DESI and LSST: Powerful Synergies for Cosmology and Astrophysics

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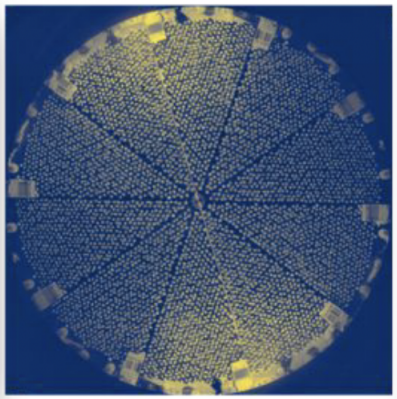
What is DESI?

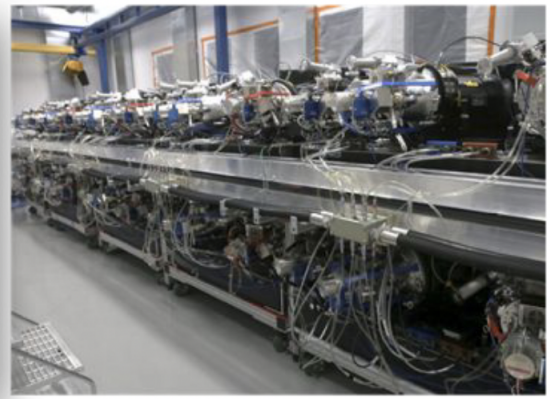
- Dark Energy Spectroscopic Instrument (DESI)
- 5000-fiber multi-object spectrograph on 4m Mayall Telescope
- Survey covering 14,000 sq deg
- Will measure spectra of 40 million galaxies and quasars over 5 years
- Main science goal: Measure expansion history of universe and growth of structure
- Timeline:
  - 2020-2021: Survey validation
  - 2021-2026: Main 5-year survey
  - 2026-2028: 2-year survey extension
  - 2028+: Potential DESI-II upgrade.

4-m Telescope at Mayall in Kitt Peak Arizona, USA



5000 fibers and robotic positioners in the focal plane

8 sq.deg. Field of View 14,000 sq. deg coverage

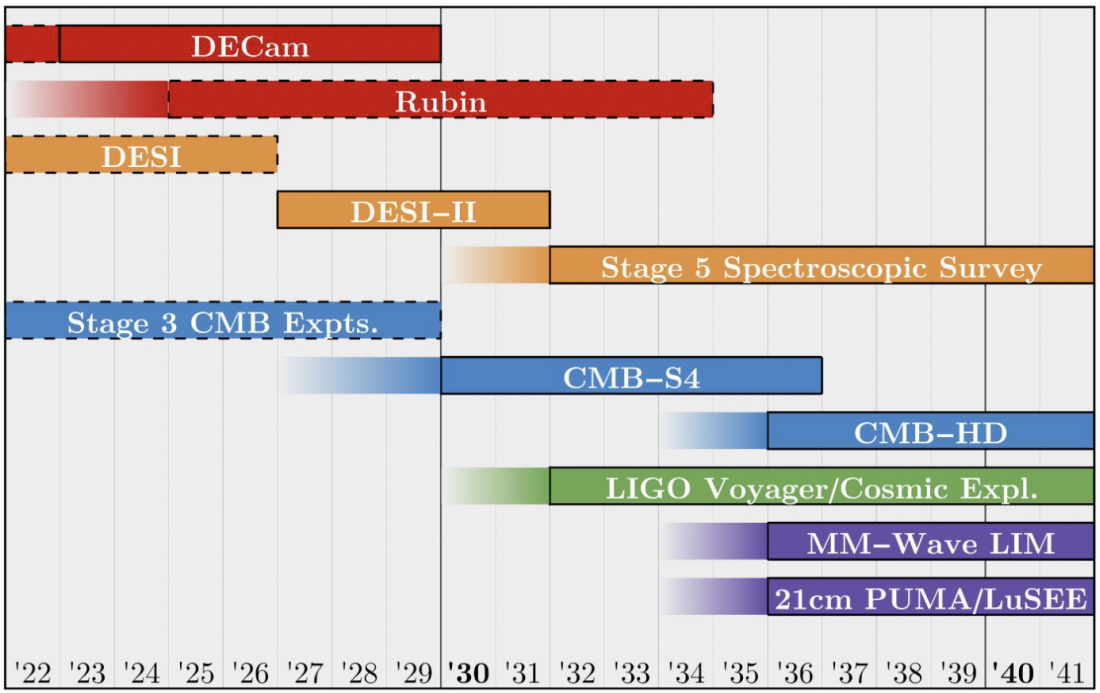


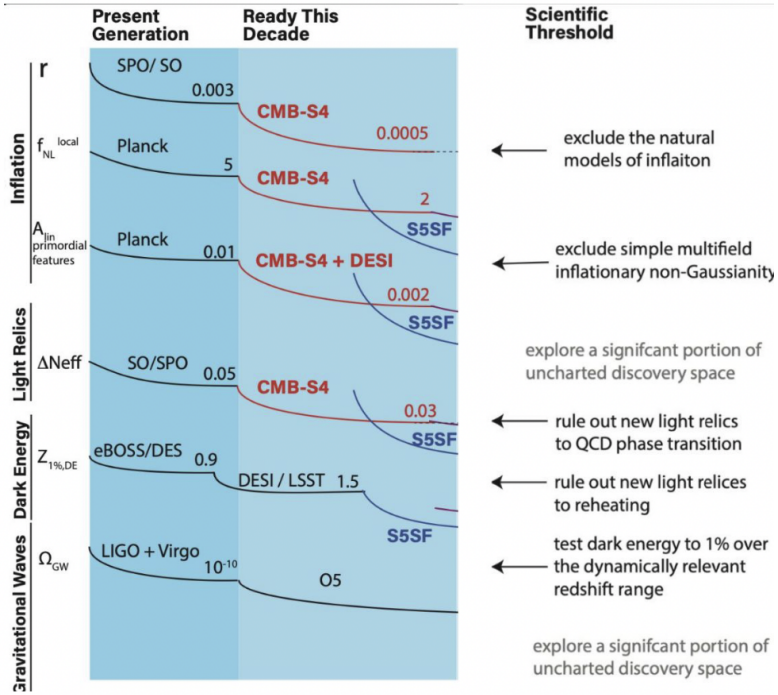
10 Spectrographs: 360-980 nm range

What is LSST?

- Legacy Survey of Space and Time (LSST) using Vera C. Rubin Observatory
- 8.4m telescope with 3.2 gigapixel camera
- 10-year survey imaging 18,000 sq deg of sky
- Will detect billions of galaxies and measure their shapes/colors
- Main science goals: Dark energy, dark matter, transients, Milky Way structure
- Timeline:
  - 2025: First light and commissioning
  - 2025-2035: Main 10-year survey

Rubin Observatory and DESI, DESI-II, Stage 5 Spectroscopy Survey in Snowmass Cosmic Frontier

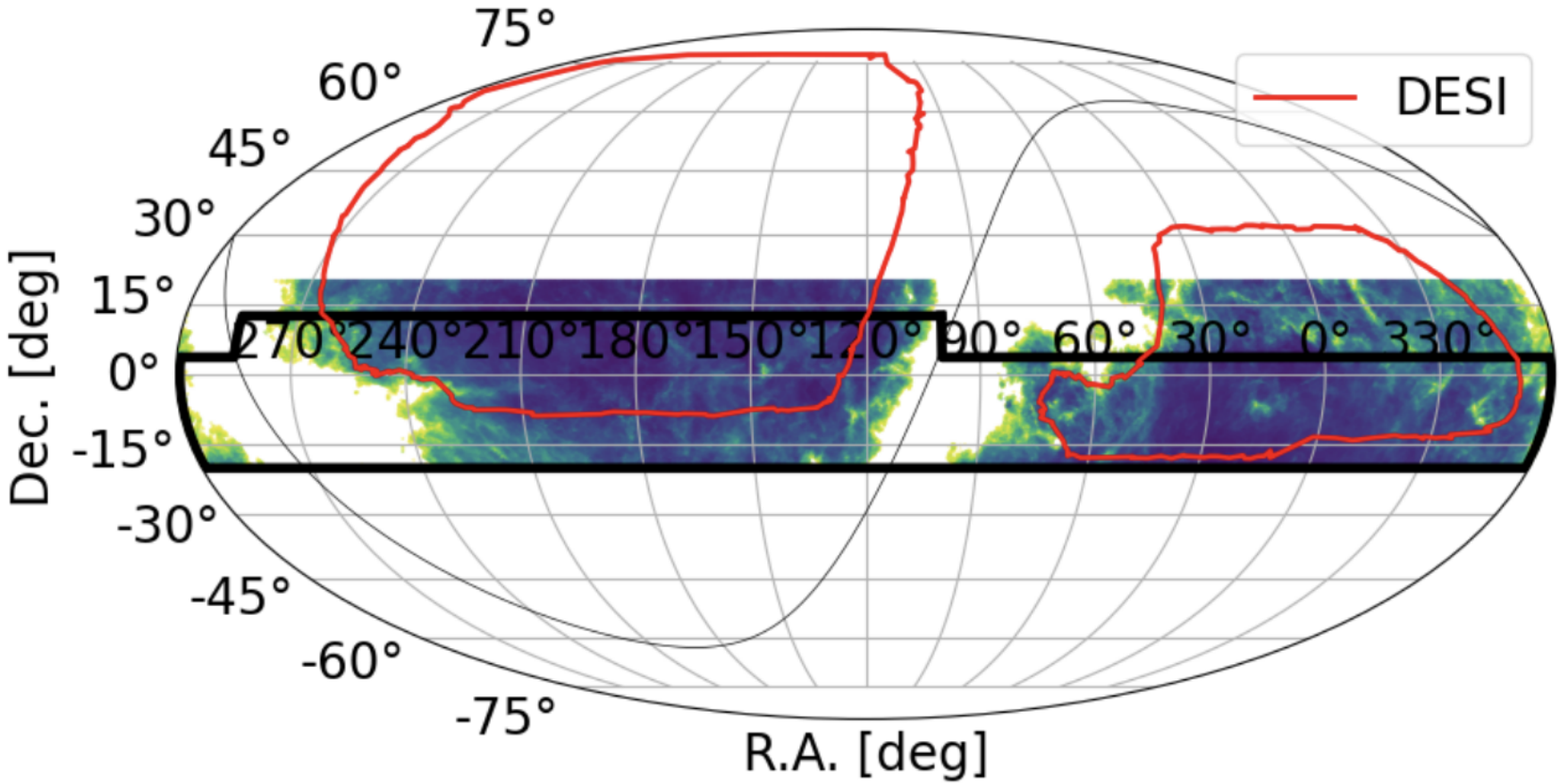




Credit: Tim M.P. Tait, Cosmic Frontier Science Highlights, Snowmass 2022

DESI and LSST Overlap

- DESI covers ∼4000 sq deg of LSST footprint
- Complementary data:
  - DESI: Precise spectroscopic redshifts
  - LSST: Deep multi-band imaging, shapes, light curves
- Enables powerful joint analyses
- DESI-II upgrade could increase overlap to ∼11,000 sq deg



Key Synergy: Photometric Redshift Calibration

- LSST science requires accurate photo-z's for billions of galaxies
- DESI spectra provide "truth" sample to calibrate LSST photo-z's
- Methods:
  - Direct calibration with overlapping spec-z's
  - Clustering redshifts using cross-correlations
- Reduces systematic uncertainties in LSST cosmology

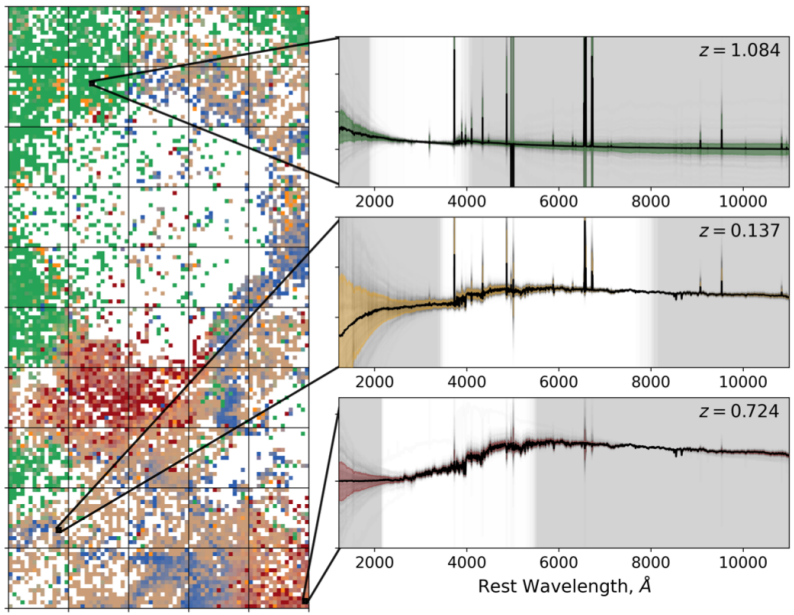
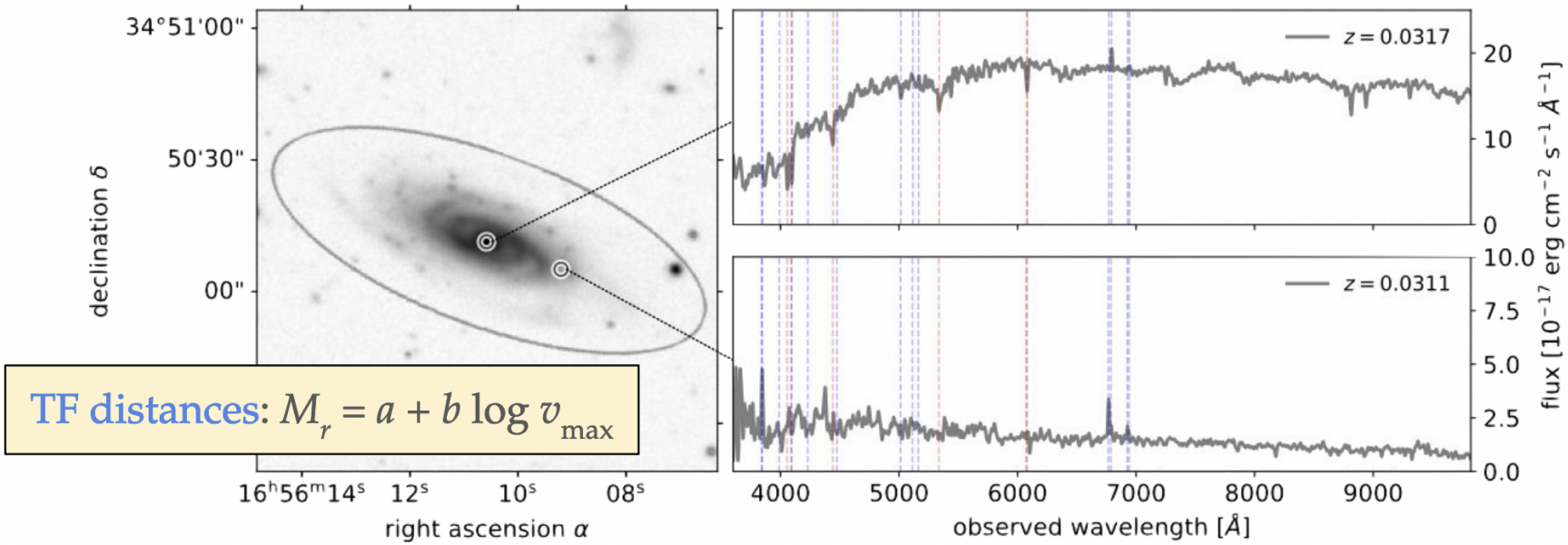


Figure 5. Depiction of the SOM with four complementary samples, post completeness cuts: Emission Line Galaxies (green), Luminous Red Galaxies (red), the

Key Synergy: Peculiar Velocities

- Measure galaxy peculiar velocities using:
  - DESI spectroscopic redshifts
  - LSST Type Ia supernova distances
- Probe growth of structure at $z < 0.1$
- $\sim$5% constraint on $f\sigma_8$ with 5000 SNe in 5 years
- Complementary to higher-z probes from BAO/RSD

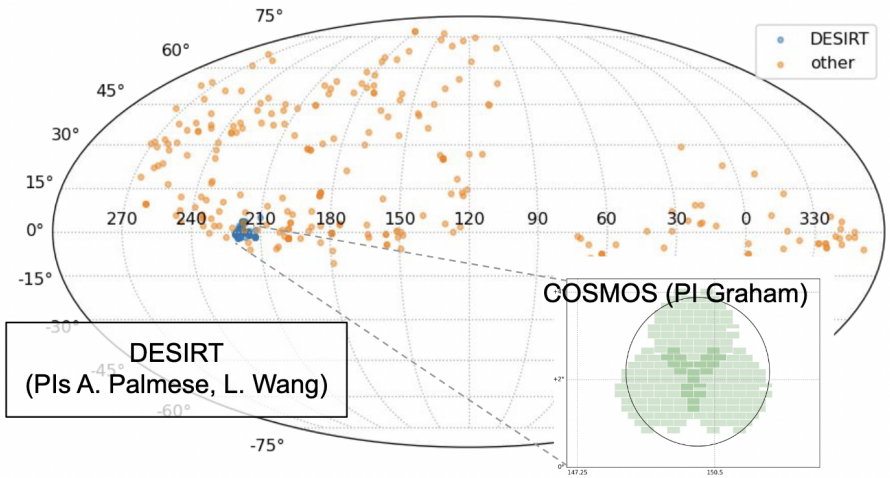
Credit: K. Douglass+ (in prep)



https://project.lsst.org/meetings/rubin2022/sites/default/files/Rubin%20Community%20Workshop_%20DESI%20Transients%20-%202022-08-11.pdf

Key Synergy: Transients and Multi-Messenger Astronomy

- LSST will discover millions of transients
- DESI enables:
  - Host galaxy redshifts for SNe, GW events, etc.
  - Spectroscopic follow-up and classification
  - Peculiar velocity measurements with SNe Ia
- Joint LSST+DESI programs:
  - DESIRT: DECam+DESI transient follow-up
  - ToO observations of multi-messenger events



DESI can provide systematic spectroscopic follow-ups of active LSST transients.

DESIRT (DECam+DESI program); see AstroNote 2022-107.

XMM-LSS and COSMOS DDFs to be used as **DESI calibration fields** every lunation. Many free fibers for ToOs!

Test recommendation engines like RESSPECT using DECam. Present focus: SNe. Future: unusual transients and outliers. **Identify new classes** and measure their number density.

https://project.lsst.org/meetings/rubin2022/sites/default/

Key Synergy: Milky Way Science

- DESI Milky Way survey: $\sim$10 million stars over 15,000 sq deg
- Combines with LSST proper motions and photometry
- Science cases:
  - Stellar streams and MW halo structure
  - Dwarf galaxy kinematics and dark matter
  - White dwarf science
  - Calibrate stellar metallicity relations
- DESI enables radial velocities for faint LSST stars

Other Synergies

- Galaxy intrinsic alignments
- Strong lensing
- AGN/quasar science
- Kinetic SZ effect
- stellar metallicities: photometric relation calib., stellar nucleosynthesis, chemical evolution

Uniandes Contributions to DESI

1 Faculty (Forero-Romero), 2 postdocs (García, Sierra-Porta), 1 graduate student (Suárez-Pérez).

- Data Systems: Software infrastructure for fiber assignment and target selection (J.E Forero-Romero)
- Survey Operations: Daily instrument operations support and spectroscopic reduction verification (J.E. Forero-Romero)
- Survey Design: Software development for survey design and validation (J.E. Forero-Romero)
- Bright Galaxy Survey (BGS): Design and validation (D. Sierra-Puerta)
- Lyman-alpha measurements: Creation of realistic datasets (L. A. Garcia)
- Outliers: Machine Learning techniques for finding data outliers (J.F. Suarez-Perez)
- Recurring support for observation shifts

Uniandes Experience with LSST-France

Collaboration with Marseille to use LSST Science Pipelines (LSSTsp) for SNIa detection (J. P. Reyes & M. Hernández).

- Pipeline stages:
  - Generation of Difference Images
  - Candidate Selection
  - Type Ia Supernova Identification
- Key improvements:
  - Input Selection for better quality coadditions
  - DIASource labeling (positive, negative, dipole, fringe, artifact)
  - Light curve generation and selection criteria
- Results:
  - 80% reduction in total detections
  - 75-78% of injected SNIa recovered
  - 85% of SNLS-reported SNIa preserved among candidates
  - Machine learning classification: F1-score of 0.96 (simulated) and 0.92 (real data)
- Demonstrates potential for efficient SNIa detection in large-scale surveys

Conclusions

- DESI and LSST are world-leading cosmic surveys this decade
- Combining spectroscopy + imaging enables unique science
- Key synergies in cosmology, transients, and Milky Way studies
- Increased DESI+LSST overlap in DESI-II would enhance science
- Coordinated observations and analysis critical to maximize return
- **Uniandes is a DESI participating institution and already has experience directly collaborating with LSST scientists (LSST France).**