Black hole growth at *very* high redshift*

or: where do SBMHs come from anyway?

*or not?

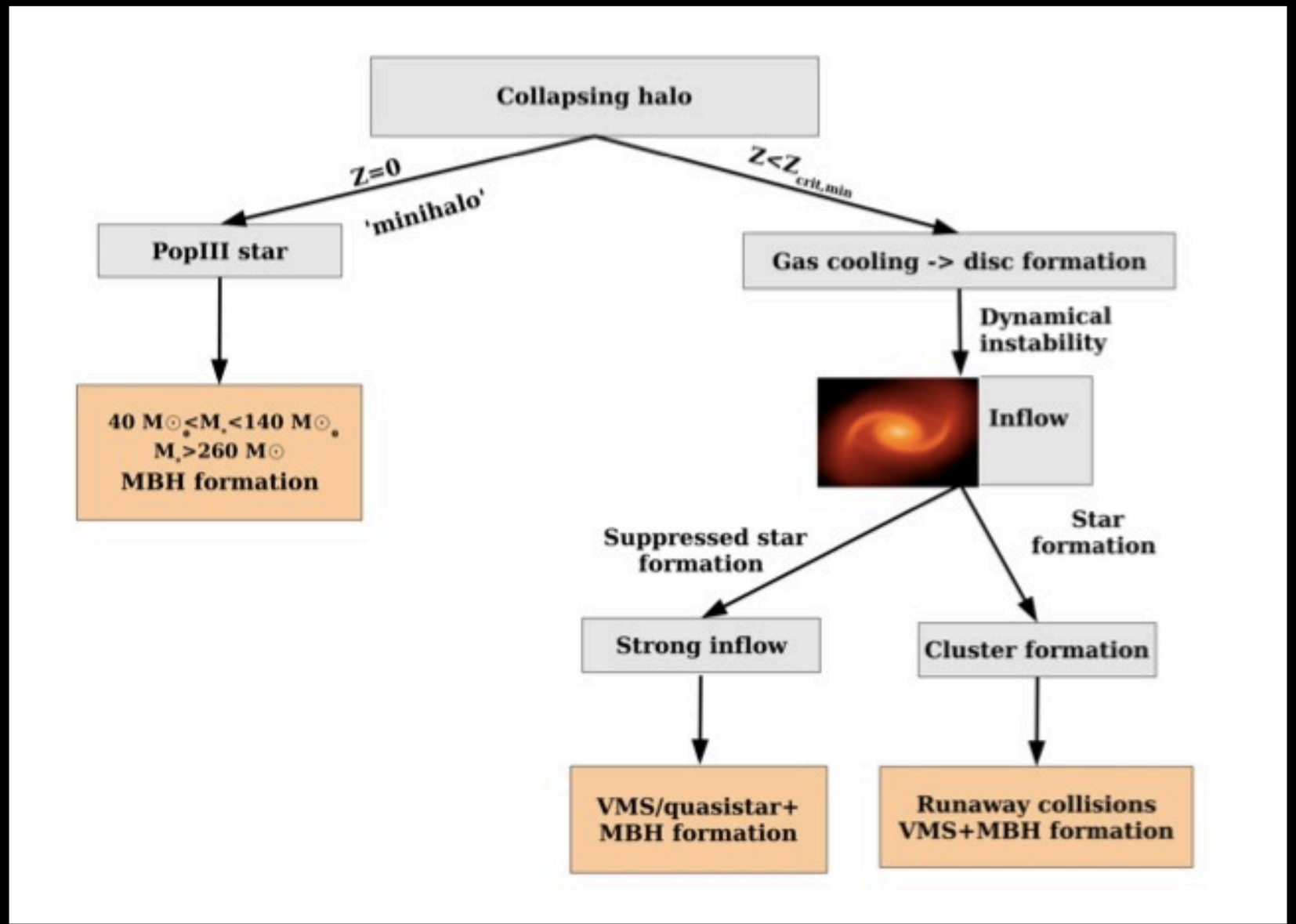
Kevin Schawinski
Institute for Astronomy
ETH Zurich

@kevinschawinski

With:
Anna Weigel (ETHZ), Ezequiel Treister (Concepcion), Priyamvada Natarajan (Yale), Marta Volonteri (Paris), Meg Urry (Yale)

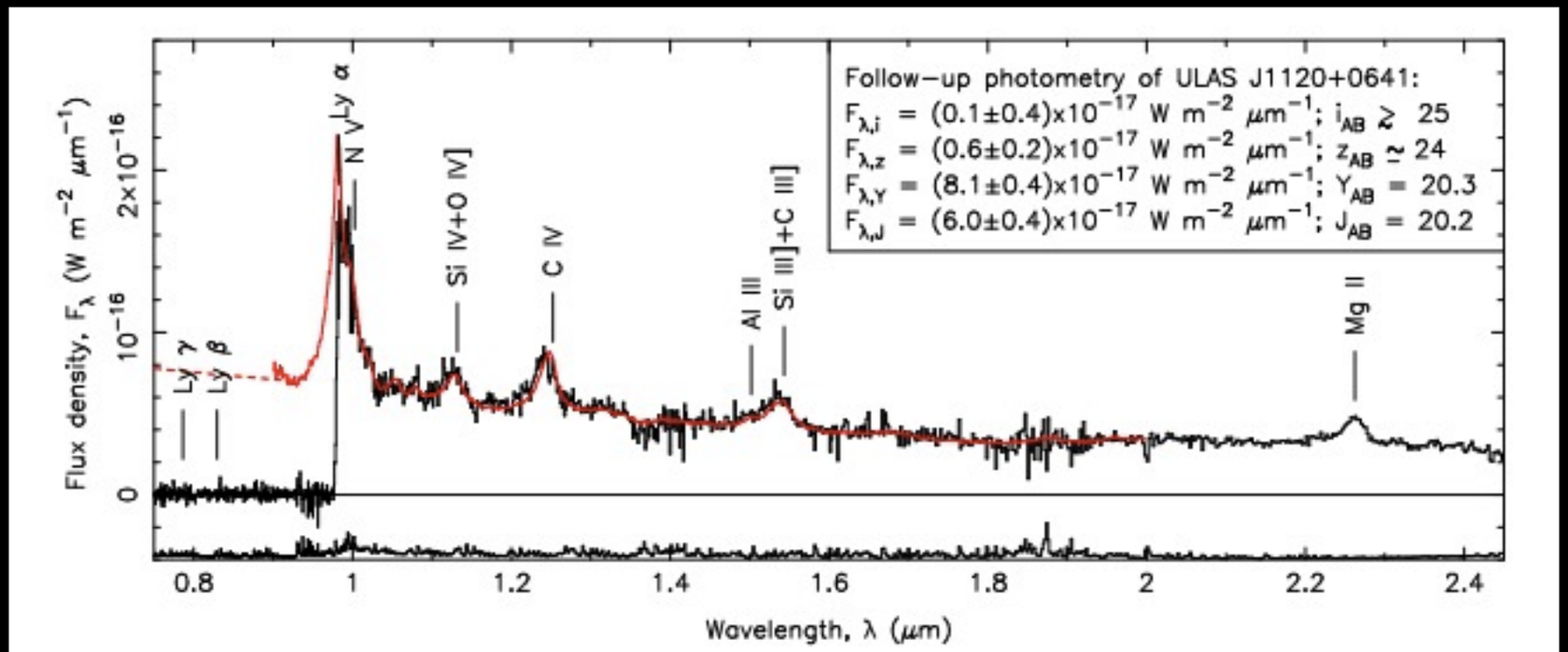
THE THEORY SLIDE

Black hole seed formation remains one of the *Unknowns* in extragalactic astrophysics



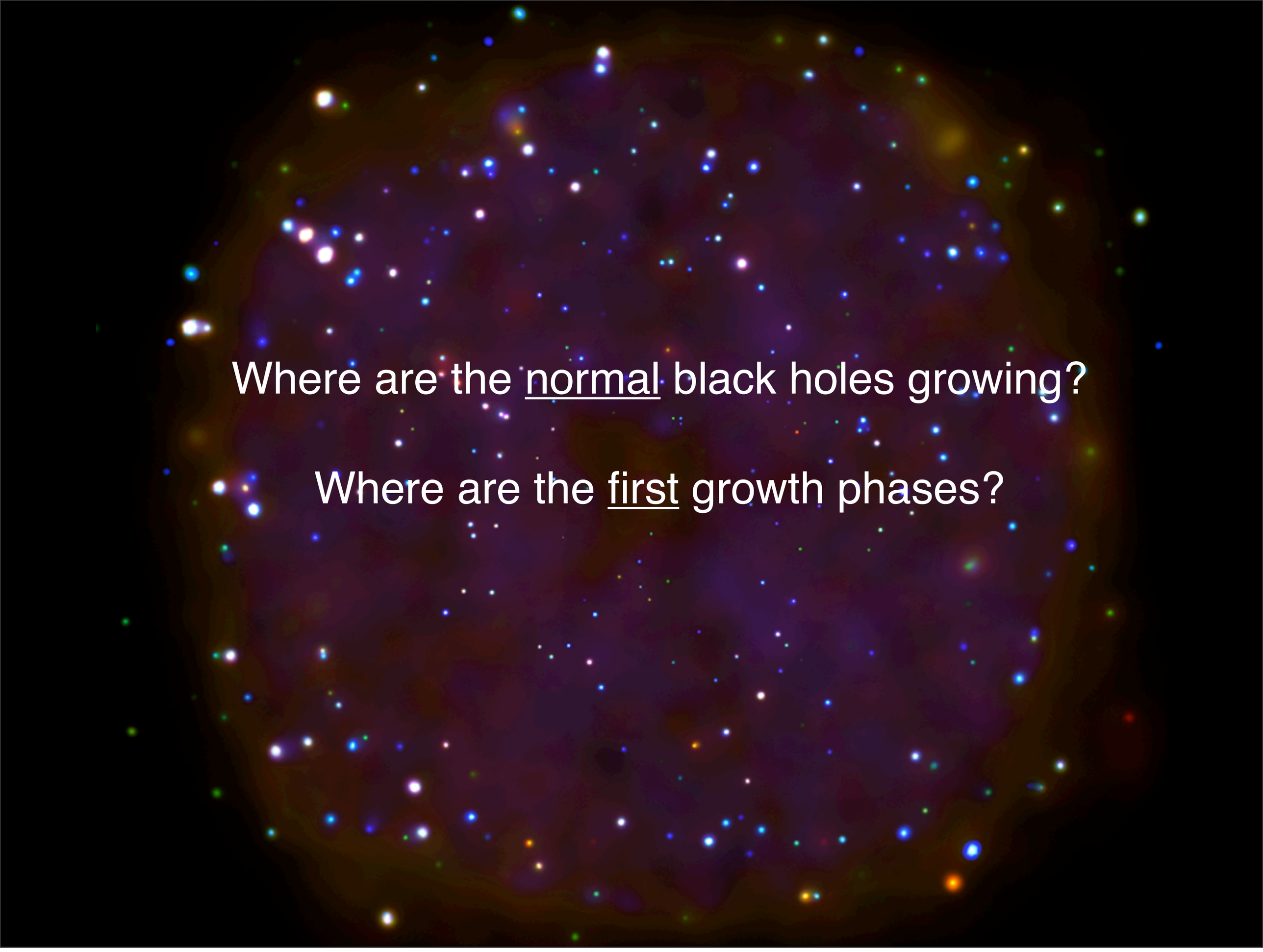
Review by Marta Volonteri
lots of references therein

We know that the Universe makes massive 10^9 M_{sun} black holes by z~7 (=750 Myr after the Big Bang)



Mortlock+11

Characteristic time scale is the Salpeter time ~45 Myr, the e-folding time for Eddington-limited growth for a radiative efficiency of ~0.1


Where are the normal black holes growing?
Where are the first growth phases?

Chandra X-ray stacking of z=[6,7,8] dropout galaxies

Treister, Schawinski, Volonteri, Natarajan in prep.

No detection in ultra-deep stacks!

Table 1. Stacking Results

Redshift	Sample				X-ray Lum[a]	BH Mass[a]
	B06	B11	F12	Combined	[erg s^{-1}]	[$M_\odot Mpc^{-3}$]
Soft Band (0.5-2 keV)						
$z\sim6$	-3.4±6.2	—	-3.6±4.7	-4.0±6.5	$<3.1\times10^{41}$	<996
$z\sim7$	—	0.7±1.4	-0.6±2.5	-0.4±2.6	$<6.8\times10^{41}$	<623
$z\sim8$	—	1.6±1.7	0.7±1.9	1.9±2.1	$<1.5\times10^{42}$	<628
Hard Band (2-8 keV)						
$z\sim6$	-6.3±9.1	—	-3.3±6.7	-9.1±9.4	$<1.6\times10^{42}$	<4750
$z\sim7$	—	0.2±2.4	1.8±4.1	1.5±4.1	$<5.3\times10^{42}$	<4704
$z\sim8$	—	-4.7±2.1	-0.4±2.6	-1.8±2.8	$<9.8\times10^{42}$	<4346

[a]For the combined sample

LBGs from: Bouwens+06,11; Finkelstein+12

Contribution from star formation ruled out by comparison to UV SFRs

Chandra X-ray stacking of z=[6,7,8] dropout galaxies

Treister, Schawinski, Volonteri, Natarajan in prep.

No detection in ultra-deep stacks!

Table 1. Stacking Results

Redshift	Sample				X-ray Lum[a]	BH Mass[a]
	B06	B11	F12	Combined	[erg s^{-1}]	[$M_\odot Mpc^{-3}$]
			Soft Band (0.5-2 keV)			
$z\sim6$	-3.4±6.2	—	-3.6±4.7	-4.0±6.5	$<3.1\times10^{41}$	<996
$z\sim7$	—	0.7±1.4	-0.6±2.5	-0.4±2.6	$<6.8\times10^{41}$	<623
$z\sim8$	—	1.6±1.7	0.7±1.9	1.9±2.1	$<1.5\times10^{42}$	<628
			Hard Band (2-8 keV)			
$z\sim6$	-6.3±9.1	—	-3.3±6.7	-9.1±9.4	$<1.6\times10^{42}$	<4750
$z\sim7$	—	0.2±2.4	1.8±4.1	1.5±4.1	$<5.3\times10^{42}$	<4704
$z\sim8$	—	-4.7±2.1	-0.4±2.6	-1.8±2.8	$<9.8\times10^{42}$	<4346

[a]For the combined sample

LBGs from: Bouwens+06,11; Finkelstein+12

Contribution from star formation ruled out by comparison to UV SFRs

Chandra X-ray stacking of z=[6,7,8] dropout galaxies

Treister, Schawinski, Volonteri, Natarajan in prep.

No detection in ultra-deep stacks!

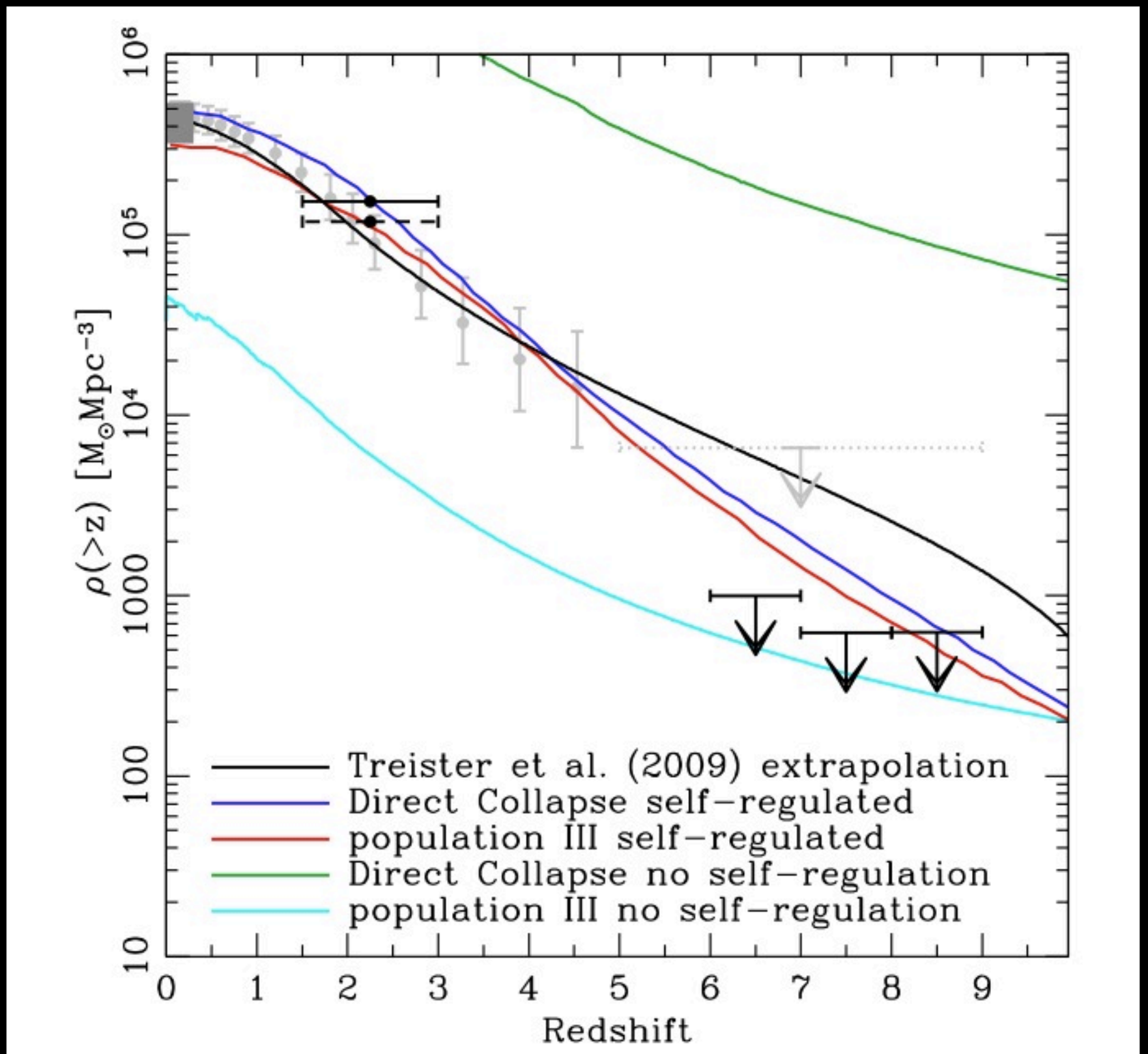
Table 1. Stacking Results

Redshift	Sample				X-ray Lum[a]	BH Mass[a]
	B06	B11	F12	Combined	[erg s^{-1}]	[$M_\odot Mpc^{-3}$]
Soft Band (0.5-2 keV)						
$z\sim6$	-3.4±6.2	—	-3.6±4.7	-4.0±6.5	$<3.1\times10^{41}$	<996
$z\sim7$	—	0.7±1.4	-0.6±2.5	-0.4±2.6	$<6.8\times10^{41}$	<623
$z\sim8$	—	1.6±1.7	0.7±1.9	1.9±2.1	$<1.5\times10^{42}$	<628
Hard Band (2-8 keV)						
$z\sim6$	-6.3±9.1	—	-3.3±6.7	-9.1±9.4	$<1.6\times10^{42}$	<4750
$z\sim7$	—	0.2±2.4	1.8±4.1	1.5±4.1	$<5.3\times10^{42}$	<4704
$z\sim8$	—	-4.7±2.1	-0.4±2.6	-1.8±2.8	$<9.8\times10^{42}$	<4346

[a]For the combined sample

LBGs from: Bouwens+06,11; Finkelstein+12

Contribution from star formation ruled out by comparison to UV SFRs



Models by Volonteri+

Chandra X-ray stacking of z=[6-8] dropout galaxies:
Possible interpretation of no detection:

Chandra X-ray stacking of z=[6-8] dropout galaxies: Possible interpretation of no detection:

1. z=[6-8] LBGs in deep fields do not contain SMBHs (or occupation fraction is low) > S*eed formation efficiency is low?*

Chandra X-ray stacking of z=[6-8] dropout galaxies: Possible interpretation of no detection:

1. z=[6-8] LBGs in deep fields do not contain SMBHs (or occupation fraction is low) > S*eed formation efficiency is low?*

2. z=[6-8] LBGs in deep fields do contain SMBHs, but they are not growing. > *If not, why not? sSFRs indicate they should be gas-rich!*

Chandra X-ray stacking of z=[6-8] dropout galaxies: Possible interpretation of no detection:

1. z=[6-8] LBGs in deep fields do not contain SMBHs (or occupation fraction is low) > S*eed formation efficiency is low?*

2. z=[6-8] LBGs in deep fields do contain SMBHs, but they are not growing. > *If not, why not? sSFRs indicate they should be gas-rich!*

3. z=[6-8] LBGs in deep fields are growing, but are either radiatively inefficient, heavily obscured, or grow by mergers > *ok???*

Chandra X-ray stacking of z=[6-8] dropout galaxies:
Possible interpretation of no detection:

1. z=[6-8] LBGs in deep fields do not contain SMBHs (or occupation fraction is low) > S*eed formation efficiency is low?*

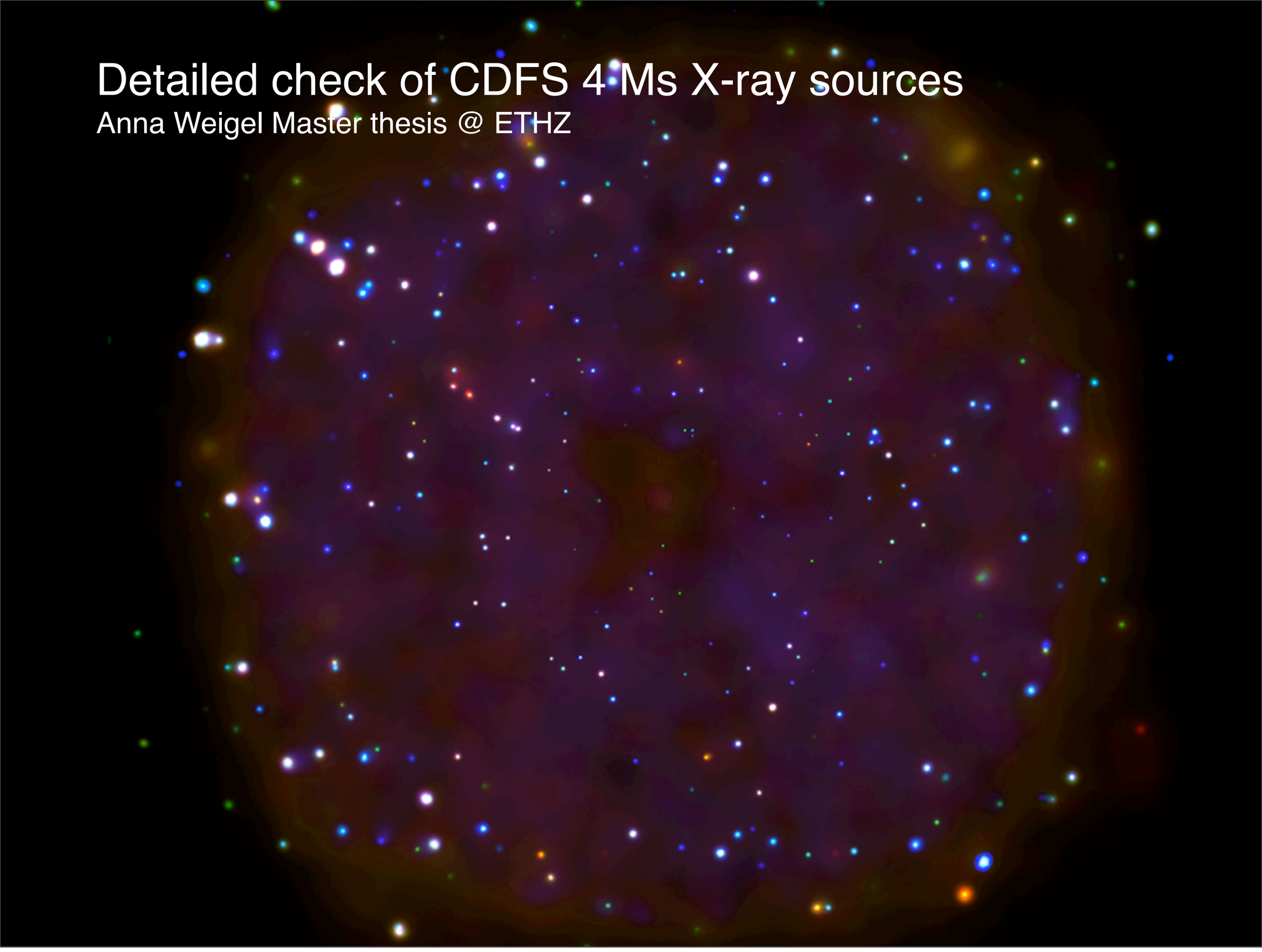
2. z=[6-8] LBGs in deep fields do contain SMBHs, but they are not growing. > *If not, why not? sSFRs indicate they should be gas-rich!*

3. z=[6-8] LBGs in deep fields are growing, but are either radiatively inefficient, heavily obscured, or grow by mergers > *ok???*

4. SMBHs grow in galaxies that elude the classical LBG selection. *> But then, where are they?*

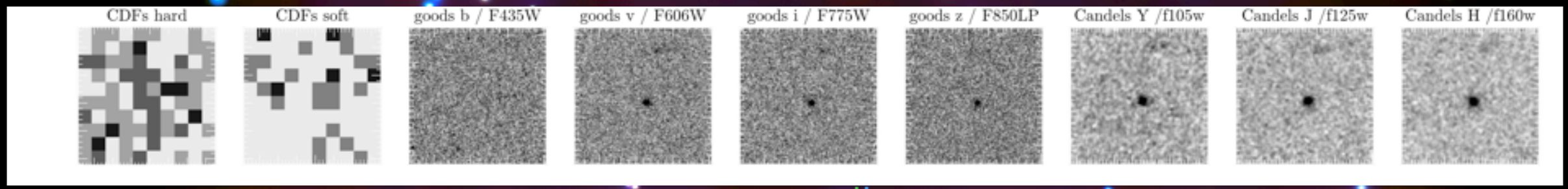
Detailed check of CDFS 4 Ms X-ray sources

Anna Weigel Master thesis @ ETHZ



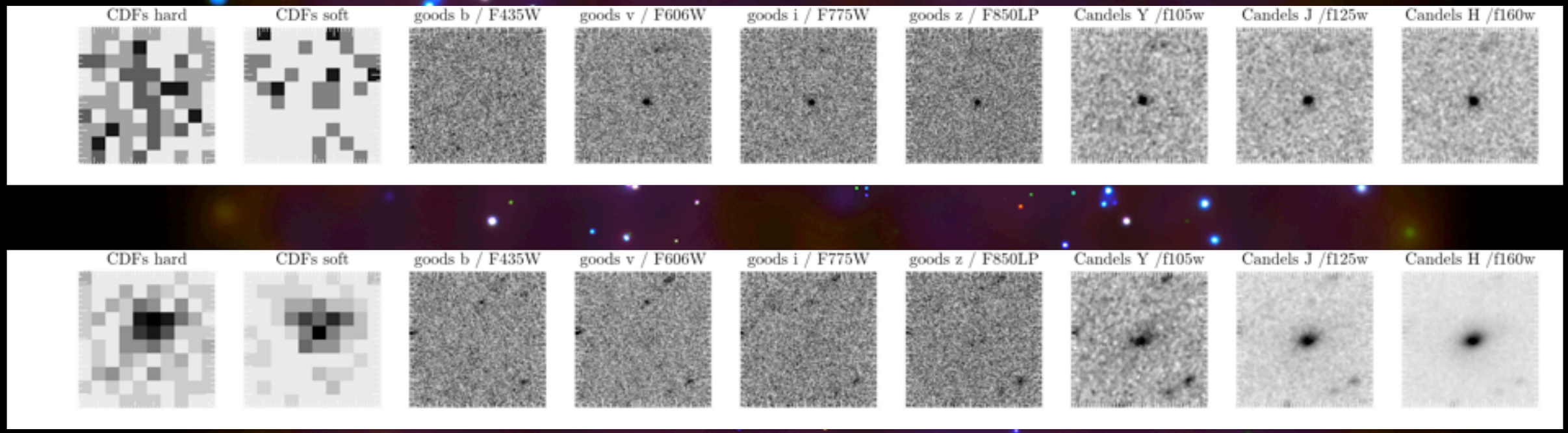
Detailed check of CDFS 4 Ms X-ray sources

Anna Weigel Master thesis @ ETHZ



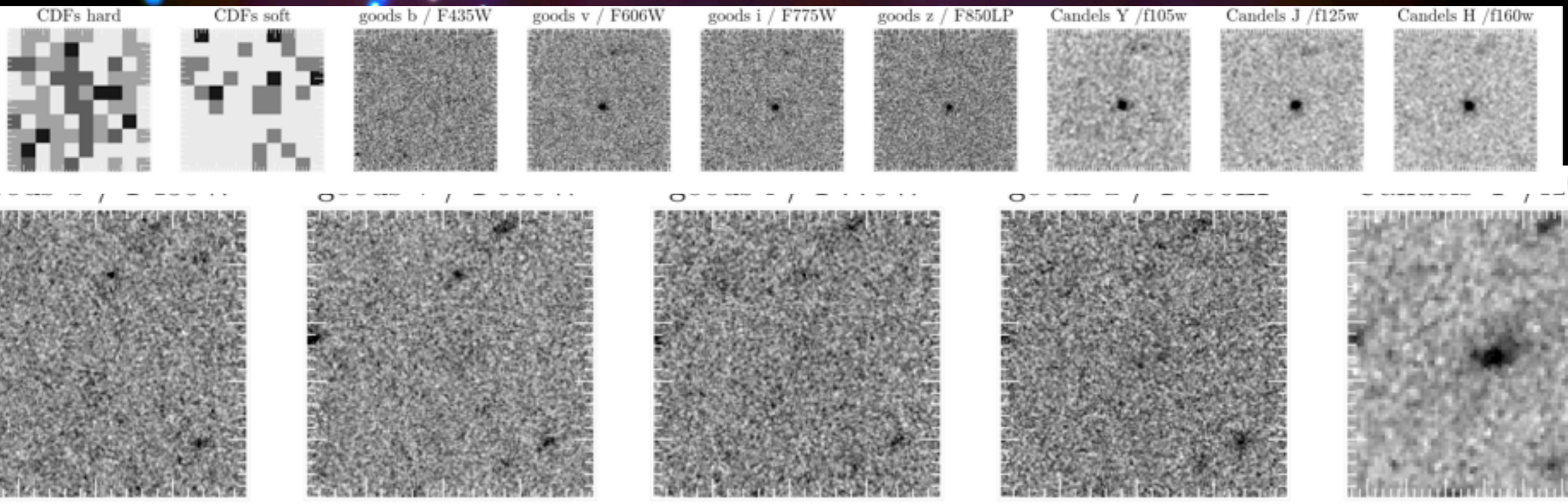
Detailed check of CDFS 4 Ms X-ray sources

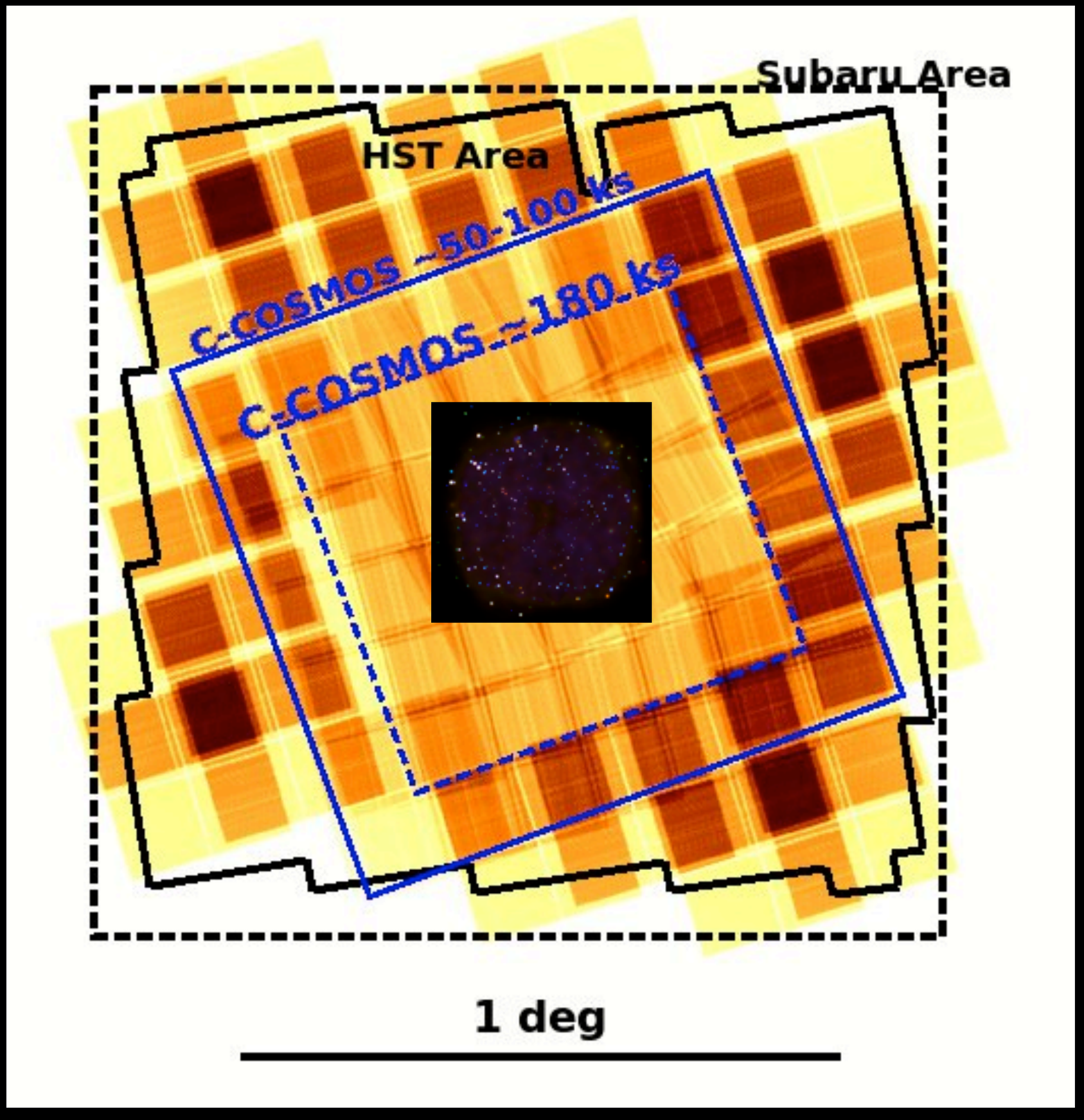
Anna Weigel Master thesis @ ETHZ



Detailed check of CDFS 4 Ms X-ray sources

Anna Weigel Master thesis @ ETHZ

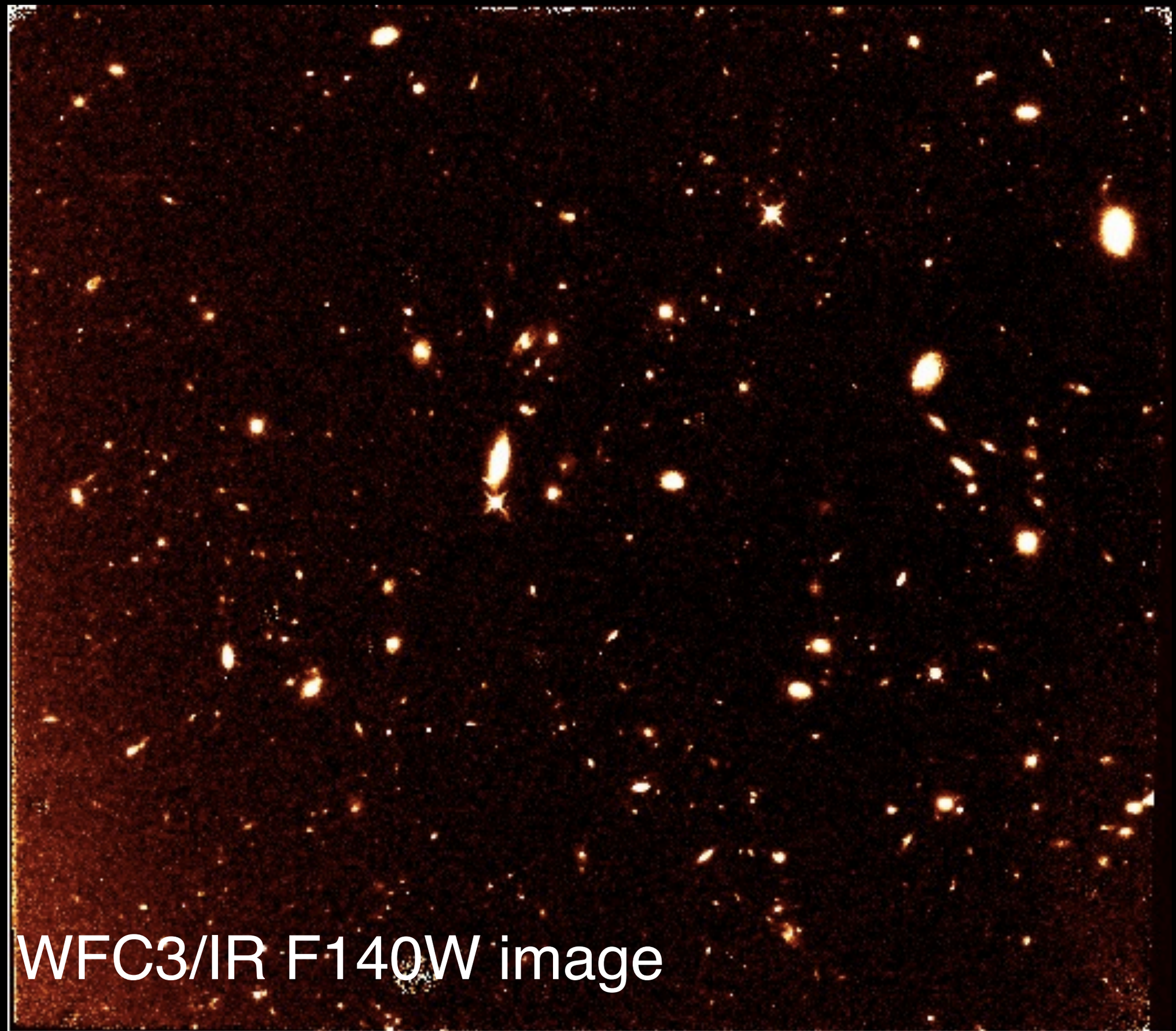


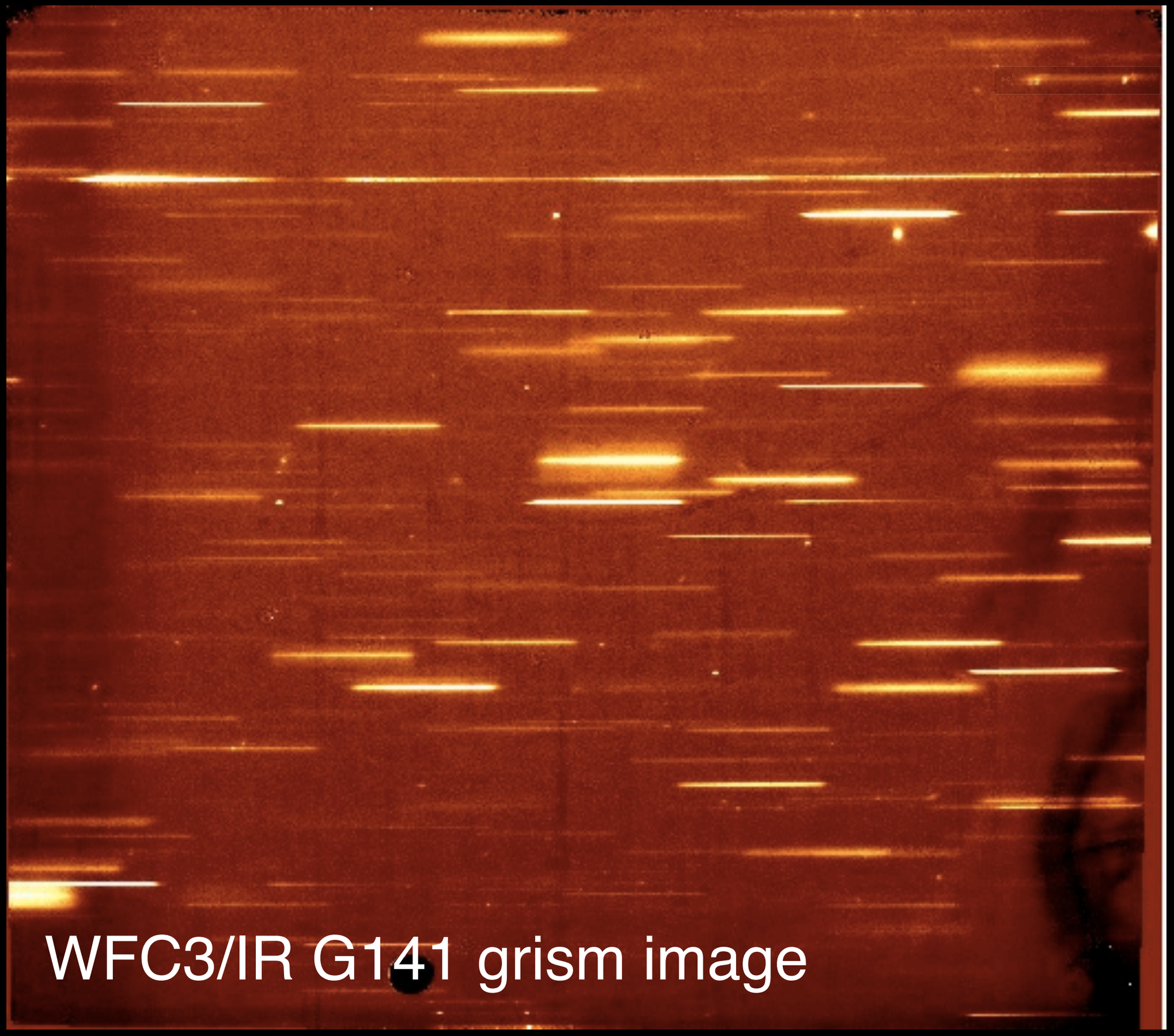


Stacking
(w/ E. Treister)

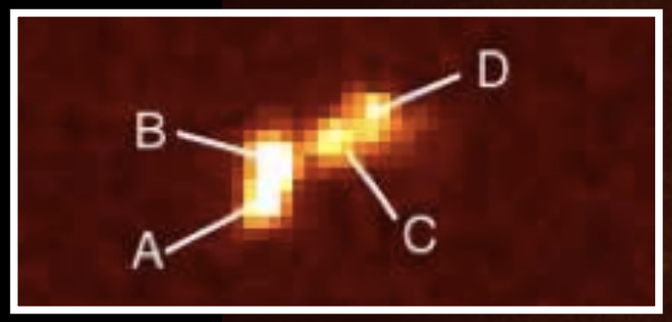
Individual
sources
(w/ A. Weigel)

don’t hold me to the scale this is Keynote!

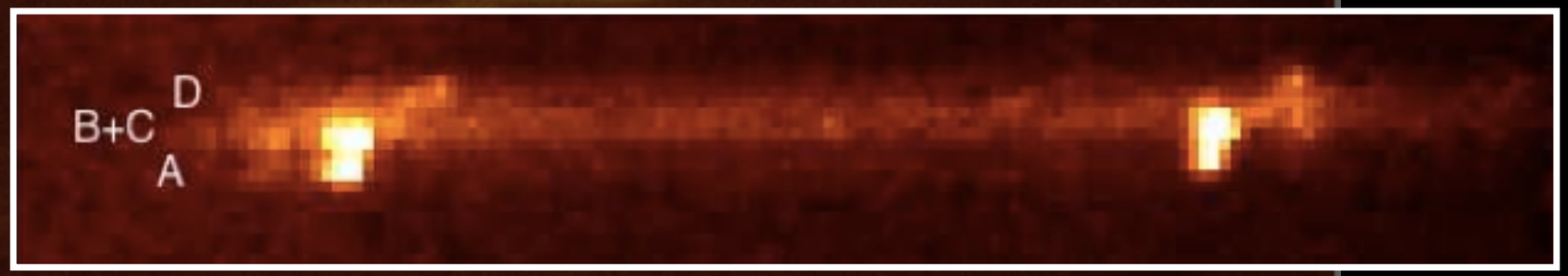

WFC3/IR F140W image


WFC3/IR G141 grism image

WFC3/IR F140W image



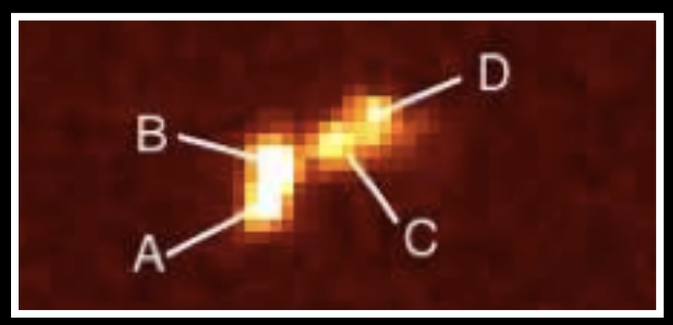
WFC3/IR G141 dispersed



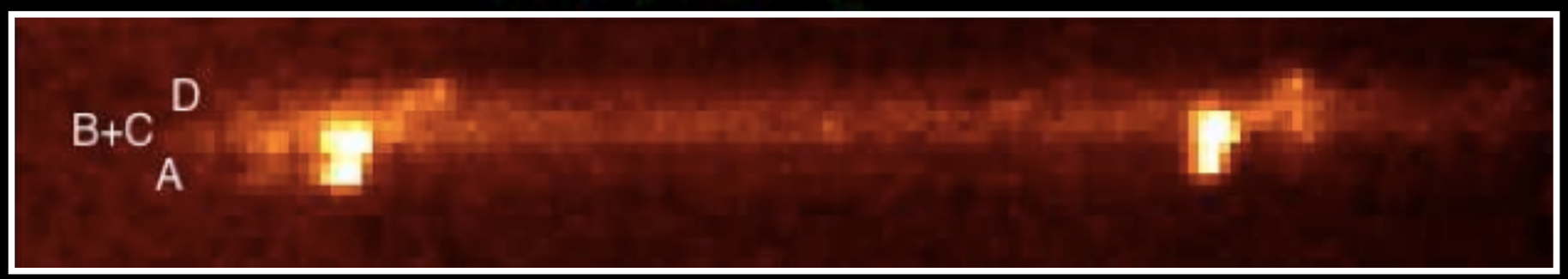
Wavelength

HST/ACS optical multi-color image

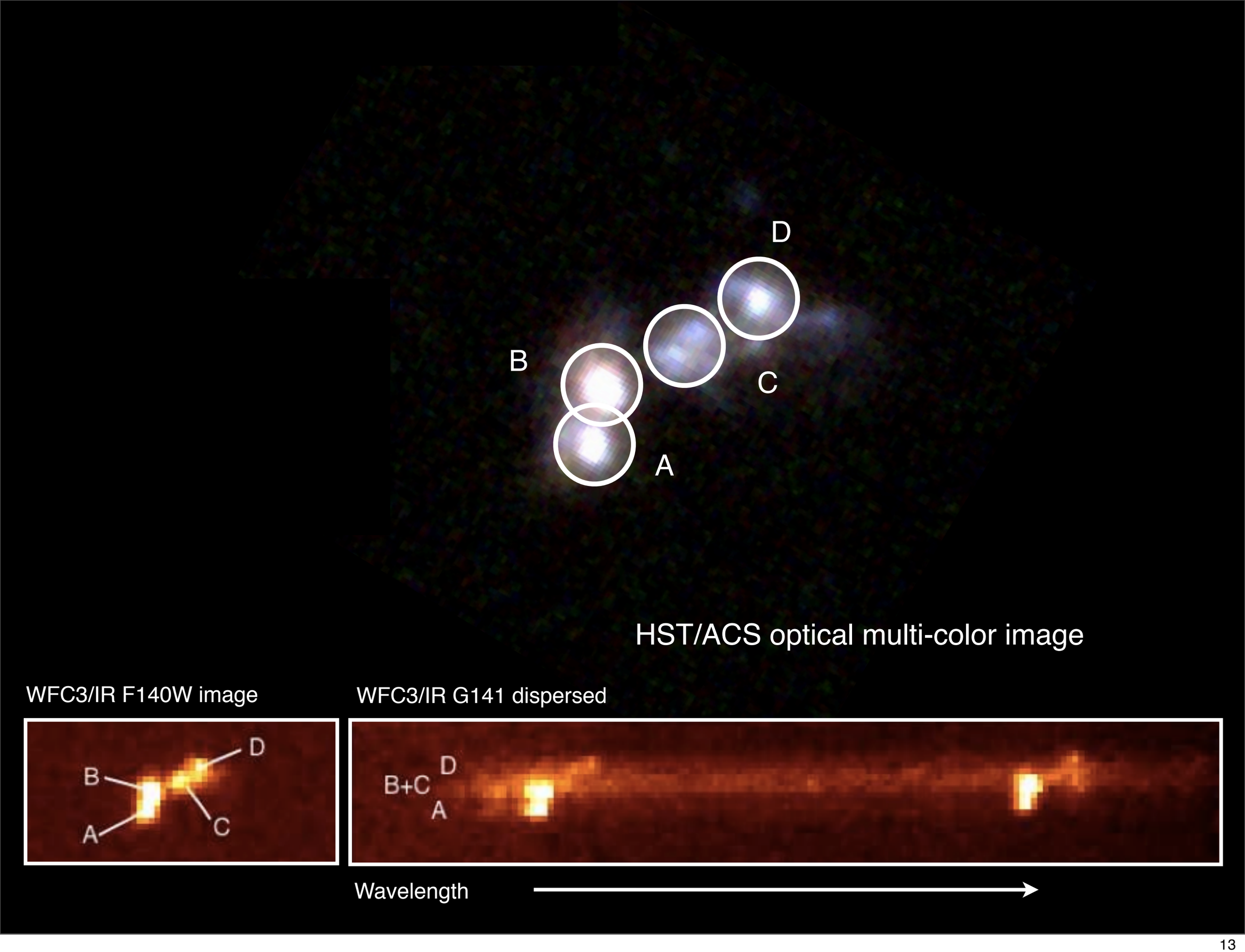
WFC3/IR F140W image

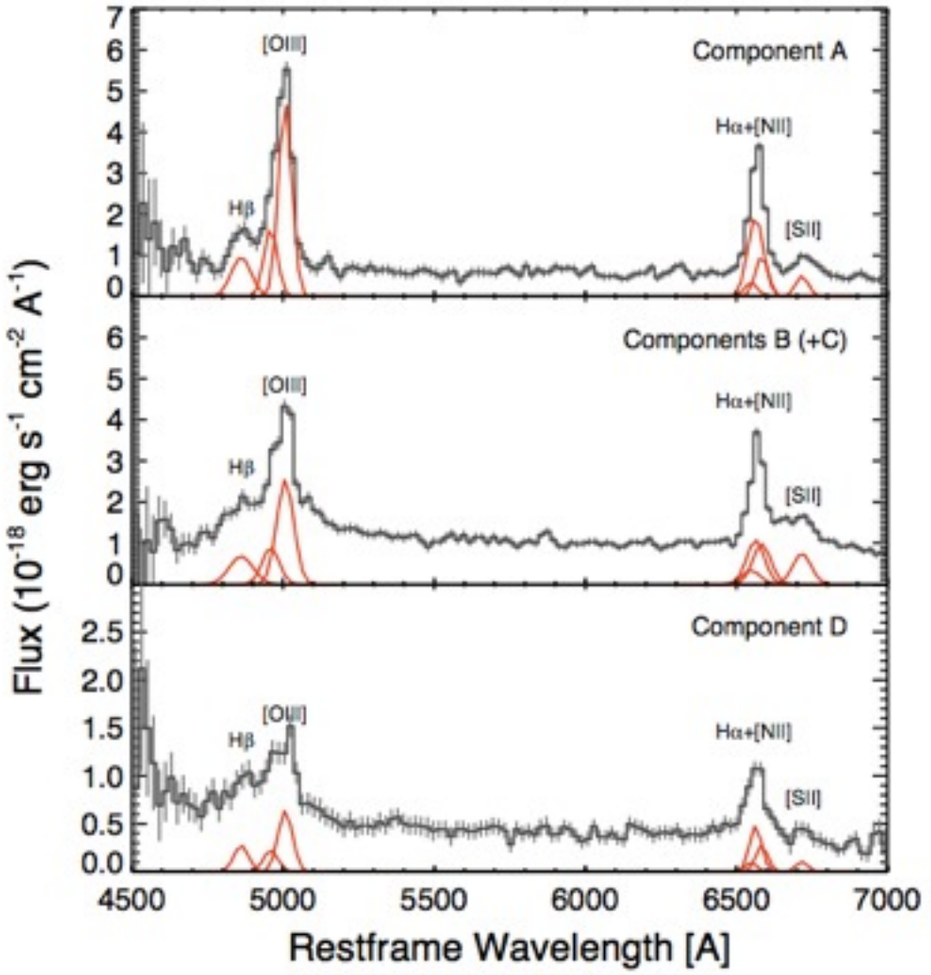


WFC3/IR G141 dispersed



Wavelength


D
B
C
A
HST/ACS optical multi-color image
WFC3/IR F140W image
WFC3/IR G141 dispersed
B
D
A
C
B+C
D
A
Wavelength



Component	L[OIII] 5007 erg/s	Black Hole Mass $M_\odot$
A	7×10^{41}	3×10^{6}
B	7×10^{41}	1×10^{7}
C	-	3×10^{6}
D	2×10^{41}	1×10^{7}

Eddington ratios implied ~0.1- 1, growth time short t~100 Myr

Summary

We are at the “  stage” on black hole seeds

Where are the z>6 growing black holes in normal galaxies? Missed, or not there?

Late formation of seeds [for normal mass galaxies] increasingly attractive possibility - need more observations!

z>6 universe still effectively unexplored,

COSMOS *Chandra* XVP will be game changer due to large volume probed