

The CFHTLS strong lensing Legacy Survey

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and the SL2S collaboration

www.cfht.hawaii.edu/~cabanac/SL2S/

The CFHTLS SL2S project

Observational experiment (Haggles, APM, SDSS)

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

> 100 -> possibly 1000

with a lens redshift up to $z = 1$

Prepare for large surveys (panSTARR, LSST, SNAP, DUNE)

Scientific collaboration

Institut d'astrophysique de Paris (France)

C. Alard, B. Fort, Y. Mellier, Hong Tu (Shanghai NU), J-F Sygnet, C. Pichon

OMP Laboratoire d'Astrophysique de Tarbes-Toulouse (France)

R. Cabanac, G. Soucail, E. Belsole (Cambridge UK), R. Pello

Laboratoire d'astrophysique de Marseille (France)

J.-P. Kneib, E. Julo (ESO), L. Tasca, O. le Fevre

UC Santa Barbara (USA)

R. Blandford (Stanford), P. Marshall, R. Gavazzi, T. Treu

University de Victoria (Canada)

Crampton (HIA) , K.. Thanjavur (UVic), J. Willis (UVic)

Durham University (G-B)

M. Swinbank

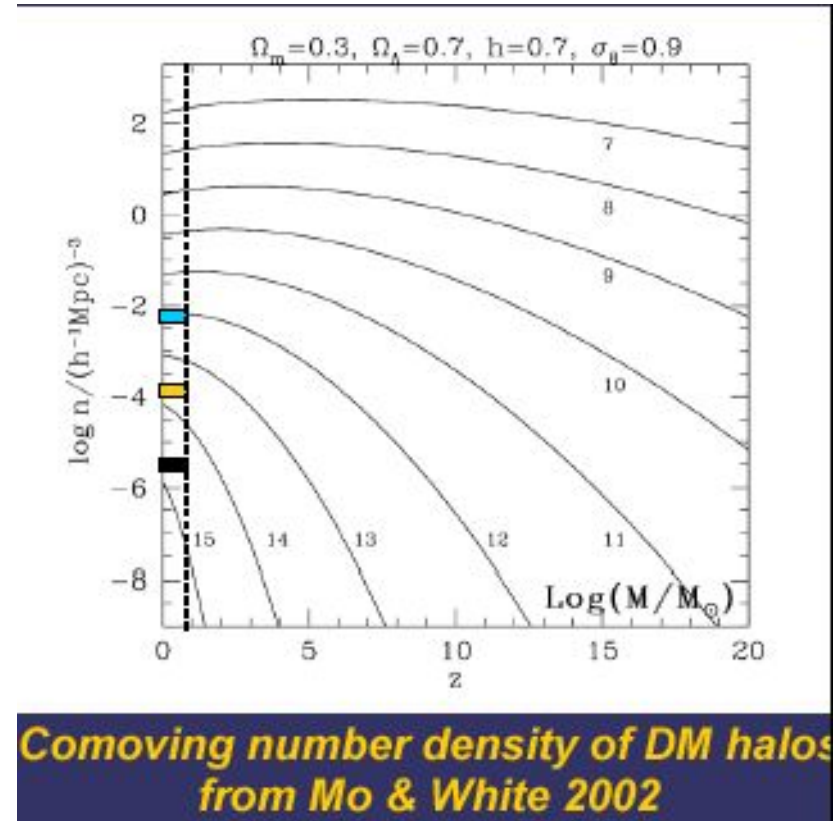
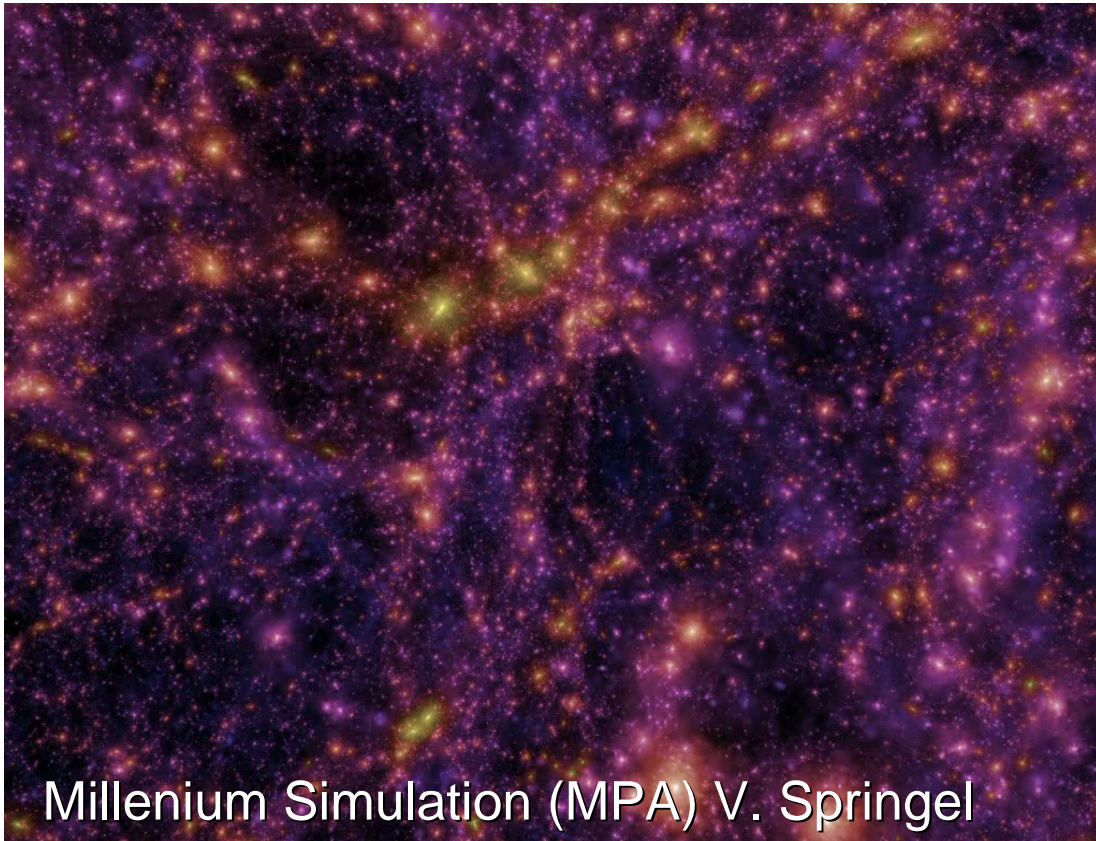
U. Valparaiso (Chile)

V. Motta

Outline of the presentation

- A brief introduction on gravitational lensing and dark matter
- CFHT Legacy Survey: a big reservoir of strong lenses
- Automated procedure to search lenses
 - arcs in groups and (distant) clusters
 - gravitational rings
- Release T003
- “To be done”s

Lensing and dark matter



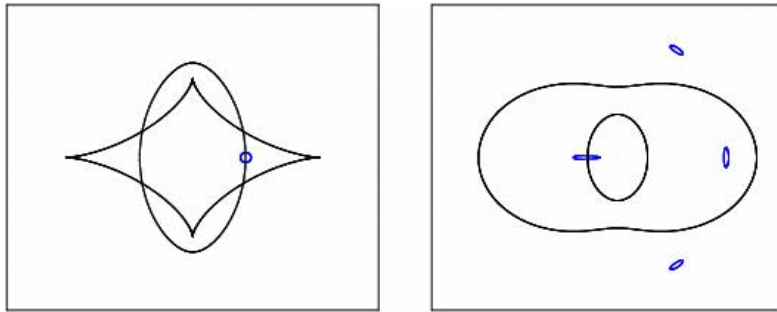
Predicted halo mass function from CDM paradigm

Properties and demographics of lensing structures well predicted

+Add galaxy formation (on small scales)

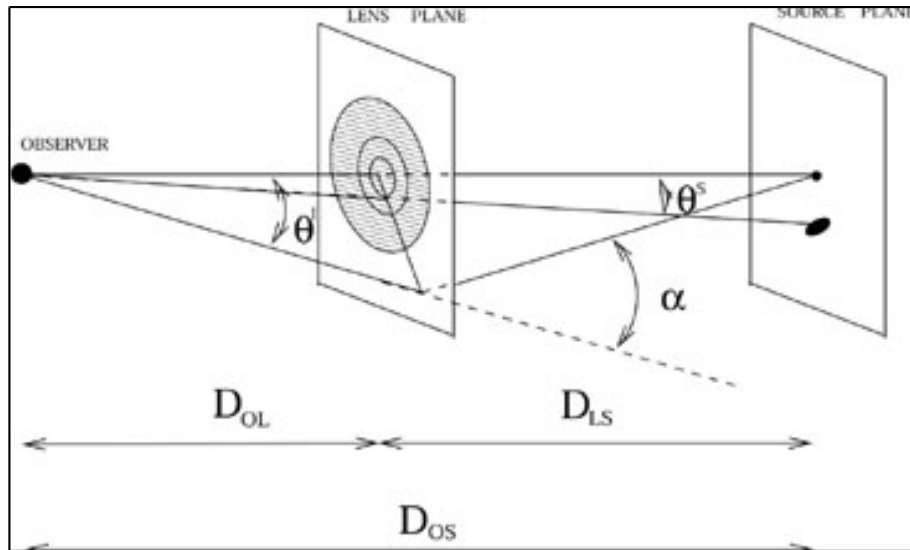
Lensing number predictions

Thin lens + hypothesis on the luminous source population



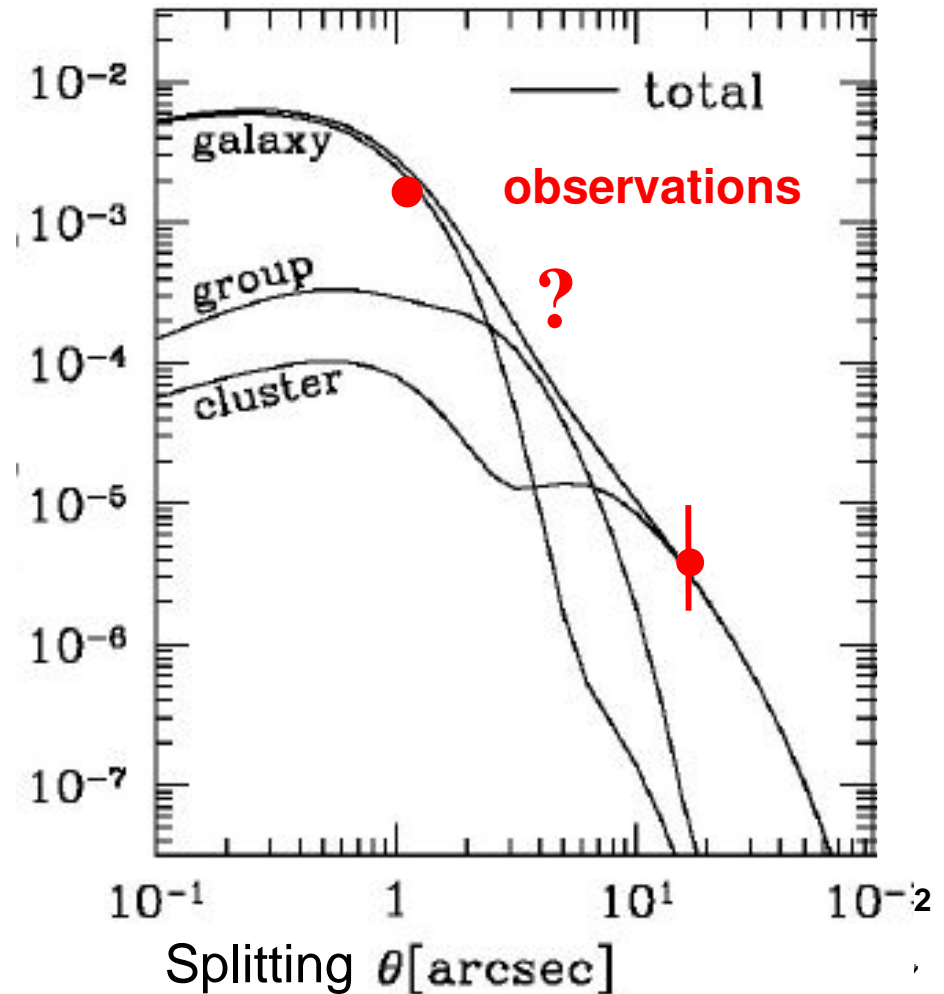
Oguri, 2006

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



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

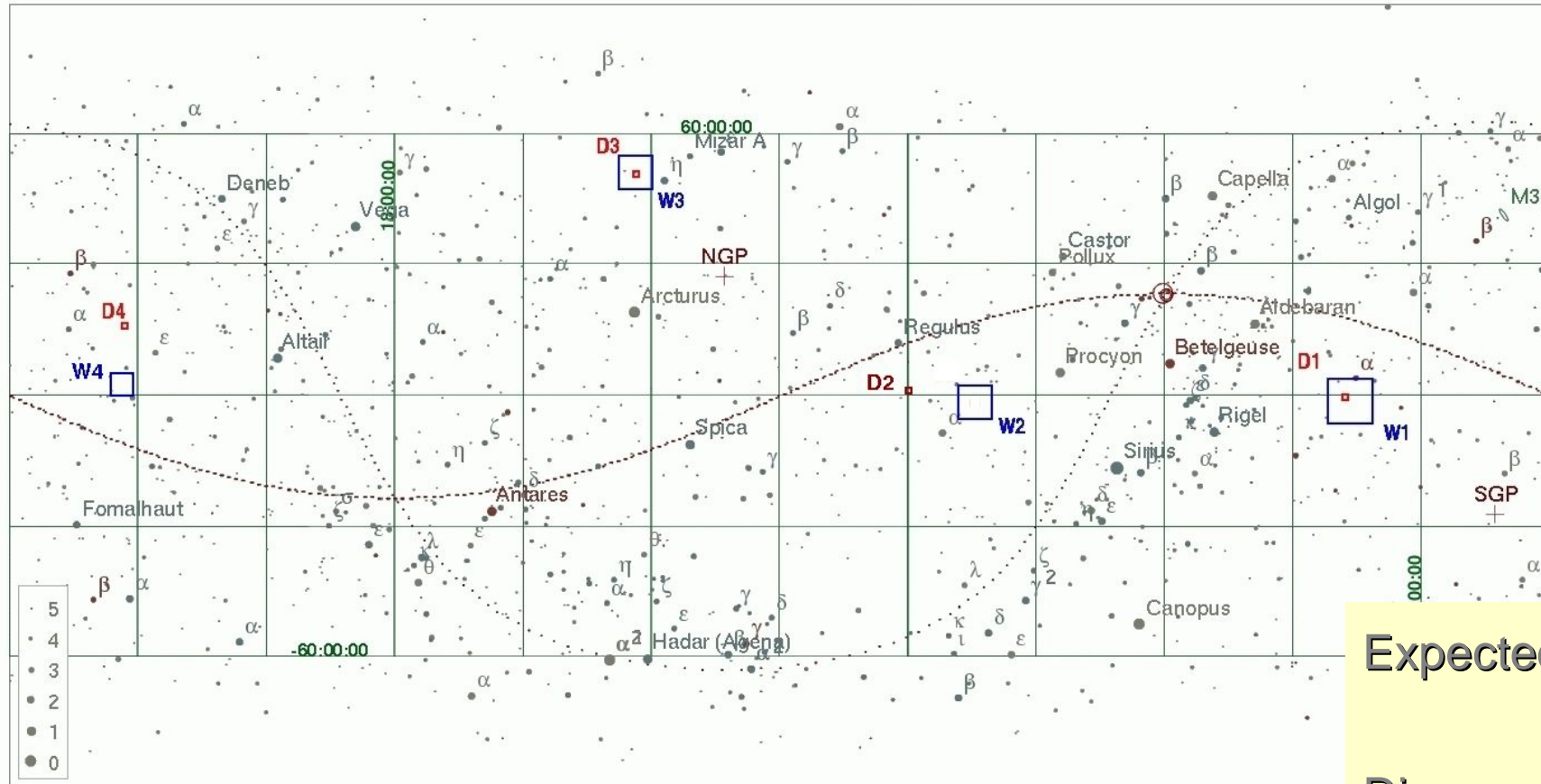
$$\psi(\vec{\theta}) = \frac{2}{c^2} \frac{D_{LS}}{D_{OS}D_{OL}} \varphi(\vec{\theta})$$





The CFHTLS Deep and Wide Fields **TERAPIX**

CFHTLS-Deep&Wide targets



MegaCam

1deg²

0.186"/pix

Wide Survey

170 deg²

IAB ~ 24

Deep Survey

IAB ~ 27

Expected CFHTLS

Rings > 1000

Groups > 100

Clusters > 50

D1 : 02 26 00 ; - 04 30 00	D3 : 14 19 28 ; + 52 40 41	W1 : 02 18 00 ; - 07 00 00	W3 : 14 17 54 ;
D2 : 10 00 28 ; + 02 12 21	D4 : 22 15 32 ; + 17 44 06	W2 : 08 54 00 ; - 04 15 00	W4 : 22 13 18 ;



The CFHTLS Terapix releases

TERAPIX

CFHTLS Releases:

T0002: 4deg² Deep ugriz (down to I~25.5)
28deg² Wide g r/2 i (24.5)



Cabanac et al. 07

T0003: 4deg² Deep ugriz (down to I~26.5)
40deg² Wide g r/2 i



Being followed-up

T0004 (soon): ... Deep ugriz (down to I~27) + new stacks with 25% best seeing (~0.5")
Wide 125deg² u r/2 i , 25 deg² ugriz (means 85 deg² new!!)

Semi-automated detection

Visual detection is not realistic...

... neither is completely automated selection

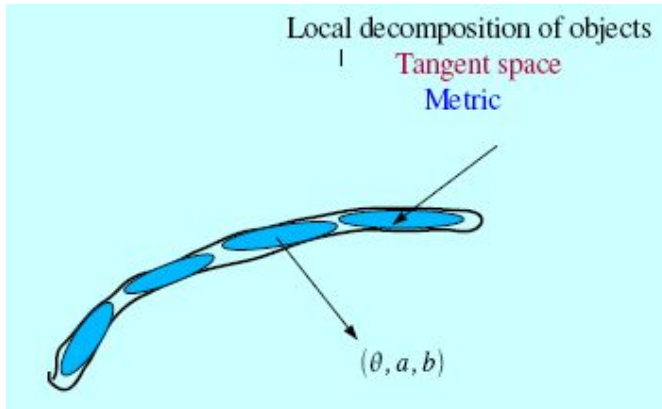
=> Hybrid procedures

ARC FINDER (Alard, astro-ph/0606757)

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

Geometric description of arcs

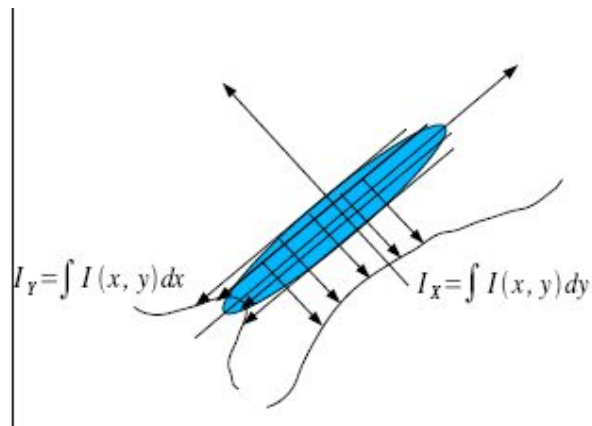
(Alard, astro-ph/0606757)



2nd order Moments $\sigma_{ij} = \int I(x_1, x_2) x_i x_j dx_1 dx_2$

Rotation, in proper axis: $\sigma_{12} = 0$

Local elongation, ratio of 2nd order moments: $\frac{\hat{\sigma}_{11}}{\hat{\sigma}_{22}}$



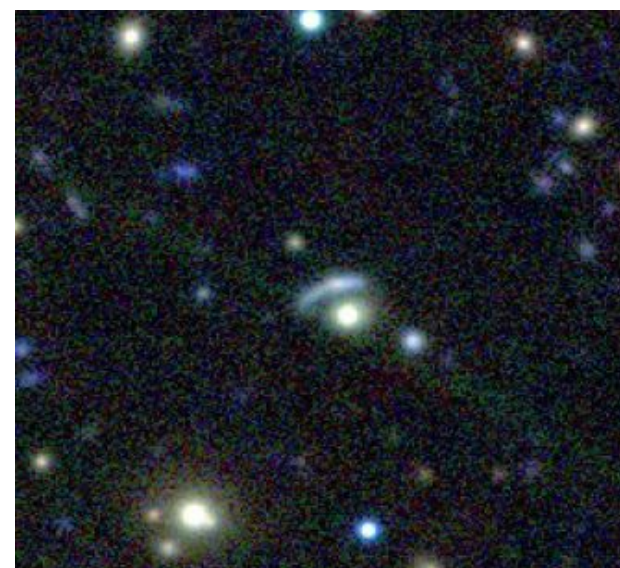
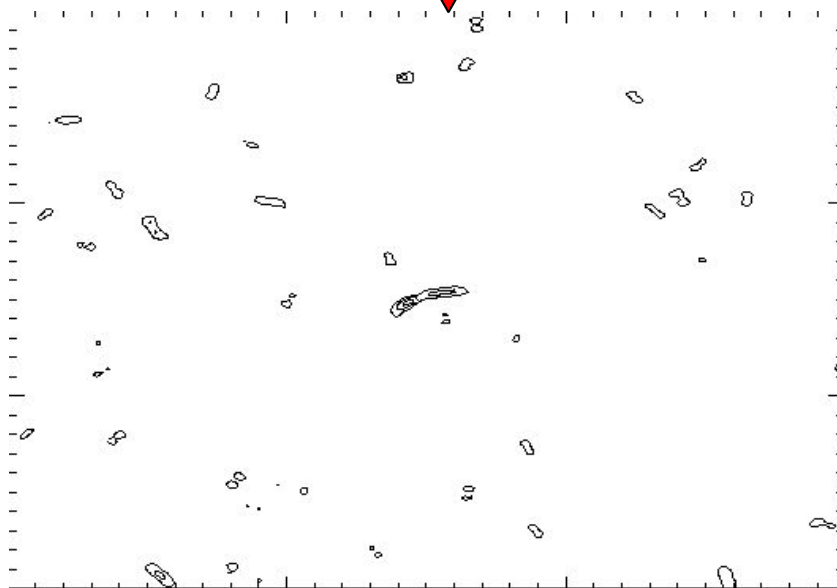
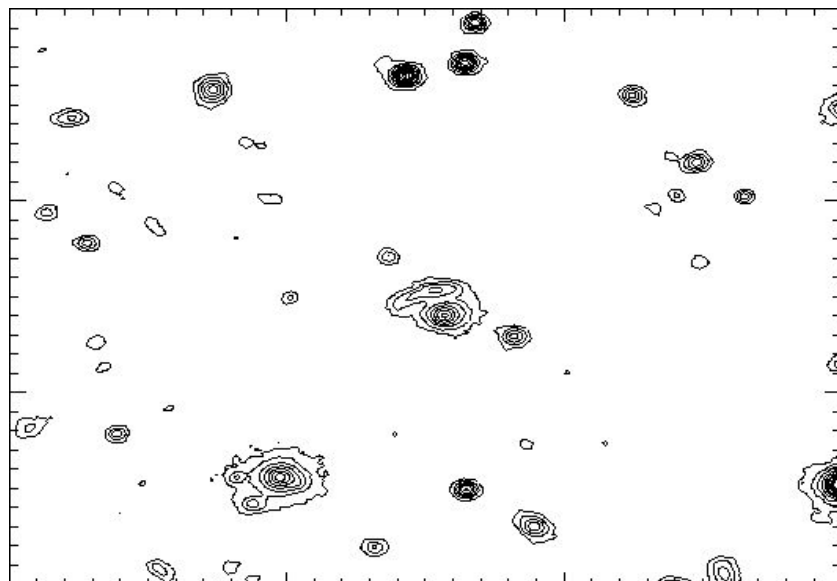
arc thickness \sim seeing

search a local elongation with $w = \text{seeing}$

Detection example

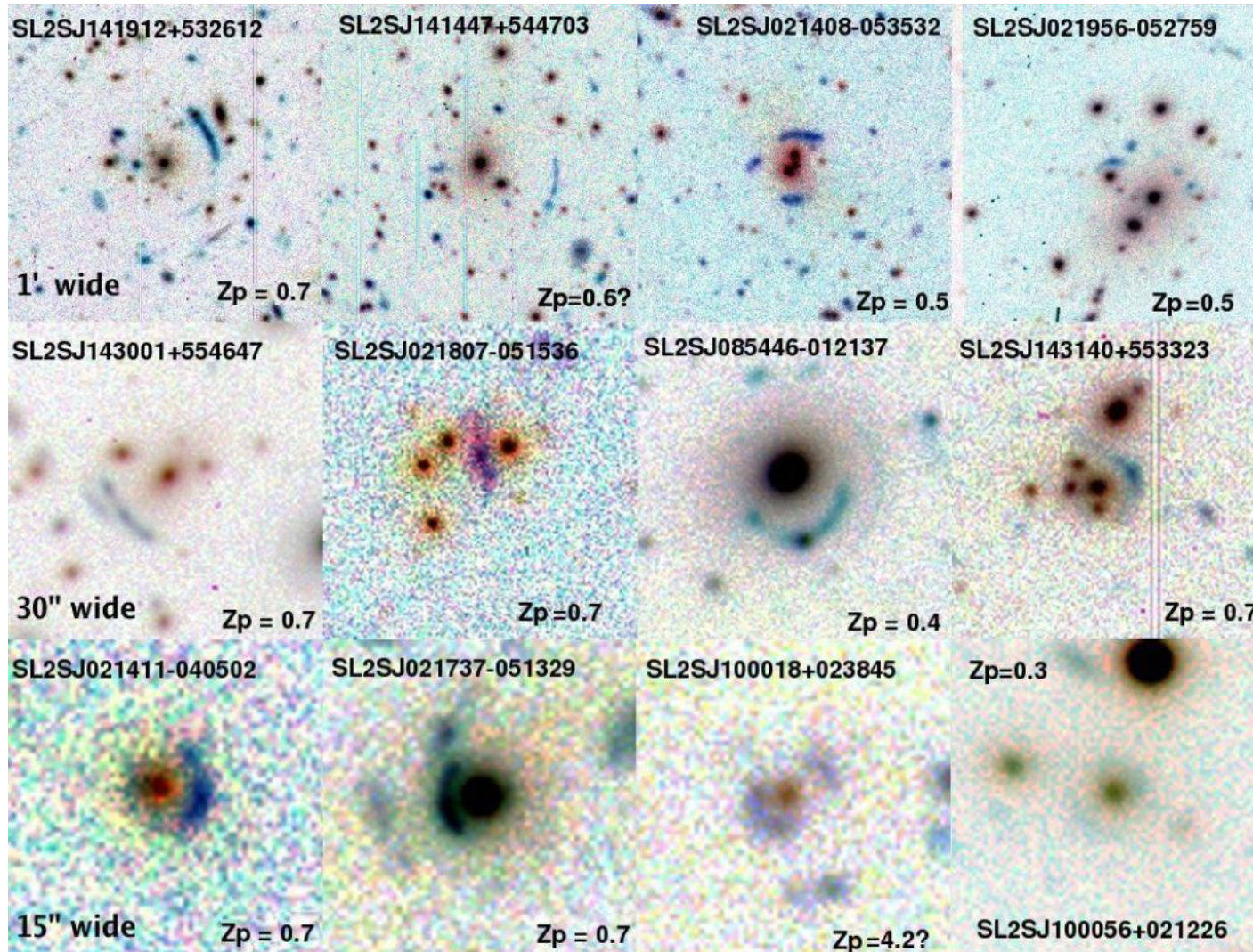
(Alard, astro-ph/0606757)

with a typical CFHTLS
arc candidate



T0002 – T0003 examples

(cabanac et al., 2007)



Clusters > 8''

3'' < Groups < 8''

Galaxies < 3'' ?

Ring finder

(Gavazzi et al., in prep)

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

Method:

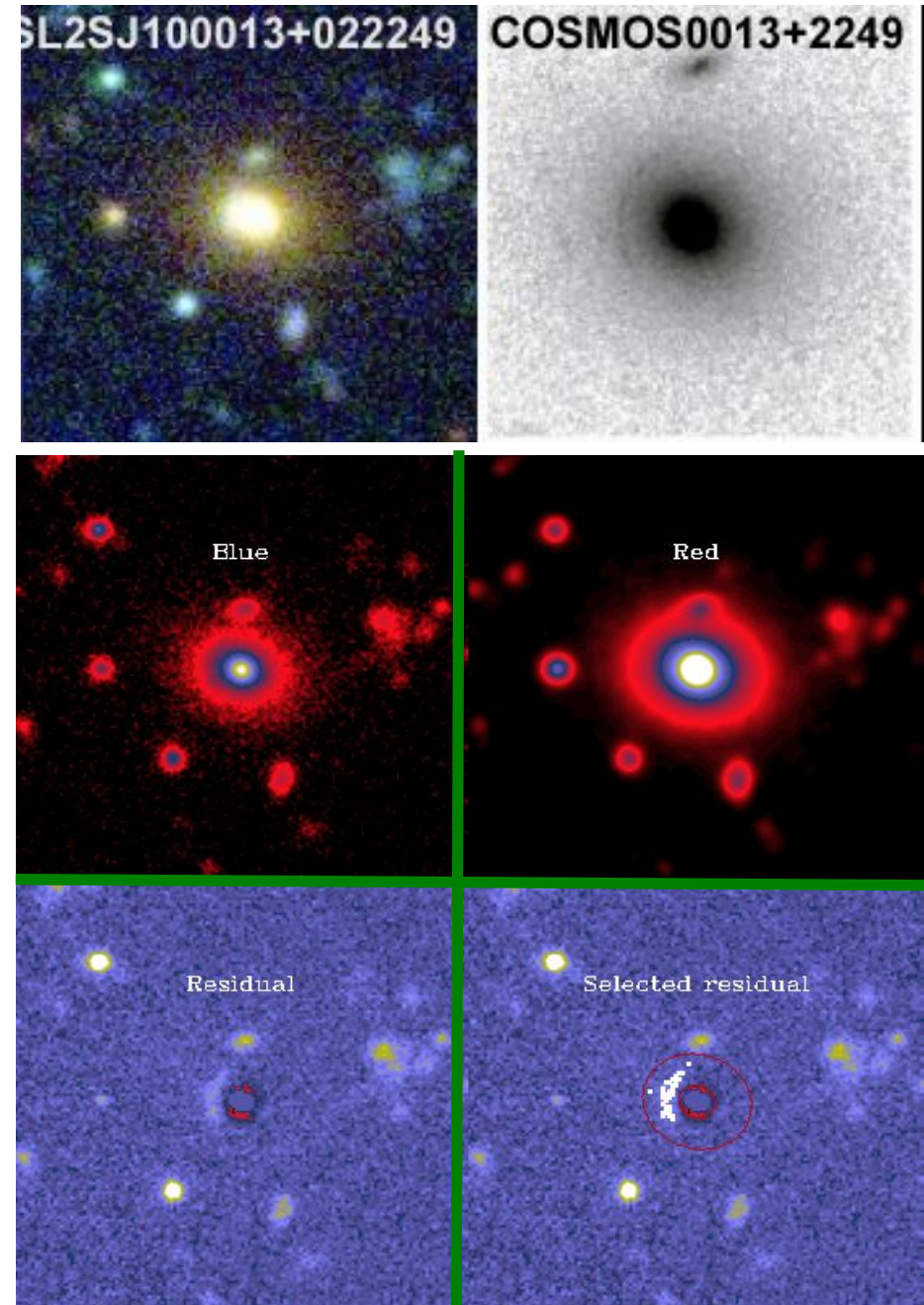
1-Fit a $B-\alpha R$ profile consistent with the
lens color.

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

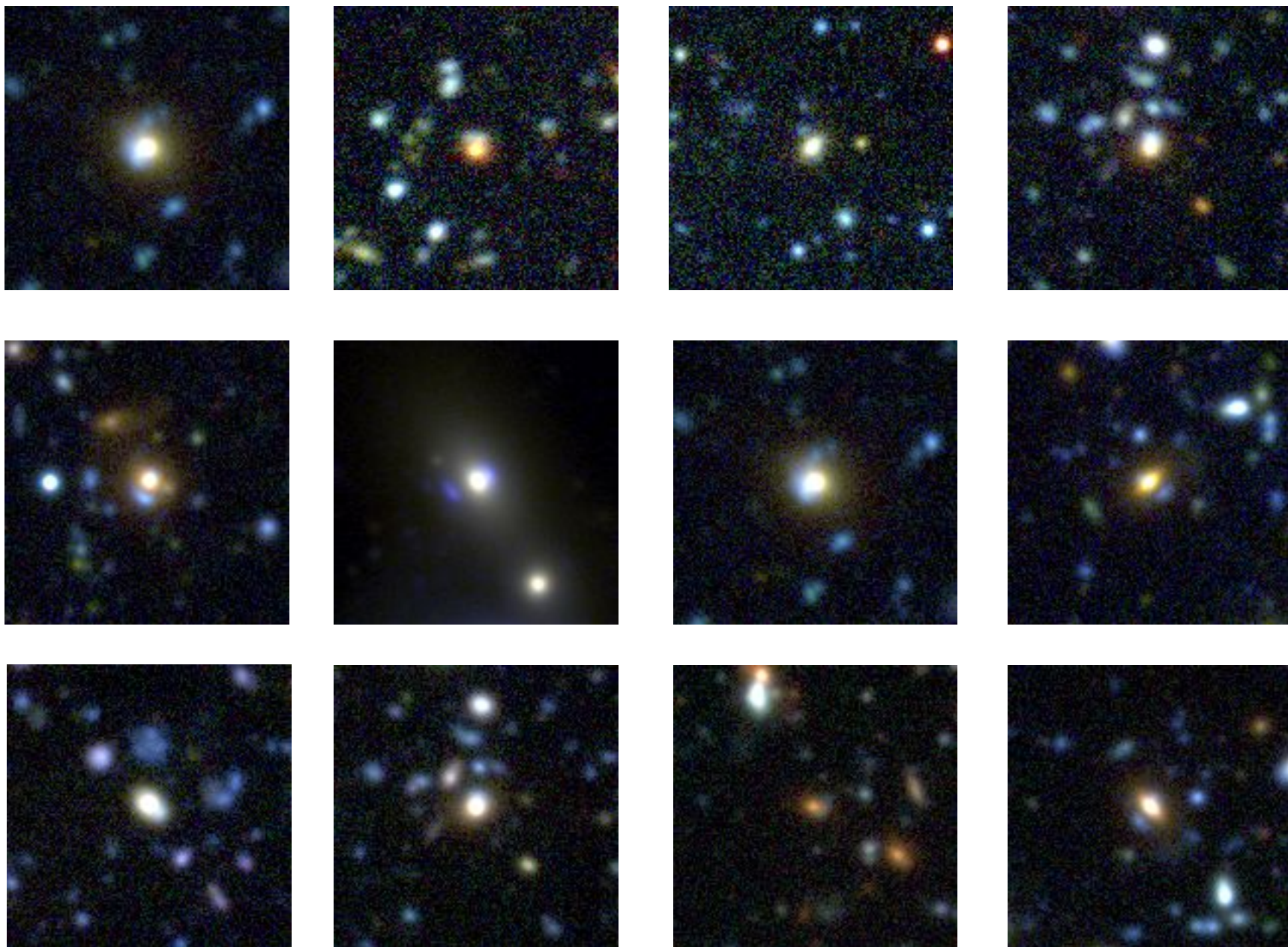
3-Visual classification or direct follow-up

Number / deg^2

1- 3000 2- 50-200 3- 20 candidates!



Ring examples in CFHTLS Deep Fields



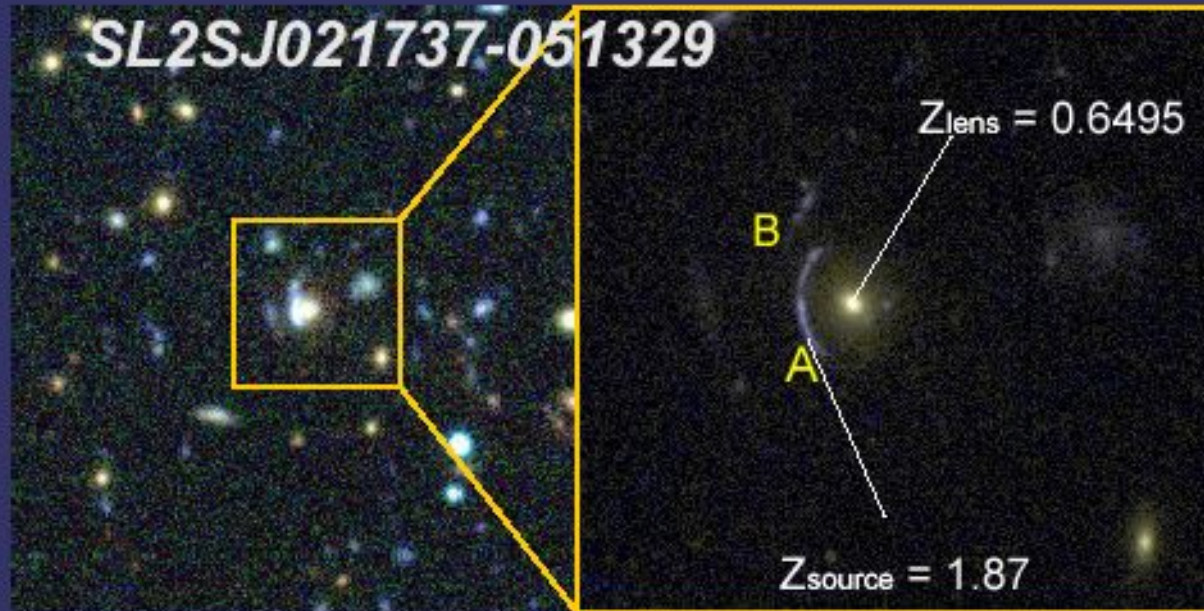
Follow-ups: high-resolution imaging + spectroscopy

(Kneib et al.)

HST imaging:

c15: 5 systems (ACS/F814)

c16: 130 snapshots...WFPC2



CFHTLS

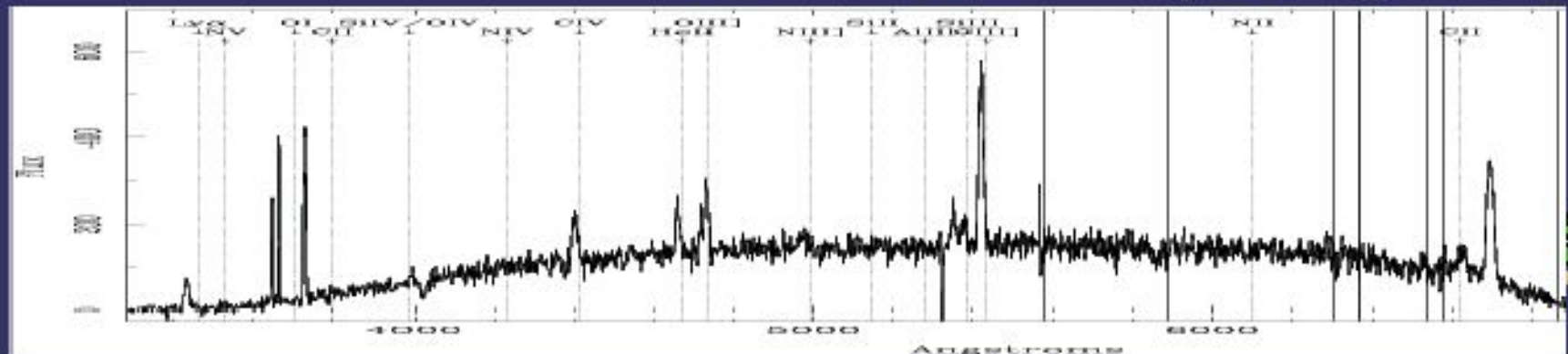
HST/ACS

Spectroscopy for lens and source redshifts:

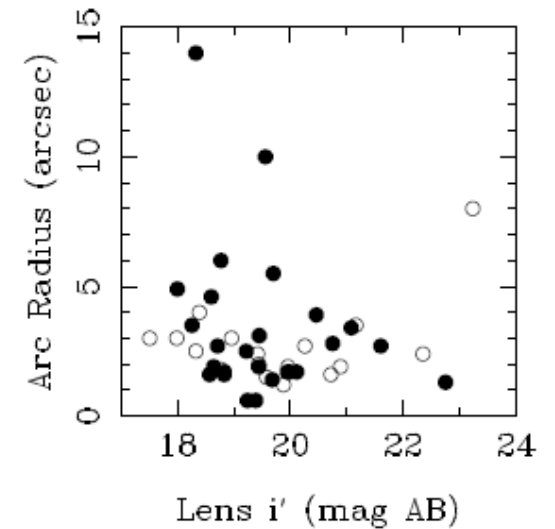
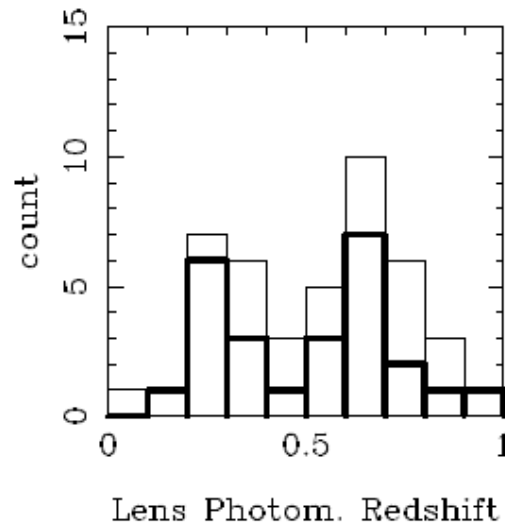
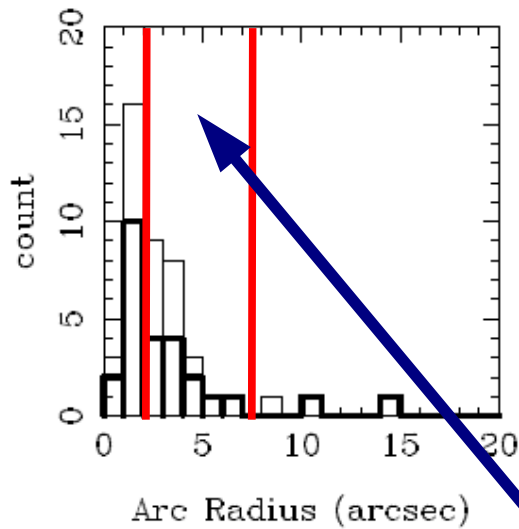
(Treu et al. + many...)

$z_l=0.650$, $z_s=1.87$

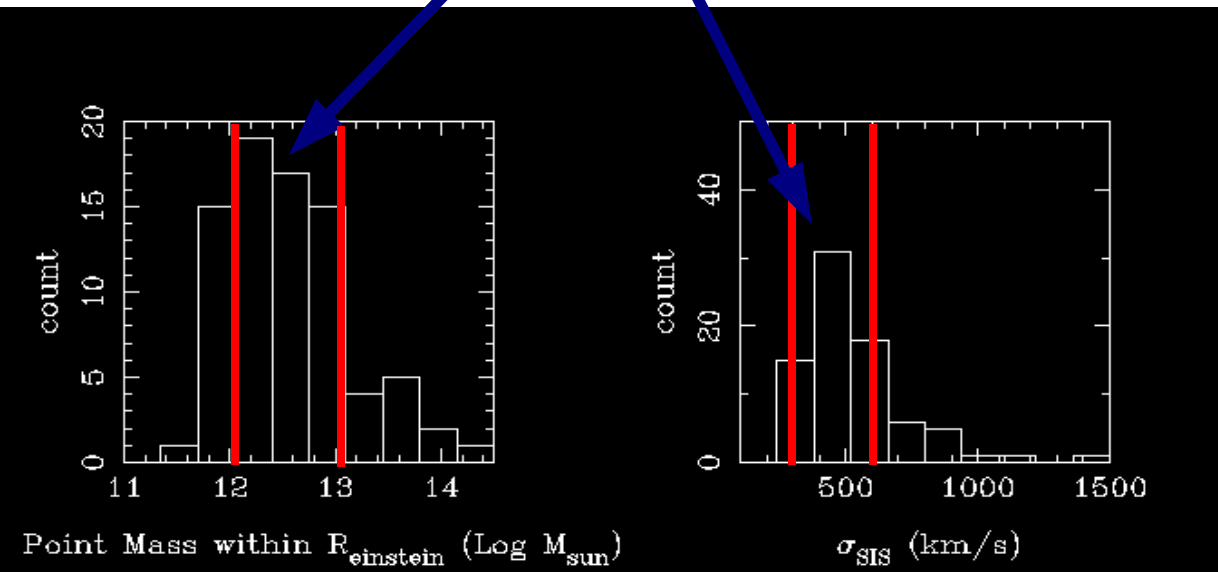
longslit LRIS@Keck



Brief overview on T0003...



Groups



Observed numbers / deg^2

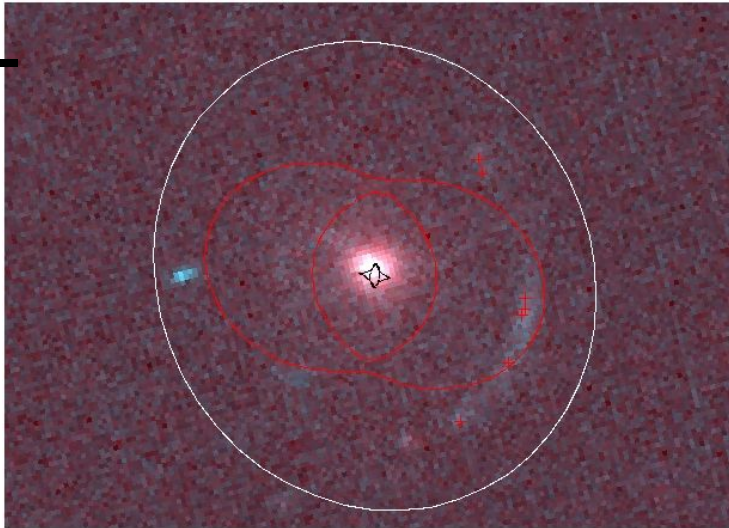
Galaxies ~ 10 (Deep)

Groups ~ 1

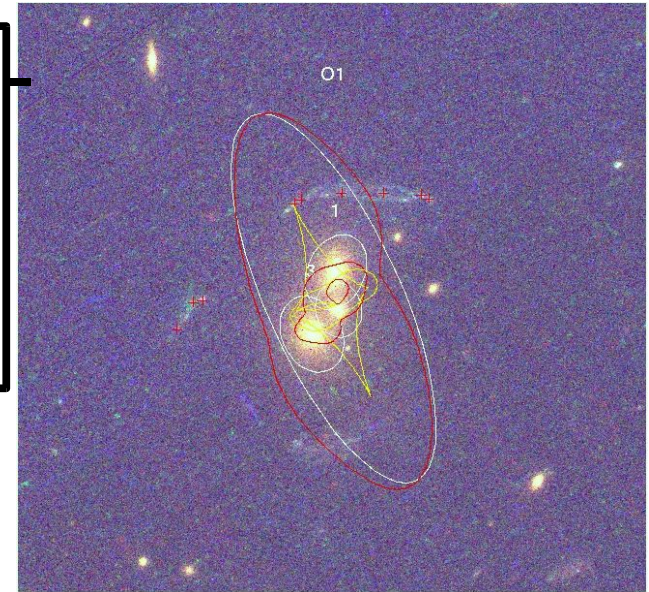
Clusters ~ 0.5

Lens modelling (Hong Tu et al.)

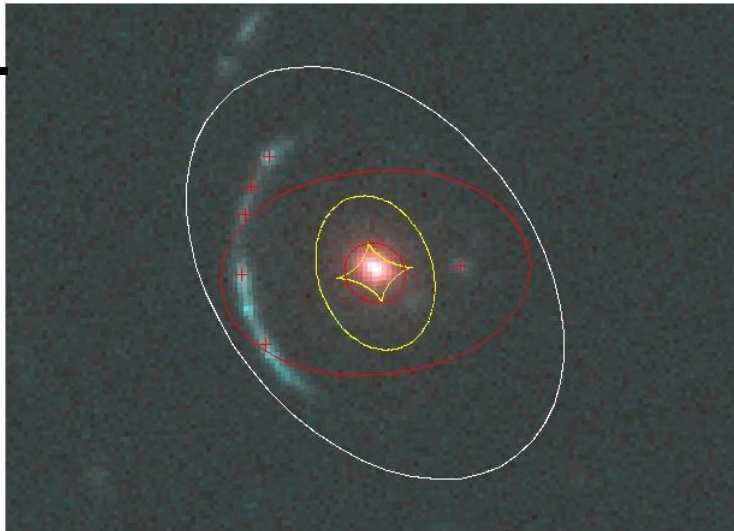
$R_{\text{core}} = 1.53''$
 $R_{\text{cut}} = 800''$
 $\epsilon_{\phi} = 0.11$
 $\text{PA} = 176^{\circ}$
 $\sigma = 352 \text{ km s}^{-1}$



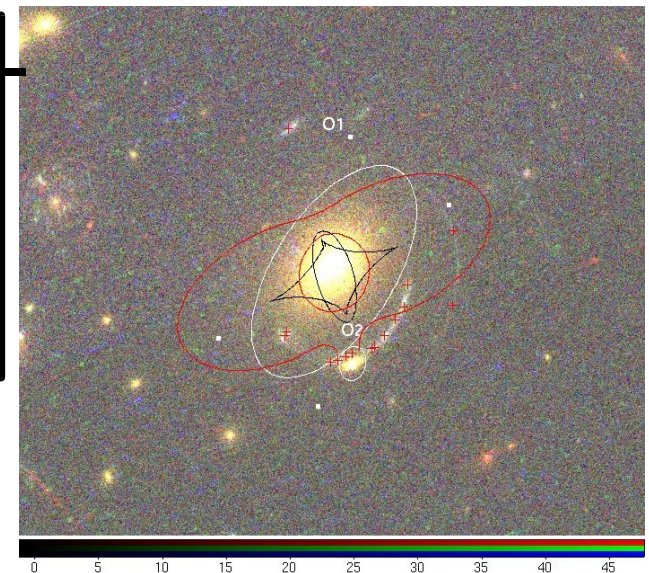
$R_{\text{core}} = 5.48''$
 $R_{\text{cut}} = 600''$
 $\epsilon_{\phi} = 0.80$
 $\text{PA} = 114^{\circ}$
 $\sigma = 692 \text{ km s}^{-1}$



$R_{\text{core}} = 0.11''$
 $R_{\text{cut}} = 400''$
 $\epsilon_{\phi} = 0.37$
 $\text{PA} = 193^{\circ}$
 $\sigma = 283 \text{ km s}^{-1}$



$R_{\text{core}} = 1.37''$
 $R_{\text{cut}} = 242''$
 $\epsilon_{\phi} = 0.6$
 $\text{PA} = 198^{\circ}$
 $\sigma = 623 \text{ km s}^{-1}$



Things to be done...

High-resolution imaging and spectro follow-ups

Analysis of coming Terapix releases

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 (need all 5 bands)

What's coming for SL2S?

Release T0004

CFHTLS Wide summary

125 sq. deg in g, r/2, i (was 40 in T0003)

27 sq. deg in all 5 bands (was < ~5 in T0003)

85 sq. deg of new fields, 100 new candidates?

HST/WFPC2 still works!

Otherwise groundbased AO in IR works well too!

Conclusions

SL2S will be the largest SL database available for years, possibly **1000** SL, if we have spectroscopic follow-ups.

SL2S will extend the lensing studies of **galaxy mass evolution at large z** and **groups (a new classe of SGL)**

Numerous rings and arc systems for a large mass spectrum allow **statistical tests** (ultimately!!).

Offer the possibility to observed magnified **galaxies at high z**

- SL2S is a **benchmark** for the preparation of SL analyses with **SNAP** or **DUNE**-like survey.