First Stars and Black Holes in the Reionization Era

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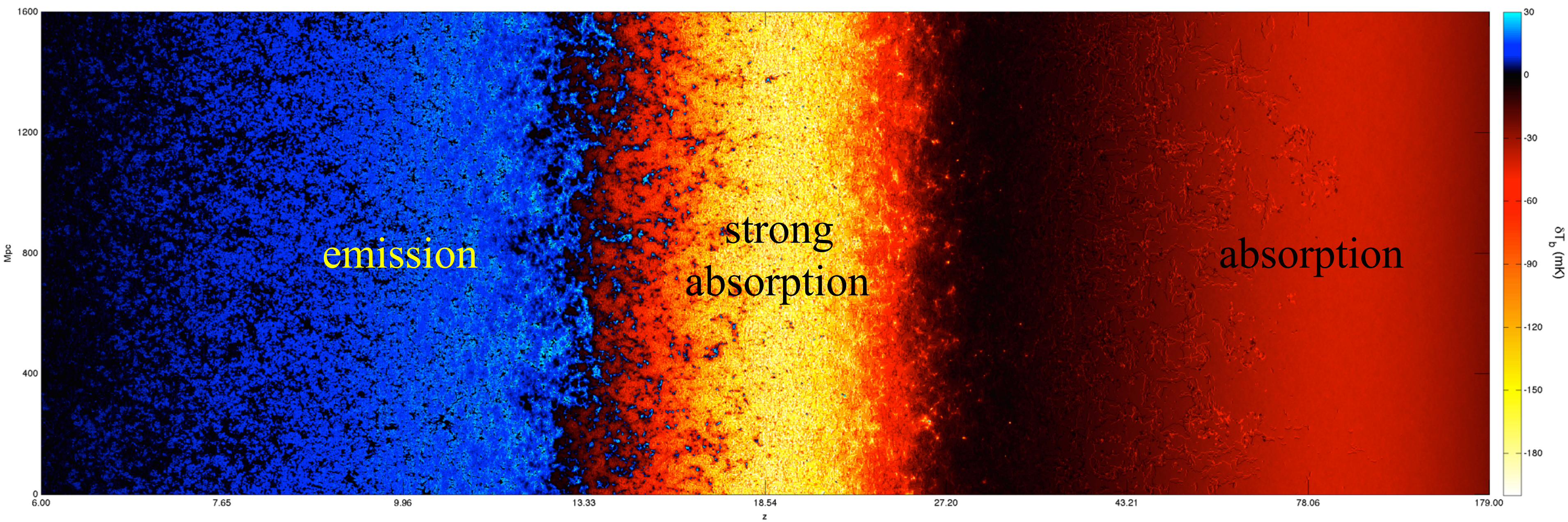
Mesinger, AF & Spiegel 2013; Pacucci+14

HI 21CM LINE VIEW

Brightness Temperature Evolution



6 — *15* — *27* — *redshift*

Epoch of Reionization

- *IGM warmer than CMB*
- *Strong $T_s - T_k$ coupling*

Cosmic Dawn

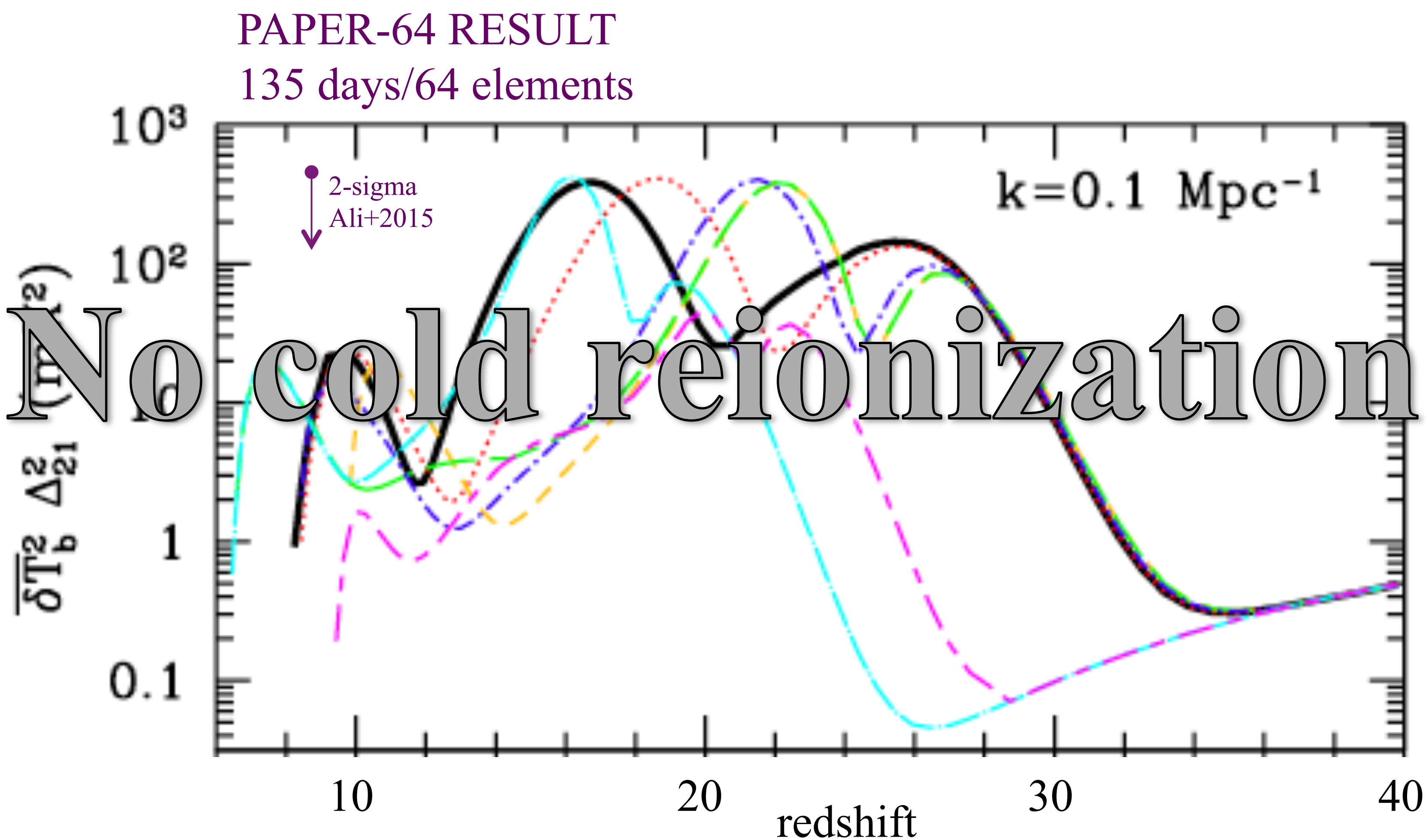
- *IGM colder than CMB*
- *Lya coupling (WF effect)*
- ***X-ray preheating***

Dark Ages

- *IGM colder than CMB*
- *Weak $T_s - T_k$ coupling*

Mesinger, AF & Spiegel 2013

21CM POWER SPECTRUM



Diving in a hydrogen sea

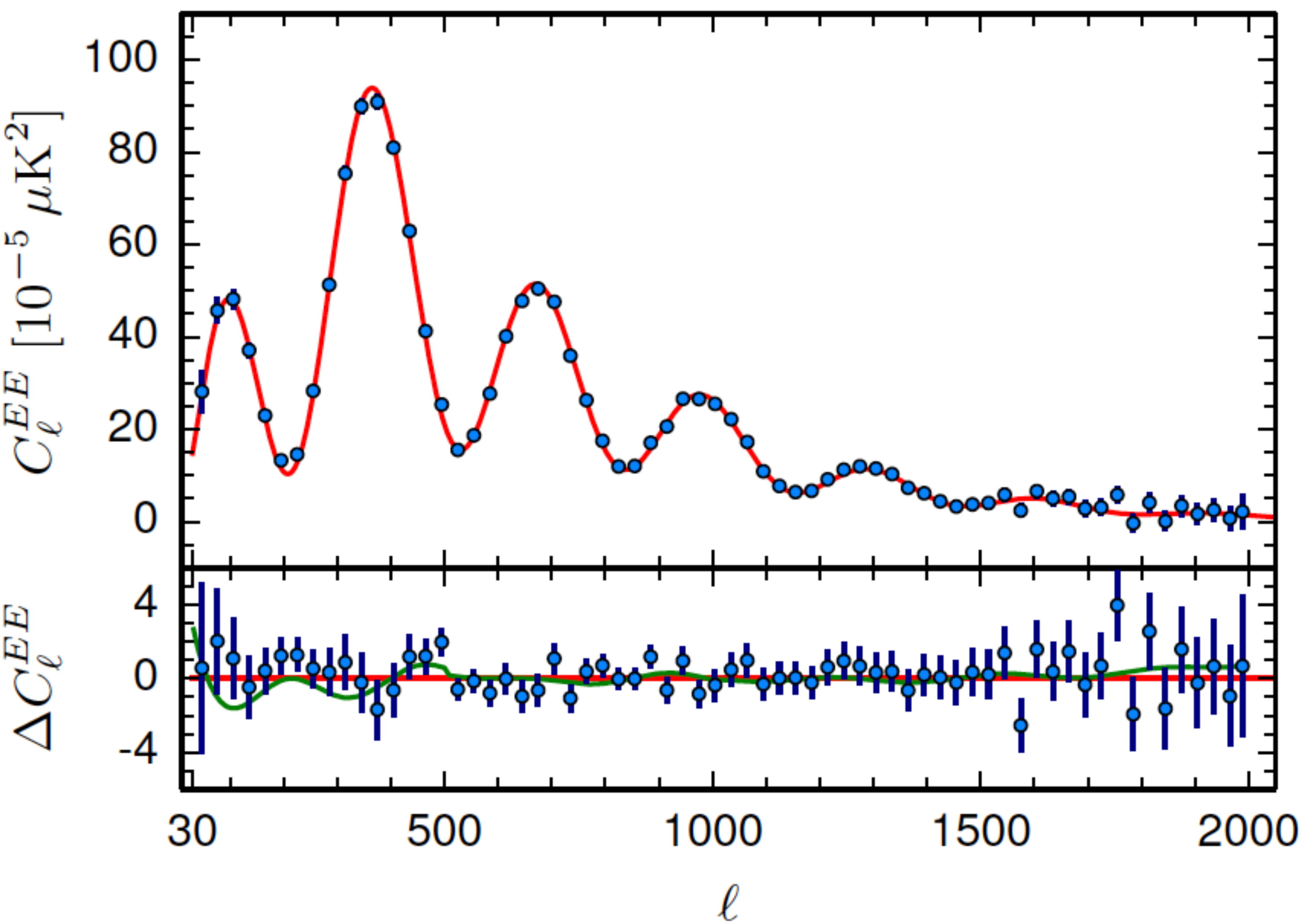
SKA
SQUARE KILOMETRE ARRAY

The world's largest radiotelescope

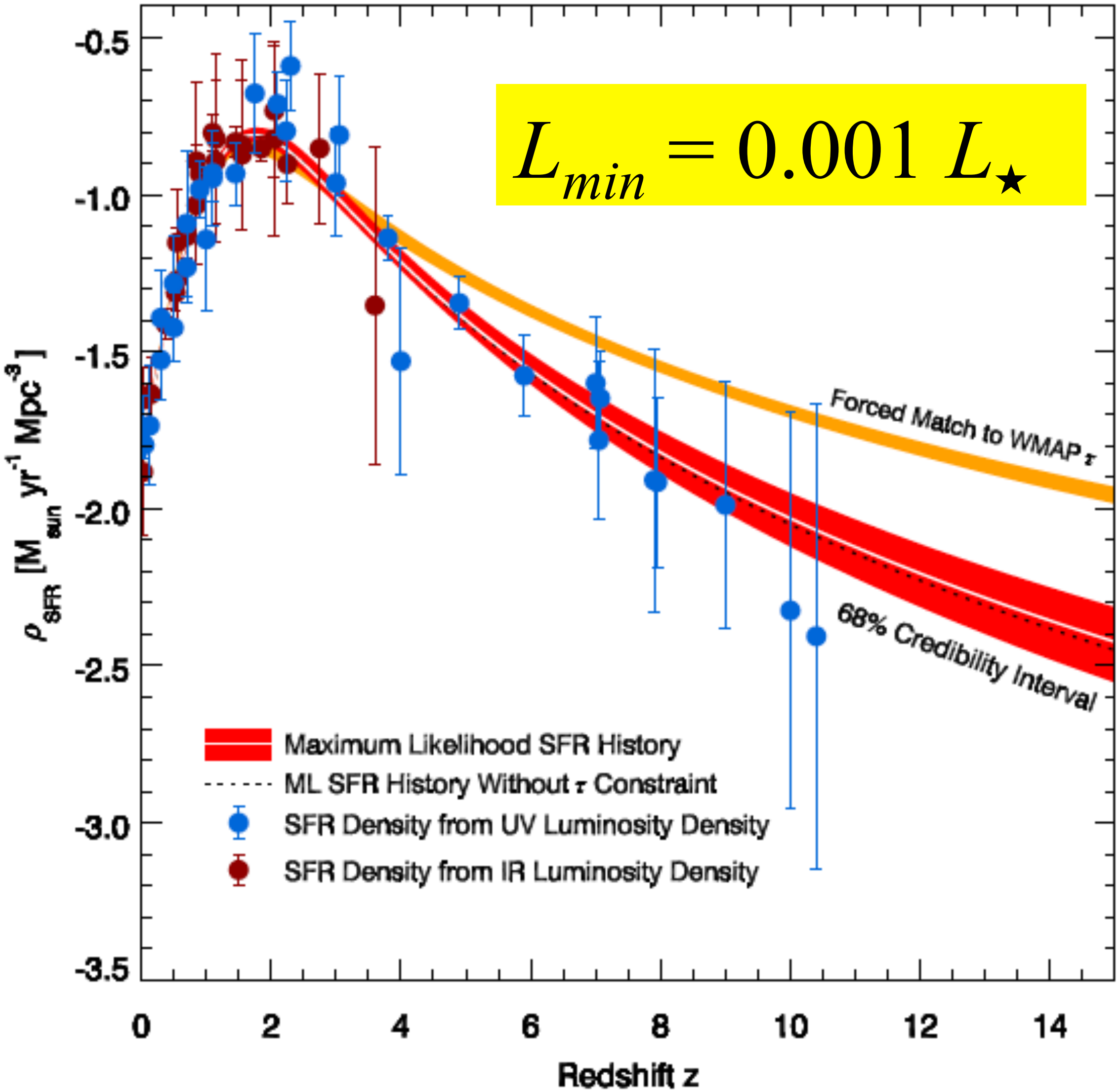
SKA Headquarters

Planck Collaboration 15

PLANCK POLARIZATION DATA



Robertson+15

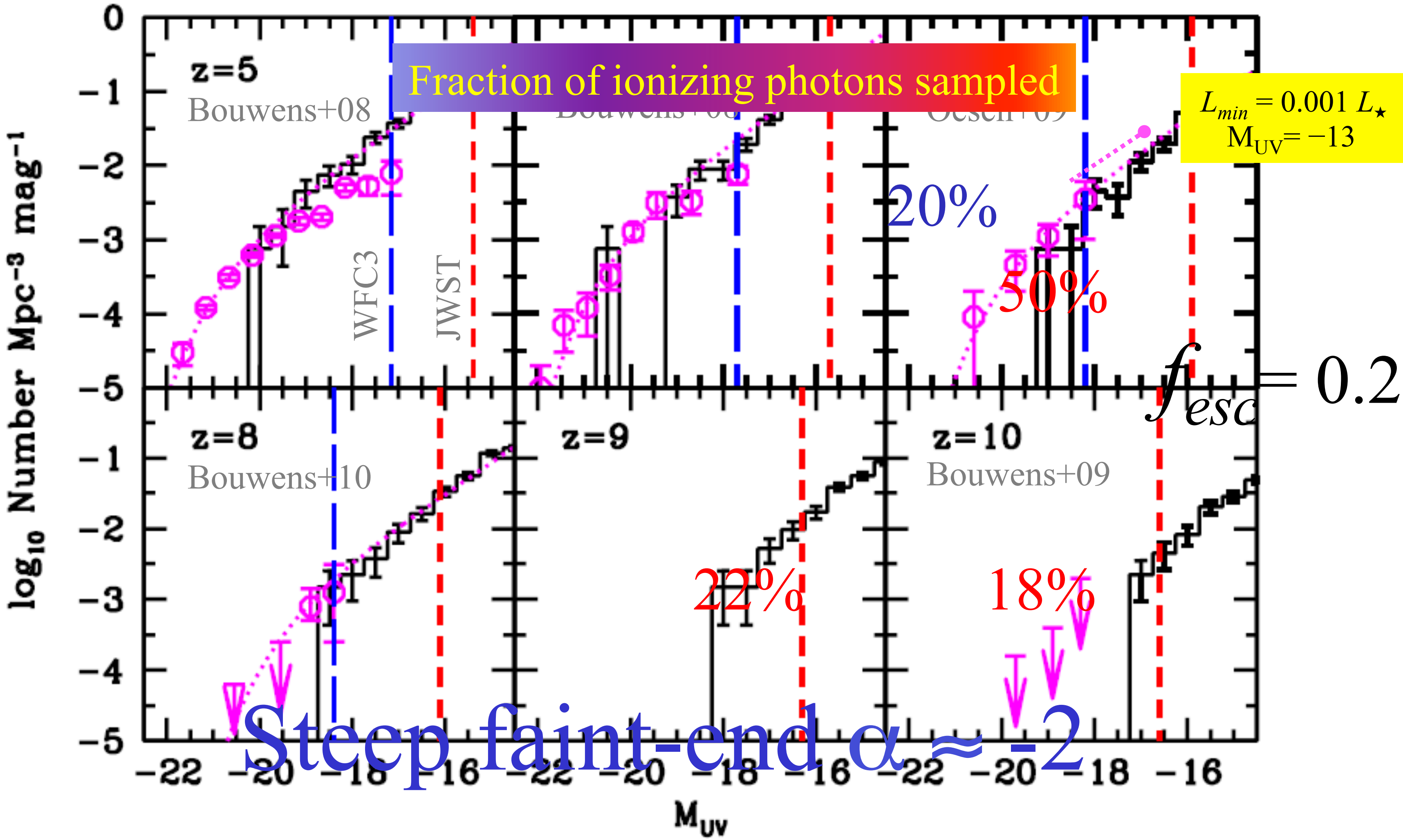


$L_{min} = 0.001\ L_\star$

$f_{esc} = 0.2$

Salvaterra, AF, Dayal 2011

SIMULATION RESULTS

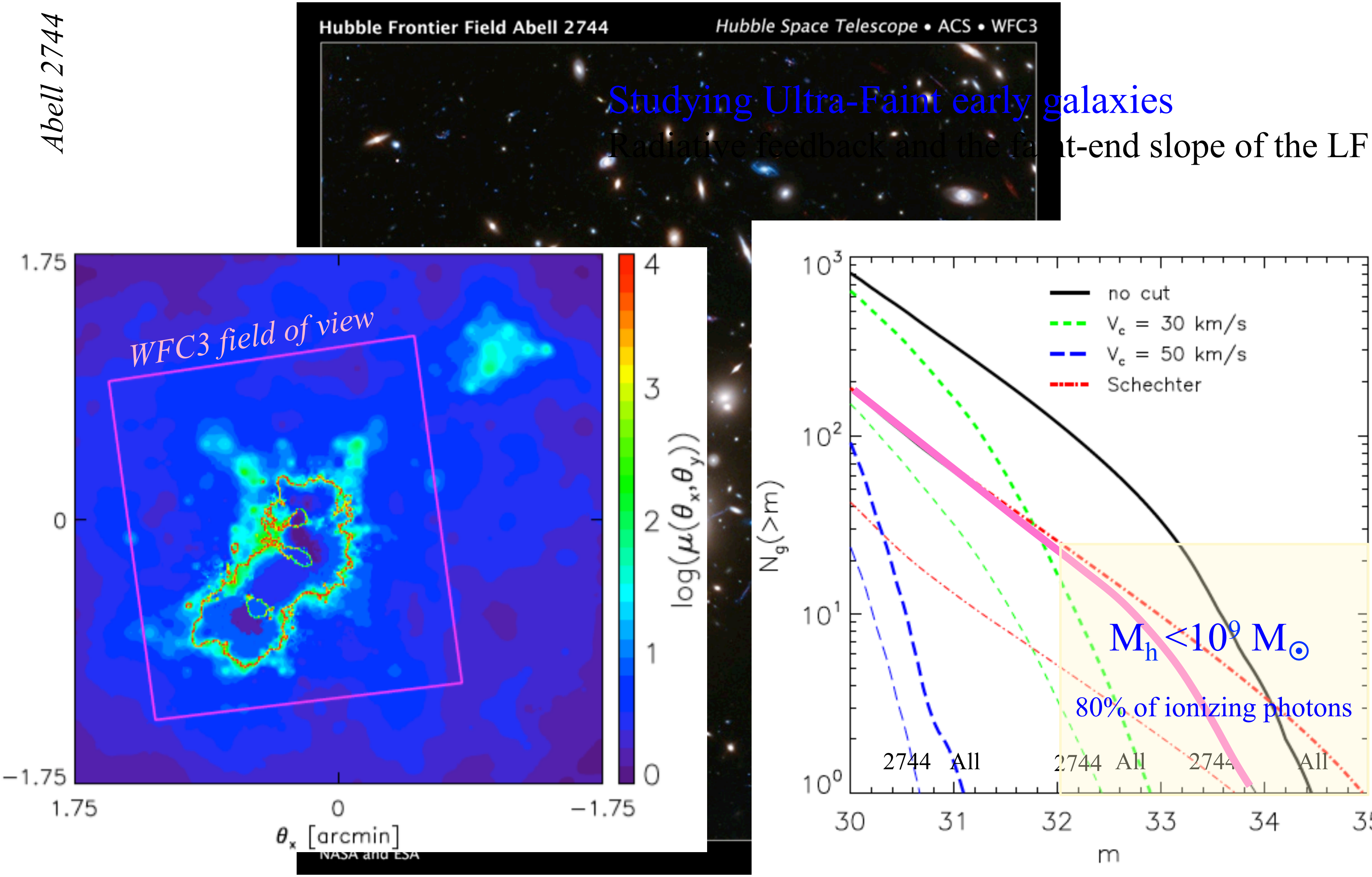


Coe+14; Atek+14; Yue, AF+14

Abell 2744

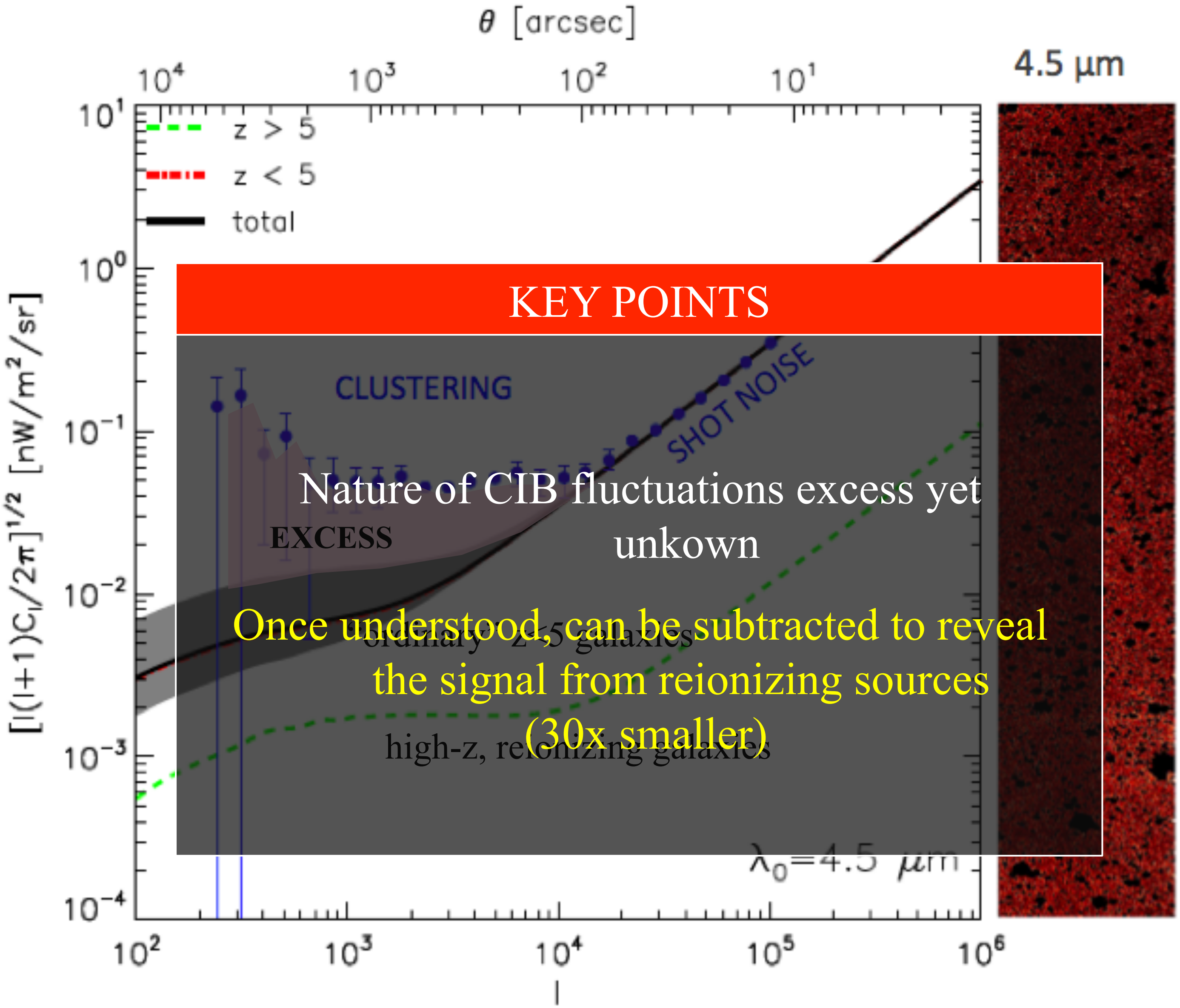
Studying Ultra-Faint early galaxies

Radiative feedback and the faint-end slope of the LF



CIB FLUCTUATIONS

Kashlinsky+12; Helgason+12; Yue+12



KEY POINTS

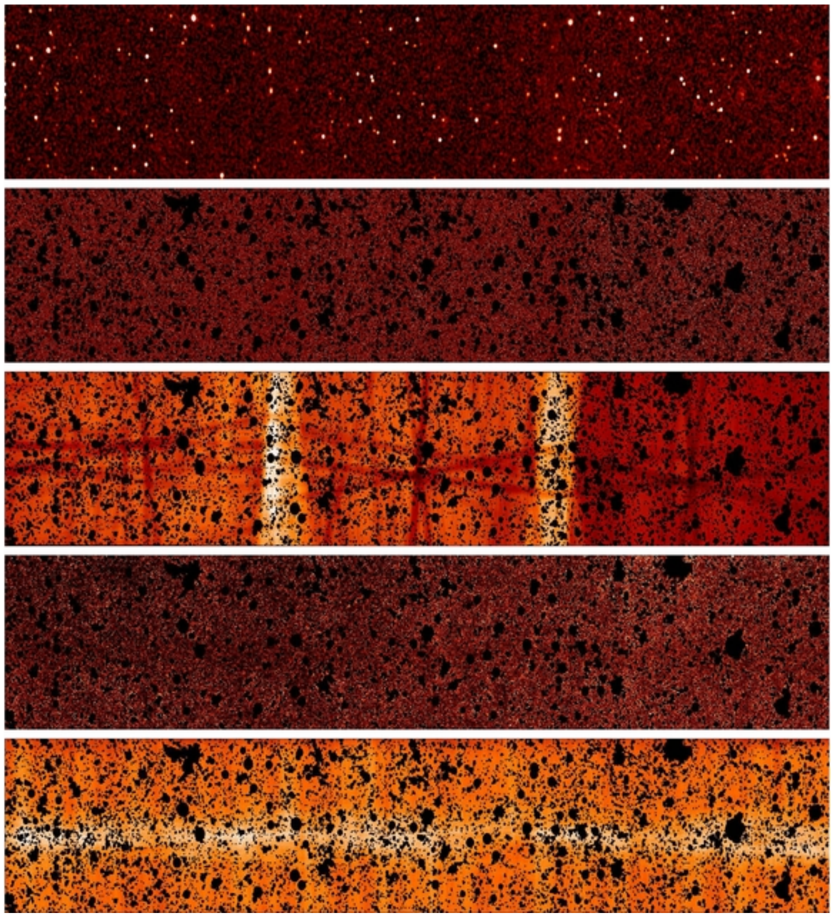
Nature of CIB fluctuations excess yet unkown

Once understood, can be subtracted to reveal the signal from reionizing sources (30x smaller)

Cappelluti+12

CIB-CXB CORRELATION

Chandra EGS/AEGIS field (45'× 8')



X-ray 0.5–2 keV count-rate map

X-ray 0.5–2 keV fluctuation map

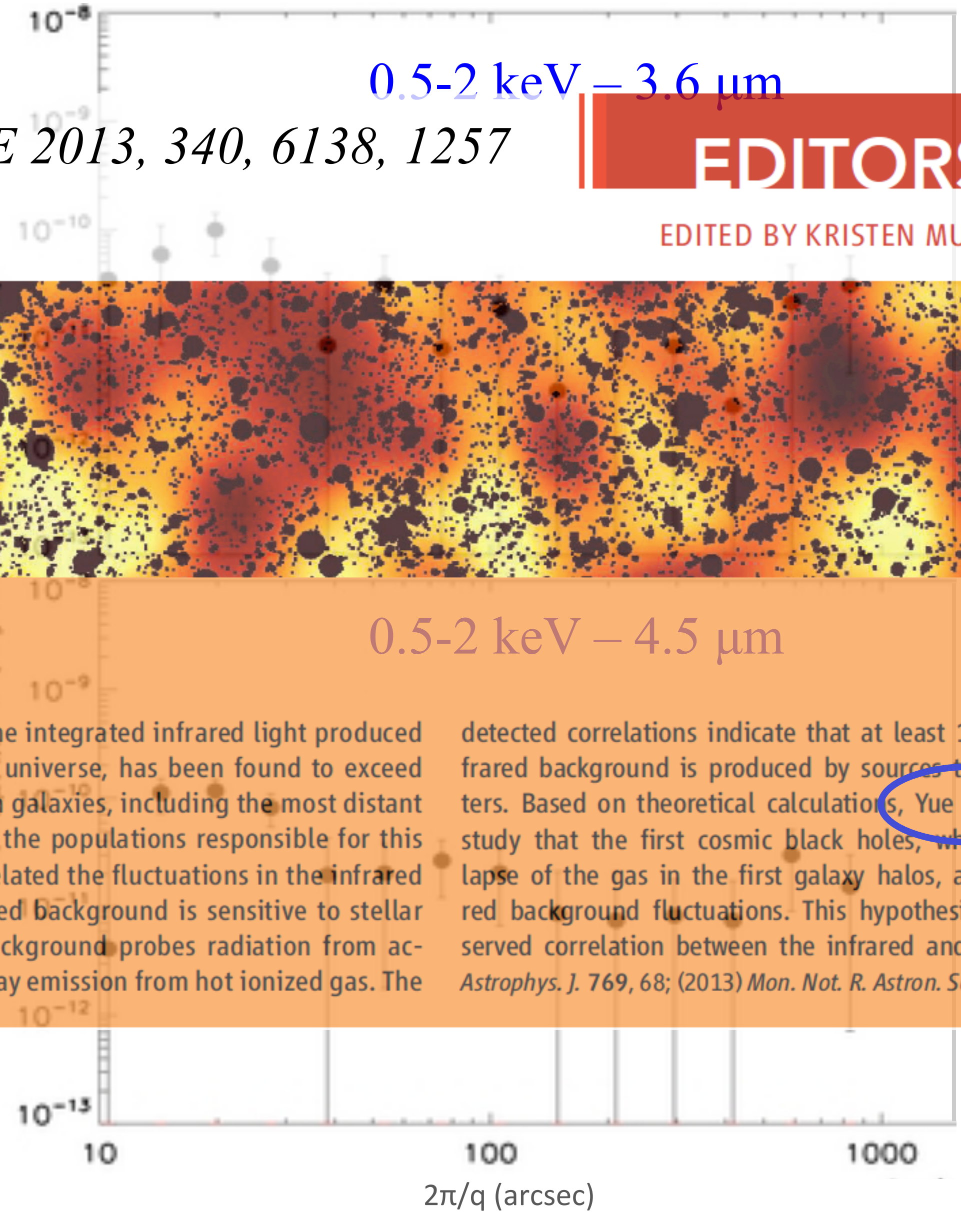
X-ray 0.5–2 keV exposure map

IRAC 4.5 μm fluctuation map

IRAC 4.5 μm exposure map

CIB-CXB Cross-Correlation

Science, 14 JUNE 2013, 340, 6138, 1257



EDITORS' CHOICE

EDITED BY KRISTEN MUELLER AND MARIA CRUZ

ASTRONOMY

Cosmic Correlation

The cosmic infrared background, the integrated infrared light produced by all extragalactic sources in the universe, has been found to exceed the expected emissions from known galaxies, including the most distant ones. To understand the nature of the populations responsible for this excess, Cappelluti *et al.* cross-correlated the fluctuations in the infrared and x-ray backgrounds. The infrared background is sensitive to stellar populations, whereas the x-ray background probes radiation from accreting black holes and thermal x-ray emission from hot ionized gas. The detected correlations indicate that at least 15 to 20% of the cosmic infrared background is produced by sources that are powerful x-ray emitters. Based on theoretical calculations, Yue *et al.* propose in a different study that the first cosmic black holes, which formed from direct collapse of the gas in the first galaxy halos, are responsible for the infrared background fluctuations. This hypothesis is consistent with the observed correlation between the infrared and x-ray backgrounds. — MJC

Astrophys. J. **769**, 68; (2013) *Mon. Not. R. Astron. Soc.* 10.1093/mnras/stt826 (2013).

une 13, 2013


First Black Holes ?

THE NEED FOR MASSIVE SEEDS

- SMBH of M=$10^9 M_\odot$ observed at z=7.085 (t=0.77 Gyr)
- Implications: (a) start early (b) (super-)Eddington rate at all times

$$m_0 = m(t) \exp\left[-\frac{1-\epsilon}{\epsilon}\frac{t(z)}{t_E}\right]$$

➔ Seed masses > 400 $M_\odot$

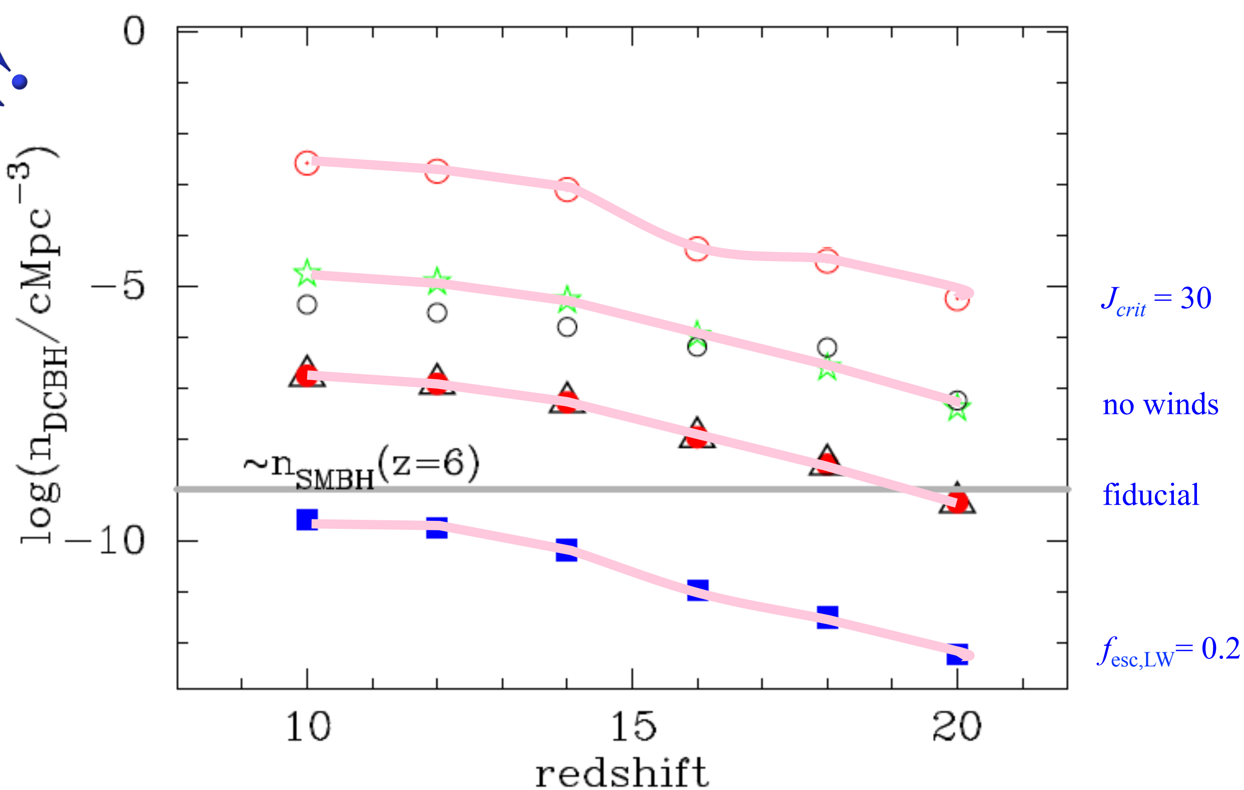
STELLAR SEEDS	DIRECT COLLAPSE
Continuous gas supply Avoid rad. fdbck depressing accretion rate Avoid ejection from halos and loosing BHs *Avoid overproducing ~ $10^6 M_\odot$ holes*	Gas driven in rapidly (deep potential) Transfer angular momentum Avoid fragmentation Reionization stops DCBH: short Era?

Dijkstra, AF & Mesinger 2014

DCBH ABUNDANCE

△	(i)	fiducial	$J_{crit} = 300$; Starformation occurs in all dark matter halos with $T_{vir} > 10^4$ K ($M_{UV,max} = -10.7$ at $z = 10$); $f_{esc,LW} = 1.0$; galactic outflows described by Eq 5.
●	(ii)	$M_{UV,max} = -14$	Same as (i), but extrapolate the UV-luminosity function to $M_{UV,max} = -14.0$
■	(iii)	$f_{esc,LW} = 0.5$	Same as (i), but with $f_{esc,LW} = 0.2$.
★	(iv)	no winds	Same as (i), but ignore galactic winds (i.e. $r_s = 0$).
○	(v)	$J_{crit} = 100$	Same as (i), but decrease J_{crit} from $J_{crit} = 300$ to $J_{crit} = 100$
⊙	(vi)	$J_{crit} = 30$	Same as (i) but use $J_{crit} = 30$ (see text for details)

UNCERTAIN!



- HI 21cm signal from Cosmic Dawn strongly affected by X-ray pre-heating
- Faint-end of UV LF is steep ($\alpha = -2$) and shaped by SN feedback
- More than 80% of photons come from halos with $M_h < 10^9 M_\odot$ ($H > 32$)
- HFF allow detection of "true" reionization sources and understand radiative feedback
- NIRB contains the cumulative light of early UF galaxies. Foreground removal?
- Black hole seeds imprint encoded in the NIRB-X-ray background correlation
- Abundance of DCBH seeds difficult to estimate, more work required