Contribution of WFIRST to Astronomy in the Next 30 years

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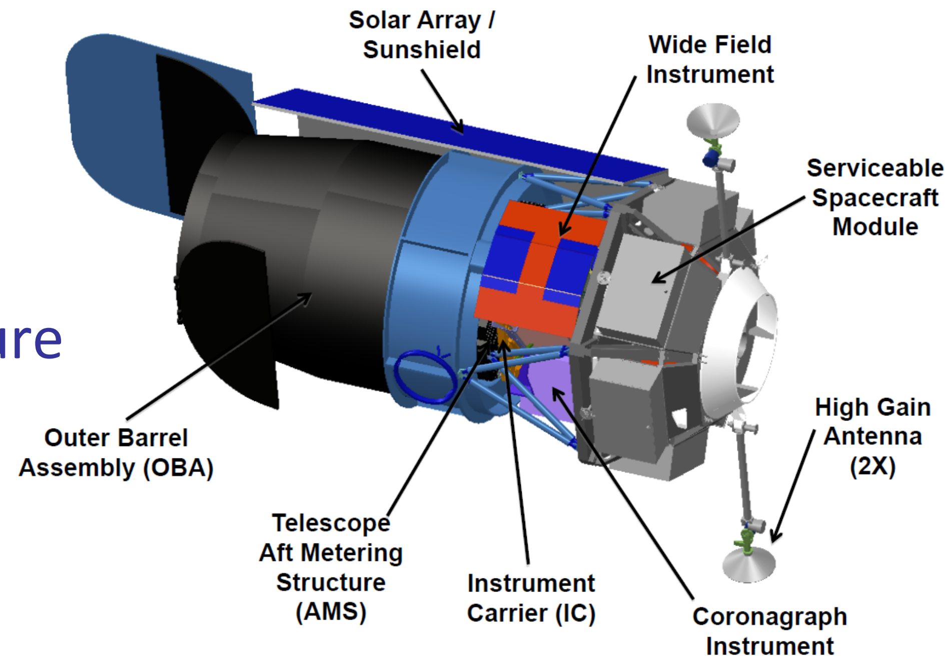
What is WFIRST-AFTA?

- WFIRST: top-ranked large space project (Decadal 2010)
  - Original vision was for a "1.5-m telescope, wide FOV, NIR imaging, low-resolution spectroscopy"
  - Current vision is for a 2.4-m telescope, wide FOV, visible-NIR imaging, low-resolution spectroscopy, & coronagraph
  - 5-year mission at GEO
- Coronagraph technology: top-ranked medium space project
  - Larger telescope permits adding coronagraph instrument
  - Science plus tech demo
  - 6-year mission at GEO
- New start FY-17
- Launch early 2020s

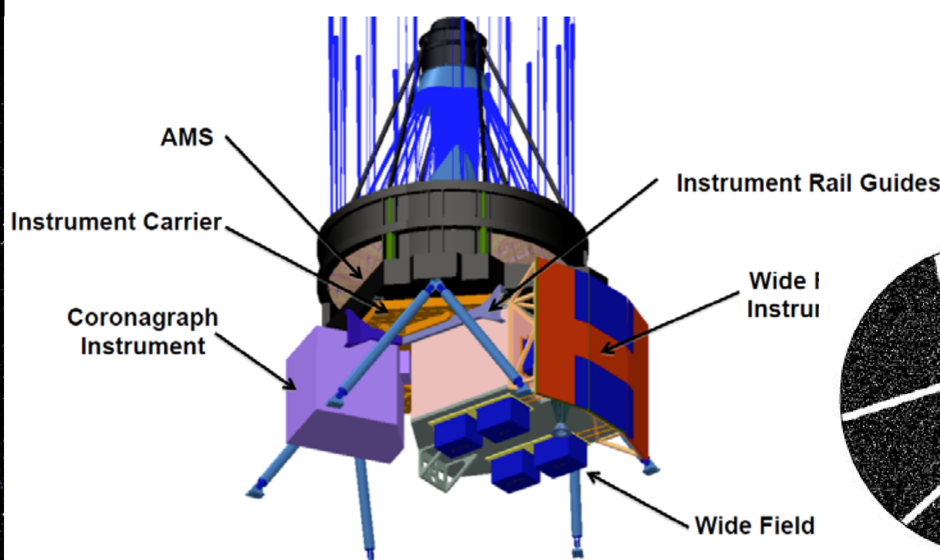
Ref.: "New Worlds, New Horizons in Astronomy and Astrophysics", pp. 16-20, NRC, NAS, 2010

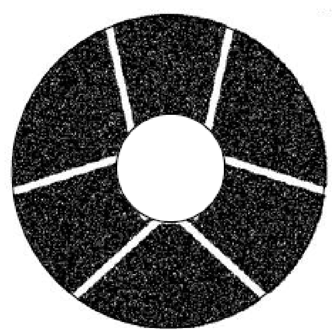
Telescope for WFIRST-AFTA

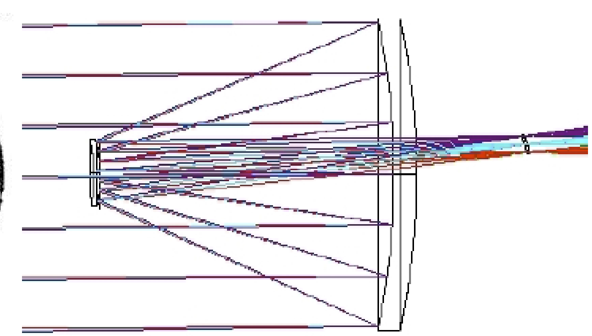
- 2.4-m donated telescope already exists
- 3-mirror anastigmat (TMA)
- On-axis secondary
- ULE lightweighted optics
- 270 K operating temperature
- GEO orbit, 24-hour period



WFIRST-AFTA SDT Interim Report



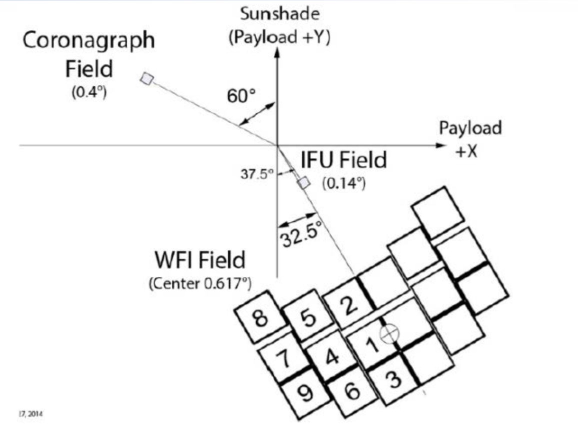


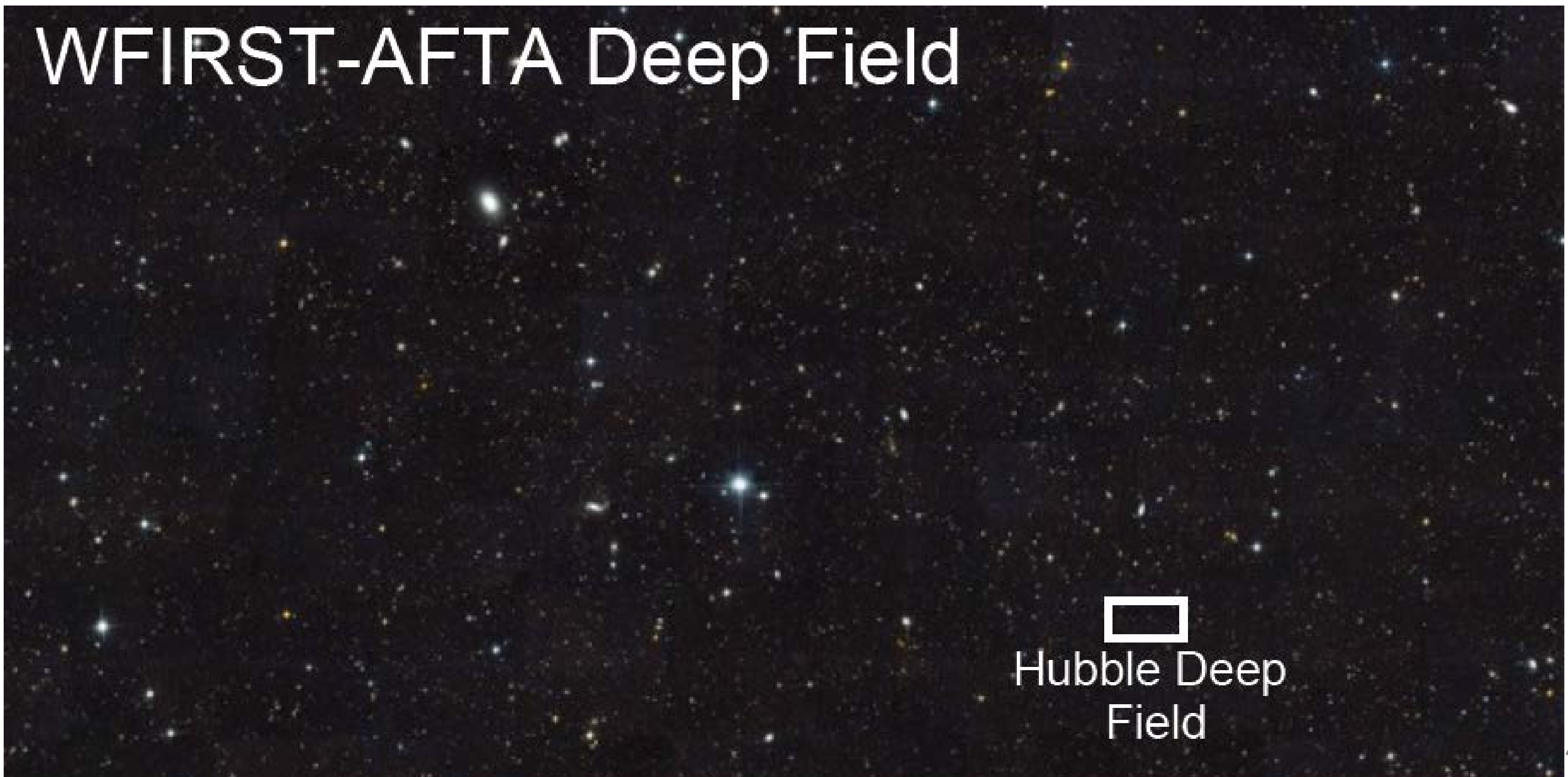


Refs.: WFIRST-AFTA_SDT_Final_Report_Rev1_130523.pdf and WFIRST-AFTA_SDT_Interim_Report_April_2014.pdf

Wide-Field Instrument on WFIRST-AFTA

- 18 H4RG HgCdTe detectors
- FOV is 0.28 deg^2 (100x JWST, 200x HST)
- 0.7 – 2.0 micron bandpass
- 6-filter imaging
- grism and IFS spectra

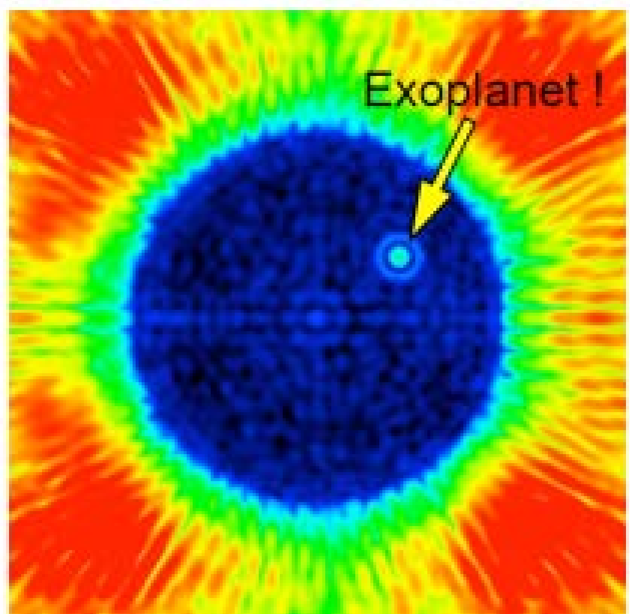




AFTA WFIRST
Wide-Field Infrared Survey Telescope

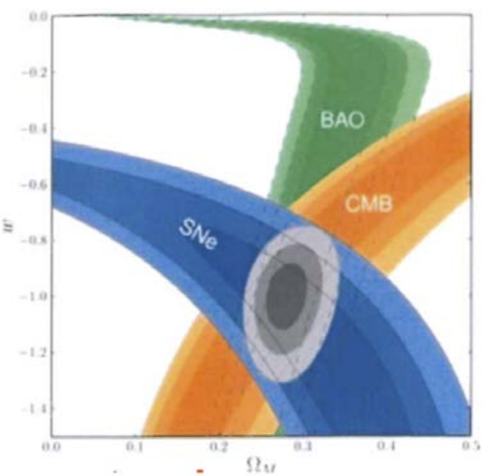
Coronagraph instrument on WFIRST-AFTA

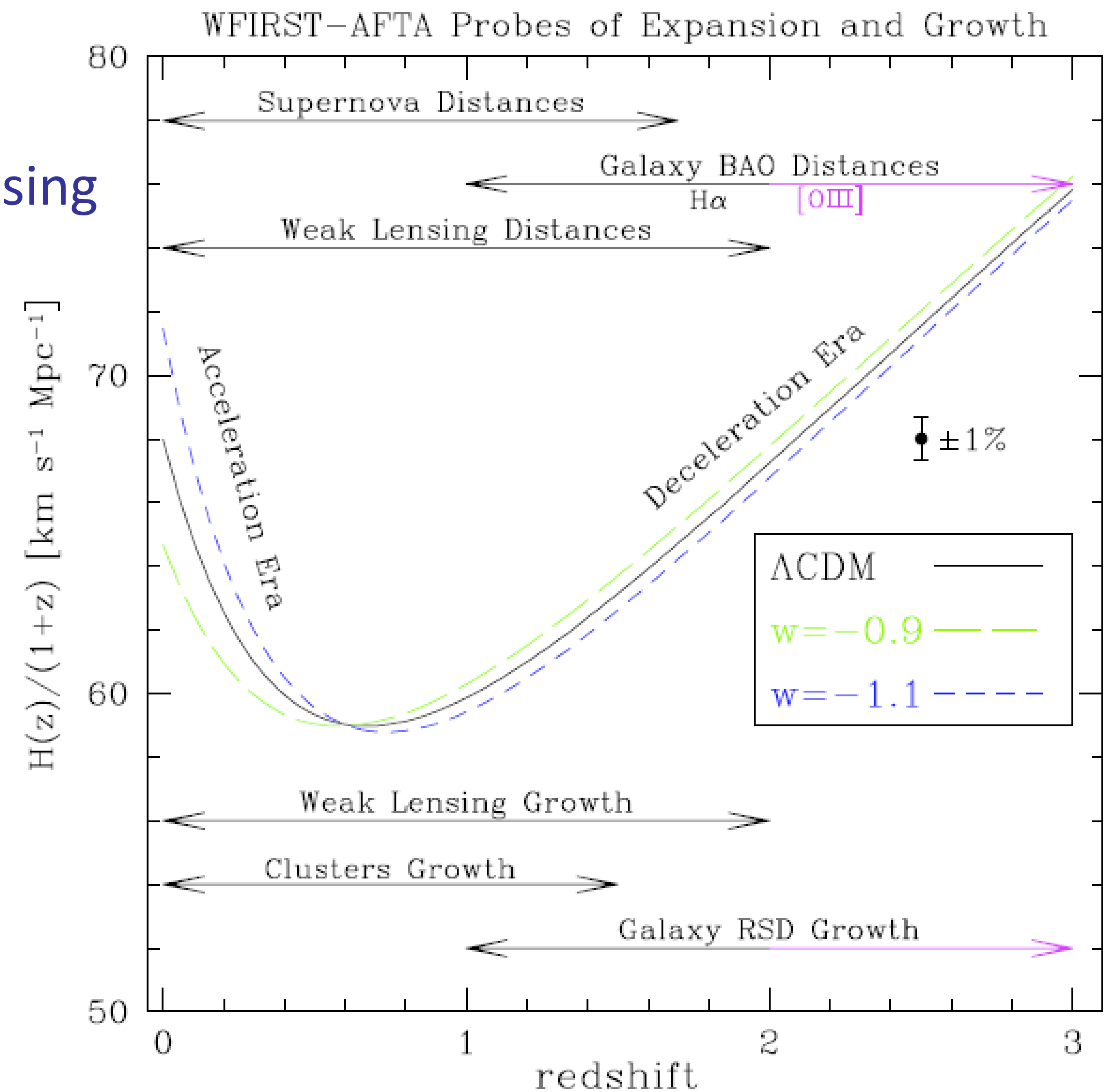
- Coronagraph
  - electron-multiplying ccd detectors
  - 0.4 – 1.0 micron bandpass
  - 6-filter imaging, 10% bands
  - 4-filter IFS spectra, resolution 70
  - 10^{-9} contrast (after post-processing)
  - 100 milliarcsec inner working angle at 400 nm



WFI Science: Cosmic acceleration (1 of 5)

- Baryon acoustic oscillations
- Gravitational lensing
- Supernovae





WFI Science: Dark energy, General Relativity (2 of 5)

Top-level questions of the field:

1. Is cosmic acceleration caused by a new energy component or by the breakdown of General Relativity (GR) on cosmological scales?
2. If the cause is a new energy component, is its energy density constant in space and time, or has it evolved over the history of the universe?

WFIRST-AFTA addresses these questions using multiple methods to measure the history of cosmic expansion and structure growth, tightly constraining the properties of dark energy, the consistency of GR, and the curvature of space.

Supernova Survey: Distance measurements, $z = 0 – 1.7$.

Weak Lensing Survey: Growth of structure from cosmic shear, galaxy-galaxy lensing, abundance of massive clusters.

Galaxy Redshift Survey: Distance and expansion rate from baryon acoustic oscillations, growth of structure from redshift-space distortions.

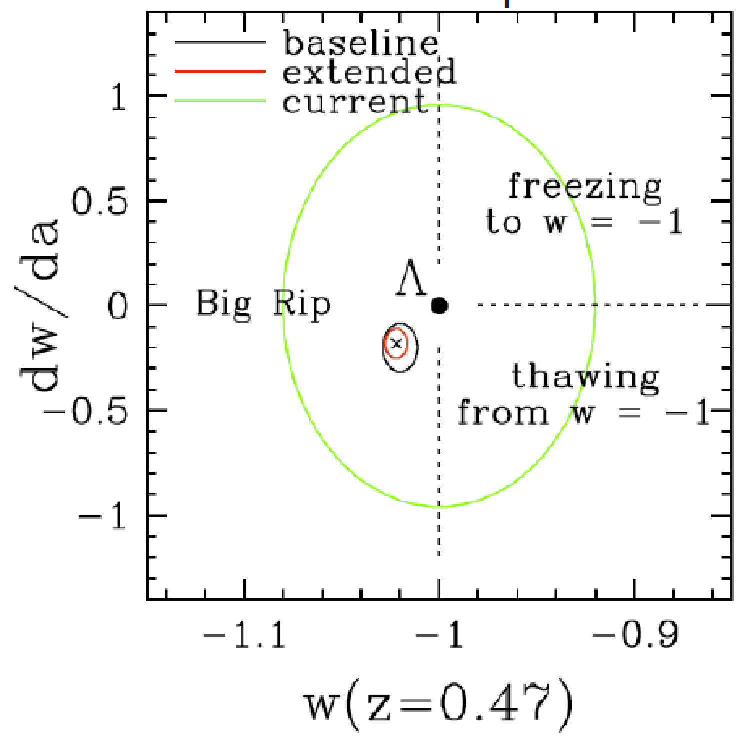
Emphasis on cross-checks and control of systematics at every level.

AFTA WFIRST Wide-Field Infrared Survey Telescope

WFIRST-AFTA will improve cosmological measurements by 1-2 orders of magnitude over current data, with greater redshift leverage, control of systematics, and cross-checks of methods.

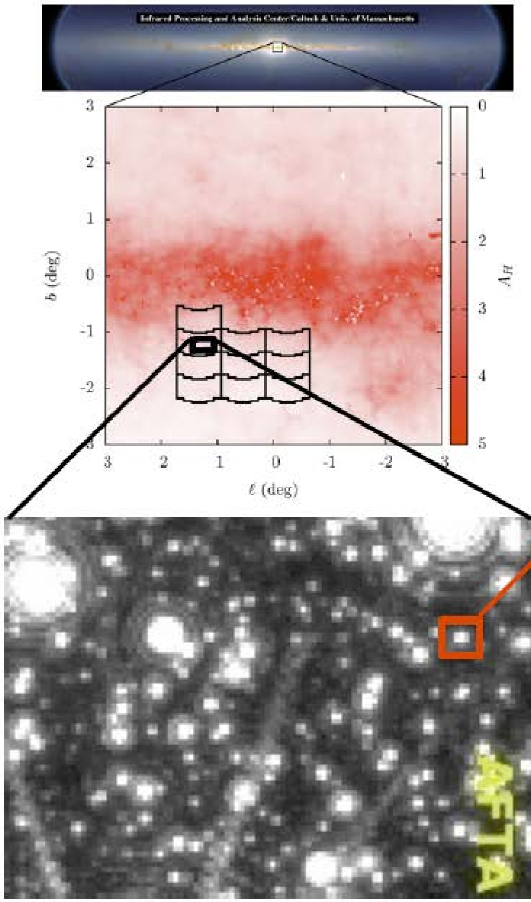
Potential to reveal surprises below the sensitivity of current data, confirm them internally with cross-checks, and investigate their physics by combining expansion and growth probes.

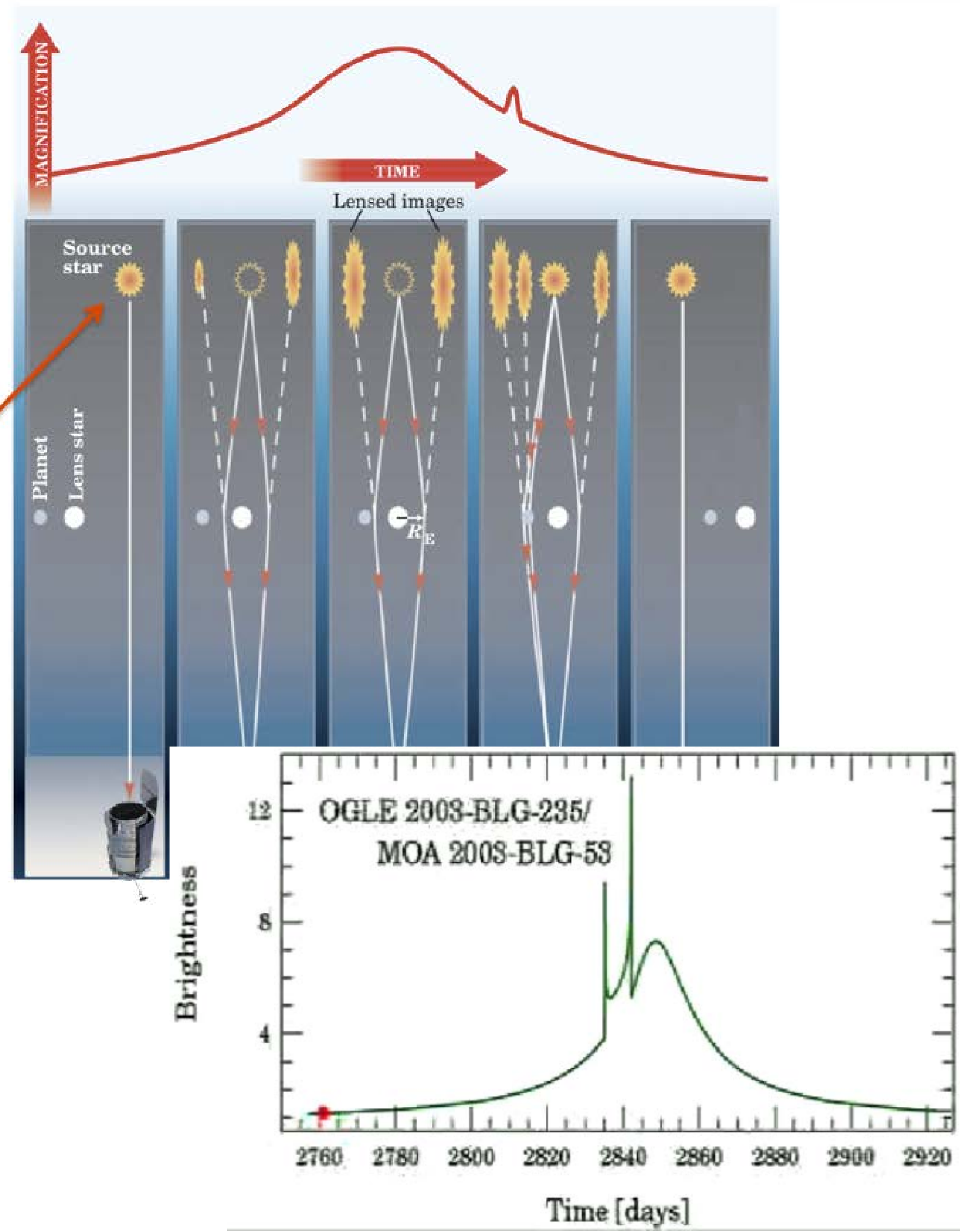
From 2013 SDT Report



Forecast dark energy constraints from baseline & extended programs, compared to current knowledge. Distinct regions of plane represent fundamentally different physics.

WFI Science: Exoplanet microlensing (4 of 5)





WFI Science: Exoplanet microlensing (5 of 5)

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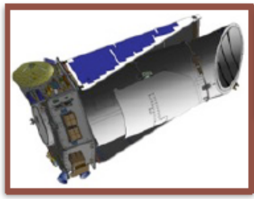
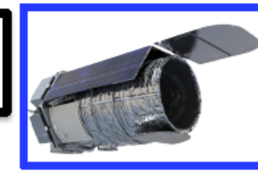
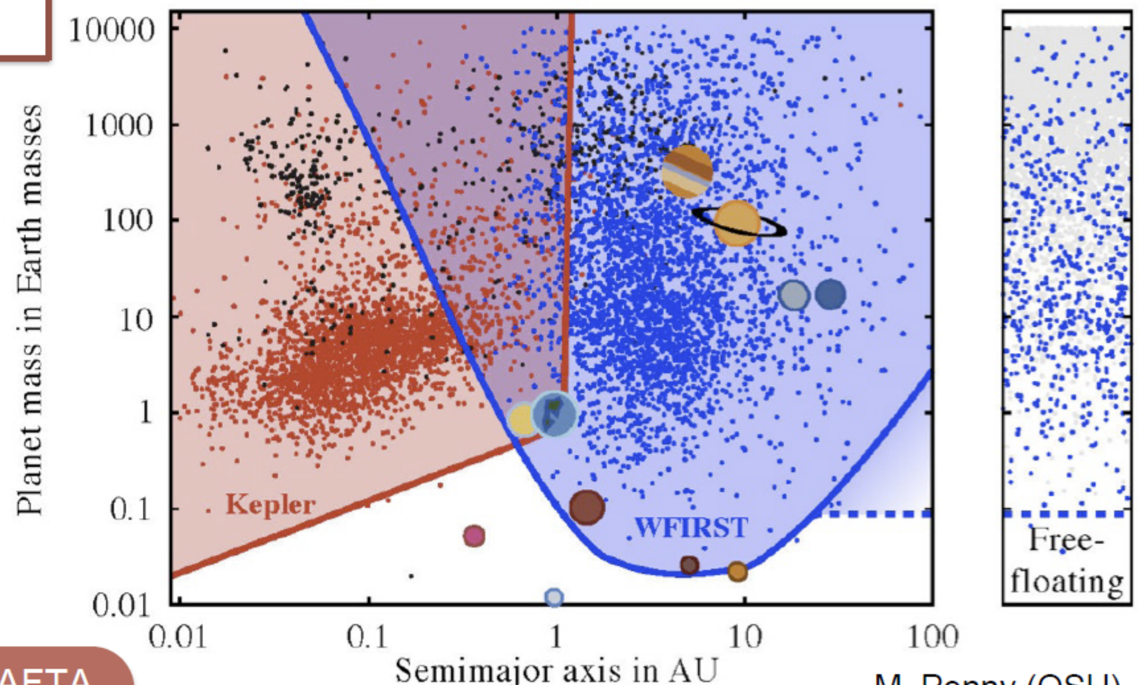


Combined with space-based transit surveys, WFIRST-AFTA completes the statistical census of planetary systems in the Galaxy.





M. Penny (OSU)

WFIRST-AFTA is more capable than the IDRM design

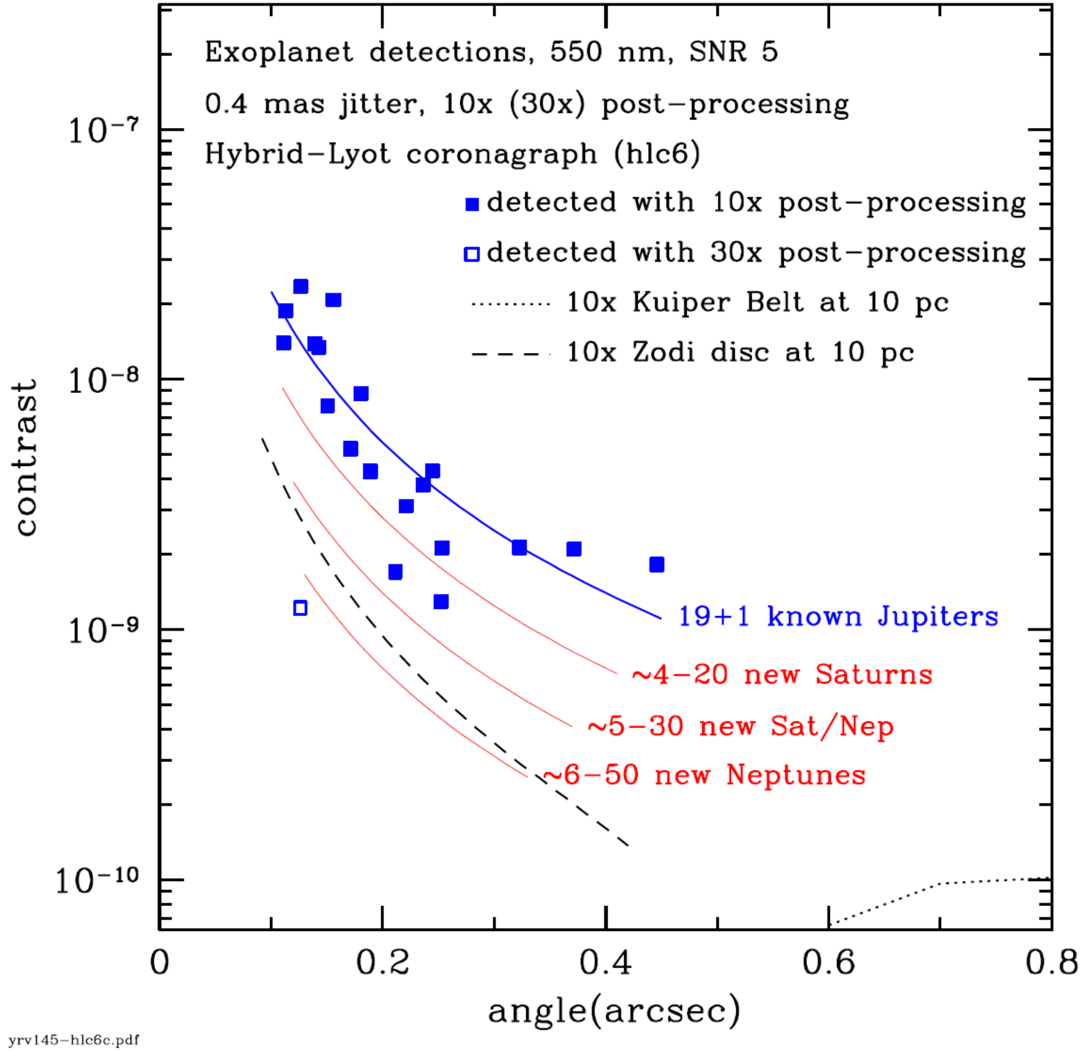
- 1.6 times larger planet yields
- Factor of two better sensitivity to Earth-mass planets.
- Improved ability to measure masses and distances to the microlensing host stars.

WFIRST-AFTA perfectly complements Kepler, TESS, and PLATO.

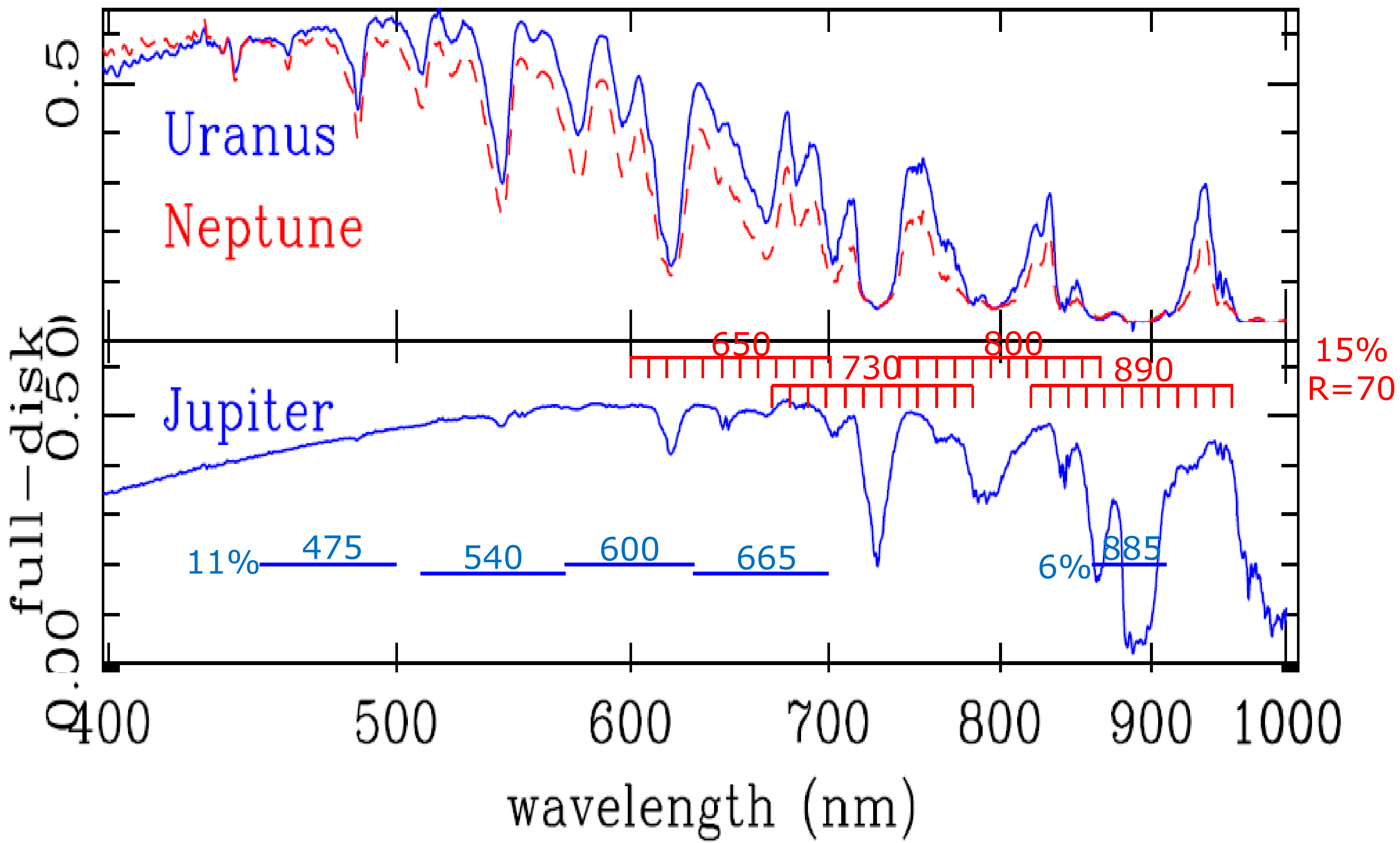
- ~3000 planet detections.
- 300 with Earth mass and below.
- Hundreds of free-floating planets.

Coronagraph science: Jupiters to Neptunes

- Detect and obtain spectra of a dozen known RV planets
- Search for new planets, from Jupiters to Neptunes
- Detect and image exo-zodi and Kuiper-type debris disks



Planet spectra: filters & IFS



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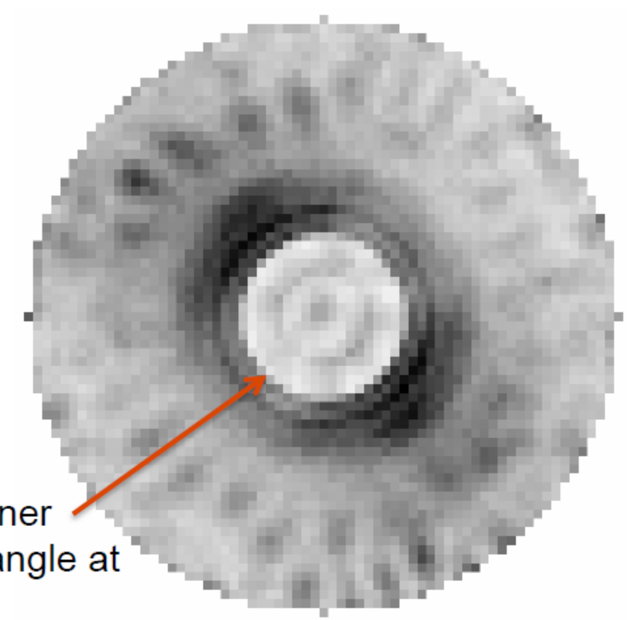
Coronagraph science: Imaging circumstellar disks

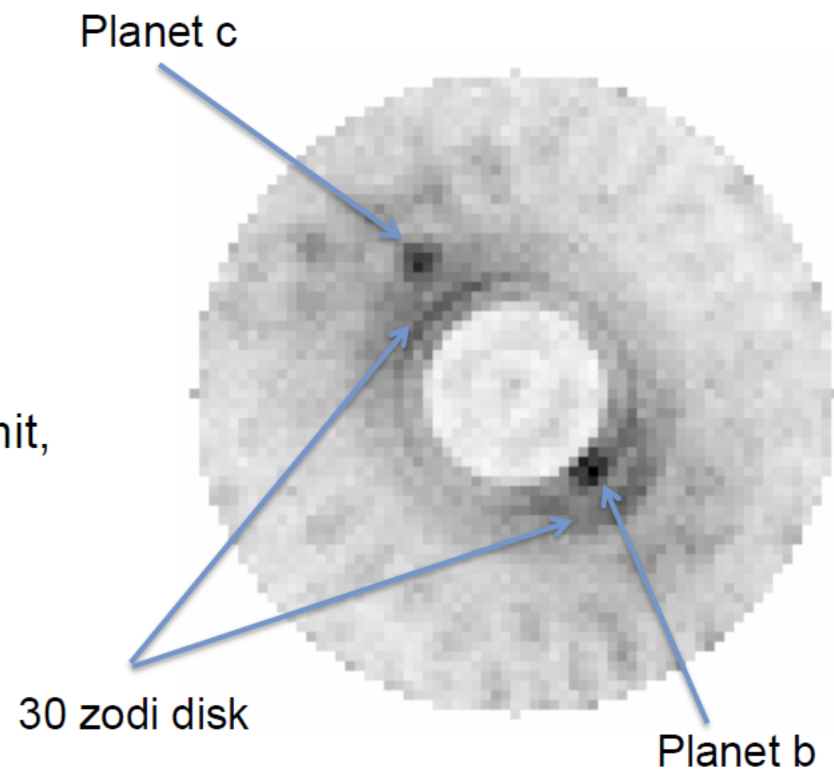
- Circumstellar disks reveal the locations of planets and trace the history of collisions
- Few disks below 100x the solar system dust level (100 zodi) have been detected, and none have resolved images
- WFIRST-AFTA will detect disks down to 10 zodi around nearby stars;
  - Important for planetary systems and for future Earth imaging missions
- WFIRST-AFTA + LBT-I are needed: LBT-I gives total dust amounts; WFIRST-AFTA then gives reflectance; both together give debris properties



Simulation of 20 zodi disk WFIRST-AFTA image (24 h at 8 pc)

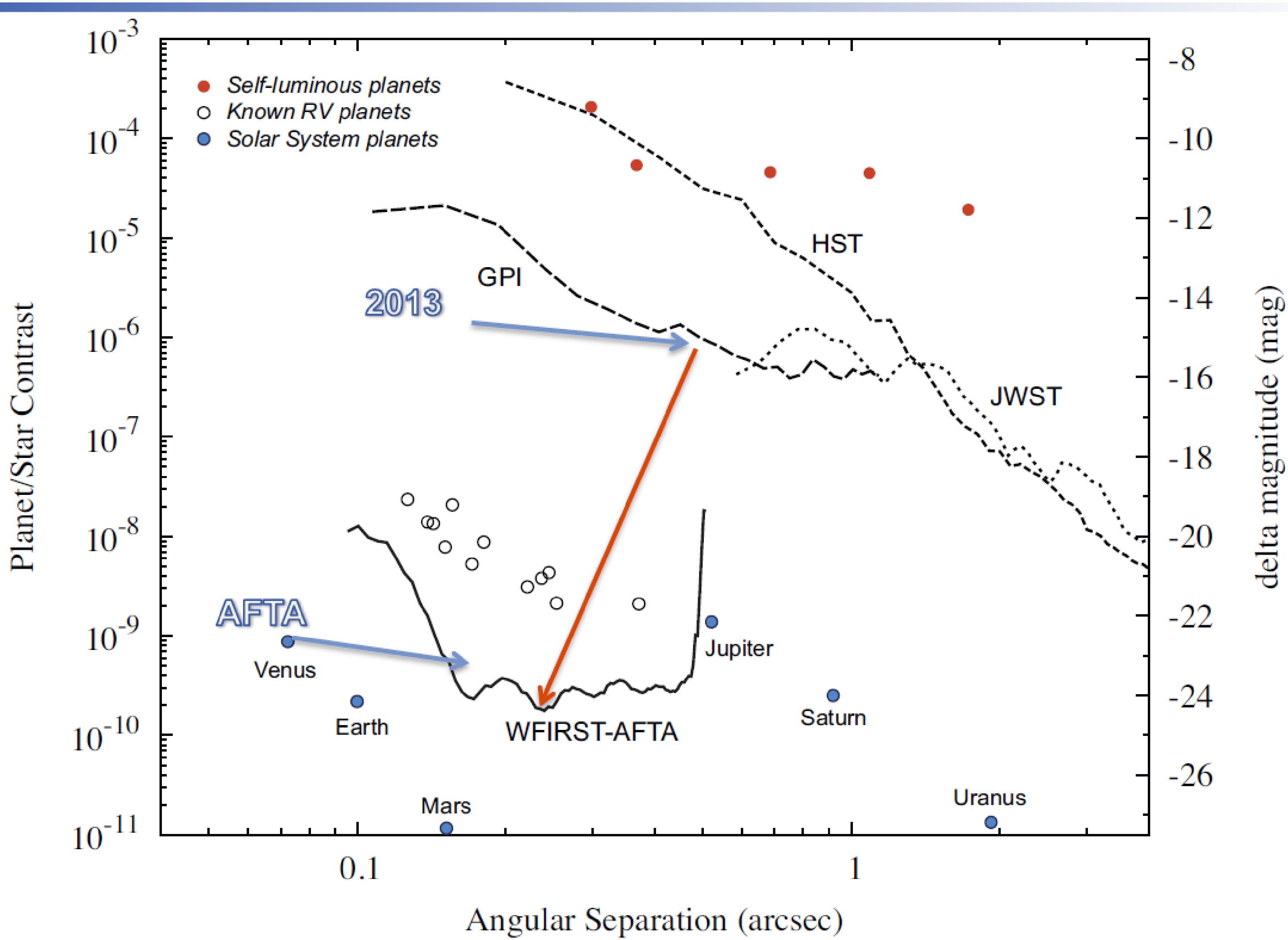
Coronagraph science: Imaging planetary systems

- The WFIRST-AFTA coronagraph will give us the first reflected light visible images of the planetary systems of nearby stars
- 47 UMa System with known RV planets (~Jupiter masses)
- G1V star at 14 pc
- Planet b has SMA = 2.1 AU, planet c has SMA = 3.6 AU
- Assume 30 zodi dust dust (628 zodi measured 3 sigma upper limit, Millan-Gabet et al. 2011)
- Assume incl 60 d, PA 45 d, pl. albedo 0.4, pl. orbit -90 d & 70 d



Simulation of a 10 hour exposure with HL coronagraph (0.4 mas jitter / 10 x speckle suppression, 550 nm 10% BW)

Coronagraph science: Jupiters to Neptunes



WFIRST-AFTA SDT Interim Report

General Observer science (25%): example of capability

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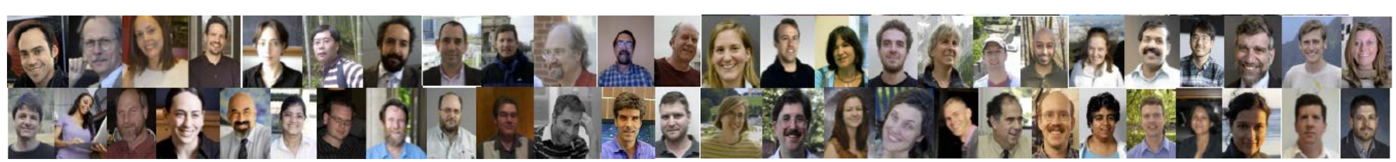
The Hubble Ultra Deep Field
seeing the Universe, 10,000 galaxies at a time

A WFIRST-AFTA Deep Field
A New Window on the Universe - **1,000,000** galaxies at a time



Science Goal 1 of "30-Year Plan": Are We Alone?

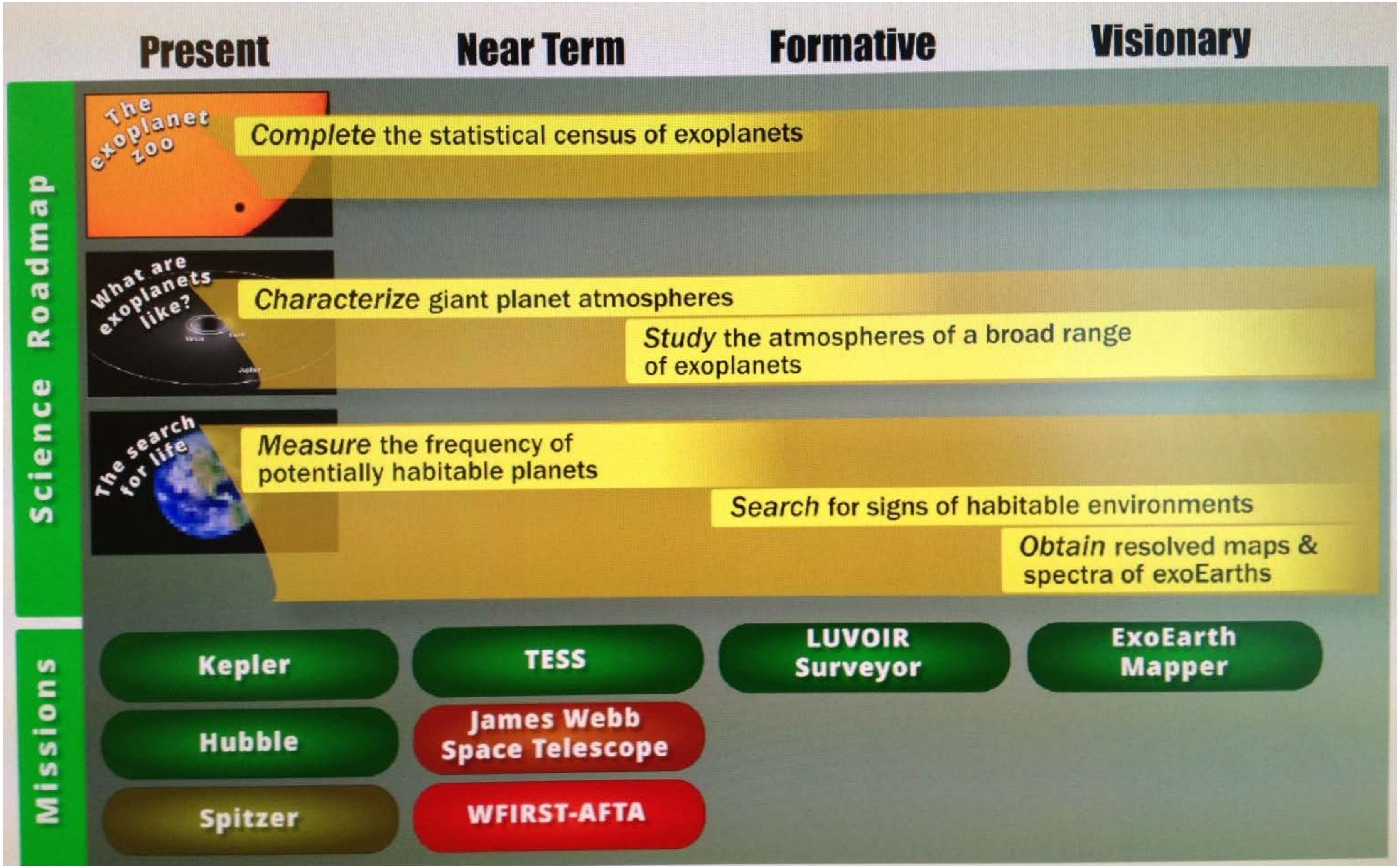
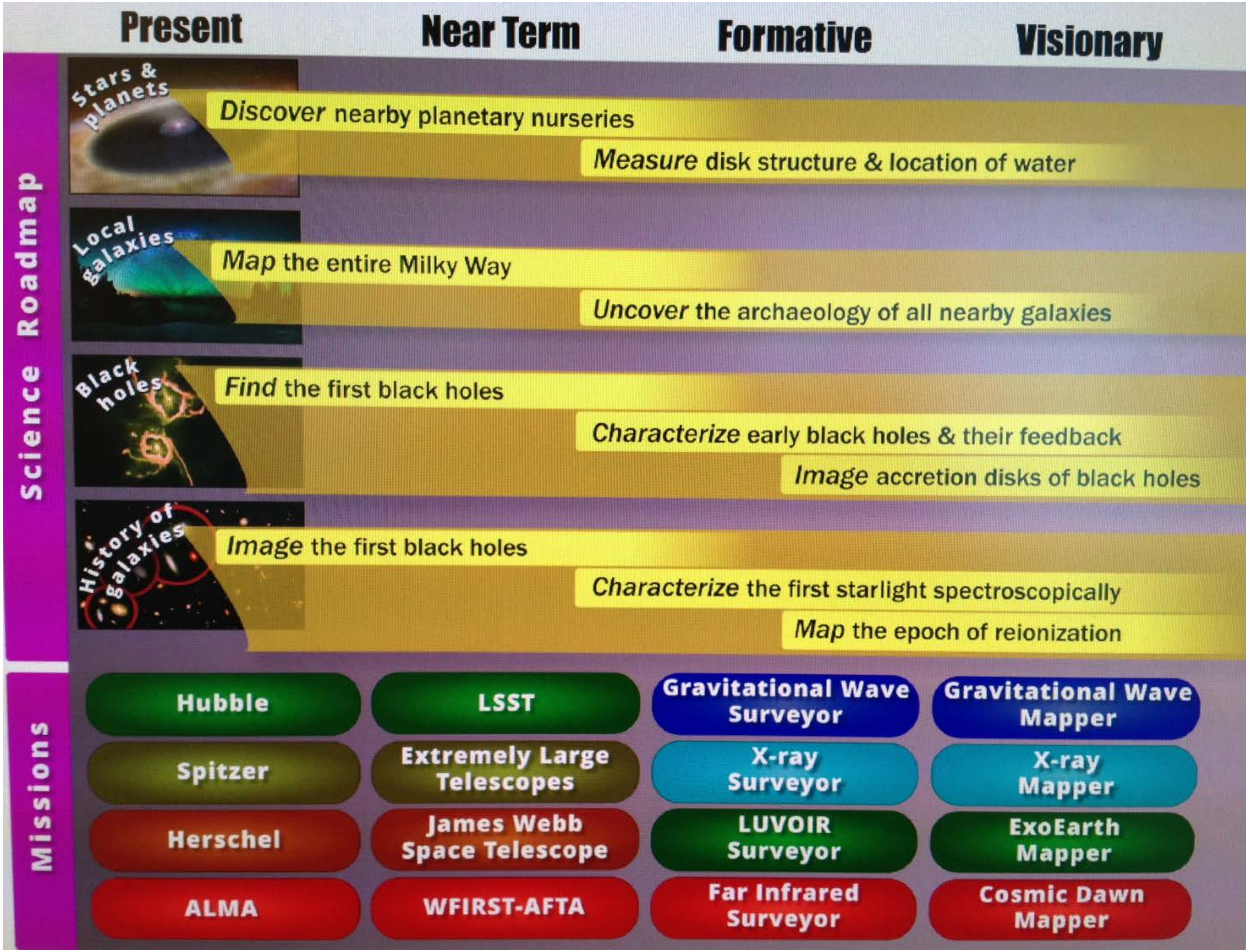


Figure 2.16 Schematic of the Exoplanets Roadmap, with science themes along the top and a possible mission sequence across the bottom. Credit: F. Reddy (NASA GSFC)

Science Goal 2 of "30-Year Plan": How did we get here?



Goal 3 of “30-Year Plan”: How does our Universe work?

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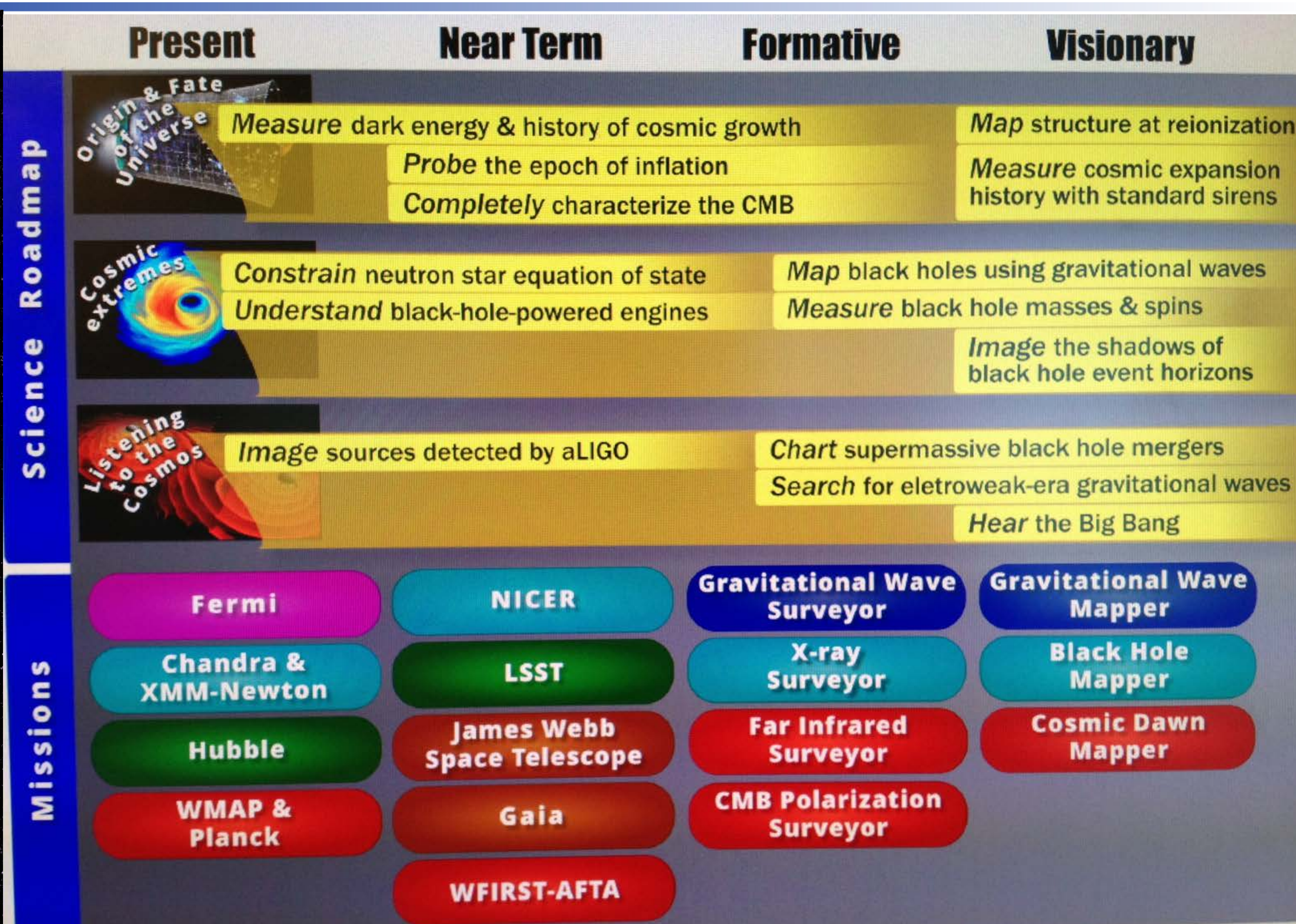

Summary

- WFIRST science in the 2020s is foundational for astrophysics science in the 2030s, in all 3 big-theme areas:

  1. exoplanet statistics, detections, and spectra lead to the search for habitable planets & maps of exoEarths
  2. maps of the Milky way lead to characterizing early black holes, the first starlight, & the epoch of reionization
  3. measuring dark energy, cosmic growth, and dark matter leads to measuring black holes with gravitational waves, black hole mergers, & echoes of the Big Bang

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Thank you!