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

We are here

Missing Parts of the Observable Space

Dark Ages

Cosmic Dawn

First Stars

Big Bang

Image Credit: Adolf Schaller/NASA-MSFC

EoR

Time

Redshift
First X-ray Sources

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)

Neutral hydrogen
Cold or hot?

Ionized bubble

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

Drivers:
- Galaxies
- Quasars
- XRB
- BHs
- Hot Gas
- SN
- First stars
- Feedbacks
- Velocity flows
- Cosmology
- Atomic physics
- Exotic physics

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

- Ionization efficiency constraints from Planck
- X-ray Heating

\( \sim 10^4 \) different models

- Star formation, 2 parameters + feedbacks
- Heating, 3 parameters
- EoR 2 parameters

- A quasar
- A black hole binary (ESO image)

Hirano et al. (2014)

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

Global 21-cm

~200 models

Coming out soon!

Cohen, Fialkov, Barkana (in prep)
The Unresolved Soft CXB

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

Unresolved extragalactic CXB yields upper limit on X-ray efficiency ($f_X = 10 – 100$).
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 cGpc³
Constraining Parameters (21-cm only)

For Faint Galaxies 1000hr
- 20% modelling uncertainty
- SKA
- HERA331

$\frac{f_\ast}{t_{int}} = 5\%$

$\frac{t_{int}}{1000 \text{ h}}$

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.
"Proof of Concept"
CXB-CIB Cross-Correlation

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

Solid line: reconstruction for known populations at z<6 (XRB + AGN + diffused)

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