# Physics of the hot evolving Universe

Science themes for a New-Generation X-ray Telescope


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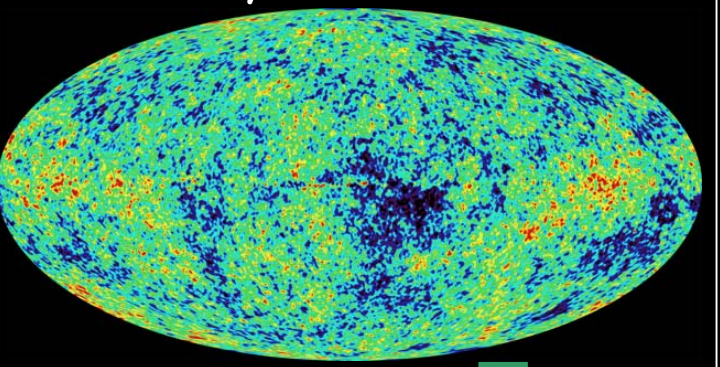
ESA Cosmic Vision 2015-2025 Workshop, Paris, September 15-16

# 1. Quest for the first massive Black Holes

# Formation of Large-Scale Structure

Picture of the Universe
380.000 years old




Klypin, Kravtsov, Gottlöber

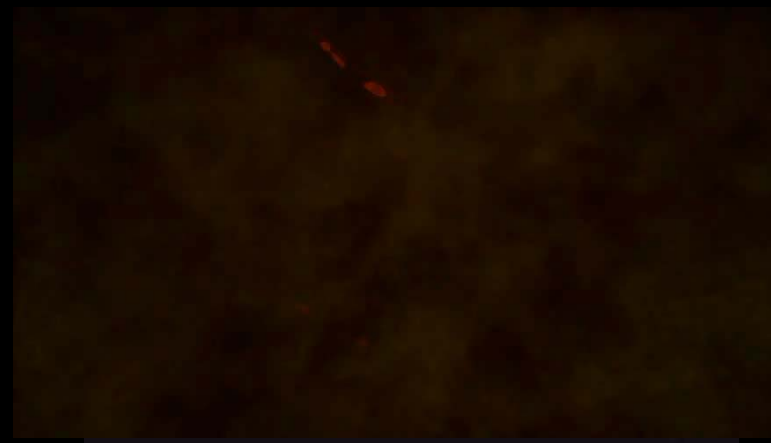
# The first Black Hole

Before the first star can form, the universe has to cool down to ~100K to allow molecular hydrogen cooling.

The first star is expected to be massive (~300 $M_\odot$), shines for ~1 Million years, sterilizes its cosmic environment, explodes in a GRB hypernova, pollutes its environment with heavy elements and leaves a seed Black Hole.

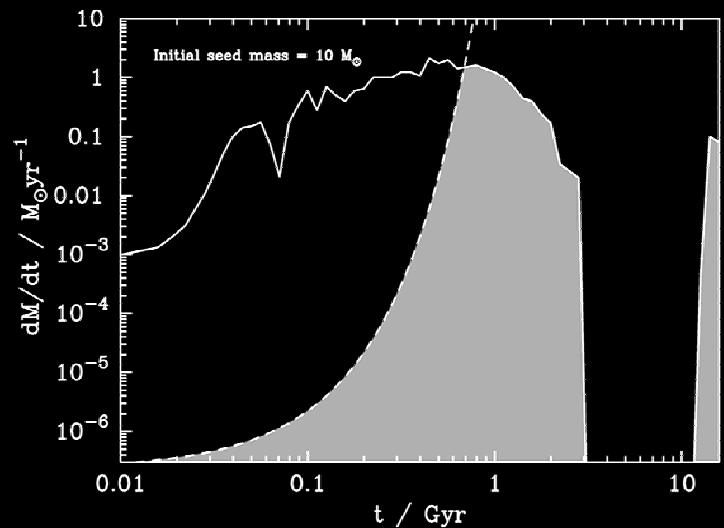
While the galaxy forms, the BH continues to grow exponentially, quickly producing a powerful quasar, if enough fuel can be provided.

Sensitive X-ray observations can study the first GRB explosions and can detect mini-QSOs with $10^4$ $M_\odot$



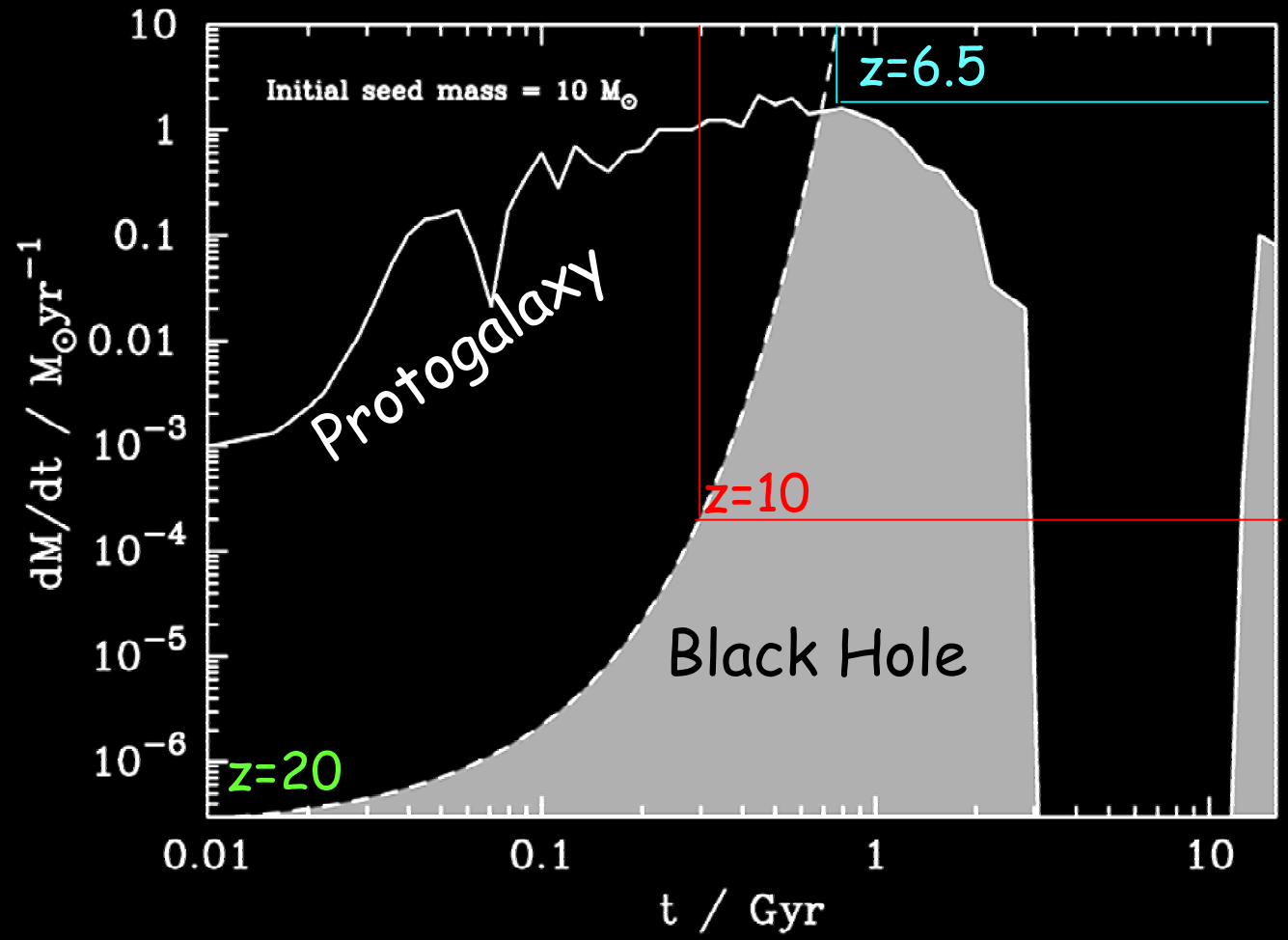
Tom Abel & Discovery Channel

NASA




Archibald et al. 2001

# QSO exponential feeding




$10^8\ M_\odot$
(known QSOs)

$10^4\ M_\odot$
Mini-QSOs

$10\ M_\odot$
Gamma Burst

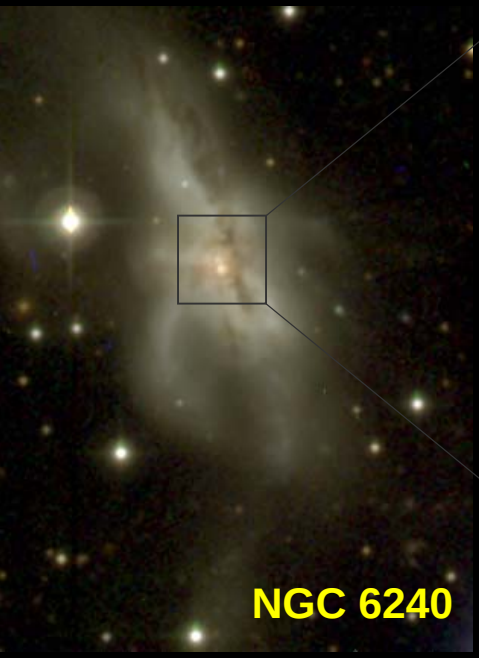
Need **N**ew **G**eneration **X**-ray **T**elescope to detect and study BH in conjunction with forming galaxy ($S_{min} \sim 10^{-18}$ erg cm$^{-2}$ s$^{-1}$).

$10^4\ M_\odot$ @ redshift 10 detectable.

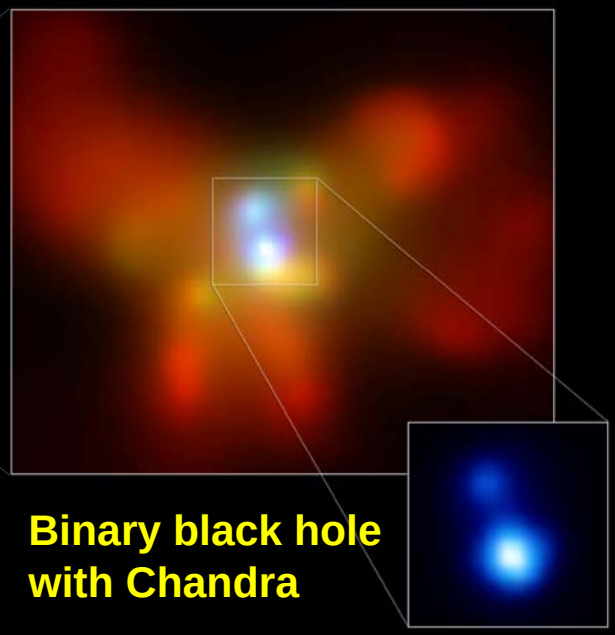
# Binary BH mergers - efficient accretion

Biggest problem: how to funnel down large amount of gas over a galactic scale on a very short timescales

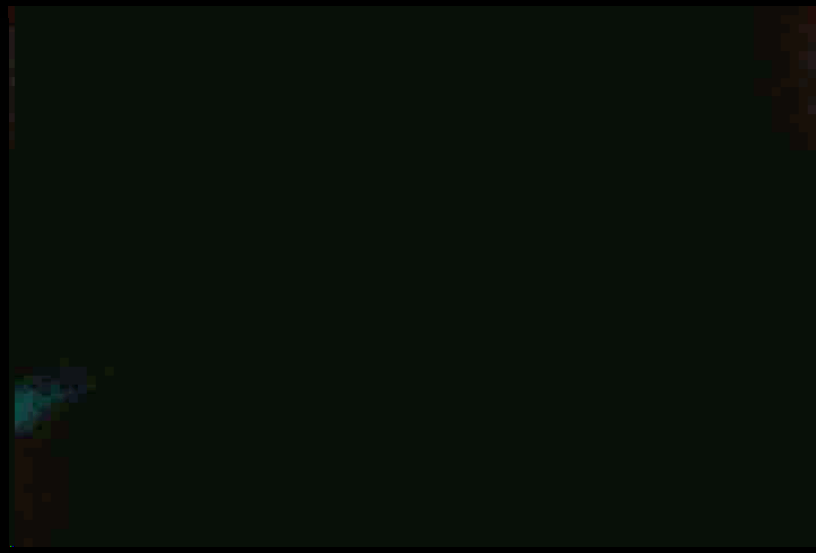
Observations tell us, that gas-rich mergers can do the trick.



NGC 6240



Binary black hole with Chandra

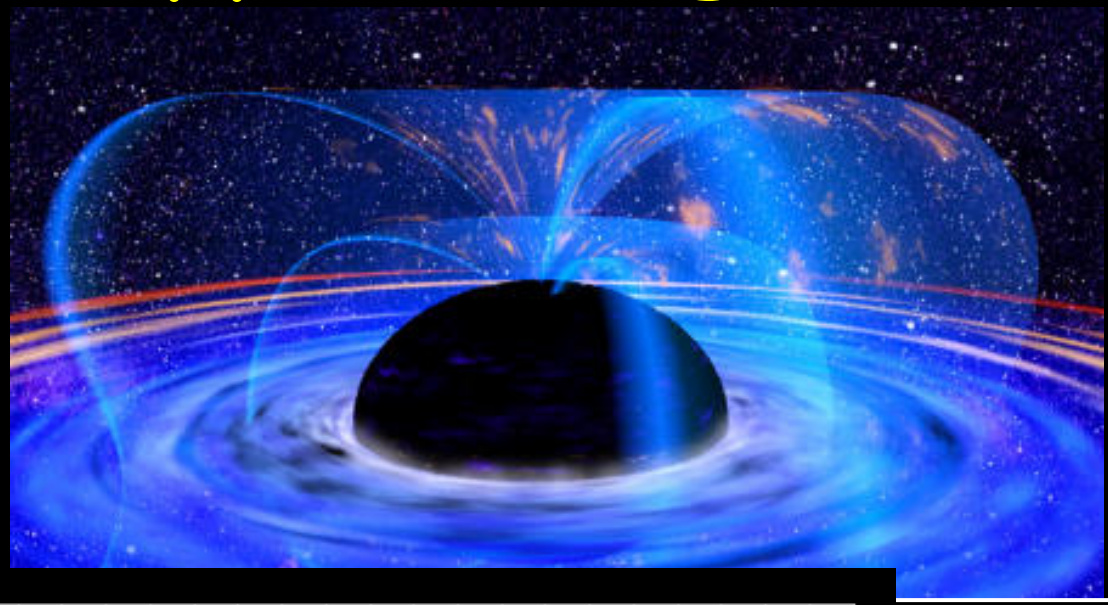


NASA/CXC/Komossa

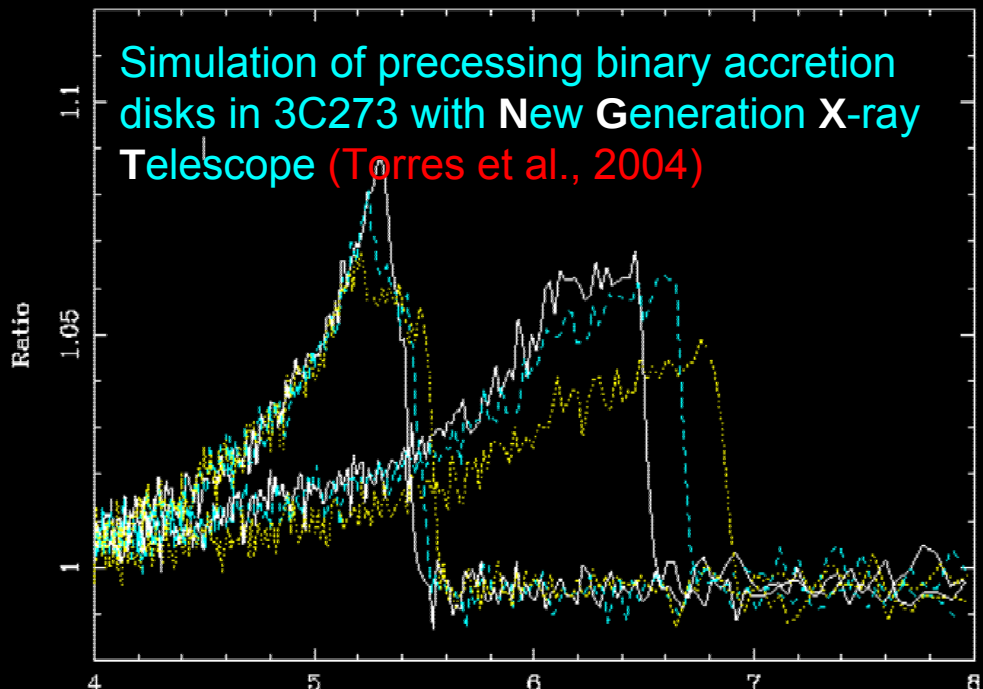
Binary Black Holes expected in powerful obscured quasars. Good prospects for gravitational wave detectors.

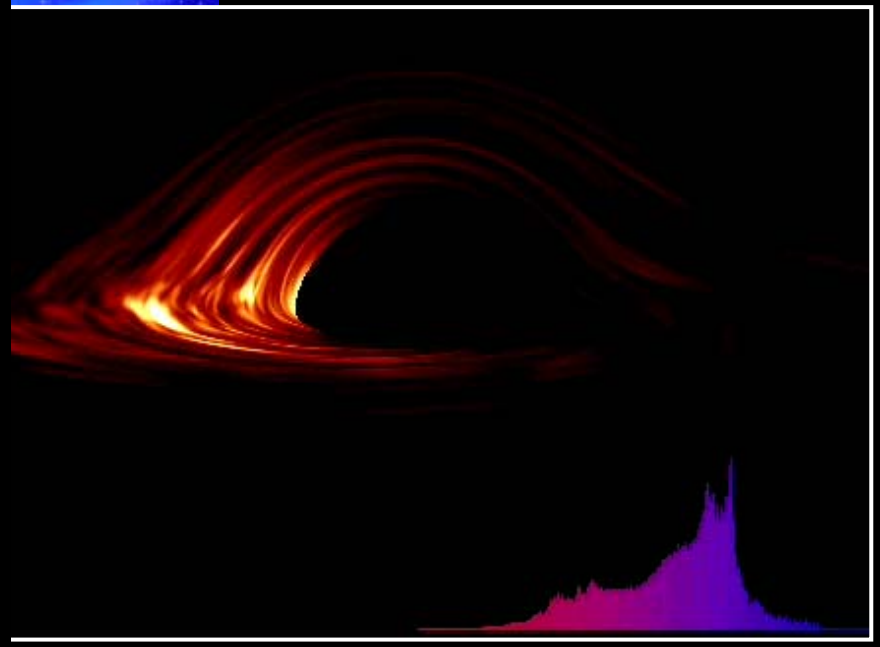
But NGXT needed for the electromagnetic waves!

# Approaching the Black Hole



Simulation courtesy Chris Reynolds

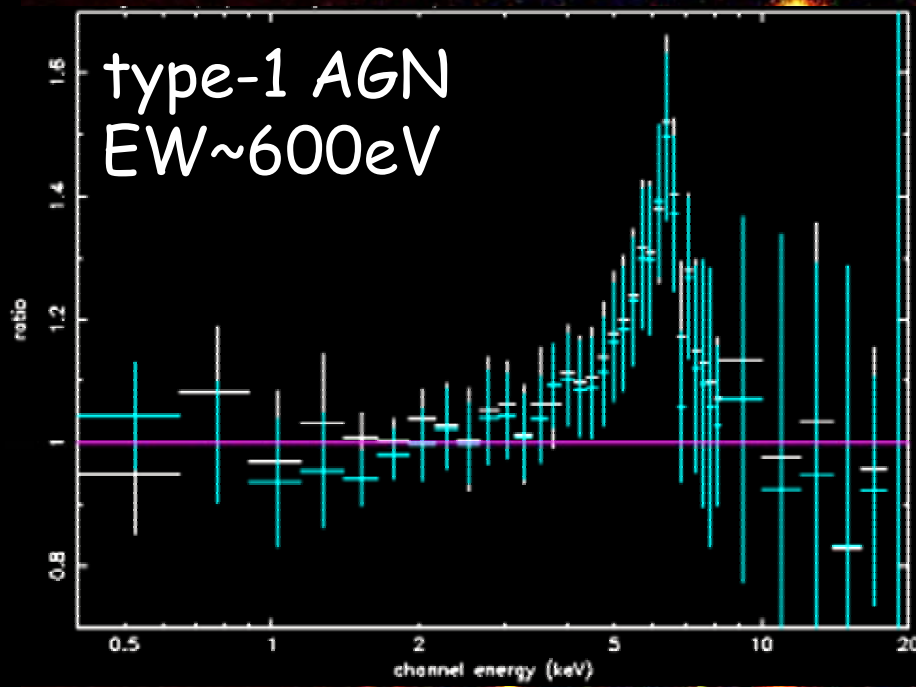


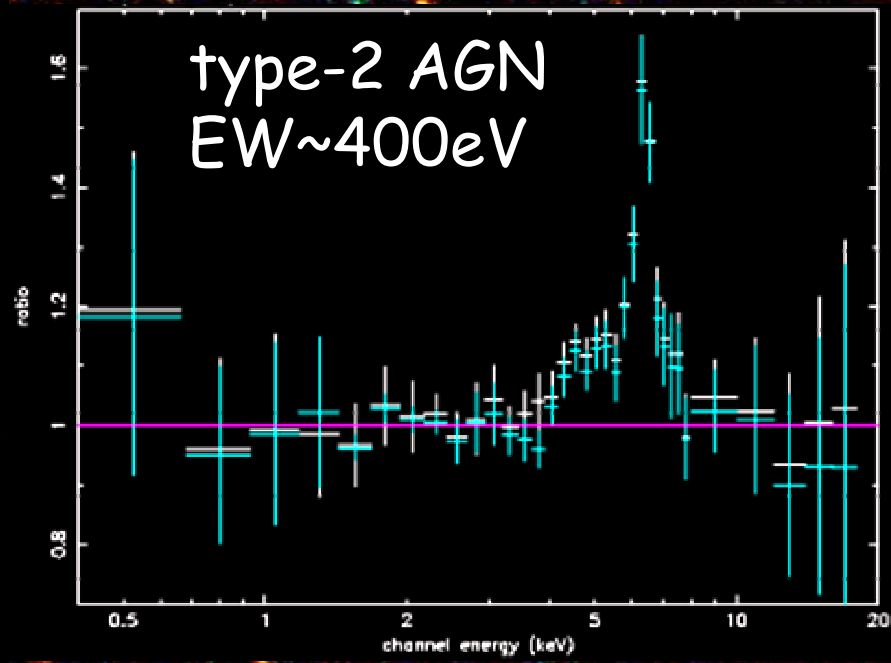



# Lockman Hole

800 ks XMM-Newton observation

Average rest-frame spectra show relativistic Fe-lines

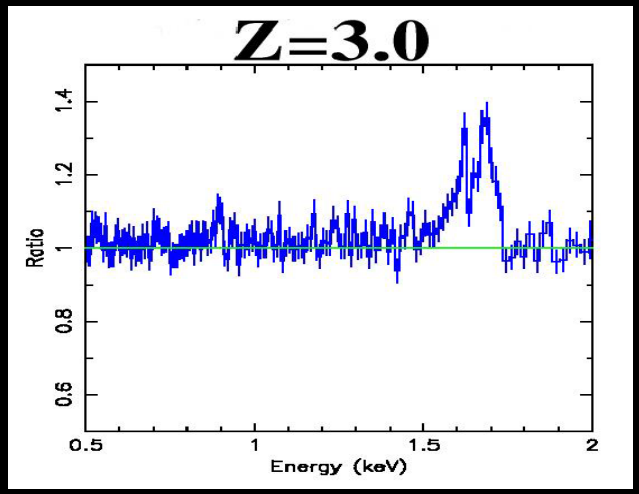


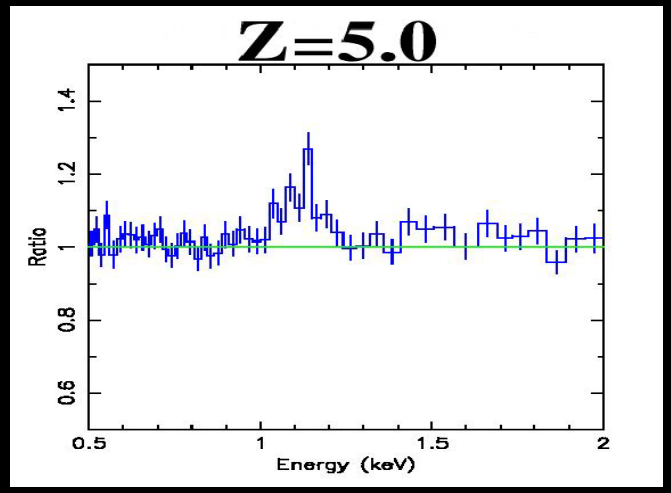



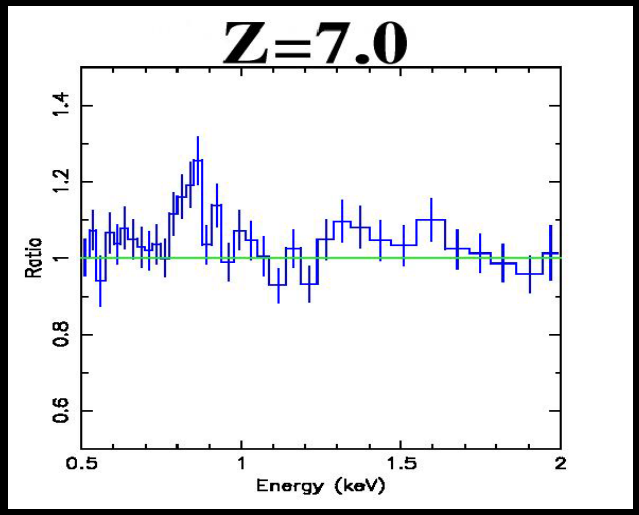

Streblyanskaya et al., 2004

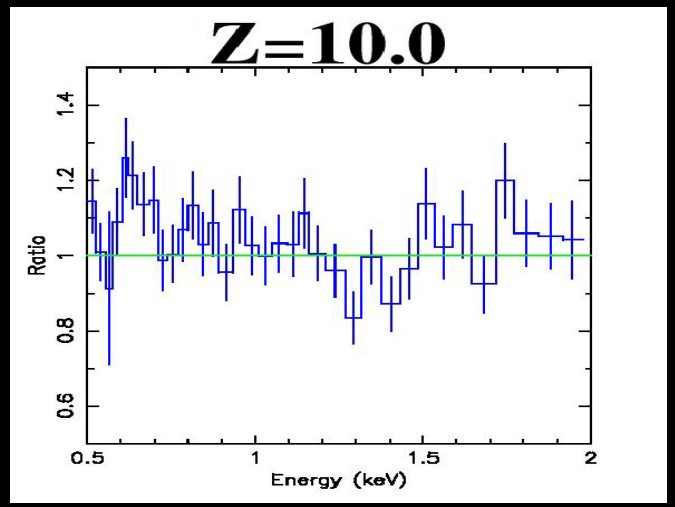
New Generation X-ray Telescope can determine redshifts and study Fe lines in each individual object

# NGXT view of relativistic Fe line

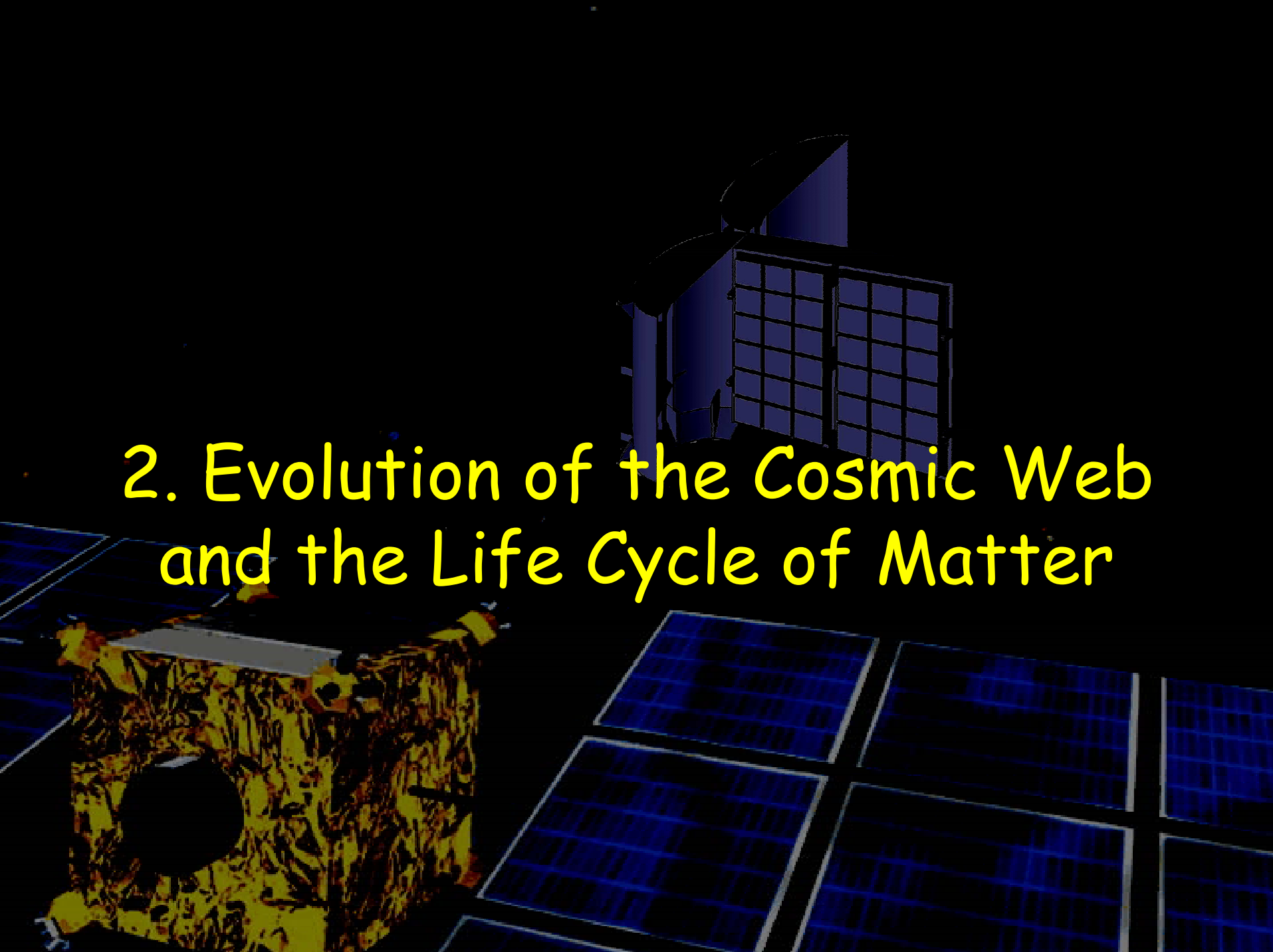


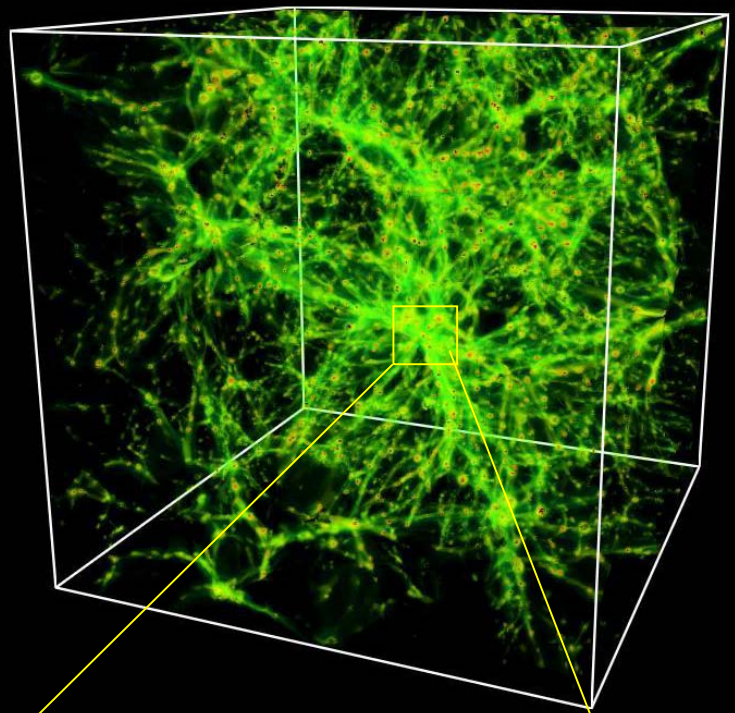




We get this or better quality for many objects in each field

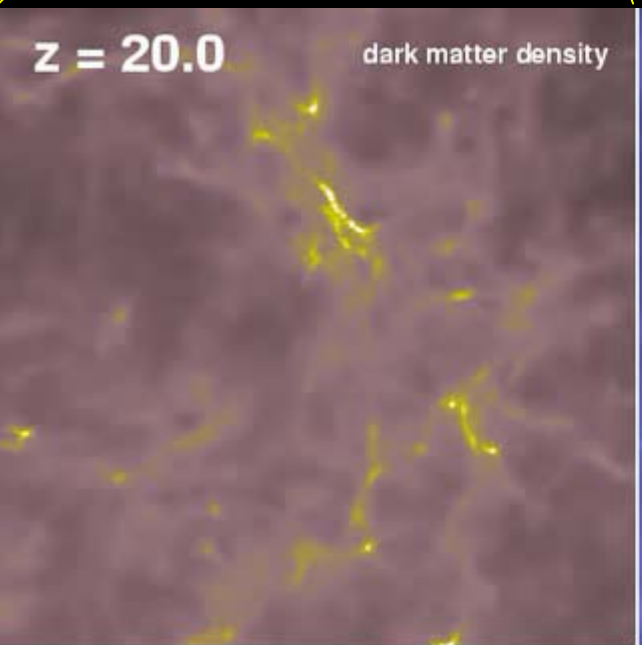


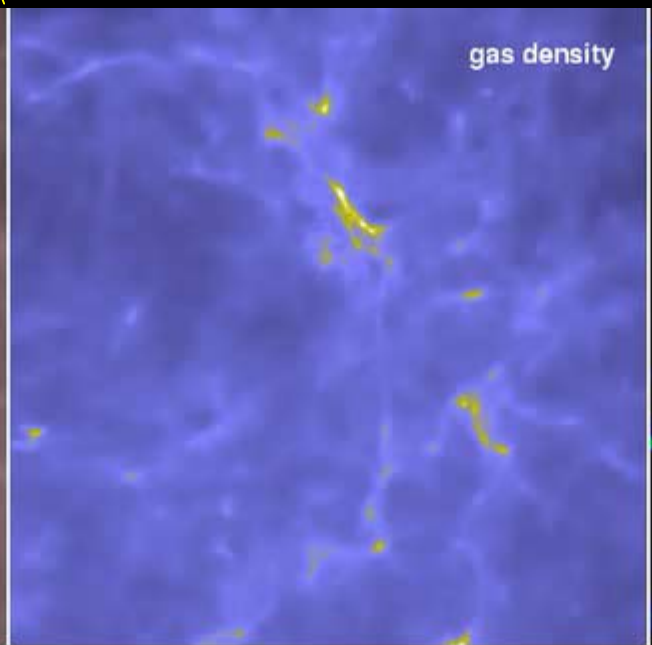
# 2. Evolution of the Cosmic Web and the Life Cycle of Matter

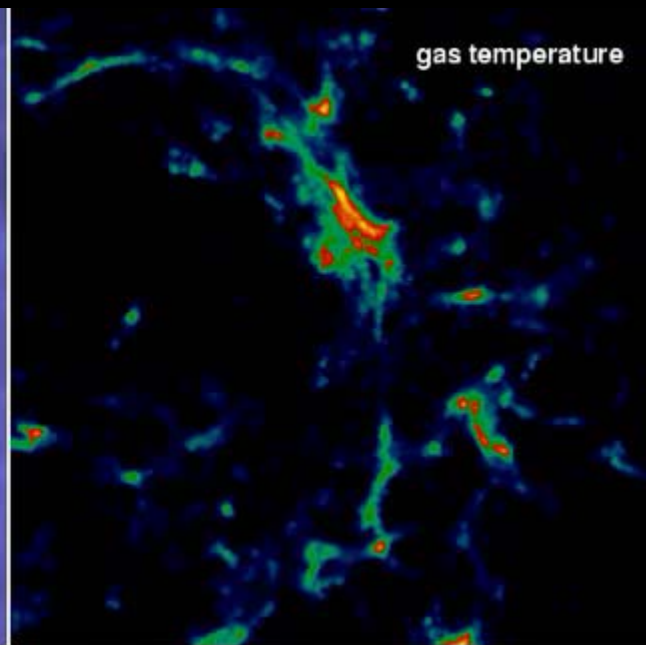


# Clusters of Galaxies: Largest Objects in the Universe

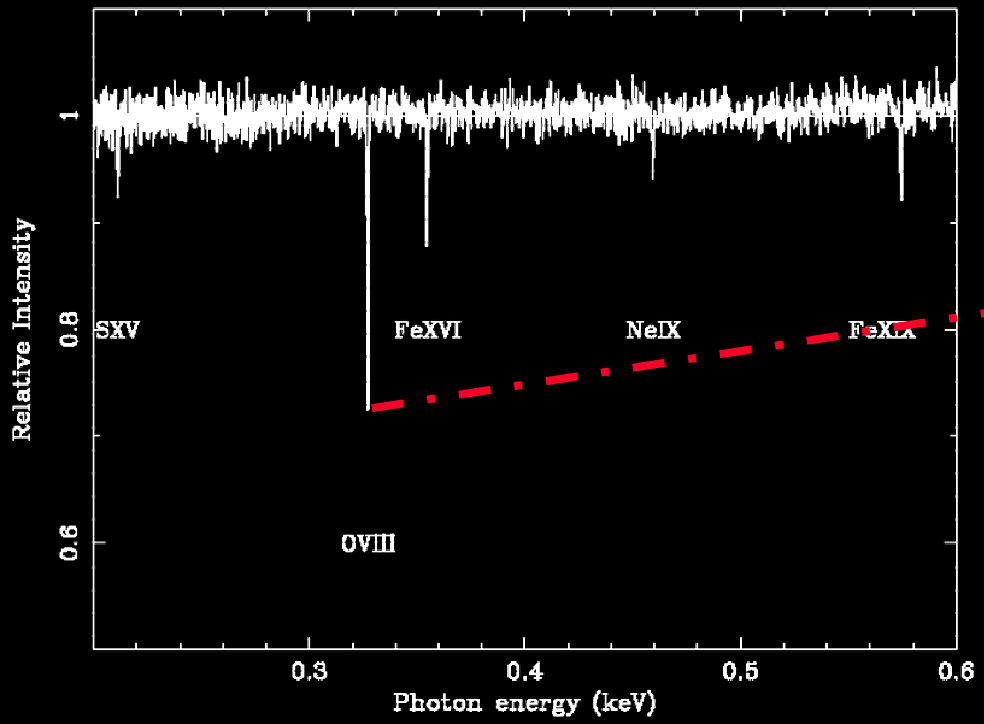
courtesy V. Springel MPA

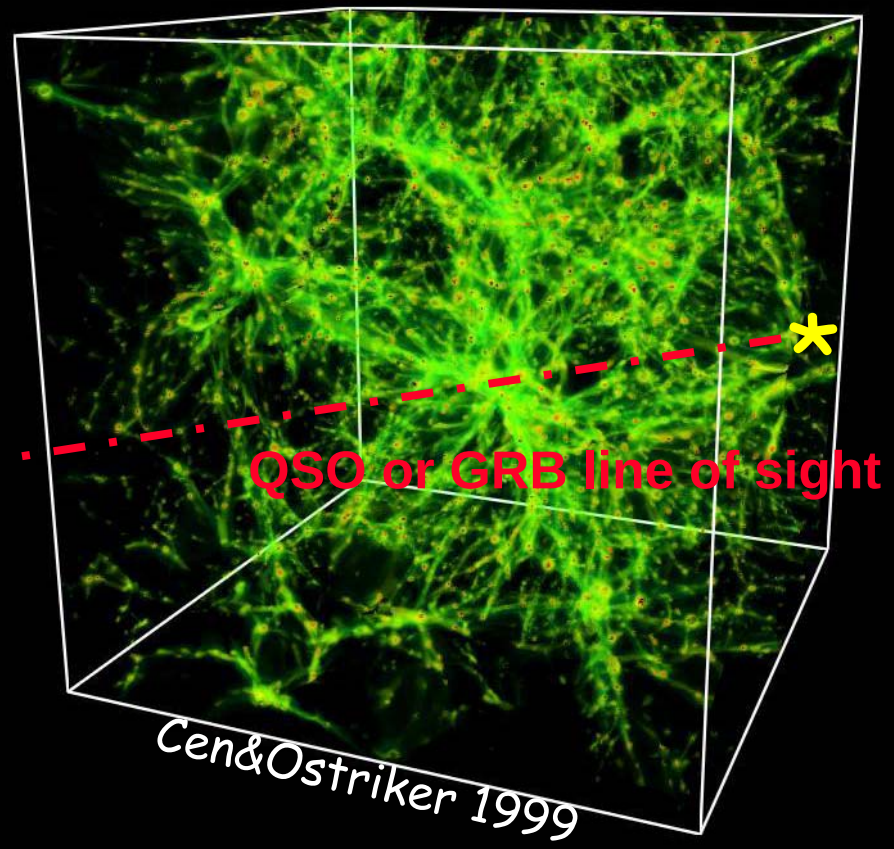


# Tracer of Baryons

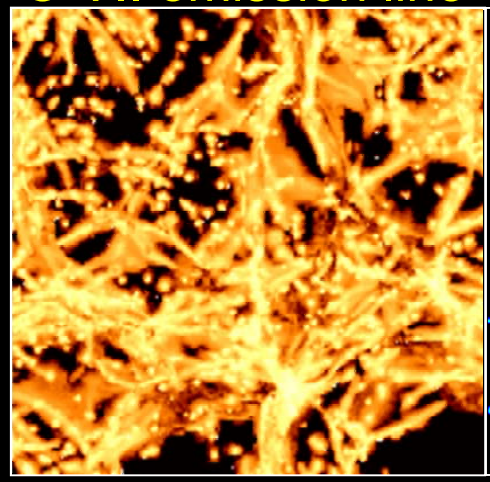


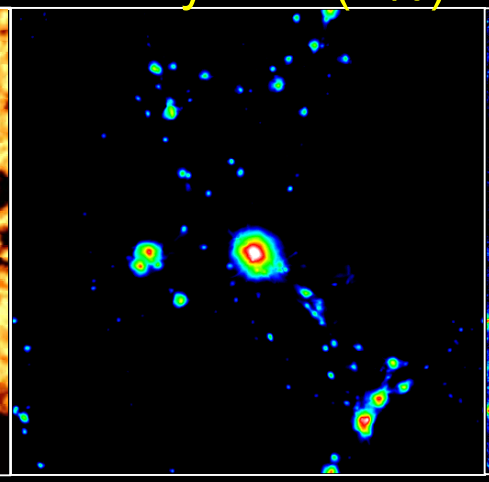

## X-ray forest

Warm/hot IGM in absorption at high z and in emission at low z (NGXT)

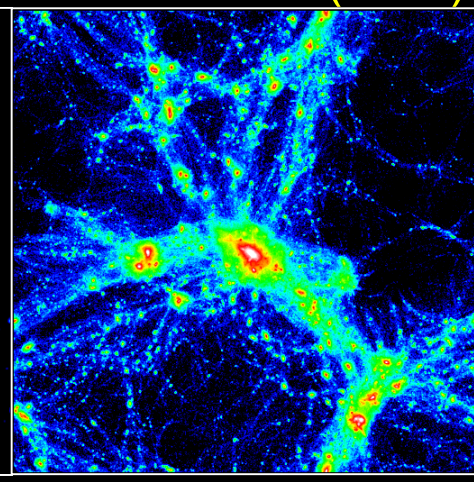
O VII emission line



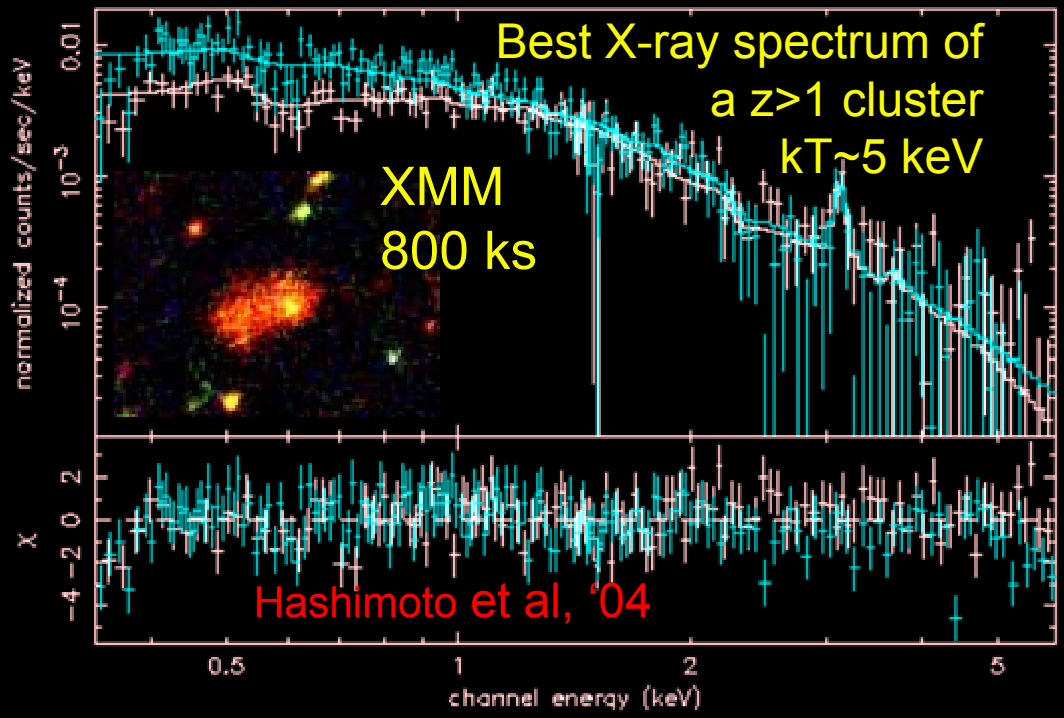
X-ray Gas (4%)

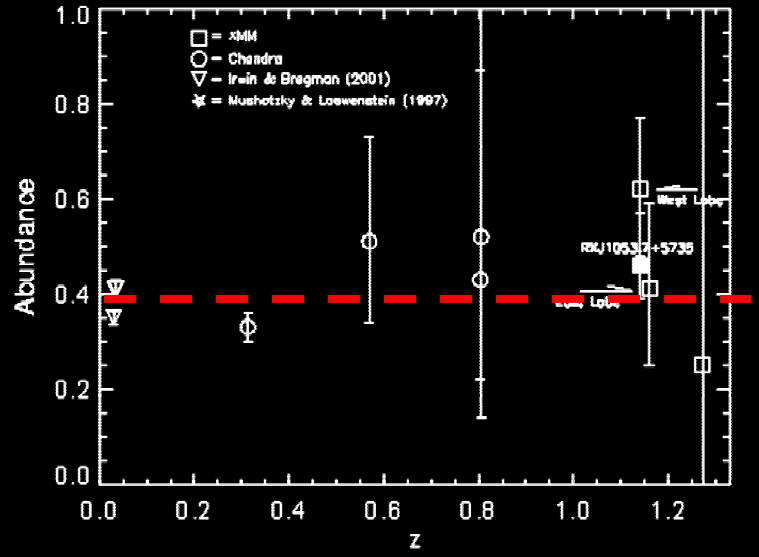


Dark Matter (23%)

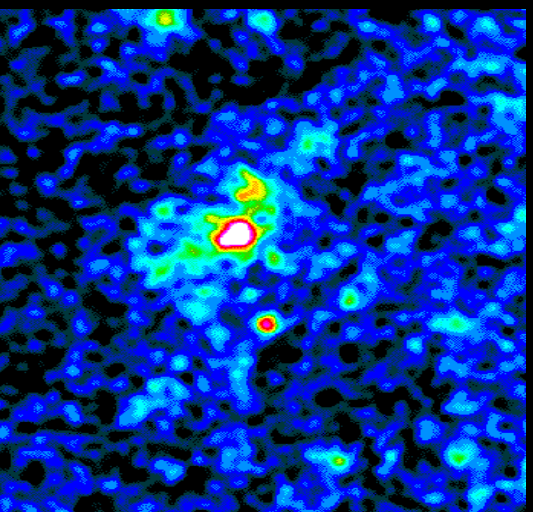


# Early clusters: enrichment of elements



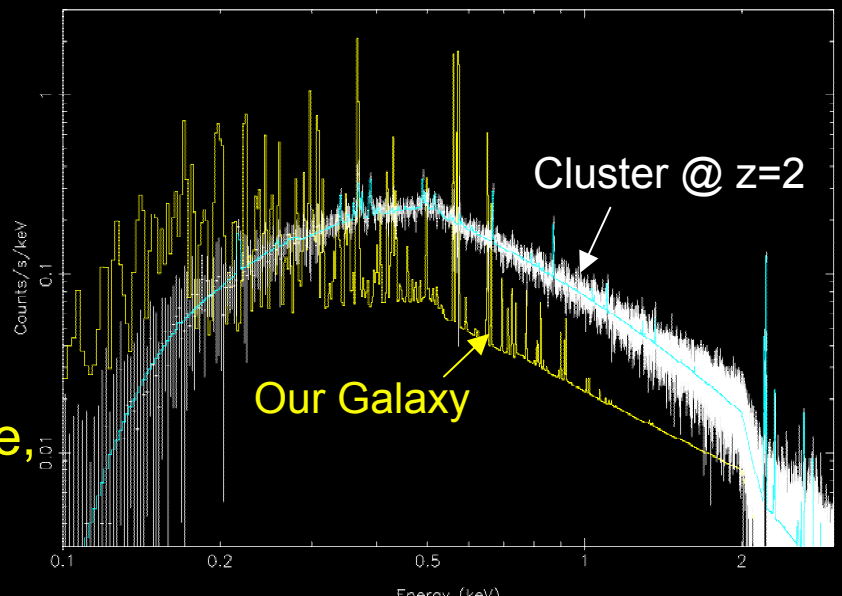




Elements formed at z>1.3!



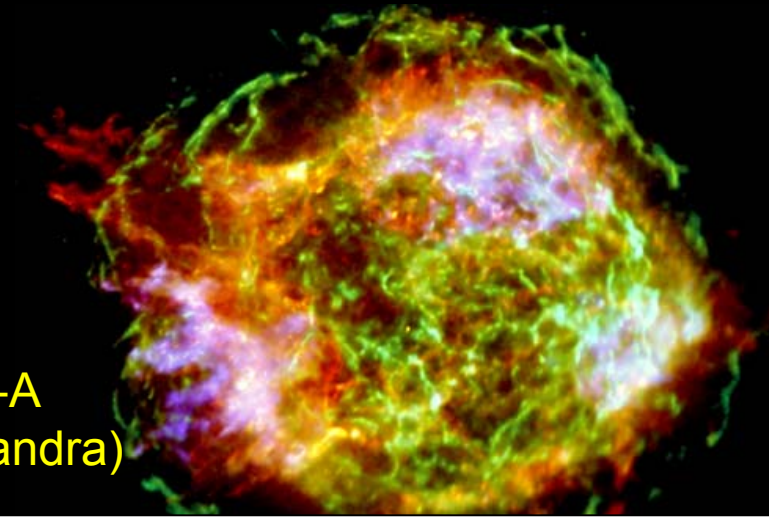
NGXT Simulation of a
5 keV cluster at z=2

Element abundances
of O, Ne, Mg, S, Si, Fe,
…

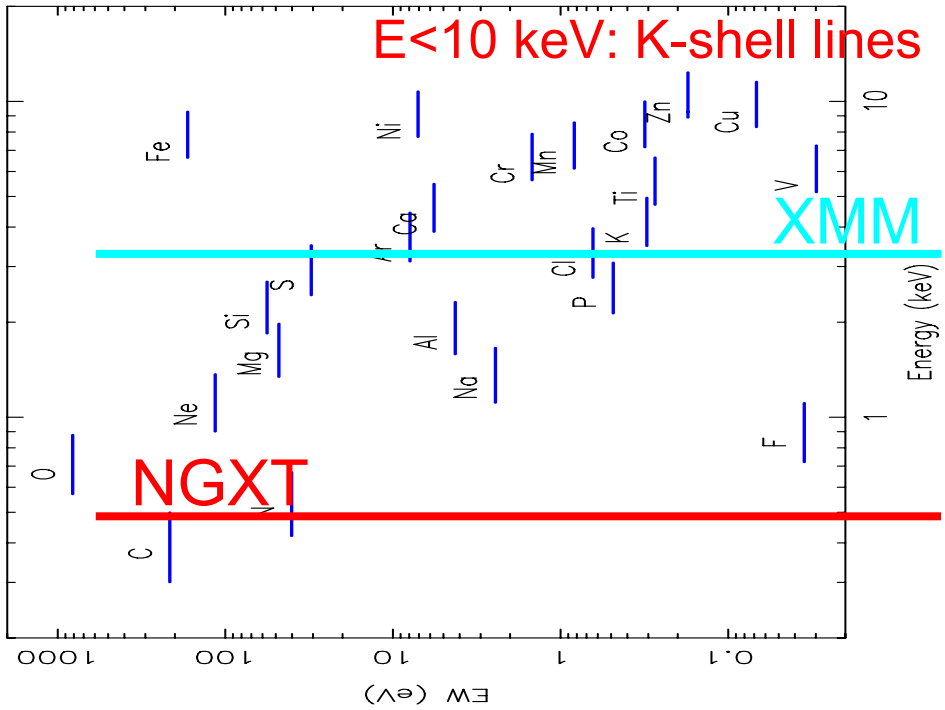


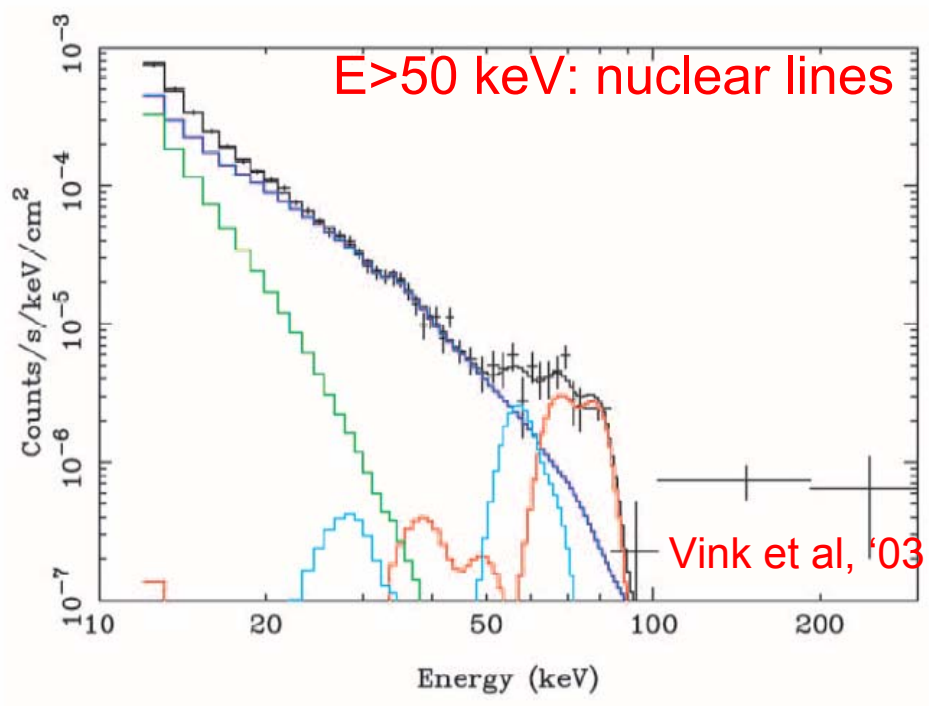
# Element Abundances from SNRs

## Closing the life cycle of matter



Cas-A
(Chandra)




Nucleosynthesis measurements in the near future technologically easier in X-rays than in (MeV) Gamma range

# Summary

- Scientific Requirements
  - Sensitivity: $10^{-18}$ erg cm$^{-2}$ s$^{-1}$ → > 10 m$^2$ area @1 keV
  - Energy Band 0.1 to ~100 keV
  - Angular resolution 2-5 arcsec
  - Spectral resolution 1-2 eV

NGXT science is exciting with strong European leadership !

Science has highest priority in national planning excercises (e.g. NAS Decadal Survey, German „Denkschrift") + ~100 scientist signatures

Coordinated planning in Europe, Japan and US

- Technology development required:
  - Factor ~ 10 lighter mirrors, high precision micropore optics
  - Formation flying, 1 mm$^3$ accuracy over ~50 m
  - Imaging calorimeter, better than 2 eV
  - Large, fast active pixel detector with µs timing

Proof of concept exists for key technologies, European lead !

Need sufficient technology investment NOW to be ready for a mission in the 2015-2020 timeframe

Thank you
very much!