



# Early strong lensing science with the LSST

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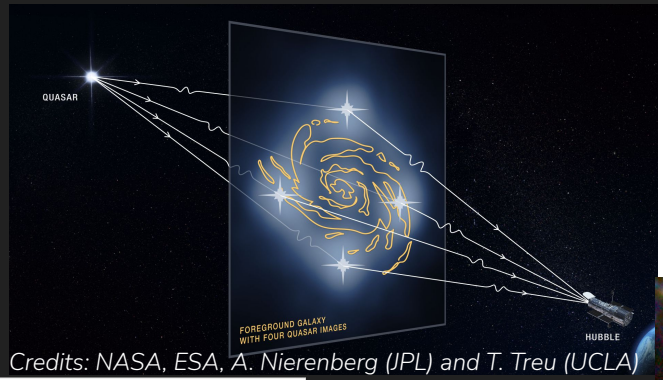
# SL: A tool/probe for diverse science objectives

**Selected Objectives:**

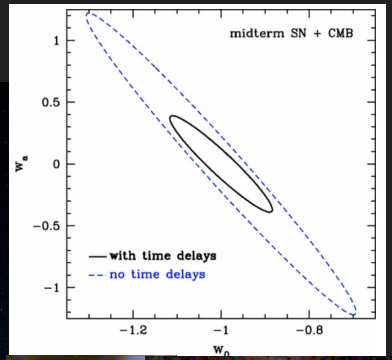
- **Weighing galaxies**: Galaxy mass and dark matter (sub-)structure of $10^{4\text{-}5}$ lenses
- **Cosmography**: Lensed QSO, SNe & transients, double source plane lenses
- **Calibrating the cluster mass function**: SL+WL constraints on DM in 100 clusters
- **Quasar microlensing**: accretion disk structure of 1000 lensed AGN + IMF of lensing galaxies
- **Cosmic Telescopes**: Hi-res properties of high-redshift galaxies
- **Rare and Exotic** lenses
- *many more...*

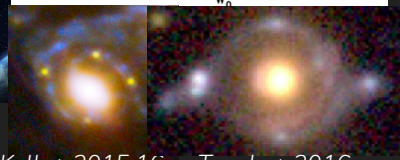
**All can be started in early science**

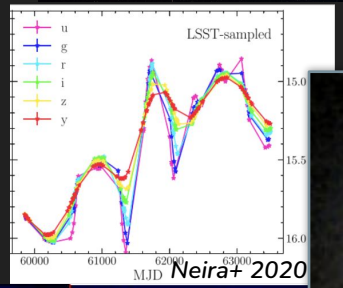


Credits: NASA, ESA, A. Nierenberg (JPL) and T. Treu (UCLA)

Linder 2011

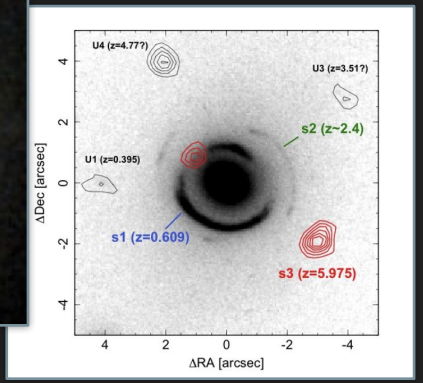


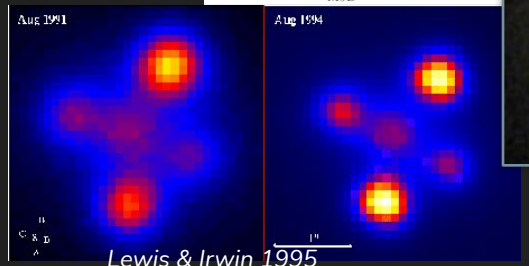


Kelly+ 2015,16 Tanaka+ 2016



Neira+ 2020


Collett & Smith 2020



Lewis & Irwin 1995

# What can we do early?

Single visit depths on any part of the sky are going to yield strong lenses from day 1

**We will find new lenses**

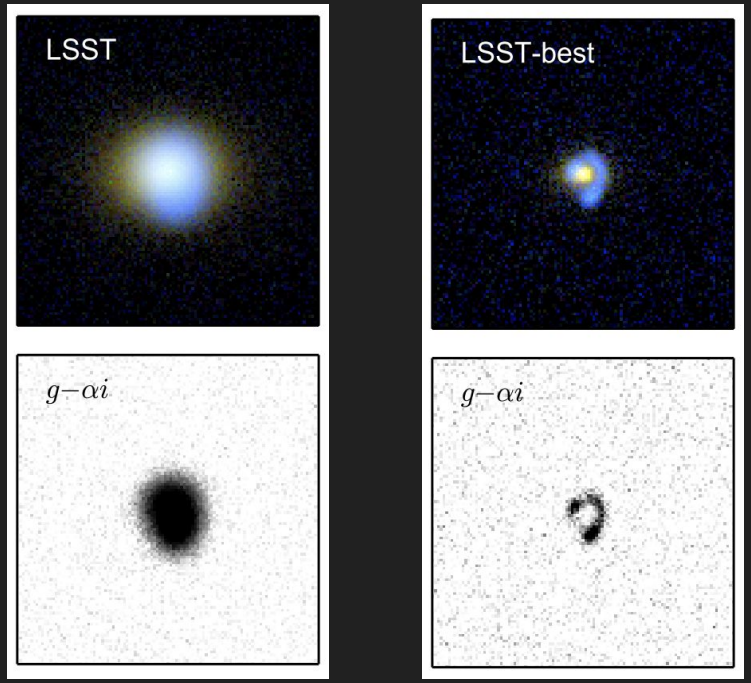
Key targets as these are the goldens sample for which FUP with 8m-ELT type telescopes will be possible

Monitor list for SL transients:

- Quasars
- SNe/GRBs
- Gravitational wave sources

Without monitoring new & known lenses, strongly lensed transients may be unidentified in the regular transients stream

**Maximise image quality**




Collett et al. 2015

Simulated LSST gri and g-$\alpha$i images of lens, full depth and best seeing composite and difference image

Don't necessarily need all the depth, but the *best* seeing can help lens discovery

# SL Quasars and SNe as commissioning targets

A Challenging use case (Smith, Verma, Collett et al.)

Strongly lensed quasars and supernovae around massive galaxies - source/lens crowding & complex backgrounds

For SL, of any kind, **high IQ is very important**

Potential to deliver insight in a different way to regular point sources

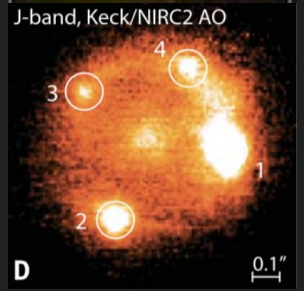
Use these complex cases to test and deliver the best possible performance considering active optics over the focal plane

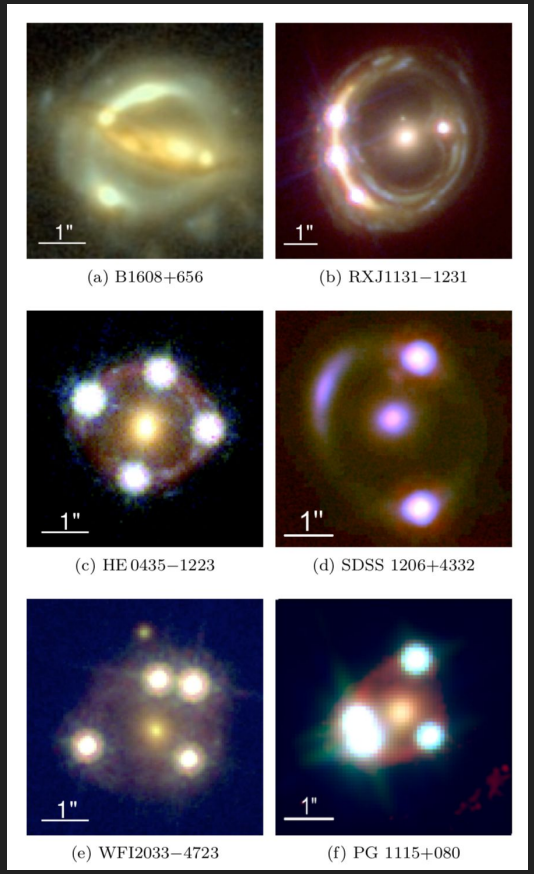
Key params: seeing, photometry (flux ratios), airmass, off-axis angle, active optics and detector parameters, and observing strategy.

- Span a wide range of RA
- Well matched to single-visit depth
- filler/snapshot target list

Provide hands-on effort to work with the SIT-Com to analyse results

**Ensure high image quality & synergies with many other science cases and technical issues**

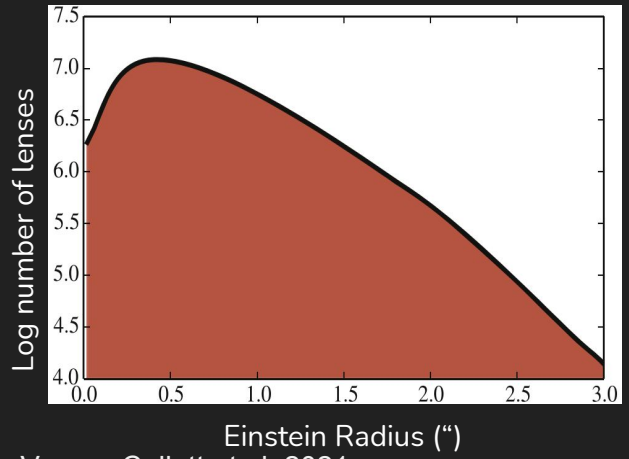


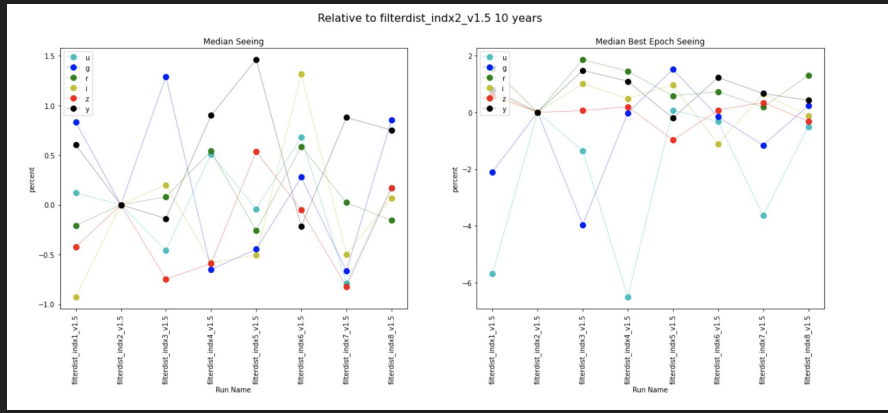
# SL Observing Strategy Input

- ★ Requirements for general strong lens discovery *Verma, Collett+ arXiv:1902.05141*
  - Wide area with reasonable sensitivity in all bands (increases sample size) - *early reference survey* achieved in Y1 all strategies
  - Good image quality (to discern lensed images from lenses, better $R_{ein}$ sampling, accurate image positions, majority have low $R_{ein}$)
  - Blue sensitivity (detect typically blue SFGs)
    - Good "blue"/g-band seeing
- ★ Strongly Lensed Gravitational Wave events *Smith+ arXiv:1902.05140*
  - ToO modes & early reference survey

Theoretical Einstein Radius distribution




Anguita, Verma, Collett et al. 2021




Early Science: WFD-like best single or good IQ stacks - much achieved with ERS/Y1

# Summary

## SL can achieve rapid science from day 1

- Early single-visit WFD-like reference survey
- Good image quality over all bands
- Preserving good image quality in the blue
- ‘Golden samples’ needed for transients (templates) and follow-up
- Feed into Rubin’s Early science/alert generation discussion

## Commissioning

- Unique lensed QSO/SNe targets
- Ensure IQ is maximised
- Synergies with other science areas

## Join us!

https://sites.google.com/view/lsst-stronglensing