Updates in B03 (cosmology with spectroscopic survey)

Masahiro Takada (Kavli IPMU)

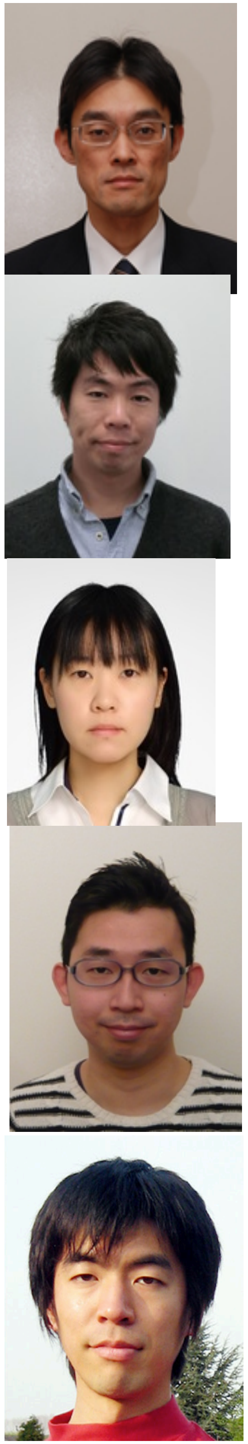
KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

東京大学 THE UNIVERSITY OF TOKYO

wpi

Cosmic Acceleration @ YITP, March 2019

Our team



- Masahiro Takada: oversee
- **Naoyuki Tamura**: PFS Project Manager
- Ryuichi Takahashi: simulations
- Naoki Yasuda: pipeline
- Ikuru Iwata: Subaru
- Yousuke Minowa: Subaru
- Kiyoto Yabe: PFS
- Yuki Moritani: PFS
- Tomomi Sunayama
- **Keigo Nakamura**
- Ryu Makiya
- Miho Ishigaki (IPMU → Tohoku)
- Hillary Child (JSPS, from Chicago)
- Kohei Hayashi (KIAA → NAOJ->iCRR)
- Hironao, Miyatake (Nagoya)
- Chiaki Hikage
- Collaborators: Takahiro Nishimichi, Masato Shirasaki, …
- Students: H. Niikura, K. Akitsu, R. Murata, Y. Kobayashi, T. Nozawa, H. Ito, R. Tateishi, N. Sugiyama, T. Kurita

New member! Keigo Nakamura

(Kyoto → IPMU)

T2K (TOKAI TO KAMIOKA) EXPERIMENT

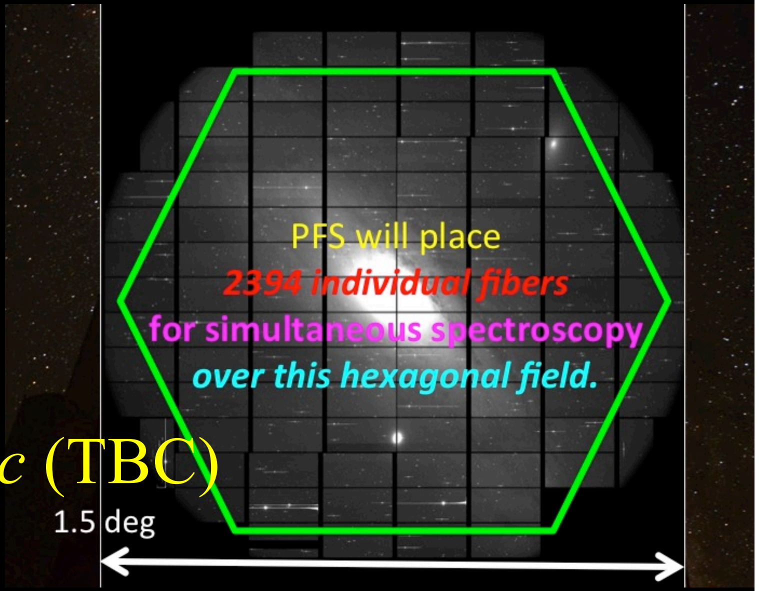
- Measure neutrino oscillations with neutrinos generated by J-PARC accelerator.
- A Large Collaboration: 13 Country ~500 people.
- measure the CP violation in the lepton sector

FY2018 Publications

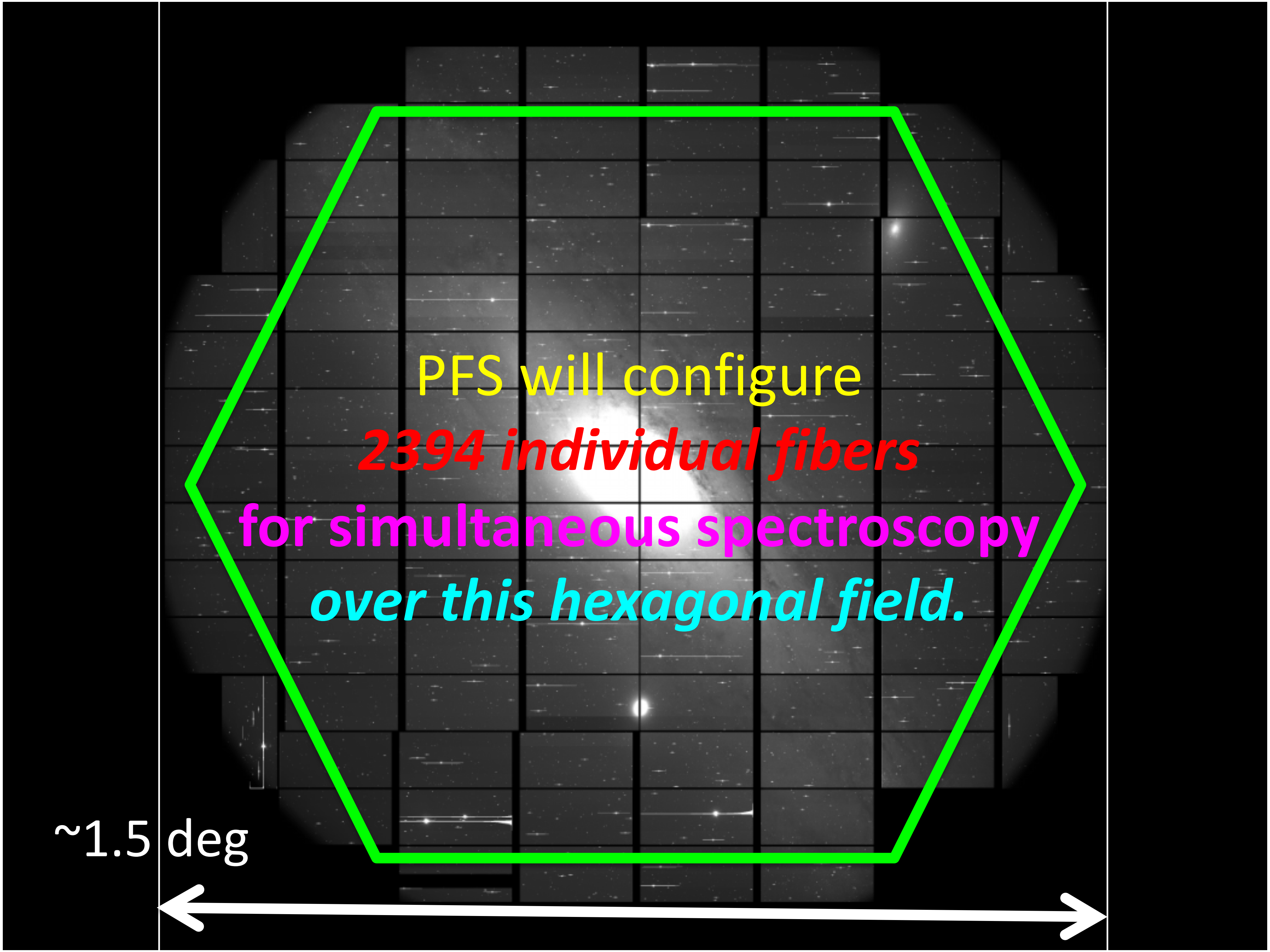
- ~30 papers
- Many HSC papers including HSc cosmology paper (Hikage et al. 2018)
- Niikura, MT, Yasuda+: HSC PBH constraints
- Niikura, MT, Yokoyama+: OGLE PBH constraints
- Hillary, MT, ….: BAO bispectrum
- Osato et al.: *large-scale tide and halo shapes*
- Akitsu & Takada: *LSS & large-scale tide*
- Shirasaki et al*:* MNRAS: *mock catalogs* of HSC cosmic shear data
- Okumura, Takada, More, Masaki, MNRAS: *RSD*
- Murata et al.: *modeling of SDSS clusters*
- *….*

PFS - Fast facts

- Subaru *Prime Focus Spectrograph*:
  The spectroscopy part of the "SuMIRe" project.
  - Wide field: *~1.3 deg* diameter
  - High multiplicity: *2394 fibers*
    - Fiber diameter: ~1.05 arcsec
    - Fiber positioner pitch: ~85 arcsec
    - Minimum fiber separation: ~30 arcsec
  - Quick fiber reconfiguration: *~60-120 sec* (TBC)
    - *Dynamic* survey strategy is allowed.
  - VIS-NIR coverage: *380-1260nm simultaneously*
    - Low resolution mode: ~2.5 A resolution
    - Medium resolution mode (around 800nm): ~1.6 A resolution



- Aiming at start of science operation & survey program in *2021, as a facility instrument on Subaru Telescope.*



PFS will configure

2394 individual fibers

for simultaneous spectroscopy

over this hexagonal field.

~1.5 deg

10th PFS collaboration meeting

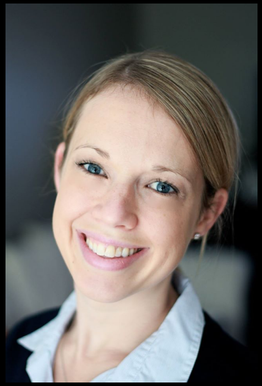
Dec 10-14 2018 at Shanghai Jiao Tong University

Official members of the PFS collaboration!

David Schiminovich
Columbia University

Chair of

Danilo Marchesini
Tufts University

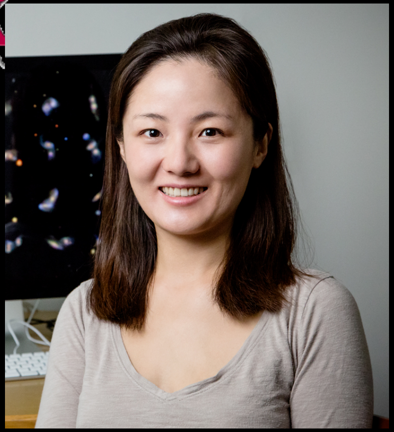


Katherine Whitaker
University of Connecticut

Anna Sajina
Tufts University

NEPG

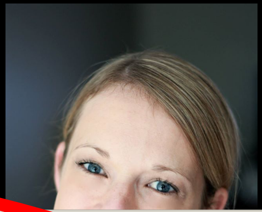
Rachel Bezanson
University of Pittsburgh



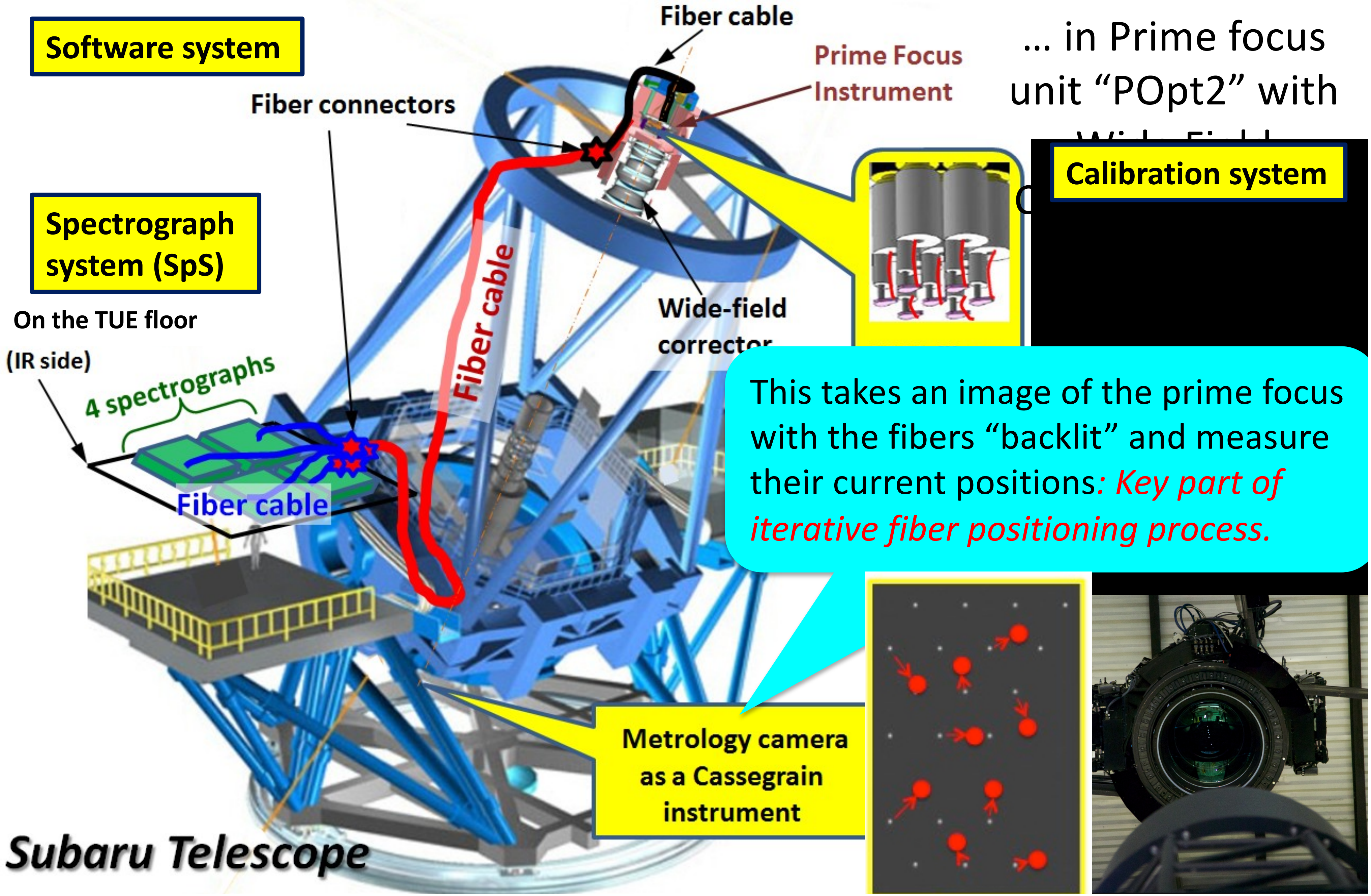
Xin Liu
University of Illinois

Jonathan Trump
University of Connecticut

Official members of the PFS collaboration!



PFS subsystems distribution



Software system

Spectrograph system (SpS)

On the TUE floor (IR side)

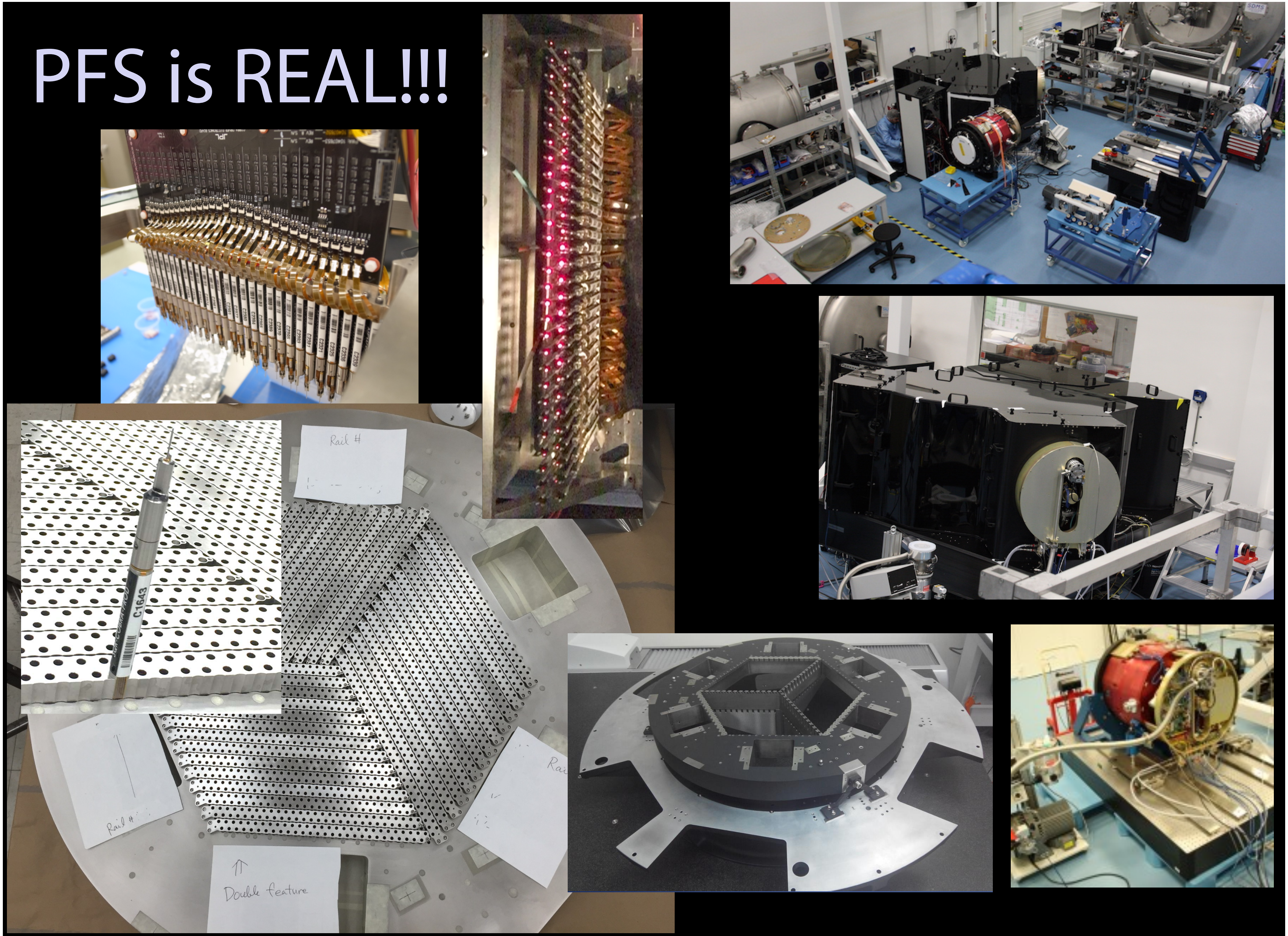
… in Prime focus unit "POpt2" with

Calibration system

This takes an image of the prime focus with the fibers "backlit" and measure their current positions: *Key part of iterative fiber positioning process.*

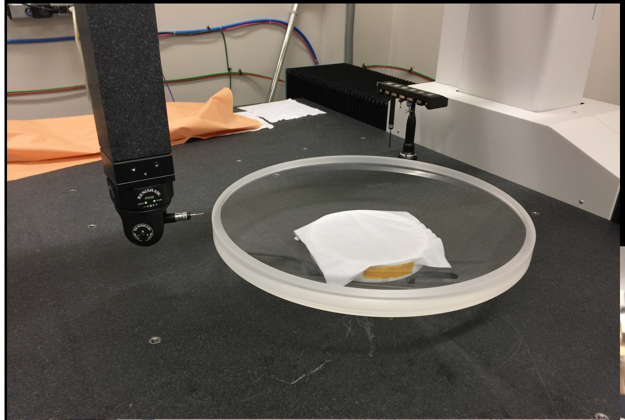
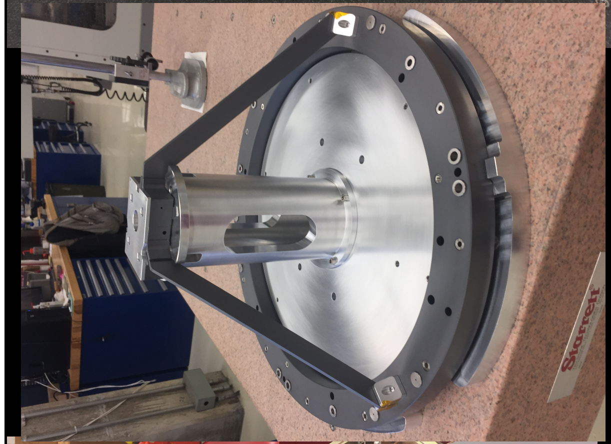
Metrology camera as a Cassegrain instrument

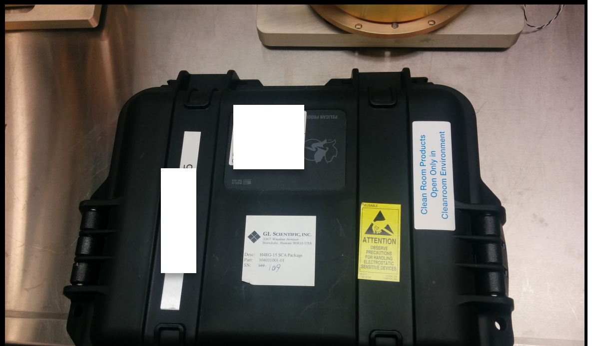
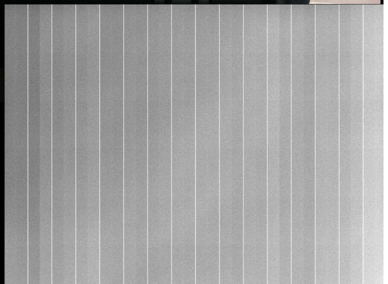
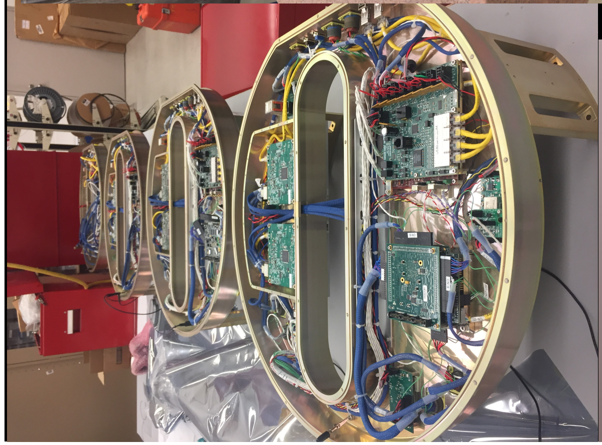
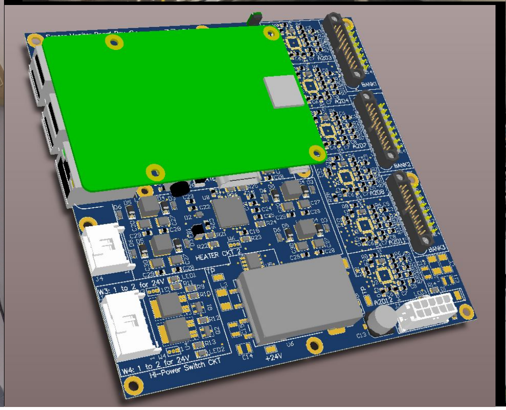
PFS is REAL!!!

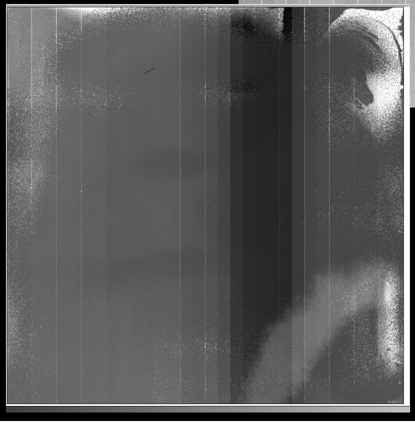


NIR camera development

- 4x science-grade H4RG devices in hand. Characterization is ongoing.
- Parts production and integration are ongoing.

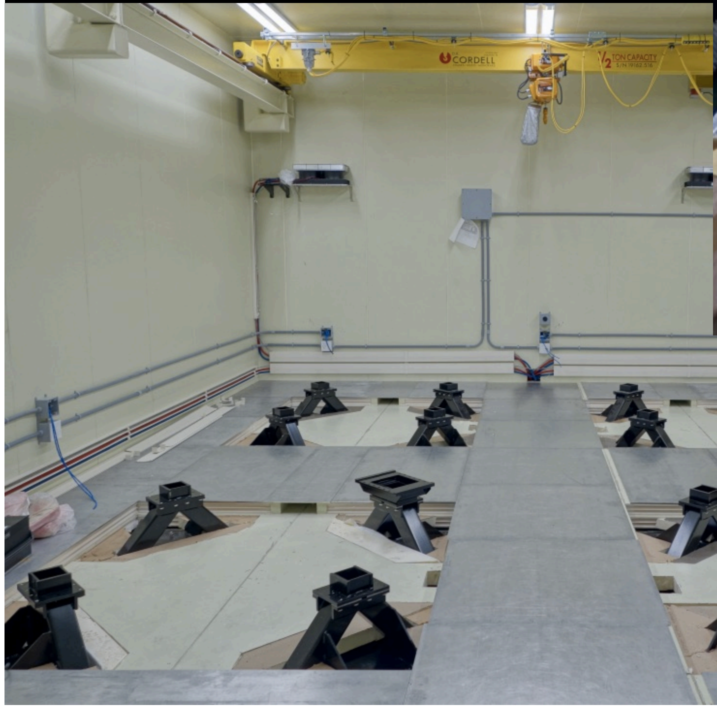





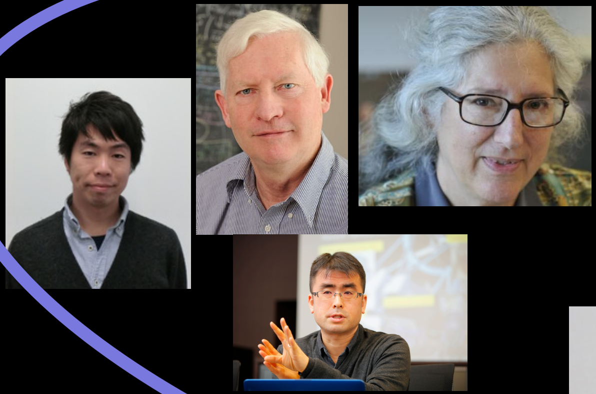
Spectrograph Clean Room (SCR)

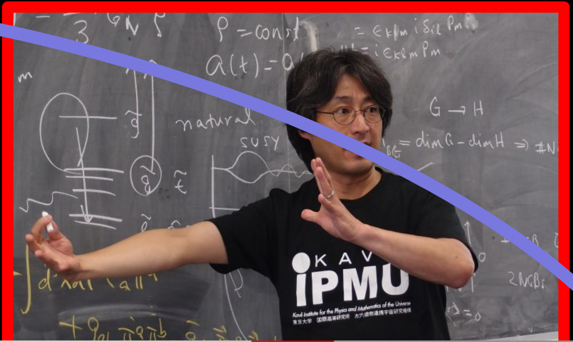
Naruhisa Takato
(NAOJ)



- Cabling & piping for facility resources are nearly complete.
- SpS cabling and optical bench legs fitting will be next.
- Environmental control testing will also start soon.

PFS is a perfect suite for *Panoramas of the Evolving Cosmos*





Hitoshi Murayama
[PI of PFS project]

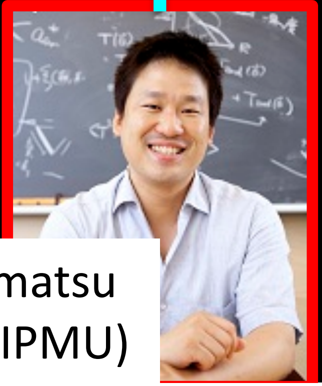
Survey integration team

Masahiro Takada
[Kavli IPMU]

Richard Ellis
[UCL]

Science working group co-chairs

Cosmology



Eiichiro Komatsu
(D01: MPA/IPMU)

Galaxy/AGN
evolution

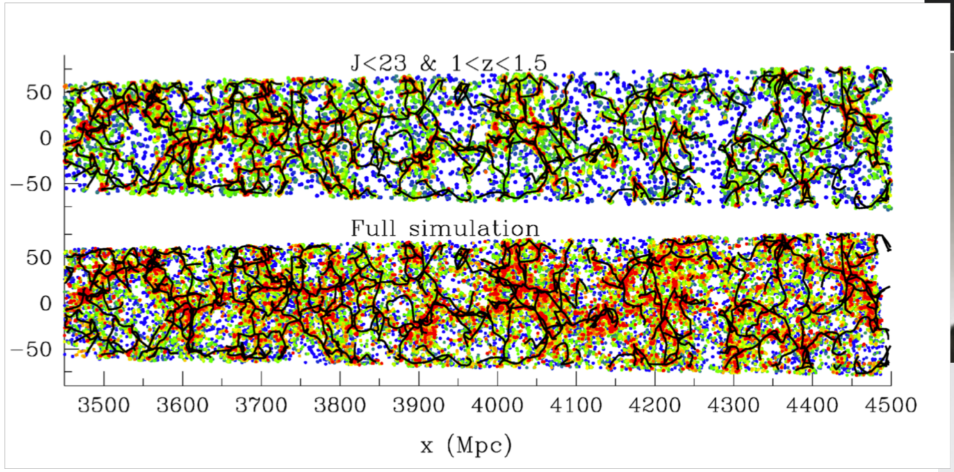
Jenny Greene (Princeton)

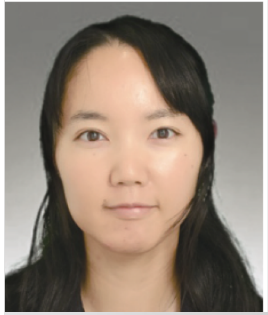
Galactic
Archaeology

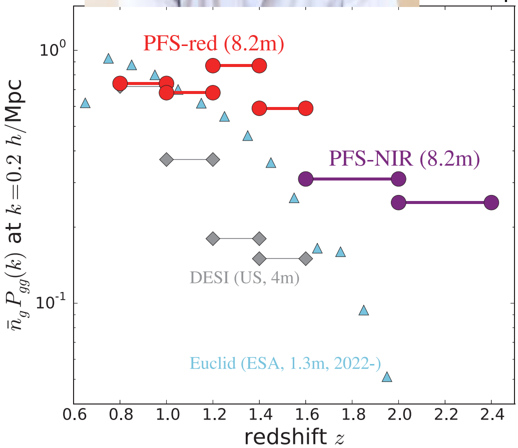
Masashi Chiba
(A02: Tohoku U.)

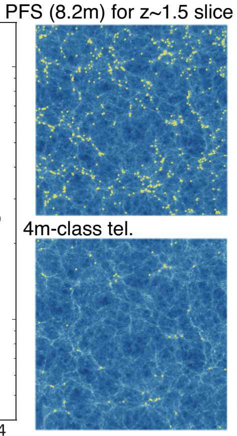
Science opportunities with PFS!

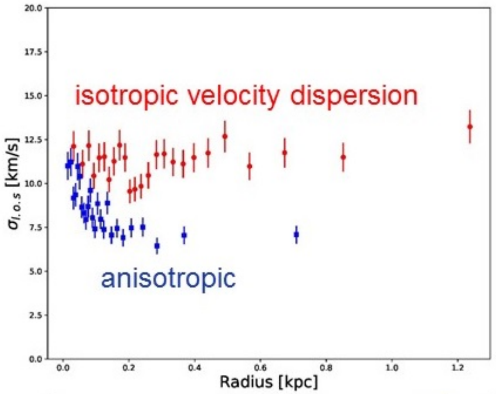
E. Komatsu
(D01)

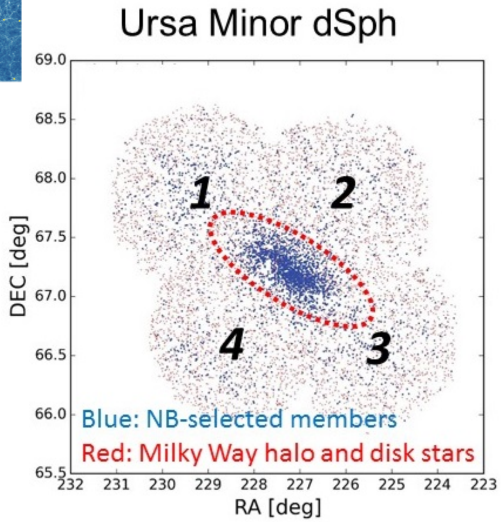


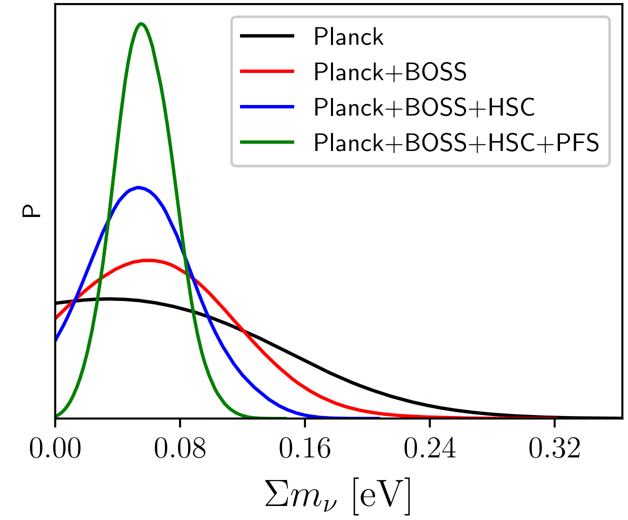


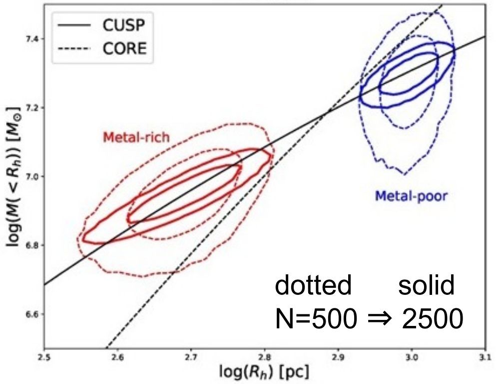








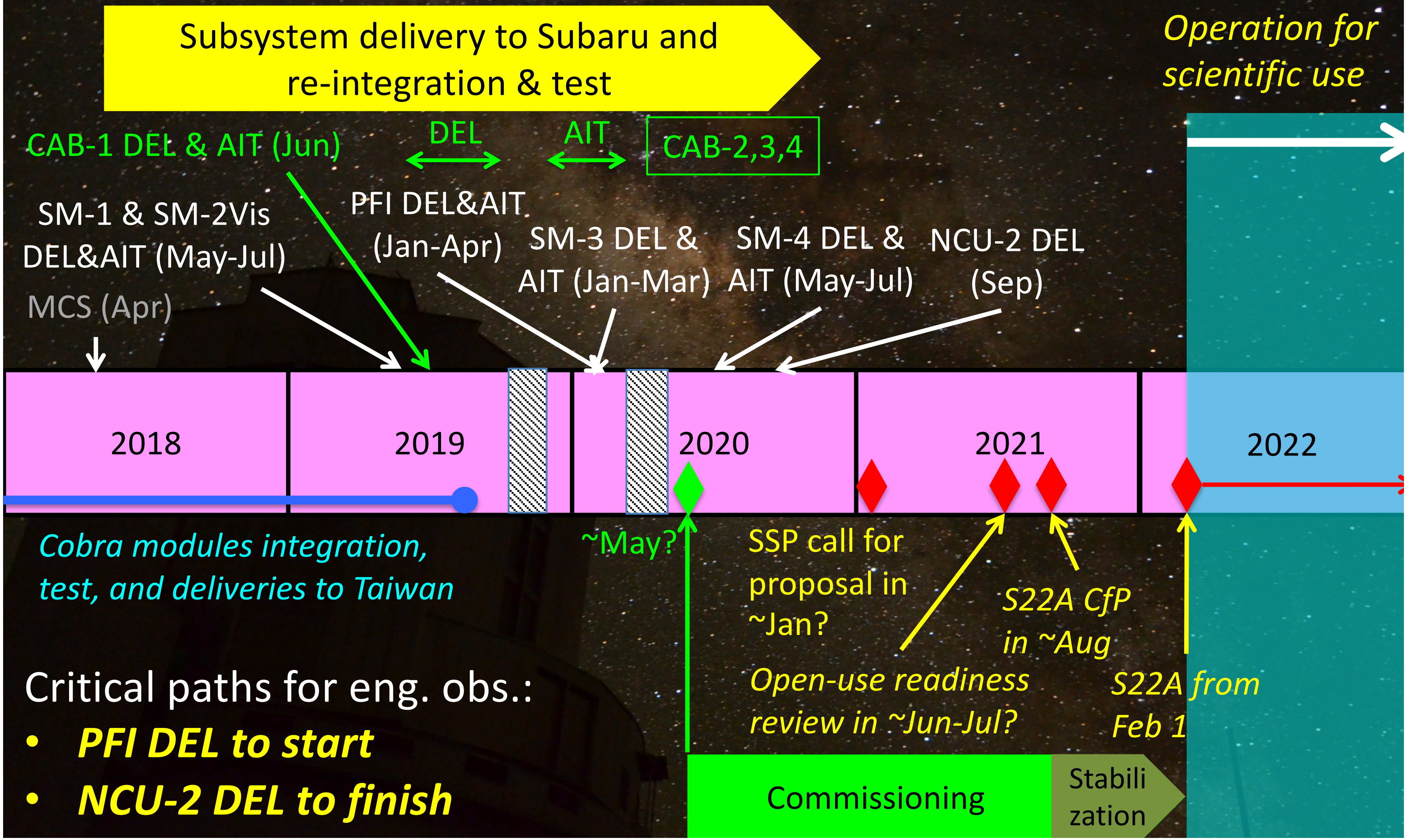




Updated top-level schedule

Optimizations are still ongoing.

"SM-N": Nth Spectrograph Module
"PFI": Prime Focus Instrument
"MCS": Metrology Camera System
"CAB-N": Nth Fiber Cable on Telescope



Subsystem delivery to Subaru and re-integration & test

Operation for scientific use

CAB-1 DEL & AIT (Jun)

DEL

AIT

CAB-2,3,4

SM-1 & SM-2Vis DEL&AIT (May-Jul)

MCS (Apr)

PFI DEL&AIT (Jan-Apr)

SM-3 DEL & AIT (Jan-Mar)

SM-4 DEL & AIT (May-Jul)

NCU-2 DEL (Sep)

2018

2019

2020

2021

2022

Cobra modules integration, test, and deliveries to Taiwan

~May?

SSP call for proposal in ~Jan?

S22A CfP in ~Aug

Open-use readiness review in ~Jun-Jul?

S22A from Feb 1

Commissioning

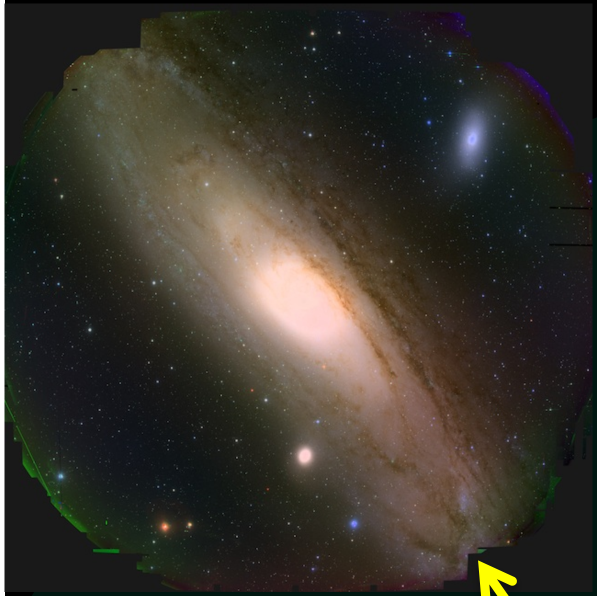
Stabilization

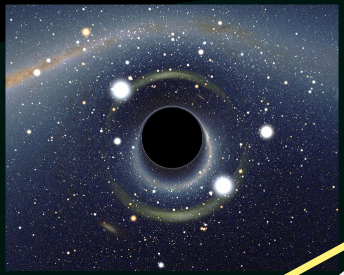
Critical paths for eng. obs.:

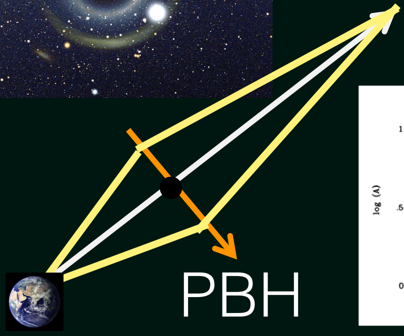
- ***PFI DEL to start***
- ***NCU-2 DEL to finish***

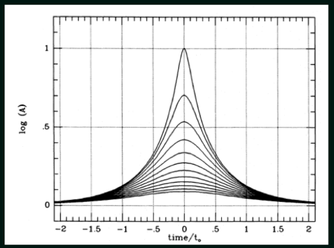
Constraining PBH with microlensing

Hiroko Niikura
(U. Tokyo/IPMU
just graduated!)

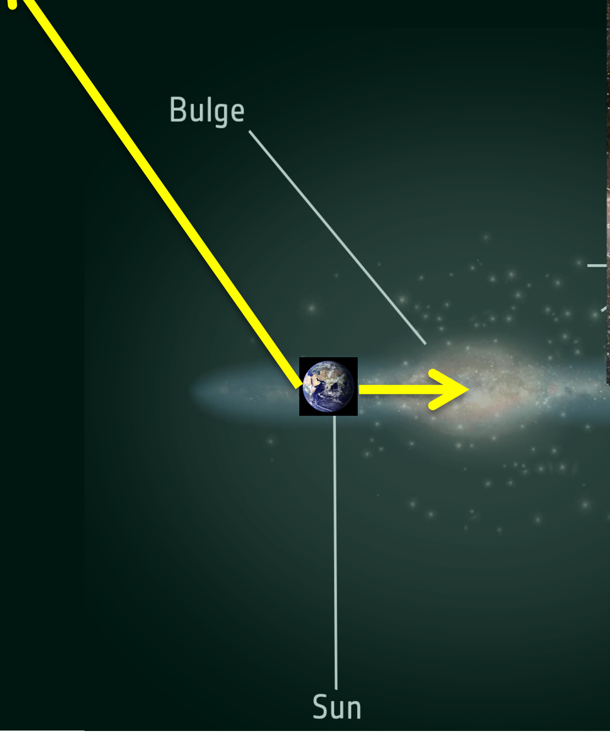


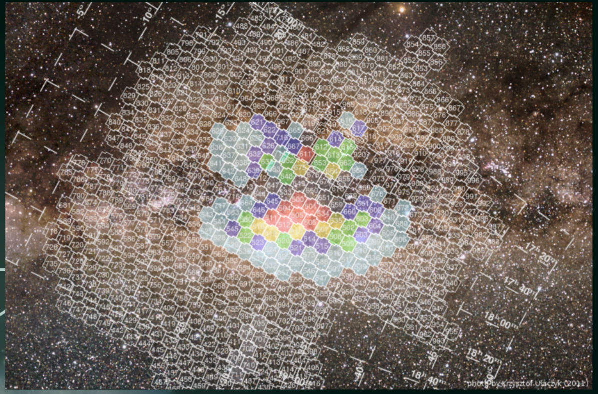






HSC M31
PBH
microlensing
search

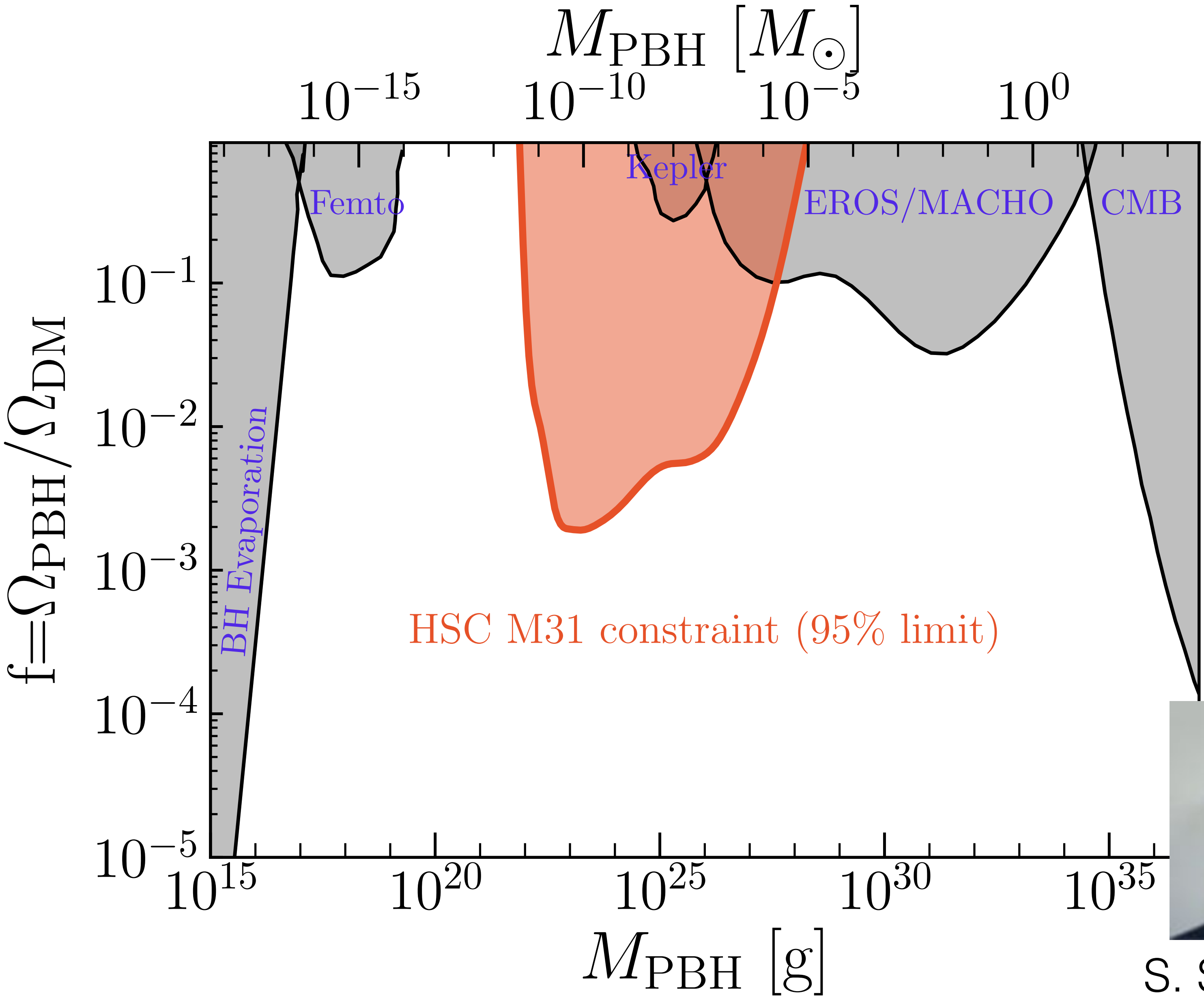


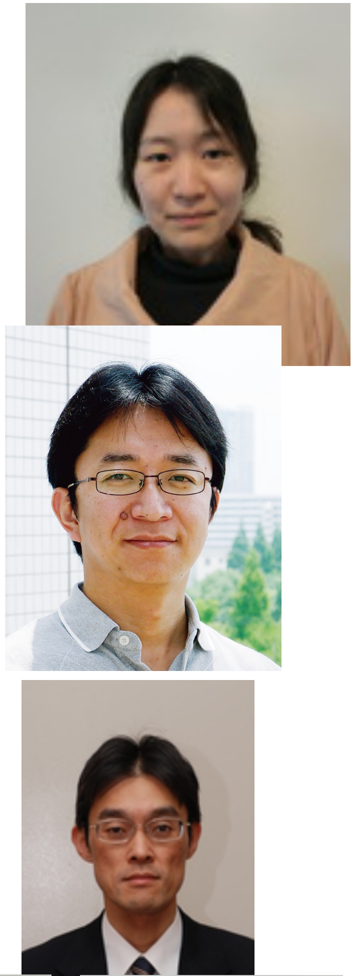


Use OGLE (Optical Gravitational Lensing Experiment) for PBH search

PBH constraints with HSC M31 ML search

Nature Astronomy in press (Niikura et al.)



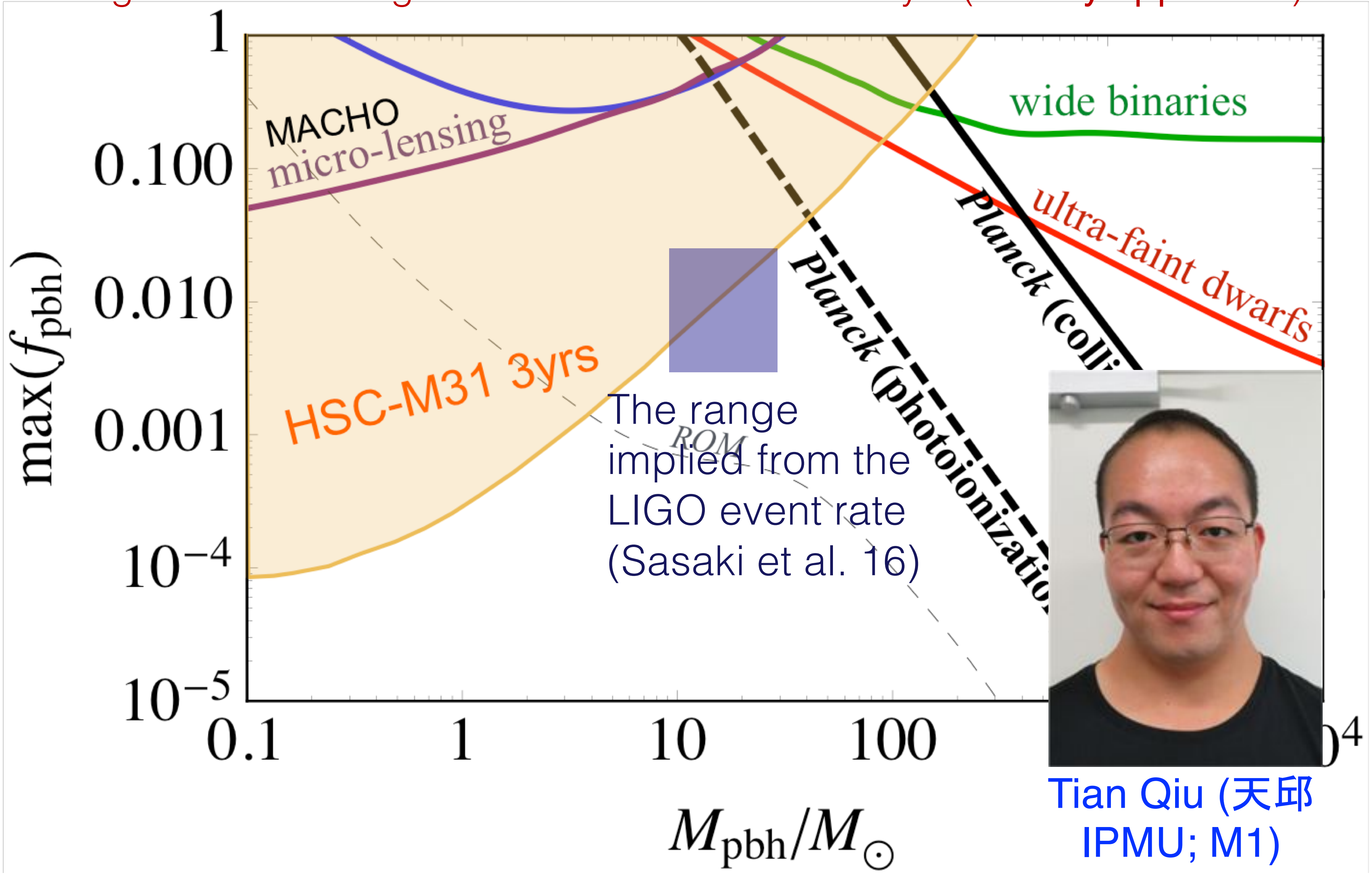


S. Sugiyama

T. Kurita

Constraining ~10Msun PBHs with HSC

a long-term monitoring obs of M31 with HSC over 3yrs (**already approved!**)



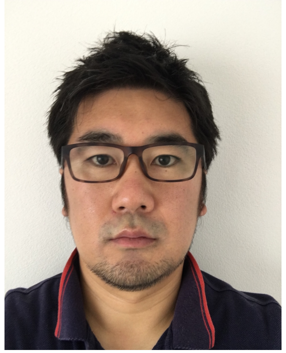
The range implied from the LIGO event rate (Sasaki et al. 16)

Tian Qiu (天邱
IPMU; M1)

Earth mass BH?

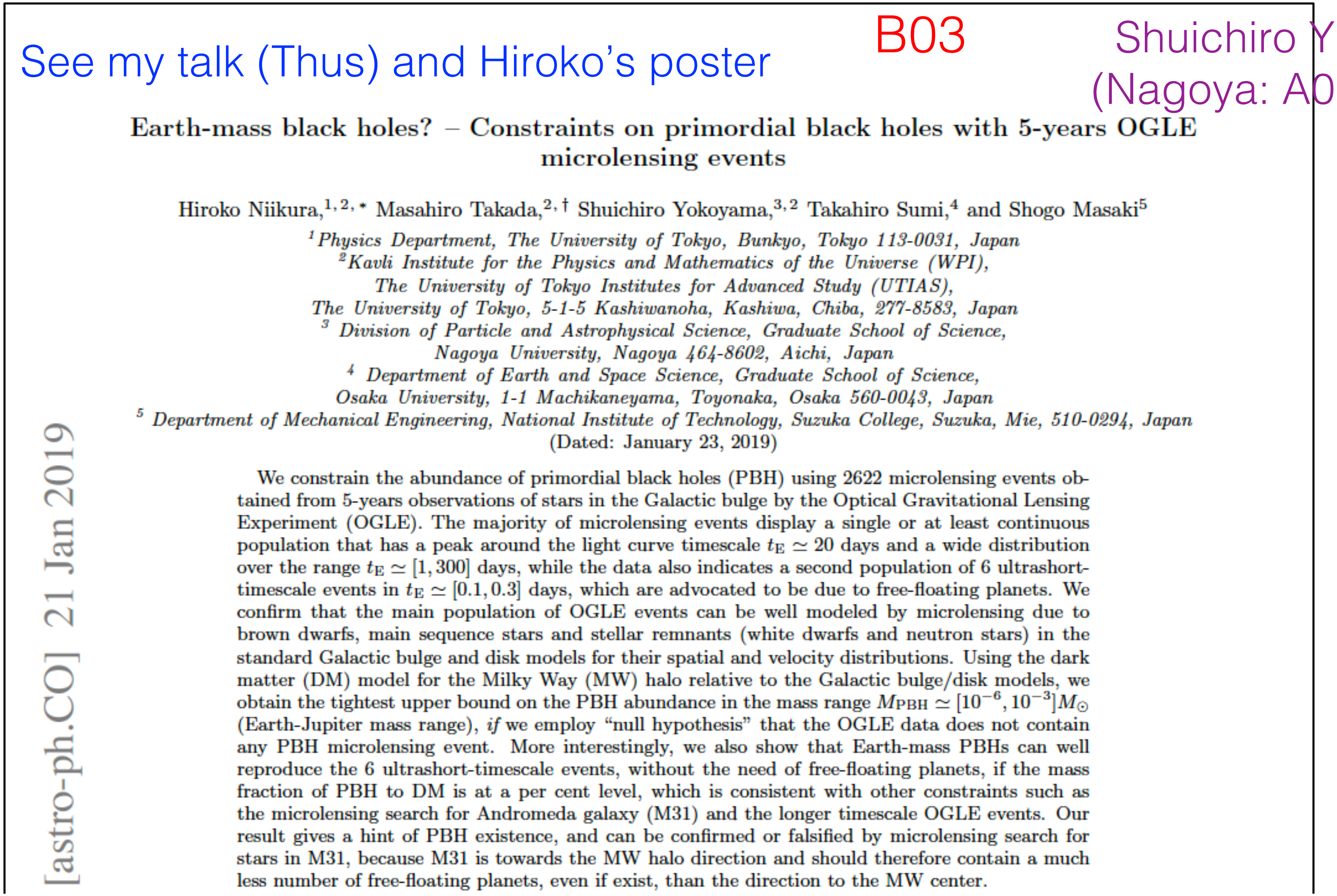
PRD in press

B03



Shuichiro Yokoyama
(Nagoya: A02 or A03?)

See my talk (Thus) and Hiroko's poster



[astro-ph.CO] 21 Jan 2019

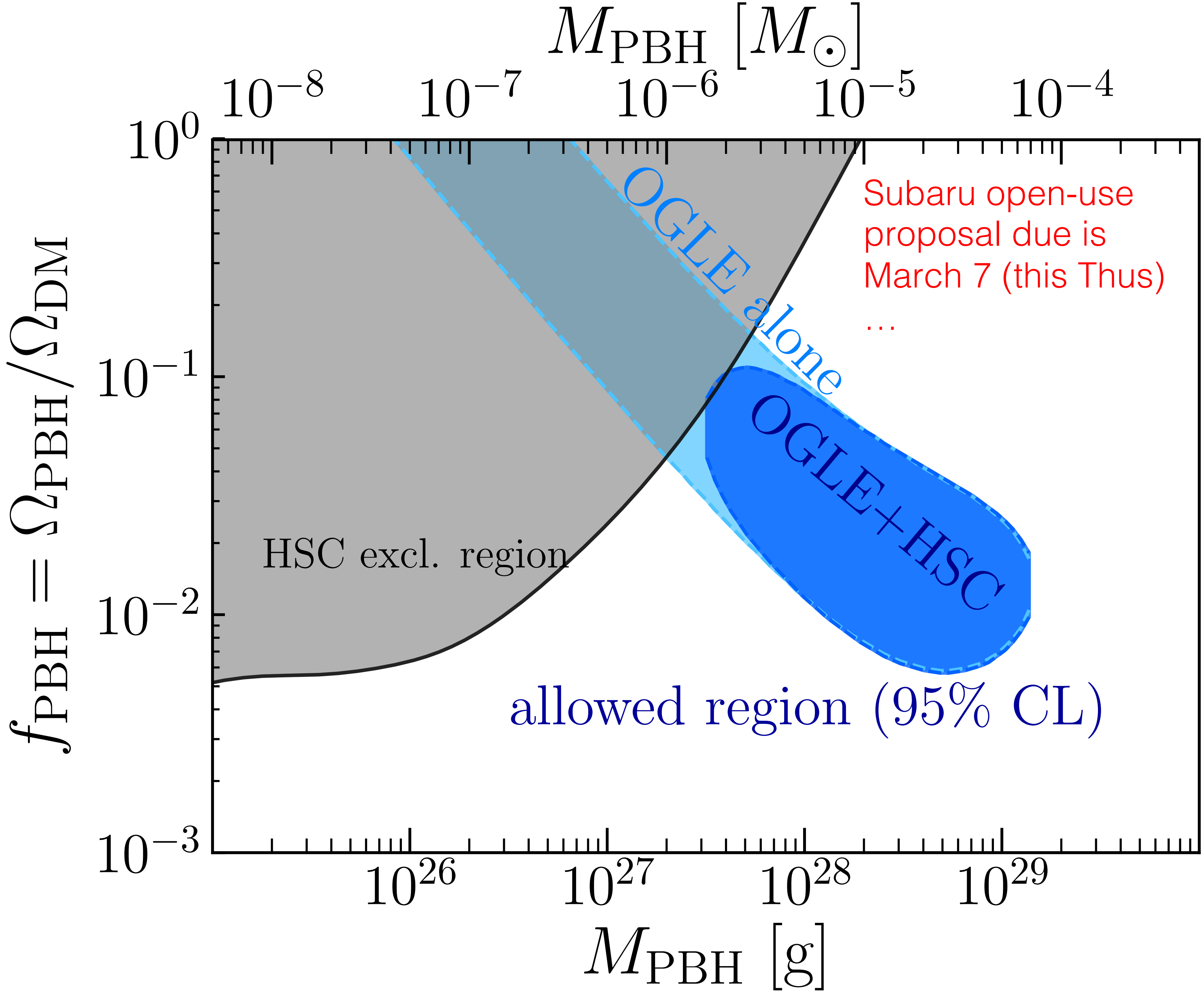
Earth-mass black holes? – Constraints on primordial black holes with 5-years OGLE microlensing events

Hiroko Niikura,[1,2,*] Masahiro Takada,[2,†] Shuichiro Yokoyama,[3,2] Takahiro Sumi,[4] and Shogo Masaki[5]

[1] *Physics Department, The University of Tokyo, Bunkyo, Tokyo 113-0031, Japan*
[2] *Kavli Institute for the Physics and Mathematics of the Universe (WPI),*
The University of Tokyo Institutes for Advanced Study (UTIAS),
The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, 277-8583, Japan
[3] *Division of Particle and Astrophysical Science, Graduate School of Science,*
Nagoya University, Nagoya 464-8602, Aichi, Japan
[4] *Department of Earth and Space Science, Graduate School of Science,*
Osaka University, 1-1 Machikaneyama, Toyonaka, Osaka 560-0043, Japan
[5] *Department of Mechanical Engineering, National Institute of Technology, Suzuka College, Suzuka, Mie, 510-0294, Japan*

(Dated: January 23, 2019)

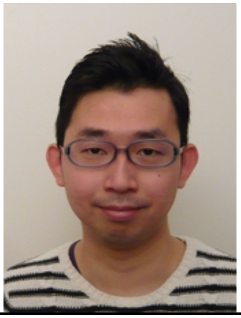
We constrain the abundance of primordial black holes (PBH) using 2622 microlensing events obtained from 5-years observations of stars in the Galactic bulge by the Optical Gravitational Lensing Experiment (OGLE). The majority of microlensing events display a single or at least continuous population that has a peak around the light curve timescale $t_{\rm E} \simeq 20$ days and a wide distribution over the range $t_{\rm E} \simeq [1, 300]$ days, while the data also indicates a second population of 6 ultrashort-timescale events in $t_{\rm E} \simeq [0.1, 0.3]$ days, which are advocated to be due to free-floating planets. We confirm that the main population of OGLE events can be well modeled by microlensing due to brown dwarfs, main sequence stars and stellar remnants (white dwarfs and neutron stars) in the standard Galactic bulge and disk models for their spatial and velocity distributions. Using the dark matter (DM) model for the Milky Way (MW) halo relative to the Galactic bulge/disk models, we obtain the tightest upper bound on the PBH abundance in the mass range $M_{\rm PBH} \simeq [10^{-6}, 10^{-3}]M_{\odot}$ (Earth-Jupiter mass range), *if* we employ "null hypothesis" that the OGLE data does not contain any PBH microlensing event. More interestingly, we also show that Earth-mass PBHs can well reproduce the 6 ultrashort-timescale events, without the need of free-floating planets, if the mass fraction of PBH to DM is at a per cent level, which is consistent with other constraints such as the microlensing search for Andromeda galaxy (M31) and the longer timescale OGLE events. Our result gives a hint of PBH existence, and can be confirmed or falsified by microlensing search for stars in M31, because M31 is towards the MW halo direction and should therefore contain a much less number of free-floating planets, even if exist, than the direction to the MW center.



Subaru open-use
proposal due is
March 7 (this Thus)
…

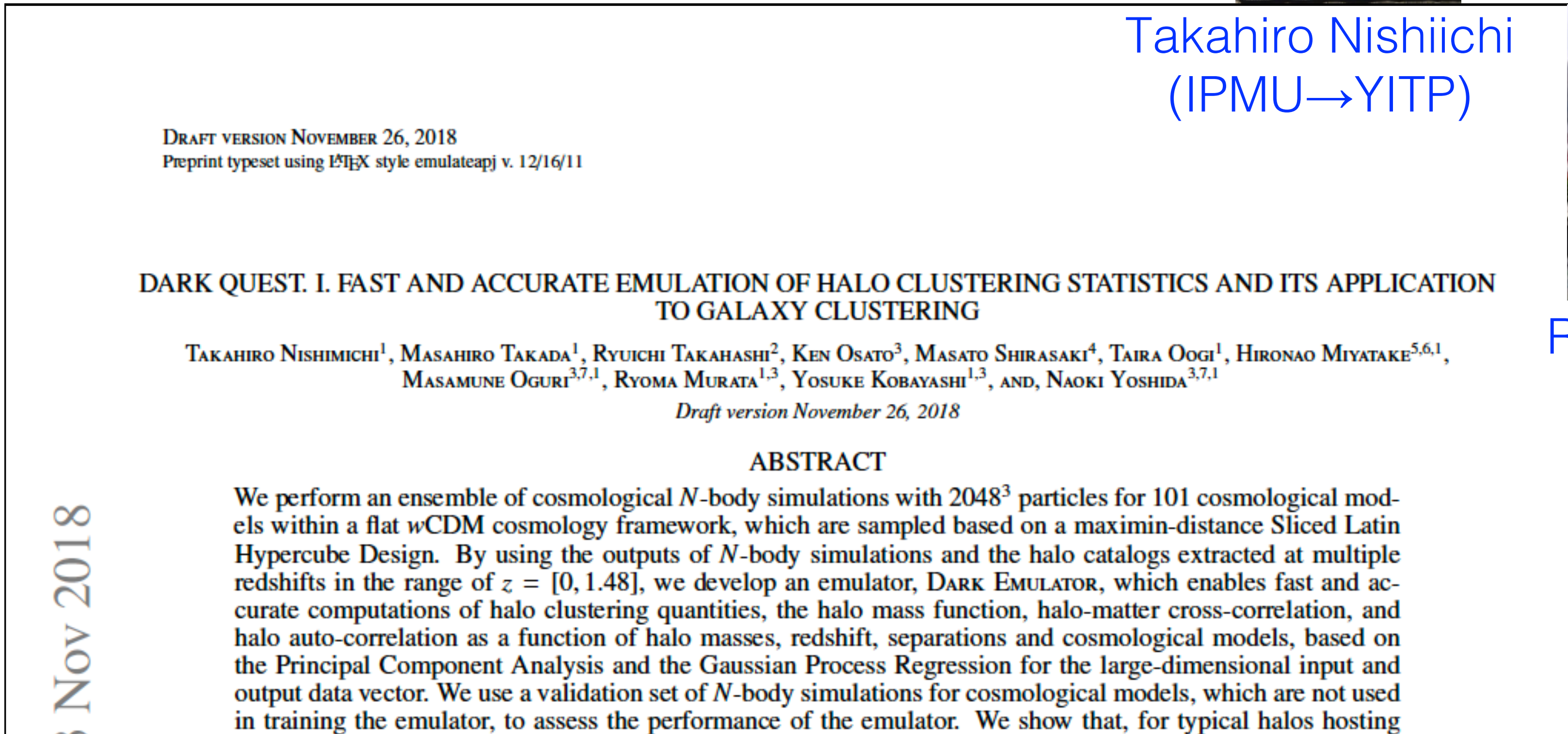
Dark Quest & Dark Emulator

Nishimichi, MT, Takahashi et al.



Takahiro Nishiichi
(IPMU→YITP)

R. Takahashi (B03)



DRAFT VERSION NOVEMBER 26, 2018
Preprint typeset using LaTeX style emulateapj v. 12/16/11

DARK QUEST. I. FAST AND ACCURATE EMULATION OF HALO CLUSTERING STATISTICS AND ITS APPLICATION TO GALAXY CLUSTERING

TAKAHIRO NISHIMICHI[1], MASAHIRO TAKADA[1], RYUICHI TAKAHASHI[2], KEN OSATO[3], MASATO SHIRASAKI[4], TAIRA OOGI[1], HIRONAO MIYATAKE[5,6,1],
MASAMUNE OGURI[3,7,1], RYOMA MURATA[1,3], YOSUKE KOBAYASHI[1,3], AND, NAOKI YOSHIDA[3,7,1]

Draft version November 26, 2018

v1 [astro-ph.CO] 23 Nov 2018

ABSTRACT

We perform an ensemble of cosmological N-body simulations with 2048^3 particles for 101 cosmological models within a flat wCDM cosmology framework, which are sampled based on a maximin-distance Sliced Latin Hypercube Design. By using the outputs of N-body simulations and the halo catalogs extracted at multiple redshifts in the range of $z = [0, 1.48]$, we develop an emulator, DARK EMULATOR, which enables fast and accurate computations of halo clustering quantities, the halo mass function, halo-matter cross-correlation, and halo auto-correlation as a function of halo masses, redshift, separations and cosmological models, based on the Principal Component Analysis and the Gaussian Process Regression for the large-dimensional input and output data vector. We use a validation set of N-body simulations for cosmological models, which are not used in training the emulator, to assess the performance of the emulator. We show that, for typical halos hosting
CMASS galaxies in the Sloan Digital Sky Survey, the -matter cross correlation, rel-
evant for galaxy-galaxy weak lensing, with an accura alo auto-c
for galaxy clustering correlation, with an accuracy bett l demonst
of the emulator. For instance, the emulator outputs can s of halo m
such as the mass-concentration relation and splashbac gy and re
We also show that the emulator outputs can be combin iption of h
tion such as the halo occupation distribution at the equ g the moc
accurate predictions of galaxy clustering statistics su eak lensin
correlation function for any model within the wCDM ime of a fe
Keywords: large-scale structure of the universe — nu hine learni

1. INTRODUCTION

Cosmic large-scale structures are promising avenues to fundamental questions in cosmology. Various wide-area imaging

ellite
syste
the g
in the relation between distributions

Y. Kobayashi
(IPMU: D2)

M. Oguri (B02)

M. Shirasaki
(NAOJ: solicited)

H. Miyatake
(Nagoya: solicited)

Dark Quest

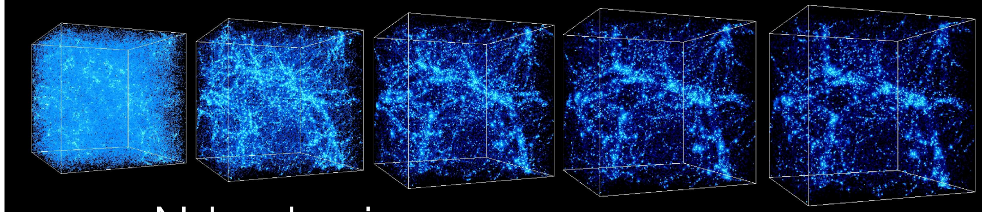
- Towards an accurate modeling of nonlinear structure formation

specify wCDM model

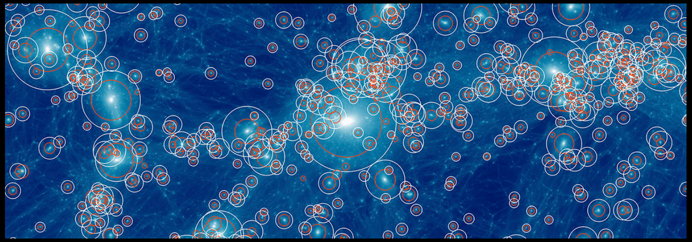
$$p_\alpha = \{\omega_\mathrm{c}, \omega_\mathrm{b}, \Omega_\mathrm{de}, \ln(10^{10}A_s), n_s, w_\mathrm{de}\}$$

Credit:NAOJ

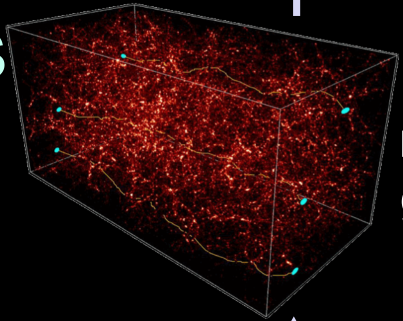
~a few days



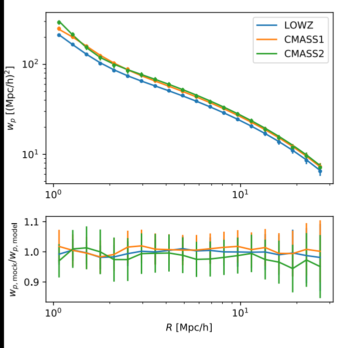
run N-body sim.



post processing (identify halos ~ place where galaxies form)



make a mock of galaxy survey (gals, lensing fields, …)



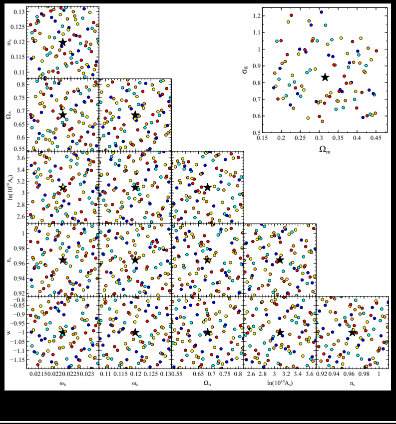
a measurement from the mock

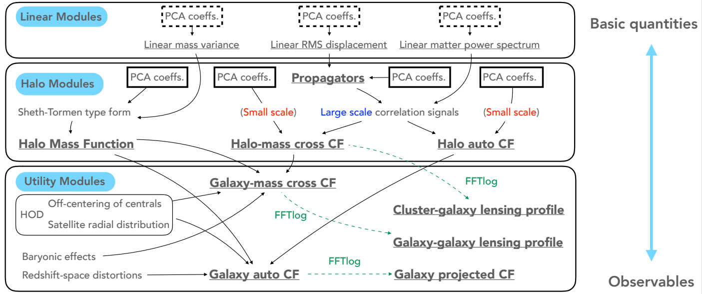
Dark Emulator

Nishimichi et al. +18

- Stored all data (~200TB)
- Gauss process & ML
- Make an “emulator” from the tabulated data

Allow a fast computation of galaxy clustering observables (<1sec)





Linear Modules

PCA coeffs. → Linear mass variance

PCA coeffs. → Linear RMS displacement

PCA coeffs. → Linear matter power spectrum

Halo Modules

PCA coeffs. → Sheth-Tormen type form → Halo Mass Function

PCA coeffs. → (Small scale) → Halo-mass cross CF

PCA coeffs. → Propagators → Large scale correlation signals

PCA coeffs. → (Small scale) → Halo auto CF

Utility Modules

Galaxy-mass cross CF

HOD: Off-centering of centrals, Satellite radial distribution

Baryonic effects

Redshift-space distortions → Galaxy auto CF

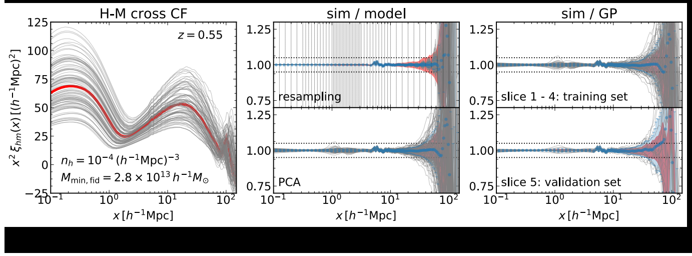
FFTlog → Cluster-galaxy lensing profile

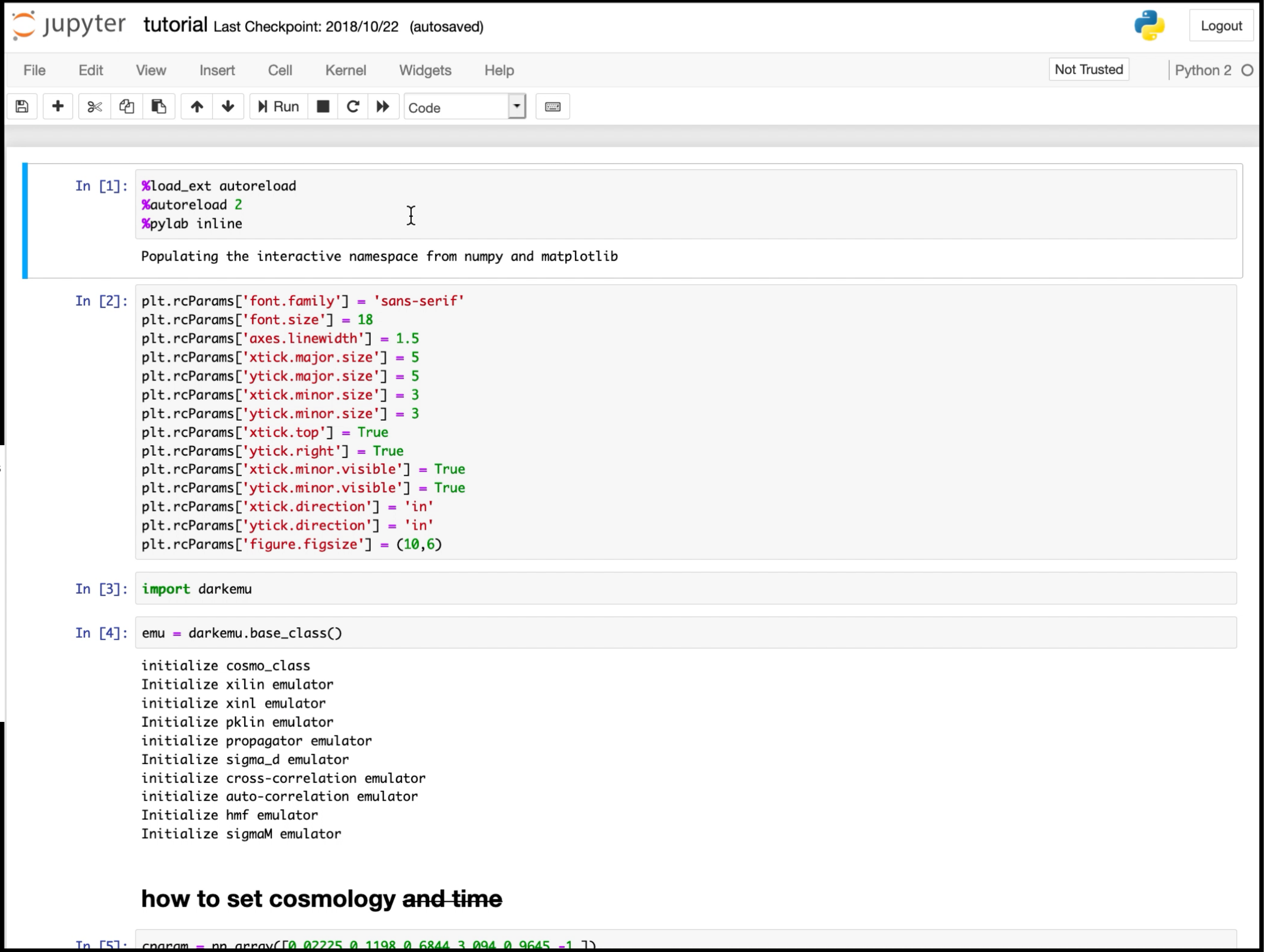
FFTlog → Galaxy-galaxy lensing profile

FFTlog → Galaxy projected CF

Basic quantities

Observables





In [1]:
```
%load_ext autoreload
%autoreload 2
%pylab inline
```

```
Populating the interactive namespace from numpy and matplotlib
```

In [2]:
```
plt.rcParams['font.family'] = 'sans-serif'
plt.rcParams['font.size'] = 18
plt.rcParams['axes.linewidth'] = 1.5
plt.rcParams['xtick.major.size'] = 5
plt.rcParams['ytick.major.size'] = 5
plt.rcParams['xtick.minor.size'] = 3
plt.rcParams['ytick.minor.size'] = 3
plt.rcParams['xtick.top'] = True
plt.rcParams['ytick.right'] = True
plt.rcParams['xtick.minor.visible'] = True
plt.rcParams['ytick.minor.visible'] = True
plt.rcParams['xtick.direction'] = 'in'
plt.rcParams['ytick.direction'] = 'in'
plt.rcParams['figure.figsize'] = (10,6)
```

In [3]:
```
import darkemu
```

In [4]:
```
emu = darkemu.base_class()
```

```
initialize cosmo_class
Initialize xilin emulator
initialize xinl emulator
Initialize pklin emulator
Initialize propagator emulator
Initialize sigma_d emulator
initialize cross-correlation emulator
initialize auto-correlation emulator
Initialize hmf emulator
Initialize sigmaM emulator
```

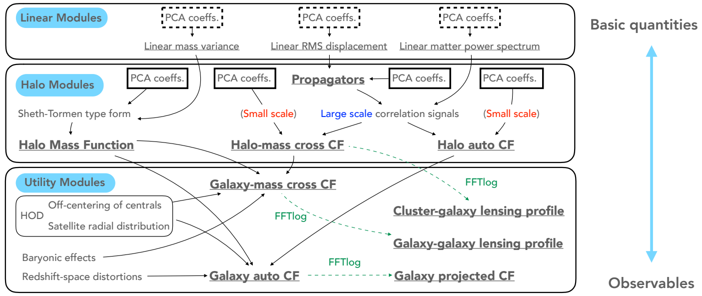
how to set cosmology ~~and time~~

In [5]:
```
cparam = np.array([0.02225,0.1198,0.6844,3.094,0.9645,-1.])
```

Cosmology challenges: validation of method

See Hironao’s talk (Thus) and Yosuke’s poster

- Cosmology with HSC + SDSS (imaging + spectroscopic surveys): Miyatake + in prep.



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Linear mass variance

Linear RMS displacement

Linear matter power spectrum

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PCA coeffs.

Sheth-Tormen type form

(Small scale)

Large scale correlation signals

(Small scale)

Halo Mass Function

Halo-mass cross CF

Halo auto CF

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Satellite radial distribution

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Galaxy-galaxy lensing profile

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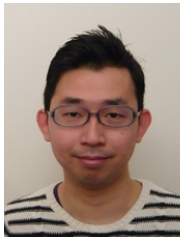
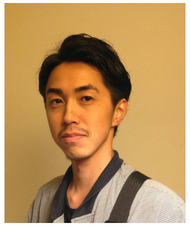
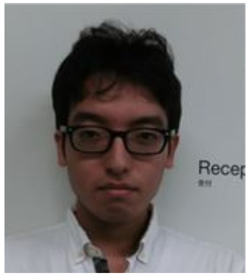
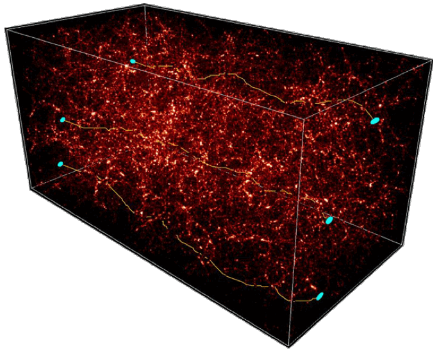


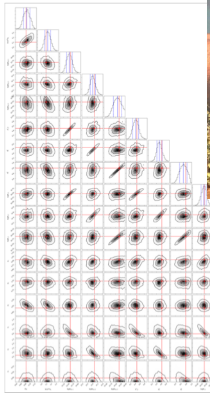




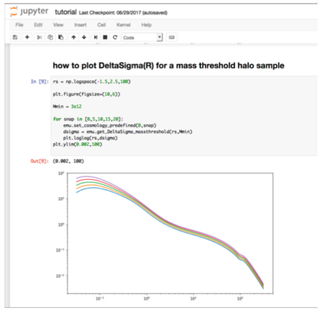
Y. Kobayashi



Make mock of HSC/SDSS surveys using a prescription of galaxy-halo connection



Blind cosmological parameter inference (MCMC)



jupyter tutorial Last Checkpoint: 06/29/2017 (autosaved)

how to plot DeltaSigma(R) for a mass threshold halo sample

```
In [9]: rs = np.logspace(-1.5,2.5,100)

        plt.figure(figsize=(10,6))

        Mmin = 3e12

        for snap in [0,5,10,15,20]:
            emu.set_cosmology_predefined(0,snap)
            dsigma = emu.get_DeltaSigma_massthreshold(rs,Mmin)
            plt.loglog(rs,dsigma)
        plt.ylim(0.002,100)

Out[9]: (0.002, 100)
```