Strong lensing with Euclid

Metcalf et al, Bologna Lens Factory

Philippa Hartley, Neal Jackson, for the Strong Lensing SWG
SLSWG – Jean-Paul Kneib (EPFL), Massimo Meneghetti (OABO)

WP1 Theory
WP2 Galaxy lenses/evolution (joint with GAWG) (Jackson/Serjeant)
WP3 Cluster lensing
WP4 Cosmological likelihoods
WP5 Exotic lenses
WP6 Image simulations
WP7 Modelling
WP8 Finding

Full meetings every 6 months
(next one Jodrell Bank, Manchester, May 11-12 2015)
Scientific drivers for strong lensing

Mass distributions in galaxies


Top left: SLACS lenses: combination of lensing + stellar dynamics (Bolton et al. 2006, Koopmans et al. 2006):
“isothermal conspiracy”

Left: Combination of SL + stacked WL in SLACS (Gavazzi et al. 2007)

More recently:
- evolution of mass slope with redshift (Brownstein et al. 2012, Ruff et al. 2013)
- population analysis (Sonnenfeld et al. 2014) – individual galaxies less evolving vs. overall population change

Current sample sizes: ~100
Scientific drivers for strong lensing

Mass distributions in galaxies II: substructure

Missing satellite problem (Moore et al. 1999)

Flux ratio anomalies in radio quasars -> substructure
(Mao & Schneider 1998, Dalal & Kochanek 2002, Xu et al. 2011, 2012...) Sample size: 7 but can see small substructures

Mapping of substructure in extended lenses

Also: IMFs

Vegetti et al. 2012
Scientific drivers for strong lensing

Magnification and stretching of the sources

Submm: ID81 (Negrello et al. 2010)

THE FAINTEST RADIO SOURCE YET: EVLA OBSERVATIONS OF THE GRAVITATIONAL LENS SDSS J10044+4412

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ABSTRACT

We present new radio observations of the large separation, gravitationally-lensed quasar SDSS J10044+4412, taken in a total of 9 hours of observations with the Expanded Very Large Array (EVLA). The maps reach a thermal noise level of approximately 4μJy. We detect four of the five lensed images at the 15-20μJy level, representing a source of intrinsic flux density, after allowing for lensing magnification, of about 1μJy, intrinsically probably the faintest radio source yet detected. This reinforces the utility of gravitational lensing in potentially allowing us to study non-luminous sources before the advent of the SKA. In an optical observation taken three months after the radio observation, image C is the brightest image, whereas the radio map shows flux density ratios consistent with previous optical observations. Future observations separated by a time delay will give the bivariate flux ratios of the images in this source.

Subject headings: gravitational lensing--strong, -- quasars:individual(SDSS J10044+4412) -- radio continuum emissions

Jackson 2011 (JVLA of 1μJy RQQ)
Scientific drivers for strong lensing

Cosmology

Double-plane system
(Collett et al. 2012, Collett & Auger 2014)
Sample size: 1

Modelling + stellar dynamics + LOS corrections
-> H0, other cosmological parameters w/CMB (Suyu et al. 2012, 2013) Sample size: 10-20
Need more lenses

- statistical studies (wrt. z, Hubble type....)
- rare objects (cosmology)

Current samples: few hundred

Euclid (and LSST): tens of thousands

BUT

Finding them is non-trivial (false positives outnumber true positives)

Faure et al. 2008, COSMOS

Jackson 2008 (L: HST, R: Euclid)
Numbers: extrapolate from COSMOS

- 20 “easy”: any algorithm should find
- 5-10 more “harder”
- by eye: 50-100 candidates, a few probable, most unconvincing

-> sensitivity/resolution: divide by 2-3
-> area coverage: multiply by 20000

-> overall number: **200000 (cf. existing total of 500)**
First problem: galaxy subtraction
Joseph et al. 2014: PCA works better than Sersic
Next problem: identification of lensed structure
Joseph et al. 2014: PCA works better than Sersic
Tradeoff completeness: purity
Results from KiDS
Results from KiDS
Large image-recognition problem

Citizen science

Spacewarps.org
(Marshall, Verma, More, Geach et al.)
Large image-recognition problem

Citizen science

Spacewarps.org (Marshall, Verma, More, Geach et al.)

Tests using Bologna Lens Factory simulations (Metcalf et al. In prep)
Synergy with other surveys – e.g. SKA

- Independent surveys for rare objects are good because they have different sources of false positives
- Euclid and SKA are particularly complementary; see star-forming things with one and quiescent things with the other; similar source densities with SKA-final (lower with SKA1)
Synergy with other surveys – e.g. SKA

<table>
<thead>
<tr>
<th></th>
<th>EUCLID</th>
<th>SKA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lens is red</td>
<td>OK</td>
<td>Difficult</td>
</tr>
<tr>
<td>Lens has structure</td>
<td>Not good</td>
<td>Doesn't matter</td>
</tr>
<tr>
<td>Source is blue</td>
<td>Not good</td>
<td>OK</td>
</tr>
<tr>
<td>Source is faint</td>
<td>Not good</td>
<td>Fine if it has SF</td>
</tr>
<tr>
<td>Source often star-forming</td>
<td>OK</td>
<td>Very good</td>
</tr>
<tr>
<td>Source needs redshift</td>
<td>Really not good</td>
<td>Fine if it has gas</td>
</tr>
</tbody>
</table>

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Large image-recognition problem

Machine learning

- collaboration with Remi Flamary (Nice) – SVM applied to simulated data
- preliminary indications: does better than simple algorithms
- next steps: test against COSMOS and COSMOS convolved to Euclid resolution