Mid-IR emission from X-ray sources in NGC1399

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Spitzer and Chandra

- Spitzer – Infrared
  - IRAC – 3.6, 4.5, 5.8, 8.0 micron (~2")
  - MIPS – 24, 70, 160 microns
  - IRS – 5 - 40 microns

- Chandra – X-ray
  - HRC – High resolution camera
  - ACIS – advanced CCD imaging spectrometer
  - HETGS, LETGS
What are Ultra-luminous X-ray sources (ULX)?

- Off-nuclear sources detected in nearby galaxies with $L_X > 10^{39}$ ergs/s
- e.g. M82 X-1, Holmberg IX X-1, NGC 4490 etc.
- Their luminosities are greater than the Eddington luminosity of an accreting 10 solar mass BH in a binary system – mass limit > 100 Msun
- Mass limits from Dynamical friction - < $10^6$ Msun
- One explanation is the presence of an accreting intermediate mass BH (100-$10^5$ Msun).
- Stellar evolution models predict not more than 30 Msun
ULX-facts

- Usually the companion stars are young massive stars
- Sometimes it can also be a red giant star
- Measurements of the BH mass in these objects are yet to be made
- Interesting class of objects in terms of their formation and evolution
- Important to find distinguishing characteristics at other wavelengths that may identify them to be more like AGN or Galactic X-ray binaries.
- e.g. look for counterparts in the Optical and Infrared
MIR (3-30 microns) properties of AGN

- Supermassive BH at centre
- AGN – strong correlation between $L_{\text{IR}} \sim L_{\text{X}}$
- Extends to low luminosity AGN
- Presence of dusty torus
- Unique MIR colors of AGN
- Positive log (5.8/3.6) flux ratio, indicating heating of dust due to AGN

Horst et al. (2008)
Flux ratios for different temperatures
MIR properties of GXB

Class of binary stars that emit X-rays due to matter falling from donor star to accretor.

- GXB -- $L_{\text{IR}} << L_{\chi}$
- Emission from jet + accretion disk
- Not detectable for extragalactic sources
- Difference in MIR emission due to environments

Are MIR properties of ULX like AGN or GXB?

Do ULX influence their environment

Russell et al. (2006)
Previous studies of ULX in MIR

Vázquez et al. (2007) – MIR line ratios from IRS used to separate accretion powered from star-formation powered systems 5/6 ULX in NGC4490

Berghea et al. (2010a) - [OIV] 25.89μm emission line detection in ULX Holmberg II, evidence of ULX influencing environment

Photoionization by soft X-ray FUV from accretion disc
Photometric data

- Significant results also possible with photometric measurements.
- The host galaxy should have smooth IR continuum to model and subtract out to reveal true point sources.
- Large elliptical galaxy with large number of X-ray sources ideal.
- Suitable candidate - NGC1399.
X-ray sources in NGC1399

- NGC1399 – central elliptical galaxy in Fornax cluster (d=18Mpc)
- Host to ~900 GC
- Several off-nuclear X-ray point sources detected
- Some of them are ULX
Available data for NGC1399

- **X-ray data** – Chandra – ACIS-S data. 118 sources detected reliable spectra (0.3-8.0 keV) extracted for 35 of them.

- **MIR data** – Spitzer IRAC data (3.6 & 5.8 microns) – 827 IR point sources detected, 33/118 X-ray sources detected.

- 16 of 35 detected at 3.6 microns at the 3-sigma level.

- **IRAC aperture fluxes** using APEX software – Luminosities using distance to NGC1399.
MIR source distributions

- Histogram of all 827 IR point sources (dashed line)
- 33 X-ray point source counterparts (solid line)
- 16 sources with spectra
- K-S test
- D = 0.15, p = 0.43
- Not different from parent population
Distribution of MIR flux ratios

- Histogram of MIR flux ratios 827 sources (dashed line)
- 33 counterparts (solid line)
- 16 sources (dotted line)
- K-S test
- $D=0.29$, $p=0.006$
- Siginificantly different distributions
- 10% of IR sources have positive ratio, 5% have negative ratios
Distribution of X-ray counts

- Histogram of X-ray counts of 118 sources (dashed line)
- 33 sources with IR emission
- K-S test $d=0.24$, $\text{prob} = 0.089$
- Brighter X-ray sources more likely to have IR counterparts
- correlation?
Correlation with X-ray counts

- X-ray counts v/s IR luminosity for 33 IR source counterparts
- No overall correlation
- For sources with AGN like flux ratio, correlation = 0.49, prob = 0.06
- Only sources with counts > 50, prob = 0.03
MIR – X-ray luminosity correlation for AGN-like sources

- AGN have positive log(5.8/3.6) flux ratio indicating an additional heating source for dust grains
- Using the same criterion, we find 8 sources in NGC 1399
- High IR luminosities
- Very good correlation between the X-ray and MIR luminosities
- Co-efficient = 0.91, p=0.002
- Better than with counts
MIR – X-ray correlation for remaining sources

- No correlation between MIR and X-ray luminosities
- $3.6 \mu m \text{ v/s X-ray}$ - Co-efficient = 0.29, $p=0.49$
5.8 micron v/s X-ray

- Positive ratios (circles)
- Negative ratios (triangles)
- Co-eff = 0.83, p=0.01
- Co-eff = 0.02, p=0.96
Optical colors

- g-z optical colors for 17/35 sources
- 16 sources fall into category of Globular Clusters (1.3<g-z<2.5) (Paolillo et al. 2011)
  - 7 are blue
  - 9 are red
- AGN-like sources 3- blue  1-red indicates they are primarily blue
- Difference in environment or GC type
- Presence of dusty torus like AGN?
Contamination by background AGN

- Possibility of background AGN contamination
- Then the observed correlation is expected
- One e.g. of red GC having non-AGN like MIR ratio
- Several may not be AGN
- 1 source has red optical colour but AGN-like MIR ratio
- Sources of Vázquez et al. are not redshifted w.r.t. host galaxy
- They have AGN-like ratios
- Only spectra of these sources can resolve this
Results

- MIR counterparts detected for 16 / 35 X-ray sources
- Good correlation for AGN-like sources extending the correlation seen in AGN down to $10^{39}$ ergs/s
- The remaining sources uncorrelated
- Background AGN? Blue optical colours.
- Not AGN – Sources with red colours + 2 sources in NGC4490 have similar positive ratios and are not AGN
- If not background AGN, this might mean that there are 2 types of X-ray sources, one like AGN and other like GXB
- Need for further IR or optical spectroscopic observations
- The sources identified in this study – an important sample for further studies
Thank you.