DETECTING EMISSION LINES USING SLITLESS SPECTROSCOPIC OBSERVATIONS

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CLASH OF THE REDSHIFTS: ARE WE REALLY SEEING THE FIRST GALAXIES?*

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(*): We don't prove, we test and disprove..

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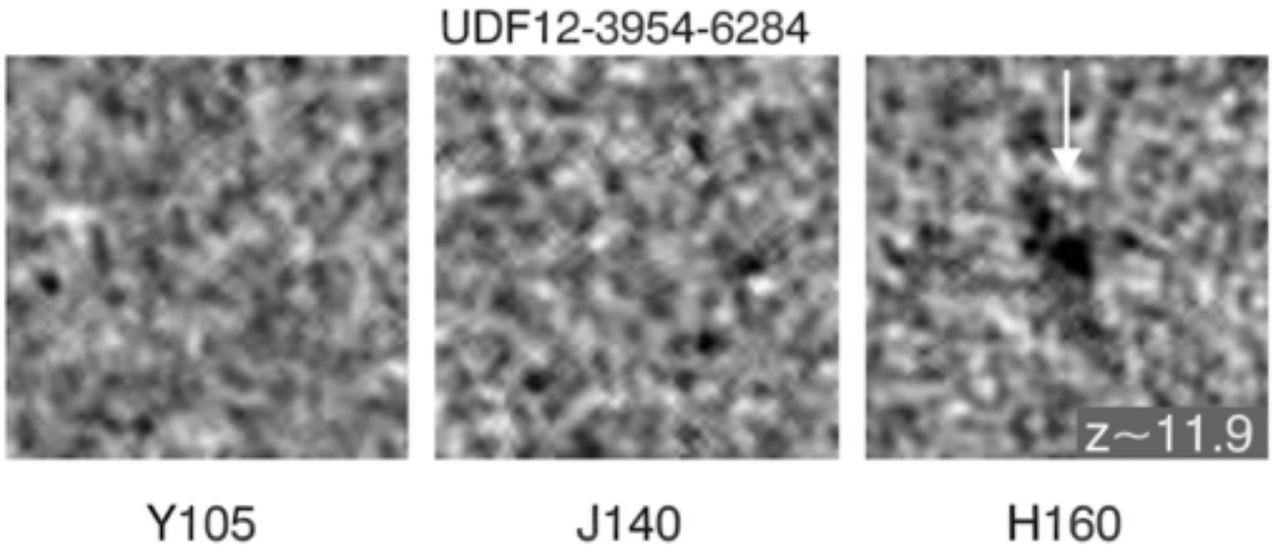
THE EARLY DAYS OF Z>10 CANDIDATES

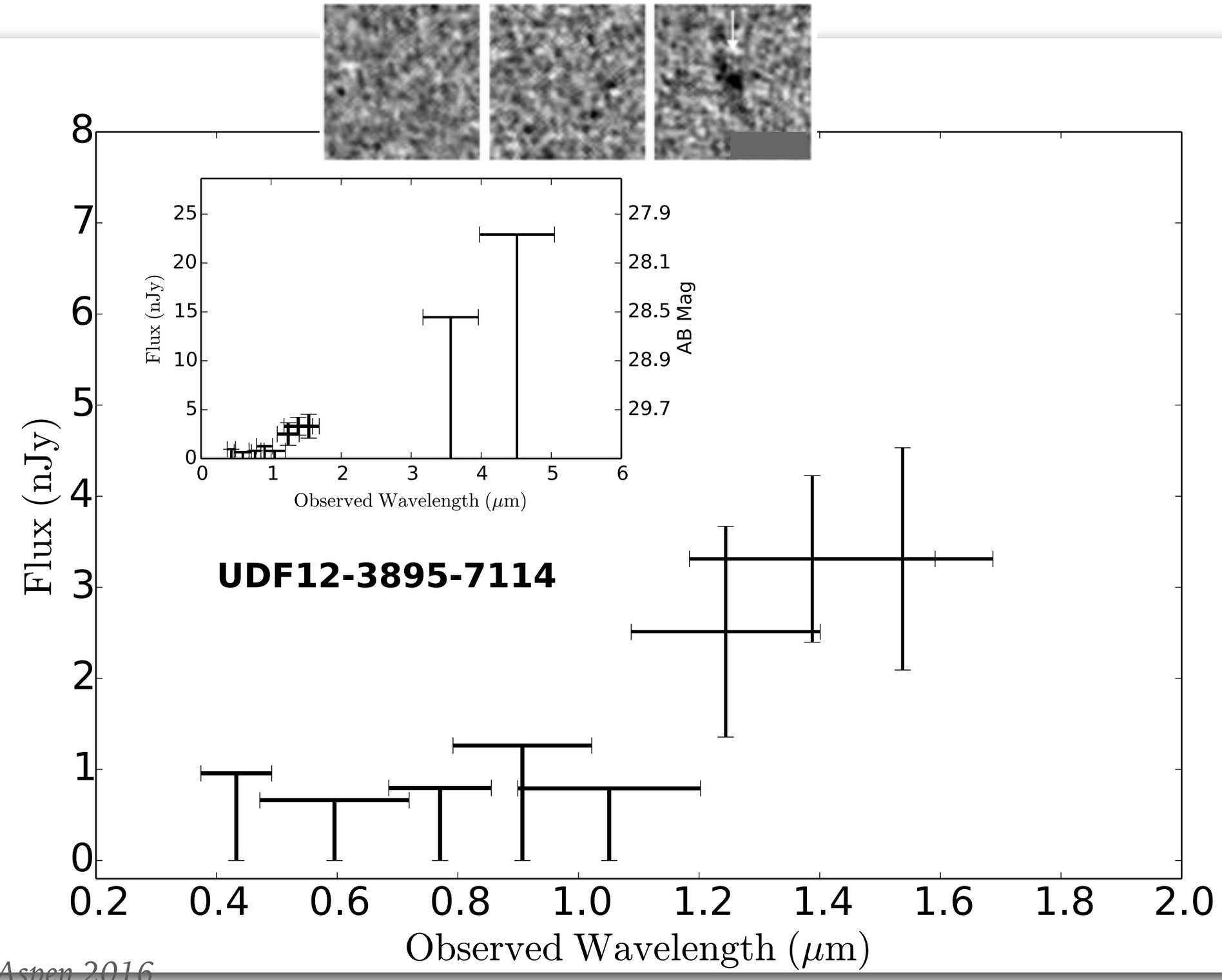
TABLE 1
$z > 8.5$ Candidates

ID	RA	Dec	$z_{SED}(\pm 1\sigma)$	Y_{105W}	J_{125W}	J_{140W}	H_{160W}	Notes
UDF12 Survey Depth 5-σ AB (aperture diameter arcsec - 70% enclosed point source flux)				30.0 (0.40)	29.5 (0.44)	29.5 (0.47)	29.5 (0.50)	
UDF12 Galaxies[a]								
UDF12-3954-6284	3:32:39.54	-27:46:28.4	$11.9^{+0.3}_{-0.5}$	> 31.2	> 30.7	> 30.5	29.3 ± 0.2	UDFj-39546284 B11[b]
UDF12-4106-7304	3:32:41.06	-27:47:30.4	$9.5^{+0.4}_{-0.8}$	> 30.8	> 30.0	29.8 ± 0.3	29.7 ± 0.3	
UDF12-4265-7049	3:32:42.65	-27:47:04.9	$9.5^{+0.4}_{-0.7}$	> 31.2	30.4 ± 0.6	29.9 ± 0.4	29.7 ± 0.4	
UDF12-3921-6322	3:32:39.21	-27:46:32.2	$8.8^{+0.4}_{-0.2}$	> 31.2	29.9 ± 0.3	29.6 ± 0.3	29.9 ± 0.3	
UDF12-4344-6547	3:32:43.44	-27:46:54.7	$8.8^{+0.5}_{-0.5}$	> 31.2	30.0 ± 0.3	30.1 ± 0.4	30.1 ± 0.3	
UDF12-3895-7114	3:32:38.95	-27:47:11.4	$8.6^{+0.8}_{-0.6}$	> 30.9	30.4 ± 0.5	30.1 ± 0.3	30.1 ± 0.4	
UDF12-3947-8076	3:32:39.47	-27:48:07.6	$8.6^{+0.2}_{-0.2}$	31.0 ± 0.5	29.5 ± 0.2	29.0 ± 0.1	29.0 ± 0.1	UDFy-39468075 B11[b]
Earlier Candidates[a]								
UDFj-39546284	3:32:39.54	-27:46:28.4	$11.9^{+0.3}_{-0.5}$	> 31.2	> 30.7	> 30.5	29.3 ± 0.2	B11[b] $z \simeq 10.3$
UDFj-38116243	3:32:38.11	-27:46:24.3	–	> 31.2	> 30.1	30.3 ± 0.5	30.0 ± 0.3	B UDF09[c] #1, B11[b] #2
UDFj-43696407	3:32:43.69	-27:46:40.7	$7.6^{+0.4}_{-0.6}$	31.0 ± 0.6	> 30.1	29.9 ± 0.3	29.5 ± 0.2	B UDF09[c] #2
UDFj-35427336	3:32:35.42	-27:47:33.6	$7.9^{+0.5}_{-0.8}$	> 30.8	30.3 ± 0.4	30.2 ± 0.4	29.6 ± 0.2	B UDF09[c] #3
UDFy-38135539	3:32:38.13	-27:45:53.9	$8.3^{+0.2}_{-0.1}$	30.1 ± 0.2	28.6 ± 0.1	28.5 ± 0.1	28.4 ± 0.1	B11[b] $8.5 < z < 9.5$
UDFy-37796000	3:32:37.79	-27:46:00.0	$8.1^{+0.1}_{-0.2}$	29.8 ± 0.1	28.6 ± 0.1	28.7 ± 0.1	28.7 ± 0.1	B11[b] $8.5 < z < 9.5$
UDFy-33436598	3:32:33.43	-27:46:59.8	$7.9^{+0.2}_{-0.3}$	30.3 ± 0.4	29.3 ± 0.2	29.4 ± 0.2	29.4 ± 0.1	B11[b] $8.5 < z < 9.5$



- UDF 2012 WFC3 IR Campaign
- 7 “promising” z>8.5 candidates
- Including one z∼12 candidate
- Photometric selection, using break technique

Ellis et al. 2012, etc…



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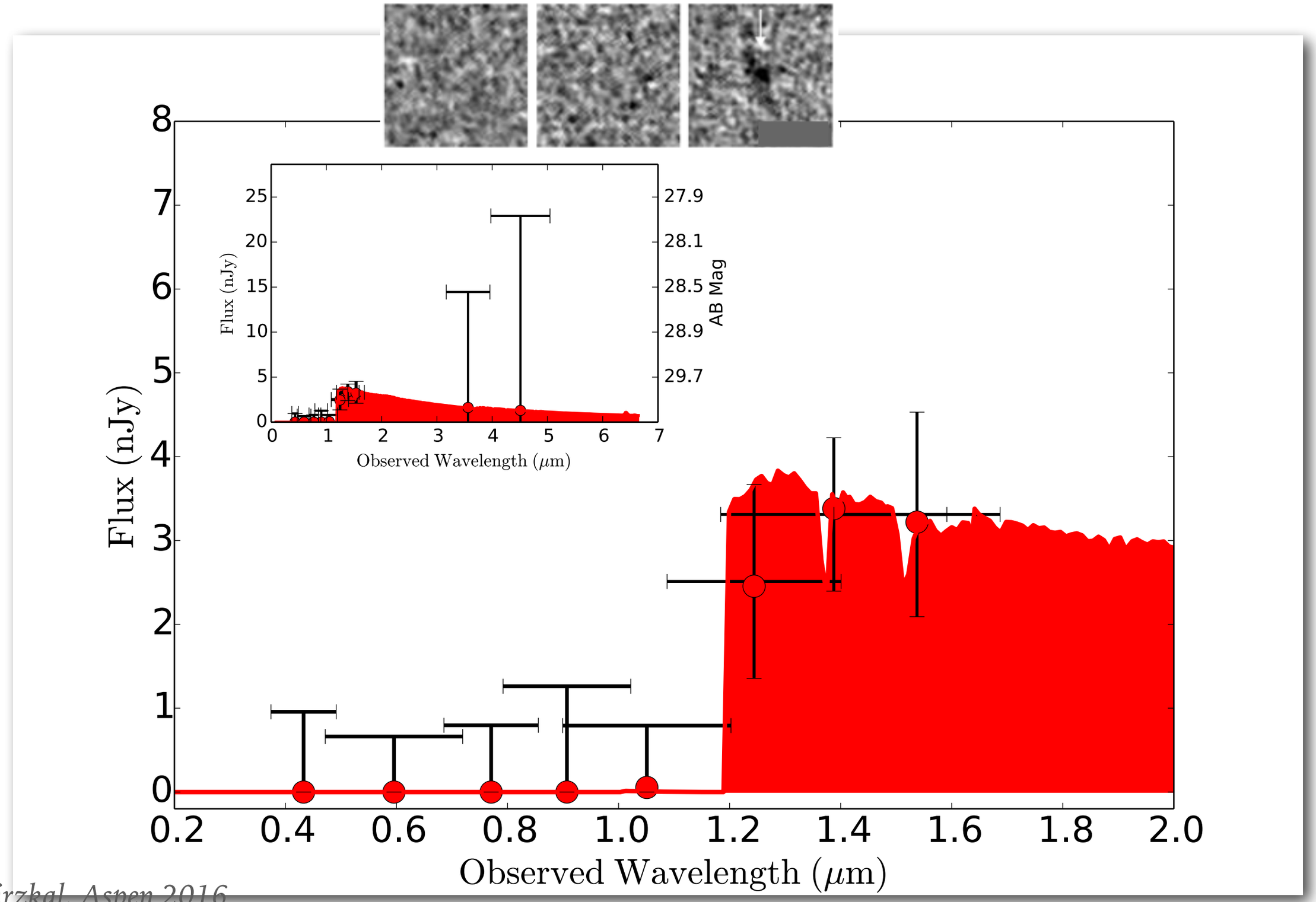
HIGH-Z / LBG ?



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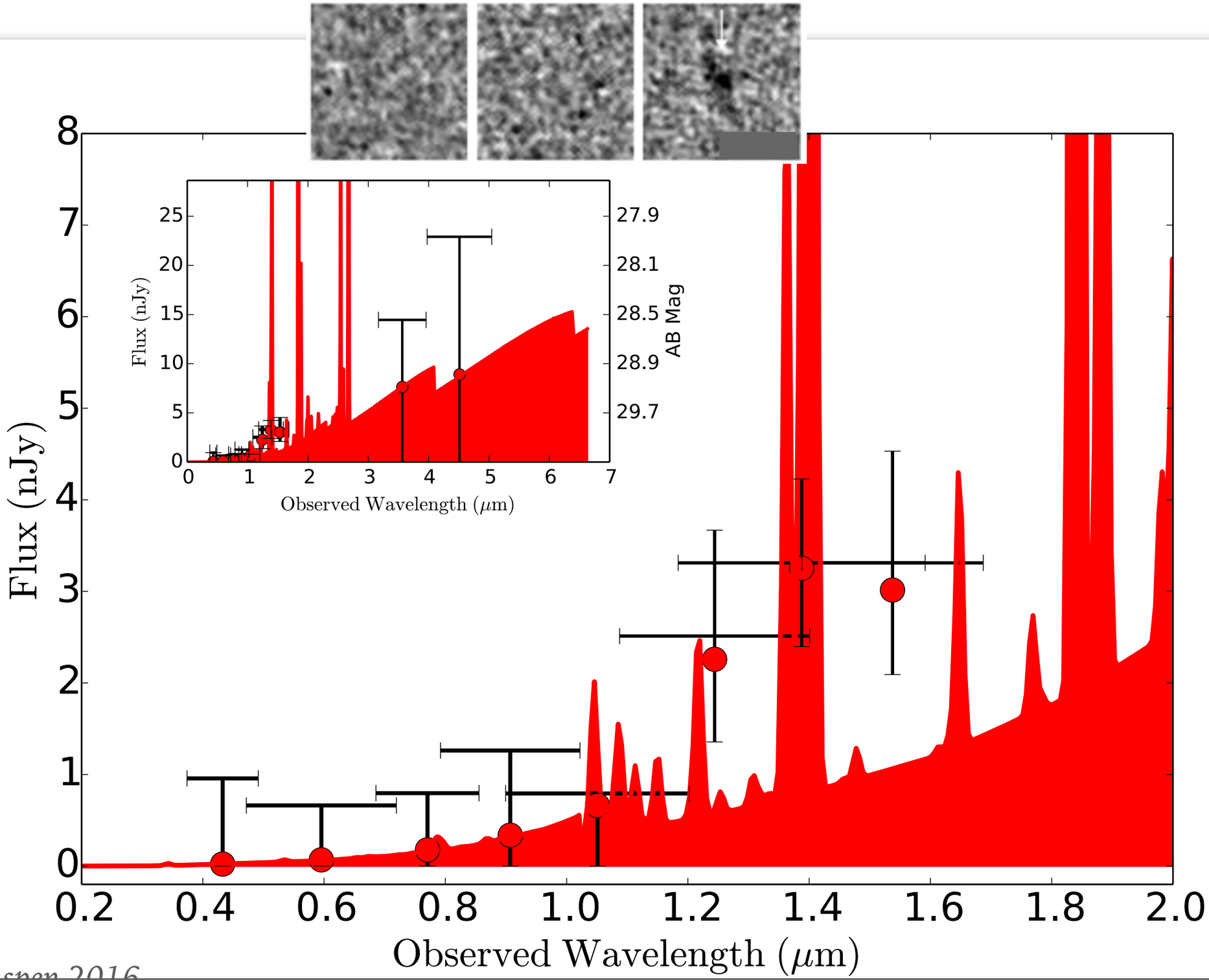
LOW Z WITH NEBULAR EMISSION?



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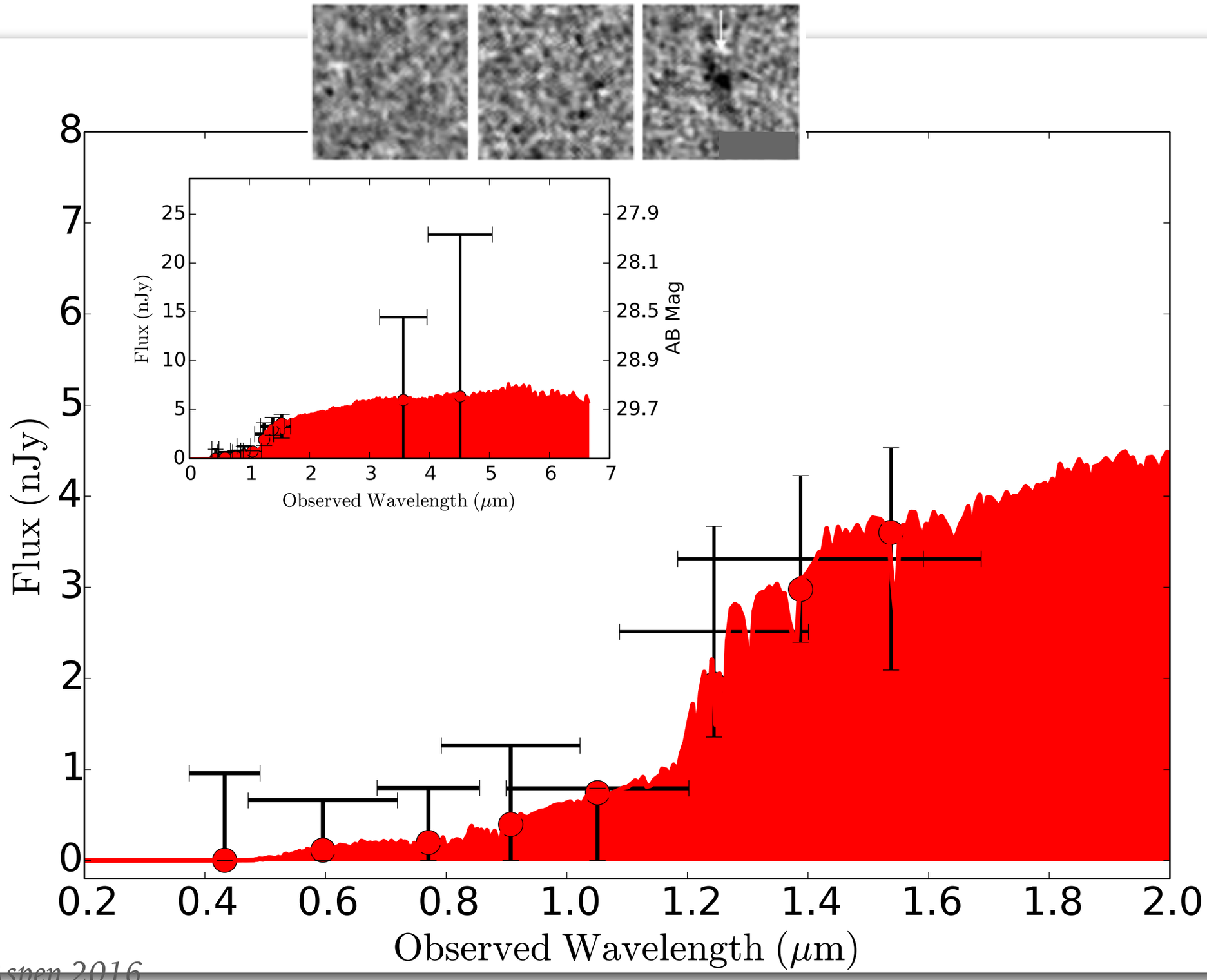
LOW Z OLD GALAXY?



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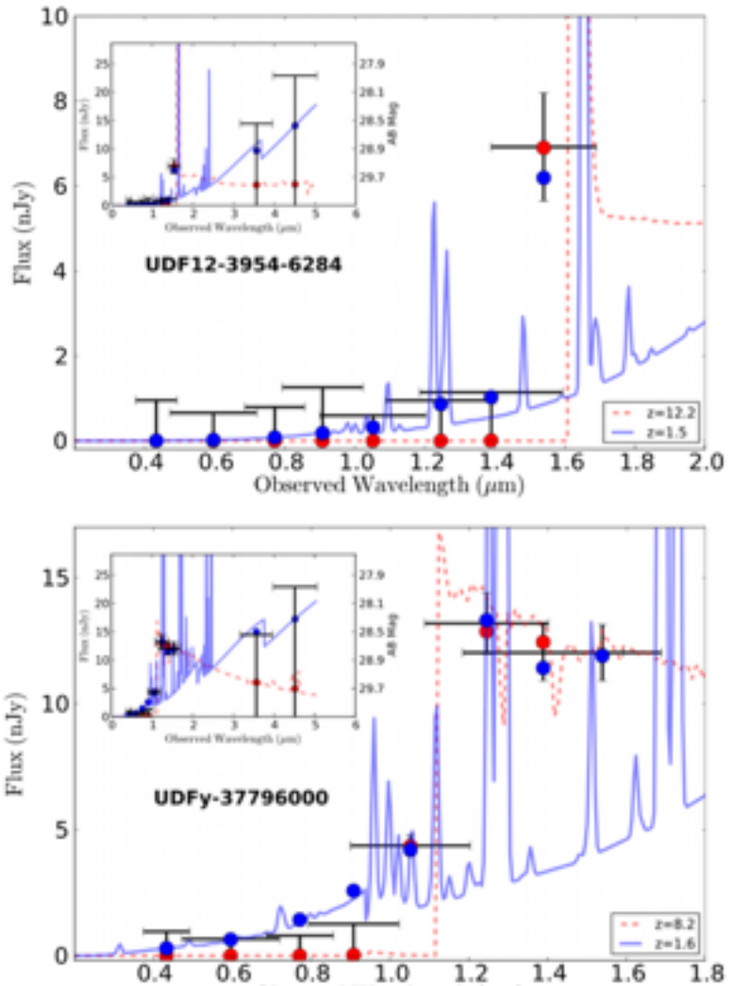
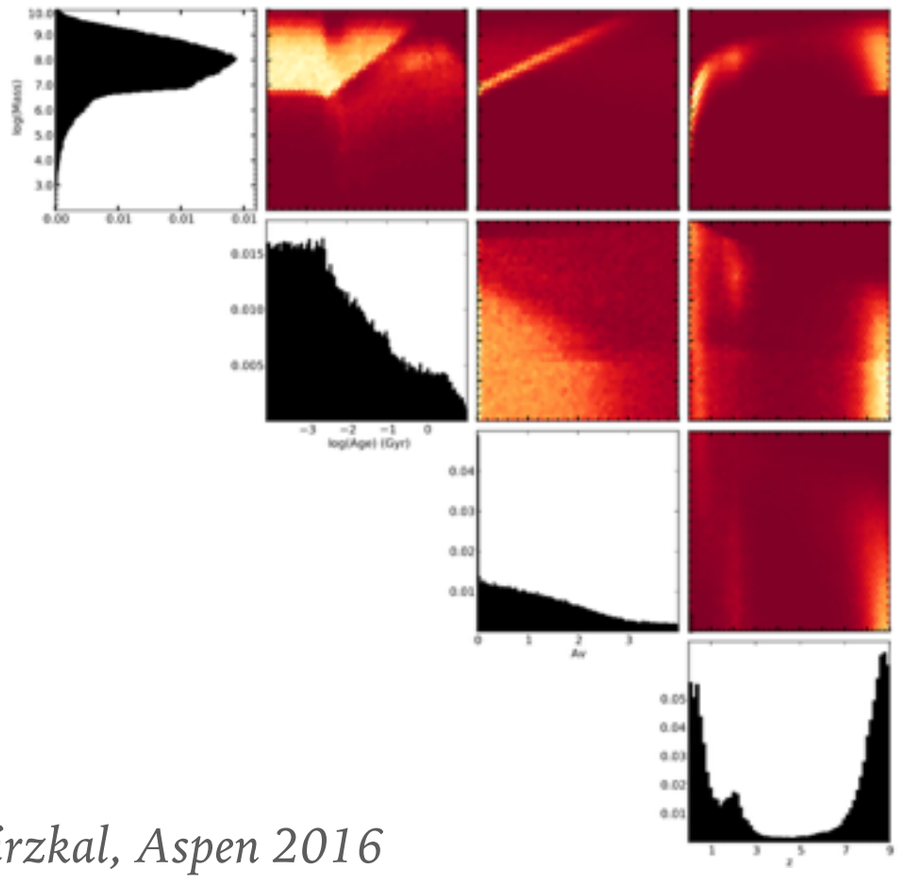
IMPROVED SED MODELING





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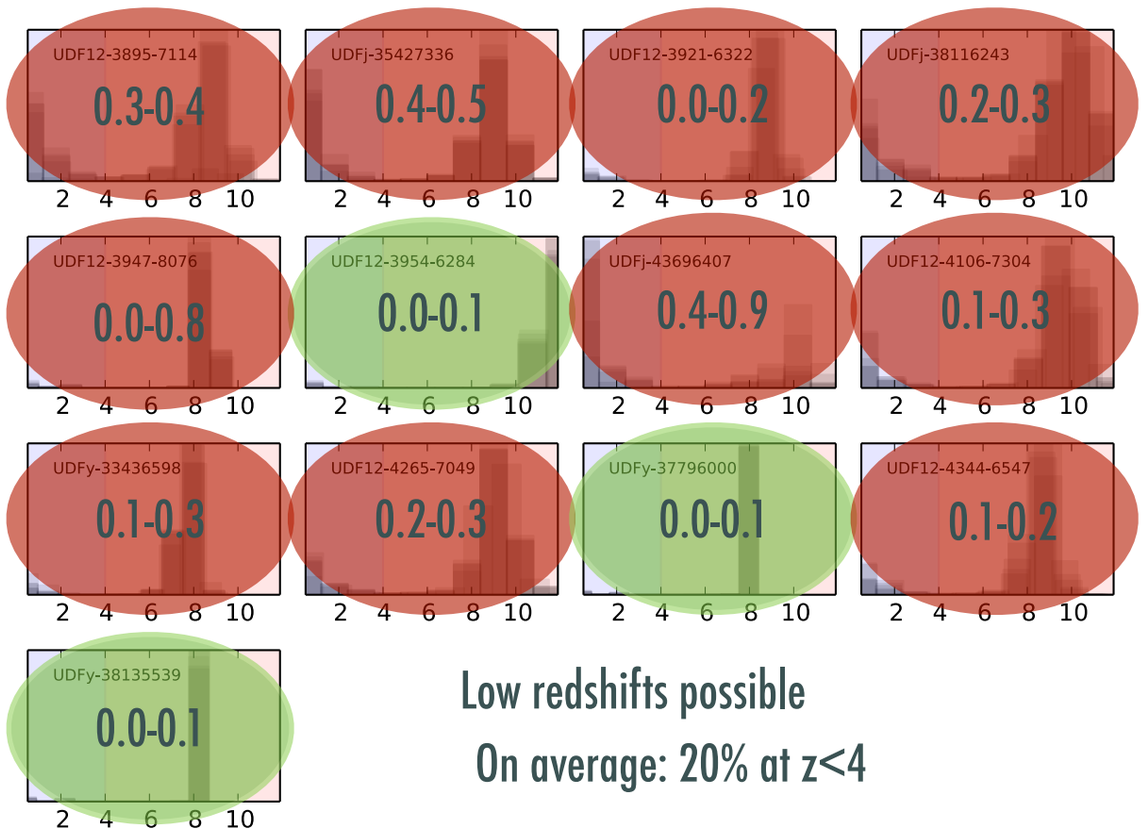
- πMC, SED fitting and alternate solutions
  - Allow for a wide and continuous range of model parameters
  - Found it crucial to not paying too much attention to the best fit solution, as it can be misleading
  - Deriving full PDF is significantly more informative
    - e.g. One really quickly learns that estimates of stellar ages are often very poorly constrained
- Single filter detection (with poor constraints in the Spitzer bands) are less secure
- IRAC upper limit measurements often provide little help

Pirzkal et al. 2012

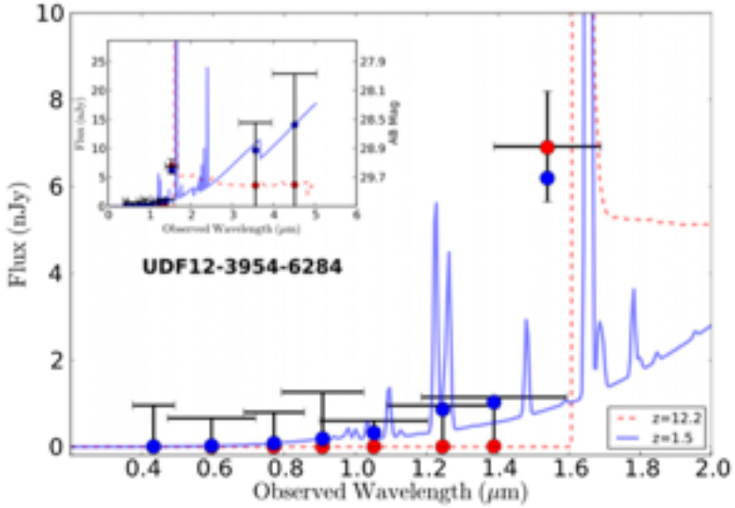


Low redshifts possible

On average: 20% at z<4

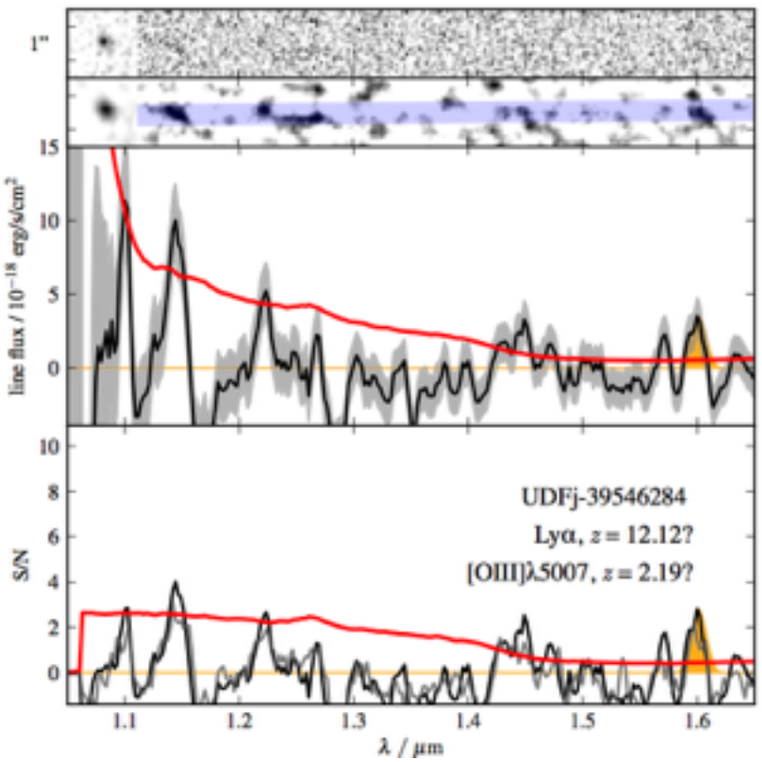
SPECTROSCOPIC (UN-)CONFIRMATION?

- Spectroscopic confirmation are required
  - Allows us to look for breaks, but also emission lines
- But, current spectroscopy is being pushed to its limits with z>10 candidates
  - Low signal to noise implies that we really cannot "prove the null hypothesis" and that we need to concentrate old-school rejection of models…



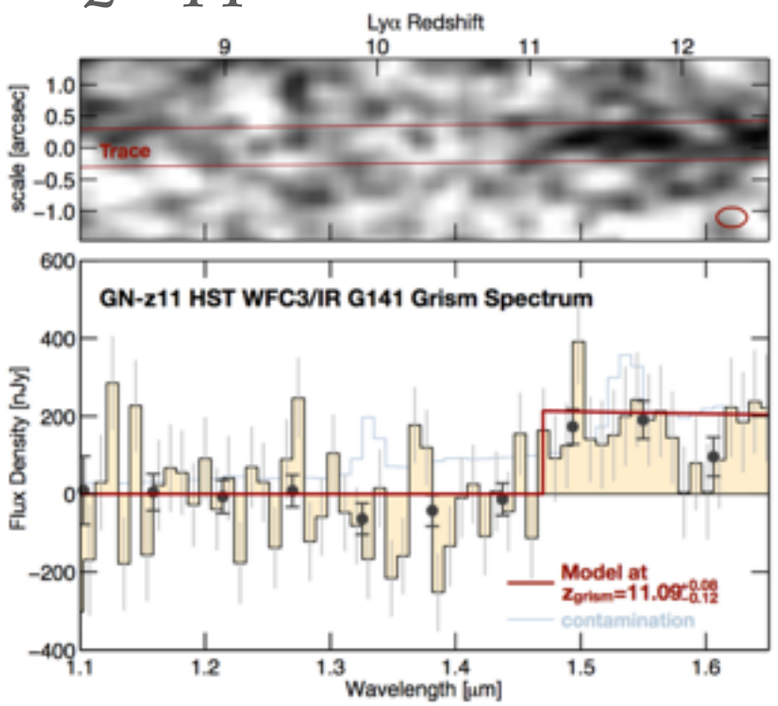
z=12

Pirzkal et al. 2012



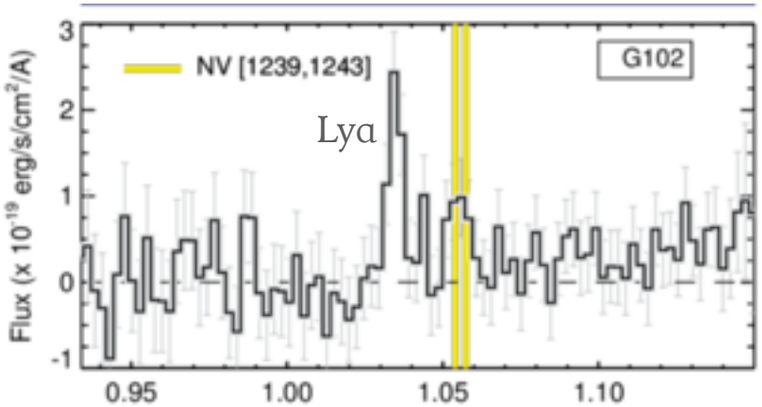
Brammer et al. 2013

z=11



Oesch et al. 2014

z=7.5



Tilvi et al. 2016, in prep

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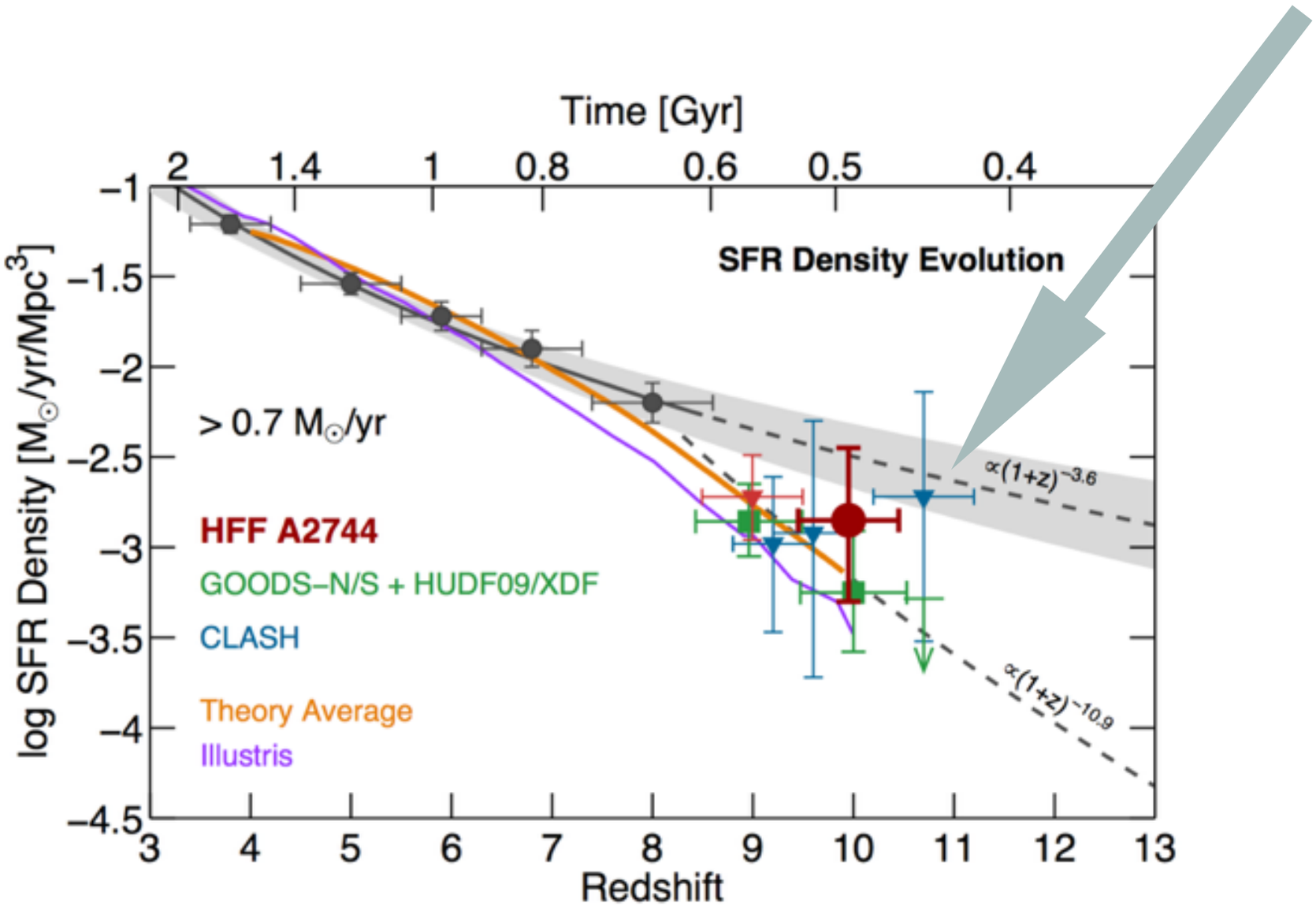
It's

INTERMISSION

Time, Folks!

MACSJ0647-JD: THE OTHER Z=11 CANDIDATE...



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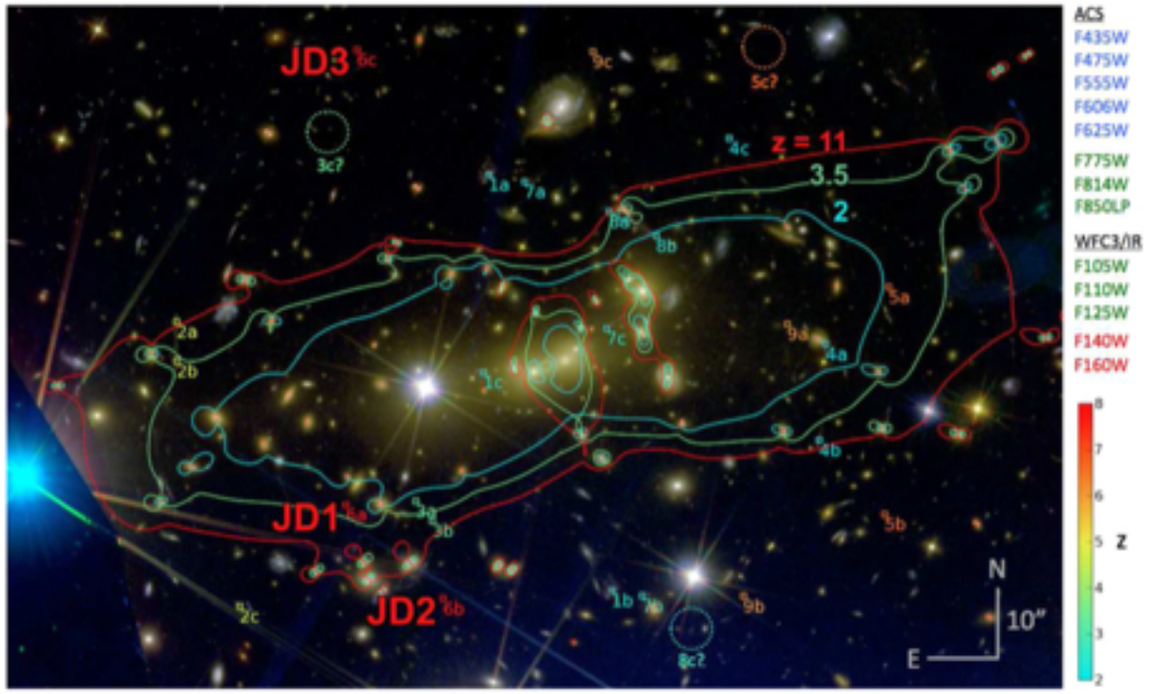
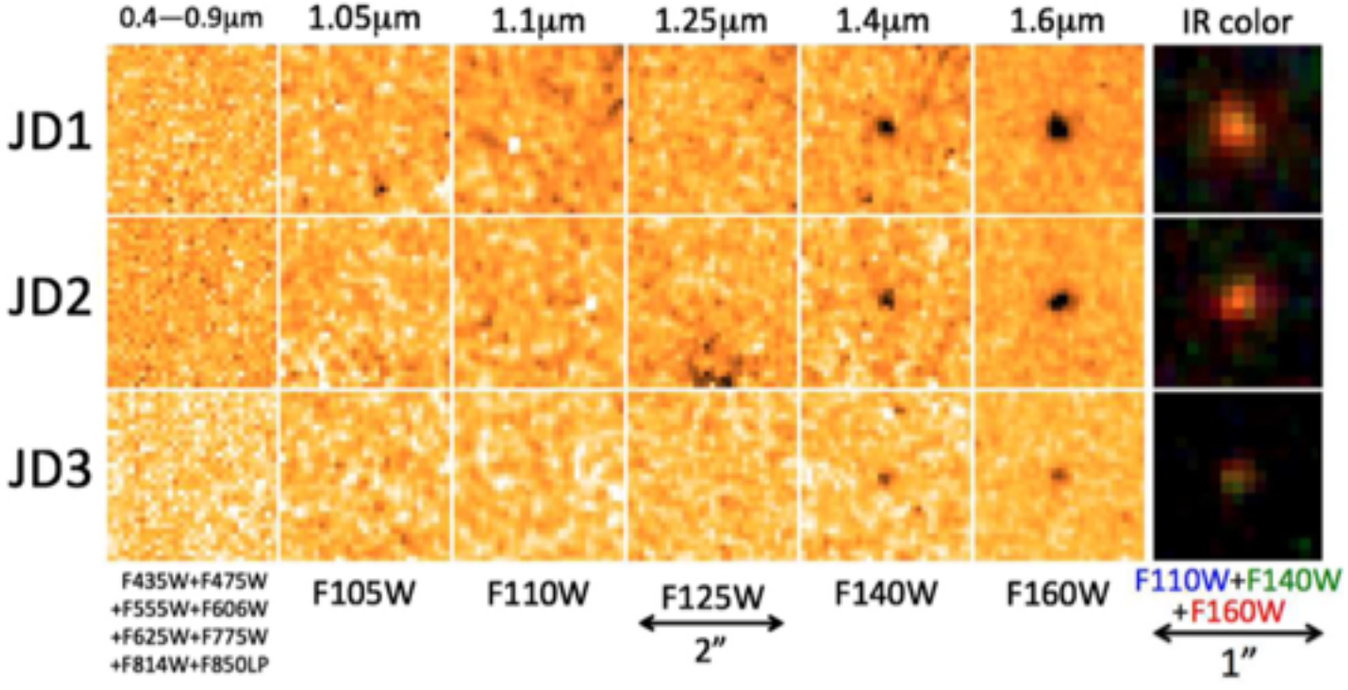
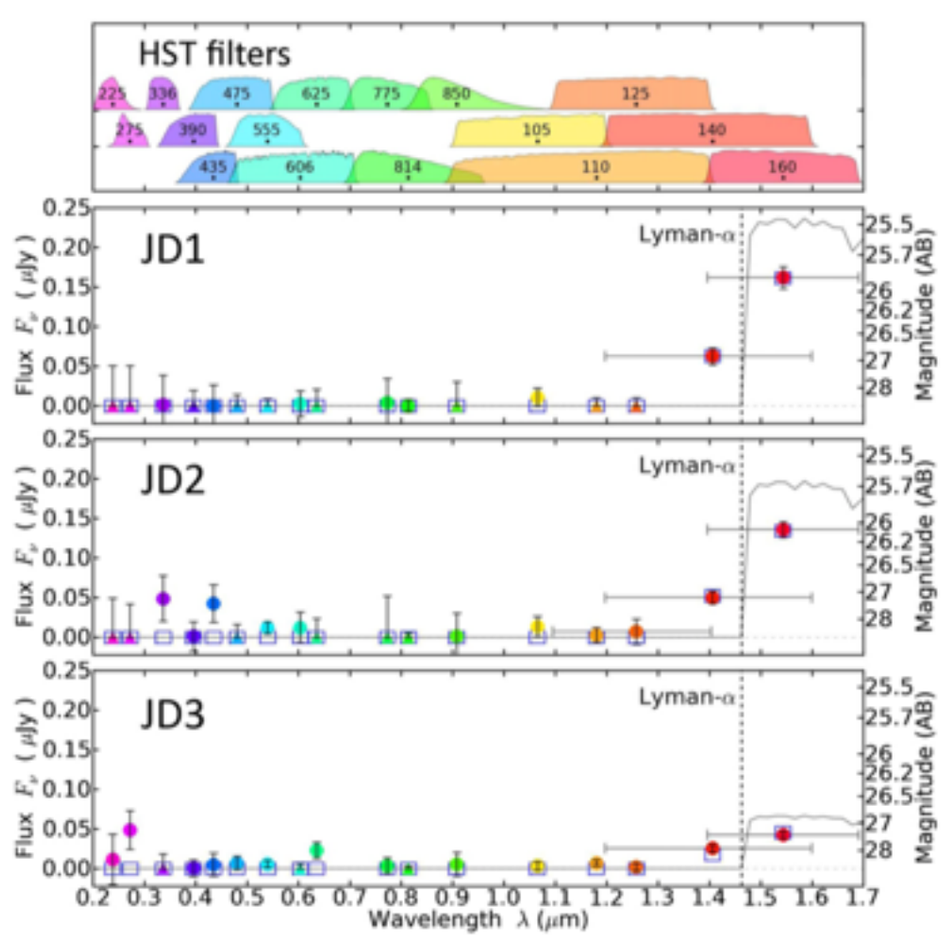


CLASH Z11 CANDIDATE MACSJ 0647-JD

- Three lensed images
- z~11 L* galaxy. Not peculiarly bright.
- Clear break detected in two filters and in the three independent images.
- So, why were we worried?



Coe et al. 2013



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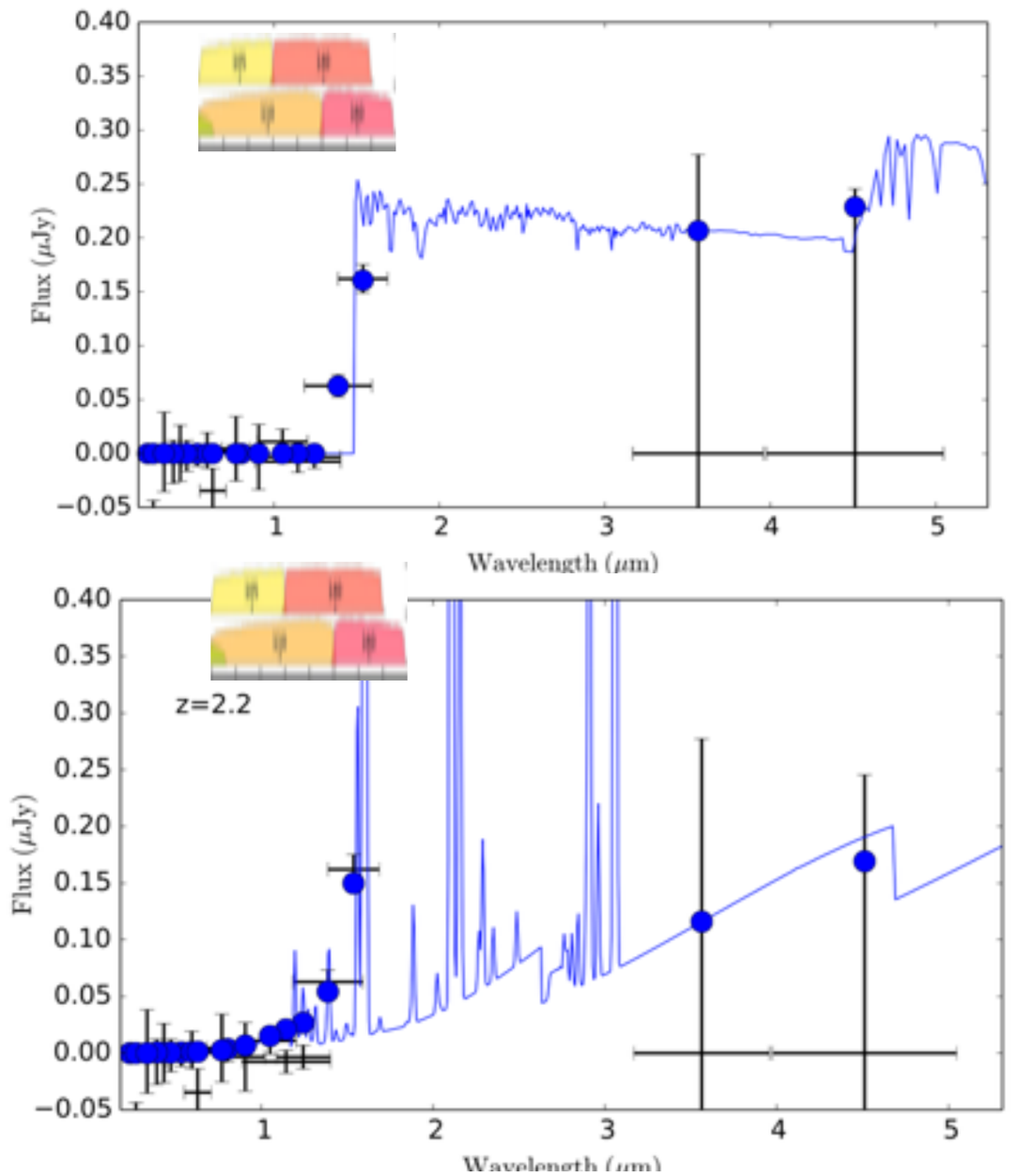

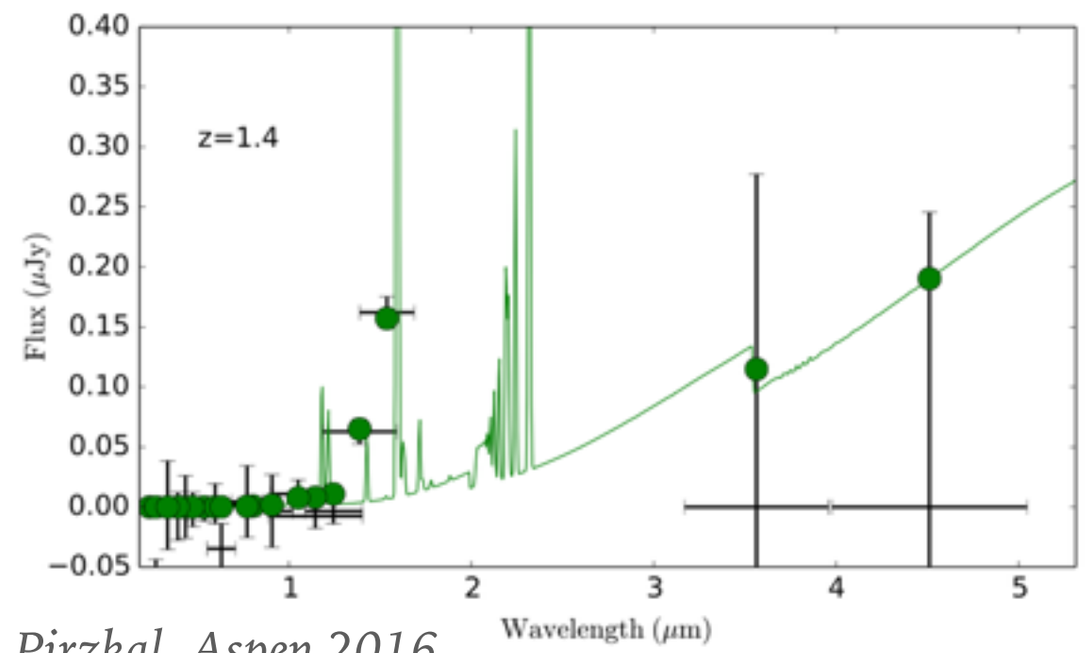

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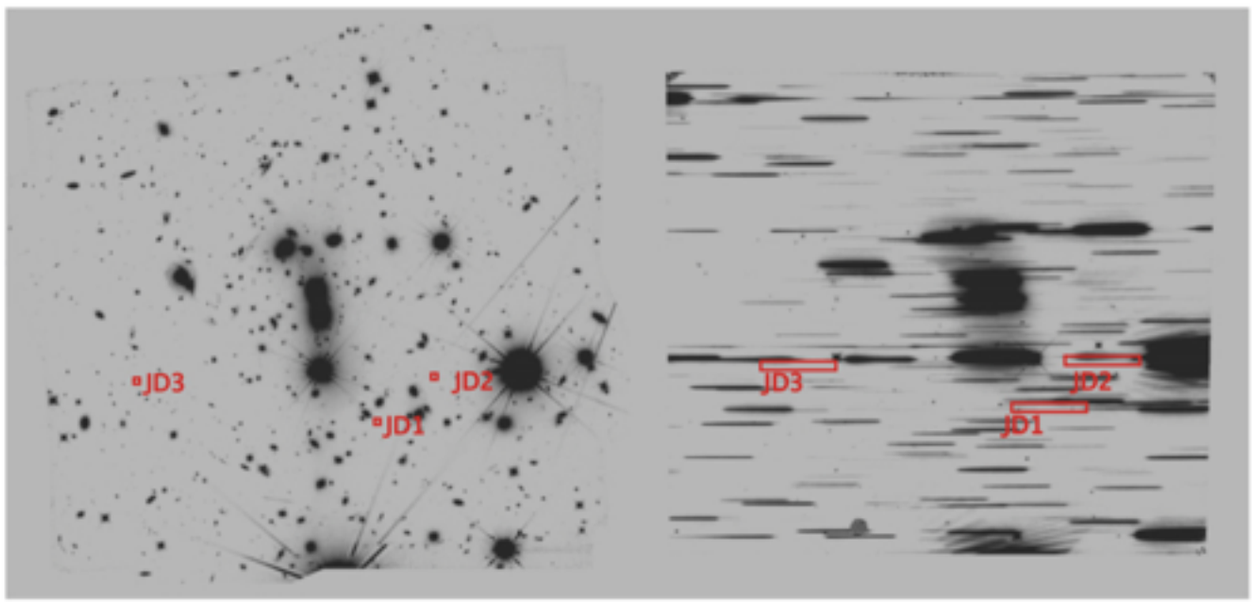
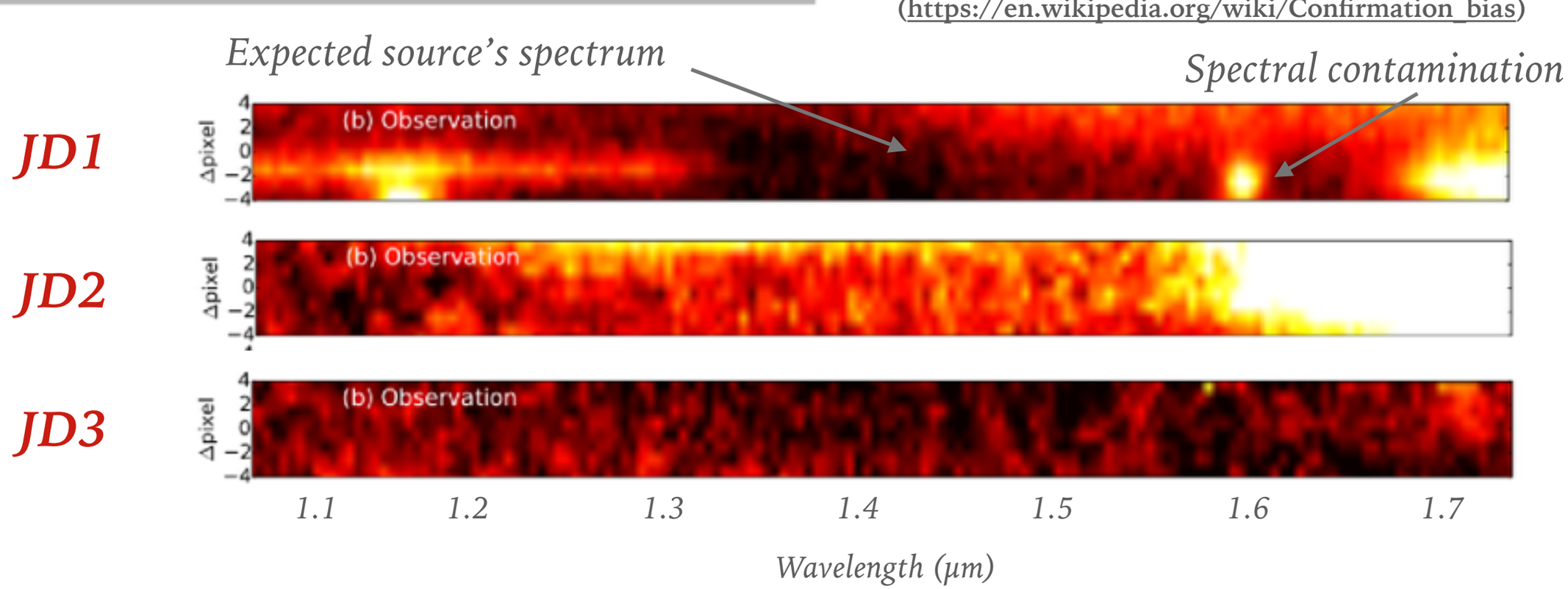
MACSJ0647-JD MODELS

- The photometric break is well established since this object is detected two filters
- But, as in the case of the earlier z~12 candidate, there is a slight probability that we are fooling ourselves…
- Solutions with BRIGHT emission lines at either z=1.4 or z=2.2 are also consistent with the data (Pirzkal et al. 2015)

WFC3/G141 OBSERVATIONS TO THE RESCUE?

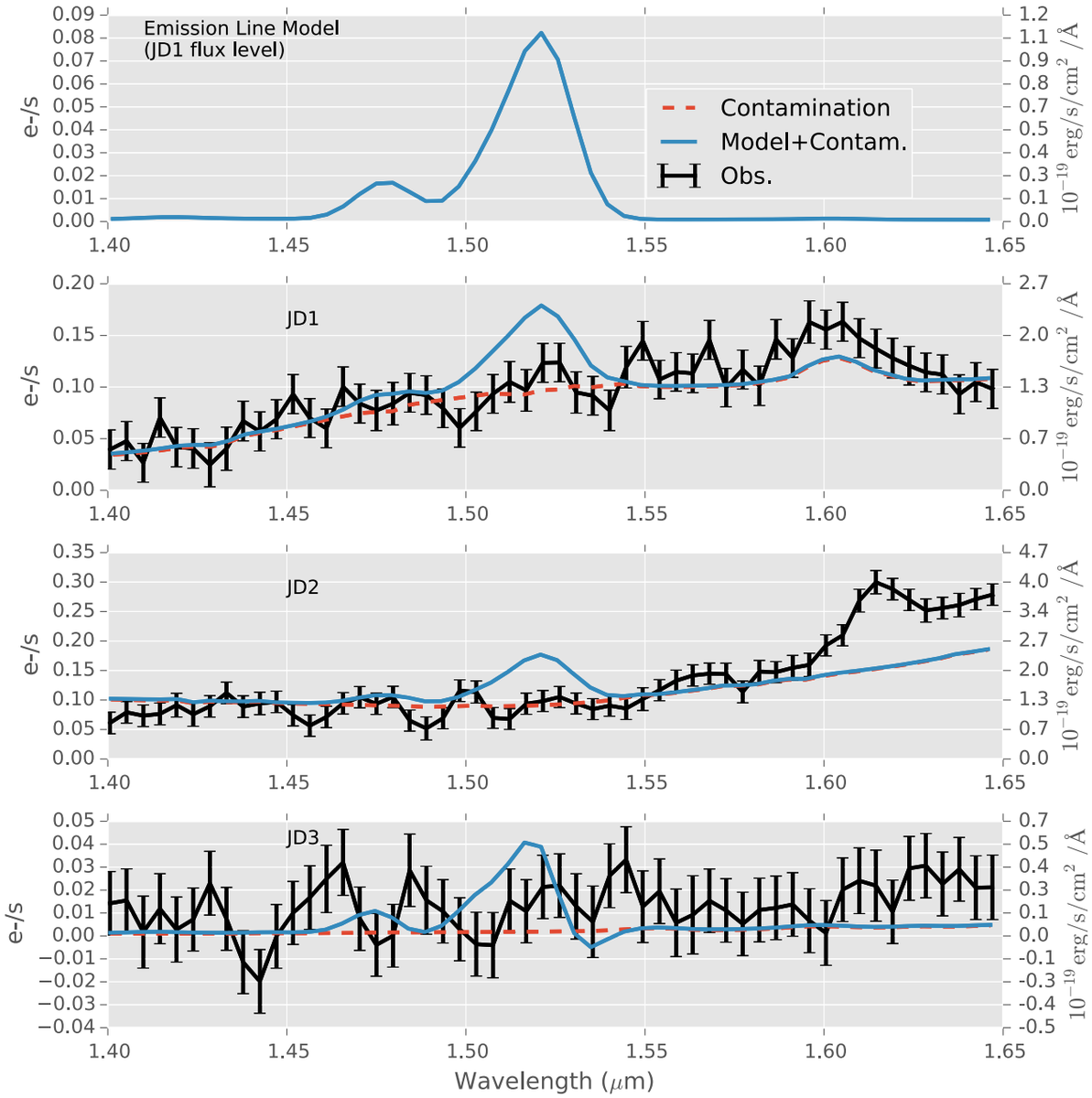


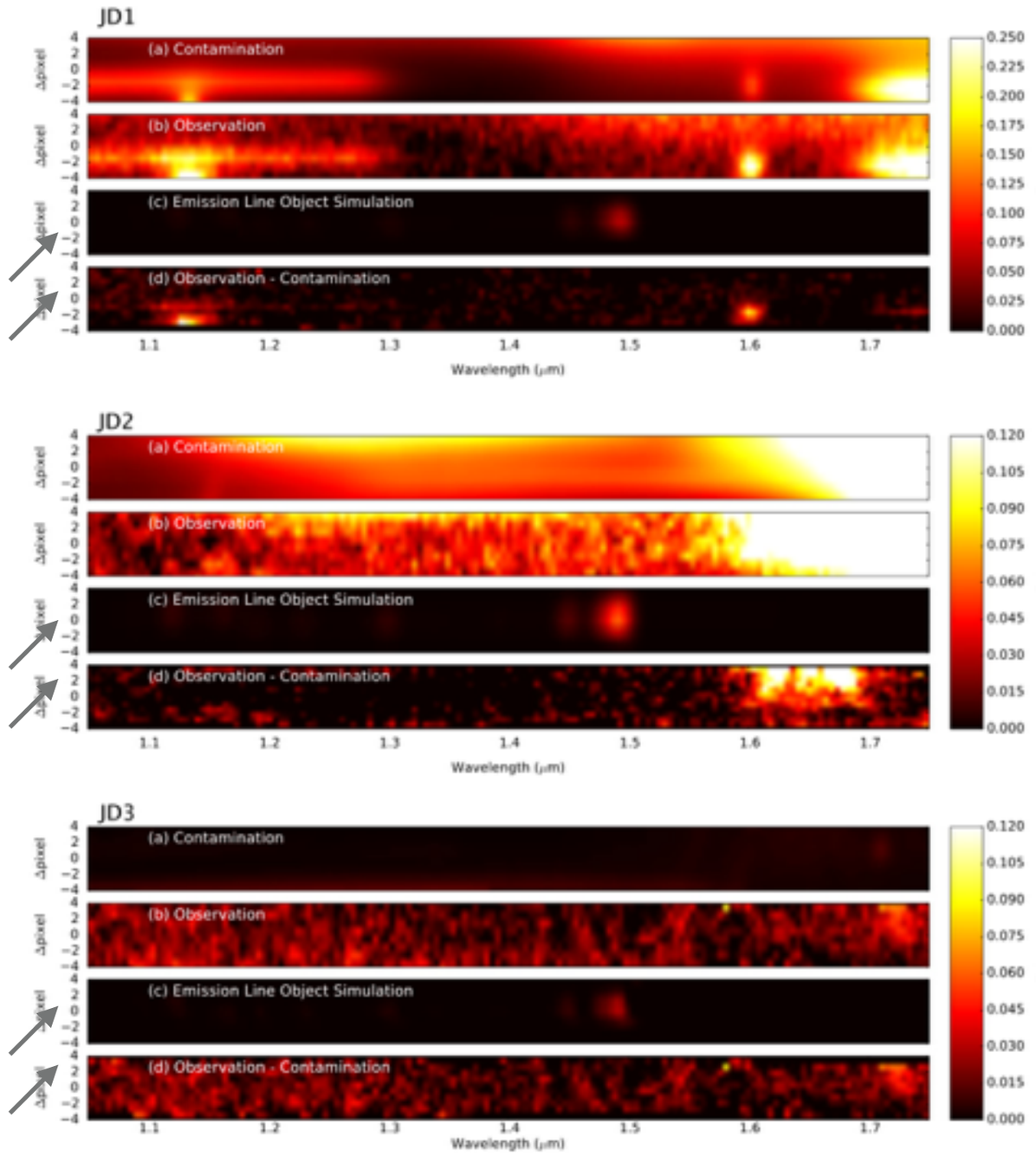
- MACSJ 0647-JD observed using 12 (3x4) orbits G141 observations
- Faint continuum (~26) makes convincingly detecting the continuum break an exercise in Confirmation Bias
  (https://en.wikipedia.org/wiki/Confirmation_bias)



- Pirzkal et al. 2015

OH SAY, CAN YOU SEE THE LINE?





- The G141 grism is modeled well enough that we can simulate both the spectral contamination AND what the required emission line would look like
- If due to an emission line, we would expect to detect this line (>5σ) in all three lensed images of the z11 candidate in a single (4 orbit epoch)
- **We are able to rule out an emission line interloper!!!**
  - **This rules out the z<3 models, the only possible alternatives to a z~11 solution.**

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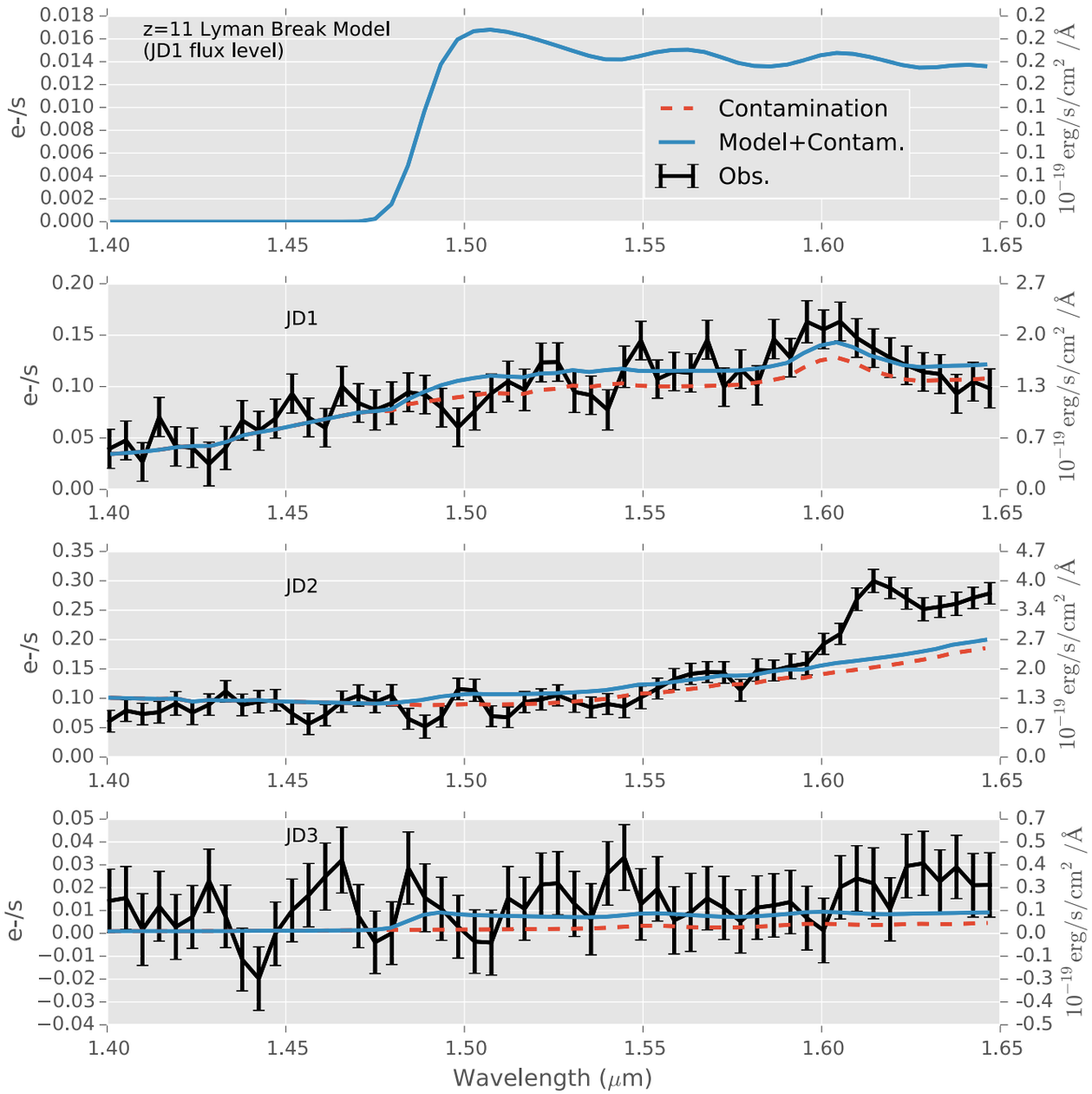
Pirzkal et al. 2015

WHAT ABOUT A CONTINUUM BREAK?



- m_{F140W}~26 continuum detection using G141 is difficult
- Statistically, we can state that the non-detection of the break is completely consistent with what we would expect.
- Recent progress in the G141 calibration might allow for the detection of the continuum, but low S/N is expected
- Detecting a low significance break with likely not (and probably should not) convince everybody

SUMMARY/CONCLUSION*

- Identifying z>10 objects near EOR remains difficult
- SED fitting almost always allow for some low z solution (although sometimes a bit eccentric..)
- Spectroscopy confirmation, via the detection of a break or an emission line is the only sure way to confirm these high-z candidates
- Unfortunately, spectroscopic confirmation is rather difficult
- In the case of the z=11 MACSJ 0647-JD, we have shown that even using short G141 observations we can rule out a low redshift interloper.

(*): We don't prove, we test and disprove..

ALMOST

That's all Folks!