AFTA Study
Presentation to Astrophysics Division Director

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and Project Team

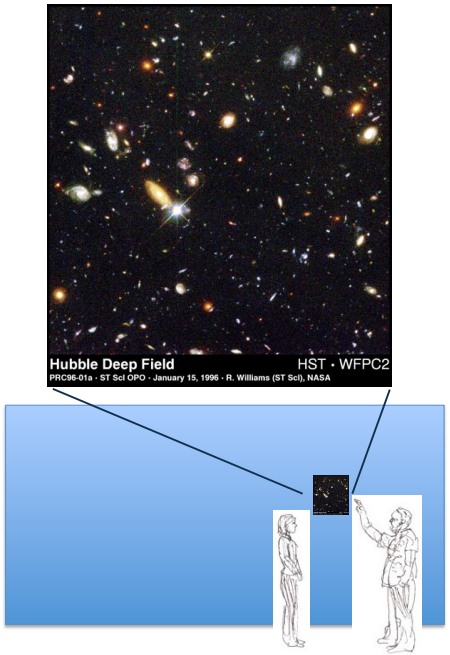
April 19, 2013

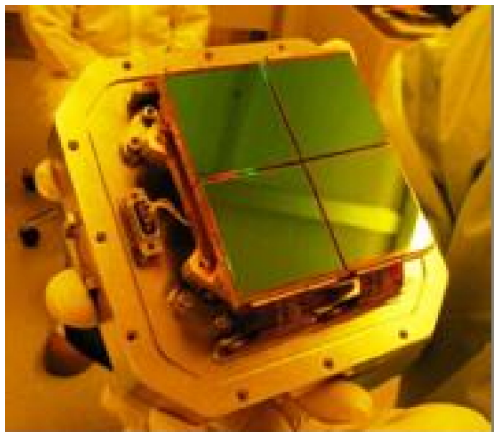
WFIRST Summary

- WFIRST is the highest ranked large space mission in 2010 US Decadal Survey
  - exoplanet microlensing
  - exoplanet coronagraphy (optional)
  - dark energy
  - galactic and extragalactic astronomy
  - Guest Investigator program

- Measurements:
  - NIR sky surveys for BAO & weak lensing
  - NIR monitoring for SNe & microlensing

- Enabled by US-developed large format HgCdTe detectors



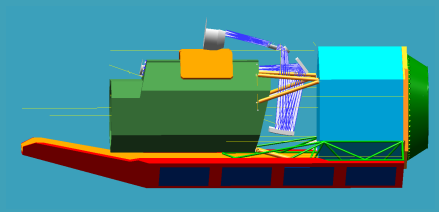


WFIRST Status

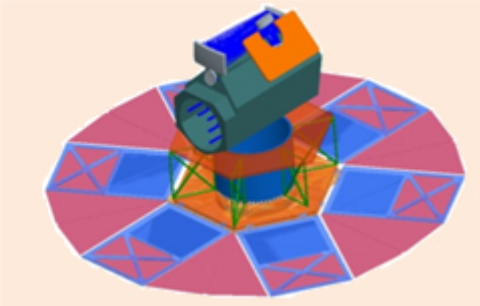
- WFIRST design specified by Astro2010 with 1.5m telescope.
- 2012: NRO makes available two 2.4m telescope to NASA; one under consideration for WFIRST
- Science Definition Team formed to study WFIRST-AFTA
- There is enthusiasm the community for AFTA. Capabilities greatly expanded compare to DRM-1
- There is good hope for overlap of LSST, Euclid, JWST & WFIRST. Great win for science due to complementarity of capabilities.

Design Concepts

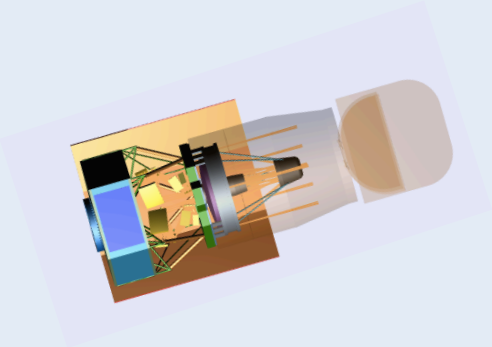
- **DRM1**
  - 1.3 meter off-axis telescope
  - 150 Mpixels, 0.4 deg^2
  - 5 year mission (2.5 yr Dark Energy)
  - Atlas V Launch Vehicle



- **DRM2**
  - 1.1 meter off-axis telescope
  - 234 Mpixels, 0.6 deg^2
  - 3 year mission (1.5 yr Dark Energy)
  - Falcon9 Launch Vehicle



- **WFIRST-2.4m AFTA**
  - 2.4 meter on-axis telescope
  - 288 Mpixels, 0.3 deg^2
  - Additional IFU for SN slit spectroscopy
  - 5 year mission (2.5 yr Dark Energy)
  - Falcon9 Heavy or Atlas V Launch Vehicle



SDT Charter

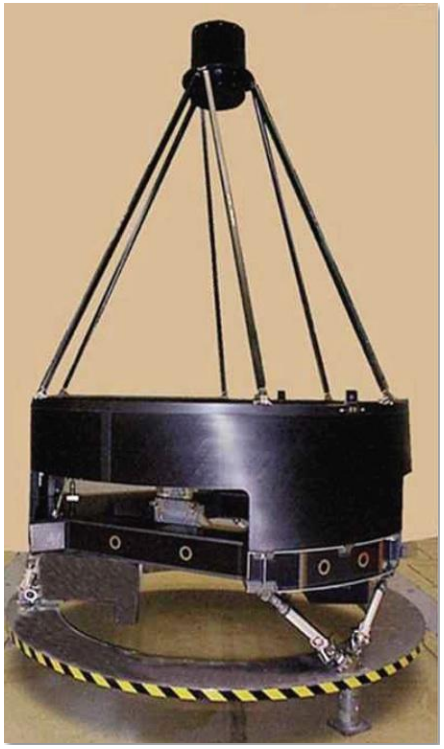
- Determine science requirements and key mission parameters
- Work with Project office to develop a Design Reference Mission using one of the 2.4m telescope assets
- Use telescope "as is"
- Maintain the technical viability for a 2022 launch
- Incorporate modularity in design and attach points to facilitate on-orbit servicing and I&V testing. Consider GEO orbit.
- Keep overall mission cost as low as possible
- Study including a coronagraph instrument as an option
- Study utilizing optical communication as an option

Science Definition Team #2

Neil Gehrels, GSFC Co-Chair
David Spergel, Princeton Co-Chair

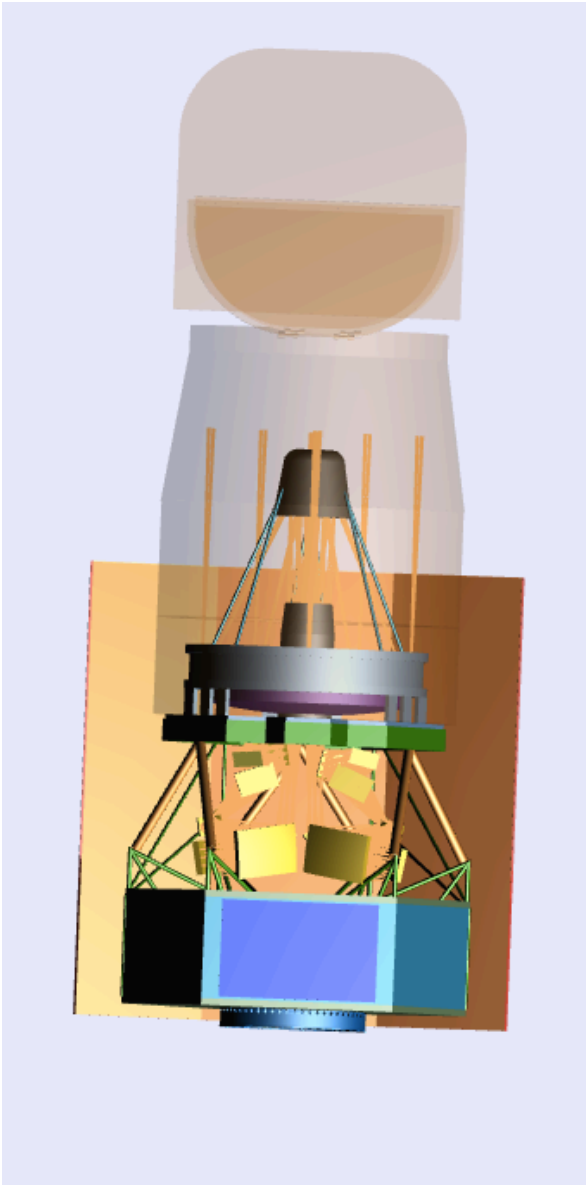
James Breckinridge, Caltech
Megan Donahue, Michigan State Univ.
Alan Dressler, Carnegie Observatory
Chris Hirata, Caltech
Scott Gaudi, Ohio State Univ.
Thomas Greene, Ames
Olivier Guyon, Univ. Arizona
Jason Kalirai, STScI
Jeremy Kasdin, Princeton
Warren Moos, Johns Hopkins
Saul Perlmutter, UC Berkeley / LBNL
Marc Postman, STScI
Bernard Rauscher, GSFC
Jason Rhodes, JPL
Yun Wang, Univ. Oklahoma
David Weinberg, Ohio State U.

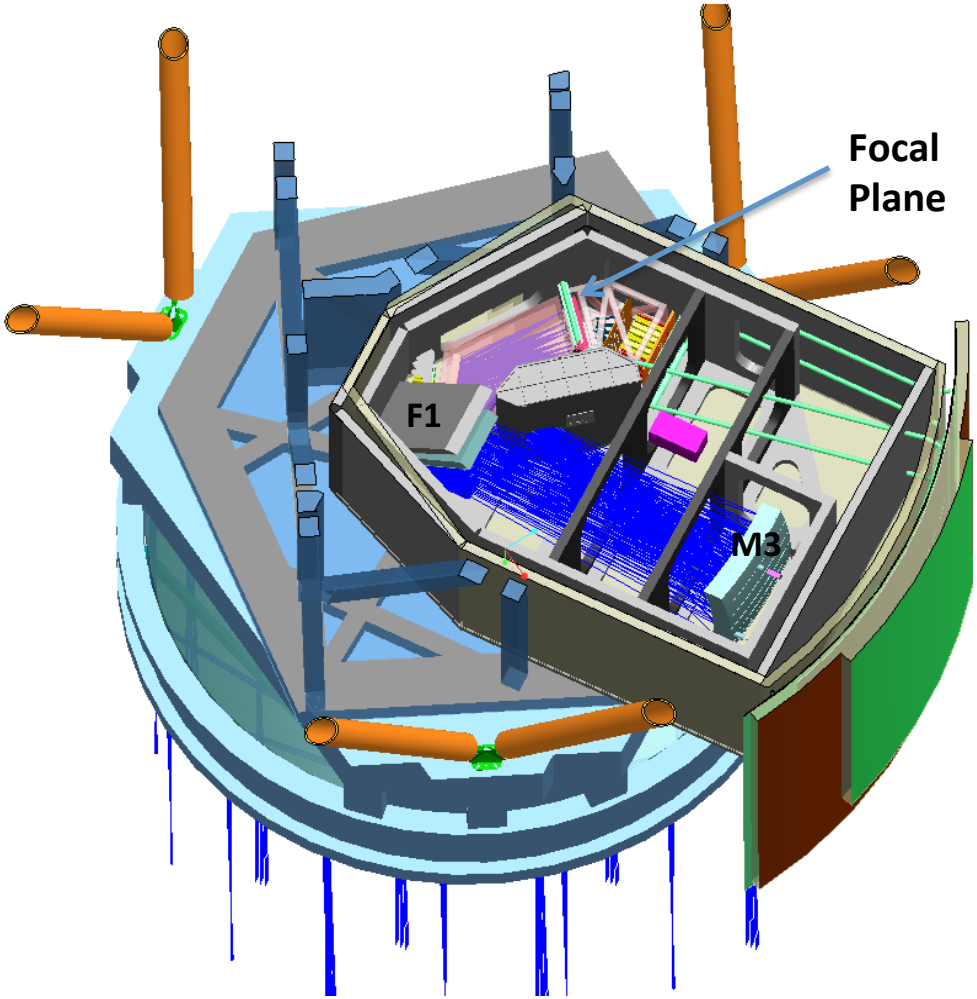
Wes Traub, JPL Ex-Officio
Joan Centrella, NASA HQ Ex-Officio



AFTA
Astrophysics Focused
Telescope Assets

Optics



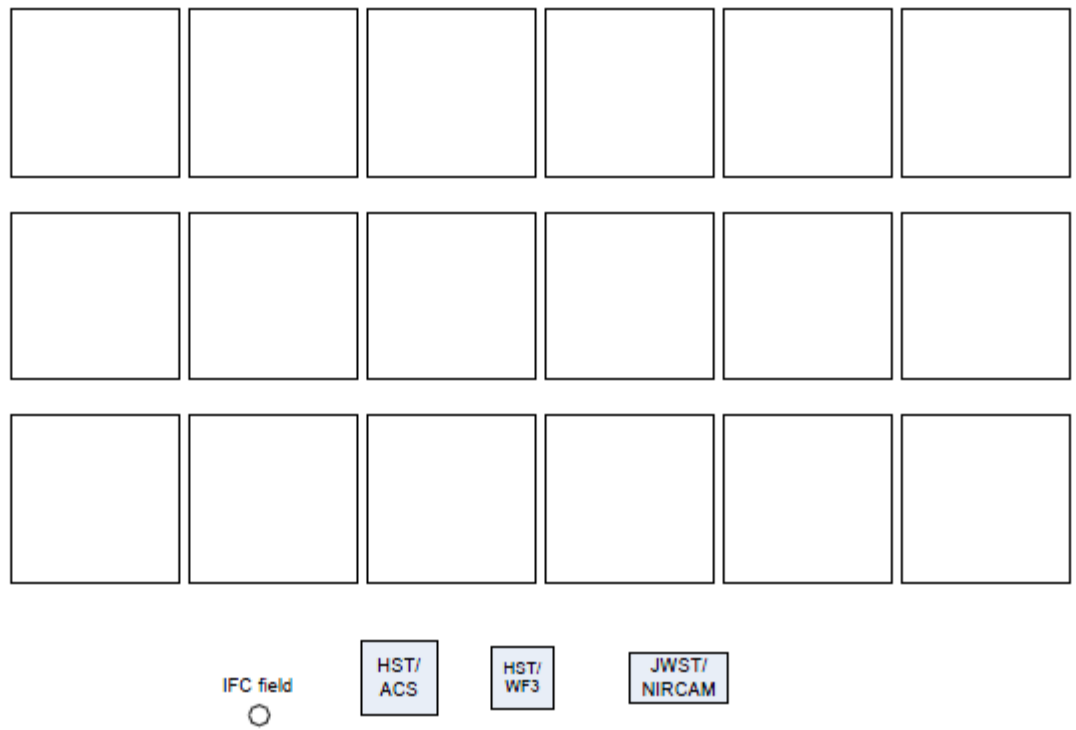


looking up
from bottom

Detector Layout on Sky

Each square
is a H4RG-10
288 Mpixels total

0.11 arcsec/pixel 0.33 deg^2

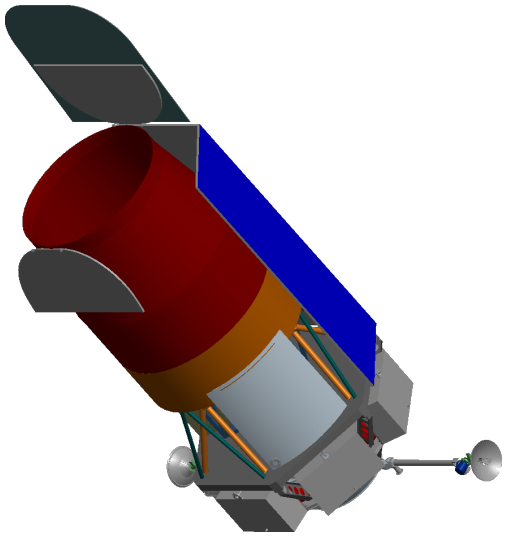


Moon (average size
seen from Earth)

Slitless spectroscopy with grism in filter wheel
R_θ ~ 100 arcsec/micron

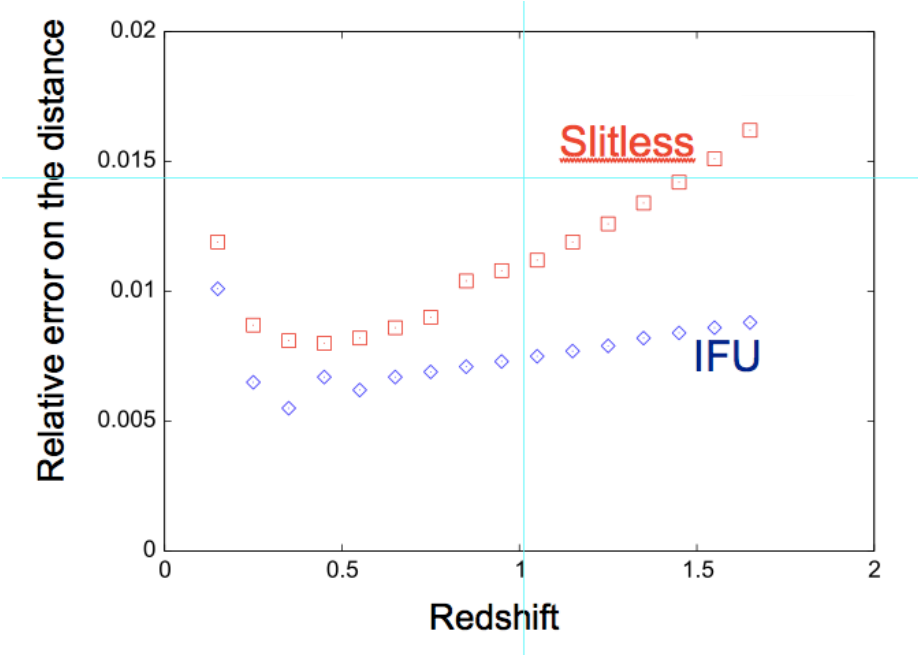
Evolution of Imaging Speed

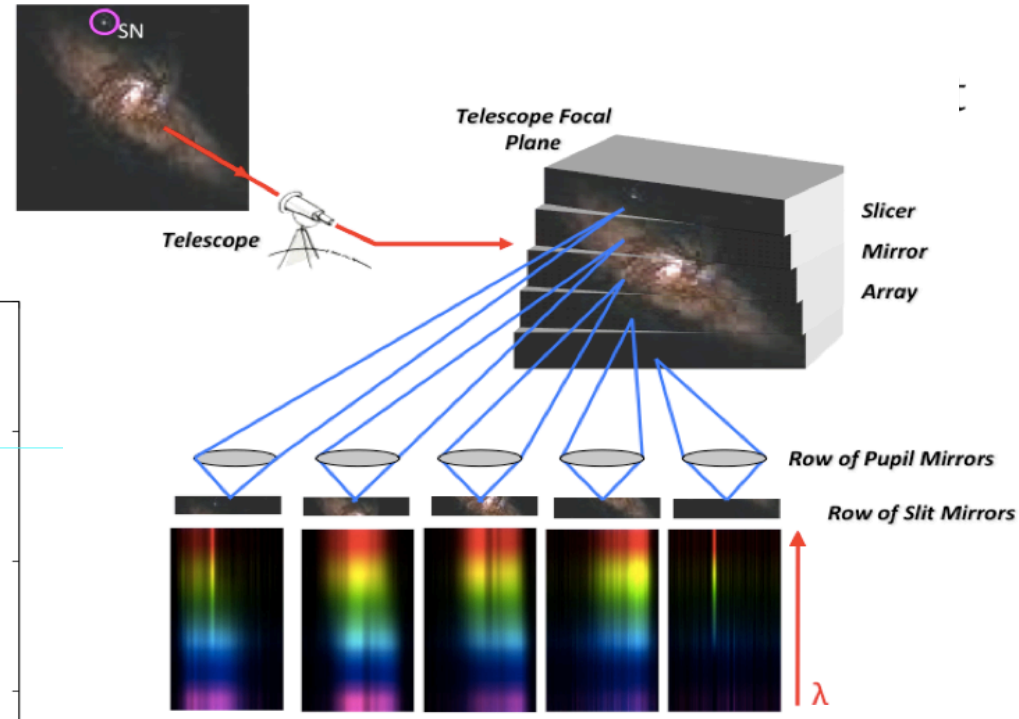
HST



AFTA

IFU Spectrometer





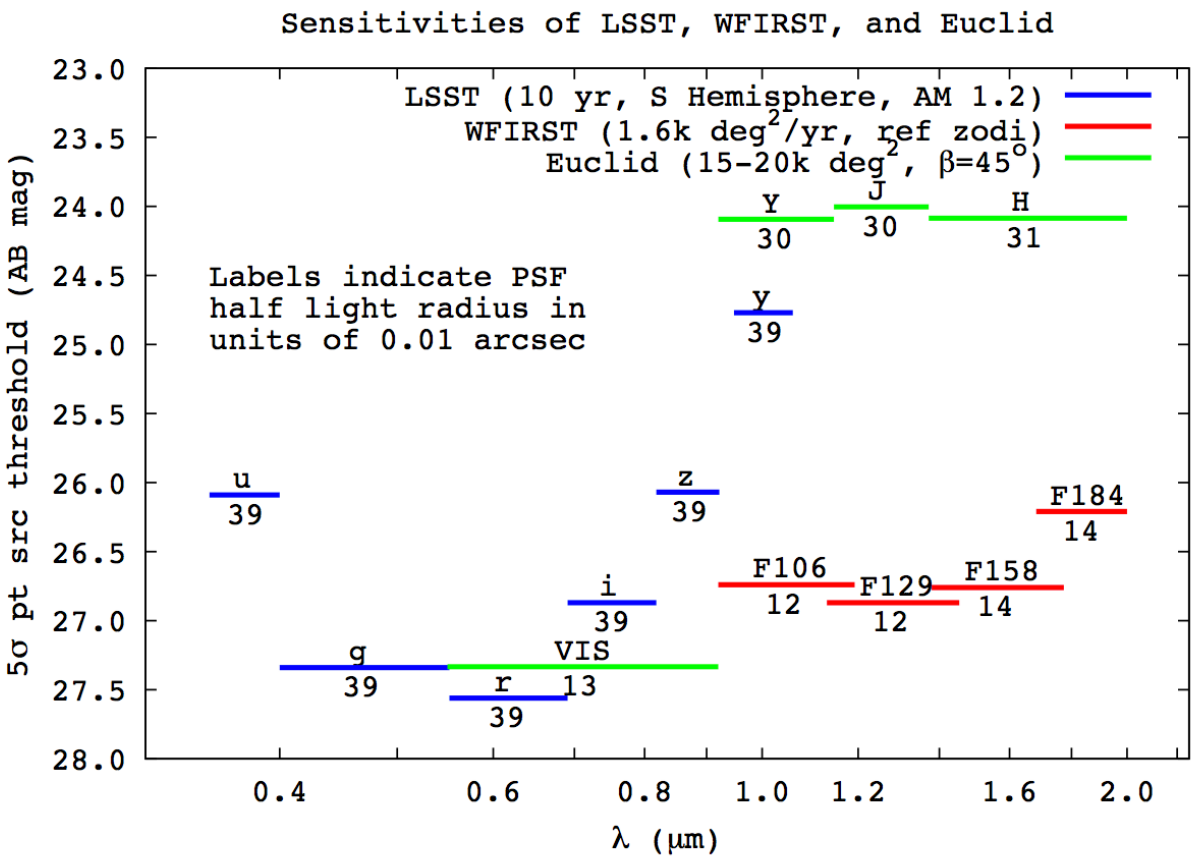
R ~ 75 spectral resolution

Background zodi is 100X less than with slitless grism spectroscopy

NRO Telescopes for NASA and Astrophysics

- 2.4 meter telescope
  - High quality mirror and optical system
  - Easily used in a TMA design
    - Wide field of view
  - Well suited towards WFIRST mission concept
    - Higher spatial resolution enhances science capability
    - Larger collecting area enables more science in fixed time

Complementarity to LSST & Euclid



WFIRST-2.4 IR depth well matched to LSST optical. Scan strategy achieves 100% overlap with LSST

Compared to Euclid IR,

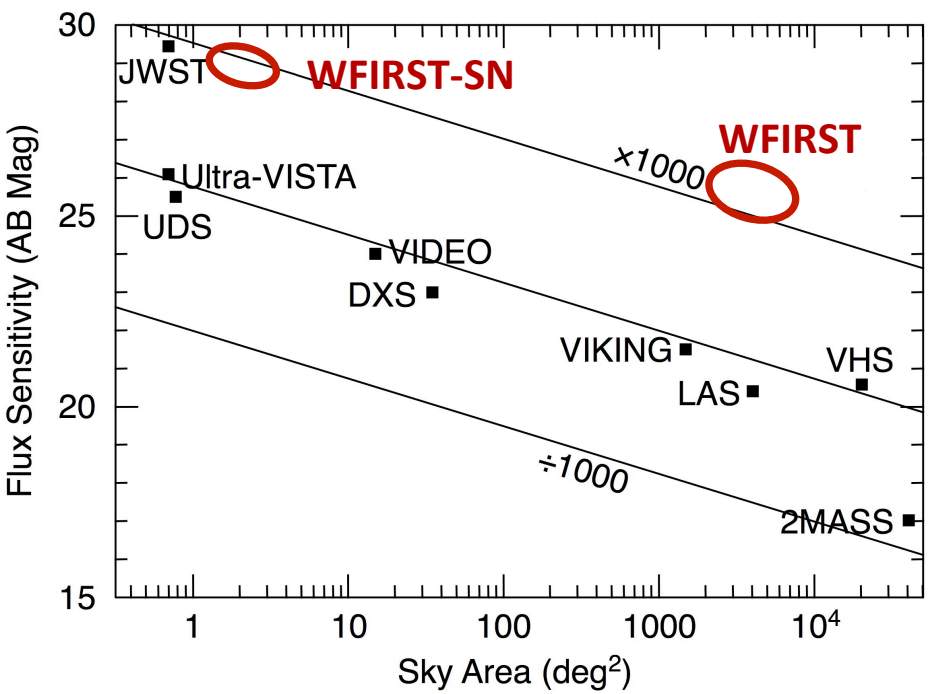
- WFIRST-2.4 is ~10x deeper
- 2.3 higher angular resolution
- Less time spent in prime mission on DE survey (2.5 vs 6.25 years)

Near IR Capabilities

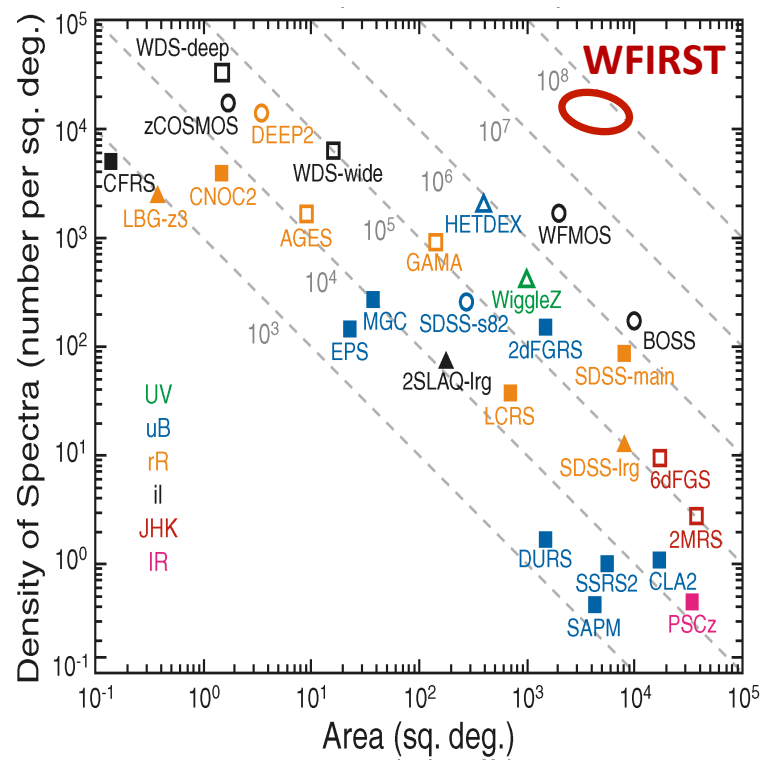
instrument	telescope	pixel scale	field of view	wavelength
WISE	0.4m	2.75 arcsec	47 arcmin	3 – 28 μm
ISO	0.6m	12 arcsec	3 arcmin	2.4 – 240 μm
Akari	0.7m	1.5 arcsec	10 arcmin	1.8 – 180 μm
Spitzer	0.85m	1.2 arcsec	5.2 arcmin	3 – 8 μm
Hubble/NICMOS	2.4m	0.04 – 0.20 arcsec	0.2 – 0.9 arcmin	0.8 – 2.5μm
Hubble/WFC3 IR	2.4m	0.13 arcsec	2 arcmin	0.9 – 1.7 μm
Euclid	1.2m	0.3 arcsec	44 arcmin	0.9 – 2.0 μm
WFIRST – 2.4m	**2.4m**	**0.11 arcsec**	**25 x 52 arcmin**	**1.0 – 2.0 μm**

WFIRST NIR Surveys

NIR Imaging Surveys



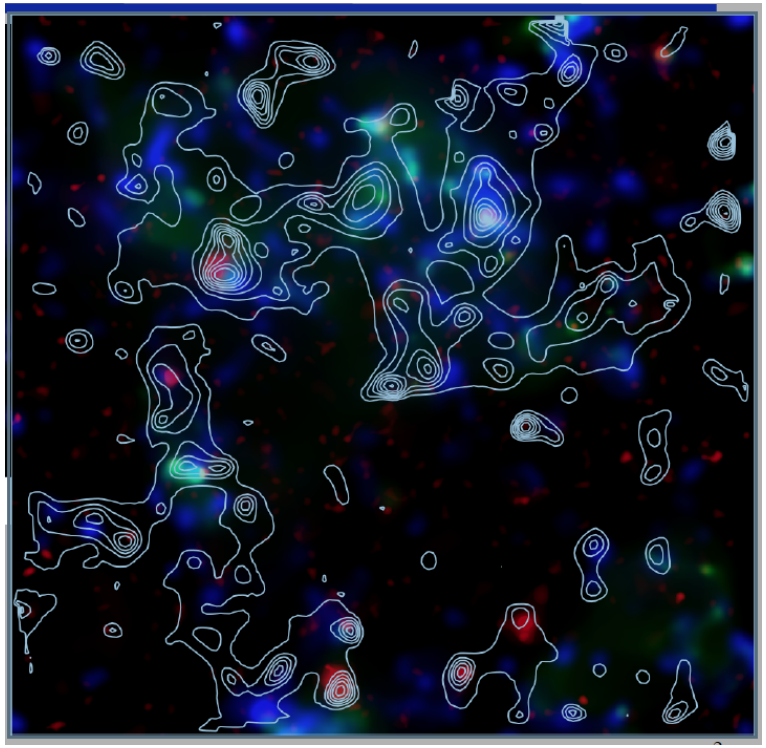
NIR Redshift Surveys



WFIRST provides a factor of 100 improvement in IR surveys

New Science Enabled by 2.4 m

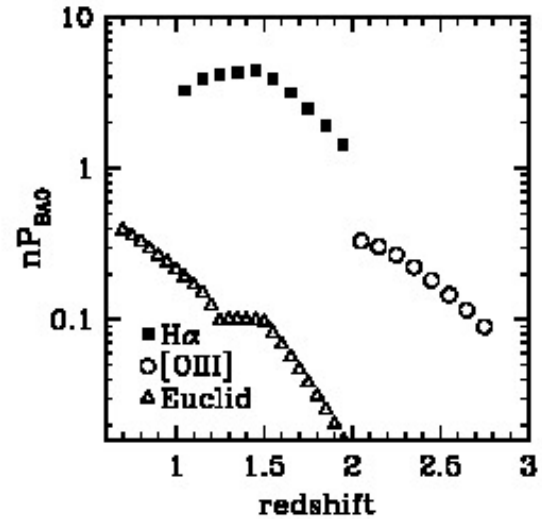
- Higher Resolution Galaxy Survey
  - More galaxies enables mapping large-scale distribution of dark matter
  - Detailed galaxy morphology enables detailed study of galaxy evolution (HST imaging with more than 100 x FOV)
  - *How Do Cosmic Structures Form and Evolve?*
    - "It is most important to obtain HST-like imaging to determine the morphologies, sizes, density profiles and substructure of dark matter, on scales from galaxies to clusters by means of weak and strong gravitational lensing, in lens samples at least an order-of-magnitude larger than currently available" (GCT, p97)

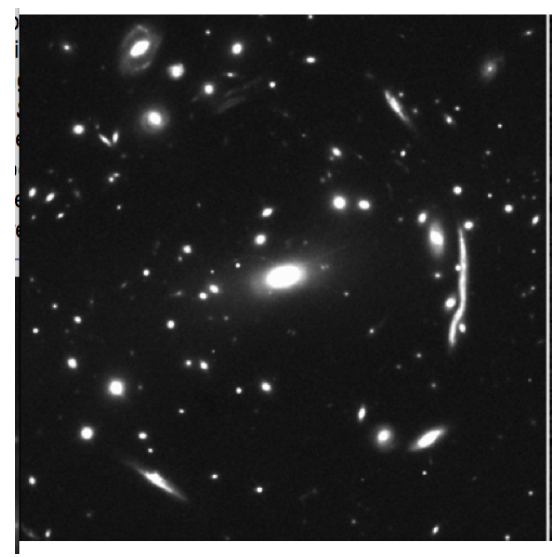


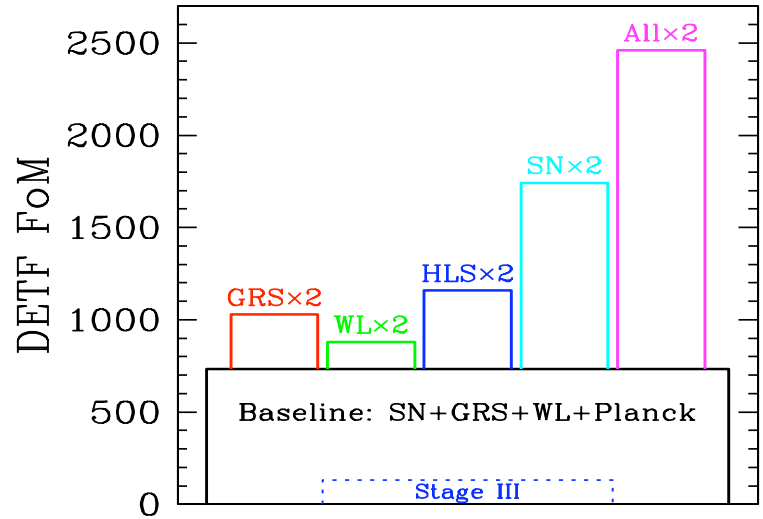
Imagine a 2000 sq. degree version of the Cosmos dark matter map!

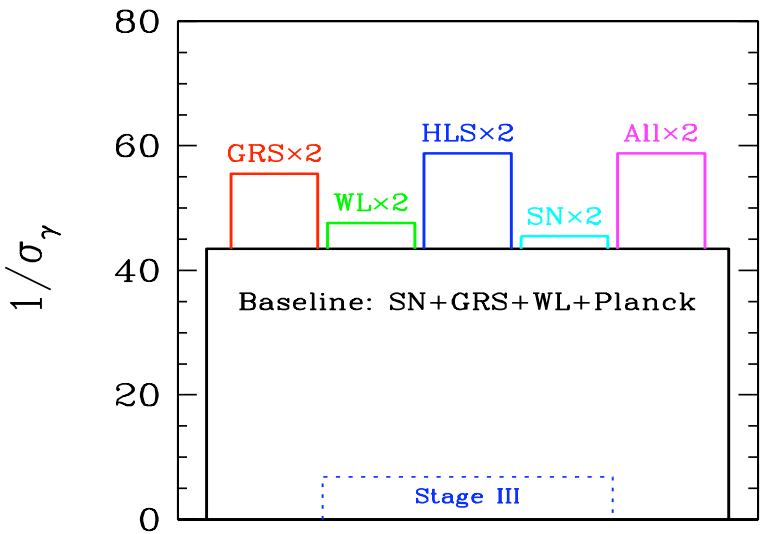
New Science II: Improved Dark Energy Measurements

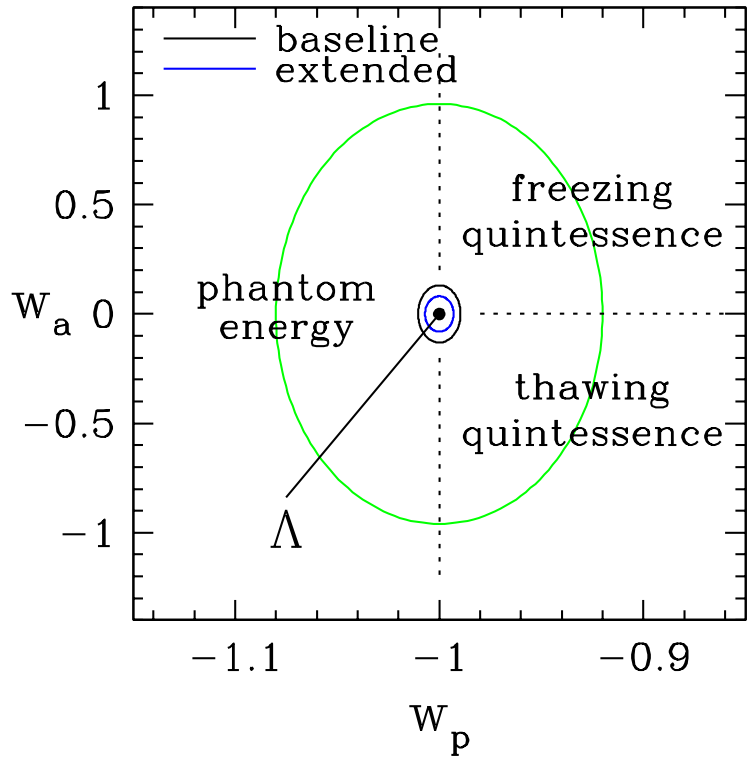
- Supernova
  - IFU improves SN info.
- BAO with OIII
- Strong Lensing
- Redshift Space Distortions

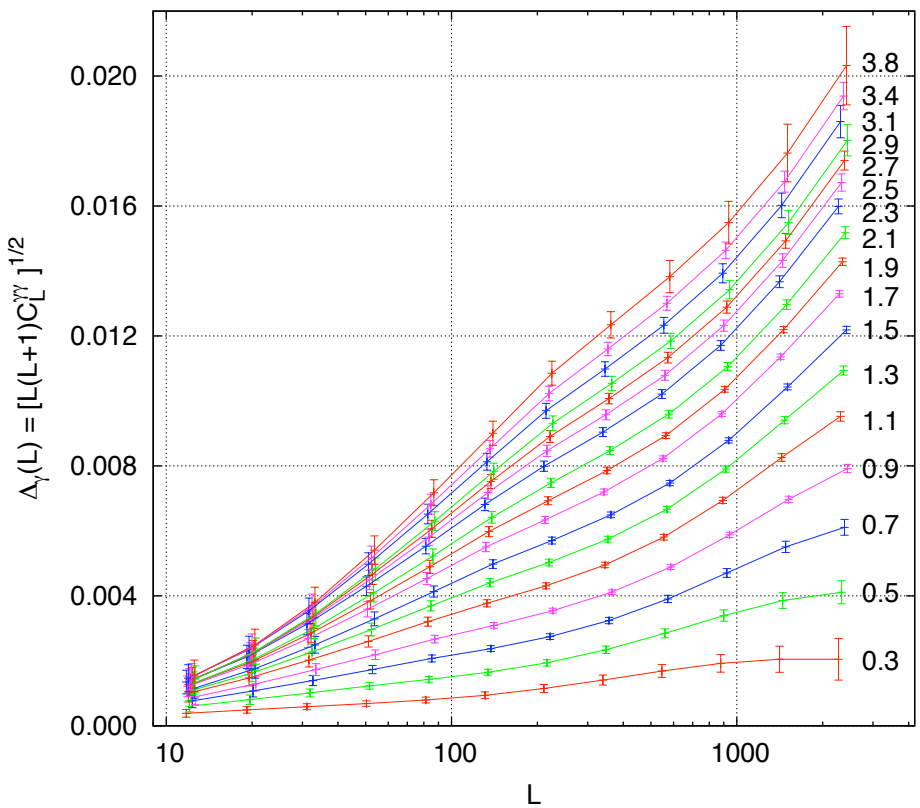


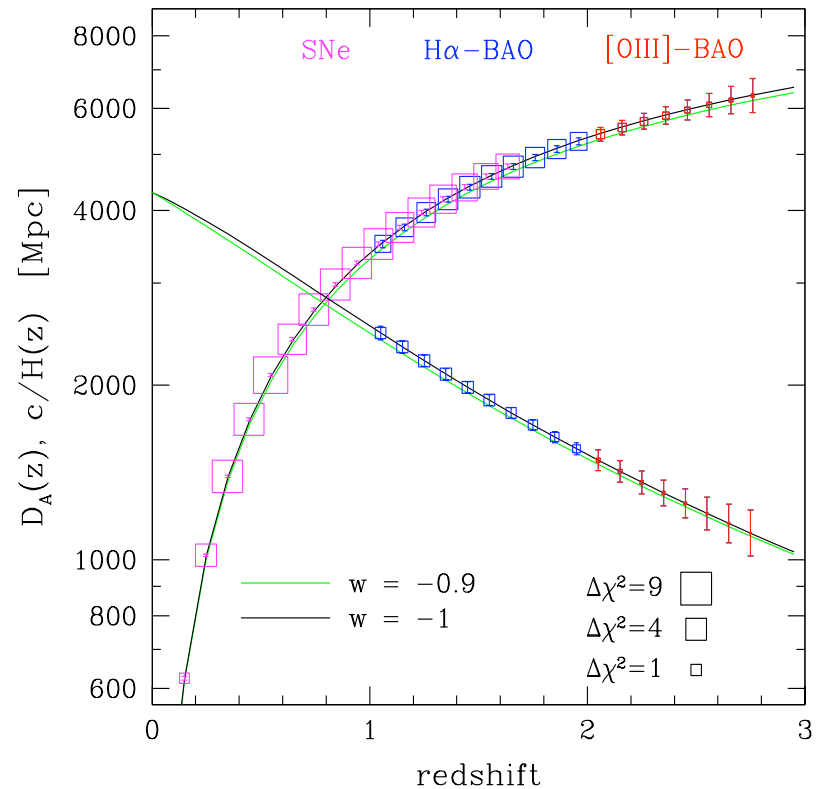



DETF FoM
2500
2000
1500
1000
500
0
GRS×2
WL×2
HLS×2
SN×2
All×2
Baseline: SN+GRS+WL+Planck
Stage III


$1/\sigma_\gamma$
80
60
40
20
0
GRS×2
WL×2
HLS×2
SN×2
All×2
Baseline: SN+GRS+WL+Planck
Stage III


baseline
extended
w_a
1
0.5
0
−0.5
−1
w_p
−1.1
−1
−0.9
freezing
quintessence
phantom
energy
thawing
quintessence
Λ

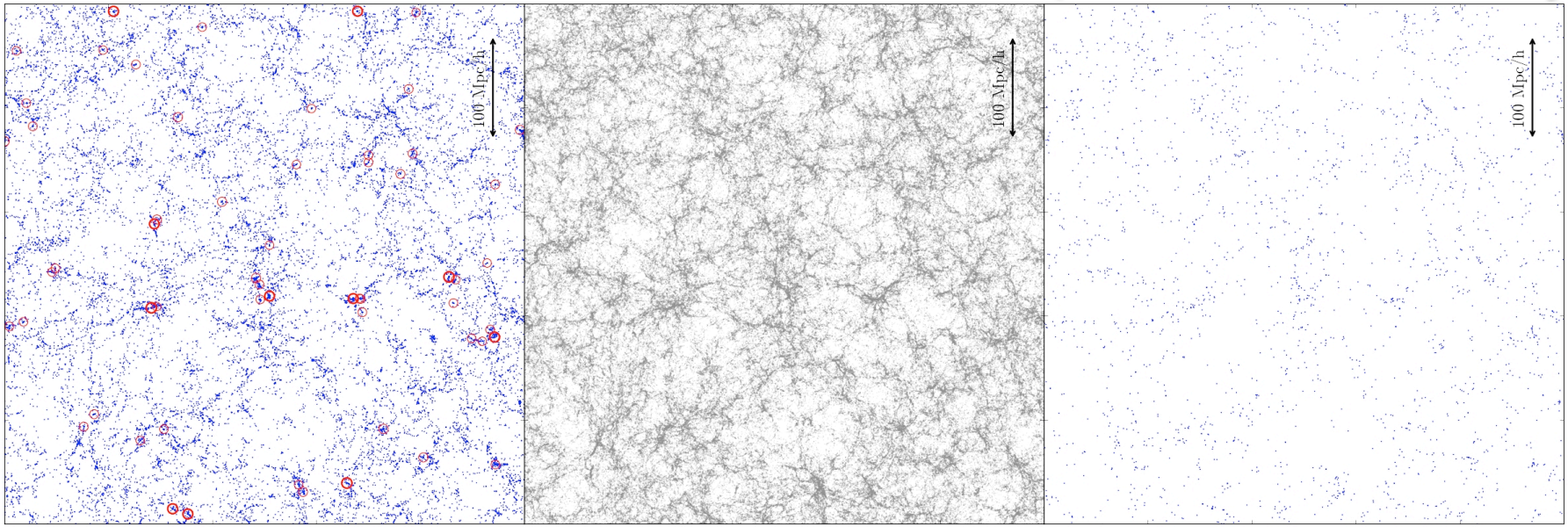

$\Delta_\gamma(L) = [L(L+1)C_L^{\gamma\gamma}]^{1/2}$
0.020
0.016
0.012
0.008
0.004
0.000
10
100
1000
L
3.8
3.4
3.1
2.9
2.7
2.5
2.3
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
0.3


SNe
Hα−BAO
[OIII]−BAO
$D_A(z)$, c/H(z) [Mpc]
8000
6000
4000
2000
1000
800
600
0
1
2
3
redshift
w = −0.9
w = −1
$\Delta\chi^2=9$
$\Delta\chi^2=4$
$\Delta\chi^2=1$

Millennium Simulation

z = 1.5

500 h^{-1} Mpc
9 degrees



galaxies at luminosity threshold to match WFIRST-2.4m space density

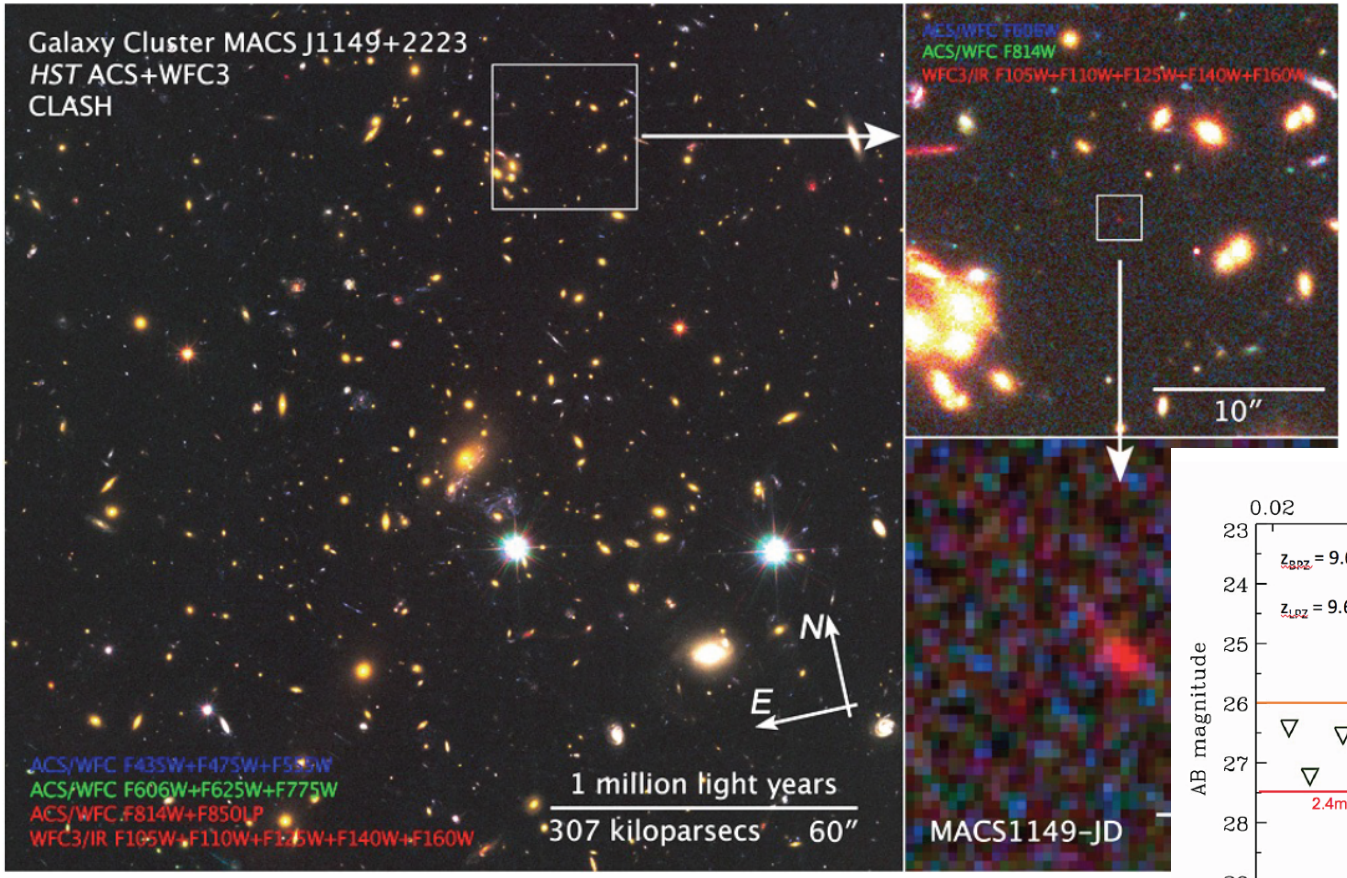
dark matter

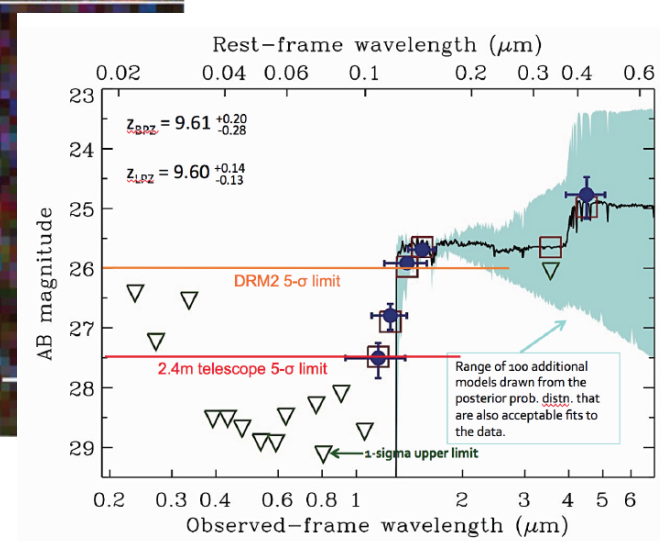
galaxies at luminosity threshold to match Euclid space density

Figure by Y. Zu

Springel et al. 2005

New Science III: Strong Lensing

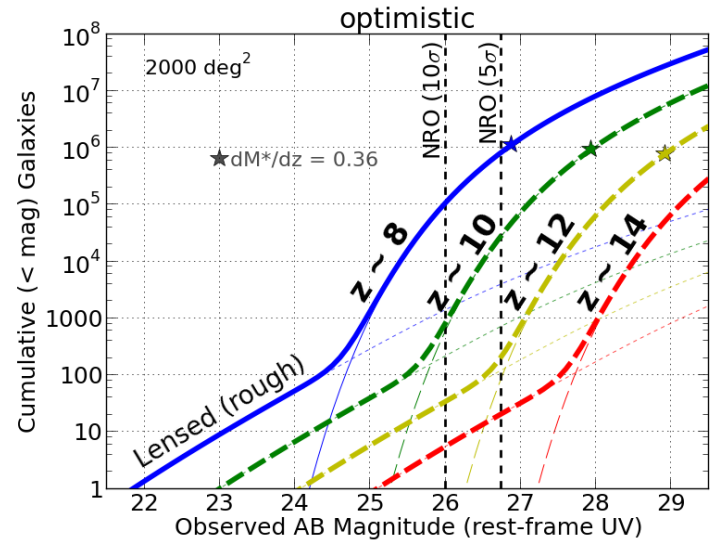


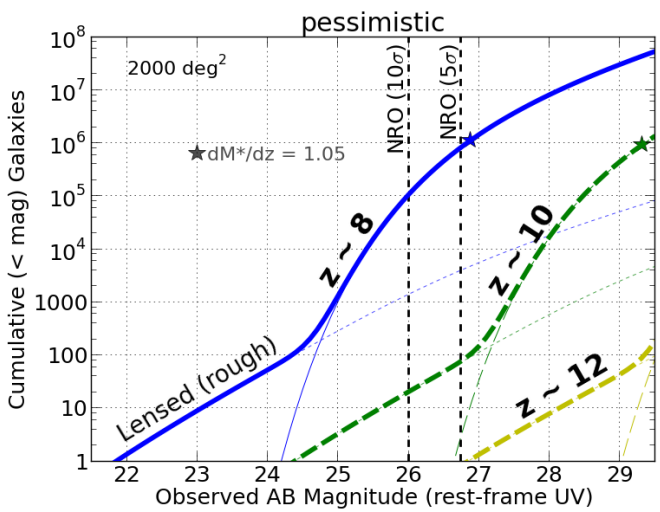


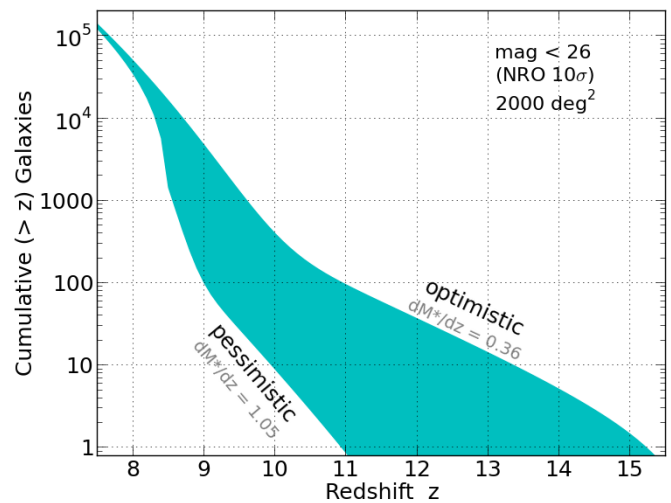
CLASH Survey across 2600 sq. deg

New Science IV: JWST Target Finder

- Deeper HLS (mag 26 (10 σ) rather than 25) enables the detection of large number of high z target galaxies for JWST

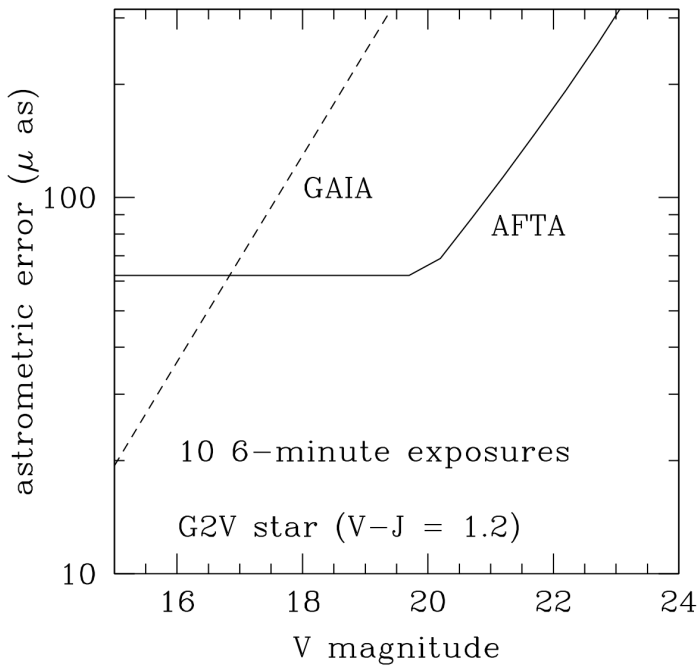






New Science (V): Astrometry and Dark Matter

- Astrometry
  - Higher resolution and improved collecting area enables AFTA/WFIRST to achieve same astrometric accuracy 10 times faster than DRM1
  - Trace substructure in globular cluster tidal tails: test whether dark matter is warm dark matter
  - *GAN 4: What are the connections between dark and luminous matter?*
    - *Using local universe as dark matter laboratory*
    - *What is the baryon-dark matter connection at low galaxy masses?*
    - *How much Low-Mass Substructure Exists Locally*
  - *GAN DA: Astrometry as a General Area of Discovery Potential*



New Science VI: Exoplanet Science

- Replace with Kasdin slides

Rich GO Science
(New Science VII.....)

Planetary Bodies

A Full Portrait of the Kuiper Belt, including Size Distributions, Colors and Binarity
Free-floating Planets in the Solar Neighborhood
Exoplanet Spectroscopy with WFIRST
Extending Open Cluster and Star Forming Region IMFs to the Planetary Mass Regime
WFIRST: Additional Planet Finding Capabilities - Astrometry
WFIRST: Additional Planet Finding Capabilities - Transits

Stellar Astrophysics

Stellar and Substellar Populations in Galactic Star Forming Regions
Identifying the Coldest Brown Dwarfs
Stellar Fossils in the Milky Way
The Infrared Color-Magnitude Relation
Finding the Closest Young Stars
The Most Distant Star-Forming Regions in the Milky Way
Super-resolution Imaging of Low-mass Stars with Kernel-phase & Precision Wavefront Calibration with Eigen-phase

Galactic Astrophysics and the Local Volume

Proper Motions and Parallaxes of Disk and Bulge Stars
Quasars as a Reference Frame for Proper Motion Studies
The Detection of the Elusive Stellar Counterpart of the Magellanic Stream
Near-field Cosmology: Finding the Faintest Milky Way Satellites
Dissecting Nearby Galaxies
Substructure Around Galaxies Within 50 Mpc
Resolved Stellar Populations in Nearby Galaxies
Deep Surface Photometry of Galaxies and Galaxy Clusters

Extragalactic Astrophysics

Galaxy Structure and Morphology
Strong Lensing
Searching for Extreme Shock-dominated Galaxy Systems from $1 < z < 2$
Mapping the Distribution of Matter in Galaxy Clusters
Merging Clusters of Galaxies
Group-Scale Lenses: Unexplored Territory
The Evolution of Massive Galaxies: the Formation and Morphologies of Red Sequence Galaxies
Finding and Weighing Distant, High Mass Clusters of Galaxies
Probing the Epoch of Reionization with Lyman-Alpha Emitters
Obscured Quasars
The Faint End of the Quasar Luminosity Function
Strongly Lensed Quasars
High-Redshift Quasars and Reionization
Characterizing the sources responsible for Reionization
Finding the First Cosmic Explosions With WFIRST

General

Synergy Between LSST and WFIRST
The Shapes of Galaxy Haloes from Gravitational Flexion
WFIRST and IRSA: Synergy between All-Sky IR Surveys

Project