16th IACHEC Working Group report
Timing

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(Timing WG chair/co-chair)

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Detail note is on Timing WG Wiki (https://wikis.mit.edu/confluence/display/iachec/Timing)

Summary of the Working Group

Logistics

- Co-chair of Timing WG, Dr. Megumi Shidatsu (XRISM, Ehime Univ., Japan)
- Working group members & ML were updated (**welcome!!**)

Presentations

1. Pulsar Cross-calibration (Matteo Bachetti)
2. Challenges to Keep the Timing Accuracy of XRISM Timing System in GPS Failure Mode (Megumi Shidatsu)
3. Timing cross-calibration with the Crab in March 2024 (Yukikatsu Terada)

Discussions & Future plan

1. Systematic timing cross calibration
2. Summary of Timing calibration of Crab campaign in Mar 2024
3. Discussion on Solar ephemeris (barycentric correction tools)
4. Timing calibration status table
5. Publication plan

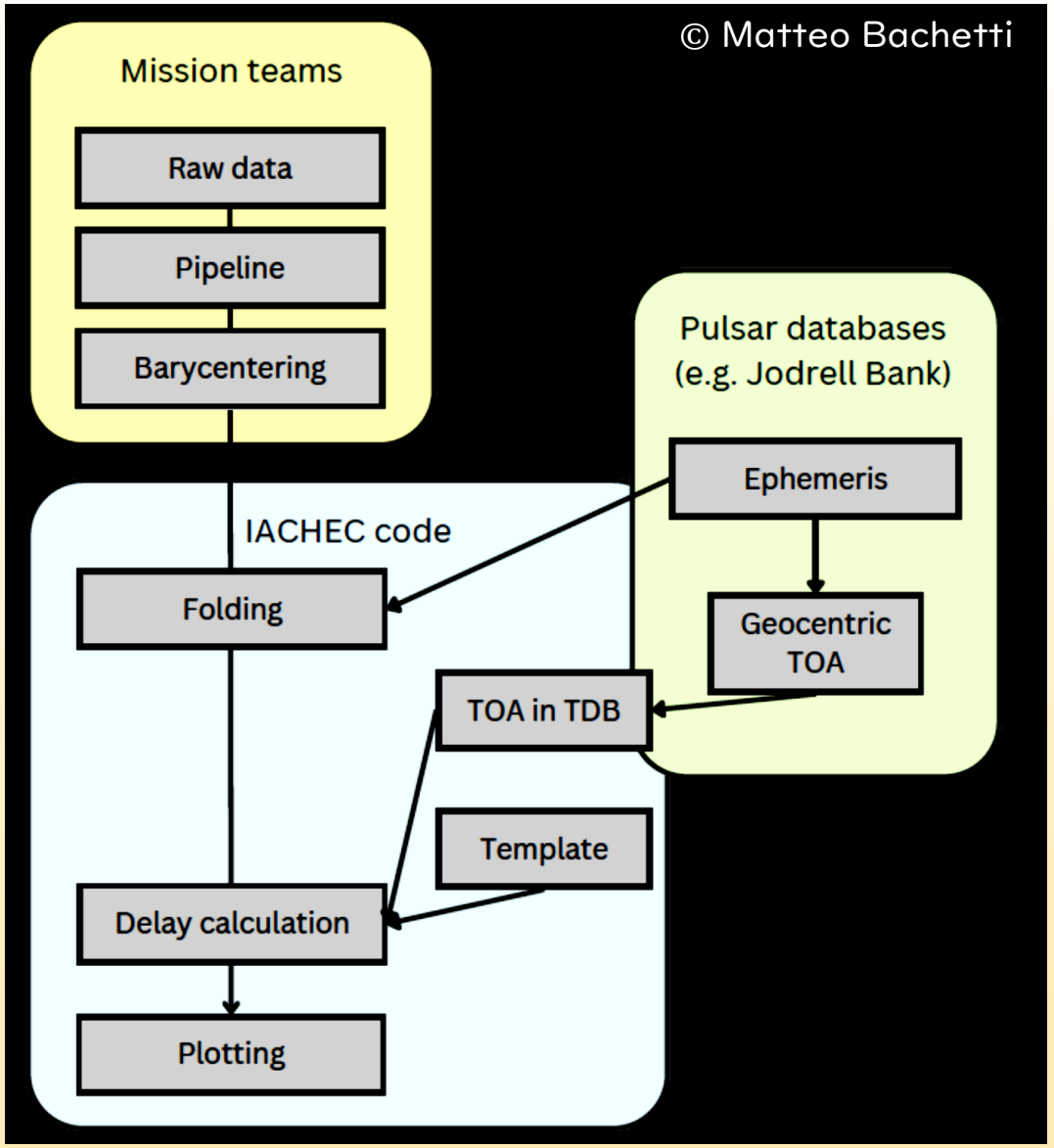
I. Systematic timing cross calibration

- **Goal of this activity**
  Systematic study of timing accuracy among multiple missions.

- **Missions**
  XMM-Newton, Suzaku, NuSTAR, Astrosat, Hitomi, Swift,
  XRISM, NinjaSat, EP, HXMT (**NEW**)

- **ToDO (short term)**
  - ✓ gather Event FITS on Google Doc repository
  - ✓ Run IACHEC code (Matteo)

- **ToDO (long term)**
  - ✓ try other pulsars (PSR1821, PSR1936, etc)
  - ✓ start drafting a paper by the next IACHEC



2. Crab campaign in Mar 2024

Simultaneous Crab observations twice!

- Early Mar 2024: EP/FXT, XMM, INTEGRAL, NuSTAR
- Mid Mar 2024: XRISM, NICER, NuSTAR, NinjaSat

Preliminary result from the 2nd campaign

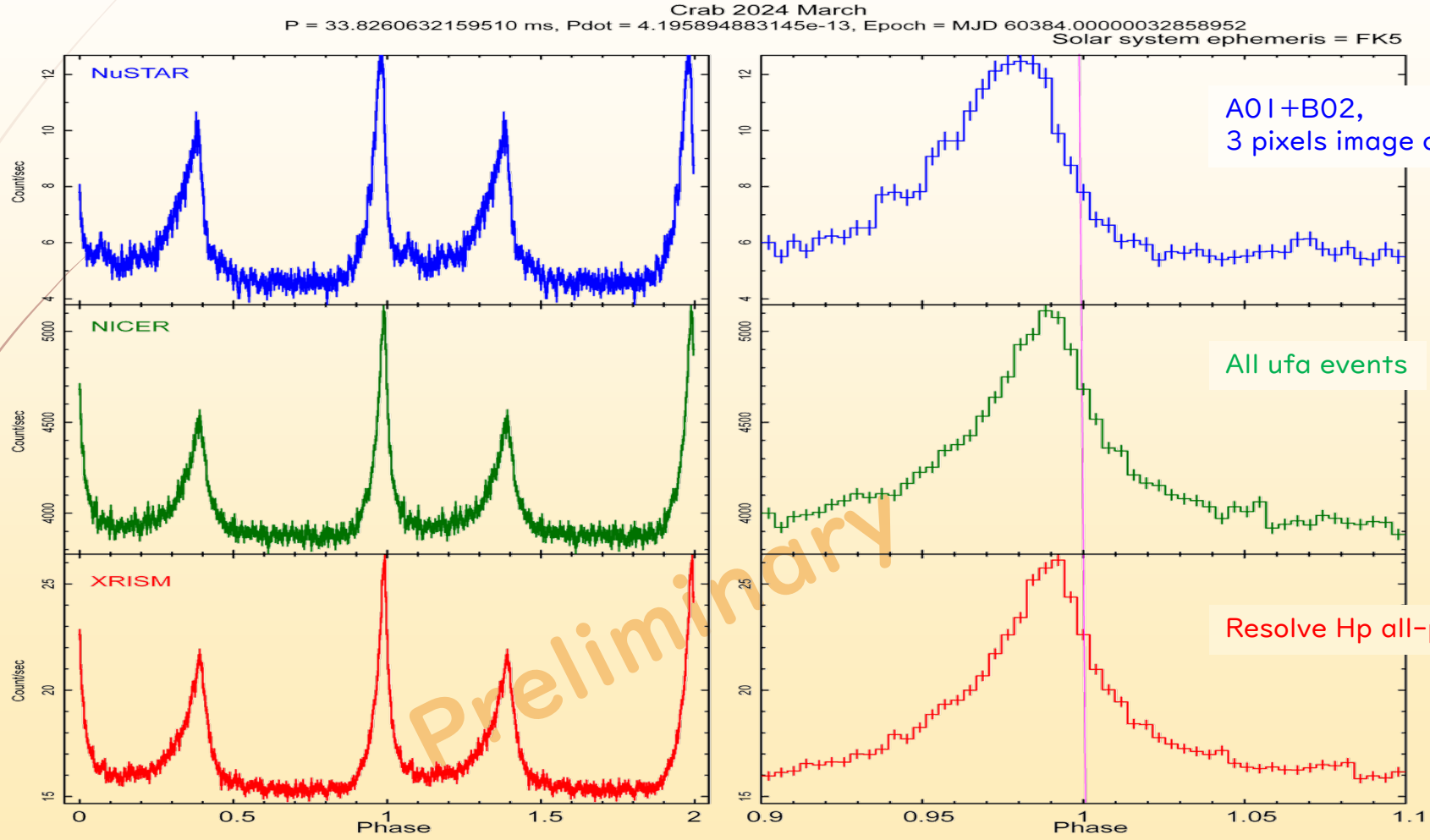
- See the next page

ToDo (short term)

- ✓ XRISM: tuning timing parameter
- ✓ NuSTAR: apply latest clock correction table, dead time correction
- ✓ NICER: change screening criteria
- ✓ Then, check the arrival time etc.

2. Crab campaign in Mar 2024

Preliminary result from the 2nd campaign



Note that the XRISM time assignment is still preliminary.
Please do not distribute the figure.

3. Timing calibration status table

Table, timing calibration requirement and status

- 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	Offset from the Reference	Deviation, sigma	Reference Time	Notes			
RXTE/PCA ★	10μsec	none	No		Calibrated: 1 μsec Uncalibrated: ~0 usec (Absolute, not relative to radio)	Calibrated: 3.4 μsec Uncalibrated: 100 usec (max) ~50 usec (std)	TAI	Calibration: Spline-based calibration against ground timing standards, including ground time assignment error. Uncalibrated: Mission operations maintained on-board clock to within 100 usec of UTC using clock frequency steering	PSR B1821-24 60 μsec	Before 1997-04-29, increased timing jitter 8 μsec	rxte_time.html Timing Budget Jahoda et al. 2006 (10.1086/500659) PSR B1821 Rots et al. 1998 (10.1086/305836) Crab Rots et al. 2004 (10.1086/420842)
RXTE/HEXTE ★	10 μsec	none			See above	See above		Event by event has 7.6 μsec resolution. "the HEXTE absolute time reference is accurate within a fraction of a millisecond.(10.1086/305377)"	delay 0-1 μsec (corrected?)	None	HXTE Timing (10.1086/305377)
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			Number is dominated by estimated engineering systematic uncertainty. Further analysis is required to figure out offset from Crab.		None at present	Davis et al. 2003 (davis.pdf)
Chandra/HRC		16 μsec			4 ± 4 μsec				Crab PSR B1821-24	Note: Precision relative to RXTE. Due to a wiring problem, photon 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. In order to avoid telemetry saturation, a higher value of the lower-level discriminator is set, which causes low PHA events to be discarded on board. This results in significant loss in QE for epochs when gain is low.	Davis et al. 2003 (davis.pdf) Rots 2006 (CXOClock.pdf)
XMM-Newton/EPIC-PN	1 ms	none	No	-	-354±11 μsec	108 μsec (1 sigma)		Note: Timing = -306 +/- 16 μsec, Burst = -387+/-13 μsec. Timing mode is affected by pile up. Note: XMM-Newton EPIC-MOS was deleted from the table.	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)~~ CAL-TN-0220-1-5.pdf
INTEGRAL/SPI											L.Kuiper 2003 (10.1051/0004-6361:20031353)

ToDo (short)

- ✓ update latest missions (XRISM, EP)

4. Solar ephemeris

Conclusion

- Not to use DE200, except for Crab studies using Jodrell bank ephemeris
- Use DE430

ToDo (short term)

- Update ‘barycen’ to use DE430 ,
  or update ‘barycorr’ to apply Suzaku/Hitomi/XRISM
  (A/I for XRISM Science Operations team)

5. Publication plan

Paper 1) Pulsar cross-timing calibration

1. Study never stop, but a snapshot can be summarized as a journal paper.
2. Let's concentrate on the calibration (science is in a separate paper).
3. Plan (ToDo)
    1. Use 'barycorr' to use ephemeris DE430 - commands shared via ML.
    2. Finish XRISM timing calibration and provide FITS for study, in summer-autumn 2024.
    3. Try drafting by the next IACHEC (May-June 2025).
    4. Crab first, then another pulsar in 2nd paper.

Paper 2) XRISM timing using simultaneous observation of Crab in Mar 2024

- Describe in XRISM timing calibration paper or prepare Cross-calibration paper

-- To be defined.