Development of a micro-satellite TSUBAME for X-ray polarimetry of GRBs

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TSUBAME is a micro-satellite that the students of Tokyo Institute of Technology took the lead to develop for measuring hard X-ray polarization of Gamma-Ray Bursts(GRBs) in order to reveal the nature of the central engine of GRBs. *TSUBAME* has two instruments: Wide-field Burst Monitor (WBM) and Hard X-ray Compton Polarimeter (HXCP). WBM, which consists of five X-ray detectors mounted on the five faces of the satellite, detects GRBs and determines those positions by monitoring the count rates. In order to measure the polarization of the gamma-ray prompt emission, *TSUBAME* calculates the position of GRB with on board CPU and starts pointing observation within 15 s after the detection by cooperating with the high speed attitude control system. *TSUBAME* will be launched **in Oct 2014 or later**. In this presentation, we will show the details of HXCP and WBM instruments and the current development status of *TSUBAME*.

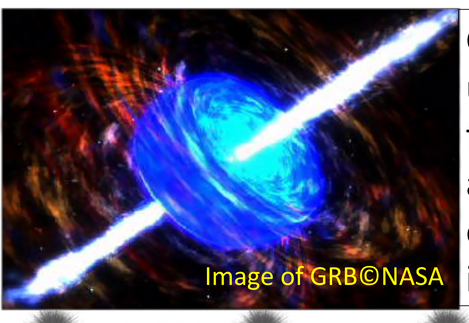
1. TSUBAME Mission

TSUBAME has 3 missions:

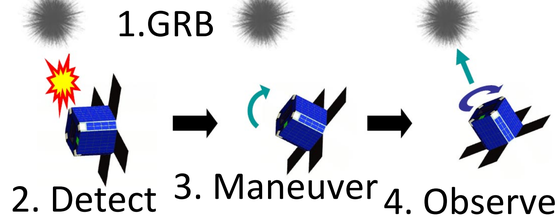
-X-ray polarimetry for GRBs (Science mission)

-Demonstration of high-speed attitude control with Control moment gyroscopes(CMGs)

-Visible earth observation using small camera



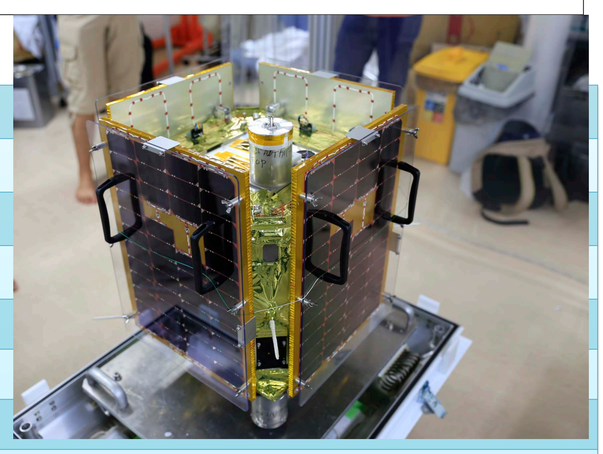
GRBs are the most energetic explosions in the universe. However, it is not yet clear how to form the collimated outflow wave and accelerate particles. X-ray polarimetry of prompt emission is believed to provide crucial information of magnetic fields.



When a GRB occurs, TSUBAME detects it and starts an observation, pointing to the GRB. To accomplish the mission, TSUBAME has 2 scientific instruments, HXCP and WBM.

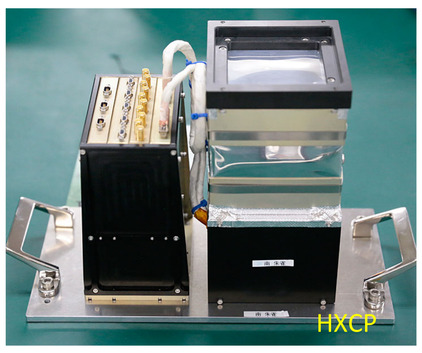
2. BUS System

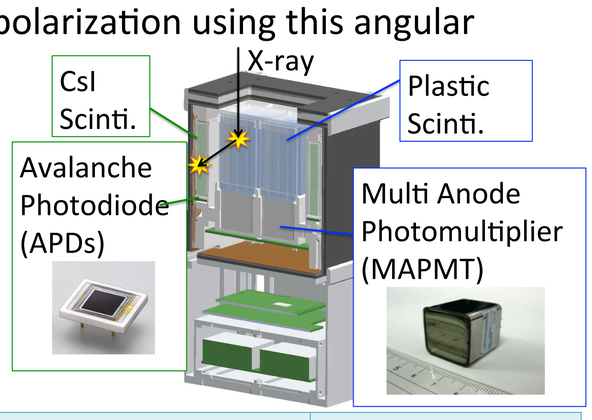
Size	50 x 50 x 47 cm^3	
Mass	50 kg	
Orbit	600 km (Sun Synchronous)	
Launch	No sooner than Oct 2014	
Electrical Power Supply (EPS)	Cell	InGaP/InGaAs/Ge
	Power	134 W(EOL)
	Battery	Li-Polymar
Command & Data Handling (C&DH)	Tx	S-band (BSPK-100 kbps)
		UHF (CW/GMSK-9600bps AFSK-1200bps)
	Rx	VHF AFSK-1200 bps
Attitude Determination and Control Systems (ADCS)	3-axis zero momentum control	
	Actuator	Control Moment Gyro. / Magnetic Torquers
	Sensor	Gyro (MEMS/FOG), Sun Sensor,Magnetometer, Star Tracker, GPS



3. Hard X-ray Compton Polarimeter (HXCP)

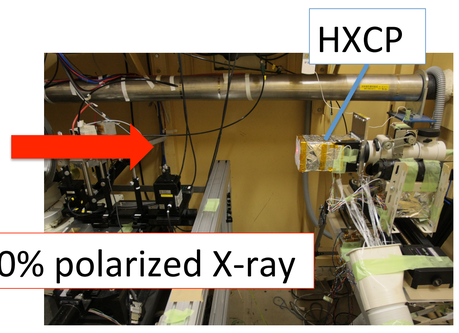
Linearly polarized photons tend to be scattered perpendicular to the polarization plane. HXCP measures GRB polarization using this angular dependence.

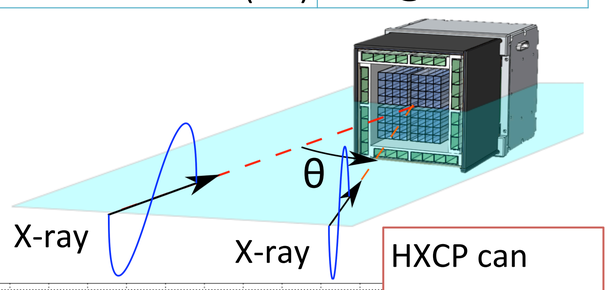




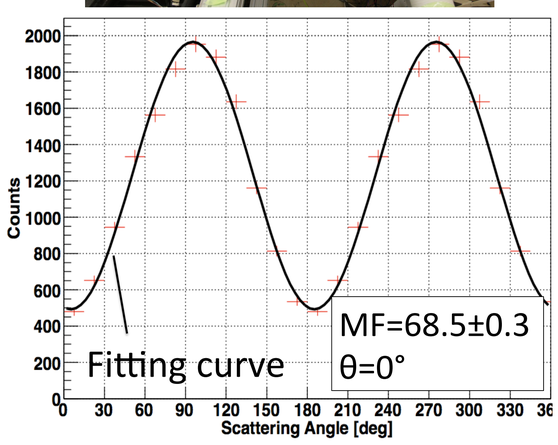
We did performance tests with 80 keV on-axis 90 % polarized synchrotron X-ray at KEK.

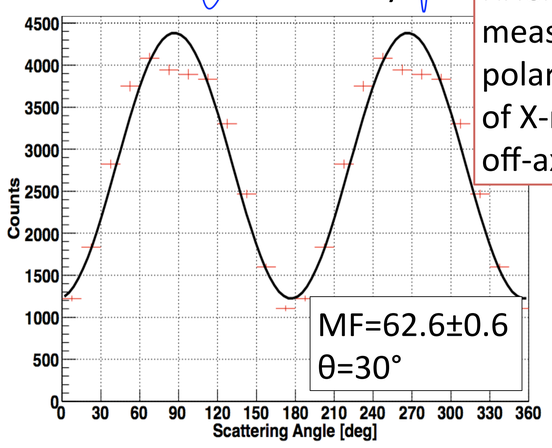
Energy band	30 - 200 keV
Field of View	60 x 60 deg^2
Effective Area	2.4 cm^2
Detectable Polarization(3 σ)	23% @ ~10 Crab





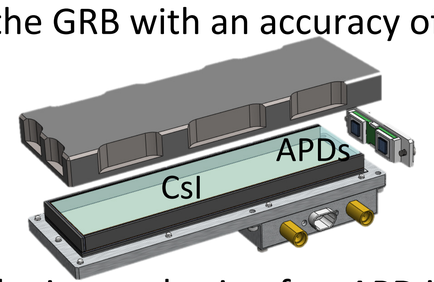
HXCP can measure a polarization of X-ray with off-axis angle.





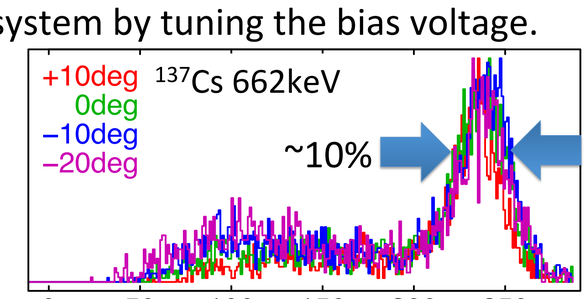
4. Wide-field Burst Monitor (WBM)

WBM consists of five detectors mounted on the five faces of the satellite. Monitoring the count rate, it detects GRBs and determines the position of the GRB with an accuracy of ~ 5 deg.

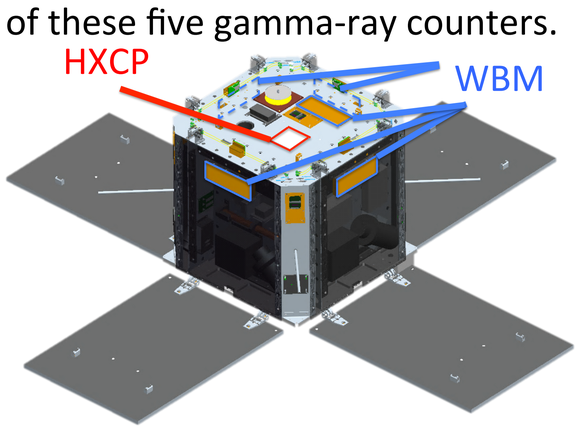


Energy band	30 - 200 keV
Field of View	2π str
Effective Area	35.6 cm^2/unit @ 100 keV
Accuracy	5 deg @ ~10 Crab

The internal gain of an APD is sensitive to the operation temperature and bias voltage. Therefore we implemented a temperature compensation operation system by tuning the bias voltage.

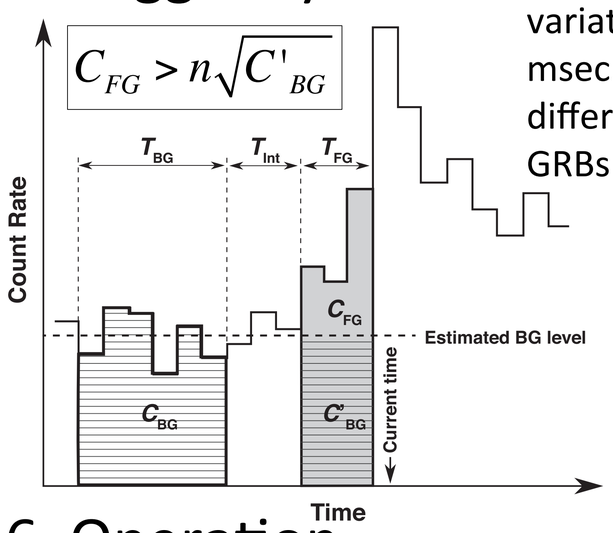


WBM determines the position of GRBs by comparing the event rates of these five gamma-ray counters.

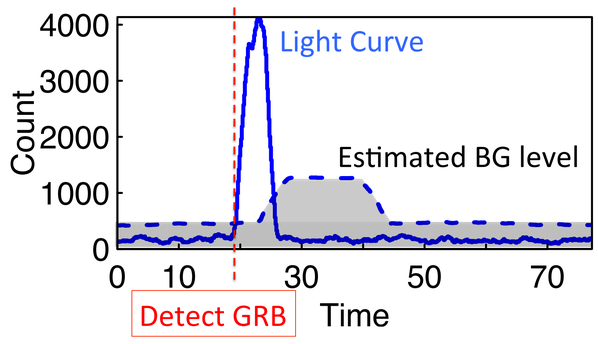


5. Trigger System

$$C_{FG} > n\sqrt{C'_{BG}}$$



To detect GRBs on board CPU checks the variation of gamma-ray count rate every 125 msec. WBM employs 4 trigger systems with different time constants which covers short GRBs and long GRBs simultaneously.



6. Operation

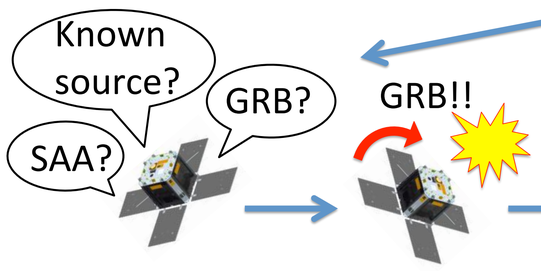
TLE

SAA map, known source coordinate, ground station coordinate, trigger mode, etc…

Graphical command check sheet for TSUBAME
➔Check by eyes

Command (HEX, ~2 kByte)
➔Uplink via FM 140MHz band

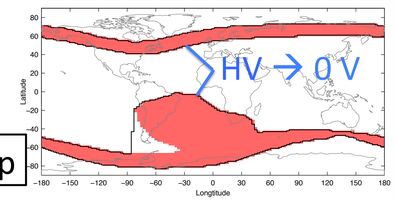
Computer



Downlink
- Observation data 6 M Byte / GRB via S-band
- HK data 72 Byte / frame via FM(430 MHz band)

SAA mask – protecting the MAPMTs of HXCP from SAA

TSUBAME has 3 ways to decide whether the satellite is in SAA:
- Comparing GPS information with input SAA map
- SAA trigger systems by WBM
- Commands by predicted satellite orbit



SAA map

Known source mask – preventing fake GRB trigger by known sources

Because WBM can not distinguish between an increase in count rate by GRB and known sources appearing from the earth rim, we disable GRB trigger systems by commands at that time.

After observations, we will downlink six kinds of data: data list (trigger time, event count, etc…), observation data, time stamps (every photon event, synchronization of mission clock and GPS), orbital and attitude data, command log, and house keeping data log. The data size is ~ 6 MB / GRB, and it will take ~80 min to downlink a GRB observation data(~10kbps).

7. Integration Test

In Aug 2014, we assembled TSUBAME and performed an integration test. We operated TSUBAME continuously during ~2 weeks, and fixed all bugs. We successfully operated all the sequence.

The development of TSUBAME was almost finished. TSUBAME will be launched in Oct 2014 or later.