NICER

Neutron star Interior Composition ExploreR

A NICER Look at Cross-calibration using 3C 273

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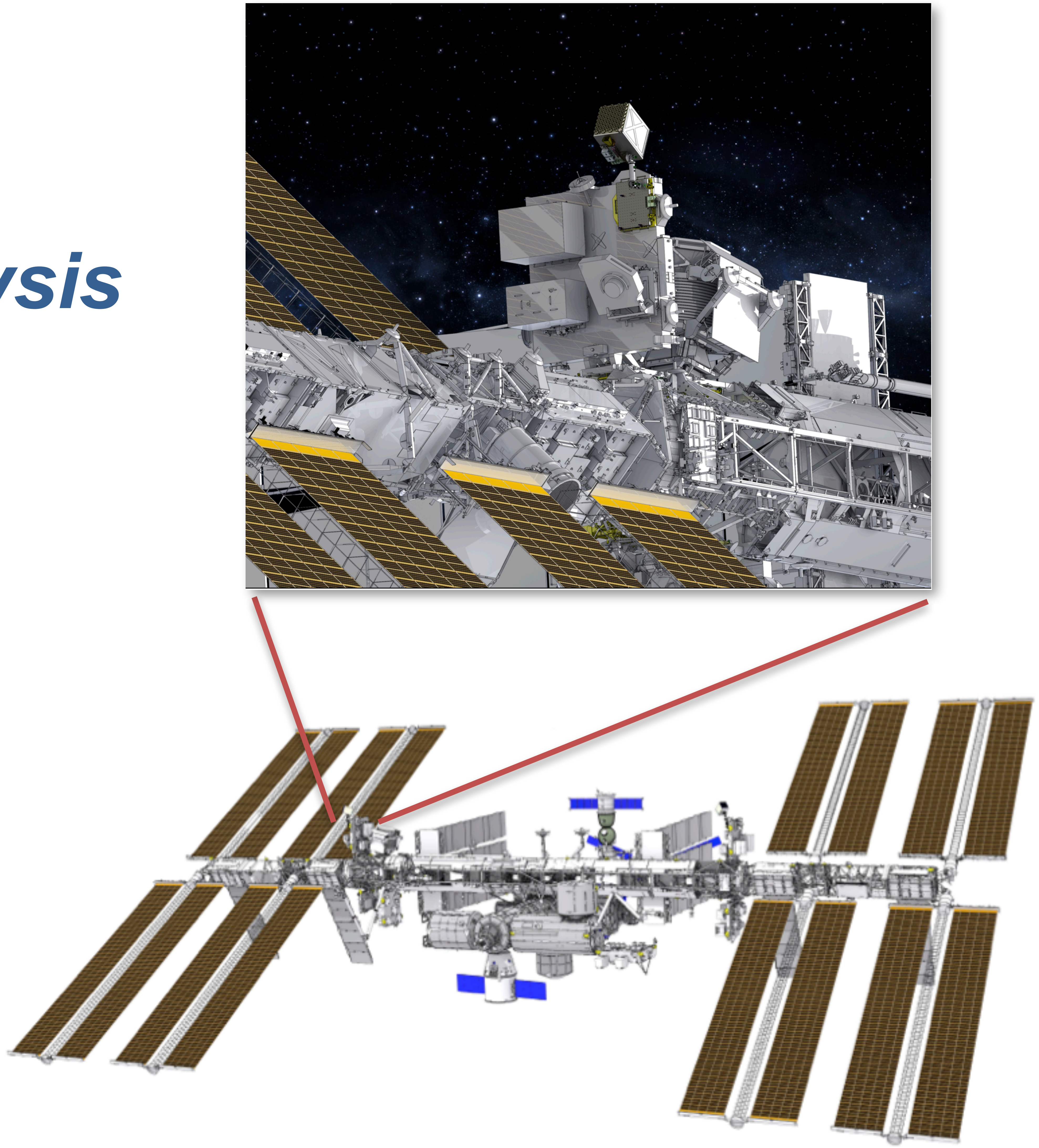
on behalf of the NICER team

NASA GSFC MIT KAVLI INSTITUTE DTU BROAD REACH MOOG

Overview

1) NICER Light Leak work
2) Update on 3C 273 analysis
3) IACHEC Online
4) Summary



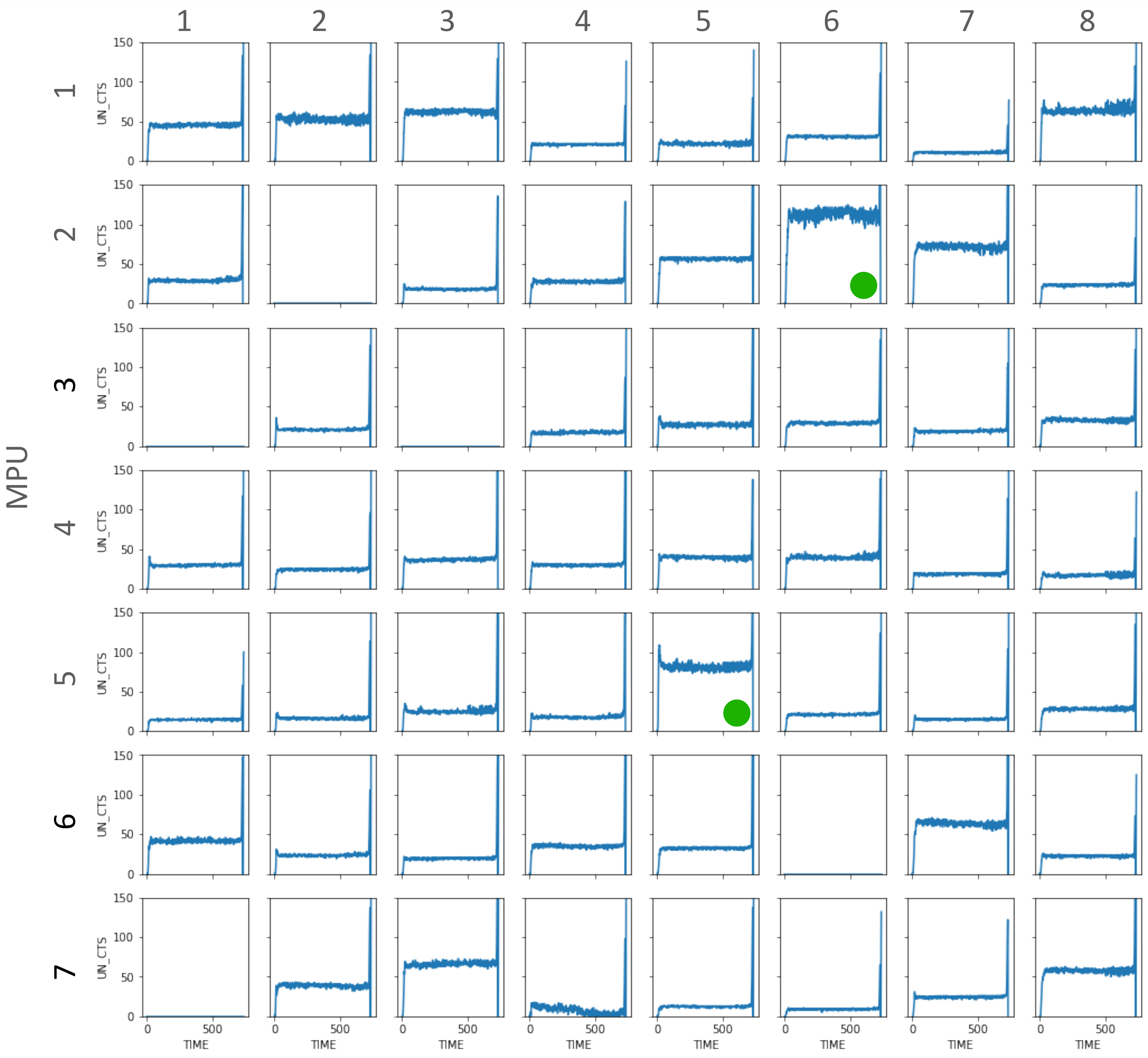
Light Leak

First Jupiter Observation

Example undershoot rate versus time plot for all detectors

Taken from first observations of Jupiter from Nov. 16, 2023

Note 5-5 and 2-6 are highly elevated



Light Leak

Area missing calculated from high fidelity images taken by astronaut on ISS

Detectors that agree (i.e., are in the top five between image and undershoot analysis highlighted in green

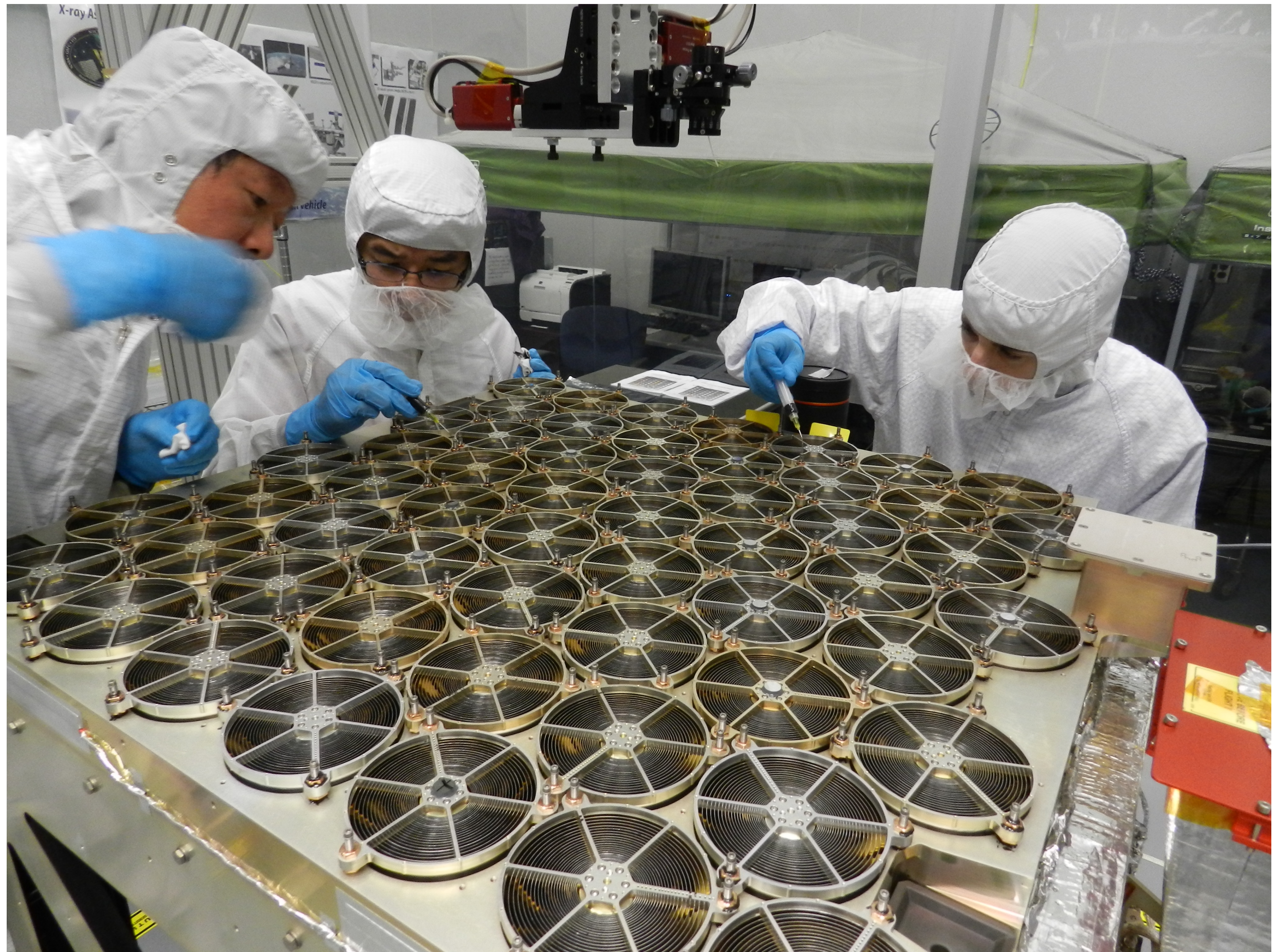
Relatively good agreement between image and undershoot analysis

Other work: Detector window analysis, optical blocking filter analysis, shelf analysis, pulsed crab emission

#	Area Missing	Jupiter 1	Jupiter 2	VEGA_1	VEGA_2	Betel
1	5-5	2-6	2-6	2-6	2-6	2-6
2	7-3	5-5	5-5	5-5	5-5	2-7
3	4-5	2-7	2-7	1-3	1-3	6-7
4	1-8	7-3	7-3	2-7	2-7	5-5
5	2-6	1-8	6-7	1-8	1-8	1-3

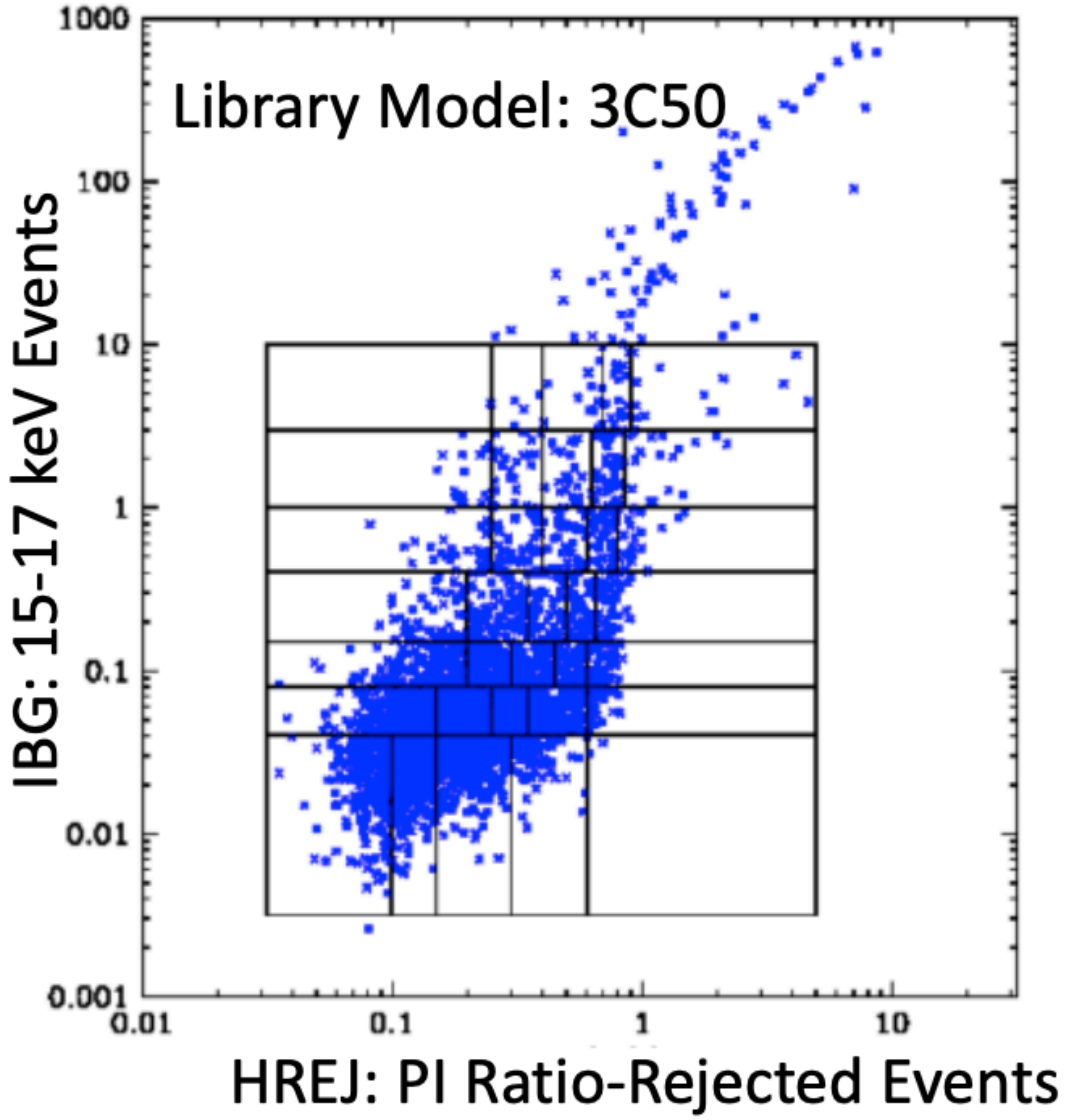
Background

- *NICER is a non-imaging instrument so no simultaneous background is obtained*
- *Must rely on blank sky backgrounds and/or background models to subtract background*

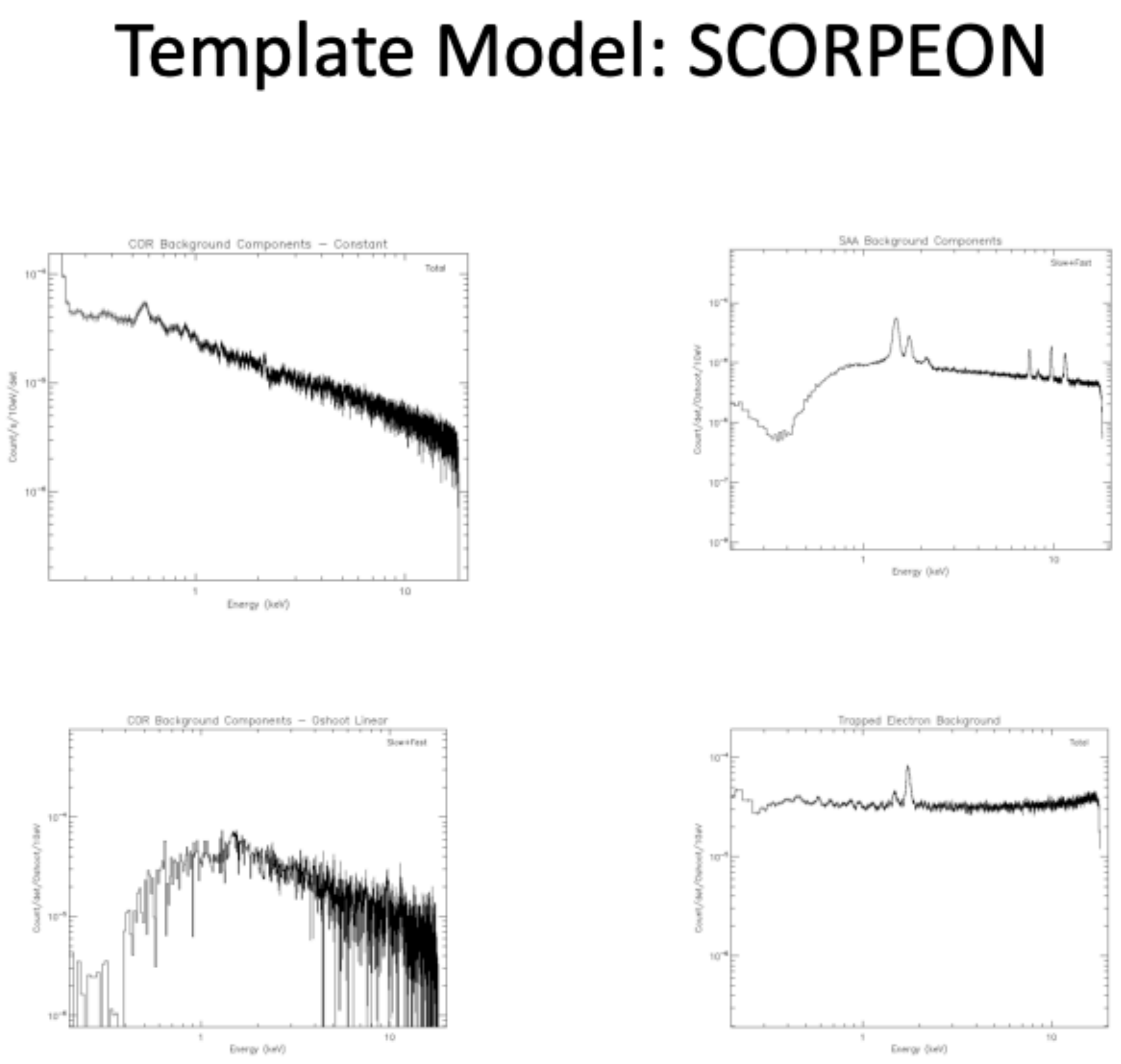


Two ways of handling background

Remillard et al. 2022

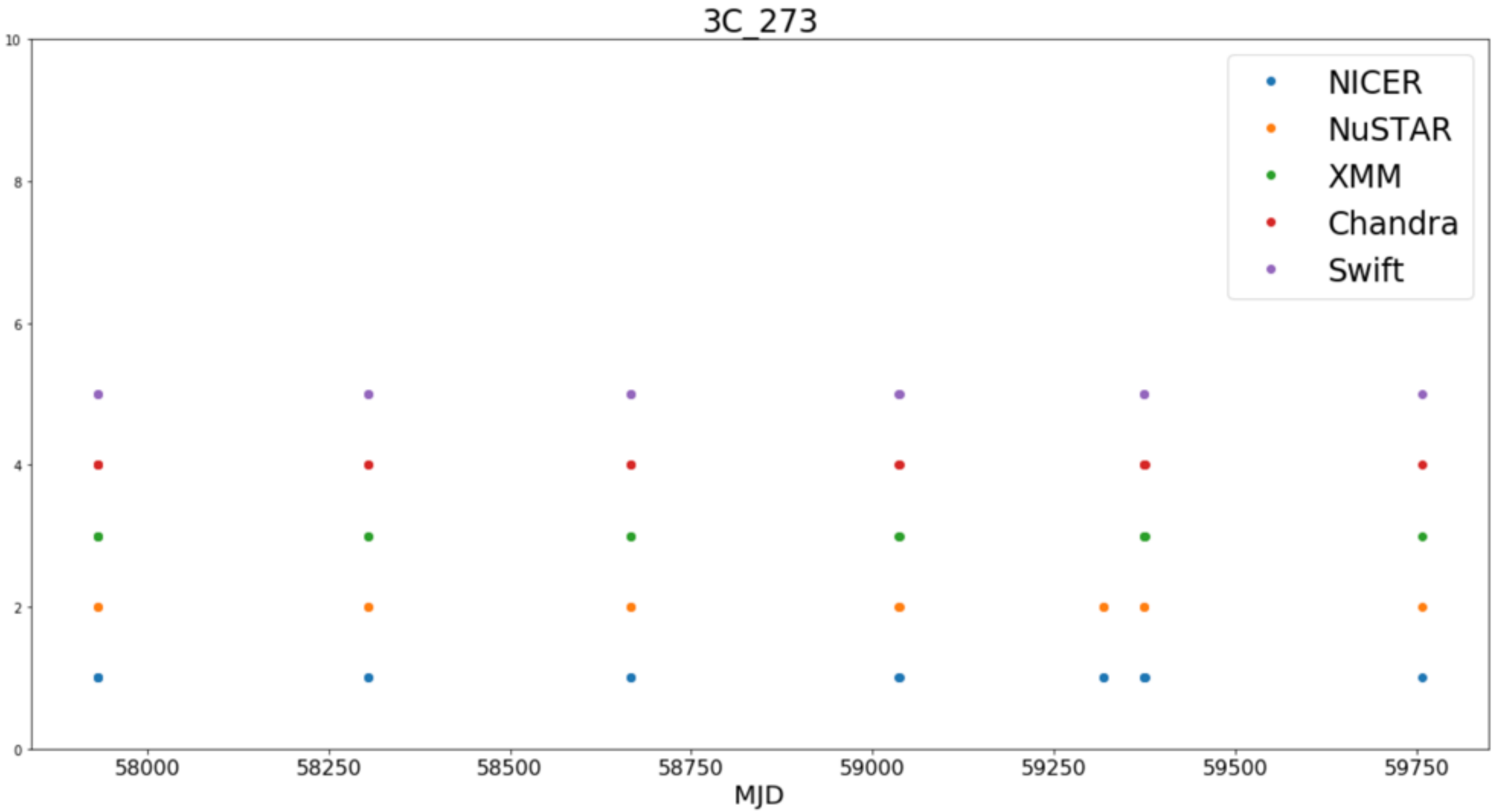


- Break parameter space into cells, measure background in each shell (library of spectra)
- Application: calculate exposure in each shell, make weighted sum of library spectra



- Measure ”basis vector” of each unique component
  - Make smoothed version of template as XSPEC model
- Normalized based on known telemetry (overshoots, etc)
- Application: predict norms from telemetry & load into XSPEC

IACHEC Observing Campaign 3C 273

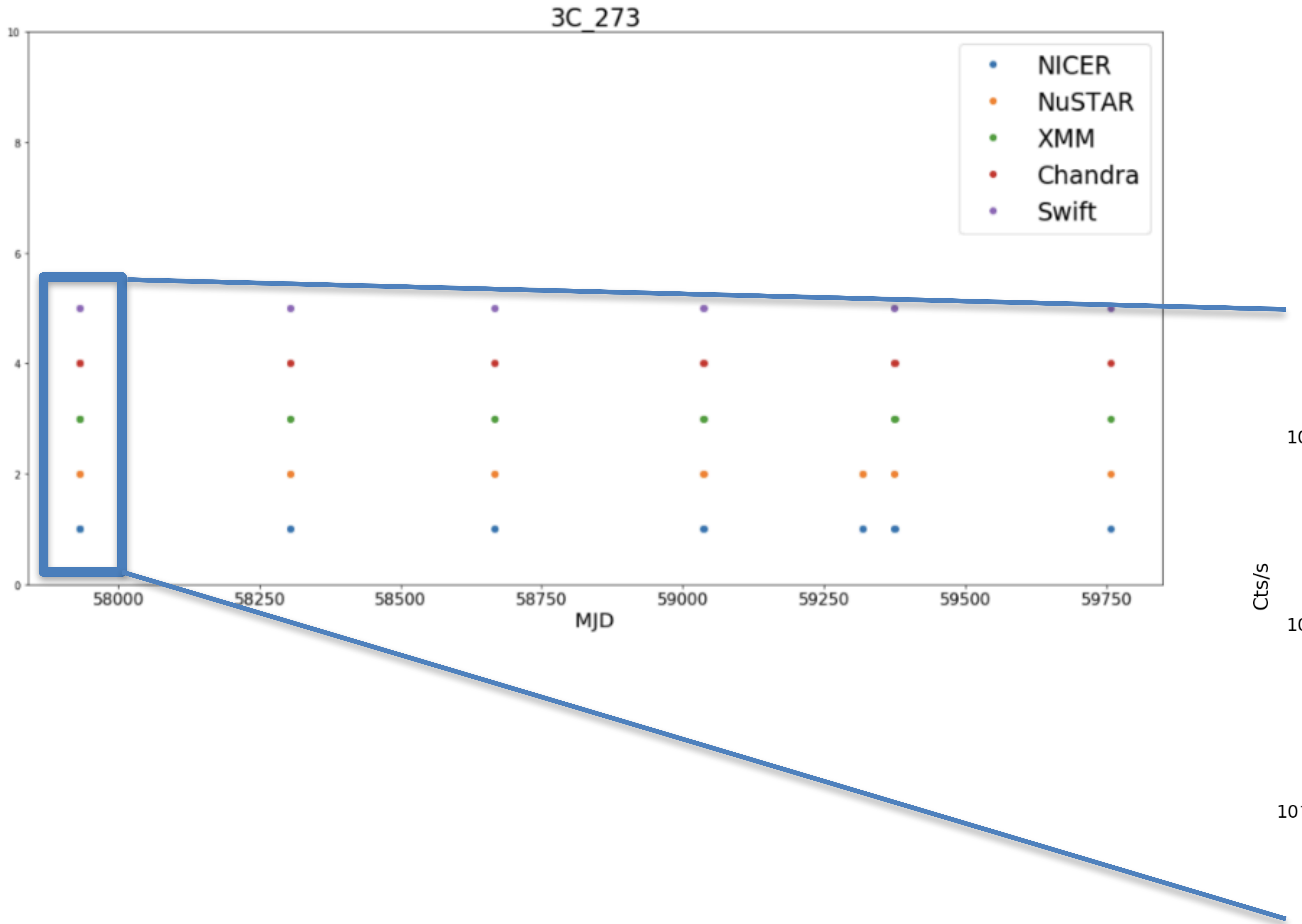


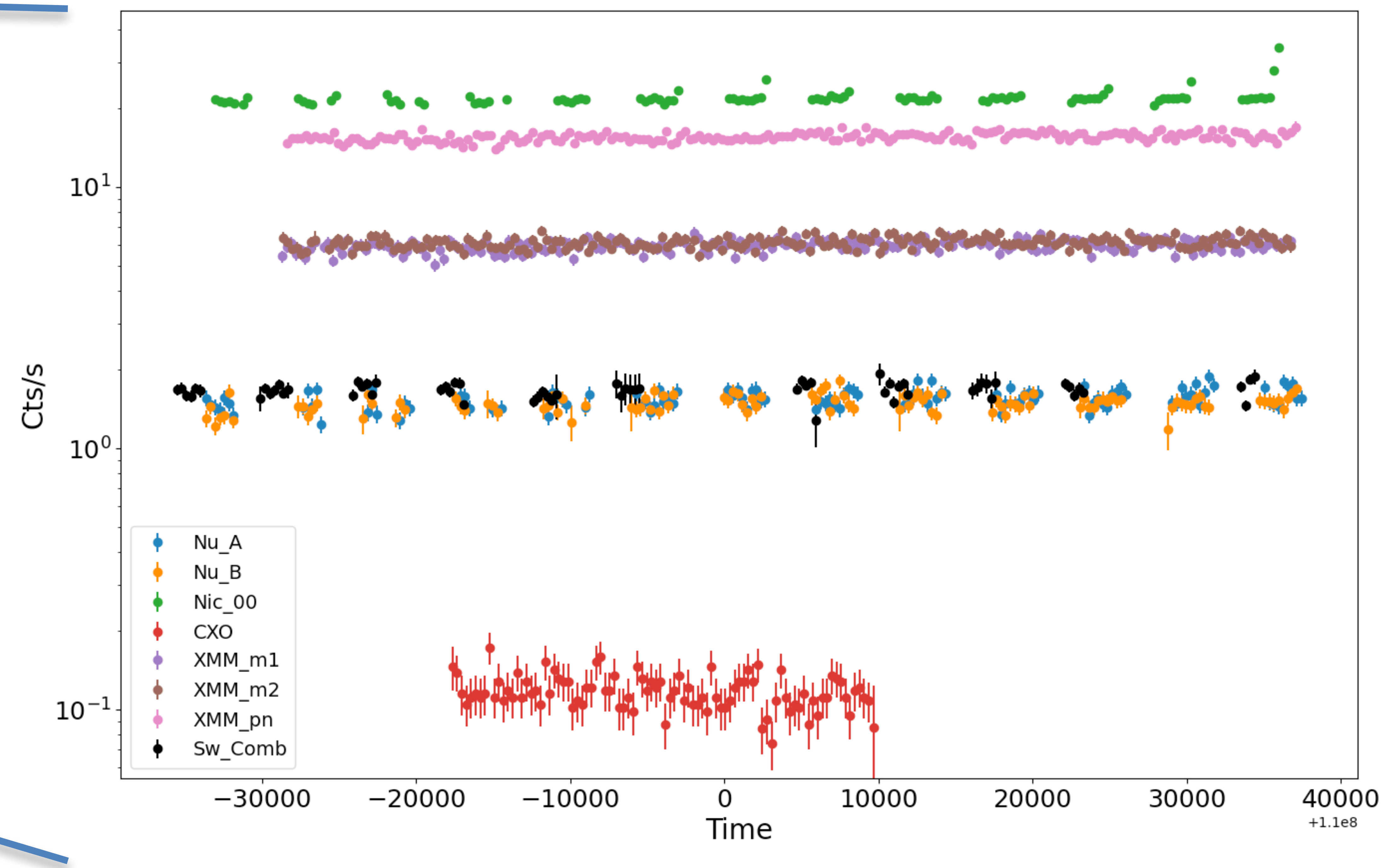
IACHEC Observing Campaign 3C 273

7 total epochs included

TIME	NIC_ID	NU_ID	NU_S	CH_ID	CH_S	XMM_ID	XMM_S	SW_ID_1	SW_S_1
57931	10100101	10302020002	S	19867	S	414191301	S	50900023	S
57931	10100102	10302020002	S	19867	S	414191301	S	50900024	S
57932	10100103	...	...	19867	NS	414191301	NS	...	...
58304	1010100104	10402020006	S	20709	S	414191401	S	50900025	S
58304	1010100105	10402020006	S	20709	S	414191401	S	50900025	S
58667	2010100101	10502620002	S	21815	NS	810820101	S	50900026	S
58667	2010100102	10502620002	S	21815	S	810820101	S	50900027	S
59036	3010100101	10602606002	S	22828	S	810821501	S	89029001	S
59037	3010100102	10602606002	S	22828	NS	810821501	S	89029002	S
59319	3626010102	60601004002	S	...	...	...	...	...	...
59319	3626010103	60601004002	S	...	...	...	...	...	...
59375	4010100101	10702608002	S	24585	NS	810821601	S	50900028	S
59375	4010100102	10702608002	S	24585	S	810821601	S	50900029	S
59376	4010100103	...	...	24585	NS	810821601	NS	...	...
59758	5010100105	10802608002	S	25691	S	810821901	S	89372001	S

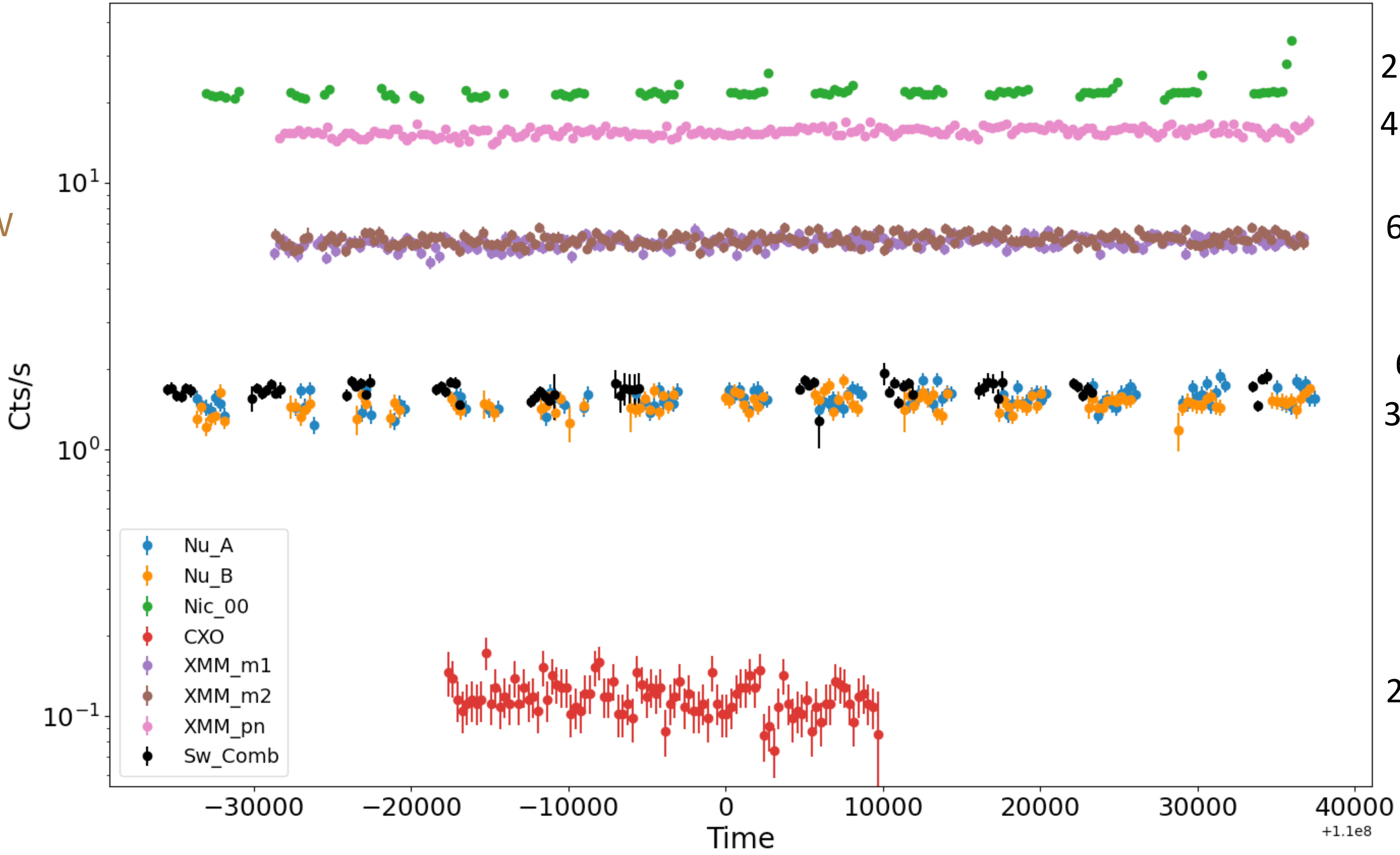
First NICER observation of 3C 273





First observation light curves

NICER
XMM pn (SW)
XMM MOS1/2 SW
Swift-XRT WT
NuSTAR FMPA/B
Chandra HETGS



26.75 ks
45.9 ks
64.5/62.7 ks
6.7/11.7 ks
34.7 ks
26.9 ks

Procedure

- Followed Madsen et al. (2017)
- Spectra extracted from each observatory following standard procedures (e.g., reprocessing, cleaning)
- Spectra binned to 1 count per bin for use with C-stat
- Spectra fit in 1-5 keV energy range
- Updated HI4PI N_H maps give 1.69×10^{20} cm^{-2} (HI4PI collab. et al. 2016)
- N_H fixed to 1.79×10^{20} cm^{-2} using Wilms abundances (Wilms et al. 2000) and Verner cross-sections (Verner et al. 1996)
- C-stat used for fitting spectra
- Chi-square/d.o.f. reported by loading in best-fit cstat model and using 50 cts/bin data

Analysis updates

- Updated Swift-XRT analysis, now using online analysis tools, improved light curve and better agreement between Swift and other spectra

Old

			N_H	Γ	$F_{1-5\ keV}$	χ^2/dof
			10^{20} cm^{-2}		10^{-11} cgs	
Swift	Sub	00050900023	1.79	1.35(6)	5.0(1)	20.4/27
Swift	Sub	00050900024	1.79	1.32(4)	5.7(1)	28.1/29

New

			N_H	Γ	$F_{1-5\ keV}$	χ^2/dof
			10^{20} cm^{-2}		10^{-11} cgs	
Sw	Sub	00050900023	1.79	1.55(2)	5.42(6)	119.52/154
Sw	Sub	00050900024	1.79	1.48(2)	5.47(5)	204.92/205
Sw	Sub	23+24	1.79	1.51(1)	5.45(4)	339.05/361

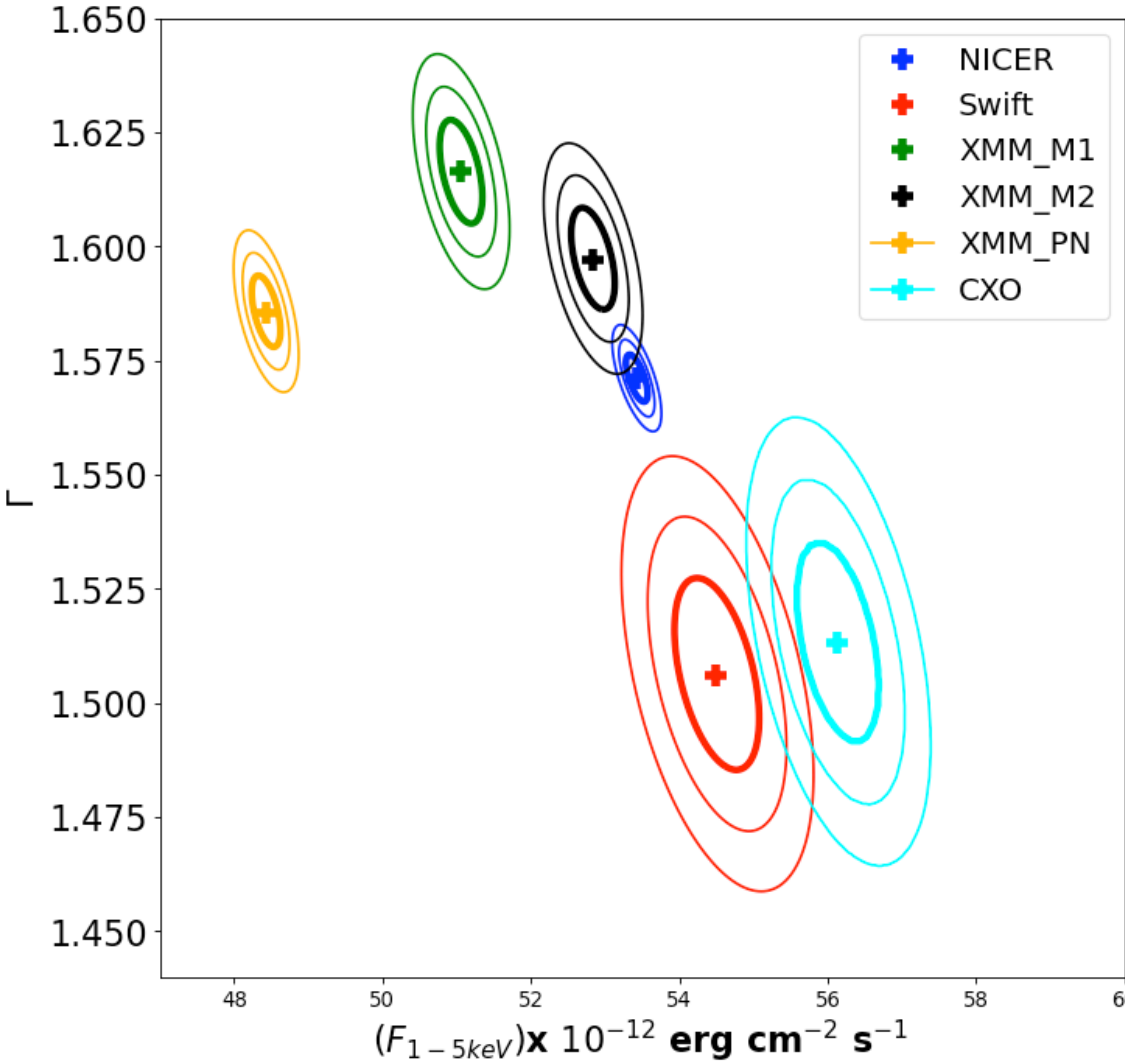
- Now using fluxcorr and caladjustment for XMM-Newton.
- Merging both NICER observations and both Swift observations

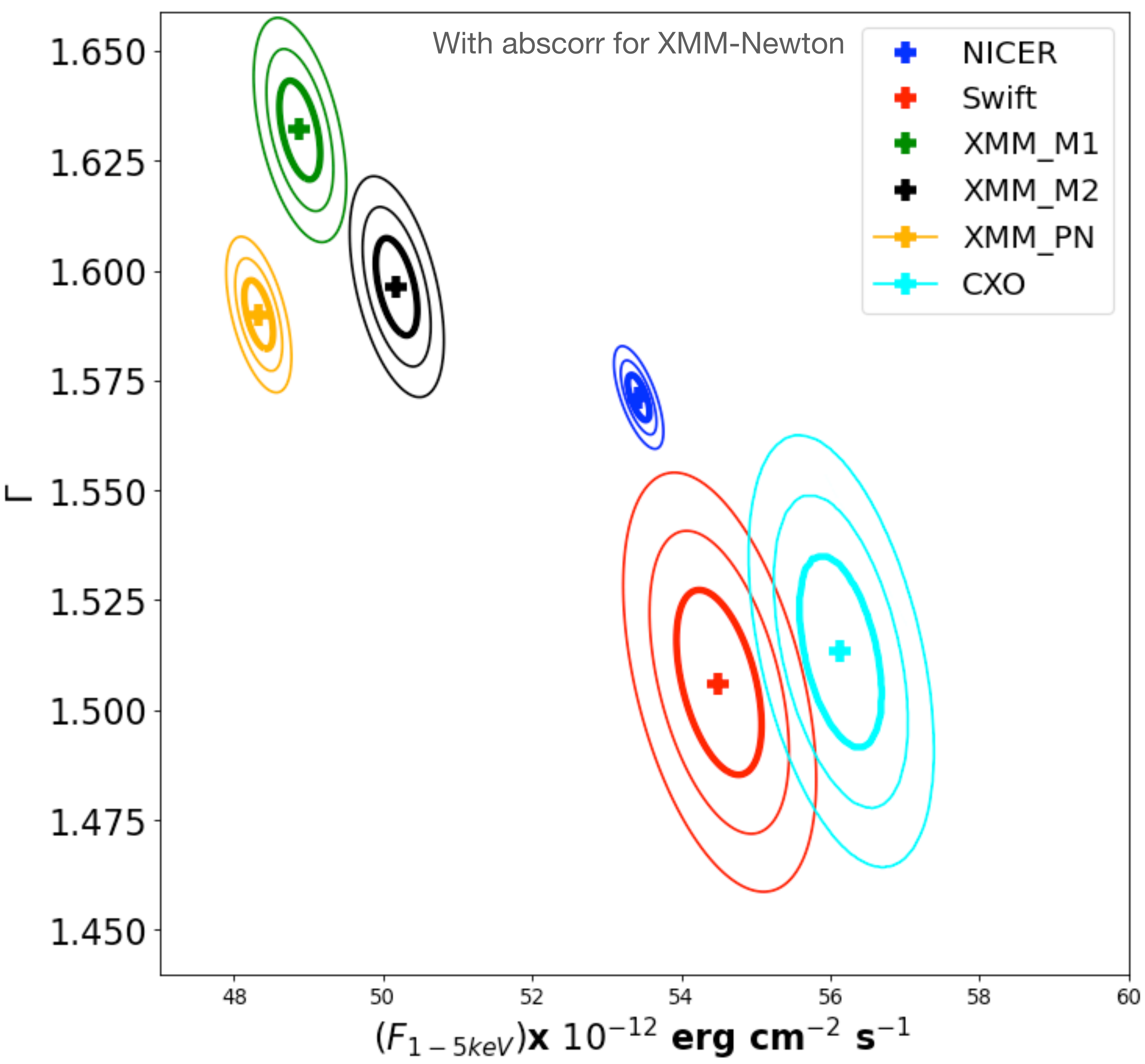
Preliminary Results 1-5 keV

Table 2. Fits performed in the 1-5 keV energy range using cstat.

Obs.	Bkg	ObsID	$N_{\rm H}$	Γ	$F_{1-5\ \rm keV}$	χ^2/dof
			10^{20} cm^{-2}		10^{-11} cgs	
NIC	3C50	10100101	1.79	1.593(7)	5.17(2)	376.3/378
NIC	3C50	10100102	1.79	1.565(4)	5.39(1)	364.15/397
NIC	3C50	10100100	1.79	1.571(3)	5.34(1)	361.10/397
CXO	Sub	19867	1.79	1.51(1)	5.61(4)	228.14/583
Sw	Sub	00050900023	1.79	1.55(2)	5.42(6)	119.52/154
Sw	Sub	00050900024	1.79	1.48(2)	5.47(5)	204.92/205
Sw	Sub	23+24	1.79	1.51(1)	5.45(4)	339.05/361
XMM_{PN}	Sub	0414191301	1.79	1.586(5)	4.84(1)	887.03/800
XMM_{MOS1}	Sub	0414191301	1.79	1.616(7)	5.11(2)	800.05/664
XMM_{MOS2}	Sub	0414191301	1.79	1.597(7)	5.28(2)	720.57/675
$XMM_{PN,abs}$	Sub	0414191301	1.79	1.590(5)	4.83(1)	887.03/800
$XMM_{MOS1,abs}$	Sub	0414191301	1.79	1.632(7)	4.89(2)	721.77/664
$XMM_{MOS2,abs}$	Sub	0414191301	1.79	1.596(7)	5.02(2)	686.90/675

Preliminary Results 1-5 keV



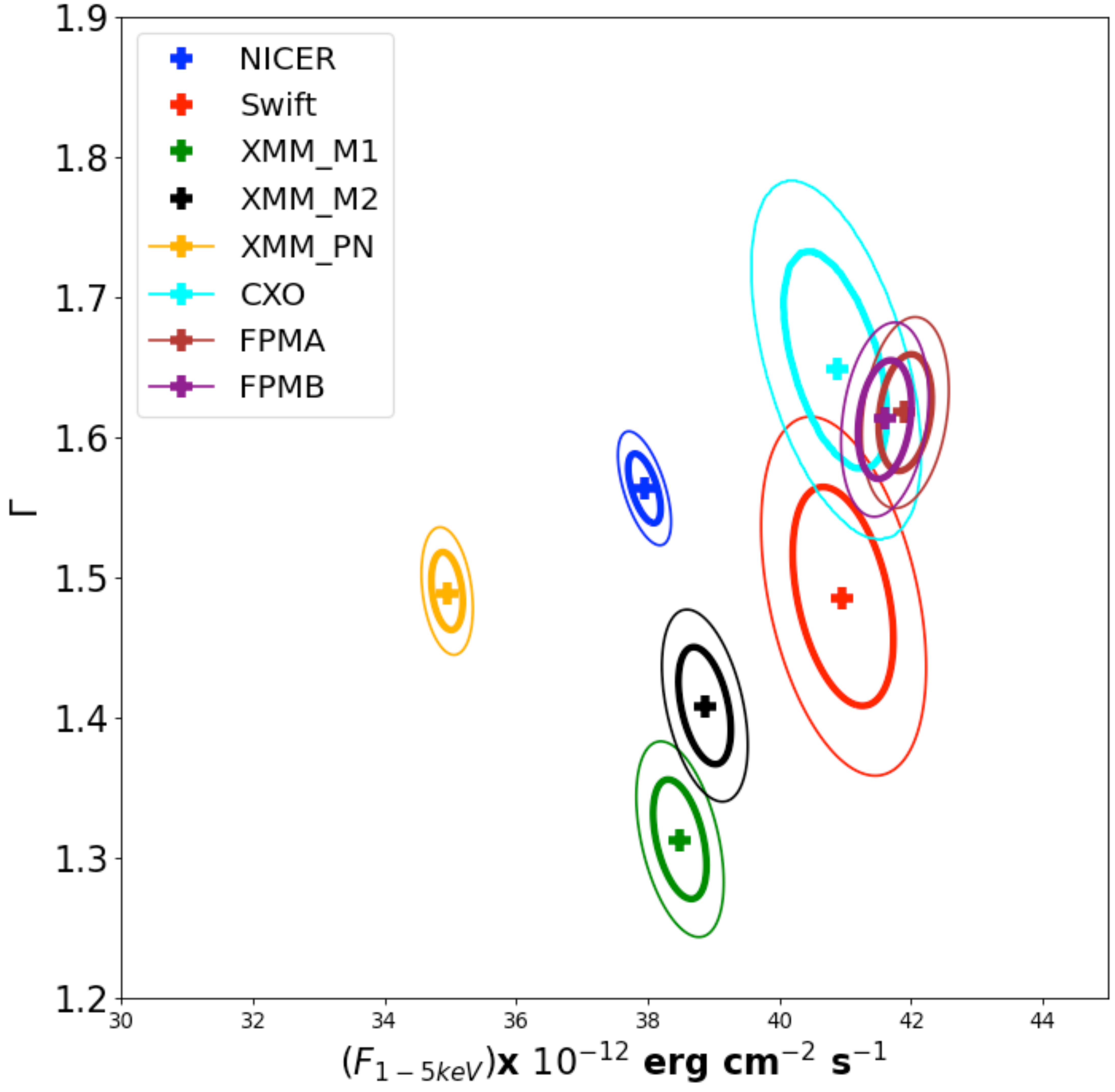


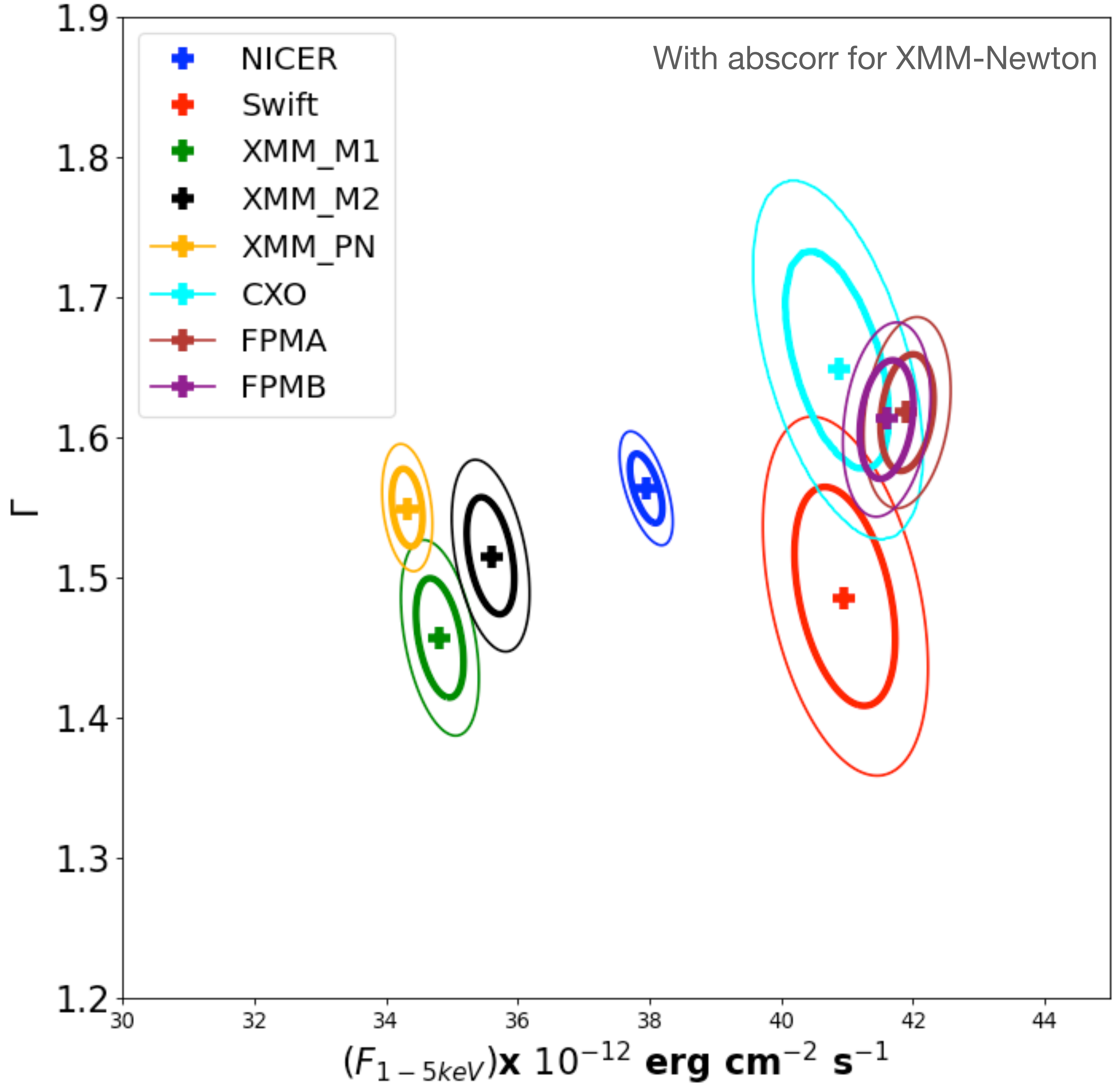
Preliminary Results 3-7 keV

Table 3. NEW Fits performed in the 3-7 keV energy range using cstat.

Obs.	Bkg	ObsID	N_H	Γ	$F_{1-5\ keV}$	χ^2/dof
			10^{20} cm^{-2}		10^{-11} cgs	
NIC	3C50	10100101	1.79	1.63(4)	3.58(3)	249.76/258
NIC	3C50	10100102	1.79	1.55(2)	3.86(2)	398.18/392
NIC	3C50	10100100	1.79	1.56(2)	3.79(2)	409.35/397
XMM_{PN}	Sub	0414191301	1.79	1.49(2)	3.49(2)	671.99/653
XMM_{M1}	Sub	0414191301	1.79	1.31(3)	3.85(3)	416.37/380
XMM_{M2}	Sub	0414191301	1.79	1.41(3)	3.89(3)	421.74/395
$XMM_{PN,abscorr}$	Sub	0414191301	1.79	1.55(2)	3.43(2)	852.11/797
$XMM_{M1,abscorr}$	Sub	0414191301	1.79	1.46(3)	3.48(2)	416.55/380
$XMM_{M2,abscorr}$	Sub	0414191301	1.79	1.51(3)	3.56(2)	424.64/395
CXO	Sub	19867	1.79	1.65(5)	4.08(5)	68.35/158
Swift	Sub	00050900023	1.79	1.32(8)	4.06(8)	48.53/53
Swift	Sub	00050900024	1.79	1.59(6)	4.12(6)	70.45/84
Swift	Sub	23+24	1.79	1.49(5)	4.10	127.5/139
$NuSTAR_{FPMA}$	Sub	10302020002	1.79	1.62(3)	4.19(3)	98.27/97
$NuSTAR_{FPMB}$	Sub	10302020002	1.79	1.61(3)	4.16(3)	107.18/97

Preliminary Results 3-7 keV





3C 273 Observations and Data Overview

Made by Felix

Created by Felix Fuerst, last modified on Jul 28, 2023 05:37

Purpose

This page is intended to collect all relevant observations of 3C273 performed under the coordinated IACHEC calibration program. We want to collect observation information (e.g., dates, exposure times, modes, etc.) as well as the extracted data by the instrument teams. The data will be available for use by any calibration team within the IACHEC consortium to perform instrument calibration.

Common GTIs

While most observations have a significant overlap, the start and stop times between the different missions do not align. We aim to provide a set of common GTIs that should be used for all instruments to select on the most useful overlapping time range. Data should be provided for the whole observation for each instrument, as well as the one filtered for the common GTI.

Observation overview

2021

Instrument	ObsID	StartDate	EndDate	Good exposure	Link to Data
XMM-Newton EPIC/pn	0810821601	2021-06-09 19:26:58	2021-06-10 13:30:18		
NuSTAR FPM	10702608002	2021-06-09 18:36:09			
Chandra	24585				

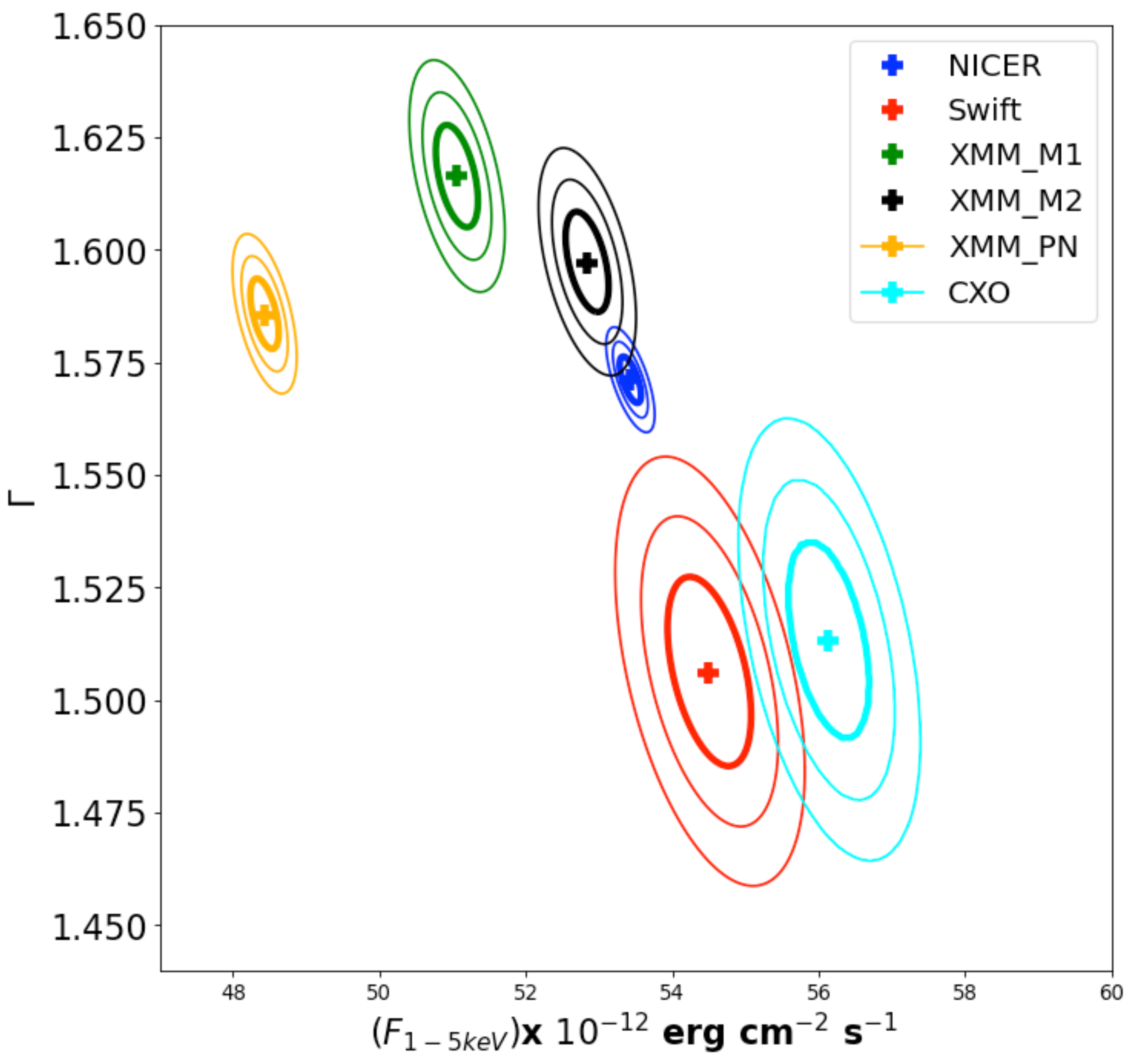
2020

Instrument	ObsID	StartDate	EndDate	Good exposure (ks)	Link to Data
XMM-Newton EPIC/pn	0810821501	2020-07-06 11:59:20	2020-07-07 07:24:20	47.632	0810821501_ann135-720_spec.tar.gz
NuSTAR FPM	10602606002	2020-07-06 04:56:09	2020-07-08 08:22:01		
Chandra	22828				

No labels

IACHEC Online

- Website includes spectra reduced by each observatory team
- Python notebooks that will download the spectra from website
- Models used will also be included
- Notebooks can be used to choose energy ranges and produce contour plots



IACHEC Online

- Can eventually include analysis scripts through Python notebooks, which will download the observations and reduce them, fit the spectra, and plot contours.
- Swift online has API, so is scriptable. All other pipelines can also be run through a python interface (CIAO, heasoftpy, SAS notebooks).

Good and Bad

- **Good:** Would allow for results from all IACHEC observing campaigns to be easily accessible to the community
- Many datasets go unpublished, once scripts are made, all subsequent datasets for a given source can be analyzed quickly
- Users can fit in energy ranges they are most interested in and not ones predefined by us
- **Bad:** Users can fit in energy ranges they are most interested in and not ones predefined by us. Model may be invalid in energy range chosen.
- Some models are complex and may need lots of explanation (e.g., Cas A)
- May lead to users asking many questions about analysis that would need to be answered

Summary

- NICER has taken part in 6 (7 with NuSTAR) calibration observing campaigns of 3C 273
- Re-started the analysis of these is observations with an updated analyses for XMM-Newton and Swift-XRT, with results still consistent with Madsen et al. (2017)
- We should consider ways to make the IACHEC datasets and analyses more accessible to the community, hosting these spectra in a public database could hep facilitate this, but will require some upfront work from the observatory teams

- I appreciate any feedback, questions, and/or suggestions!