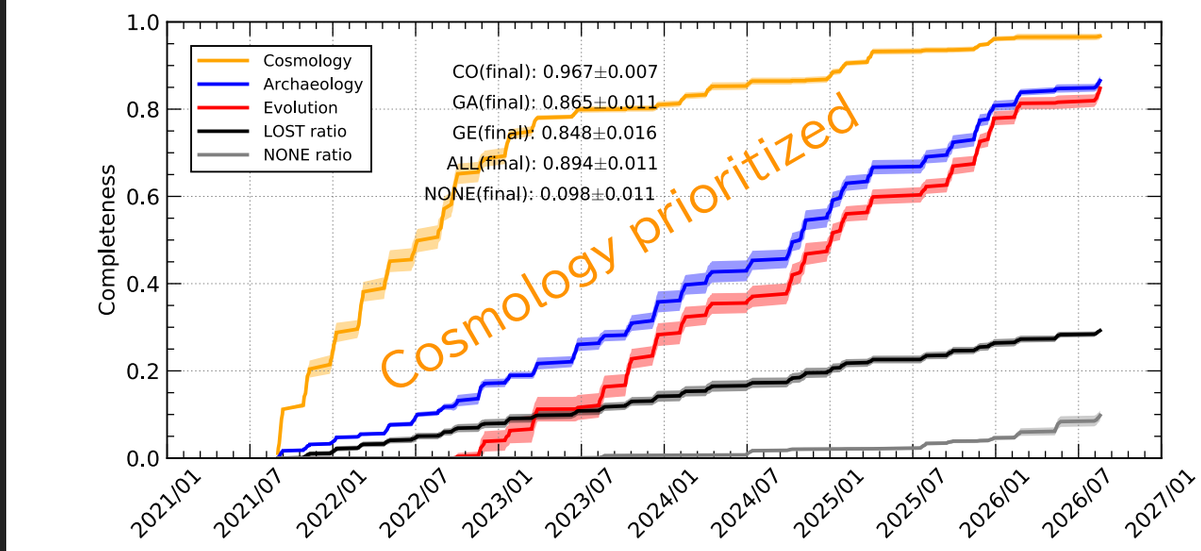
- Using a set of weights [w_{CO}, w_{GA}, w_{GE}] for the score, the progress of a specific science program can be controlled

- Strategy will be discussed in the collaboration with being led by ”survey integration team”

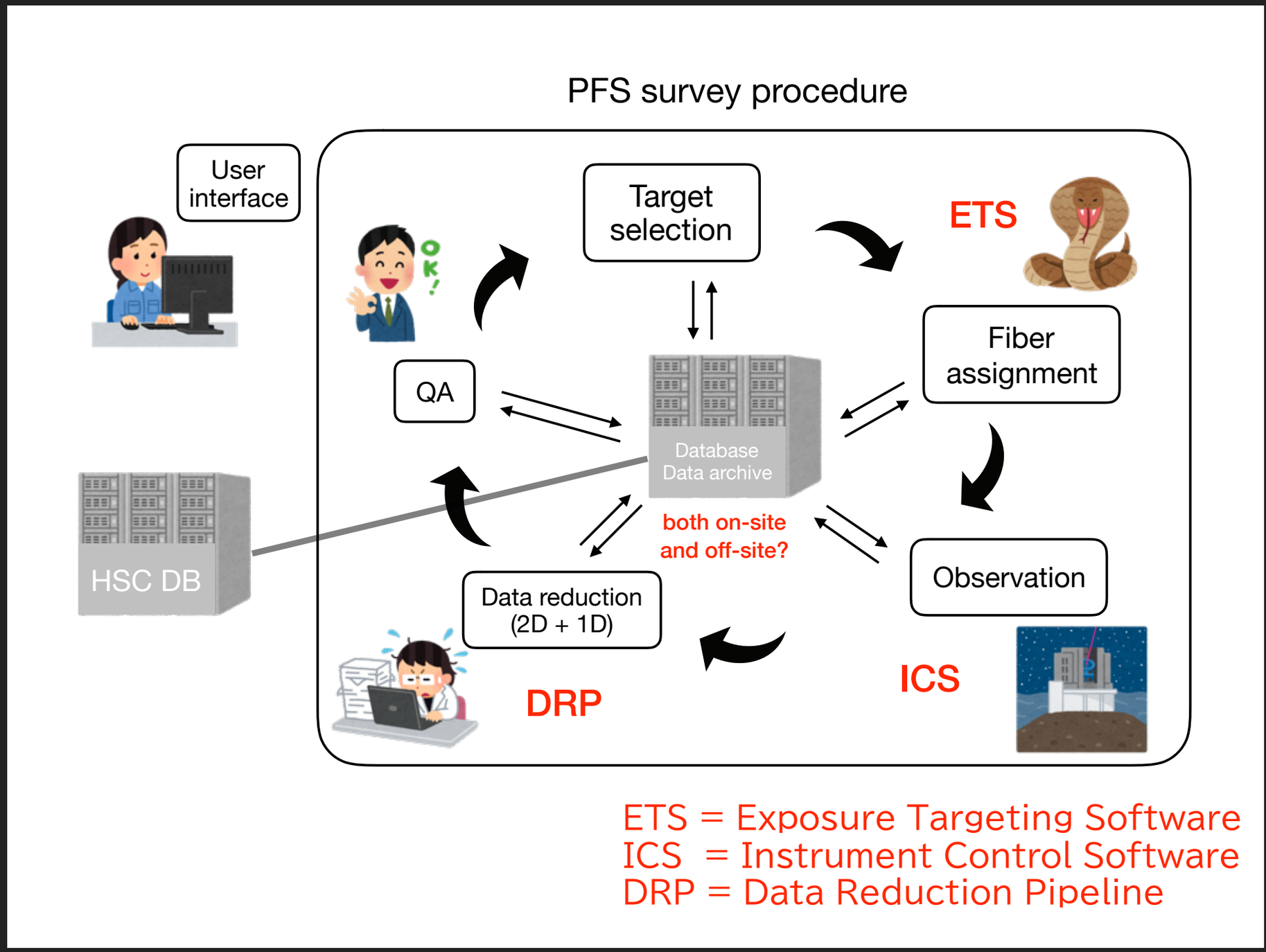
- We want to maximize the scientific outputs from the survey, but how to evaluate/ quantify the output?





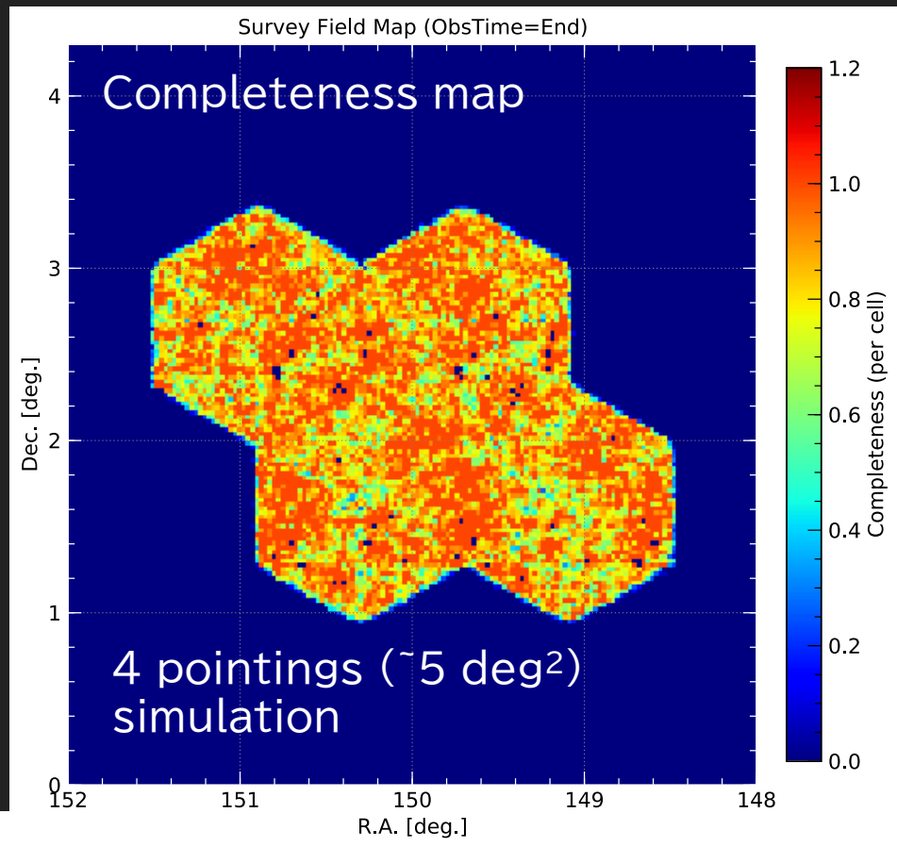


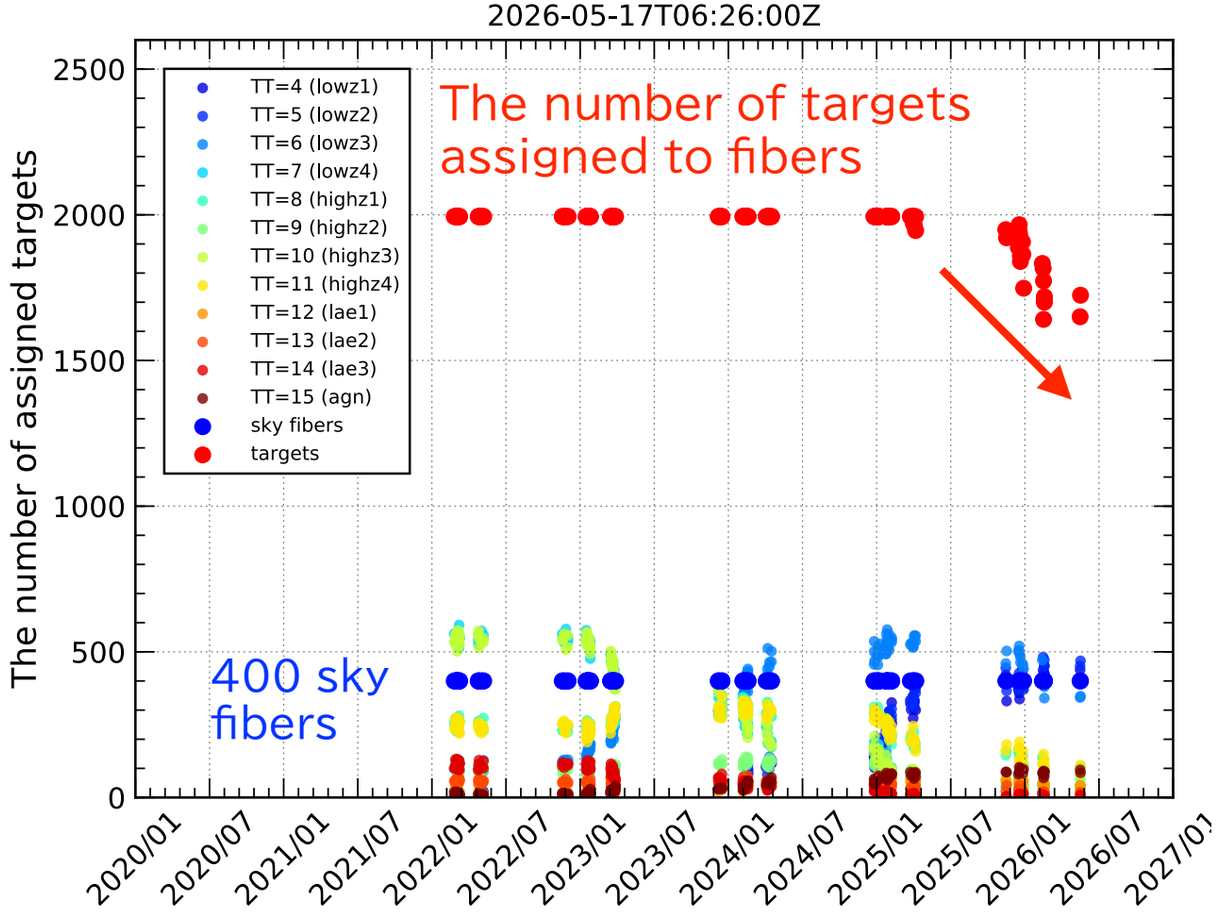
PFS survey planning and simulations

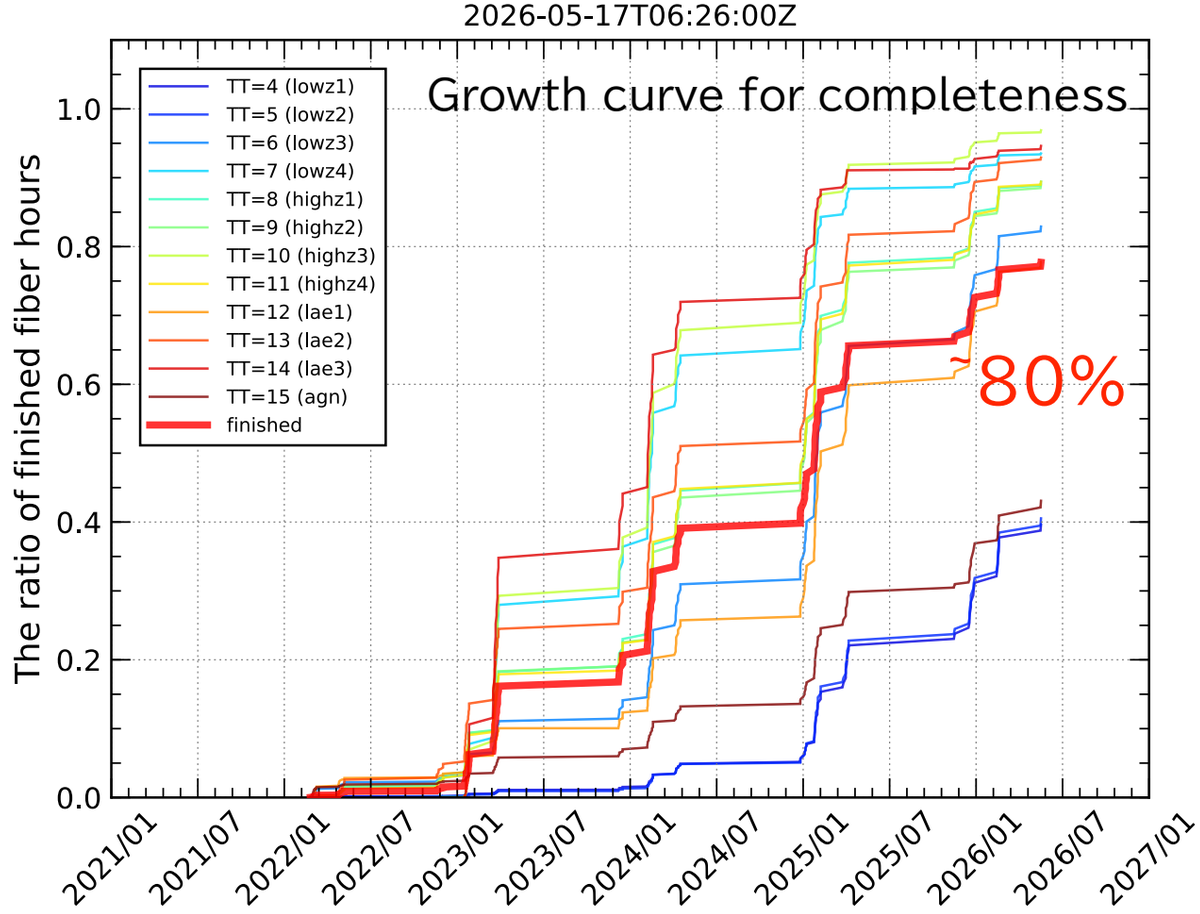


Repeating the observing cycle with connecting to each component

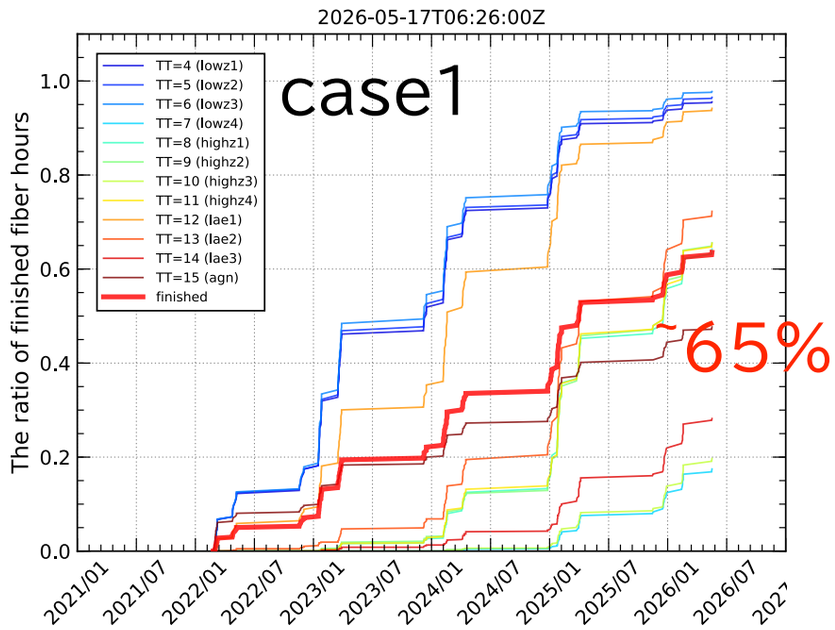
- Targets
  - Galaxy/AGN evolution survey
  - 12 different sample components
  - COSMOS galaxy catalog
  - ~40 hour-visits per pointing
- The number of galaxies assigned to fibers per visit decreases slightly in the end of the survey
- The (fiber-hour-base) completeness reaches ~80%

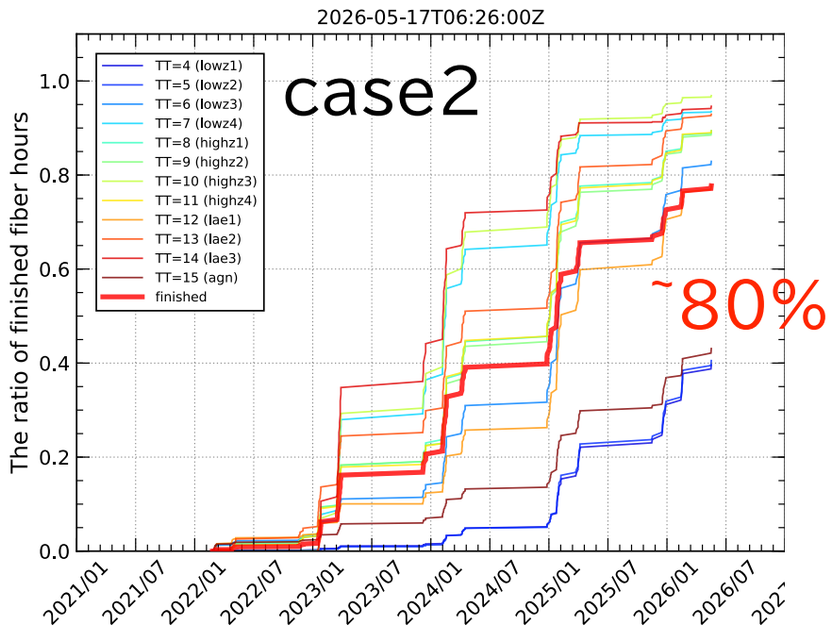


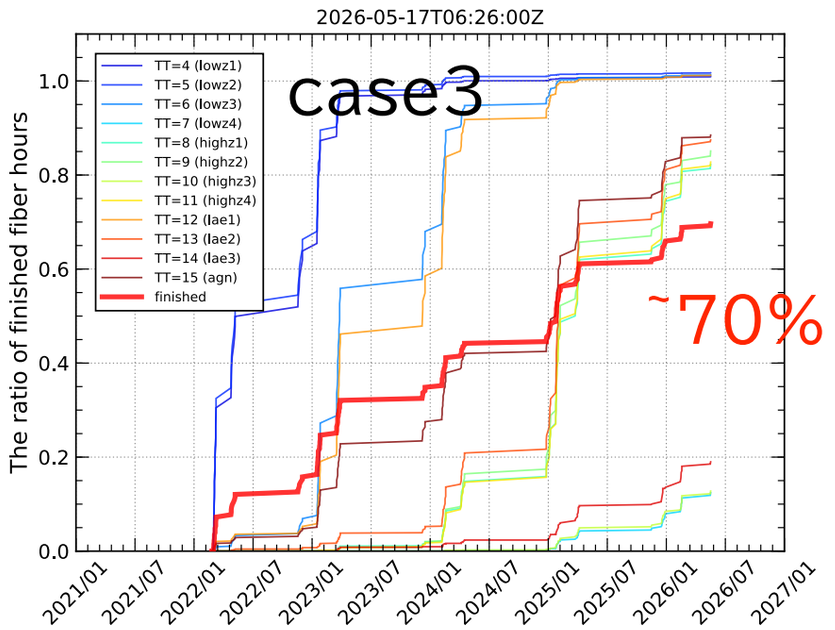


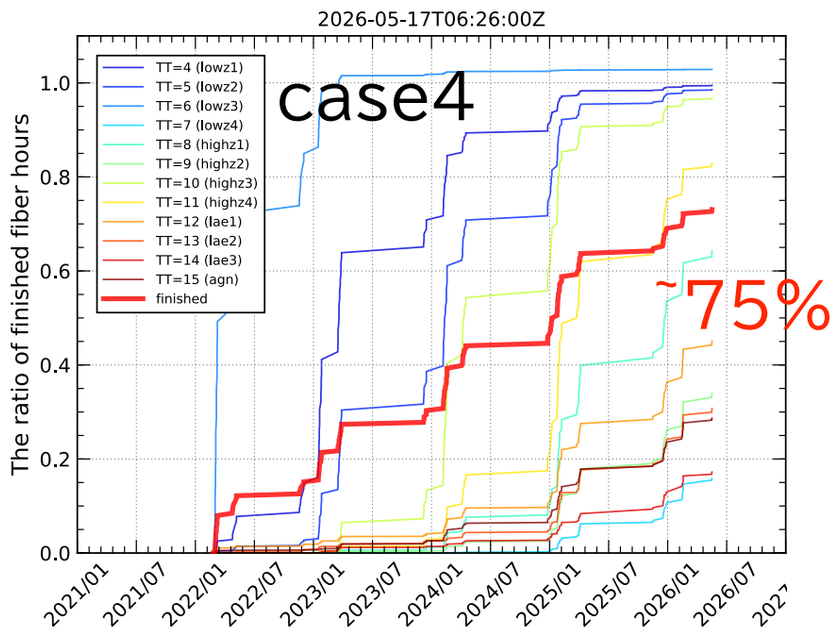


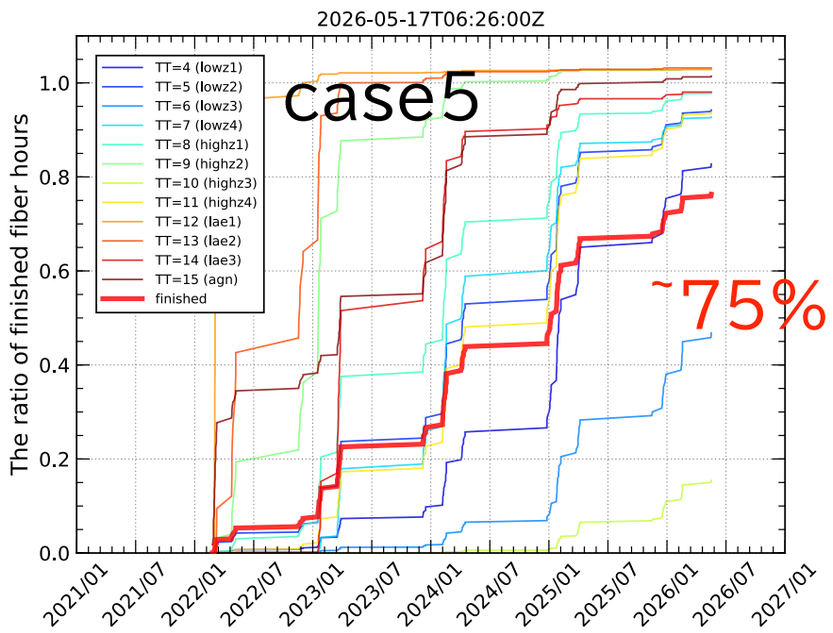
- Different prioritization leads to different results
- How do we optimize the prioritization?
  - Maximize the total survey completeness?
  - Minimize the target-to-target variation?











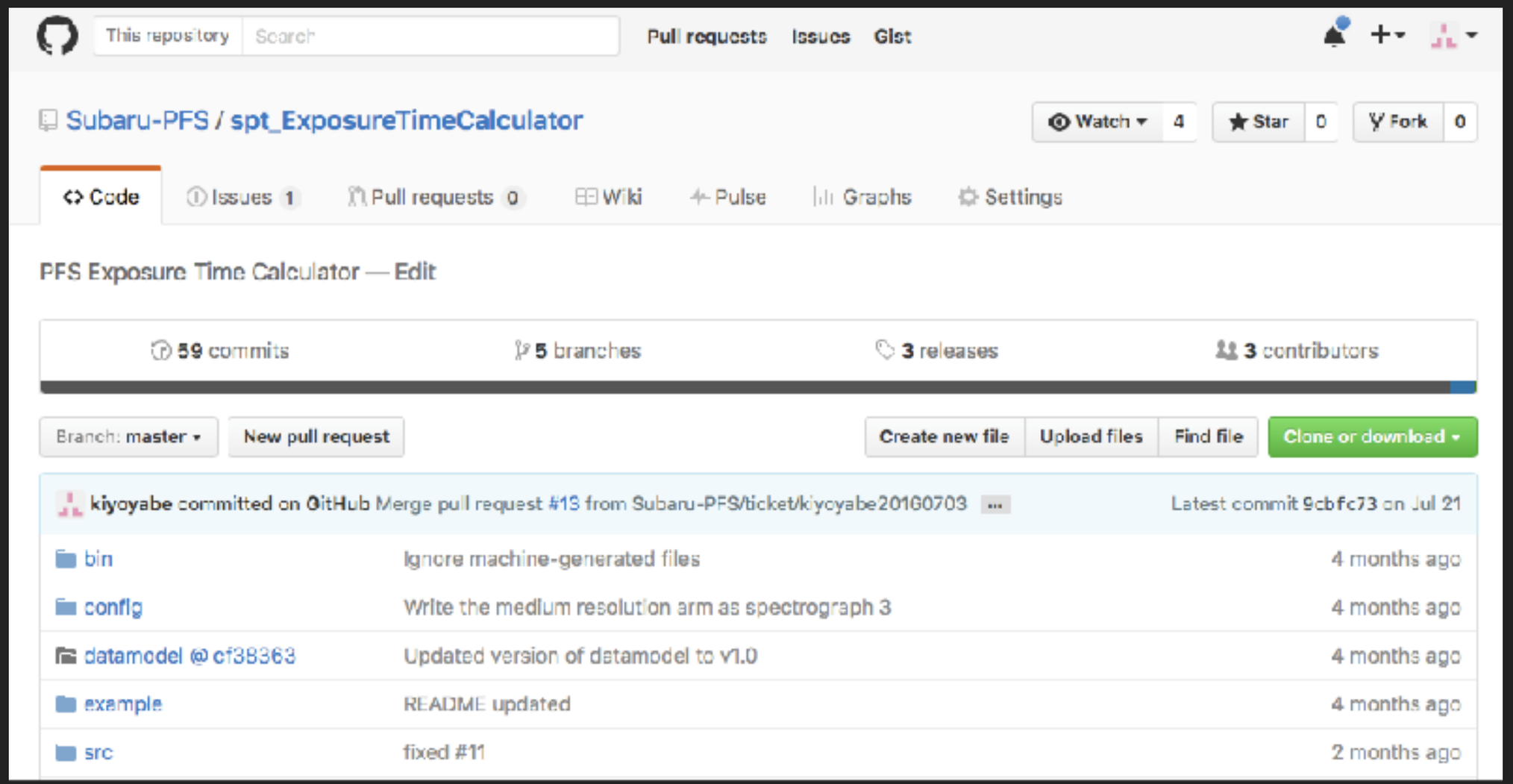
Further tests and discussion are now on-going

How to be involved with the collaboration?

- We discuss how to get involve this project later
- New science cases to make the survey stronger are welcome
- Detailed process to call for additional targets is currently under discussion
  - Is the science case interesting?
  - Is the science case feasible?
  - Does it fit with the story of the proposal?
  - Does it fit with the current survey plan?
- If you have some thoughts, please let us (PFS people) know
- We have prepared some tools for your idea

ETC and spectral simulator

- The project office presents information on the baseline of performance
  - summarizing the instrument throughput and the expected sensitivity and presenting them on our official website (https://pfs.ipmu.jp)
  - providing a package of exposure time calculator (ETC) and spectral simulator on GitHub



https://github.com/Subaru-PFS/spt_ExposureTimeCalculator

PFS performance

5σ sensitivity for 1-hour exposure

Spectral arm	Wavelength range [nm]	Throughput [%]	Continuum sensitivity [AB mag]		Line sensitivity [10^{-17} erg/s/cm^2]	
			mean	representative	mean	representative
Blue	380 - 450	14.9	22.0	22.1	2.9	2.8
	450 - 550	24.5	22.4	22.5	1.5	1.4
	550 - 650	23.9	22.1	22.2	1.5	1.3
Red Low res.	630 - 750	29.1	22.2	22.5	1.2	1.0
	750 - 850	30.1	22.0	22.4	1.1	0.9
	850 - 970	27.8	21.6	22.1	1.2	0.9
Mid. res.	710 - 775	26.4	21.6	21.8	1.3	1.1
	775 - 825	28.4	21.6	21.8	1.1	1.0
	825 - 885	27.3	21.5	21.7	1.2	1.0
NIR	940 - 1050	17.9	20.9	21.5	2.0	1.3
	1050 - 1150	19.5	21.0	21.4	1.6	1.2
	1150 - 1260	17.1	20.9	21.3	1.5	1.2

Sensitivity:
Continuum ~22 AB
Line ~10^{-17} erg/s/cm^2

*1 Here a point source is assumed
*2 For continuum, 3-pix binning along spec. direction is applied
*3 The representative value at the wavelength free from OH line
*4 The average value in the wavelength window
*5 Seeing FWHM of 0.8 arcsec. is assumed

https://pfs.ipmu.jp/research/performance.html

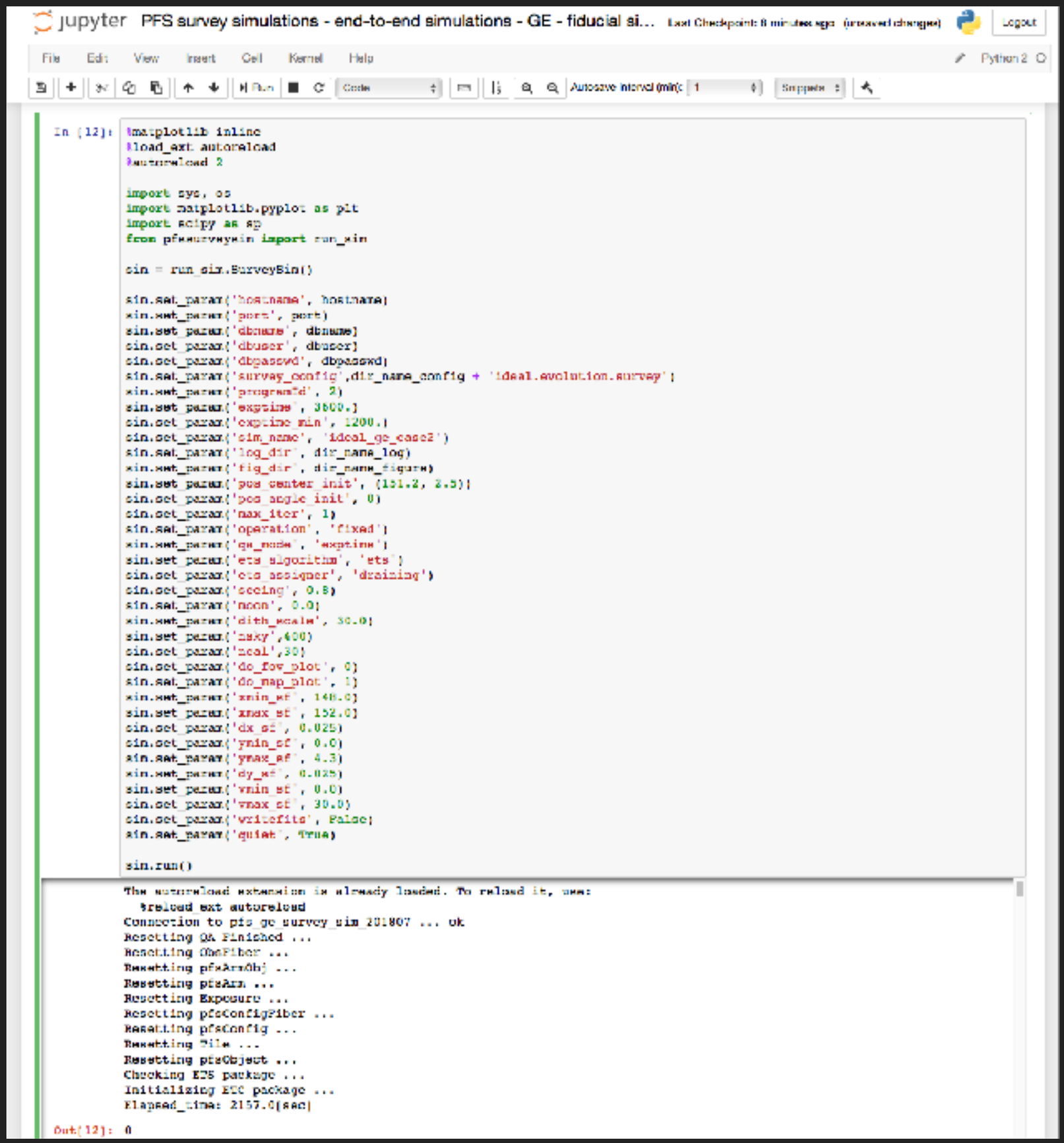
PFS survey simulator

- The simulator is open for the collaboration
- Python + Jupyter notebook running on a remote server

https://pfs.ipmu.jp/jupyter-spt/notebooks/example/example_end-to-end_simulation.ipynb

PFS account is required

If you are interested, please let us know



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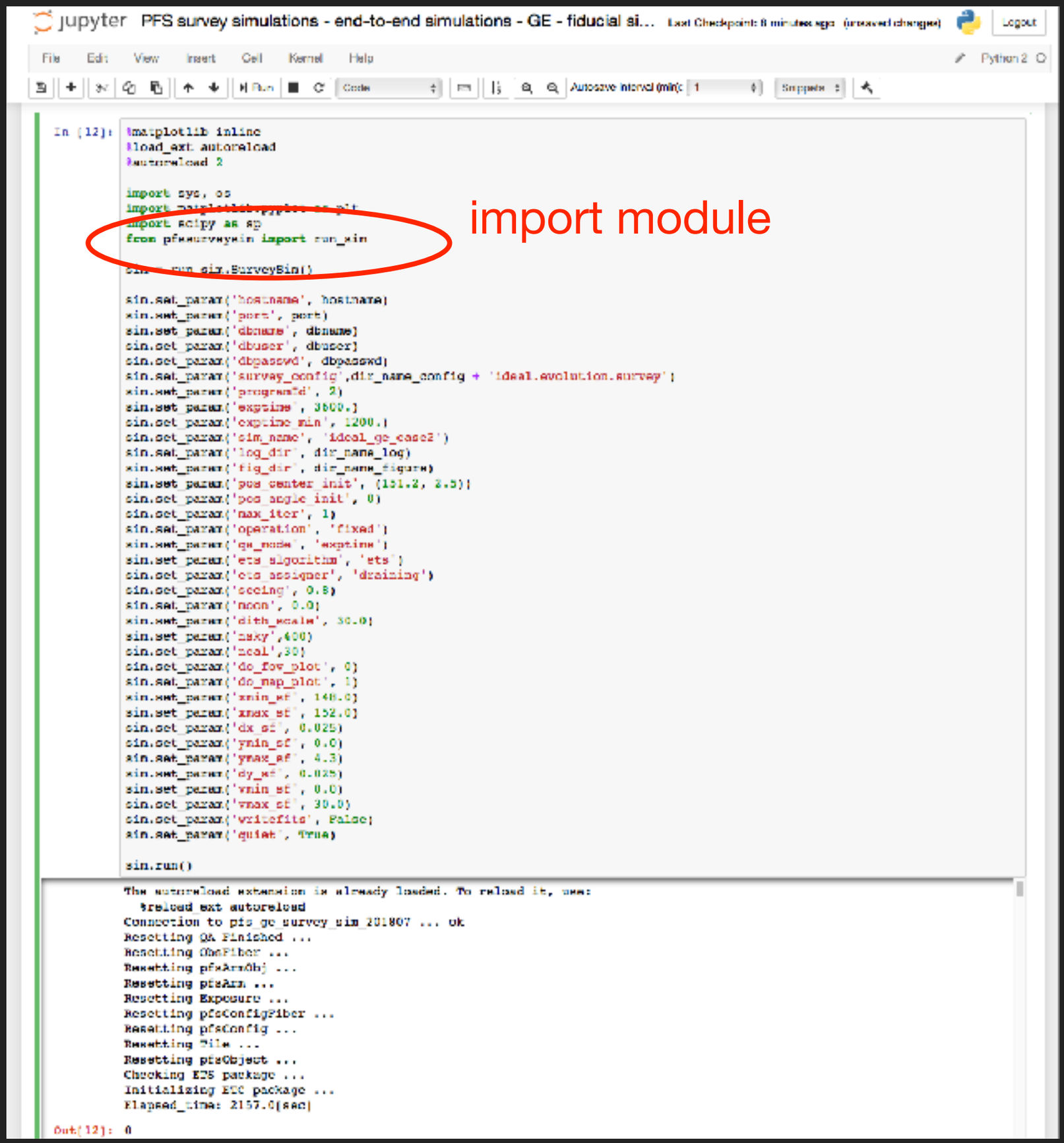

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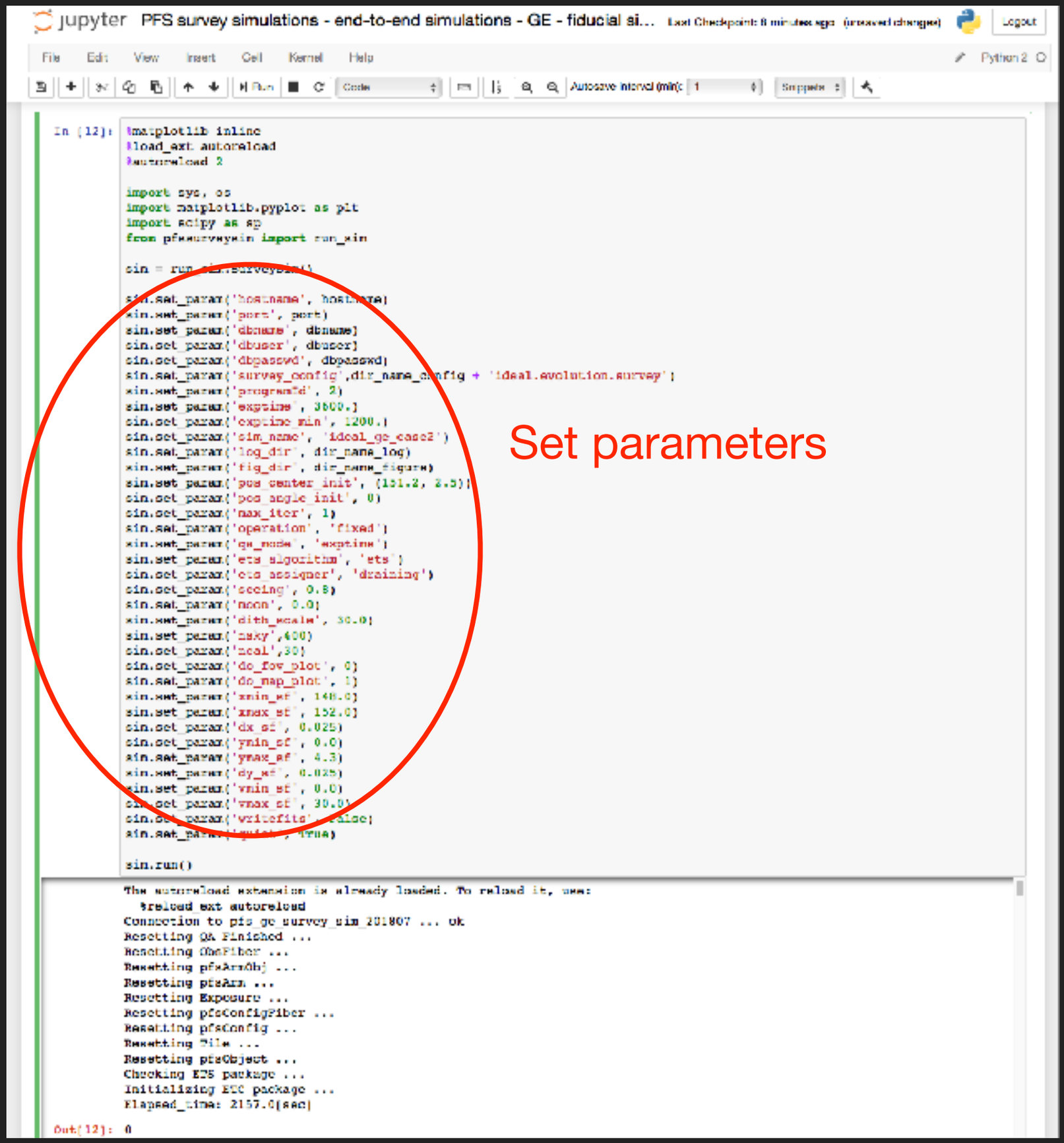

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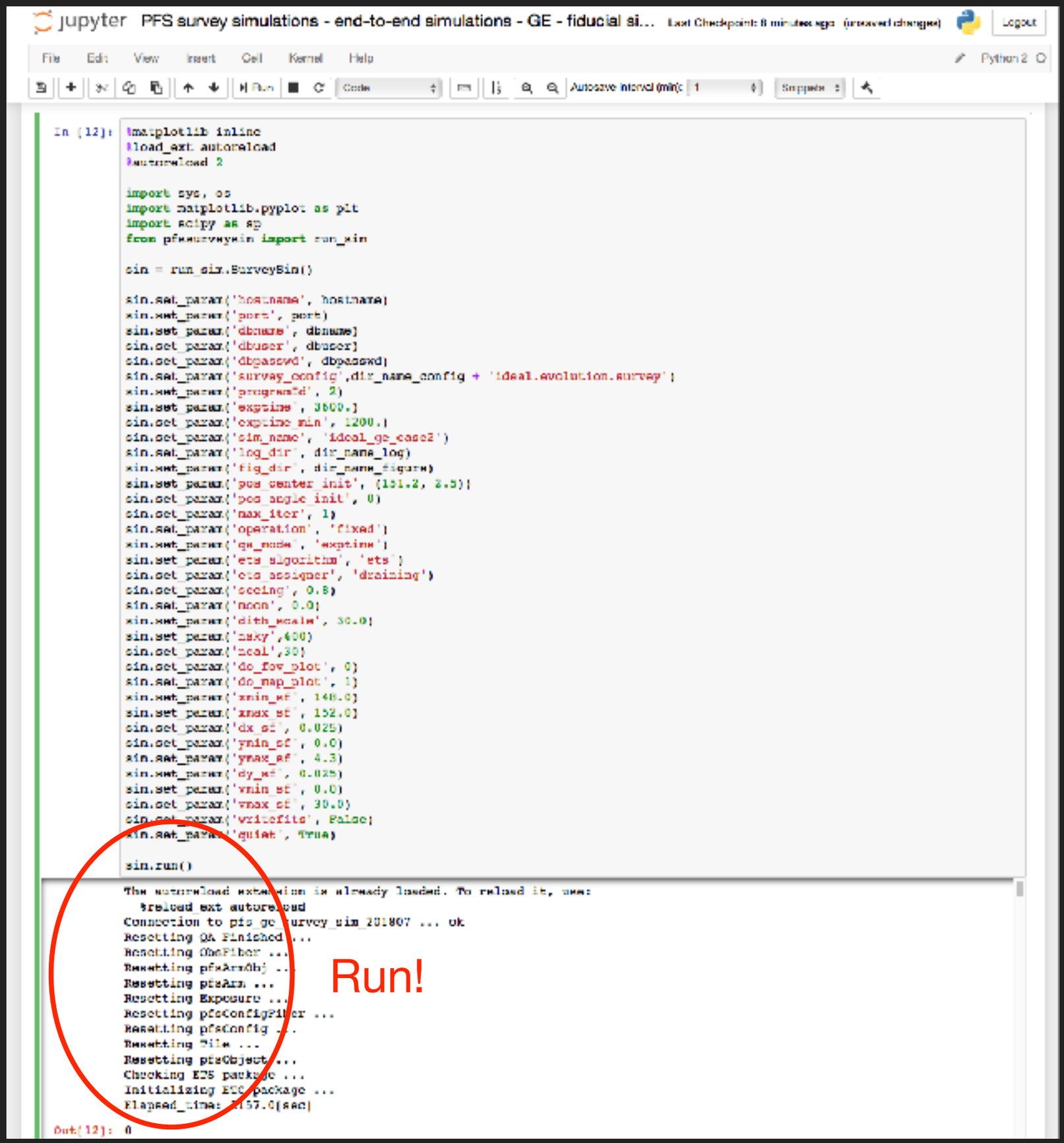

Summary

- PFS SSP survey
  - Cosmology survey
    - ✓ ~1400 deg² of the HSC-wide fields
    - ✓ Precise measurement of cosmological parameters and constraint on the neutrino mass hierarchy
    - ✓ Competitiveness to other large surveys
  - Galaxy/AGN Evolution survey
    - ✓ ~15 deg² of the HSC-deep fields
    - ✓ Understand how galaxies form and evolve along the cosmic large scale structure
    - ✓ Many science cases have been discussed so far
- Survey planning and simulation are on-going
- Some tools have been provided for your own science