Clustering of AGN in eROSITA all-sky survey

Gert Hütsi

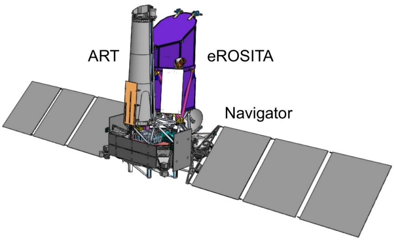
Max Planck Institute for Astrophysics

Ripples in the Cosmos
Durham, July 2013

Outline

1. eROSITA Intro
2. X-ray AGN clustering
3. Cosmology with AGN: BAO
4. Conclusions

Spectrum-Röntgen-Gamma (SRG) satellite



- Russian-German joint mission, planned to be launched to L_2 in 2014
- Two instruments:
  ART-XC (IKI)
  eROSITA (MPE)

extended ROentgen Survey with an Imaging Telescope Array

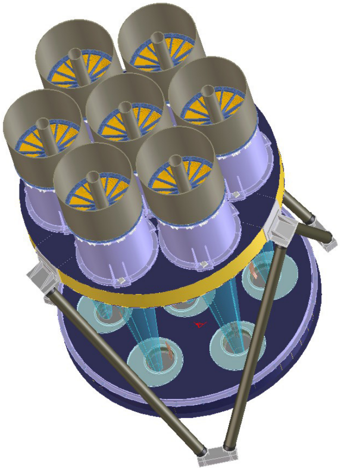
- Some basic characteristics of eROSITA:

energy range	0.5 – 10 keV
effective area	$\sim$ 2300 cm^2 @ 1 keV
FoV	$\sim 1^\circ \varnothing$
angular resolution	$28''$ aver. over FoV
energy resolution	$\sim$ 140 eV @ 6 keV
mission lifetime	7 years: 4 years all-sky survey (8$\times$ full sky), 3 years pointing

- For more details see:
  Merloni, A., et al. 2012, eROSITA Science Book: Mapping the Structure of the Energetic Universe

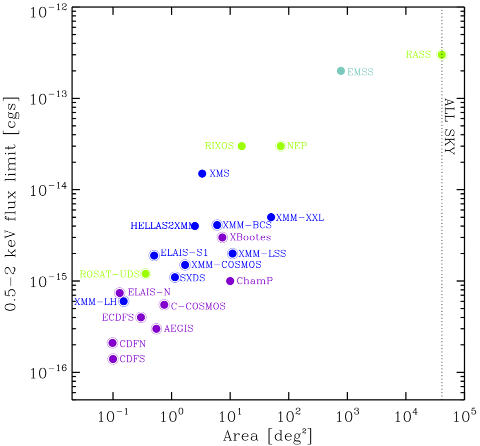
eROSITA: comparison to previous X-ray surveys

- Sky mapping speed determined by the $\mathrm{Grasp} \equiv A_{\mathrm{eff}} \times \mathrm{FoV}$
- A_{eff} slightly smaller than XMM's, but FoV is larger, leading to $\sim 4\times$ larger grasp
- This leads on average $\sim 30\times$ better point source detection limit ($\sim 10^{-14}$ erg s^{-1} cm^{-2}) in the $0.5 - 2$ keV band than the previous all-sky survey conducted by ROSAT



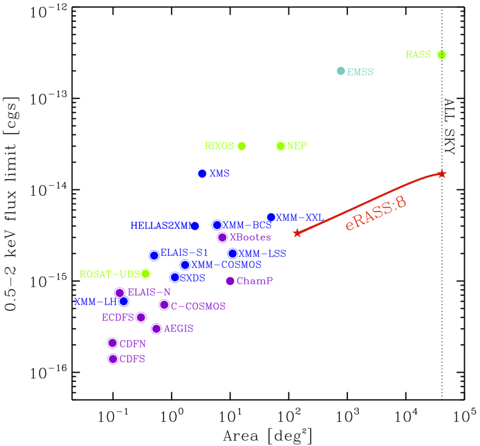
eROSITA: comparison to previous X-ray surveys

- Sky mapping speed determined by the $\mathrm{Grasp} \equiv A_{\mathrm{eff}} \times \mathrm{FoV}$
- A_{eff} slightly smaller than XMM's, but FoV is larger, leading to $\sim 4\times$ larger grasp
- This leads on average $\sim 30\times$ better point source detection limit ($\sim 10^{-14}$ erg s^{-1} cm^{-2}) in the $0.5 - 2$ keV band than the previous all-sky survey conducted by ROSAT



eROSITA: comparison to previous X-ray surveys

- Sky mapping speed determined by the Grasp $\equiv A_{\rm eff} \times {\rm FoV}$
- $A_{\rm eff}$ slightly smaller than XMM's, but FoV is larger, leading to $\sim 4\times$ larger grasp
- This leads on average $\sim 30\times$ better point source detection limit ($\sim 10^{-14}$ erg s^{-1} cm^{-2}) in the $0.5-2$ keV band than the previous all-sky survey conducted by ROSAT



eROSITA: science

- Main driver: $\sim 10^5$ galaxy clusters
  statement from eROSITA Science Book:
  eROSITA will likely be the 1st Stage IV Dark Energy probe (according to the DETF report categories, Albrecht et al. 2006) to be realized and it is even more powerful than DUO-like Stage IV probe considered by the DETF

eROSITA: science

- Main driver: $\sim 10^5$ galaxy clusters
  statement from eROSITA Science Book:
  eROSITA will likely be the 1st Stage IV Dark Energy probe (according to the DETF report categories, Albrecht et al. 2006) to be realized and it is even more powerful than DUO-like Stage IV probe considered by the DETF
- However, there is other interesting science possible:
  - AGN and normal galaxies
  - Stellar mass compact objects
  - Studies of diffuse X-ray emission: SNRs, superbubbles and the hot ISM
  - Solar System studies

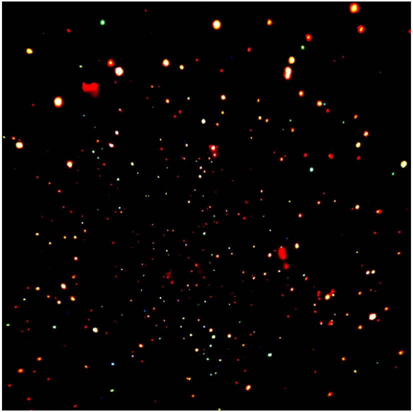
eROSITA: science

- Main driver: $\sim 10^5$ galaxy clusters
  statement from eROSITA Science Book:
  eROSITA will likely be the 1st Stage IV Dark Energy probe (according to the DETF report categories, Albrecht et al. 2006) to be realized and it is even more powerful than DUO-like Stage IV probe considered by the DETF
- However, there is other interesting science possible:
  - AGN and normal galaxies
  - Stellar mass compact objects
  - Studies of diffuse X-ray emission: SNRs, superbubbles and the hot ISM
  - Solar System studies
- In this presentation I will focus on AGN related science, in particular on clustering of X-ray selected AGN

What do we know about X-ray AGN?

- powered by accretion onto SMBH
- X-ray emission is the primary signature
- unobscured, obscured, Compton thick
- make up $\gtrsim 85\%$ (possibly up to $\sim 95\%$) of the CXB
- sit in galaxies, which sit in the dark matter halos
- the most distant accreting SMBH at $z \sim 5 - 5.5$

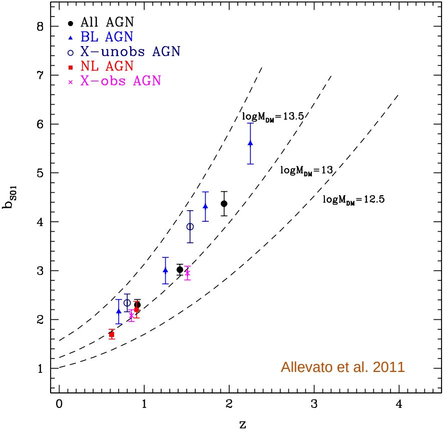
Chandra deep field North



Credit: NASA/CXC/Penn State

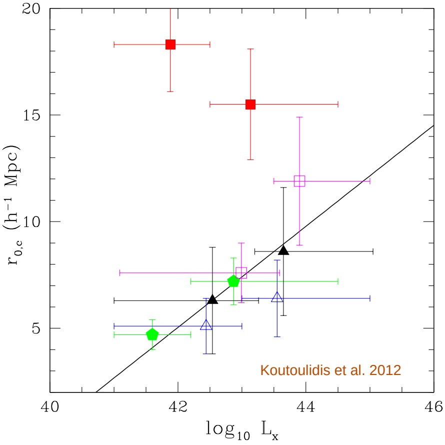
Basic characteristics of X-ray AGN population

- LF of X-ray AGN as a function of L_{X} and z relatively well known
- However, concerning clustering, not much is known beyond that X-ray selected AGN clustering strength is compatible of them typically populating group-sized DM halos. Many questions remain unanswered: e.g., is there dependence on L_{X}? etc



Basic characteristics of X-ray AGN population

- LF of X-ray AGN as a function of L_{X} and z relatively well known
- However, concerning clustering, not much is known beyond that X-ray selected AGN clustering strength is compatible of them typically populating group-sized DM halos. Many questions remain unanswered: e.g., is there dependence on L_{X}? etc
- But there are some hints for possible depencence on L_{X}

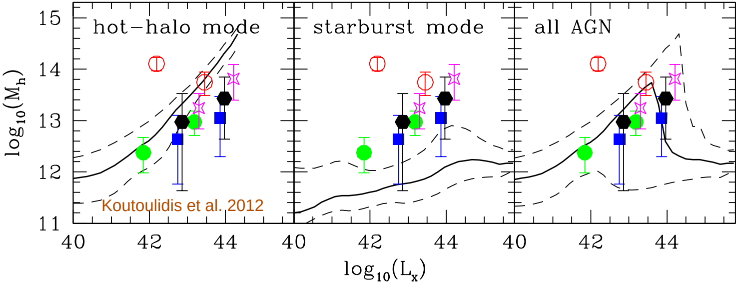


What can be learned from AGN clustering?

- Clustering strength makes a direct connection to the effective mass scale of dark matter halos AGN is populating
- Since the hierarchical formation of DM halos is well understood, one can naturally link the AGN population to the underlying evolving DM distribution
- That helps in constraining various AGN triggering and fuelling models

AGN fuelling modes

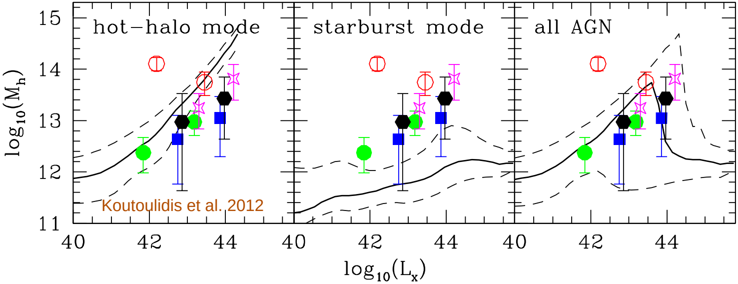
Results from semianalytic AGN-galaxy co-evolution models of Fanidakis et al. 2012:



- Hot-halo mode:
  SMBH embedded in a hydrostatic hot halo environment, cooling luminosity is mostly determined by the halo mass, gas cooling is moderated by the feedback from the SMBH
- Starburst mode:
  cold gas accretion due to mergers & disk instabilities

AGN fuelling modes

Results from semianalytic AGN-galaxy co-evolution models of Fanidakis et al. 2012:

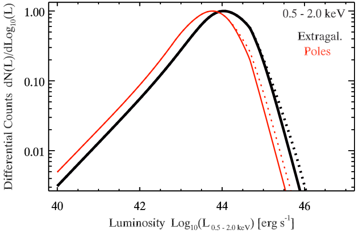


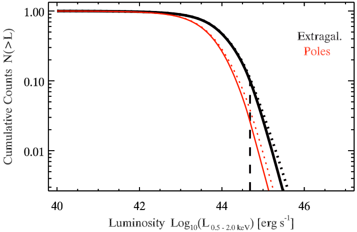
- Hot-halo mode:
  SMBH embedded in a hydrostatic hot halo environment, cooling luminosity is mostly determined by the halo mass, gas cooling is moderated by the feedback from the SMBH
- Starburst mode:
  cold gas accretion due to mergers & disk instabilities
- In fact, in Hütsi, Gilfanov & Sunyaev 2013 we showed that by starting out with a power law $M_{\mathrm{h}} - L_{\mathrm{X}}$ scaling relation it is possible to obtain a good match to the observed LF and clustering bias, simultaneously

AGN in eROSITA all-sky survey

The full four year all-sky survey will provide:

- $\sim 3 \times 10^6$ AGN in the extragalactic sky ($\sim 35,000$ deg^2), i.e. ~ 85 deg^{-2}
  - $\sim 130,000$ in the hard band
  - $\sim 340,000$ AGN after the 1st half-year
- Will resolve $\sim 30 - 50\%$ of CXB in the soft band ($\sim 5 - 7\%$ in the hard band)
- Luminosity distribution



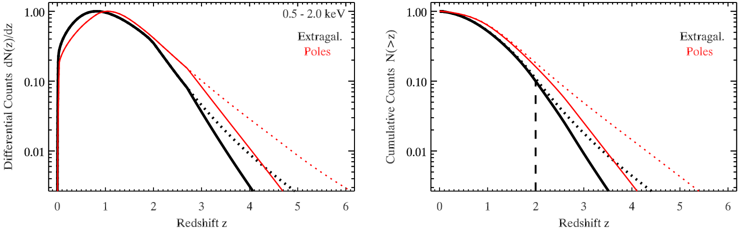


- For full details see Kolodzig et al. 2013 [arXiv:1212.2151]

AGN in eROSITA all-sky survey

The full four year all-sky survey will provide:

- $\sim 3 \times 10^6$ AGN in the extragalactic sky ($\sim 35,000$ deg^2), i.e. ~ 85 deg^{-2}
  - $\sim 130,000$ in the hard band
  - $\sim 340,000$ AGN after the 1st half-year
- will resolve $\sim 30 - 50\%$ of CXB in the soft band ($\sim 5 - 7\%$ in the hard band)
- Redshift distribution

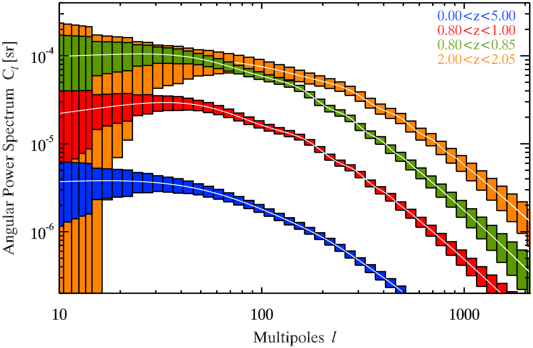


- For full details see Kolodzig et al. 2013 [arXiv:1212.2151]

Clustering of AGN in eROSITA all-sky survey

- Assume L_X-independent clustering where AGN populate DM halos with mass $M_{\rm eff} = 2 \times 10^{13} h^{-1} M_\odot$
- Bin up the full redshift range into multiple redshift bins and calculate angular clustering spectra in each of these

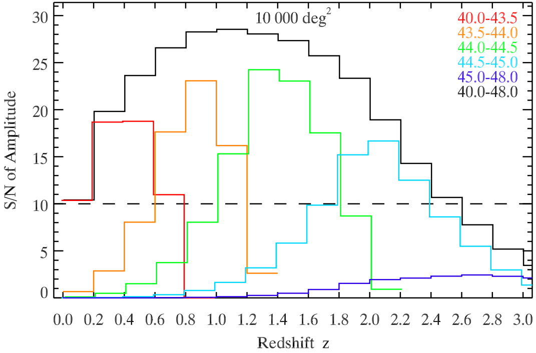
some example spectra:



- For full details see Kolodzig et al. 2013 [arXiv:1305.0819]

Clustering of AGN in eROSITA all-sky survey

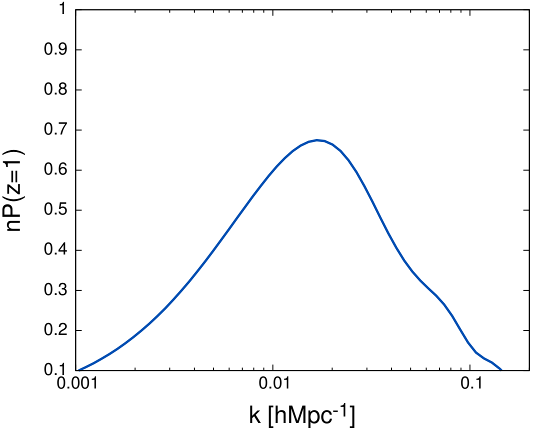
- Can bin in z and $L_{\rm X}$ & thus probe $b(L_{\rm X}, z) \Rightarrow M_{\rm eff}(L_{\rm X}, z)$



- All this is quite fine with moderate accuracy photo-z

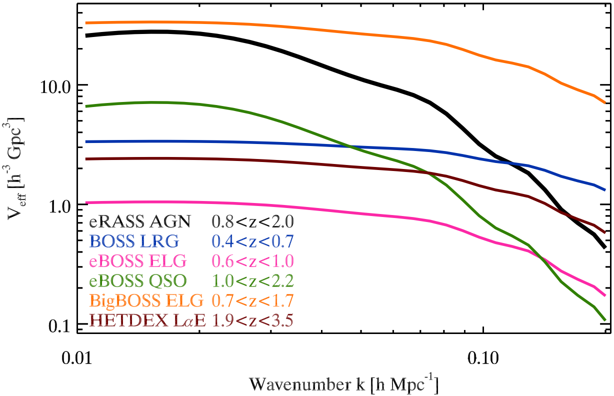
Cosmology: probing LSS with X-ray AGN

- Number density peaks at $z \sim 1$, where $n \sim 10^{-5}$ $h^3 Mpc^{-3}$
- High clustering bias, $b(z = 1) \sim 2.5$
- Even though sampling density suboptimal...



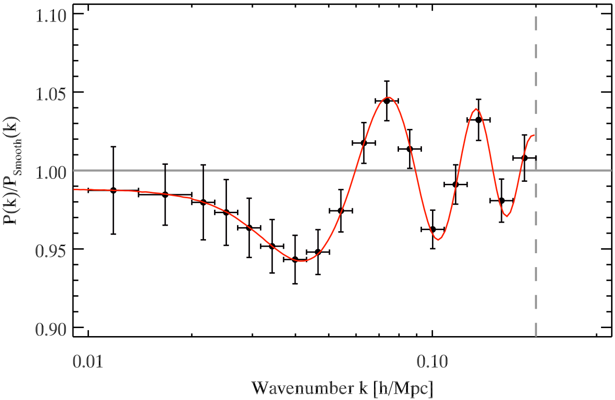
Cosmology: probing LSS with X-ray AGN

- Number density peaks at $z \sim 1$, where $n \sim 10^{-5}$ $h^3 Mpc^{-3}$
- High clustering bias, $b(z = 1) \sim 2.5$
- Thanks to large survey volume accurate clustering measurements still possible



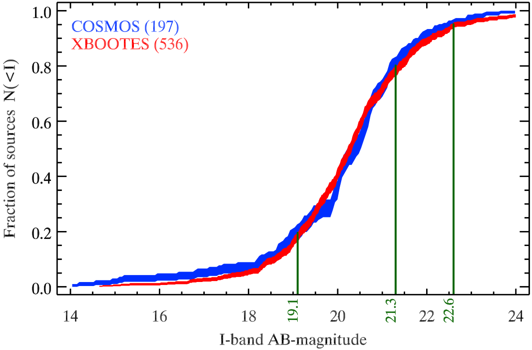
Cosmology: probing LSS with X-ray AGN

- Number density peaks at $z \sim 1$, where $n \sim 10^{-5}$ h^{3}Mpc^{-3}
- High clustering bias, $b(z = 1) \sim 2.5$
- ... which leads to $\sim 14\sigma$ detection of BAO, assuming availability of a complete optical follow-up



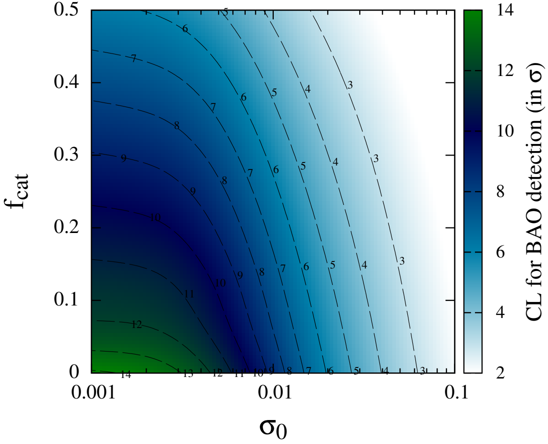
Need for optical follow-up

- Magnitude distribution of AGN with $F_X > 10^{-14}$ erg s^{-1} cm^{-2} in COSMOS and XBOOTES fields:



- $\sim$ 80% of eRASS AGN in SDSS field will have SDSS counterparts $\Rightarrow \sim 10^6$ objects
- $\sim$ 95% of eRASS AGN will have Pan-STARRS PS1 counterparts

BAO detection & quality of follow-up



- These calculations are restricted to (quasi)linear regime, assume redshift range $z = 0.5 - 2.0$ which is binned up into narrow z bins. In addition to autocorrelations also cross-spectra included + linear redshift-space distortions + BAO damping following Matsubara's resummed LPT

- photo-z rms scatter: $\sigma_z = \sigma_0(1+z)$
- fraction of catastrophic errors: f_{cat}
- some examples:
  $\sigma_0 = 10^{-3}$ & $f_{\mathrm{cat}} = 0.0$: $\sim 14\sigma$
  $\sigma_0 = 10^{-2}$ & $f_{\mathrm{cat}} = 0.0$: $\sim 8\sigma$
  $\sigma_0 = 10^{-2}$ & $f_{\mathrm{cat}} = 0.3$: $\sim 5\sigma$
  assuming redshift range $z = 0.5 - 2.0$
- should be compared with current detections at lower z: $\sim 3 - 6\,\sigma$

Conclusions

- AGN clustering can be measured to better than 10% in many z and $L_{\rm X}$ bins over redshift and luminosity ranges $z \simeq 0.2 - 2.5$ and $\log_{10} L_{\rm X} \simeq 40.0 - 45.0$, respectively $\Rightarrow$ allows one to constrain AGN triggering and fuelling models
- If eROSITA AGN sample is complemented with spec-z/high quality photo-z then one can also do 'precision' cosmology

Thank You!