In-orbit timing calibration of Suzaku satellite, and the design of the timing system on Astro-H

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on behalf of the Suzaku (and Astro-H) team

Timing System onboard Suzaku

Satellite bus | *Sub systems (payload)*

No on-board GPS system

Onboard Main computer

Master clock

Free RUN
+ temperature drift correction
10^{-6} → 10^{-9} stability

512 kHz clock

TI (20+12 bit)

Onboard computer

Intelligent Node

TI

20+12 bit

128 kHz clock

Electronics DAQ

Non-Intelligent Node

Time counter

5+14 bit

Sensor

Sensor

Long coverage

Compare
Every observation
(typically 2 days)

Fine resolution

Ground

Downlink Station

Compare
(5 contacts par day)

UTC (yyyymmdd hh:mm:ss.uuuuuu)

resolution ~ 10,100 us

Orbit error 10km ~ 30 us

HXD	**61 μ sec** (32 μ s in condition)
XIS	**8 sec** (normal mode)
	2 or 1 sec (normal mode with 1/4 or 1/8 window option)
	7.8 msec (Psum mode)

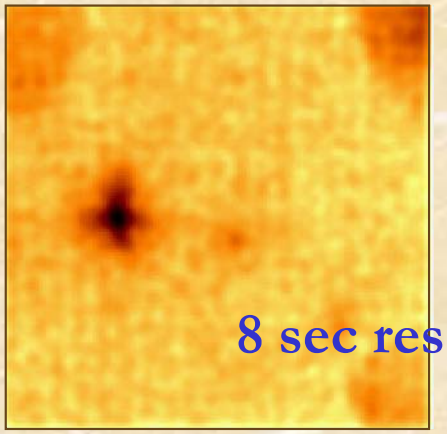
Relative Timing Calibration between instruments, the XIS and HXD

by Matsuta and the XIS team

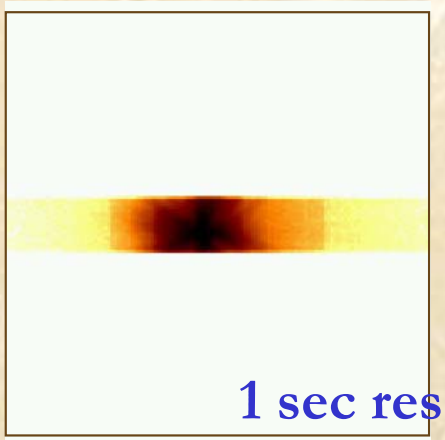
The HXD has higher timing resolution.

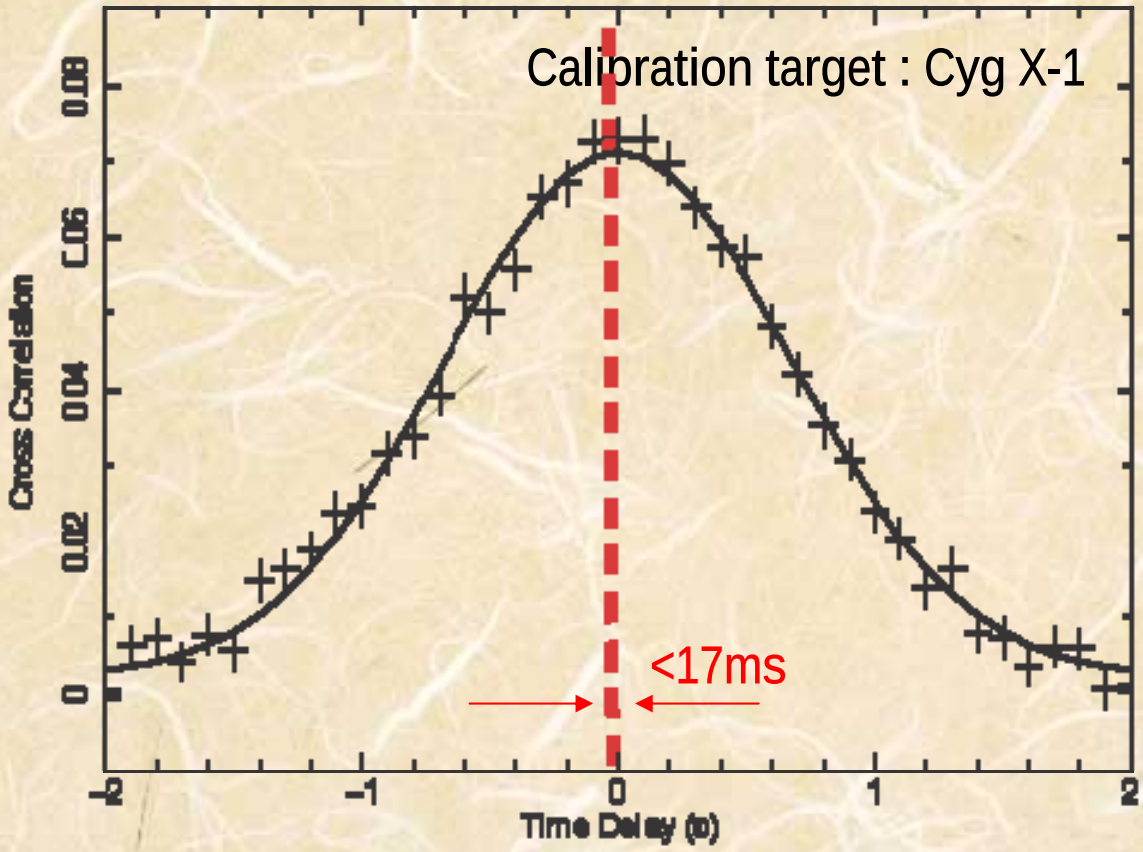
→ Check cross correlation function between light curves of the XIS (1/8 option) and HXD PIN

Clocking Mode: Normal
Full Window



1/8 Window Option

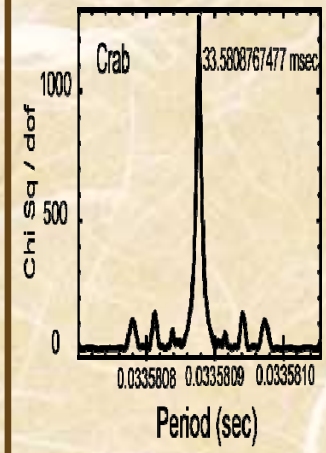
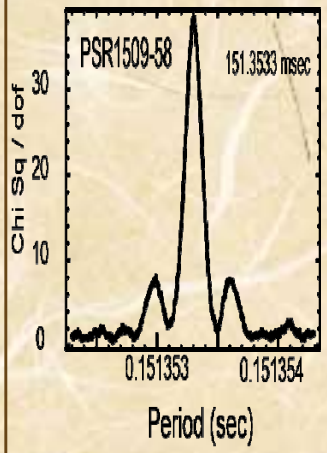
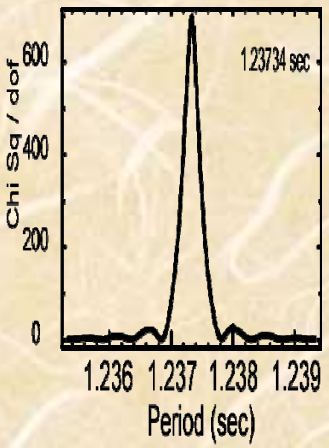
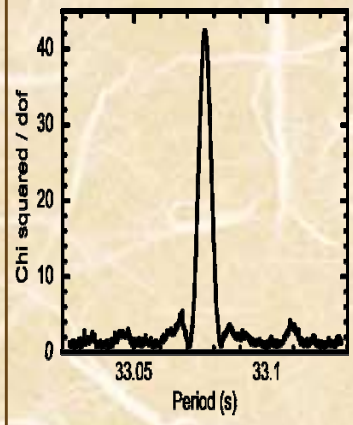
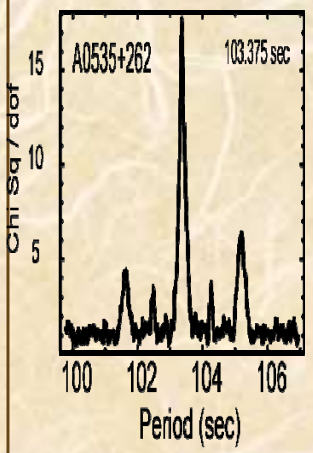
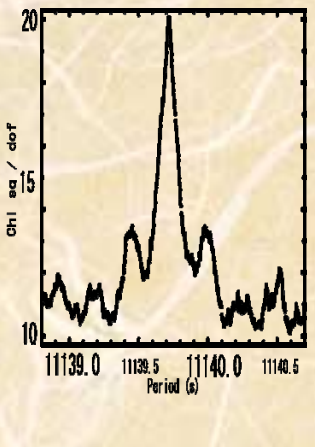
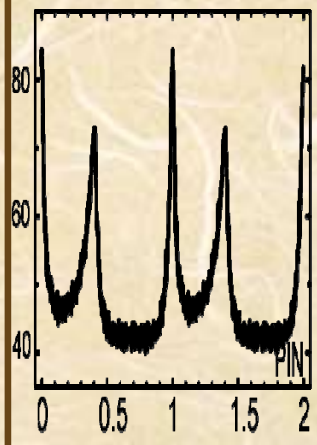
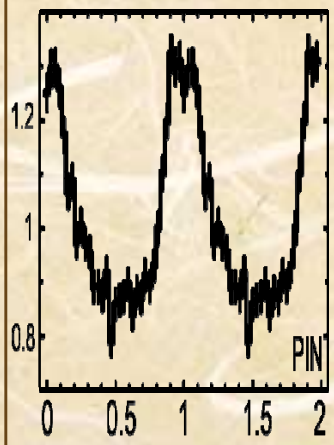
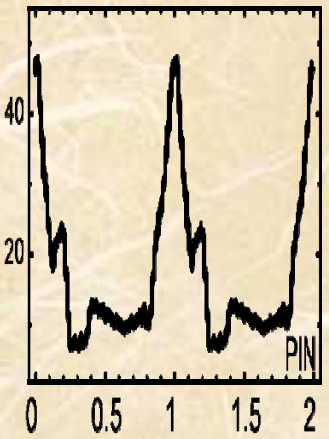
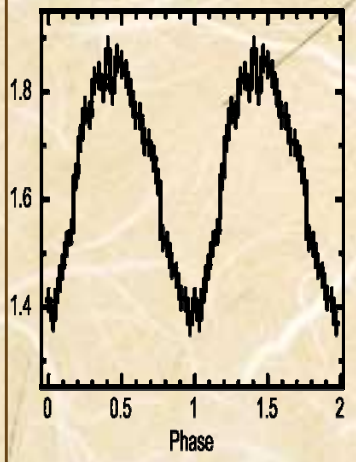
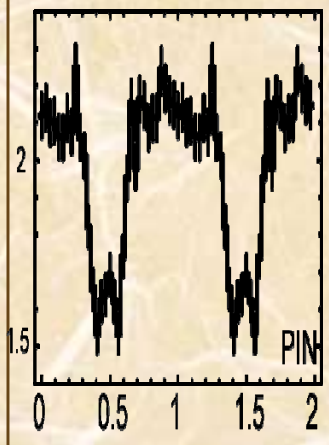
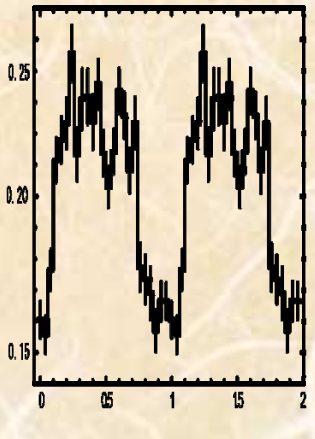




The XIS time is consistent with the HXD time.

→ Concentrate on the HXD timing.

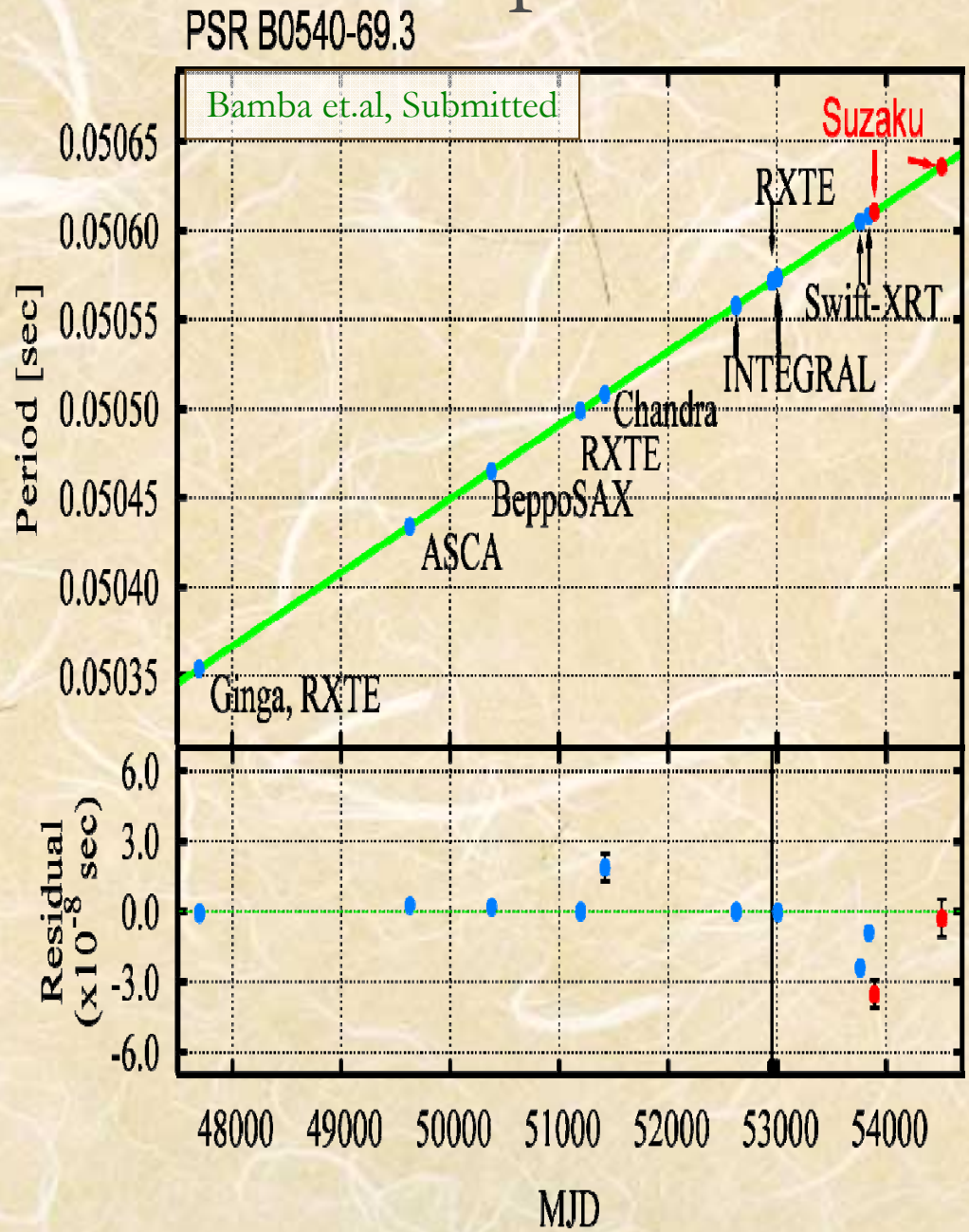
Relative Timing Calibration with periodic signals

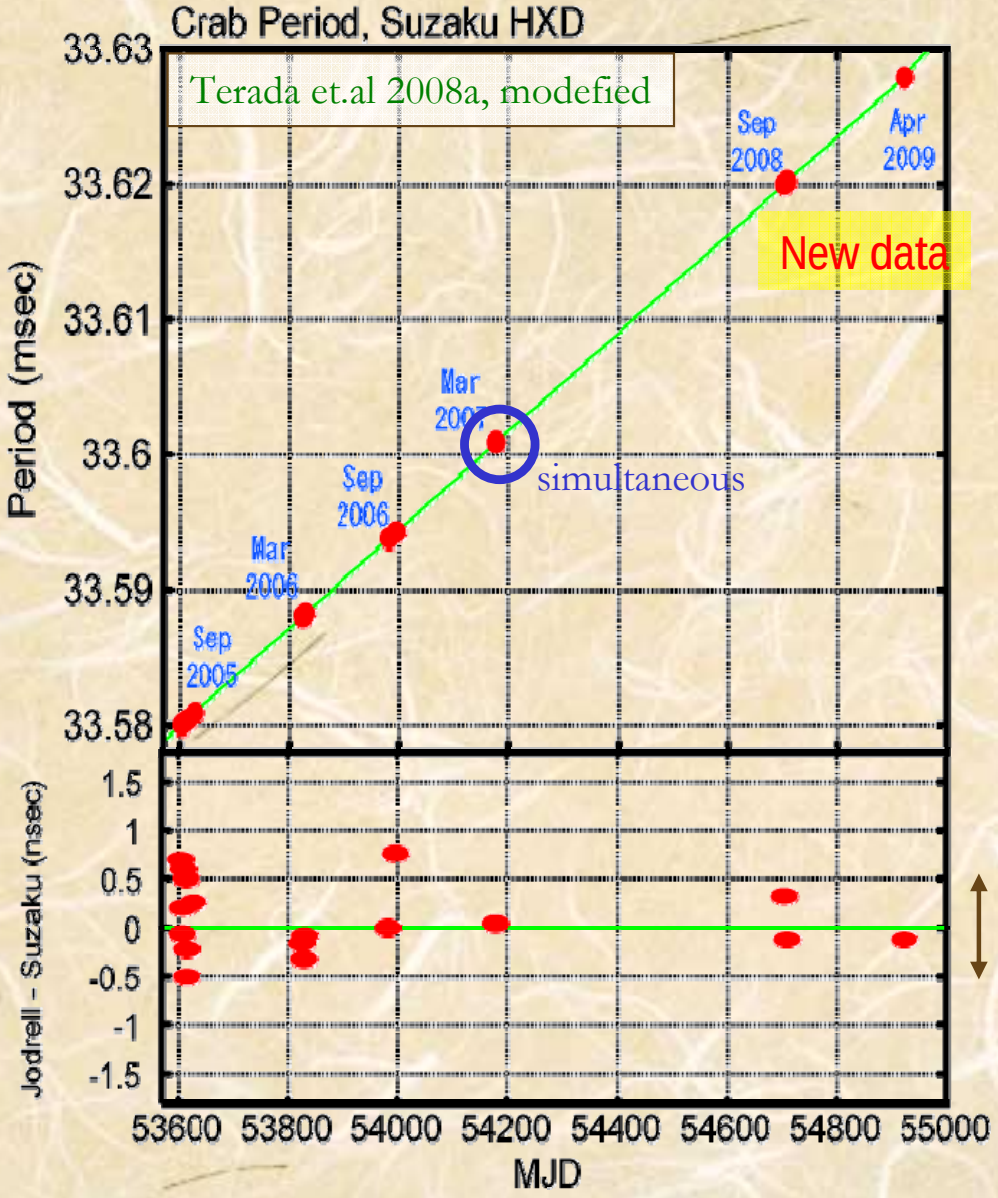
Crab	PSR B1509-58	Her X-1	AE Aqr	A0535-262	AM Her
33ms	151 ms	1.24 s	33 sec	103.4 s	11139s
					
					
Terada et.al 2008a	Terada et.al 2008a	Enoto et.al 2008	Terada et.al 2008b	Terada et.al 2006	In studying now

OK in 33ms – 11 ksec range

Periodic signals:

Comparison with other observations



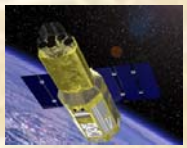


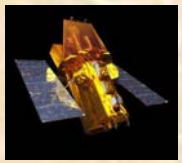
Confirmed , 1 nsec stability par day (1.9×10^{-9})

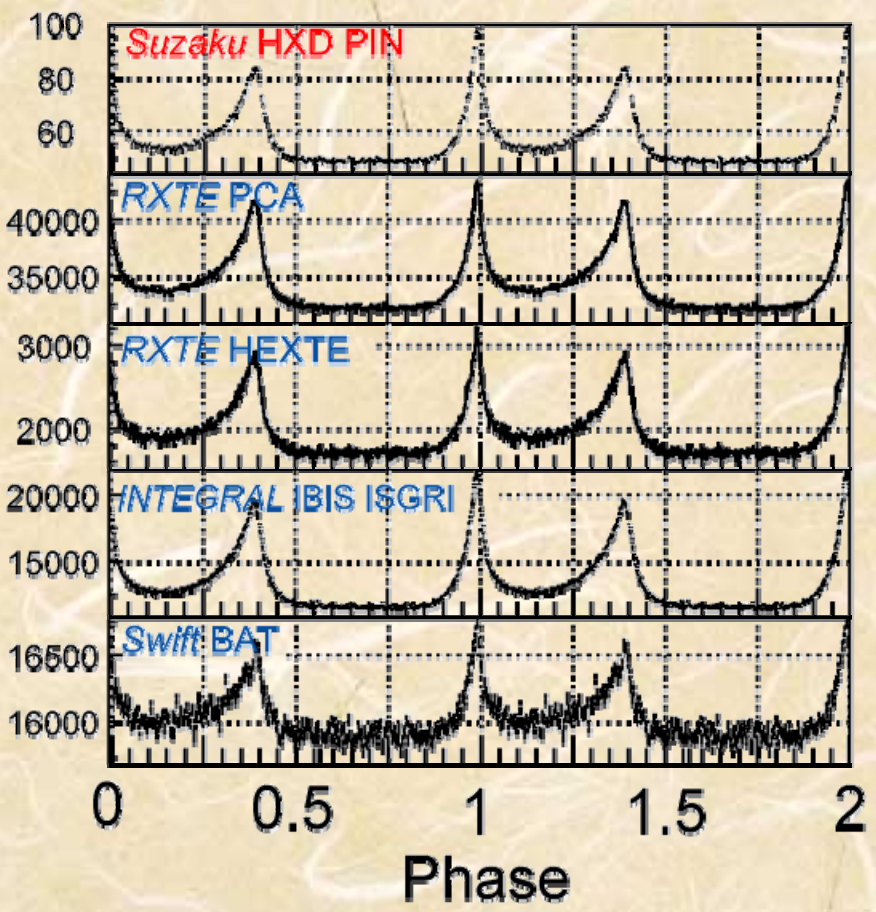
Cross Timing Calibration with Crab

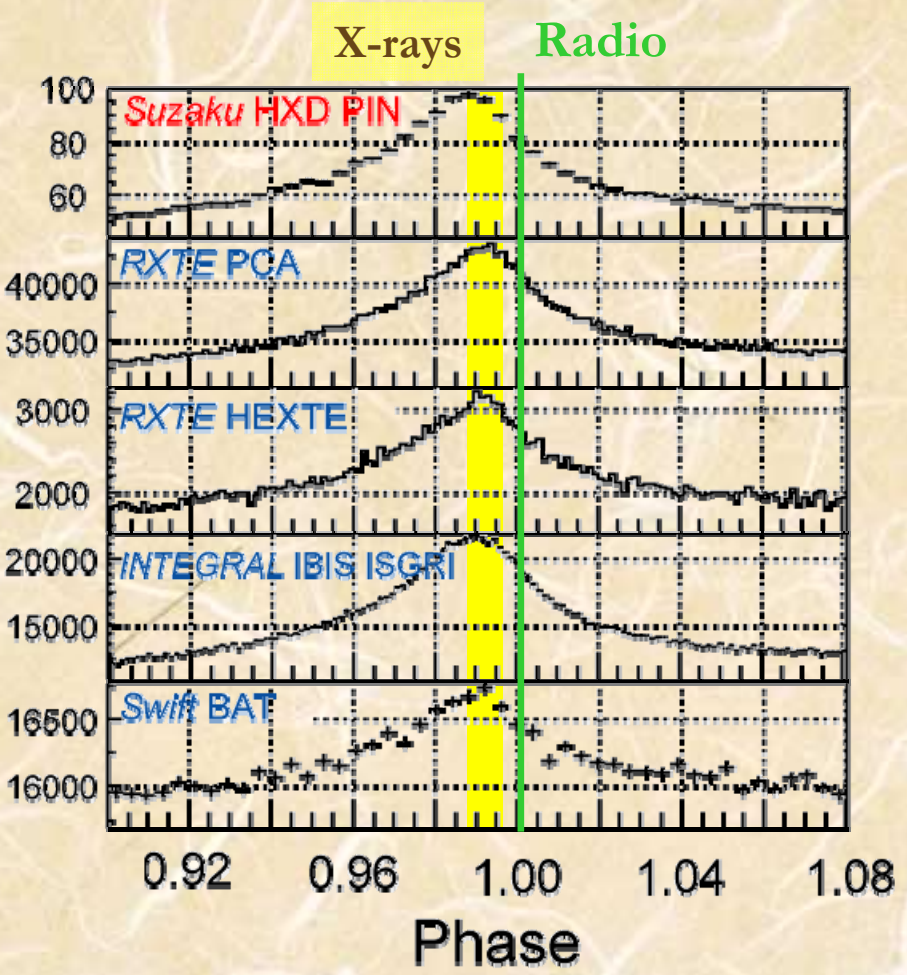
March 17-20, 2007, simultaneous observation of Crab (Y.Terada et.al 2008a)

One of the successful results of IACHEC activities!



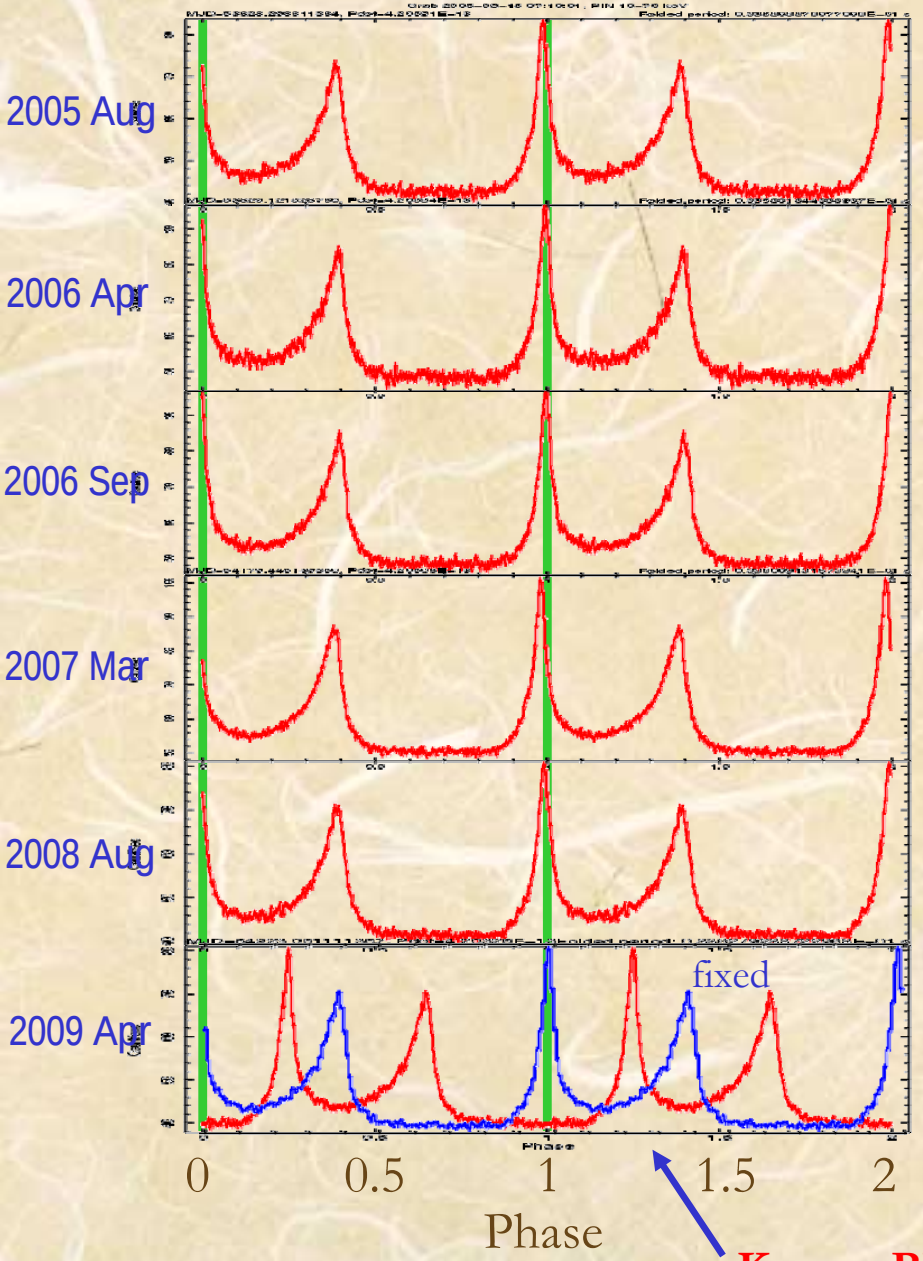


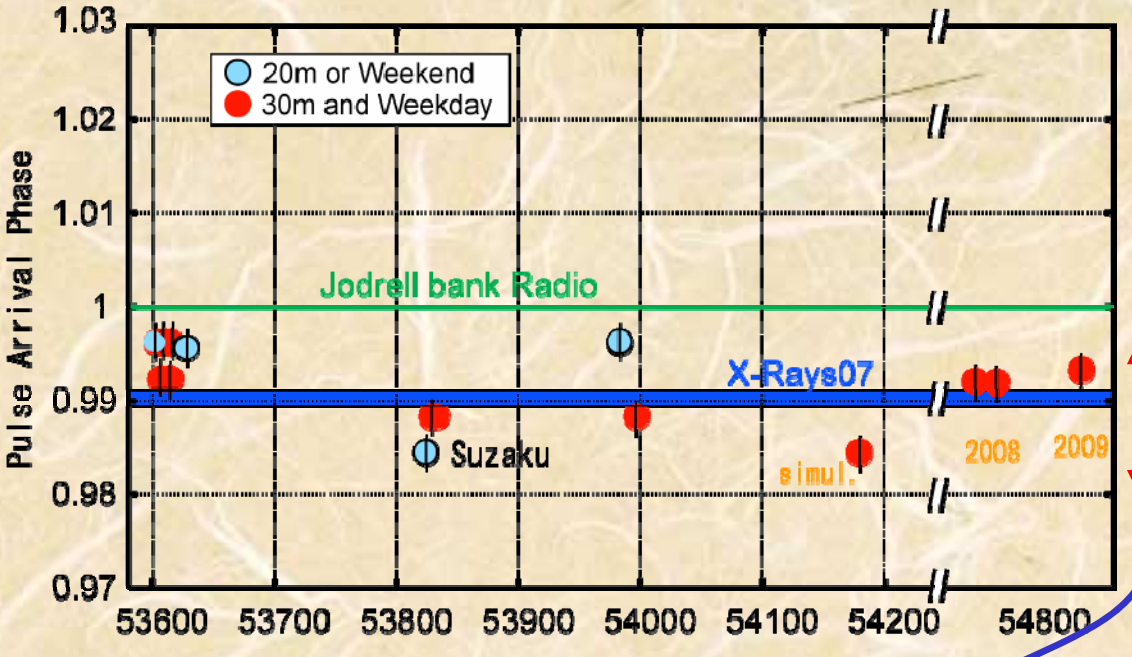


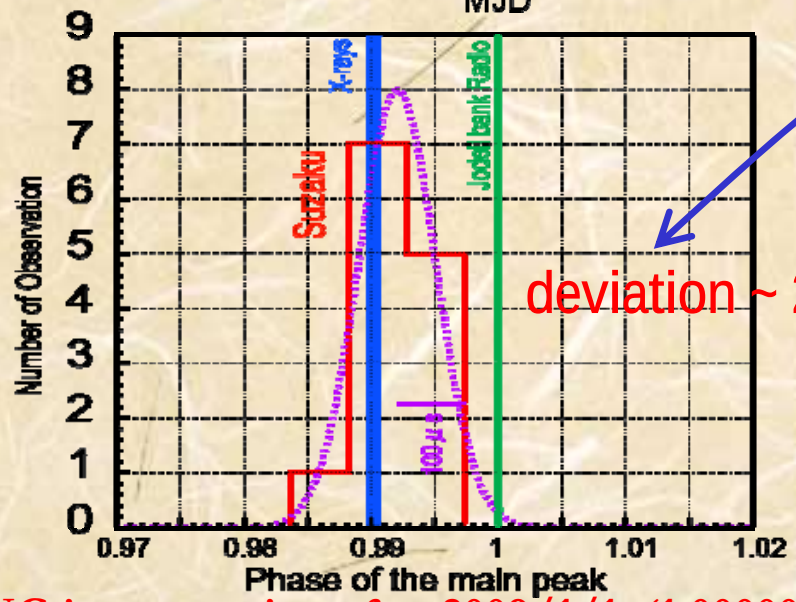
- Arrival time in X-ray exceeds 330 μ sec from that in Radio band. (same result as Rots etal 04)
- Arrival times with X-ray satellites are consistent within ~ 100 μ sec

Absolute Timing Calibration with Crab

Compared with Pulse arrival times of Jodrell Bank Radio Observatory







deviation ~ 230 μ sec

Known BUG in processing after 2009/1/1 (1.000000 sec) / FIXED

Timing System in the future mission, Astro-H

Now in design phase

Satellite bus | *Sub systems (payload)*

On-board GPS system

Onboard Main computer

Master clock

1 M, 1 Hz clock

Synchronized

SpaceWire link

Fixed delay + jitter

TI (26+6 bit)

Onboard computer

Intelligent Node

TI

26+ 6 bit

Electronics DAQ

Non-Intelligent Node

Time counter

TBD bit

Free RUN

Sensor

Sensor

Compare (every sec)

Long coverage

Fine resolution

Ground

Downlink Station

Compare (5 contacts par day)

UTC (yyyymmdd hh:mm:ss.uuuuuu)

- Use GPS system, master clock is synchronized to this
- Use SpaceWire Link
  - no exclusive line from master clock
  - deliver sub-sec information via TIME_CODE and over-sec information via RMAPwrite
  - having fixed delay and jitter (depends on network configuration)

Summary

- Suzaku carries the HXD with 61 usec timing resolution and the XIS with normally 8 sec timing resolution.
- The times between the XIS and the HXD are consistent with each other within 20msec.
- The stability was confirmed as 1.9 x 10^-9 from the comparison between arrival time of the main pulse of Crab in Radio and Suzaku.
- Simultaneous observation of Crab with Suzaku, INTEGRAL, Swift, and RXTE was performed in 2007 as a timing calibration. The absolute timing of these satellites are confirmed in 100 usec order.
- The timing accuracy of Suzaku was tested by many Crab observations, and confirmed as <230 usec.
- We are now developing the timing system on Astro-H, which uses Spacewire network.

Timing working group was inactive in the last IACHEC workshop.
→ Restart the activity in this 4th workshop?