Title: IACHEC Timing WG telecom
Date: 15 Sep, 2020
Time: 14:00 ~ 15:10 UTC = 23:00 ~ 24:10 JST = 10:00 EDT = 7:00 PDT = 16:00 CEST
Zoom: https://zoom.us/j/95522030320 (passcode: iachec)
Notes: https://docs.google.com/document/d/1Bhq00Vqd-S584JOUDCz1KU4lceA7cv9VLyL9MEZYy30/edit?usp=sharing
Participants: Yukikatsu Terada, Dipankar Bhattacharya, Simon Rosen, Takaaki Tanaka, Matteo Bachetti, Vinay Kashyap, Katja Pottschmidt, Amy Lien,Teruaki Enoto, Guillaume Belange

Meeting Notes are shown in Red. (Participants can edit this page.)

Agenda

1. Working Group Management
2. Summary Table of Timing Performance/Calibration
3. Systematic survey of Timing Calibration of multi missions using Crab pulsar
4. Other Discussion

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1. Working Group Management (short announcement)

1.1 Definition of PoCs (latest 10 Sep 2020)

Yukikatsu Terada (Suzaku,Hitomi, XRISM),
Craig Markwardt (NICER), Teruaki Enoto (NICER),
Matteo Bachetti (NuSTAR), Katja Pottschmidt (NuSTAR),
Felix Fuerst (XMM-Newton), Simon Rosen (XMM-Newton),
Vinay Kashyap (Chandra),
Amy Lien (Swift),
Guillaume Belanger(INTEGRAL), Volodymyr SAVCHENKO(INTEGRAL),
Xiaobo LI (HXMT),
Gulab Dewangan (Astrosat), Dipankar Bhattacharya(Astrosat)
Makoto Sawada(XRISM), Takaaki Tanaka (XRISM)

Any update?
… We are asking Vadim Burwitz for eROSITA PoC (no response at this moment)

1.2 IACHEC Timing ML

- Address:
  iachec-time@heal.phy.saitama-u.ac.jp
  (Please ask Yuki for update.)
  → Recommend to use iachec.org domain. (A/I, Guillaume) please provide the procedure to Yuki
- Members:
  terada@mail.saitama-u.ac.jp,
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1.3 IACHEC Slack

- We have 9 members on IACHEC/Timing Slack at this moment
  - Yuki, Vinay, Felix, Gulab, Katja, Matteo, Simon, Teru, and Xiaobo
- Please Join.
  - https://join.slack.com/t/iachec/shared_invite/zt-h9werwzm-vqNmhd8gsQPErWHv2tD3MA
- Very useful!

1.4 IACHEC Timing WWW

- Address: https://iachec.org/timing/
- Only chairs have permission to edit. Please ask Yuki to update.
- (We had a problem on editing the page, and fixed on 9 Sep with Kristin)

1.5 IACHEC Timing Wiki page

- Address: https://wikis.mit.edu/confluence/display/iachec/Timing
- Instruction to get account to edit this Wiki page: https://iachec.org/iachec-wiki/ (Ask Eric)
- Do you have some trouble getting an account??
- No permission to have a new account at this moment. (A/I, Yuki) ask Eric on MIT Wiki.

2. Summary Table of Timing Performance/Calibration

- Please see https://wikis.mit.edu/confluence/display/iachec/Timing

Mission/ Instruments	Science Requirement Absolute Time		Timing System Design		Timing Calibration Status	In-orbit Timing Calibration Targets	Reported Issues	Reference
	Requirement	Goal	GPS Receiver	Clock Stability	(Absolute Timing Precision)			
RXTE/PCA ⭐								
Chandra / ACIS	0.25625 s (one minor frame start time)	0.001 s (synchronize minor frame starts)	No (sync DSN)	3.2 μsec	285 ± 6 μsec		None at present	Davis et al. 2003 (davis.pdf)
Chandra / HRC		16 μsec			4 ± 4 μsec	Crab PSR B1821-24	Time tag gets attached to next event; correctable under special mode for HRC-S which telemeters all events and then reassigns times on the ground	Davis et al. 2003 (davis.pdf) Rots 2006 (CXOClock.pdf)

XMM-Newton/EPIC-MOS								
XMM-Newton/EPIC-PN	1 ms		No		108 μsec	Crab pulsar (bi-annual)	None currently	Kirsch et al, SPIE, 5165, 85 (10.1117/12.503559) Martin-Carrillo et al, A&A, 545, A126 (2012) (10.1051/0004-6361/201116576) CAL-TN-0220-1-4.pdf (Limited access)
INTEGRAL/SPI								
INTEGRAL/IBIS								
Swift/BAT	~ 0.3 ms	GRB light curves	Yes	~ 6.572 x 10^-8 s/s	~ 100 μs (with offset of ~ 80 μs)	Crab pulsar (anual)	None at present	BAT team wiki page; private communication with Michael Tripicco see BAT Wiki: Pre-launch Timing, BAT Wiki (410.4-SPEC-0005F.pdf) (Limited Access)
Swift/XRT	~ 10 ms				~ 270 μs	Crab pulsar	None at present	G. Cusumano et al 2012 (10.1051/0004-6361/201219968) D. Burrows et al. 2005 (10.1007/s11214-005-5097-2)
Suzaku/XIS ⭐	No science requirement defined.		No	1.9 x 10^-9 s/s (measured)	Not confirmed.	A0535+262, Her X-1, etc	N/A	Y.Terada et al 2008 (10.1093/pasj/60.sp1.S25)
Suzaku/HXD ⭐					360±150 μsec (270±130 μsec in condition)	Crab for coordinated PSR1509-58	Timing shift by a failure in time stamp at the ground station during 2012-2014 (Shu Koyama, Fixed)	

NuSTAR/ FPM	Should be 100 ms	none	No	Freely drifting by ~3 ms/day. Reduced to 20 us/day using the clock correction file	65 us (1-sigma)	Crab B1821-24A B1937+21	~5ms offset using millisecond pulsars (Lucien Kuiper) Corrected through clock correction file v108+	Bachetti+ in prep (can distribute early copy)
AstroSat/ LAXPC	None defined		Yes(offline referral)	4 μsec rms after GPS synchronization	fixed offset +316±70μs w.r.t. Fermi-LAT	Crab Pulsar (with Radio)	None at present	D. Bhattacharya 2017 (10.1007/s12036-017-9461-x) Basu et al (in prep)
AstroSat/ CZTI	None defined		Yes(offline referral)	3 μsec rms after GPS synchronization	fixed offset -650±70μs w.r.t. Fermi-LAT	Crab Pulsar (with Radio) GRBs	None at present	D. Bhattacharya 2017 (10.1007/s12036-017-9461-x) Basu et al 2018 (10.1051/0004-6361/201832913) Basu et al (in prep)
HXMT								
Hitomi/SXS, SXI, HXI, SGD ⭐	350 μsec	35 μsec	Yes	0.01μsec(GPSR) <3.0 μsec(SpW) 0.3 ns (orbit)	~ 120-230 μsec	Crab (with radio) note: using out-of-time event for SXI	absolute timing accuracy is much larger than expected on ground (3 μsec)	Y.Terada et al 2018 (10.1117/1.JATIS.4.1.011206)
NICER	100 ns (RMS)	none	Yes	N/A	Approx. 3 μs	Crab Pulsar PSR B1821-24A PSR B1937+21	Precise 1-second offset in on-board timestamps due to flight software bug; corrected using TIMEZERO keyword in pipeline-processed FITS data files. (see HEASARC page for detail)	Markwardt et al. (in prep.)
eROSITA								

XRISM/Resolve ★	1 msec	none	Yes	same as Hitomi		(under discussion)		
XRISM/Xtend ★	10 msec	none	Yes			(under discussion)		

Clock stability includes effects of clock drift & temperature fluctuation, and the values after the synchronization are useful for users. Swift has several values on clock stability. This is the latest value.

Absolute time information can have Offset (relative to Crab main pulse, radio/xray) + Deviation.
→ Divide them into two columns.

Teru provided the Crab pulse profile of NICER and arrival phase relative to radio.
(No permission to be public)

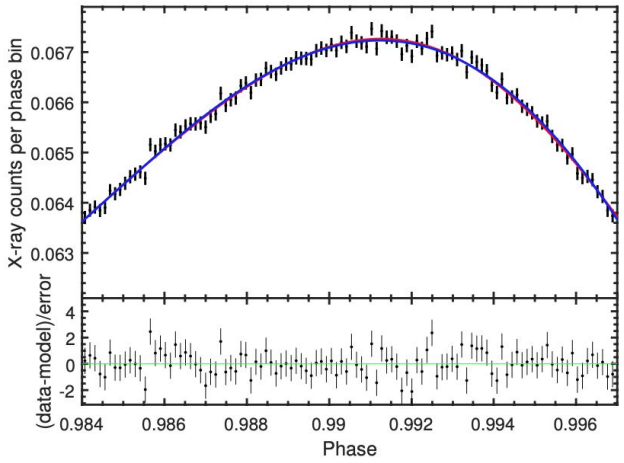

Figure S11: MP X-ray pulse profile of the Crab Pulsar observed with *NICER* (top panel), fitted with a (red line) Fourier series with 100 harmonics and a (blue line) 4-th order polynomial function. The data from all the observations are stacked into 8192 phase bins. The fit residuals with respect to the best-fit former model are shown in the bottom panel. The errors are 1σ statistic uncertainties.

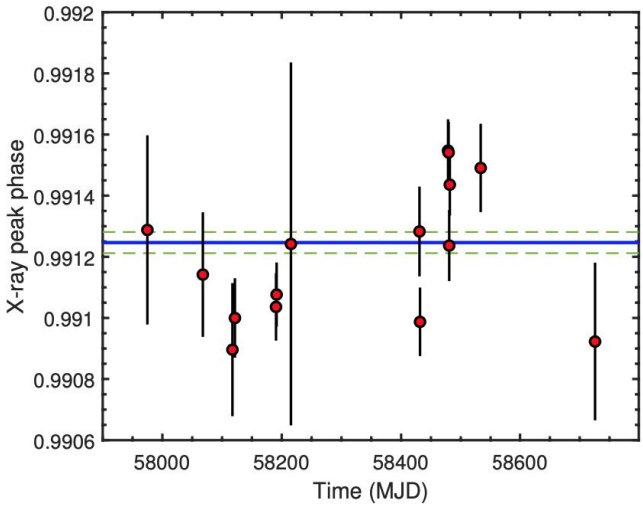

Figure S12: MP peak phase as a function of the observation date. In individual pulse profile fittings, 4096 bins are used in the same way as in Figure S11. Blue solid and green dashed lines indicate the X-ray peak determined from all the stacked profile and its 1-sigma interval, respectively.

Comments on Dispersion measure (Teru) : Jodrell-Bank radio observatory has performed the Crab observation monthly on every 15th: http://www.jb.man.ac.uk/~pulsar/crab/crab2.txt. The average DM (~56.8 pc/cm^3) corresponds to delay of the radio pulse (1.4 GHz) relative to the X-rays at ~120 ms. The measured DM is fluctuating in time, and the attached figure shows a histogram of DM extracted from recent 339 Jodrell-Bank observations. The 1-sigma values is 0.028 pc/cm3. This means that, if XRISM
will observe the Crab pulsar apart from the monthly Jodrell-Bank observation period, we would expect an uncertainty of the time delay (i.e., absolute timing relative to the radio peak) at 1-sigma (68%) level due to the unknown DM fluctuation as,

120 ms * (0.028 / 56.8) ~ 60 us.

3. Systematic survey of Timing Calibration of multi missions using Crab pulsar

- **The A/I in the last telecom:** Survey current archive data of coordinated observations and perform analyses on timing calibration aspects
  - First step is to list archive data, coordinated observation between multiple X-ray missions, suitable for timing calibration (i.e., variable, periodical, etc).
- Matteo proposed the following idea
  - I think it would be easy to produce multiple folded profiles of the Crab in different energy bands with a standard reference “clock" (e.g. aligning them to the Jodrell Bank Monthly ephemeris) for every mission.We could then distribute them in a common file format, and even make them public.These would form a uniform calibration database of folded profiles of the Crab across the mission lifespan (because most missions have multiple observations of the Crab). I think it would be useful for IACHEC, as a standard reference for people wanting to test the accuracy of their own instruments or their timing code.I can share some Python code to do it, with minimal changes, for any mission. Or even do it myself an all data if people provide me with the correctly barycentered datasets.If you are interested, we could discuss the details here and during the telecon.
- Discussion & Next Step
  - Jodrell Bank ephemeris : define the same time system.
  - Note: some radio observatory also joined the simultaneous Crab observation with X-ray mission(s).
  - Gather barycenter event fits file.

- ✧ send barycenter event fits file to Matteo. **(A/I for PoCs)**
  - (TIME list or event)
  - (cut energy by the recommendation of instrument) (provide PI to Energy conversion formula)
  - multiple epochs
- ✧ Matteo can share the code among this WG.
- ✧ Matteo will provide the repository.
  - https://drive.google.com/drive/folders/15Zoz3M7BkeoC33ip3ezP0kWXLOtcS94C?usp=sharing

 Define the output (table)

 (Independent check of the results by two persons/tools is also helpful.)

- Search for a second target for timing calibration. Very important topic. (NuSTAR has information)

4. Other Discussions, if we need

EOF