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Supernovae Ia, Gravitational Lensing with Supernovae Legacy Survey (SNLS)

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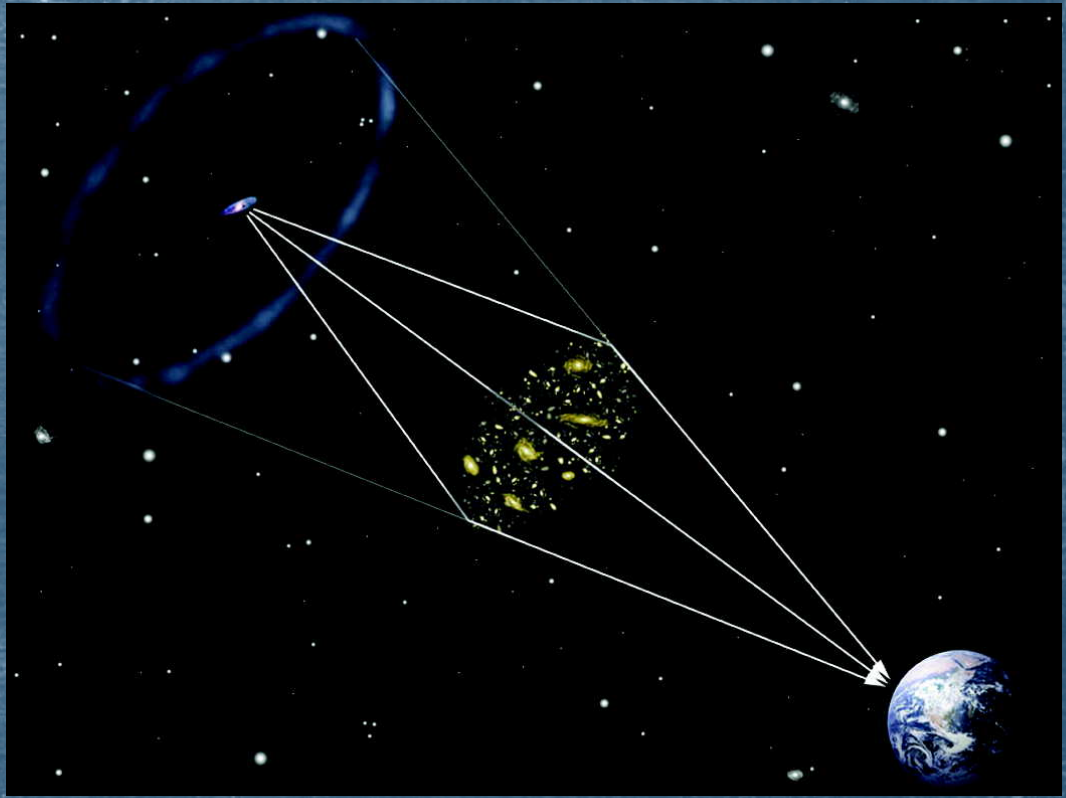
Gravitational Lensing

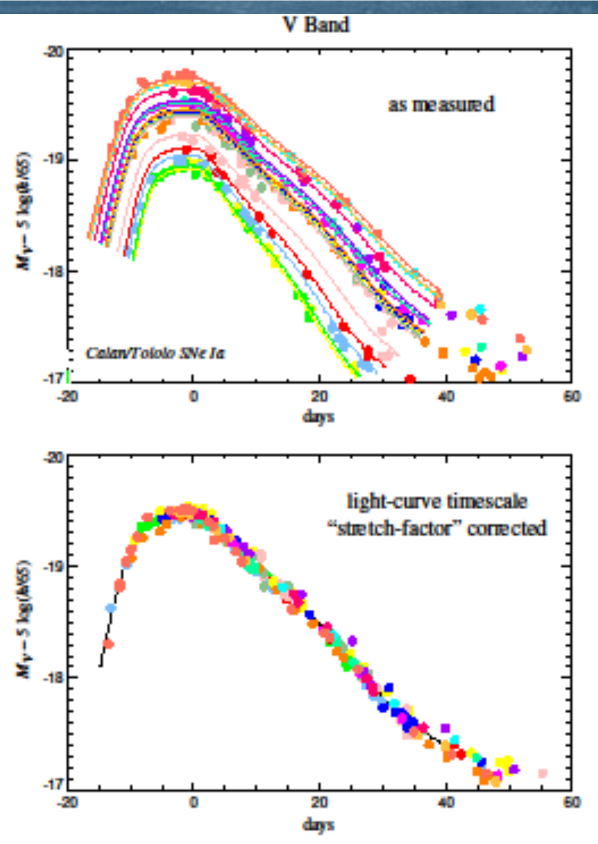
- It is the bending of light rays in the presence of massive object .
- The angle of deflection caused by an object of mass *M* for rays of light passing at a distance of *r* is : $\alpha = \frac{4GM}{rc^2}$



- weak lensing requires studying a lot of sources statistically to infer information about the foreground mass.

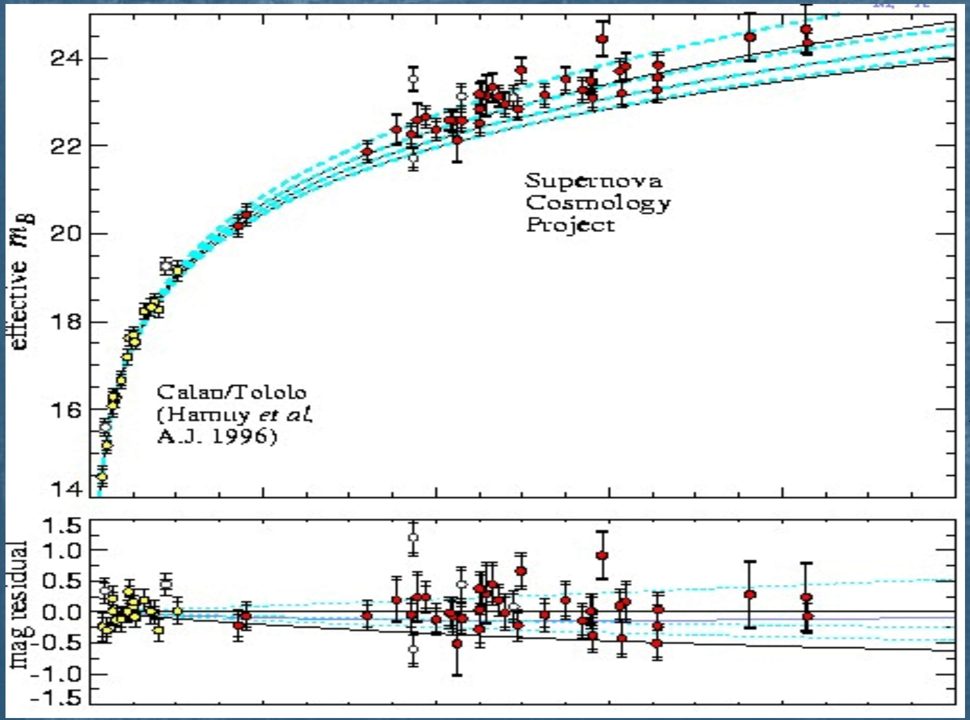
SNe as cosmological tool

- SN Ia are believed to be result of an explosion of a white dwarf accreting matter and reaching Chandrasekhar mass.
- Supernovae type I lack H emission or absorption lines. Type Ia shows a clear Si absorption line at 6700 angströms.
- if L≈ cste, then we can measure **relative** distances without knowing L.



By fitting for one parameter, the "stretch" (Perlmutter 1997; Perlmutter et al. 1997; Goldhaber et al. 2001), the observed variation in Type Ia SNe can be reduced to $\sigma_M = 0.15$.

$$D_L^2 = \frac{L}{4\pi F}$$

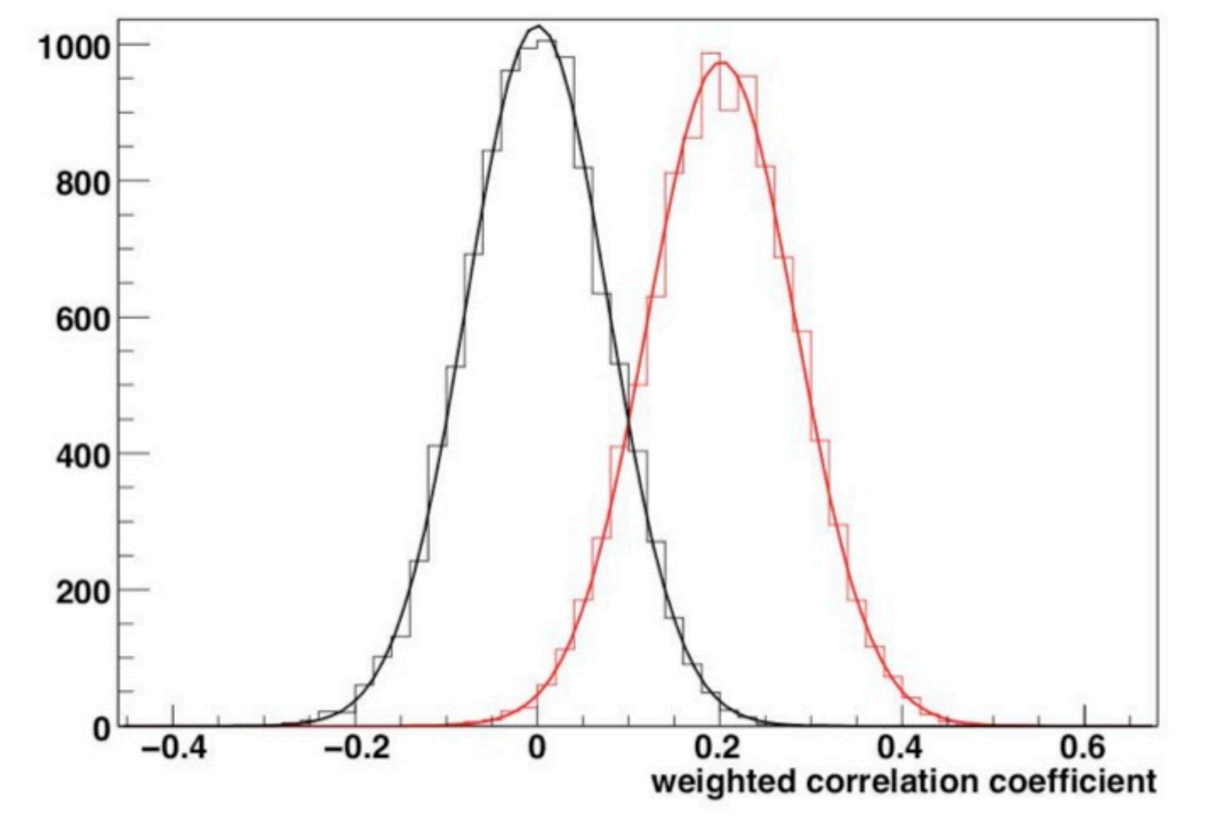


SNe Ia exhibit remarkable homogeneous light curves when corrected for the stretch factor parameter. Enabling them to be used as standard candles.

L≈ cste, at 16%.

Background

- *Kronborg et. al. 2010*
  - SNLS 3 sample analysis
  - 171 SNe Ia selected out of 233 total SNe
  - Ray tracing algorithm used.
  - Detection of 3σ lensing signal at 35% chance
- *Jonsson et.al. 2006*
  - GOODS sample SNe
  - 32 SNe analyzed
  - No strong signs , $<\mu>=1$
  - Zero correlation within 68%
- *Jonsson et. al. 2010*
  - SNLS 3 sample analysis
  - Application of weak lensing approximation
  - Result within 5% deviation with ray tracing algorithm



Kronborg et.al. 2010

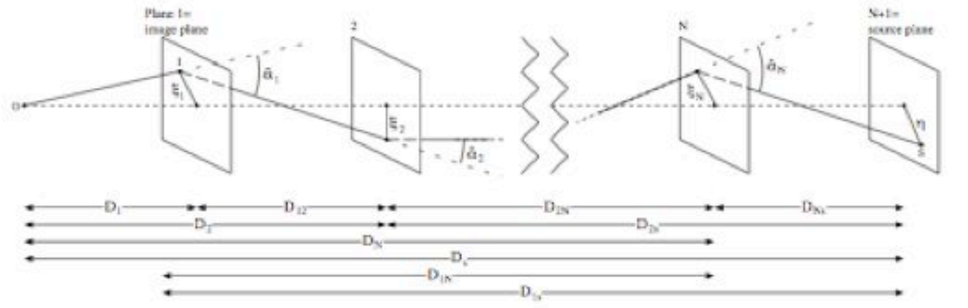
Gravitational Magnification Computation

SNLS-3 : Lensing Analysis

Qlet

Ray tracing algorithm

Gunnarsson et al. 2003



Multiple lens-plane method

- SNLS-5 : Lensing Analysis
- Get_magnification
- Weak Lensing approximation

$$\Delta m_{\rm lens} \simeq -2.17\kappa$$

- Ray tracing vs weak approx. : Deviation in value < 5% (*jonssonet.al. 2010*)

Gravitational Magnification Computation

- To be used on SNLS-5 sample , so to be used on SNe
- To be also used on Simulation

Supernovae Data

1st step : To repeat the same process of SNLS-3 analysis with the same set of data with the **new program.**

- 4 Fields data from SNLS-3
- D1(79)
- D2(62)
- D3(86)
- D4(80)
- Total 307 SNe

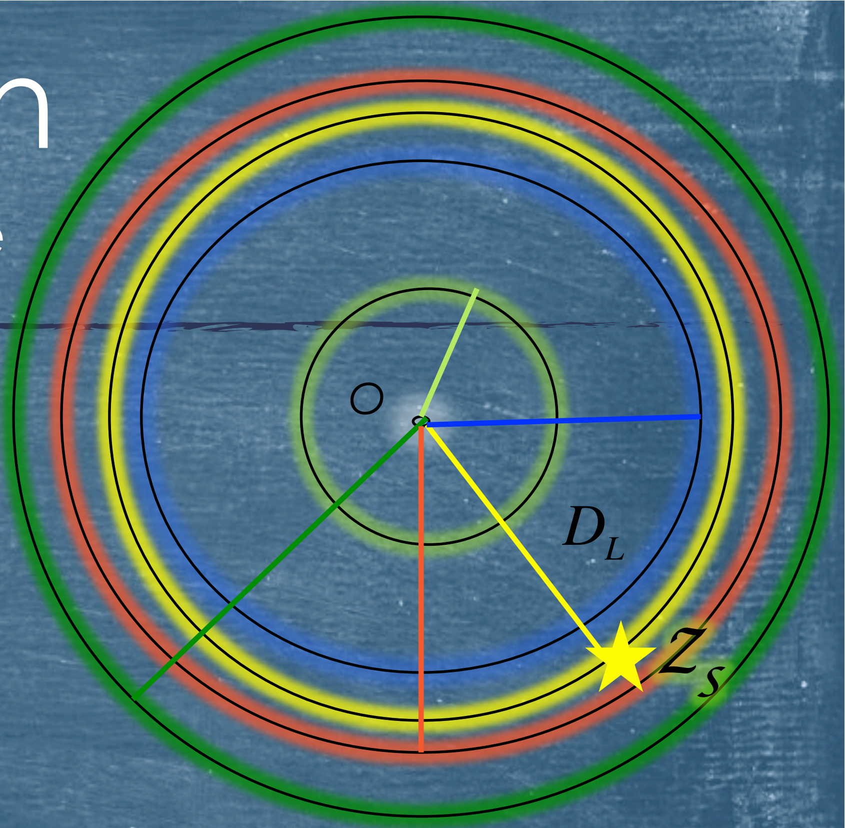
Magnification Normalization

$$\mu = \frac{F}{F_0}$$

F = Flux in inhomogeneous universe

F_0 = Flux in homogeneous universe

where, $F_0 = \frac{1}{4\pi}\frac{L_S}{D_L^2}$



with D_L the luminosity distance in a homogeneous universe that fits the cosmological data : FLCDM model with Ω_m=0.27

So that (mean over sphere at redshift z_s) : $\langle \mu \rangle = 1$

But in our case we estimate F using : homogenous FLCDM Ω_m universe + DM haloes around line-of-sight galaxies so that : $\langle \mu \rangle > 1$

-> need for normalization.

Simulation

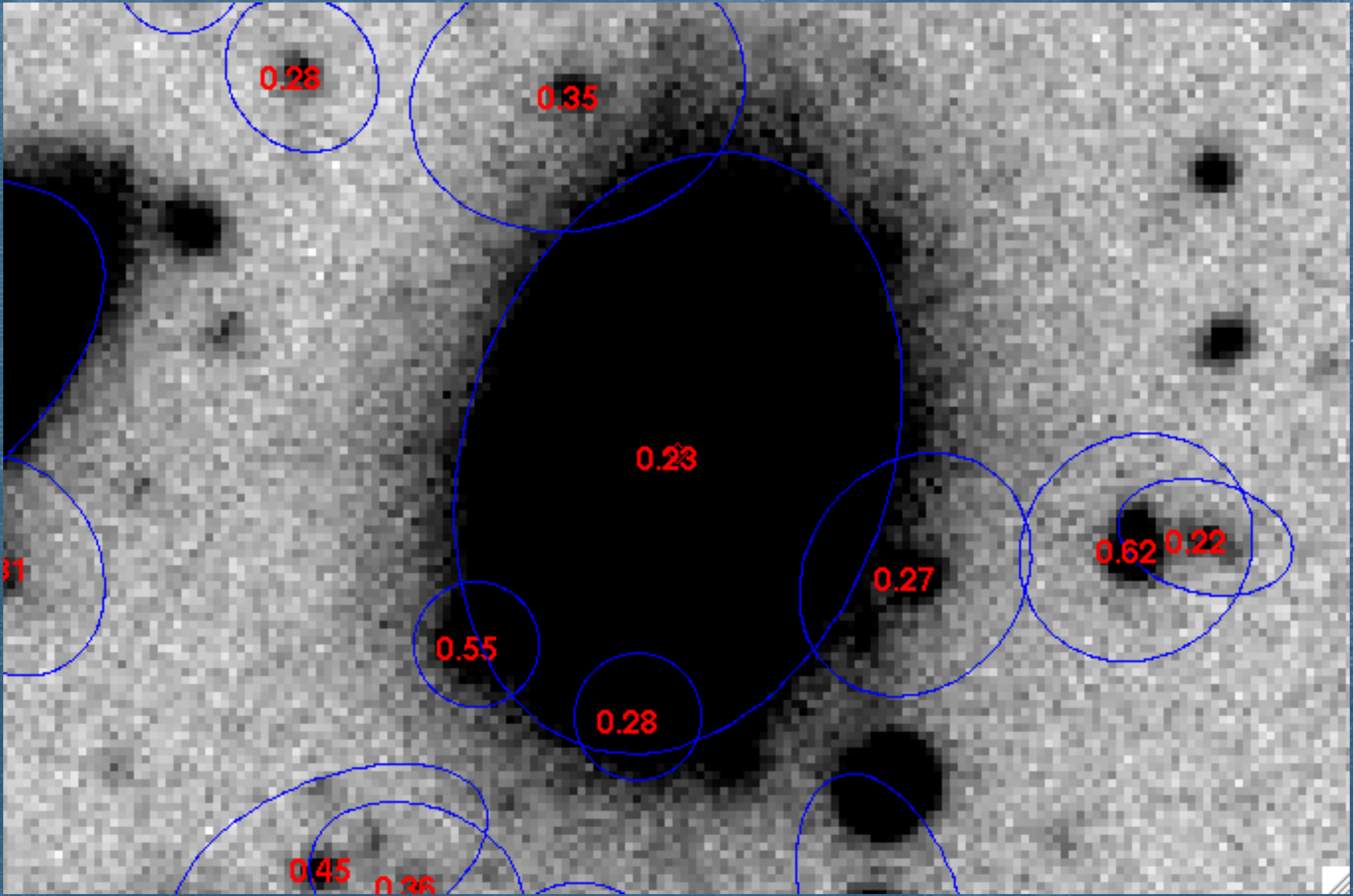
Total 12000 SNe
With 12 bins divided into redshift

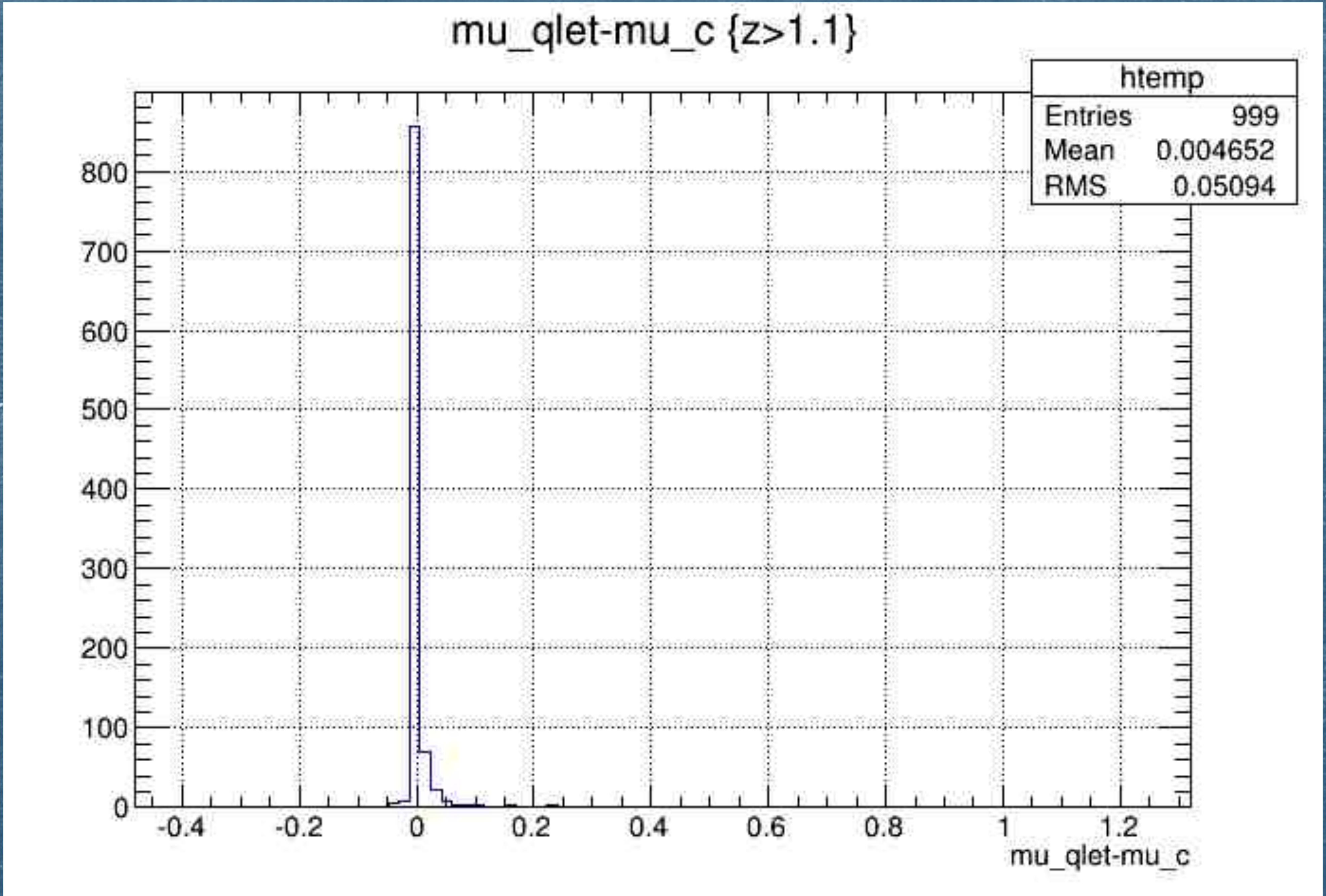
- Z=0.1 — 1000 SNe
- Z=0.2 — 1000 SNe
- Z=0.3 — 1000 SNe
- Z=0.4 — 1000 SNe
- Z=0.5 — 1000 SNe
- Z=0.6 — 1000 SNe
- Z=0.7 — 1000 SNe
- Z=0.8 — 1000 SNe
- Z=0.9 — 1000 SNe
- Z=1.0 — 1000 SNe
- Z=1.1 — 1000 SNe
- Z=1.2 — 1000 SNe

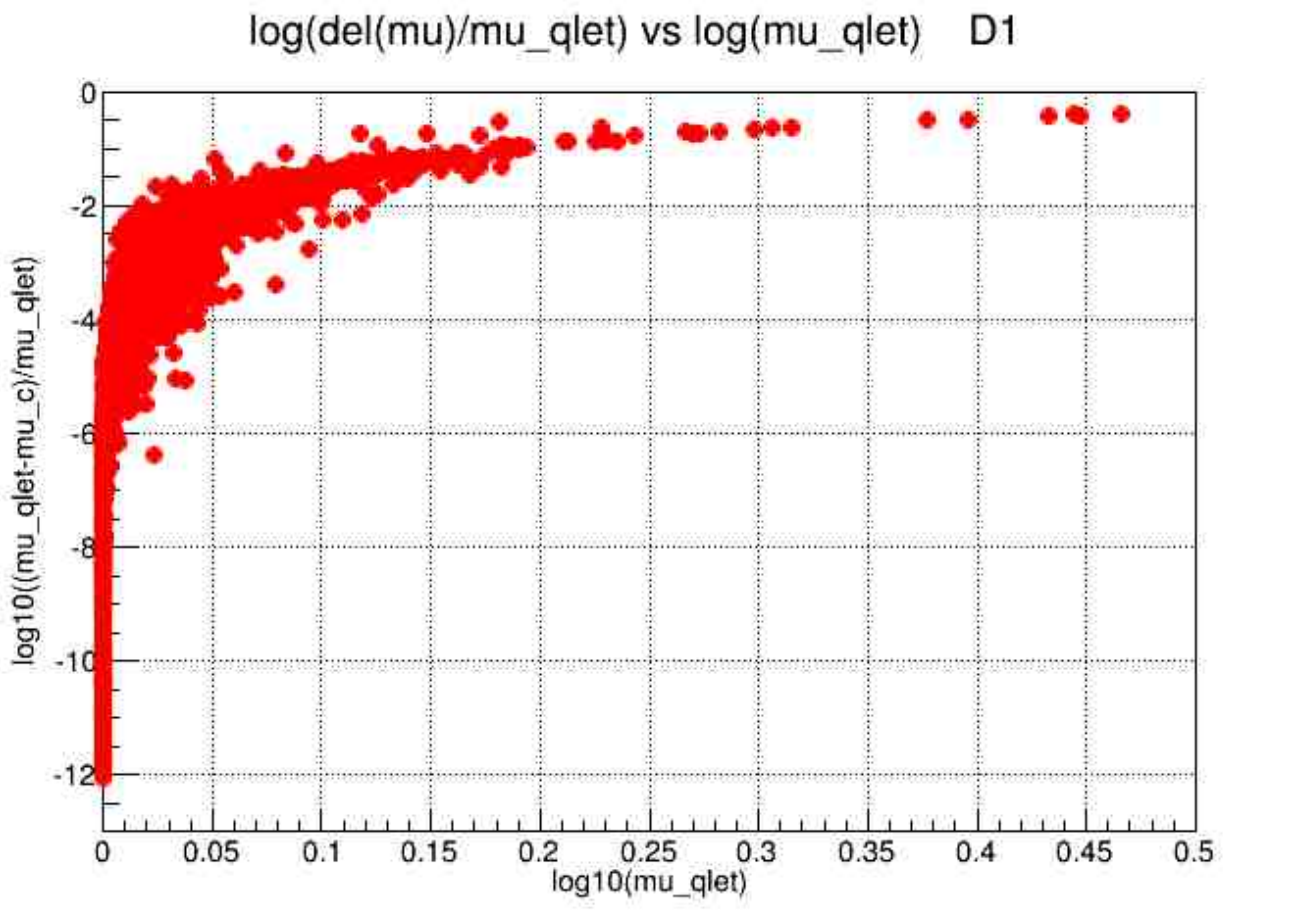
- Random SNe positions
- True galaxy catalog

Comparison of the ray-tracing and weak-lensing approach

- Both *qlet and get_magnification* are feed with the these artificial data
- We compare the result between them
- 144 from the total number of simulation line-of-sight are omitted for going through intervening galaxies -> condition for strong lensing.


0.28
0.35
0.23
0.27
0.62
0.22
0.55
0.28
0.45
0.36

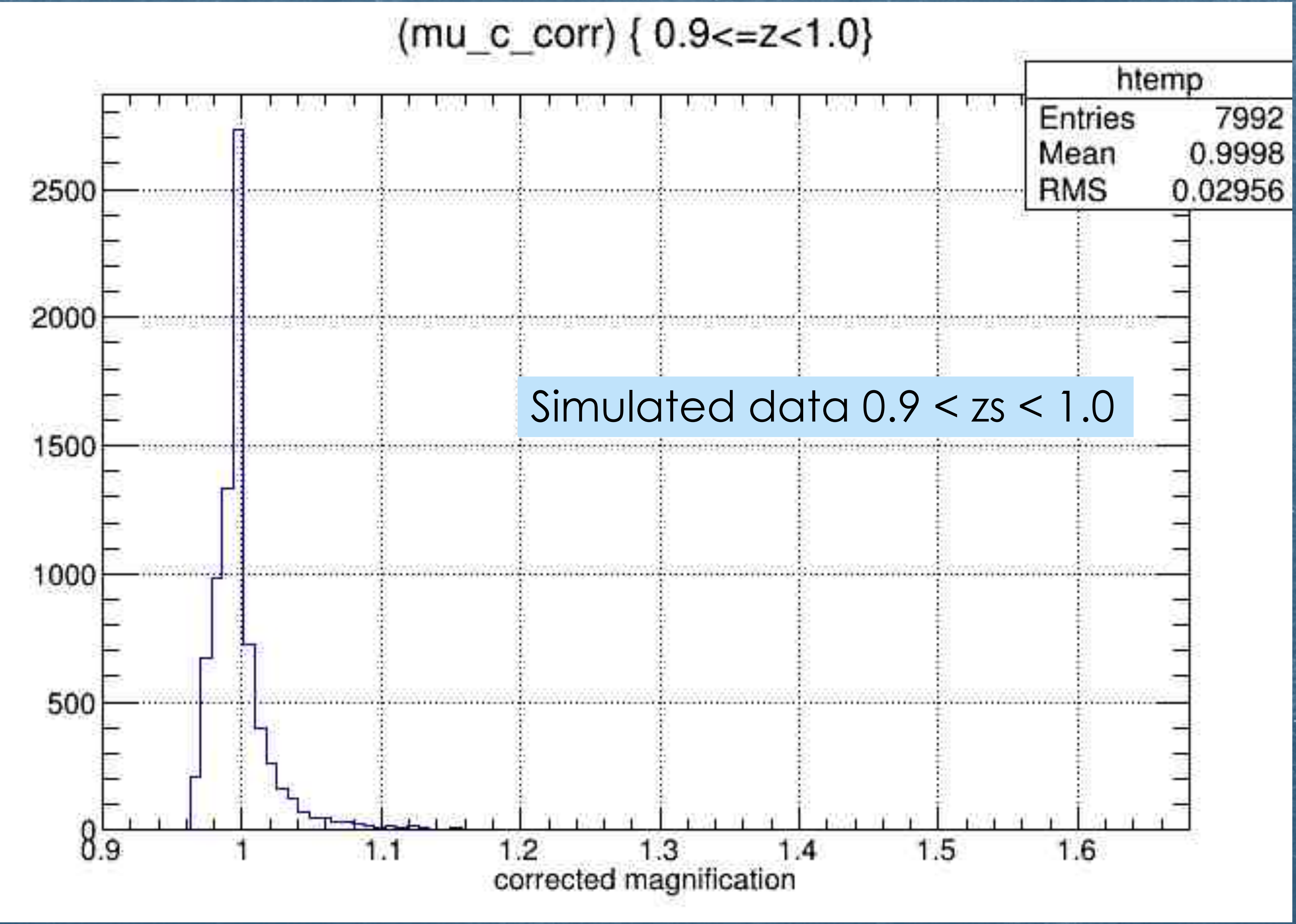

mu_qlet-mu_c {z>1.1}
htemp
Entries 999
Mean 0.004652
RMS 0.05094
800
700
600
500
400
300
200
100
0
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
mu_qlet-mu_c

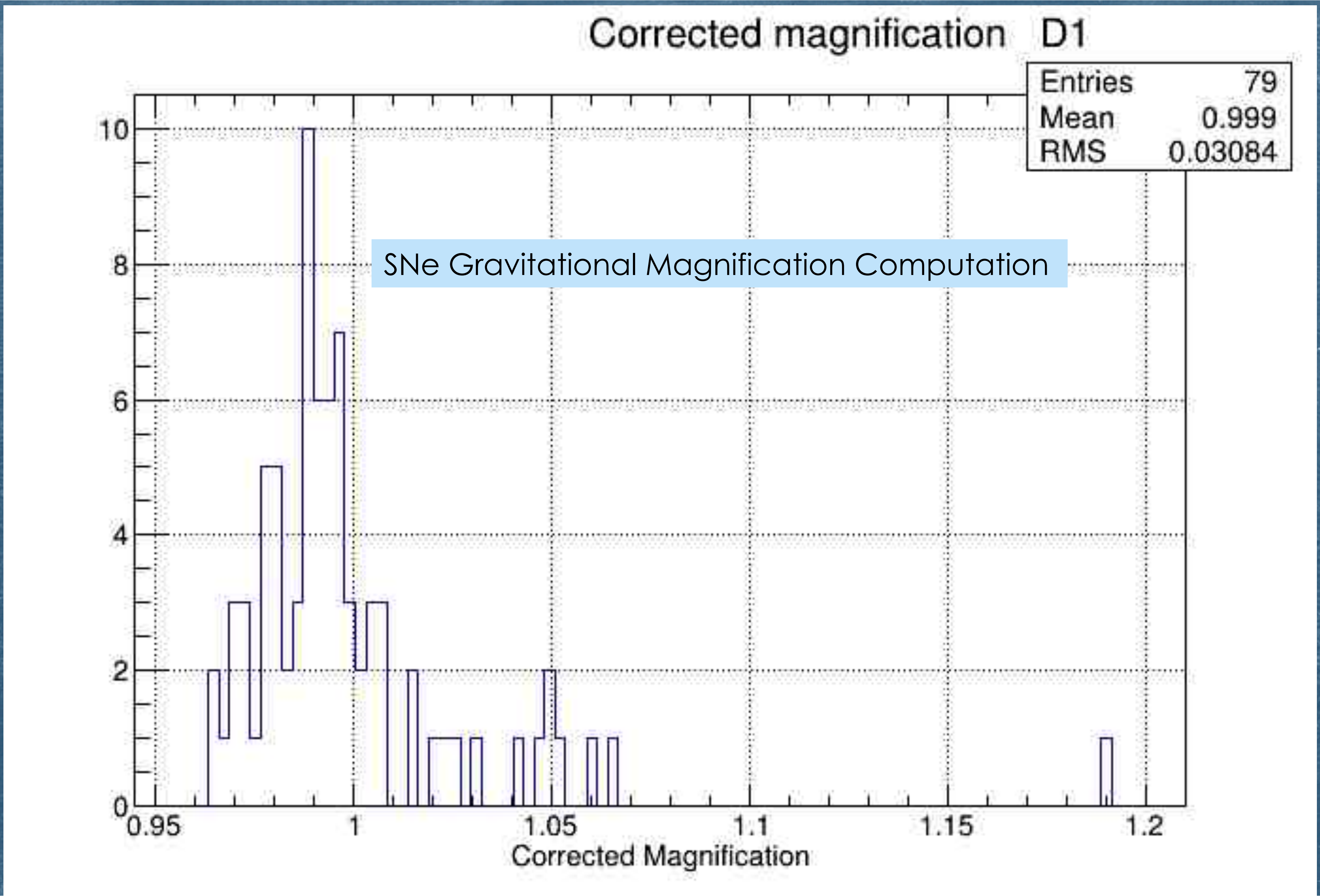


log(del(mu)/mu_qlet) vs log(mu_qlet)   D1
0
-2
-4
-6
-8
-10
-12
log10((mu_qlet-mu_c)/mu_qlet)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
log10(mu_qlet)

Magnification Normalization procedure

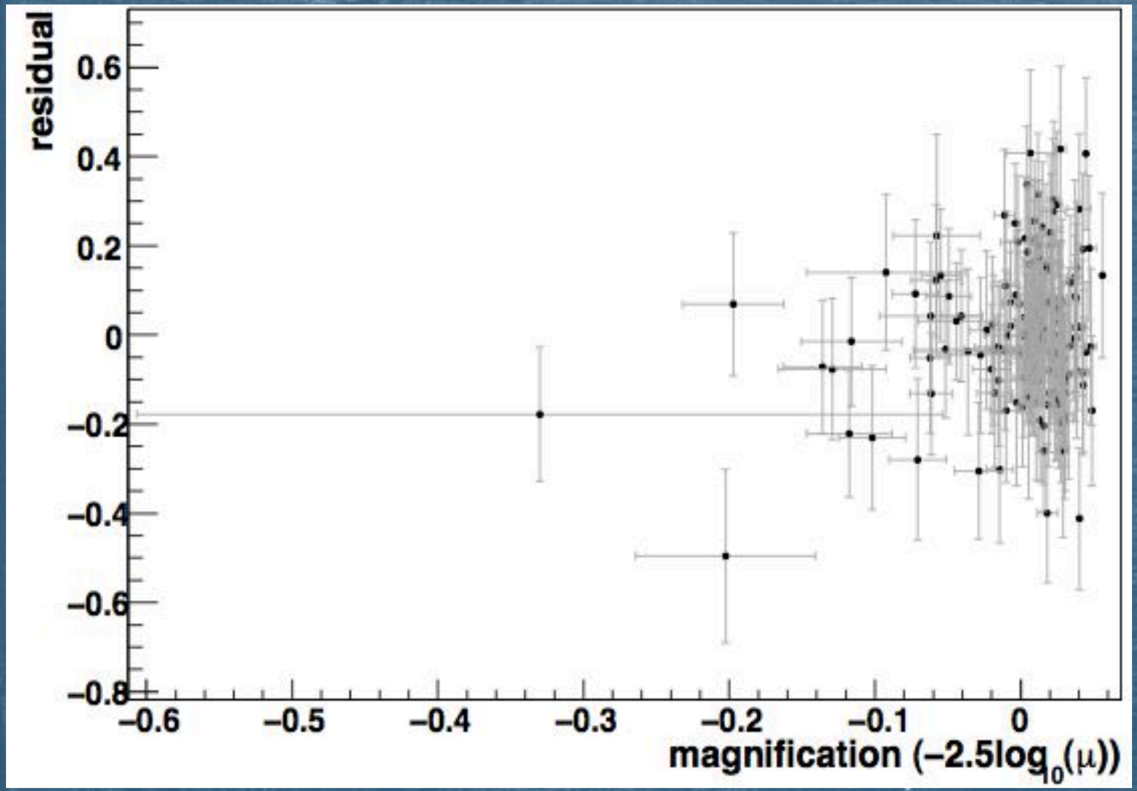
- Mean magnification computation in 12 redshift (z_s) bins
- Polynomial Fitting(3rd order) in z_s
- All SNe magnification values corrected

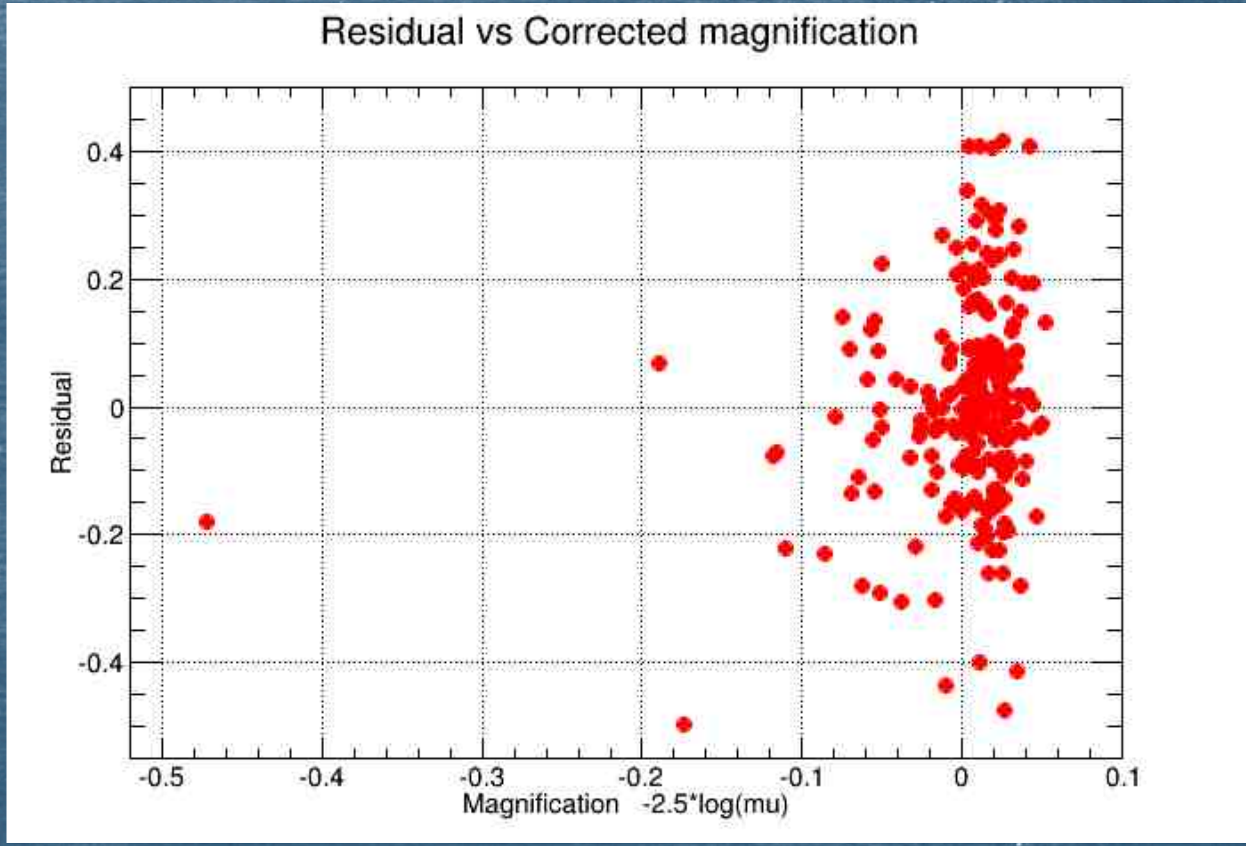

(mu_c_corr) { 0.9<=z<1.0}
htemp
Entries 7992
Mean 0.9998
RMS 0.02956
Simulated data 0.9 < zs < 1.0
2500
2000
1500
1000
500
0
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
corrected magnification


Corrected magnification D1
Entries 79
Mean 0.999
RMS 0.03084
SNe Gravitational Magnification Computation
0
2
4
6
8
10
0.95
1
1.05
1.1
1.15
1.2
Corrected Magnification

Correlation & Hubble residual

- Correlation coefficient of 0.177368 in comparison to 0.18 from SNLS-3





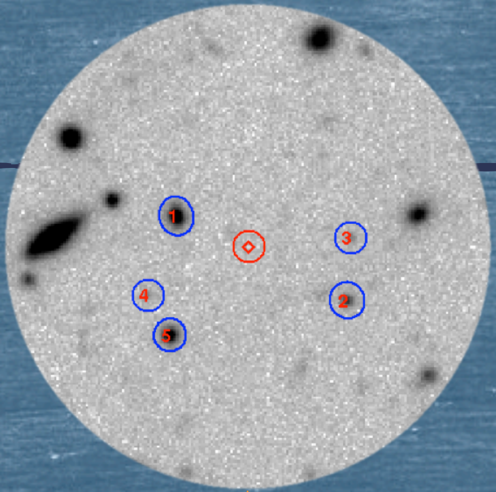
- correlation coefficient : 0.18 (from SNLS3 Kronborg 2010)
- $r = (0.65 \pm 0.30) \times \mu_m$
- weak signal

Future Works

New line of sight modeling while using the SNLS-5 sample including :

- host galaxy identification
- new galaxy catalog & photo-z's
- new masking
- testing other galaxy-halo models

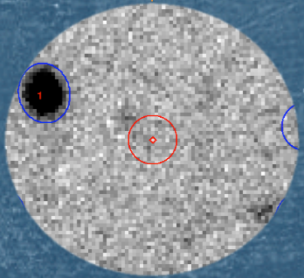
Host Galaxy Detection



Various cut-offs

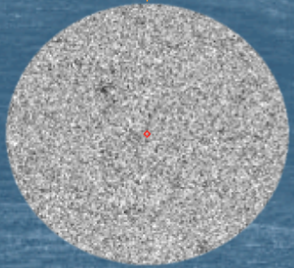
Broadly :

Redshift and Distance $d=\sqrt{(ax^2+bxy+cy^2)}/KRON\ factor$



Host Detected :

Isolating the best galaxy from other galaxies as the 1st host



Not Detected : May include faint hosts

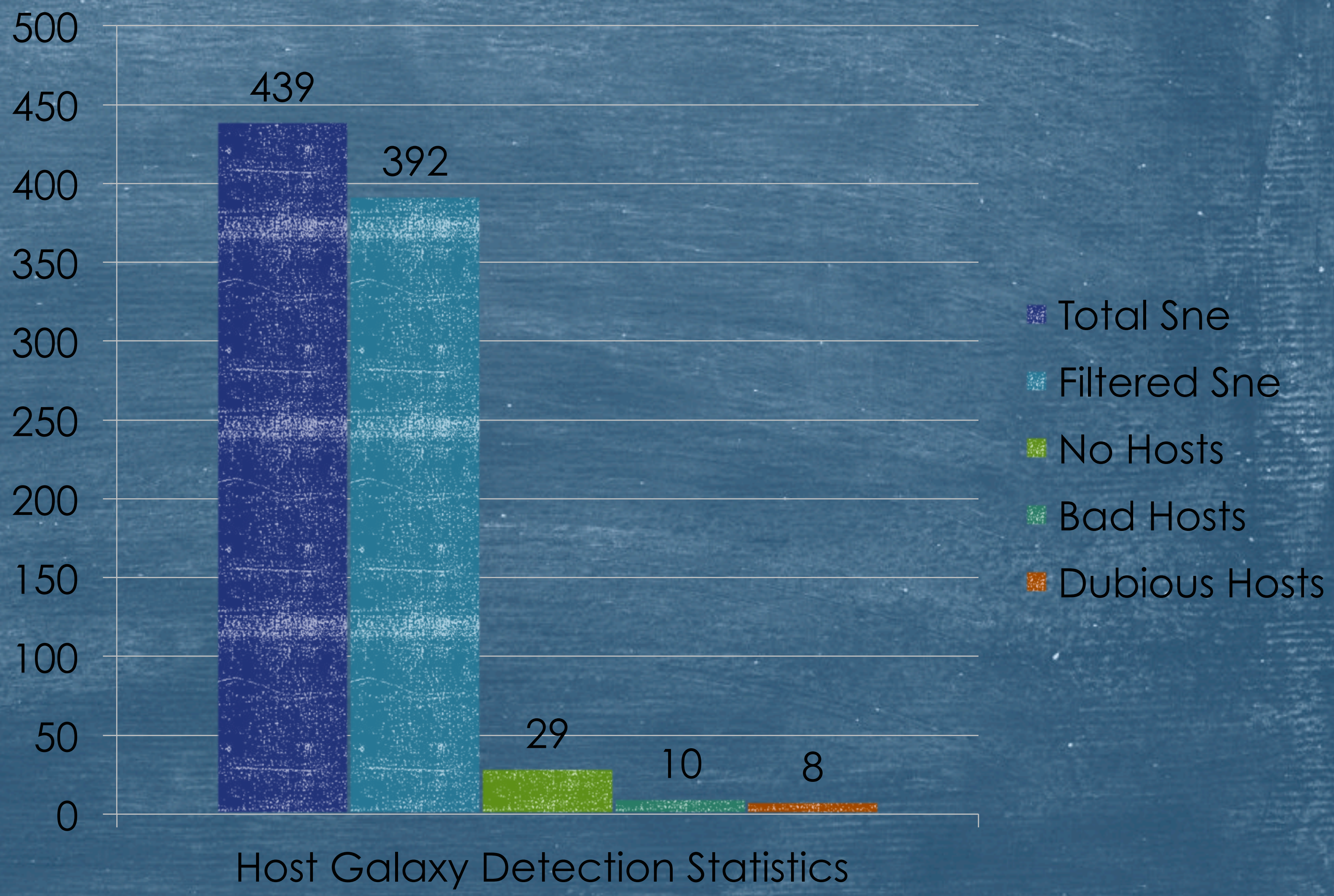
or bad hosts due to polluted image.

Also detection of background host galaxies.

Latest Status

Tentative Detection results :

- Number of SNe : 439
- SNe with hosts OK : 392
- SNe with no hosts : 29
- SNe with bad hosts : 10
- SNe with dubious hosts : 8

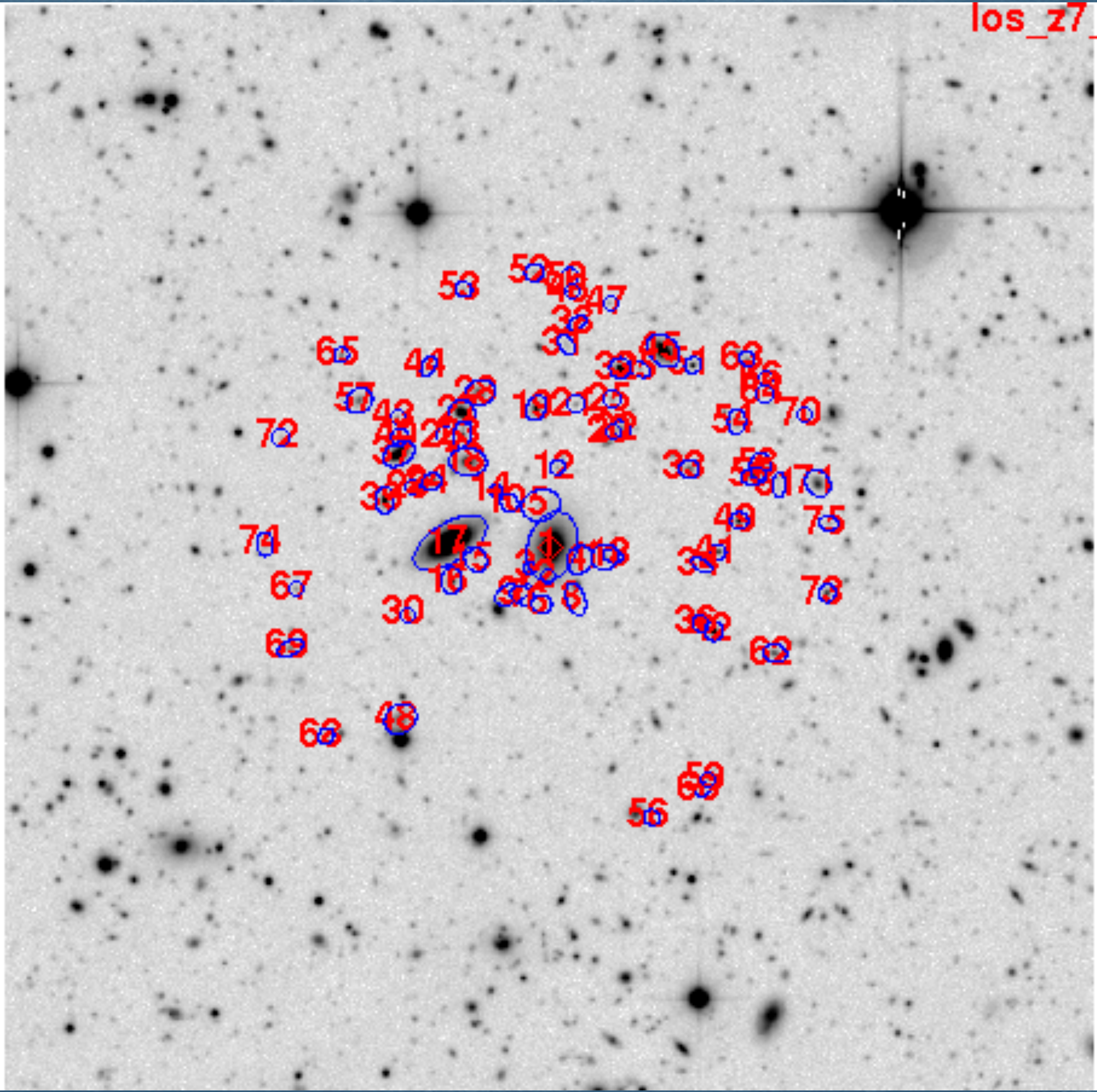


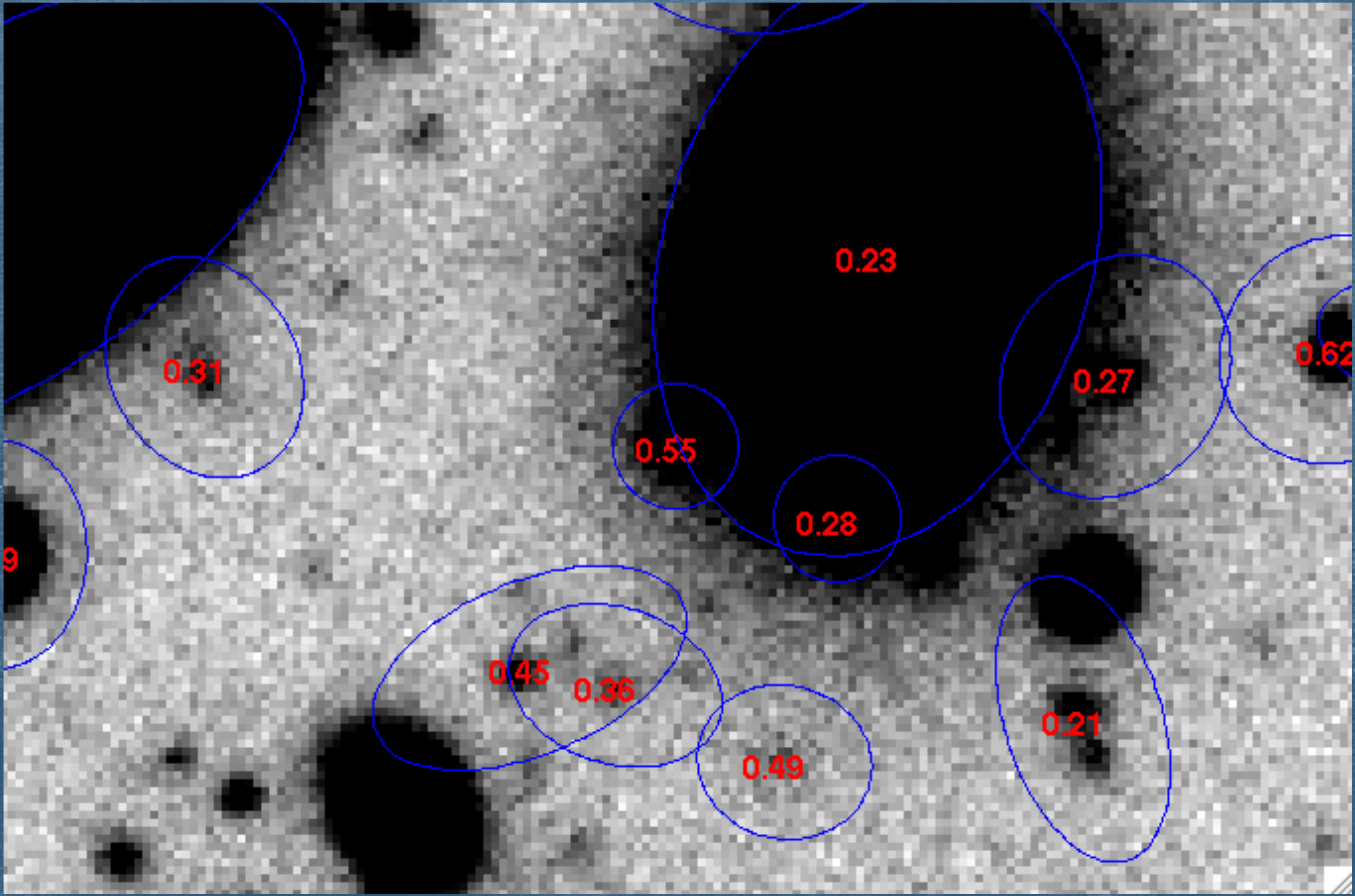
New line of sight modeling while using the SNLS-5 sample including :

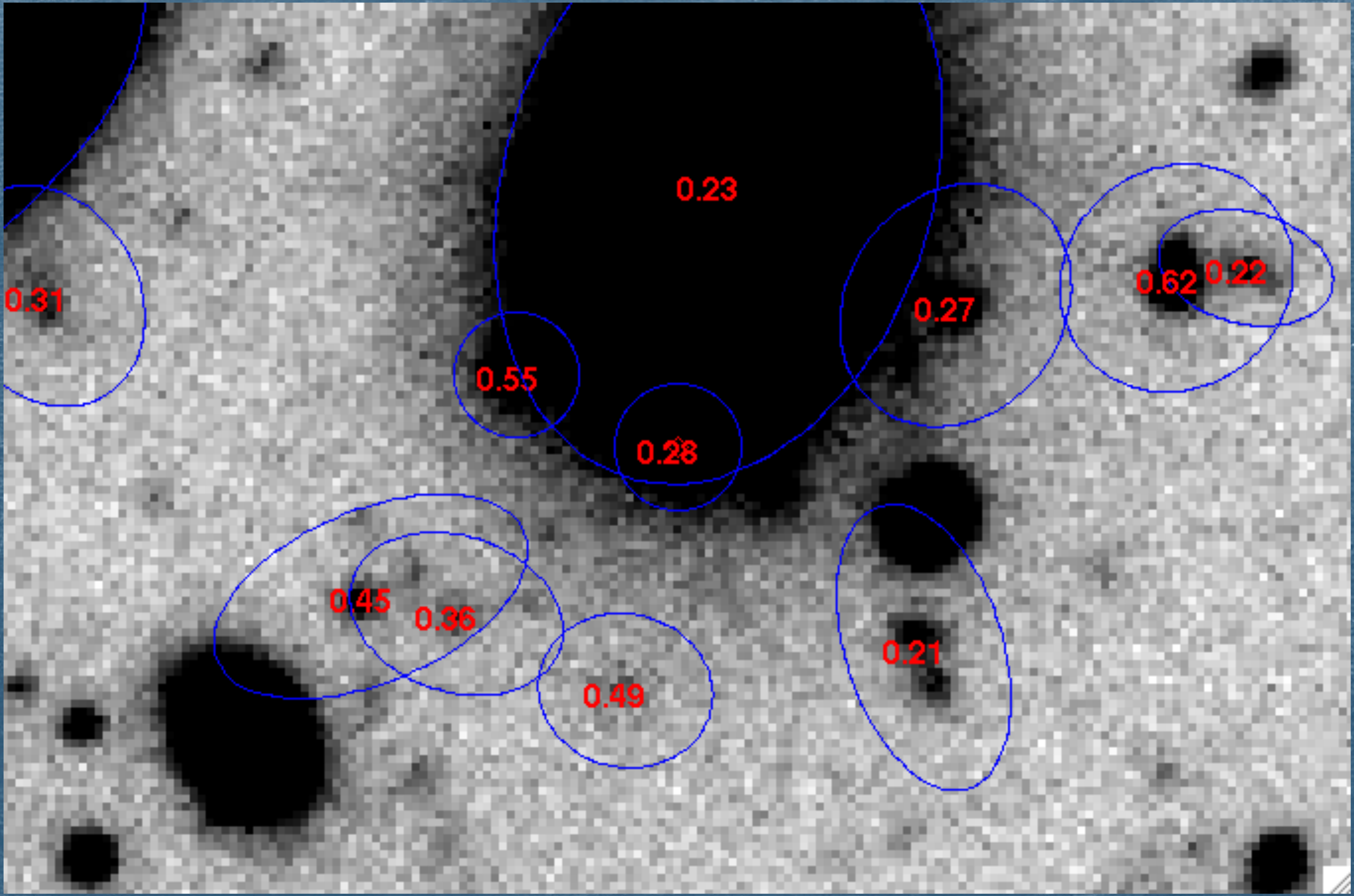
- host galaxy identification
- new galaxy catalog & photo-z's
- new masking
- testing other galaxy-halo models

The end

- Selection of good SNe using new masking los_z7_262



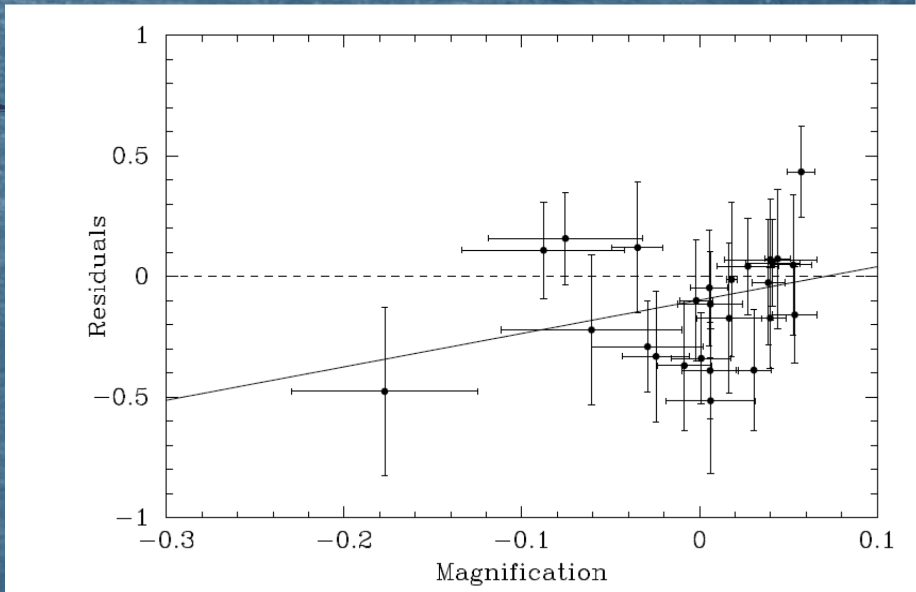

0.23
0.31
0.27
0.62
0.55
0.28
9
0.45
0.36
0.49
0.21


0.23
0.31
0.62
0.22
0.27
0.55
0.28
0.45
0.36
0.49
0.21

- Looking for better halo models/scaling laws

Signal Detection

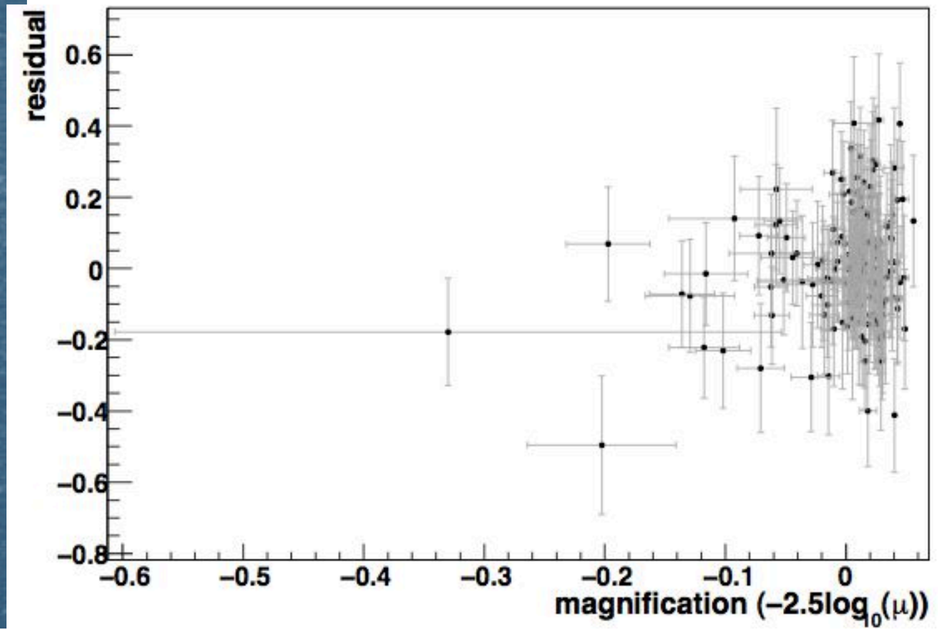
Hubble residual: r = $\mu_L(SN) - \mu_L(z; cosmologie)$, $\mu_L(SN)$ estimated with SN mags.



correlation between :

$\mu_m = -2.5 \log_{10}(\mu)$ **& r**

Tentative detection:**(Jonsson2007)** with 27 SNe from GOODs survey : evidence of a positive correlation at 91%



- correlation coefficient : 0.18 for SNLS3 Kronborg 2010
- $r = (0.65 \pm 0.30) \times \mu_m$
- weak signal