

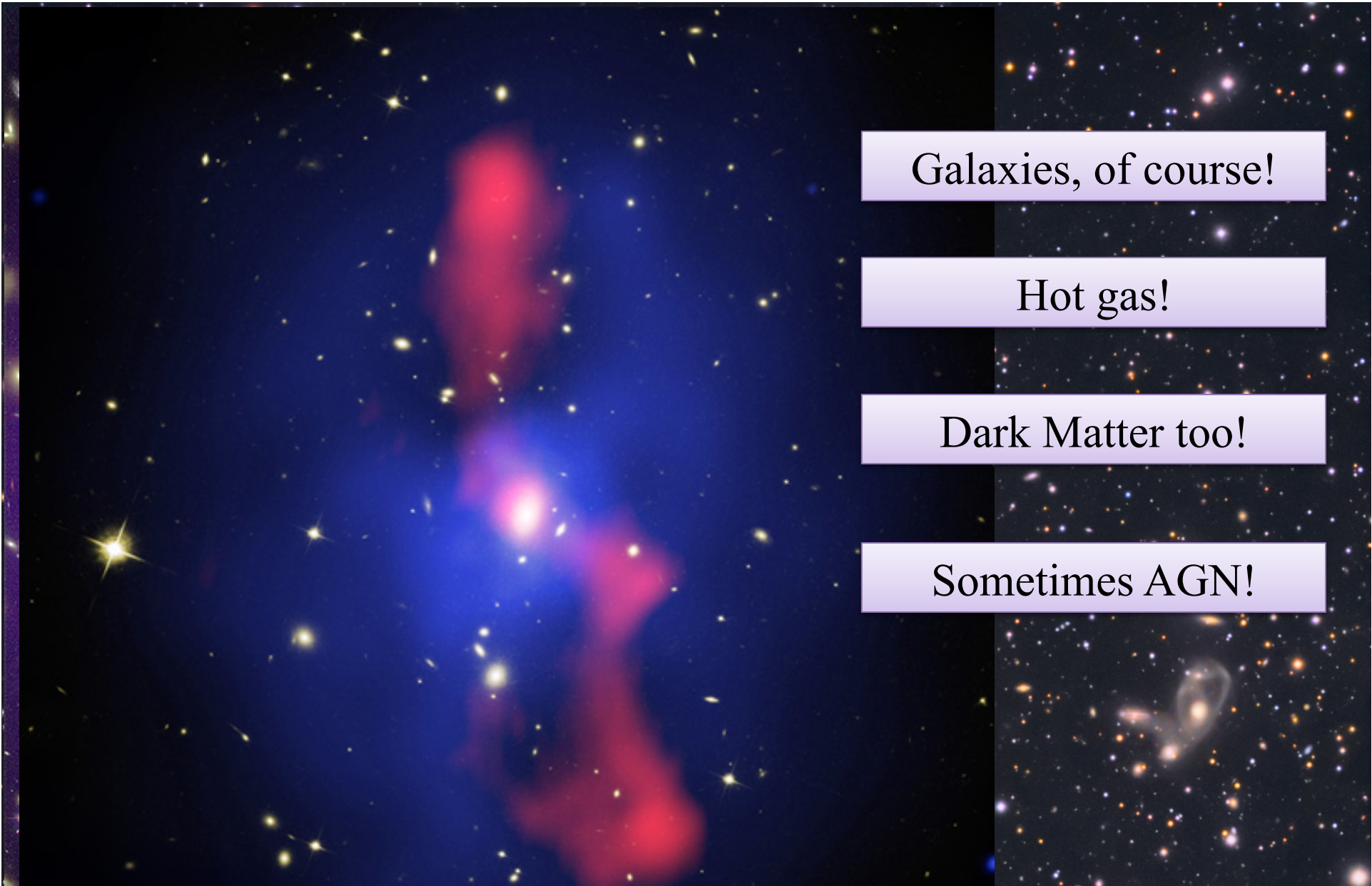
Orientation Bias of Optical Galaxy Clusters and Relevance to *Stacked Weak Lensing* Analyses

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Based on Dietrich in prep.
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What are clusters of galaxies made of?

[image credit: HST/NASA/ESA]



Galaxies, of course!

Hot gas!

Dark Matter too!

Sometimes AGN!

Astrophysical & Cosmological Usage

- Galactic physics
 - e.g., Evolution in luminosity function
 - Evolution of galaxy population
- Cosmological probe
 - e.g., Evolution in cluster number density
 - Constraining cosmological parameters

$$\frac{d^3 N}{dM d\Omega dz}(M, z) = \frac{dn_M}{dM}(M, z) \cdot \frac{d^2 V_{comoving}}{dz d\Omega}(z)$$

Estimating Clusters Mass 101

- X-ray
 - $M \sim T^{3/2}$
 - assuming in equilibrium settled down at *spherically symmetric* gravitational potential well
- Sunyaev-Zel'dovich effect (SZE)
 - Measuring distortion of background CMB via inverse Compton scattering
 - Amount of dip \sim gas density
- Strong lensing
 - Using multiple images and arcs
- Weak lensing
 - Measuring distortion of background sources due to gravity of clusters

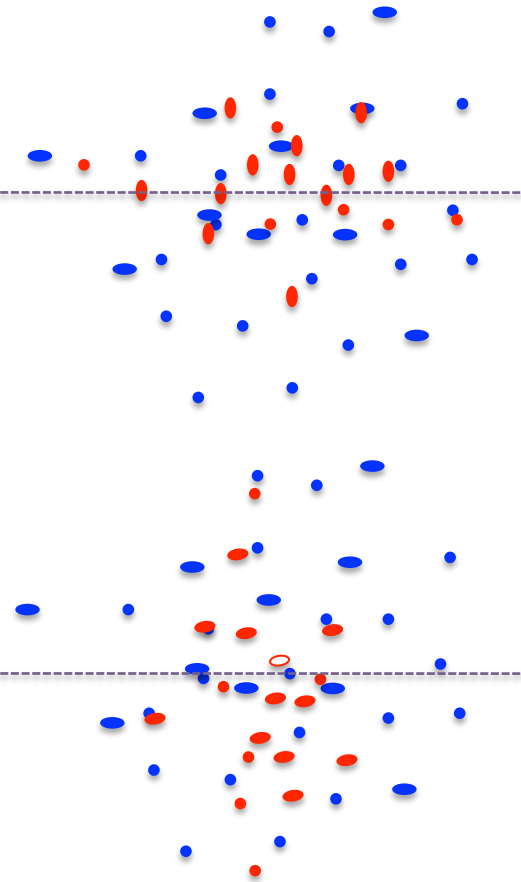
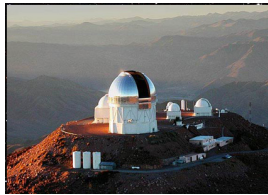
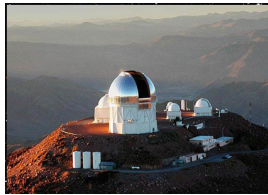
Weak Lensing on Clusters 101

- **Individual** clusters
 - Large enough
 - Fitting NFW profile to **shear** profile around individual clusters
 - Warning: **scatter** and **bias** due to triaxial shape or **correlated** (bias) and **un-correlated** (scatter) LSS along LoS
- **Stacked** clusters
 - Wimpy kids “**averaged**” to beat down noise / boost signal
 - Averaged clusters shape : **spherical**



?!

Does Orientation Affect Detectability?



Weak Lensing on Clusters 101

- Individual clusters
 - Large enough
 - Fitting NFW profile to shear profile around individual clusters
 - Warning: scatter and bias due to triaxial shape [ex] or correlated (bias) and un-correlated (scatter) LSS along LoS

- Stacked clusters

- Wimpv kids “

ONLY VALID if i) selection is free of bias, ii) mass proxy independent of orientation!!

clusters shape : spherical

How to proceed?

- Use *multiple* cluster finders
- Use **realistic** cosmological simulation
- Run cluster finders on cosmological simulation
- Measure **shapes** of **clusters**, as well as those of **halos**
- Measure **richness** λ on all clusters and halos

Cluster Finders

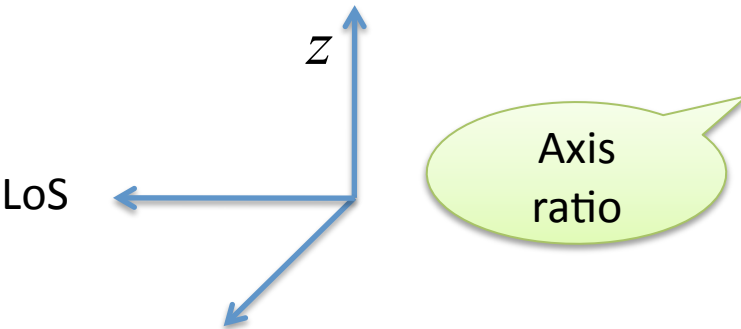
- **redMaPPer** (Rykoff et al. 2013)
 - Overdensity of *red-sequence* galaxies
 - Empirically calibration and iterative process
- **gmBCG** (Hao et al. 2010)
 - Fitting error corrected Gaussian mixture around BCG
 - Identify “*blue cloud*” as well as red members
- **C4** (Baruah in prep, Miller 2005)
 - Galaxy *photoz* along with physical *distance*, *color* and *magnitude*
- **WAZP** (Benoist in prep)
 - Wavelet Adapted z Photometric
 - 2D (RA,Dec) and 1D (photoz) density field reconstruction based on the *wavelet* transform

N-body Simulation

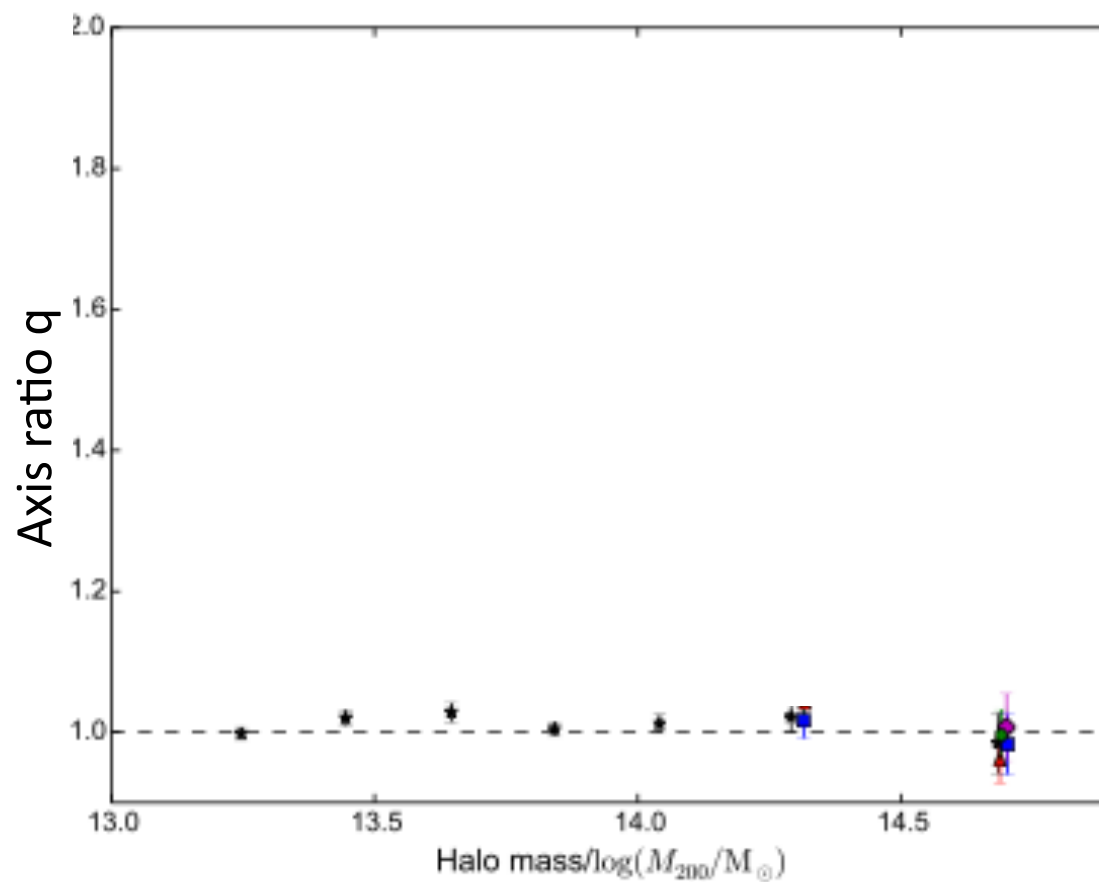
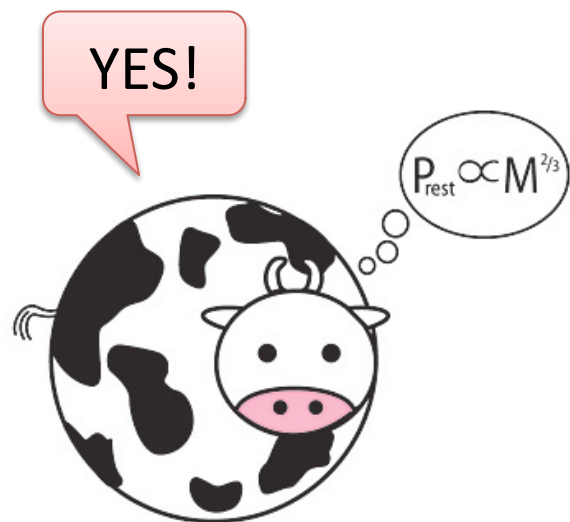
- Flat Λ CDM universe
- $\Omega_m=0.25$ $\sigma_8=0.8$ in a $1 h^{-1}\text{Gpc}$ box with 11203 particles
- 220 sqdeg light cone up to $z=1.33$
- ADDGALS to populate galaxies (Wechsler in prep, Busha in prep)
- Reproducing various observations, such as LF, color distribution and clustering properties

Ellipticity (Definition)

- Elongation along LoS : overestimation in mass (“**prolate**”)
- Elongation in the plane of the sky : underestimation in mass (“**oblate**”)

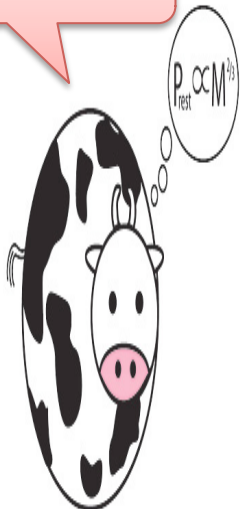
$$r^2 = q^2 \xi^2 + z^2$$

$$q^2 \begin{cases} < 1 & \text{Oblate} \\ = 1 & \text{Spherical} \\ > 1 & \text{Prolate} \end{cases}$$

Are *Stacked Halos* Spherical?

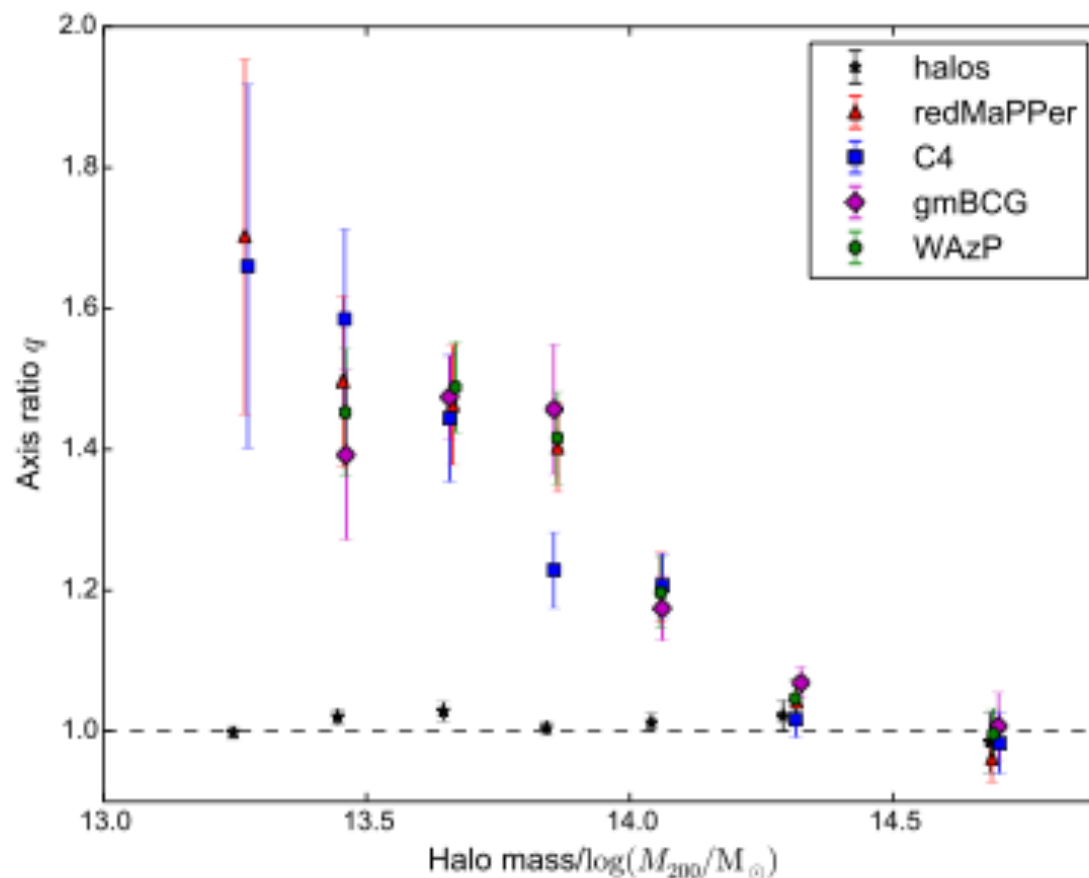


Are *Stacked* Clusters Spherical?

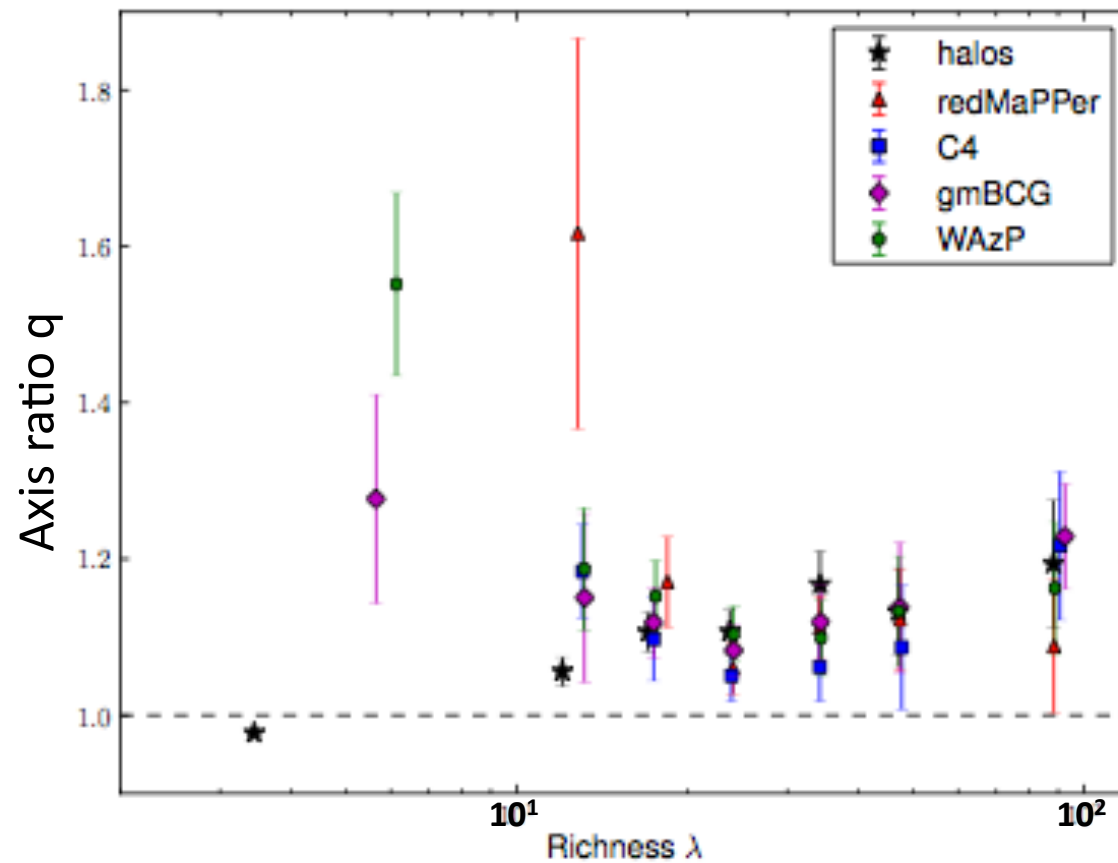
NO!



Axis ratio q

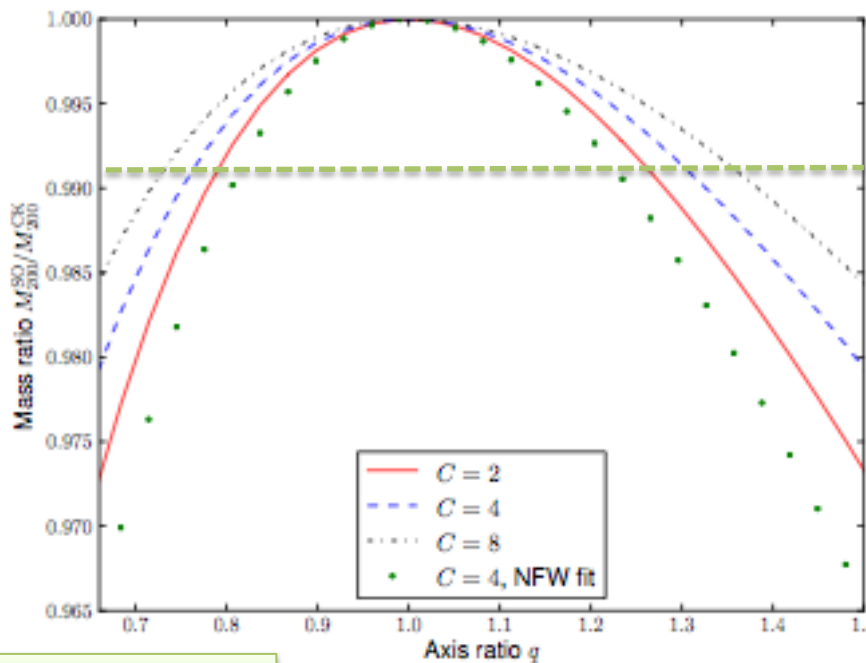


Does λ Make them Elliptical?

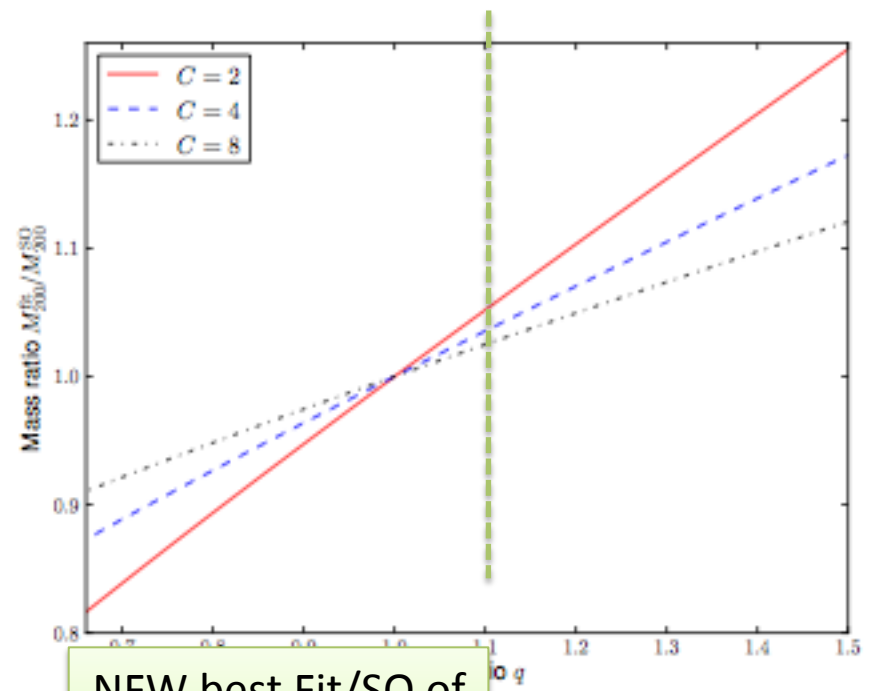


How Do *Elliptical* Cows Affect Stacked WL **Mass**?

- **Prolate**-overestimation, **oblate**-underestimation
- WL alone **not** able to determine level o bias in mass
 - **Degeneracy** in shape & concentration



SO/Elliptical



NFW best Fit/SO of
elliptical

Summary

- Title: **Orientation Bias** of Optical Galaxy Clusters and **Relevance** to *Stacked Weak Lensing* Analyses
 - Yes, cluster finders **prefer elongated halos** along LoS
 - Typical axis ratio ~ 1.1 (slightly prolated)
 - Orientation bias results in **3~6% bias in mass**