Mid-IR emission from X-ray sources in NGC1399

Shalima Puthiyaveettil
Postdoctoral Fellow
IUCAA, Pune

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Collaborators:

Profs. Ranjeev Misra, Swara Ravindranath,

G. C. Dewangan - (IUCAA)

Prof. B. R. S. Babu, Dr. C. D. Ravikumar,

Dr. K. Jeena, V. Jithesh - (Calicut University)

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

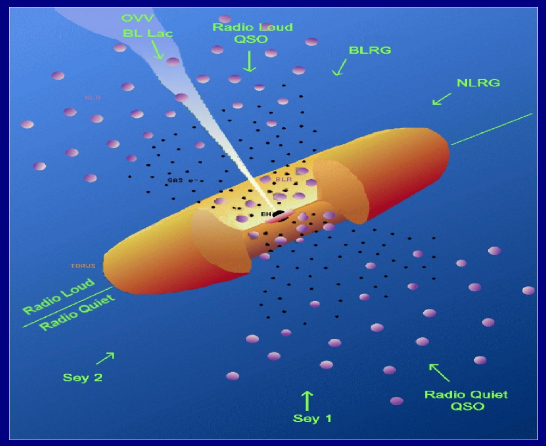
What are Ultra-luminous X-ray sources (ULX)?

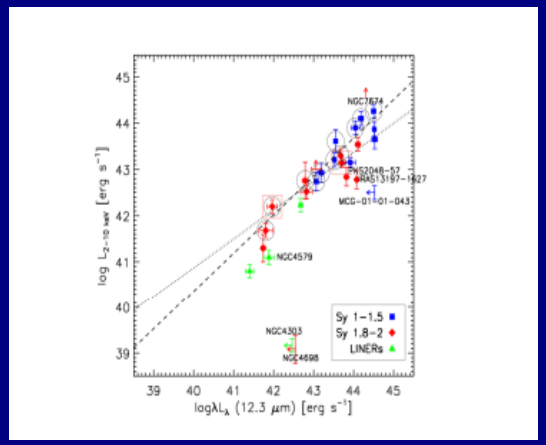
- Off-nuclear sources detected in nearby galaxies with $L_X > 10^{39}$ ergs/s
- e.g. M82 X-1, Holmberg IX X-1, NGC 4490 etc.
- Their luminosities are greater than the Eddington luminosity of an accreting 10 solar mass BH in a binary system – mass limit > 100 Msun
- Mass limits from Dynamical friction - < 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

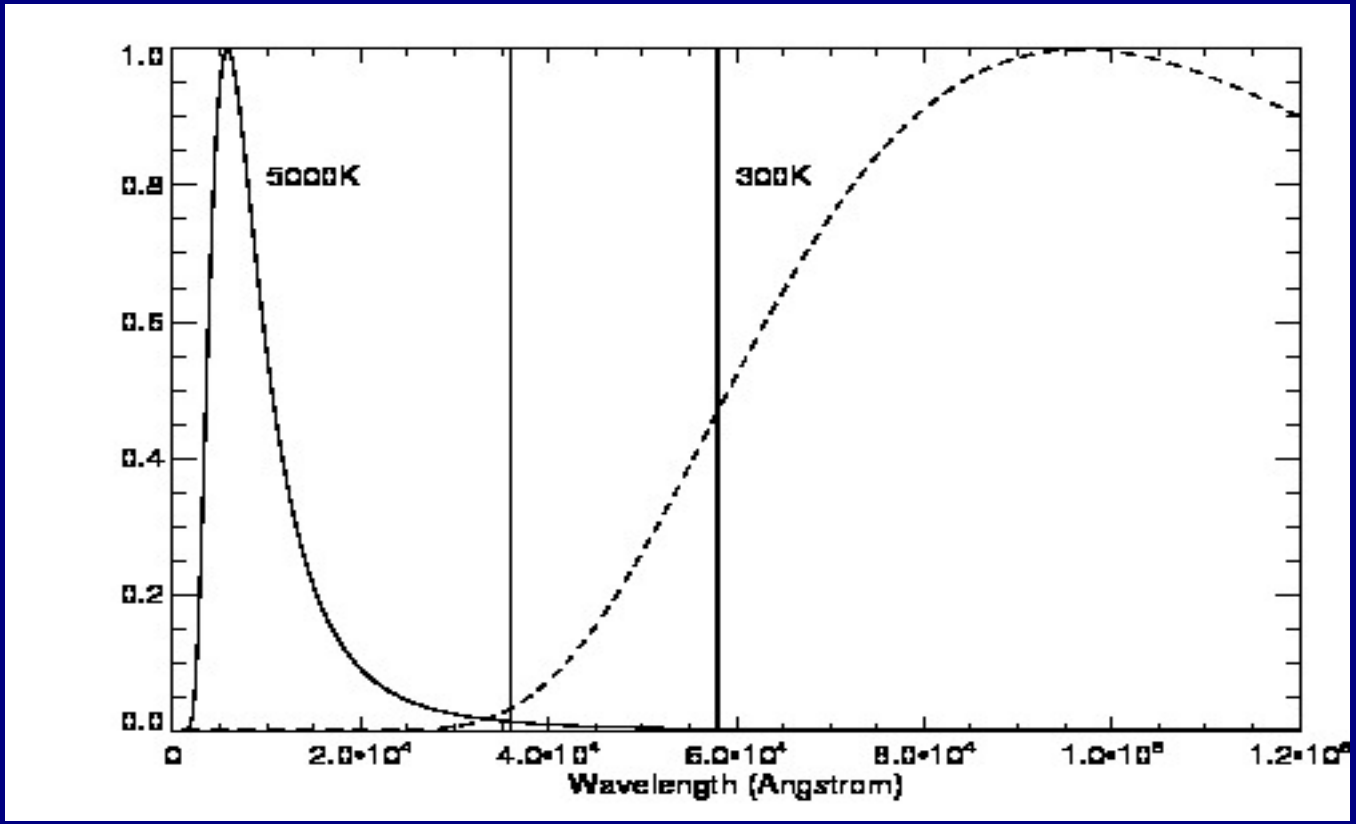




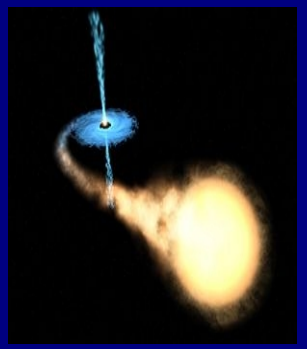
Horst et al. (2008)

- Supermassive BH at centre
- AGN – strong correlation between $L_{IR} \sim L_X$
- 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

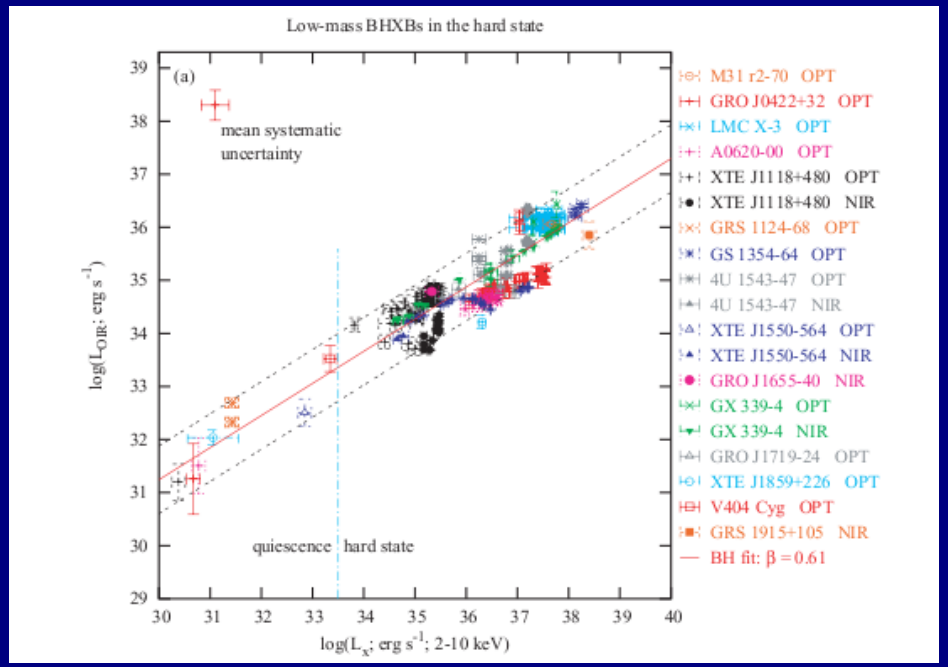
Flux ratios for different temperatures



MIR properties of GXB



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



Russell et al. (2006)

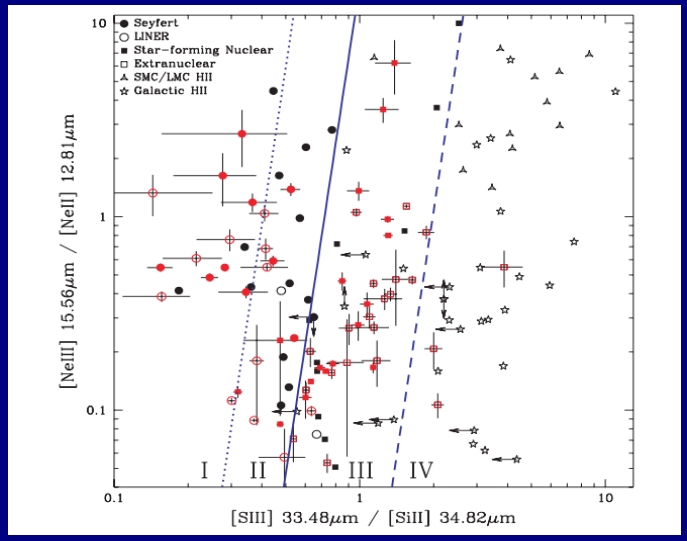
- GXB -- $L_{IR} << L_X$
- Emission from jet + accretion disk
- Not detectable for extragalactic sources
- Difference in MIR emission due to envionments

Are MIR properties of ULX like AGN or GXB?

Do ULX influence their environment

Previous studies of ULX in MIR

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



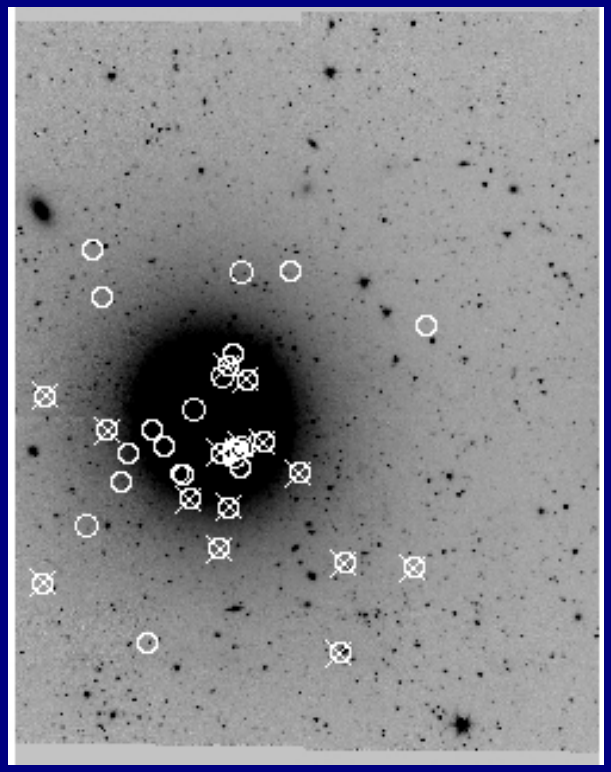
Berghea et al. (2010a) - [OIV] 25.89μm emission line detection in ULX Holmberg II, evidence of ULX influencing environment

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



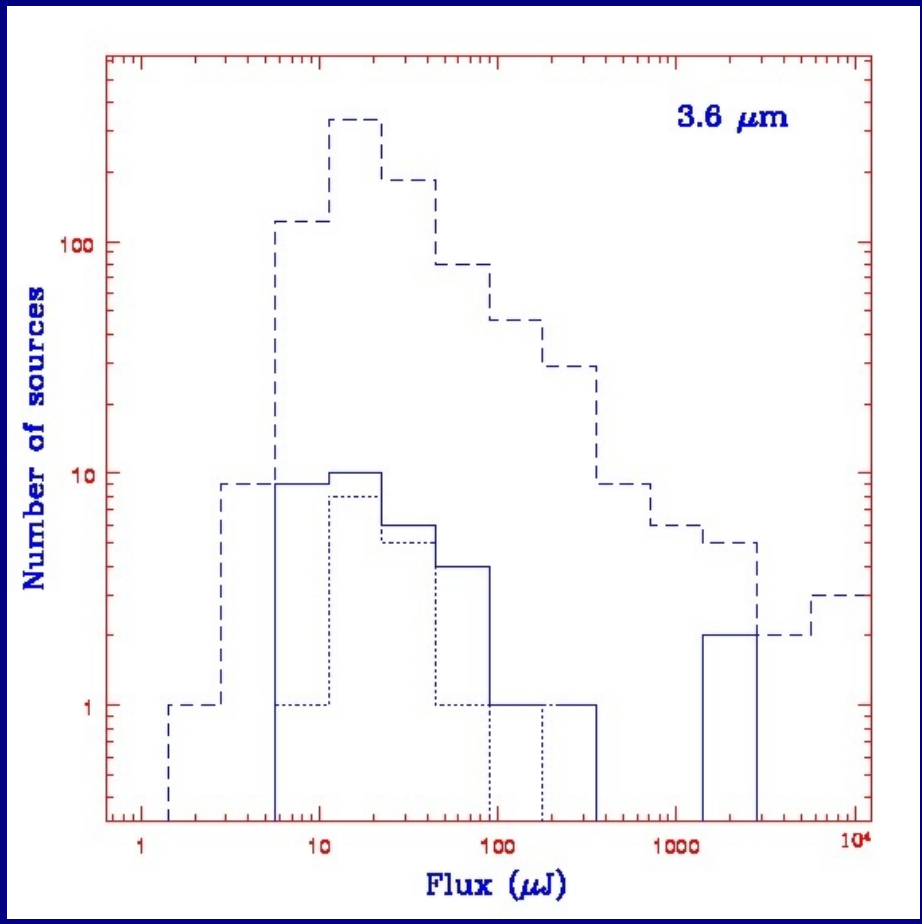
- NGC1399 – central elliptical galaxy in Fornax cluster (d=18Mpc)
- Host to ~900 GC
- Several off-nuclear X-ray point sources detected
- Some of them are ULX

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.

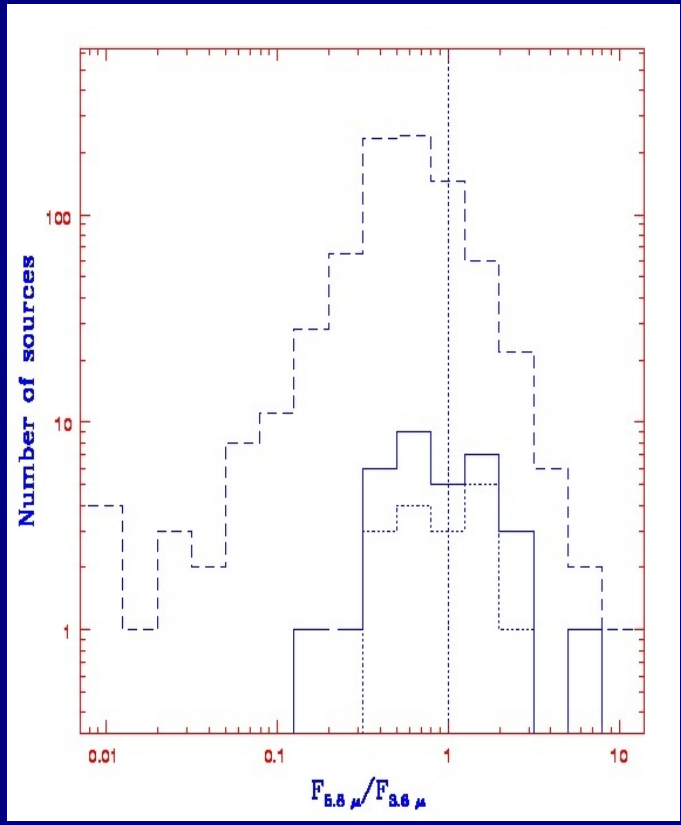
MIR source distributions

- Histrogram 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

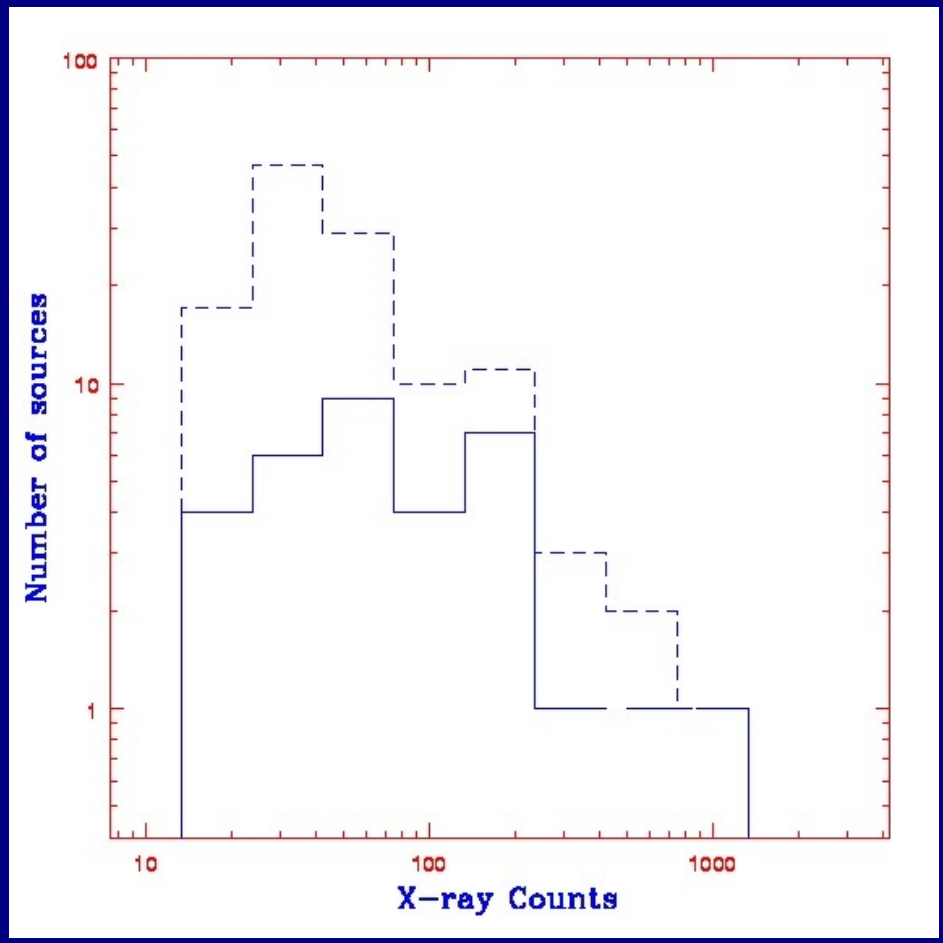
- Histogram of MIR flux ratios 827 sources (dashed line)
- 33 counterparts (solid line)
- 16 sources (dotted line)
- K-S test
- D=0.29, p =0.006
- Siginificantly different distributions
- 10% of IR sources have positive ratio, 5% have negative ratios



Distribution of X-ray counts

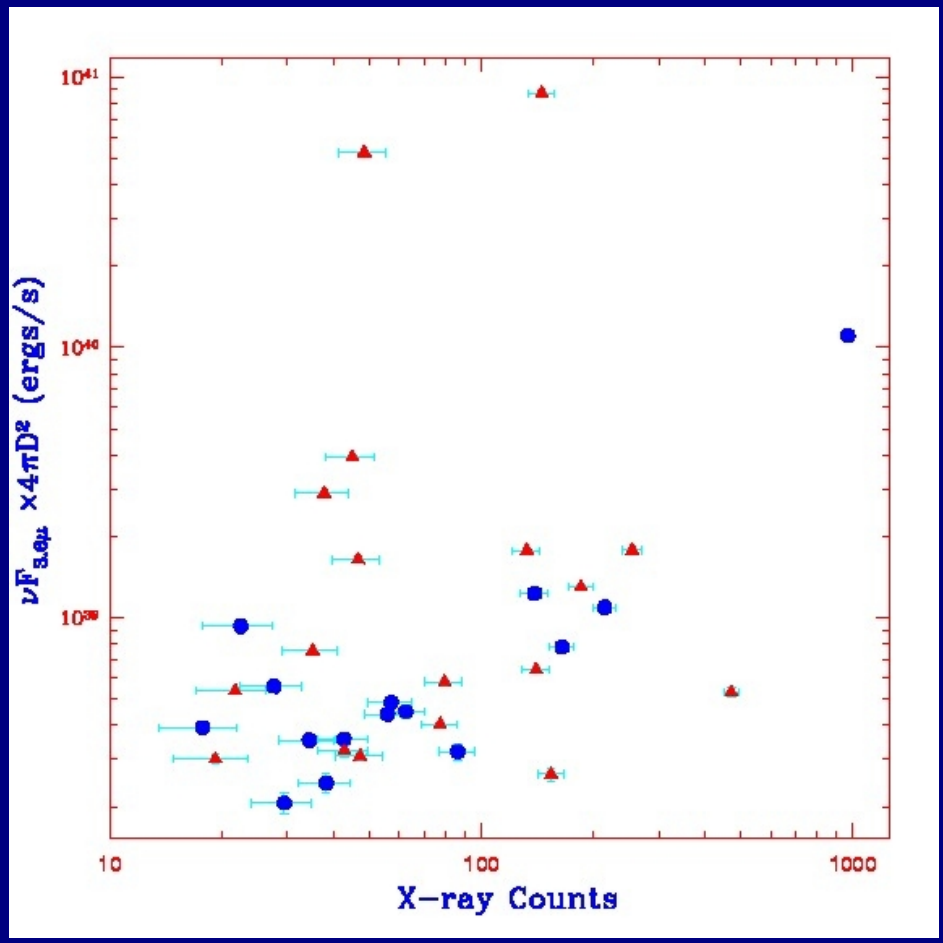
- Histogram of X-ray counts of 118 sources (dashed line)
- 33 sources with IR emission
- K-S test d=0.24,

  prob = 0.089
- Brighter X-ray sources more likely to have IR counterparts
- correlation?

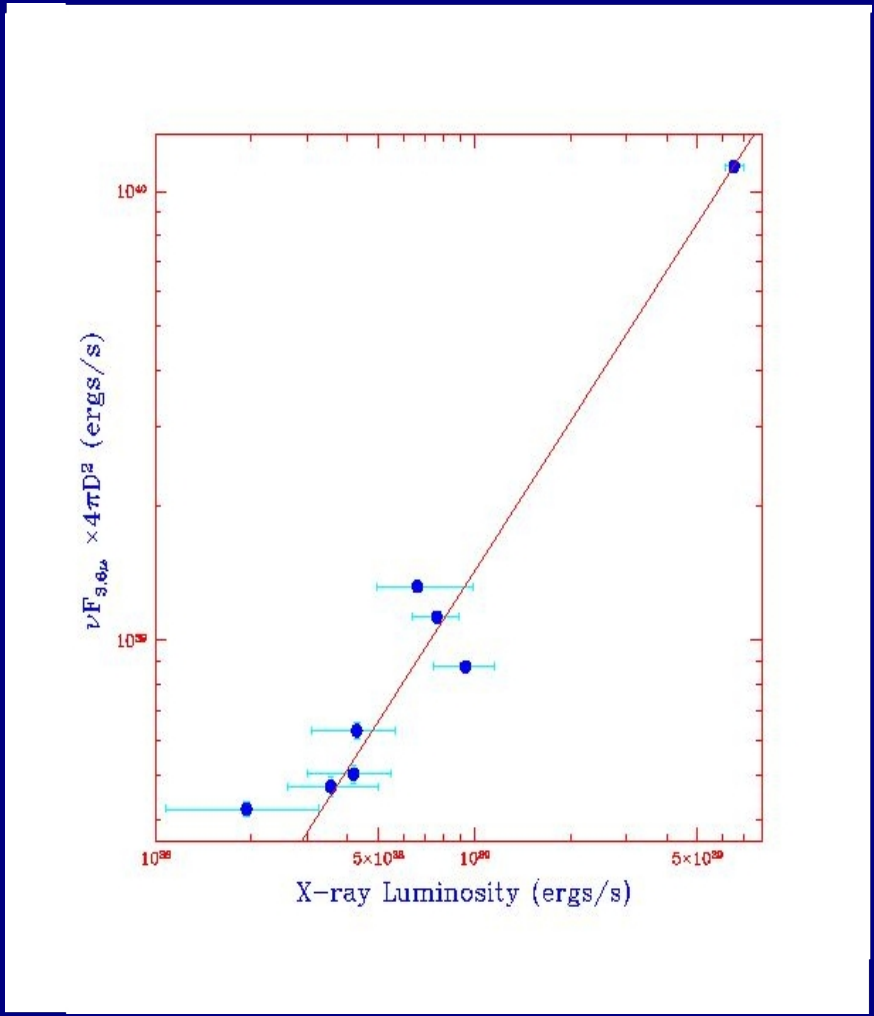


Correlation with X-ray counts

- 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

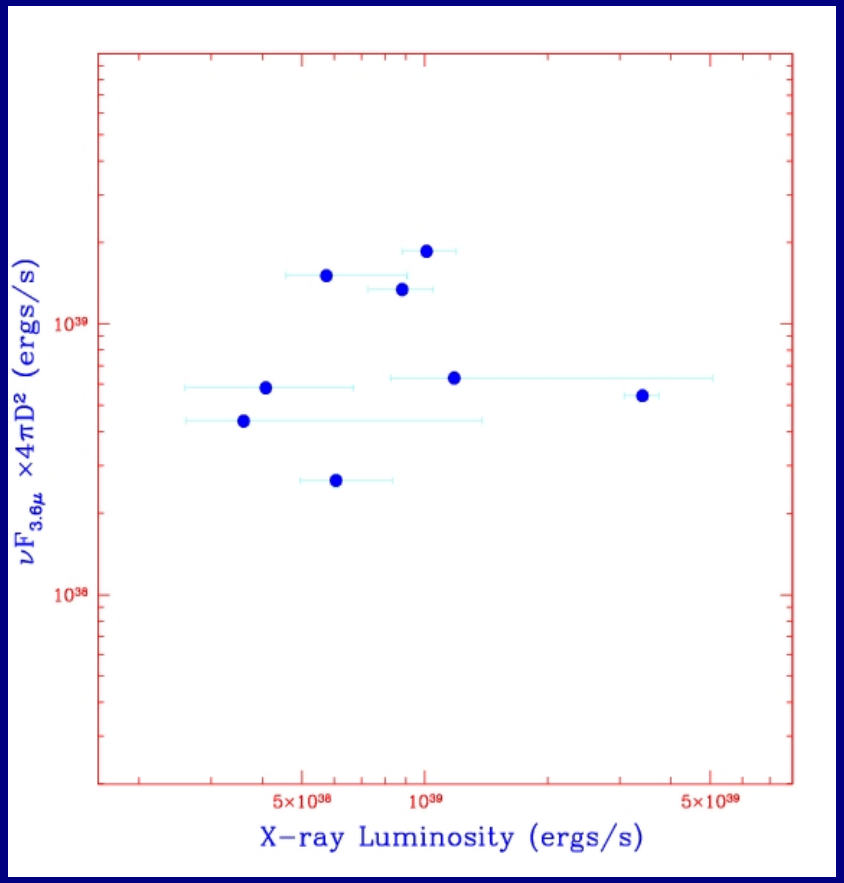


MIR – X-ray luminosity correlation for AGN-like sources



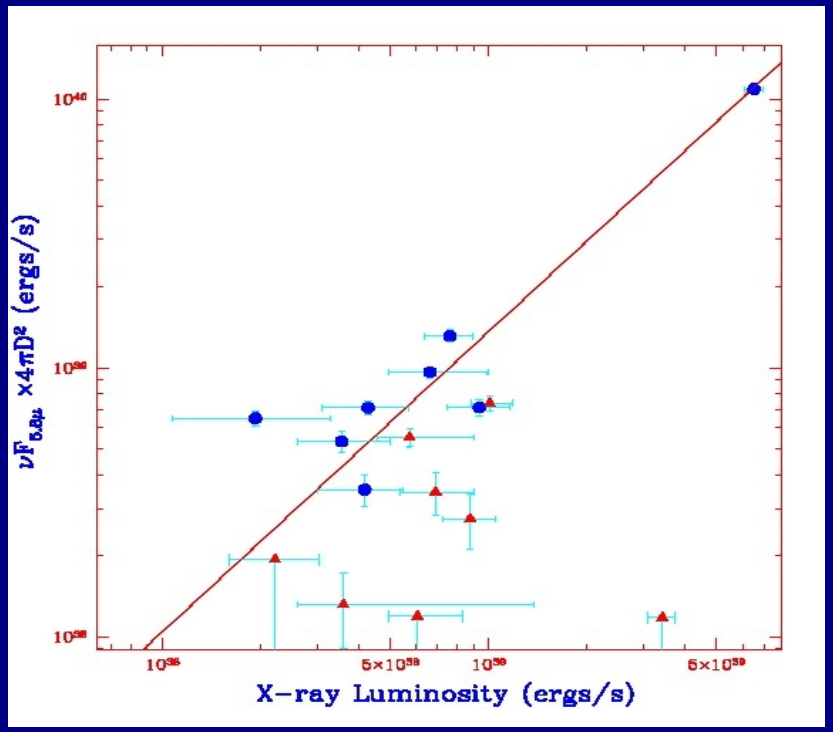
- AGN have positive log(5.8/3.6) flux ratio indicating an additional heating source for dust grains
- Using the same criterion, we find 8 sources in NGC 1399
- High IR luminosities
- Very good correlation between the X-ray and MIR luminosities
- Co-efficient = 0.91, p=0.002
- Better than with counts

MIR – X-ray correlation for remaining sources



- No correlation between MIR and X-ray luminosities
- 3.6μm v/s X-ray - Co-efficient = 0.29, p=0.49

5.8 micron v/s X-ray



- Positive ratios (cirlces)
- 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.