Weak lensing cluster mass

Introduction

What we did Sources of noise Profile uncertainty Optimized apertures Mass results

Modelling the Covariance

Conclusions

Minimum variance weak lensing cluster mass estimates

AlfA Lens/Cosmology Seminar

2012-08-28

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Daniel Gruen, G. Bernstein, T. Y. Lam, S. Seitz (2011)

Structure

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Clusters of Galaxies

Weak lensing cluster mass

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- most massive structures: 10¹⁴ M_☉, 1Mpc
- dark matter, gas, galaxies
- formation \leftrightarrow cosmology



RXJ2248, source: WFI / own reduction

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- Clusters bend space-time and light
- Multiple images: strong lensing
- shear: weak lensing
- mass measurements
- model fitting
- aperture mass



Source: galileospendulum.org

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$$\gamma_t(\theta) = \langle \kappa(\theta') \rangle_{\theta' < \theta} - \kappa(\theta)$$

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 $\begin{aligned} \mathbf{M}_{\mathrm{ap}} &= \int \mathbf{2}\pi\theta \; \mathbf{d}\theta \; \mathbf{u}(\theta) \cdot \kappa(\theta) \\ \mathbf{M}_{\mathrm{ap}} &= \int \mathbf{2}\pi\theta \; \mathbf{d}\theta \; \mathbf{q}(\theta) \cdot \gamma_t(\theta) \end{aligned}$



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Faces of galaxy clusters

Weak lensing cluster mass

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M. Gruendl, Institute of Psychology, Uni Regensburg

Faces of galaxy clusters



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Simulations: van den Bosch, MPA

Tall tales of NFW Weak lensing cluster mass $\rho(r) = \frac{\rho_0}{(r/r_s)(1+r/r_s)^2}$ Yes, Introduction Navarro, Frenk, White (1996) What we did average profile of dark Sources of noise $c = r_{200}/r_s = c(M, z)$ matter halos Profile uncertainty Optimized apertures Mass results Modelling the but ... Covariance Conclusions $\gamma_{\mathrm{t,NFW}}(\mathrm{r}) / \gamma_{\mathrm{t,NFW}}(0)$ 0.1 10

100

r/r_

Tall tales of NFW Weak lensing cluster mass 30 Yes, Introduction 20 What we did average profile of dark Sources of noise 10 matter halos Profile uncertainty Optimized apertures **Jrcsec** Mass results Modelling the but ... Covariance -10 asphericity Conclusions -20 - 30 -30 -20-10

- surrounding structures
- core and outskirts

Source: Verdugo et al. (2007)

0 10 20 30

arcsec

Tall tales of NFW Weak lensing cluster mass $\sigma_{\log c} \approx 0.18$ Yes, Introduction Bullock et al. (2001) What we did average profile of dark Sources of noise matter halos Profile uncertainty Optimized apertures Mass results Modelling the but ... Covariance asphericity Conclusions concentration scatter

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Tall tales of NFW

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Yes,

 average profile of dark matter halos

but ...

- asphericity
- concentration scatter
- substructure
- surrounding structures

core and outskirts



Source: van den Bosch, MPA

Tall tales of NFW

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Yes,

• average profile of dark matter halos

but ...

- asphericity
- concentration scatter
- substructure
- surrounding structures
- ore and outskirts



Source: Becker & Kravtsov (2011)

What we did: four steps

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Sources of Noise

NFW signal + shape noise + LSS + intrinsic mess

Intrinsic profile variability

Can we explain the scatter in shear profiles we see?

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Optimized apertures

What do optimized apertures look like?

Mass uncertainty

Does it help at all?

Sources of noise in Weak Lensing



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Sources of noise in Weak Lensing



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Sources of noise in Weak Lensing



14,000 clusters $> 10^{14} M_{\odot}$ at z = 0.245

Profile uncertainty: components



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Profile uncertainty: components



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Profile uncertainty: components



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Aperture mass

Weak lensing cluster mass

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$$egin{aligned} M_{\mathrm{ap}} &= \int 2\pi heta \; d heta \; u(heta) \cdot \kappa(heta) \ M_{\mathrm{ap}} &= \int 2\pi heta \; d heta \; q(heta) \cdot \gamma_t(heta \ M_{\mathrm{ap}} &= \sum_i \mathcal{Q}_i \gamma_i \end{aligned}$$



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Minimum variance aperture

 $ar{\mathcal{Q}} \propto \hat{\mathcal{C}}^{-1} ec{\gamma}_{ ext{true}}$

for uncorrelated LSS: Dodelson (2004), Maturi et al. (2005) including correlated structures: this work

Aperture mass

Weak lensing cluster mass

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$$\begin{array}{l} M_{\rm ap} = \int 2\pi\theta \; d\theta \; u(\theta) \cdot \kappa(\theta) \\ M_{\rm ap} = \int 2\pi\theta \; d\theta \; q(\theta) \cdot \gamma_t(\theta) \\ M_{\rm ap} = \sum_i Q_i \gamma_i \end{array}$$



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Minimum variance aperture

 $ec{Q} \propto \hat{C}^{-1} ec{\gamma}_{ ext{true}}$

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Mass uncertainty



Mass uncertainty



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Mass uncertainty



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Modelling the Covariance

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Why model the covariance of cluster shear?

- prediction of mass uncertainty
- full Bayesian mass estimation
- peak detection completeness

lea.

Use two simple components:

- concentration variation
- Poisson noise of correlated halos

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and rescale to fit

Modelling the Covariance

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Why model the covariance of cluster shear?

- prediction of mass uncertainty
- full Bayesian mass estimation
- peak detection completeness

Idea

Use two simple components:

- concentration variation
- Poisson noise of correlated halos

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and rescale to fit

Modelling the Covariance [preliminary]

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Can we model the variations of cluster shear profiles...in small mass bins using these components?



Modelling the Covariance [preliminary]

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Modelling the Covariance [preliminary]

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Can we model the variations of cluster shear profiles... also for off-diagonal components?



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NFW

spherical NFW is only a good approximation on average

Halo structure

(M, c) is no sufficient description either possible to model variations

Mass uncertainty

 σ_M > naive expectations; deeper only marginally better

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Optimized apertures

Weak lensing cluster mass

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Optimized apertures

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Optimized apertures