





The DOSIS 3D Project Onboard the International Space Station

# Analysis of the Solar Particle Event in September 2017

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#### **Space Weather**

AGU100 ADVANCING EARTH AND SPACE SCIENCE

#### **RESEARCH ARTICLE**

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#### **Special Section:**

Space Weather Events of 4-10 September 2017

#### Key Points:

- A solar particle event—also seen as GLE 72 on Earth—was measured in September 2017 inside the International Space Station
- Data were provided by two detector systems, DOSIS 3D-DOSTEL and ISS-RAD, both in close proximity to each other in the Columbus Laboratory
- The additional absorbed dose due to the 10 September 2017 solar particle event was in the range of 67.8 to 146.2 μGy in Si

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# The Solar Particle Event on 10 September 2017 as observed onboard the International Space Station (ISS)

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**Abstract** The nominal radiation environment in low Earth orbit, especially for the International Space Station (ISS), is dominated by two sources. The first is galactic cosmic radiation, which is modulated by the interplanetary and the Earth's magnetic fields, and the second is trapped radiation in the form of the Van Allen belts. The trapped radiation inside the ISS is mostly due to protons of the inner radiation belt. In addition to these sources sporadic solar particle events (SPEs) can produce high doses inside and outside the ISS, depending on the intensity and energy spectrum of the event. Before 2017, the last SPE observed inside the ISS with relevant radiation detectors occurred in May 2012. Even though we are currently approaching the next solar minimum, an SPE was observed in September 2017, which was (a) a ground-level enhancement, (b) measured with various radiation detector systems onboard the ISS, and (c) observed on the surface of Mars. This paper gives an overview of the 10 September 2017 SPE measured with the DOSIS 3D-DOSTEL and the ISS-RAD (Radiation Assessment Detector) instruments, both located at this time in close proximity to each other in the Columbus Laboratory of the ISS. The additional dose received during the SPE was 146.2  $\mu$ Gy in Si as measured by ISS-RAD and 67.8  $\mu$ Gy in Si as measured by the DOSIS 3D-DOSTEL instruments. In comparison, the dose measured on the surface of Mars with the Mars Science Laboratory-RAD instrument accounted to 418  $\mu$ Gy in Si.

**Plain Language Summary** Severe solar particle events can be the source for deterministic radiation effects on humans, commonly summarized under the term "radiation sickness." We examine the evolution of the solar particle event from 10 September 2017, which was the first event since May 2012 seen inside the International Space Station. Radiation dose values are provided by two instruments (DOSIS 3D-DOSTEL and ISS-RAD) positioned in close proximity to each other in the Columbus Laboratory.



## **Outline**

- Instrumentation
- "Historical" SPEs on MIR and the ISS
- Measurements during the Hungry Ghost Festival (中元节事件) event
- Side effects / electron belt changes
- Dosimetric implications



# **DOSTEL Detector**



The DOSTEL Detector Head consists two circular PIPS detectors (D1/D2) by Canberra. These two are forming a telescope.

The thickness is 315  $\mu$ m and the active area of the detectors is 6.93 cm<sup>2</sup>.

Mounted in a distance of 1.5cm this leads to an opening angle of 120°.



# **DOSTEL Data**

- Each DOSTEL can provide count rate profiles, dose rate profiles and energy deposition spectra
- The energy spectra can be used to obtain LET-Spectra because of the path length limitation due to its telescope geometry
- The LET spectra can be used to get information such as average quality factors which leads to dose equivalent
- DOSTEL-1 has an additional mode 2 where the PHA data for every single particle is taken

# **DOSIS-MAIN-BOX**



## DOSTEL 1



DDPU – DOSTEL Data and Power Unit



#### International Space Station - Columbus

ieap





#### International Space Station – Columbus II

ieap





#### SPEs with DOSTEL type instruments: Overview



September 2018, Tsuruga, Japan

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#### Space Station MIR (1997)





Russia's Mir space station seen from Space Shuttle Atlantis during the approach for docking on 15 January 1997



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Space Station MIR (1997) – GLE 55





Note 2: Data reevaluated based on Burmeister et al. 2000; Beaujean et al. 2002; Badhwar et al. 2002





The ISS seen from Space Shuttle Endeavor during the approach for docking at 30 April 2001

ISS (2001) – GLE 60 and GLE 61



Note 1: Contributions from SAA crossings have been removed from (b) and (c). Note 2: Data reevaluated based on Reitz et al. 2005







#### ISS (2017) – GLE 72 10 September 2017





Matthiä, D., et al. *Space Weather*, *16.* https://doi.org/10.1029/2018SW001921





### ISS (2017) – ISS-RAD beneath COL Biolab

ieap



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#### ISS (2017) – DOSIS 3D-DOSTEL beneath COL EPM







## ISS (2017) – View into Columbus

< >



× International Space Station





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**The Hungry Ghost Festival** 中元节事件) **Event** in Sept 2017

Onset could already observed by GOES 16:06 UTC on on September 10 2017.

The ISS transited through "safe" orbits until September 11 around 04:30, then the first SPE protons observed by both were at high southern instruments latitudes.

Date [dd] in September 2017



Tsuruga, Japan

2018,

September

7 – 16 September (L)



(a) Count rates and (b) absorbed dose rates in Si for DOSTEL-2 and ISS  $\text{RAD}_{\text{B}}$  for September 7–16 as a function of L

Four distinct populations which are clearly separated by L value can be seen.

The **first** population is the crossing of the SAA for L values between 1 and 2.

The **second** population is the nominal GCR variation due to the orbit of the ISS for L-shell values 1-6 with the nominal minimum at L = 1 and the maximum at L = 6.

In addition, a **third** population is seen in the count rate for L values between 2.5 and 4.

The **fourth** populations for  $3 \le L \le 6$ , showing count rates of up to 20 p/cm<sup>2</sup>s, are the protons from the SPE.



7 – 16 September (L)





(a) Count rates D3D D-2 ISS RAD<sub>B</sub>

Note: SAA cut using  $|B| < 23 \mu T$  and L < 3; (Rios, 2017)



7 – 16 September (L)





(b) absorbed dose rates in SiD3D D-2ISS RAD<sub>B</sub>

Note: SAA cut using  $|B| < 23 \mu T$  and L < 3; (Rios, 2017)



#### **DOSIS 3D-DOSTEL-2:** Outer Belt Electrons













#### **DOSIS 3D-DOSTEL-2:** Energy Deposition Spectra





- (a) Energy deposition spectra recorded with the DOSTEL-2 instrument for the day before the event and the day of the event.
- (b) solar particle event spectra from the subtraction.

## **DOSIS 3D-DOSTEL-1:** Single Event Mode Data





ISS-RAD<sub>D</sub>: Proton data





Proton flux from ISS-RAD<sub>D</sub> sub-detector for the three proton channels (20 - 35; 35 - 72; and 72 - 122 MeV) for 9 to 16 of September 2017. Note 1: SAA-like contributions have been cut out Note 2: The data are selected for values of L > 3 in order to account only for SPElike contributions. CAU

**DOSIS 3D-DOSTEL-2:** Daily dose

1eap





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**DOSIS 3D-DOSTEL-2:** Daily Dose













ISS (2017) – GLE 72



## Hungry Ghost Festival (中元节事件) Event



Note 2: Data based on Berger et al. 2018



#### 10 September 2017: SPE ISS & Moon & Mars



Berger, T., Matthiä, D., Burmeister, S., Rios, R., Lee, K., Semones, E.; Hassler, D.M., Stoffle, N., Zeitlin, C. (2018). The Solar Particle Event on 10 September 2017 as observed on-board the International Space Station (ISS). Space Weather, https://doi.org/10.1029/2018SW001920

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10 September 2017: SPE ISS & Moon & Mars





Dose: 146 μGy in Si ISS-RAD instrument 68 μGy in Si DOSIS 3D-DOSTEL-2 instrument 110 μGy in Si (GEANT4 calculation)

Schwadron et al. (2018) concluded "... that the lens and skin dose on the surface of the Moon would approach the NASA 30 day limits, however even moderate shielding would reduce the radiation dose below the limits."



Dose: 418 µGy in Si for MSL-RAD





10 September 2017: SPE ISS & Mars





Zeitlin, C., et al. (2018). *GRL*, 45, https://doi.org/10.1029/2018GL077760

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Tsuruga, Japan

September 2018,



#### SPEs with DOSTEL type instruments: Summary





- The Hungry Ghost Festival Event has been measured on board the space station at least by DOSIS 3D and the ISS-RAD instrument
   Changes in the electron belt could be observed with
- Changes in the electron belt could be observed with minor / no impact to dosimetry inside the station
- Additional dose due to the event was about 68 µGy for the DOSIS 3D-DOSTEL-2 location and about 146 µGy for the ISS-RAD<sub>B</sub> location
- GEANT4 calculations showed 110µGy

# - For more details see:

Thomas Berger, Daniel Matthiä, Sönke Burmeister, Ryan Rios, Kerry Lee, Edward Semones, Donald M. Hassler, Nicholas Stoffle, Cary Zeitlin (2018). The solar particle event on 10 September 2017 as observed onboard the International Space Station (ISS). *Space Weather*, *16*. <u>https://doi.org/10.1029/2018SW001920</u>

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