Searching for Strong Gravitational Lenses with LSST

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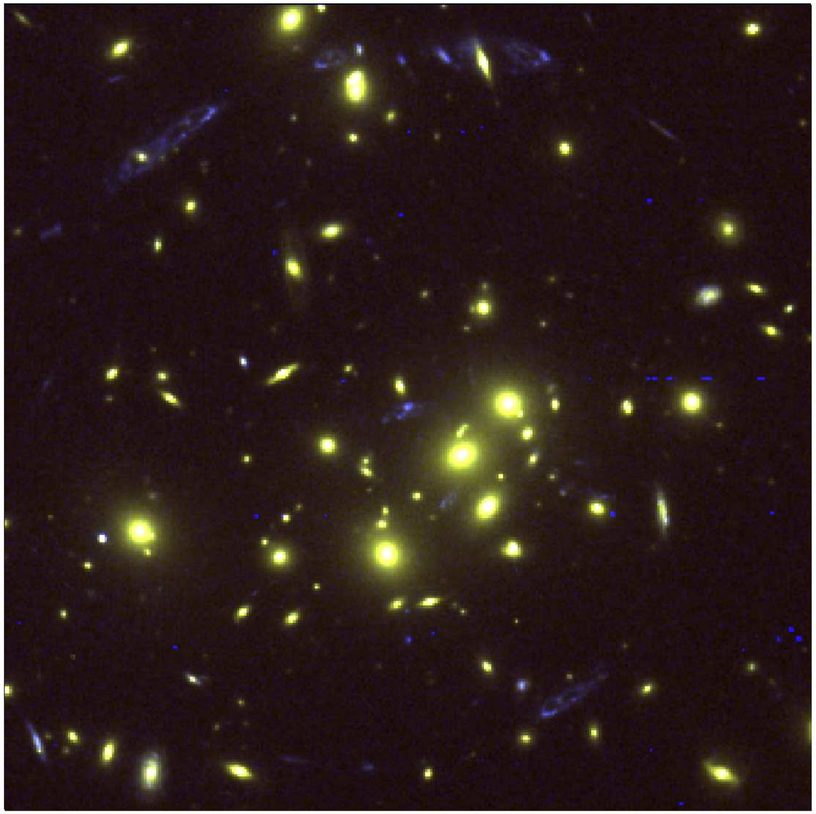
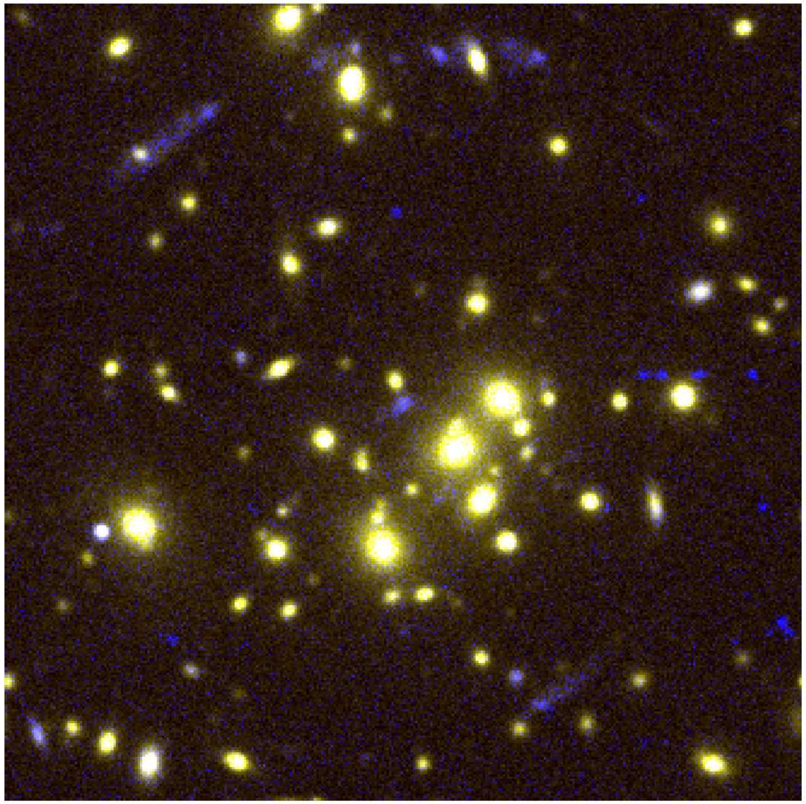
Overview

- Strong gravitational lensing: multiple image systems
- LSST: good imaging capability and unprecedented optical sky coverage
- Strong lens surveying:
  - Limited to wide image separations by PSF
  - Multi-colour dataset vital
  - Time dimension is opened up
  - Synergy with other telescopes
- Work in progress – some example science projects

Experiments

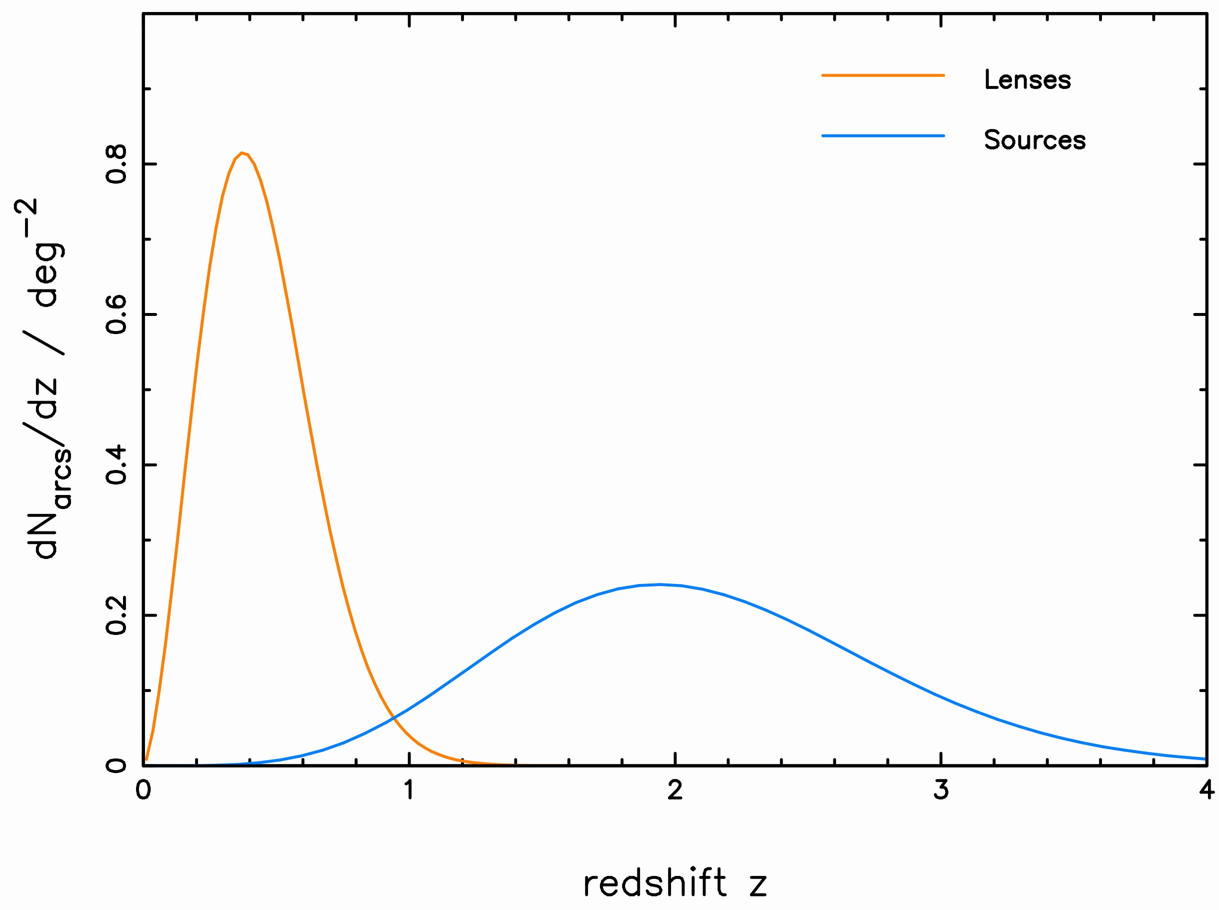
- Cluster lenses:
  - Giant arcs
  - Arc statistics, mass measurement
- Lensed AGN:
  - Pointlike, variable, easier to detect
  - Wide separation lenses, time delays
  - LSST alone: galaxy mass distributions
  - LSST + high resolution follow-up: H_0
- Rare lensing events:
  - Large lensed volumes
  - High magnifications, unusual image configurations
  - Double lenses

Cluster lenses

- CL0024+1654 with HST from Colley et al (1996)
- Ground-based searches underway: ~ 100 arcs

Arc counts



- Optical depth from numerical simulations (Dalal et al 2004)
- 6000 arcs with $l/w > 10$

Cluster lens applications

- Finding:
  - Focus search on photometrically-identified galaxy overdensities
  - Automated arc-finding
  - Sample of very wide separation images
- Multiple image systems: cosmography (need large sample, Meneghetti et al 2004, Dalal et al 2004)
- Monitoring. . .
- Mass measurment: greater accuracy on high-end subsample of cluster masses
- Widest separations: at worst an indicator of good cosmic telescope, at best a powerful probe of structure formation models

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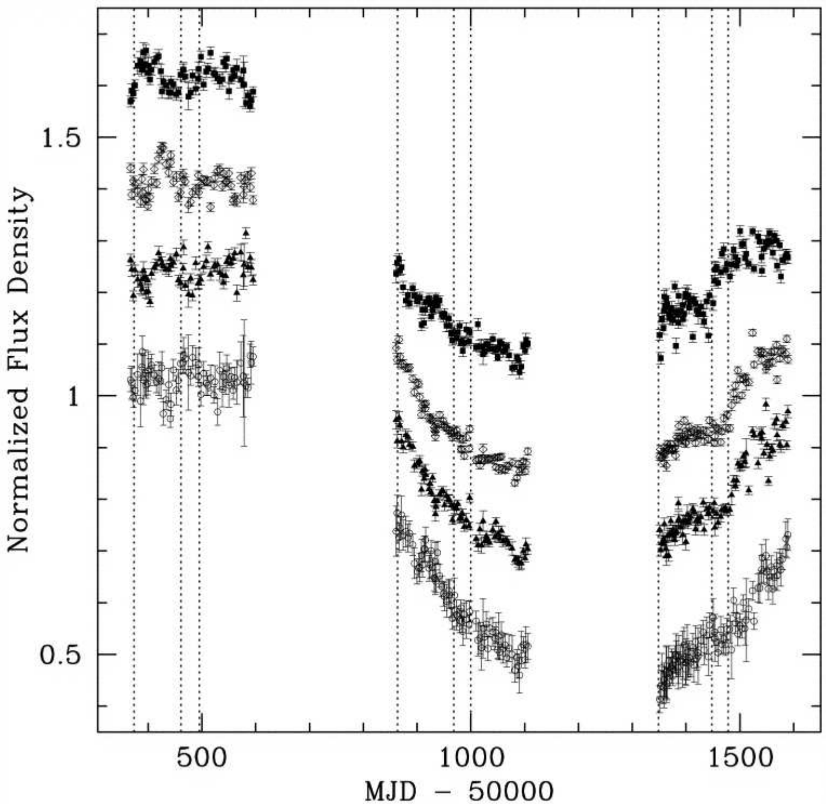
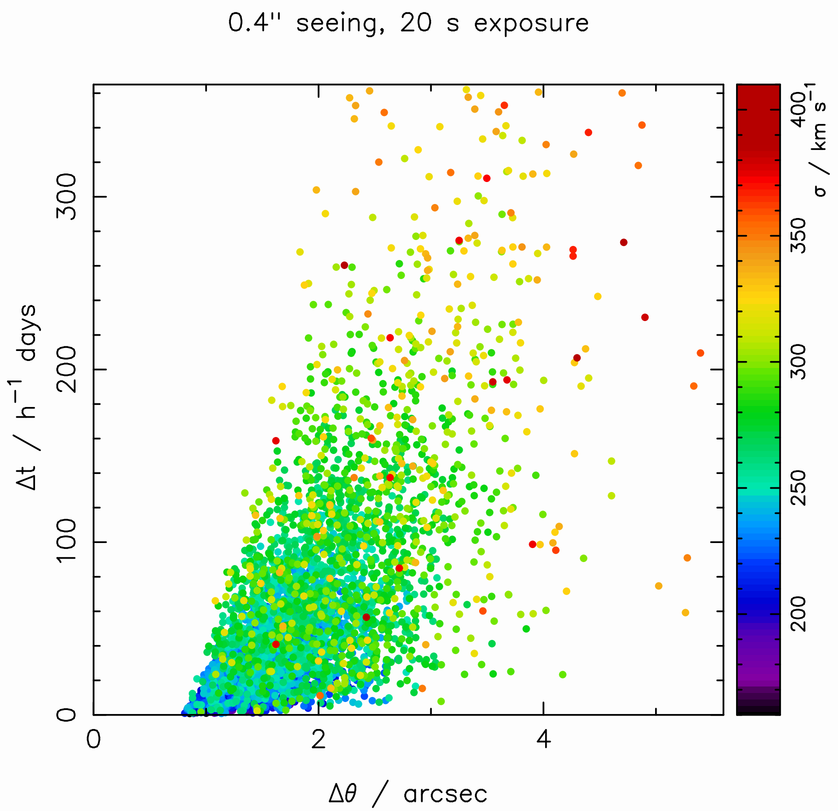
Measuring time delays



- B1608: $1 < \Delta\theta < 2$ arcsec, $30 < \Delta t < 80h^{-1}$days
- $\sigma_{\Delta t} \approx 1$day $\longrightarrow \sigma_{H_0} \approx 1 \text{ km s}^{-1}$ (Fassnacht et al 2002, Koopmans et al 2003)
- Requirements:
  - Photometry to 2%
  - 3 observing seasons of ~ 8 months
  - 2-3 day cadence
  - Total observing period of 3.5 years (220 exposures)
- Anticipated LSST performance:
  - Photometry to better than 2%
  - 10 observing seasons of ~ 4 months
  - 2-3 day cadence
  - Total observing period of 10 years (~ 500 exposures in 5 bands)

Experiment 1

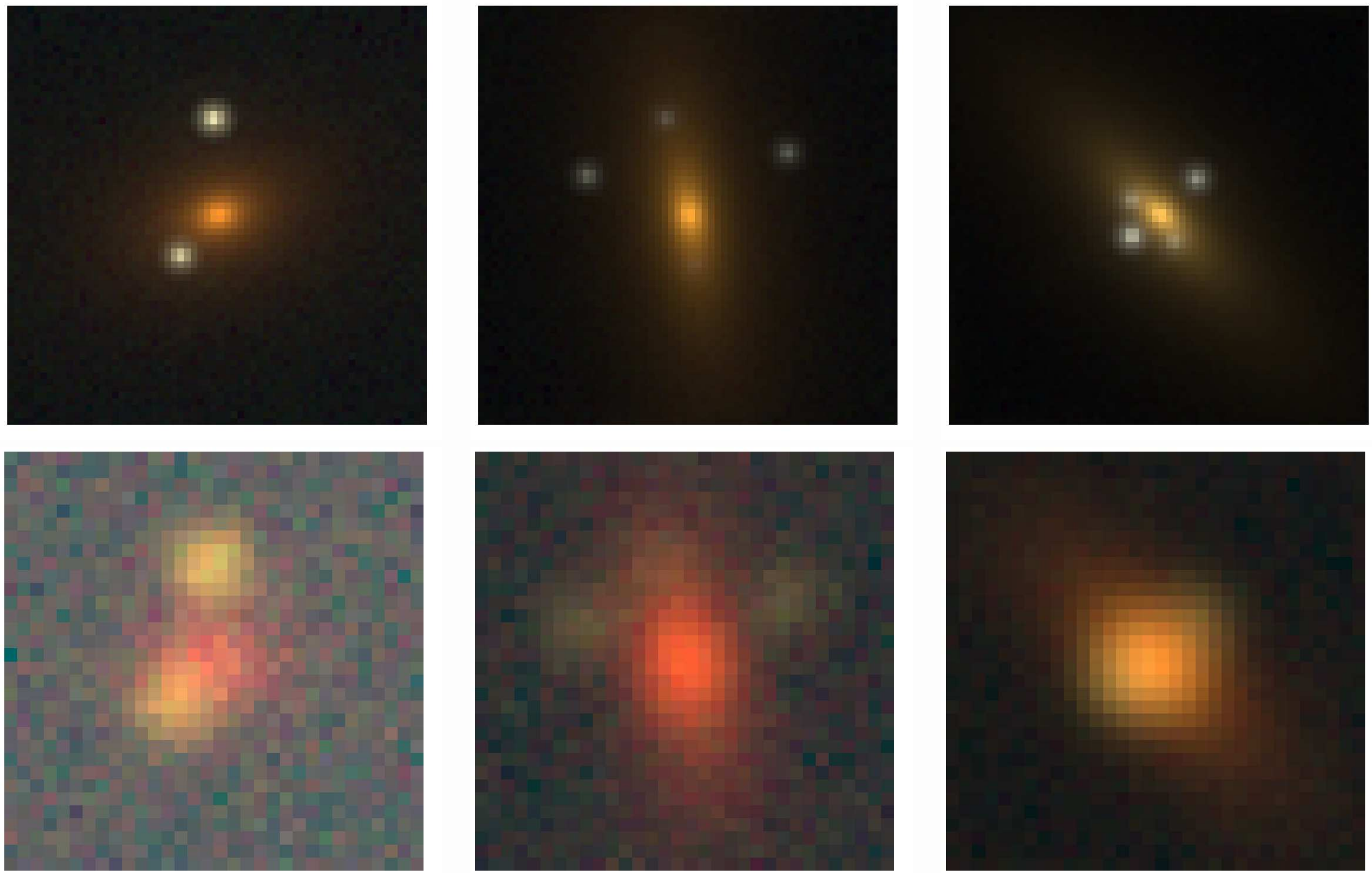


- Wide separation only (PSF limited): lens ID helped by Δt
- Not all image systems resolved all the time: statistical time delay modelling or high resolution follow-up required
- $\sim 10^3$ systems in 20000 sq. deg. (extrapolating 2dFQRS. . .)
- Massive elliptical galaxy lenses
- Time delay statistics probe inner halo profile (Oguri et al 2002)

Experiment 2

- Detect lenses at high resolution from elsewhere
- e.g. $\sim 10^3$ systems in 1000 sq. deg. SNAP WL survey
- Mostly elliptical galaxy lenses
- Archival LSST image data for time delays – joint analysis – deconvolution
- Good lens models $\longrightarrow H_0 \pm \sigma_{H_0}$

Image examples



- Elliptical SIE lenses, drawn from SDSS $\phi(v)$
- Deep space observations, 20 second LSST exposures

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Rare events

- Discovery space: rare lensing configurations
- Multiply-imaged supernovae:
  - ~ 1000 per year in 20000 sq. deg. (depending on SFR, Oguri et al 2003),
  - ~ 100 per year with LSST-observable image separations: challenge for photometry...
  - Light curve extends for few cadence periods, but not all sky surveyed at once
  - Expect ~ 1 per year to lie in a giant arc system
- Double lenses: cosmography?
- High amplifications, strong constraints on potential

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Rare events - demo

- 1 in 20 high redshift lensed sources may encounter two (merging) caustic networks (Moller and Blain 2001)
- High magnifications and strange image configurations can ensue
- Cross-volume is small – but HDF suggests $>> 100$ galaxy sources per sq. arcmin, many of them with compact cores…
- Cross-section increases with source redshift:

Outlook

- LSST will discover large numbers of wide image separation gravitational lenses
- The statistics of these objects place constraints on models of structure formation
- High resolution follow-up will be needed for some science projects, including measuring H_0
- Time delays can be measured well, and provide valuable extra information about the DM in galaxy-sized haloes
- You never know what you might find. . .