(X-ray) AGN surveys

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Outline

- AGN X-ray surveys:
  - Why bother?
- Results:
  - Evolution and the CXB
  - Relation to galaxy evolution
  - Imaging and spectral stacking
- The future (eROSITA, *Athena*)
- Summary

AGN X-ray surveys: why bother?

- Why X-rays?:
  - Not so prone to be obscured out as UV/optical/NIR:
    - Together with MIR (see Silvia Mateos' and Angel Ruiz's talks)
    - Together with radio (see Beatriz Mingo's talk)
  - X-rays from energetic processes close to SMBH:
    - Good discrimination against host galaxy starlight: "smoking gun"
    - X-ray spectral information (see Maria de Santos' talk)

- Why surveys?:
  - Statistical descriptions of sources and populations: Cosmology

- Why AGN?

Why AGN?: Co-evolution with galaxies

- SMBH in centers of most local gals (Kormendy & Gebhardt, 2001)

- Correlation between mass of central BH and spheroid (Magorrian et al. 1998, McLure & Dunlop 2002)

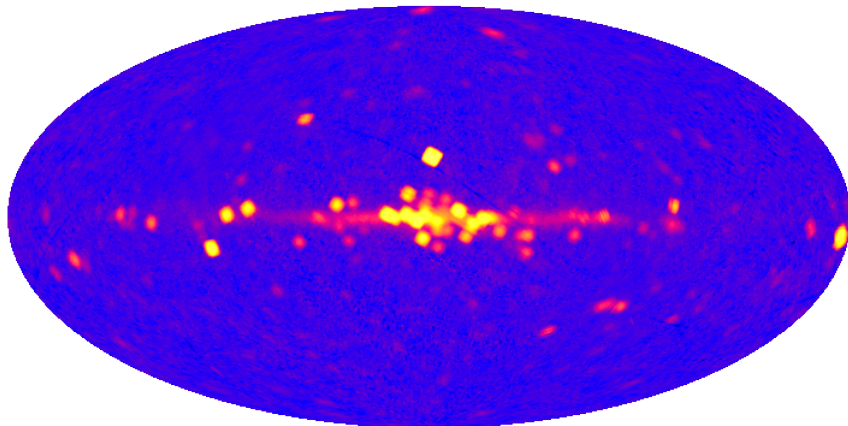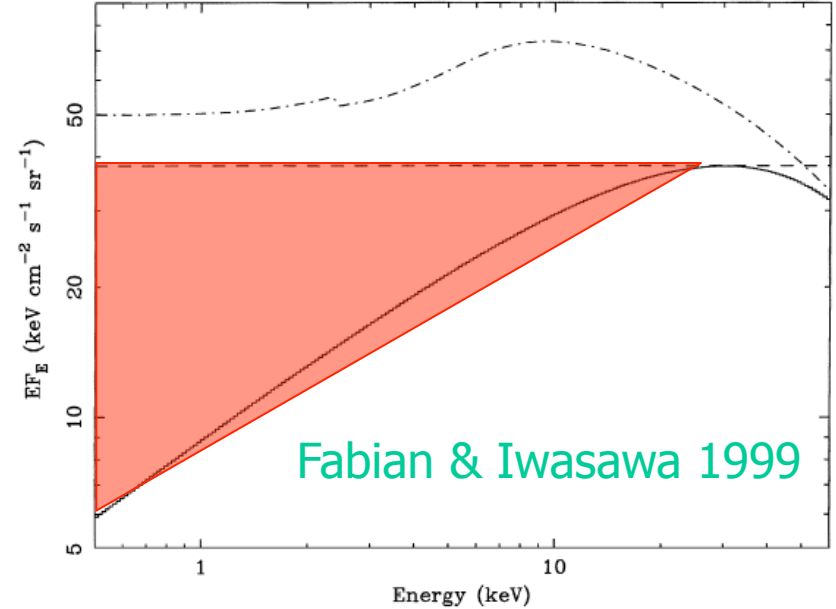- Similar evolution of X-ray AGN and optical galaxies (...Ebrero et al. 2009b...)

Connected growth of central BH through accretion, and spheroid through star formation

Why AGN?: Cosmic X-ray Background

Giacconi+62


Fabian & Iwasawa 1999
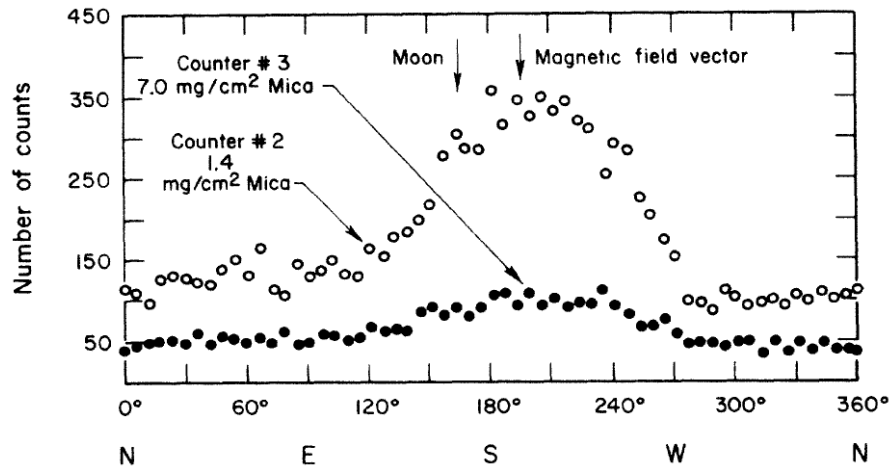
HEAO-1 A2 2-10 keV

- Oldest discovered cosmic background radiation

- Soon clear integrated contribution of AGN: "fossil of energy emitted by accretion across cosmic history"

- From spectrum: most (85%) have to be obscured (K. Iwasawa's talk)
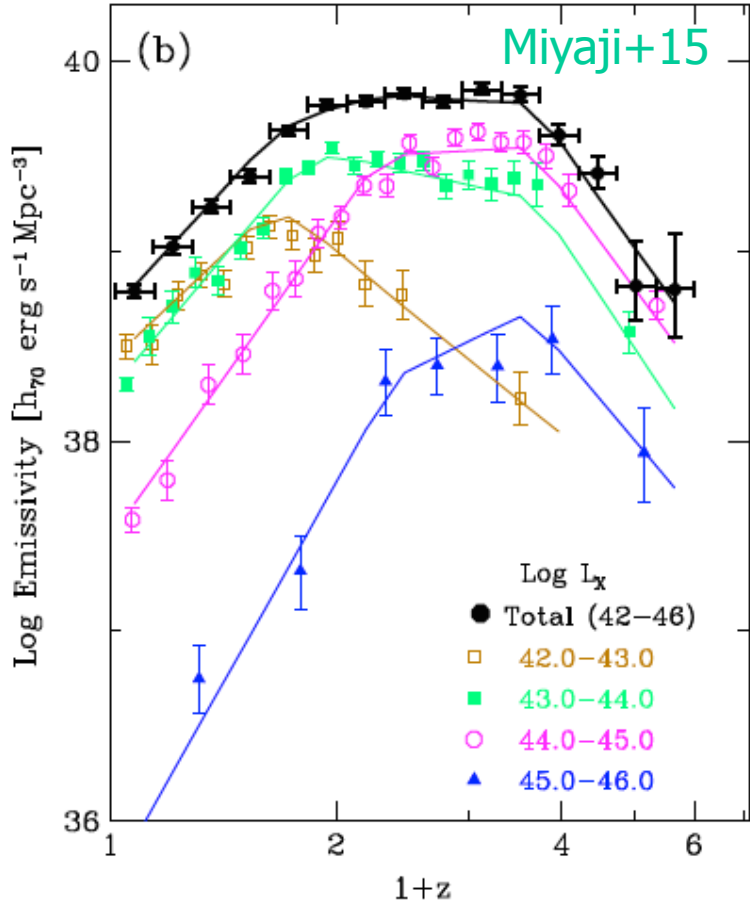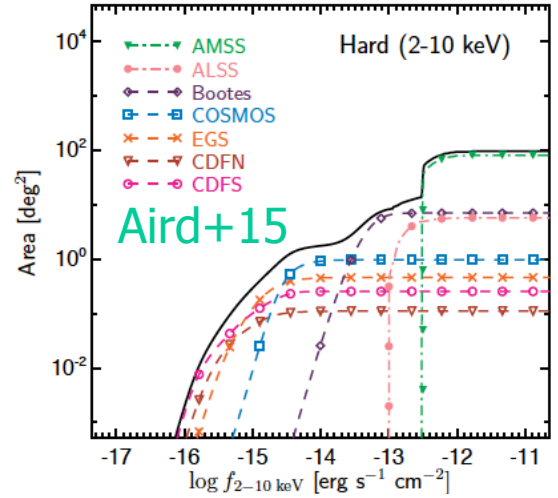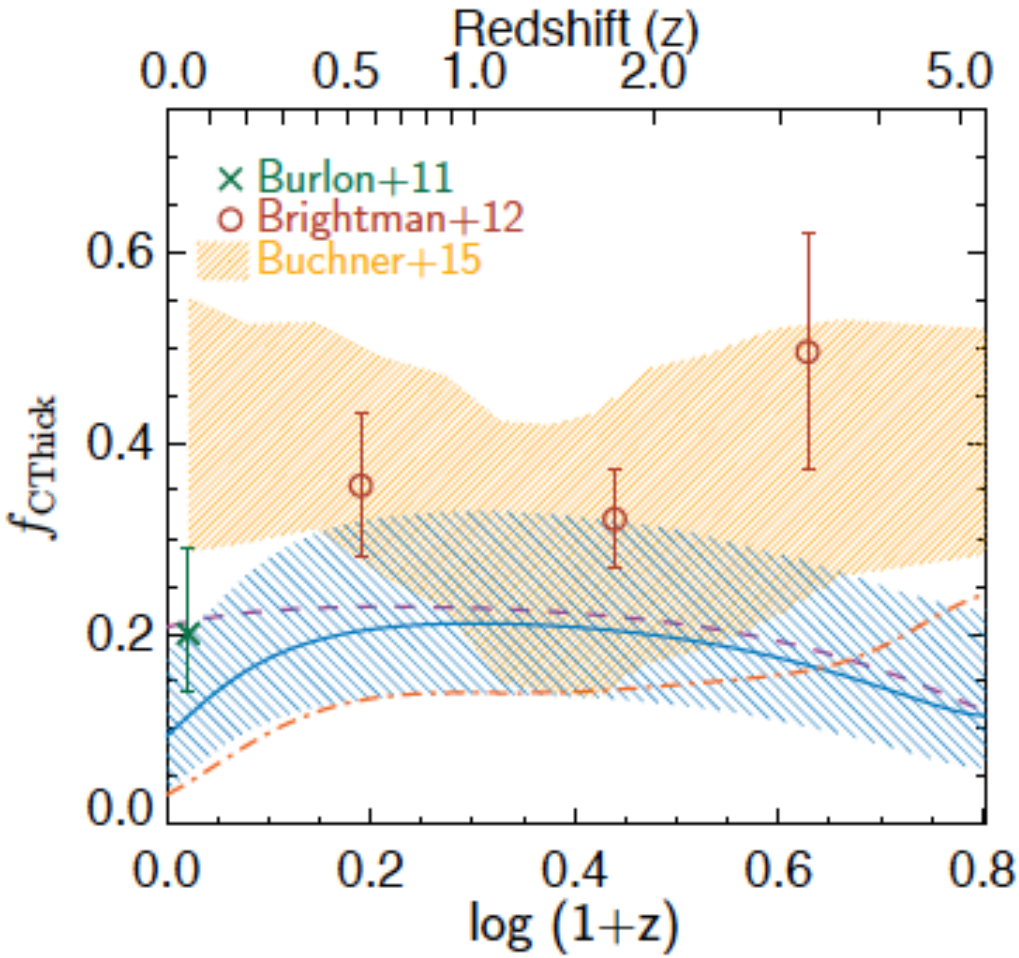
Evolution and the CXB

(..., Ueda et al. 2014, Miyaji et al. 2015, Buchner et al. 2015, Aird et al. 2015)

- Long history
  - Combining wide/shallow with narrow/deep surveys
  - Sophisticated treatment of uncertainties and spectral shapes

- Strong z evolution z≲3(-4):
  - Both of density and luminosity
  - Downsizing: higher L form first
  - Evidence for differentiated major merger and secular evolution? M+15

- Evolution of obscured fraction:
  - Different evolution of absorbed and unabsorbed sources? B+15, A+15
  - Compton Thick contribution:
    - ~40% of total B+15, U+15 (20-50%)
    - ~20% of total A+15
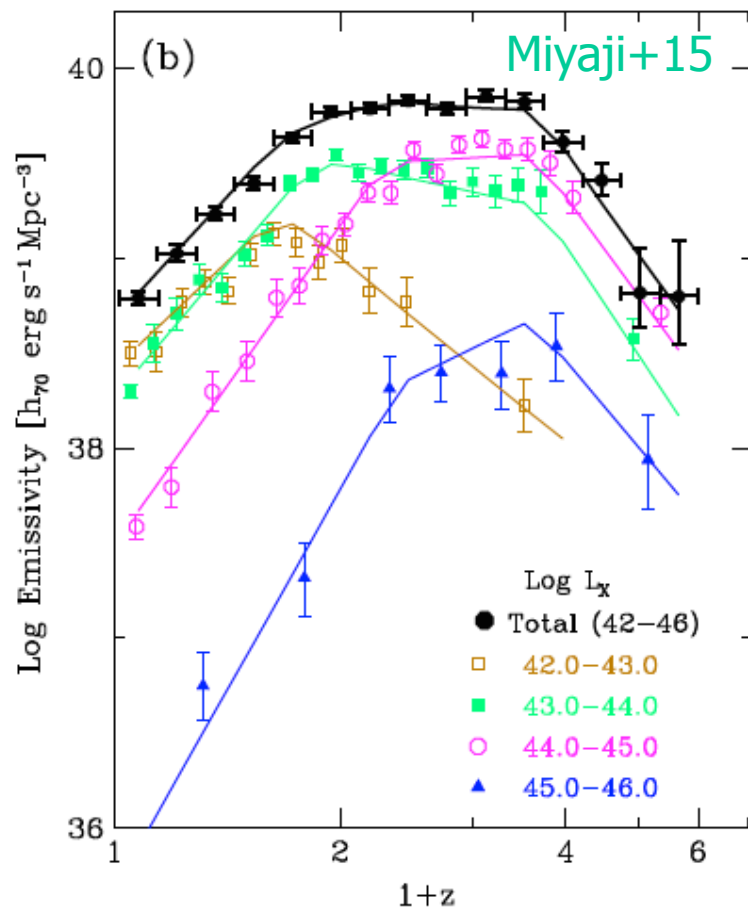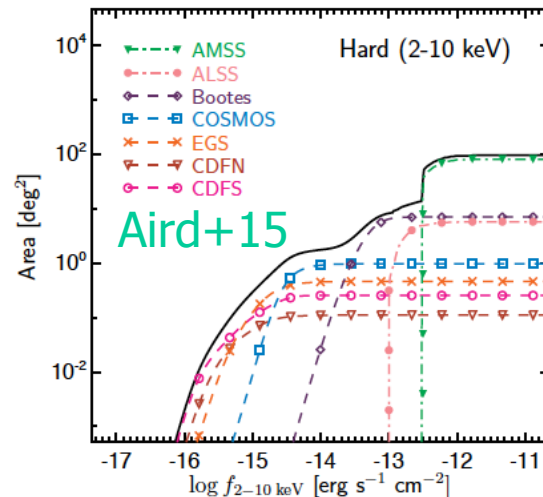
Aird+15

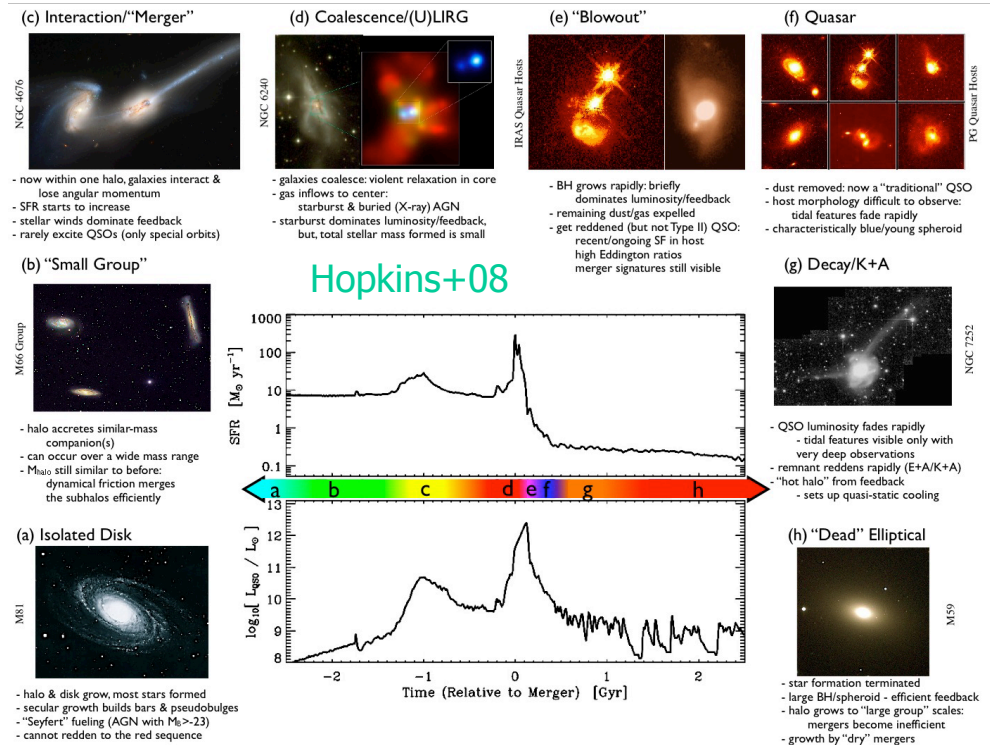Miyaji+15

Evolution and the CXB

(..., Ueda et al. 2014, Miyaji et al. 2015,
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Aird+15

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Miyaji+15

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– Compton Thick contribution:
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Evolution: AGN and their host galaxies

(c) Interaction/"Merger"
NGC 4676
- now within one halo, galaxies interact & lose angular momentum
- SFR starts to increase
- stellar winds dominate feedback
- rarely excite QSOs (only special orbits)

(d) Coalescence/(U)LIRG
NGC 6240
- galaxies coalesce: violent relaxation in core
- gas inflows to center: starburst & buried (X-ray) AGN
- starburst dominates luminosity/feedback, but, total stellar mass formed is small

(e) "Blowout"
IRAS Quasar Hosts
- BH grows rapidly: briefly dominates luminosity/feedback
- remaining dust/gas expelled
- get reddened (but not Type II) QSO: recent/ongoing SF in host high Eddington ratios merger signatures still visible

(f) Quasar
PG Quasar Hosts
- dust removed: now a "traditional" QSO
- host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

(b) "Small Group"
M66 Group
- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- M_{halo} still similar to before: dynamical friction merges the subhalos efficiently

(a) Isolated Disk
M81
- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- "Seyfert" fueling (AGN with M_B>-23)
- cannot redden to the red sequence

Hopkins+08

(g) Decay/K+A
NGC 7252
- QSO luminosity fades rapidly
- tidal features visible only with very deep observations
- remnant reddens rapidly (E+A/K+A)
- "hot halo" from feedback
- sets up quasi-static cooling

(h) "Dead" Elliptical
M59
- star formation terminated
- large BH/spheroid - efficient feedback
- halo grows to "large group" scales: mergers become inefficient
- growth by "dry" mergers

- What is the origin of the correlations between SMBH mass and host galaxy bulge mass? (Kormendy & Ho 2013):
  - Common evolution driven by external regulator: L_{AGN} ↑ SF ↑
    - Mergers ⇒Distorted host morphologies
    - Gas accretion from halo (angular momentum Cen 2015)
  - Feedback (quenching):
    - from Star Formation (SF)
    - from AGN (quenching): jets? outflows? L_{AGN} ↑ SF ↓
- Complications: time offset between SF and AGN activity (Hickox+14, Volonteri+15), AGN flickering (Schawinski+15)...
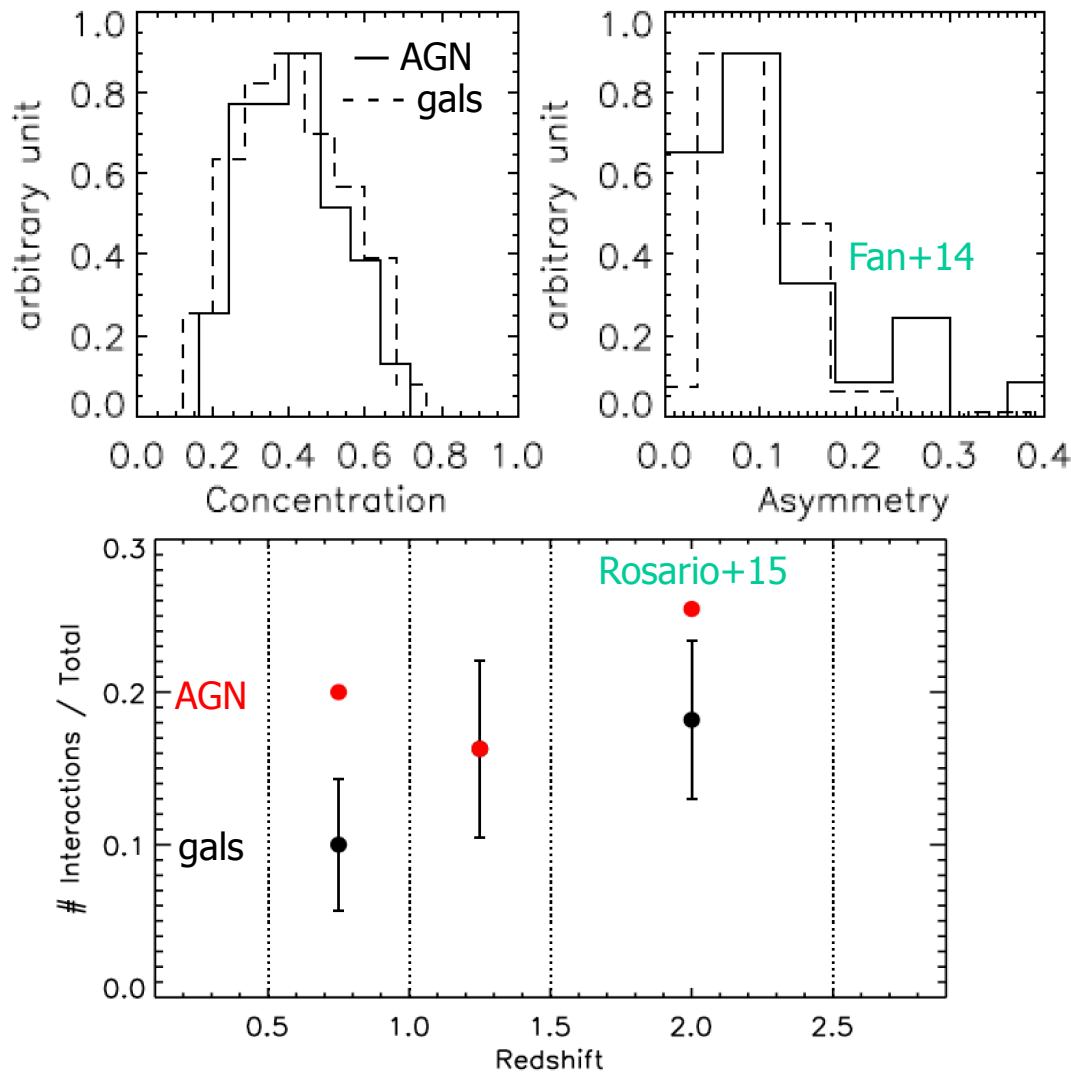
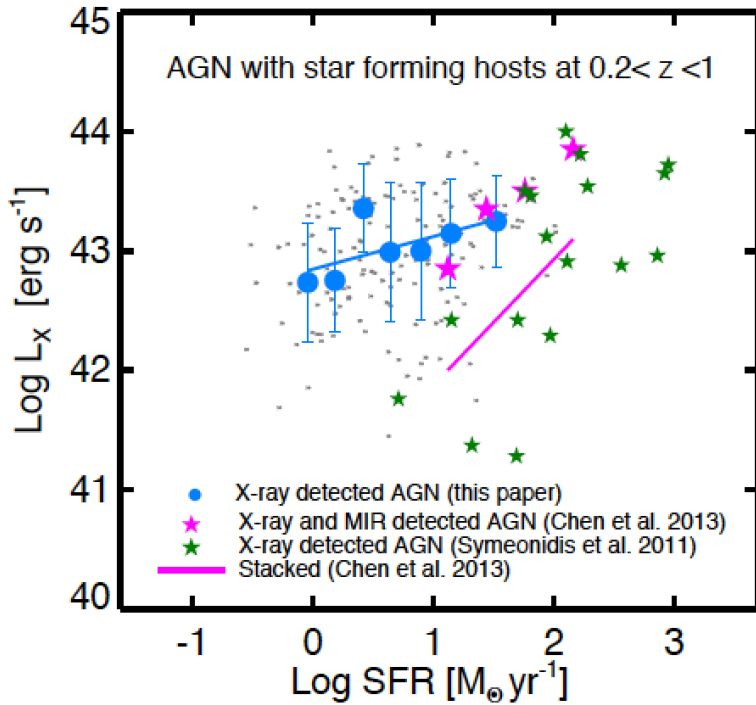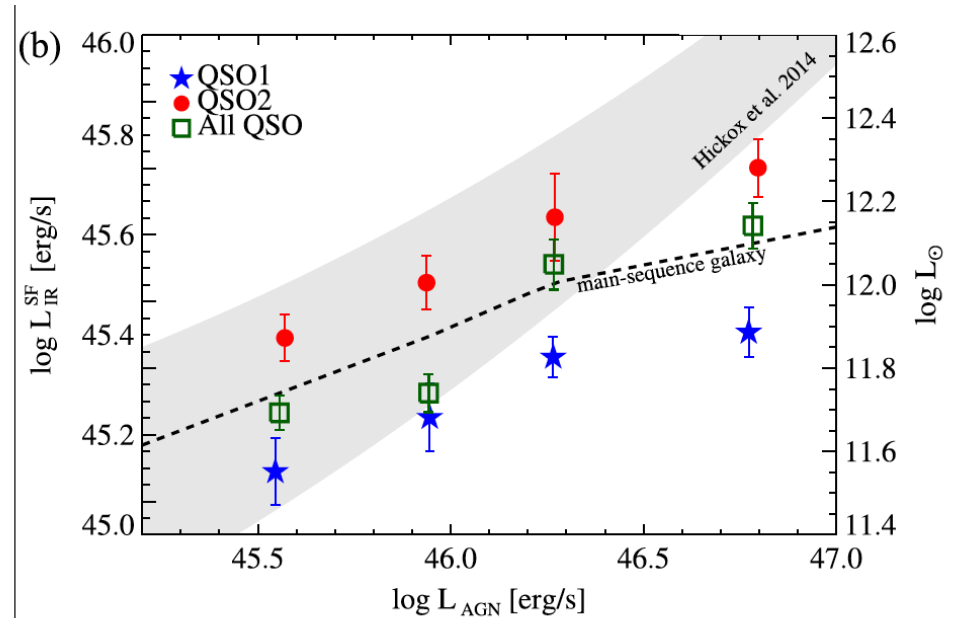# Evolution: AGN vs. host morphology
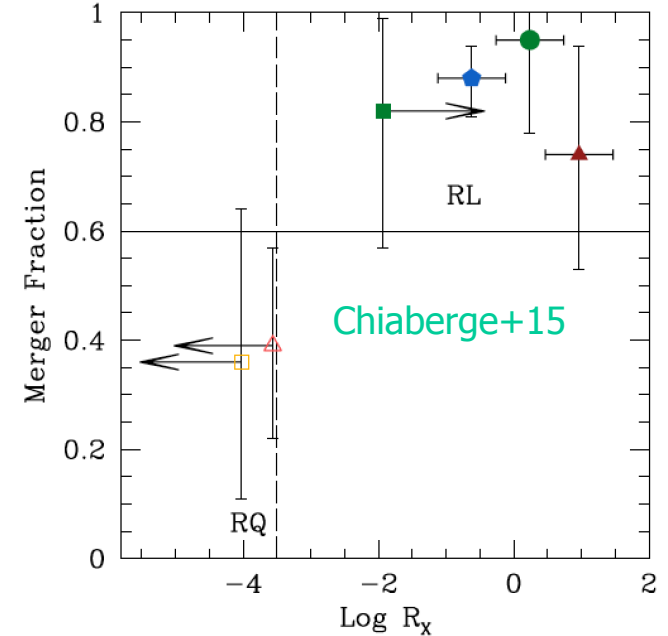
- Fraction of (mostly RQ) AGN hosts z=1-3 with distorted morphology ~ gals. same z (Fan+14)

- z~1 AGN modest enhancement of disturbed morph. but similar z~2 (Rosario+15)

- Many (most?) RL AGN at z>1 associated to recent or ongoing mergers, while RQ AGN ~gals. same z (Chiaberge+15)
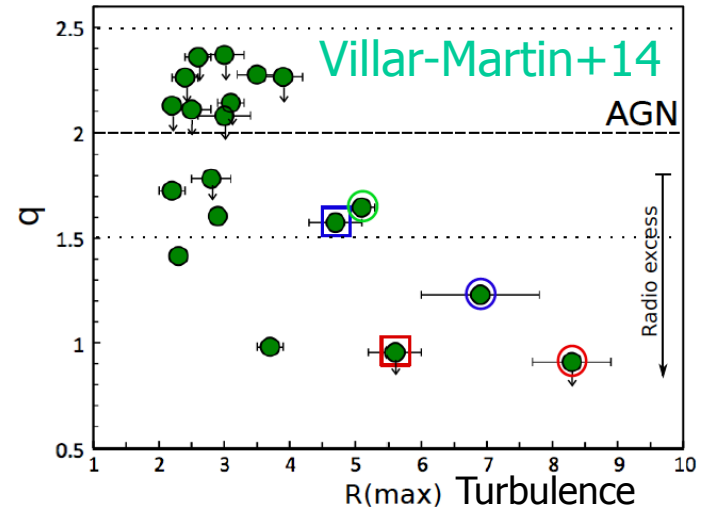
Evolution: AGN vs. SFR

Azadi+15

Chen+15

- AGN hosts younger stellar populations and higher extinctions z~1 (Hernan-Caballero+14)
- Higher SFR in bulge-dominated AGN hosts at z~1 (Rosario+15)
- SF gal. x2-3 likely to host AGN than quiescent gal. z<1, weak SFR-L_X (Azadi+15)
- Signif. correlation L_{SF}-L_{AGN}, stronger for QSO2 (Chen+15)
- See also Anuar Khan-Ali's talk

Evolution: AGN feedback

- Direct observational evidence for strong outflows:
  - 95% obscured QSO $z \lesssim 1$ ion. outflows: turbulence ↑ RL ↑ : jets vs. outflows? (Villar-Martin+14)
  - Ultra-Fast Outflows (UFO): just lower-distance higher-velocity extension of widespread Warm Absorbers (≥50% AGN)? (Tombesi+13)
    - See for local examples: Jacobo Ebrero's talk WA and Maria de Santos' talk UFO

Stacking
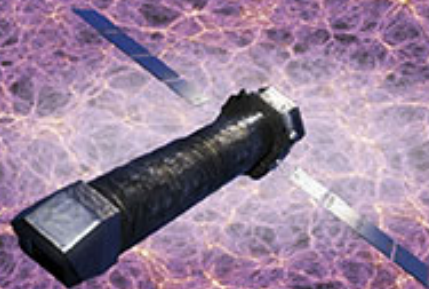

Falocco+14 (>400kcts)
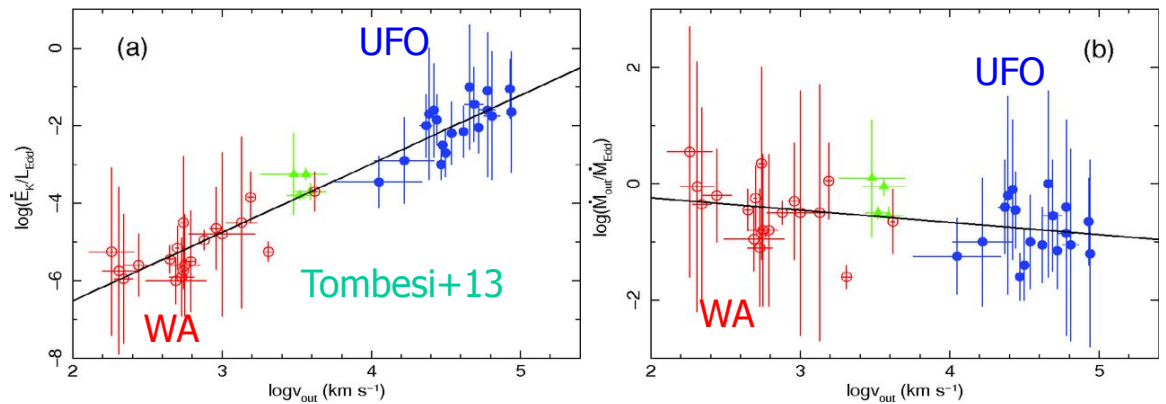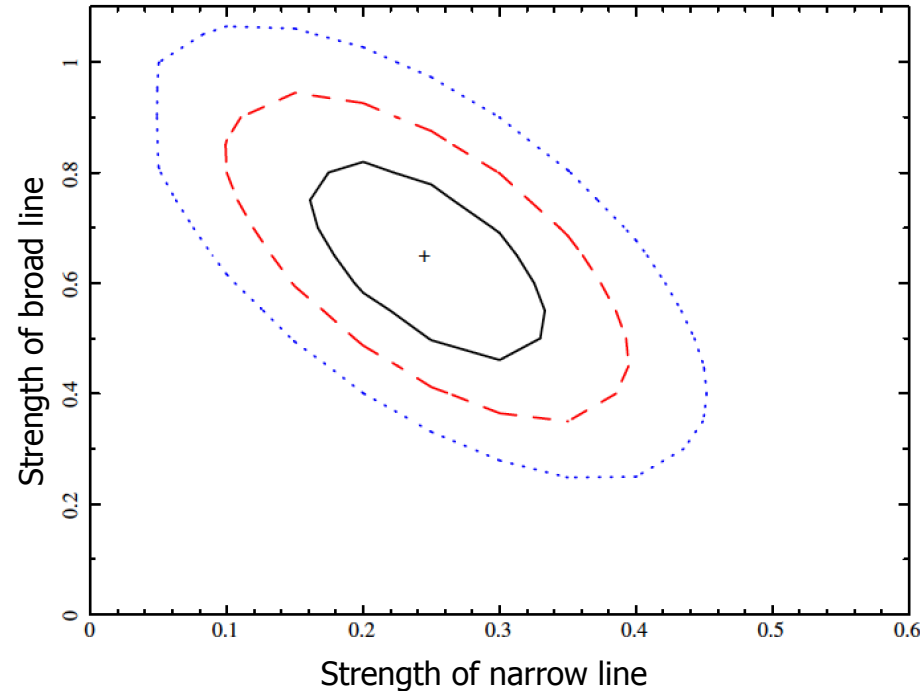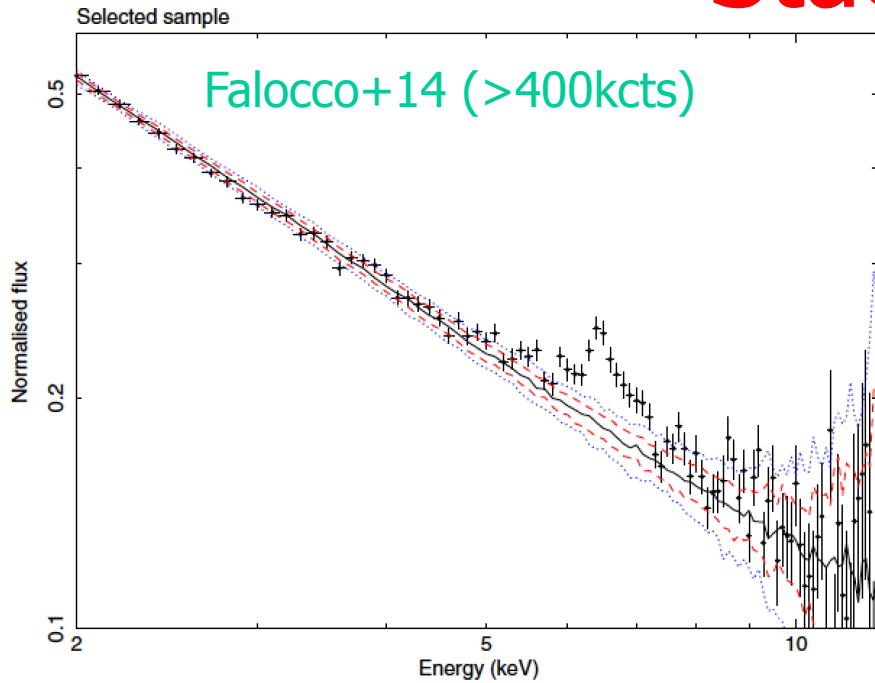
- Allows detections in populations, even when individual sources do not show features

- Image stacking (mostly Chandra):
  - Overall spectral characteristics of populations: galaxies (Chen+13, Jones+14), sub-millimetre galaxies (Wang+13), AGN (Mignoli+13)

- Spectral stacking:
  - Several different techniques: need to take into account properly response matrix and z
  - Already detected narrow Fe from far away neutral gas (…Corral+11, Iwasawa+12, Falocco+12,13, …)
  - First detection of significant broad component from relativistic disk (Falocco+14)

The Future

- XMM-Newton, Chandra (Swift) still in good shape
  - Cheaper to operate in survey mode in future?

- Imminent: eROSITA:
  - THE survey telescope: full sky plus deeper ones
  - Huge numbers in local Universe
  - But: no clusters z>1, no AGN z>>, no obscured AGN z>

- Need higher effective area, sharper imaging, larger FOV: *Athena* (Nandra et al. 2013, astro-ph:1306.2307)
  - Wow!

The Future: *Athena*: CT AGN

Compton Thick AGN z=3 $N_H=3.2 \times 10^{22}$ cm^{-2} L(2–10 keV)=5×10^{44} erg/s

Athena proposal survey configuration

Georgakakis, Carrera et al. 2013, astro-ph:1306.2328

ATHENA
THE ASTROPHYSICS OF THE
HOT AND ENERGETIC
UNIVERSE

HOW DOES ORDINARY MATTER
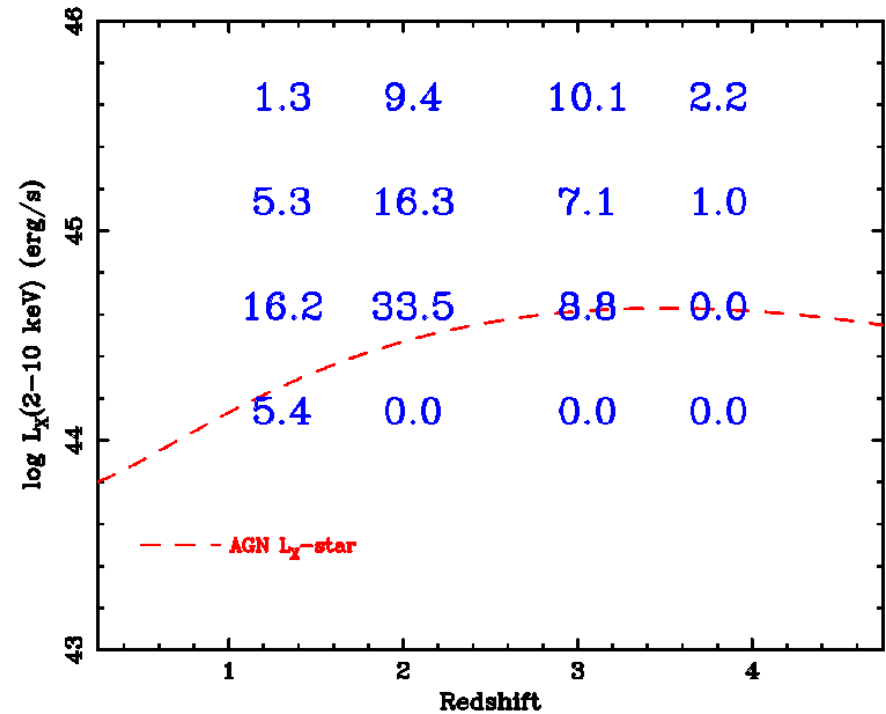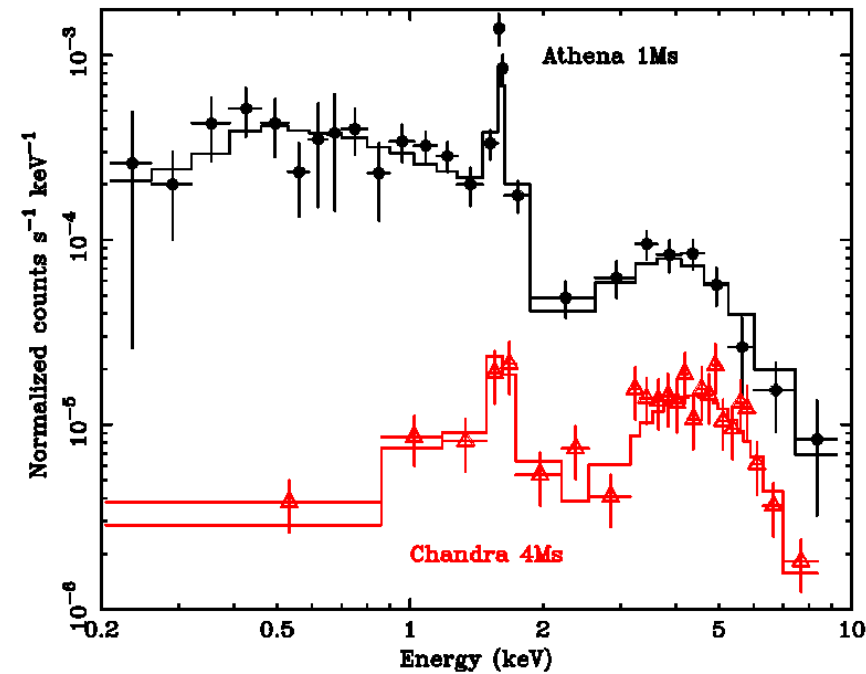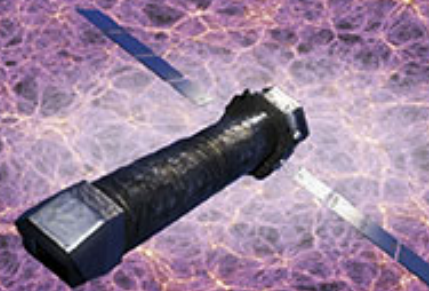ASSEMBLE INTO THE LARGE SCALE
STRUCTURES THAT WE SEE TODAY?

HOW DO BLACK HOLES GROW
AND SHAPE THE UNIVERSE?

Europe's next generation X-RAY OBSERVATORY

Summary

- Over the years, extragalactic X-ray surveys have:
  - Discovered the origin of (some of) the Cosmic X-ray Background
  - Unravelled (part of) the history of accretion in the Universe
  - Disentangled (partially) the co-evolution of galaxies and AGN

- eROSITA in near future to complete our knowledge of the local Universe

- To remove the brackets in the above statements for cosmologically-relevant epochs we need *Athena*:
  - Higher effective area
  - Sharper imaging
  - Larger FOV