The CFHTLS strong lensing Legacy Survey
Window on group-scale lenses

Rémi Cabanac

and the SL2S collaboration

www-sl2s.iap.fr

The CFHTLS strong lensing Legacy Survey
Window on group-scale lenses

Coming talks:

Tomas Verdugo and Marceau Limousin

Poster:

Veronica Motta

Scientific collaboration

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R. Cabanac, G. Soucail, R. Pello

Laboratoire d'astrophysique de Marseille (France)
J.-P. Kneib, E. Jullo, M. Limousin

UC Santa Barbara (USA)
R. Blandford (Stanford), P. Marshall, T. Treu

University de Victoria (Canada)
Crampton (HIA) , K.. Thanjavur (UVic), J. Willis (UVic)

Durham University (G-B)
M. Swinbank, Johan Richard

U. Valparaiso (Chile)
V. Motta, T. Verdugo, R. Muñoz

Shanghai NU (China)
Hong Tu

The CFHTLS SL2S project

Summary...

Observational experiment (Haggles, SDSS)

Extract and study a large sample of strong gravitational lenses from the CFHTLS Deep and Wide fields

> 100 -> possibly 1000

of intermediate mass scales and with lens redshift up to z =1

Prepare for large surveys (panSTARR, LSST)

The CFHTLS SL2S project

Summary ...

Extracting a well-defined statistically significant sample is a painful task on ground-based datasets.

-> JDEM, EUCLID

Massive IR telescope -> high-redshift sources, dusty lenses.

The intermediate mass scales: Galaxy Groups

Three mass scales:

Galaxies $10^7 < \text{mass} < 10^{12}\ M_\odot$ (Baryon dominated)

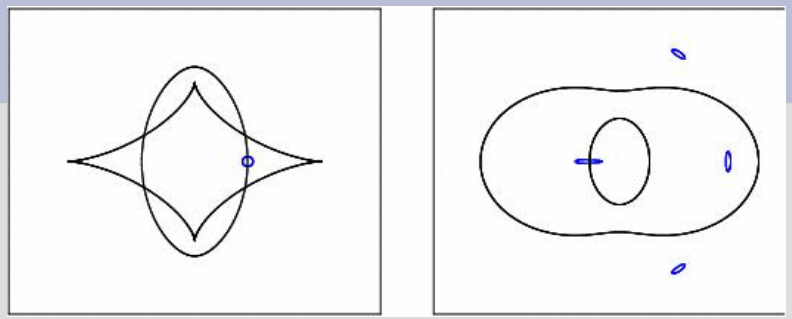
Clusters mass $> 10^{14}\ M_\odot$ (DM dominated)

Groups $10^{12} < \text{mass} < 10^{14}\ M_\odot$ (ideal labs for Baryon-DM interface)

Most galaxies belong to groups

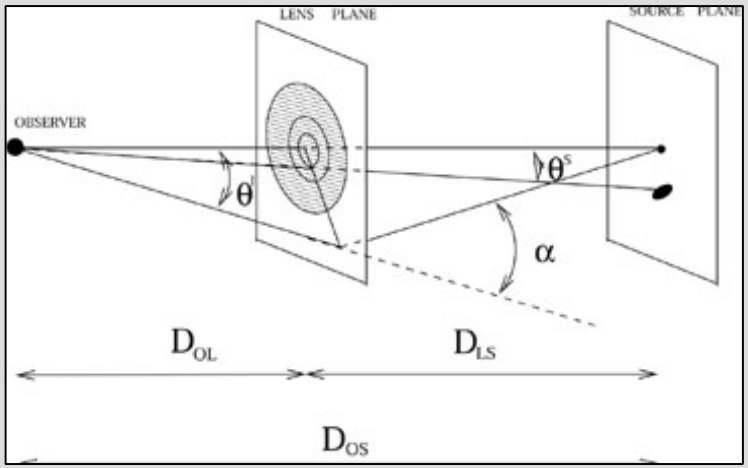
Groups are building blocks of clusters

Lensing and dark matter



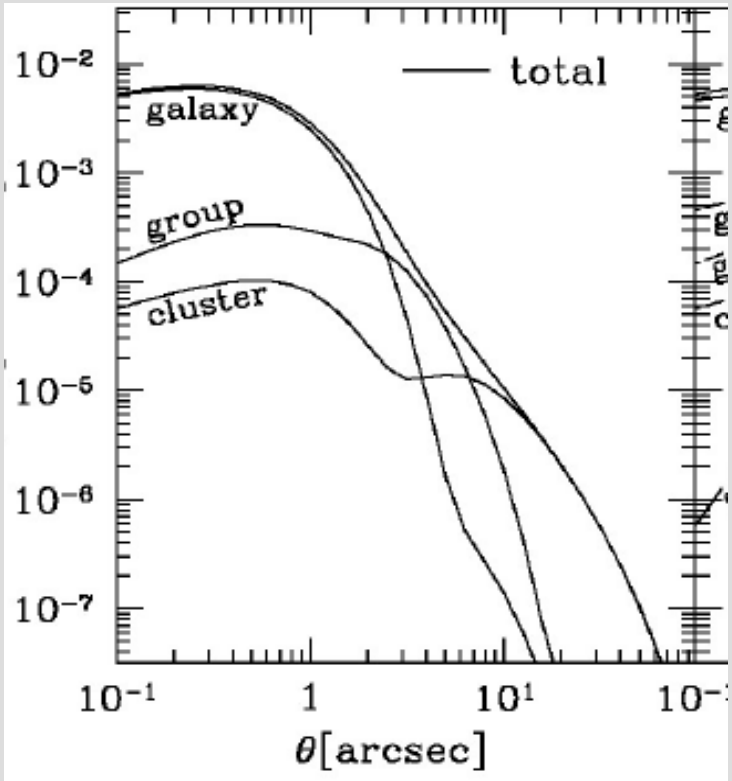
Thin lens + hypothese on the luminous source population (Oguri 2006)

predicted n / 1 sq°
Rings->**10** Groups->**1-2** Clusters->**0.5** (1)



$$\vec{\beta} = \vec{\theta} - \vec{\alpha} \equiv \vec{\theta} - \vec{\nabla}\psi(\vec{\theta})$$

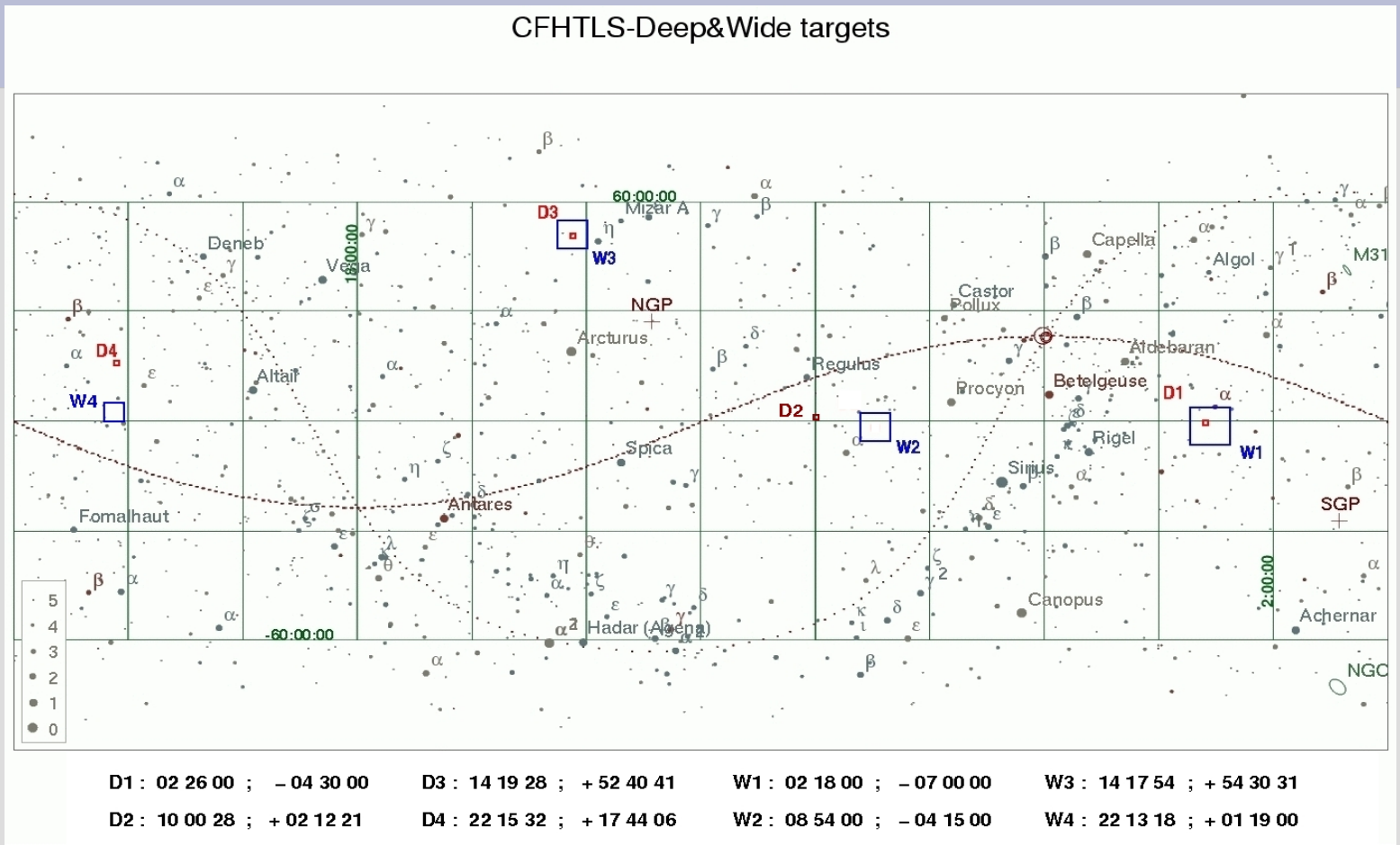
$$\psi(\vec{\theta}) = \frac{2}{c^2}\frac{D_{LS}}{D_{OS}D_{OL}}\varphi(\vec{\theta})$$



Splitting

The CFHTLS Deep and Wide Fields

TERAPIX



MegaCam

1deg² 0.186”/pix

T0006

Wide Survey

171 tiles

155 deg²

146 unmasked

u_{AB} ~ 25

z_{AB} ~ 23

SDSS *ugriz*

Expected CFHTLS

Rings > 1000 Groups >100 Clusters > 50

Pucon Meeting: Clusters Nov 9-13

The SL2S methodology

- Semi-automated detection on CFHTLS
- High-resolution imaging follow-up (HST/AO)
- Spectroscopic follow-up (Keck, VLT, Gemini)
- Detailled lens modelling (Lenstool, ...)
- Complete photometric analysis of lens environment (CFHTLS)
- Simulations for statistical completeness

Semi-automated detection

Visual detection is not realistic...
... neither is completely automated selection

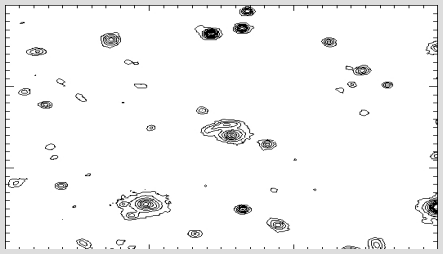
=> Hybrid procedures

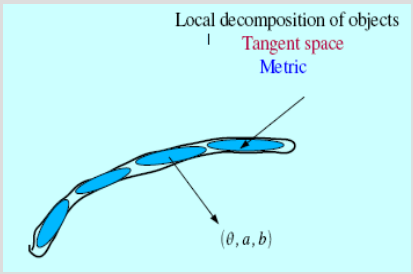
ARC FINDER (Alard, astro-ph/0606757, More 2009)

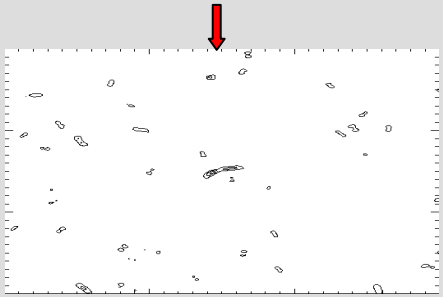
RING FINDER (Gavazzi et al., in prep. 2007)

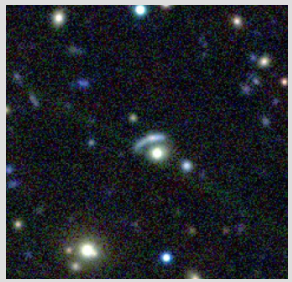
Semi-automated detection

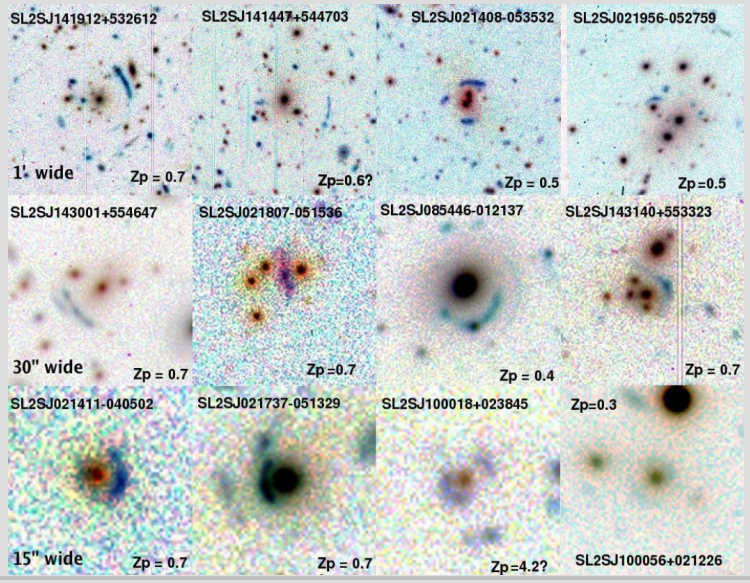
ARC FINDER (Alard, astro-ph/0606757)











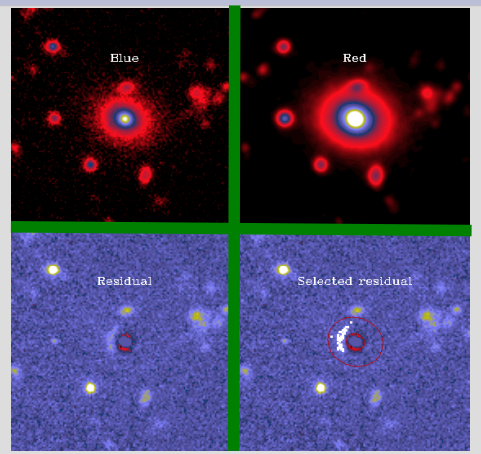
RING FINDER (Gavazzi et al., in prep.)

Detection: Based on color information (often rings are blue and lenses are red early-type galaxies)

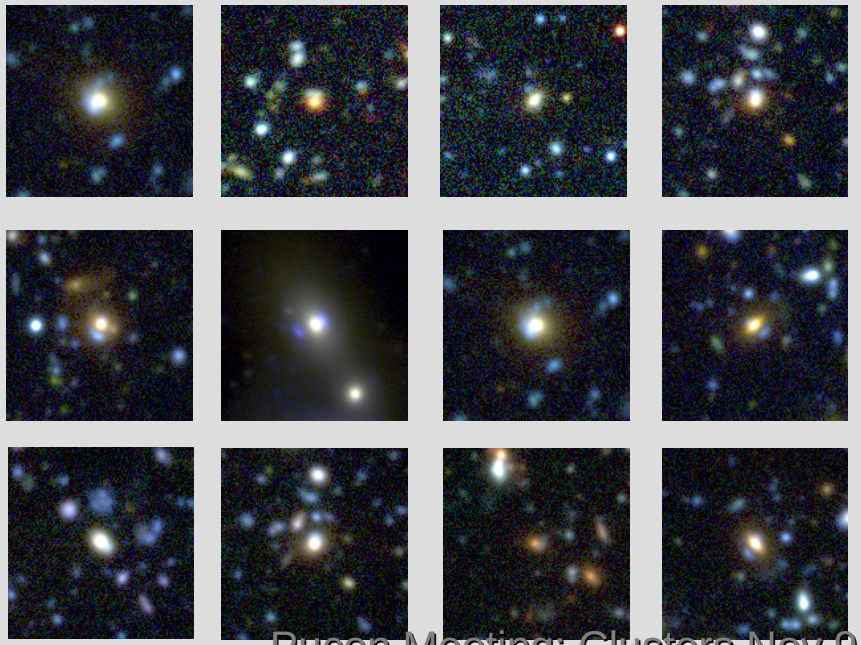
Method:
1-Fit a B-σR profile consistent with the lens color.

2-Identify a sharp elongated blue excess at 0.8<r<2.5" above the (B-σR) noise.
-> Selection in size, shape, orientation, multiplicity

3-Visual classification or direct follow-up

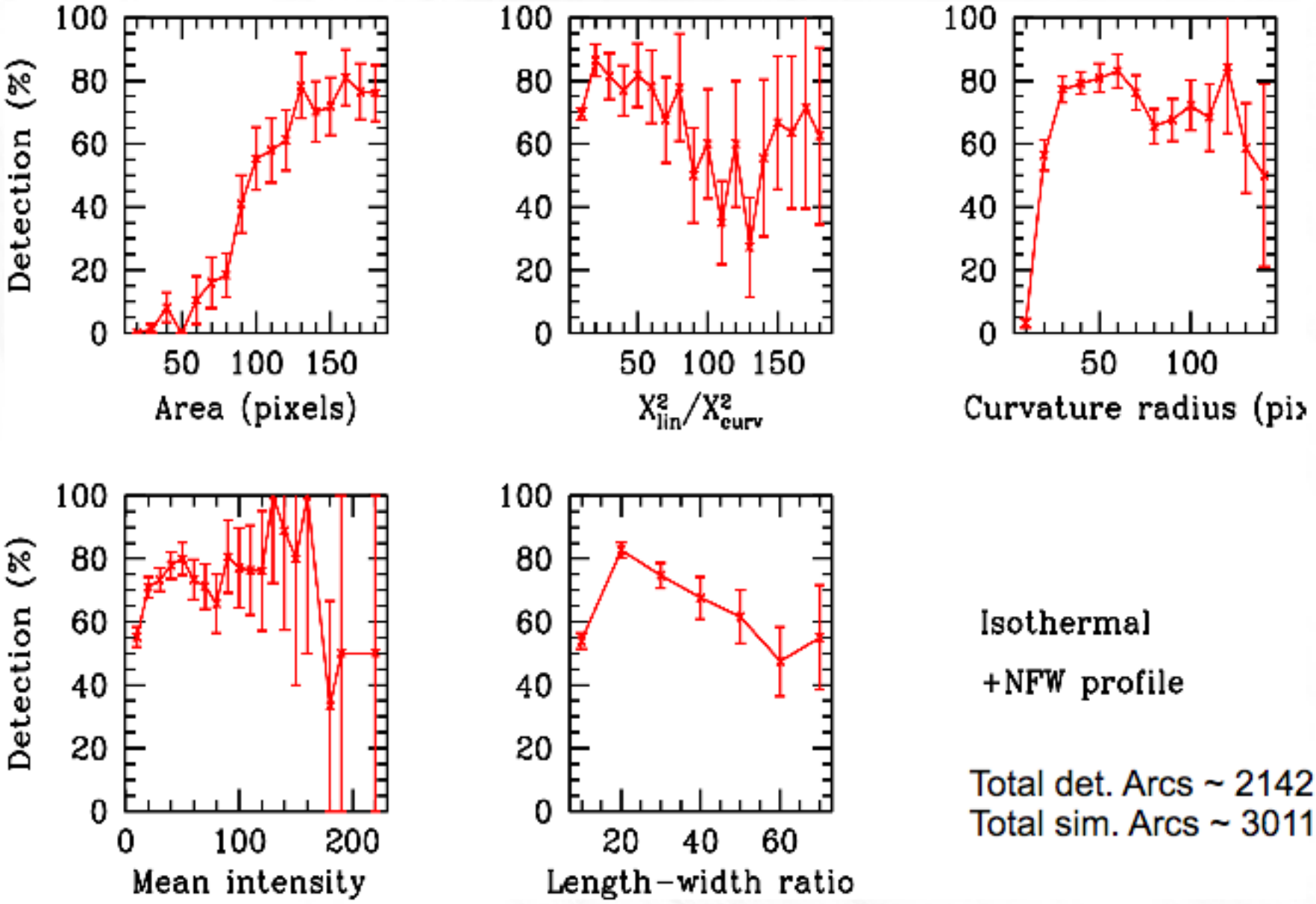


Number / deg²
1- 3000 2- 50-200 3- 20 candidates!



ARCFINDER EFFICIENCY ANALYSIS

Anupreeta More (in prep)



ARCFINDER EFFICIENCY ANALYSIS

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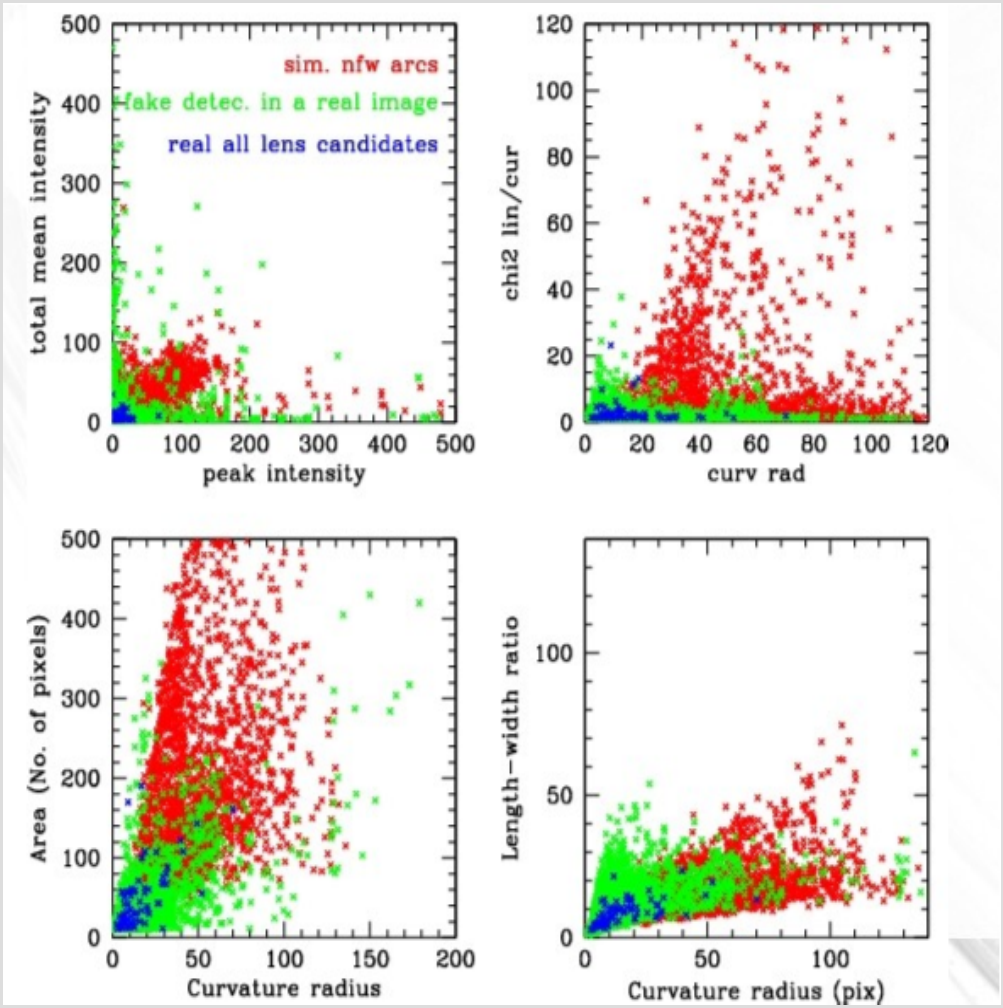
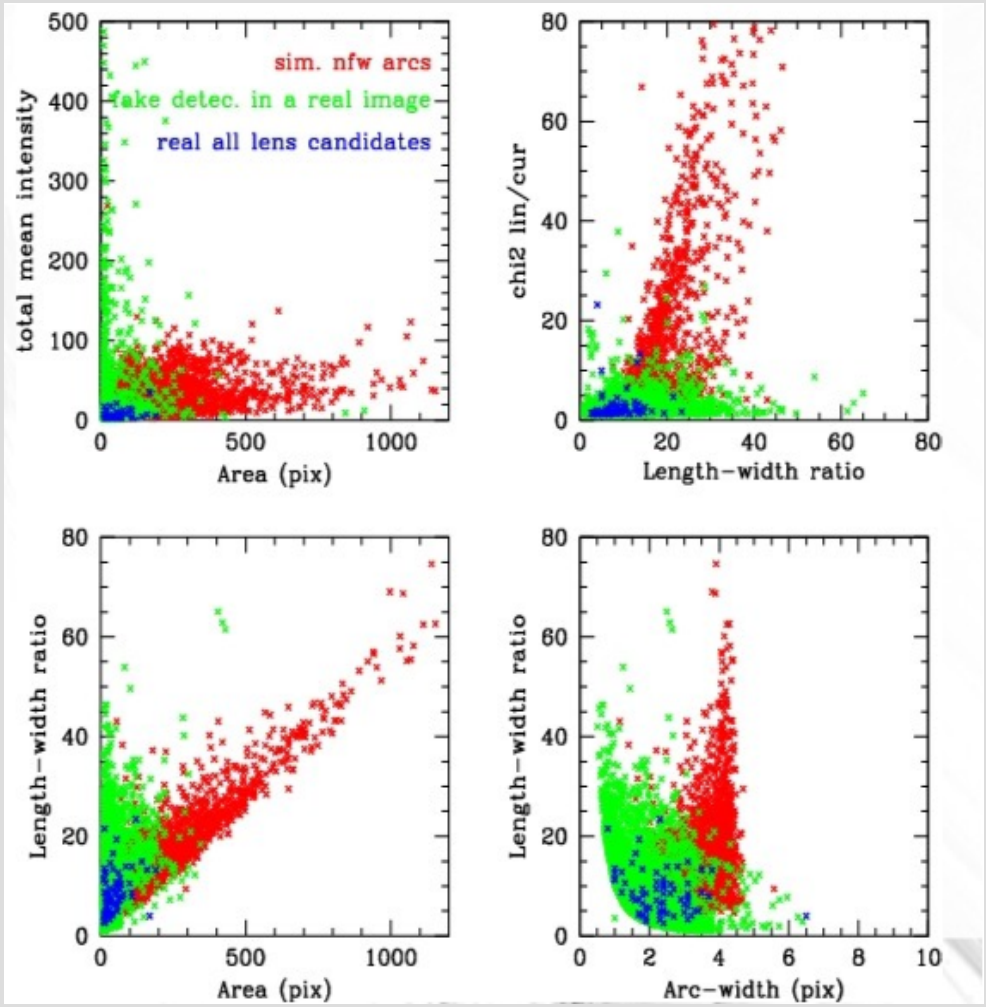
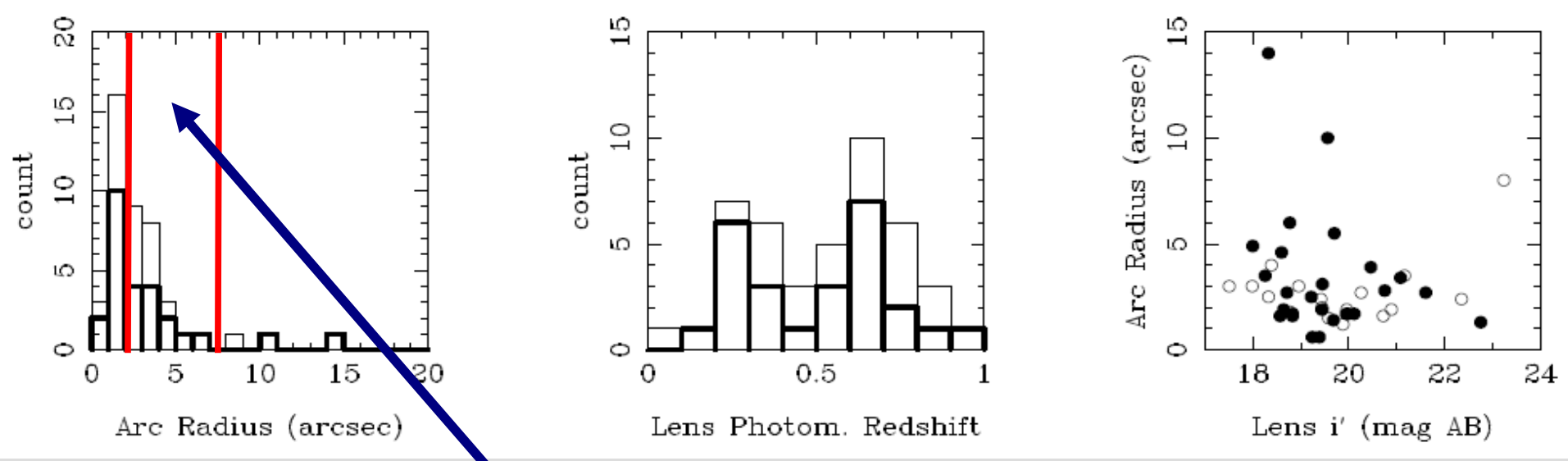
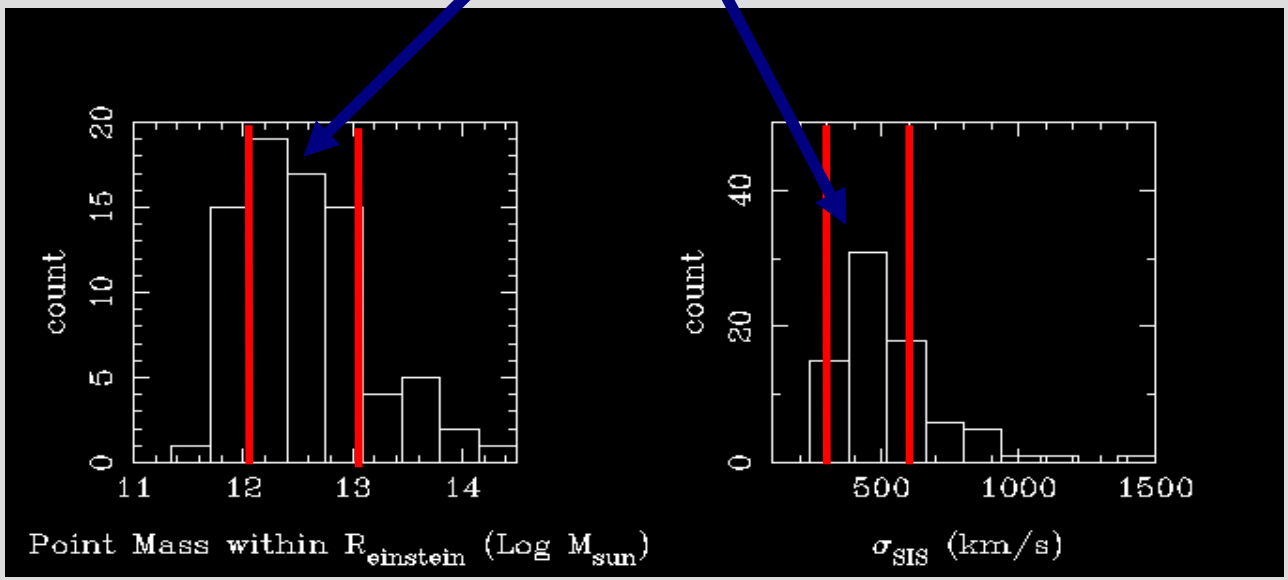




Brief overview on T0004...



Groups



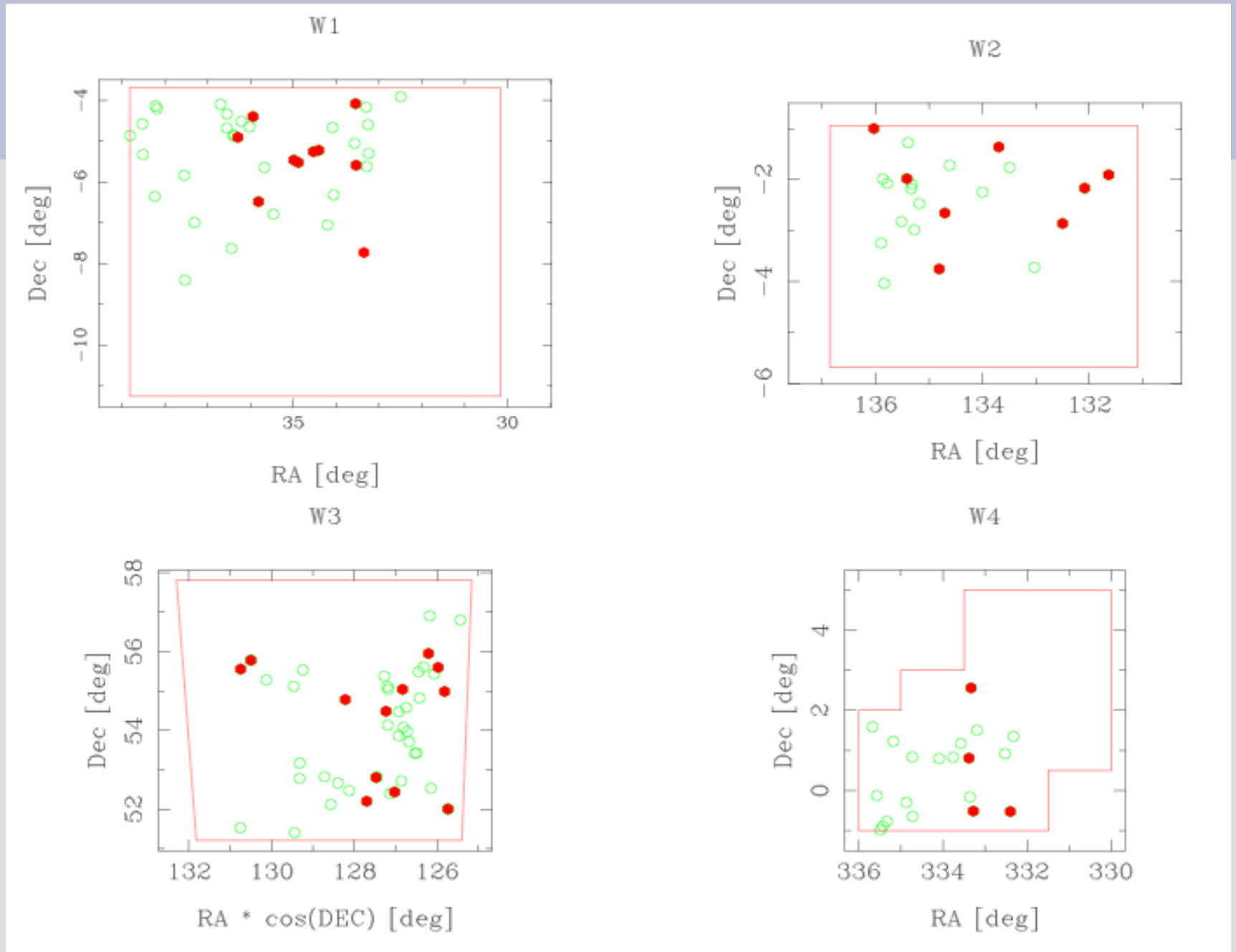
Observed numbers / deg^2

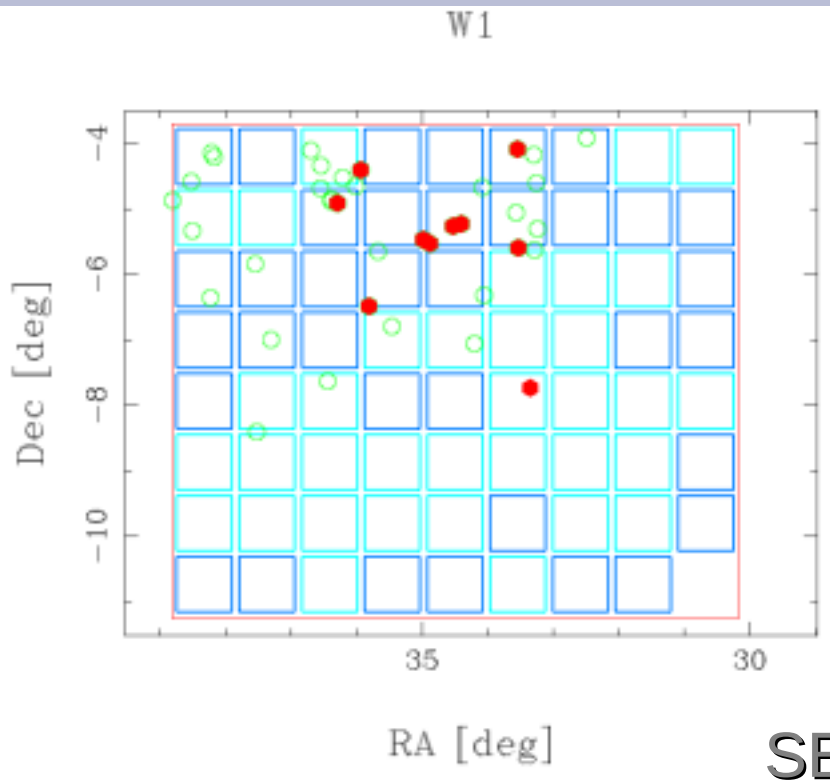
Galaxies ~ 10 (Deep)

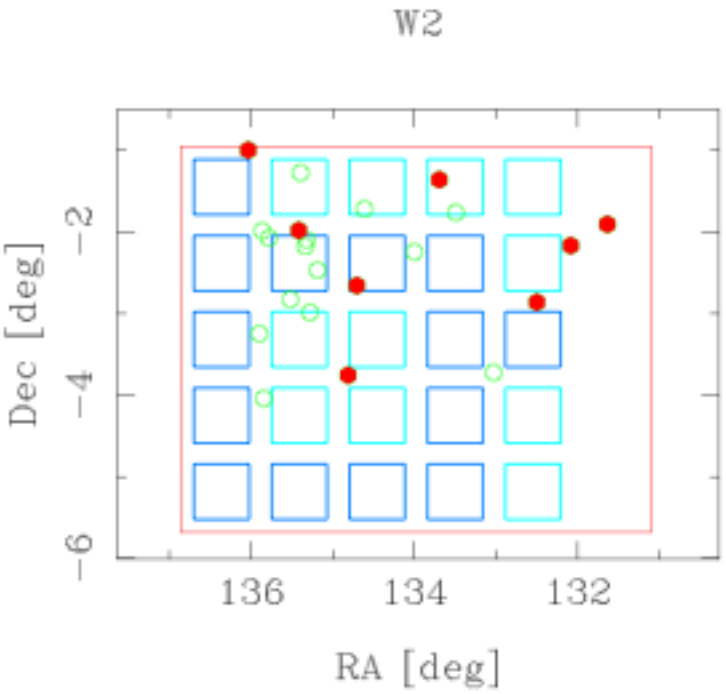
Groups ~ 1

Clusters ~ 0.5

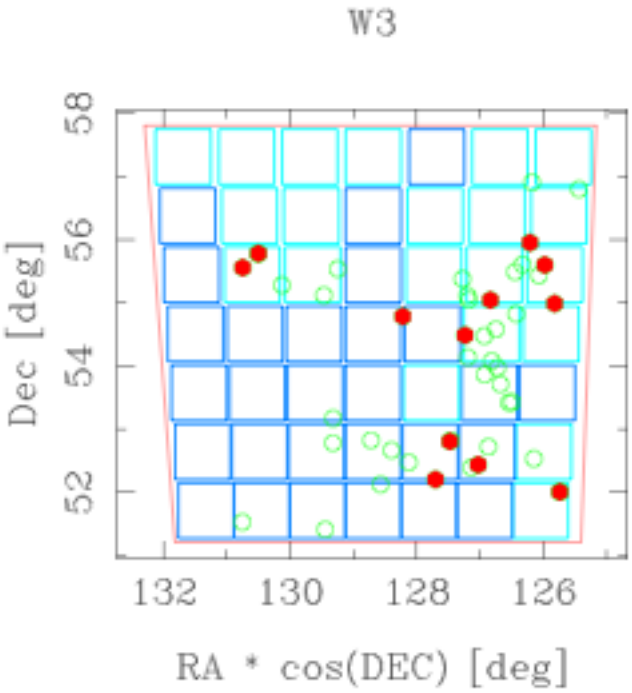
Large scale distribution of SL2S lenses...

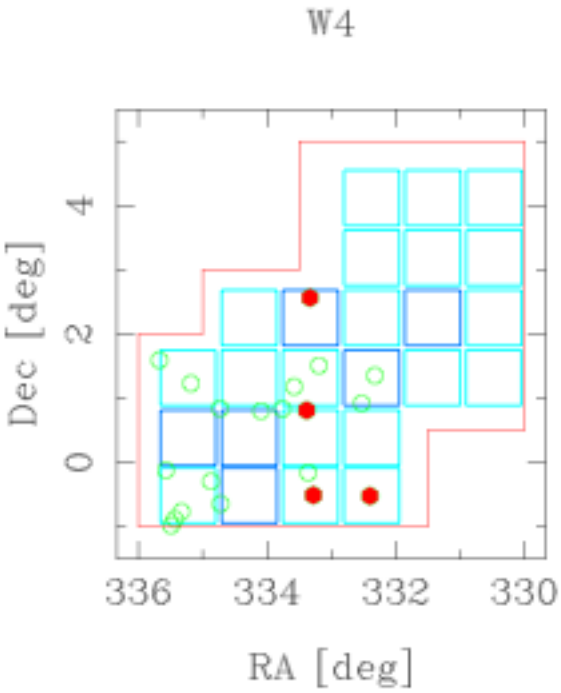



W1
Dec [deg]
-4
-6
-8
-10
35
30
RA [deg]

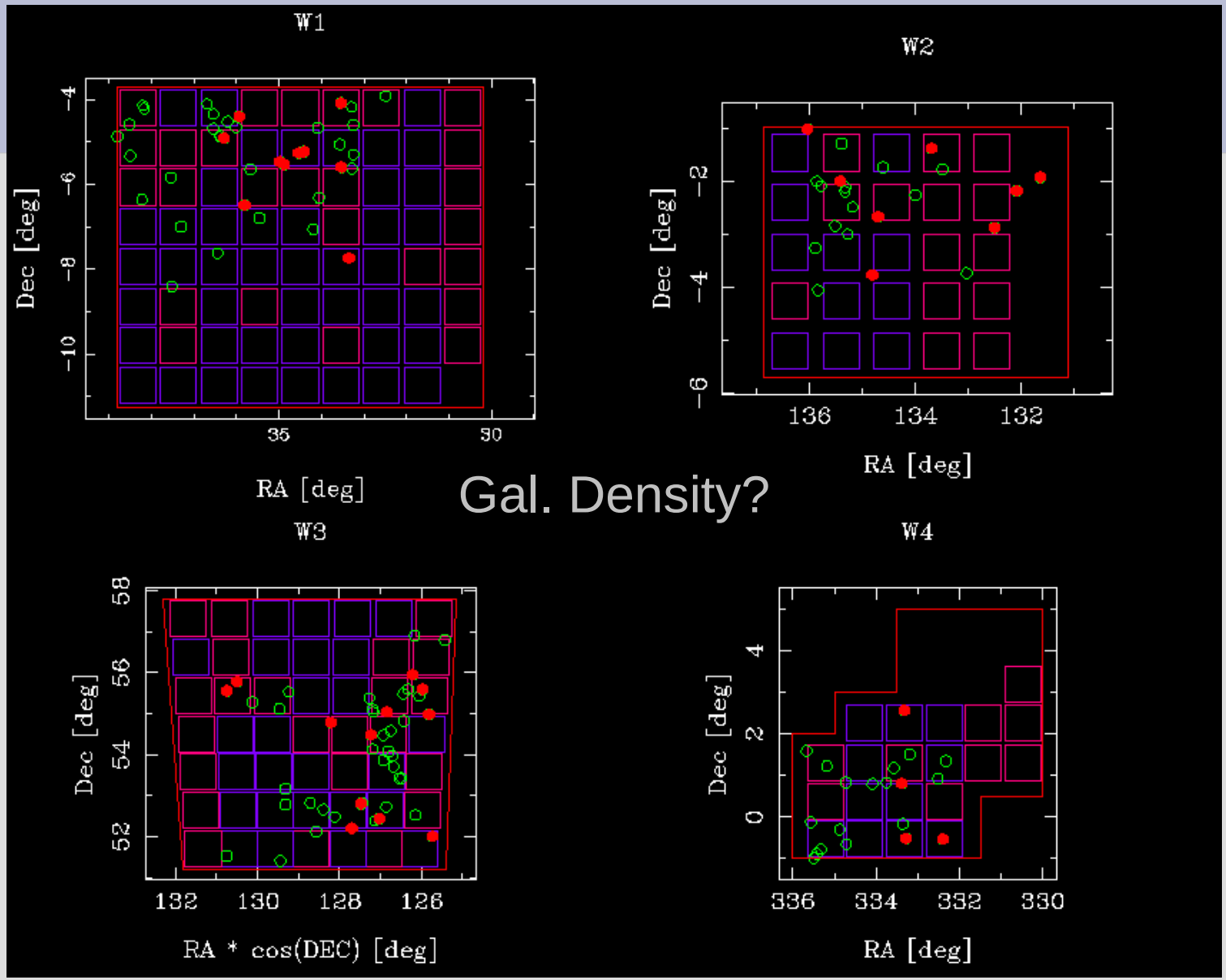

W2
Dec [deg]
-2
-4
-6
136
134
132
RA [deg]

SEEING?


W3
Dec [deg]
58
56
54
52
132
130
128
126
RA * cos(DEC) [deg]

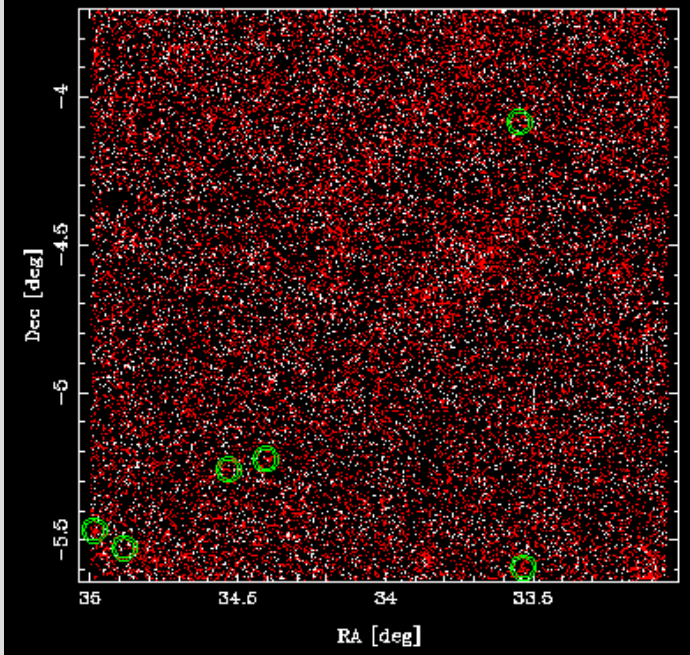

W4
Dec [deg]
4
2
0
336
334
332
330
RA [deg]

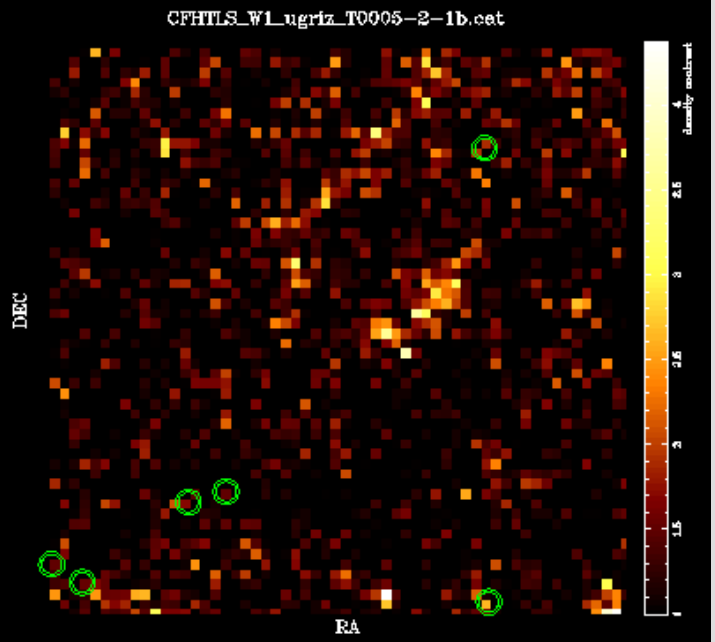
Large scale distribution of SL2S lenses...



Large scale distribution of SL2S lenses...

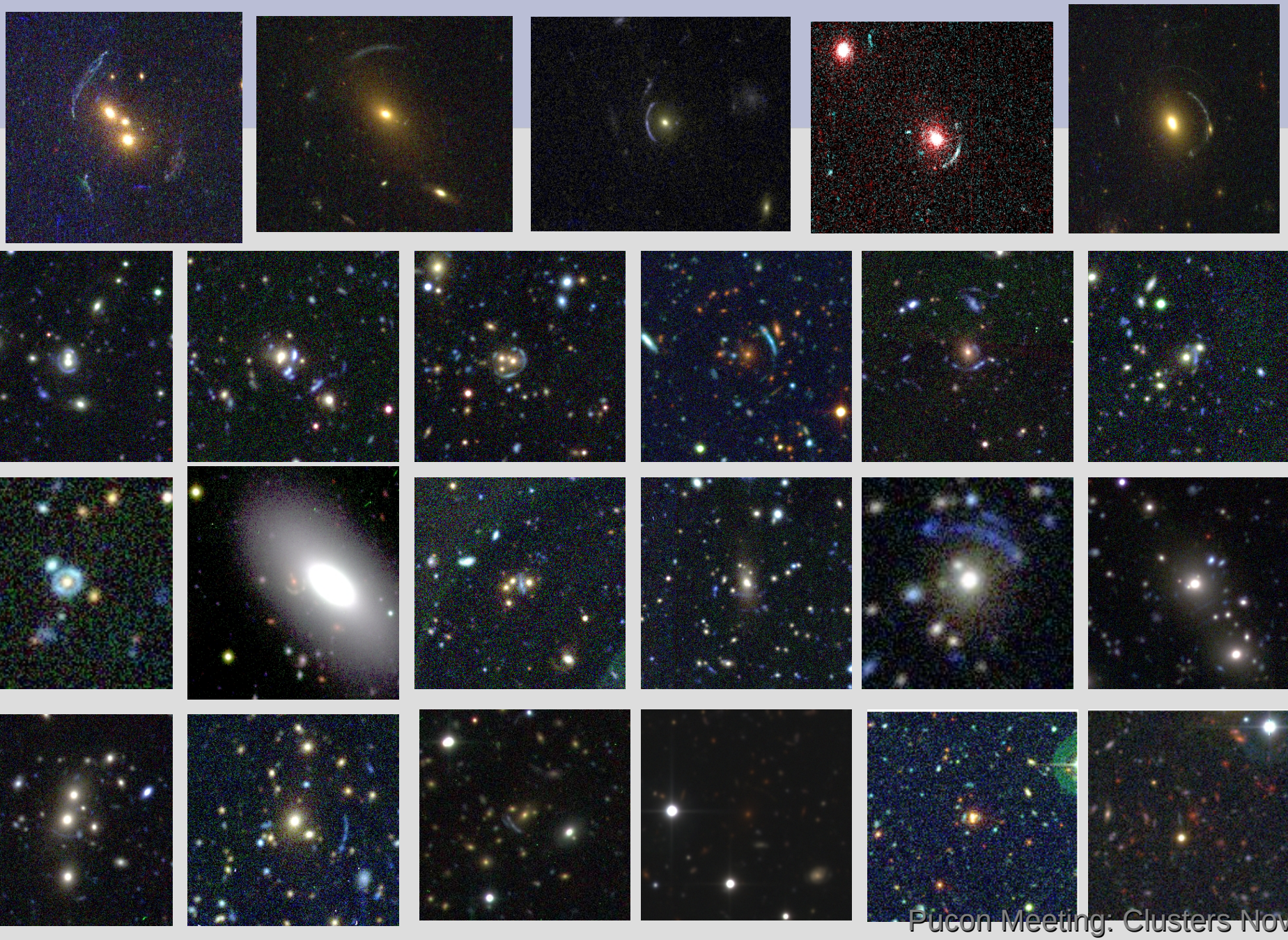
@ z=0.5 1'->550kpc



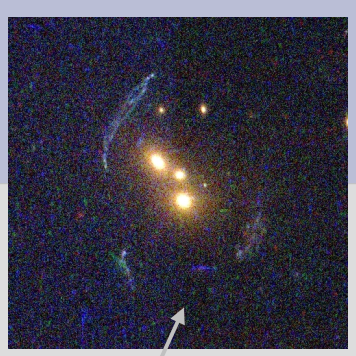
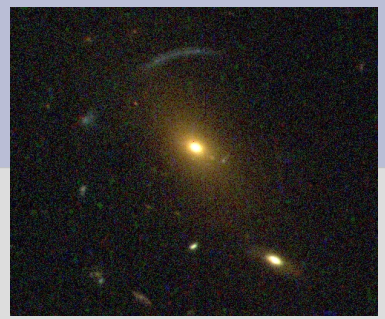
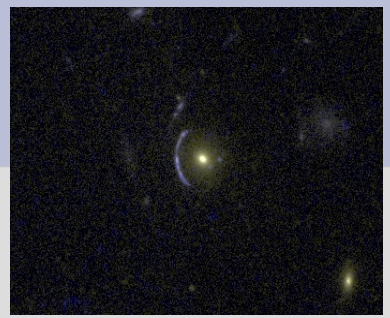
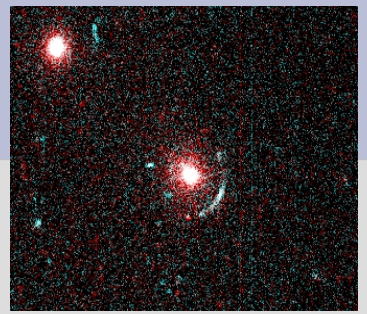
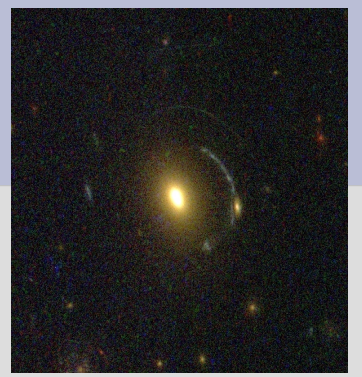


Local structure?

SL2S T0005 bona-f de sample



High-resolution follow-up

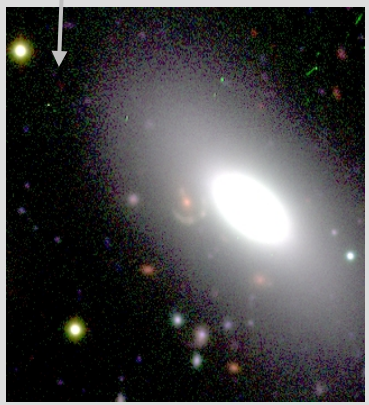
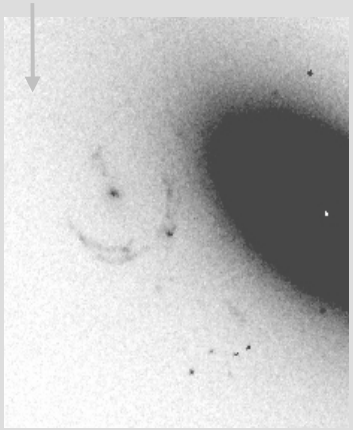
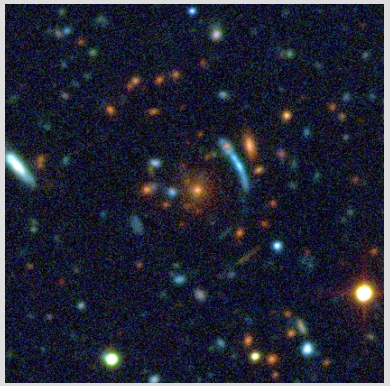
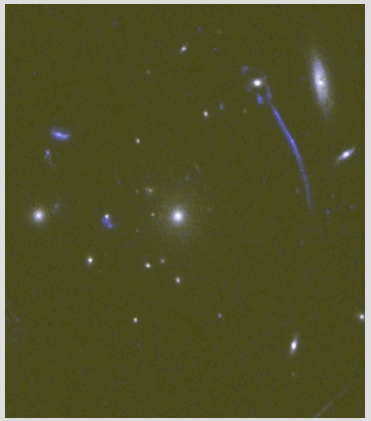
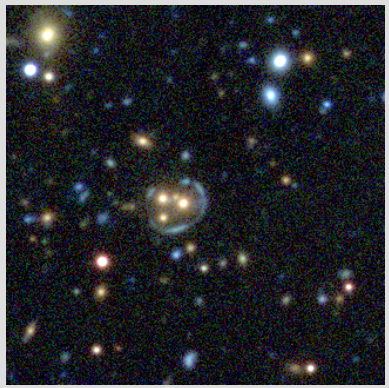
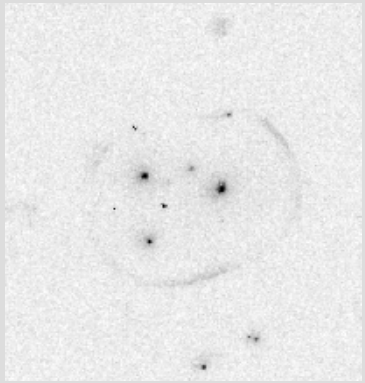
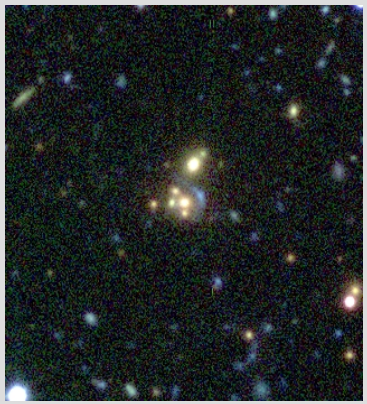
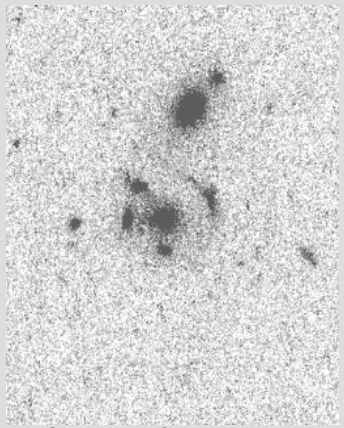






ACS CFHTLS WFPC2/f606 mix

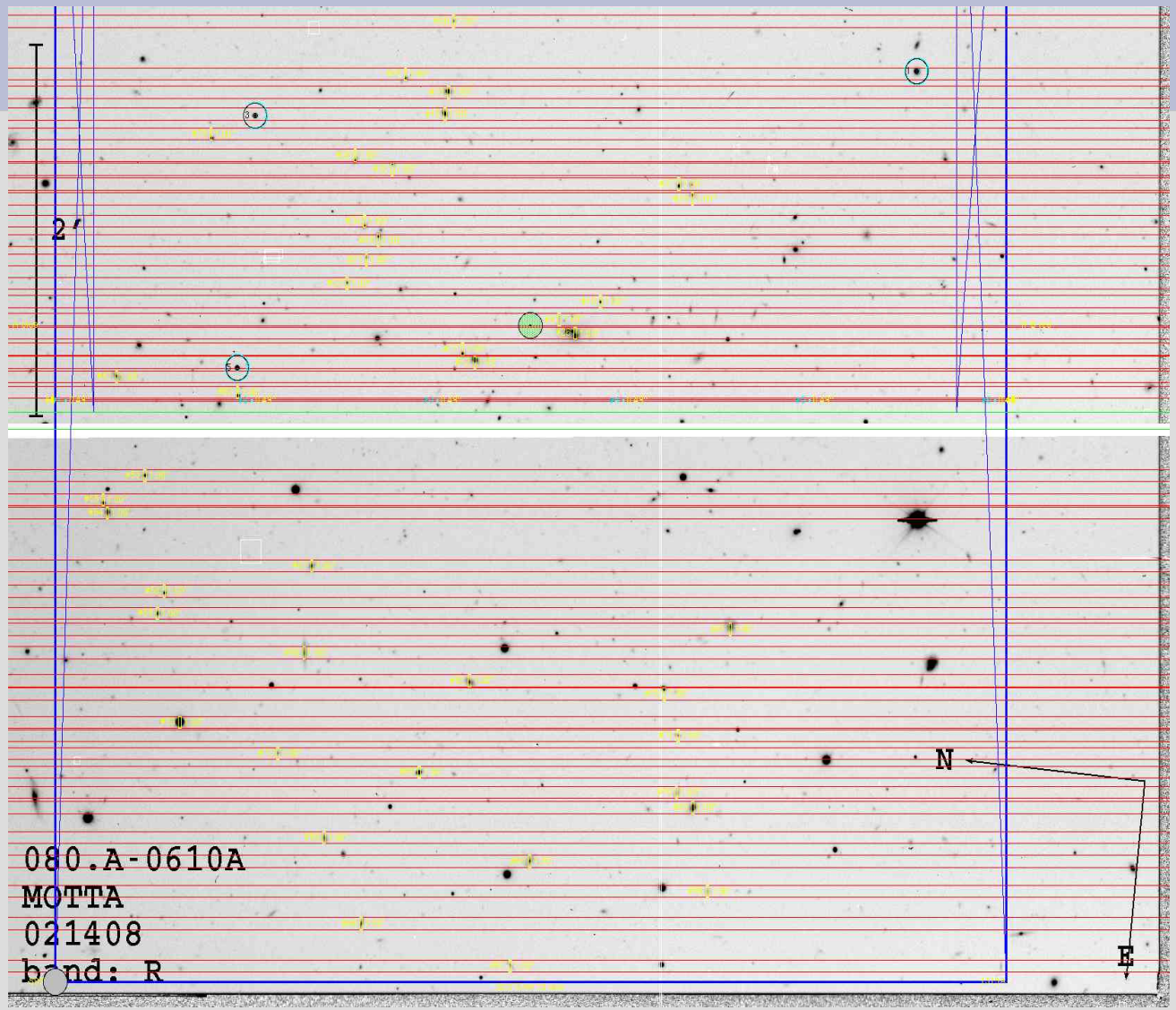
ACS
5

WFPC
38

ARCH
3
+
cosmos

Follow-ups: high-resolution imaging + spectroscopy



VLT/MOS

ongoing...

Vel. Disp.
Lens Group

relaxed vs
Merging

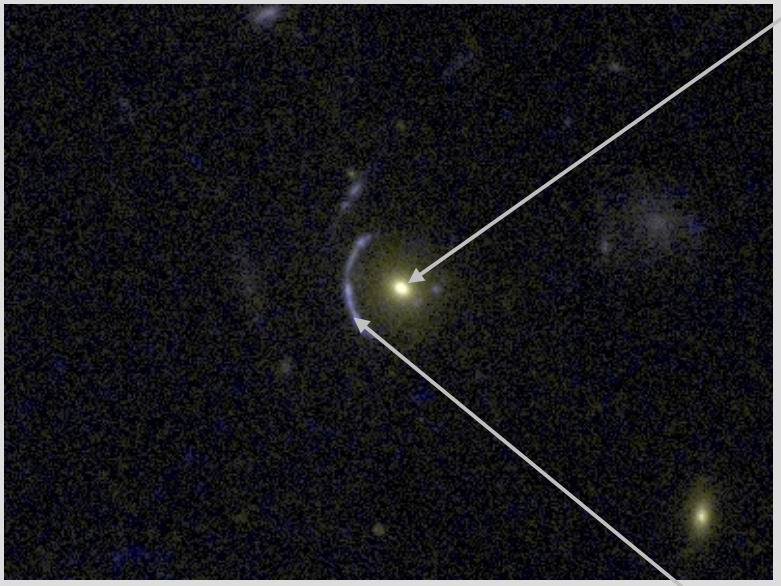
Talk by T. Verdugo

Poster Motta et al

Follow-ups: high-resolution imaging + spectroscopy

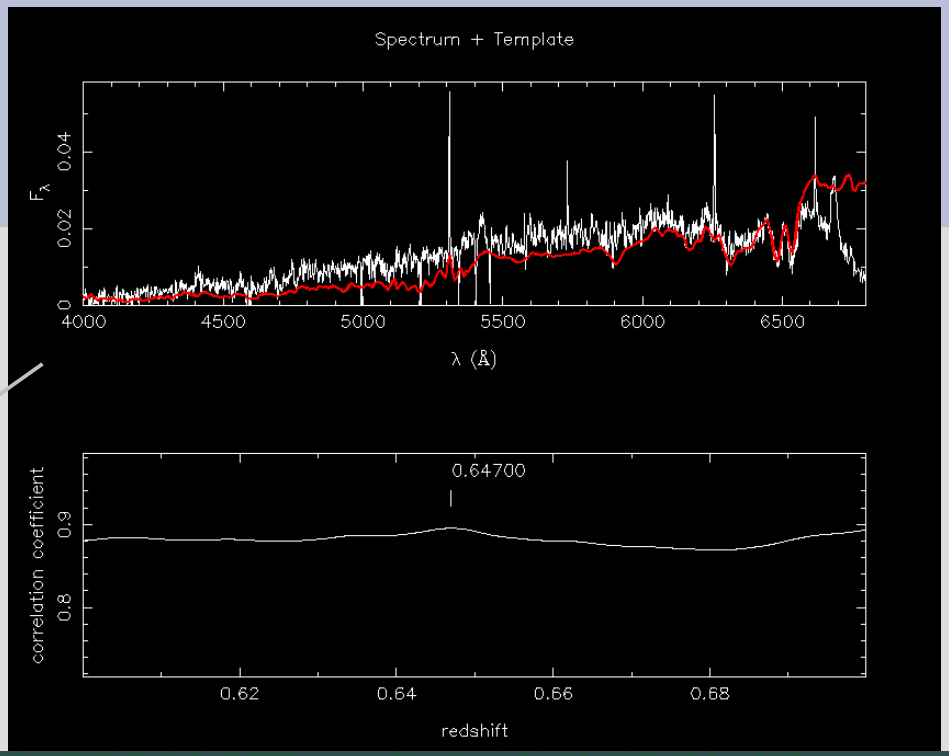
ACS imaging (Kneib et al.)

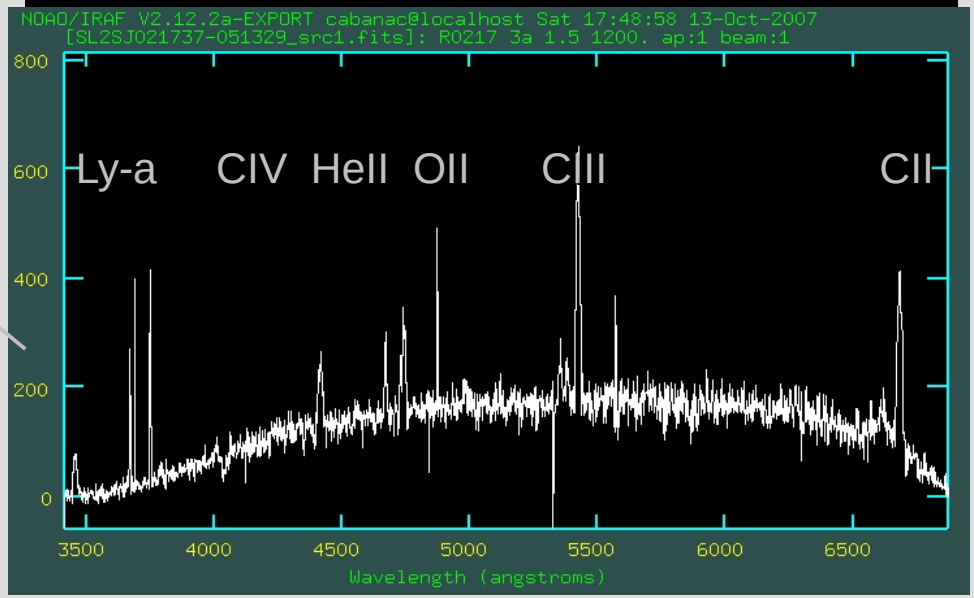
z_lens = 0.647



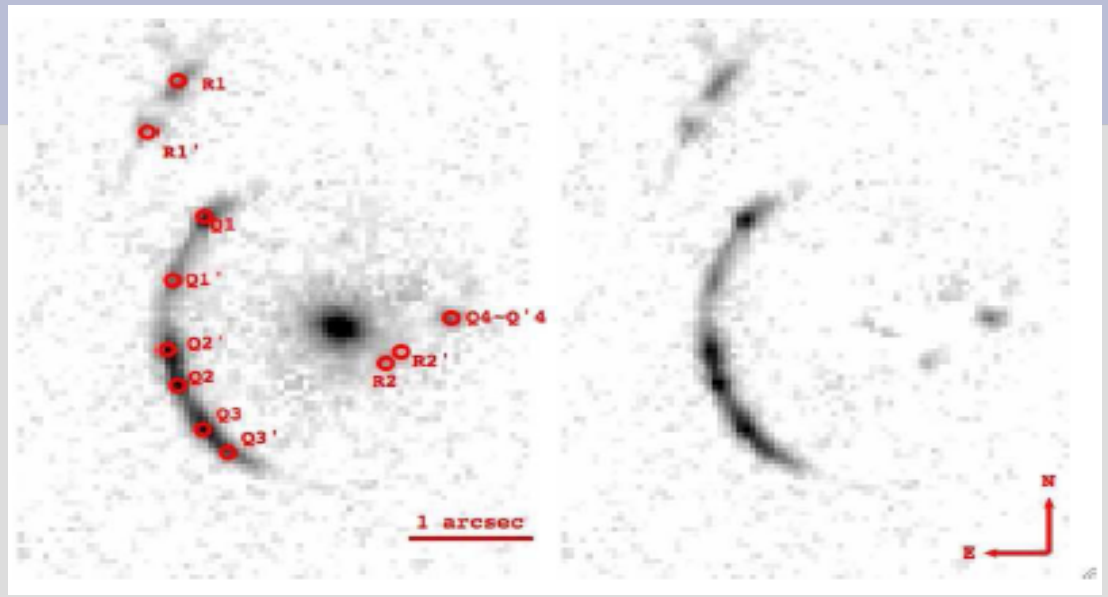
z_source = 1.847, 2.9

Keck Spec. (Treu et al.)

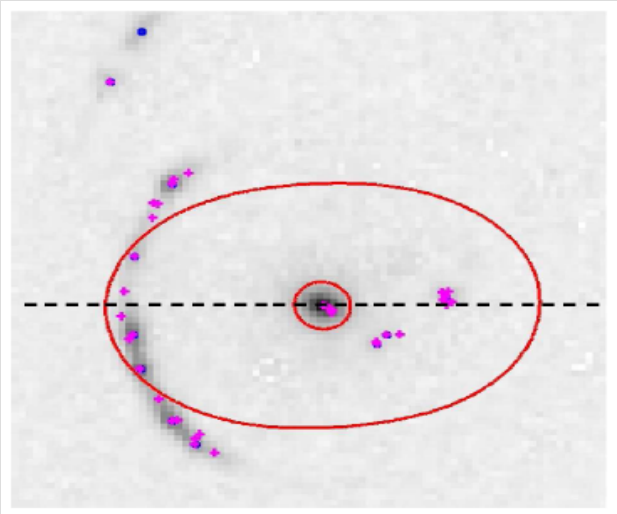




DETAILED MODELLING OF RING SL2SJ02176-0513



Modelling with 6 parameters, double arc system with 20 constraints



SL2S02176-0513

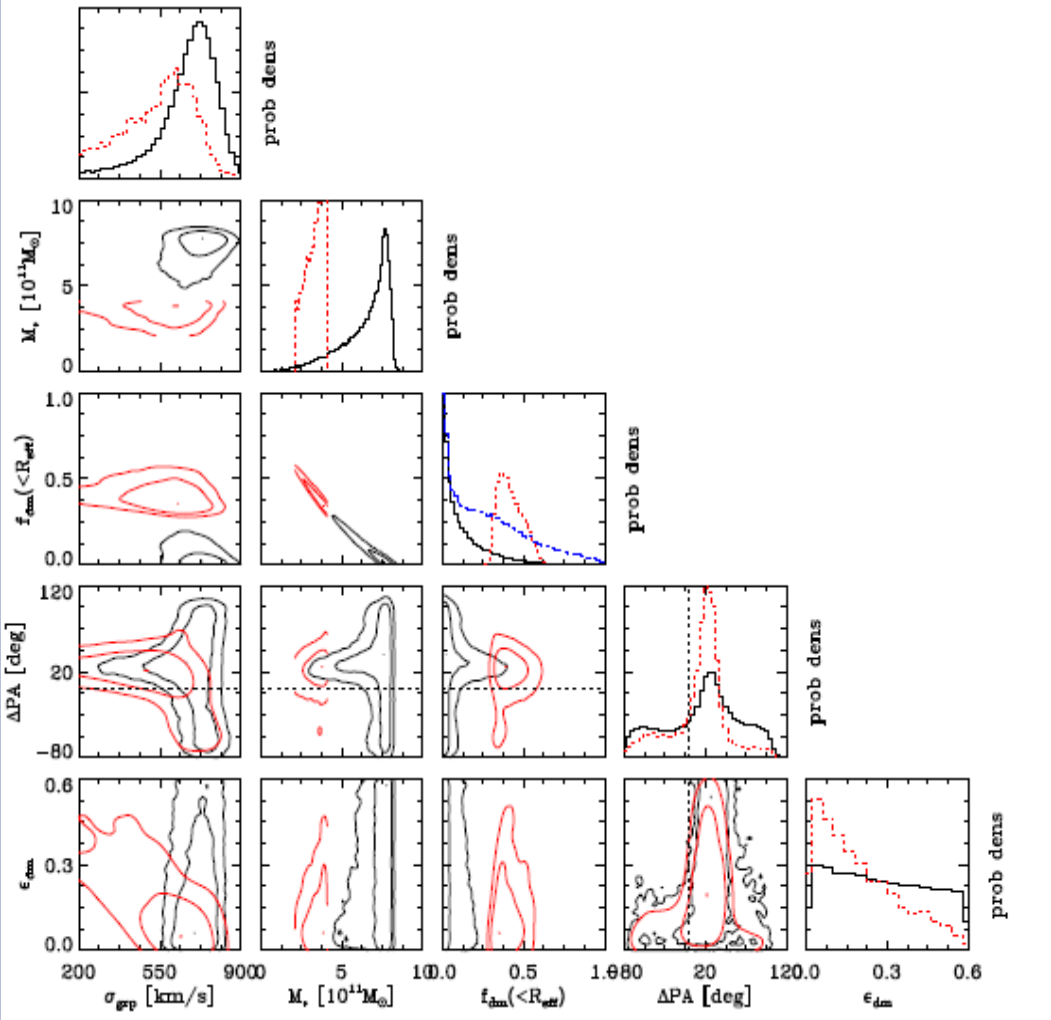
Core/Cusp How many components?

Prof le Halo Lens SIE vs NFW?

Does Light traces DM, environment?

Hong Tu, Gavazzi et al., 2009

Follow-ups: high-resolution imaging + spectroscopy



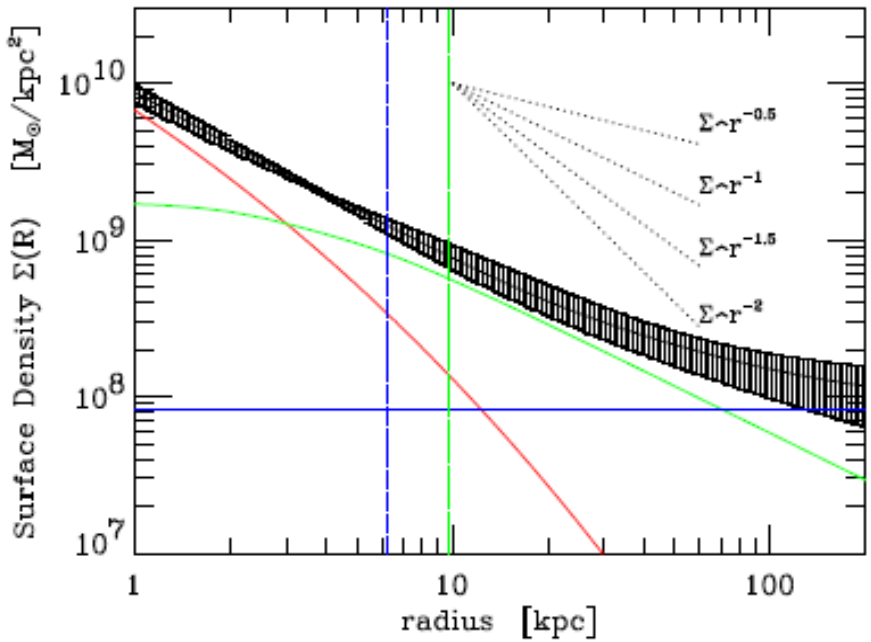


Fig. 5. Total surface mass density profile. The effective radius and the Einstein radii are shown as vertical dashed blue and dot-dashed green lines (respectively at ~ 6.2 and ~ 10.3 kpc). The envelope around median values shows the 68% confidence interval. We show the median stellar density profile (red curve), the median DM halo profile (green) and the median effective external convergence (blue horizontal line) that successively dominate from left to right.

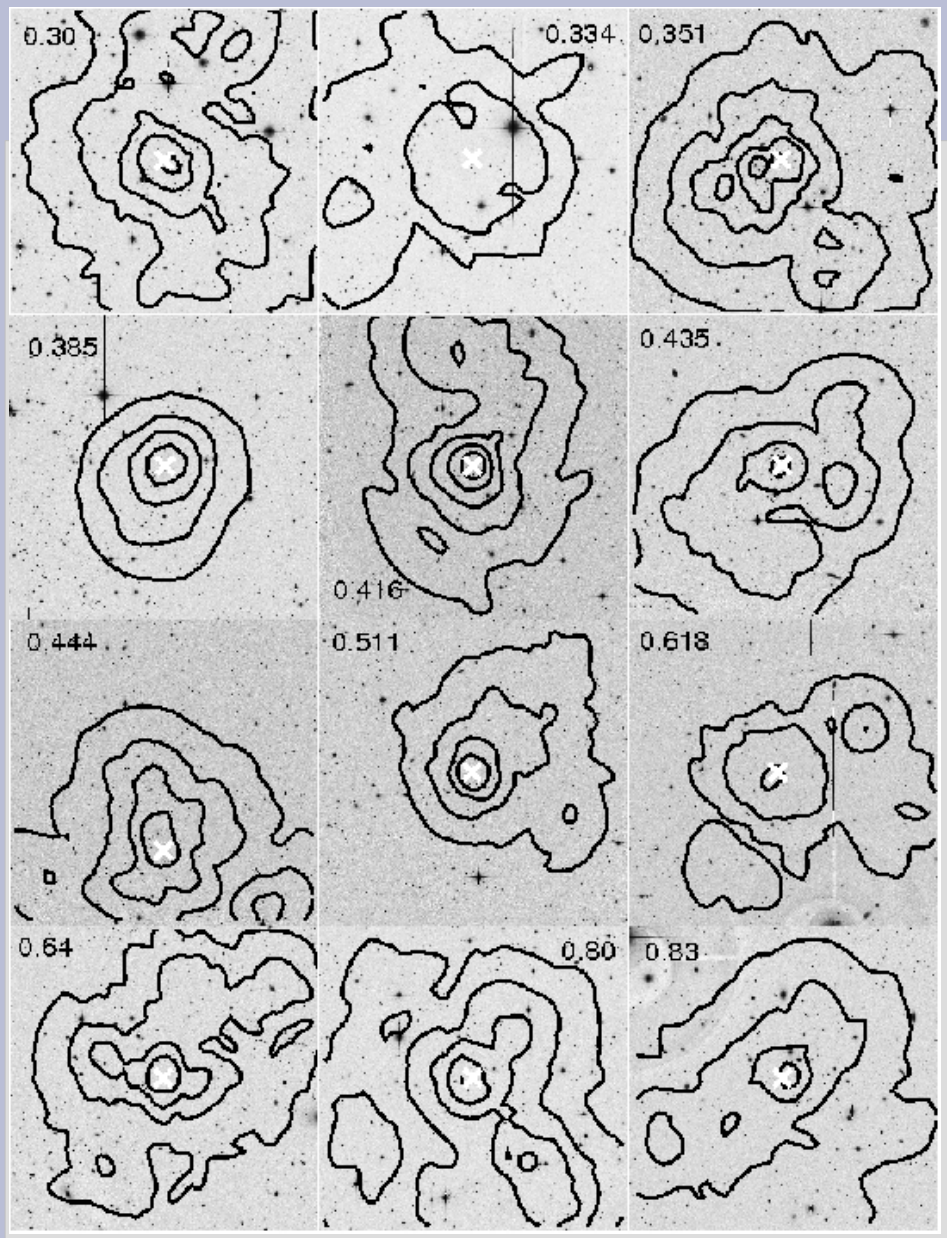
Group Lenses

(Marceau Limousin et al., 2009)

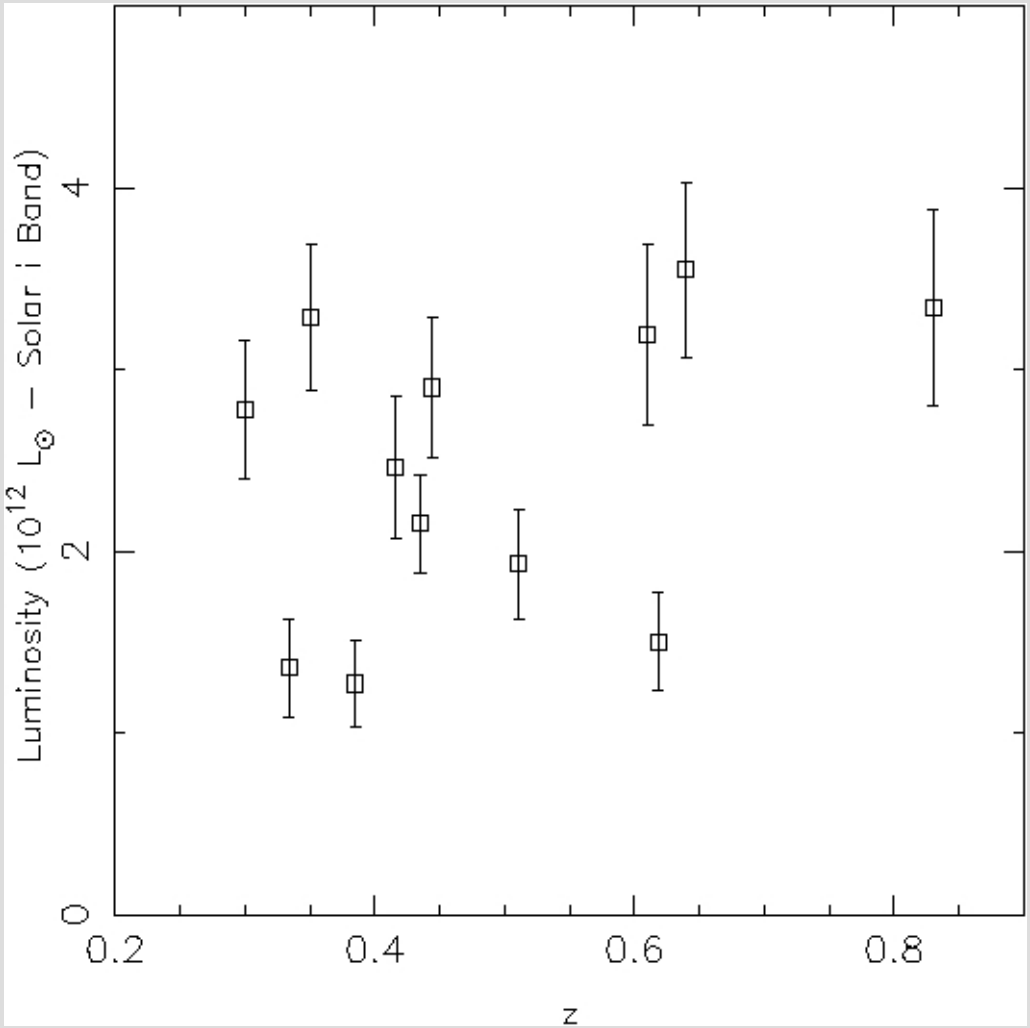
Strong Lensing by Groups of Galaxies:
Opening a New Window of Exploration in the Mass Spectrum

- New Insight into the intermediate mass regime
- Strong Lensing as a Probe of the Mass Distribution Beyond the Einstein Radius
- 15 Groups, z = 0.2 0.9
- M/L(z) vs. Clusters & Galaxies
- sub-structures

Group Lenses

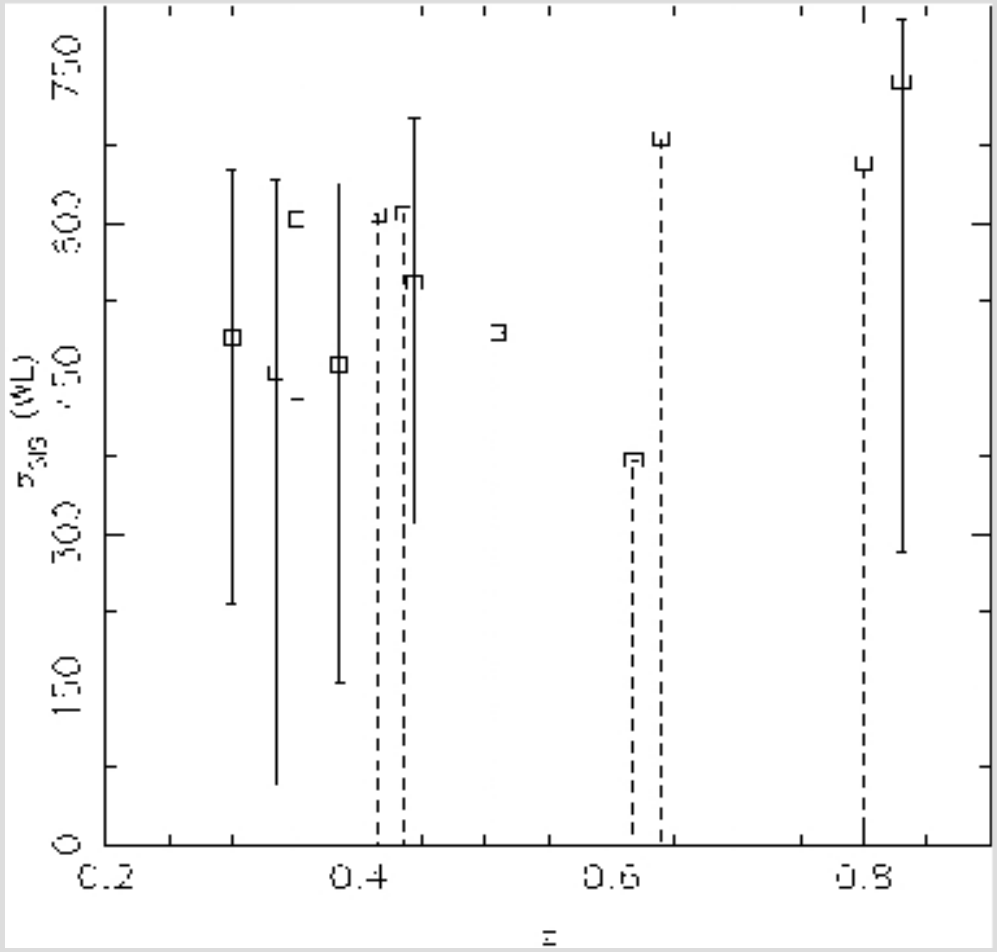


Luminosité vs redshift

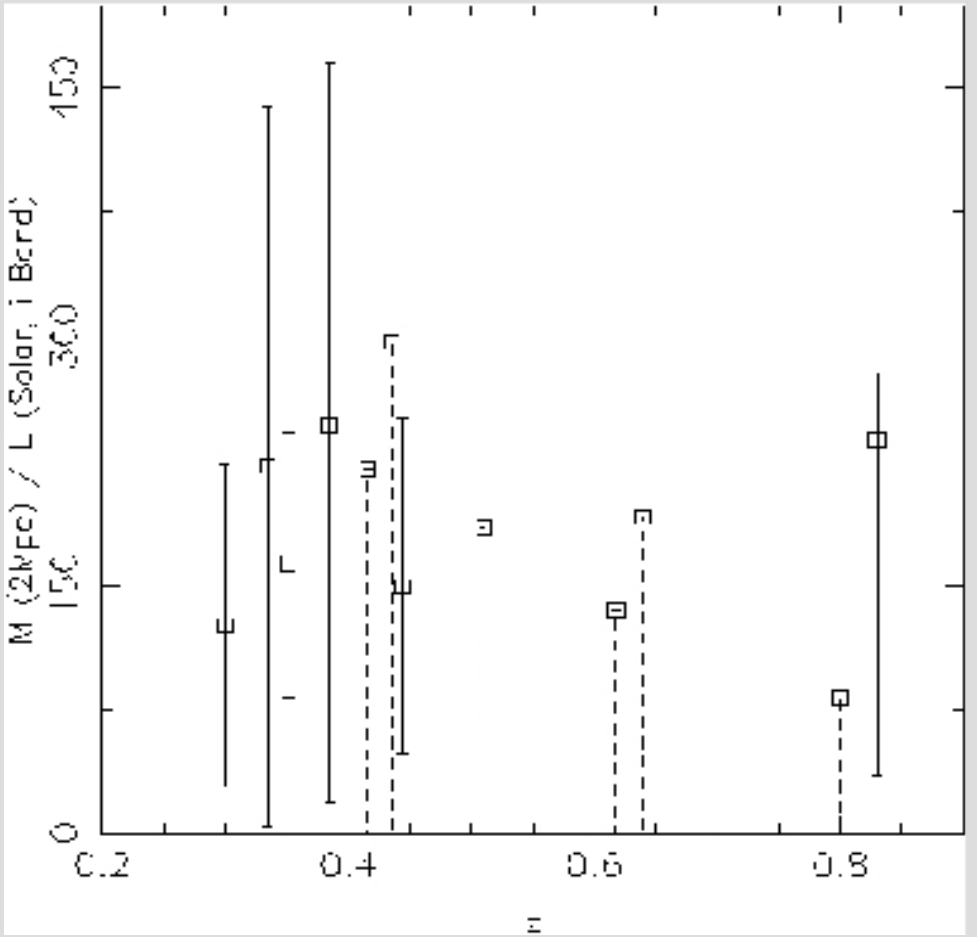


Group Lenses

Sigma_WL vs redshift



M/L vs redshift



To Be Done

Ray tracing in simulated groups: lens statistics

Statistical analyses to characterize the SL2S sample, coupling CDM/SPH simulations with ray-tracing for theoretical prediction (Pichon, Aubert, Alard, ...)

Characterizing the observational selection, and lensing environment for all lenses/arcs

Weak lensing analyses on the more massive lenses

CONCLUSIONS

The CFHTLS offer a large sample of group lenses to be studied as a homogeneous sample: SL2S.

We are beginning to understand the selection biases and selection function of SL2S.

Anisotropies may be seen in the distribution of SL2S lenses on scales of 300 Mpc