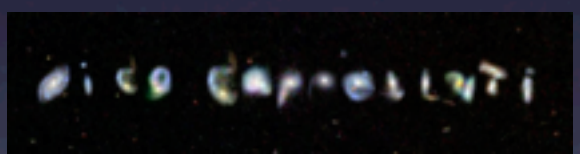
The Nature of the unresolved soft CXB:

a population synthesis model of its fluctuations



INAF-OABO

Mauro Roncarelli and the XMM-CDFS team

Open questions on the sources of the unresolved CXB

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Unresolved CXB actually contains all those sources that we haven't seen,... yet!

How many AGN at high-z?

AGN Number Density
at high-z

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Formation of the black hole seeds that form SMBHs

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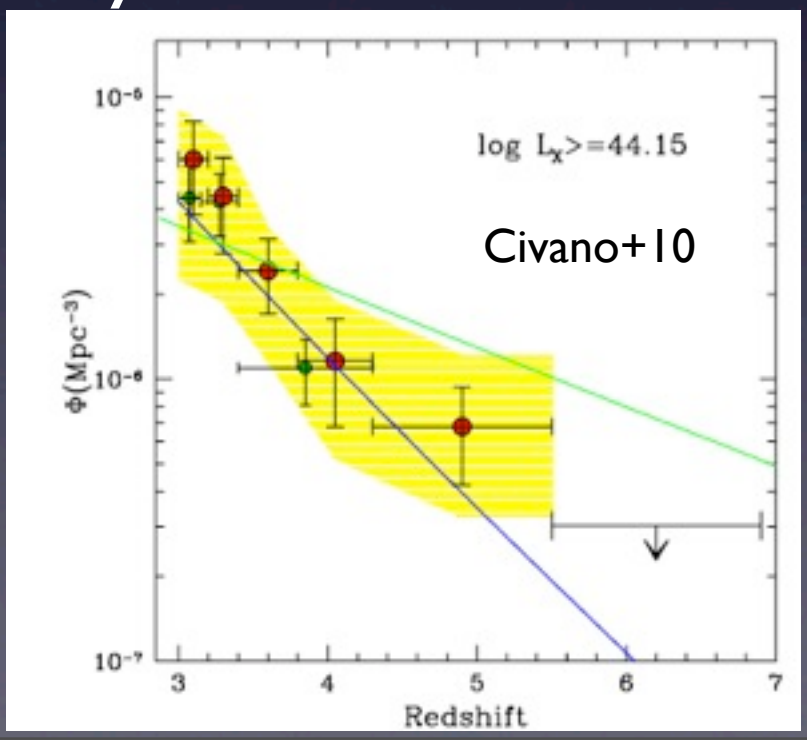

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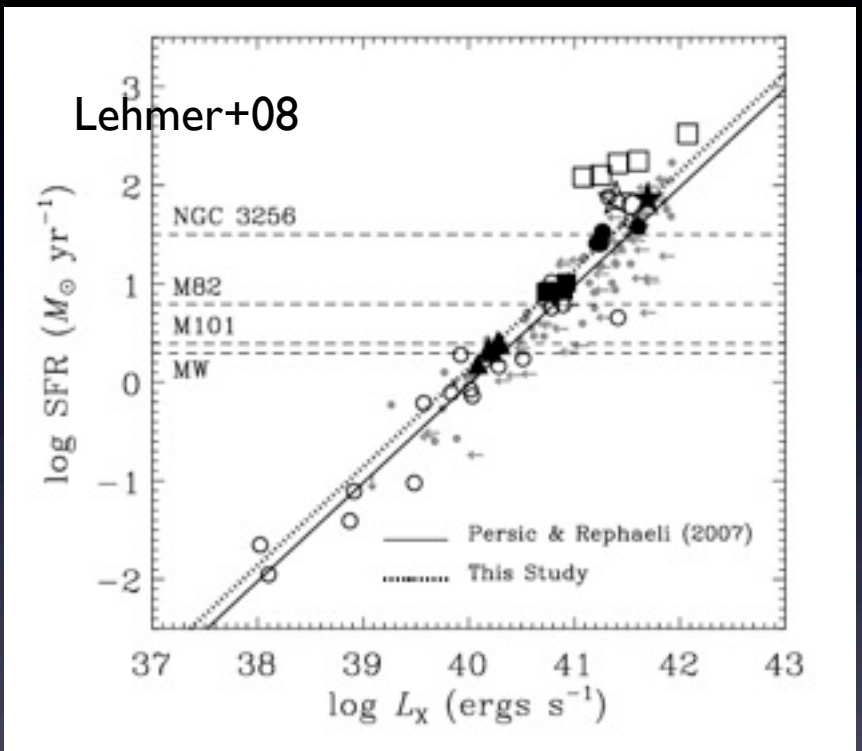

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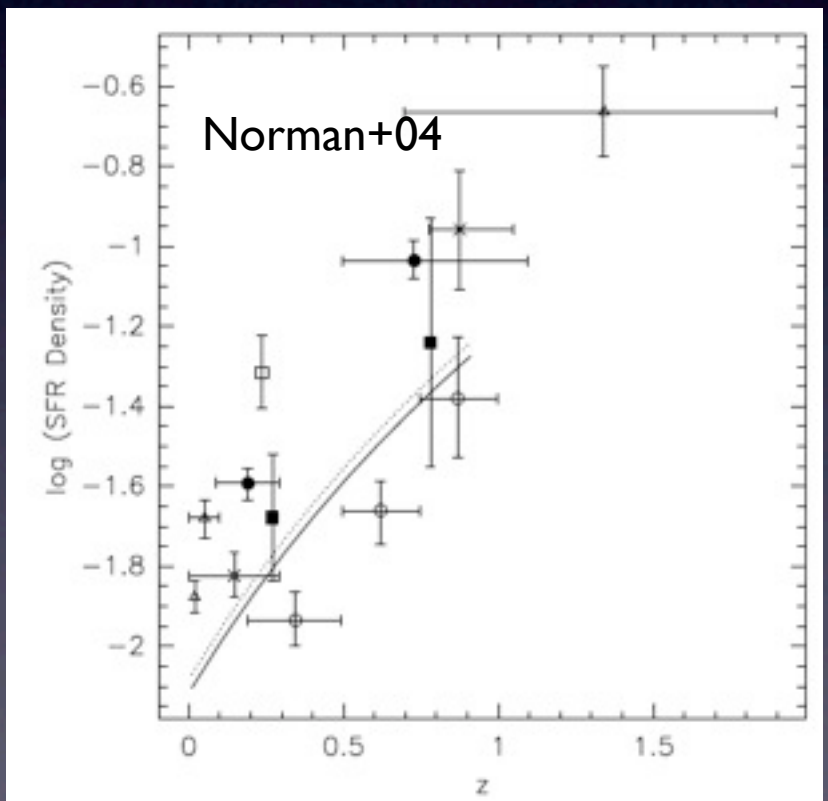

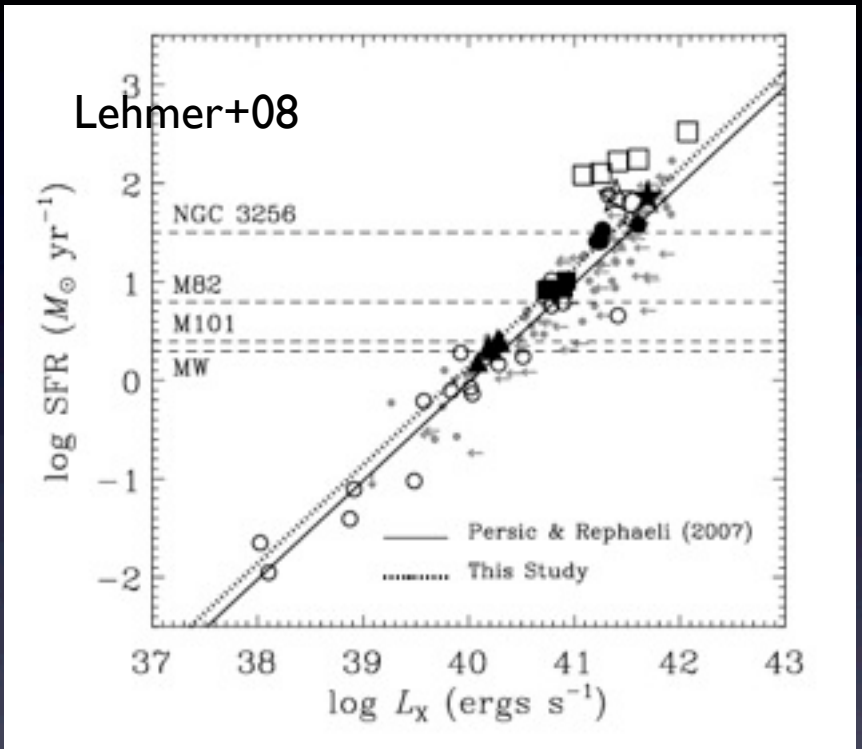

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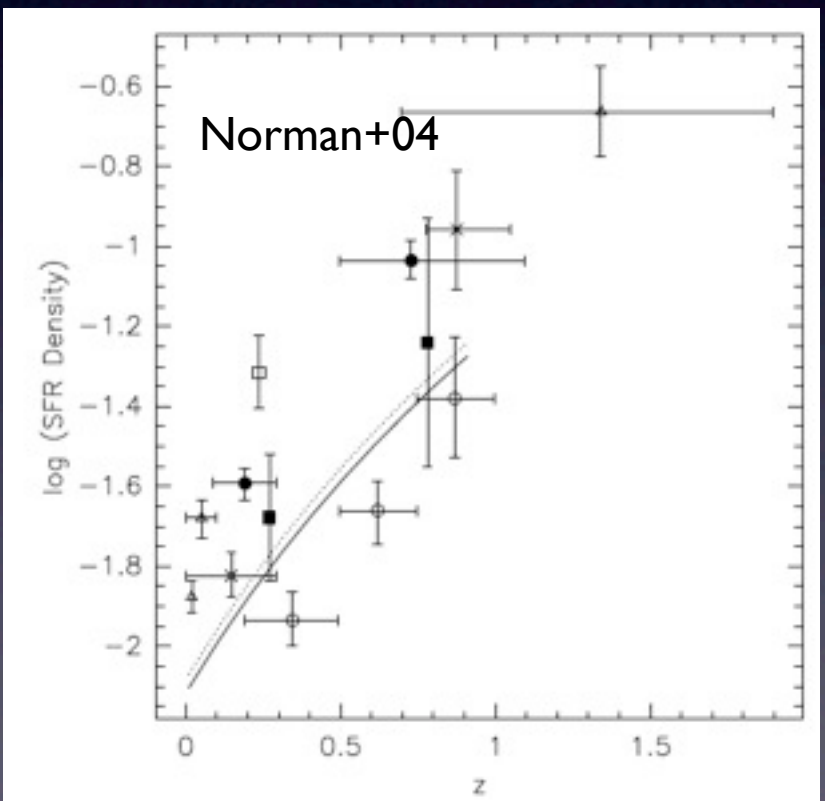

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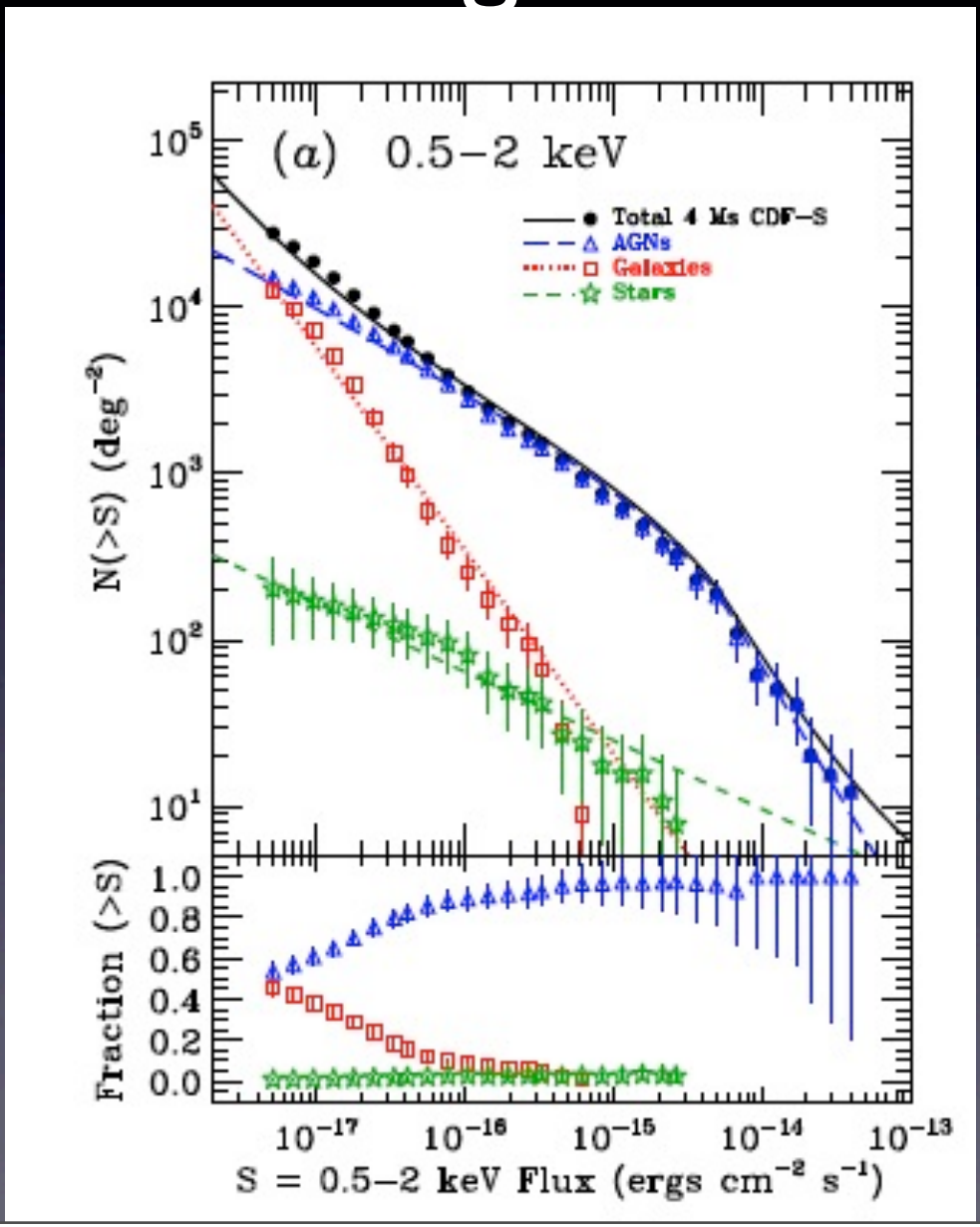

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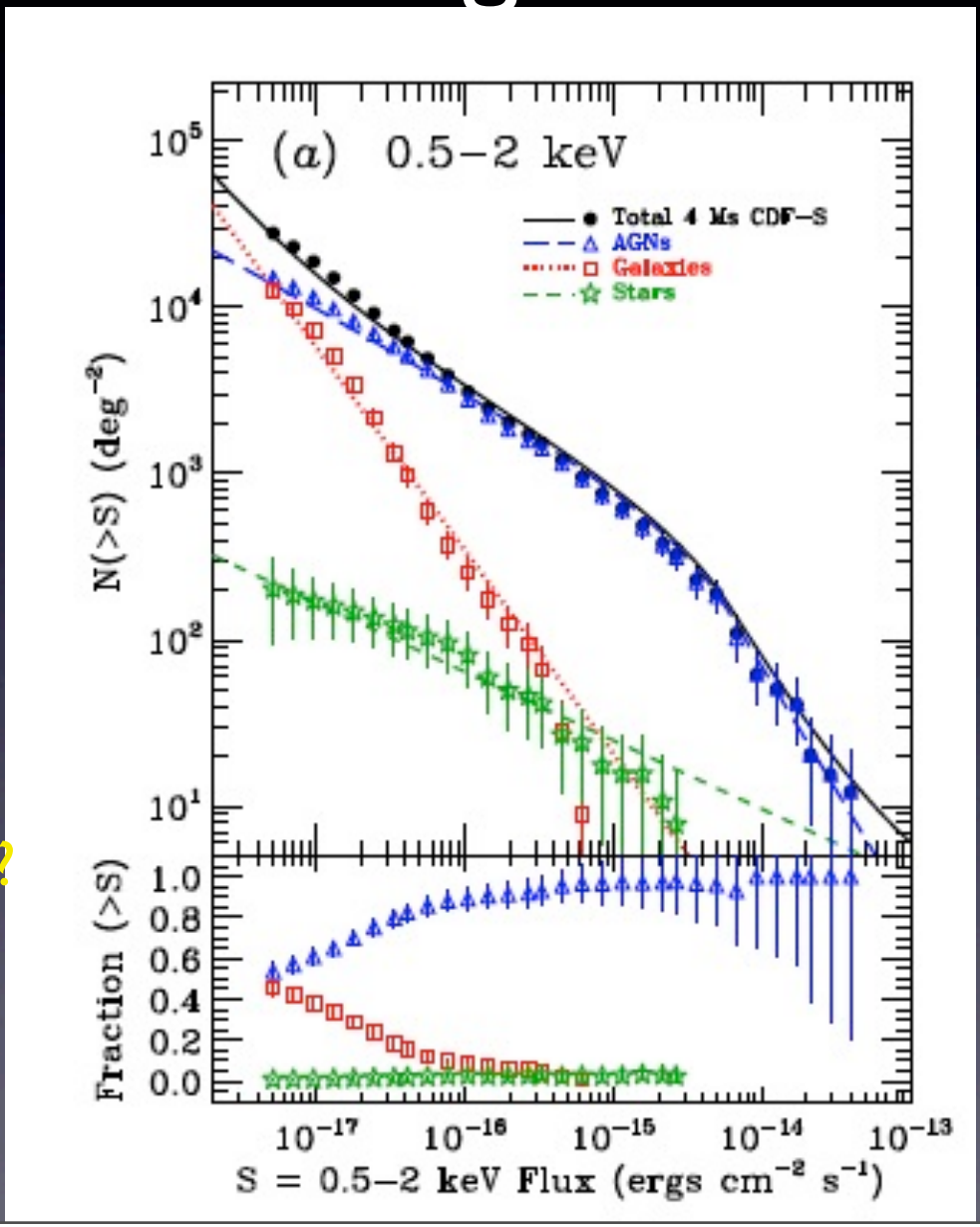
How does the X-ray emission evolve?



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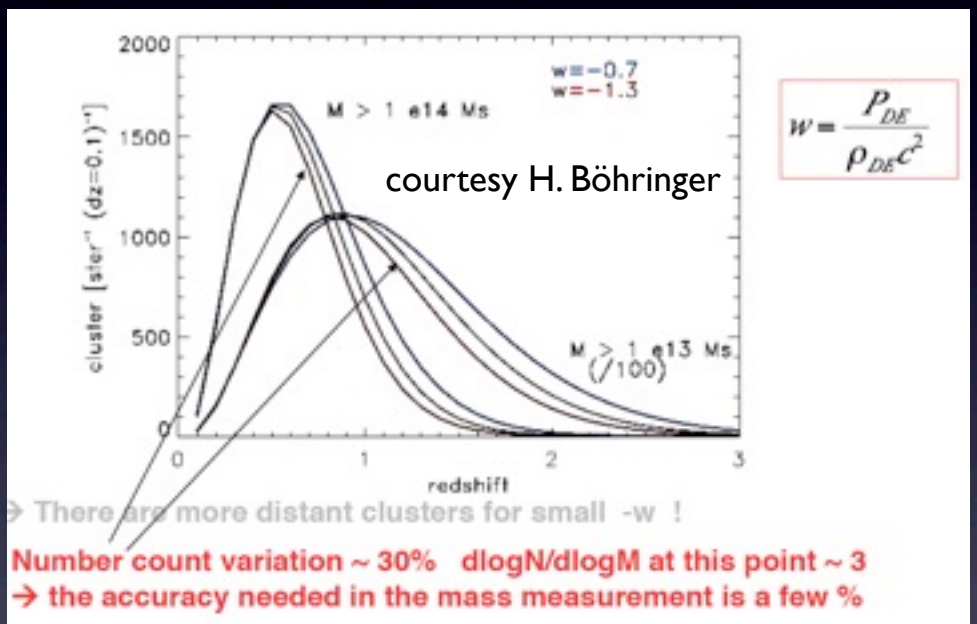

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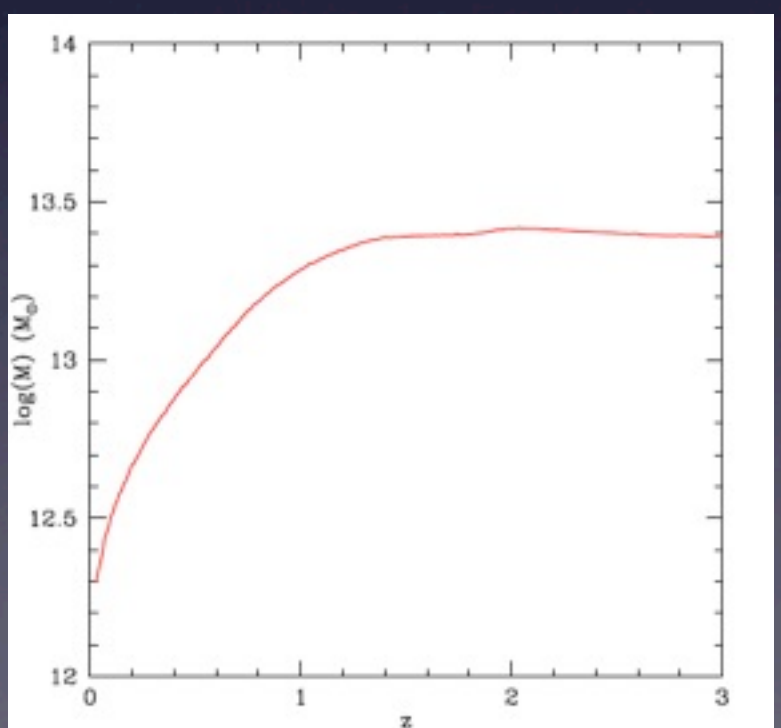

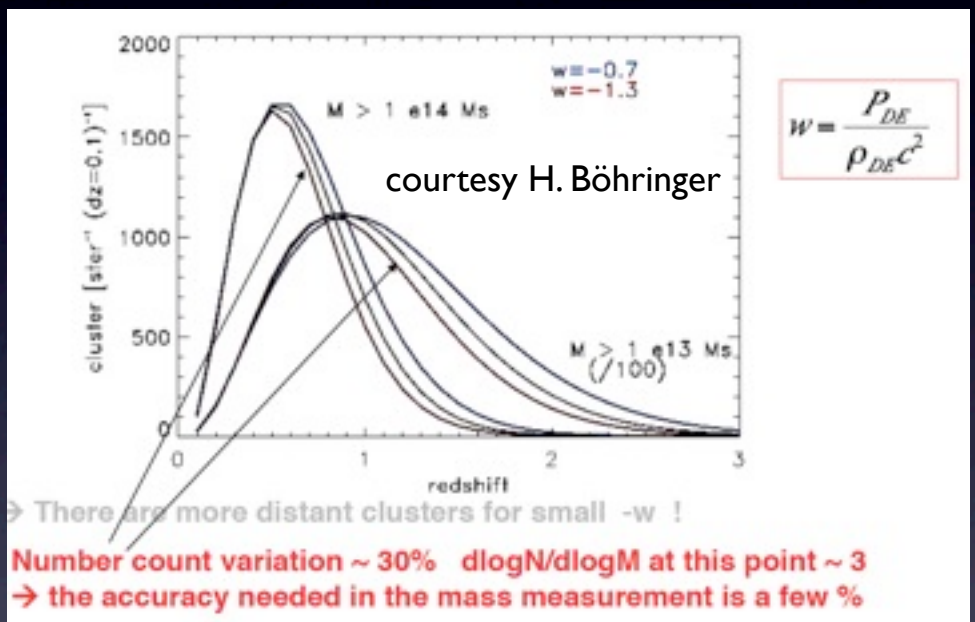

Limits of 4 Ms CDFS

How do SMBH form?

We need to explain how to make
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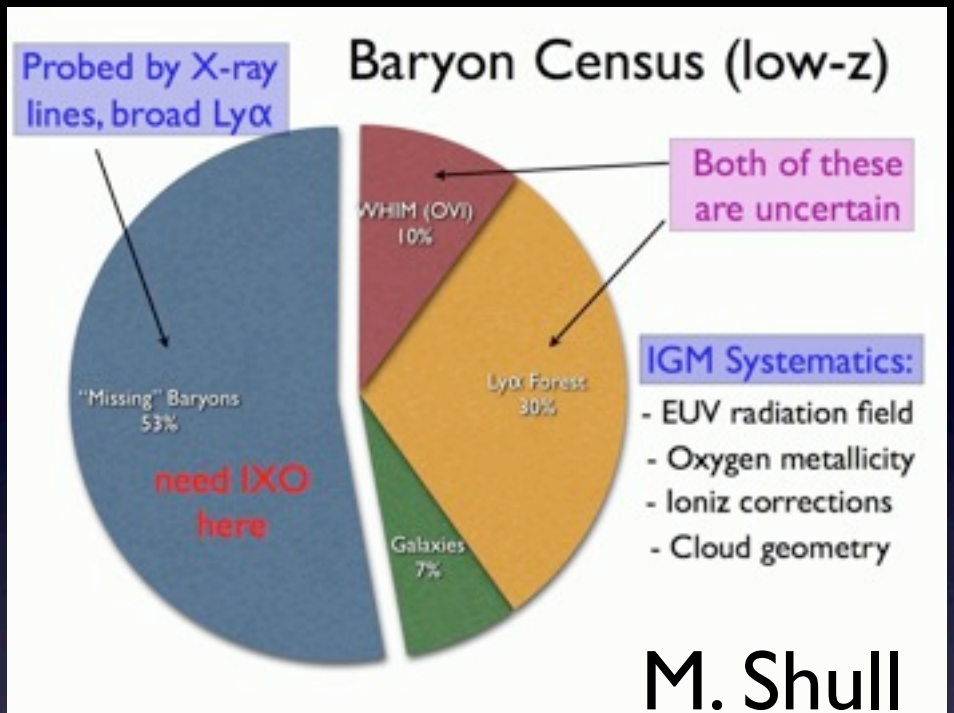
These sources should leave their signature in the anisotropies of Cosmic backgrounds
Kashlinsky+05,07,12

Missing Baryons (WHIM)



Half of the baryons are missing in the Local Universe wrt to z~3 and are supposed to lie in the WHIM

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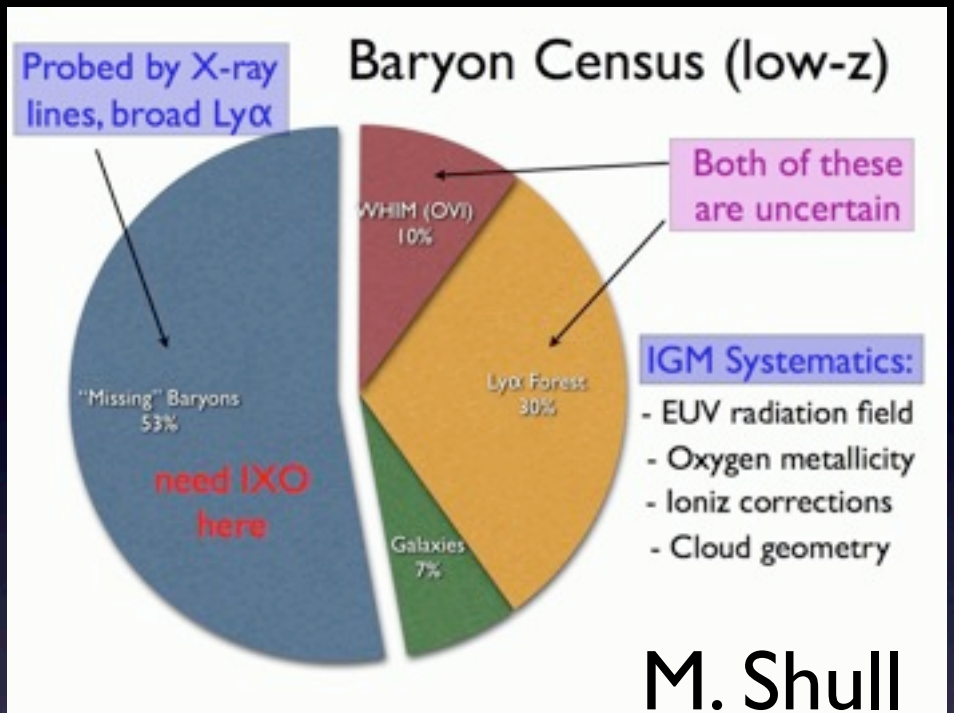

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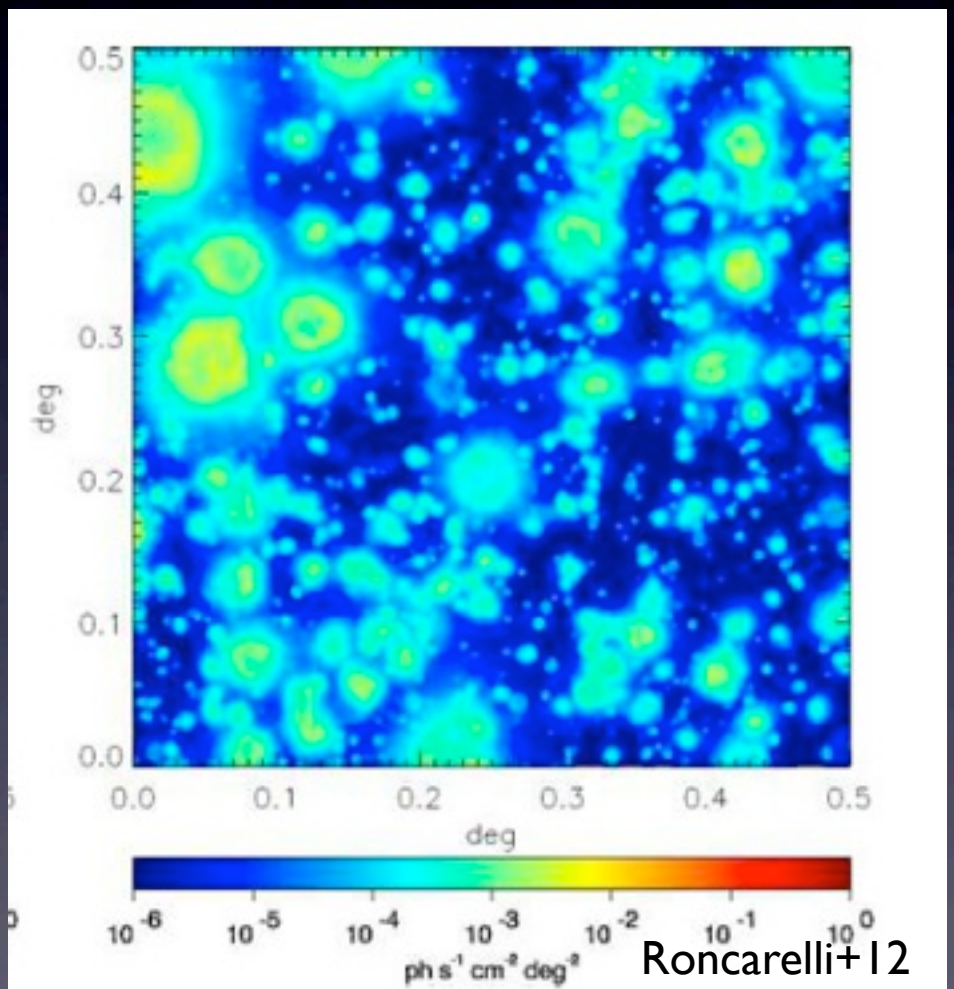
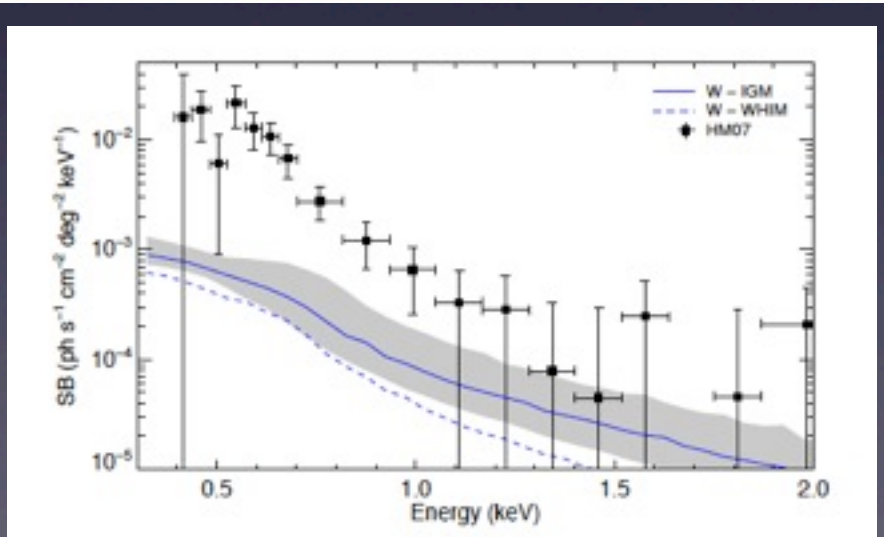
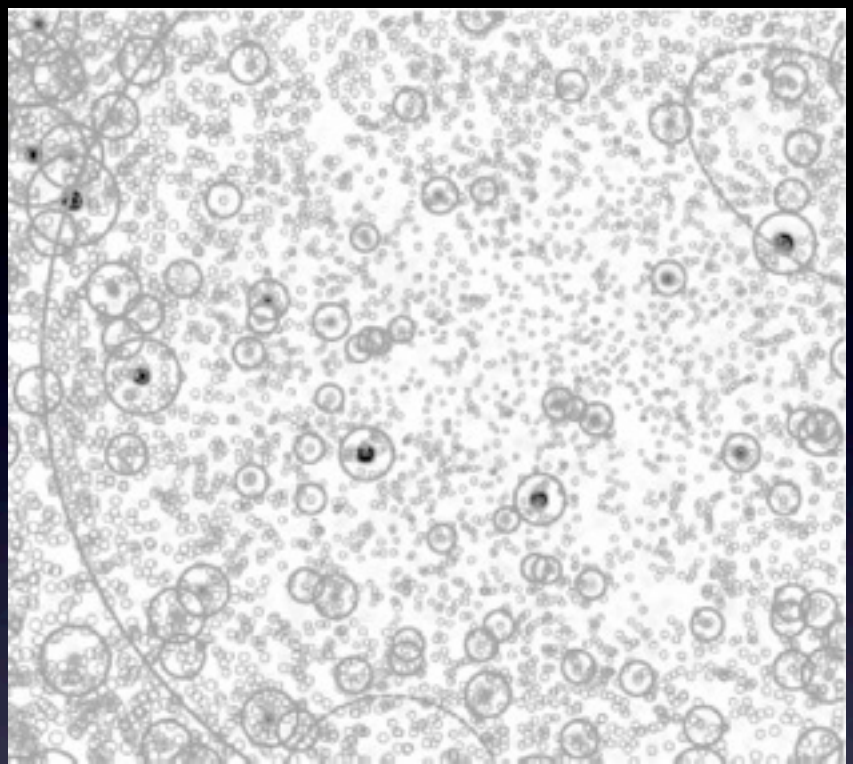


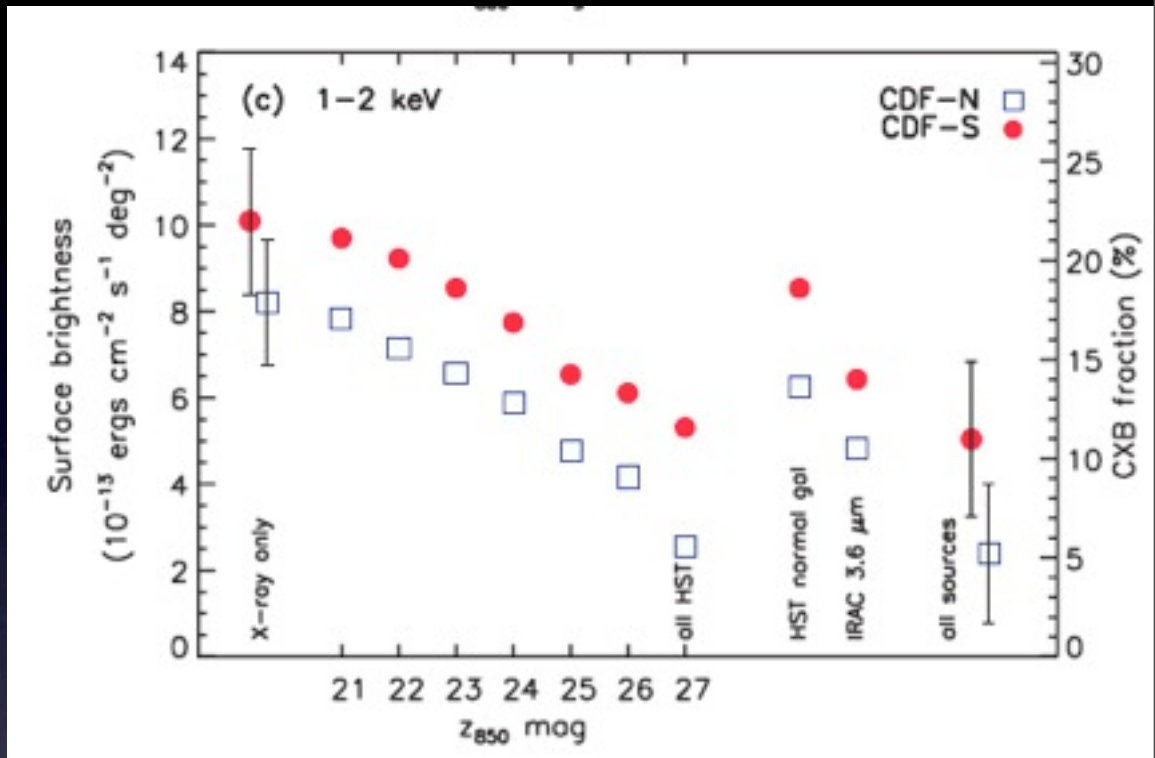


Significant contribution to the soft CXB

3-The unresolved CXB

Previous studies





Removal of HST Galaxies down to z_{850}=27 and X-ray sources in CDFS, only 50% of the soft unresolved 1-2 keV CXB is explained

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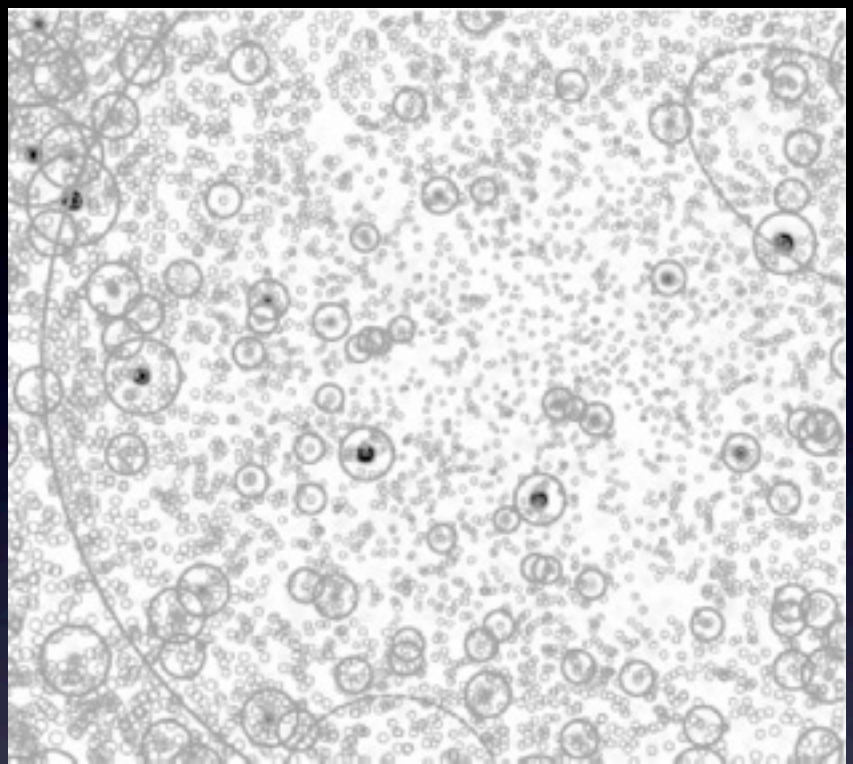

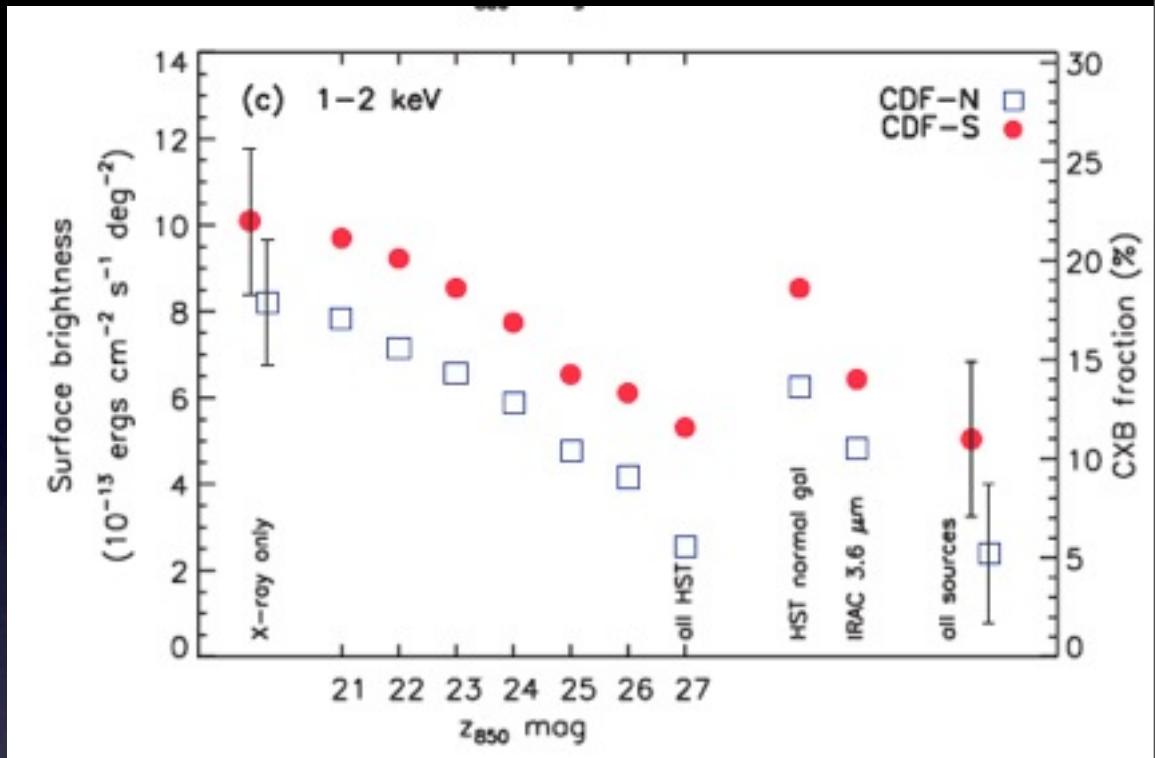

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Faint or diffuse sources should produce the remainder CXB

The Power Spectrum of fluctuations in the CDFS

- The PS contains information on both clustering and emissivity evolution of a given source population

$$P_{2,AGN}(q) = \int_0^z \left(\frac{dS}{dz}\right)^2_{AGN} \frac{P_{3,AGN}(qd_A^{-1}, z)}{c\ dt/dz\ d_A(z)^2}\ dz$$

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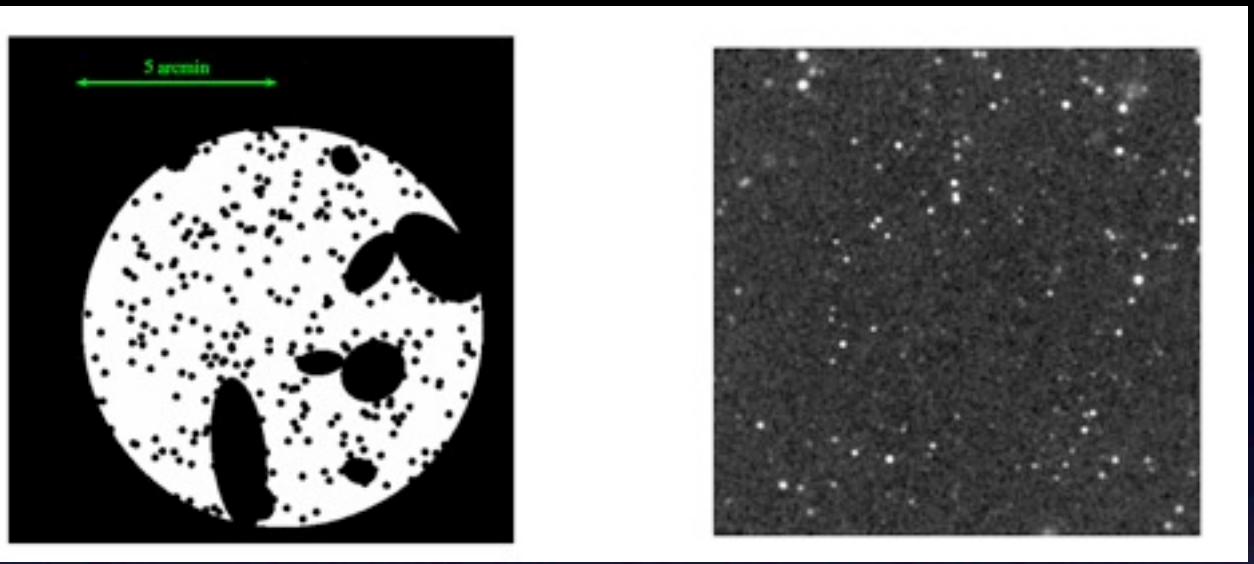
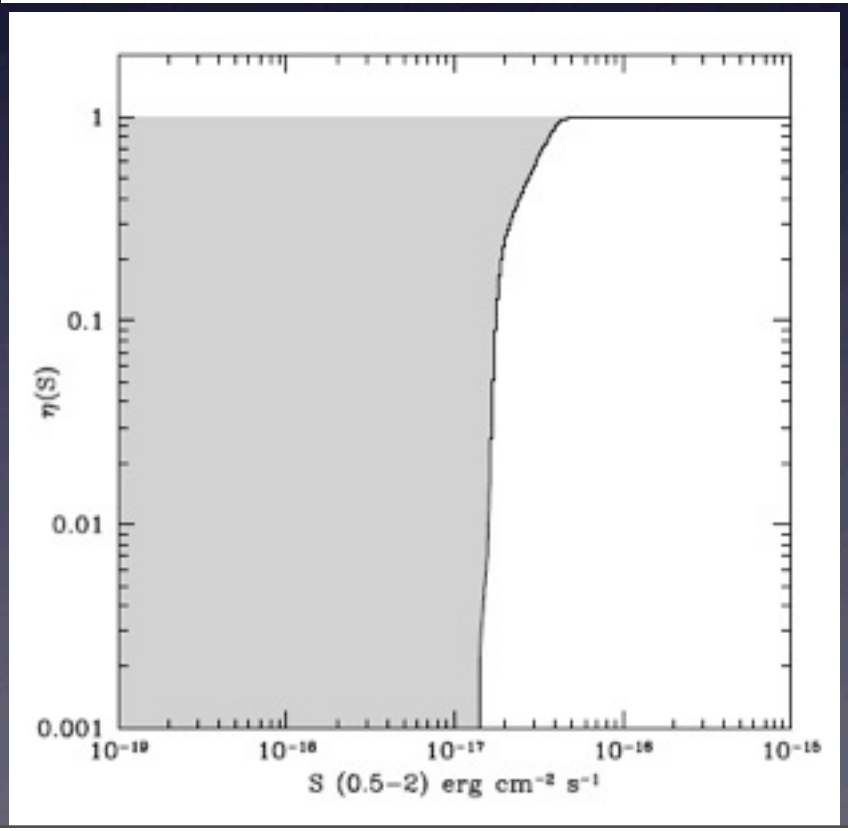
- PS can be decomposed in additive components

$$P_{2,CXB}(q) = P_{2,SN}(q) + P_{2,AGN}(q) + P_{2,GAL}(q) + P_{2,IGM}(q)$$

Dataset



4 Ms 0.5-2 keV
CDFS survey
Xue+11



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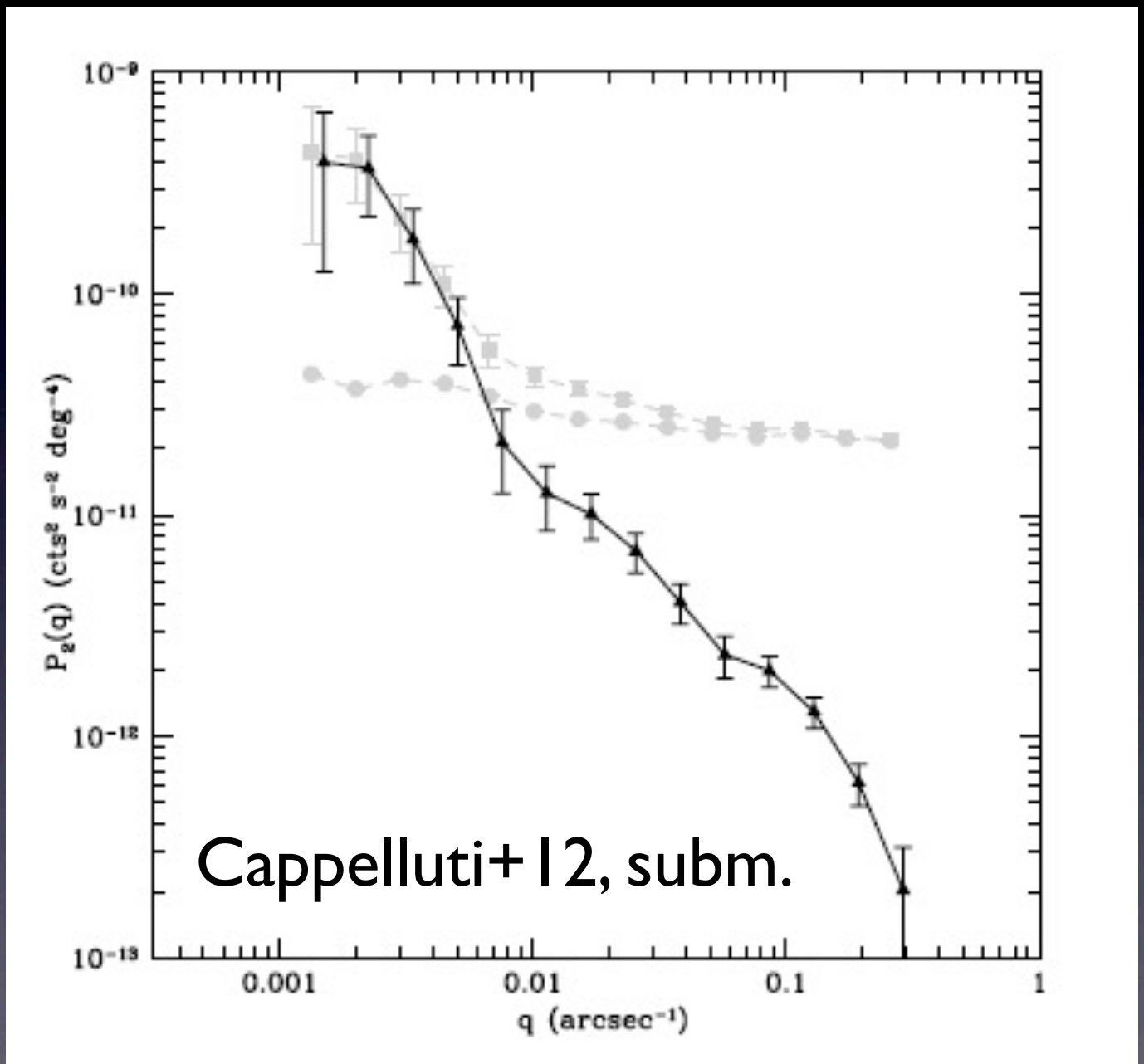


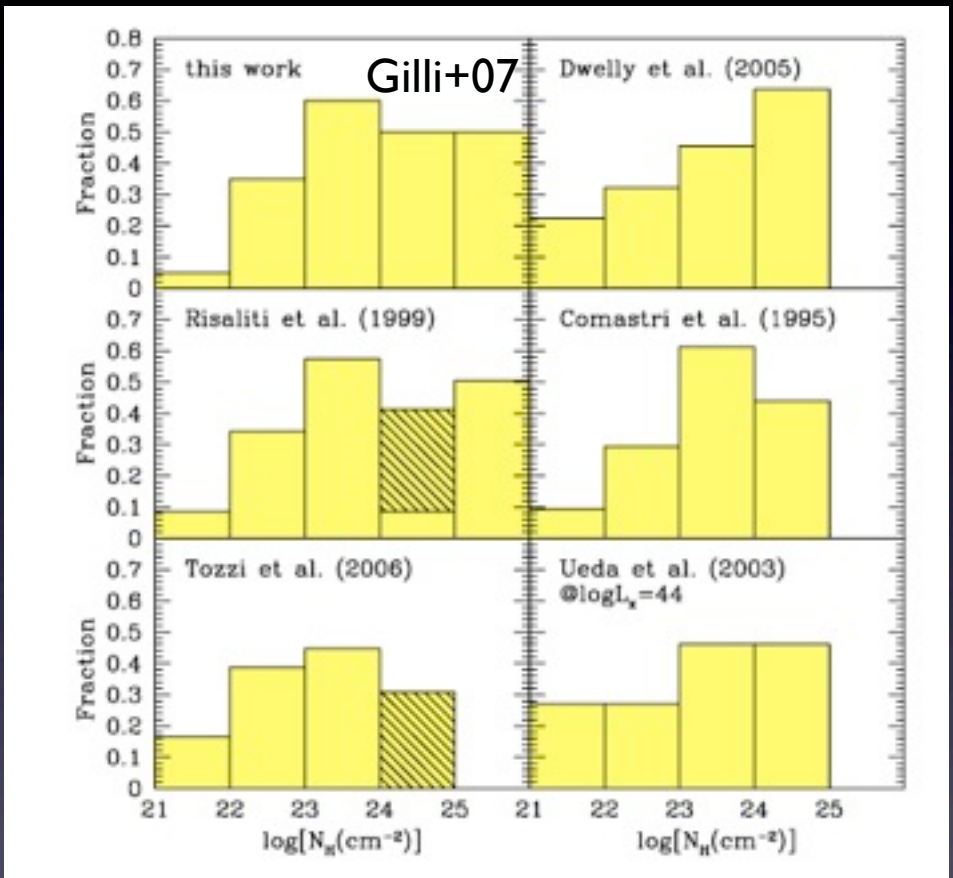
Power Spectrum of the 0.5-2 unresolved CXB after removal of background

How do we explain these fluctuations?

Model of AGN

- We need to feed into the model a recipe for
- XLF evolution, absorption distribution
- Bias evolution
- Cosmology... (we believe in ΛCDM)

AGN population synthesis model



Large fraction of obscured sources

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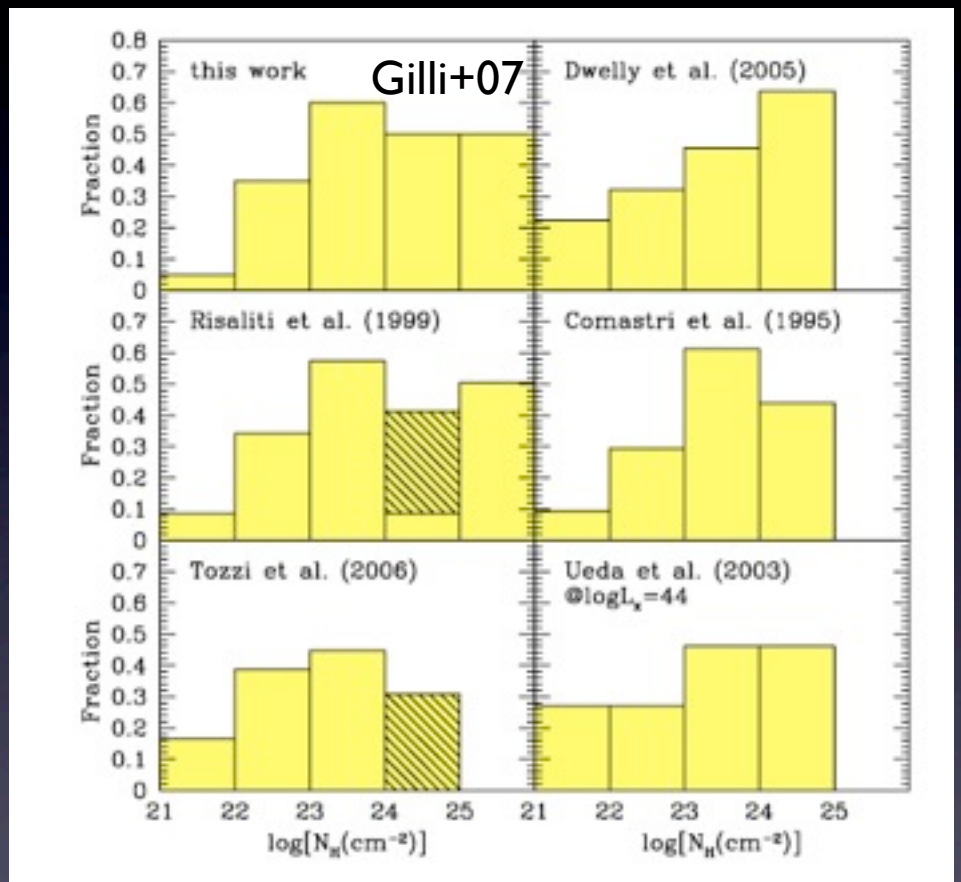

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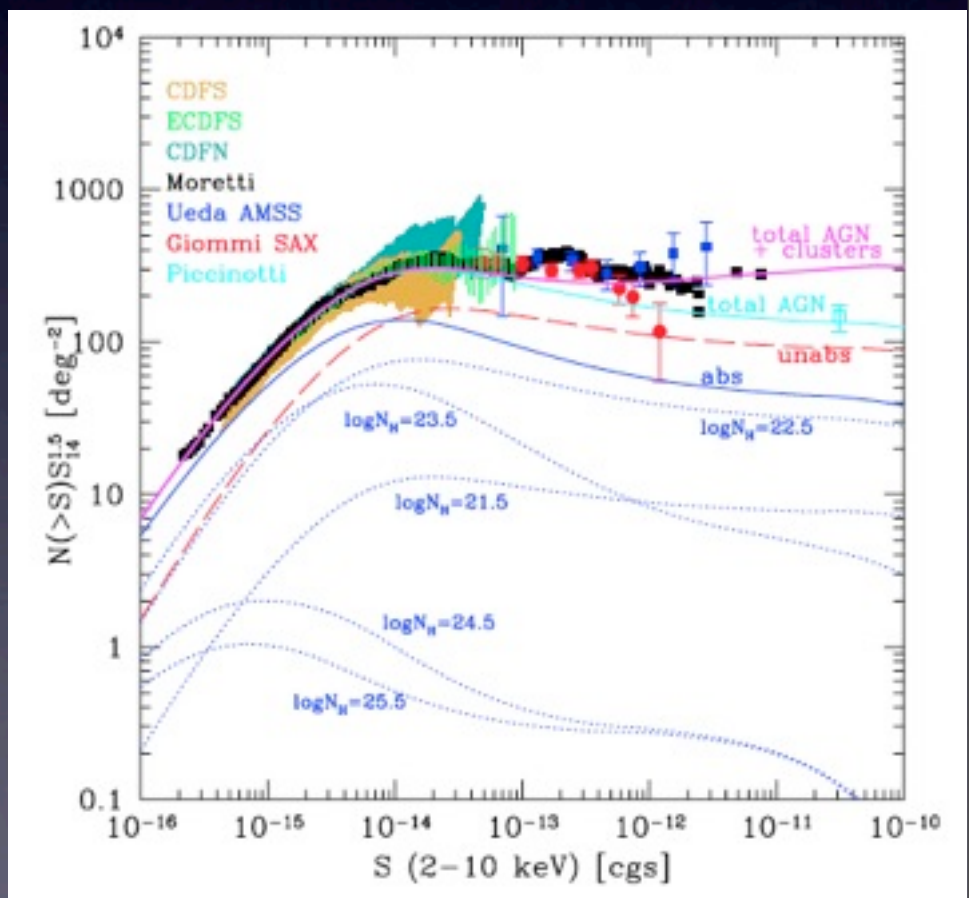

The model reproduces well the observed source counts

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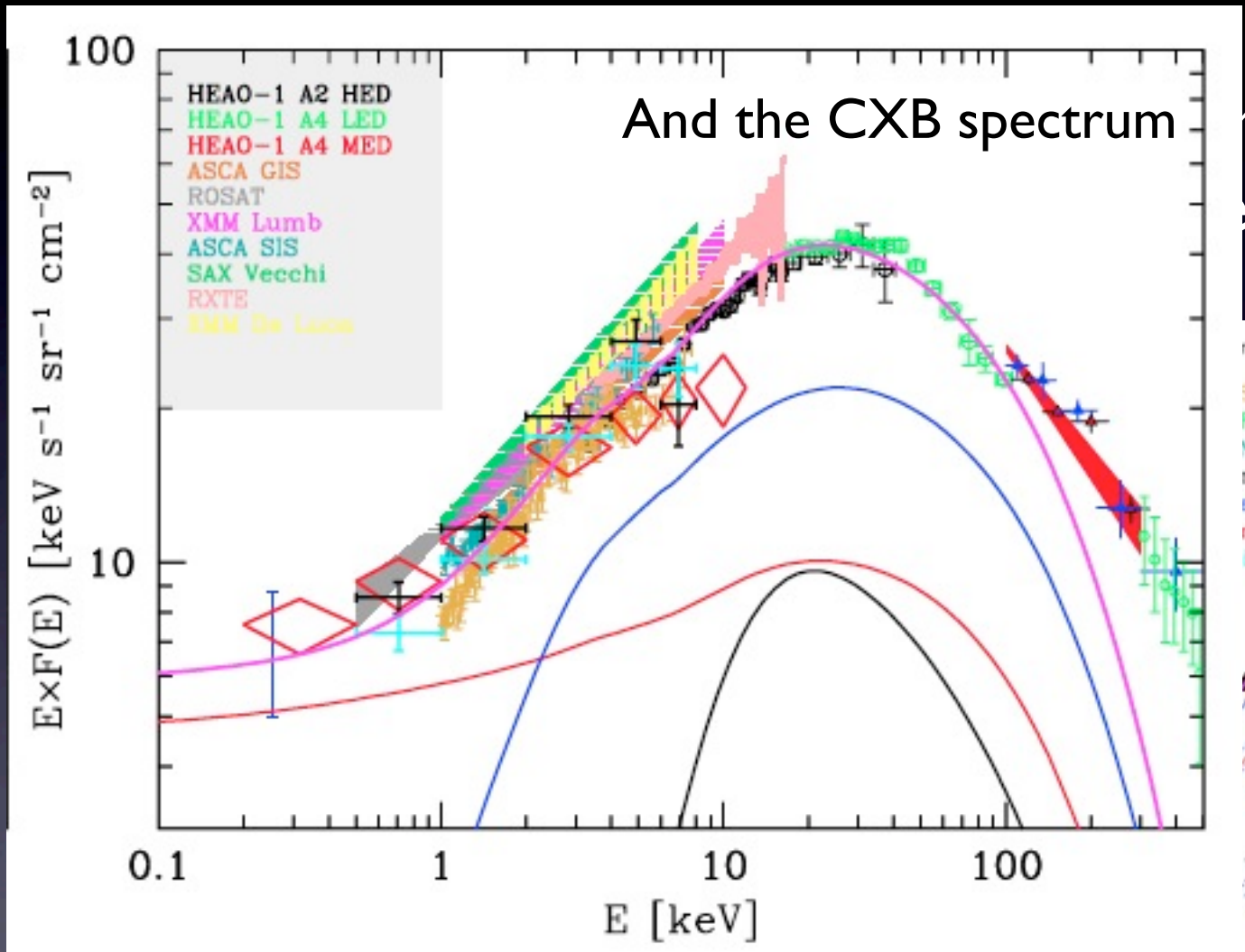
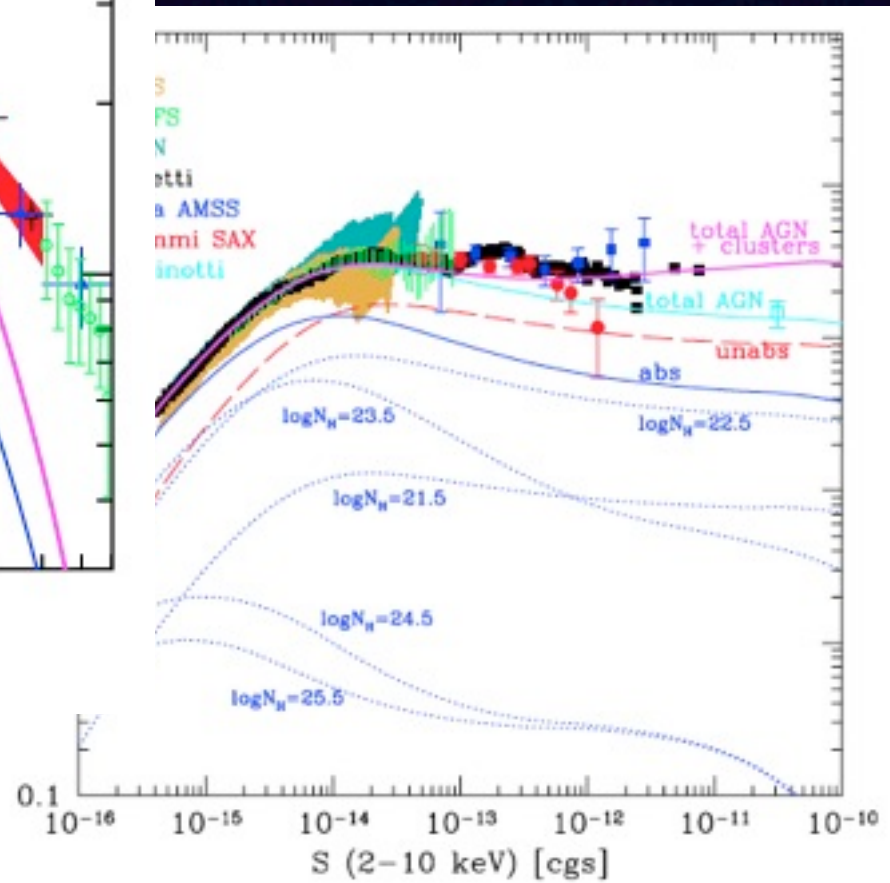


And the CXB spectrum

raction of
d sources



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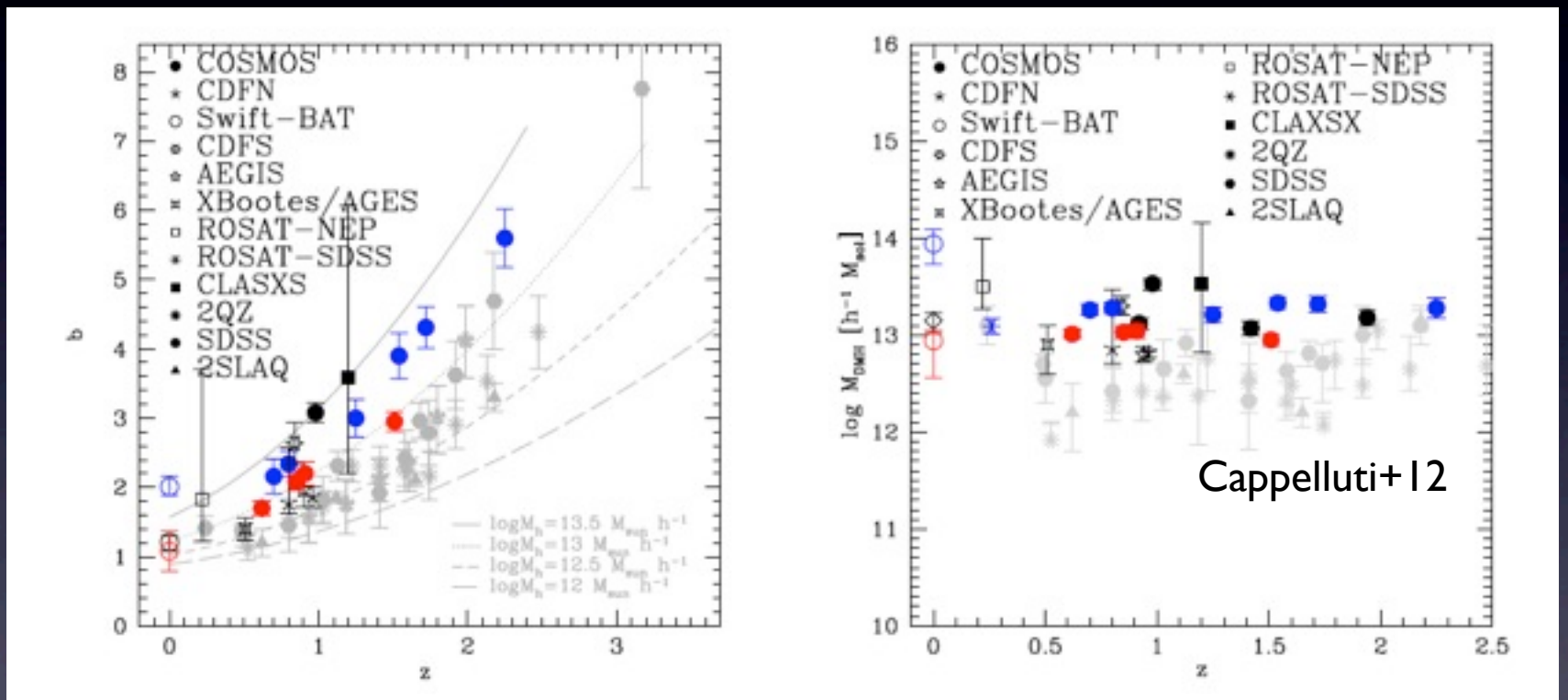
AGN clustering

$$P_{3,AGN}(k,z) = b(z)^2 P_{3,M}(k,z),$$



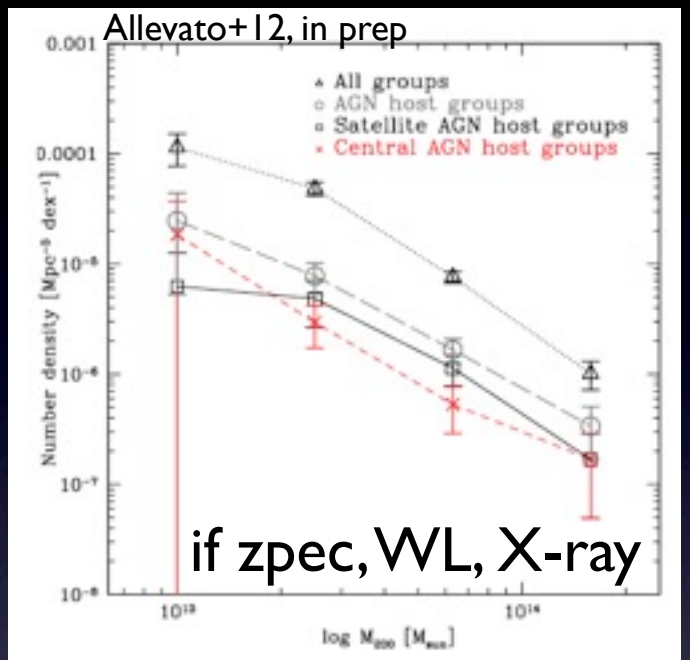
AGN follows logM~13 at all z!

AGN biasing evolution is strictly related with the AGN activation mechanisms!

Halo Occupation of AGN

Fraction of
DMH hosting
an AGN as f(M)

Halo Occupation of AGN



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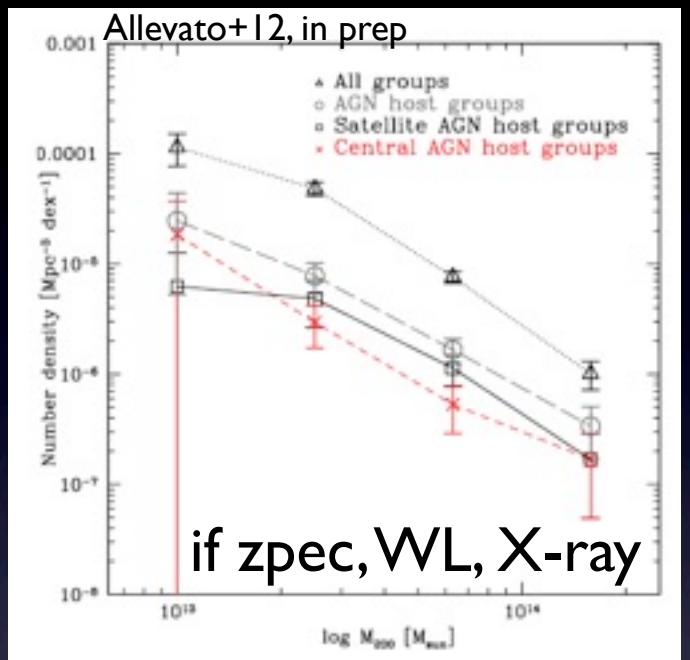

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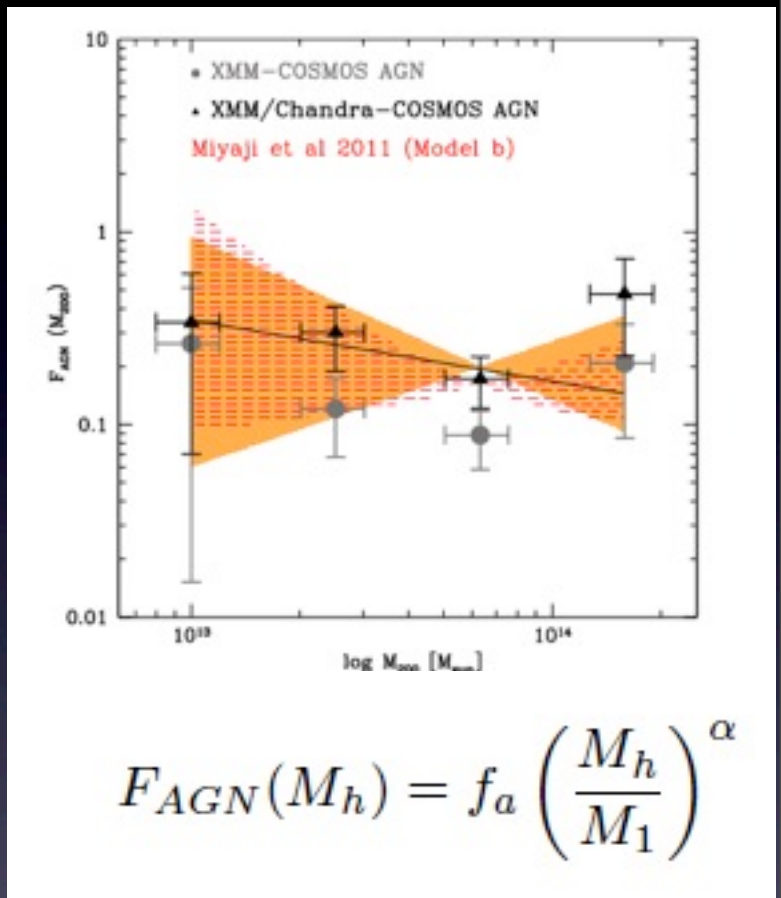

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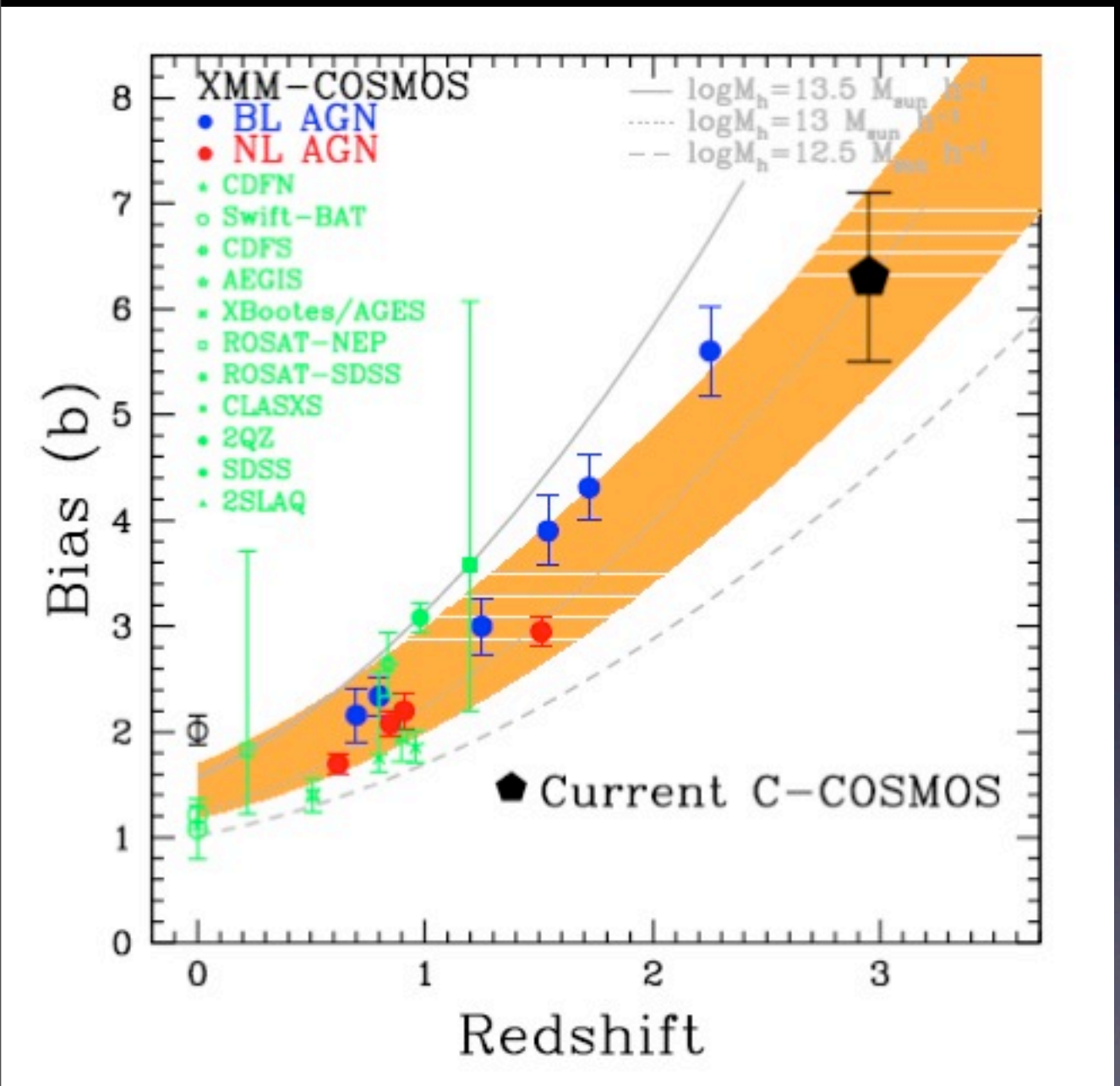

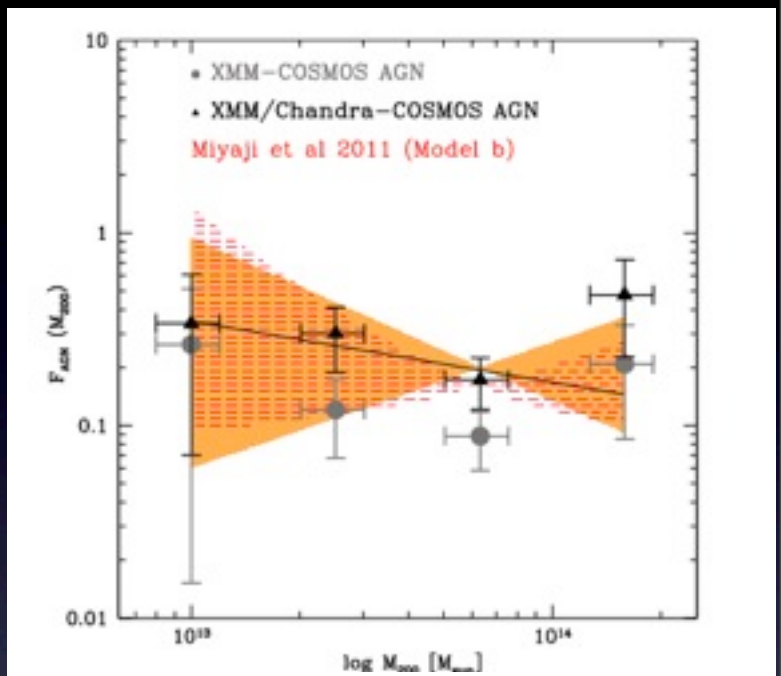

$$F_{AGN}(M_h) = f_a \left(\frac{M_h}{M_1}\right)^{\alpha}$$

If HOD=const
not only mergers should
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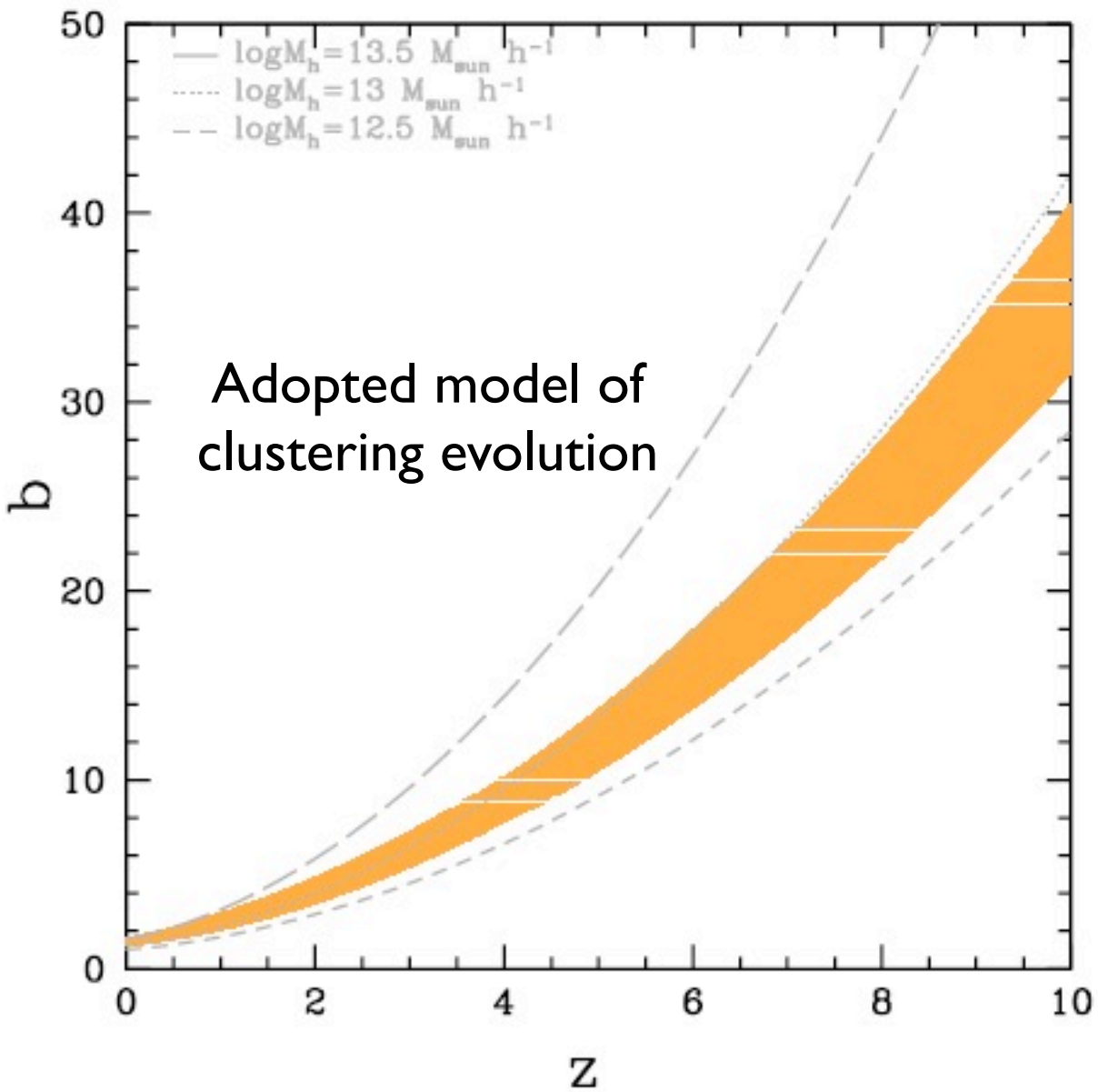
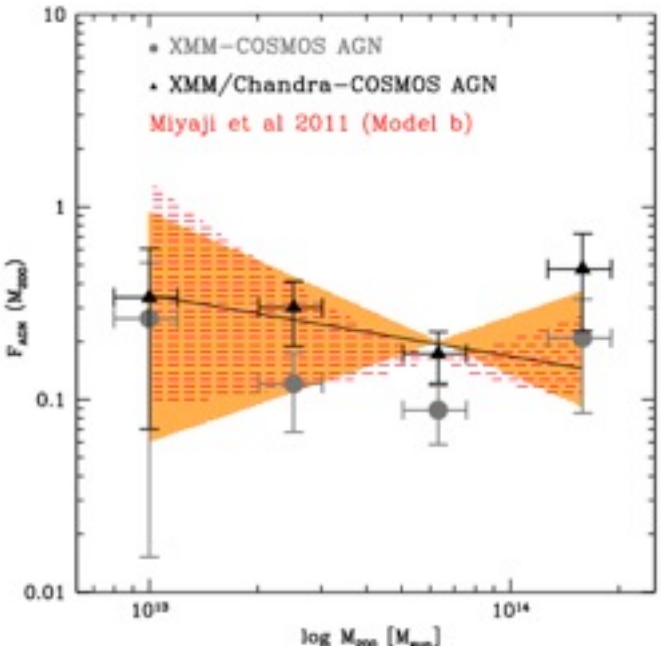
Halo Occupation of AGN



Adopted model of clustering evolution



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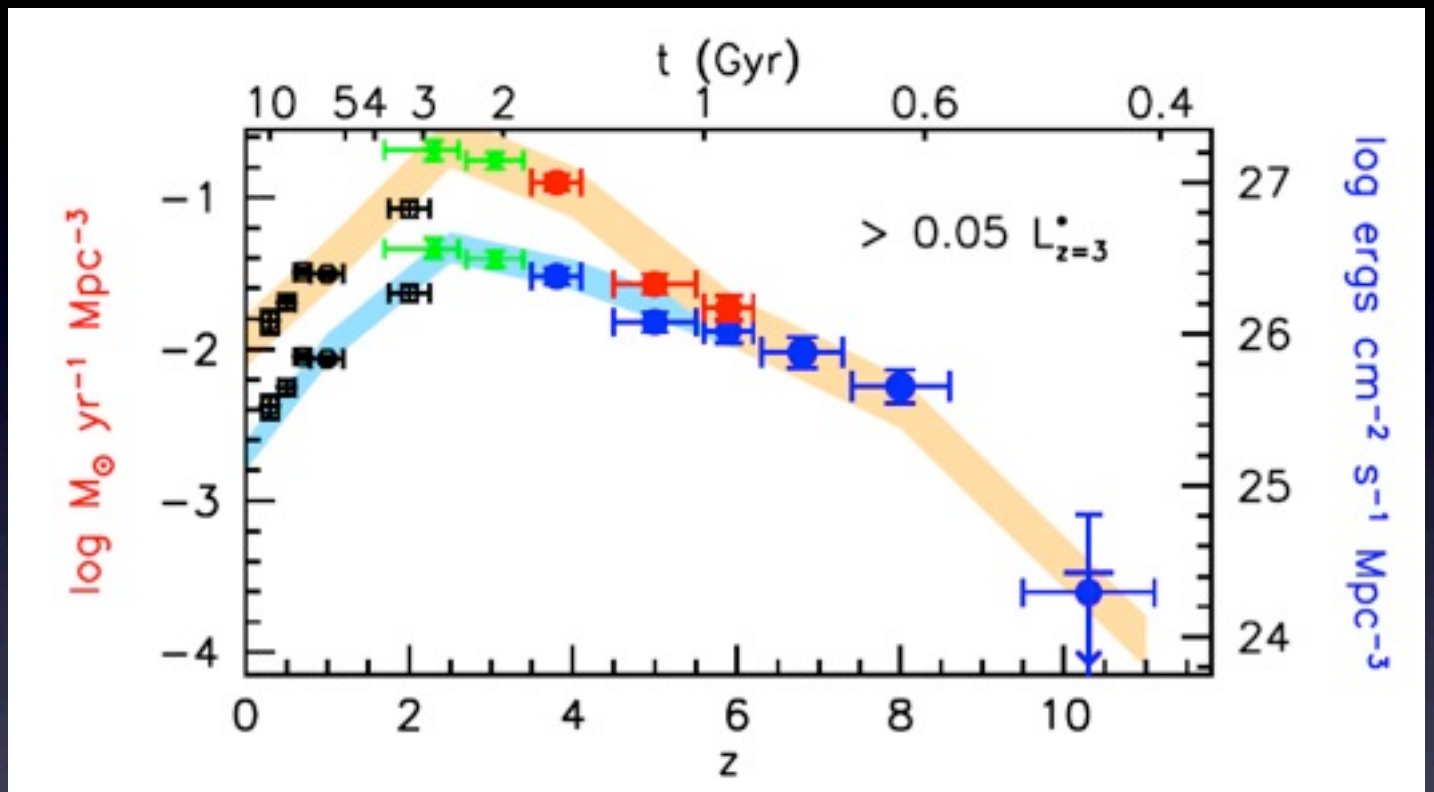
Model of Galaxies

Assumption:
X-ray galaxies evolve like SFR (Bouwens+10) starting from z~0 XLF (Ranalli+06)



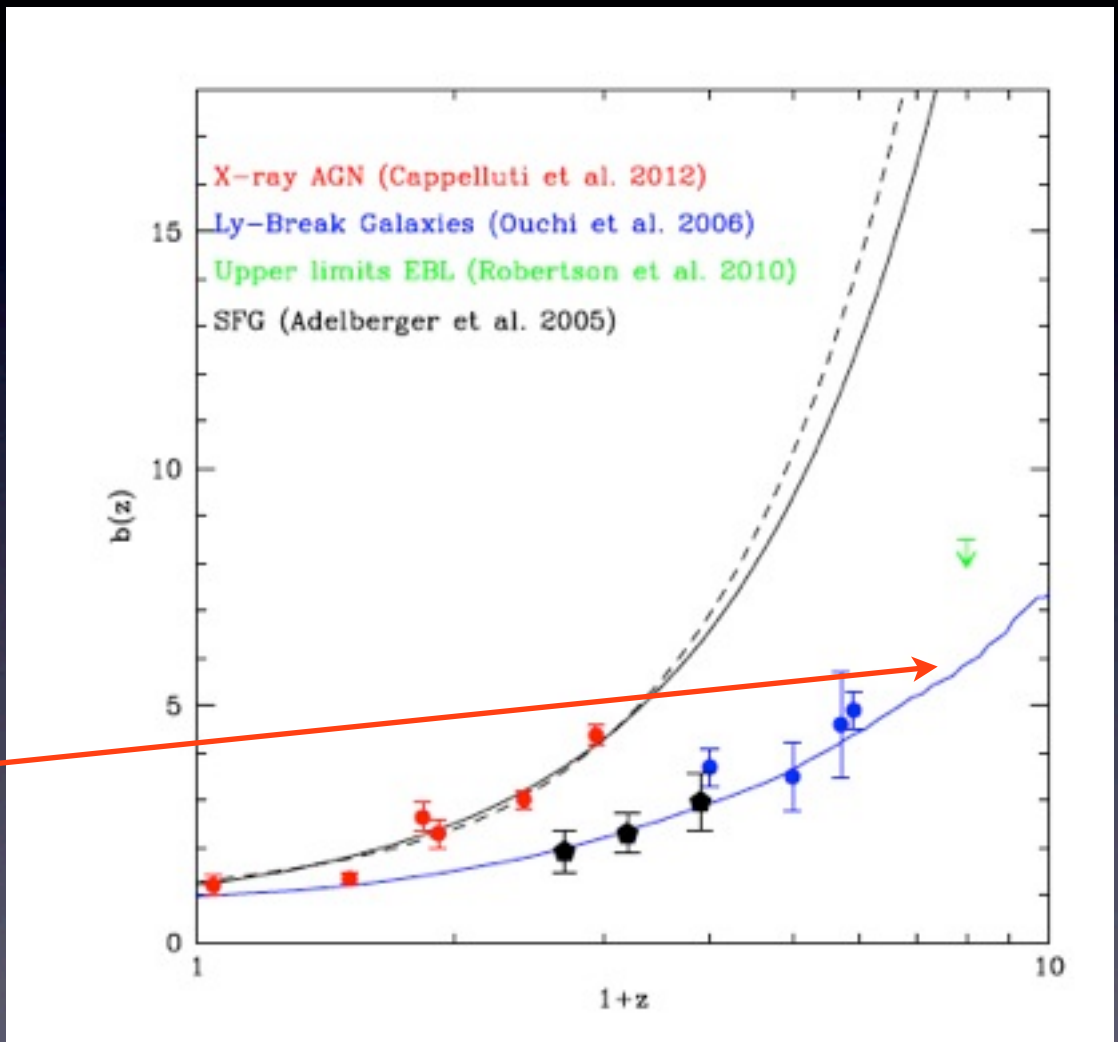
X-ray galaxies evolution is not known above z~1

Galaxies Bias

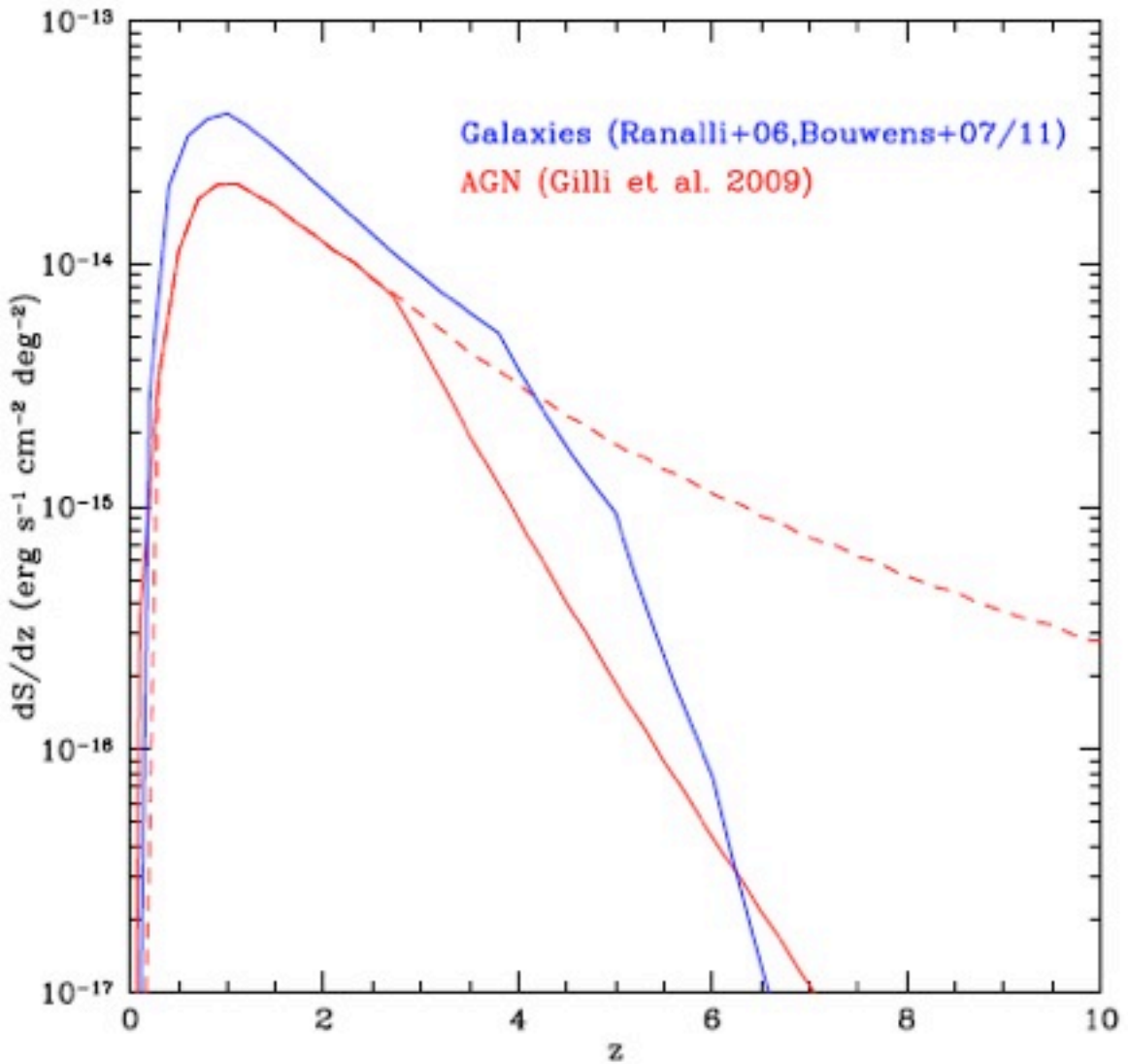
Assuming r_0=4.5 Mpc/h, γ=1.6 like for SFG

$$(\sigma_{8,G})^2 = J_2(\gamma)\left(\frac{r_0}{8Mpc/h}\right)^{\gamma}$$

$$b(z) = \sigma_{8,G}(z)/\sigma_{8,DM}(z),$$

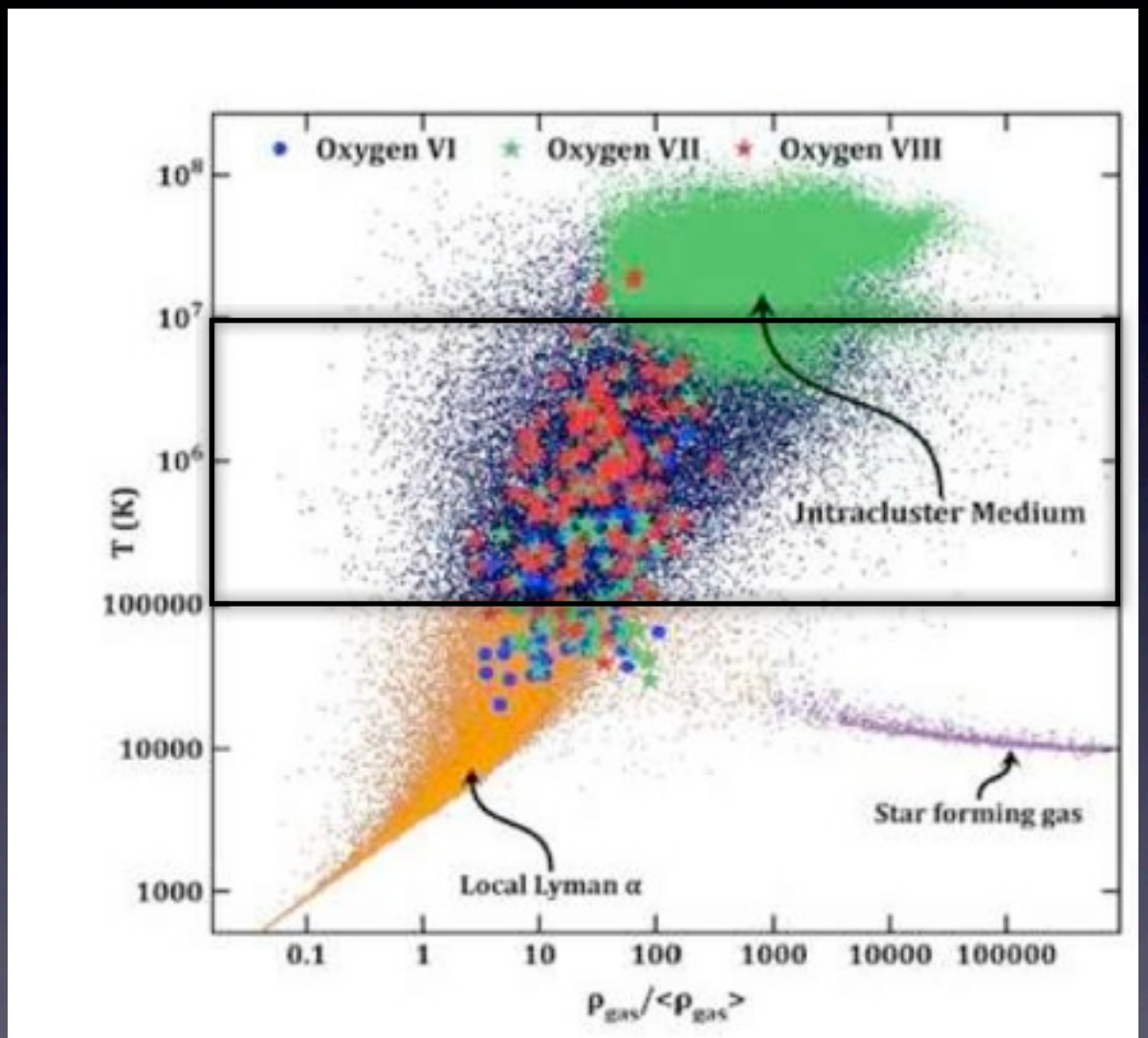


Contribution of undetected point sources to the CXB



Galaxies are the main contributors in flux and like AGN peak at z~1

Model of WHIM



WHIM is by definition whatever has $10^5 < kT < 10^7$ K

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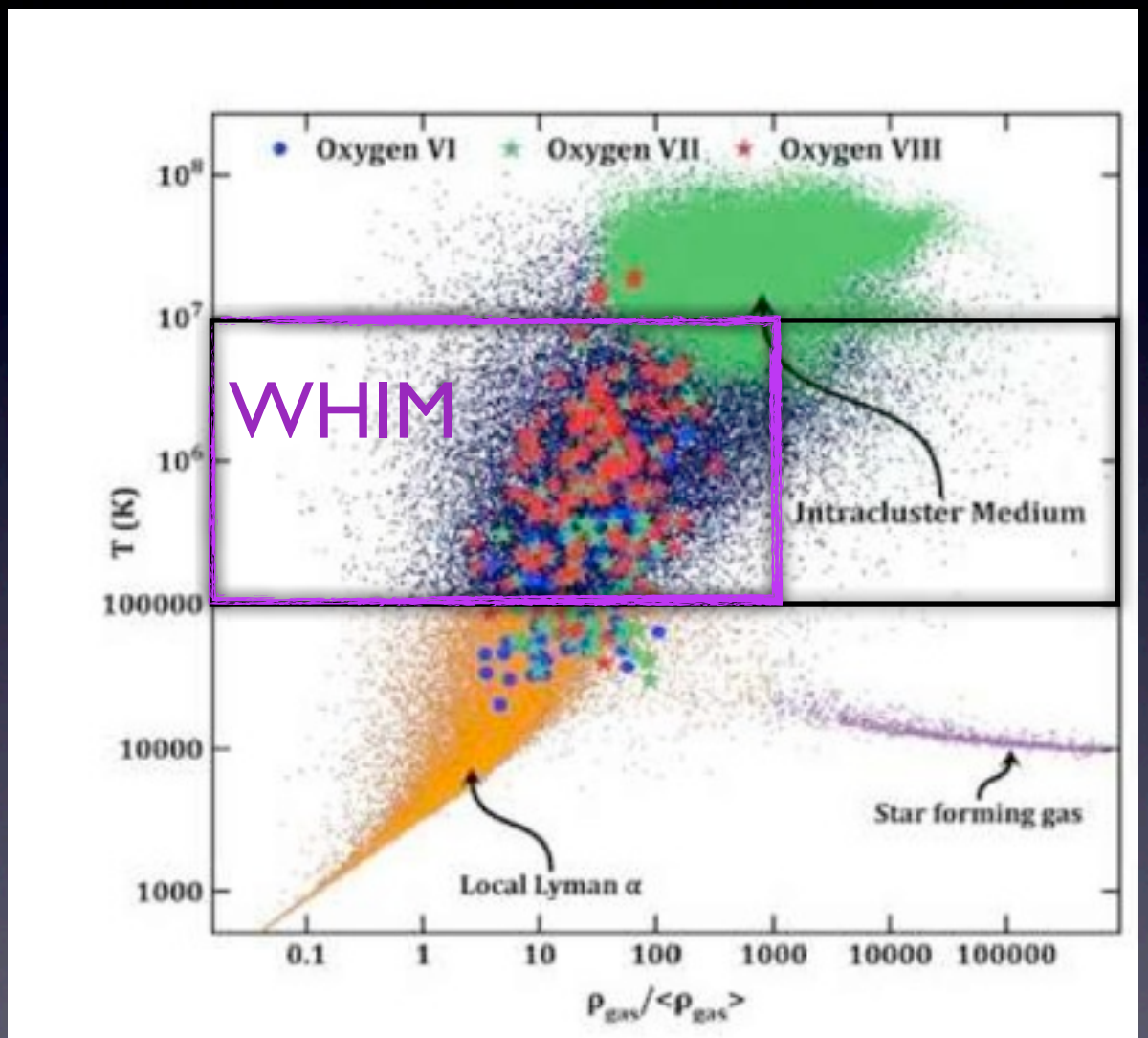


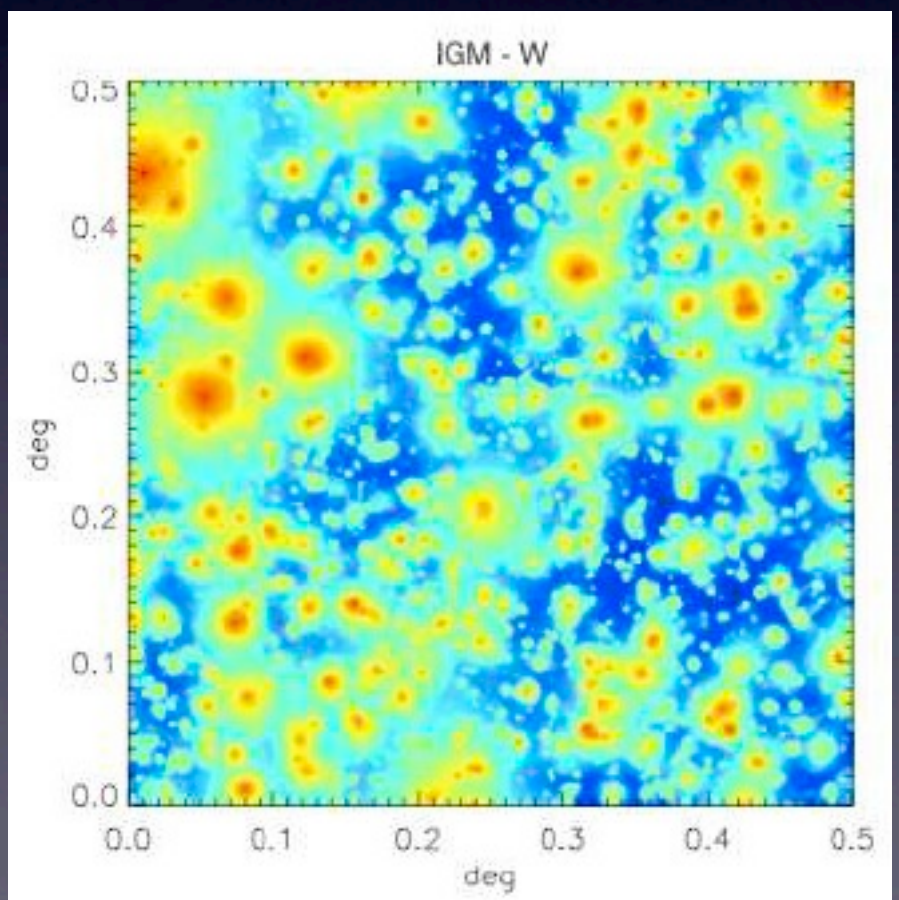
WHIM is by definition whatever has $10^5<kT<10^7$ K

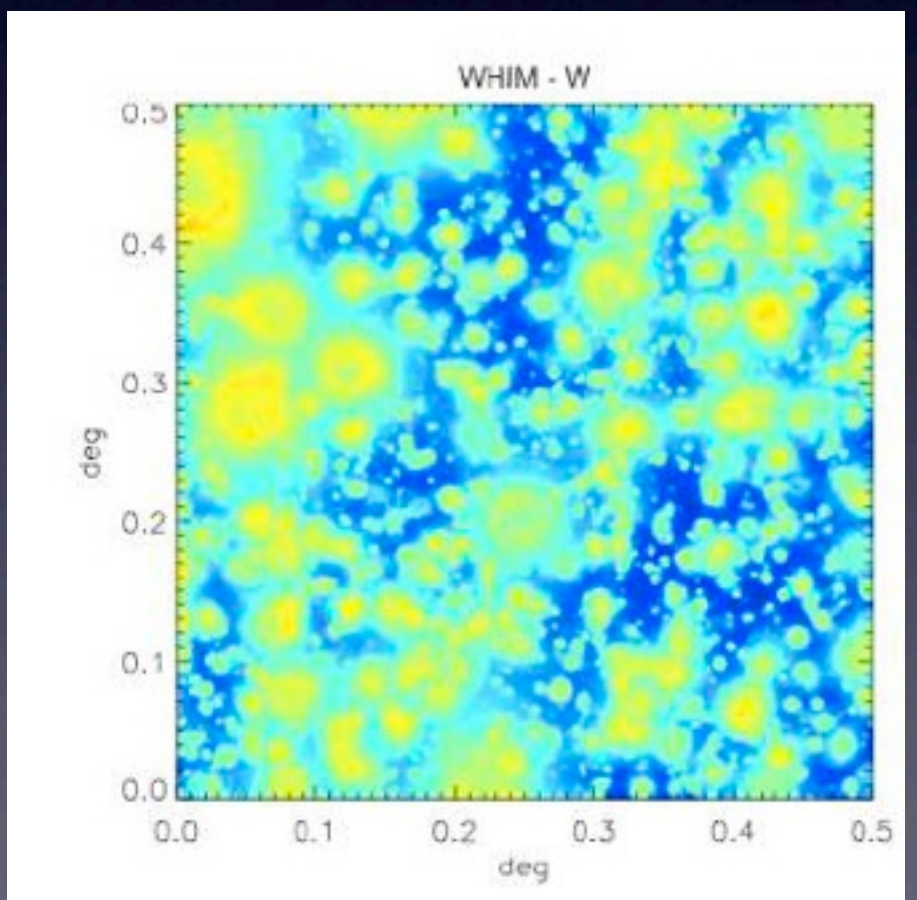
30-40% of Missing baryonsare expected to lie in a medium with $10^5<kT<10^7$ K and $\delta<1000$

Needs simulations to define diffuse emission

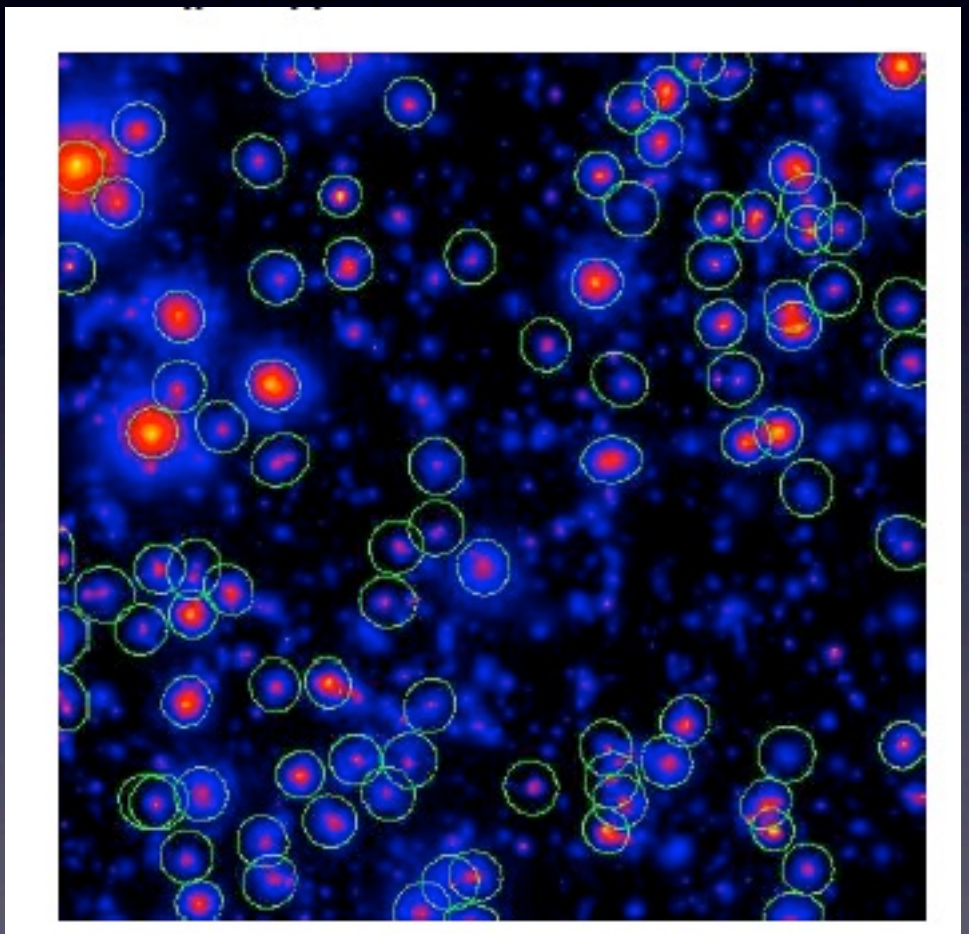
The WHIM emissivity depends the metallicity
on how the IGM is enriched of Metals

Wind Driven
feedback (Roncarelli+2012, for details)
20 simulations of 1deg2 each and averaged





4 Ms CDFS observable sources



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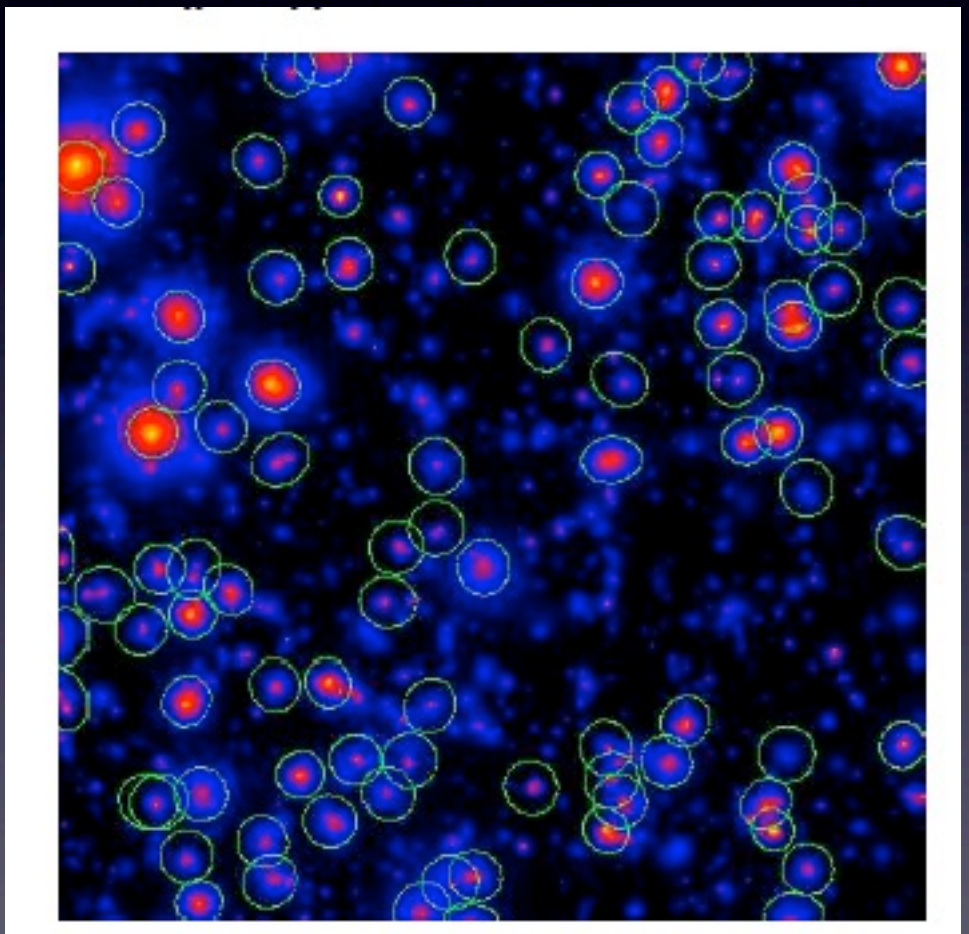
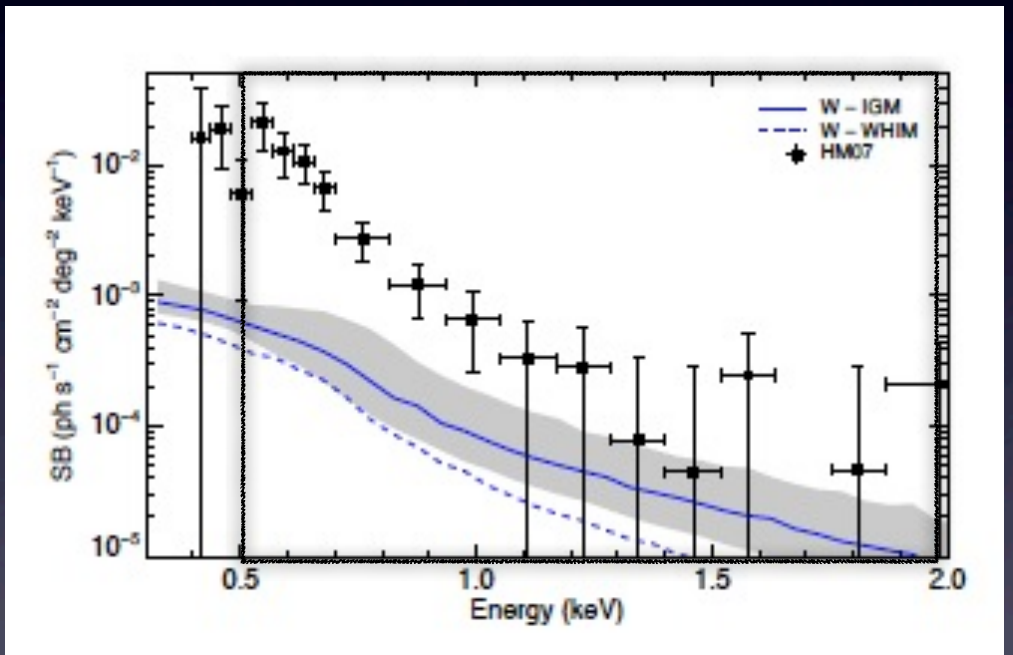
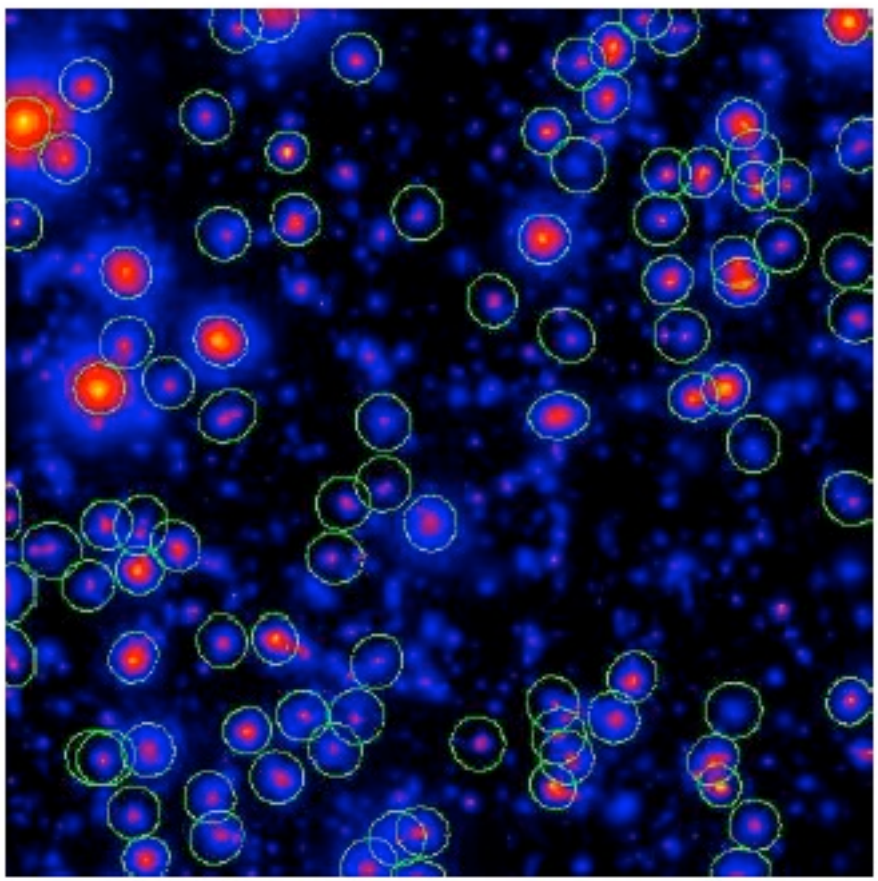


Comparison with unresolved CXB spectrum

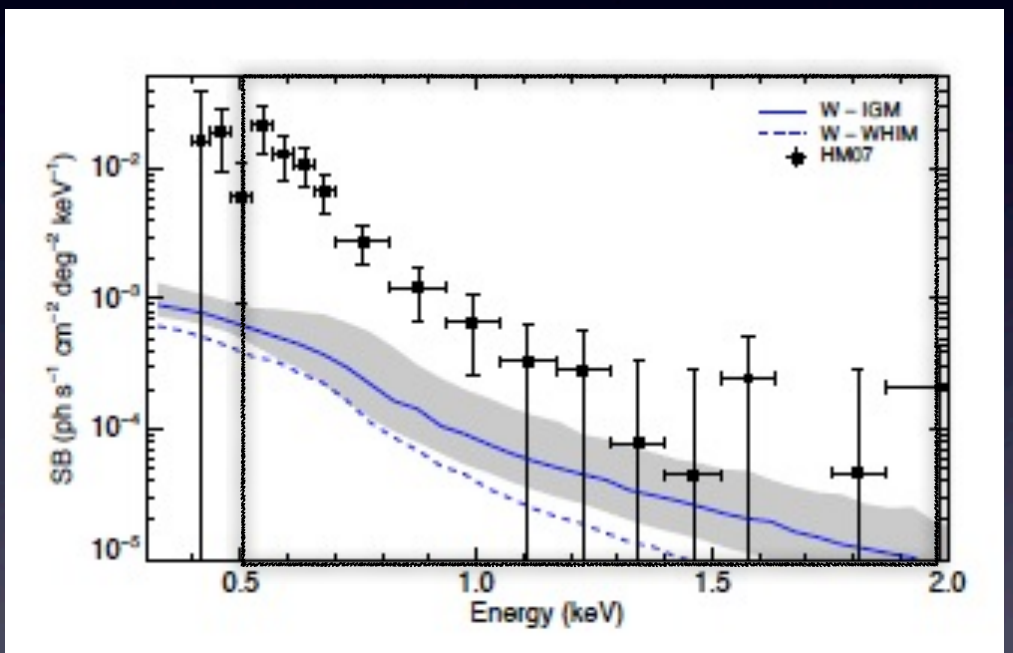


50% of the unresolved CXB made by IGM

4 Ms CDFS observable sources



Comparison with unresolved CXB spectrum

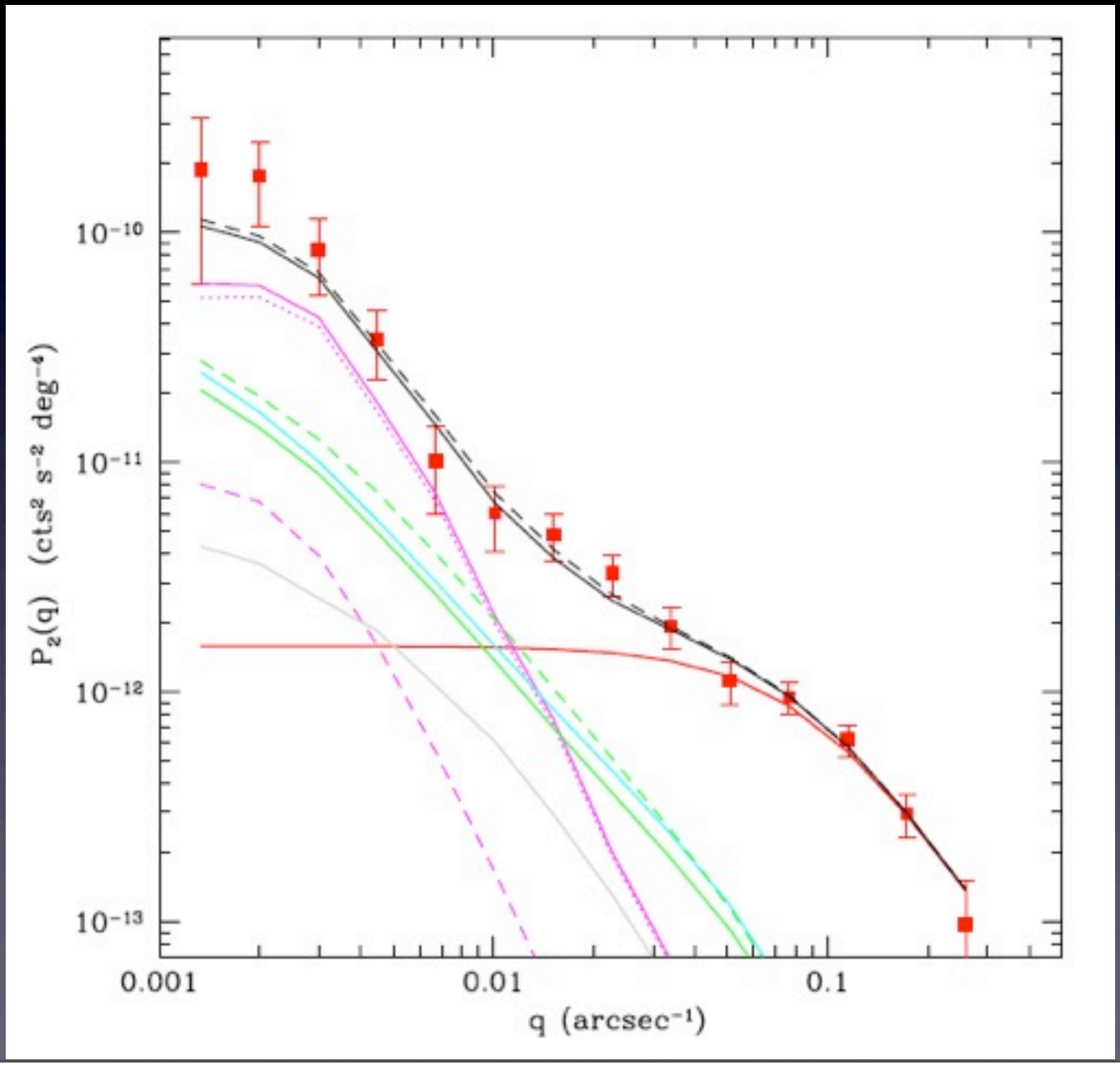


50% of the unresolved CXB made by IGM

Taking the PS of the remaining area

4-Results of modeling

PS of CXB fluctuations



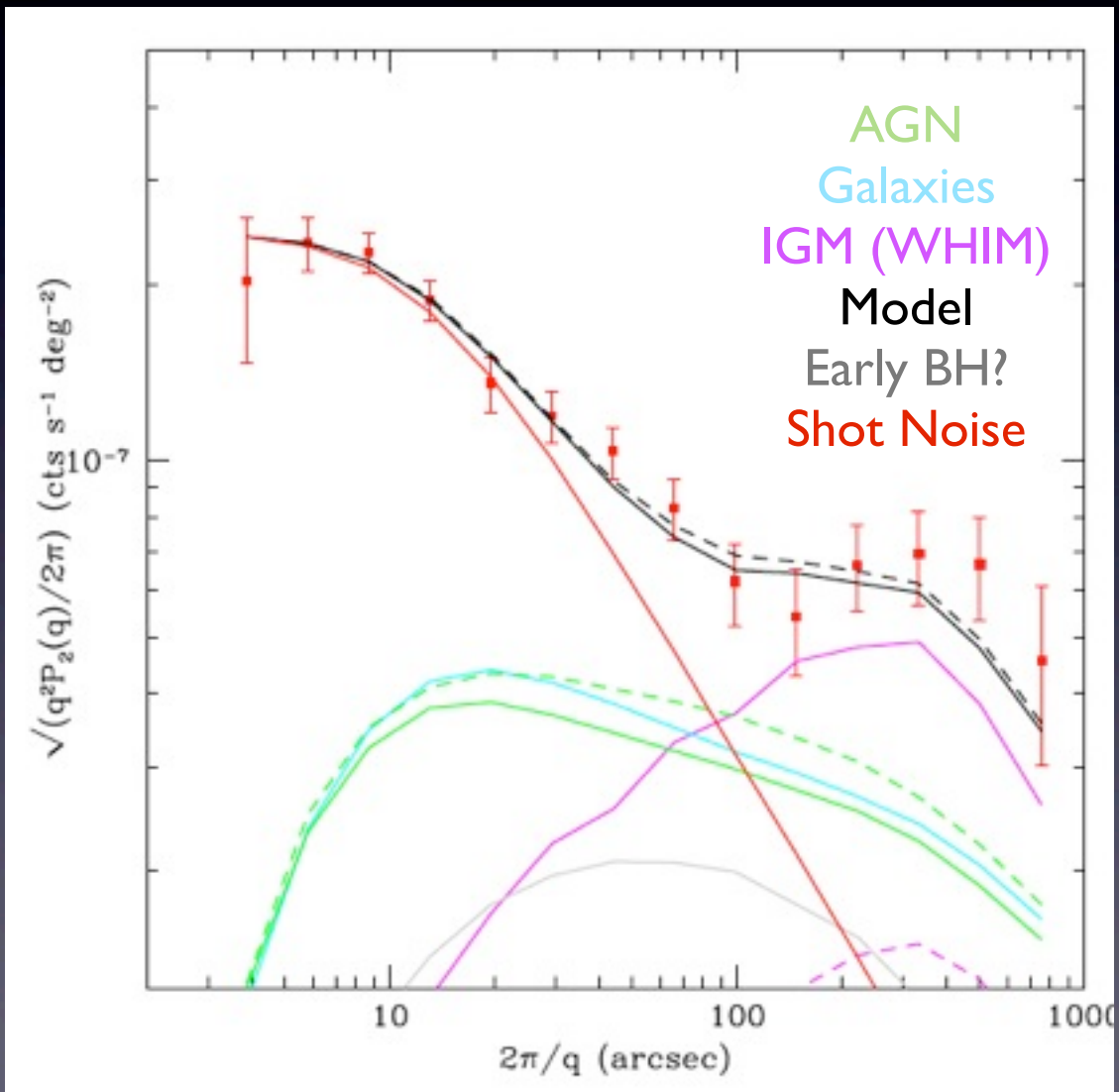
AGN+IGM+Gal required >4σ

High-z BH not necessary but not excluded

Model 1
AGN with High-z decline

Model 2
without

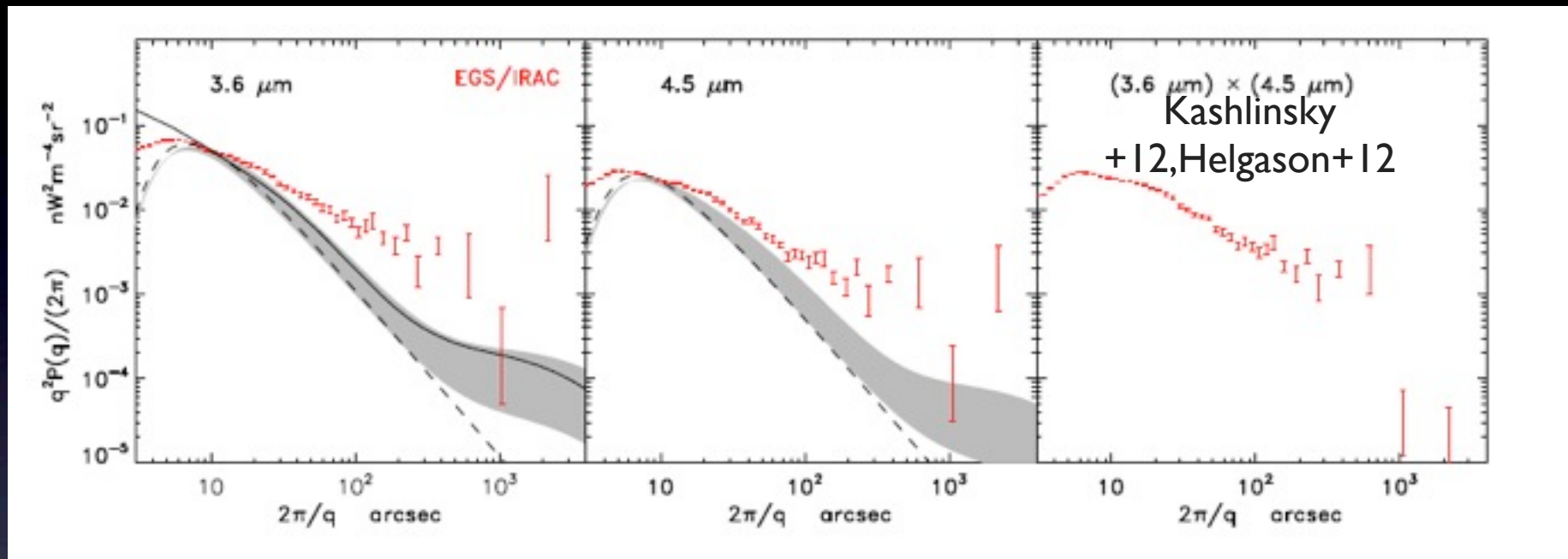
RMS fluctuations



$$C(0) = \langle \delta S^2 \rangle_\theta = \frac{1}{2\pi} \int_0^\infty P_2(q) W_{TH}(q\theta) q dq \sim \frac{1}{2\pi} q^2 P_2(q) \Big|_{q \sim \pi/\theta}$$

Estimate of <δS> at any scale

Signatures of z>7.5 sources



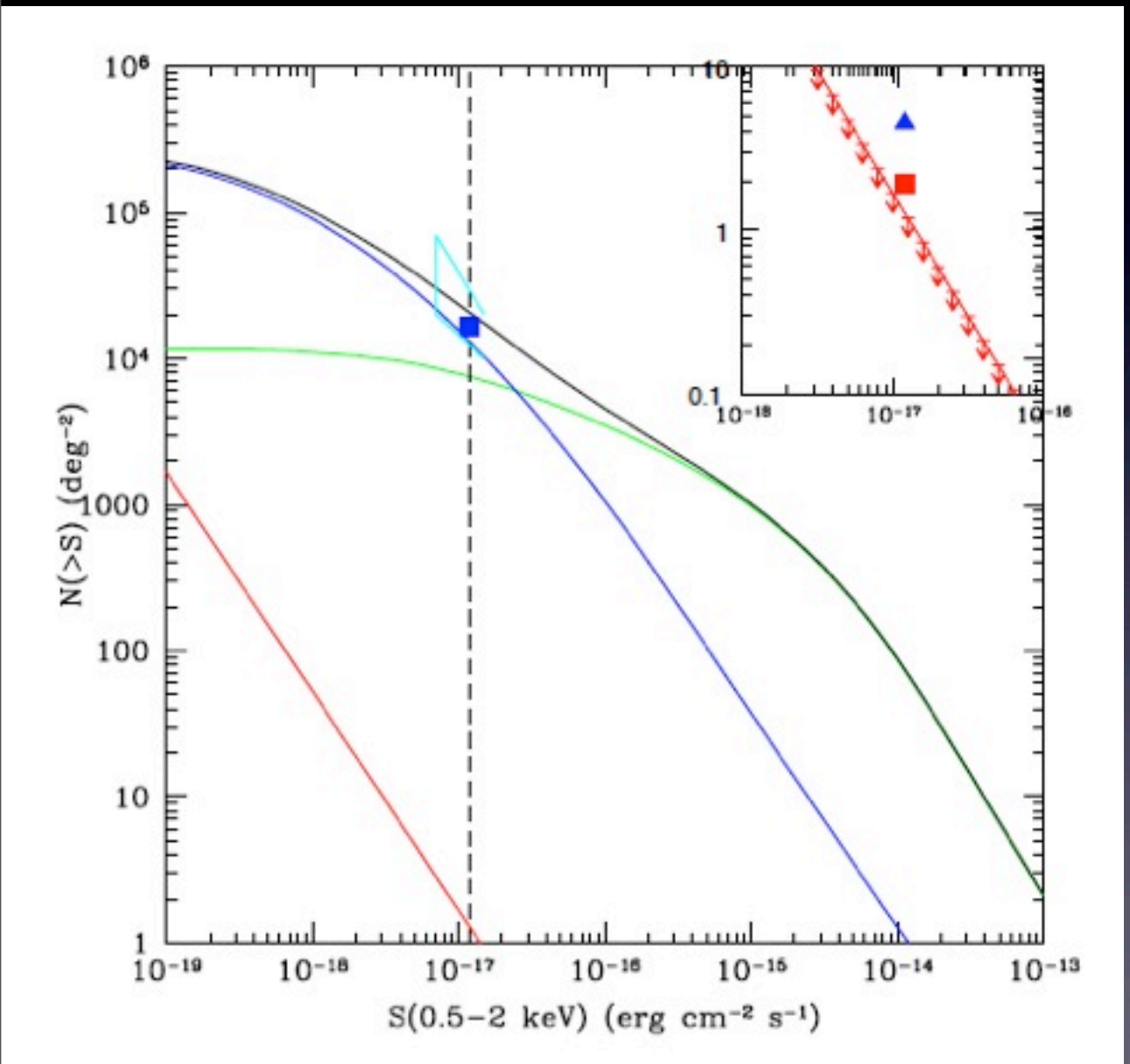
Excess power wrt to galaxies
No correlation with HST sources
z>7.5

Fluctuations from first stars/BH era

Very high-z sources

- Source of the CIB make early BH
- $P_{BH,CXB}(q) \sim (SCXB/SCIB)^2 * P_{HZ,CIB}(q, z=9)$
- Basic assumption CIB fluctuations come from first stars era
- This would make <8% of the unresolved CXB

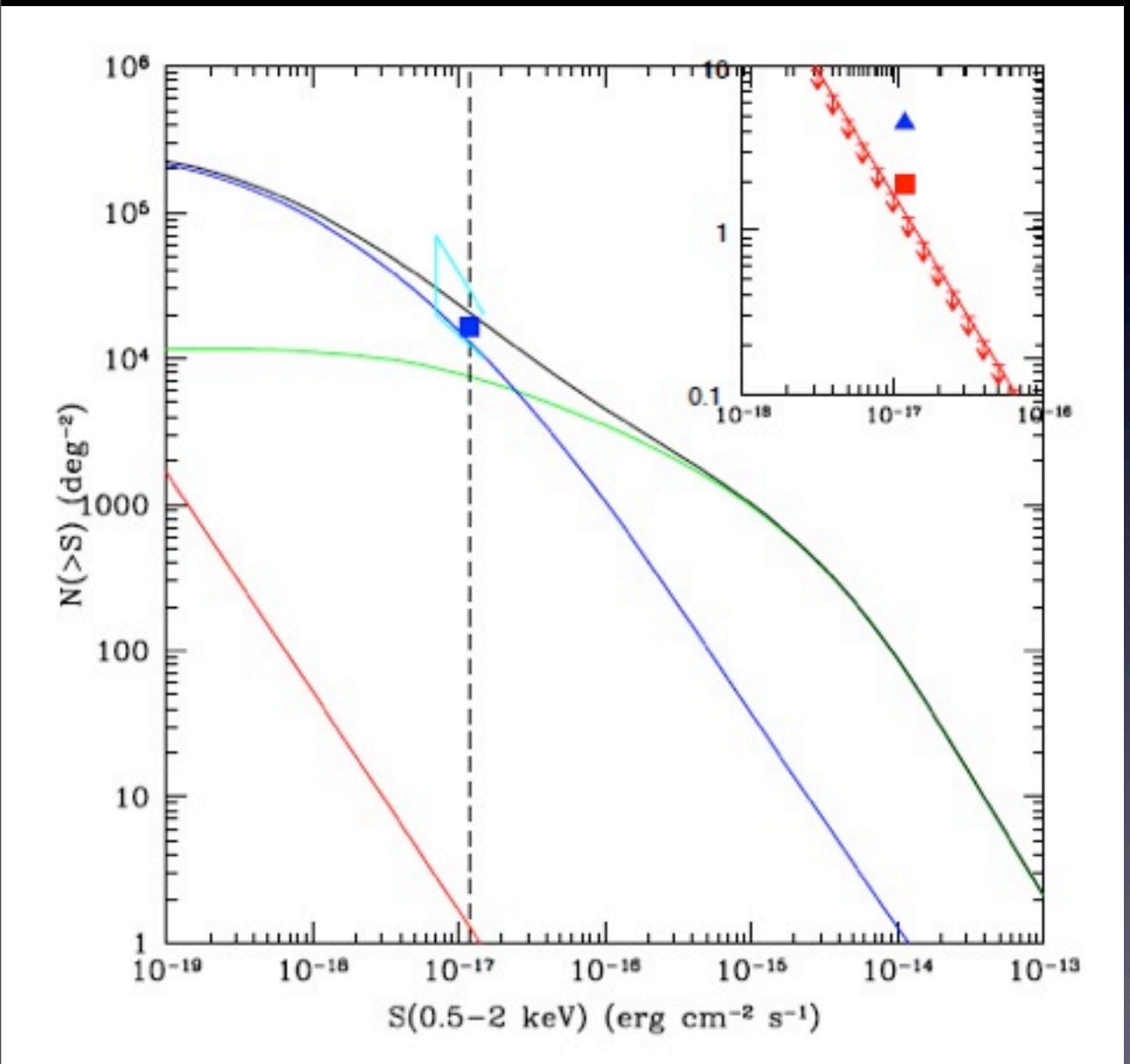
Source counts of undetected sources



Galaxies are the larger population

AGN almost "finished"

Source counts of undetected sources



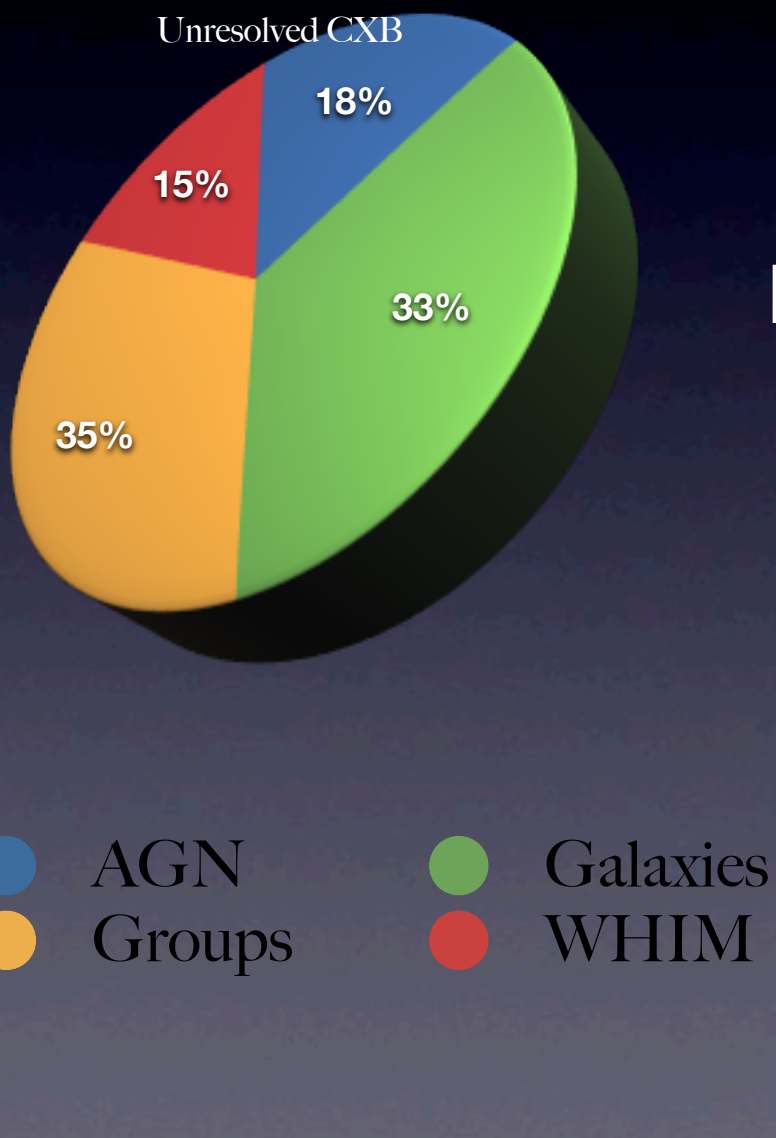
Galaxies are the larger population

AGN almost "finished"

At the flux limit of future X-ray observatories possible detection of early BH

current upper limit in agreement with declining QSO

The nature of the unresolved CXB



14% of the overall CXB
MUST NOT BE CONFUSED
WITH THE QUOTED ~5%
Lehmer+12, Moretti+04

What's next?

Constrain faint end high-z AGN evolution → Deeper survey

10 Ms CDFS

Athena :(

Smart-X

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High-z sources (BH) →

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High-z sources (BH) → WFXT COSMOS-like Athena survey :(

What's next?

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WHIM emissivity (metallicity) → Wide field survey Calorimeter

Athena :(
WFXT

High-z sources (BH) → WFXT COSMOS-like Athena survey :(

CXB-CIB correlations?... work in progress

Conclusions

- Nature of the unresolved soft CXB via PS
- 50% IGM, 14% WHIM, however WHIM is whatever is Warm....
- AGN make 20% of the unresolved CXB, hint of shallower decline wrt to high-L AGN
- 30% Galaxies
- This technique will likely help us to find signature of SMBH seeds

Soon on MNRAS..

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The nature of the unresolved soft CXB

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ABSTRACT

In this paper we investigate the power spectrum of the unresolved 0.5-2 keV CXB with deep *Chandra* 4 Ms observations in the CDFS. We measured a signal which, on scales >30″, is significantly higher than the Shot-Noise and is increasing with the angular scale. We interpreted this signal as the joint contribution of clustered undetected sources like AGN, Galaxies and IGM. The power of cosmic sources fluctuations is consistent with a flux of the order of ∼14% the 0.5-2 keV extragalactic CXB. We developed a model which satisfactorily explains all the observed power from fluctuation by taking into account AGN and Galaxy X-ray evolution and biasing. Overall, our modeling predicts that ∼20% of the unresolved CXB flux is made by low luminosity AGN, ∼30% by galaxies and ∼50% by the IGM. We do not find any direct evidence of the so called Warm Hot Intergalactic Medium (i.e. matter with 10^5K<T<10^7K and density contrast δ <1000), but we estimated that it produces ∼1/7 of the unresolved CXB. We also speculated the presence of a population of high redshift sources which may result from the collapse of early massive stars or gas clouds. Although we did not detect their signature, our data are still well fitted by a model that includes such a component. We placed upper limits to space density of z>7.5 X-ray sources.

This paper therefore snapshots the population of sources that will be sampled by next generation X-ray telescopes.

Key words: (cosmology:) dark matter, (cosmology:) large-scale structure of universe, X-rays: galaxies, galaxies: active, (cosmology:) diffuse radiation