Environments of Strong Gravitational Lenses

(- An Inconvenient Truth -)

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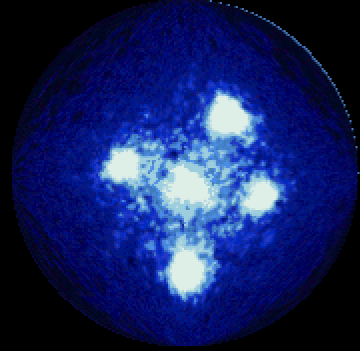
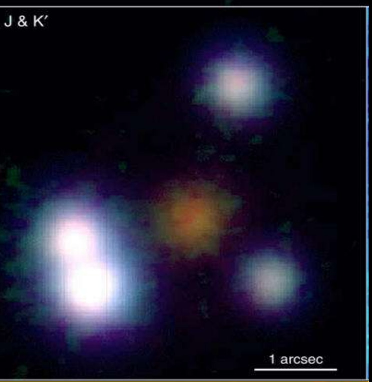
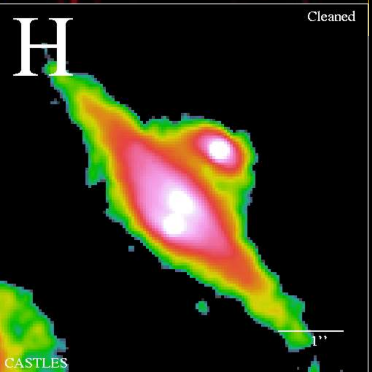
Chuck Keeton (Rutgers), Catherine Grant (MIT), Christy Tremonty (Arizona)



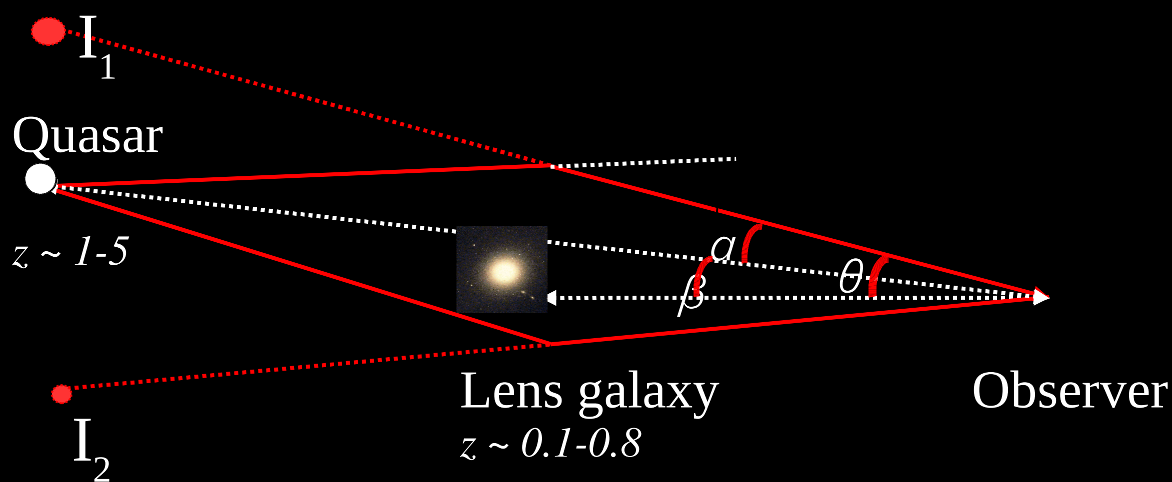




Which strong lenses?

"... I made some calculations which show that extragalactic nebulae offer a much better chance than stars for the observation of gravitational lens effects."

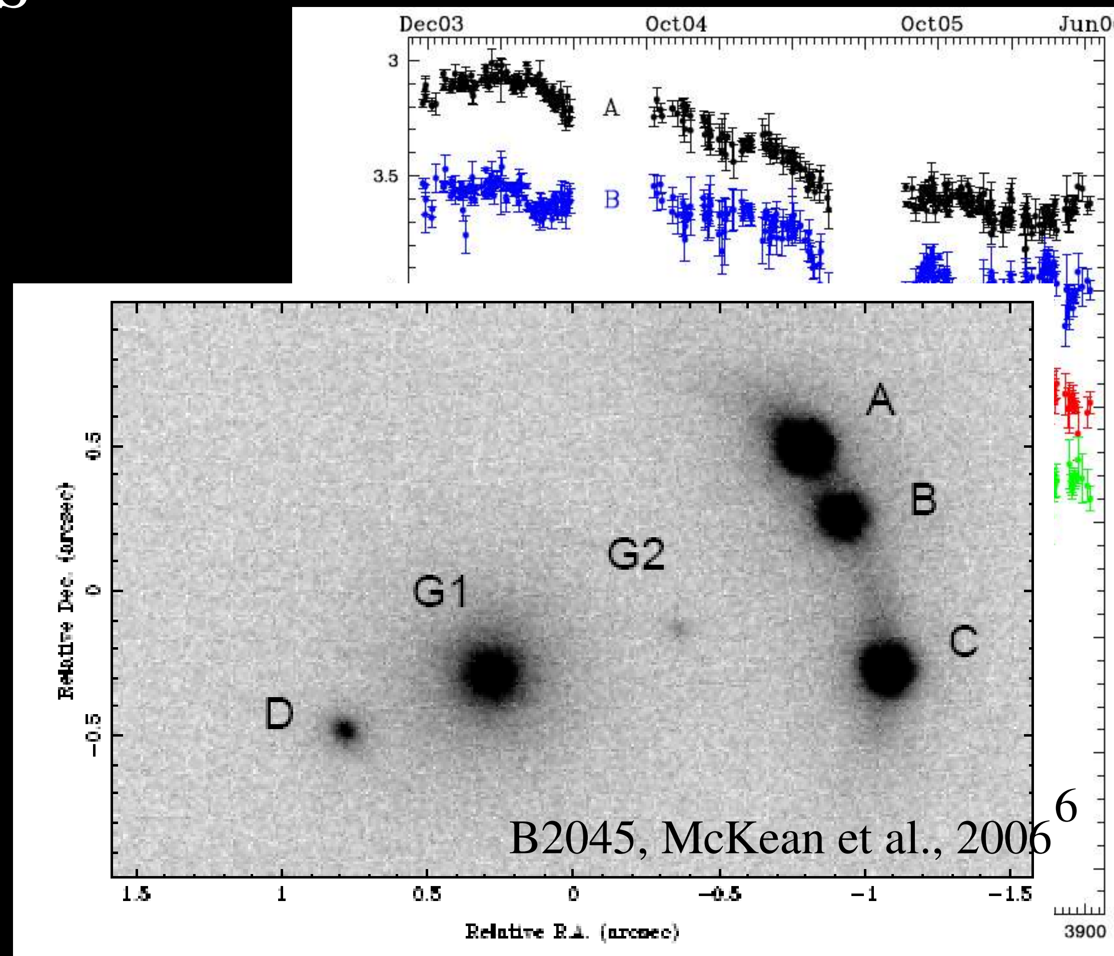
F. Zwicky, 1937, in "Nebulae as Gravitational Lenses"



Lens equation: $\beta = \theta - \alpha (\theta$

Motivation

- Sample increases (SDSS – 17 (100 expected), LSST – 1500 expected)
- Masses and shapes of DM halos
- Time delays and H0
- Microlensing, substructure and flux anomalies



B2045, McKean et al., 2006

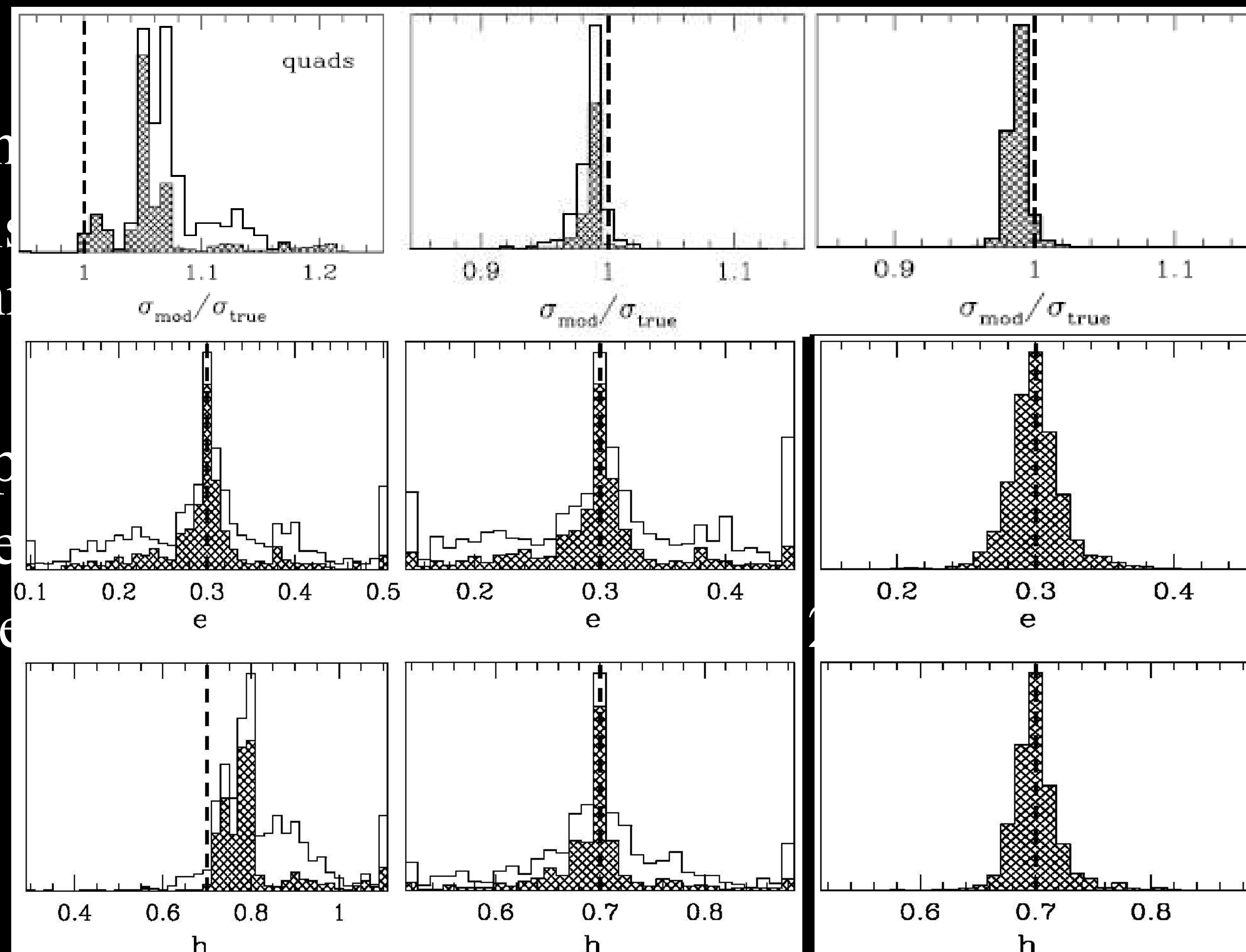
But …

- What are the en
  - Lenses not i
    (Keeton, Ch

    field

    group

    cluste
- Biases and unce

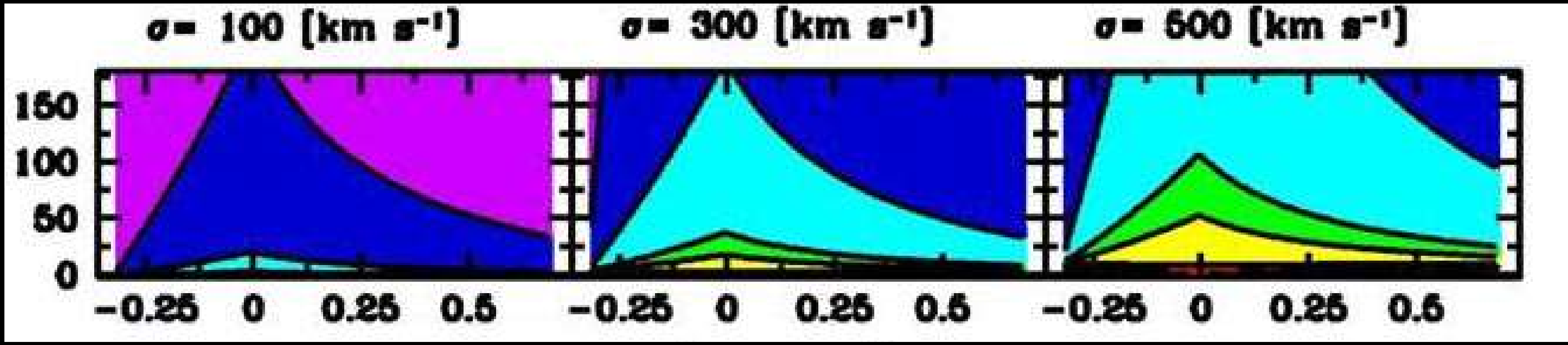


With shear With convergence Group included

- Both convergence κ and shear γ need to be included

Importance of line-of-sight structures

- Line-of-sight structures produce large convergence κ and shear γ (≥ 0.05 in green and yellow)



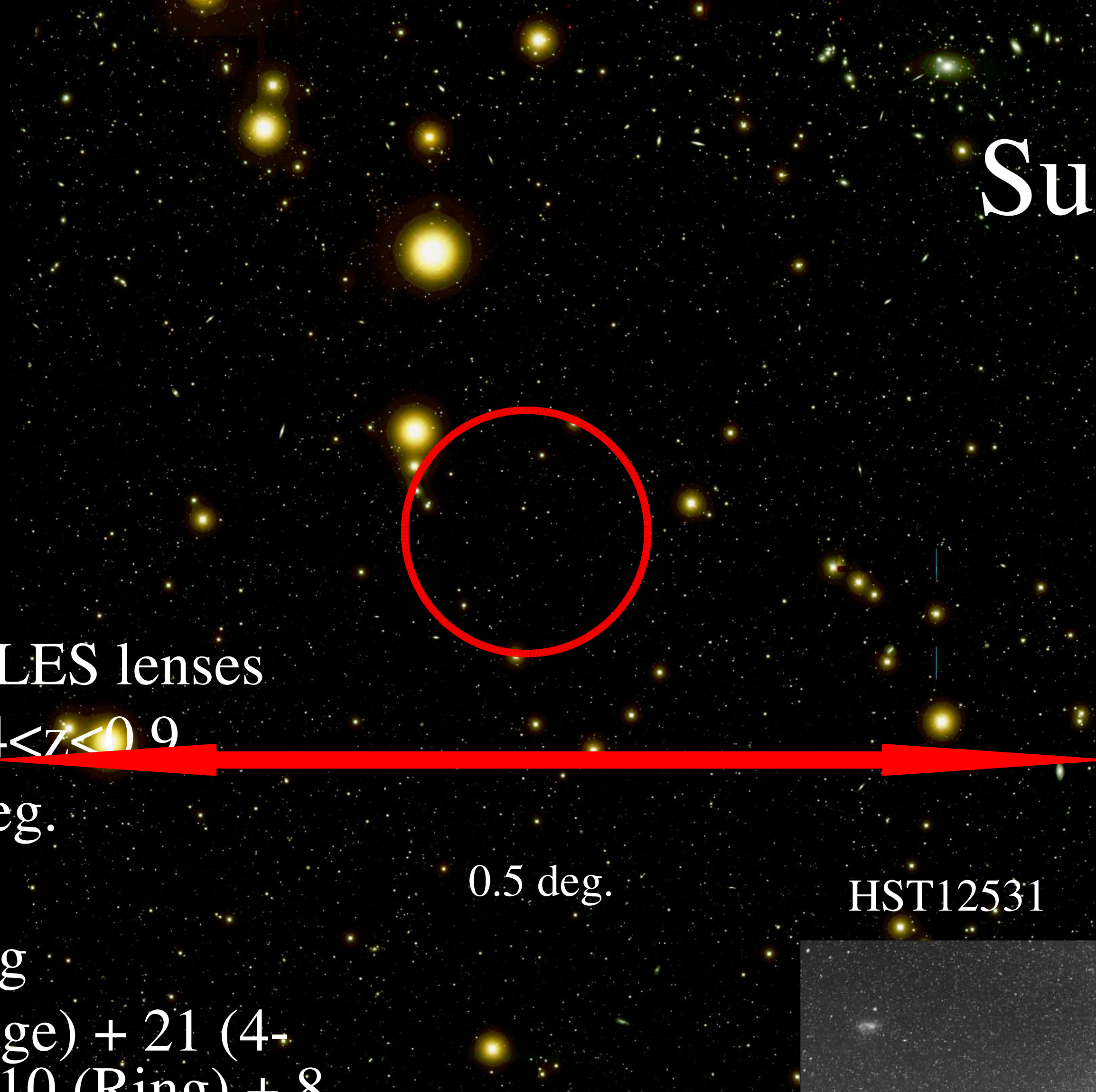
Impact parameter b [“]

Redshift offset Δ z = z_lens – z_perturber

- κ adds as scalar but γ adds in quadrature, so κ rises faster.

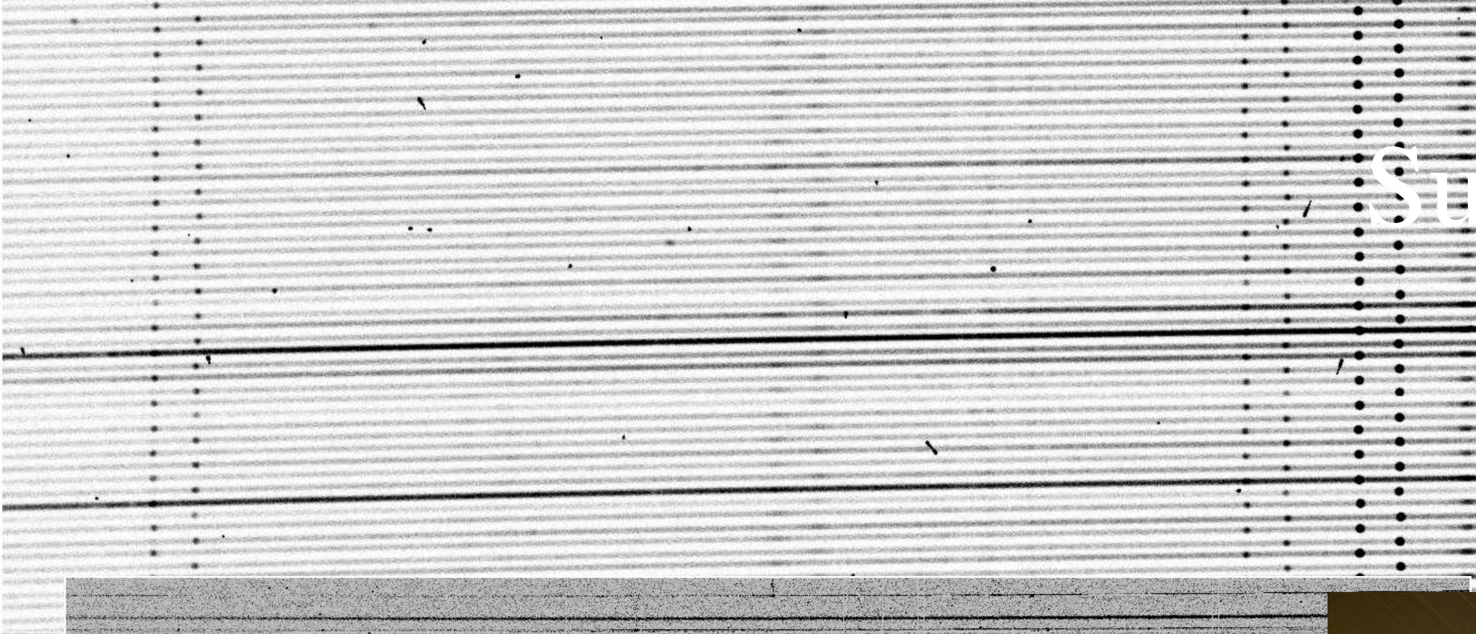
PG1115, $z_l = 0.31$, $z_s = 1.7$ (Momcheva et al. 2005)

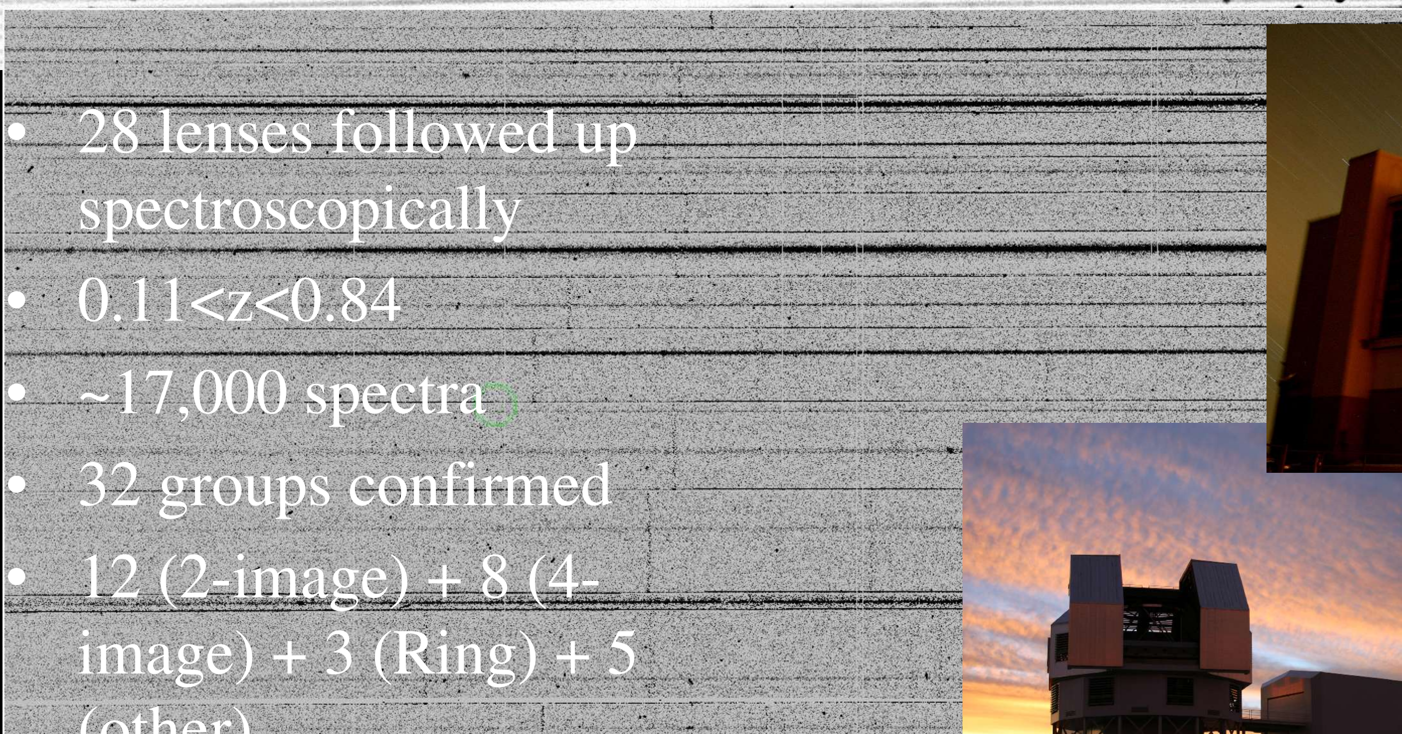
Survey I

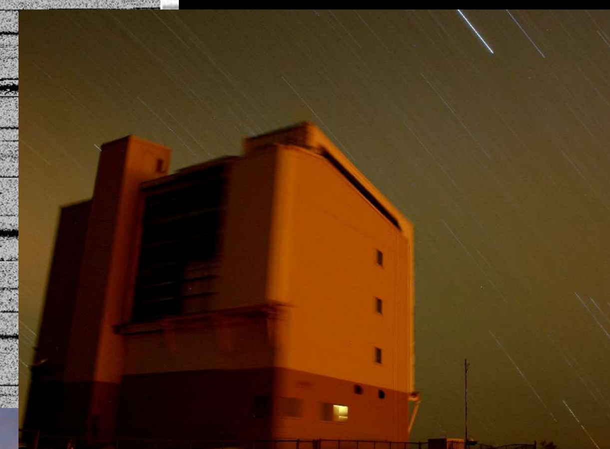


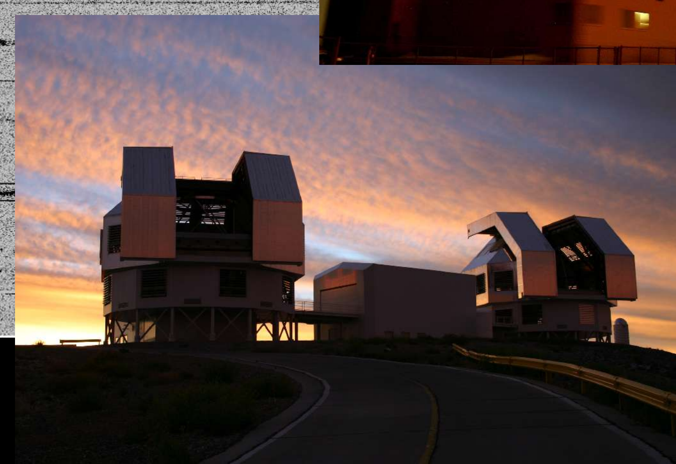
- 69 CASTLES lenses
- Most 0.04<z<0.9
- ~17 sq. deg.
- 2 bands
- I > 24 mag
- 30 (2-image) + 21 (4-image) + 10 (Ring) + 8 (other)
- 14 time-delay lenses

Survey II





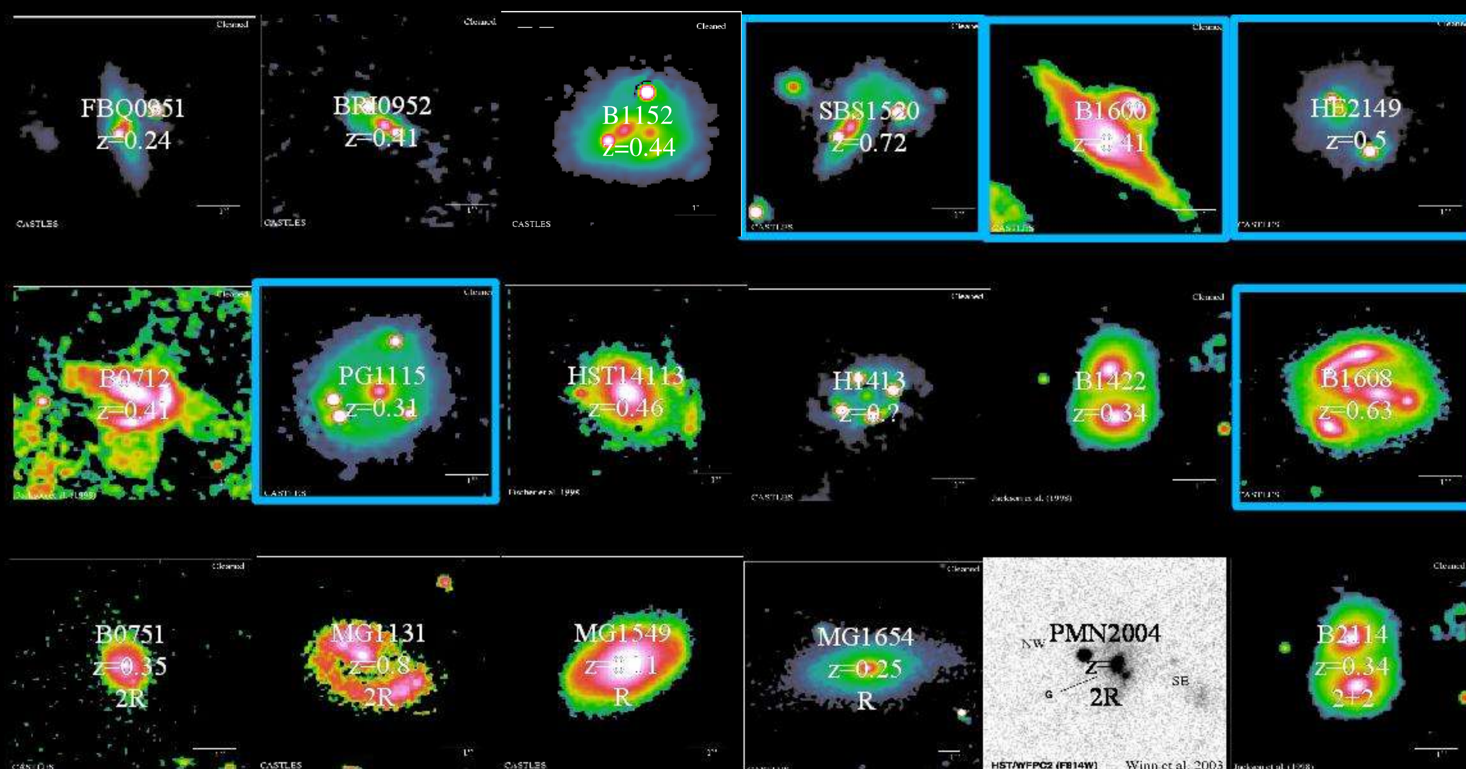




- 28 lenses followed up spectroscopically
- 0.11<z<0.84
- ~17,000 spectra
- 32 groups confirmed
- 12 (2-image) + 8 (4-image) + 3 (Ring) + 5 (other)
- 8 time-delay lenses

Lens Environments

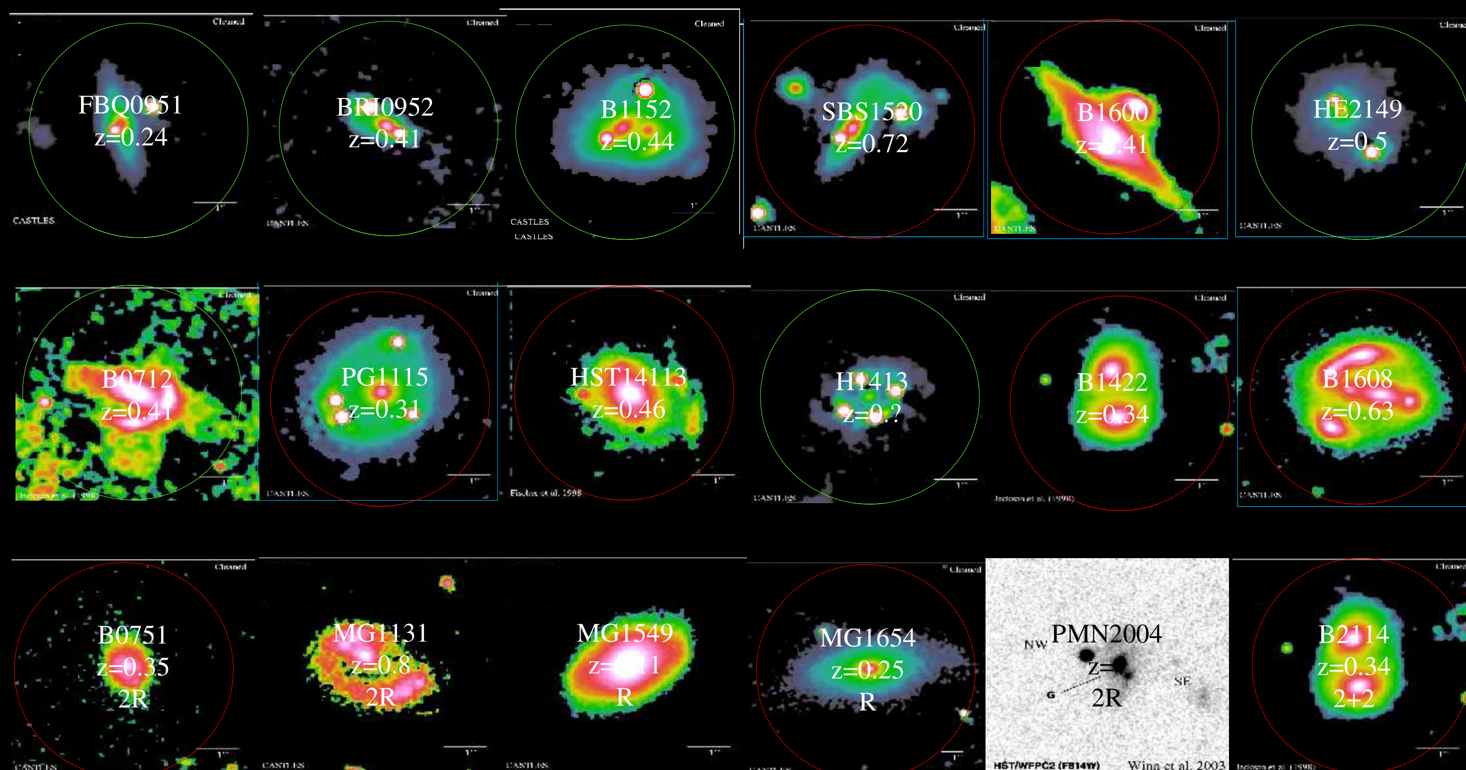
- Doubles
- Quads
- Others



CASTLES Survey (Kochanek et al.)

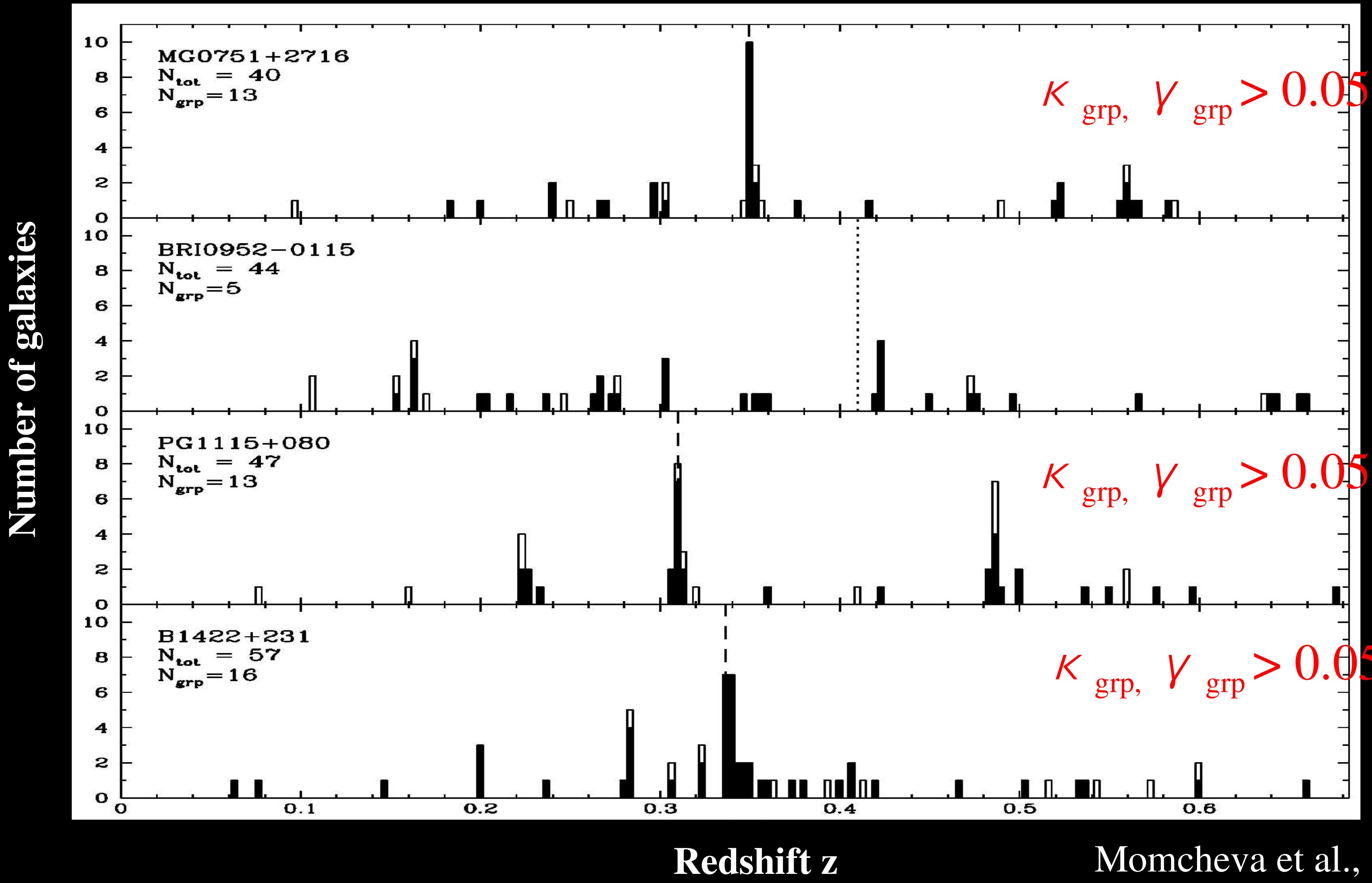
Lens Environments

- Doubles
- Quads
- Others



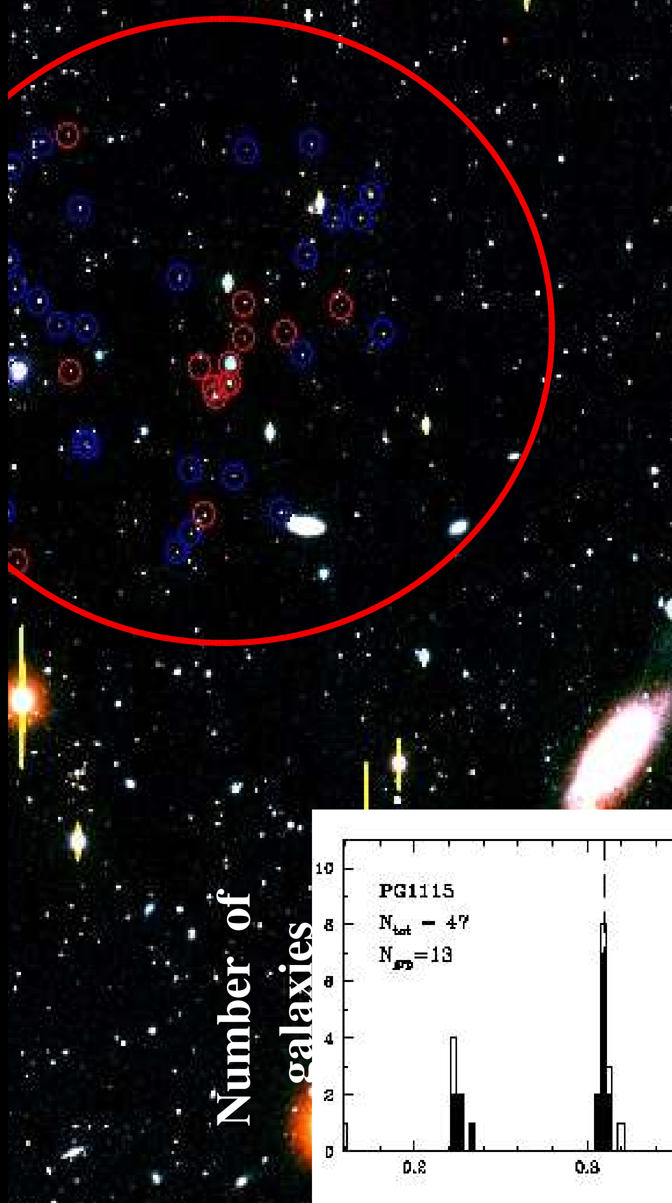
CASTLES Survey (Kochanek et al.)

Lens Environments

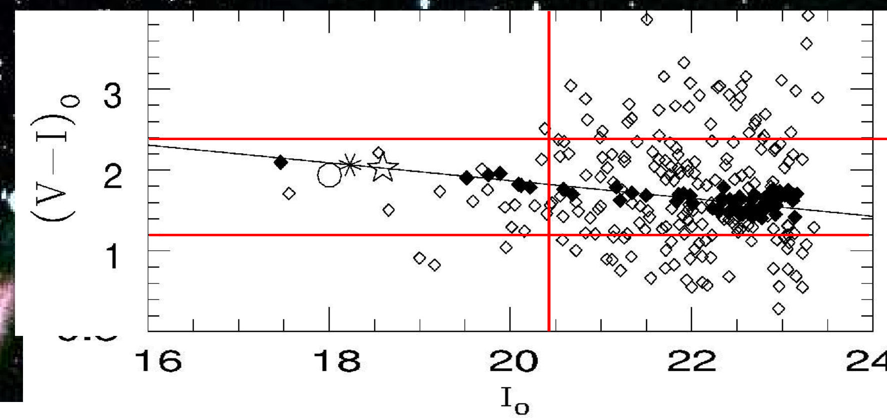


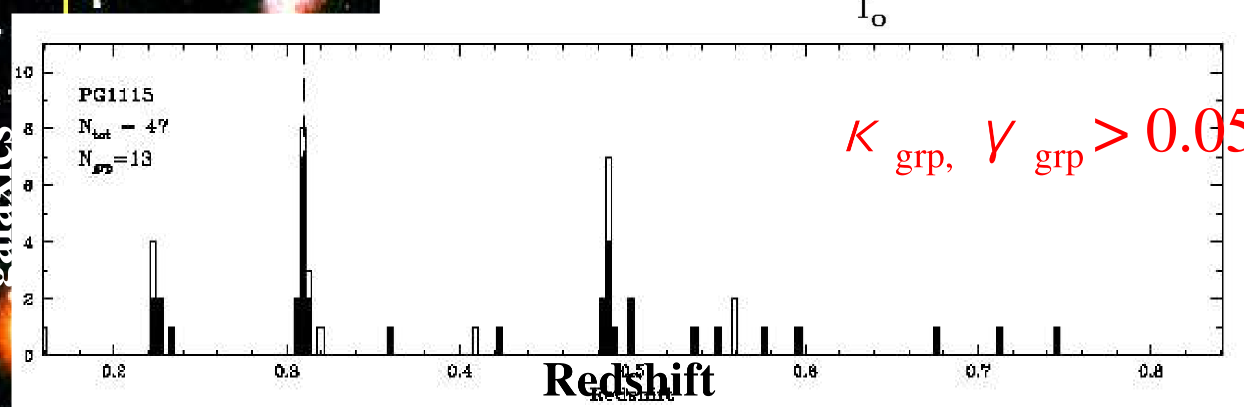
Momcheva et al., 2006

Lens Environments – PG1115



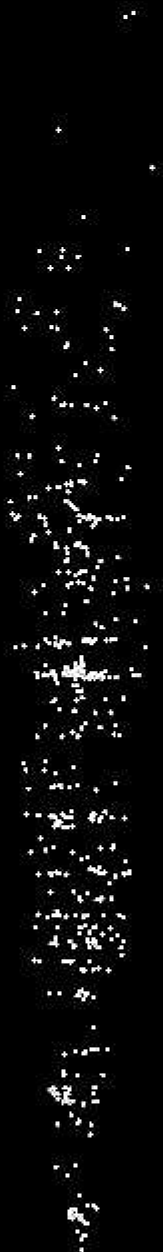
Momcheva et al., 2006
Williams et al., 2006

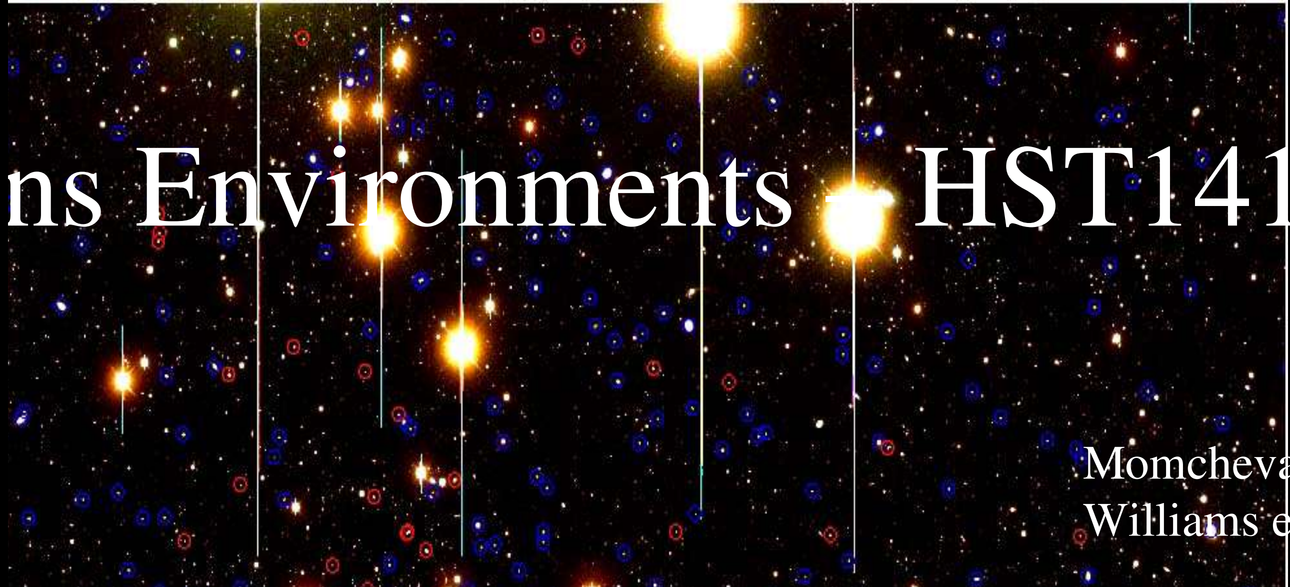




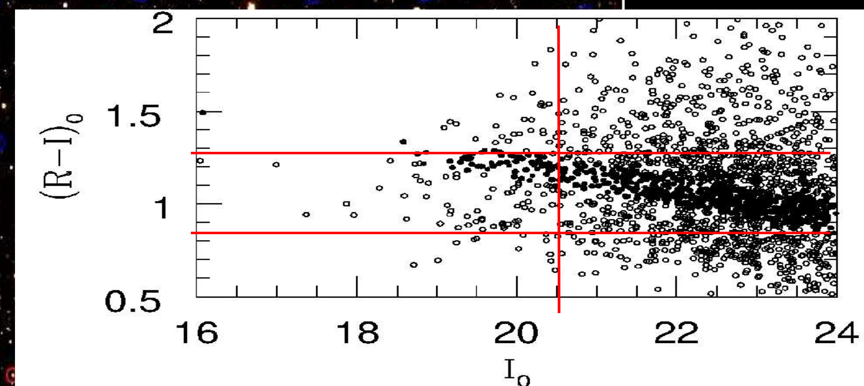
$\kappa_{grp}, \gamma_{grp} > 0.05$

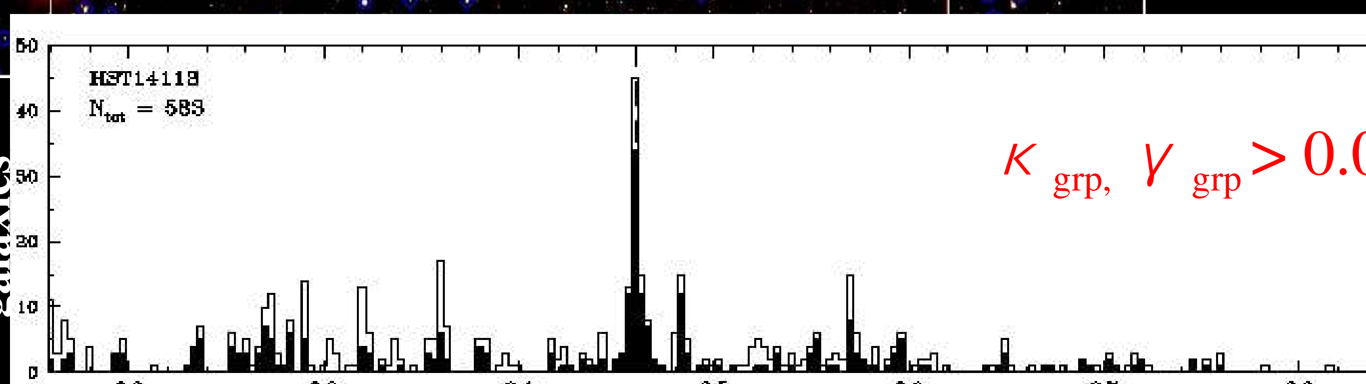
ns Environments – HST14113





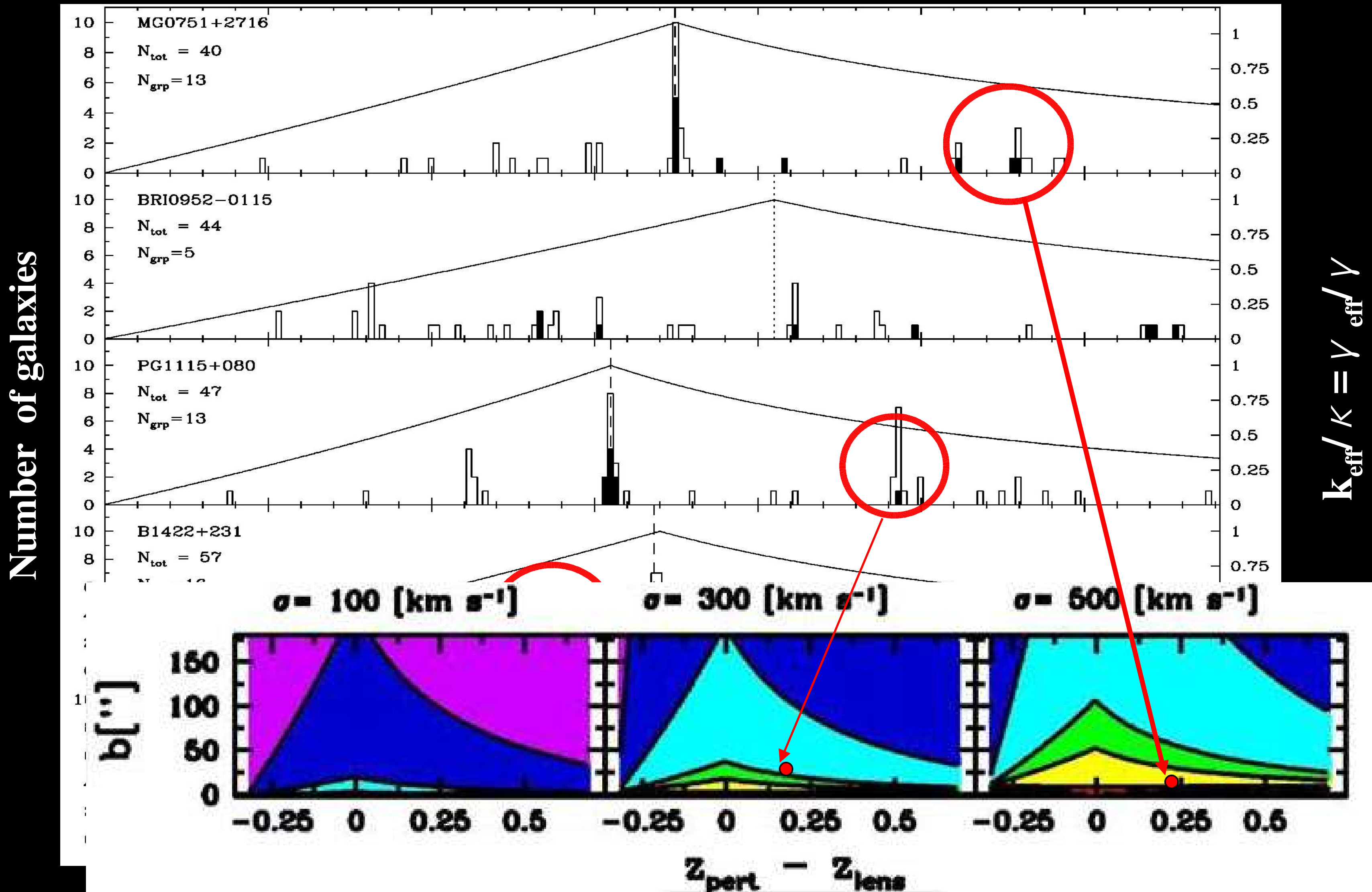
Momcheva et al., in prep
Williams et al., in prep.





$\kappa_{\text{grp}}, \gamma_{\text{grp}} > 0.05$

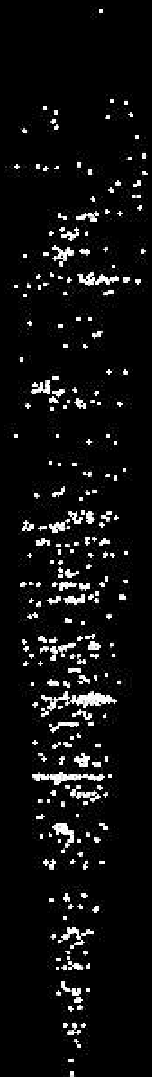
Interloping Structures

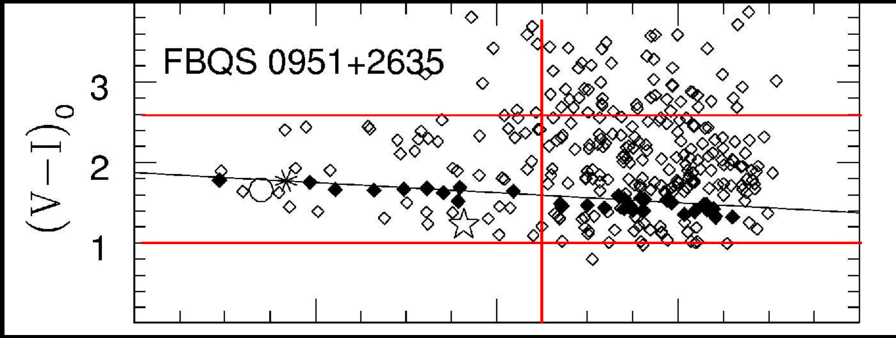


Redshift

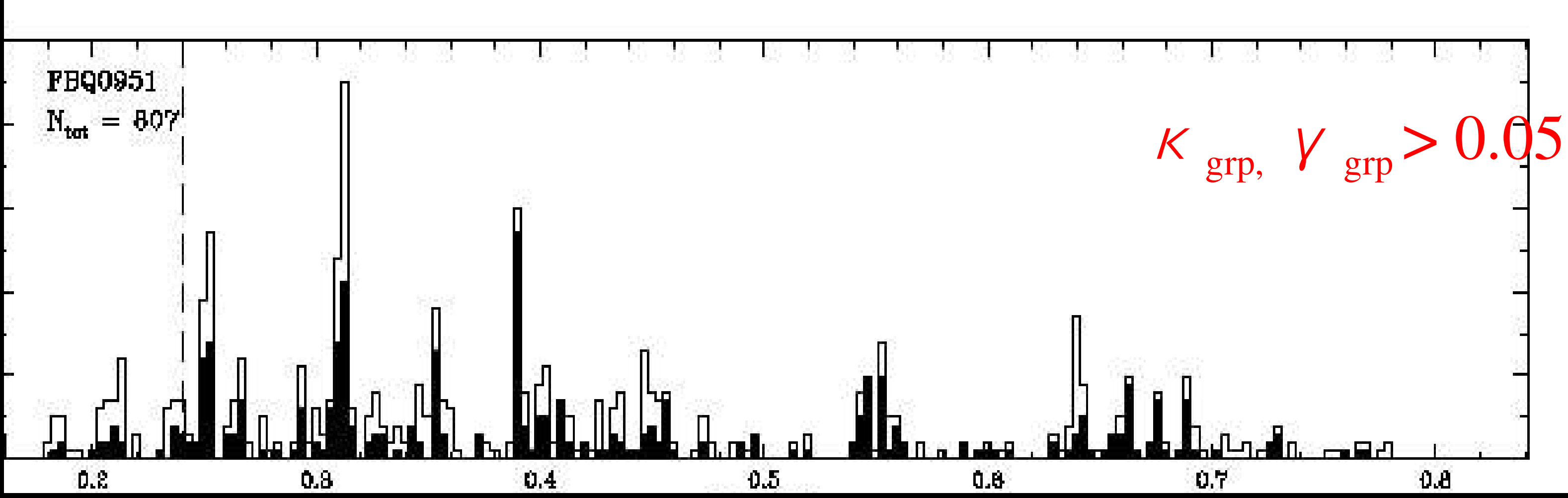
Momcheva et al., 2006

erloping structures – FBQ0951





I mag



$\kappa_{\,grp,}\ \gamma_{\,grp} > 0.05$

Redshift

Momcheva et al., in prep
Williams et al., 2006

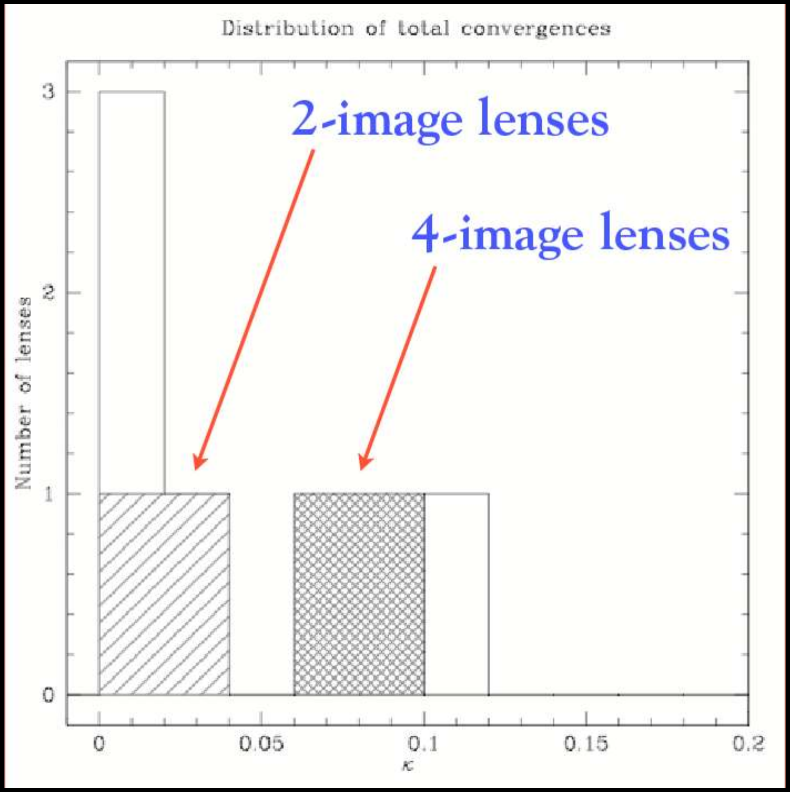
Results

- Characterized lens environments
- 4-image lenses problematic more often
- ~50% of lenses in groups which affect lens potential
- ~50% along dense lines of sight
- ~10 % interlopers affect lens potential

Golden Lenses?

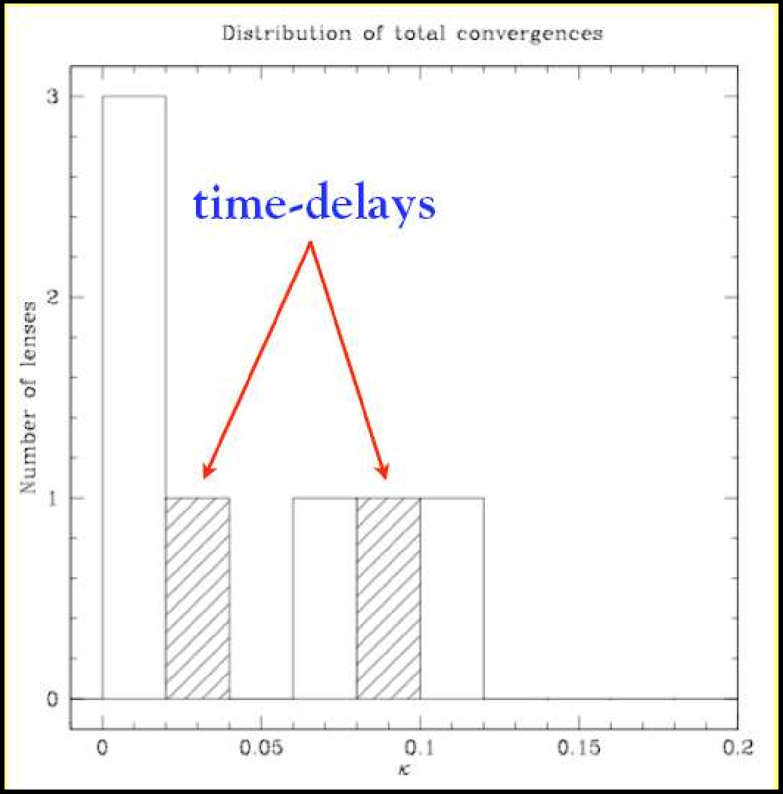
- Exclude/account for interlopers and environment

Number of lenses



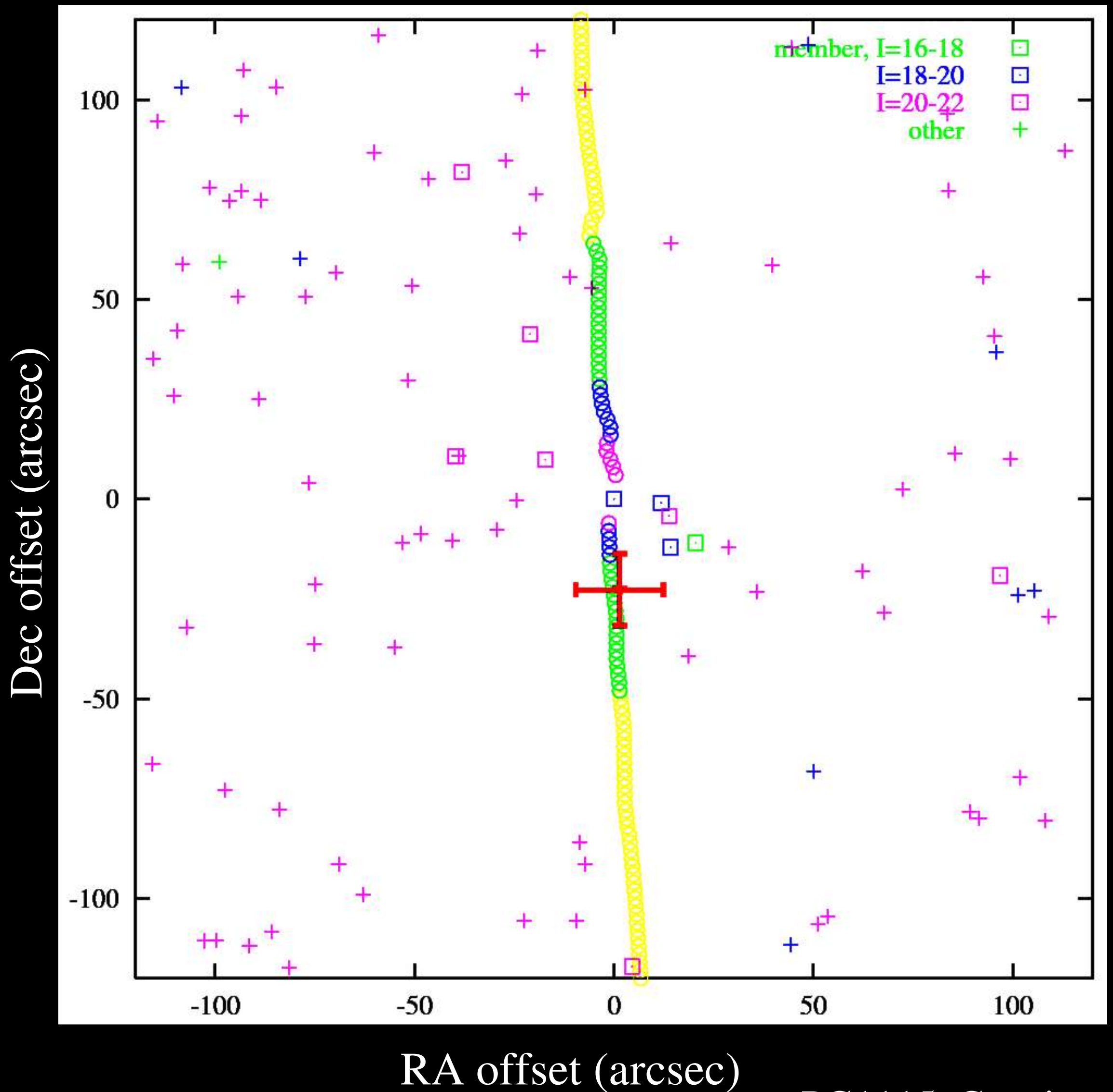
Convergence

Number of lenses



Convergence

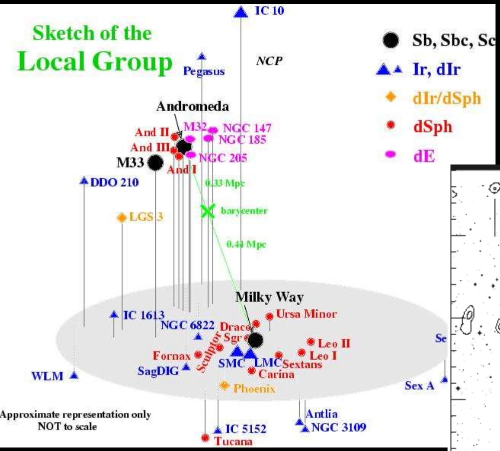
The Kitchen-Sink Model

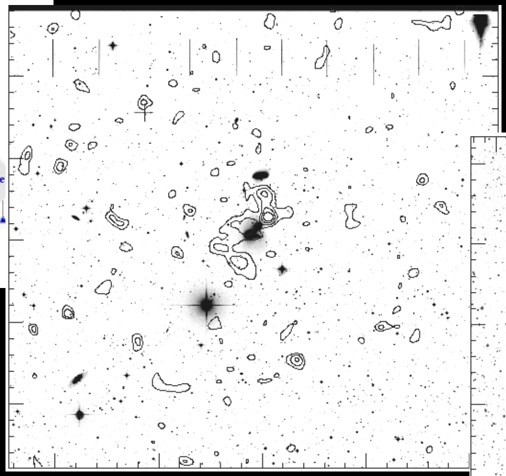


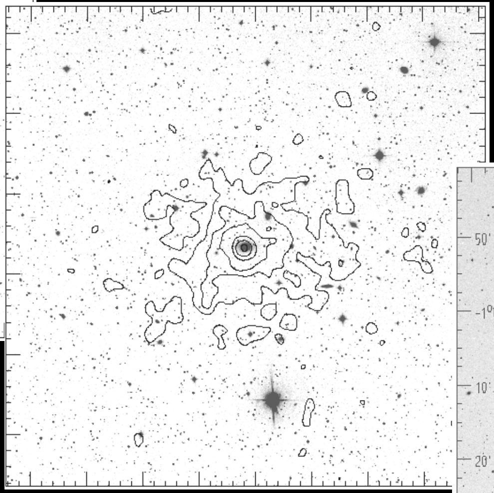
- Include group galaxies and group halo

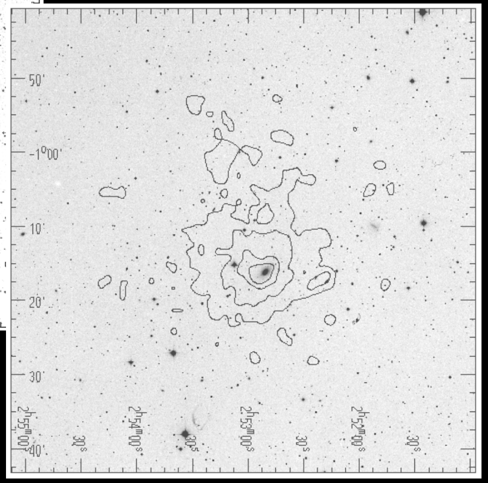
PG1115, Cangi et al., in prep.

Group Evolution





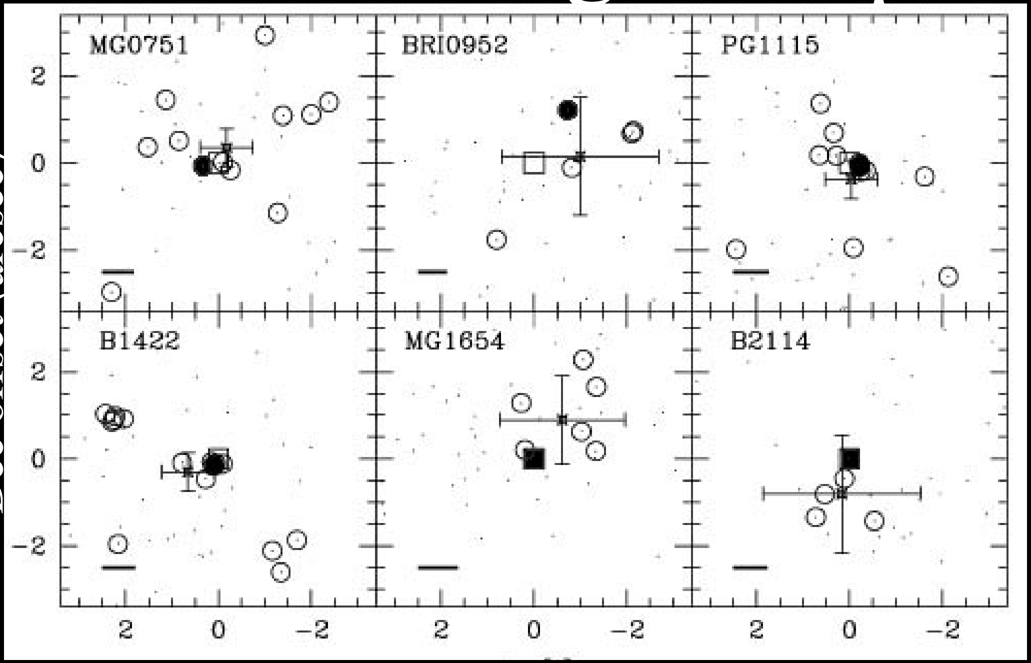




- Few z>0.1 groups
- Simple environments
- Mergers, tidal interactions dominant
- Preprocessing of cluster galaxies

E. Grebel
Mulchaey & Zabludoff

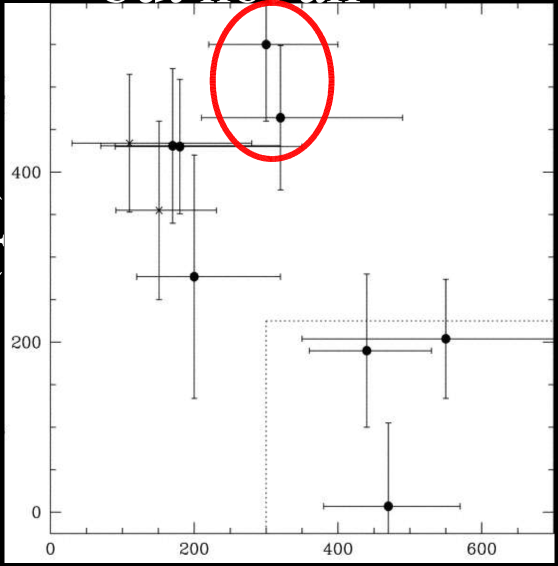
Observing Group Evolution Directly



Dec offset (arcsec)

RA offset (arcsec)

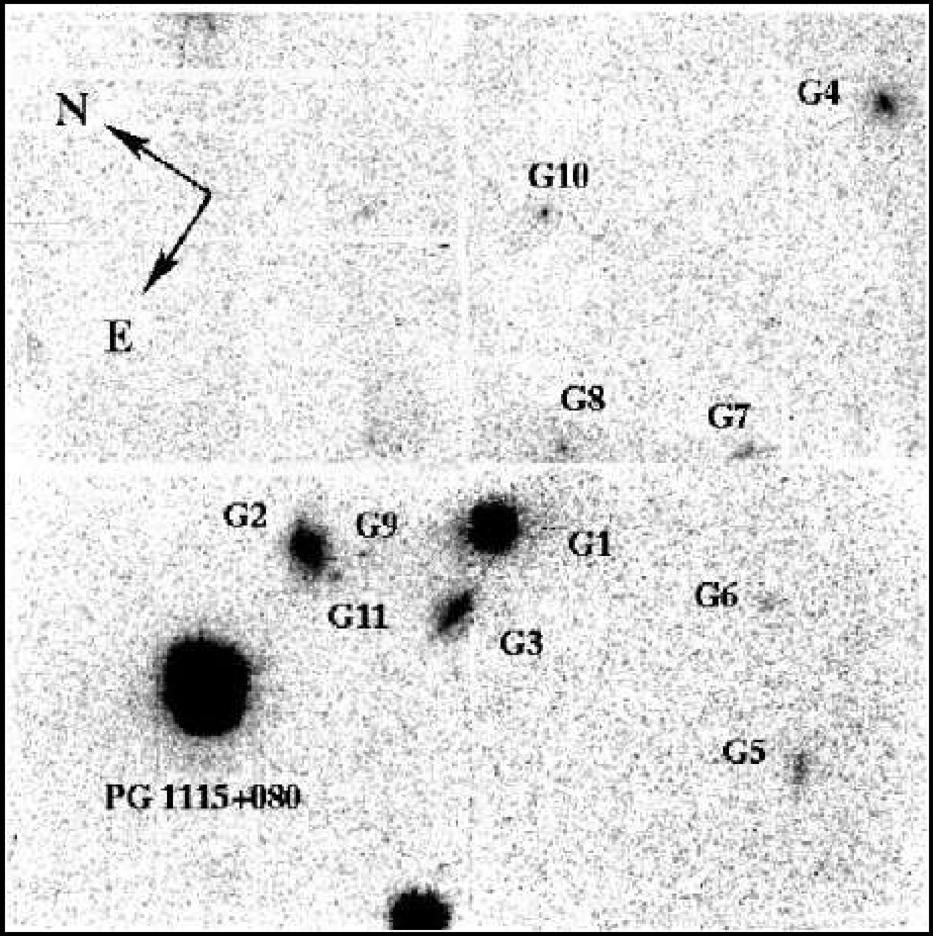
- z=0.25 – 0.5
- Span a range of σ
- BGG is early type
- BGG is not the lens in all but two cases.
- There are evolved groups but not all

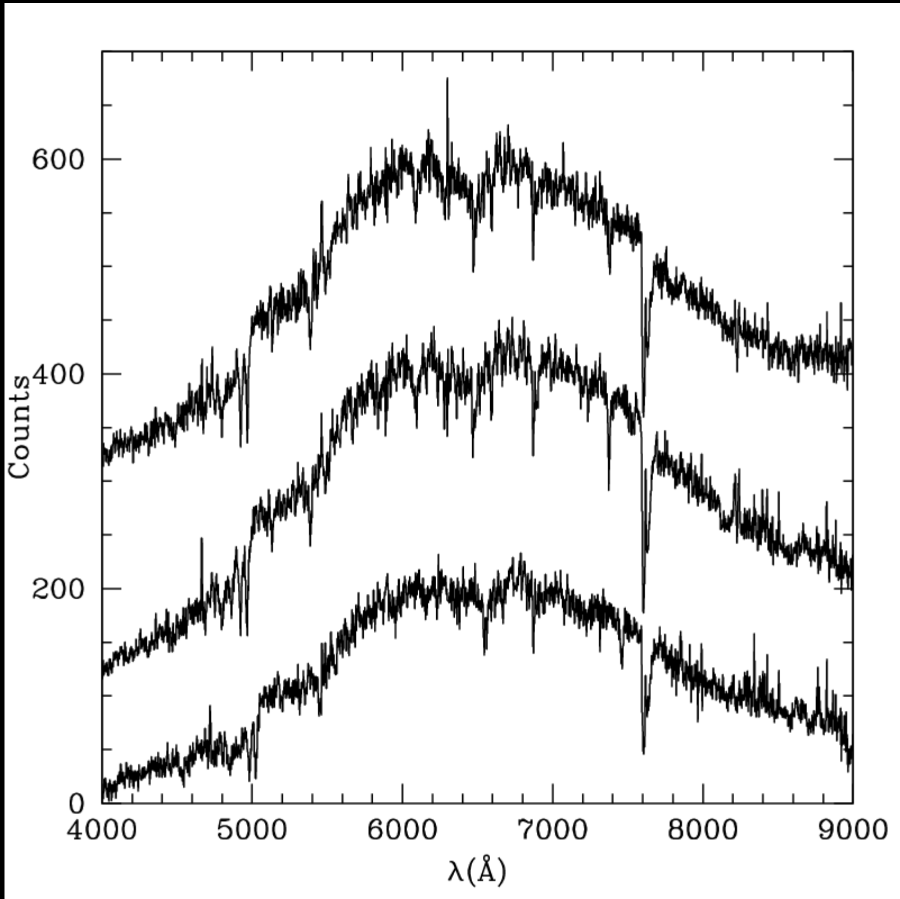


BGG offset (kpc)

Velocity dispersion

Group evolution – future work





Conclusions

- Characterized lens environments
- ~50% of lenses in groups which affect lens potential
- ~10 % interlopers affect lens potential
- Can we find a golden (unperturbed) lens?
- Or can we guild (model) it?
- New sample of intermediate-z groups