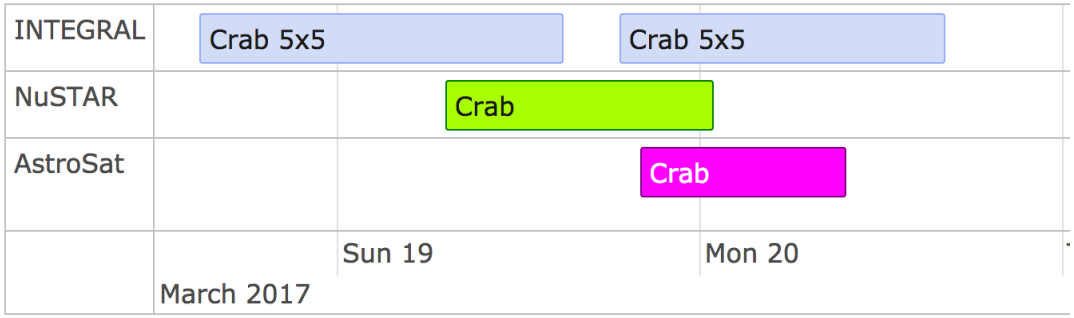
Recent and upcoming cross-calibration campaigns

- Crab calibration in 2014 with XMM and INTEGRAL
- IACHEC campaign on 3C273 on 2012, 2015, 2016: Chandra, NuSTAR, Suzaku, XMM and INTEGRAL
- NuSTAR Observations coordinated with Astrosat: Cyg X-1, Cyg X-3, GRS 1915+105
- Next Crab observations coordinated with Astrosat and NuSTAR



Courtesy: P.Kretschmar

Other efforts

Cross calibration using archival data:

- IACHEC efforts:
  G21.5-0.9 (Tsujimoto+2010), to be revised against NuSTAR results.
  Crab (Natalucci+?), to re-run data with new calibration for NuSTAR (and possibly XMM)
- Significant data to be exploited using public data for INTEGRAL pointings simultaneous with other satellites (advantage of the large FOV)

Crab

Energy bands and epochs

Instr.	Energy Bands (keV)
XIS	3-10
PIN	10-25, 25-80
GSO	25-80^ 100-300
PCA	3-10, 10-25, 25-80
IBIS	25-80, 100-300
SPI	25-80, 100-300
NuSTAR	3-10, 10-25, 25-80
EPIC	3-10
GBM	(25-80), 100-300

^for GSO, E >40 keV

Epochs	Instruments	Period	<1 week(*)
A	PCA,PIN,GSO, IBIS,SPI	2005-09-15 to 2005-10-11	
B	PCA,PIN,GSO, IBIS,SPI	2006-09-05 to 2006-09-29	
C	XIS,PCA,PIN,GSO, IBIS,SPI	2007-03-11 to 2007-03-22	
D	PCA, IBIS,SPI	2007-09-22 to 2007-09-27	Y
E	PCA,PIN,GSO, IBIS,SPI,GBM	2008-08-27 to 2008-09-26	
F	PCA, IBIS,SPI,GBM	2009-08-14 to 2009-08-26	
G	PCA, IBIS,SPI	2010-02-23 to 2010-03-04	
H	PCA,PIN,GSO, GBM	2010-04-03 to 2010-04-17	
I	PCA, SPI,GBM	2010-09-22 to 2010-09-25	Y
J	PCA, IBIS,SPI,GBM	2011-02-12 to 2011-02-19	Y
K	PCA,PIN,GSO, GBM	2011-03-17 to 2011-03-27	
L	NUSTAR,(PIN,GSO),IBIS,SPI,GBM	2012-09-21 to 2012-09-26	Y
M	EPIC,NUSTAR, IBIS,SPI,GBM	2014-10-01 to 2014-10-02	Y

(*) except for GBM (obs. elapsed time ~40days)

Results of cross-cal campaigns on 3C273

- Focusing on XMM/NuSTAR/INTEGRAL comparison. Collaboration among IBIS teams at IAPS and IASF Bologna
- Previous results of 3C273 with INTEGRAL and NusTAR joint fits published by Madsen et al 2016 (ApJ 812,14)
- Previous results in the soft band (<10 keV) published in Madsen+16 (arXiv:1609.0903)

Observation log: three epochs

Epoch 1

INTEGRAL+NuSTAR

Start date: 2012-07-14, ExposureTime: 184ks

XMM/NuSTAR

Start date: 2012-07-16, ExposureTime: 27ks

Epoch2

NuSTAR/INTEGRAL

Start date: 2015-07-15, ExposureTime: 33.6ks

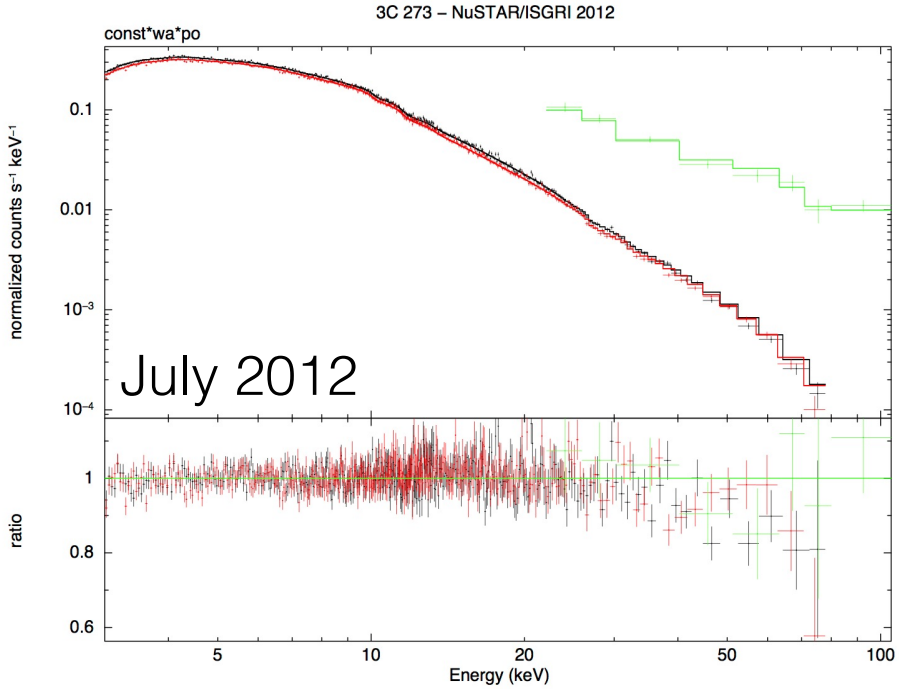
Epoch3

NuSTAR/INTEGRAL

Start date: 2016-06-26, ExposureTime: 60.2ks

NuSTAR & IBIS/ISGRI (OSA10.2)

- Fitting the same model parameters for the three instruments: Model const*wabs*powerlaw. Strictly simultaneous data windows
- Good quality of fit; $\chi^2_{red} = 0.992$ (2356 dof)
- NuSTAR residuals at high energy deviate from PL shape. Possible bias in the model, but no strong reflection component exists
- Similar result discussed in Madsen+15. Possible high energy component due to jet emission with HE cutoff at ~260 keV. Reason to limit the IBIS spectral channels to < 110 keV



- For NuSTAR, FPMB flux has always a higher flux normalisation compared to FPMA (approx. 1-3%)
- Relative flux normalization IBIS/NuSTAR(*)

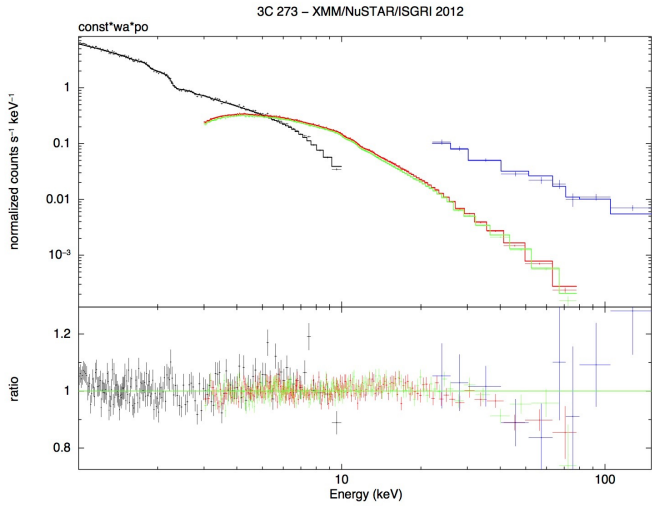
2012:	0.98-1.12
2015:	0.74-1.10
2016:	0.89-0.98

(*) average of the two FPMs

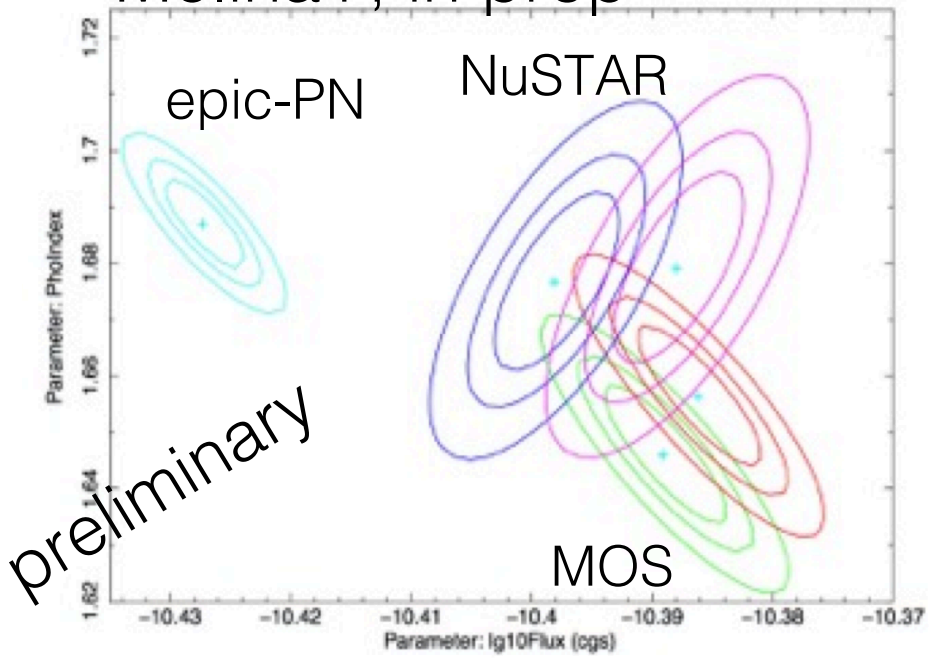
(Molina et al., in prep)

NuSTAR vs XMM

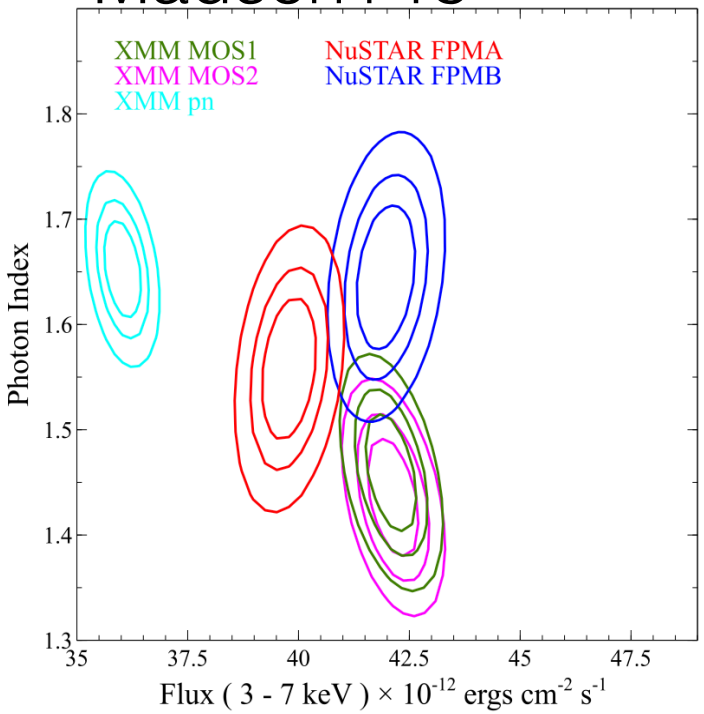
- Relative flux NuSTAR/XMM from this work and Madsen+15.
- NuSTAR and MOS flux normalisation is substantially higher than epic-PN
- NuSTAR to PN is ~8% (this work) and ~12% (Madsen+15)



Molina+, in prep

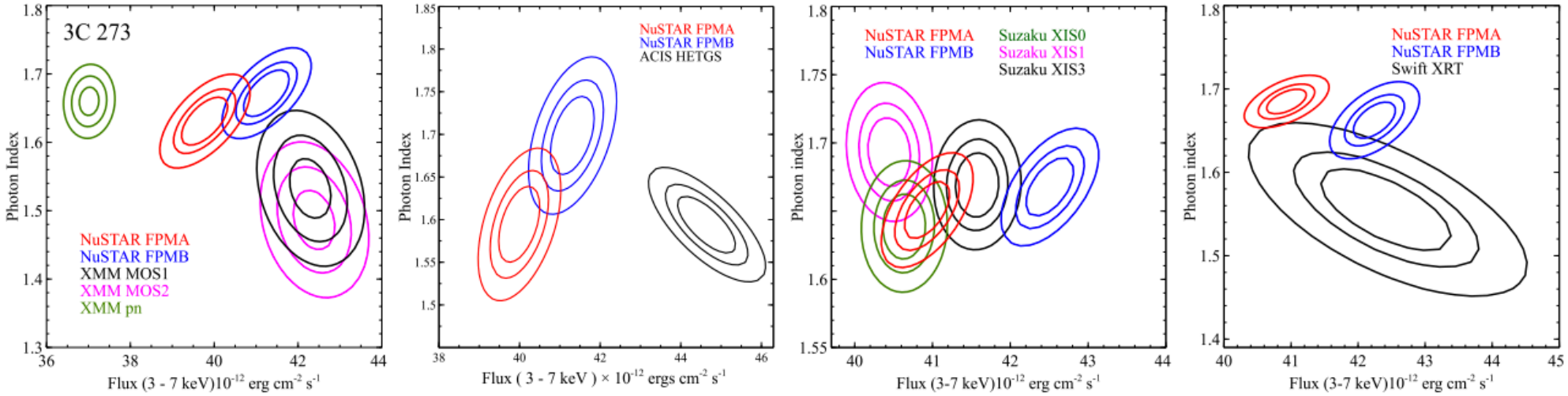


Madsen+15



NuSTAR against soft band instruments

- NuSTAR is covering both soft band and hard band (>10 keV), similar to RXTE but with enhanced sensitivity in the hard band
- Results from cross-cal campaign on 3C 273 (Madsen+2016)



- Flux normalization relative to NuSTAR (3-7 keV):
- EPIC-pn: ~0.9, ACIS HETGS: ~1.1, within ~5% for Suzaku/XIS & Swift/XRT

Some conclusions relevant to INTEGRAL

- NuSTAR effective area re-normalization has been calibrated taking into account an average normalization on Swift, Suzaku, XMM and Chandra (Madsen+16)
- Taking the reference Crab Nustar & IBIS models we expect a relative flux normalization of IBIS/NuSTAR = 1.11
- This difference seems to follow a global trend for hard X-ray instruments to have higher flux normalization respect to the soft band instruments (except Chandra)

IACHEC Meeting, 27-30 March 2017

- IACHEC meeting to take place in Lake Arrowhead, California 27-30 March 2017
- Attendees from many high energy astrophysics mission teams. Many Japanese members are back to IACHEC after few years absence.
- Current activities focus mainly on:
  - Assess our final knowledge of the relative broadband effective areas for all instruments: using IACHEC coordinated campaigns, and past observation of standard candles from soft X-rays to the ~MeV range
  - Estimating calibration uncertainties on statistical basis using various methods
  - X-ray spectroscopy analysis on cluster samples (related Athena impact)
- This 2017 meeting foresees a special session on Hitomi
- V. Sanchenko and L. Natalucci will attend the meeting