FERMILAB-SLIDES-20-041-PPD

LSST in 10 minutes

Javier Sánchez (FNAL)

New Perspectives 2020

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Introduction

- **What is LSST?**
  - The **L**egacy **S**urvey of **S**pace and **T**ime is a photometric survey that will be carried at the Vera C. Rubin Observatory at Cerro Pachón (Chile). Planned to start in 2022.

Status of the site on Apr 14th 2020. Image credits: lsst.org/ Google Maps

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LSST: Key Numbers

- It uses the 8.4-m mirror Simonyi telescope.
  - Using the LSST Camera 3.2 Gpix. 189 CCD 4096x4096 pixel sensors.
  - Field-of-view ~9.6 square-degrees (approx 40 full moons).
  - 10 year survey in 6 different bands (filters): u, g, r, i, z, y.
  - 37 billion stars and galaxies.
  - 10 million transient alerts (supernovae, meteorites, planets, things that are variable in the sky)
  - 20 TB of data every night! Expected ~15 PB database for the final data release.

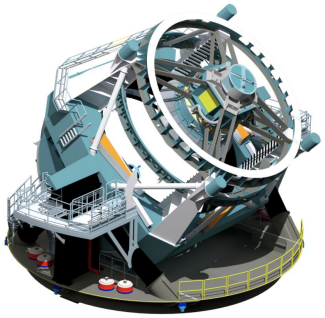
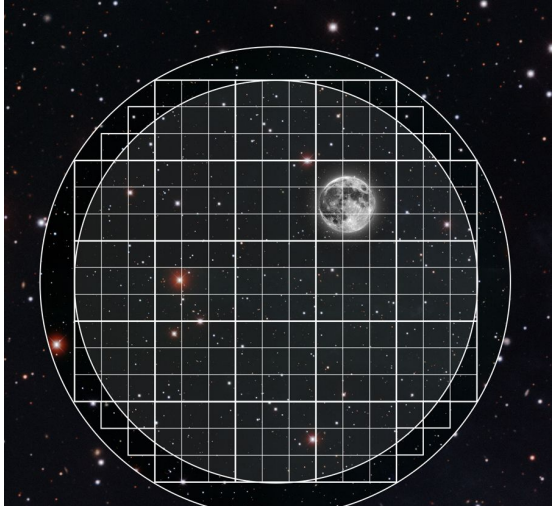
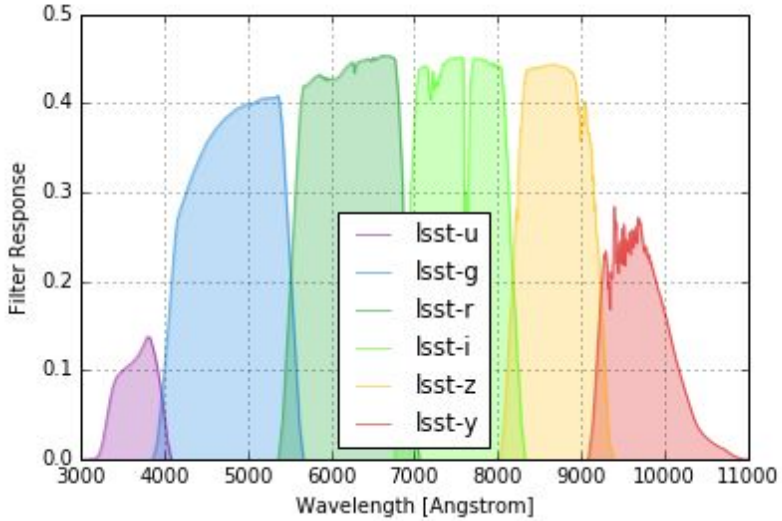


Image credits: LSST/ NSF/ AURA

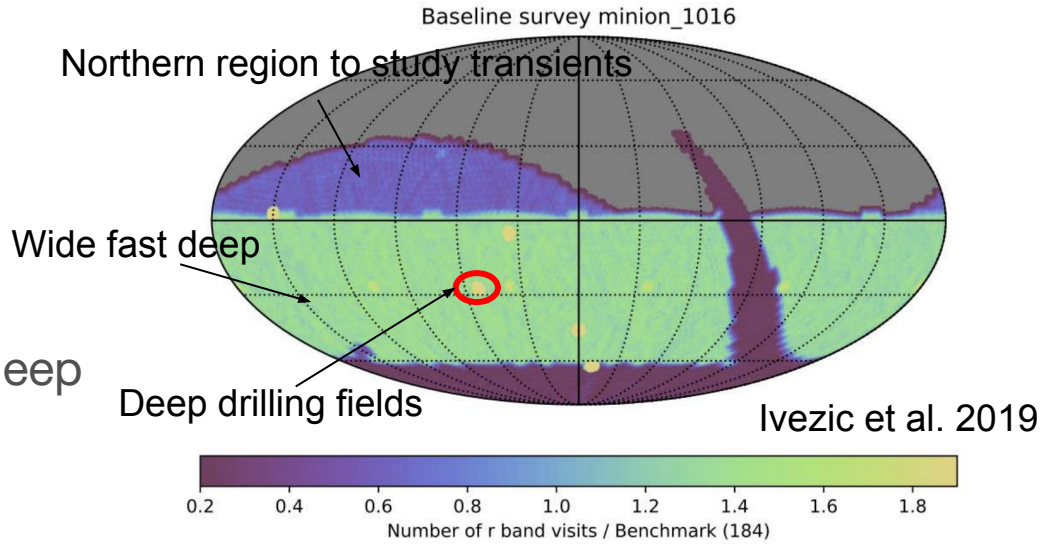
[Filters from speclite]

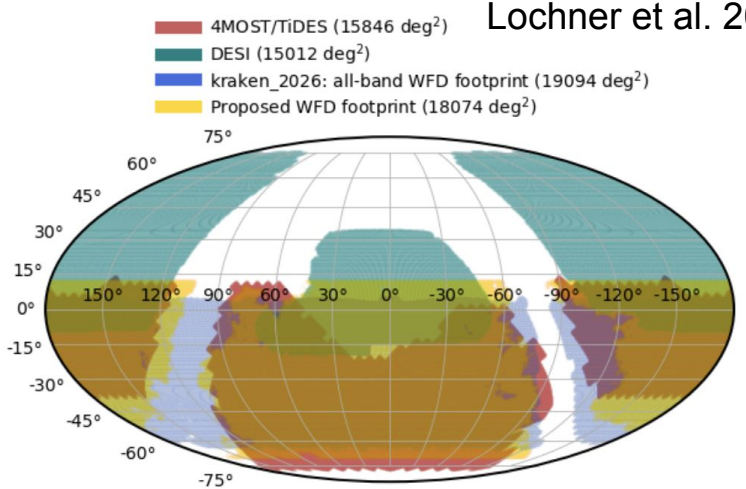




LSST: Science

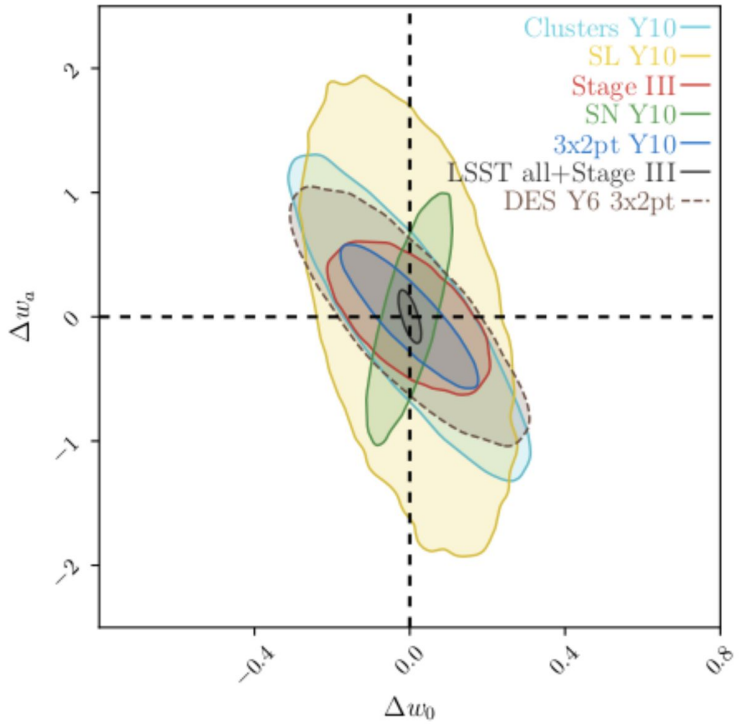
- 8 science collaborations.
- Map 30,000 square-degrees total.
- 90% of survey time to map uniformly ~18,000 square-degrees (wide-fast-deep survey).
- Main science drivers:
  - Dark matter and dark energy.
  - Solar system.
  - Transients/variable objects.
  - Milky way.





Dark Energy Science with LSST

- Dark Energy probes:
  - **Weak gravitational lensing.**
  - Baryon Acoustic Oscillations and galaxy clustering.
  - Clusters of galaxies.
  - Strong gravitational lensing.
  - Supernovae.



Lochner et al. 2018

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Weak Lensing: Intro

- Gravity bends light.
- Object shapes appear sheared to us due to the presence of matter.
- Measuring shapes we can get information about the (mostly dark) matter distribution.
- We repeat this at different cosmic times (tomography).

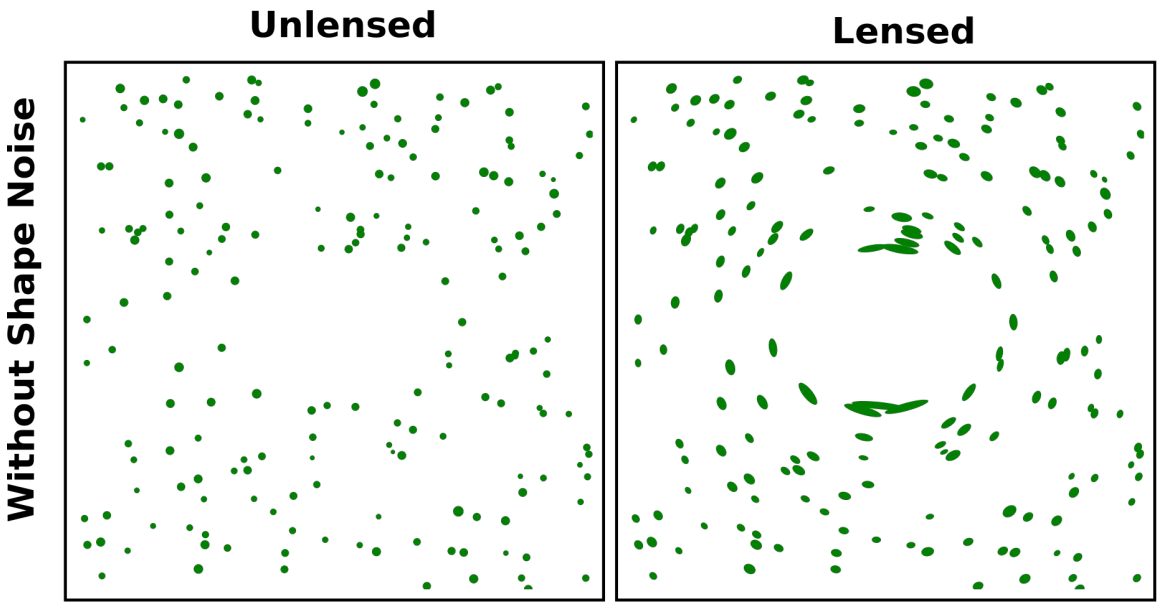


Image credit: Wikipedia

Weak Lensing: Challenges

- Galaxies aren't round.
- Shapes are random at first order.
- We can still get information but we have noise due to the intrinsic variance in the shapes (shape noise).
- We need a lot of galaxies since the shear effect is typically 3-300 times smaller than the intrinsic shape.

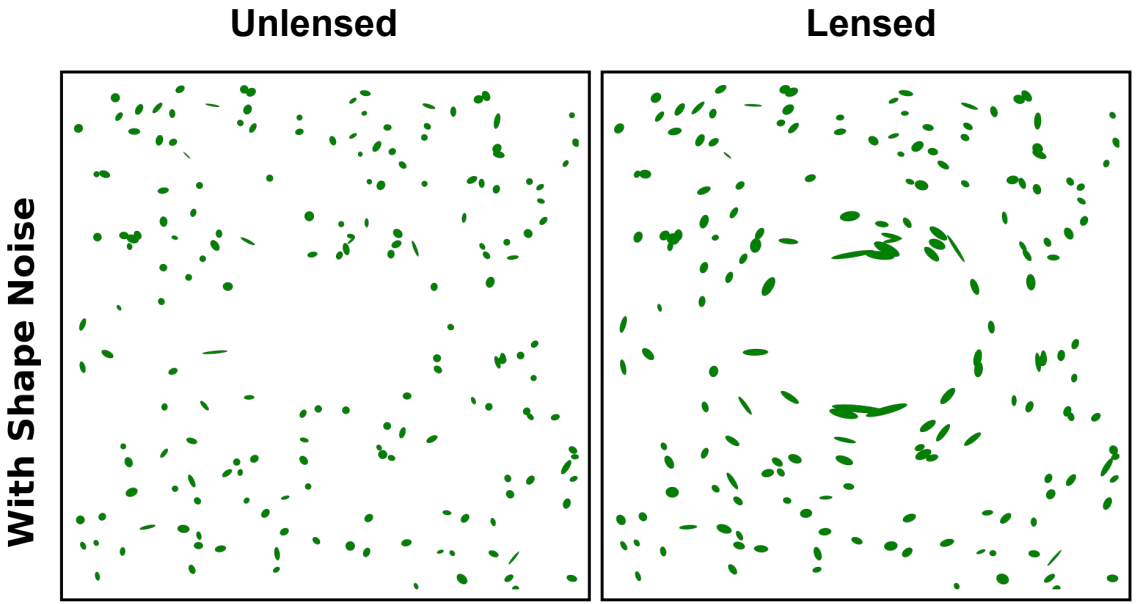
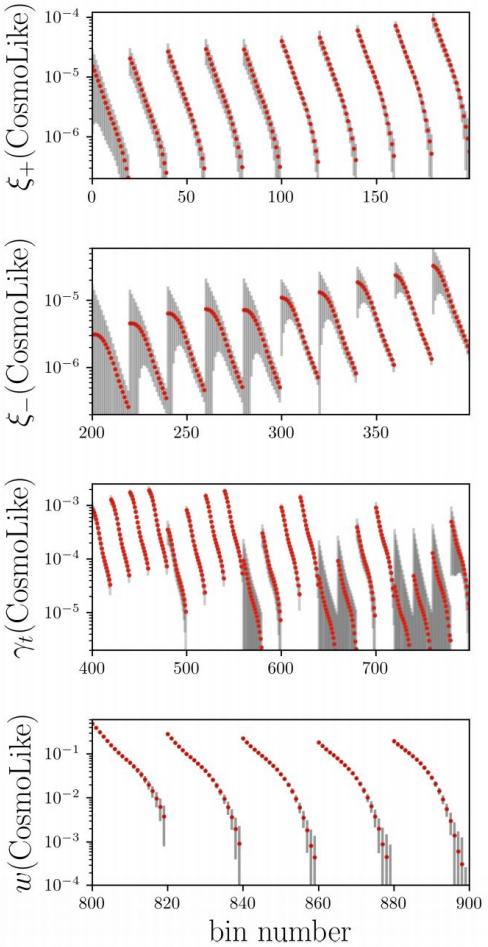


Image credit: Wikipedia

3x2pt analysis

- Cosmic shear is one of the dark matter density tracers. But galaxies are also dark matter density tracers.
- Initial density fluctuations are close to Gaussian. 2-point statistics can fully determine the field.
- Combining 3 different (although correlated) 2 point statistics we can improve cosmological constraints:
  - Shear-shear (cosmic shear).
  - Shear-galaxy (galaxy-galaxy lensing).
  - Galaxy-galaxy (galaxy clustering).

Error-bars for LSST should be ~10 times smaller.



DES Y1. Krause et al. 2018

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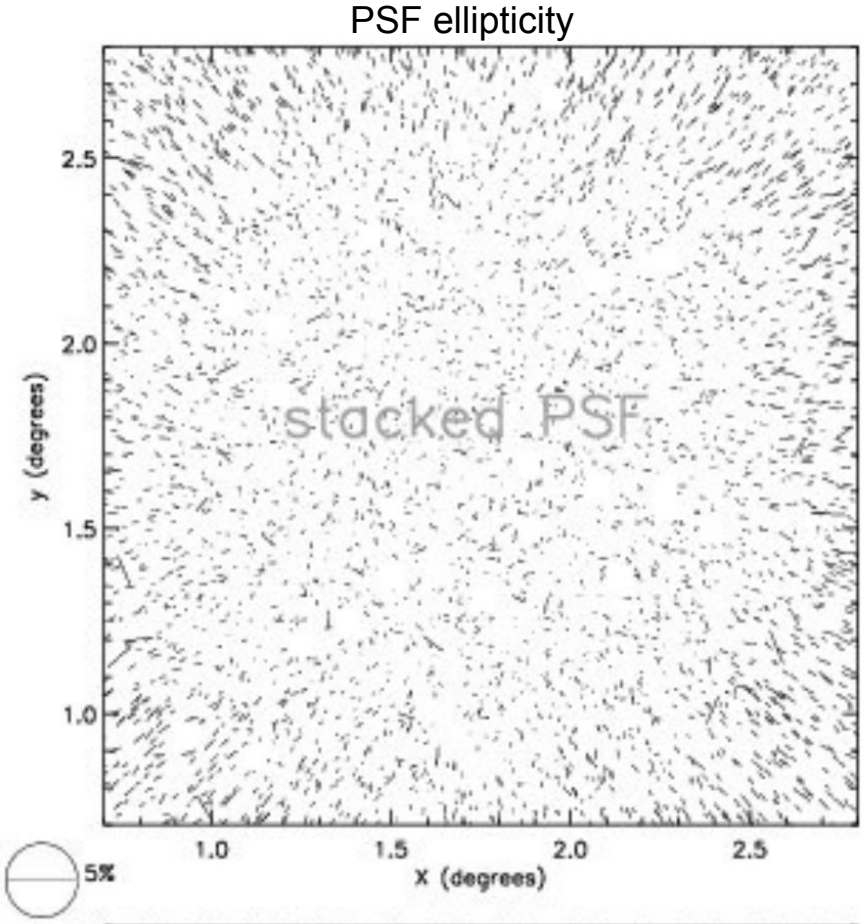
3x2pt analysis challenges

- LSST will accurately determine shapes for 2 billion objects.
- This means that it will be systematics limited!
- Atmosphere and optics can introduce spurious shears.
- This imposes very strict requirements in image quality and the knowledge/determination of the point-spread-function (PSF).



Jee & Tyson 2011

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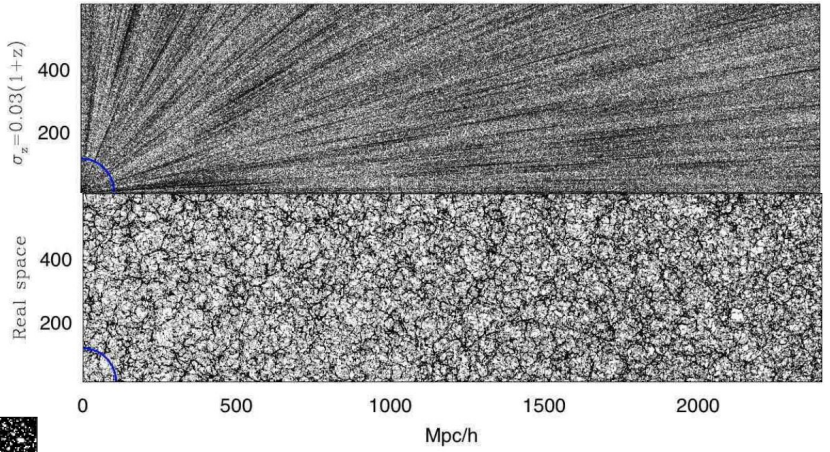
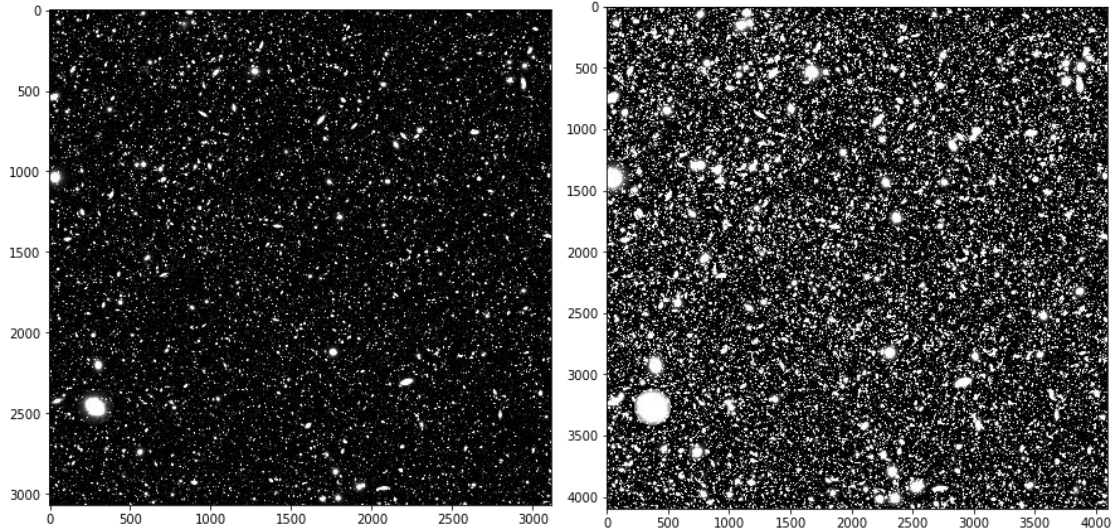
3x2pt analysis challenges

- LSST will perform “low-resolution” tomography.
- More objects in the field, increases the probability of overlaps: Blending.



Benítez et al. 2009



Left: DES Y6
Right: LSST Y10

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LSST @FNAL

- FNAL involved in Rubin Observatory project and different LSST Science Collaborations.
- Key Roles in Rubin/LSST Operations: Observatory operations, data production and data performance.
- Heavy involvement in LSST DESC:
  - Survey Simulations: Image Simulations (Montecarlo), ++
  - Dark Matter studies: Preparation for the search of Low Surface Brightness objects, ++
  - Cluster studies.
  - Strong Lensing studies.
  - Galaxy clustering/weak lensing/3x2pt: Contributions to analysis pipeline.
  - Blending studies: Forecasting of impact of blending and mitigation with overlapping observations.
  - Cross-correlations with CMB experiments: SPT, CMB-S4.
  - Transient/Gravitational wave follow-up.
  - And many others!