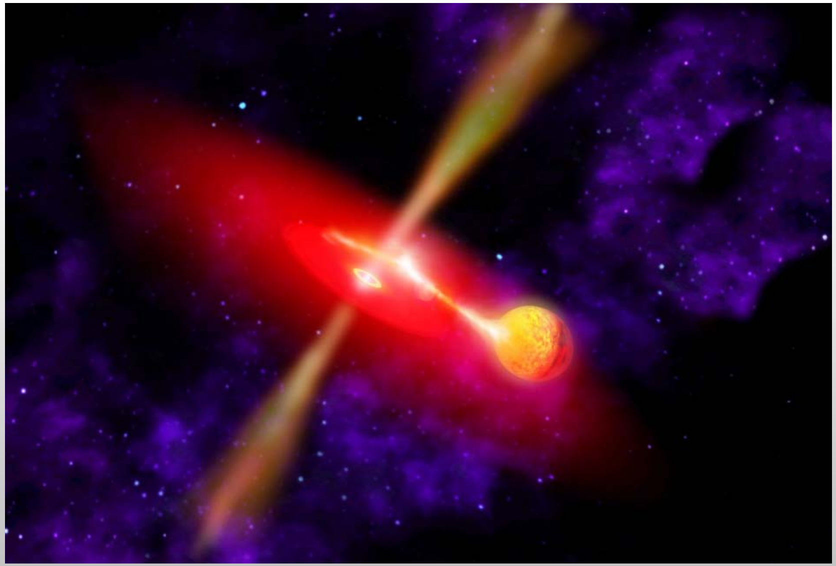
A deficit of ultraluminous X-ray sources in luminous infrared galaxies



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Stefano Mineo (CfA and Durham)

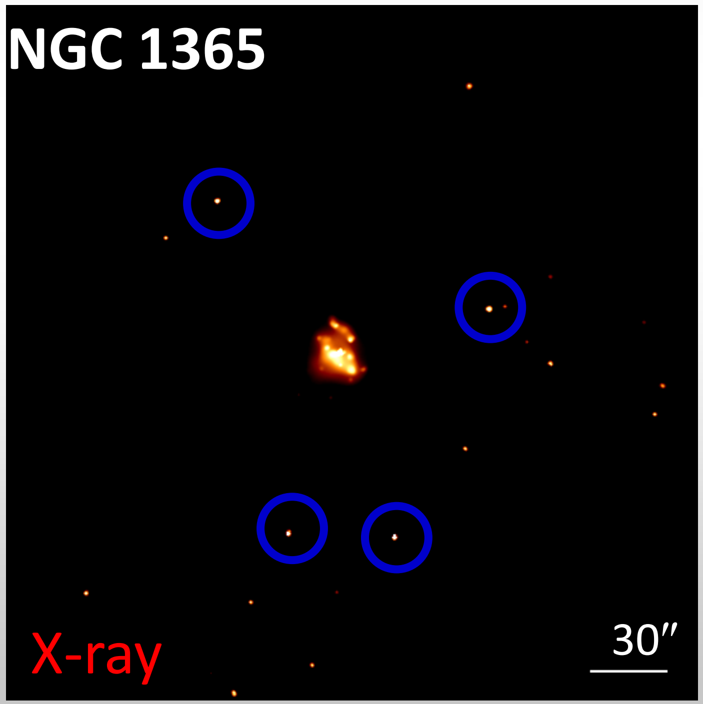
Bret Lehmer (Johns Hopkins)

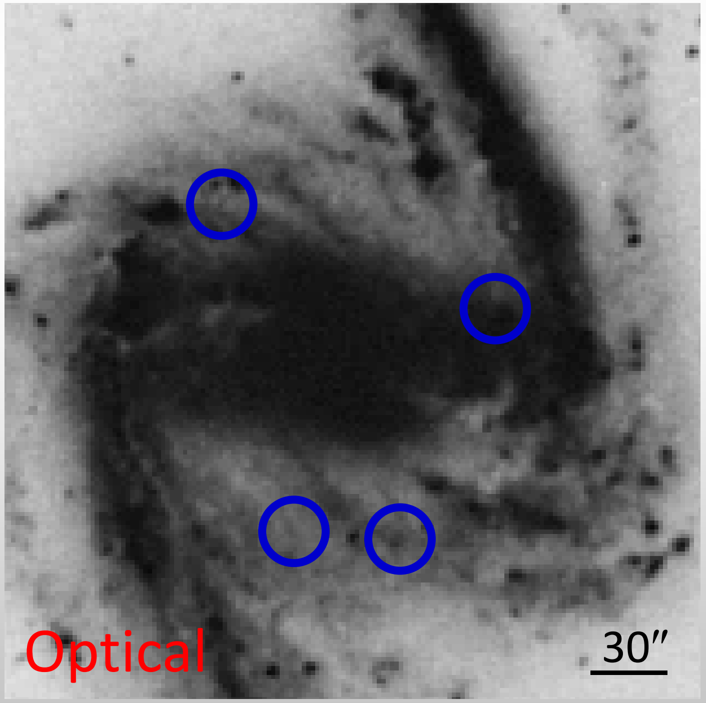
David Alexander (Durham)

et al…

Ultraluminous X-ray Sources (ULXs)

- Extragalactic X-ray sources with $L_x > 10^{39}$ erg s^{-1}
- Non nuclear point-like sources; cannot be SMBHs



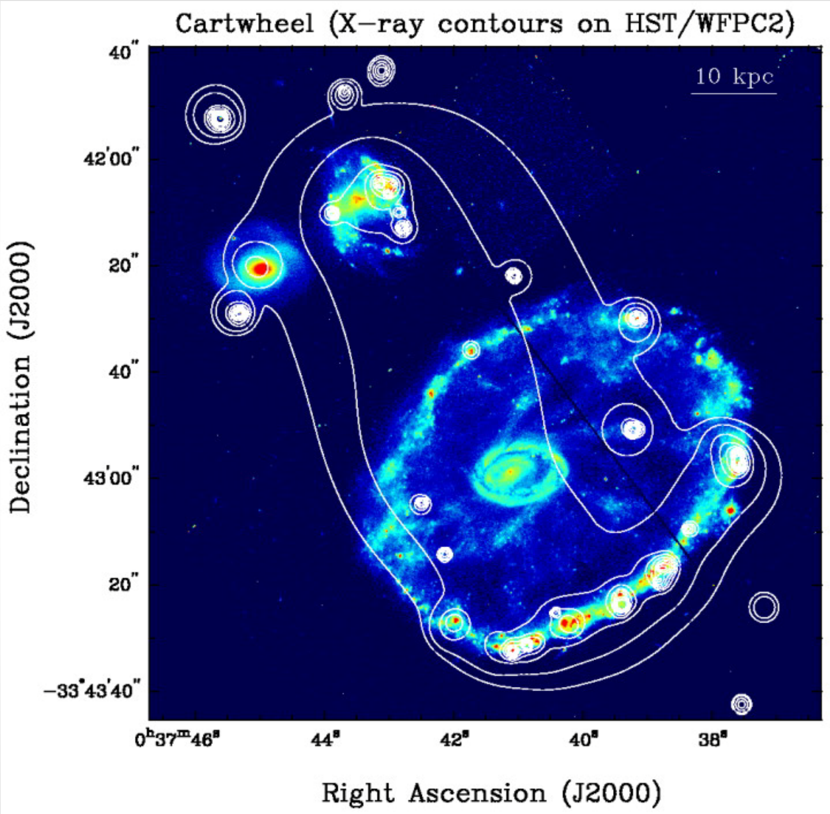


Possibilities for ULXs

- **Intermediate mass black holes** that accrete material at sub-Eddington rates
- **Stellar mass black holes** that accrete material at super-Eddington state

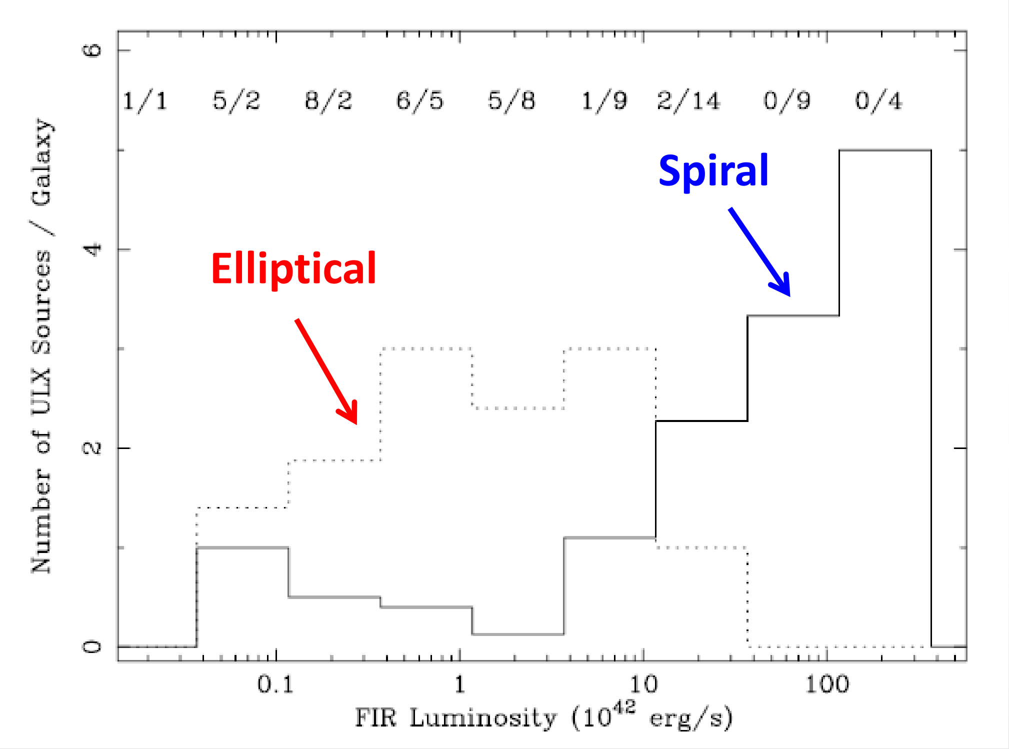
ULX population

- Generally found in all types of galaxy.
- Majority found in spiral galaxies.
- Colliding or interacting galaxies have largest individual populations.
- Tends to be found in star-forming regions.



Gao et al. (2003)

ULX population

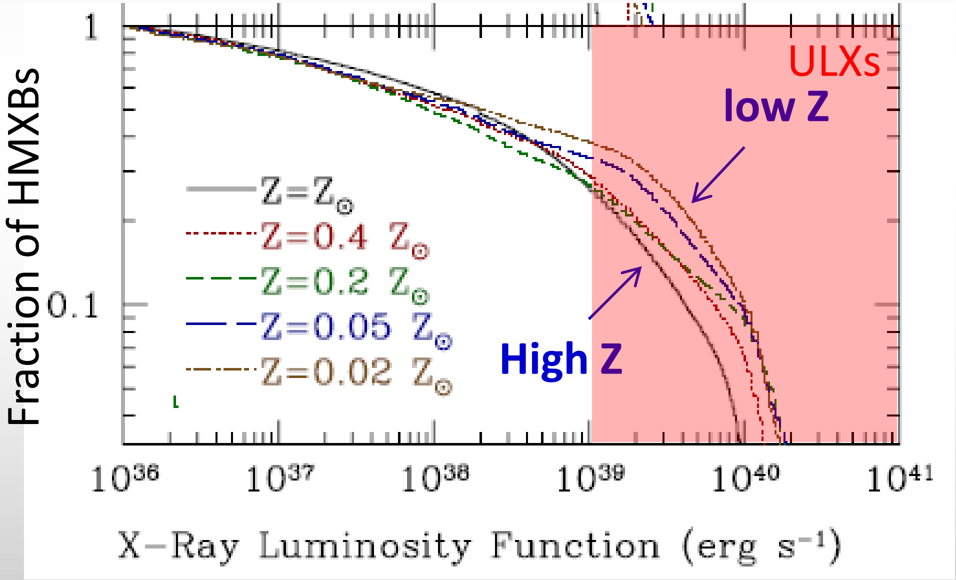


Swartz et al. (2004)

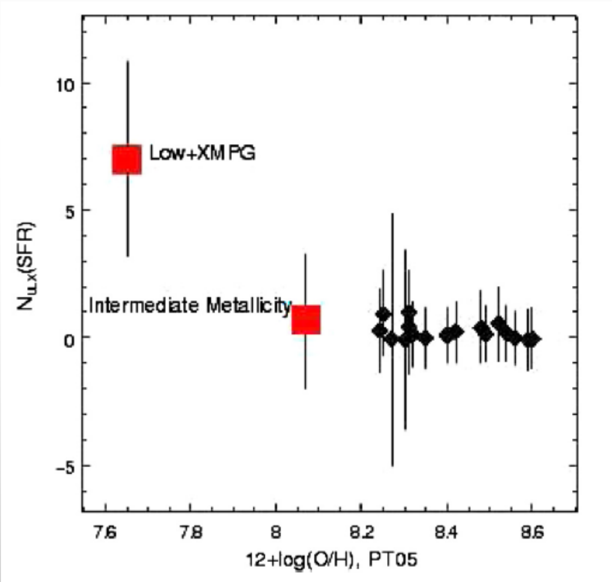
Expectation that one will detect many ULXs in high star formation rate galaxies such as U/LIRGs.

Effect of metallicity

ULX formation is more efficient in low metallicity galaxies.



Linden et al. (2010)



Prestwich et al. (2013)

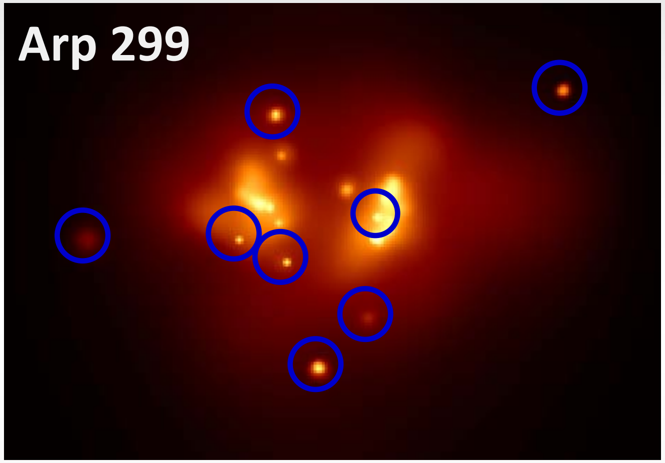
Work outline

ULXs in 17 LIRGs
(SFR > 7 $M_{\odot}$ yr^{-1} , $Z \sim Z_{\odot}$)

- Population study
  - X-ray luminosity functions
  - Number of ULXs per unit luminosity
- Spectral analysis

Detected ULXs

- From 17 LIRGs with $N_H \leq 5\times10^{20}$ cm^{-2} and 14 Mpc $\leq D_L \leq$ 60 Mpc
- **53 ULXs** were detected
- <9 sources might be background contamination.
- Statistically complete sample (<10% of ULXs are missing).



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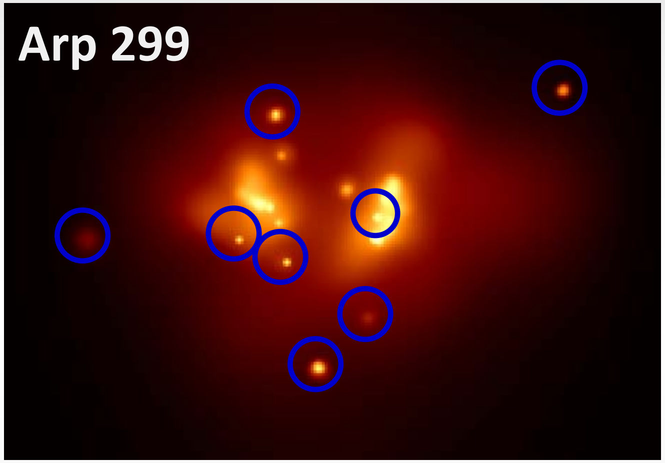
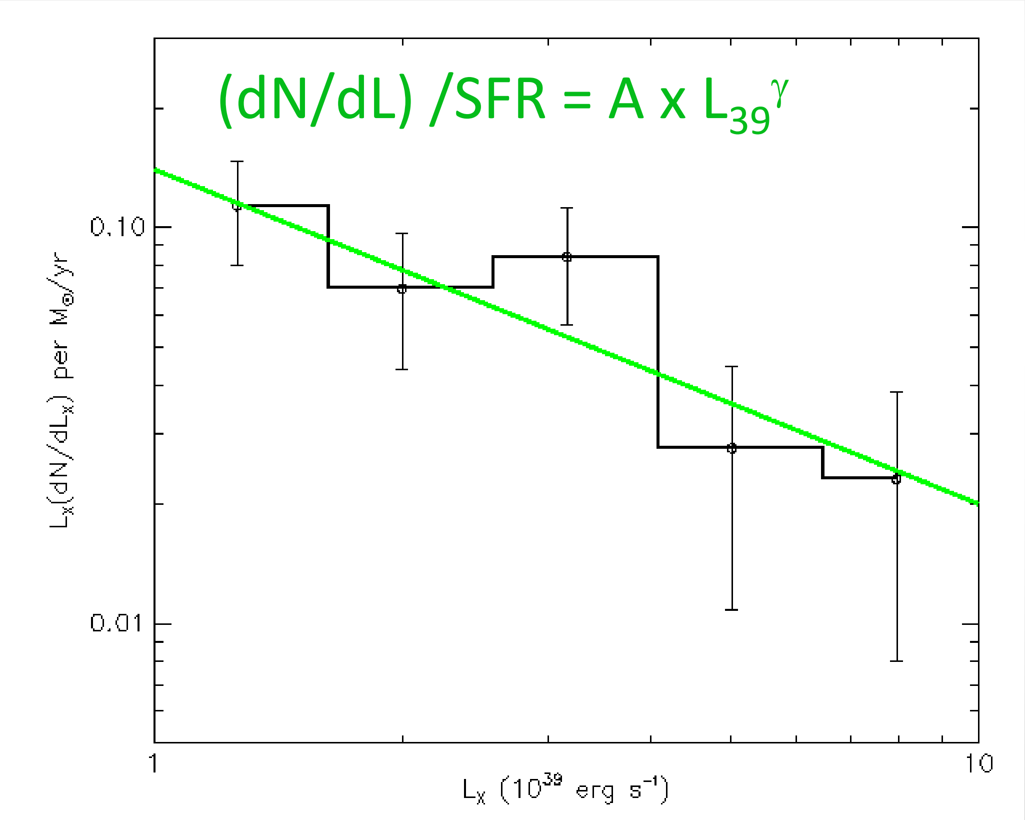


Swartz et al. (2011) sample has 2 ULXs per unit SFR.

~**500 ULXs** should be detected in the LIRG sample but only ~1/10 detected!

X-ray luminosity function

Differential form

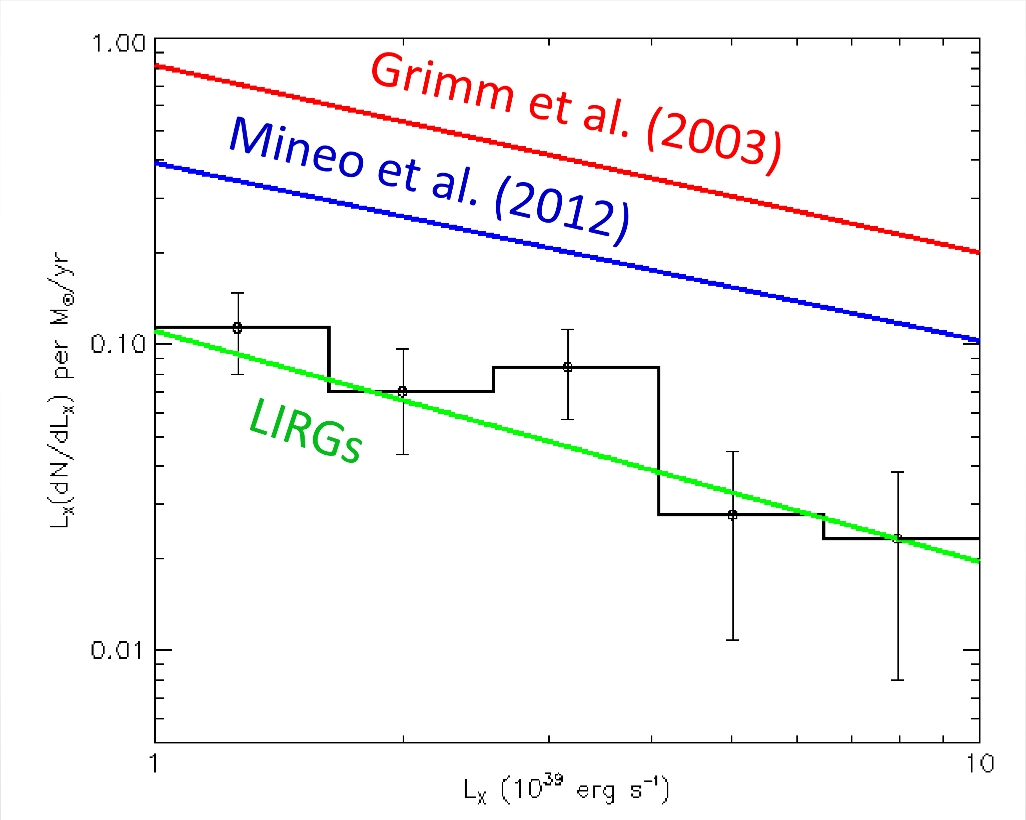


Construct and fit with pure power-law model

Slope = -1.75 ± 0.25
A = 0.11 ± 0.02

X-ray luminosity function

Differential XLF

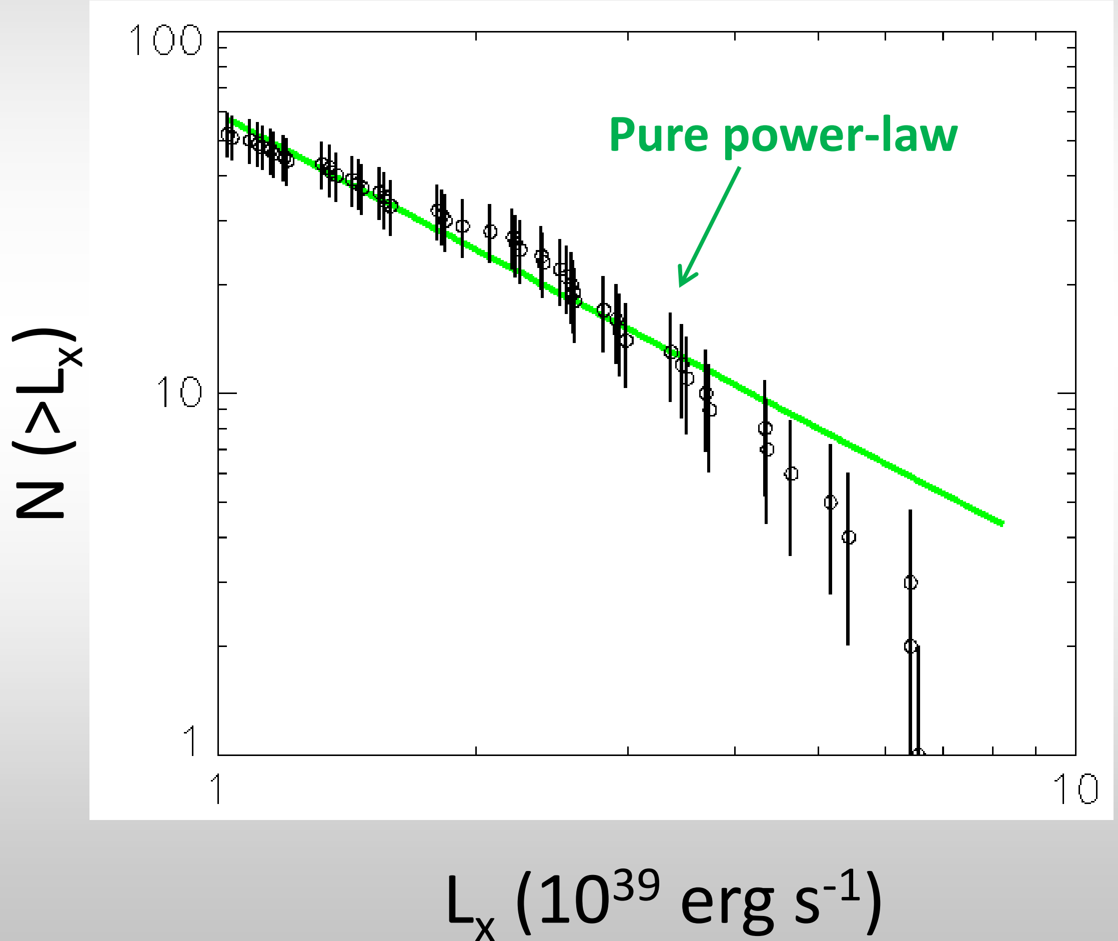


Compare with literatures

- Slope is consistent with that of HMXBs.
- But normalisation is lower.
- Support a deficit of ULXs in the sample.

X-ray luminosity function

Cumulative XLF



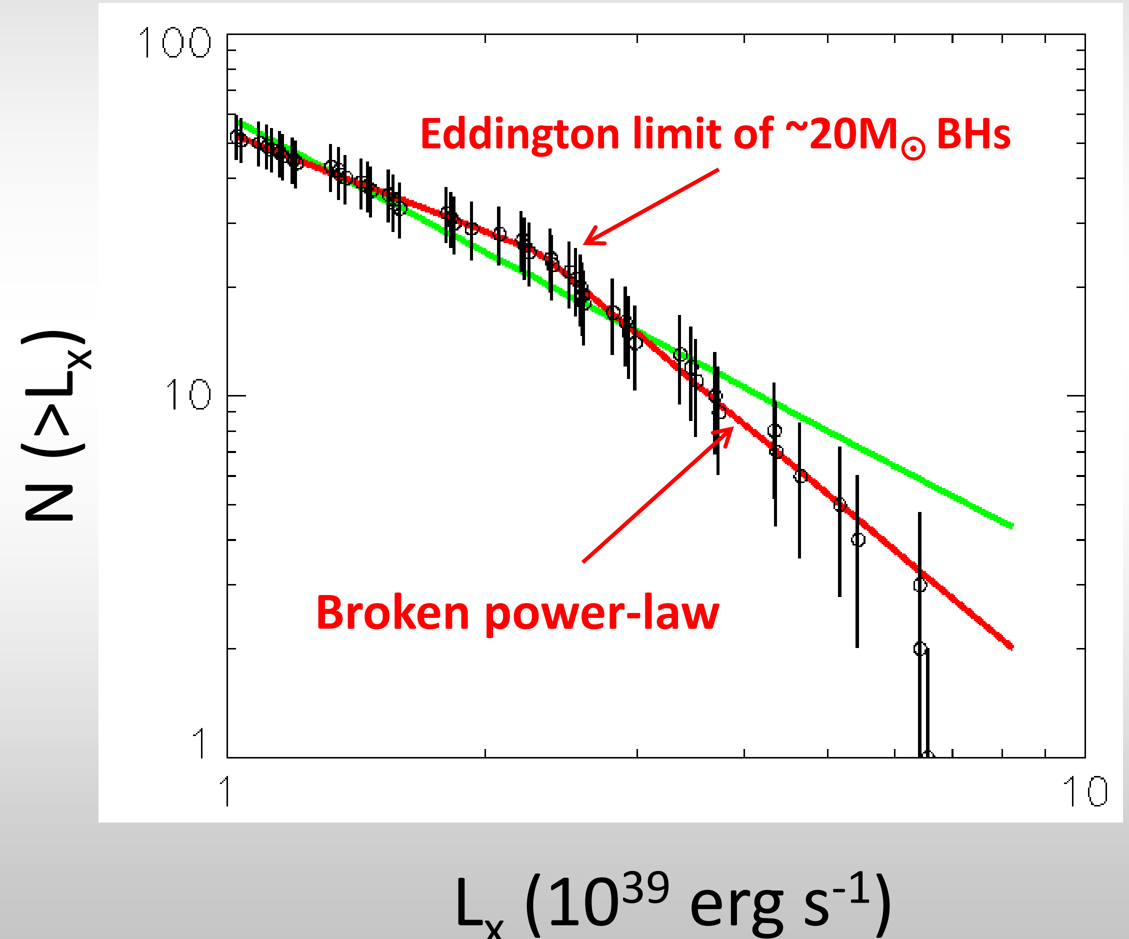
Construct and fit with pure power-law model

Slope = -1.2 ± 0.1

Stat. / d.o.f. = 16.4 / 48

X-ray luminosity function

Cumulative XLF



Slope 1 = -0.9 ± 0.2
Slope 2 = -2.0 ± 0.5
Break L_x = 2.3 ± 0.5 keV
Stat. / d.o.f. = 1.2 / 46

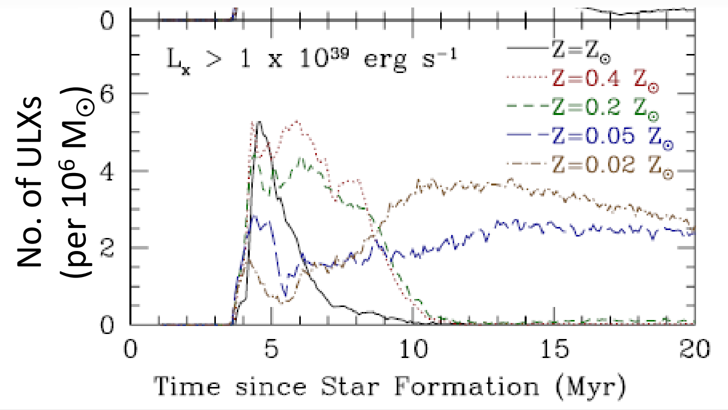
Might be difficult to form massive stellar black holes in regions of ~ solar metallicity.

Metallicity effect?

- Prestwich et al. (2013) show that the number of ULXs formed in high metallicity environments is **only suppressed by a factor ~2** compared to lower metallicity regions.
- This effect alone cannot explain the deficit of ULXs by factor of ~10.

Stellar population is too young?

Need 5-10 Myr for ULX population to form

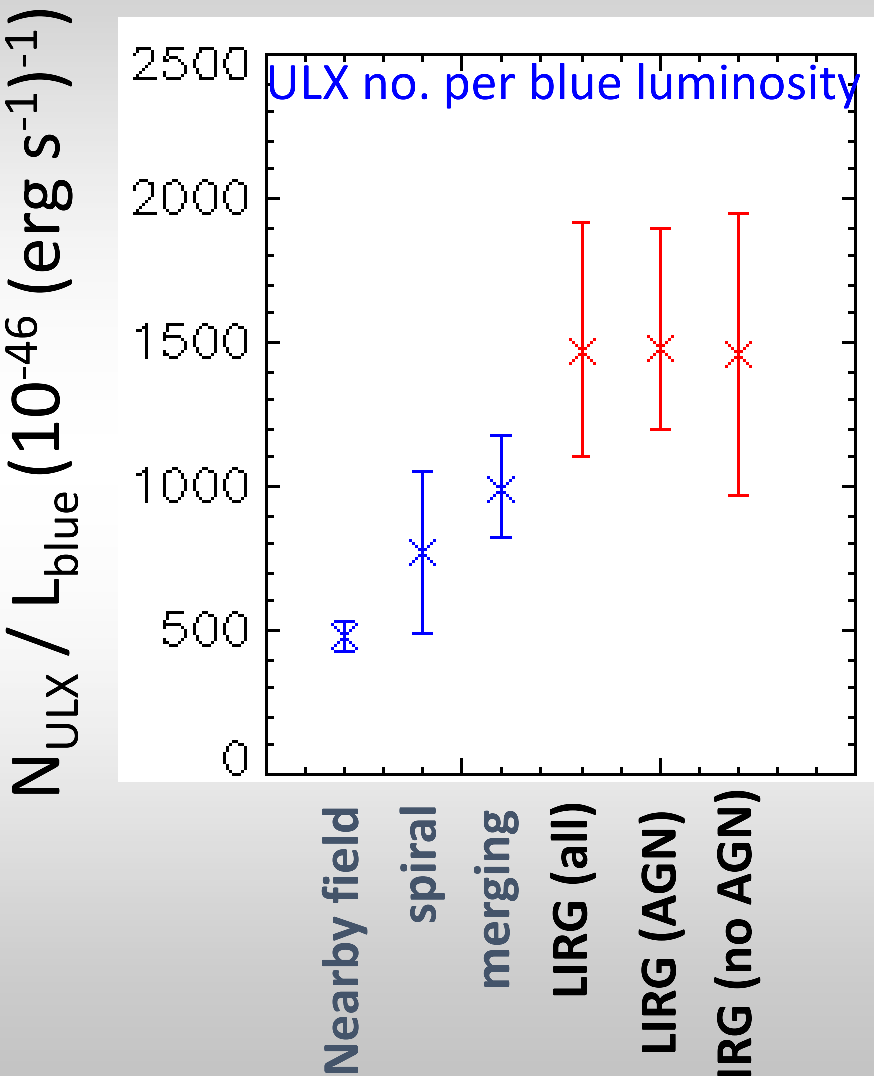


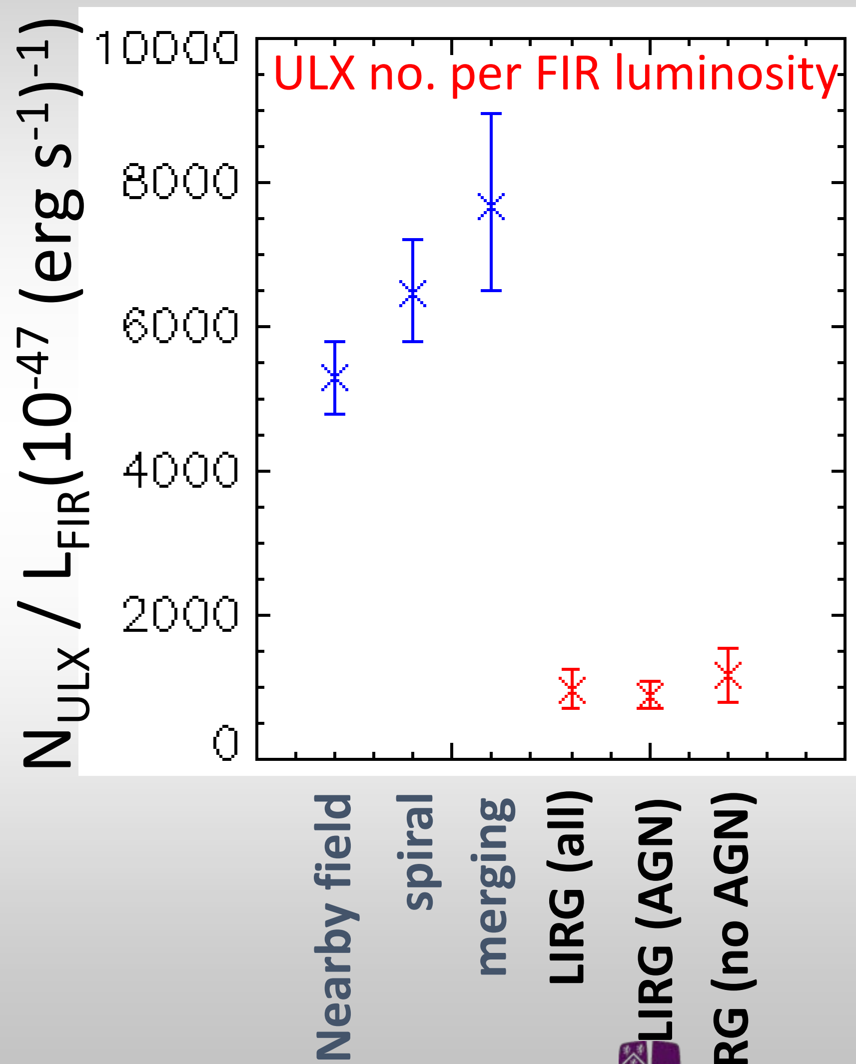
Linden et al. (2010)

- Bracket γ and FIR correlation showed that the star formation age of LIRGs is > 10 Myr (Goldader et al. 1996).
- SED estimates of the star formation age of U/LIRGs between 5 -100 Myr (Vega et al. 2008).

it seems unlikely that the LIRGs are too young switch on ULXs.

Number of ULX per unit luminosity

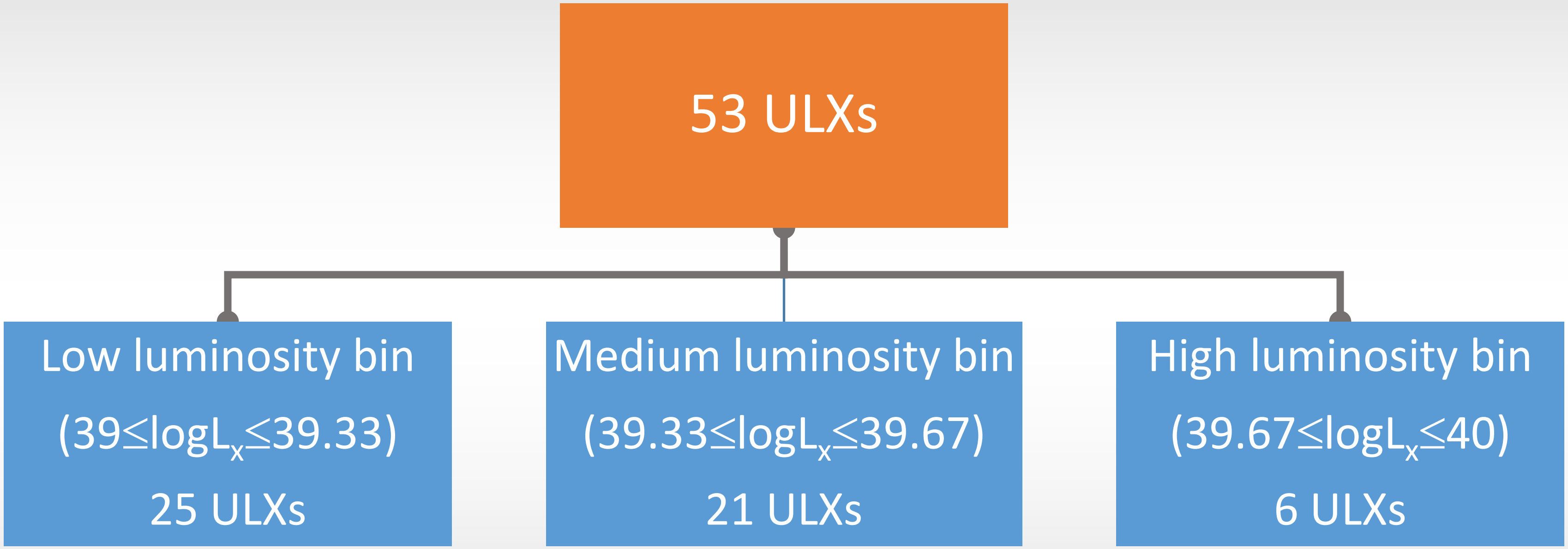




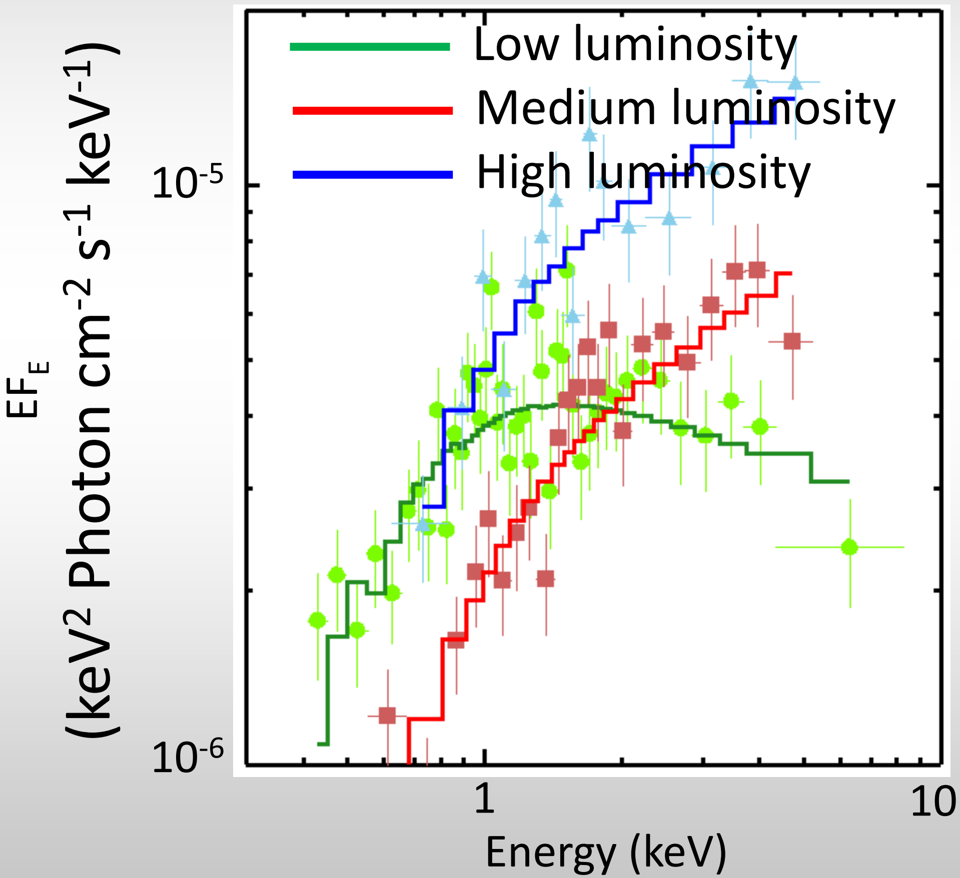
High level of dust in LIRGs

- Suppress the blue light of the galaxies via absorption/extinction
  - ➢ high number of ULX per unit blue luminosity
- Also substantially increasing the FIR luminosity.
  - ➢ low number of ULX per unit FIR luminosity
- Obscure most of ULXs from our view.
- Support by optical surveys of core-collapse supernovae: 17% are detected! (Horiuchi et al. 2011; Mattila et al. 2012)

Spectral analysis



Spectral analysis



Fit with absorbed power-law model

We are seeing a change in accretion stage from disc-dominated to super-Eddington stage (see Sutton et al. 2013).

Conclusion

- We see a large deficit of ULXs in LIRGs.
- Metallicity and star formation age may have some influence on ULX numbers.
- The main deficit could be explained by the high levels of dust in LIRGs, obscuring the bulk of their ULX population.
- A stacked spectra support the accretion state changing from ~Eddington rate disc-like spectra to super-Eddington 'ultraluminous' state above ~$2x10^{39}$ erg s^{-1}.