Identifying (Typical) First X-ray Sources

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From Chandra to Lynx

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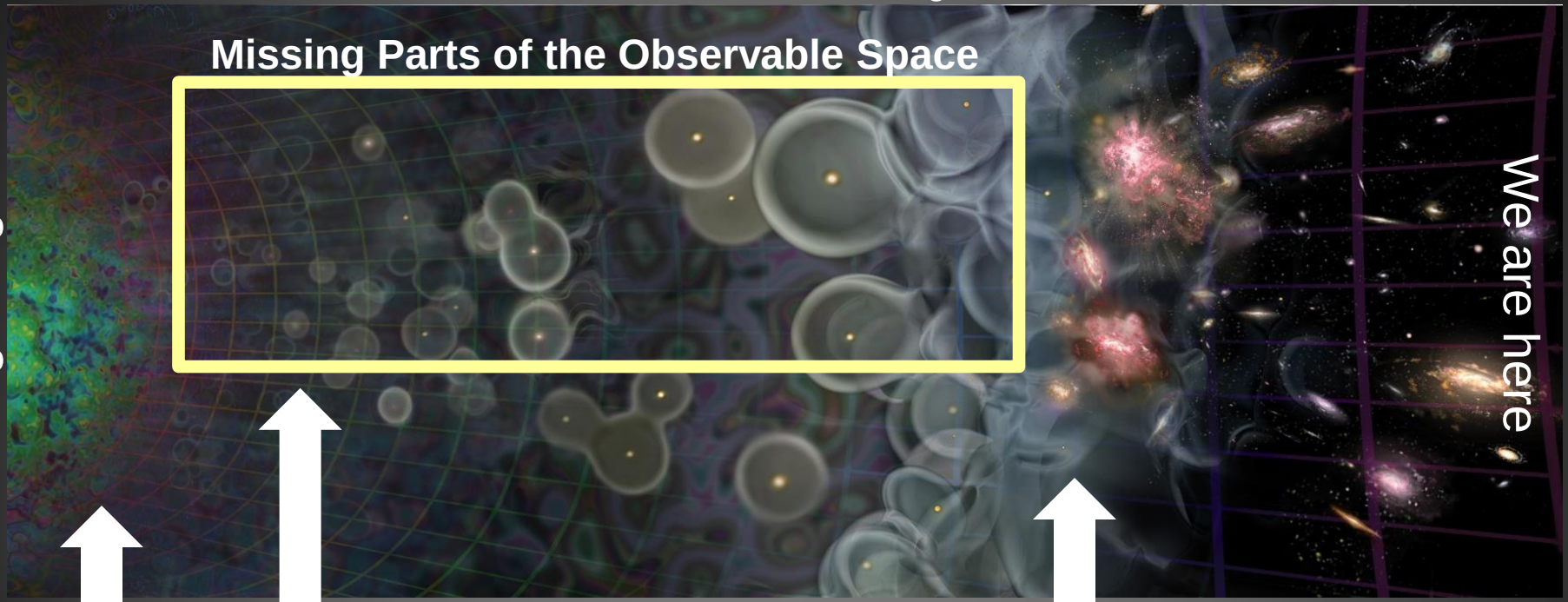
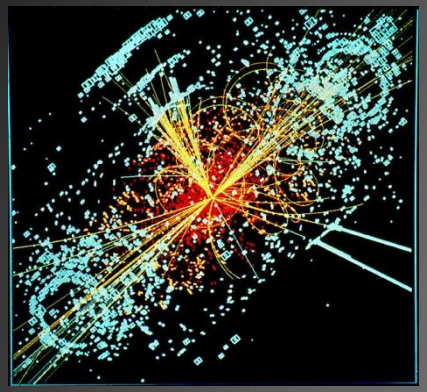
The Universe after the Big Bang

Image: Loeb, Scientific American 2006



First X-ray Sources



Dark matter annihilation

A black hole binary
(ESO image)

A quasar

Possible heating sources:

X-ray binaries?

Thermal emission from galaxies?

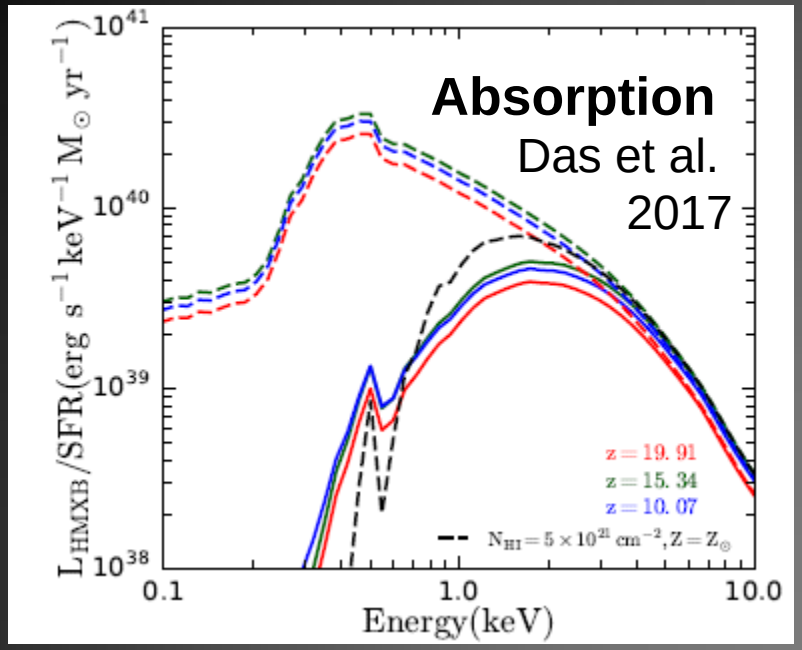
Black holes, mini quasars?

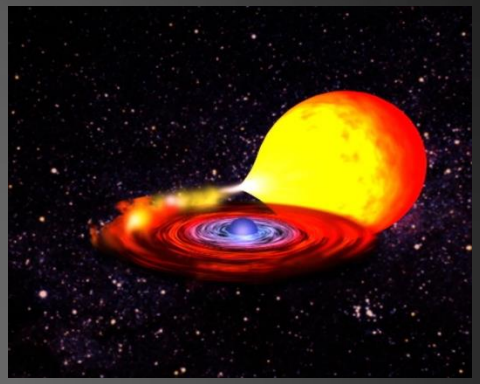
Dark matter annihilation?

Cosmic rays?

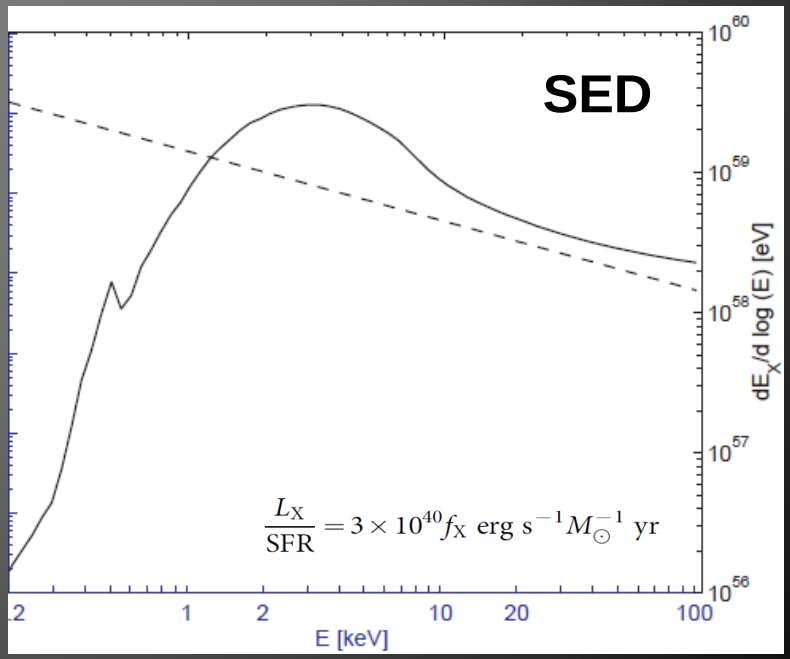
Magnetic fields?

Important Properties of X-ray Sources



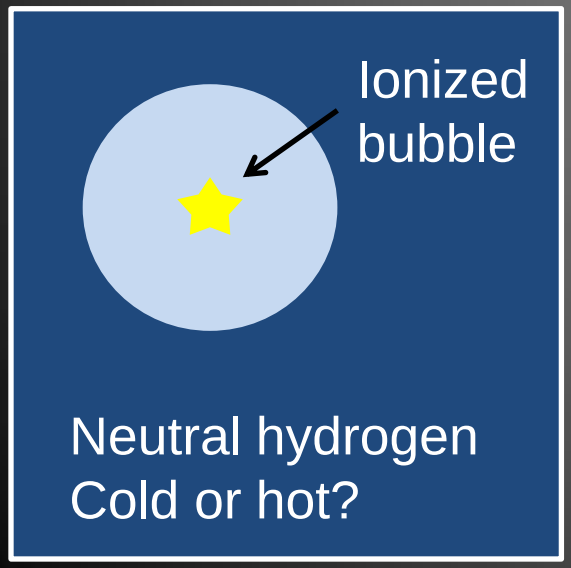


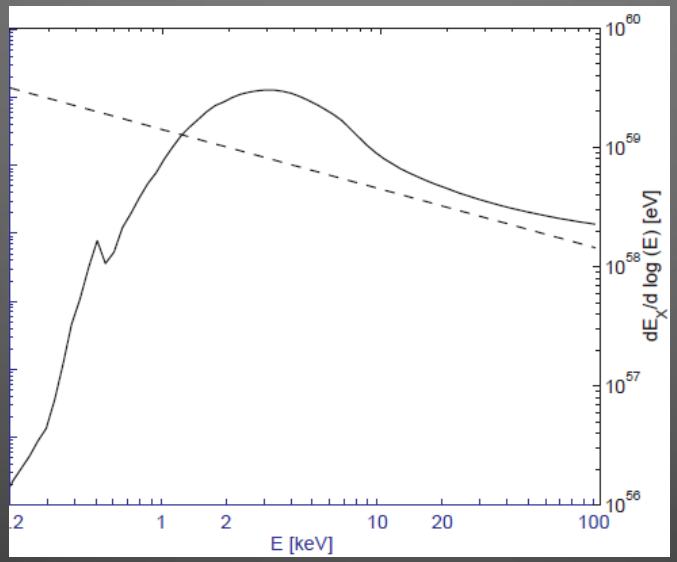
- X-ray efficiency (effect of metallicity)
- SED (XRB/quasars vs hot gas)
- Absorption (ISM of the host)
- Growth of population with redshift (XRB vs quasars)

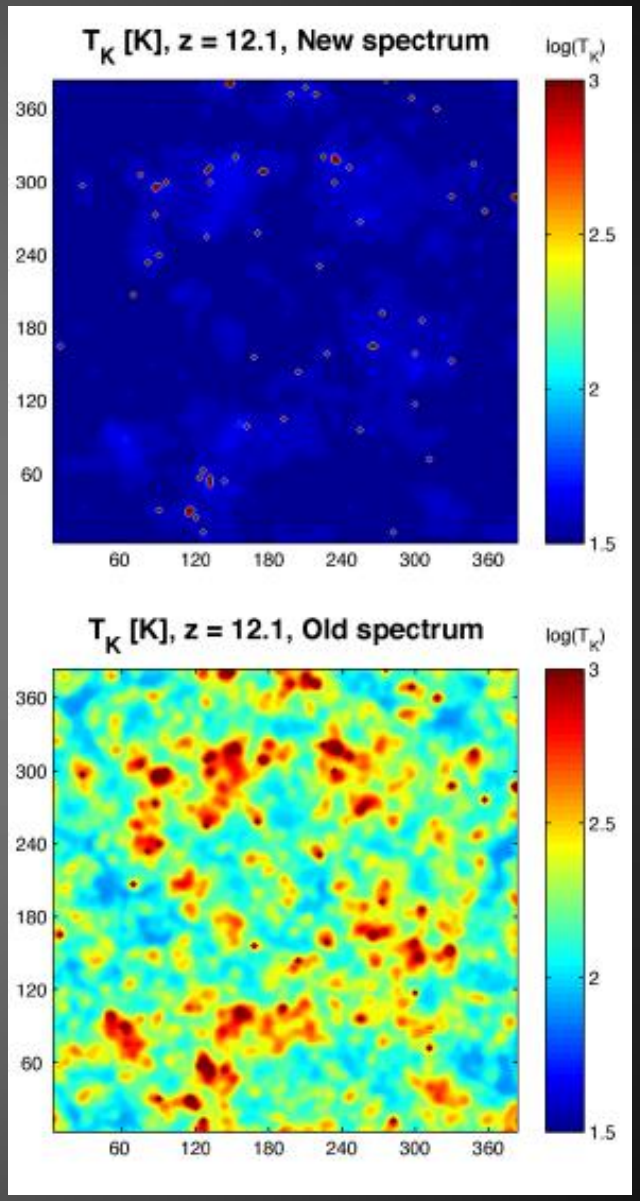


Effects of First X-ray Sources on the Environment

- X-rays can easily escape from their host galaxies
- Heat and ionize IGM 10-1000 Mpc away from the source
- Temperature of the IGM fluctuates (non-homogeneous distribution of X-ray sources)

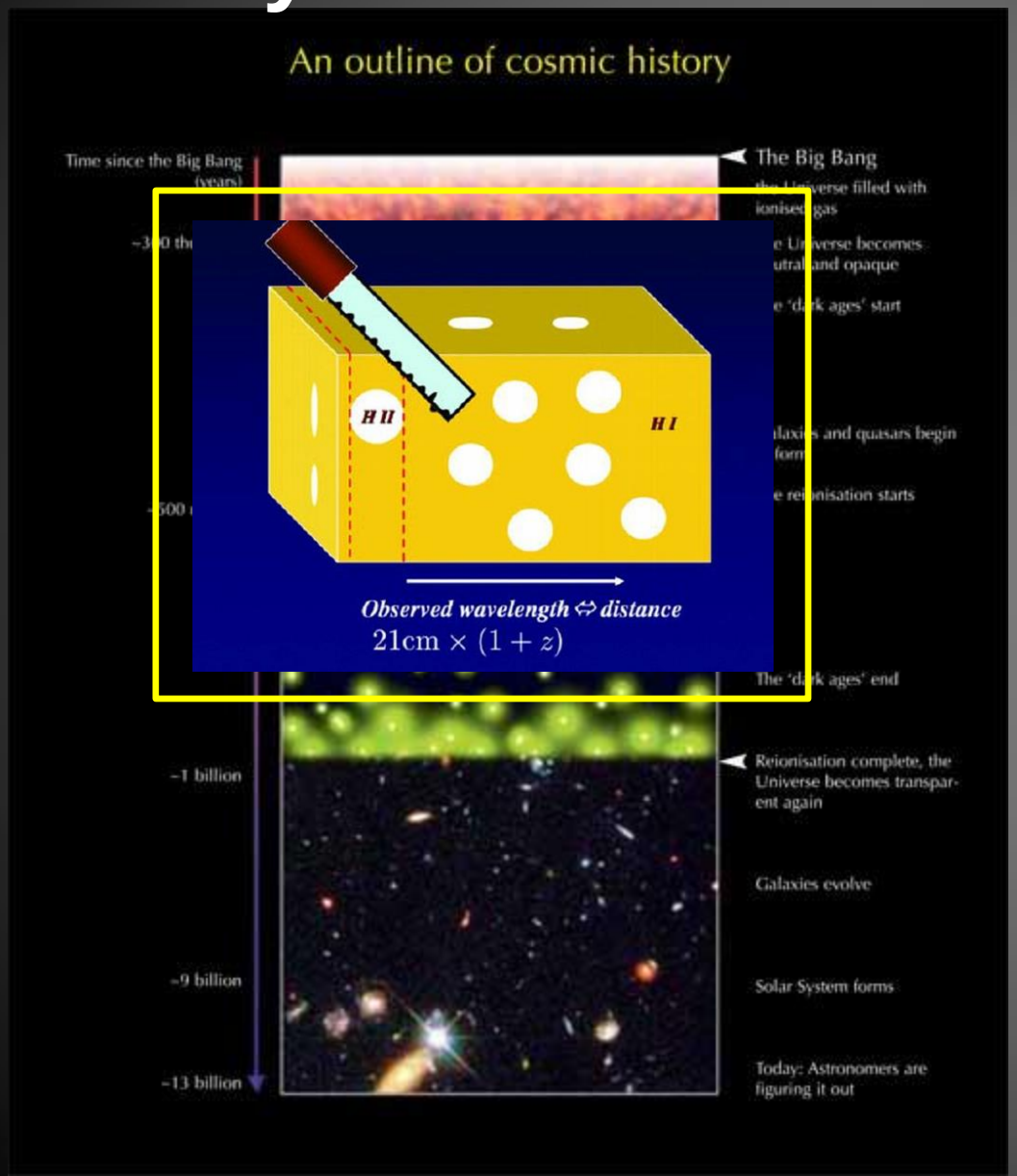


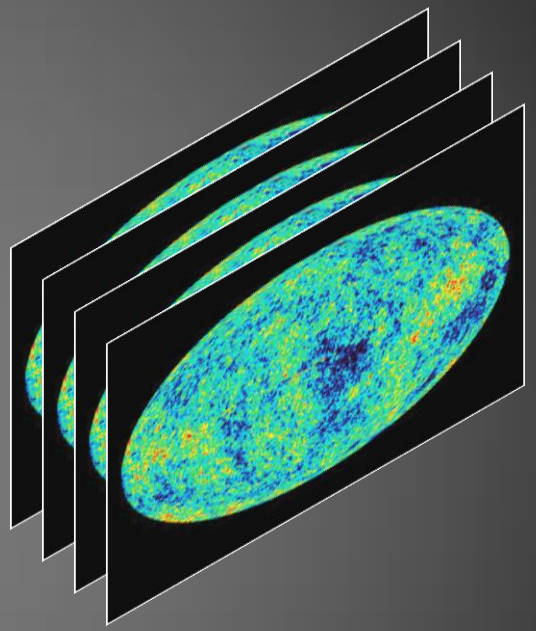




Fialkov & Barkana (2014)

21-cm Signal: Alternative Probe of X-ray Sources

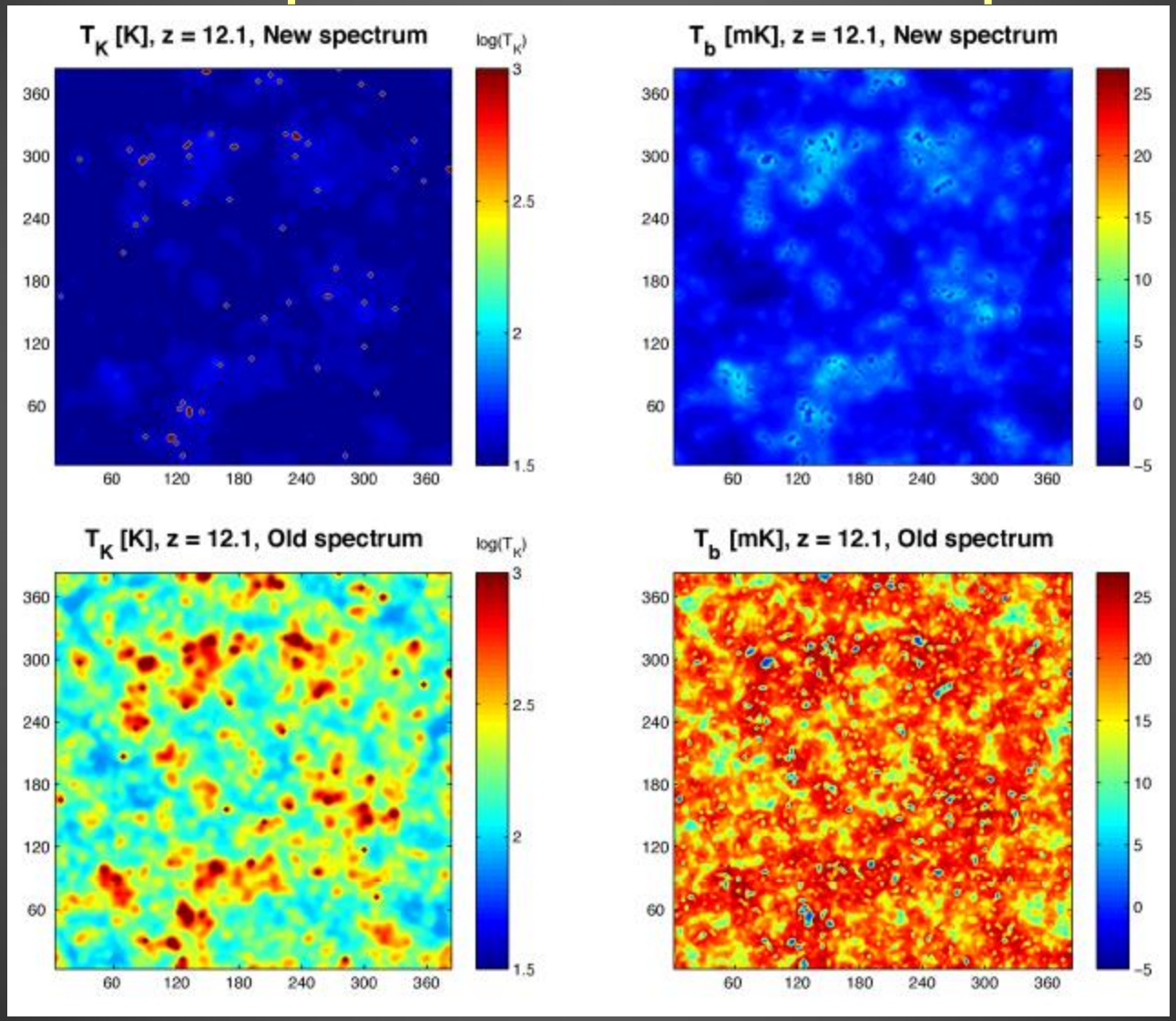




- 21-cm is a spectral line
- Tomographic scan of the Universe at z>6

Sensitive to X-ray Heating

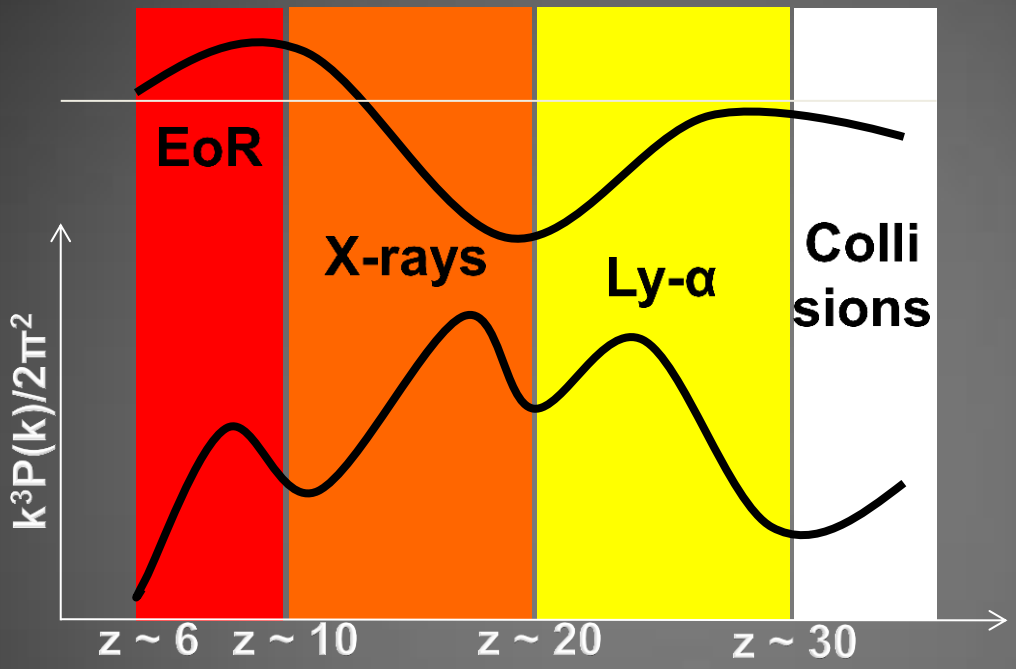
Gas Temperature **21-cm Map**



Fialkov & Barkana (2014)

Signature of X-ray Sources in 21-cm Signal

Global Signal



Power Spectrum

- Produced at $z \gtrsim 6$
- 3D scan of the neutral IGM
- Effect of X-ray sources at $10 \lesssim z \lesssim 20$

Drivers:

Galaxies

Quasars

XRB

BHs

Hot Gas

SN

First stars

Feedbacks

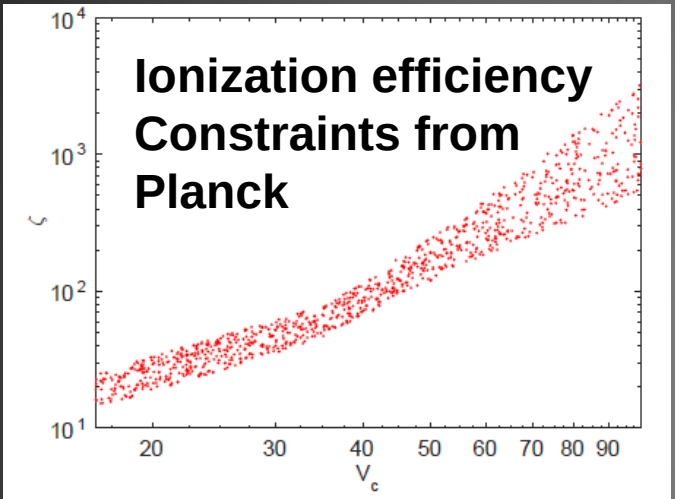
Velocity flows

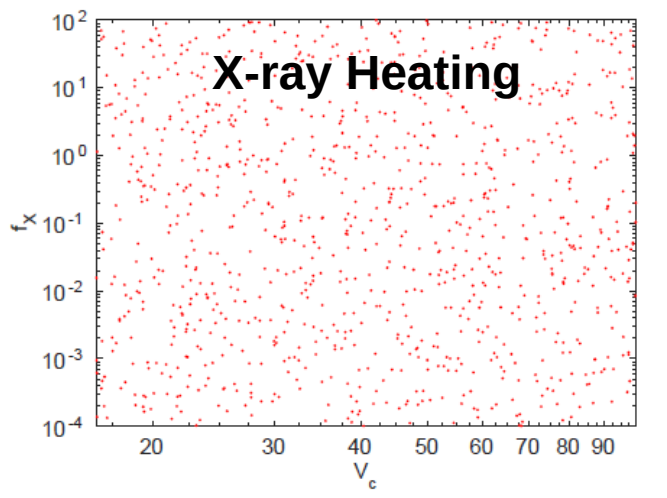
Cosmology

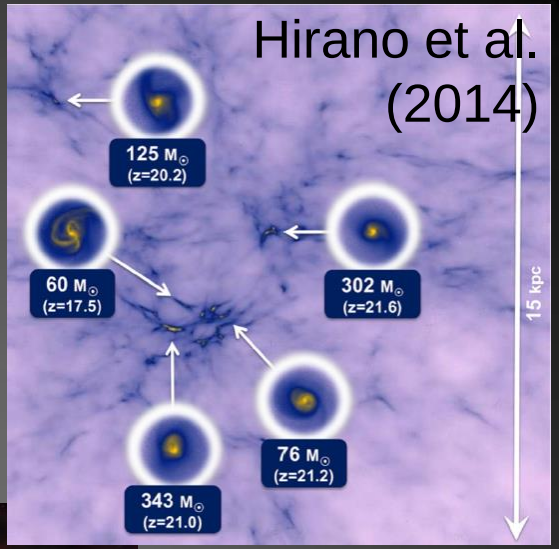
Atomic physics

Exotic physics

Large Uncertainty in Astro Parameters







$\sim 10^4$ different models

Star formation,
2 parameters
+ feedbacks

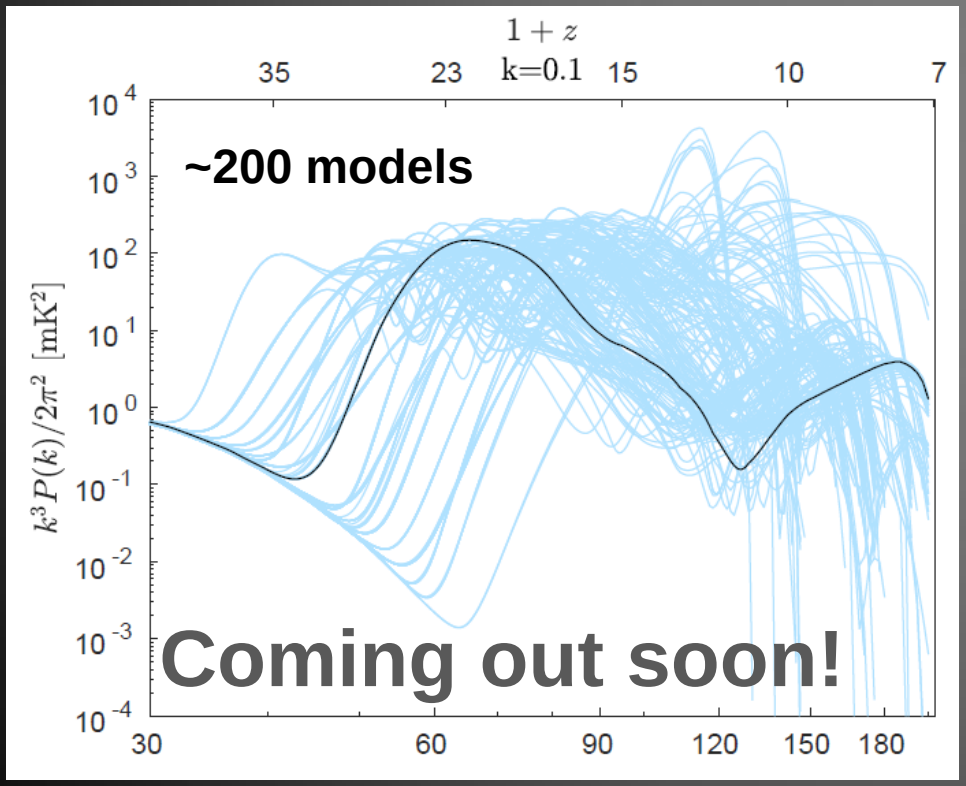
Heating,
3 parameters

EoR 2 parameters

Fialkov, Cohen, Barkana (in prep)

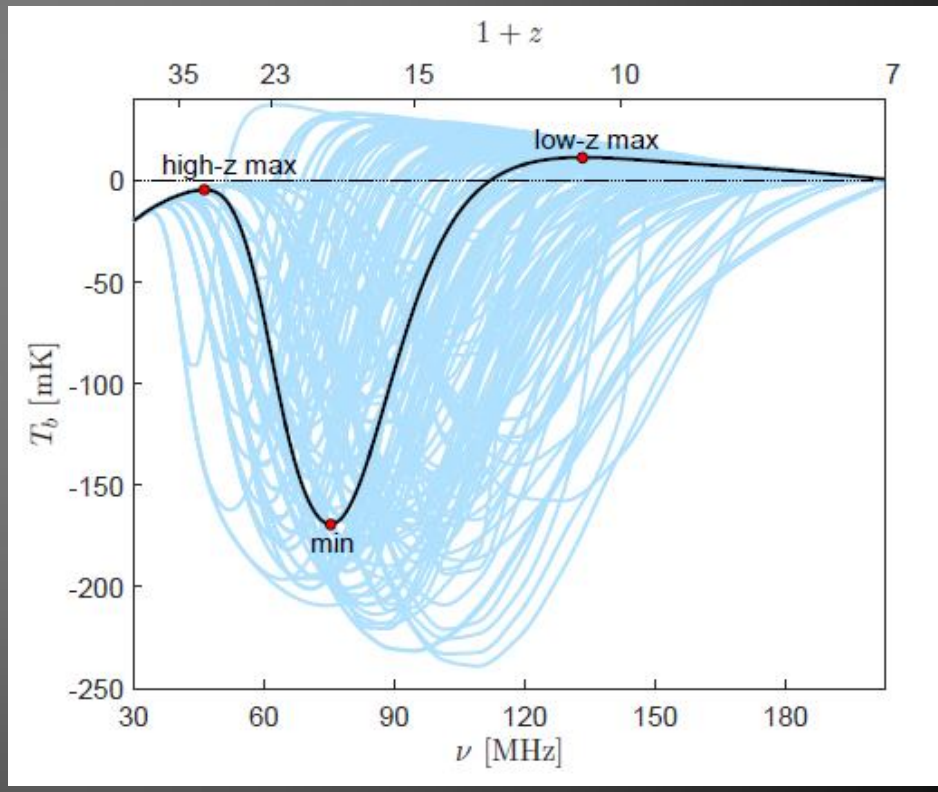
- Currently very weak observational constraints
- Exact shape and amplitude of the 21-cm signal are unconstrained
- Both detection and non-detection will transform our understanding

Power Spectra



Cohen, **Fialkov**, Barkana (in prep)

Global 21-cm

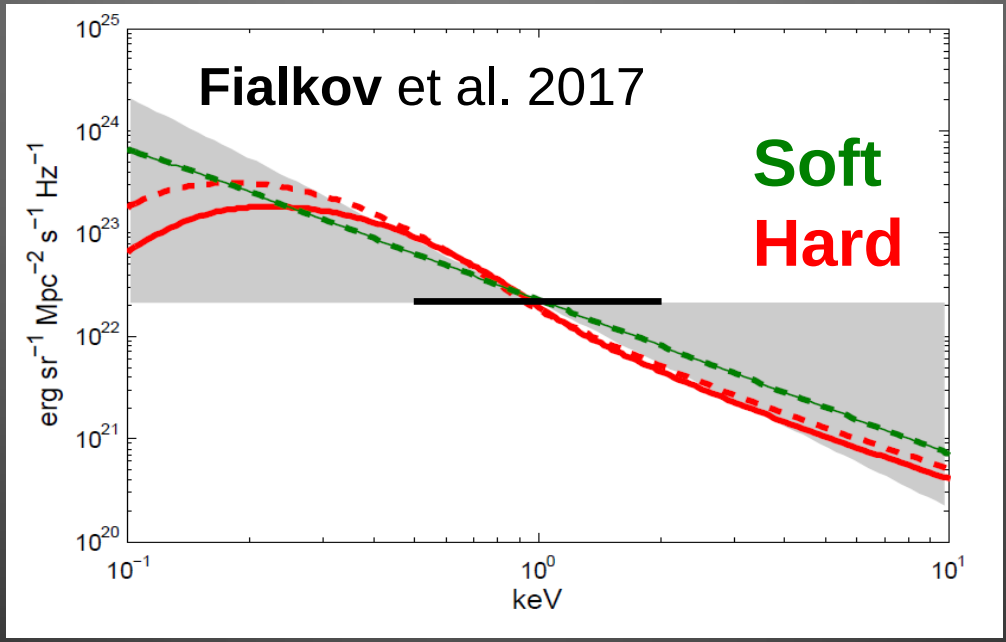


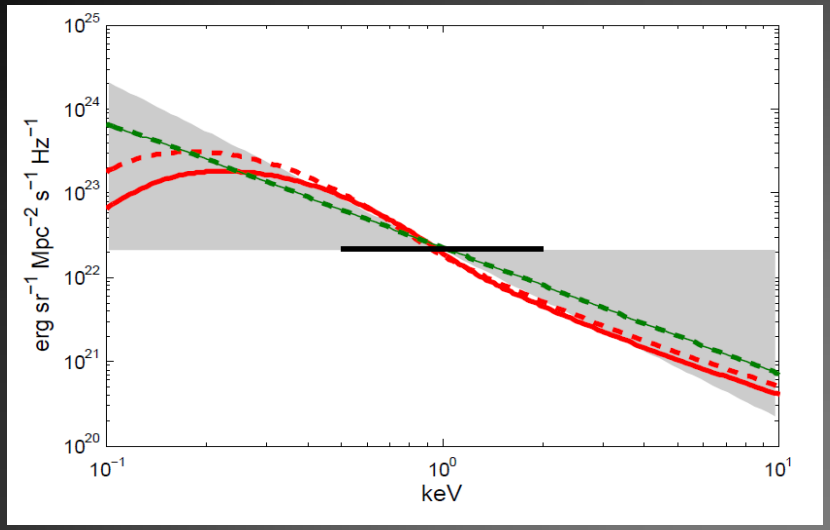
Cohen, **Fialkov**, Barkana (submitted)

The Unresolved Soft CXB

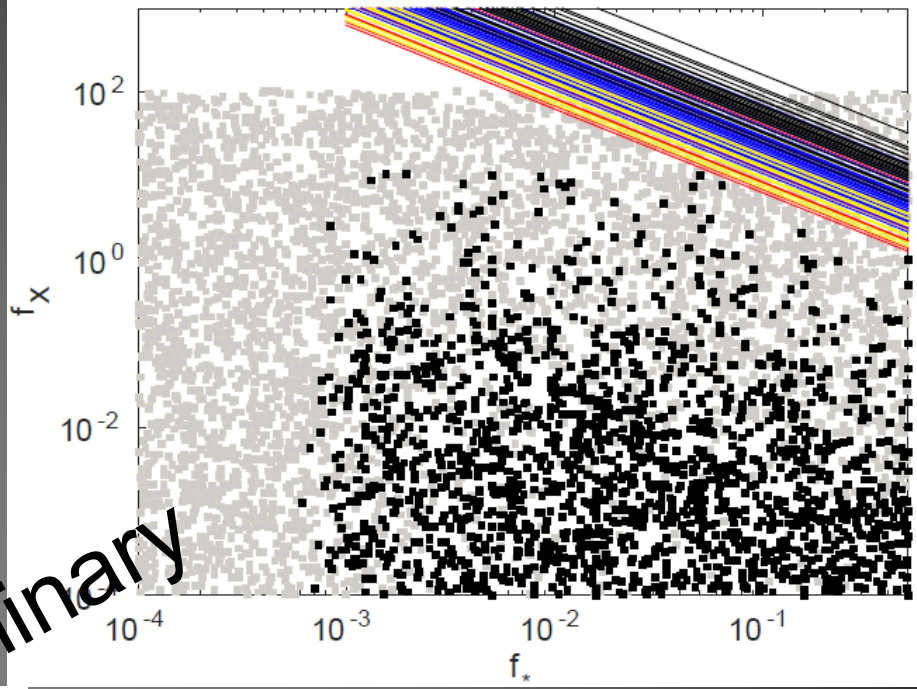
Total intensity of the extragalactic CXB attributed to high-z population $< 7 \times 10^{-12}$ $[erg\ cm^{-2} s^{-1} deg^{-2}]$ for 0.5 – 2 keV
(Cappelluti et al. 2017)

Unresolved extragalactic CXB yields upper limit on X-ray efficiency ($f_X = 10 - 100$).

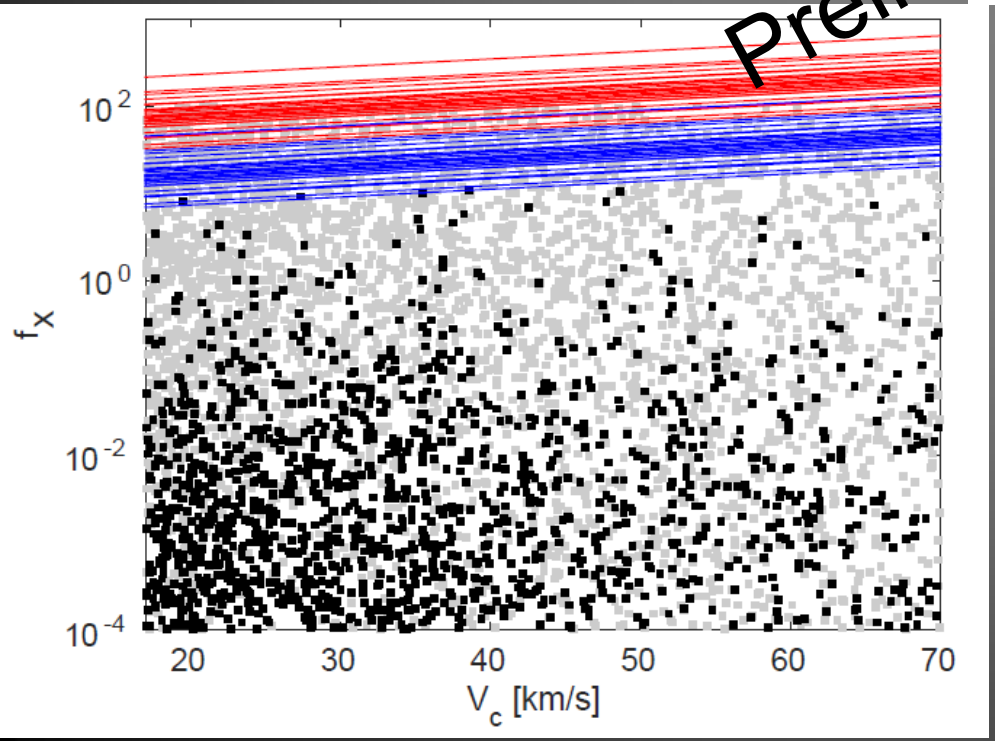




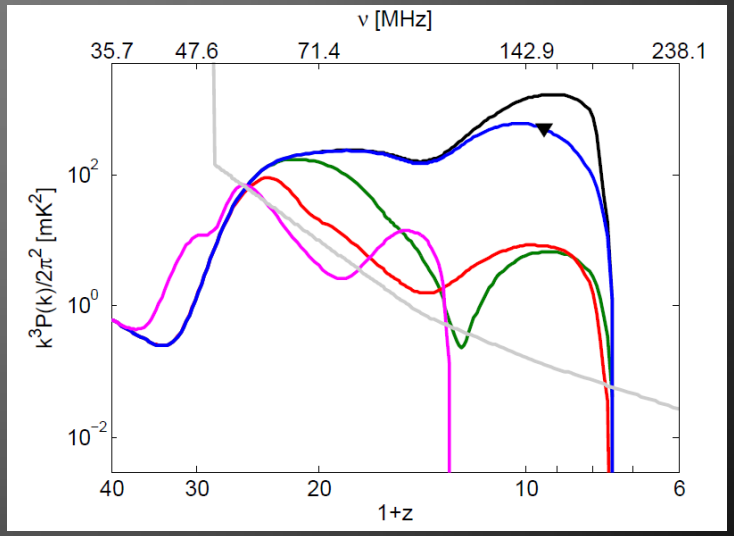
fX vc Vc



Preliminary



fX vs SFE



Most Promising Experiments

SKA:

Under construction

Redshifts: 6-28

FoV: 5 deg

Resolution: 1’

Survey volume: TBD

HERA:

Taking Data

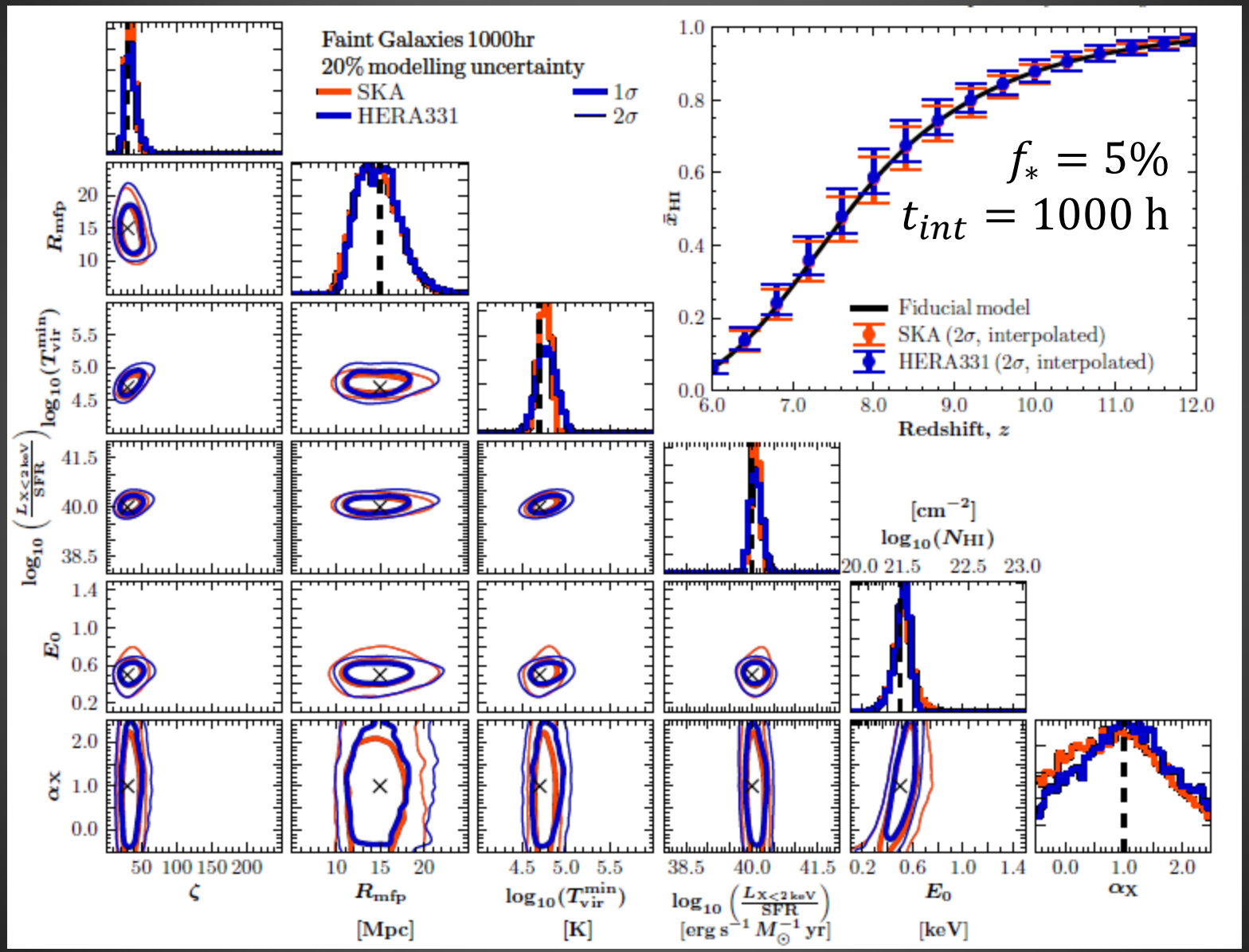
Redshifts: 4.7-27.4

FoV: 9deg

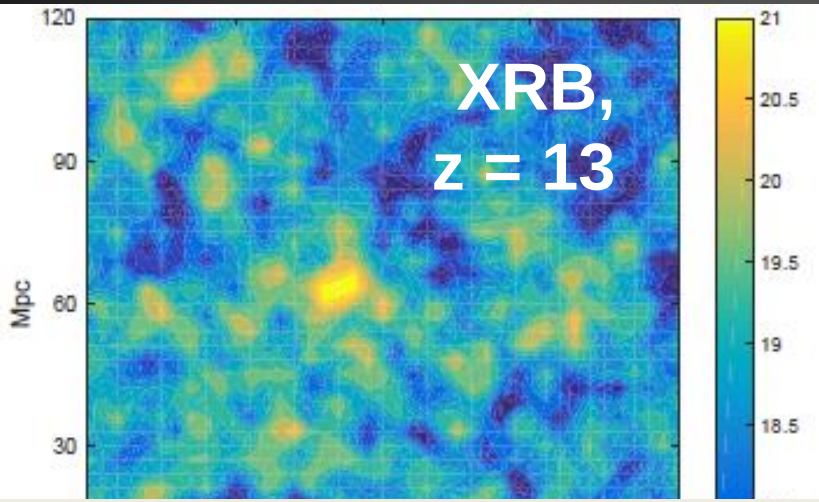
Resolution: 25’

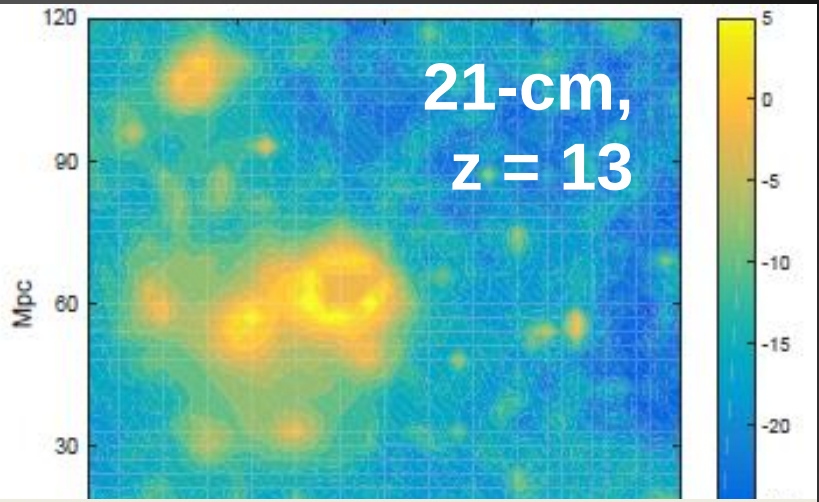
Survey volume 150 $cGpc^3$

Constraining Parameters (21-cm only)

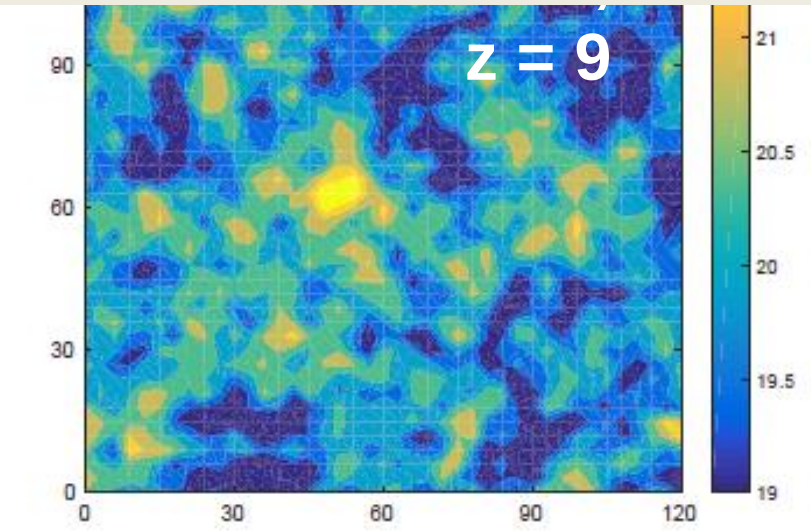


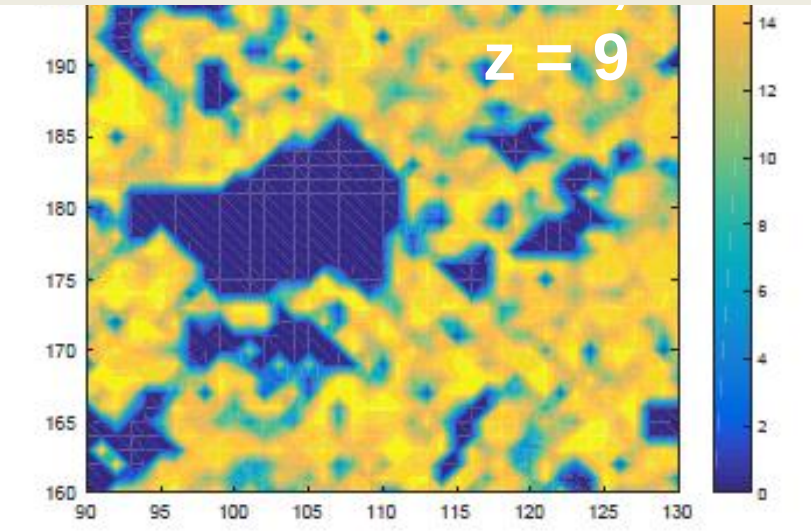
Greig & Mesinger 2017 (see also Kern et al. 2017)



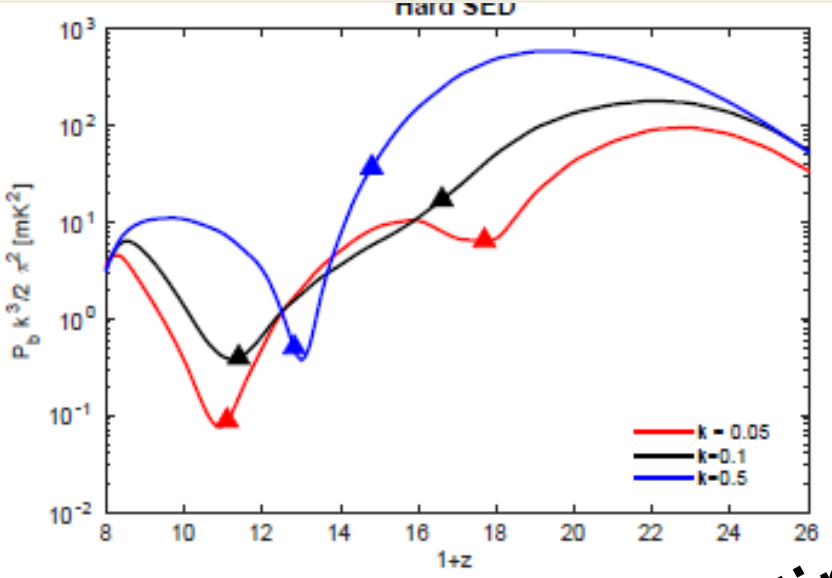


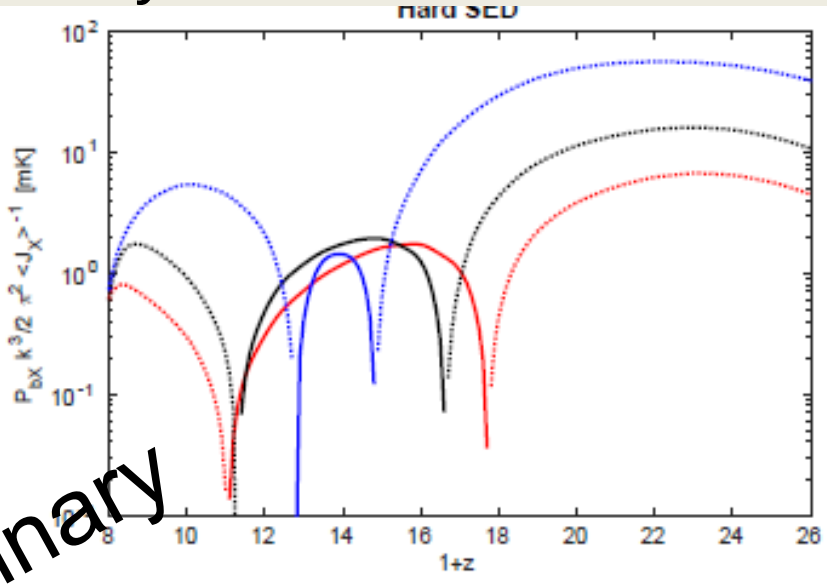
Cross-correlation with large-scale X-ray background can improve understanding of large-scale effect of X-rays



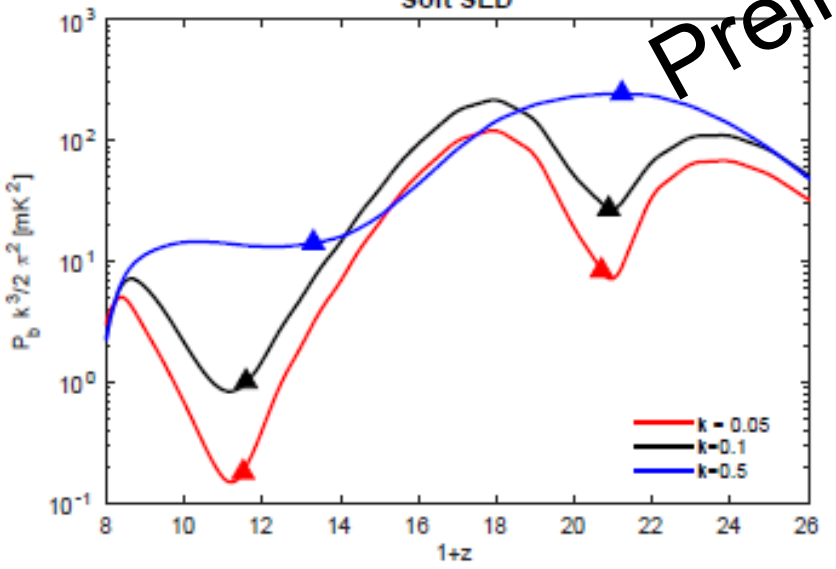


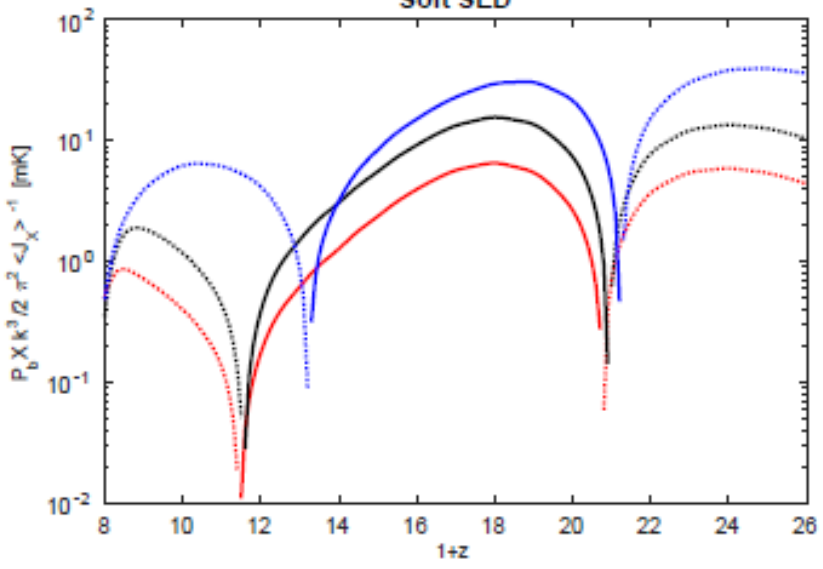
Even in cases when the X-ray peak is not evident in 21-cm, cross-correlating with X-rays background can highlight the effect of X-rays





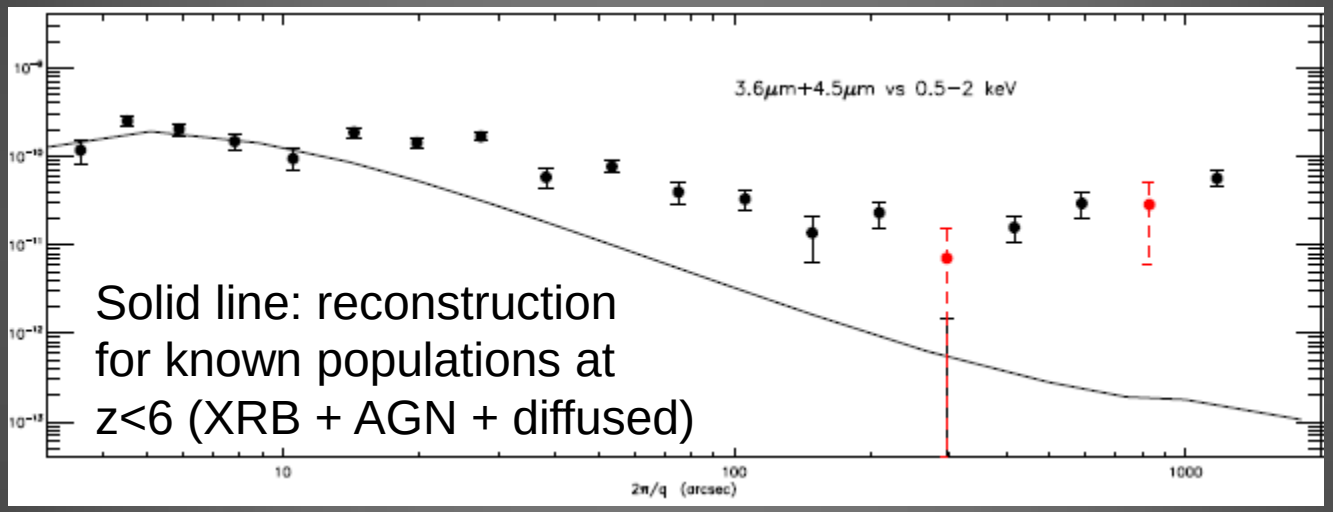
Preliminary





“Proof of Concept”
CXB-CIB Cross-Correlation

First detection of the cross-power signal between CIB and CXB on large scales (> 20′) at 5σ



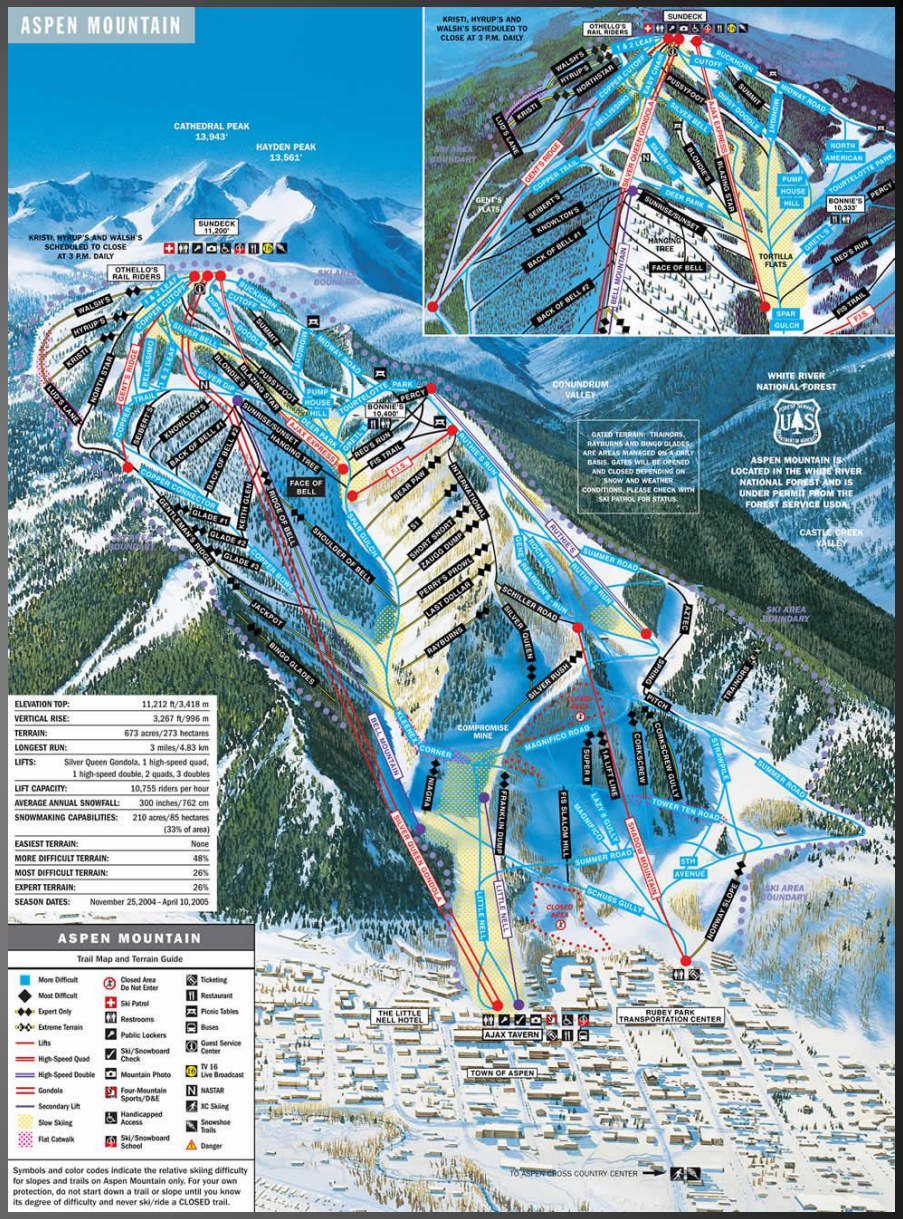
Cappelluti et al. 2017

- Known populations alone cannot explain the observed signal
- Similar technique will be used for 21-cm & CXB cross-correlation (work is ongoing)

Aspen Meeting

Cosmological Signals from Cosmic Dawn to the Present
Feb 4-10, 2018

- Line intensity mapping
- The 21-cm signal from EoR and cosmic dawn
- First UV and X-ray sources
- Physics of reionization and cosmic dawn



Organizers: Anastasia Fialkov, Tzu-Ching Chang, Rennan Barkana, Judd Bowman, Adam Lidz, Anthony Pullen.

Conclusions:

Prospects to constrain the high-z population of X-ray sources(z>6) using 21-cm and CXB crosscorrelation

Work is ongoing

- Better modeling of the cross-power
- Methods to measure the cross power