Hexabundles & Gravitational Lensing

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**Gravitational Lensing**

**Key uses:**
- Magnifying distant sources
- Measure mass distributions (inc. dark matter)
- Probing cosmology

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Sydney 24th November 2008
One of the key gravitational lensing observables is multiple imaging. This is HST imaging of ER0047-2808 with the foreground galaxy removed.

Lensing reconstruction can reveal sub-arcsecond structure in the background source, as well as constraining the mass distribution in the foreground lensing galaxy.

The vast majority of reconstructions use photometric imaging, although techniques are improving to simultaneously reconstruct images at different wavelengths.
VLA observations slice through the CO(J=2→1) line at z=4.12, giving a series of images at slightly different velocities. The gravitational lensing inversion uses all the images to model the mass distribution and reconstruct the source structure. The CO gas is found to lie in a rotating disk on kiloparsec scales.
There is a growing sample of optical Einstein Rings, and any hexa-bundle galaxy survey will throw up more (e.g. anomalous emission lines). As well as revealing kinematic structure in the source, the spatially resolved galaxy dynamics will tighten the lensing mass.
Multiply imaged quasars can be subject to gravitational microlensing. This introduces time-dependent brightness variations that are dependent upon the size of the source. This allows us to “resolve” the structure at the heart of quasars down to sub-parsec scales.

We need spatially resolved spectra, although this is difficult with slits, and has proved tricky with IFUs.
Clusters of galaxies are amongst the most spectacular gravitational lensing systems. Multiple sources at differing redshifts allowing detailed mass distributions to be reconstructed, showing large- and small-scale dark matter structure.
As well as the striking giant arcs in the core, clusters also produce weaker shearing on very large scales.

Including these in a lensing reconstruction is vital to properly normalizing the overall mass distribution, using the lensing-induced ellipticity to constrain the larger-scale density profile.

However, we must know the cosmological distances for this normalization, and using photometric redshifts introduces errors.

Hence, with a survey of source redshifts, we can construct an accurate maps of the lensing mass distribution.
DARK MATTER
Most of the universe can’t even be bothered to interact with you.

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A real ring of dark matter?

Dark Matter Ring in Galaxy Cluster Cl 0024+17 (ZwCl 0024+1652)
Hubble Space Telescope • ACS/WFC

NASA, ESA, and M.J. Jee (Johns Hopkins University)

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Critical lines in A370

Sources that sit near caustics in the source plane appear as images near critical lines. These images are strongly magnified (i.e. this is where the giant arcs sit).

However, where the caustics and critical lines sit depends upon the lensing configuration. As we move to higher redshift, the caustic and critical lines tend towards the $z=\infty$ structure.

If you want to find sources at a particular redshift, then you should survey sources in the vicinity of the associated critical line (as these will be the most magnified and easiest to detect).
Z~7 sources in A2218

J.P. Kneib and collaborators know this!

What we need, however, is a deep spectroscopic survey of the high redshift candidates in the critical line regions.

As these highest redshift sources will be spatially extended, we can still recover the kinematic structure, giving clues to the earliest epochs of galaxy formation.
Weak lensing and cosmological parameters

A lot of the focus of future instruments is the use weak lensing to fix cosmological models (through the measurement of large scales shearing).

As before, the use of photometric redshifts introduces errors into the measure, so spectroscopic redshifts will significantly tighten constraints on parameters.
The End