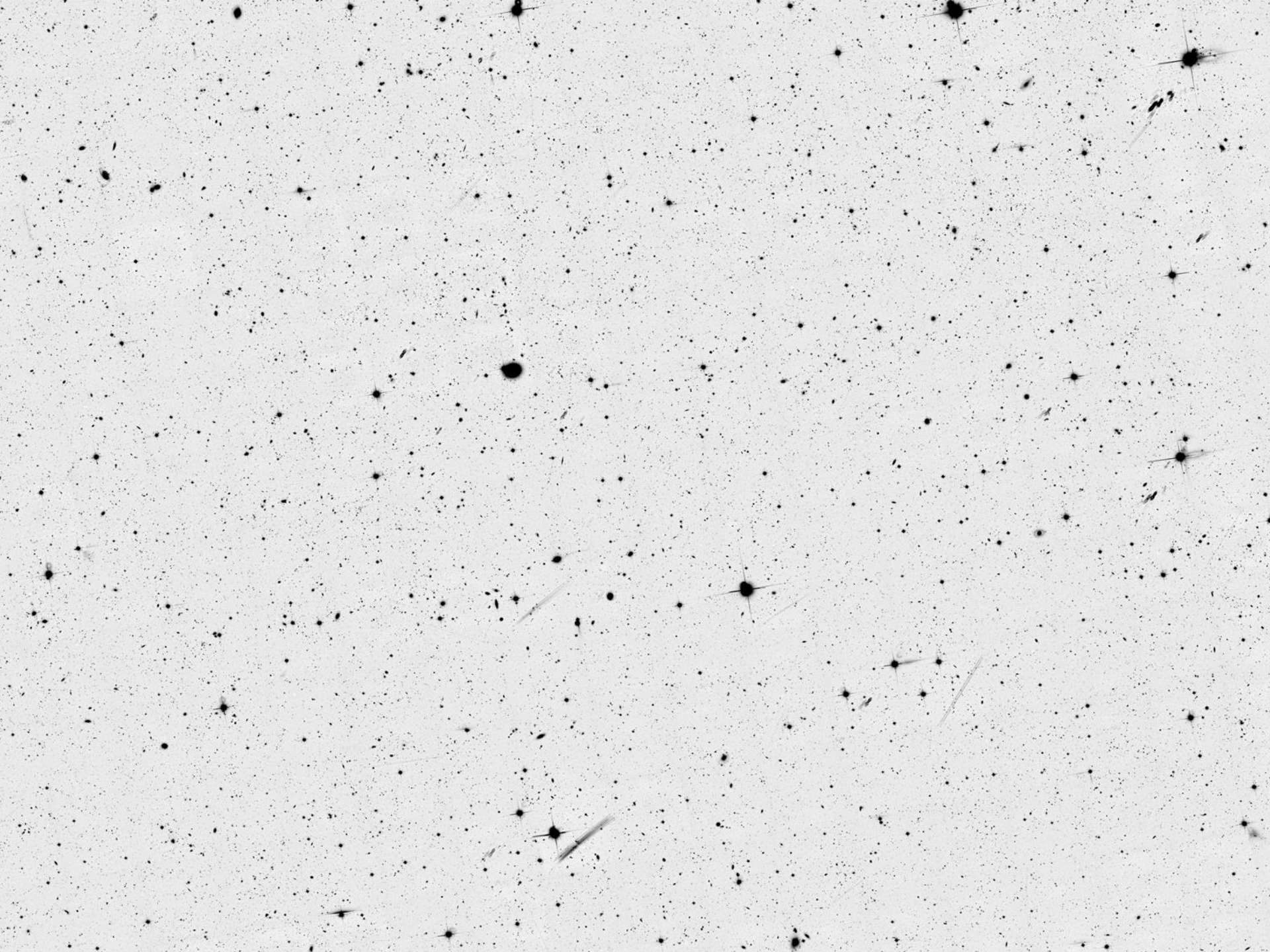
High Redshift Galaxies in 3D-HST

Exploring Cosmic Dawn

John Weaver
w. Michael Maseda

LEAPS Symposium
11.08.16



“Because it is there.”

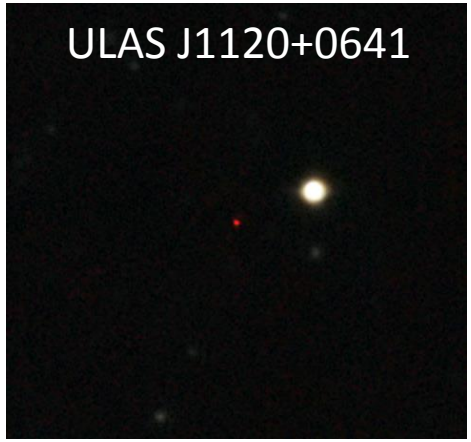
- G. Mallory (1886 – 1924)

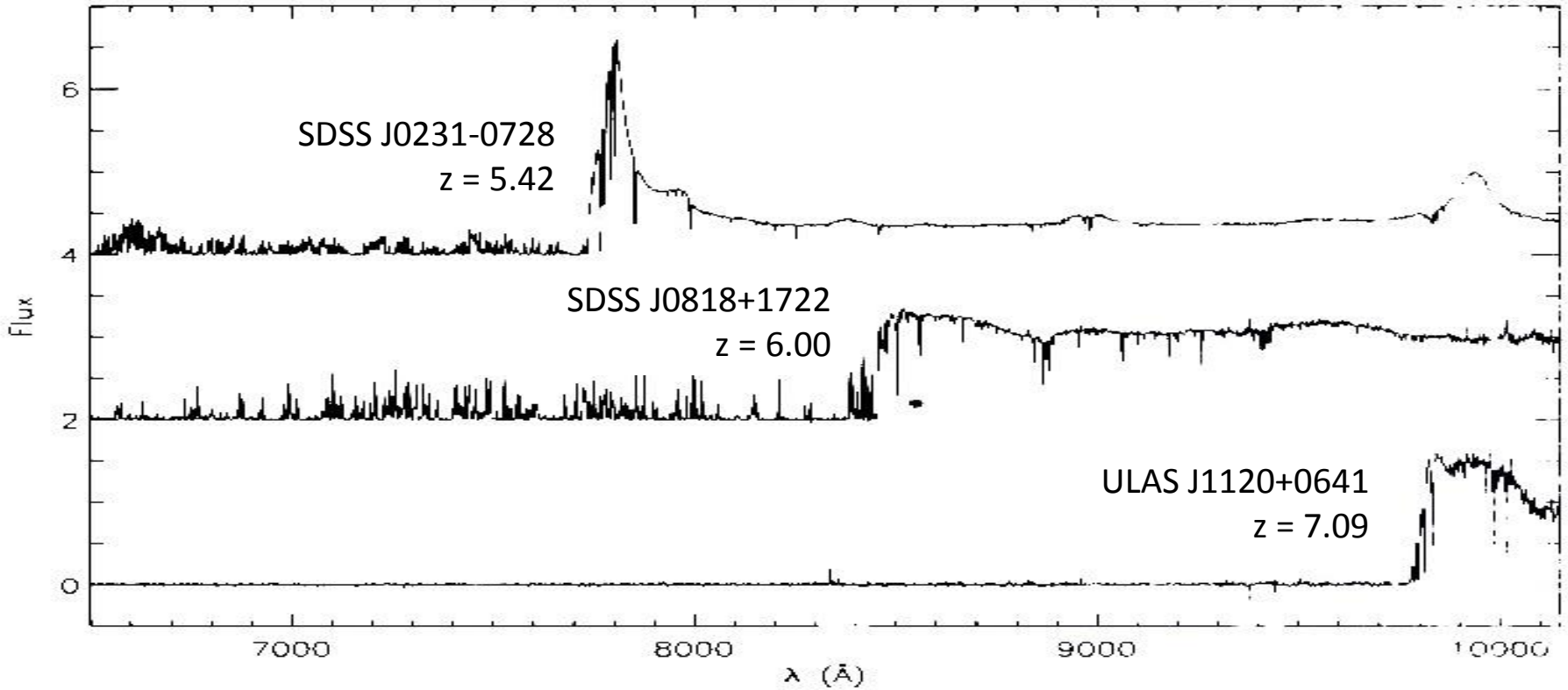
Motivation
Searching for High Redshift

Photometric candidates are abundant

Rely on the Lyα line to confirm redshifts

Increasingly neutral IGM absorbs Lyα





The CANDELS Survey
Probing the Distant Universe

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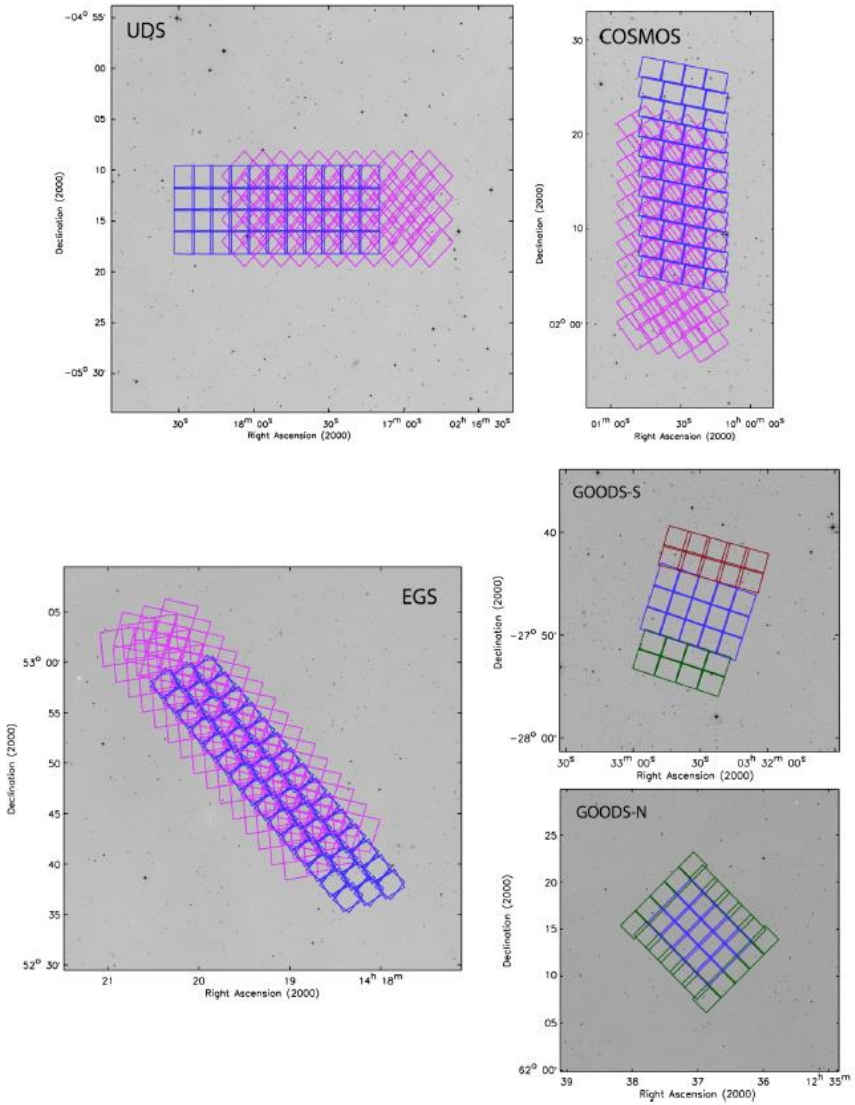
HST photometry over five famous fields



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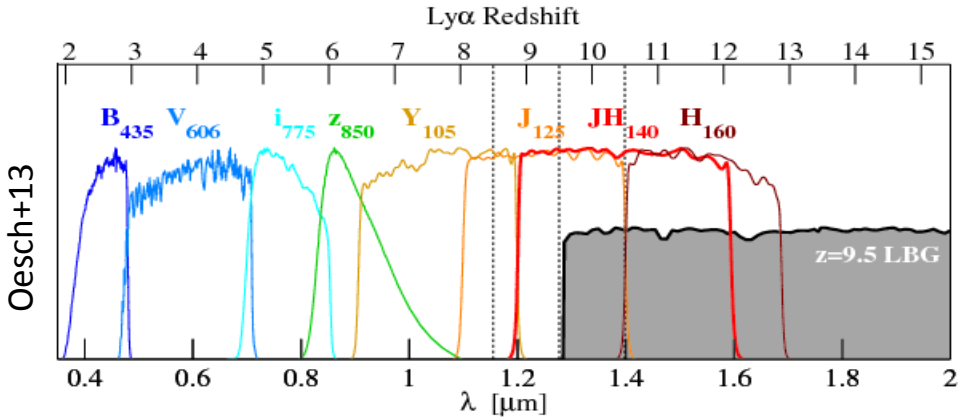
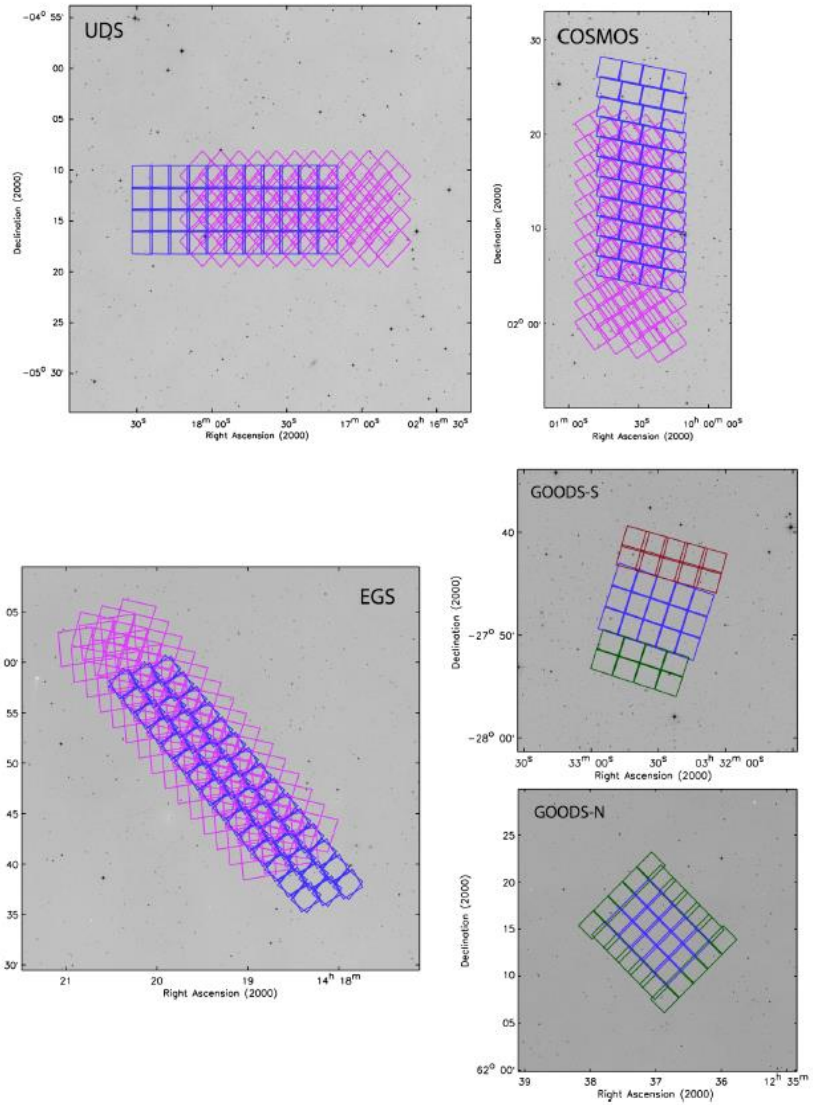
HST photometry over five famous fields

Provides **deep** multi-band imaging





The CANDELS Survey
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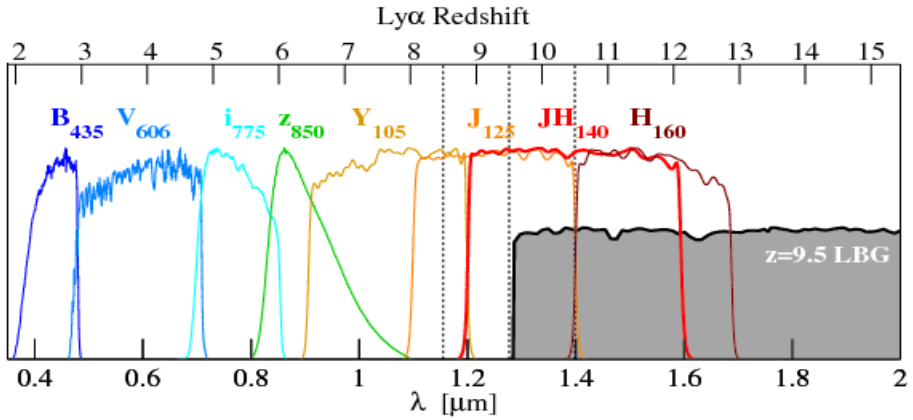
HST photometry over five famous fields

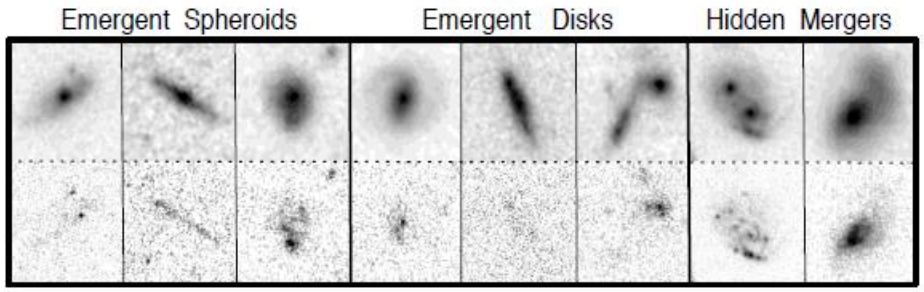
Provides **deep** multi-band imaging

10,241 photometric candidates from z >4

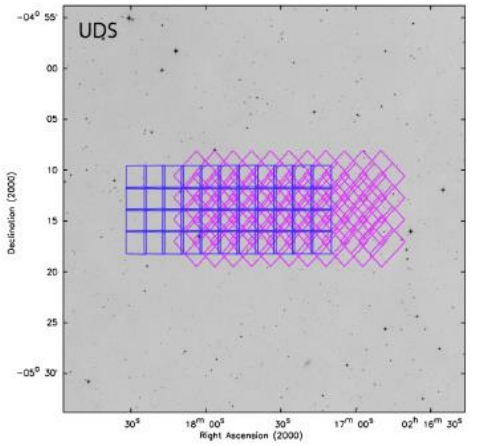
Bouwens+15

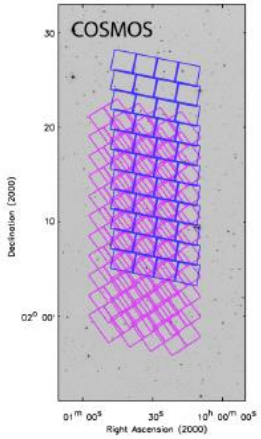


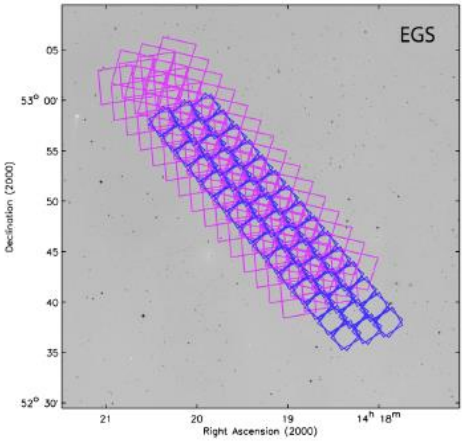
Oesch+13

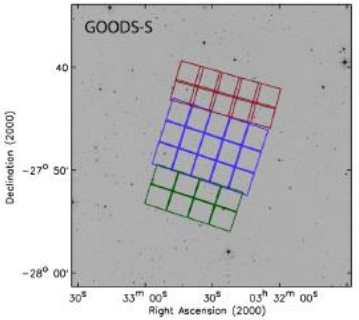


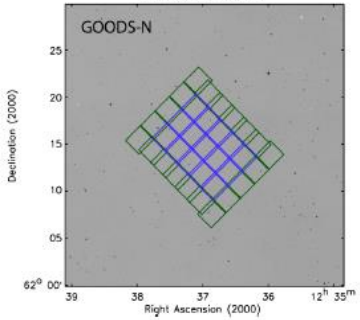
Grogin+11











Is it Magic?

Photometric Redshifts

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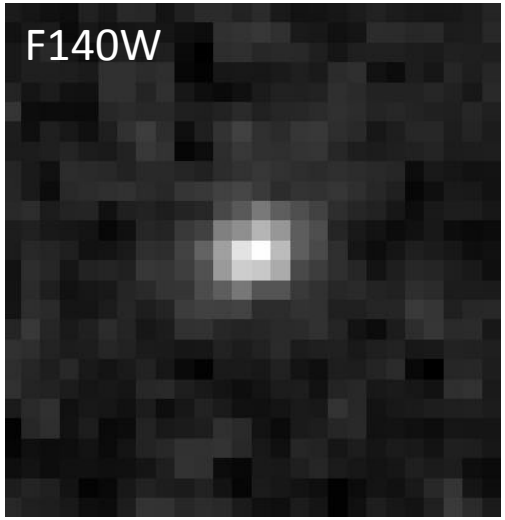
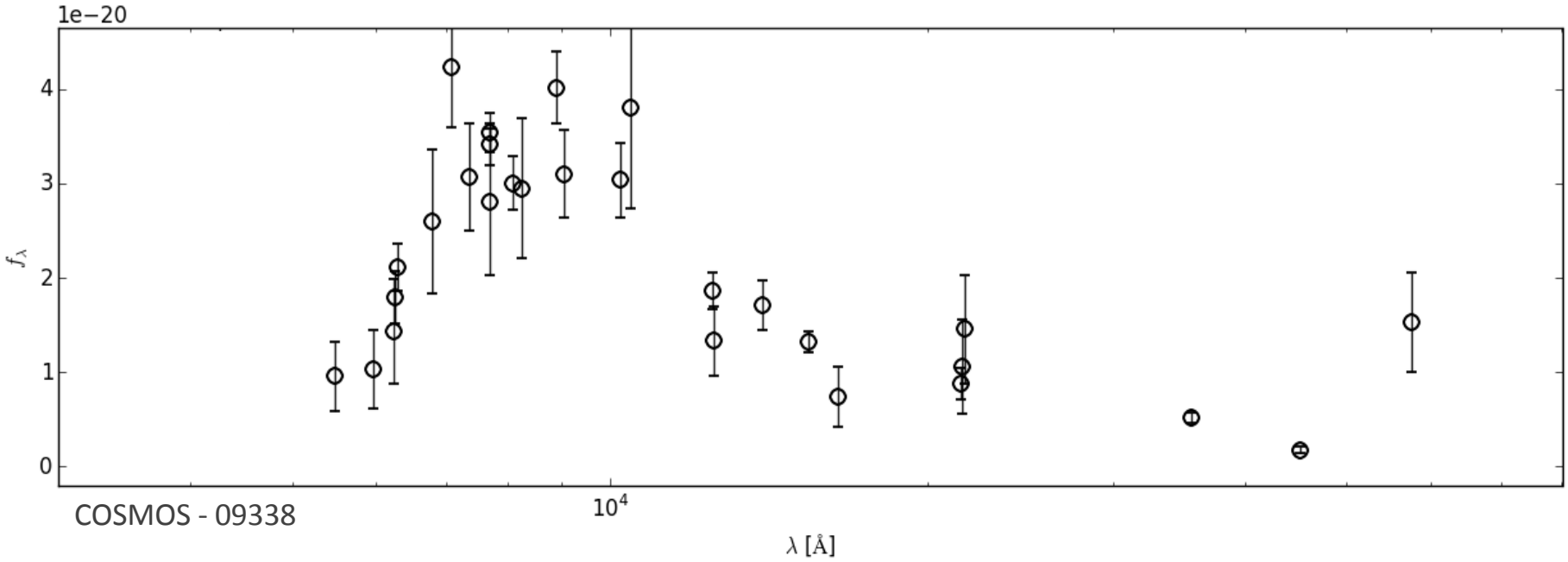
Photometric Redshifts

Start with multi-band imaging





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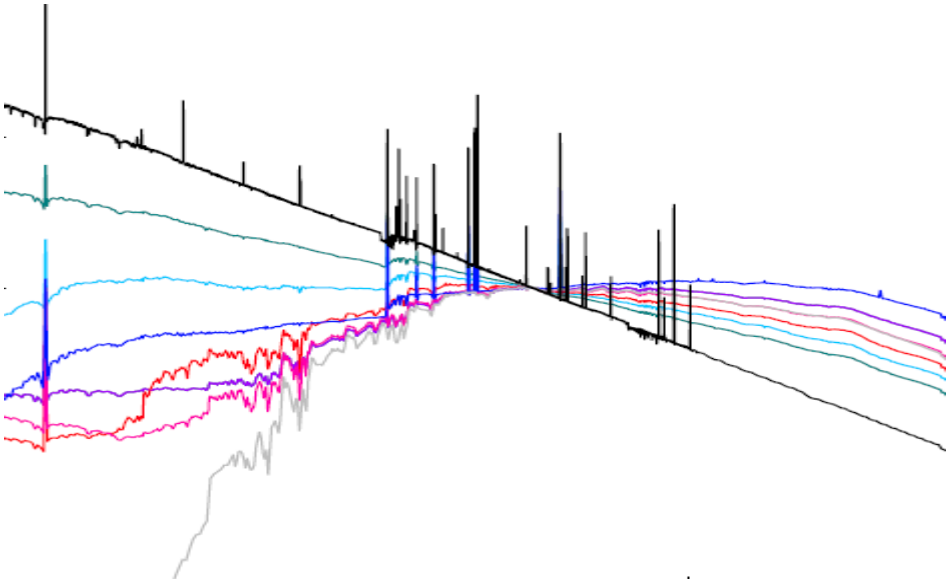
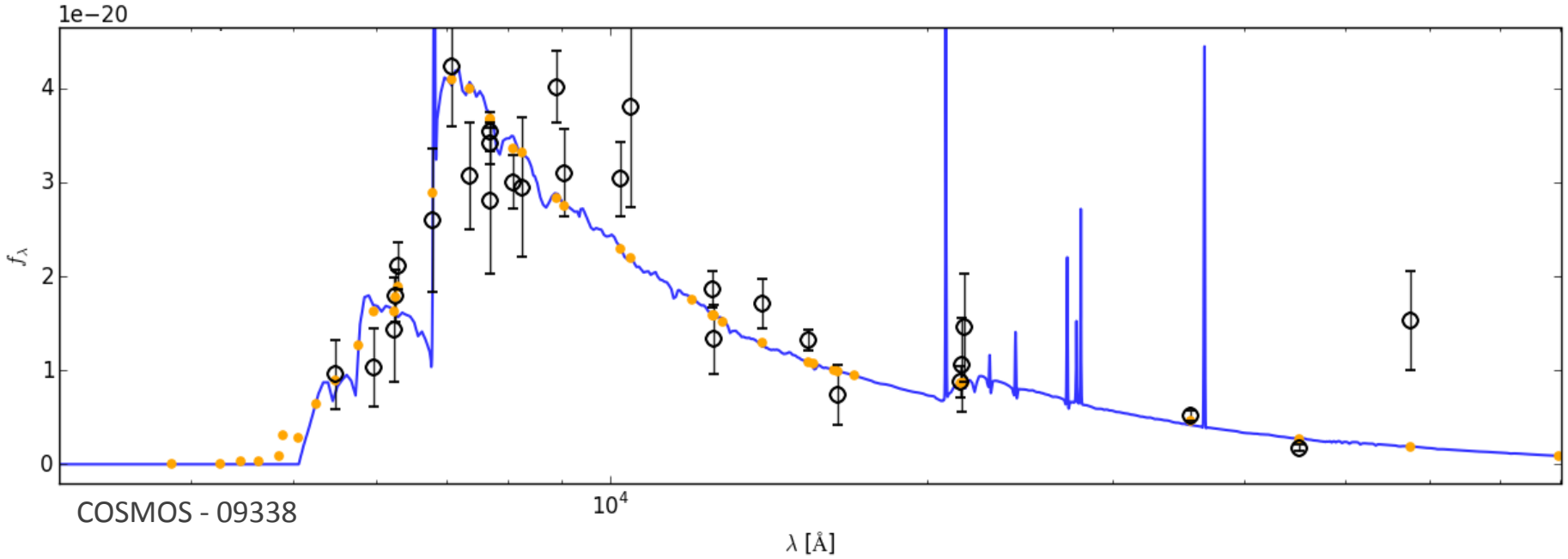
Photometric Redshifts

Start with multi-band imaging

Fit to a library of galaxy spectra





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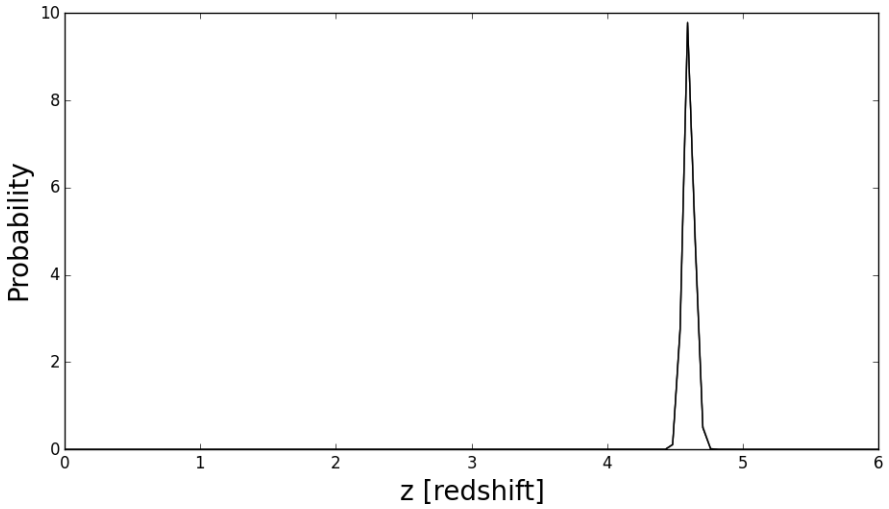
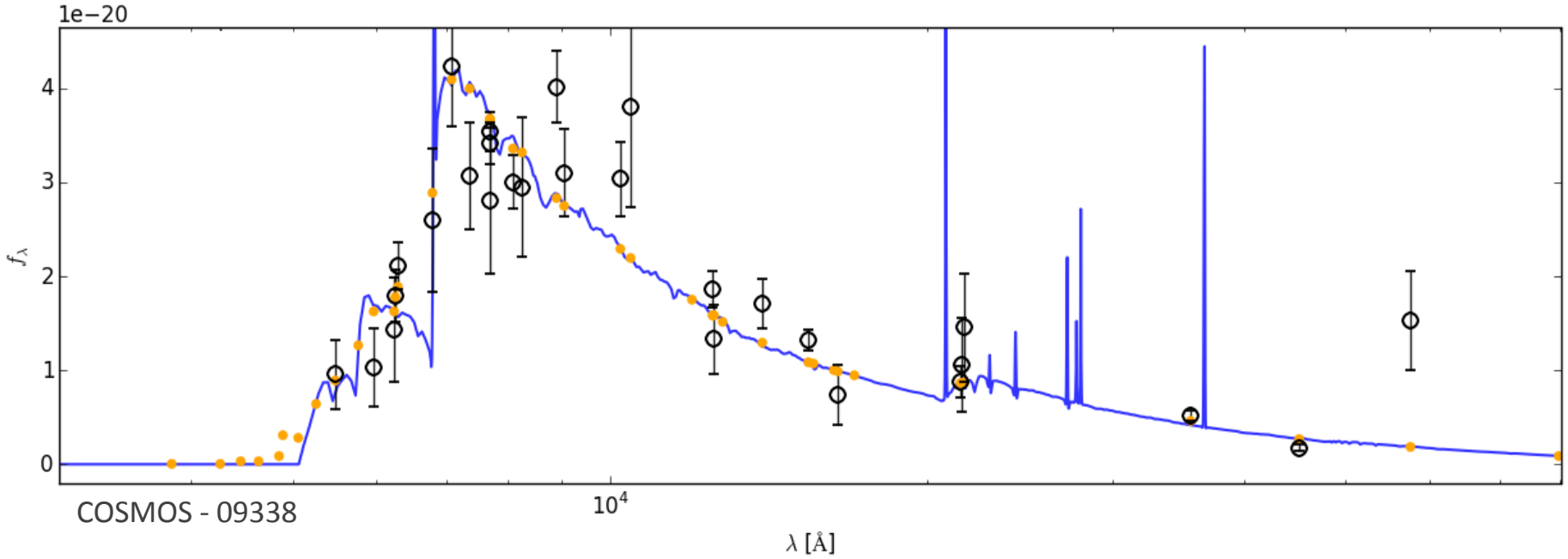
Photometric Redshifts

Start with multi-band imaging

Fit to a library of galaxy spectra

Study redshift distributions





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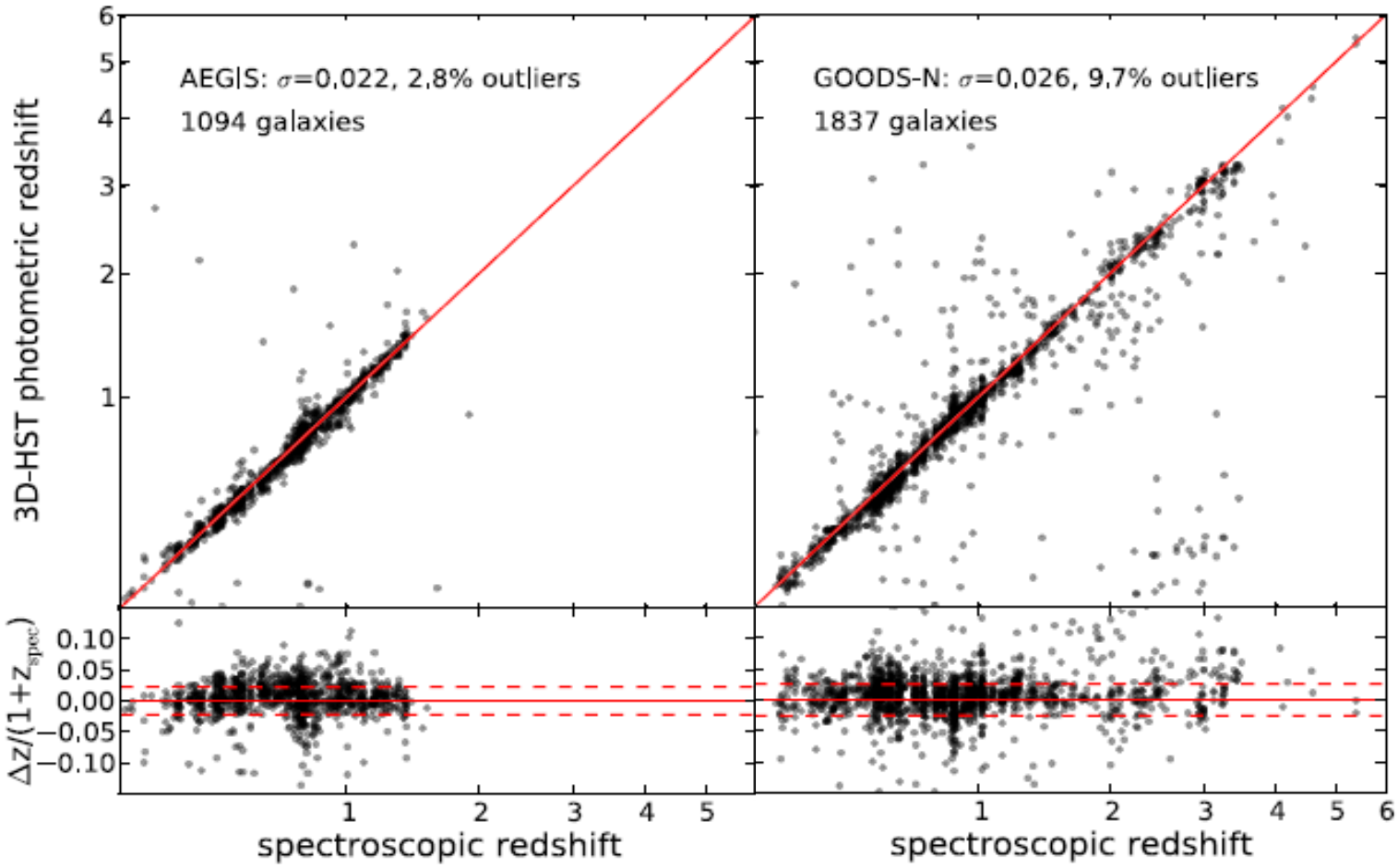
Photometric Redshifts

Remarkably accurate!

Skelton+14



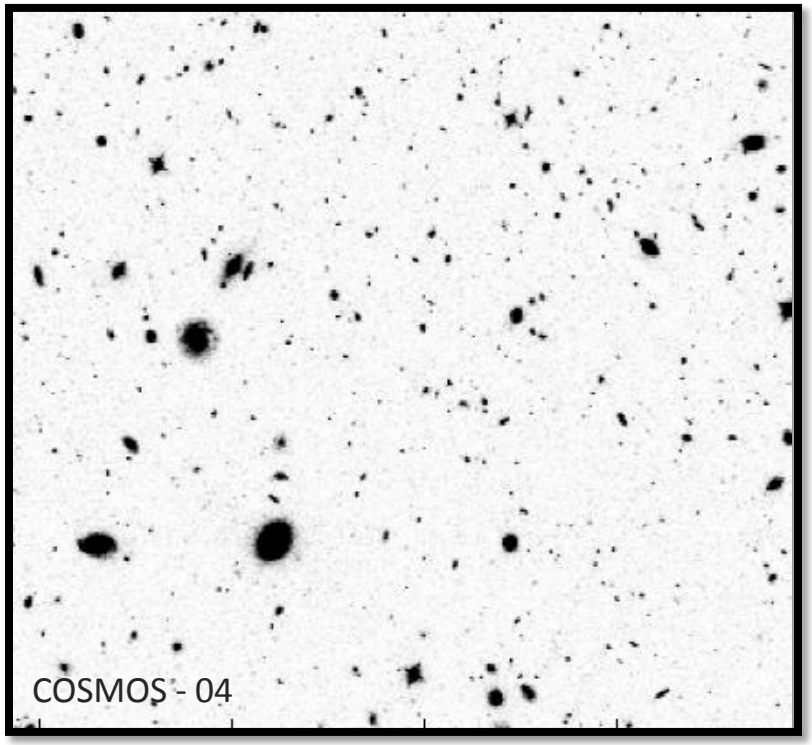
Dissecting the Light

The Purpose of 3D-HST

NIR spectroscopy survey of 100,000 galaxies z > 1

Covers 70% of the CANDELS fields

Low resolution multi-object grism spectrograph



Momcheva+15

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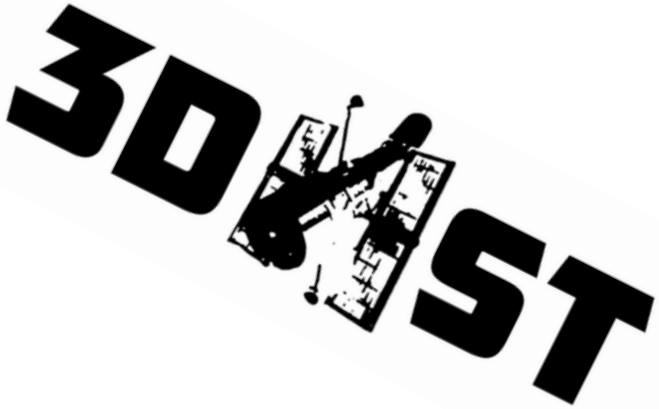
The Purpose of 3D-HST



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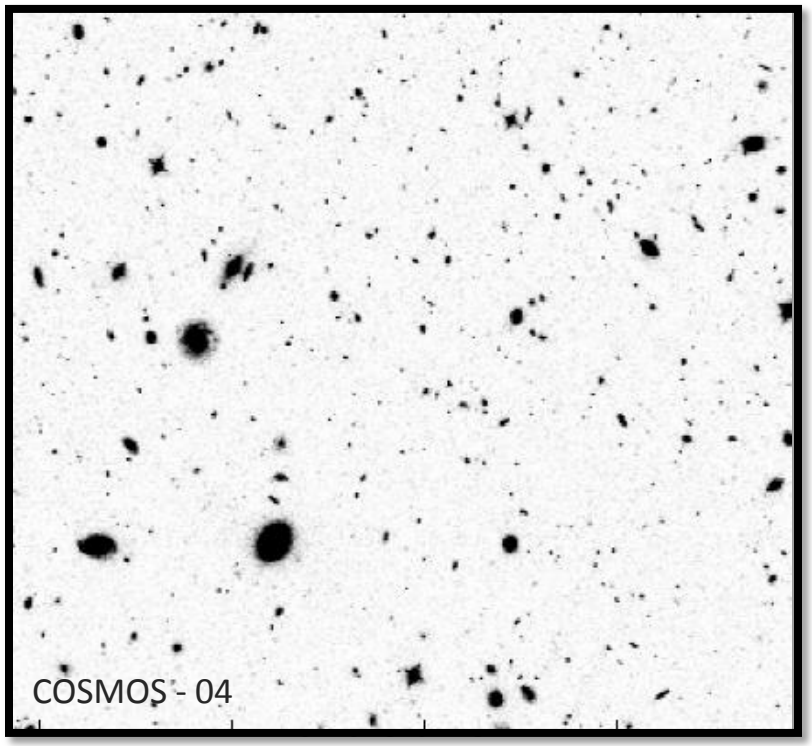
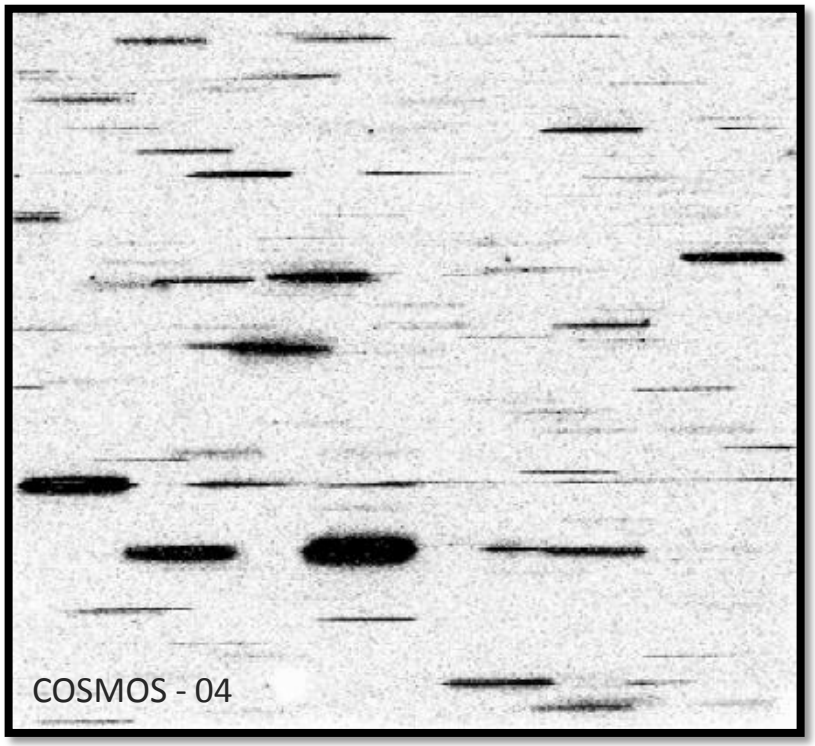
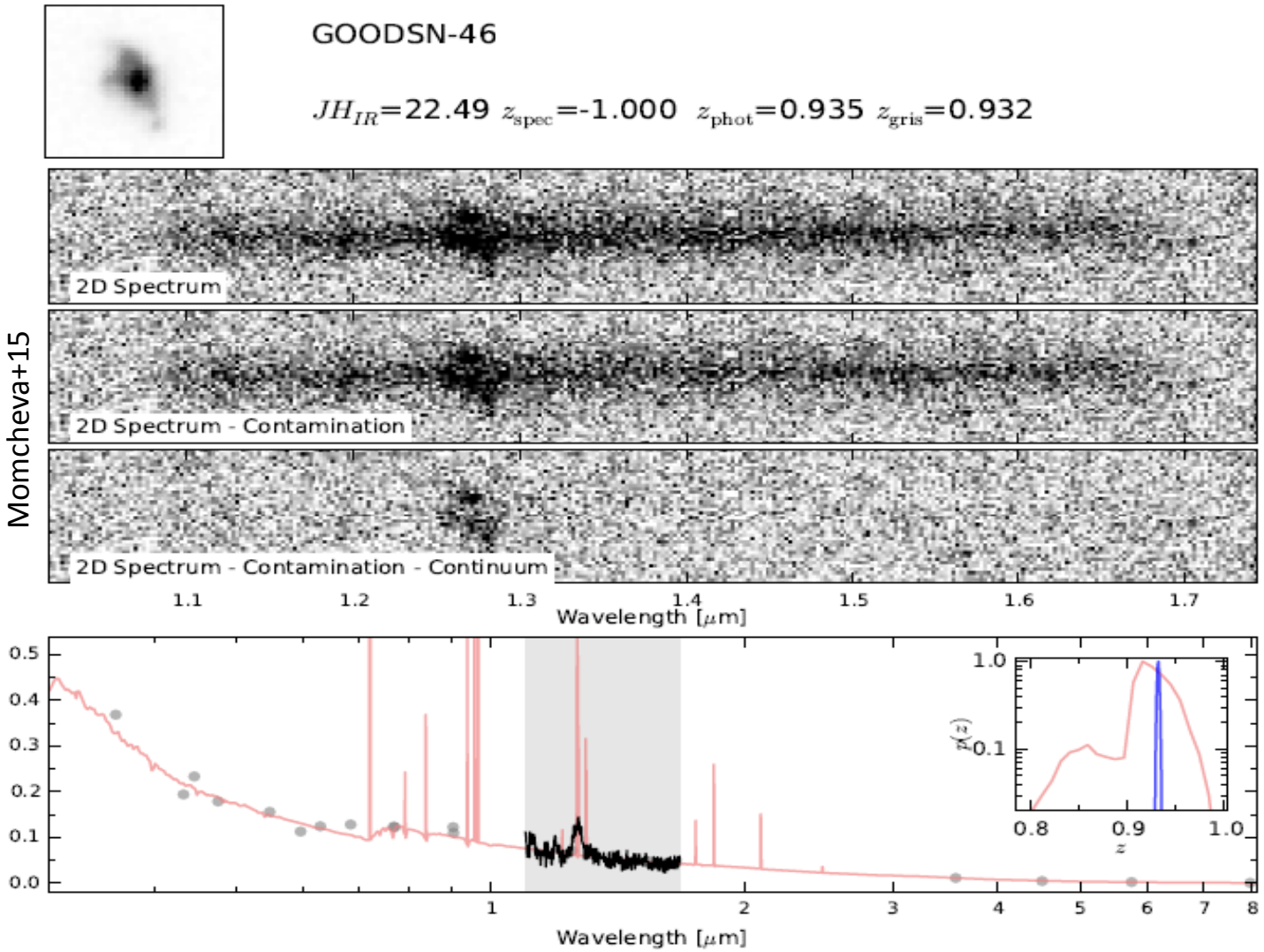
Low resolution multi-object **grism** spectrograph



Momcheva+15



Grism Spectroscopy
Multiplexing is Powerful



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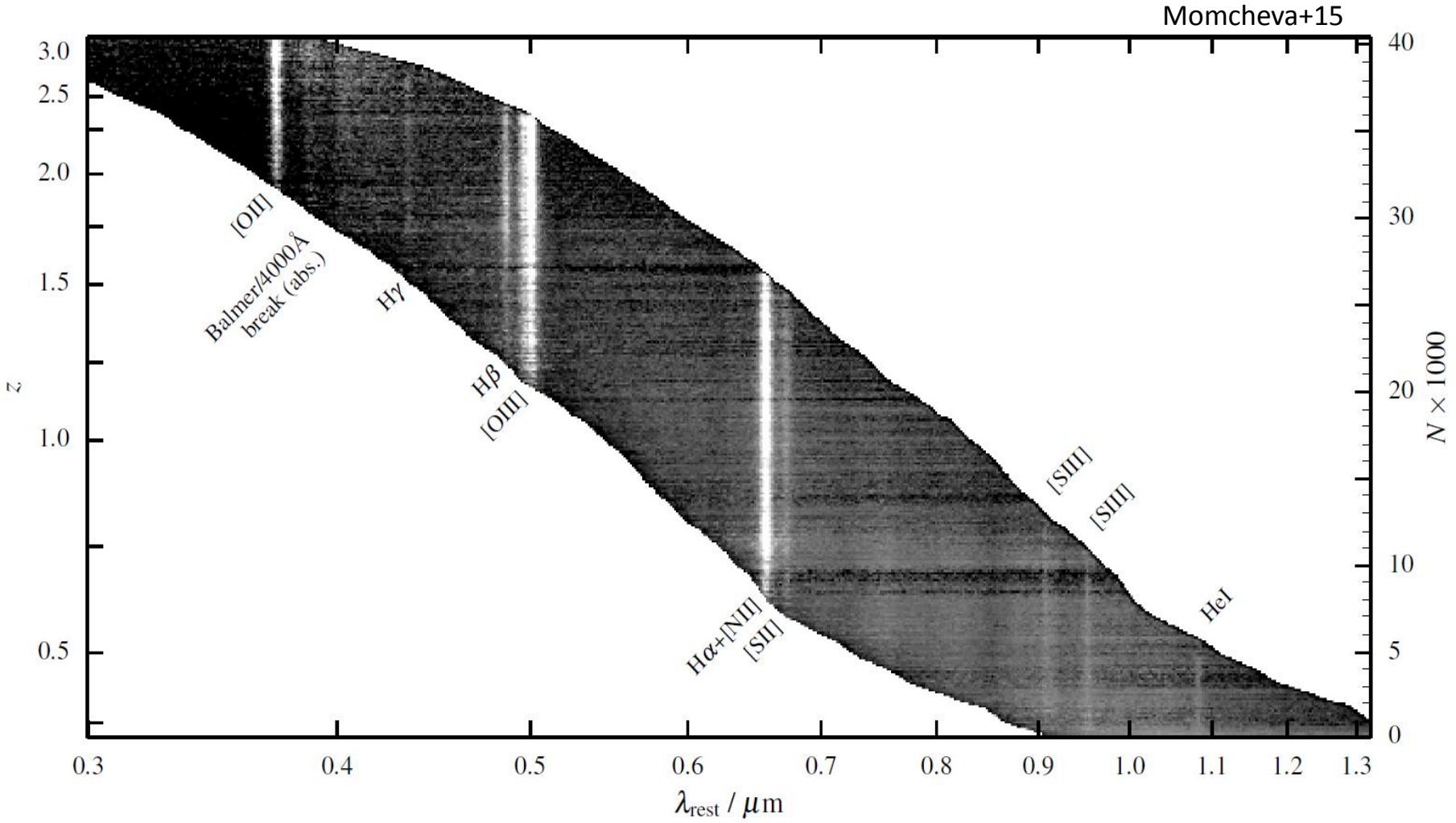


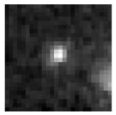
Interpretation

Bayesian Line Detections

Probabilistic treatment of line identifications

$$p(A > 0|\{S\}, \Delta x) = \int_{>0}^{1} p_{posterior}(A|\{S\}, \Delta x) dA.$$

Maseda+16



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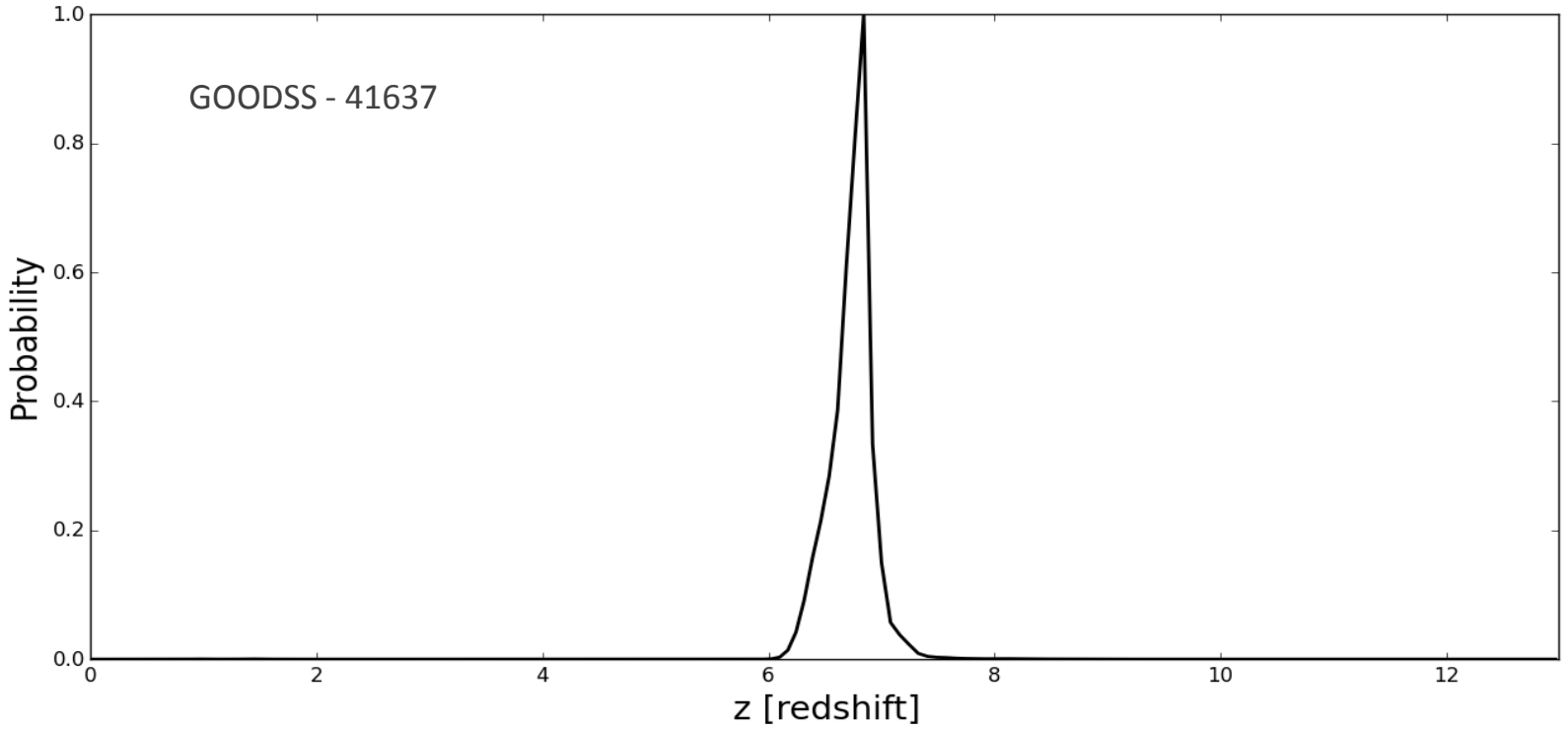

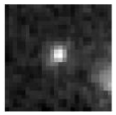

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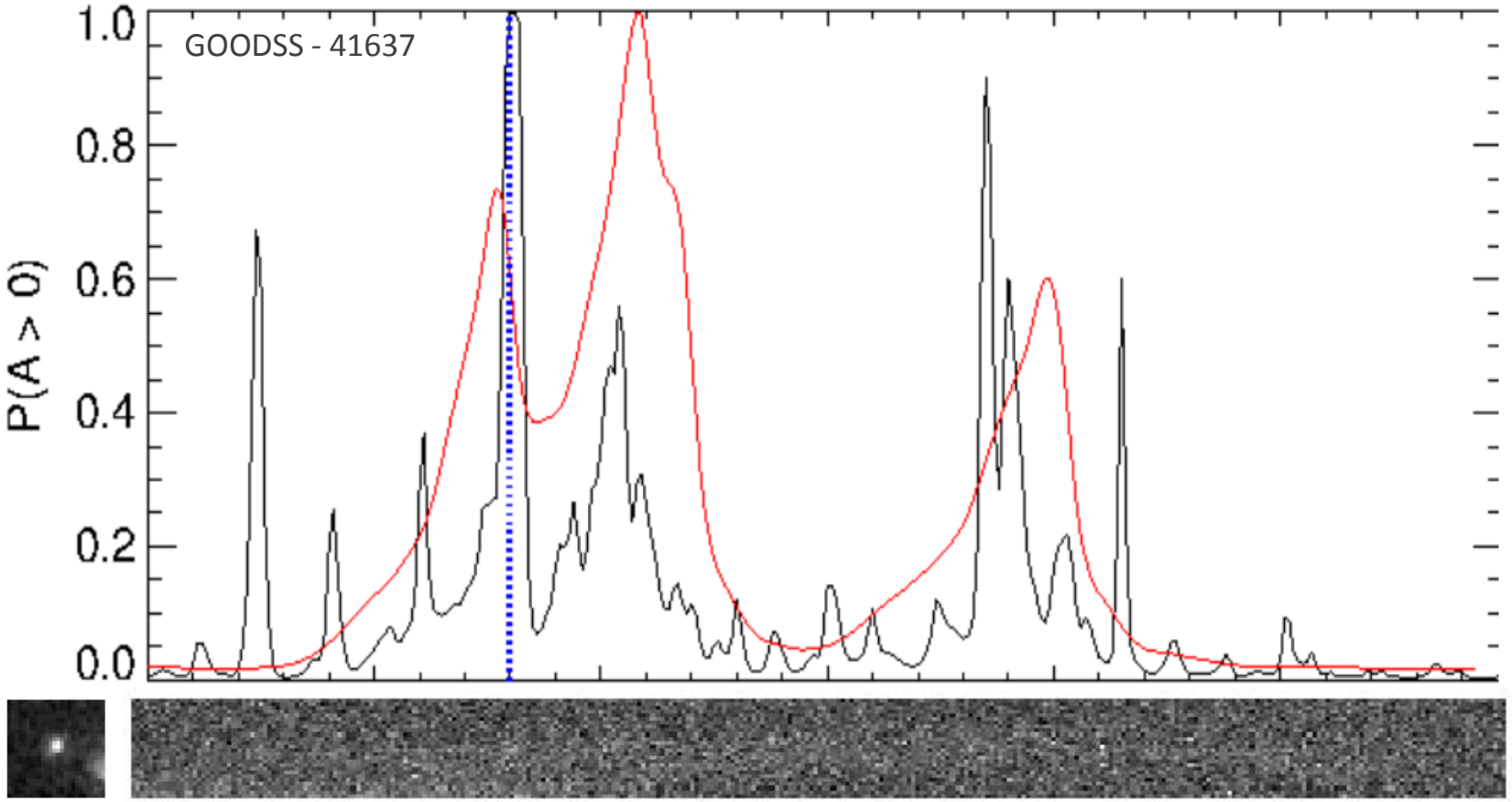

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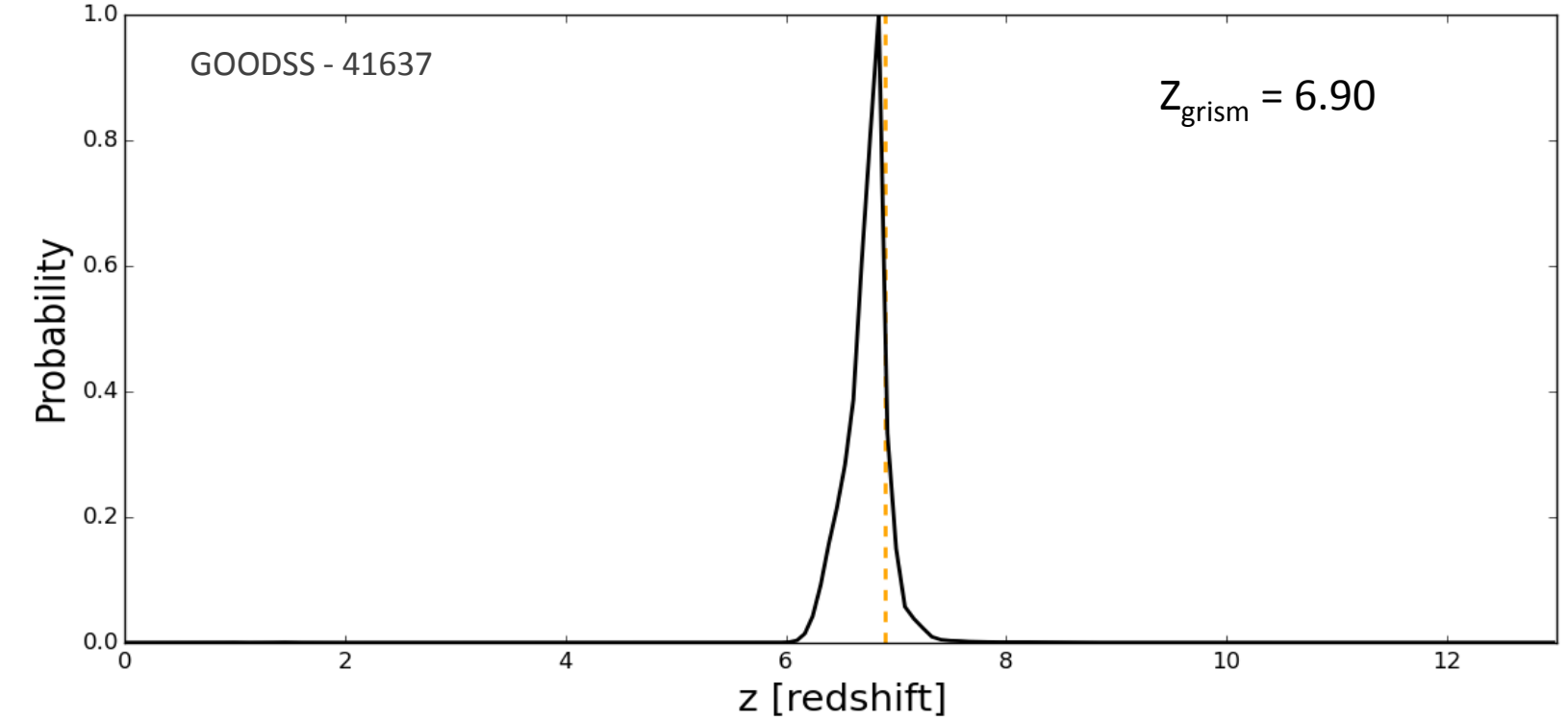

Quality Control

Inspecting the Candidates

Require as much information as possible

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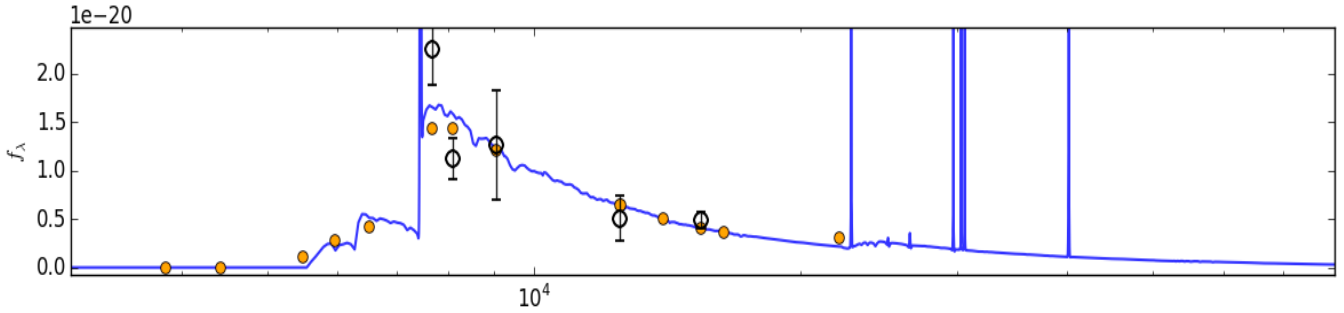

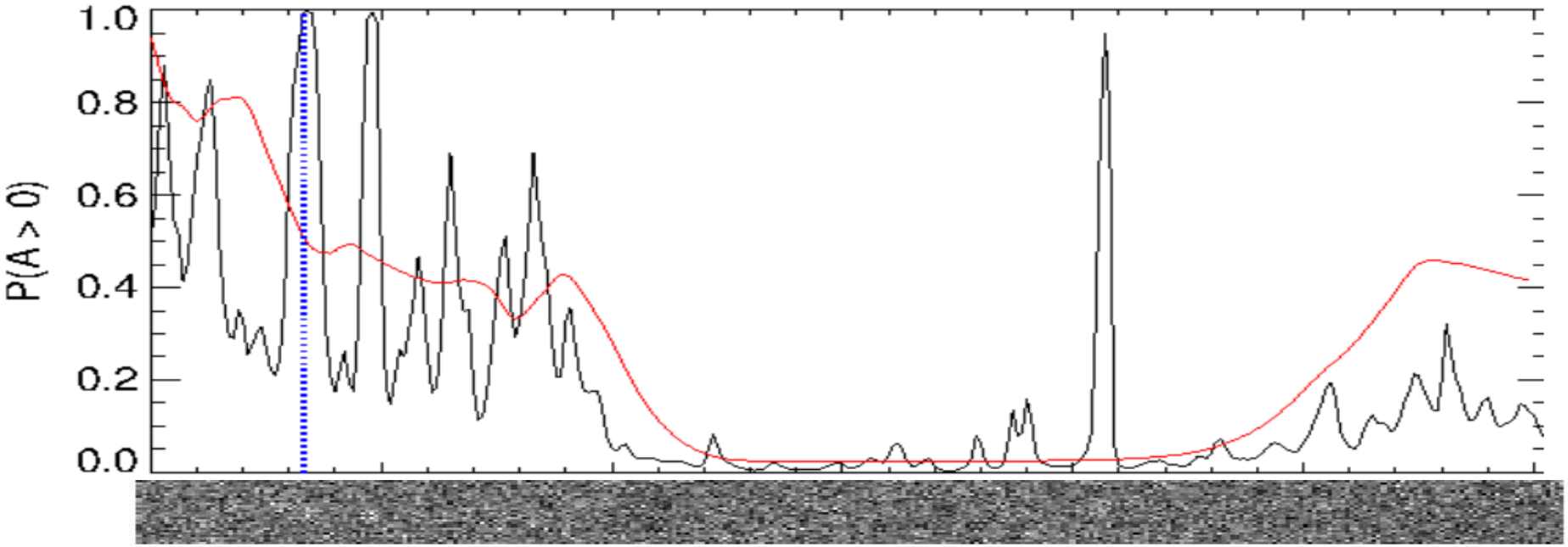

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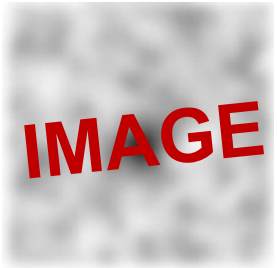

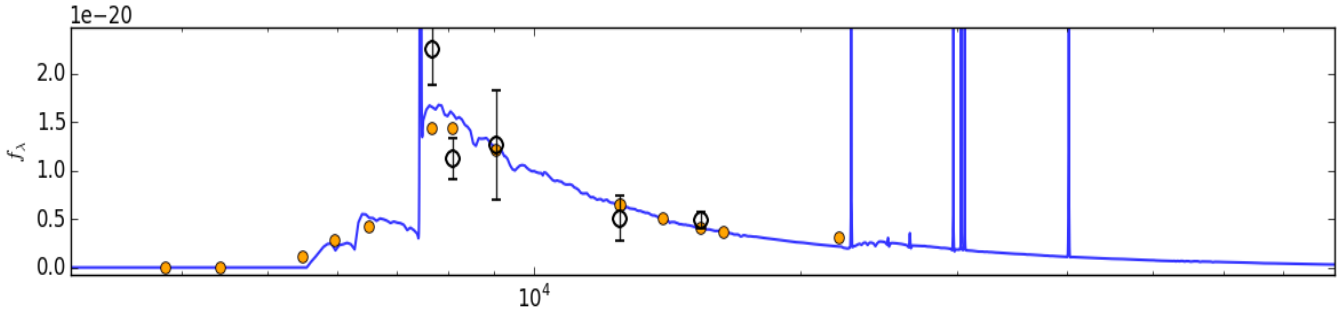

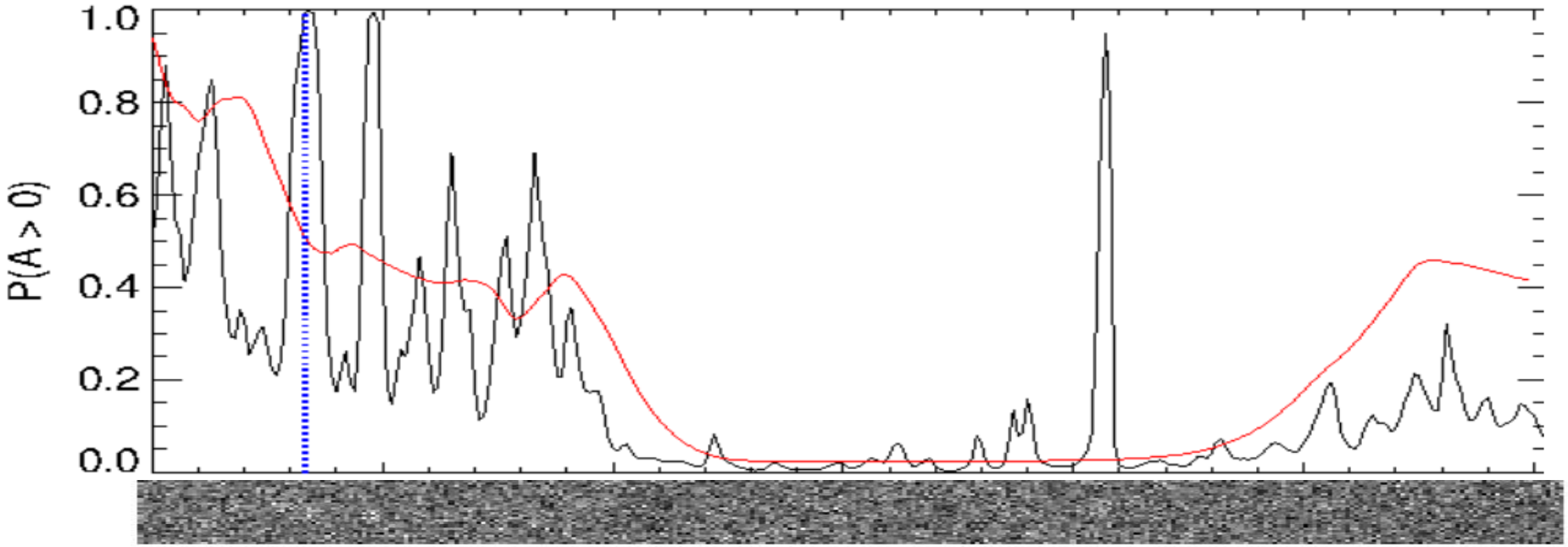

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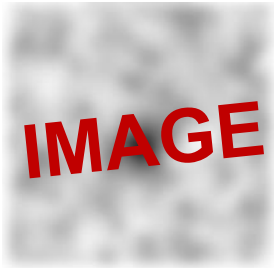

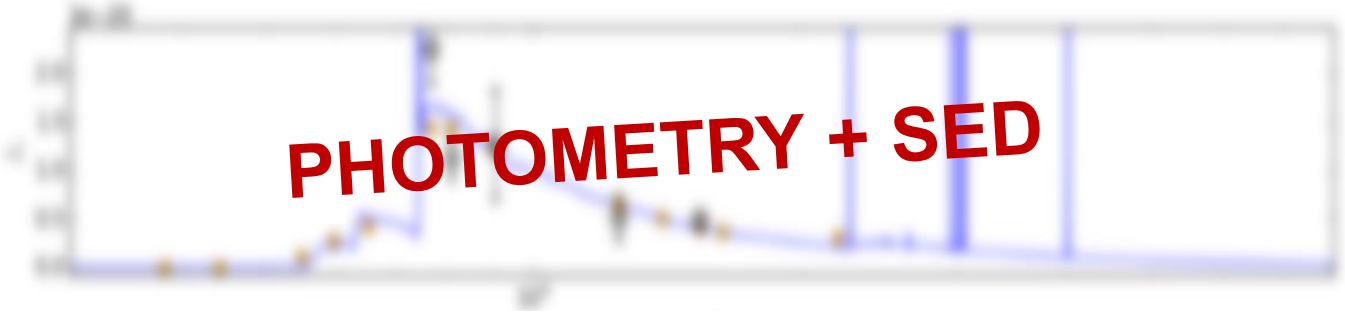

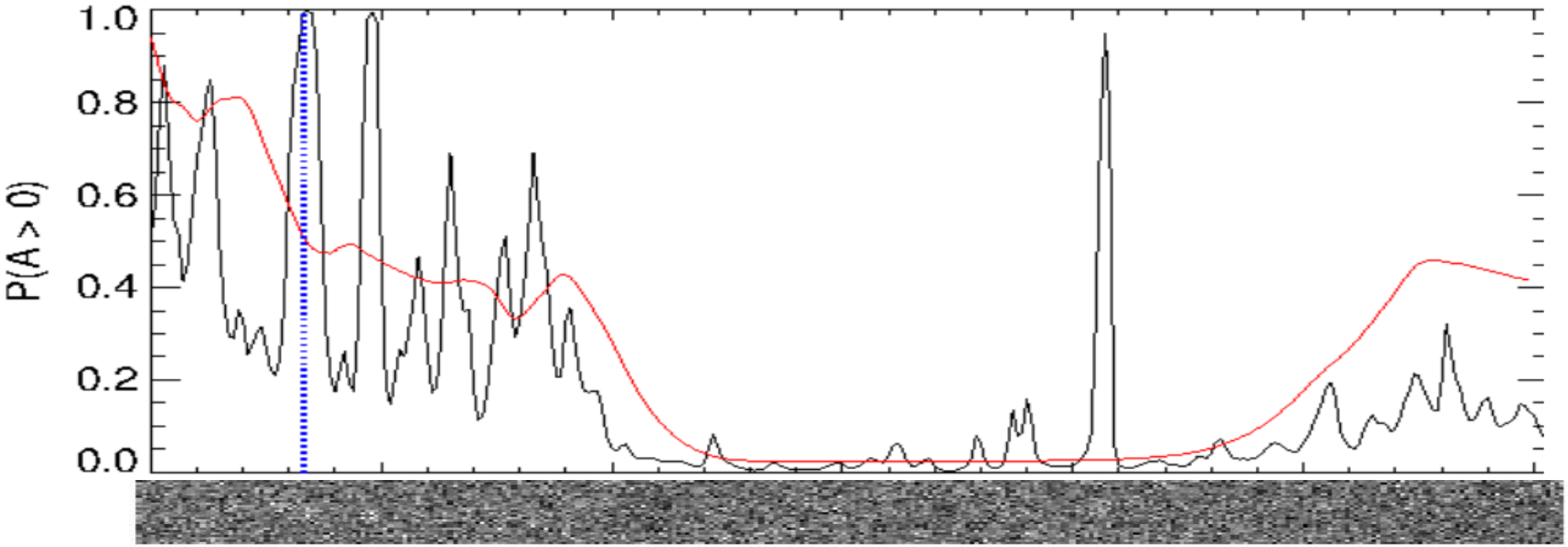

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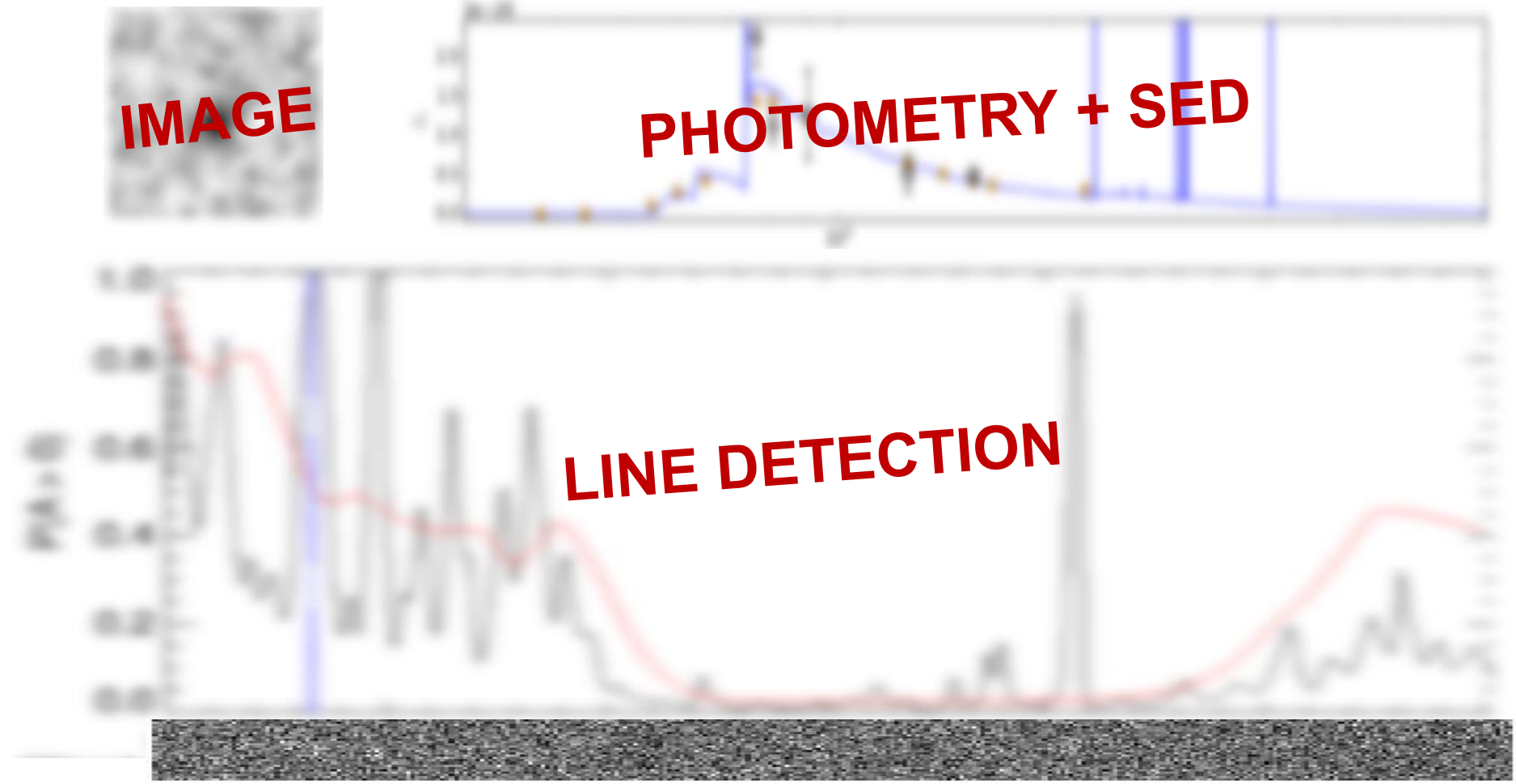

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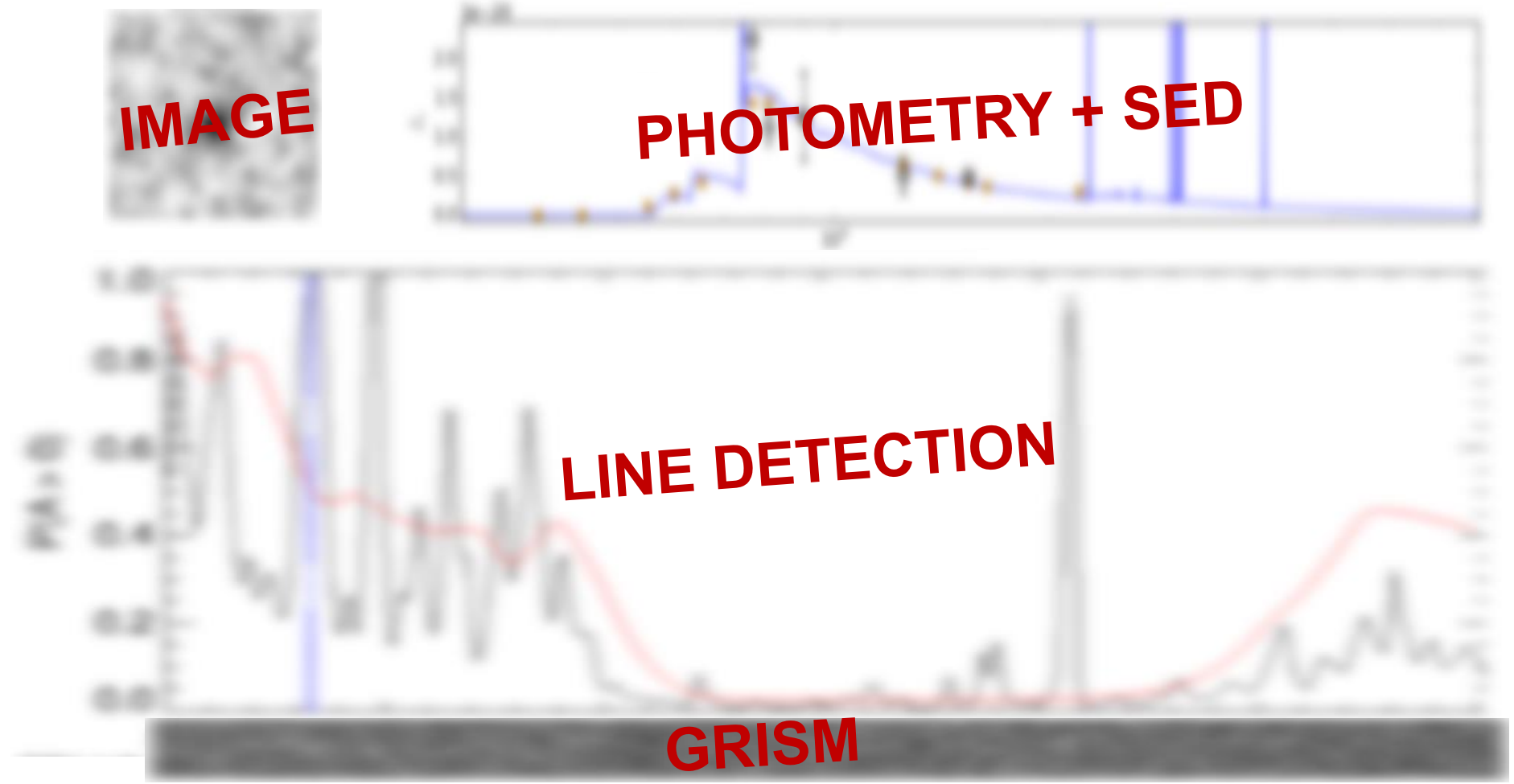
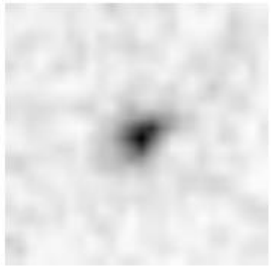
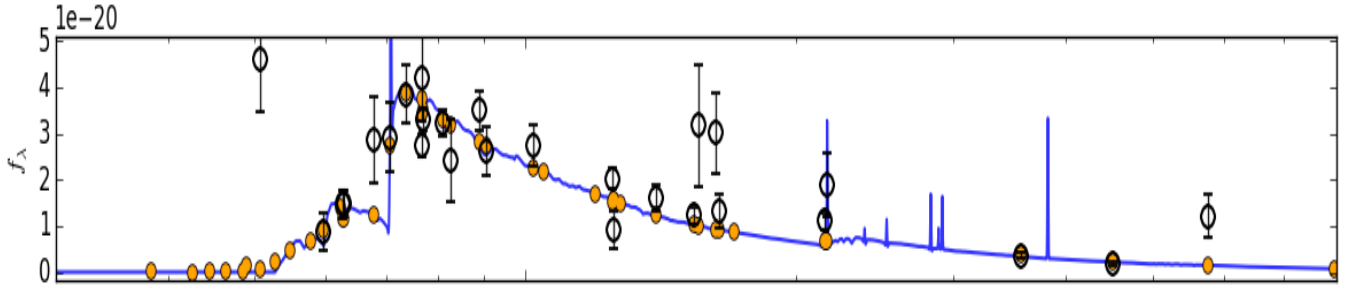
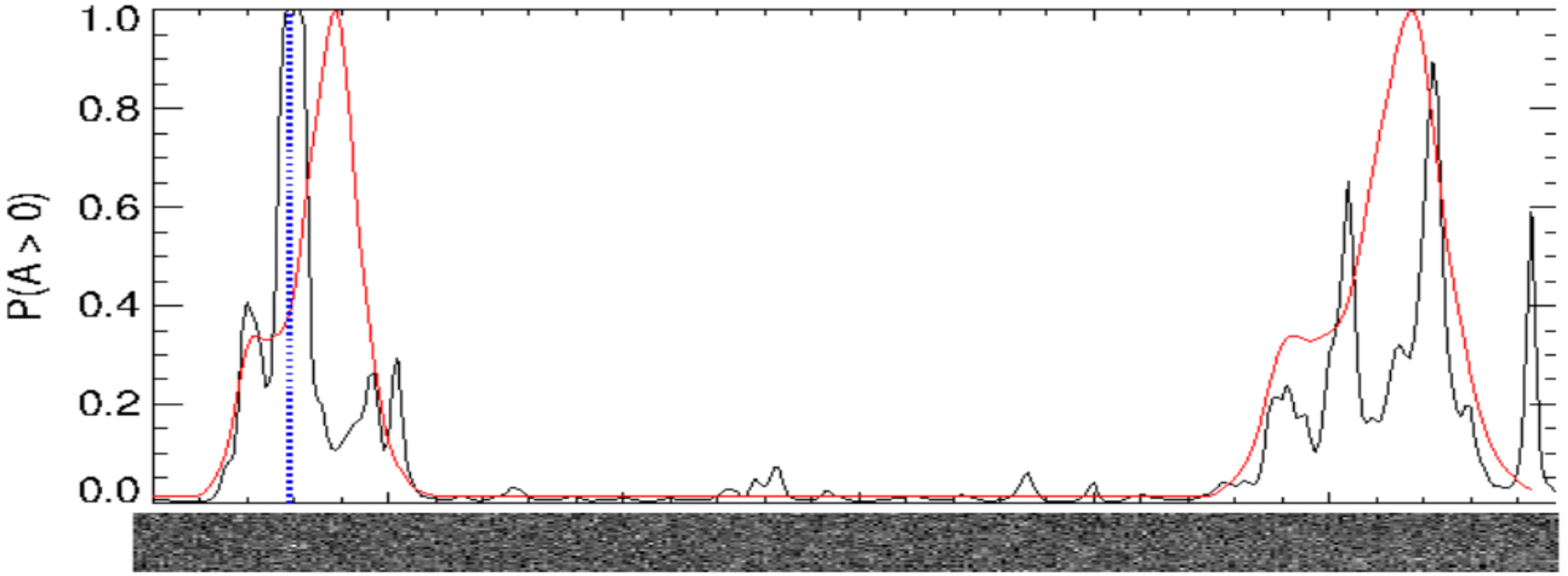


Quality Control
COSMOS - 13141







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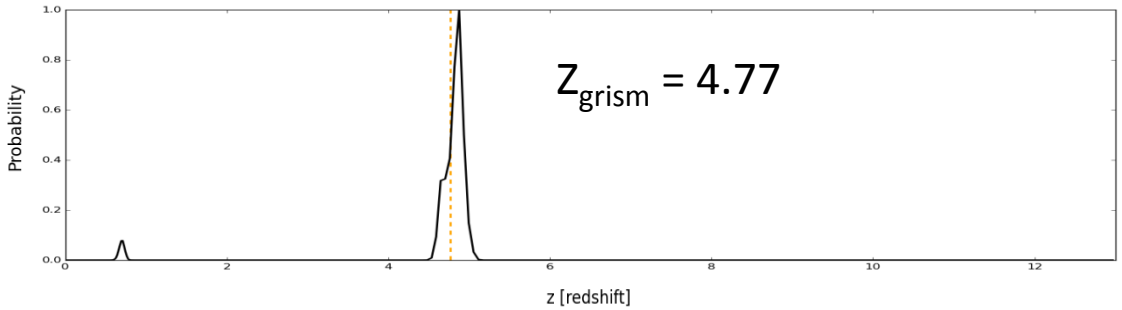
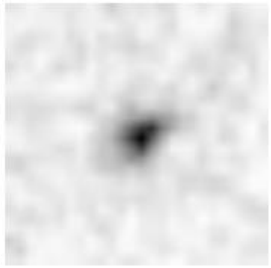
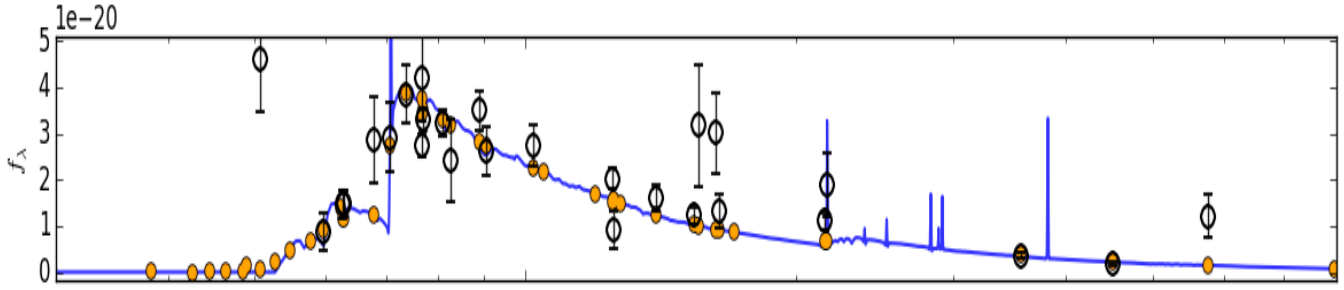
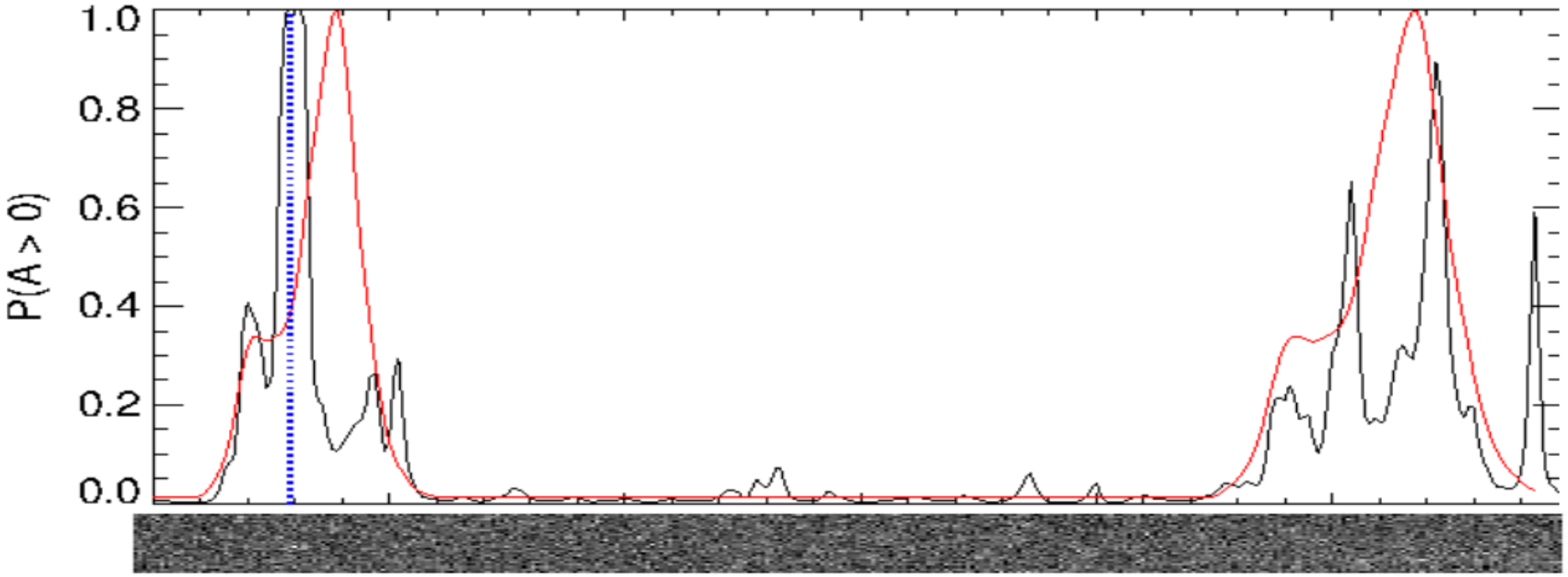
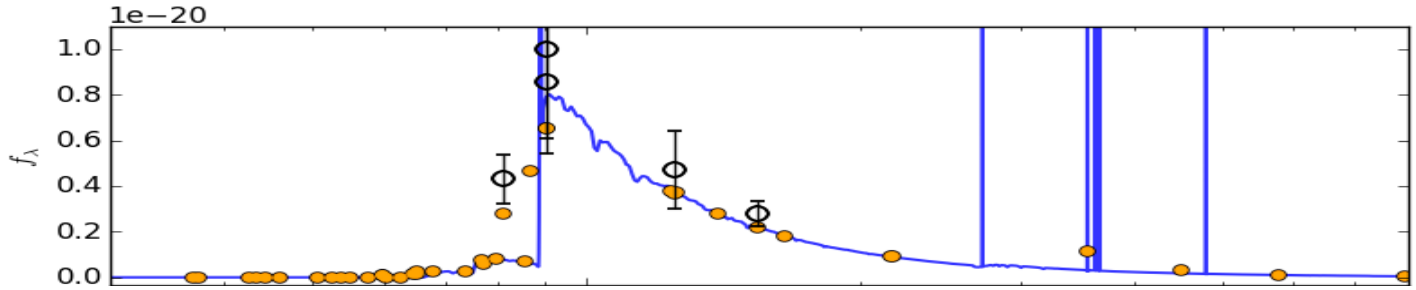


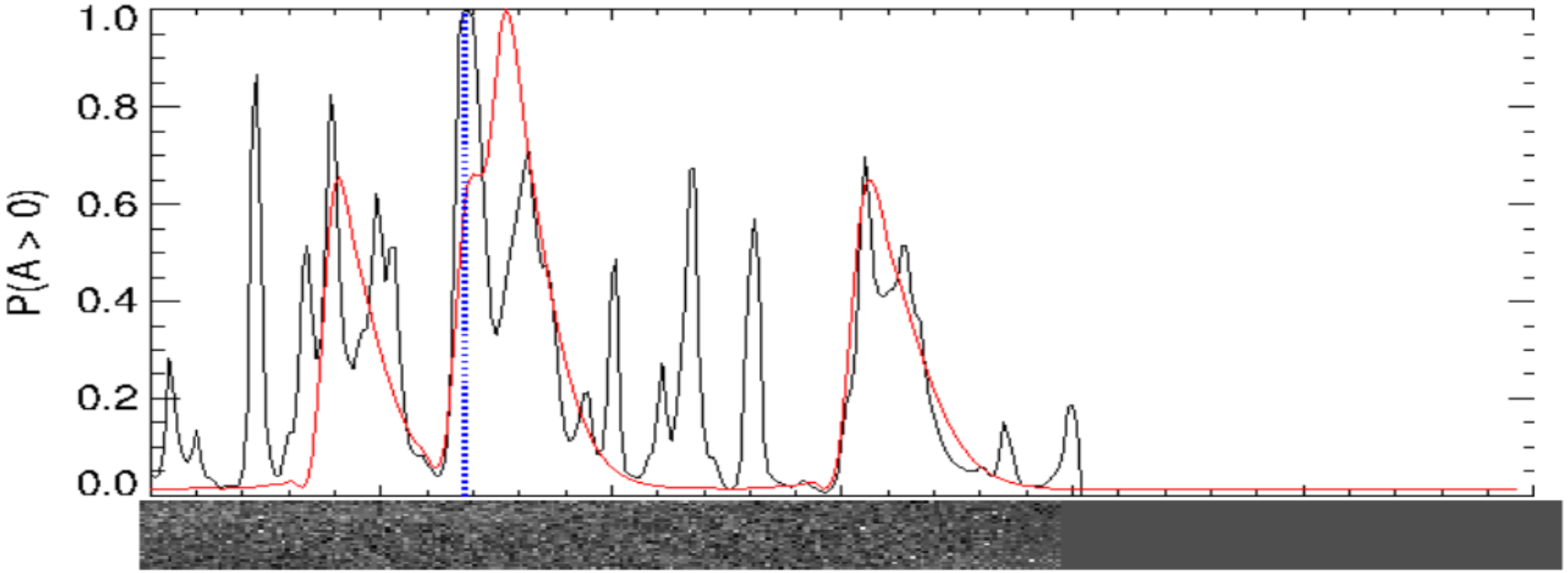






Quality Control
GOODSS - 26864





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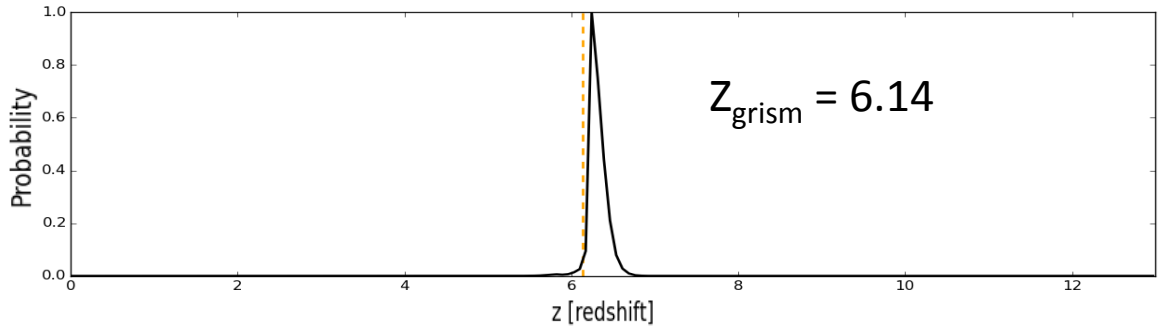
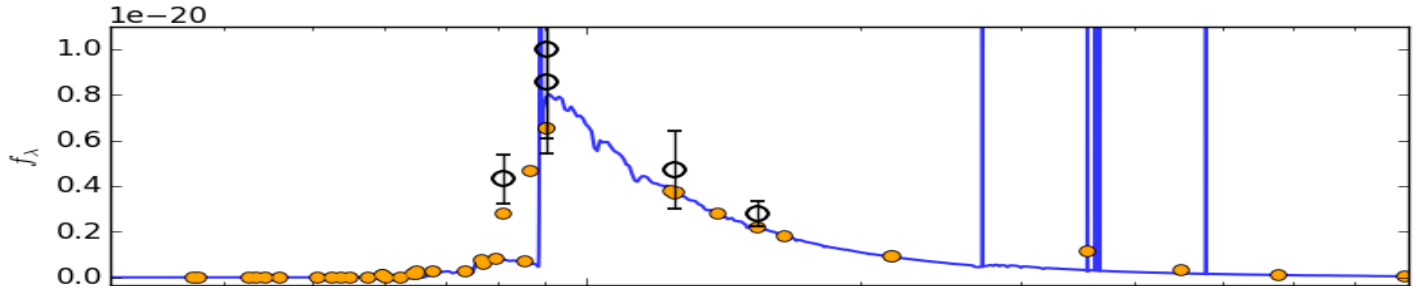
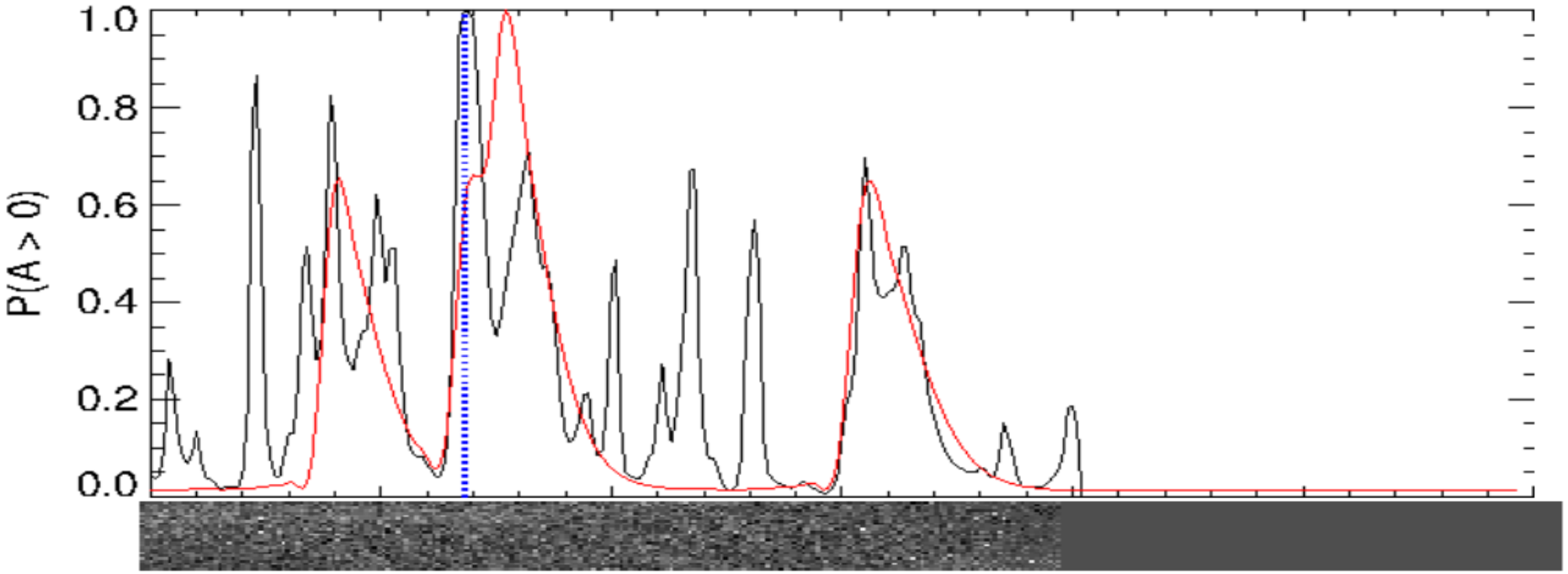
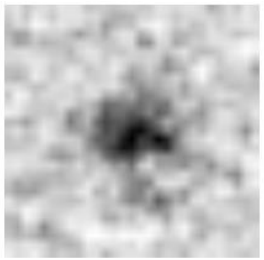
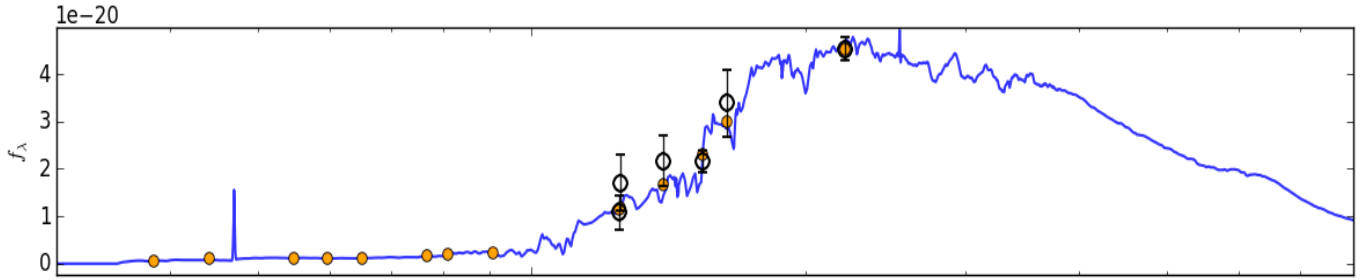


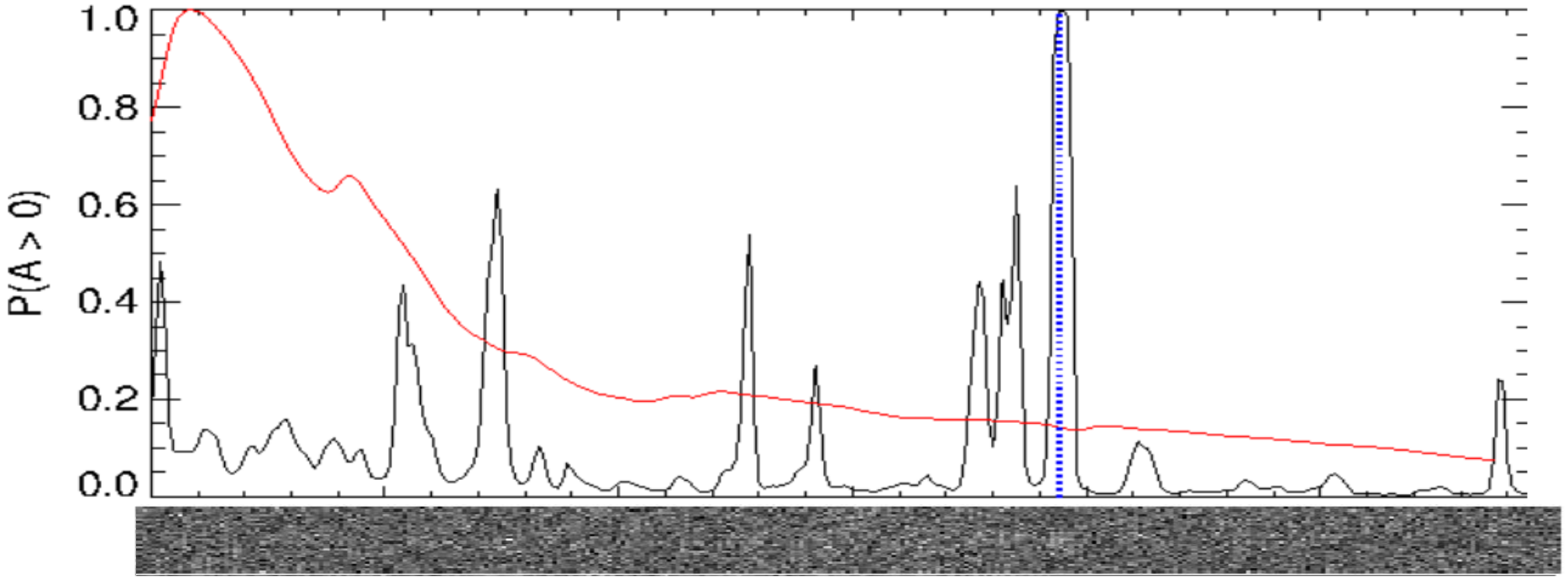




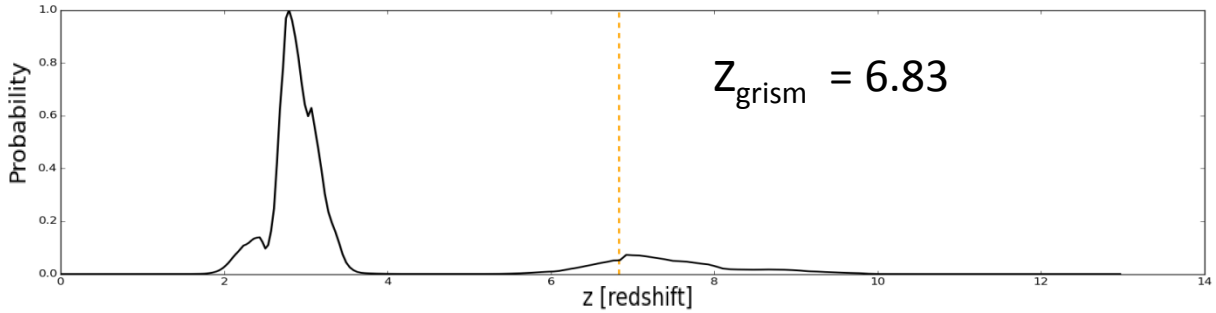
Quality Control
UDS - 18763

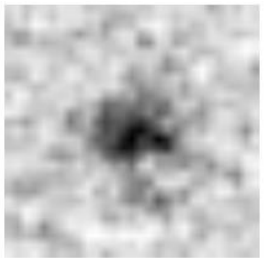


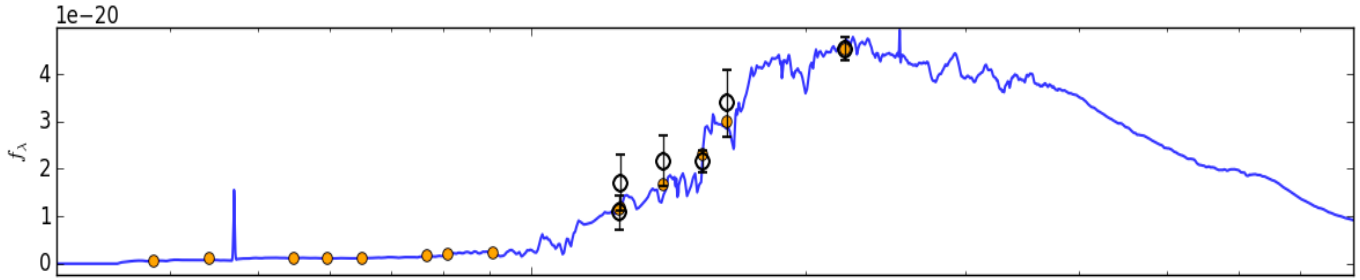


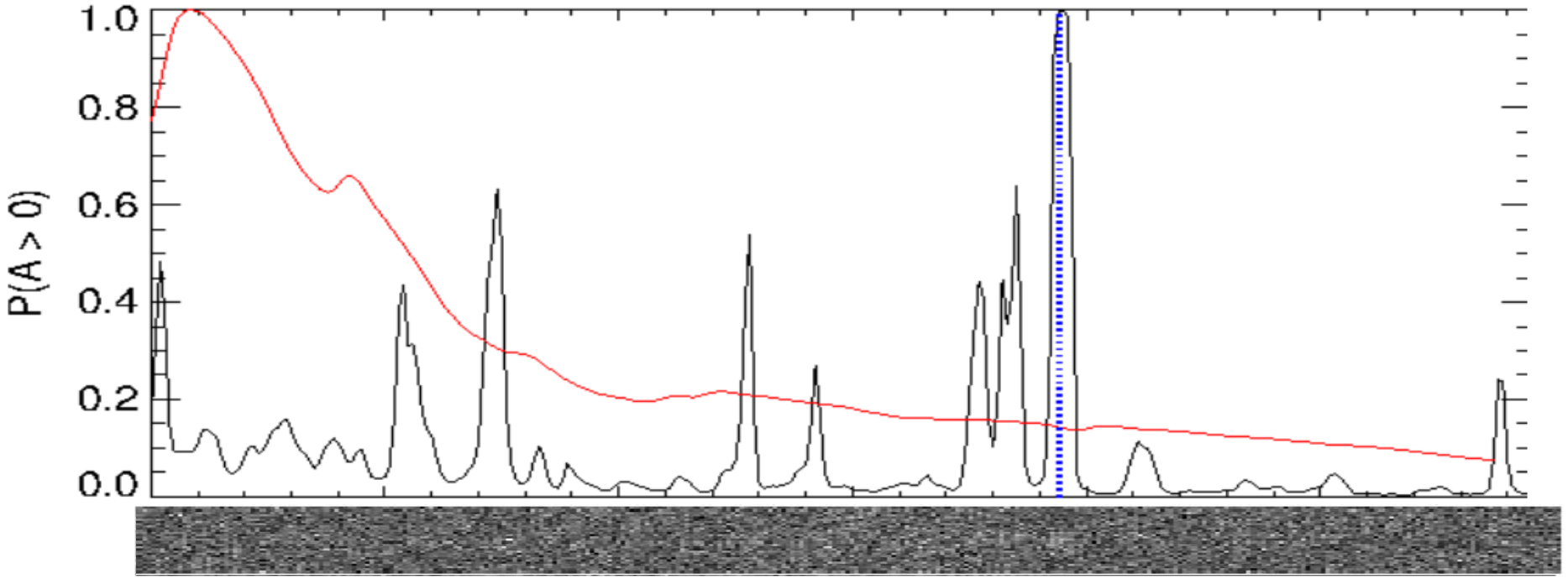


Quality Control
UDS - 18763









Results

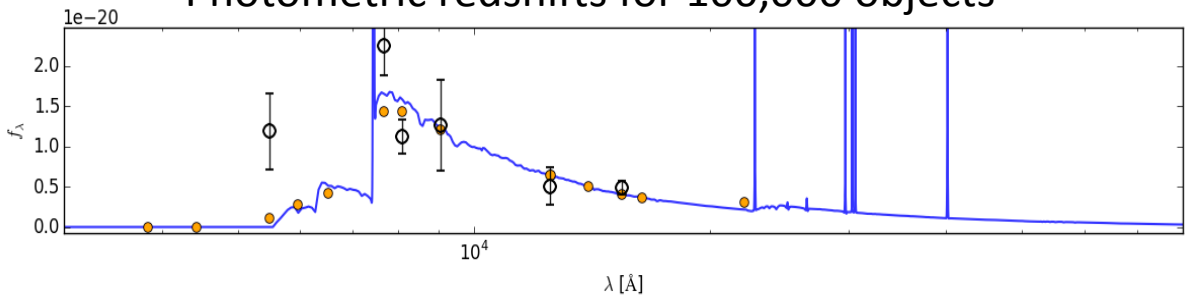
Preliminary Object Catalogue

ID	Field	RA	Dec	z_{phot}	z_{line}
10381	AEGIS	215.08174133	52.95420837	6.92	6.93
13718	AEGIS	214.91113281	52.84708023	6.17	6.15
17931	AEGIS	214.7802124	52.77084351	1.79	8.17
20187	AEGIS	214.94522095	52.89733887	1.55	7.3
31282	AEGIS	214.68658447	52.75674438	2.4	7.05
34307	AEGIS	214.74450684	52.80994034	1.76	6.97
5956	COSMOS	150.08717346	2.23826909	0.91	5.29
7696	COSMOS	150.12722778	2.25735831	6.46	6.24
9338	COSMOS	150.0864563	2.27407551	4.59	4.51
10912	COSMOS	150.11653137	2.29063773	5.43	5.54
13141	COSMOS	150.10752869	2.31298637	4.88	4.77
13254	COSMOS	150.17713928	2.3141129	4.65	4.62
25077	COSMOS	150.11746216	2.43756771	5.62	5.75
4742	GOODSS	53.128404	-27.890518	6.24	6.53

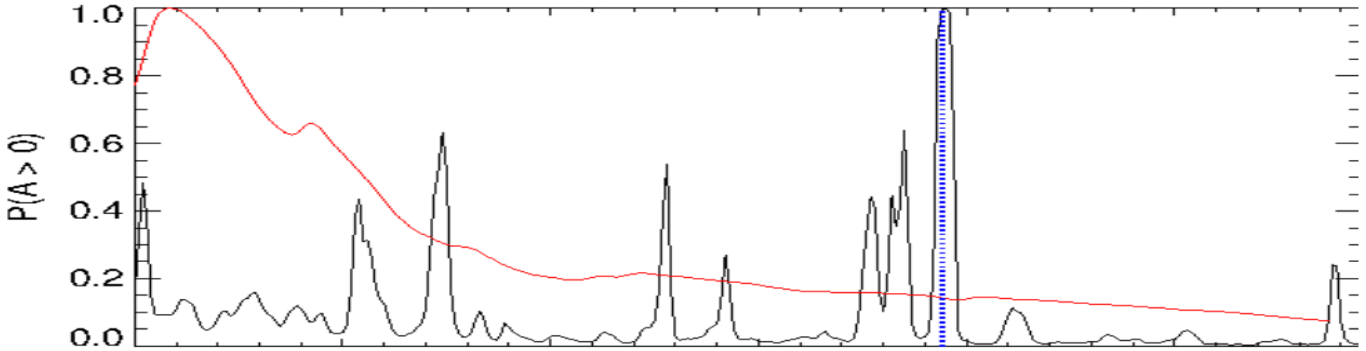
Summary

High Redshift Galaxies in 3D-HST

Photometric redshifts for 100,000 objects



Bayesian line detections in grism spectra



Carefully review each object

ID	Field	RA	Dec	z_{phot}	z_{line}
10381	AEGIS	215.08174133	52.95420837	6.92	6.93
13718	AEGIS	214.91113281	52.84708023	6.17	6.15

Supplementary
Bayesian Methods

Want more? See Maseda+16

Prepare spectrum **S** by subtracting continuum and contamination

Use science image **I** as model for spatial extent of emission line **A** at $\Delta\mathbf{x}$

$$\ln \mathscr{L}(\{S\}|A,\Delta x) = \\ -\frac{1}{2}\sum_{x=0}^{x_{max}}\sum_{y=0}^{y_{max}} \frac{(S_m(x,y|A) - S(x+\Delta x, y))^2}{\sigma_S^2(x+\Delta x, y)},$$

Posterior distribution function dictated by Bayes' Theorem, given **prior**

$$p_{posterior}(A|\{S\},\Delta x) \propto \mathscr{L}(\{S\}|A,\Delta x) \times p_{prior}(A|\Delta x).$$

Calculate the probability of A>0 at any given position

$$p(A>0|\{S\},\Delta x) = \int_{>0}^{1} p_{posterior}(A|\{S\},\Delta x)dA.$$

Supplementary

Photometric Priors

Want more? See Maseda+16

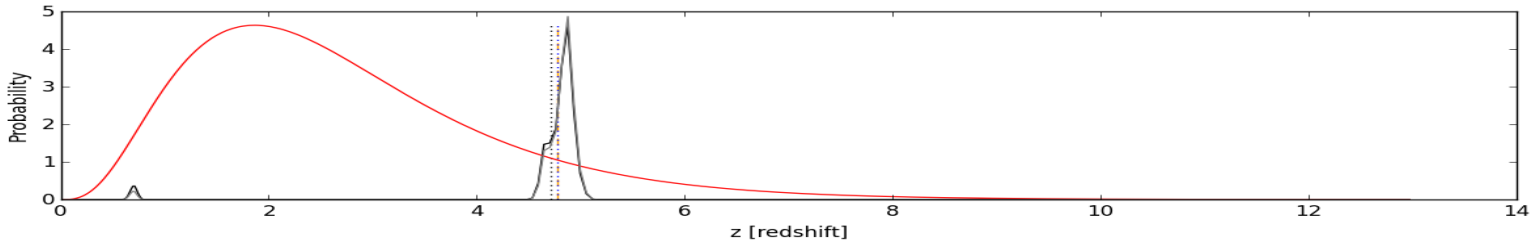
Independent information can be incorporated in a prior distribution

Choose F160W band for photometric prior + unbiased flat prior

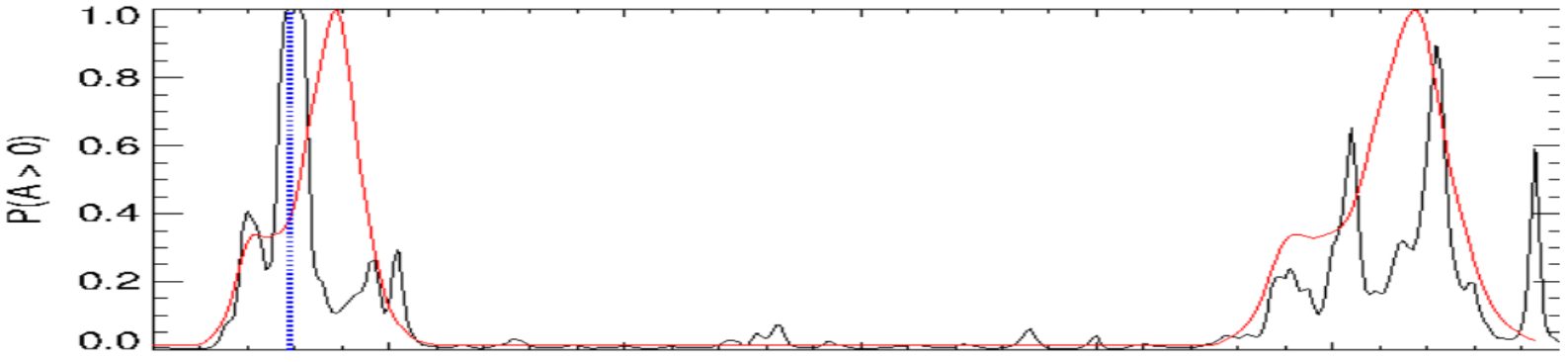
Incorporate prior information from both $\mathbf{A}$ and $\mathbf{\Delta x}$

$$p_{prior}(A|\Delta x) = (1 - p_{prior}(\Delta x)) \times \delta(A = 0) + p_{prior}(\Delta x) \times p_{prior}(A),$$

Folds into SED fitting directly, thus effects $\mathbf{P(z)}$



Convolve P(z) with rest frame wavelengths of expected emission lines



Supplementary

3D-HST Survey Details

Want more? See Momcheva+16

Treasury program with 248 orbits during Cycles 18/19

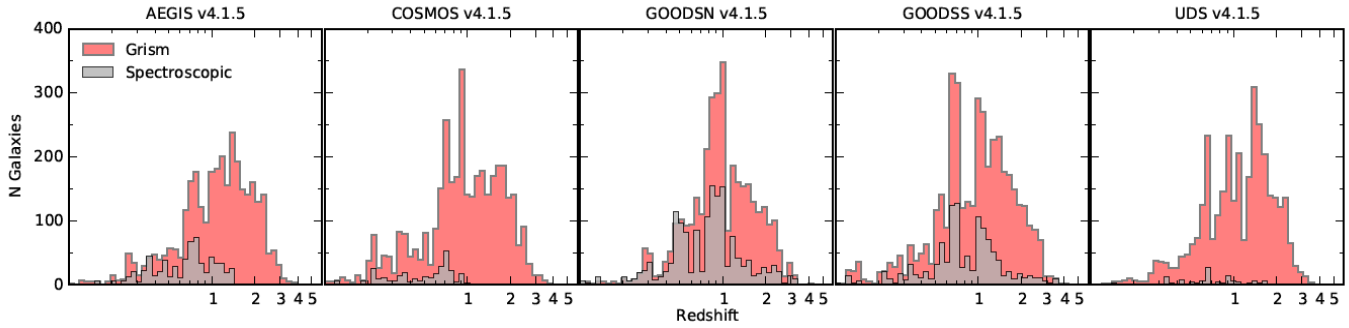
Spectroscopy with WFC3/G141 slitless grism

Acquisition frames taken in WFC3/140W and ACS/F814W filters

Field	RA (h m s)	Dec (d m s)	G141 Area (arcmin^2)	G800L Area (arcmin^2)
AEGIS	14:18:36.00	+52:39:00.0	121.9	102.5
COSMOS	10:00:31.00	+02:24:00.0	122.2	112.7
GOODS-N	12:35:54.98	+62:11:51.3	116.0	84.1
GOODS-S	03:32:30.00	-27:47:19.0	147.3	134.6
UDS	02:17:49.00	-05:12:02.0	118.7	107.4
Total			626.1	541.3

GOODS-N appended in post from B. Weiner

Photometric companion dataset described in Skelton+14



Supplementary
Emission Lines

Want more? See Momcheva+16

Line search technique is tuned to high redshift emission lines

Line Name	Rest Wavelength [A]
CIII	1909.0
OIII	1665.9
HeII	1640.4
Lyα	1216.0
CIV	1549.5
MgII	2800.0

Supplementary

Direct Image and Grism Coverage

Want more? See Brammer+12

Direct Image chosen in F140W to match G141 spectral coverage