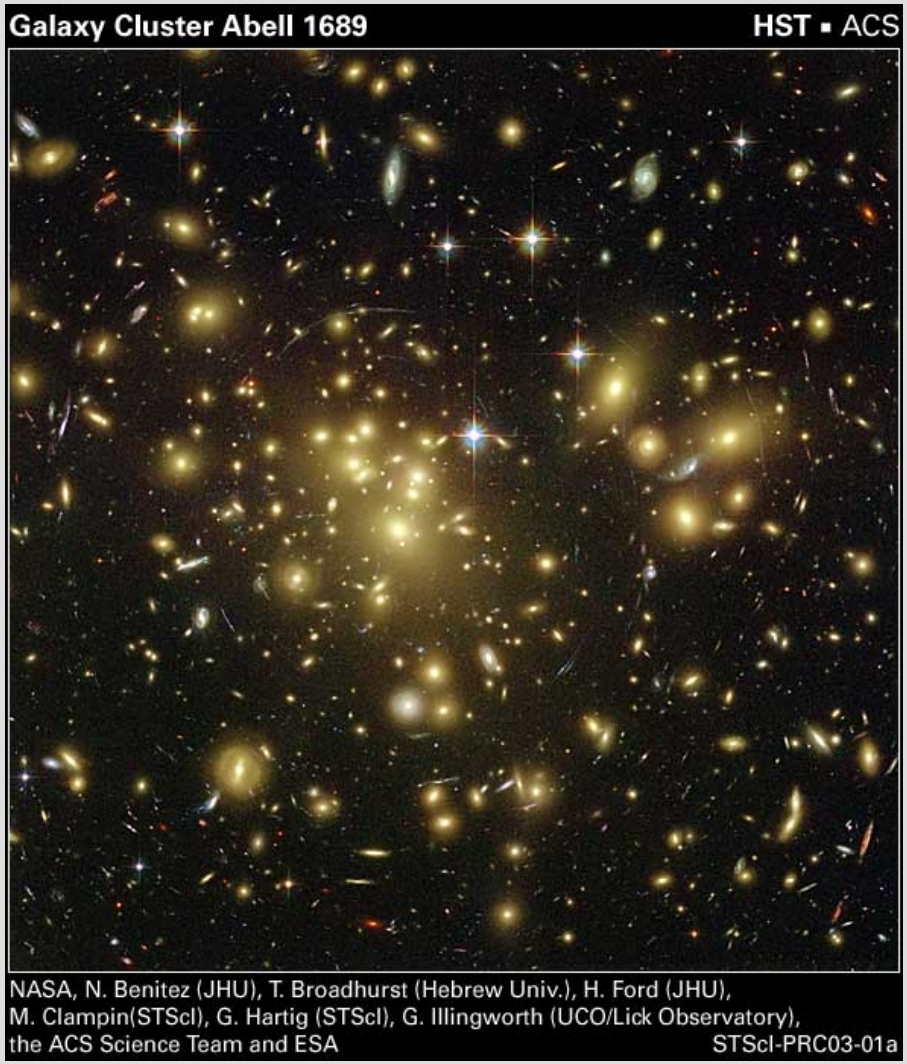
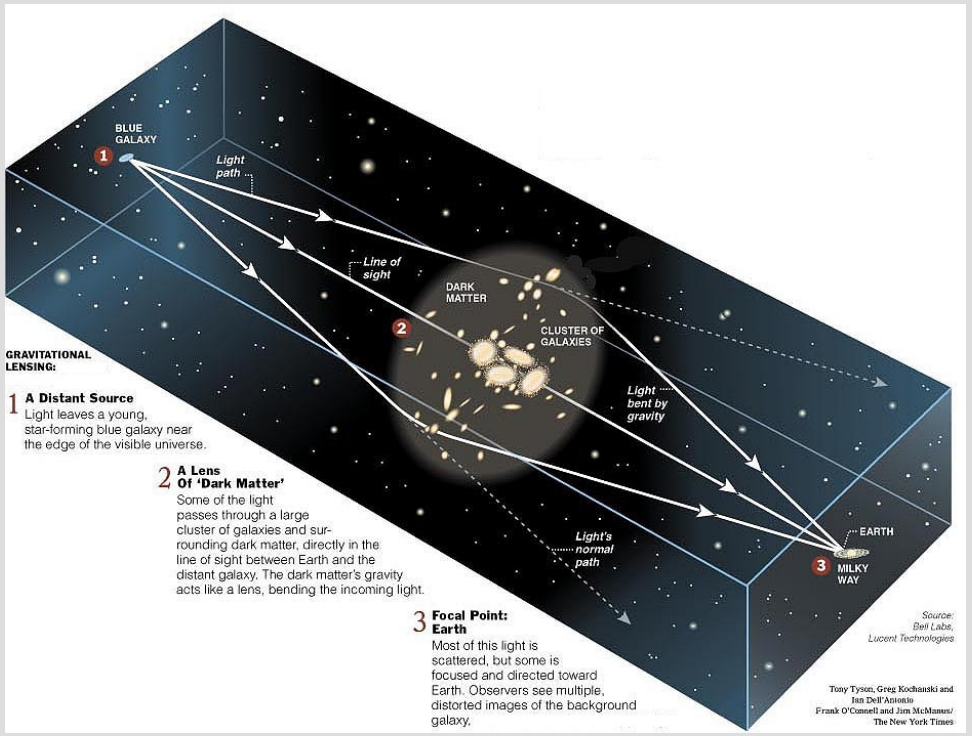
Weighing the 0957+561 Cluster





Cluster Weighing Workshop
July 31, 2008 Garching, Germany
Reiko Nakajima, UC Berkeley

Weak Lensing Aperture Mass is Exact

- If:
  - Shear γ is known
  - Shear is integrated out from infinity
  - No other intervening LSS
  - Two-dimensional cluster

Weak Lensing Aperture Mass is Exact

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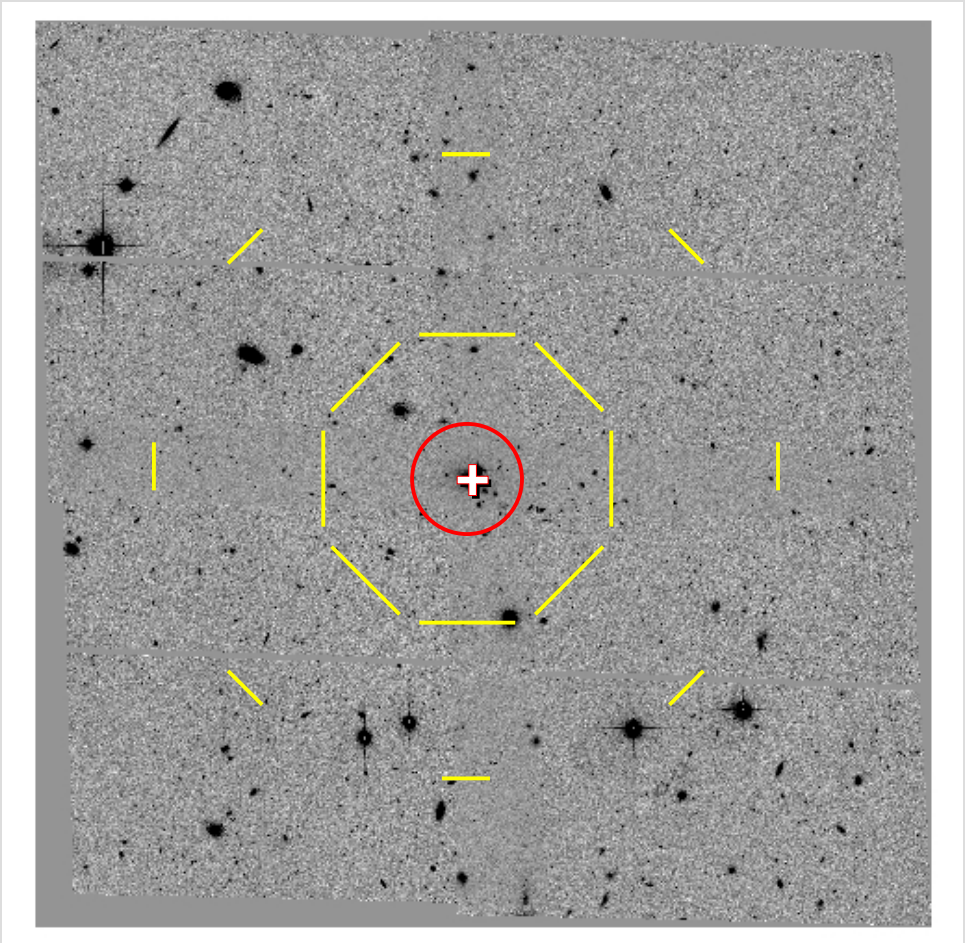
Exact when Universe consists of:

- You (observer)
- Pancake-shaped cluster
- Some shear pattern around the pancake
- Nothing between you and the pancake

Weak Lensing Aperture Mass is Exact



Weak Lensing Aperture Mass is Exact

- If:
  - Shear γ is known
  - Shear is integrated out from infinity
  - No other intervening LSS
  - Two-dimensional cluster

- Unrealistic assumptions
- Use simulation or modeling to estimate magnitude of systematics

Weak Lensing Aperture Mass is Exact

- If:
  - Shear γ is known
  - Shear is integrated out from infinity
  - No other intervening LSS
  - Two-dimensional cluster

- Stacking shear info from multiple clusters to average out LSS effects

Weak Lensing Aperture Mass is Exact

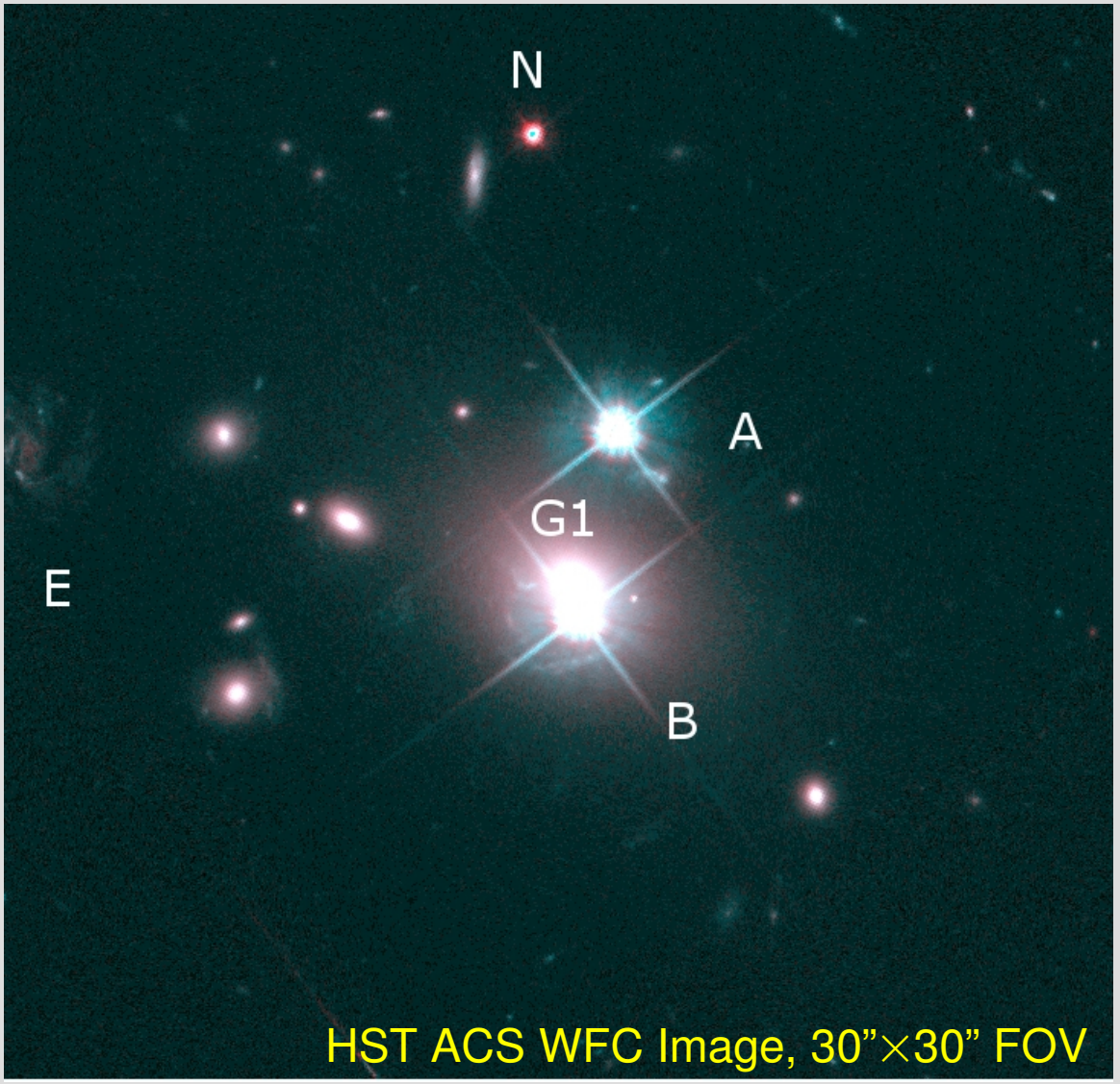
- If:
  - Shear γ is known
  - Shear is integrated out from infinity
  - No other intervening LSS
  - Two-dimensional cluster

- Increase FOV

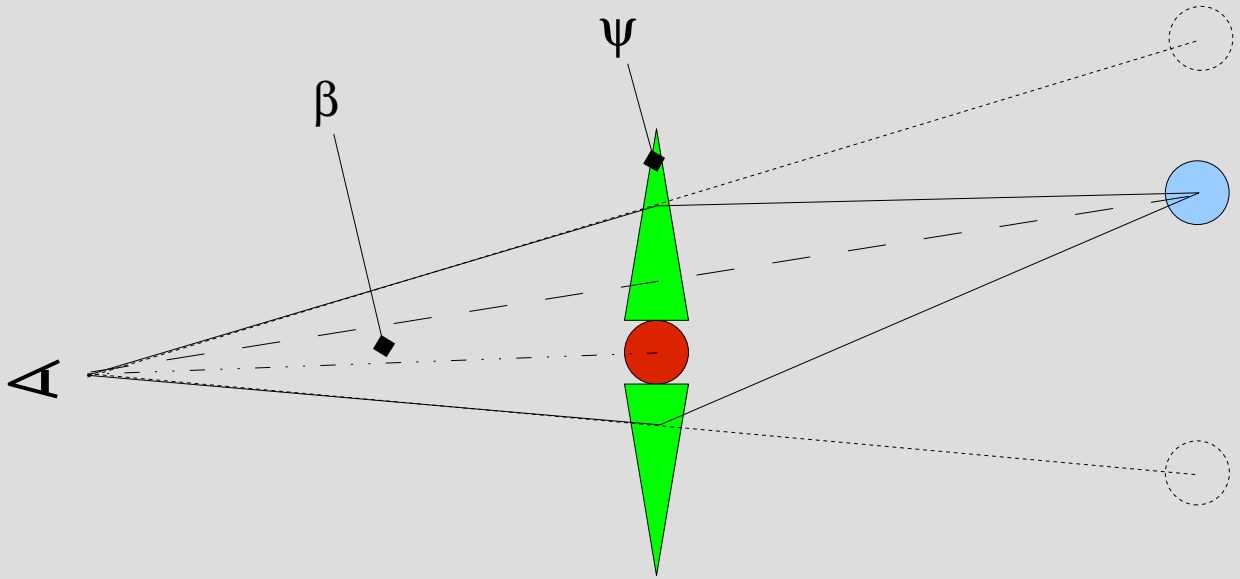
Weak Lensing Aperture Mass is Exact

- If:
  - Shear γ is known
  - Shear is integrated out from infinity
  - No other intervening LSS
  - Two-dimensional cluster
- Shear estimation
  - Infinite number of source images
    - deep images
    - bands
  - Shape measurement
    - PSF
    - method
- Angular diameter dist.
  - Redshifts known
  - Cosmology known

Q0957+561 Lens System



Strong Lens



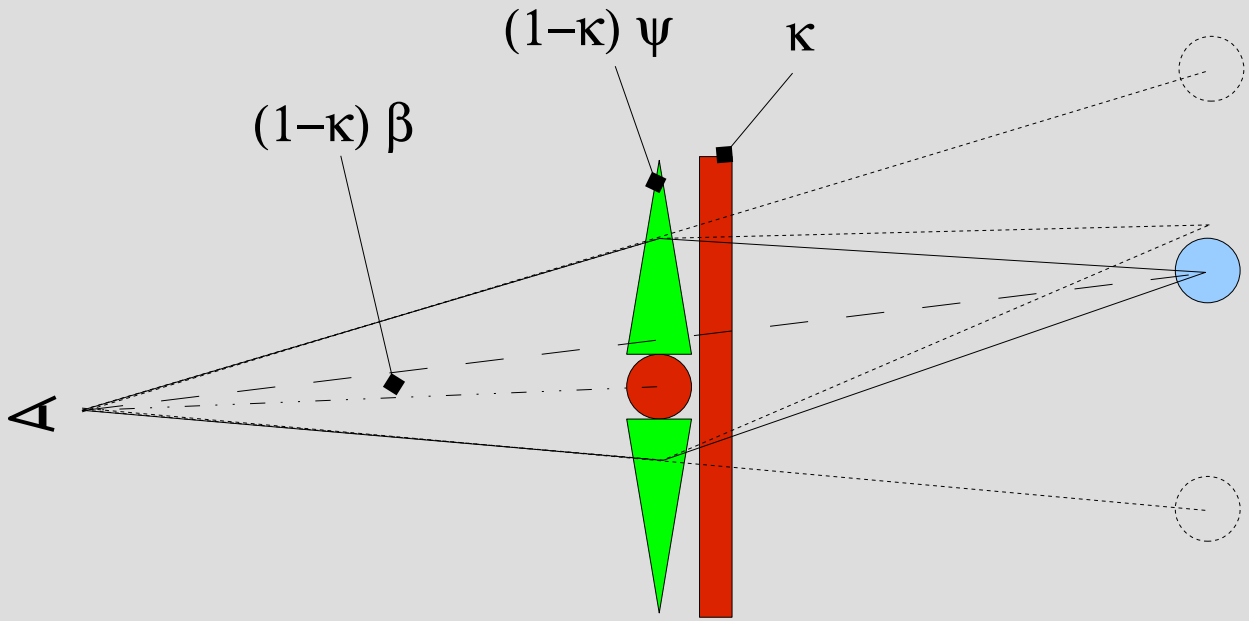
Observer

z = 0

Lens
(Galaxy)
z = 0.355

Source
Quasar
z = 1.414

SL Mass Sheet Degeneracy



Observer

z = 0

Lens

(Galaxy + Cluster)

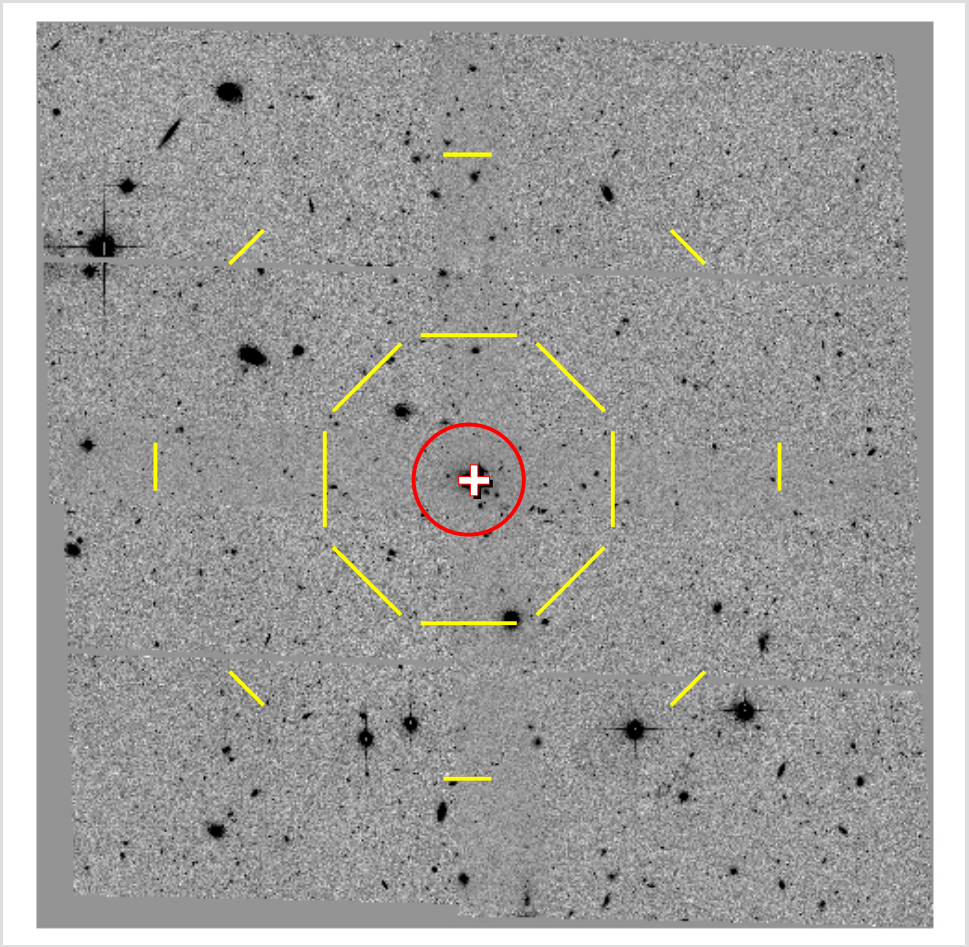
z = 0.355

Source

Quasar

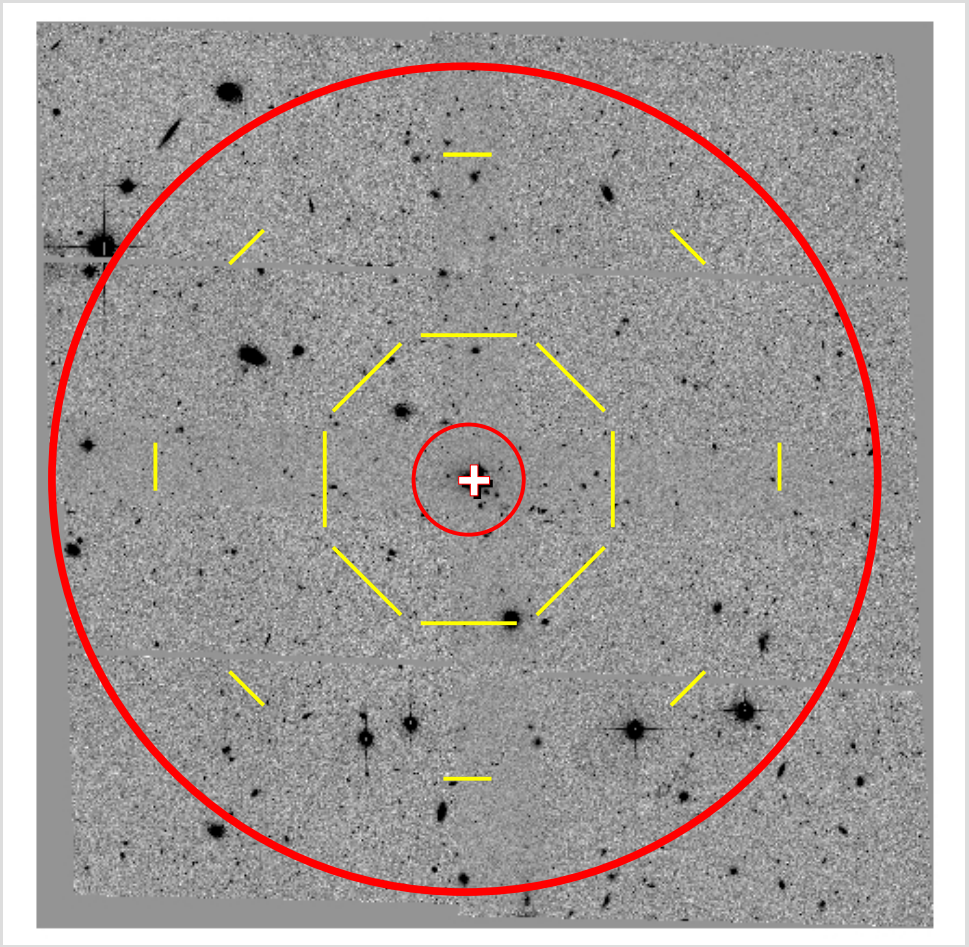
z = 1.414

Weak Lensing



HST ACS WFC Image, 6'×6' FOV

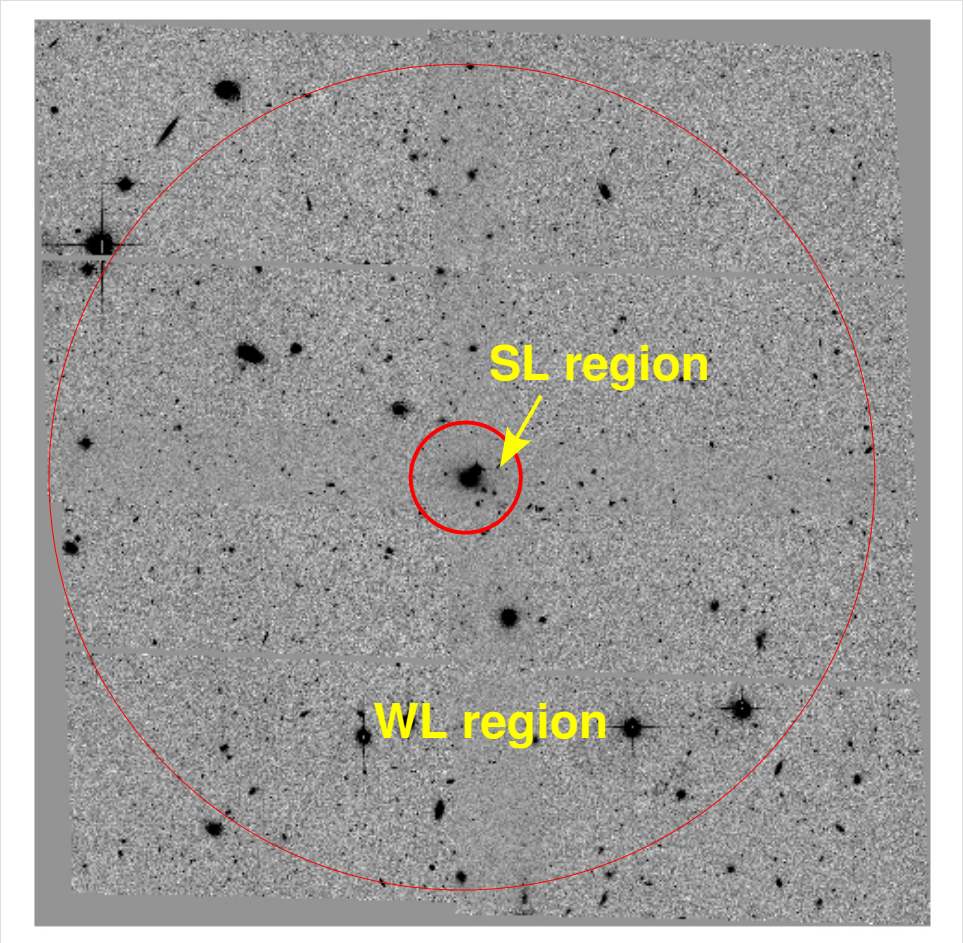
WL Mass Sheet Degeneracy



HST ACS WFC Image, 6'×6' FOV

- Set outer bounds
- Model contribution from infinity

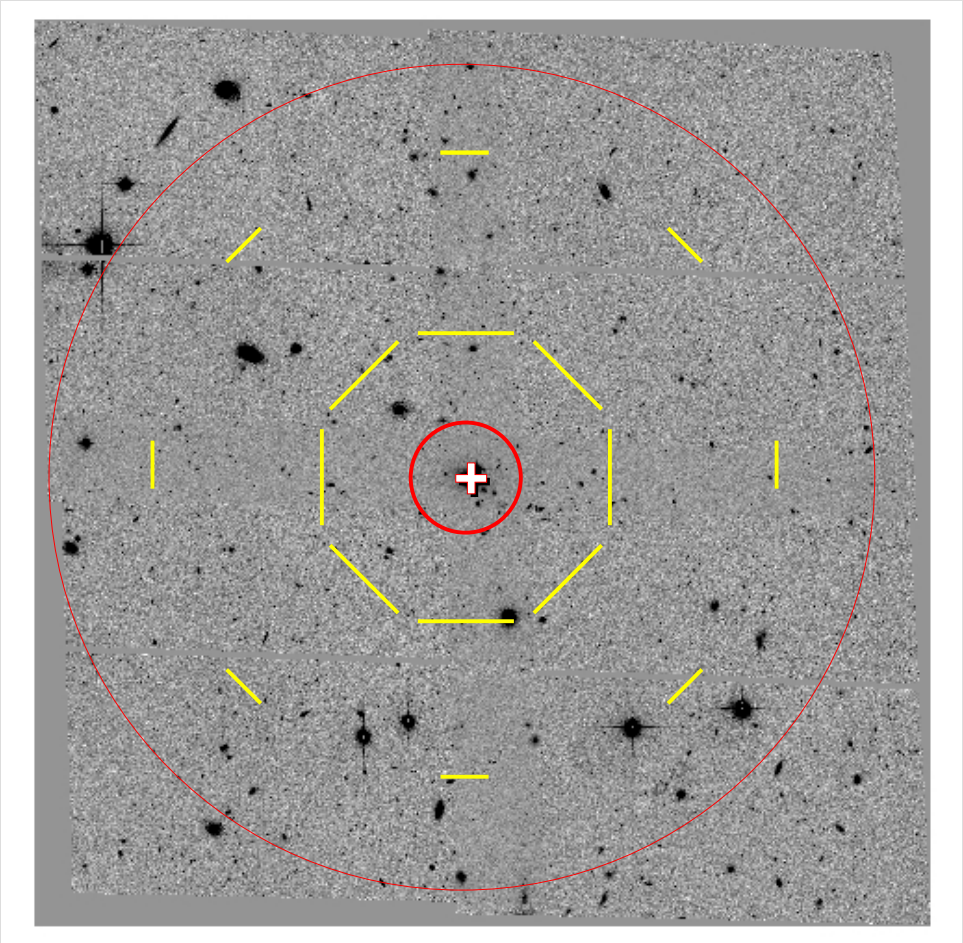
0957+561 Cluster Model



HST ACS WFC Image, 6'×6' FOV

- Model the strong lens region (r < 30”) as
  - galaxy $\psi_g(\theta)$, and
  - cluster $\psi_c(\theta)$ to 3rd order
    - mass sheet κ_c
    - + dipole σ_c
    - + constant shear γ_c
    - + external sextupole δ_c
- Measure cluster terms in 30”< r <186”

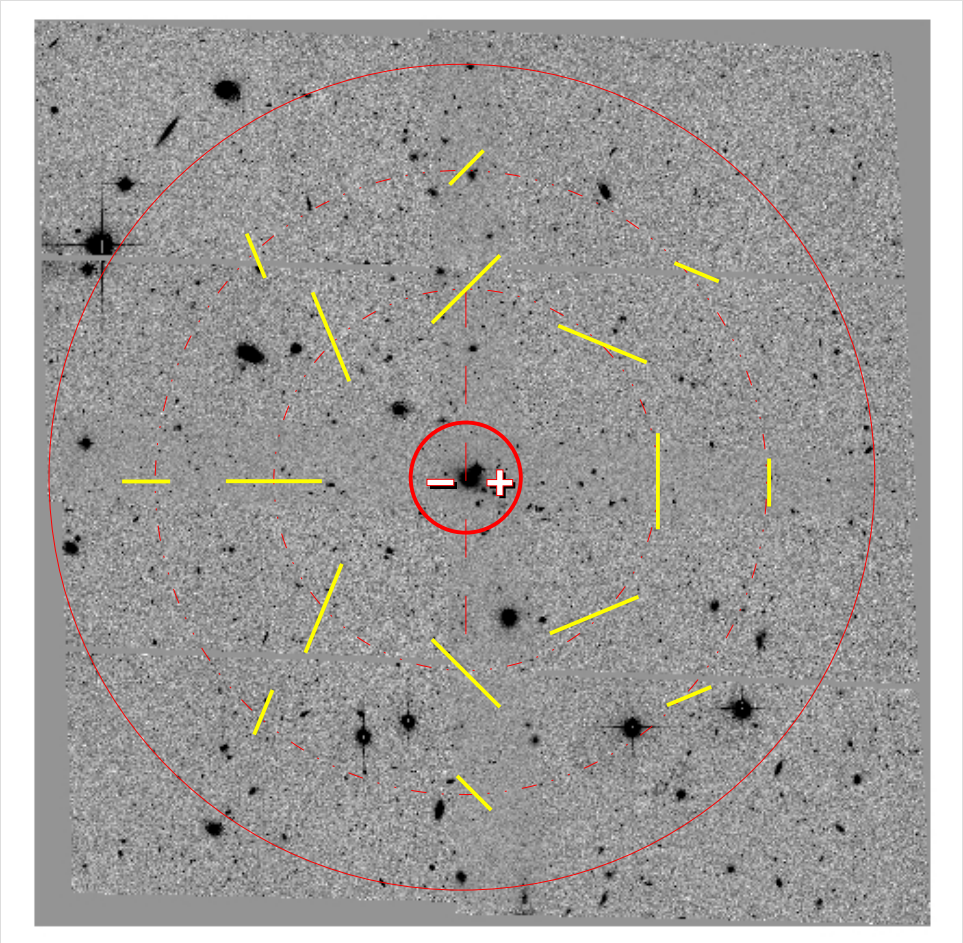
Mass Sheet = Monopole



HST ACS WFC Image, 6'×6' FOV

- Mass sheet κ_c (internal monopole)
- Net tangential shear, dropoff $\propto r^{-2}$
- $\kappa_c = 0.146 \pm 0.049$
  $\Rightarrow$ 6% uncertainty in $(1-\kappa_c)$

Internal Dipole



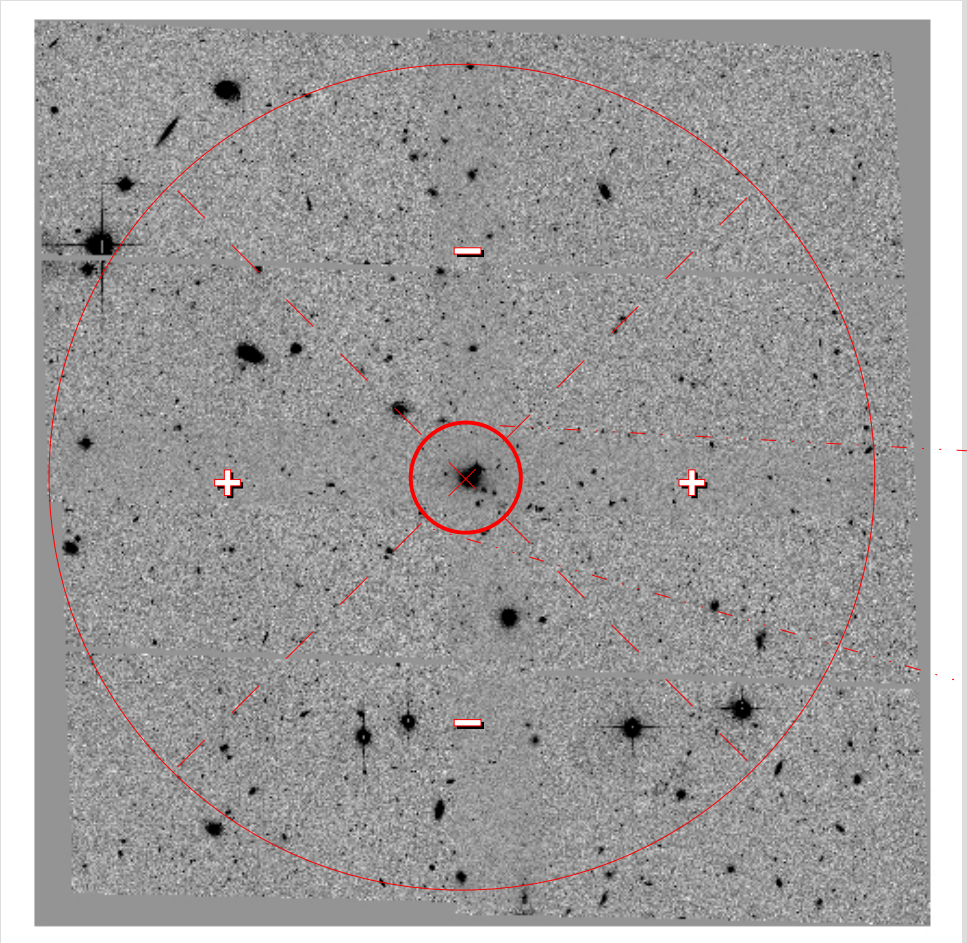
HST ACS WFC Image, 6'×6' FOV

- Mass dipole σ_c (internal mass dipole)
- Dipole ⇒ cluster center offset from G1
- Dropoff $\propto r^{-3}$

- $(1 - \kappa_c)\,\sigma_c =$

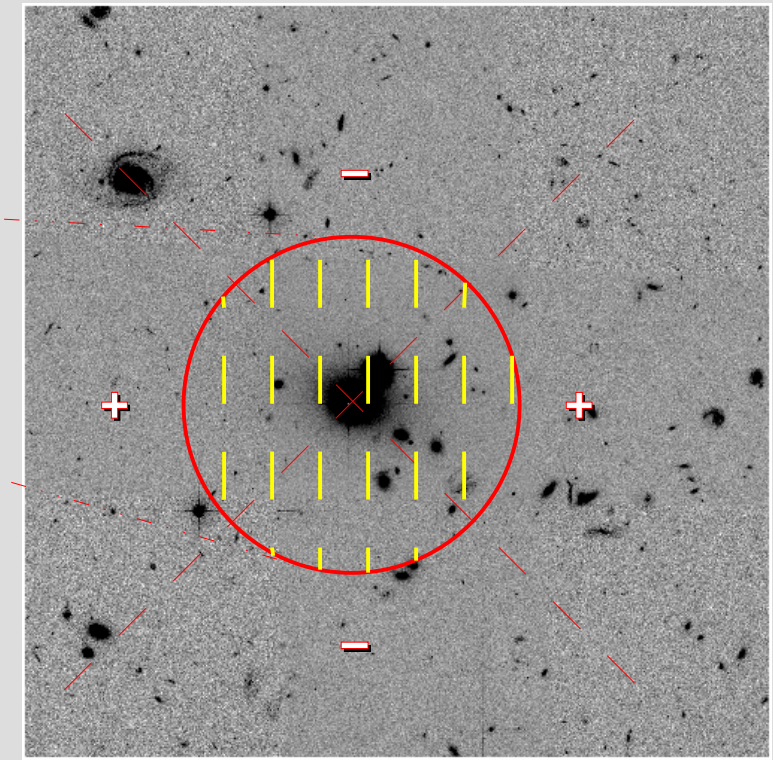
$$\begin{cases} -0.0028 \pm 0.0048 \\ -0.0054 \pm 0.0053 \end{cases}$$

Constant Shear = External Quadrupole

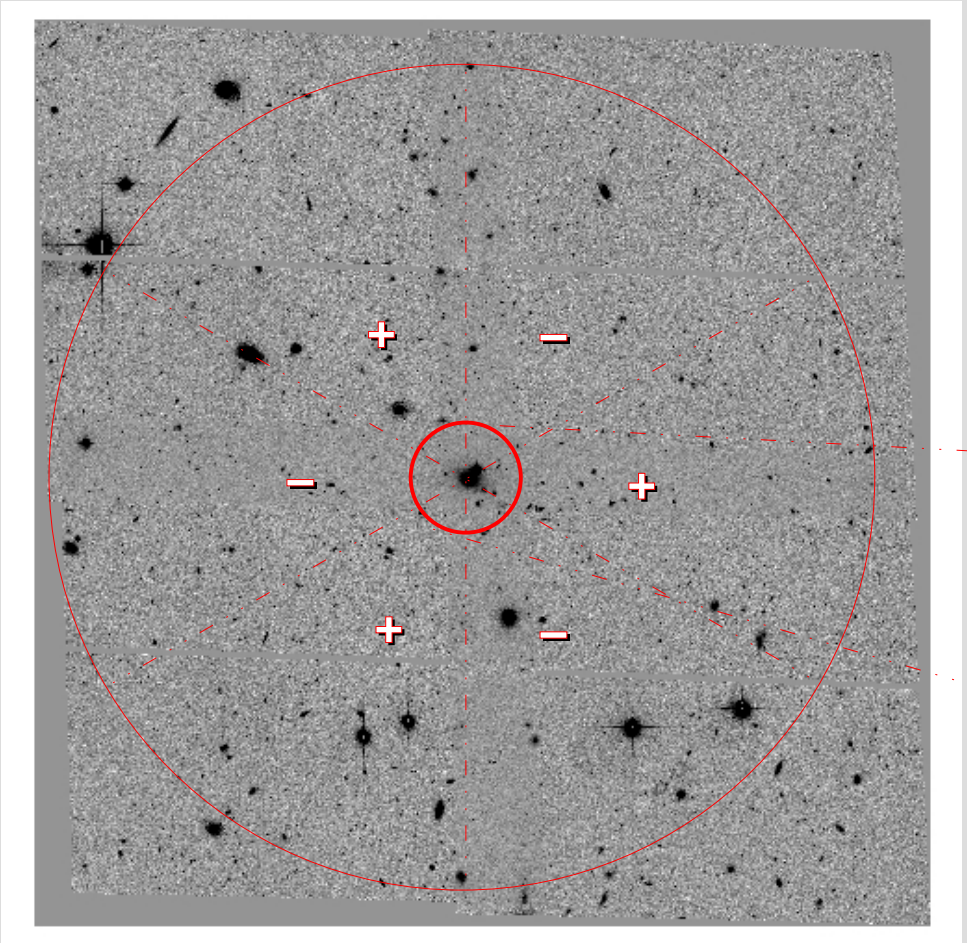


HST ACS WFC Image, 6'×6' FOV

- Constant shear γ_c

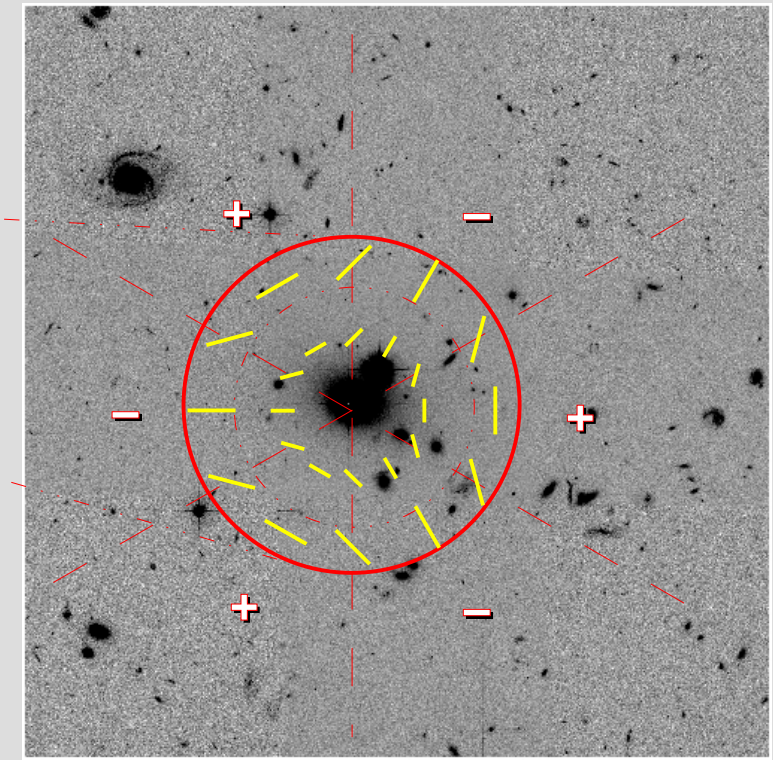


External Sextupole

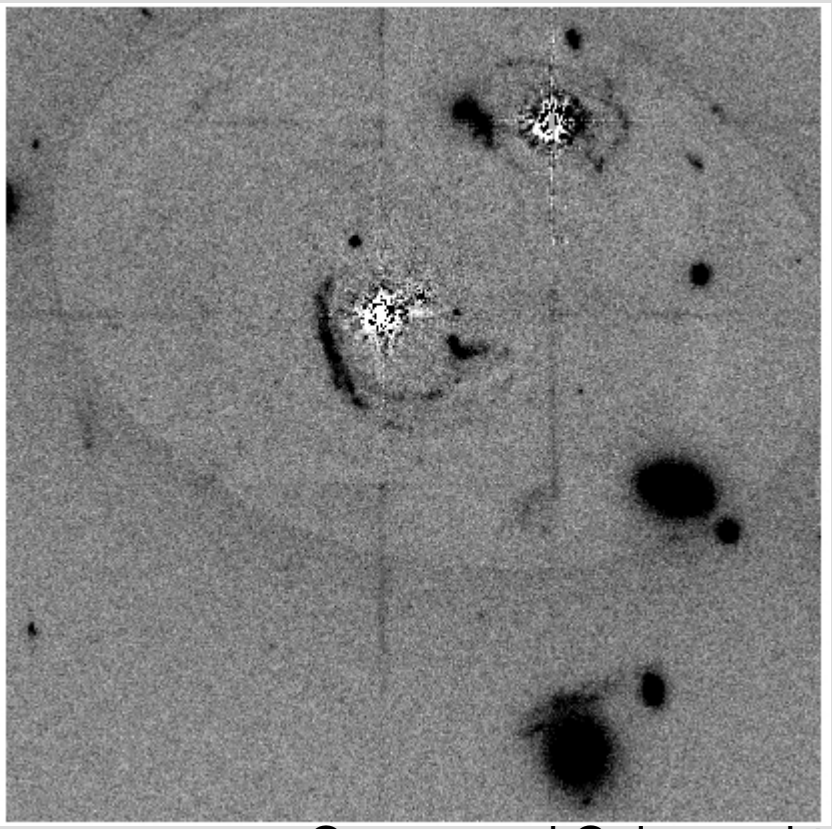


HST ACS WFC Image, 6'×6' FOV

- External Sextupole δ_c
- Internal shear $\propto$ r



0957+561 Cluster Results
WL Data for SL Modeling



Quasar and Galaxy subtracted

- Strong lensing models $\psi(\theta)$, σ_c, γ_c, δ_c
- Internal multipole measurements provide constraints (κ_c, σ_c)
- External multipole measurements noisy

The End