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

On the survival of super-massive black holes in faint spheroids

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AMUSE: science goals

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

- SMBH occupation fraction/mechanical heating (Chandra+Spitzer+Hubble+VLA)

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

- Testing SMBH mass scaling relations at the low mass end (Hubble+Keck)
AMUSE: the survey

- Targets 100 early type galaxies which compose the HST ACS Virgo Cluster Survey (ACSVCS, Cote’ et al 04)
  - 84 new targets with Chandra ACIS-S (454 ksec; PI: Treu) + 16 archival
  - 57 new targets with Spitzer MIPS (9.5 hr) + 43 archival
  - HST ACS archival data (100 orbits)
  - VLA, in progress (with D. Axon)

- AMUSE, the team: E. Gallo, T. Treu, J.-H. Woo, J. Jacob, R. Antonucci, P. Marshall, L. Bildsten, C. Liepski (UCSB)
  - http://tartufo.physics.ucsb.edu/~amuse/
The quest for SMBHs:

- prolonged periods of low-level SMBH activity needed in order to reproduce the galaxies’ colors (‘radio mode’, Croton et al. 06).

Do SMBH exist in faint early types?

- SMBH/active stellar nuclei competition at B mag fainter than –20 (Ferrarese et al. 06)
- Low BH occupation fraction (Volonteri et al. 07)
Scaling relations: SMBH in faint spheroids

- SMBHs replaced by ‘compact stellar nuclei’ moving down the mass function. SMBHS:
  - Dominate B mag < −20
  - Disappear B mag > −18
  - Coexist in between

Ferrarese et al. 2006
AMUSE: first Chandra results I.

✓ Search for accretion-powered activity from SMBH:
  - improve astrometry (match to SDSS-DR5)
  - separate hot gas from low mass X-ray binaries (LMXBs)
  - search for point like nuclear X-ray source

✓ Contamination:
  - CXB: negligible (<1e-7 sources, Chandra DF South, Rosati et al 02)
  - LMXBs (<1e-2 sources within the Chandra PSF, luminosity function, Gilfanov 03)
AMUSE: first Chandra results II.

- 32 galaxies: 16 archival (>500 ksec), 16 new (5.4 ksec each: sensitive to L_Edd for a 3 M_Sun object)

- Point-like nuclear X-ray source detected in 16 objects:
  - 4/16 belong to the new 5.4 ksec obs. Of the remaining 12 (archival data):
  - 9/12 already reported in the literature
Non detections: stacking

- 12 snapshot observations, 62.3 ksec net exposure
- $L_X < 3.8 \times 10^{37}$ erg/sec
  (average distance 16.5 Mpc)
- $L_X/L_{Edd} < 3 \times 10^{-8}$
  (average $M_{BH} = 9.3 \times 10^6$ M$_{Sun}$)
AMUSE: SMBH survival

- 2 of the detected nuclei in galaxies with $B$ mag > -18:
  - vcc1178: $M^* = 1.4 \times 10^{10} \, M_\odot$
  - vcc1297: $M^* = 6.7 \times 10^9 \, M_\odot$

- 15% of the targets with $\log (M^*/M_\odot) < 10.5$ harbor active SMBHs
2 of the detected nuclei in galaxies with B mag > -18: vcc1178 also hosts a compact stellar nucleus

15% of the targets with log (M*/M_Sun) < 10.5 harbor active SMBHs
For the 16 detected nuclei
\[-8.4 < \log(L_X/L_{\text{Edd}}) < -5.8\]

Bolometric correction
\[f_{\text{bol}} = 8-60 \text{ (Marconi et al. 04)}\]

Mechanical SMBH feedback:
\[-4.6 < \log(L_{\text{kin}} / L_{\text{Edd}}) < -3.3\]
(applying Merloni & Heinz 07)
Nuclear SMBH in 16/32 galaxies: $-8.4 < \log(L_X/L_{Edd}) < -5.8$

$L_{\text{kin}}$ in agreement with models for cosmic structure formation (AGN `radio mode')

Two of the detected nuclei hosted in galaxies with B mag $> -18$. SMBH and compact stellar nuclei are NOT mutually exclusive.

SMBH occupation fraction $f > 15\%$ below $M^* = 10^{10.5} M_{\odot}$

Gallo et al., in prep.

see: http://tartufo.physics.ucsb.edu/~amuse