国際宇宙ステーションからの雷放電と高高度発光現象観測（GLIMS）の概要と現状

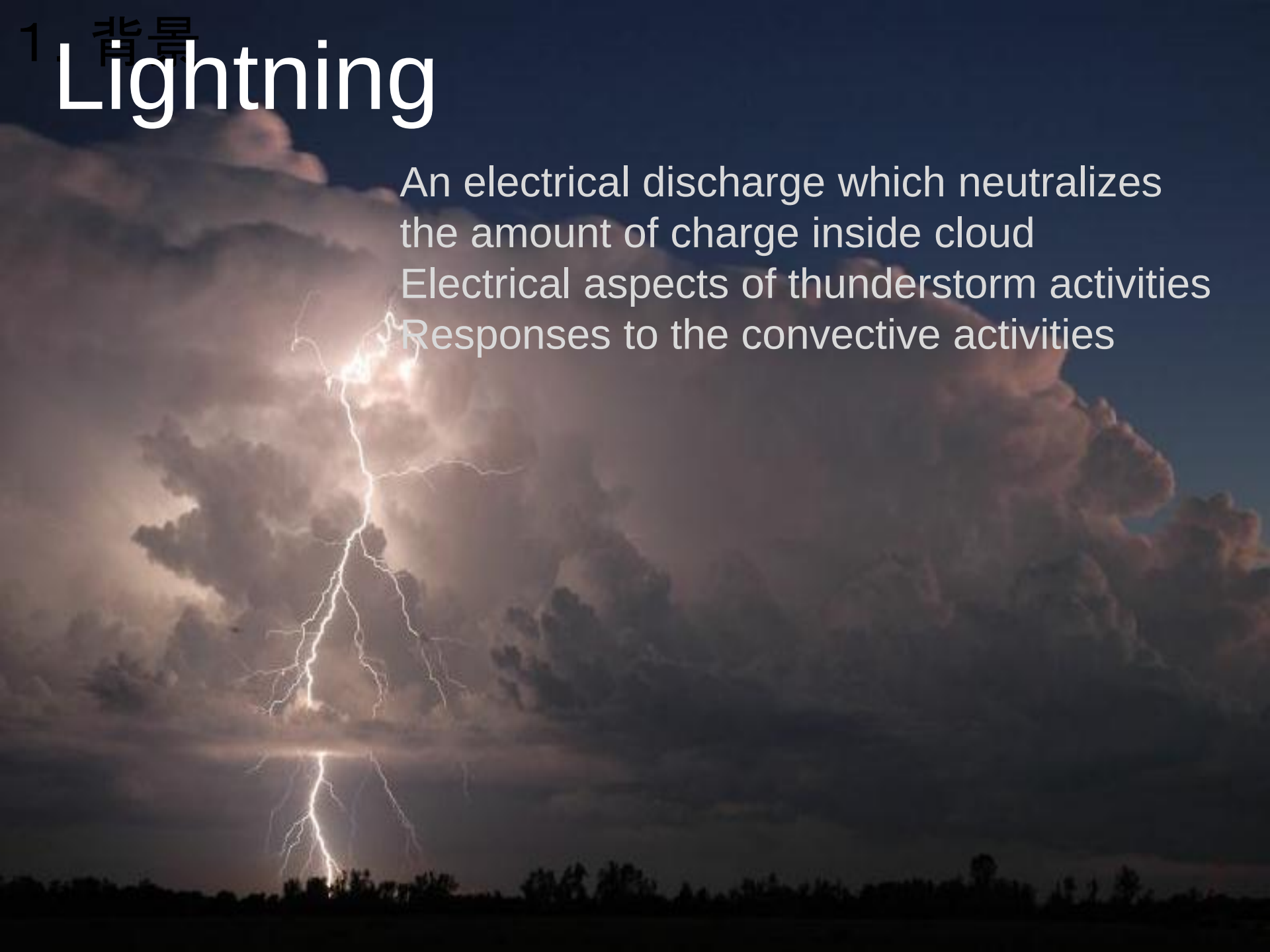
T. Ushio, M. Sato, M. Suzuki, T. Morimoto,
Y. Hobara, Y. Takahashi, M. Kikuchi, R. Ishida,
A. Yamazaki, T. Abe, Y. Sakamoto, K. Yoshida,
U. Inan, I. Linscott, Z-I. Kawasaki, S. Watanabe,

Outline

- Science background
- Sensor concept and design
- Current status of the mission
- Initial results

1. 背景

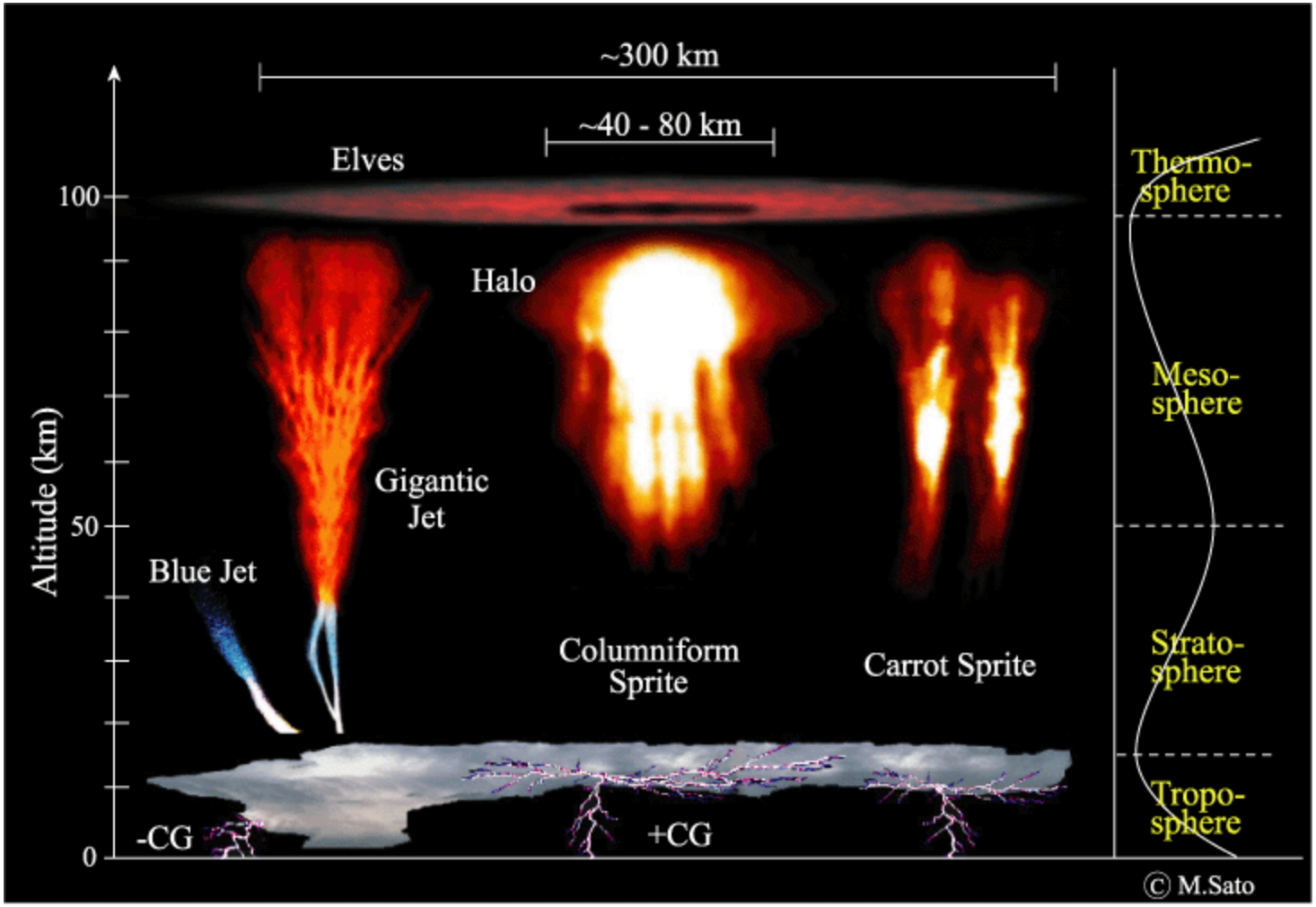
Lightning



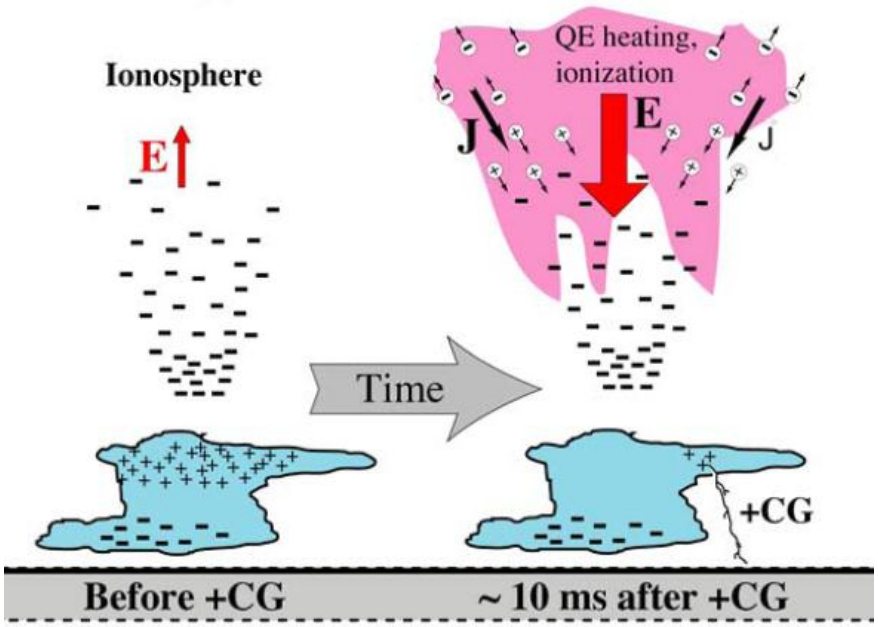
An electrical discharge which neutralizes the amount of charge inside cloud
Electrical aspects of thunderstorm activities
Responses to the convective activities

Luminous events at high altitude

- Associated with lightning, high altitude luminous events were reported in 1990's.
- Sprites are believed to be associated with giant lightning which have large currents.



What is the producing mechanism of sprites?



QE model

Generally accepted explanation is the Runaway breakdown model that the breakdown is caused by the quasi-static electric field associated with lightning

【Problems】

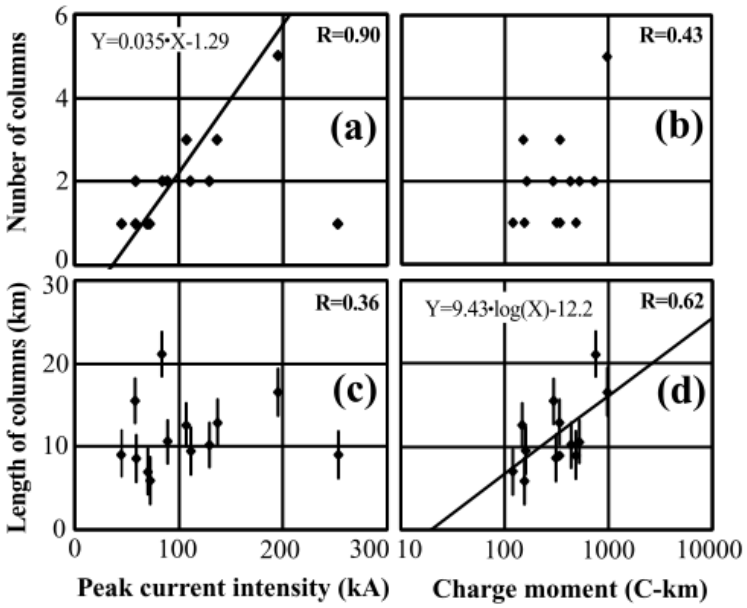
(a) Sprites can be caused by the lightning which has the charge moment less than a few hundred ckm

(b) Sprites are not always coincident with the cloud to ground lightning. The spatial difference reported so far is maximum 50 km.

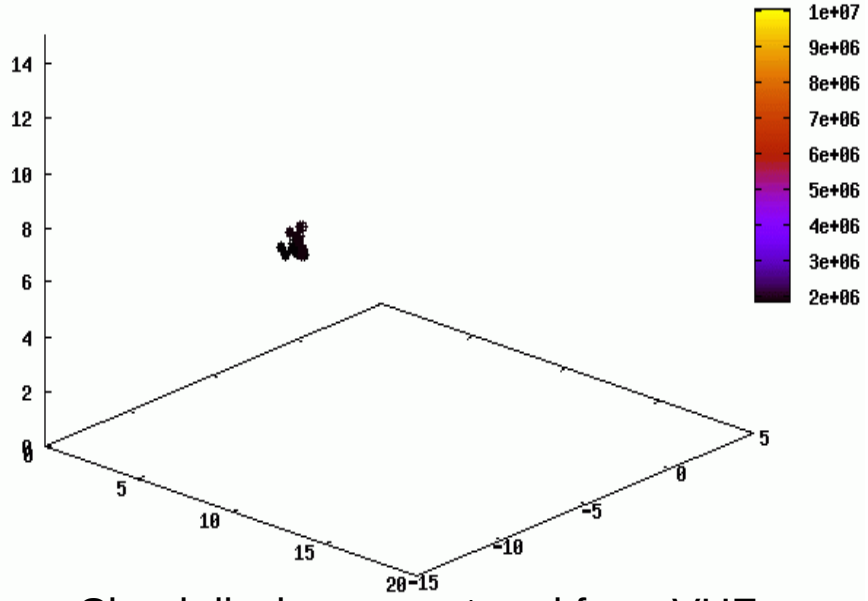
(c) Sprites take place from several ms to hundreds ms just after the occurence of cloud to ground lightning.

(d) The QE model cannot explain the horizontal structure of sprites such as column or carrot type, and also multiple column type sprites.

Electromagnetic pulses from lightning



Figs. Correlation between number of columns and peak current [*Adachi et al.*, 2004]



Cloud discharge captured from VHF impulse observation

Recently there are some reports that the lightning electro-magnetic impulses are correlated with the horizontal structure of the sprites.

↓

It is difficult to simultaneously measure the horizontal structure of sprite and lightning impulse from ground observation.

↓

It is essential to observe the sprites and lightning at nadir direction from space.

Global distribution of TLEs

Estimation from satellite obs.

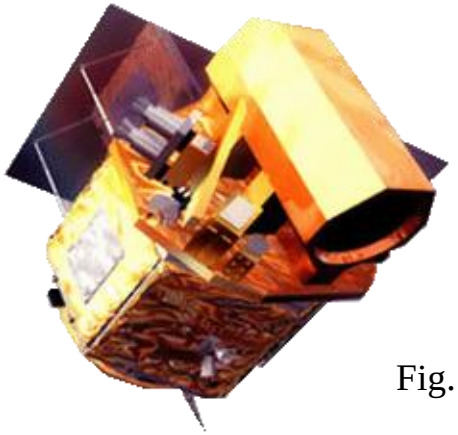
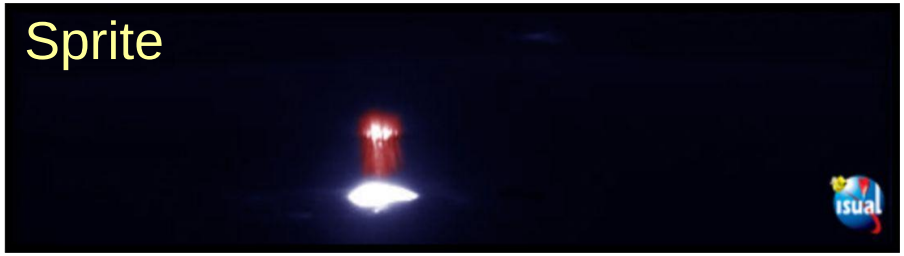
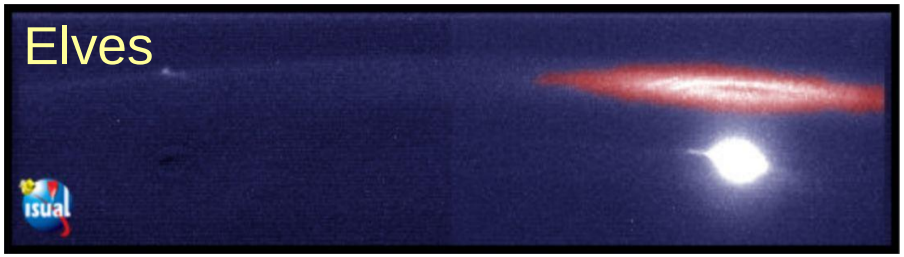
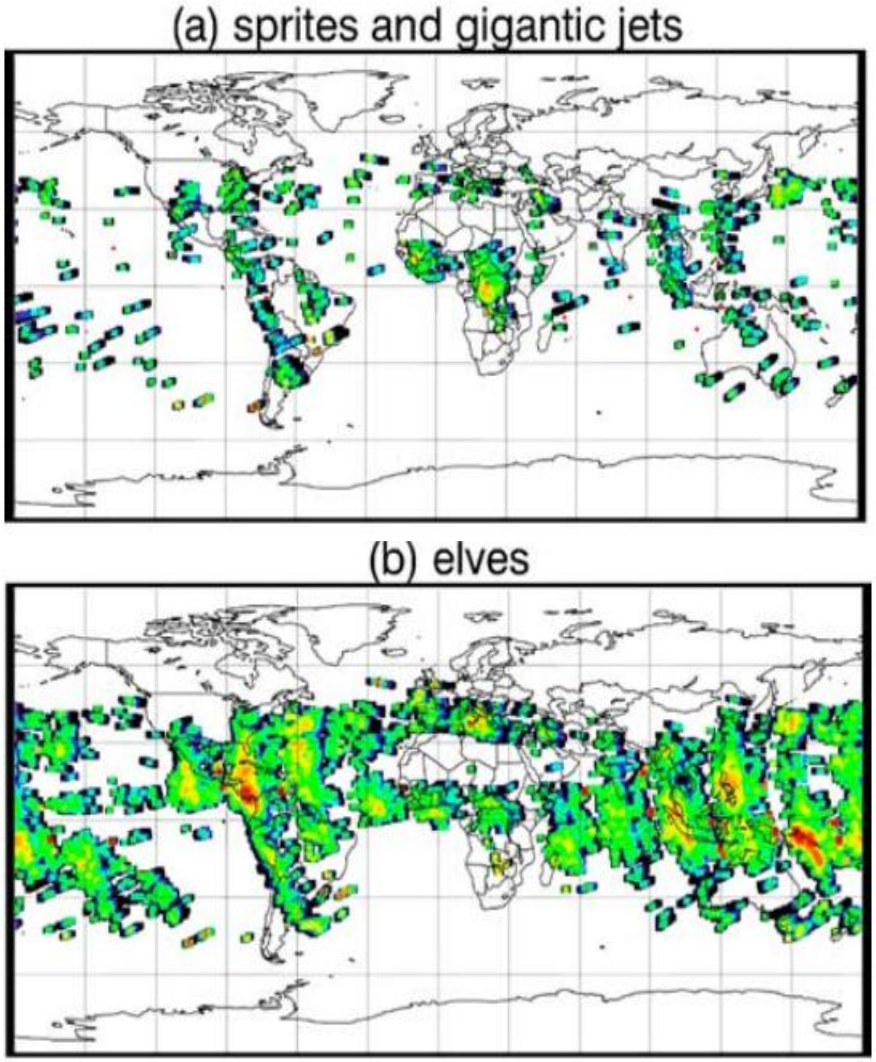


Fig. FORMOSAT-2衛星





Figs. FORMOSAT-2衛星に搭載されたカメラによって撮像されたスプライト, エルブス.

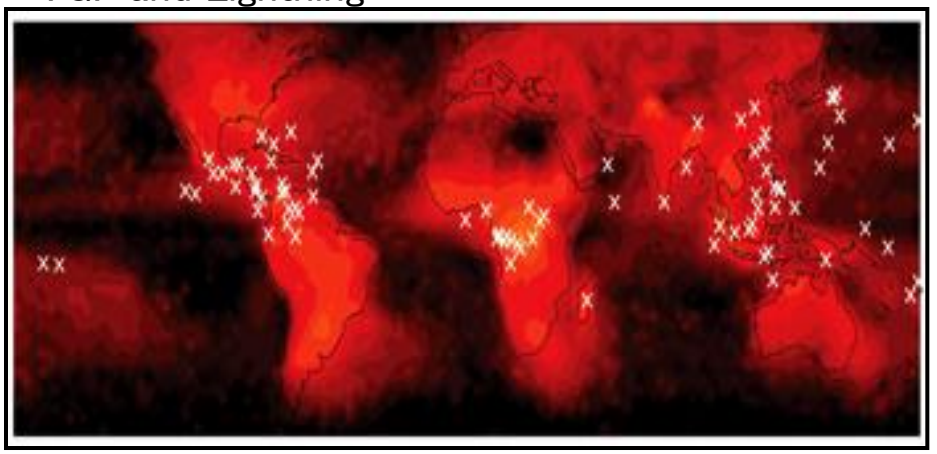


Figs. (上)スプライトおよび(下)エルブスの全球発生頻度分布. [*Chen et al.*, JGR, 2008]

Background

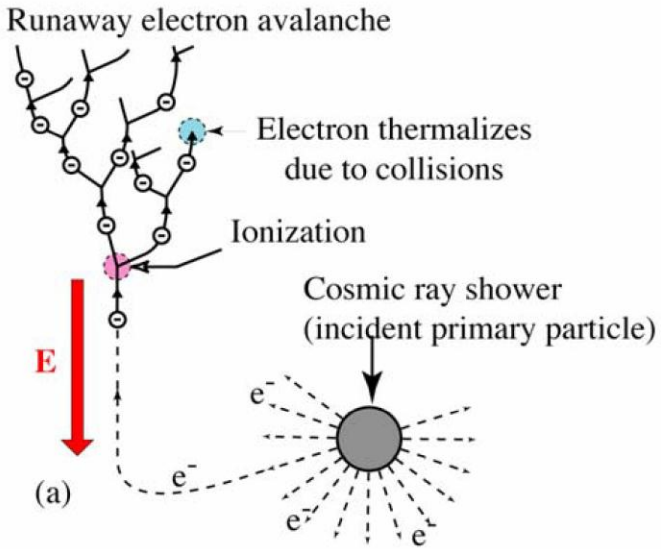
- Gamma emission observed by the CGRO/BATSE, RHESSI satellites
- High occurrence (1 event/2 day)
- Are these from lightning ?

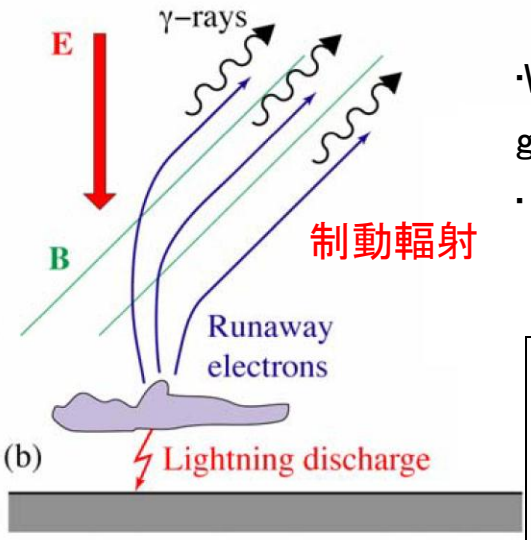
TGF and Lightning



Smith et al. [2005]

Runaway electrons





·Which lightning process produce gamma emission?

· Is there any connections to TLE?

↓

Needs for the simultaneous observation with lightning

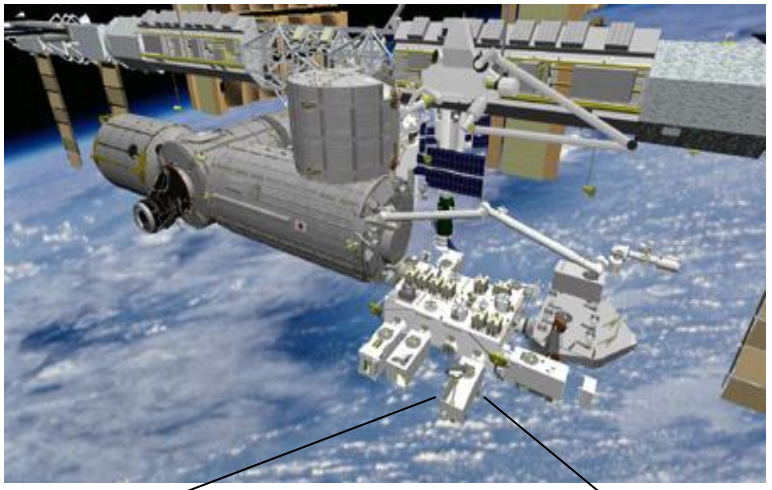
Mission Overview

JEM-GLIMS Mission

Global **L**ightning and spr**I**te **M**easurement**S** on JEM-EF

- Nadir observation of lightning and TLEs
  - = Optical observation of lightning and TLE emissions
  - = Electromagnetic observation of electromagnetic waves excited by lightning and TLEs

	Criteria
Science Requirement 1 【SR1】	Capture temporal and spatial distribution of lightning and its associated phenomena
Science Requirement 2 【SR2】	Characterize the relationship between horizontal structure of sprite and lightning
Science Requirement 3 【SR3】	Characterize the relationship between the lightning/sprites and gamma emission



MCE (Multi-mission Consolidated Equipment)

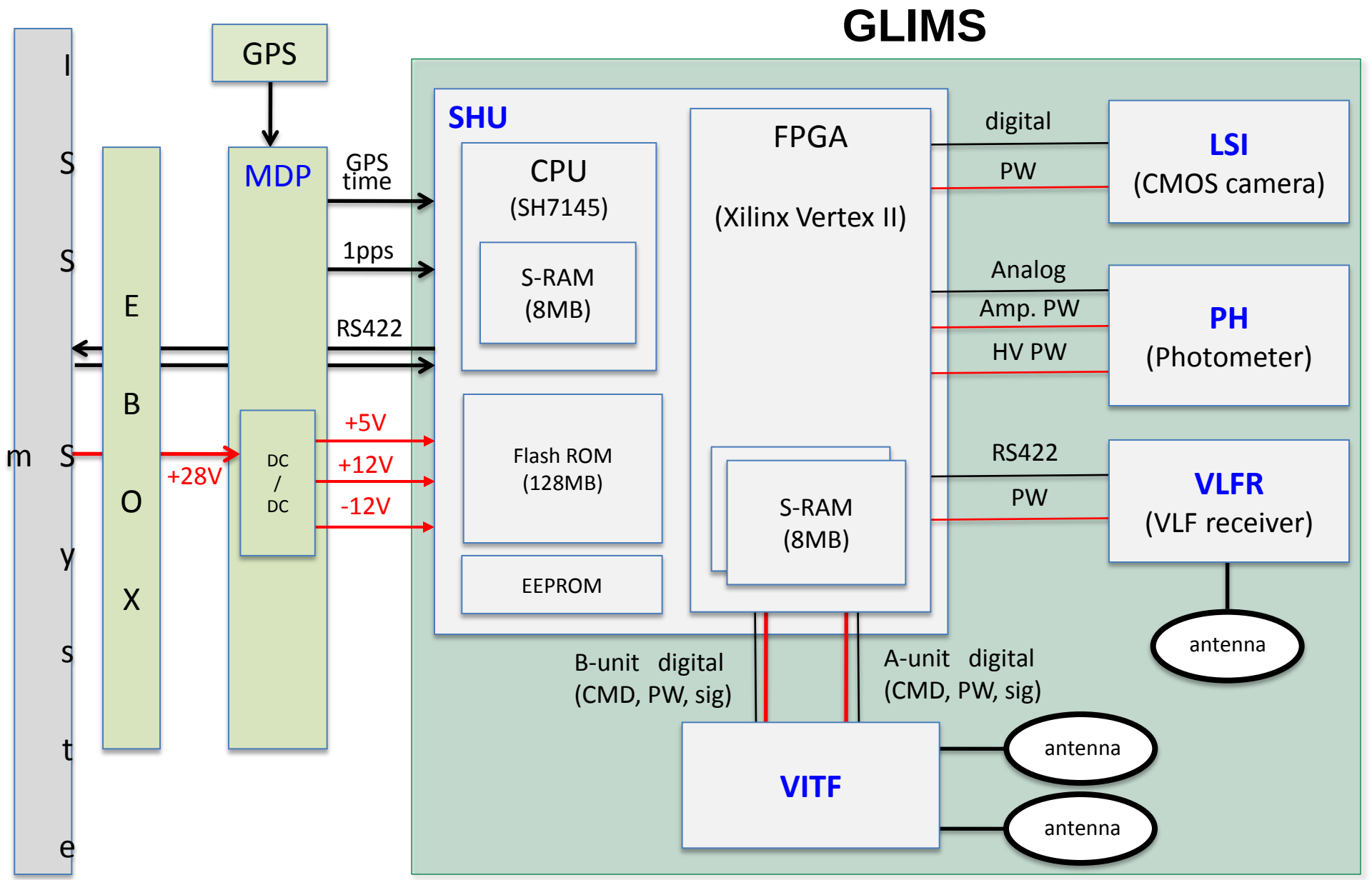
Success criteria

	Minimum Success	Full Success	Extra Success
Global Distribution	Continuously observe TLEs and lightning for more than 1 year with CMOS camera or VHF interferometer. Obtain data on the seasonal variation of the TLEs and lightning.	Observe TLEs and lightning within the 80% of the area from -50 to 50 in latitude with 1 km and 200 us resolution for more than 2 years. Obtain data for estimating the effects on atmospheric composition due to the occurrence of TLEs and for assimilating the lightning data into meteorological models.	Discover a new type of TLE.
Spatial Structure	Obtain at least one set of TLE data by using LSI or VITF. Determine the spatial and temporal difference between the horizontal progression of lightning and TLEs.	Detect the TLEs with 1 km and 10 us resolution and lightning with 10 km and 10 us resolution. Clarify the mechanism by which TLEs are generated.	Clarify the generation mechanism of the new type of the TLEs due to the EMP from horizontal progression of lightning
Spectrum Observation	-	Detect at least one TLE by using the photometer at near-ultraviolet. Determine the electron temperature and existence or non-existence of the N_2 ion.	Obtain the spectrum data for all the TLEs observed, and understand the mechanism of the electron acceleration
Gamma ray observation	-	-	Detect lightning which is correlated with a gamma ray emission with 1 km and 10 us resolution. Specify the lightning process producing gamma rays. Understand the sources of the gamma ray emission from statistical data sets
VLF	-	-	Detect at least one VLF signal from lightning

GLIMS観測機器構成

名称	ID	仕様・目的・利点
CMOS カメラ	LSI	CMOSセンサを用いた2台のカメラ ・雷とスプライトの撮像観測 ・雷発光とスプライト発光を空間的に分離できる！ ・CCDで必要となる冷却装置が必要無い（省電力）
フォトメタ	PH	6台のフォトメタ ・雷とスプライトの発光強度を50μ sの時間分解能で測定 ・雷発光とスプライト発光を時間的に分離できる！
VLF レシーバ	VLFR	1式のVLF帯電波受信アンテナ ・雷から放射されるVLF帯電波(ホイッスラー波)を観測 ・スプライトの親雷放電の電流特性がわかる！
VHF 干渉計	VITF	2式のVHF帯電波受信アンテナ ・雷から放射されるVHF帯電波を観測 ・スプライトの親雷放電の時間的・空間的進展がわかる！
理学機器制御ユニット	SHU	搭載コンピュータ ・LSI, PH, VLFR, VITFを制御する心臓部 ・コマンドによって観測器を自由に制御できる！

GLIMS観測機器構成



雷・スプライトカメラ(LSI)

- ２台のCMOSカメラ

- LSI−1：　広帯域フィルタ：雷
- LSI−2：　狭帯域フィルタ：スプライト

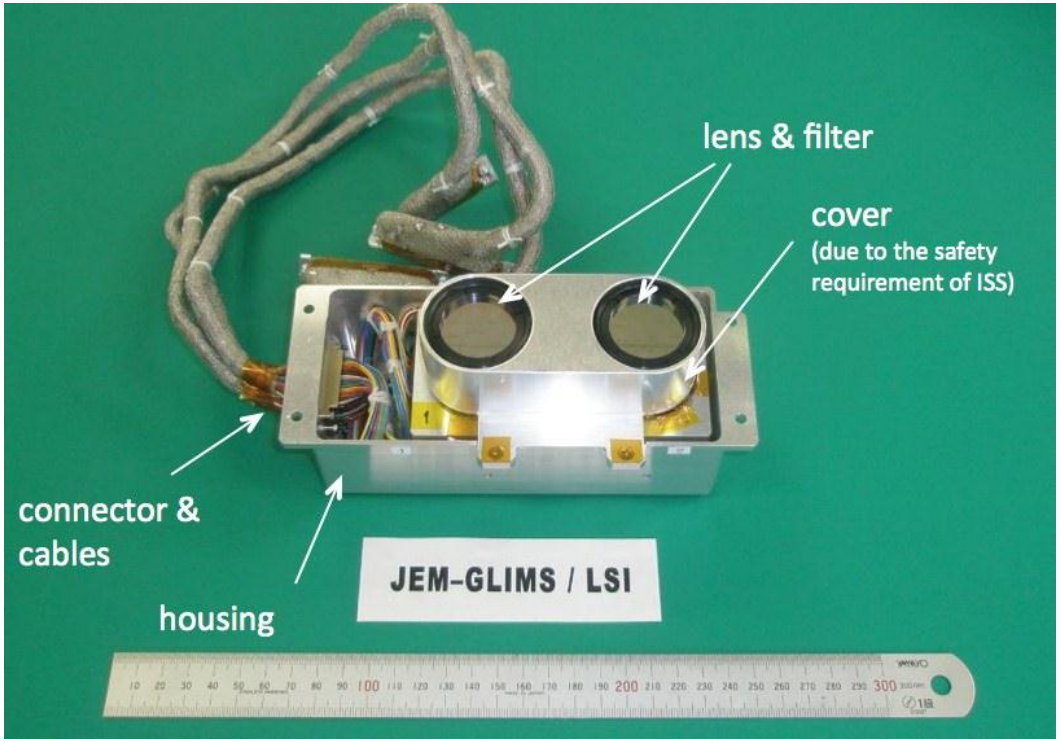
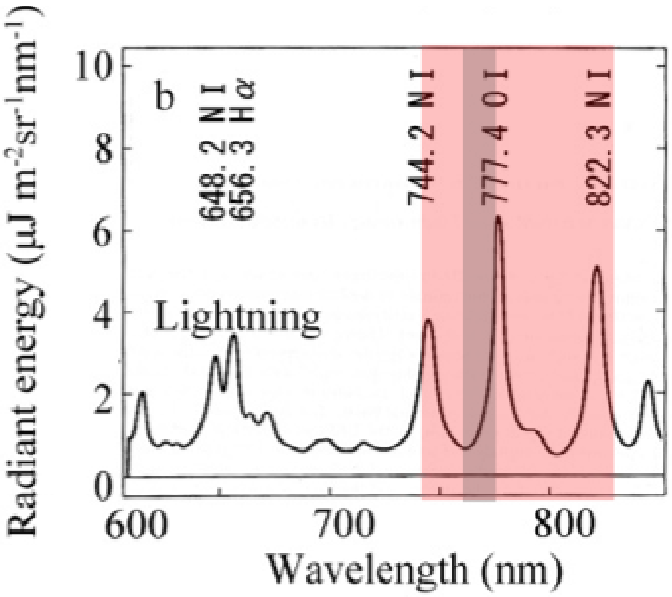
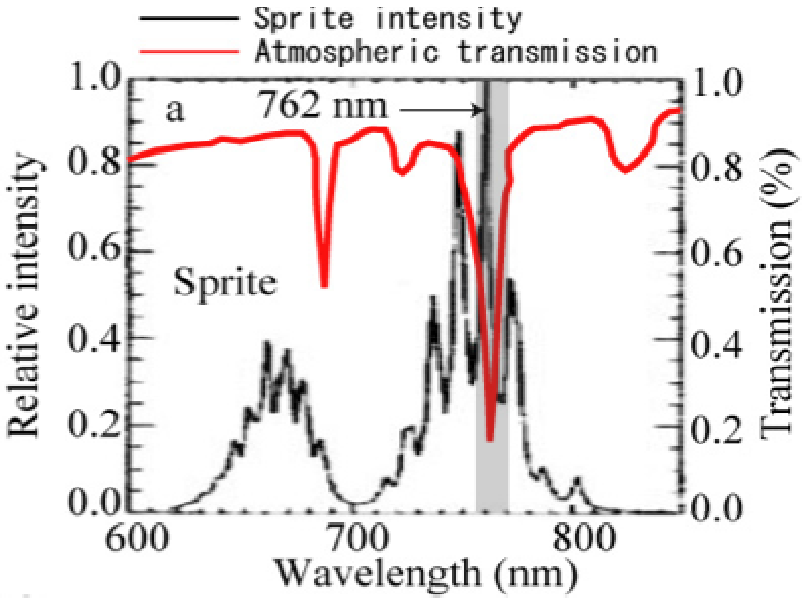


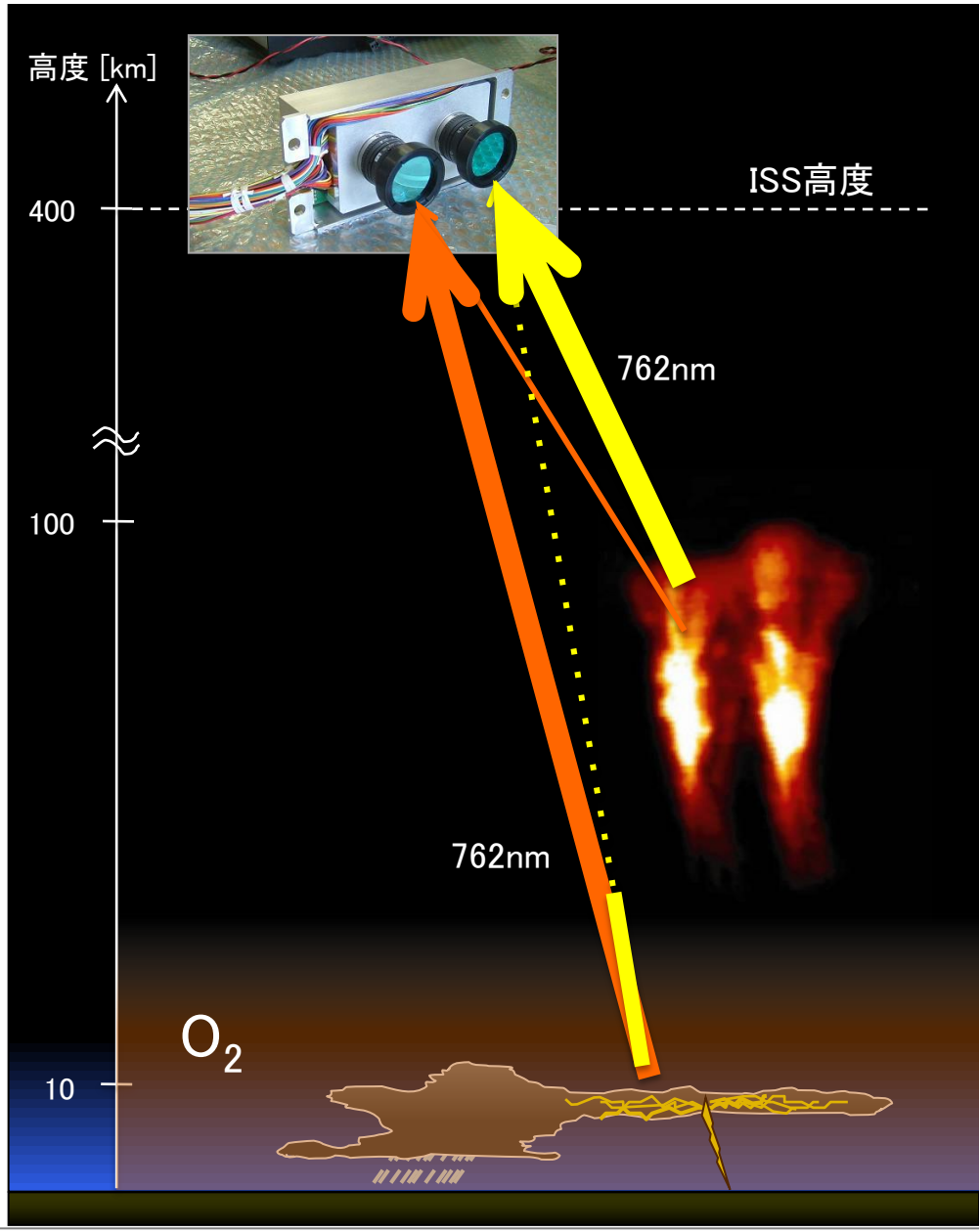
Table　Summary of LSI specification.

Item	Value
Wavelength	740-830 nm (LSI-1) 762+/-5 nm (LSI-2)
FOV	28.3° × 28.3°
Optics	F=1.4, f=25mm
Detector	CMOS (STAR-250)
Pixel Number	512 × 512
Sensitivity	6.9E-6 W/m^2
Resolution	10 bit
Spatial Resolution	0.55 km/pix @ nadir ground surface
Time Resolution	34.5ms, 8.6ms, 2.1ms (29fps, 116fps, 464fps) selectable
Size	185 × 87 × 75 mm^3
Mass	0.7 kg
Power	0.8 W

雷・スプライトカメラ(LSI)

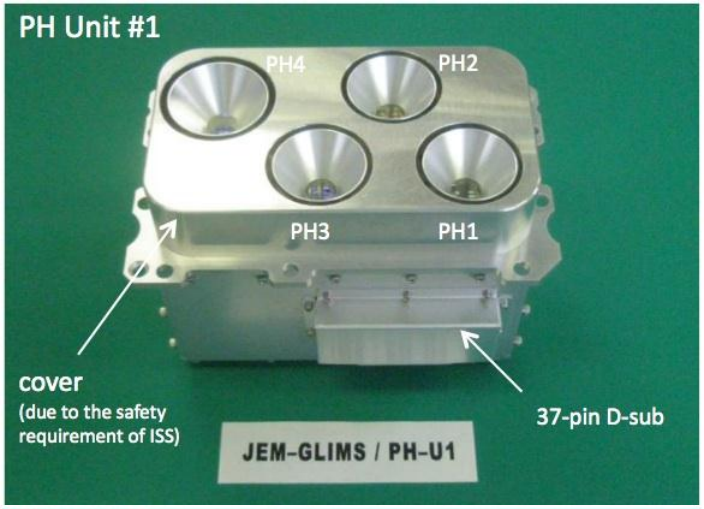






フォトメタ(PH)

- 6台のフォトメタ
- N_2 1P, 2P, N_2^+ 1Nの発光強度測定



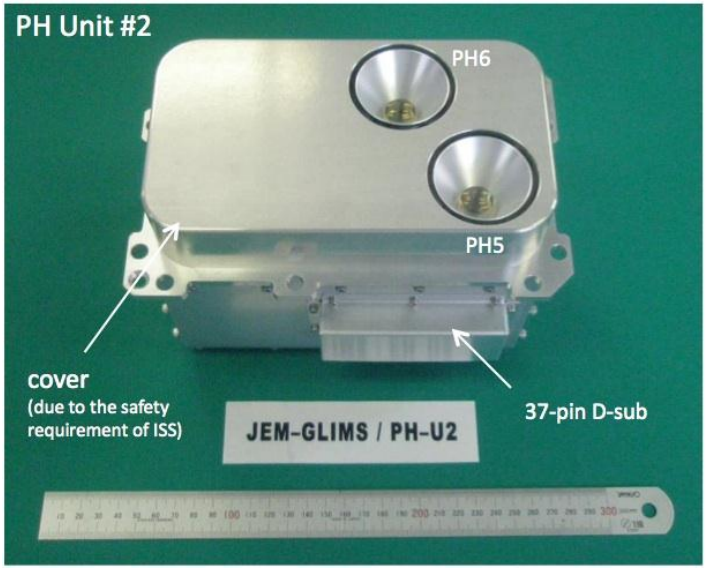
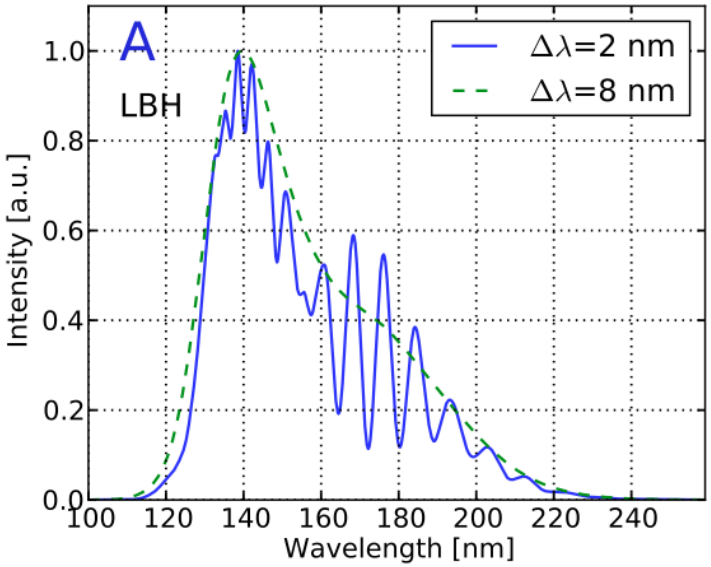
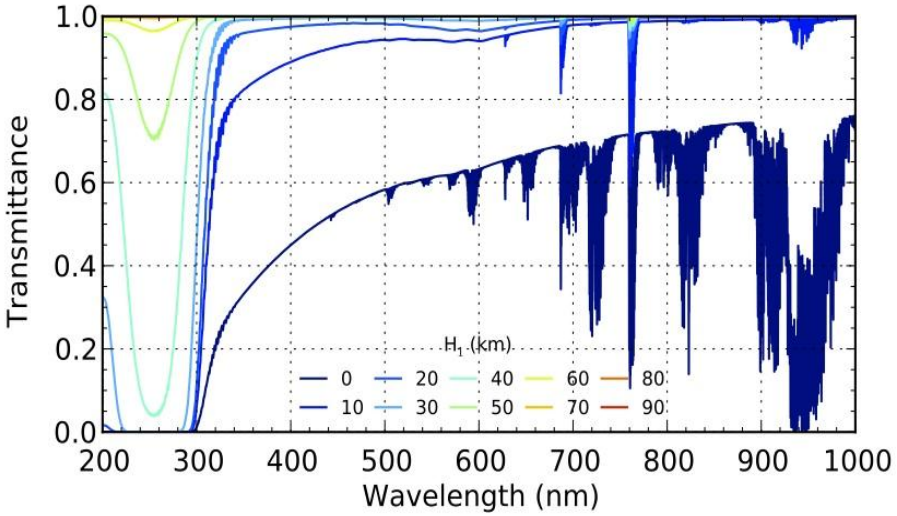


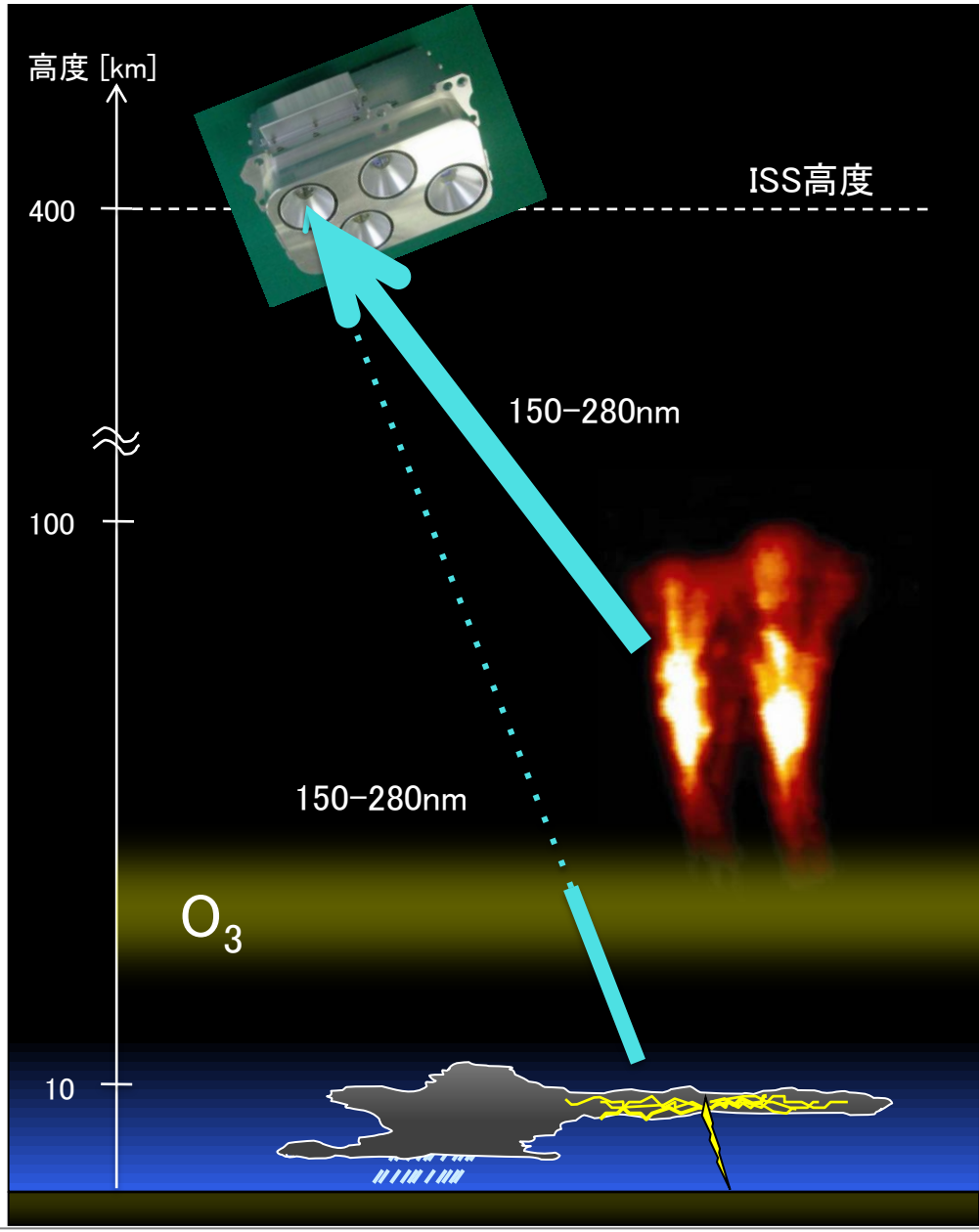
Table Summary of PH specification.

Item	Value		
Wavelength	150-280 nm 337+/-5 nm 762+/-5 nm 600-900 nm 316+/-5 nm 392+/-5 nm	PH1 PH2 PH3 PH4 PH5 PH6	N_2 LBH N_2 $2P_{(0,0)}$ N_2 $1P_{(3,1)}$ N_2 $2P_{(0,0)}$ N_2 $2P_{(1,0)}$ N_2^+ $1N_{(0,0)}$
FOV	42.7° 86.8°	for PH1~3,5,6 for PH4	
Optics	F1.5 F1.72	for PH1~3,5,6 for PH4	
Detector	PMT (R7400) PDD (S1227)	for PH1~3,5,6 for PH4	
Sensitivity @SNR=10	0.1E-6 W/m^2 10E-6 W/m^2	for PH1~3,5,6 for PH4	
HV Range	0-1000 V		
Resolution	12 bit		
Sampling Freq.	20 kHz		
Size	209 × 136 × 130 mm^3 / UNIT		
Mass	2.3 kg 2.0 kg	for Unit #1 for Unit #2	
Power	5.4 W		

雷・スプライトカメラ(LSI)





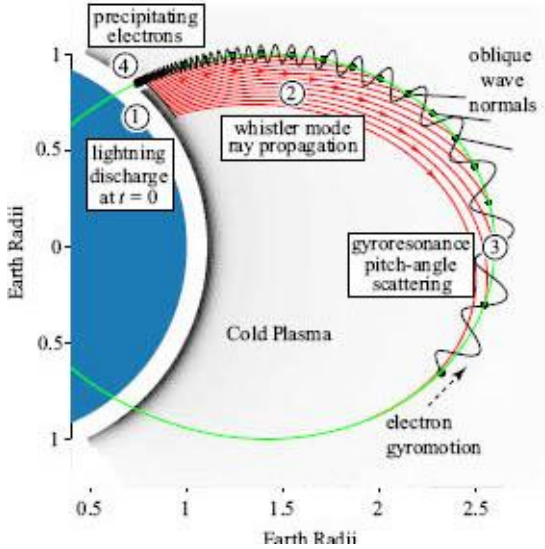


VLF波動レシーバ (VLFR)

- VLFレシーバ (VLF Receiver)
- 雷放電励起のWhistler波の検出

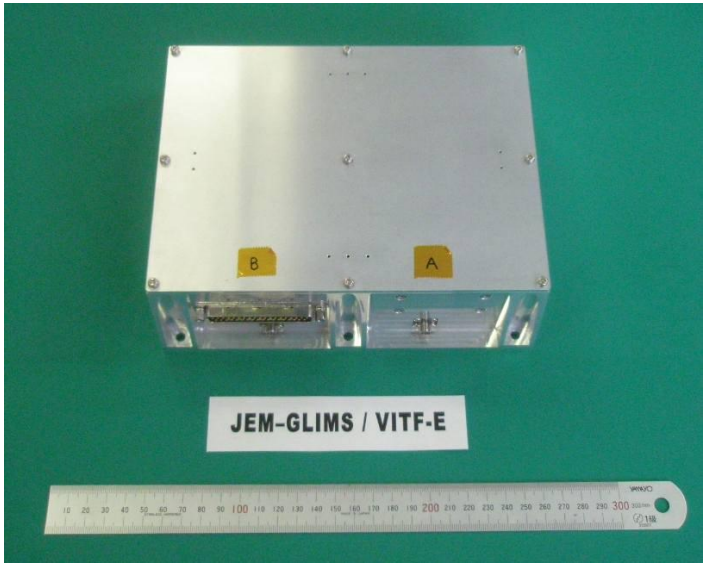
Table Summary of VLFR specification.

Item	Value
Freq. Range	1-30 kHz
Resolution	14 bit
Sampling Freq.	100 kHz
Antenna	monopole antenna (15cm)
Size (electronics)	126 × 83 × 20 mm^3
Size (antenna)	ϕ212 mm × 66 mm
Mass	0.5 kg
Power	0.8 W



VHF電波受信器(VITF)

- VHF干渉計 (VHF InTerFerometer)
- 雷励起のVHFパルスの計測



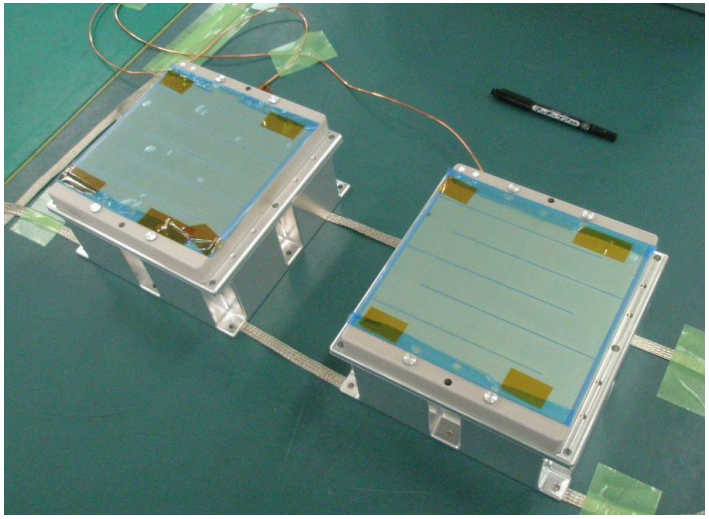


Table Summary of VITF specification.

Item	Value
Freq. Range	70-100 MHz
Resolution	8 bit
Sampling Freq.	200 MHz
Antenna	patch-type antenna
Size (electronics)	208 × 180 × 57 mm^3
Size (antenna)	192 × 192 × 105 mm^3
Mass	9.25 kg
Power	9.8 W

VITF Antennas

- VITF antenna structure and location of these antennas at the bottom plate of MCE are shows in Figure 3.5-2.

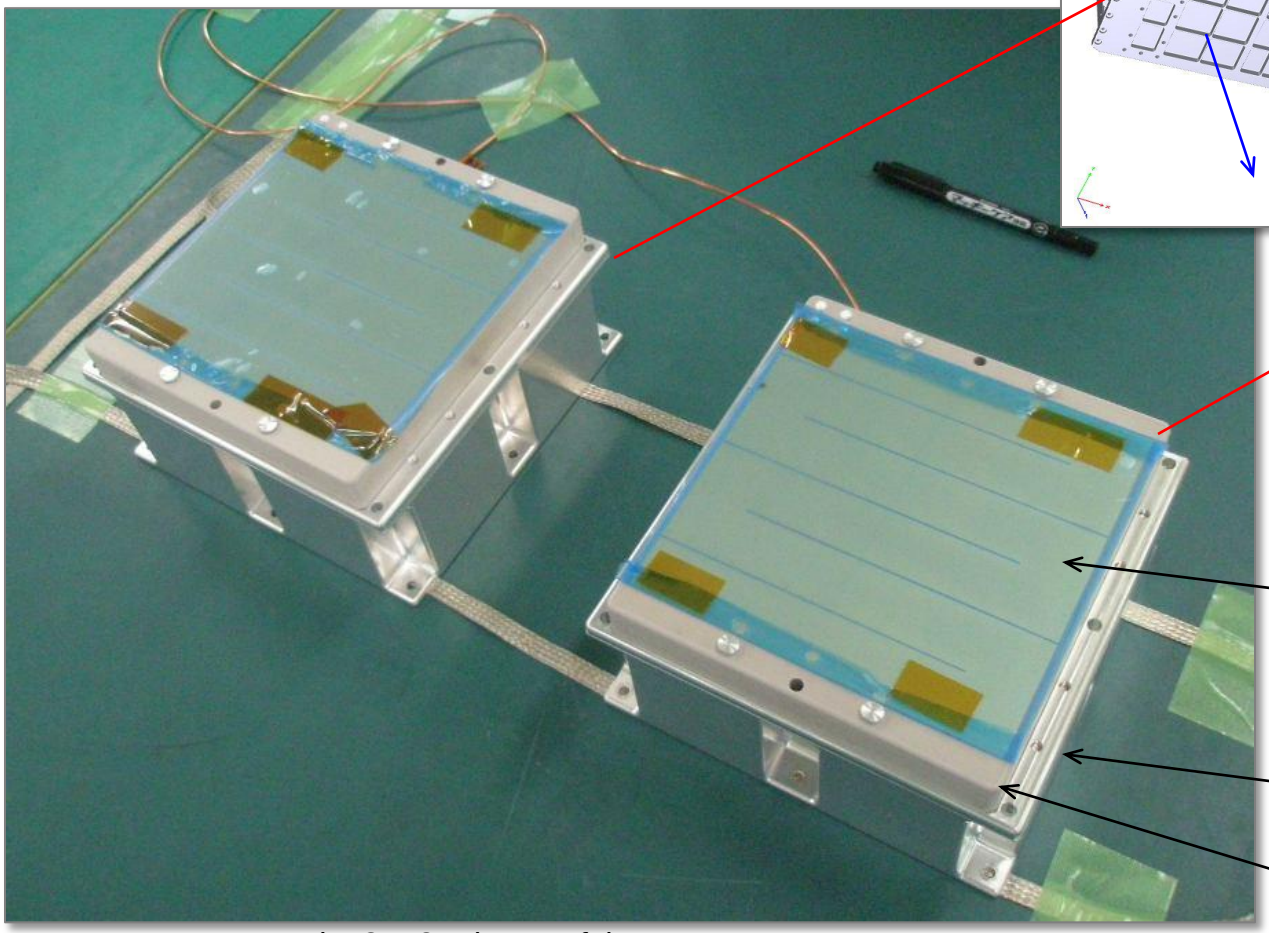


Fig. 3.5-2 Picture of the VITF antennas.

理学機器制御装置(SHU)

SHU (Science instruments Handling Unit)

- 全観測機器の制御 (power, A/D)
- イベントトリガ, データ取得
- GPSとの同期
- データ圧縮： HIREW (lossless compression)
- テレメトリ, コマンド

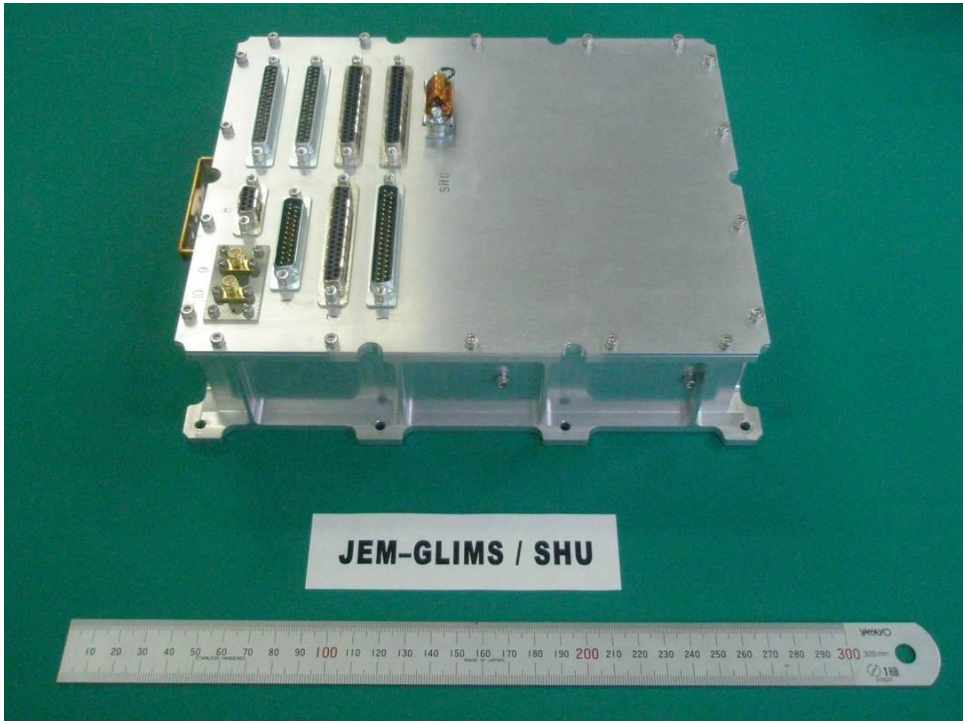


Table Summary of SHU specification.

Item	Value
Main Function	Power control Data acquisition Event trigger Data compression (HIREW encoding) GPS time synchronization Command, Telemetry I/F (RS422 I/F)
FPGA	Xilinx Vertex II
CPU	SH2
S-RAM	8MB x 2 for FPGA (temporal data buffering) 8MB for CPU
Mass Memory	128MB (FIFO memory for TLM)
Size (electronics)	208 × 180 × 57 mm^3
Mass	1.7 kg
Power	10.3 W

GLIMS観測器

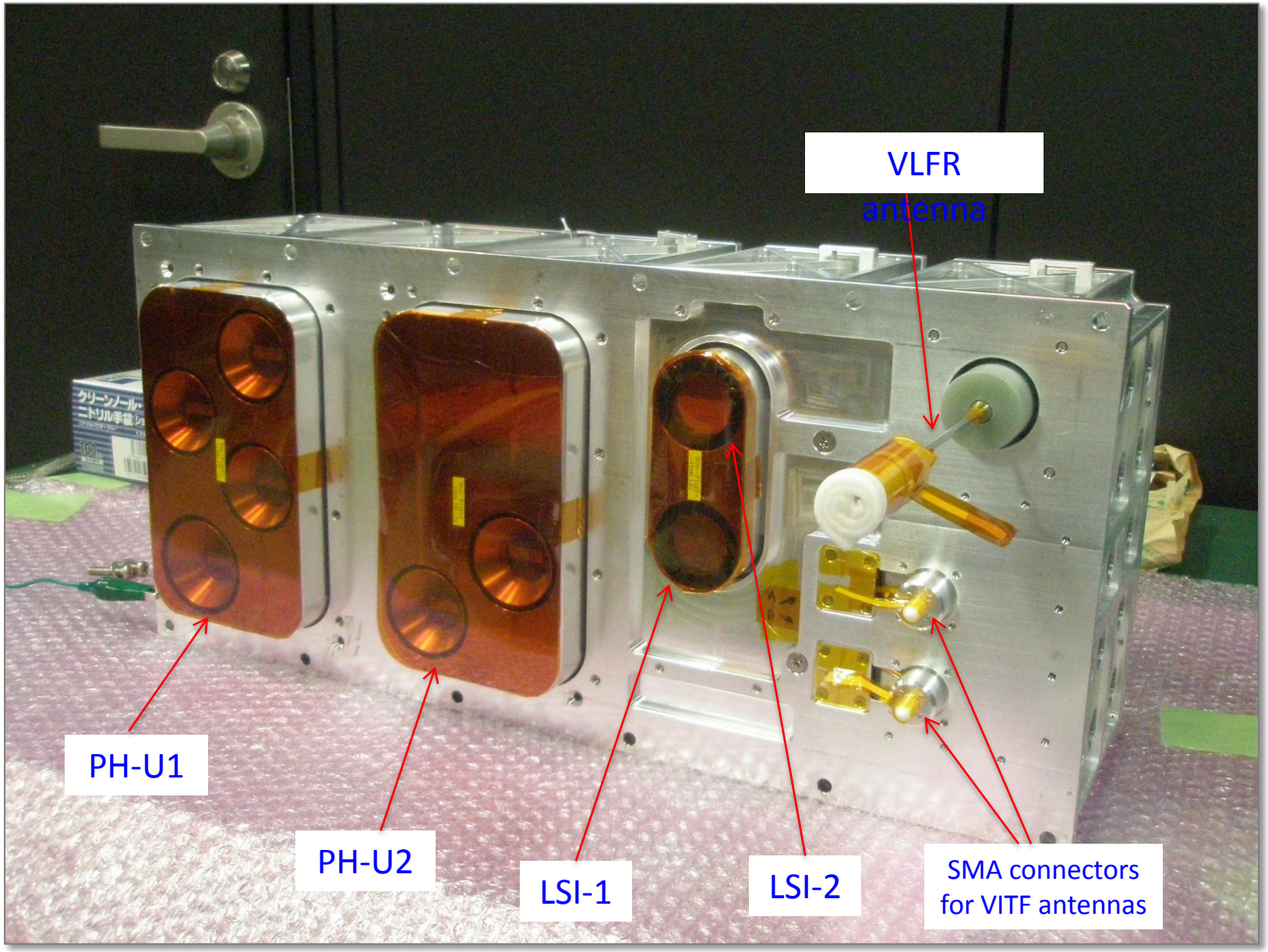
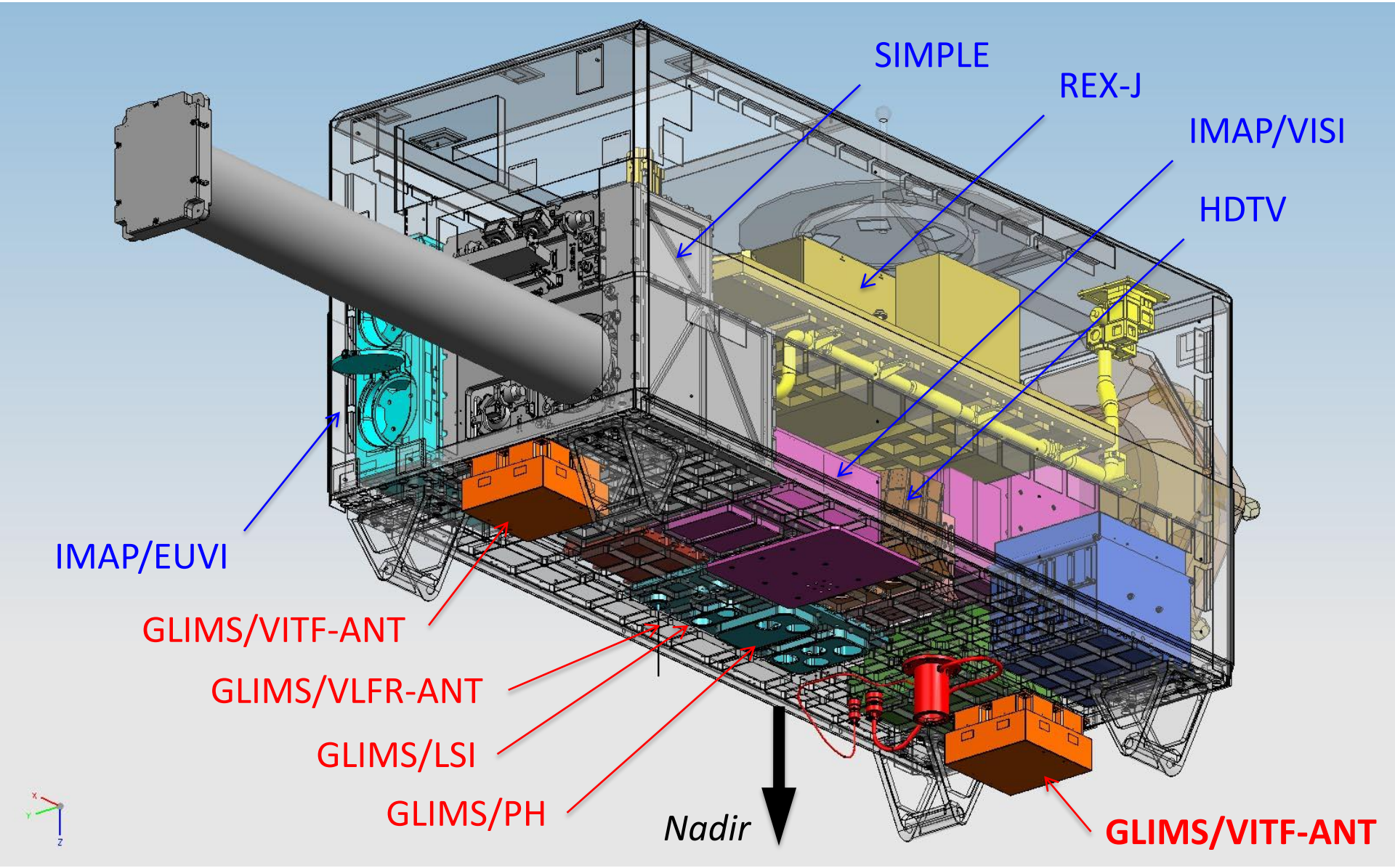


Fig. Picture of GLIMS flight model.

GLIMS機器とMCE



GLIMS機器とMCE

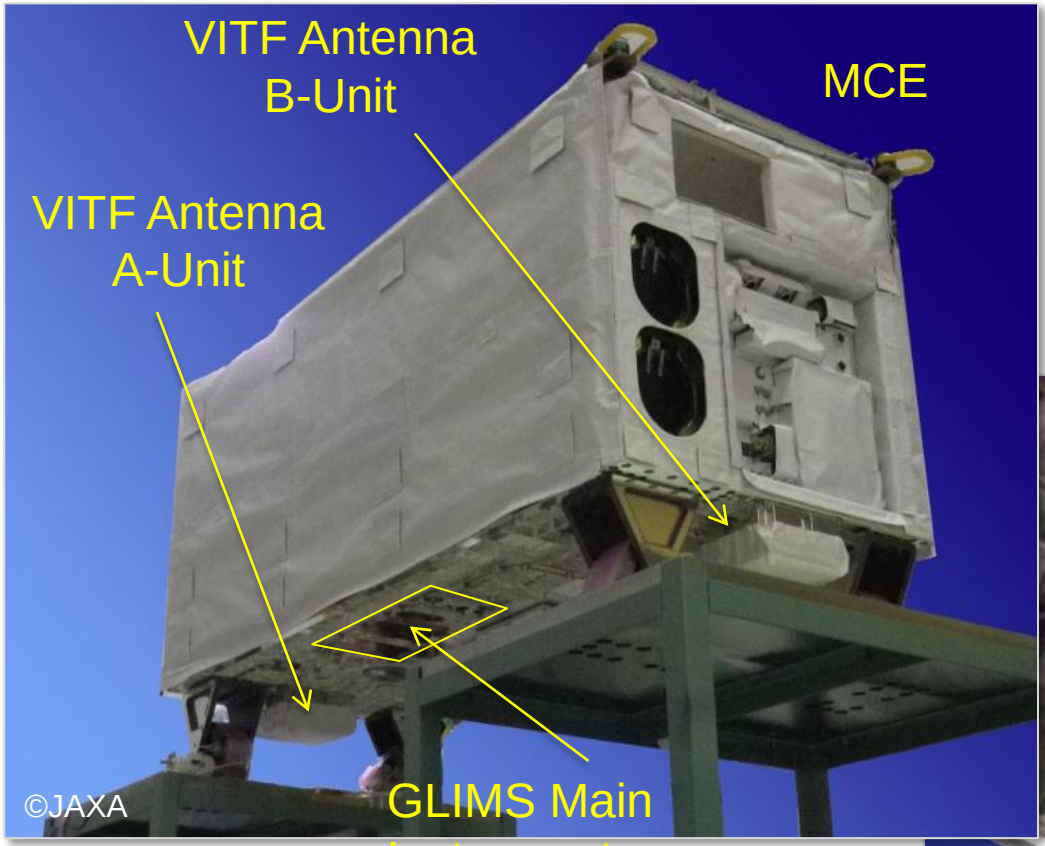


Fig. Picture of MCE flight model. This picture was taken just before the MCE was installed into HTV3 / H-IIB.

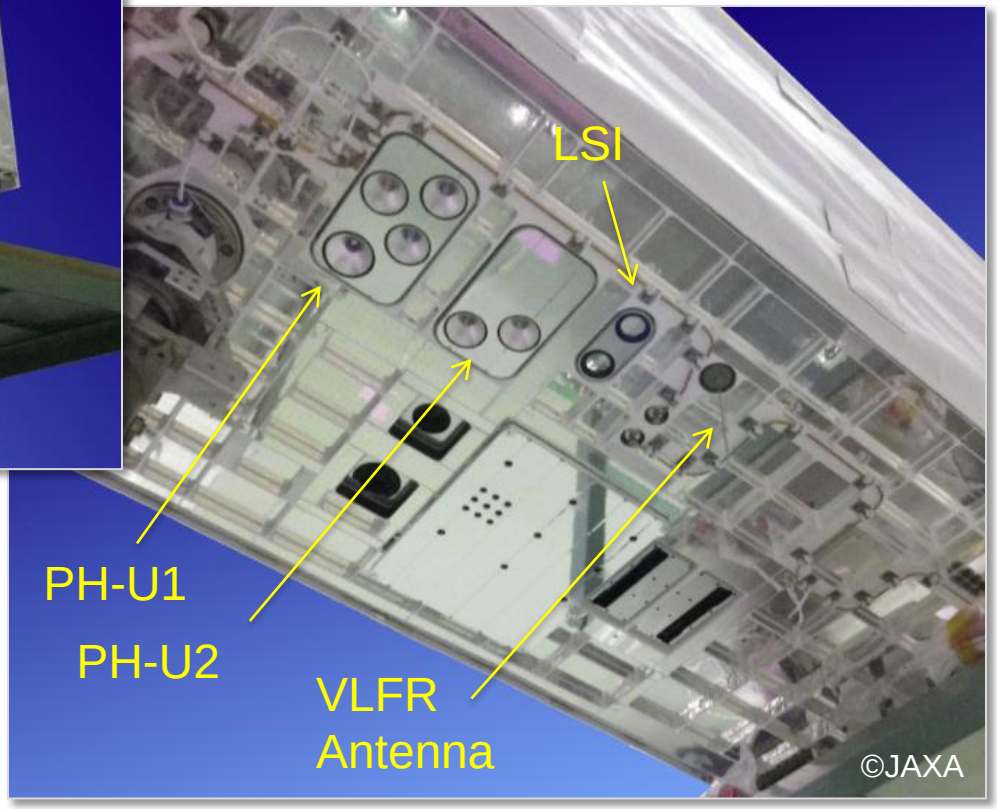
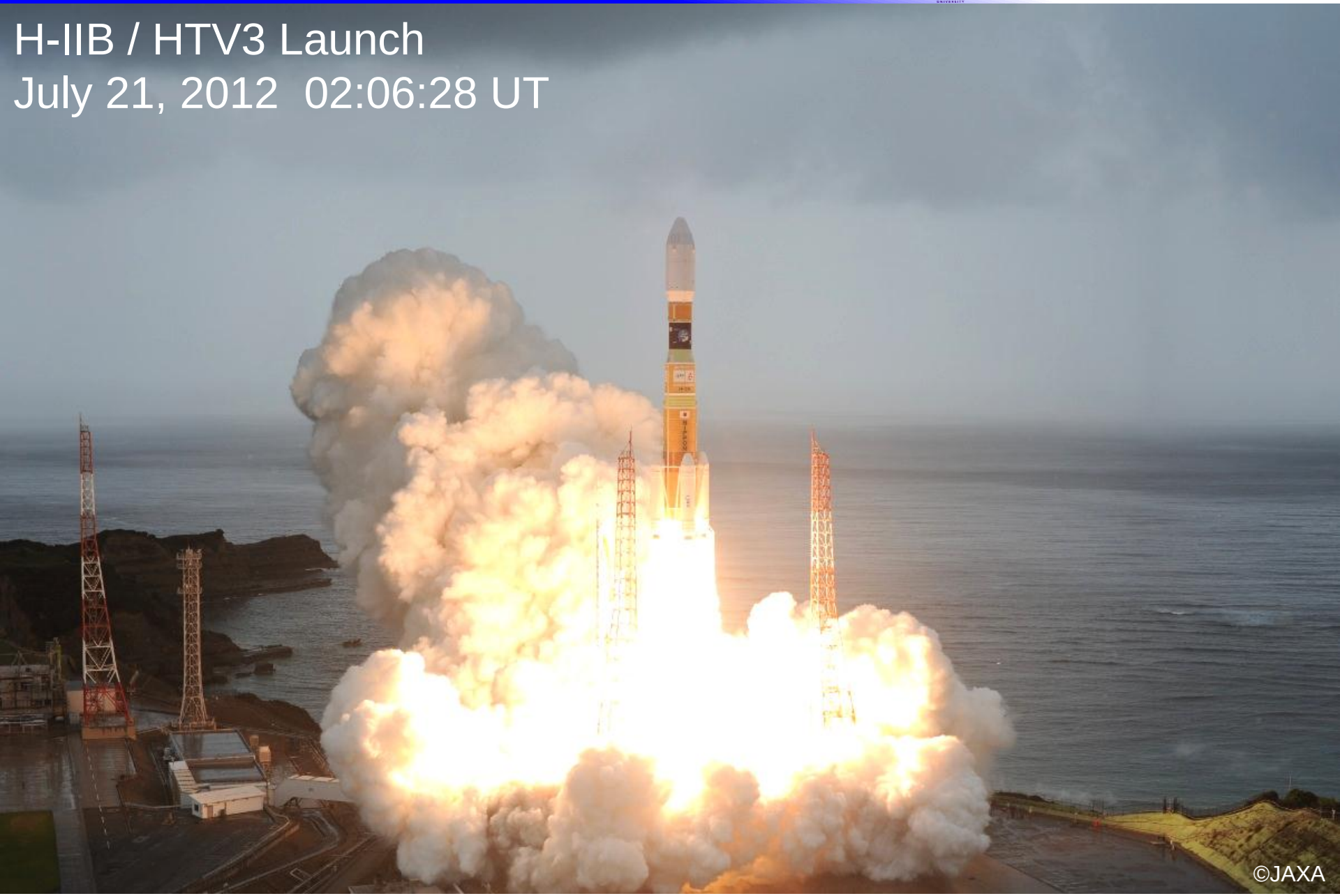


Fig. Picture of MCE base plane which would look nadir direction. LSI, PH, VLFR antenna, and VITF antennas were installed at this plane.

GLIMS 打上げ

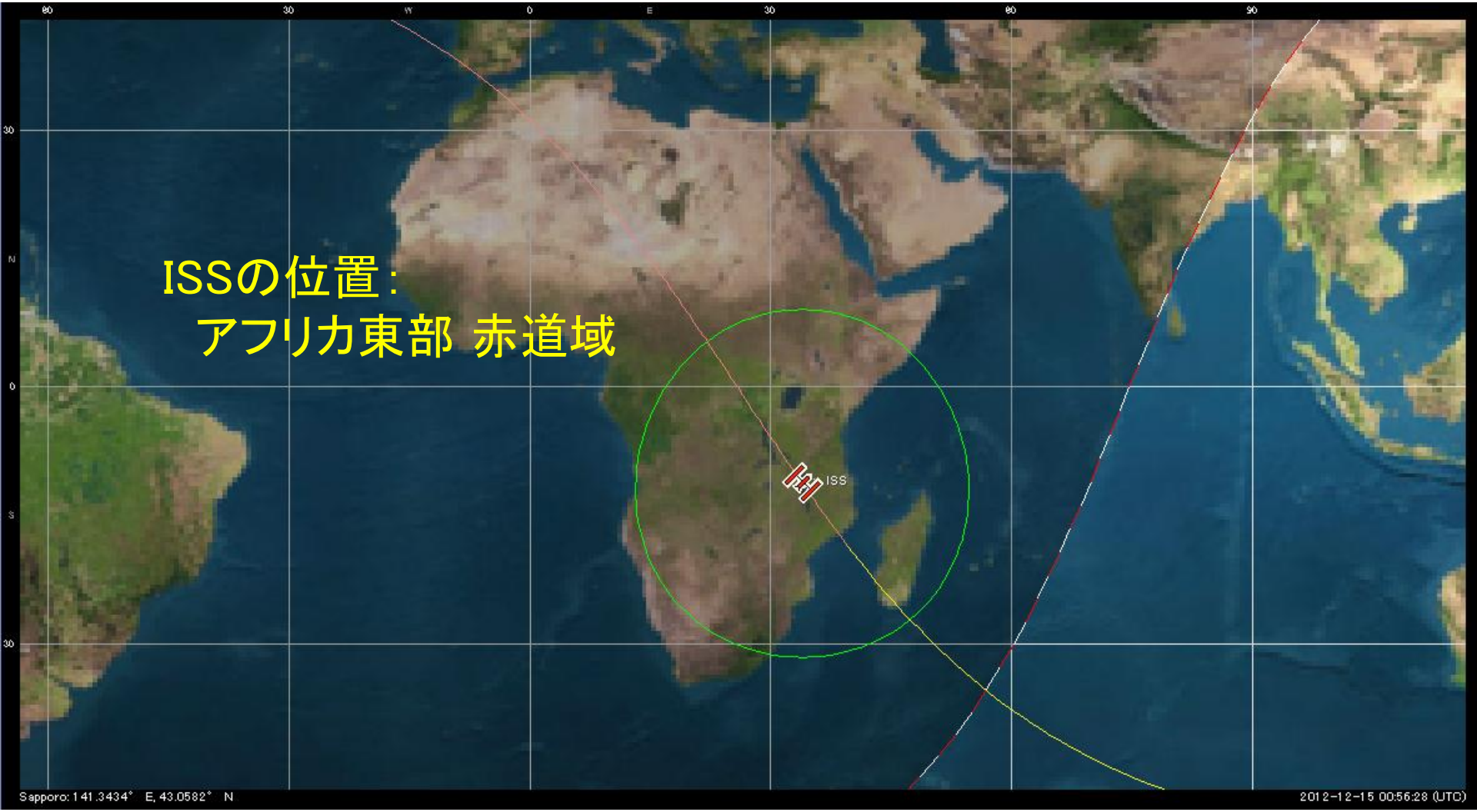
H-IIB / HTV3 Launch
July 21, 2012 02:06:28 UT



GLIMS取得データ例(1)

2012/12/15 00:56:28.198 UT

スプライト発生イベントの可能性



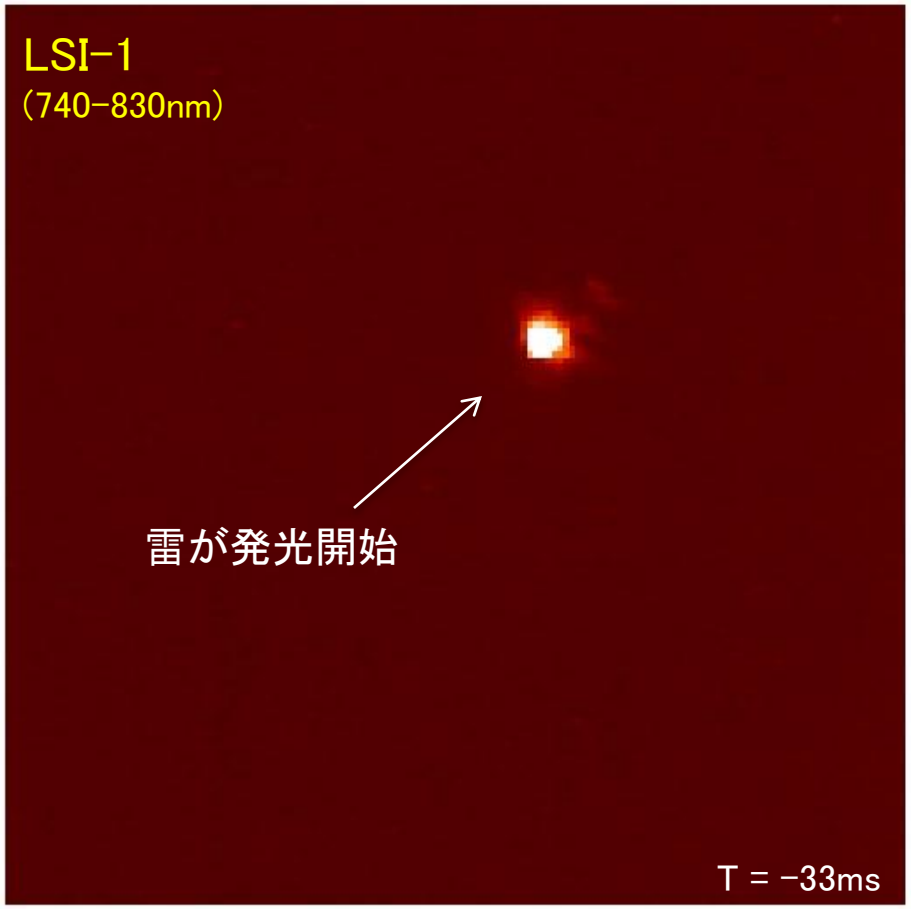
GLIMS取得データ例(1)

2012/12/15 00:56:28.198 UT

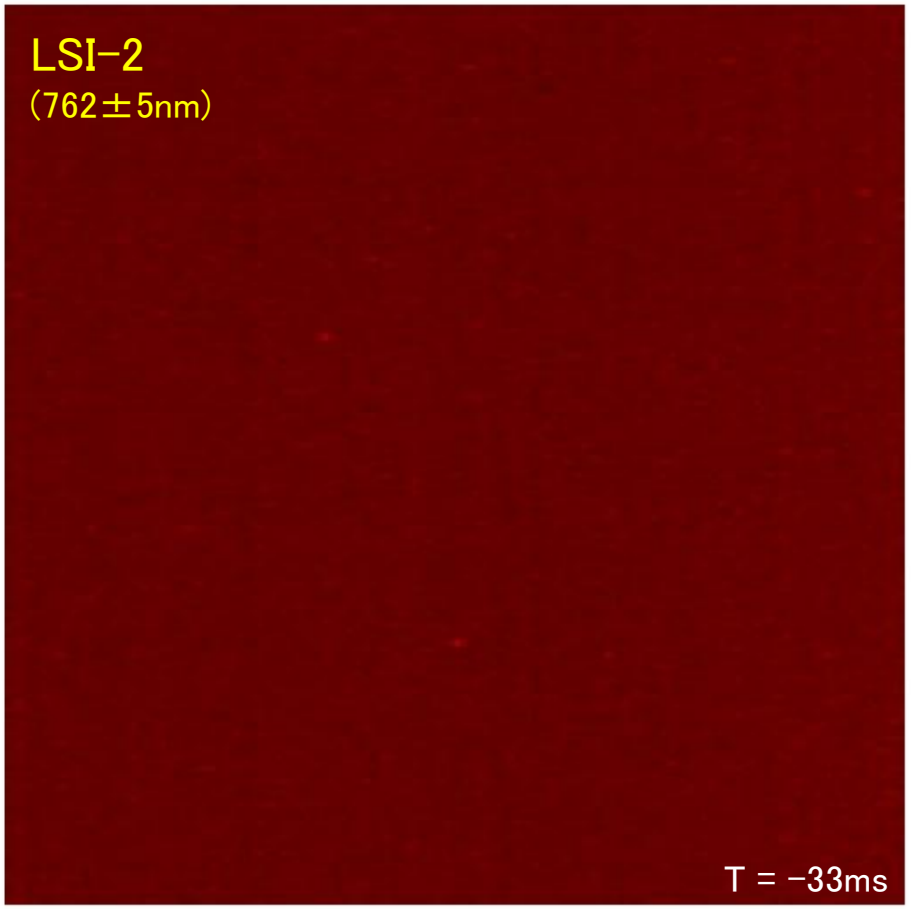
スプライト発生イベントの可能性

DATA FILE : /Volumes/GLIMS-HDD/GLIMS_TLM/2012/12/2012-12-17/2012-12-15_005628.19808/2012-12-15_005628.19808_00.BIN

LSI-1 Expanded Image (150 x 150 pixels)



LSI-2 Expanded Image (150 x 150 pixels)

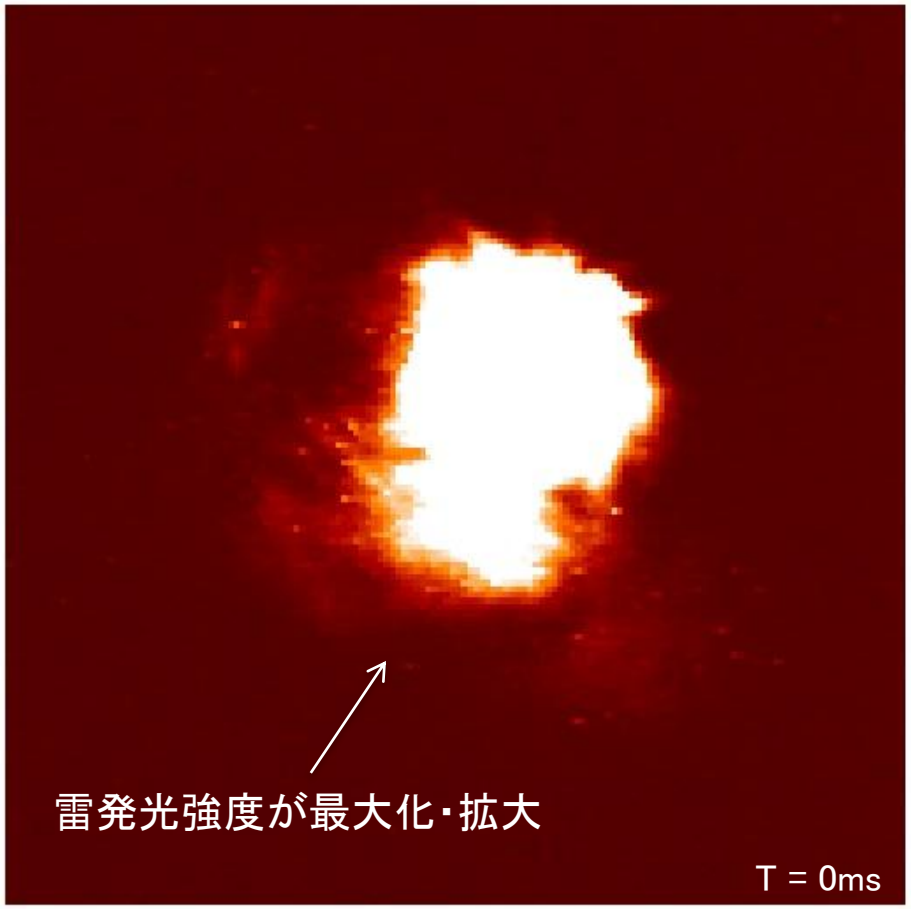


GLIMS取得データ例(1)

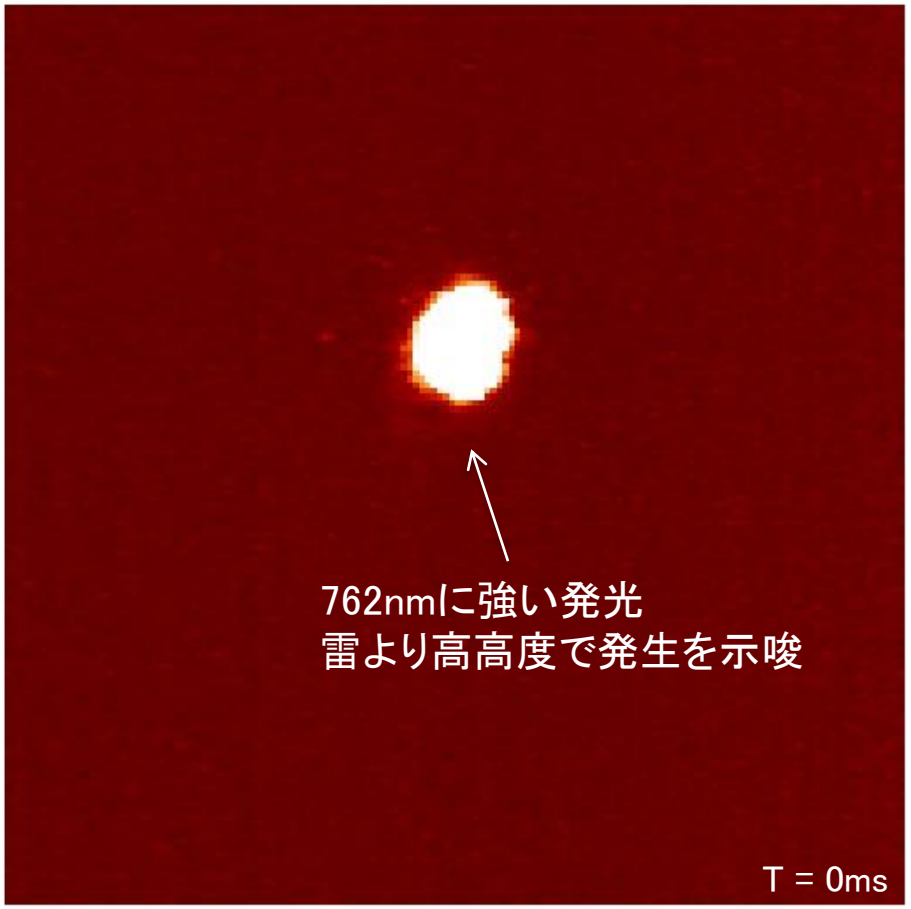
2012/12/15 00:56:28.198 UT

DATA FILE : /Volumes/GLIMS-HDD/GLIMS_TLM/2012/12/2012-12-17/2012-12-15_005628.19808/2012-12-15_005628.19808_01.BIN

LSI-1 Expanded Image (150 x 150 pixels)



LSI-2 Expanded Image (150 x 150 pixels)

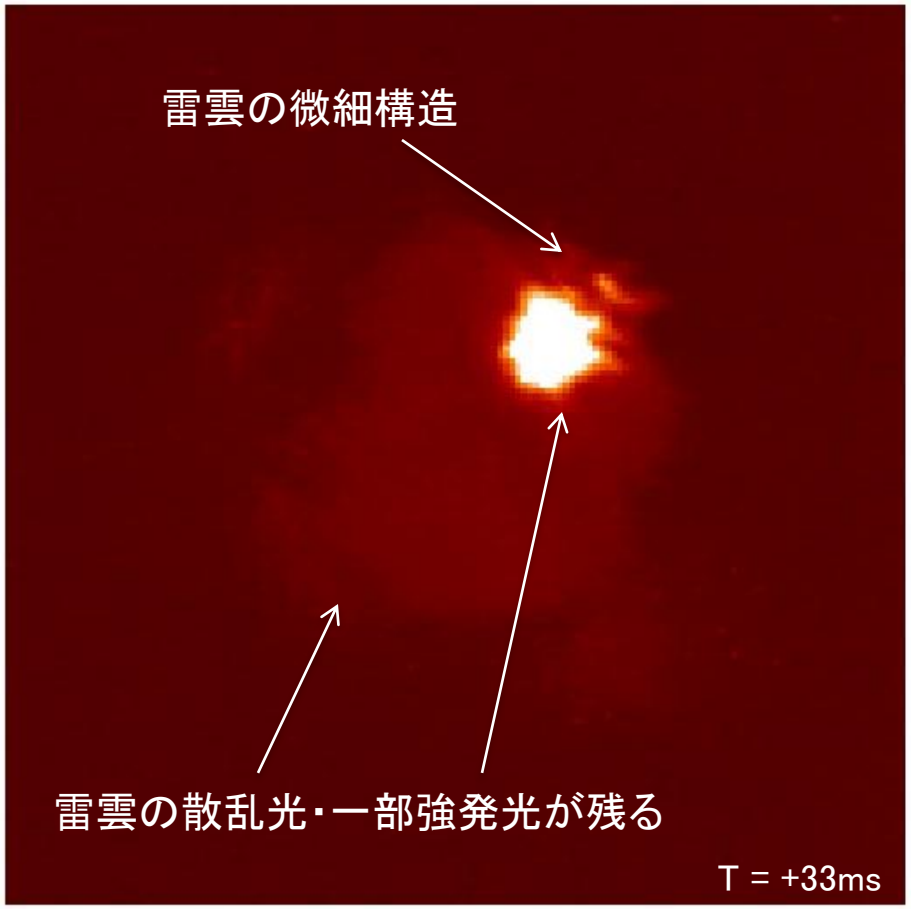


GLIMS取得データ例(1)

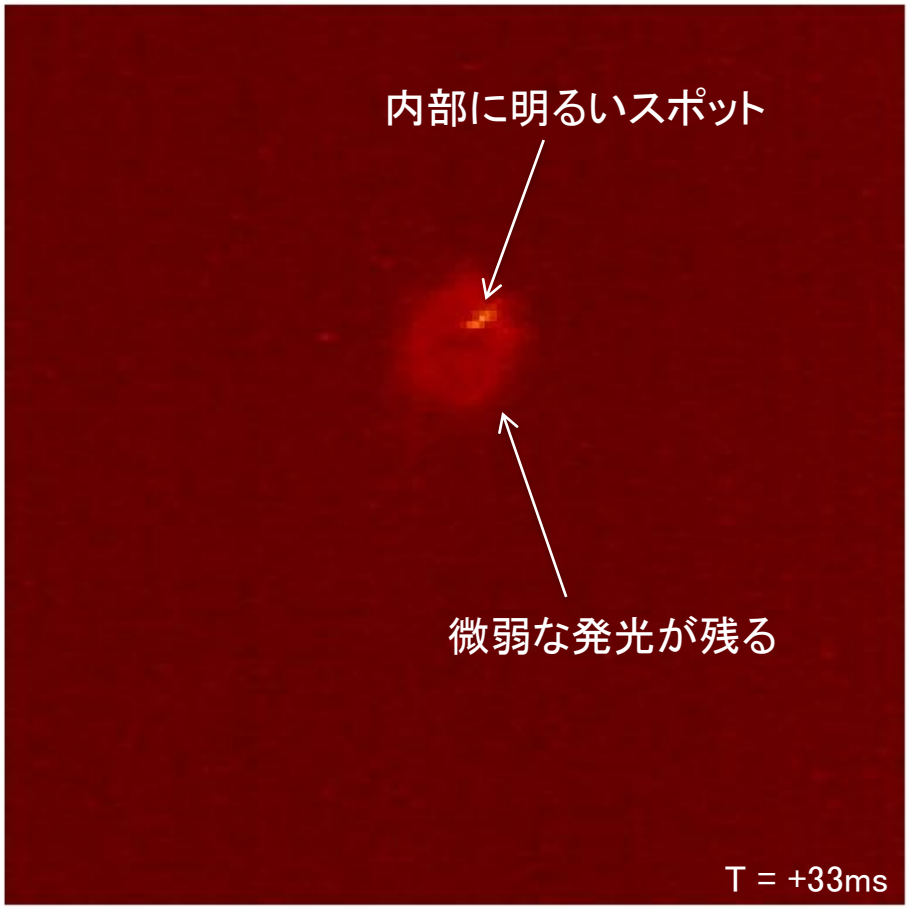
2012/12/15 00:56:28.198 UT

DATA FILE : /Volumes/GLIMS-HDD/GLIMS_TLM/2012/12/2012-12-17/2012-12-15_005628.19808/2012-12-15_005628.19808_02.BIN

LSI-1 Expanded Image (150 x 150 pixels)



LSI-2 Expanded Image (150 x 150 pixels)

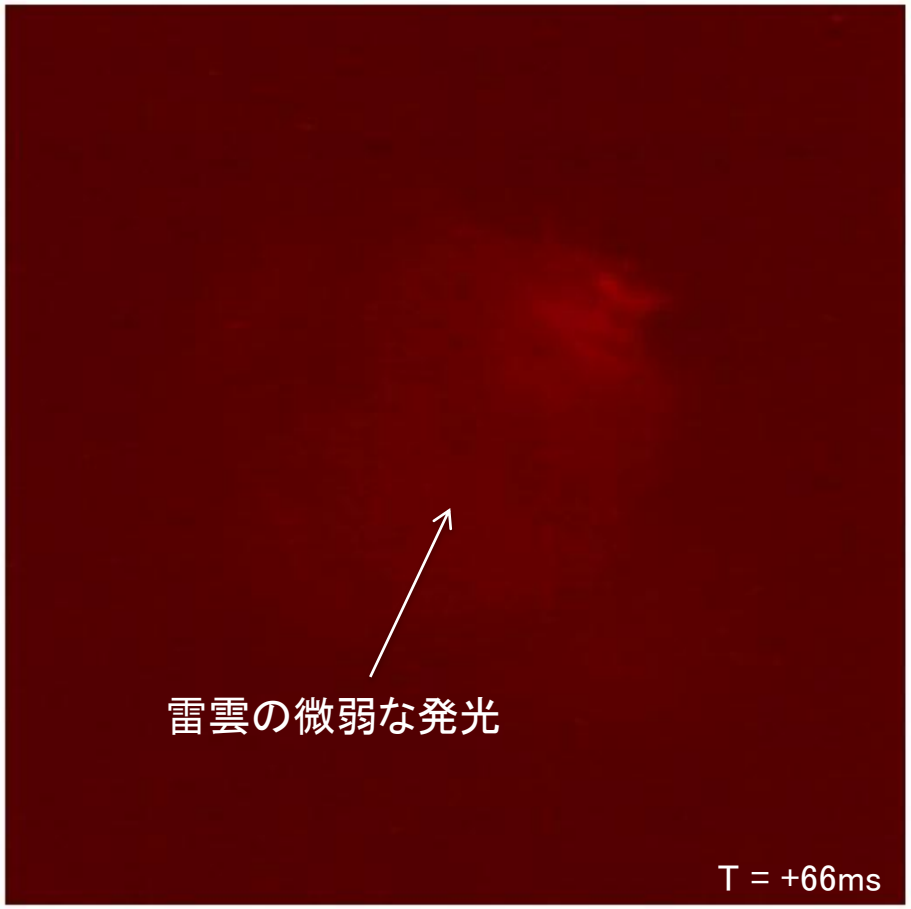


GLIMS取得データ例(1)

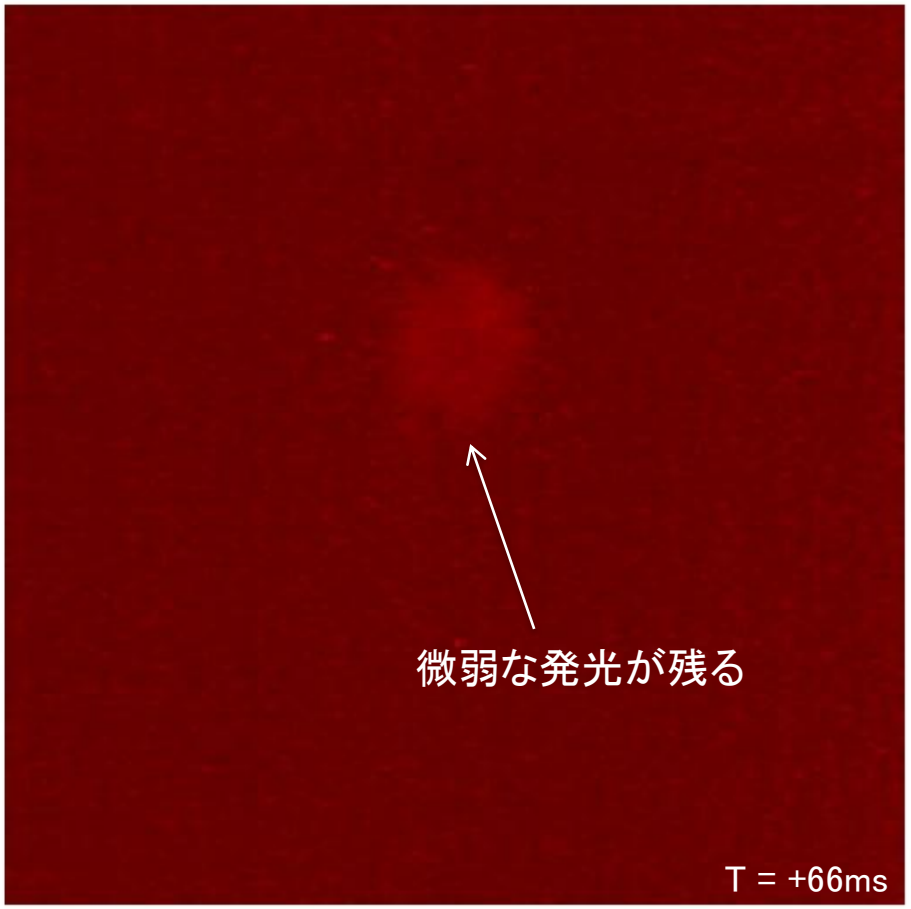
2012/12/15 00:56:28.198 UT

DATA FILE : /Volumes/GLIMS-HDD/GLIMS_TLM/2012/12/2012-12-17/2012-12-15_005628.19808/2012-12-15_005628.19808_03.BIN

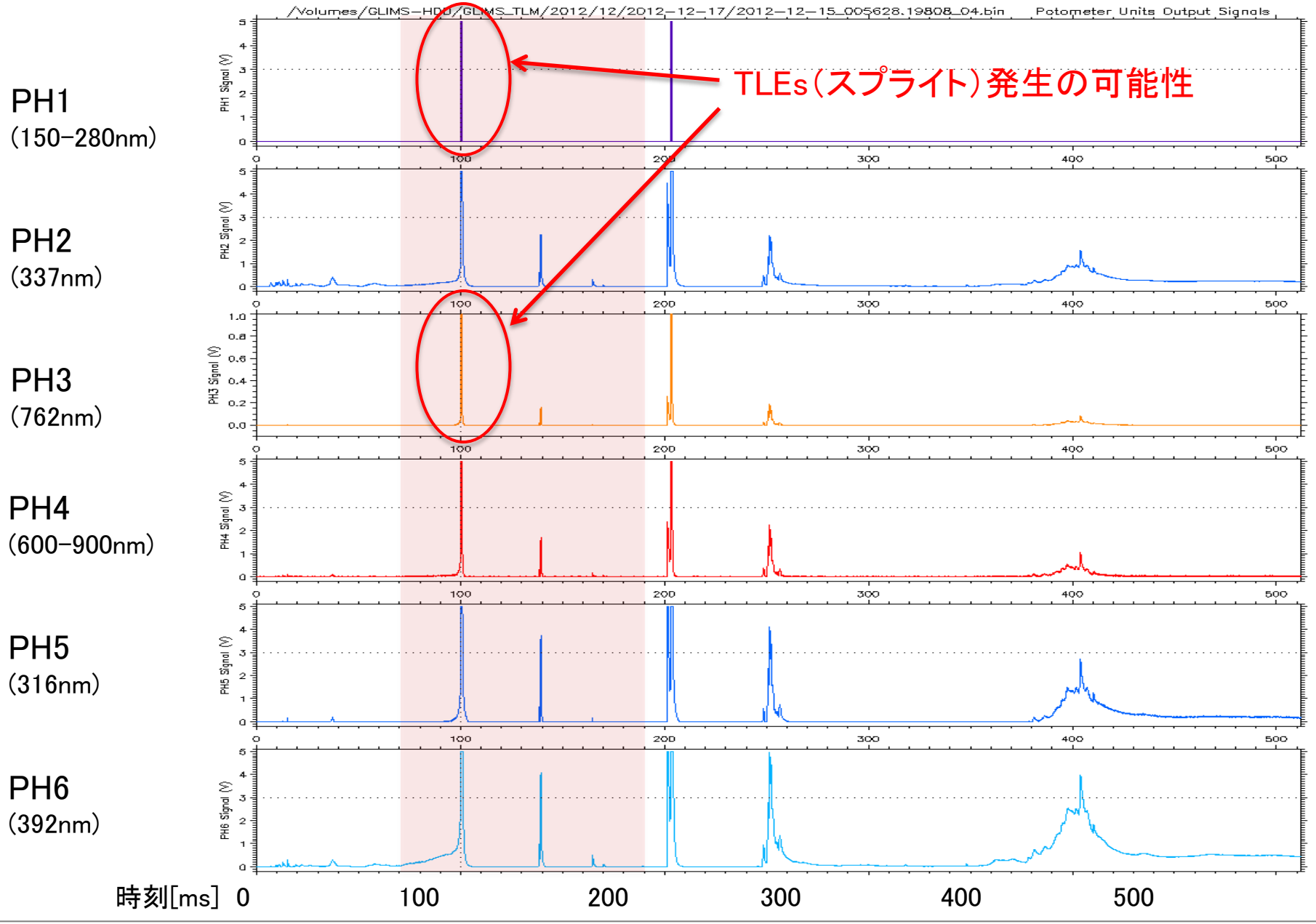
LSI-1 Expanded Image (150 x 150 pixels)



LSI-2 Expanded Image (150 x 150 pixels)



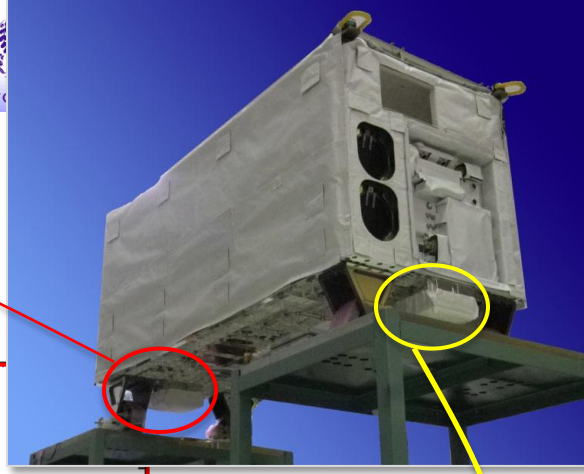
GLIMS取得データ例(1)

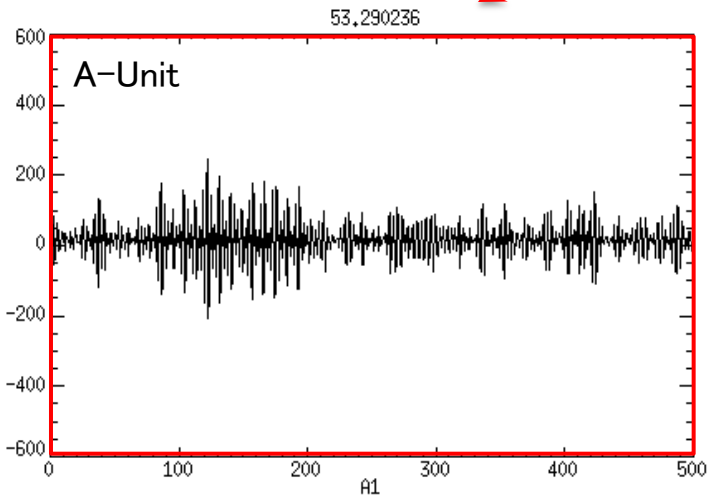


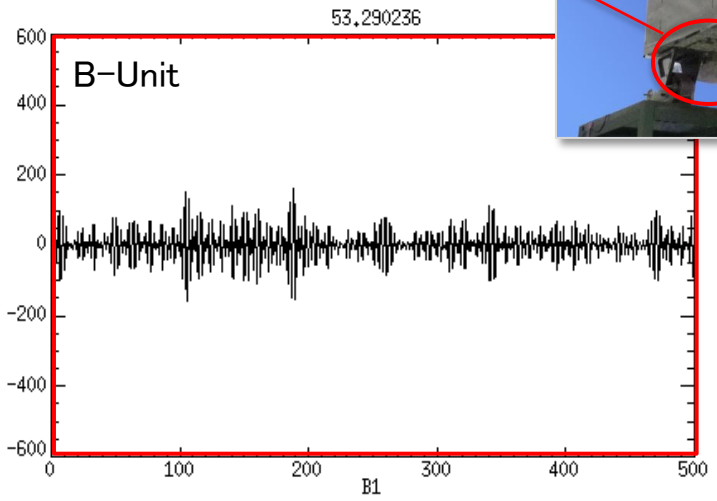
GLIMS取得データ例(1)

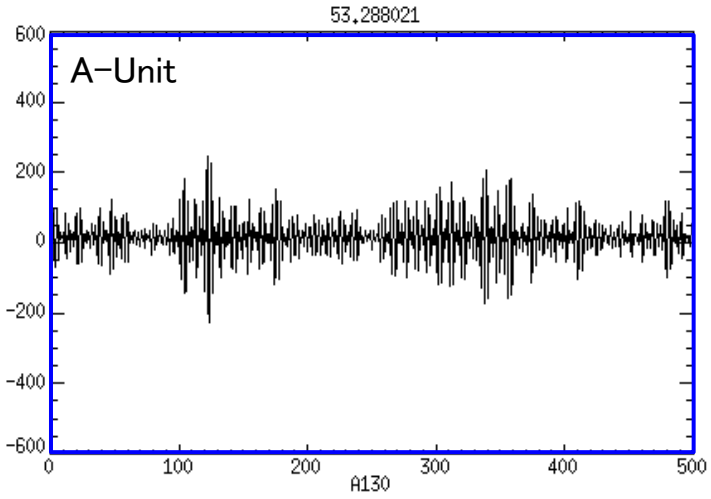
2012/12/15 00:56:28.198 UT

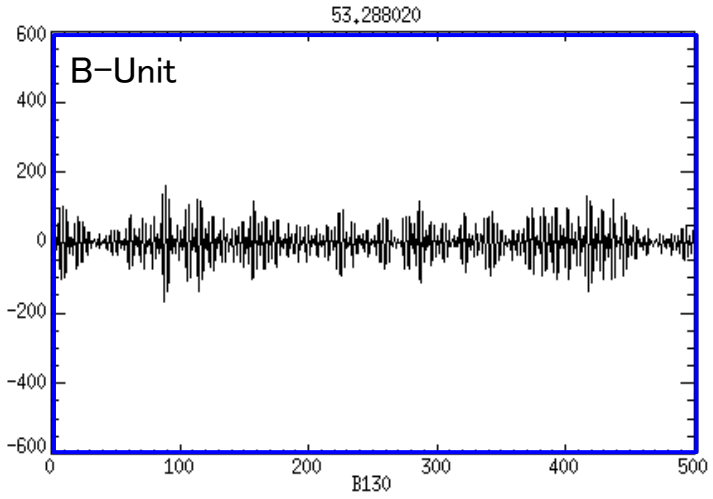
VITF波形データ







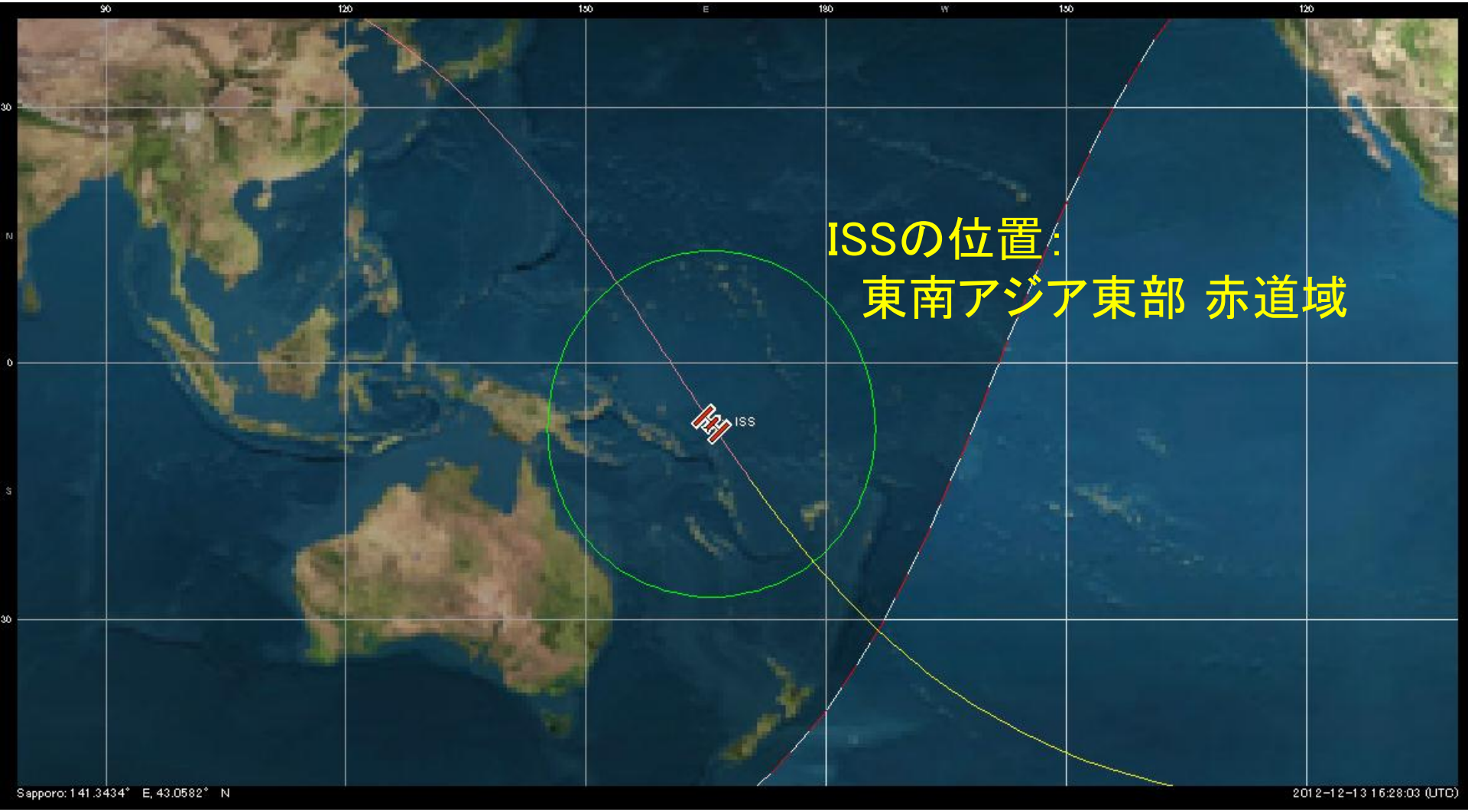




GLIMS取得データ例(2)

2012/12/13 16:28:03.874 UT

スプライト発生イベントの可能性



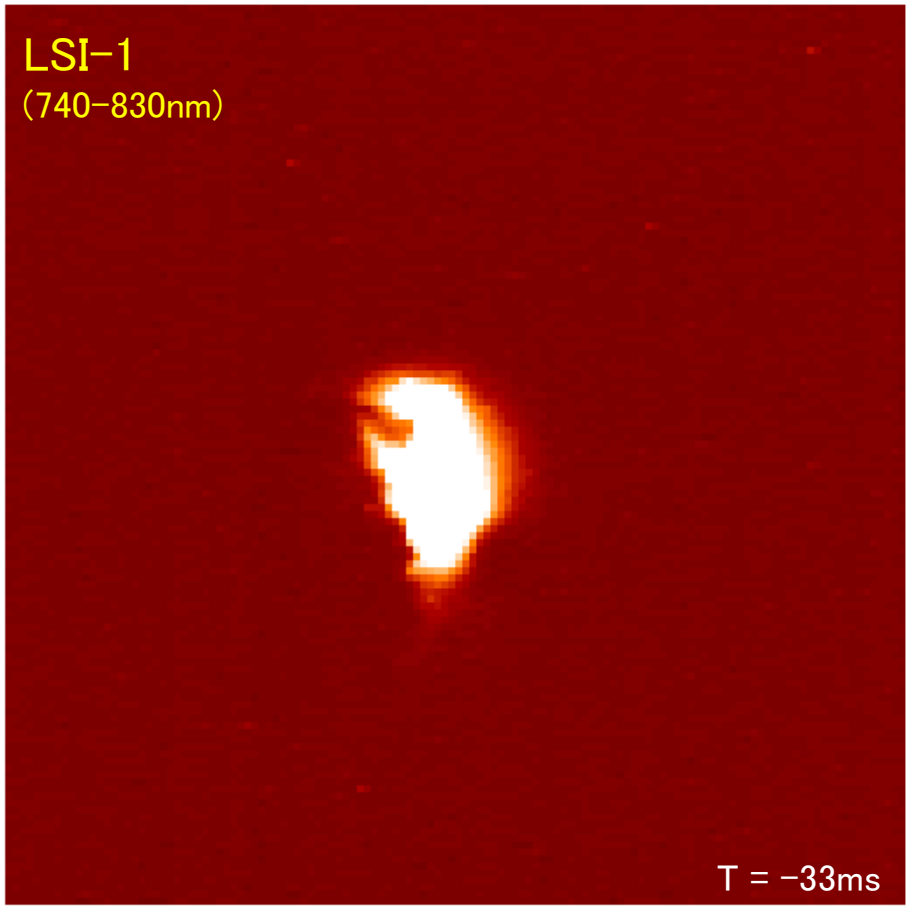
GLIMS取得データ例(2)

2012/12/13 16:28:03.874 UT

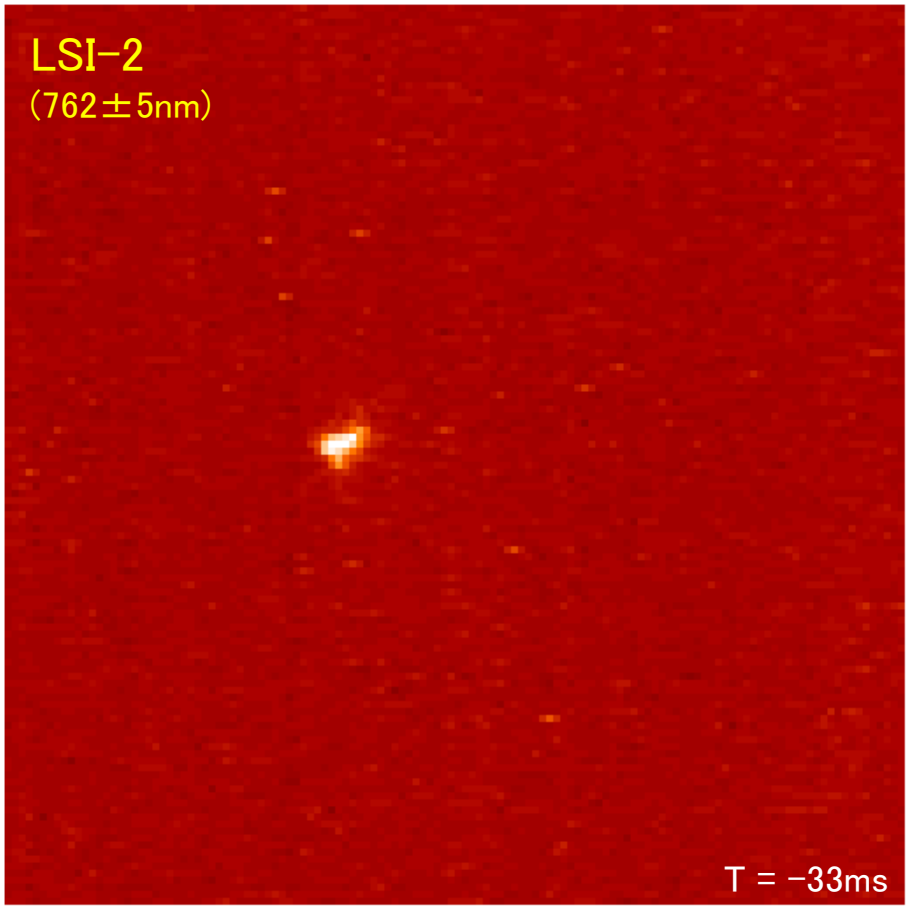
スプライト発生イベントの可能性

DATA FILE : /Volumes/GLIMS-HDD/GLIMS_TLM/2012/12/2012-12-13/2012-12-13_162803.87397/2012-12-13_162803.87397_00.BIN

LSI-1 Expanded Image (128 x 128 pixels)



LSI-2 Expanded Image (128 x 128 pixels)

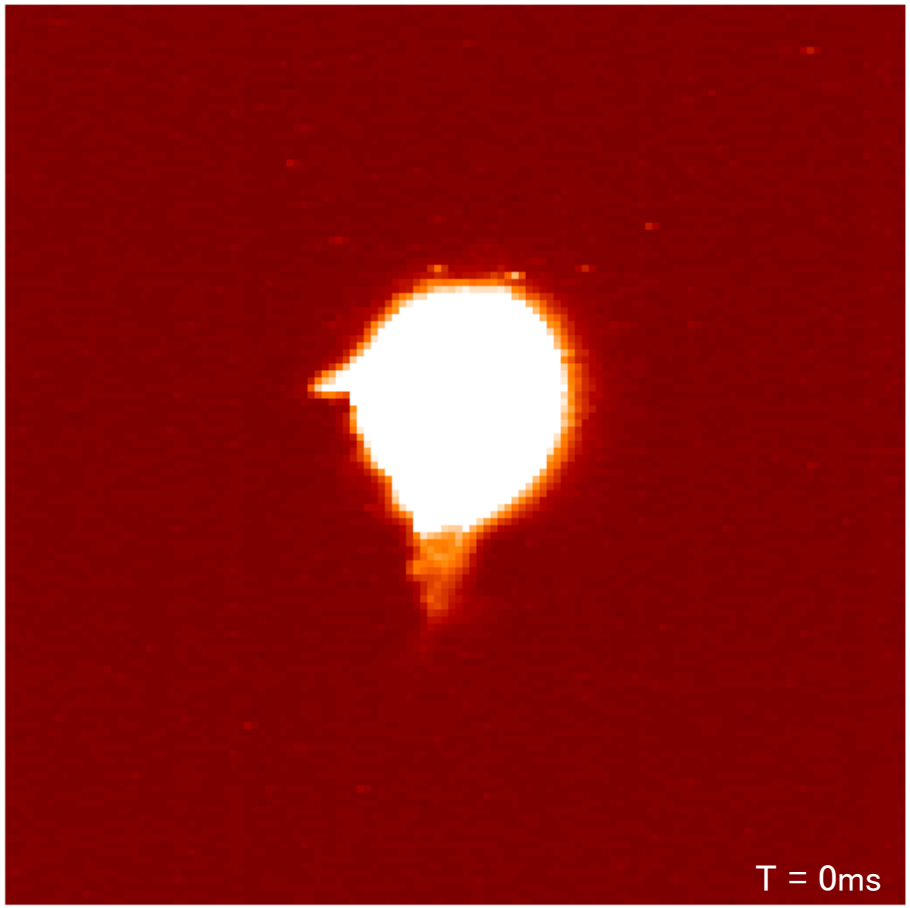


GLIMS取得データ例(2)

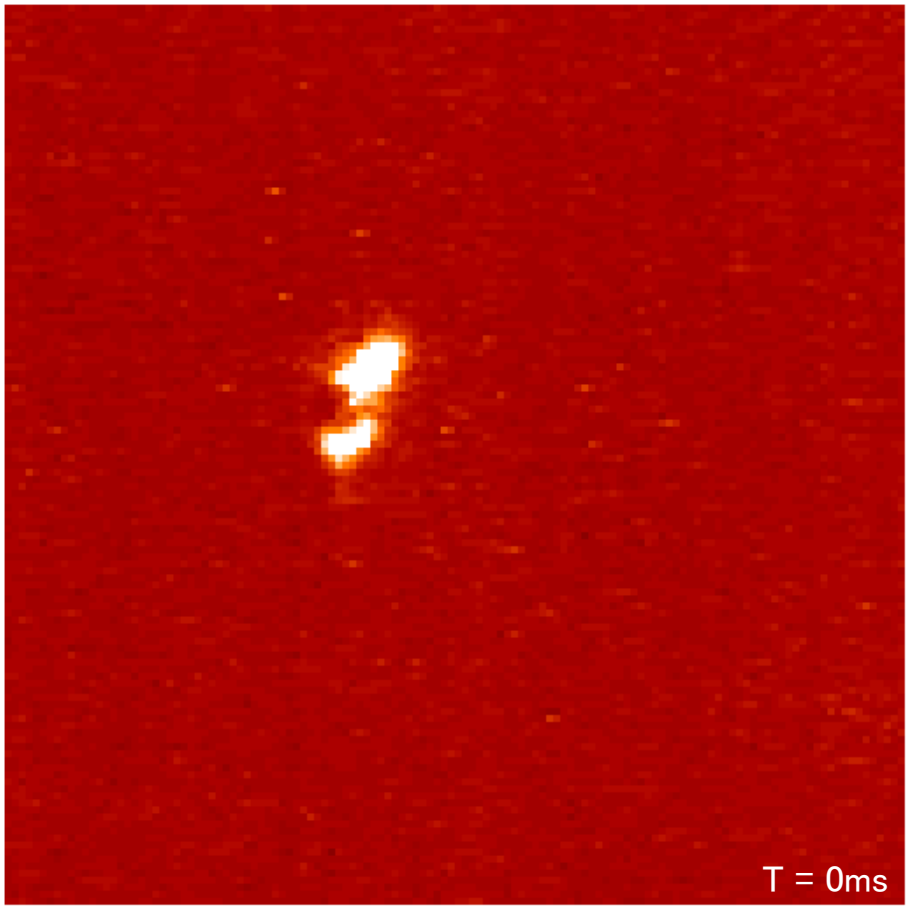
2012/12/13 16:28:03.874 UT

DATA FILE : /Volumes/GLIMS-HDD/GLIMS_TLM/2012/12/2012-12-13/2012-12-13_162803.87397/2012-12-13_162803.87397_01.BIN

LSI-1 Expanded Image (128 x 128 pixels)



LSI-2 Expanded Image (128 x 128 pixels)

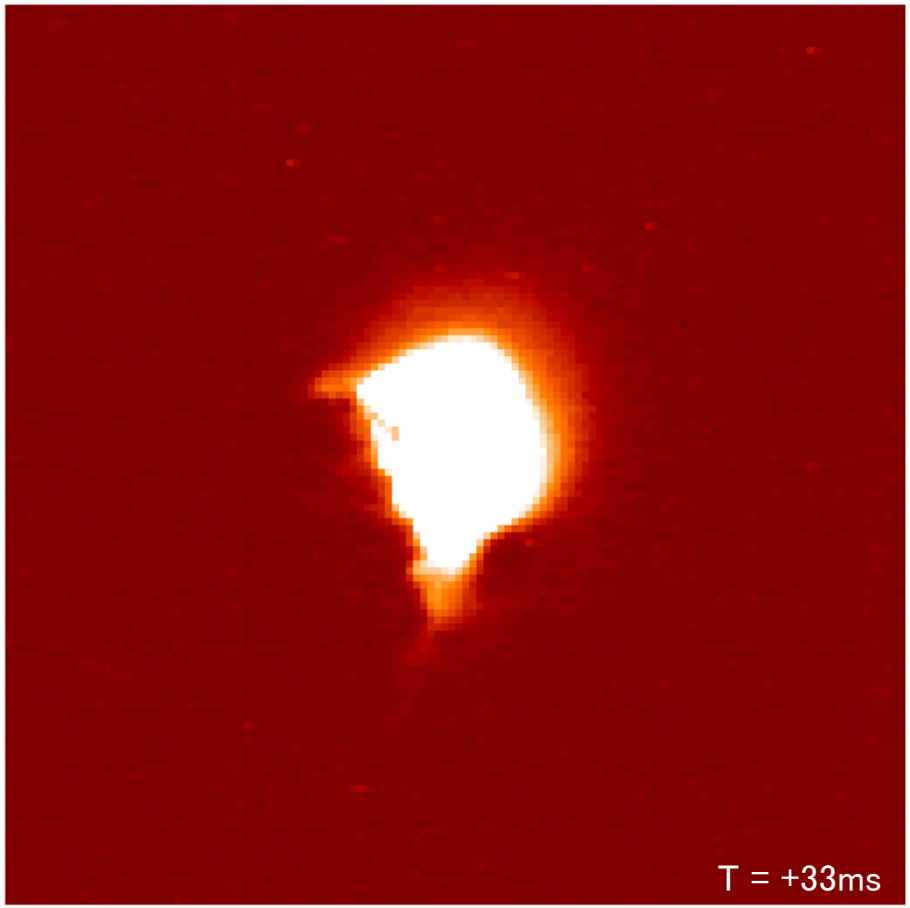


GLIMS取得データ例(2)

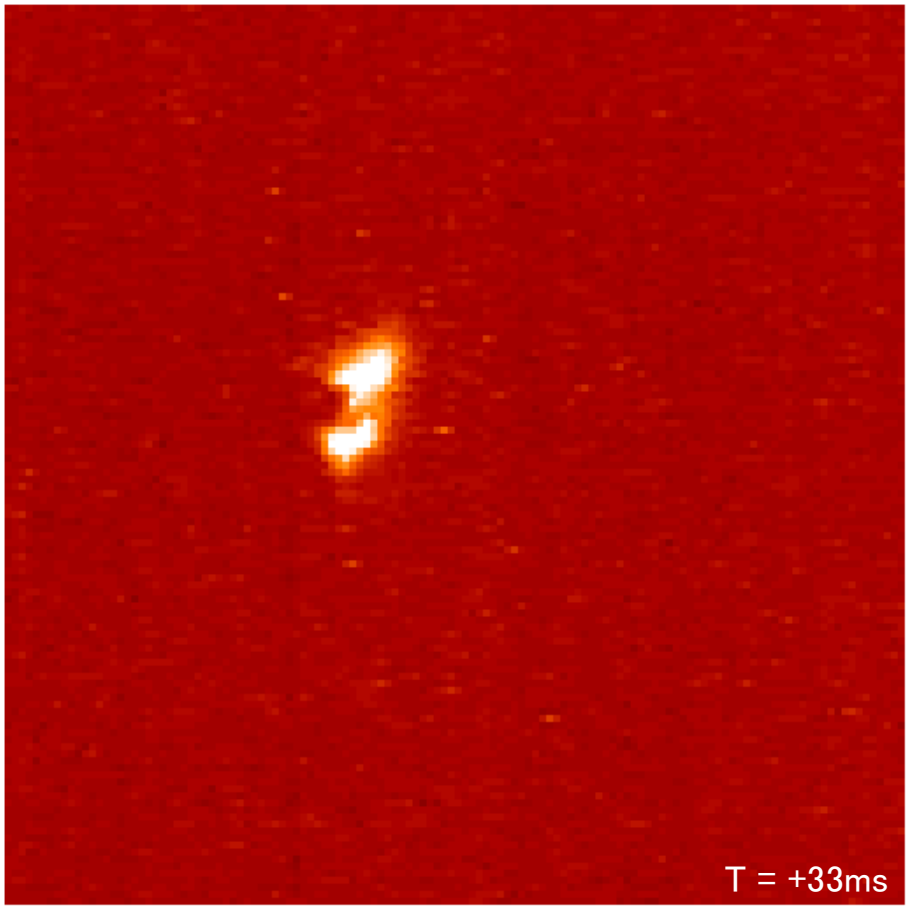
2012/12/13 16:28:03.874 UT

DATA FILE : /Volumes/GLIMS-HDD/GLIMS_TLM/2012/12/2012-12-13/2012-12-13_162803.87397/2012-12-13_162803.87397_02.BIN

LSI-1 Expanded Image (128 x 128 pixels)



LSI-2 Expanded Image (128 x 128 pixels)

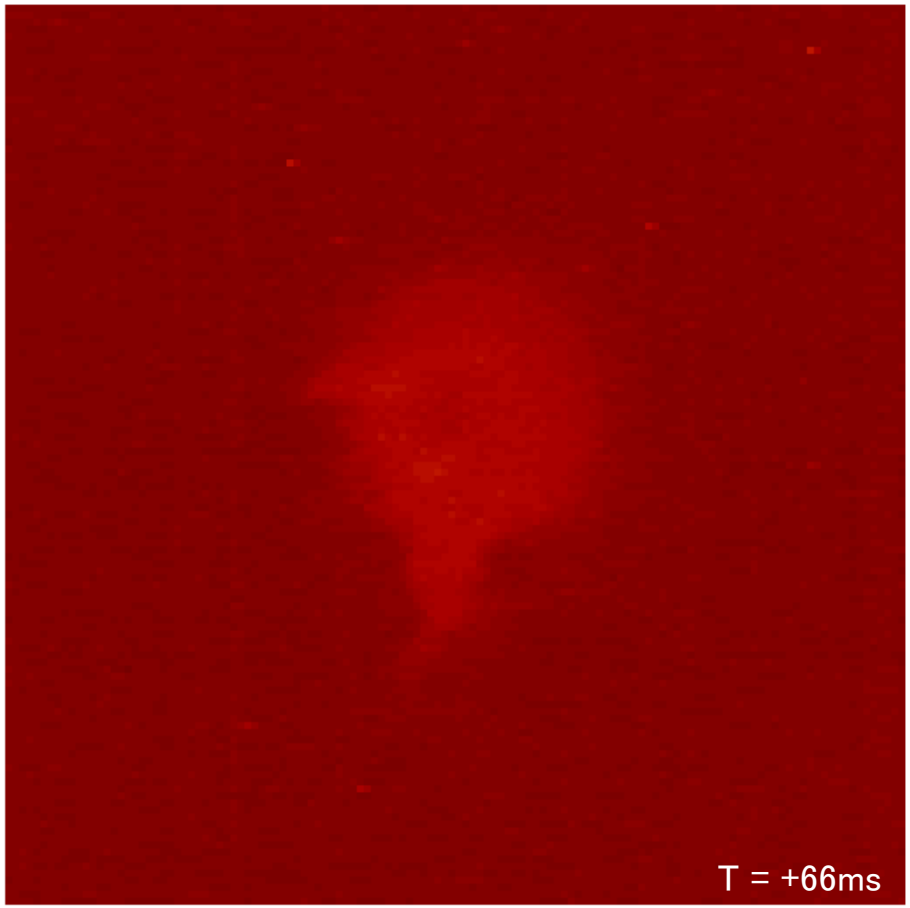


GLIMS取得データ例(2)

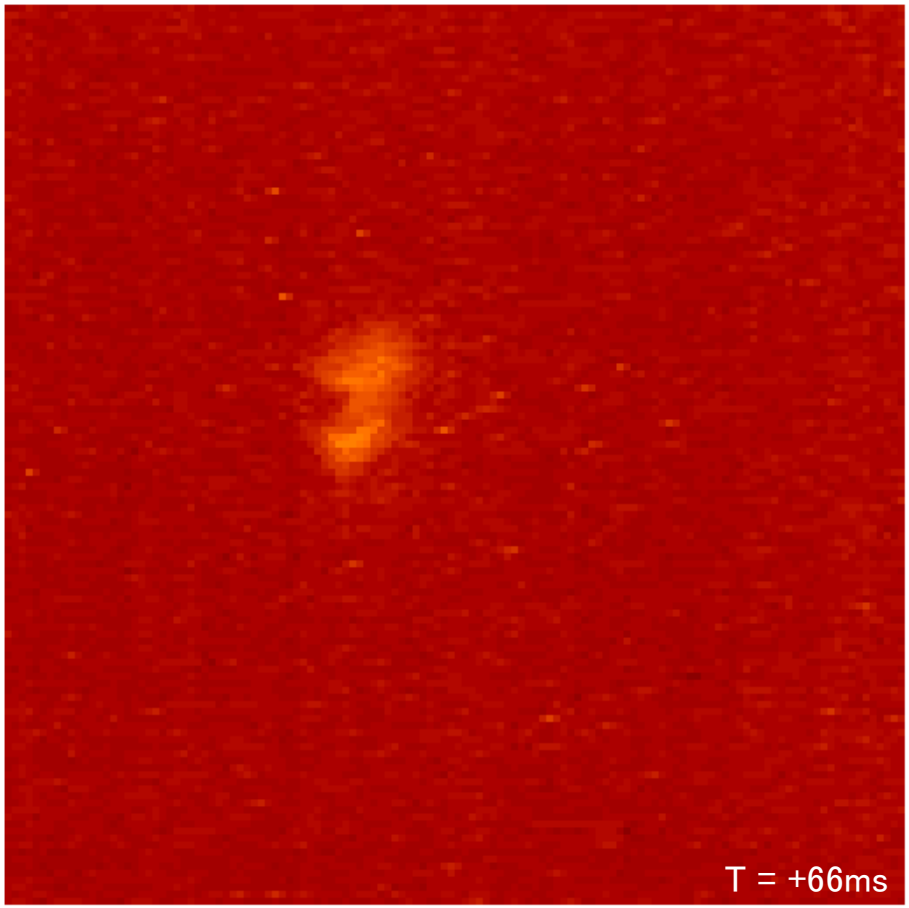
2012/12/13 16:28:03.874 UT

DATA FILE : /Volumes/GLIMS-HDD/GLIMS_TLM/2012/12/2012-12-13/2012-12-13_162803.87397/2012-12-13_162803.87397_03.BIN

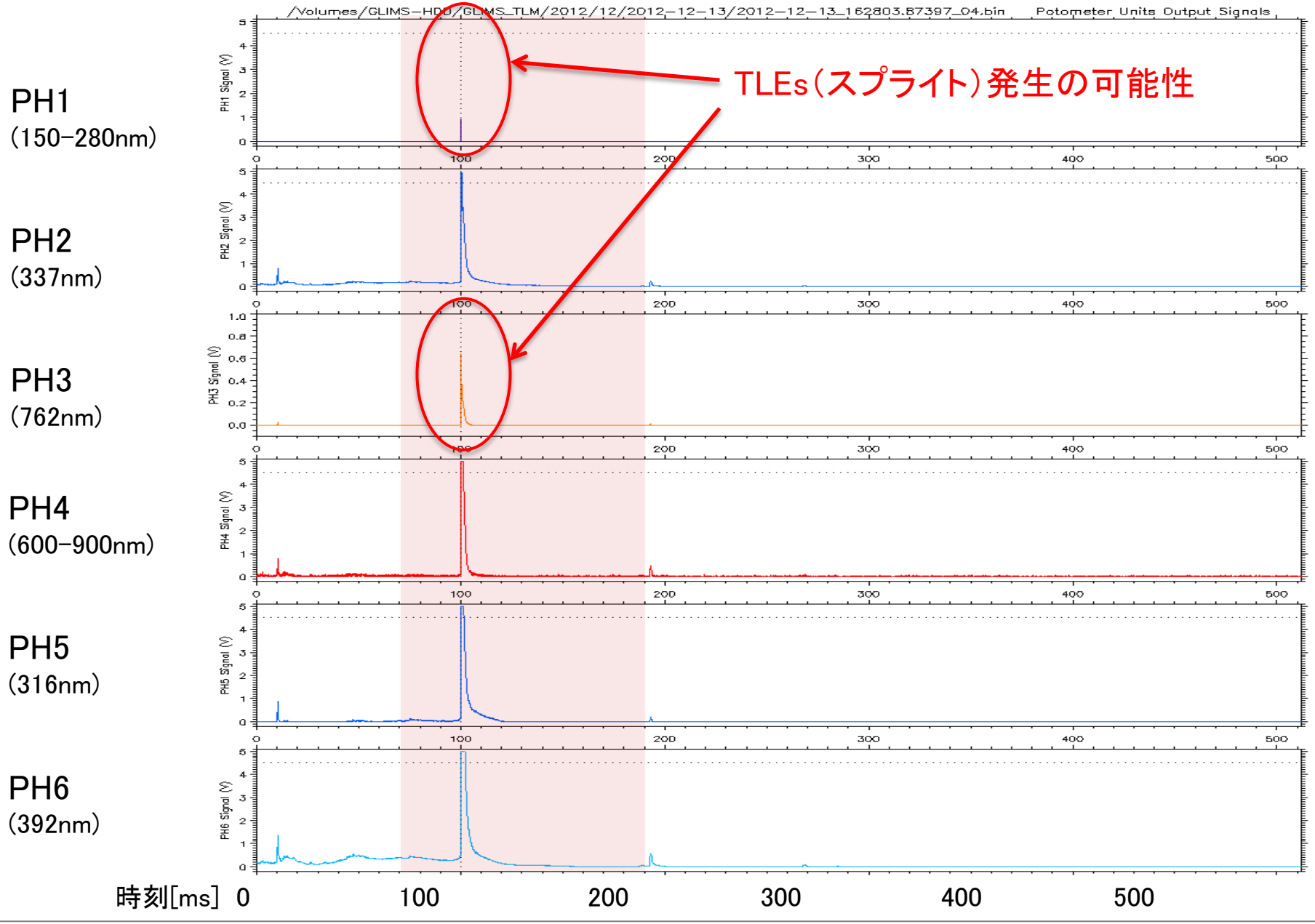
LSI-1 Expanded Image (128 x 128 pixels)



LSI-2 Expanded Image (128 x 128 pixels)



GLIMS取得データ例(2)



GLIMS取得データ例(3)

2012/12/14 18:44:11.469 UT

雷発光イベント

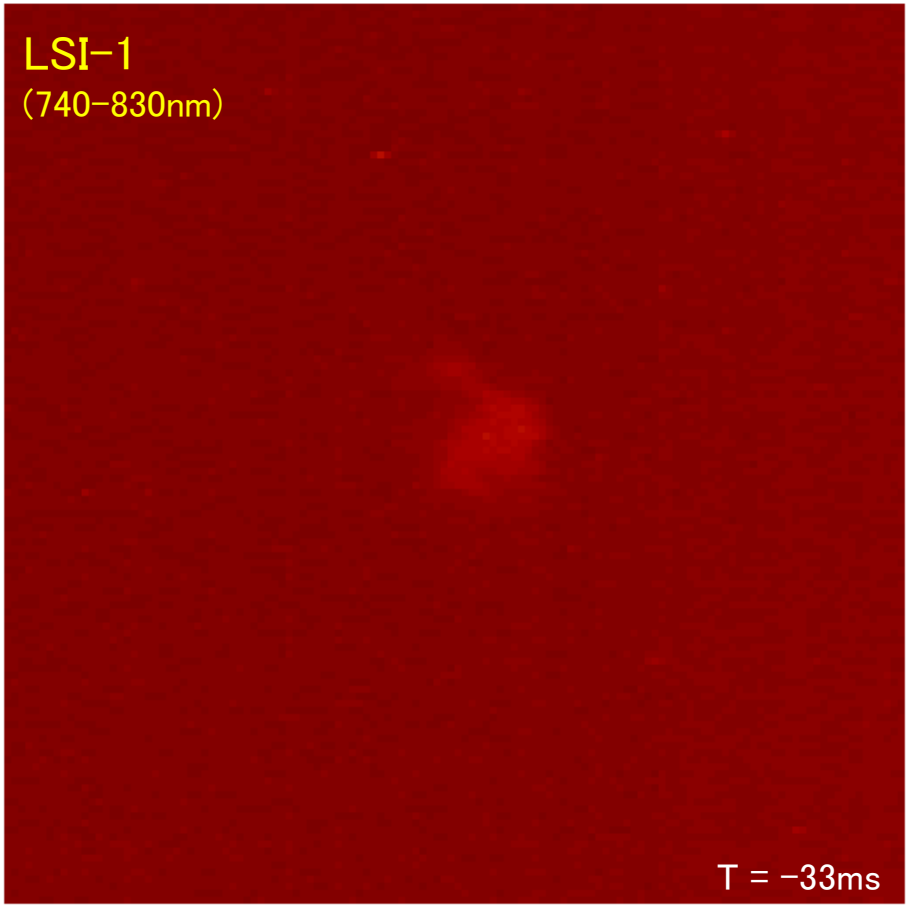
GLIMS取得データ例(3)

2012/12/14 18:44:11.469 UT

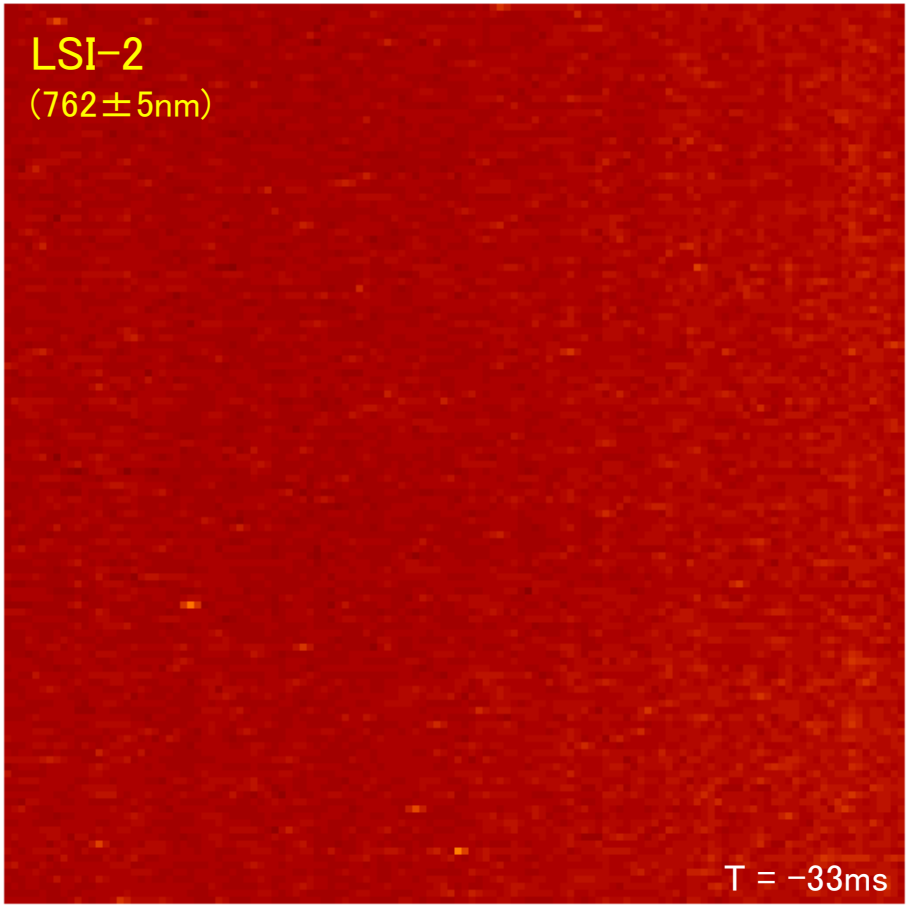
雷発光イベント

DATA FILE : /Volumes/GLIMS-HDD/GLIMS_TLM/2012/12/2012-12-15/2012-12-14_184411.46858/2012-12-14_184411.46858_00.BIN

LSI-1 Expanded Image (128 x 128 pixels)



LSI-2 Expanded Image (128 x 128 pixels)

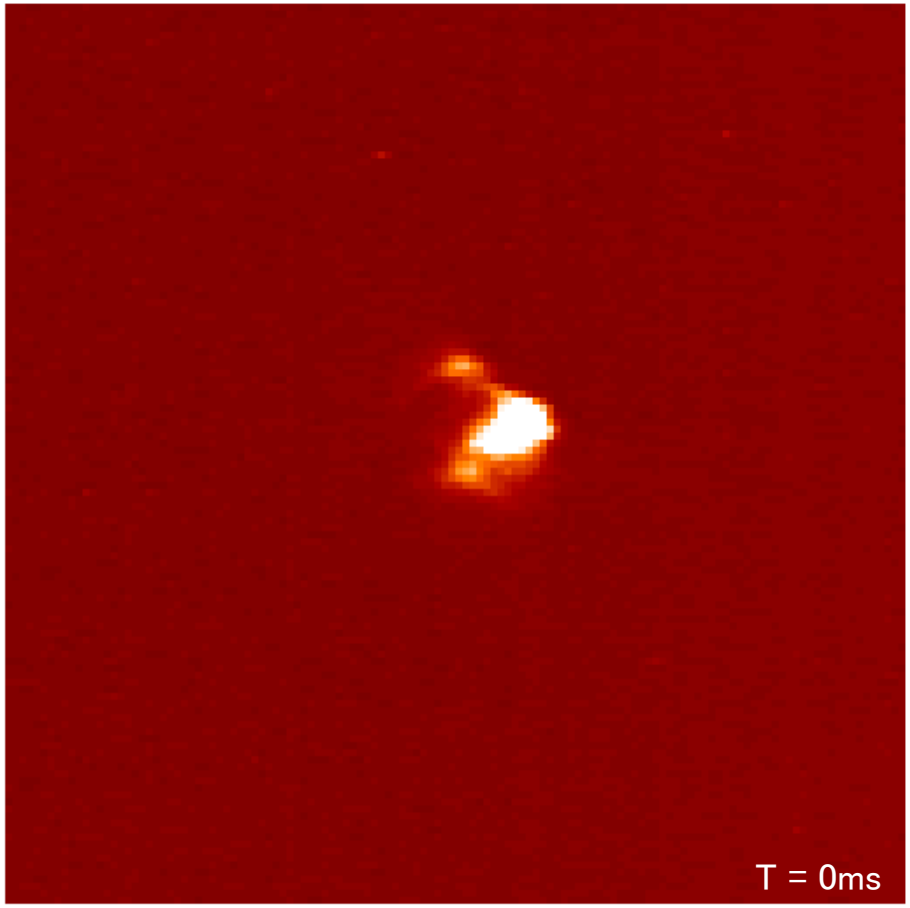


GLIMS取得データ例(3)

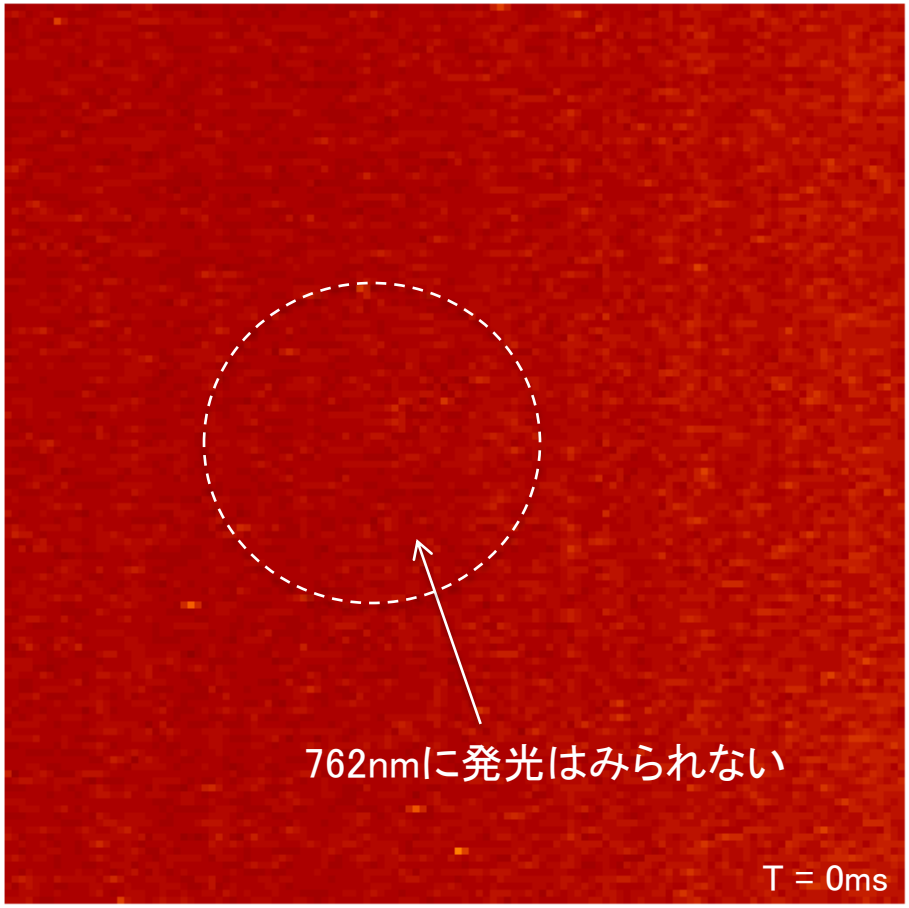
2012/12/14 18:44:11.469 UT

DATA FILE : /Volumes/GLIMS-HDD/GLIMS_TLM/2012/12/2012-12-15/2012-12-14_184411.46858/2012-12-14_184411.46858_01.BIN

LSI-1 Expanded Image (128 x 128 pixels)



LSI-2 Expanded Image (128 x 128 pixels)

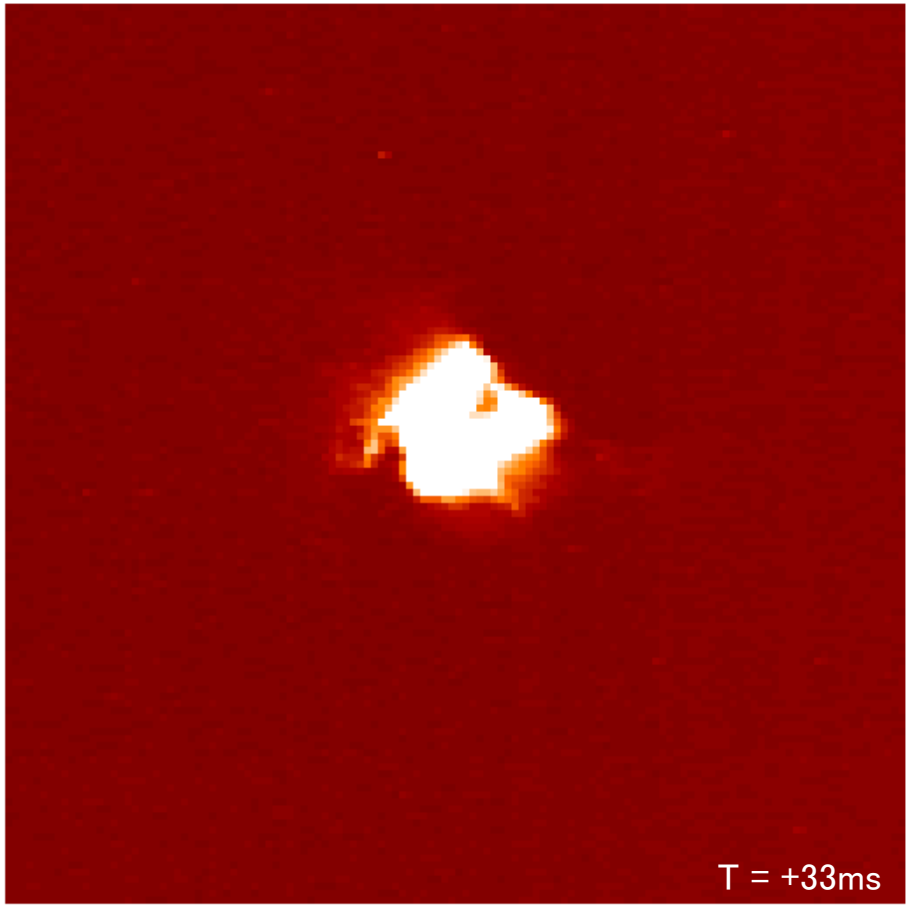


GLIMS取得データ例(3)

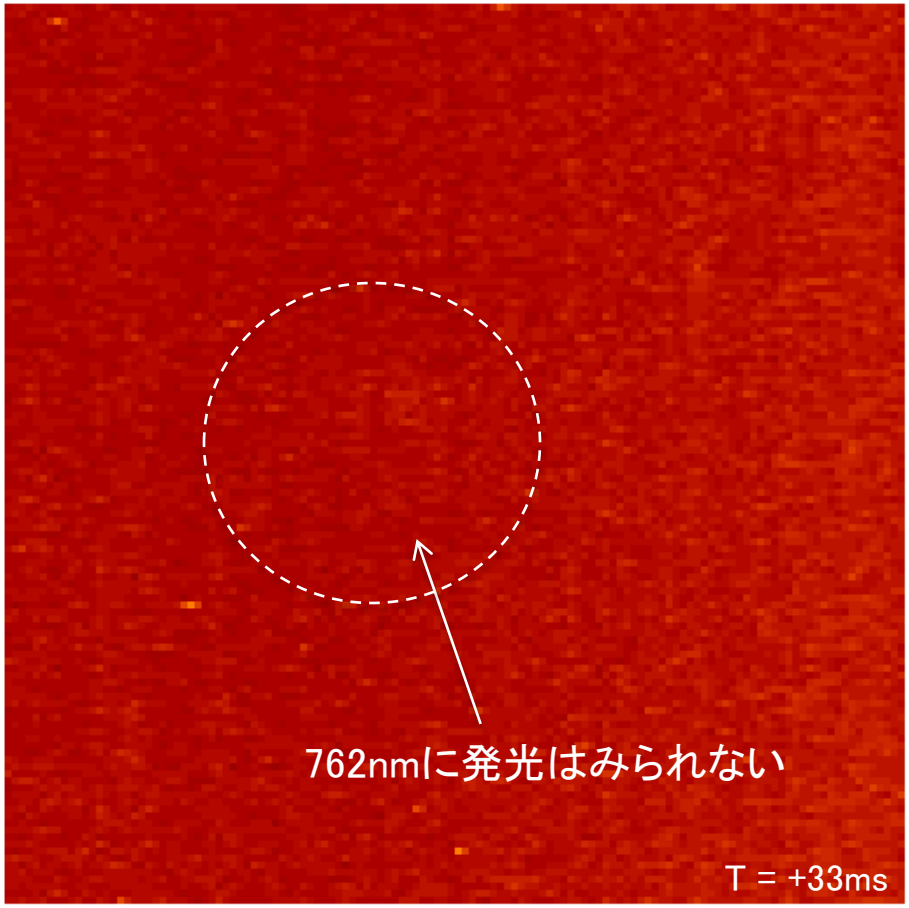
2012/12/14 18:44:11.469 UT

DATA FILE : /Volumes/GLIMS-HDD/GLIMS_TLM/2012/12/2012-12-15/2012-12-14_184411.46858/2012-12-14_184411.46858_02.BIN

LSI-1 Expanded Image (128 x 128 pixels)



LSI-2 Expanded Image (128 x 128 pixels)

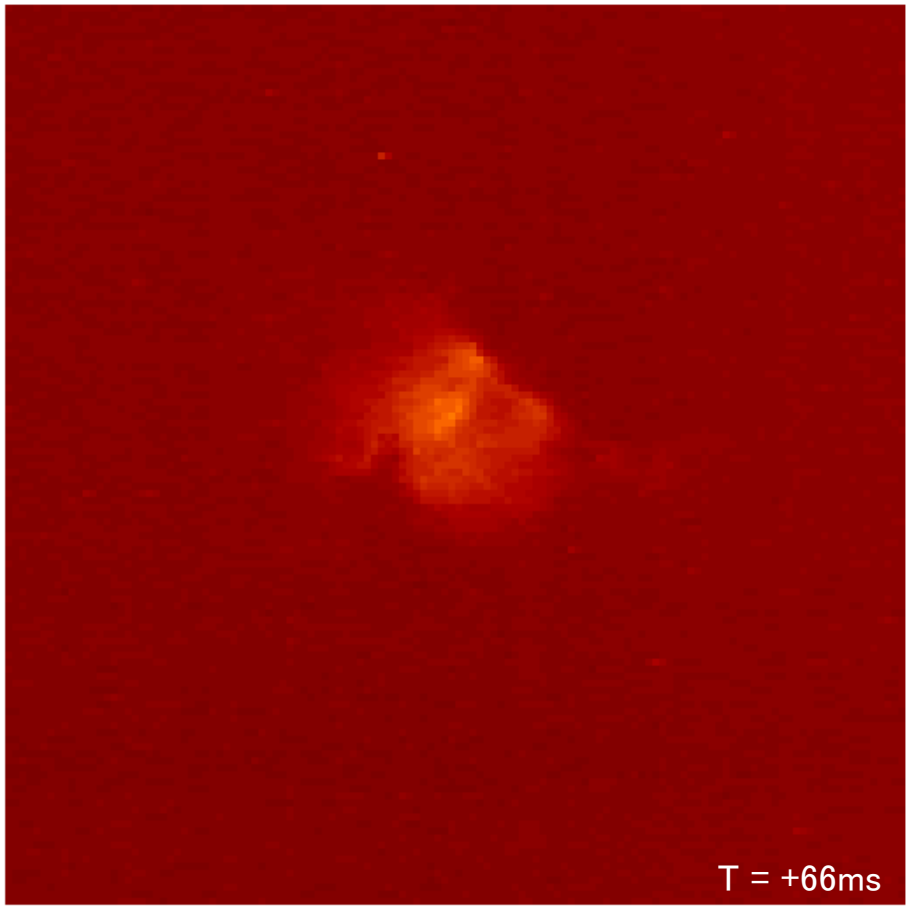


GLIMS取得データ例(3)

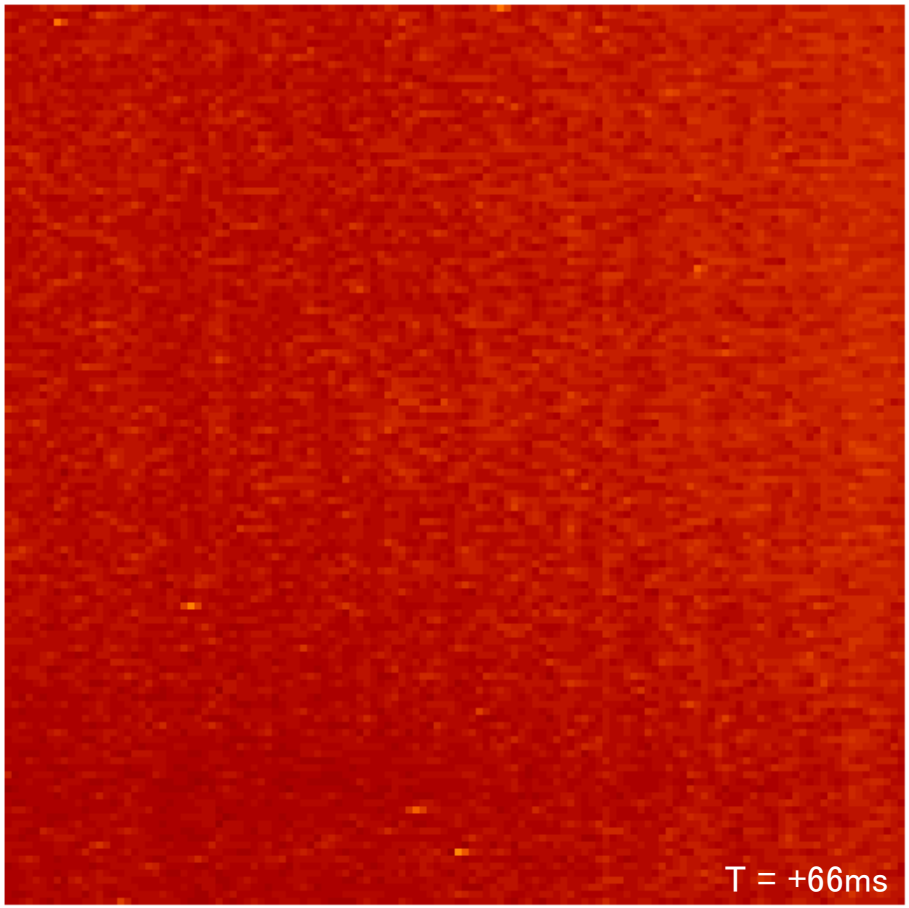
2012/12/14 18:44:11.469 UT

DATA FILE : /Volumes/GLIMS-HDD/GLIMS_TLM/2012/12/2012-12-15/2012-12-14_184411.46858/2012-12-14_184411.46858_03.BIN

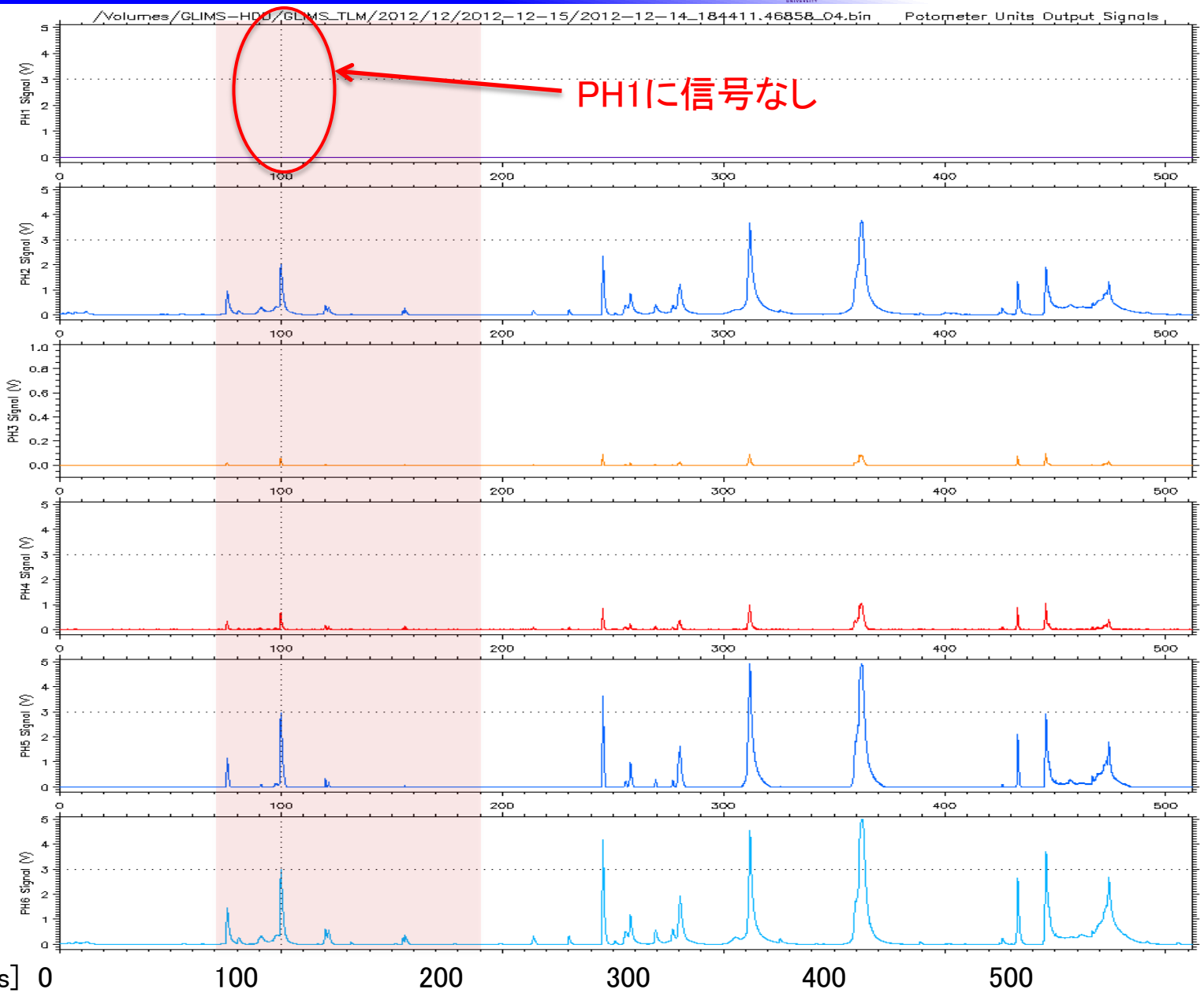
LSI-1 Expanded Image (128 x 128 pixels)



LSI-2 Expanded Image (128 x 128 pixels)



GLIMS取得データ例(3)



PH1
(150-280nm)

PH2
(337nm)

PH3
(762nm)

PH4
(600-900nm)

PH5
(316nm)

PH6
(392nm)

GLIMS取得データ例(4)

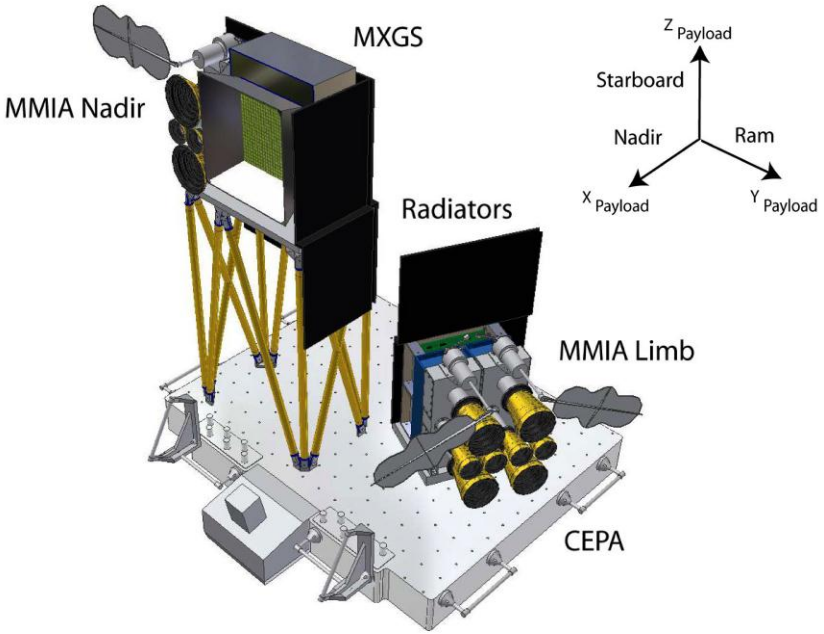
2012/12/13 19:30:01.374 UT

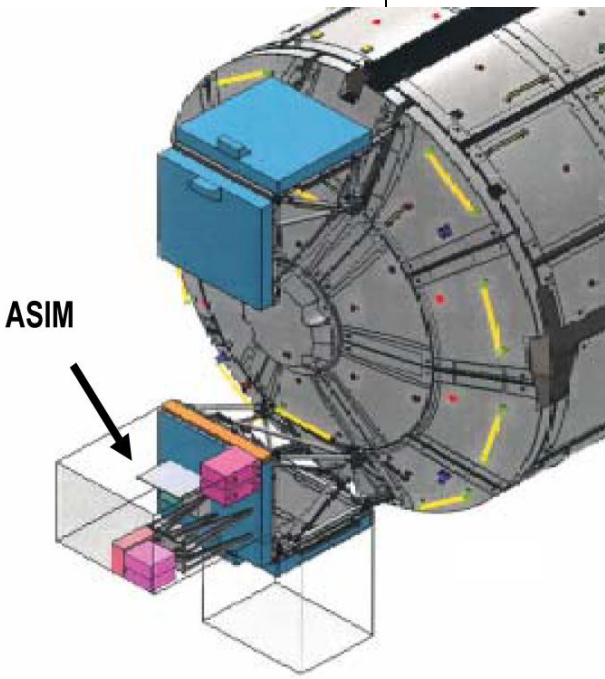
エルブス発光イベントの可能性

INTERNATIONAL COLLABORATIONS

ASIM (The Atmosphere-Space Interactions Monitor)

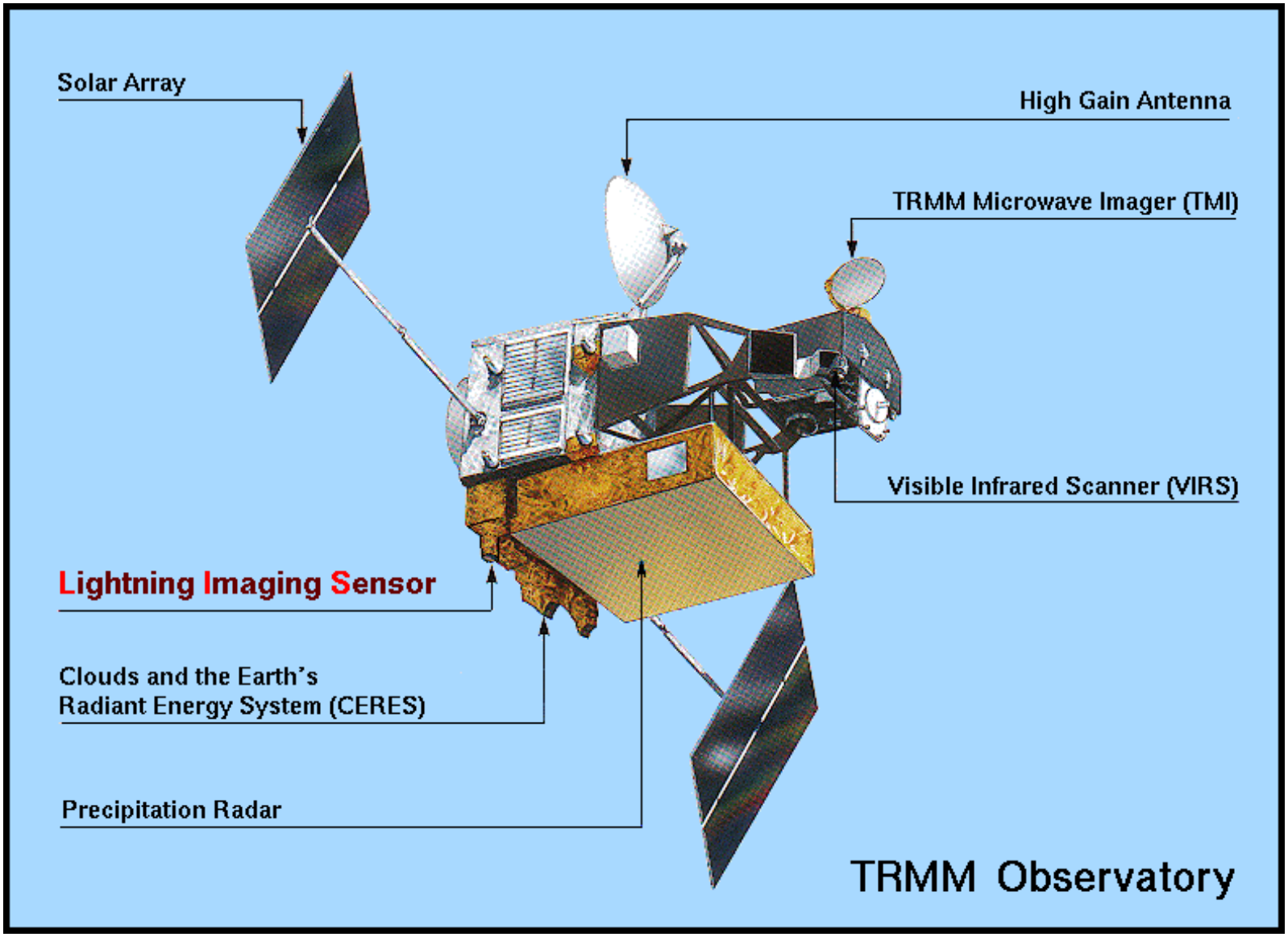
- ESA module
- MMIA (Modular Multispectral Imaging Array)
  - 4 cameras and 4 fotometers look forward towards the limb
  - 2 cameras and 2 fotometers look dornwards towards the nadir
- MXGS (Modular X- and Gamma Ray Sensor)
  - 1 detector looking downwards towards the nadir





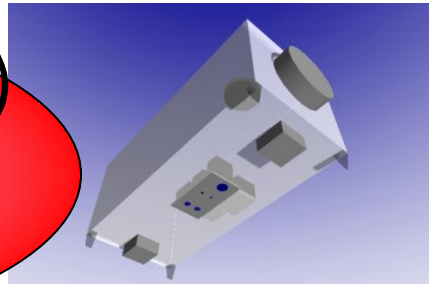
@ ISS Columbus module

LIS on TRMM

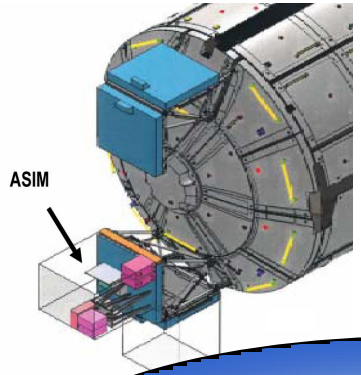

Solar Array
High Gain Antenna
TRMM Microwave Imager (TMI)
Visible Infrared Scanner (VIRS)
Lightning Imaging Sensor
Clouds and the Earth's
Radiant Energy System (CERES)
Precipitation Radar
TRMM Observatory

Complimentarities with other sensors

Our mission (Japan)
CMOS Camera, Photometers
VHF interferometer
Spectrometer



Simultaneous observation from various sensors. Only ISS can do this!



ASIM(ESA)
TLEs, TGFs

LIS(US)
Lightning Imaging Sensor

● Research Organization

T. Ushio (Osaka Univ.)
P.I.

Institute for the sensor development： JAXA・ISAS
Program Manager: Makoto Suzuki
Sub PI. : M. Sato

CMOS Camera and Photometer
M. Sato, S. Watanabe, Y. Takahashi (Hokkaido Univ.)

VLF receiver
Y. Takahashi (Hokkaido Univ.), Y. Hobara (Univ. Electr. Comm.),
U. Inan, I. Linscott (Stanford Univ.)

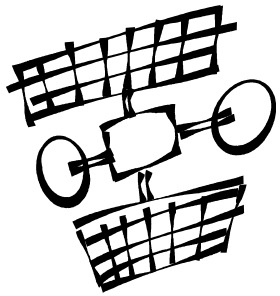
VHF Broad band interferometer
T. Morimoto, T Ushio, Z-I. Kawasaki (Osaka Univ.)

Electronics
M. Kikuchi (NIPR), M. Sato (Hokkaido Univ.)

Structure design
R. Ishida (Osaka Pref. Univ.), Sakamoto, K. Yoshida (Tohoku Univ.),

Summary

- GLIMS mission was introduced.
- Science objectives and sensor concept were presented.
- Current status of the mission was briefly reported.
- Through the collaborations with other sensors on ESA and US modules, fruitful scientific results are expected.



Jul. 21, 2012!!