SuMIRe
Hyper Suprime-Cam (HSC)
and
Prime Focus Spectrograph (PFS)

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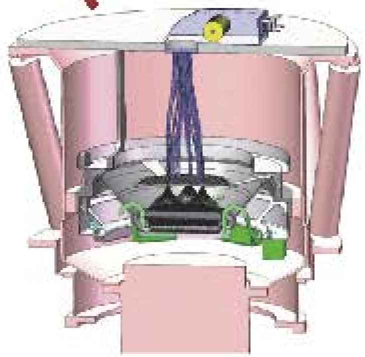
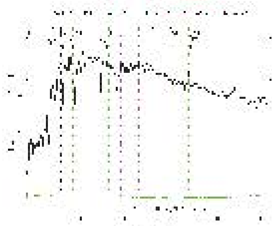
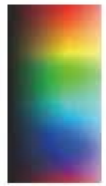
@ IPMU, Nov 21, 2012

SuMIRe = Subaru Measurement of Images and Redshifts

- IPMU director Hitoshi Murayama funded (~ $32M) by the Cabinet in Mar 2009, as one of the stimulus package programs
- Build *wide-field* camera (Hyper SuprimeCam) and *wide-field* multi-object spectrograph (Prime Focus Spectrograph) for the Subaru Telescope (8.2m)
- Explore the fate of our Universe: dark matter, dark energy
- Keep the Subaru Telescope a world-leading telescope in the TMT era
- Precise images of 1B galaxies
- Measure distances of 1M galaxies

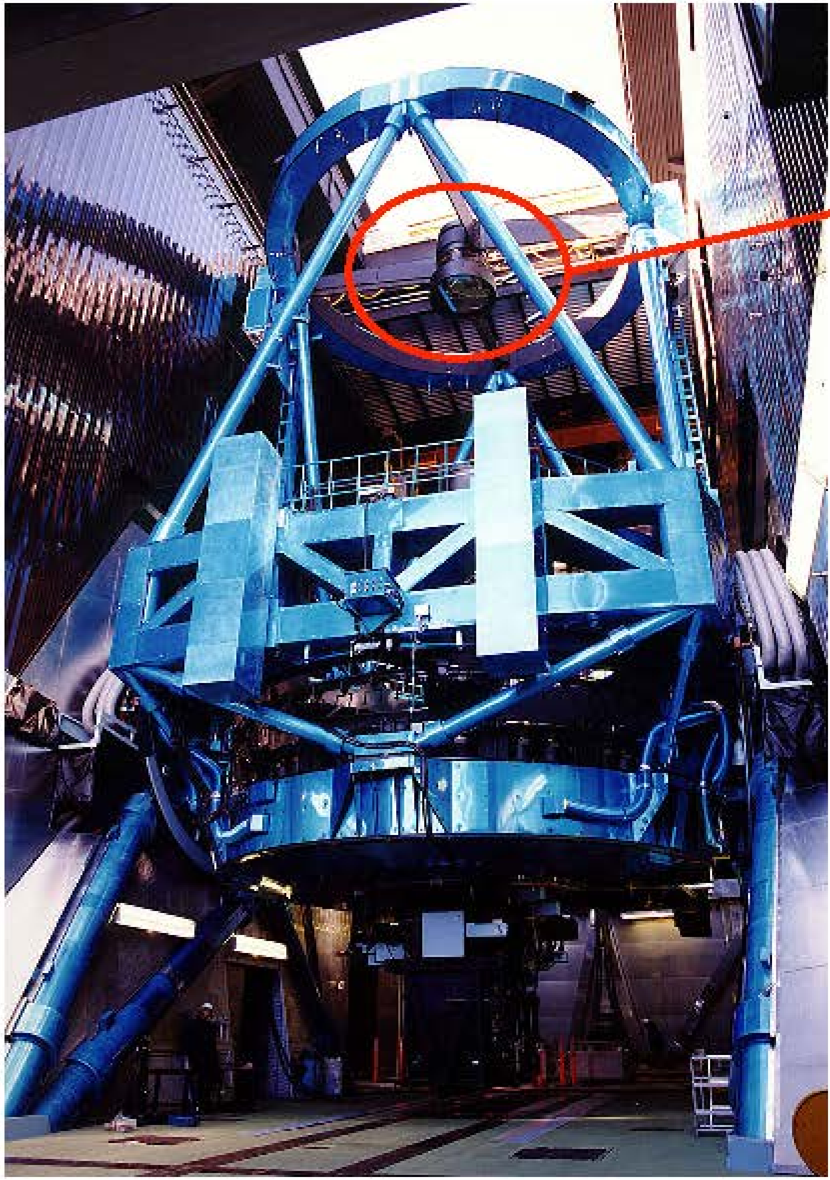




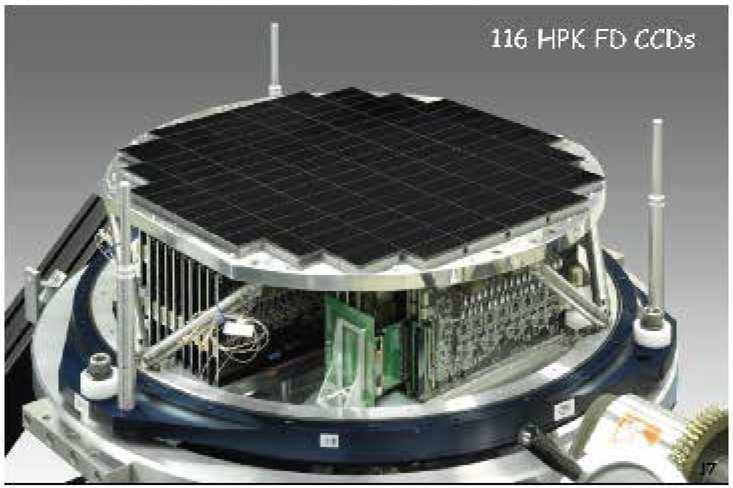


Hyper Suprime-Cam Project

A big excitement = the engineering first light! (Aug 16 – Sep 3)



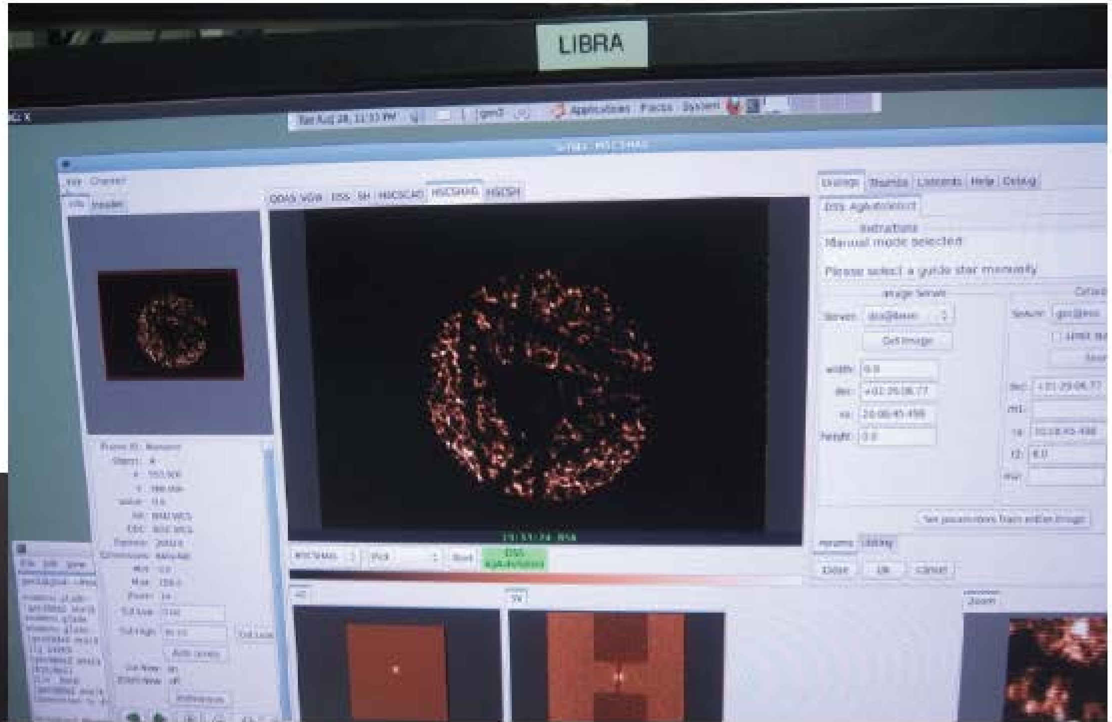
- All instruments at Mauna Kea
- The *largest* camera in the world
- 3m high
- 3 tons weighed
- 116 CCD chips (870 millions pixels)



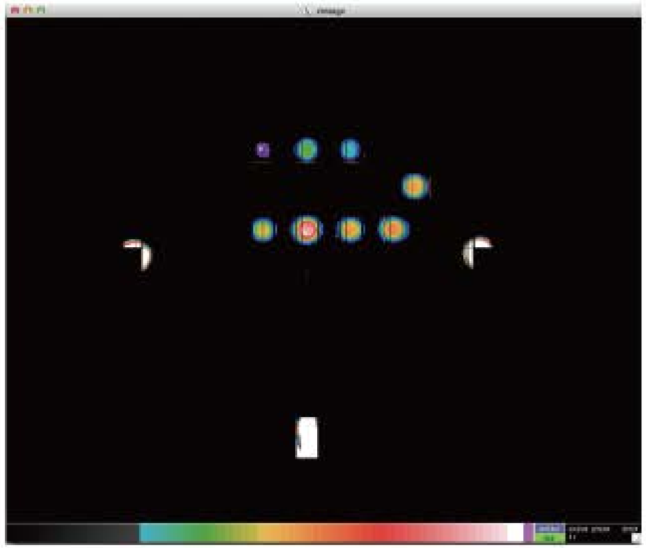
The Engineering first light!

From Satoshi Miyazaki (NAOJ, HSC PI)

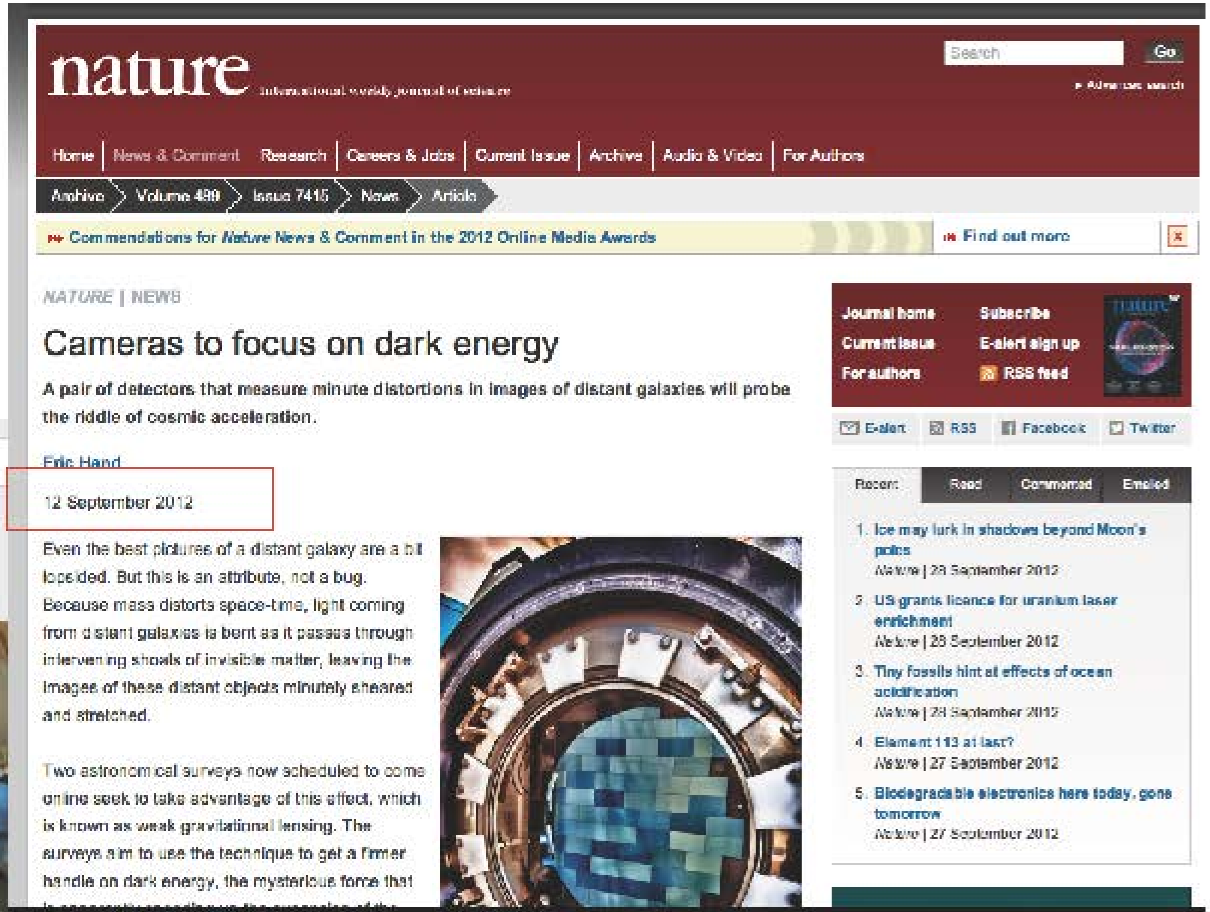

Shack-Hartmann unit




The first image of Vega



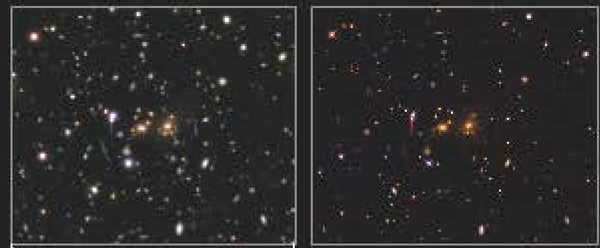
HSC Engineering First Light

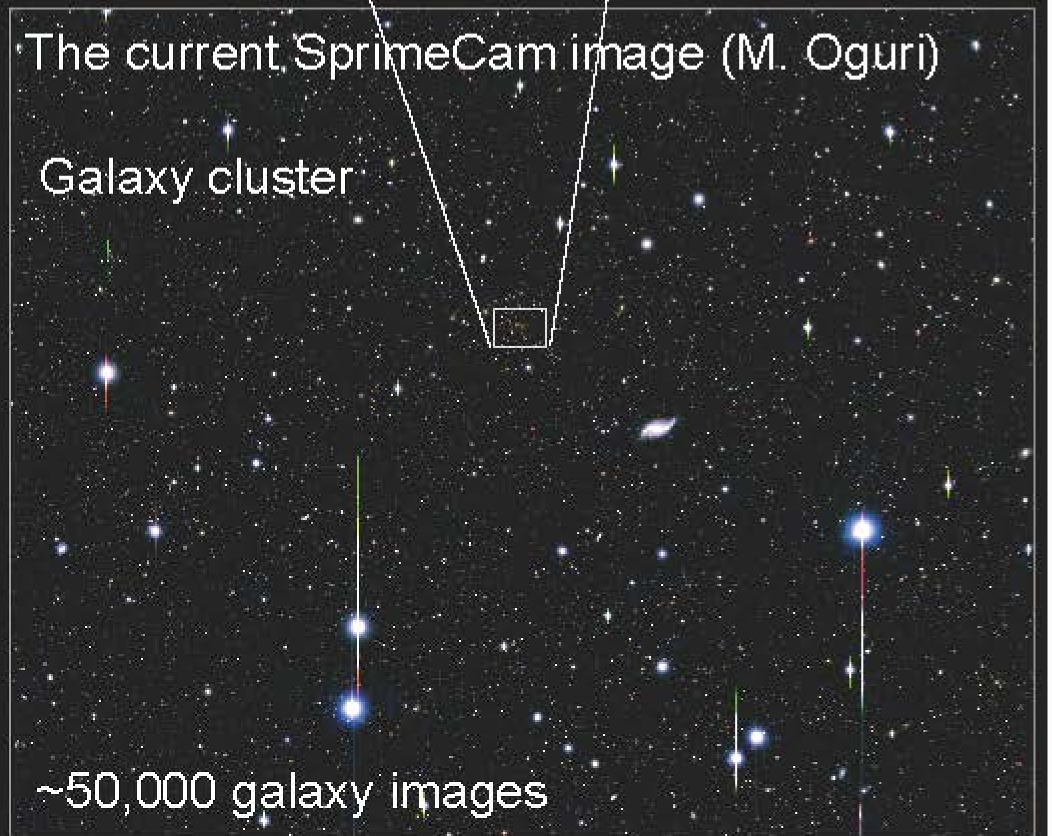


- Press release (Sep 12)
- From homepages of IPMU and NAOJ
- Nature, the newspapers in Japan, YouTube
- YouTube: 3,998 hits (as of Nov 13)

Subaru Telescope: wide FoV & excellent image quality

- **Fast, Wide, Deep & Sharp**
- Ideal for a cosmological survey





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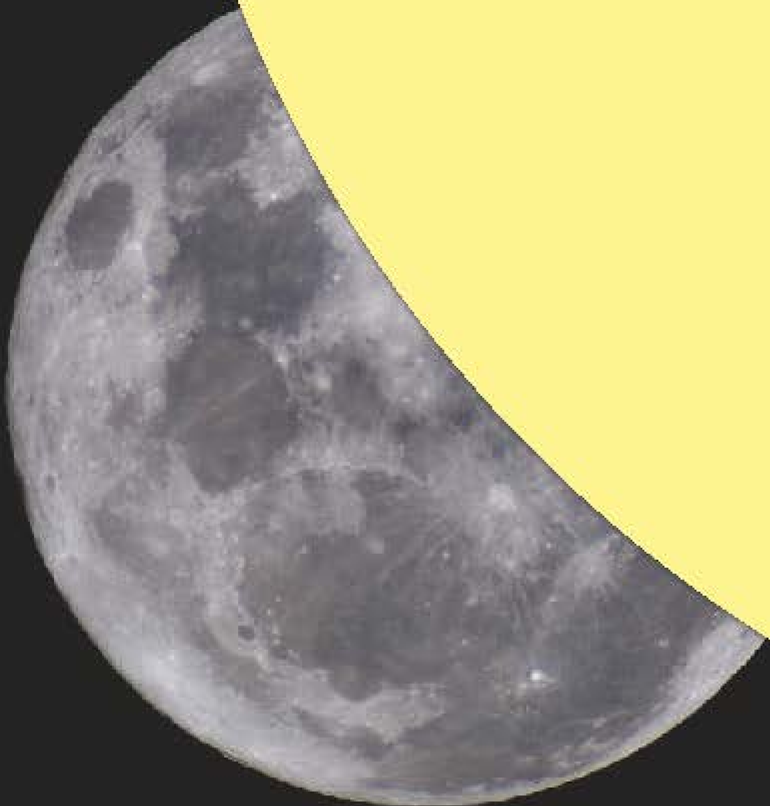
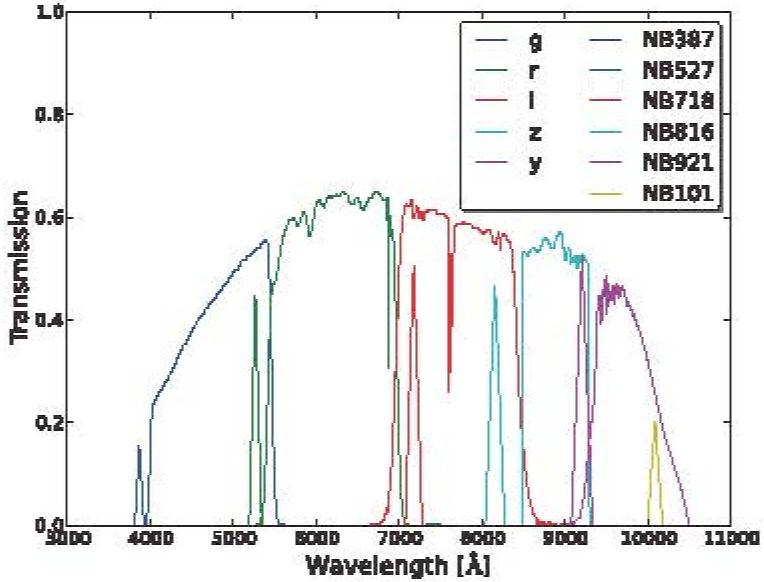
- **Fast**
- Ideal

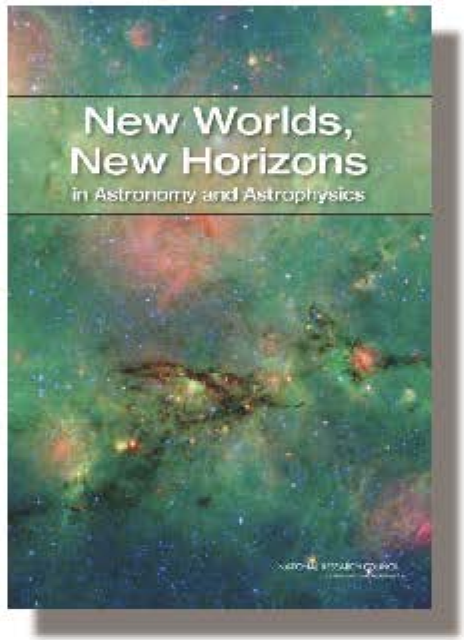
Hyper Suprime-Cam FoV
(1.5 degrees in diameter)



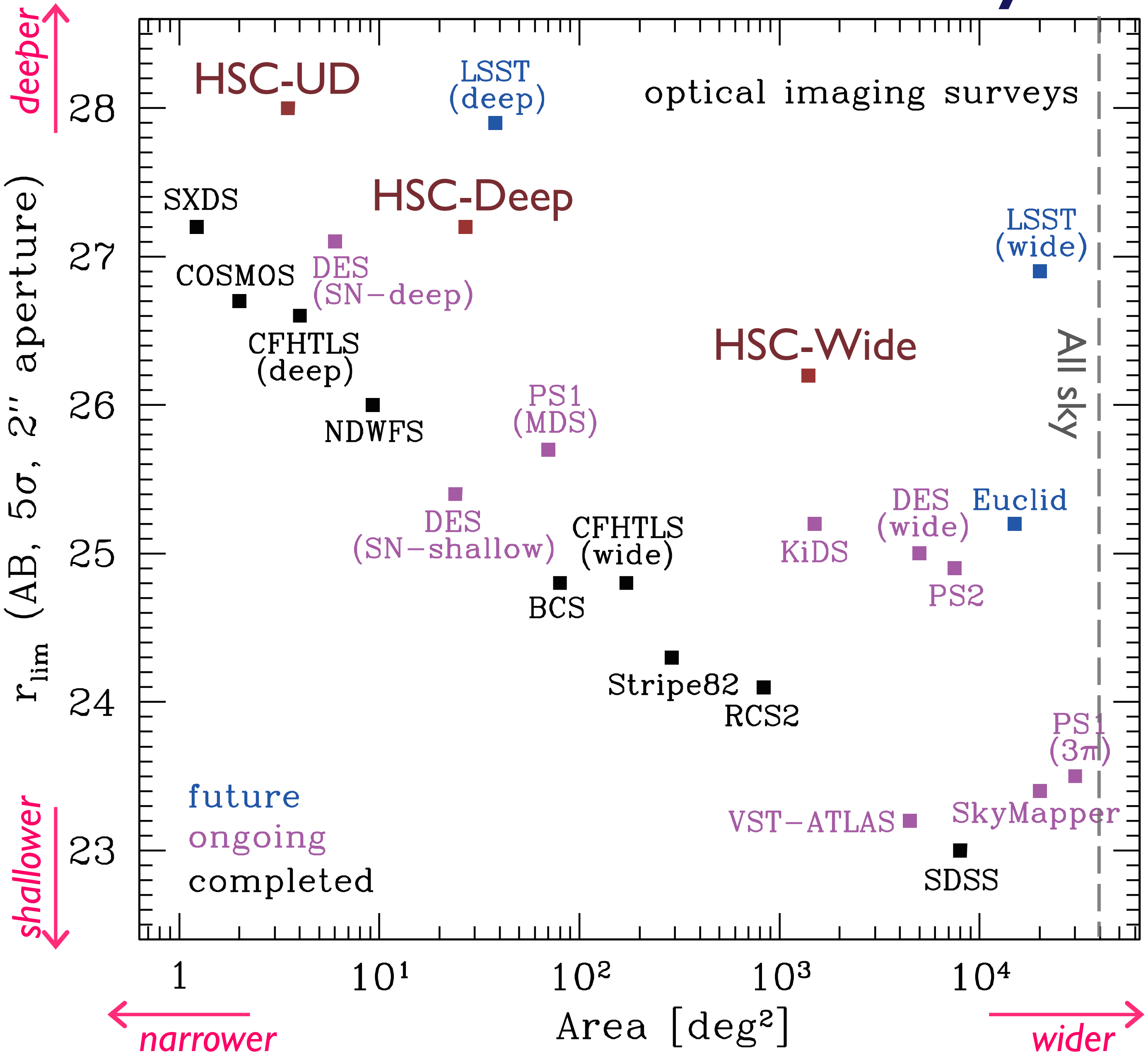
Planned HSC Survey: 3 tiers

- Wide: 1400 sq. degs., *grizy* (i_{AB}=26, 5σ)
  - *Weak gravitational lensing*
  - Galaxy clustering, properties of z~1 L_* galaxy
  - *Dark Energy*, *Dark Matter*, neutrino mass, the early universe physics (primordial non-Gaussianity, spectral index)
- Deep: 28 sq. degs, *grizy*+NBs (*i*=27)
  - For a calibration of HSC-Wide WL/photo-z
  - LAEs, LBGs, QSO
  - Galaxy evolution up to z~7
  - *The physics of cosmic reionization*
- Ultra-deep: 2FoV, *grizy*+NBs (i~28)
  - Type-Ia SNe up to z~1.4
  - LAEs, LBGs, Galaxy evolution
  - *Dark Energy, the cosmic reionization*





Planned HSC survey: 3 tiers



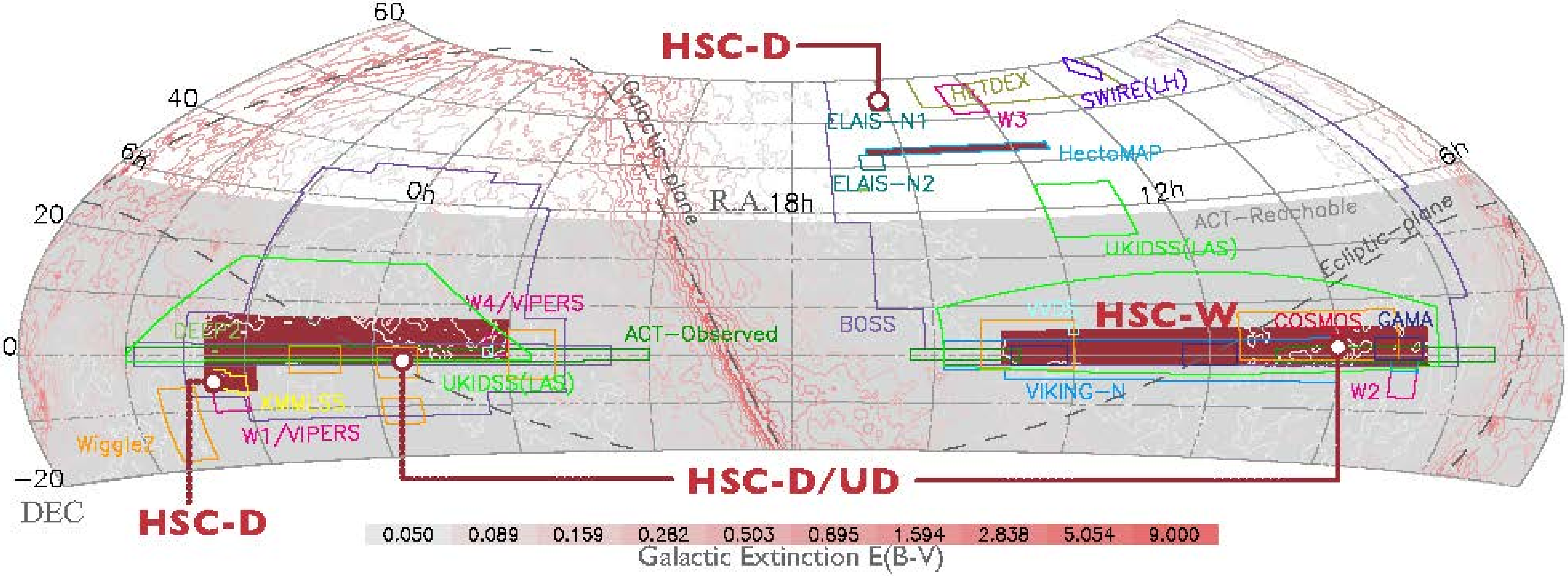
Black: existing

Magenta: upcoming

Blue: future

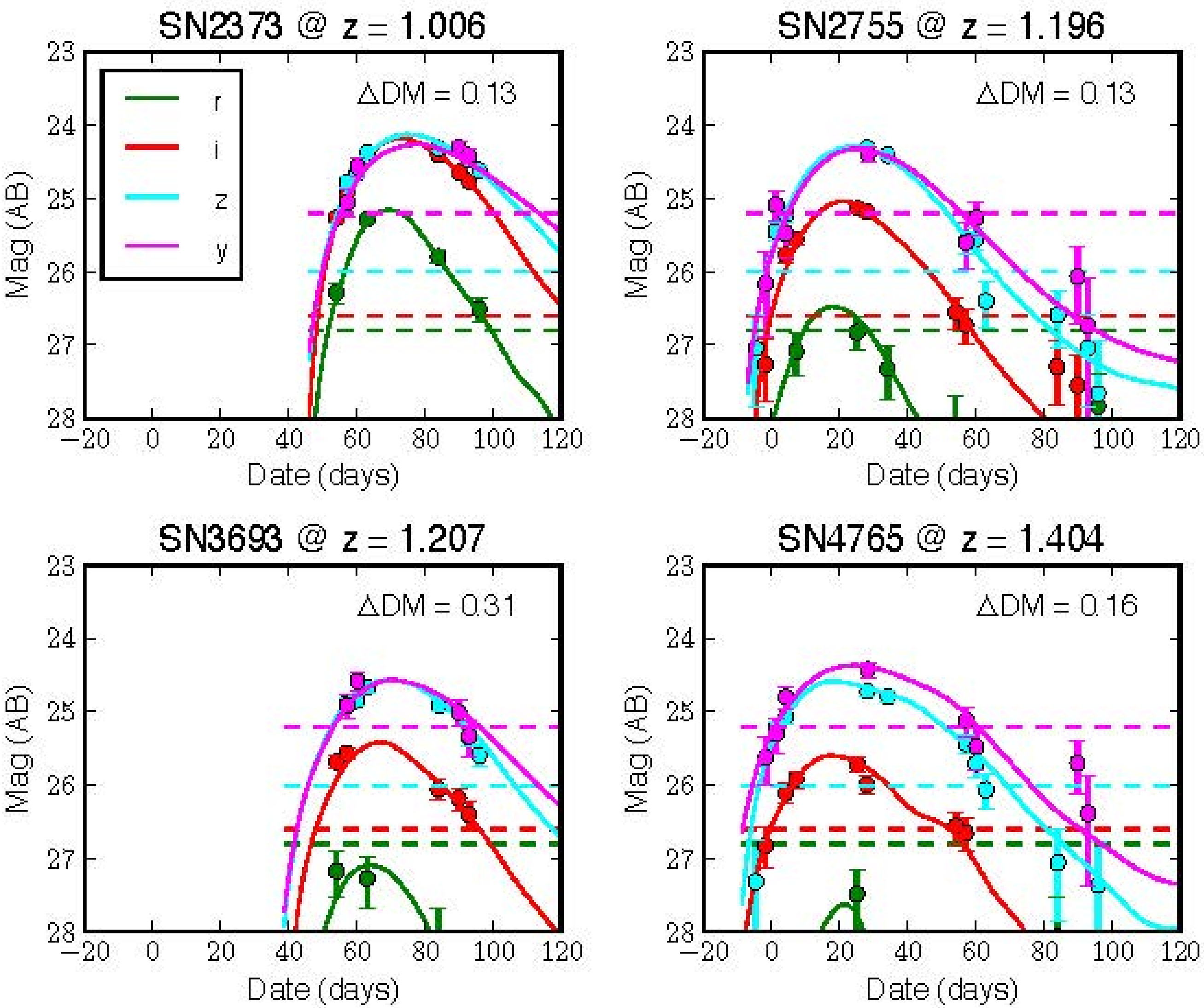
HSC Layers will explore new regions in survey parameter space

HSC Survey Fields



- The HSC fields are selected based on …
  - Synergy with other data sets: SDSS/BOSS, The Atacama Cosmology Telescope CMB survey (from Chile), X-ray (XMM-LSS), spectroscopic data sets
  - Spread in RA
  - Low dust extinction

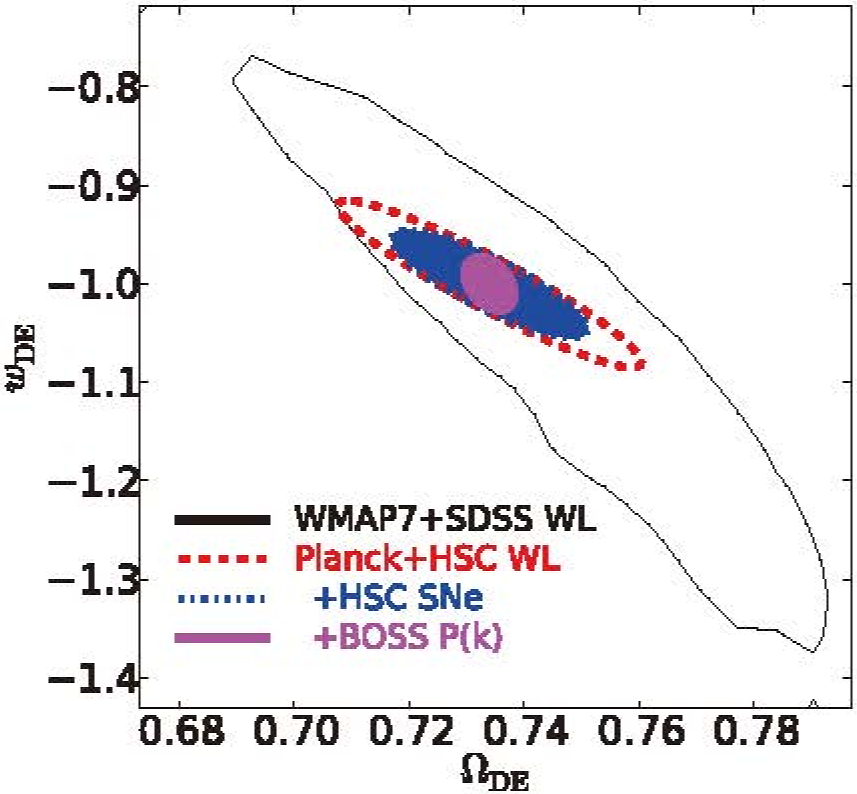
HSC Supernova Survey



- About 50 nights in total
- For HSC ultradeep, about 20 visits for each field, in grizy
- Each exposure is 60-80min
- Achieve >5sigma detection of type-Ia SNe at z~1.4, one week before and two weeks after the peak
- 40 SNe at 1<z<1.4

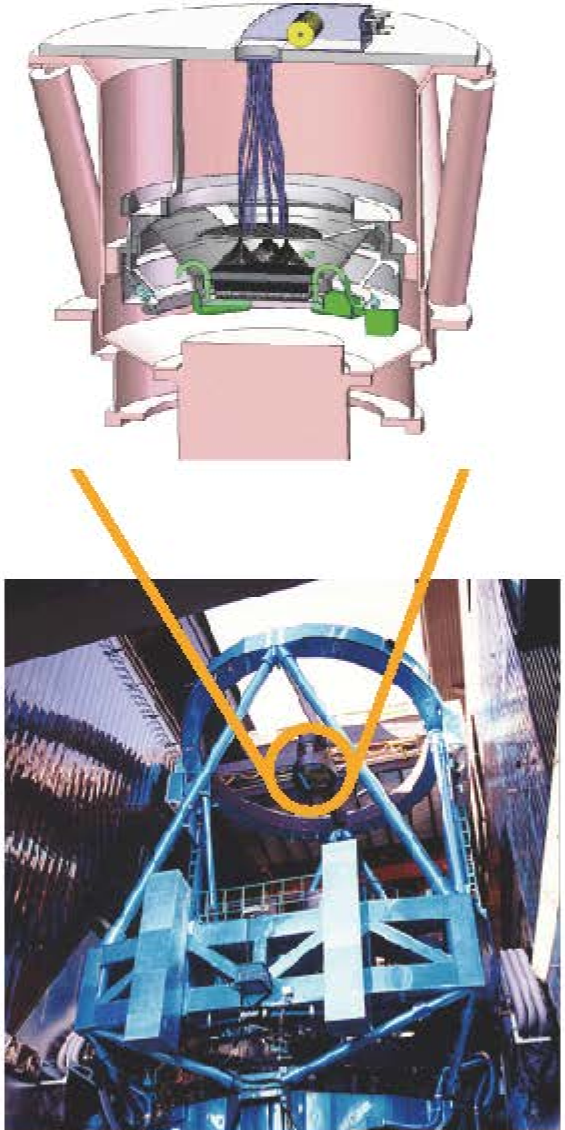
HSC-expected cosmological constraints

Data	$w_{\rm pivot}$	w_a	FoM	γ_g	$m_{\nu,\rm tot}$[eV]	$f_{\rm NL}$	n_s	α_s
BOSS-*BAO*	0.064	1.04	15	–	–	–	0.018	0.0057
HSC(WL)-*B* (baseline)	0.080	0.86	15	0.15	0.16	30	0.014	0.0041
HSC(WL)-*O* (optimistic)	0.068	0.66	22	0.083	0.082	18	0.013	0.0040
HSC(WL+SN)-*B*	0.043	0.60	39	0.15	0.16	30	0.014	0.0041
HSC(WL+SN)-*O*	0.041	0.45	54	0.081	0.081	18	0.013	0.0040
HSC-*O*+[BOSS-$P(k)$]	0.028	0.36	99	0.038	0.076	17	0.011	0.0029
HSC-*O*+[BOSS+PFS]	0.027	0.19	196	0.035	0.07	17	0.009	0.0022



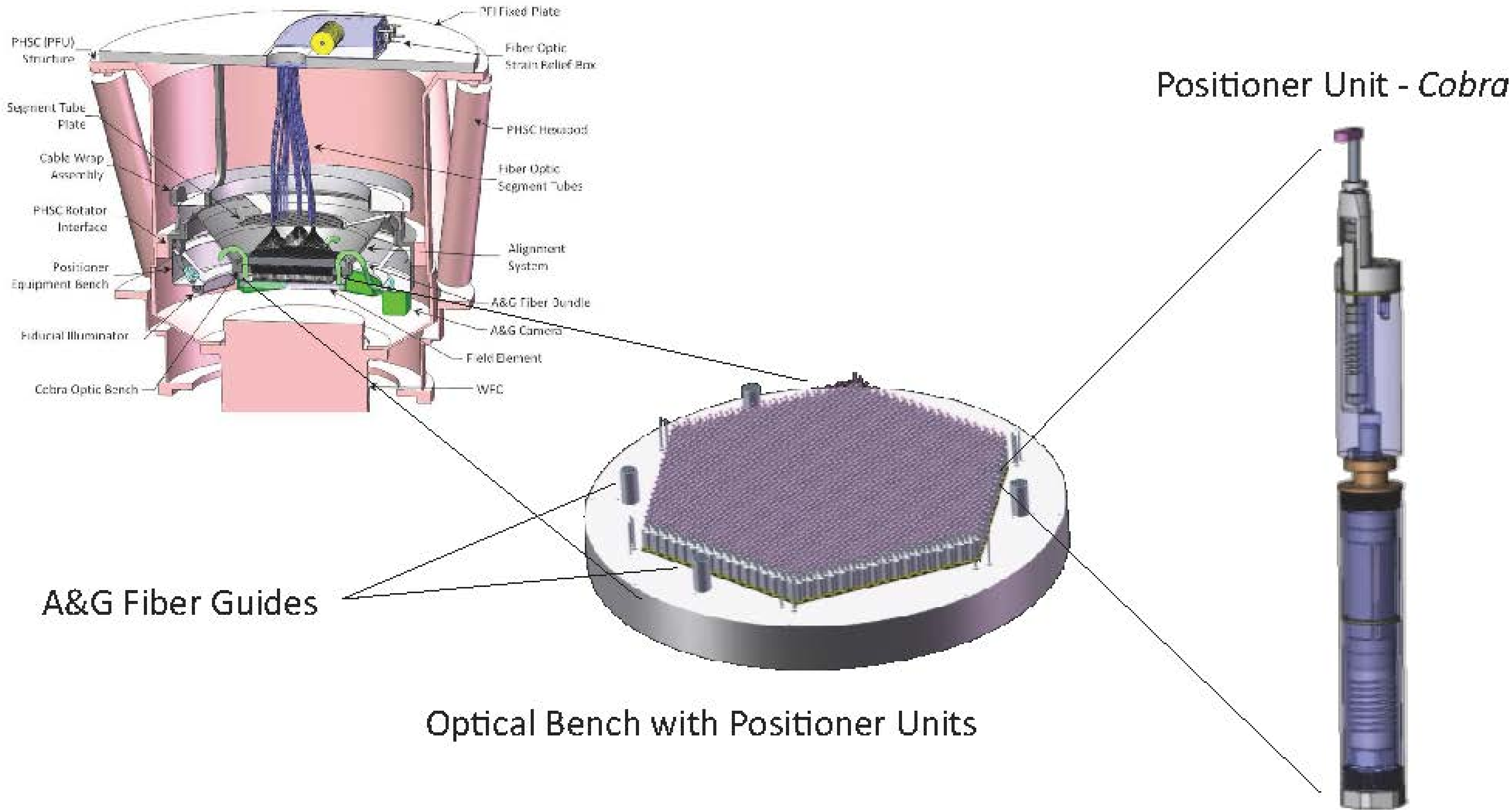
- The HSC promises a significant improvement in our understanding of the universe (dark energy, neutrino mass, other cosmological parameters)

Prime Focus Spectrograph (PFS)



- Multi object fiber spectrograph for 8.2m Subaru
- International collaboration; Japan (IPMU+), Princeton, JHU, Caltech/JPL, LAM, Brazil, ASIAA
- Initiated by the stimulus funding (~$30M secure); $50M needed for the instrumentation
- The current baseline design
  - The same optics to HSC
  - 2400 fibers
  - 380-1300nm wavelength coverage
  - R~2000, 3000, 5000 (blue, red, NIR)
- The target first light; around 2017
- Capable of various science cases: cosmology, galaxy, galactic archeology

PFS Positioner



Cobra system is the most essential part of PFS, and will be built at JPL

Designed to achieve 5 μm accuracy in < 8 iterations (40 sec)

- *Concept Design Review* (Mar 2012)
- Next milestone: Preliminary Design Review (Feb or Mar 2013)

PFS Science Document in arXiv

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EXTRAGALACTIC SCIENCE AND COSMOLOGY WITH THE SUBARU PRIME FOCUS SPECTROGRAPH (PFS)

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Draft version June 21, 2012

ABSTRACT

The Subaru Prime Focus Spectrograph (PFS) is a massively-multiplexed fiber-fed optical and near-infrared spectrograph ($N_{\rm fiber}$=2400, 380≤ λ ≤ 1300nm), offering unique opportunities in survey astronomy. Following a successful external design review the instrument is now under construction with first light predicted in late 2017. Here we summarize the science case for this unique instrument in terms of provisional plans for a Subaru Strategic Program of ≃300 nights. We describe plans to constrain the nature of dark energy via a survey of emission line galaxies spanning a comoving volume of $9.3h^{-3}$Gpc^3 in the redshift range $0.8 < z < 2.4$. In each of 6 independent redshift bins, the cosmological distances will be measured to 3% precision via the baryonic acoustic oscillation scale and redshift-space distortion measures will be used to constrain structure growth to 6% precision. As the near-field *cosmology* program, radial velocities and chemical abundances of stars in the Milky Way and M31 will be used to infer the past assembly histories of both spiral galaxies as well as the structure of their dark matter halos. Complementing the goals of the Gaia mission ($V < 17$), radial velocities and metallicities will be secured for 10^6 Galactic stars to $17 < V < 20$. Data for fainter stars to $V \simeq 21$ will be secured in areas containing Galactic tidal streams. The M31 campaign will target red giant branch stars with $21 < V < 22.5$ over an unprecedented area of 65 deg^2. For the extragalactic program, our simulations suggest the wide wavelength range of PFS will be particularly powerful in probing the galaxy population and its clustering over a wide redshift range and we propose to conduct a color-selected survey of $1 < z < 2$ galaxies and AGN over 16 deg^2 to $J \simeq 23.4$, yielding a fair sample of galaxies with stellar masses above $\sim 10^{10} M_\odot$ at $z \sim 2$. A two-tiered survey of higher redshift Lyman break galaxies and Lyman alpha emitters will quantify the properties of early systems close to the reionization epoch. PFS will also provide unique spectroscopic opportunities beyond these currently-envisaged surveys, particularly in the era of Euclid, LSST and TMT.

Subject headings: PFS — cosmology — galactic archaeology — galaxy evolution

1. INTRODUCTION

There is currently a major expansion in survey imaging capability via the use of CCD and near-infrared detector mosaics on a wide range of ground-based telescopes. Such imaging surveys provide accurate photometric and other data to enable the study of gravitational lensing signals which trace the distribution of dark matter and to conduct census studies of Galactic structures and distant star-forming galaxies. For over a decade it has been recognized that a similar revolution

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PFS collaboration

Caltech

NASA Jet Propulsion Laboratory
California Institute of Technology

NAOJ

Academia Sinica

PRINCETON UNIVERSITY

lead institution

IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

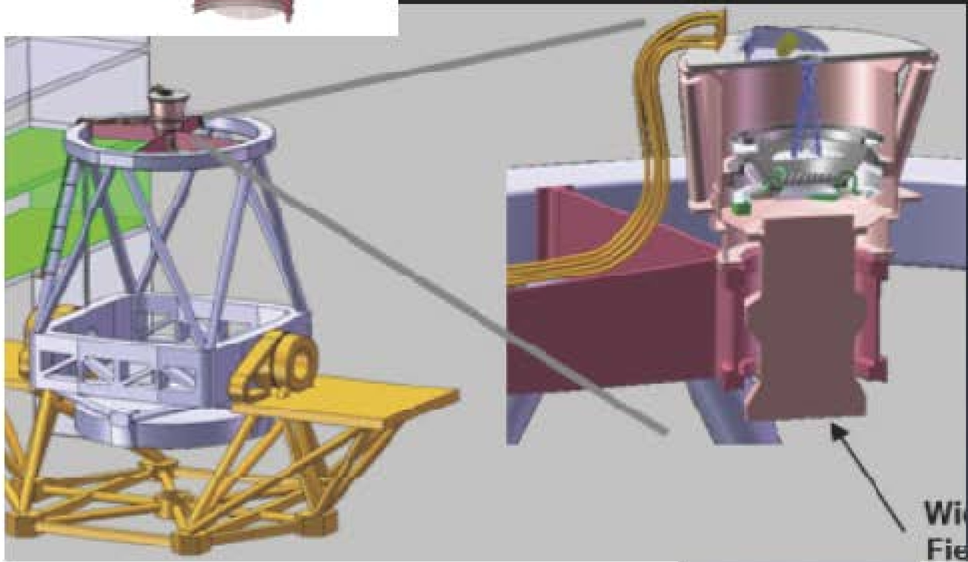
LNA LABORATÓRIO NACIONAL DE ASTROFÍSICA

LAM LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE

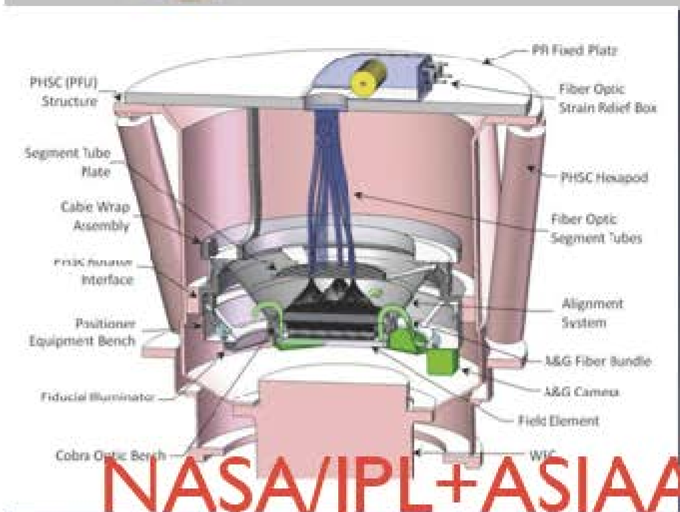
JOHNS HOPKINS UNIVERSITY

instrument team

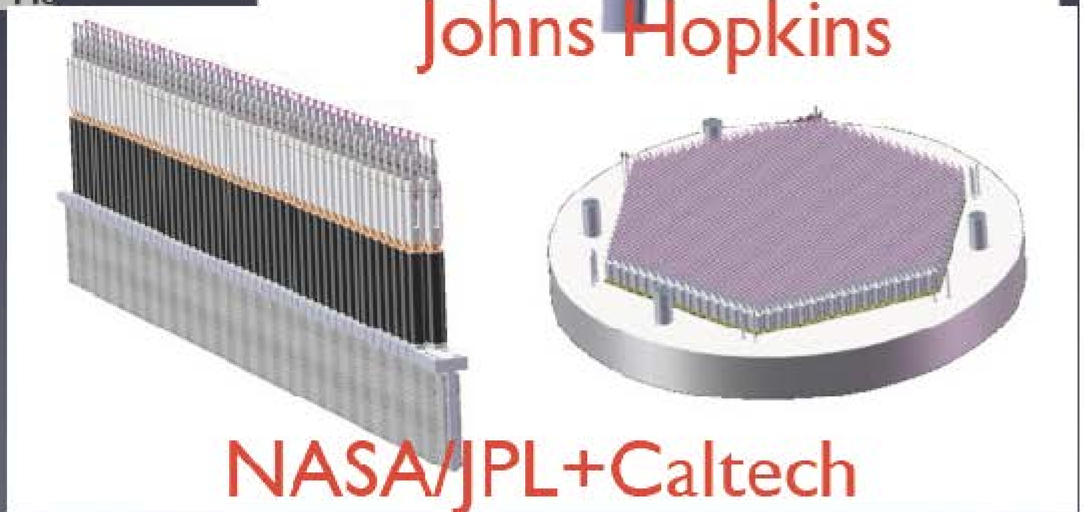
ASIAA



Princeton, Marseille, Johns Hopkins

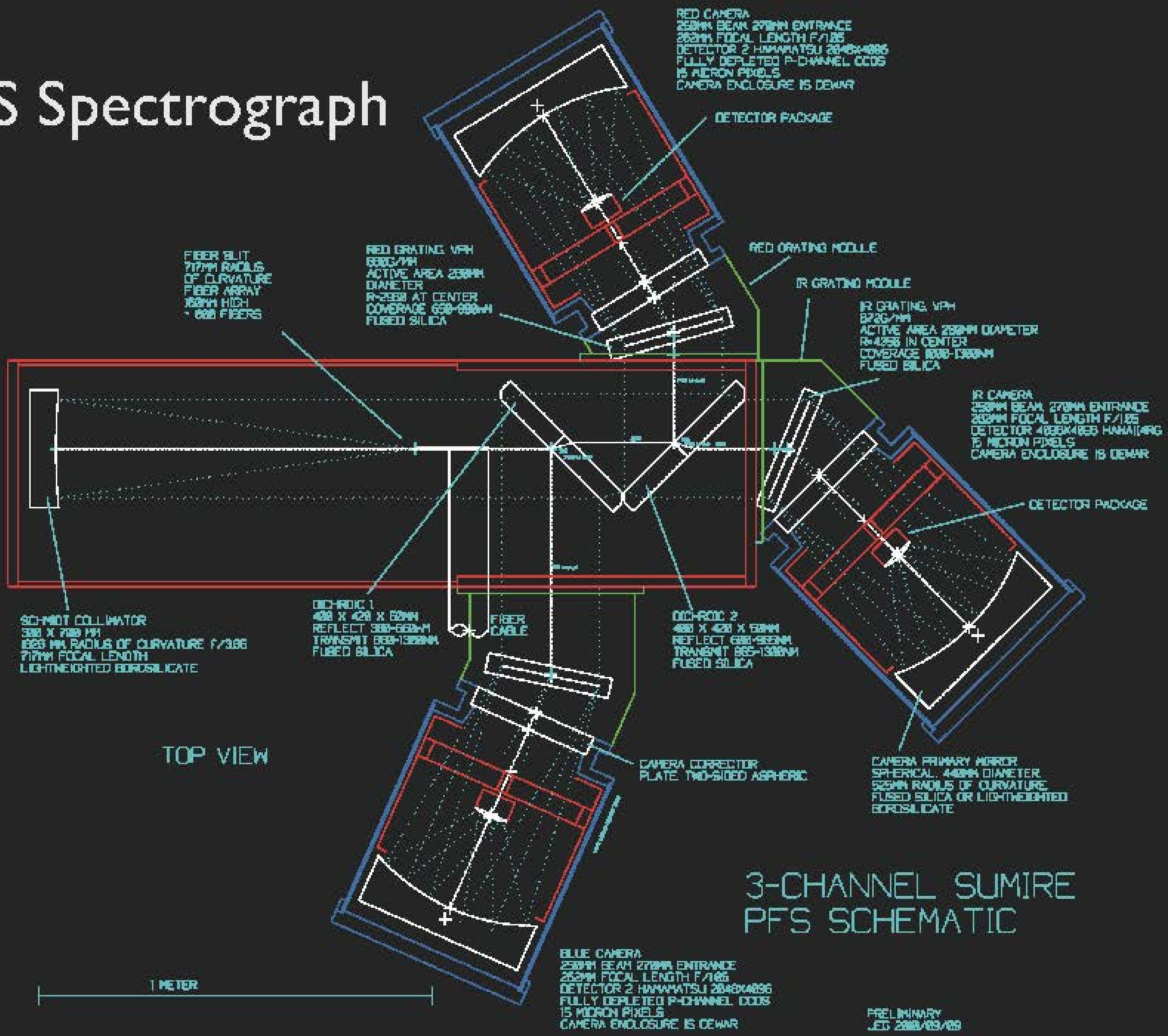


NASA/JPL+ASIAA



NASA/JPL+Caltech

PFS Spectrograph

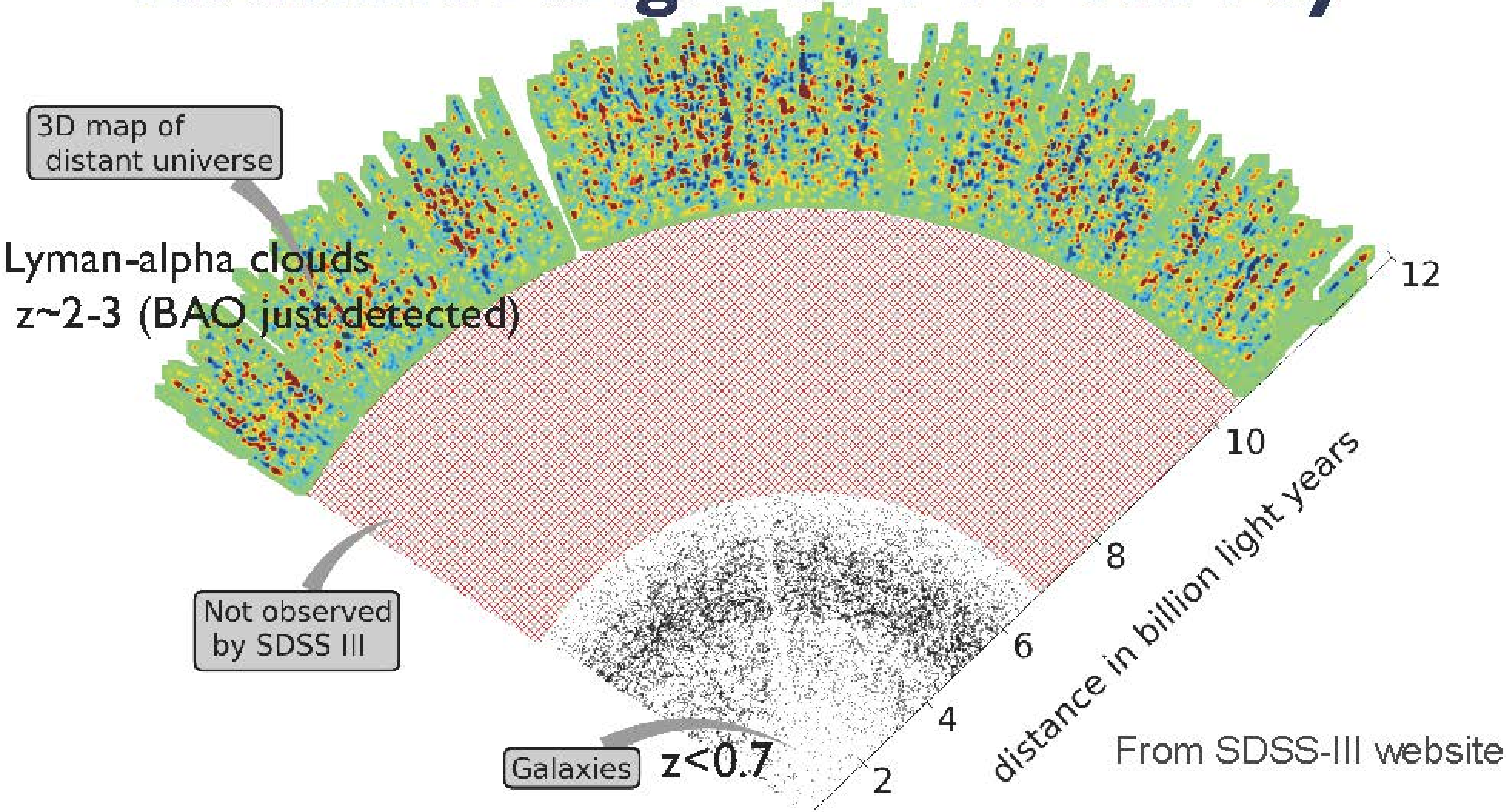


Basic parameters

- The current baseline design parameters

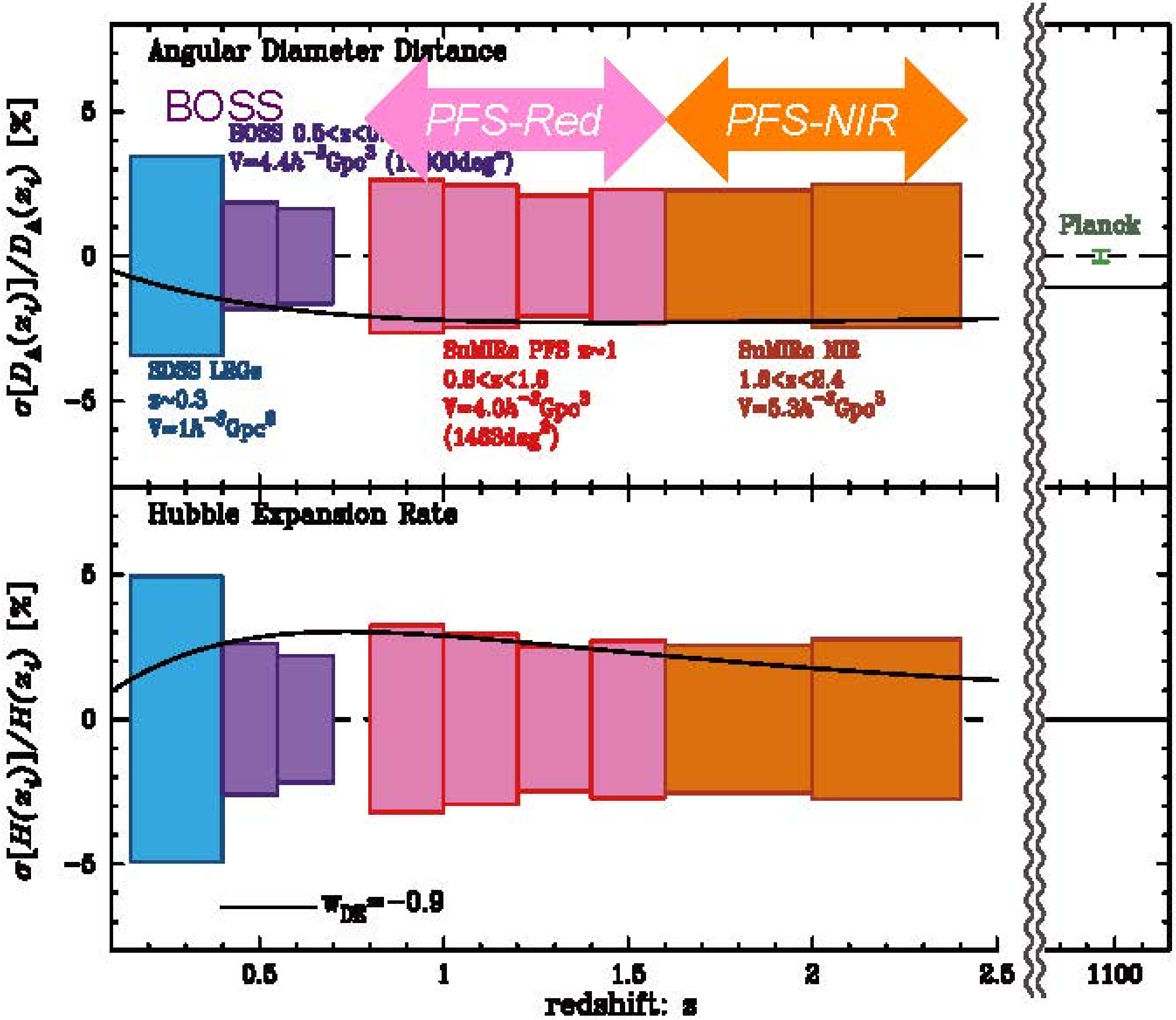
Number of fibers	~2400 (600 for each spectrograph)		
Field of view	1.3 deg (hexagonal diameter) 1.1 sq. degs		
Fiber diameter	1.13" diameter at the field center, 1.03" at the edge		
	Blue arm	Red arm	IR arm
Wavelength cov.[nm]	380 – 670	650 – 1000	970 – 1300
Spectral resol.	~2000	~3000	~4000
Pixel scael [A/pix]	0.71	0.85	0.81
Read-out [e rms/pxi]	3	3	4
Detector	CCD	CCD	HgCdTe
Thermal bckg [e/pix/s]	None	None	0.013

Redshift range for PFS survey



- 0.7<z<2 universe not yet observed
- SuMIRe = Imaging & spectroscopic surveys of the *same* region of the sky with the *same* telescope

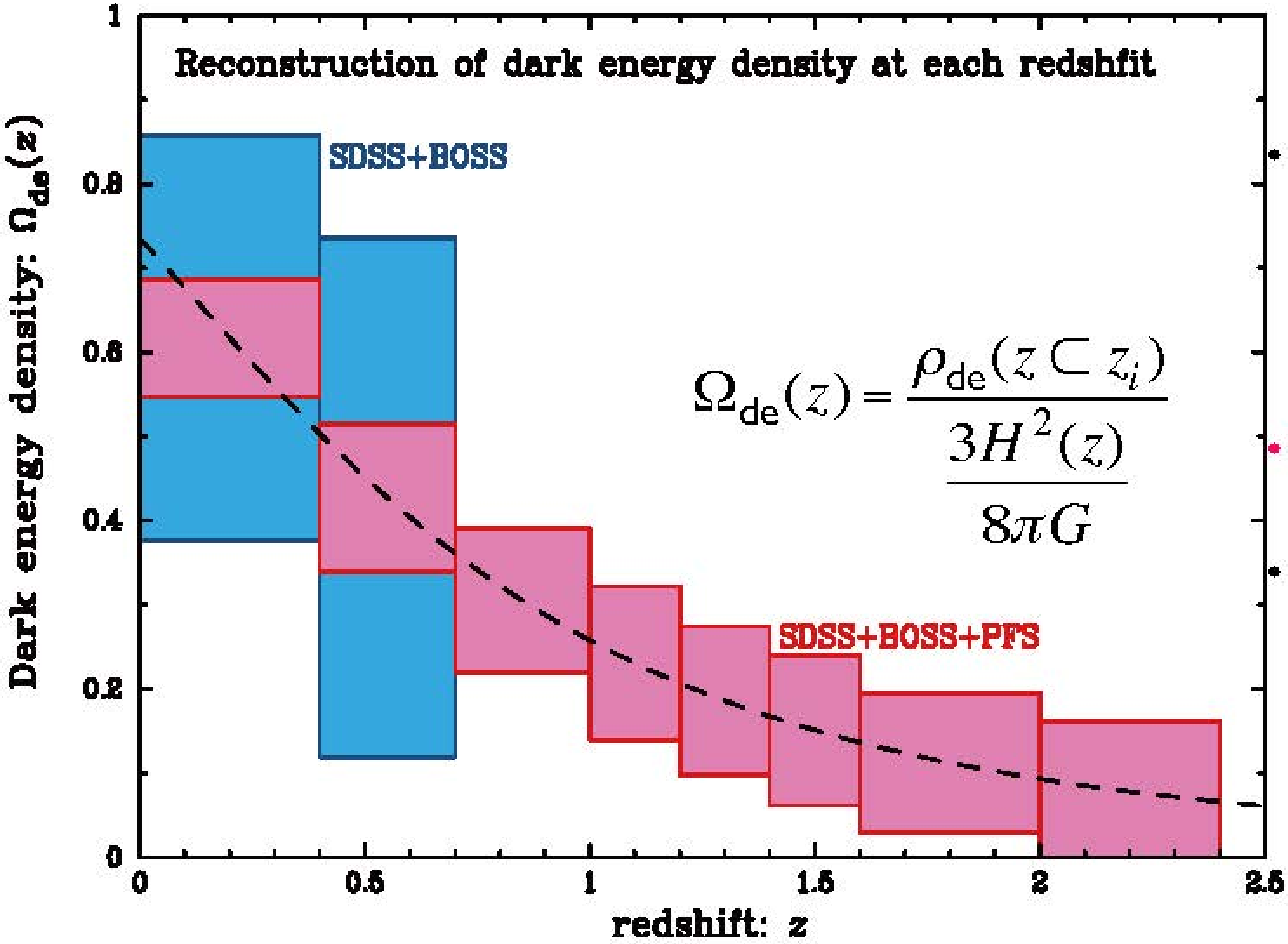
Expected BAO constraints



- The PFS cosmology survey enables a 3% accuracy of measuring $D_A(z)$ and $H(z)$ in each of 6 redshift bins, over 0.8<z<2.4
- This accuracy is *comparable* with BOSS, but extending to higher redshift range
- Also very efficient given competitive situation
  - BOSS (2.5m): 5 yrs
  - PFS (8.2m): 100 nights

DE reconstruction

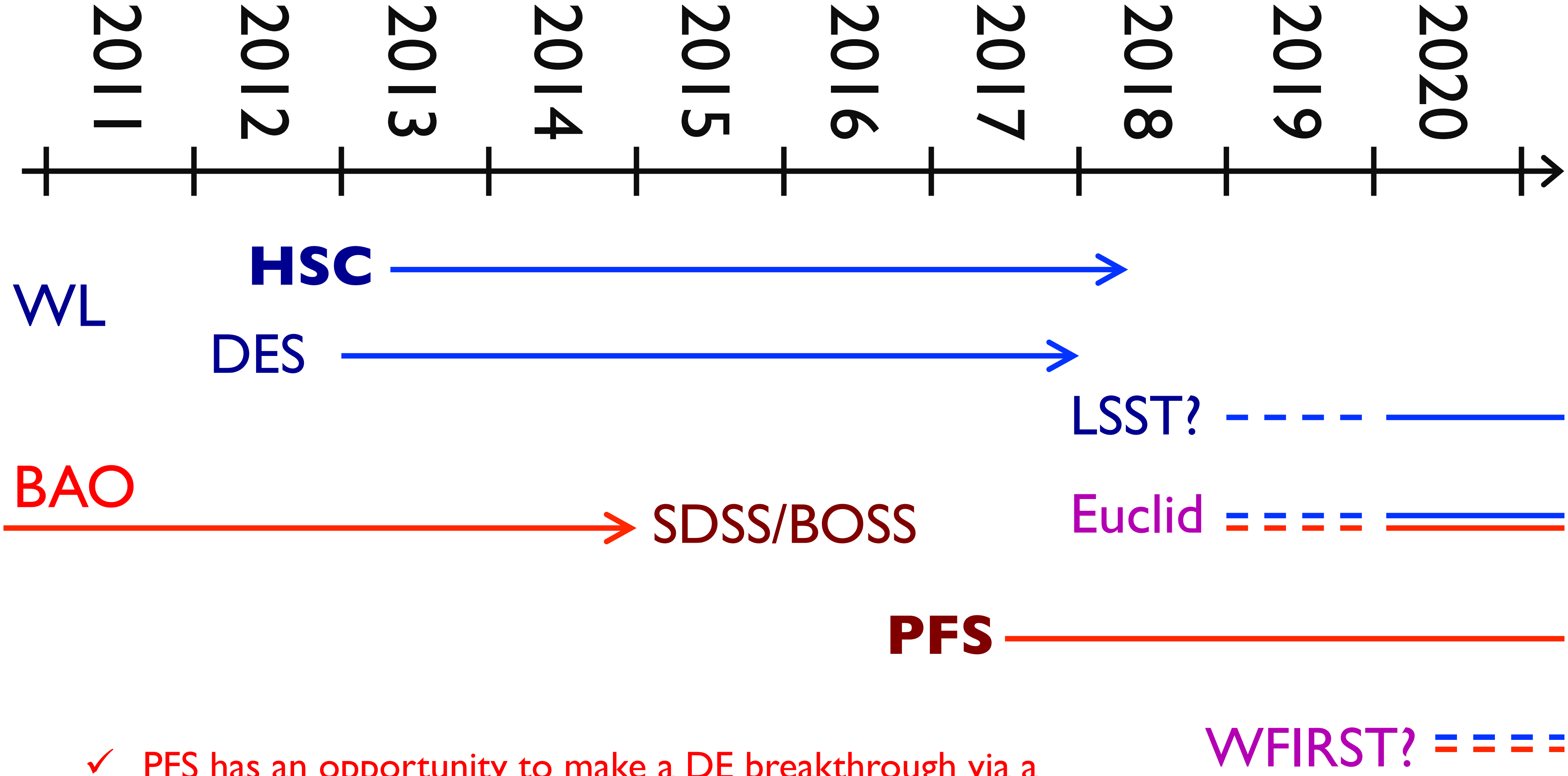
- The wide-z coverage of PFS+BOSS enables a reconstruction of DE densities as a function of redshift → can constrain a broader range of DE models



- PFS can significantly improve the accuracy of the reconstruction due to the increased z-bins
- 7% accuracy of $\Omega_{de}(z)$ in each of z-bins
- PFS+SDSS+Planck allows a detection of dark energy up to z~2, for a Λ-type model


Dark Energy Competition
SDSS III
BOSS (2009-)
KIDS (2012-)
Euclid (2020)
DARK ENERGY SURVEY
DES (2012-)
BigBOSS (2015?-)
A Proposal to NOAO for the
BigBOSS Experiment
at Kitt Peak National Observatory
October 1, 2010
LSST
Large Synoptic Survey Telescope
LSST (2020?-)
WFIRST (2020?-)
Wide Field Infrared Survey Telescope

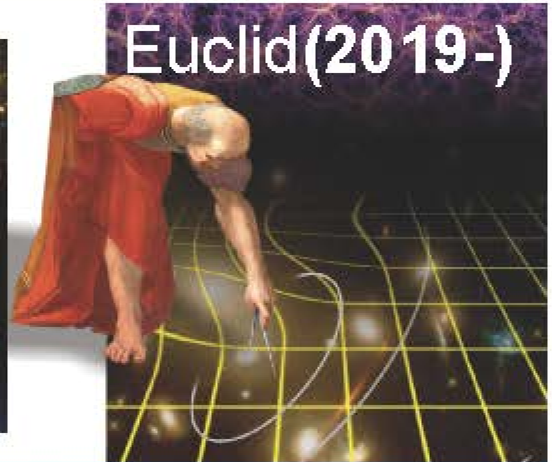
Time line (DE experiments)



✓ PFS has an opportunity to make a DE breakthrough via a 3-5 year survey prior to the launch of Euclid

Synergy of PFS with future

- HSC & PFS allow for making Subaru Telescope a unique facility even in 2020era – just like SDSS (2.5m) vs. 8m tels now
- Various synergy with future
  - GAIA (2013)
  - Euclid (2019)
  - LSST (2018 or 19?)
  - WFIRST (???)
  - TMT& E-ELT (???)



Summary

- SuMIRe = Subaru Measurement of Images and Redshifts
  - Unique capabilities of 8.2m Subaru Telescope (other projects all 4m-class telescopes besides LSST)
- Hyper Suprime-Cam Survey (HSC) = imaging of 1B gals
  - Start the wide-area survey from around Aug 2013 for 5 years
  - Use WL to recover the DM distribution up to z~1
  - Also study galaxy evolution and cosmic reionization
- Prime Focus Spectrograph (PFS) = redshifts of 4M gals
  - Start the wide area survey from around 2018 for 5 years
  - Baryon Acoustic Oscillations to measure the cosmic expansion rate
- Imaging + spectroscopic survey is a very powerful combination
  - Cosmology: DE, DM, neutrino masses, curvature, inflation models (f_NL)
  - Not only for cosmology, also for galaxy evolution, the origin of Milky Way
- *First* wide-area, massive galaxy surveys with Subaru