AMUSE-Virgo
AGN
MUlti-wavelength Survey in Early type galaxies

Super-massive black holes vs. nuclear star clusters: the X-ray view
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Scaling relations in faint/low-mass spheroids

Do massive black holes \textit{exist} in faint / low-mass early types?
Do massive black holes exist in faint / low-mass early types?

- ACS Virgo Cluster Sample (ACSVCS Cote’ et al 04)
- Nuclear star clusters increasingly prominent moving down the mass function (present in 80% of the galaxies with stellar masses <1E M_Sun)

Ferrarese et al 2006 Wehner & Harris 2006 Kormendy et al 2009
AMUSE-Virgo: science goals

- Census of super-massive black hole activity in the local universe (Chandra+Spitzer +Hubble)

- Black hole occupation fraction (Chandra +Spitzer+Hubble)

- X-ray luminosity function of globular clusters + Ultra-luminous X-ray sources in early type galaxies (Chandra+Hubble)

- Testing super-massive black hole mass scaling relations at the low mass end
AMUSE-Virgo: the survey

Targets **100 early type galaxies** which compose the HST ACS Virgo Cluster Survey (ACSVCS, Cote’ et al 2004)

- Stellar mass range: 1E+8.5-1E+12
- Nuclear black hole mass range: 1E+5-1E+9

- 84 new targets with Chandra ACIS-S (454 ksec) + 16 archival (>1Msec) complete down to L_Edd for a 3 M_Sun object
- 57 new targets with Spitzer MIPS (9.5 hr) + 43 archival
- HST ACS g- & z-band archival images (100 orbits)
- VLA 5 GHz, in progress

AMUSE, the team: E. Gallo (MIT), T. Treu, R. Antonucci

http://tartufo.physics.ucsb.edu/~amuse/
Contamination from Low-Mass X-ray Binaries (LMXBs) addressed quantitatively: each nuclear X-ray source \( L_x \) is assigned a prob. \((1-P_x)\) to be an active black hole, where \( P_x \) is the chance probability of having a LMXB \( \geq L_x \) within the ACIS PSF, based on X-ray luminosity function of LMXBs:

- in the FIELD (Gilfanov 2004) in the absence of nuclear star clusters
- in GLOBULAR CLUSTERS (Sivakoff et al. 2007) in the presence of a nuclear cluster

Gallo et al. 2008 (Paper I.), Gallo et al. 2009, to be submitted (Paper II.)
AMUSE-Virgo: Nuclear X-ray census

- 32/100 show a nuclear X-ray source
- 51/100 show a massive nuclear star cluster
- 6/100 show both a nuclear X-ray source and a star cluster
- 24-34% of the galaxies host an active super-massive black hole (95% C.L.)
- Measured X-ray luminosities range between $1 \times 10^{-8.5}$ and $1 \times 10^{-6} L_{\text{Edd}}$
AMUSE-Virgo: Active black hole fraction

Active fraction raises with host stellar mass (Paper I.; agrees with e.g. Kaufmann et al. 2003, Decarli et al. 2007, Seth)
Active fraction raises with host stellar mass

HOWEVER

Dealing with `Eddington-limited' sub-samples results in no evidence that the fraction of active black holes depends on host mass
Substantially different from XLF of LMXBs (Gilfanov 2004) Slope agrees with Zhang et al. 2009 (187 galaxies < 15 Mpc)
AMUSE-Virgo: Summary

- 32/100 nuclear X-ray sources; 51/100 nuclear clusters; 6/100 hybrids

- *Bona fide* active black holes (after LMXB contamination assessment): between 24-34% host an accreting black hole. Strong lower limit to occupation fraction in the local universe.

- No evidence for increase in the active fraction of X-ray active with host stellar mass when Eddington-limited samples are considered.

- Measured X-ray luminosities between $1\times10^{-8.5}$ and $1\times10^{-6}$ times Eddington lum.
X-rays: AGN vs. ‘inactive’ galaxies

X-rays from inactive galaxies:

ROSAT effectively sensitive down to 1e40 erg/sec for nearby galaxies

Chandra bridges the gap between active (>1E-2 L_Edd) and (formally) inactive galaxies

Pellegrini 2005, Soria et al 2006
AMUSE-Virgo: parameter space

Host stellar mass distribution

Nuclear black hole mass distribution