SCUOLA
NORMALE
SUPERIORE

First stars, first black holes

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DAVID

The Dark Ages VIrtual Department

http://www.arcetri.astro.it/twiki/bin/view/DAVID/WebHome


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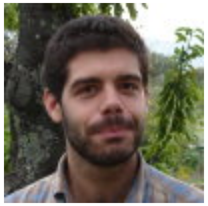
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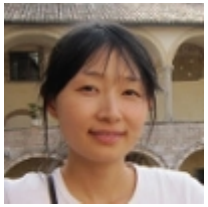
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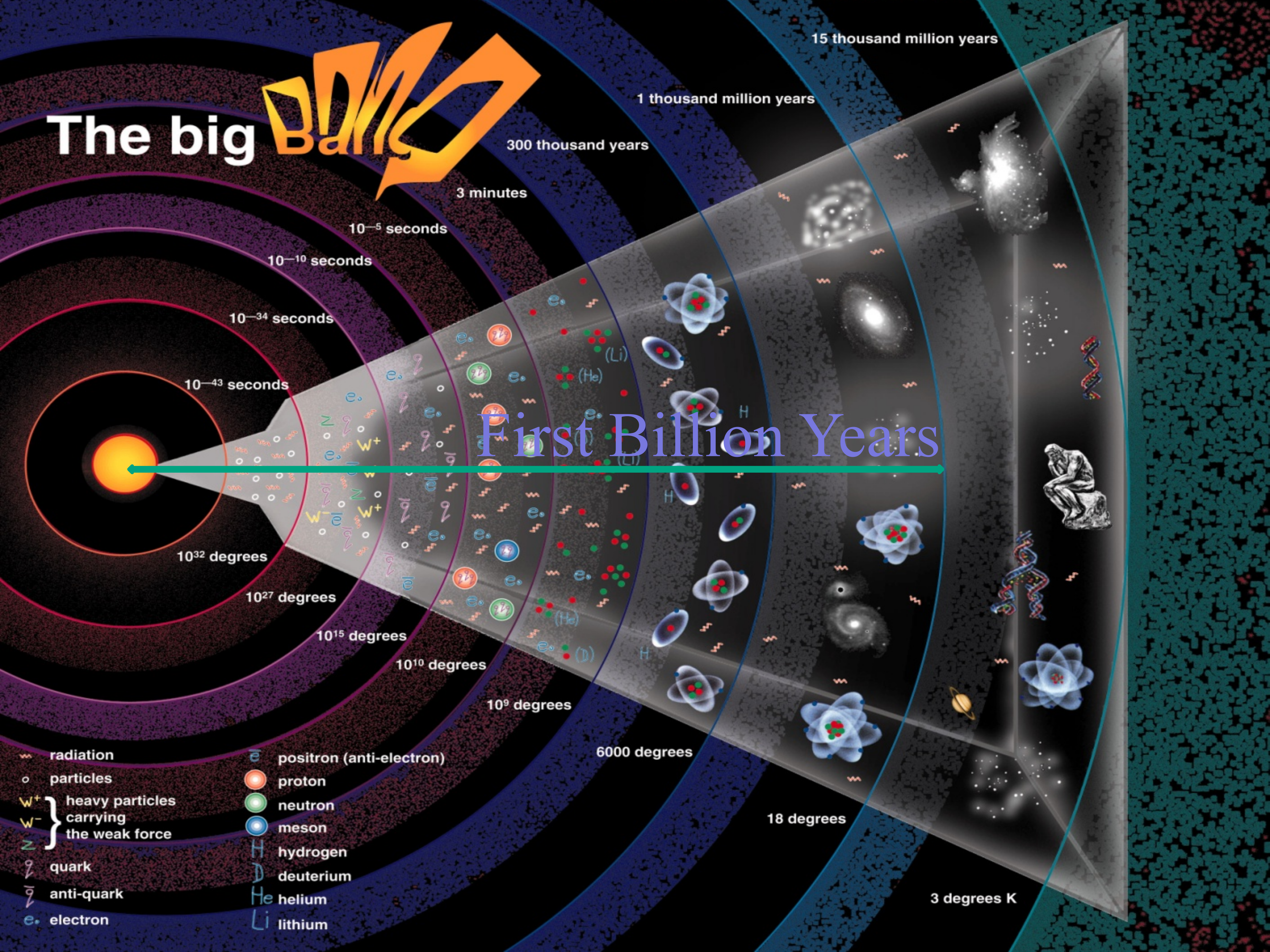
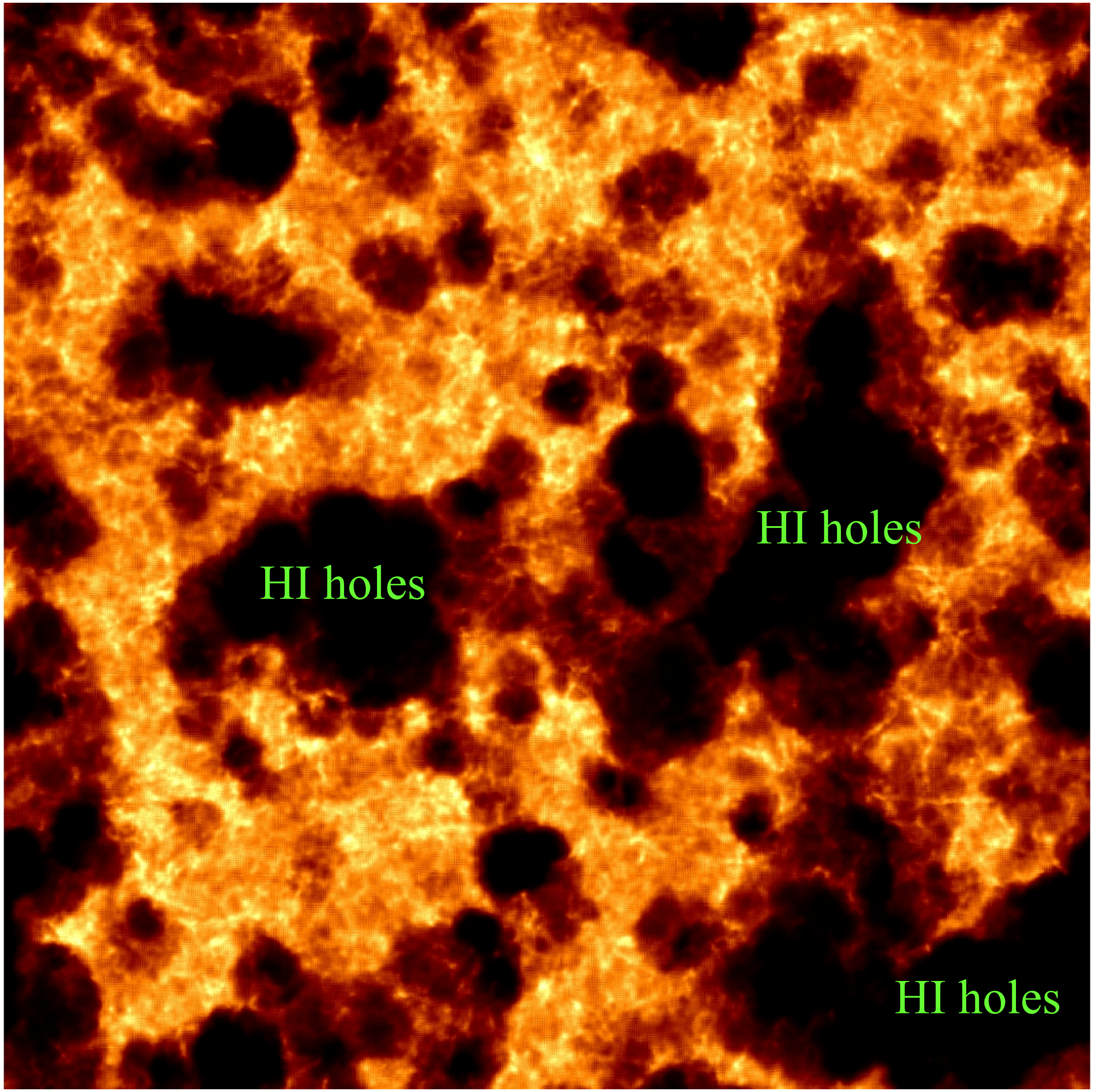


First Billion Years

HI density map in a 400 cMpc box @ z=8



Baek & AF 12

SOURCE LIST

- Stars: Pop II and/or (massive) Pop III

  In what proportion ? $N\gamma = (4, 30, 100)\times 10^3$ *phot/baryon into stars*

- Quasars

  Too rare, too late; key sources for HeII reionization

- Supernova explosions

  Filling factor too small; Compton-y limited

- Dark Matter: decays/annihilations

  Light particles (LDM, sterile neutrinos) can produce a $\tau_e < 0.01$
  Heavy particles (neutralinos, gravitinos) totally negligible

- Mini-quasars

  Limited by unresolved SXRB
  Only 3 phot/baryon in IGM in 10 Salpeter times

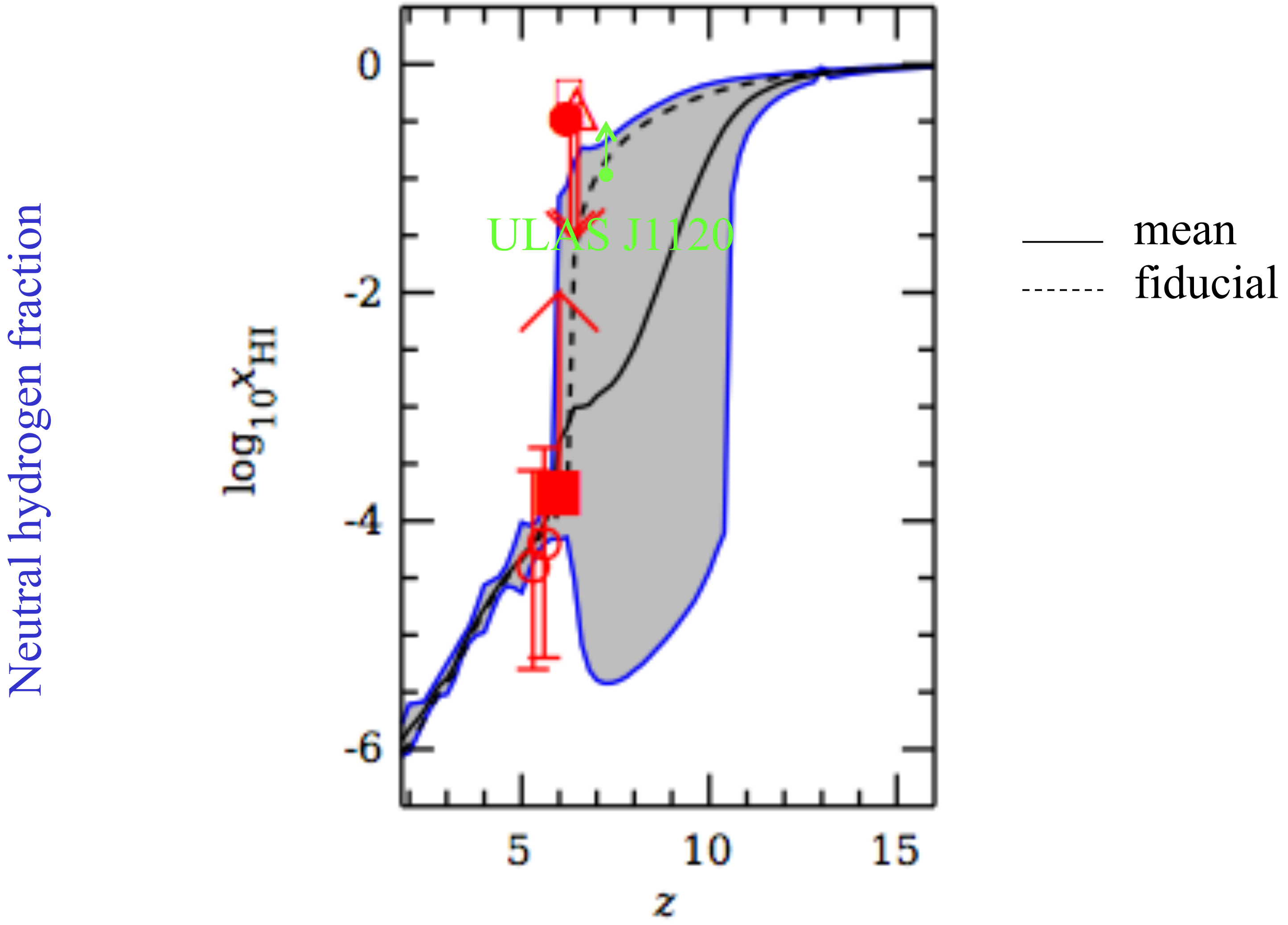
- Structure formation

EXPERIMENTAL CONSTRAINTS

- Lyα Gunn-Peterson opacity
- CMB: e.s. optical depth + TT, TE, EE power spectra
- Lyβ Gunn-Peterson opacity
- UV Background intensity
- Redshift evolution of Lyman Limit Systems
- IGM Temperature evolution
- IGM Metallicity
- Cosmic star formation history
- High-z galaxy counts
- Near Infrared Background

Mitra, Choudhury & AF 11,12

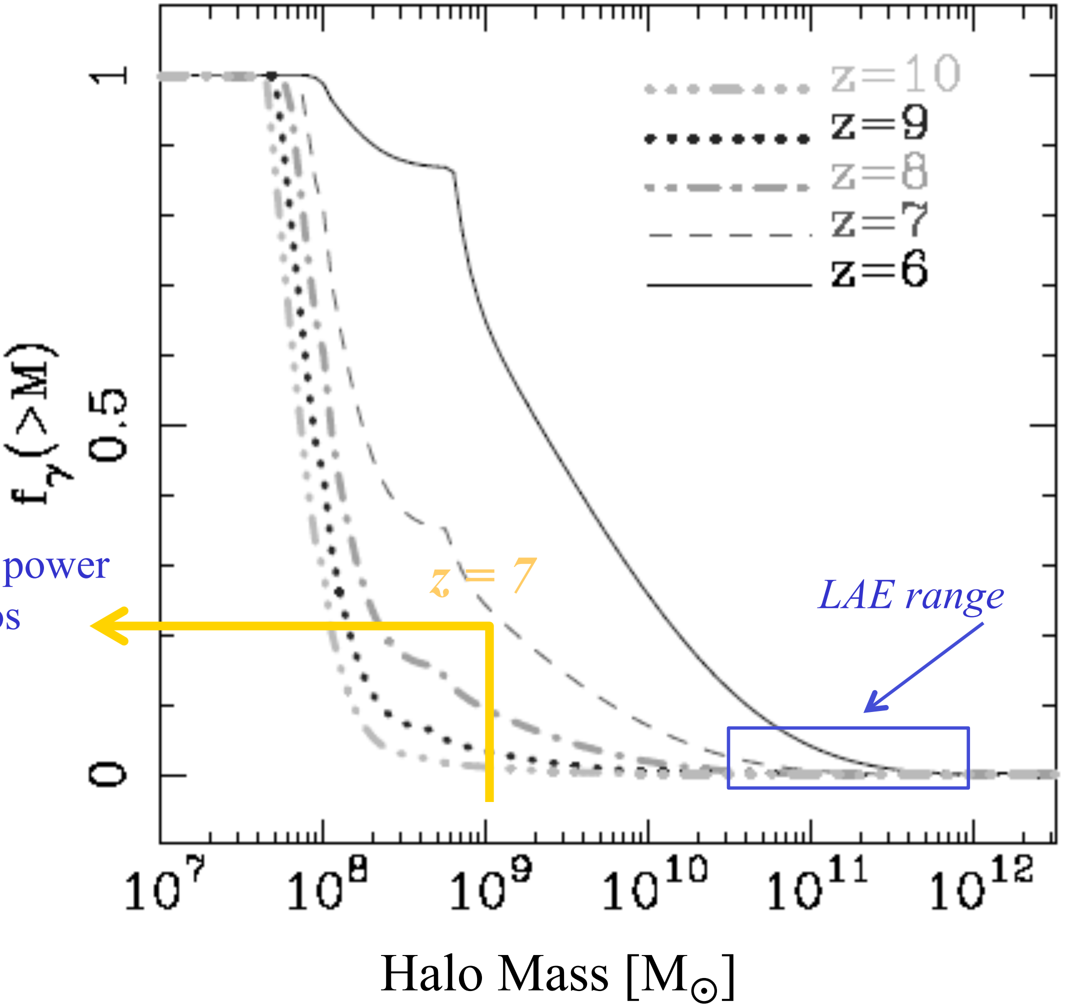
NEUTRAL H EVOLUTION



NATURE OF REIONIZATION SOURCES

Choudhury & AF 2007

IONIZING PHOTON BUDGET



z = 7

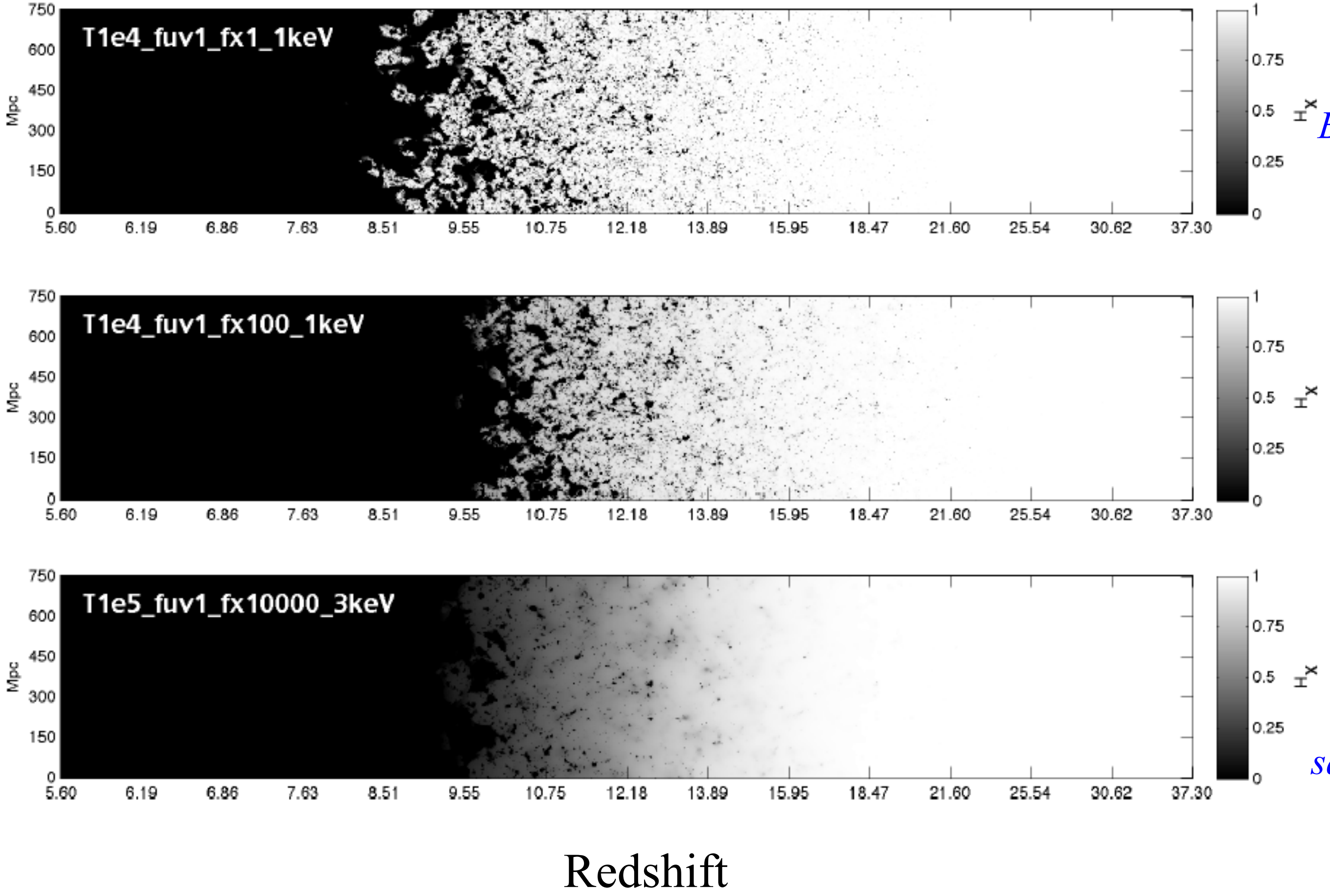
LAE range

$f_\gamma > 80\%$ of the ionizing power from $M < 10^9\ M_\odot$ halos

X-RAY EFFECTS

Mesinger, AF & Spiegel 2012

REIONIZATION HISTORY



$N_X = 0.4$

Best fit model, τ_e=0.092

"fiducial"

$N_X = 40$

τ_e=0.107

$N_X = 4000$ +

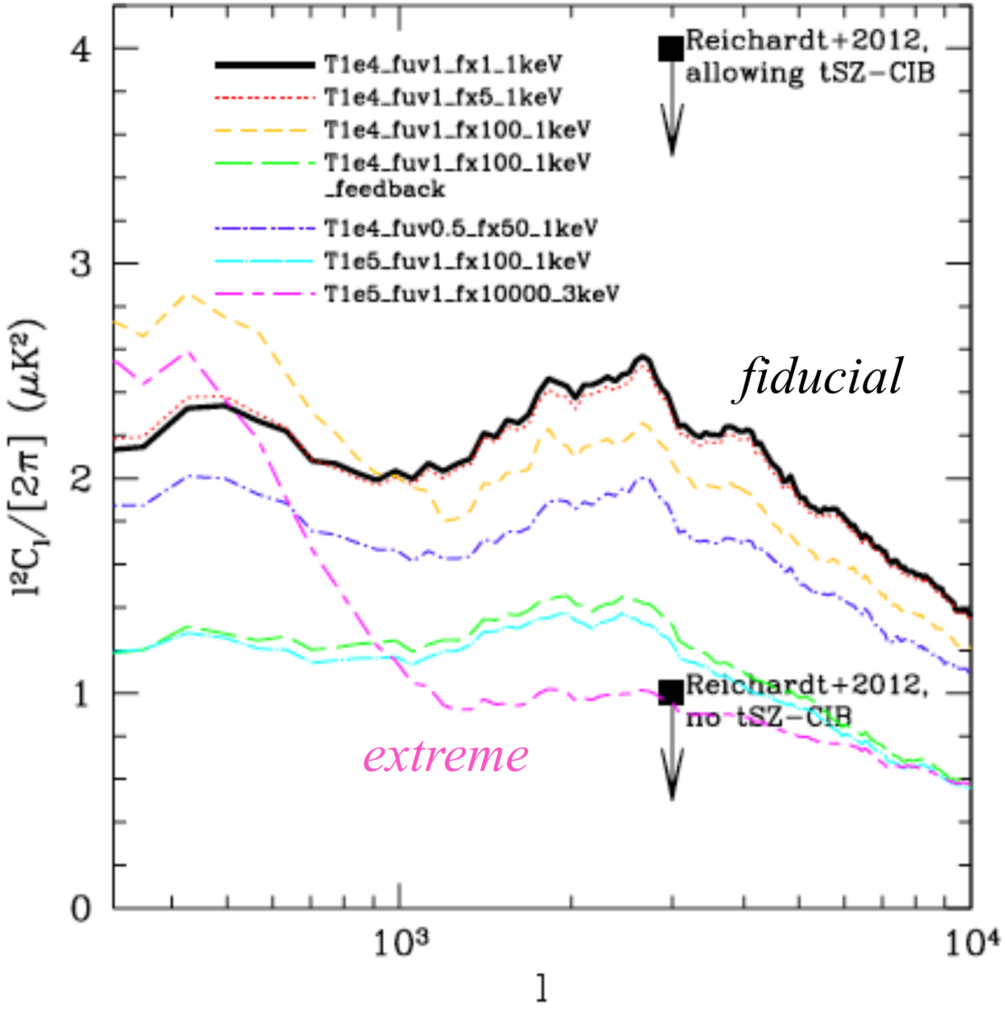
radiative feedback

saturates SXRB, τ_e=0.108

"extreme"

Mesinger, AF & Spiegel 2013

KINETIC SZ SIGNAL

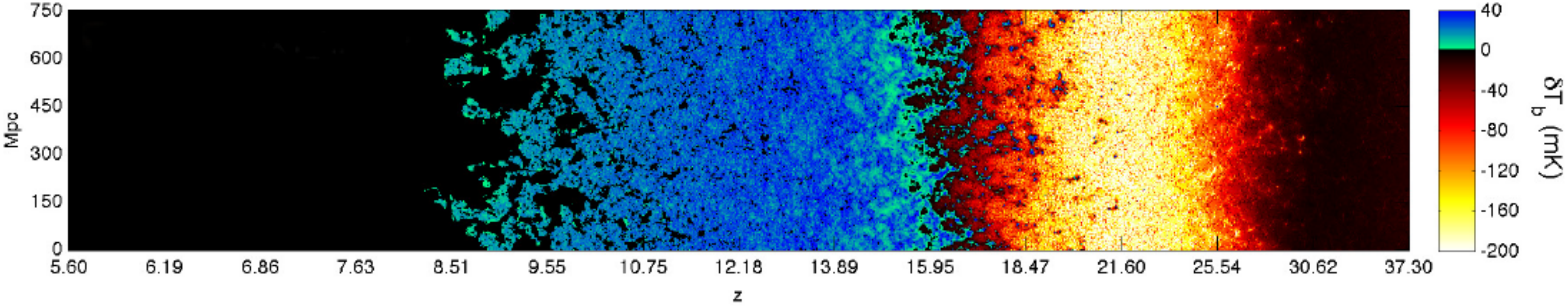


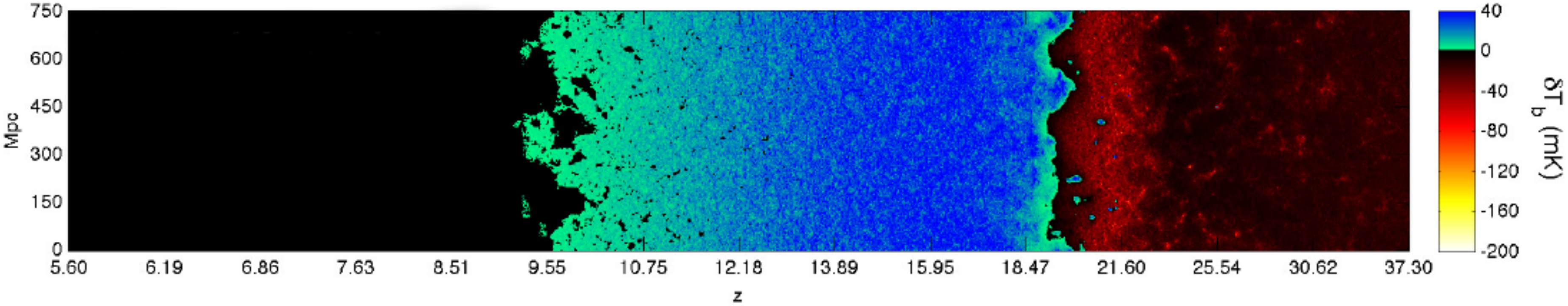
REIONIZATION: THE FUTURE

Valdes, Evoli, Mesinger, AF & Yoshida 2013

21 CM SIGNAL

fiducial

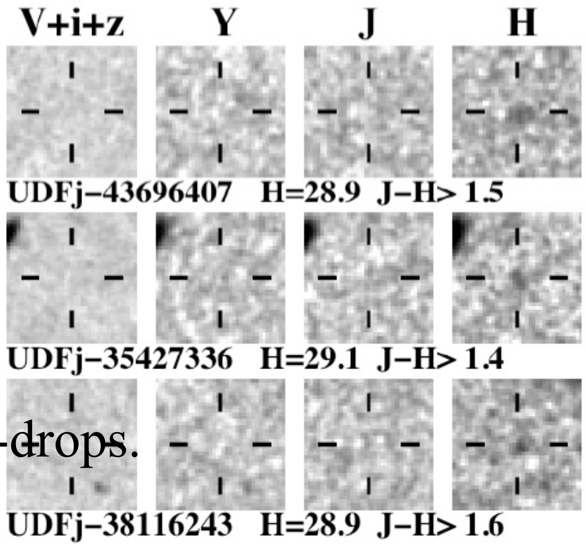




extreme

What about galaxies ?

SEARCH TECHNIQUES

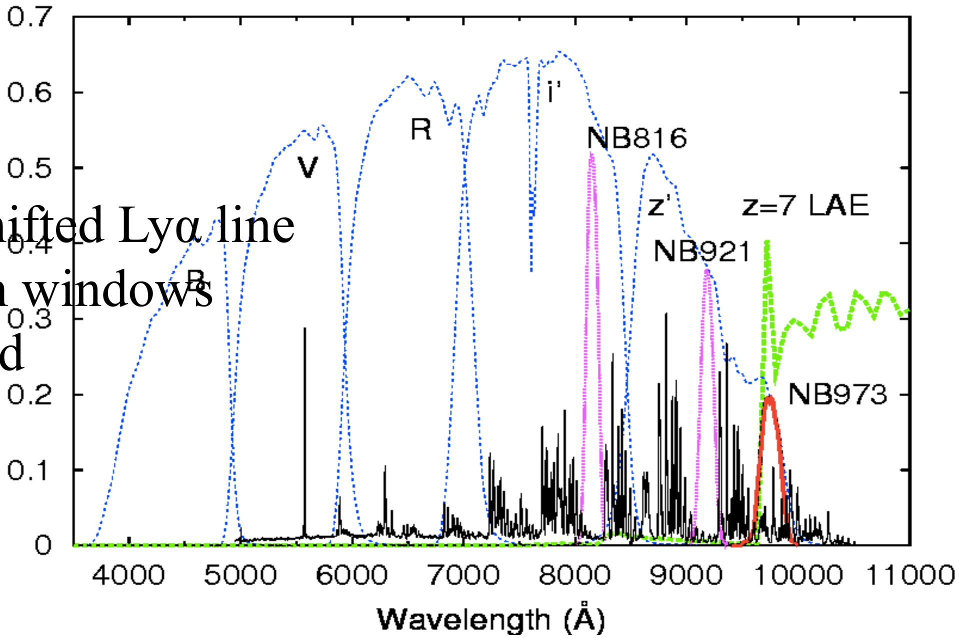


DROP-OUTS

- Sharp drop in flux shortwards than Lya line
- Finding galaxy candidates at z>6 : using *i, z, Y, J*-drops.
- Contamination by stars and low-z ellipticals

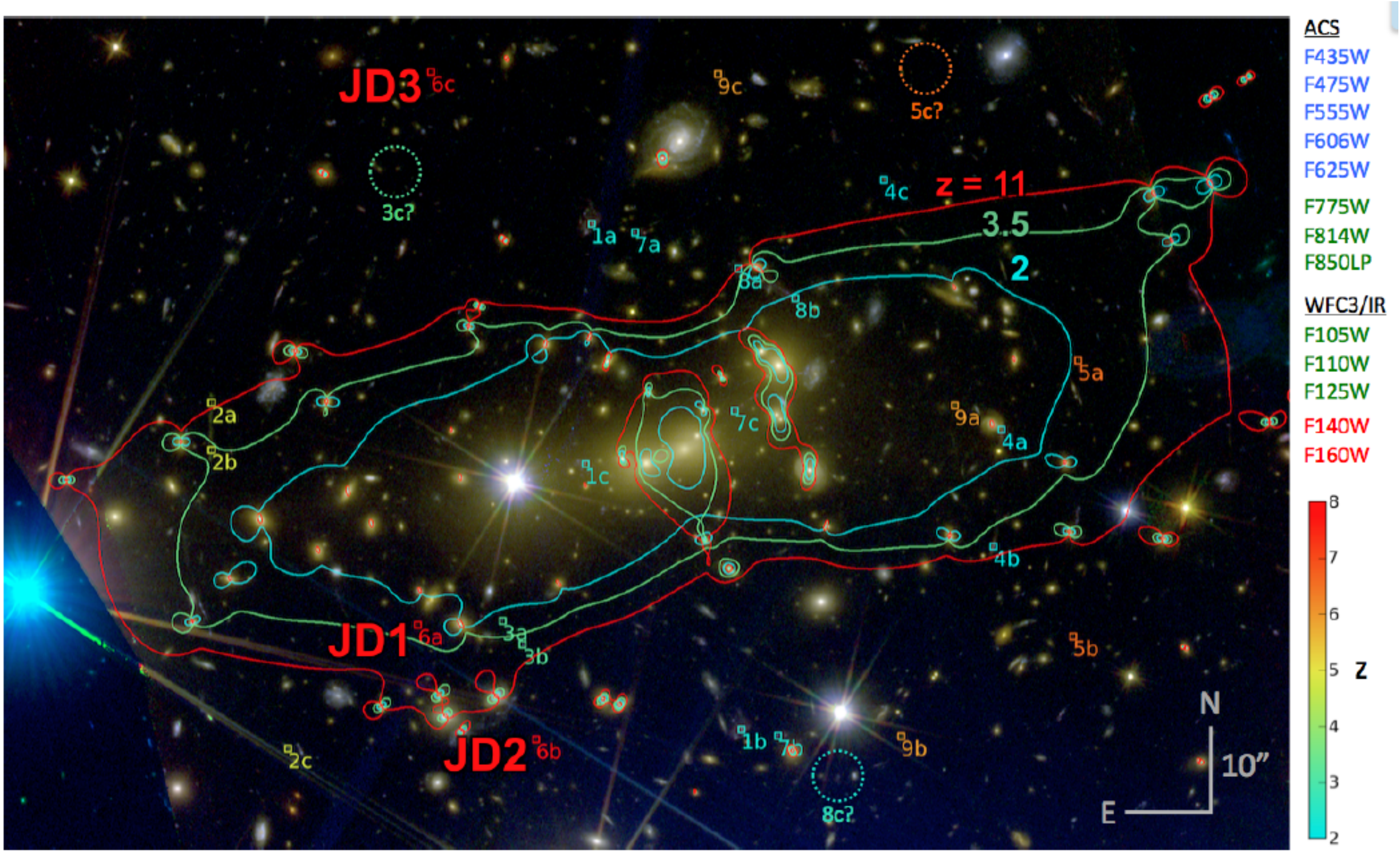
LYMAN ALPHA EMITTERS

- Narrow band filters tuned on redshifted Lyα line
- Few and narrow atmospheric clean windows
- Not all spectroscopically confirmed



Coe+2013

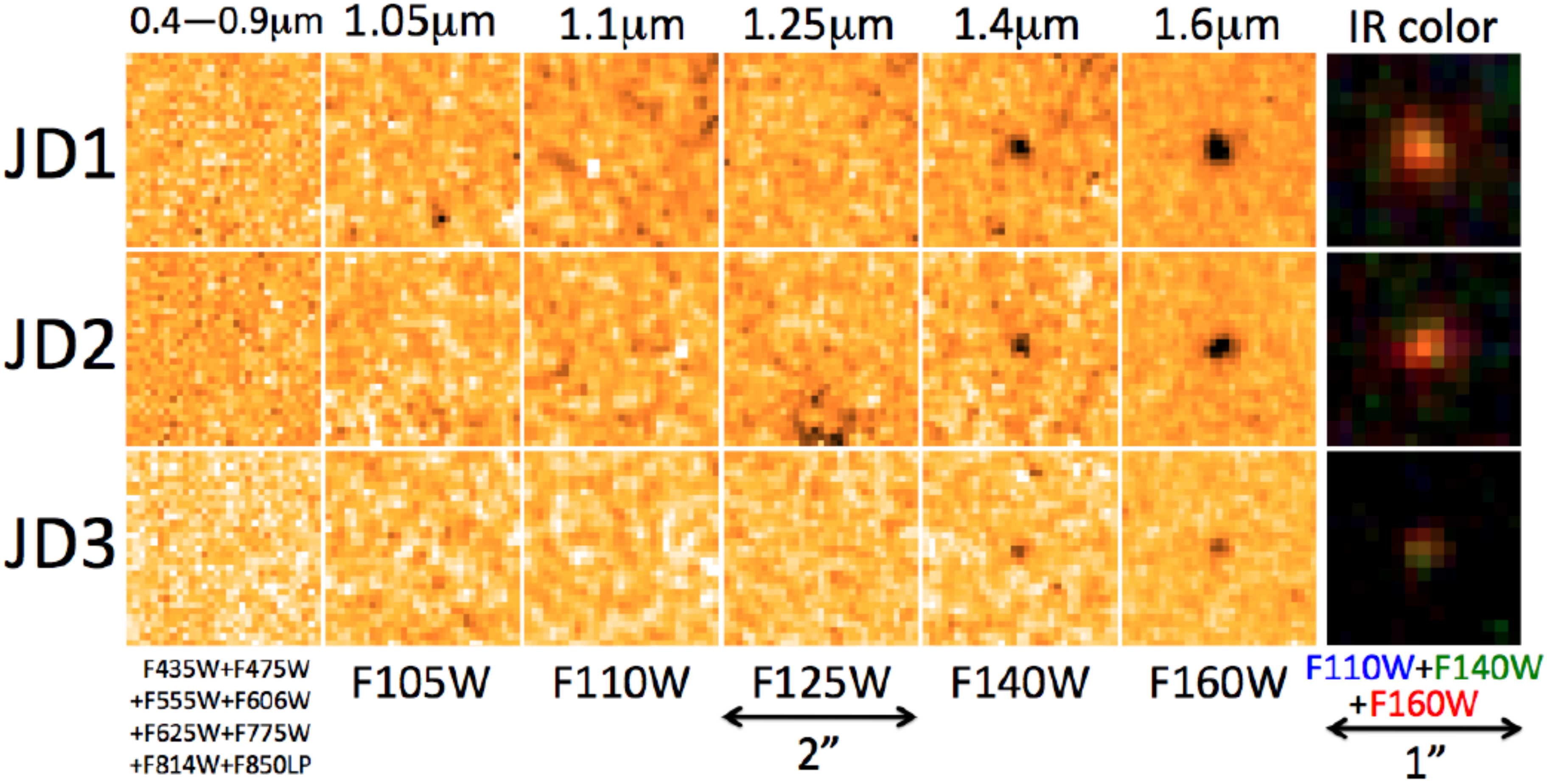
THE MOST DISTANT GALAXY z=11



Coe+12

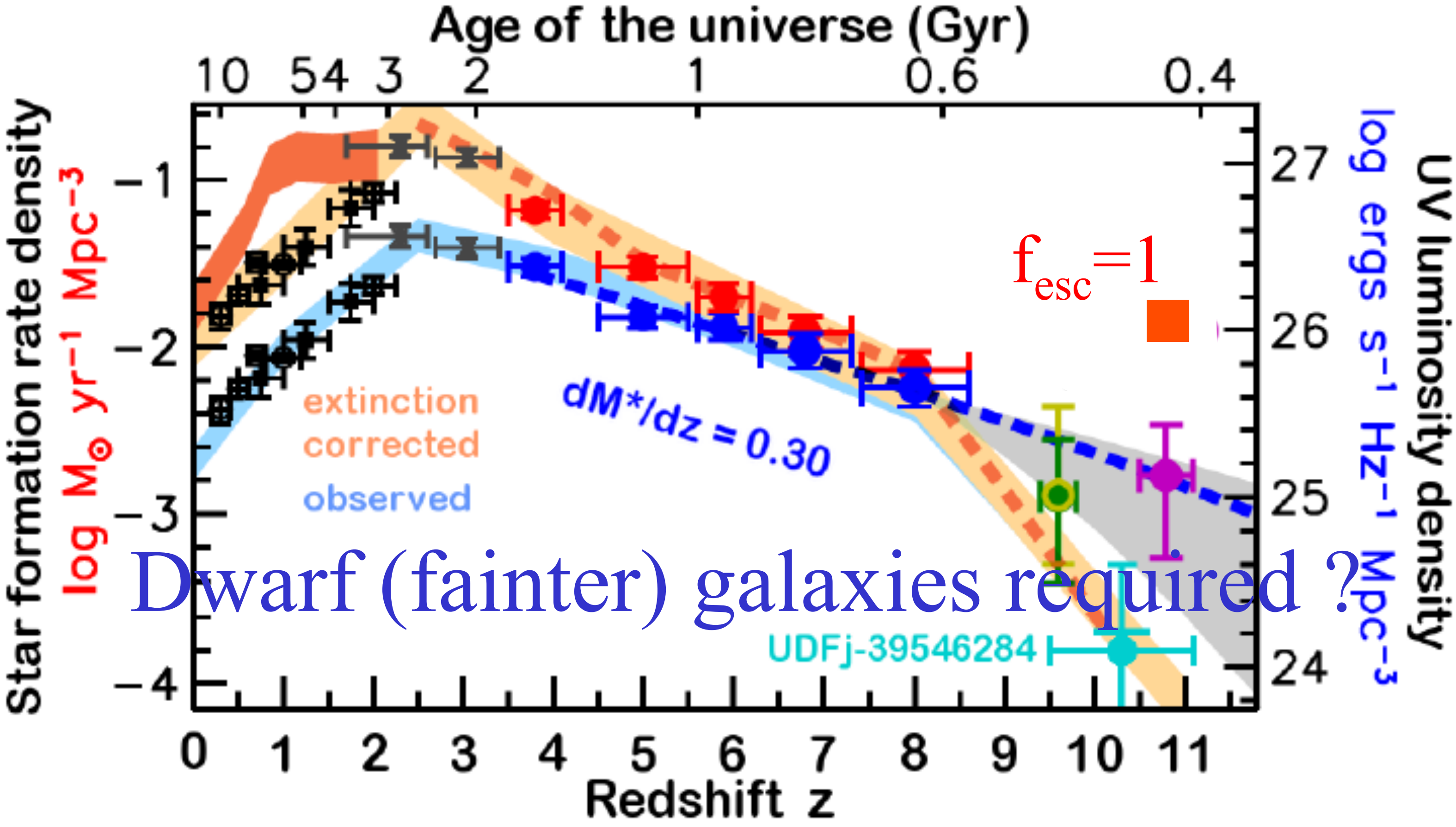
THE MOST DISTANT GALAXY Z=11

HST CLASH Survey (19 orbits)



DROPOUTS CONSTRAINTS

$$\dot{\rho}_{\rm crit} = (0.018\ M_\odot\ {\rm yr}^{-1}\ {\rm Mpc}^{-3}) \left[\frac{(1+z)}{8}\right]^3 \boxed{\left[\frac{C_H/3}{f_{\rm esc}/0.2}\right]} \left[\frac{0.004}{Q_{\rm LyC}}\right] T_4^{-0.845}$$

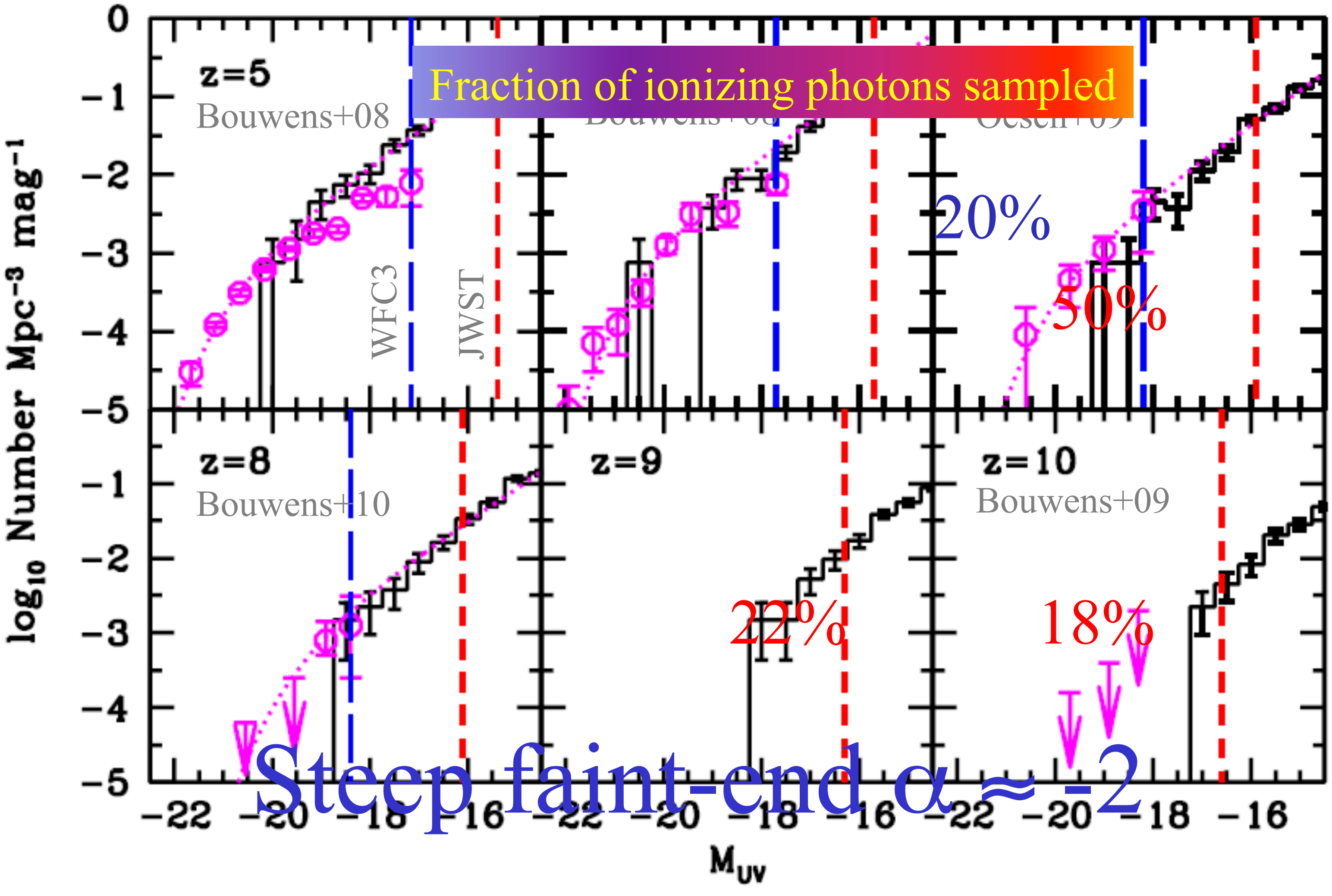


$f_{\rm esc}=1$

Dwarf (fainter) galaxies required ?

Salvaterra, AF, Dayal 2011

HIGH-Z LUMINOSITY FUNCTIONS



Fraction of ionizing photons sampled

20%

50%

22%

18%

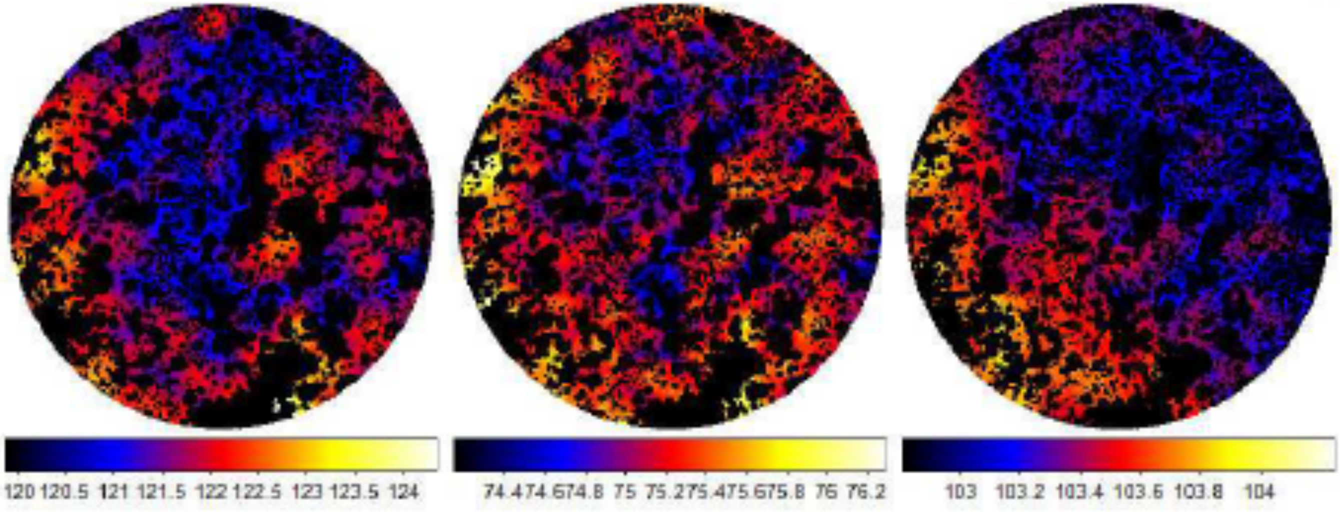
Steep faint-end α ≈ -2

Matsumoto+11

NIRB FLUCTUATIONS

AKARI @ 2.4 µm   3.2 µm   4.1 µm

600 arcsec

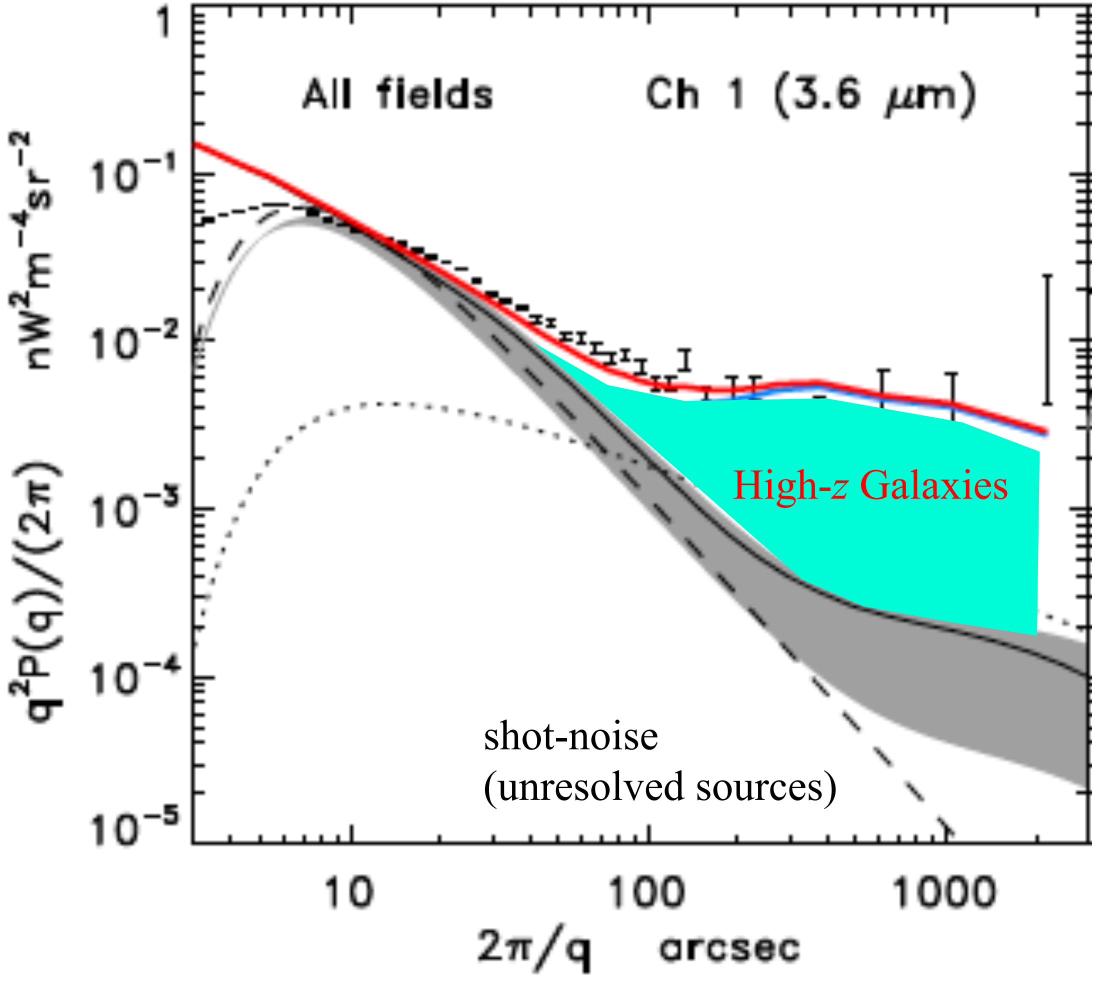


$\mathrm{nW\ m^{-2}\ sr^{-1}}$

Kashlinsky+12

NIRB FLUCTUATIONS

Spitzer @ 3.6 μm



High-*z* Galaxies

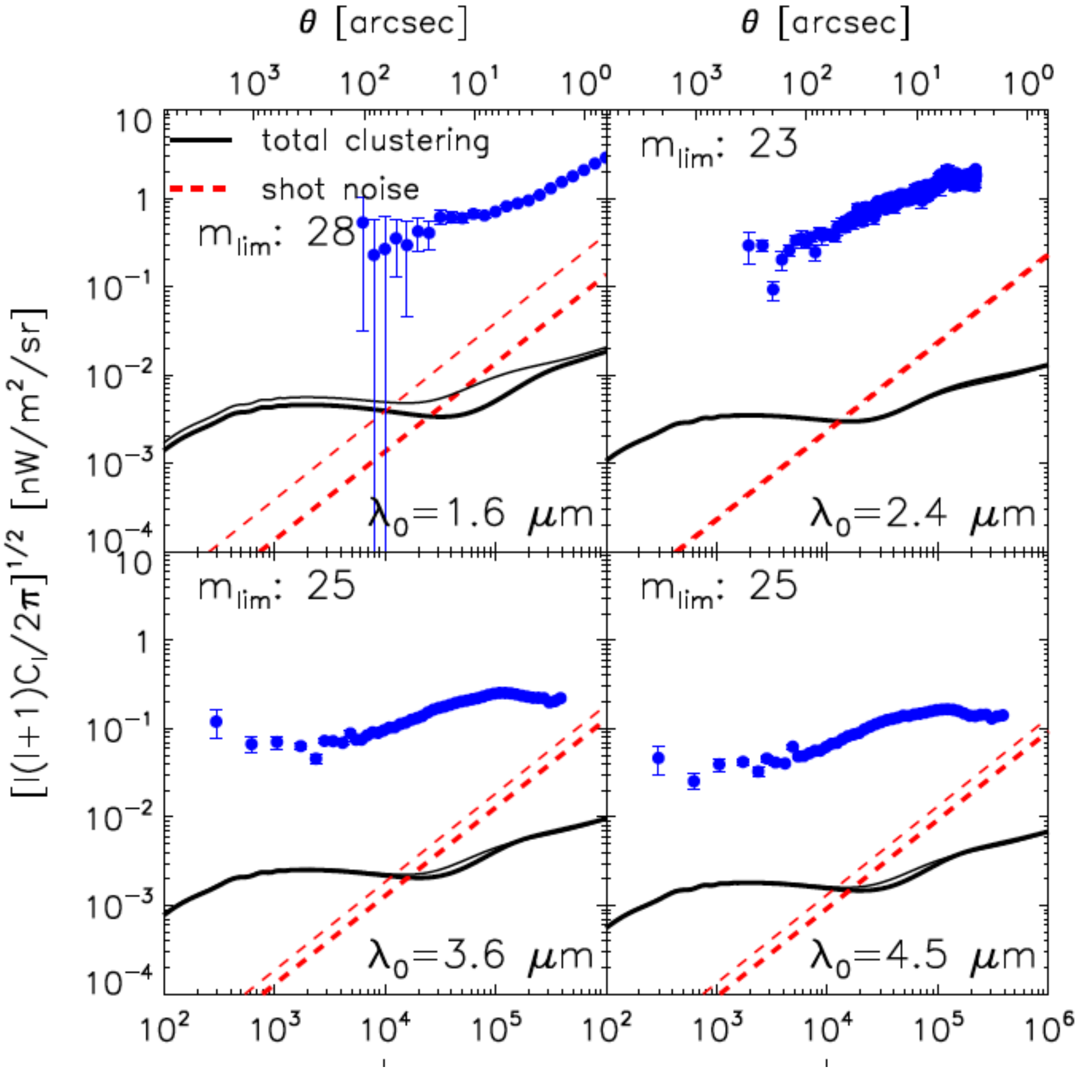
shot-noise
(unresolved sources)

Total including high-z
galaxy clustering

“ordinary”
galaxies

NIRB FLUCTUATIONS

Yue+12



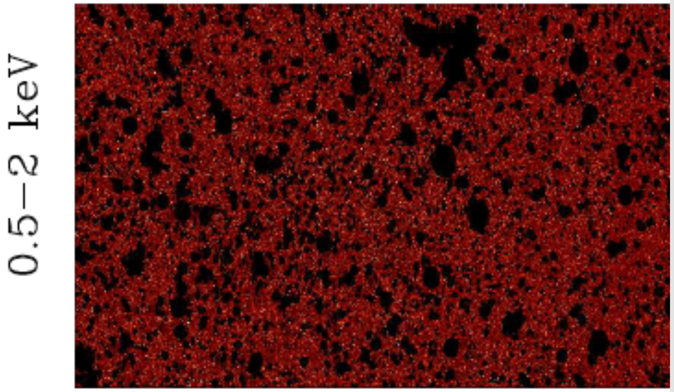
High-z galaxies cannot reproduce NIRB fluctuations

Cappelluti+12

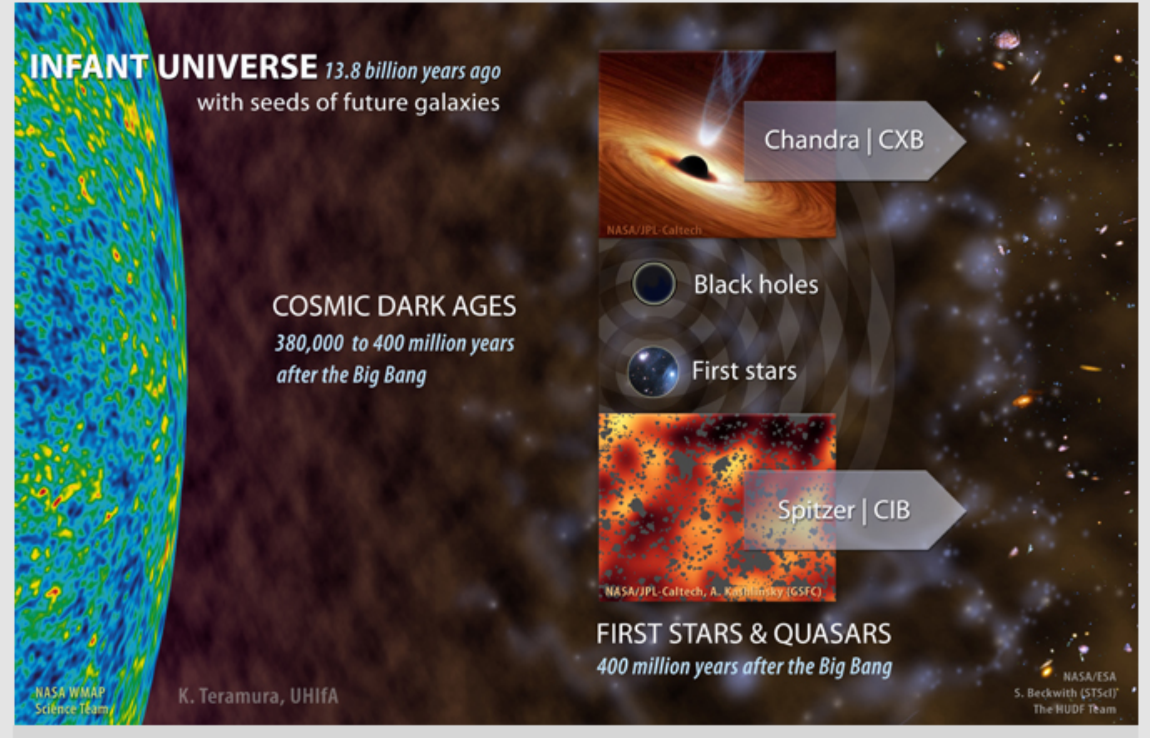
XRB-NIRB CORRELATION

News
06.05.13

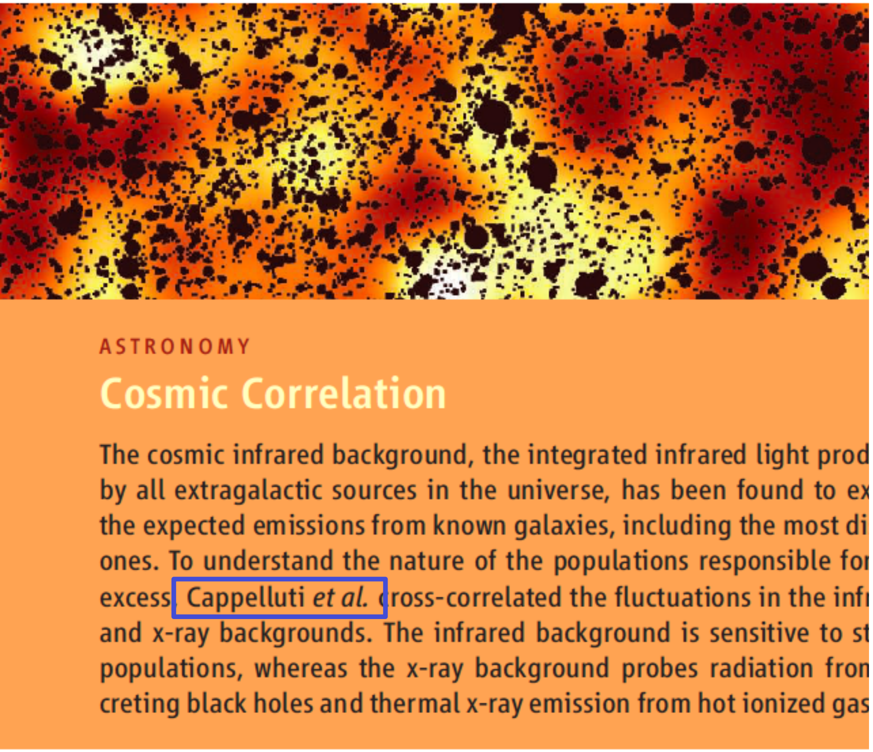
Char



X-ray 0.5-2 keV fluctuat



Science, 14 JUNE 2013, 340, 6138



ASTRONOMY

Cosmic Correlation

The cosmic infrared background, the integrated infrared light prod
by all extragalactic sources in the universe, has been found to ex
the expected emissions from known galaxies, including the most di
ones. To understand the nature of the populations responsible for
excess, Cappelluti *et al.* cross-correlated the fluctuations in the infr
and x-ray backgrounds. The infrared background is sensitive to st
populations, whereas the x-ray background probes radiation from
creting black holes and thermal x-ray emission from hot ionized gas

SIMULAZIONI CONFERMANO I DATI DI SPITZER E AKARI

Taglia media per i buchi neri primordiali

Sarebbero i buchi neri con masse dell'ordine di centomila volte quella del Sole, formatisi quando l'Universo aveva meno di 300 milioni di anni e direttamente dal collasso dei primi aloni di materia primordiale, le sorgenti responsabili delle fluttuazioni di radiazione infrarossa di fondo registrate dai satelliti Spitzer e AKARI. Questi i risultati di uno studio a cui ha partecipato anche Ruben Salvaterra dell'INAF.

di Marco Galliani 17/06/2013 17:48

Buchi neri e universo primordiale. Due argomenti di frontiera dell'astrofisica contemporanea, dove molto è ancora da scoprire e spiegare. È facile quindi immaginare quanto sia complesso avventurarsi contemporaneamente nel loro studio: ovvero indagare quanti erano, come erano e quale è stato il ruolo dei buchi neri *nelle prime fasi dell'universo*. Nei giorni scorsi un lavoro guidato da Nico Cappelluti dell'INAF ha gettato nuova luce sull'argomento, mettendo in evidenza come il numero di questi oggetti estremi tra le prime stelle fosse molto più elevato di quanto ritenuto finora (vedi la news di Media INAF *Moltissimi i buchi neri fra le prime stelle*). Un risultato ottenuto mettendo in relazione le fluttuazioni della radiazione di fondo cosmico nei raggi infrarossi con quelle registrate nei raggi X. Ora una nuova indagine guidata da Bin Yue, dell'Accademia Cinese delle Scienze e a cui ha partecipato **Ruben Salvaterra dell'INAF-IASF di Milano** e **Andrea Ferrara**, della Scuola Normale Superiore di Pisa, fa un ulteriore passo in avanti per spiegare come questo inatteso affollamento di buchi neri nell'universo primordiale sia stato possibile. Il team, basandosi sui dati raccolti nell'infrarosso dai satelliti Spitzer della NASA e AKARI dell'agenzia spaziale giapponese JAXA, ha realizzato un modello teorico di formazione ed evoluzione dei buchi neri subito dopo il Big Bang, osservando dai dati della simulazione che la distribuzione e le proprietà della radiazione emessa sono in buon accordo con le osservazioni, sia nell'infrarosso che nei raggi X.

"Il nostro lavoro mostra come si possa spiegare l'esistenza di fluttuazioni nel vicino infrarosso e contemporaneamente nei raggi X come dovute all'emissione di buchi neri di massa intermedia (centomila volte la massa del Sole) nell'universo primordiale" spiega Salvaterra. "**Questi buchi neri si sarebbero formati quando l'universo aveva meno di 300 milioni di anni**, e direttamente dal collasso dei primi aloni di materia primordiale (ovvero una mistura di idrogeno ed elio) prodotta nel Big Bang. Il nostro modello dà conto del livello di fluttuazioni osservate nel vicino

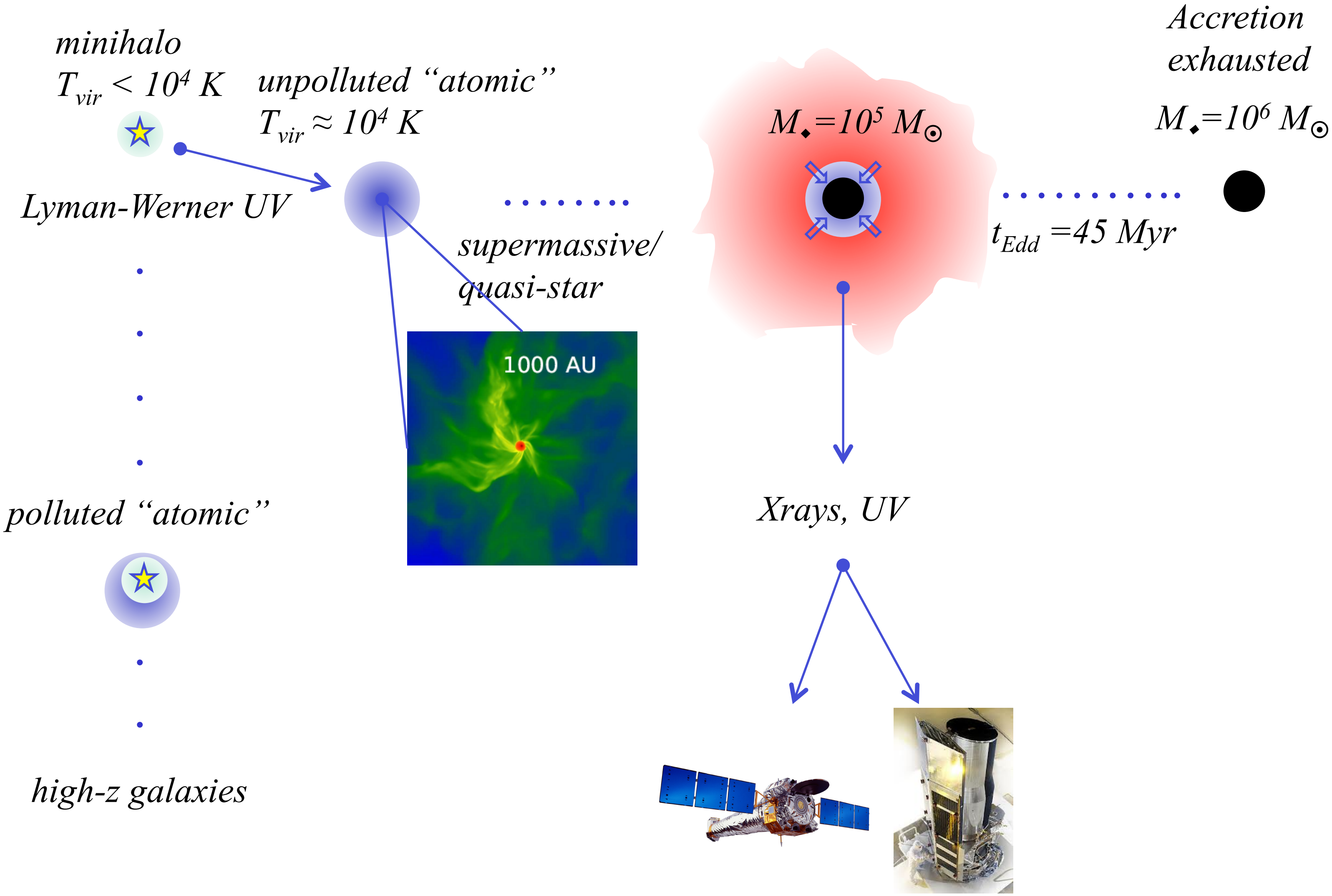
INAF, 17 JUNE 2013

First Black Holes ?

Yue, AF, Salvaterra, Xu, Chen 2013

FIRST BLACK HOLE ERA

BH ERA z>12



minihalo

$T_{vir} < 10^4$ K

Lyman-Werner UV

unpolluted "atomic"

$T_{vir} \approx 10^4$ K

supermassive/ quasi-star

polluted "atomic"

high-z galaxies

$M_\bullet=10^5\,M_\odot$

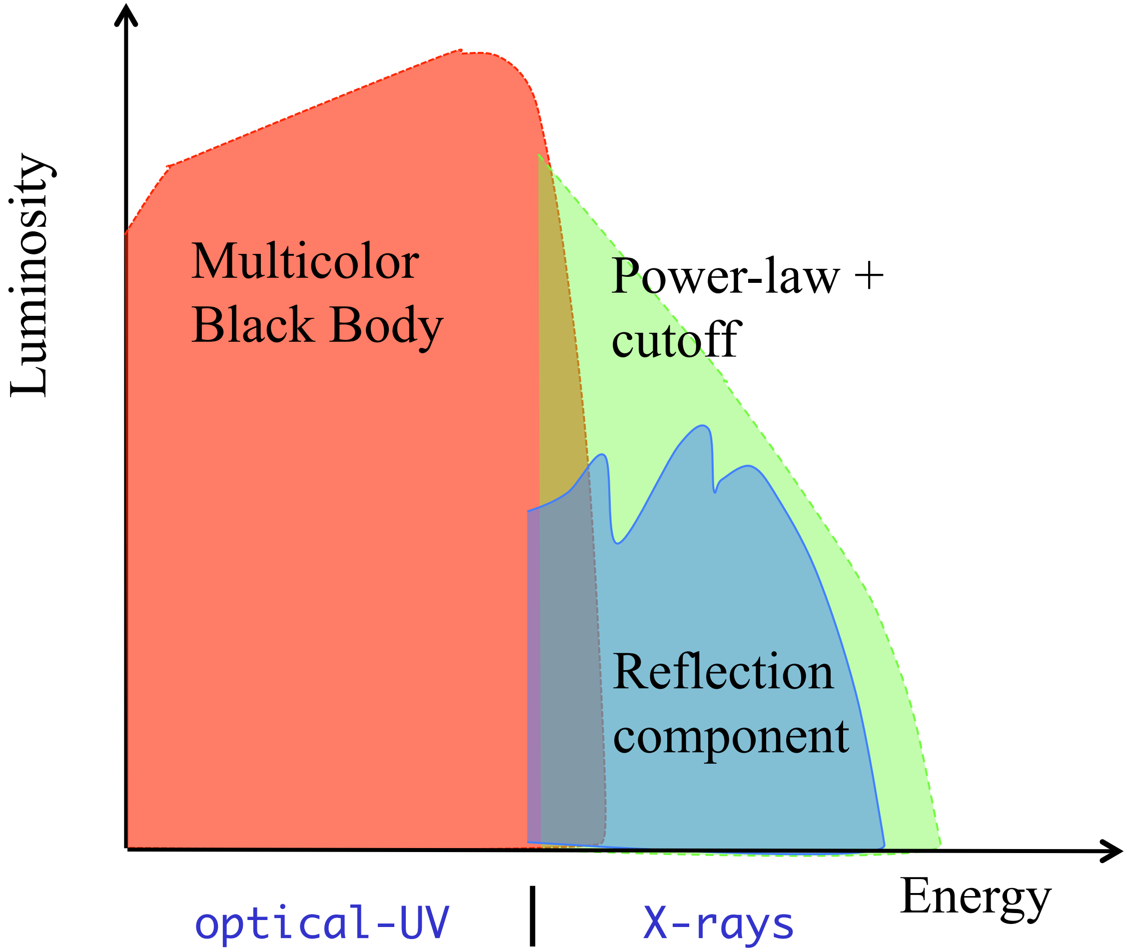
Xrays, UV

Accretion exhausted

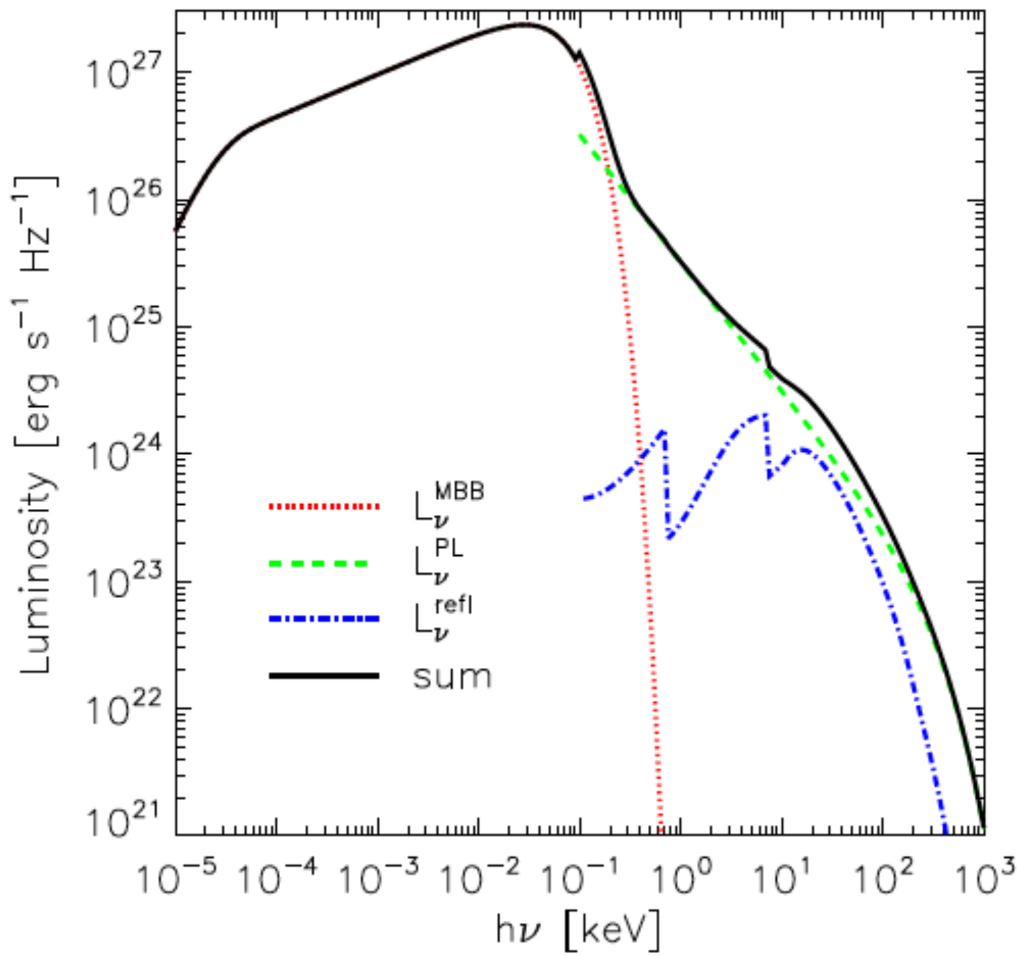
$M_\bullet=10^6\,M_\odot$

t_{Edd} =45 Myr

DCBH SPECTRUM

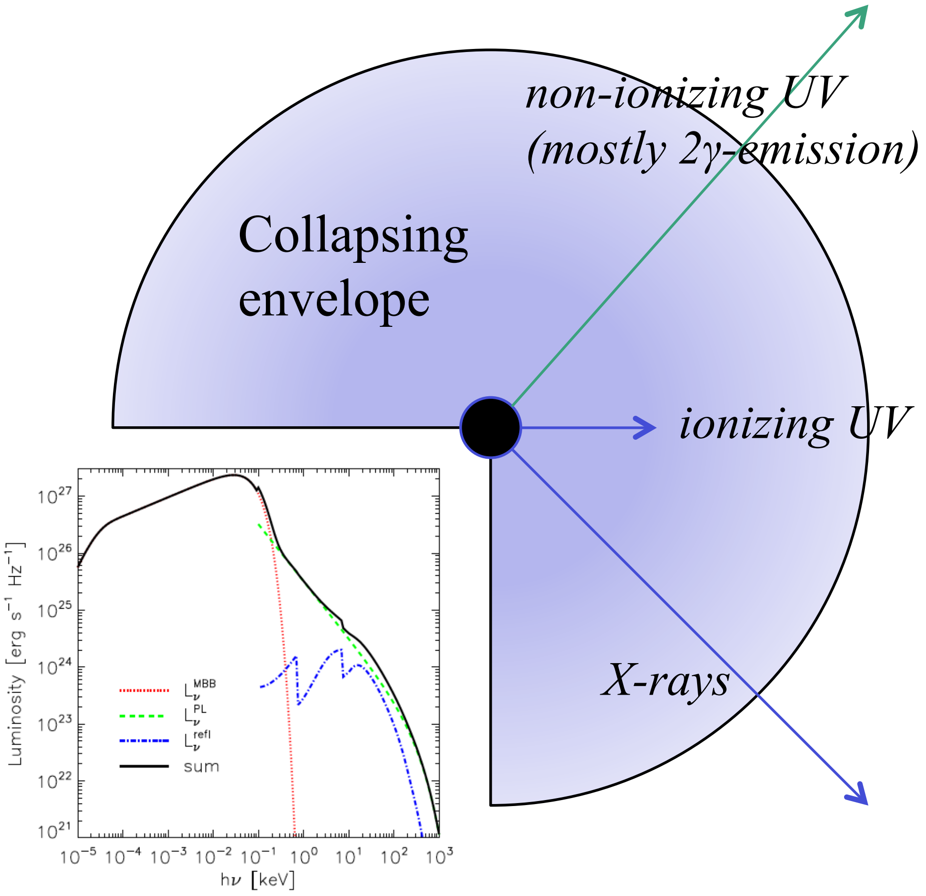


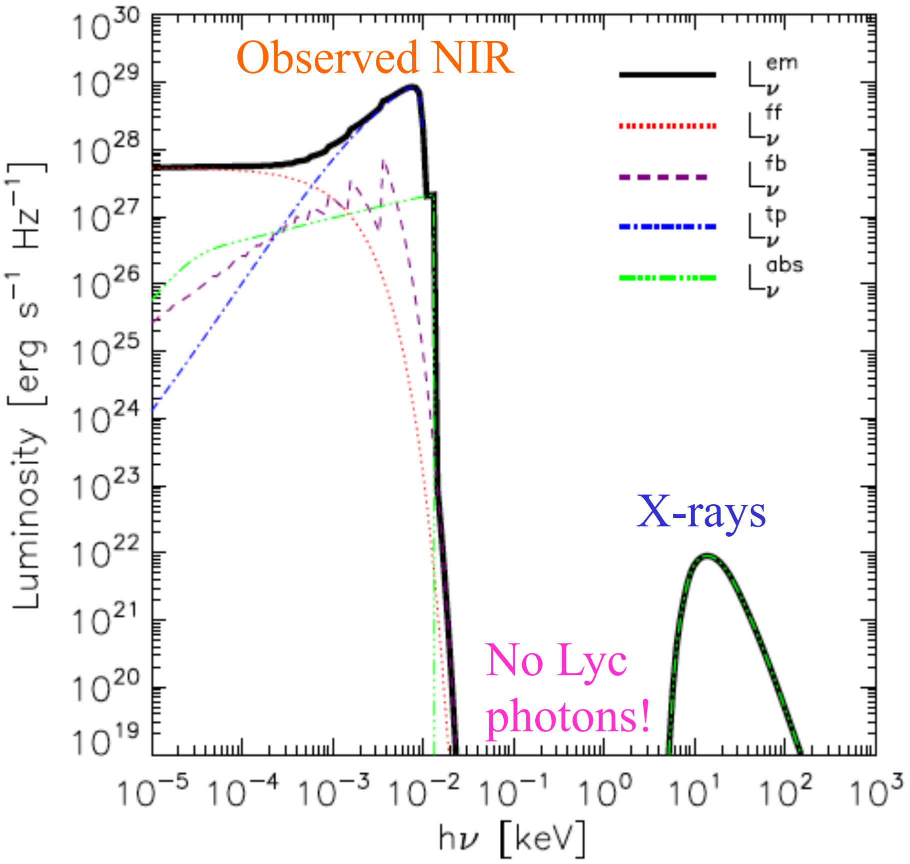
INTRINSIC SPECTRUM



ABSORBED SPECTRUM

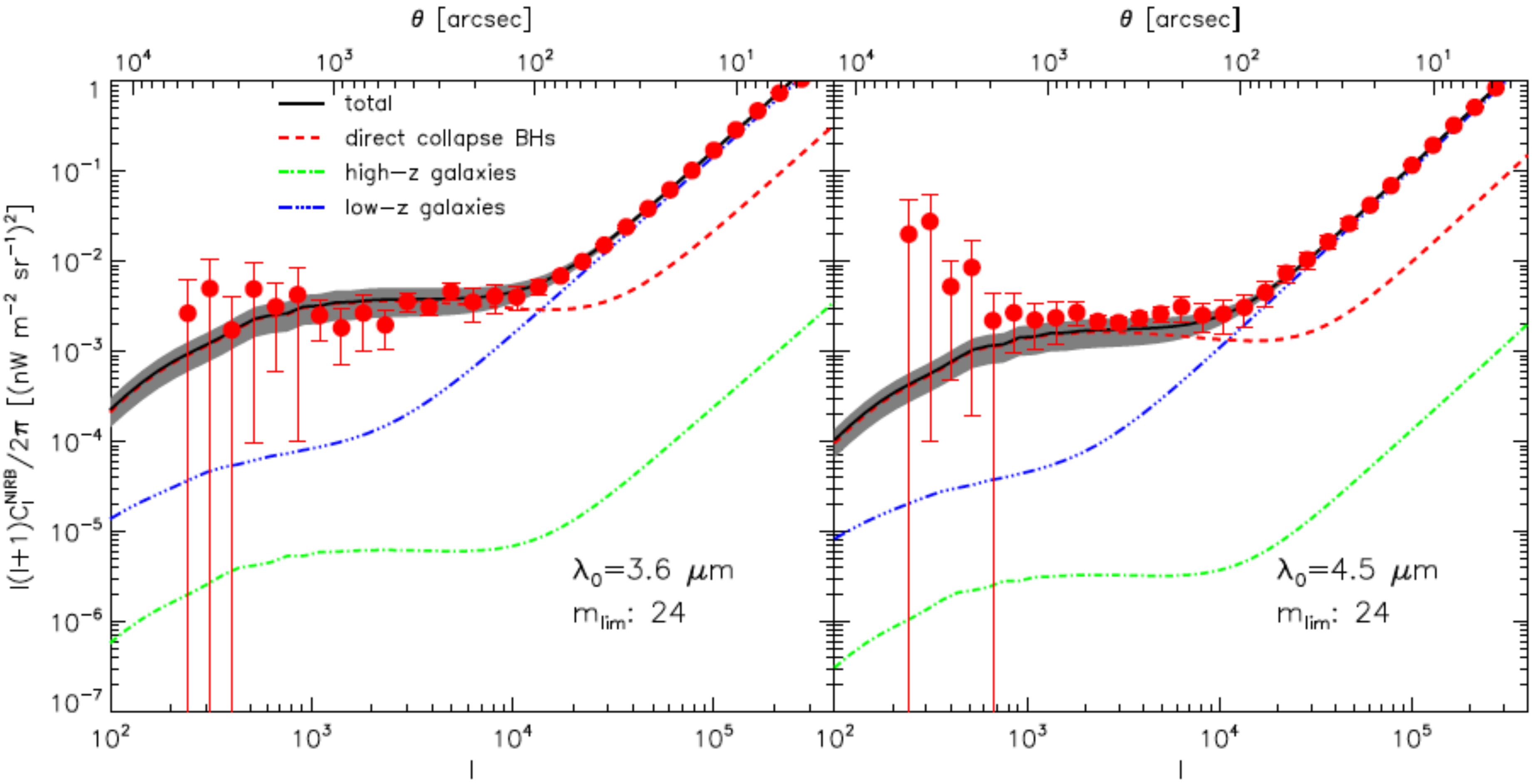
N_H=1.5x10^{25} cm^2
(Compton thick)



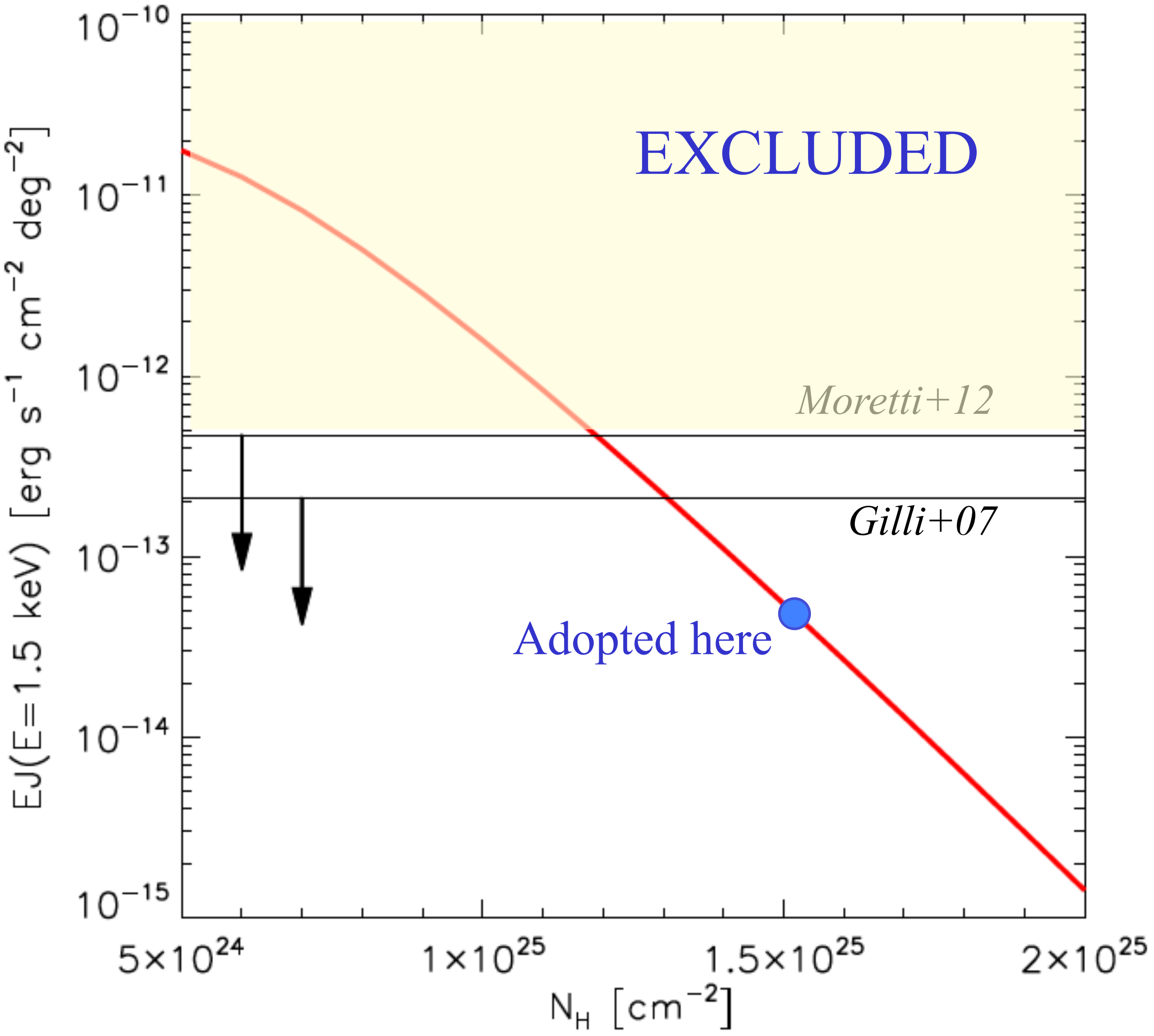


$M_\bullet$=10^6 $M_\odot$
(Direct collapse black hole)

NIRB POWER SPECTRUM

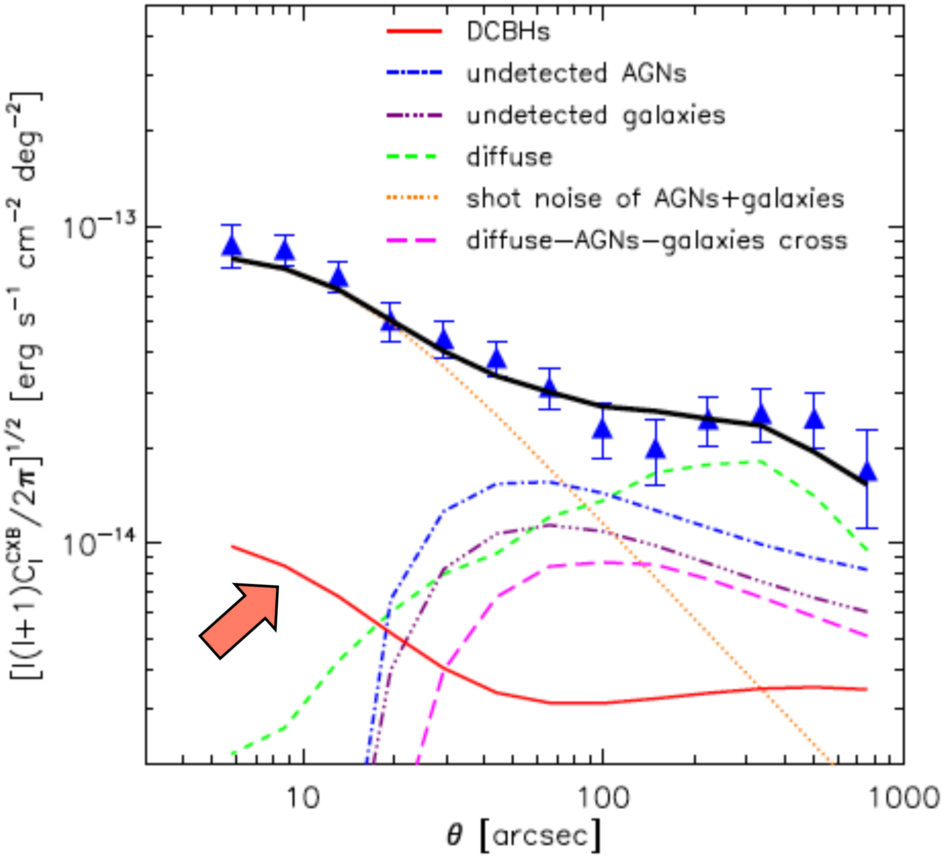


CXB CONTRIBUTION BY DCBH



THE XRAY CONNECTION

CXB Power spectrum



SELECTED SUMMARY

- $f_\gamma > 80\%$ of the ionizing power at $z > 7$ from halos of $M < 10^9\ M_\odot$
- kSZ can be used to quantify the X-ray effects on reionization history
- Current drop-out high-*z* candidates are not the reionization sources
- Reionization sources populate the (steep) faint-end of LF ($M_{UV} > -18$)
- Their clustering signal 30× smaller than observed NIRB fluctuations
- Highly obscured DCBHs in $T_{vir} \approx 10^4$ K metal-free halos at $z>12$ could:
  - Explain 3.6 and 4.5 μm NIRB fluctuations on scales > 100”
  - Explain CXB-NIRB cross-correlation signal

THE END