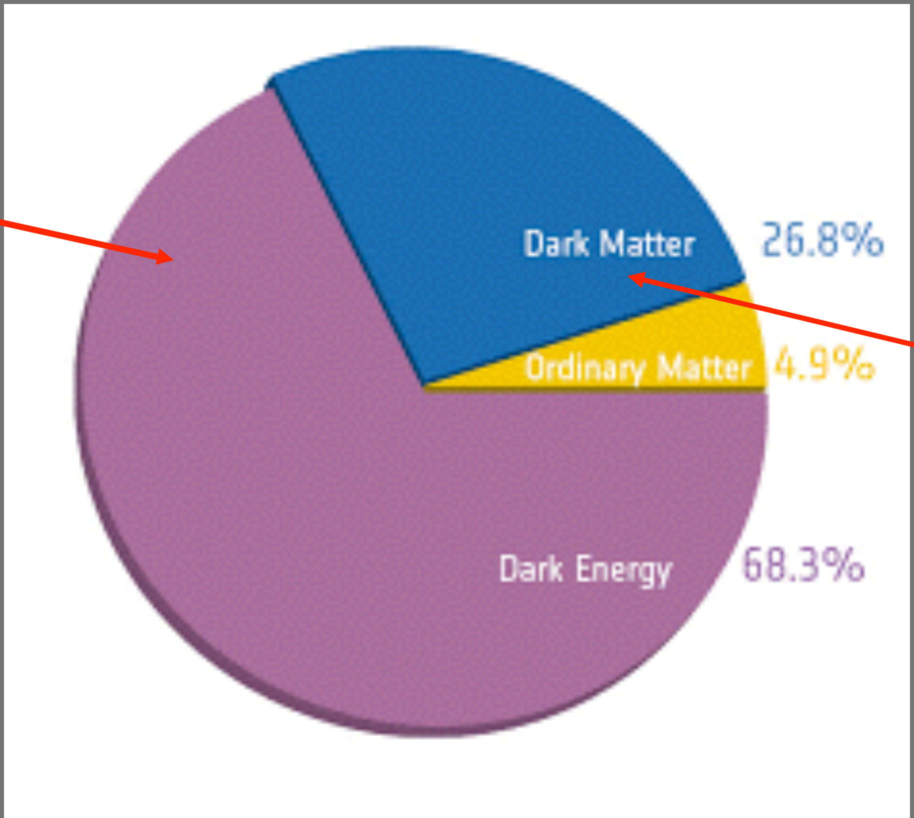
Cosmology and dark energy with WFIRST HLS
+
WFIRST/LSST synergies

Rachel Mandelbaum (Carnegie Mellon University)

With many contributions from Olivier Doré and members of the SIT "Cosmology with the WFIRST High-Latitude Survey"

The contents of the universe

We don’t know what this is!



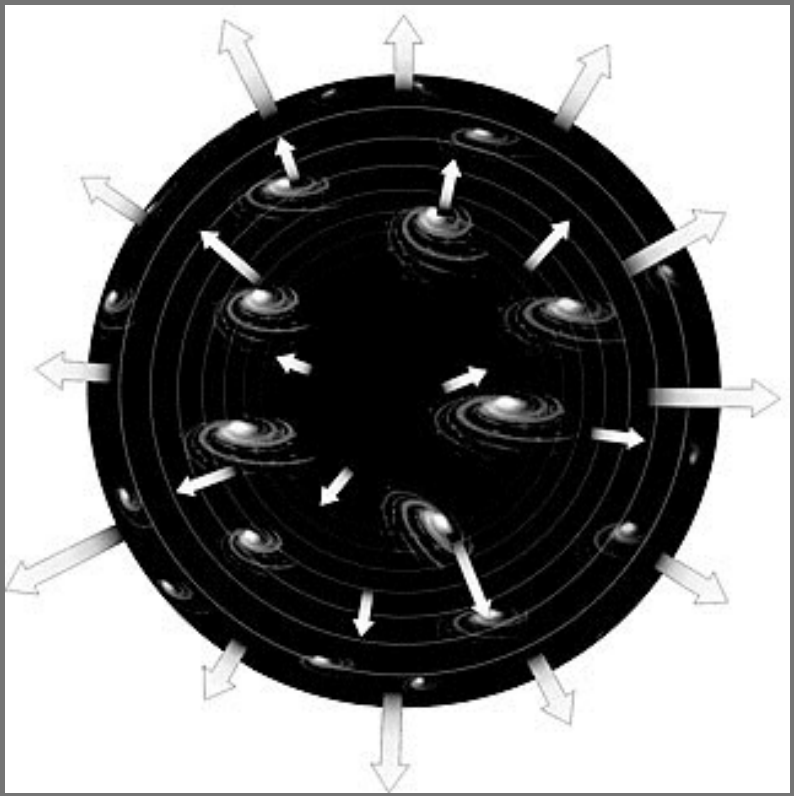
We don’t know what this is, either!

Name for model: ΛCDM

Picture credit: ESA/Planck

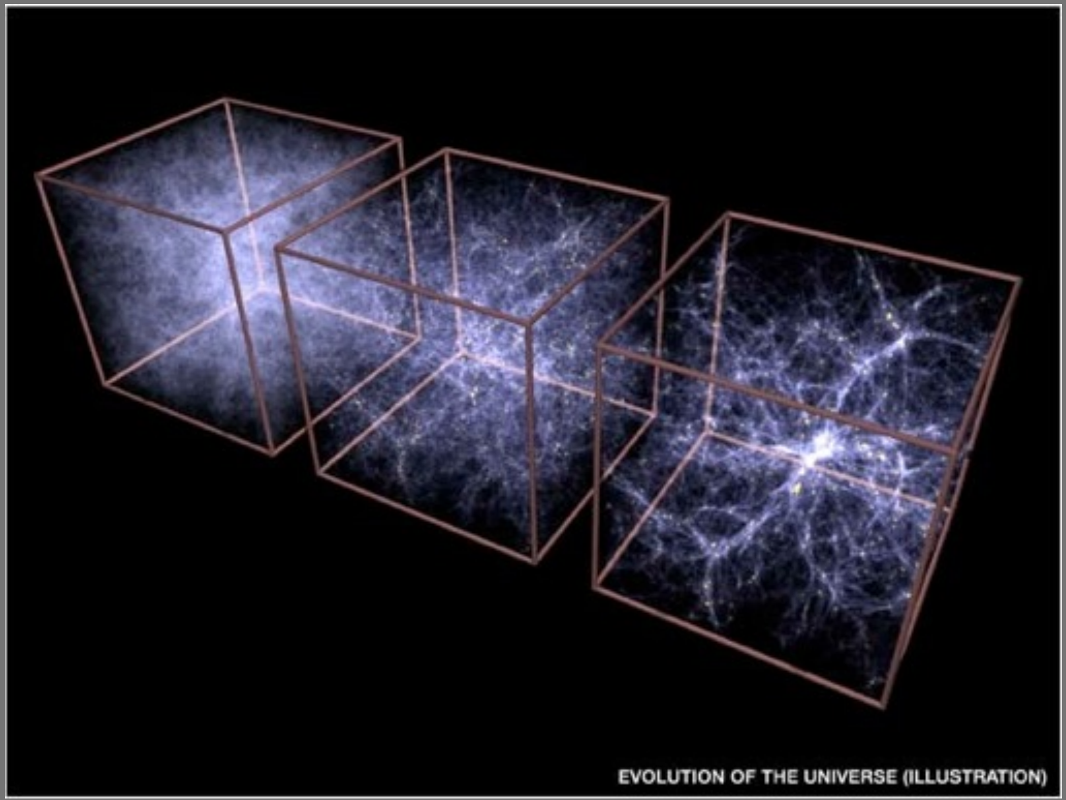
Two types of cosmological measurements

Geometric



Cosmic acceleration:
pulls galaxies apart

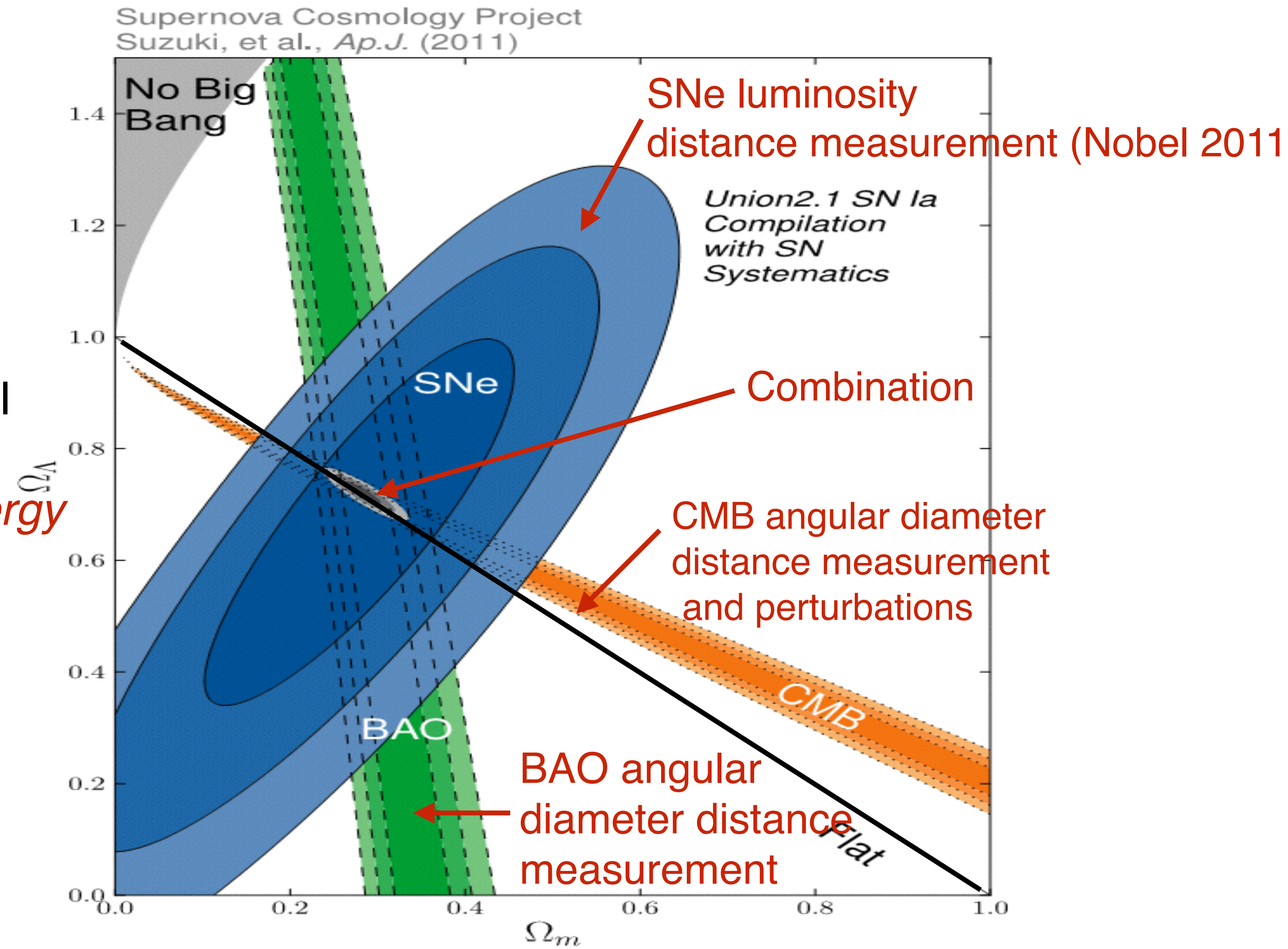
Growth of structure



Gravity:
draws galaxies together

Measure BOTH to learn about dark matter, dark energy, and gravity!

The Observational Foundations of Dark Energy



Cosmological Constant, i.e. *Dark Energy density*

Matter Density

- Weak lensing (not plotted) is also very complementary.

WFIRST Dark Energy Surveys

Weak Lensing (2200 deg^2)

- High angular resolution
- Galaxy shapes in IR
- 380 million galaxies
- Photo-z redshifts
- 4 imaging filters

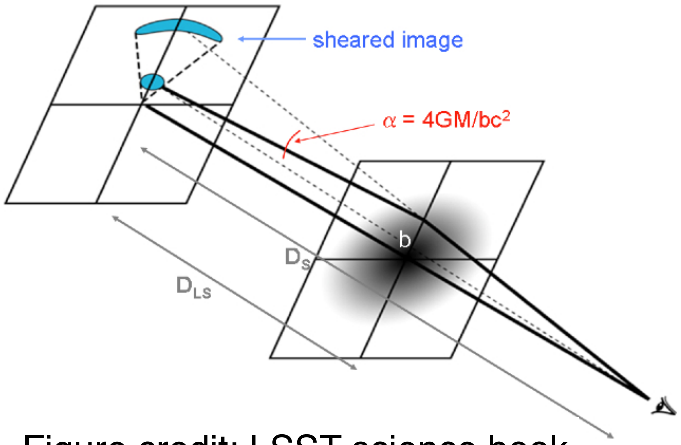
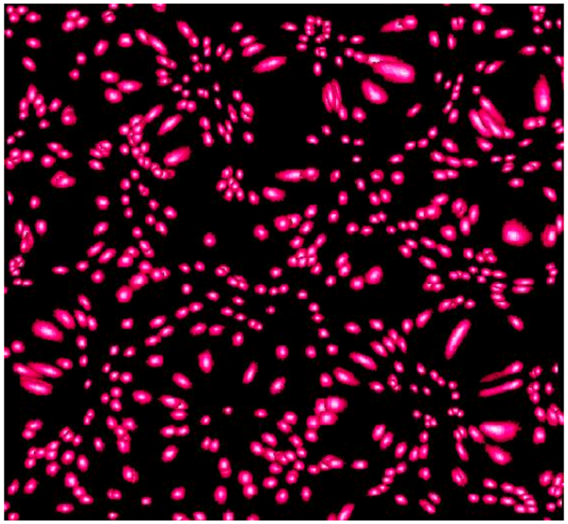


Figure credit: LSST science book



Supernovae

- High quality IFU spectra
- 5 day sampling of light curves
- 2700 SNe

Redshift survey (2200 deg^2)

- BAO & Redshift Space Distortions
- High number density of galaxies
- 16 million galaxies

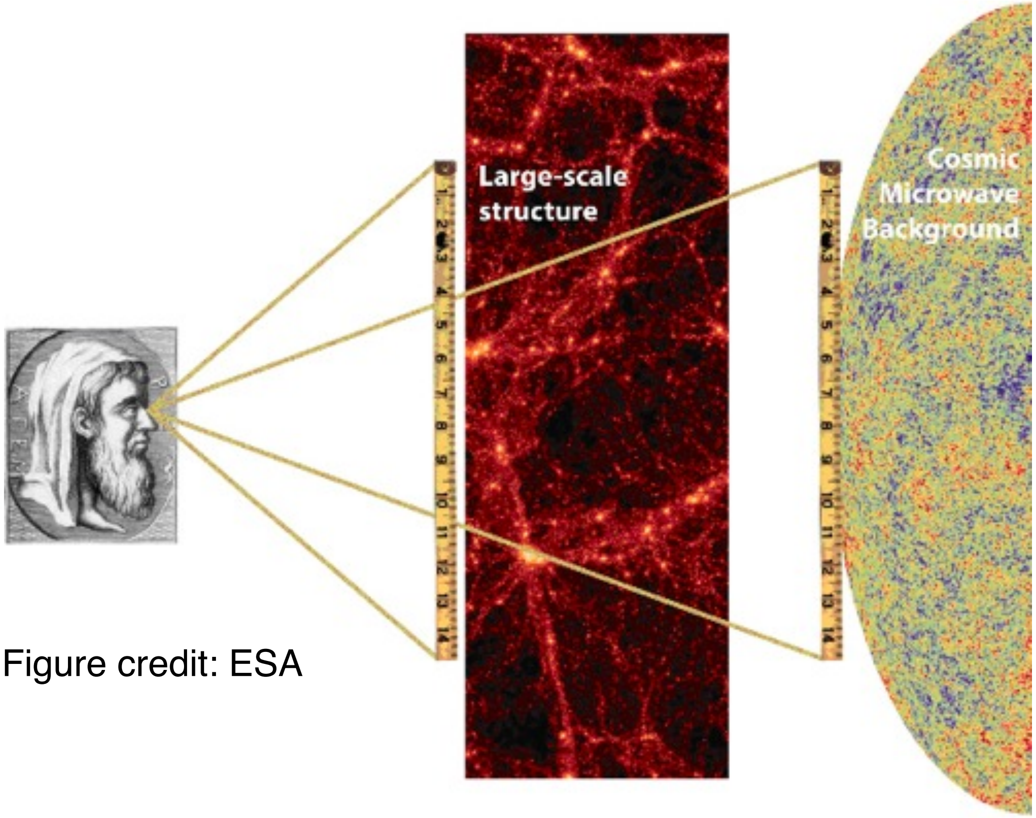


Figure credit: ESA

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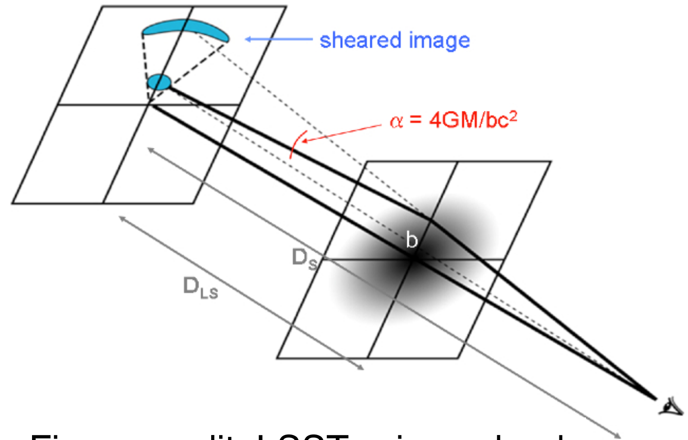

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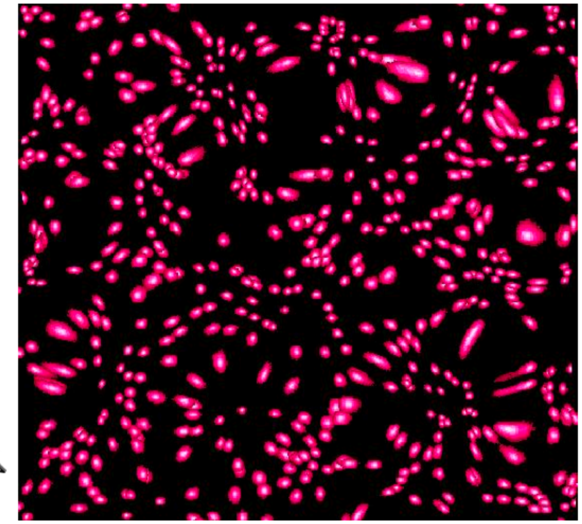

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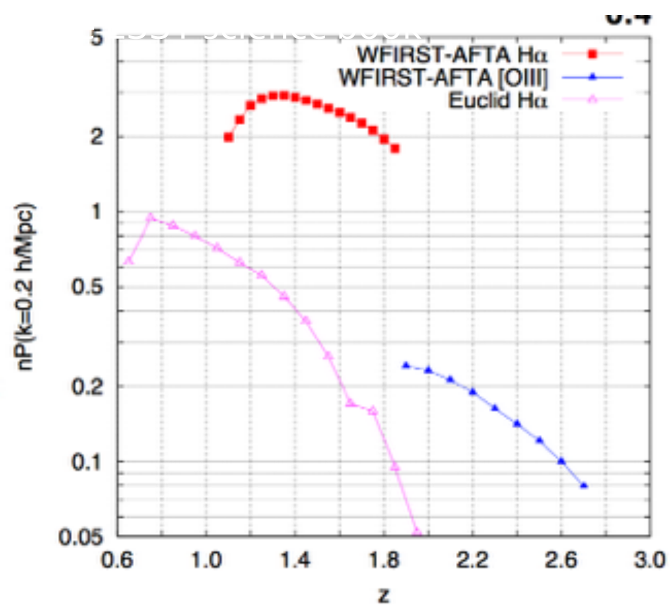


From WFIRST-AFTA SDT Final Report

SIT led by Olivier Doré:

Cosmology with the WFIRST High Latitude Survey

WFIRST Science Investigation Team

Goal Team News Products Contact

Explaining the Origin of Cosmic Acceleration with WFIRST

Check out our public webpage:
http://www.wfirst-hls-cosmology.org/

Who are we??

- Rachel Bean (Cornell)
- Andrew Benson (Carnegie)
- Peter Capak (Caltech/IPAC)
- Ami Choi (OSU)
- ☆ Olivier Doré (JPL/Caltech, PI)
- Tim Eifler (JPL/Caltech)
- Katrin Heitmann (ANL)
- George Helou (Caltech/IPAC)
- Shoubaneh Hemmati (IPAC/Caltech)
- Shirley Ho (LBL)
- Albert Izard (JPL)
- Bhuvnesh Jain (Penn)
- Mike Jarvis (Penn)
- Alina Kiessling (JPL/Caltech)
- Elisabeth Krause (Stanford)
- ☆ Chris Hirata (OSU, Weak lensing lead)
- Robert Lupton (Princeton)
- Niall MacCrann (OSU)
- Rachel Mandelbaum (CMU)
- Elena Massara (LBL)
- Alex Merson (Caltech/IPAC)
- Hironao Miyatake (JPL/Caltech)
- Nikhil Padmanabhan (Yale)
- Andres Plazas Malagon (JPL/Caltech)
- 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 (Brookhaven)
- ☆ Yun Wang (Caltech/IPAC, Galaxy redshift survey lead)
- ☆ David Weinberg (OSU, Galaxy clusters lead)
- Ying Zu (OSU)

Cosmology with the High Latitude Survey: SIT Deliverables

- Full requirement flow-down.
- Survey tools:
  - ➡ Forecasts of the cosmological performances of the HLS.
  - ➡ Operations concept for the HLS Imaging and Spectroscopy program
  - ➡ Simulated imaging and spectroscopic data sets.
  - ➡ Prototype imaging and spectroscopic pipeline.
  - ➡ Development of methods for interpreting cosmological measurements.
- Strategies:
  - ➡ for calibration
  - ➡ for the determination and calibration of photometric redshifts
  - ➡ for ancillary observations with other facilities
- Broad engagement with the cosmological community.
  - ➡ All software will be made public!

Some public content up on SIT webpage already…

Cosmological parameters forecast chains

Please find below some cosmological parameters MCMC chains corresponding to forecast for the current survey of the WFIRST High Latitude Survey, combining weak-gravitational lensing (WL), cluster count (CC) and redshift space distortions (GRS). These chains were computed using the CosmoLike software Krause & Eifler 2016.

Multi-probe cosmology forecasts (incl SN from both SN teams) with realistic systematics budget

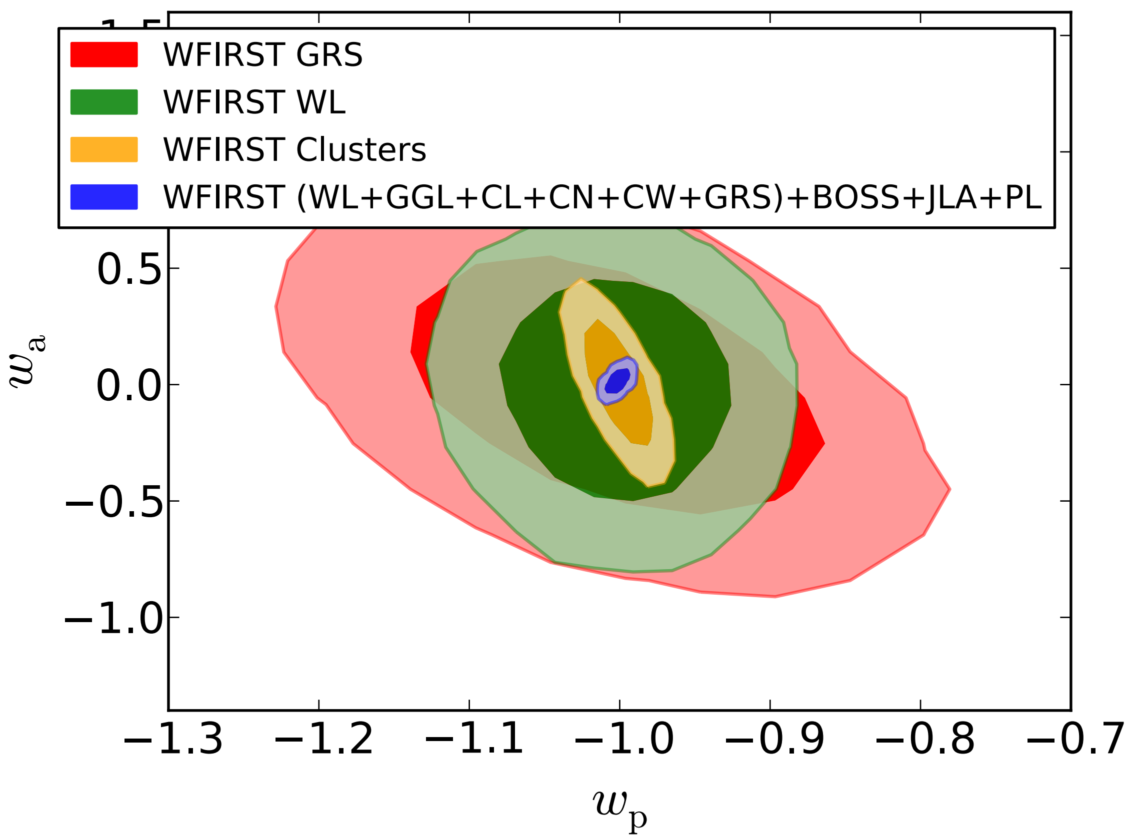


Figure credit:
Tim Eifler

Includes contributions from other SITs (e.g., for supernova constraints)

Jain, Spergel et al. White Paper, Feb. 2015

The Whole is Greater than the Sum of the Parts: Optimizing the Joint Science Return from LSST, Euclid and WFIRST

B. Jain,[1] D. Spergel,[2] R. Bean, A. Connolly, I. Dell'antonio, J. Frieman, E. Gawiser, N. Gehrels, L. Gladney, K. Heitmann, G. Helou, C. Hirata, S. Ho, Ž. Ivezić, M. Jarvis, S. Kahn, J. Kalirai, A. Kim, R. Lupton, R. Mandelbaum, P. Marshall, J. A. Newman, S. Perlmutter, M. Postman, J. Rhodes, M. A. Strauss, J. A. Tyson, L. Walkowicz, W. M. Wood-Vasey

The scientific opportunity offered by the combination of data from LSST, WFIRST and Euclid goes well beyond the science enabled by any one of the data sets alone. The range in wavelength, angular resolution and redshift coverage that these missions jointly span is remarkable. With major investments in LSST and WFIRST, and partnership with ESA in Euclid, the US has an outstanding scientific opportunity to carry out a combined analysis of these data sets. It is imperative for us to seize it and, together with our European colleagues, prepare for the defining cosmological pursuit of the 21st century.

Why we should think now about WFIRST+LSST

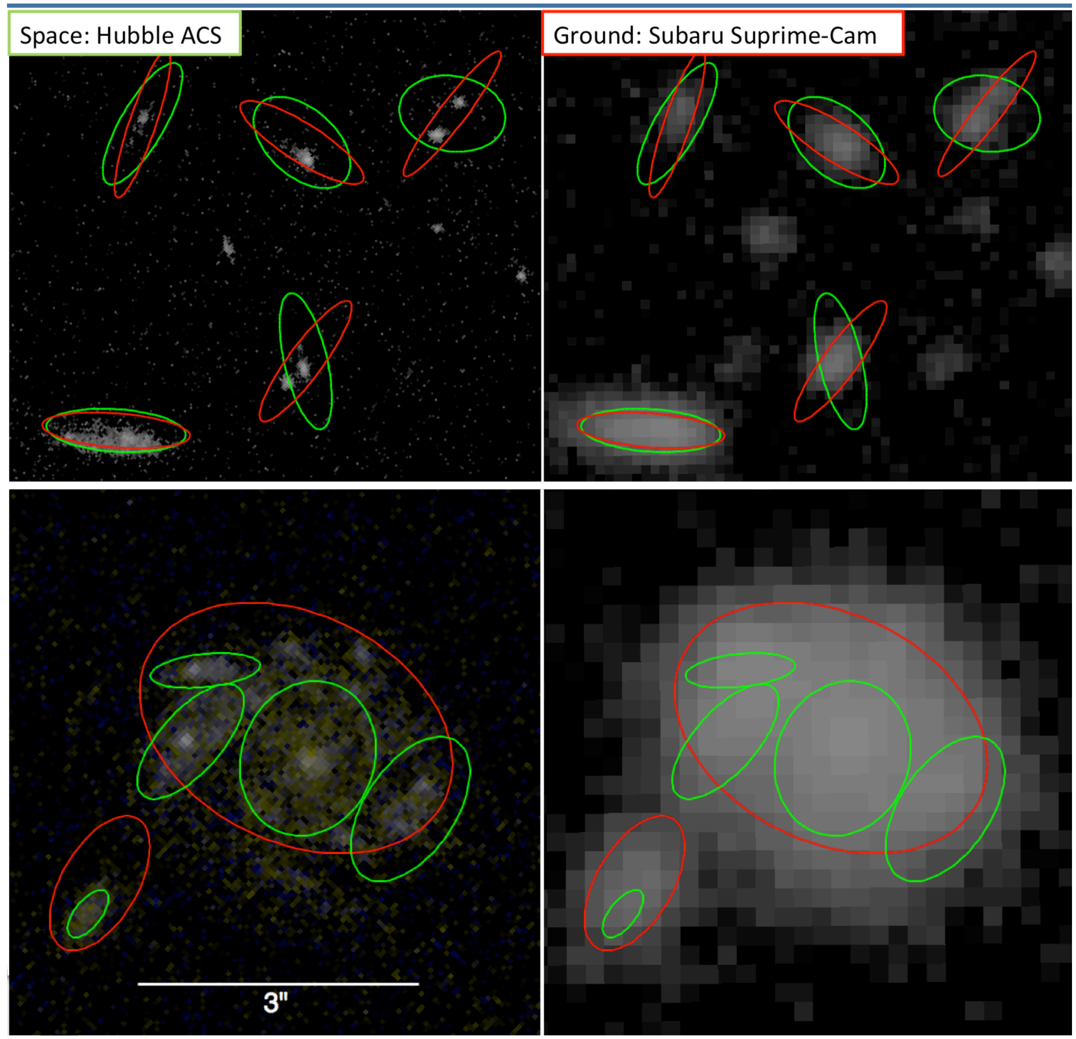
- The era of multi-probes/multiple surveys:
  - ➡ The richer insights will come from combining multiple probes (gravitational lensing, redshift space distortions, cluster counts) *reliably*.
- Win/win:
  - ➡ WFIRST needs LSST optical imaging for photometric redshifts
  - ➡ LSST may benefit from the higher-resolution WFIRST imaging
- Joint analysis of pixel data may be the only way to get certain benefits
  - ➡ preparing for this early on can avoid duplication of efforts
- Some cosmology infrastructure (e.g., large-volume simulations) is common to both projects, should avoid duplication of effort
- Cross-correlations: cancel uncorrelated systematics (e.g. PSF effects)
  - ➡ More robust results, cross-checks
- WFIRST options as a function of LSST discoveries (or other Stage III surveys):
  - ➡ Can we think about changing the WFIRST strategy based on LSST on-sky performance?

WFIRST/LSST workshop (Sept. 2016)

Photos P. Bull

Examples: the blending problem

- Catalog cross-matching is confused by significant object blending as seen by LSST.
- Blending problem is serious for LSST, leads to serious bias in shear estimation and photometric redshifts.
- Situation is worse in galaxy clusters and will lead to bias if uncorrected (Jain, von der Linden).



Melchior, Schneider

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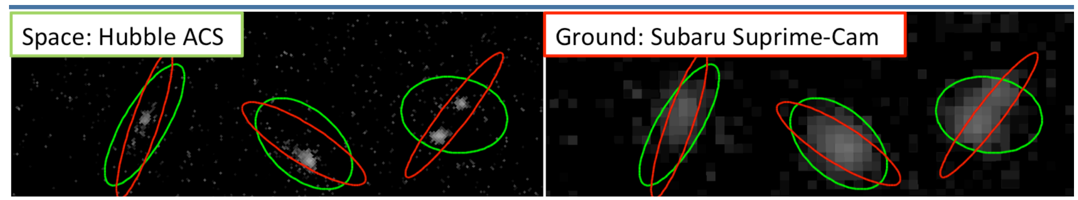
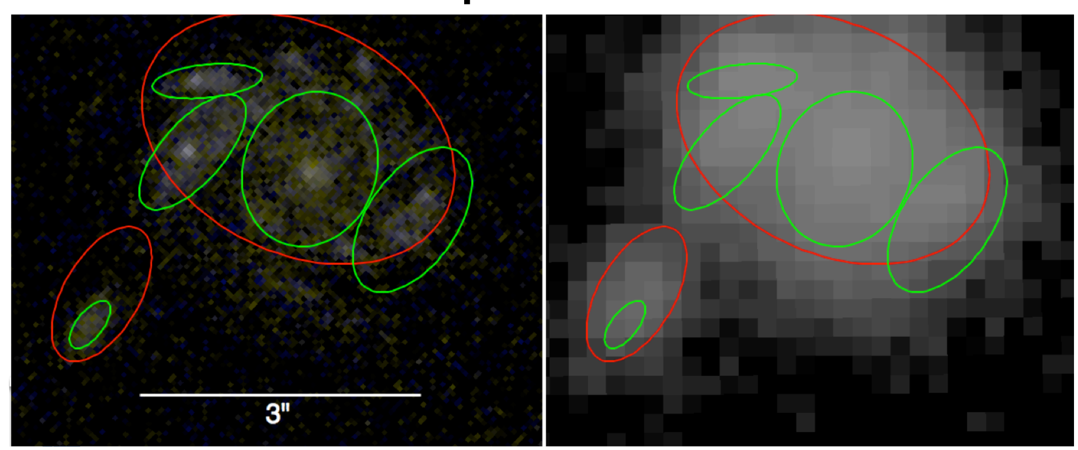


There are other scientific opportunities for the combination of surveys, e.g., strong lensing.

Community input welcome during this ongoing process!
There will be more workshops…

photometric redshifts.



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Melchior, Schneider

Conclusions

- WFIRST dark energy constraints will come from multiple complementary cosmological measurements.
  - ➡ Measurements take advantage of the unique opportunities of space-based data, e.g., by carrying out the first infrared lensing survey.
- SITs are already working on the deliverables needed for survey planning now (requirements on hardware for each science case, etc.)
  - ➡ They will provide tools for the broader benefit of the community.
- WFIRST will take place in a broader cosmological context given other surveys happening in the 2020s
  - ➡ Rich opportunities for carrying out precision cosmology and mitigating limiting systematics using the combination of the surveys.
  - ➡ Groups are already hard at work on how to best take advantage of these opportunities and do amazing science.