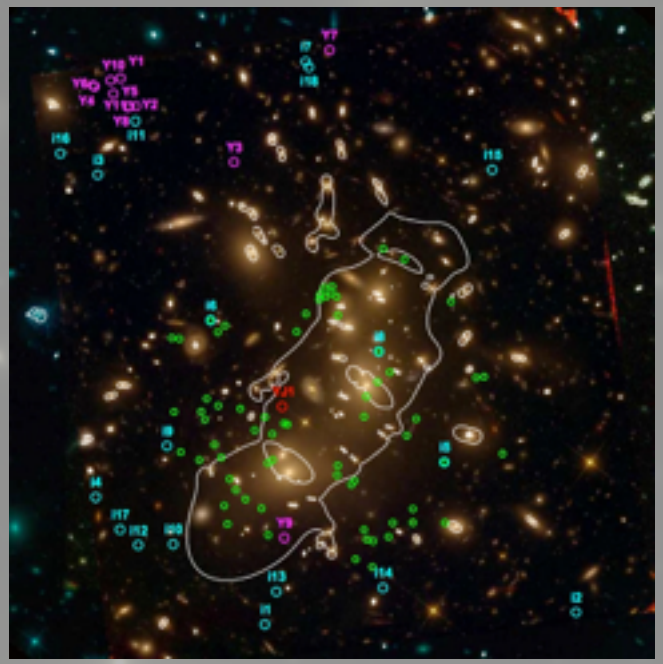
Uncovering the First Galaxies in the Frontier Fields

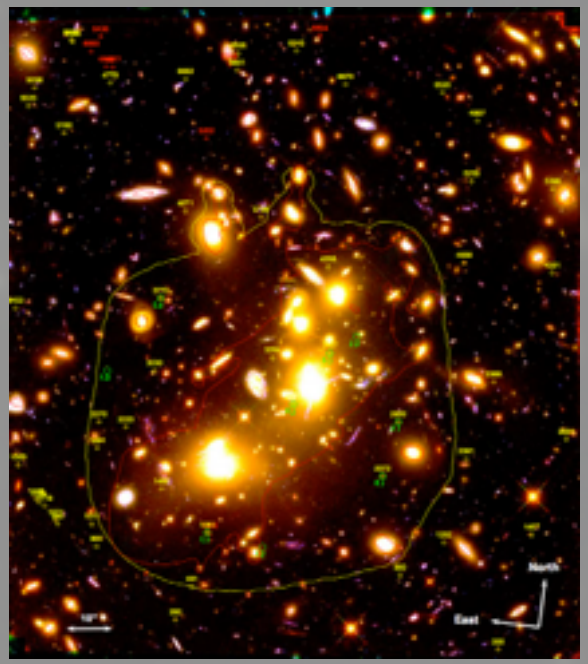
Rachael Livermore

University of Texas at Austin

The Problem:
It is difficult to detect faint sources in the most magnified regions of cluster fields



Ishigaki+ 2014



Atek+ 2014

The Problem:
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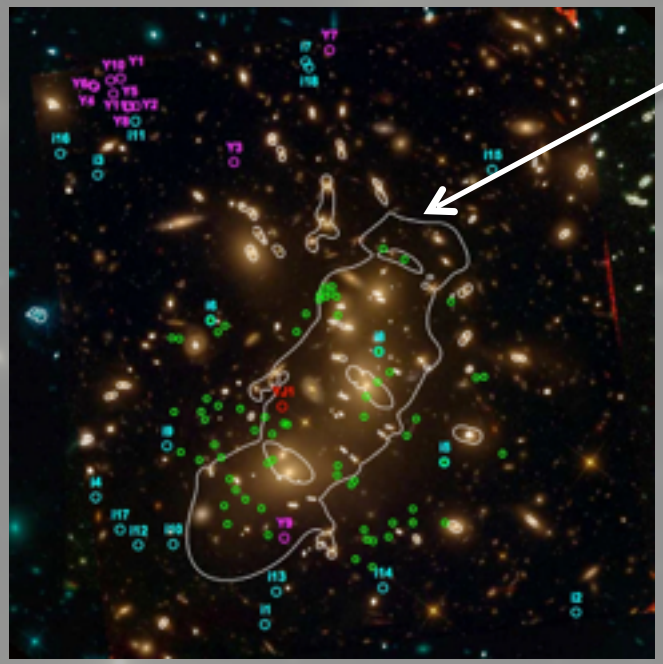
Critical line at z=7 denotes region of maximum magnification



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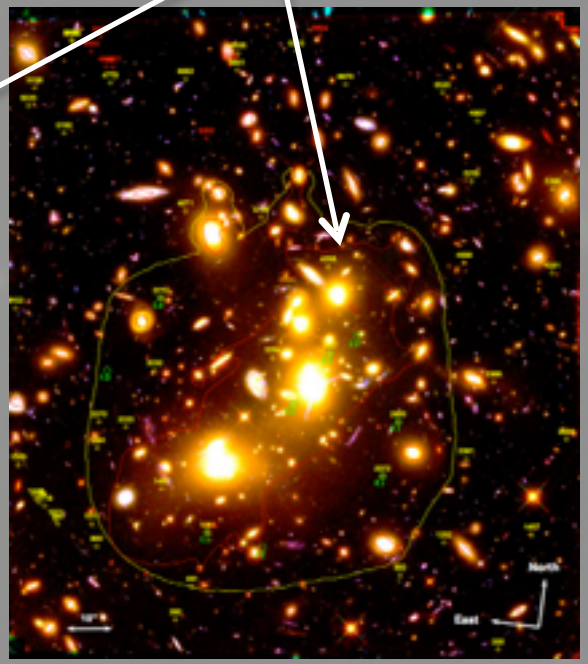

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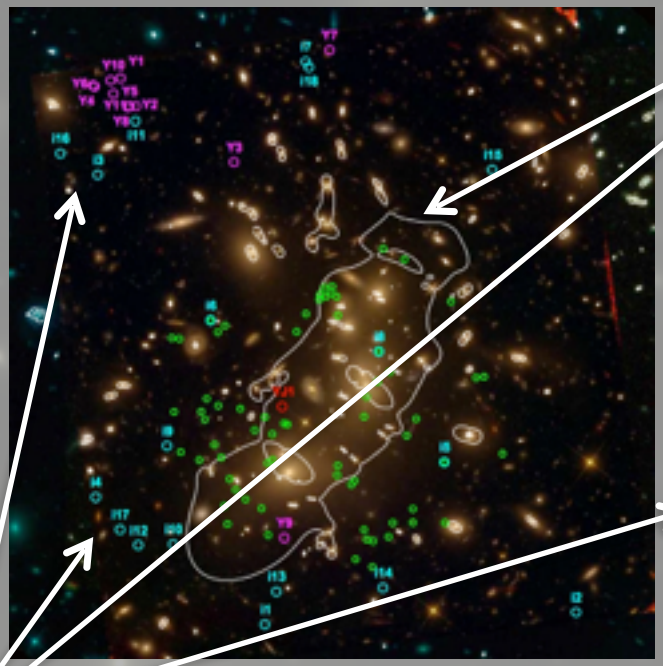

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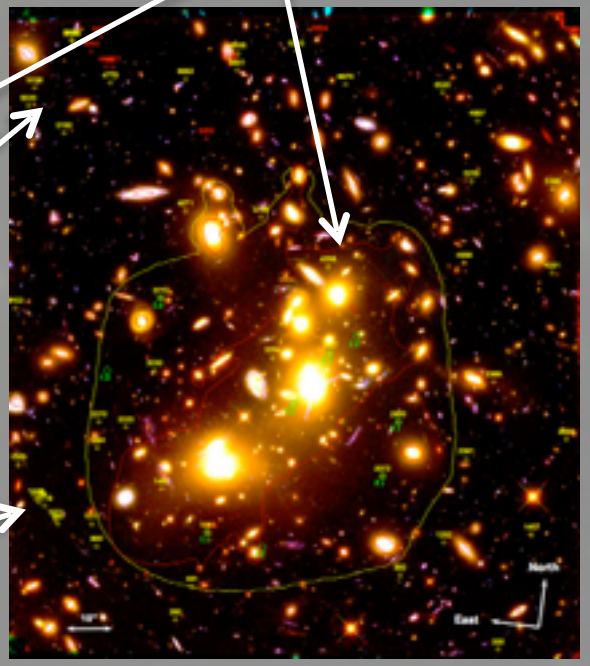
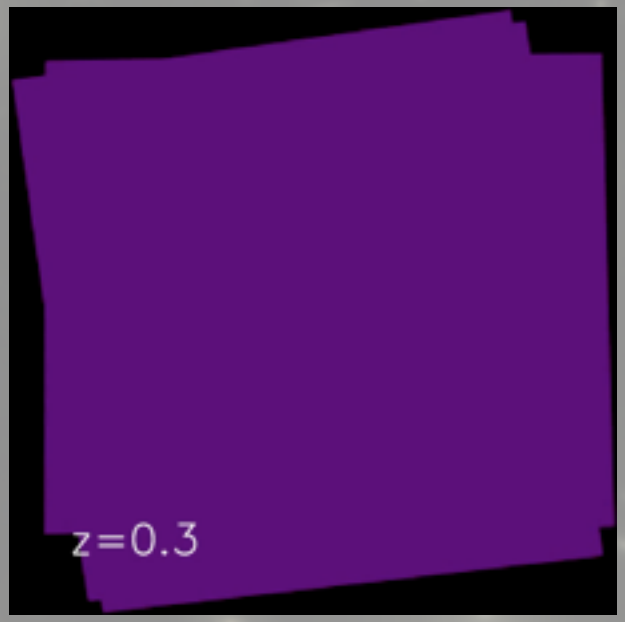


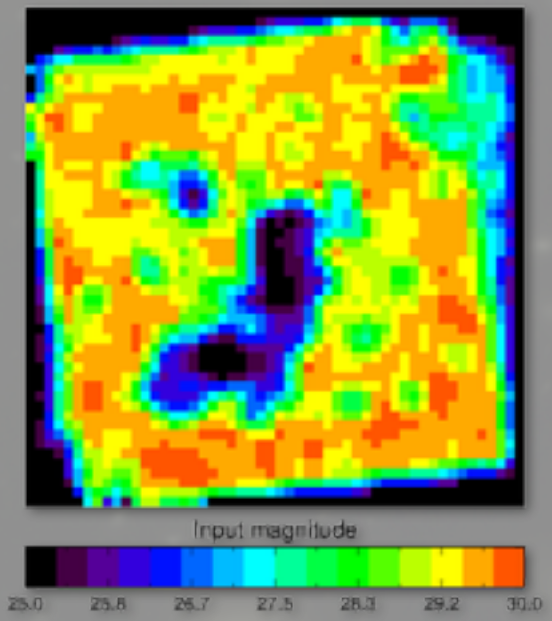
Atek+ 2014

High-z sources concentrated around outskirts of cluster where magnification → 1

The highly magnified regions represent the smallest volume…



…and the bright foreground galaxies and intracluster light limit the depth of the image in the central regions



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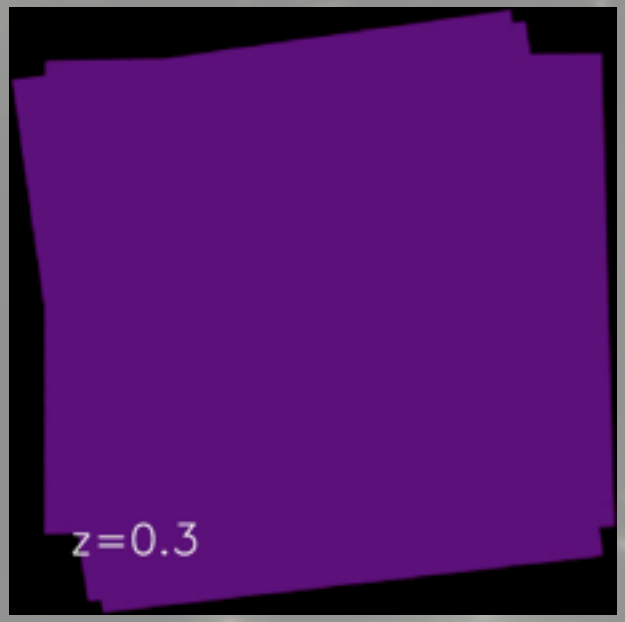

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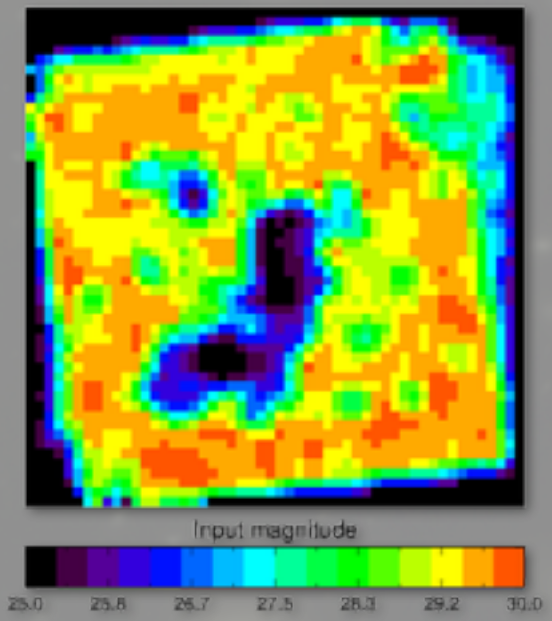

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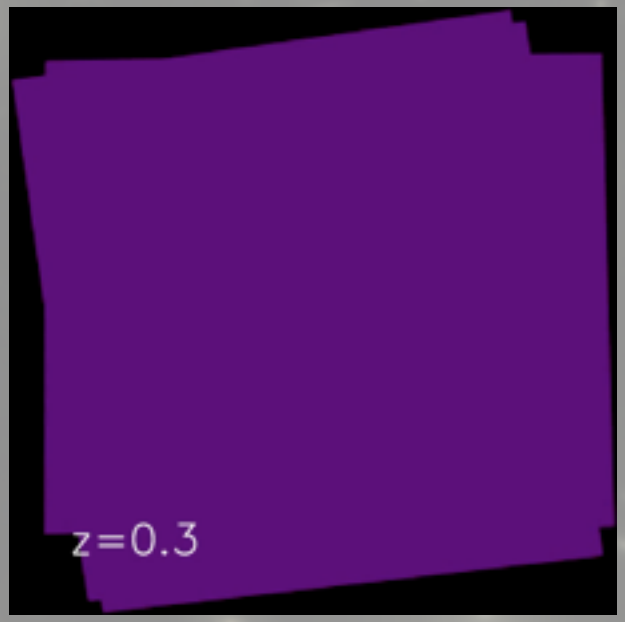

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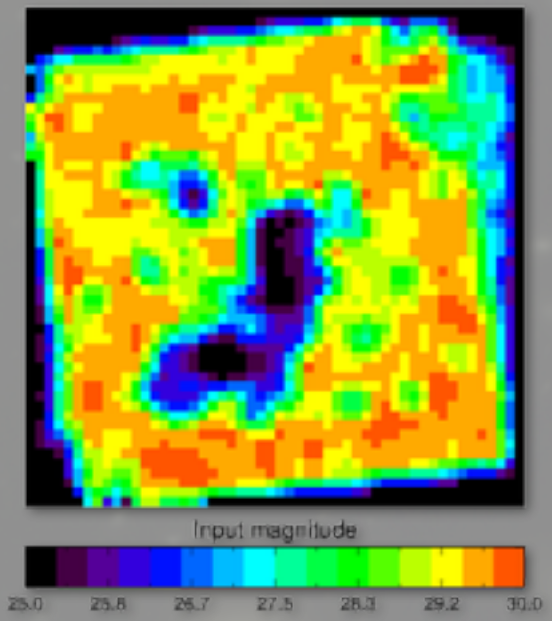

Wavelet Decomposition

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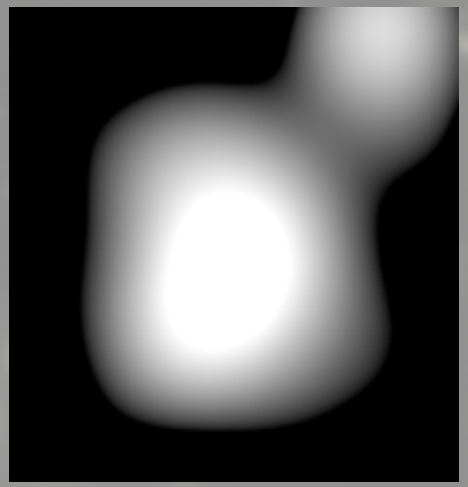

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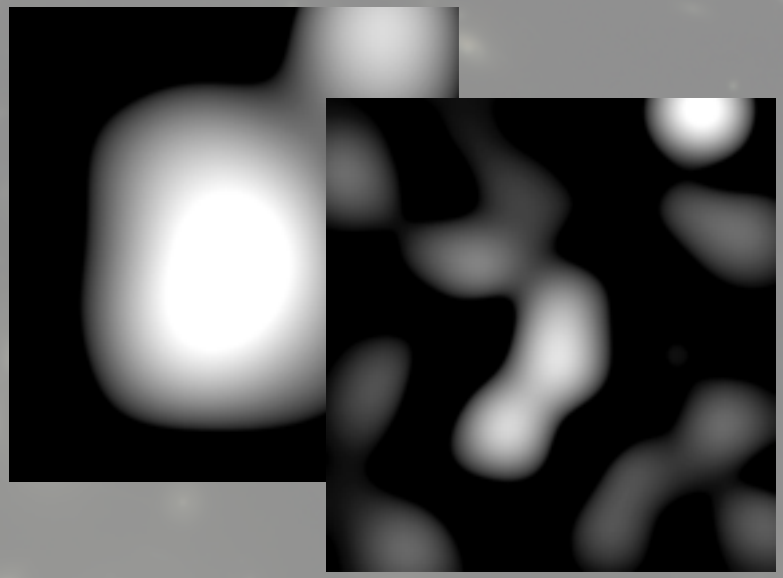

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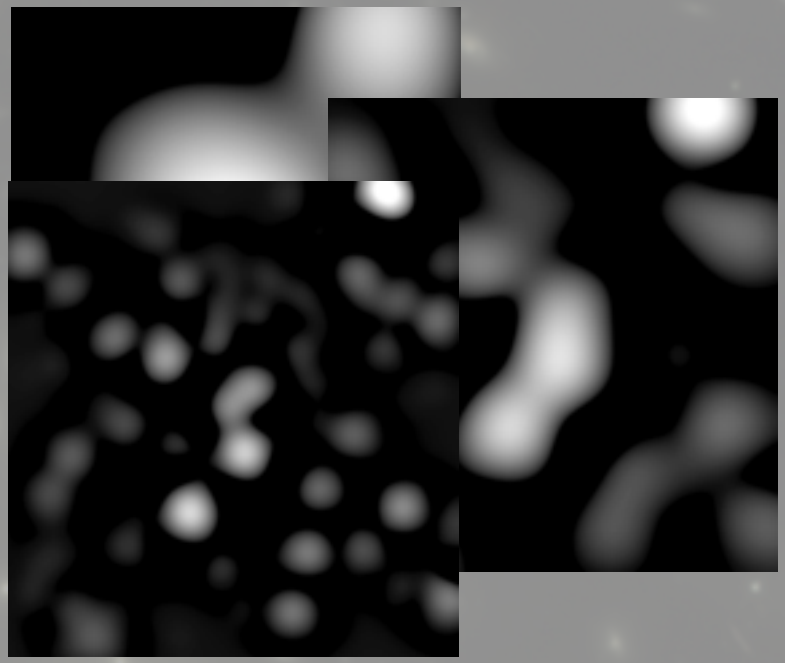

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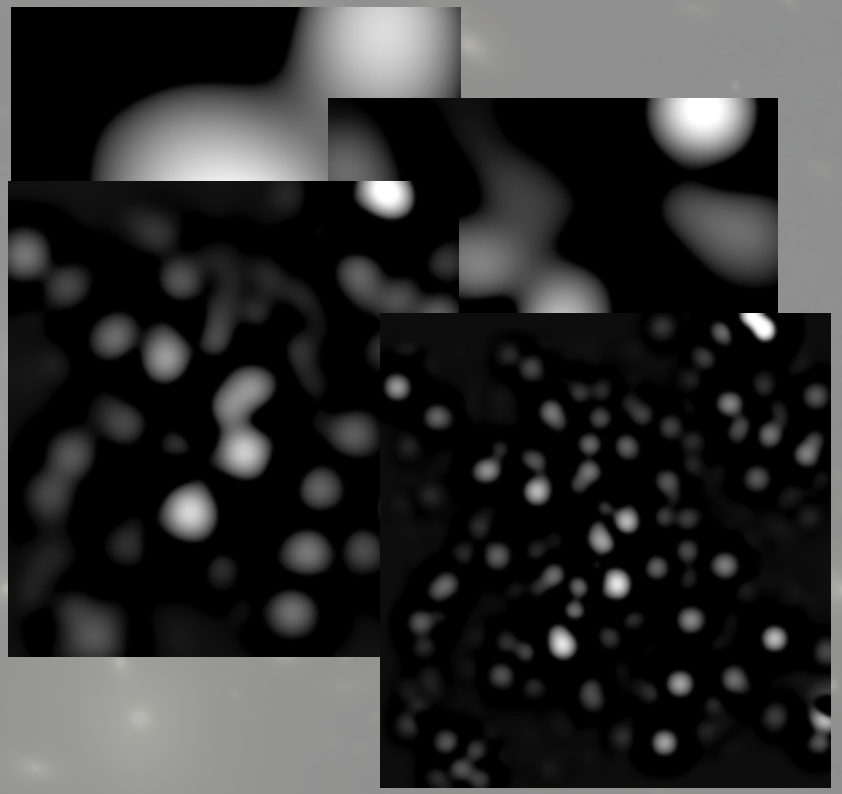

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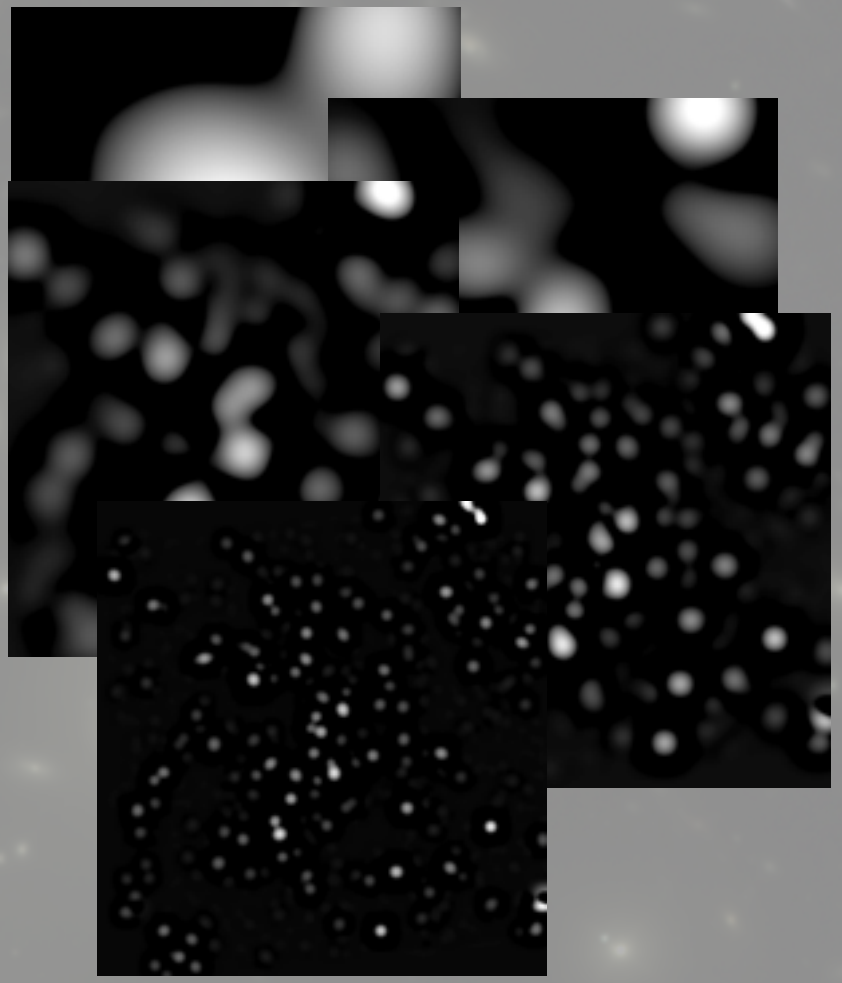

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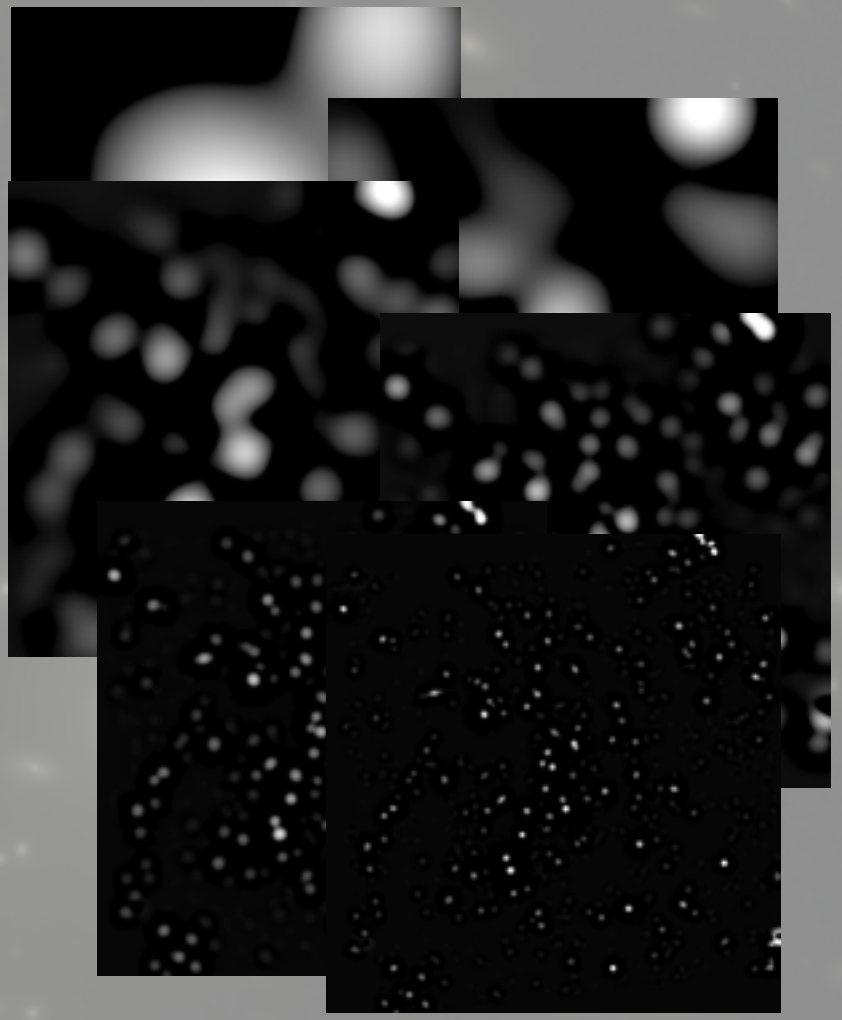

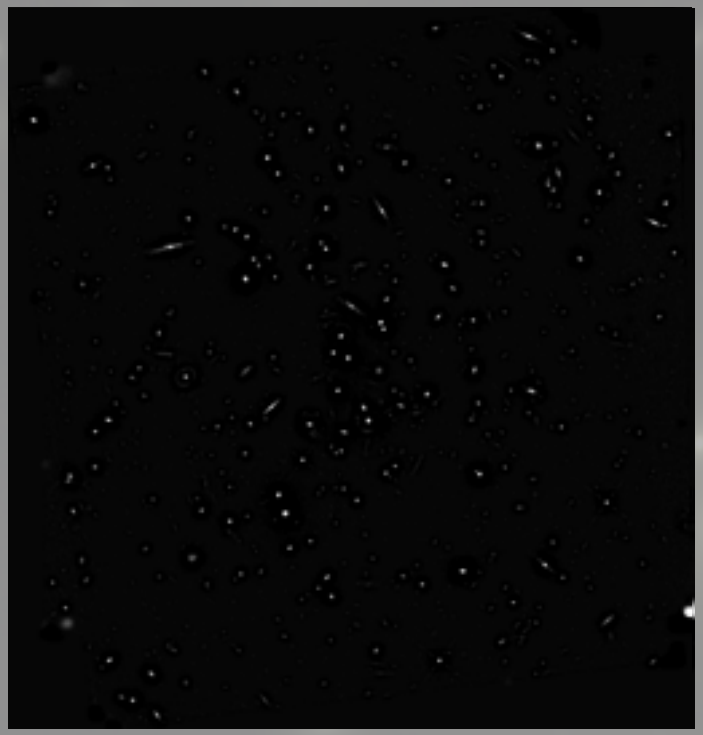

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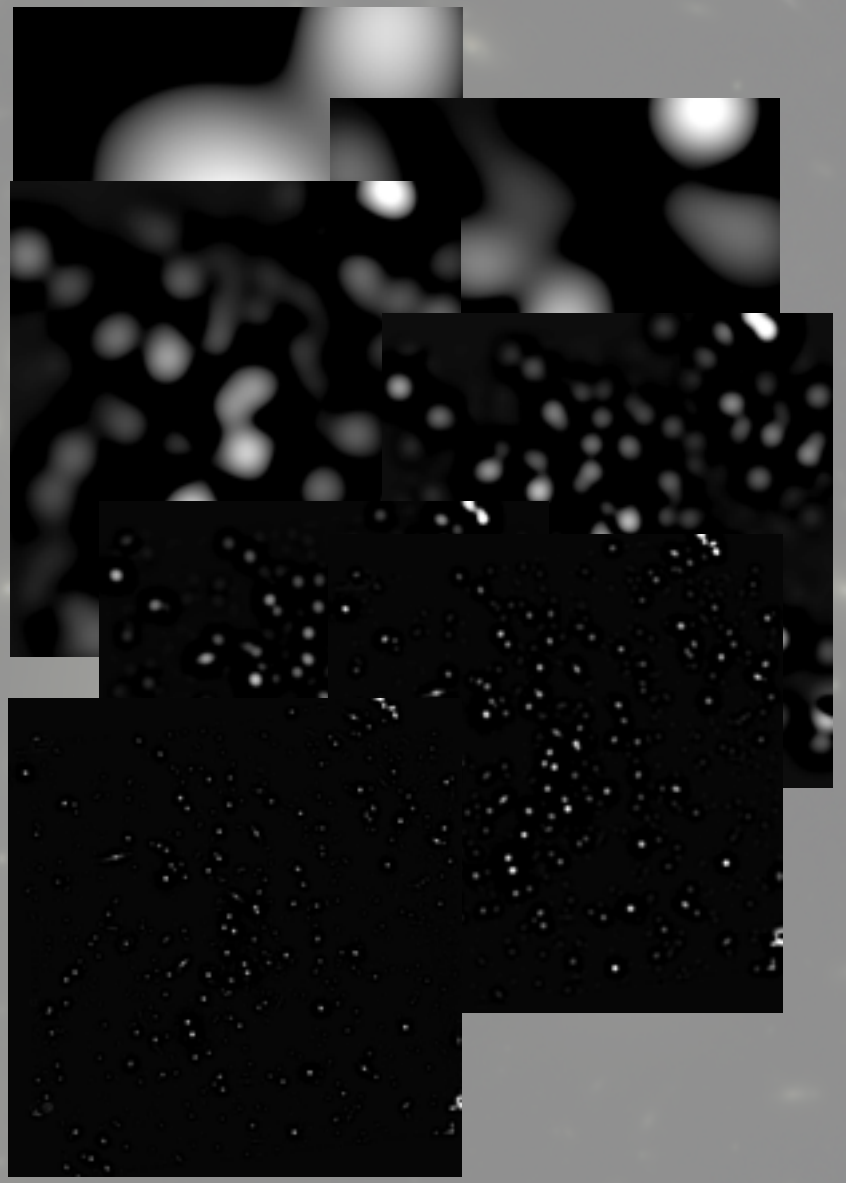

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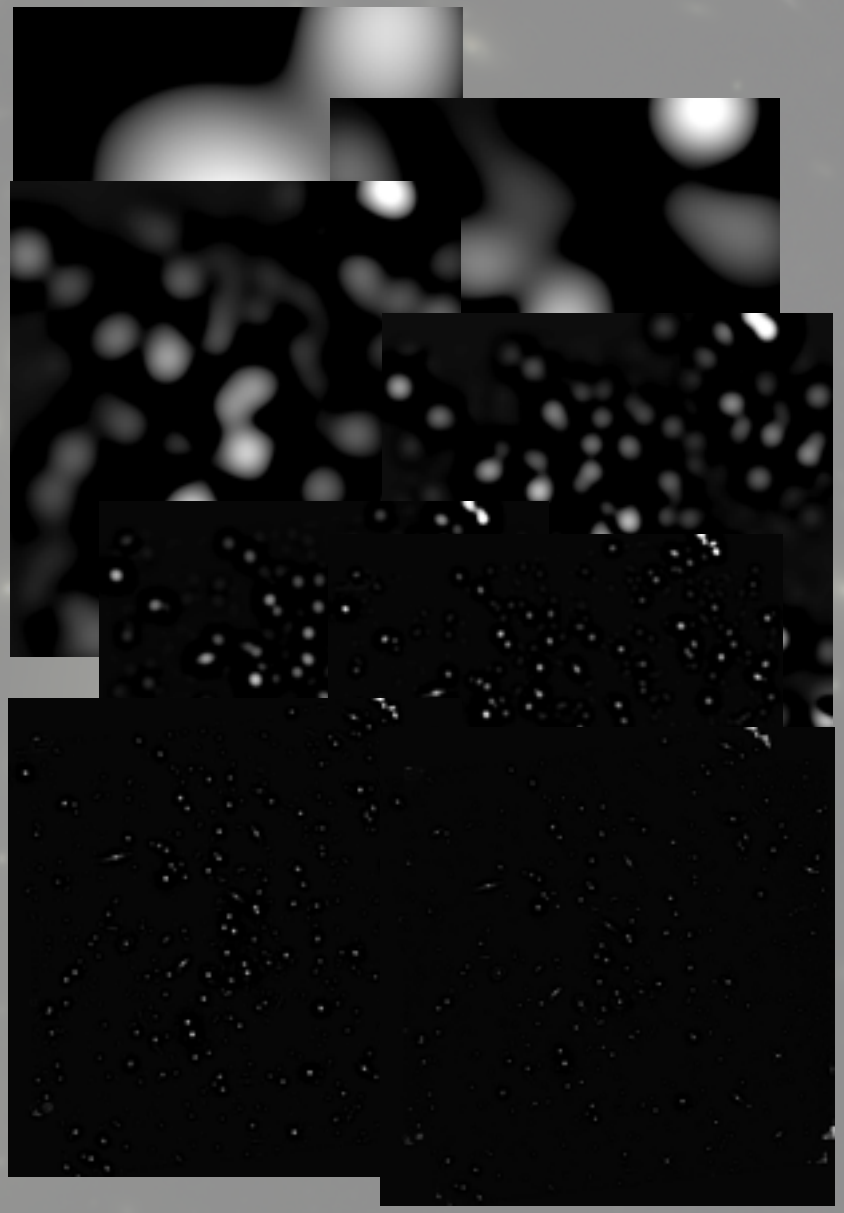

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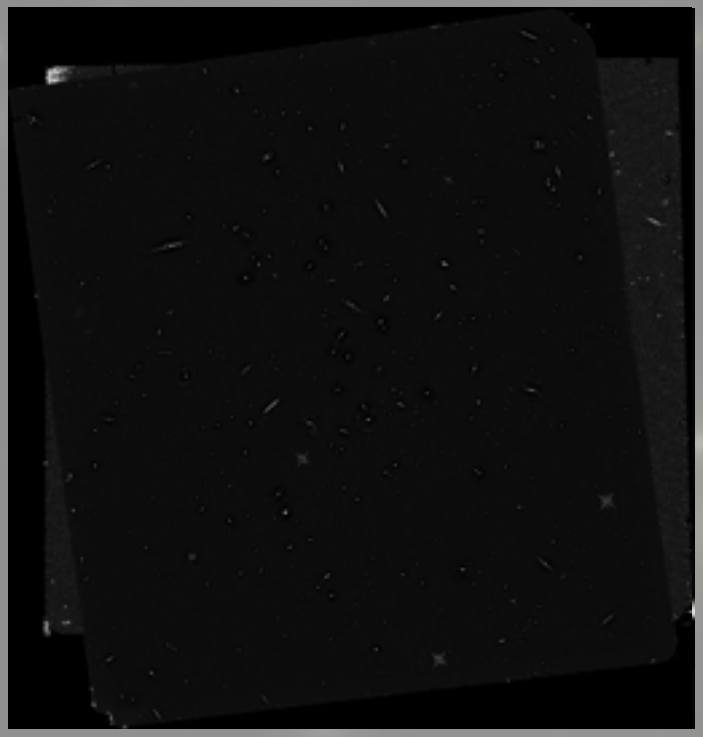

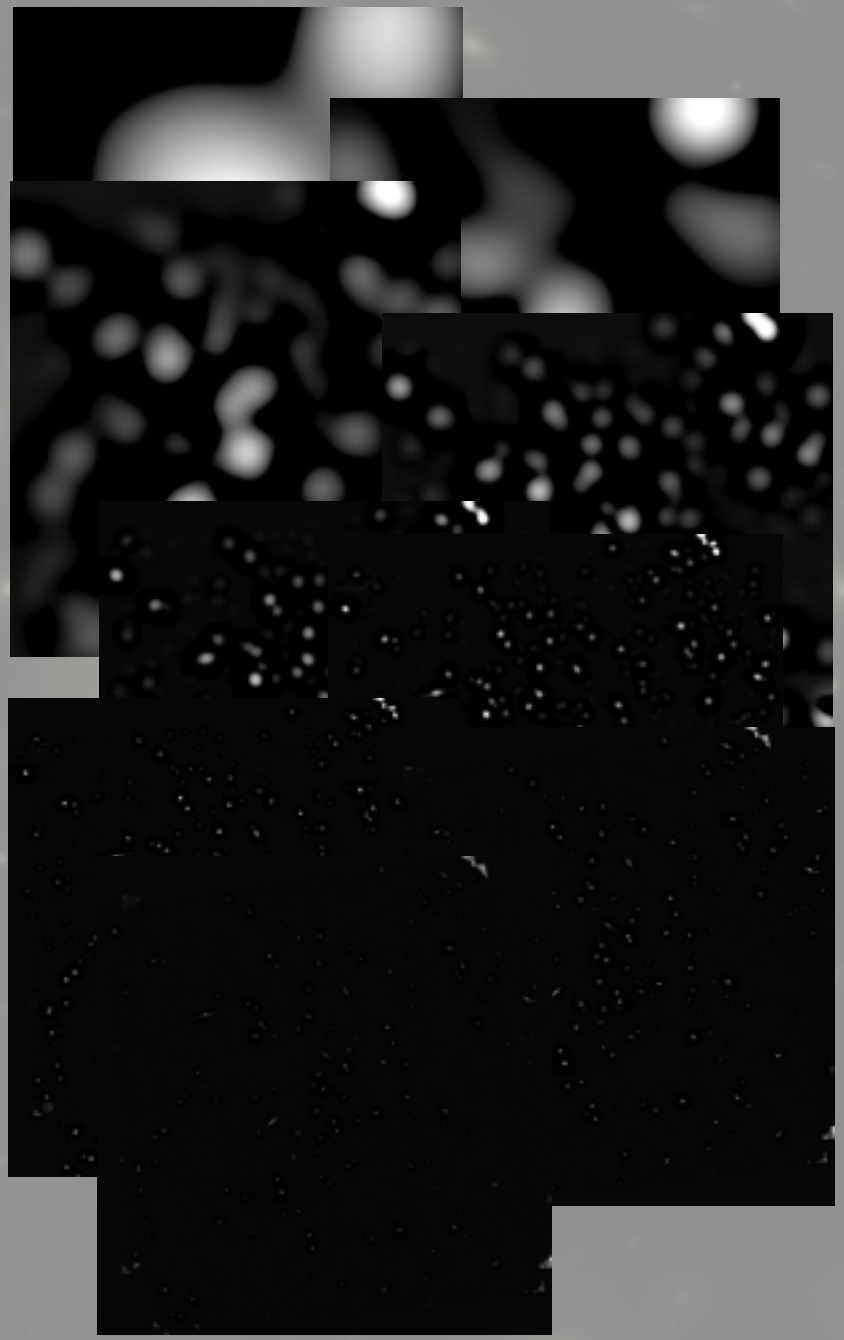

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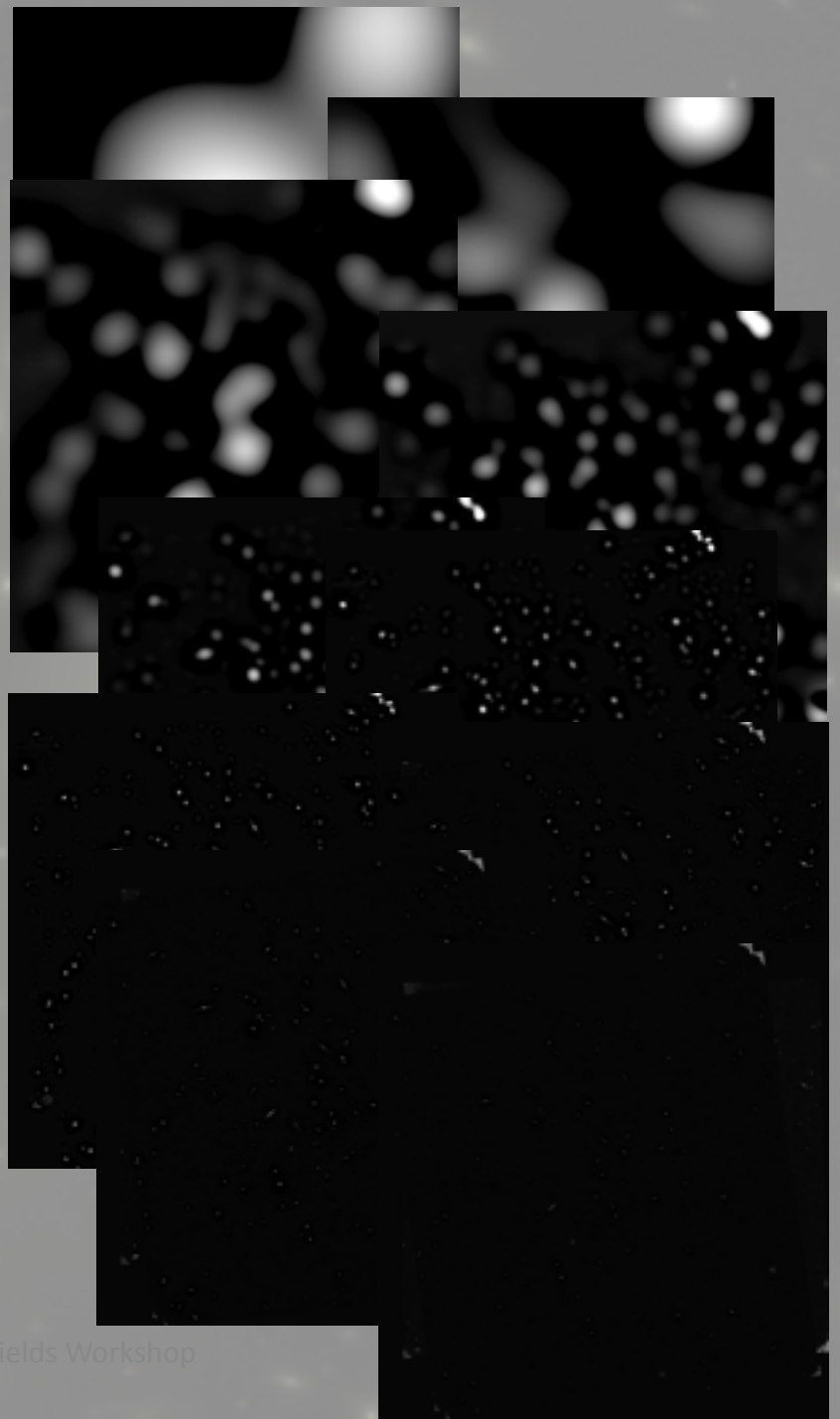

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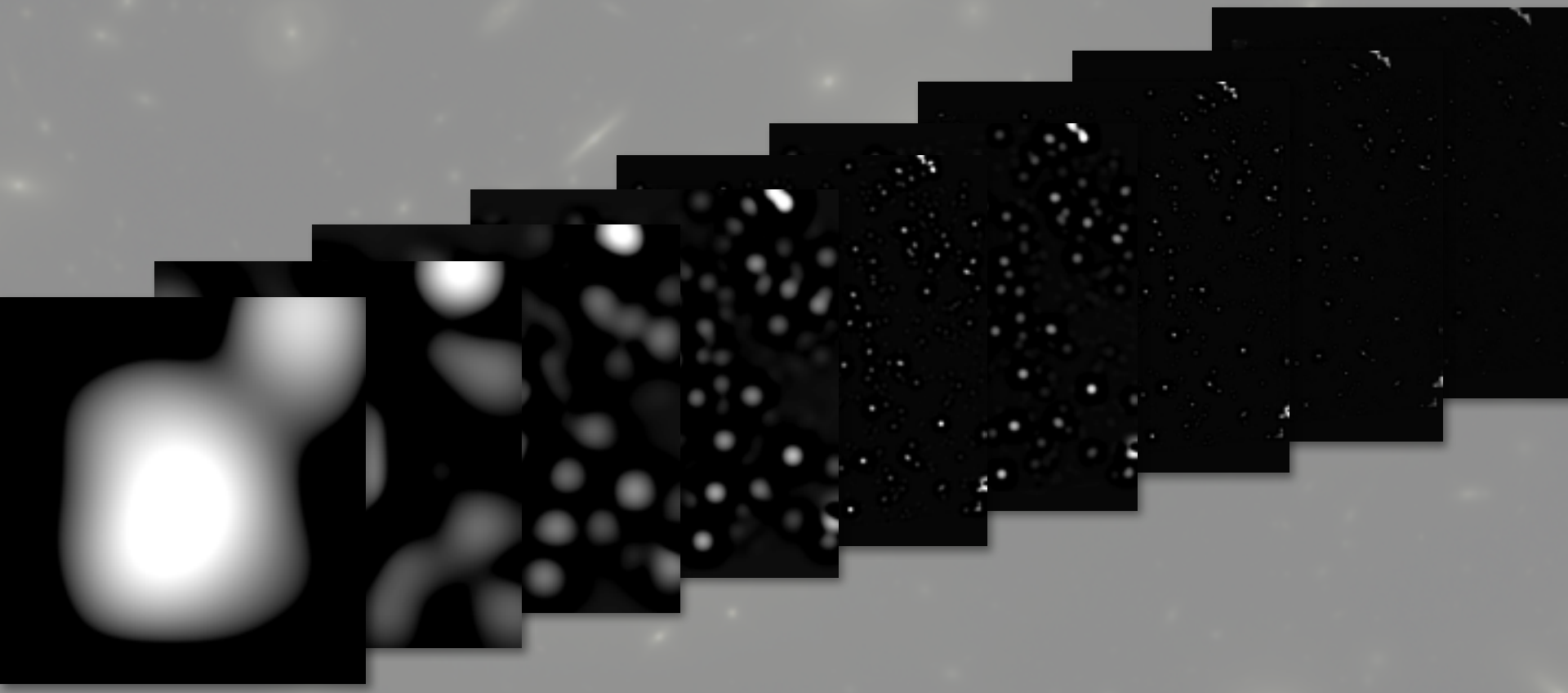

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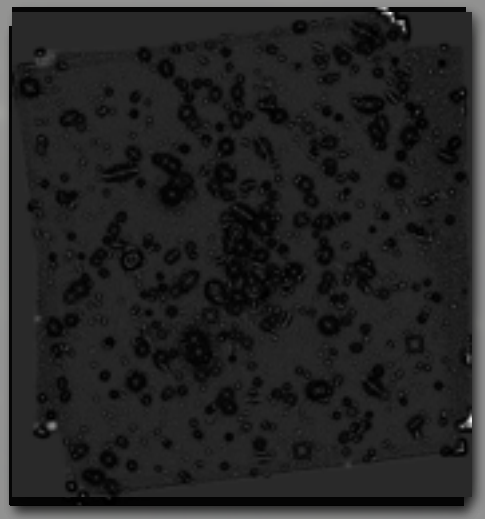
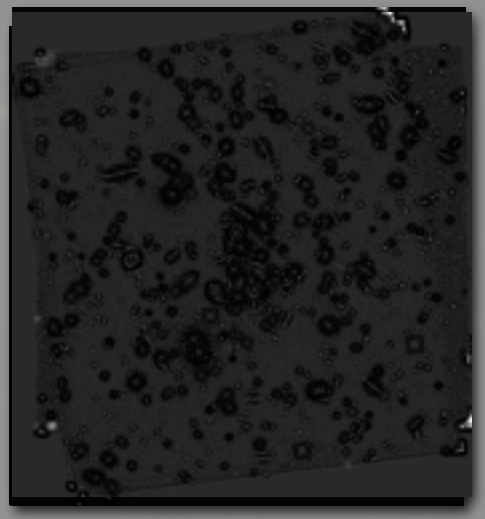


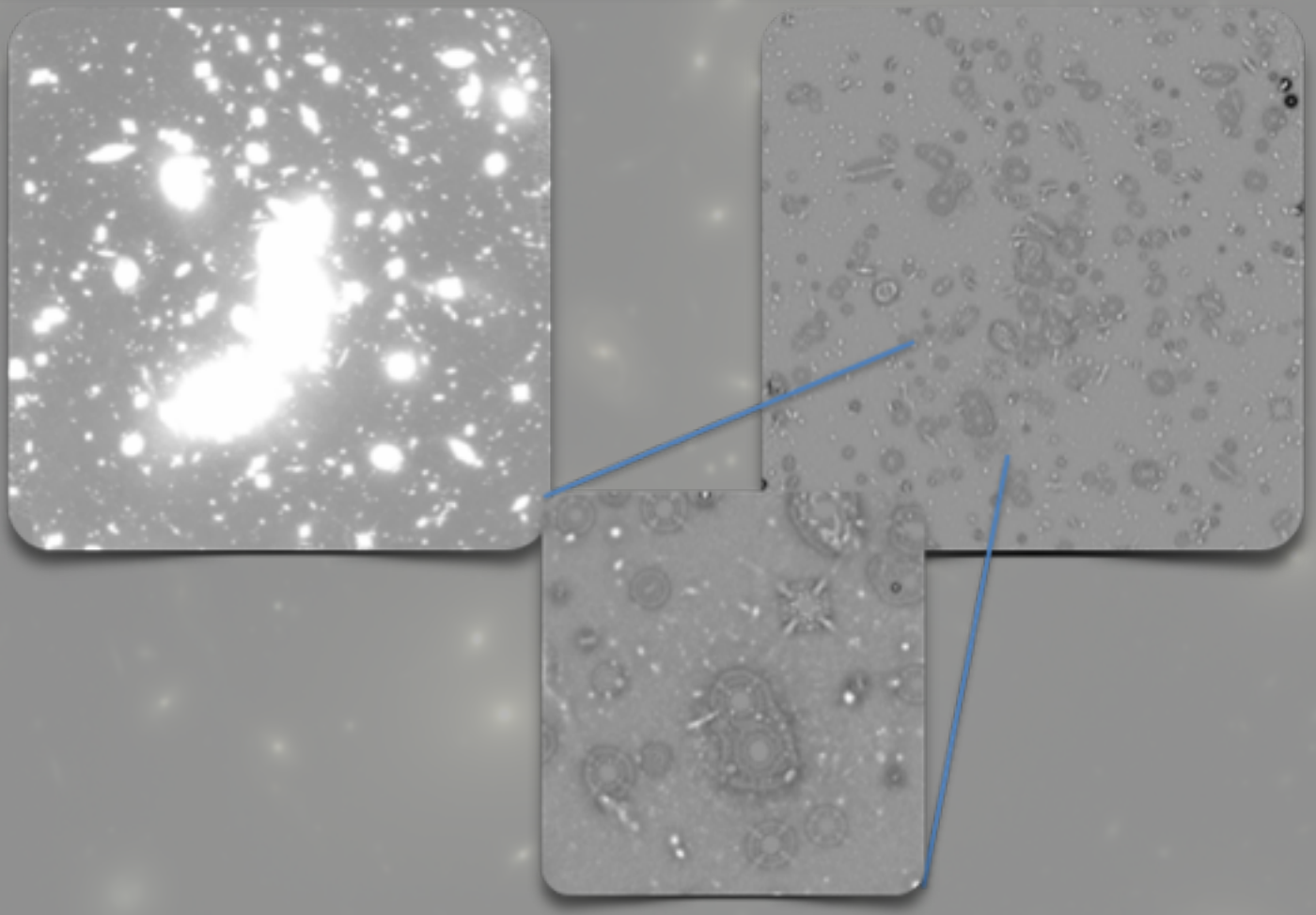
Wavelet Decomposition

Cluster model

Wavelet-subtracted image

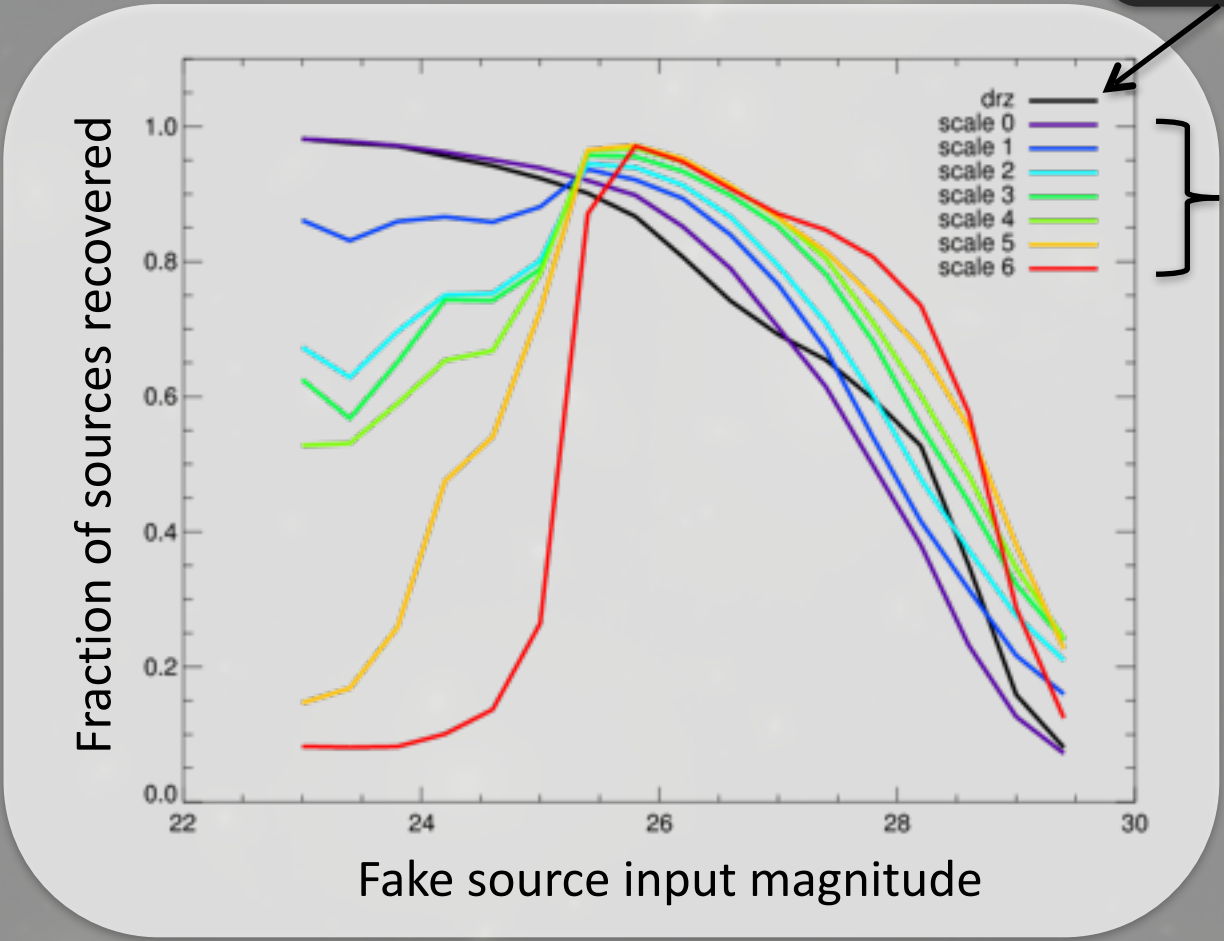


Removing the foreground light makes it easier to detect small, faint objects behind the cluster



Simulations show we recover more faint sources when wavelet-subtracted images are used for detection

Original (unsubtracted) image



Increasingly aggressive subtraction

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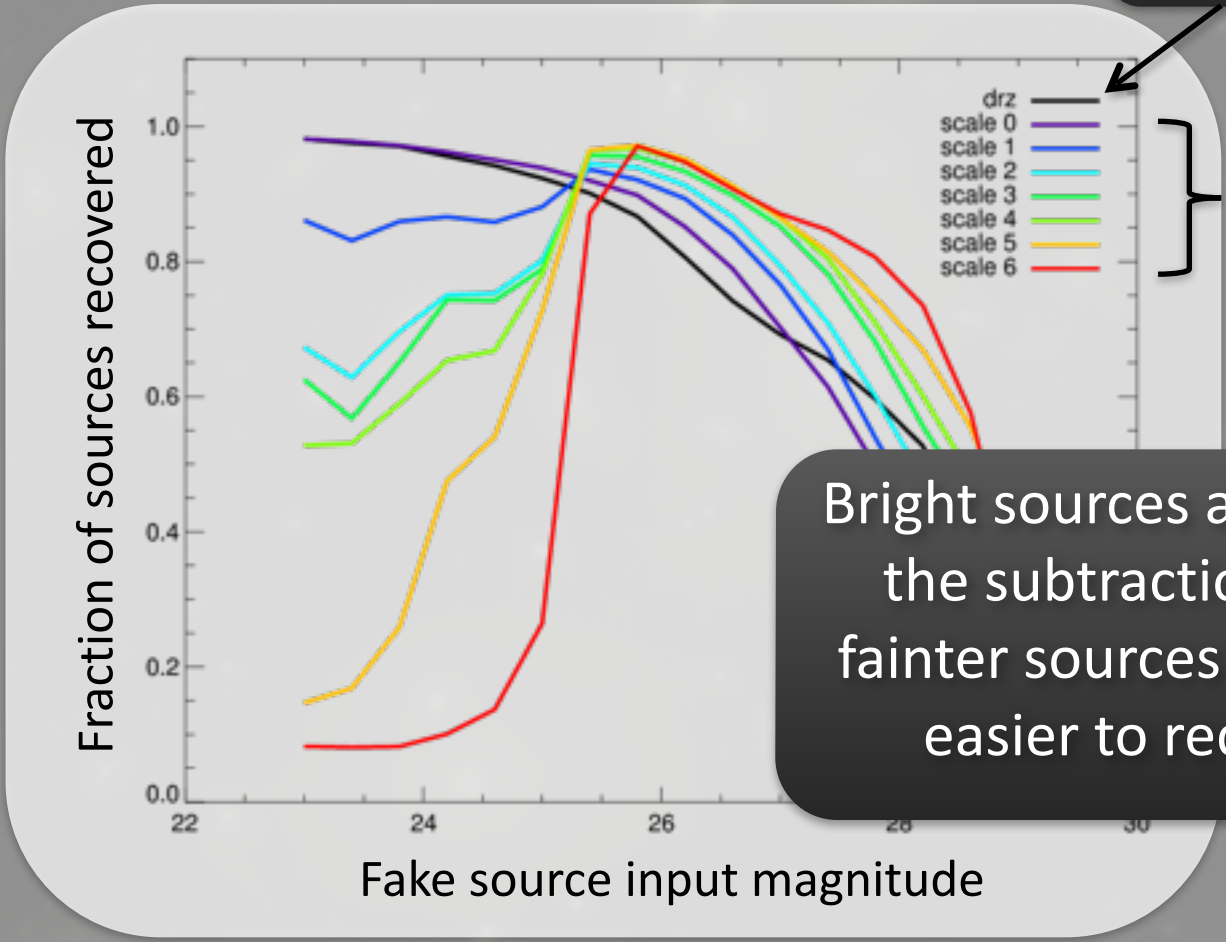
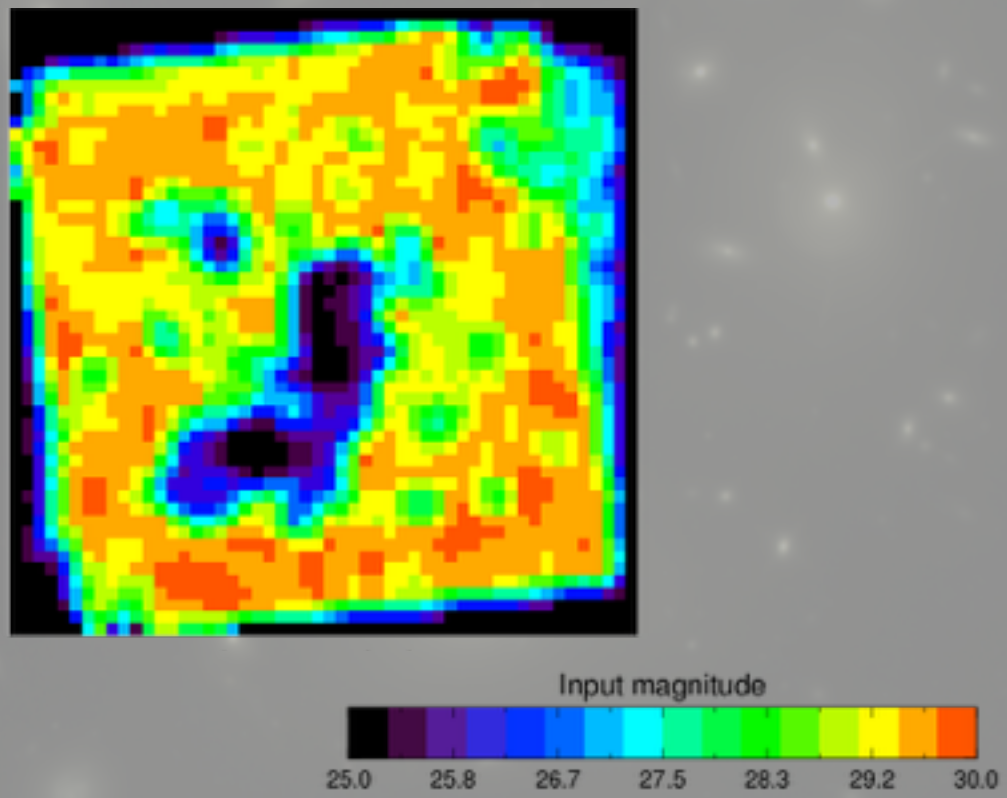


Increasingly aggressive subtraction

Bright sources are lost in the subtraction, but fainter sources become easier to recover

Wavelet subtraction improves depth across the field, particularly the crucial central region

Original image



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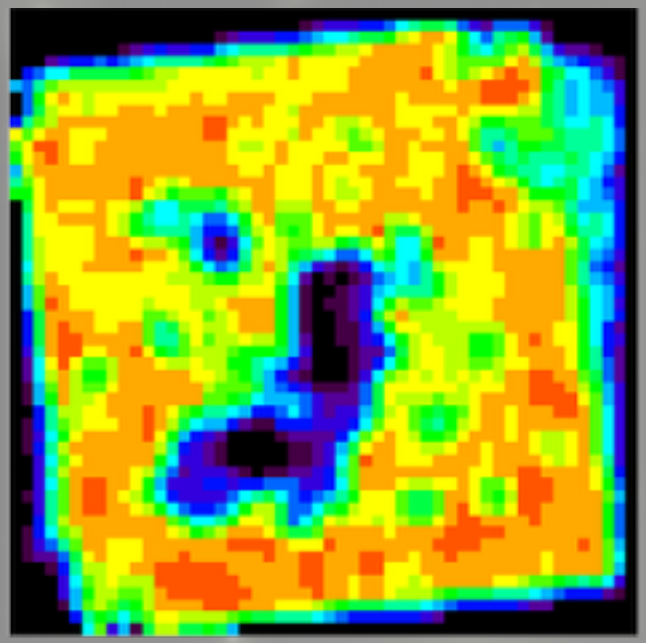
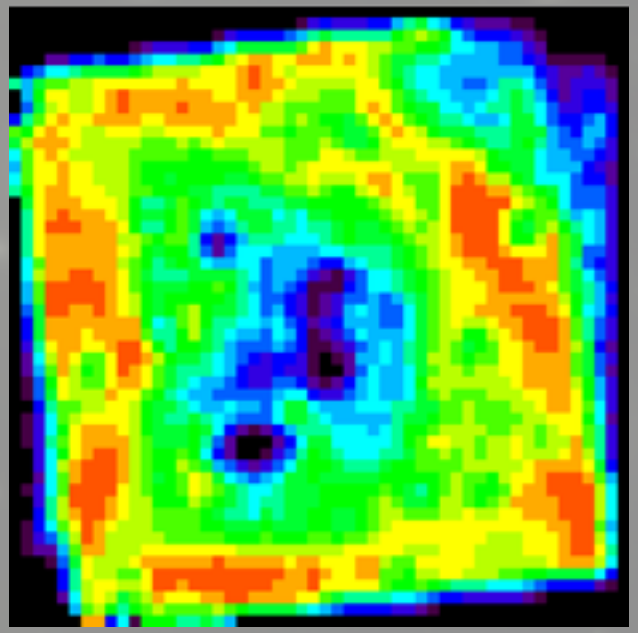
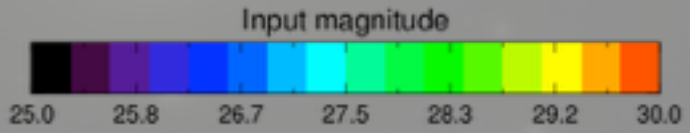


Subtraction scale 0





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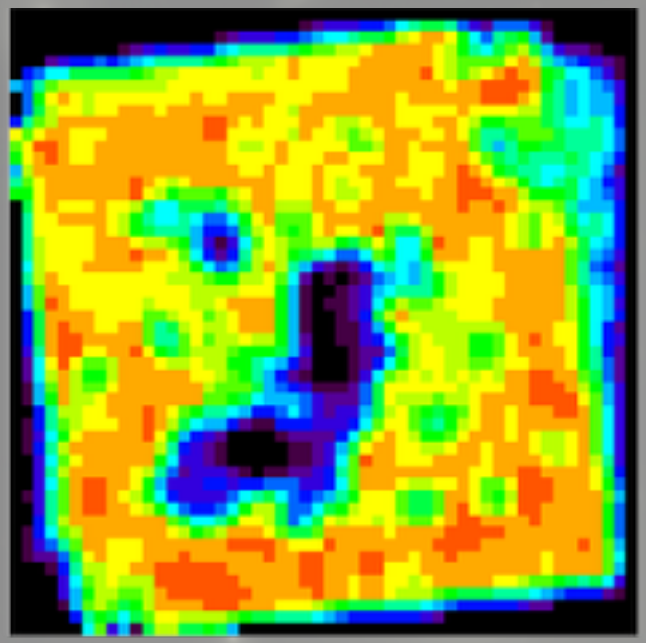
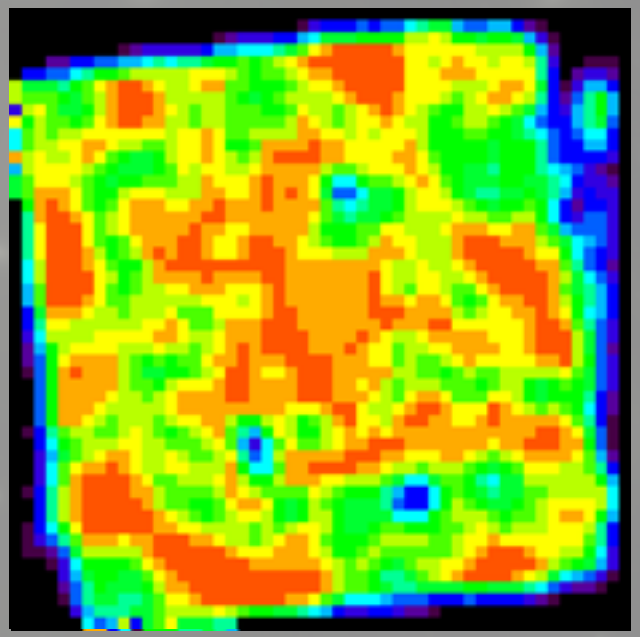
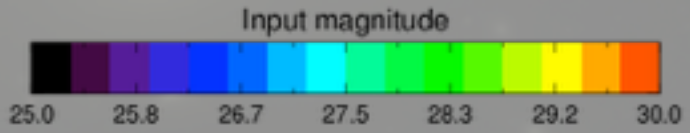


Subtraction scale 1

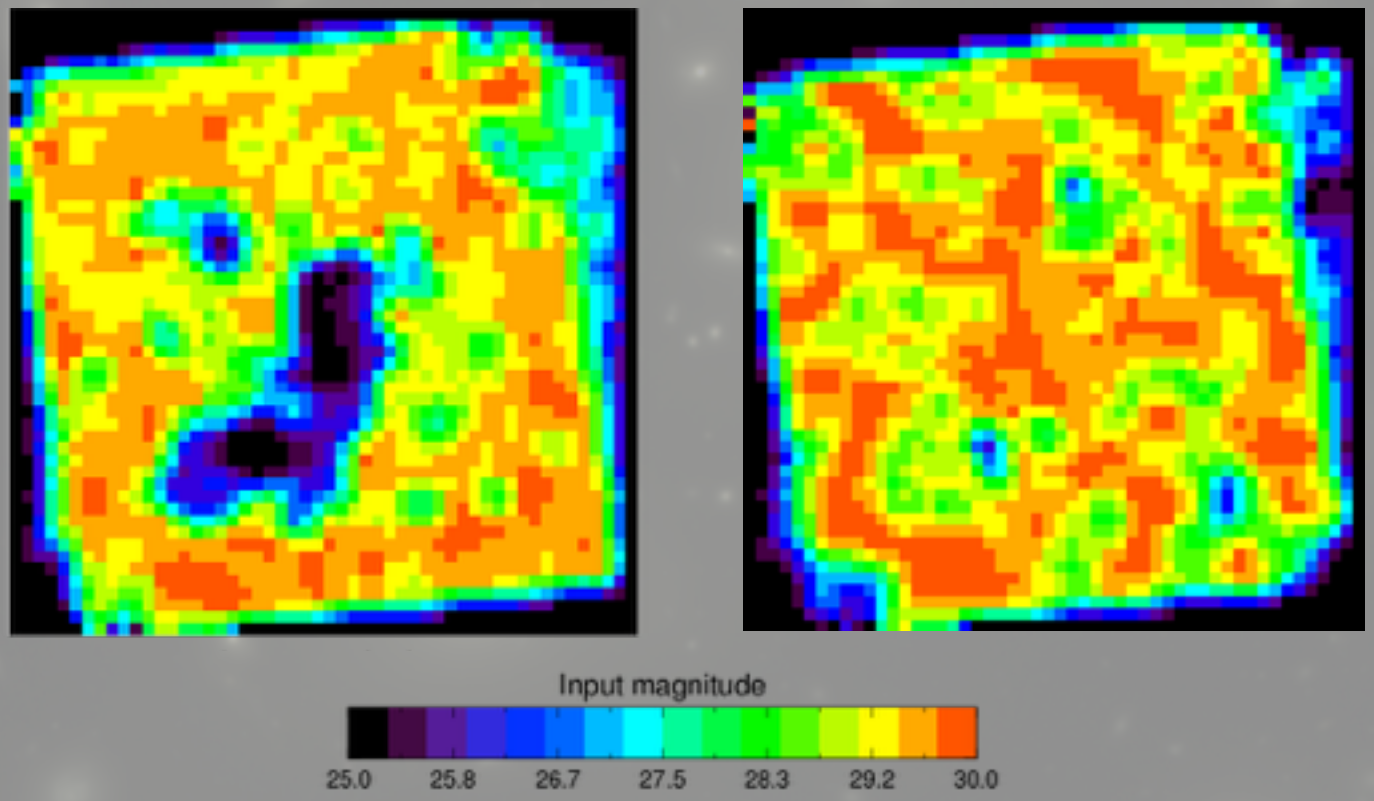




Wavelet subtraction improves depth across the field, particularly the crucial central region

Original image

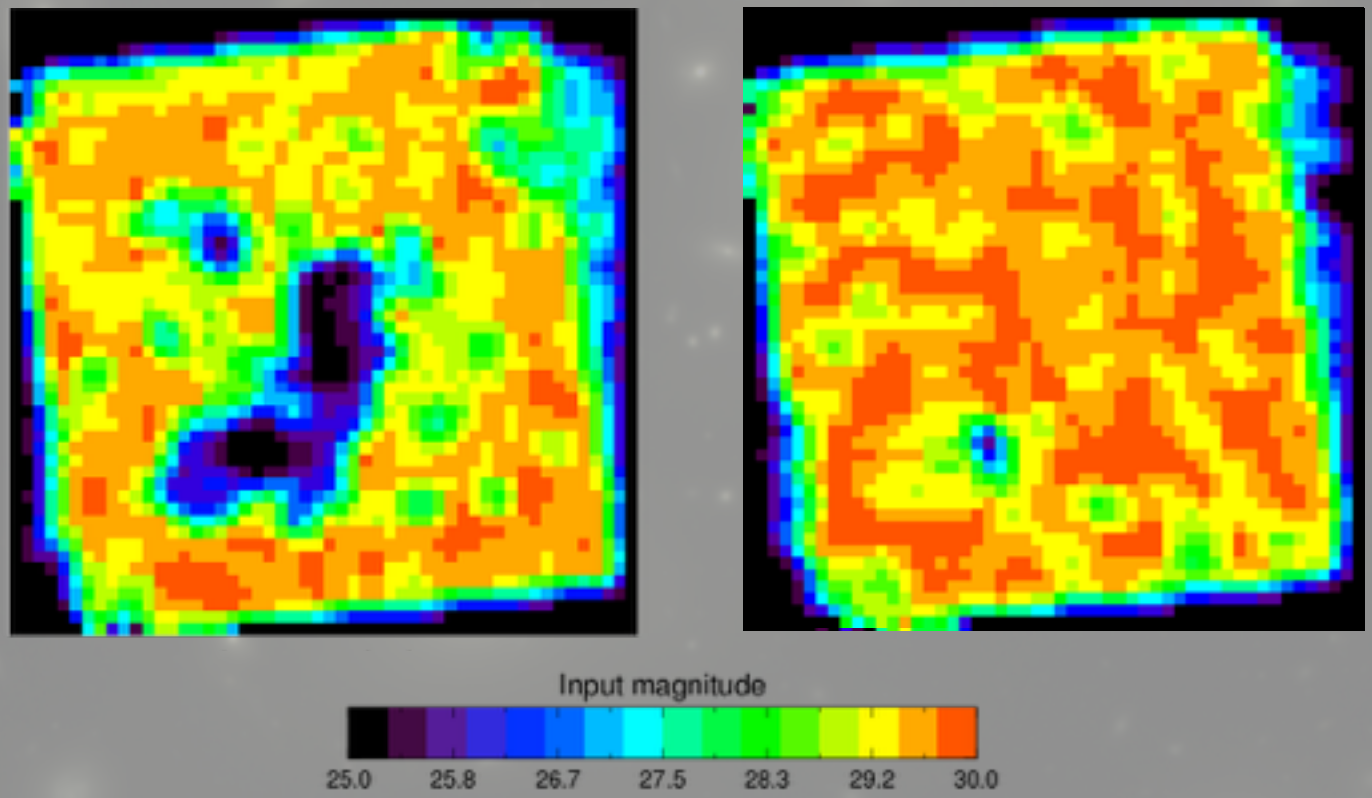
Subtraction scale 2



Wavelet subtraction improves depth across the field, particularly the crucial central region

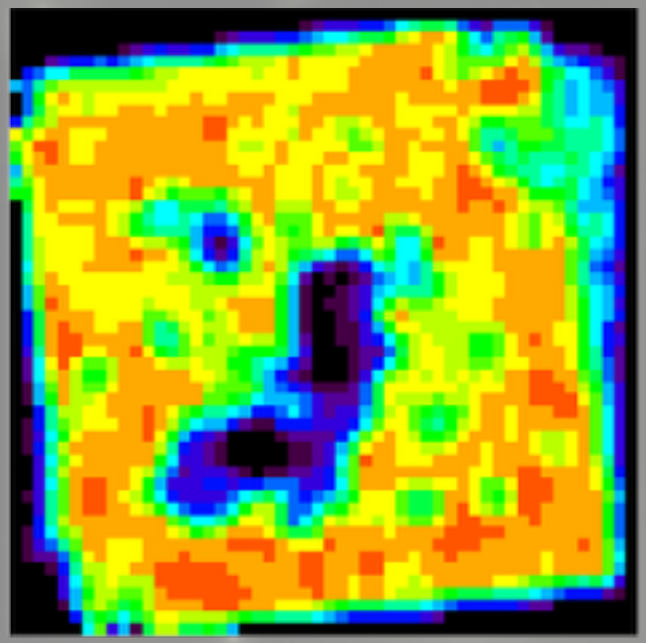
Original image

Subtraction scale 3

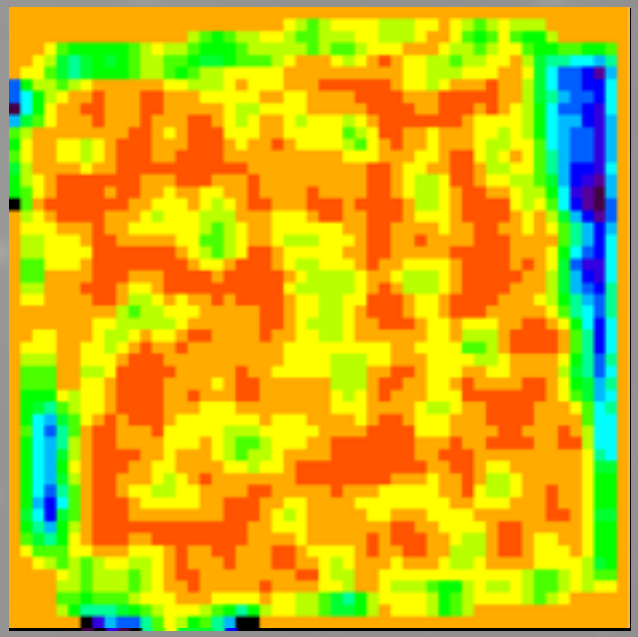


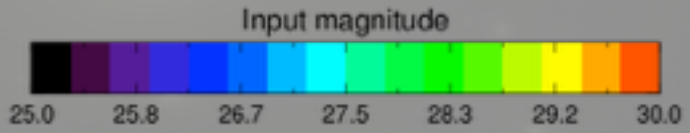
Wavelet subtraction improves depth across the field, particularly the crucial central region

Original image



Subtraction scale 4

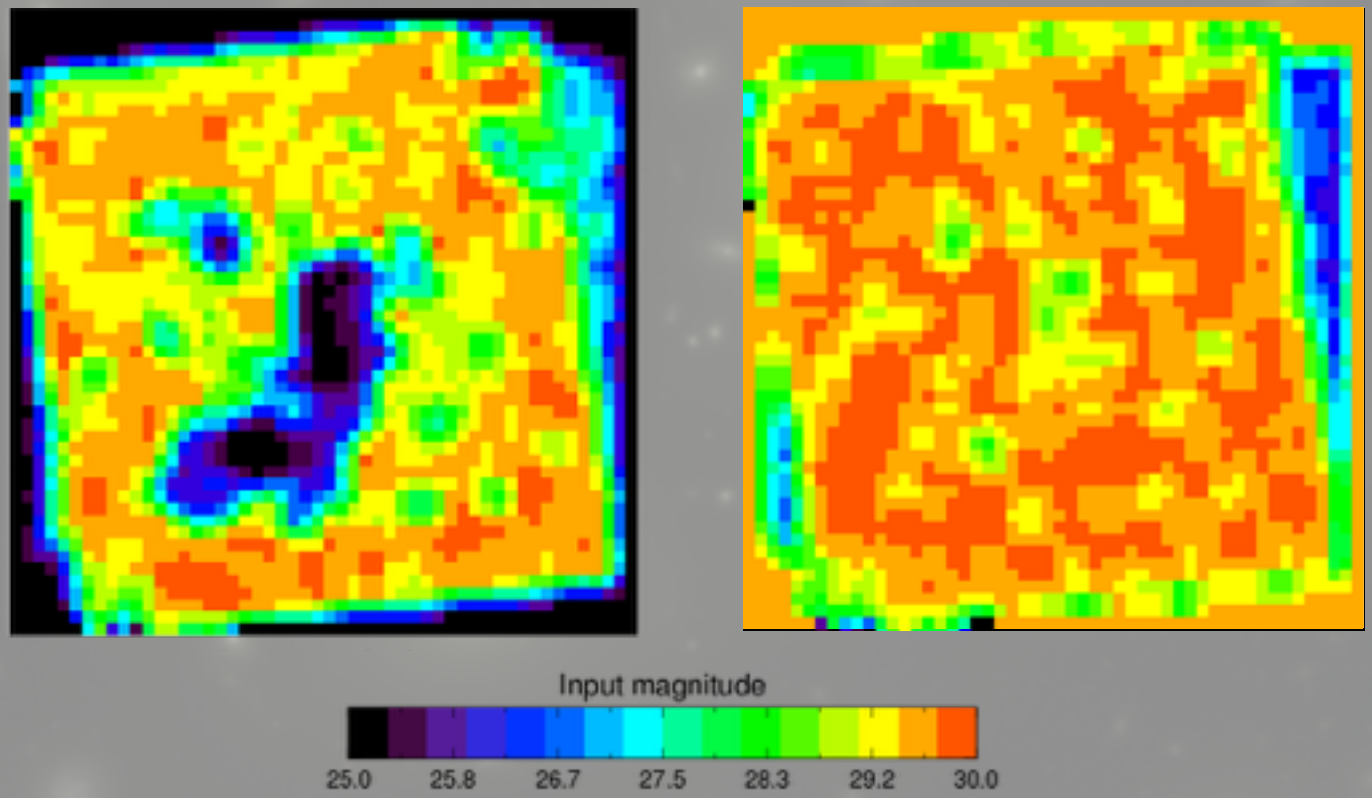




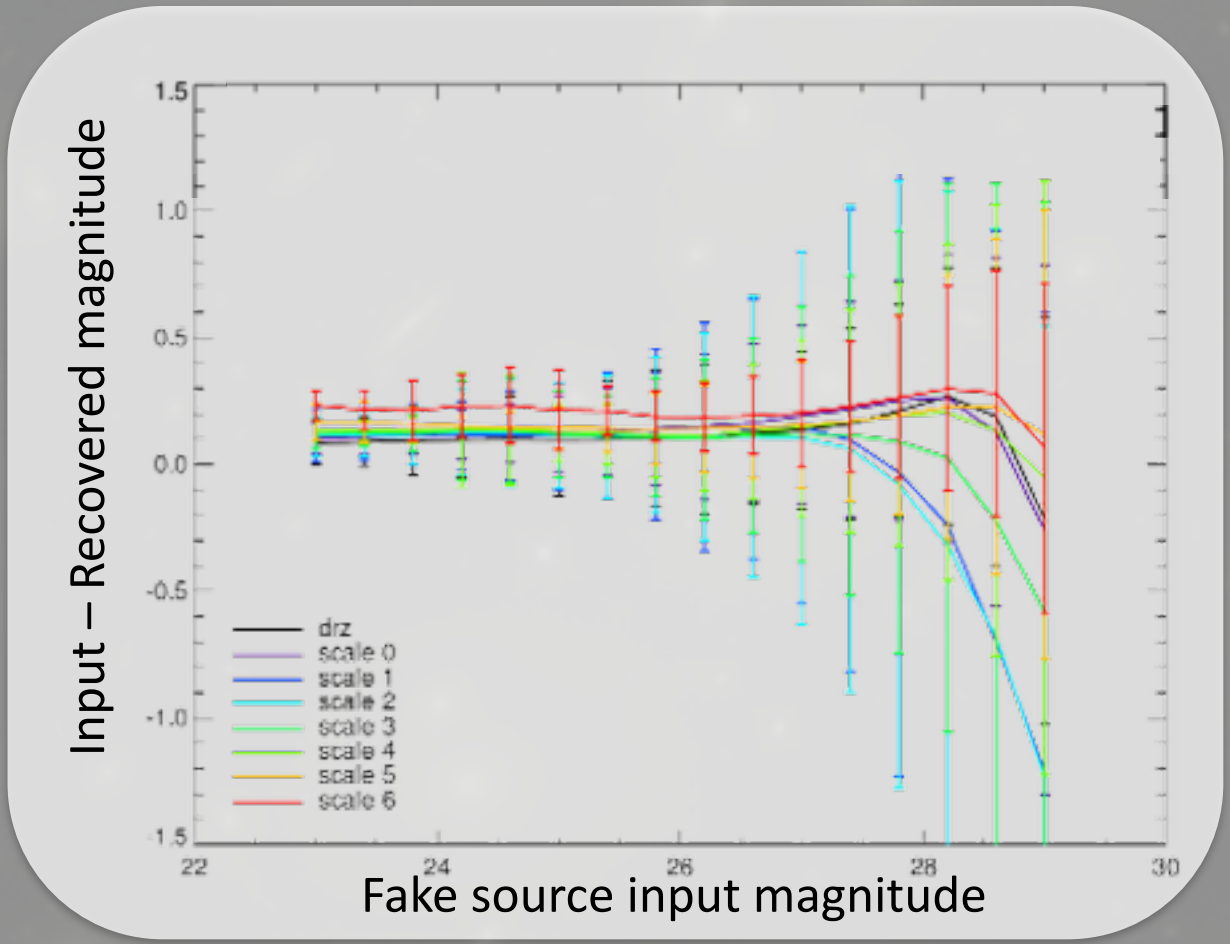
Wavelet subtraction improves depth across the field, particularly the crucial central region

Original image

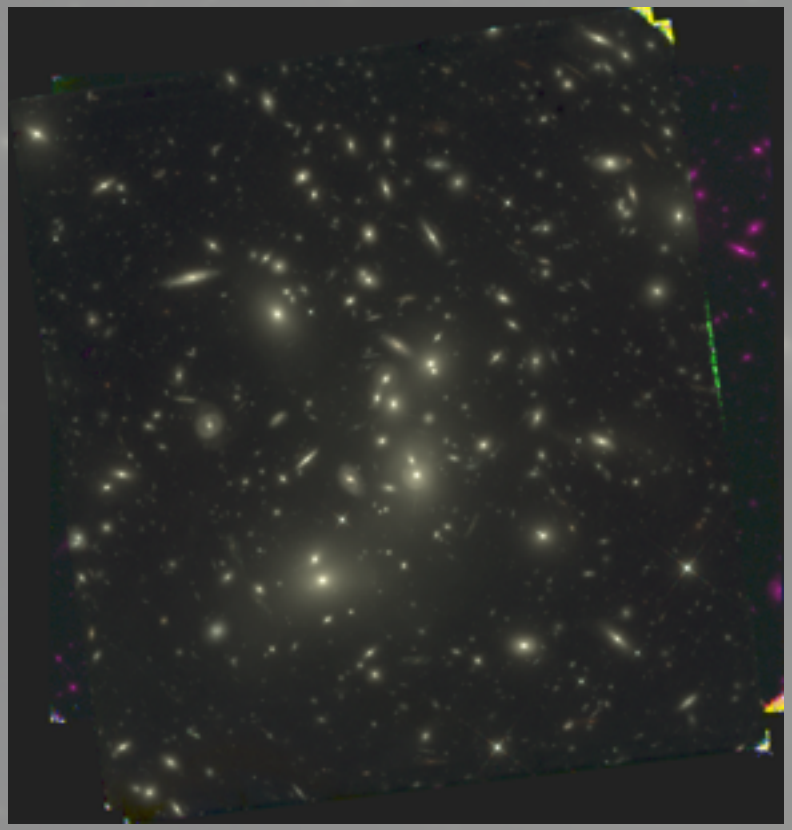
Subtraction scale 5



Up to scale 5, flux recovery remains robust if the original image is used for photometry



Candidate selection in Abell 2744



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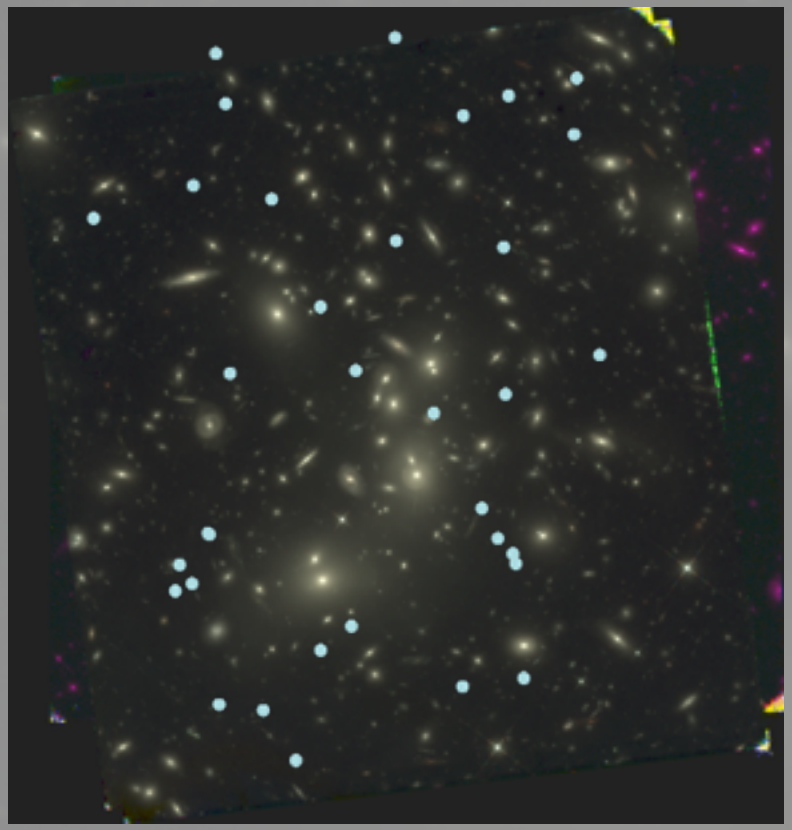
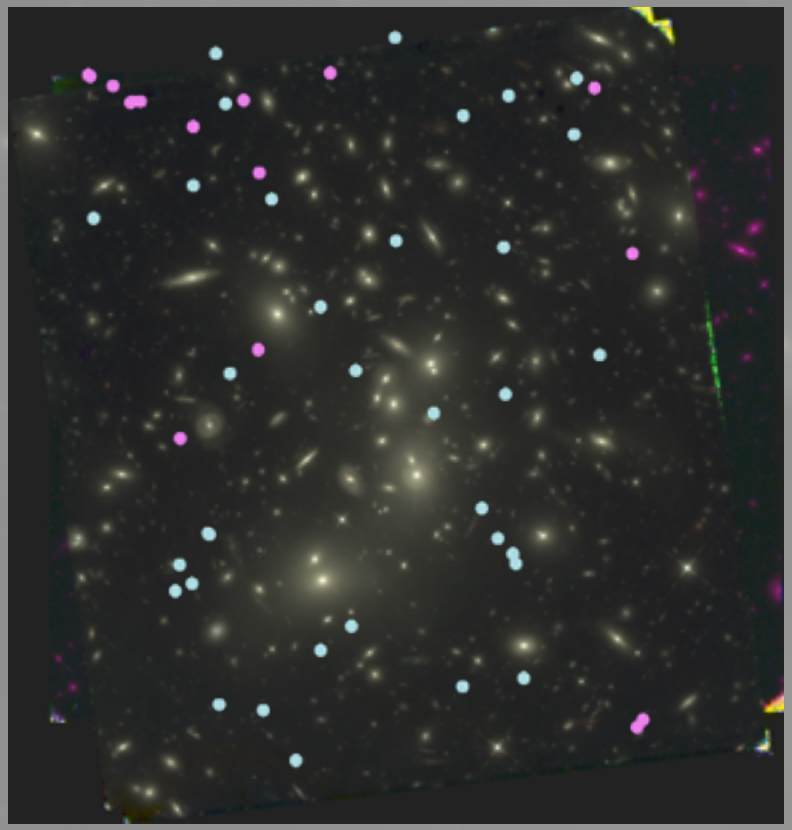


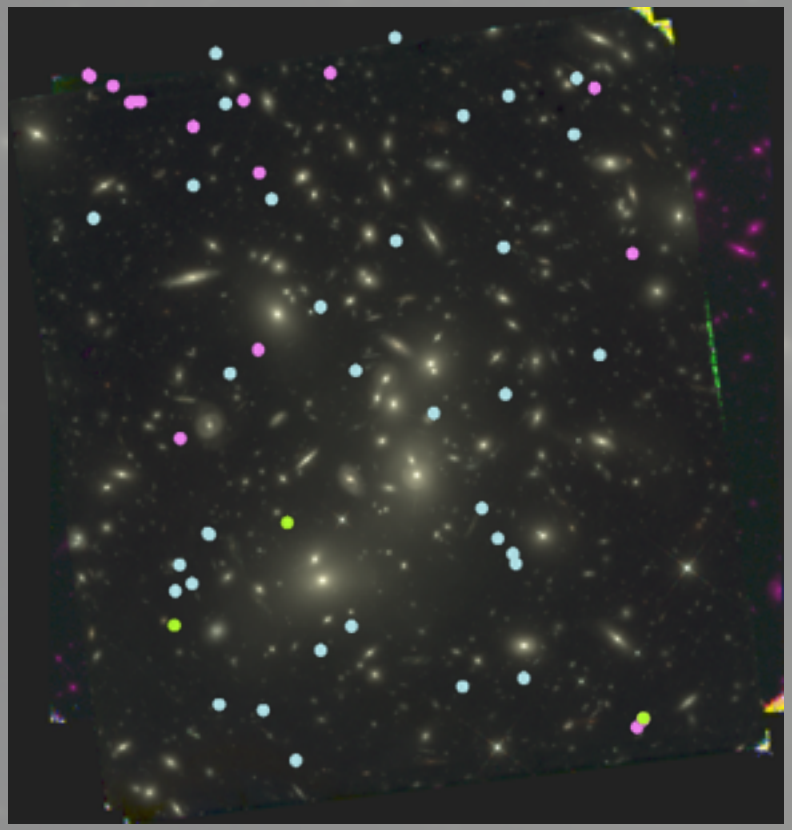
- z ~ 7

Candidate selection in Abell 2744



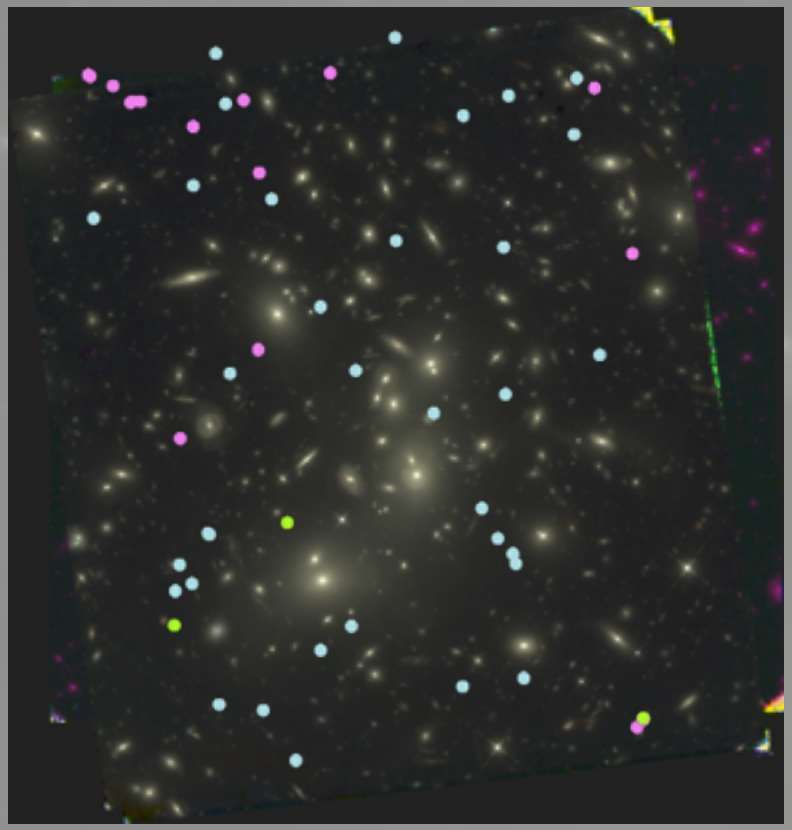
- z ~ 7
- z ~ 8

Candidate selection in Abell 2744



- z ~ 7
- z ~ 8
- z ~ 9

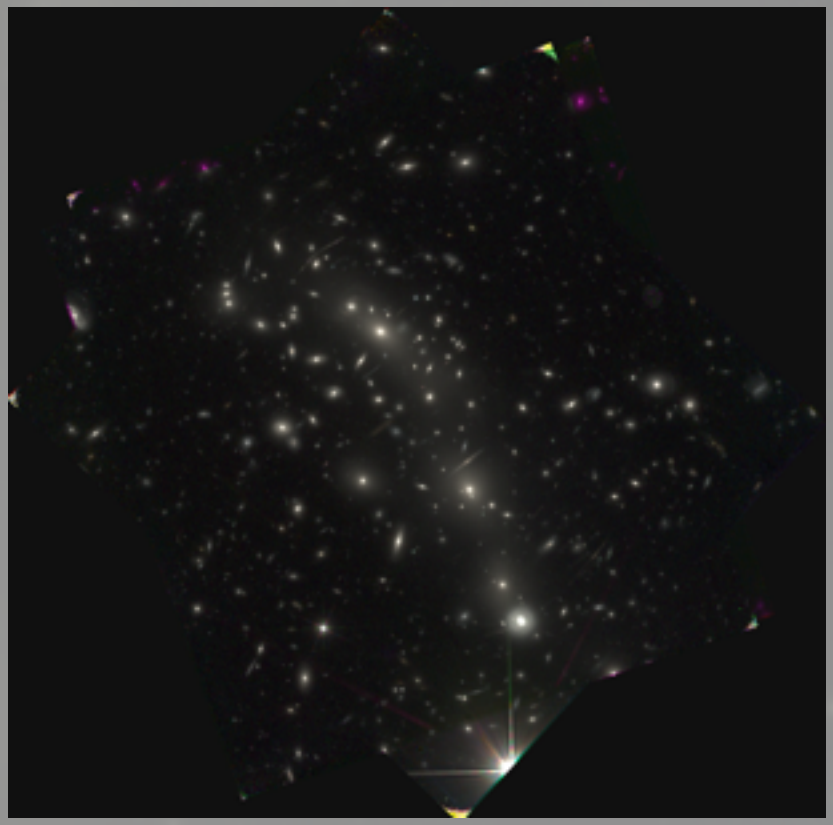
Candidate selection in Abell 2744



- z ~ 7
- z ~ 8
- z ~ 9

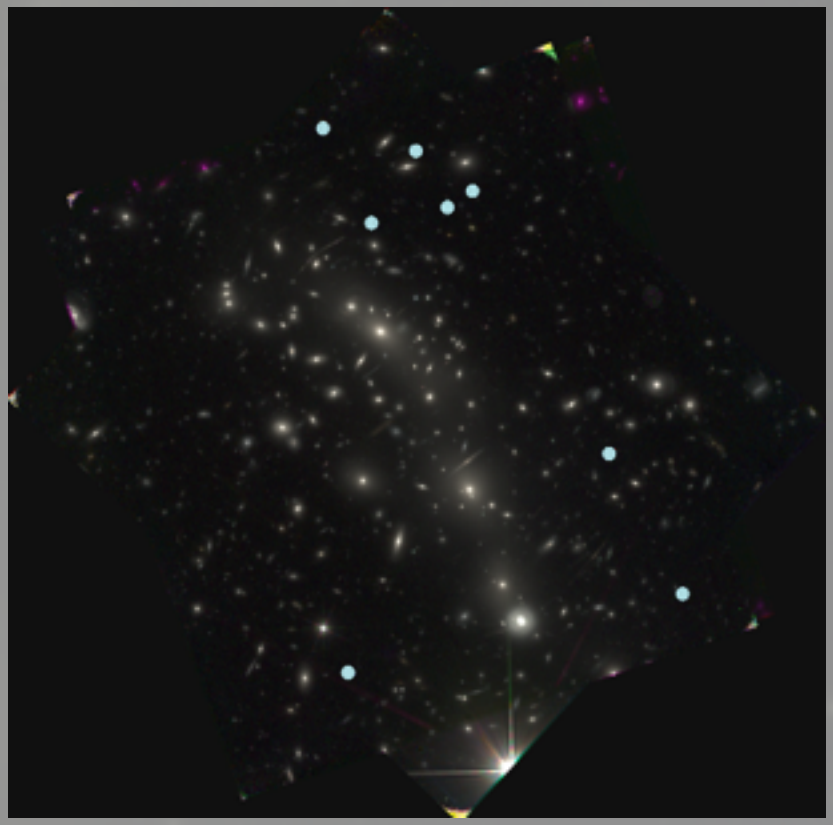
We find 53 galaxies at z ≥ 7:
34 at z ≈ 7
16 at z ≈ 8
3 at z ≈ 9

Candidate selection in MACS0416



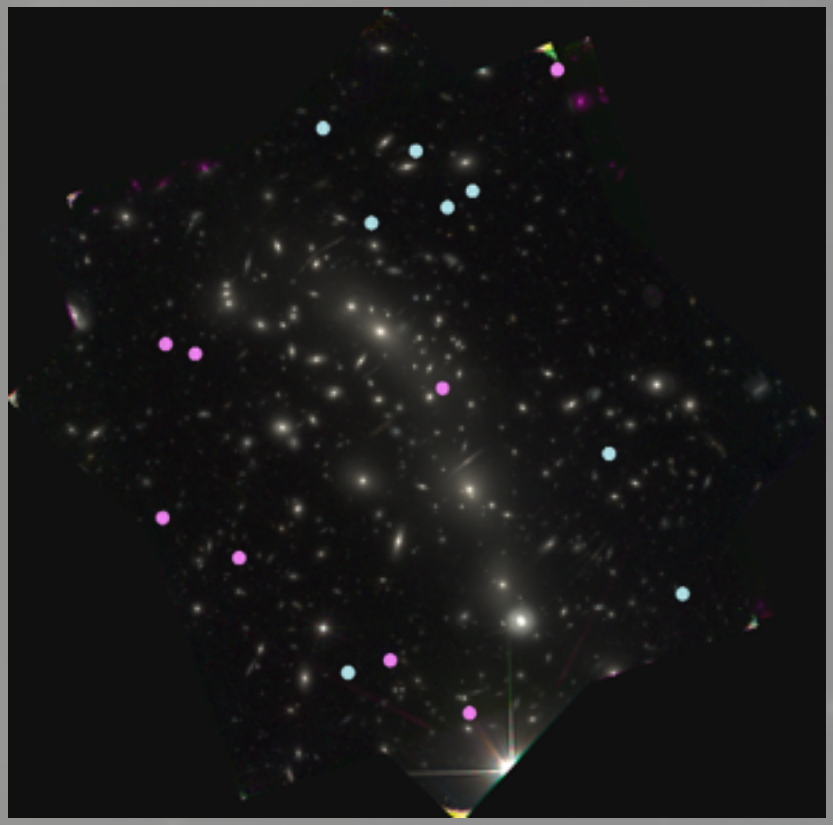
Candidate selection in MACS0416

- z ~ 7



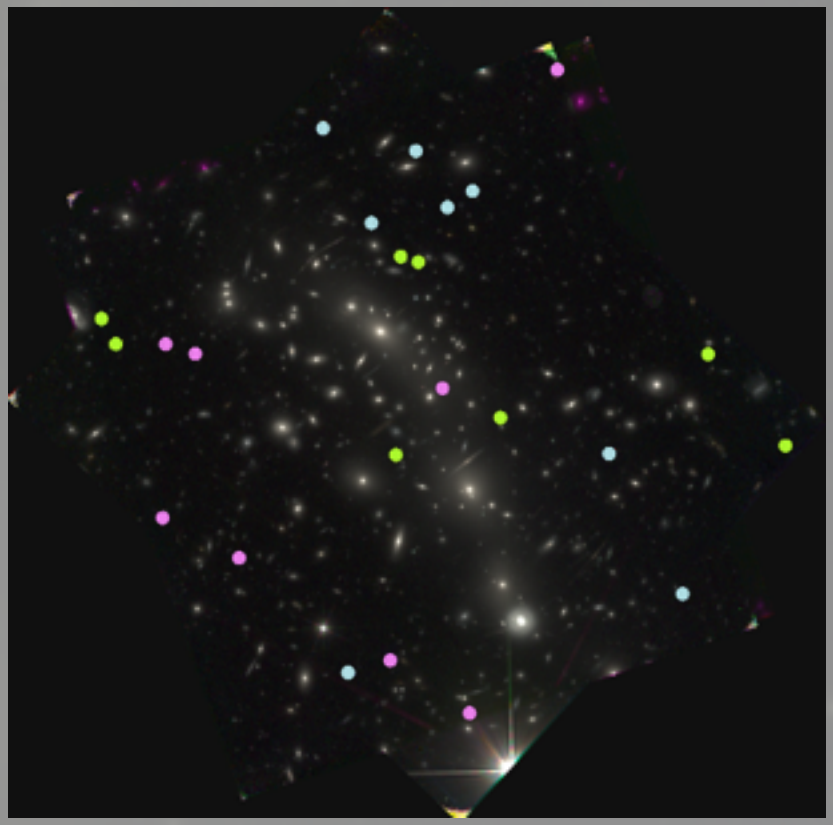
Candidate selection in MACS0416

- z ~ 7
- z ~ 8



Candidate selection in MACS0416

- z ~ 7
- z ~ 8
- z ~ 9



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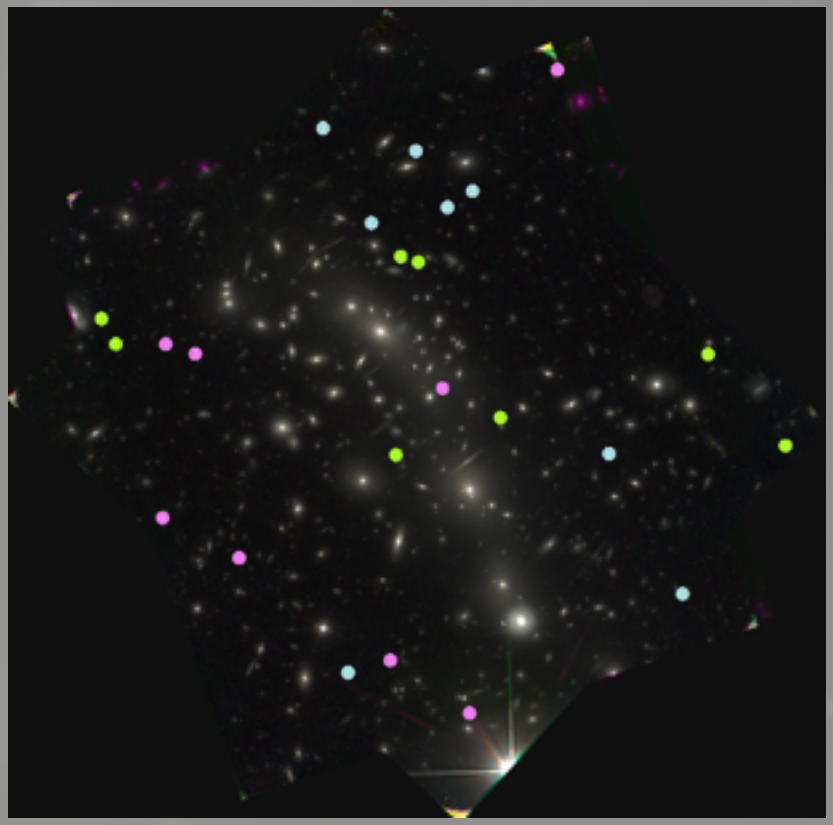
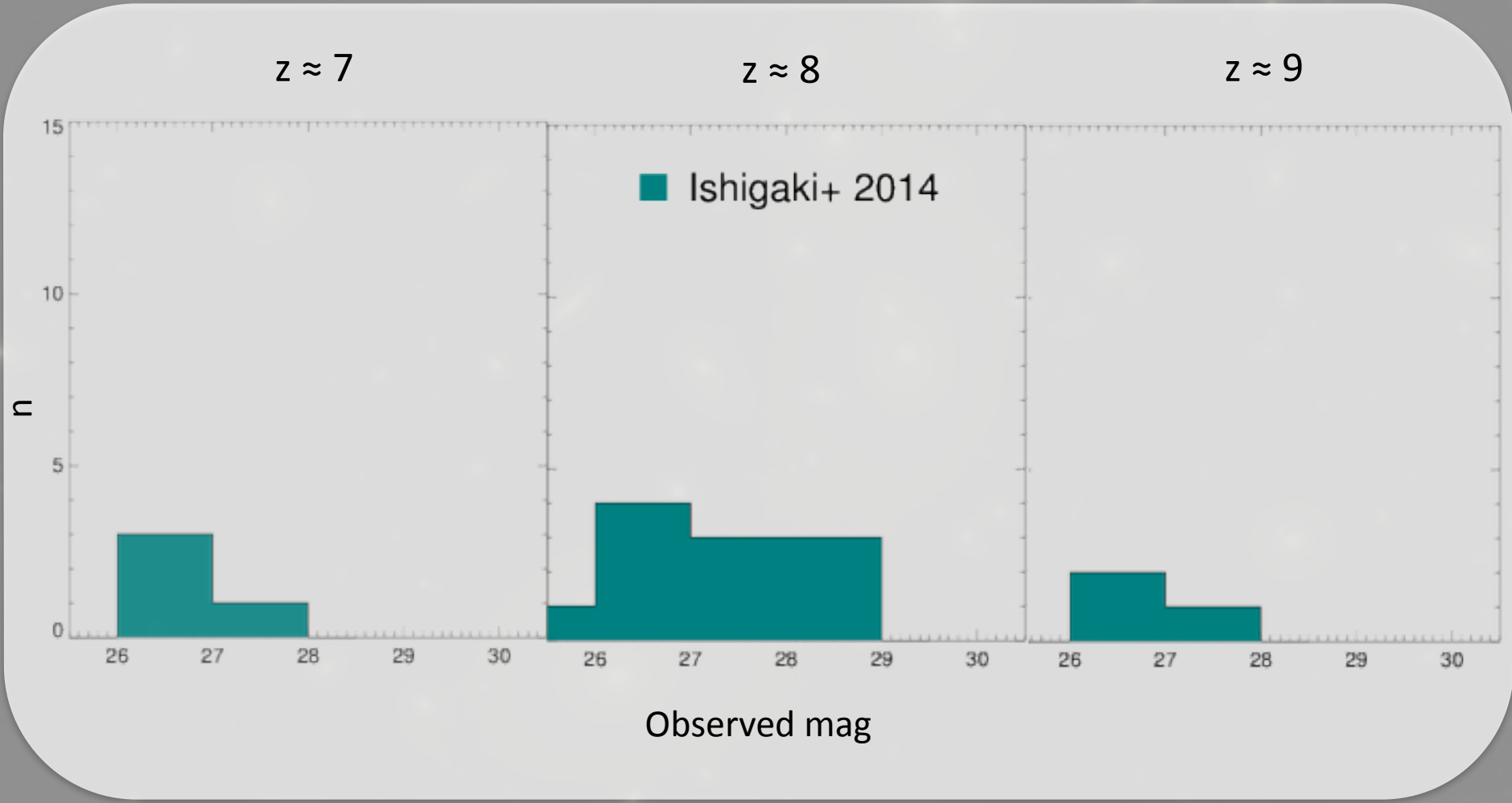
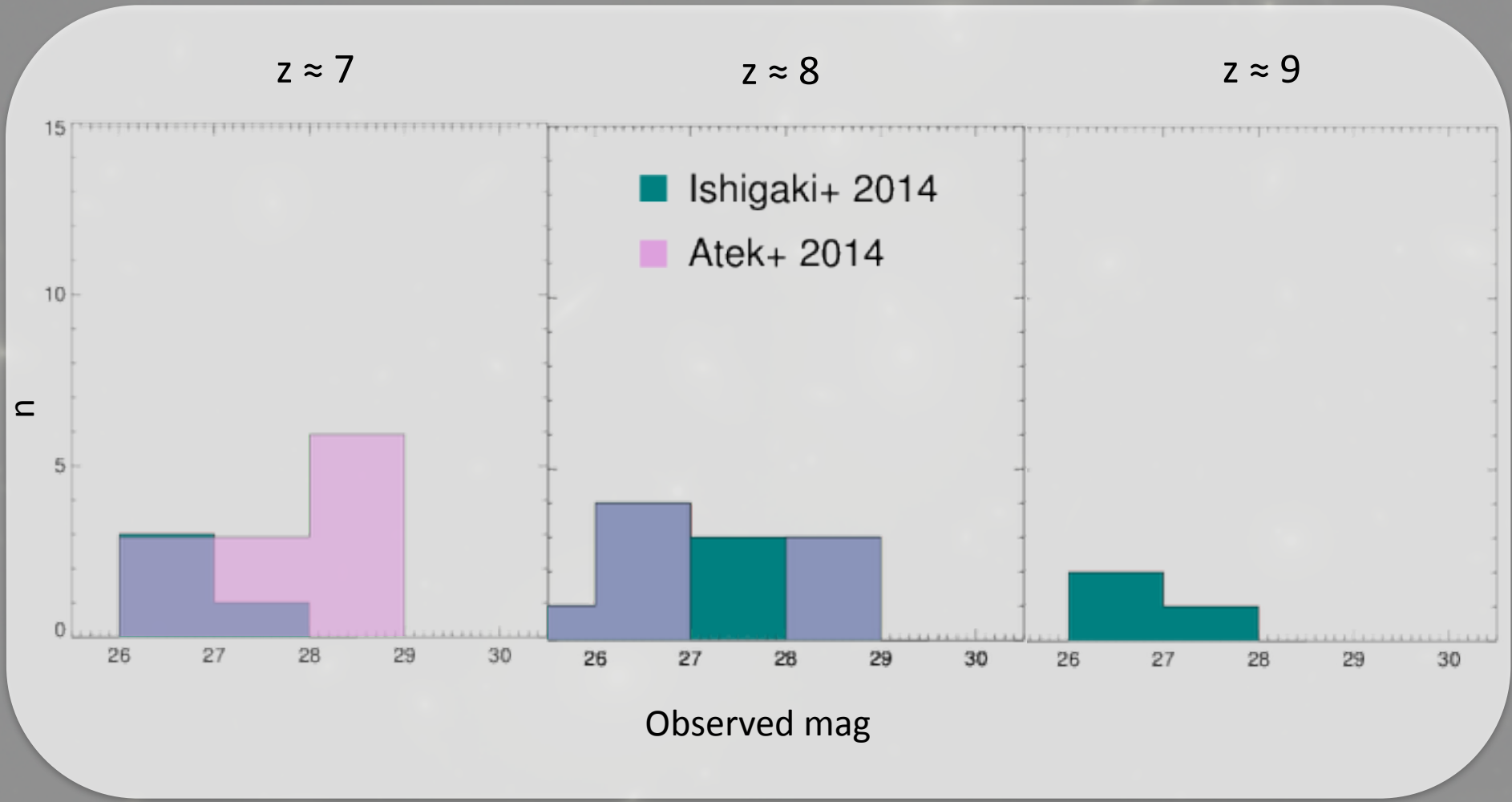


We find 23 galaxies at z ≥ 7:
7 at z ≈ 7
8 at z ≈ 8
8 at z ≈ 9

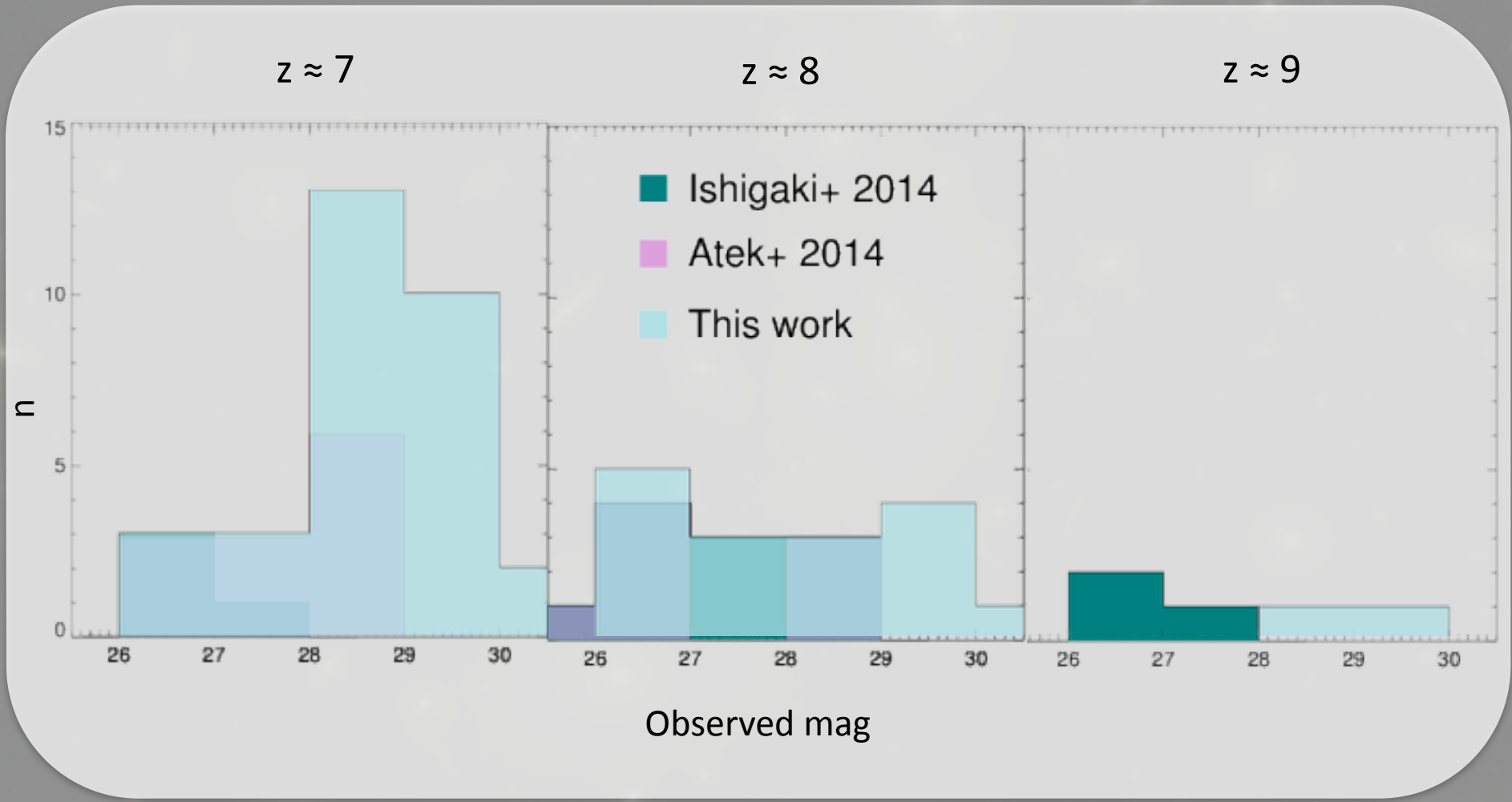
Observed number counts at z ≥ 7



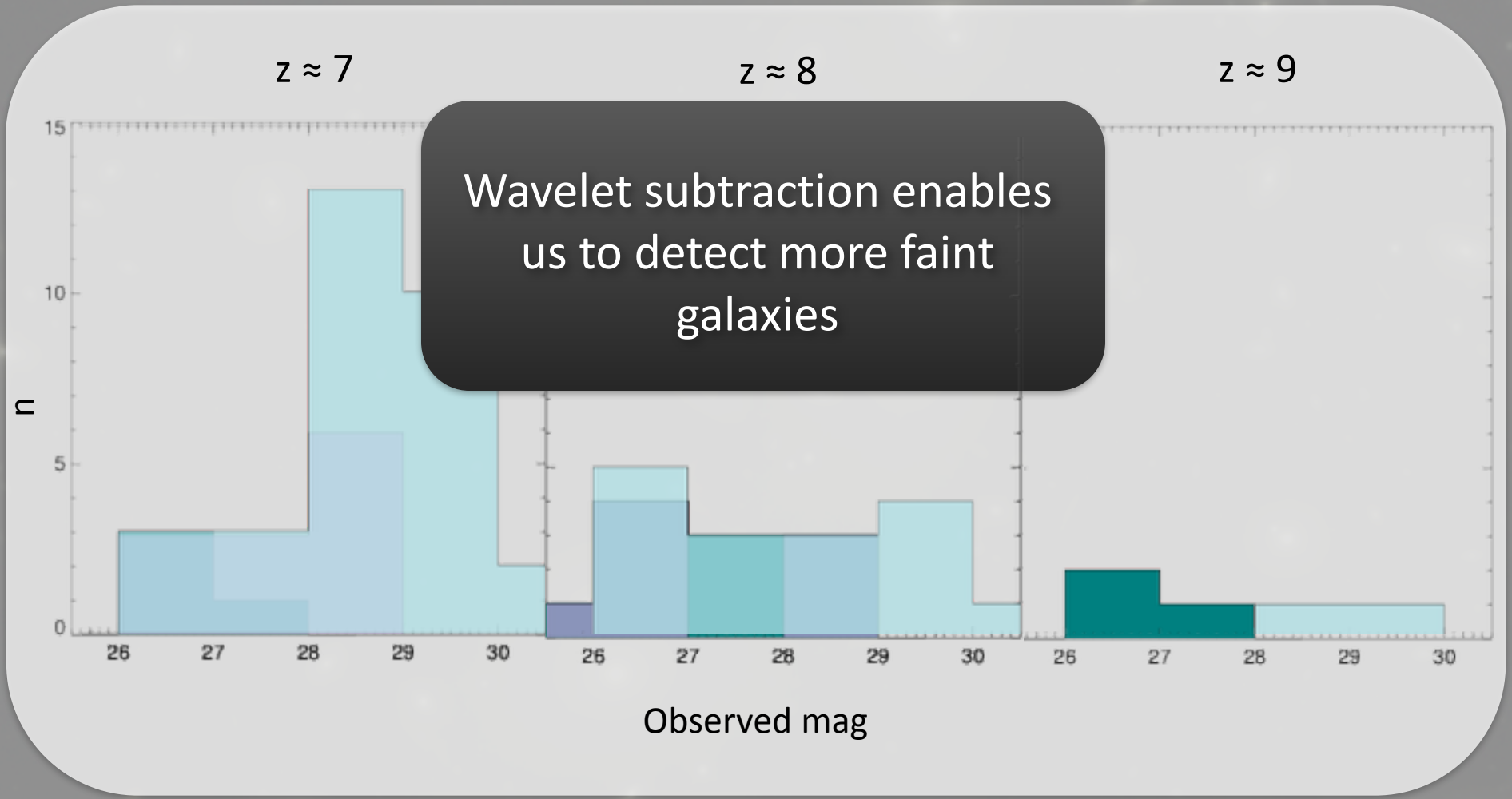
Observed number counts at z ≥ 7



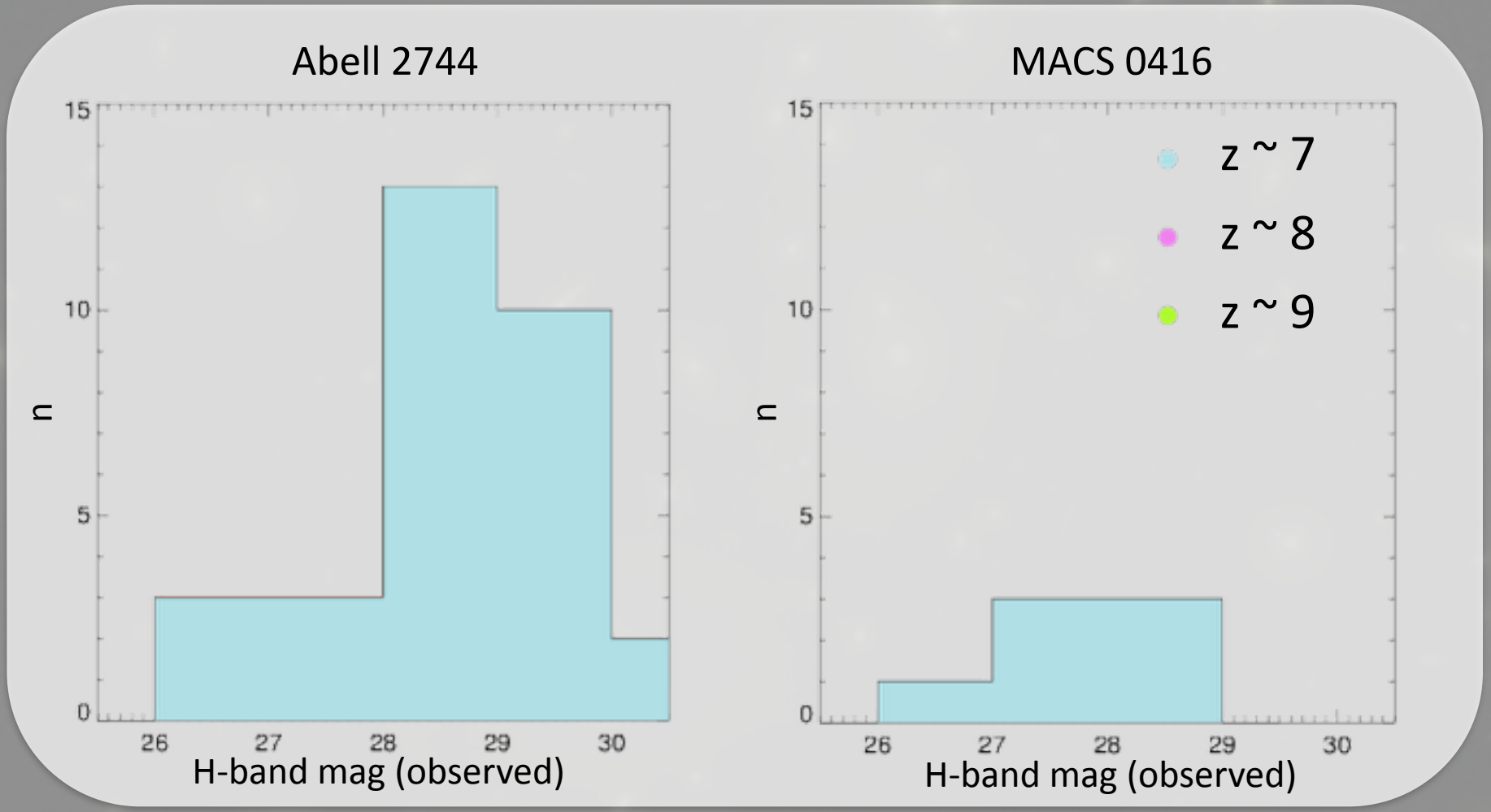
Observed number counts at z ≥ 7



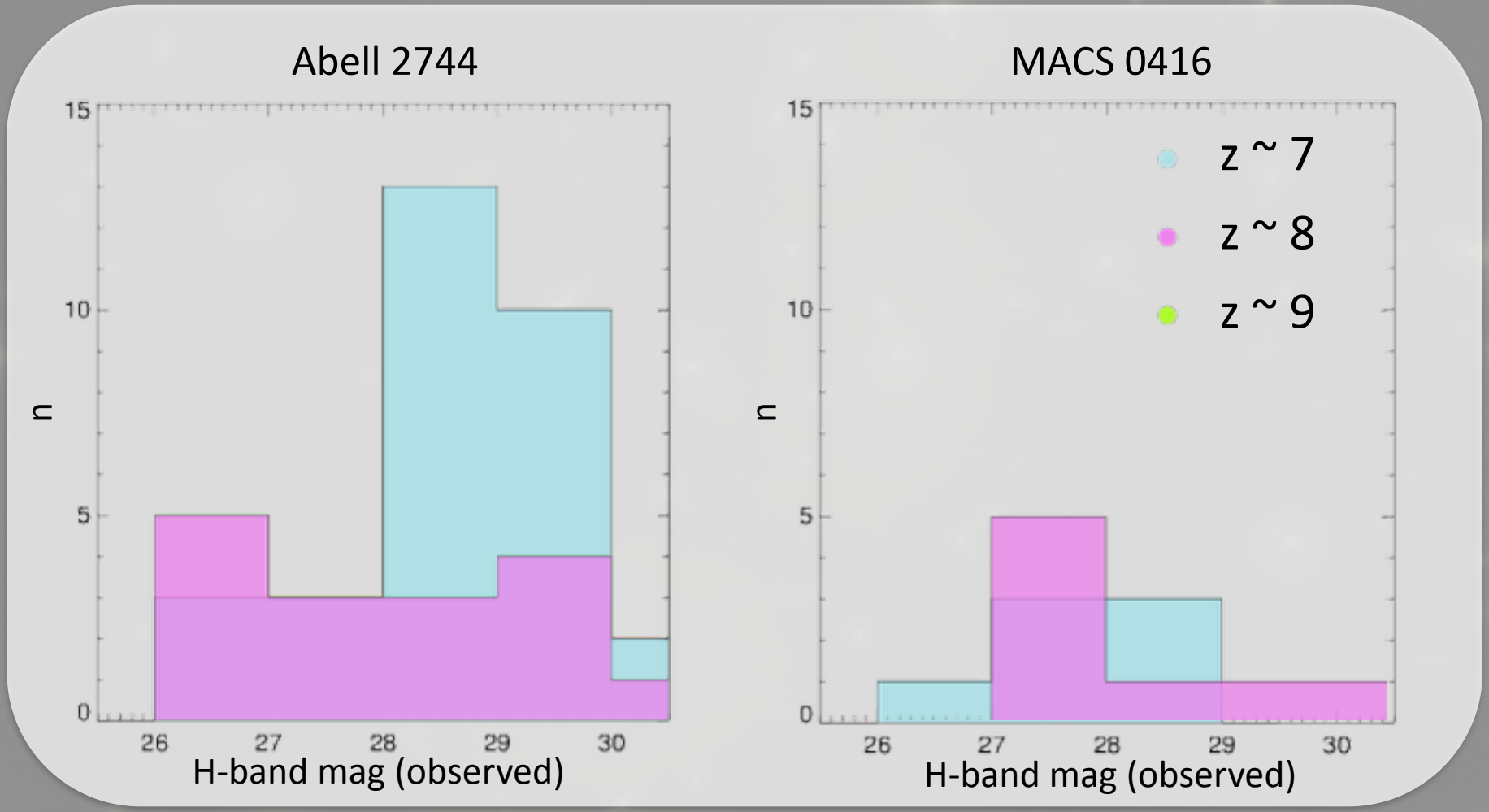
Observed number counts at z ≥ 7



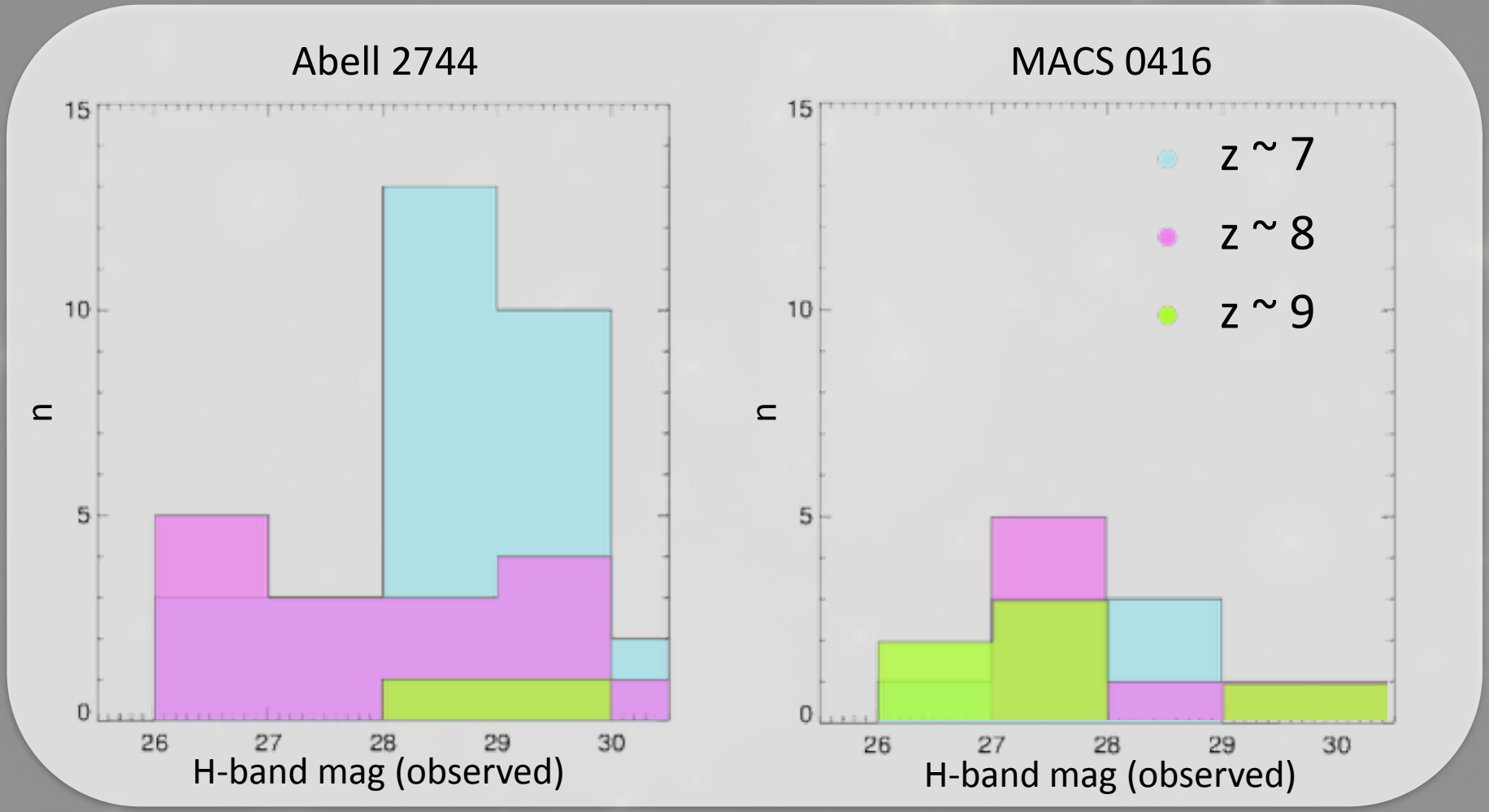
Observed magnitudes of z>7 candidates



Observed magnitudes of z>7 candidates



Observed magnitudes of z>7 candidates



Magnification

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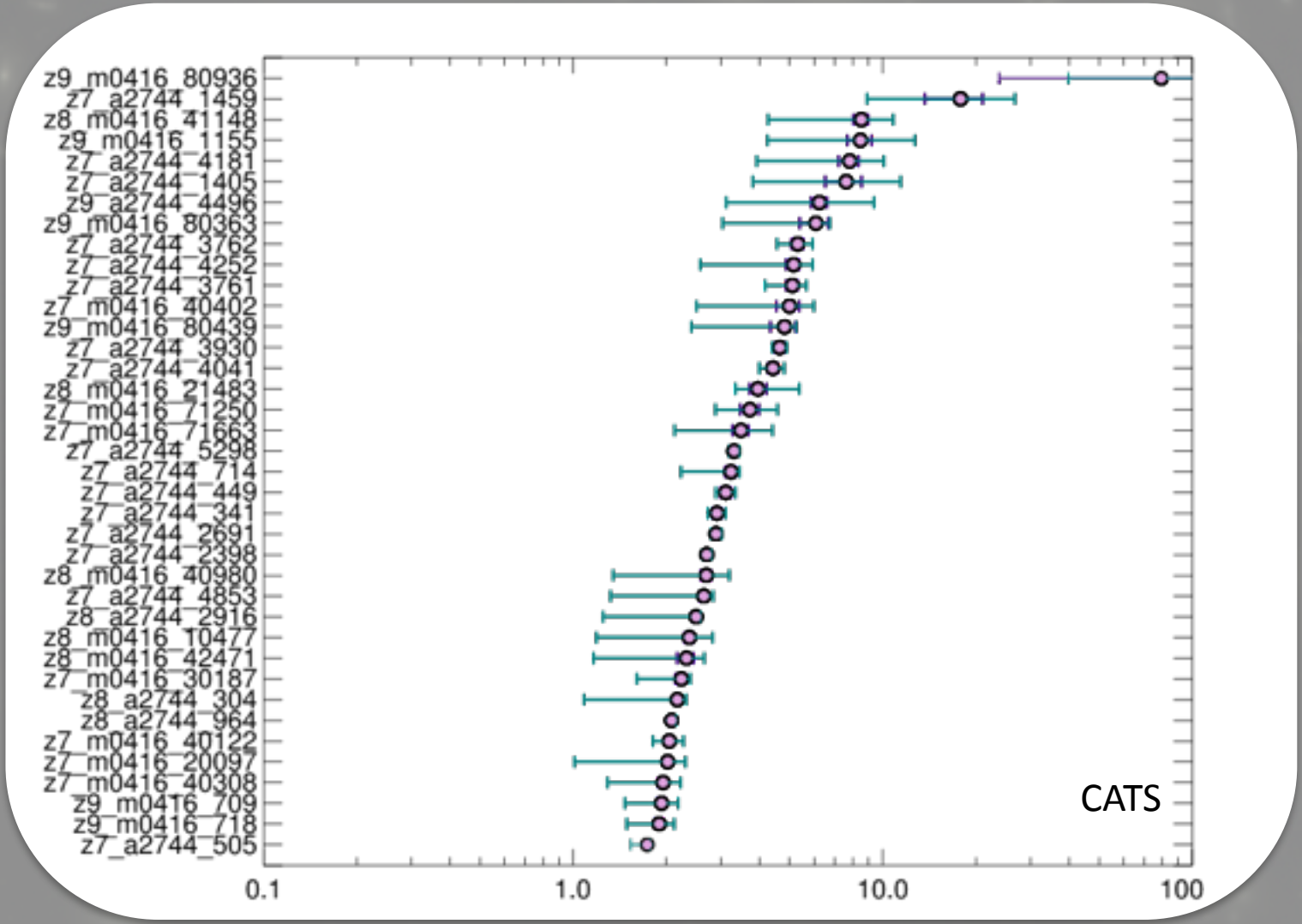

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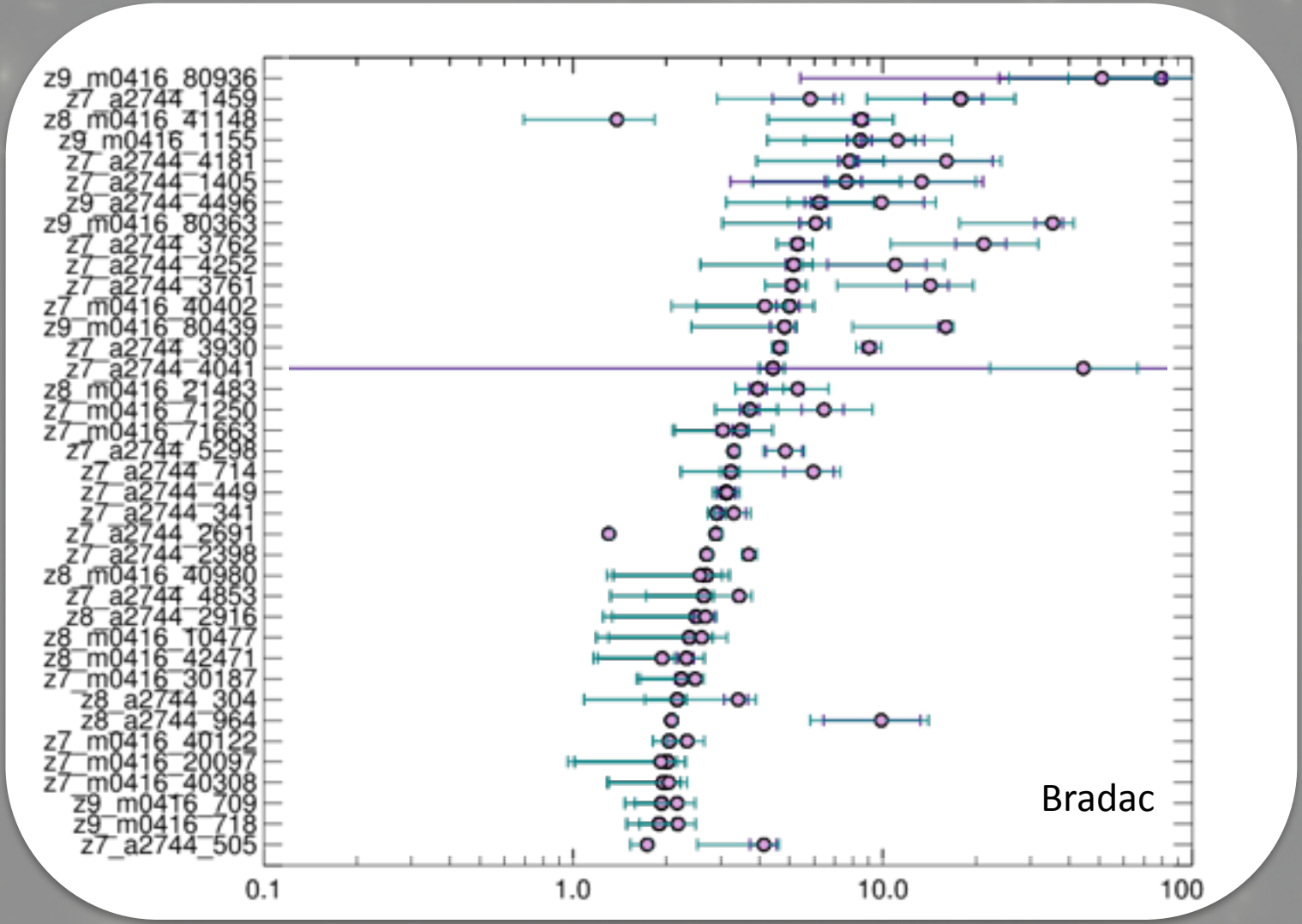

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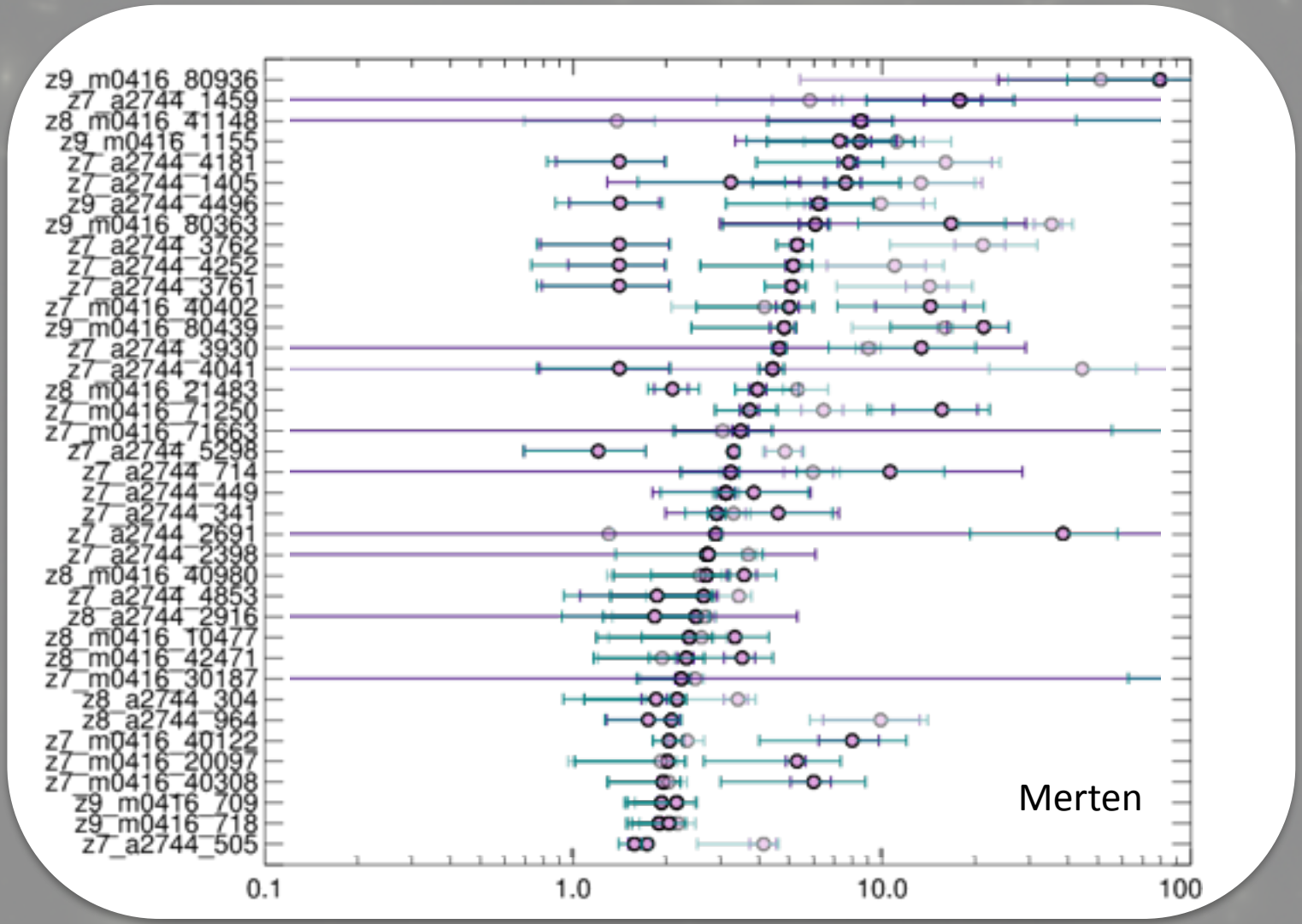

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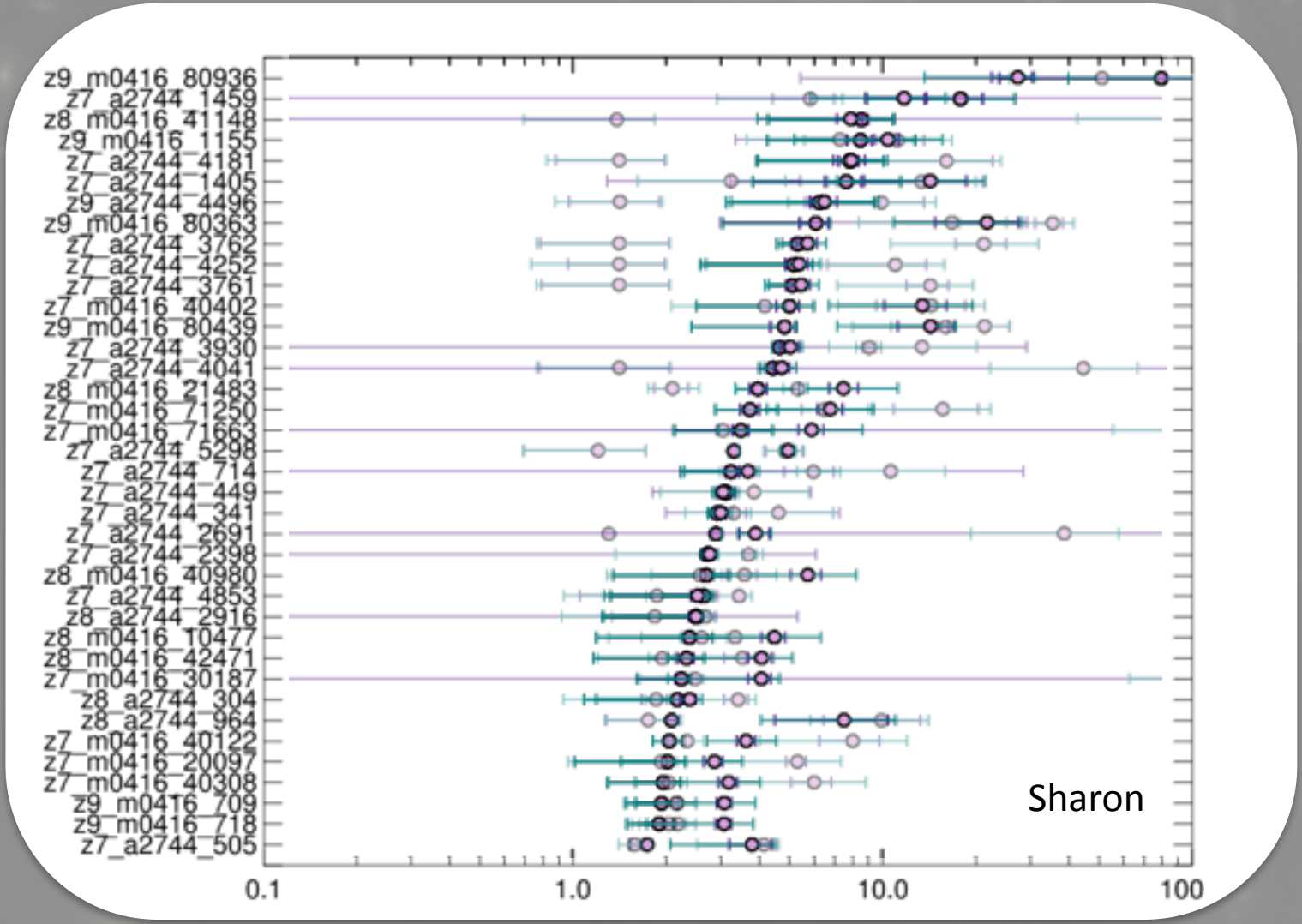

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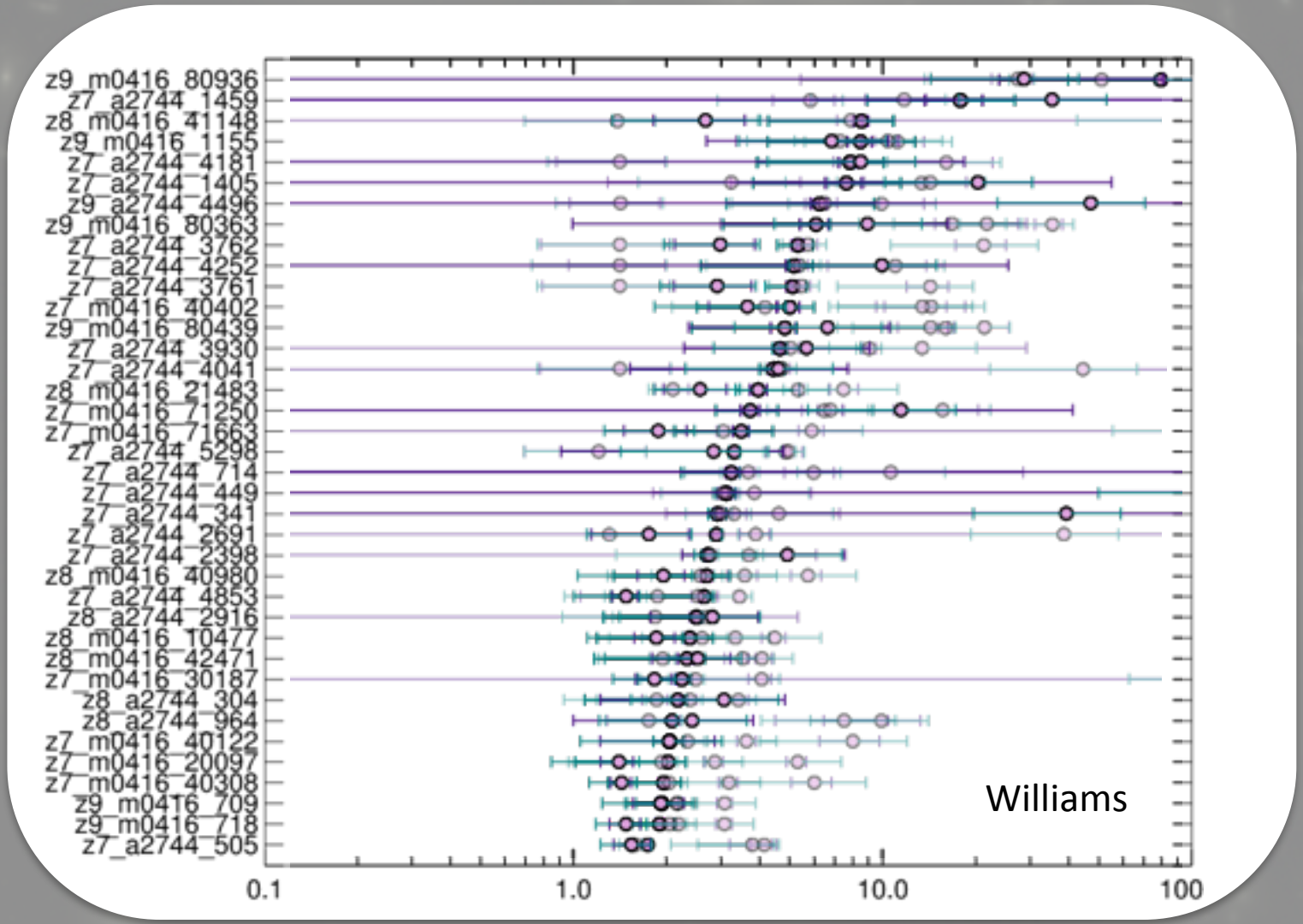

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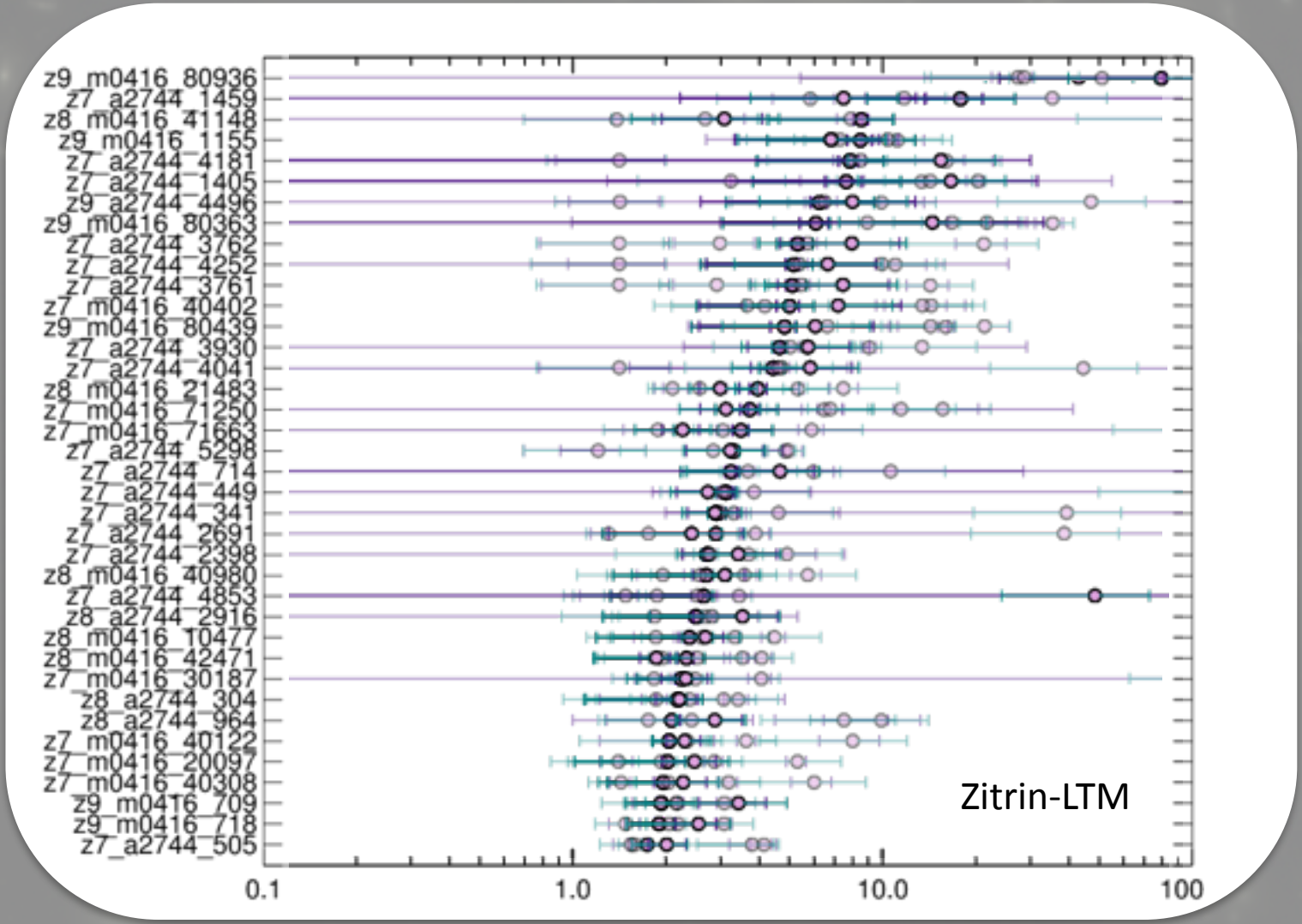

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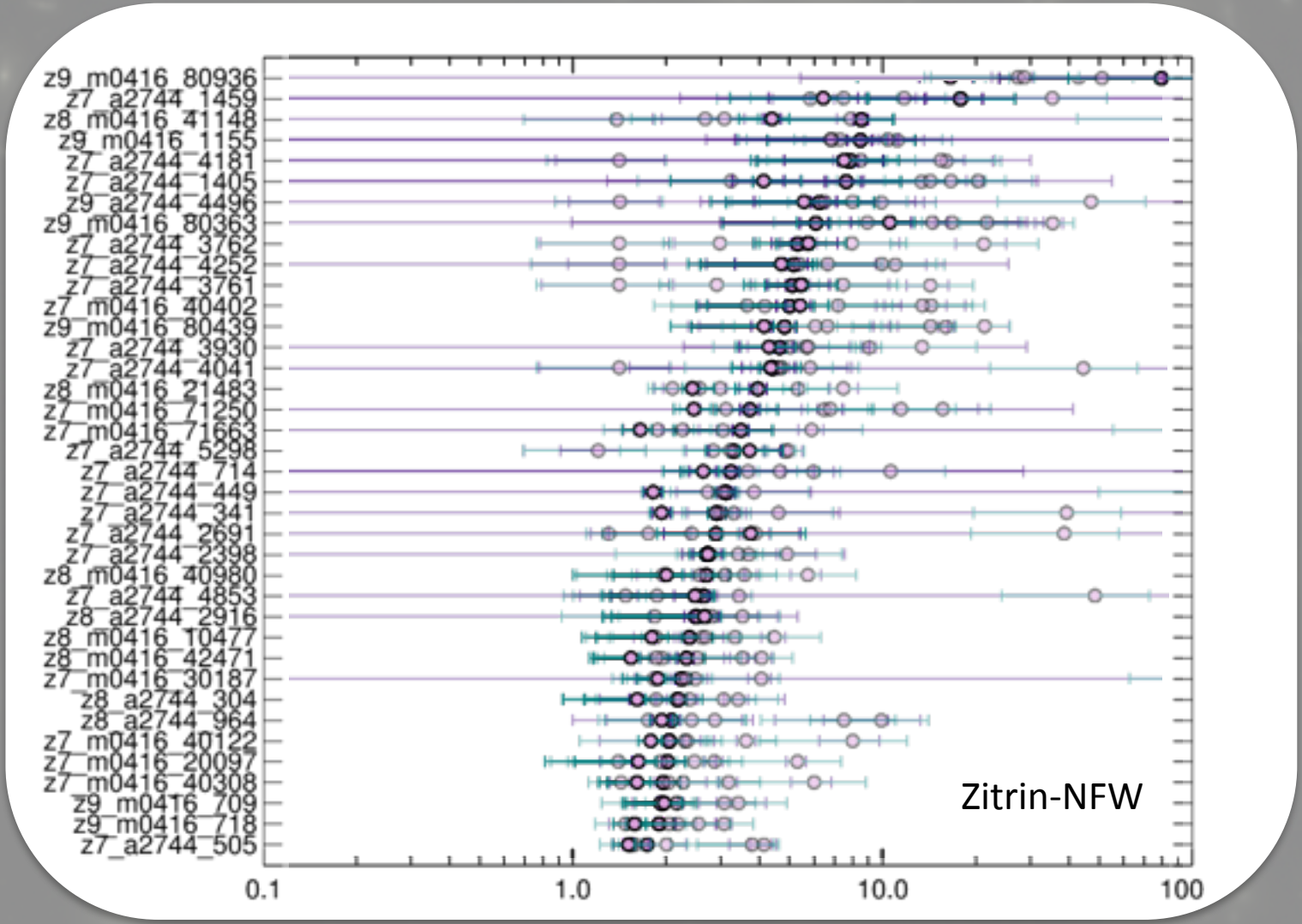
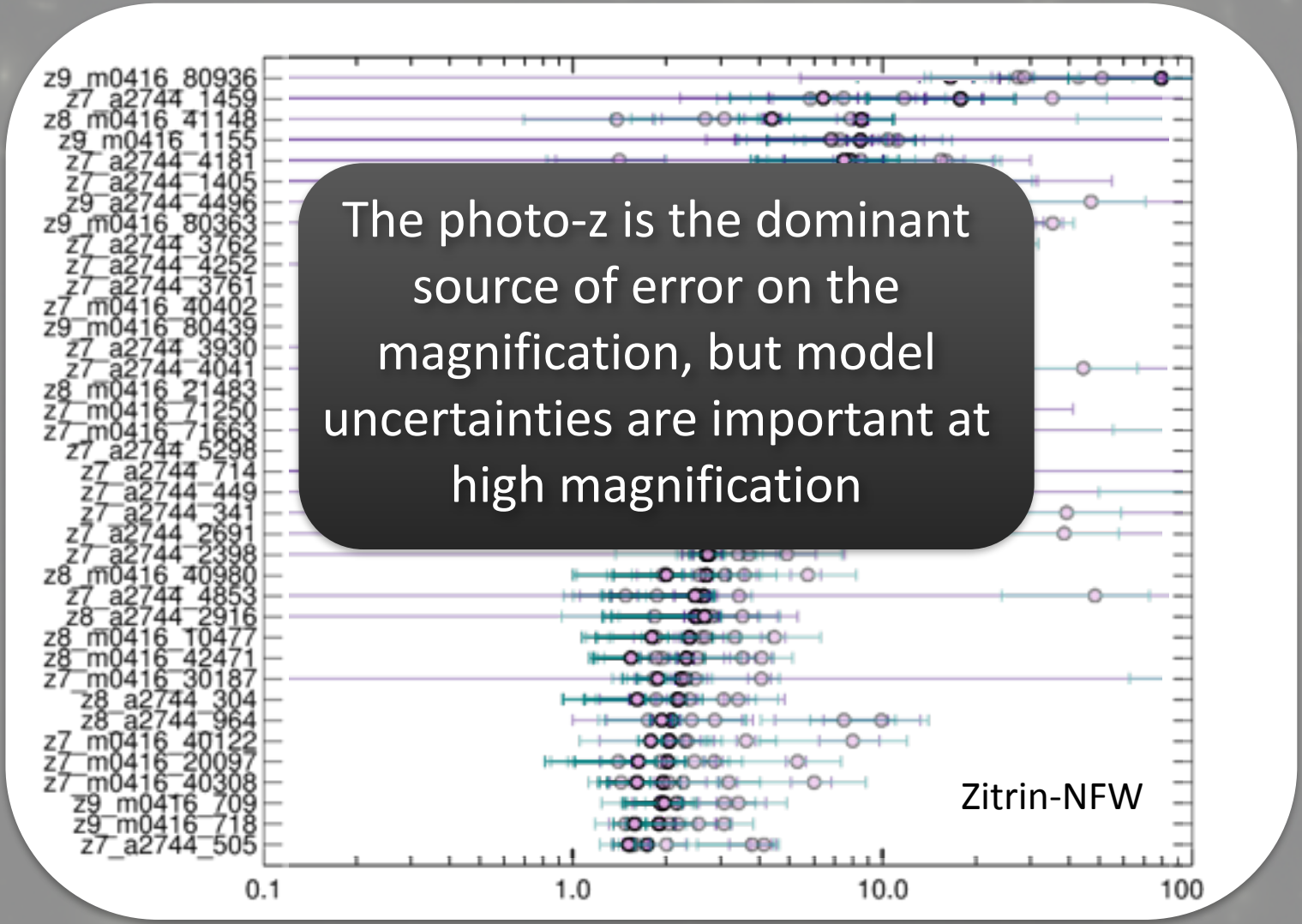
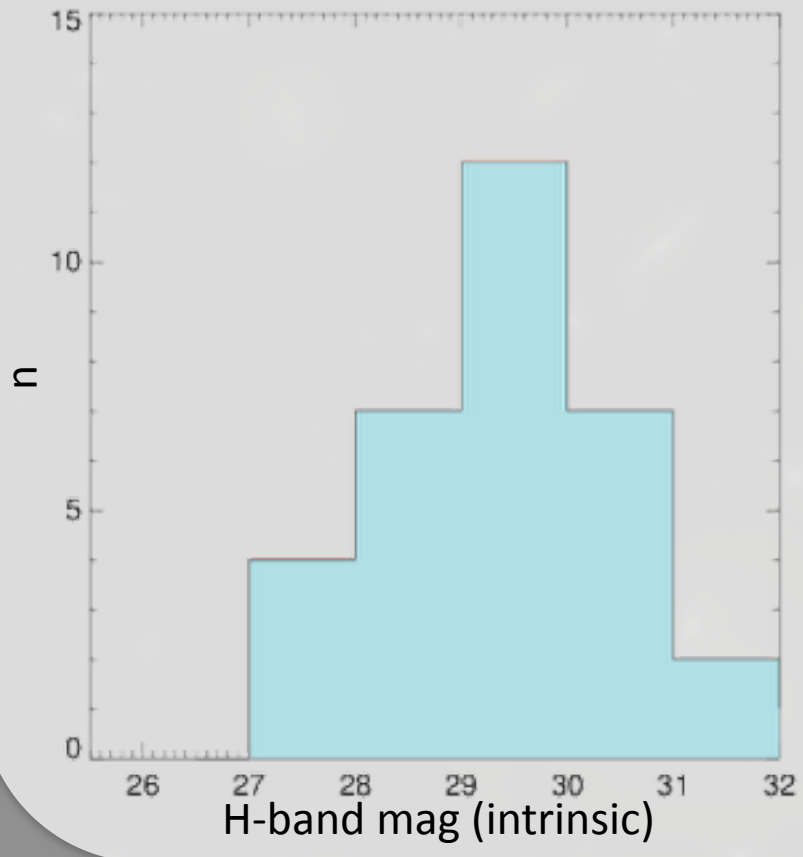


Magnification

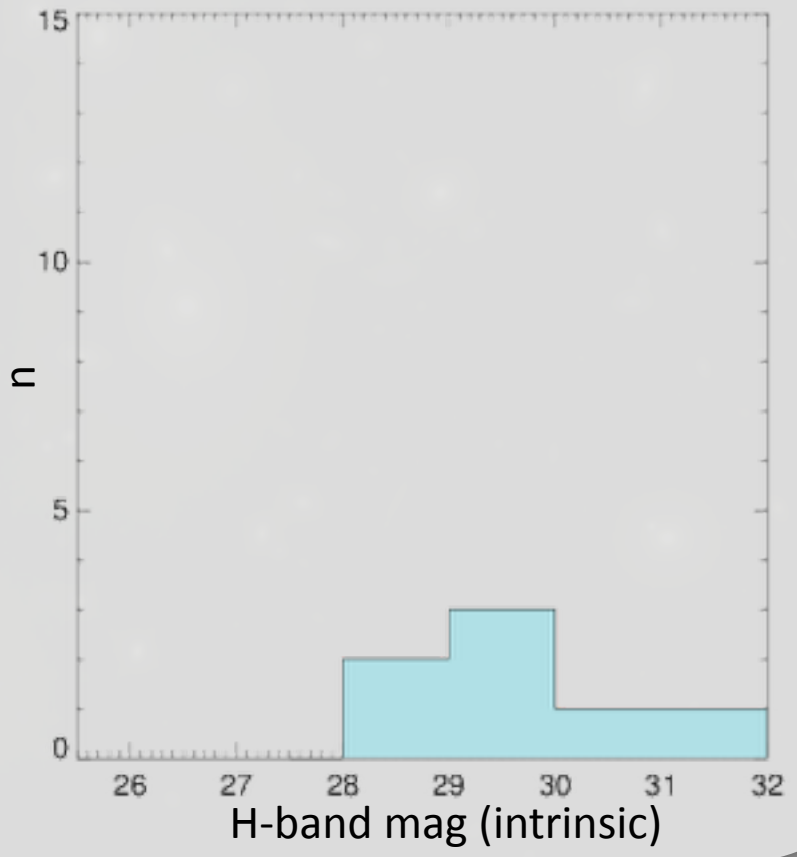


Intrinsic magnitudes of z ≥ 7 candidates

Abell 2744

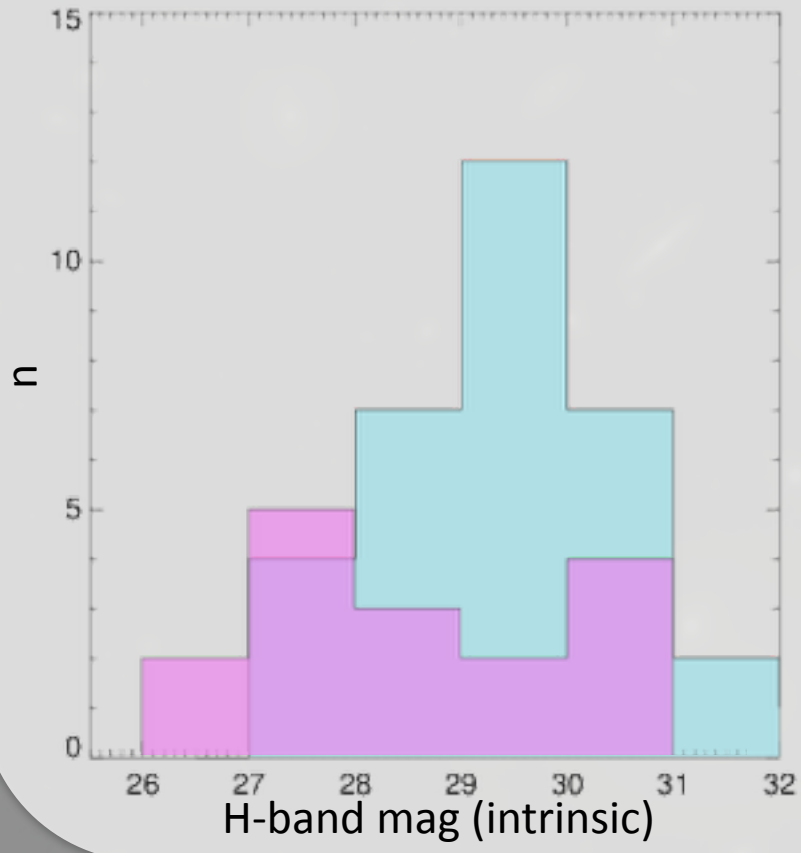


MACS 0416



Intrinsic magnitudes of z ≥ 7 candidates

Abell 2744



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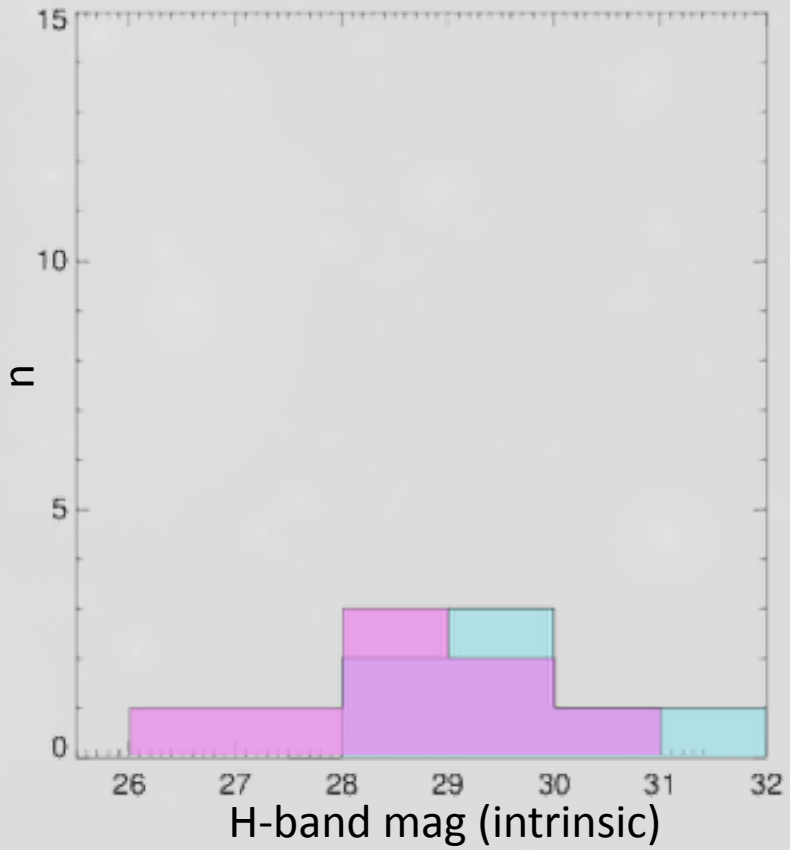
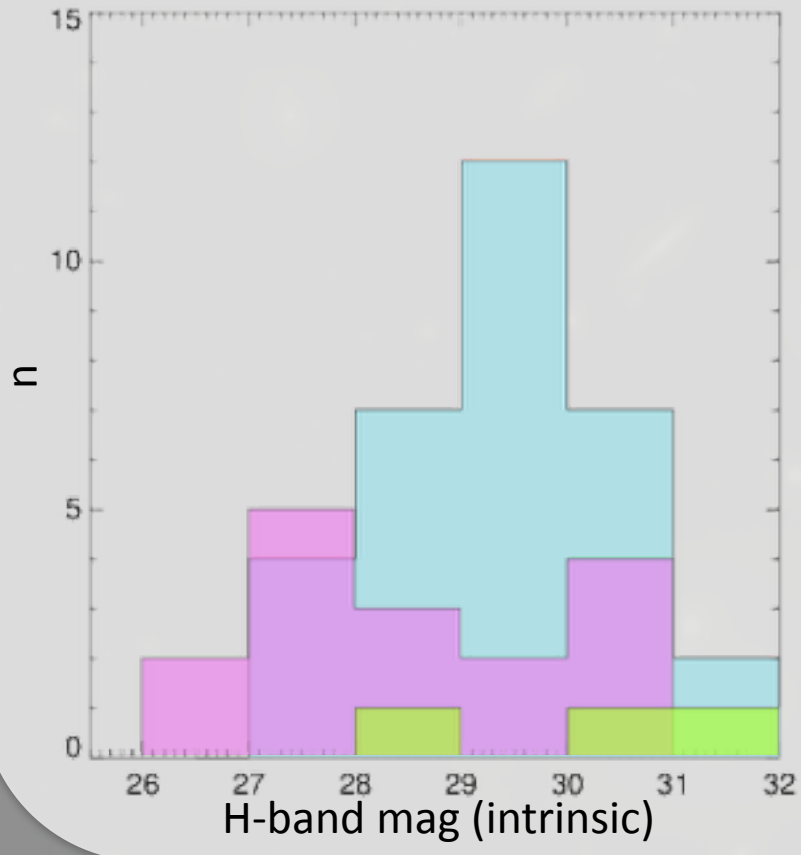


Intrinsic magnitudes of z ≥ 7 candidates

Abell 2744



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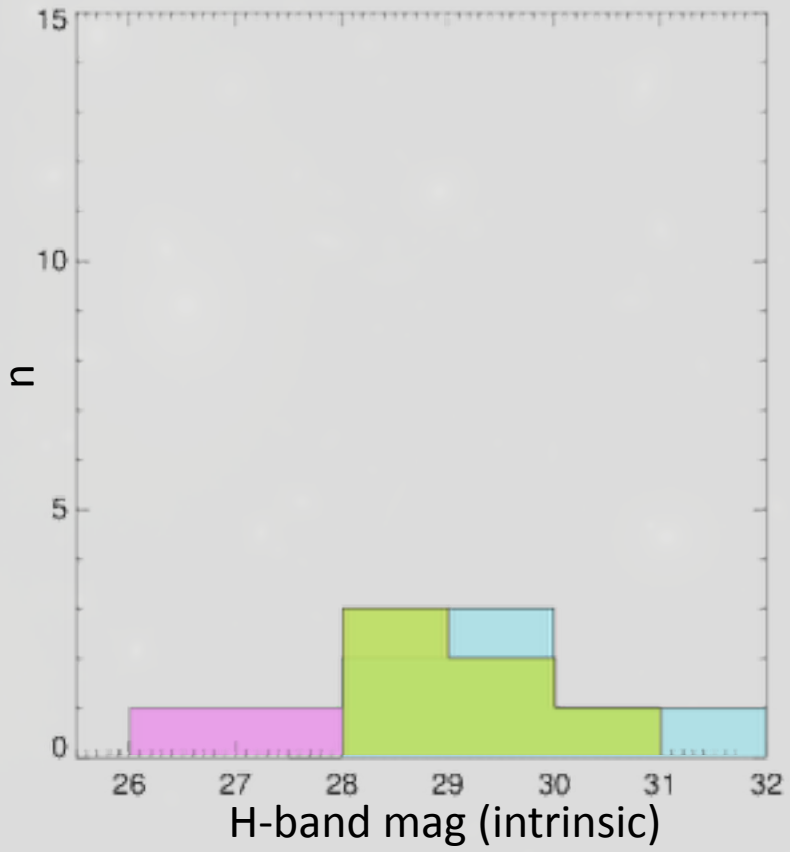

Summary

- We are using wavelet decomposition to remove foreground cluster light
- We find this increases the depth of the image without impacting the photometry
- Early results indicate 78 lensed $z \geq 7$ galaxies in the first two clusters