WFIRST Update

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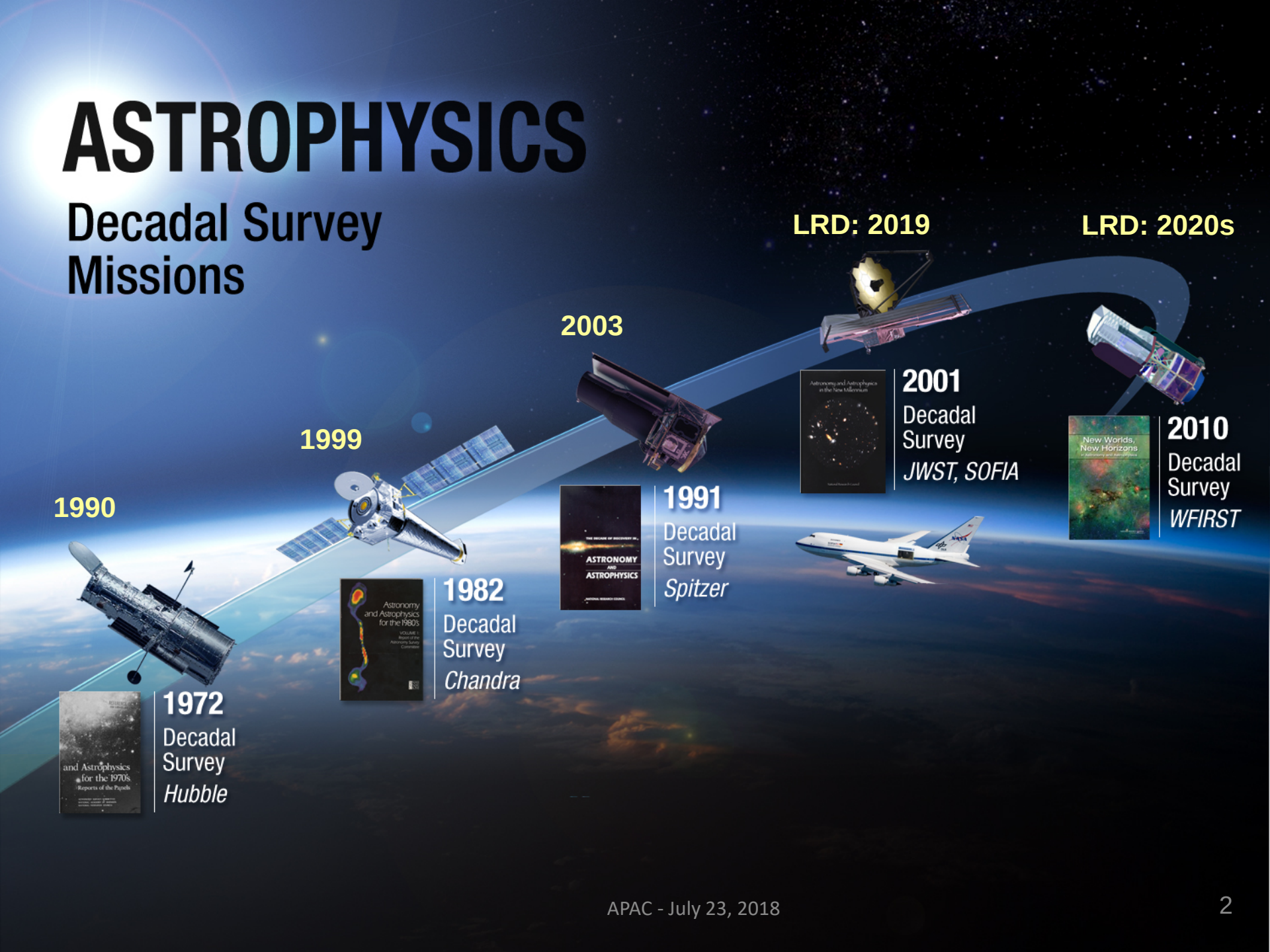
ASTROPHYSICS

Decadal Survey Missions

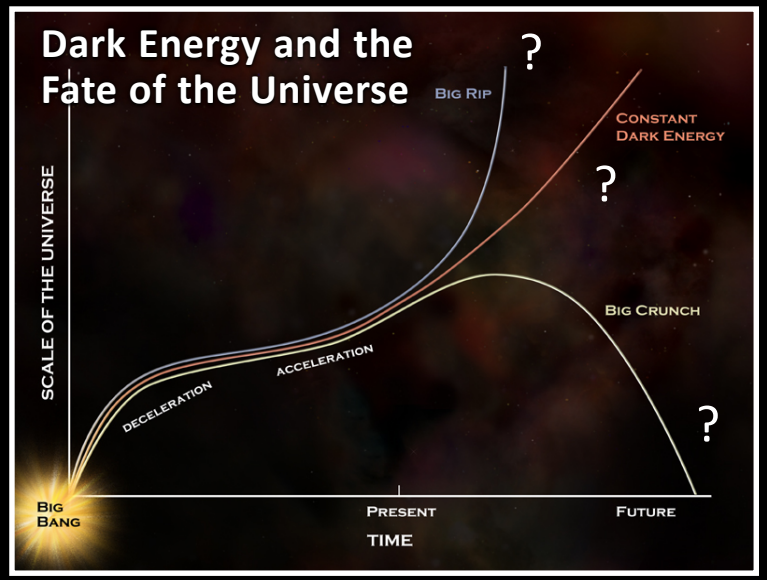


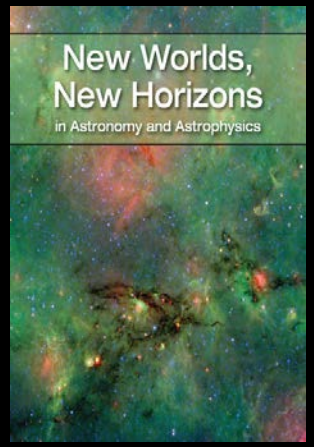
WFIRST

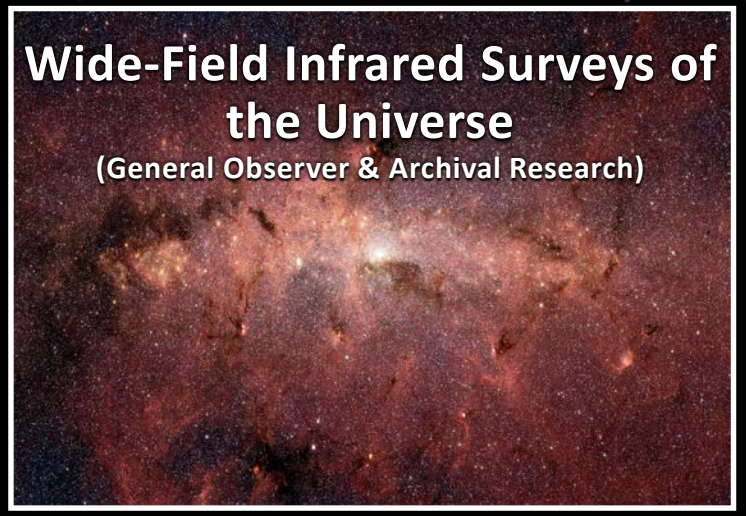
WIDE-FIELD INFRARED SURVEY TELESCOPE

DARK ENERGY • EXOPLANETS • ASTROPHYSICS

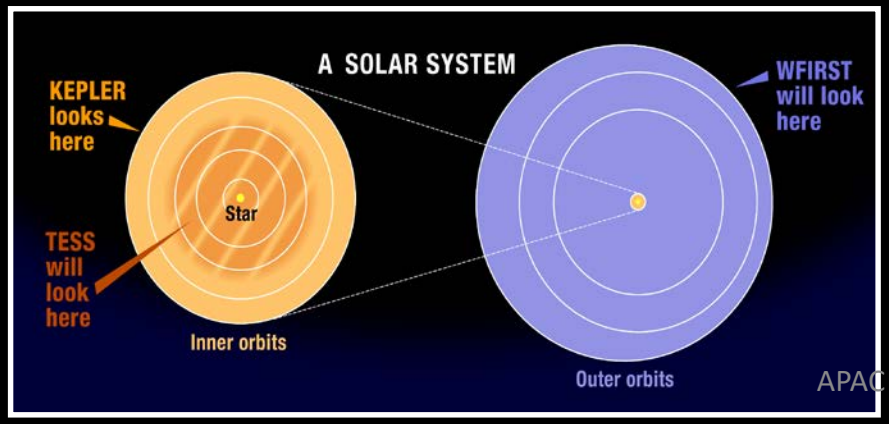
Guidance from NWNH







The full distribution of planets around stars



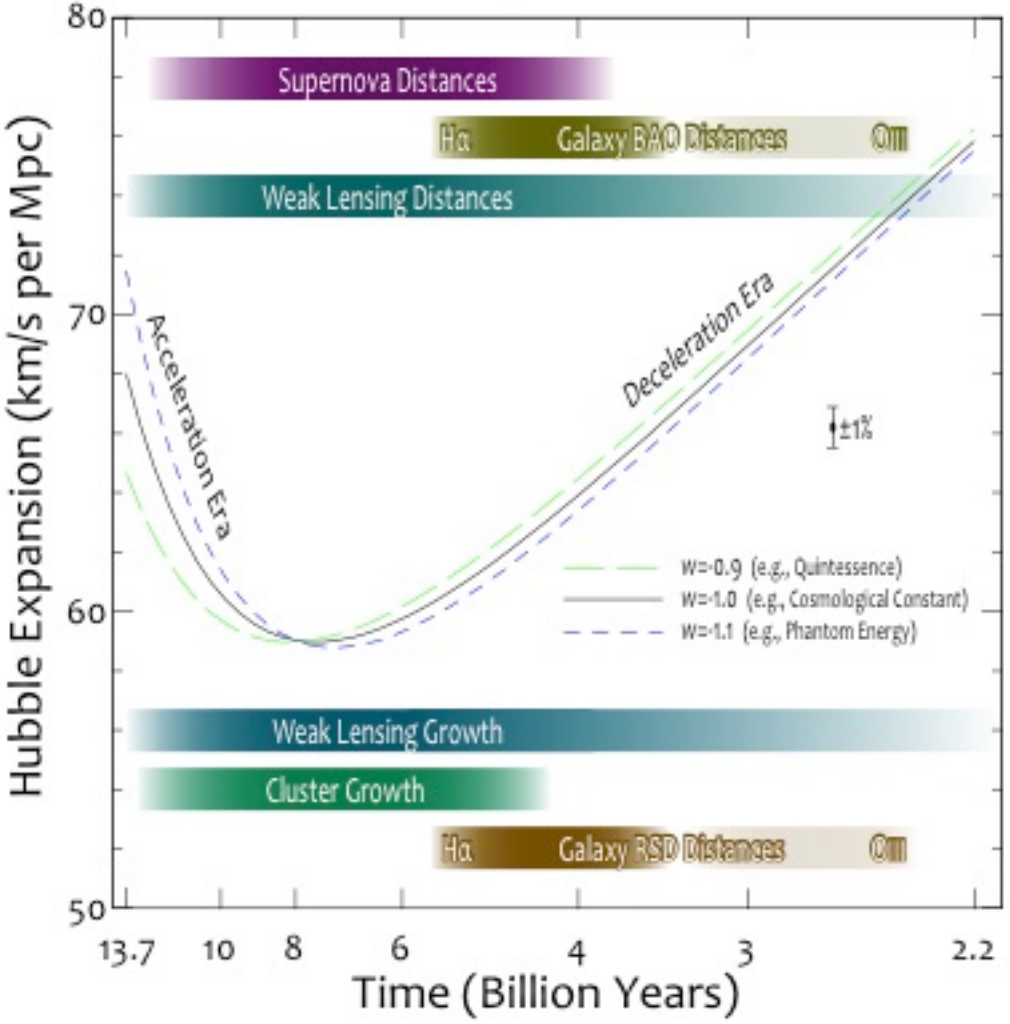
Science Goals

- **Produce Hubble quality infrared images and spectra over 1000's of square degrees of sky**
- **Determine the expansion history of the Universe and the growth history of its largest structures in order to test possible explanations of its apparent accelerating expansion including Dark Energy and modifications to Einstein's gravity.**
- **Complete the statistical census of planetary systems in the Galaxy, from the outer habitable zone to free floating planets**
- **Demonstrate new technologies enabling direct imaging & spectroscopy of giant planets and debris disks from habitable zones to beyond the ice lines and characterize their physical properties.**
- **Provide a robust guest observer program utilizing a minimum of 25% of the time over the 5 year baseline mission and 100% in following years.**
- **Provide a robust archival research program with access to all data from the mission.**

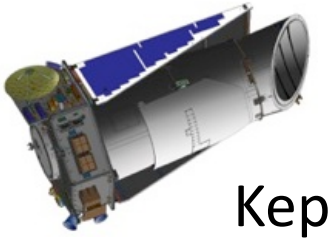
WFIRST Dark Energy Program

- WFIRST combines all techniques to determine the evolution of the universe and the Dark Energy and Dark Matter.
- WFIRST is the only observatory doing such comprehensive observations

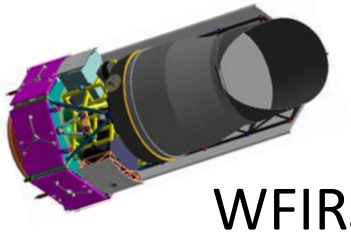
WFIRST Measures Expansion and Growth



Compete the Census of Exoplanets - Microlensing



Kepler



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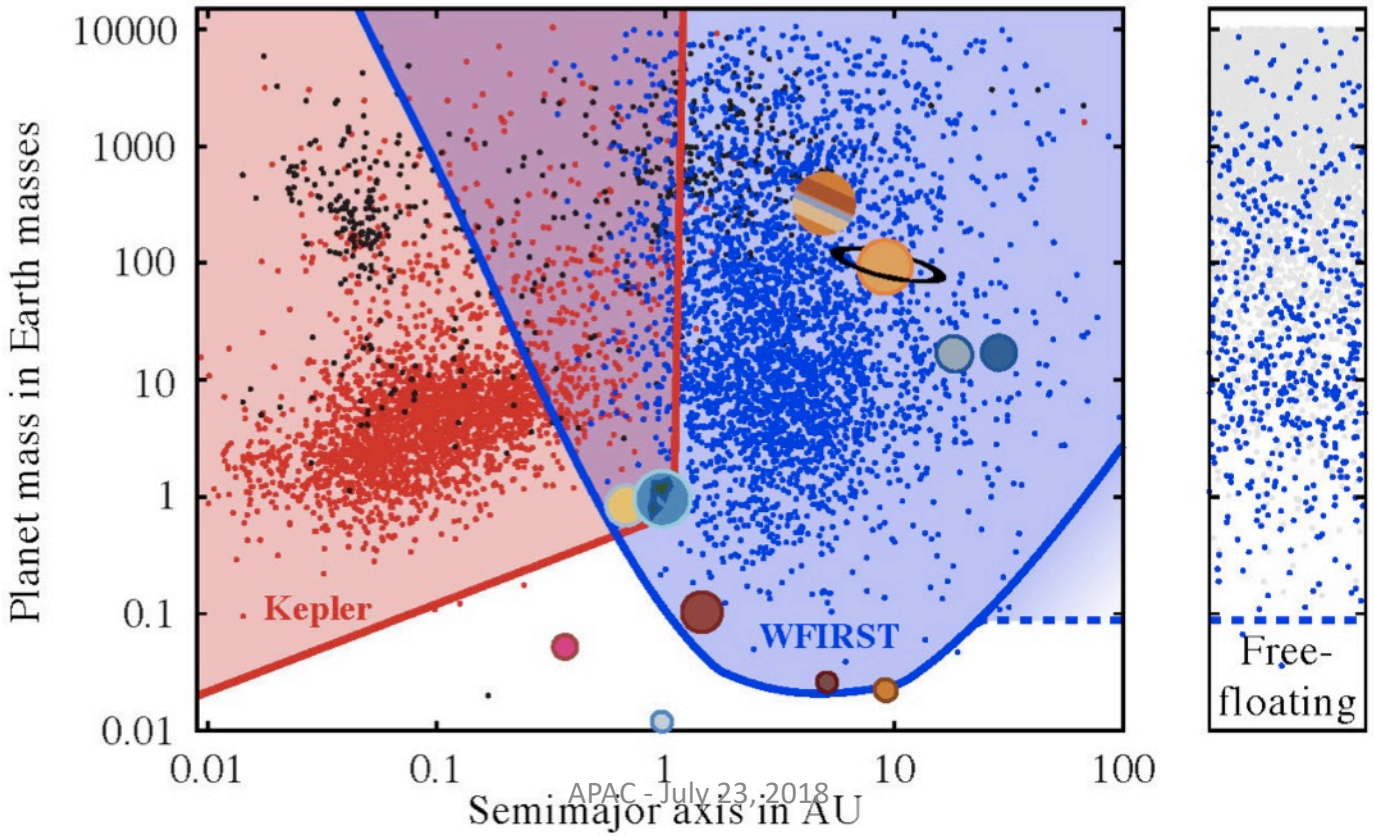
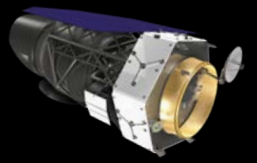


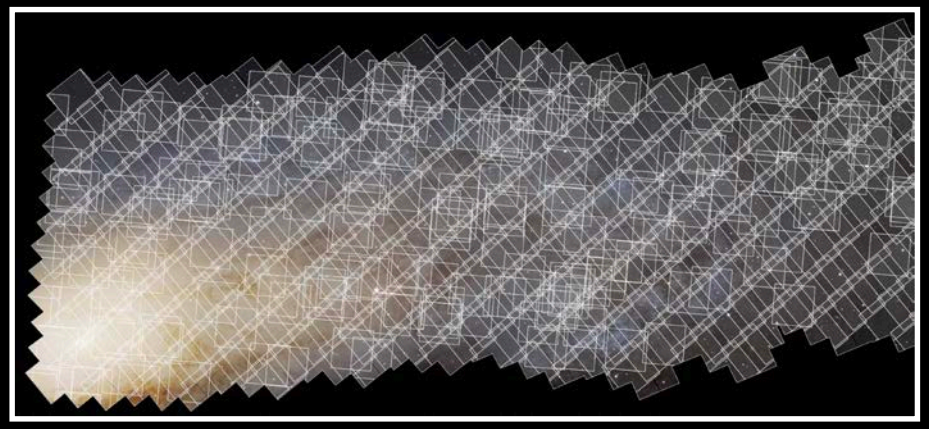
Sample GO Program
Assembly of Galaxies

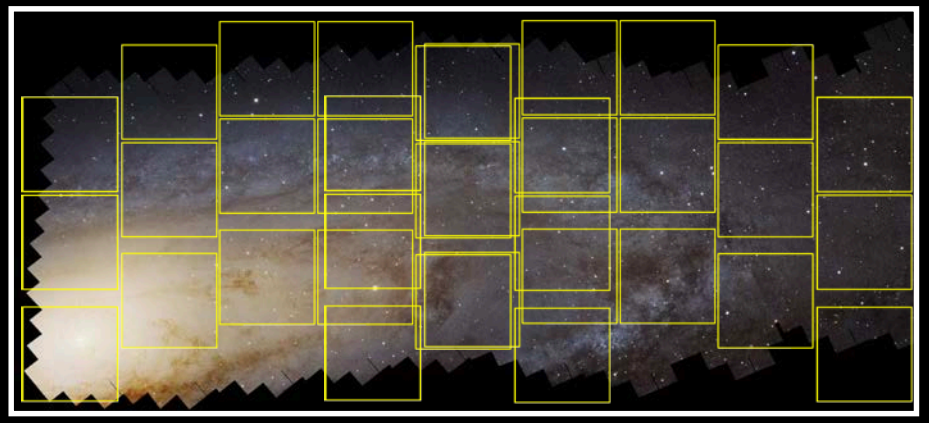
Andromeda - PHAT Survey

The Hubble Way
(400+ individual pointings)

The WFIRST Way
(2 pointings)



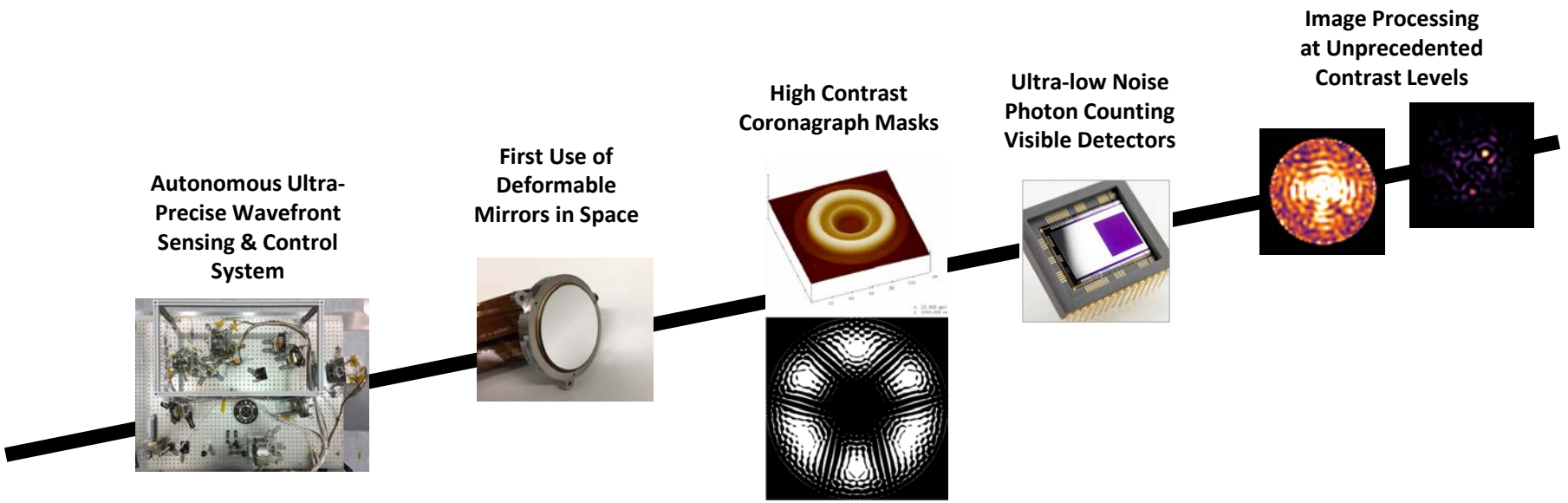




WFIRST will survey nearby galaxies 100x faster than Hubble

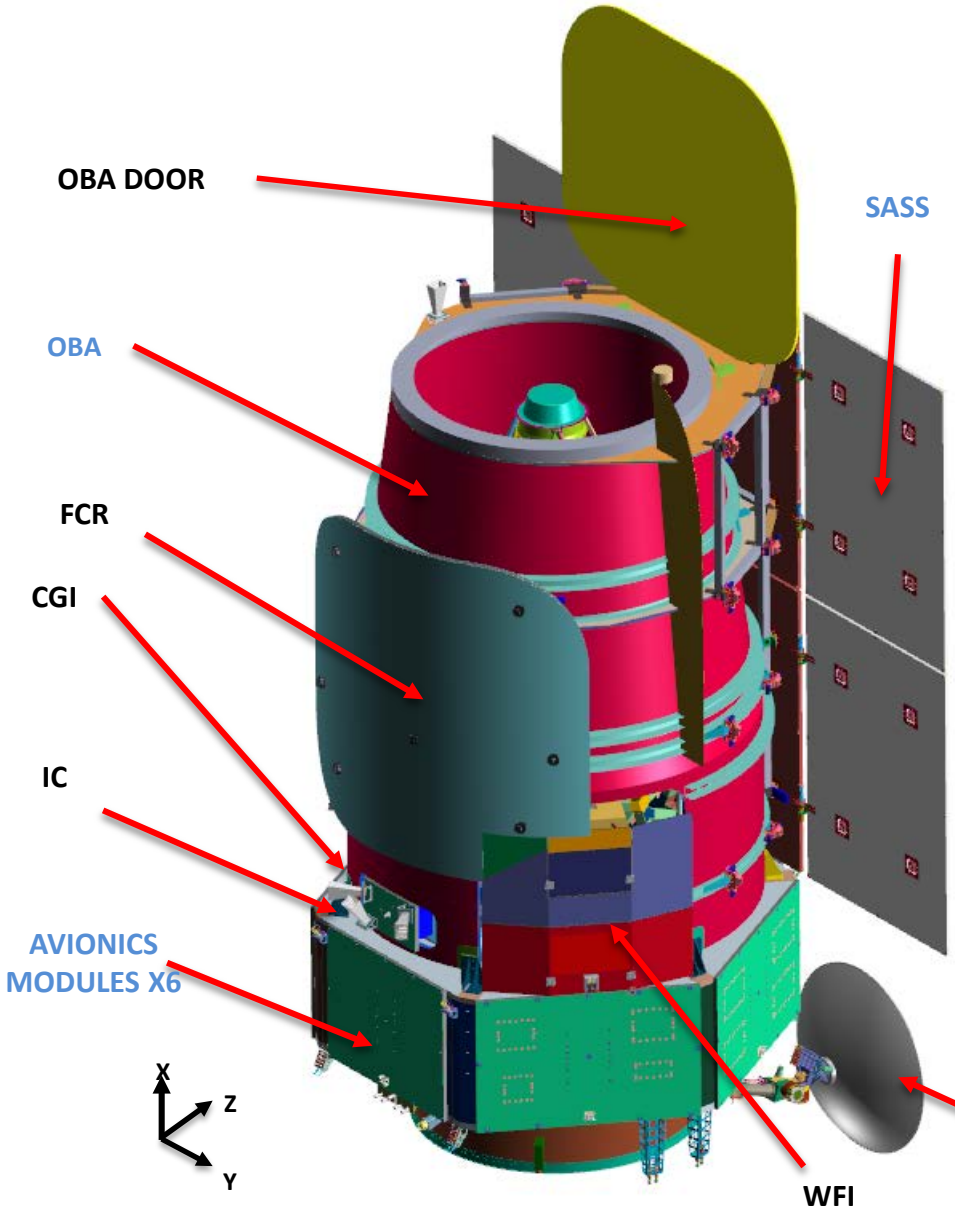
CGI Tech Demonstrations Along the Beam Path

Technology	• Low-order Wavefront Sensing and Control • Deformable Mirrors • Broad-band Coronagraphic Masks for Very High Contrast • Ultra-low Noise Photon Counting Detectors • High Contrast Imaging on Obscured / Discontinuous Aperture • Integral Field Spectrograph at Very High contrast



- CGI will premiere in space many key technologies required for the characterization of rocky planets in the Habitable Zone (HZ), significantly reducing the risk and cost of future possible mission concepts such as HabEx and LUVOIR
- CGI is a direct & necessary predecessor to these missions, and is a *crucial* step in the exploration of Sun-like planetary systems

WFIRST Observatory Concept



Key Features

Telescope: 2.4m aperture

Instruments:

- Wide Field Imager / Slitless Spectrometer
- Internal Coronagraph with Integral Field Spectrometer

Data Downlink: 275 Mbps

Data Volume: 11 Tb/day

Orbit: Sun-Earth L2

Launch Vehicle: 4 options

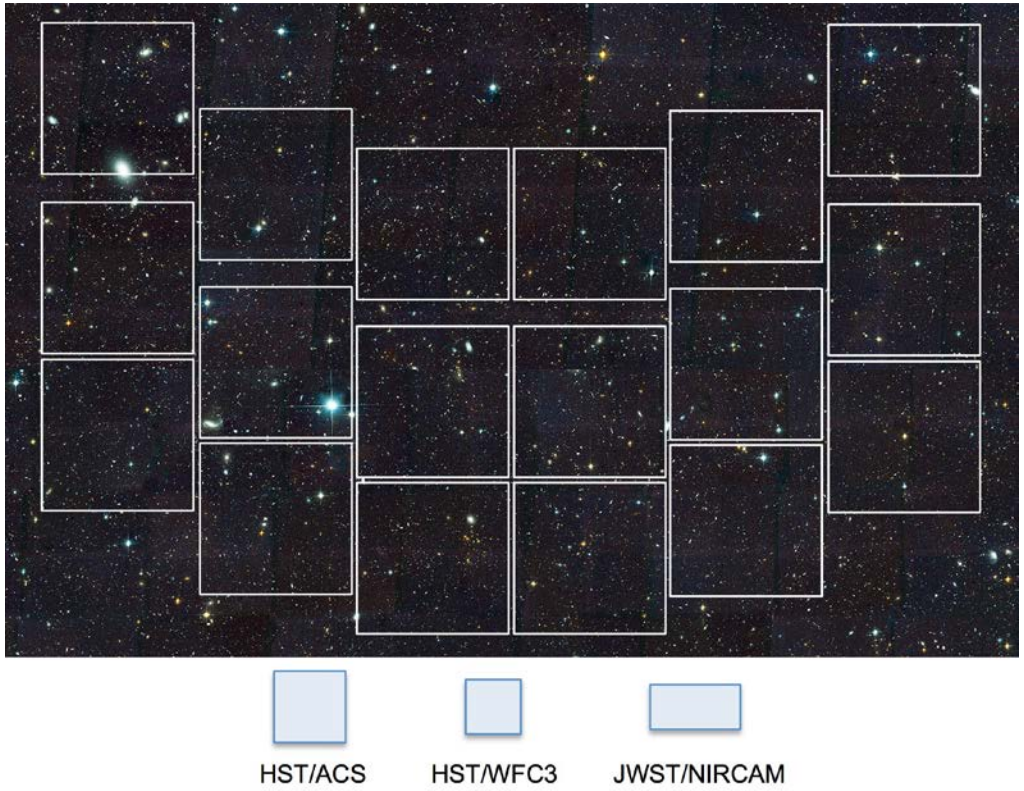
Mission Duration: 5 yr, 10yr goal

Serviceability: Observatory designed to be robotically serviceable

Starshade compatible

Wide-Field Instrument

WFIRST Field of View



Diffraction-limited imaging
0.28 square degree FoV
0.11” pixels
R~4 filters spanning 0.48-2.0 μm
Sensitivity: 27.8 H(AB) @5σ in 1hr

Slitless grism:
1.0-1.93 μm
R: 435-865

Representative Surveys

- Actual survey designs won't be chosen until close to launch, but those presently being studied can illustrate the type of data that will be available in the archive.

Representative Surveys

High Latitude Survey 5σ point-source sensitivity (AB mag), 6.5σ line flux						
	Area	Y106	J129	H158	F184	Grism
Wide	2000	26.9	26.95	26.9	26.25	1.0E-16
Deep	20	28.2	28.2	28.2	27.55	2.5E-17

Supernova Survey 5σ point-source sensitivity (AB mag) *5-day cadence*, 146 visits							
	Area	R062	Z087	Y106	J129	H158	F184
Wide	14 sq deg	28.1	27.8	27.8	28.3	28.7	---
Deep	5 sq deg	----	28.7	29.5	29.4	29.6	29.7

Representative Surveys

- Microlensing: 2 sq deg monitored at cadences:
  - 15min W149 filter, 12hr in 2 other filters (R or Z, and Y or J), all filters on occasion (weekly?)
  - 6 seasons of 60-72 days each
  - Excellent temporal sampling, astrometry
    - what do we get by stacking one season of data?

5σ point-source sensitivity (AB mag) from one season

Cadence	Visits/season	R062	Z087	Y106	J129	H158	F184	W149
15 min	6912							>30
12 hr	144	28.0	27.65	27.60	27.50			
Week(?)	10	26.55	26.2	26.1	26.0	26.0	25.55	

GO Surveys

- We don't know what they will be, but can think about possibilities.

Limiting point-source sensitivity (AB) in 1 hour 5σ imaging, 10σ grism continuum flux							
R062	Z087	Y106	J129	H158	F184	W149	Grism
28.5	28.15	28.1	28.0	28.0	27.5	28.5	20.25

Assuming twice minimum zodiacal light & conservative throughput & instrument background properties

Project Status

- White House FY2019 budget proposed termination of WFIRST to fund other priorities

- Direction from HQ is to proceed while Congress deliberates
  - *Preliminary indications are that WFIRST will be fully funded in FY2019*

Project Status

- System Requirements Review / Mission Definition Review held February 27 – March 1
  - Do we have the right requirements? / Does the mission design meet those requirements?
  - Are detailed schedules and budgets reasonable?
  - SRRs completed for Spacecraft, Coronagraph, Telescope, Ground System, & Instrument Carrier
  - Wide-Field Instrument SRR scheduled for early August
- KDP-B completed May 22, 2018
  - **WFIRST now in Phase B!**

SMD/APMC Direction

- Mission technical baseline unchanged, except:
  - Integral Field Channel descoped – 4/27/2018
    - CSA budget constraints
- Phase A-E cost remains at $3.2B (50% CL)
  - APD to provide optimal funding profile
  - Project to provide study on options for reducing CGI cost by additional $30-$50M
- Notional schedule:
  - PDR: late 2019
  - CDR: mid 2021
  - **Launch: 3rd quarter 2025**

Partnerships

JAXA	Coordinated, contemporaneous ground-based observations on Subaru Ground station for telemetry and tracking Polarization optics for the CGI Microlensing data from the MOA project
DLR	Precision mechanisms for the CGI
ESA	Star trackers, possibly other S/C components EMCCD detectors for the CGI Ground station for telemetry and tracking
CNES	Superpolished optics for the CGI Grism data processing Cosmology simulations

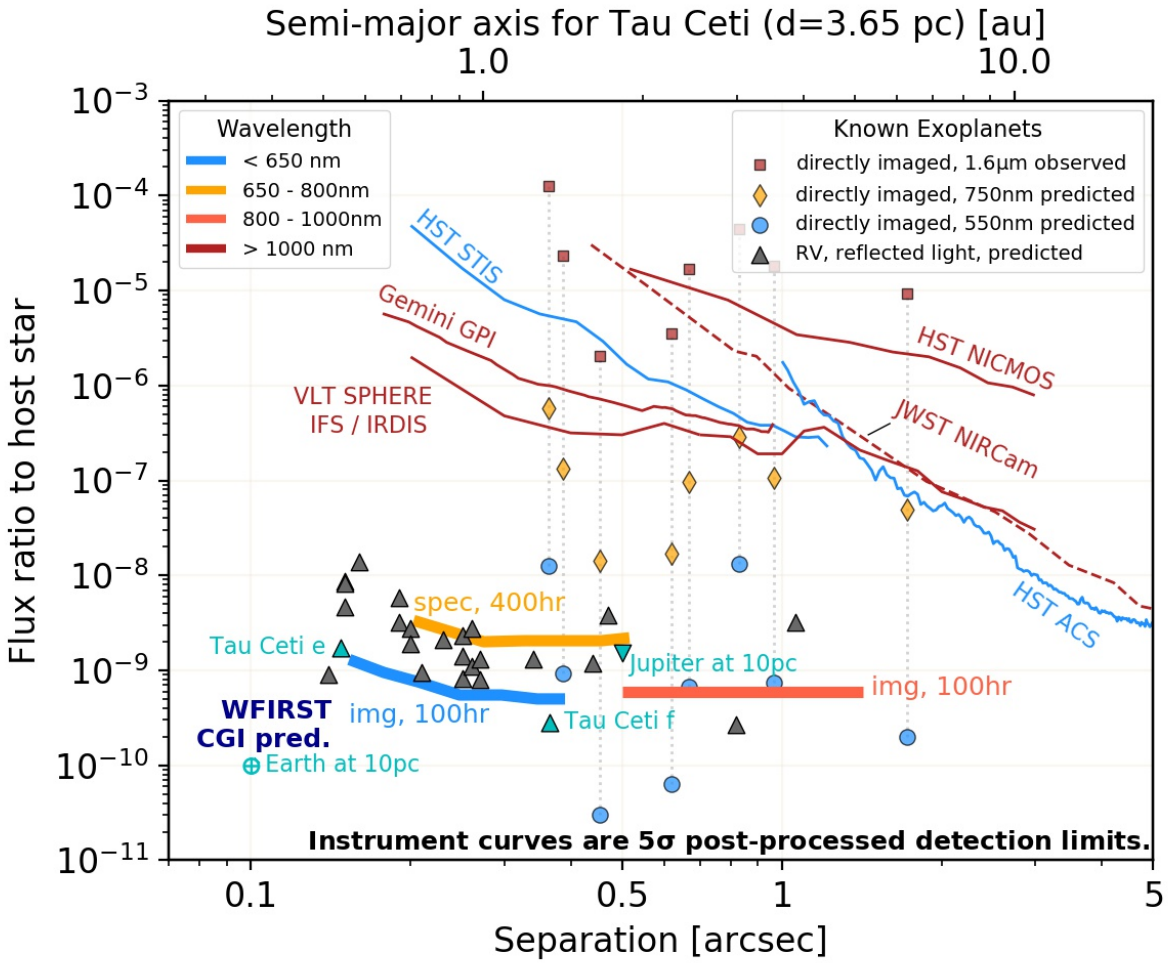
Coronagraph

- Confirmed approach to coronagraph as a technology demonstration instrument.
  - Masks & filters limited to what is required to demonstrate all modes – science program will guide choices w/in that constraint
  - Change to participating scientist program eliminates most associated science operation center costs
    - Model similar to PI-class instrument
  - Retained Class C designation with potential change to Class D investigated during Phase B
  - *No further changes to CGI architecture & functions in KDP-B process*

WFIRST Brings Humanity Closer to Characterizing exo-Earths

If present performance predictions are realized, there is potential for:

- 1000-fold improvement over present capabilities.
- Dozens of planets within reach of characterization
- Detection limit can reach super-Earths



Science Investigations

- All observing time to be selected competitively
  - Some close to launch, the rest periodically thereafter
- All data will be public immediately
  - Archival research will be funded on a par with GO programs
- Scientific priorities to be updated throughout mission, based on landscape at the time
- Coronagraph available through a Participating Scientist Program

Science Investigations: Open Questions

- How best to allocate time & organize teams for large programs?
  - WFIRST differs from prior NASA missions
    - Our “key projects” require a significant fraction of the total mission time, unlike HST or JWST
    - We’re not a pure survey mission either
  - Many of us have tended to think of defining teams in a manner similar to the HST Multi-Cycle Treasury programs – but is that the best model?

Science Investigations: Open Questions

- Start with a blank slate:
  - What does NASA *need* to fund, and when?
- We have Level-1 requirements to execute certain science investigations
  - Need to ensure that adequate datasets are taken
  - Need to ensure that S/W tools exist to perform the proper analyses
    - may include simulation tools
- Thus need teams/working groups that have authority to define the key surveys, and teams funded to develop the necessary software
- Do not necessarily have to follow prior types of team structures or proposal calls

Science Investigations: Open Questions

- Some examples for large programs:
  - Could have call for key project teams that would define the observing plans
    - Augmentation for other science (other filters, additional observations for better time domain astronomy cadence, etc) via GO program
  - Solicit community working groups to define the large surveys
    - All analysis of large surveys done through archival research proposals

Science Investigations: Open Questions

- Separate proposals for analysis S/W from proposals for observing time
  - Allows funding of analysis S/W to begin long before observing program selection – allows latter to occur close to launch
  - All S/W to be delivered for community use
  - S/W might be general purpose, or might be specific to a particular science program
  - Analysis S/W development will have to continue throughout, but effort has to begin long before one wants to define the observing plan.

Science Investigations: Open Questions

- Beginning to plan for community-based working groups
  - First one is for planning deep fields
    - In part for preparation of white paper for joint deep field with LSST, in part for more long-term planning
    - Workshop to be held August 30-31
      - First announcement just sent out
      - http://www.astro.princeton.edu/~dns/deep.html


WIDE-FIELD
INFRARED
SURVEY
TELESCOPE
WFIRST
DARK ENERGY • EXOPLANETS • ASTROPHYSICS

QUESTIONS?

WIDE-FIELD INFRARED SURVEY TELESCOPE

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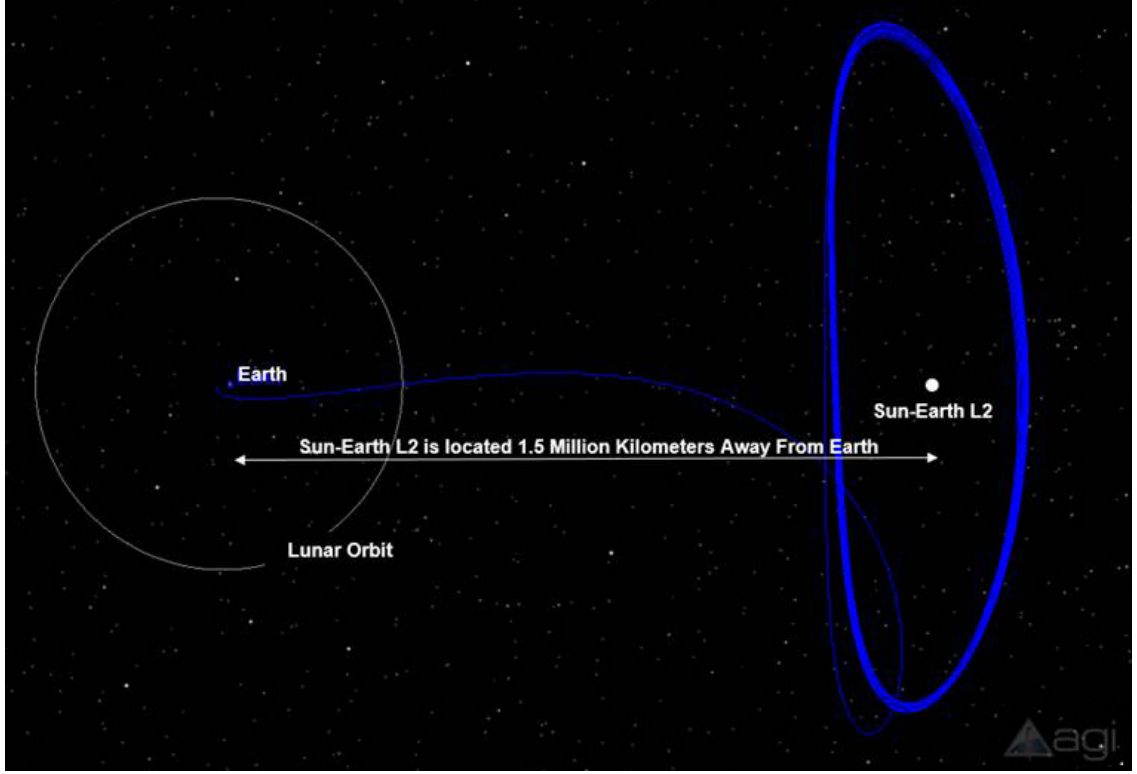
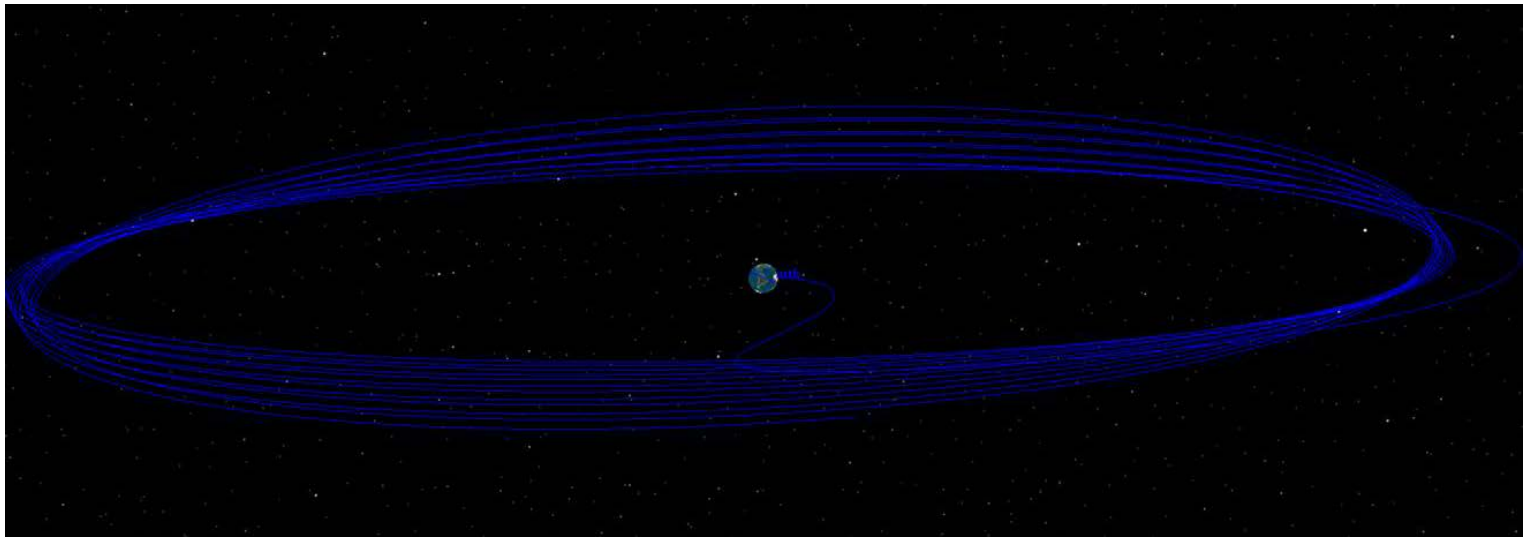
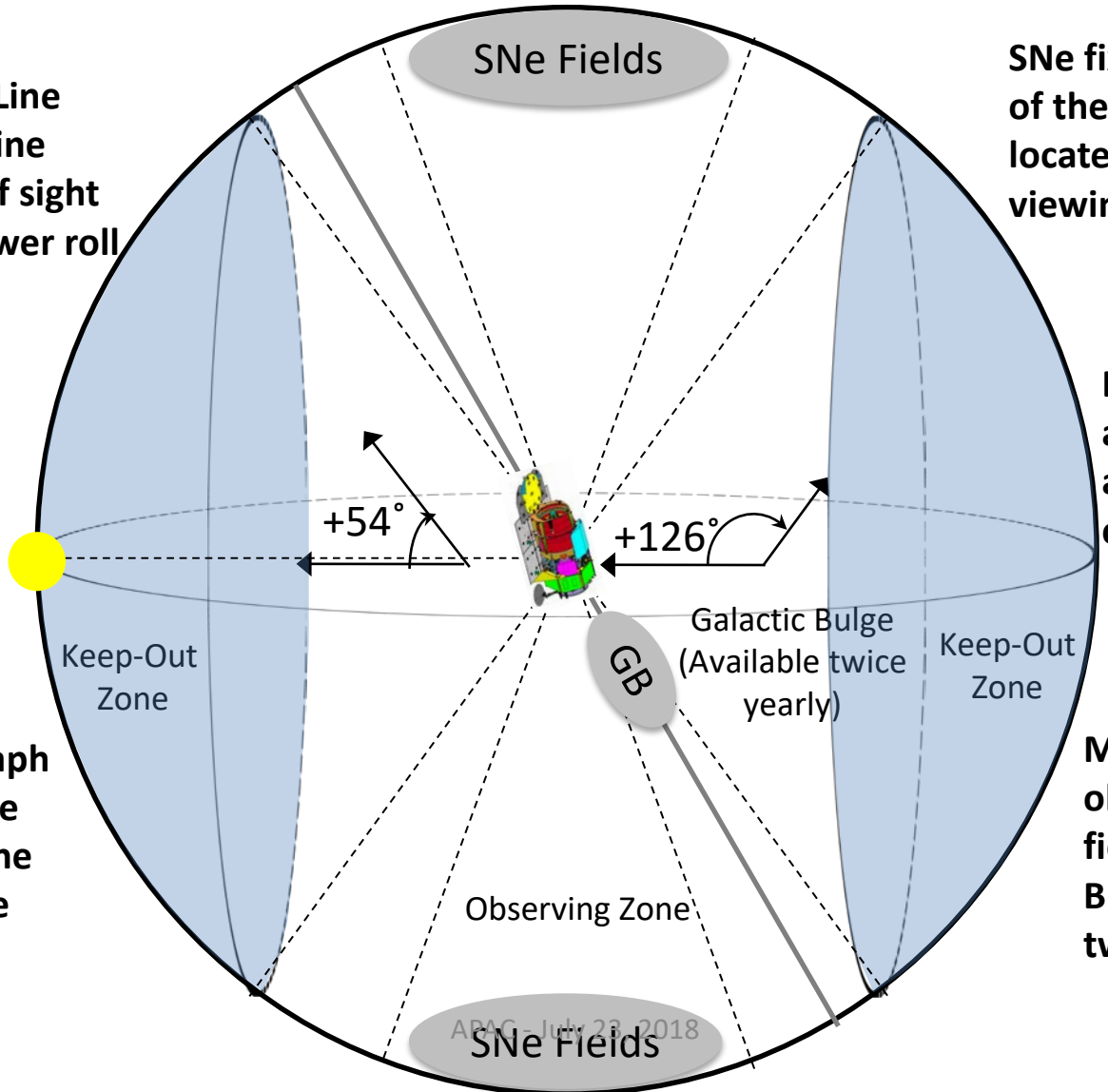




Field of Regard (FOR)

Observing Zone:
- **54˚-126˚ off Sun Line**
- **360˚ about Sun Line**
- **±15˚ about line of sight (LOS) off max power roll angle**



SNe fixed fields ±20˚ off of the ecliptic poles, located in continuous viewing zone

Earth/Moon LOS avoidance angles are a minor sporadic constraint

HLS/GO/Coronagraph observations can be optimized within the full Observing Zone

Microlensing can observe inertially fixed fields in the Galactic Bulge (GB) for 72 days twice a year

Wide-field Instrument Filters

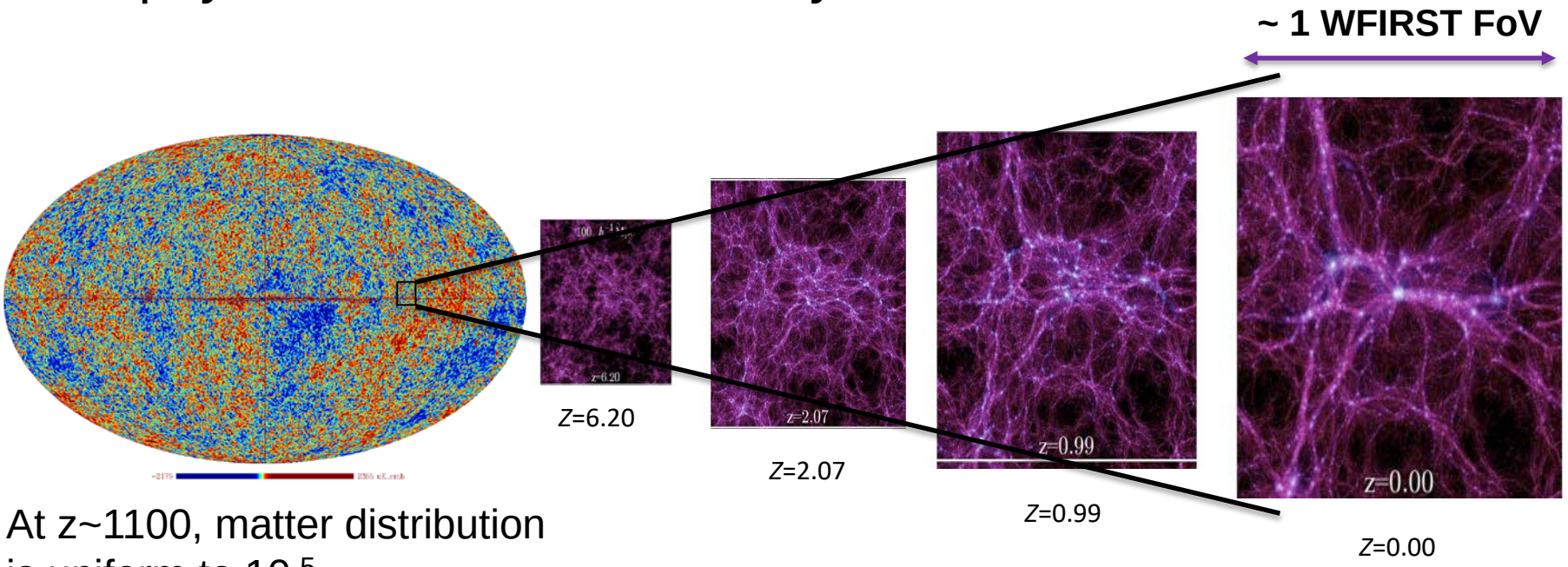
Band	Element name	Min (μm)	Max (μm)	Center (μm)	Width (μm)	R
R	R062	0.48	0.76	0.620	0.280	2.2
Z	Z087	0.76	0.977	0.869	0.217	4
Y	Y106	0.927	1.192	1.060	0.265	4
J	J129	1.131	1.454	1.293	0.323	4
H	H158	1.380	1.774	1.577	0.394	4
	F184	1.683	2.000	1.842	0.317	5.81
Wide	W146	0.927	2.000	1.464	1.030	1.42
GRS	G150	1.00	1.93	1.465	0.930	461λ(2px)

Wide FoV enables study of evolution of the Universe

WFIRST will measure expansion history *and* growth of structure

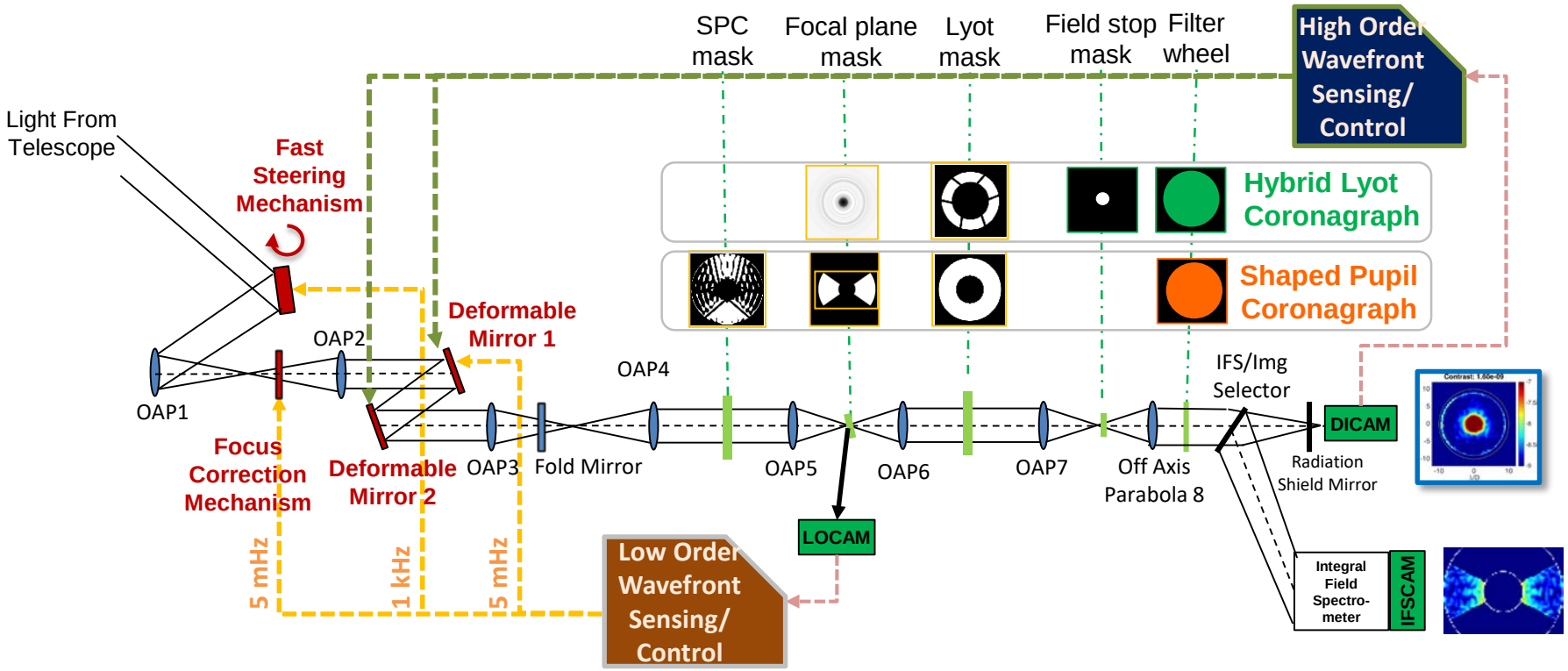
- If results discrepant -> breakdown of general relativity
- If results agree -> learn about nature of dark energy

WFIRST provides multiple probes, enabling cross-checks for astrophysical and instrumental systematics



At z~1100, matter distribution is uniform to 10^{-5}

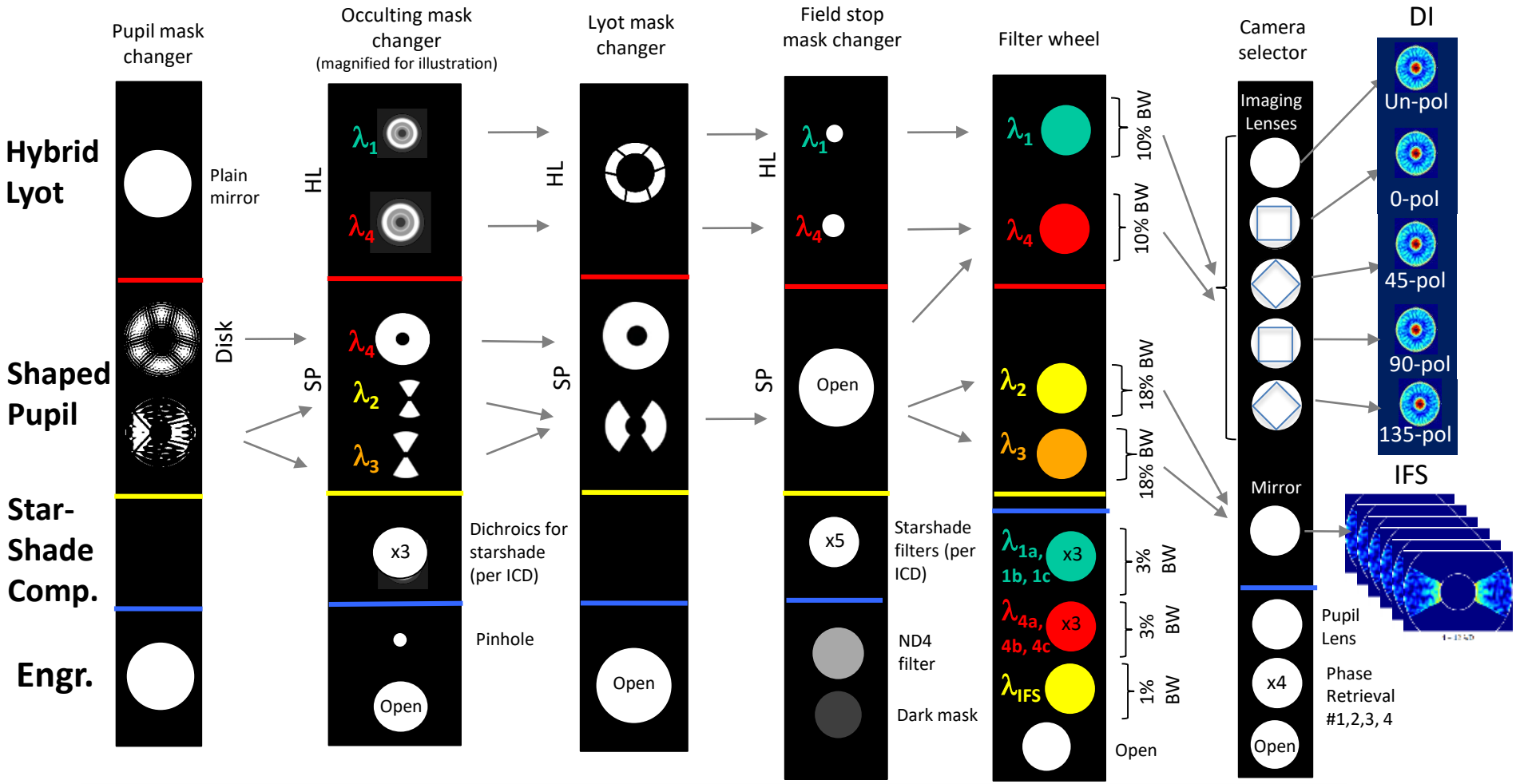
Coronagraph architecture



Basic architecture unchanged.

Some modes removed and some not tested to reduce cost.

CGI Configuration



λ_1=575 nm, 10% (annular, 3-9 λ/D)
λ_2=660 nm, 18% (bow-tie / IFS, 3-9 λ/D)
λ_3=760 nm, 18% (bow-tie / IFS, 3-9 λ/D)
λ_4=825 nm, 10% (annular, 3-19 λ/D)