Comparing baryonic mass estimates from Stellar Population Synthesis and total mass measurements via surface mass density reconstruction for lens galaxies opens a window to probe the dark matter content of early-type galaxies. With the photometric data for as many band passes as possible one can assemble pixel by pixel a generic galaxy with the same properties as the observed one in consideration of the most likely distribution of colours among the stars, assuming an initial mass function (IMF) and metallicity distribution and special chemical abundances for the lens galaxy to be synthesized. The pixel map out of the synthesis in combination with the reconstructed pixelated density mass map reveals a detailed view on the mass-to-light distribution within early-type galaxies. In the ongoing analysis a sample of 20 lens galaxies from the CfA Arizona Space Telescope Lensing Survey (CASTLES) can be used to study the interdependency between dark and luminous matter, such as which radius the dark halo becomes dominant over the stellar mass and how sharp this transition is. In the following we present first results for the lens B2045.

Measuring Baryonic Mass

In early-type galaxies the baryon budget is dominated by the stellar mass content. We estimate stellar masses using population synthesis models and the observed photometry from HST to set constraints on the star formation history (SFH).

Even though photometry is a poor way to determine stellar ages and metallicities, it can give good estimates of the stellar mass for a given Initial Mass Function.

As a first step a lensing galaxy at a certain redshift is observed through different passbands and compared with a large grid of exponentially decaying SFHs.

The synthetic spectral energy distribution is obtained by convolving simple populations from the models of Bruzual & Charlot (2003, 2008). This methodology reduces the formation history to three free parameters: metallicity, formation epoch and formation timescale.

Moreover we adopt a Chabrier (2003) initial mass function (IMF). Unlike the traditionally used Salpeter IMF - which assumes a single power law for all stellar masses - the Chabrier IMF has a more realistic distribution at low mass stellar masses. Ferreras et al. (2007) found that the Salpeter IMF predicted stellar masses higher than the (total) lensing mass within the core of some early-type galaxies.

Our method computes the stellar surface mass density within each pixel of the modeled galaxy along with a robust estimate of the statistical uncertainty related to the process of constraining M/L from photometry, as one can see in the colour-to-mass diagram. An assumed colour of F435W-F814W=2.0±0.1 gives e.g. a -0.2 dex uncertainty in the mass (see Mass-colour relations).

Measuring Total Mass

As a second step the total (lensing) mass is estimated using a non-parametric approach which consists of pixelating the system and exploring the surface mass density in each pixel using the image positions and time delays (if available) as constraints. The method generates an ensemble of models which are compatible with the observations and given constraints. The ensemble allows us to determine robust uncertainties on the total surface mass density distribution. This method is explained in detail in Coles (2008).

A JAVA applet (PixeLens) can be run from http://www.qgd.uzh.ch/projects/pixelens/

Stellar-to-Total Mass Map

Combining the above two outputs a false colour stellar-to-total mass map is computed, which carries three pieces of information in each pixel: The intensity scales with the total surface mass density, the colour gives the ratio between stellar and total mass within each pixel of the modeled galaxy along with a robust estimate of the statistical uncertainty related to the process of constraining M/L from photometry, and finally, the uncertainty of this ratio is coded in the hue of the colour.

A galaxy assumed to be at redshift z=0.5 (red), 0.3 (green) or 0.1 (blue) here exemplarily observed through B and I passbands is pixel by pixel reconstructed to be of exponentially decaying SFHs. Colours / grey shades for each redshift correspond to two different formation epochs: z=0.5 and 2, respectively.

References:

Stellar-to-Total Mass Map

Baryon-dominated regions appear red and dark matter-dominated regions appear blue. Strong red/ blue tones representing an exact measurement and pale red/blue corresponding to a 20% error.

A lens in 3 different bands

We take photometric data for as many band passes as possible. In this case, this is done for the quadruplet lens B2045 in H, I, and v band.

Models

By careful removal of possibly contaminating light emissions from nearby objects and the multiply-imaged source an exclusive model of the central mass is obtained in each band.

Mass-colour relations

A galaxy assumed to be at redshift z=0.5 (red), 0.3 (green) or 0.1 (blue) here exemplarily observed through B and I passbands is pixel by pixel reconstructed to be of exponentially decaying SFHs. Colours / grey shades for each redshift correspond to two different formation epochs: z=0.5 and 2, respectively.

Lensing Mass Map

The surface mass density map shows the contours of equal surface density and the image positions of the lensing system (red circles), Box size 6" x 6''.