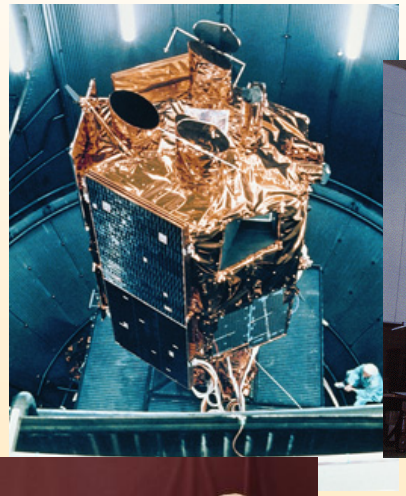
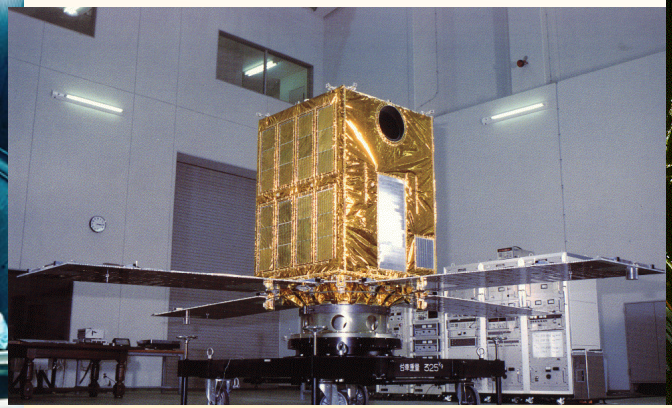
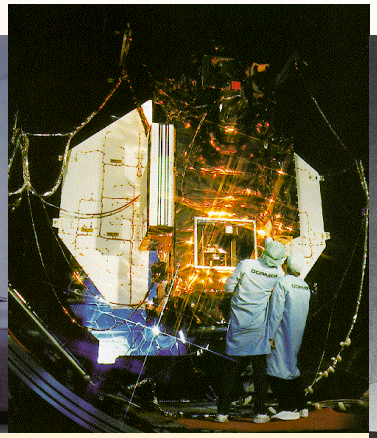
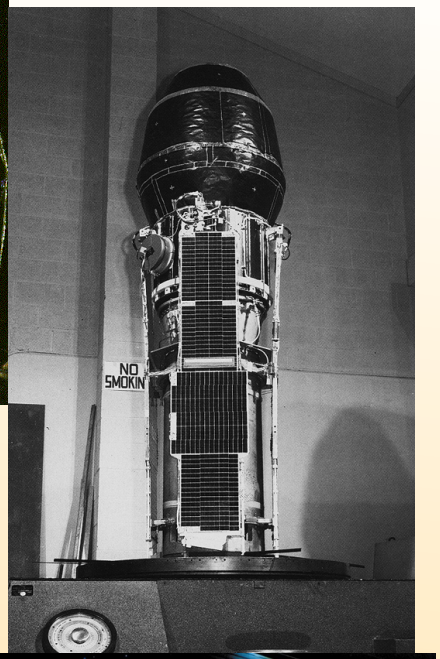
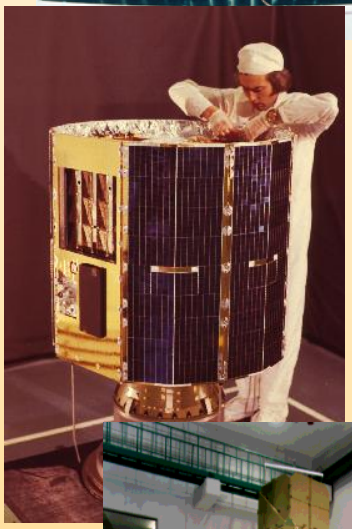
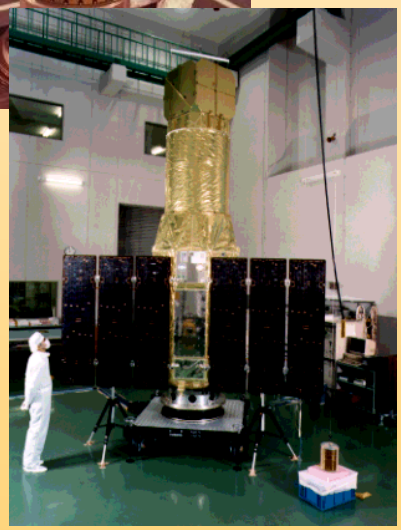
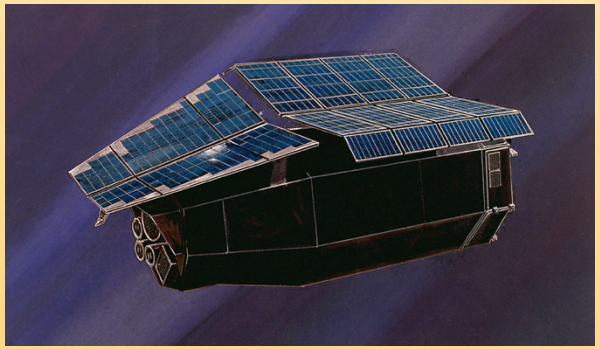
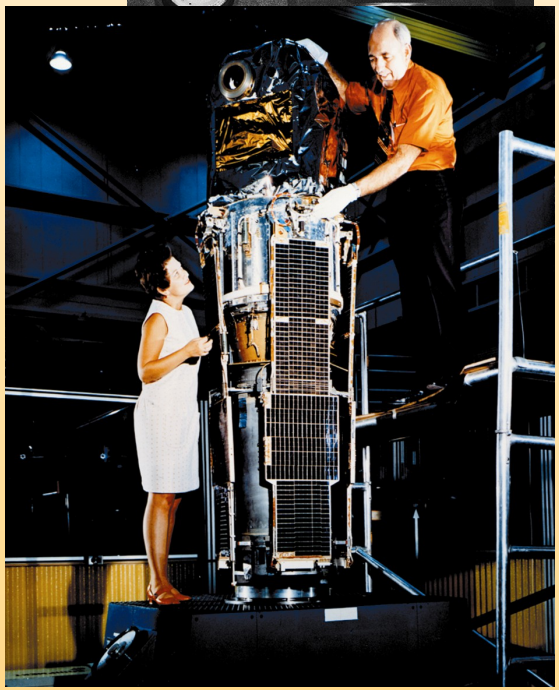







Can coordination of science programs improve cross calibration?

Karl Forster

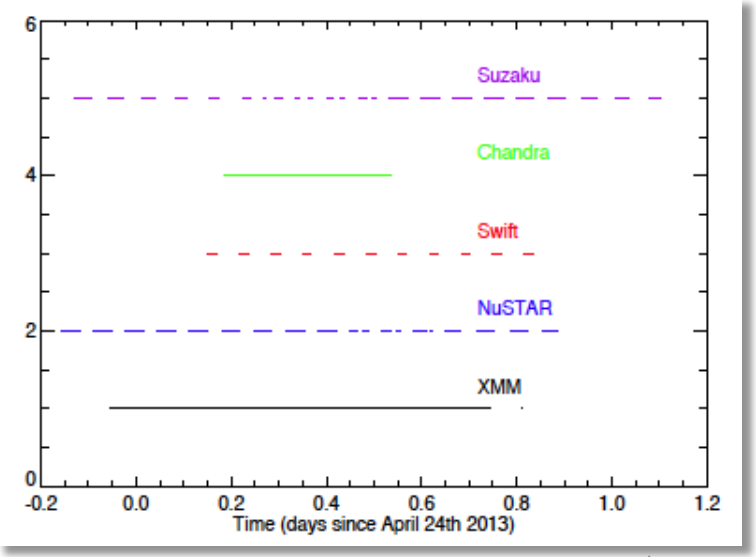
NuSTAR SOC – Caltech

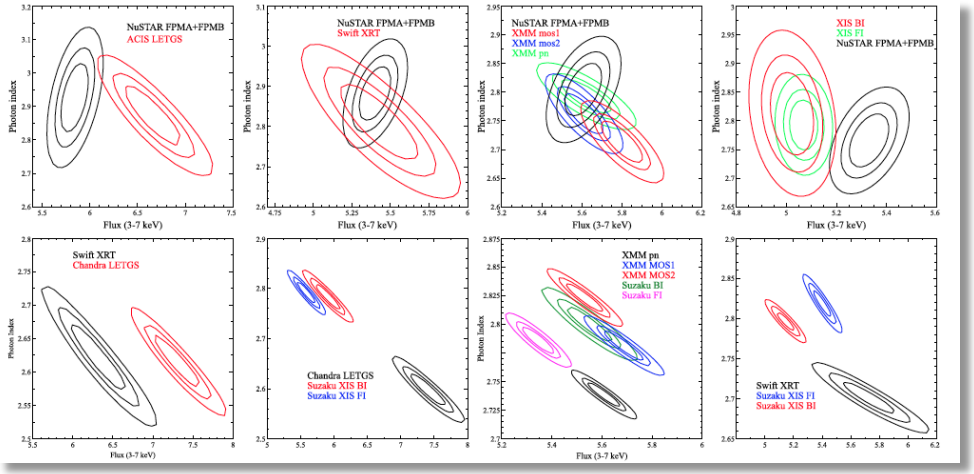




9th IACHEC meeting, Airlie Center (VA) 12-15 May 2014

Motivation

- NuSTAR has many joint observation programs
  - 15% of NuSTAR observations are coordinated with other observatories
  - MOU with Swift to observe all NuSTAR targets
    - 1 ksec for each target inc. survey areas (7 ksec for BAT selected AGN)
- Observatories offer official proposals for joint programs
  - Chandra AO16 – HST/XMM/NOAO/NRAO/Suzaku/Spitzer/Swift/NuSTAR (0.5 Msec)
  - XMM AO13 – INTEGRAL/Chandra/VLT/HST/Swift/NuSTAR (1.5 Msec)
- IACHEC coordinated calibration observations
  - E.g. **PKS 2155-304** in April 2013





Madsen et al. in prep.

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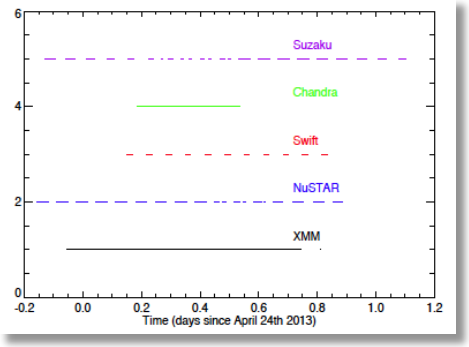
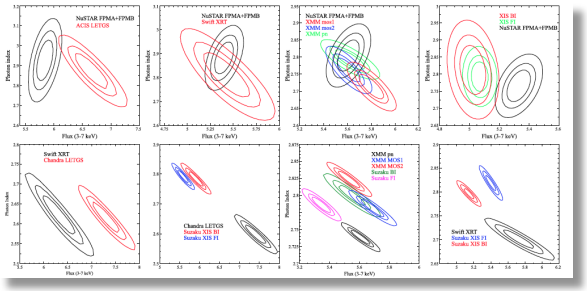


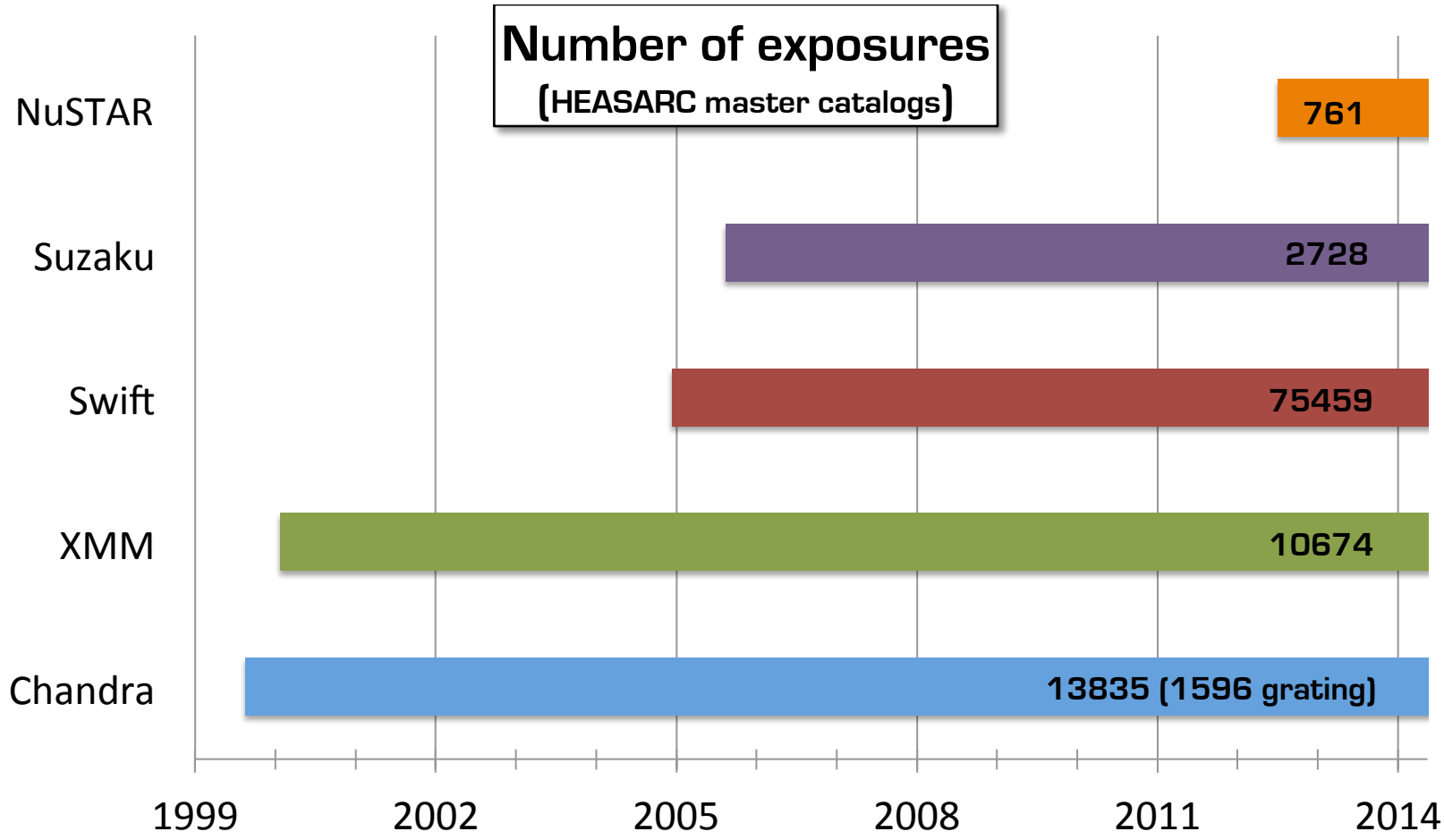


Madsen et al. in prep.

- **Will (have) serendipitous observations provide additional cross calibration?**

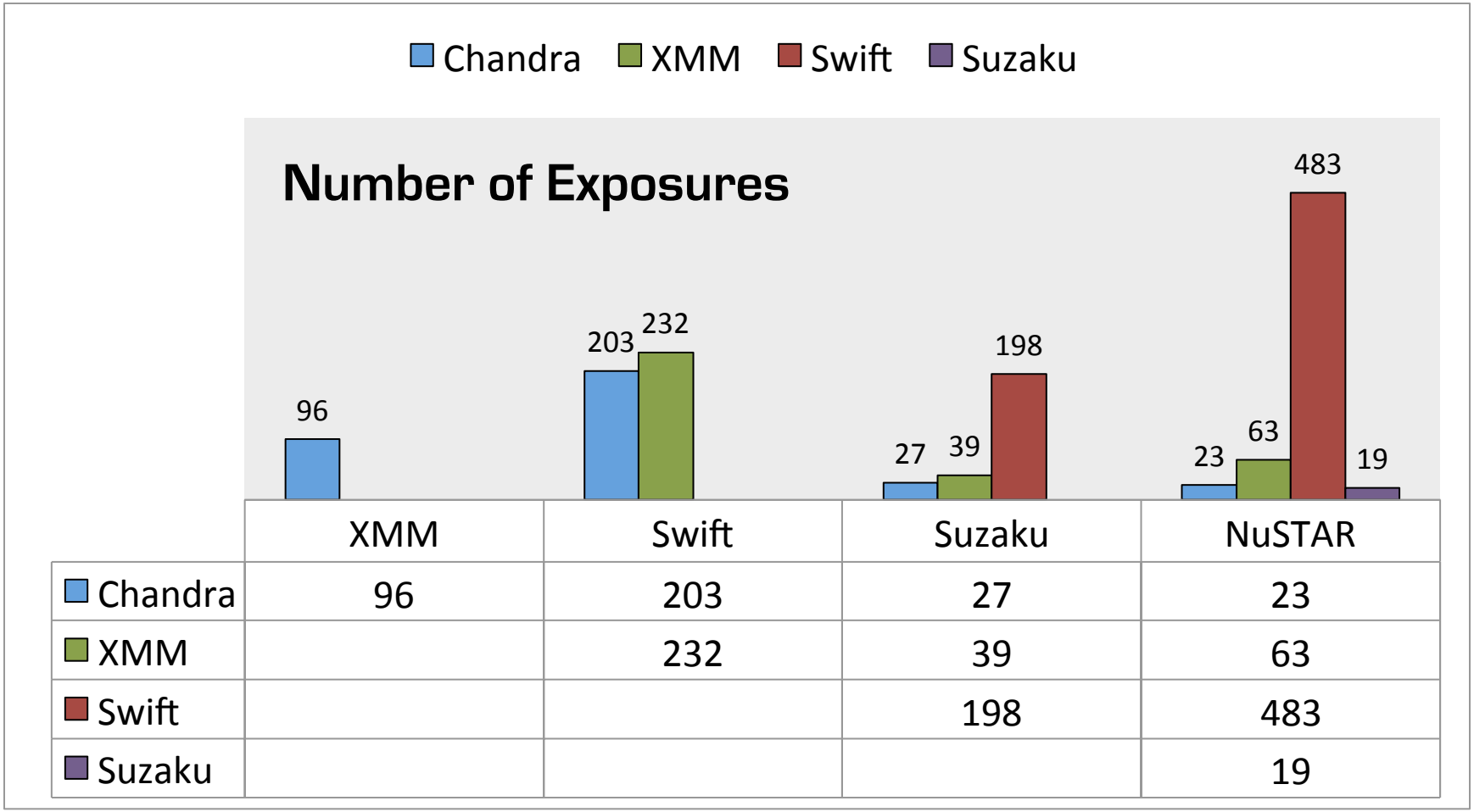
Active Mission Timeline

(sans Integral & Fermi)



Simultaneous observations

(Overlap of GTI's)



	XMM	Swift	Suzaku	NuSTAR
Chandra	96	203	27	23
XMM		232	39	63
Swift			198	483
Suzaku				19

Simultaneous observations

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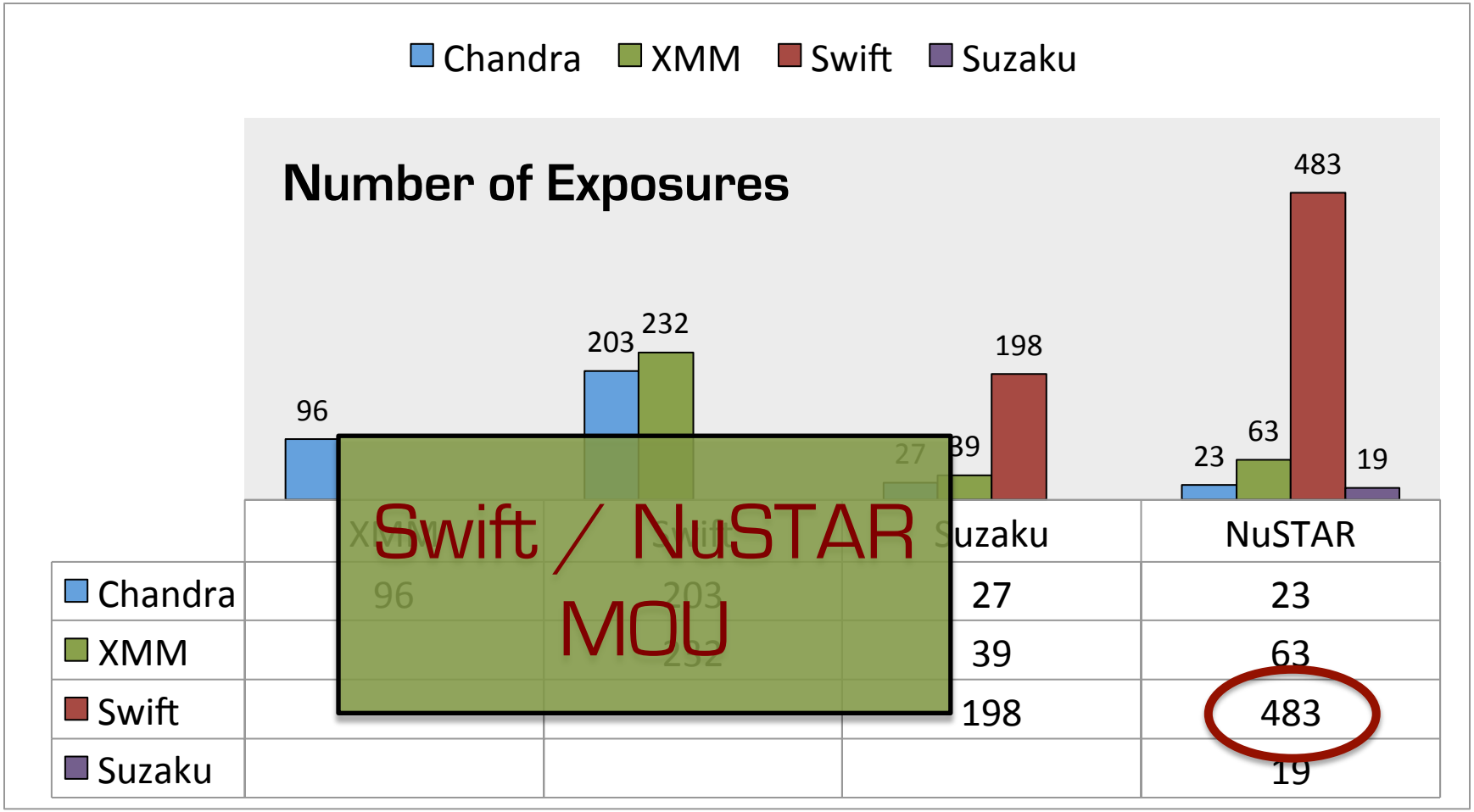

Swift / NuSTAR MOU

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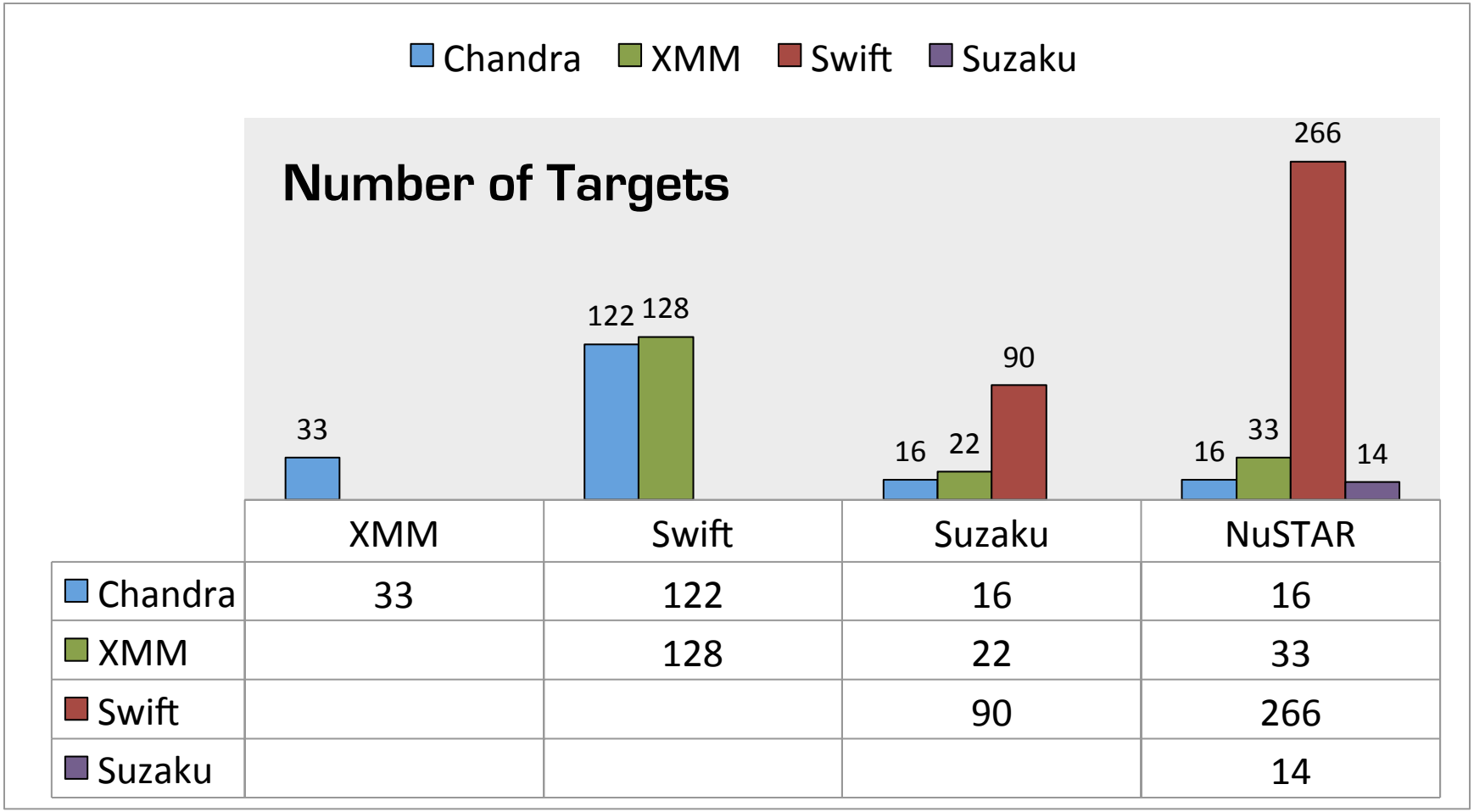

	XMM	Swift	Suzaku	NuSTAR
Chandra	33	122	16	16
XMM		128	22	33
Swift			90	266
Suzaku				14

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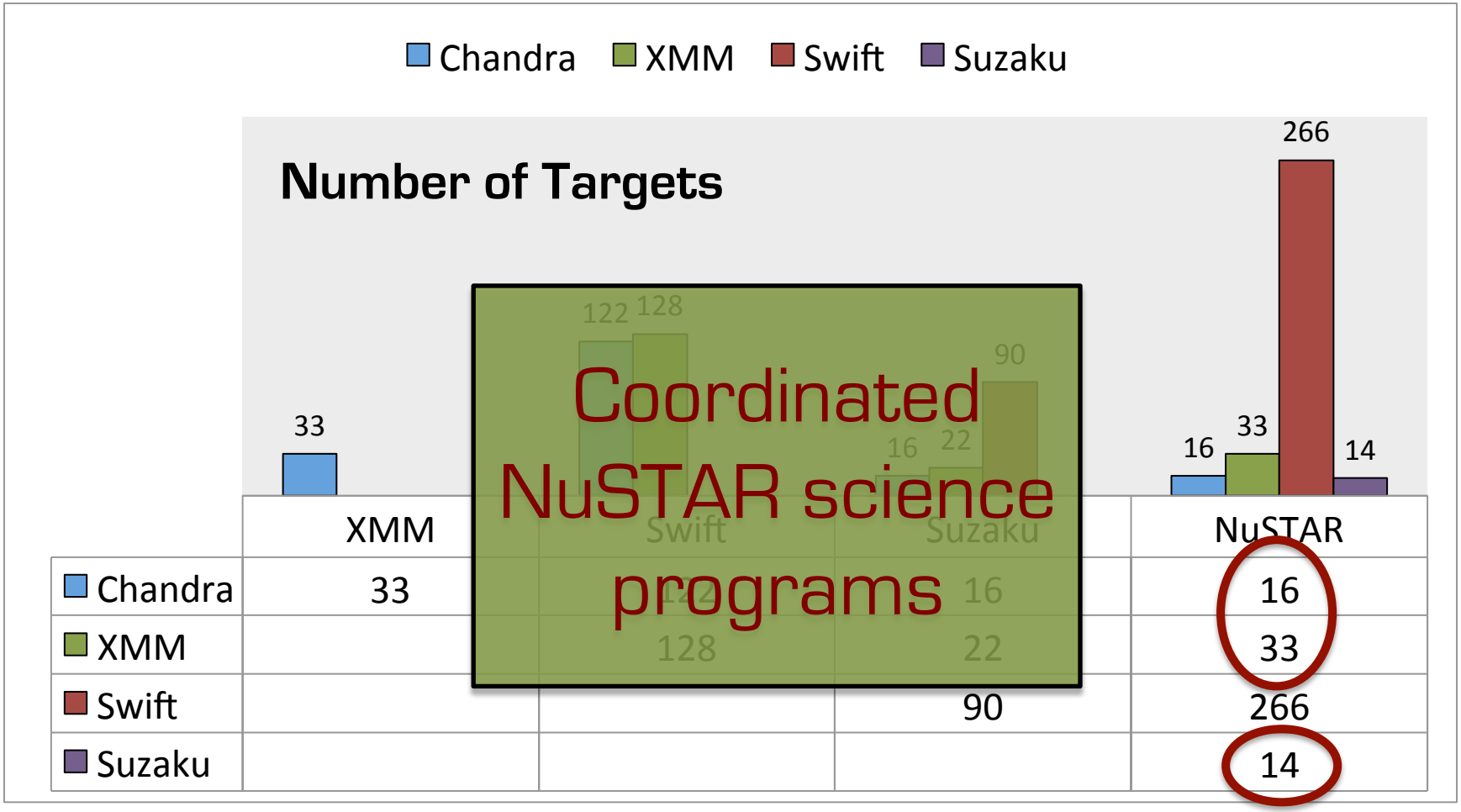

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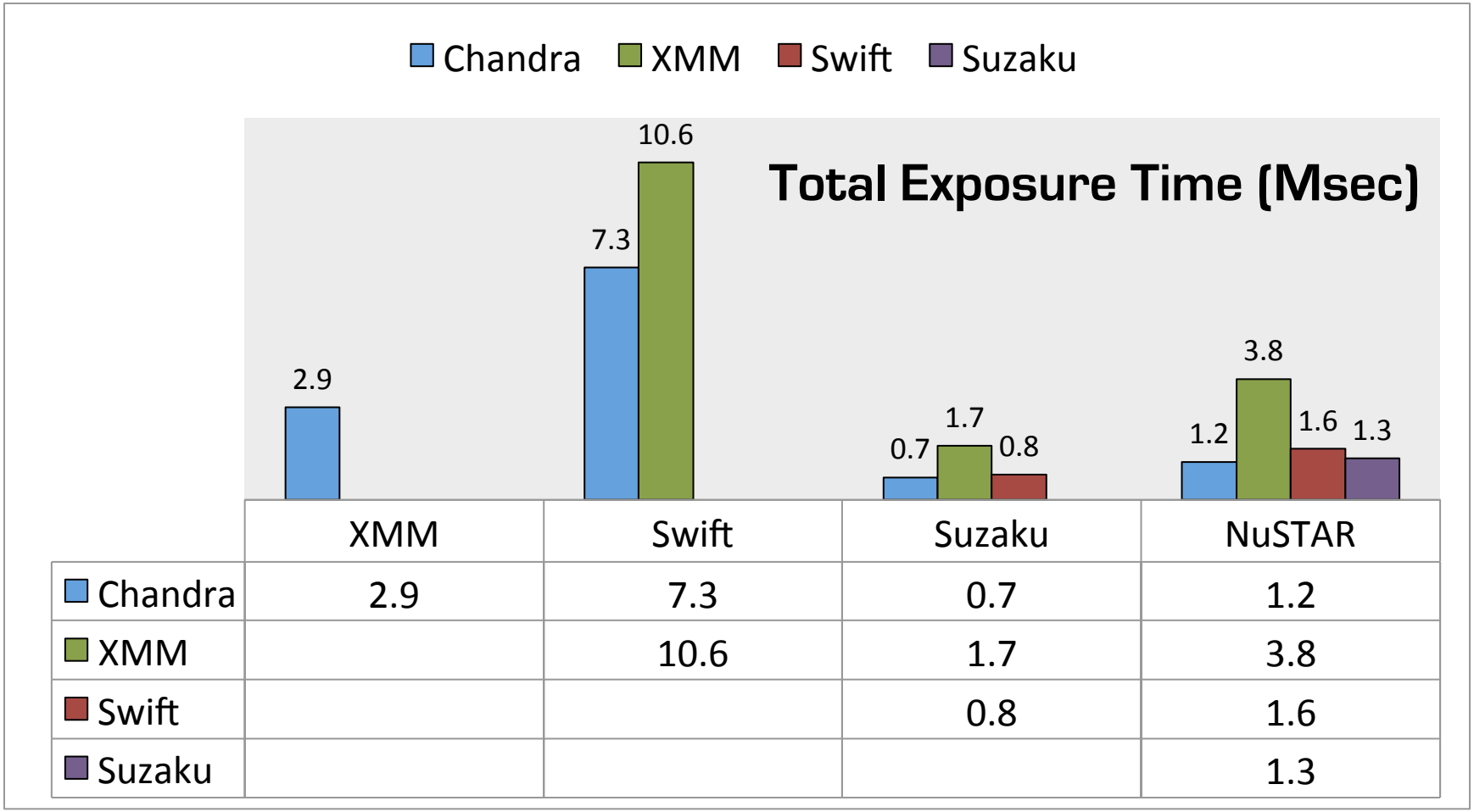

	XMM	Swift	Suzaku	NuSTAR
Chandra	2.9	7.3	0.7	1.2
XMM		10.6	1.7	3.8
Swift			0.8	1.6
Suzaku				1.3

Simultaneous observations

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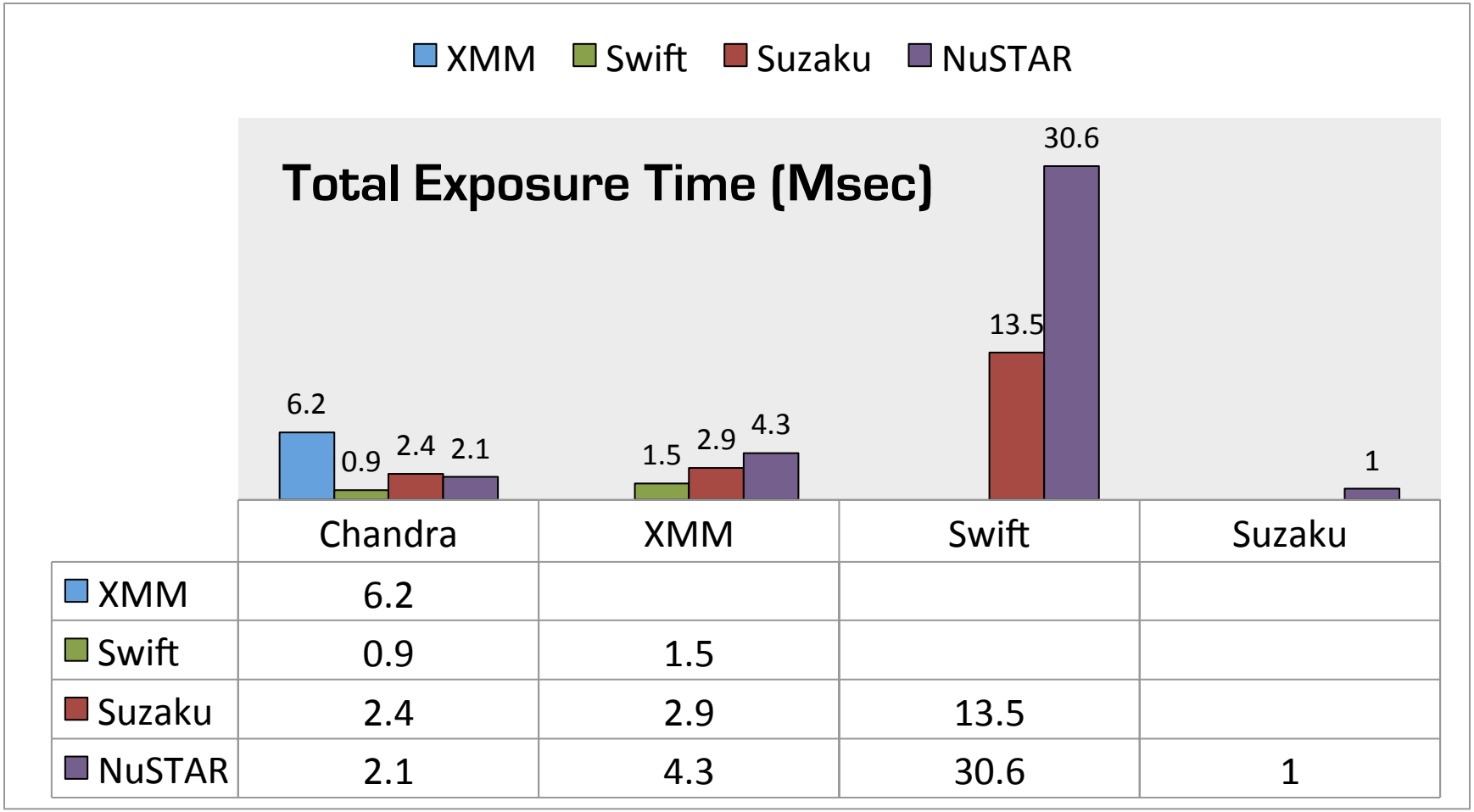
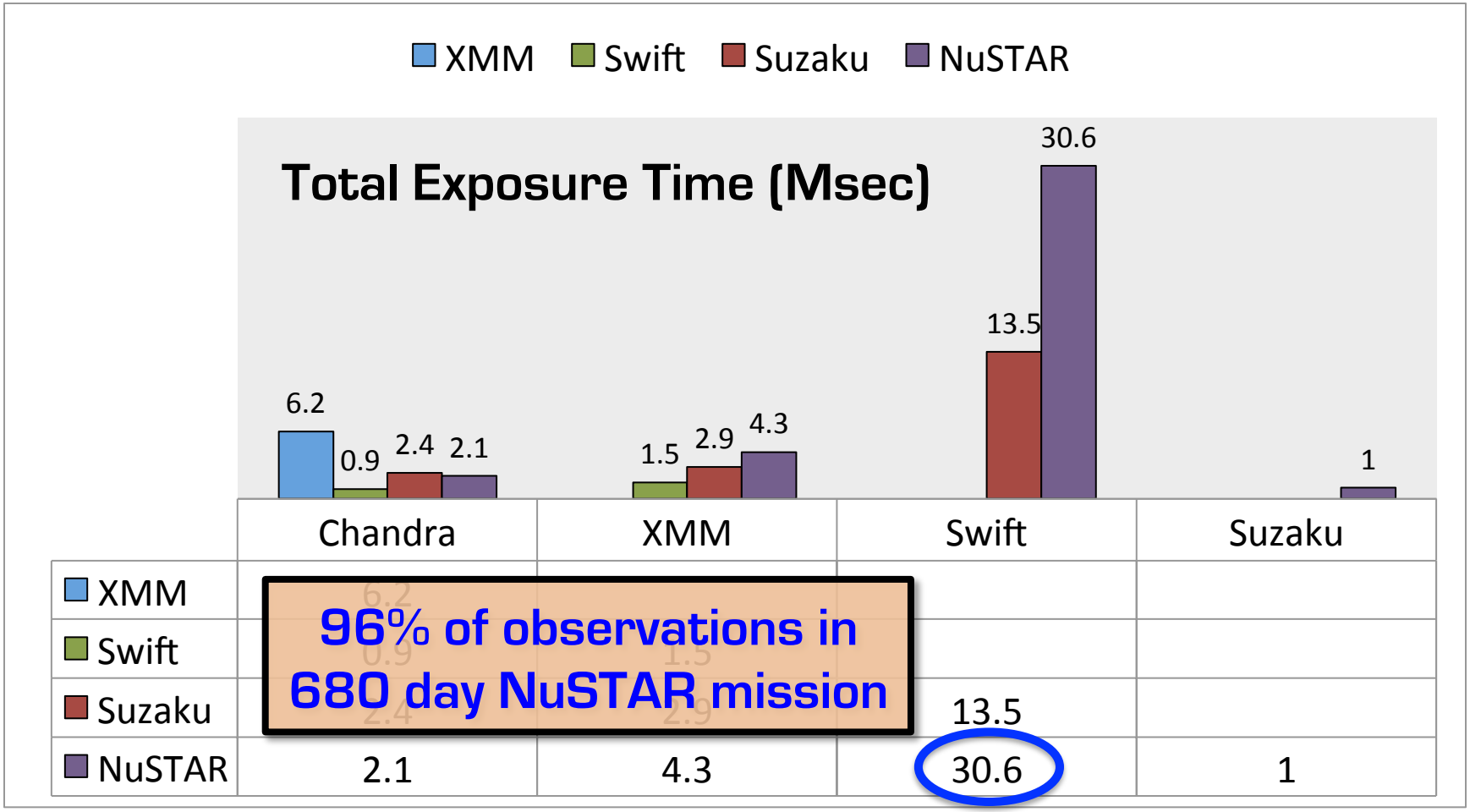


	Chandra	XMM	Swift	Suzaku
XMM	6.2			
Swift	0.9	1.5		
Suzaku	2.4	2.9	13.5	
NuSTAR	2.1	4.3	30.6	1

Simultaneous observations

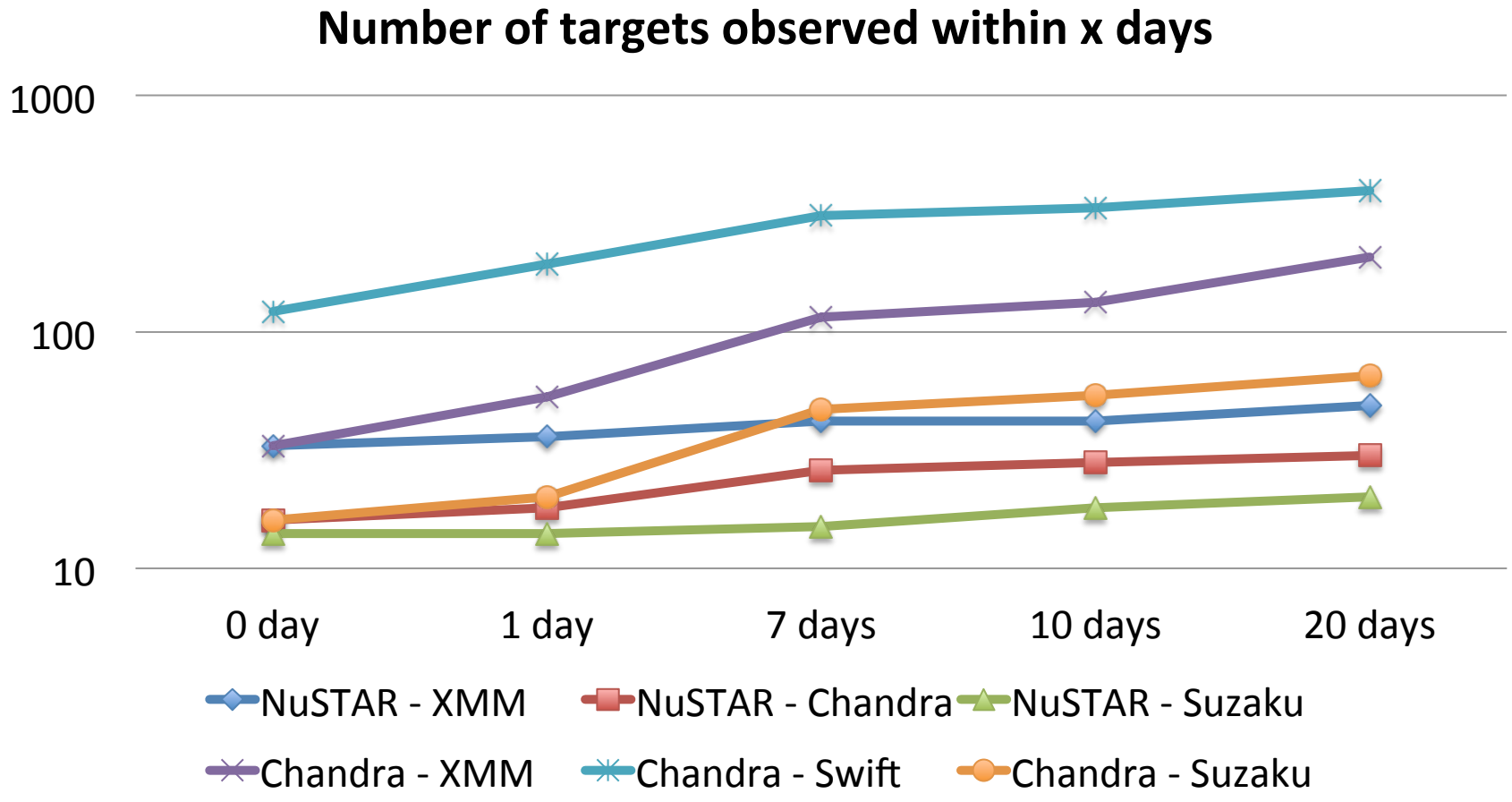
(Overlap of GTI's)



	Chandra	XMM	Swift	Suzaku
XMM	6.2	1.5		
Swift	0.9	2.9		
Suzaku	2.4	4.3	13.5	
NuSTAR	2.1	4.3	30.6	1

96% of observations in 680 day NuSTAR mission

Contemporaneous observations



...but wait, there's more!

Multi-multi-mission observations

Target	Date	Exposure (ksec)				
		Chandra	XMM	Swift	Suzaku	NuSTAR
3C273	2012-07-16	30	39	13	40	244
PKS 2155-304	2013-04-24	30	69	18	47	48
NGC 1313	2012-12-16	10	125	2	-	101
NGC 1313	2012-12-22	10	125	2	-	127
Ark 120	2014-03-22	48	133	2	-	65

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Coordinated NuSTAR science programs

...but wait, there's more!

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Swift / NuSTAR MOU

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IACHEC Calibration Targets

...but wait, there's more!

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Combo (over ~10 years)	Exposures	Targets other then those above
Chandra + XMM + Swift	21	7
Chandra + XMM + Swift + Suzaku	14	2

1H1426+428
4U 0142+61

MCG-5-23-16
WPVS 007

9P/ Tempel 1
Sgr A*

Cyg X-1

...but wait, there's more!

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Interesting to follow up?

Combo (over ~10 years)	Exposures	Targets other then those above
Chandra + XMM + Swift	21	7
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1H1426+428
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Sgr A*
Cyg X-1

Usefulness of simultaneous observations

- Two-mission – many observations are available
  - Leverage historical databases (RXTE, ASCA, ROSAT, etc.)
- Some targets may not be useful (e.g. Comet Tempel-1)
  - Can we automate analysis?
  - Is the best-fit model important -> trend cross calibration coefficients?
    - use narrow energy band flux measurements, how to handle background?
- More than two mission simultaneous observations
  - ***IACHEC is the only game in town***
- It is important to have early coordinated calibration campaign
  - 3C 273 observed one month after NuSTAR launch
  - Six Simultaneous observations: XMM, Chandra, Swift, Suzaku, & INTEGRAL
  - Potential to double that within a few years
    - Astro-H, eROSITA, ASTROSAT, HXMT, POLAR, NICER

Contemporary observations

- Will contemporaneous observations of select sources be useful?
  - galaxy clusters, SNR -> standard candles
- How best to handle time variations between missions
  - background
  - source confusion
  - energy range overlap
  - intrinsic variability
- Large numbers of relative cross calibration values may discover trends in instrument calibration

Questions

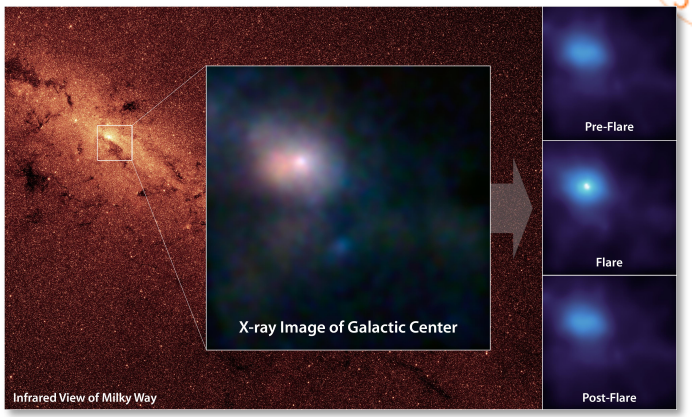
- Many targets are repeatedly observed by multiple observatories (some every year)
  - is there any free energy in scheduling to coordinate observations outside official programs?
  - is this even allowable (data rights)?
- Can GO cycle timing be adjusted?
  - is this even desirable?

AO – proposal deadline – TAC – Acceptance – Cycle start

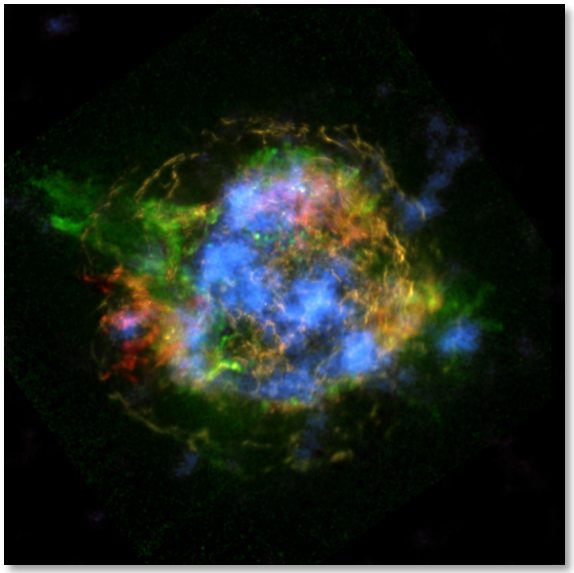
Hidden target lists

Shameless plug

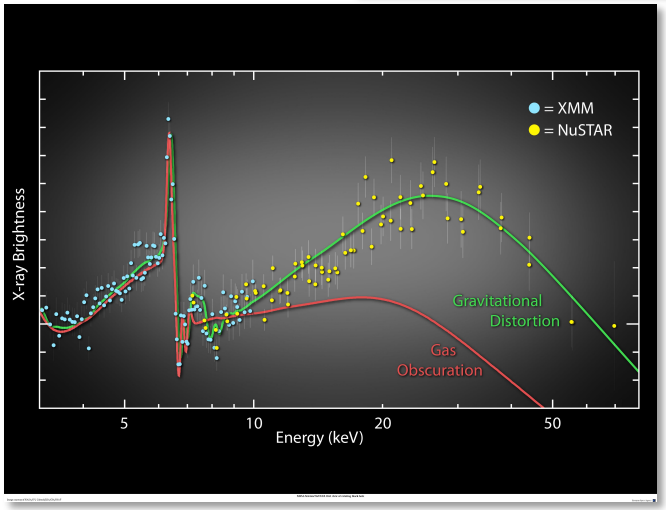
- **NuSTAR GO cycle 1**
  - AO this year
  - Observations start in 2015



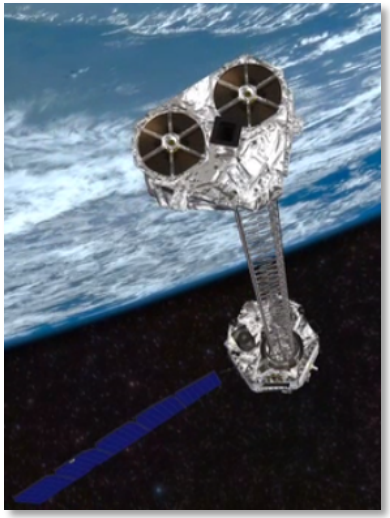
Sgr A* flare
Barriere et al 2014, ApJ 786,46



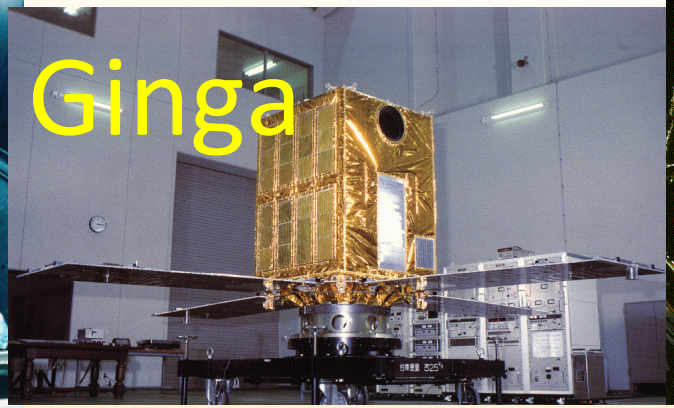
Cas A NuSTAR + Chandra
Grefenstette et al 2014, Nature 506, 339

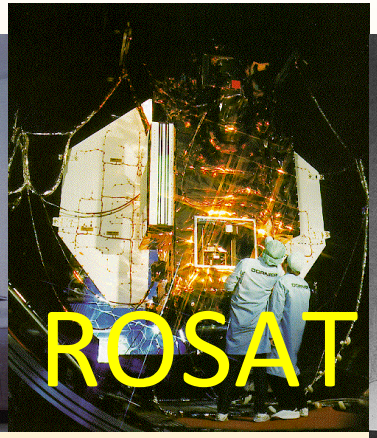


NGC 1365 NuSTAR + XMM
Risaliti et al 2013, Nature 494, 449



NuSTAR
Harrison et al 2013, ApJ 770,103





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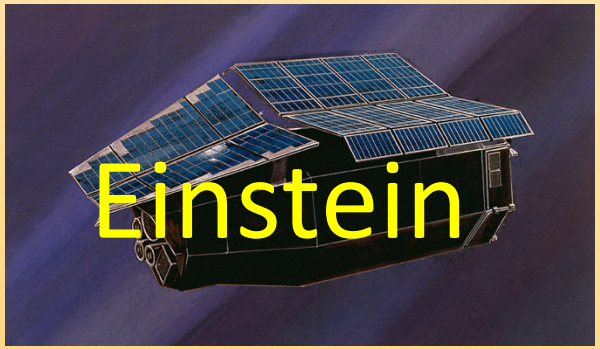

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