Institute for Astronomy

THE UNIVERSITY OF EDINBURGH

Flexed universe

Massimo Viola

DEX Meeting 13/01/2012

What is gravitational flexion ?

Abell 370 (HST)

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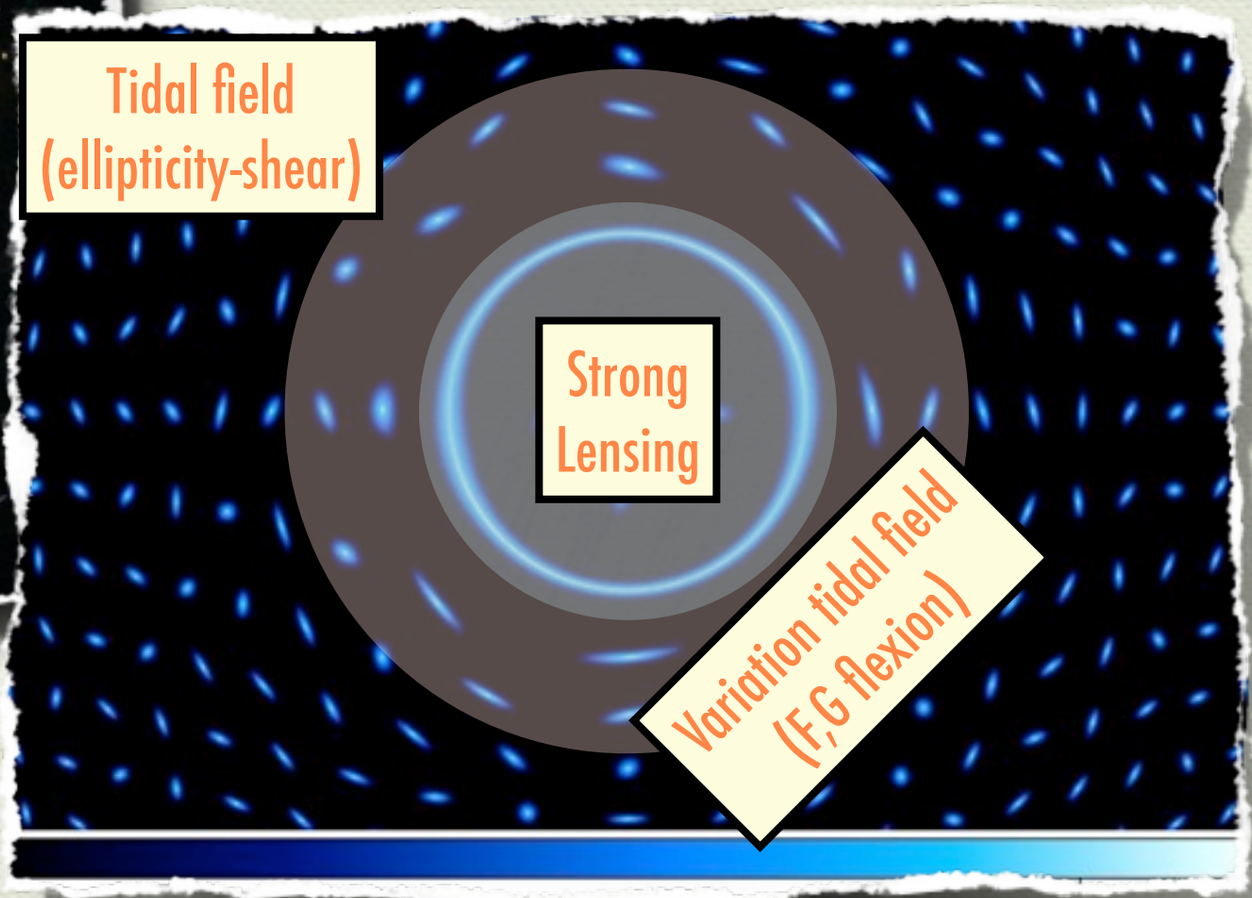
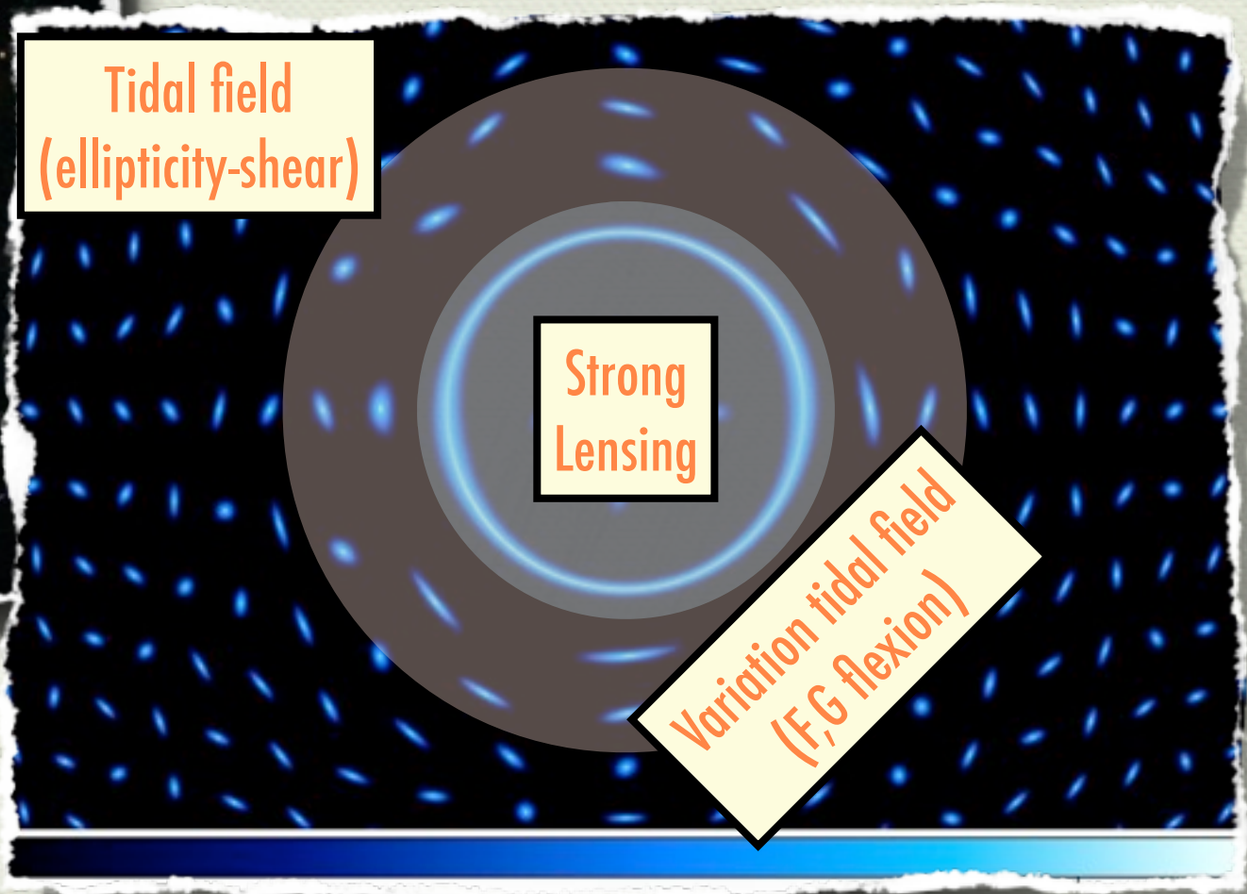


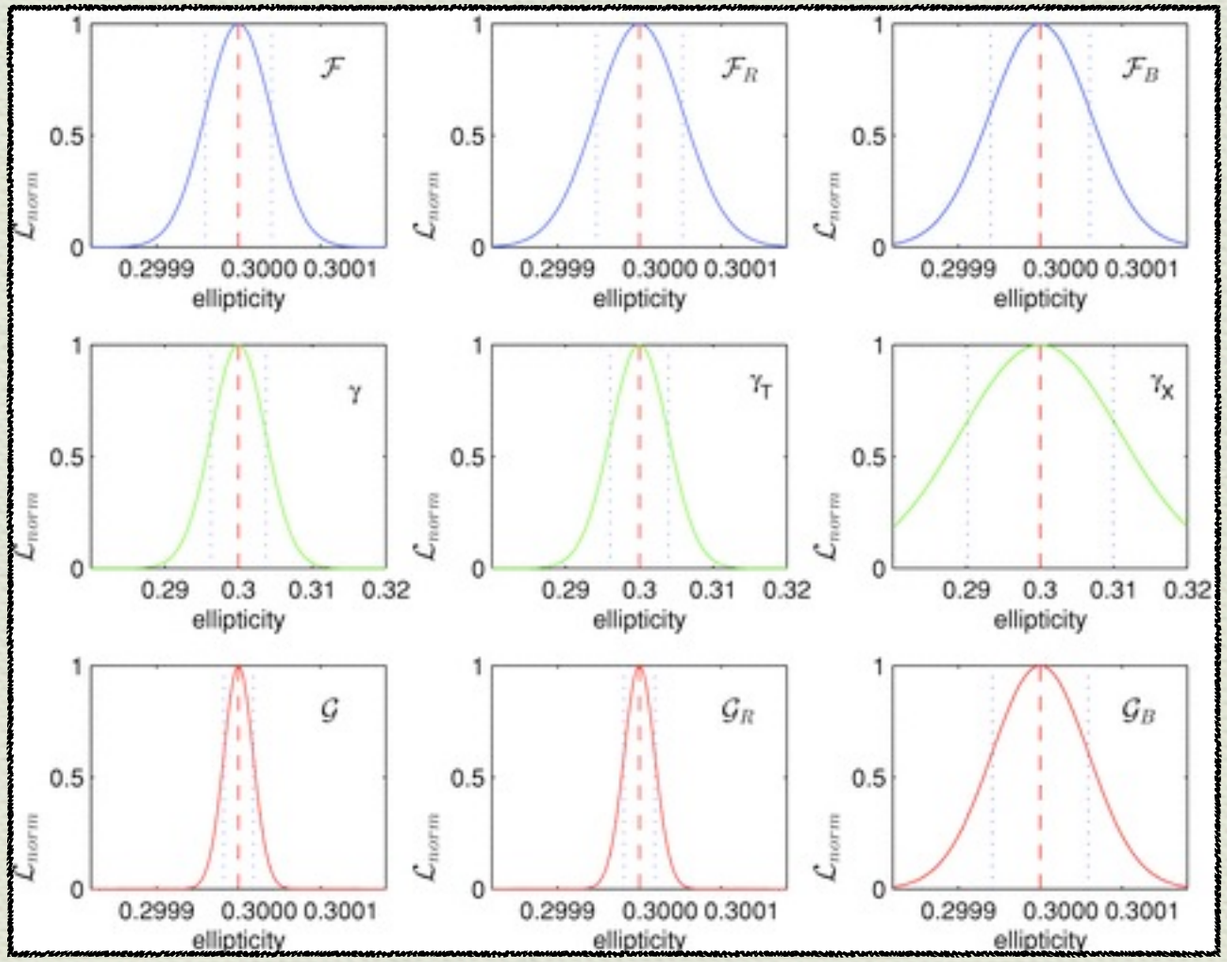
What is gravitational flexion ?

Abell 370 (HST)



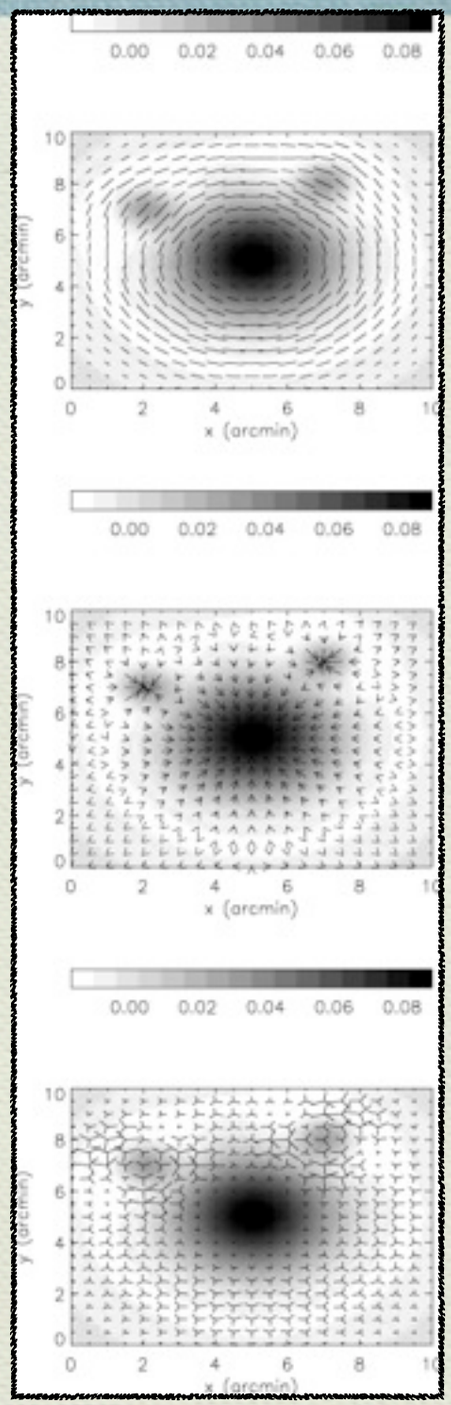
Why is flexion interesting ?

20000 deg^2 & 35 gal/arcmin^2

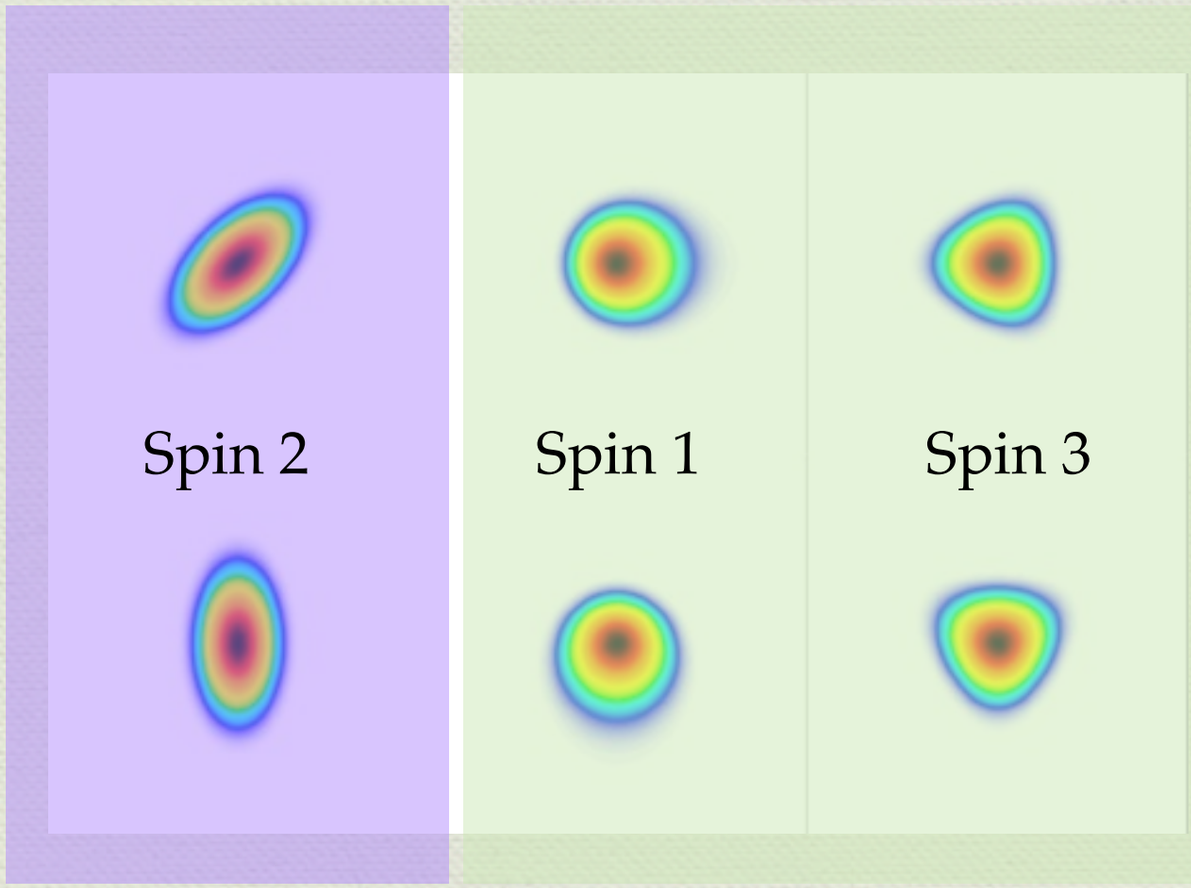


Hawken & Bridle 2009

Bacon et al. 2006



The game is about measuring shapes...



$$Q_{ij\ldots k} = \int I(\vec{\theta})\theta_i\theta_j\ldots\theta_k \mathrm{d}^2\theta$$

$$\chi = \frac{(Q_{11} - Q_{22}) + 2iQ_{12}}{Q_{11} + Q_{22}}$$

$$\zeta \equiv \frac{(Q_{111} + Q_{122}) + i(Q_{112} + Q_{222})}{\xi}$$

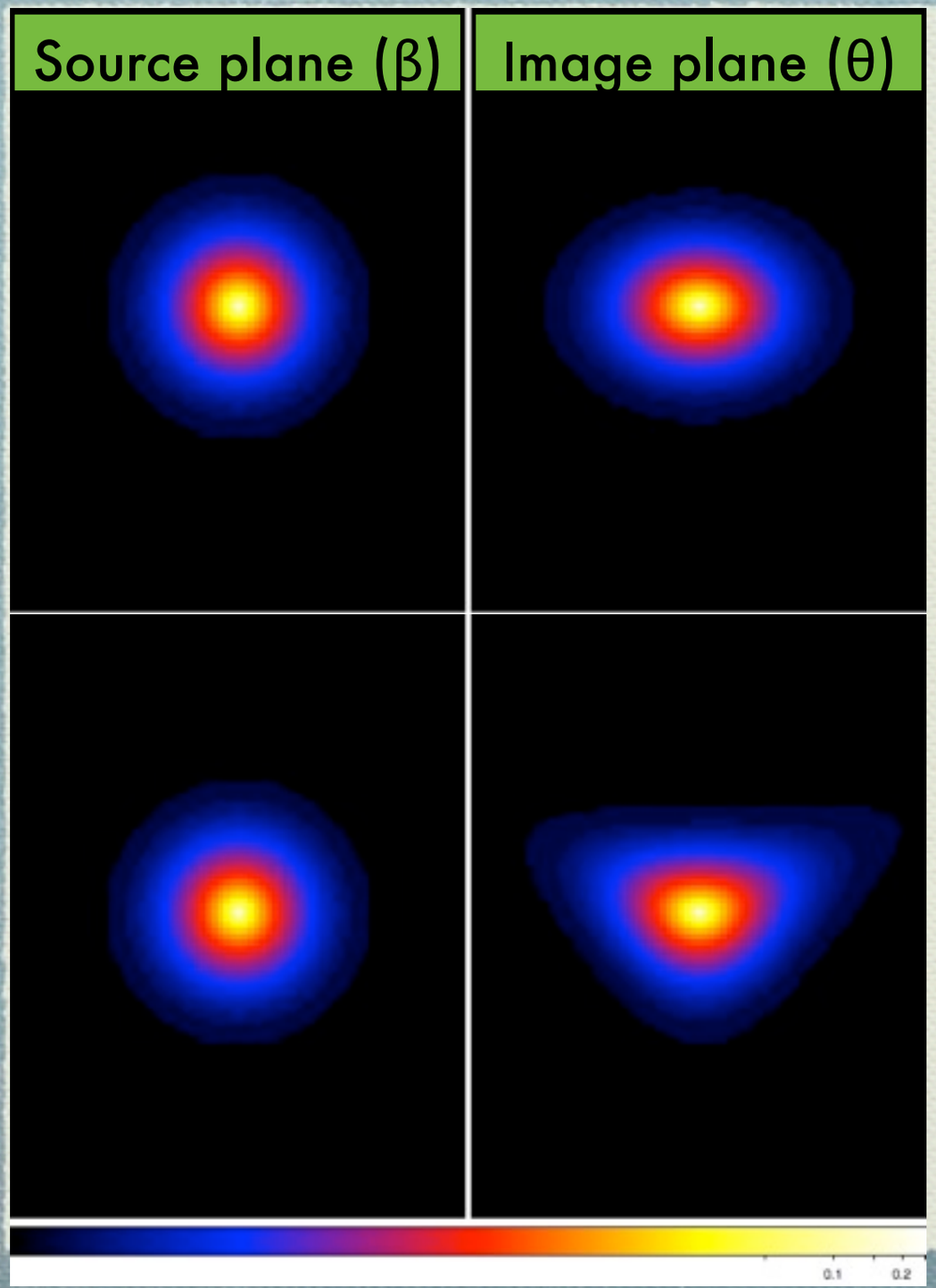
$$\delta \equiv \frac{(Q_{111} - 3Q_{122}) + i(3Q_{112} - Q_{222})}{\xi}$$

$$\xi \equiv Q_{1111} + 2Q_{1122} + Q_{2222}$$

Deformation = Intrinsic + induced by lensing

Intrinsic deformation is expected to vanish **on average**.

...and doing some math!



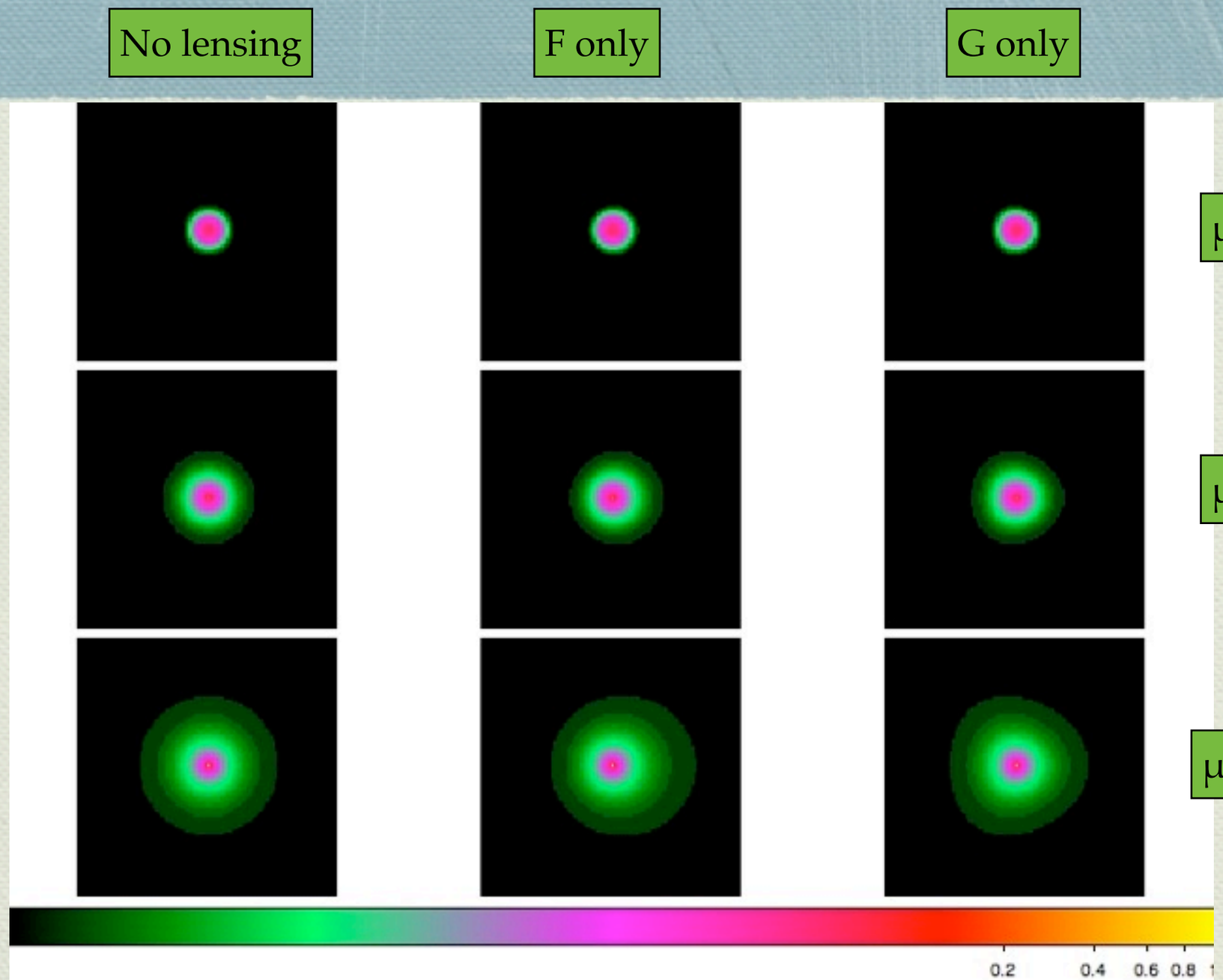
$$\chi^{\rm s} = \frac{\chi - 2g + g^2\chi^\star}{1 + |g|^2 - 2\Re(g\chi^\star)}$$

$$\zeta^{\rm s} \simeq \zeta - 2g\zeta^* - g^*\delta - \frac{9}{4}F + 3F^*g... + \mu\left(gG^\star\chi + 3F + Gg^\star + ...\right)$$

$$\delta^s \simeq \delta - 3g\zeta - \frac{3}{4}G + 6Fg + ... + 3\mu\left(-3Fg + ...\right)$$

	Depends on scale	Depends on morphology
Shear	✗	✗
Flexion	✓	✓

Flexion depends on morphology



Viola et al. 2011

$$\mu \equiv \frac{(Q_{11}+Q_{22})^2}{Q_{1111}+2Q_{1122}+Q_{2222}}$$

Simplest statistic: average

$$\langle\zeta\rangle \simeq \left(\frac{9}{4} - 3\langle\mu\rangle - \frac{5}{4}\langle\mu|\chi|^2\rangle\right)F + \left(\frac{9}{4} - \frac{5}{4}\langle\mu|\chi|^2\rangle - \langle\mu\rangle\right)Gg^\star + \left(\frac{15}{2} - 3\langle\mu|\chi|^2\rangle - 2\langle\mu\rangle\right)F^\star g - 4\langle\mu\chi\rangle F^\star - \frac{1}{2}\langle\mu\chi^\star\rangle G$$

$$\langle\delta\rangle \simeq \frac{3}{4}(1 - \langle\mu|\chi|^2\rangle)G + \left(\frac{33}{4} - \frac{3}{4}\langle\mu|\chi|^2\rangle\right)gF - \frac{9}{2}\langle\chi\mu\rangle F$$

General

$$\langle\zeta\rangle \simeq \left(\frac{9}{4} - 3\langle\mu\rangle\right)F$$

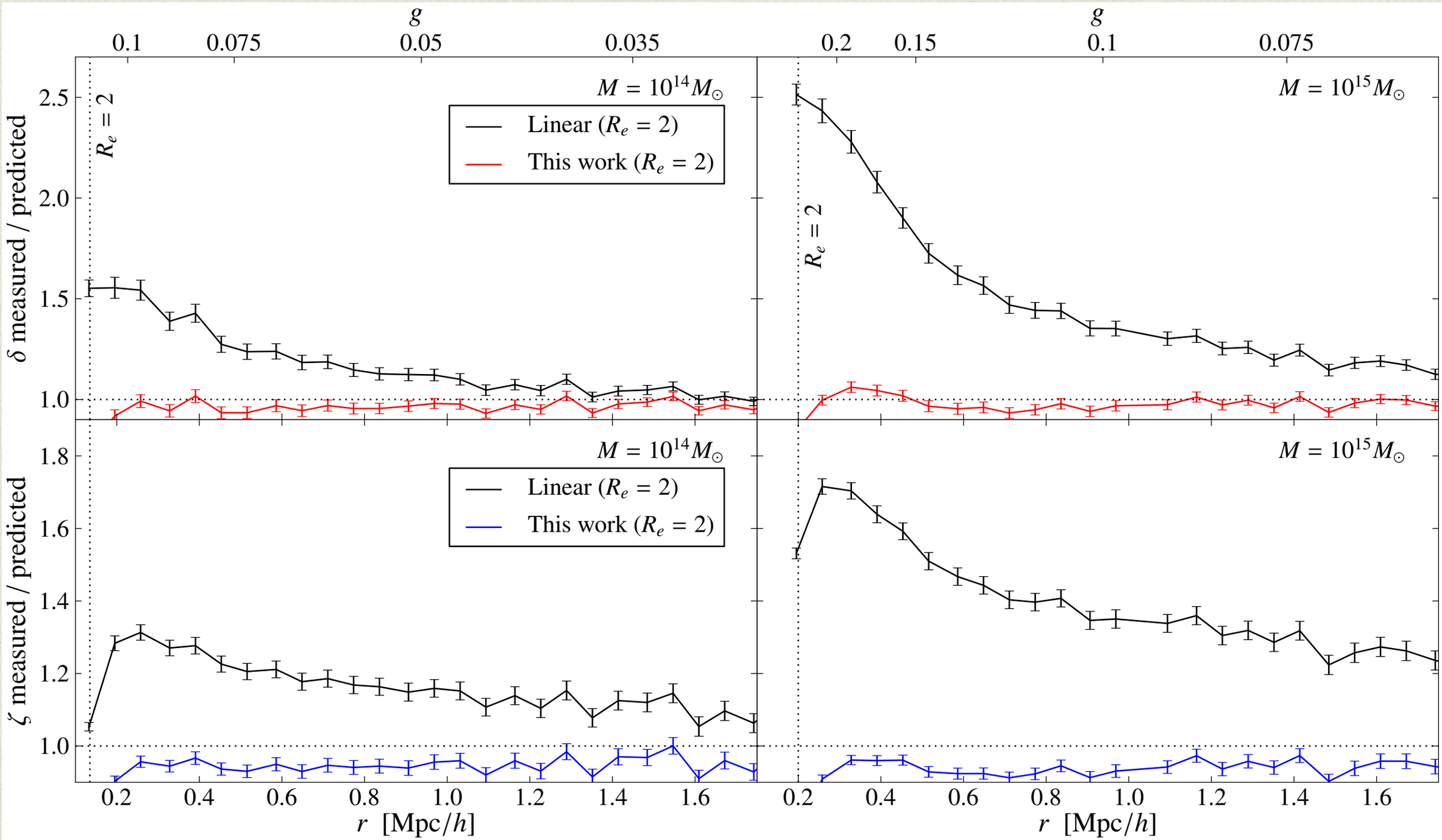
$$\langle\delta\rangle \simeq \frac{3}{4}G$$

Okura et al. 2007,2008
Leonard et al. 2007,2010

Viola et al. 2011

What do we measure ?

Viola et al. 2011



Spin-1 or Spin-3 ?

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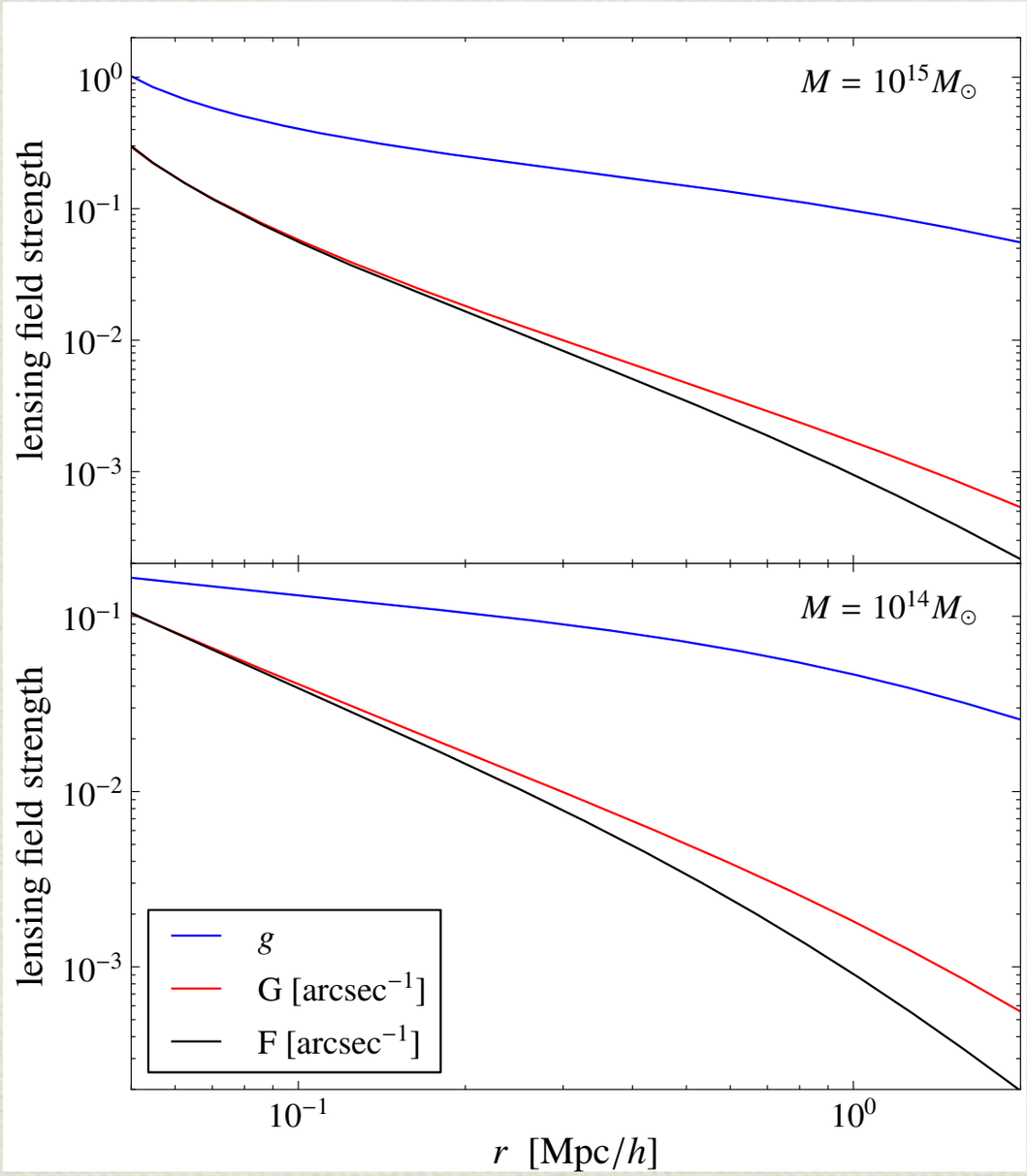

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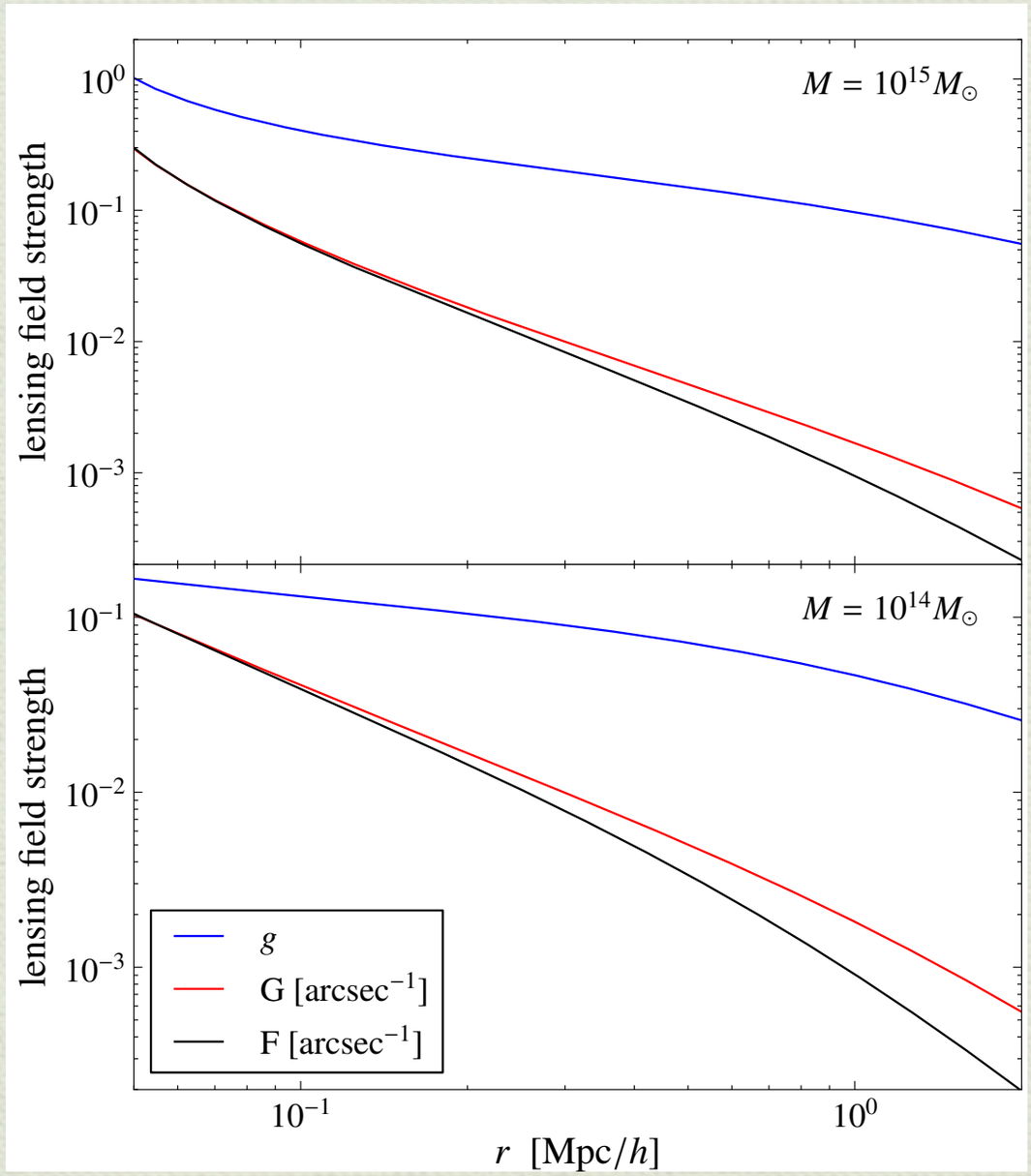

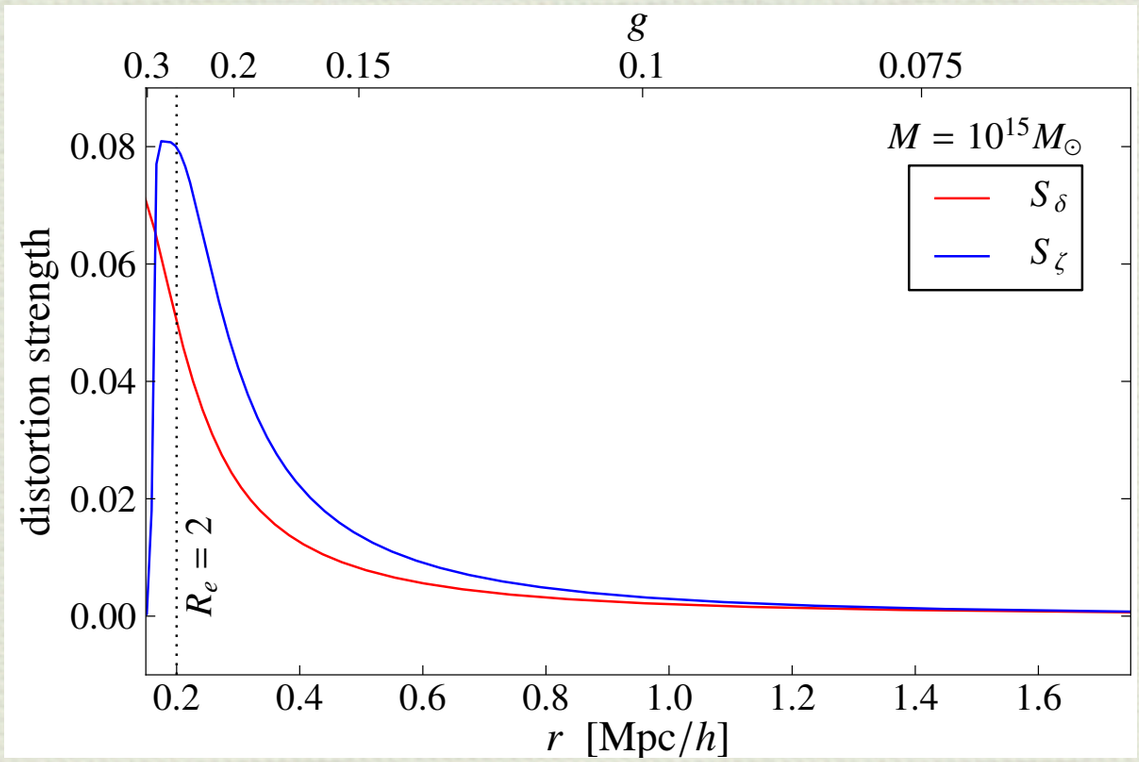

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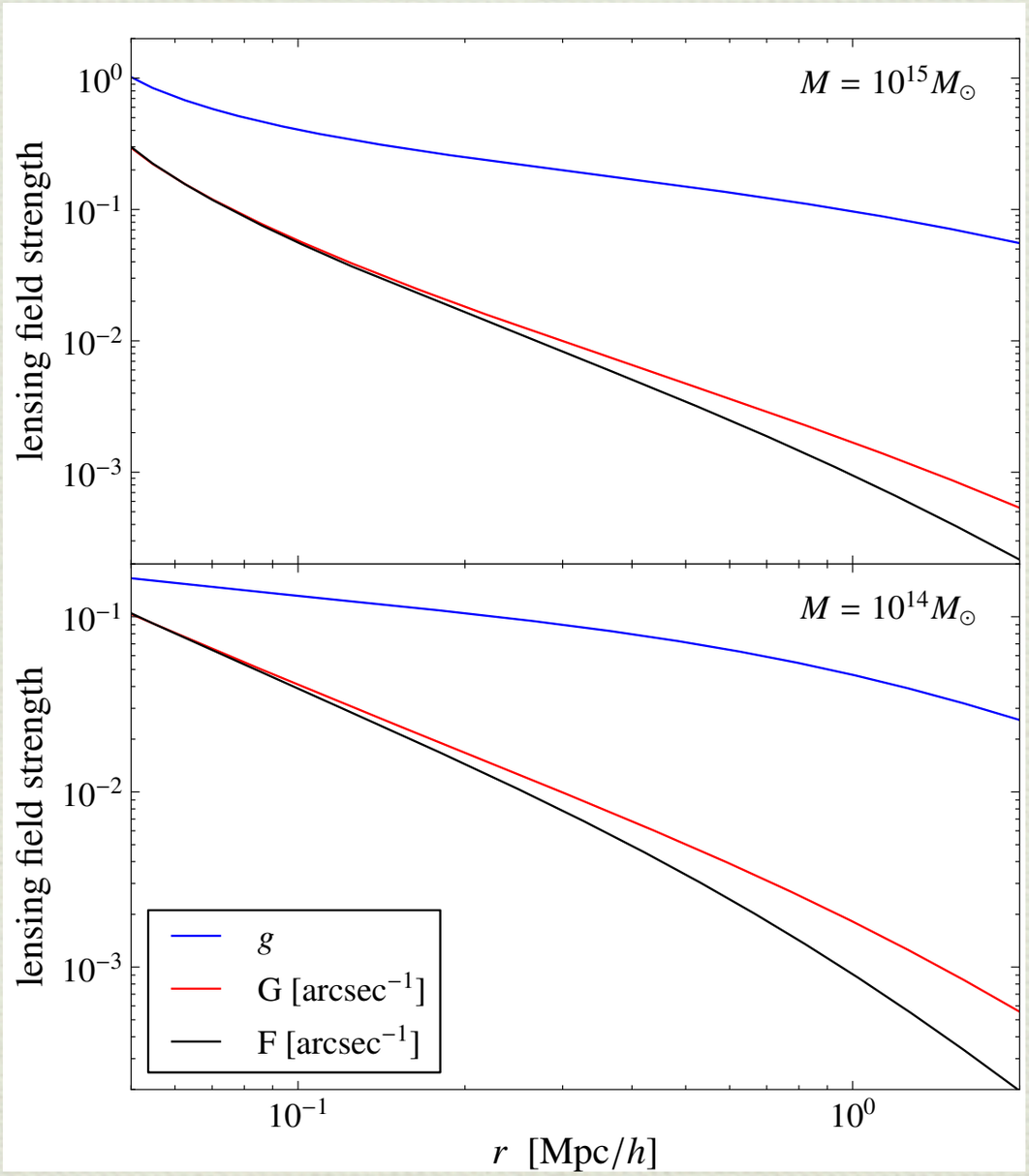

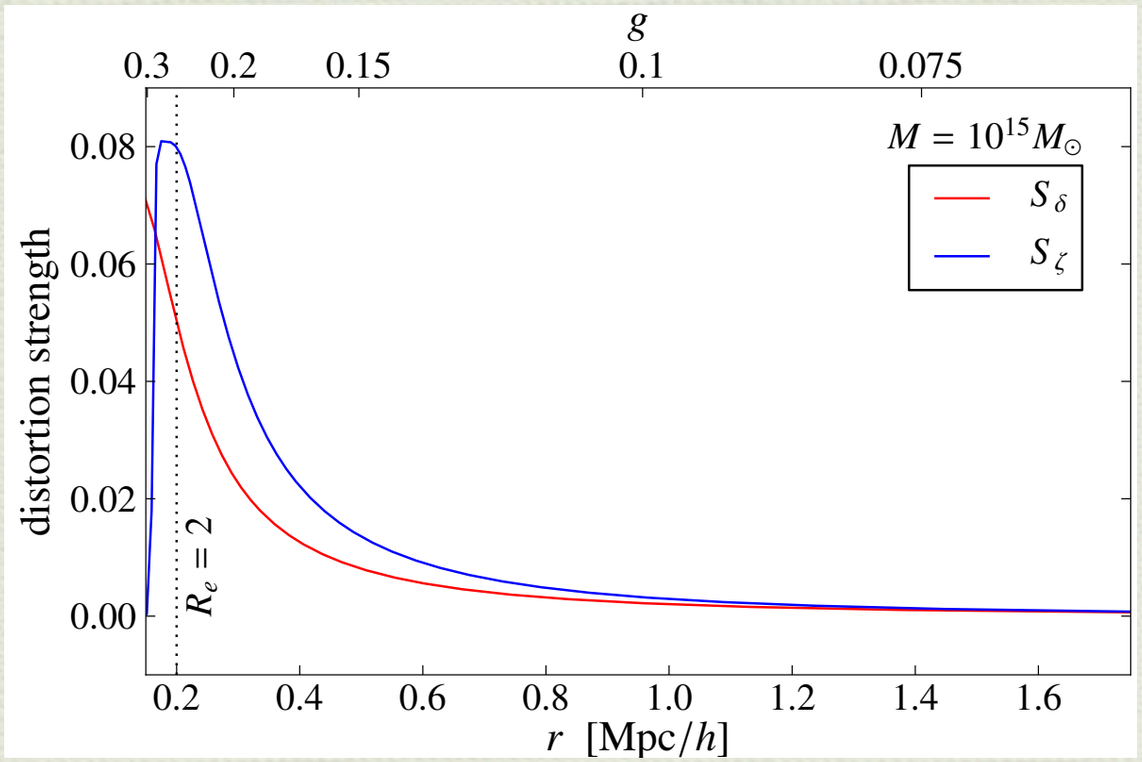

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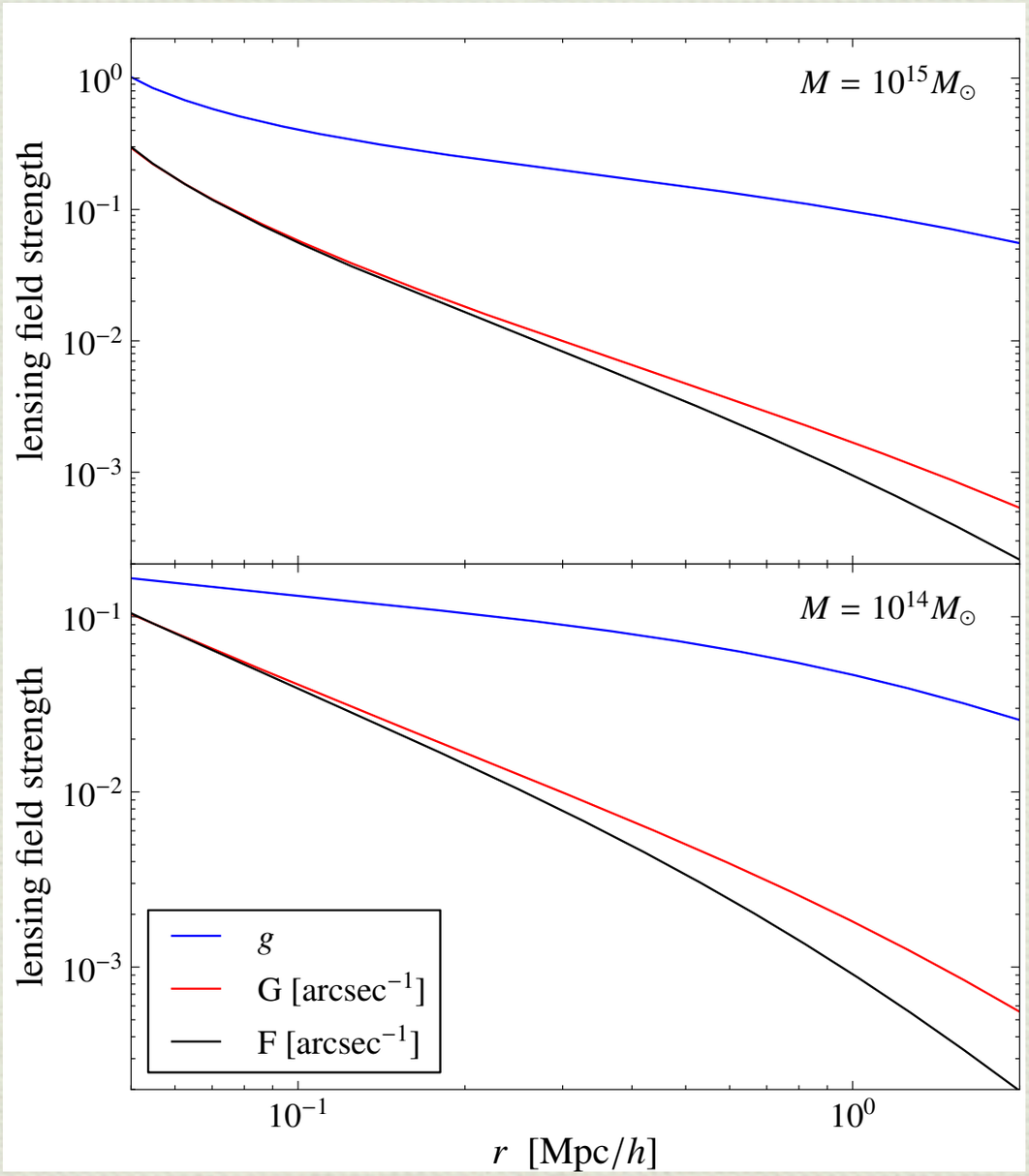

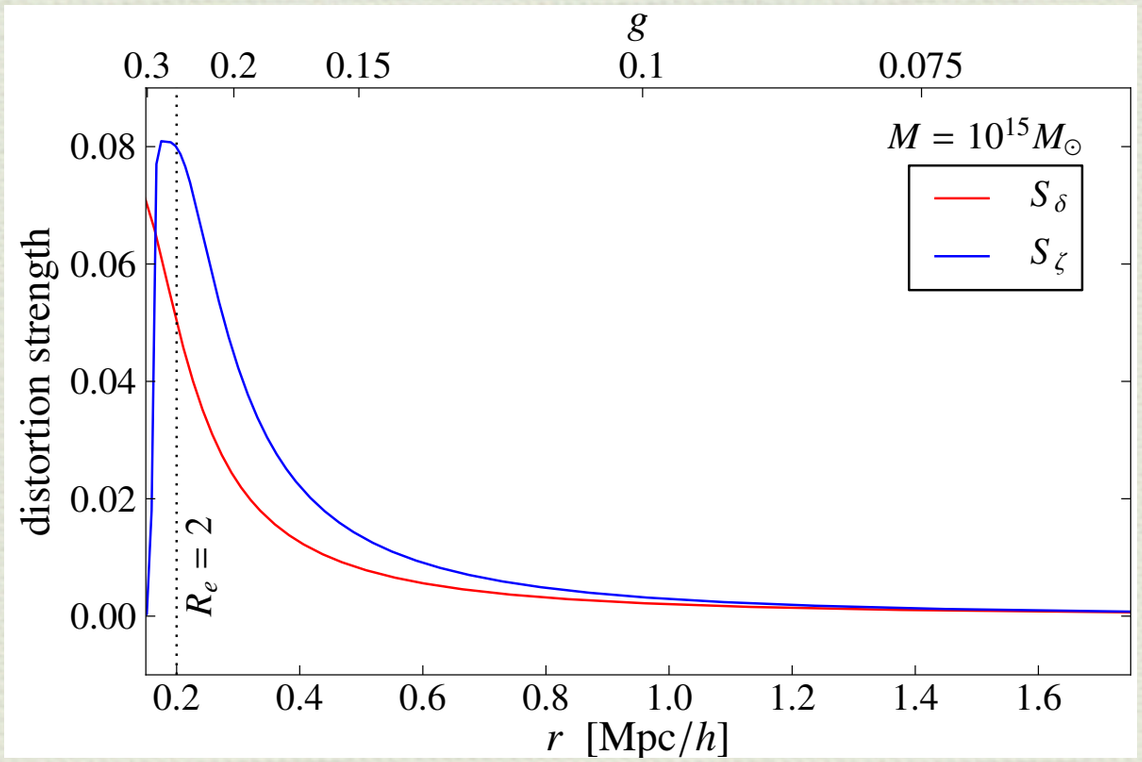

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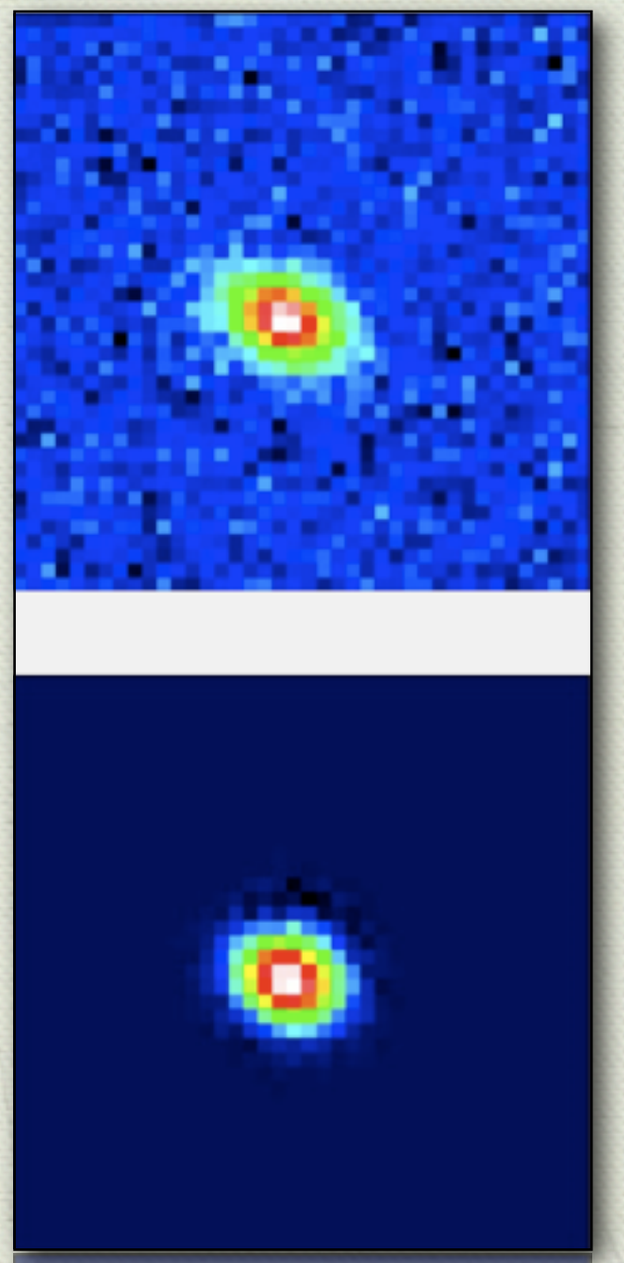
$$\frac{(S/N)_\zeta}{(S/N)_\delta} = \sqrt{5}\,\frac{S_\zeta}{S_\delta}$$

DEIMOS for flexion...

- Model independent as KSB, HOLICS
- It allows an **exact** PSF deconvolution as shapelets



$$G^{w,\star}_{ijk} = \int W(\vec{x}) I^c(\vec{x}) x_i x_j x_k \mathrm{d}\vec{x}$$

DEWEIGHTING (real space)

$$G^{\star}_{ijk} = \int I^c(\vec{x}) x_i x_j x_k \mathrm{d}\vec{x}$$

DECONVOLVING (moment space)

$$\{G^{\star}\}_{i,j} = \sum_k^i \sum_l^j \binom{i}{k}\binom{j}{l} \{G\}_{k,l} \{P\}_{i-k,j-l}$$

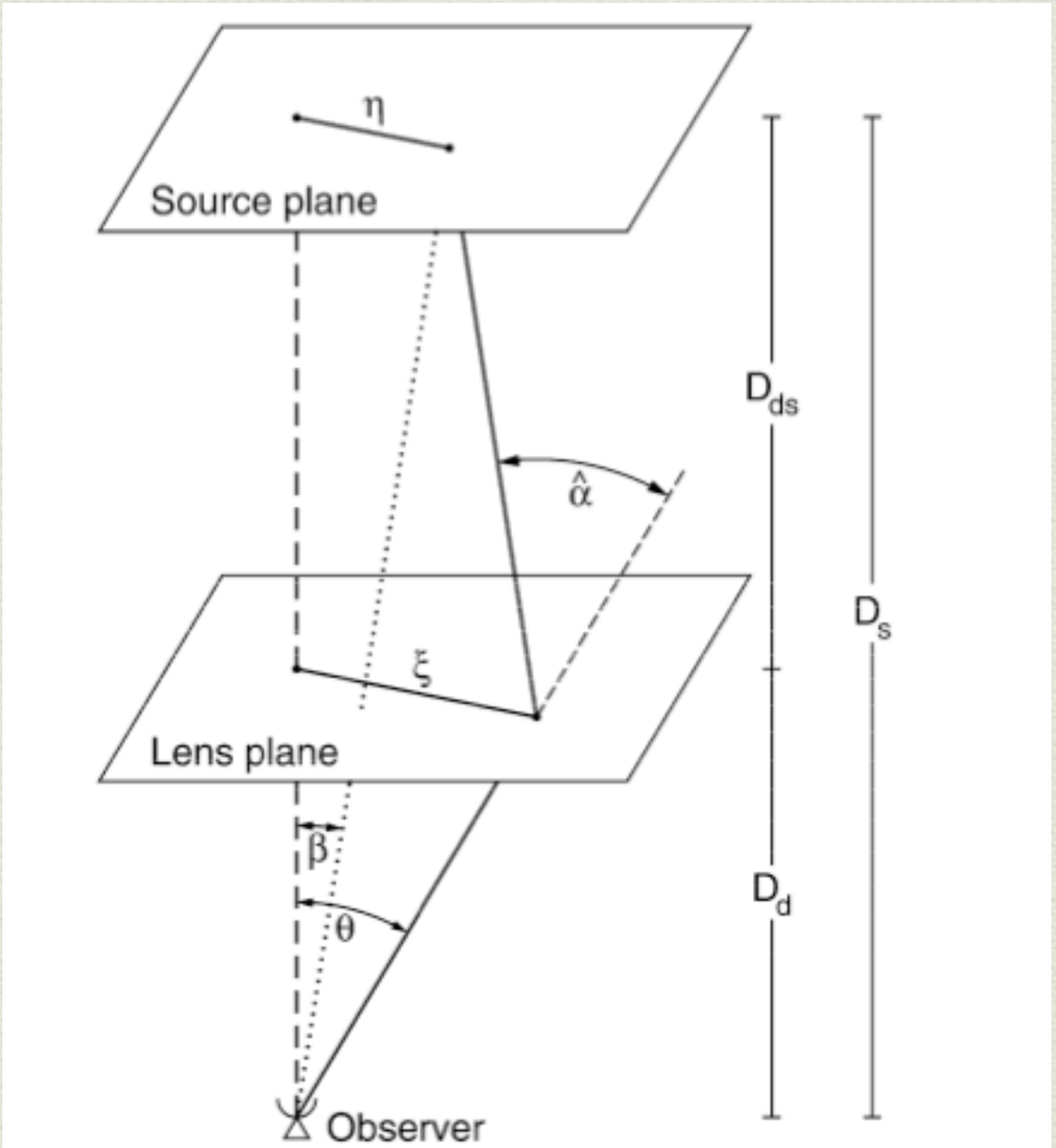
FORMING Spin-1 and Spin-3 estimators

Melchior,MV et al. 2011

Conclusions

- Flexion probes the gravitational potential at small scales. Very useful for having extra info on cluster potential, substructures detection, halo's ellipticity...
- Measurements of spin-1 and spin-3 distortions DOES NOT mean a direct measurement of F and G flexion! [shear-flexion cross talk]
- Spin-1 and spin-3 distortions depend on the galaxy morphology: use this information to select your galaxies !
- Intrinsic flexion ?
- What is the optimal weighting function for measuring flexion ?
- New systematics ?

Derivatives of the gravitational tidal field



$$\beta = \theta - \alpha(\theta)$$

It is a non linear equation!

$$\beta_i \simeq \theta_i - \Psi_{,ij}\theta_j - \frac{1}{2}\Psi_{,ijk}\theta_j\theta_k$$

$$\beta \simeq (1-\kappa)\theta - \gamma\theta^* - \frac{1}{4}\mathcal{F}^*\theta^2 - \frac{1}{2}\mathcal{F}\theta\theta^* - \frac{1}{4}\mathcal{G}(\theta^*)^2$$

Second derivative of the gravitational potential

Third derivative of the gravitational potential