SDSS4 + ngCFHT

제2회우주탐사연구회 (Survey Science Group) 워크숍

장소: 하이원 리조트

일시: 2013. 2. 13-16일

박 창 범

The SDSS-IV surveys (APOGEE, MaNGA and eBOSS)

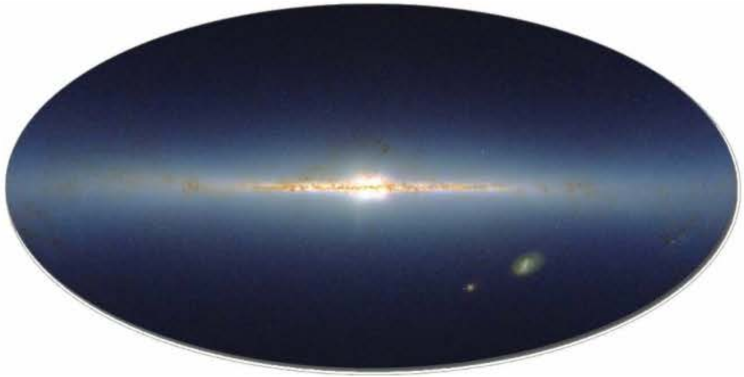
Telescope: the Sloan Foundation 2.5-m Telescope
at Apache Point Observatory (APO) in New Mexico
Period: from July 2014 to July 2020.

Key advantage : its wide-field spectrographs that observe many objects simultaneously, spreading the light of each into its separate wavelengths, yielding a spectrum that allows the study of each object's detailed physical nature. These spectra also yield Doppler velocities, which measure stellar motions, the internal motions within other galaxies, and galaxy distances based on Hubble's Law.

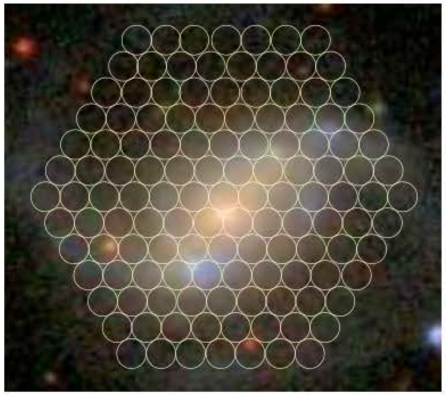
Full project budget is $59M • a Sloan Foundation grant of $10M approved

SDSS-IV Overview

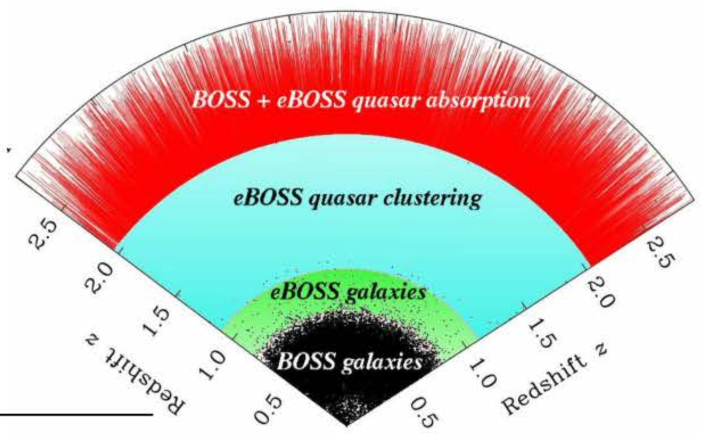
APOGEE-2 100% bright time @ APO and 75+ nights/year du Pont time @ LCO to map Milky Way
(S. Majewski, P.I.)



MaNGA 50% dark time @ APO to map 10,000 nearby galaxies
(K. Bundy, P.I.)



eBOSS 50% dark time @ APO to map distant Universe + Time-Domain Spectroscopic Survey + SPIDERS eROSITA follow-up
(J.-P. Kneib, P.I.)

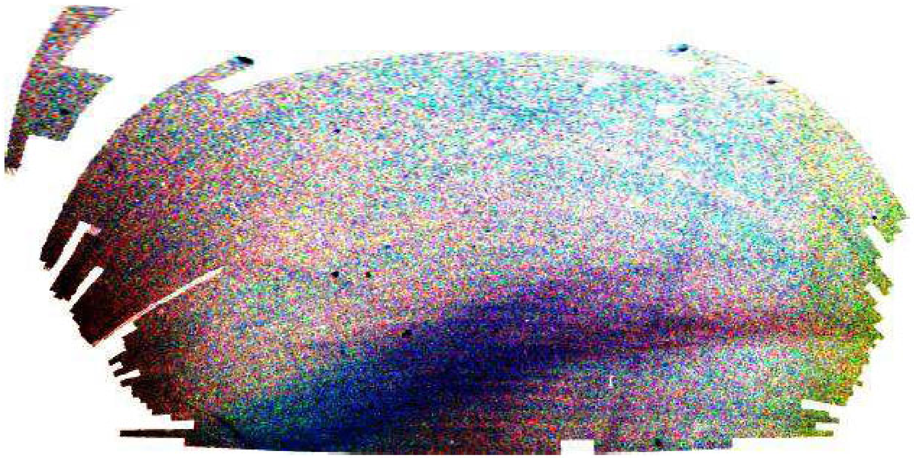


APOGEE-2

The APO Galactic Evolution Experiment 2 will explore the formation of the Milky Way using a comprehensive archaeological record based on 325,000 spectra of stars, revealing the structure of the Galaxy and its stars.

Simultaneously, it will be able to detect "exoplanets" around other stars and in addition conduct an unprecedentedly large study of known exoplanet systems.

The northern component (APOGEE-2N) will continue observations from APO while the southern component (APOGEE-2S) will observe the other half of the sky from the 2.5-m du Pont Telescope at Las Campanas Observatory (LCO) in Chile.



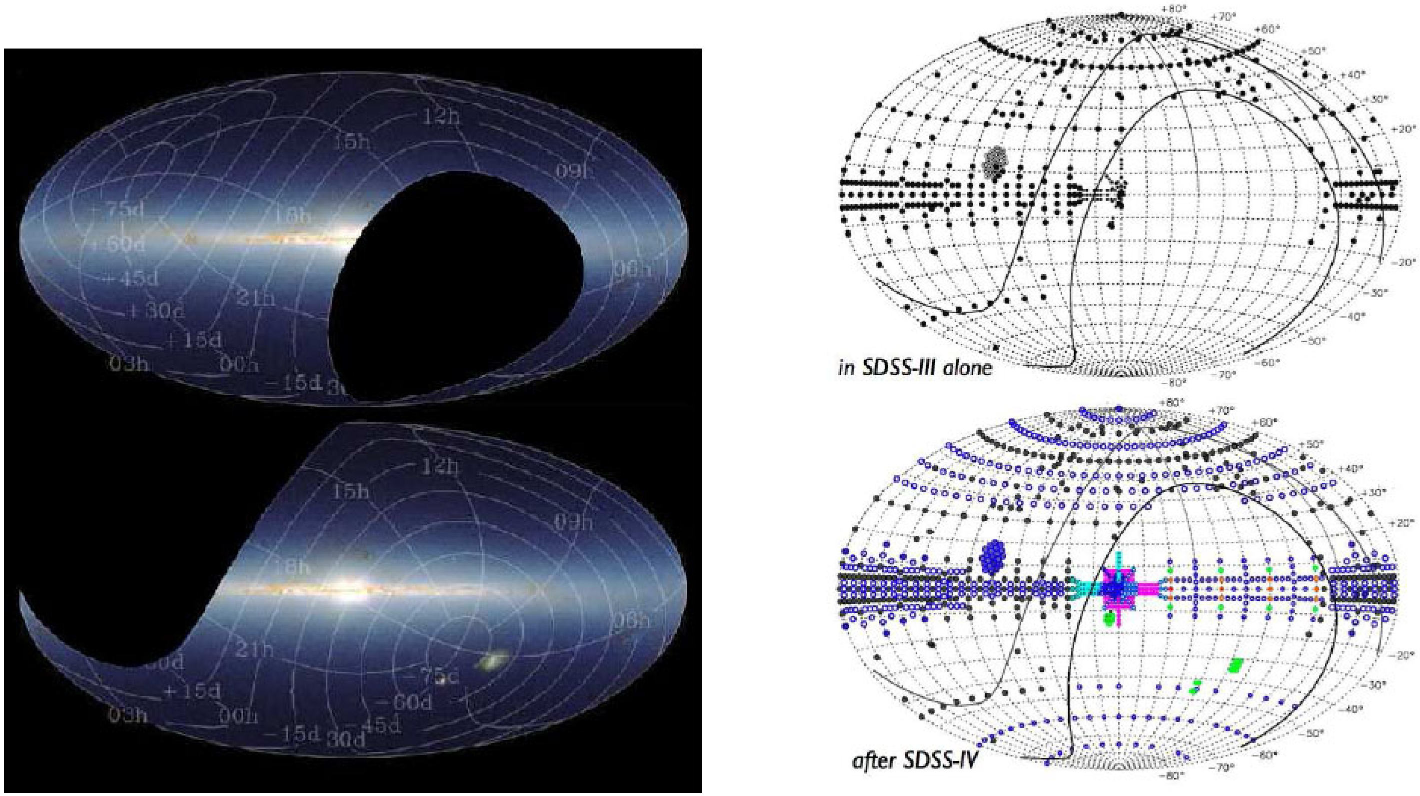


Fig. 4.— *Left:* Panoramic views of the accessible sky at the Sloan Foundation (*top*) and the du Pont (*bottom*) Telescopes. The 2MASS data in these images prominently show the Milky Way structure and the Magellanic Clouds. *Right:* The APOGEE targeting plan for SDSS-III (*top*) and SDSS-IV (*bottom*).

- mass of the Milky Way
- growth in the outer disk
- follow-up of Kepler stars
- long-term velocity monitoring

MaNGA

Mapping Nearby Galaxies at APO will uncover the internal structure and formation history of 10,000 galaxies and characterize the diversity of their evolutionary histories. It will contain the largest sample of galaxies ever observed in resolved spectroscopy by a factor of ten.

With many spectra across the extent of each galaxy to trace its assembly history and dark matter content, MaNGA will provide a uniquely rich legacy data set.

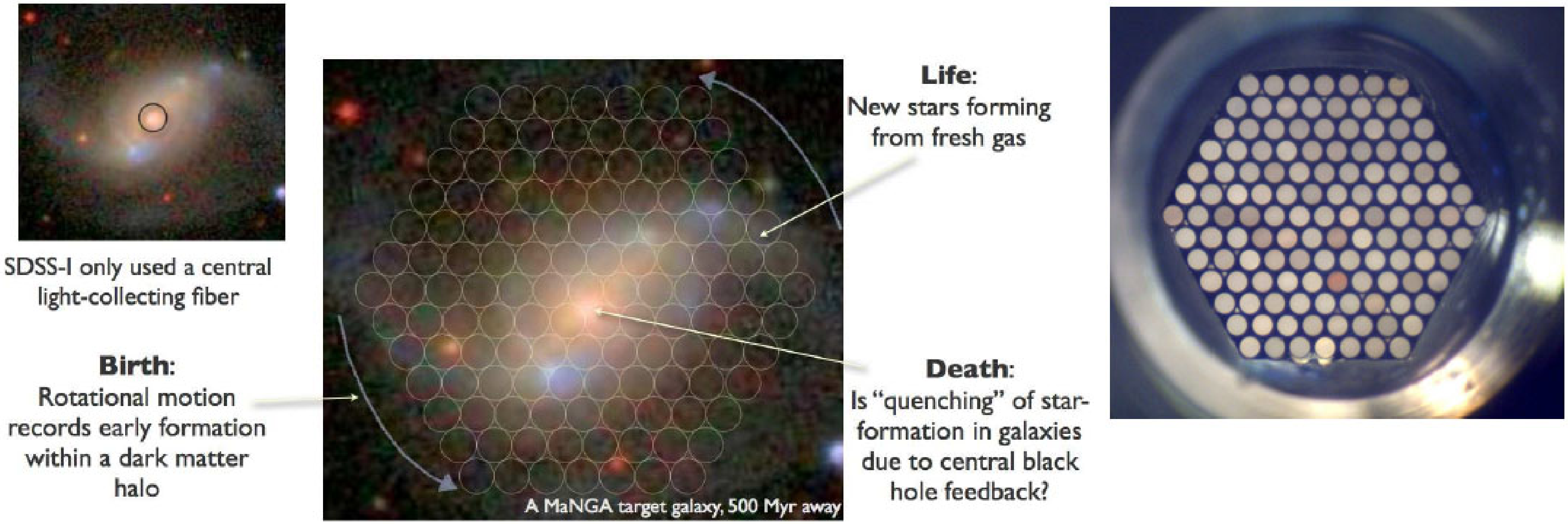


Fig. 5.— A schematic description of MaNGA's ability to probe fundamental questions in our understanding of galaxy formation and evolution. *Left:* Coverage of a standard single-fiber observation of a nearby galaxy. *Middle:* MaNGA resolved spectroscopic coverage of the same galaxy. The grid of circles represents the 127 fibers in MaNGA's largest fiber bundles. *Right:* An image of an actual hex-packed fiber bundle recently built by the MaNGA team.

• calibrating virial mass estimators • distinguishing fast-/slow-rotators • extended LINER emission • stellar initial mass function constraints from dynamics • stellar population gradients

MaNGA: *hardware design*

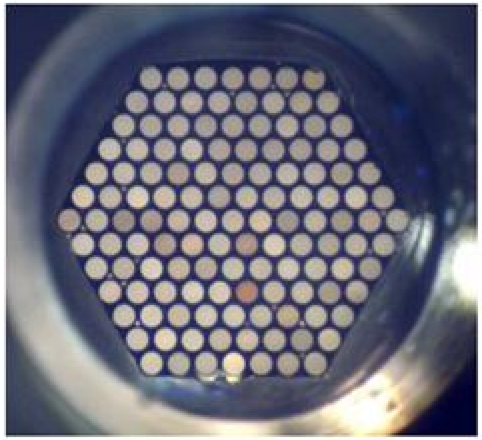
BOSS spectrograph: New slit heads to accommodate more fibers (can tolerate greater cross talk)

Multiplexed observations: 15 or 20 bundles per plate (depending on fiber distribution and total number of fibers), spread over 1.5 deg radius field

Range of bundle sizes: 19, 37, 61, 91,127-fiber bundles, tuned to target angular size

Spectrophotometry: Bundles on standards? Fat fibers? Range of fiber sizes?

(Unlike standard fiber spectrophotometry, we do not want ADR contribution to throughput)



eBOSS

The Extended Baryon Oscillation Spectroscopic Survey will achieve the best ever measurements of cosmic expansion to a distance of 12 billion light-years. It will provide the first measurements across the critical epoch between 6.5 and 11 billion light-years, the predicted “onset time” for dark energy.

eBOSS will also include a massive sample of variable stars selected from time-domain imaging surveys, follow-up on a unique sample of X-ray sources, and create the largest existing sample of accreting supermassive black holes.

2500 deg2. 1h exposure
400k ELG(z=0.6~1.6), 250k QSO(z=1~2.2), 200k LRG(0.6~0.8),
Ly-a forests (100k z>2.2 QSOs)

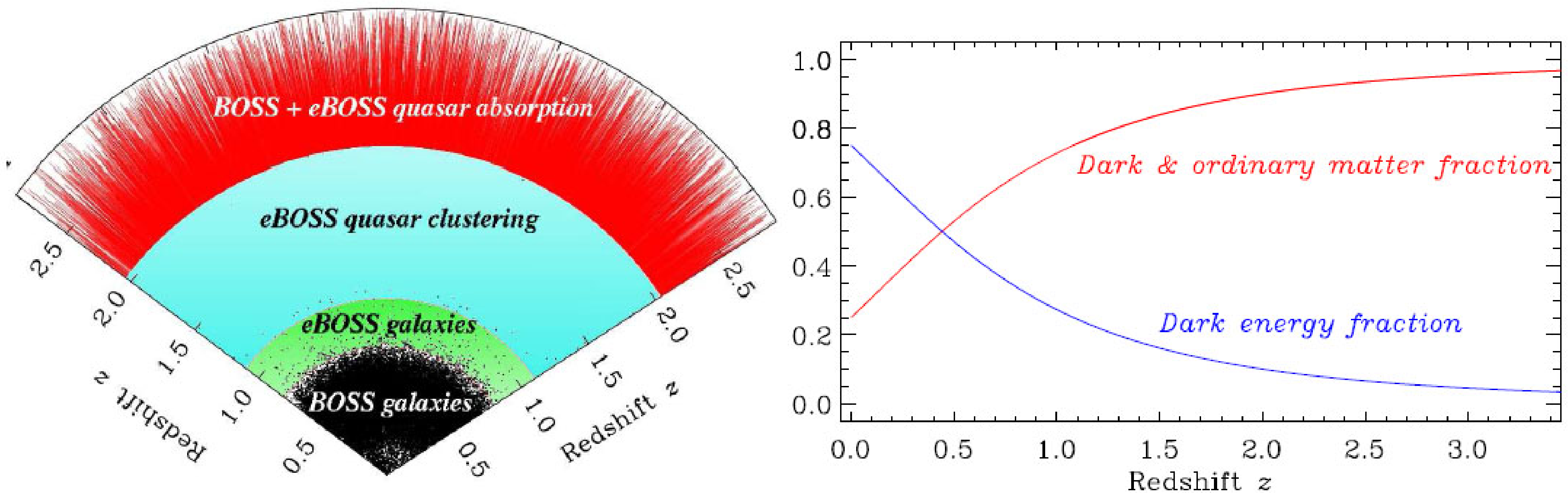


Fig. 7.— *Left:* eBOSS redshift coverage. eBOSS will be the first large-scale structure survey in the critical range $0.7 < z < 2$. *Right:* Fraction of energy density due to dark and ordinary matter (red line) and dark energy (blue line), showing onset of dark energy at $z \sim 2$.

2500 deg^2. 1h exposure
400k ELG(z=0.6~1.6), 250k QSO(z=1~2.2), 200k LRG(0.6~0.8),
Ly-a forests (100k z>2.2 QSOs)

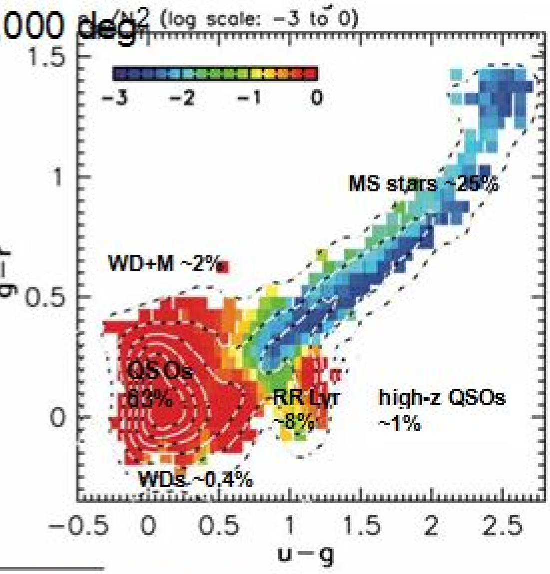
Time Domain Spectroscopic Survey (TDSS)

BOSS Spectroscopy of Celestial Variables

P. Green, S. Anderson (PIs)

• The first large sky area spectroscopic survey of variables.
• Pathfinder for LSST, GAIA.
• Up to 30 deg^{-2} or ~ 100,000 spectra of variables
• Selected from PanSTARRS-1 3π survey:
~ 12 imaging epochs in *grizy* bands over 30,000 deg^2

• Boost QSO completeness amid the stellar locus (z~0.9 and z~.27)
• Constrain accretion disk models
• New M/L dwarfs and eclipsing binaries
• RR Lyr to map halo kinematics
• New pulsating WDs
• Cataclysmic Variables
• Transient hosts (SNe, TDEs, GRBS)
• Systematic serendipity!



The Future of the Sloan Digital Sky Survey (2014-2020): http://sdss3.org/future

Data Release of SDSS-IV

The schedule for public releases is within 1-3 years after the data taking.

Jul 2016: DR13
- eBOSS target imaging & catalogs
- eBOSS "EDR-level" spectro data set
- No new APOGEE data
- MaNGA "EDR-level“

Jul 2017: DR14
- No new eBOSS data
- APOGEE-N data through Jul 2016
- No APOGEE-S data
- MaNGA data through Jul 2016

Jul 2018: DR15
- eBOSS data through Jul 2017
- APOGEE-N+S data through July 2017
- No new MaNGA data

Jul 2019: DR16
- No new eBOSS data
- APOGEE-N+S data through Jul 2018
- MaNGA data through Jul 2018

Dec 2020: DR17
- **Final release of all raw and reduced AS3 data**

ngCFHT

Baseline requirement

Aperture	10 m (segmented)
Field of View (FOV)	1.5 deg^2 (hexagonal)
Wavelength Range	370 to 1300 nm
Telescope Image Quality (†)	EE80D < 0.45" (FWHM ~ 0.3")
Total System Throughput (*)	>25% over 90% of the wavelength range >30% peak (goal)
Number of Fibers	3,200 (low + medium resolution) 800 (high resolution)
Spectral Resolution	R2,000 (370-1300 nm) R6,500 (370–510 nm & 770–910 nm) R20,000 (420-620 nm)

Wide-Field Imaging/Astrometry Facilities: 2000-2020

Instrument	Telescope	D_{M1} (m)	Status	»	Available	FOV (deg^2)	A© (m^2 deg^2)	©tot (10^3 deg^2)
MegaCam	CFHT	3.6	Operational	Optical	2003	1	10.2	6.1
WFCAM	UKIRT	3.8	Operational	IR	2004	0.19	2.2	...
WIRCAM	CFHT	3.6	Operational	IR	2005	0.11	1.1	4.0
Pan-STARRS-1		1.8	Operational	Optical	2009	7.3	18.6	30.9
VIRCAM	VISTA	4.1	Operational	IR	2010	0.6	7.5	20.0
OmegaCam	VST	2.6	Operational	Optical	2011	1.0	5.3	4.5
Skymapper		1.35	Operational	Optical	2011	5.7	8.2	20.6
Hyper-SC	Subaru	8.2	Pending	Optical	2012	1.7	90	2.0
ODI	WIYN	3.5	Pending	Optical	2012	1	9.6	...
DEC	Blanco	4.0	Pending	Optical	2012	3	38	5.0
Pan-STARRS-2		2x1.8	Pending	Optical	2013	7.3	37	30.9
GAIA		2x(1.4x0.5)	Pending	Optical	2013	All Sky		41.2
LSST		8.4	Pending	Optical	2019	6.7	370	24.2
Euclid		1.2	Pending	IR/Optical	2020	0.5	0.6	15 -20
WFIRST		1.5	Pending	IR/Optical	2025?	0.5	0.9	23.2

All sky=41253

Wide-Field Spectroscopy is a Missing Capability

Instrument	Telescope	D_{M1} (m)	Status	» (µm)	Available	© (deg^2)	A© (m^2 deg^2)	N_{MOS}	R
2dF	AAT	3.9	Operational	0.37-1.0	1996	3.14	15.1	400	1000-17000
SDSS		2.5	Operational	0.38-0.92	2000	1.54	7.6	640	1800
DEIMOS	Keck	10.0	Operational	0.41-1.1	2002	0.023	1.8	150	2500-5500
VIMOS	VLT	8.2	Operational	0.37-1.0	2002	0.062	3.3	600	180-2500
FLAMES	VLT	8.2	Operational	0.37-0.95	2003	0.136	7.2	130	5600-25000
Hectospec	MMT	6.5	Operational	0.36-0.92	2004	0.79	26.1	240-300	1000-40000
Hydra	WIYN	3.5	Operational	0.37-1.0	2005	0.79	7.5	90	800-40000
IMACS	Magellan	6.5	Operational	0.36-1.0	2008	0.16	5.3	400	1100-16000
FMOS	Subaru	8.2	Operational	0.9-1.8	2012	0.20	10.4	400	600-2200
LAMOST		4.0	Pending	Optical	2013	19.6	247	4000	1000-10000
HERMES	AAT	3.9	Pending	4 windows*	2013	3.14	15.1	400	28000 (50000)
PFS	Subaru	8.2	Pending:	Optical	2017:	1.3	70.0	2400	1900-4500
GAIA		2x(1.4x0.5)	Pending	0.85-0.87	2013	All Sky (V < 17)			11500
Euclid		1.2	Pending	1.1-2.0	2020	0.55	0.6	...	250
WFIRST		1.5	Pending	1.1-2.0?	2025?	0.5	0.9	...	75-320
BigBOSS	Mayall	4.0	Proposed	0.36-1.05	2018?	7.1	89	5000	3000-4800
WEAVE	WHT	4.2	Proposed	0.37-1.0	2018	3.14	41	~1000	5000-20000
MOONS	VLT	8.2	Proposed	0.8-1.8	2018	0.14	7.3	~1000	4000-20000
4MOST	VISTA	4.1	Proposed	4 windows †	2018	3	40	1500	3000-20000
ngCFHT		10.0	Proposed	0.36-1.3	2022	1.5	120	3200	2000-20000

* 0.472-0.490 µm (blue), 0.550-0.587 µm (green), 0.648-0.674 µm (red), 0.759-0.789 µm (IR).

† 0.420-0.650 µm (blue), 0.650-0.900 µm (red). High-resolution mode = 0.390-0.450 µm (blue), 0.585-0.675 µm

The Next Generation CFHT Proposal

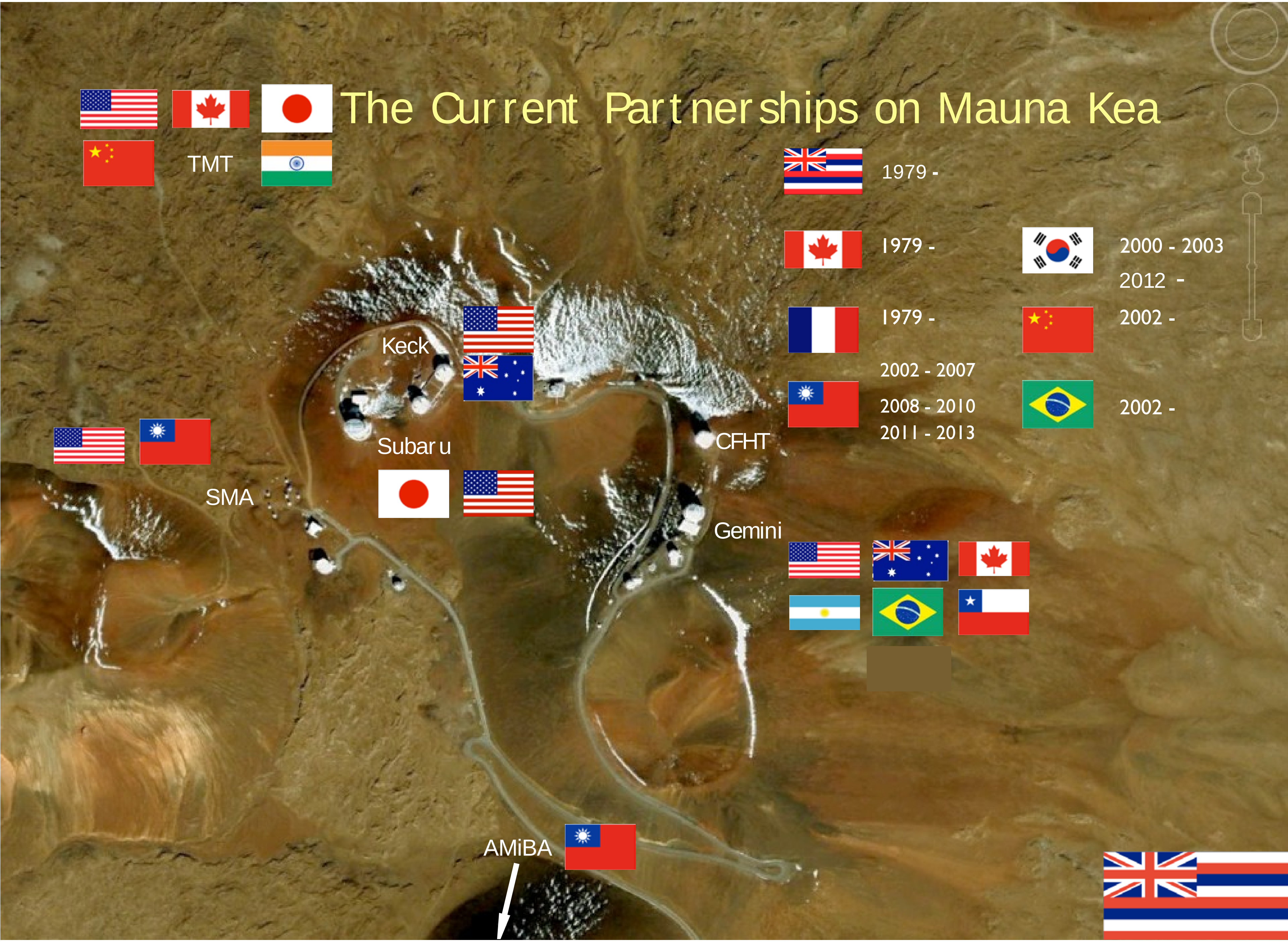
- Concept introduced in late-2010 as a grassroots movement that gained momentum.
- The project aims to create a new and expanded partnership to:

  1. replace the present 3.6m primary mirror with a 10m-class (segmented) mirror, mounted on the existing pier.
  2. install a dedicated wide-field (1.5 deg^2) multi-object spectrograph that can simultaneously collect spectra for >3000 sources.
  3. do this by the early 2020s and immediately begin spectroscopic surveys.

- ngCFHT would be the only dedicated, 10m-class, wide-field MOS facility capable of capitalizing fully on the many upcoming imaging and astrometric surveys.

- the 10m analog of the SDSS spectroscopic survey.

- For maximum scientific impact, the facility should also enable focussed science on key targets (i.e., PI or GO observations).

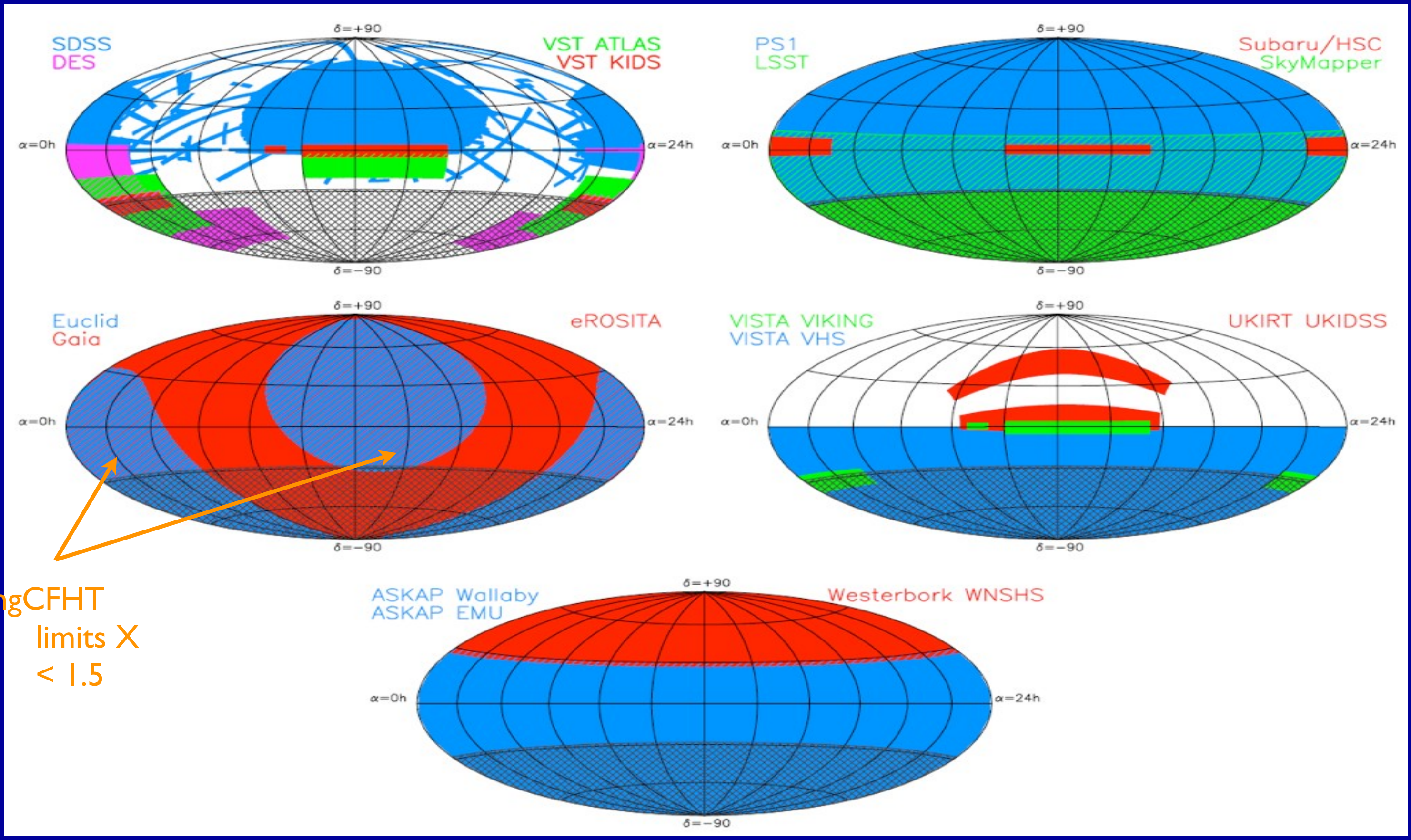


The Current Partnerships on Mauna Kea
TMT
1979 -
1979 -
2000 - 2003
2012 -
1979 -
2002 -
2002 - 2007
2008 - 2010
2011 - 2013
2002 -
Keck
Subaru
CFHT
SMA
Gemini
AMiBA

ngCFHT Specifications and Characteristics

Parameter	Specification
Primary Mirror (M1) Diameter	10m (segmented, equivalent)
M1 Segments	1.45m (hexagonal, corner-to-corner)
Overall f-ratio	f/2.1
Instantaneous Field of View	1.5 deg^2 (hexagonal)
Telescope Image Quality$^\diamond$	EE80 diameter $< 0\farcs45$ (FWHM $\sim 0\farcs3$)
Site Image Quality	FWHM = $0\farcs40 \pm 0\farcs05$ (free atmosphere median)
Vignetting	0% on axis, 13% max at edge of field
Total System Throughput†	$>$ 25% over 90% of the wavelength range
Plate Scale	102 arcsec/mm
Observing Modes	low resolution (LR)
	medium resolution, high multiplexing (MR-HM)
	medium resolution, full coverage (MR-FC)
	high resolution (HR)
Wavelength Range	370 – 1300 nm (LR)
	370 – 1000 nm (MR-HM)$^\otimes$
	370 – 1000 nm (MR-FC)
	370 – 1000 nm (HR)
Multiplexing	N = 3200, with full coverage from 370 – 1300 nm (LR)
	N = 800, with full coverage from 370 – 1000 nm (MR-FC)$^\otimes$
	N = 3200, with two (selectable) windows ($\lambda/7$) in the visible (MR-HM)
	N = 800, with two (selectable) windows ($\lambda/7$) in the visible (HR)
Resolving Power	2 000 (low)
	6 500 (medium)
	20 000 (high)
Fibre Configuration Timescale	$\leq$ 40s
Time Dedicated to Survey Observations	$\geq$ 80%
Available Zenith Angles	$0° – 60°$
Location	$19\fdg8250$ N, $155\fdg4683$ W
Median Precipitable Water	0.9 mm
Useable Nights	80% spectroscopic, 55% photometric

Survey Visibility from Mauna Kea



Telescope/Instrument	D_{M1} (m)	Status	Wavelength/Filters	Available	Ω (deg^2)	$A\Omega$ (m^{2}deg^2)	Ω_{tot} (10^3 deg^2)	$f^{\ddagger}_{MK}$
Ground-Based								
SDSS	2.5	Existing	u,g,r,i,z	2000	1.54	7.6	14.6	1
CFHT/MegaPrime	3.6	Existing	u,g,r,i,z	2003	0.90	9.2	6.1	1
UKIRT/WFCam	3.8	Existing	Z,Y,J,H,K	2005	0.19	2.1	4.0	1
PanSTARRS-1	1.8	Existing	g,r,i,z,y,w	2009	7.3	18.6	30.9	1
VISTA/VIRCam	4.1	Existing	Z,Y,J,H,K_s	2010	0.6	7.5	20.0	0.48-0.64*
VST/OmegaCam	2.6	Existing	u,v,g,r,i,z	2011	1.0	5.3	4.5	0.60-0.64*
Subaru/HSC	8.2	Existing	g,r,i,z,y	2012	1.7	90	2.0	1
Blanco/DEC	4.0	Existing	g,r,i,z,y	2012	3.0	38	5.0	0.33
WIYN/ODI	3.5	Planned	u,g,r,i,z	2013	1.0	9.6	....	1
Skymapper	1.35	Planned	u,v,g,r,i,z	2013	5.7	8.2	20.6	0.46
PanSTARRS-2	2×1.8	Planned	g,r,i,z,y,w	2013	7.3	37.2	30.9	1
LSST	6.7$^\diamond$	Planned	u,g,r,i,z,y	2020	6.7	370	24.2	0.39
Space-Based								
Gaia	2×(1.4×0.5)	Planned	0.85–0.87 μm	2013	all sky survey ($V < 17$)		41.2	0.75
Euclid	1.2	Planned	RIZ,Y,J,H	2020	0.55	0.62	15	$\simeq 0.77$
WFIRST	1.5	Proposed	Z,Y,J,H,K	2025:	0.5	0.9	3.4†	$\sim 0.5^{\otimes}$

> Our terms of reference were to propose a set of recommendations to ESA and ESO for optimising the exploitation of their current and planned missions. However, the Galaxy is an all-sky object; in fact, from the ground, the outer parts of the Galaxy are best observed from the Northern hemisphere, as the extinction is on-average lower there. In parallel with Recommendations 2(a) to 2(d), there is a real need for dedicated highly multiplexed spectrographs in the Northern hemisphere.

Turon et al. (2008)

- CFHT site is an outstanding location for a dedicated spectroscopic survey telescope.
- Equatorial location gives full access to the northern skies and extensive coverage to the southern skies as well.

Science Team

- Science working groups (SWGs) formed to examine the concept in 10 distinct subfields.
- ngCFHT is presently supported by roughly 60 scientists from Canada, France and Hawaii, as well as Australia, Brazil, China, India, Japan, South Korea, Taiwan, and the USA.

1. Exoplanets
   - Magali Deleuil (Laboratoire d'Astrophysique de Marseille, France)
   - Francois Bouchy (IAP, France)
   - Ernst de Mooij (Toronto, Canada)
   - Norio Narita (NAOJ, Japan)
2. The Interstellar Medium
   - Rosine Lallement (GEPI/Observatoire de Paris, France)
   - Patrick Boissé (Institut d'Astrophysique de Paris, France)
   - Ryan Ransom (Okanagan College, DRA, Canada)
3. Stars and Stellar Astrophysics
   - Kim Venn (University of Victoria, Canada)
   - Katia Cuhna (NOAO, USA)
   - Patrick Dufour (Montreal, Canada)
   - Zhanwen Han (Yunnan Observatory, China)
   - Chiaki Kobayashi (ANU,Australia)
   - Rolf-Peter Kudritzki (IfA, Hawaii, USA)
   - Else Starkenburg (Victoria, Canada)
4. Milky Way Structure and Stellar Populations
   - Piercarlo Bonifacio (GEPI, Université Paris Diderot, France)
   - Nobou Arimoto(NOAJ, Japan)
   - Ken Freeman (ANU,Australia)
   - Bacham Eswar Reddy (IIA, India)
   - Sivarani Thirupathi (IIA, India)
5. The Local Group
   - Alan McConnachie (Herzberg Institute of Astrophysics, Canada)
   - Andrew Cole (Tasmania,Australia)
   - Rodrigo Ibata (Strasbourg, France)
   - Pascale Jablonka (Observatoire de Paris, France)
   - Yang-Shyang Li (KIAA, China)
   - Nicolas Martin (Strasbourg, France)
6. Nearby Galaxies and Clusters
   - Michael Hudson (University of Waterloo, Canada)
   - Richard de Grijs (KIAA, China)
   - Simon Driver (ICRAR ,Australia

6. Nearby Galaxies and Clusters (cont'd)
   - Eric Peng (Peking University, China)
   - Yen-Ting Lin (IPMU, Japan)
7. Galaxy Evolution
   - Michael Balogh (University of Waterloo, Canada)
   - Sebastien Foucaud (NTNU,Taiwan)
   - Damien Le Borgne (IAP, France)
   - Karl Glazebrook (Swinburne,Australia)
   - Lihwai Lin (ASIAA,Taiwan)
   - Changbom Park (KIAS , South Korea)
   - Swara Ravindranath (IUCAA, India)
   - Marcin Sawicki (St. Mary's, Canada)
   - Luc Simard (HIA, Canada)
8. The Intergalactic Medium
   - Céline Péroux (Laboratoire d'Astrophysique de Marseille, France)
   - James Bolton (Melbourne,Australia)
   - Sara Ellison (Victoria, Canada)
   - Raghunanathan Srianand (IUCAA, India)
9. QSOs and AGNs
   - Pat Hall (York University, Canada)
   - Len Cowie (IfA, Hawaii)
   - Scott Croom (Sydney,Australia)
   - John Hutchings (HIA, Canada)
   - Patrick Petitjean (AIP, France)
   - Thaisa Storchi-Bergmann (UFRGS, Brazil)
   - Ting-Gui Wang (USTC, China)
   - Chris Willott (HIA, Canada)
   - Jong-Hak Woo (Seoul, South Korea)
   - Xue-Bing Wu (Peking University, China)
10. Cosmology and Dark Energy
    - Jean-Paul Kneib (Laboratoire d'Astrophysique de Marseilles, France)
    - Carlo Schimd (LAM, France)
    - Charling Tao (CPPM, France and Tsinghua, China)
    - Martin Makler (Rio de Janeiro, Brasil)
    - Keiichi Umetsu (ASIAA,Taiwan)

Scientific Performance in Context

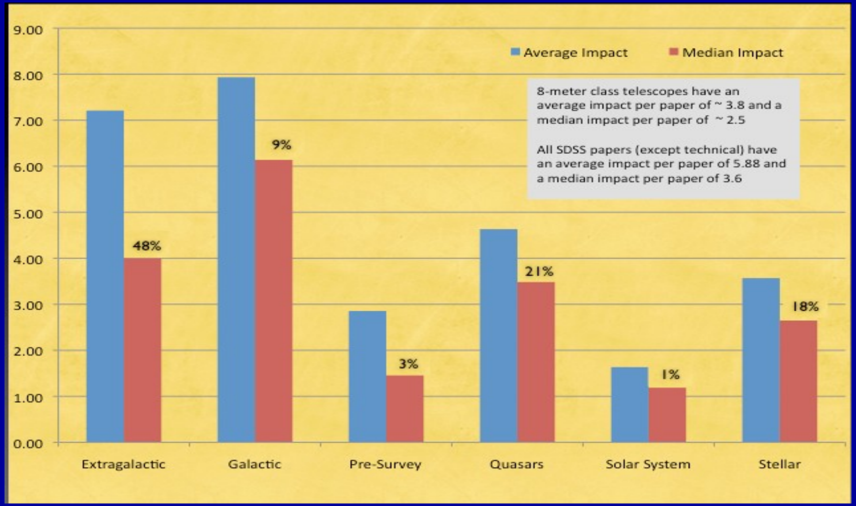
- SDSS (11 years):

- 2.3M spectra to date (DR9) ➞ 1.5M galaxies, 0.2M quasars, 0.7M stars.

TABLE 1. HIGH-IMPACT OBSERVATORIES

Madrid (2009)

Rank	Facility	Citations	Participation
1	SDSS	1843	17.4%
2	ESO	1365	12.9%
3	HST	1124	10.6%
4	WMAP	1121	10.6%
5	Keck	642	6.0%
6	Kamiokande	372	3.5%
7	Chandra	365	3.4%
8	ACBAR	207	2.0%
9	NOAO	202	1.9%
10	Las Campanas	176	1.7%



- ngCFHT (10 years):

  - R=6,500 spectroscopy for H15 million stars (g < 21.4)
  - R=20,000 spectroscopy for H5 million stars (g < 20.0)
  - R=2,000 spectroscopy for H20 million galaxies (down to g H23.5, with some surveys reaching to g H26).

- one SDSS survey per 3.7 months (stars) [plus factors of 3.6-11 gains in spectral resolution, and 2-4 mags in depth]
- one SDSS survey per 4.6 months (galaxies) [with 5-8 mag gains in depth, plus NIR coverage]

Representative Surveys

Survey	u_{sky}	Area(deg^2)	Resolution	» (nm)	g_{lim}	T (ngts)
Multiplicity & Exoplanets	bright	115	20,000	425-491; 585-675	16.0	110
			2,000	0.37-1.3		
ISM Survey	bright	5,000	20,000	369-425; 761-879	16.0	140
Galactic Archaeology I	bright/grey	10,000	20,000	425-491; 585-675	20.4	1150
Galactic Archaeology II	grey	10,000	6,500	381-439; 770-889	21.4	290
Andromeda	grey/dark	350	6,500	436-504; 770-889	23.0	50
LOWZ	dark	1,000	2,000	0.37-1.3	i=22	190
Rich Clusters	dark	30	2,000	0.37-1.3	r=22	45
Virgo Cluster	dark	100	6,500	436-504; 770-889	23.6	30
			2,000	0.37-1.3		
Dark-Wide	dark	4,300	2,000	0.37-1.3	i=23.5	520
Dark-Medium	dark	100	2,000	0.37-1.3	i=24.25	480
Dark-Deep	dark	1.5	2,000	0.37-1.3	i=26	105
Quasar Rev. Mapping	dark	1.5	2,000	0.37-1.3	i=22.7	105
Cosmological Cluster	dark	750	2,000	0.37-1.3	i=23.5	195
BAO/Cosmology	dark/grey	10,000	2,000	0.37-1.3	r=23.7	600

ngCFHT Scientific Legacy. Major Science Thrust # 1

1. Galactic Archaeology

- Most ngCFHT bright/grey time devoted to a comprehensive, Galactic Archaeology programme (H 1400 nights over a decade).
  - Aim: map 1/4 of the Galactic volume to a depth of g H21.4 (R=6,500) and 20.4 (20,000).
  - 5 million stars at R=20,000 and 15 million stars at R=6,500. Fully half of these targets will belong to the halo. This would be the definitive follow up of the Gaia mission.

	R=6,500	R=20,000
WD	1.9 (kpc)	1.2 kpc
MSTO	30	20
HB	140	90
TRGB	470	300

- Included/related programmes focus on: (1) chemical labeling of halo stars, (2) the thin and thick disk populations, (3) the bulge and halo metallicity distributions, (4) density structure of the halo using BHB/BS/MSTO stars, (5) the most metal-poor halo stars, (6) the phase-space structure of the halo, (7) the shape of the Galactic potential, (8) tests of dark matter vs. non-equilibrium dynamics vs. non-Newtonian gravity, (9) ages of Galactic subcomponents from WDs, (10) structure of low-mass dark matter halos; (11) intermediate-mass black holes in star clusters; etc. .

ngCFHT Scientific Legacy. Major Science Thrust #2

2.Galaxies and Cosmology

•“Wedding Cake” strategy for three important extragalactic dark-time surveys:

1. Dark-Wide (4300 deg^2, i H23.5), 10% completeness.
2. Dark-Medium (100 deg^2, i H24.25), >95% completeness.
3. Dark-Deep (1.5 deg^2, i H26.0), high completeness and repeated coverage.

•Dark-Wide would yield spectra (R = 2,000, » = 0.37-1.3µm) for more than 10 million galaxies,

allowing galaxy evolution studies in seven redshift bins from z = 0.5 to 1.5, each with the same statistical power as the SDSS.

-How does stellar mass growth relate to halo mass growth?

-How does satellite galaxy evolution differ from that of central galaxies?

-What are the effects of environment on galaxy formation and evolution?

-How does feedback work?

-How do galaxies get their gas?

- Main Cosmology/DE programmes include

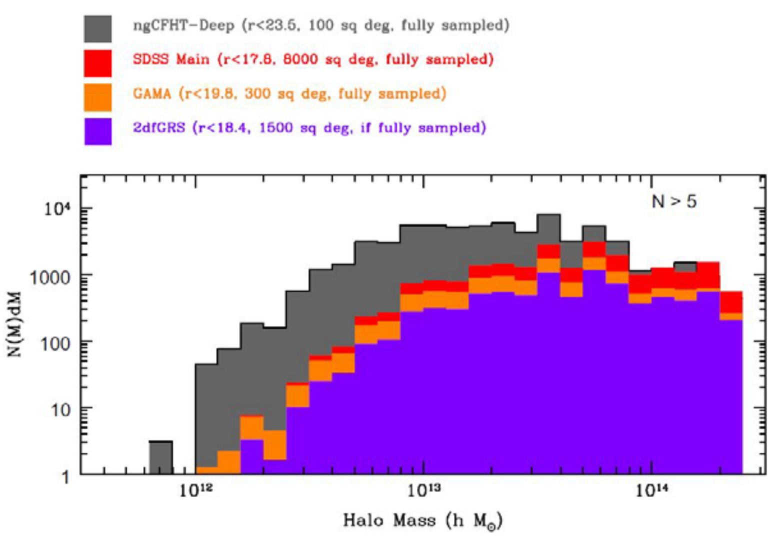
  1.BAO Cosmology Survey (10,000 deg^2, r H23.7), LRGs, ELGs, QSOs, QSO Ly-± forest. 1% distance precision over the range 1 < z < 3.

  2.Cluster Cosmology Survey (500 massive clusters in optical, SZ and X-rays), 0.3 < z < 1. Redshift

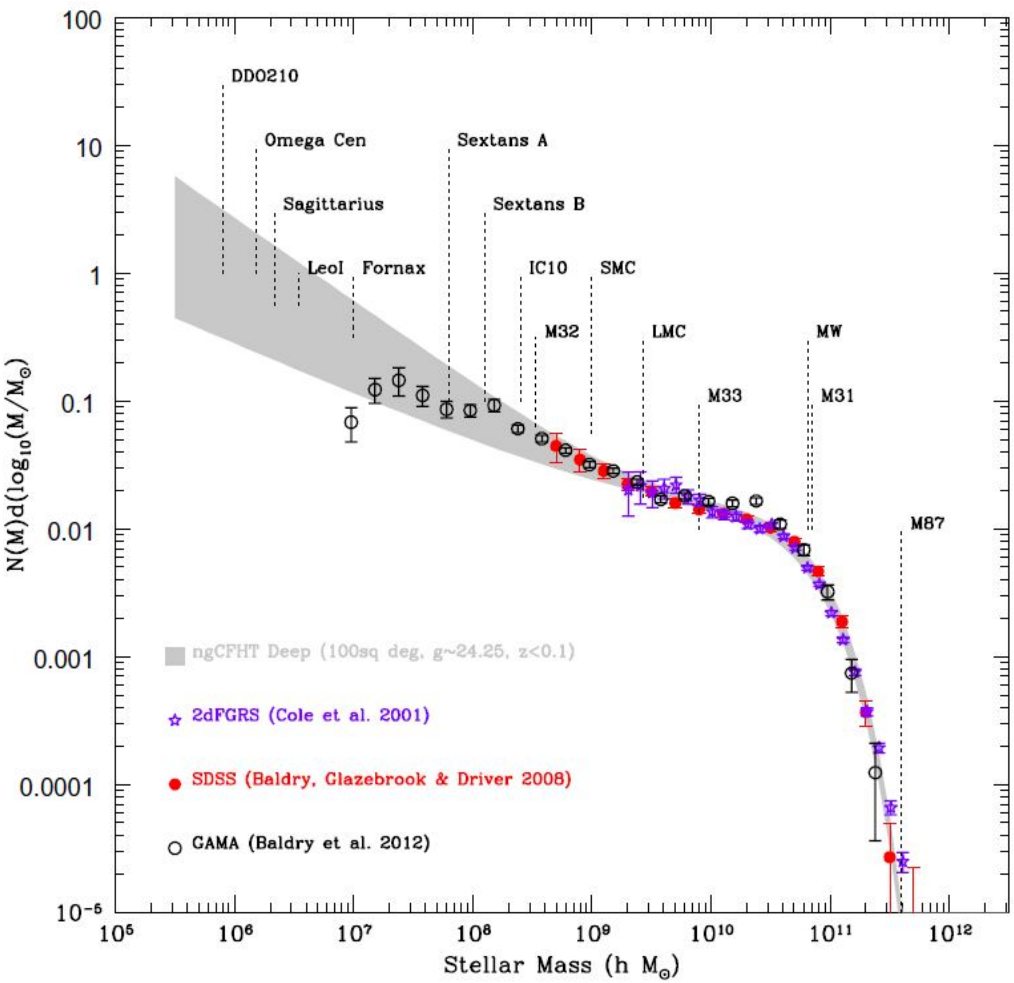
- Space Distortions in BAO Survey ➜ law of gravity, neutrino mass, non-Gaussianity. Cluster Survey ➜
- mass density of the universe, normalization of the power spectrum, dynamics of dark energy.

Nearby Galaxies and Clusters

The abundance of halos with at least five kinematic tracers showing the expected improvement with ngCFHT over previous surveys that extend to halo masses below that of the Milky Way



The galaxy stellar mass function (SMF) at z < 0:1 from the SDSS, 2dFGRS and GAMA compared to the ngCFHT Dark-Deep survey. The r-band selection assumes a constant M/L ratio.



ngCFHT Scientific Legacy. Much, Much More..

- A 3D map of the Galactic ISM, with the density structure and kinematics measured along hundreds of thousands of sight lines using high-resolution, absorption-line spectroscopy of molecular, atomic and ionized gas.

  •Characterization of planetary host properties for exoplanet transit surveys (e.g., Kepler) including spectral types, ages, chemical properties; sample definition/selection for pointed planet surveys using direct imaging of 100-200 Myr stars (i.e., targets selected on the basis of Ca HK, Li, rotational velocity, UVW, etc).

  •Baade-Wesselink parameters of pulsating variables throughout the Milky Way and Local Group, giving masses and radii for stars evolving through the instability strip.

- Fundamental parameters (e.g., spectroscopic masses, distances, metallicities, rotation rates) for high-mass stars belonging to the Milky Way and nearby galaxies.

  •Time-domain spectroscopic surveys (e.g., stellar multiplicity, pulsating and eclipsing stars, novae and supernovae).

  •The identification of rare stellar types, such as solar twins, white dwarfs associated with the Milky Way thick disk or halo, and extremely metal-poor stars.

- Chemo-dynamical surveys of Local Group galaxies, from low-mass, dark-matter-dominated dwarfs to M31.

  •The measurement of gravitational masses and density profiles for dark matter halos in the nearby clusters.

  •A complete census of compact stellar systems in the Local Volume, including masses, ages and abundances.

  •The relationship between stellar and gravitational mass, baryon dynamics, and star formation efficiency in dark matter halos spanning a range of H10^6 in stellar mass; survey would yield spectra for half a million galaxies within $z < 0.15$

- A spectroscopic survey of 100 bright quasar fields allowing an order-of-magnitude improvement in our ability to probe the Galaxy-IGM connection based on 40,000 Ly-absorbers, and spectroscopy for 1000–2000 damped Ly-alpha systems to probe early nucleosynthesis and the evolution of metals out to z H 4.

- AGN feedback through high-S/N, high-resolution, time-domain spectroscopy, as well as an independent determination of the redshift evolution of dark energy through BAOs in the Ly forest, and an AGN Hubble diagram calibrated through reverberation mapping.

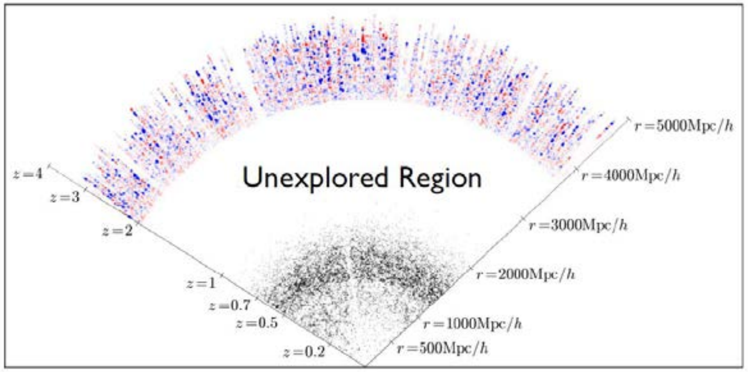


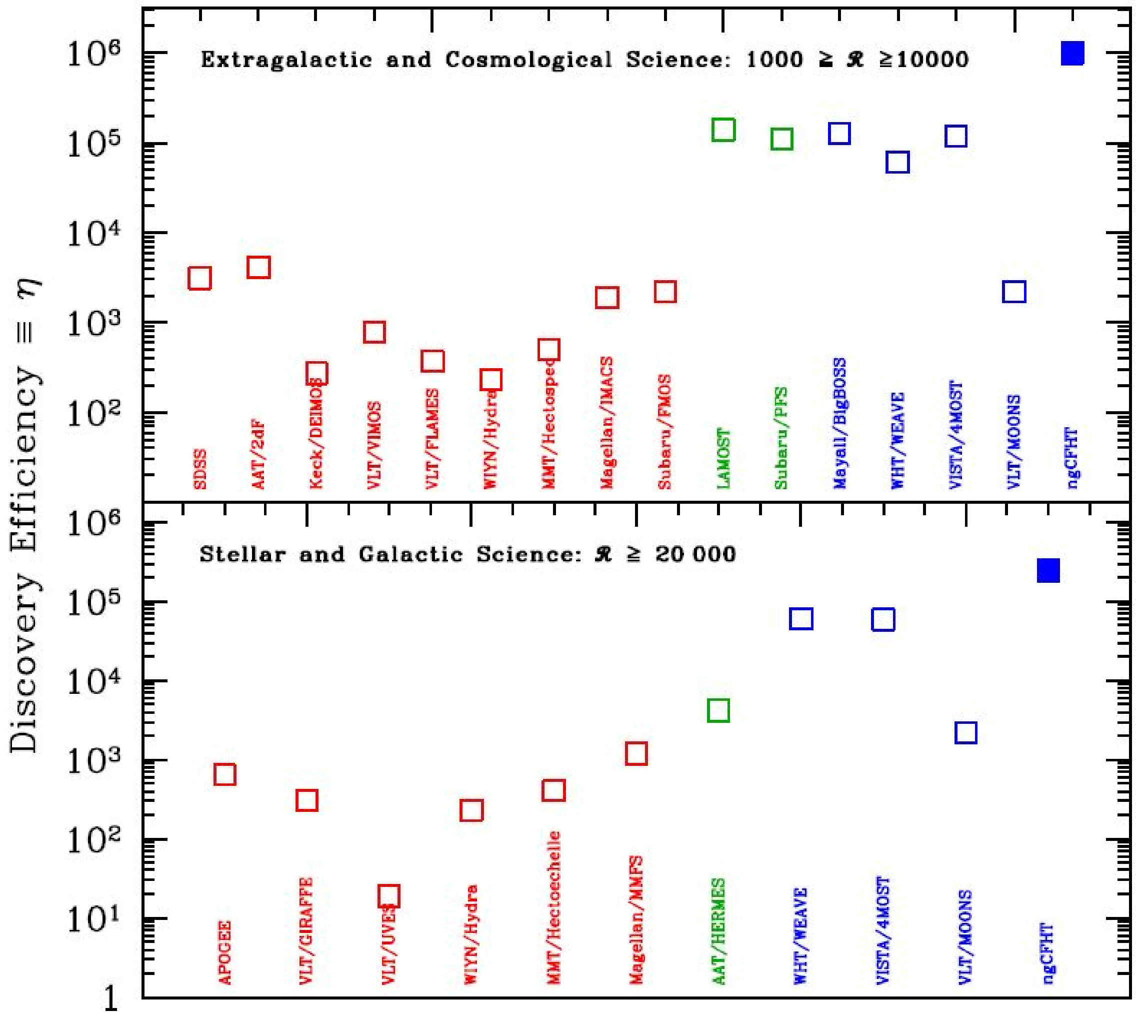
Table 22: Current and Future Cosmological Spectroscopic Surveys

	Wiggle-z	BOSS	e-BOSS	BigBOSS	PFS	*Euclid*
Telescope (m)	AAT (3.9)	Sloan (2.5)	Sloan (2.5)	Mayall (4)	Subaru (8.2)	*Euclid* (1.2)
Image quality (arcsec)	~1.5-2	~1.5	~1.5	~1.2	~0.7	~0.6
Wavelength (μm)	0.37–0.95	0.36–1.0	0.36–1.0	0.36–1.0	0.4–1.3	1.2–2.0
Field-of-View (deg^2)	2	6.7	6.7	6.7	1.8	0.5
Multiplexing	400	1,000	1,000	5,000	2,400	—
Spectral Resolution	1,300	1,600-2,600	1,600-2,600	2,000-5,000	2,000-4,000	500
Imaging	SDSS/GALEX	SDSS	SDSS+DES	ZTF/PS?	HSC	*Euclid*
Mag Limit	$r < 22.5$	$i < 20$	$g < 22.5$	$r < 23.5$	$r < 23.5$	$H < 22$
Survey Area (deg^2)	800	10,000	3,000	14,000	1,500	15,000
Target density (deg^{-2})	275	140	500	2,300	1,500	~3,000
Survey Duration (year)	4.5	5	6	4	5	5
Night/year	60	150	150	120	60	—
Spectra (in million)	0.2	1.5	1.5	20	4	30
Redshift(Gal)	0.3–0.7	0.2–0.6	0.6–1.0	0.6–1.6	0.6–2	1–2
Redshift(QSO)	–	2.2–4	1–4	1–4	1–6	3–4(?)

Discovery efficiency

$$\eta \equiv D_{\rm M1}^2 \Omega N_{\rm mos} f / IQ^2$$

ngCFHT is the ultimate spectroscopic survey facility.



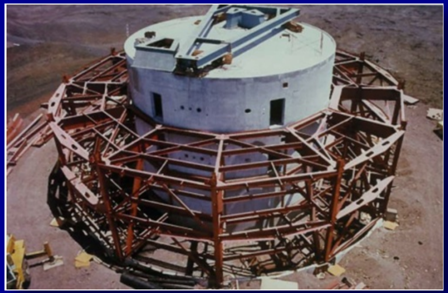
Summary of Technical Studies

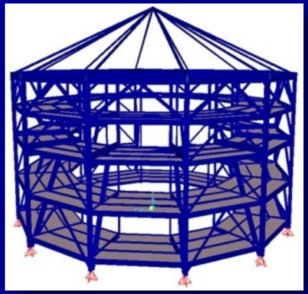
- The Office of Mauna Kea Management has produced a **Comprehensive Management Plan (CMP)** that outlines the redevelopment principles for CFHT:

- Our philosphophy: the new facility will stay within the current three dimensional “footprint”.

1. Load Capacity Studies

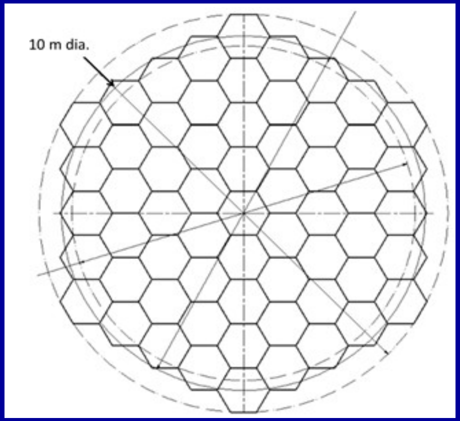
- Evaluate the capacity of the current telescope and enclosure piers based on modern design codes.
- The load capacity studies did not identify major structural deficiencies.

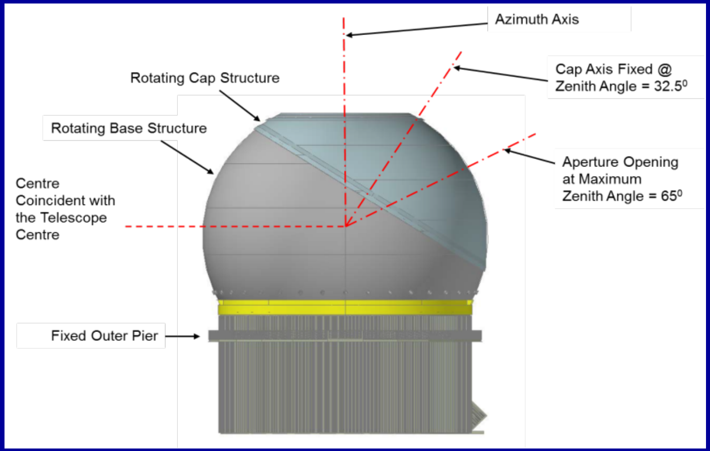




2. Telescope and Enclosure Configuration Studies

- current preferred solution: 1-mirror design with f/1.83 segmented primary mirror of 10m diameter.
- A Calotte design is the adopted enclosure configuration; provides a zenith observing range of 0° to 65°.

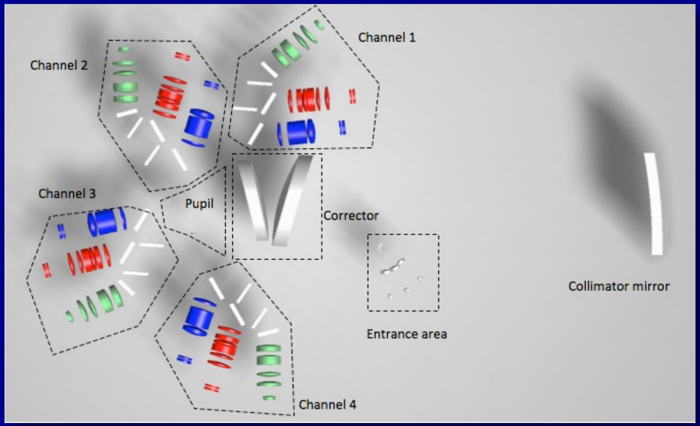




Summary of Technical Studies (cont'd)

3. Spectrograph Concept Studies

- Two options explored in detail:
  - two distinct spectrographs:
    1. a dedicated, PFS-like instrument (or PFS itself) for R~2,000 resolution; and
    2. separate spectrograph for R~6,500 and 20,000.
  - a triple-resolution spectrograph design using pupil slicing technologies (4 channels, 3 arms per channel).



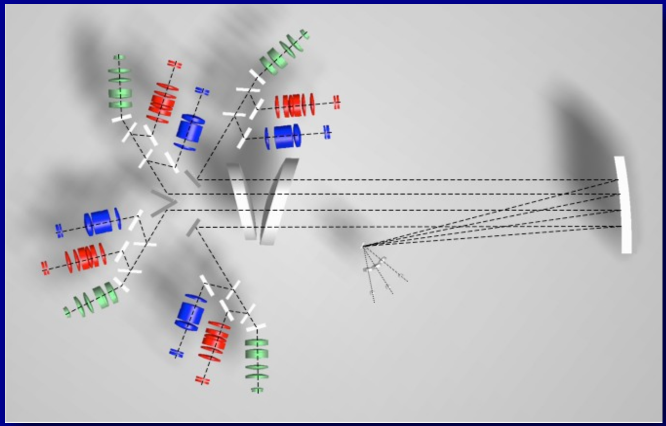


Table 1 - Characteristics of Spectrograph Observing Modes

Mode	Resolution in visible (Blue + Red arms)	Resolution in NIR arm	Simultaneous Coverage	# of Objects	
LR	2,000	2,000	Full	Nx4	
HR	20,000	NA	Two windows of λ/7 in visible	N	
MR-FC	6,500	NA	Full (visible only)	N	Full Wavelength Coverage
MR-HM	6,500	2,000	Two windows of λ/7 in visible	Nx4	High Multiplexing

최근 활동

- Delivered to the CFHT SAC and Board (early November 2012):
  - The Next Generation CFHT Concept Study. I. Science Report
  - The Next Generation CFHT Concept Study. II. Technical Report

The feasibility studies have shown that the project is technically feasible, is of relatively low risk, and has a cost in line with estimates from 2010 (H$195M). Its scientific potential is immense, with high-impact science that serves large and diverse communities virtually guaranteed.

Prospective partners are looking to CFHT for leadership.

ngCFHT would be unrivaled in its ability to perform panoramic, multi-object spectroscopy of the faint universe. It would fill what is arguably the single most important "missing capability" in the portfolio of international astronomy projects. The opportunities for scientific collaboration are nearly unlimited.

Next Generation CFHT Workshop

Place: Hilo, Hawaii, March 27 - 29 2013.
Web: http://ngcfht.cfht.hawaii.edu/

10 m facility dedicated to wide field spectroscopy

“The Next Generation of the CFHT: A wide field spectroscopic facility for the coming decade”