Cosmological Synergies with WFIRST and Euclid

Jason Rhodes (JPL)

SPHEREx Science Community Workshop

© 2016. California Institute of Technology. Government sponsorship acknowledged

The next decade

Proposed lifetime	2022 - 2032	2021 - 2027	2024 - 2030
Mirror size (m)	6.5 (effective diameter)	1.2	2.4
Survey size (sq deg)	20,000	15,000	2,227
Median z (WL)	0.9	**0.9**	1.2
Depth (AB mag)	~27.5	~24.5	~27
FoV (sq deg)	9.6	0.5 (Vis) 0.5 (NIR)	0.28
Filters	u-g-r-i-z-y	Y-J-H-Vis	Y-J-H-F184
Cosmological probes	WL, LSS, SN, SL, Cl	WL, LSS, SL, Cl,	WL, LSS, SN, SL, Cl

Table From Alina Kiessling

Euclid

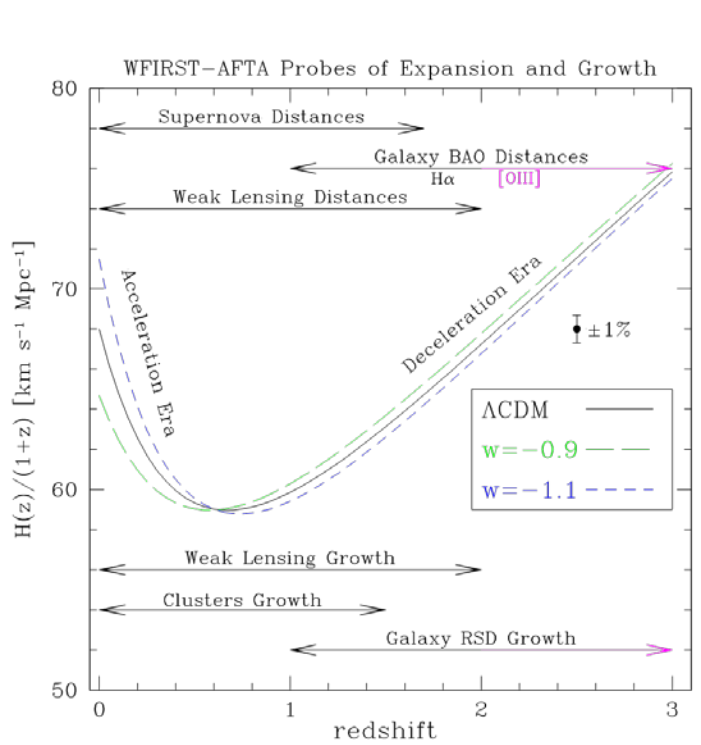
- Measures cosmological parameters (primarily) dark energy Equation of state using two probes
- Weak gravitational lensing
- Galaxy clustering (BAO/RSD) 0.7<z<1.8 using Hα

	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν /eV	f_{NL}	w_p	w_a	*FoM*
Euclid primary (WL+GC)	0.010	0.027	5.5	0.015	0.150	430
EuclidAll (clusters,ISW)	**0.009**	**0.020**	5.5	**0.013**	**0.048**	**1540**
Euclid+Planck	0.007	0.019	5.5	0.007	0.035	**6000**
Current (2009)	**0.200**	**0.580**	5.5	**0.100**	**1.500**	**~10**
Improvement Factor	**30**	**30**	**50**	**>10**	**>40**	**>400**

Ref: Euclid RB
arXiv:1110.3193

WFIRST

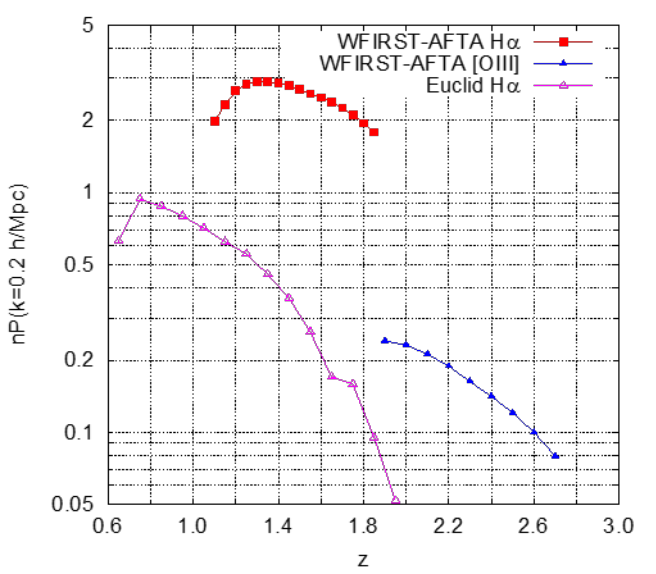
- Measures cosmological parameters (primarily) dark energy equation of state using three primary probes
- Weak gravitational lensing
- Galaxy clustering (BAO/RSD) 1<z<2 using Hα and 2<z<3 using OIII
- SN 0.1<z<1.7



From 2015 WFIRST SDT report

For nP>2, statistical errors are dominated by sample variance in LSS

For nP<1, statistical errors are dominated by shot noise in galaxy distribution



From 2015 WFIRST SDT report

Areas of Synergy

- SPHEREx excels at different cosmological parameters than WFIRST/Euclid
  - —Provides stronger constraints on early Universe (primordial power spectrum) and non –Gaussianity (f_{NL})
  - —SPHEREx covers $z<1$ redshift range for BAO that are not covered by WFIRST/Euclid emission line galaxy spectroscopic surveys
- Systematics mitigation for WFIRST and Euclid
  - —Photometric redshifts
  - —Intrinsic alignments
- Higher S/N galaxy-galaxy-lensing
- Fuller wavelength coverage, especially in Deep Fields

Redshift range

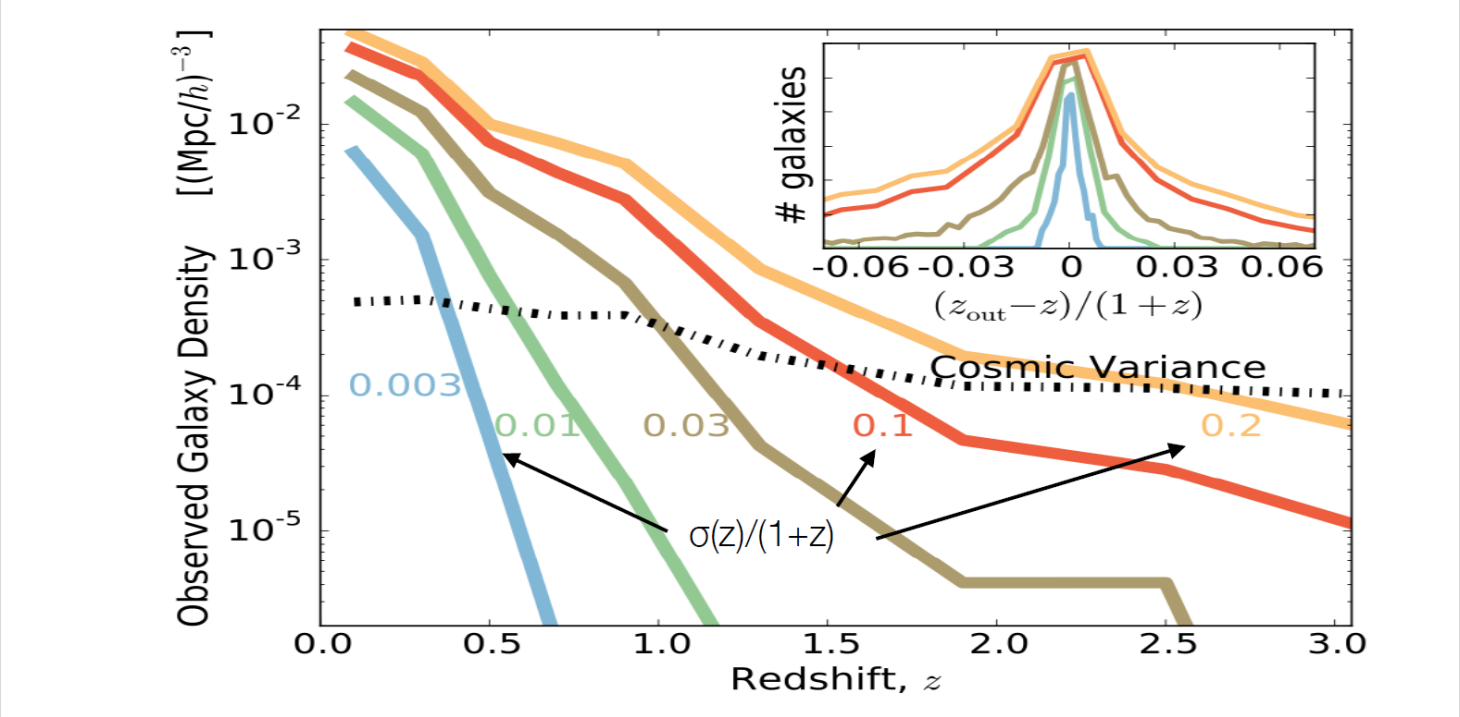


Figure from O Doré

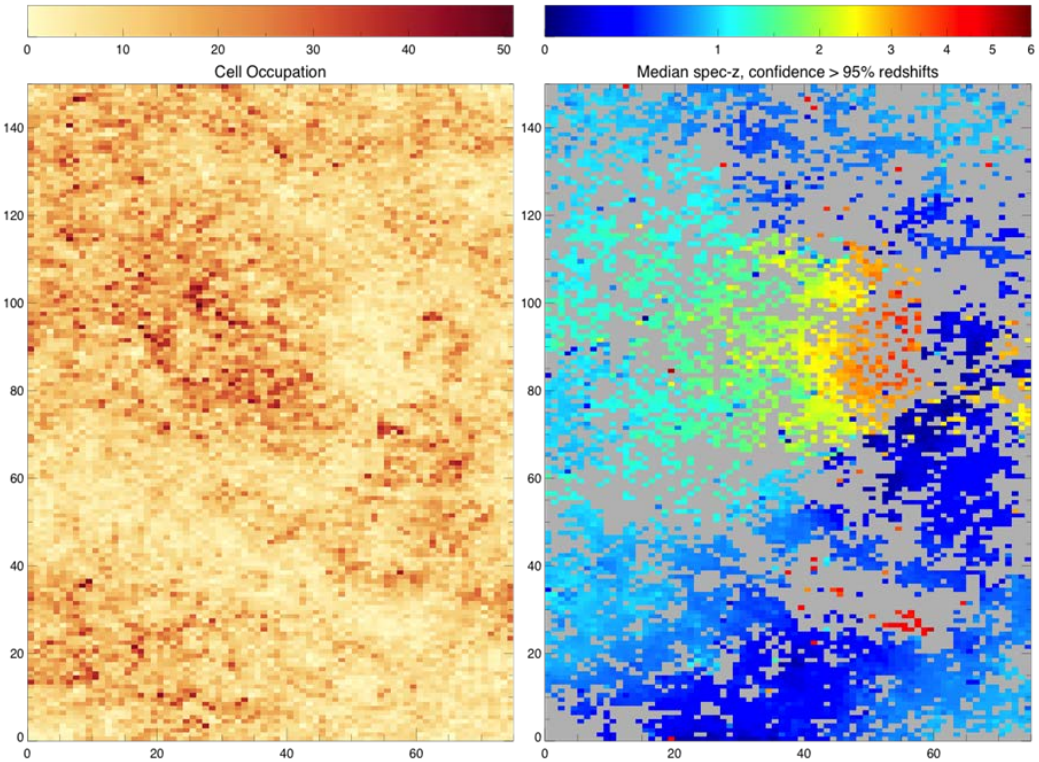
SPHEREx will survey the entire sky and get spectra of an immense amount of galaxies at z<1 (1.4B sources!)

Complements the Euclid and WFIRST z>1 surveys in NIR

How will we achieve the challenging Euclid photometric redshift requirements?

- Photo-z bias requirement for WL presents a major challenge: mean z known to 0.2%.
- Incomplete or unrepresentative spec-z training and calibration samples can easily lead to significant biases in photo-z estimates, particularly for machine learning methods.
- Masters et al developed a method based on the self-organizing map (SOM; Kohonen 1995), to empirically map the distribution of galaxy SEDs in the high-dimensional color space probed by the Euclid broadband filters
- Useful for WFIRST as well
- Deep Keck spectroscopy will help and is underway

- SPHEREx will provide a huge sample of very accurate calibration spectra over the entire Euclid survey area

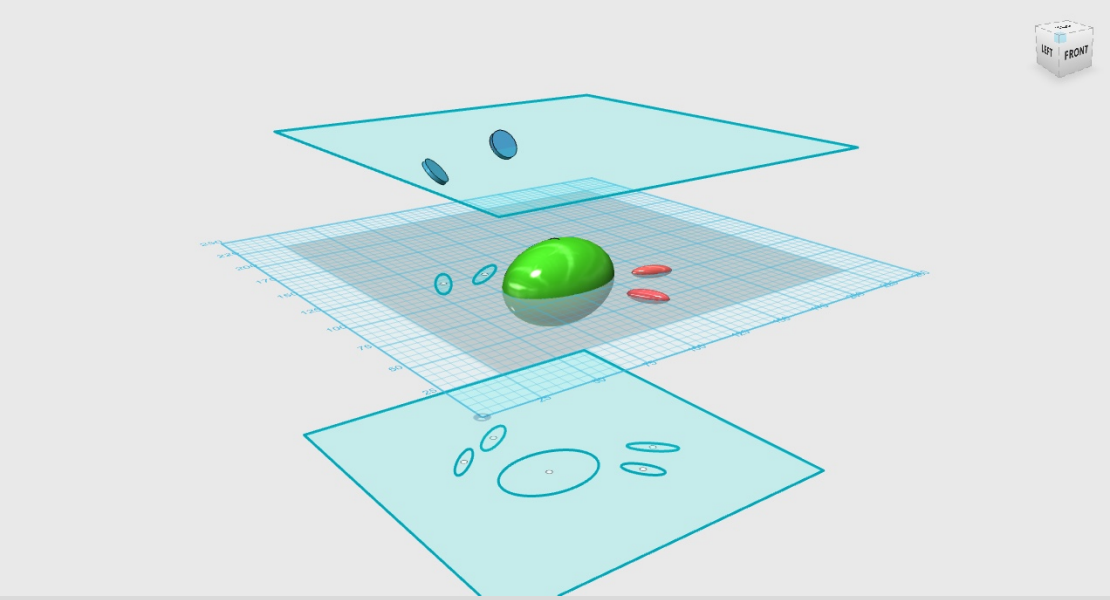


Left: The density of galaxies from COSMOS on the SOM. This is our estimate of the density of galaxies as a function of position in color space, $\rho(C)$. *Right:* The map colored by the median spectroscopic redshift of high-quality spec-z objects in each cell. The gray regions are parts of color space for which no high-quality spectroscopic redshifts have been obtained, which represents ~50% of the cells

Slide adapted from Capak and Masters (IPAC)

Galaxy Intrinsic Alignments

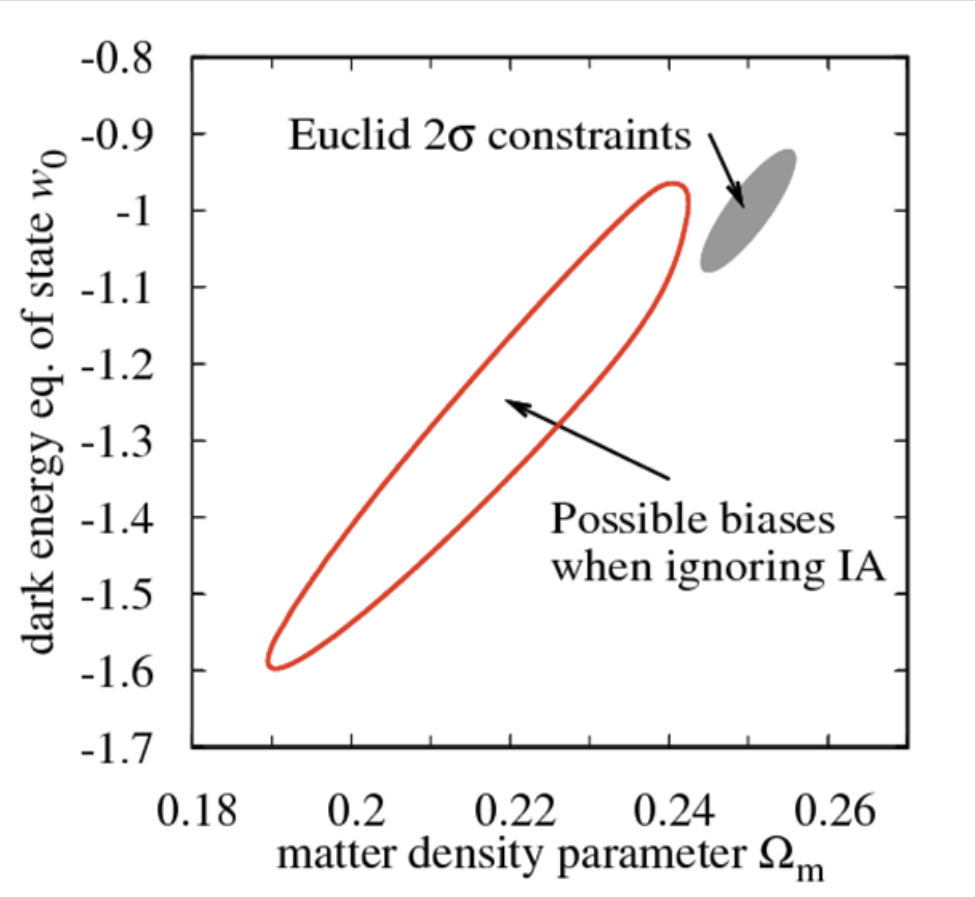
- Two types of primordial alignments that can enhance or dilute the cosmic signal
- Largest astrophysical systematic



From Joachimi et al 2015

- Light travels downward
- Cyan (distant) galaxies are gravitationally lensed to have correlated shapes- **signal**!
- Pink galaxies are intrinsically aligned during formation- contaminant
- Pink and cyan galaxy images are anti-aligned – contaminant

Intrinsic Alignments



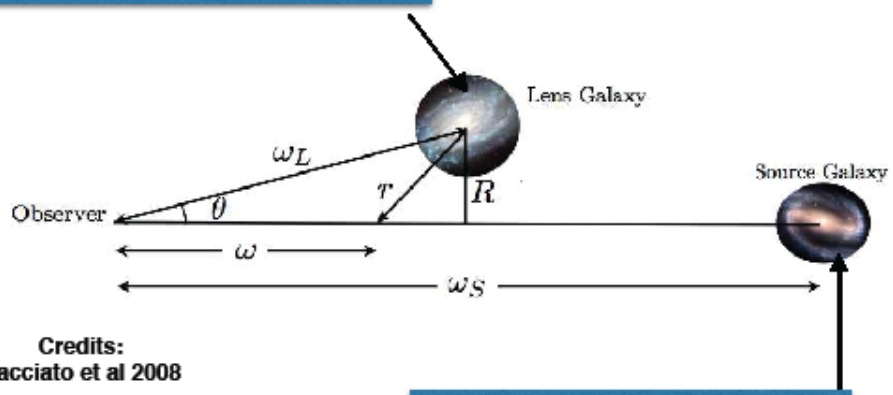
- Example Euclid constraints (gray) and possible biases if IA are ignored (Joachimi et al 2011)
- See also Krause, Eifler and Blazek, 2016, which shows that if IA is controlled at z<1, Euclid will be virtually unbiased
- Modeling and understanding sources of IA is key

Exquisite and abundant spectra of foreground (z<1) objects from SPHEREx may provide the mitigation we need

Euclid+SPHEREx=New Science

Combination of both data sets enables NEW science through high-precision galaxy-galaxy lensing

SPHEREx galaxy sample as foreground lenses -> exact redshift known



Credits:
Cacciato et al 2008

Euclid galaxies as background sources -> excellent shape measurements

Knowing the redshift of the lens determines physical distances R

1) Study galaxy-halo connection as a function of galaxy luminosity, type, and environment (bias, HOD models, etc)

2) Study baryonic feedback processes in halos again as function of galaxy variables

3) Unlocks information from higher-order statistics such as galaxy-galaxy-galaxy lensing (Simon et al 2012)

Slide from Tim Eifler

Deep Fields

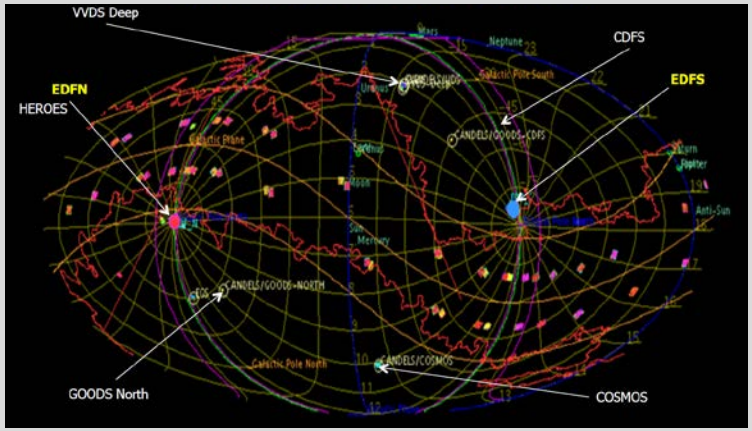


Figure from Roberto Scaramella, Euclid Survey Scientist

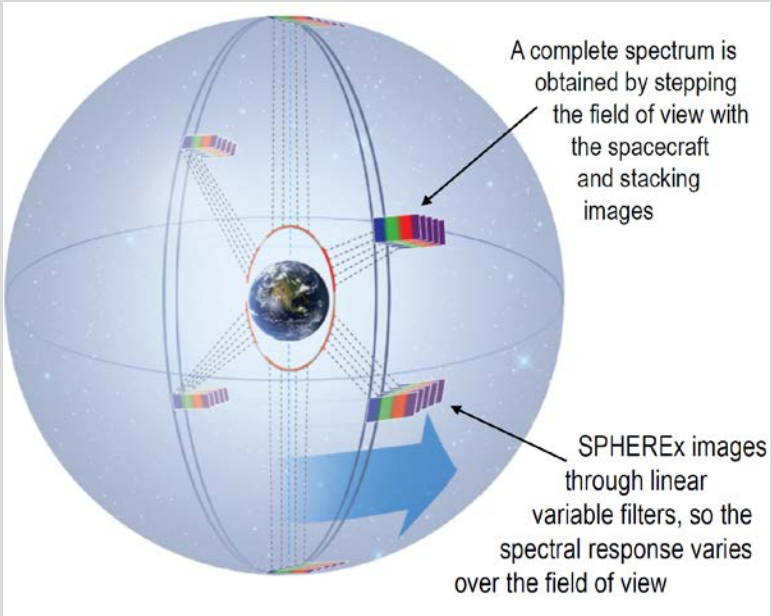


Figure from Olivier Doré

- Both Euclid and SPHEREx will have deep fields with multiple passes at ecliptic poles
- New science always comes from deep observations (especially with time series)
- These fields will become standard fields and we can start with ancillary observations now
- Last chance for Spitzer (see Capak)

The Path Forward

- Euclid, WFIRST, and SPHEREx will continue to develop
- Synergies will continue to be identified and optimal exploitation takes careful planning
- Synchronization among these projects is important
  - —Doré is a Project Scientist (SPHEREx), Science Investigation Team lead (WFIRST), and Consortium member (Euclid)!