Intensity Mapping Tomography: Method and Application to Data

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Broadband intensity mapping?

- **Potential:** unlock the use of diffuse light in the rich legacy of sky surveys

- **Challenge:** frequency information is largely lost, \( R = \frac{\lambda}{\Delta \lambda} \sim 5 \)

  more foregrounds, junk, and redshift projection ➔ intensity mappers' nightmare
How can we deal with foregrounds, junk & redshift projection?

\[ w_{lr}(z) \propto \frac{dl}{dz}(z) b_l(z) b_r(z) w_{DM}(z) \]

Clustering redshift estimation

Formalism: Newman+08, Menard+13, McQuinn+13

Applications in galaxy surveys: Rahman+16 (SDSS), Scottez+16 (CFHTLS), Morrison+16 (KiDS), Davis+18 (DES)
The extragalactic background light (EBL)

- microwave
- infrared
- ultraviolet
- x-ray
- gamma-ray
- radio
- optical

ISM, CGM, IGM

- dust
- relic
- stars
- accreting blackholes

Cosmic UV background tomography

Far-UV (FUV) 1500 Å

Chiang, Ménard & Schiminovich 2019

Near-UV (NUV) 2300 Å
GALEX
Far-UV (FUV)
1500 Å
GALEX

Far-UV (FUV)
1500 Å
GALEX
Far-UV (FUV)
1500 Å
10 deg scale
Redshift tomography for the Cosmic UV background

\[ \frac{dI}{dz} \times b \ [\text{Jy/sr}] \]

FUV (1500 Å)  

NUV (2300 Å)

SDSS + BOSS + eBOSS spectroscopic redshifts (2M objects)

Chiang+ 2019
Redshift tomography is simultaneously a frequency tomography

UV background spectrum

- $\alpha_{1100}(z)$
- $\alpha_{1500}(z)$
- $f_{LyC}(z)$
- $EW_{Ly}(z)$

Near-UV (NUV): 2300 Å

Far-UV (FUV): 1500 Å

Response

$\frac{dI}{dz} \times b$

Lyα in FUV

Lyα in NUV

Chiang+ 2019
Redshift tomography is simultaneously a frequency tomography

UV background spectrum

Response

Far-UV (FUV) 1500 Å
Near-UV (NUV) 2300 Å

Chiang+ 2019
Redshift tomography is simultaneously a frequency tomography

UV background spectrum

Far-UV (FUV) 1500 Å
Near-UV (NUV) 2300 Å

Response

Chiang+ 2019

UV background spectrum

EW_{Ly\alpha}(z)
\alpha_{1100}(z)
\alpha_{1500}(z)

f_{Ly\alpha}(z)

z=0
z=0.3
z=0.6
z=1
z=1.5
z=2.1

Lyman break

Redshift tomography is simultaneously a frequency tomography

dI/dz \times b

Ly_{\alpha} \text{ in FUV}
Ly_{\alpha} \text{ in NUV}

Lyman break

continuum
Constraining the UV background spectrum

FUV  (1500 Å)  
NUV  (2300 Å)

Best-fit UV background spectrum

Chiang+ 2019

Lyα — Lyman Break

FUV (1500 Å)

NUV (2300 Å)

Best-fit UV background spectrum

dI/dz × b [Jy/sr]

$\epsilon_\nu \left[ \text{ergs}^{-1} \text{Hz}^{-1} \text{Mpc}^{-3} \right]$

$\lambda_{\text{rest}} \left[ \text{Å} \right]$
Constraining the UV background spectrum

FUV

NUV

SDSS

\[ \frac{dI}{dz} \times b \text{ [Jy/sr]} \]

FUV (1500 Å)

NUV (2300 Å)

Ly\(\alpha\) luminosity density constraints

cosmic Ly\(\alpha\) escape fraction 5-10% at z=1

Chiang+ 2019

see also Croft+18
The flow of information content

- Cosmic star-formation
- Leakage of ionizing photons
- Ly$\alpha$ escape from the ISM

spatial fluctuations $\rightarrow$ redshift $\rightarrow$ spectra $\rightarrow$ physics

All is done without using any spectroscopic IM data in the UV

Only 30% of GALEX photons are in detected sources; we have recycled the rest 70%
Multiwavelength view of the diffuse sky

- 21 cm - HI4Pi
- radio - Planck 100 GHz
- CMB - Planck SMICA
- tSZ - Planck NILC
- dust - SFD 100 µm
- PAH - WISE 12 µm
- optical reddening Pan-STARRS
- UV - GALEX 2300 A
- X-ray - ROSAT 0.1-2.4 keV
Take-away messages

- GALEX redshift+spectral tomography constrains the full UV background spectrum at $z<2$

- Clustering redshift analysis could be an integrated part of many experiments, including CMB, HI 21cm, CII, CO, and Ly$\alpha$ intensity mapping to:
  1. test if the foreground maps are free of extragalactic contamination
  2. get $p(z)$ of the extragalactic light