

MAC1331+4707

IC4277

# SPECTRAL ANALYSIS OF ULXs IN PAIRS OF INTERACTING GALAXIES M51 AND NGC 4485/90 USING SWIFT-XRT

MAC1330+4701

Sulistiyowati (M51)

MAC1328+4723

K. Vierdayanti, H. R. T. Wulandari, P. W. Premadi, M. Priajana

*Dept. of Astronomy, Institut Teknologi Bandung, Indonesia*

MAC1329+4700



MAC1328+4712

**Texas Symposium on Relativistic Astrophysics 2015, Geneva**

Image courtesy: NASA

## Objectives:

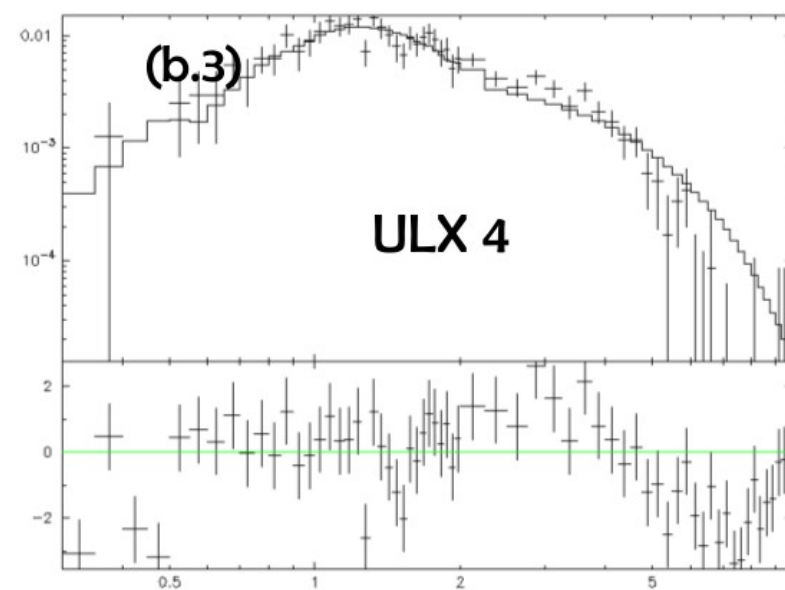
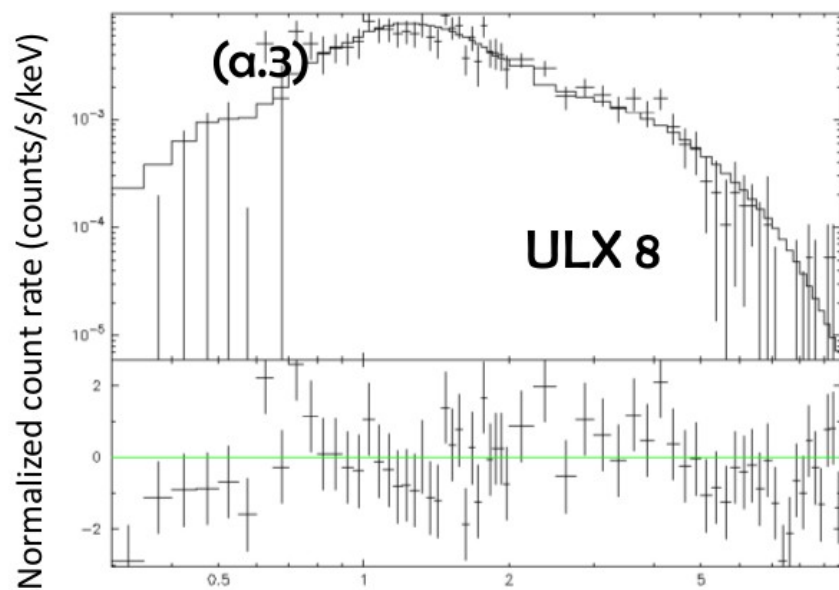
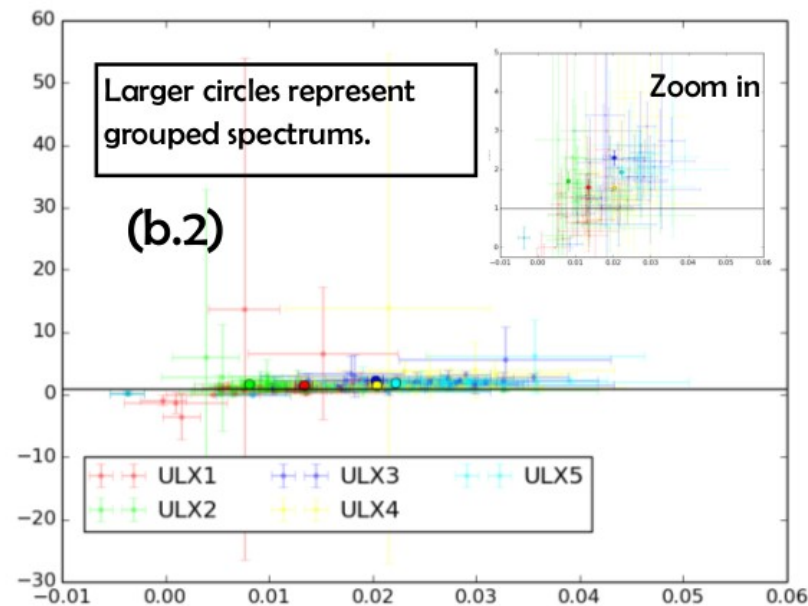
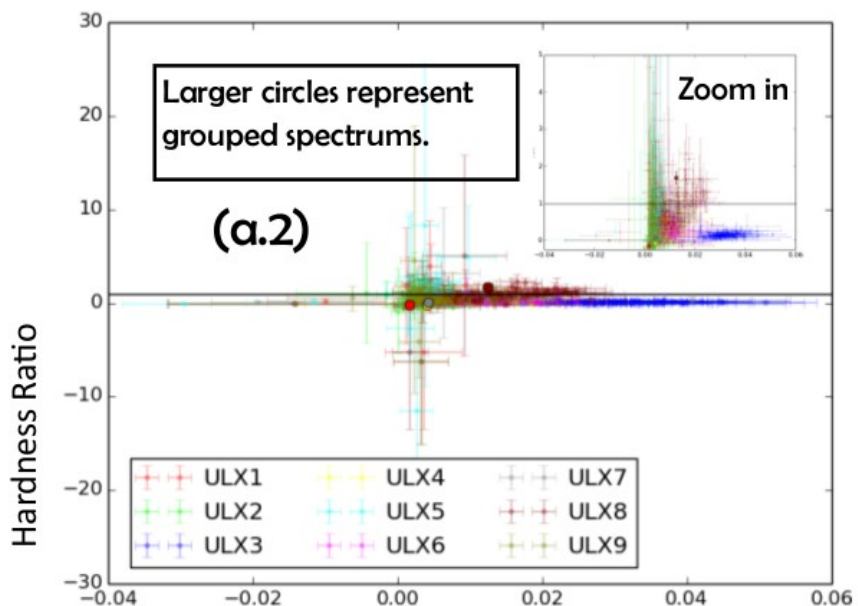
Studying the nature of ULXs ( $L_x \sim 10^{39} - 10^{41}$  erg/s) by looking at them as a population.

### Idea:

- More average number of ULXs in interacting galaxies (Swartz *et al.* 2004; 2011)
- Swift XRT → monitoring → a lot of data,  
spans: 2004 – today  
short exposure → combine spectra with similar characteristic

# Summary:

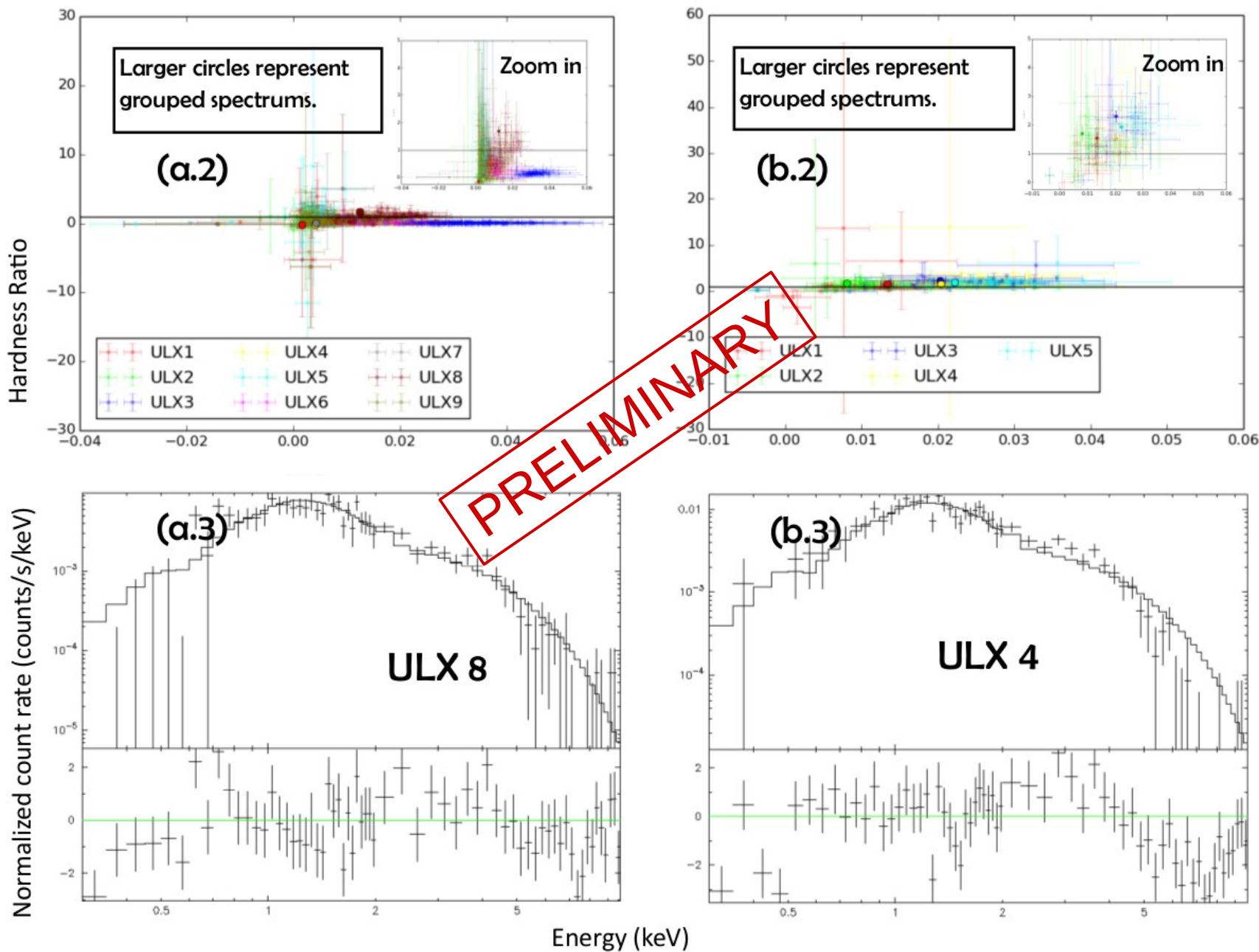
**M51 → spectral transition (MCD, PL); NGC 4485/90 → uniform spectra (PL)**



Energy (keV)

# Summary:

**M51 → spectral transition (MCD, PL); NGC 4485/90 → uniform spectra (PL)**





# Poster #13, Thank you,. :)

## SPECTRAL ANALYSIS OF ULXs IN PAIRS OF INTERACTING GALAXIES M51 AND NGC 4485/90 USING SWIFT-XRT

Author : Sulistiyowati<sup>1</sup>

Co-authors : Kiki Vierdayanti<sup>1</sup>, Hesti R. T. Wulandari<sup>1</sup>, Premana W. Premadi<sup>1</sup>, Mahadipa Priajana<sup>1</sup>, Fabrie A. Azizi<sup>1</sup>  
<sup>1</sup>Dept. of Astronomy Institut Teknologi Bandung, Jl Ganesa 10 Bandung, Indonesia



### ABSTRACT

In this study, we report the examinations of the spectra of ULXs in two nearby (< 10 Mpc) pairs of interacting galaxies M51 and NGC 4485/90 collected by Swift-XRT observations from 2005 to 2014 and 2008 to 2016 for each target, respectively. We consider 9 ULXs in M51 and 5 ULXs in NGC 4485/90. We obtain 116 ObsIDs of M51 and 37 ObsIDs of NGC 4485/90. For each pair of interacting galaxy, there are about 10% data that do not meet our criteria for further Analysis.

The count rate of individual observation ranges from 0.00003 to 0.05 counts/s in 0.3-10 keV band with typical error bar ~30%. Some ULXs in M51 exhibit a considerable fluctuation of intensity, up to three times, from 0.01 counts/s to 0.03 counts/s. ULXs in NGC 4485/90 show more stable light curves with no significant changes in intensity. For every source, we divide the data into two categories, e.g. hard-state (those with hardness ratio > 1) and soft-state (those with hardness ratio < 1). Due to the short exposure time during the observations, we got low S/N data with wide error bar. Therefore, we combine spectrum from many observations with similar spectral characteristics for fitting purpose. We fit the co-added spectra with commonly used models: disk blackbody, power law and the combination of several models.

### 1 INTRODUCTION

Ultraluminous X-ray sources (ULXs) are bright, off-nuclear X-ray sources whose luminosity ranges between  $10^{41} - 10^{42}$  erg/s. The nature of ULXs remains an open question since its discovery in 1970s until today. ULXs are found in all morphological types of galaxies (Swarz et al. 2004; 2011) although most of them are observed to reside spiral galaxies. Study of ULXs are commonly focused on bright ones and those located in nearby galaxies (in the order of several Mpc). This yields bias due selection effect if that kind of study is going to be used to describe general properties of ULXs.

We aim to study ULXs as a population in a galaxy. Interacting galaxies are known to host a higher average number of ULXs (S. 2). Therefore it is interesting to study ULXs as a population in interacting galaxies, as the first step for population study of ULXs. For this purpose, we choose M51 and NGC 4485/90 interacting galaxies as our main concern.

### 2 Swift-XRT Data

M51  
 196 ObsIDs (05-14) d = 8.4 Mpc: 9 ULXs

ID	RA (J2000.0)	Dec (J2000.0)
ULX0	12 19 43	+71 43 70
ULX1	12 19 43.0	+71 43 70
ULX2	12 19 43.0	+71 43 70
ULX3	12 19 43.0	+71 43 70
ULX4	12 19 43.0	+71 43 70
ULX5	12 19 43.0	+71 43 70
ULX6	12 19 43.0	+71 43 70
ULX7	12 19 43.0	+71 43 70
ULX8	12 19 43.0	+71 43 70
ULX9	12 19 43.0	+71 43 70

NGC 4485/90  
 37 ObsIDs (08-15) d = 7.8 Mpc: 5 ULXs

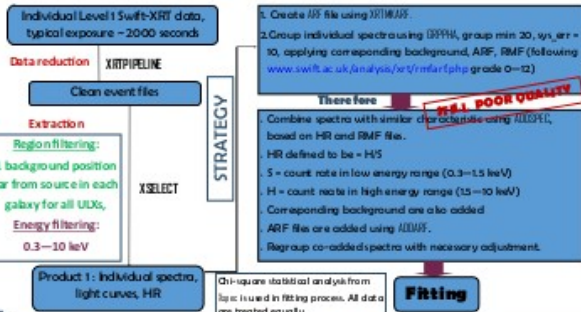
ID	RA (J2000.0)	Dec (J2000.0)
ULX0	12 00 40.0	+41 48 00
ULX1	12 00 40.0	+41 48 00
ULX2	12 00 40.0	+41 48 00
ULX3	12 00 40.0	+41 48 00
ULX4	12 00 40.0	+41 48 00

Number of ULXs and their position are taken from Liu & Meinel (2004).  
 Adapted from Verbeke et al. 2007, A&AS, from July 2008

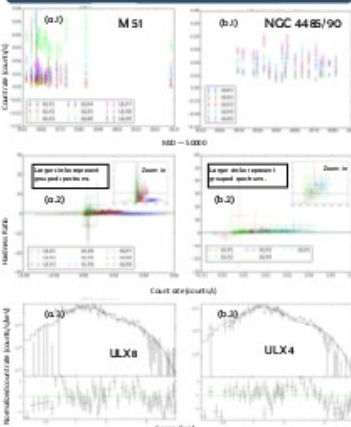
### Remarks

This research is funded by STP Research Grant. Thanks you for Prof. L. Koper for granting our LAMP Grant (Abdulloh-Abdulloh Family) to cover the trip and Dr. Mahadipa Priajana for helping us with the application. The big plus for the supporting committee of STP Team. Special thanks you to R. Astuti for helping us to make this presentation possible.

### 3 DATA PROCESSING with HEASOFT v6.16



### 4 RESULT and DISCUSSION



Figures 0 refer to M51, 1 to NGC 4485/90. The light curves (sample on Figures 1), show ULXs in M51 have more fluctuations than those in NGC 4485/90. Figure 2 provides all hardness ratio from Product 1 which is used to justify spectral addition. Figure 3 give sample of spectral fitting in both galaxies using simple power law.

Spectral fitting are successfully carried out for 3 ULXs in M51 and 5 ULXs in NGC 4485/90. Fitting parameters are given in the bottom tables. ULXs in M51 show spectral transition and can be described by power law (PL) and multi color disks (MCD) while ULXs in NGC 4485/90 are more uniform. They can be explained by simple power law (PL). ULXs with HR greater than or equal to 1 belong to hard class, while the others belong to soft class.

Other ULXs in M51 do not give good fitting and need further special treatment. Some of them give negative value of count rate after being subtracted by background. Reduced chi square value are high since the data quality are still poor even after spectral addition. This is a preliminary result.

- Future plan:
- Use better statistical method for spectral analysis.
  - Try other background locations.
  - Add spectrums with different RMF

Fitting parameters of 4 ULXs in M51

ID	$n_H(10^{22} \text{ cm}^{-2})$	PL $_{\text{index}}$	$kT_{\text{diskbb}}$ (keV)	Chi square/dof	Class	Model
ULX1	0.98 +/- 0.14	2.28 +/- 0.24	63.6/50		Hard	PL
ULX2	0.64 +/- 0.12	2.23 +/- 0.24	35.5/35		Hard	PL
ULX3	1.04 +/- 0.16	2.28 +/- 0.18	46.4/32		Hard	PL
ULX4	0.38 +/- 0.07	1.82 +/- 0.13	51.6/30		Hard	MCD

Fitting parameters of all ULXs in NGC 4485/90

ID	$n_H(10^{22} \text{ cm}^{-2})$	PL $_{\text{index}}$	Chi square/dof	Class	Model	
ULX0	0.88 +/- 0.09	3.12 +/- 0.03	57.24/53		Hard	PL
ULX1	0.88 +/- 0.09	3.12 +/- 0.03	57.24/53		Hard	PL
ULX2	0.88 +/- 0.09	3.12 +/- 0.03	57.24/53		Hard	PL
ULX3	0.88 +/- 0.09	3.12 +/- 0.03	57.24/53		Hard	PL
ULX4	0.88 +/- 0.09	3.12 +/- 0.03	57.24/53		Hard	PL

