Astro2020 (USA; Deadline July 20th 2019)
Voyage 2050 (Europe; Aug 5th 2029)
Status Report

Kavli IPMU 鈴木尚孝

- Astro2020 I: Facilities (310 White Papers)
- Astro2020 II: Science (584 White Papers)
  http://sites.nationalacademies.org/DEPS/astro2020/index.htm
- Voyage 2050 (97 White Papers)
  https://www.cosmos.esa.int/web/voyage-2050/white-papers

Astro2020

6 panels

- Cosmology
- Stars, the Sun, Stellar Populations
- Galaxies
- Exoplanets, Astrobiology, the Solar System
- ISM, Star and Planet Formation
- Compact Objects, Energetic Phenomena

Recap: 2010 Decadal Survey Recommendations

SPACE

- 1: WFIRST
- 2: Small (SMEX) and medium-size (MIDEX) Explorer missions (5-Year Time Scale) NuStar, WISE, TESS, SPHEREx
- 3: LISA
- 4: IXO (International X-ray Observatory) Cancelled

Ground Based Facilities

- 1: LSST
- 2: Mid-Scale Innovation Program:

SDSS-IV, ACT, ZTF, EHT, Polarbear, CARMA, PAPER

- 3: GMT
- 4: Cherenkov Telescope Array

2020 Decadal Survey 勝手な予想

Keywords: GW, Planet, Reionization, Neutrino, FRB

SPACE

- 1: LUOVIR/OST/HabEx/LynX
- 2: LISA x Pathfinder
- 3: ngVLA / SKA
- 4: Mid/Small-Size Projects
- AXIS, CDIM, CETUS, Earthfinder, GEP, PICO, PEMMA, Starshade, STROBE-X, TAP

Ground Based Facilities

- 1: GMT x TMT
- 2: Southern Hemisphere Multi-Spectrograph
- 3: Multi-Messenger Astronomy
- 4: Mid/Small-Size Projects

光赤外天連：LoI
Missing Factors

- 12件の応募は少ない、小型中型計画があってもよいのでは？
- 2030年代のすばる望遠鏡の姿 (HSC & PFS)
- Multi-Messenger Astronomy (GW & Neutrino e.g. POEMMA)
- 日本独自の計画
- 予算規模と地上とスペースを分けて考える
- LSST を参考にすばるの将来を考える

Ground Based Facilities
Post LSST (2022-32) by Steven Kahn

Astro2020: Activity, Project, and Statement of the Profession Consideration White Paper

Future Uses of the LSST Facility: Input from the LSST Project Science Team

Thematic Areas:
☒ Planetary Systems ☒ Star and Planet Formation
☒ Formation and Evolution of Compact Objects ☒ Cosmology and Fundamental Physics
☒ Stars and Stellar Evolution ☒ Resolved Stellar Populations and their Environments
☒ Galaxy Evolution ☒ Multi-Messenger Astronomy and Astrophysics

Principal Author:
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- 0: Extend the Survey
- 1: Modest Cost Modification
- 2: Replacement of Camera

Post LSST : Extend the Survey

Table 1: Various science metrics as functions of survey duration.

Quantity	Year 1	Y3	Y5	Y8	Year 10	Y12
r_5 coadd[a]	26.3	26.8	27.1	27.4	27.5	27.6
$\sigma(i{=}25)$[b]	0.12	0.07	0.06	0.05	0.04	0.04
color vol.[c]	316	20	6	1.7	1	0.6
# of visits[d]	83	248	412	660	825	990
σ_π (r=24)[e]	9.5	5.5	4.2	3.3	3.0	2.7
σ_μ (r=24)[f]	32	6.1	2.8	1.4	1.0	0.8

[a] The coadded depth in the r band (AB, 5σ; point sources).

[b] The photometric error for a point source with $i = 25$.

[c] The volume of the 5-dimensional color space, normalized by the final value.

[d] The number of visits per sky position (summed over all bands).

[e] The trigonometric parallax accuracy for a point source with r=24 (milliarcsec).

[f] The proper motion accuracy for a point source with r=24 (milliarcsec/yr).

延長するメリットはあまりない

唯一、固有運動測定がより正確になる

Post LSST : Modest Modification

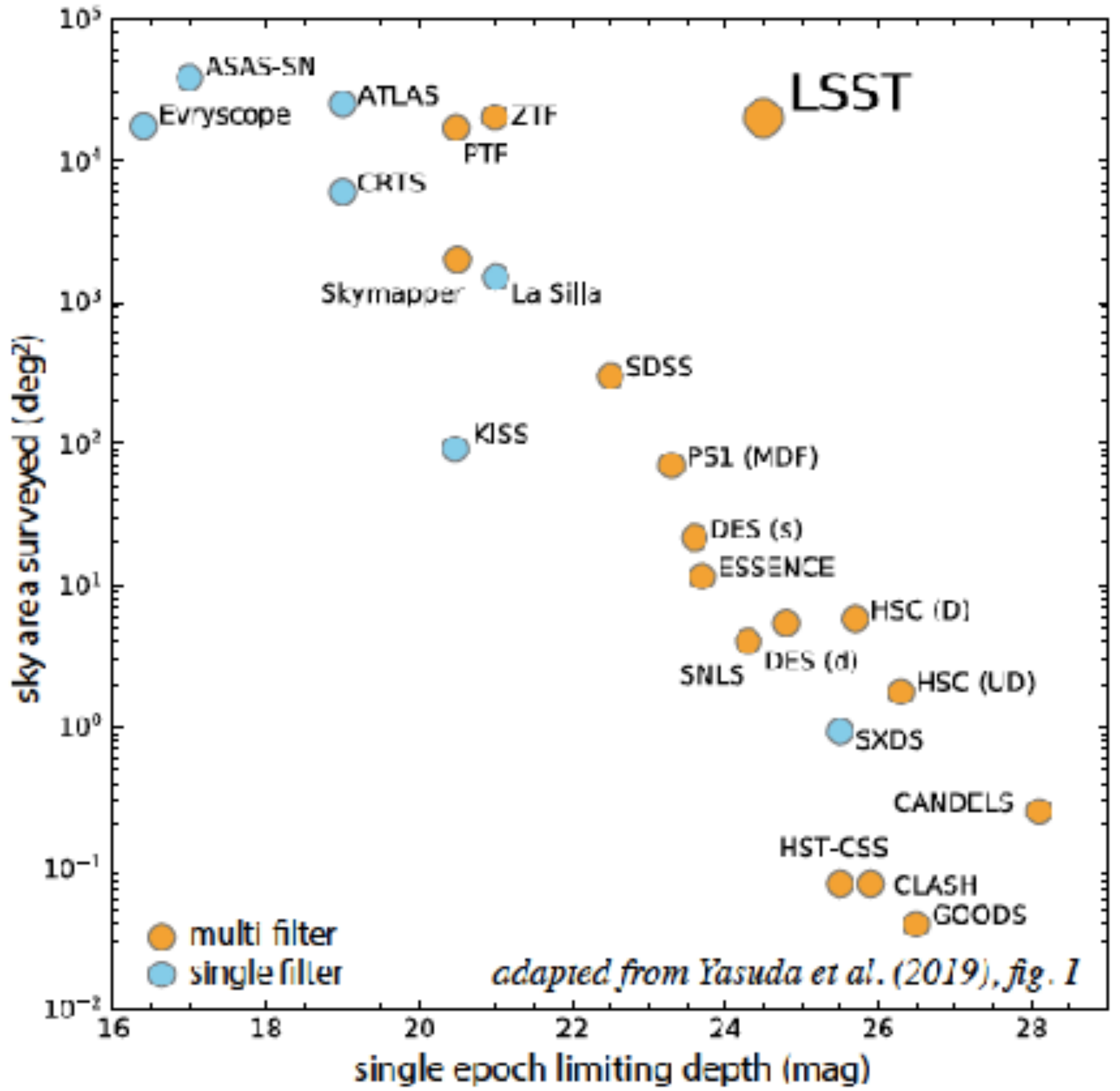


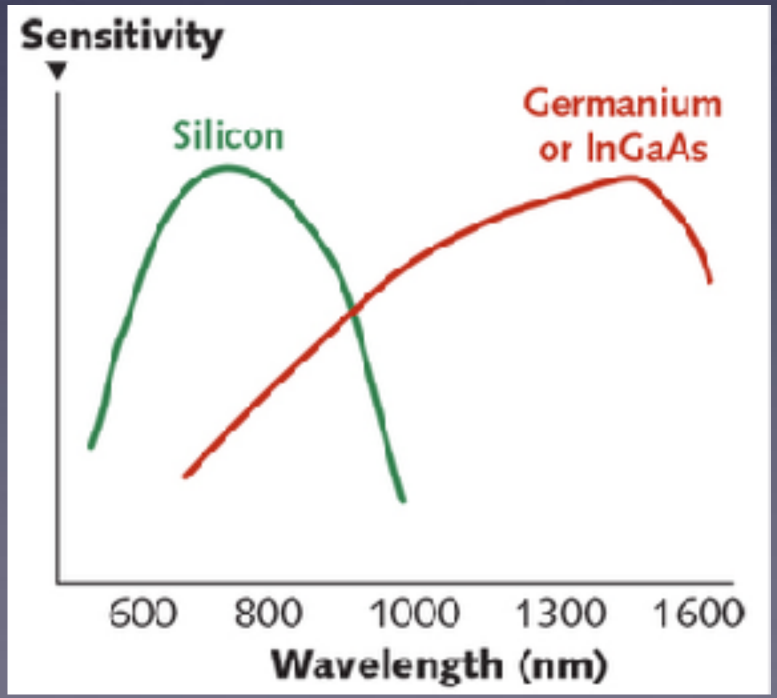
Figure 1: Sky area versus single-epoch depth for time-domain optical surveys. LSST is unique in its ability to characterize the changing sky, and it should remain as the premier facility in this application even after its 10-year survey. *This figure is adapted from Yasuda et al. (2019).*

- Upgrade CCDs
- Intermediate Filter (5-bands)
- Narrow-band ($\Delta\lambda$15-20nm)

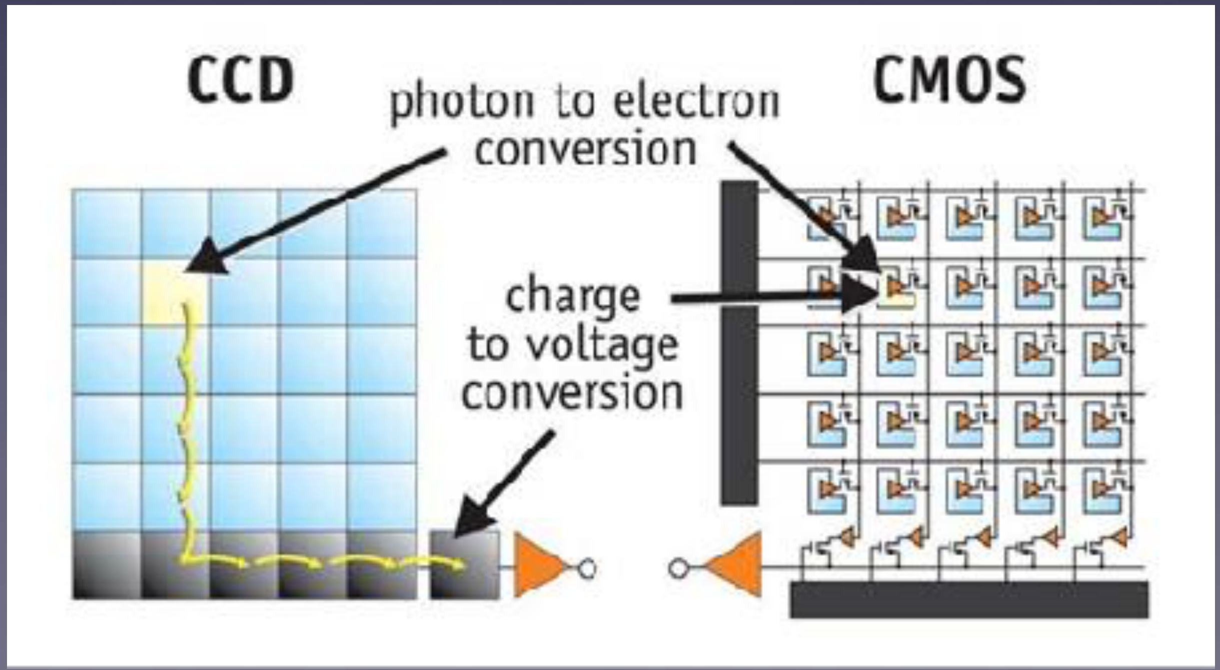
Post LSST : Replacement of Camera

- 1: Multi-Spectrograph ($500M)
- 2: IR Camera ($500M) : 1.0-1.8 micron
    - HgCdTe (MCT), Germanium CCD, InGaAs
- 3: CMOS ($100M) : Hz - kHz survey

Germanium CCD



CMOS



MegaMapper
Southern Hemisphere Multi-Spectrograph

Astro2020 APC White Paper

The MegaMapper: a $z > 2$ spectroscopic instrument for the study of Inflation and Dark Energy

Thematic Areas: Ground Based Project, Cosmology and Fundamental Physics

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Component	Cost ($M)	Basis of estimate
Telescope facility	70	Magellan 1 & 2
Secondary	10	Vendor ROM
Corrector	20	DESI
Focal plane	10	DESI
Fibers	5	DESI
Spectrographs	24	DESI and SDSS-V
Total	139	

Table 3: MegaMapper costing and basis of estimates

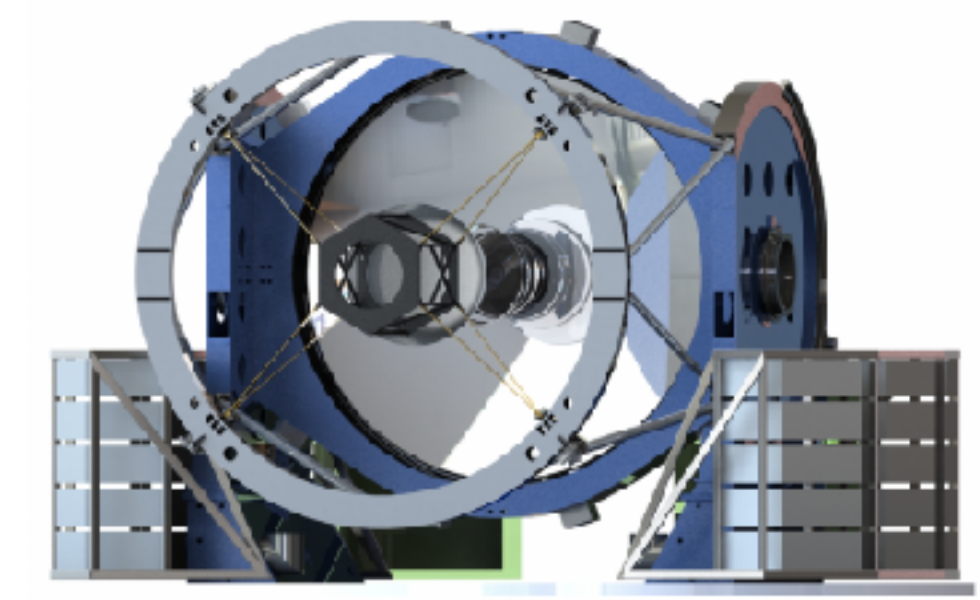
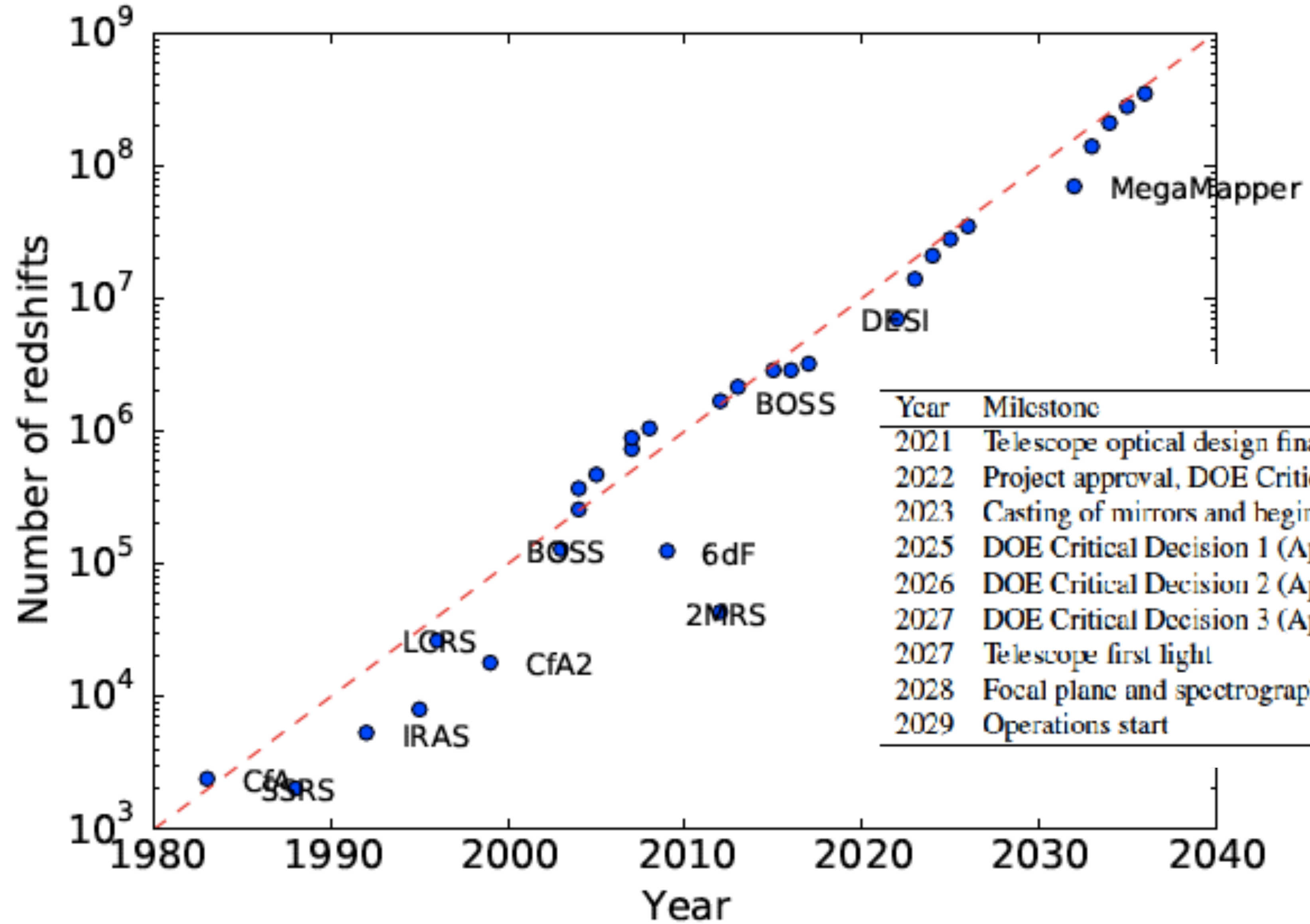


Figure 2: Rendering of the Magellan-style telescope with the secondary mirror and 7-element corrector, pointed towards the horizon. The 32 MegaMapper spectrographs are parked on the base with a fiber run that is substantially shorter than the 50-meter run for DESI.

MegaMapper (20,000 fibers, FoV 7 deg) on Magellan-Style Telescope



Year	Milestone
2021	Telescope optical design finalized
2022	Project approval, DOE Critical Decision 0 (Mission Need)
2023	Casting of mirrors and begin aquisition of corrector blanks
2025	DOE Critical Decision 1 (Approve Alternative Selection)
2026	DOE Critical Decision 2 (Approve Alternative Analysis and Cost Range)
2027	DOE Critical Decision 3 (Approve Start of Construction)
2027	Telescope first light
2028	Focal plane and spectrograph installation start
2029	Operations start

Figure 1: Number of galaxy redshifts as a function of time for the largest cosmology surveys. The dotted line represents an increase of survey size by a factor of 10 every decade. Fielding the MagaMapper in ten years maintains this pace into the 2030s, and enables the Inflation and Dark Energy measures proposed in this and other white papers.

MegaMapper, MSE, LSSTspec & SpecTel

Instrument (year)	Primary/m^2	Nfiber	Reflections	Product	Speed vs. SDSS
SDSS (1999)	3.68	640	0.9^2	1908	1.00
BOSS (2009)	3.68	1000	0.9^2	2980	1.56
DESI (2019)	9.5	5000	0.9^1	42,750	22.4
PFS (2020)	50	2400	0.9^1	108,000	56.6
4MOST (2022)	12	1624	0.9^2	15,800	8.3
MegaMapper	**28**	**20,000**	$\mathbf{0.9^2}$	**454,000**	**238.**
Keck/FOBOS	77.9	1800	0.9^3	102,000	53.6
MSE	78	3249	0.9^1	228,000	119.
LSSTspec	35.3	8640	0.9^3	222,000	116.
SpecTel	87.9	15,000	0.9^2	1,070,000	560.

Table 1: Survey speeds for multi-fiber spectrographs as measured by the product of the telescope clear aperture, number of fibers and losses from mirror reflections. This speed assumes a dedicated program, which would not be possible in all cases. Keck/FOBOS [9], MSE [10], SpecTel [11] and MegaMapper are proposed experiments. LSSTspec [12] is a notional number using MegaMapper positioners on the LSST focal plane, if optical design limitations could be overcome injecting f/1.2 light into fibers.

Instrument (year)	Primary/m^2	FOV/deg^2	Reflections	Product	Speed vs. SDSS
SDSS (1999)	3.68	7.06	0.9^2	21.0	1.00
BOSS (2009)	3.68	7.06	0.9^2	21.0	1.00
DESI (2019)	9.5	8.04	0.9^1	68.7	3.27
PFS (2020)	50	1.33	0.9^1	59.9	2.85
4MOST (2022)	12	4.90	0.9^2	58.8	2.80
MegaMapper	**28**	**7.06**	$\mathbf{0.9^2}$	**160.**	**7.62**
Keck/FOBOS	77.9	0.087	0.9^3	4.94	0.23
MSE	78	1.52	0.9^1	107.	5.10
LSSTspec	35.3	9.60	0.9^3	247.	11.76
SpecTel	87.9	4.91	0.9^2	350.	16.65

Table 2: Survey speeds as measured by the raw product of collecting area and field-of-view. This is the appropriate metric for a wide-area survey with sparse targets. Even without taking full advantage of multiplexing, the MegaMapper survey speed is competitive with larger telescopes owing to its large field-of-view.

SpecTel: 8-12m
New Telescope
Ellis & Dawson

Schlegel et al
arxiv: 1907.1171

Astro2020: ATLAS Probe

Astro2020 Project White Paper

ATLAS Probe: Breakthrough Science of Galaxy Evolution, Cosmology, Milky Way, and the Solar System

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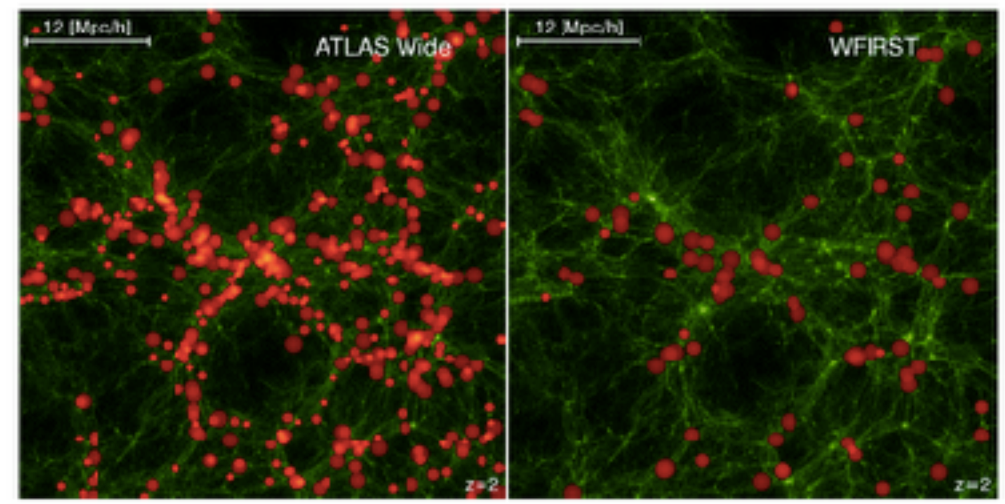


Fig. 1. Cosmic web of dark matter (green) at z=2 traced by galaxies (red filled circles) from the *ATLAS* Wide survey (left), which obtains spectra for 70% of galaxies in the *WFIRST* weak lensing sample, compared to *WFIRST* GRS (right). The larger circles represent brighter galaxies. (Wang et al. 2019a)

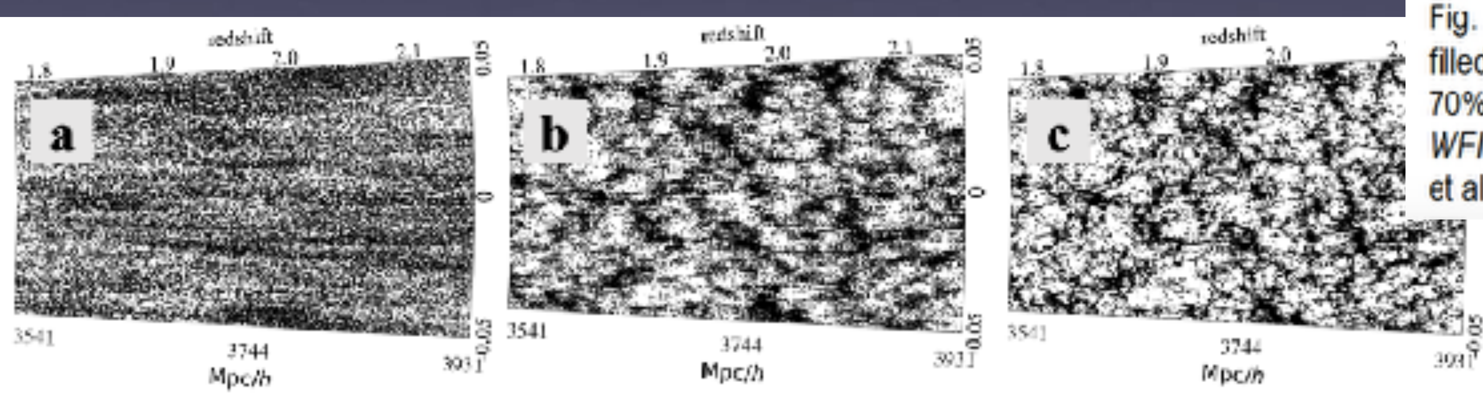
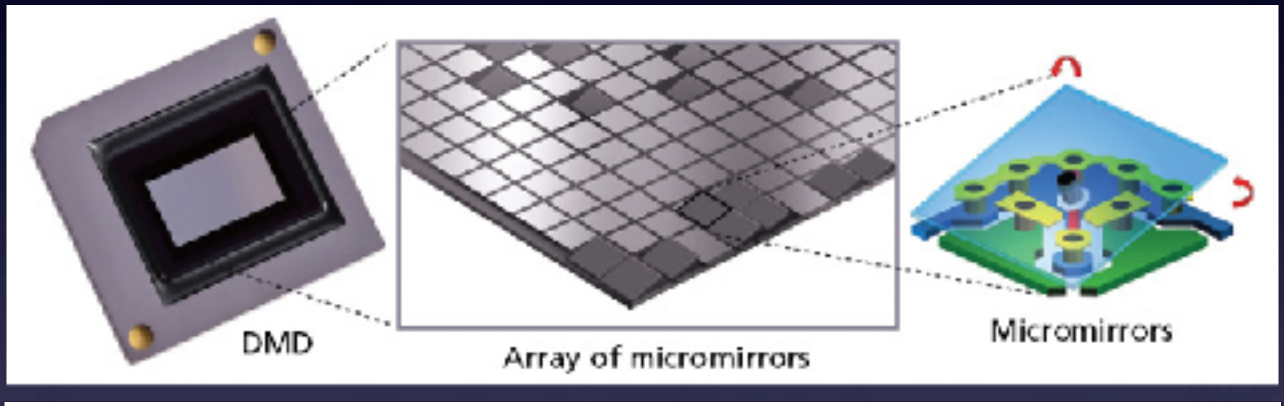


Fig.2: The spatial distribution of Hα-emitting galaxies at z=2 from the semi-analytical galaxy formation model GALFORM. Each panel illustrates a different survey of the same galaxy distribution, with redshift accuracy $\sigma_z/(1+z)$ equal to (a) 10^{-2} (most optimistic photo-zs); (b) 10^{-3} (slitless spectroscopy); and (c) 10^{-4} (*ATLAS* slit spectroscopy).

ATLAS (1.5m, R-1000, FoV 0.4 deg^2 NIR λ1-2.1 micron, MIR 2.1-4 micron)

DMD:
Digital Micro Mirror Devices



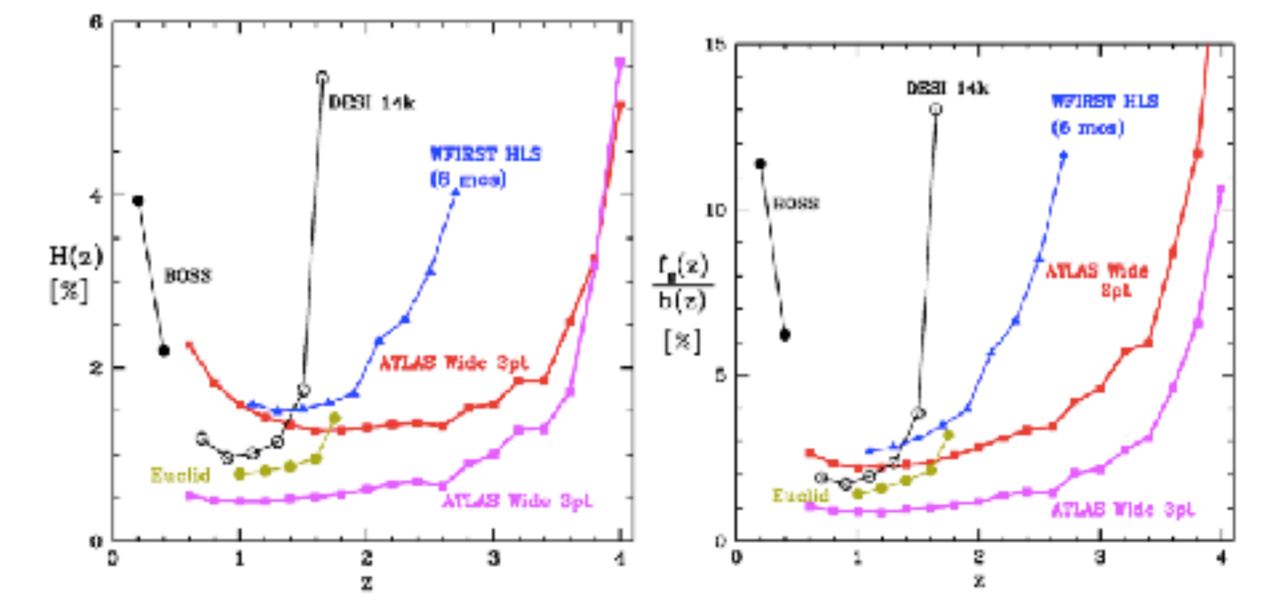


Fig.3. Expected $H(z)$ and $f_g(z)$ from future surveys. "2pt" refers to galaxy power spectrum, "3pt" refers to galaxy bispectrum. Constraints are derived following Wang et al. (2013) & Samushia et al. (2019). The constraints on $D_A(z)$ (not shown to avoid cluttering) provide a cross-check on $H(z)$. The bias between galaxy and matter distributions is $b(z)$. *ATLAS* overlaps ground-based projects 0.5<z≲1 for key cross-check and mitigation of systematic effects).

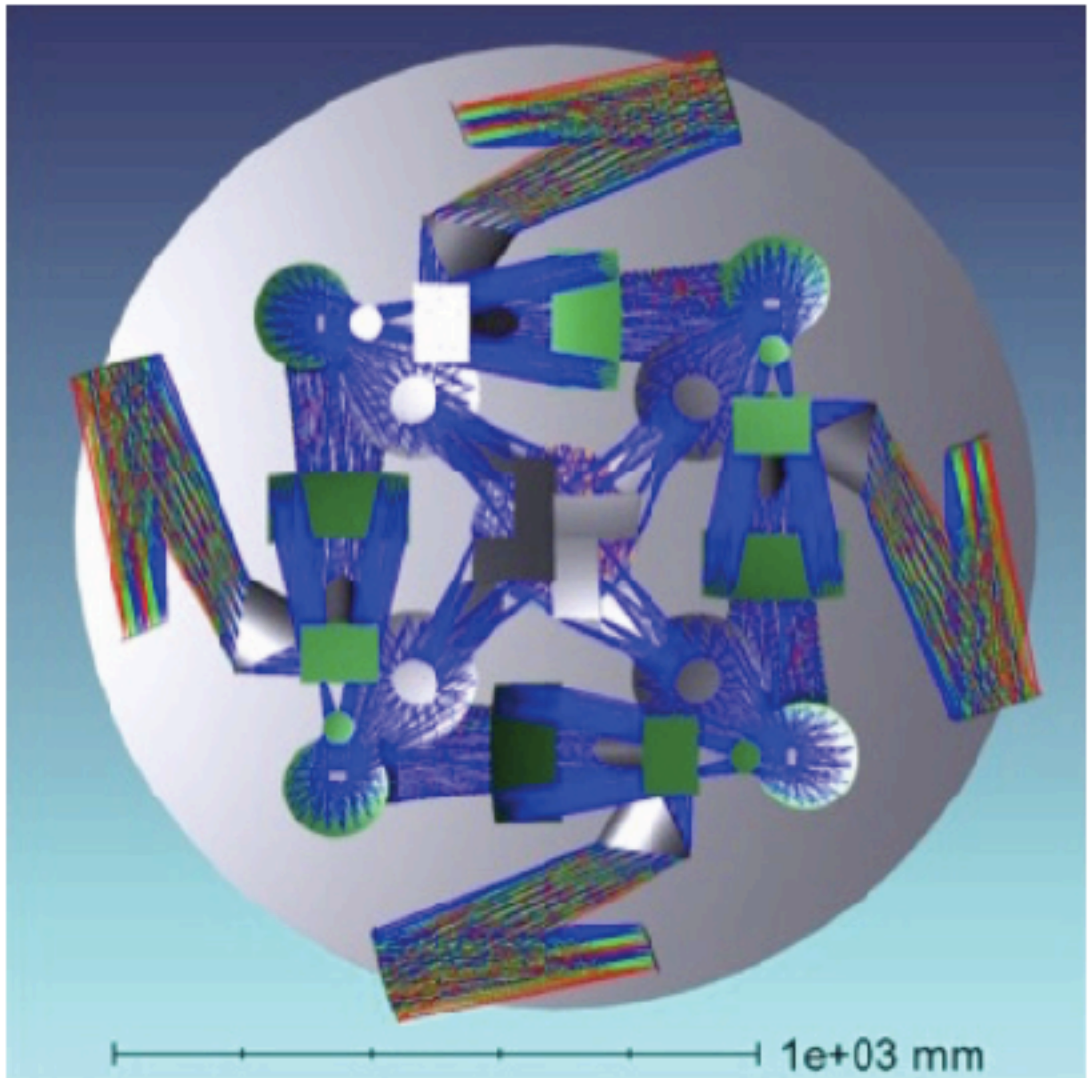


Fig.5: A full view of the preliminary optical design for the *ATLAS* Probe instrument. The large gray circle is the back of the primary.

The End of Galaxy Surveys
by Jason Rhodes

Astro2020 Science White Paper

The End of Galaxy Surveys

Thematic Areas: ☐ Planetary Sy

☐Formation and Evolution of Compact Ob

☐Stars and Stellar Evolution ☐Resolved S

☒Galaxy Evolution ☐Multi-Messe

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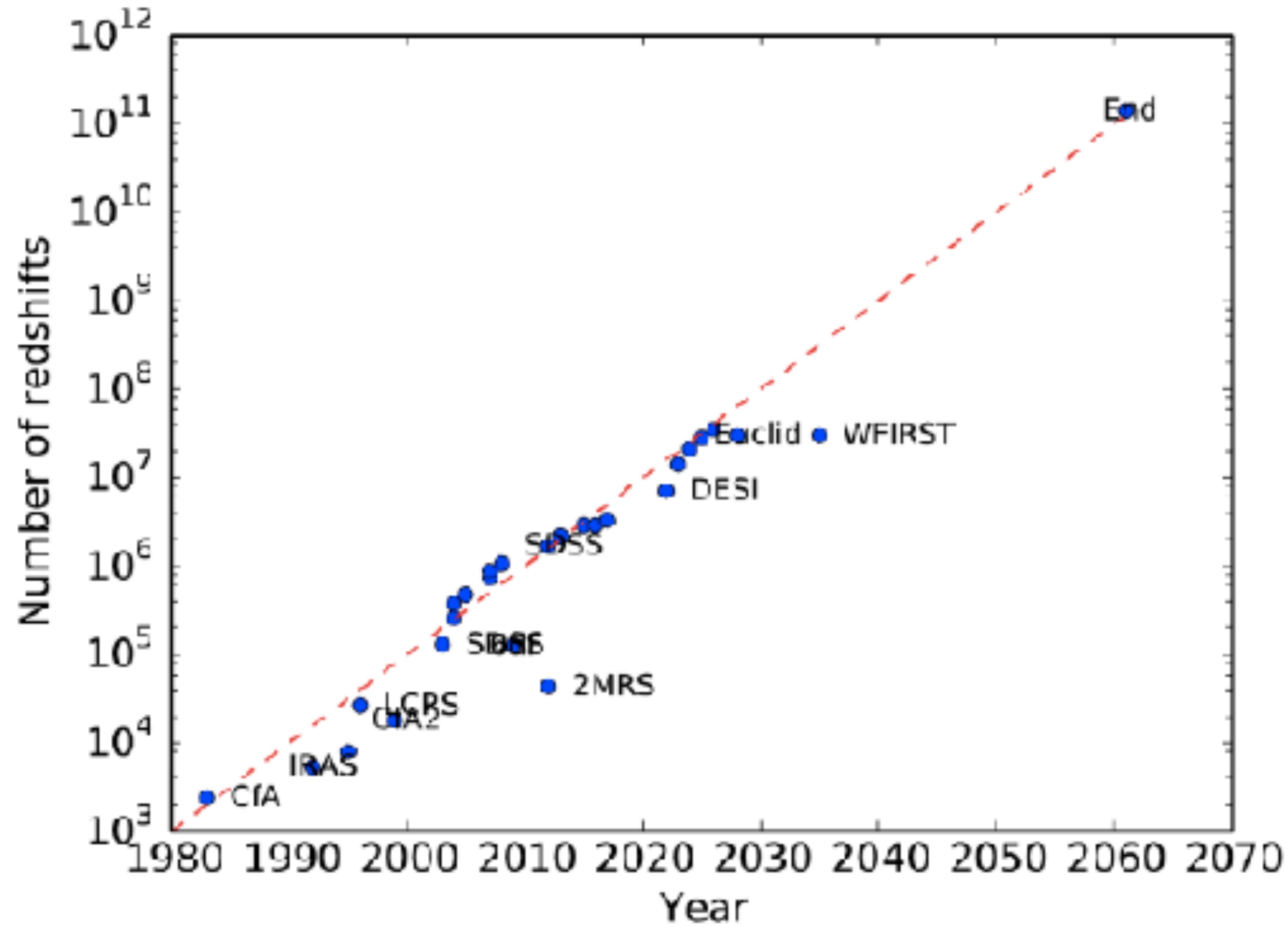

Figure 1: Spectroscopic redshifts as a function of year. The number goes up be a factor of 10 every decade.

Summary

- 新しい Technology も積極的に
- スペースと地上それぞれの発展を
- 独自の案も進めたい
- LoIを12月に！
- 2030年代のすばる望遠鏡の課題（北天探査、HSC改造、PFSによるLSST領域探査等)

Telescope Ranking
What is the successful Telescope？

2009　Nature　Article
Madrid & Macchetto
arxiv : 0901.4552

High-Impact Observatories

Rank	Facility	Citations	Participation
1	SDSS	1892	14.3%
2	Swift	1523	11.5%
3	HST	1078	8.2%
4	ESO	813	6.1%
5	Keck	572	4.3%
6	CFHT	521	3.9%
7	Spitzer	469	3.5%
8	Chandra	381	2.9%
9	Boomerang	376	2.8%
10	HESS	297	2.2%

Key
SDSS - Sloan Digital Sky Survey
HST – Hubble Space Telescope
ESO – European Southern Observatory
CFHT – Canada France Hawaii Telescope
HESS - High Energy Stereoscopic System

2010-2019
ADS Citation ranking

- 1: Planck
- 2: SDSS
- 3: LIGO
- 4: WMAP
- 5: HST
- 6: Hershel
- 7: Kepler