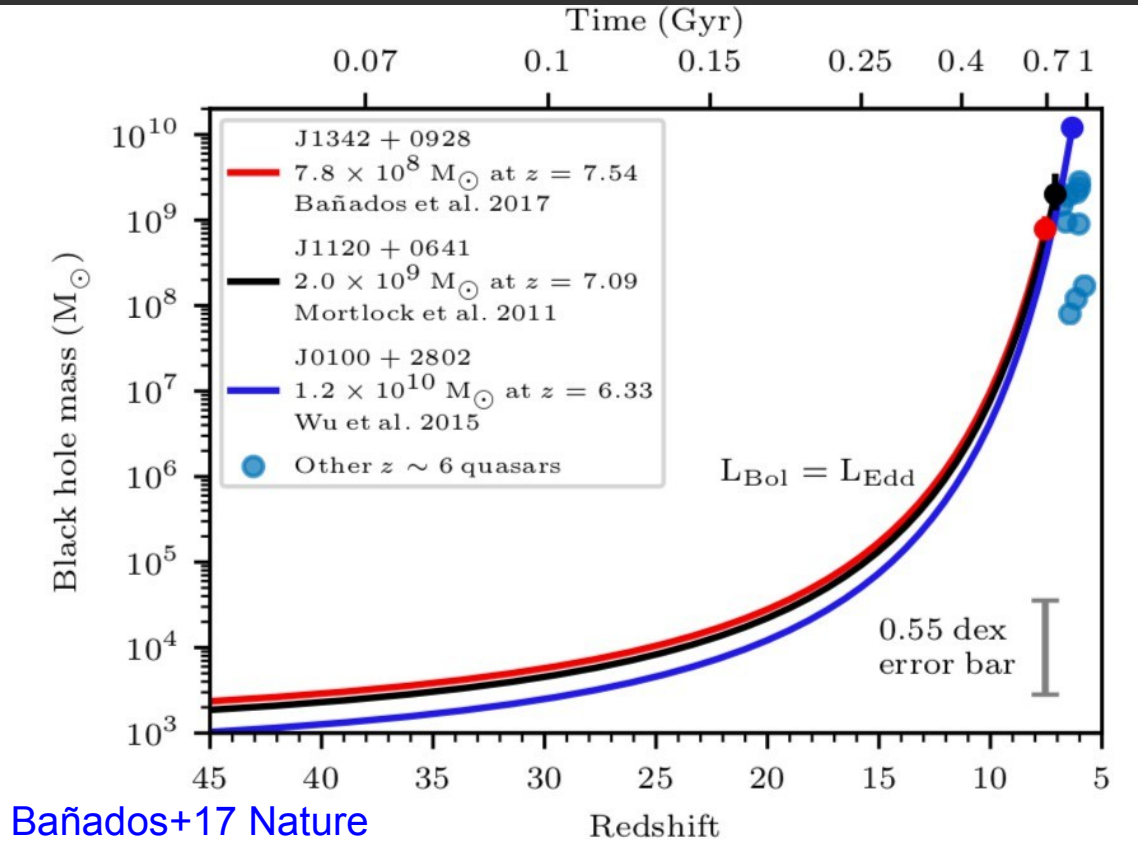


Formation and growth of the earliest SMBH and the Athena-WFI Survey

G. Lanzuisi, **A. Comastri**, **J. Aird**,
M. Brusa, N. Cappelluti, R. Gilli, F. Vito, I. Matute...



How the $z > 6$ SMBH got their mass?

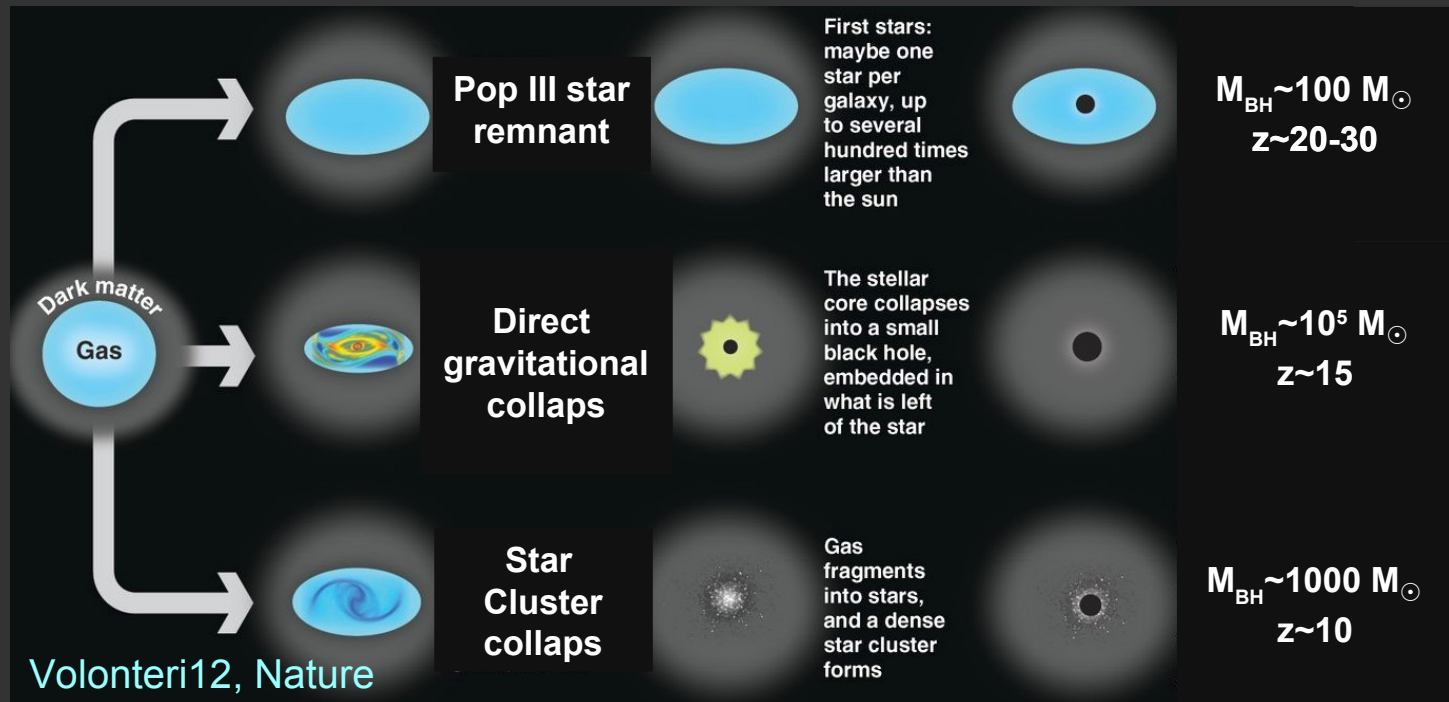


$z > 6-7$ QSOs with
 $M_{\text{BH}} > 10^8 M_{\odot}$

Continuous Edd-limited
accretion needed for
 ~ 1 Gyr?

Heavy vs. light seeds?

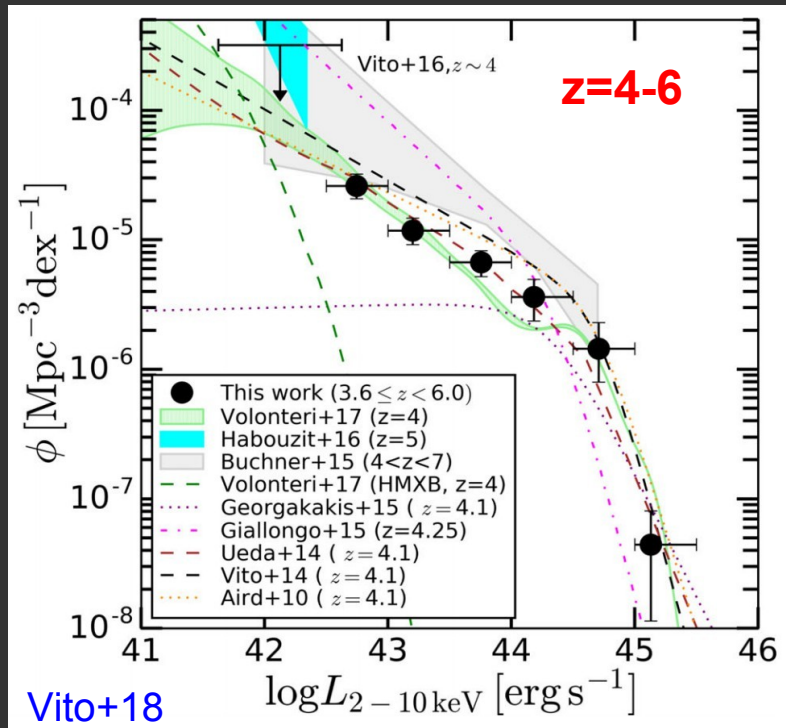
BH seeds models



- (episodic) **Super-Eddington** accretion needed?
- Different seeds work for 10^6 wrt. $10^{10} M_{\text{BH}}$ at $z \sim 6$?

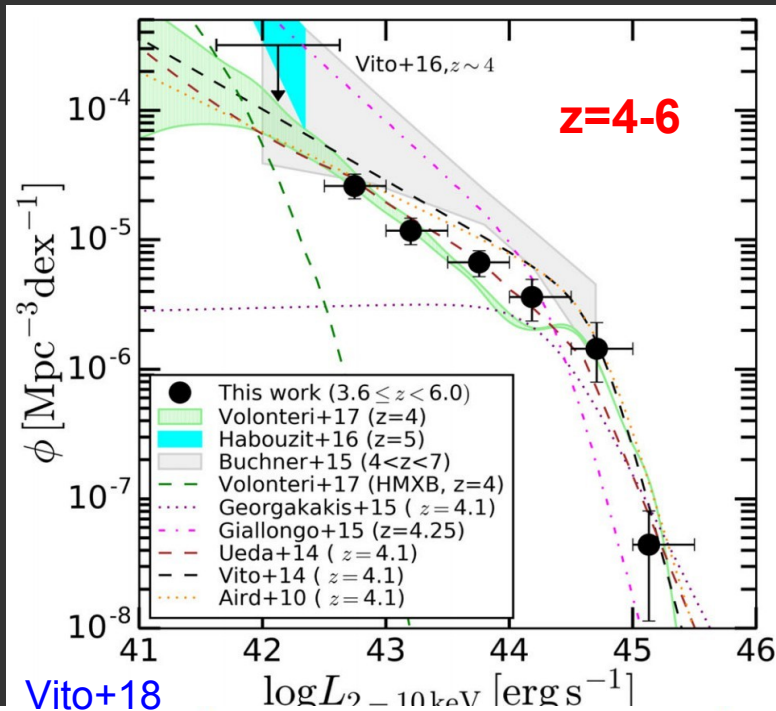
Abel+02, Broom&Loeb03, Volonteri&Rees05, Lodato&Natarajan06,
Tanaka&Haiman09, Madau+14, Pezzulli+16

State of the art: observations...



7Ms CDFS + 2Ms CDFN
+staking of undetected...

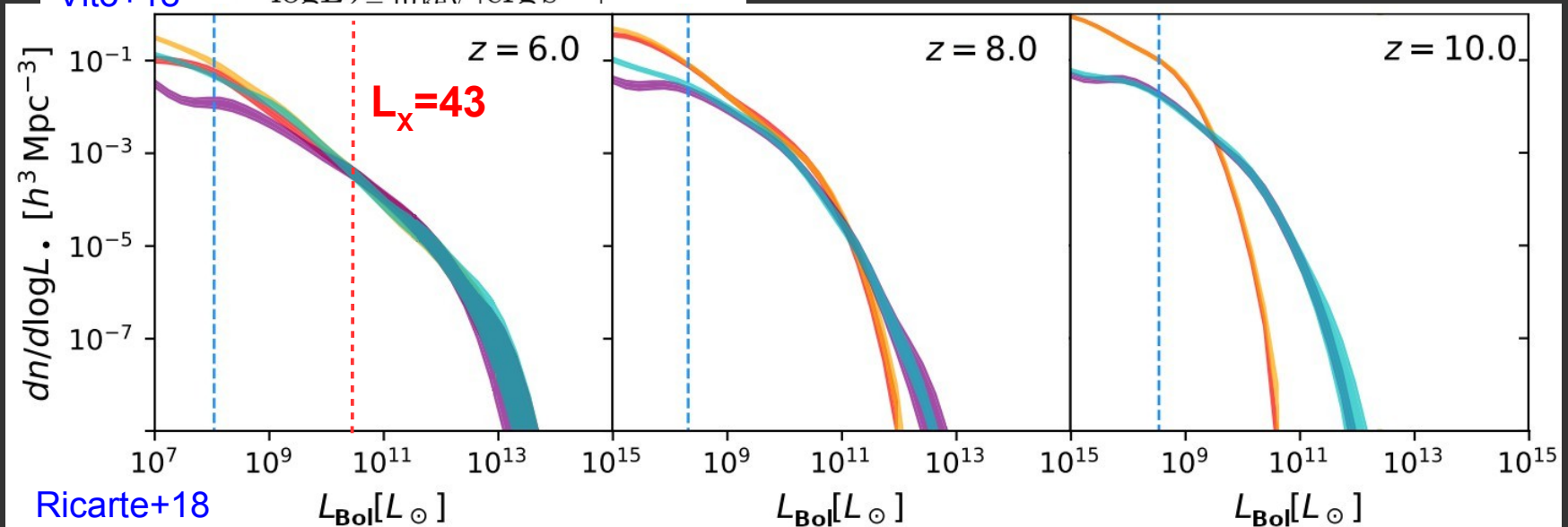
State of the art: observations... and models



7Ms CDFS + 2Ms CDFN
+steking of undetected...

Not able to constrain seed
models

Need to go **z>6!**



Athena-WFI survey capabilities

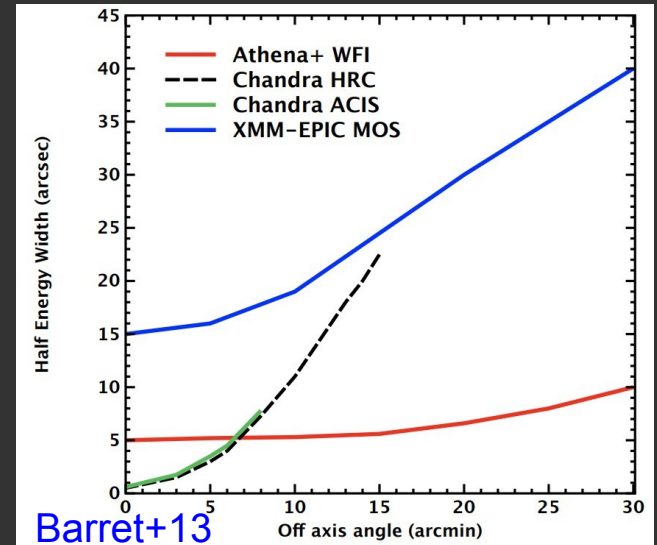
Large field-of-view (40' x 40')

+

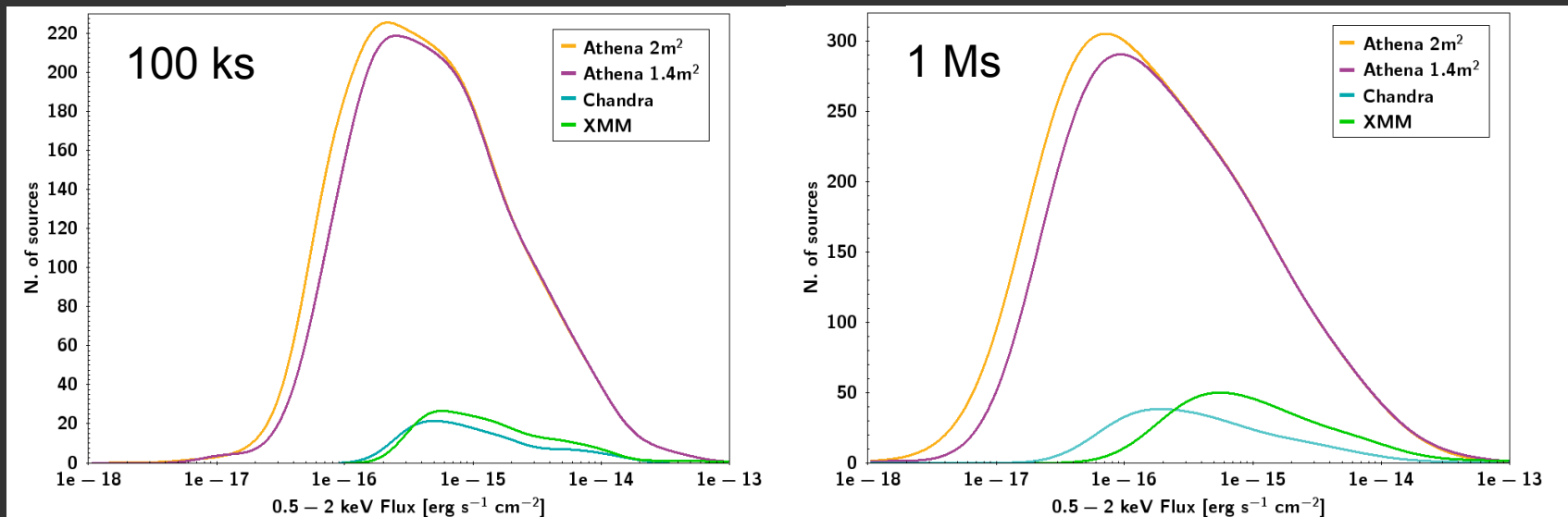
Large collecting area (1.4m²@1keV)

+

Good quality (~5") PSF over large fraction of FOV



Powerfull survey machine! 100 times Chandra/XMM

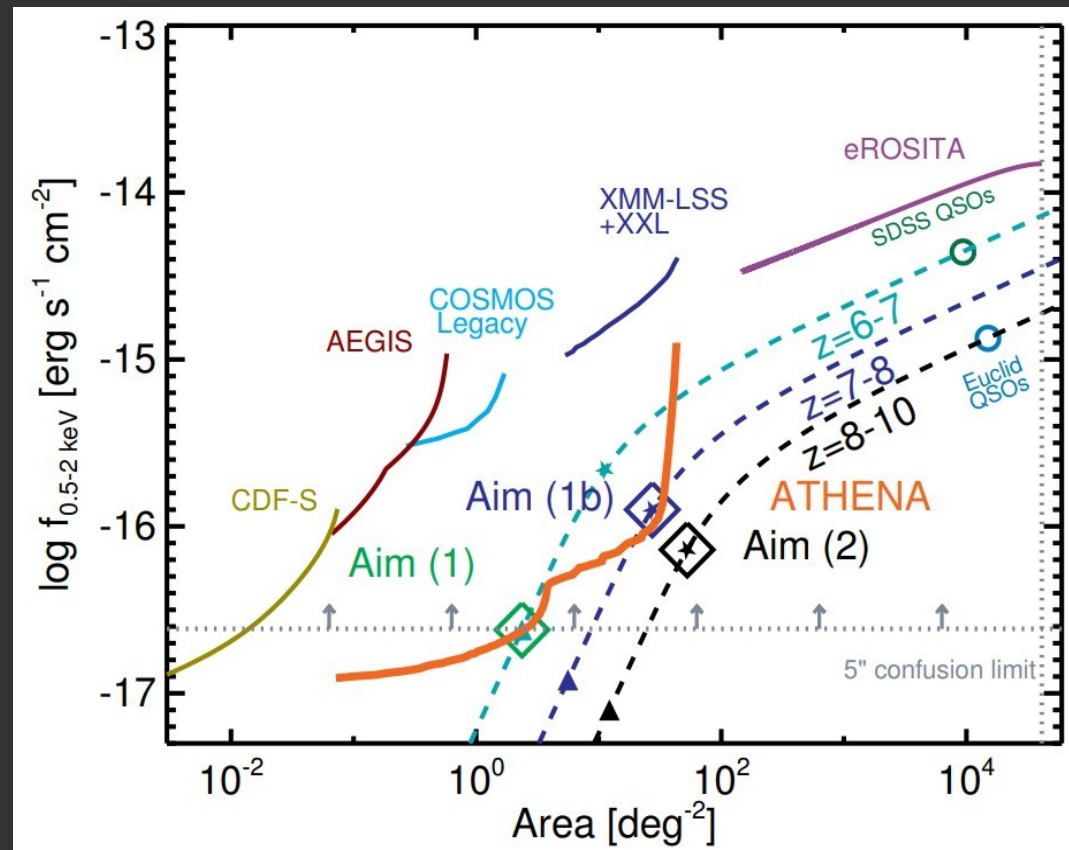


Athena-WFI survey

SciObj-211: Detect at least

Aim1: 10 AGN $z=6-7$ @ $L_x=43-43.5$ erg/s \rightarrow Flim 2.4×10^{-17} over 2.4 deg^2

Aim1b: 10 AGN $z=7-8$ @ $L_x=43.5-44$ erg/s \rightarrow Flim 1.3×10^{-16} over 27.4 deg^2



Athena-WFI survey

SciObj-211: Detect at least

Aim1: 10 AGN $z=6-7$ @ $L_x=43-43.5$ erg/s \rightarrow Flim 2.4×10^{-17} over 2.4 deg^2

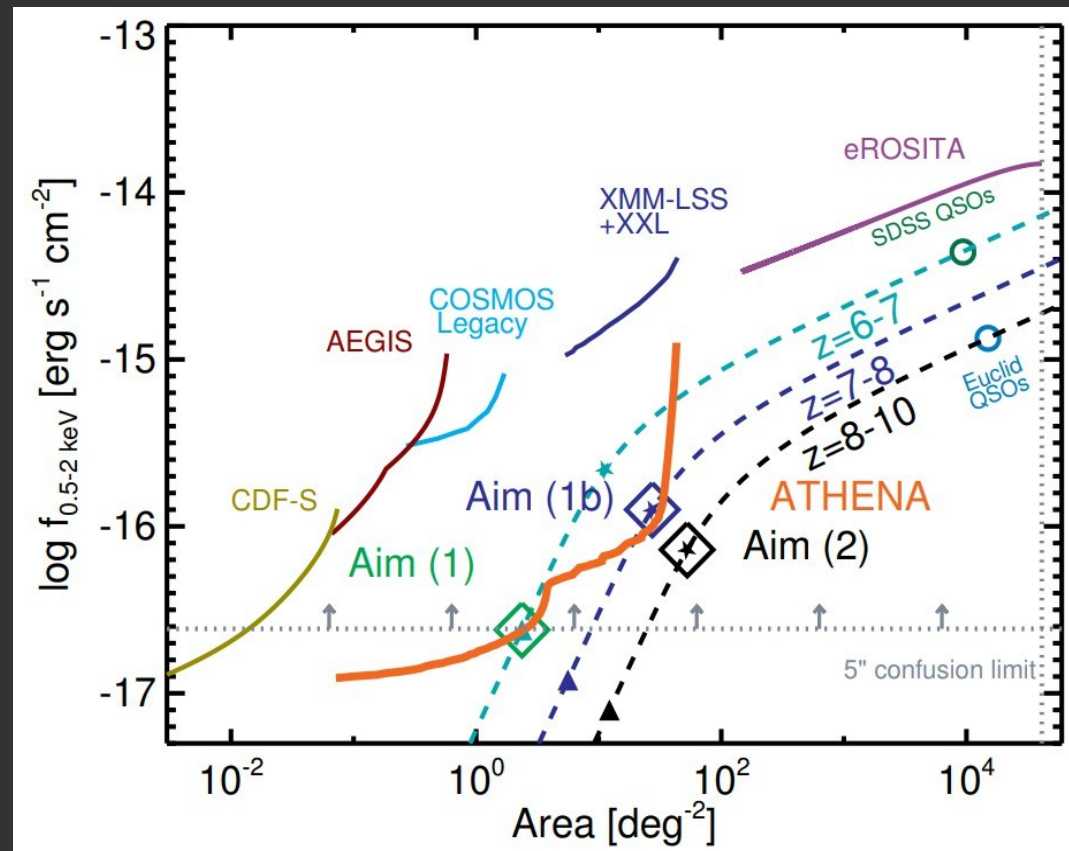
Aim1b: 10 AGN $z=7-8$ @ $L_x=43.5-44$ erg/s \rightarrow Flim 1.3×10^{-16} over 27.4 deg^2

Plus SciObj-111 **First Groups**
and SciObj-221 **CT AGN**
 \rightarrow Consolidated survey strategy:

Deep
12x1-1.5Ms

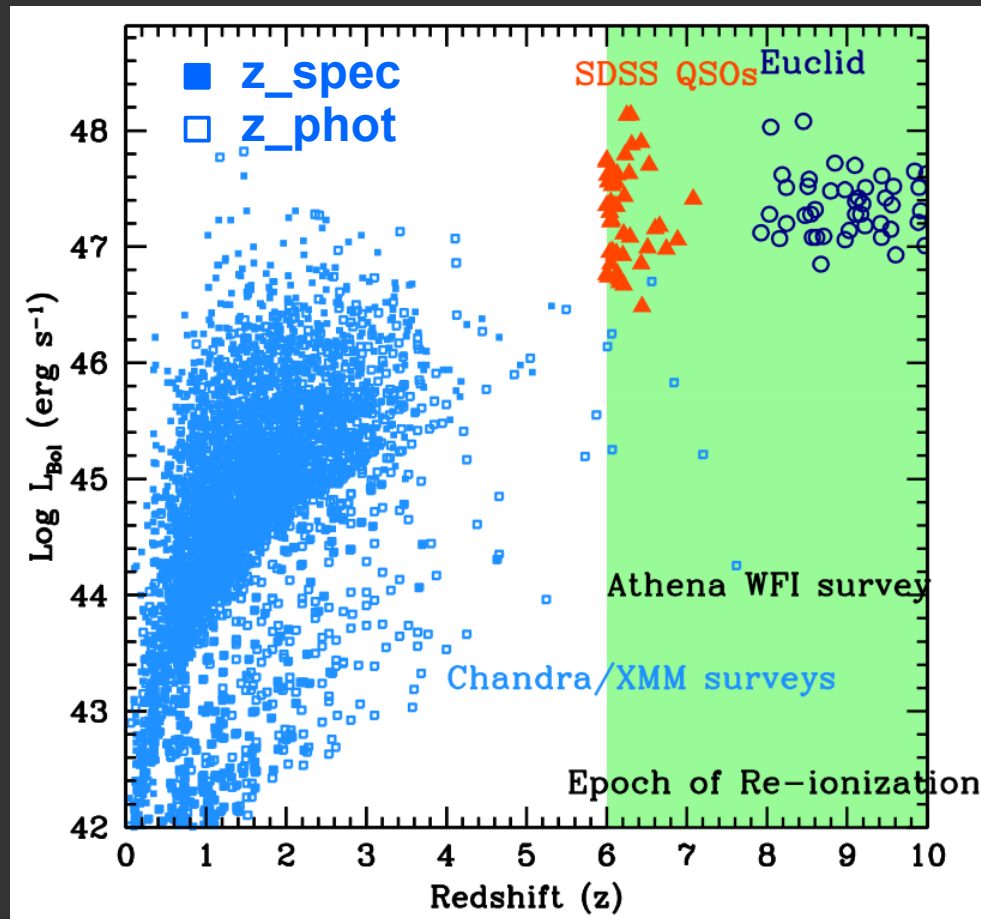
Shallow
108x90ks

Tot=23.62 Ms



Athena-WFI survey

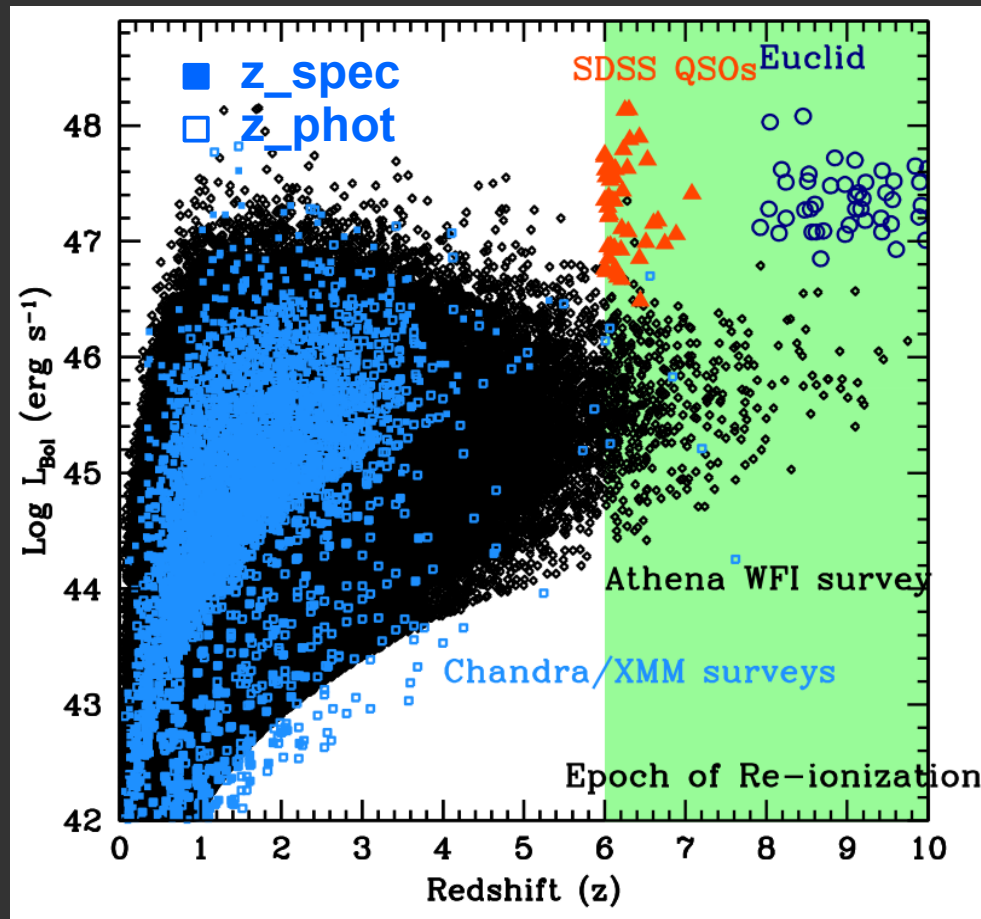
Known $z > 6$ AGN are extremely **luminous/rare QSOs** from Opt/IR surveys



Athena-WFI survey

Known $z > 6$ AGN are extremely **luminous/rare QSOs** from Opt/IR surveys

Goal: populate the $z > 6$ Lum-z plane with **hundreds of moderate luminosity AGN** ($L_x = 43-45$)



Full SIXTE simulation of a deep field

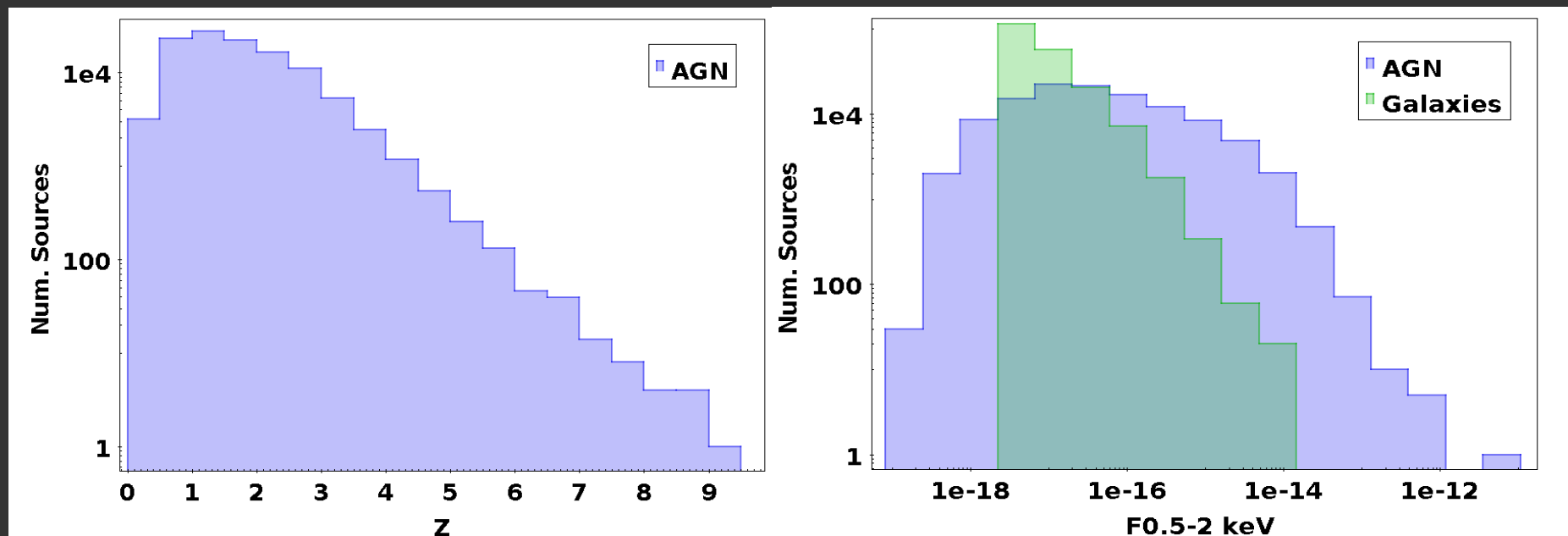
Input: Mock catalogs from [Gilli+07](#)

$\sim 10^5$ AGN in 10 deg², up to $z=8$, and with $F_{0.5-2}$ down to -18.5

Each with N_H , z , L_X

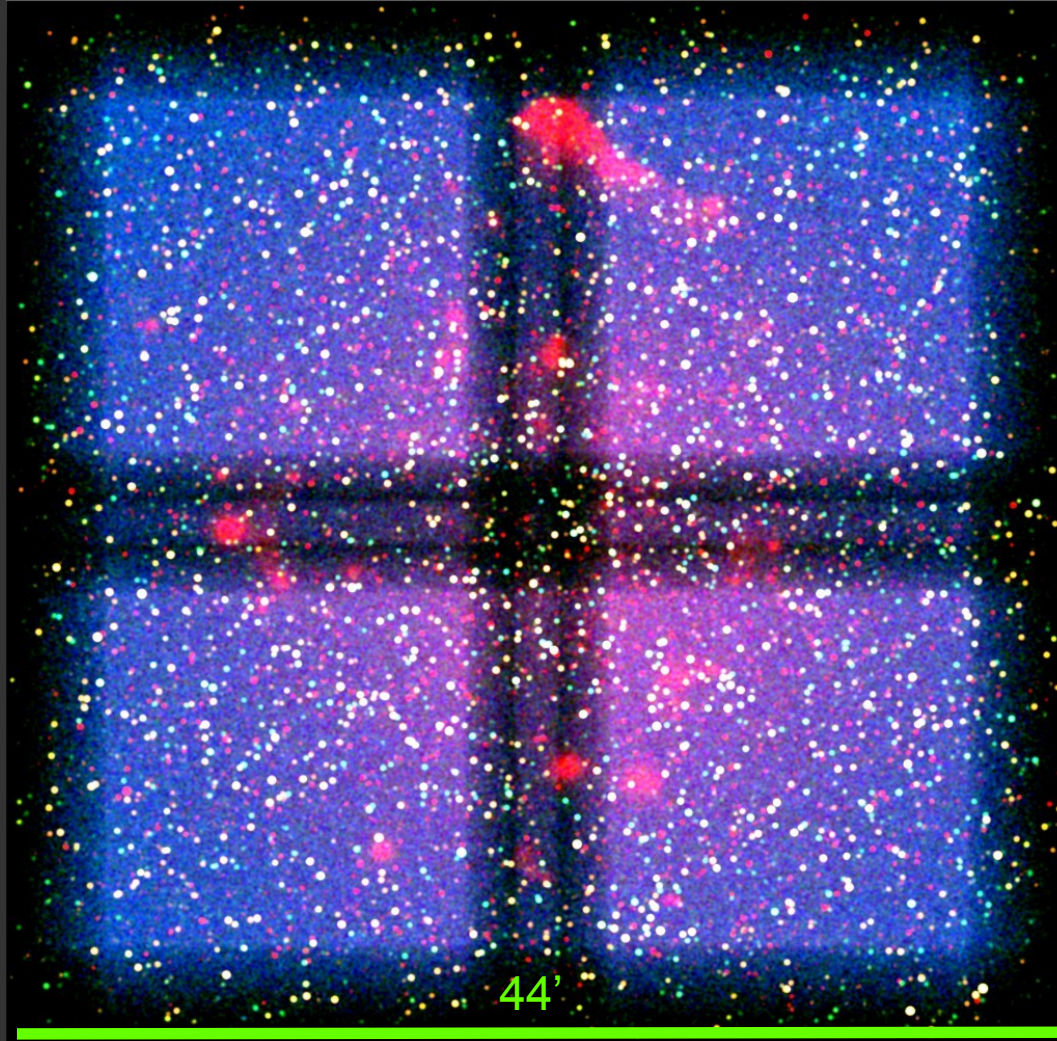
$\sim 2 \times 10^5$ Galaxies at faint fluxes

+ Extended emission from CDFS ([Finoguenov+15](#))



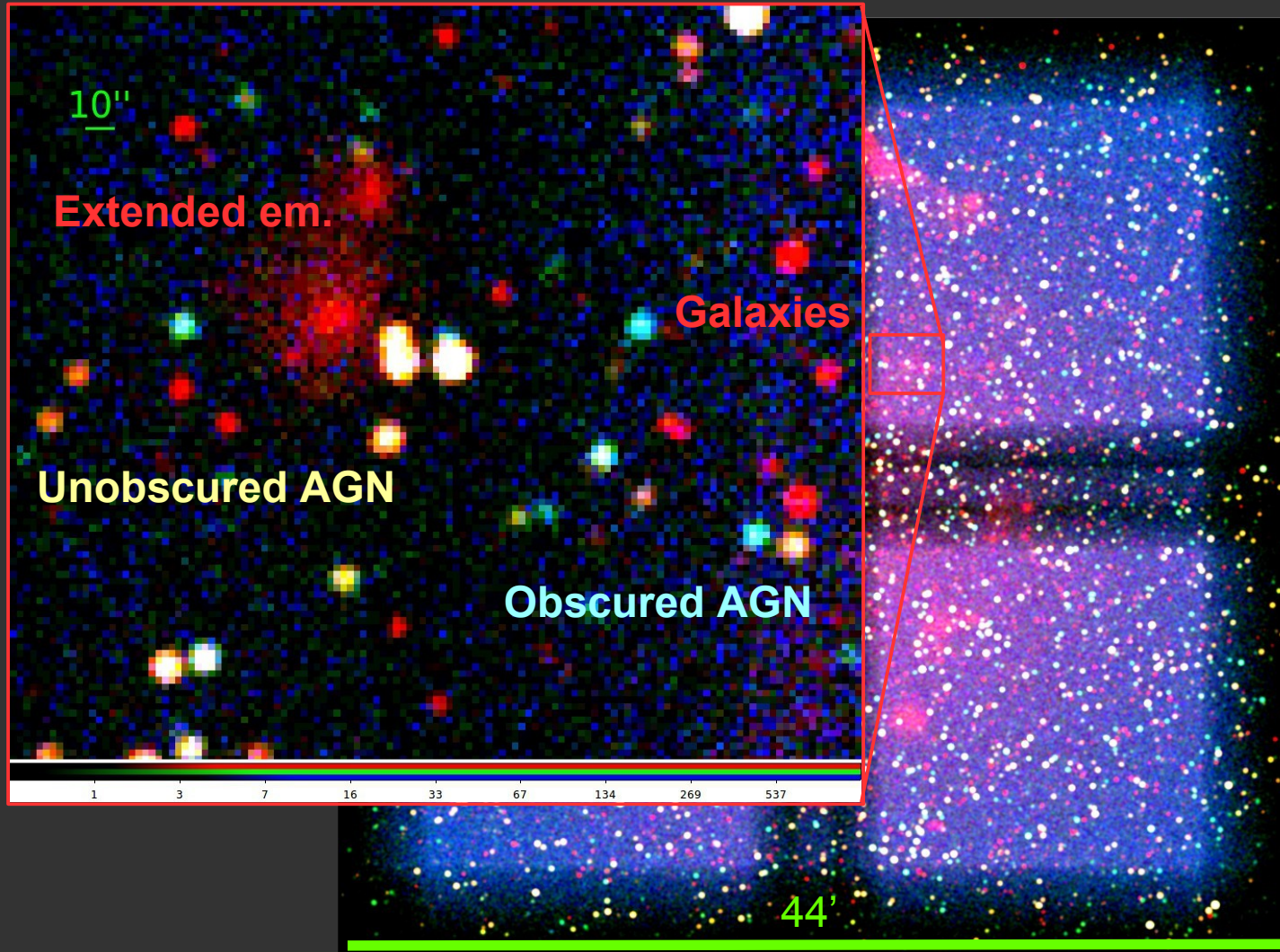
Full SIXTE simulation of a deep field

Result for 1Ms exposure (red 0.5-2, green 2-4.5 blue 4.5-10 keV)



Full SIXTE simulation of a deep field

Result for 1Ms exposure (red 0.5-2, green 2-4.5 blue 4.5-10 keV)



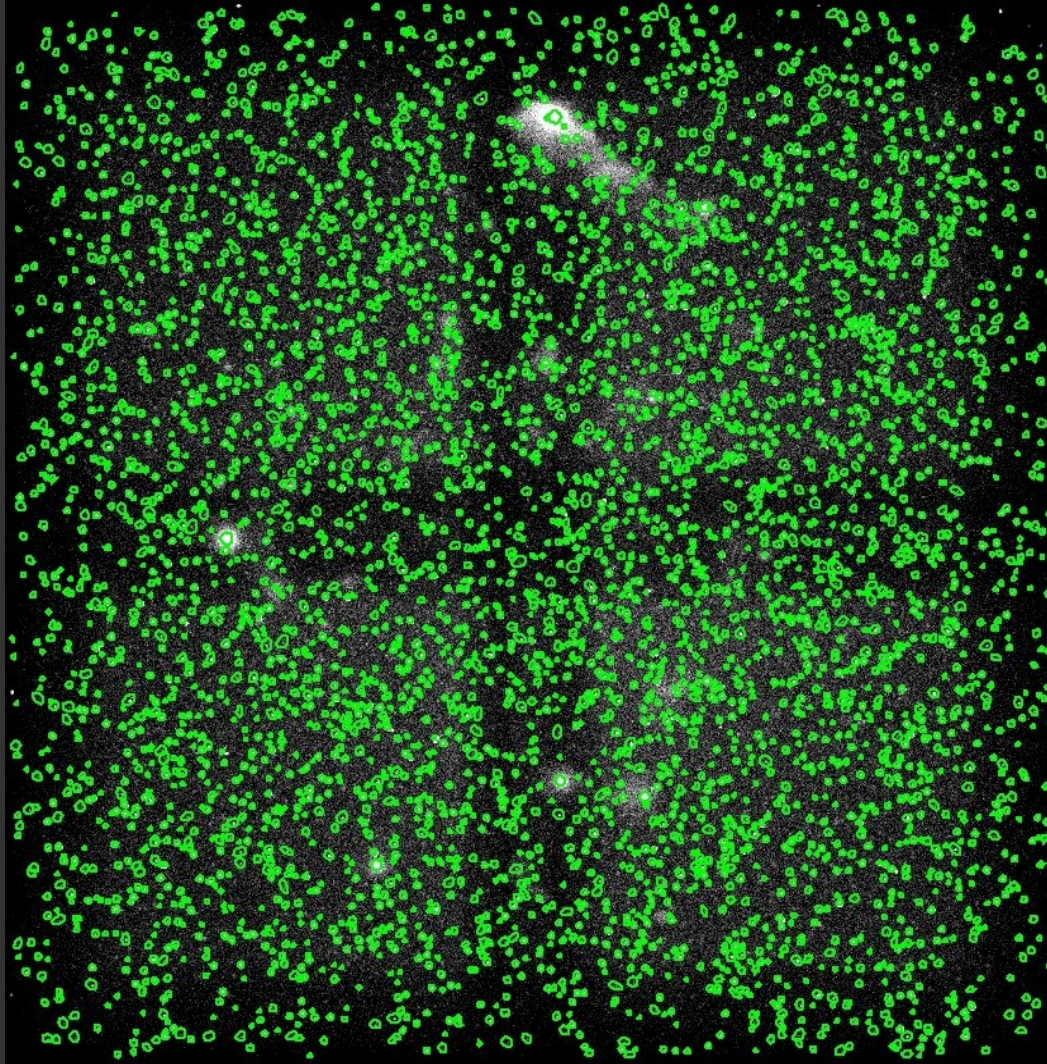
Source Detection

Run **wavdetect** on the 0.7-2 keV image



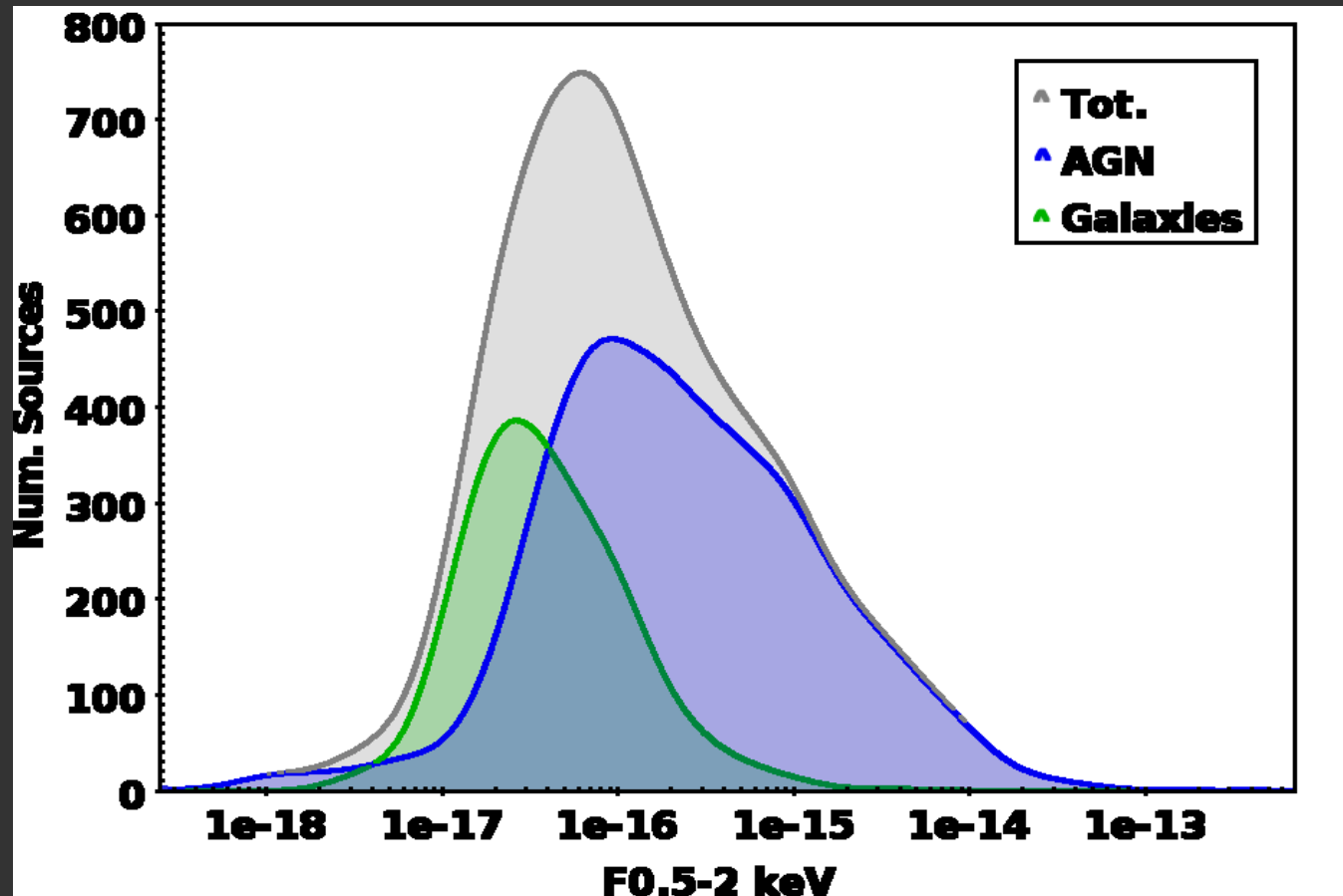
Source Detection

Run **wavdetect** on the 0.7-2 keV image → ~4300 sources detected



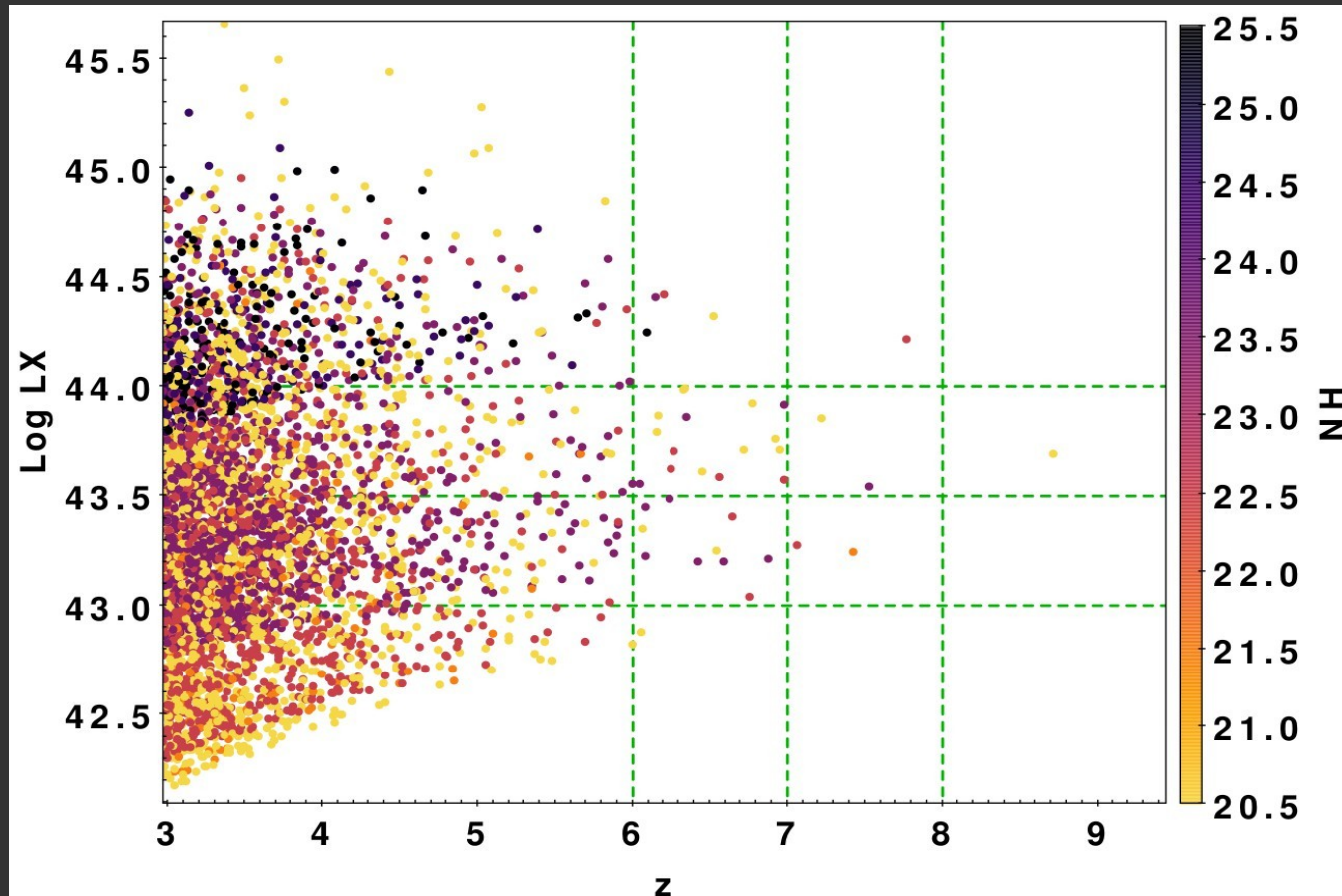
Source Detection

Run **wavdetect** on the 0.7-2 keV image → **~4300 sources detected**
~3000 AGN + 1300 Galaxies



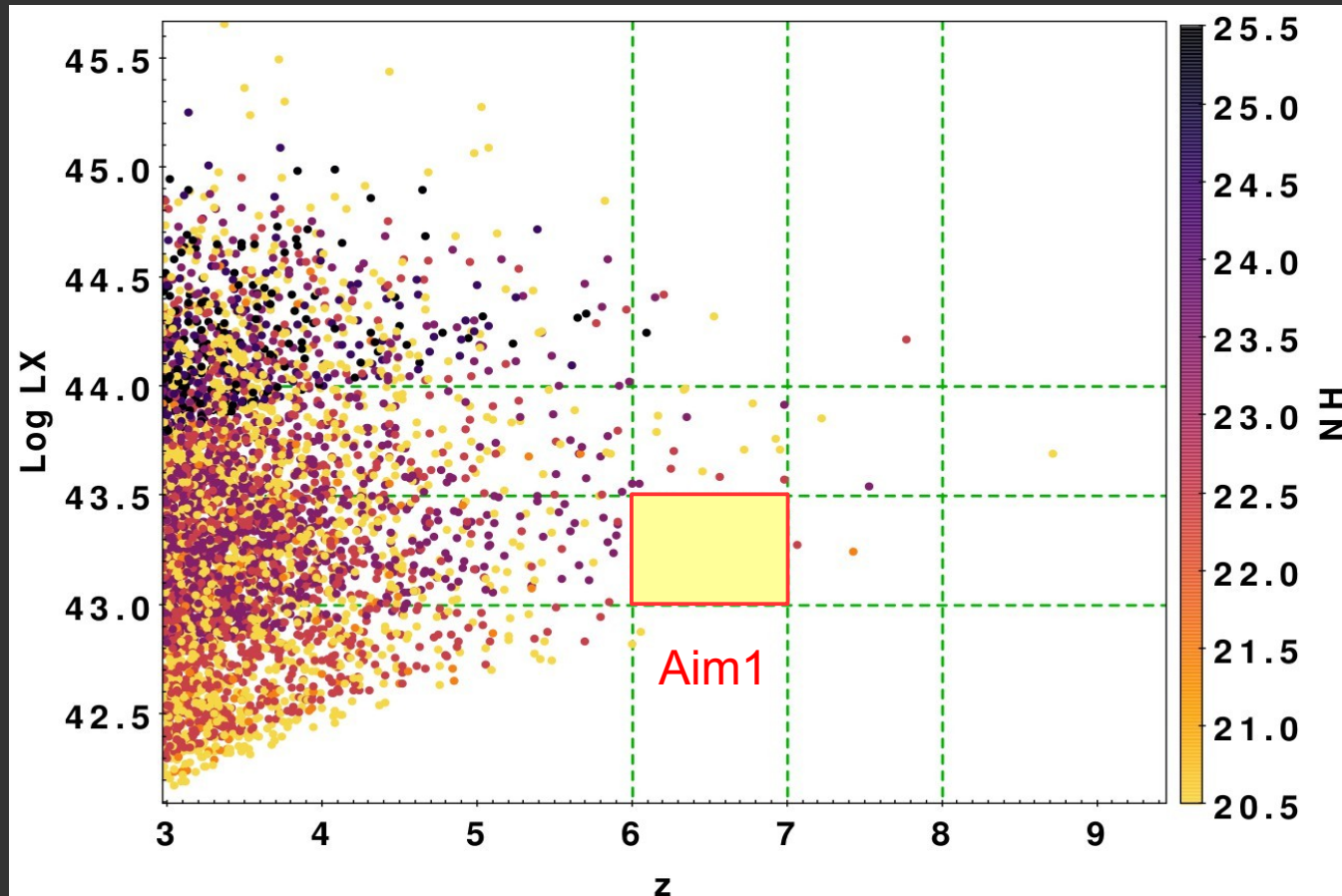
High z AGN

Over 10 deep fields \rightarrow ~ 10 AGN in the $z=6-7$ and L_X 43-43.5 box



High z AGN

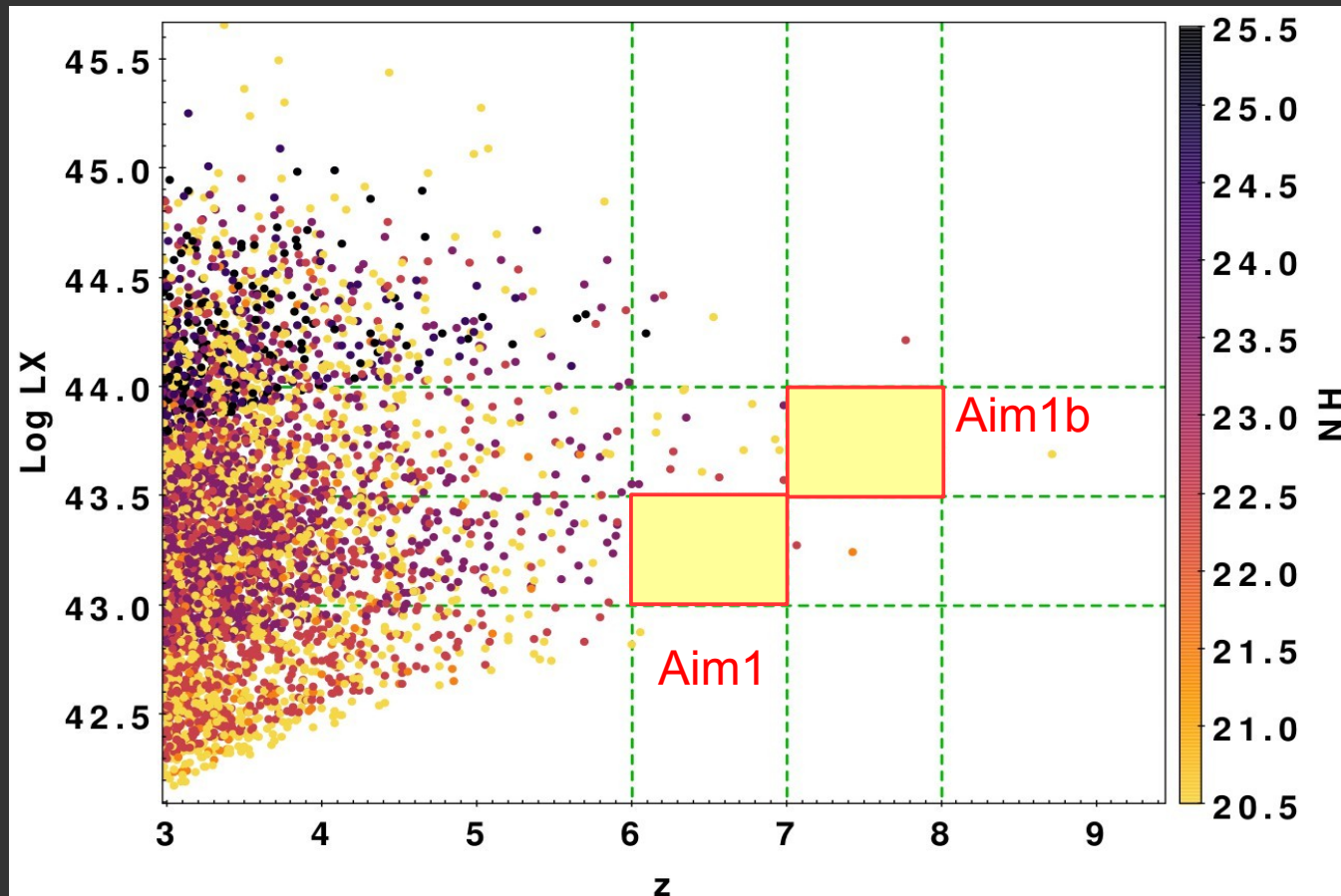
Over 10 deep fields \rightarrow ~ 10 AGN in the $z=6-7$ and L_x 43-43.5 box



High z AGN

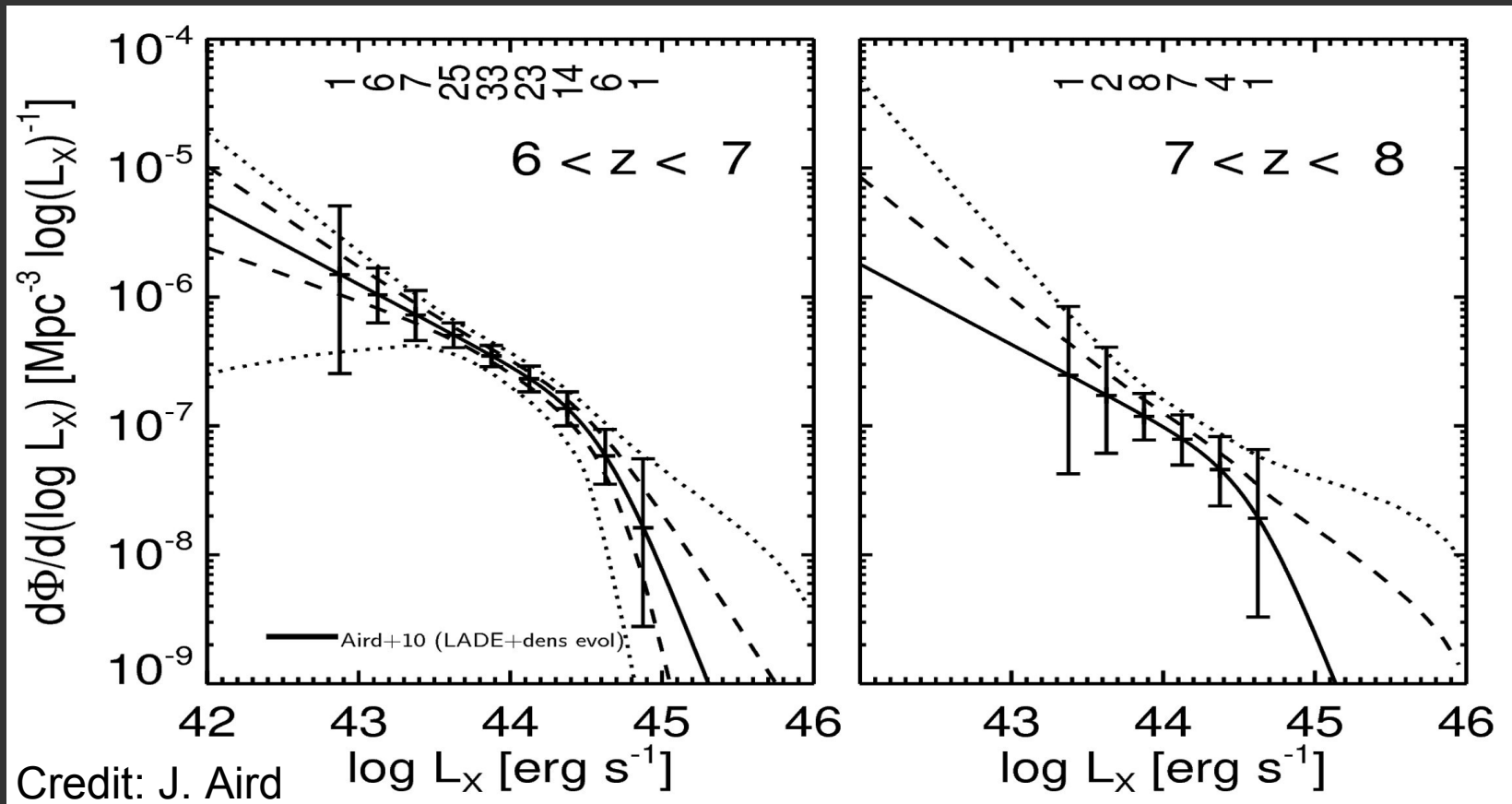
Over 10 deep fields \rightarrow ~ 10 AGN in the $z=6-7$ and L_x 43-43.5 box

TBD: test Aim1b over ~ 100 shallow fields...



Expected high-z LF

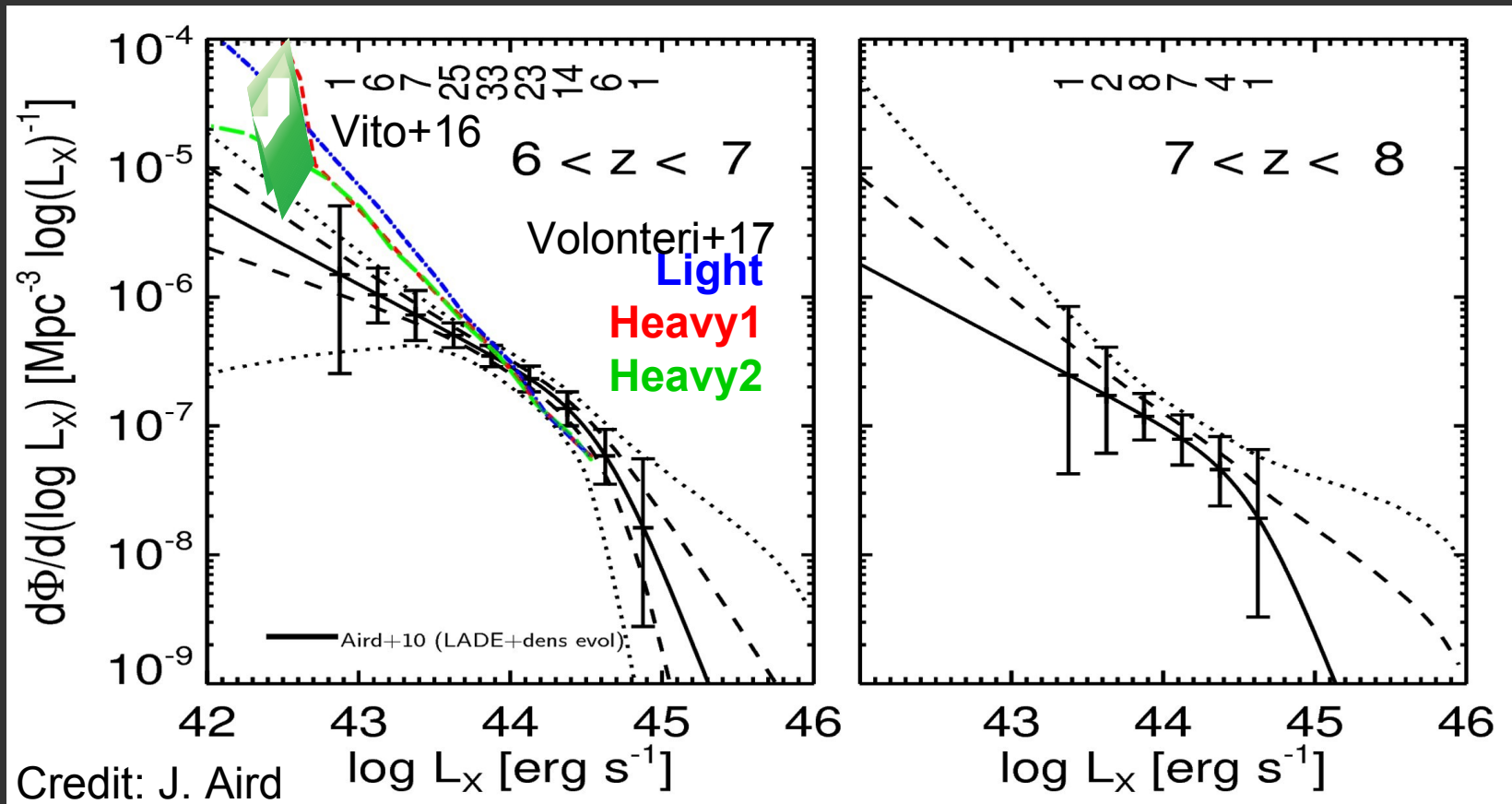
Good constraints on $z=6-7$ LF, loose on $z>7$ (wide survey reduced in CORE ex.)



Expected high-z LF

Good constraints on $z=6-7$ LF, loose on $z>7$ (wide survey reduced in CORE ex.)

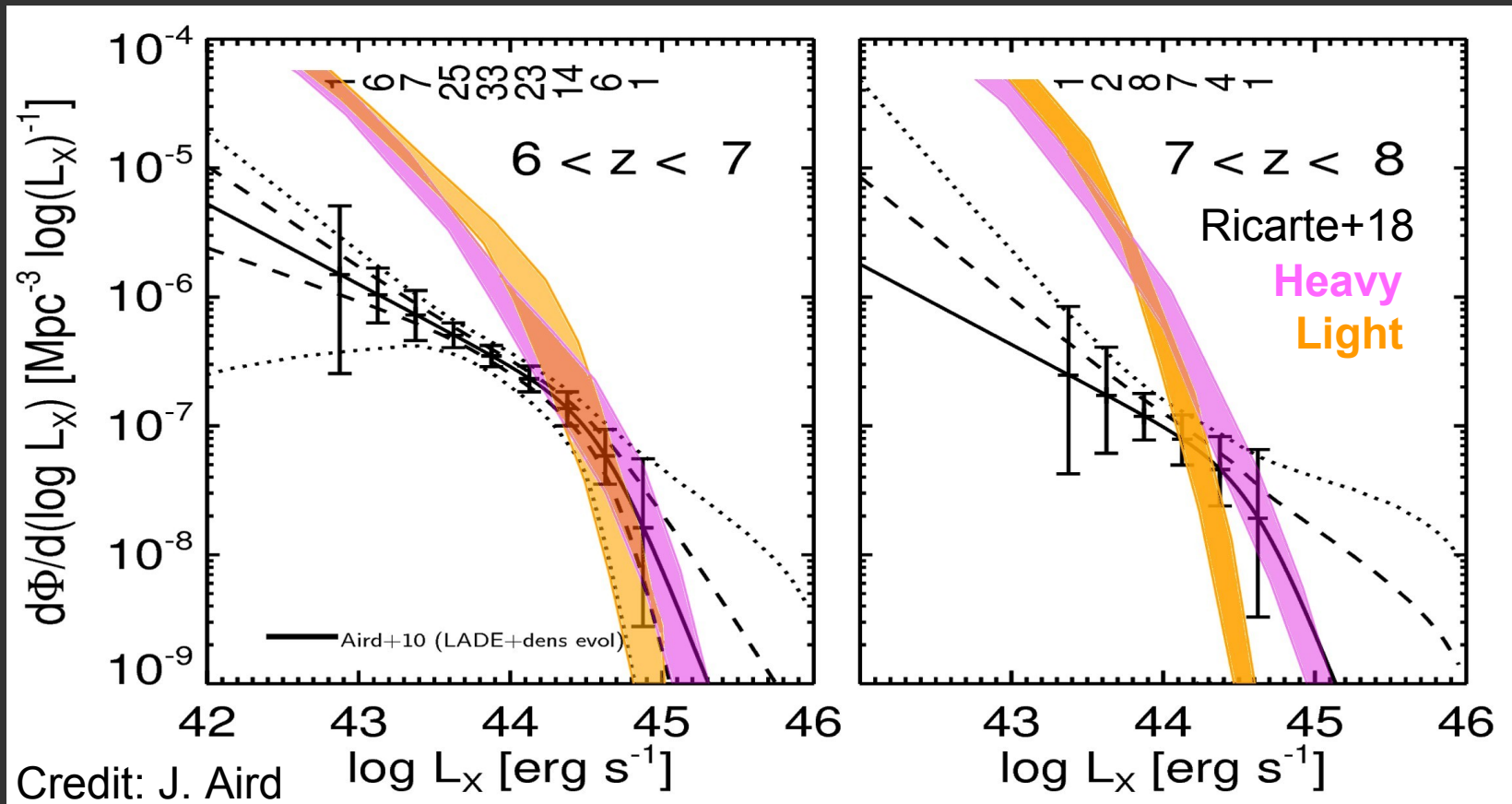
Still huge impact on **seed models!** Unexplored L_x - z range



Expected high-z LF

Good constraints on $z=6-7$ LF, loose on $z>7$ (wide survey reduced in CORE ex.)

Still huge impact on **seed models!** Unexplored L_x - z range



Conclusions

Only a minority of the $z > 6$ QSOs were uncovered even at high masses/luminosities and none of them with X-rays

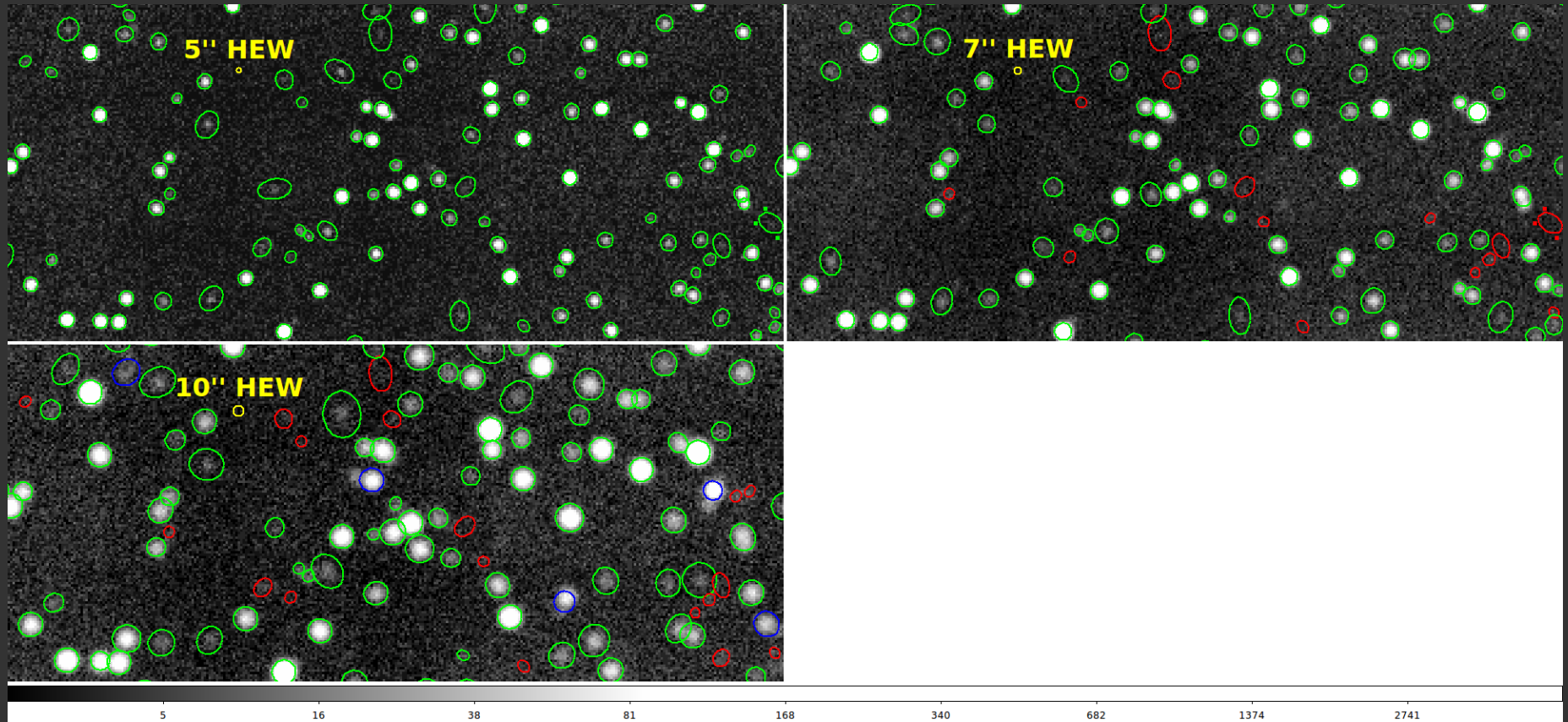
Several hundreds of moderate luminosity AGN at $z \sim 6-7$ and Luminous quasars at $z \sim 8-9$ will be detected by multi-layered Athena Surveys

Athena will open up the parameter space to a level where the key Issues concerning the formation and early evolution of the first SMBH can be addressed

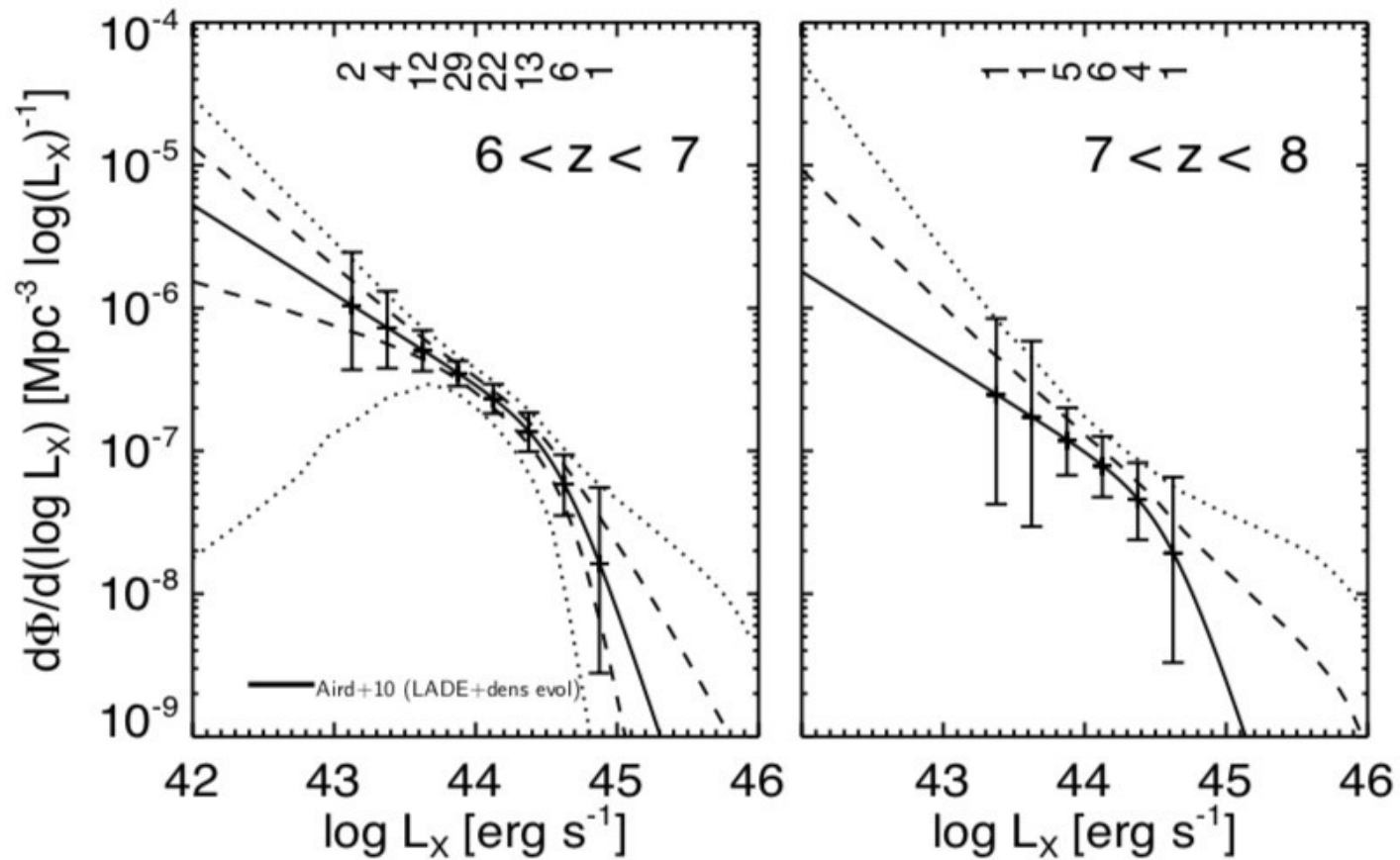
While waiting for the new missions we should aim to increase — by an order of mag — the area surveyed in the X-rays at relatively faint fluxes exploiting the survey capabilities of Chandra and XMM

Multiwavelength searches (e.g. JWST-ALMA-MUSE)

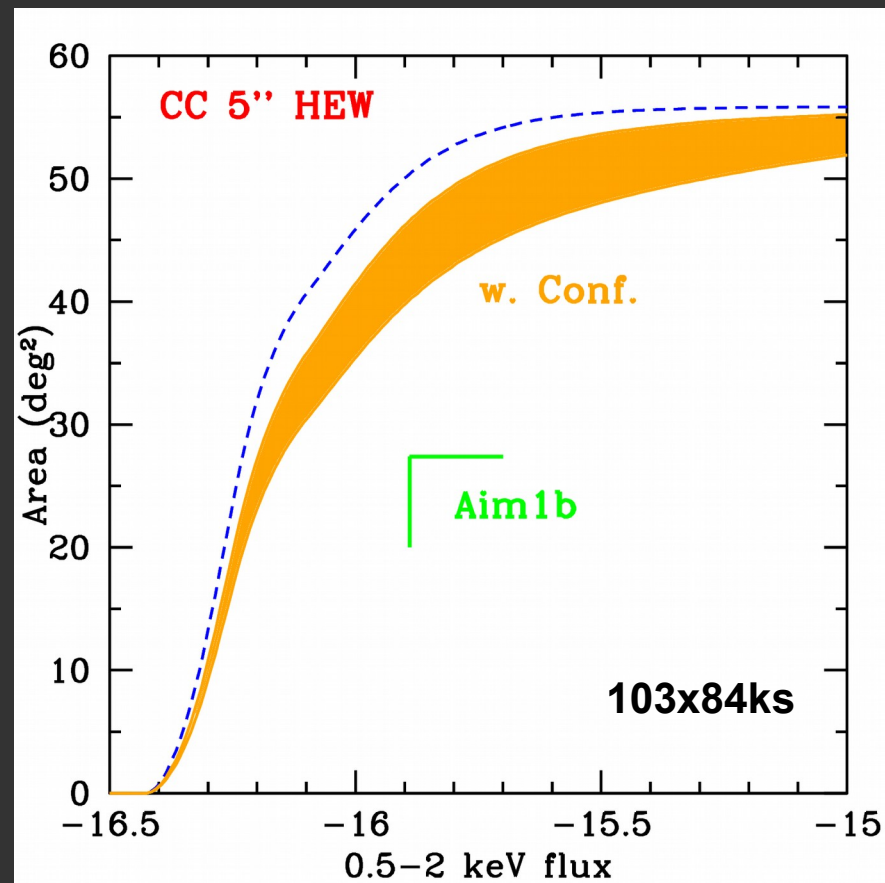
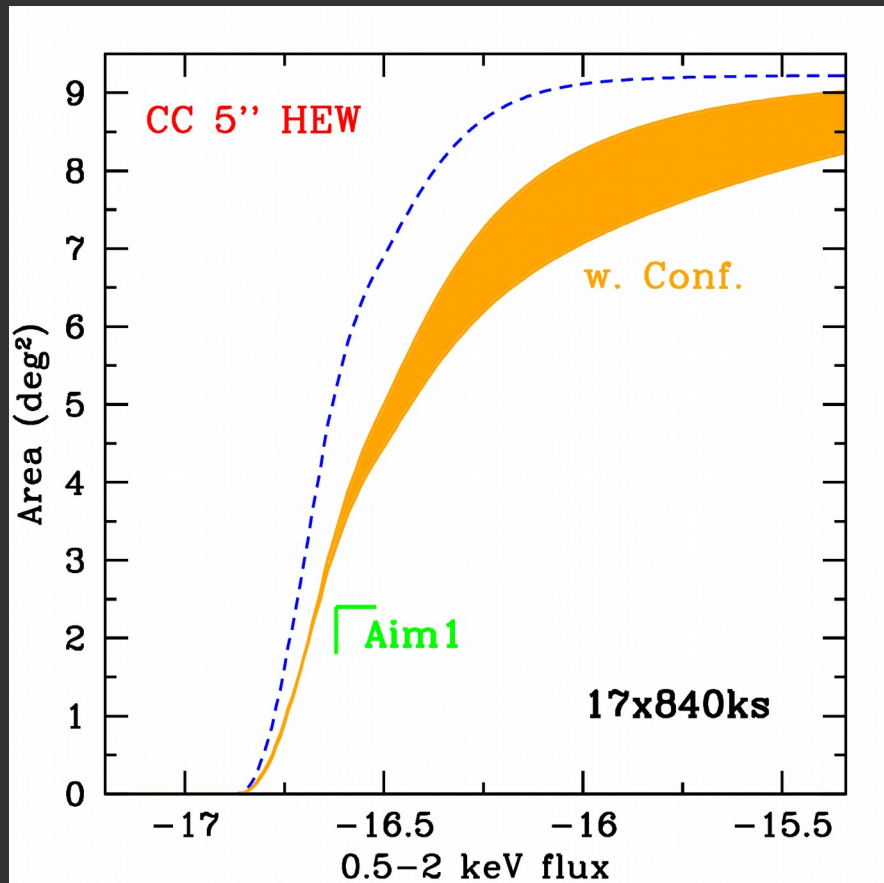
Different HEW



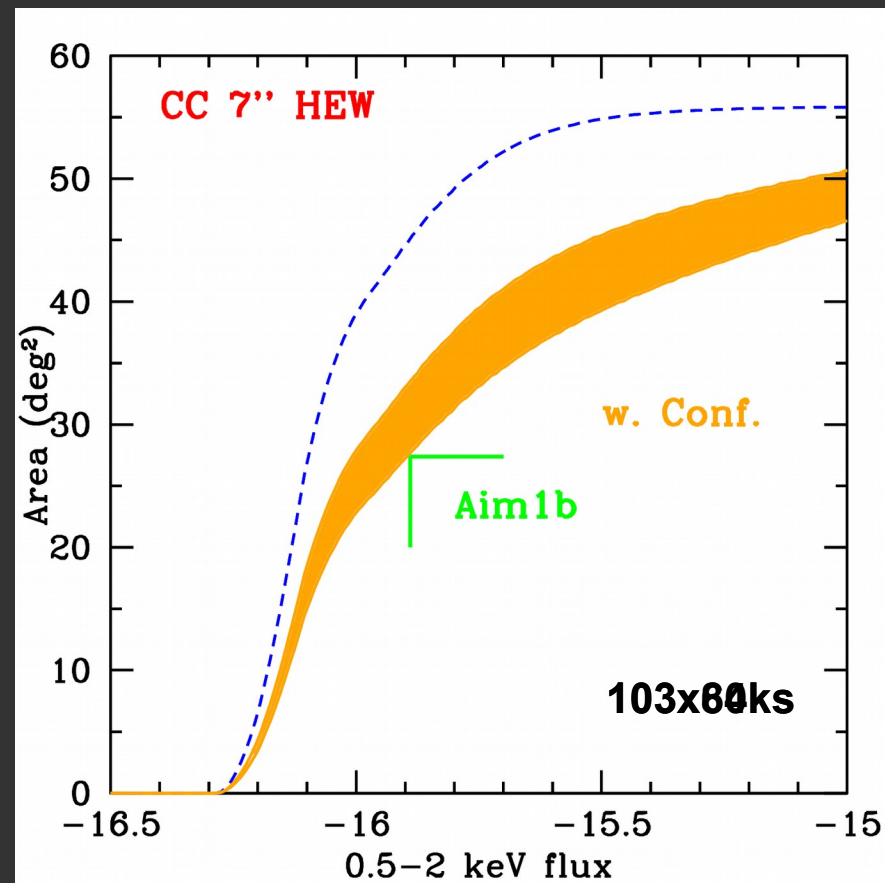
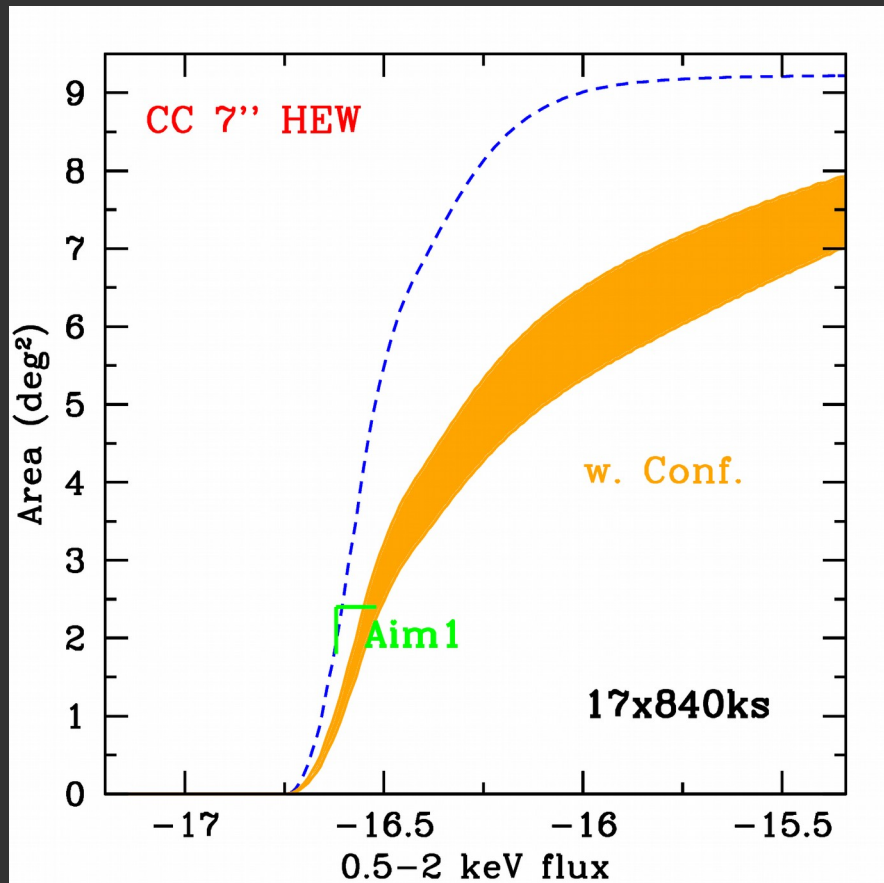
7 arcsec HEW



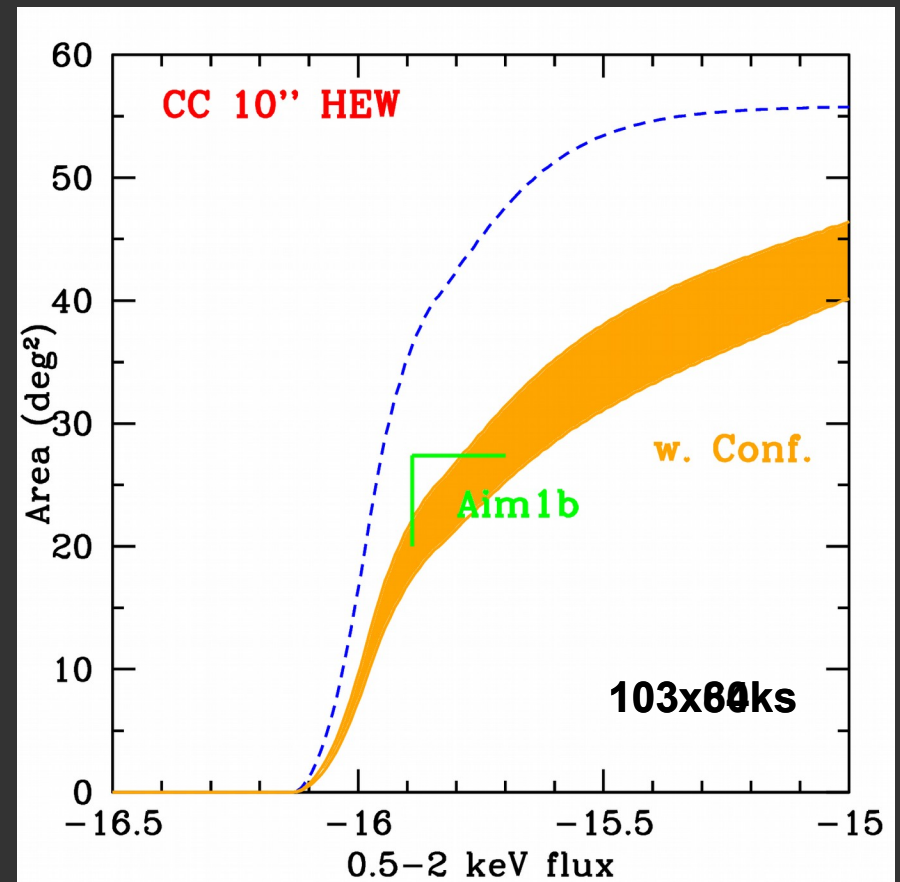
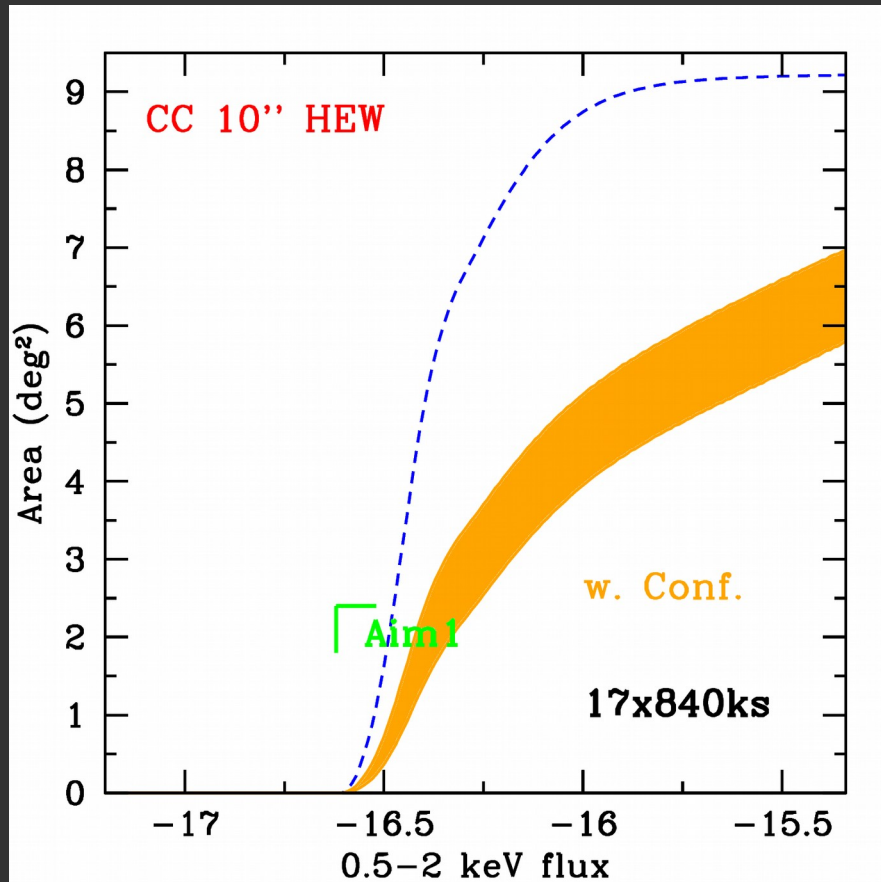
Different HEW



Different HEW



Different HEW

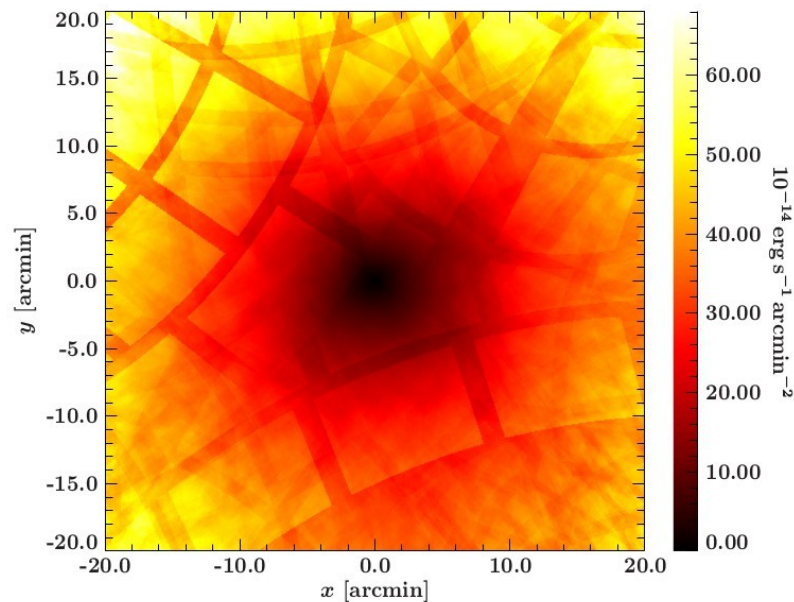


TBD: add stray-light impact

Straylight implementation into SIXTE is progressing.
Setup for CXB test simulation (Jörn Wilms):



simulations performed without WFI gaps and dithering and 5" pixel size (to be applicable also to X-IFU)



0.5-2keV flux ~ 0.3 cps averaged over FoV ($\sim 1 \times 10^{-3}$ cnt s $^{-1}$ cm $^{-2}$ keV)

BKG counts maps

- Diffuse galactic foreground
 - CXB (80% resolved)
- } Vignetted
- particle background

0.7-2 keV

optimized to reduce bkg contribution

