Development of the Solar Neutron Monitor on the ChubuSat-2 Satellite

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Abstract

The solar neutron observation is a key in understanding of the ion accerelation mechanisms at the Sun surface since neutrons are not affected by the magnetic field around the Sun and intersteller mediums. However, there have only been a few tens of detections so far since its discovery in 1982. ChubuSat is a series of 50-kg class microsatellites jointly developed by Nagoya university, Daido university, and aerospace industrial companies in the Chubu area of central Japan. ChubuSat-2 was selected as one of the four piggyback payloads of the X-ray astronomy satellite ASTRO-H in 2014 summer, and was successfully launched by the H-IIA launch vehicles from the JAXA Tanegashima Space Center (TNSC) on February 17, 2016. ChubuSat-2 carries two mission instruments, the radiation detector (RD) and the infrared camera. The main mission of ChubuSat-2 is devoted to monitoring neutrons and gamma-rays which can be background sources for ASTRO-H celestial observations. The mission also involves solar neutron observations which were originally proposed by graduate students who join the leadership development program for space exploration and research, a program for the leading graduate schools (LGS) at Nagoya University. The RD has a similar detection area and efficiency to those of the neuron detector, SEDA-AP FIBer detector (FIB) on the International Space Station (ISS), but is expected to have a lower background than that thanks to a much smaller mass of the micro-satellite. In this paper, we will describe development of the ChubuSat-2 satellite and the RD, and the current status in orbit.

Key words: solar physics — microsatellite — instrumentation — neutron — gamma-ray

1. The ChubuSat-2 Satellite

ChubuSat is a series of 50kg-class micro-satellites developed by a collaboration among Nagoya and Daido University, and aerospace industry companies (Monozukuri Aerospace Support Technology Team: MASTT) around the Chubu region in Japan. This region including Nagoya city is at the center of Japan, and it is the core region of Japanese aerospace industries. The aim of this project is to form the basis of industrialization of the micro-satellite business and revitalize the Chubu region. Another purpose is to foster global human resources with specialized knowledge about the aerospace field utilizing development of the ChubuSat satellite.

ChubuSat-2 (Yamaoka et al. 2016) is the second ChubuSat following ChubuSat-1 launched on November 2014. The primary mission for ChubuSat-2 is to monitor radiation backgrounds for the ASTRO-H astronomical satellite at the same time and orbit. We also added solar neutron observations to the radiation measurements. Solar neutrons were first observed in 1982, but there have only been about a few tens of successful detections so far. Neutrons are not affected by the magnetic field on the solar surface and in the interstellar medium unlike protons and electrons, they can be direct probes to clarify the ion acceleration mechanisms. However, the currently working space detector, SEDA-AP FIB (Muraki et al. 2012) on the ISS, was affected by the neutron background due to the ISS itself with a huge mass (∼400 ton). The tiny ChubuSat-2 is expected to have a much smaller neutron background than SEDA-AP. Such unique mission was originally proposed by graduate students who belong to the Frontier Space Program in the LGSs [1] at Nagoya University. This educational program aims to develop international leaders who can spur innovations that will expand the space utilization using the ChubuSat development.

*1 http://www.frontier.phys.nagoya-u.ac.jp/index.html

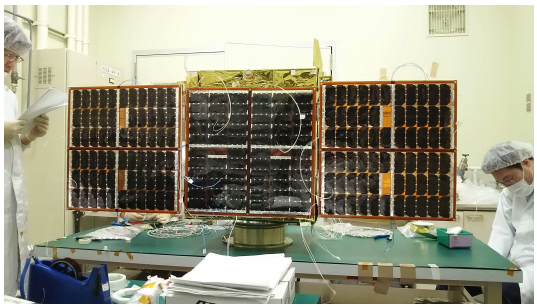

Fig. 1. A picture of the ChubuSat-2 Satellite.

2. Radiation Detector (RD)

The radiation detector (RD) has been newly designed and developed in collaboration with Clear Pulse Co., Ltd. by Nagoya University. The RD can mainly detect both neutrons and gamma-rays among radiations. It is composed of multi-layered plastic scintillator bars and a 10×10 GAGG (Ce: $Gd_3Al_2Ga_3O_{12}$) scintillator array. The plastic scintilators with 10 ×10 layers are utilized for chasing a track of protons recoiled by incident neutrons. Gamma-rays can be detected in principle of Compton camera using plastic scintillators as scatterers and the GAGG array as absorbers. Both scintillators are read out with the novel photo-sensor Multi-Pixel Photon Counter (MPPC) developed by Hamamatsu Photonics. The MPPC is very compact with a high quantum efficiency and low operation voltage at around +55 V. Thanks to a use of the MPPCs, we realized very compact detector that can be installed on the micro-satellite. The size is 15.2 cm × 17.0 cm × 18.5 cm, and the weight is approximately 6.2 kg. The RD is attached to the −Y panel just behind the solar panel, and always points towards the Sun direction. The specification of the RD is shown in table 1. Figure shows the cosmic-ray muon track in the RD on the ground. Tracks for simultaneous events can be identified in the plastic scintillator bars.

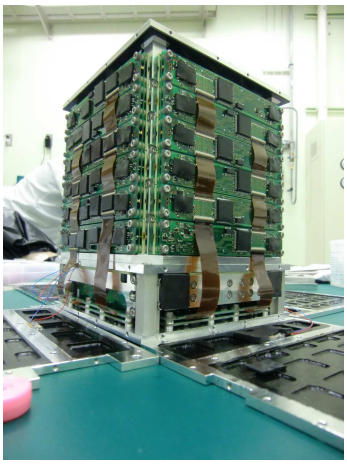

Fig. 2. A picture of Radiation Detector (RD).

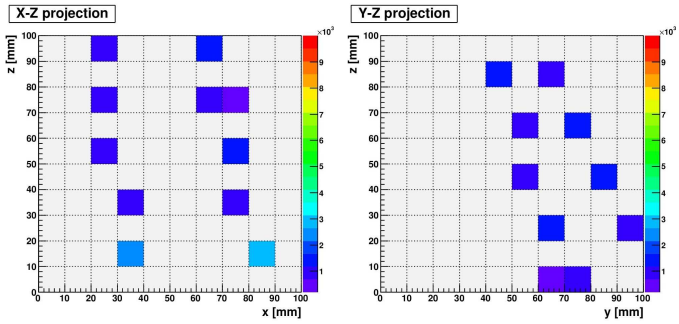

Fig. 3. Muon tracks in the Radiation Detector on the ground. Left: X-Z plane, Right: Y-Z plane.

Table 1. Specifications of the radiation detector.

Detector	100 plastic scintillator bars + GAGG (Ce) scintillator array read out with MPPC
Geometrical Area	100 cm^2
Energy Range	30–120 MeV (Neutrons) 200–1000 keV (Gamma-rays)
Detection Eff.	1∼2% (Neutrons) 1∼2% (Gamma-rays)
Weight	6.2 kg
Size	15.2 cm × 17.0 cm × 18.5 cm
Nominal Power	12 W
Down-linked Data	∼10 Mbyte per day

3. Development and Current Situation

The RD and the ChubuSat-2 satellite were built in Nagoya University. Environmental tests such as separation shock, vibration, and thermal vacuum test, have been carried out at several facilities. After the final qualification review by JAXA, it was moved to the launch site at Tanegashima island.

ChubuSat-2 was successfully launched with ASTRO-H by the H-IIA rocket #30 on February 17, 2016. The communication between the satellite and ground station was established in the amateur radio band soon after the launch. However, we had a trouble in the interface between the On-Board Computer (OBC) and Power Control Unit (PCU), so the RD has not been turned on yet. We will still continue to make an effort for recovery of the satellite.

References

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