A weak lensing analysis of Compact Groups

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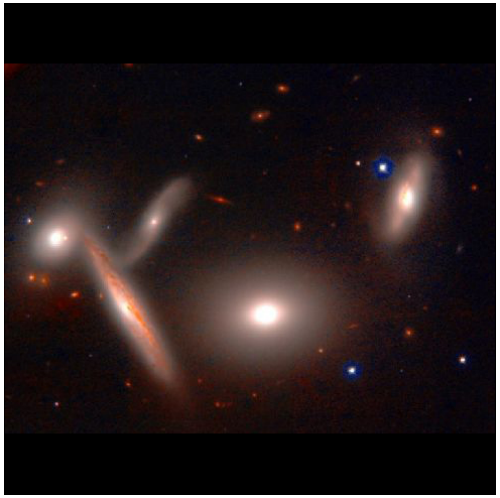
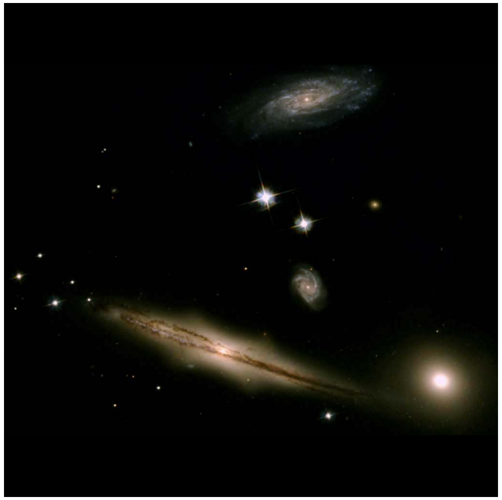
What are Compact Groups?

4 to 6 galaxies in a compact configuration





Hickson criteria (1982):

$$N\,(\triangle m = 3) \geq 4\,, \qquad \text{(Richness)}$$

$$\theta_N \geq 3\theta_G\,, \qquad \text{(Isolation)}$$

$$\mu_G \leq 26{,}0\ \text{mag arcsec}^{-2} \qquad \text{(Compactness)}$$

Lensing with Compact Groups?

- Hickson's original CGs were too close (z~0.03) to detect a lensing signal.
- Mendes de Oliveira & Giraud (1994) predicted that these systems at **z~0.1** could produce a detectable signal.

Sample of CGs

McConnachie et al. (2009) catalogues based on SDSS-DR6:

Hickson's criteria
+70k CGs
~30% are genuine bounded systems (McConnachie et al. 2008)

Catalogue A:	Catalogue B:
r<18	r<21
2297 CGs	74791 CGs

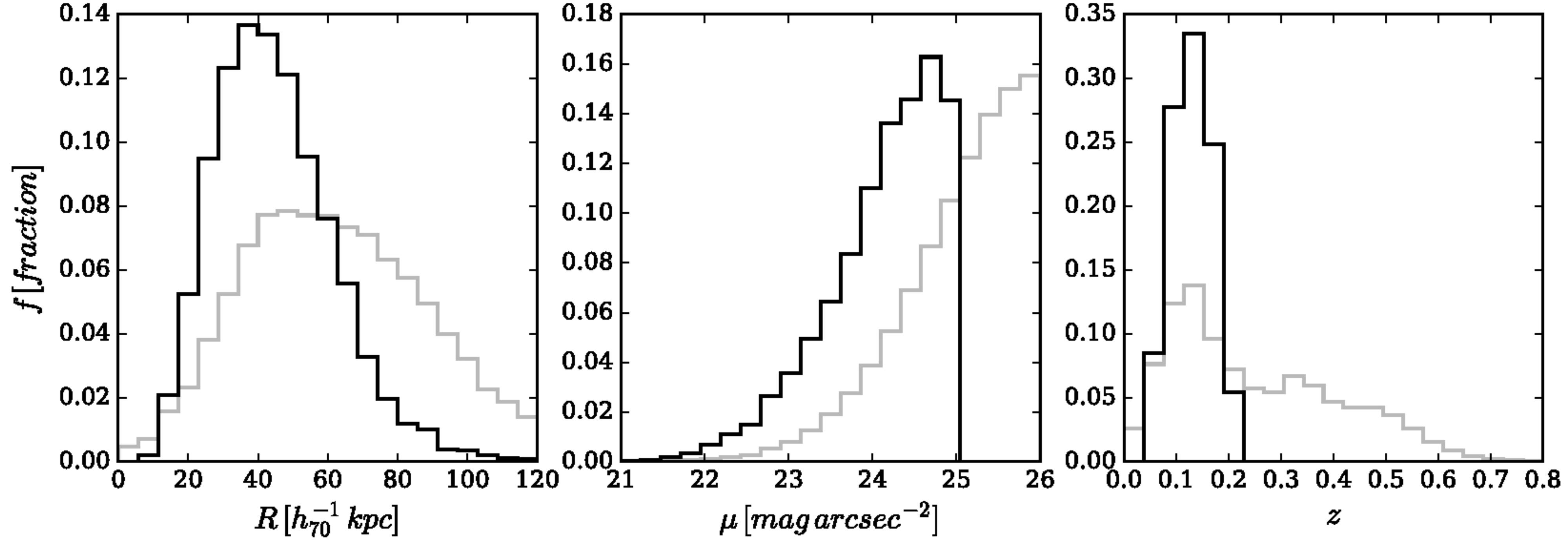
Sample selection from B:
$0.06 < z < 0.2$
$\mu_G < 25$ mag arcsec^{-2}
6257 CGs selected

→

We use frames with
seeing < 1.3 arcsec:
Final sample of 5568 CGs

Sample of CGs

CGs parameter distributions



Stacking technique

Shear:

$$\gamma_{\mathrm{T}}(r) = \bar{\kappa}(< r) - \bar{\kappa}(r)$$

Density contrast
(redshift independent):

$$\tilde{\gamma}_{\mathrm{T}}(r) \times \Sigma_{\mathrm{crit}} = \bar{\Sigma}(< r) - \bar{\Sigma}(r) \equiv \Delta\tilde{\Sigma}(r)$$

$$\boxed{\langle \Delta\tilde{\Sigma}(r) \rangle = \frac{\sum_{j=1}^{N_{\mathrm{Lens}}} \sum_{i=1}^{N_{\mathrm{Sources},j}} \omega_{ij} \times e_{\mathrm{T},ij} \times \Sigma_{\mathrm{crit},j}}{\sum_{j=1}^{N_{\mathrm{Lens}}} \sum_{i=1}^{N_{\mathrm{Sources},j}} \omega_{ij}}}$$

$$\Sigma_{\mathrm{crit},j} = \frac{c^2}{4\pi G} \frac{1}{\langle \beta_j \rangle D_{\mathrm{OL}_j}}$$

$$\sigma^2_{\Delta\tilde{\Sigma}}(r) = \frac{\sum_{j=1}^{N_{\mathrm{Lens}}} \sum_{i=1}^{N_{\mathrm{Sources},j}} (\omega_{ij} \times \sigma_\epsilon \times \Sigma_{\mathrm{crit},j})^2}{\left(\sum_{j=1}^{N_{\mathrm{Lens}}} \sum_{i=1}^{N_{\mathrm{Sources},j}} \omega_{ij}\right)^2}$$

$$\left(\frac{S}{N}\right)^2 = \sum_i \frac{\langle \Delta\tilde{\Sigma}(r_i) \rangle^2}{\sigma^2_{\Delta\tilde{\Sigma}}(r_i)}$$

Miscentring issue

Convolution given by (Yang et al. 2006):

$$\Sigma(r|r_s) = \frac{1}{2\pi}\int_0^{2\pi} \Sigma\left(\sqrt{r^2 + r_s^2 + 2r\, r_s \cos\theta}\right) d\theta$$

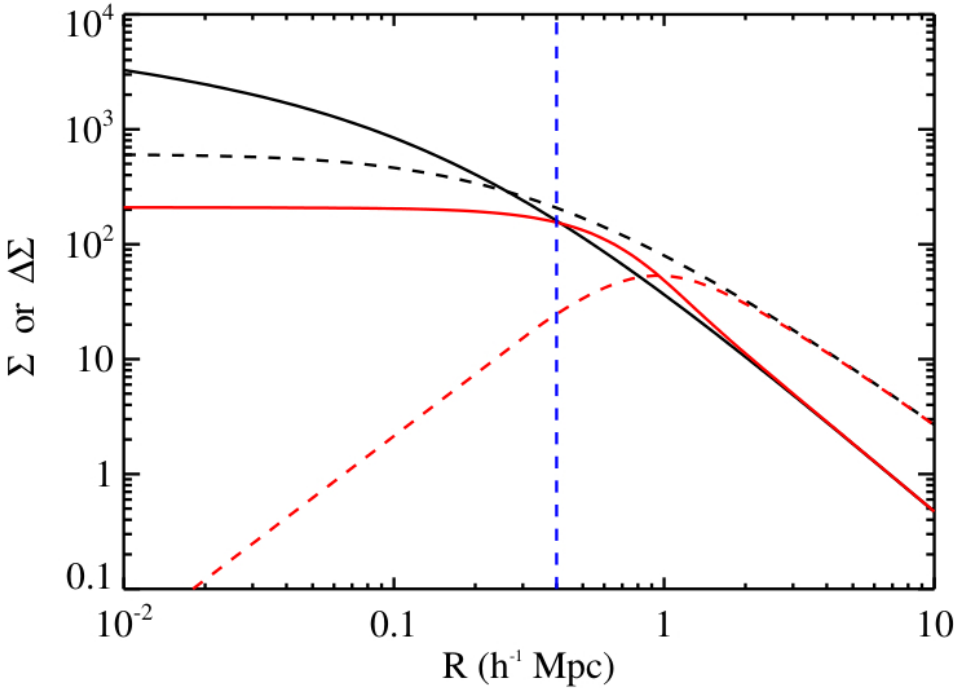
$$P(r_s) = \frac{r_s}{\sigma_s^2} \exp\left(-\frac{1}{2}(r_s/\sigma_s)^2\right)$$

$$\Sigma_s(r) = \int_0^{\infty} P(r_s)\Sigma(r|r_s) dr_s$$

We asume for CGs:

$\sigma_s = 40\ h_{70}^{-1} kpc$

$\sigma_s = 0.42\ h^{-1} Mpc$



(Johnston et al. 2007)

Physical models

We fit the halo profile with:

Singular Isothermal Sphere (SIS)

Parameter: σ_V

$$M_{200} = \frac{2\sigma_V^3}{\sqrt{50}GH(z)}$$

Navarro, Frenk & White (1997) (NFW)

Parameters: R_{200}, c_{200}

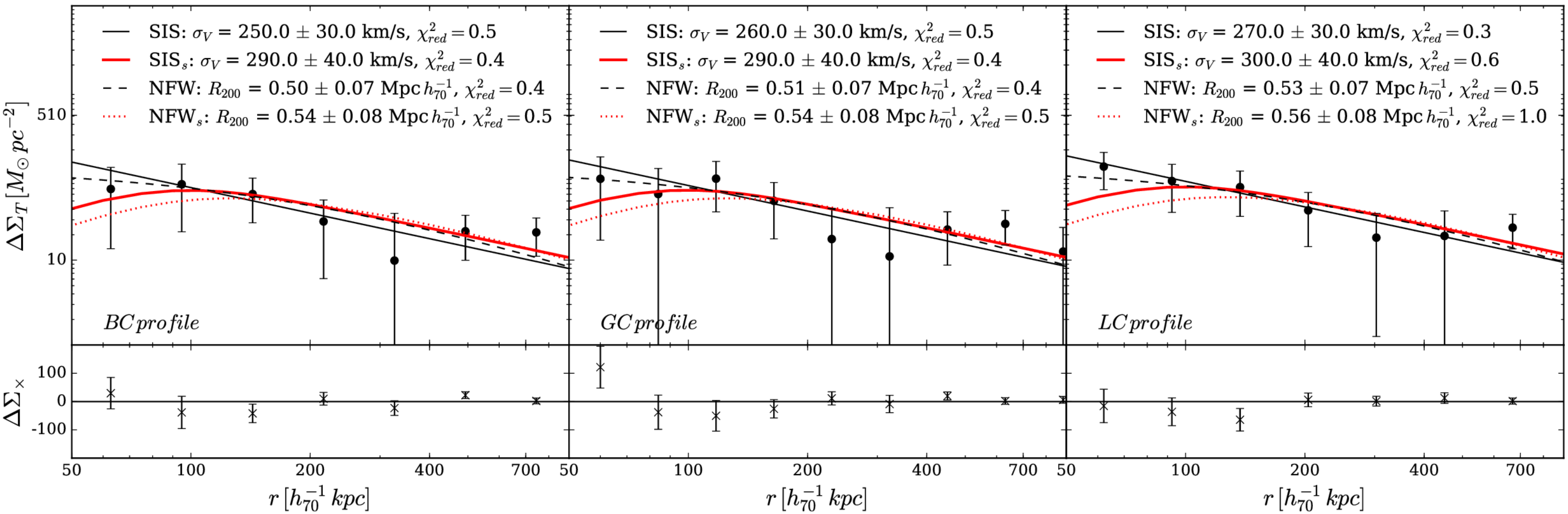
$$M_{200} = 200\rho_{crit}(z)\frac{4}{3}\pi R_{200}^3$$

$$\chi^2 = \sum_i^N \frac{(\langle\Delta\tilde{\Sigma}(r_i)\rangle - \Delta\tilde{\Sigma}(r_i, p))^2}{\sigma^2_{\Delta\tilde{\Sigma}}(r_i)}$$

Centre analysis

3 Centre Choices

Brightest member (BC) | Geometrical centre (GC) | Luminosity-weighted (LC)



Centre	SIS		SIS$_s$		NFW			NFW$_s$			S/N
	σ_V	M_{200}	σ_V	M_{200}	c_{200}	R_{200}	M_{200}	c_{200}	R_{200}	M_{200}	
BC	250 ± 60	14 ± 8	290 ± 60	21 ± 13	4.54 ± 0.23	0.50 ± 0.11	16 ± 11	4.38 ± 0.22	0.54 ± 0.12	21 ± 13	4.0
GC	260 ± 50	15 ± 10	290 ± 60	21 ± 13	4.51 ± 0.22	0.51 ± 0.11	17 ± 11	4.38 ± 0.22	0.54 ± 0.12	21 ± 14	4.2
LC	270 ± 40	17 ± 8	300 ± 60	24 ± 12	4.45 ± 0.21	0.53 ± 0.10	19 ± 11	4.33 ± 0.21	0.56 ± 0.11	22 ± 13	4.6

Dependence of the lensing signal on CG physical properties

6 subsamples using the median value of:

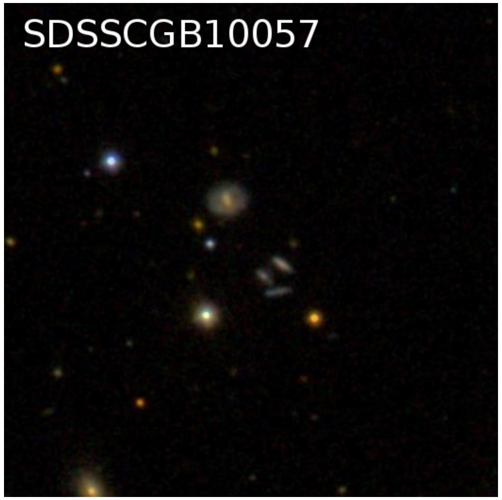
Physical radius: R

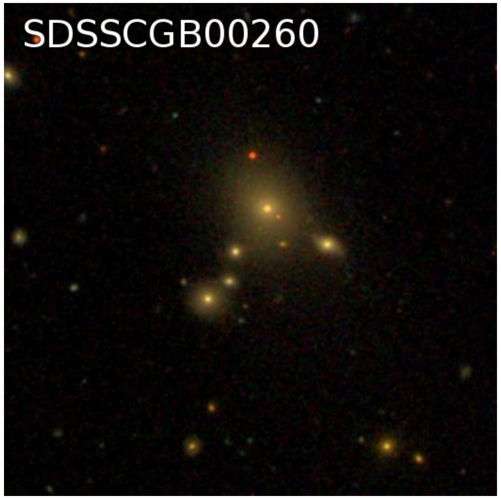
Surface brightness: μ

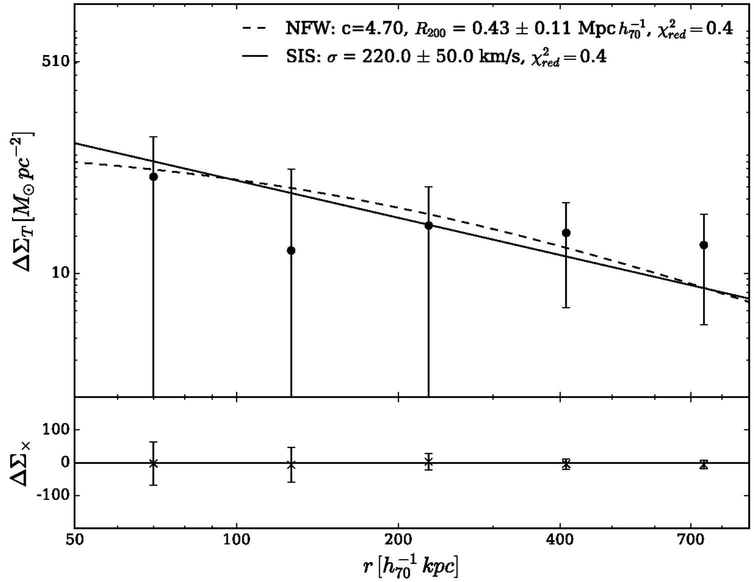
Concentration index: $C_{\mathrm{L}} = \frac{\sum c_i L_i}{\sum L_i}$

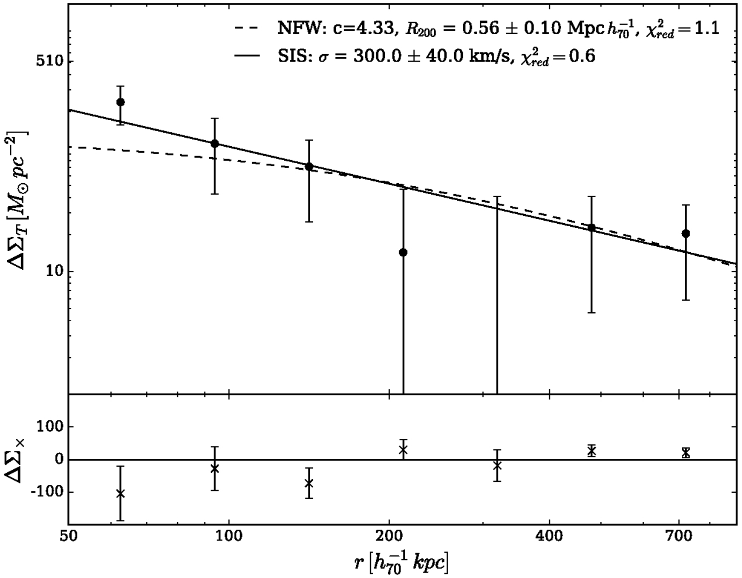
Subsample	SIS	NFW	
	σ_V	c_{200}	R_{200}
$R > 43\ h_{70}^{-1}$ kpc	270 ± 50	4.44 ± 0.24	0.49 ± 0.13
$R < 43\ h_{70}^{-1}$ kpc	260 ± 60	4.50 ± 0.25	0.51 ± 0.13
$\mu > 24.25$ mag arcsec^{-2}	290 ± 50	4.37 ± 0.22	0.58 ± 0.13
$\mu < 24.25$ mag arcsec^{-2}	240 ± 60	4.59 ± 0.27	0.45 ± 0.13
$C_{\mathrm{L}} > 2.75$	300 ± 50	4.33 ± 0.21	0.56 ± 0.13
$C_{\mathrm{L}} < 2.75$	220 ± 60	4.70 ± 0.31	0.43 ± 0.14

Dependence of the lensing signal on CG physical properties









Comparison with dynamical estimates

We choose CGs with
at least **3 members with known z**
and max(Δv)<1000 km/s

Original sample:	σ_{dyn} = 224 ± 13 km/s	σ_{len} = 270 ± 40 km/s
Higher C_L subsample:	σ_{dyn} = 238 ± 15 km/s	σ_{len} = 300 ± 50 km/s
Lower C_L subsample:	σ_{dyn} = 190 ± 22 km/s	σ_{len} = 220 ± 60 km/s

Summary

We analysed a sample of CGs from McConnachie et al. (2009) catalogue B using weak lensing stacking techniques.

We derived the average density contrast profile of the composite system for three centre definitions. **Luminosity-weighted centres were selected as the best description of the true dark matter halo centres.**

We studied the lensing signal dependence on different physical parameters, finding that **CGs composed of galaxies with larger c_i show a stronger lensing signal.** This could be explained by a lower number of interlopers, as well as by a trend to include more massive and evolved systems.

The dynamical estimate of the velocity dispersion, although slightly lower, is in good agreement with the lensing estimate within uncertainties.