小型専用X線ミッションによる ダークバリオン探査

DIOS (Diffuse Intergalactic Oxygen Surveyor) 計画の紹介

「次世代天文学　－大型観測装置とサイエンス－」
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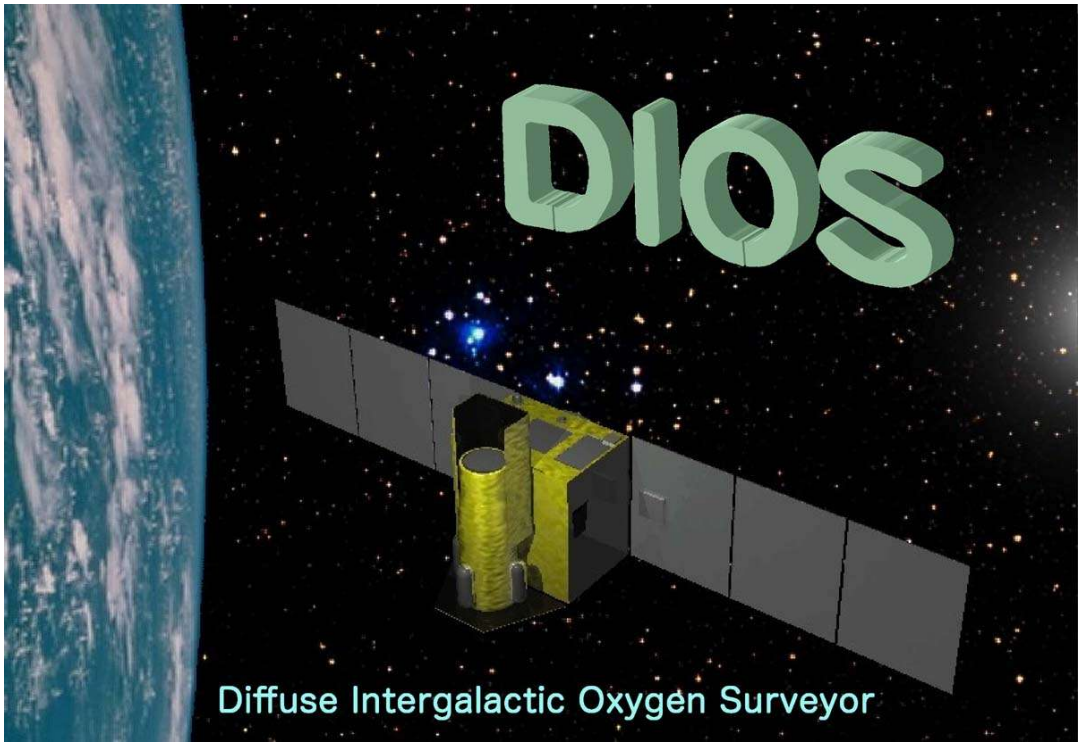
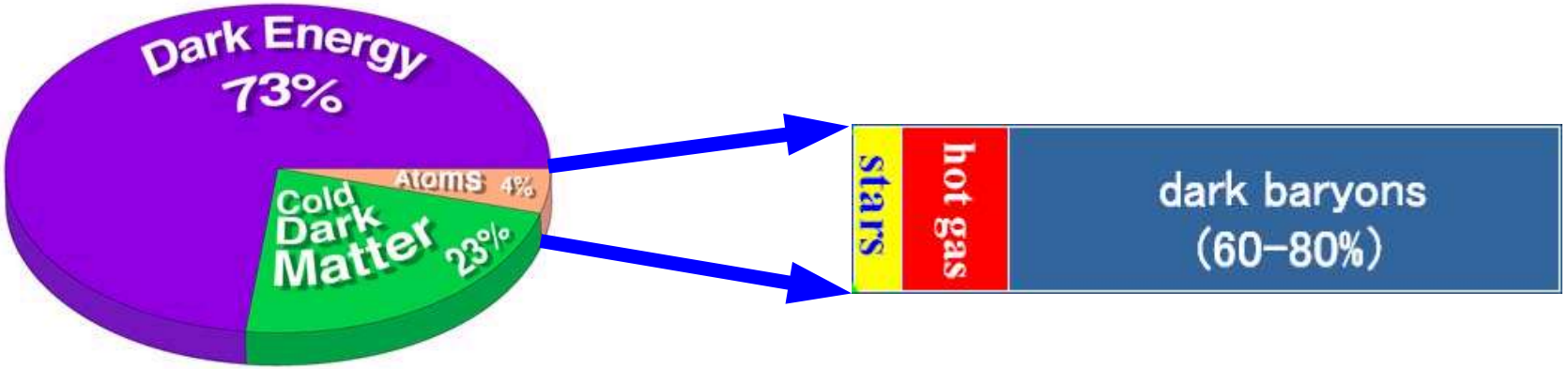


Missing Baryon (aka Dark Baryon)

Cosmic Baryon Budget

$$\Omega_{star} + \Omega_{HI} + \Omega_{H_2} + \Omega_{ICM} = 0.0068^{+0.0041}_{-0.0030} \quad vs \quad \Omega_{BBN} = 0.04 \quad (h=0.7)$$

Fukugita, Hogan, & Peebles (1998) ApJ, 503, 518



http://map.gsfc.nasa.gov

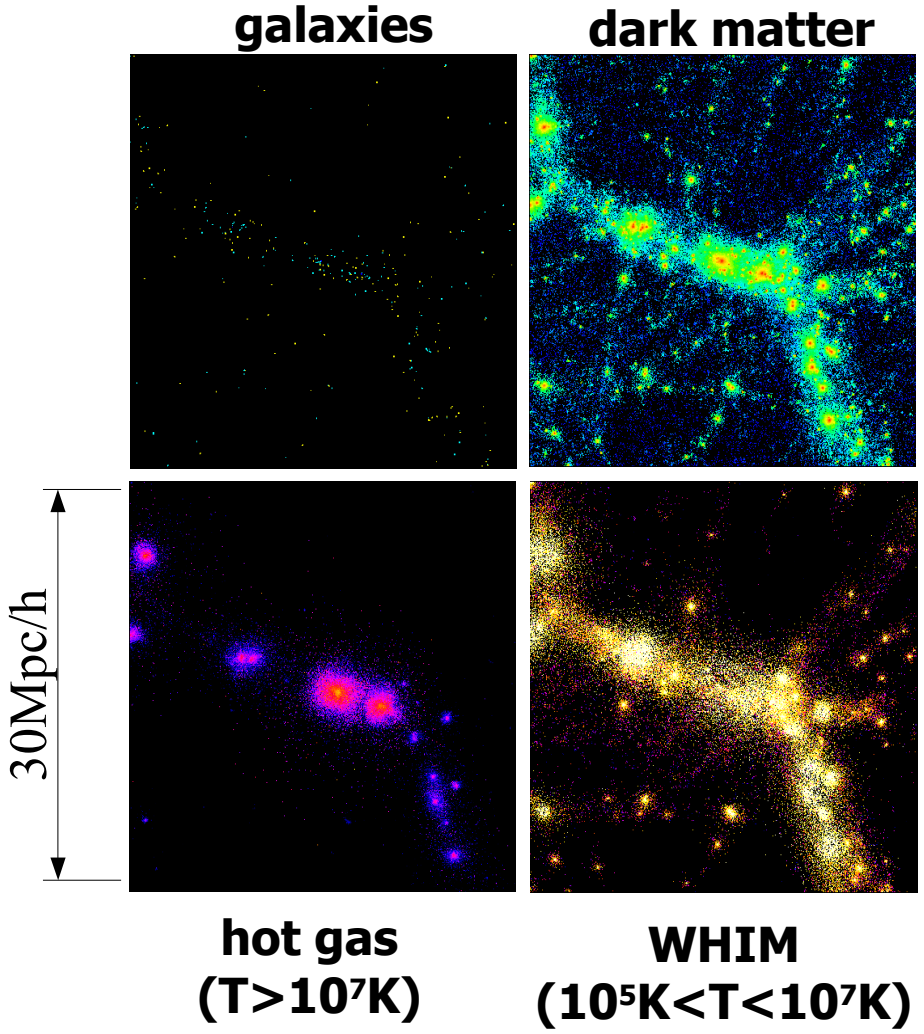
more than 50% of cosmic baryon is "DARK"
and evaded the direct detection so far.

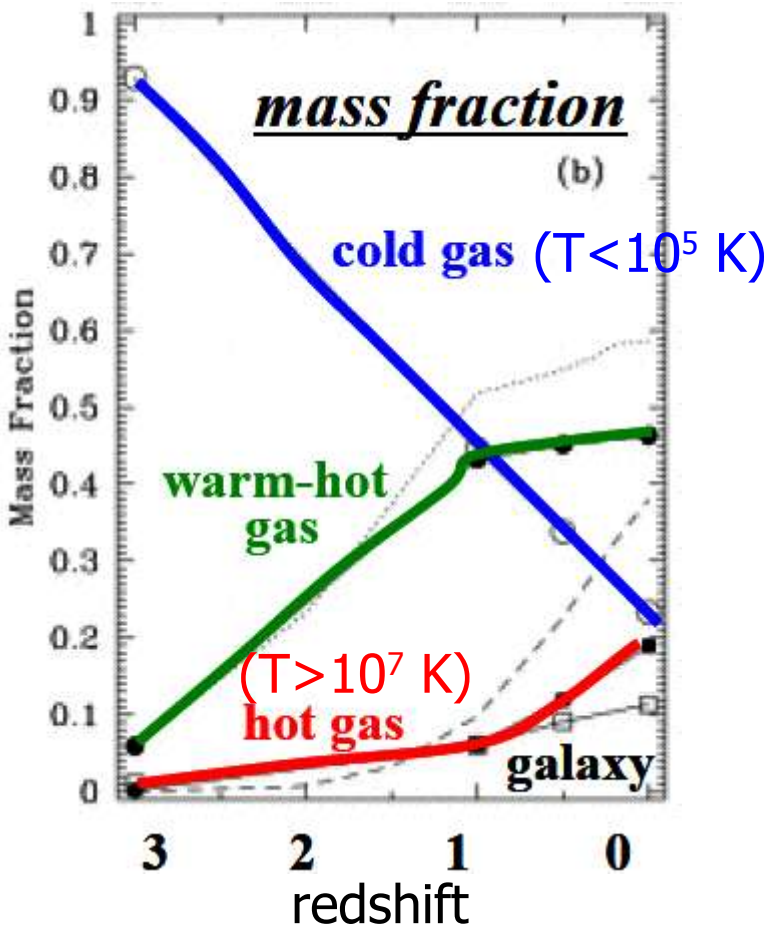
"Where are the dark baryons and in what form?"

Warm-Hot Intergalactic Medium

30~40% of the cosmic baryon at z=0 is in the form of diffuse gas with temperature of 10^5 K to 10^7 K.

Warm-Hot Intergalactic Medium (WHIM) [(h)wím]





Cen & Ostriker (1999)

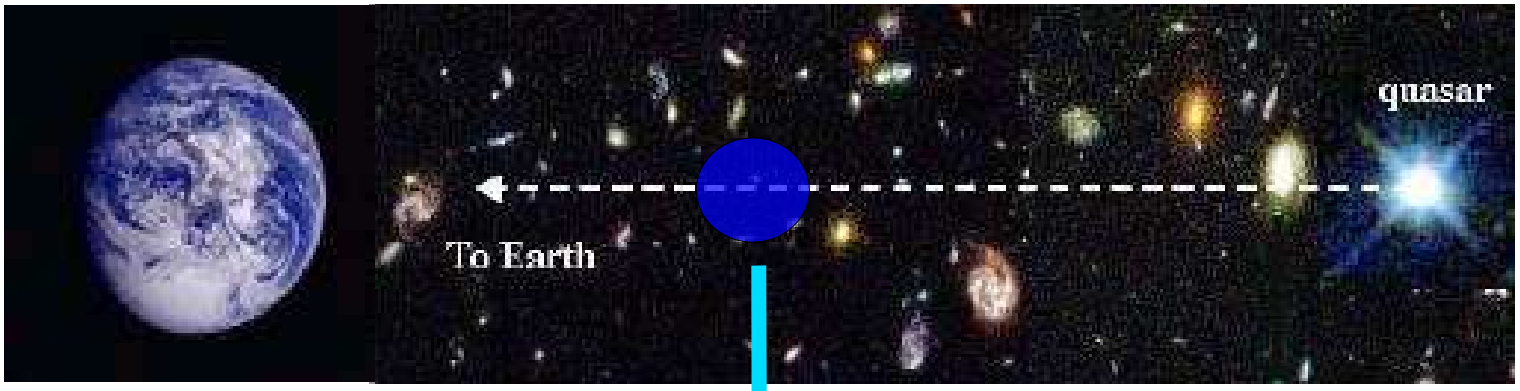
WHIM as Missing Cosmic Baryon

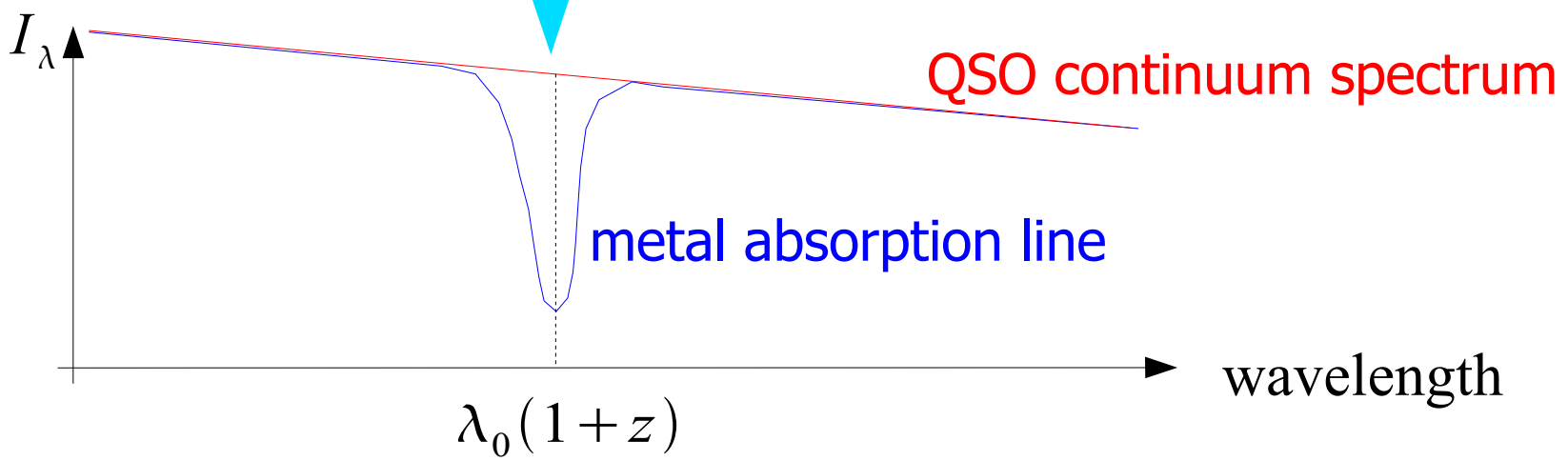
- About 40% of the total cosmic baryons may exist as Warm-Hot Intergalactic Medium (WHIM) with $10^5 K < T < 10^7 K$
- **WHIM is supposed to distribute diffusely in filamentary structures and small galaxy groups**
- **Direct detection of WHIM is difficult**
  - very faint emission in soft X-ray waveband due to low temperature and low density
  - strong contamination in actual observation

    foreground : X-ray emission of diffuse gas in our Galaxy

    background : Cosmological X-ray Background (CXB)

X-ray Forest: Absorption Features of WHIM in Spectra of Background Beacons



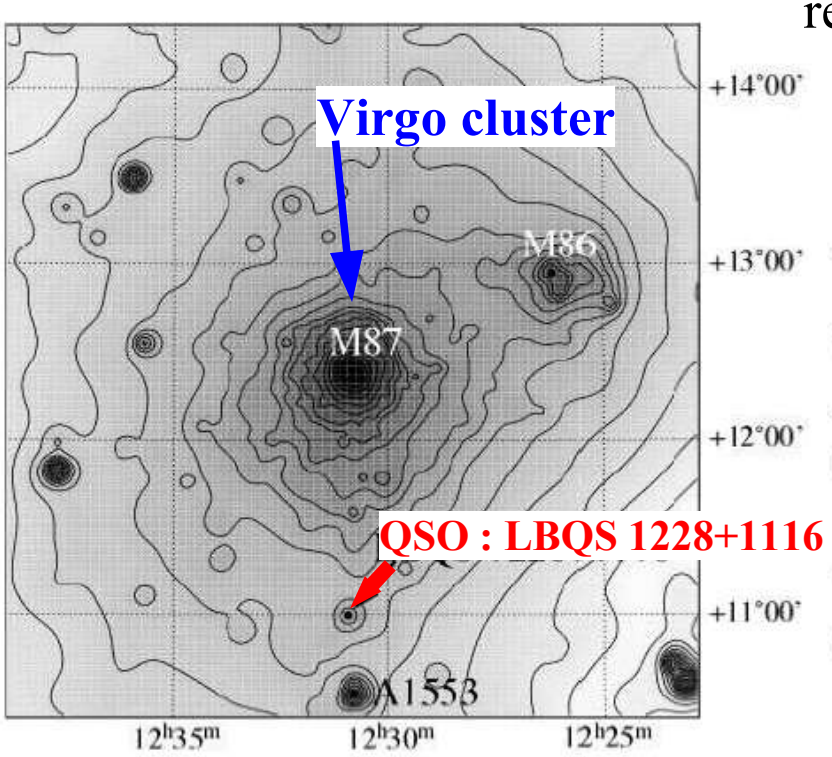


WHIM can be seen as absorption lines of ionized heavy elements (OVI-VIII, NeIX-X, NVI-VII, CV-VI) using XMM-Newton, Chandra, and FUSE.

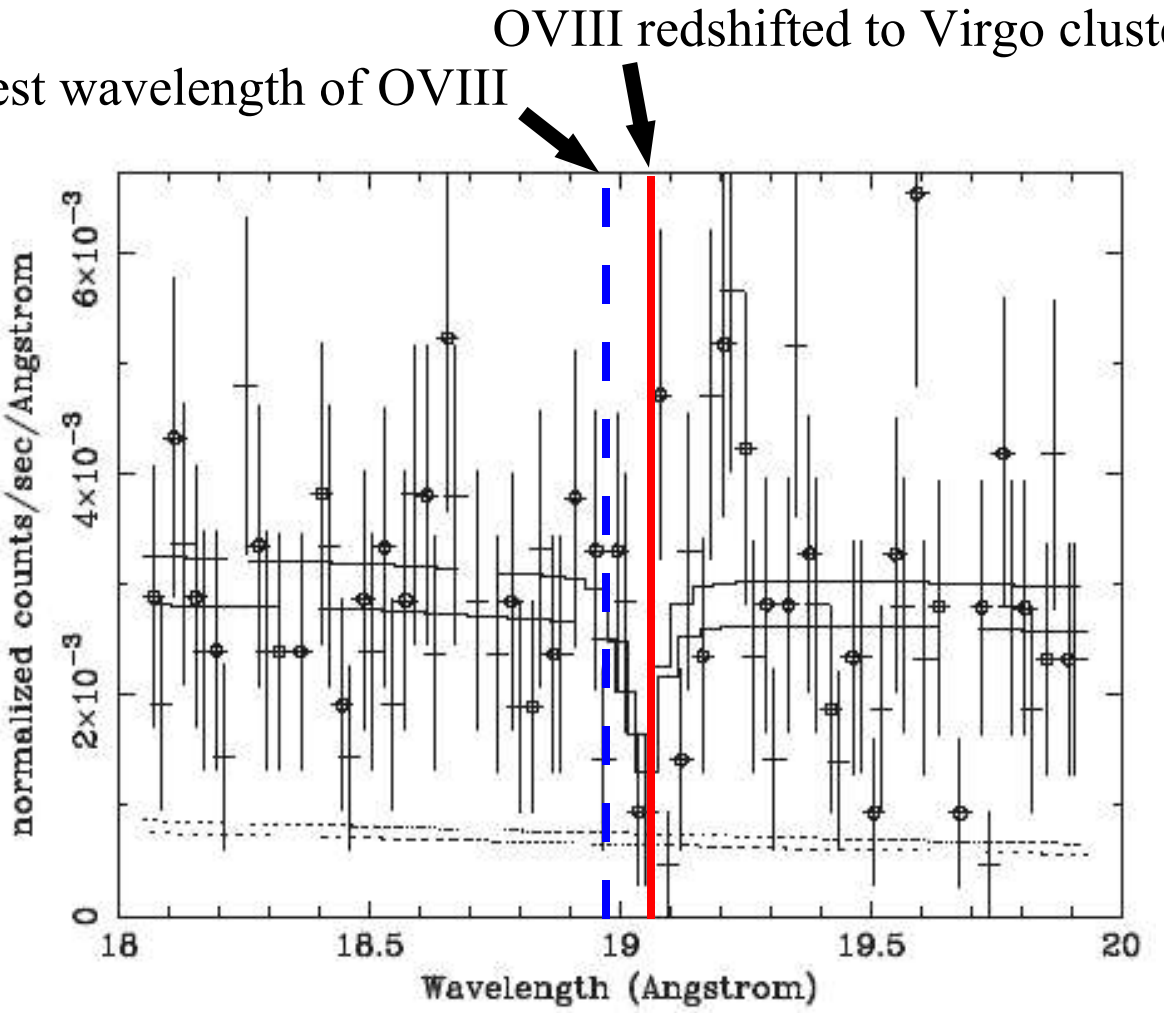
X-ray Forest : Shadow of WHIM

WHIM associated with Virgo cluster is "detected" with 2.6-σ
in the XMM-Newton spectrum of a QSO behind Virgo cluster.

Fujimoto et al. PASJ (2004) in press



ROSAT All Sky Survey Image



Emission Lines of Oxygen in WHIM

We propose the observation of its oxygen line emission instead

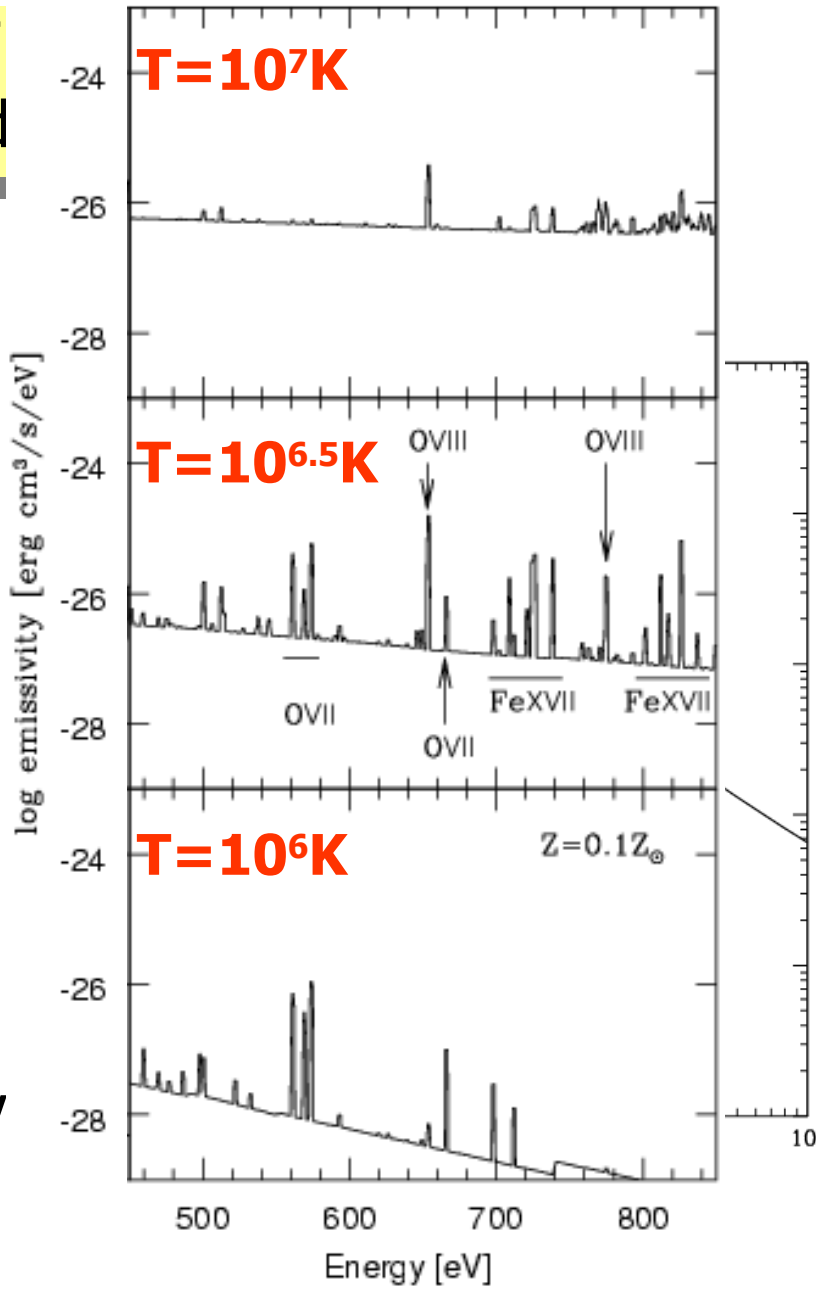
systematic WHIM survey

→ 3-dimensional structure and physical properties of WHIM

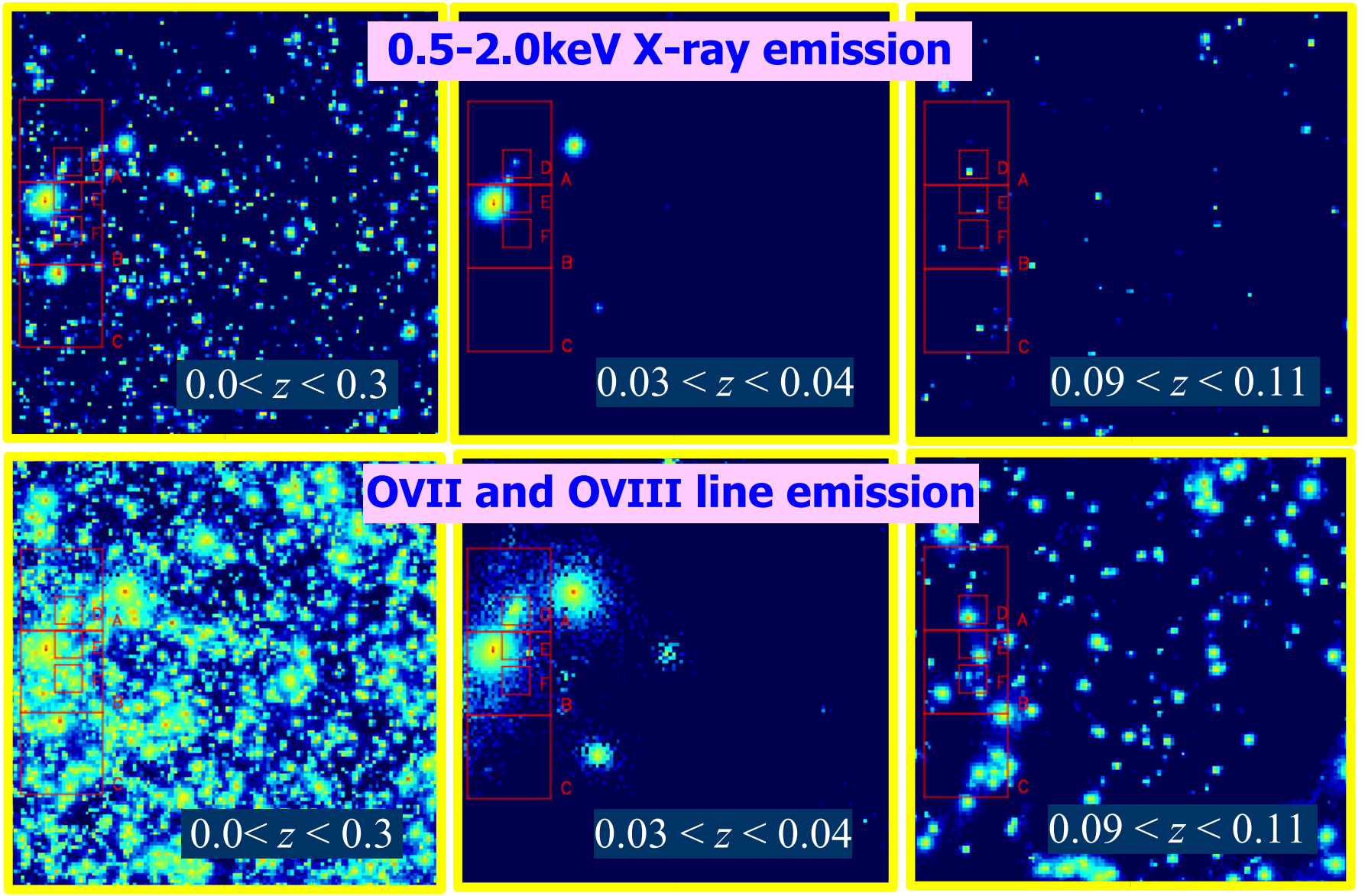
OVII (561eV, 568eV, 574eV, 665eV)
OVIII (653eV)

Why oxygen emission lines ?

- Effective tracers of gas with $T=10^6$-10^7K
- Most abundant other than H and He
- No other prominent lines in E=500-660eV



Simulated Surface Brightness on the Sky



Requirement for the Instruments

- **Identification of emission lines from various redshift**

  X-ray spectrometer with high energy resolution : $\Delta E < 5\mathrm{eV}$

  Also important for segregation from Galactic line emission

  Superconducting TES micro-calorimeter

  $\Delta E < 2\mathrm{eV}$ at $0.3<E<1.5\mathrm{keV}$

  16×16 array

- **Large field-of-view and effective area**

  Need to grasp very weak emission of spatially diffuse WHIM

  High throughput of X-ray telescope : $S_{\mathrm{eff}}\Omega_{\mathrm{FOV}} > 50\mathrm{cm}^2\mathrm{deg}^2$

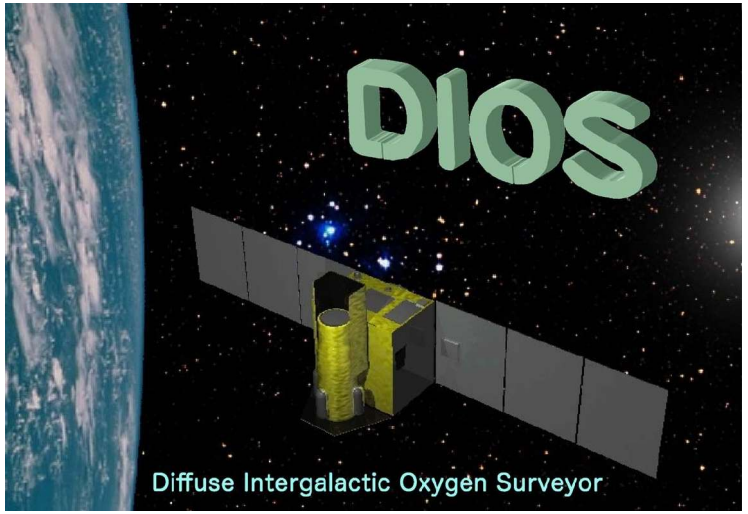
  Four-reflection X-ray Telescope

  $S_{\mathrm{eff}}\Omega_{\mathrm{FOV}} \sim 200\eta\mathrm{cm}^2\mathrm{deg}^2$ at E=0.6 keV

  $\Omega_{\mathrm{FOV}} \sim 1^\circ\times1^\circ$

DIOS Project

Diffuse Intergalactic Oxygen Surveyor (DIOS)



specification of the telescope and detector

$S_{eff}\Omega_{FOV}=100\mathrm{cm}^2\mathrm{deg}^2$, $\Omega_{FOV}\sim 1°\times 1°$, $\Delta E=2\mathrm{eV}$

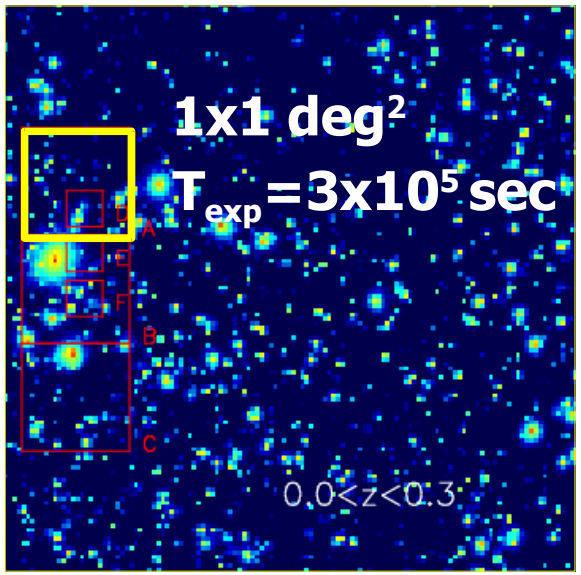
light weight (<500kg) and dedicated sattelite to observe the WHIM emission

⇒ poster p26

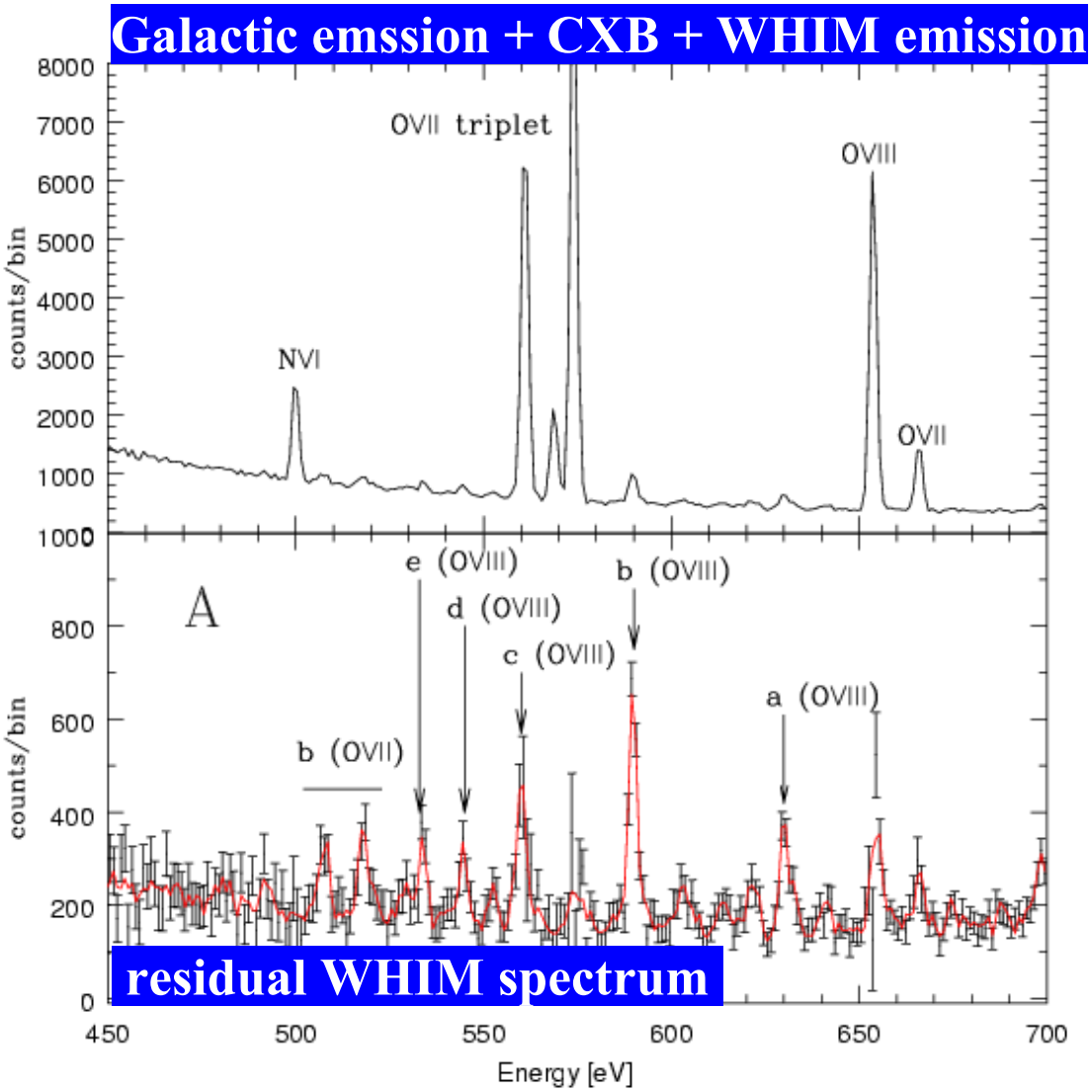
Primary observational target

- Mapping of a few 100deg^2 field in 2-year operation up to z~0.3
- Pointing observations of large scale structures in the local universe
- Detecting the absorption lines of WHIM in QSO and GRB afterglow spectra

Example of Simulated Spectra



- Observed raw spectra are contaminated by strong CXB and Galactic emission
- After subtracting contaminating spectra, intrinsic WHIM spectra can be obtained



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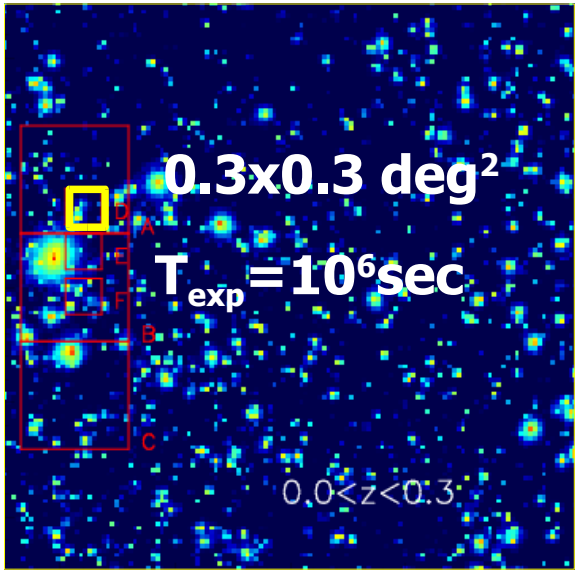
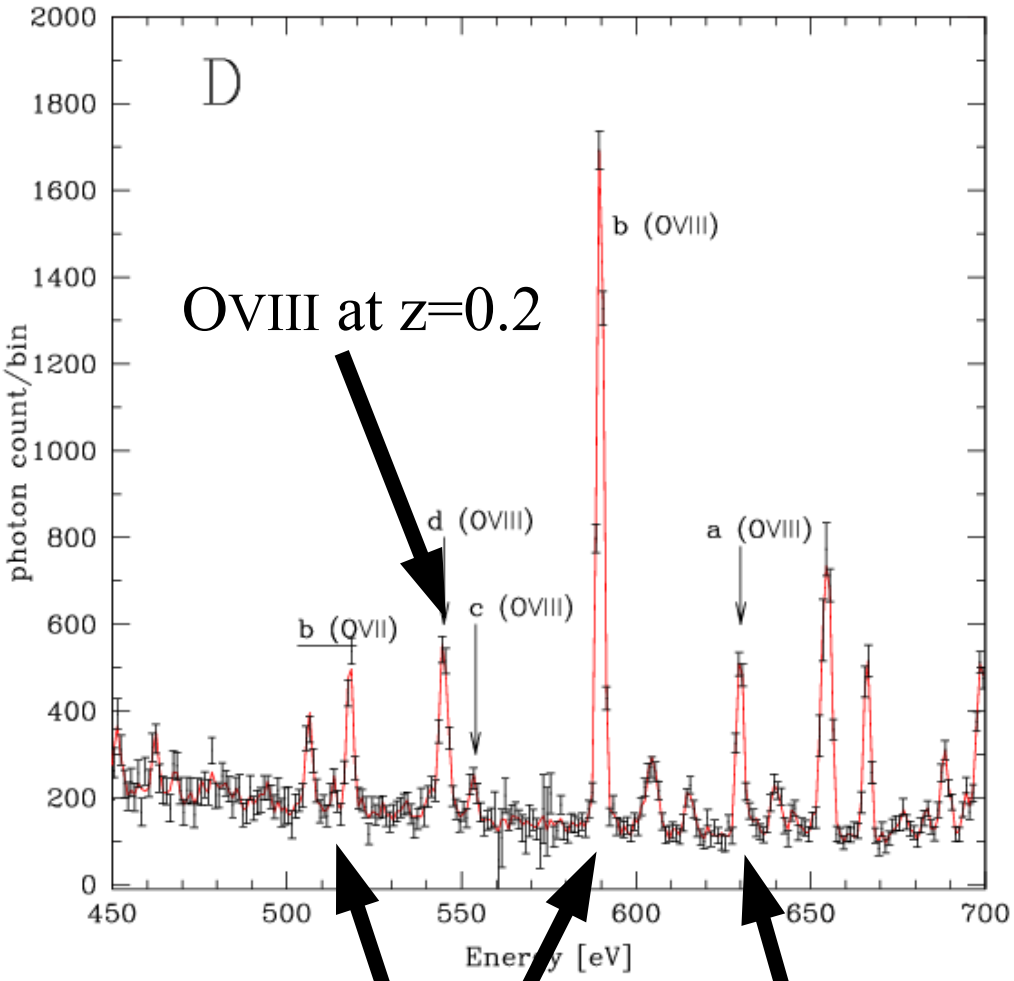
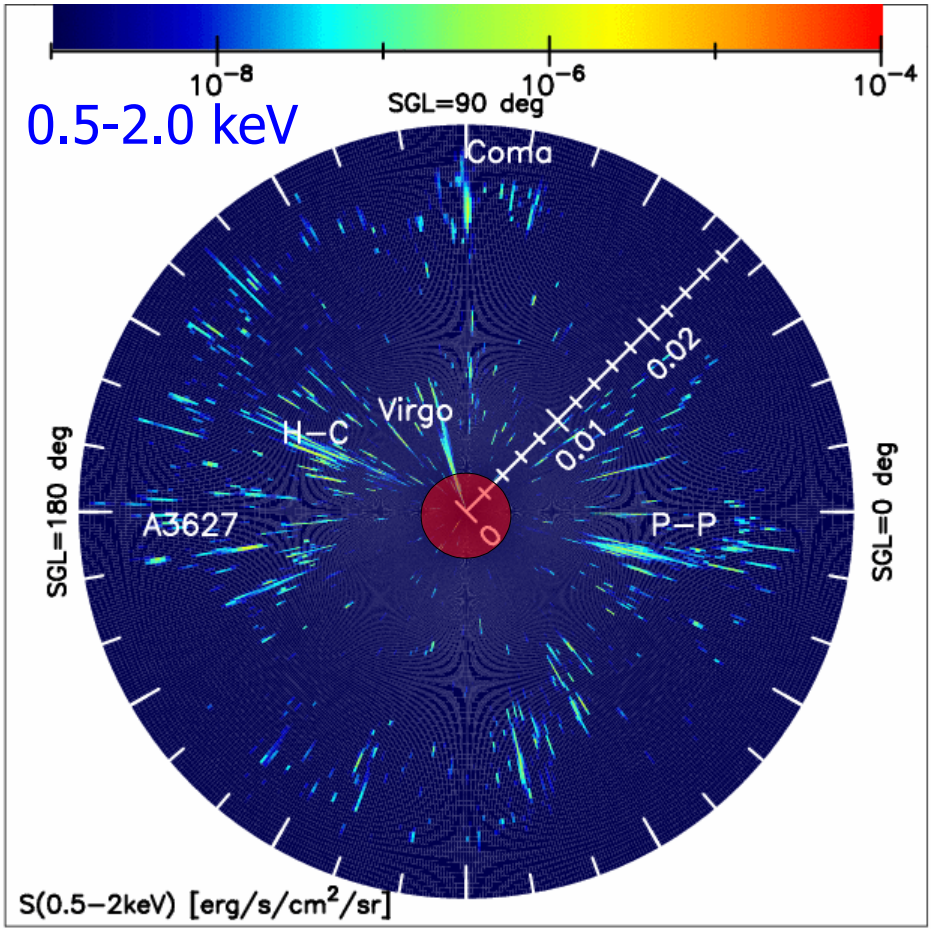


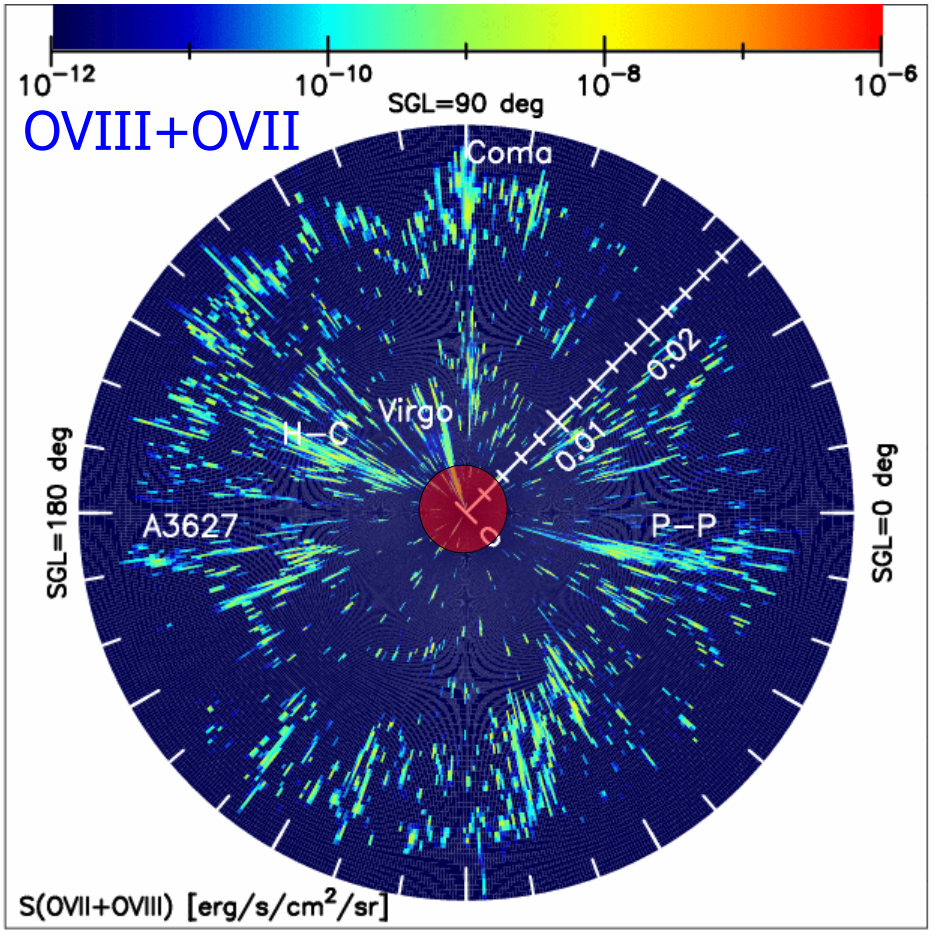


WHIM emission is "detectable" if the assumed specification is realized

DIOS View of the Local Universe

OVII and OVIII emission in the Super-Galactic plane

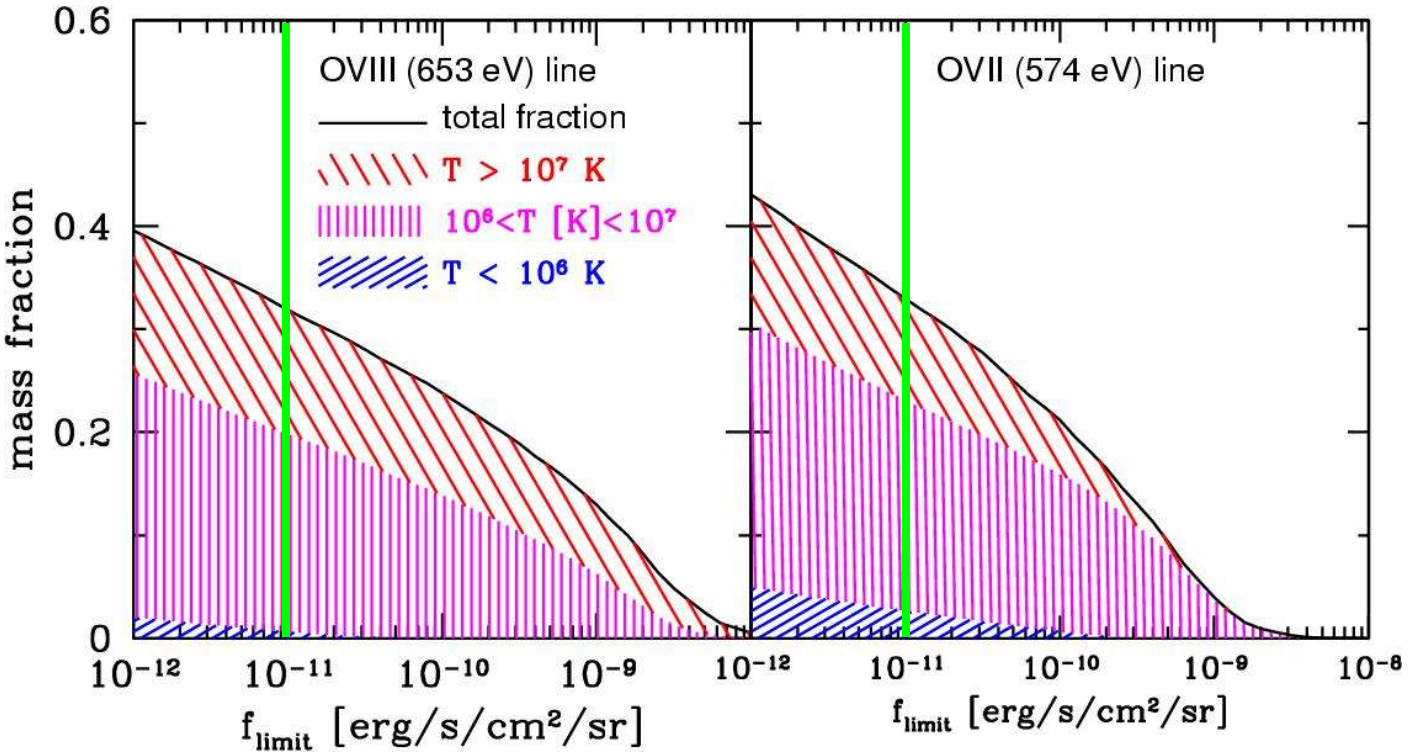




Filament and supercluster structures will be detected by DIOS

What Can Be Seen by DIOS

Fraction of detectable baryon for a give limiting flux



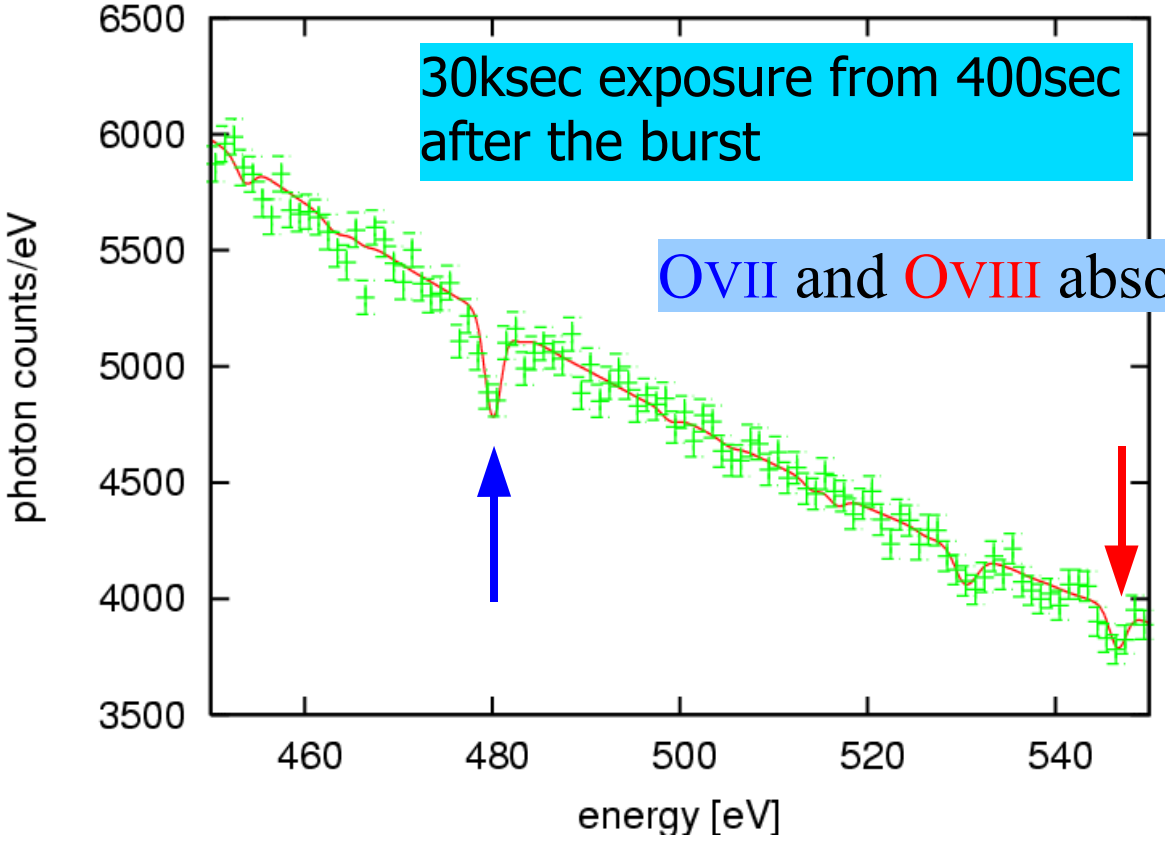
- 20-30% of the cosmic baryon will be newly detected by DIOS
- Only high temperature ($T>10^6$ K) portion of WHIM can be detected through its emission

→ Need for the complementary detection of low temperature WHIM using its absorption feature

X-ray Forest in GRB Afterglow Spectra

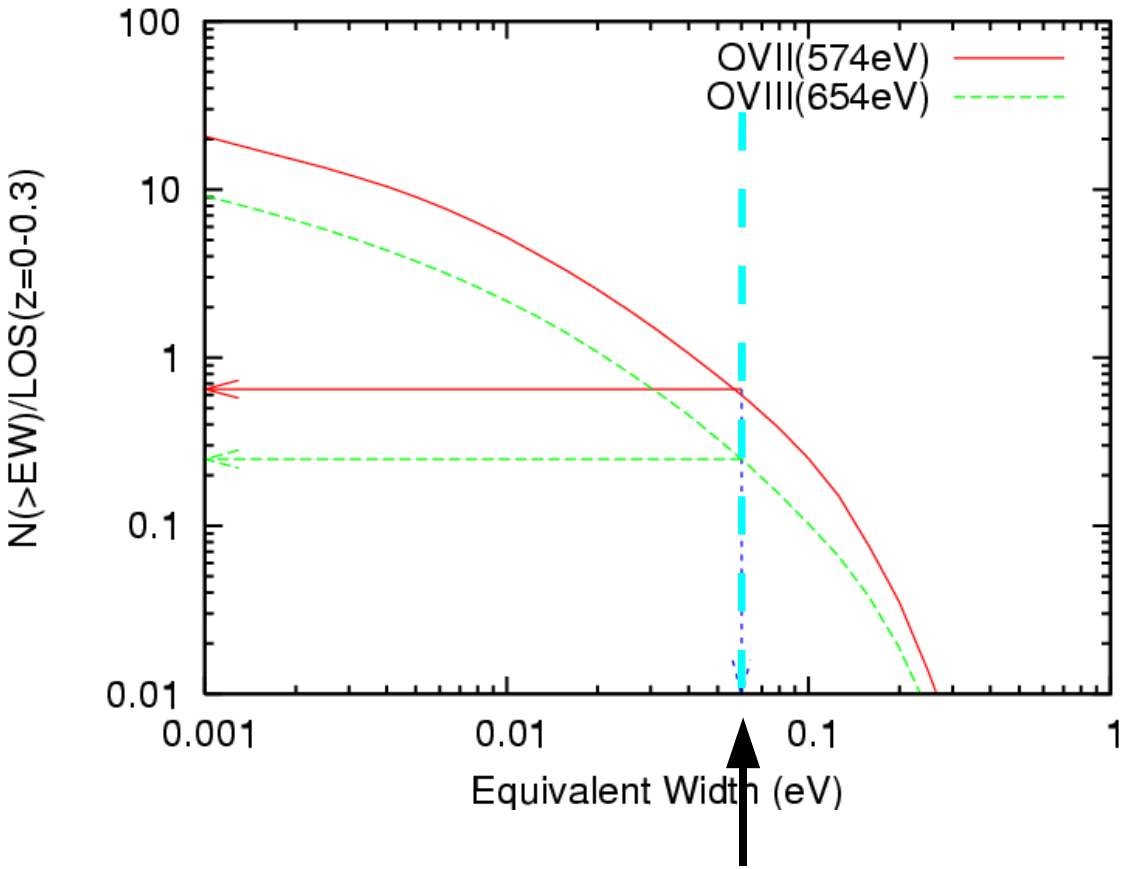
GRB afterglow can be a good background beacon to detect WHIM through its metal absorption features.

Simulated observation of a typical GRB afterglow (~ 40/year)



X-ray Forest in GRB Afterglow Spectra

Distribution function of equivalent width of OVII and OVIII absorption lines



3σ detection for a typical GRB afterglow

After GRB afterglow decayed, DIOS can try to detect WHIM through its emission.

Constrains on oxygen metallicity and filling factor of WHIM using both of its emission and absorption

DIOS is planned to be equipped with flexible pointing system for GRBs.

Mission and Science Goal

- Detection of WHIM with $T>10^6$ K through its emission

  blind survey of WHIM by mapping of a few 100deg^2 field

  pointing observation of known large-scale structures in the local universe

- Detection of WHIM metal absorption line systems in GRB spectra

  complementary search of low temperature WHIM with $T<10^6$ K

  detection of WHIM both through its emission and absorption features

→
- physical properties of WHIM (density, temperature, metallicity)
- ionization states of metals ⇒ thermal history of baryons
- WHIM distribution (⇔ dark matter/galaxy distribution)

- Dynamics of ISM and ICM

  Galactic fountain, ICM turbulence