Title: The Suprime Survey: A large shear-selected sample of galaxy clusters at z = 0.1 - 0.8

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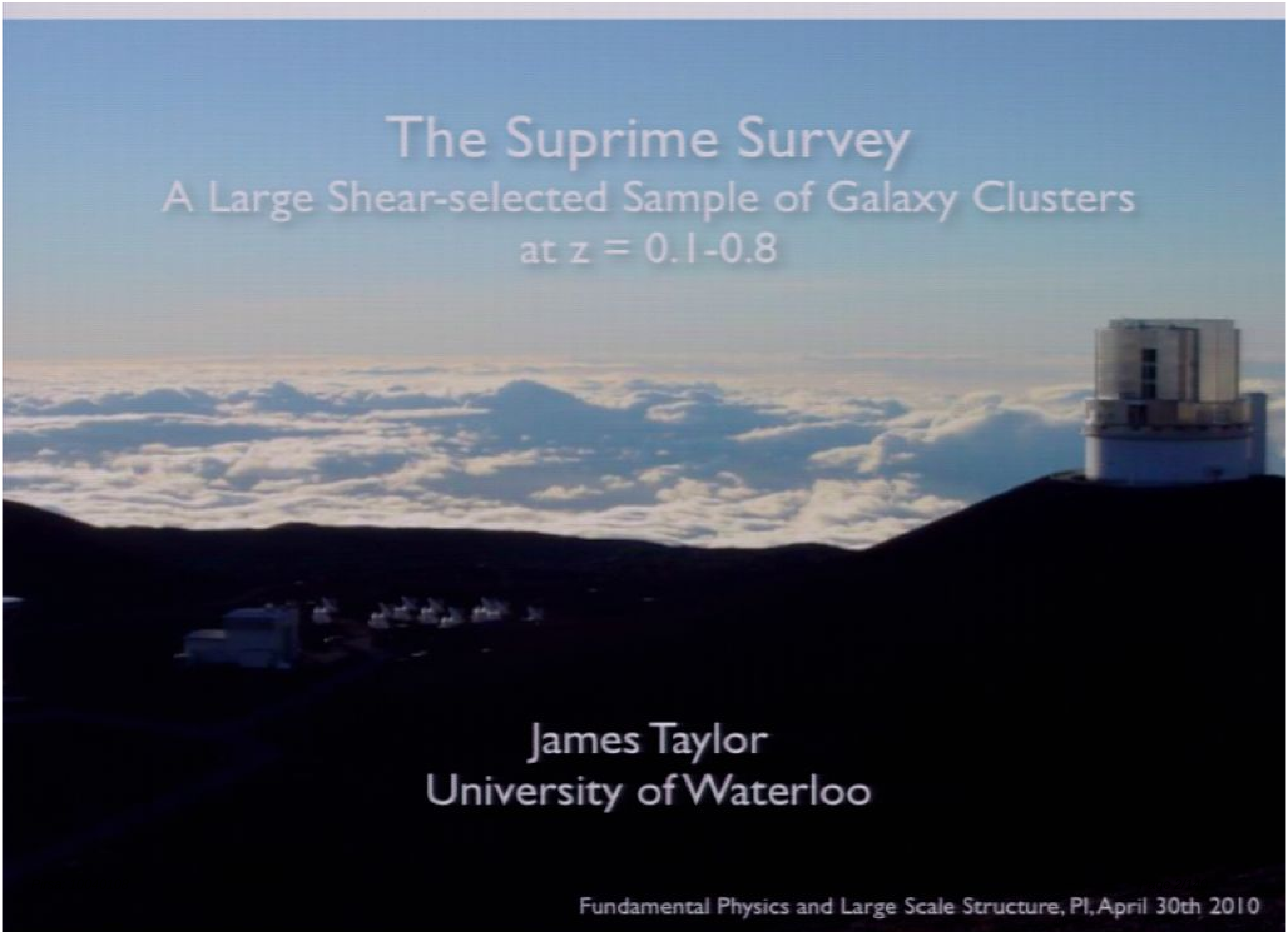
URL: http://pirsa.org/10040108

Abstract: TBA


The Suprime Survey
A Large Shear-selected Sample of Galaxy Clusters
at z = 0.1-0.8
James Taylor
University of Waterloo
Fundamental Physics and Large Scale Structure, PI, April 30th 2010

Outline:

1) Motivation for shear-selected cluster surveys

2) A quick overview of weak lensing cluster detection

3) The Suprime Survey: detection and follow-up

4) Some issues...

5) Cosmological constraints

6) From LSS to SSS:

"value-added" analysis for cluster surveys

Why Look for Clusters?

Galaxy Clusters:

- provide useful samples of galaxies versus redshift and environment
- trace high peaks in the density field

⇔ measure of initial power and subsequent growth

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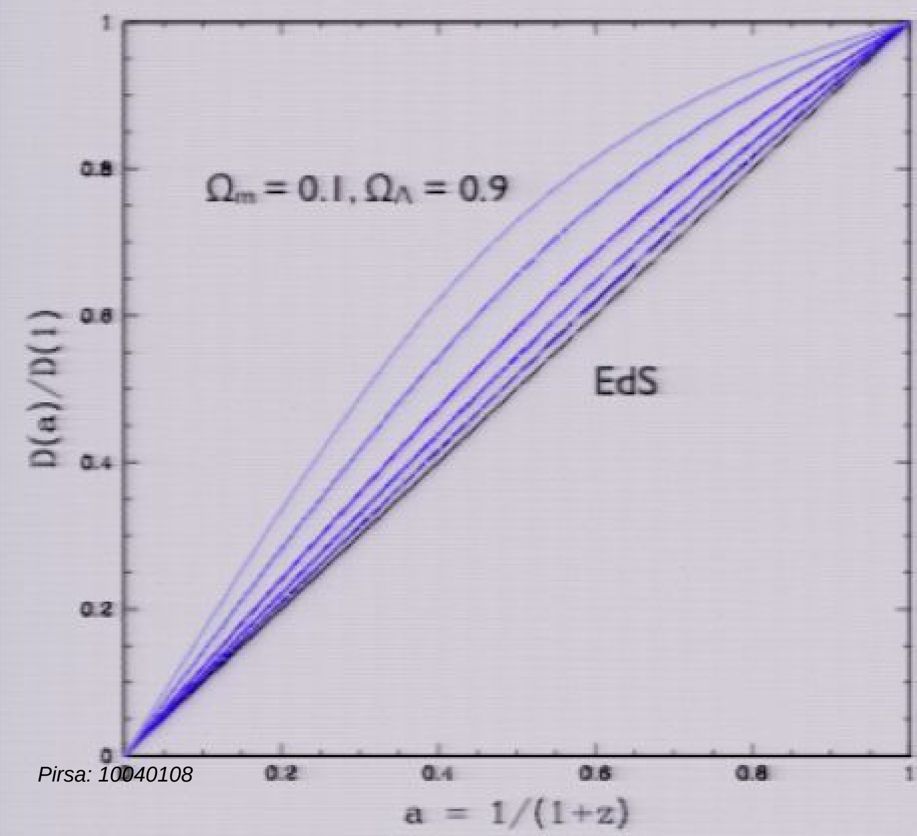

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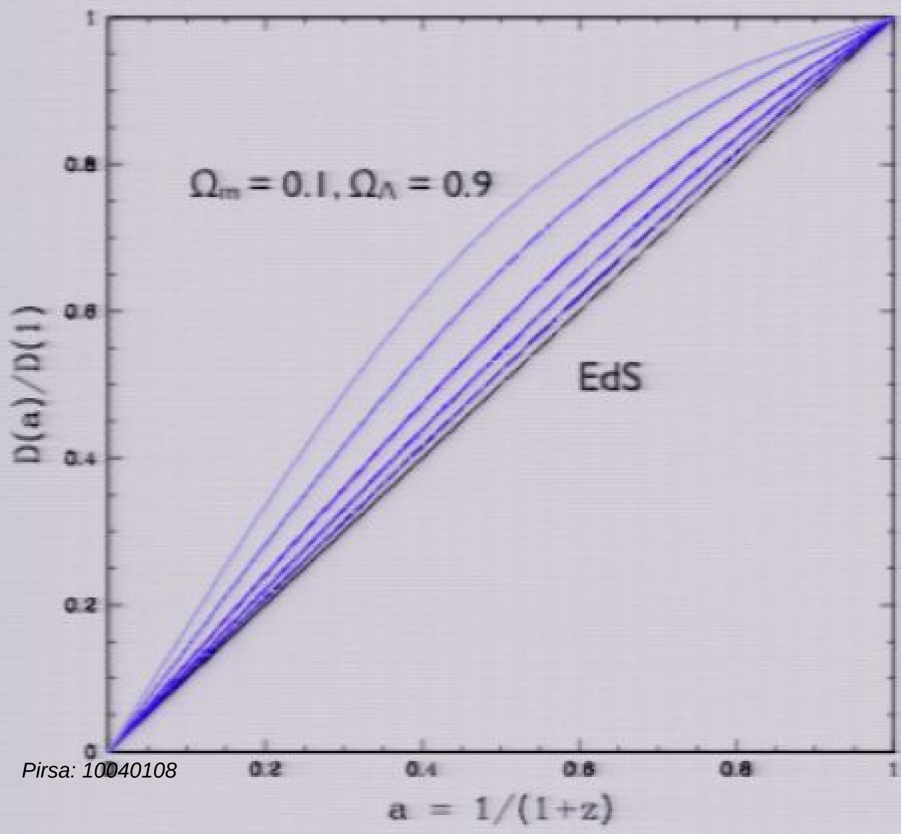
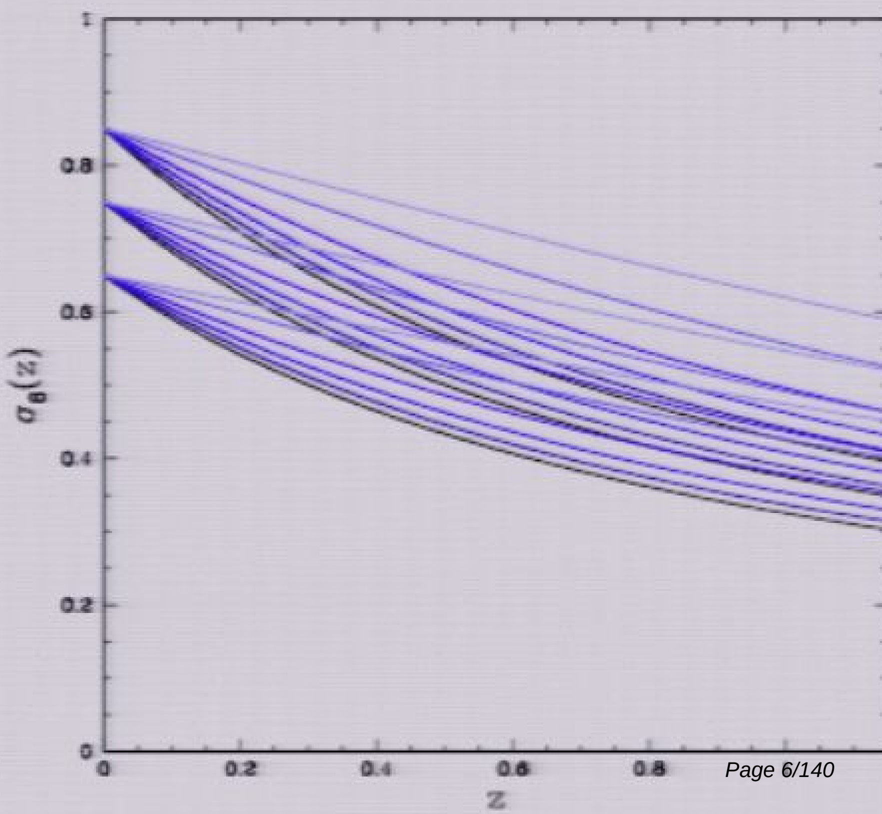
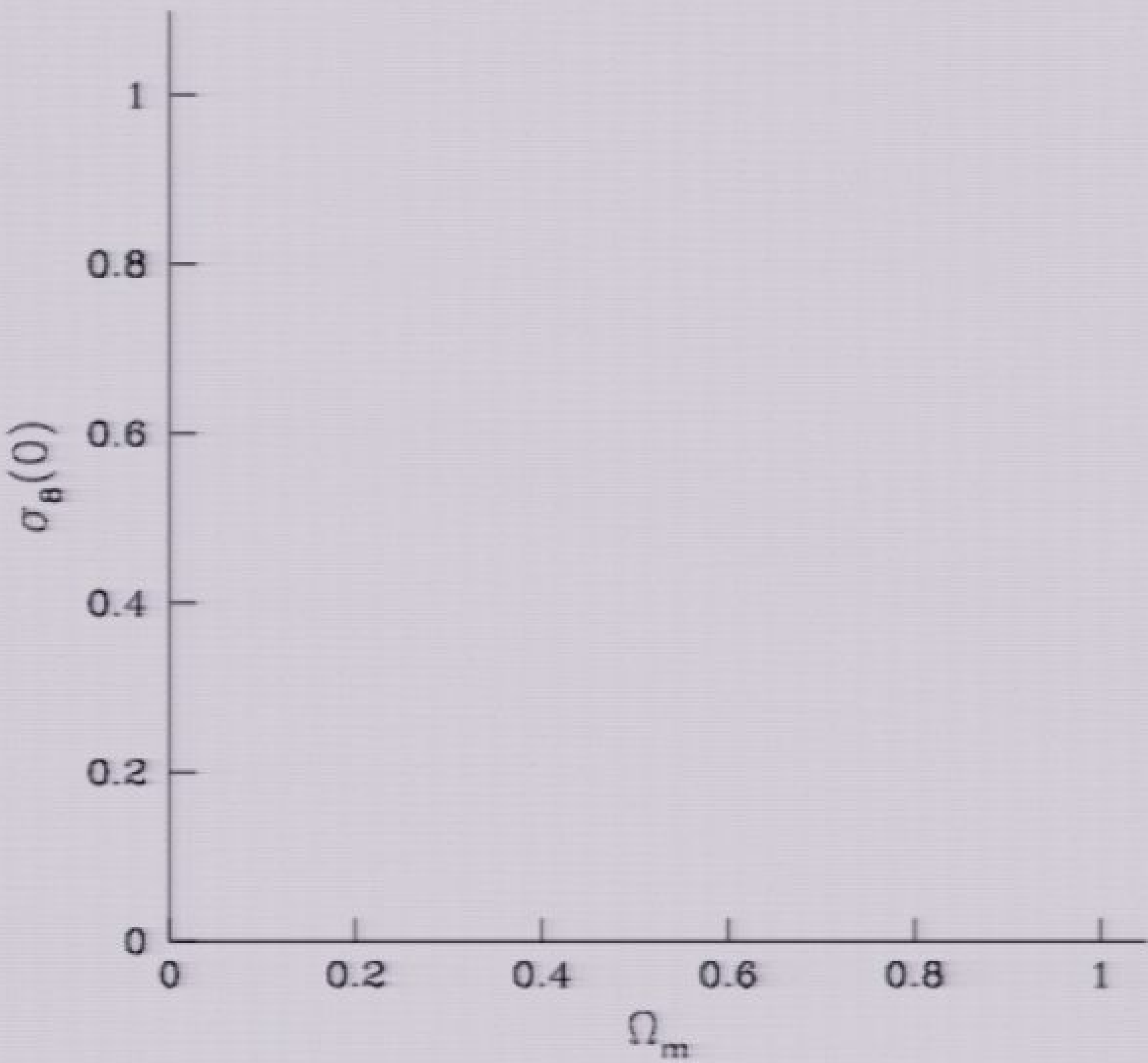
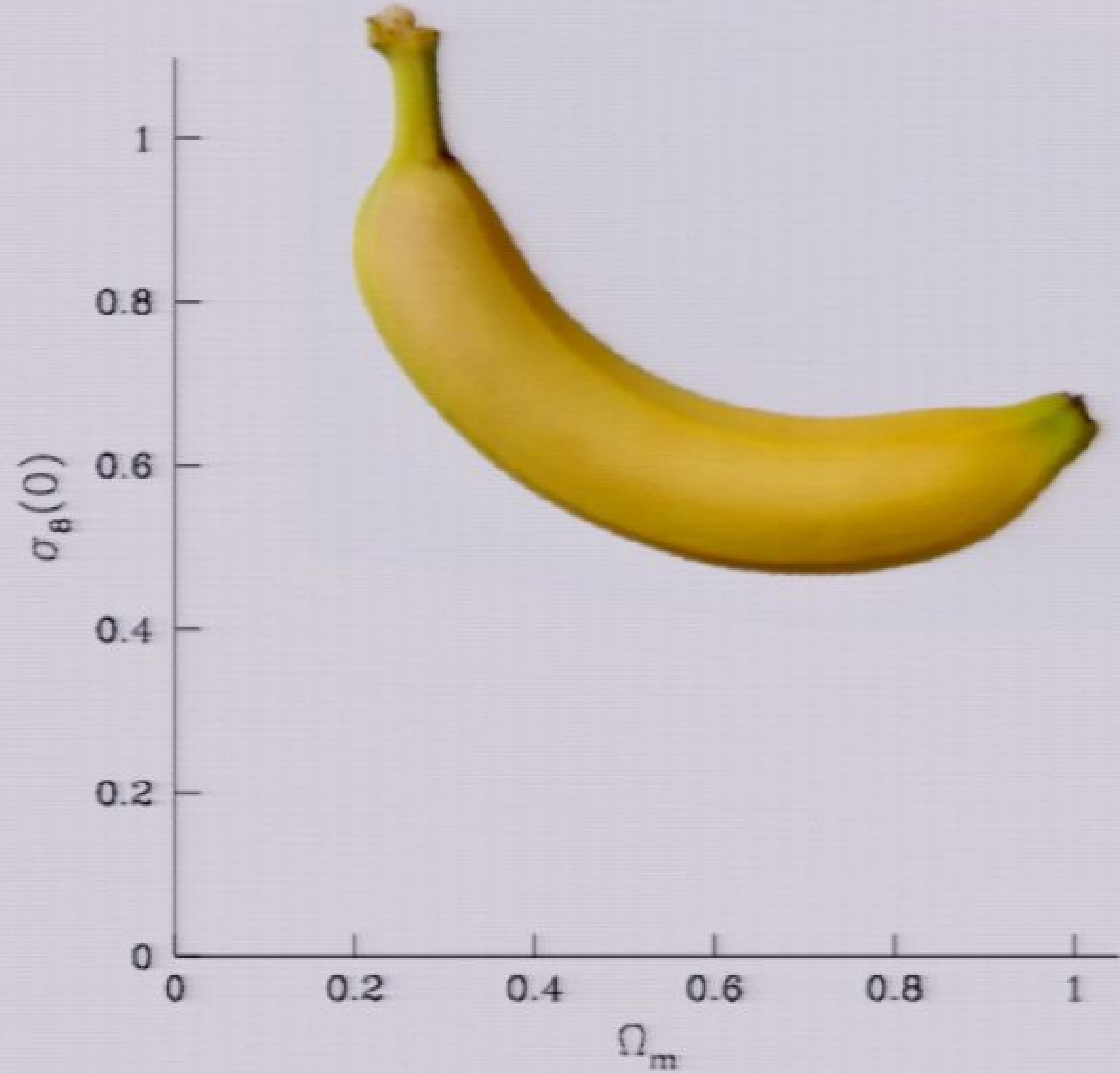






Degeneracy between amplitude (σ_8) and growth rate/equation of state (Ω_m or w)



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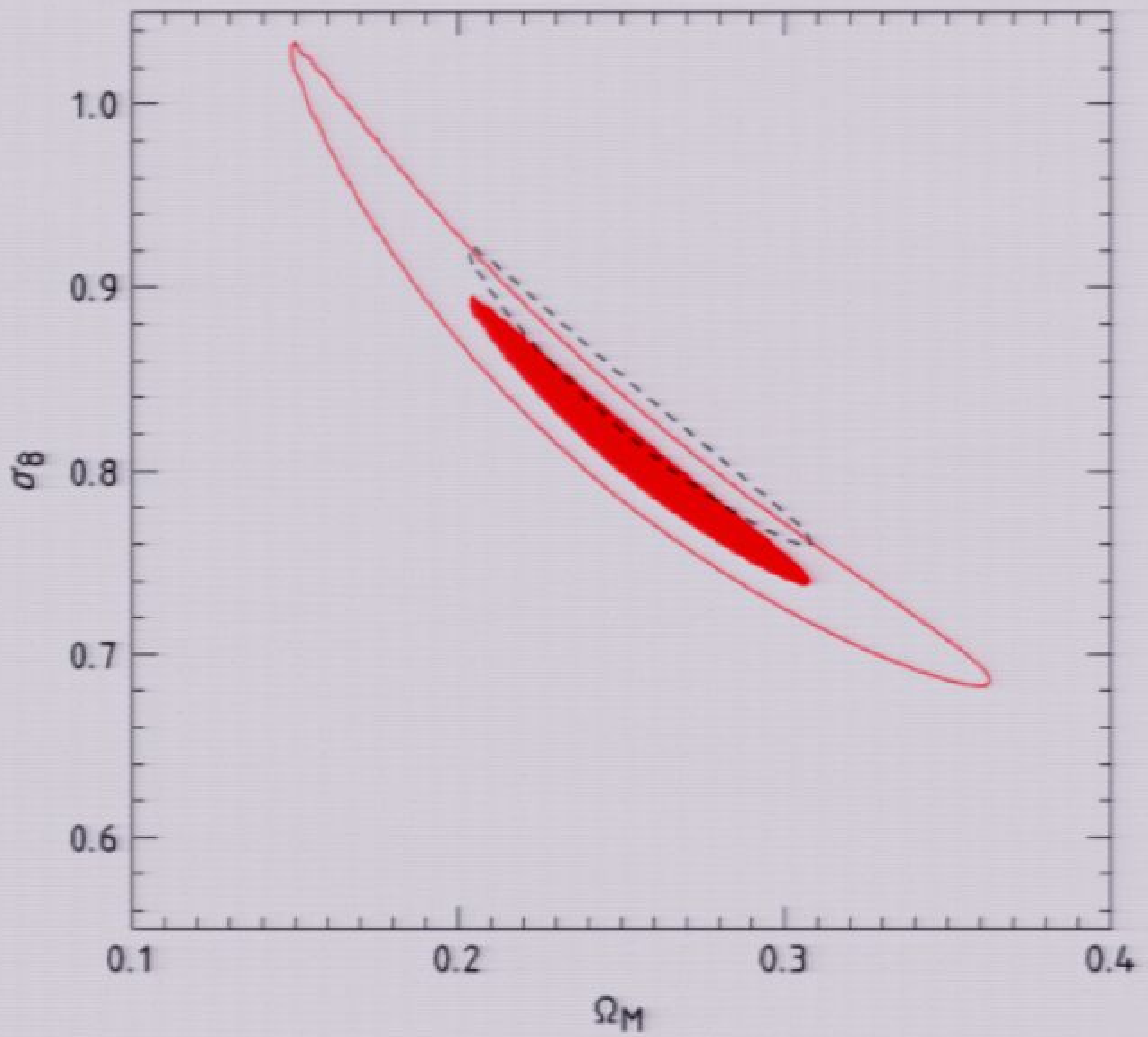

Degeneracy between amplitude (σ_8) and growth rate/equation of state (Ω_m or *w*)
(Vikhlinin et al. 2009 Chandra sample)

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Benefits of lensing selection less clear, but provides a sanity check + more generally a test of selection effects (e.g. catch unusual objects)

Finding Clusters with Gravitational Lensing

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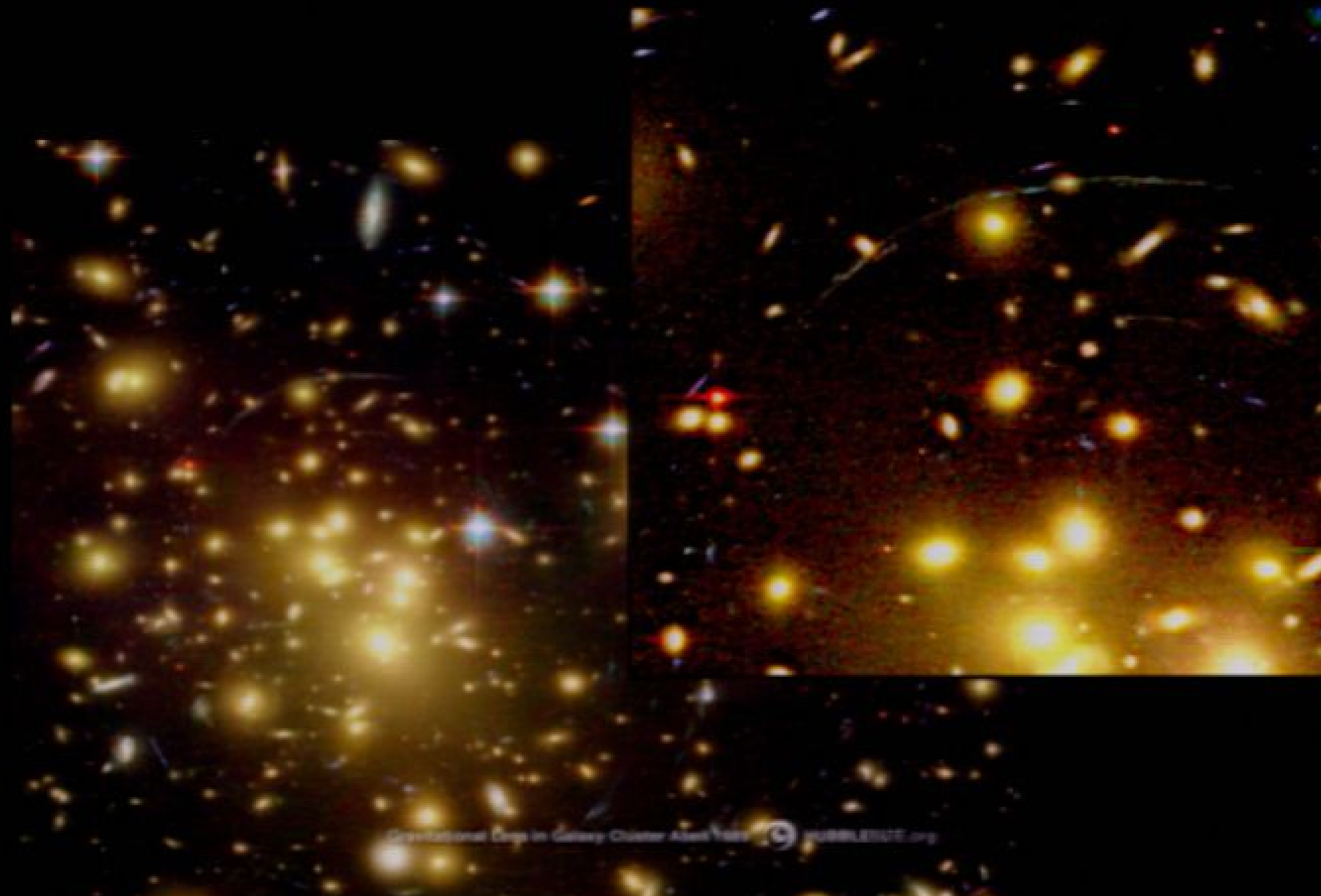

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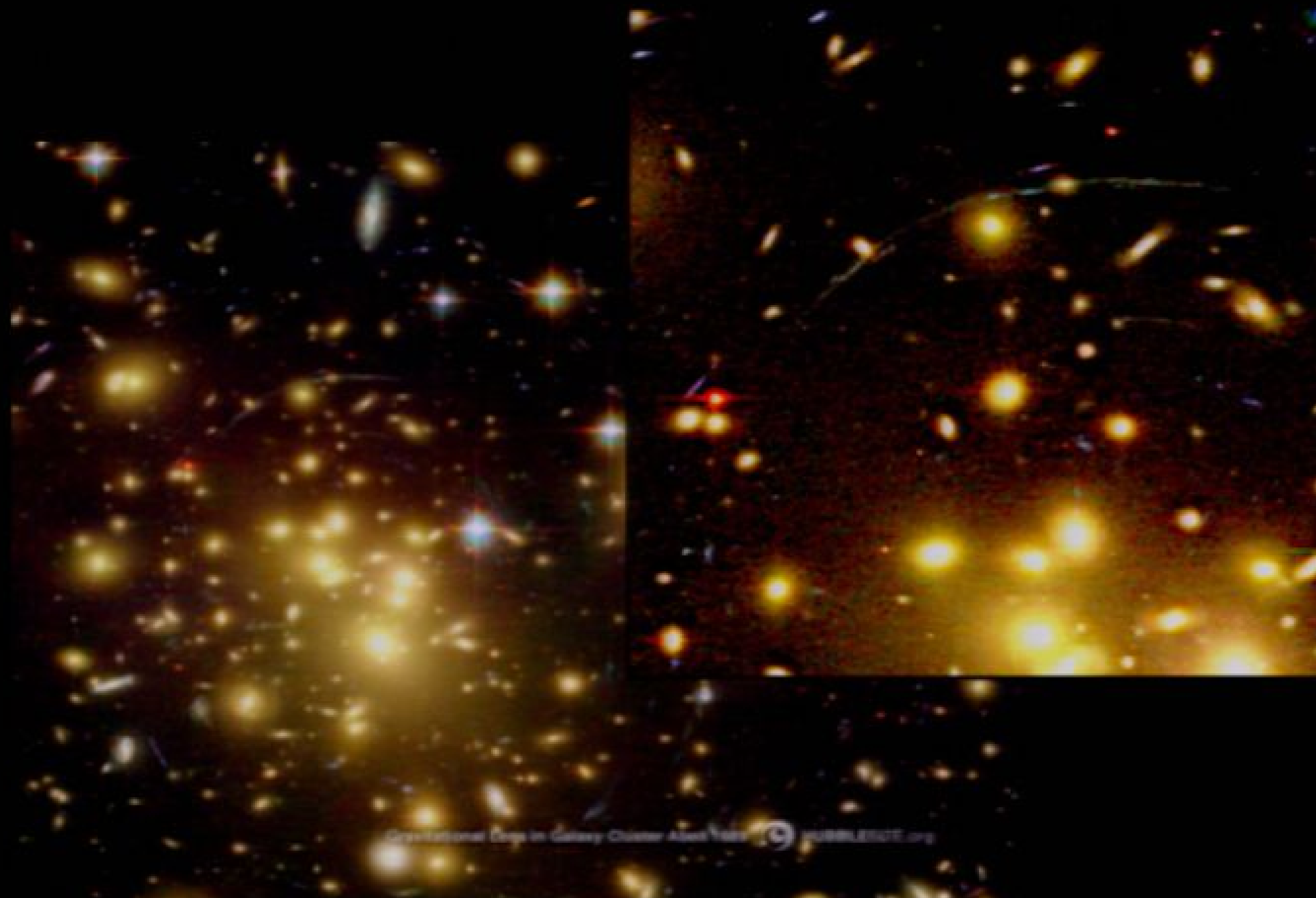

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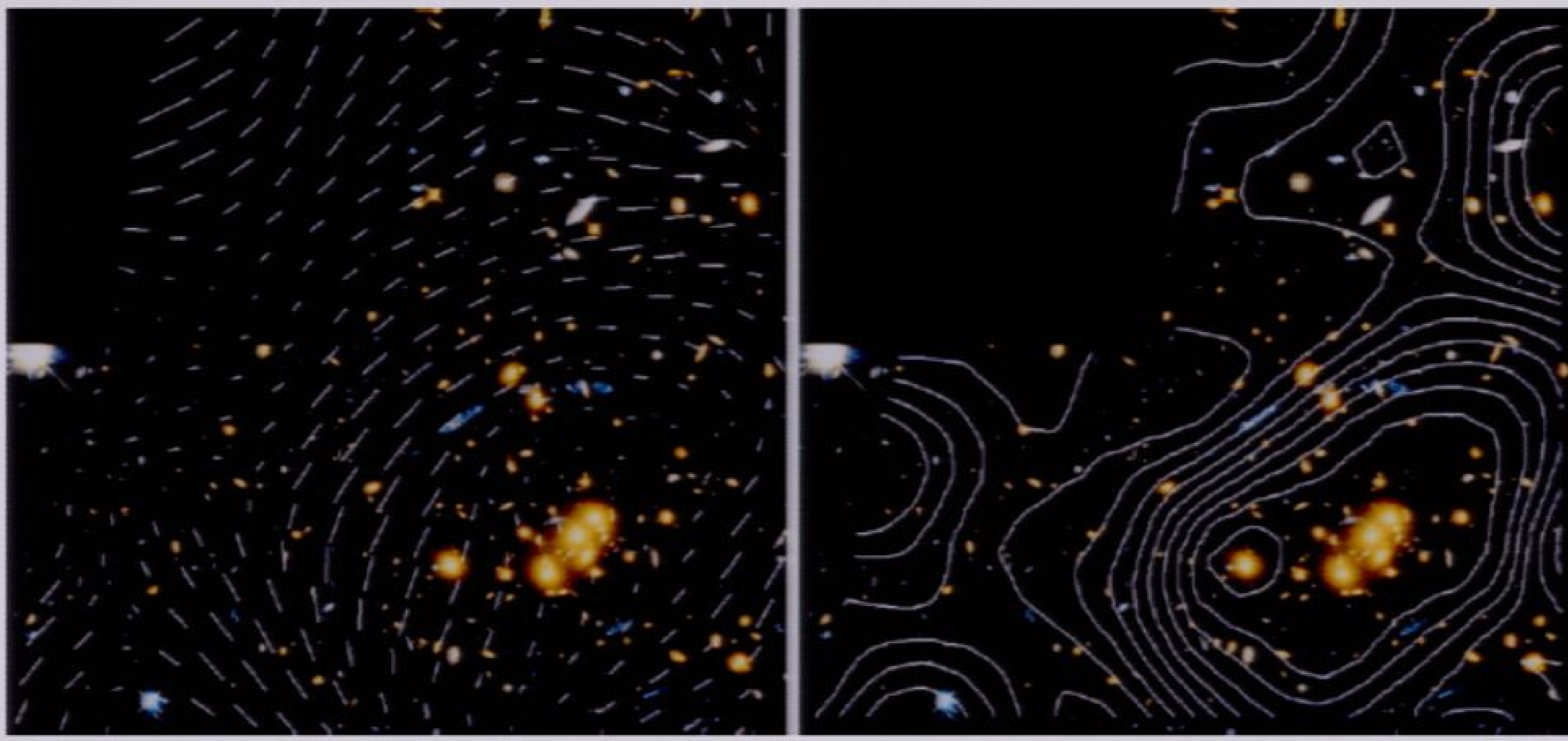


Net alignment of galaxy shapes

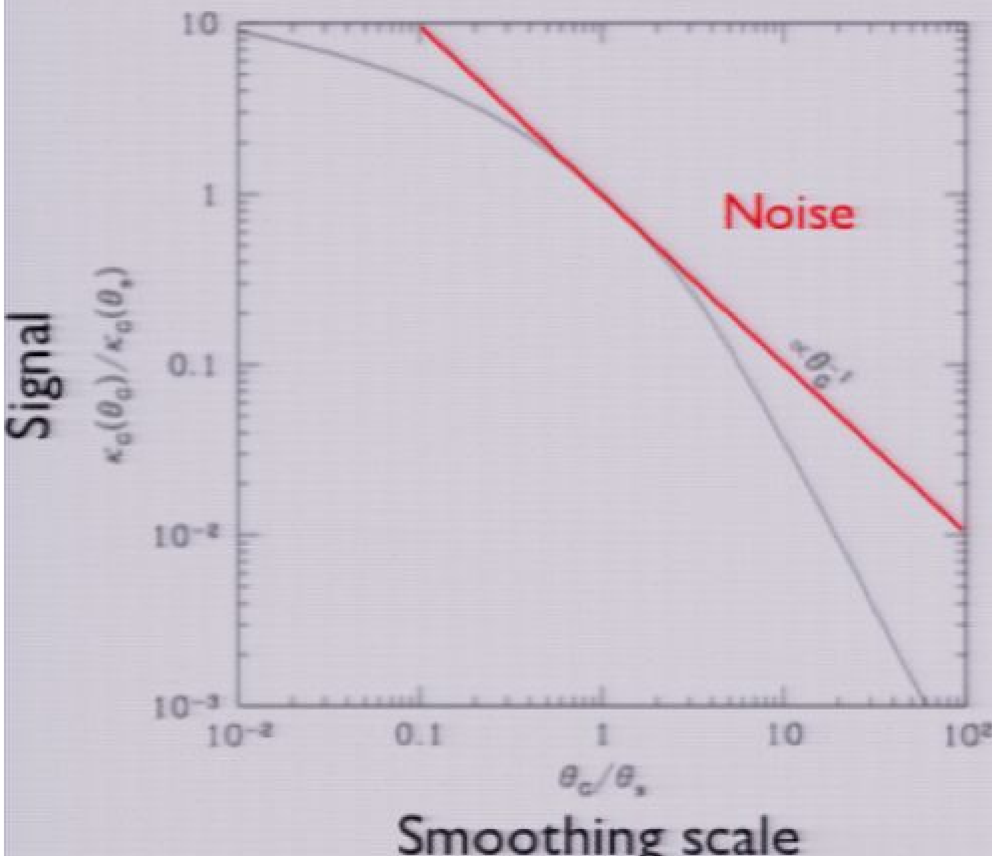
Reconstructed map of projected mass distribution

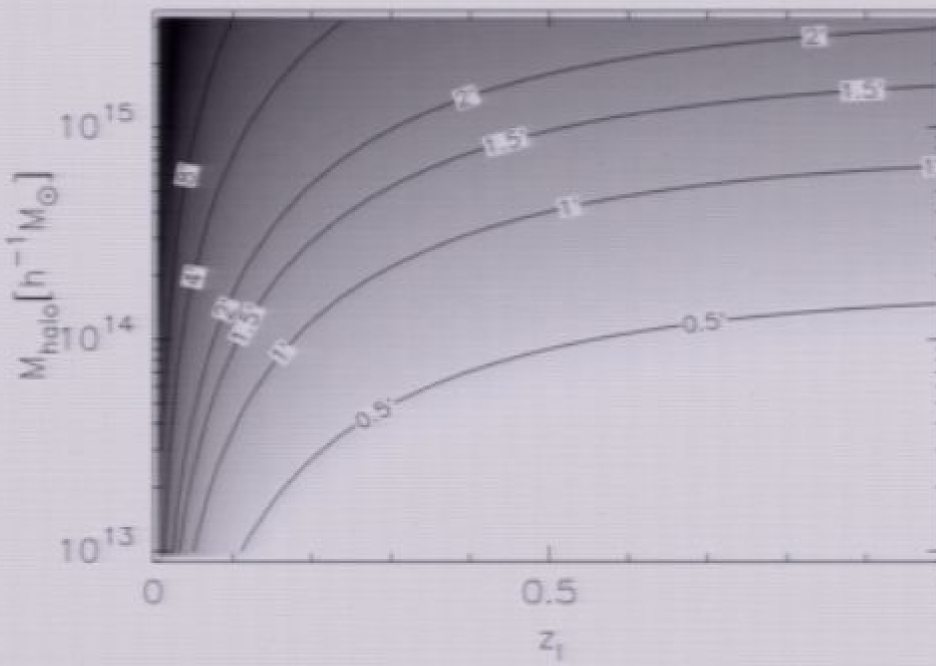
Maps noisy, typical signal small, e.g. 4-5 sigma ⇒ need to smooth over cluster scales

Expected radial profile for massive clusters:

For typical halo density profile smoothed with a Gaussian, expect maximum signal-to-noise at the NFW scale radius

⇒ ~1 arcminute for 10^{14} $M_\odot$ clusters at z = 0.2-0.3

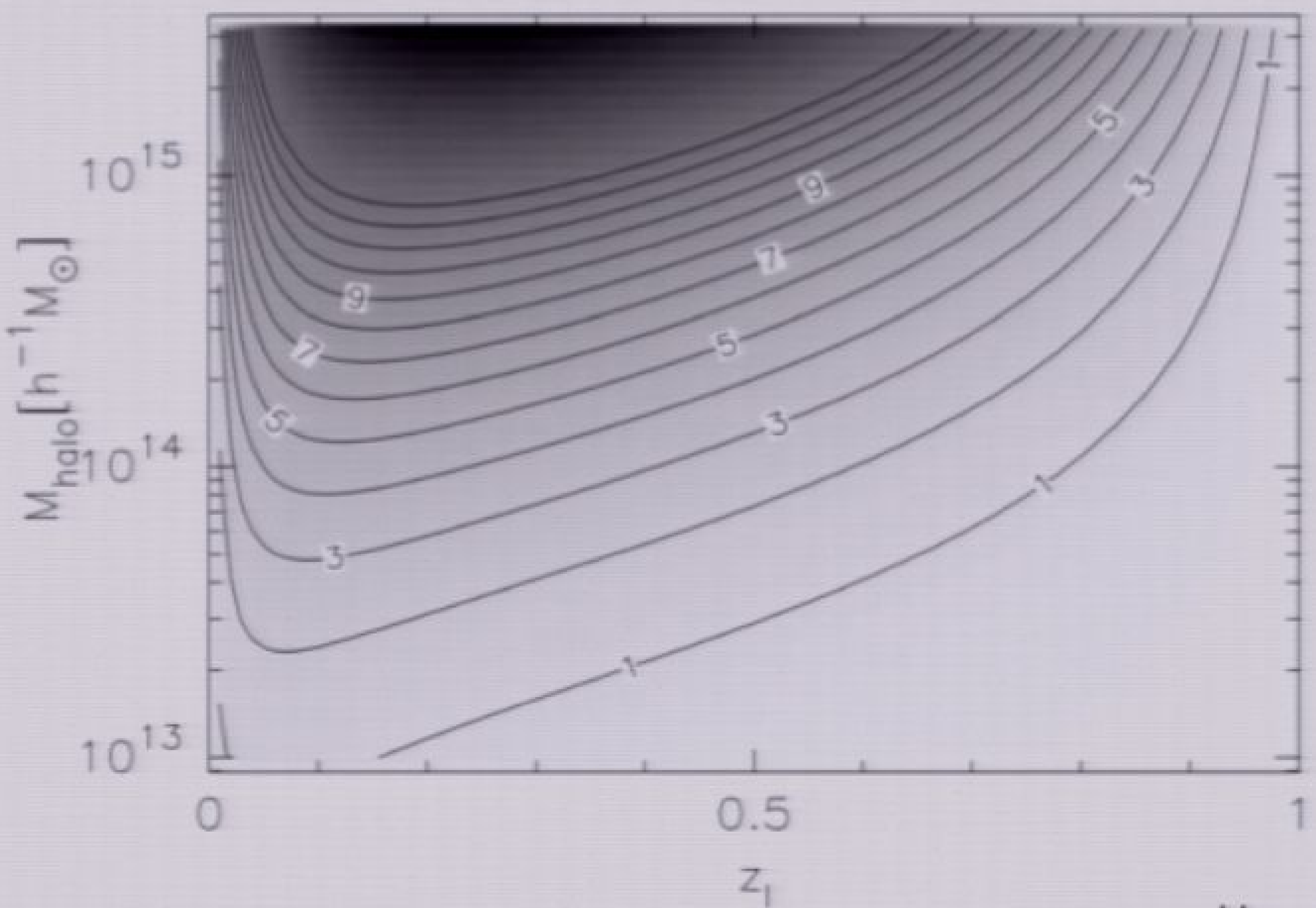




Hamana et al. 2004

Scaling with redshift

Signal goes as $\frac{D_d D_{ds}}{Ds} \sim \frac{x(1-x)}{1}$, so M_{min} goes as $\sim \frac{1}{x(1-x)}$



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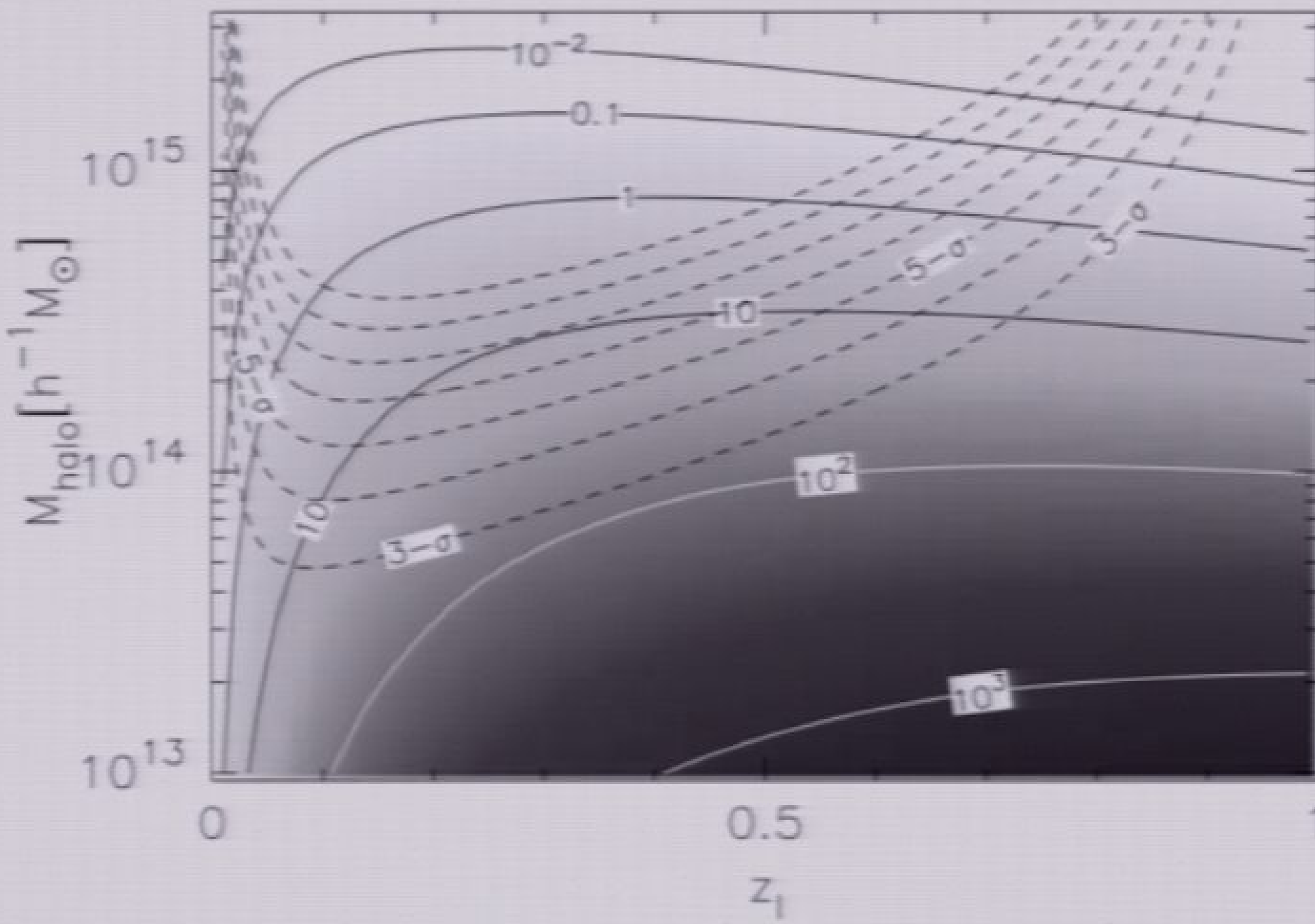

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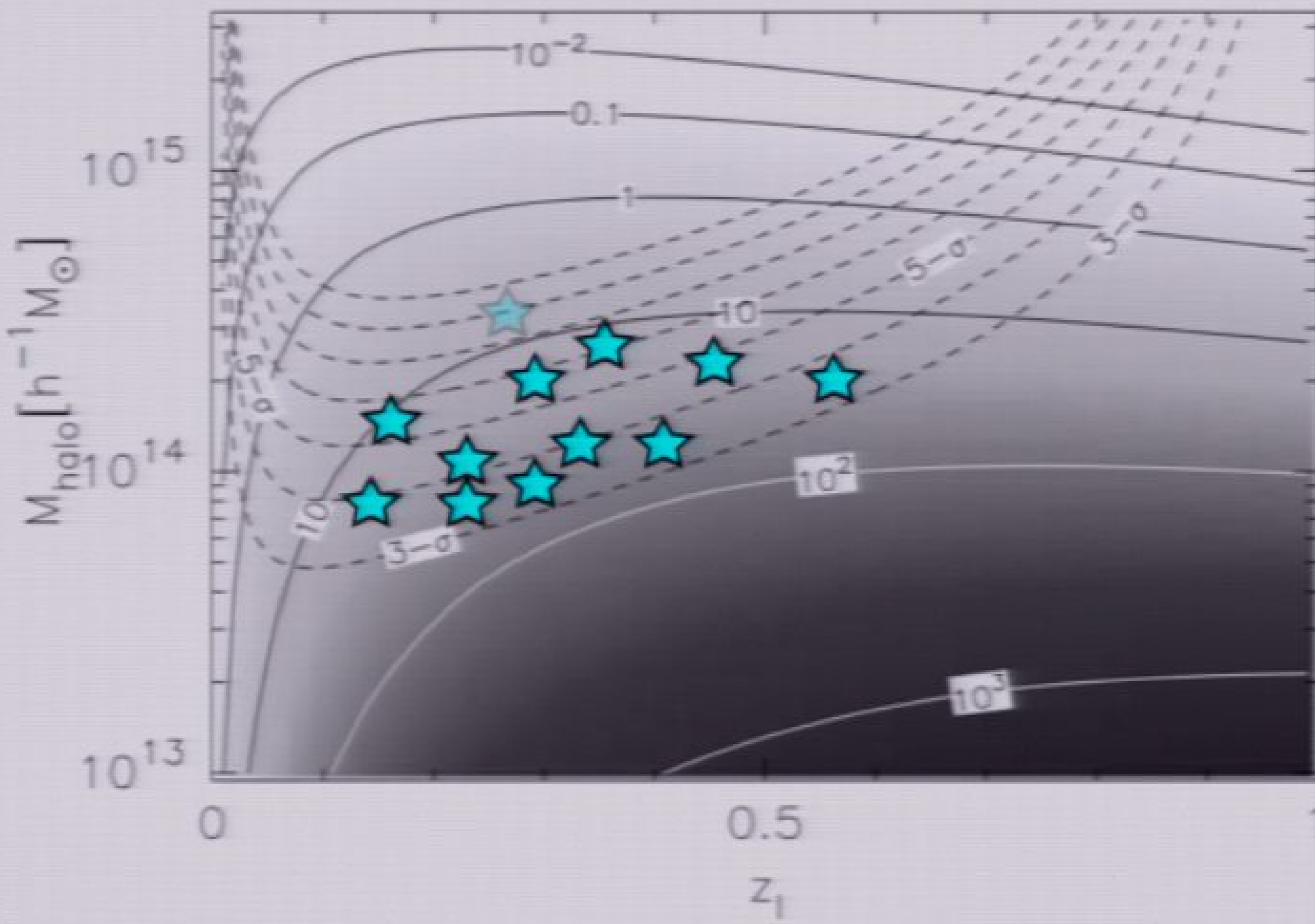

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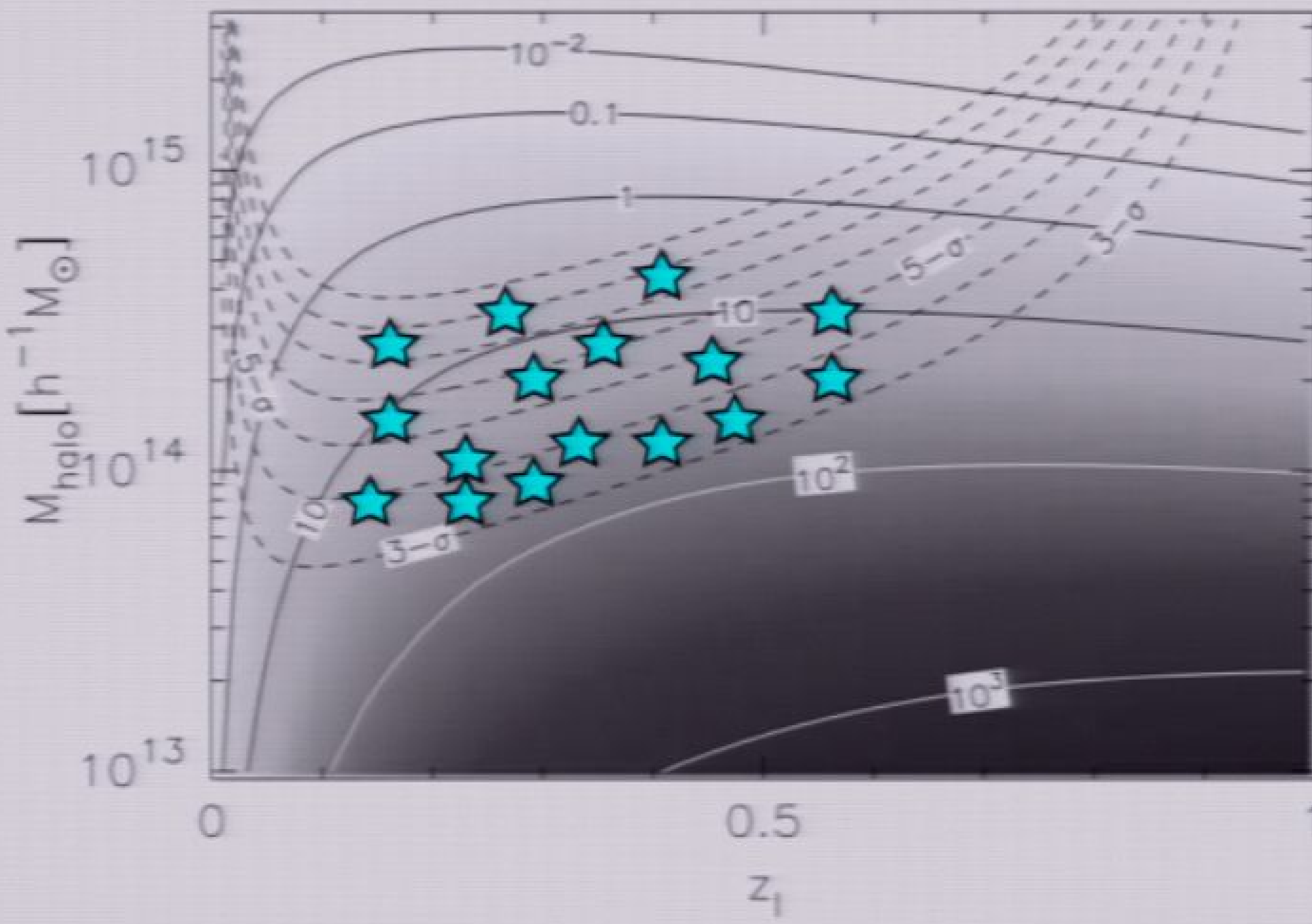

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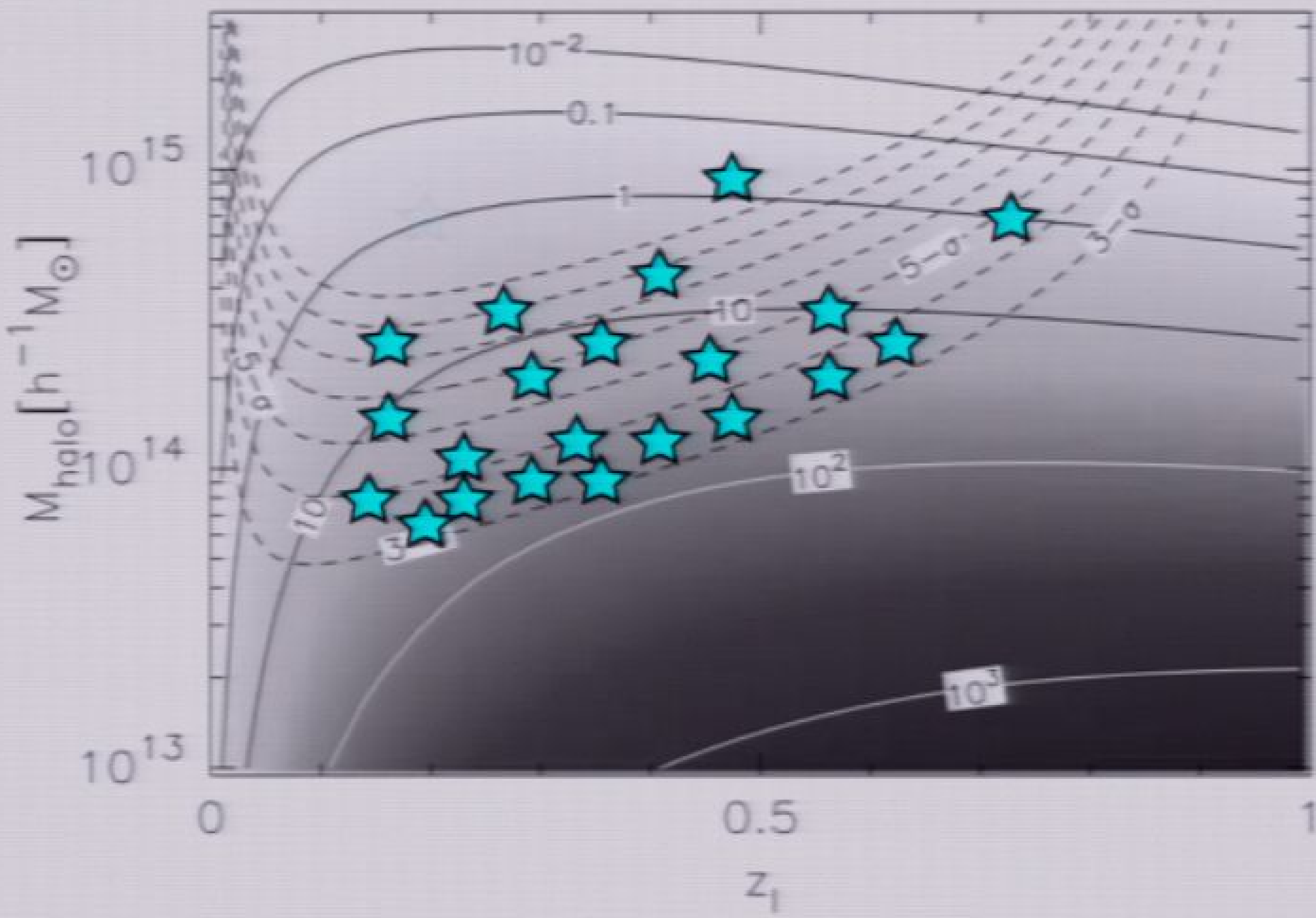

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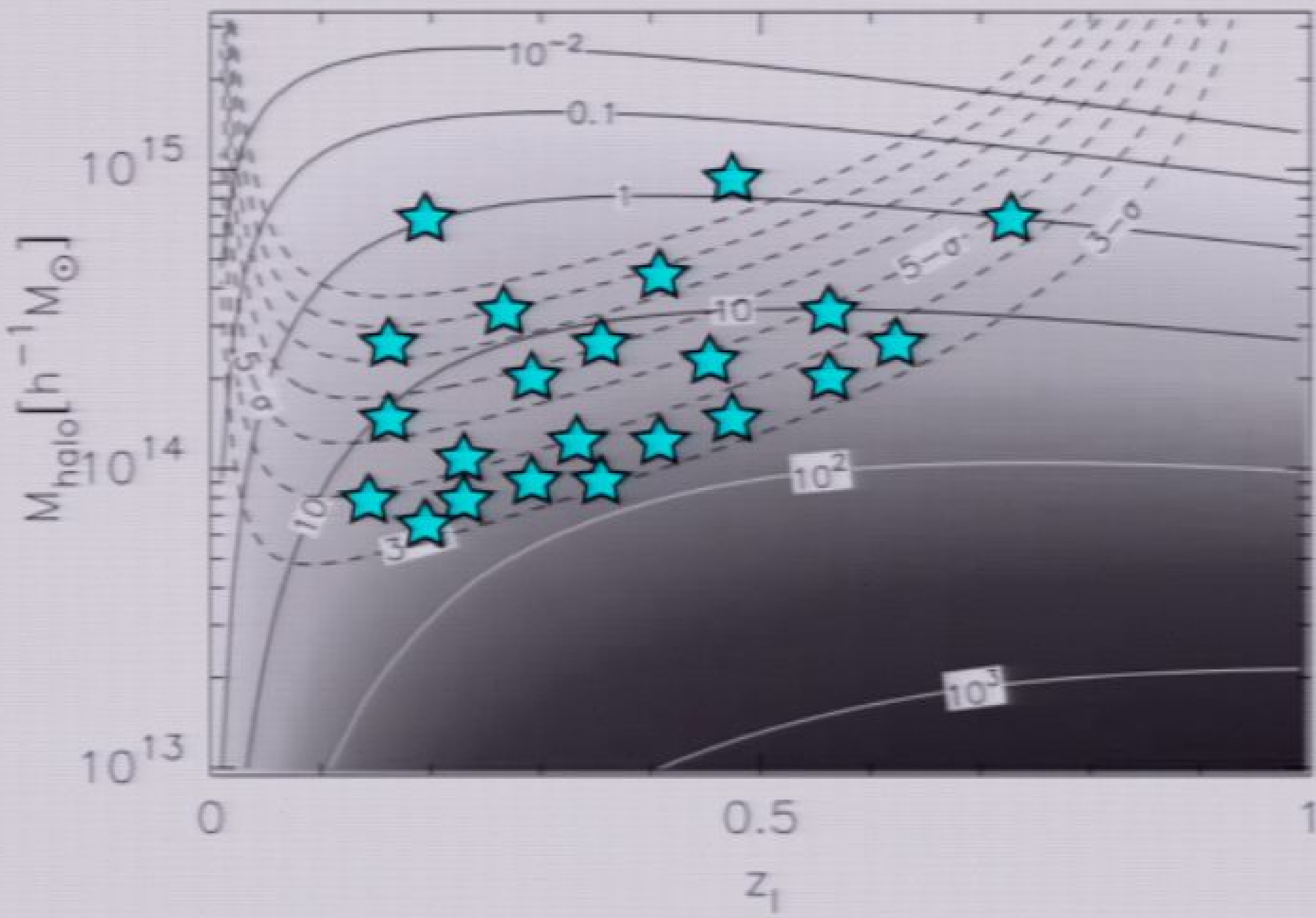

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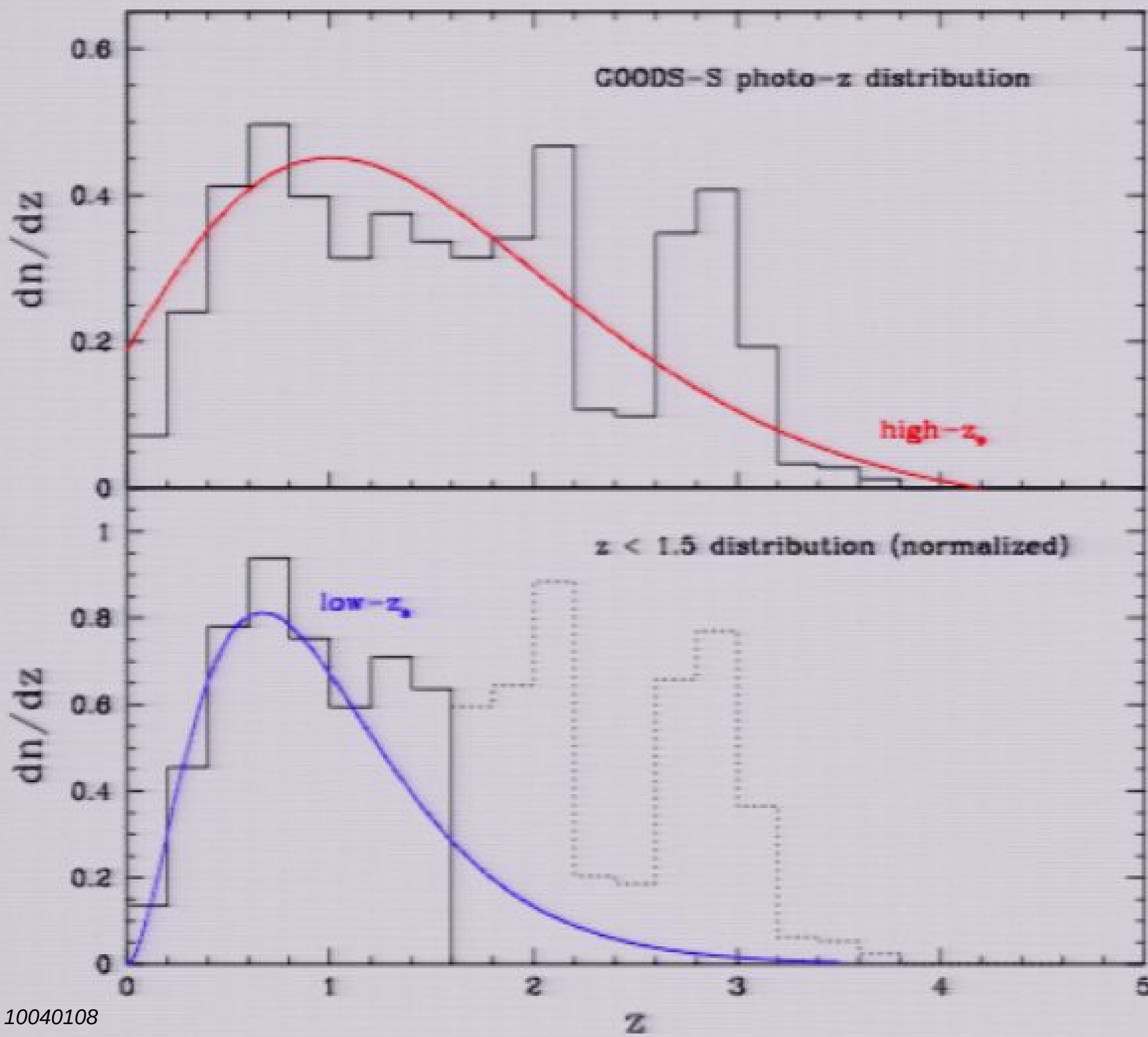

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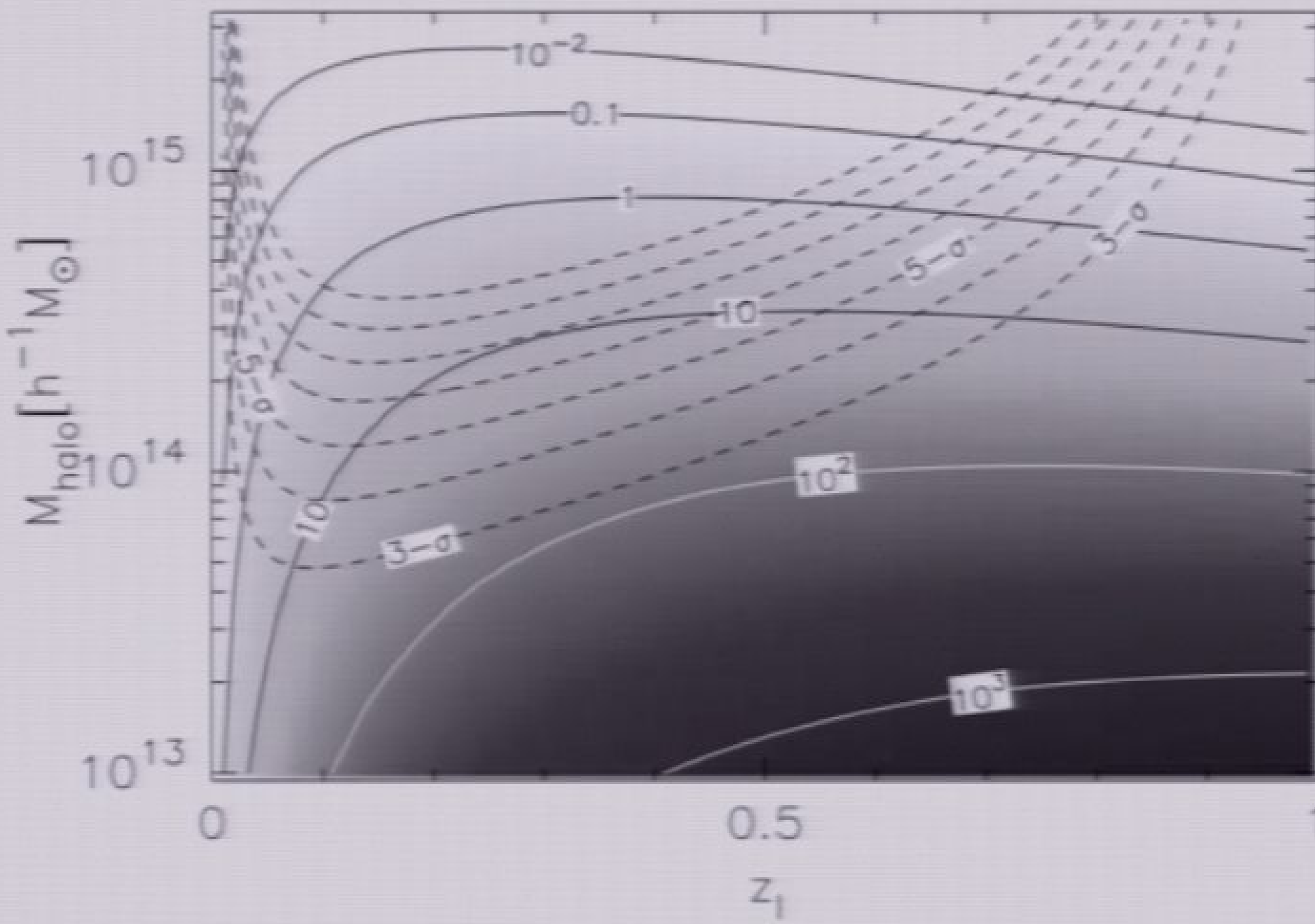

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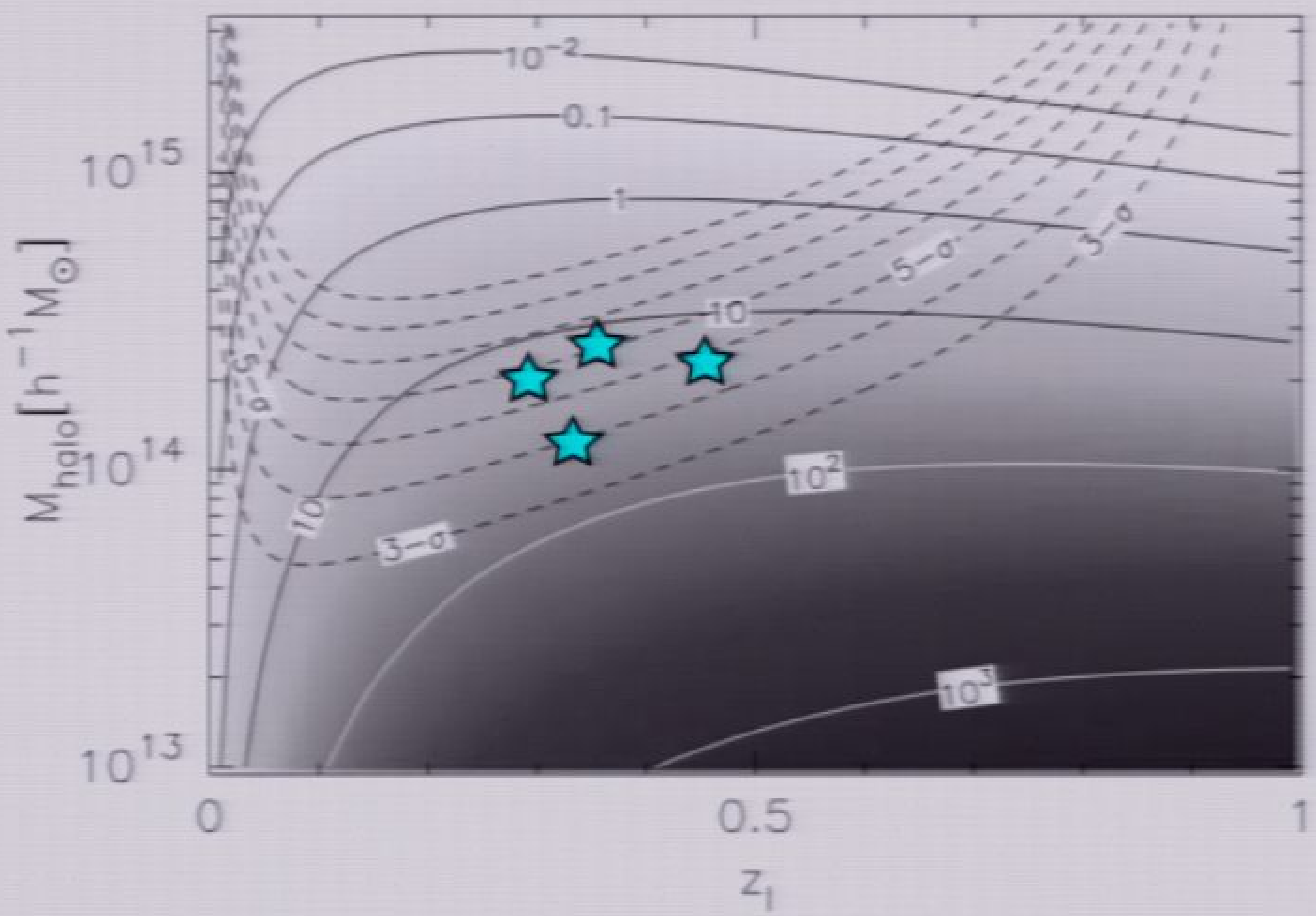

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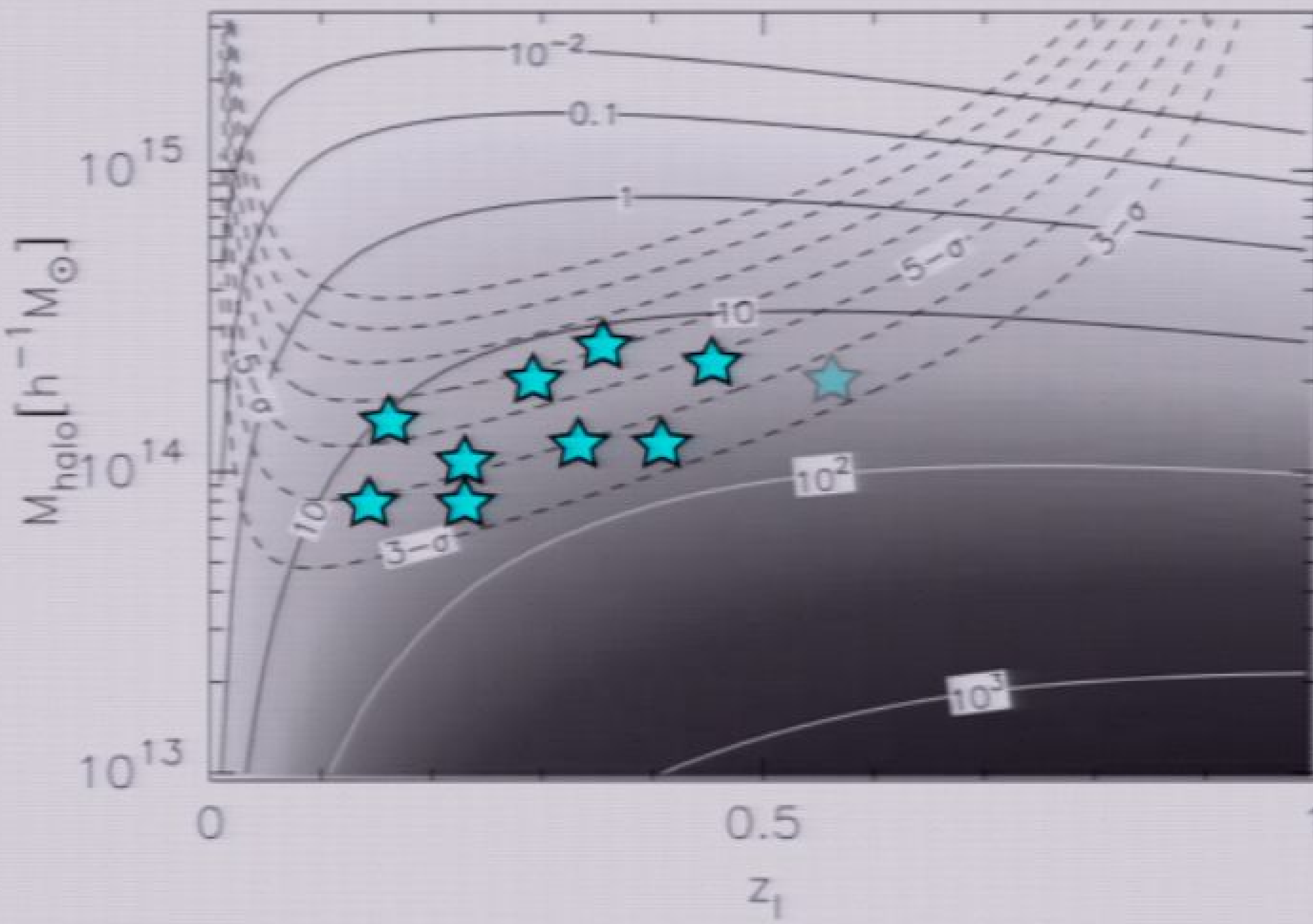

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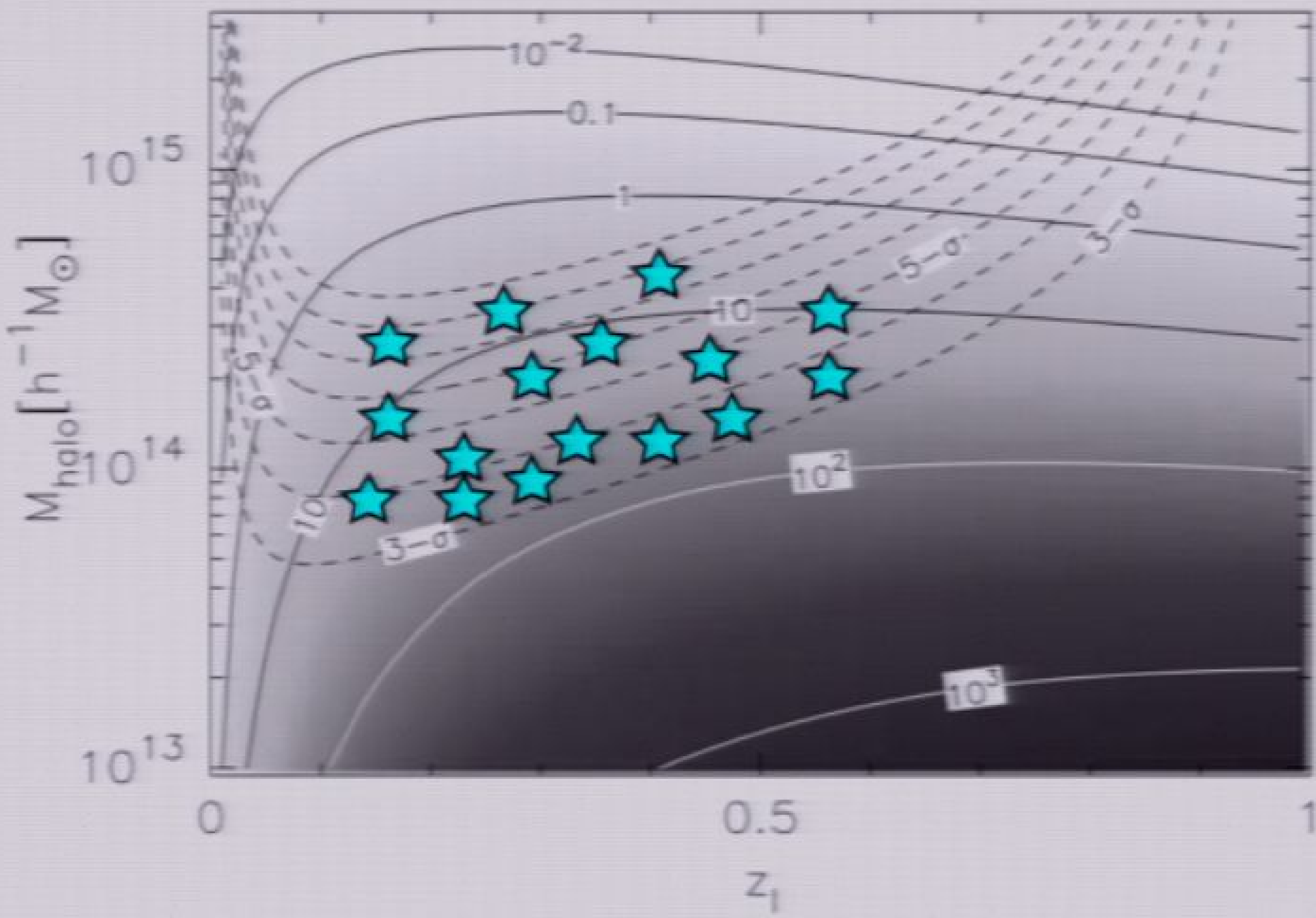

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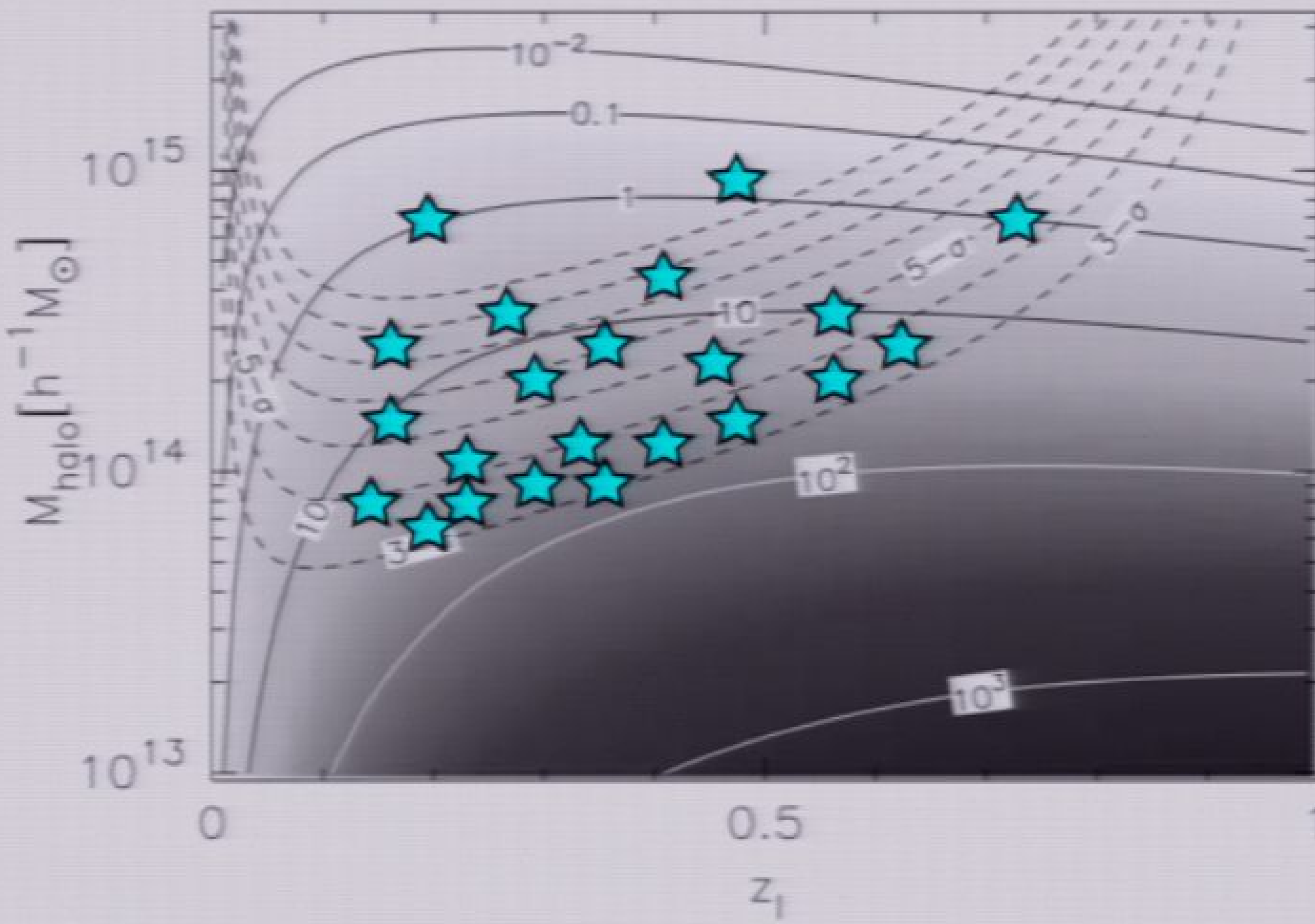

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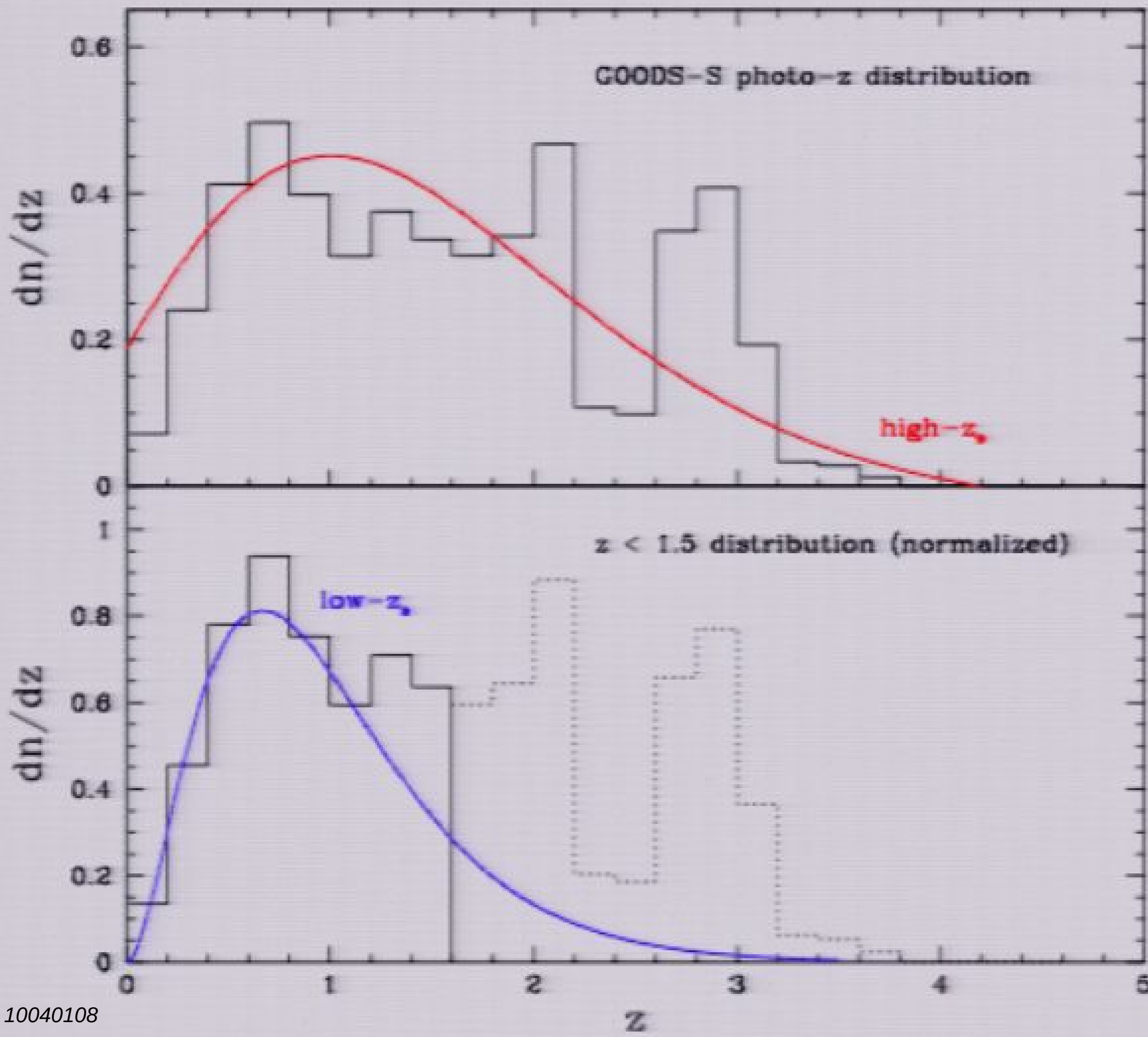

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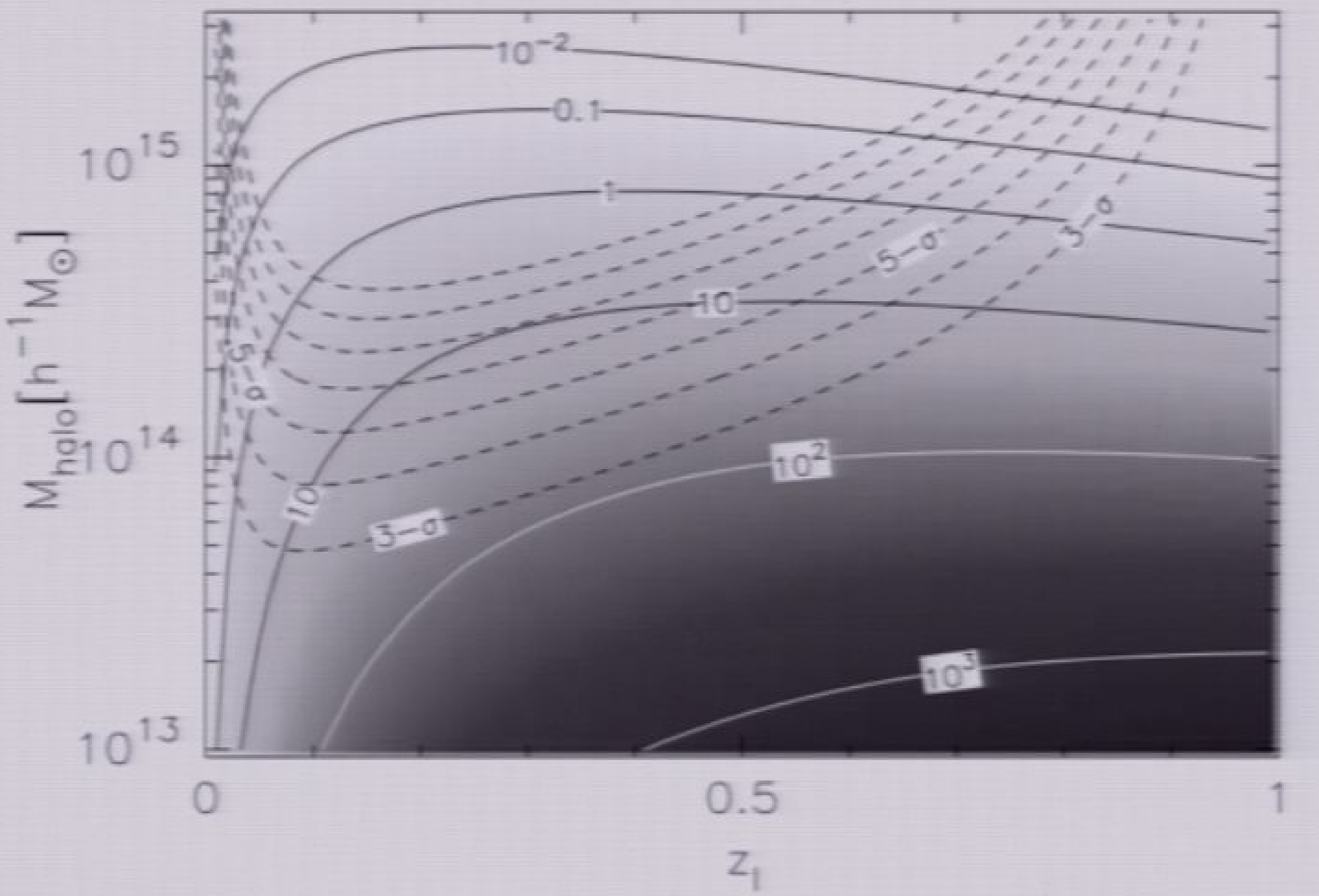

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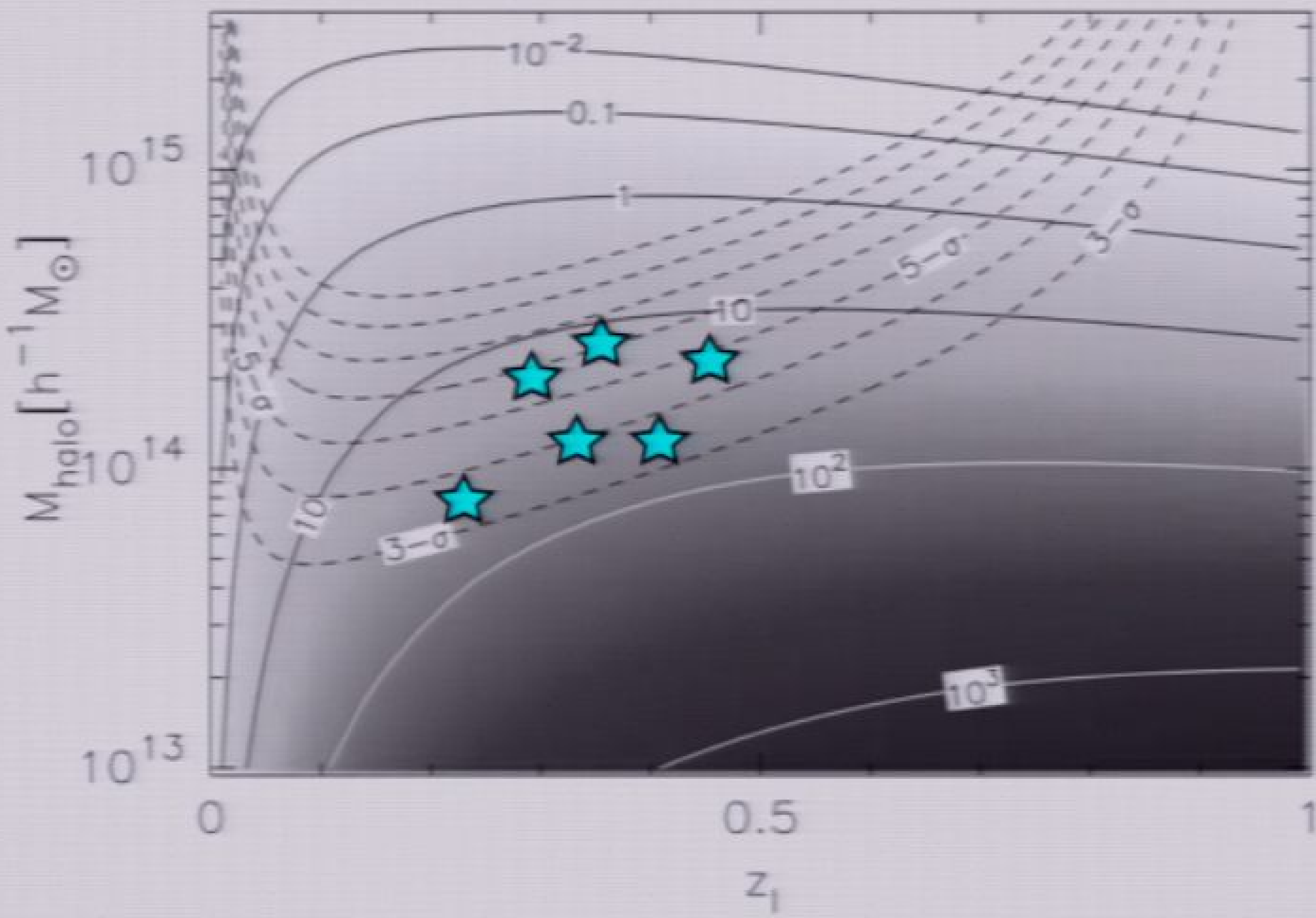

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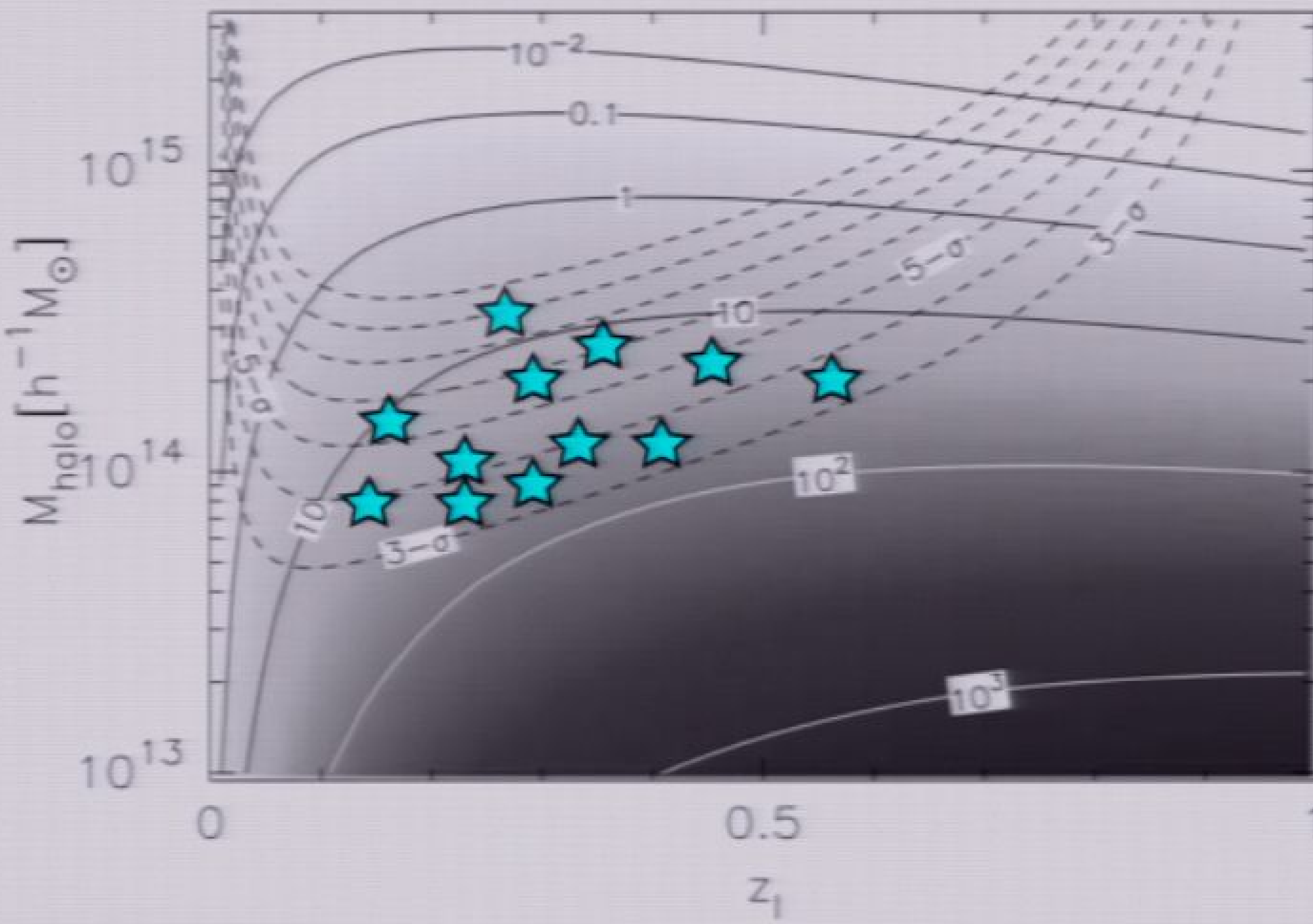

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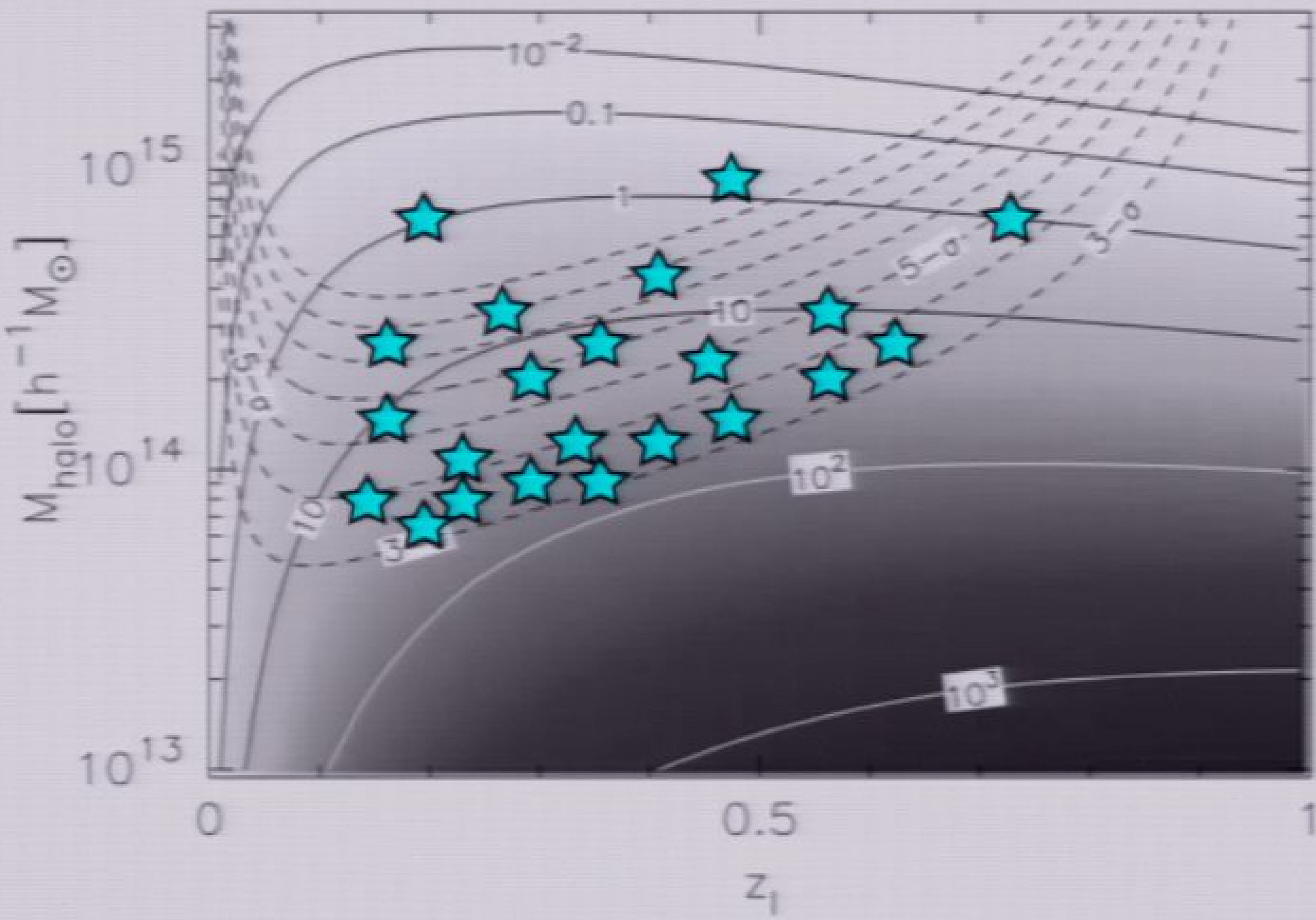

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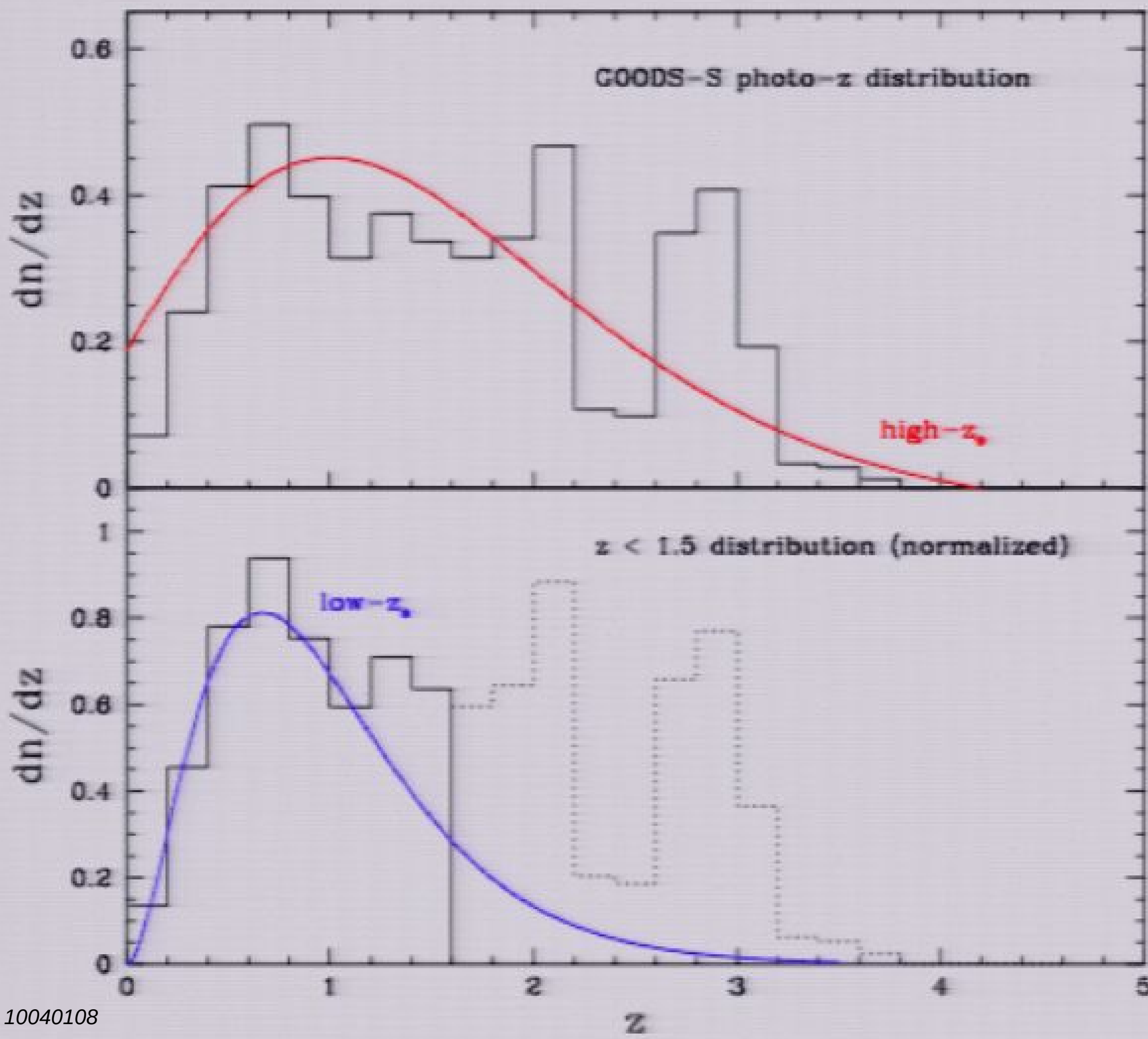

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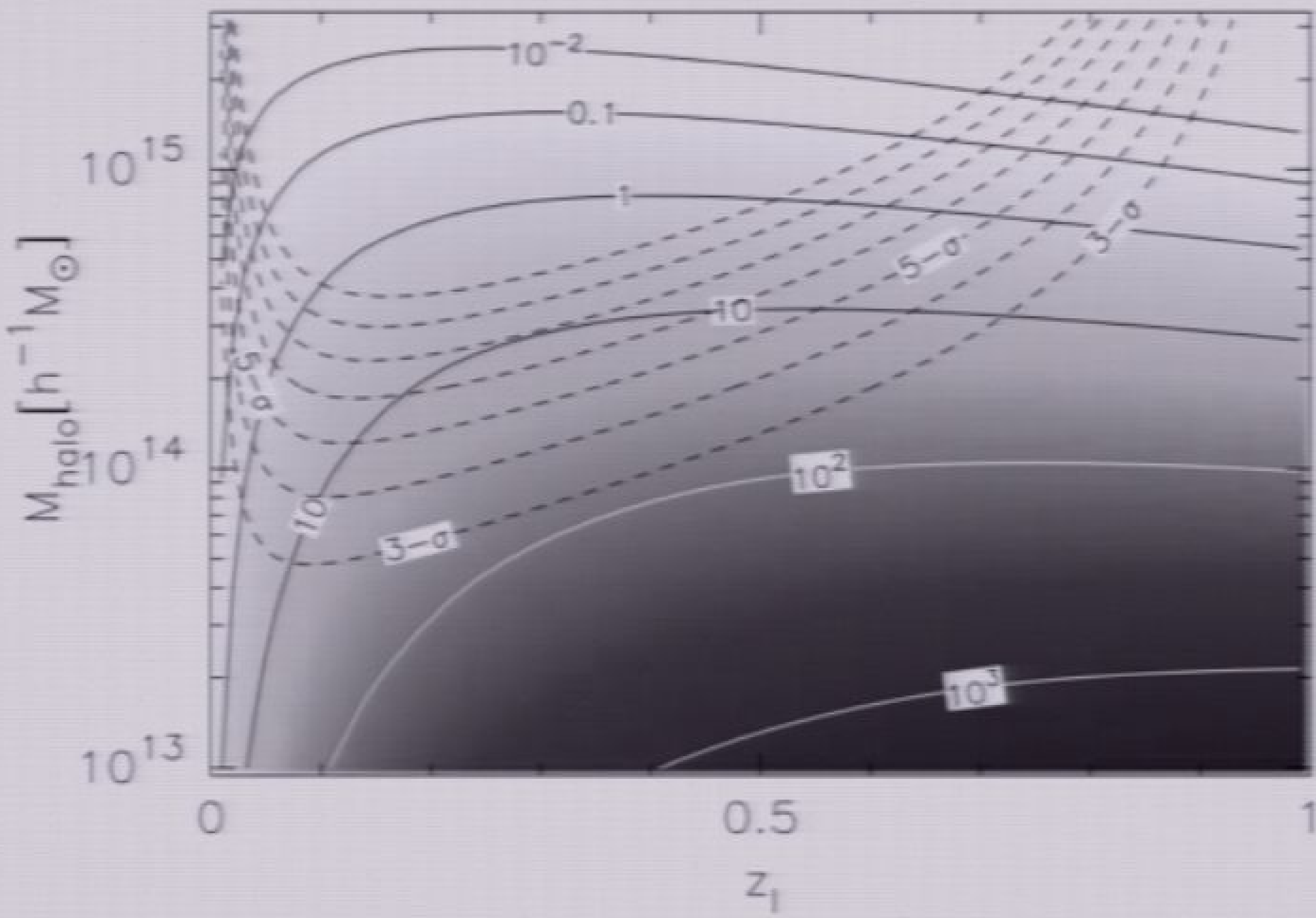

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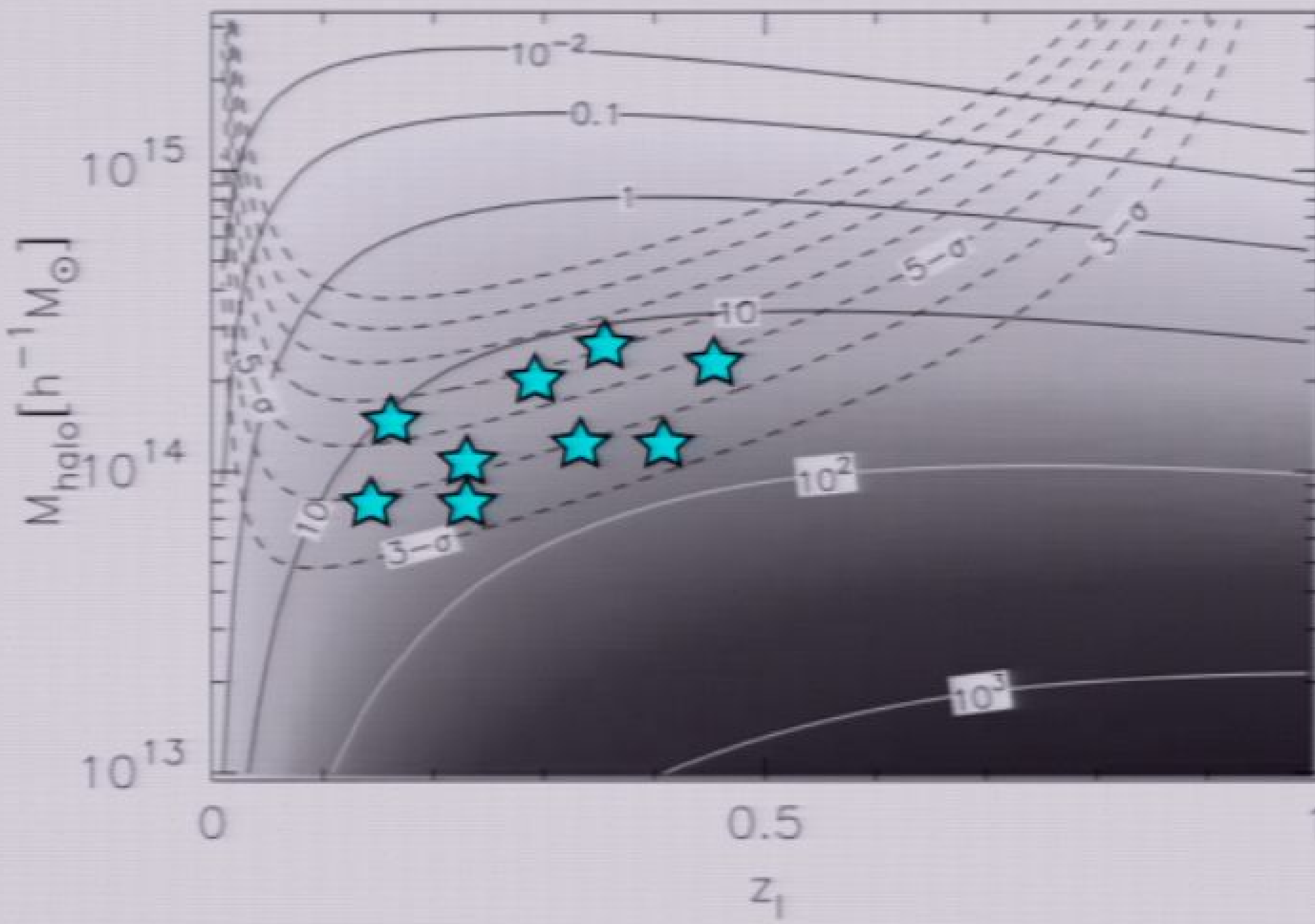

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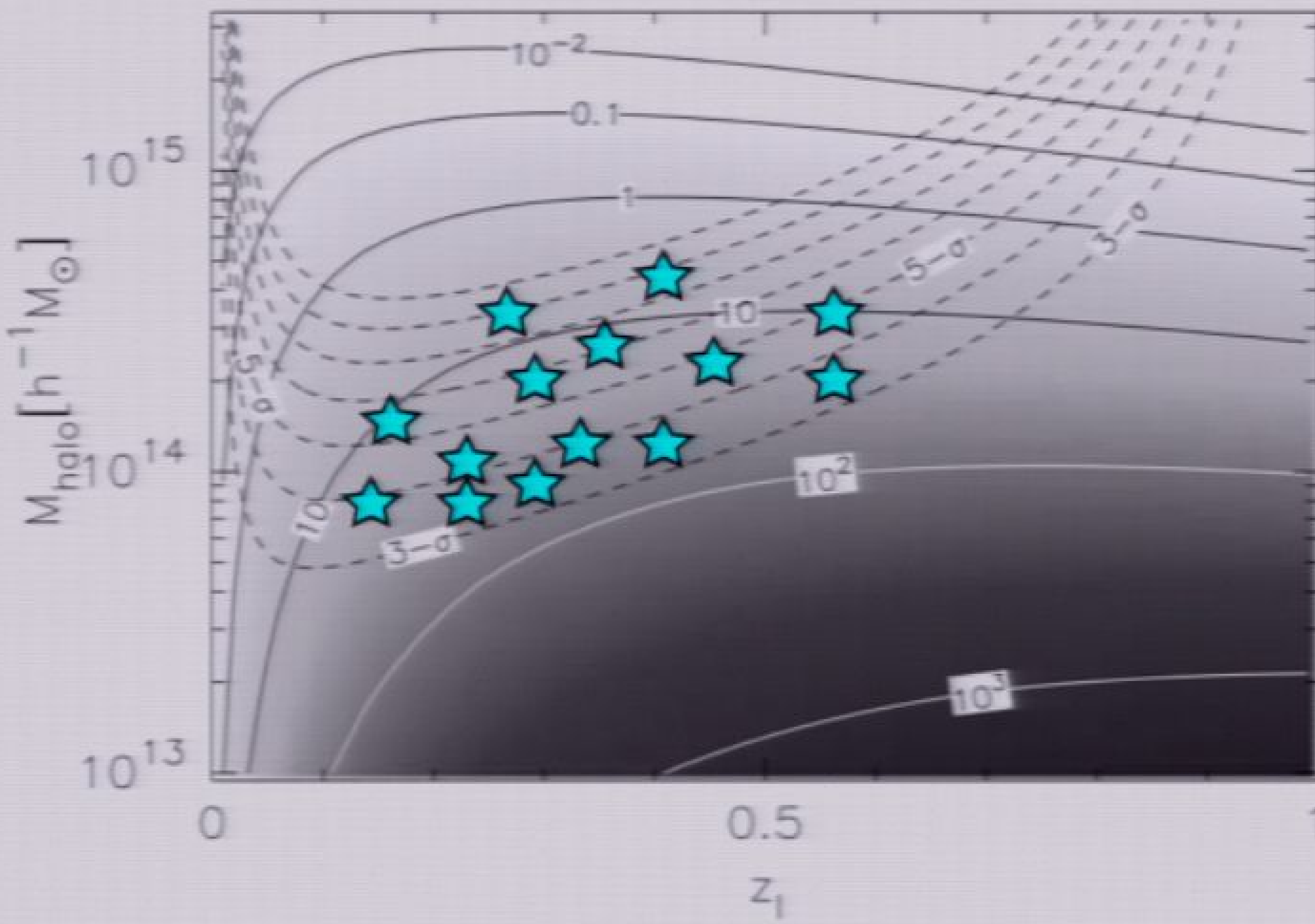

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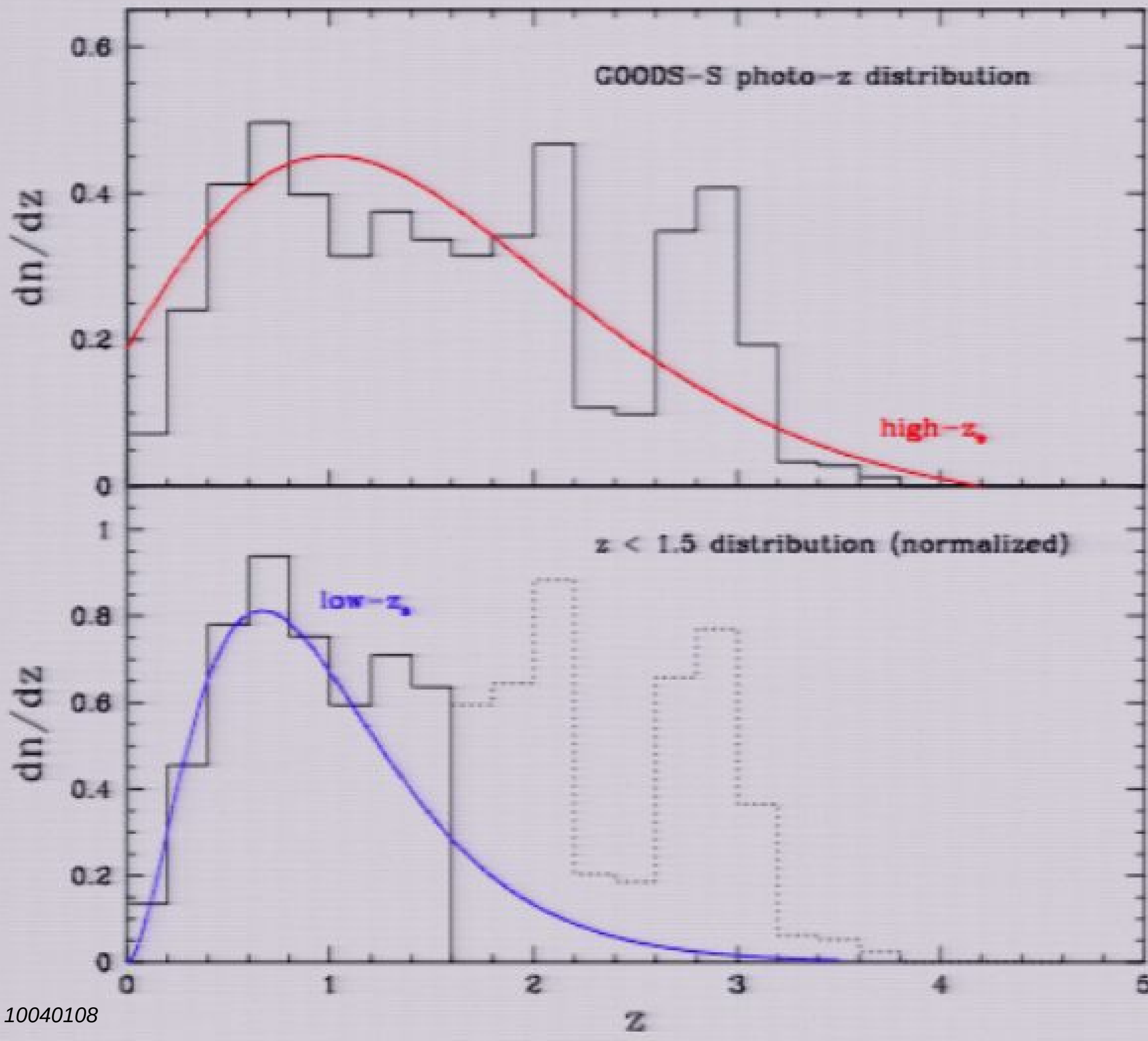


The Suprime22 Survey

NAOJ:
- Satoshi Miyazaki
- Takashi Hamana
- Nobunari Kashikawa

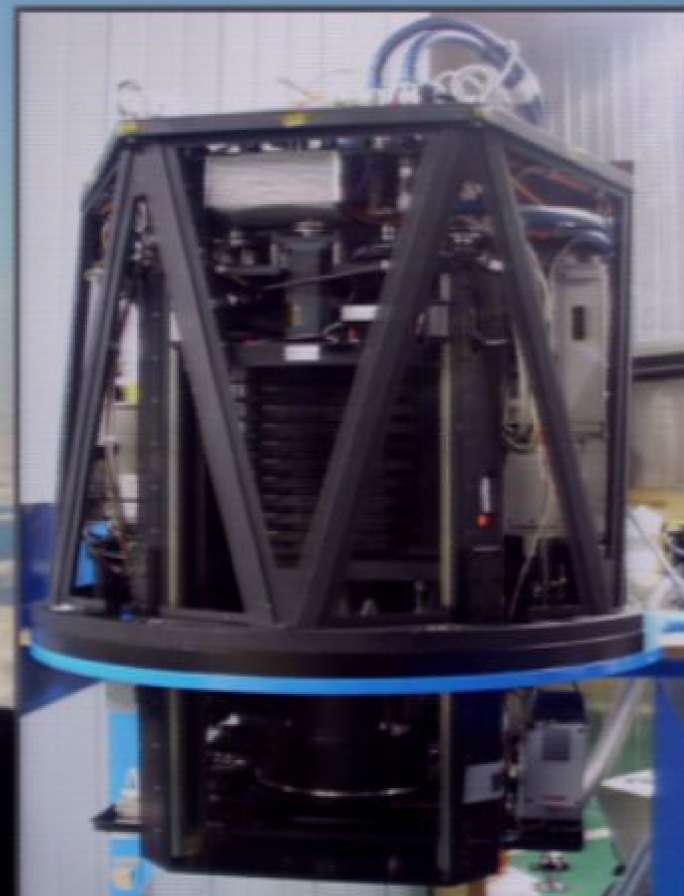
Caltech:
- Richard Ellis

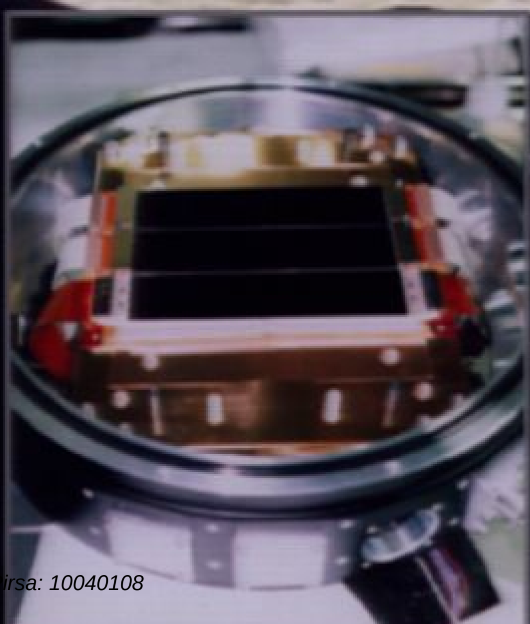
Swinburne:
- Andy Green

Edinburgh:
- Richard Massey

Waterloo:
- James Taylor

Saclay:
- Alexandre Refrigier





Suprime-cam: (Miyazaki PI)

10Kx8K mosaic covering approximately

0.5x0.5 degrees with 0.2" pixels

The Suprime22 Survey

TABLE 1
SUPRIME-CAM WEAK-LENSING SURVEY FIELDS

Field	R.A.	Decl.	Area[a] (deg^2)	Secure Area[b] (deg^2)	Seeing[c] (arcsec)	ρ_{gal}[c] ($arcmin^2$)	T_R[d] (ks)	T_C[d] (ks)
EP02	02 30	00	1.39	0.73	0.70 ± 0.06	33.5 ± 6.1	...	...
DS	02 18	−05	1.12	0.83	0.68 ± 0.06	47.7 ± 5.7	...	...
M-LSS	02 26	−04	2.80	2.24	0.55 ± 0.07	46.0 ± 6.7	...	...
ıx	08 49	+45	1.76	1.28	0.80 ± 0.08	30.7 ± 7.3	64	300
SMOS	10 02	+01	1.92	1.41	0.54 ± 0.03	37.1 ± 2.1	...	...
ckman Hole	10 52	+57	1.85	1.57	0.60 ± 0.14	39.3 ± 7.8	200	300
140	11 36	+30	1.83	1.50	0.71 ± 0.17	29.3 ± 12.9	33	...
1159−035	12 04	−04	1.43	1.19	0.75 ± 0.05	23.4 ± 3.6	51	...
13[h]	13 34	+38	2.06	1.72	0.74 ± 0.17	29.6 ± 9.6	110	120
O 2 deg^2	16 04	+43	2.01	1.53	0.67 ± 0.04	38.0 ± 3.6	26	...
Dra	16 34	+57	1.38	0.99	0.72 ± 0.12	28.4 ± 8.4	47	...
EP16	16 52	+36	1.20	0.93	0.76 ± 0.08	26.4 ± 4.0	...	...
EP23	23 30	00	1.07	0.80	0.58 ± 0.01	36.3 ± 1.3	...	...
Total			21.82	16.72				

13 fields of 1-3 deg^2 each, selected for X-ray coverage and/or ancillary data
imaged in 0.5-0.8" seeing to R_C = 25.5-26
obtain surface densities of 23-50 galaxies per $arcmin^2$

(lensing noise goes as $(S_g)^{1/2}$)

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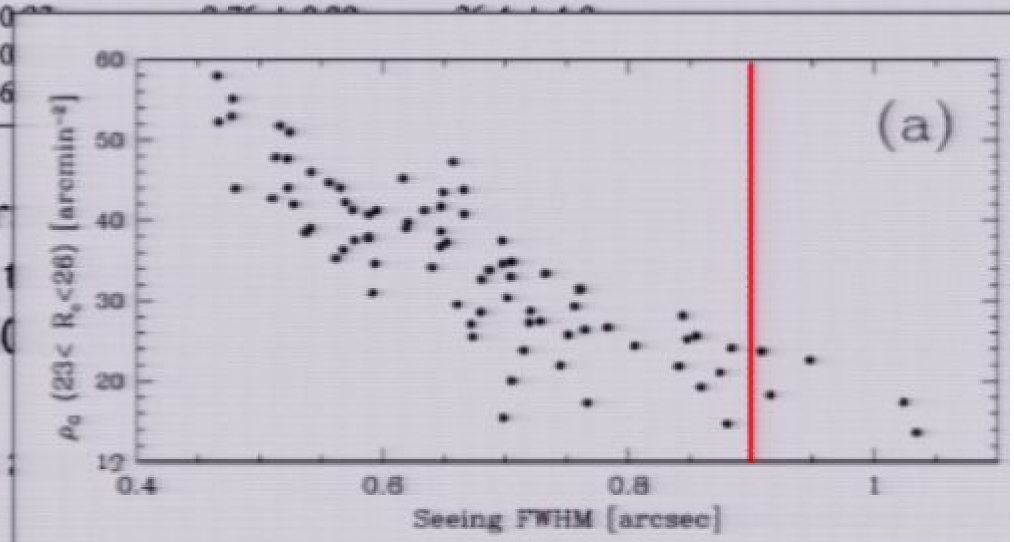
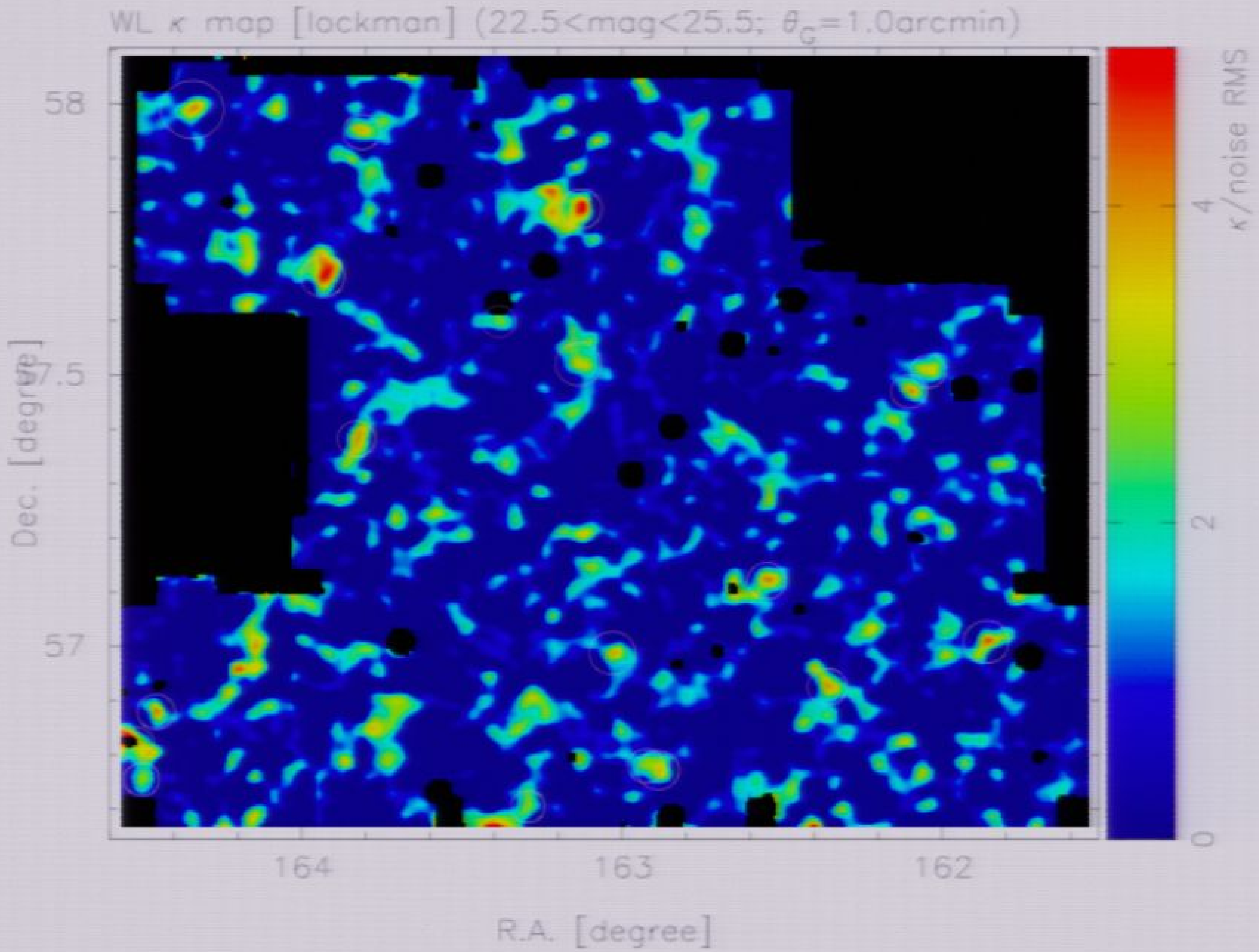
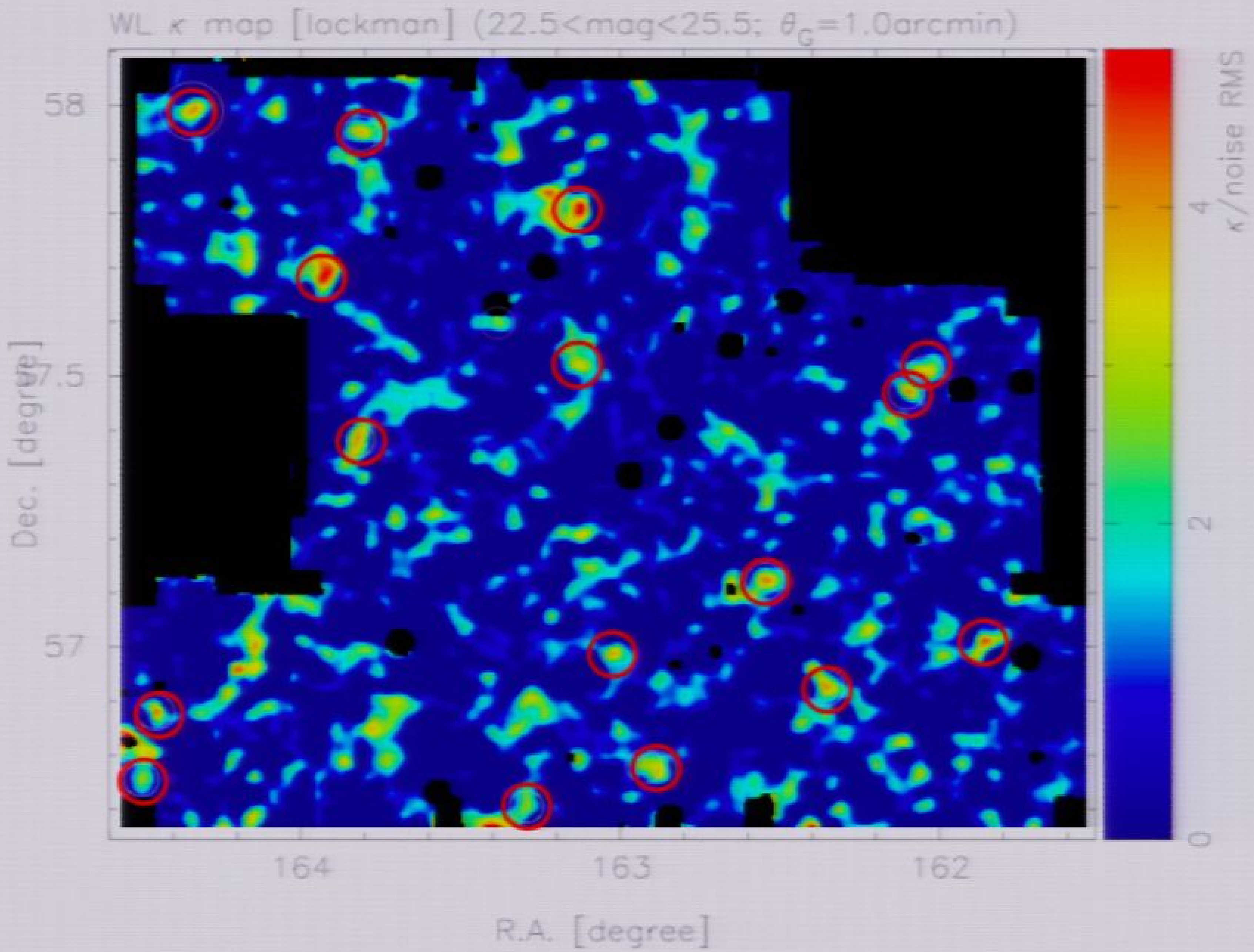




WL κ map [lockman] (22.5<mag<25.5; θ_G=1.0arcmin)
58
57.5
57
Dec. [degree]
164
163
162
R.A. [degree]
κ/noise RMS
4
2
0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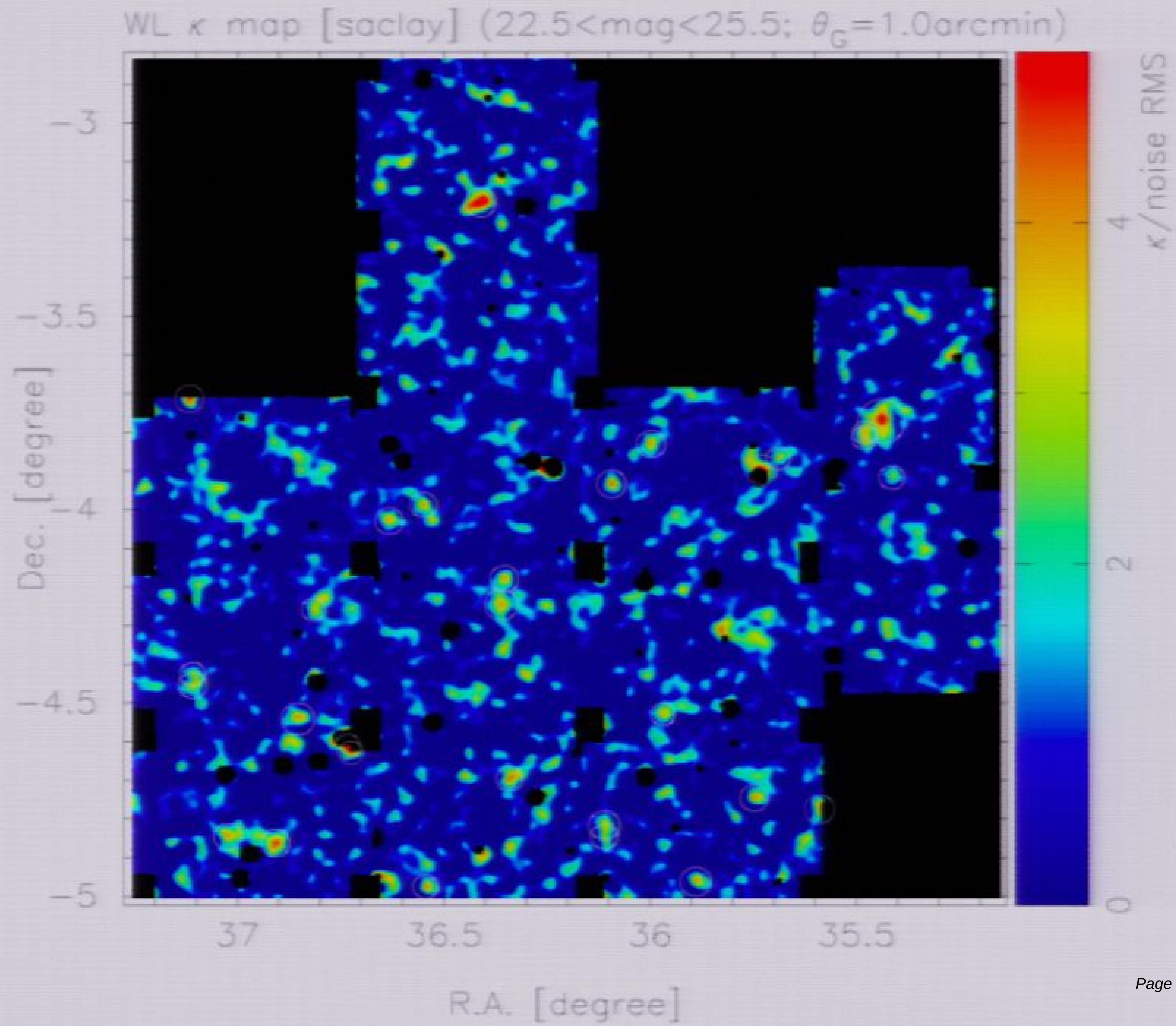
WL κ map [saclay] (22.5<mag<25.5; θG=1.0arcmin)
−3
−3.5
−4
−4.5
−5
Dec. [degree]
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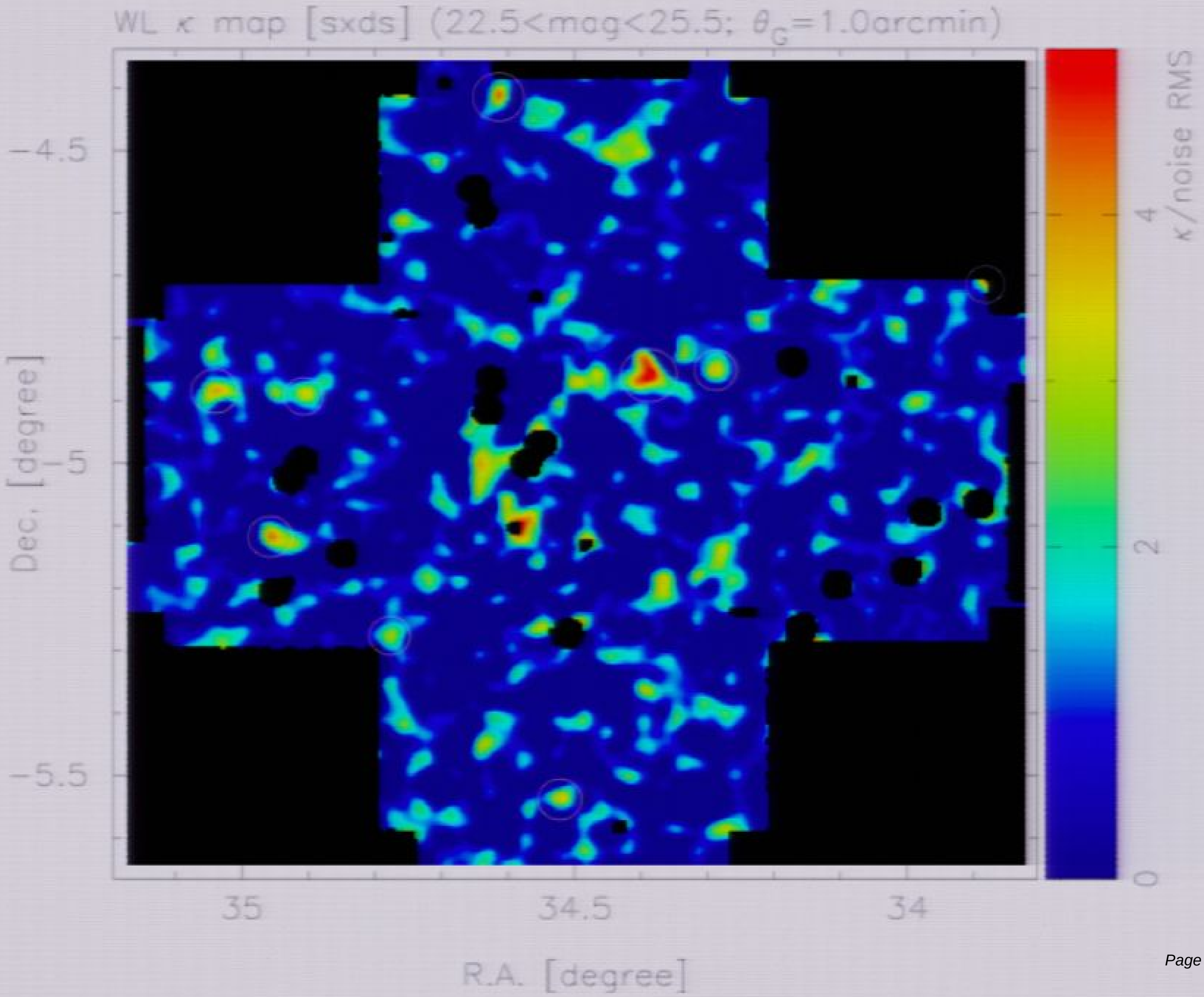
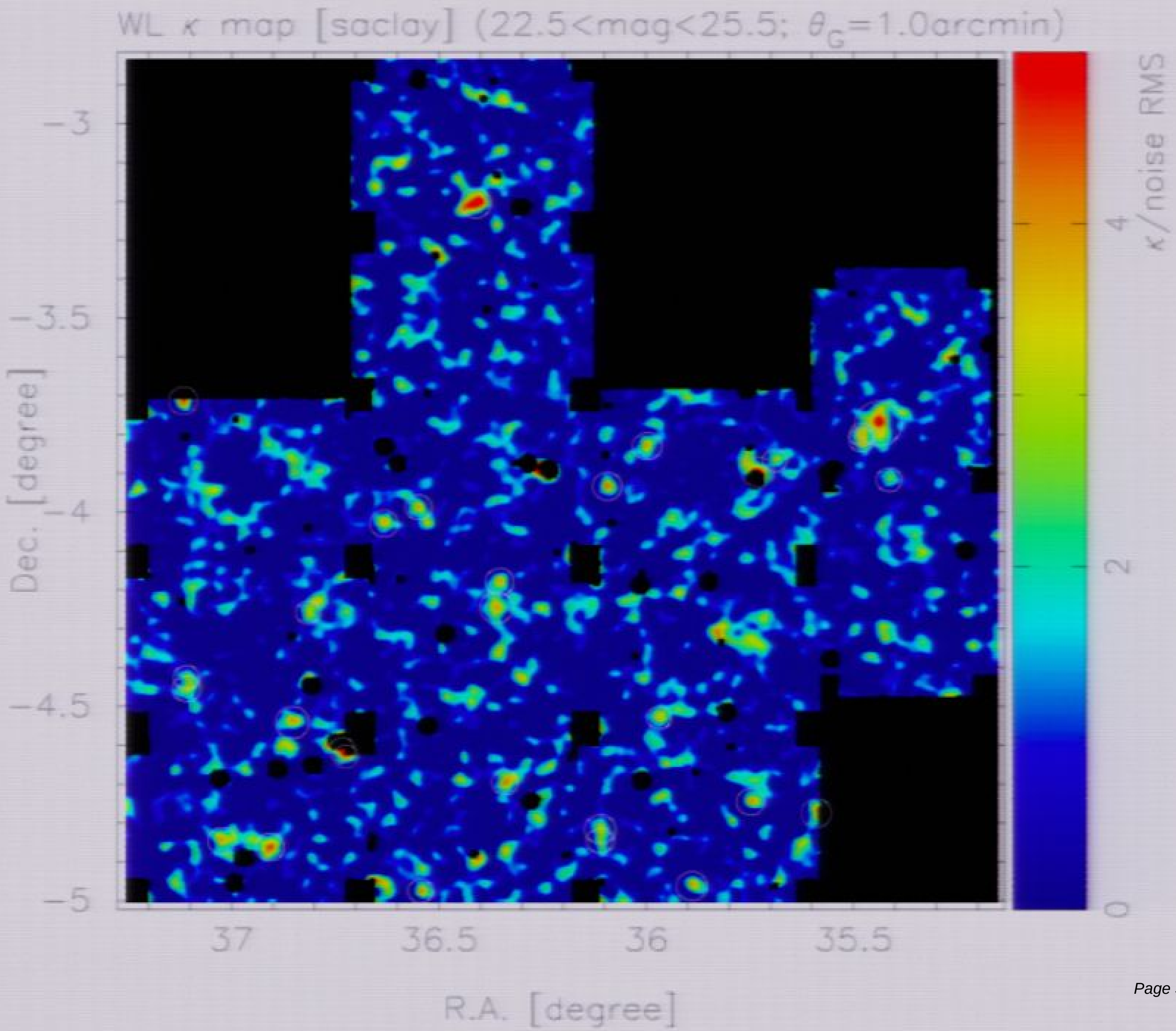
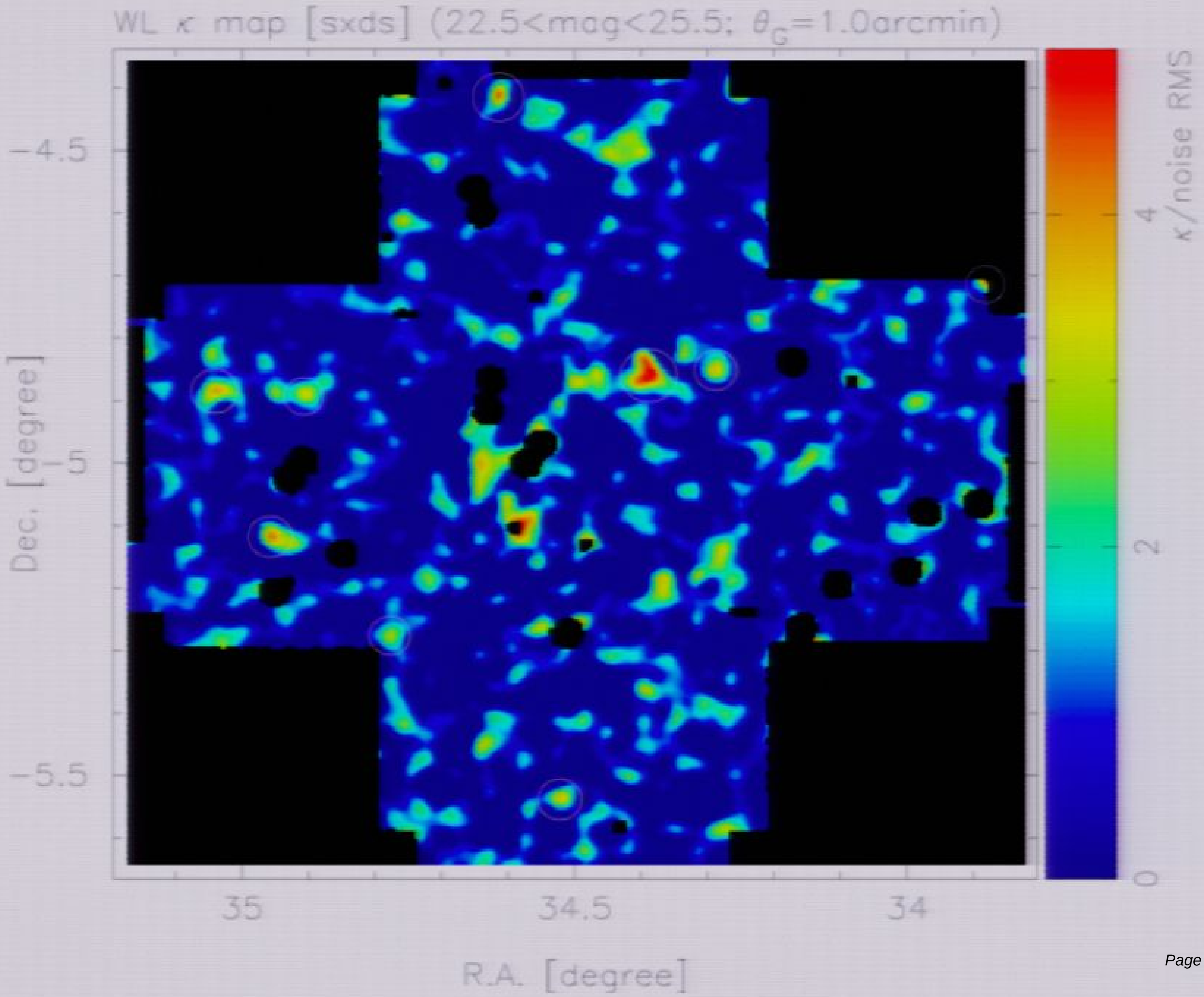
36.5
36
35.5
R.A. [degree]
0
2
4
κ/noise RMS



WL κ map [sxds] (22.5<mag<25.5; θG=1.0arcmin)
−4.5
−5
−5.5
Dec. [degree]
35
34.5
34
R.A. [degree]
κ/noise RMS
0
2
4


WL κ map [saclay] (22.5<mag<25.5; θ_G=1.0arcmin)
−3
−3.5
−4
−4.5
−5
Dec. [degree]
37
36.5
36
35.5
R.A. [degree]
κ/noise RMS
0
2
4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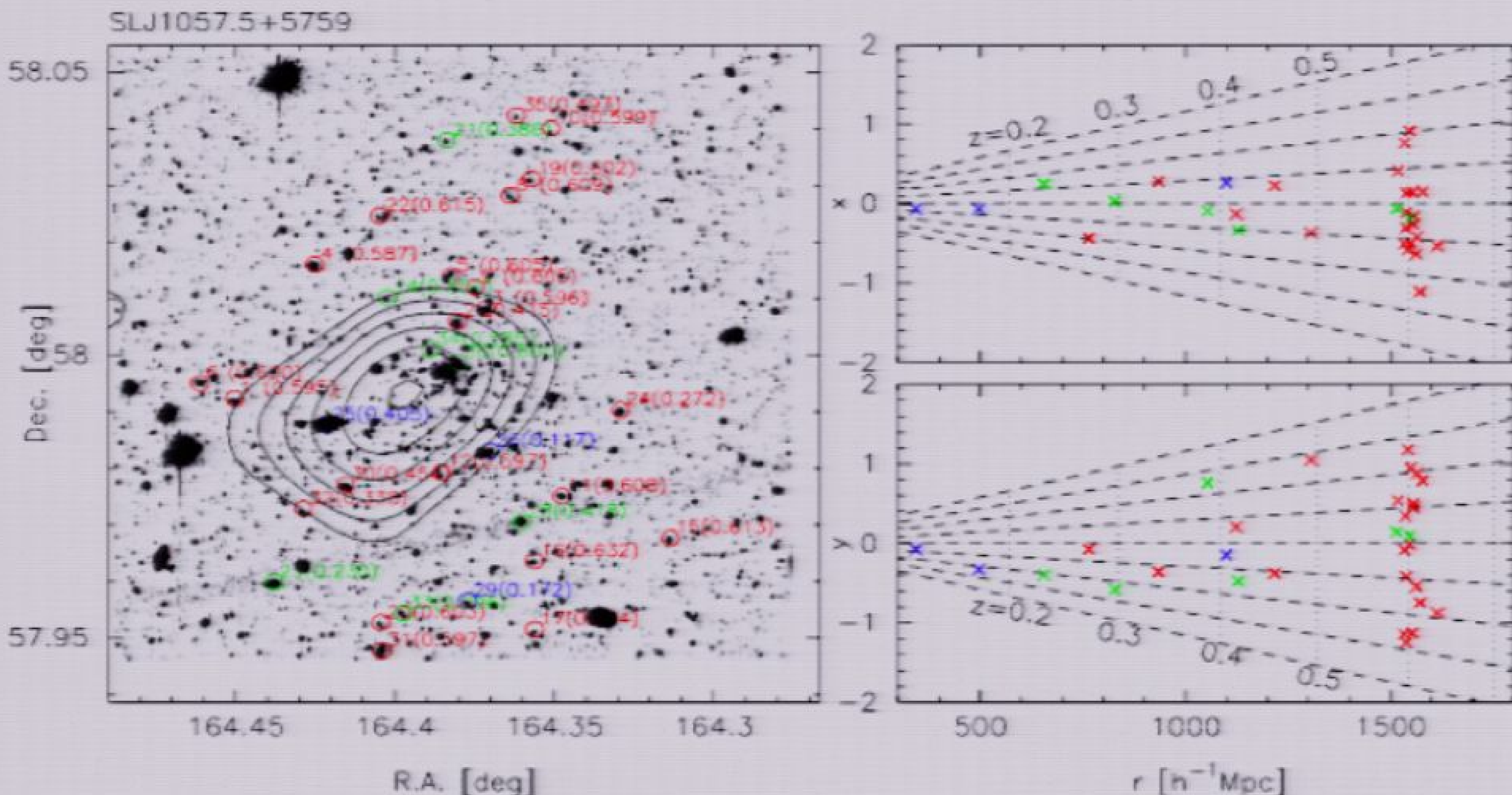
−5
−5.5
Dec. [degree]
35
34.5
34
R.A. [degree]
κ/noise RMS
4
2
0

Spectroscopic follow-up

Initial follow-up of 36 peaks with FOCAS (Hamana et al. 2009)
long-term follow up using LRIS on Keck (Green et al. 2010)



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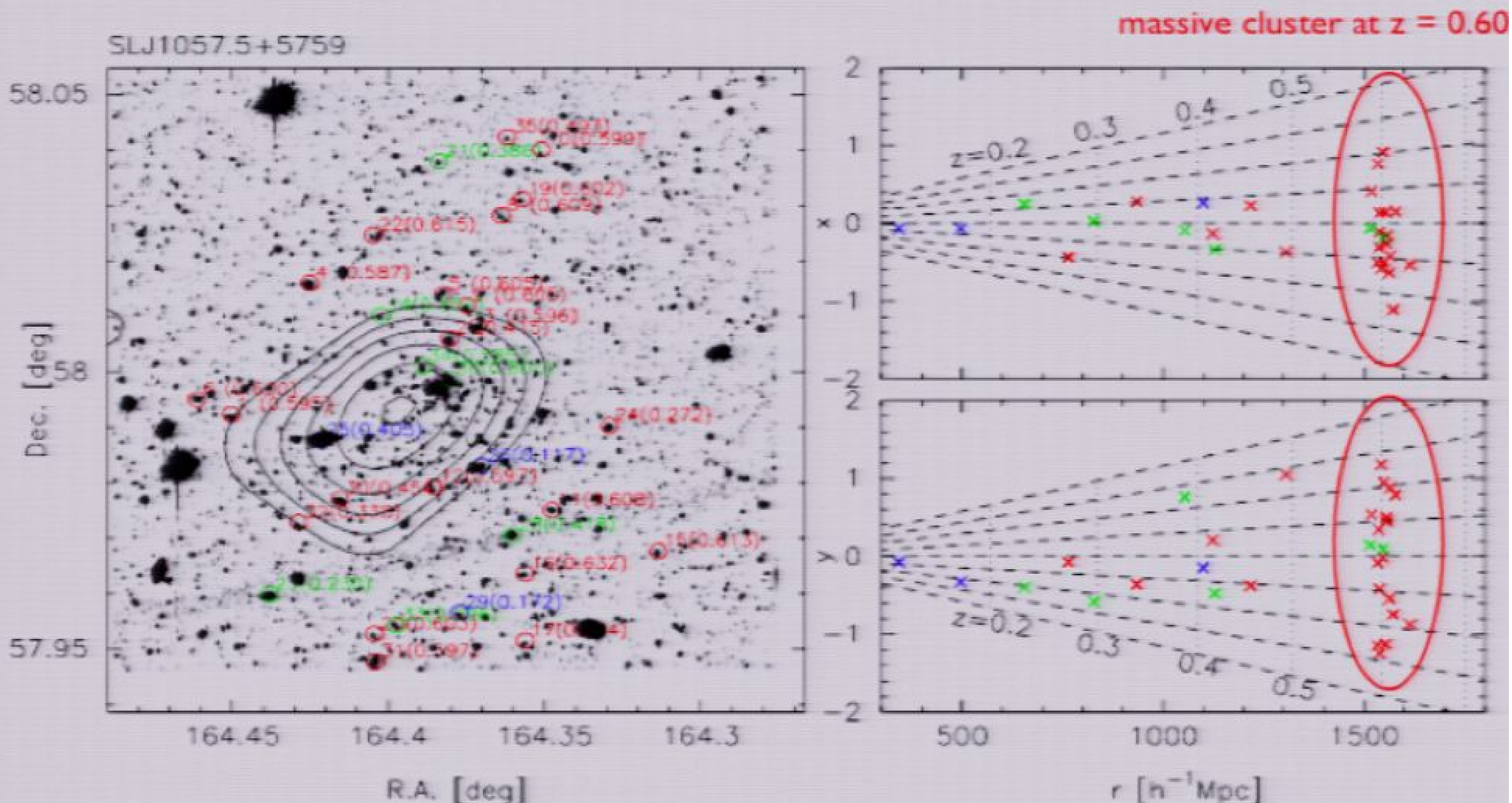

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Get lensing mass estimates,
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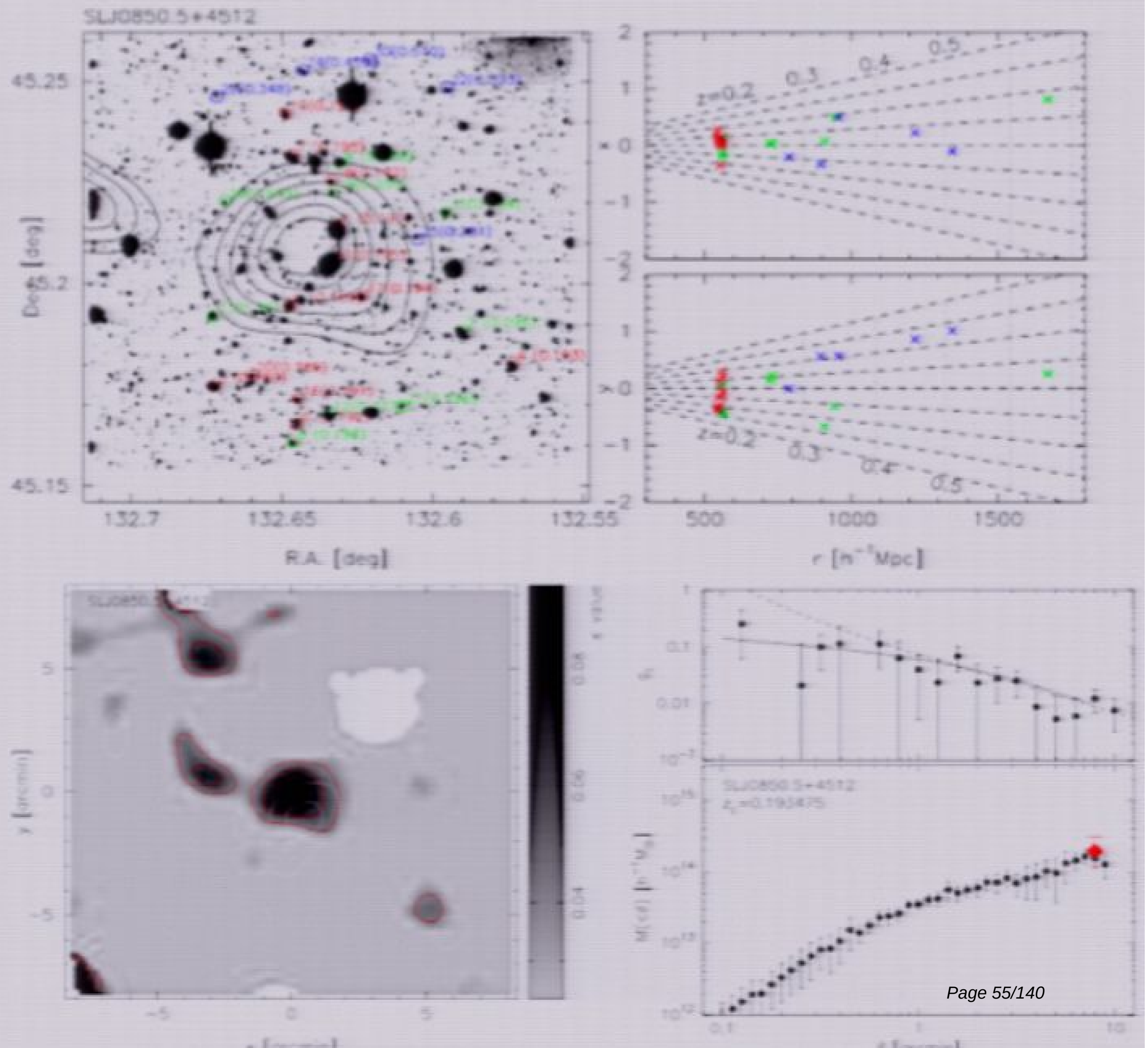

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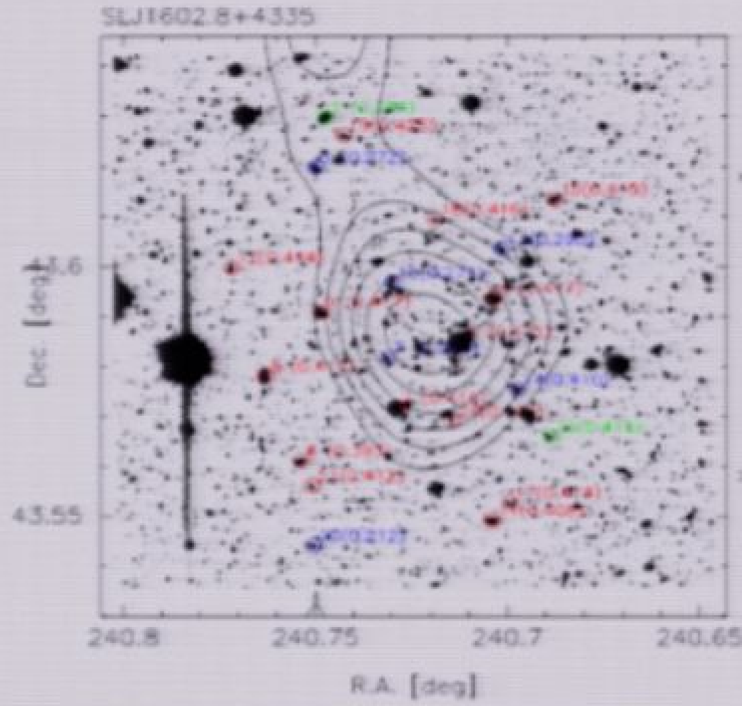

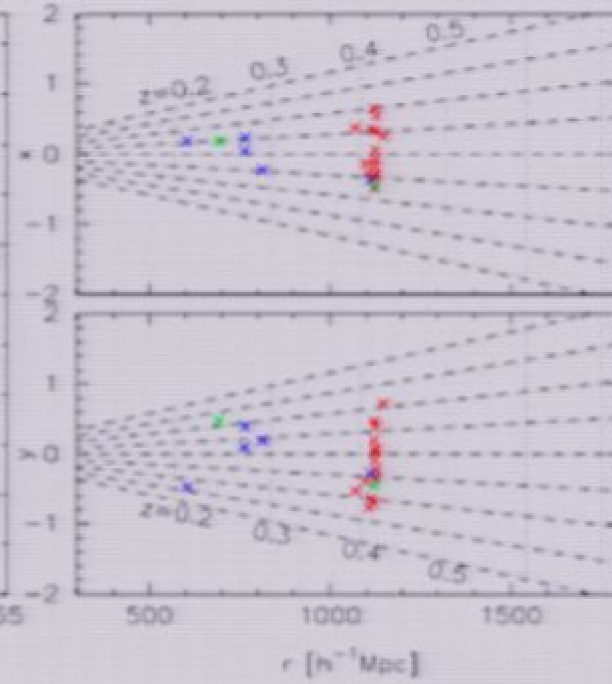

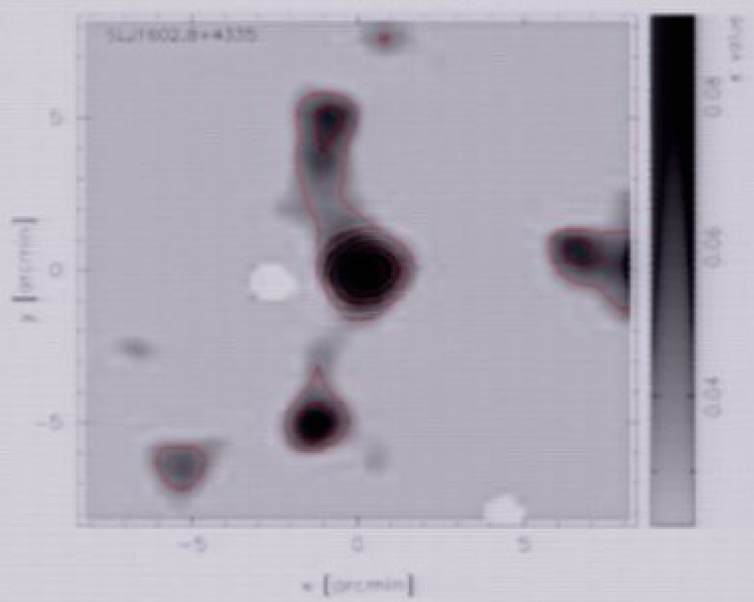

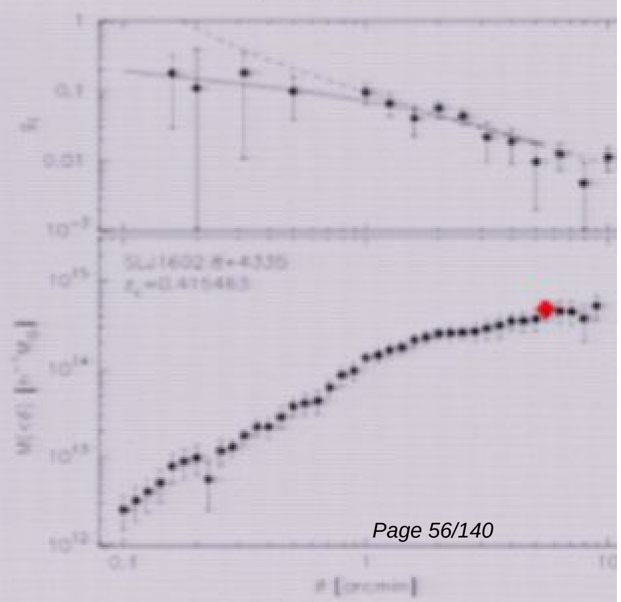

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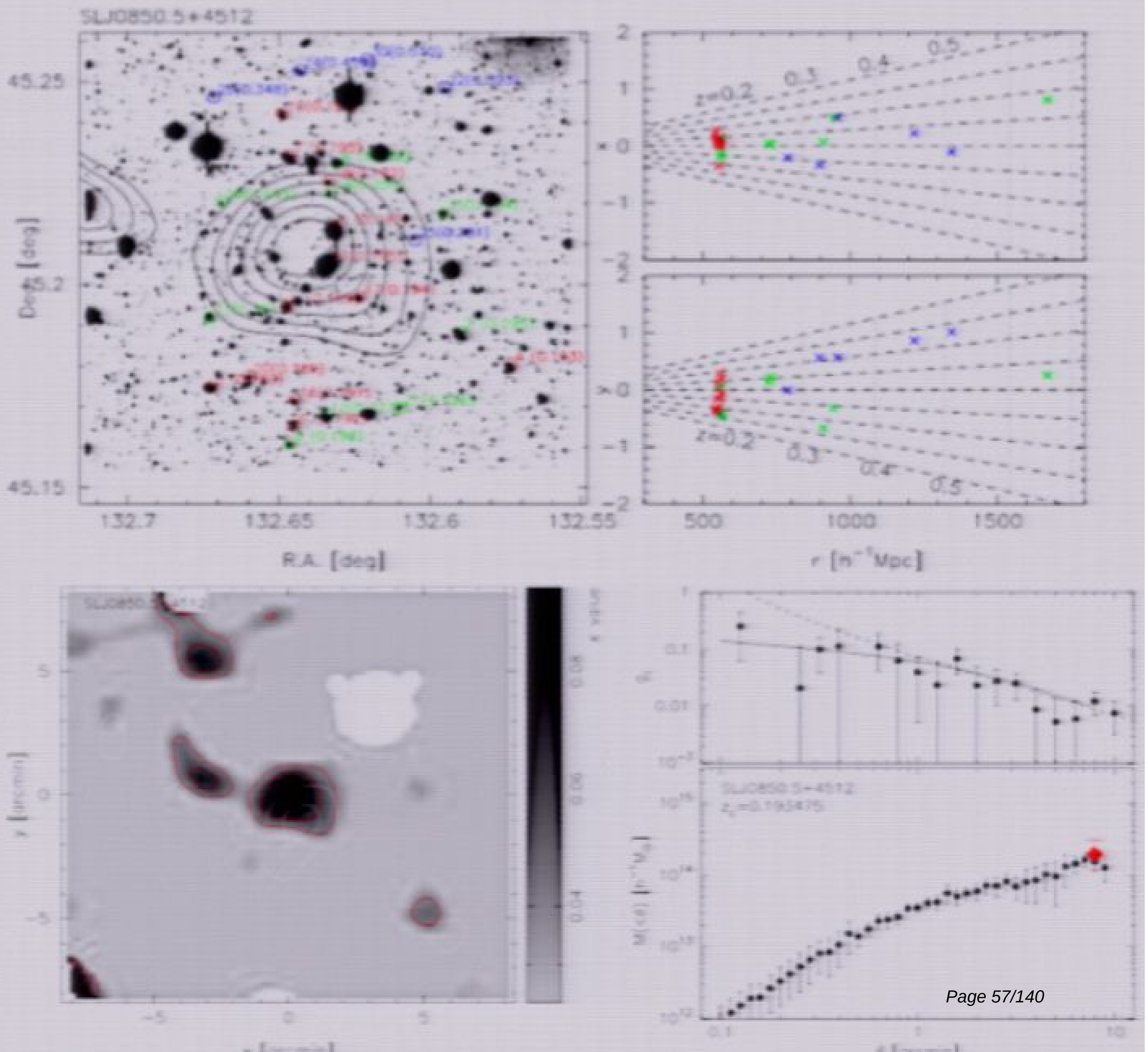

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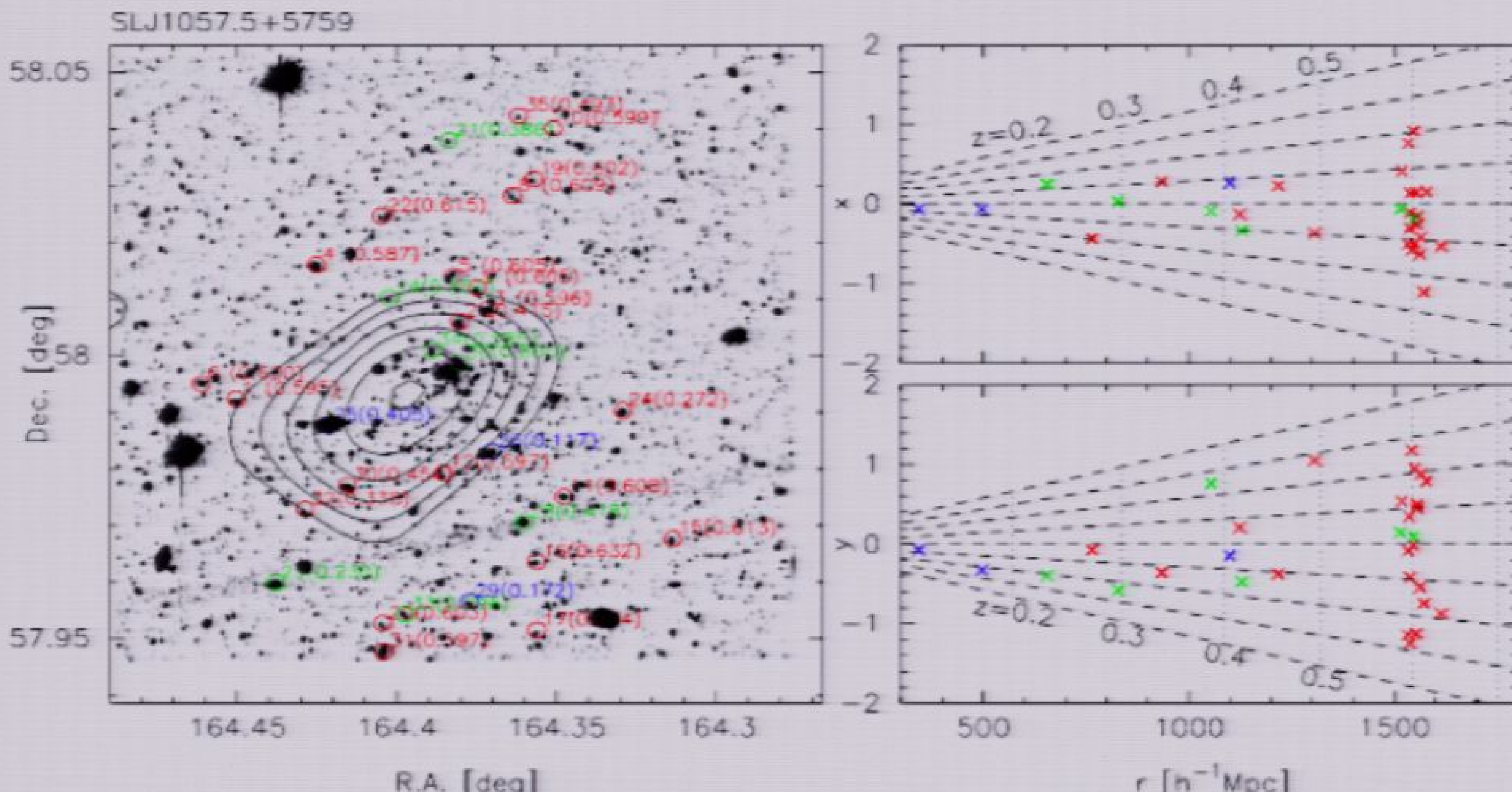

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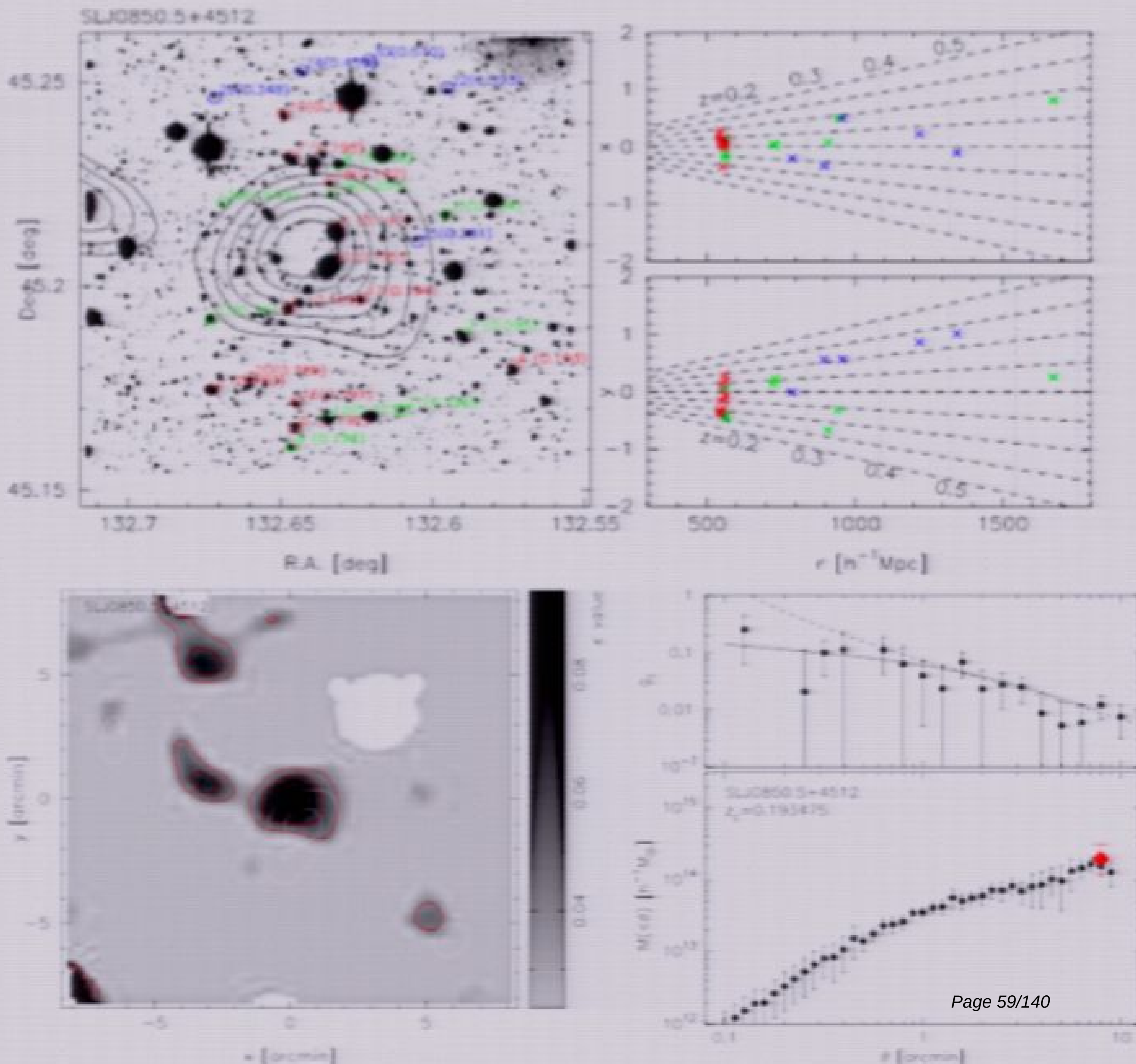

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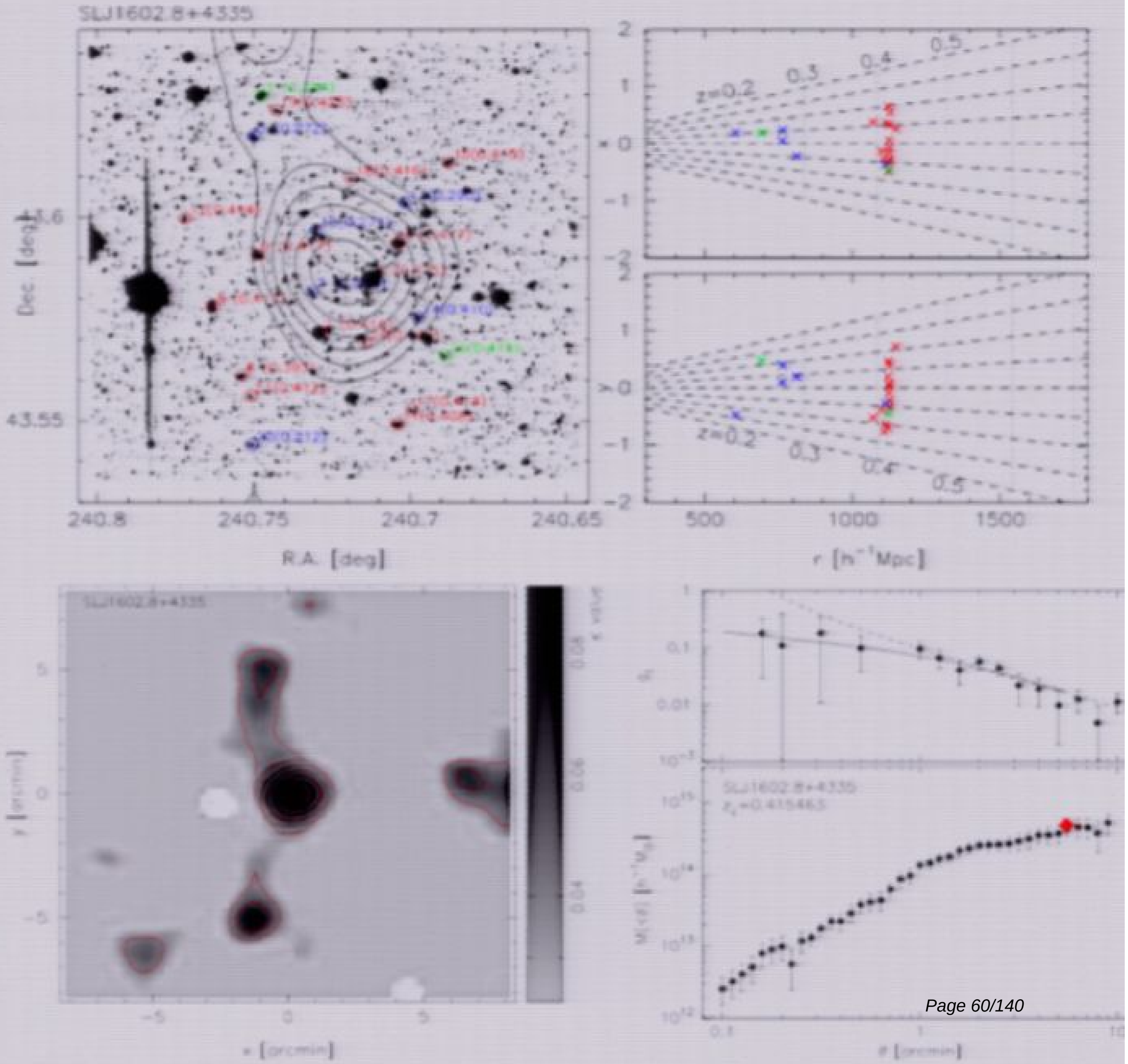

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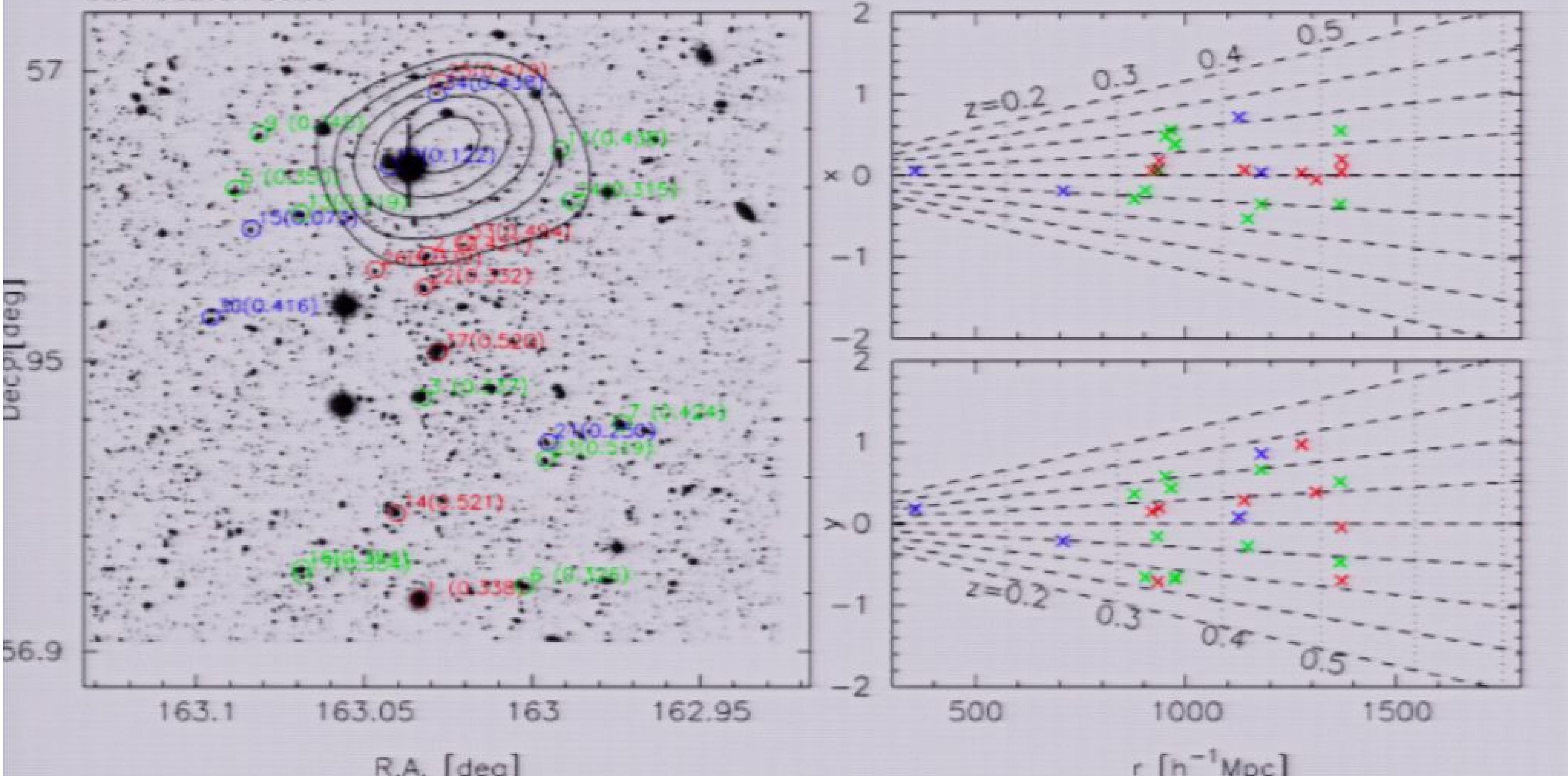
NB: Not all peaks correspond to a single massive cluster; some consist of 2 or more projected groups

SLJ1052.0+5659



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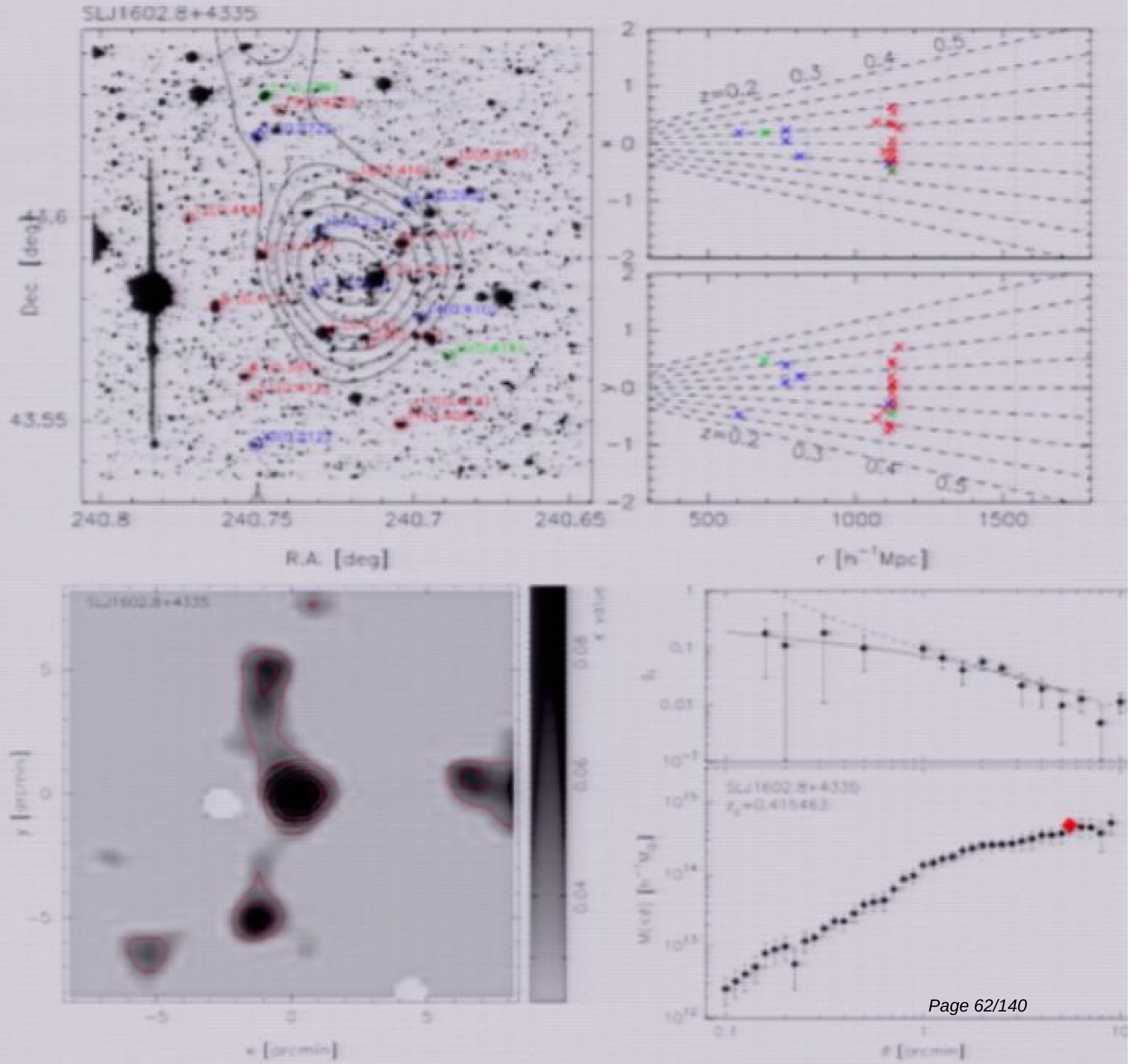

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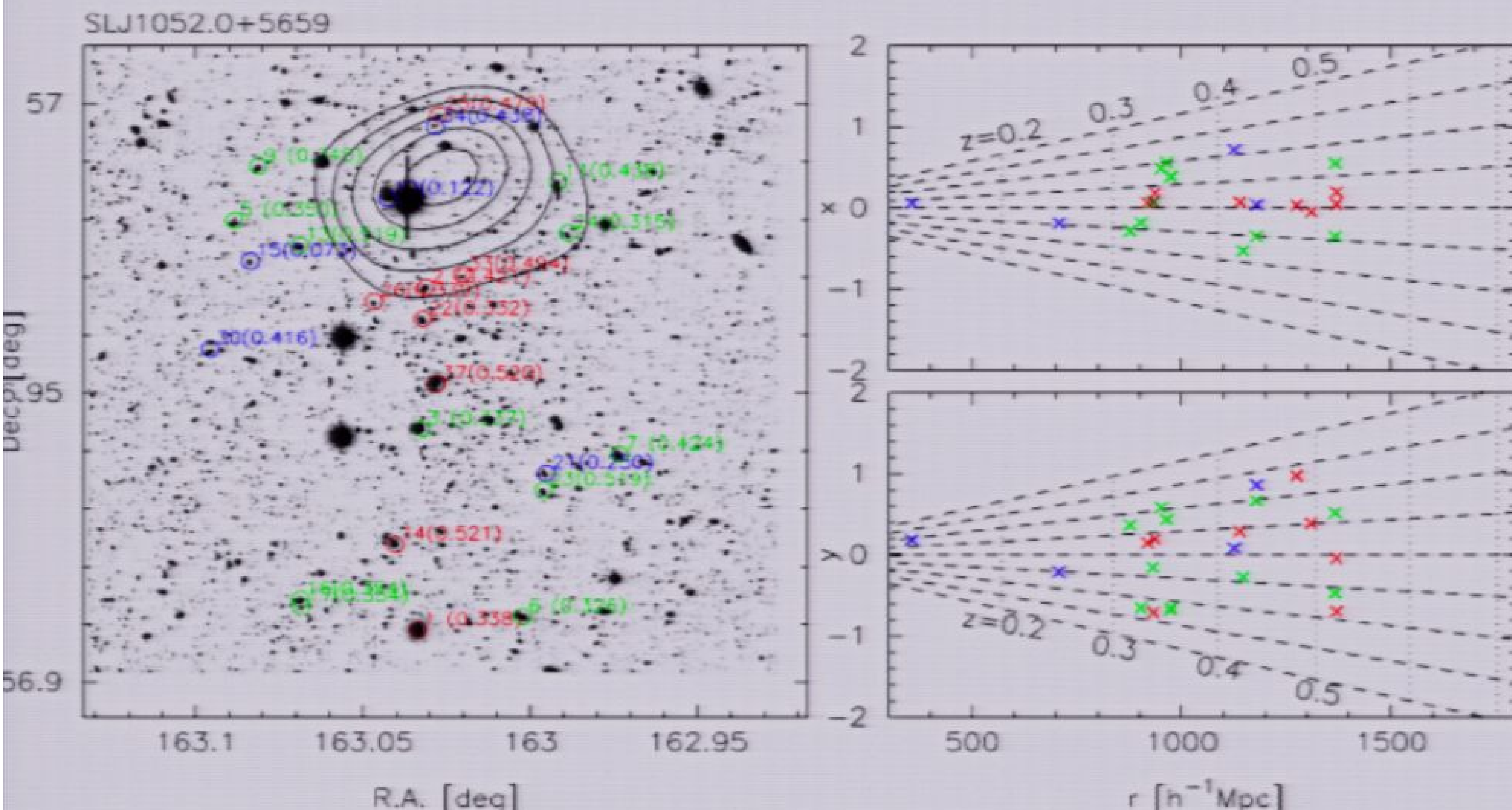
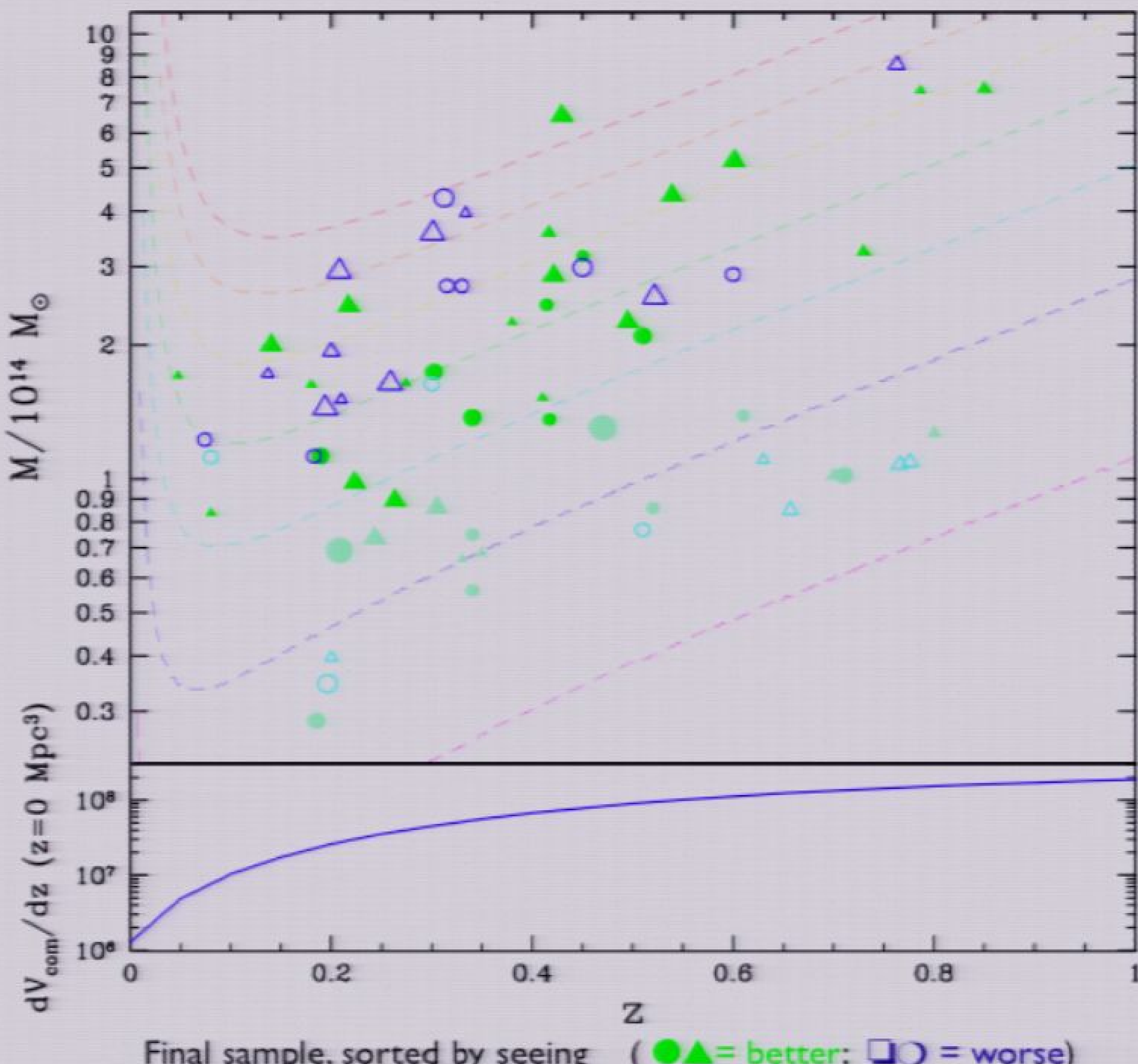
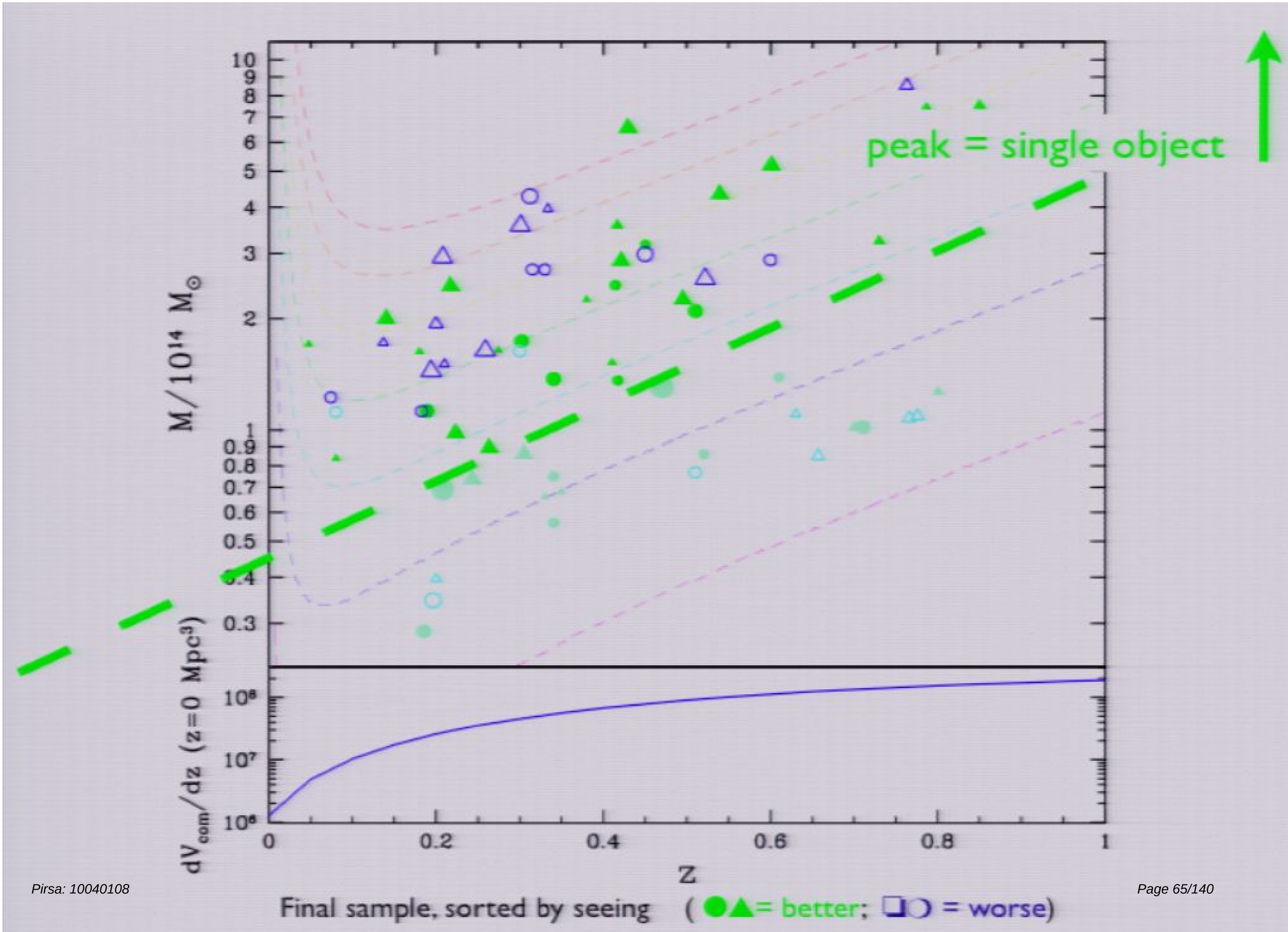




M/10¹⁴ M☉
dV_com/dz (z=0 Mpc³)
z
Final sample, sorted by seeing (●▲= better; ❏○ = worse)



peak = single object
M/10^14 M⊙
dV_com/dz (z=0 Mpc³)
z
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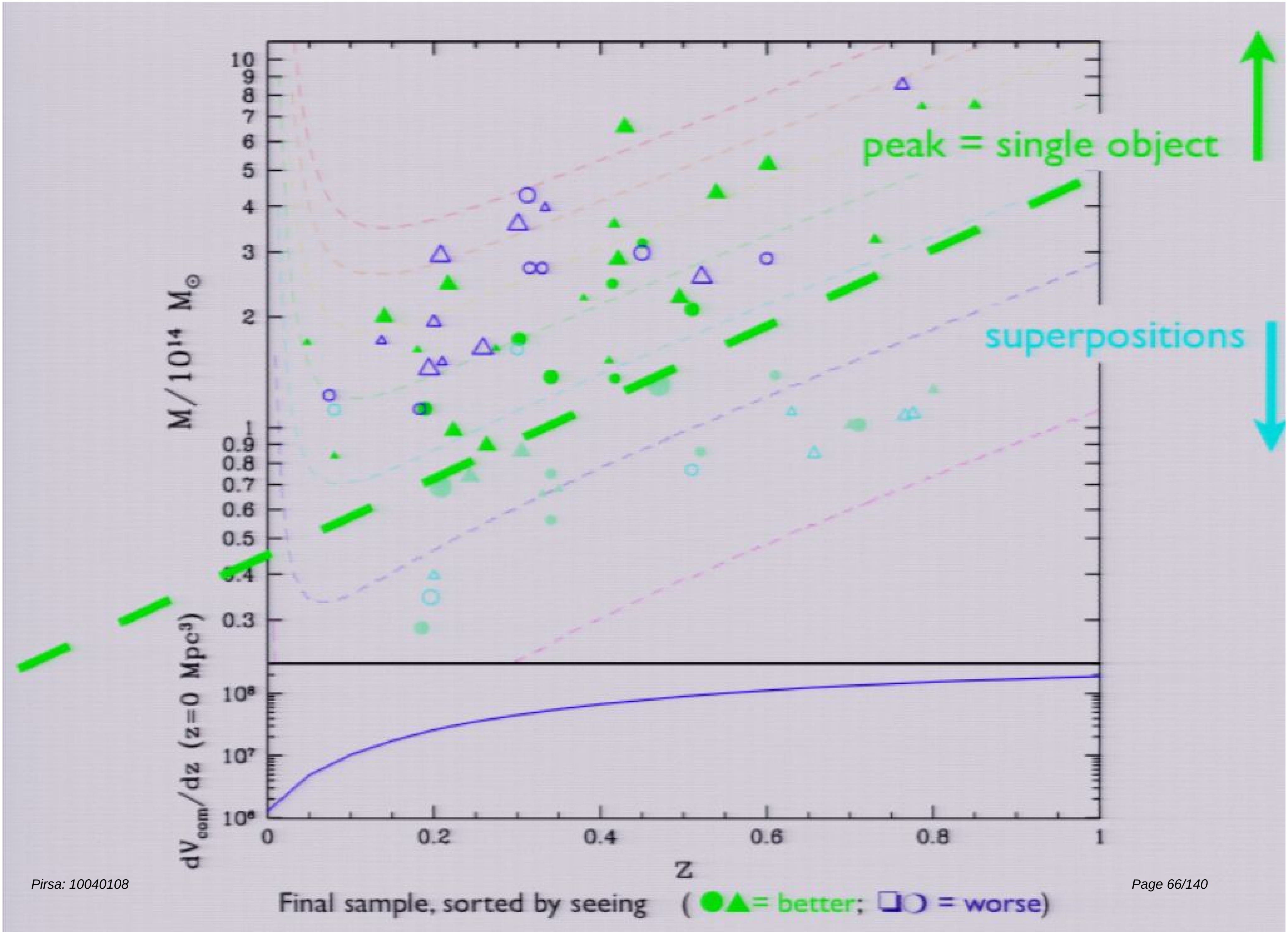

peak = single object
superpositions
M/10¹⁴ M☉
dV_com/dz (z=0 Mpc³)
z
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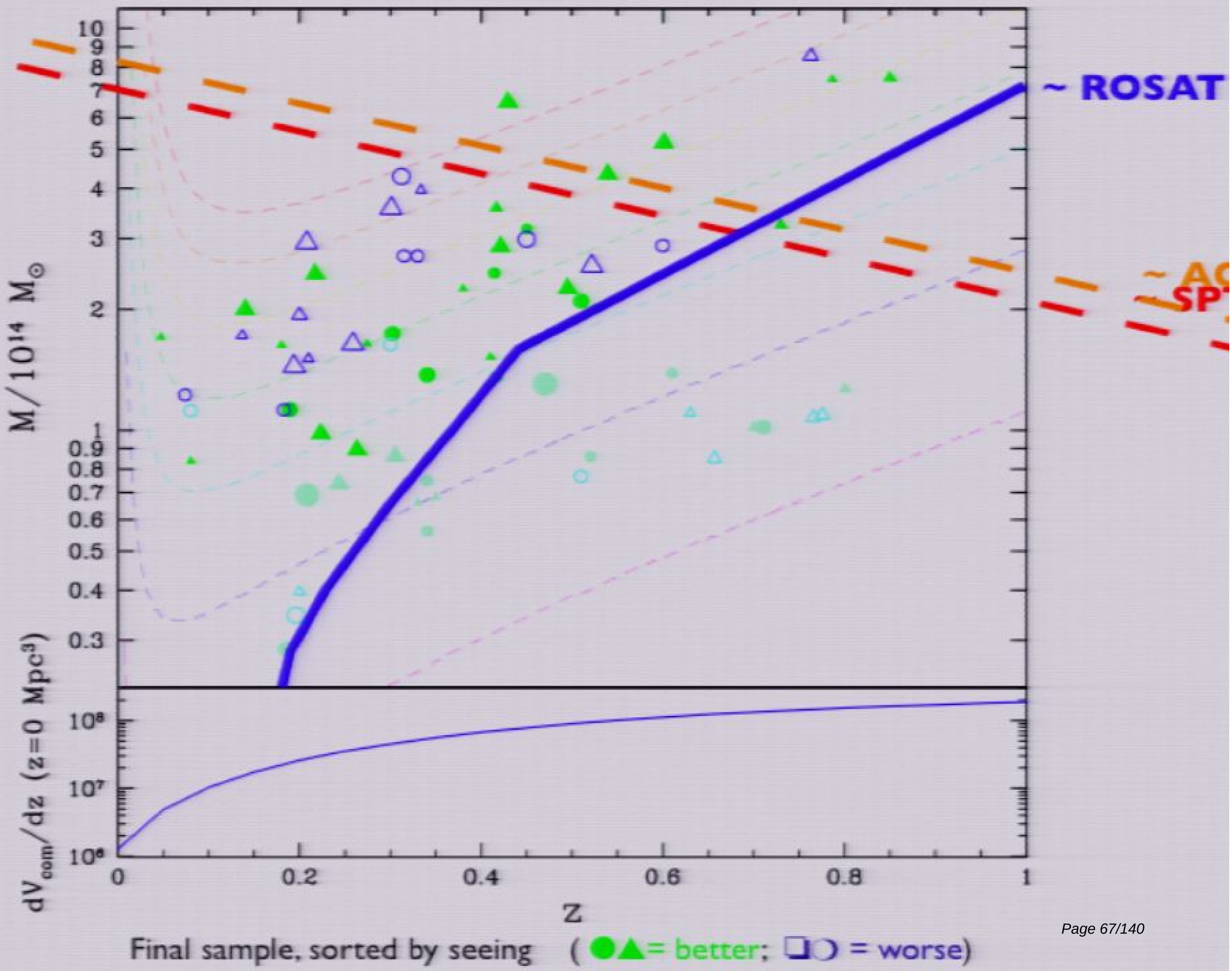

~ ROSAT
~ AC
~ SP
M/10^14 M_⊙
dV_com/dz (z=0 Mpc^3)
z
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Some observational complications...

- ✱ variable seeing (field-to-field; within fields) ⇒ noise varies by ~ 50%

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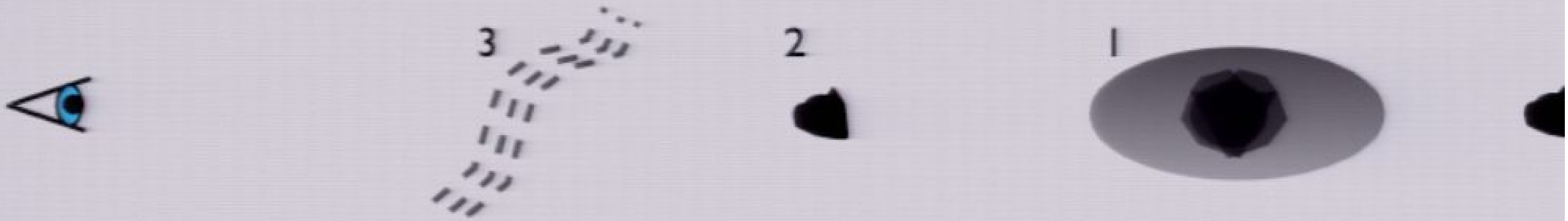
Some physical complications...



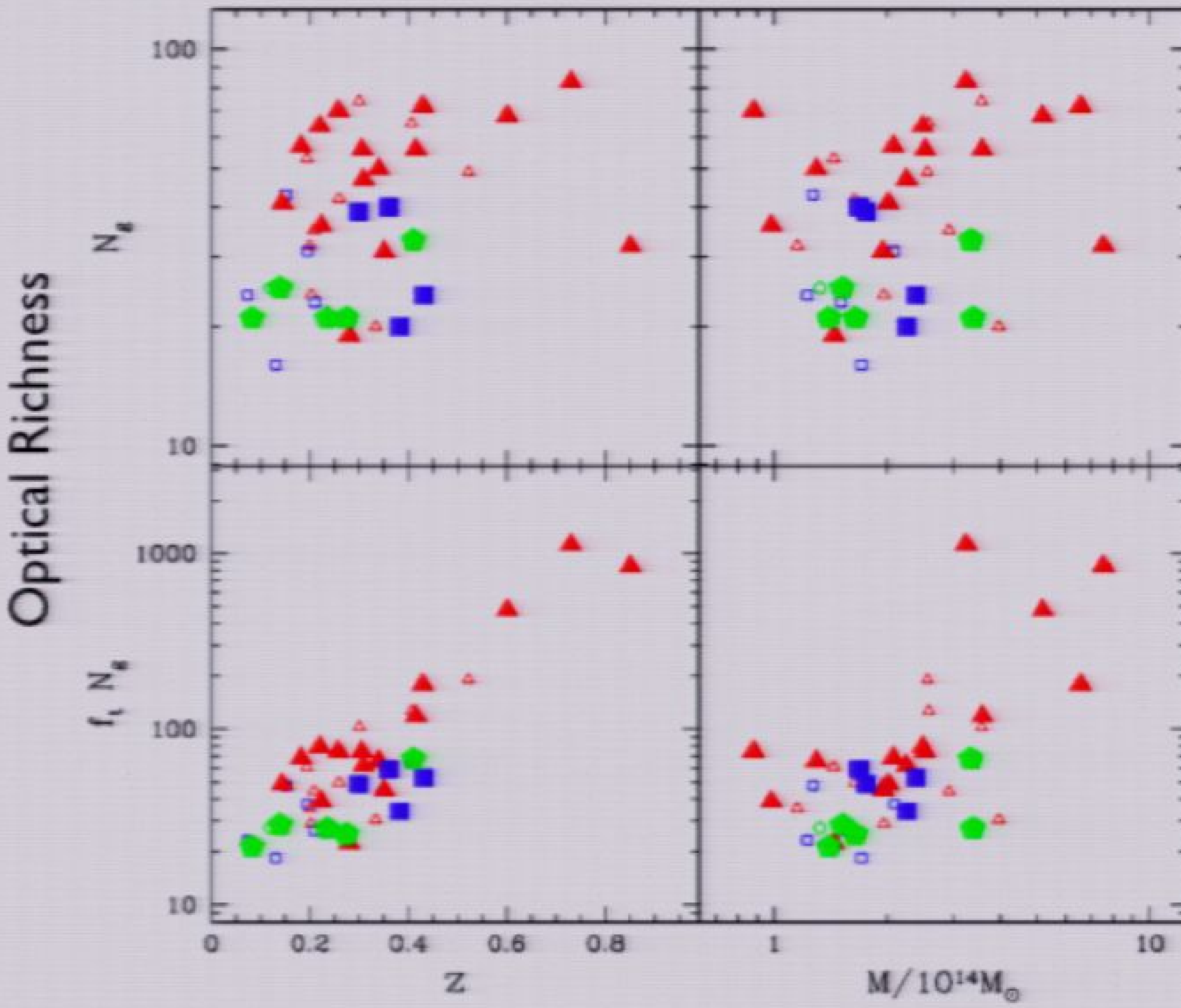
* projection effects:
  1. correlated/local,
  2. uncorrelated halos,
  3. uncorrelated LSS

  (Metzler et al. 1999, 2001; White et al. 2001; Hennawi & Spergel 2005; dePutter 2004)
  (Hoekstra et al. 2001; Hoekstra 2003; Dodelson 2004)

* variations in cluster shape, concentration, substructure
  (e.g. Brainerd1999; King et al. 2001)

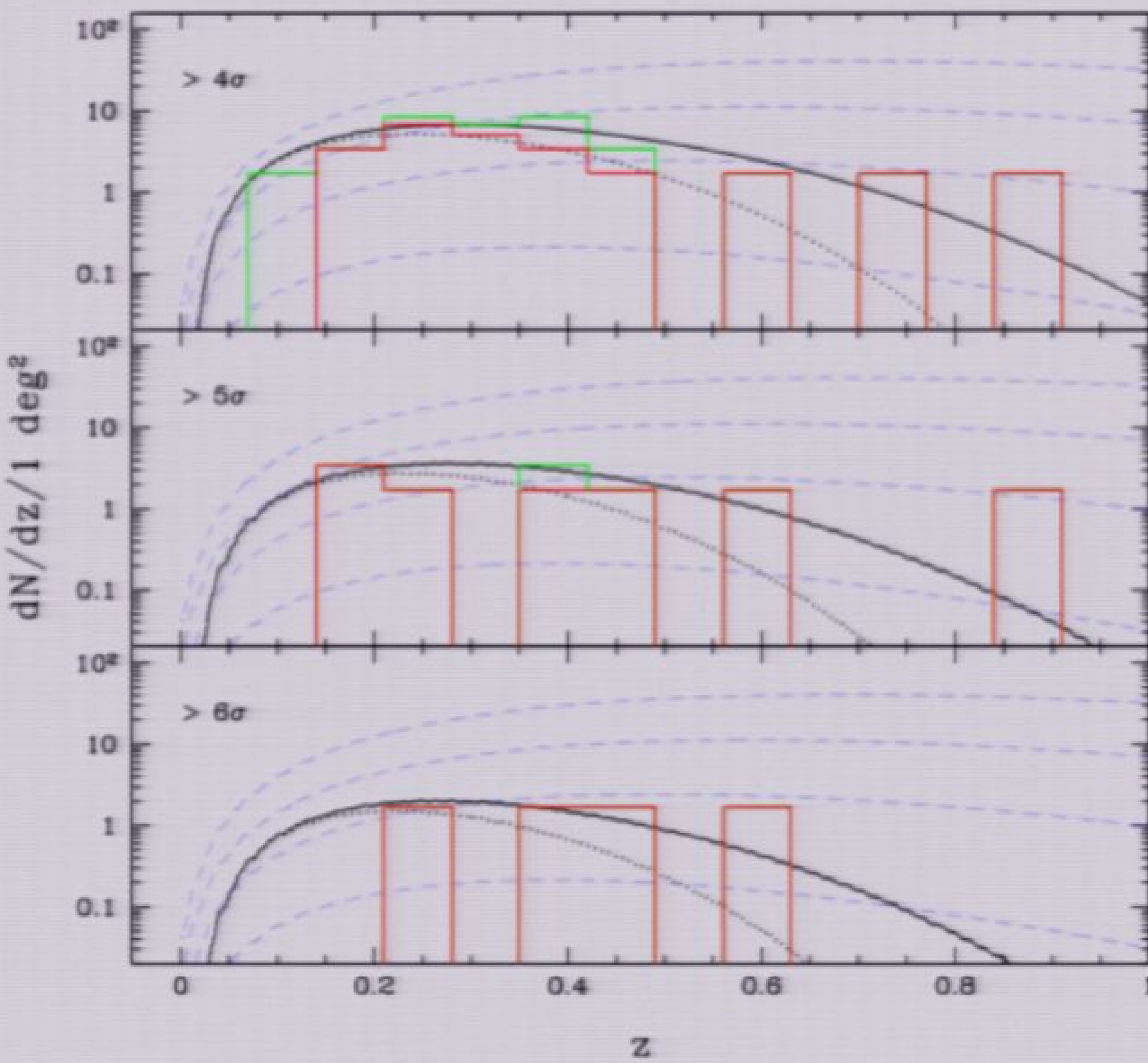
* dilution (e.g. Medezinski et al. 2007, 2008)

Tests: optical richness



Correlation with optical richness: raw (top panels) & corrected (bottom panels)

Tests: redshift distribution



Redshift distribution (histograms) versus theory (solid & dotted curves)

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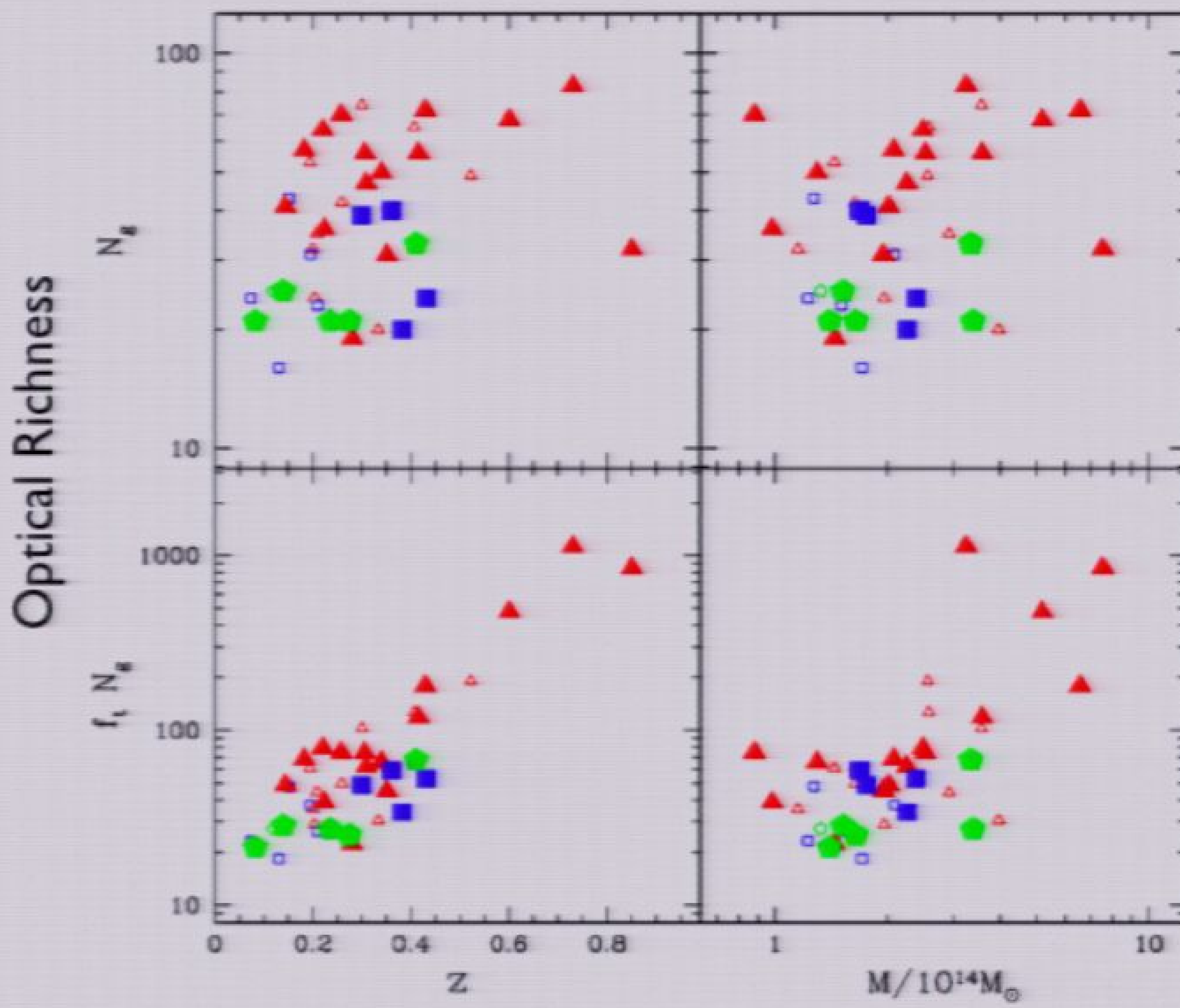

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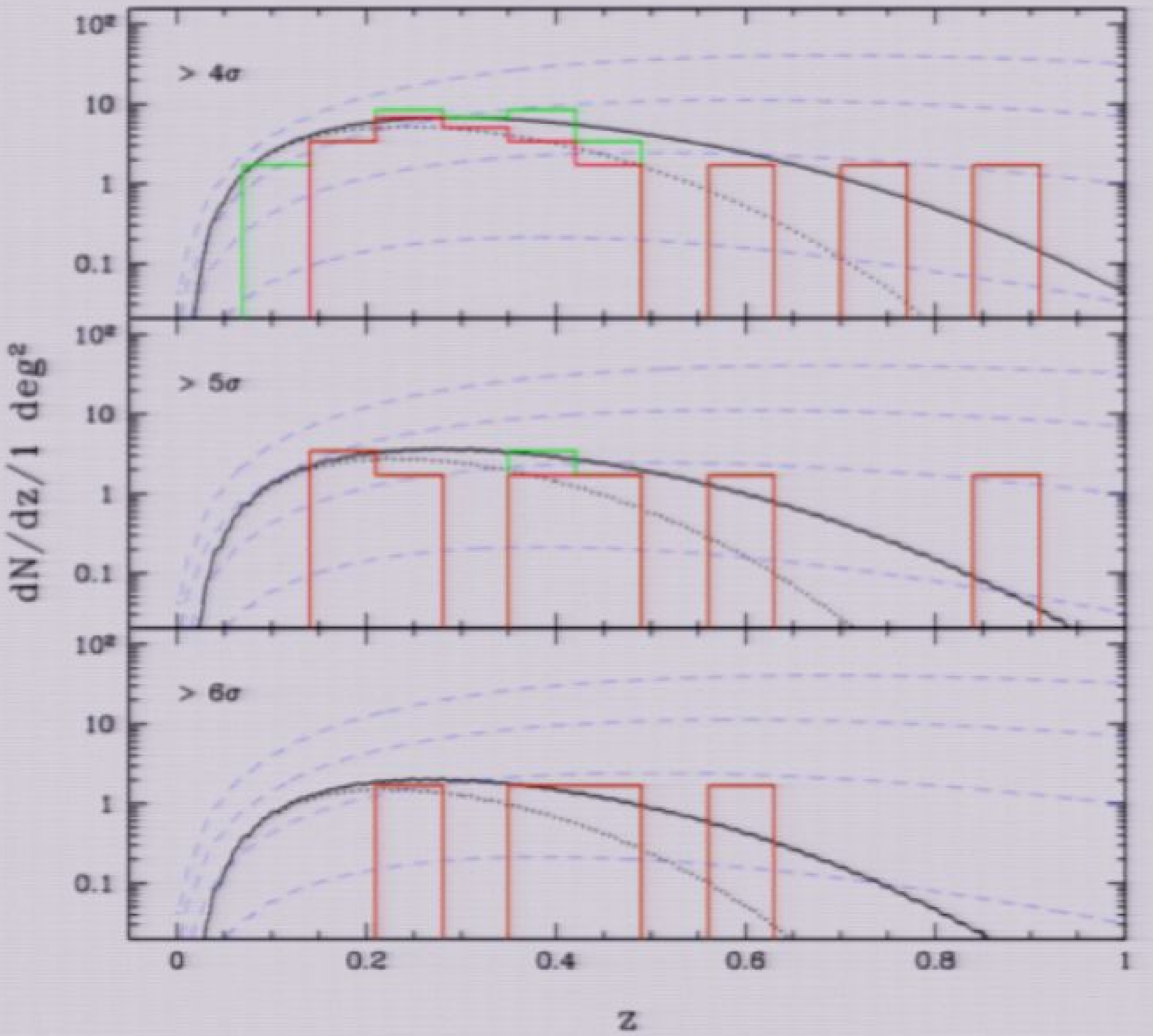
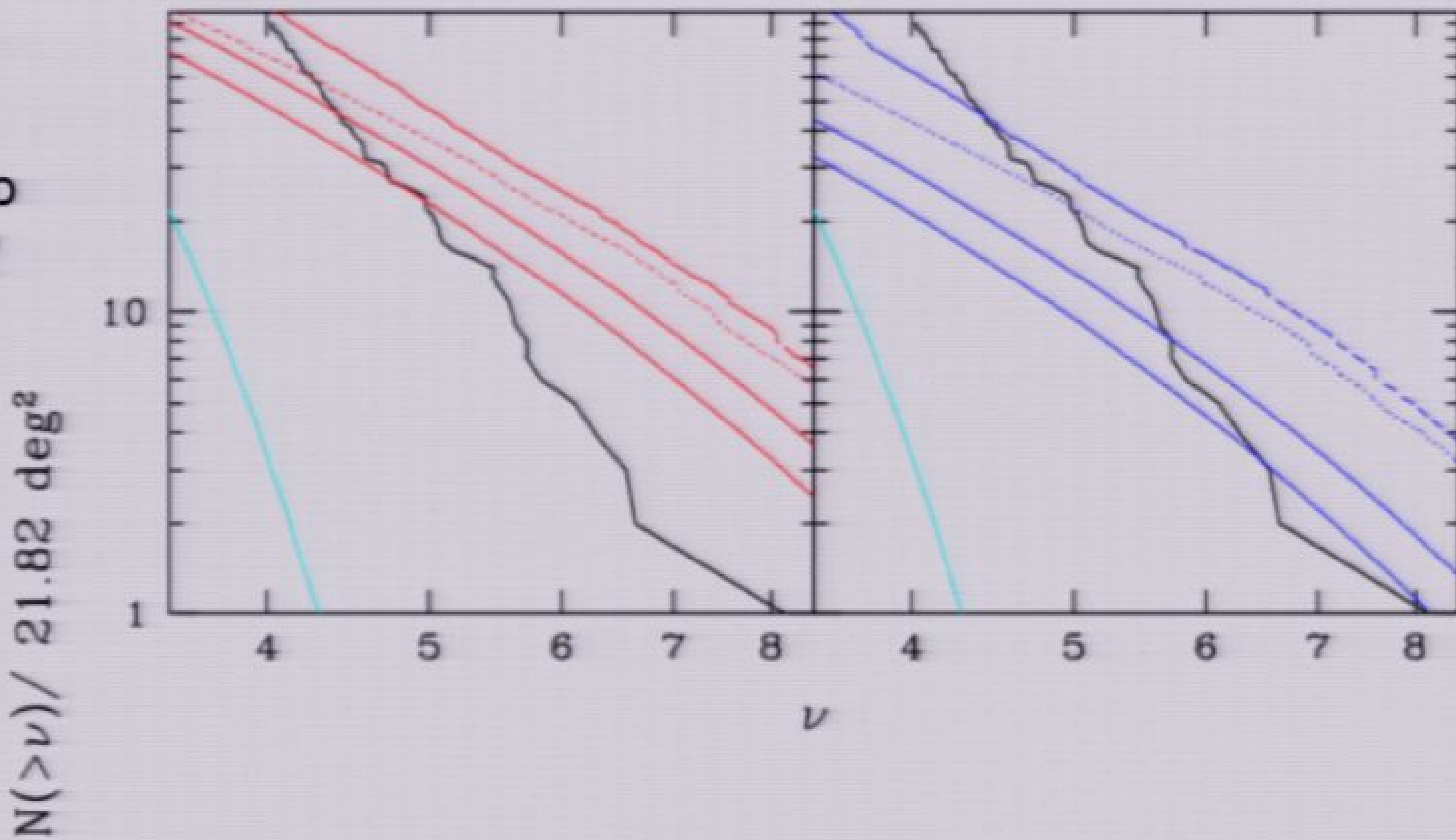


Redshift distribution (histograms) versus theory (solid & dotted curves)

So how many peaks do we find?



Measured peak height distribution distribution (black) versus theory (red, blue)
(cyan - pure noise component)

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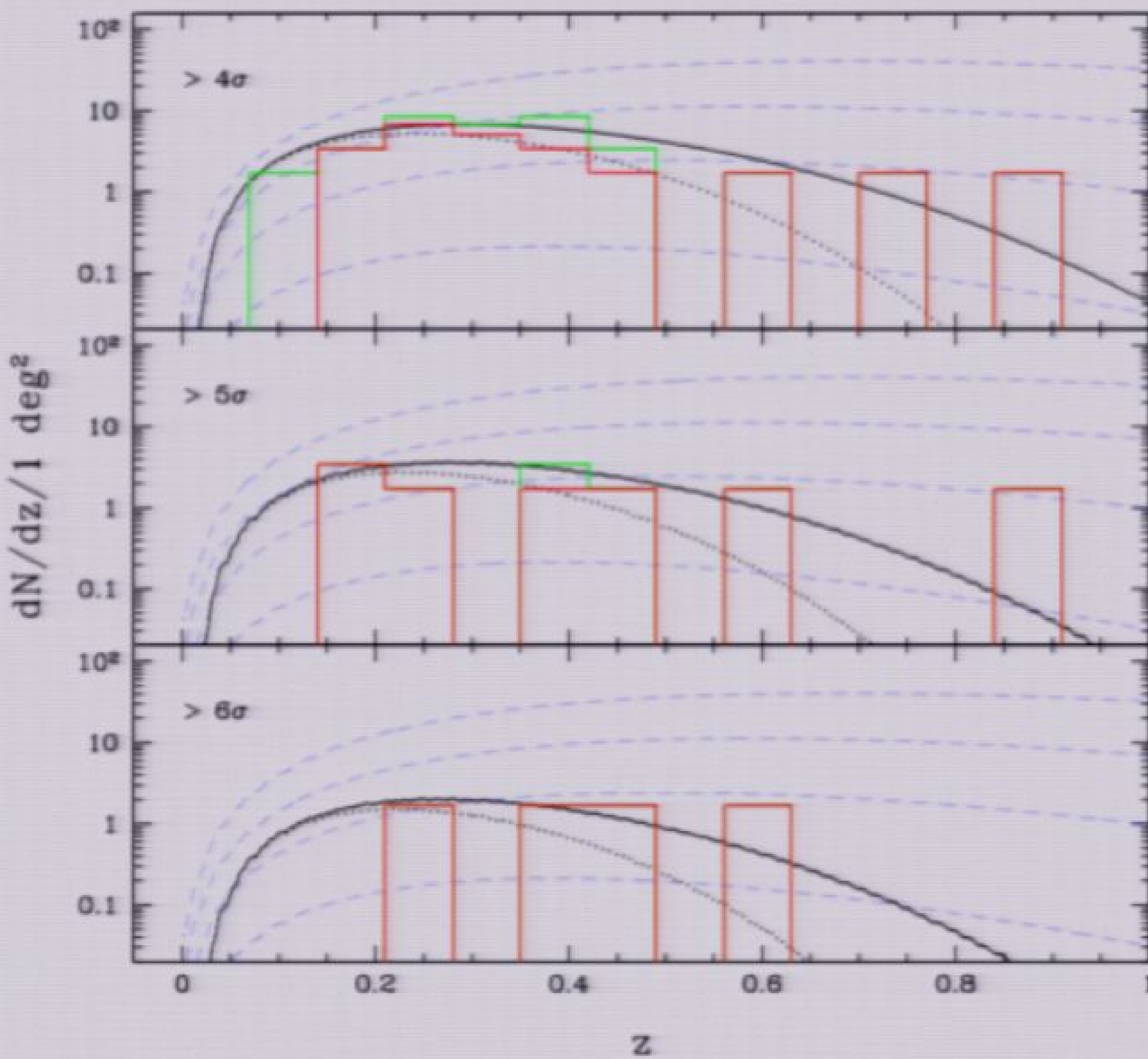

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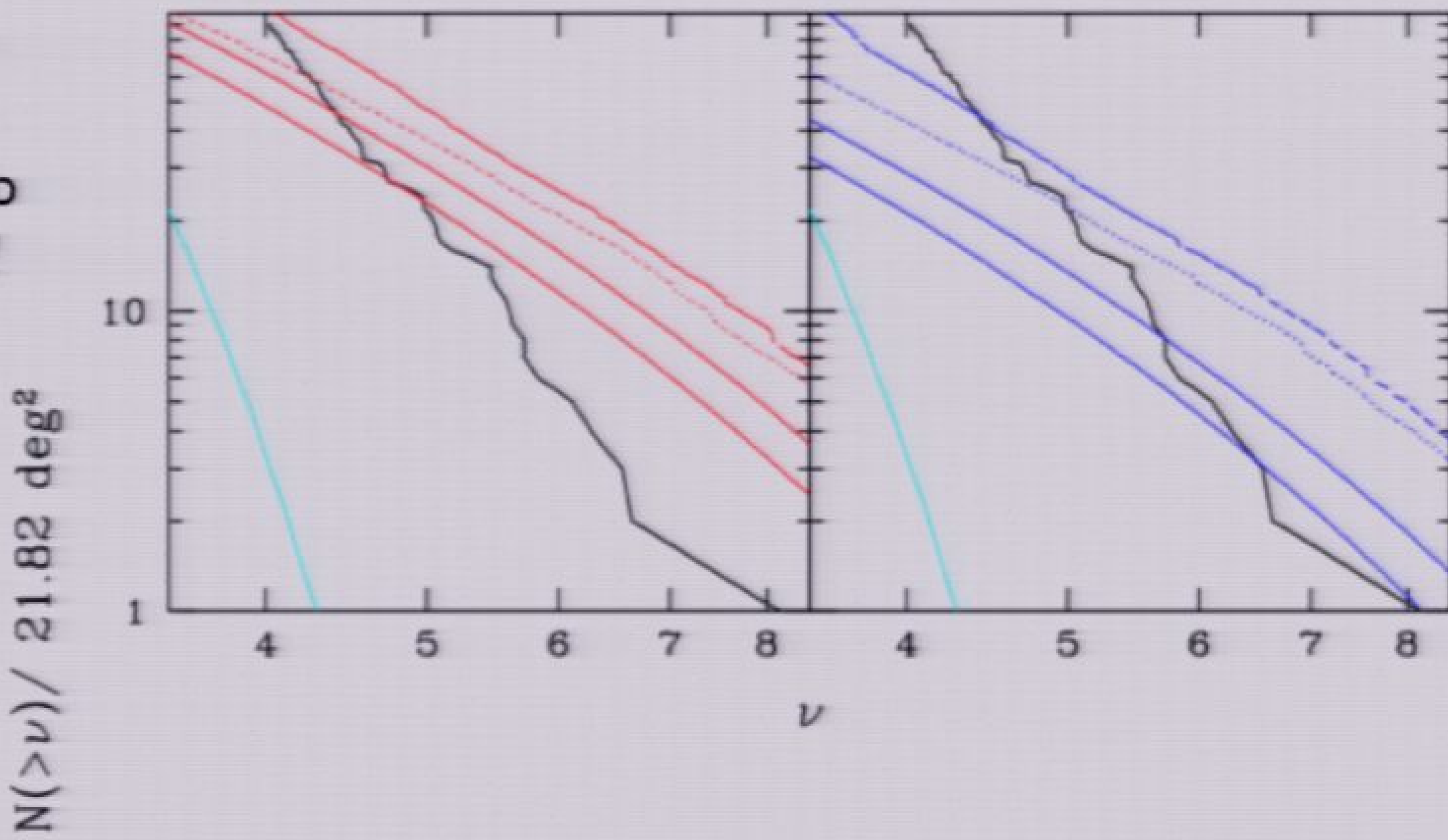

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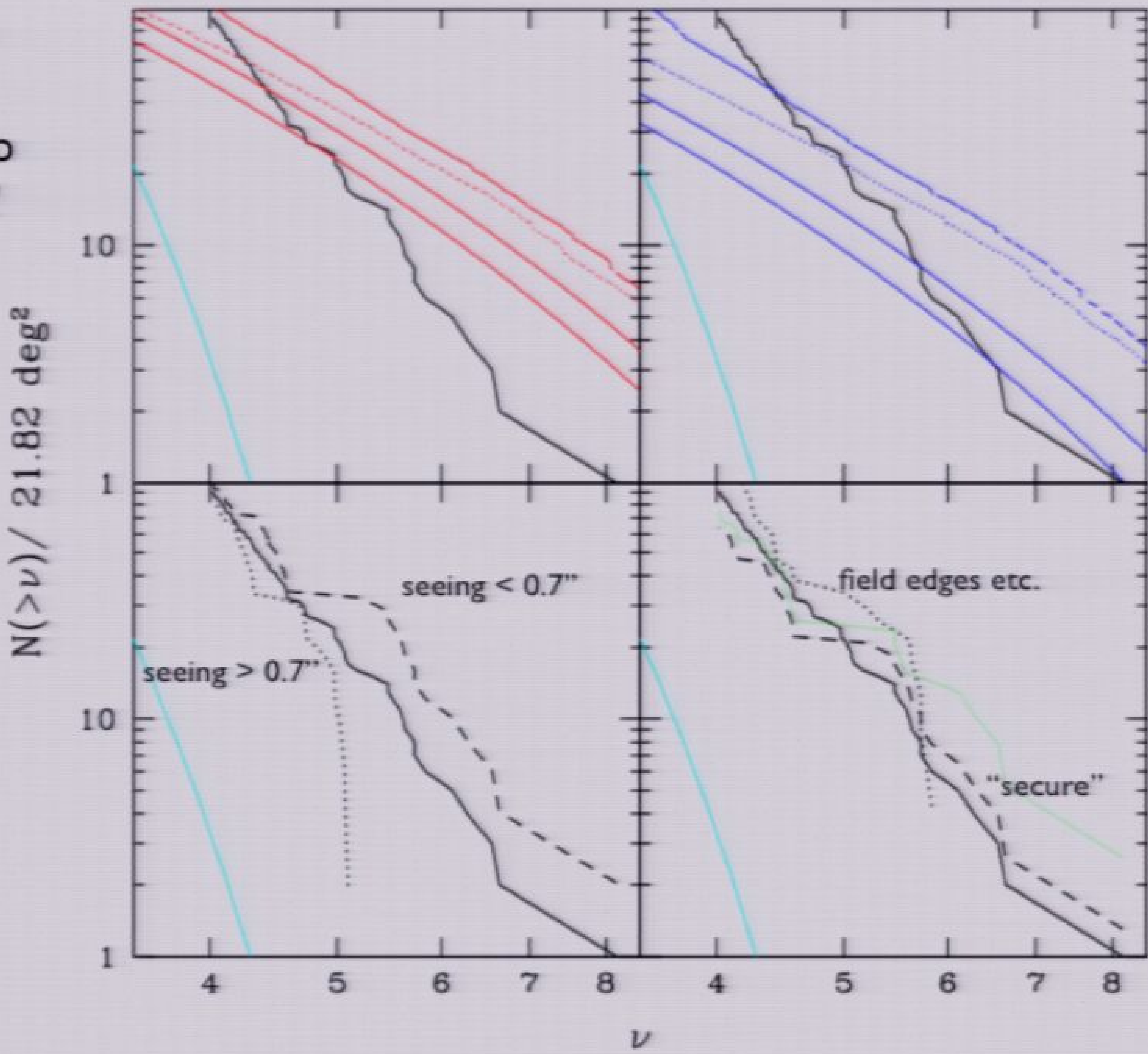

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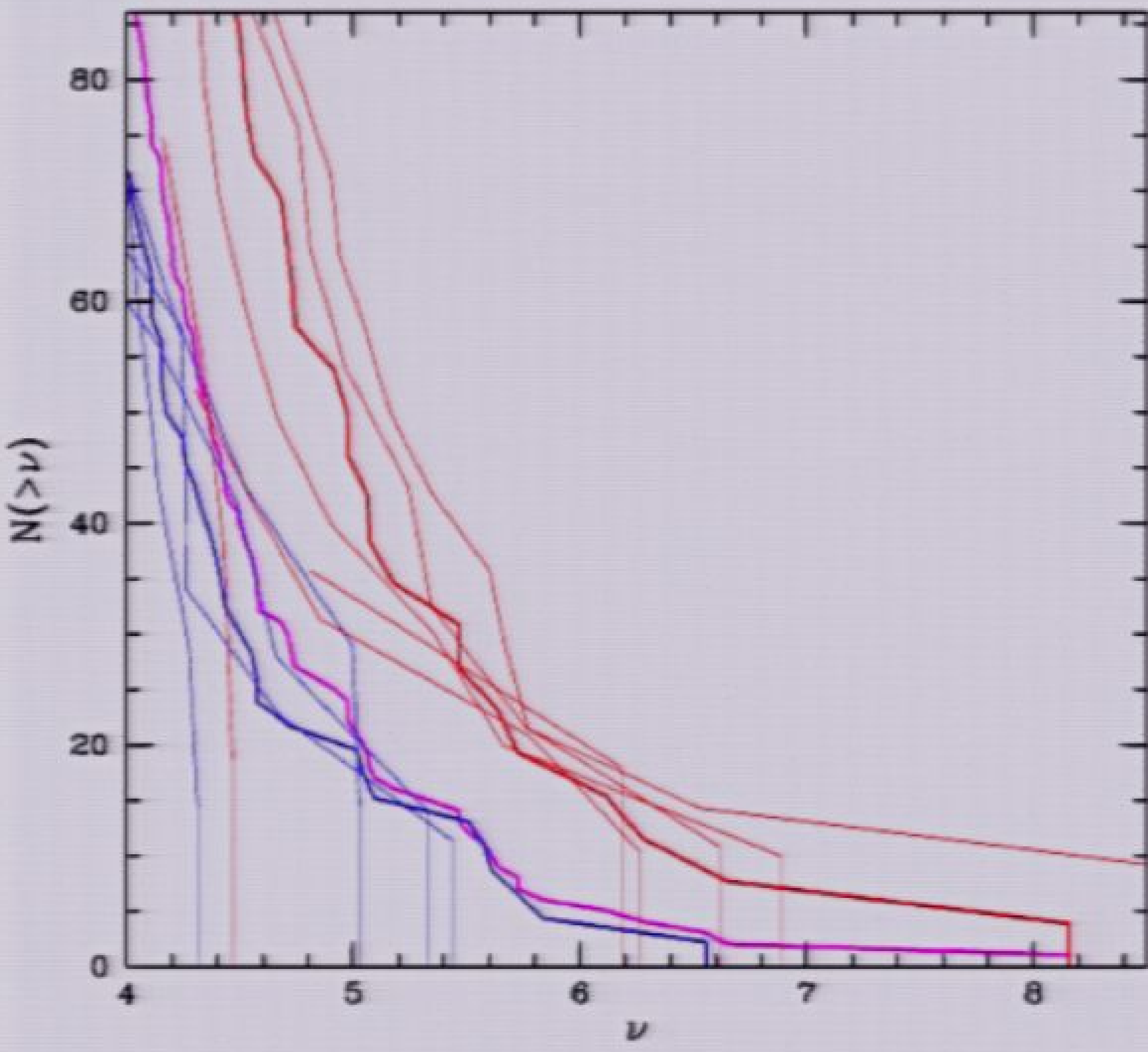
(N.B.: Cosmic Variance)



Peak height distributions: thin lines individual fields, thick lines averages whole survey (magenta); seeing > 0.7" (blue); seeing < 0.7" (red)

Why the sensitivity to seeing?

Why are we losing signal preferentially from the highest peaks?

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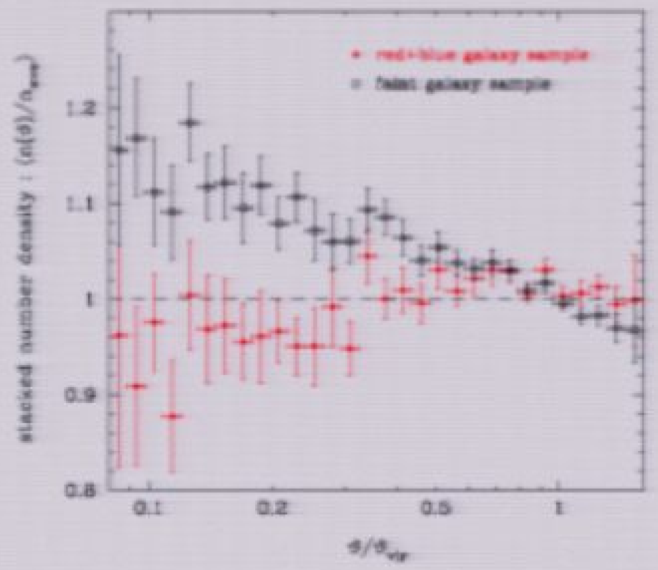

Okabe et al. 2009

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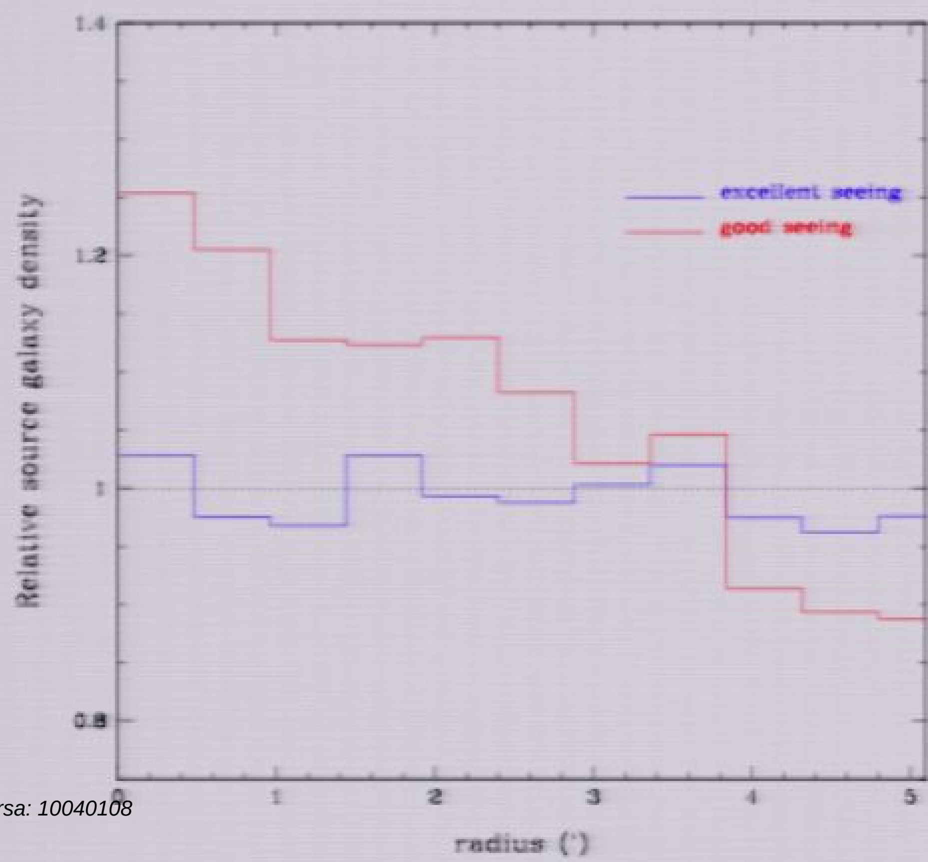

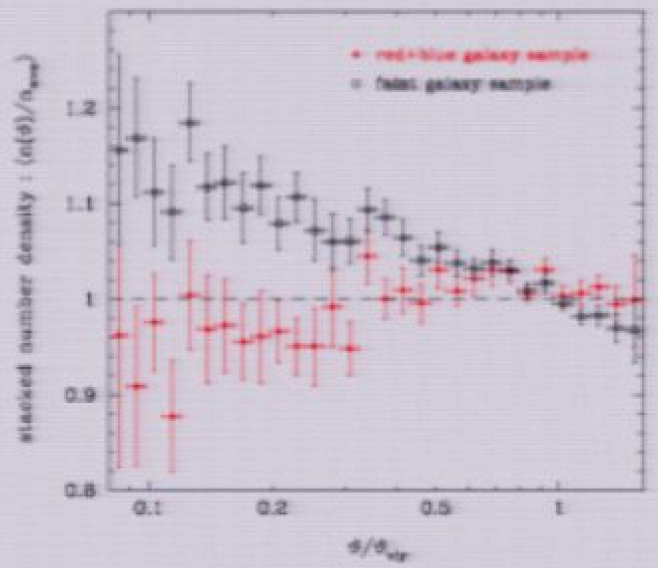

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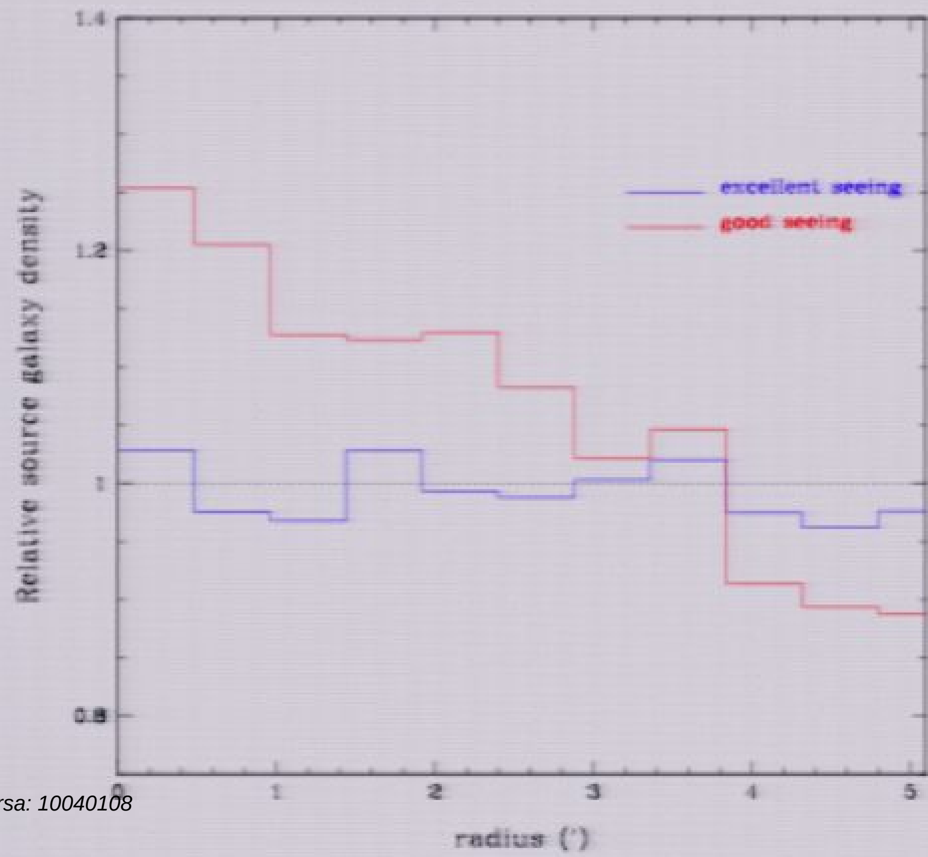

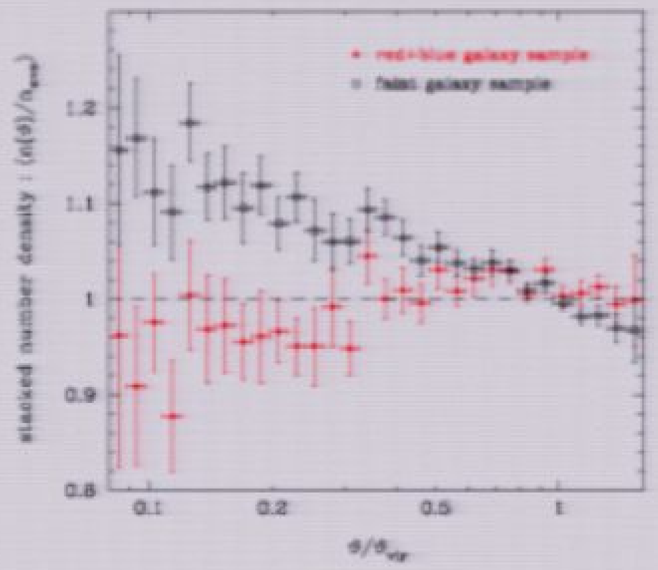

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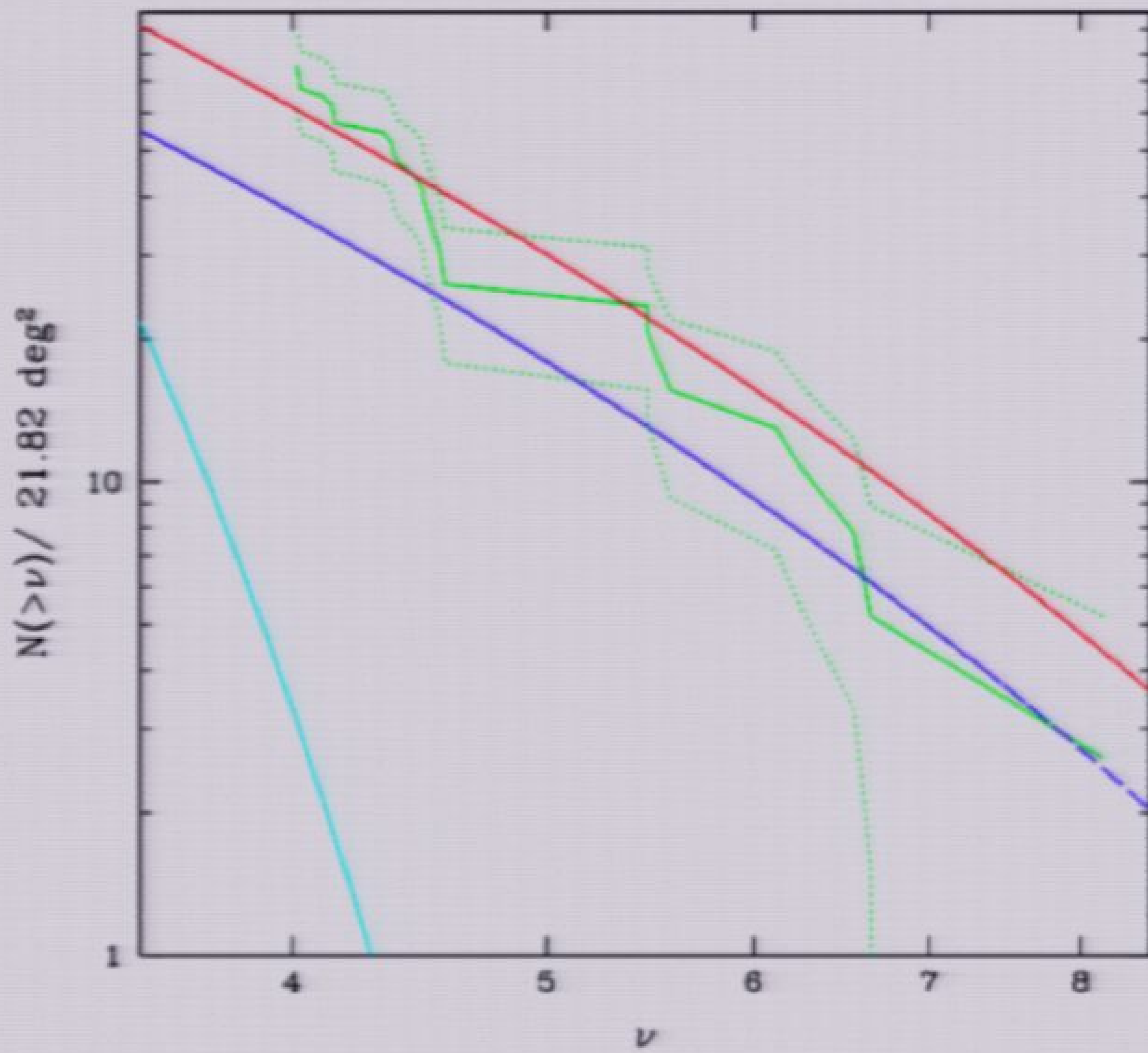
Best 35% of the survey area:



good + secure (green) versus high/low z_s models

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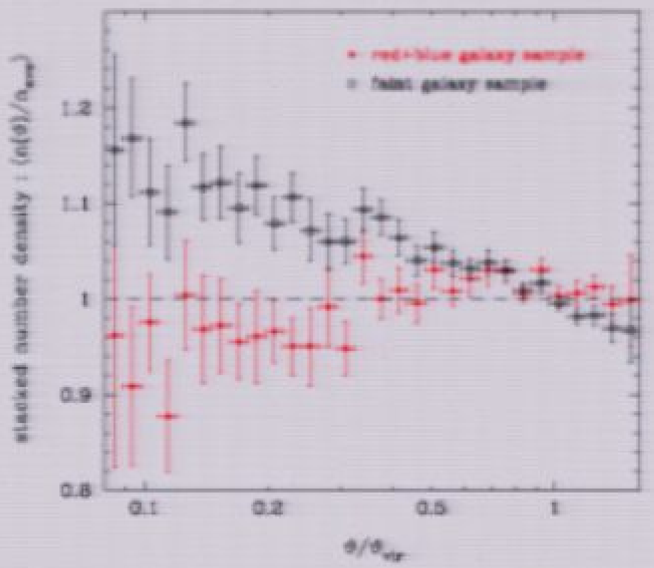

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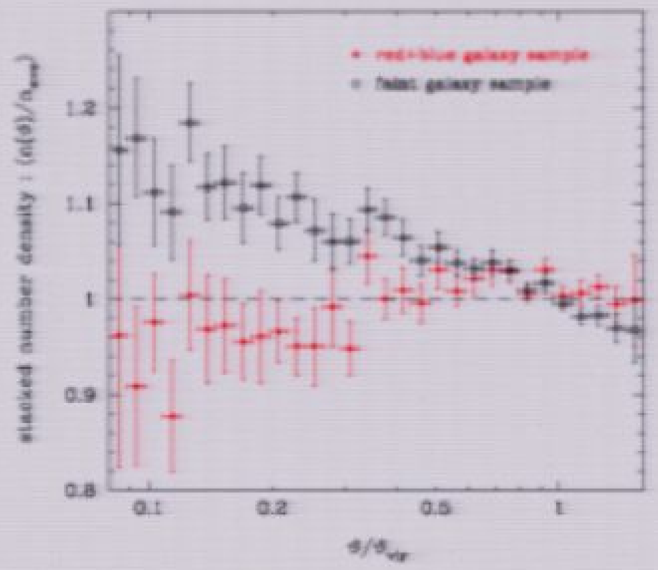

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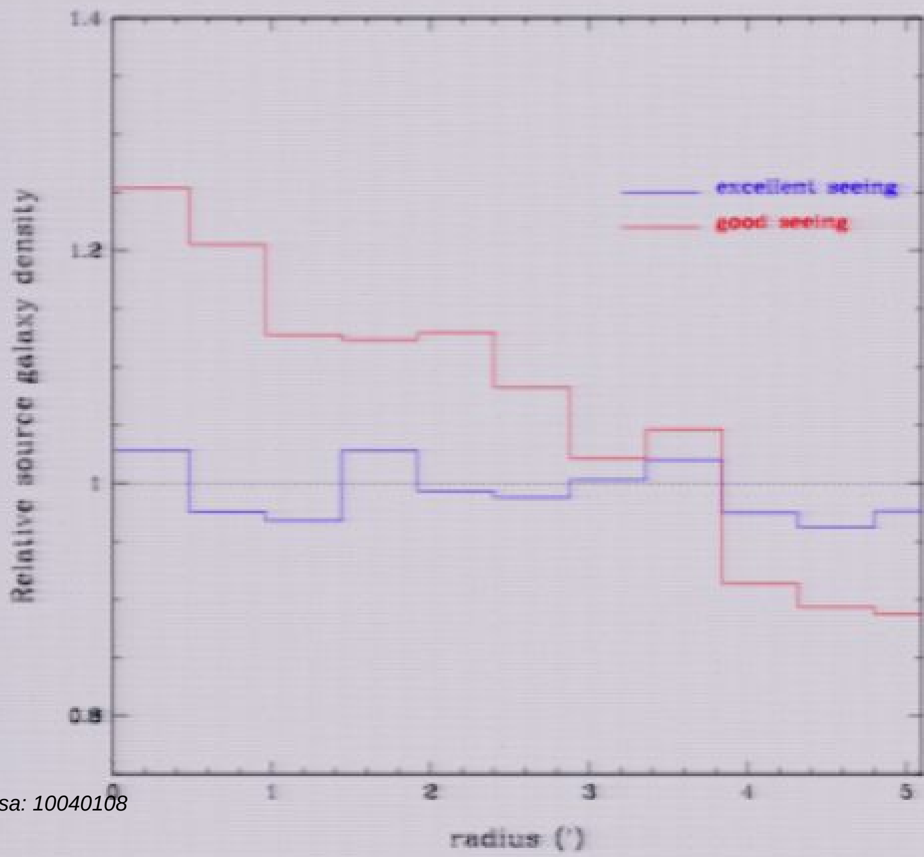

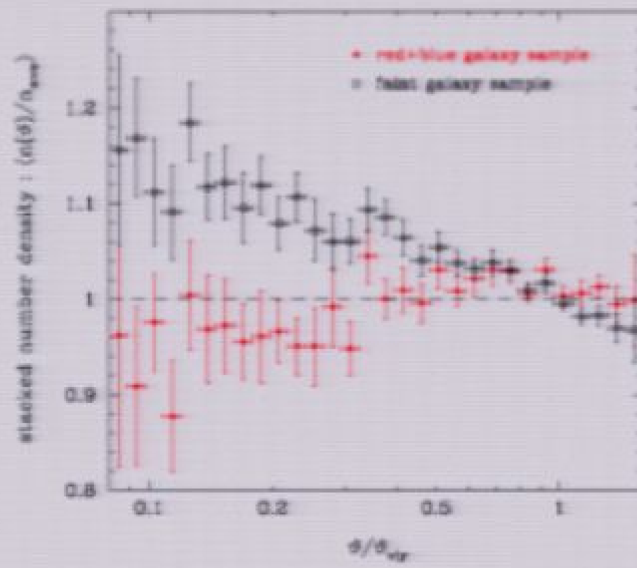

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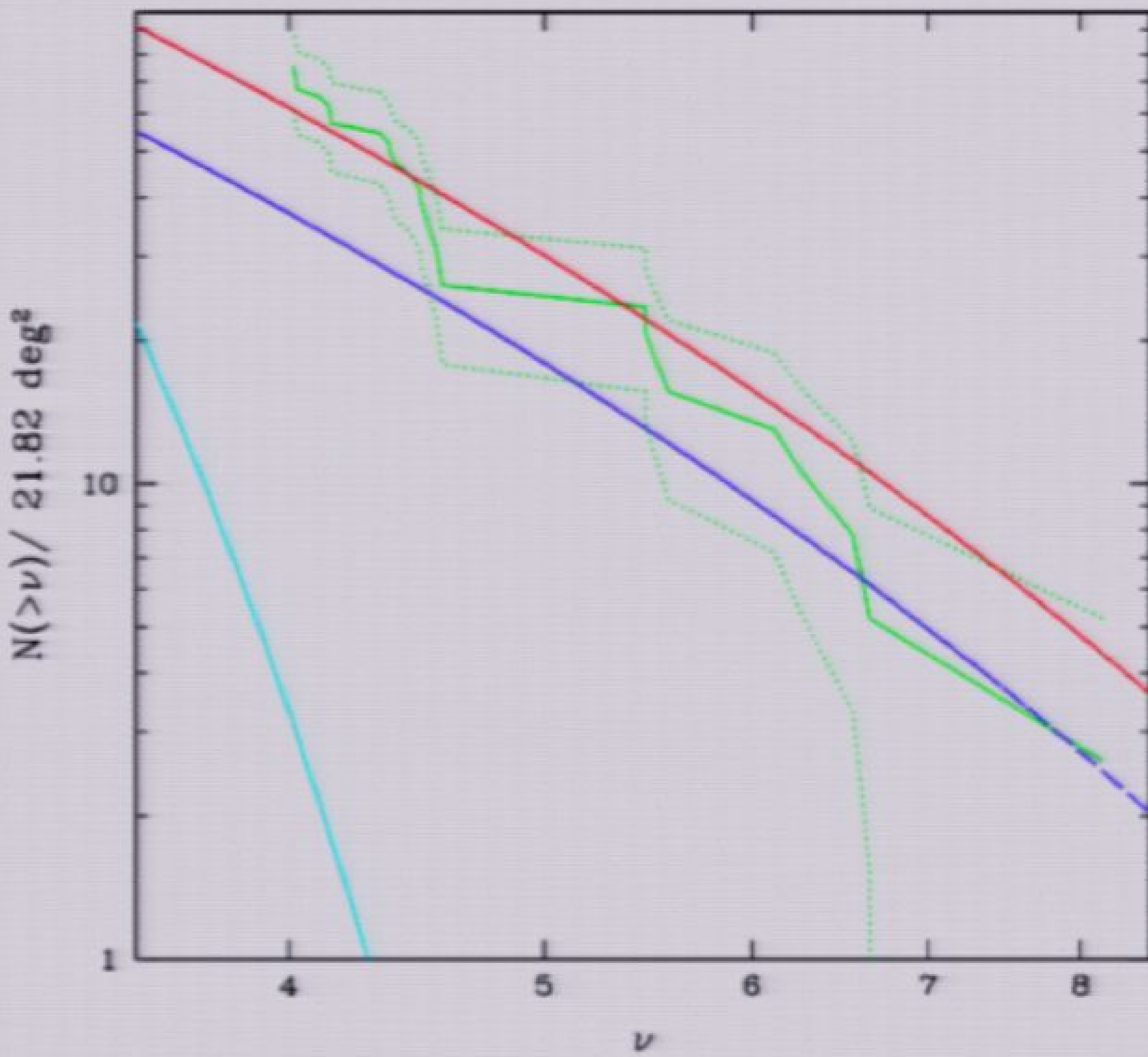

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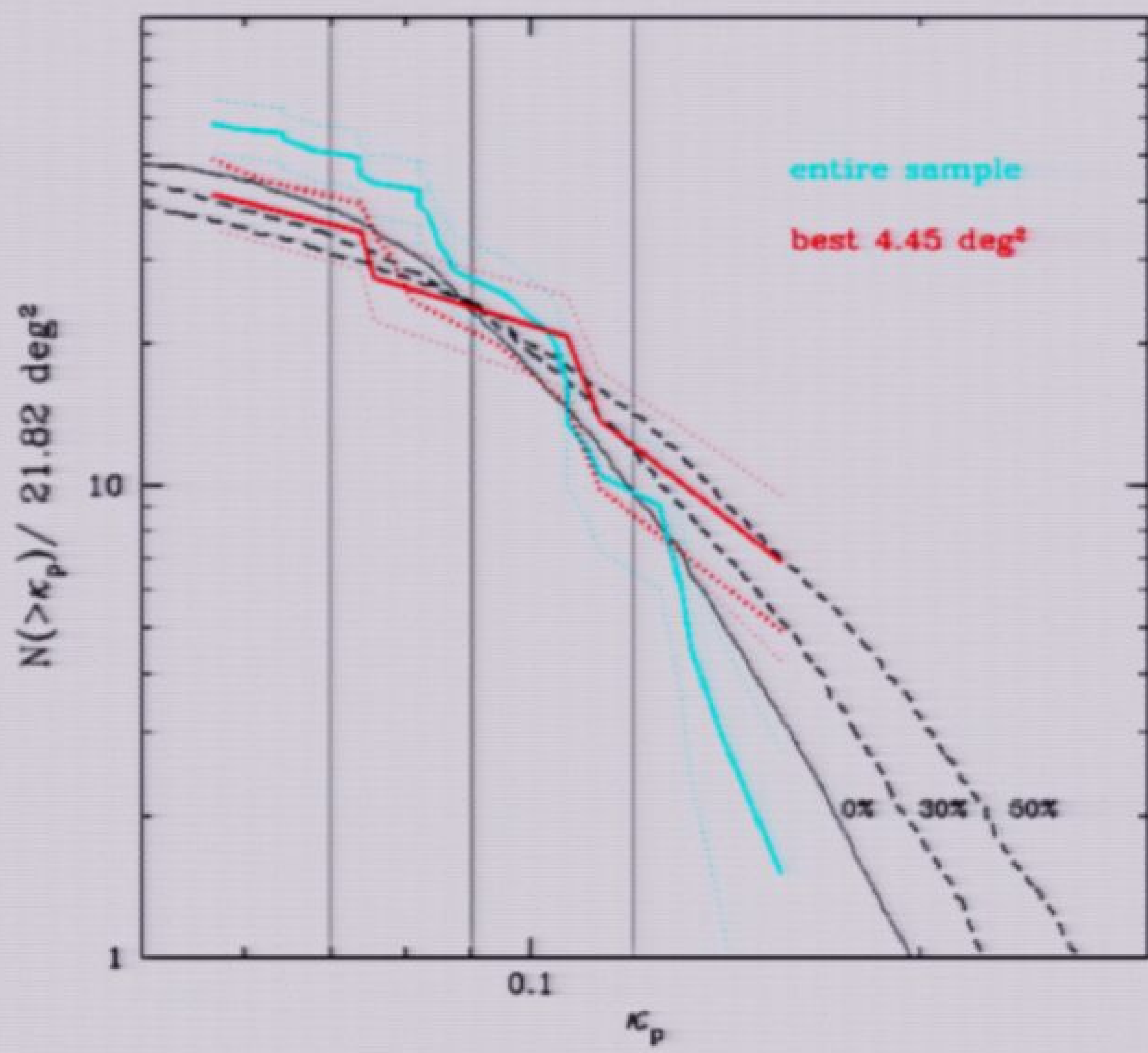
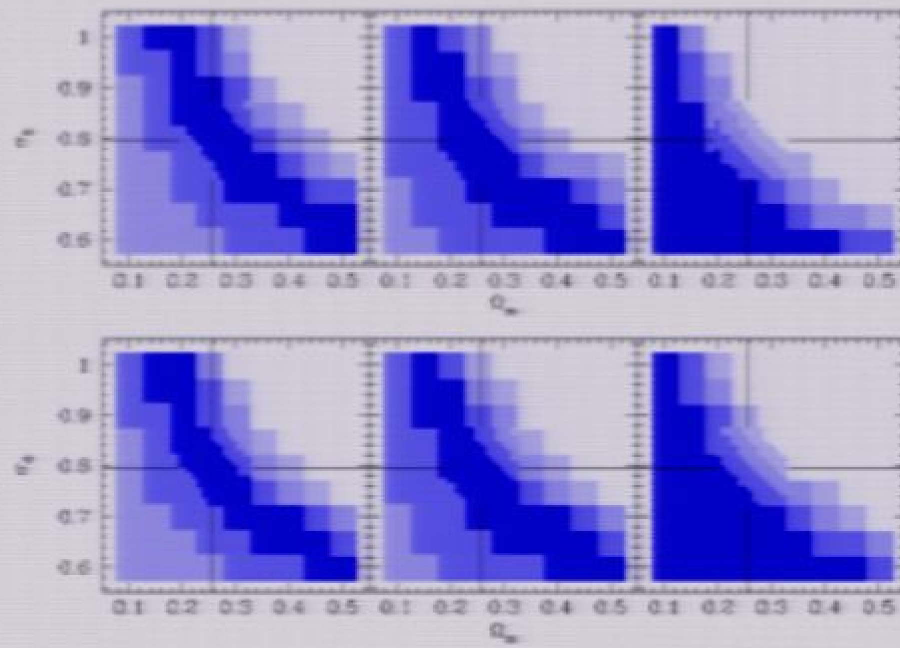


Entire survey (cyan) & final cut (red) versus model (solid black) with additional physical scatter

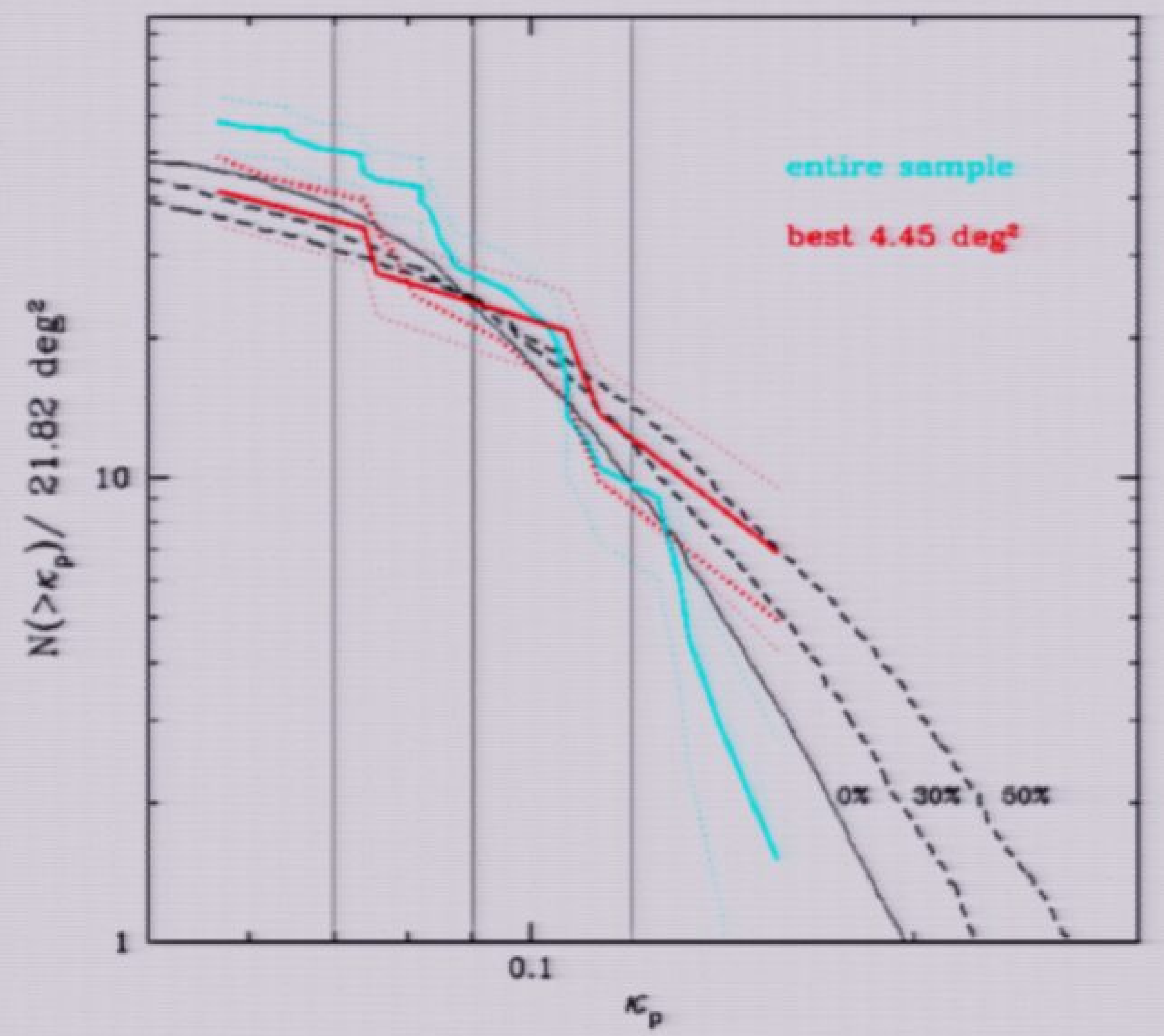
Cosmological Constraints

Cutting down to three fields observed in < 0.6" seeing, and cutting in redshift between 0.18 & 0.45 where follow-up success rate is good, get crude (10%) constraints on σ_8 & Ω_m from ~7 clusters!



Error budget appears to be ~ 1/3 shot noise, 1/3 redshift incompleteness, 1/3 systematic uncertainties in cuts

Also expect a comparable error from source redshift distribution



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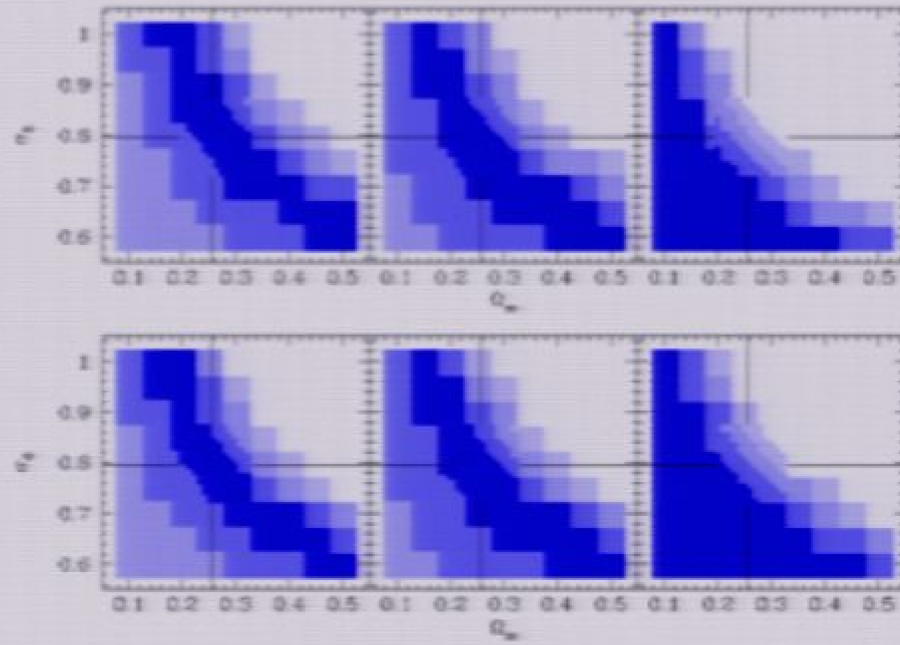

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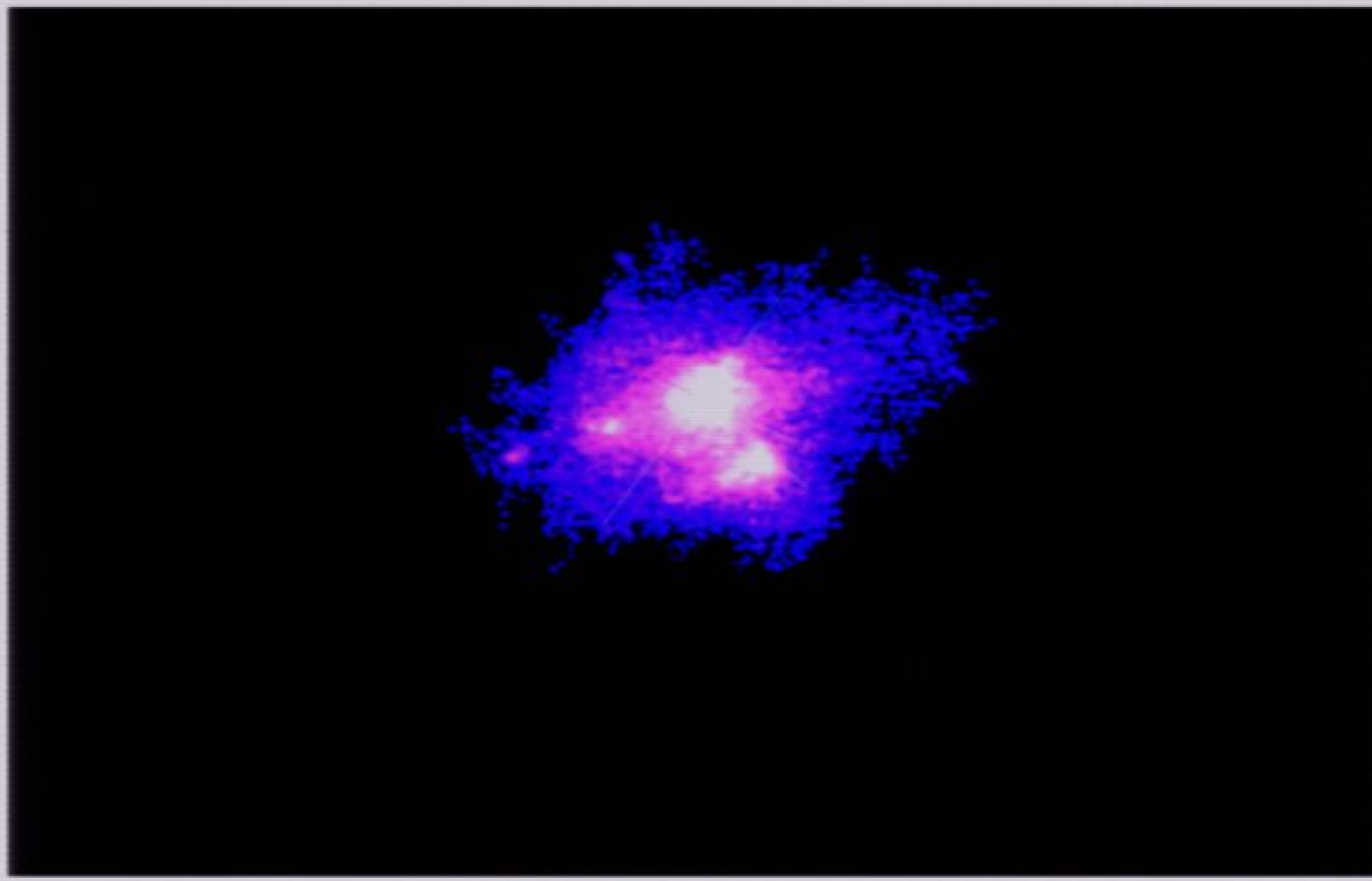
Value-added science with cluster samples:
from Large Scale Structure to Small Scale Structure



Universality of CDM Halo Properties

Dark matter halos vary in triaxiality, concentration, smoothness

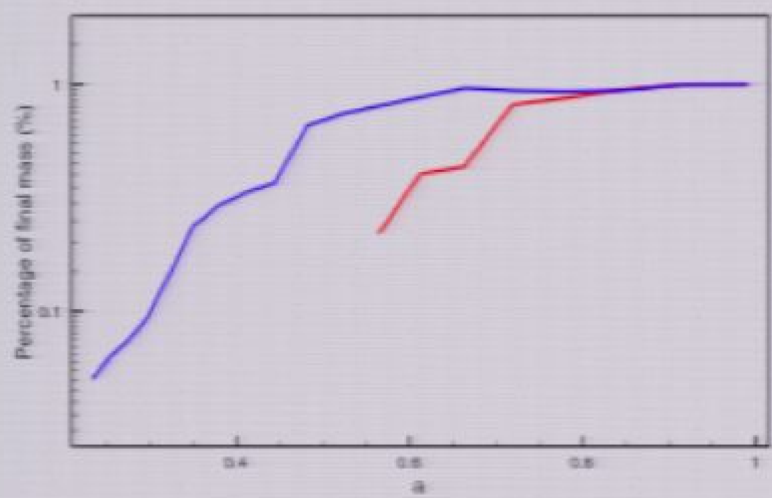
These effects are strongly correlated with age,
i.e. the time when a halo build up most of its mass

(e.g. NFW 96,97, Bullock et al. 2001, Wechsler et al. 2002, Tasitsiomi 2004, Allgood et al. 2006, work by Mo et al.)

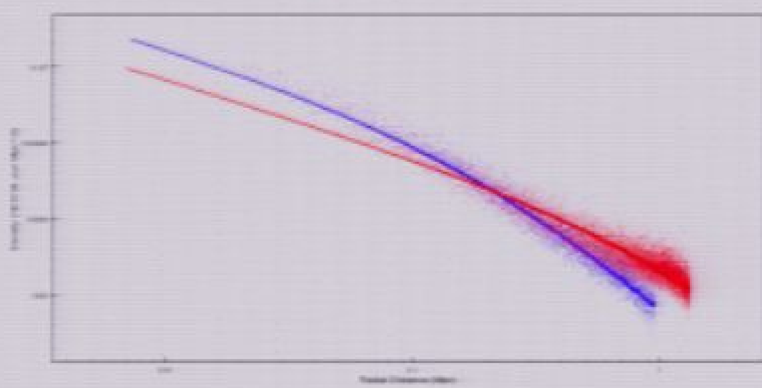
e.g. concentration ~ 4 x (a/a_f) Wechsler et al. 2002
McBride, Fakhouri & Ma 2009

$$M(z) \propto (1+z)^{\beta} e^{-\gamma z}$$

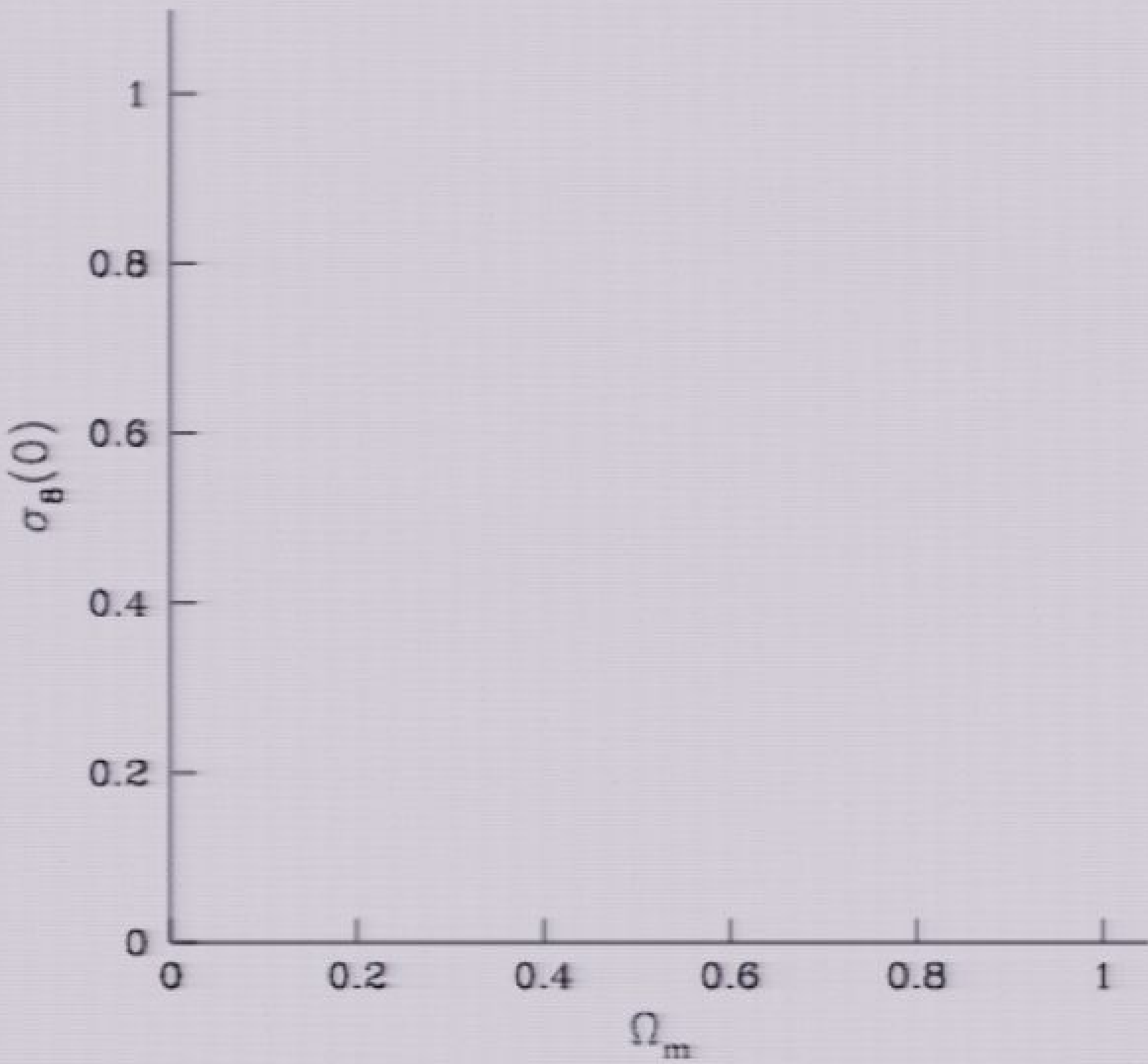
Halos build up at different times



producing more or less concentrated NFW profiles



Application: clusters should assemble earlier in high-σ_8 cosmologies relative to high Ω_m ones



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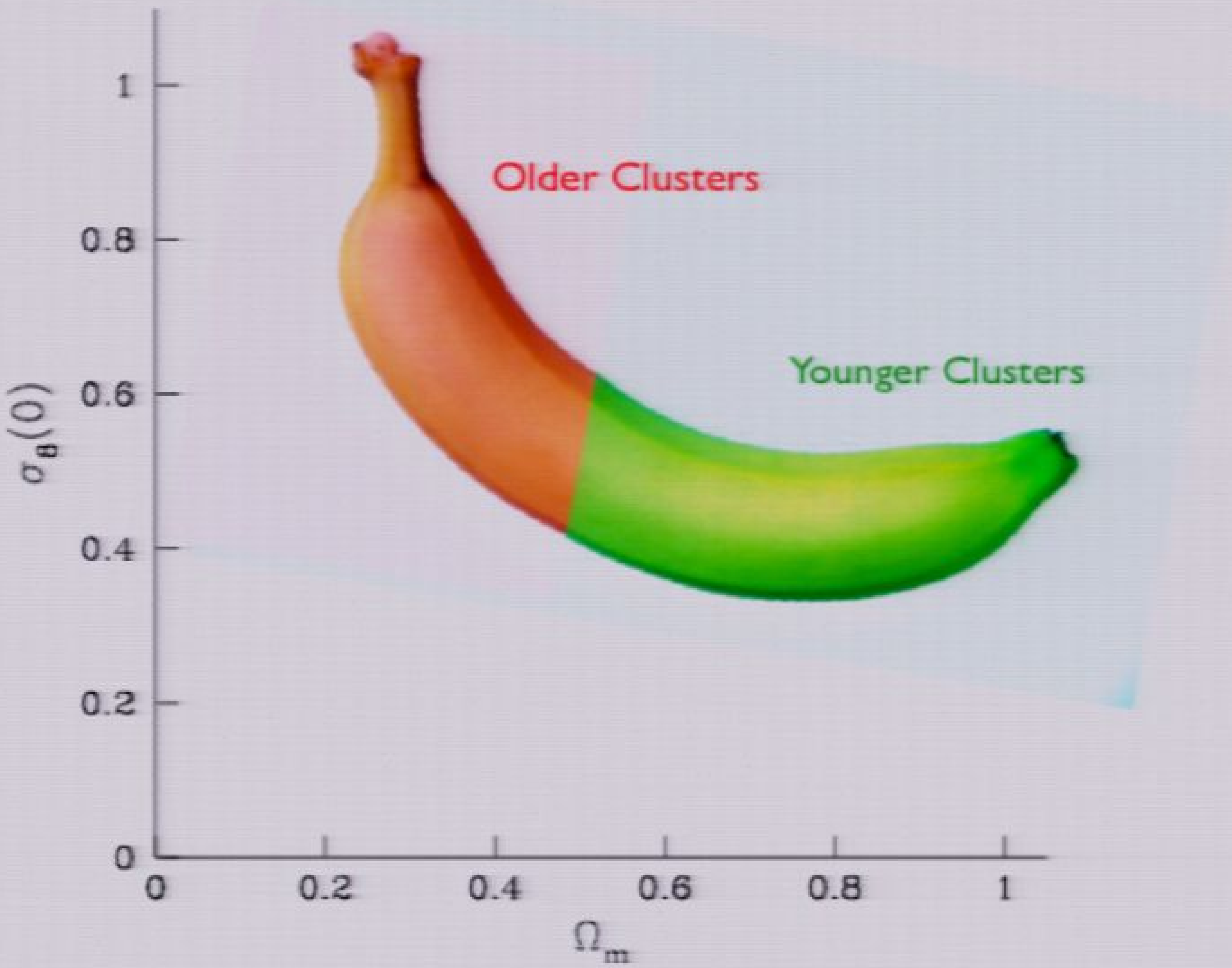

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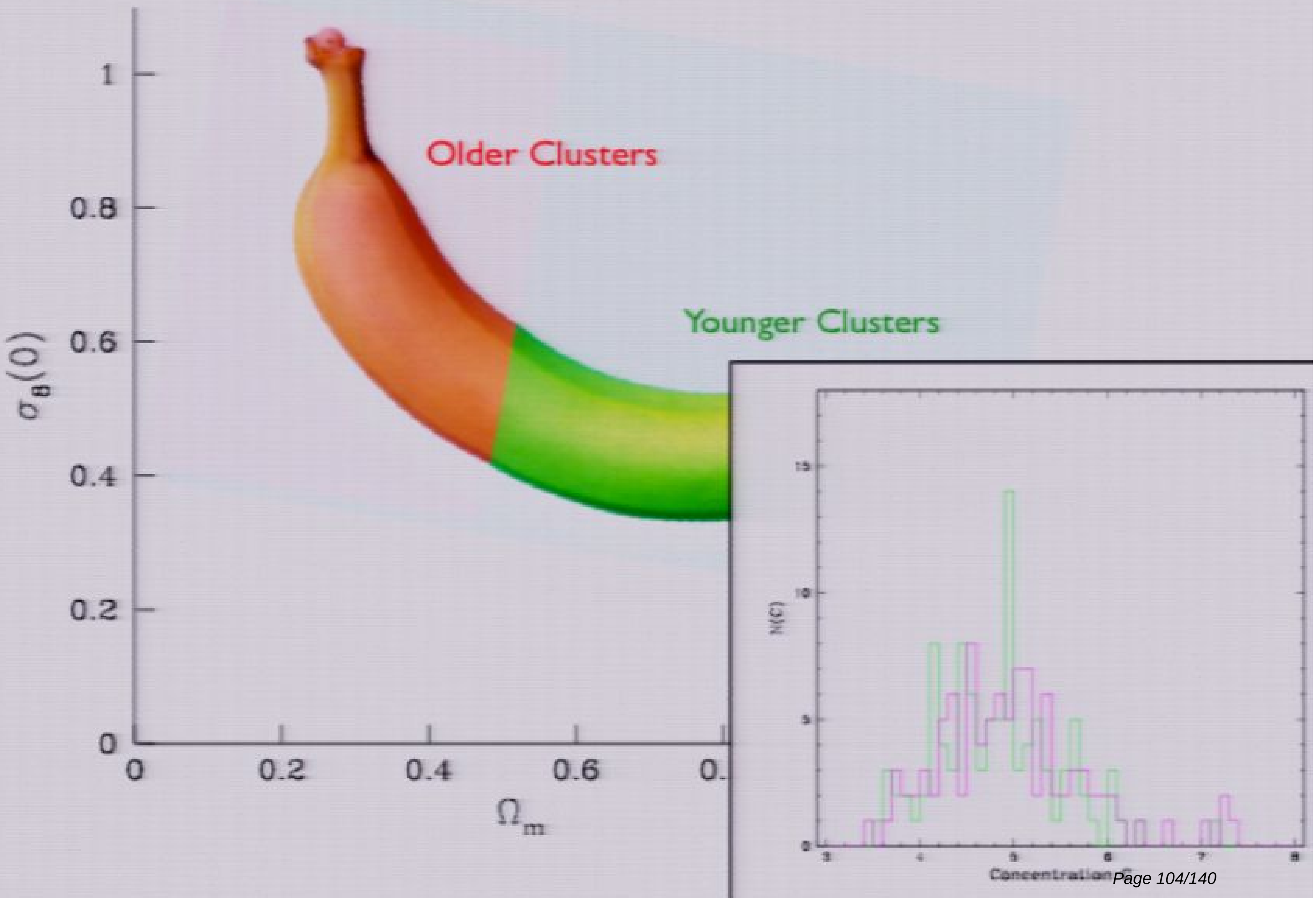

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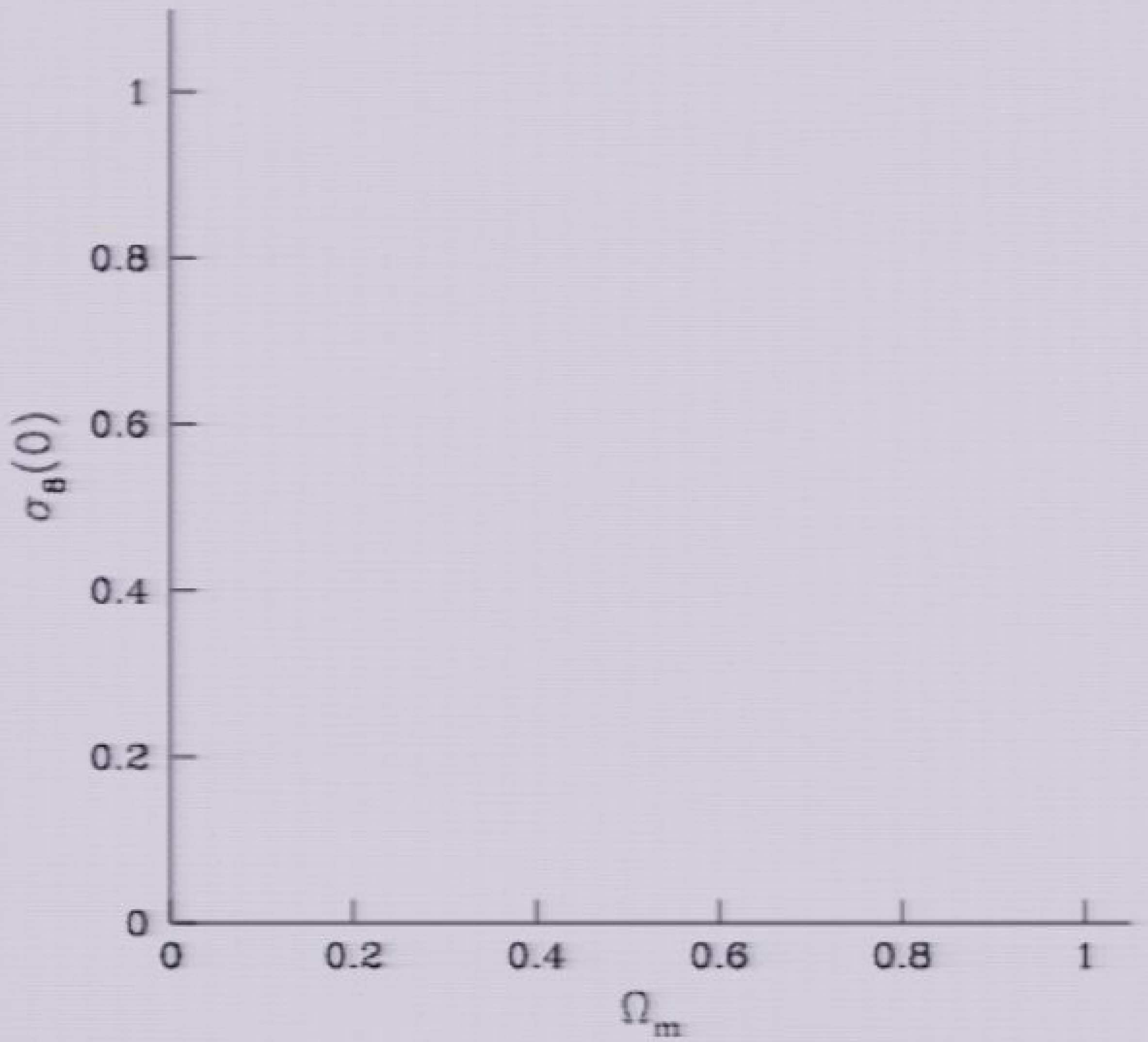
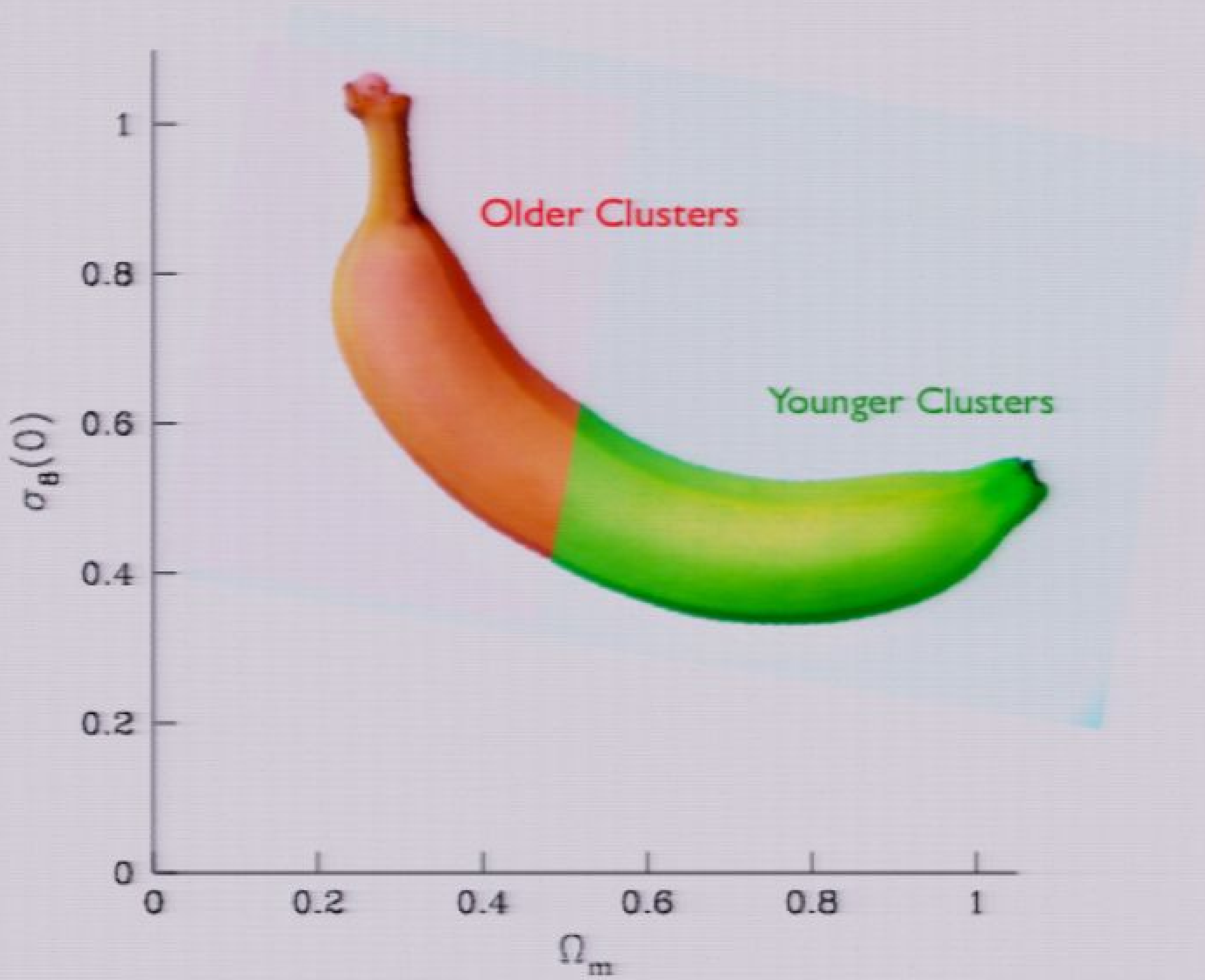


Application: clusters should assemble earlier in high-σ_8 cosmologies relative to high Ω_m ones



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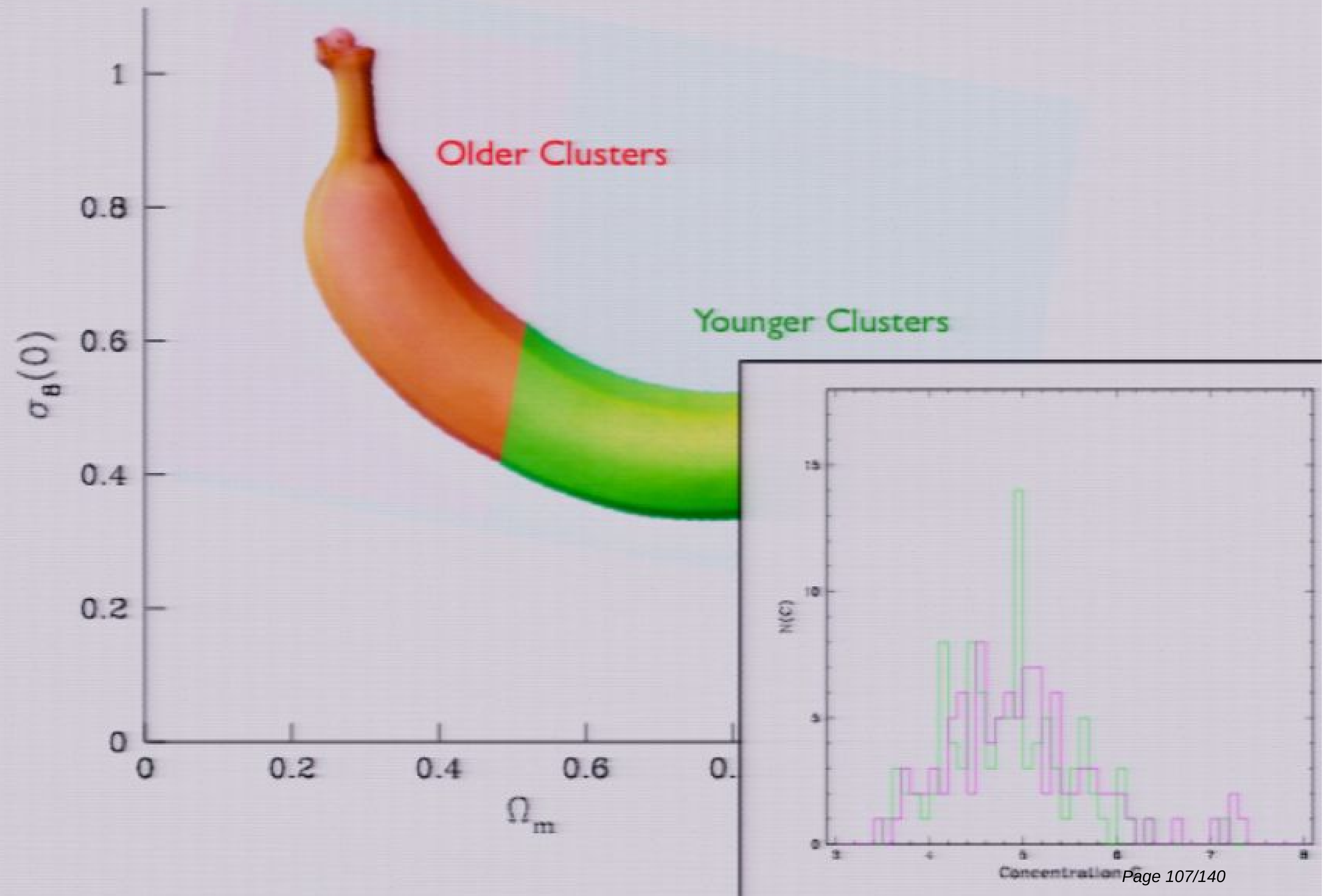
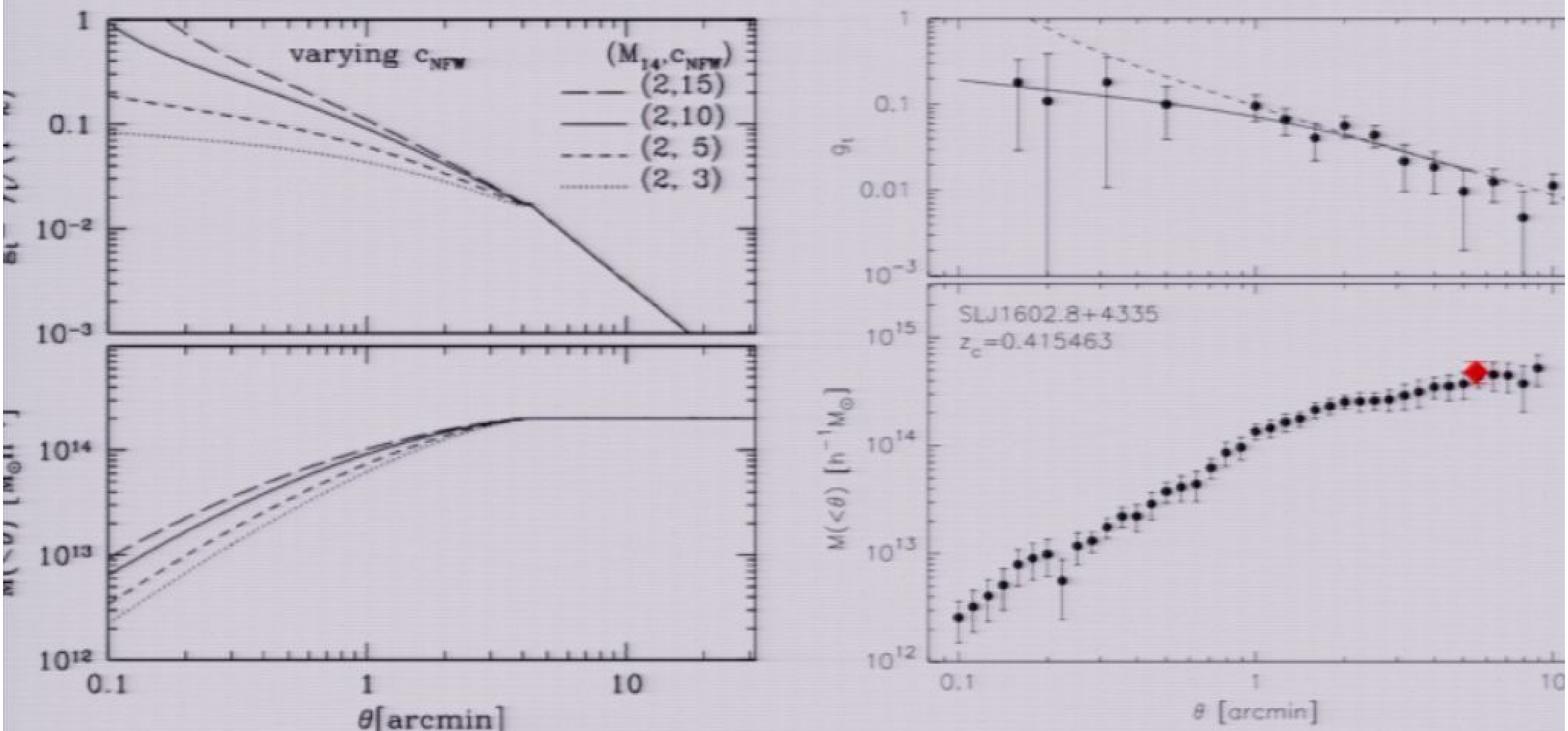


So try measuring N(M,z,conc)?

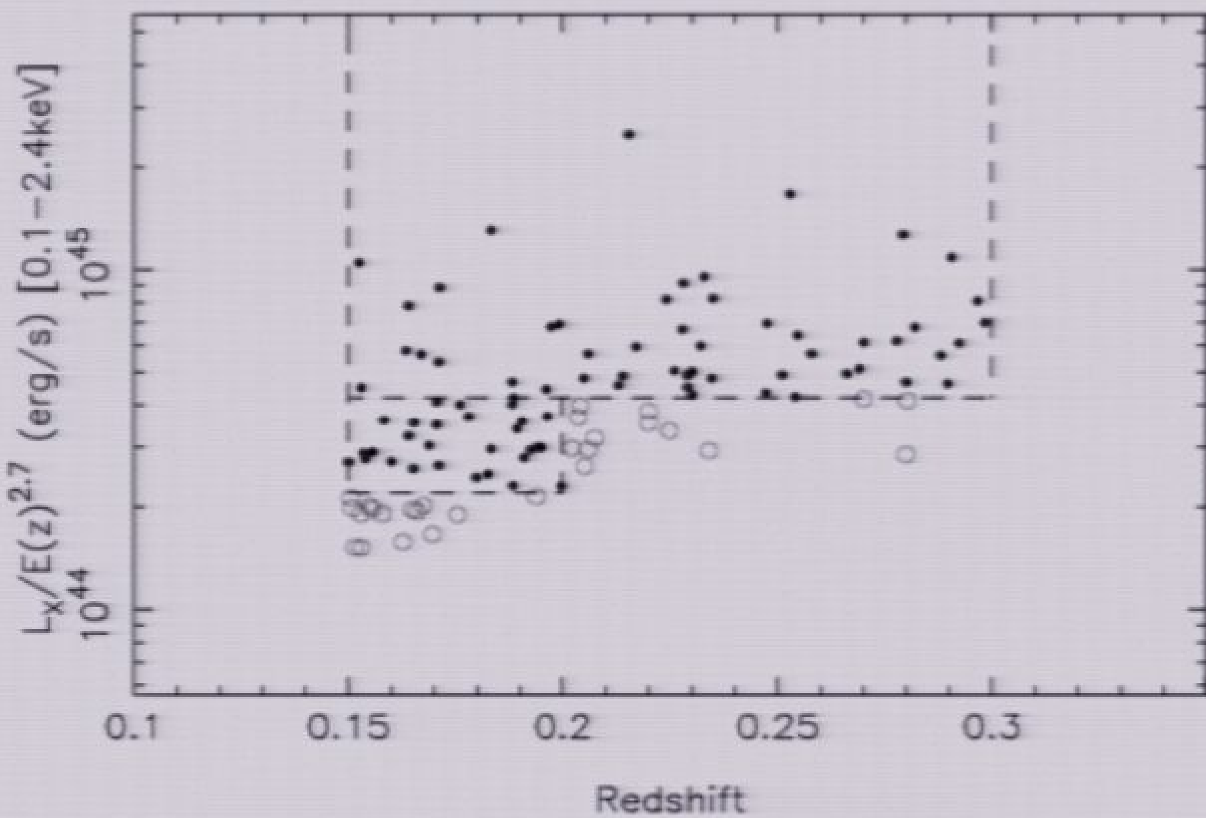
Concentration measurements currently marginal:



Could try the same thing with stacked clusters, or use shape or substructure

Substructure?
e.g. LoCuSS cluster substructure survey (G. Smith PI):

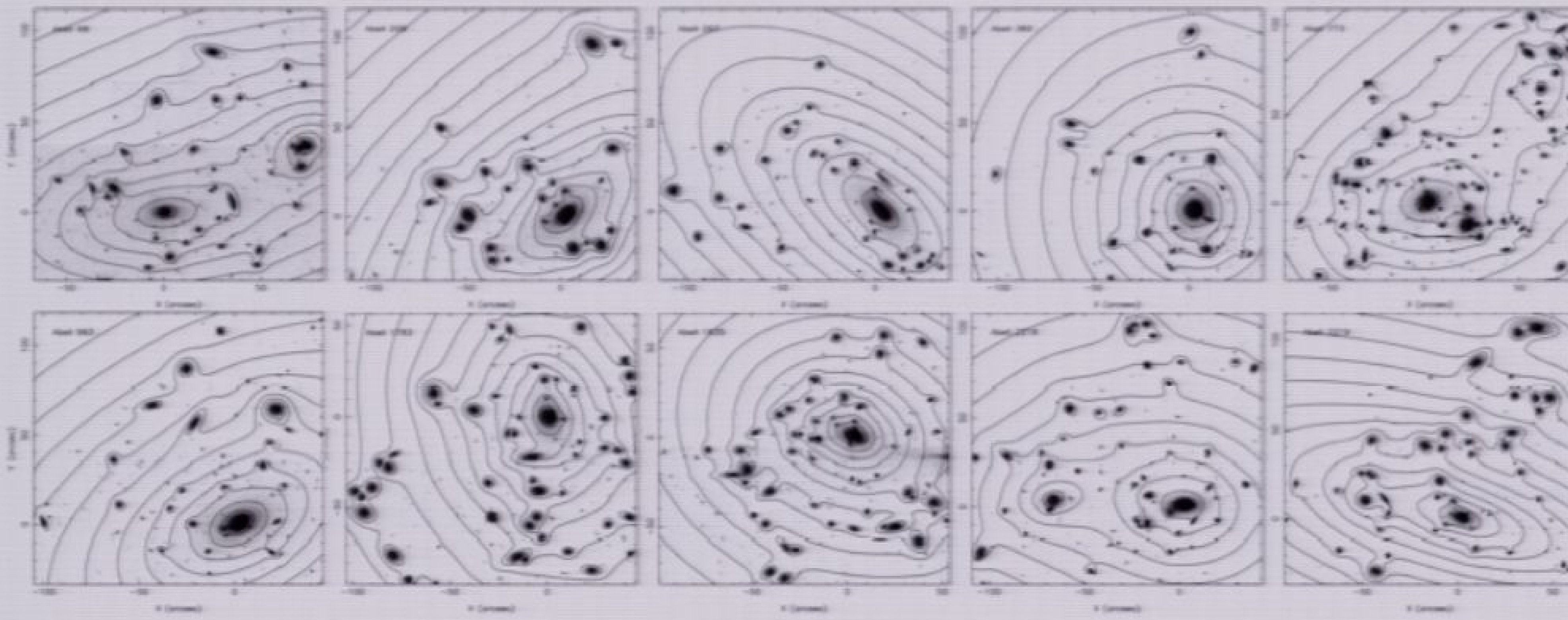
idea: - pick the clusters with the strongest expected lensing signal
- get HST snapshots (originally WFPC/ACS) or cores
- sort into smooth/lumpy, reconstructing substructure in mass distribution from weak+strong lensing



Substructure?

e.g. LoCuSS cluster substructure survey

reconstructing substructure in mass distribution from weak+strong lensing



Substructure?
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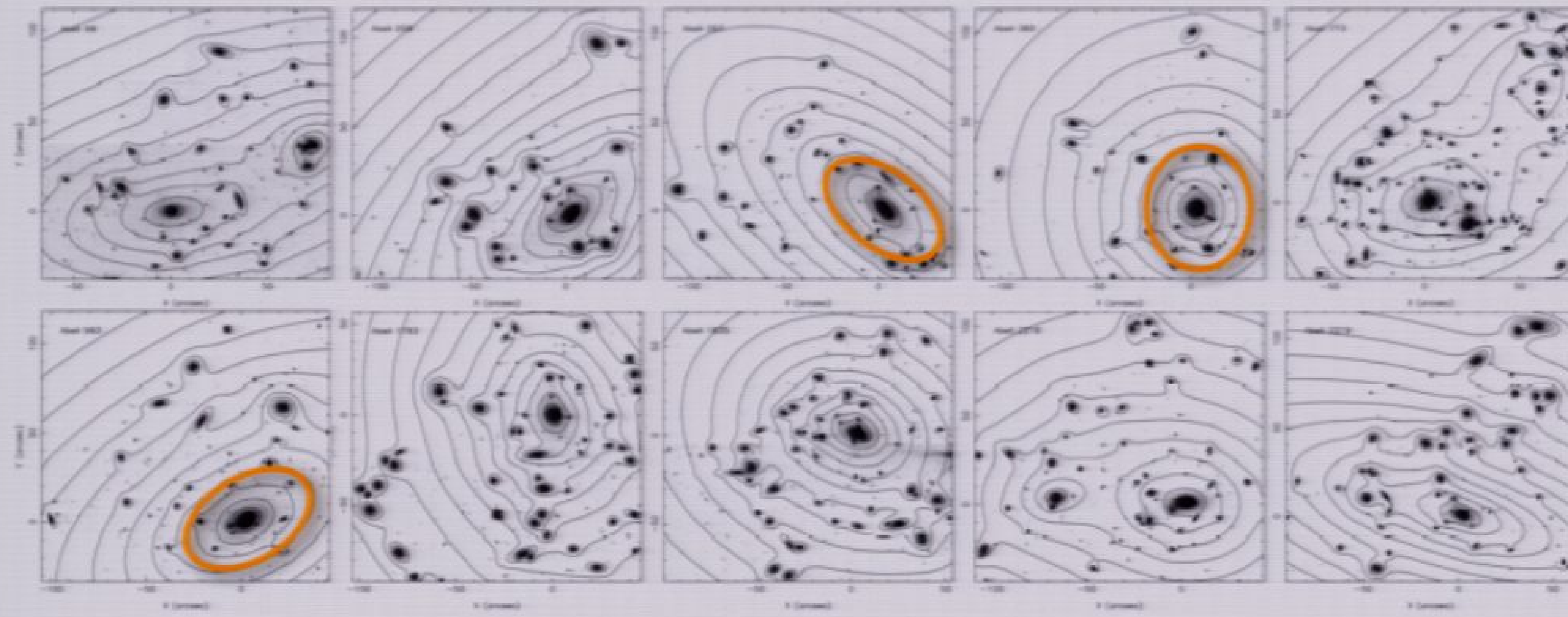
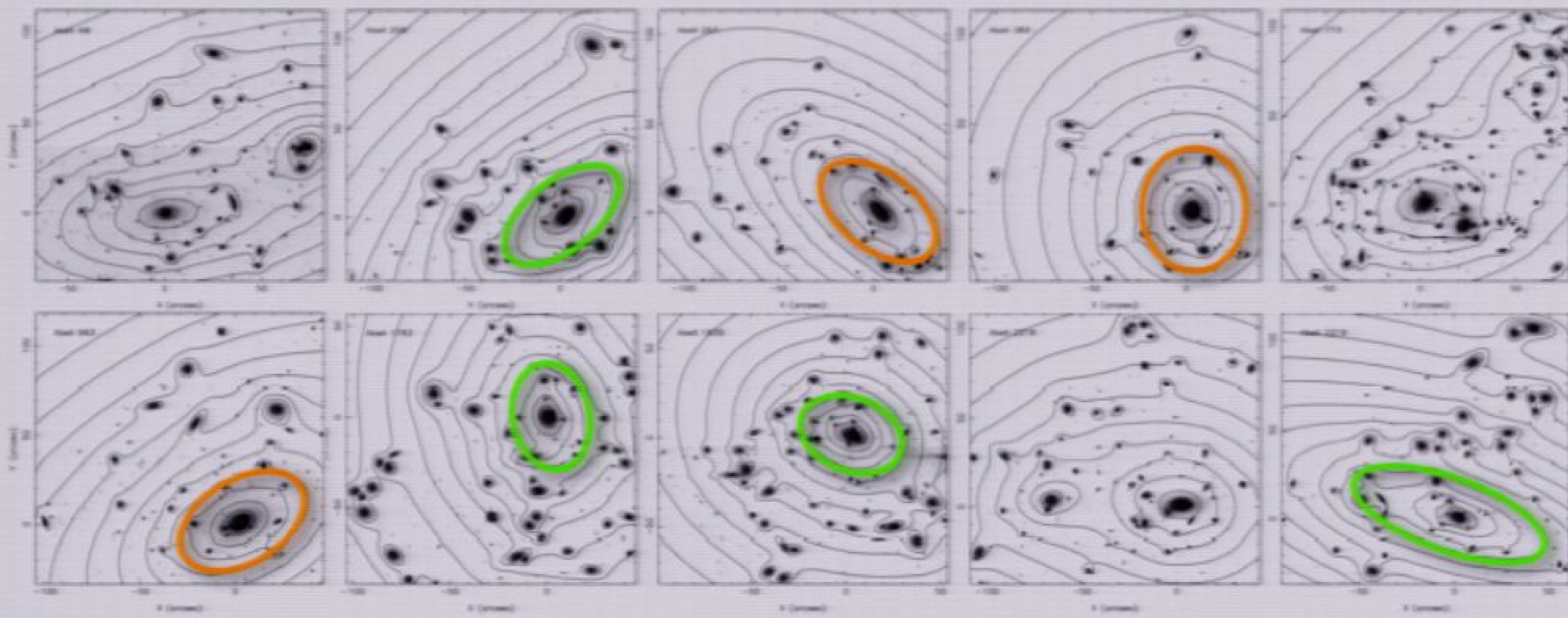


Substructure?
e.g. LoCuSS cluster substructure survey

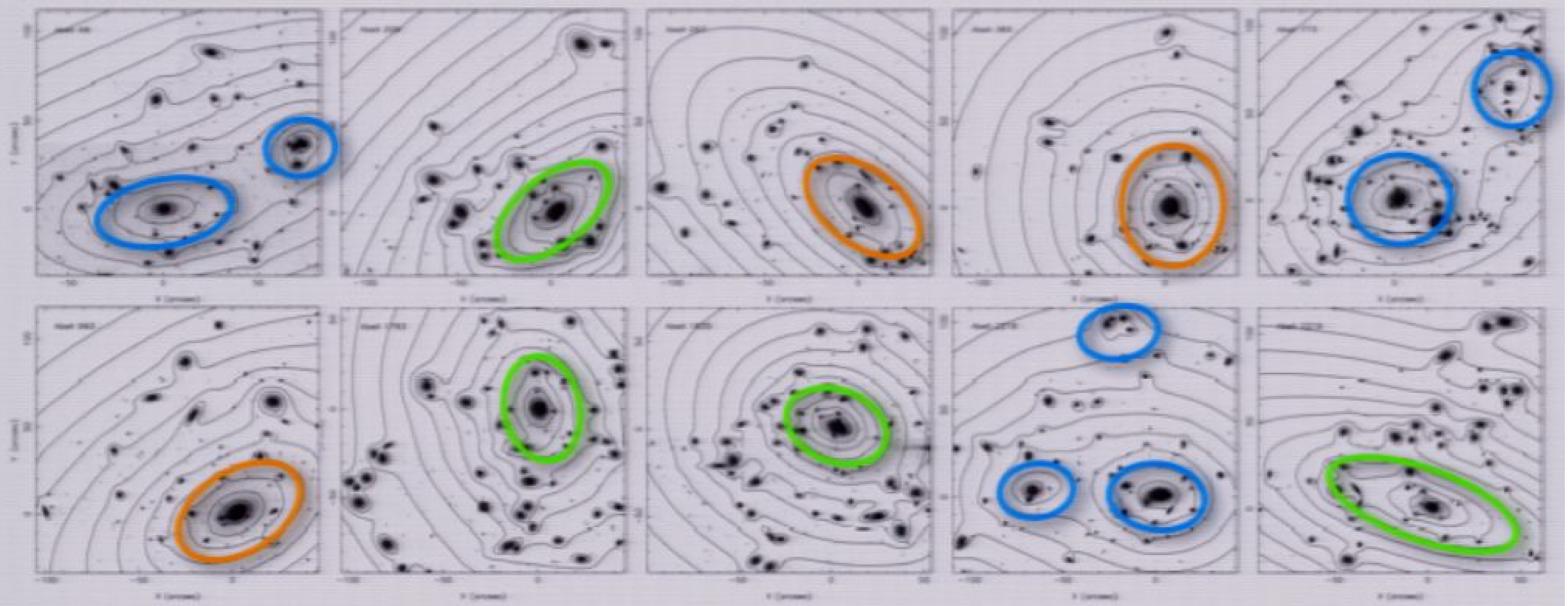
reconstructing substructure in mass distribution from weak+strong lensing



Substructure?

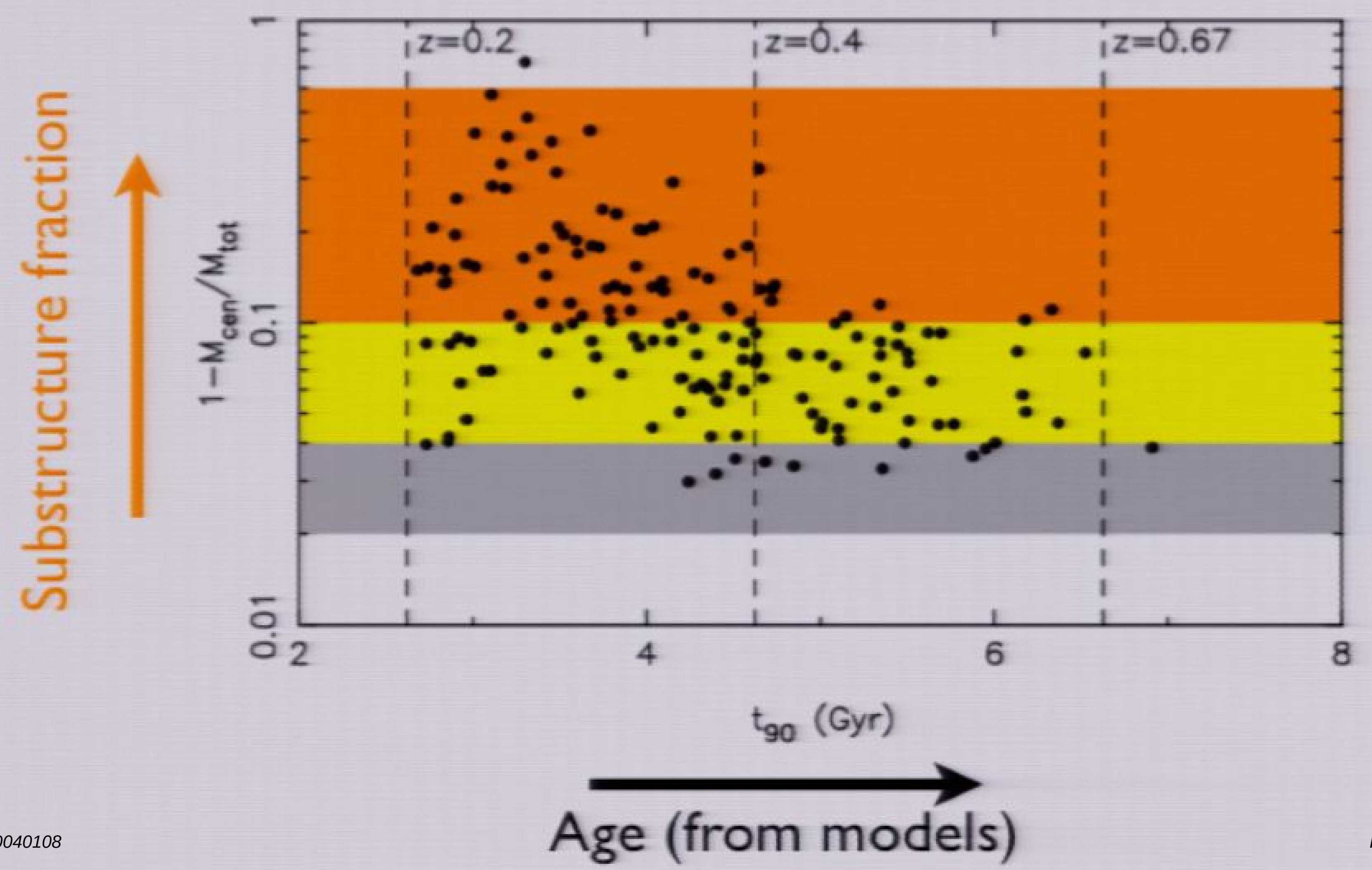
e.g. LoCuSS cluster substructure survey

reconstructing substructure in mass distribution from weak+strong lensing



LoCuSS cluster substructure survey

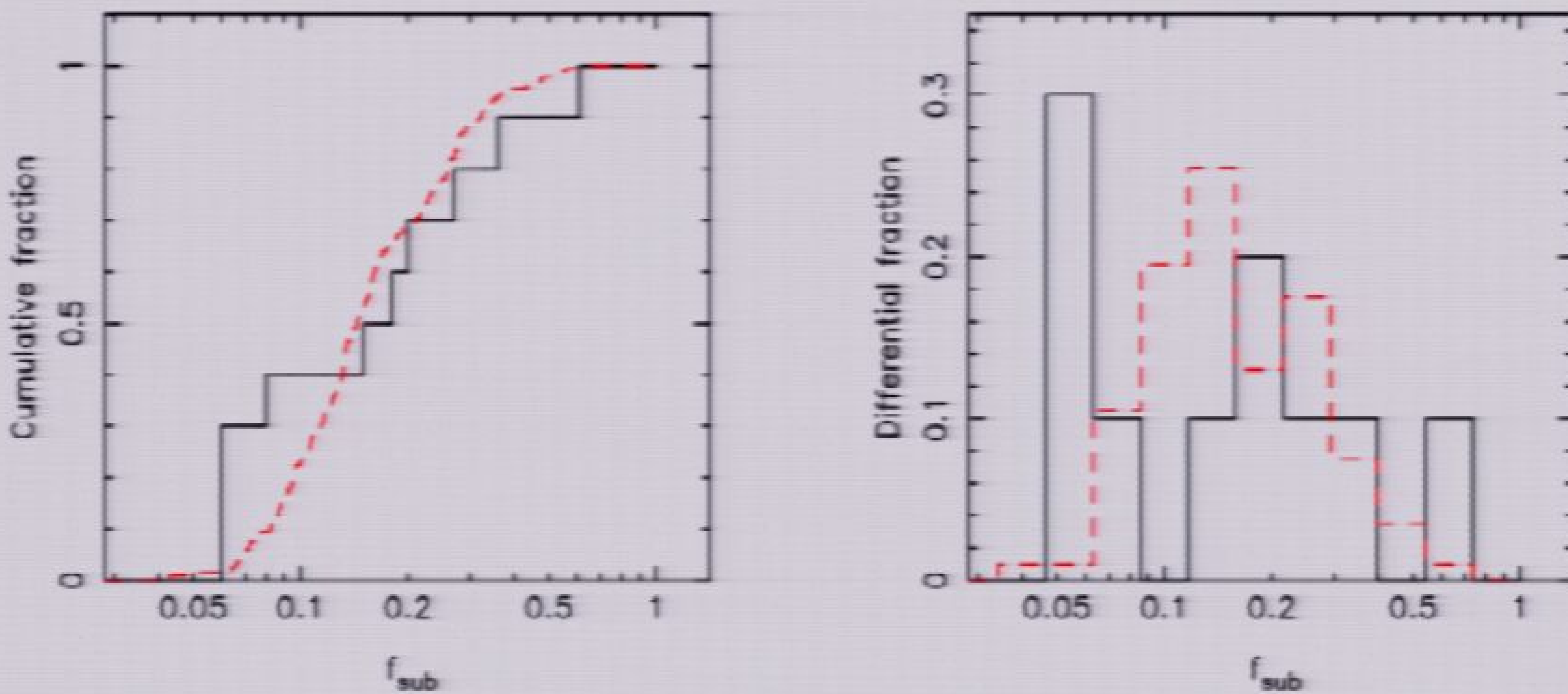
observed range of substructure matches models; should correlate with age



LoCuSS cluster substructure survey:

is substructure fraction representative?

Pilot sample (Smith et al. 2005) vs. models



Conclusions:

Lensing surveys can produce useful cluster samples, but only after a lot of work; focus on best quality data, careful shape catalogue selection & high S/N threshold

Typical objects (always) 4-5σ detections with 1-2σ systematics, so very similar to predicted SZ samples

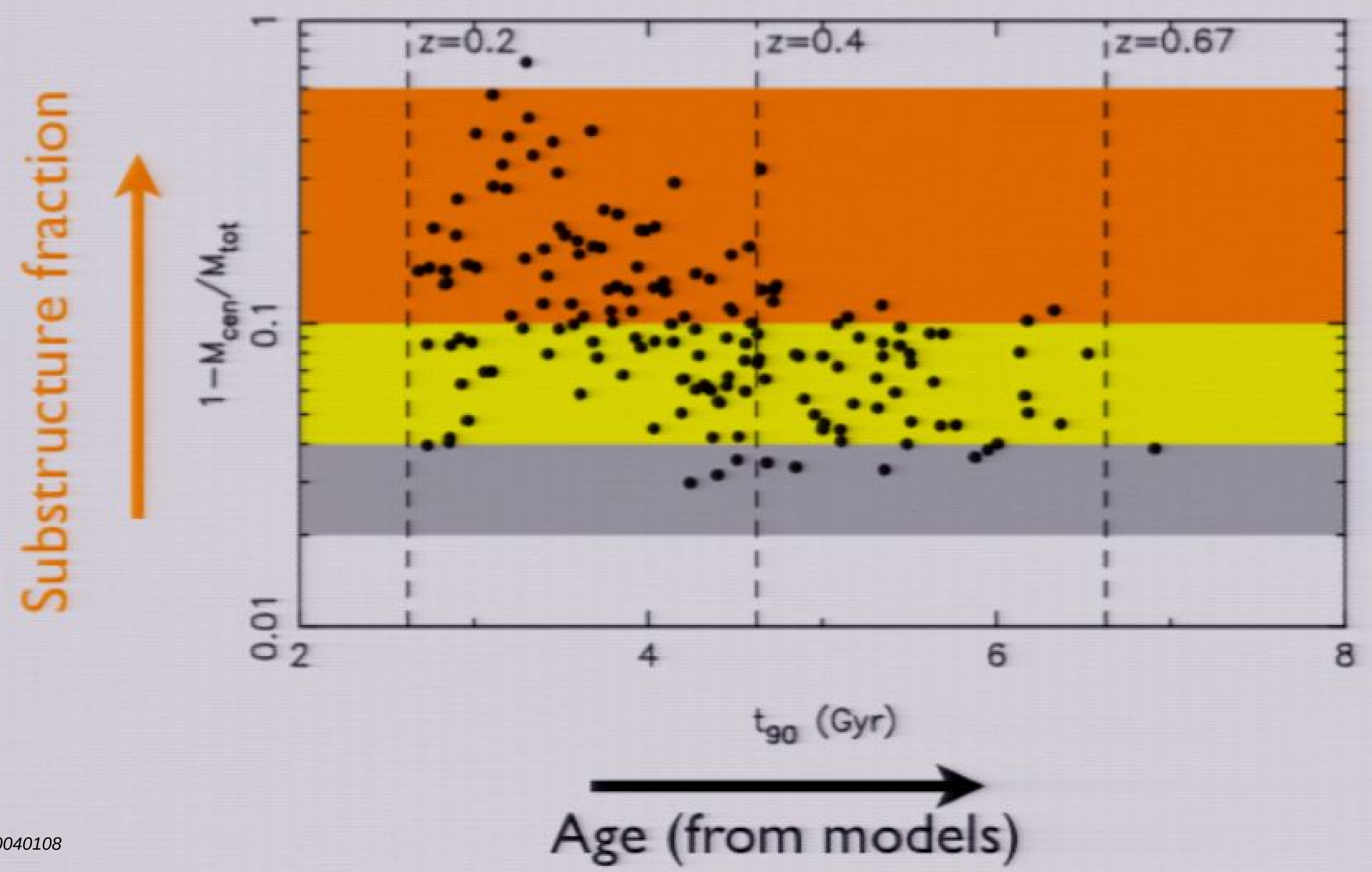
~100 deg^2 in good seeing, 2-4 filters to produce interesting constraints?

Spectroscopic follow-up would be challenging for larger samples; use photo-zs of red sequence instead? (cf. SPT)

May be able to measure higher-order cosmological dependence of shape, concentration, substructure, etc. distributions

LoCuSS cluster substructure survey

observed range of substructure matches models; should correlate with age



Substructure?

e.g. LoCuSS cluster substructure survey (G. Smith PI):

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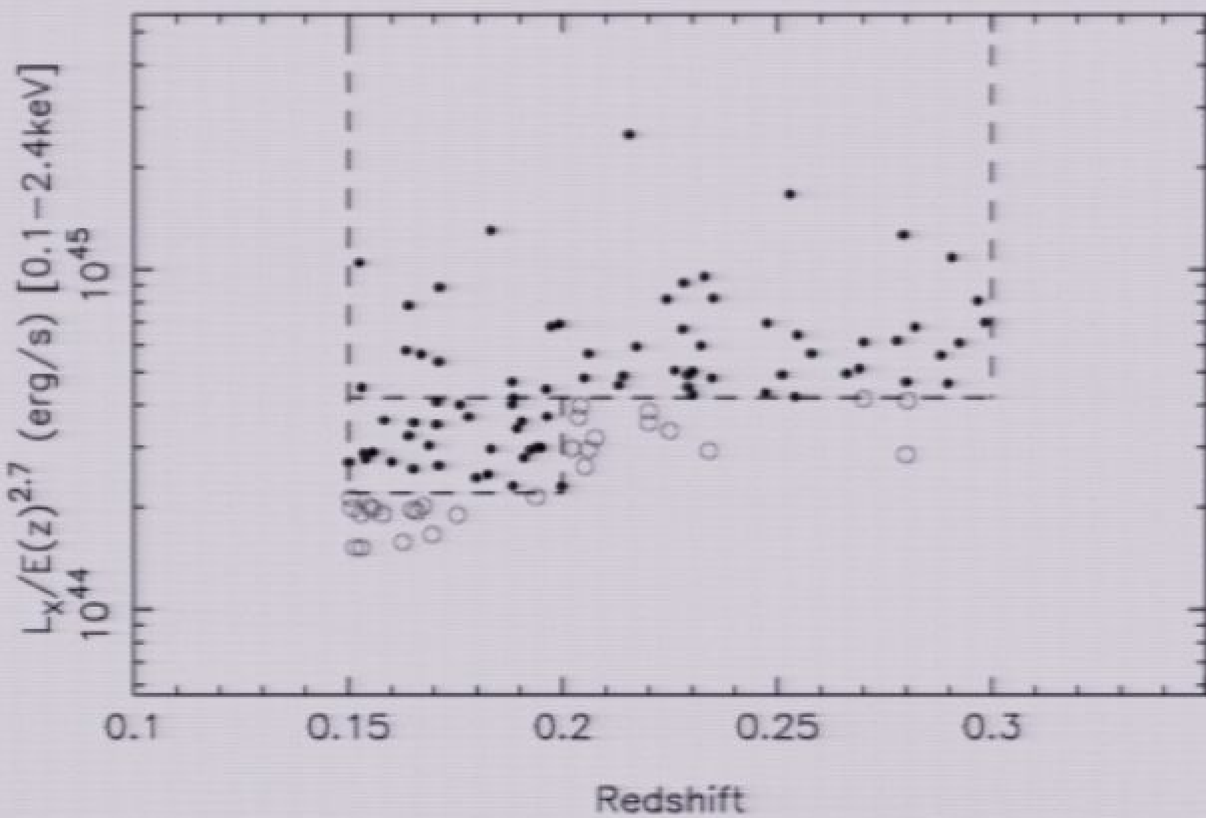
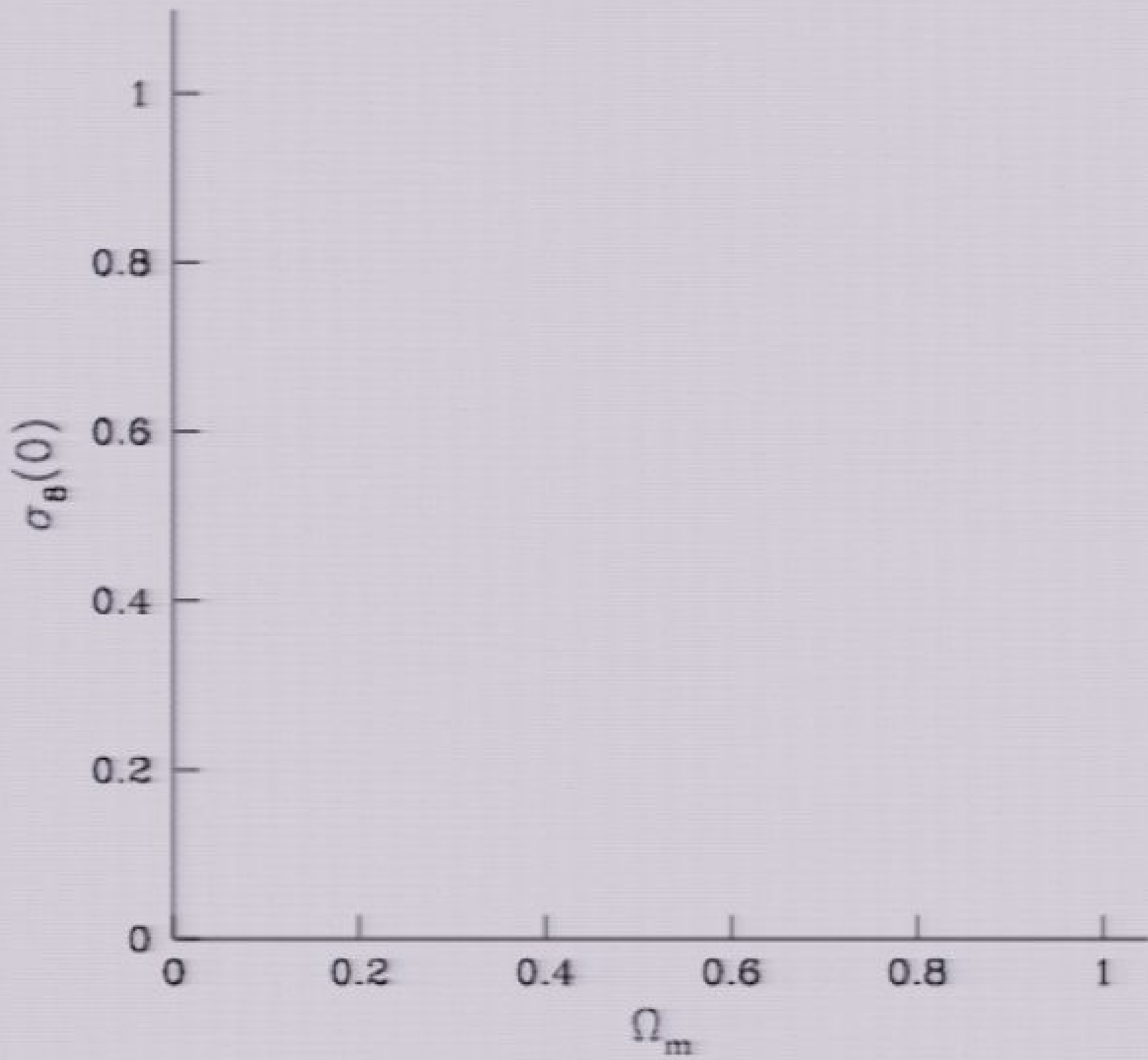
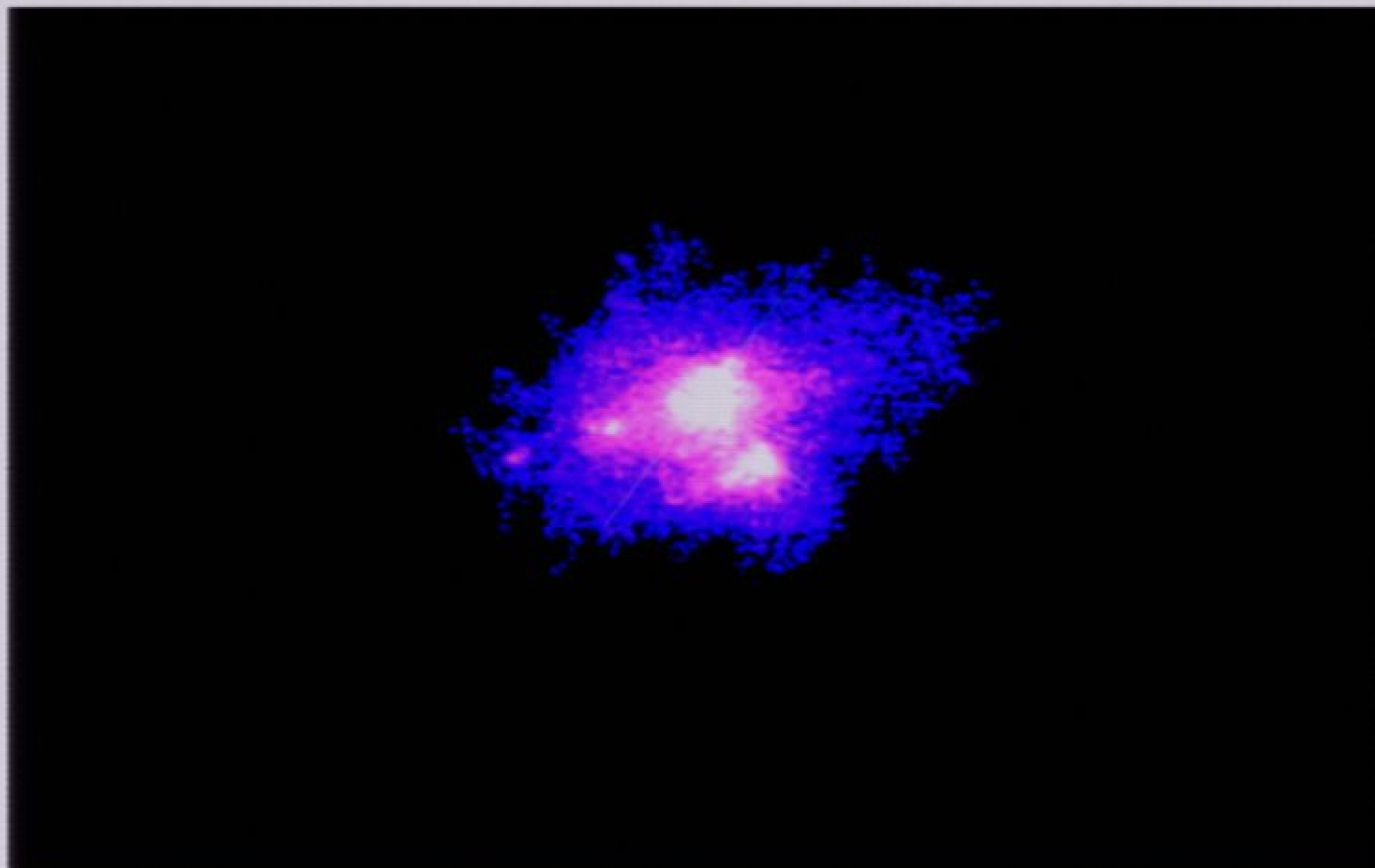


Application: clusters should assemble earlier in high-σ_8 cosmologies relative to high Ω_m ones



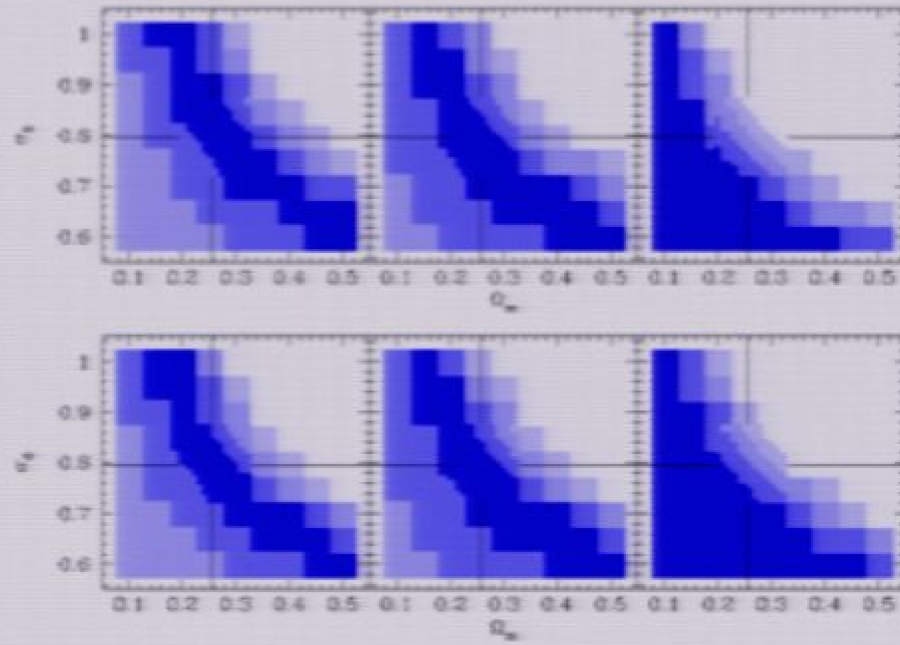
Value-added science with cluster samples:

from Large Scale Structure to Small Scale Structure



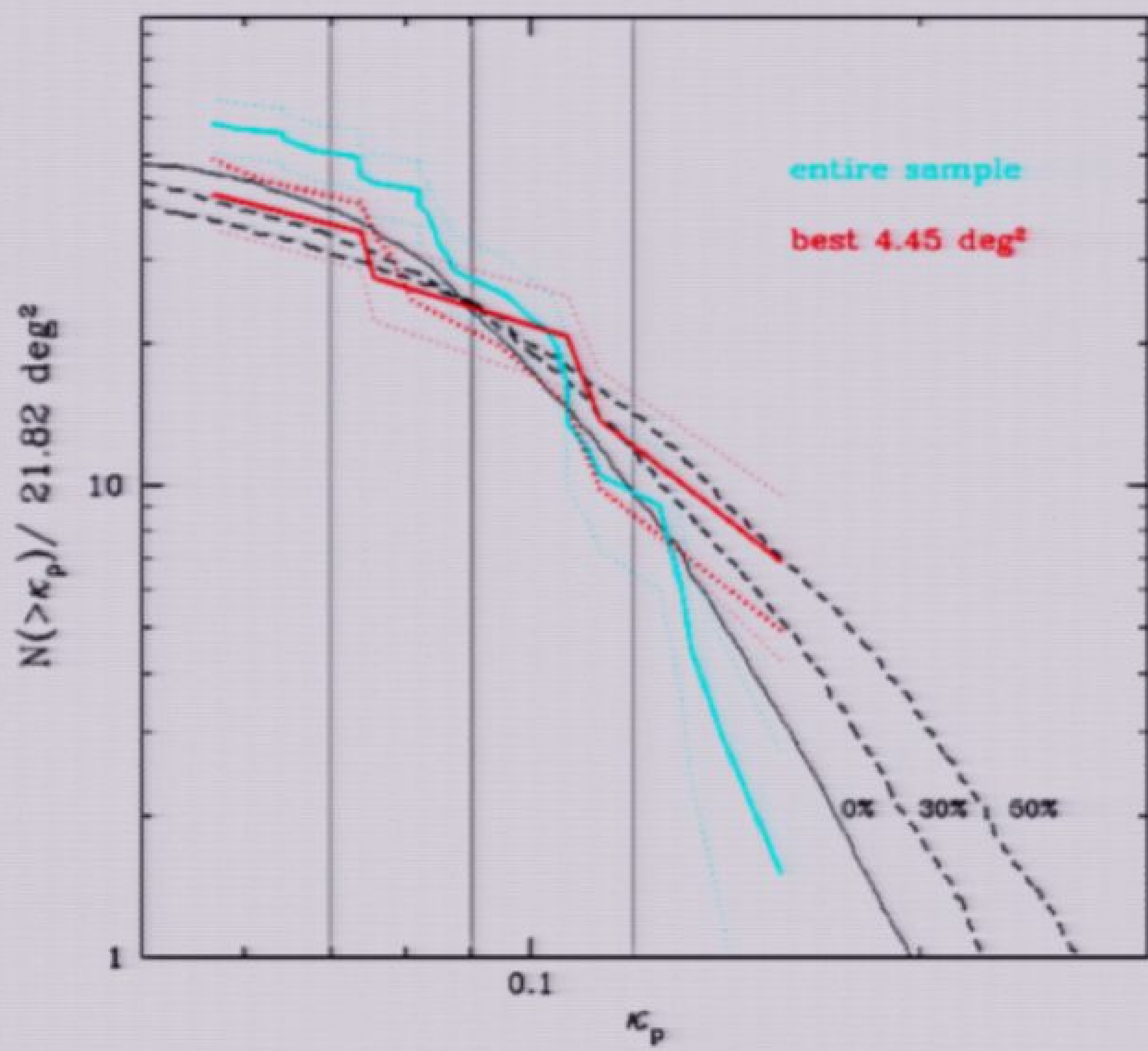
Cosmological Constraints

Cutting down to three fields observed in < 0.6" seeing, and cutting in redshift between 0.18 & 0.45 where follow-up success rate is good, get crude (10%) constraints on σ_8 & Ω_m from ~7 clusters!



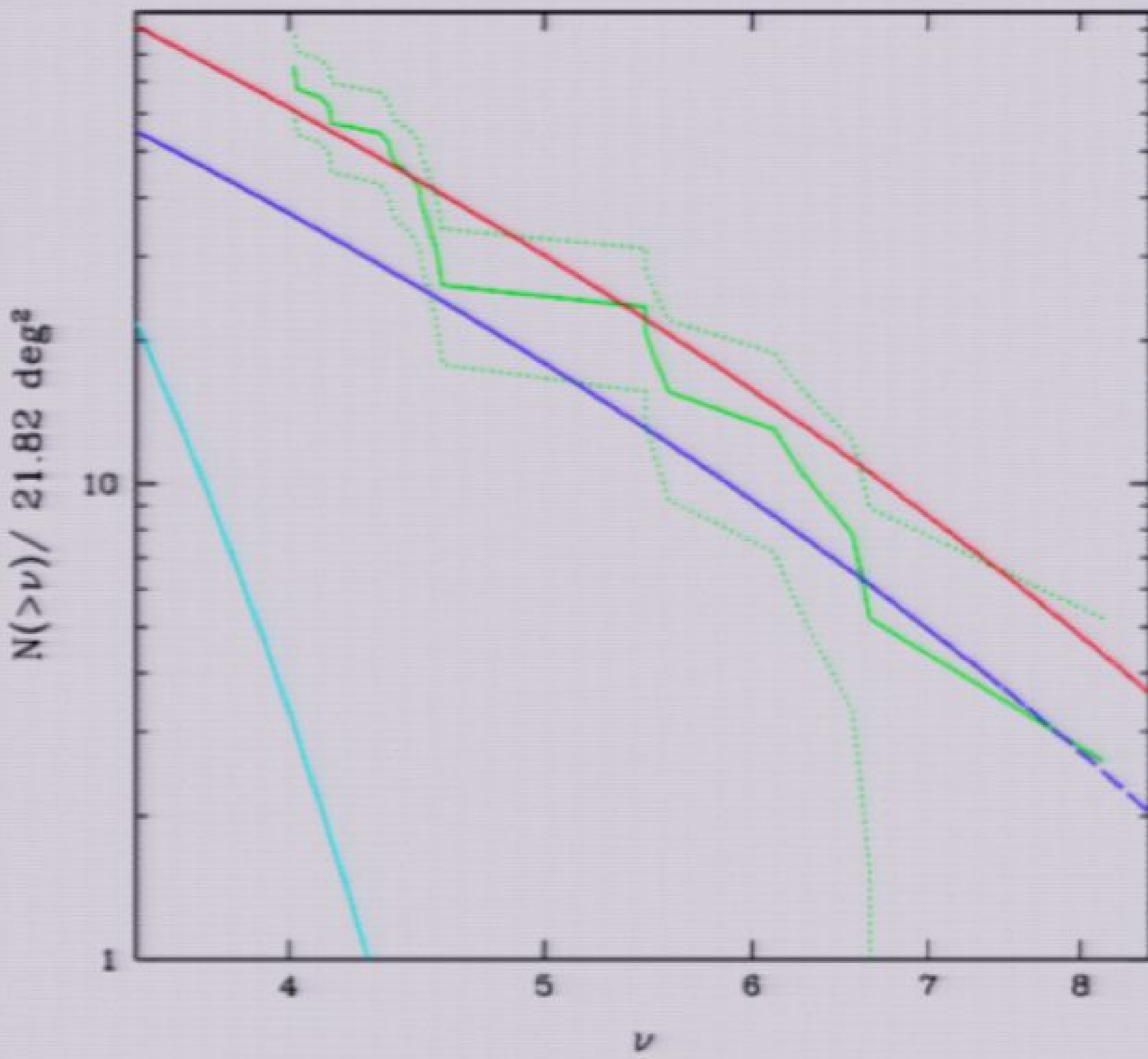
Error budget appears to be ~ 1/3 shot noise, 1/3 redshift incompleteness, 1/3 systematic uncertainties in cuts

Also expect a comparable error from source redshift distribution



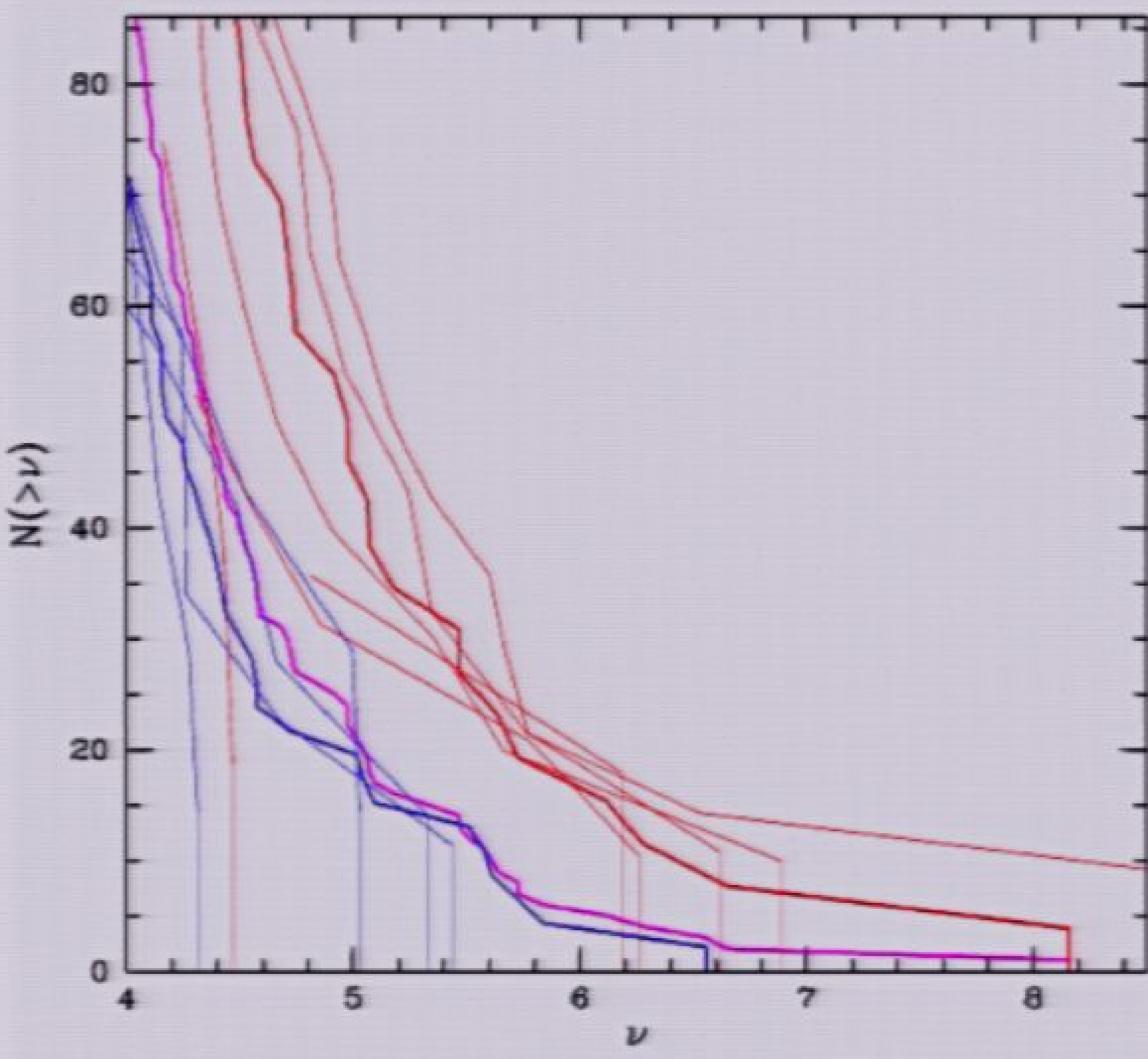
Entire survey (cyan) & final cut (red) versus model (solid black) with additional physical scatter

Best 35% of the survey area:



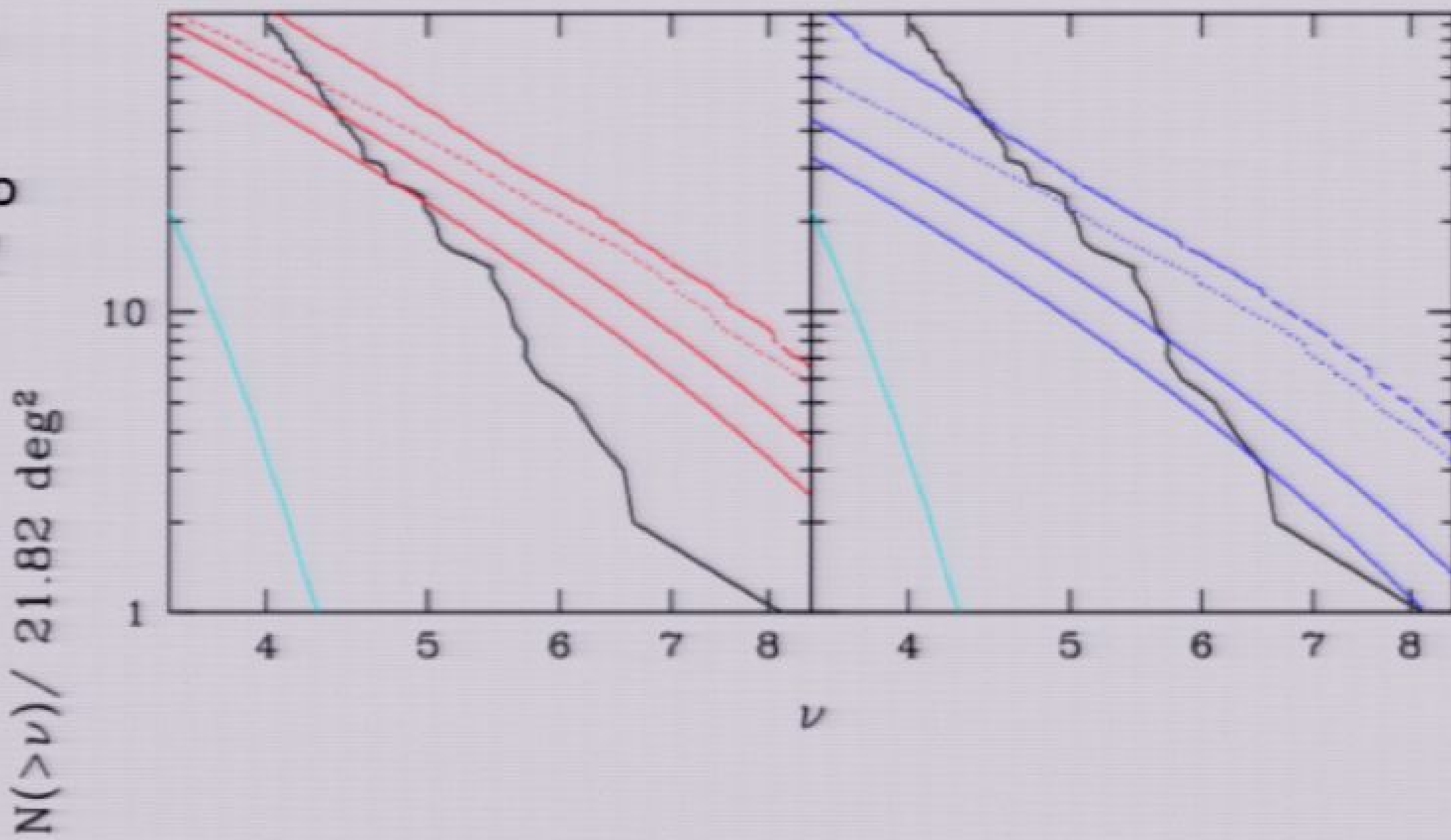
good + secure (green) versus high/low z_s models

(N.B.: Cosmic Variance)

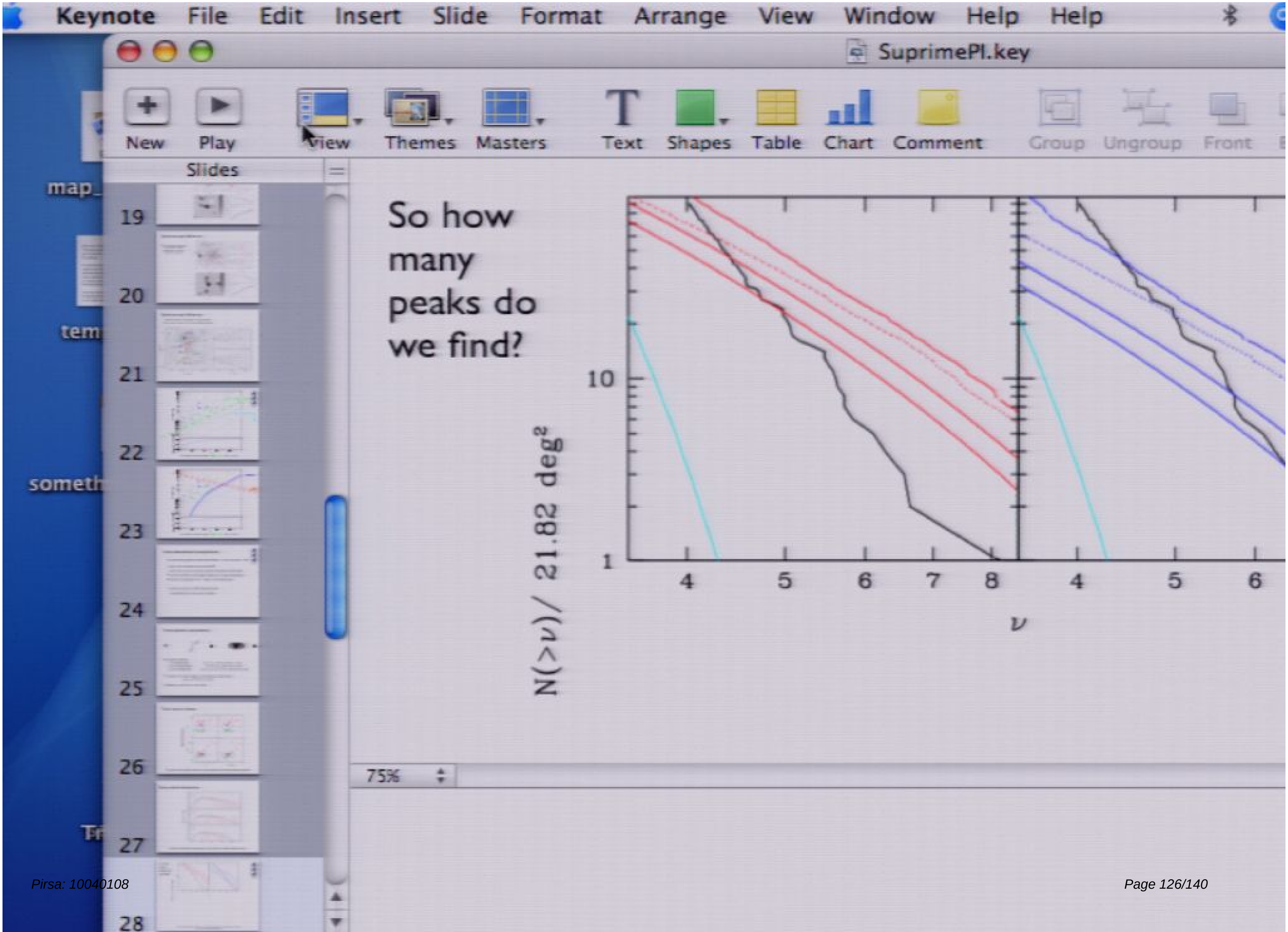


Peak height distributions: thin lines individual fields, thick lines averages whole survey (magenta); seeing > 0.7" (blue); seeing < 0.7" (red)

So how many peaks do we find?



Measured peak height distribution distribution (black) versus theory (red, blue)
(cyan - pure noise component)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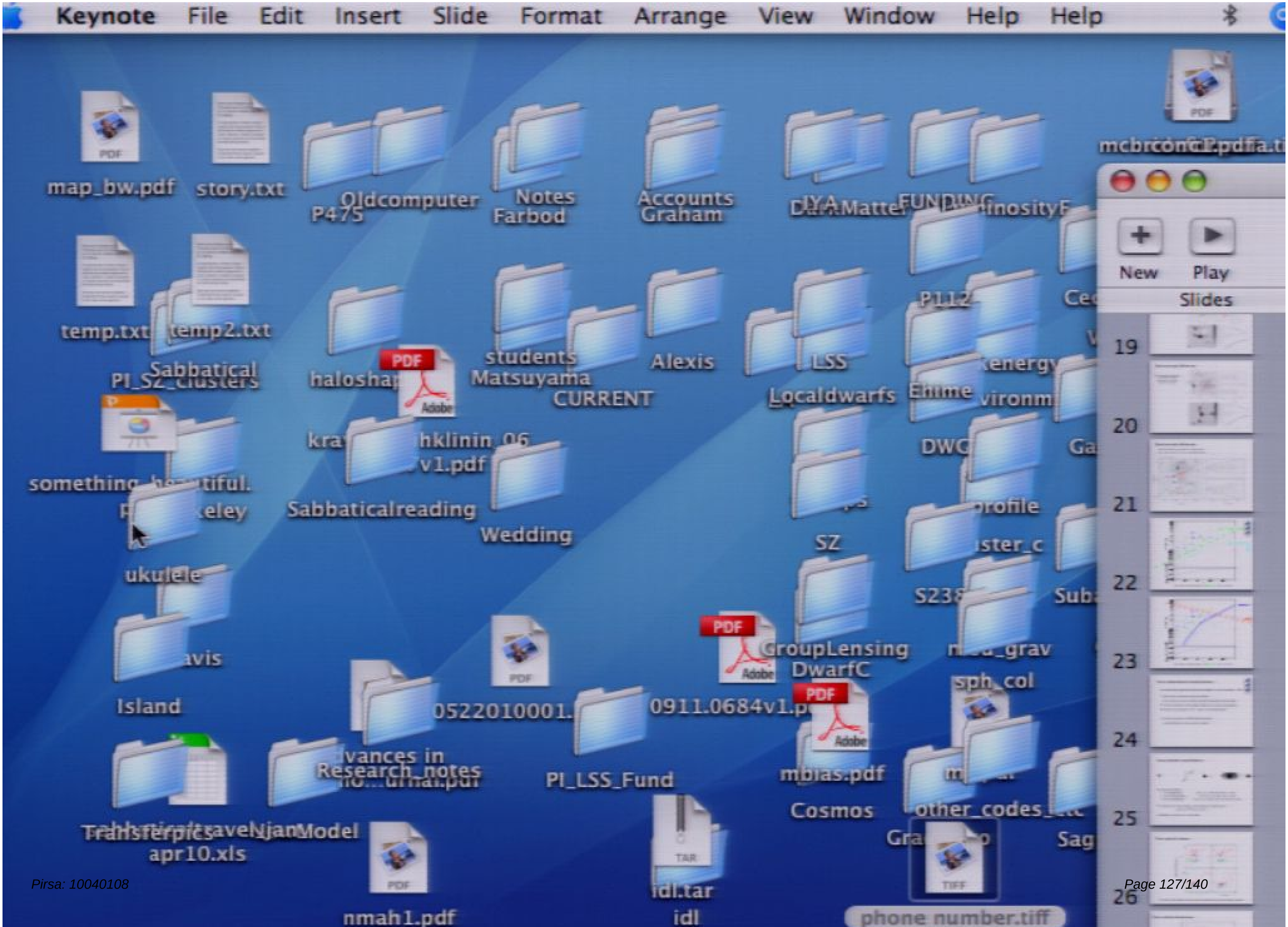
So how many peaks do we find?
N(>ν)/ 21.82 deg²
10
1
4 5 6 7 8
4 5 6
ν
75%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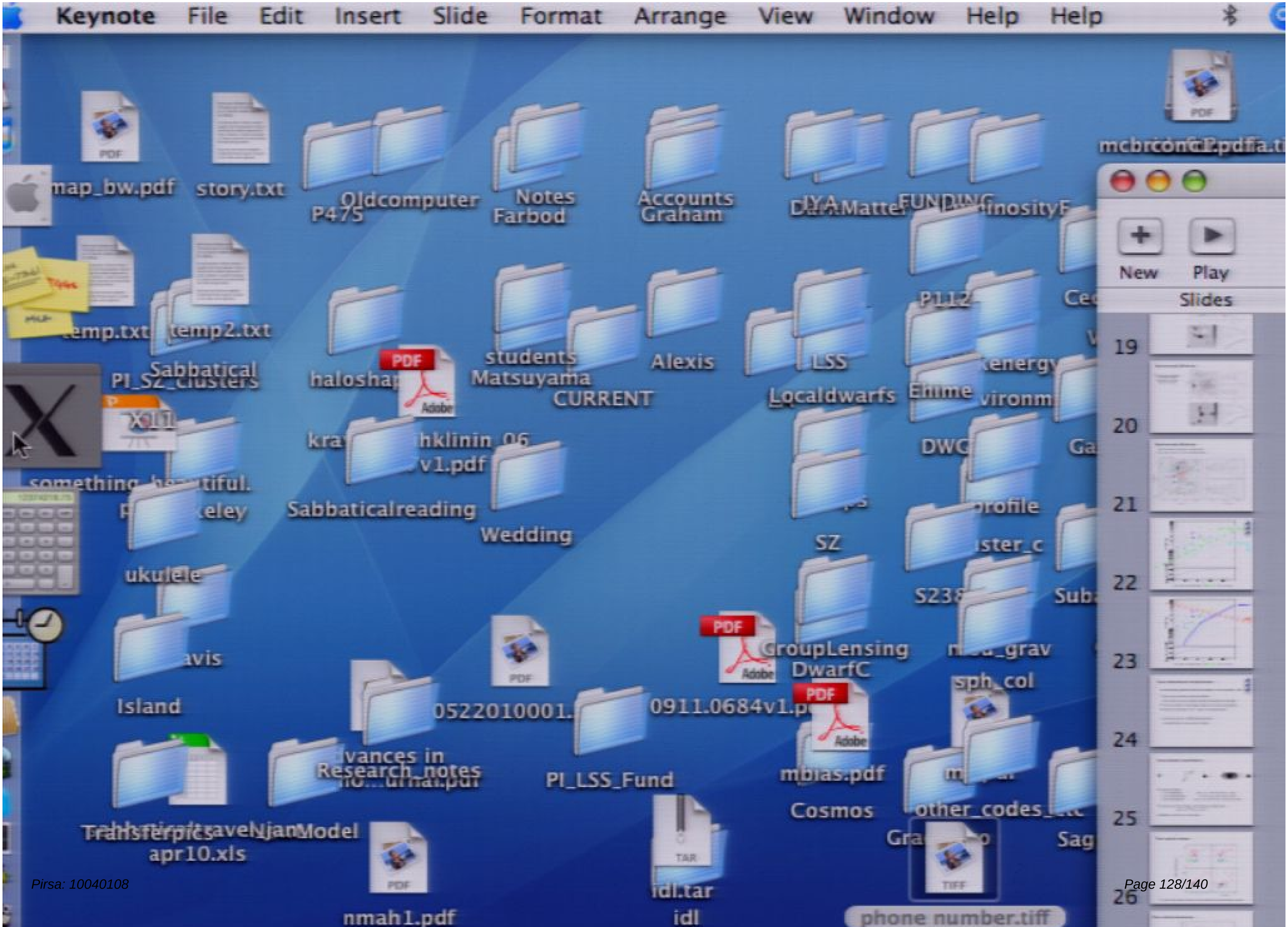

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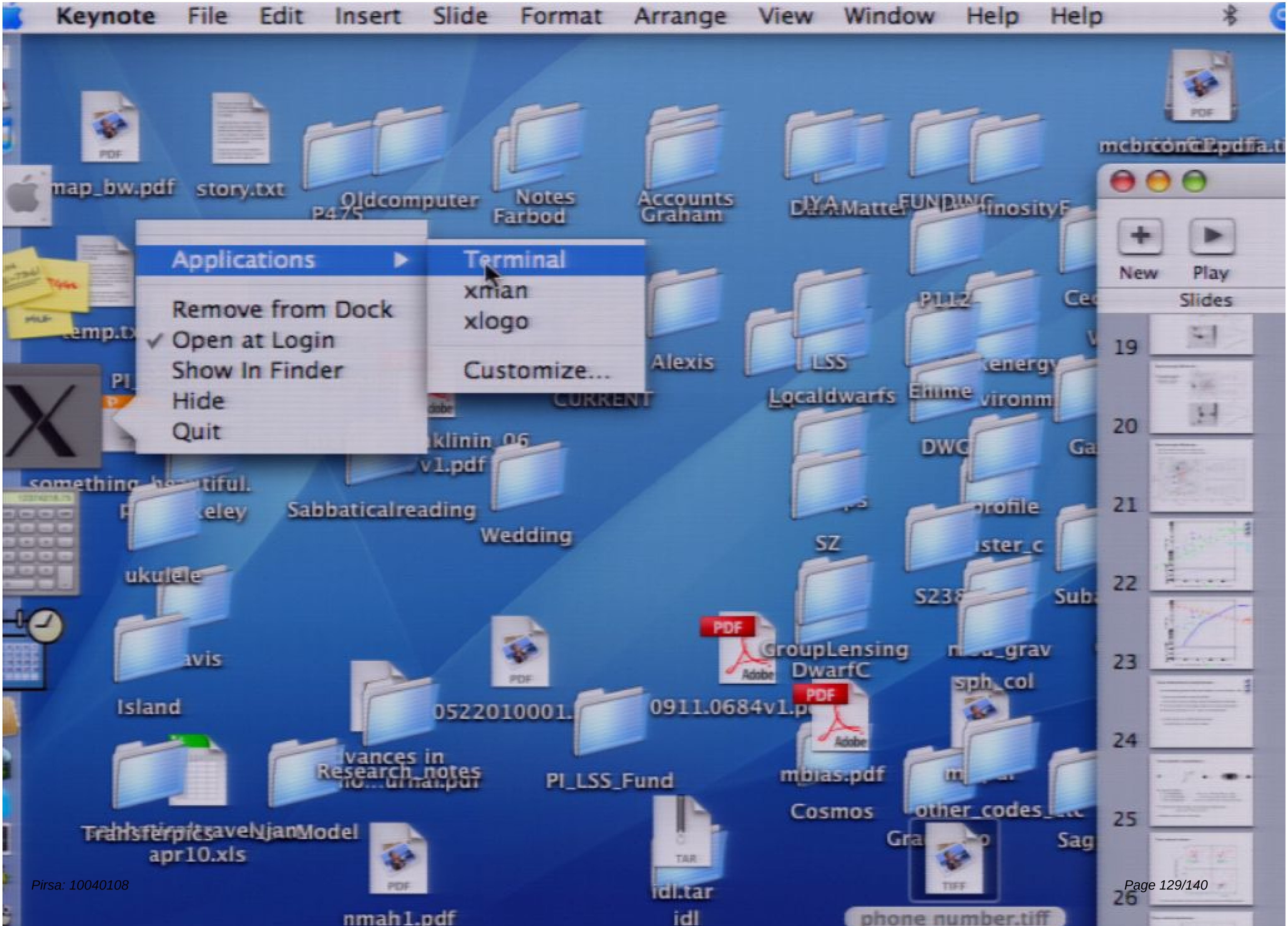
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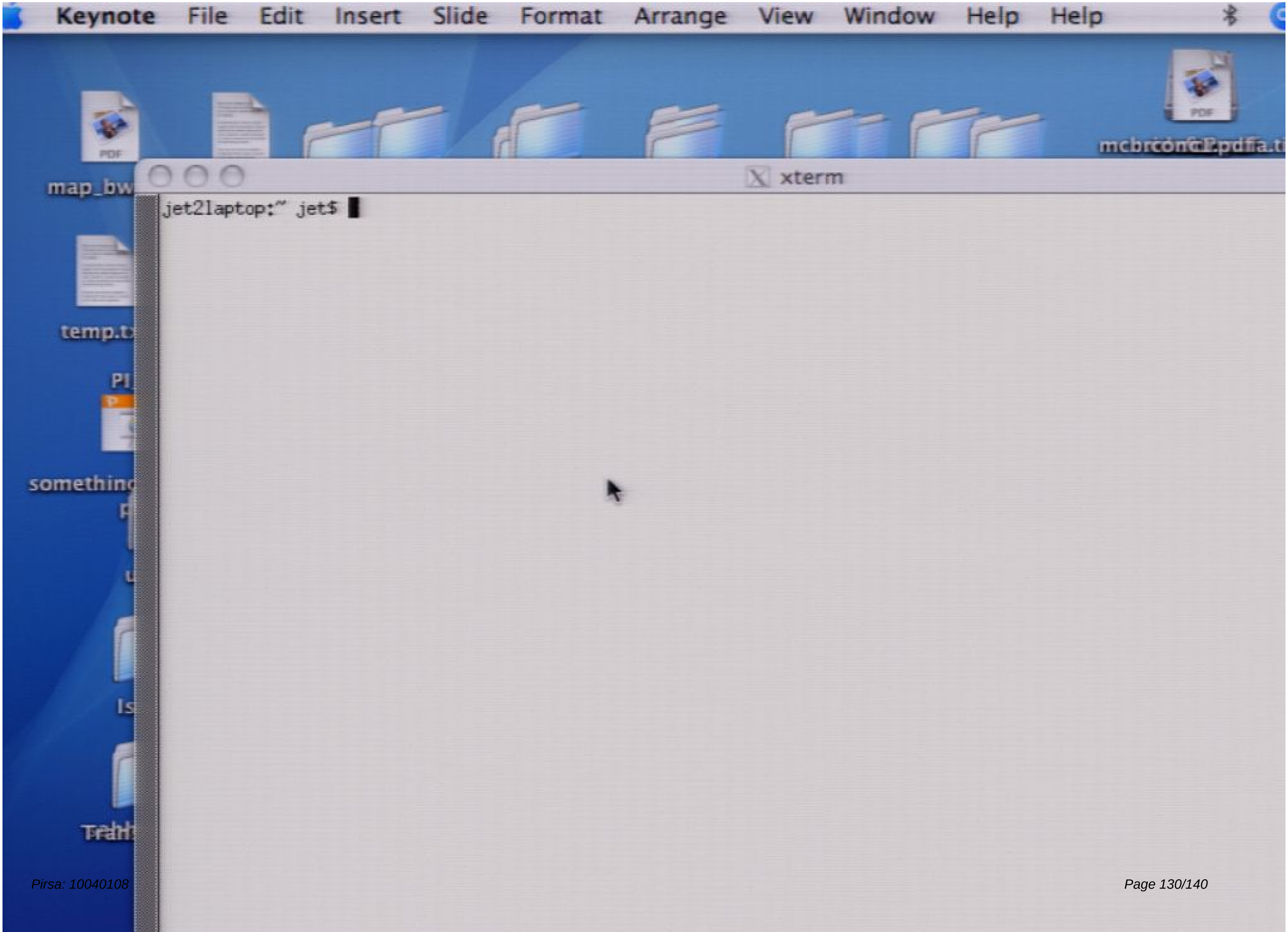
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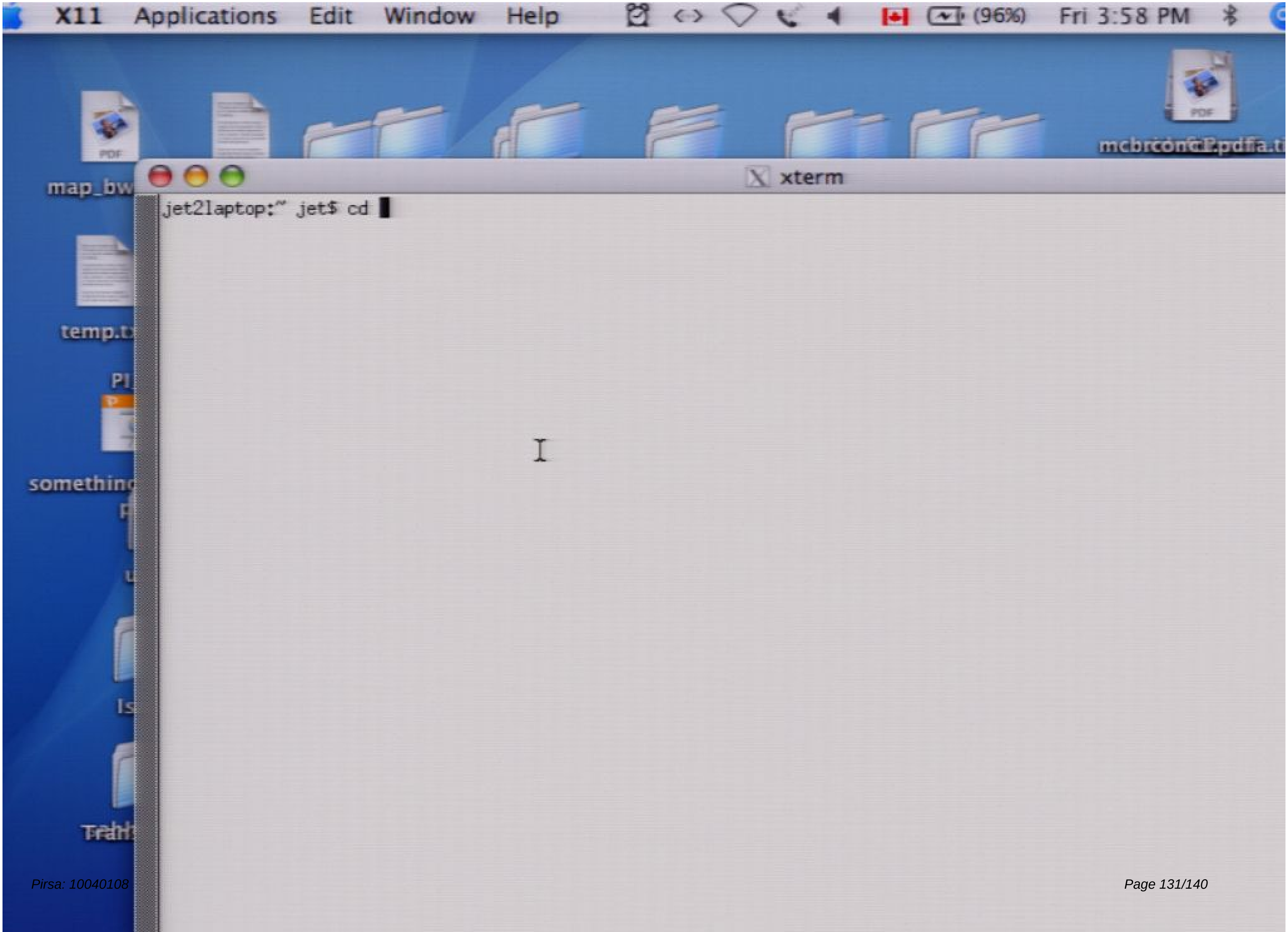
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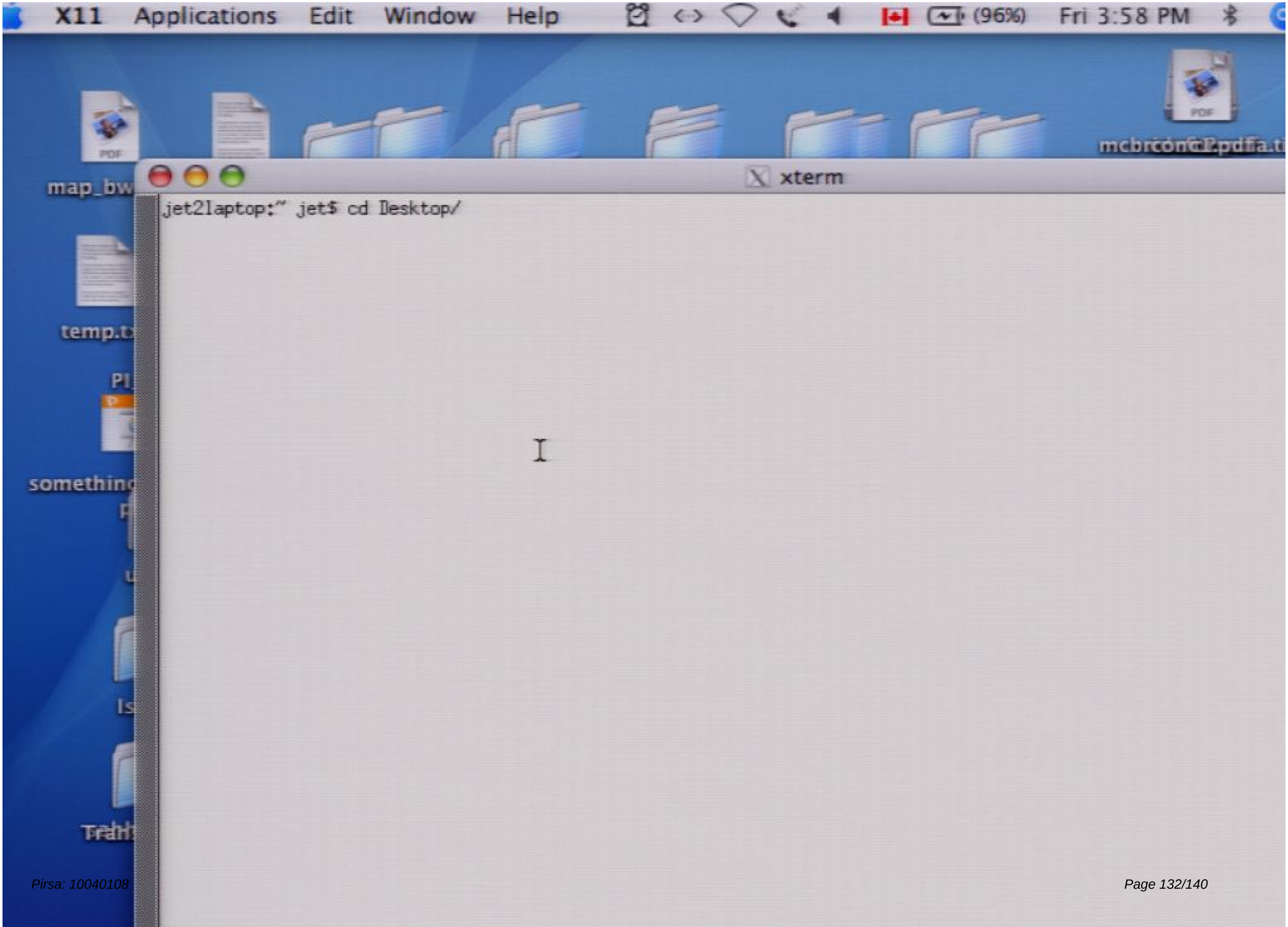
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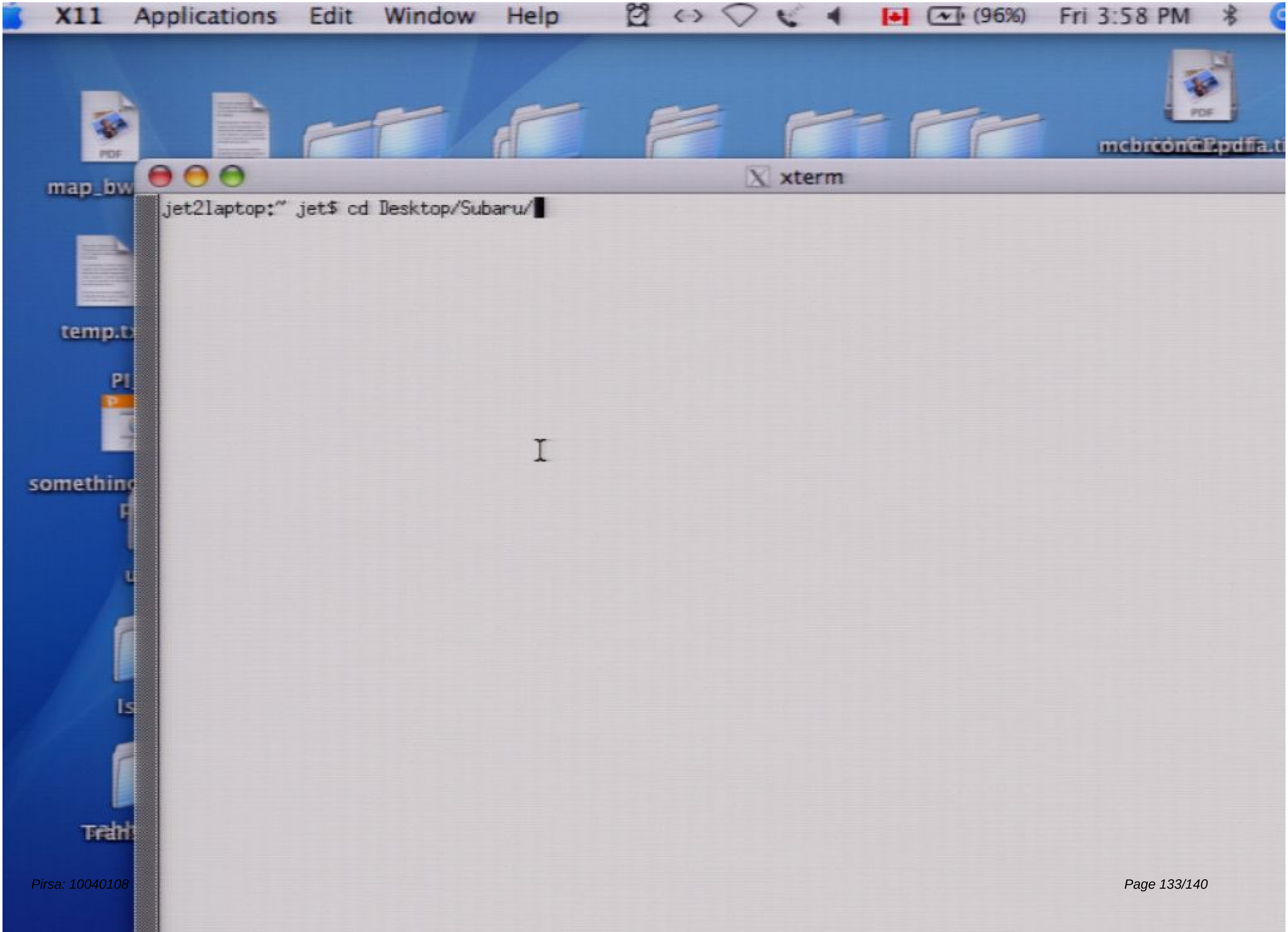
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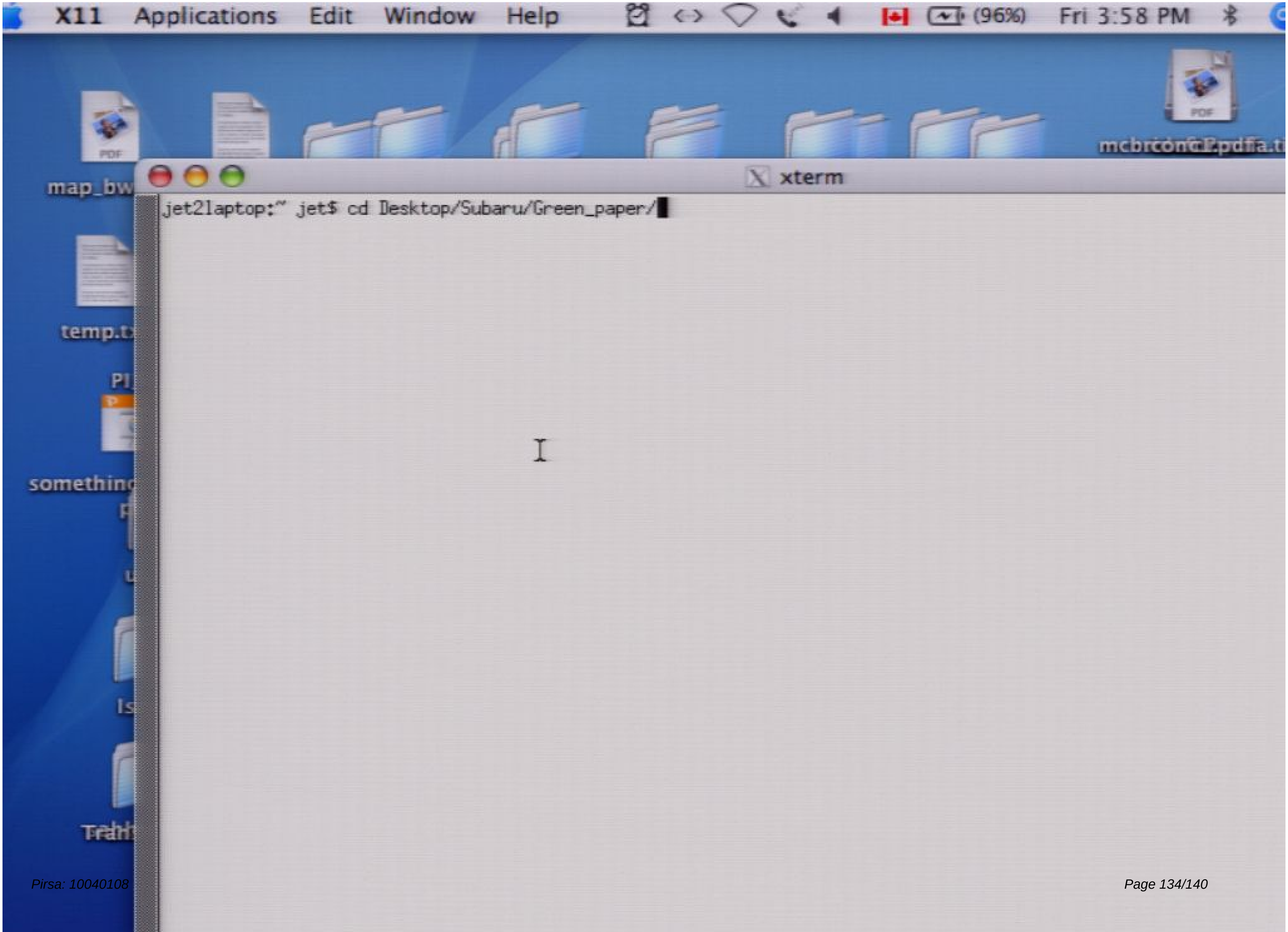
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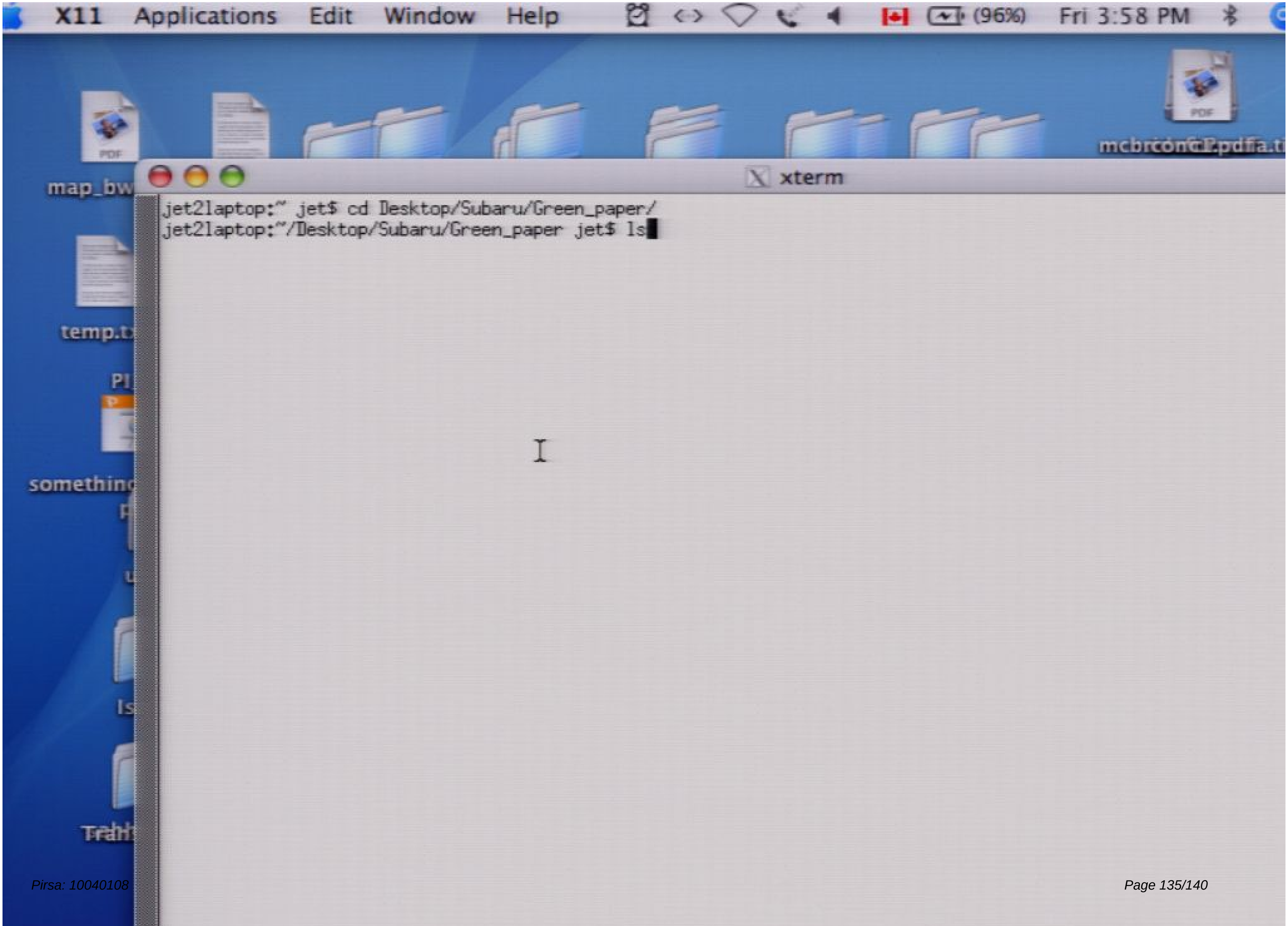
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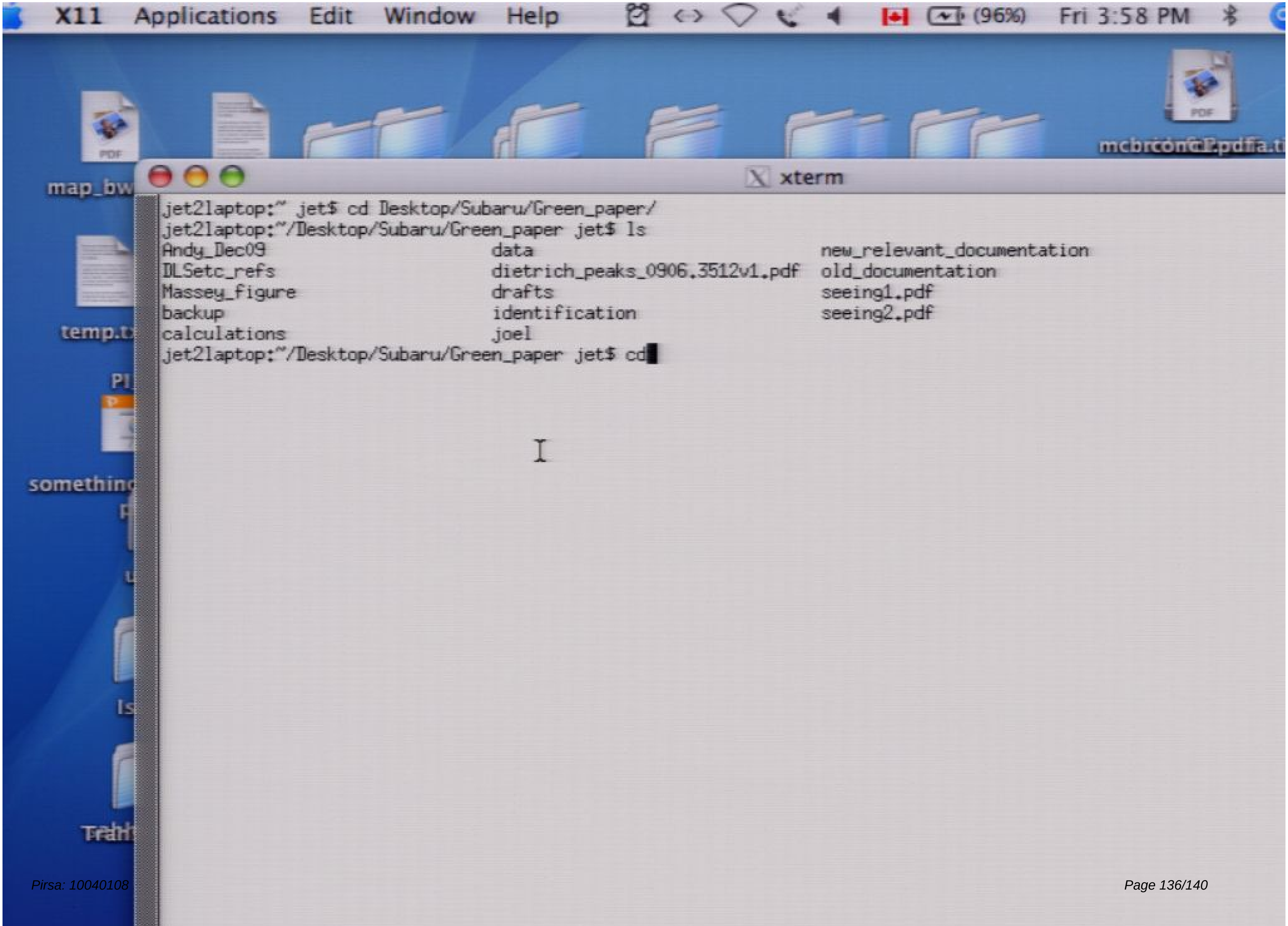
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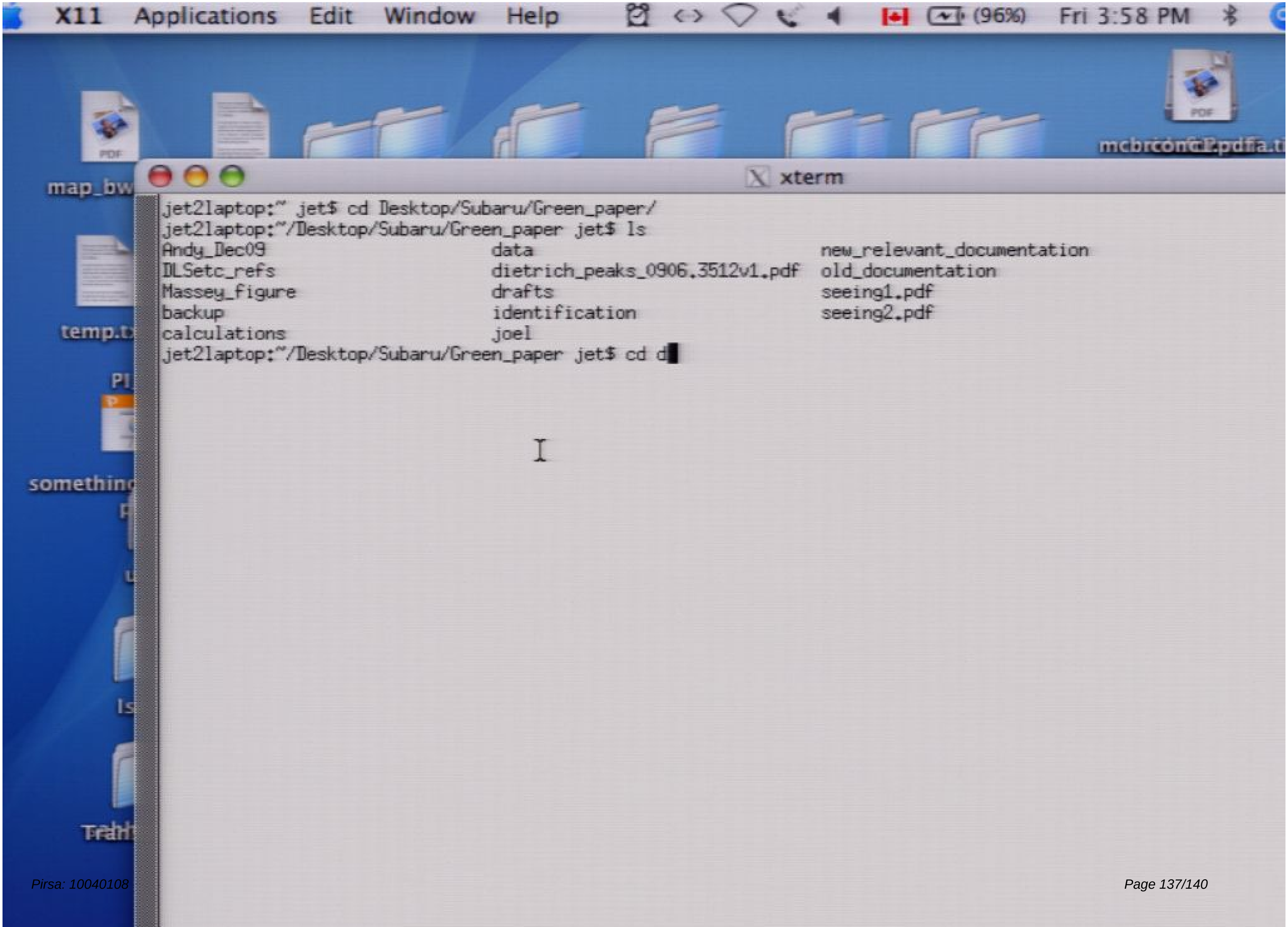
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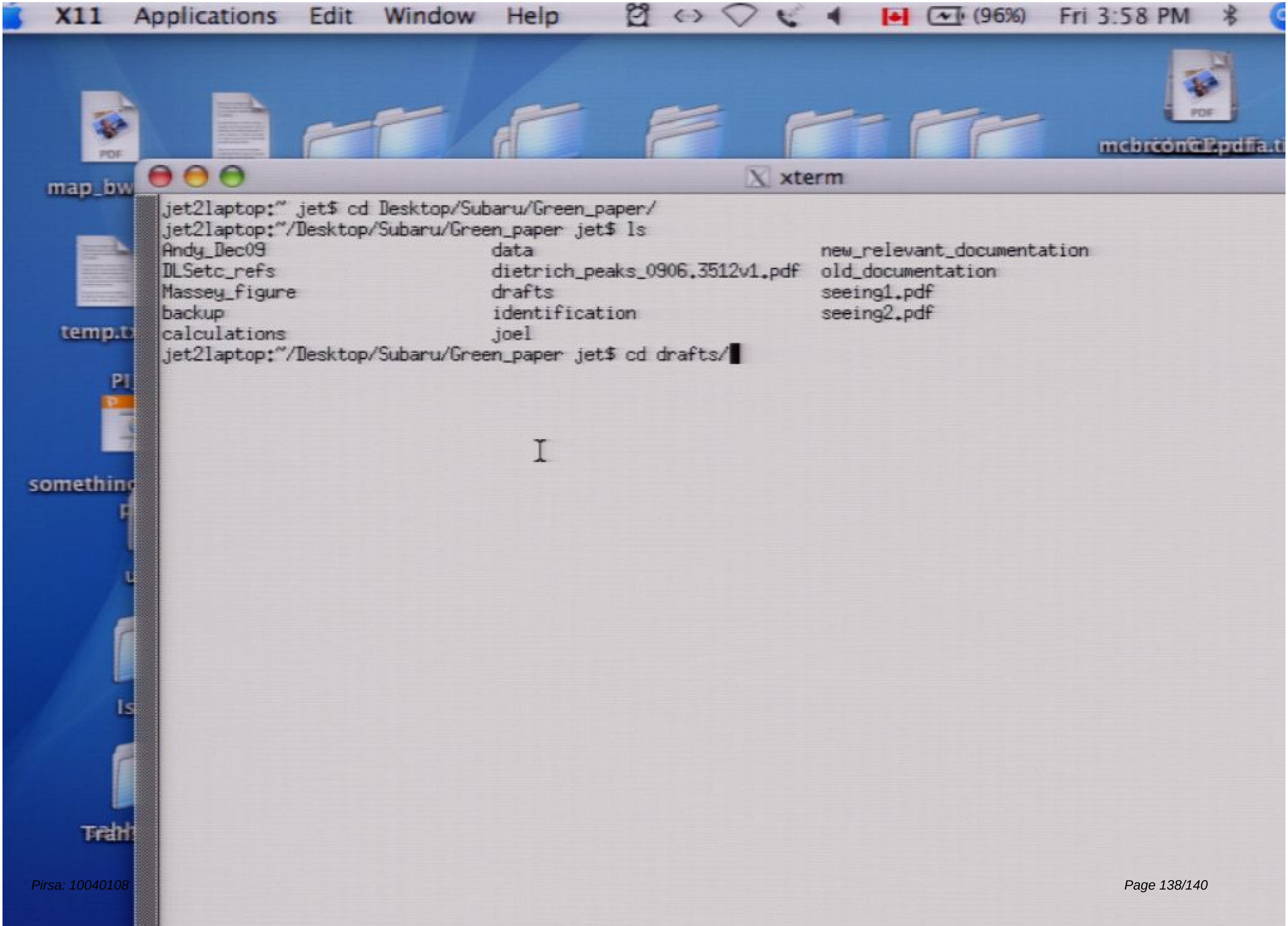
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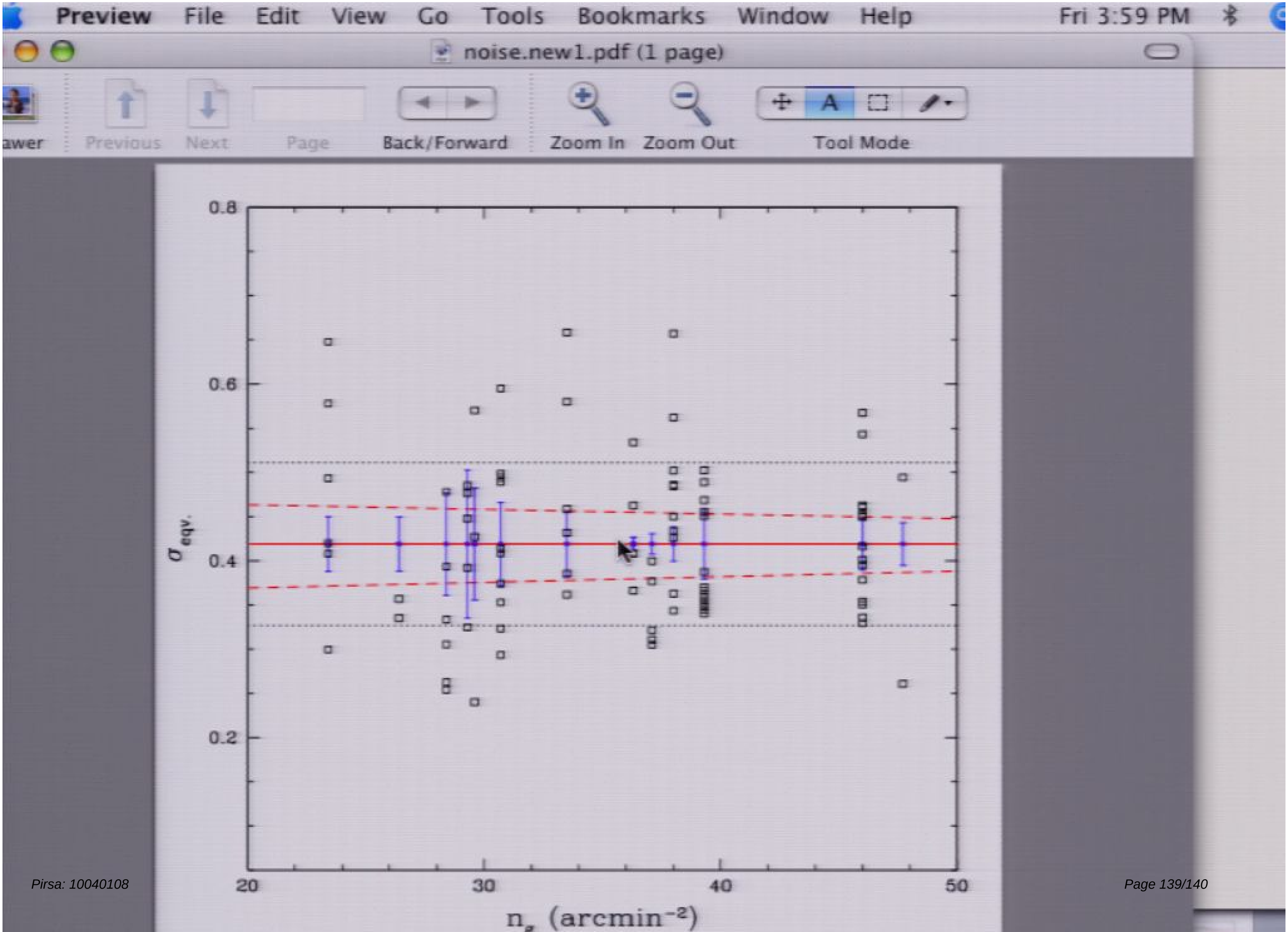
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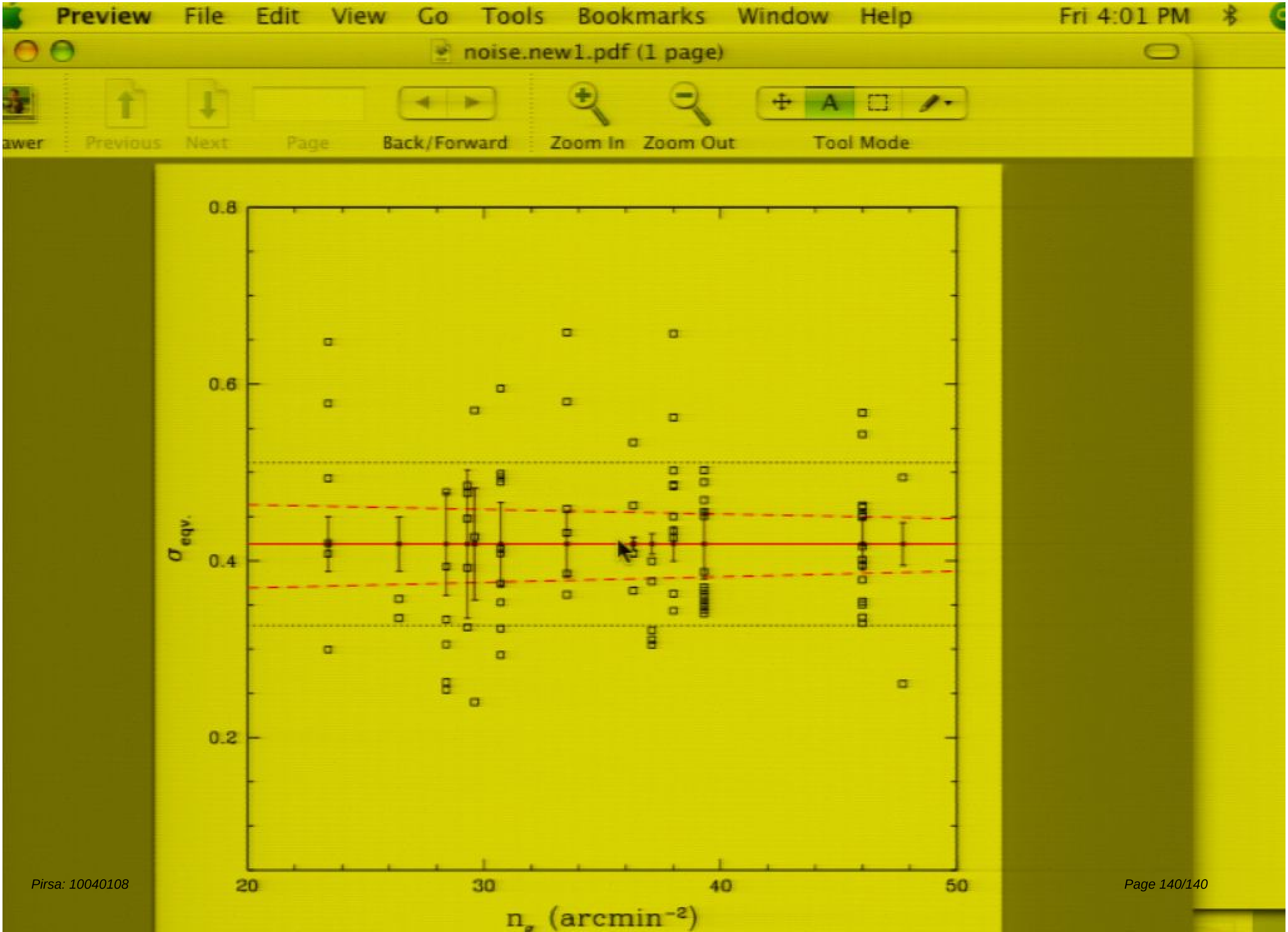
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