



# Showing spectral variability in AGN by principal component analysis (PCA)

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**SPANISH X-RAY ASTRONOMY 2015, Santander – 4<sup>th</sup> June 2015**

# ● **OUTLINE**

## ● **INTRODUCTION**

1.1- What is PCA?

1.2- Example

1.3- Simulations

## ● **NGC405 I**

2.1- Previous analysis with PCA

2.2- Another observation

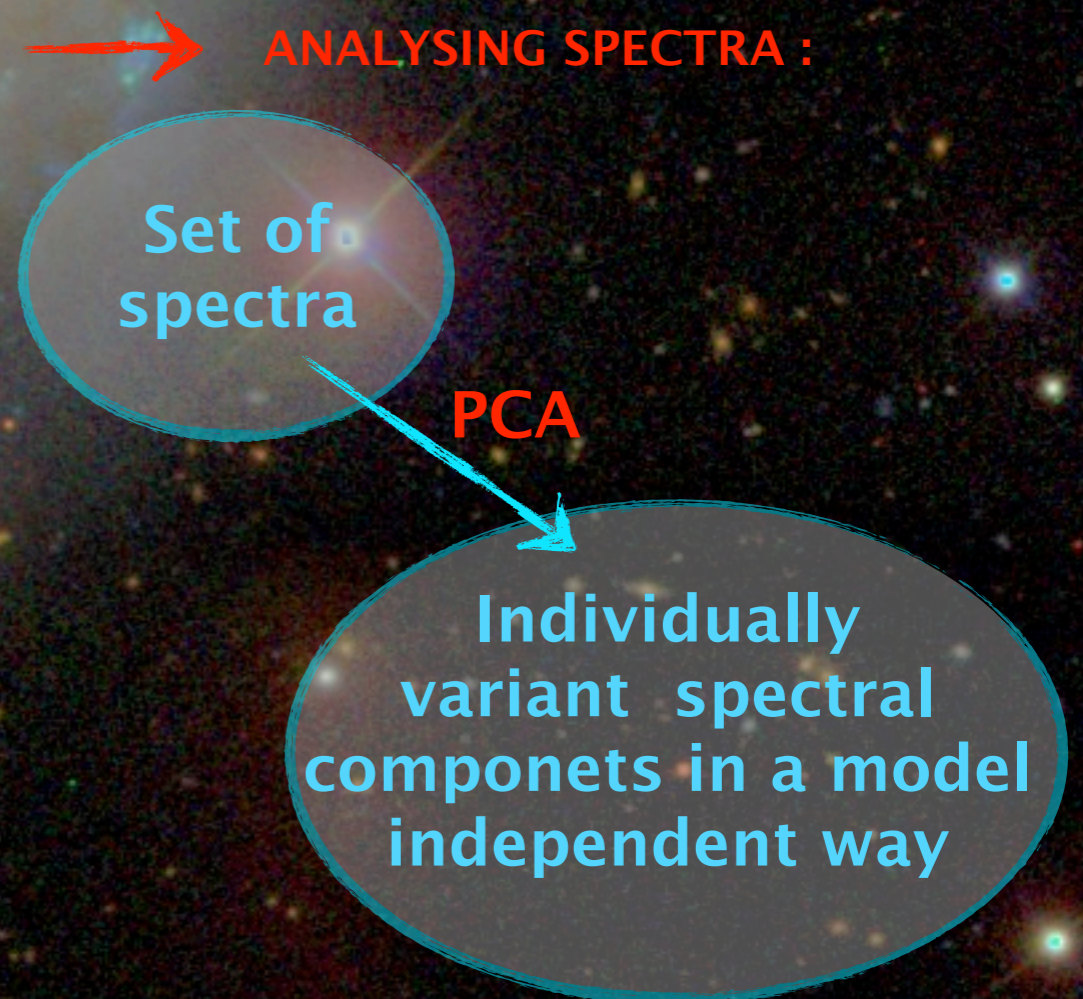
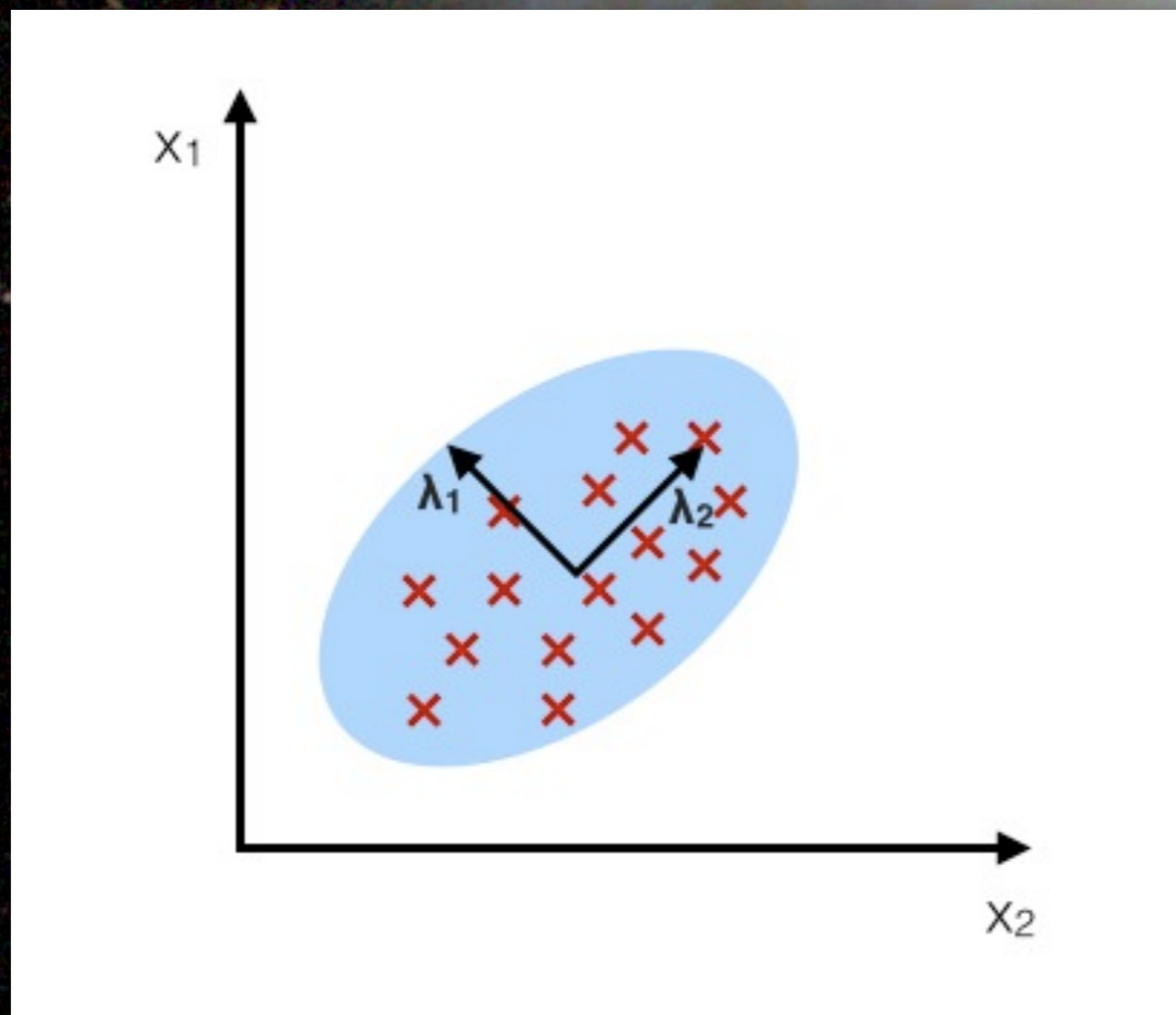
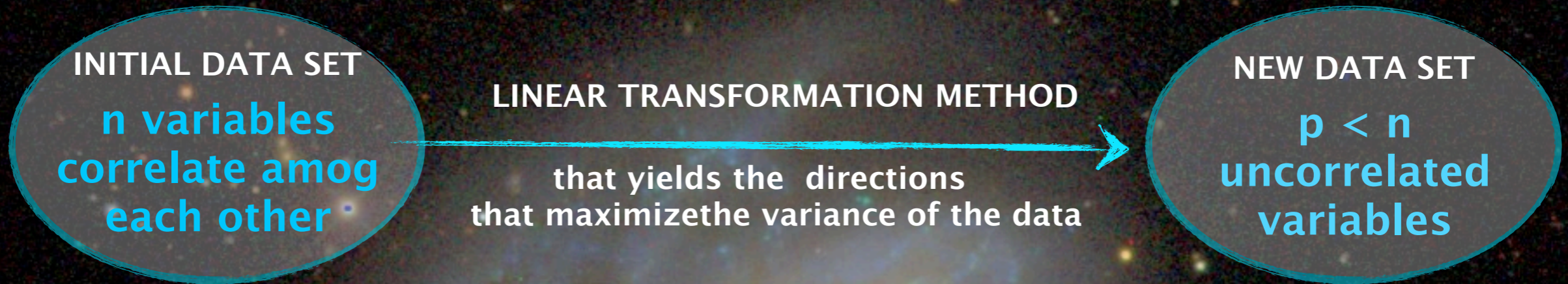
2.3- Further analysis: greatest flux

2.4- Further analysis: lowest flux

## ● **CONCLUSIONS AND FUTURE WORK**

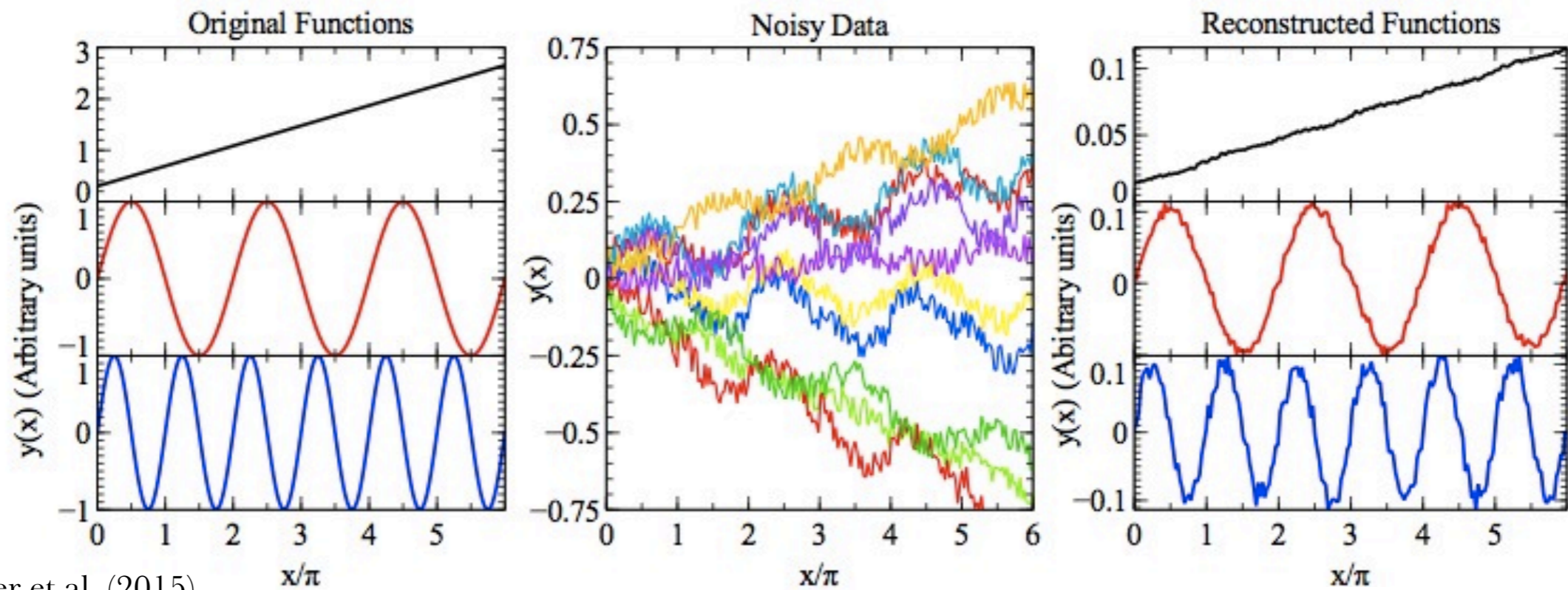
# ● I. INTRODUCTION

## ● WHAT IS PCA?



# ● I. INTRODUCTION

## ● EXAMPLE



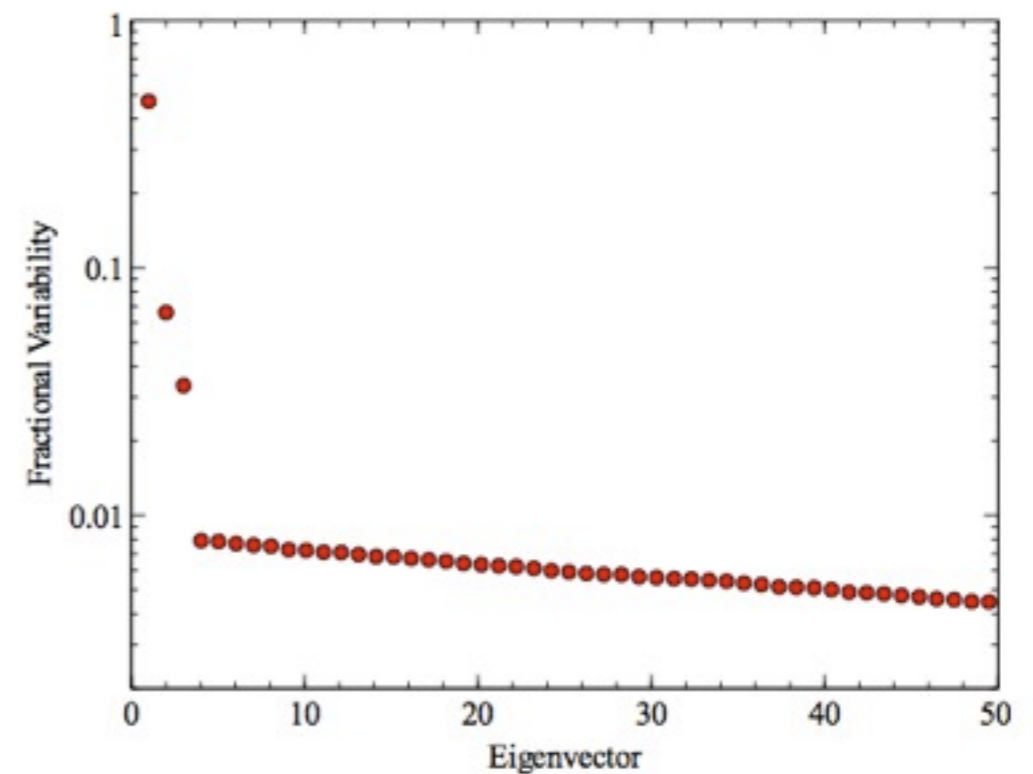
Parker et al. (2015)

$$y_1(x) = 0.3 + x/8$$

$$y_2(x) = \sin(x)$$

$$y_3(x) = \sin(2x)$$

$$y_i(x) = 0.6a_1y_1(x) + 0.2a_2y_2(x) + 0.1a_3y_3(x) + 0.1a_4$$



# ● I. INTRODUCTION

- SIMULATIONS



Number of variable components of the initial spectrum contributing to the variability in a **model independent way**



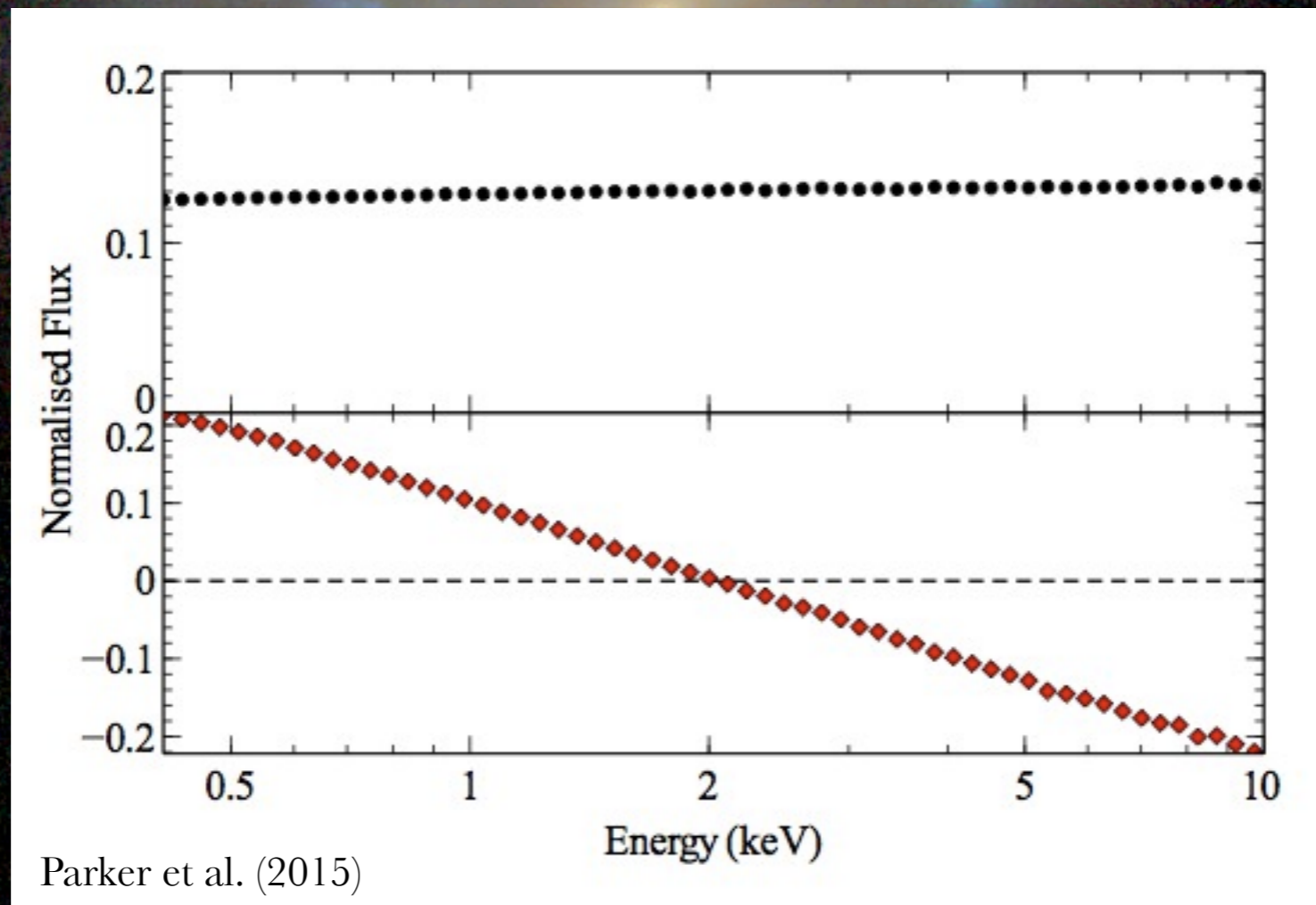
DIFFICULT INTERPRETATION  SIMULATIONS



Timesliced spectra binned in energy



Baseline Model : **POWER LAW** Varying **photon index** and **normalization**

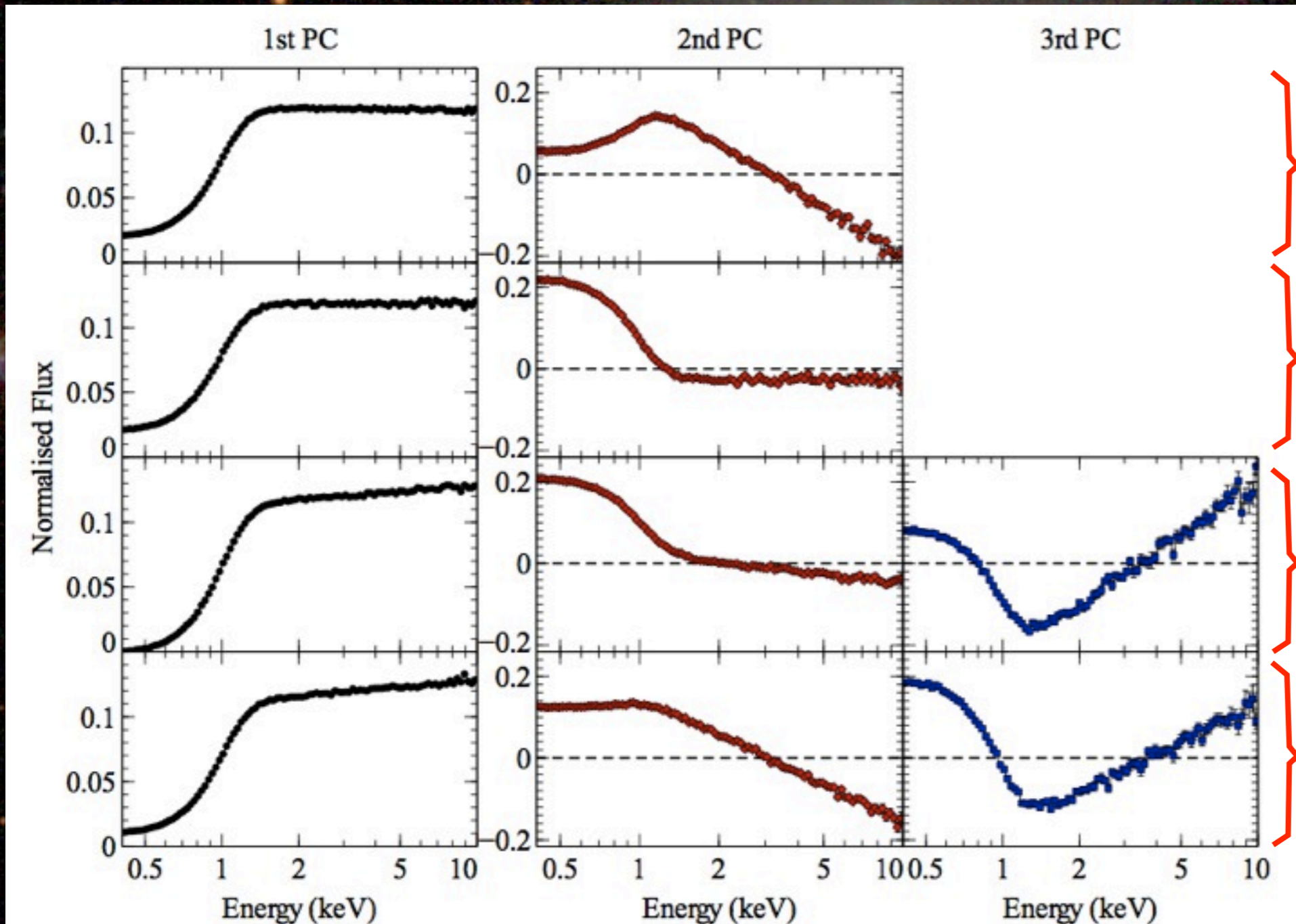


# ● I. INTRODUCTION

## ● SIMULATIONS



**POWER LAW + SOFT EXCESS**



-PP: varying **photon index**  
varying **normalization**  
-BB: **constant**

-PP: varying **normalization**  
-BB: varying **normalization**

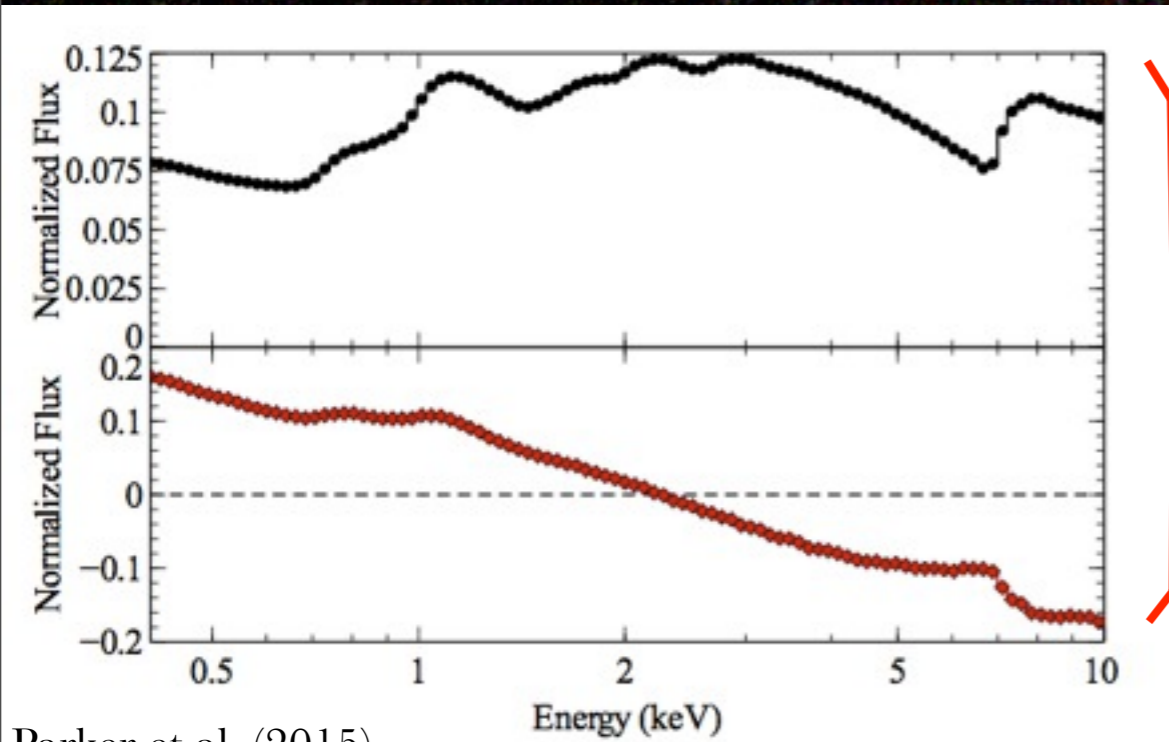
-PP: varying **photon index**  
varying **normalization**  
-BB: varying **normalization**  
(stronger **BB** variations)

-PP: varying **photon index**  
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(stronger **PP** variations)

Parker et al. (2015)

# ● I. INTRODUCTION

## ● SIMULATIONS



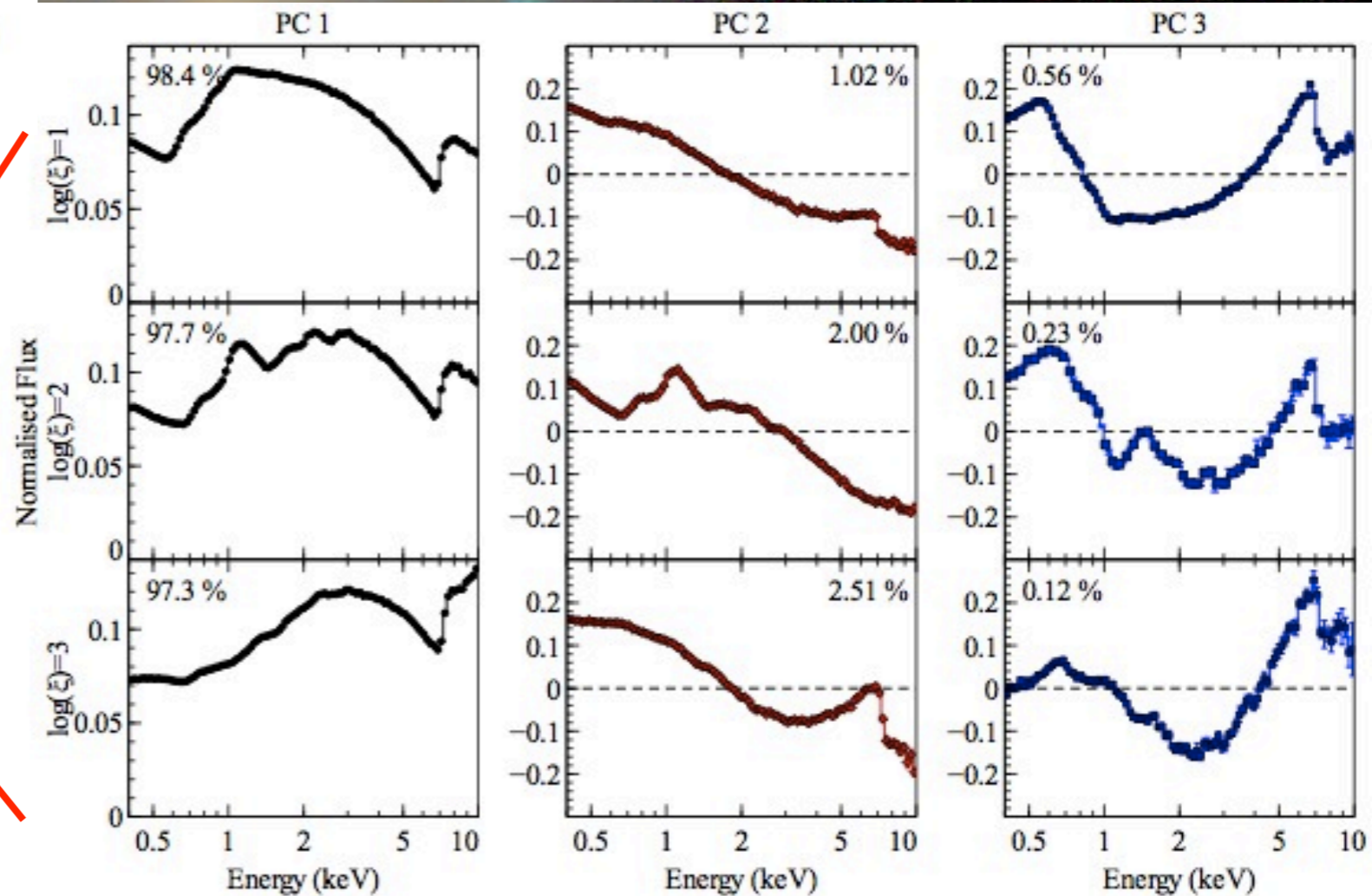
Parker et al. (2015)



**RELATIVISTIC REFLECTION COMPONENT**

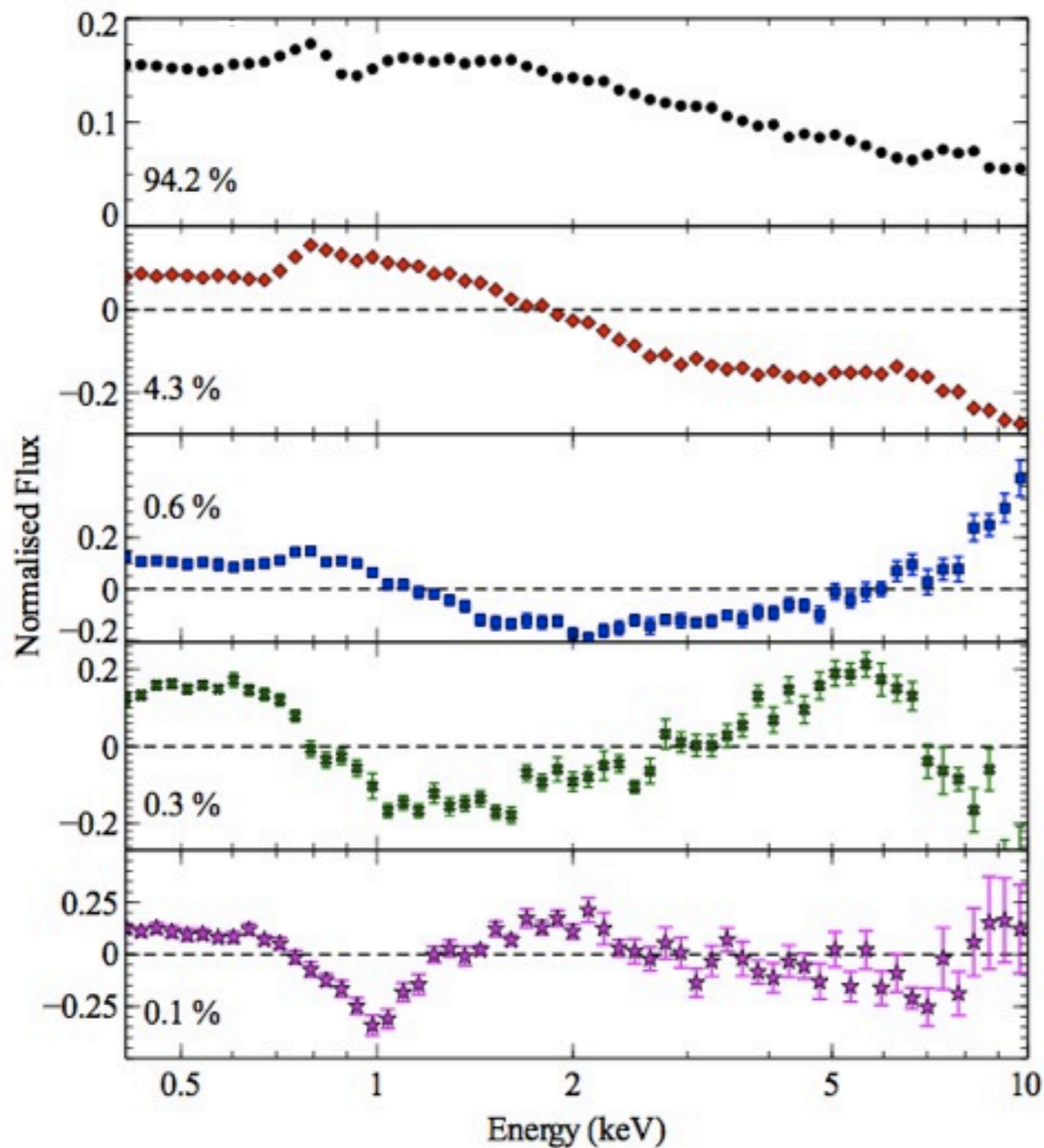
- PP: varying photon index
- varying normalization
- RR: constant

**-PP varying stronger than RR**



# ● 2. NGC 405 I

## ● PREVIOUS PCA ANALYSIS



Parker et al. (2015)

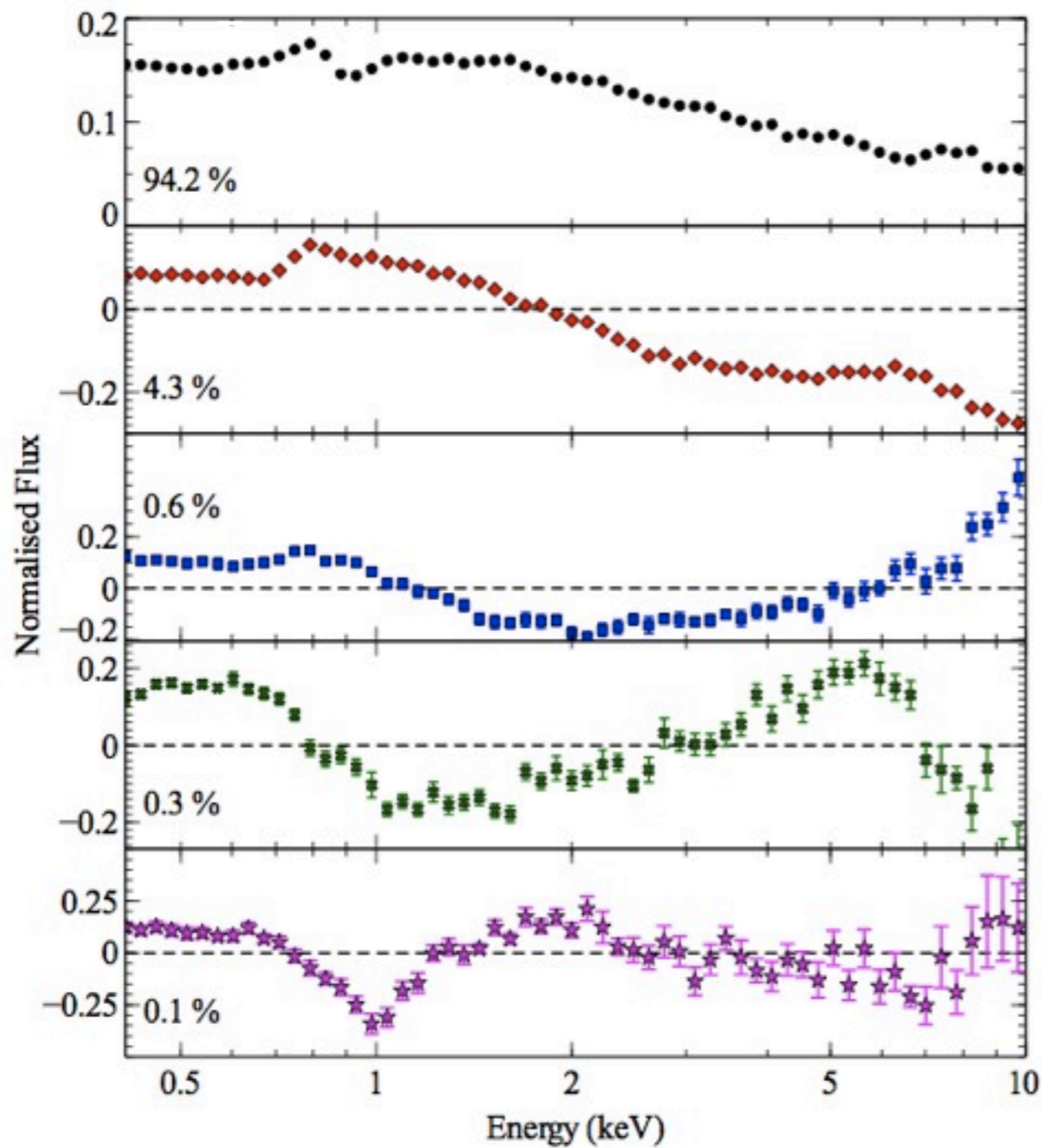
14 OBSERVATIONS  
~40ks

ΕΥΓΕΙΛΑ (ΥΓΛ)



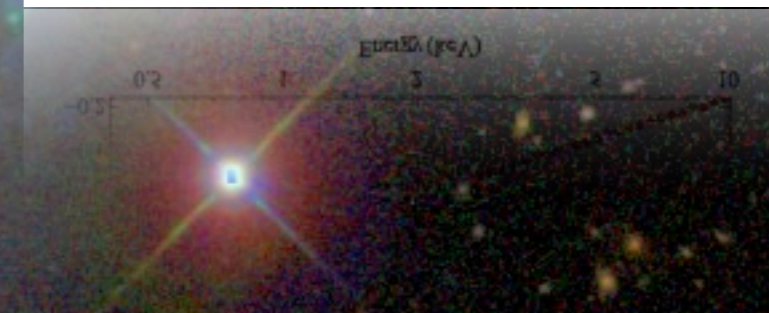
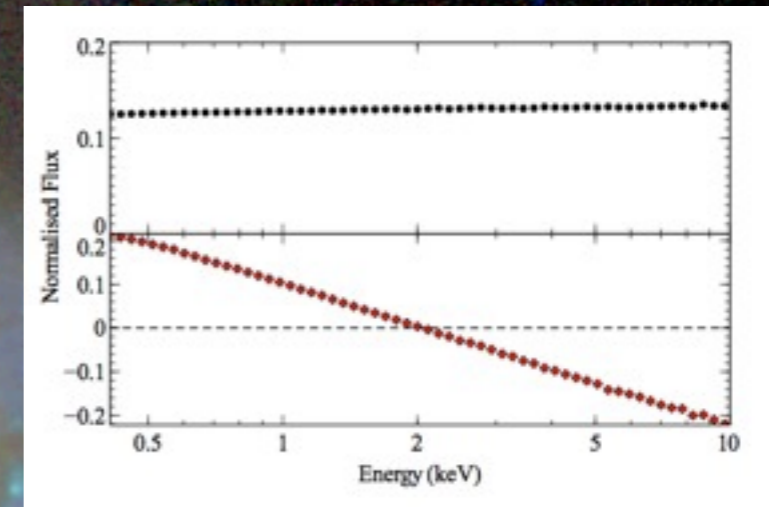
# ● 2. NGC 405 I

## ● PREVIOUS PCA ANALYSIS



Parker et al. (2015)

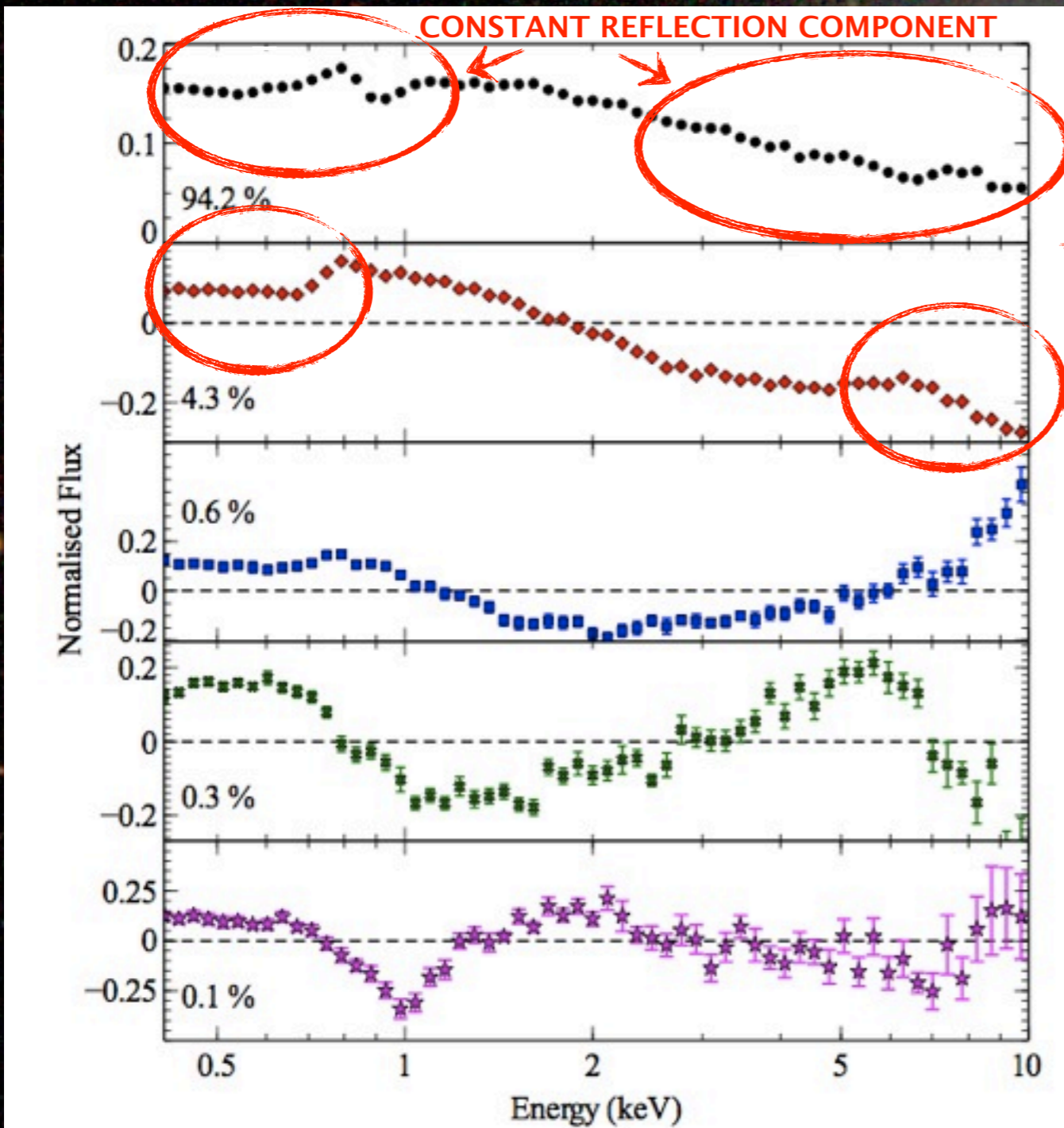
POWER LAW Varying photon index and normalization



EUGENE (keV)

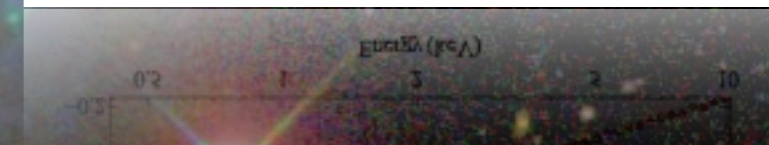
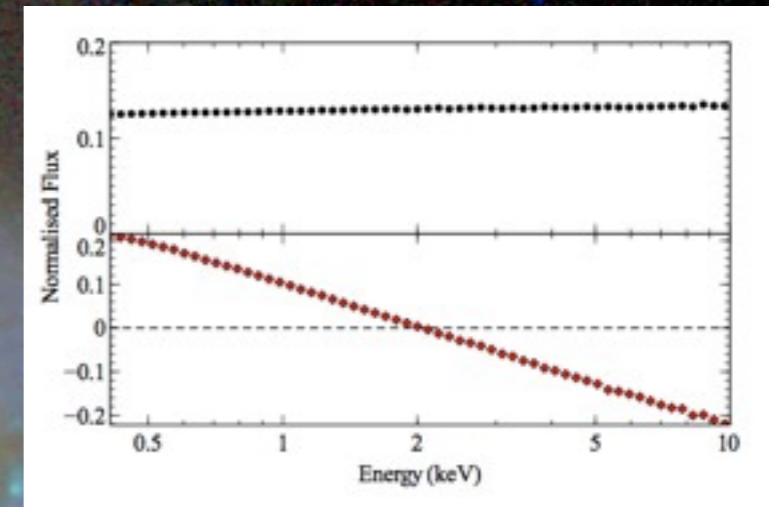
# ● 2. NGC 405 I

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Parker et al. (2015)

POWER LAW Varying photon index and normalization

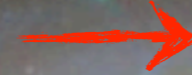
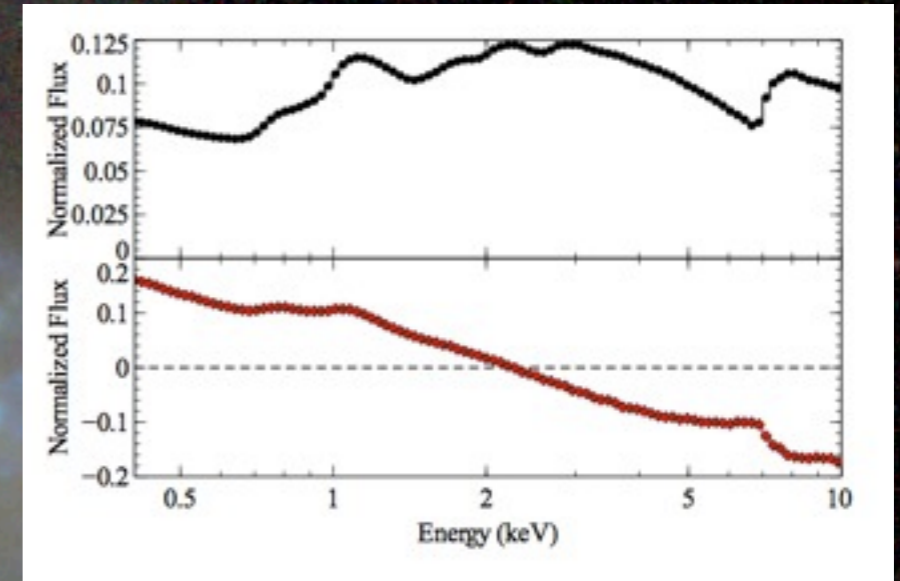
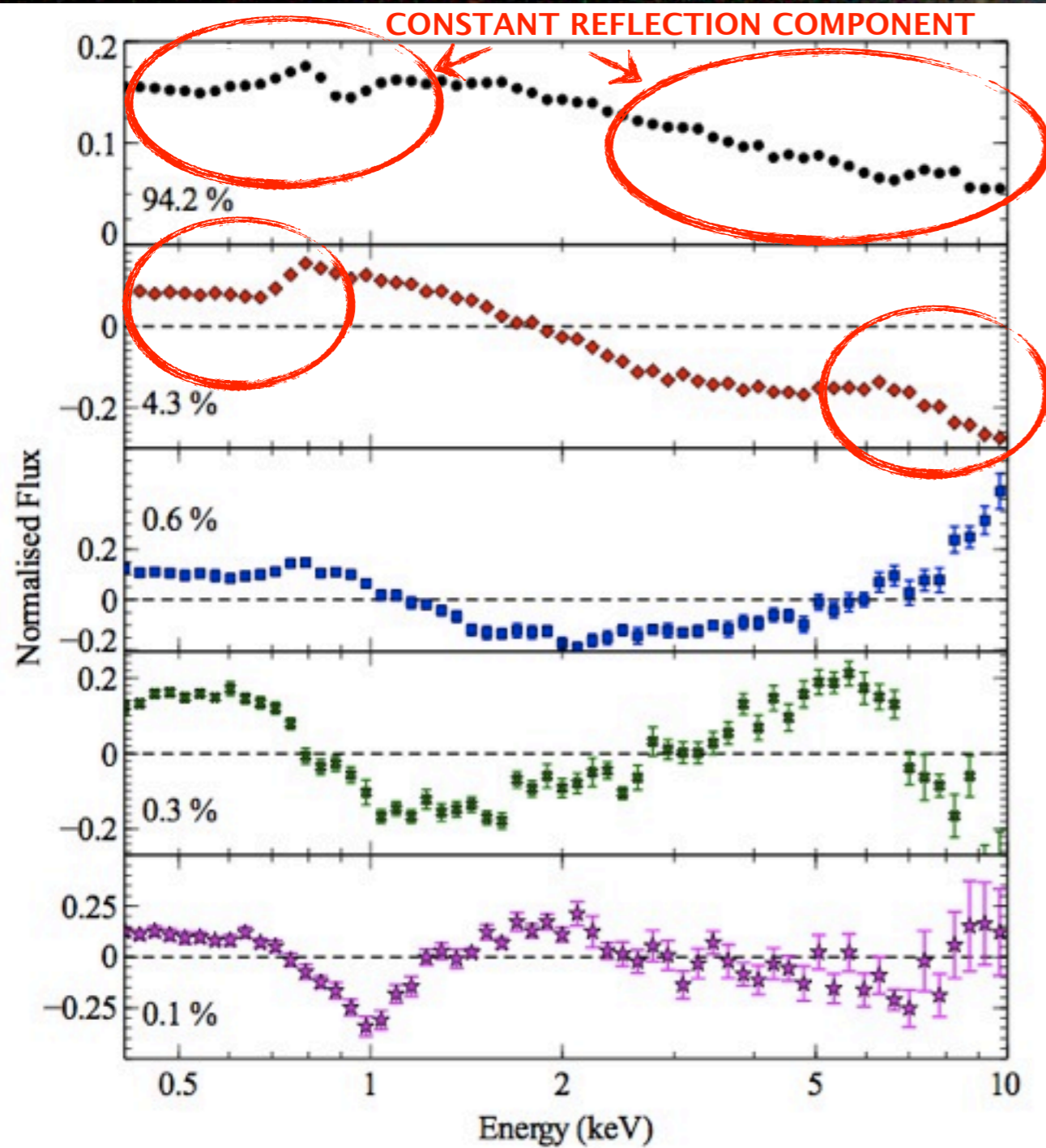


EUGENE (keV)

# ● 2. NGC 405 I

## ● PREVIOUS PCA ANALYSIS

POWER LAW Varying photon index and normalization  
&  
RELATIVISTIC REFLECTION



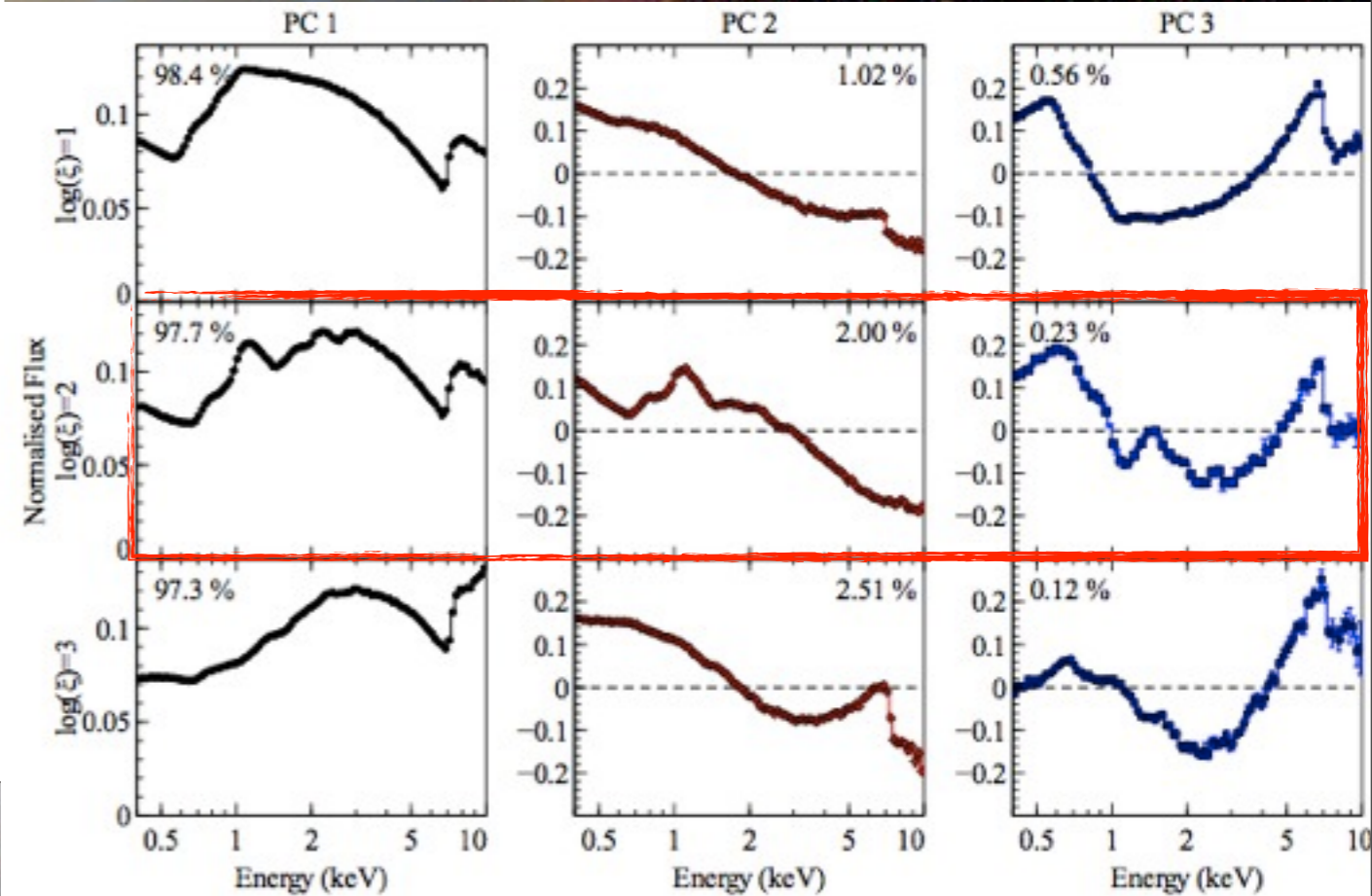
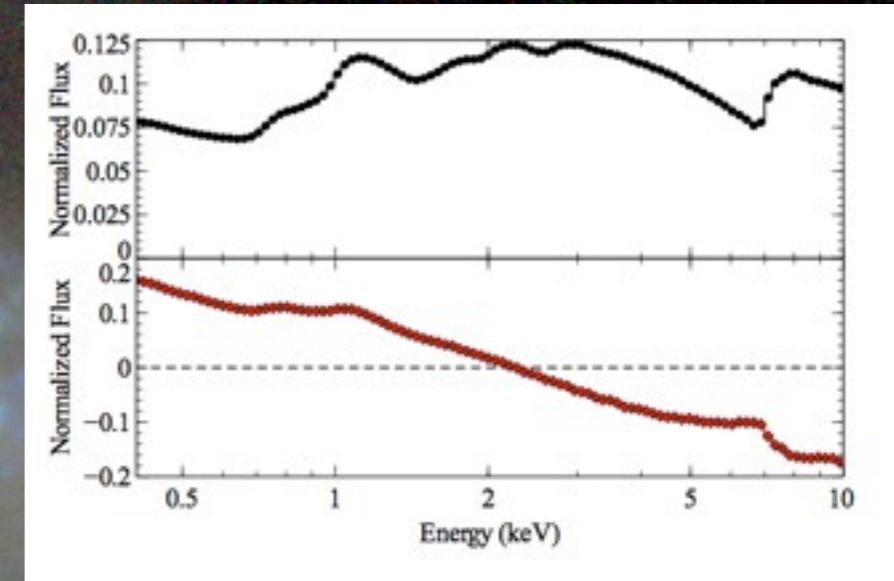
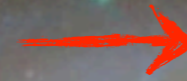
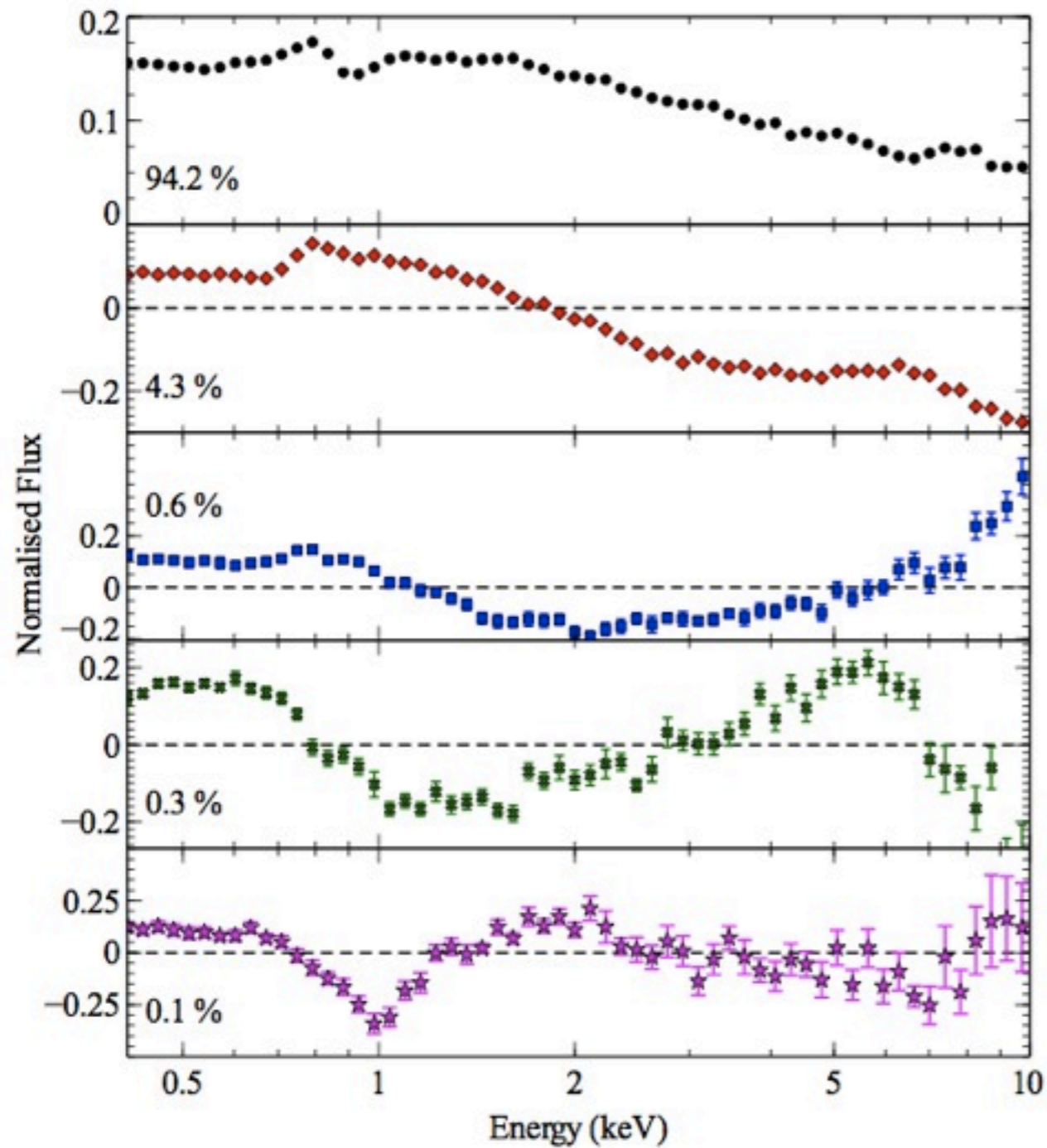
Parker et al. (2015)

EUSO (keV)

# ● 2. NGC 405 I

## ● PREVIOUS PCA ANALYSIS

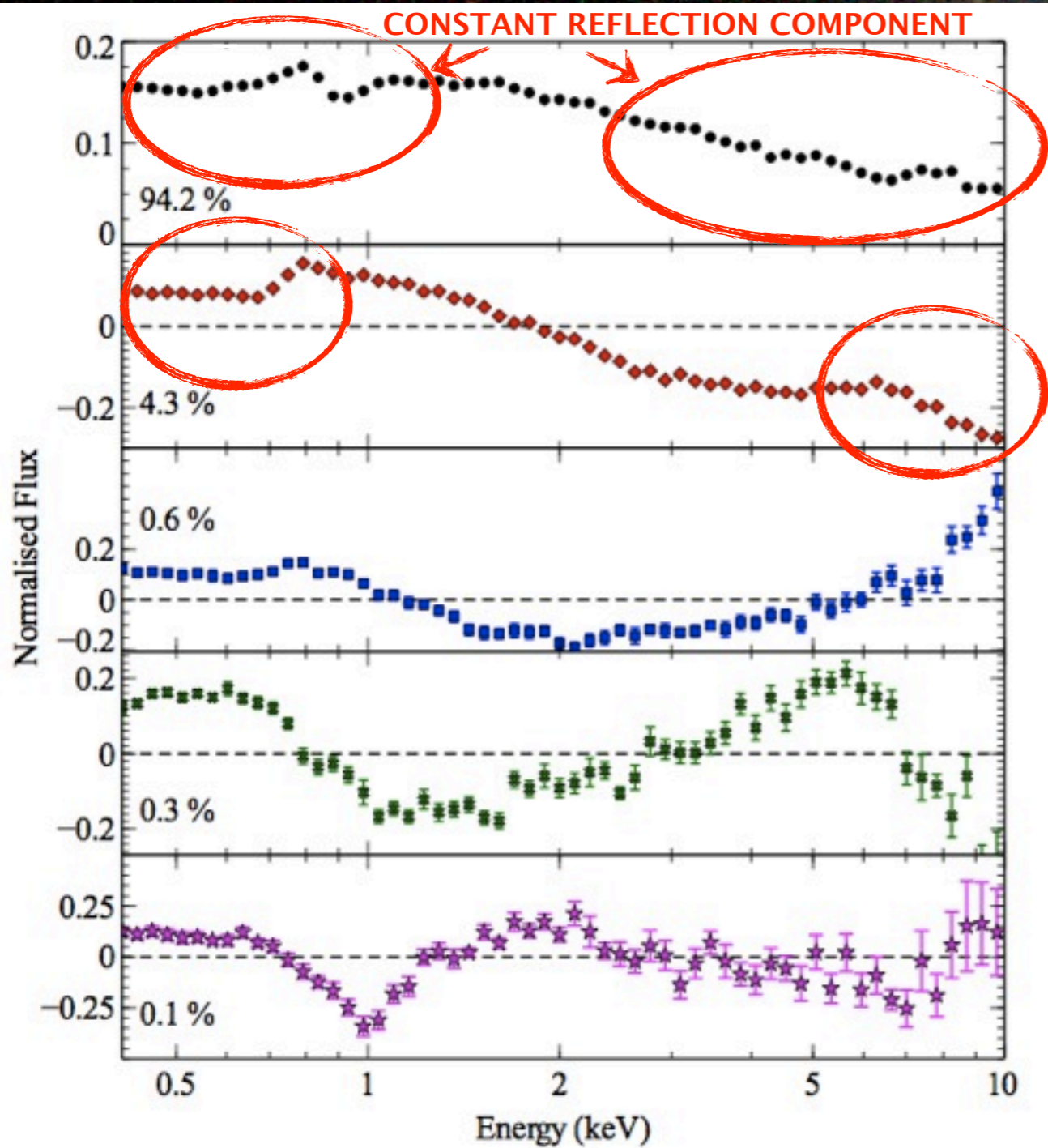
POWER LAW Varying photon index and normalization  
&  
RELATIVISTIC REFLECTION



EUCLER (keV)

# ● 2. NGC 405 I

## ● PREVIOUS PCA ANALYSIS



✓ VARYING POWER LAW & RELATIVISTIC REFLECTION

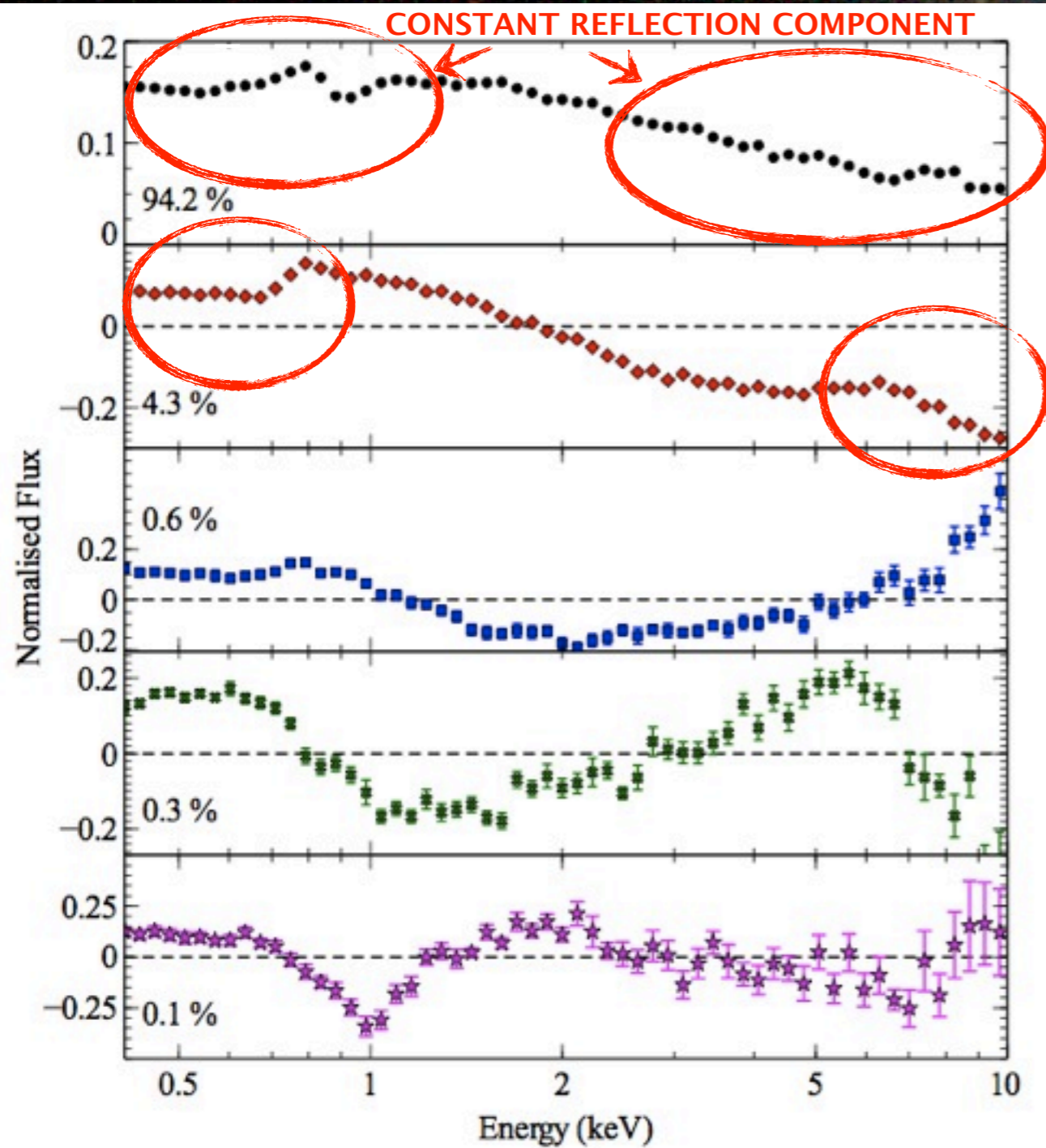


Parker et al. (2015)

EUSEIA (keV)

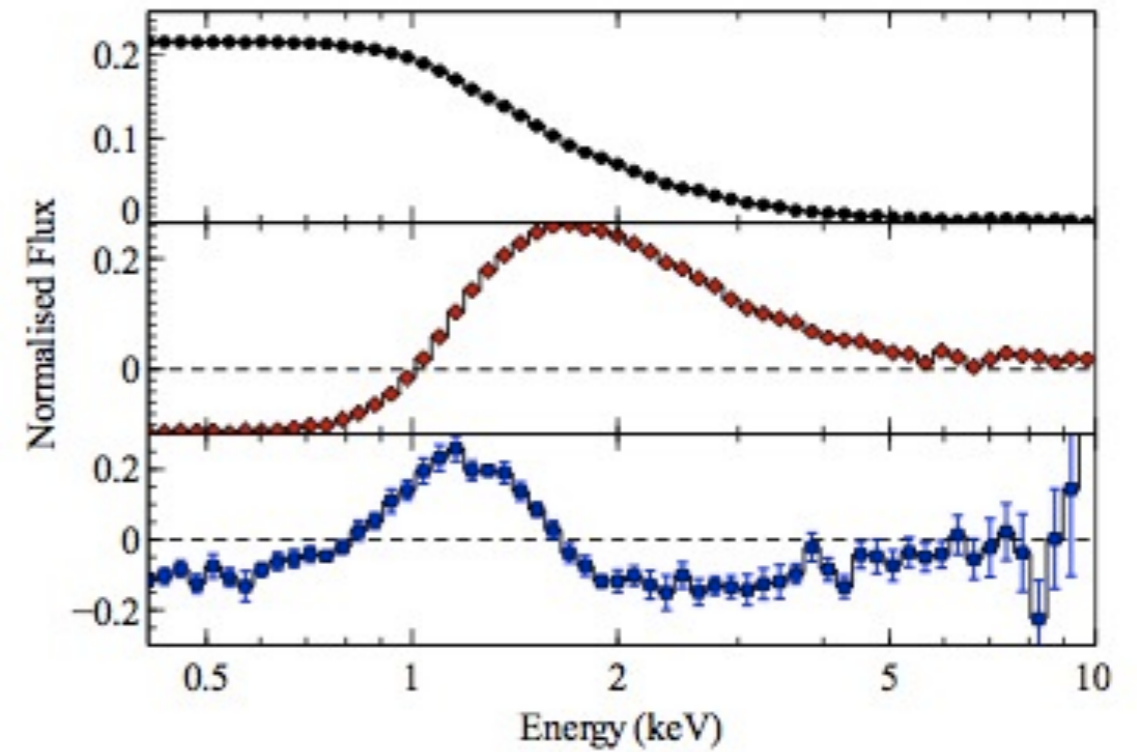
# ● 2. NGC 405 I

## ● PREVIOUS PCA ANALYSIS

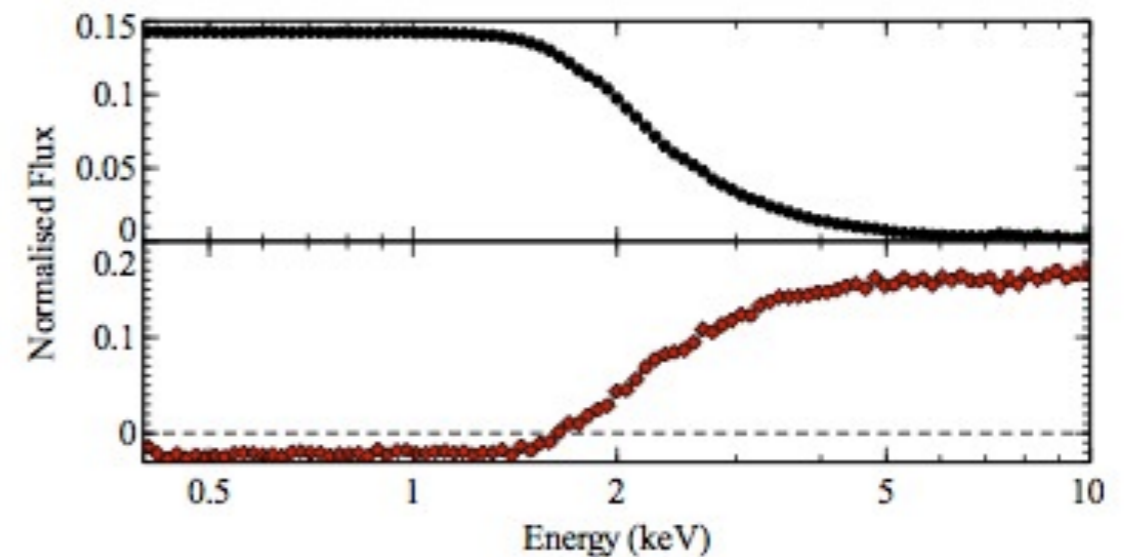


Parker et al. (2015)

✓ VARYING POWER LAW & RELATIVISTIC REFLECTION



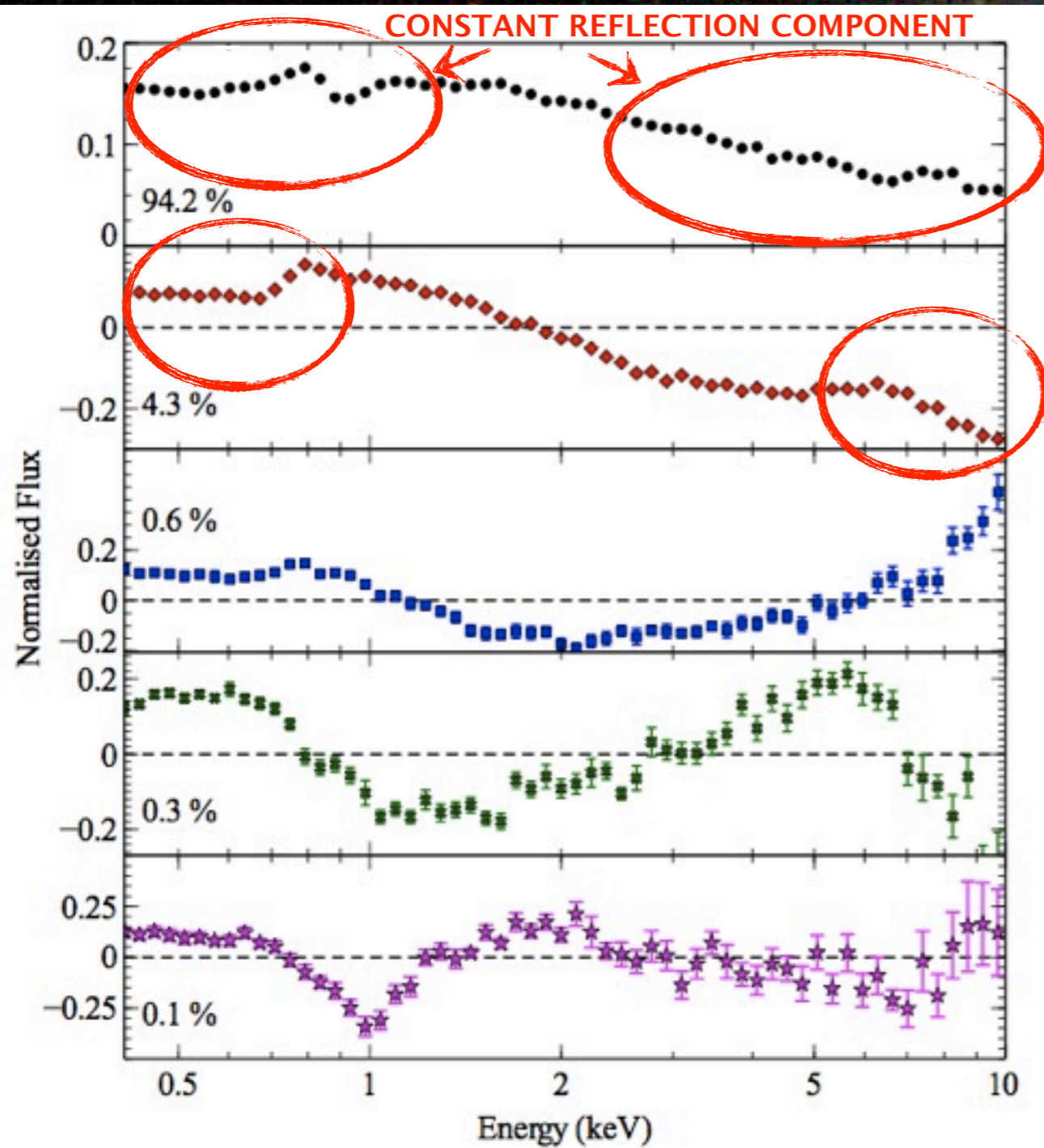
PARTIALLY COVERED  
POWER LAW



ΕΥΣΤΕΛ (keV)

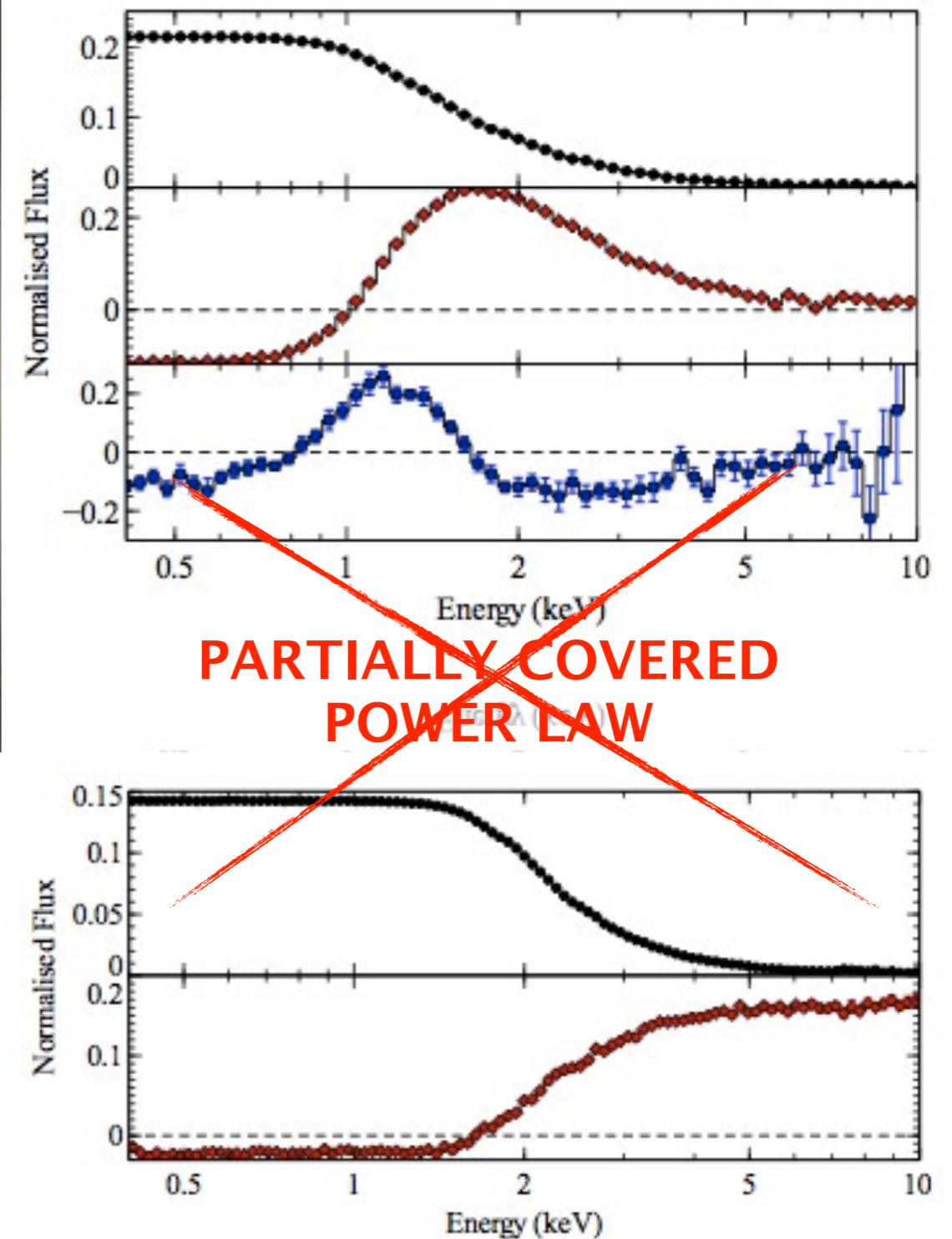
# ● 2. NGC 405 I

## ● PREVIOUS PCA ANALYSIS



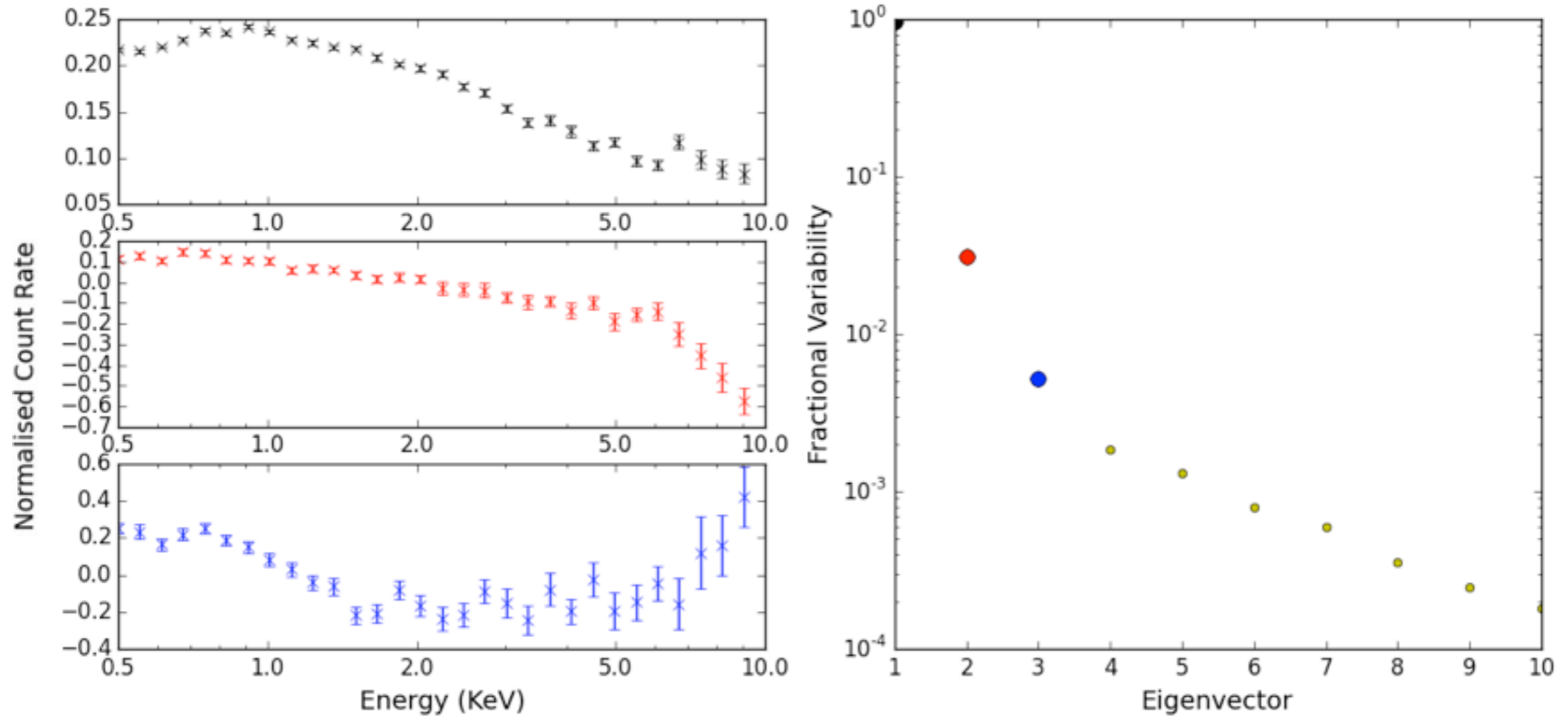
Parker et al. (2015)

✓ VARYING POWER LAW & RELATIVISTIC REFLECTION



# ● 2. NGC 405 I

- ANOTHER OBSERVATION: Same PCs

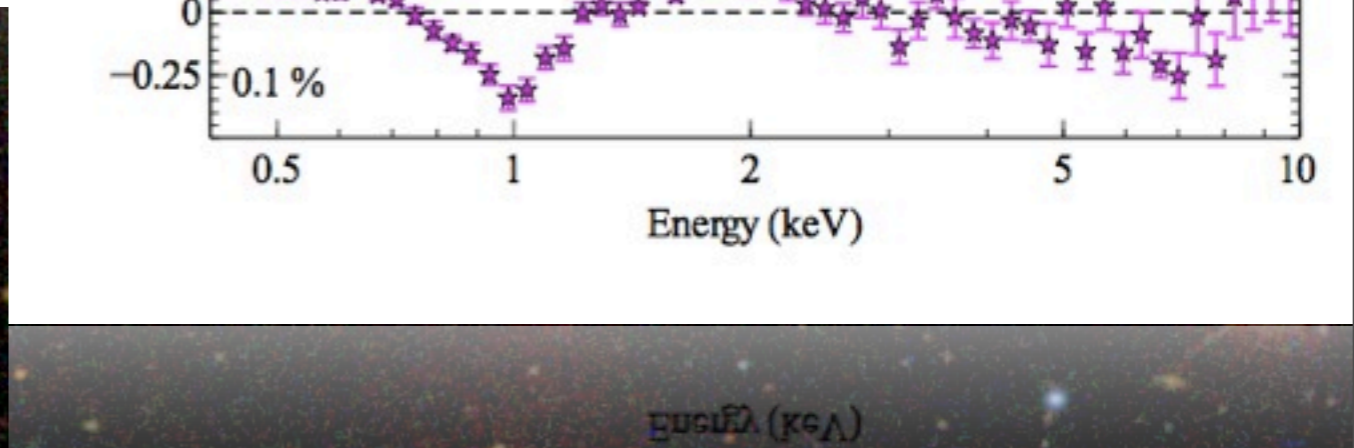
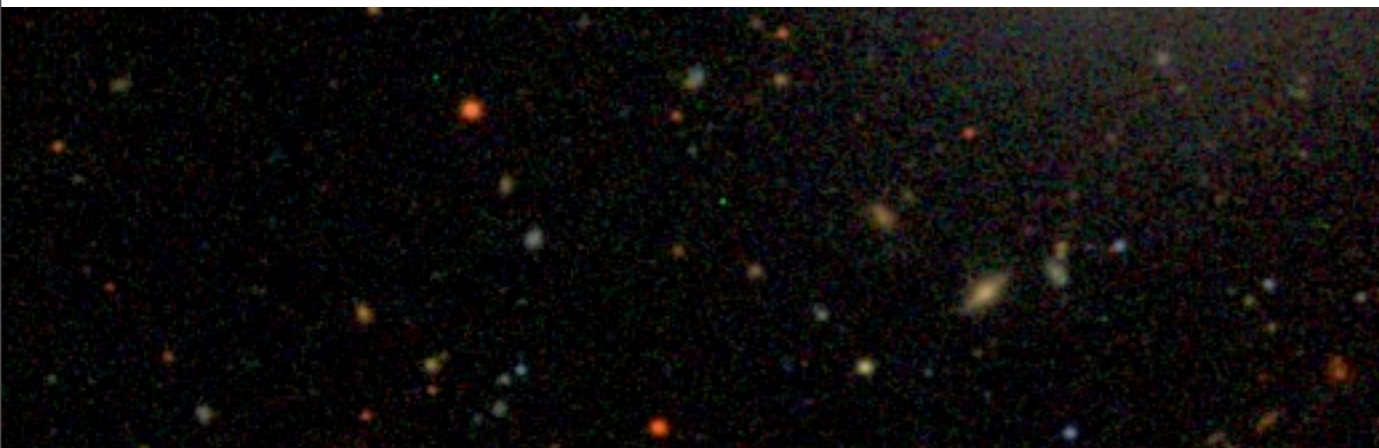
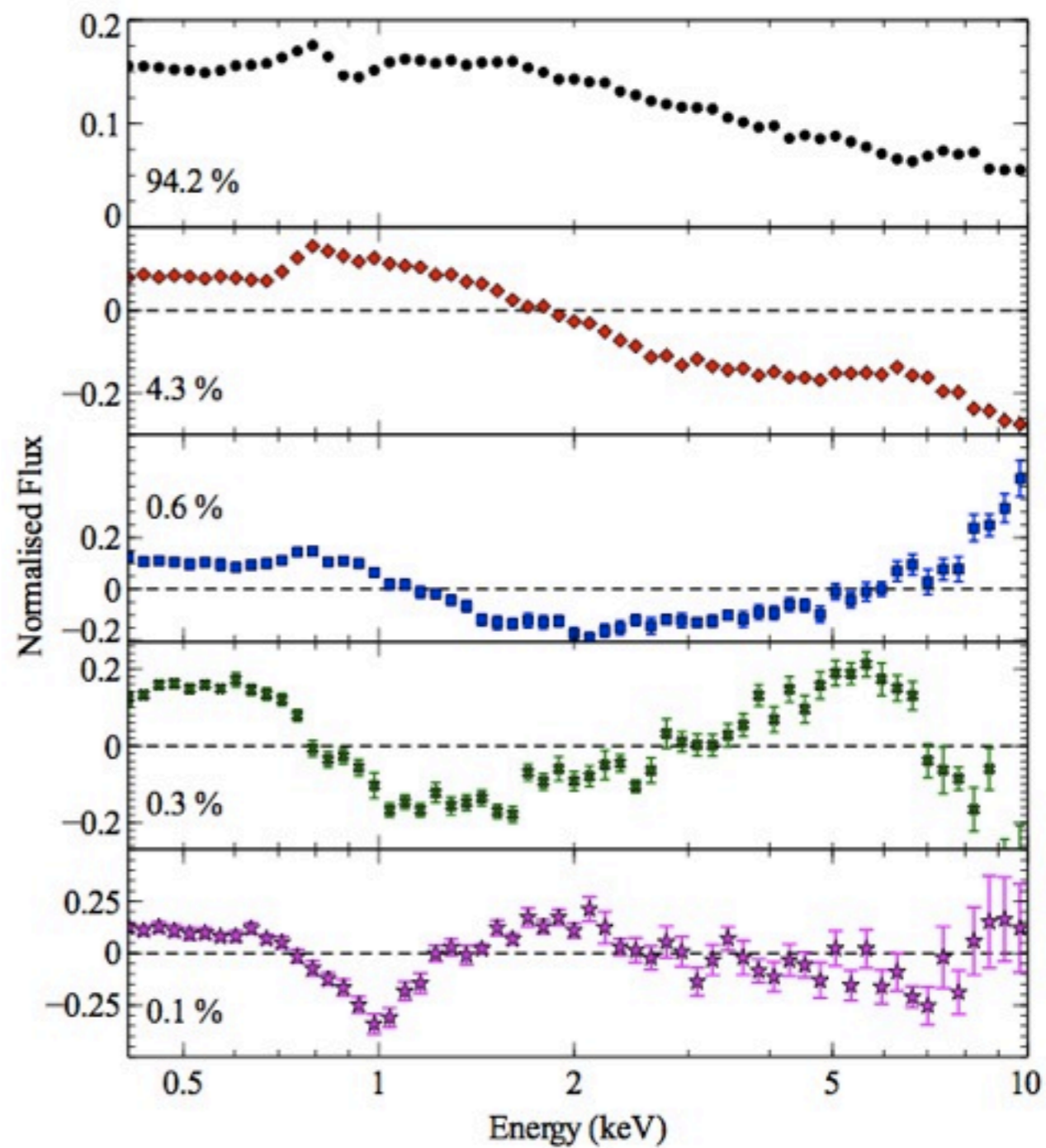
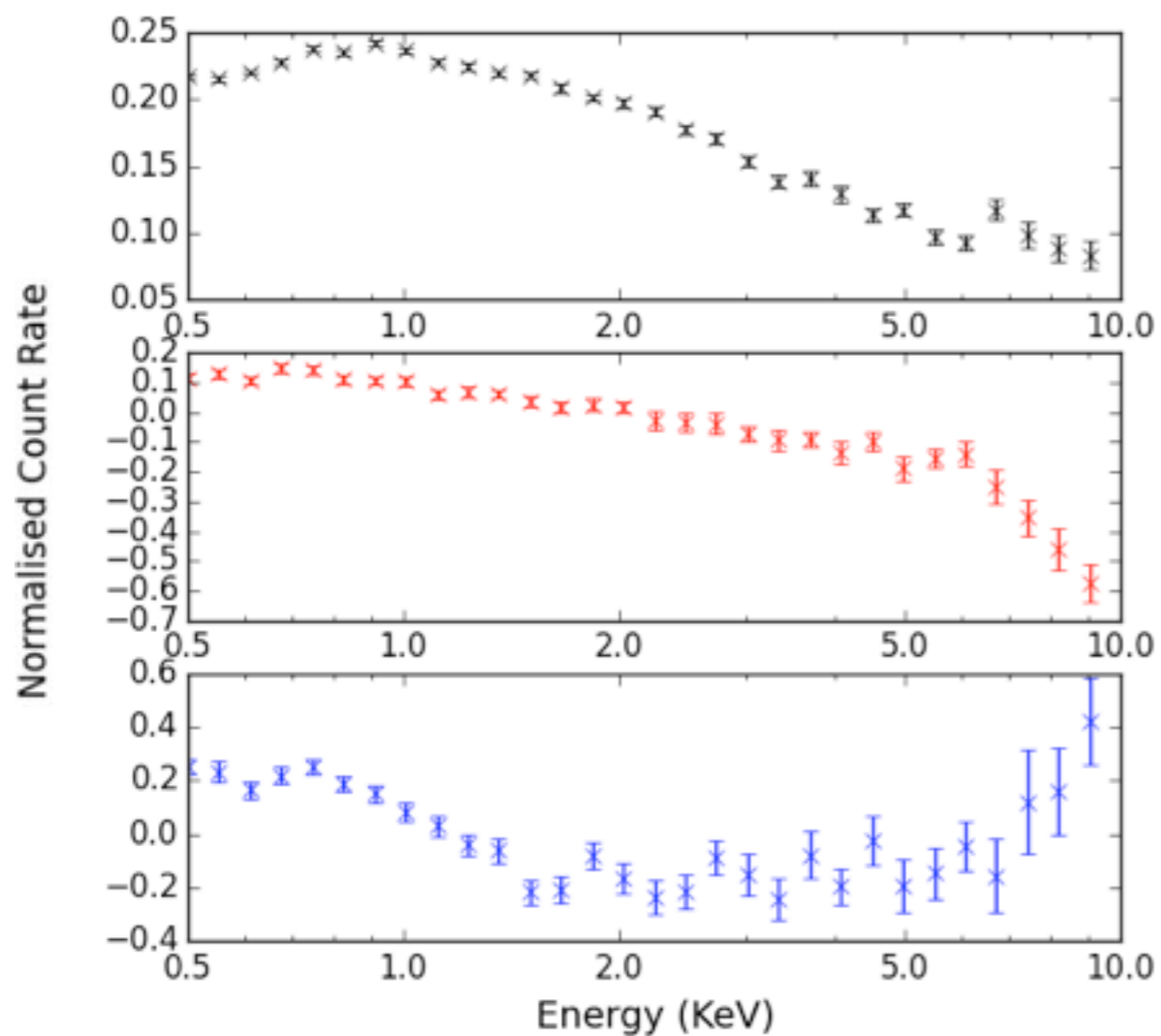


1 Observation – 05/2001 – ~ 120ks



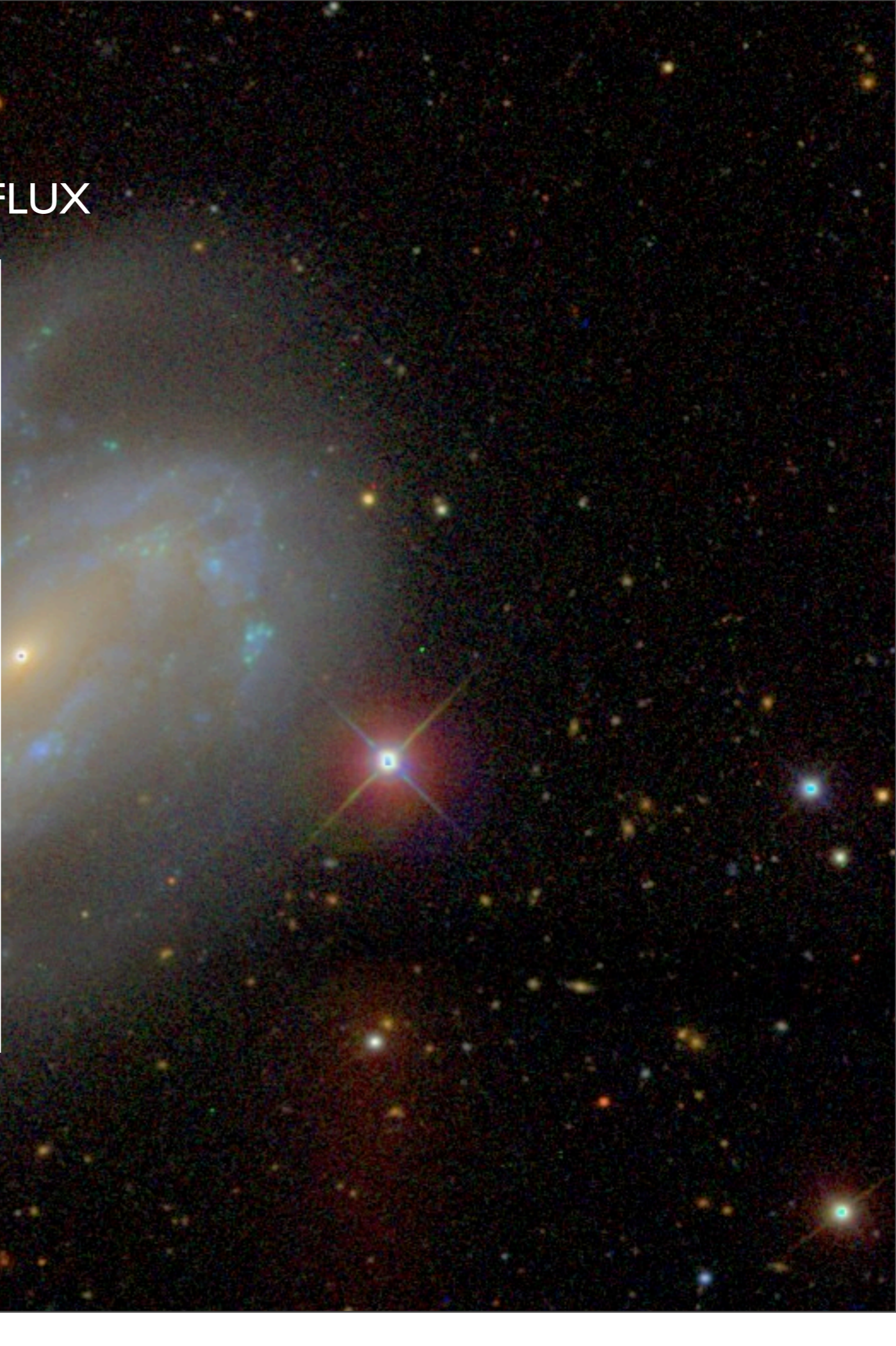
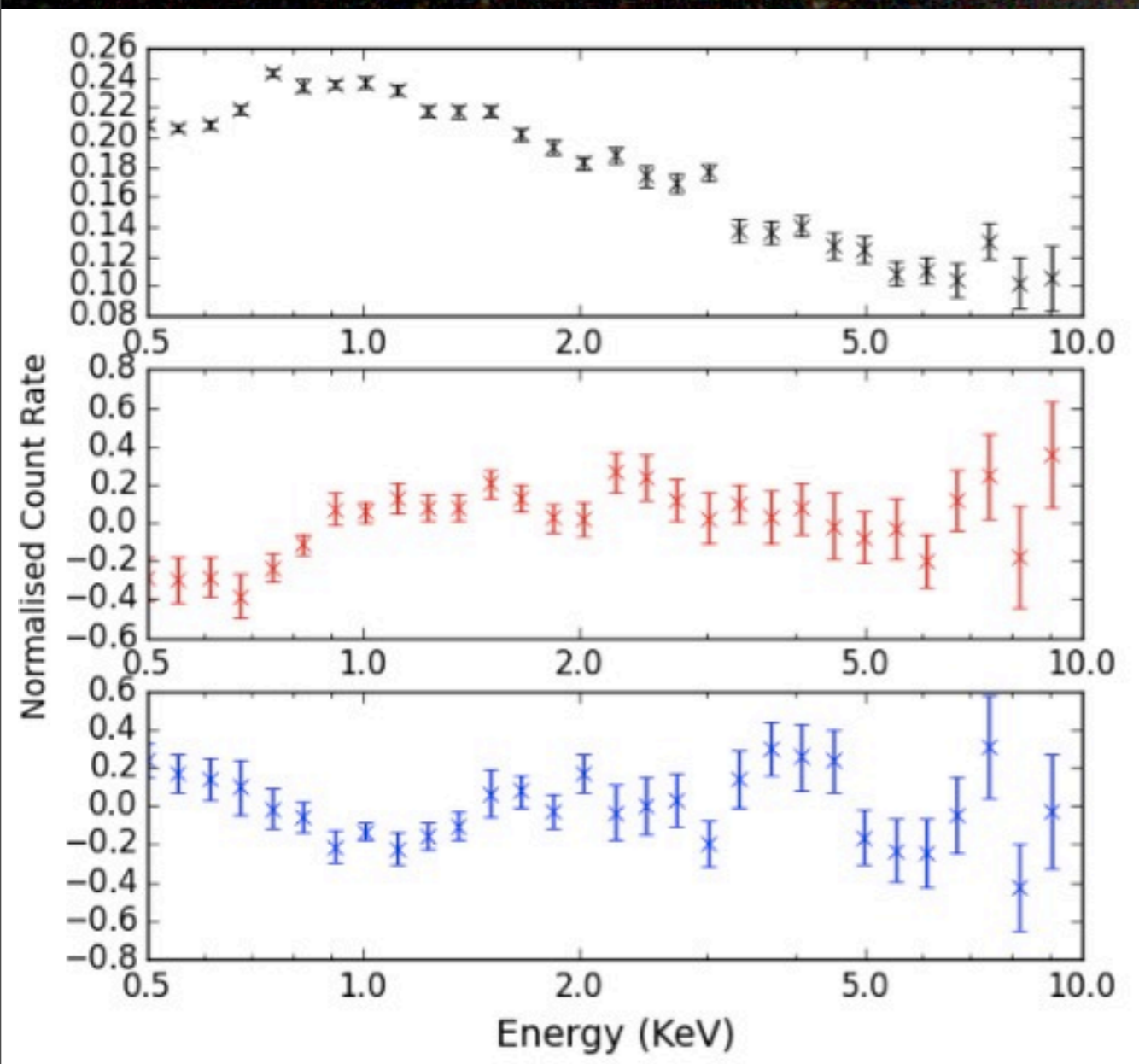
# ● 2. NGC 405 I

- ANOTHER OBSERVATION: Same PCs



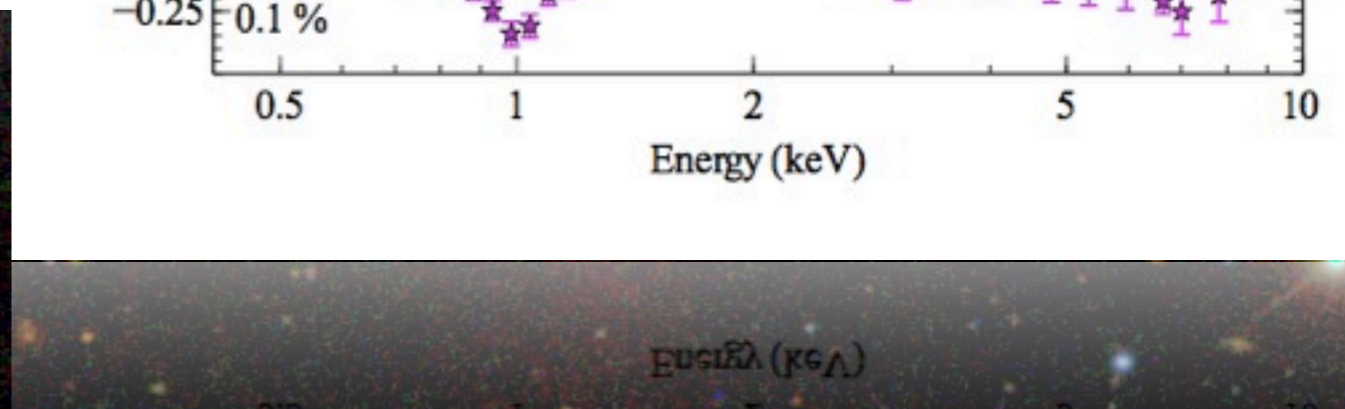
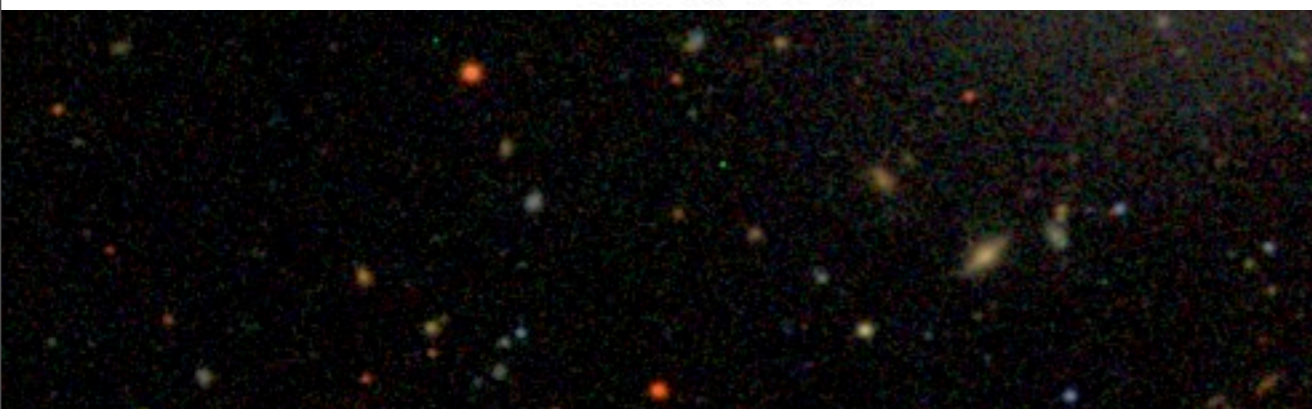
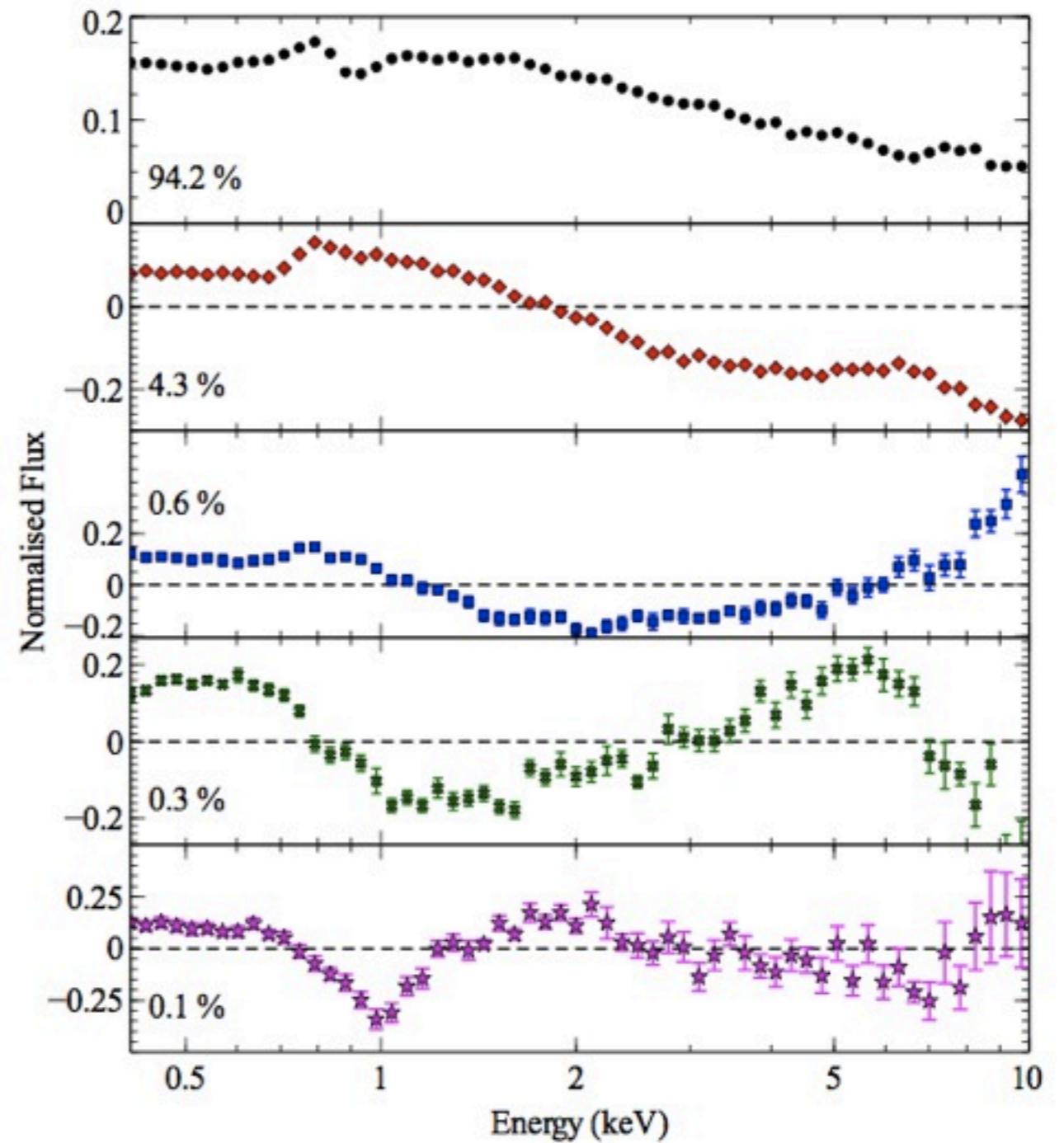
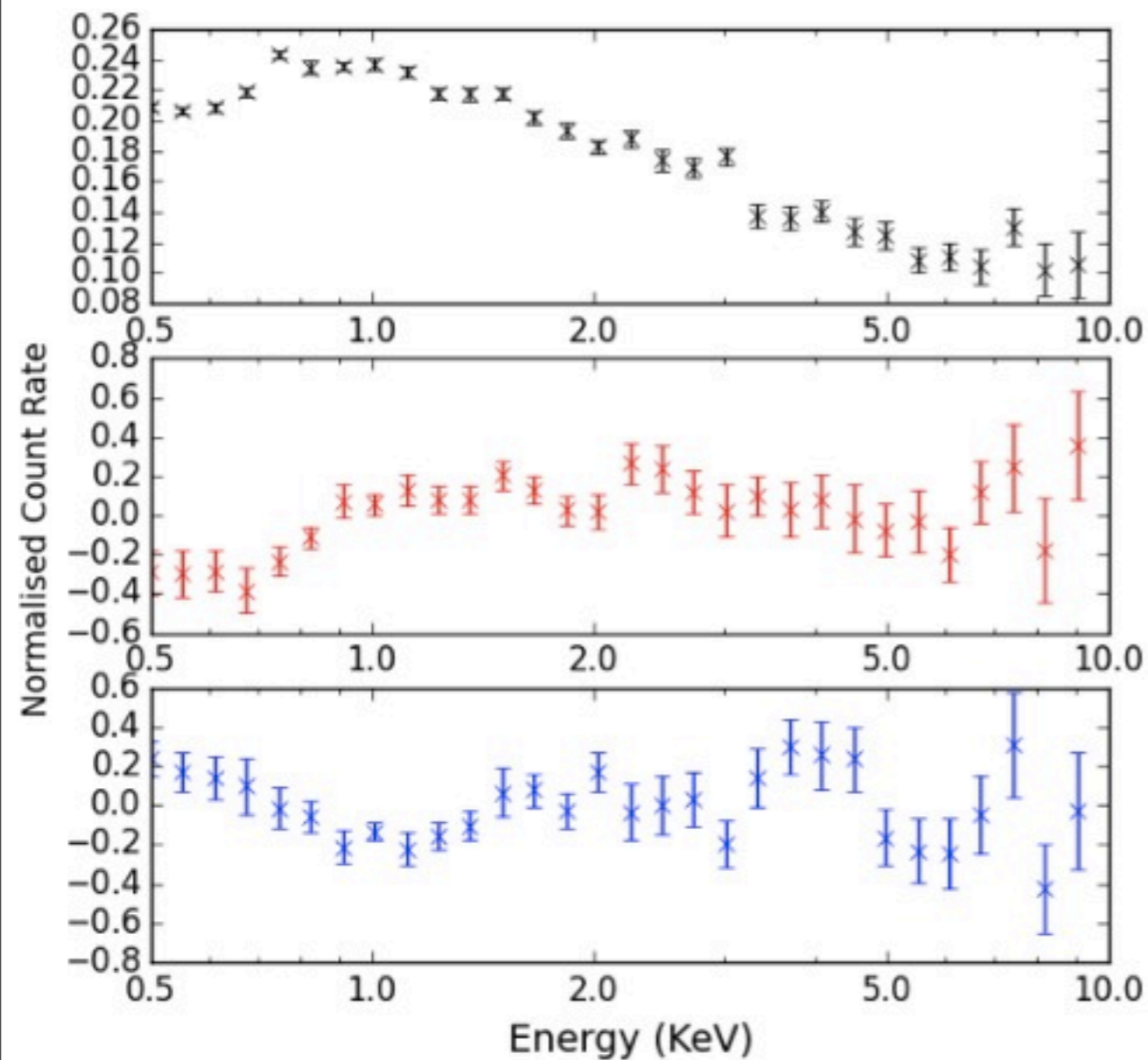
# ● 2. NGC 405 I

- Further analysis: GREATEST FLUX



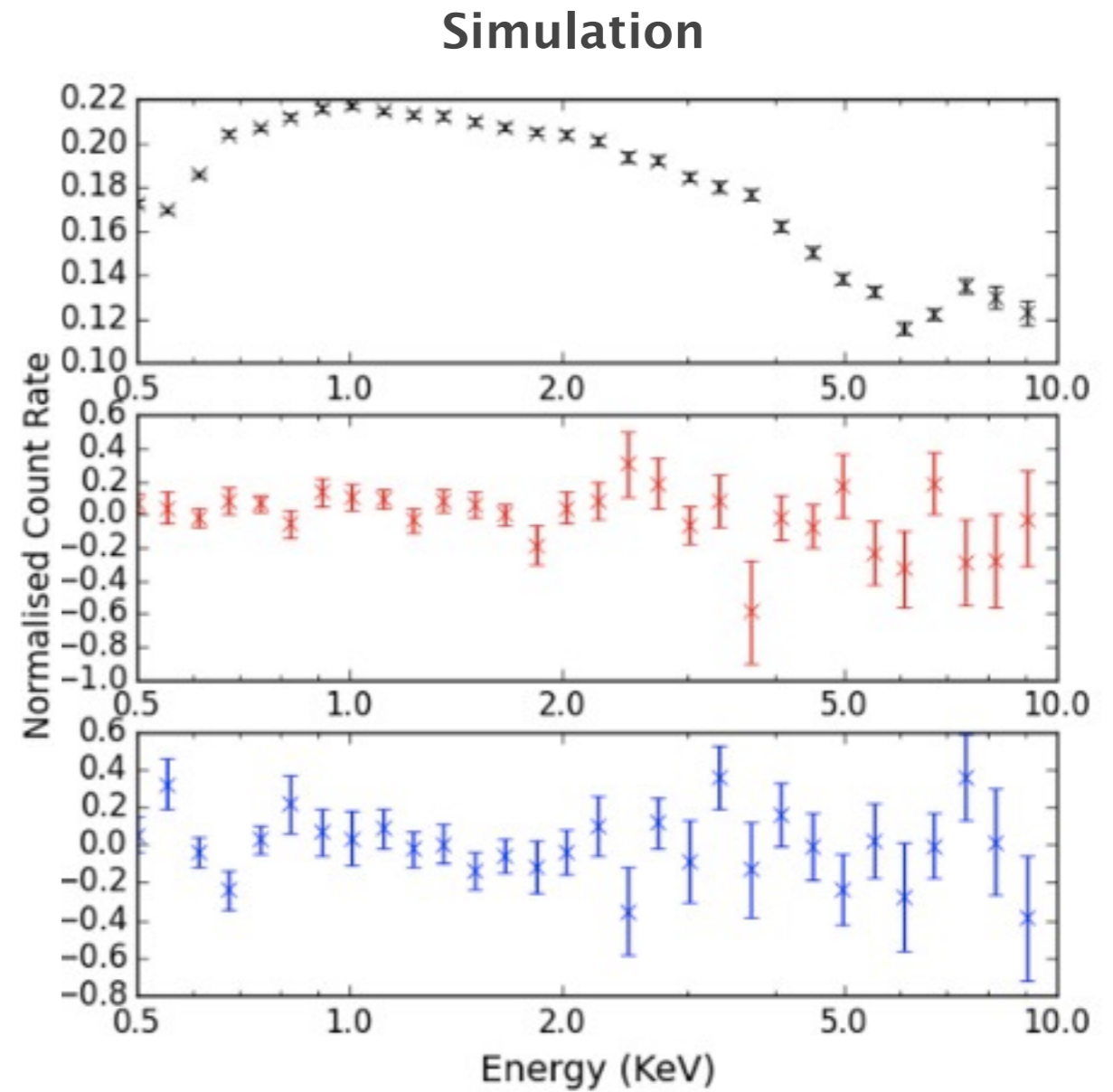
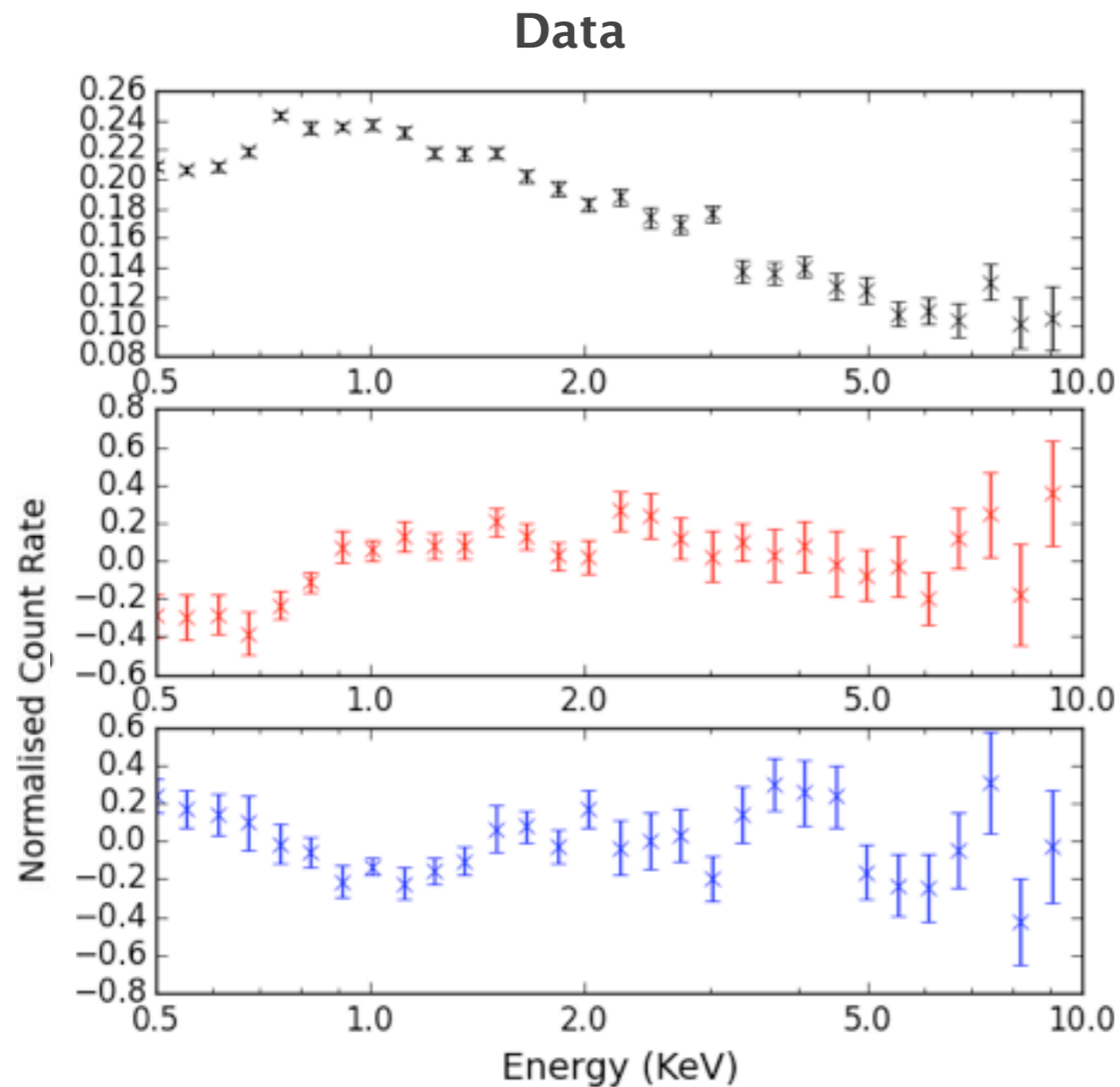
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# ● 2. NGC 405 I

- Further analysis: GREATEST FLUX

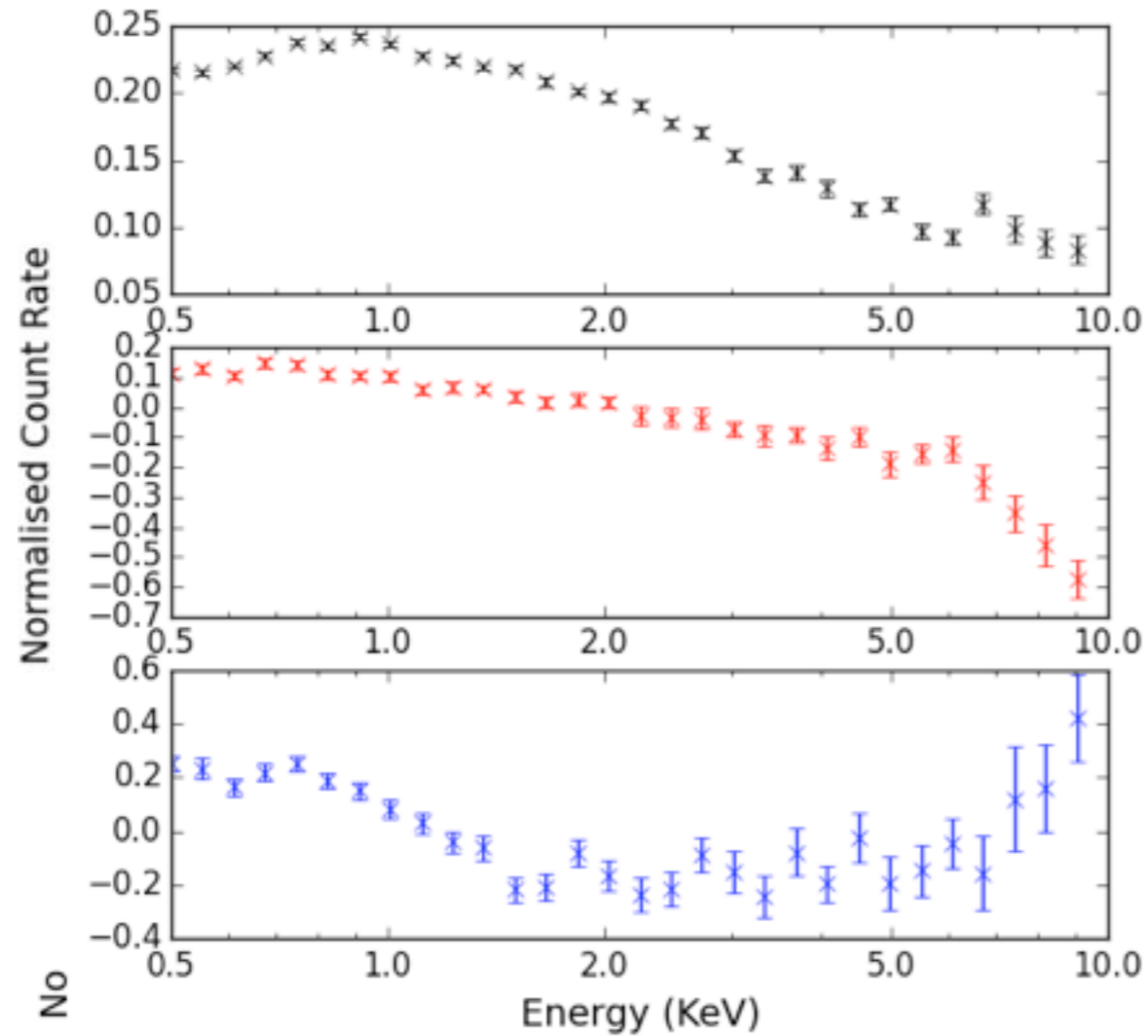


**Power law varying in normalization**  
+  
**constant relativistic reflection component**

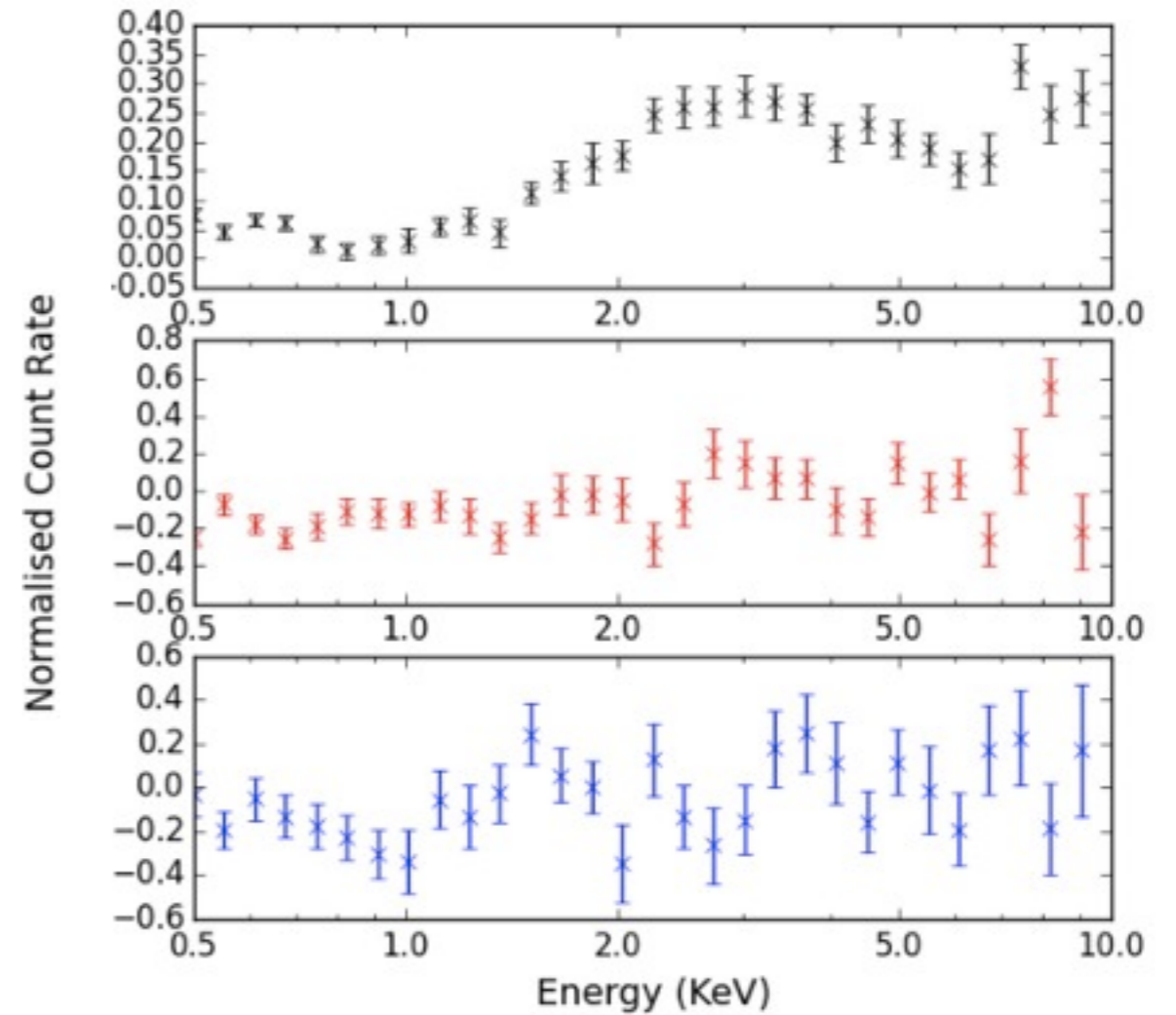
# ● 2. NGC 405 I

- Further analysis: LOWEST FLUX

### Greatest Flux



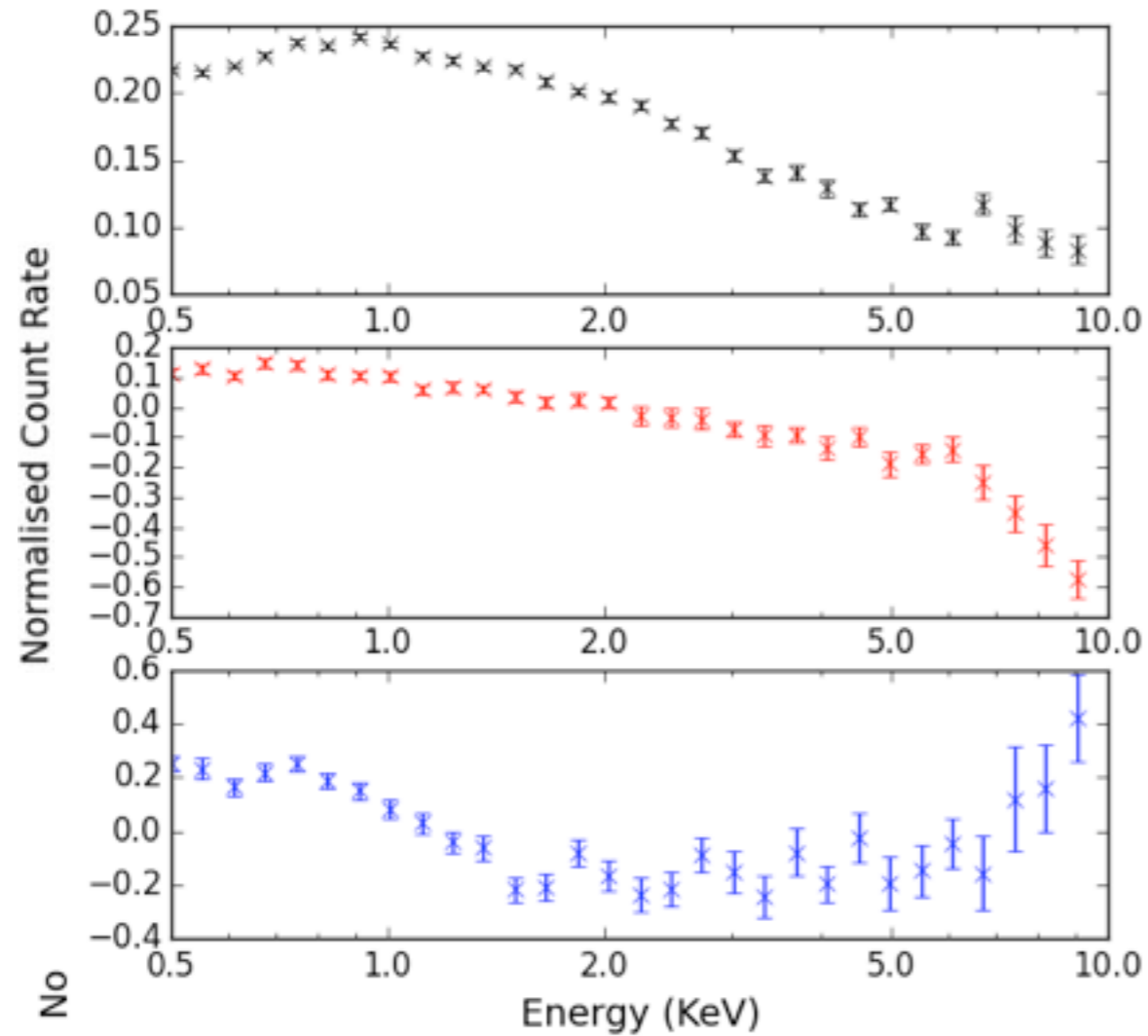
### Lowest Flux



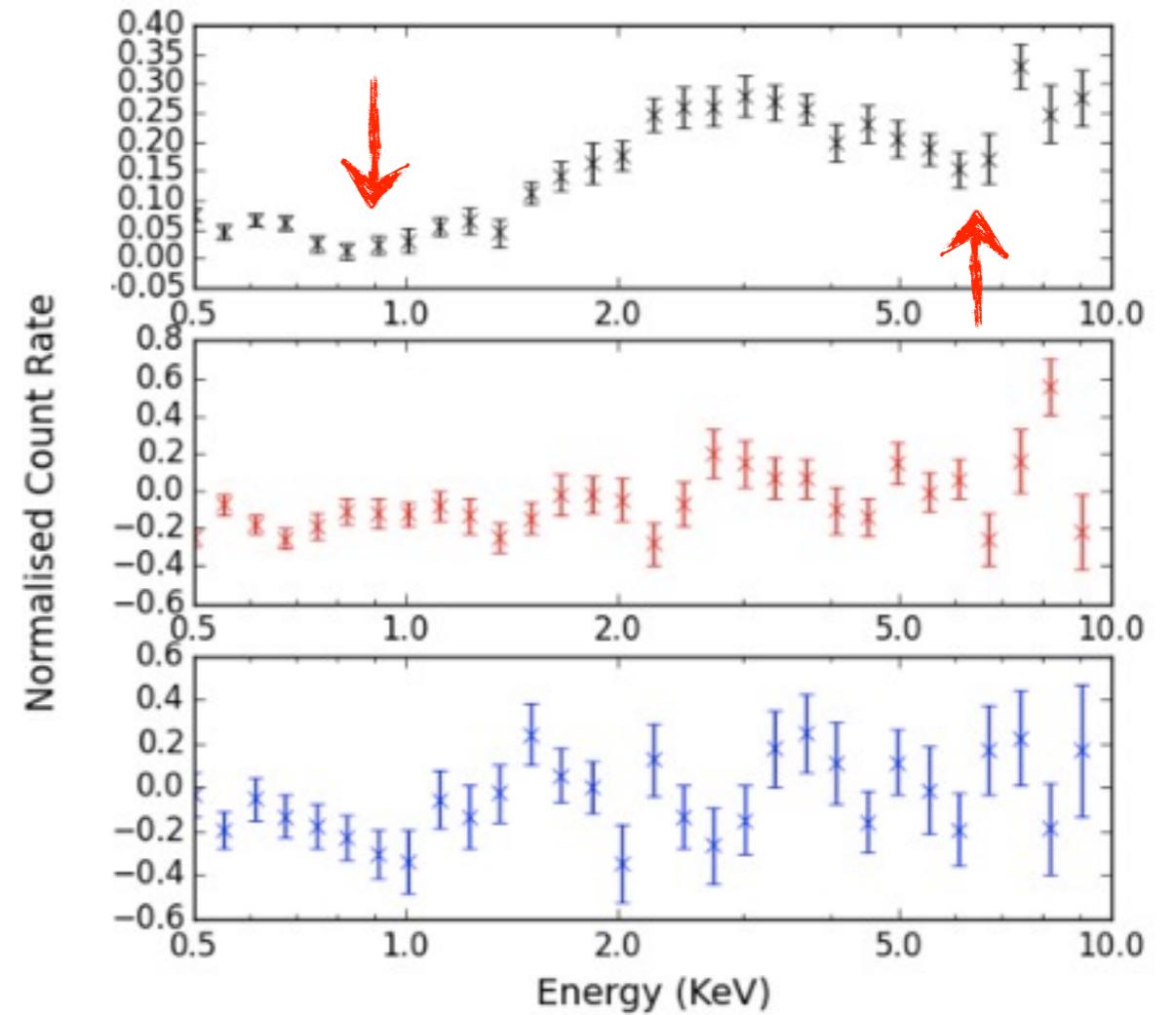
# ● 2. NGC 405 I

- Further analysis: LOWEST FLUX

### Greatest Flux

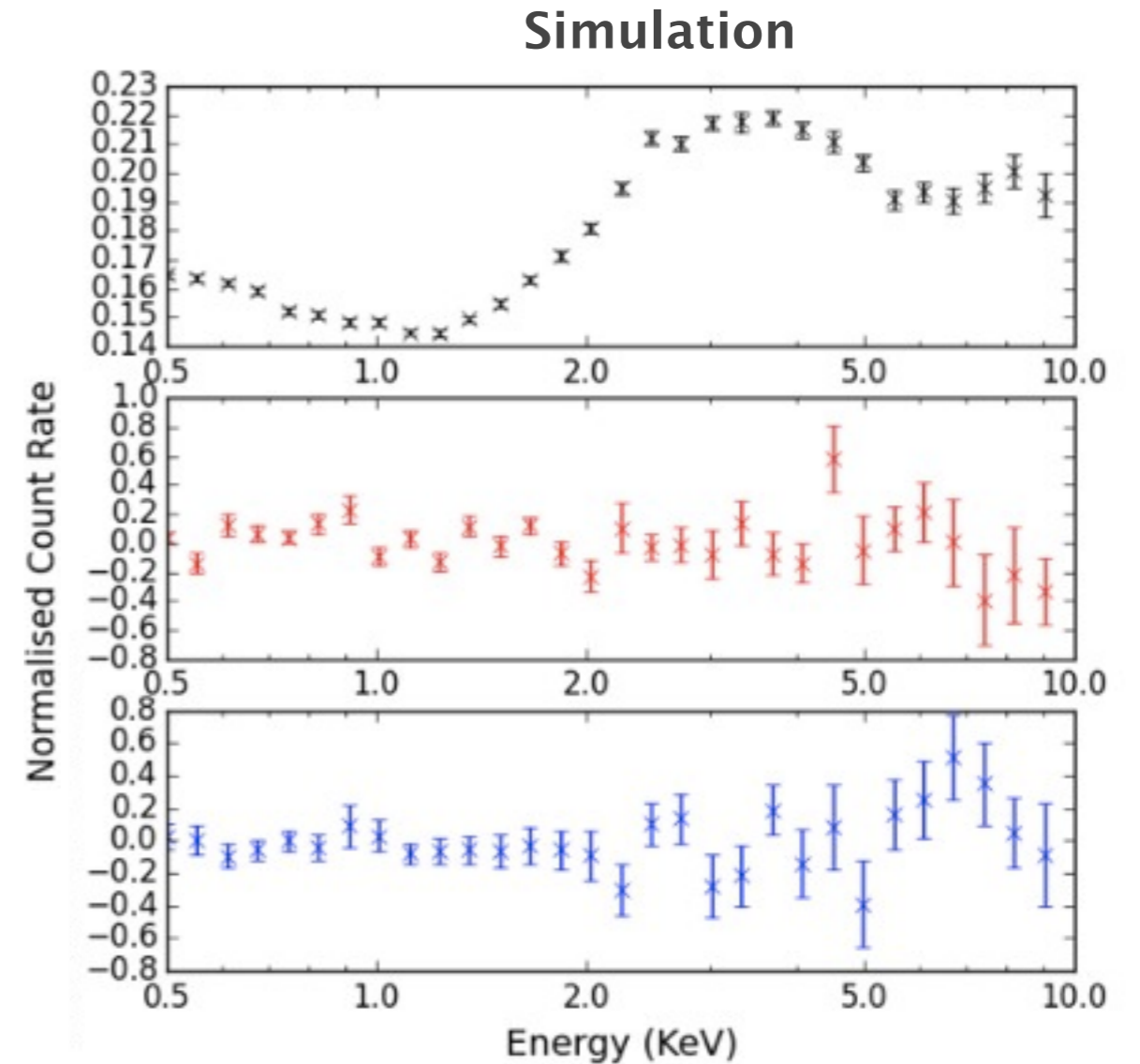
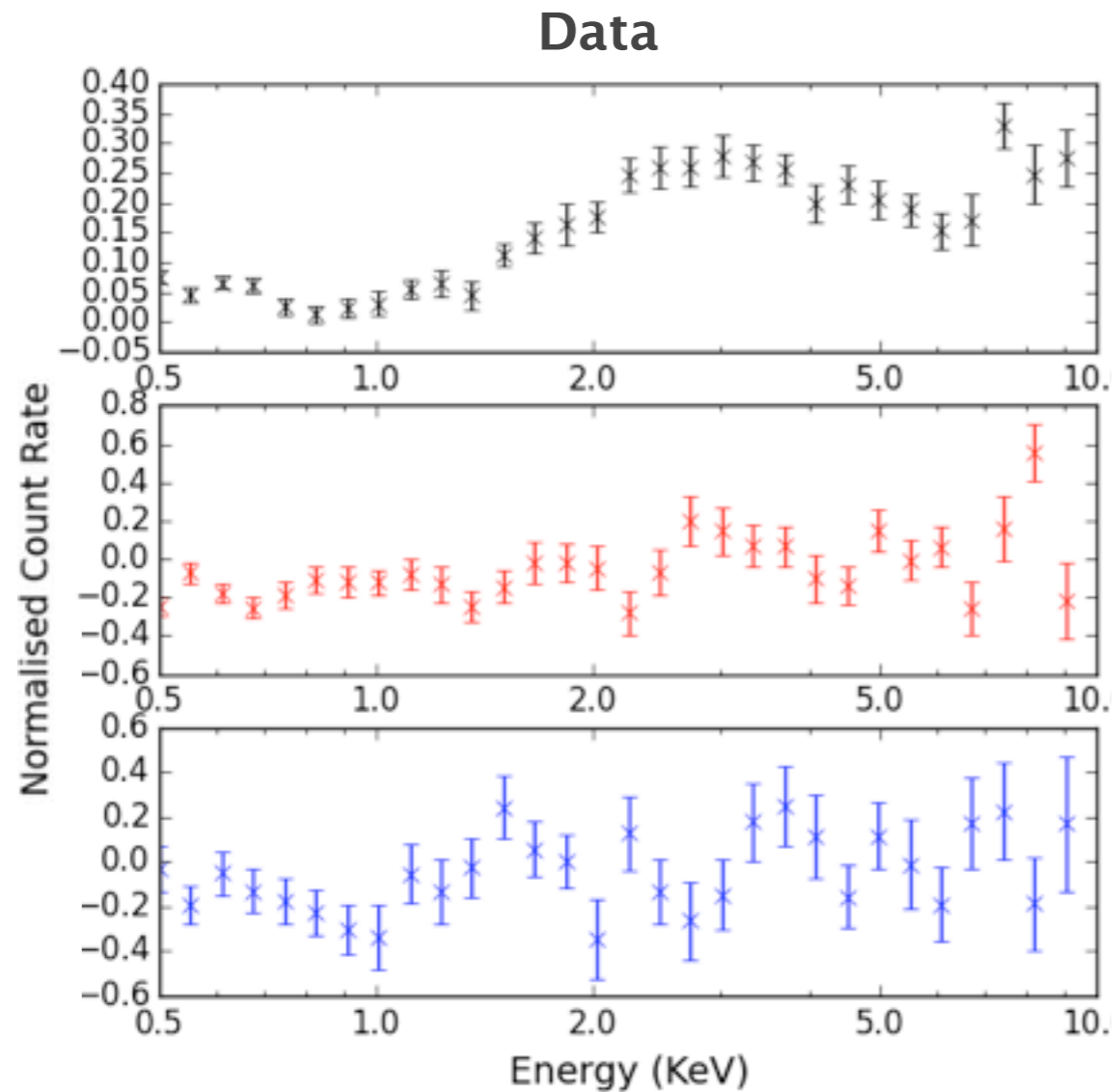


### Lowest Flux



# ● 2. NGC 405 I

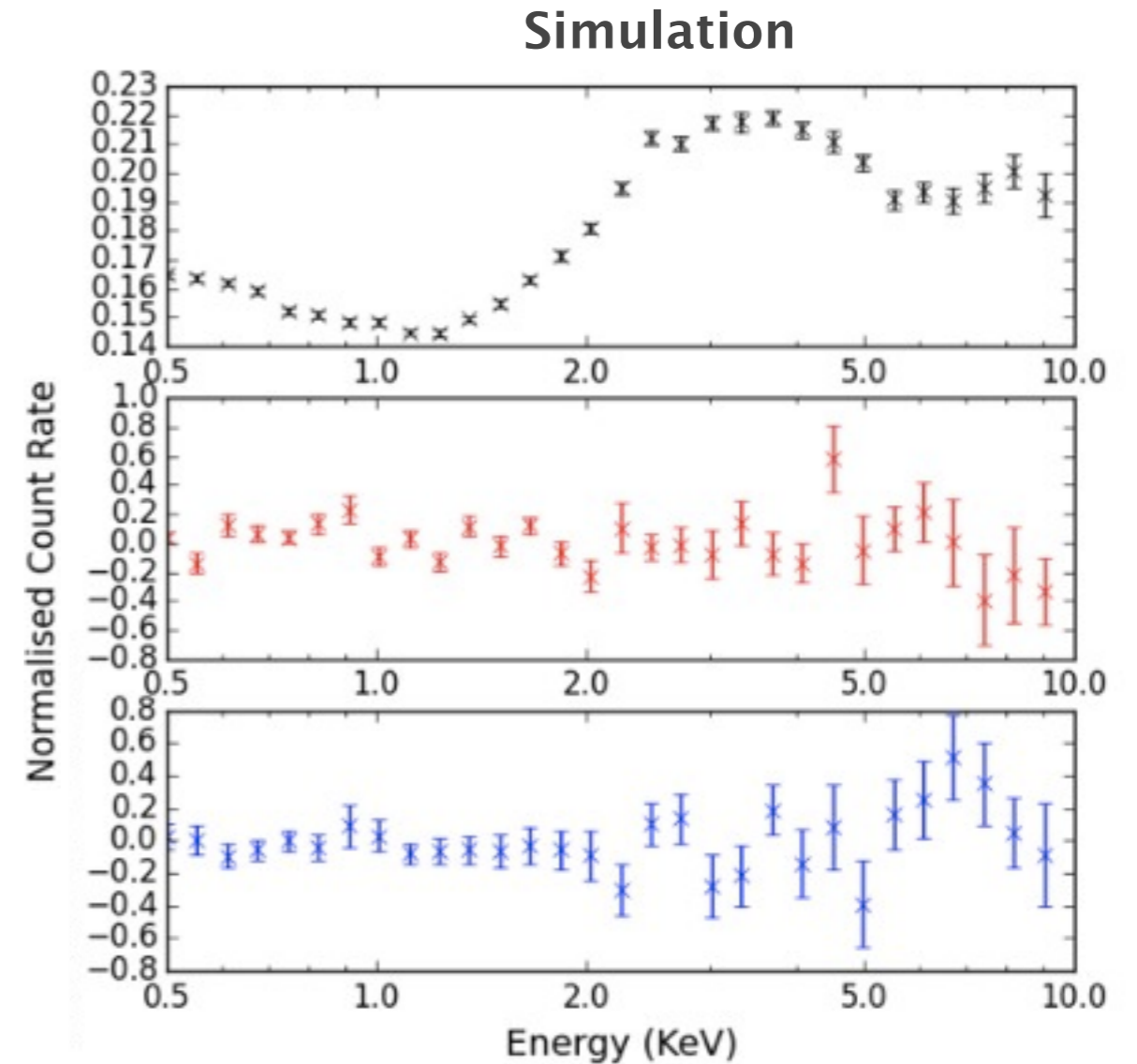
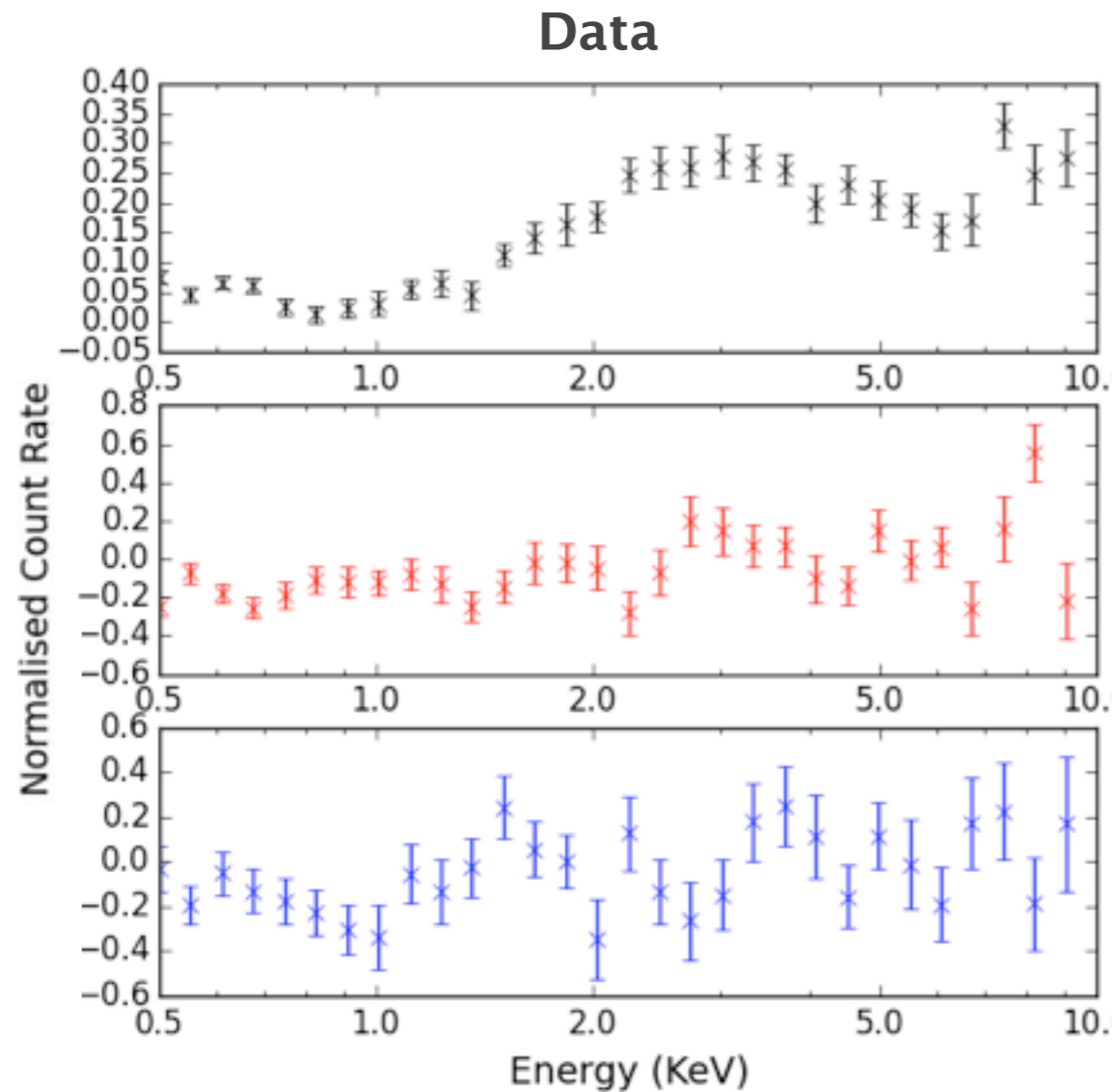
- Further analysis: LOWEST FLUX



**Power law varying in normalization**  
+  
**constant relativistic reflection component**  
+  
**Soft Excess**

# ● 2. NGC 405 I

- Further analysis: LOWEST FLUX



Power law varying in normalization  
+  
constant relativistic reflection component

+  
Soft Excess ✓ Vaughan et al. (2011)



## ● CONCLUSIONS

- Check previous Parker et al (2015)
- Corroborate constant soft excess Vaughan et al (2011)
- EVOLUTION of the PCs with FLUX

## ● FUTURE WORK

- Check and simulated intermediate flux states
- Check this evolution in other sources