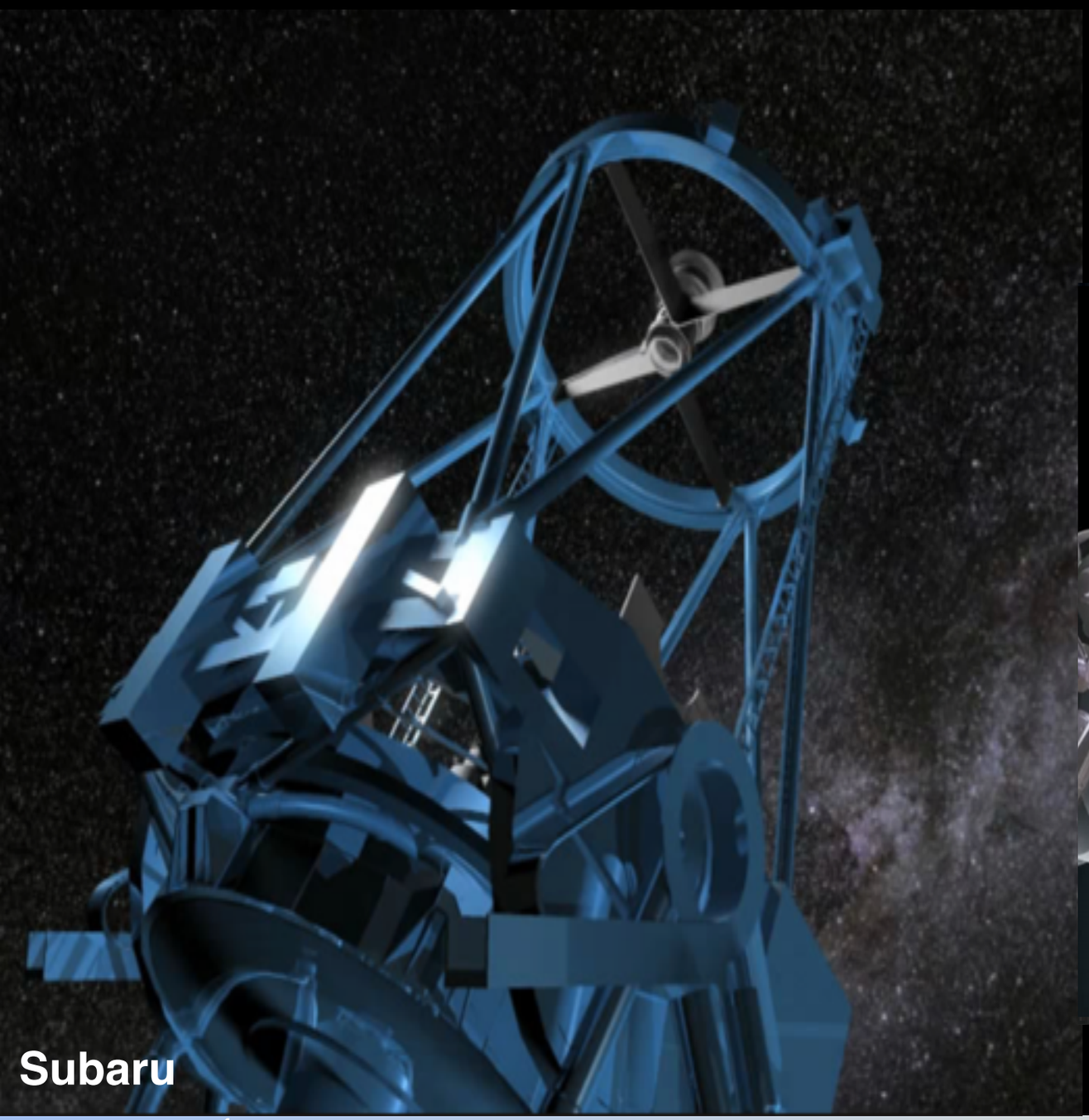
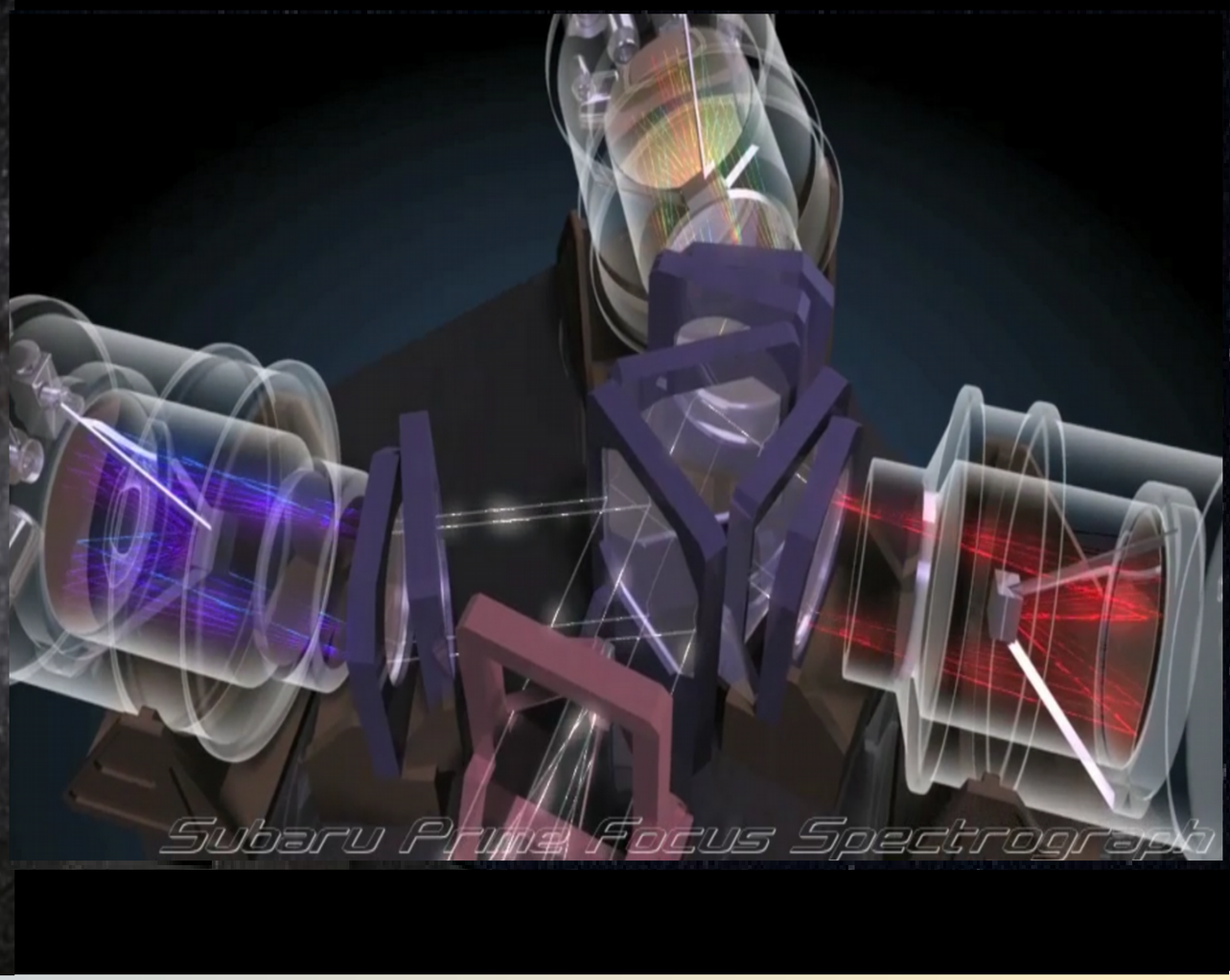
SuMIRe : HSC + PFS

SUbaru **M**easurements of **I**mages and **RE**dshifts

PI: Hitoshi Murayama (IPMU & Berkeley)



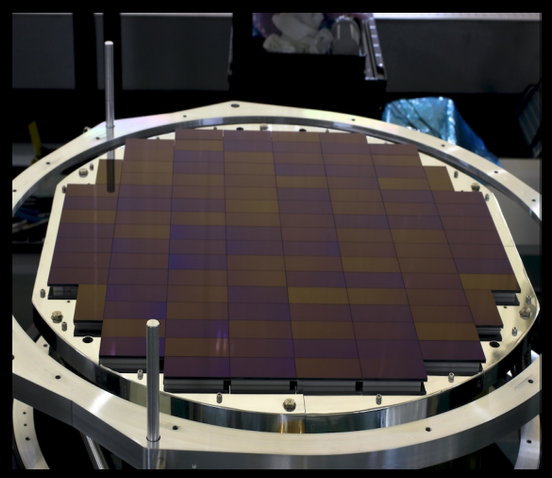


SuMIRe

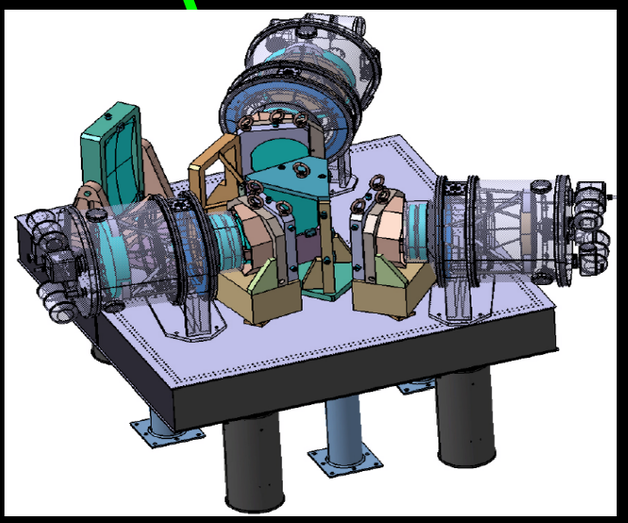
Subaru Measurements of Images and Redshifts

- a 5+5 year survey program
- exploiting FOV ~1.5° of 8.2m Subaru
- Imaging with HyperSuprimeCam (HSC)
  - ~870M pixels
  - Wide, Deep, Ultra-Deep, *grizy*
  - 2014–2019, 300 nights
- spectroscopy with PrimeFocusSpectrograph (PFS)
  - ~2400 optical fibers
  - 0.38–1.26μm
  - **2022 - 2027+ ~360 nights**

Subaru



HSC



PFS

SuMIRe

Subaru Measurements of Images and Redshifts

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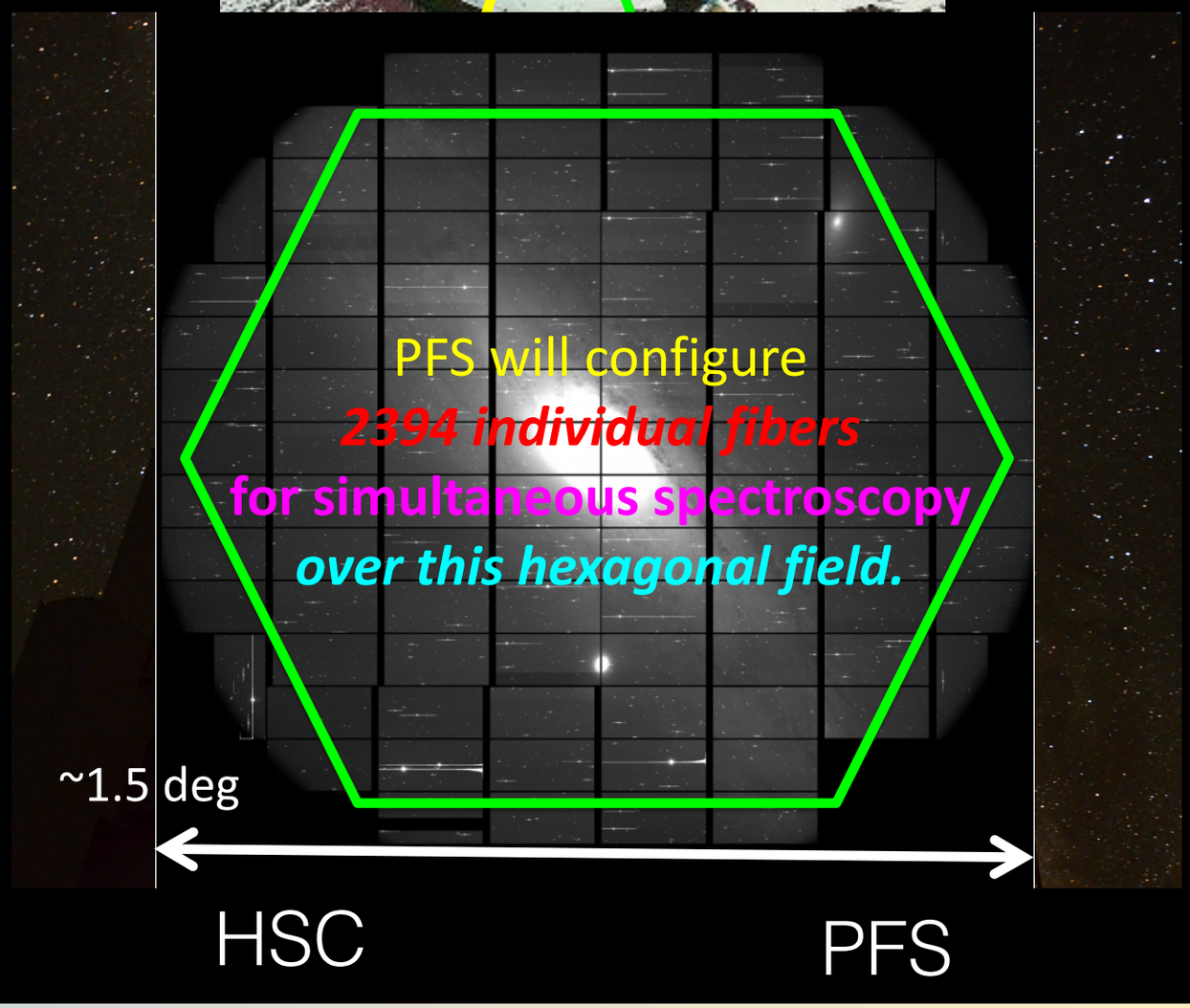
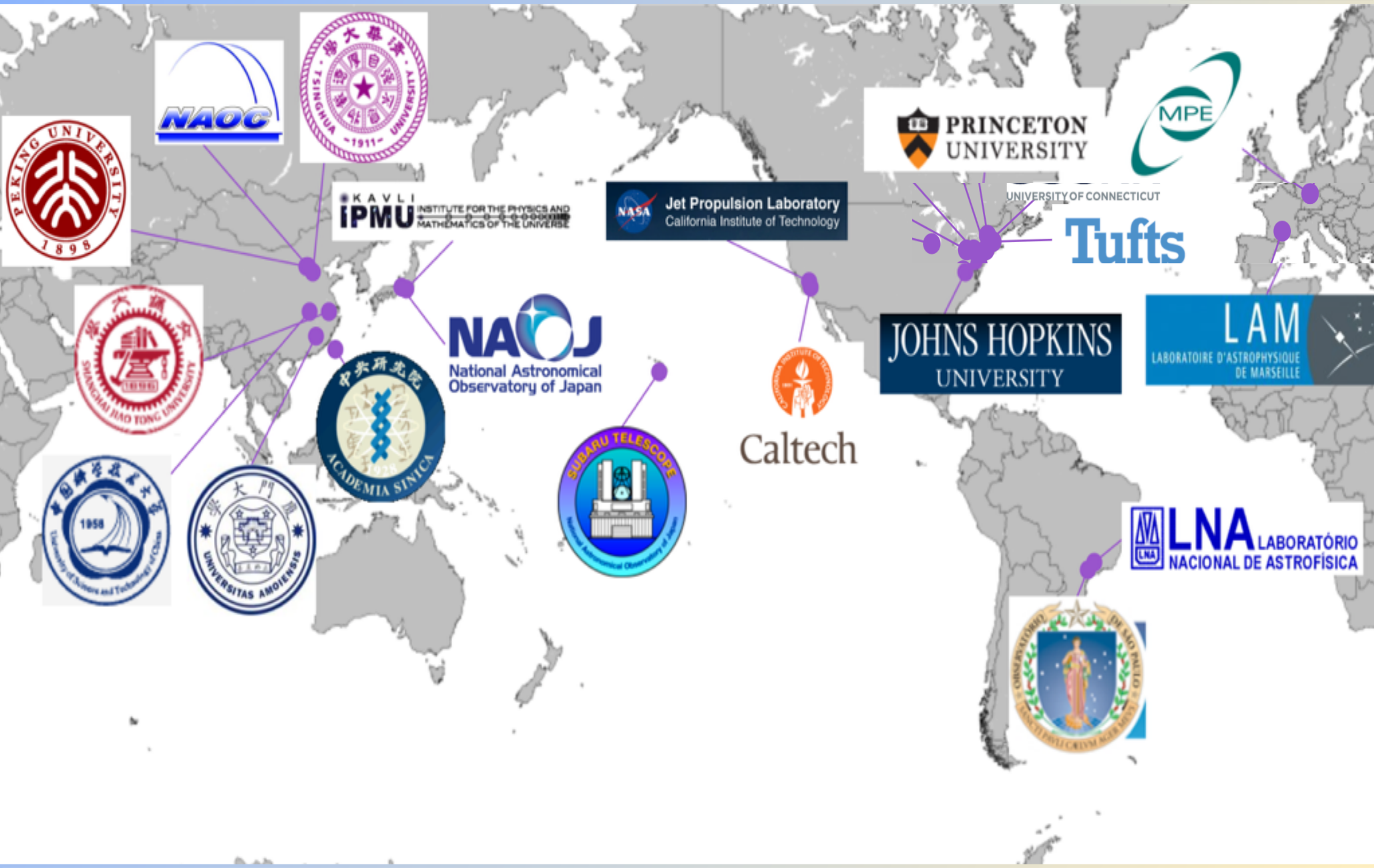


A growing international collaboration

Prime Focus Spectrograph
SuMIRe



Outline

* **Presentation**
  - **SuMIRe: HSC + PFS instruments**

* **LAM contributions :**
  - spectrographs SM1-4 integration (D. Le Mignant / F. Madec)
  - PFS 1D Data Reduction Pipeline (V. LeBrun)
  - Science …

* **Science preparation for the Strategic Subaru Program (SSP)**
  - Galaxy archeology (S. Arnouts)
  - Galaxy evolution (S. Arnouts)
  - Cosmology (S. de la Torre)

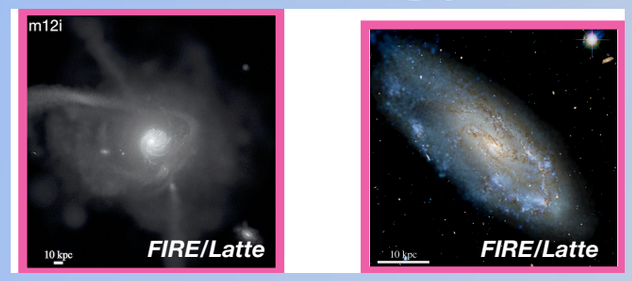
* **PFS membership**

Prime Focus Spectrograph (PFS)

three science Pillars

Galactic Archeology

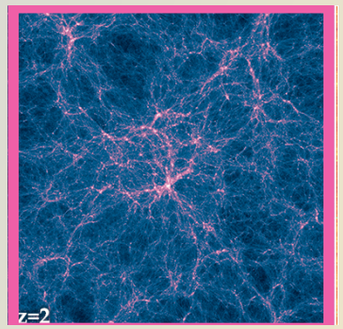
DM profiles
Assembly history



Andromeda streams & halos
Milky way disks
Dwarf galaxies

Cosmology

cosmo. parameters
neutrino mass
BAO, RSD, PS



4 million of Emission lines
over 1400 deg2 in
0.6<z<2.4

Galaxy Evolution

Galaxies & their environments
(0.7<z<7)
IGM tomography (Ly-a forest at z>2)
End of Reionization(LAE z>5.5)

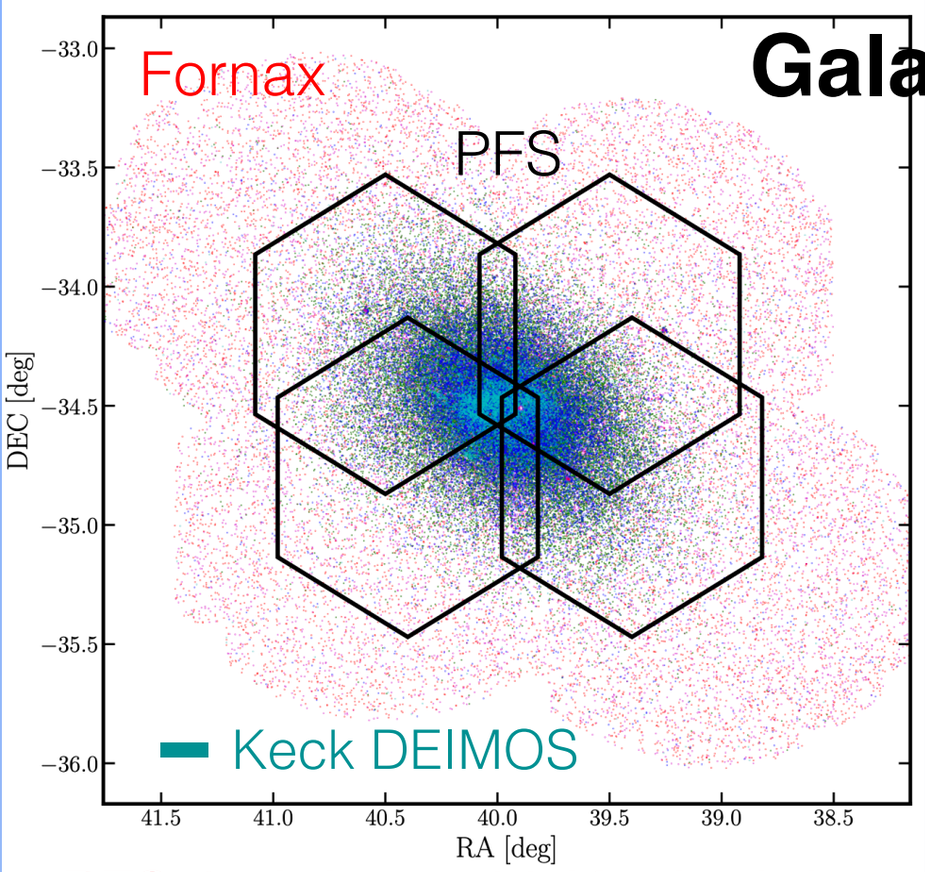
350,000 spectra over 25 deg2

Galactic Archaeology

- MW dwarf satellites
  - DM halo profile and [Fe/H] & [α/Fe] over largest areas
- M31 halo
  - DM subhalos, chemo-dynamics with spectroscopic [Fe/H] and [α/Fe]
- MW halo/streams/disks
  - Chemo-dynamics of the MW outer disks, halo dynamics, constraints on the Galactic potential

different chemical abundances
produced on
different time scale

Galactic archeology : dwarf galaxies

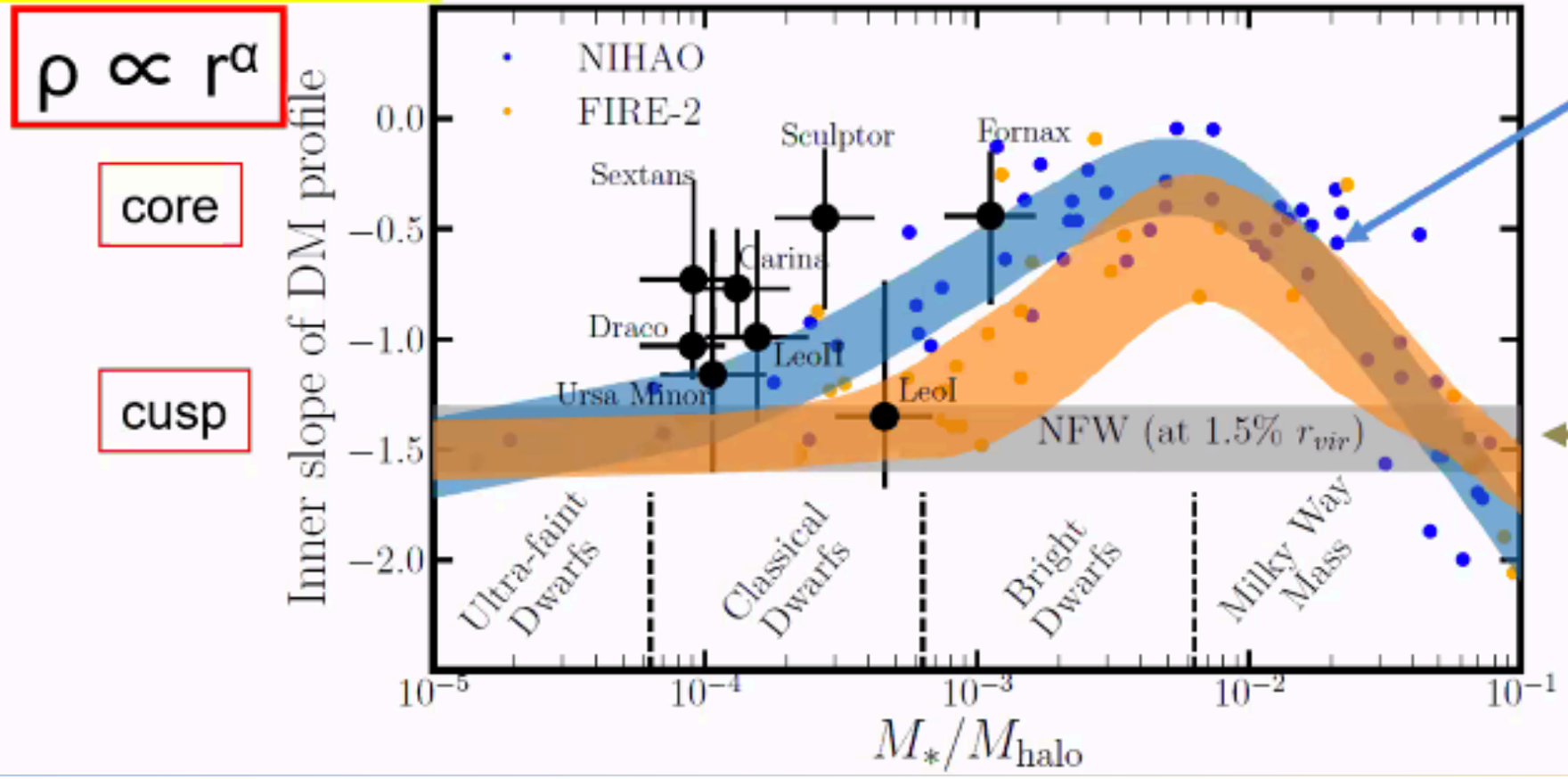


PFS 1 nights ~ 60 Keck nights

PFS unique to map dSphs
up to their tidal radii

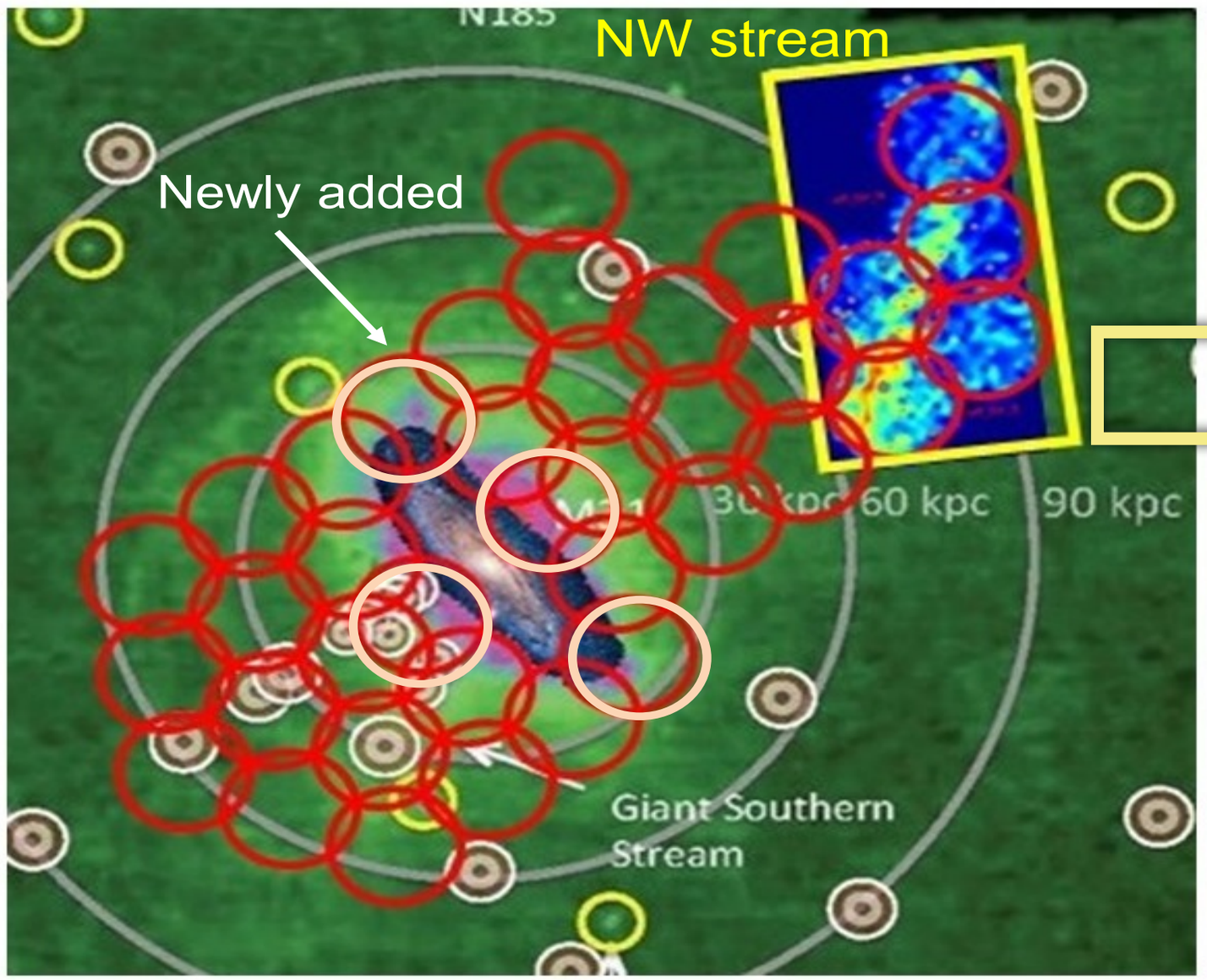
Baryonic feedback effects on CDM cusp
or other DMs ?

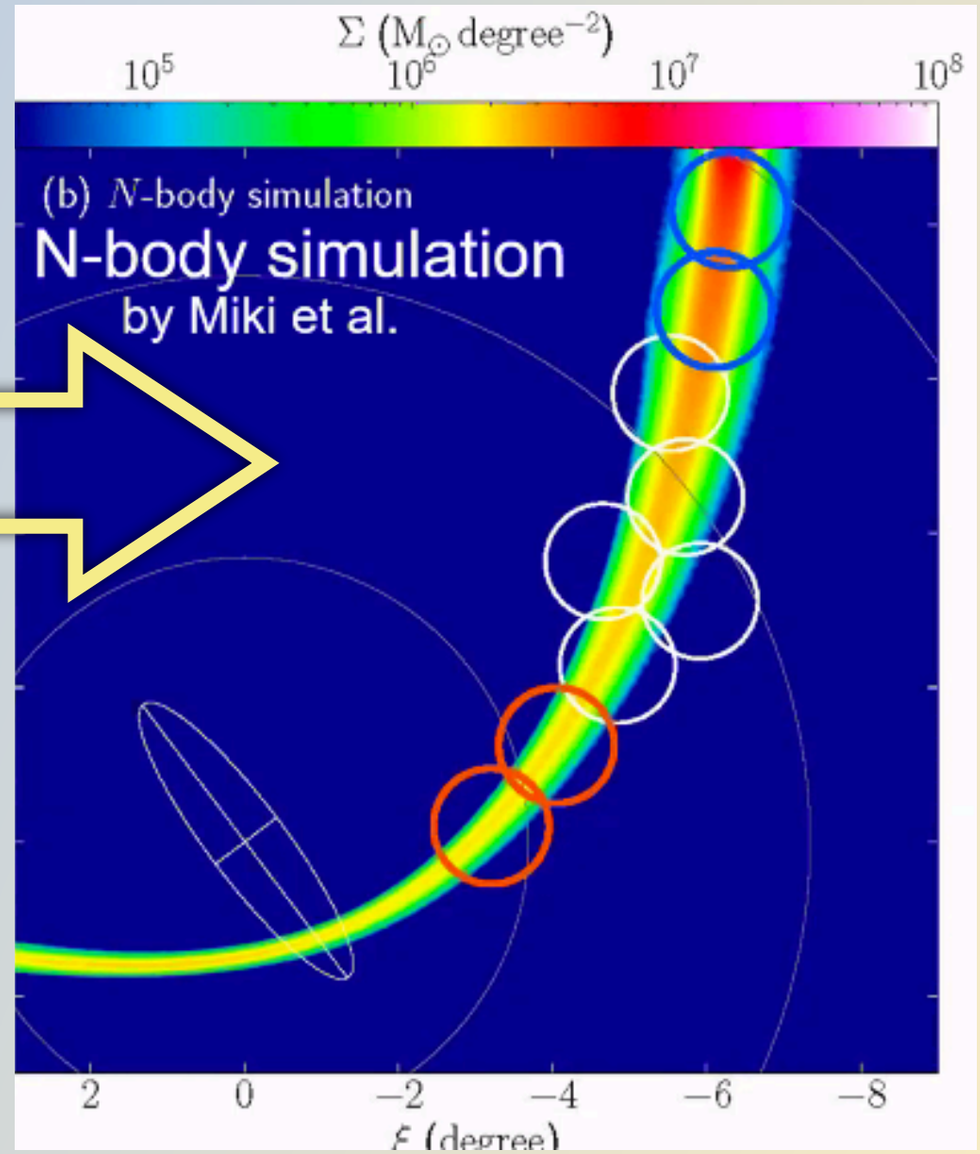
Hayashi et al. (2020a)



Galactic archeology : M31

PFS pointings for M31's halo

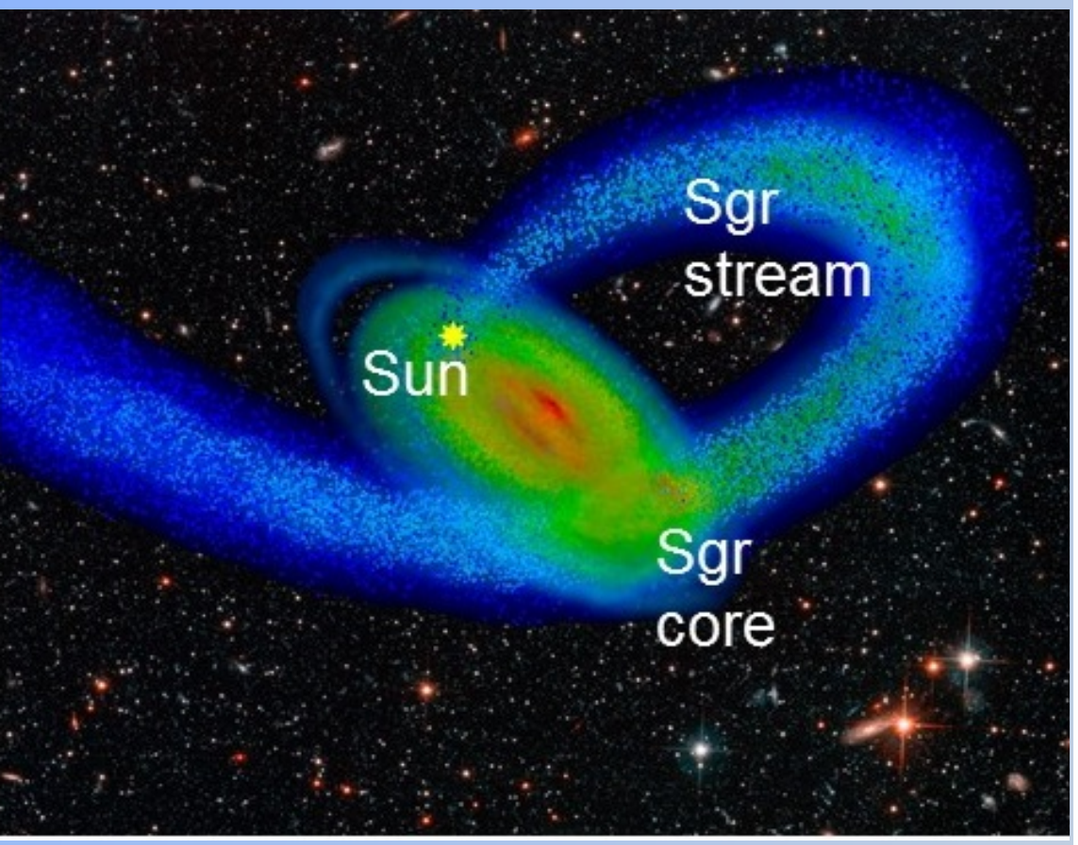


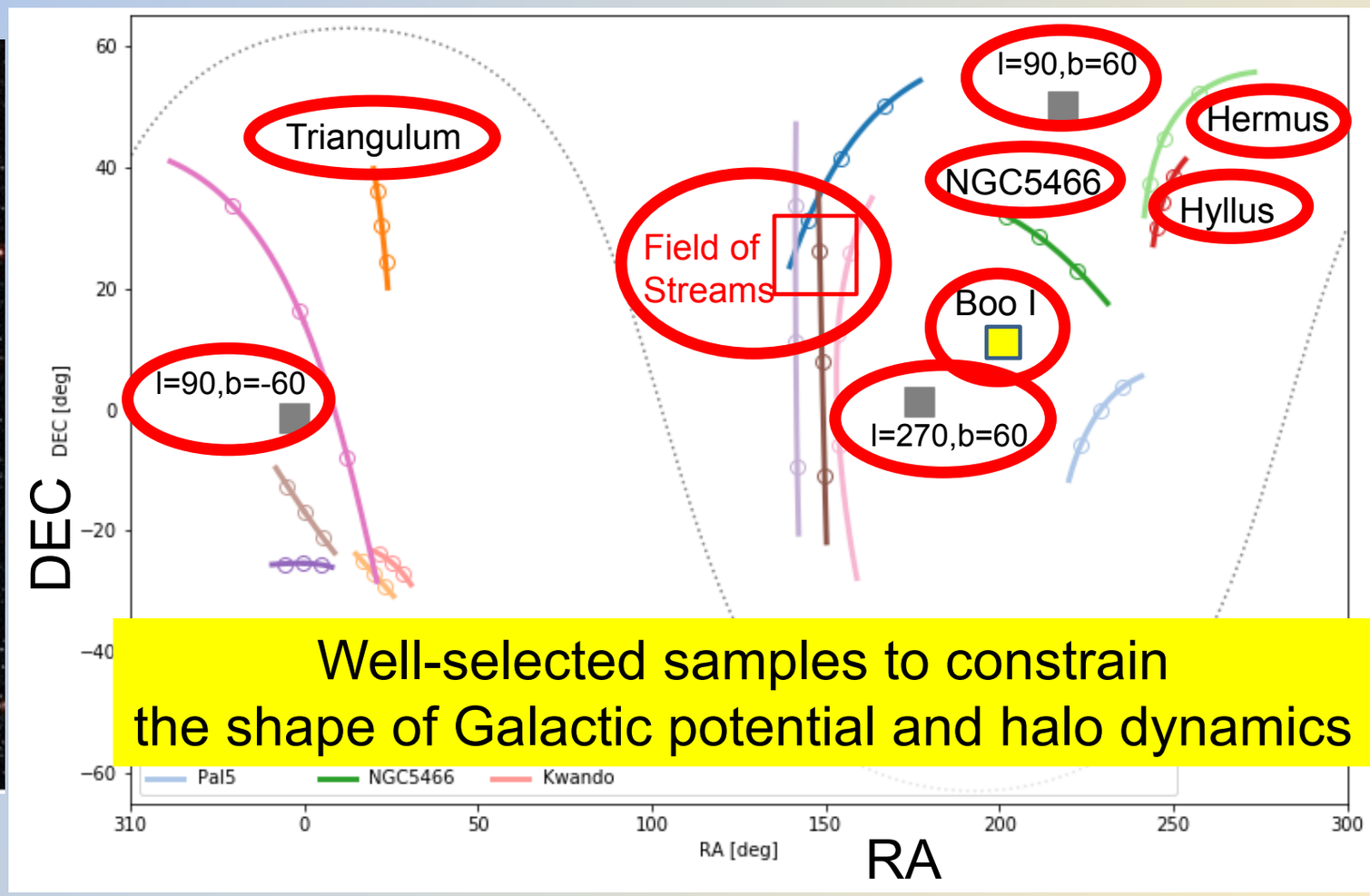


- to constrain DM subhalos and chemo-dynamics of M31
- to constrain galaxy progenitor of the NW stream

Galactic archeology : Milky Way

MW outer disk





To infer history of MW disks

- Streams for merger histories
- Halo streams to constrain Galactic potential

Prime Focus Spectrograph (PFS)

three science Pillars

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Dwarf galaxies

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cosmo. parameters
neutrino mass
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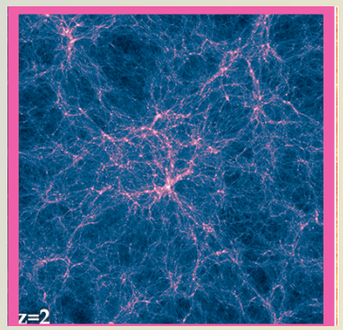

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350,000 spectra over 25 deg2

PFS Galaxy Evolution

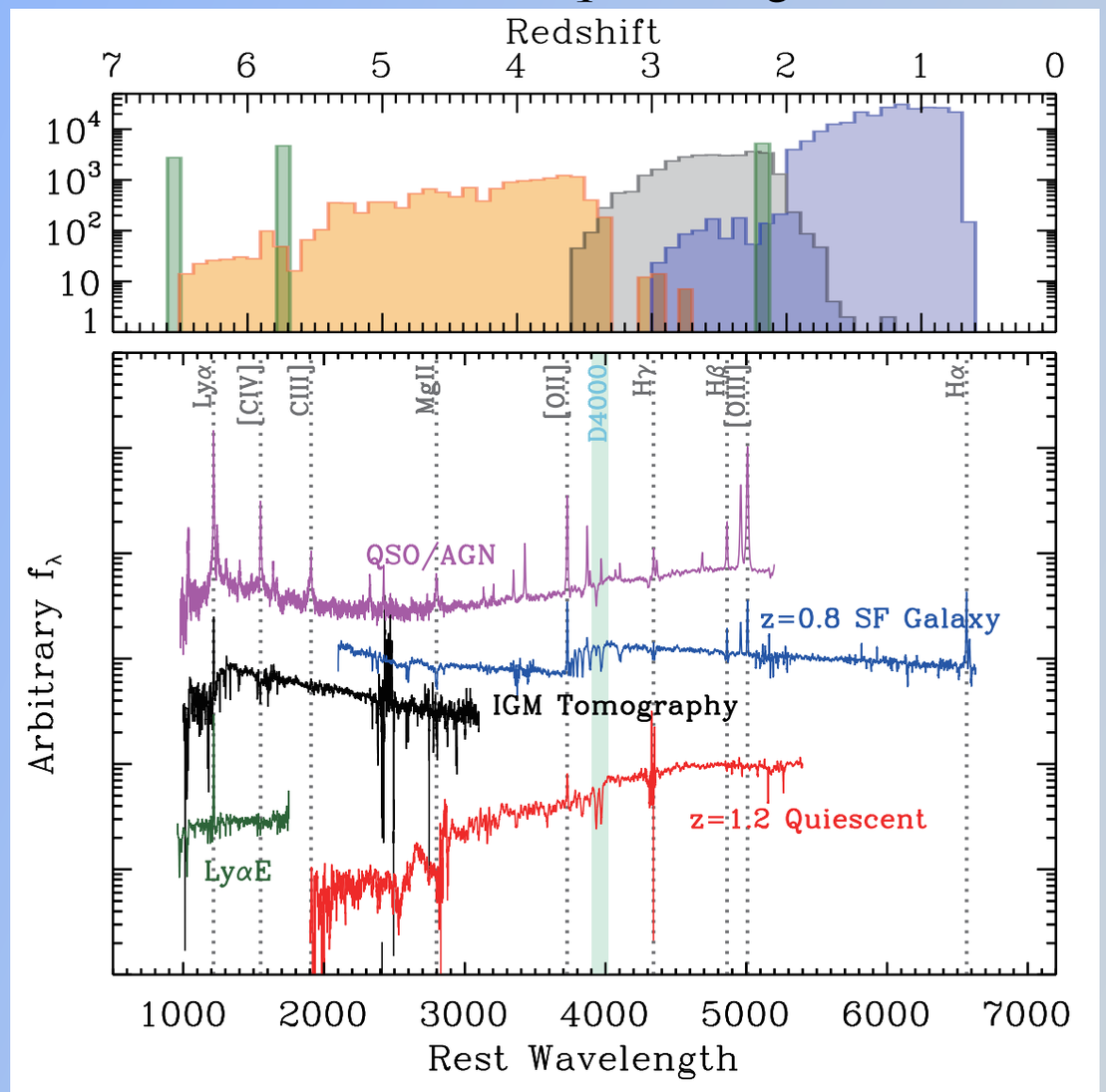
A comprehensive study of galaxy and IGM evolution over a wide z & envt

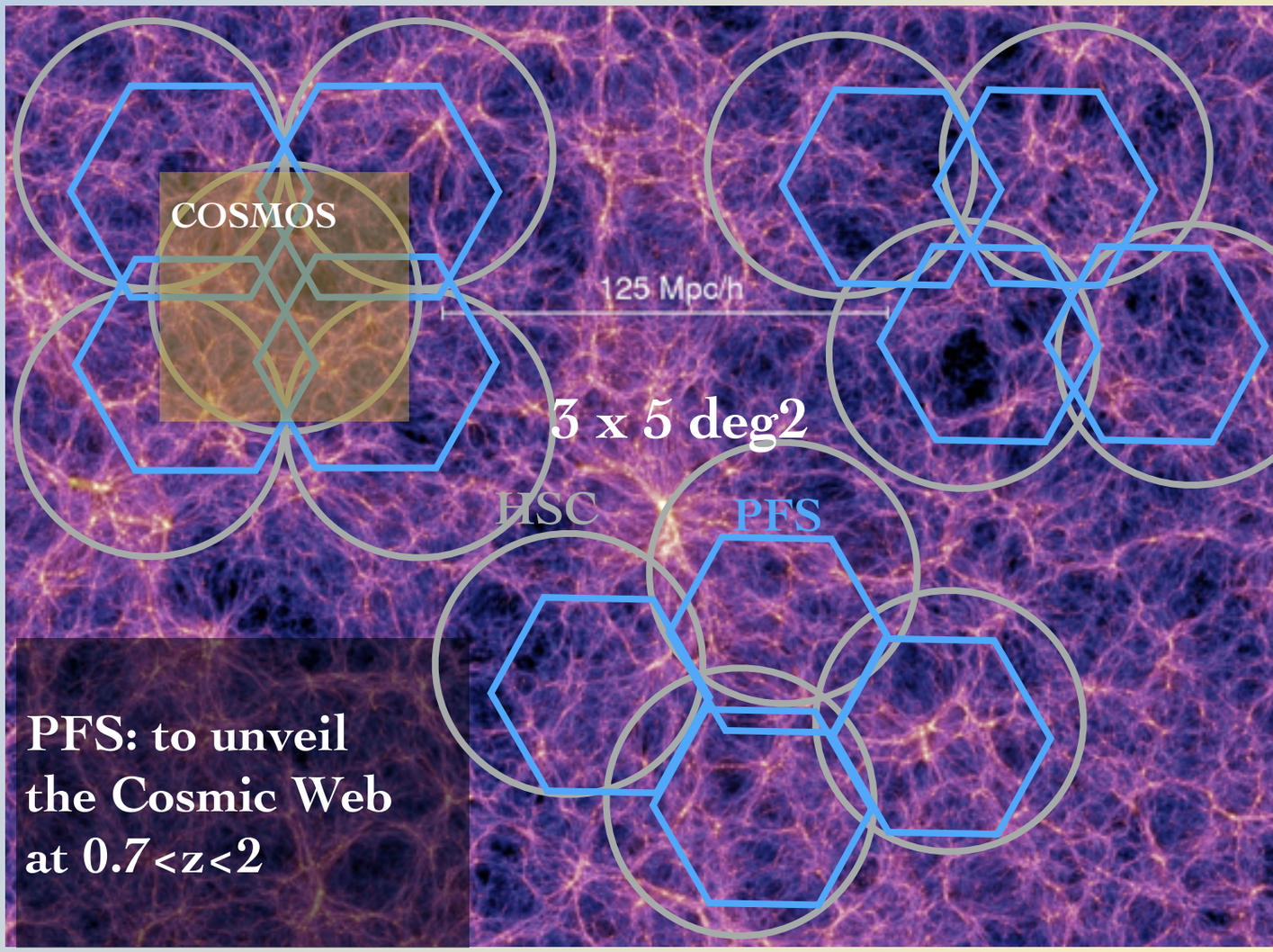
- **The first 7 Gyrs of the universe (0.7<z<7)**
- **350,000 spectra (Texp=2-12h)**

—> deep spectra for detailed studies of massive gal. :
SFR/SFH, M*,met., quenching, feedback/infall

- **A large volume to trace the Cosmic Web**

3 HSC-Deep regions covering **15 deg2**





PFS Galaxy Evolution

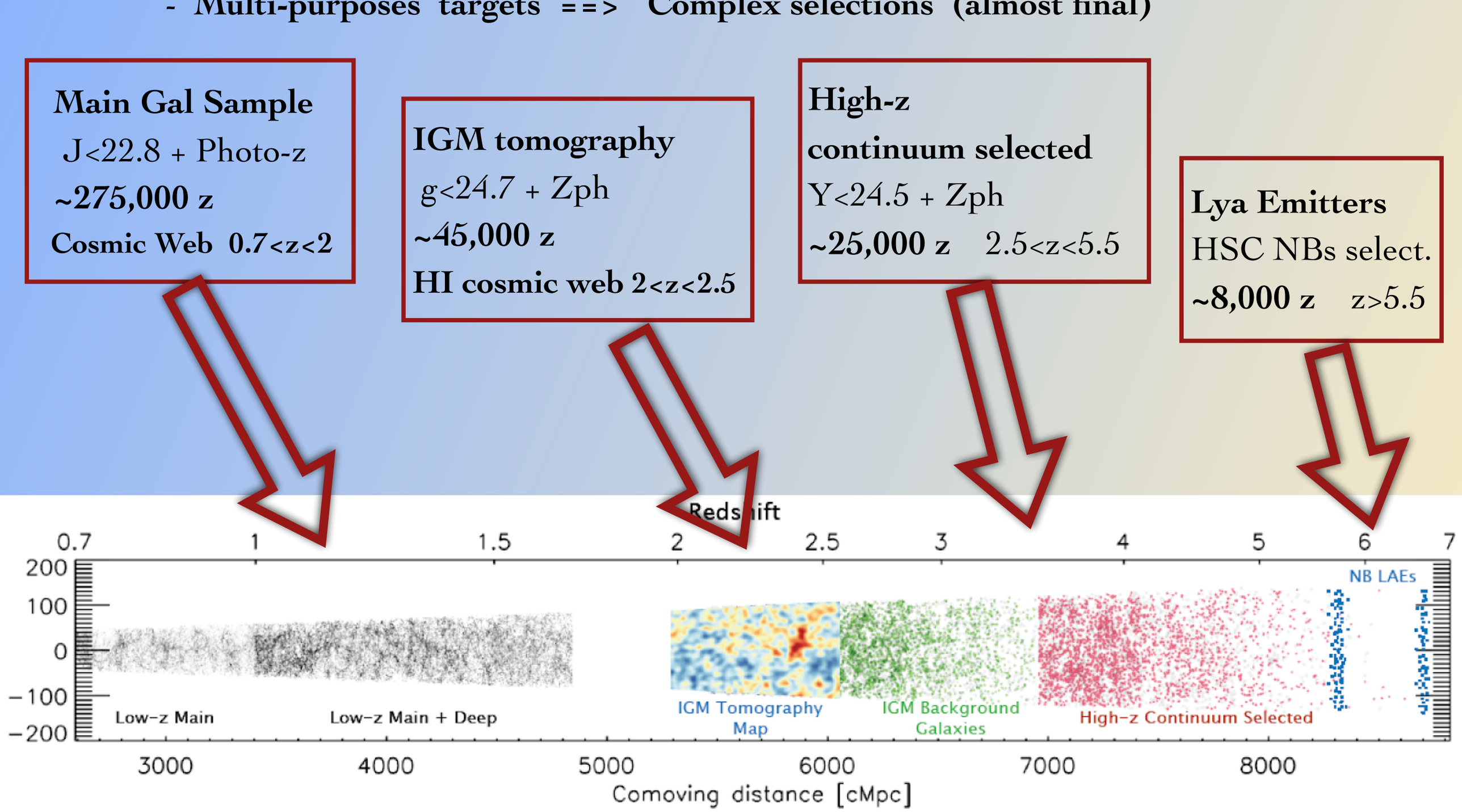
- **Multi-purposes targets ==> Complex selections (almost final)**

Main Gal Sample
J<22.8 + Photo-z
~275,000 z
Cosmic Web 0.7<z<2

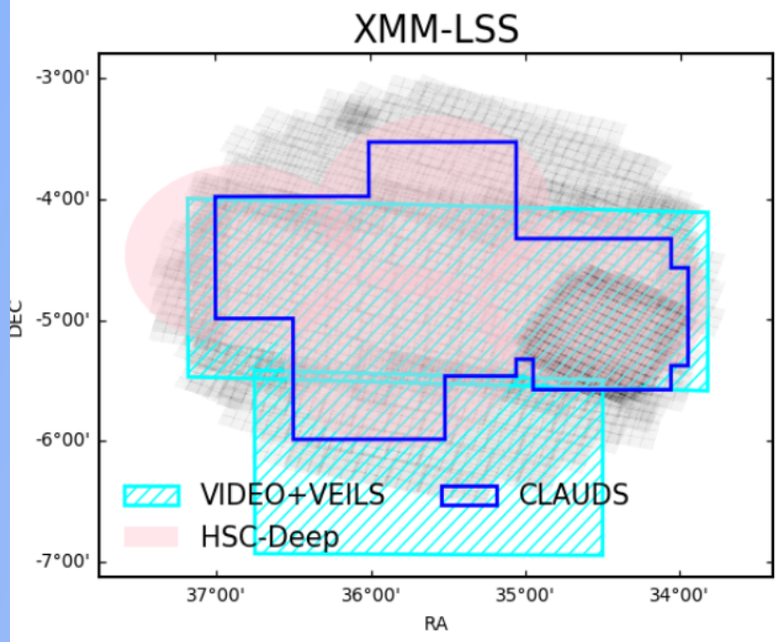
IGM tomography
g<24.7 + Zph
~45,000 z
HI cosmic web 2<z<2.5

High-z
continuum selected
Y<24.5 + Zph
~25,000 z 2.5<z<5.5

Lya Emitters
HSC NBs select.
~8,000 z z>5.5



Synergy with HSC-DEEP and its Multi-wavelength imaging

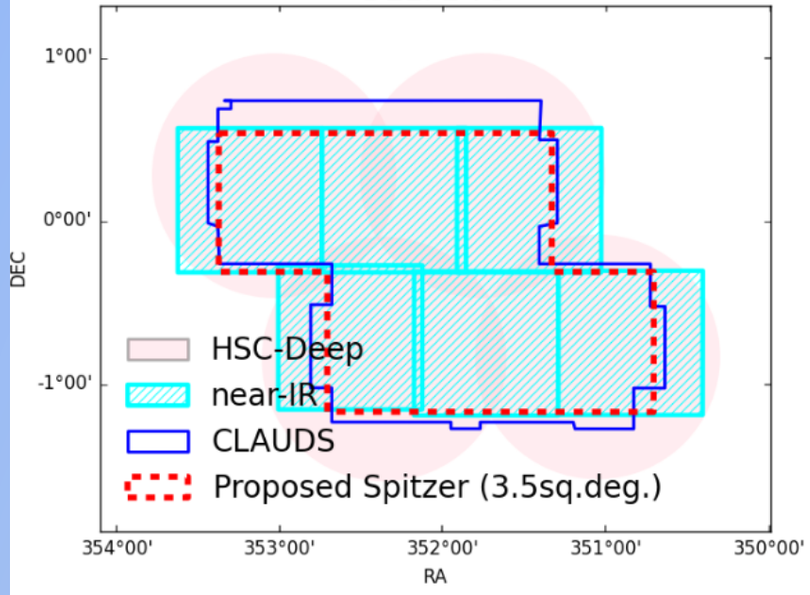


CLAUDS + HSC + NIR + IRAC
u (grizY+NBs) (JK?) (3.6/4.5um)

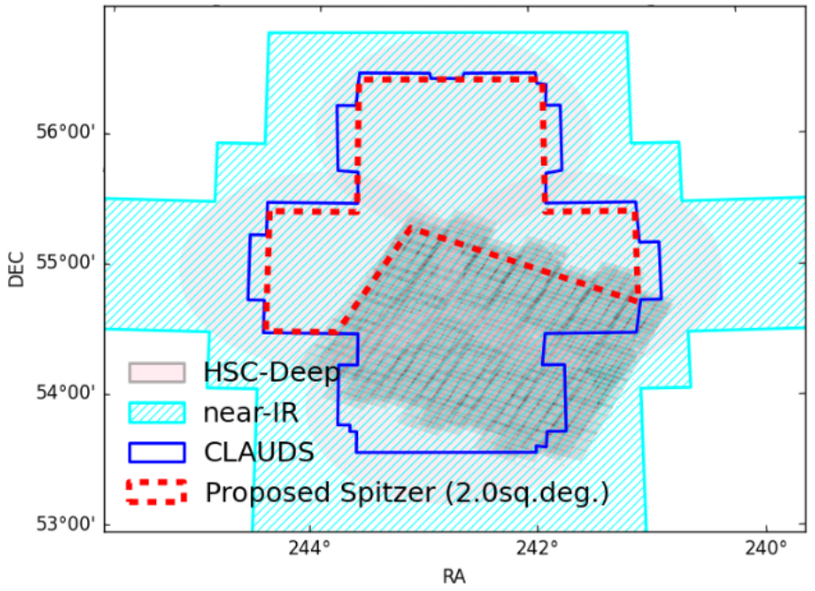
—> Sample selection with Photometric redshifts

—> still working on collecting NIR (J) data !!

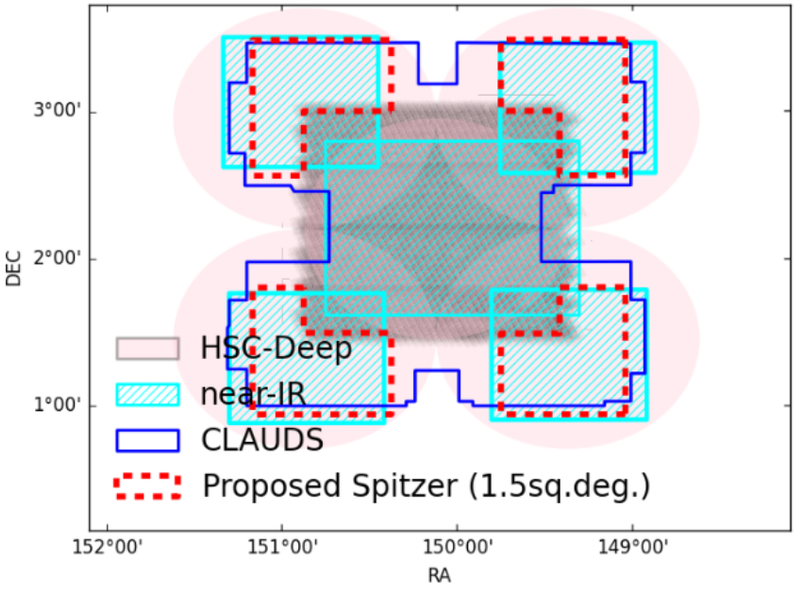
DEEP2-F3



ELAIS-N1



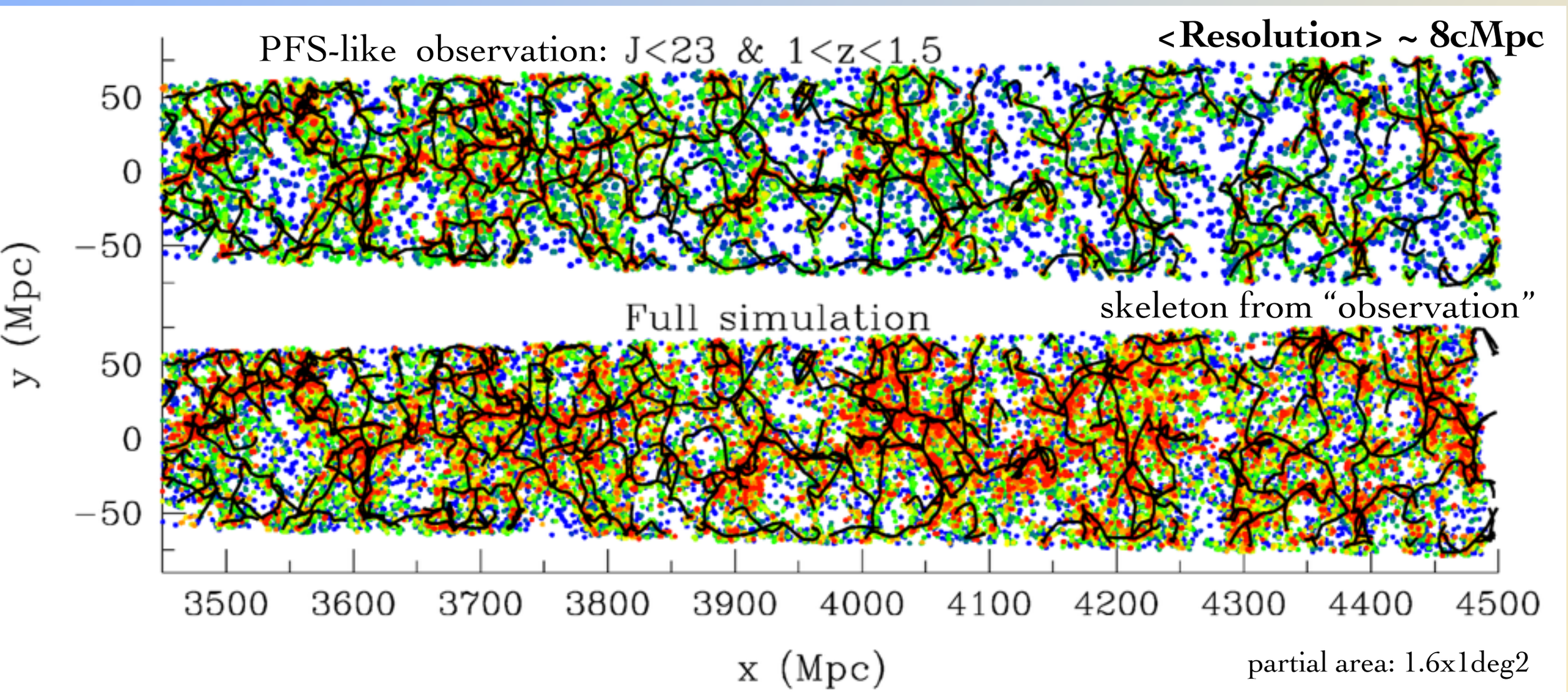
COSMOS



Reconstruction of the Cosmic Web with galaxy density field

15 deg^2 with **275,000 spectra 0.8<z<1.7**

—> Vol~ 0.13 Gpc^3 equivalent to SDSS (0<z<0.15)



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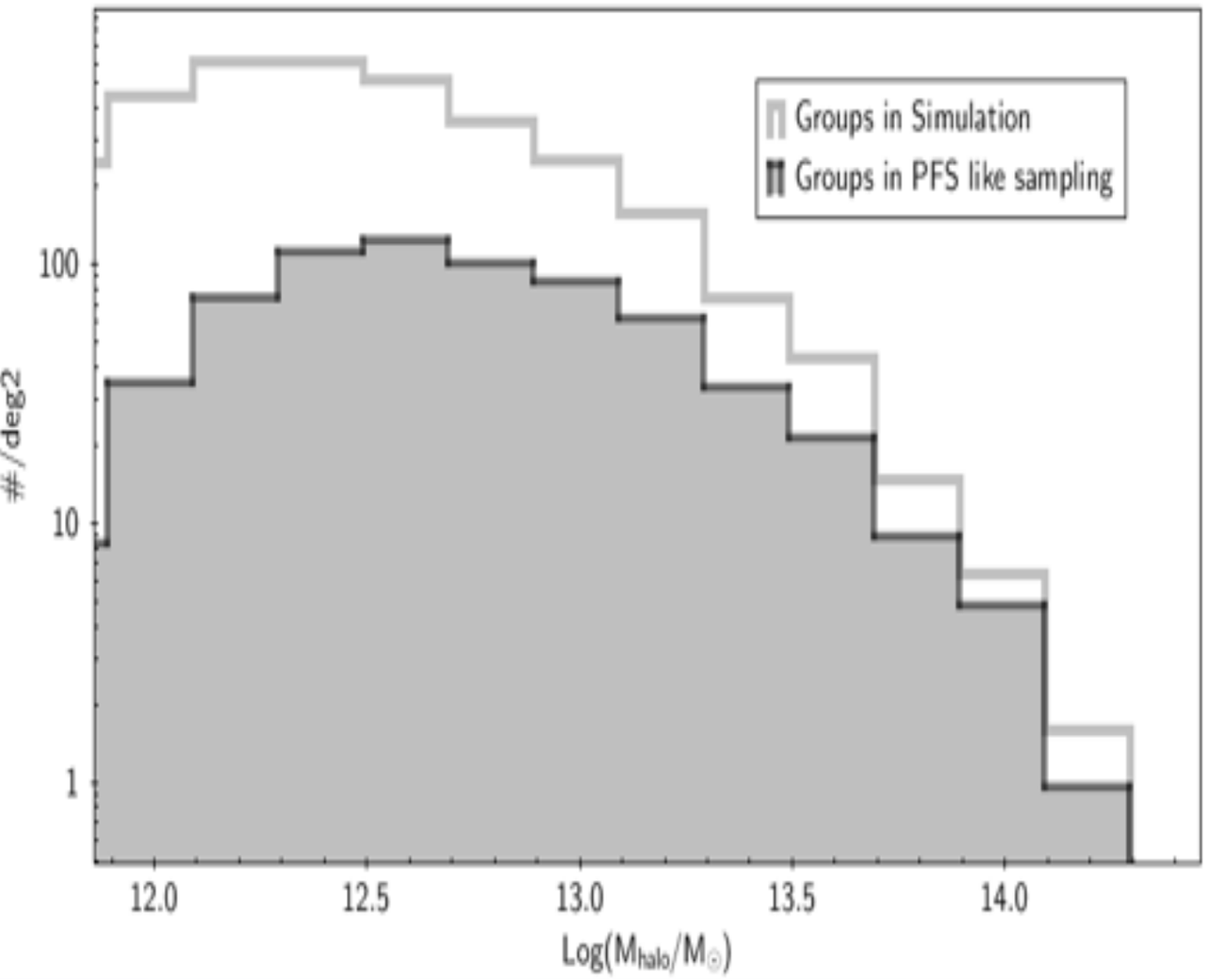
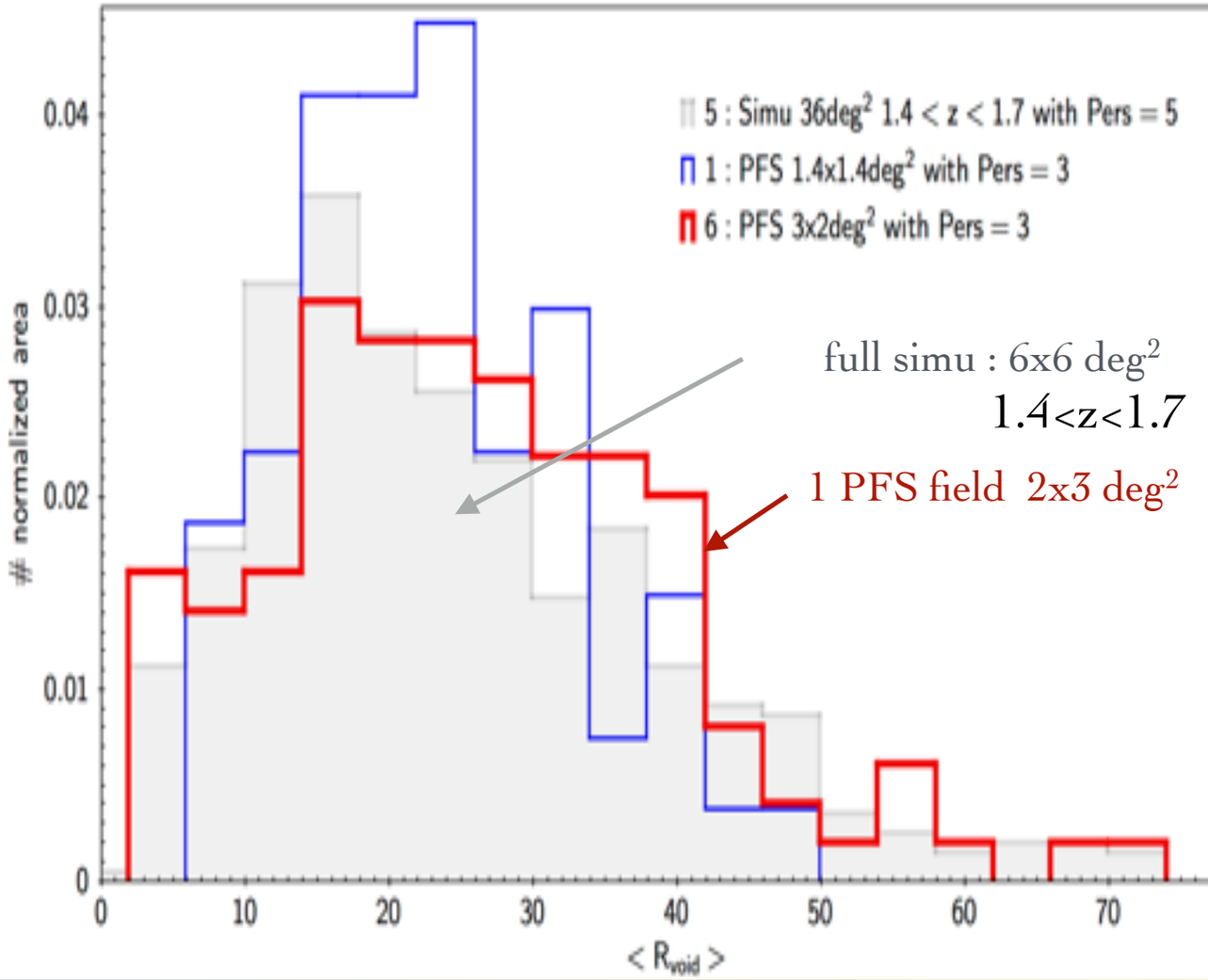
Number of expected Groups



Distribution of Void sizes



— > uniquely designed to explore the connection galaxy <-> LSS

Other past / up-coming surveys

Galaxy Redshift Surveys

IGM tomography

GALAXY

GAS

<30 deg²
30−500 deg²
1000−3000 deg²
>10000 deg²

DESI

Euclid wide

SDSS

VIPERS

WFIRST−H_α

Euclid−deep

GAMA

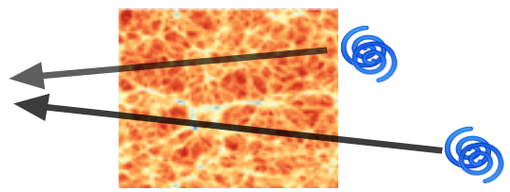
PFS
J<23

WAVES−Wide

$<D_{inter}>$ (Mpc)

20
15
10
5
0

PFS tomography



SFR Density

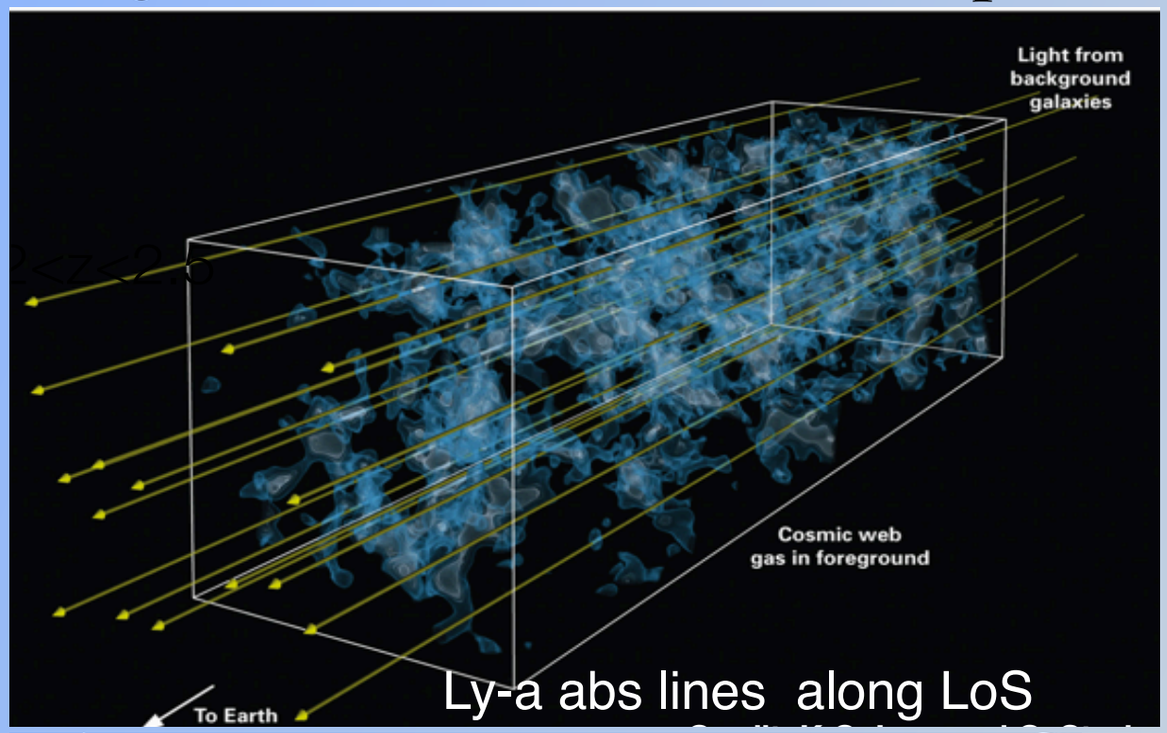
0
0.5
1
2
3
4

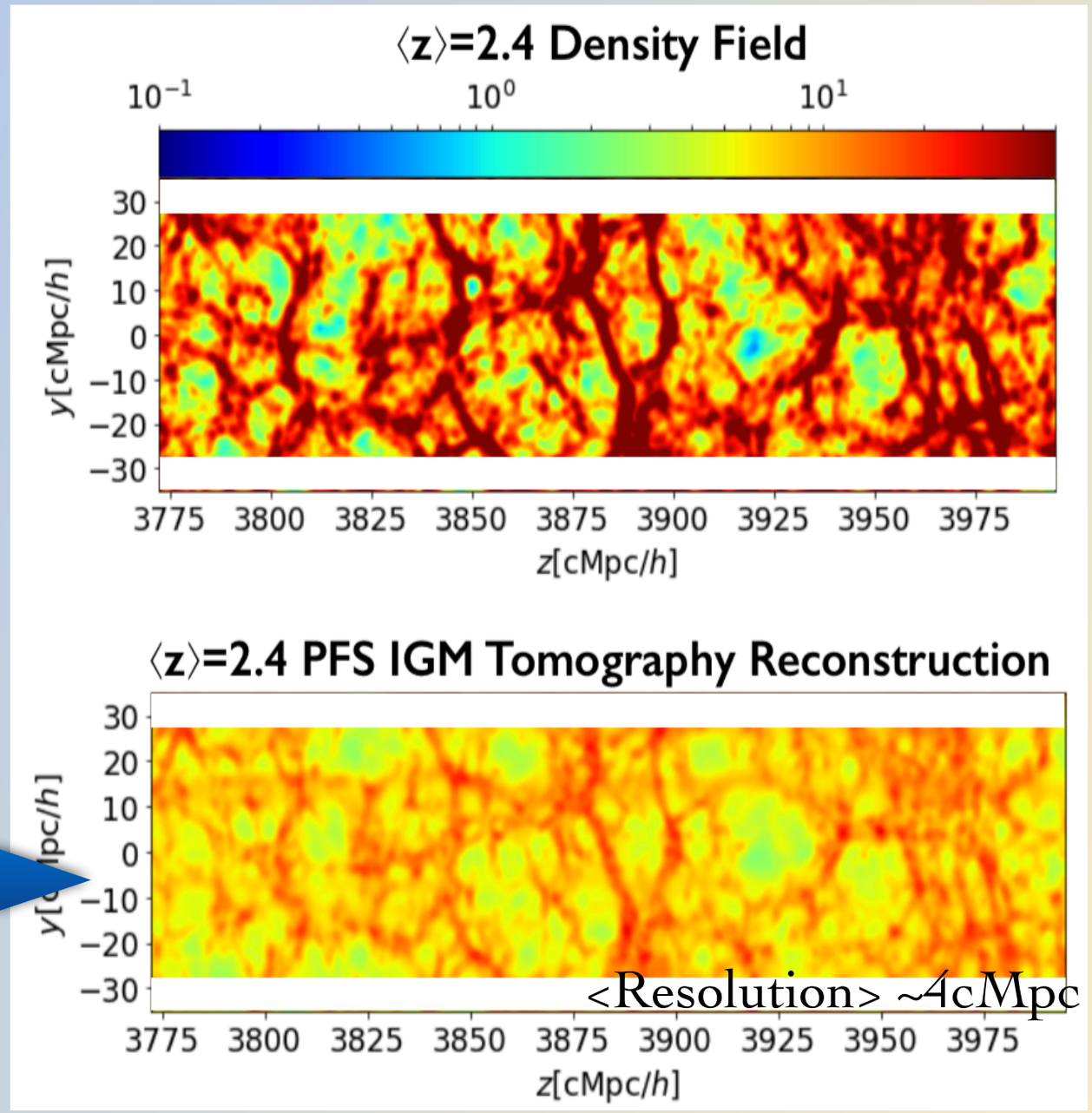
Redshift

—> uniquely designed to explore the connection galaxy <-> LSS
and with no competitor before space missions

Reconstruction of the Cosmic Web with Gas (IGM Tomography)

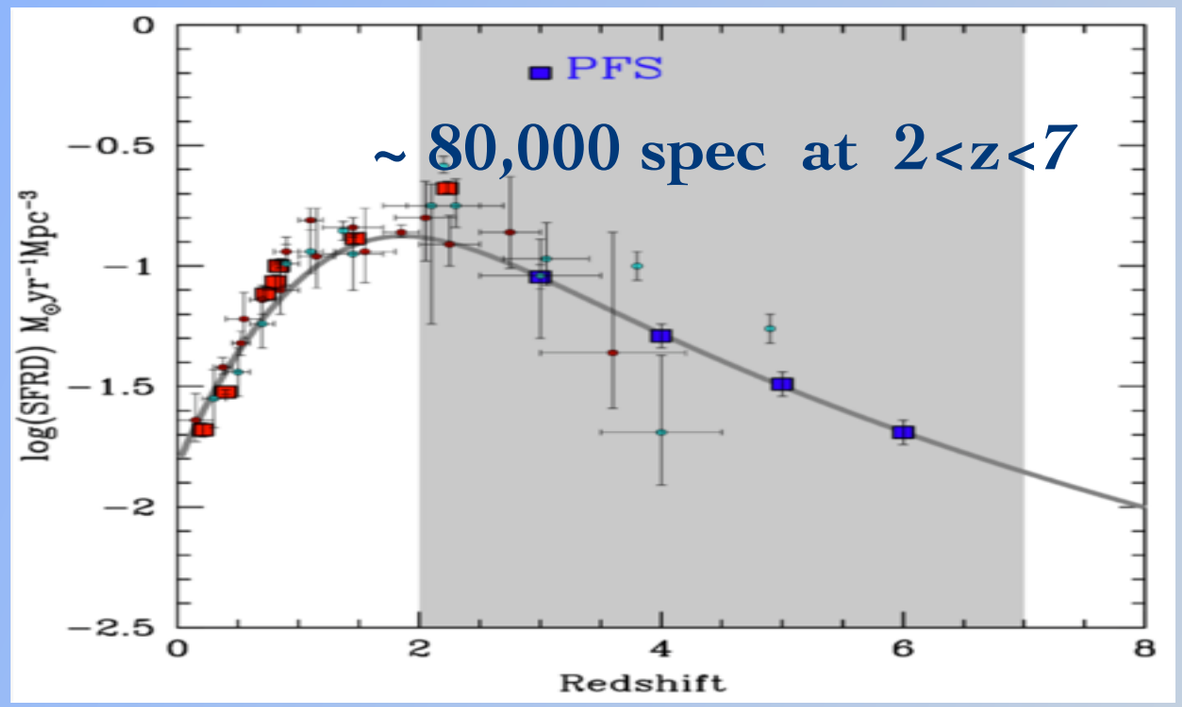
IGM tomography with background QSO/Gal at **2.1<z<3.0 : 35000 spectra**

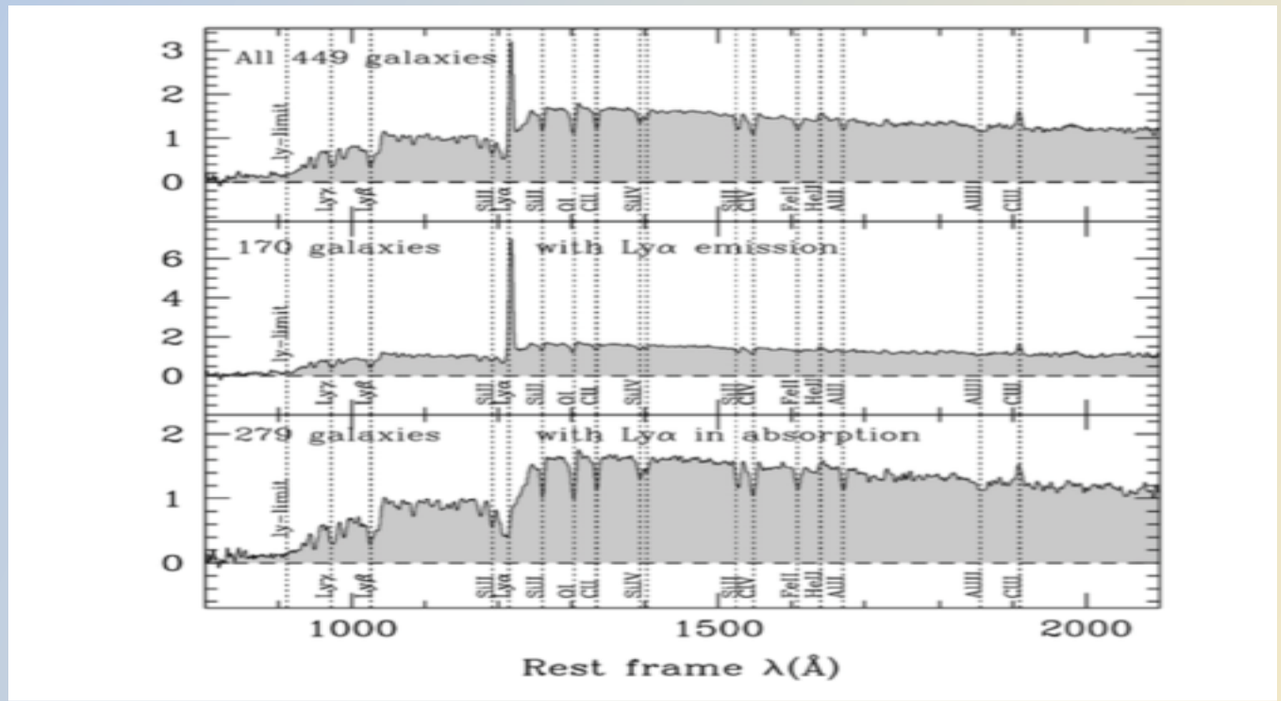




—> First connection between Galaxies and IGM Gas reservoir

Exploring the epoch of Galaxy formation / assembly from the EoR to peak of cosmic SF



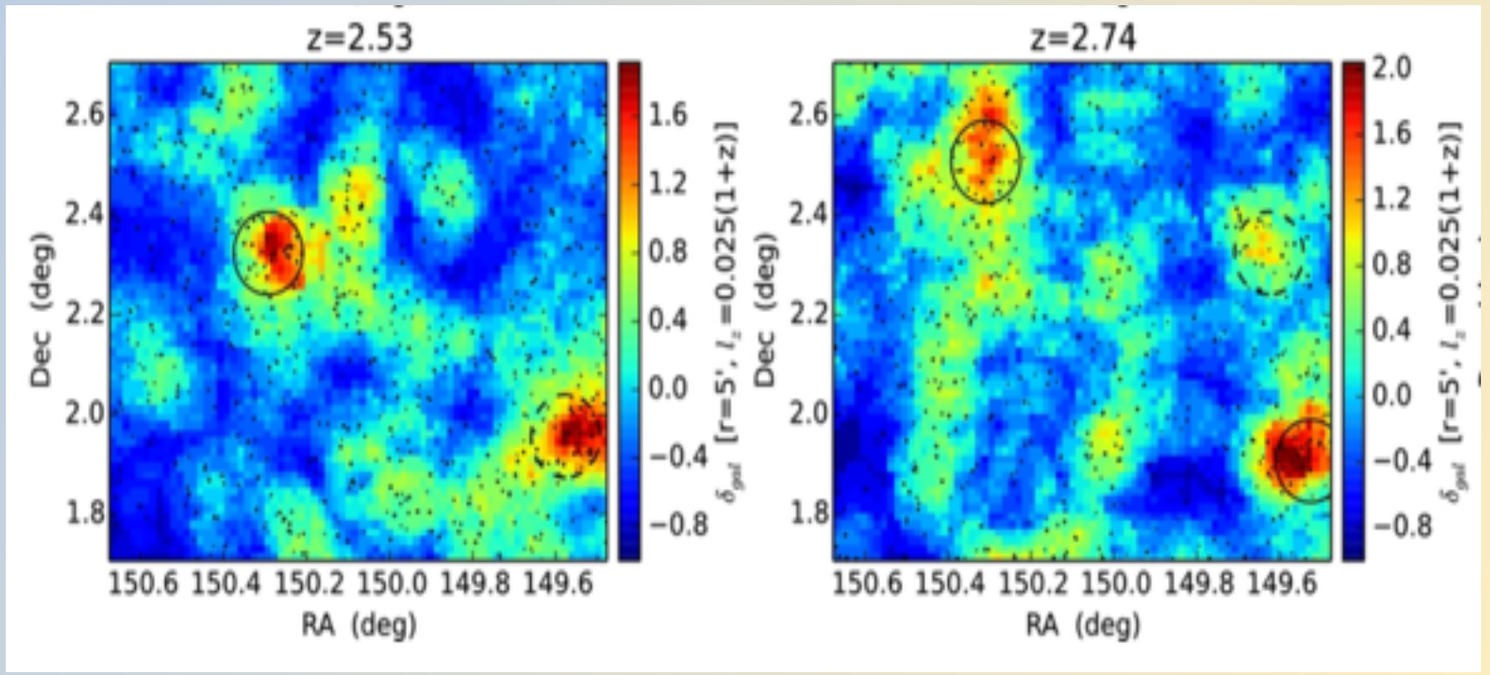


* Galaxy formation path (mergers / smooth accretion / quenching …)

  SFR with UV rest / outflows & infalls with v-shift Ly-a, ISM lines, evolution of SHMR peaks

* a unique volume for env. study & detection of proto-clusters

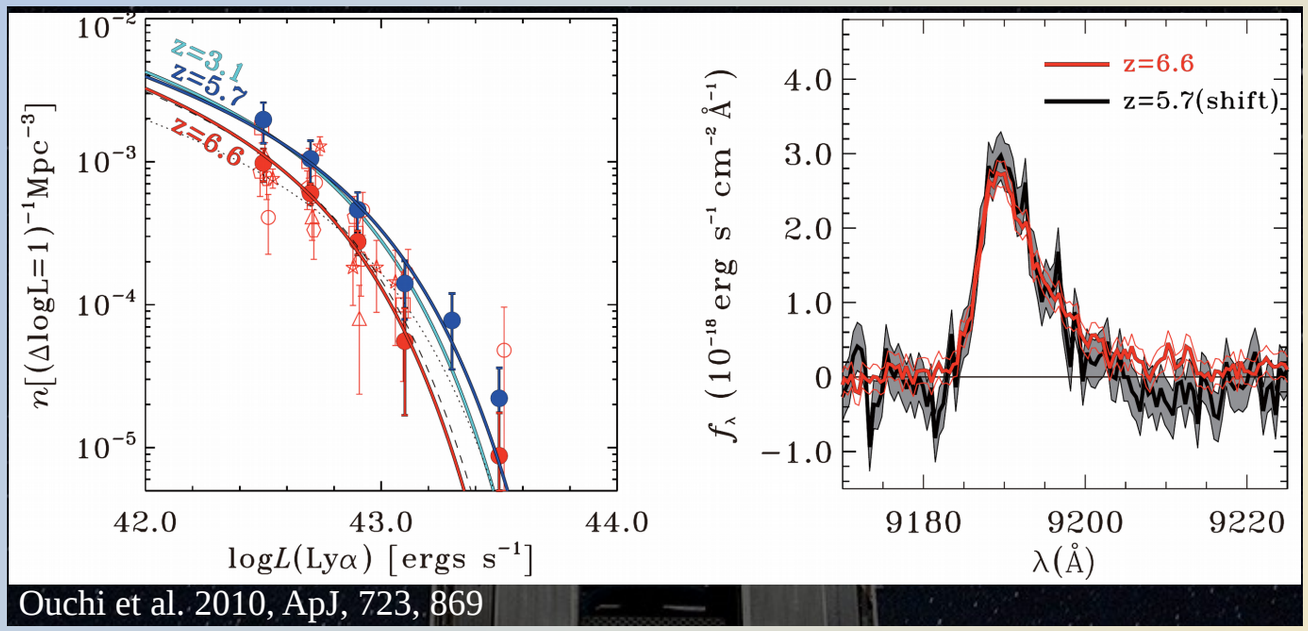
  >500 expected with $M>10^{14}Mo$



Epoch of Reionization

* **Ly-a Emitters at z>5.5 : ~ 8000 spectra**
based on HSC NB selection

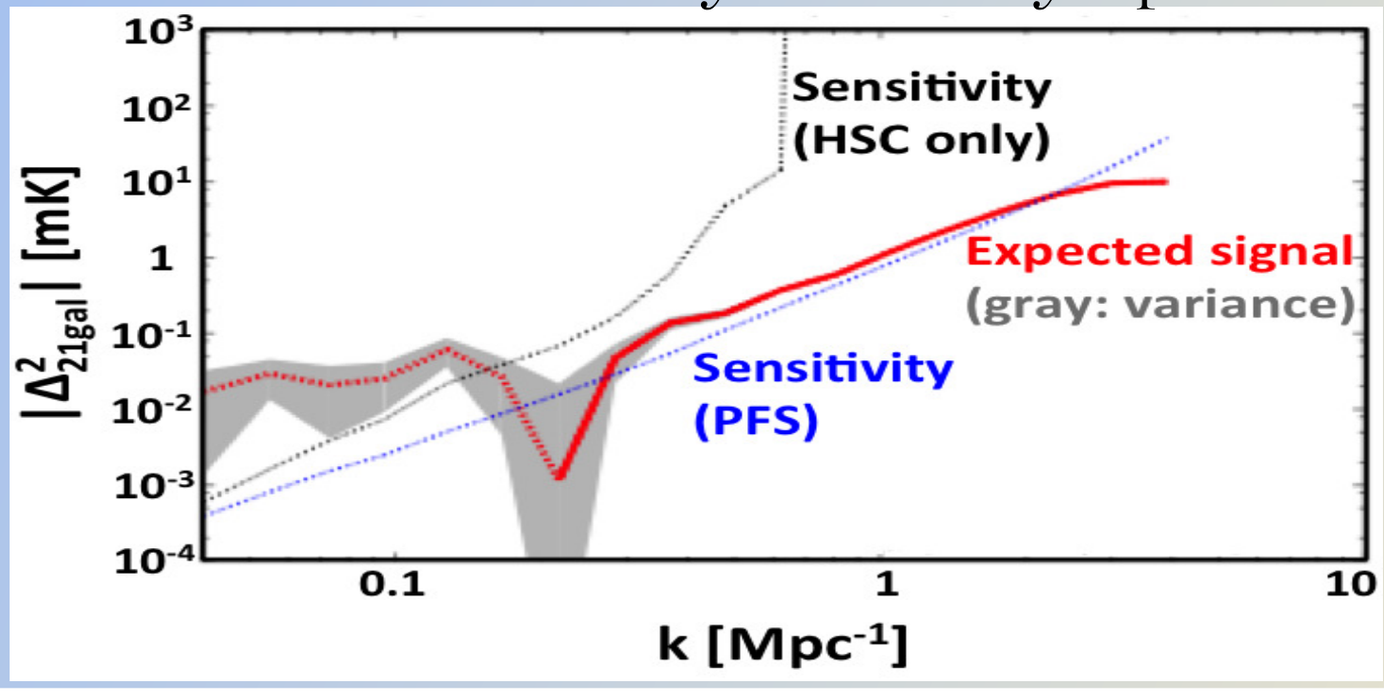
—> LF of LAE at the epoch of re-ionisation

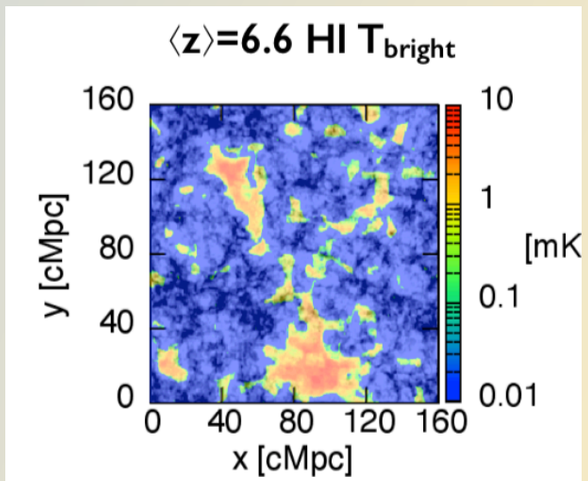


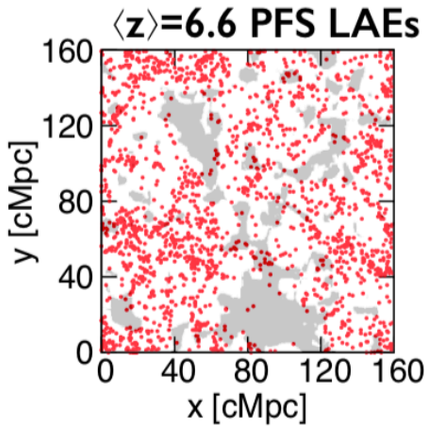
* **Connection between Galaxies (LAE, z=6.6) and Gas (21cm, SKA1)**

—> Spatial cross-PS between LAE & 21cm

—> Simulations : amplitude & transistion scale will constrain the reionization history and the way it proceeds







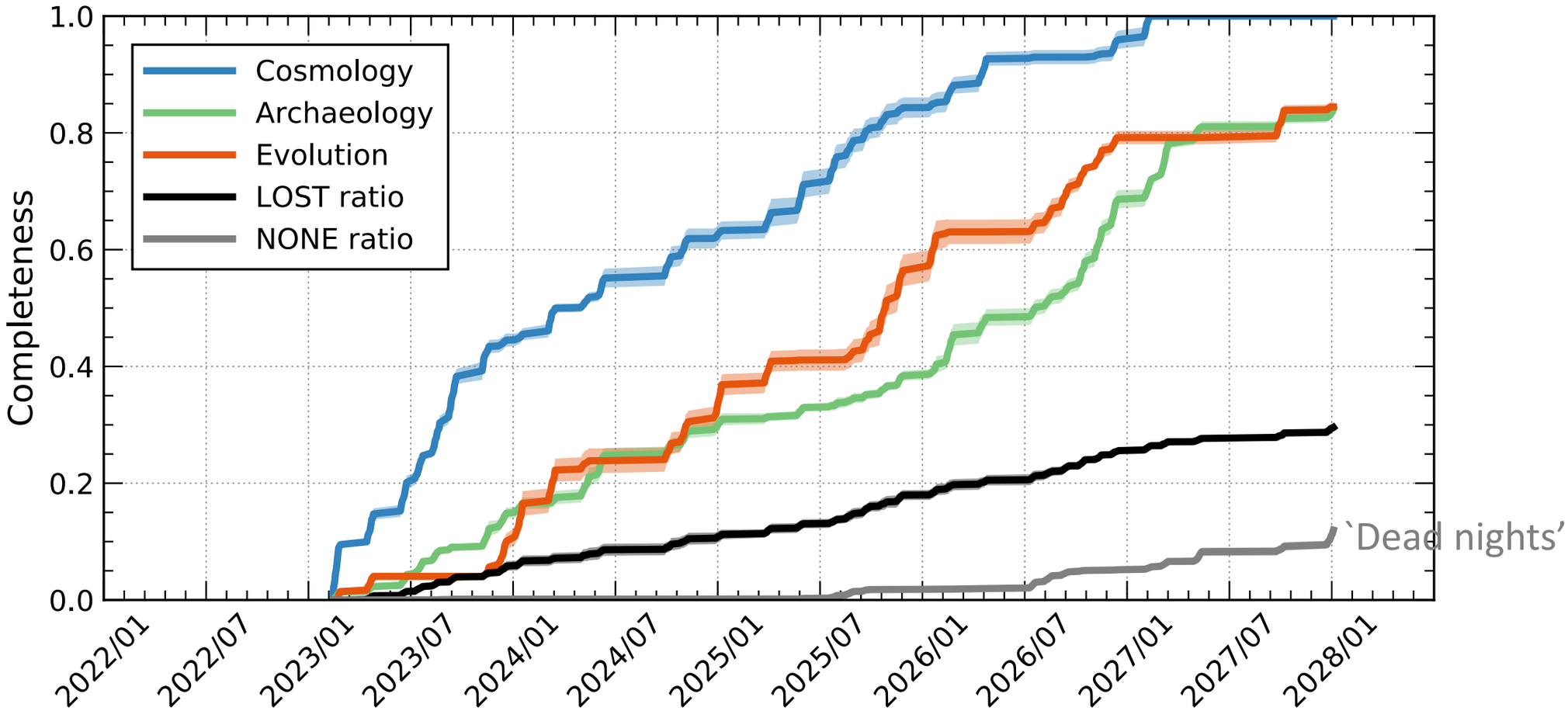
Prime Focus Spectrograph (PFS)

Testing ΛCDM	Assembly history of galaxies	Importance of IGM
• Nature & role of neutrinos • Expansion rate via BAO up to z=2.4 • PFS+HSC tests of GR • Curvature of space: Ω_K • Primordial power spectrum • Nature of DM (dSphs) • Search for DM subhalos (MW streams) • Small-scale tests of structure growth	• Stellar kinematics – MW & M31 assembly history • Halo-galaxy connection: $M_*/M_{\rm halo}$ • Outflows & inflows of gas • Environment-dependent evolution • PFS+HSC galaxy association • Absorption probes with PFS QSOs and HSC host galaxies	• Physics of cosmic reionization via LAEs & 21cm studies • Tomography of gas & DM • dSph as relic probe of reionization feedback • Search for emission from stacked spectra

PFS COSMOLOGY **PFS GA** **PFS GE**

SSP : Subaru Strategic Program
make a unified story between the 3 programs

Survey Design & Strategy

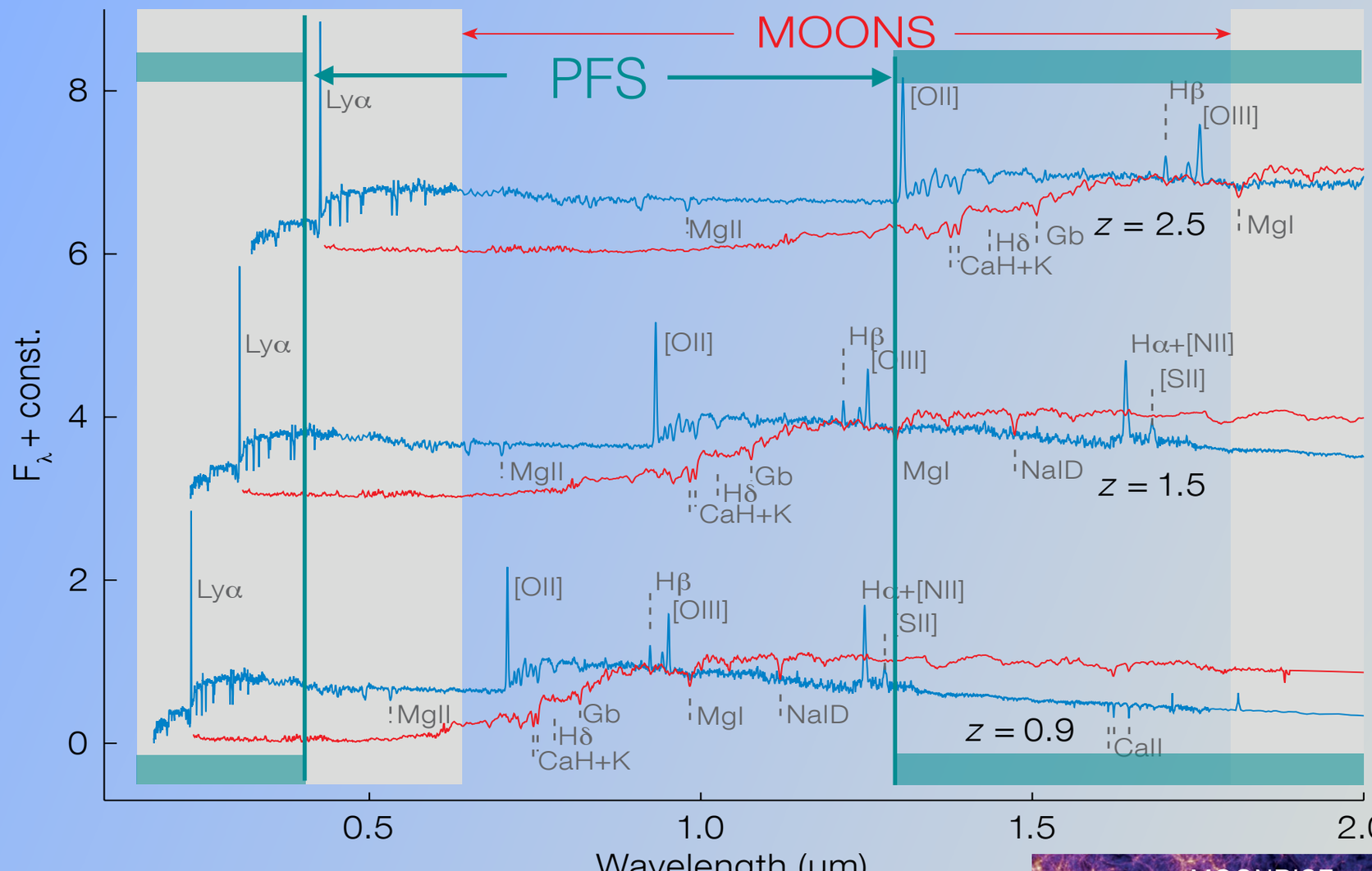


- 360 night program in 5 years
- Cosmology front-loaded at ~100 allocated nights
- GE/GA have ~130 allocated nights each
- Survey starts Semester 2023A

Competition with MOONS (GEv) and DESI (COSMO)

	PFS	MOONS	DESI	WEAVE	4MOST
Telescope	Subaru (8.2m)	VLT (8.2m)	Mayall (4m)	WHT(4.2m)	VISTA(4m)
FoV	1.2 sq. deg.	0.14 sq. deg.	7 sq. deg.	2 sq. deg.	4 sq. deg.
Wavelength	0.38-1.26	0.64-1.8	0.36-0.98	0.4-1.0	0.4-0.885
Multiplex	2394	1000/2	5000	800	800 (low-R) 800 (high-R)
Resolution	R~2,000 (blue) R~3,000 (red) R~4,000 (NIR)	R~4,000-6,600 R~9,000 R~20,000	R~3,000-4,800	R~5,000 R~20,000	R~5,000 R~20,000
Fiber diameter	1.1”	1.05”	1.45”	1.3”	1.4”
Sci. op. start	2023	2023	2020	2019(?)	2023
Survey GEv	**130 nights**	**190nights**	500 nights	5yrs+5yrs	???
Science	**Cosmology** **GA** **Galaxy Evol.**	**Galaxy Evol.** GA	**Cosmology** GA Bright galaxies	**GA** Galaxy Evol.	Cosmology GA Galaxy Evol.
Synergy	HSC TMT (LSST)	Gaia E-ELT	???	Gaia	Euclid eROSITA(X-ray) Gaia

cf. Euclid (ESA): 1.2m, 2022-, WFIRST (NASA): 2.4m, 2025-, LSST (imaging): 6.5m, 2023-



MOONRISE

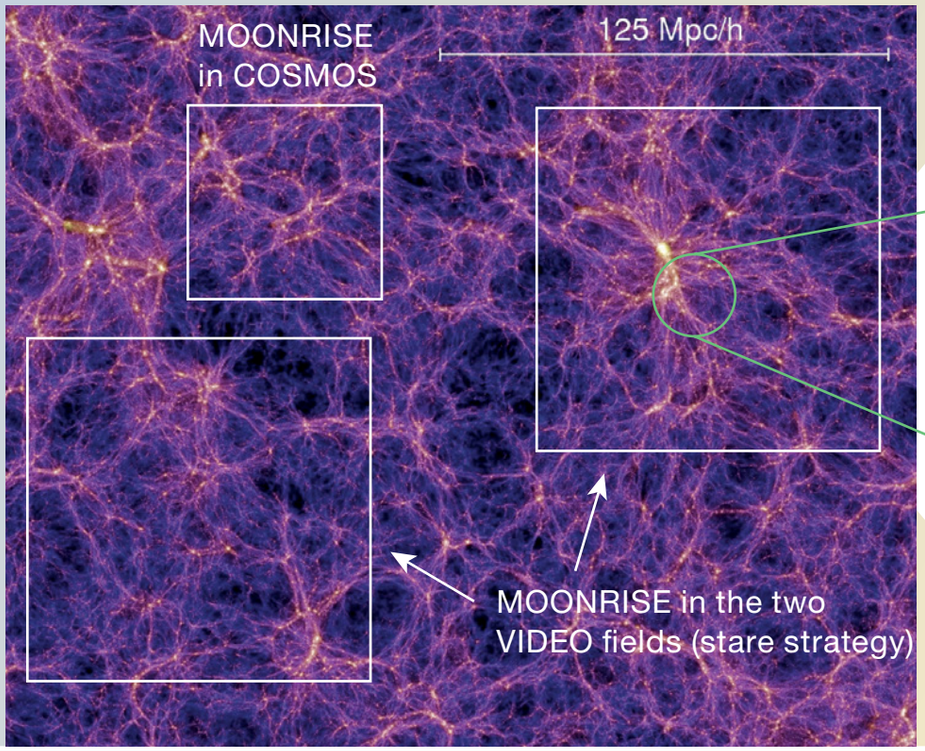
* 500,000 gal 0.9<z<2.6
* MOONS unique at high-z with line disgnostics

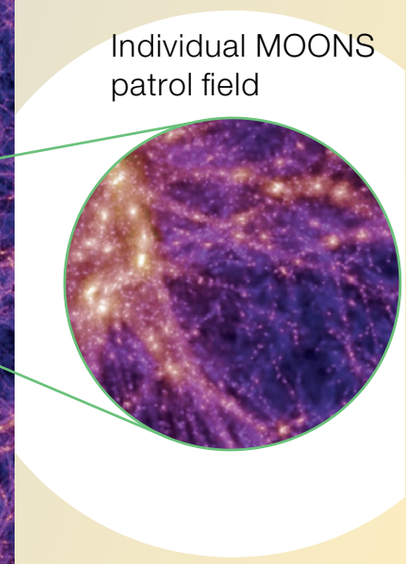
MOONS smaller fov but they plan to map 3 large area.

2 in common with PFS

-> complementarity

some collaborations ?





PFS membership for LAM

LAM major contributor thanks to the in-kind contribution to the PFS project (~$6M)

- **coordinator:** O. Le Fèvre Big thanks!

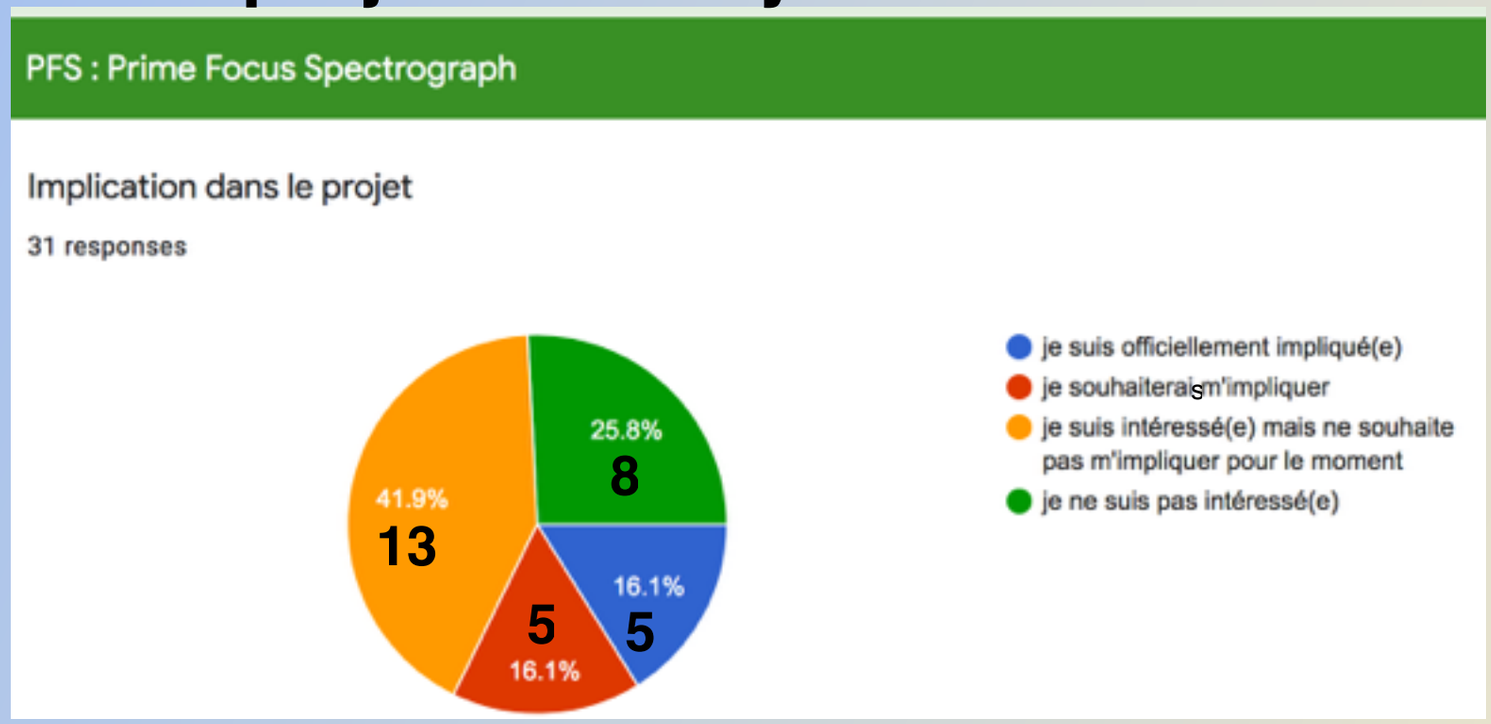
and member steering committee PFS -> interim S Arnouts

- **11 senior scientist positions available with full data access with up to 4 junior scientists / senior**

—> **involved :** P. Amram, S. Arnouts, S. de La Torre, B. Epinat, O. Ilbert, V. Le Brun, O. Le Fèvre, L. Tasca, **L. Tresse**

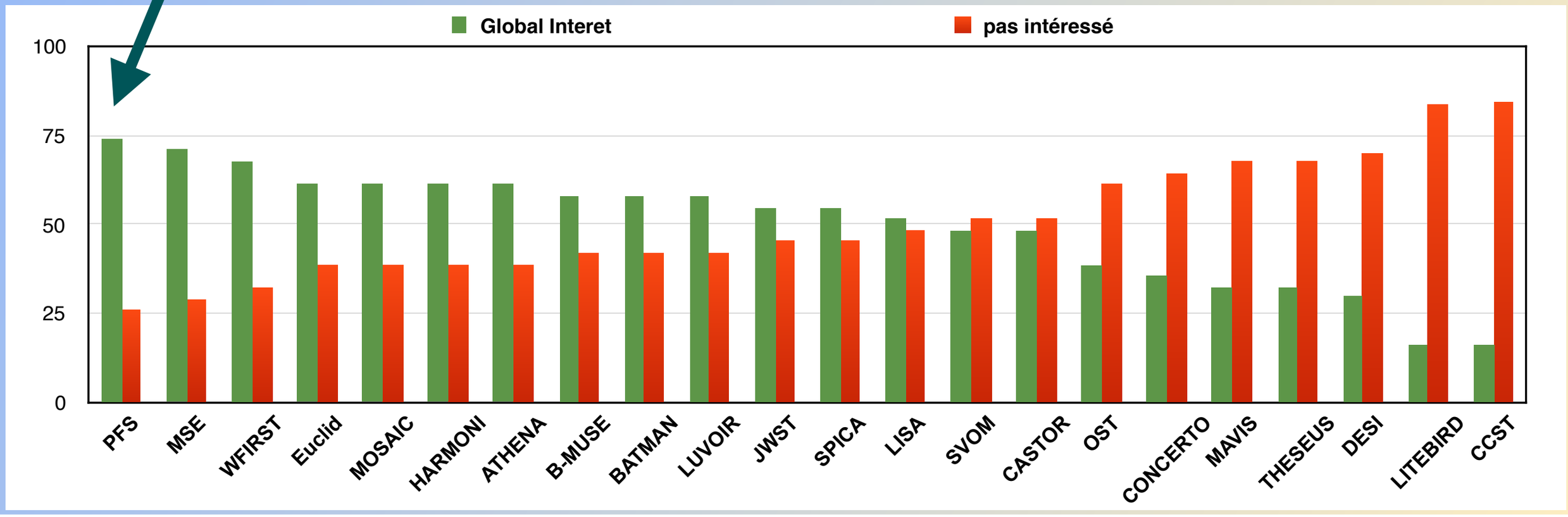
—> **two seats still available for LAM seniors ?**

GECO's projects survey

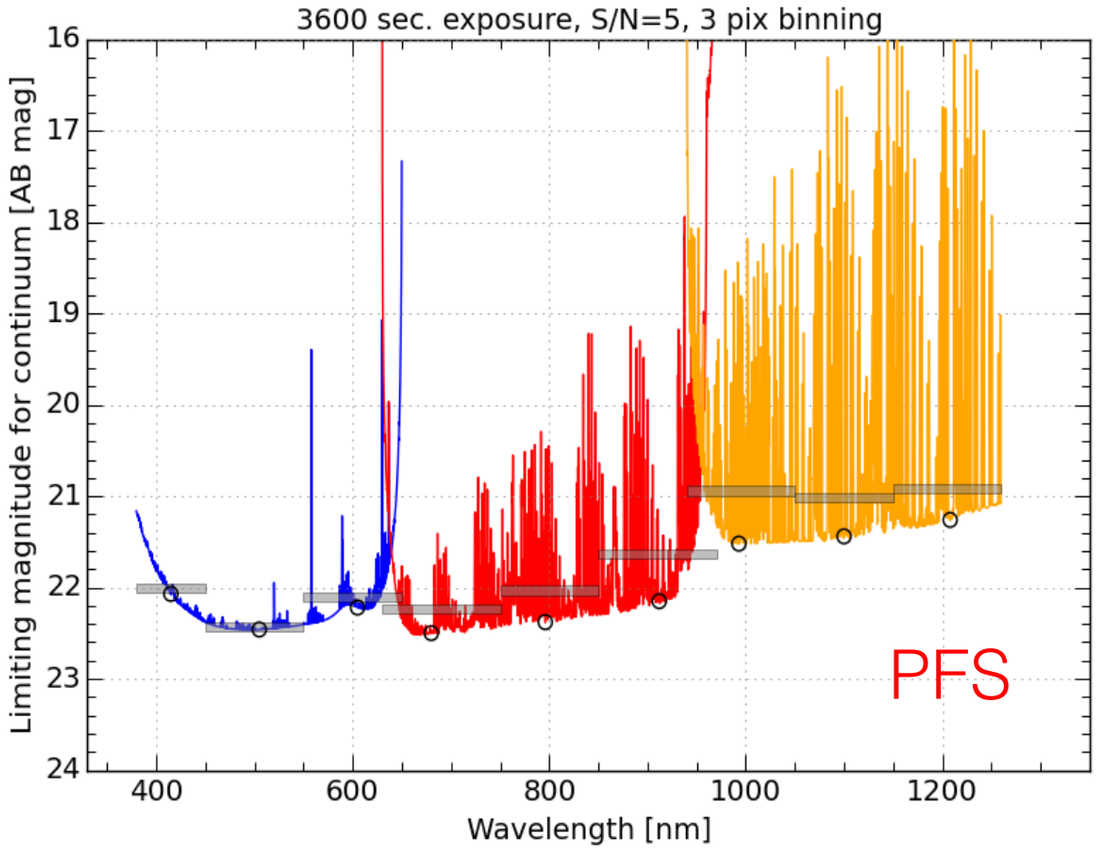


PFS ranked first

—> time to contribute & participate to WGs. Not too late !



Comparison with MOONS ([MOONS document])



1hr exposure

Limiting mag. of continuum with S/N=5