Radio counterparts of ultraluminous X-ray sources

in nearby galaxies

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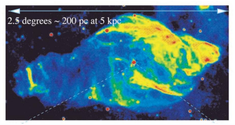
21 radio-counterpart candidates

RACS + VLASS full-sky archive search

Why search radio counterparts of ULXs?

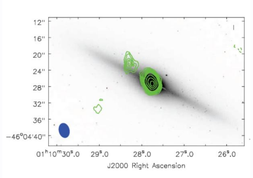
Radio emission exposes structures and accretion states that X-rays alone cannot distinguish:



SS 433 and W 50

1 SS 433-like nebulae

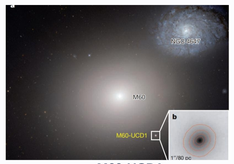
Resolved, steep-spectrum radio lobes trace jets or winds shocking the surrounding ISM. These systems reveal the mechanical feedback of supercritical accretion.



HLX-1 in ESO 243-49

2 Active IMBHs

A compact radio core combined with the X-ray luminosity can test an accreting 10^2-10^5 Msun black hole and place it on the black-hole fundamental plane.



M60-UCD1

3 Active BHs in UCDs?

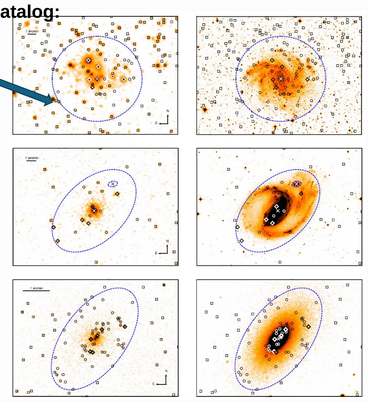
Some off-nuclear sources may be stripped galaxy nuclei. A compact radio/X-ray counterpart tests whether the over-massive black hole retained by a UCD is active.

How the search connects them

Walton 2022 ULX catalog:

Luminous X-ray source in D25

Removed know background AGNs



NGC 6946 XMM-Newton

NGC 1097 Swift XRT

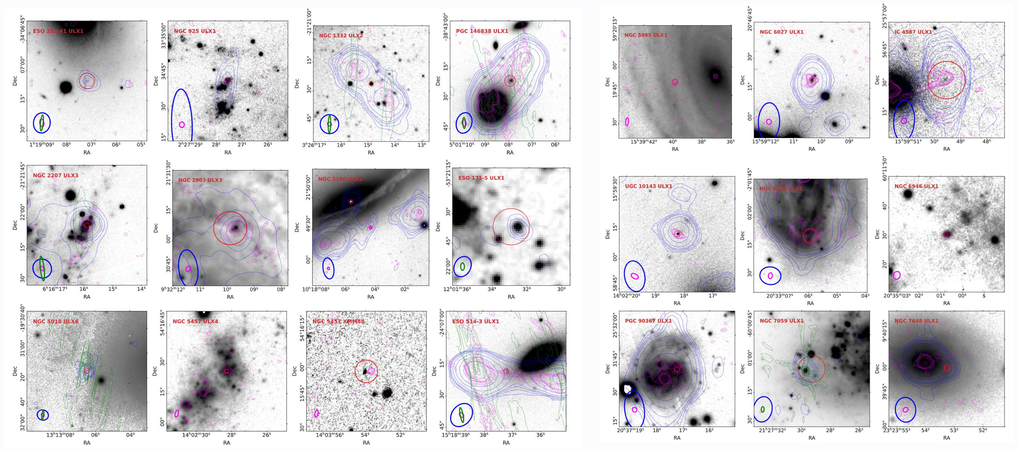
NGC 720 Chandra

X-ray | Optical

1,843 ULXs → 2' x 2' radio maps → 21 selected

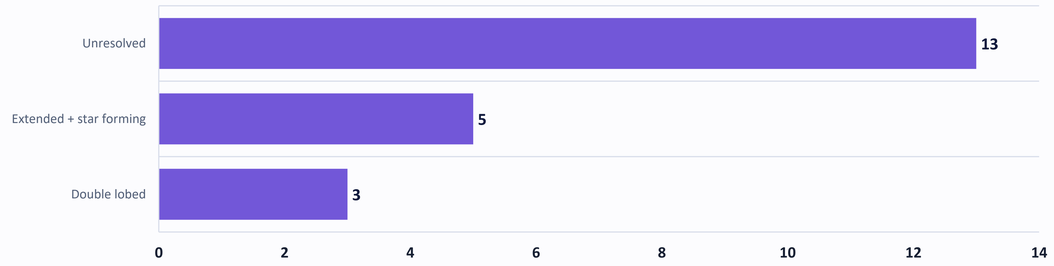
Not only use crossmatch between X-ray and radio catalogs But check the radio images one by one

The 21 counterparts span three morphologies



Optical images | RACS contours: blue | VLASS: magenta | ATCA: green | X-ray position error: red

The sample is heterogeneous

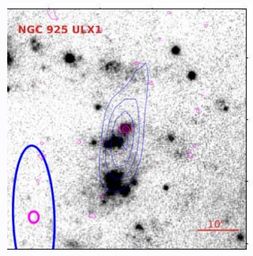


Among the 13 unresolved sources

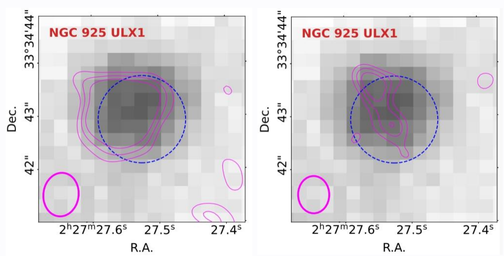
8 steep-spectrum · 2 flat/inverted · 3 without a measured slope

A steep spectrum favors optically thin synchrotron emission from a jet/wind nebula; a flat or inverted spectrum is consistent with a compact self-absorbed jet.

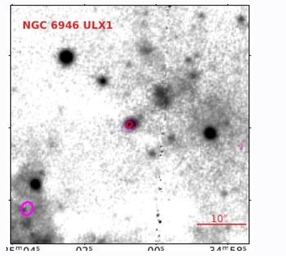
SS 433/W50-like candidates



NGC 925 ULX1
Steep spectrum + optical nebula



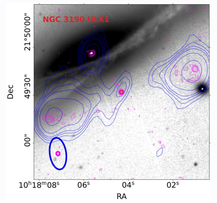
VLA C-configuration
8-10 GHz | 10-12 GHz



NGC 6946 ULX1
Well-studied with optical and radio nebular

VLBI 1.7 GHz non-detection: no compact radio core (Wang et al. 2026)

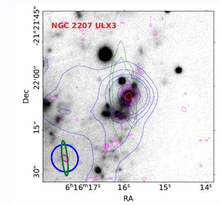
What the morphologies imply



NGC 3190 ULX1

1 Background quasar: 3

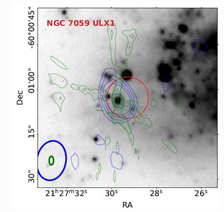
Three sources show double lobes. NGC 3190 ULX1 and ESO 514-3 ULX1 also contain a compact core; AGN-like X-ray/optical ratios support a background-radio-AGN interpretation.



NGC 2207 ULX3

2 Star-forming region: 5

Five are extended and coincide with optical H II regions. Star formation can explain much of the radio flux, but unusually steep spectra and X-ray variability show that embedded ULXs may still contribute.

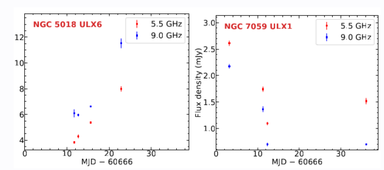


NGC7059 ULX1

3 Host-galaxy compact object?: ~10

Eight unresolved sources have steep spectra and are strong jet/wind-nebula candidates. Two flat/inverted sources resemble compact jets, but fundamental-plane masses of $> 10^6\ M_\odot$ require caution.

Follow-up already changes the picture



ATCA detects day-scale radio variability in NGC 5018 ULX6 and NGC 7059 ULX1. Such rapid changes constrain the emission region to < 10^15 cm and argue against a large static nebula.

Take home message

Redshift is of key importance

- **The 21 candidates are not one population.**
- **Most lie below the FR0/FRI radio-luminosity range; only IC 4587 ULX1 overlaps that locus.**
- **Optical spectra, subarcsecond radio imaging, and coordinated variability monitoring are the highest-value next observations.**
- **Optical spectroscopy separates nearby ULXs and UCDs from background AGNs. One redshift reveals which of the three physical motivations is real**

Zhang et al. 2026, ApJ 997, 285 ·