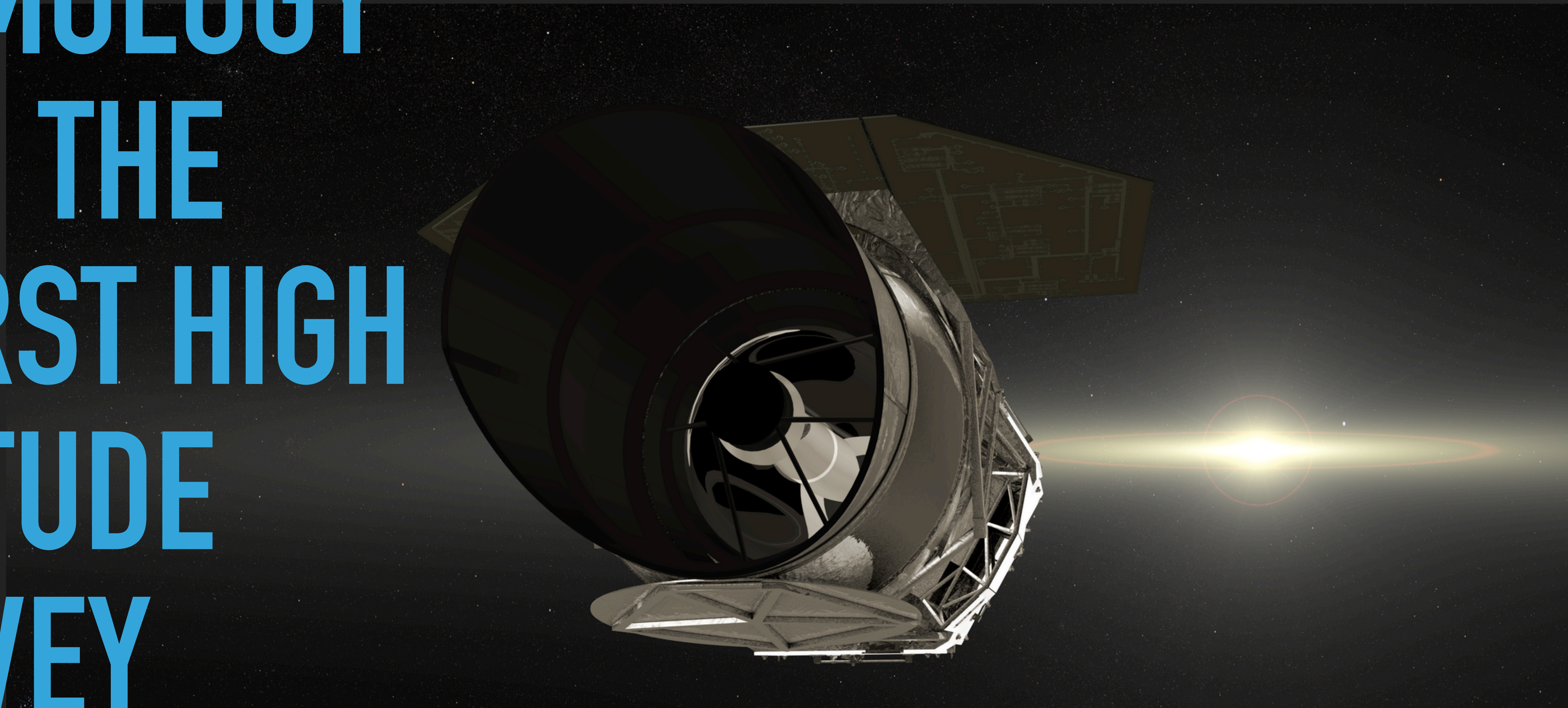
COSMOLOGY WITH THE WFIRST HIGH LATITUDE SURVEY



Ami Choi

Chris Hirata, Michael Troxel

CCAPP

The Ohio State University

on behalf of the Science Investigation Team (PI: Olivier Doré)

http://www.wfirst-hls-cosmology.org

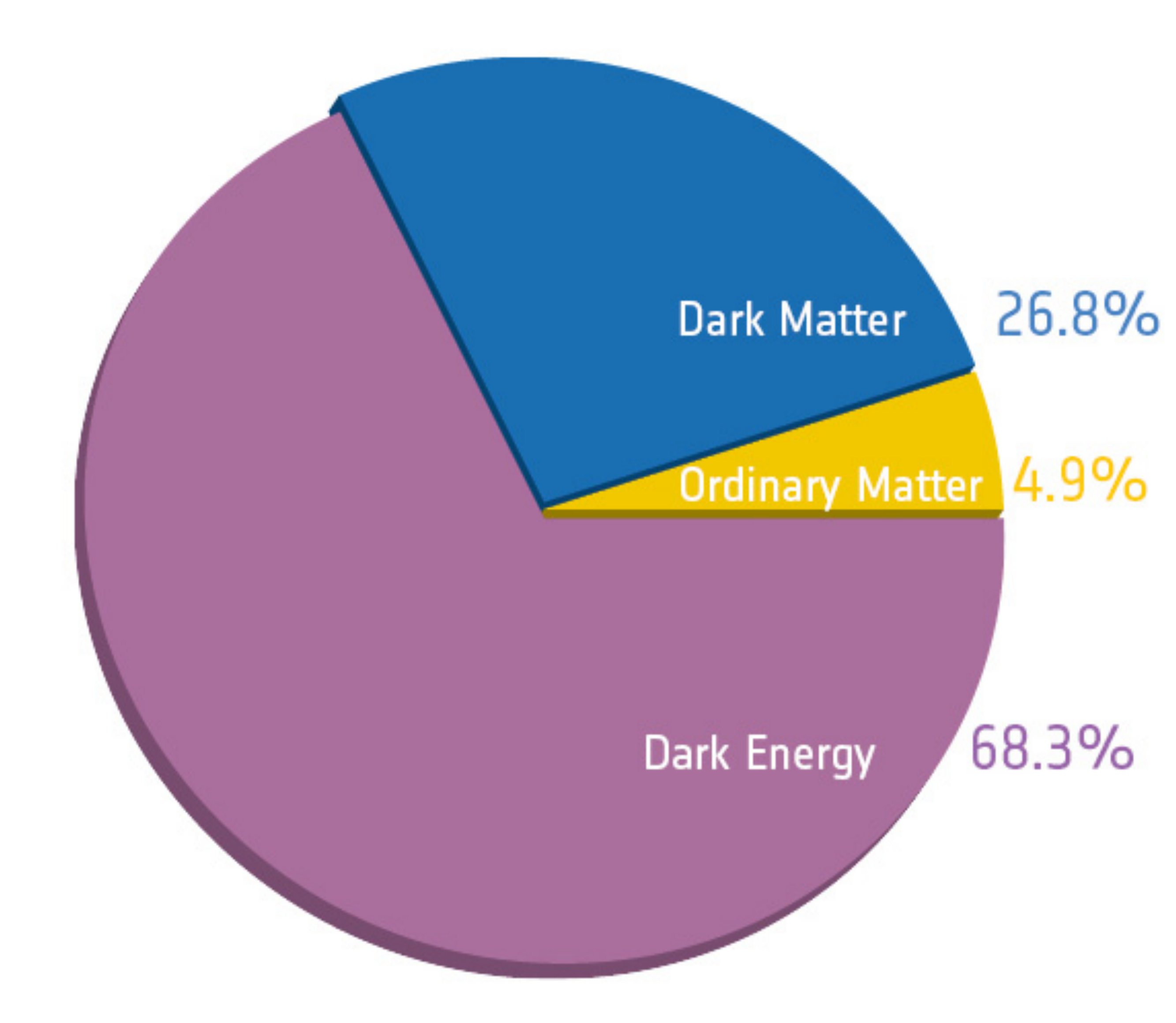
https://wfirst.gsfc.nasa.gov/

Wide-Field Infrared Survey Telescope

WFIRST

Astrophysics • Dark Energy • Exoplanets

WHAT IS THE ORIGIN OF COSMIC ACCELERATION?

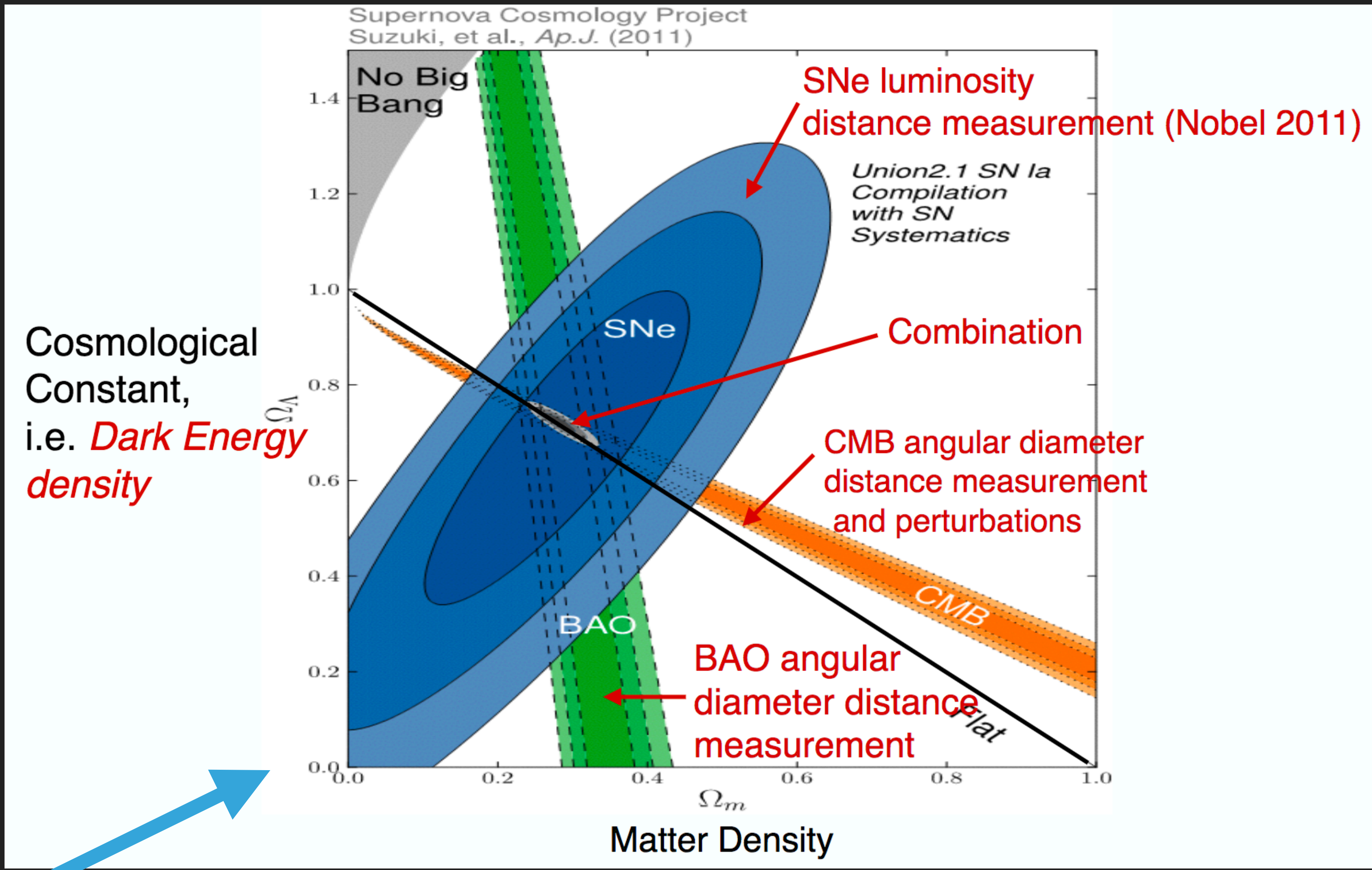


Credit: Planck/ESA

95% of the Universe is unknown!

WHAT IS THE ORIGIN OF COSMIC ACCELERATION?

- Measure both growth of structure and geometry
  - gravitational lensing
  - baryon acoustic oscillations (BAO)
  - redshift space distortions
  - supernovae

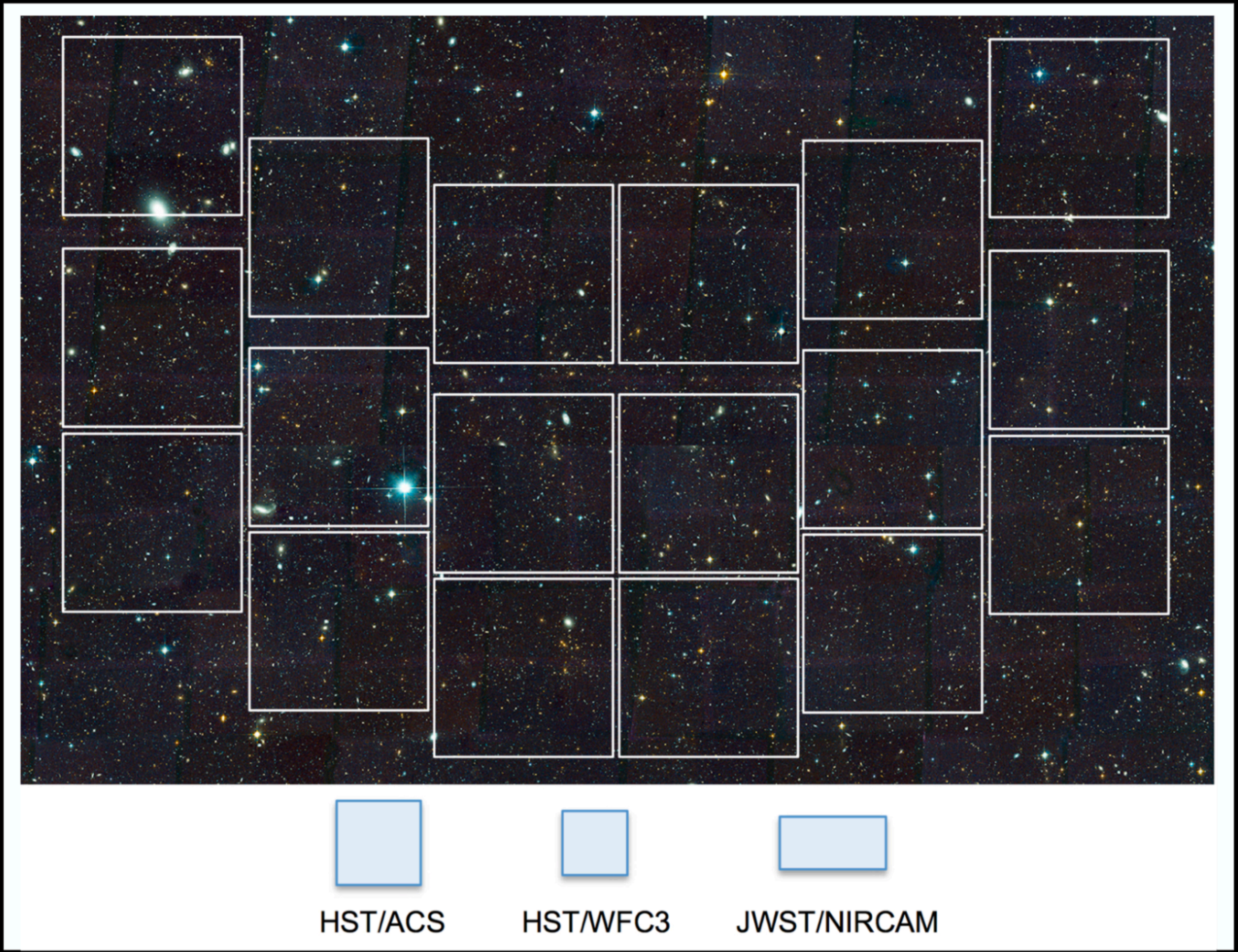


Lensing not pictured, but is complementary

THE WIDE FIELD INFRARED SURVEY TELESCOPE (WFIRST)

- Top priority from the 2010 Astrophysics Decadal Survey
- Hubble-sized telescope, power, and resolution, 100x field of view (0.28 sq. deg.)
- Dark energy, exoplanet, and wide-field survey capabilities
  - Wide-field instrument will get imaging (0.7-2µm) & spectroscopy (~1-2µm) over 1000s of sq. deg.
  - 18 H4RG detectors (288 Mpixels)
  - 6 filter imaging, grism + IFC spectroscopy
- Coronograph technology to build the ‘Search for Life’ foundation
- Guest Observer Program (>=25% time)
- All data public a few days after they are taken

0.28 SQ. DEG. FIELD OF VIEW

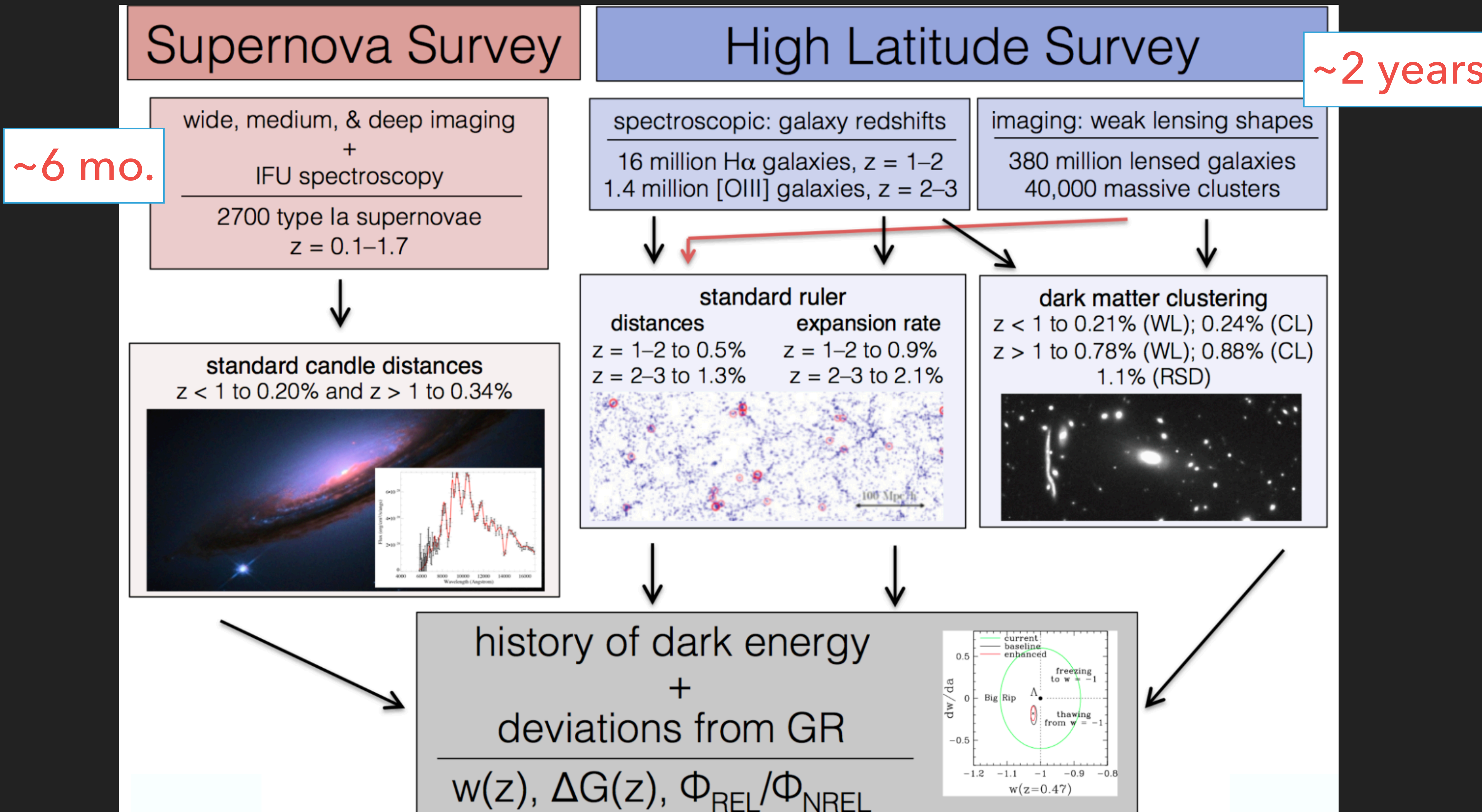


WFIRST STATUS AND RECENT TIMELINE

- WFIRST moves forward – 'Phase A' entered in 2016
  - NASA commits to the mission
- Detector, coronograph development
  - Reached TRL-6 in 2017 (NASA technology requirement)
  - First payload procurements should happen soon
- Project answers to WFIRST Independent External/Technical/Management/Cost Review (WIETR) accepted by NASA Science Mission Directorate (SMD) (Fall 2017)
- System Requirements Review/Mission Design Review (SRR/MDR) successfully completed March 2018
- Upcoming decision to pass into Phase B scheduled for May 2018
- Plan for 2025 launch with a 5 year nominal mission (designed for 10 years)
- President's *proposed* budget for FY19 released in February 2018
  - WFIRST is not cancelled!
  - First stage of negotiations between the two houses of Congress and the President's administration over FY19 budget
  - Negotiations will proceed over the next months
  - No change to project office plan for WFIRST, and recently passed FY18 budget is a very good sign (fiscal support of WFIRST remains as requested)

WFIRST DARK ENERGY PROGRAM

Slide adapted from Olivier Doré

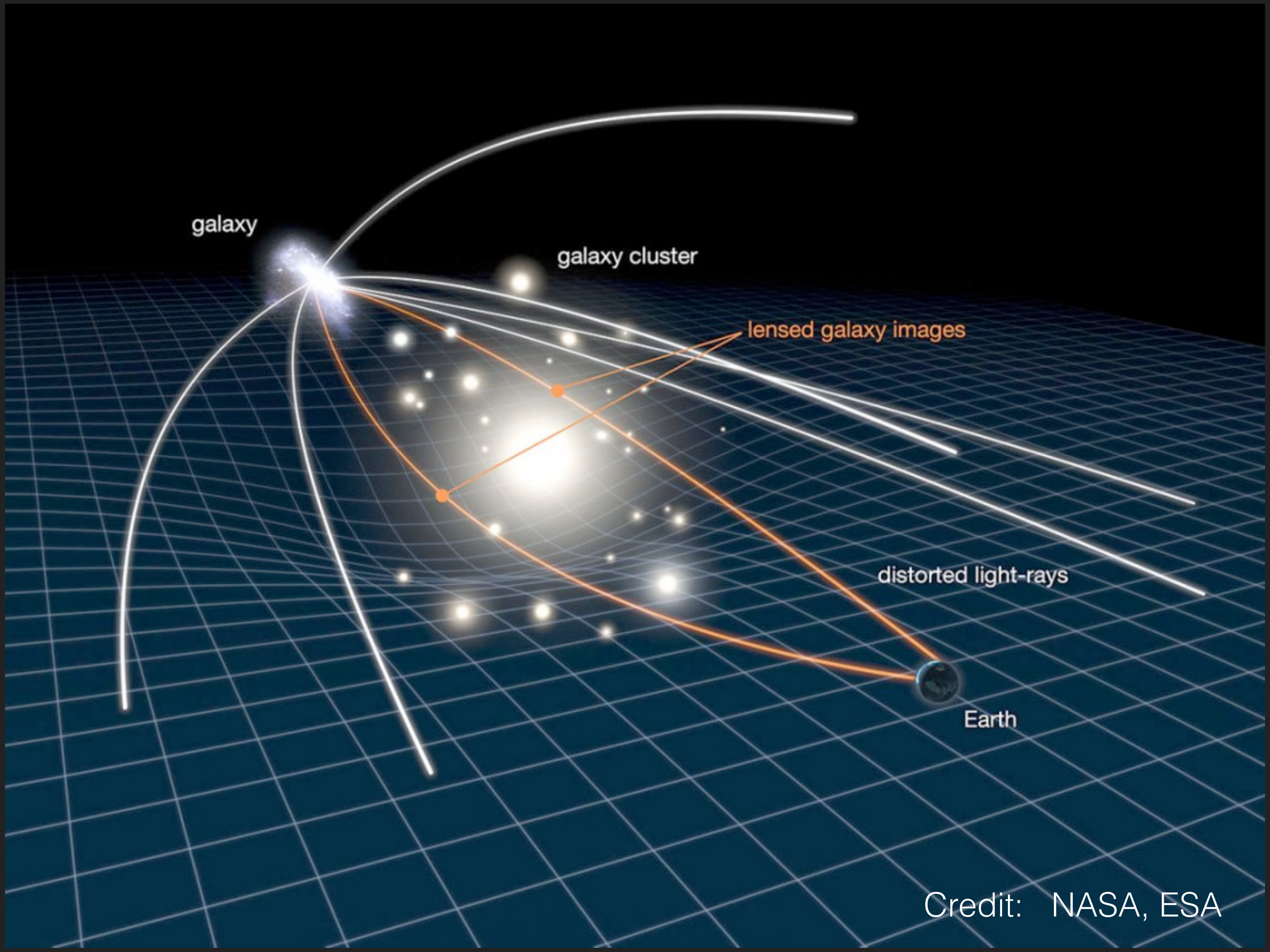


WFIRST SCIENCE INVESTIGATION TEAM

- Olivier Doré (JPL/Caltech, PI)
- **Chris Hirata (OSU, Weak lensing lead)**
- Yun Wang (Caltech/IPAC, Galaxy redshift survey lead)
- **David Weinberg (OSU, Galaxy clusters lead)**
- Anahita Alavi (Caltech/IPAC)
- Ivano Baronchelli (Caltech/IPAC)
- Rachel Bean (Cornell)
- Andrew Benson (Carnegie)
- Peter Capak (Caltech/IPAC)
- **Ami Choi (OSU)**
- James Colbert (Caltech/IPAC)
- Tim Eifler (JPL/Caltech)
- Chen He Heinrich (JPL/Caltech)
- Katrin Heitmann (ANL)
- George Helou (Caltech/IPAC)
- Shoubaneh Hemmati (IPAC/Caltech)
- Eric Huff (JPL)
- Shirley Ho (LBL)
- Albert Izard (JPL)
- Bhuvnesh Jain (Penn)
- Mike Jarvis (Penn)
- Alina Kiessling (JPL/Caltech)
- Elisabeth Krause (Stanford)
- Alexie Leauthaud (UCSC)
- Robert Lupton (Princeton)
- **Niall MacCrann (OSU)**
- Rachel Mandelbaum (CMU)
- Elena Massara (LBL)
- Dan Masters (JPL)
- Alex Merson (Caltech/IPAC)
- Hironao Miyatake (JPL/Caltech)
- Nikhil Padmanabhan (Yale)
- Alice Pisani (Princeton)
- Eduardo Rozo (U. Arizona)
- Lado Samushia (U. Kansas)
- Mike Seiffert (JPL/Caltech)
- Charles Shapiro (JPL/Caltech)
- Melanie Simet (UCR/JPL)
- David Spergel (Princeton, CCA)
- Harry Teplitz (Caltech/IPAC)
- **Michael Troxel (OSU)**
- Anja von der Linden (Stony Brook University)
- **Hao-Yi Wu (OSU)**
- **Ying Zu (OSU)**

WFIRST SIT ANNUAL REPORT 2017

https://arxiv.org/abs/1804.03628



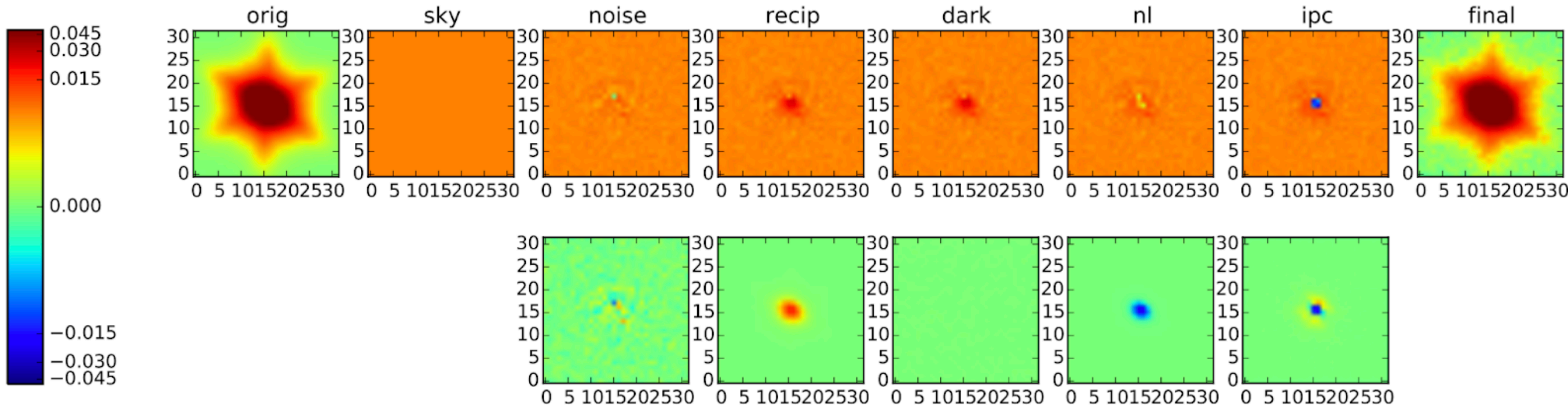
We need to measure shapes of galaxies to high precision for lensing!

- Key deliverable of our team is characterization and calibration of sources of systematic error
- OSU's contributions:
  - image simulations for weak lensing calibration
  - IR detector characterization
  - sky tiling simulations
  - line blending effects
  - cluster modelling/forecasts

Choi, Hirata, MacCrann, Troxel, Weinberg, Wu, Zu

SIMULATING OBSERVATIONS OF GALAXIES

Choi, Hirata, Jarvis, Mandelbaum, Troxel, Wu

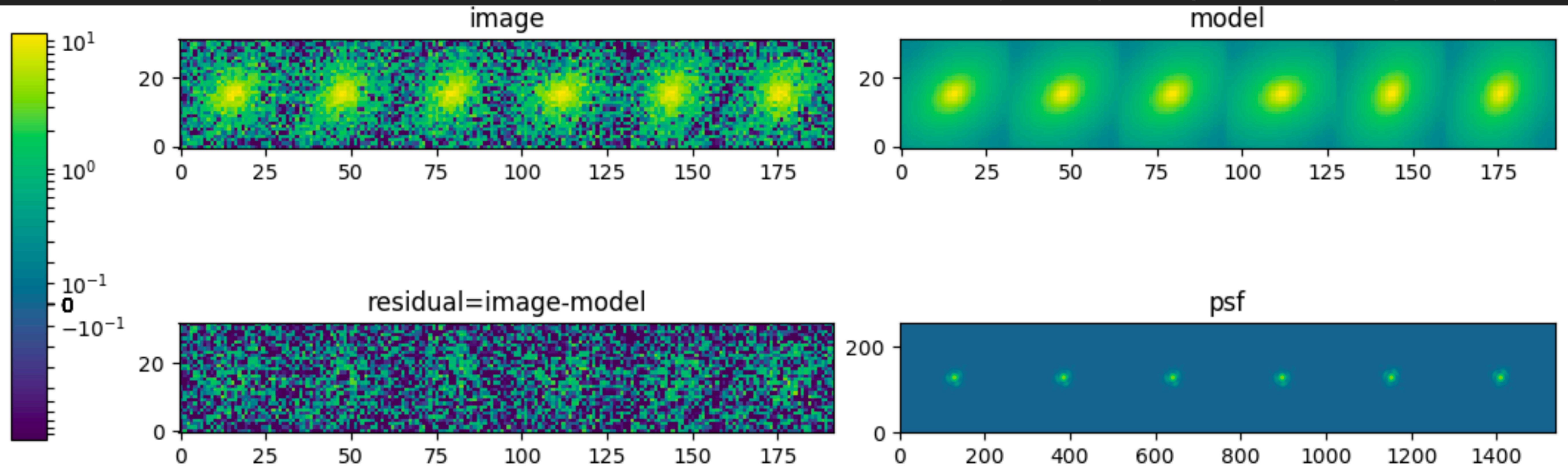


Example simulated bright elliptical (GalSim WFIRST module):

- Top row: original galaxy model (far left), “difference” images with original galaxy subtracted, final galaxy with all effects (far right)
- Bottom row: individual, isolated effects

SIMULATING OBSERVATIONS OF GALAXIES

Choi, Hirata, Jarvis, Mandelbaum, Troxel, Wu



1. Turn on different instrumental effects (e.g. shaking of the telescope along the line of sight)
2. Produce many simulated realistic galaxies – see multiple exposures of a single simulated galaxy (top left)
3. Measure the shapes of those galaxies in the way we would for the real data – see model fits (top right)
4. Compare the measured shapes to the true shapes to find out how much the effect biases our measurement

SUMMARY AND OUTLOOK

- WFIRST is an exciting instrument to investigate the origin of cosmic acceleration, via measurements of SNe, geometry, growth of structure, especially in context of complementary surveys (LSST, Euclid, DESI, PFS, etc.)
- ‘Cosmology with the WFIRST HLS’ Science Investigation Team working hard on deliverables (particularly to mitigate sources of systematic error), as evidenced in the 2017 Annual Report
    - Products publicly available: http://www.wfirst-hls-cosmology.org
    - Annual SIT report 2017: https://arxiv.org/abs/1804.03628
    - Local work focuses on shape measurement through sophisticated image simulations, characterization of the IR detectors, and forecasts of cosmology constraints using galaxy clusters
- Successful recent reviews (both internal and independent/external), nearly ready for ‘Phase B’
- Recent risk from the President’s FY19 budget request but recent FY18 funding level is positive sign, and many are rallying to show support for WFIRST

Extra Slides

WFIRST

A SURVEY, AN EXPERIMENT, AN OBSERVATORY

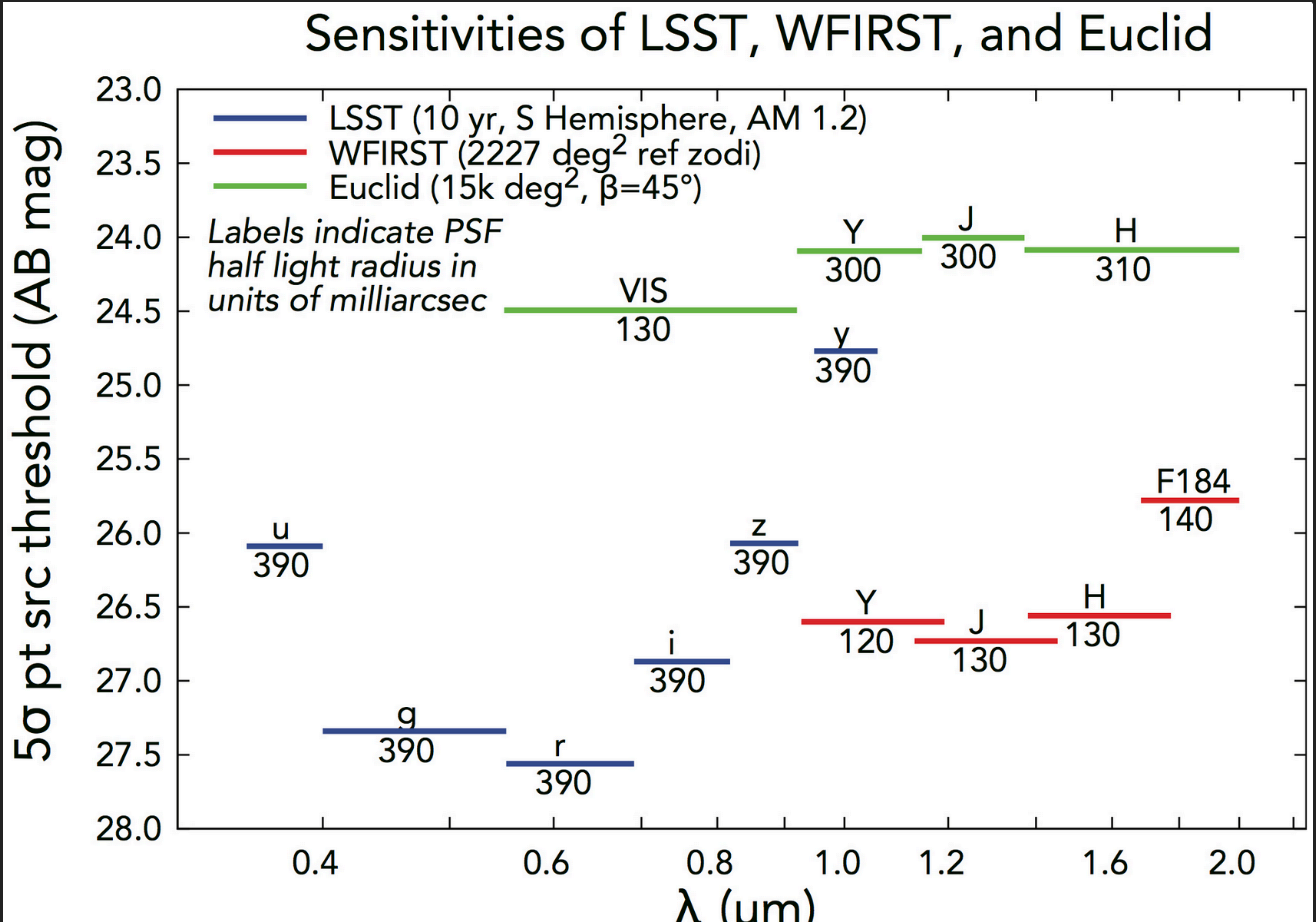
- Nominal 5 yrs mission
- Three Surveys:
  - ➡ ~2 yrs High-Latitude Survey (HLS)
    - Imaging, spectroscopy
  - ➡ ~6 months SNe search and IFC follow-up
  - ➡ ~1 yr for repeated galactic bulge observations for micro-lensing
- Experiment:
  - ➡ 1 yr for coronograph
- 25% Guest Observer program
- All data public a few days after they are taken

Slide from Olivier Doré

WFIRST BASELINE FILTERS

NAME	Wavelength [µm] (top of transmission curve)	Other names
R062	0.48-0.76	V, R, B, Orange
Z087	0.76-0.98	Z band
Y106	0.93-1.19	Y band
J129	1.13-1.45	J band
H158	1.38-1.77	H band
F184	1.68-2.00	F184
W146	0.93-2.0	W149
G150	~1.0-20	Grism
Dark	—	Dark

slides from Jason Kalirai



https://wfirst.gsfc.nasa.gov

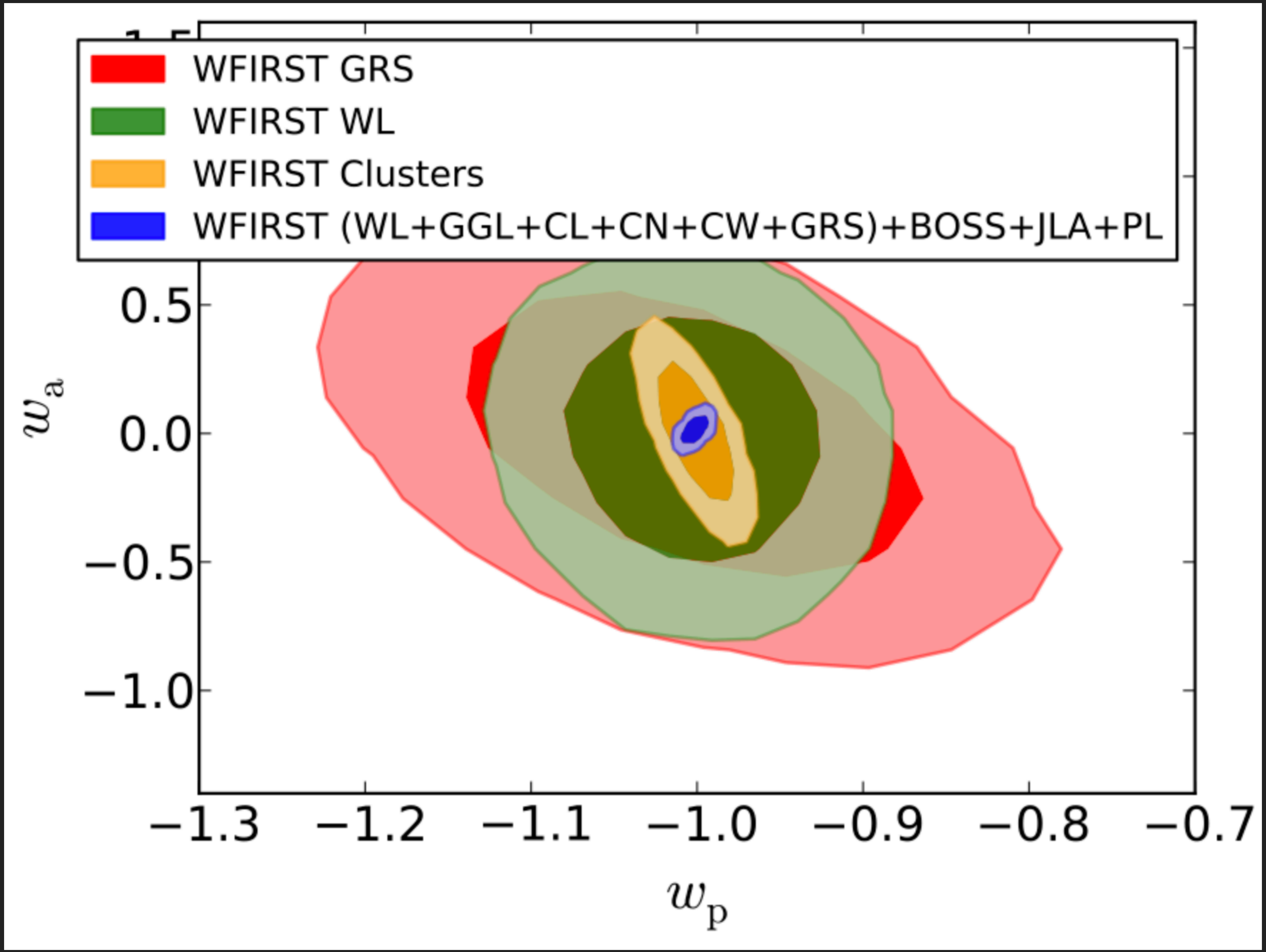
DE SURVEY COMPLEMENTARITY AT A GLANCE

Slide from Olivier Doré

STAGE IV	LSST	WFIRST	Euclid	DESI
Start, duration	2022, 10 yr	~2025, 5 (-10) yr	2021, 6 yr	2019, 5 yr
Area (sq. deg.)	20,000 (S)	2,000 (S)	15,000 (N+S)	14,000 (N)
FOV (sq. deg.)	10	0.281	0.53	7.9
Diameter (m.)	6.7	2.4	1.3	4
Photometric Survey	6 bands (u,g,r,i,z,y)	6 bands (Z,Y,J,H,F,184,W149)	4 bands (VIS,Y,J,H)	
Photometric Galaxies (w/ shapes) (#/arcmin^2)	~30 in 6 bands (ugrizy)	~68 in 4 bands (YJHF184)	~30-35, in 1 band (VIS)	
SN1a	10^4-10^5/yr z=0-0.7 photometric	2700 z=0.1-1.5 IFC spectroscopy		
Spectroscopic Survey		Grism R=550-800 1-2 μm	Grism R=250 1.1-2 μm	Fibers R=4000 0.36-0.98 μm
Spectroscopic Galaxies		ELGs z=0.5-1.8 (Ha/ ~20M) z=0.9-2.8 (OIII/ ~2M)	ELGs, z~0.7-2.1 (20M)	LRGs+ELGs z~0.6-1.7 (20-30M) QSOs/Lya 1.9<z<4 (1M)

WFIRST FORECASTS

http://www.wfirst-hls-cosmology.org



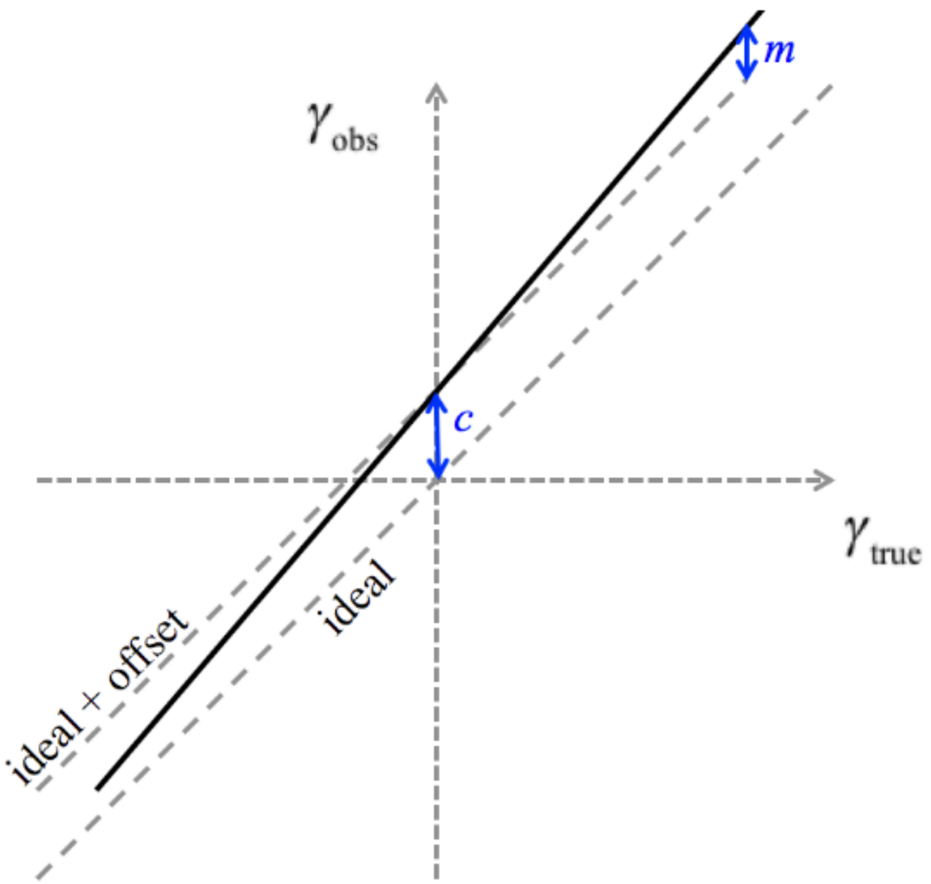
Eifler, Heinrich, Krause, Miyatake, Simet et al. 2018, *in prep*

Additive vs. multiplicative errors

- We care about two types of observational systematic errors: *additive* and *multiplicative*.
  - "Additive bias" or "spurious shear" c = WL signal that is measured even when looking at a population of unlensed galaxies.
  - "Multiplicative bias" or "calibration error" m = lensing signal on the sky is real, but the measured signal is some factor larger or smaller than the true signal.

$$\gamma_{\text{meas}} = (1+m)\gamma_{\text{true}} + c$$

Multiplicative error *Additive error*



Slide adapted from Chris Hirata

Δm (e1)	Δm(e2)	Δc(e1)	Δc(e2)
0.001445 ± 4.19e-4	0.002234 ± 4.09e-4	-0.001421 ± 5.9e-5	-0.002468 ± 5.8e-5

$de_1/dZ4p$ = -2.20e-4 ± 9e-6, $de_2/dZ4p$ = -3.82e-4 ± 9e-6, in units of nm^{-1}