A galaxy-galaxy lensing measurement by cross correlating optical and radio data

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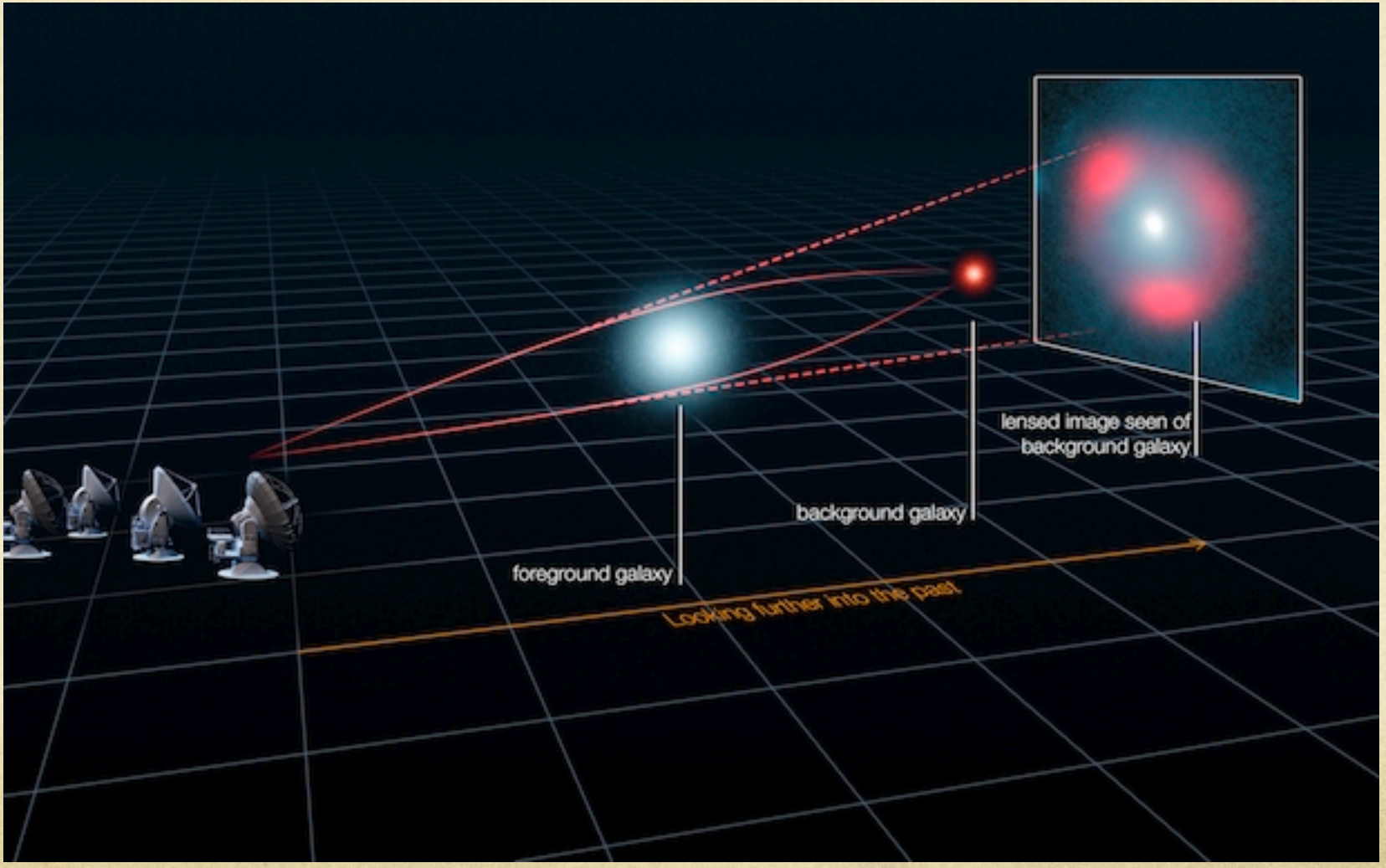
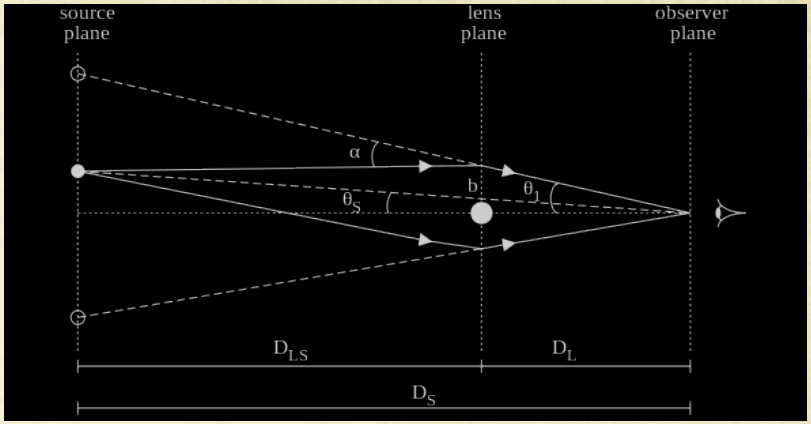
Introduction



Gravitational Lensing

Basics of WGL

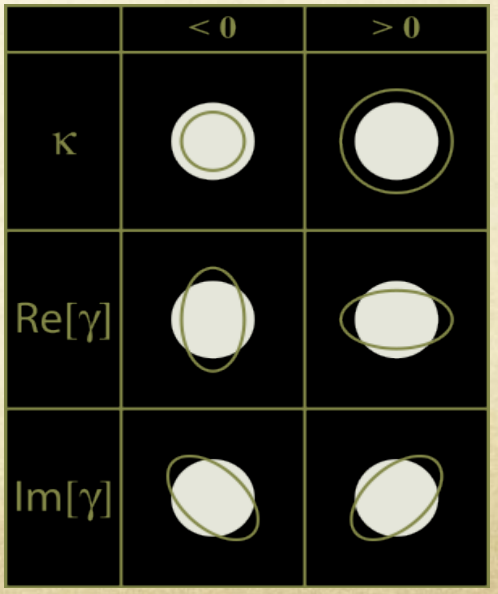
- Fundamental lensing equation



$$\Theta_s = \Theta - \frac{D_{ls}}{D_s}\alpha = \Theta - \alpha(\Theta)$$

- Distortions are of the order of 1%

$$\alpha(\Theta) = \frac{\partial \Theta_s}{\partial \Theta} = \begin{bmatrix} 1-\kappa-\gamma_1 & \gamma_2 \\ \gamma_2 & 1-\kappa+\gamma_1 \end{bmatrix}$$



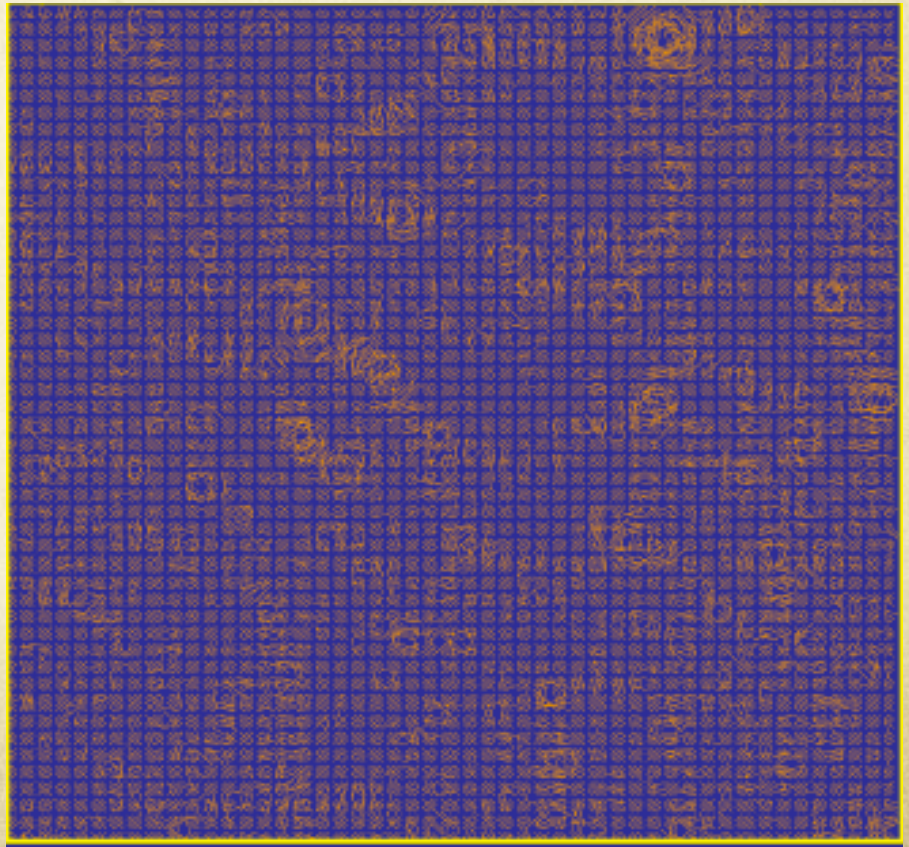
- Where
- κ is the convergence
- γ is the shear

Basics of WGL

- K requires prior knowledge of the galaxy intrinsic sizes
- Ellipticities are directly related to the shear γ

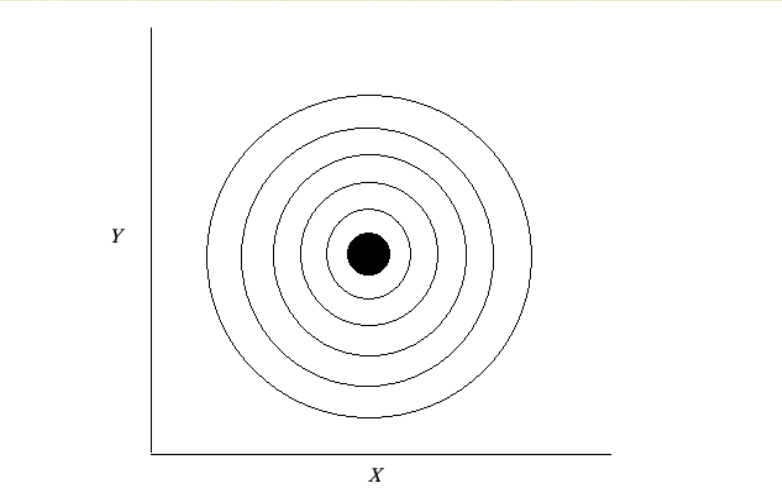
$$\varepsilon^{obs} = \varepsilon^{\text{int}} + \gamma + \varepsilon^{noise}$$

$$\hat{\gamma} = \frac{1}{N}\sum_{i=1}^{N}\gamma_i$$



Ring statistics

- Binning



- Optimized shear estimators

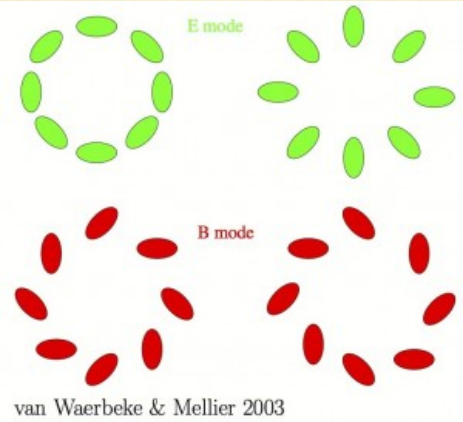
$$\hat{\gamma}_t = \gamma_1 \cos(2\varphi) + \gamma_2 \sin(2\varphi)$$

$$\hat{\gamma}_r = -\gamma_1 \sin(2\varphi) + \gamma_2 \cos(2\varphi)$$

Φ is the angle formed when moving counter clockwise from the x-axes to the great circle connecting the pair of galaxies

Ring statistics

- Shear is a headless vector
- Decomposed into B-mode and E-mode components



- E-mode is related to the tangential shear
- B-mode related to the rotated shear
- Rotated shear – non physical – used to trace systematics
- The aperture mass m_{ap} is related to the tangential shear

Weak lensing studies

- A probe of the dark Universe
  - Directly probing the total mass of the lensing source with out the need of any assumptions
  - Sensitive to the geometry of the Universe and growth of structure
- A probe of different size objects
  - Galaxies
  - Groups/Clusters of galaxies
  - Large scale structure

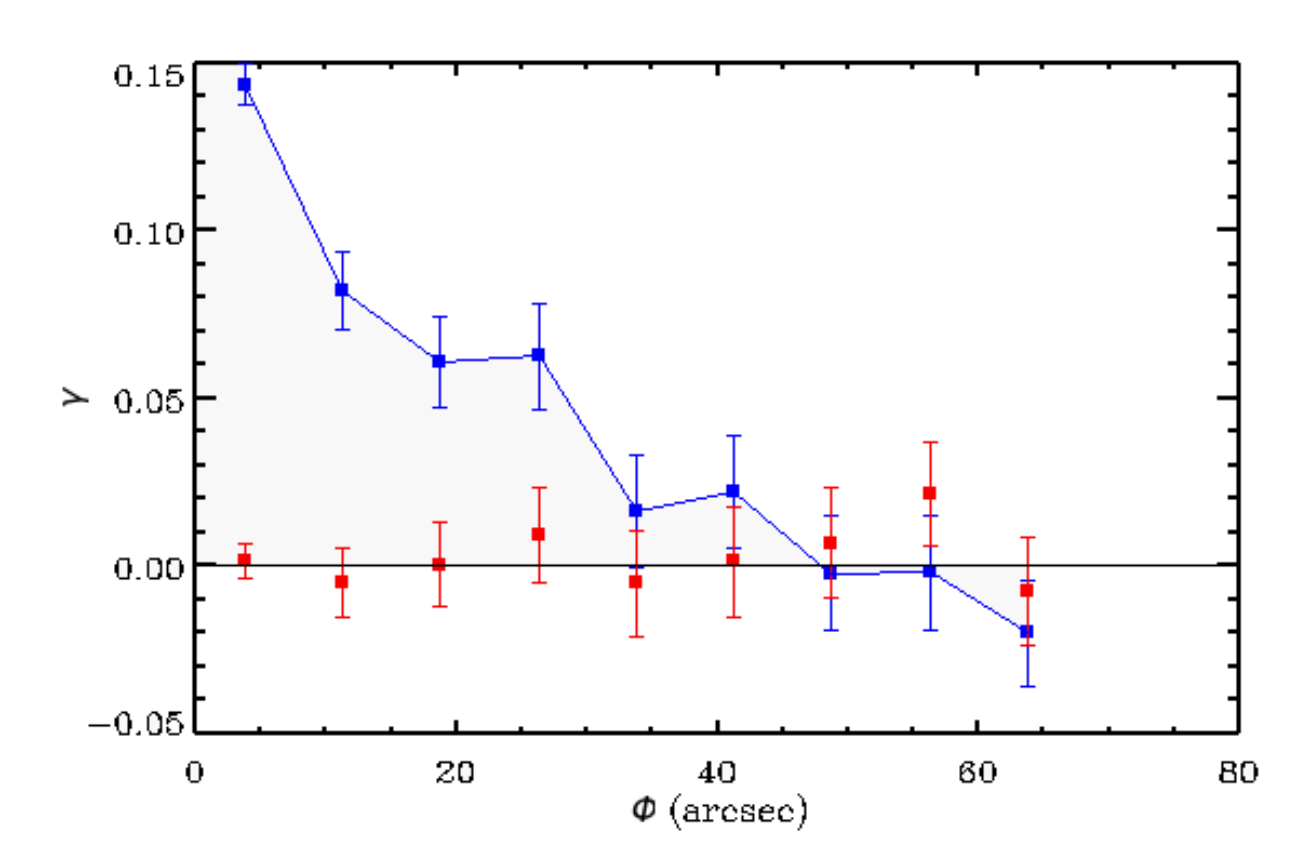
Weak lensing studies

- Most of WGL studies have been performed in the optical/ NIR
  - Much higher source counts
  - No redshifts for radio sources
  - Mature stage of source extraction and shape measurements
- Radio Weak Lensing advantages
  - Well known and deterministic beam pattern
  - Sources at higher redshifts
  - Polarisation information

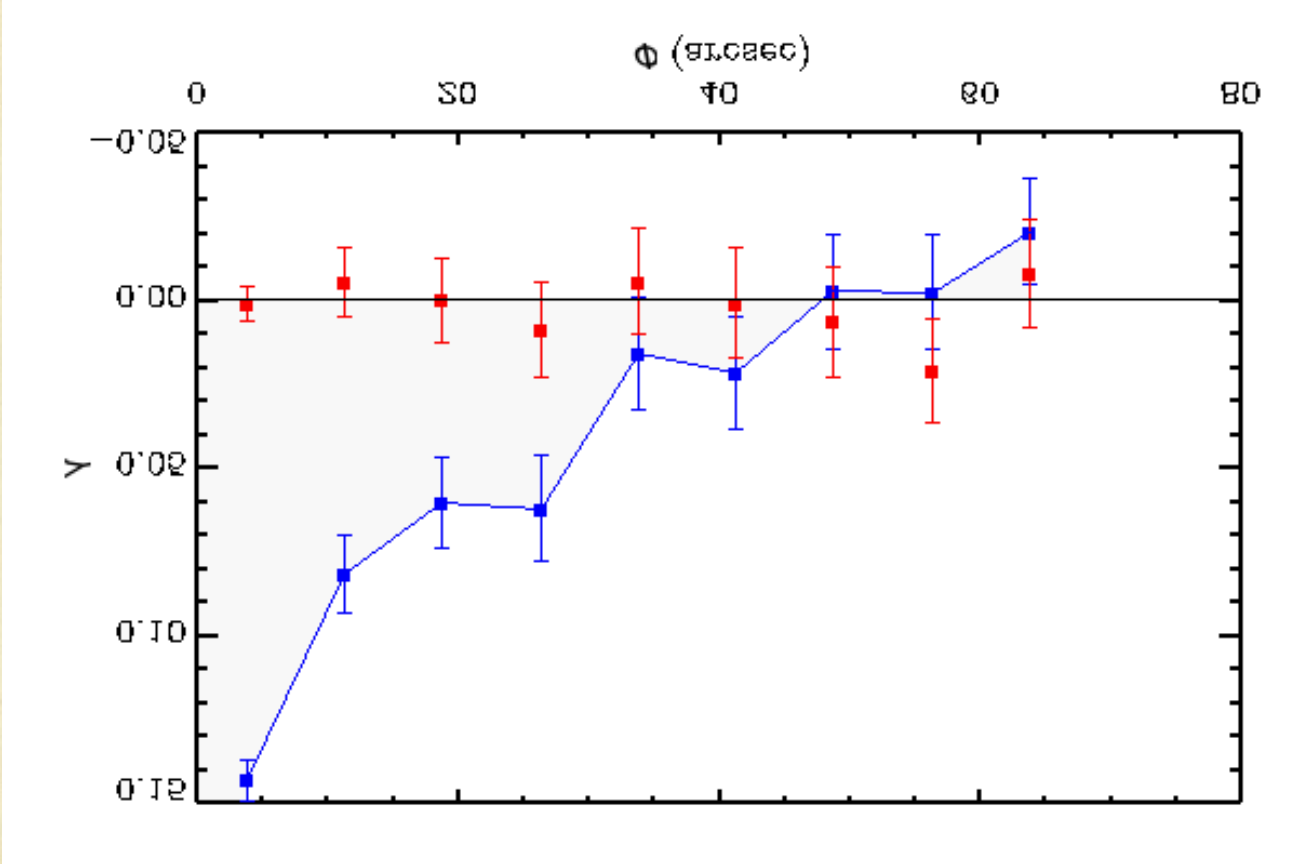
A g-g lensing measurement using radio data

- Aim: Prove that RWL can be done
- Used method: Ring statistics
- Requirements:
  - A sample of background radio sources
    - VLA FIRST
  - A sample of lenses
    - SDSS
    - BCGs
    - X-ray selected clusters
- Prior to measurements: Systematics quantification and correction

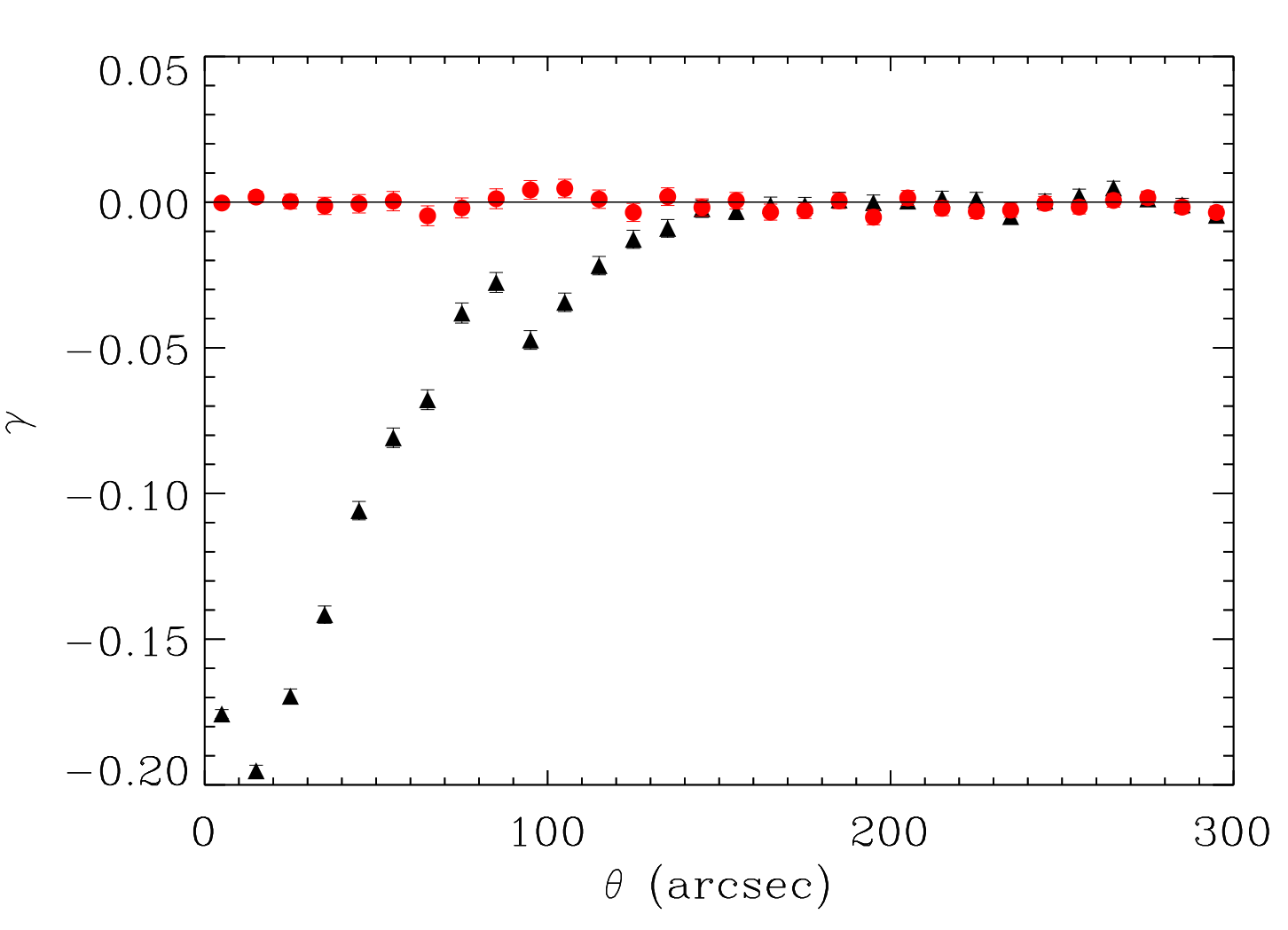
Results ???



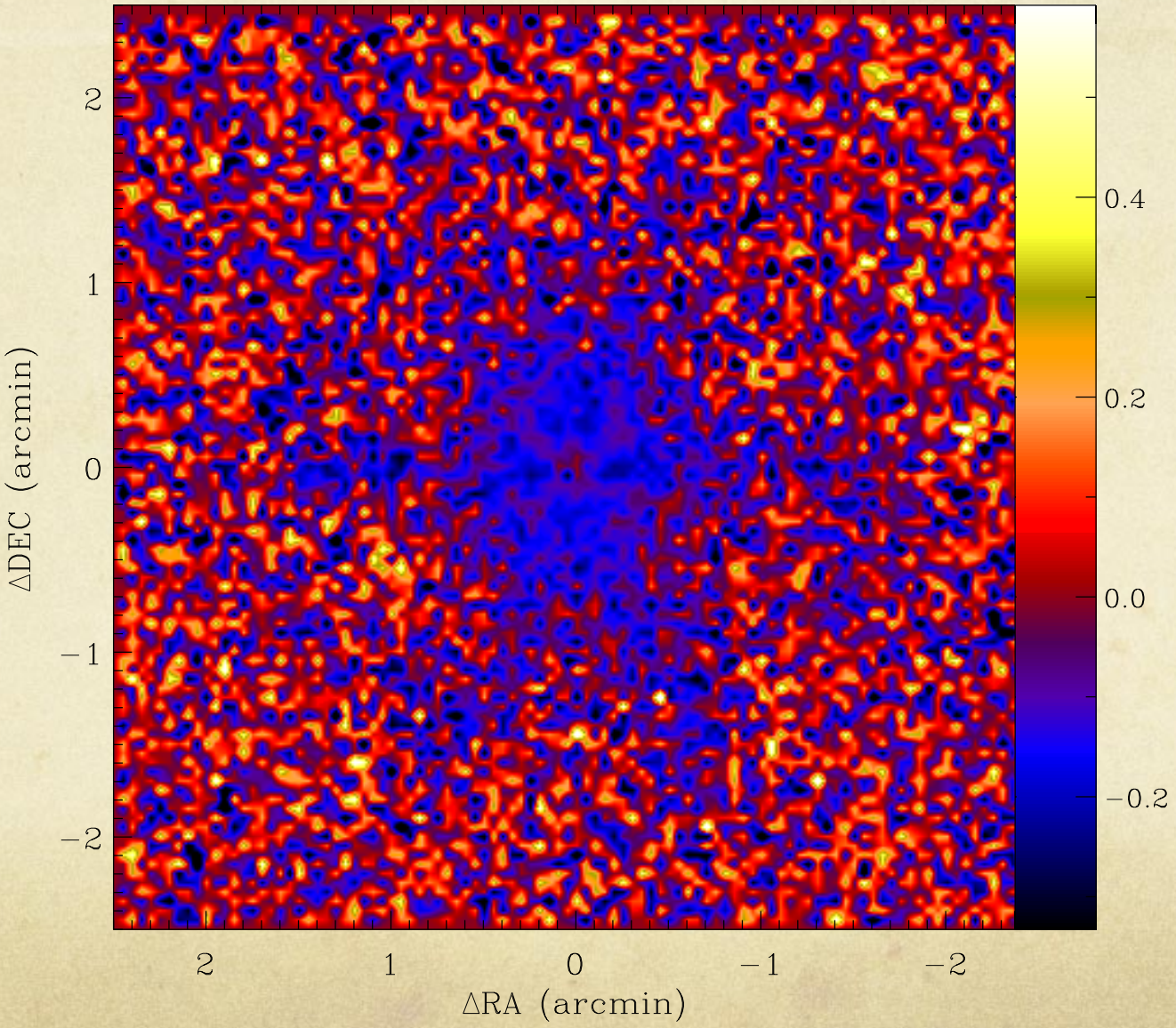
Results ???



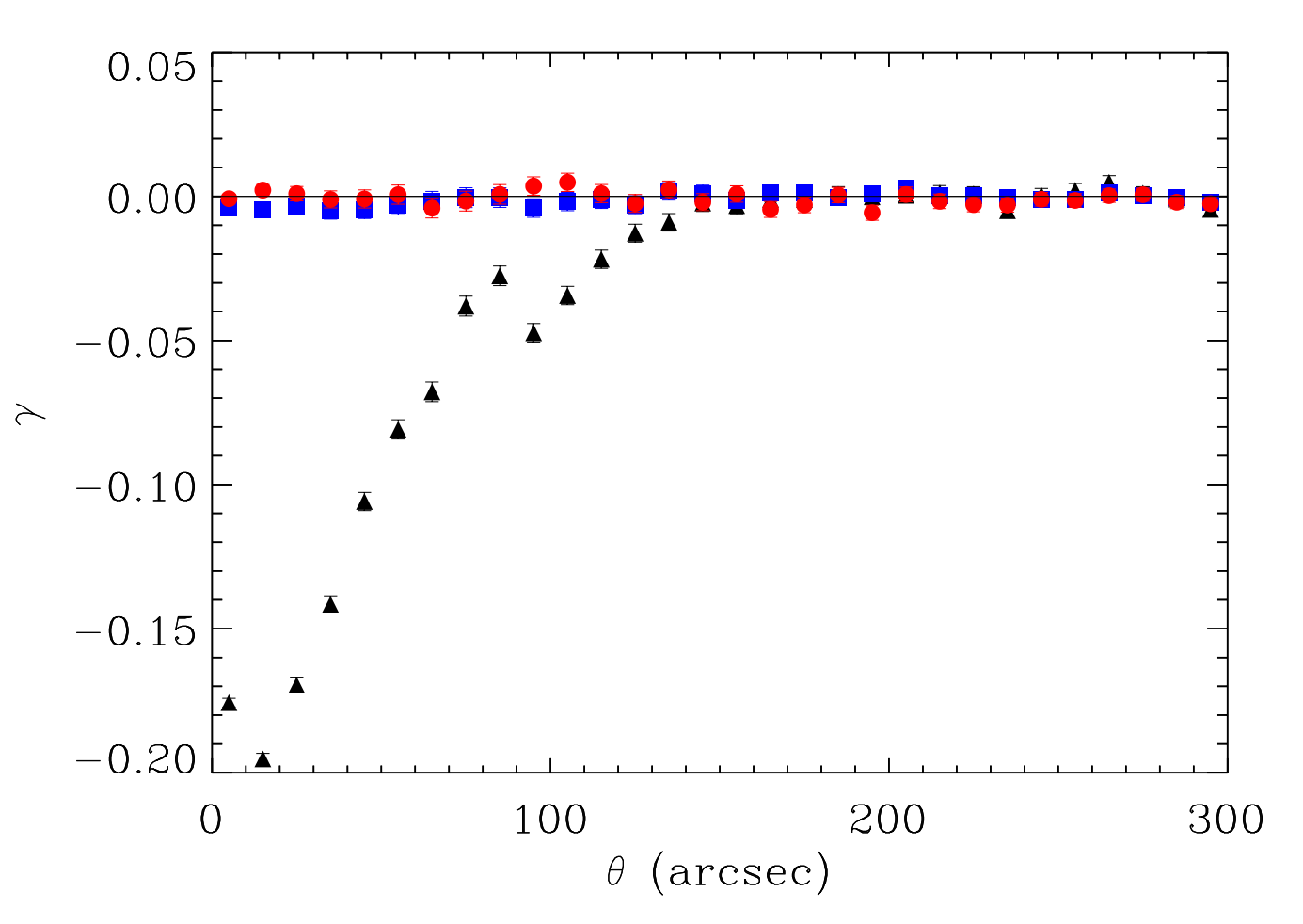
Tests for systematics



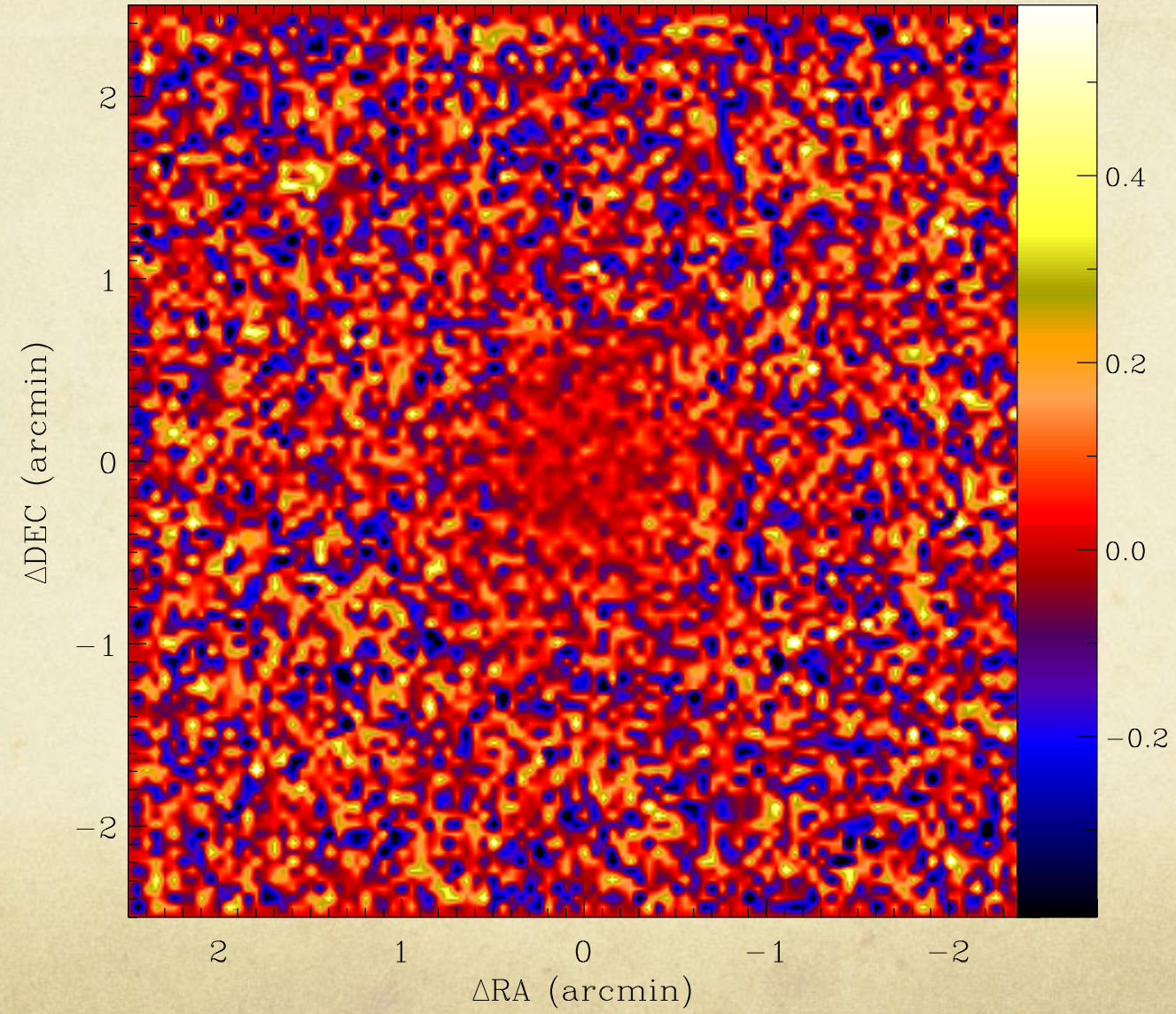
Tests for systematics



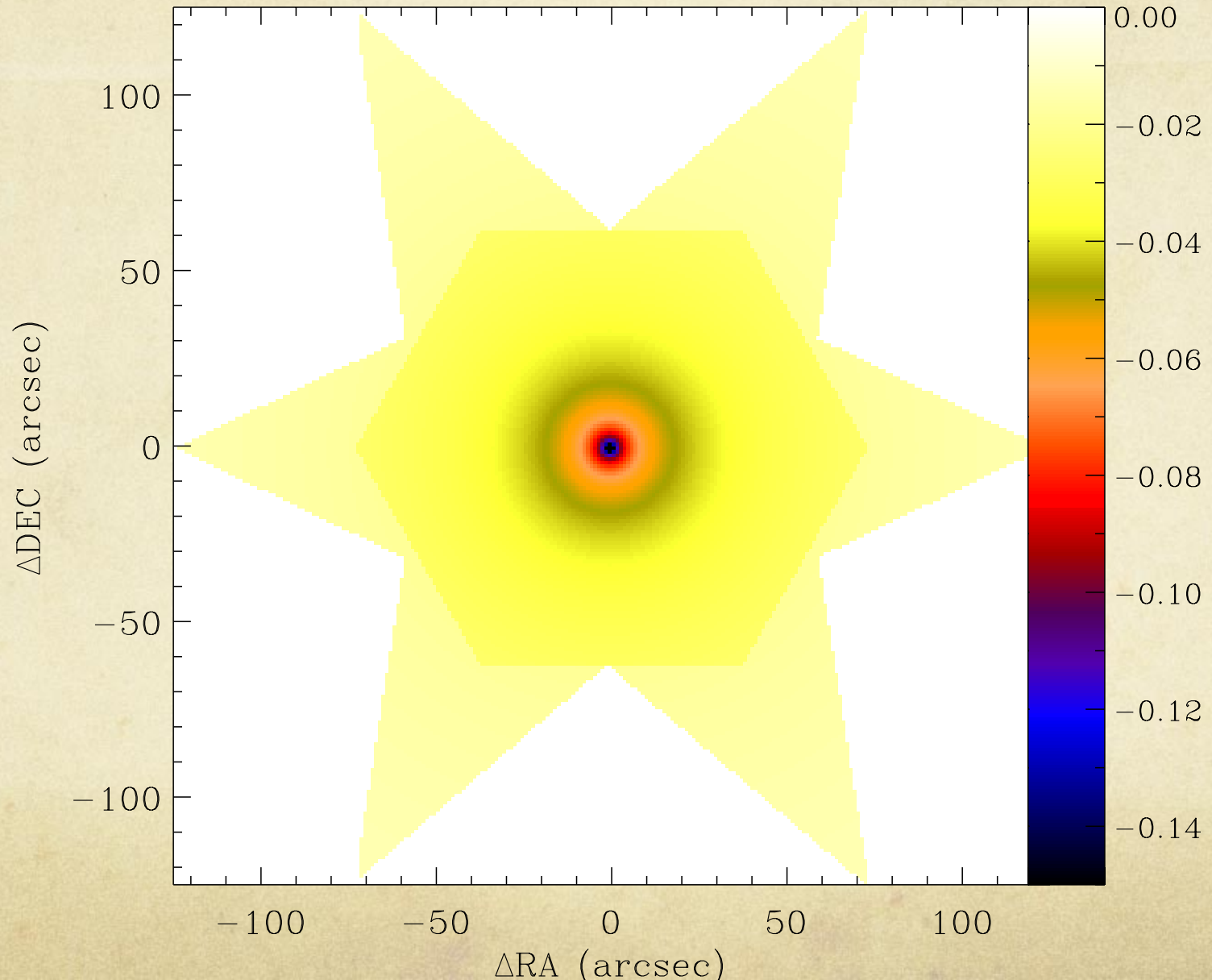
Correcting the systematics



Correcting the systematics



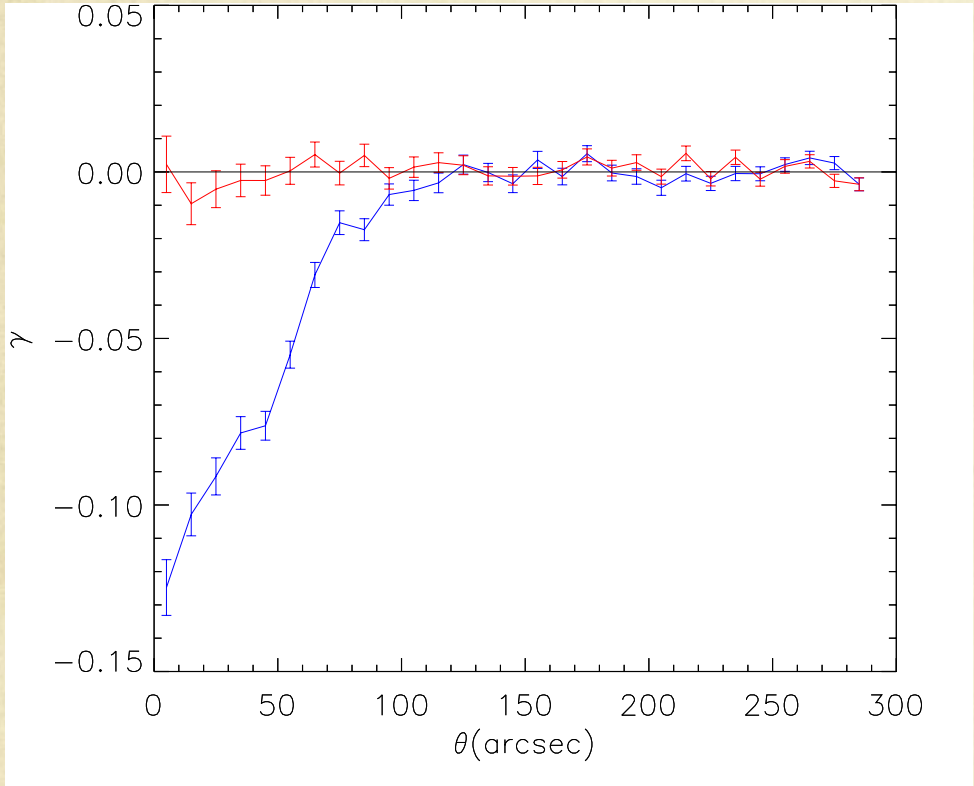
Simulations

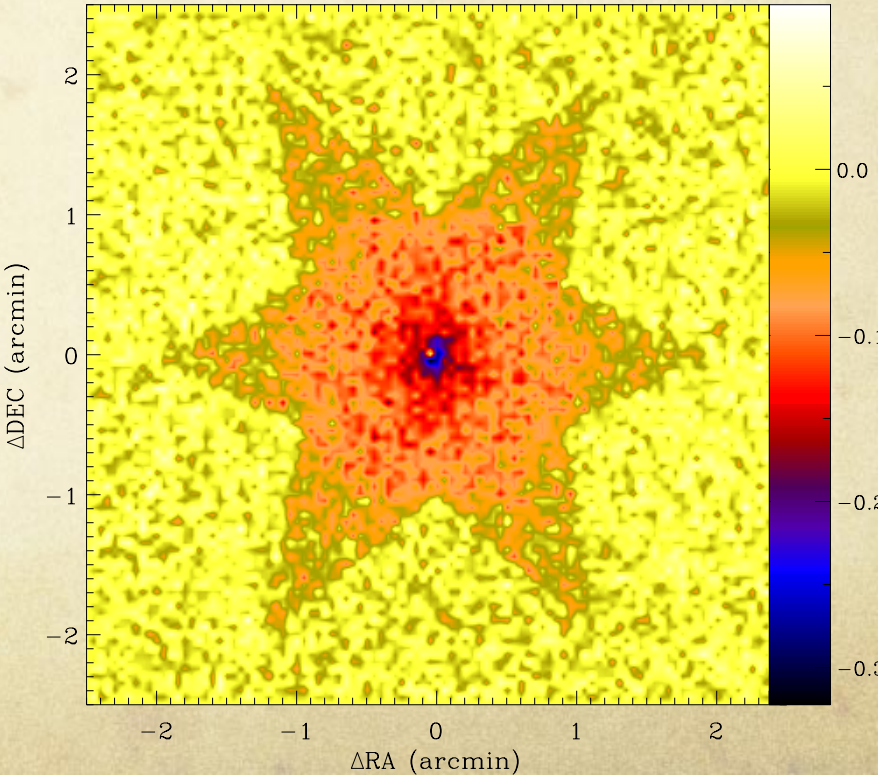


Simulations

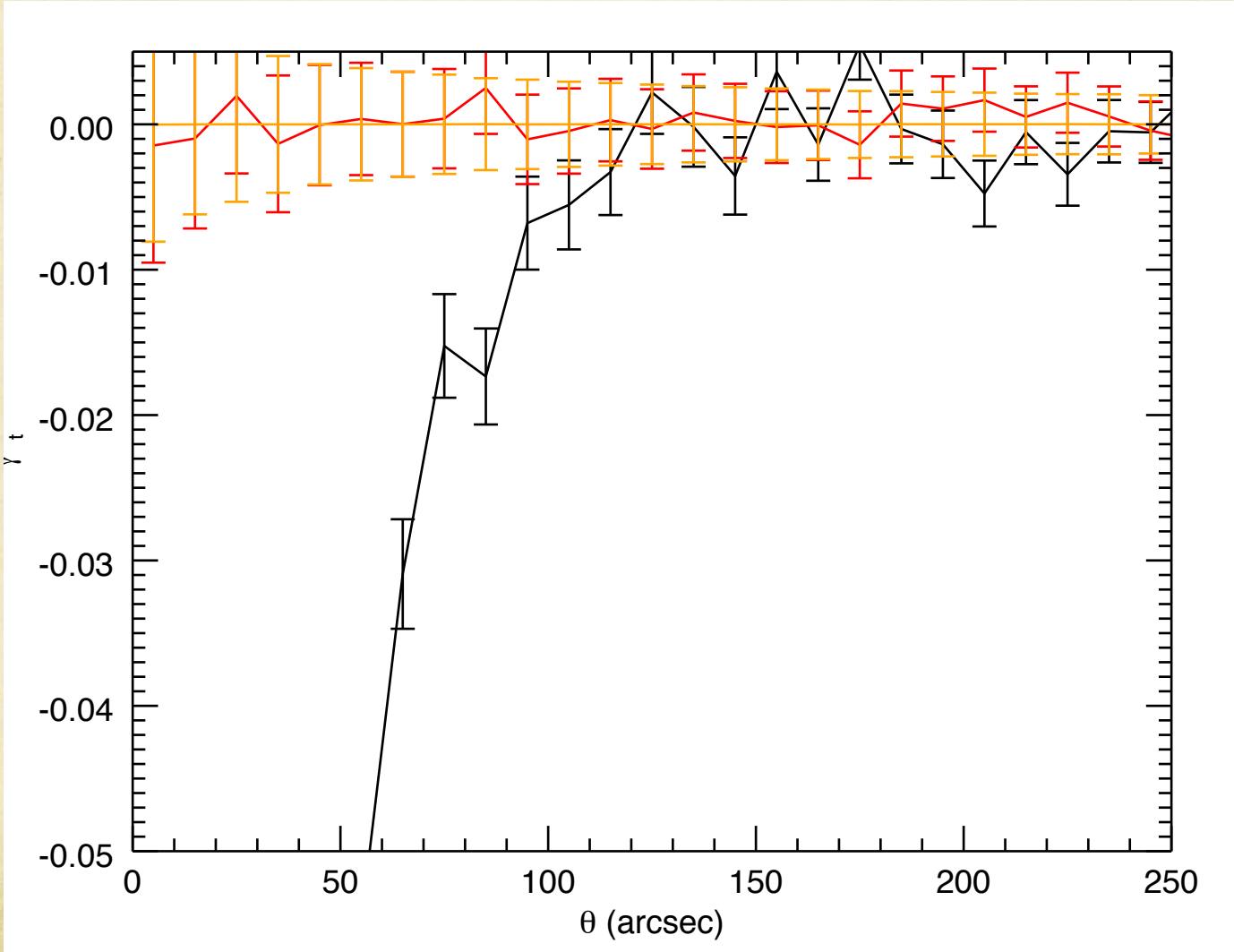
- Inputs
  - Fluxes/sizes from FIRST
  - Redshifts from S^3
  - Shear/over-density maps from a set of realistic simulations
  - Contamination template approximating the FIRST contamination
- Generates a distribution of galaxies that have a shear signal and a shape distortion to their ellipticities
- Additional e_1 and e_2 component simulating the intrinsic ellipticities of the galaxies

Simulations

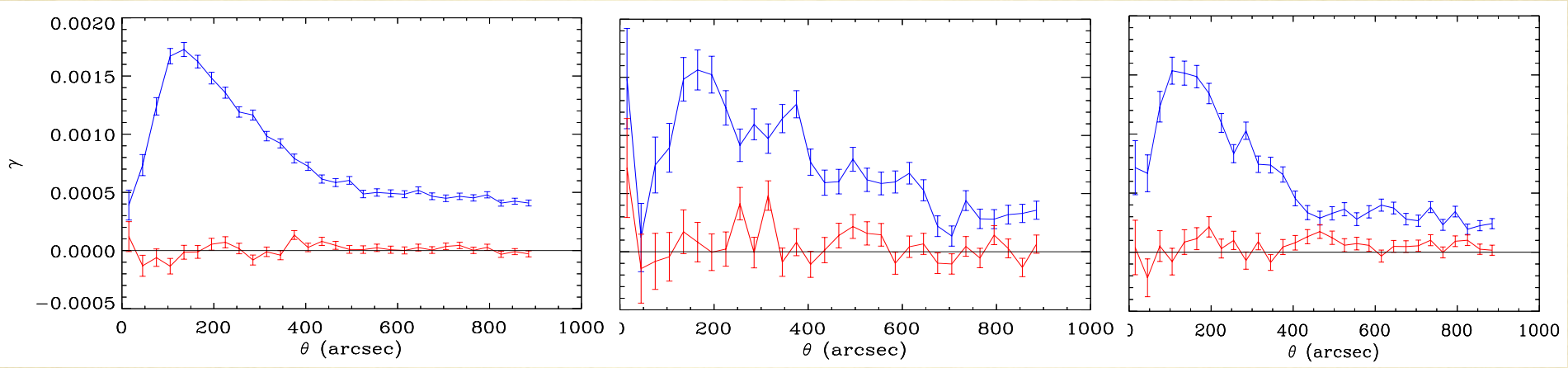


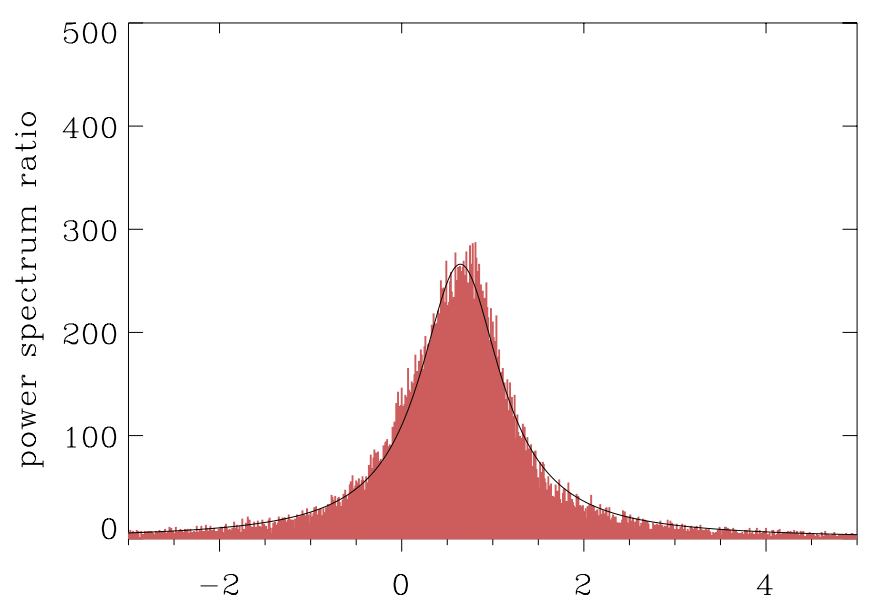


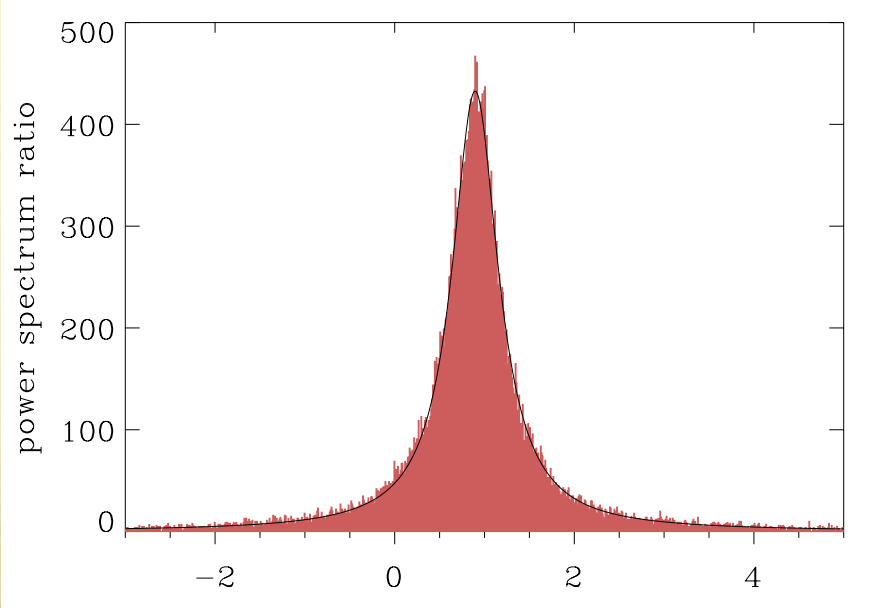
Simulations



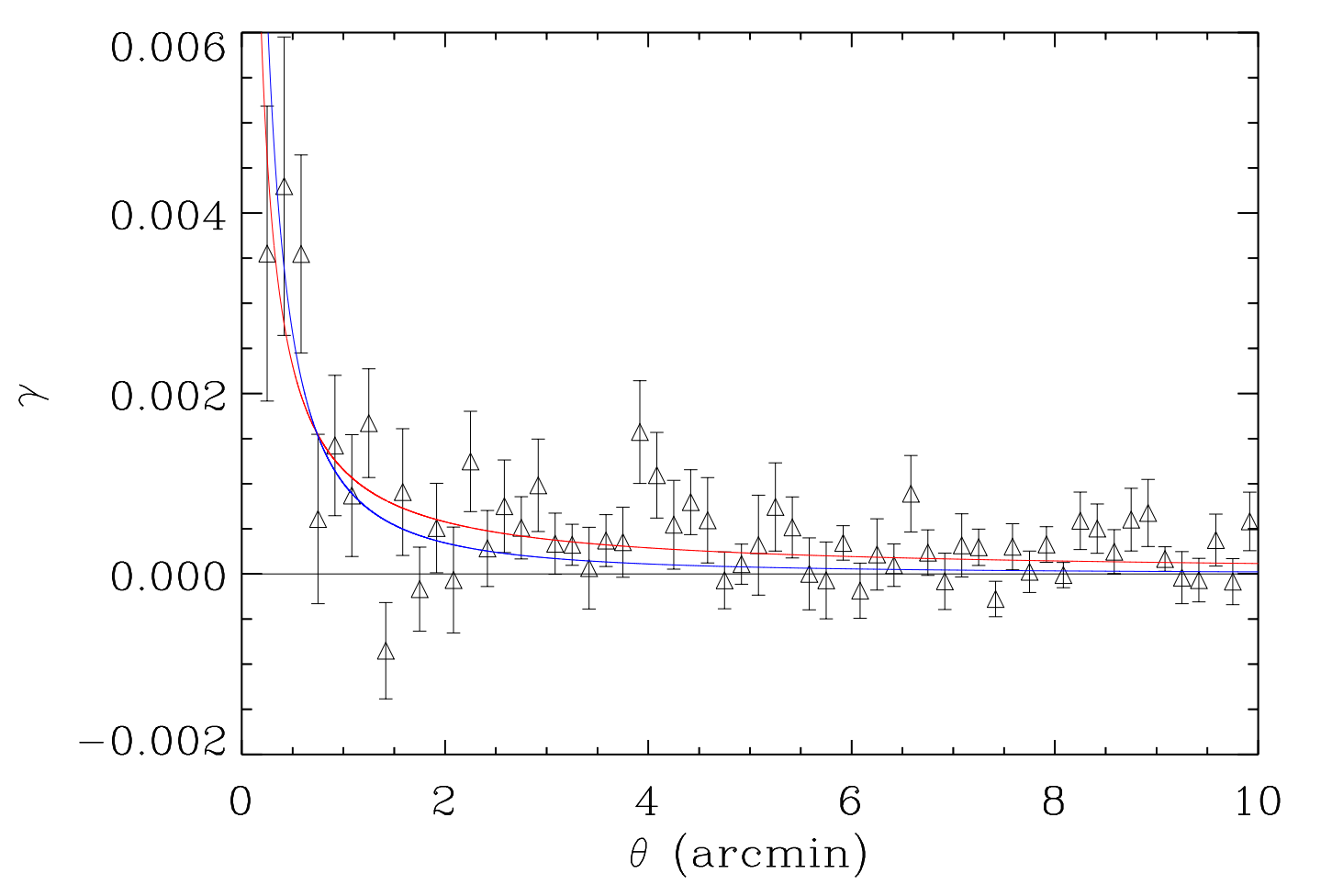
Simulations







Results – lenses SDSS sources



Our study

R_{200}=0.12 ± 0.02 Mpc h^{-1}

M_{200}=(4.63 ± 2.02)×10^{11} $M_{\odot}h^{-1}$

Θ_e= 0.22 ± 0.03 ´´

Σ_u=88 ± 9 km/s

Archival

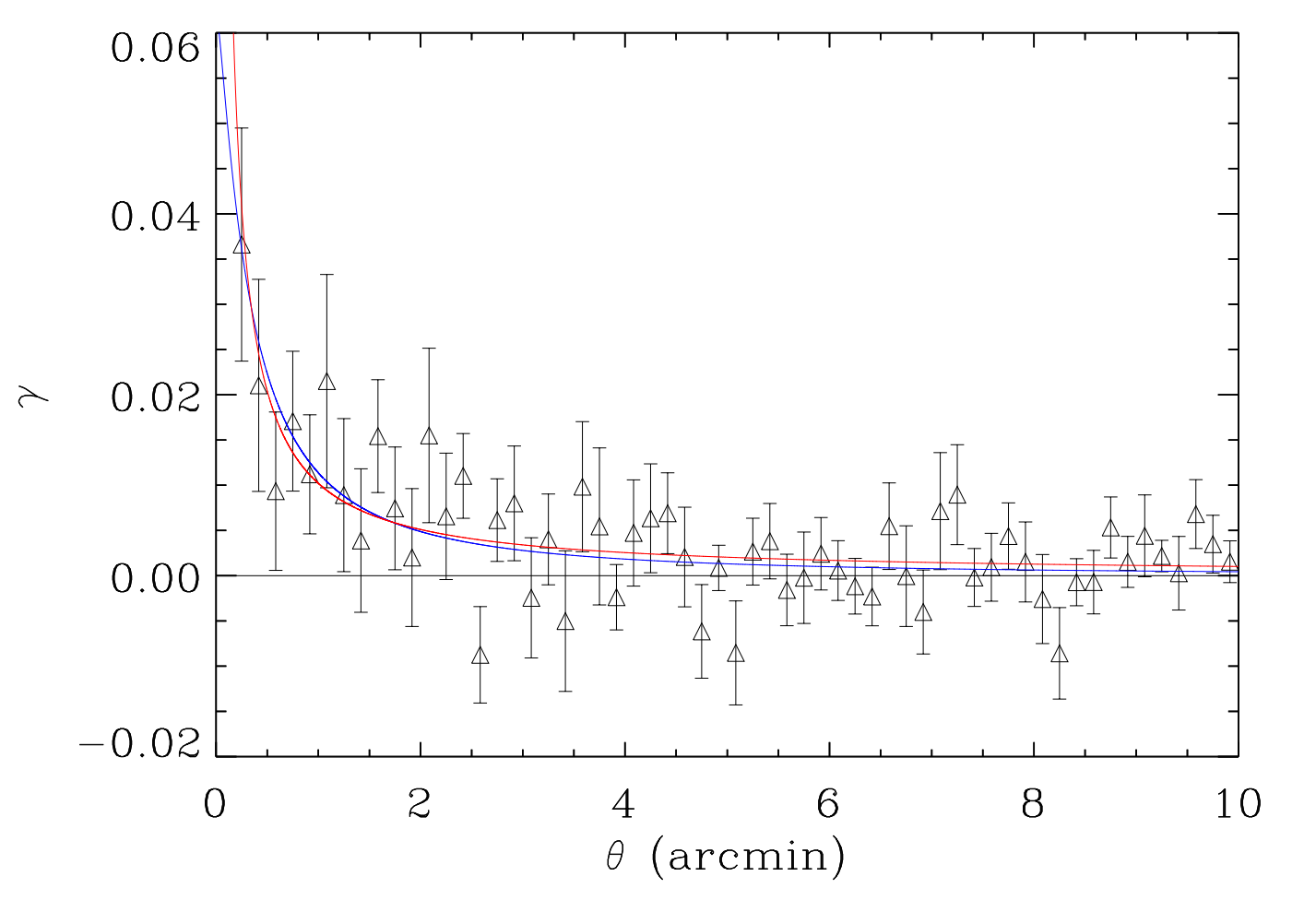
R_{200}=0.15 Mpc h^{-1} (Parker et al 2007)

M_{200}=7.6 ×10^{11} $M_{\odot}h^{-1}$ (Parker et al 2007)

Θ_e= 0.267 ± 0.005 ´´ (Velander et al 2013)

Σ_u=97.9 ± 1 km/s (Velander et al 2013)

Results – lenses BCGs



Our study

R_{200}=0.60 ± 0.10 Mpc h^{-1}

M_{200}=(2.63 ± 1.20)×10^{13} $M_{\odot}h^{-1}$

Θ_e= 2.8 ± 0.5 ″

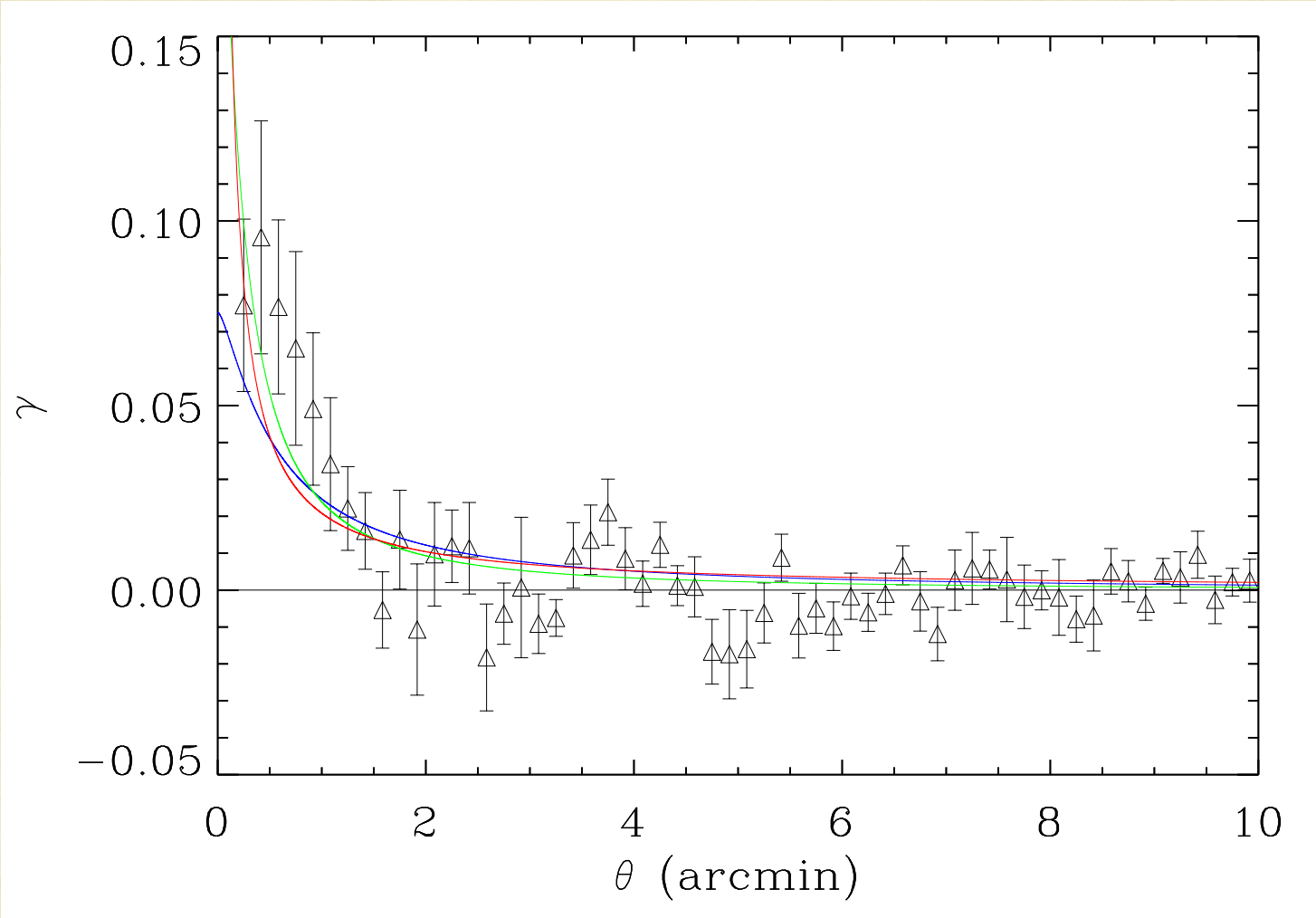
Σ_u=361 ± 31 km/s

Archival

R_{200}=0.7 Mpc h^{-1} (Sheldon et al 2009)

M_{200}=(2.85± 1.13)×10^{13} $M_{\odot}h^{-1}$ (CFHTlens)

Results – lenses Matched SDSS-FIRST sources



R_{200}=0.86 ± 0.15 Mpc h^{-1}

M_{200}=(7.75 ± 3.45)×10^{13} $M_{\odot}h^{-1}$

Θ_e= 5.9 ± 0.9 ´´

Σ_u=519 ± 43 km/s

Conclusions

- Shown that RWL can be performed
- WGL studies with data collected from the image plane
- Provided independent measurement to the optical/ NIR WGL studies
- Detected massive sizes for optical/radio matched objects

THANK YOU FOR YOUR TIME