Bubble-Detector Measurements for Matroshka-R and Radi-N2: ISS-51/52 and ISS-53/54

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Collaboration

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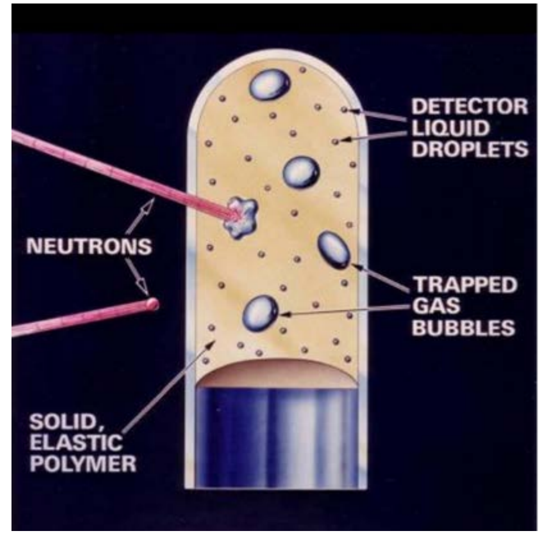
Introduction

- Radiation prediction, monitoring, and protection technologies are a key part of every space mission involving humans
  - The risk to space crews due to radiation in deep space may be a serious obstacle to Mars missions
- Neutrons are of particular interest to radiation health and protection
  - Measurements indicate that neutrons may represent 30% of the biologically-effective radiation exposure in low-Earth orbit
  - A significant neutron contribution is also expected in deep space
- Bubble detectors have been used to monitor neutrons in space since 1989 on recoverable Russian Biocosmos (Bion) satellites, the Mir space station, the space shuttle, and the ISS

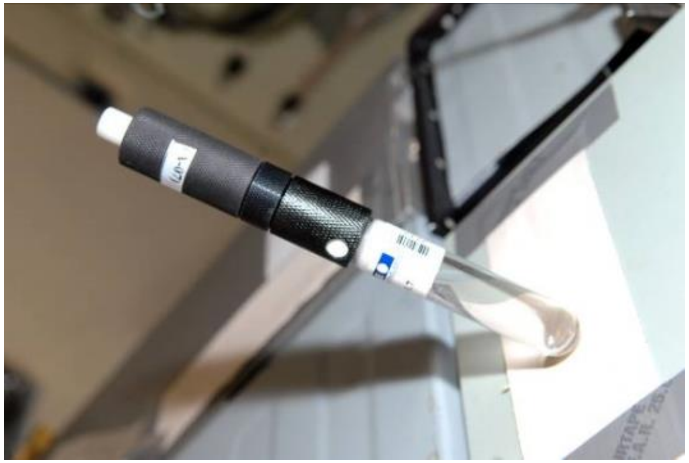
Bubble Detectors

- Bubble detectors are passive dosimeters manufactured by Bubble Technology Industries
- They contain superheated liquid droplets dispersed in an elastic polymer gel
- Particles with high linear-energy transfer (LET) interact with the droplets to form bubbles
- The elastic polymer retains the bubbles to allow visible detection of radiation
- After each measurement, the bubbles can be recompressed and the detector can be reused

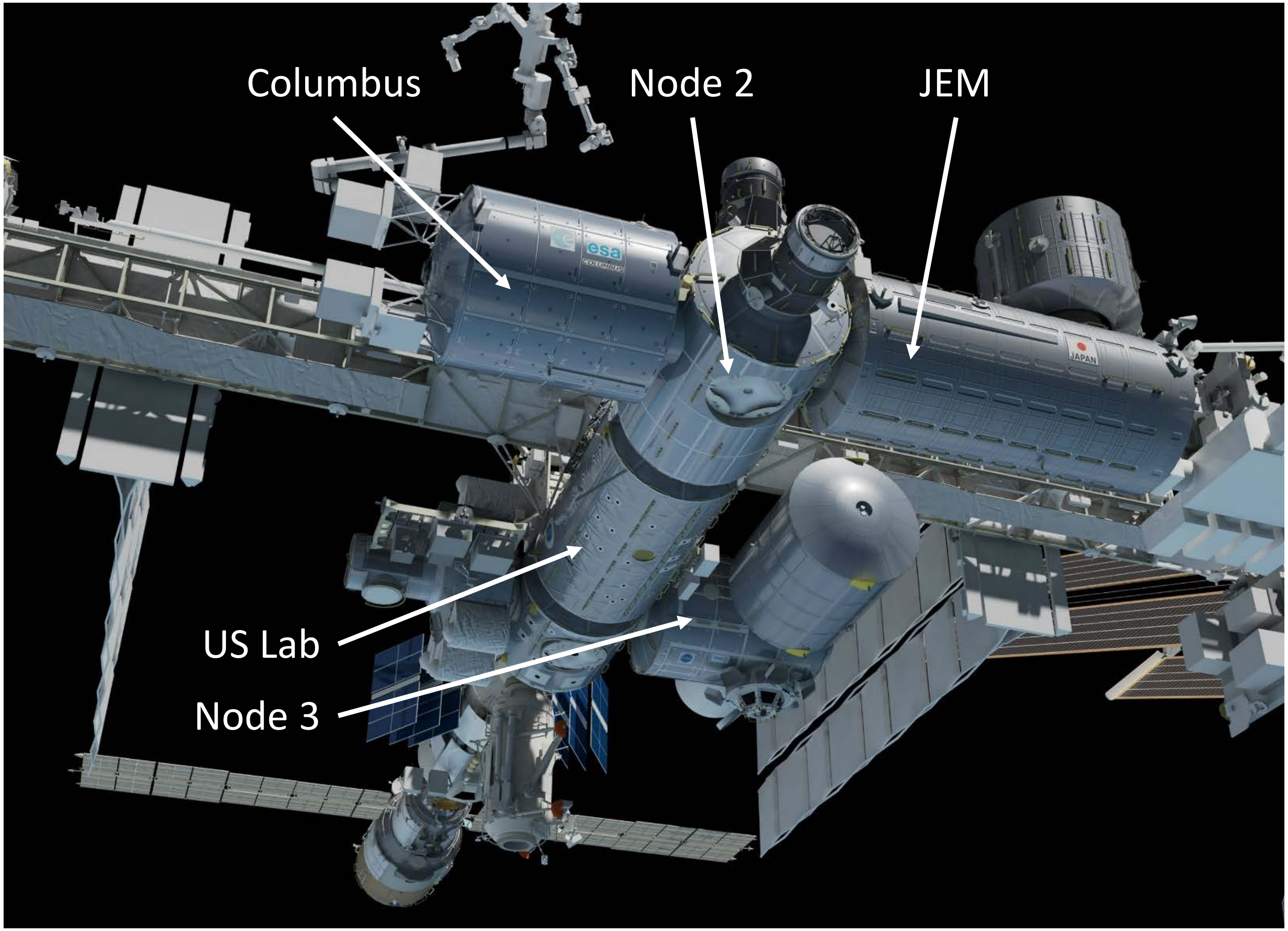


Space Bubble Detectors

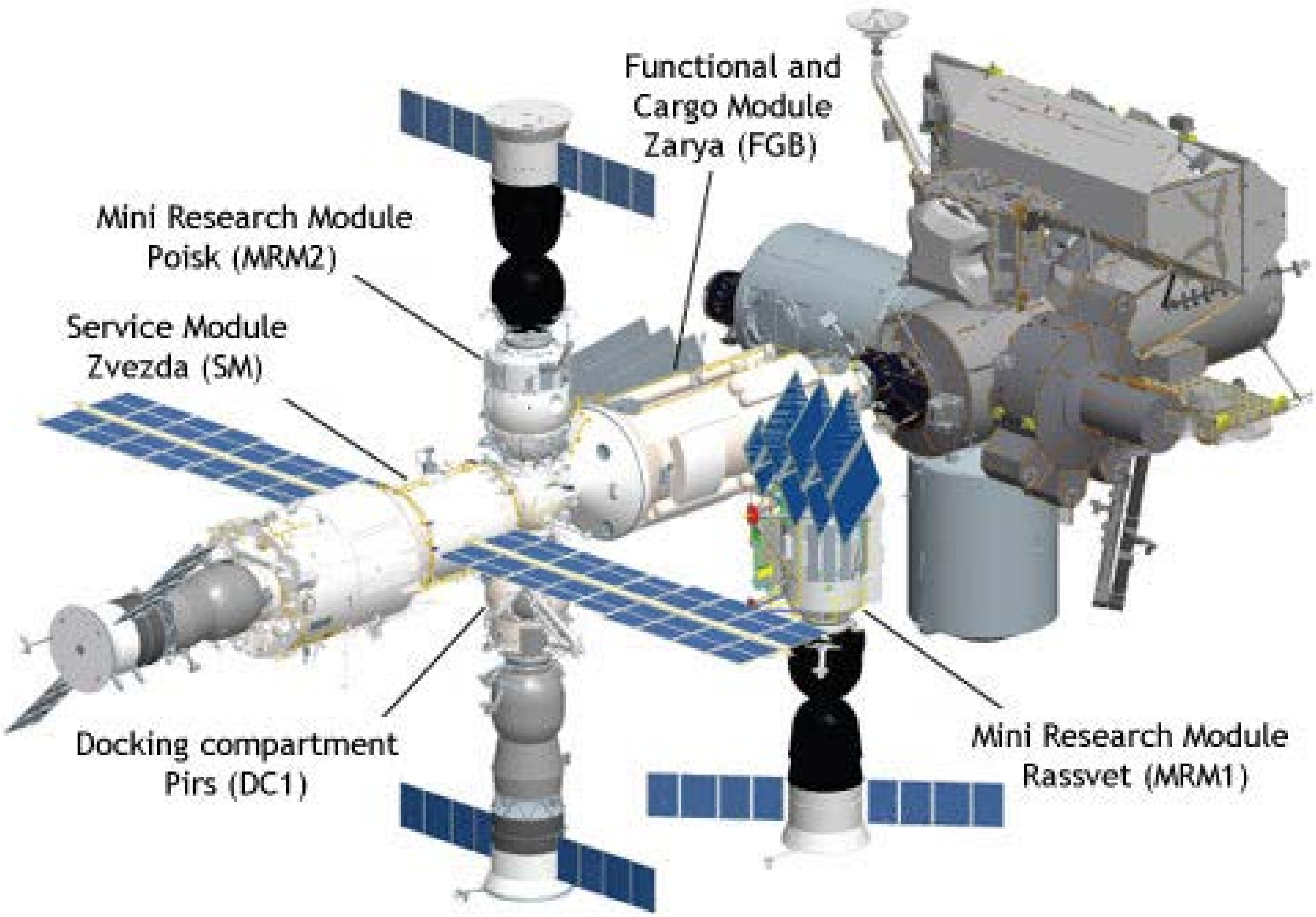
- Two types of bubble detector are used to monitor neutrons for the Matroshka-R and Radi-N2 experiments on the ISS
  - Space personal neutron dosimeter (SPND)
  - Space bubble detector spectrometer (SBDS), a set of six detectors, each with a different energy threshold, that provides a coarse neutron energy spectrum
- Space bubble detectors use a stronger polymer than terrestrial detectors
  - Allows bubbles to grow slowly during a week-long measurement
- Detectors are temperature compensated
- Bubbles are counted with the space mini reader located in the Russian segment



Radi-N2 Locations (USOS)



Matroshka-R Locations (ROS)



ISS Bubble-Detector Measurements

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Matroshka-R (2006 – present)

- Neutron dose equivalent inside a tissue-equivalent phantom is less than that at its surface
- Neutron dose equivalent in the Service Module was ~30% of the total recorded by other devices
- Solar activity and altitude do not strongly affect the neutron dose equivalent or energy spectrum

Radi-N (2009)

- First spectroscopic measurements
- Neutron dose equivalent and energy spectrum were not strongly dependent on location
- Neutron dose equivalent in the sleeping quarters was less than that received elsewhere in the ISS
- Water shield reduced the neutron dose equivalent by ~30%

Radi-N2 (2012 – present)

- Continuing measurements in the same locations used for Radi-N
- Good agreement with Radi-N data
- Data suggest that solar activity and altitude have little effect on neutron radiation inside the ISS
- Ongoing goal is to collect at least ten weeks of data in each module and to measure a full solar cycle

ISS-22 to ISS-33: Altitude

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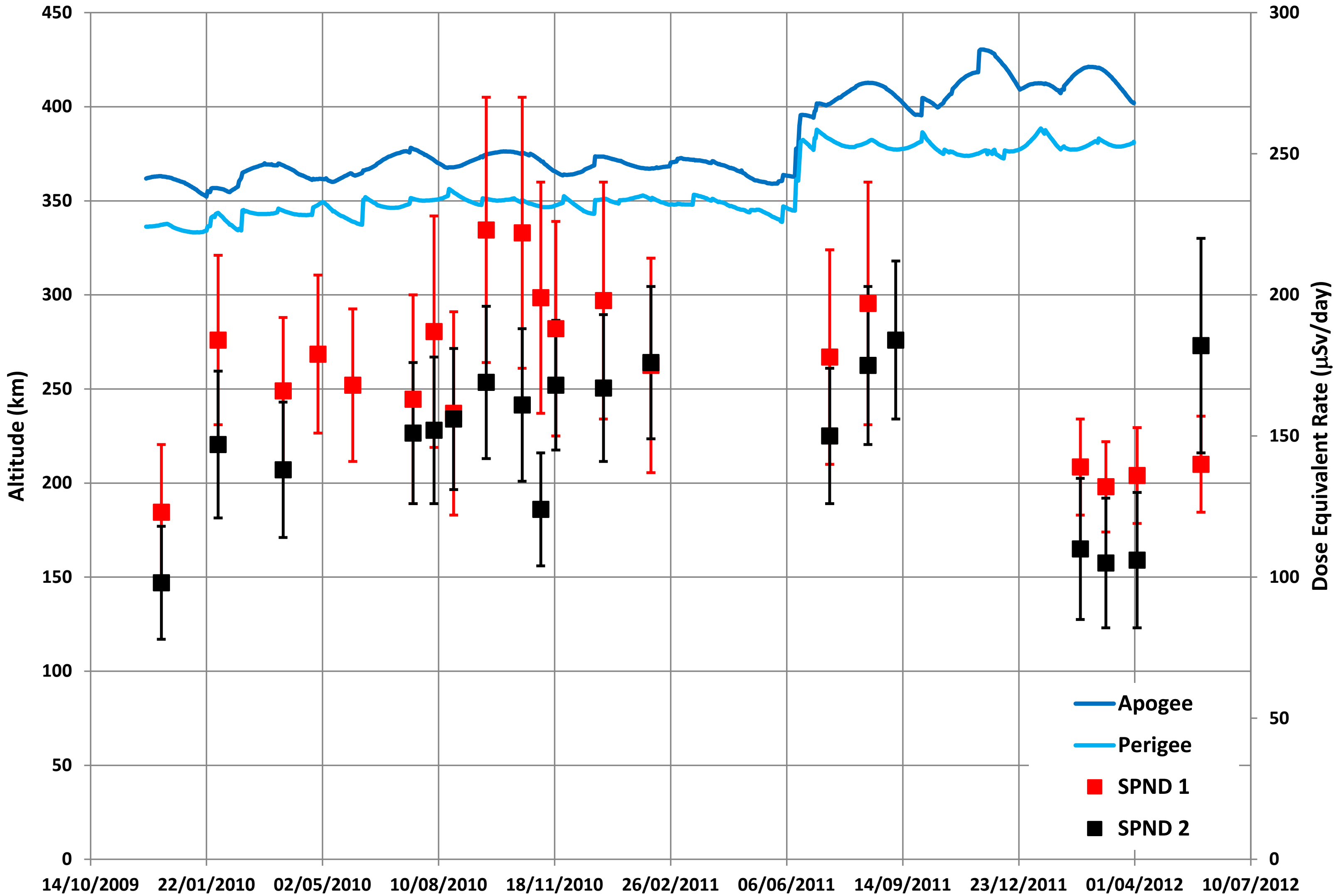

ISS-22 to ISS-33: Solar Activity

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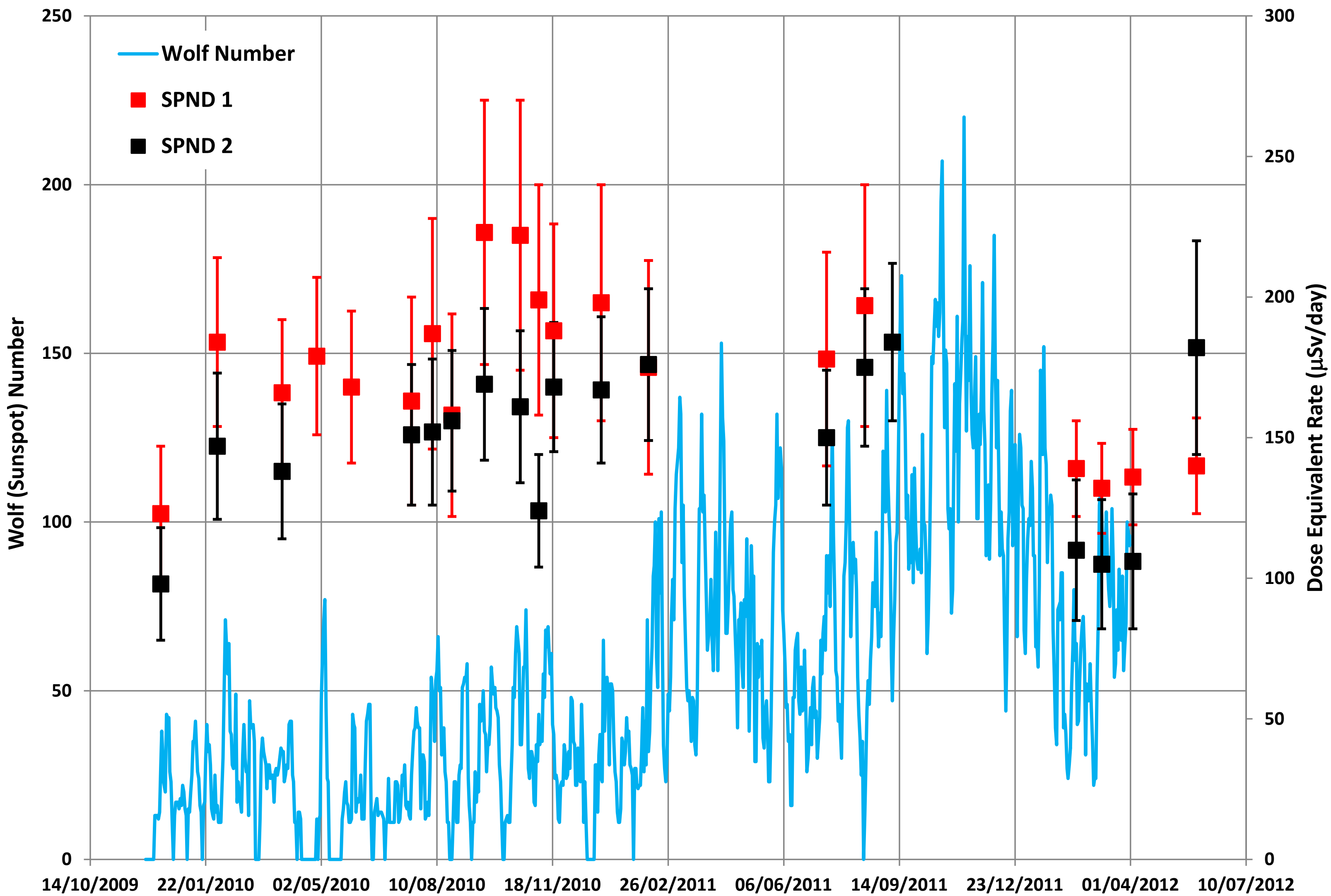

ISS-51/52 Measurements

Session	Initialization Date	Retrieval Date	Prime Location	Back-Up Location
51/52-1	25 April 2017	2 May 2017	Node 2	MRM2
51/52-2	22 May 2017	29 May 2017	Node 3	MRM2
51/52-3	26 August 2017	2 September 2017	Columbus	MRM2

The Radi-N2 detectors were co-located with the IV-TEPC for Session 1 in Node 2
The bubble detectors were co-located with the ISS-RAD during Session 2 in Node 3 and Session 3 in Columbus

ISS-53/54 Measurements

Session	Initialization Date	Retrieval Date	Prime Location	Back-Up Location
53/54-1	27 September 2017	4 October 2017	Columbus	MRM2
53/54-2	23 October 2017	30 October 2017	Columbus	FGB
53/54-3	8 November 2017	15 November 2017	FGB	FGB
53/54-4	24 November 2017	1 December 2017	US Lab	FGB
53/54-5	26 December 2017	2 January 2018	US Lab	FGB

The Radi-N2 detectors were co-located with the ISS-RAD during Sessions 1 and 2 in Columbus and Sessions 4 and 5 in the US Lab

Radi-N2: SPND Data (ISS-51 to ISS-54)

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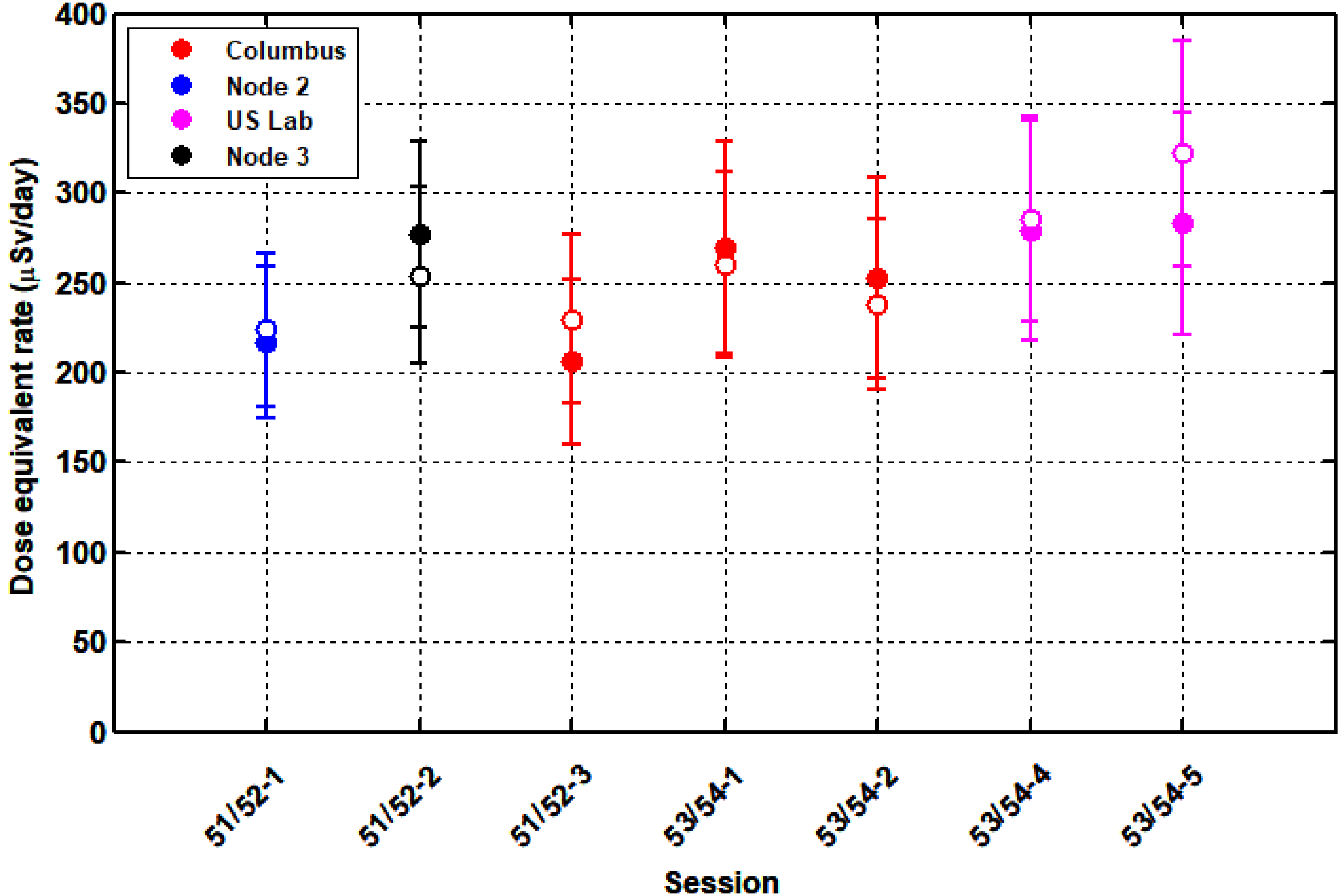
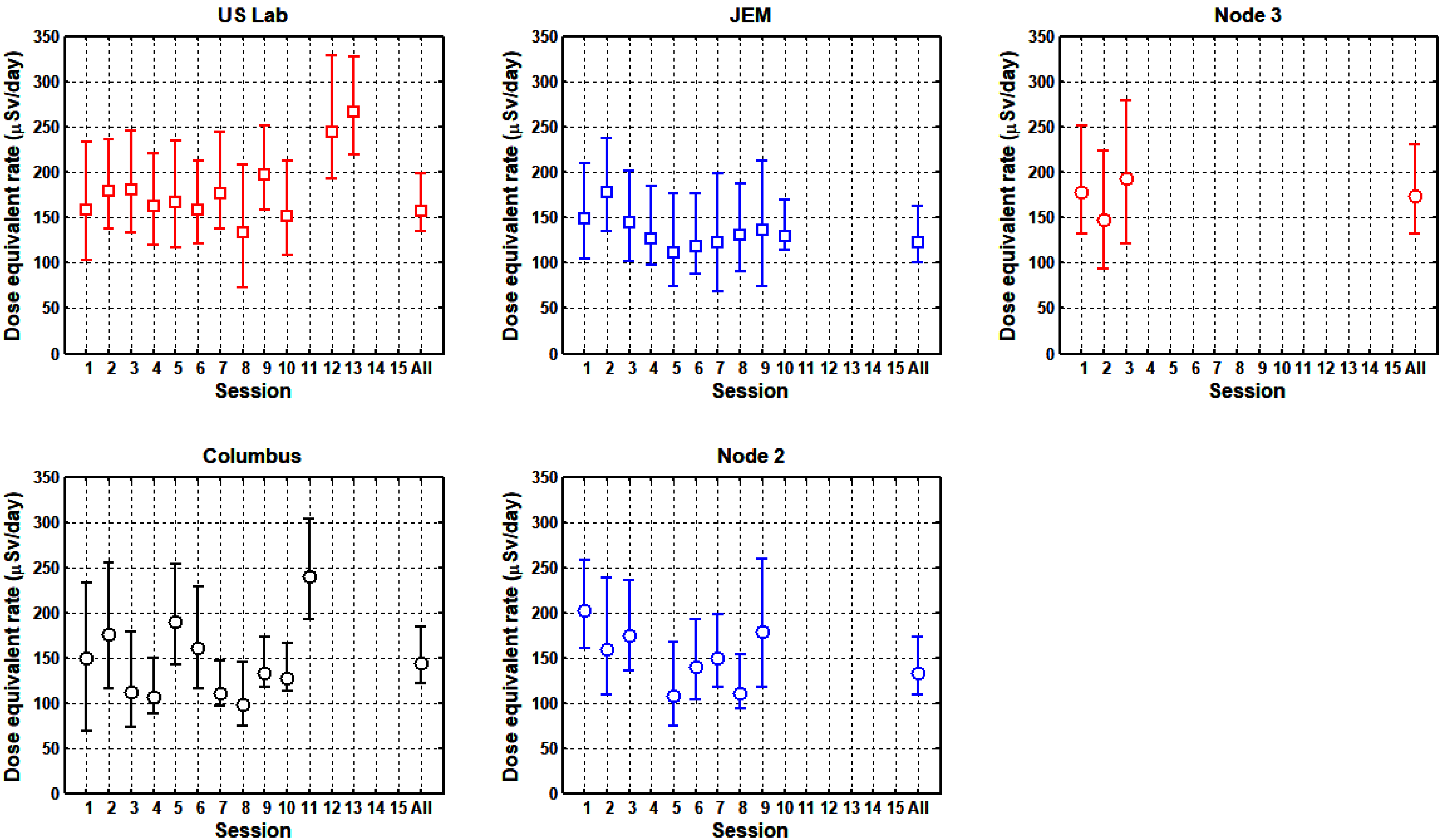


Radi-N and Radi-N2: SBDS Data



Radi-N and Radi-N2: Altitude

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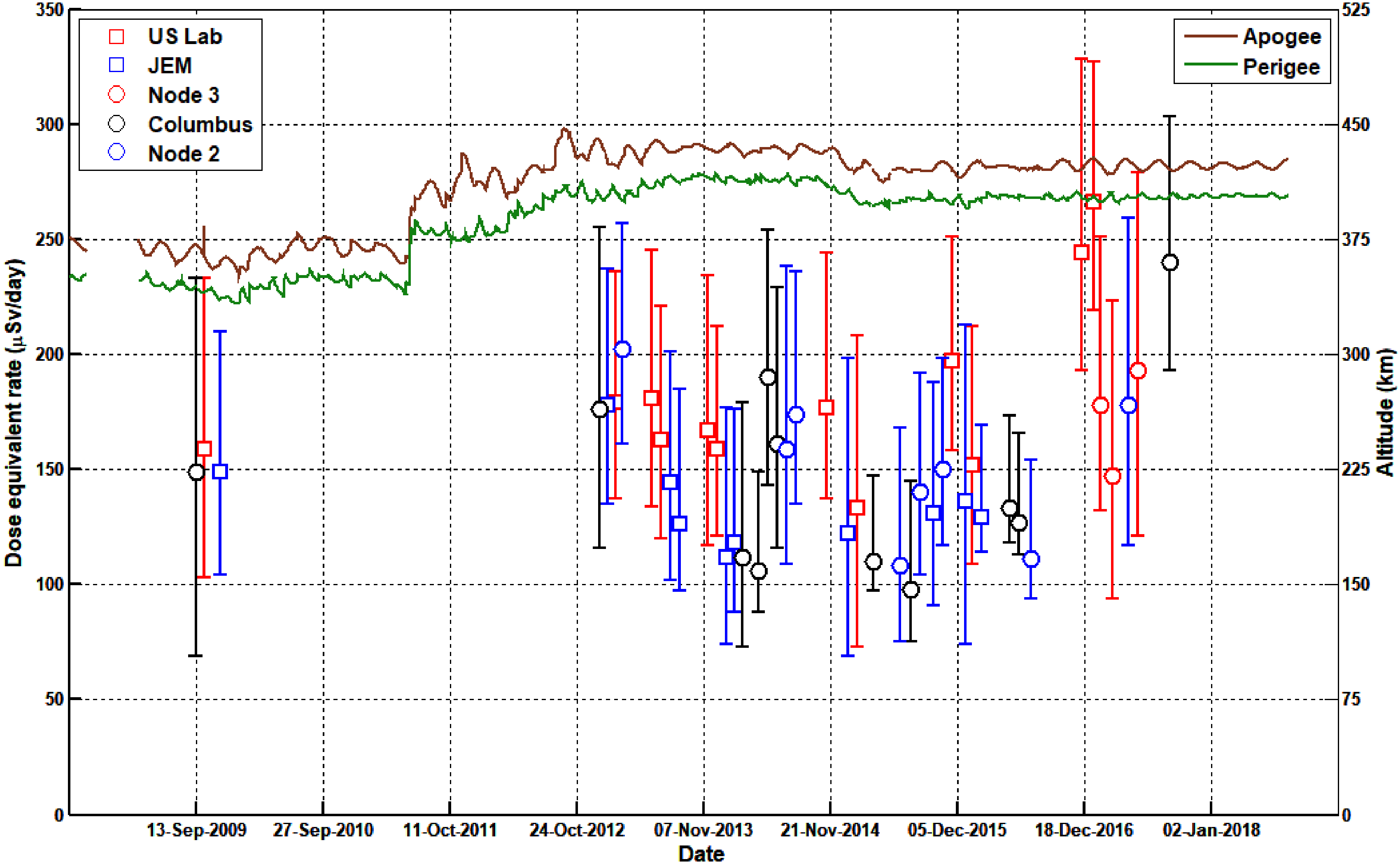

Radi-N and Radi-N2: Solar Activity

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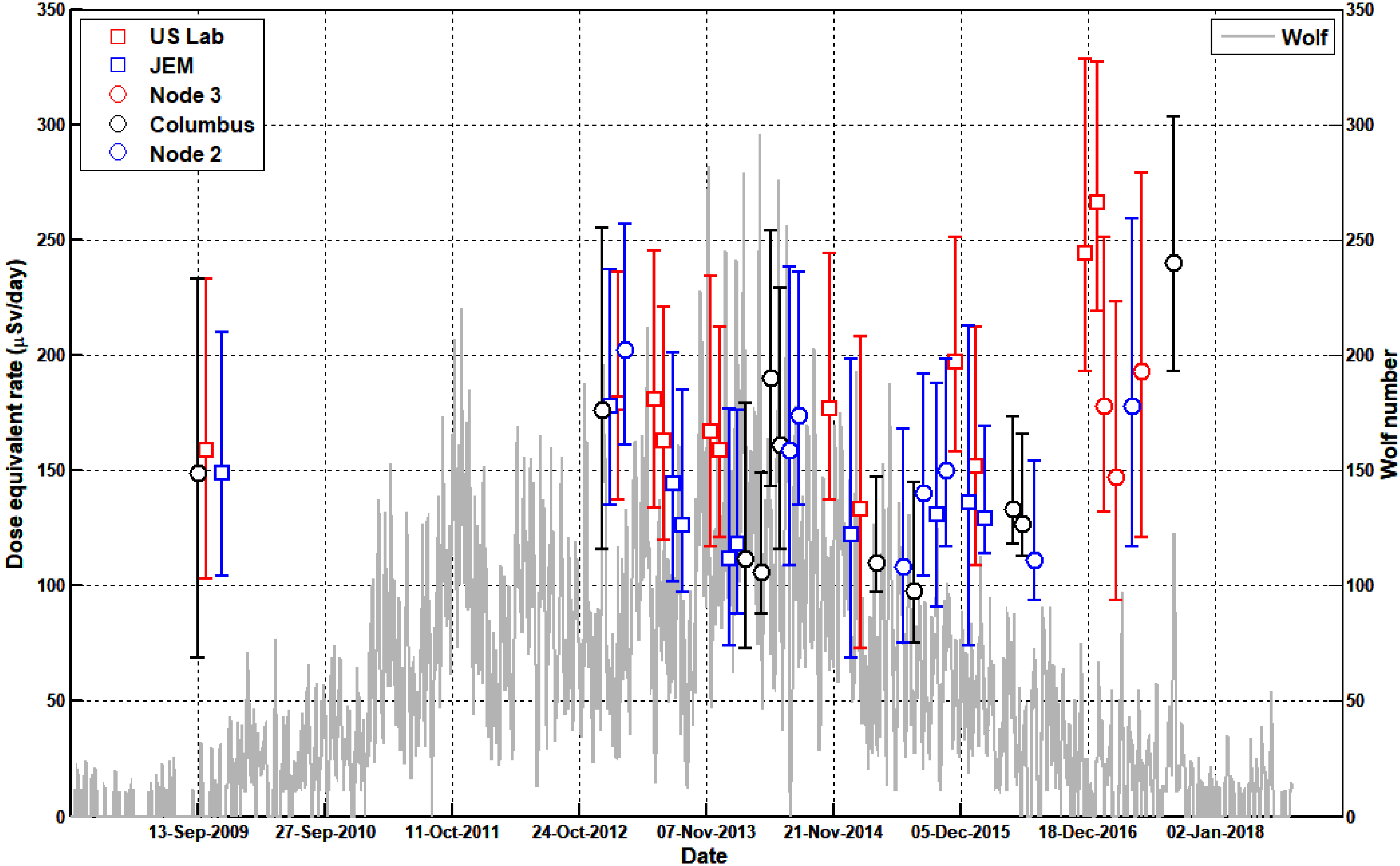
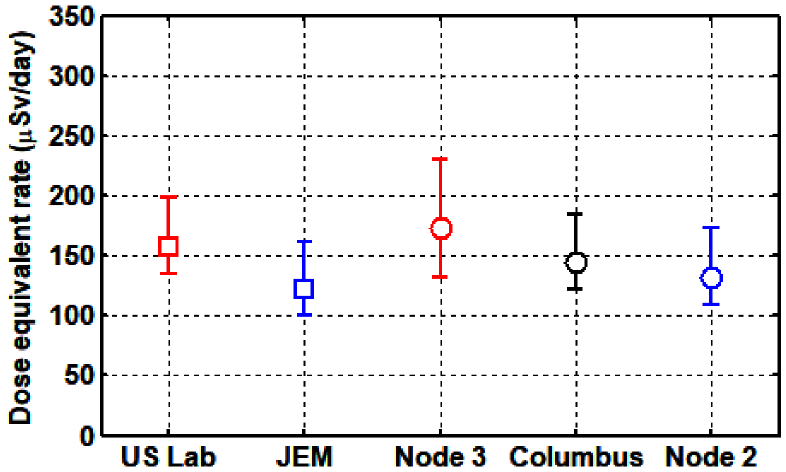
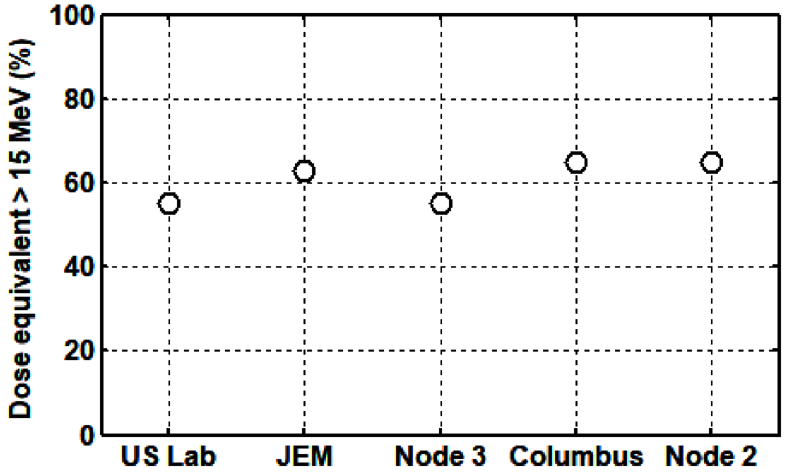


Radi-N and Radi-N2: SBDS Data

- The SBDS dose equivalent, summed over all sessions, is similar in each of the USOS locations used for Radi-N2
- The SBDS data suggest that ~60% of the dose equivalent is due to neutrons with energy > 15 MeV
- Changes in solar activity and ISS altitude since 2009 do not appear to have a strong influence on the neutron field
- Conclusions will be finalized once data have been acquired for a full solar cycle (2009 – 2020)





Matroshka-R: ISS-51 to ISS-54

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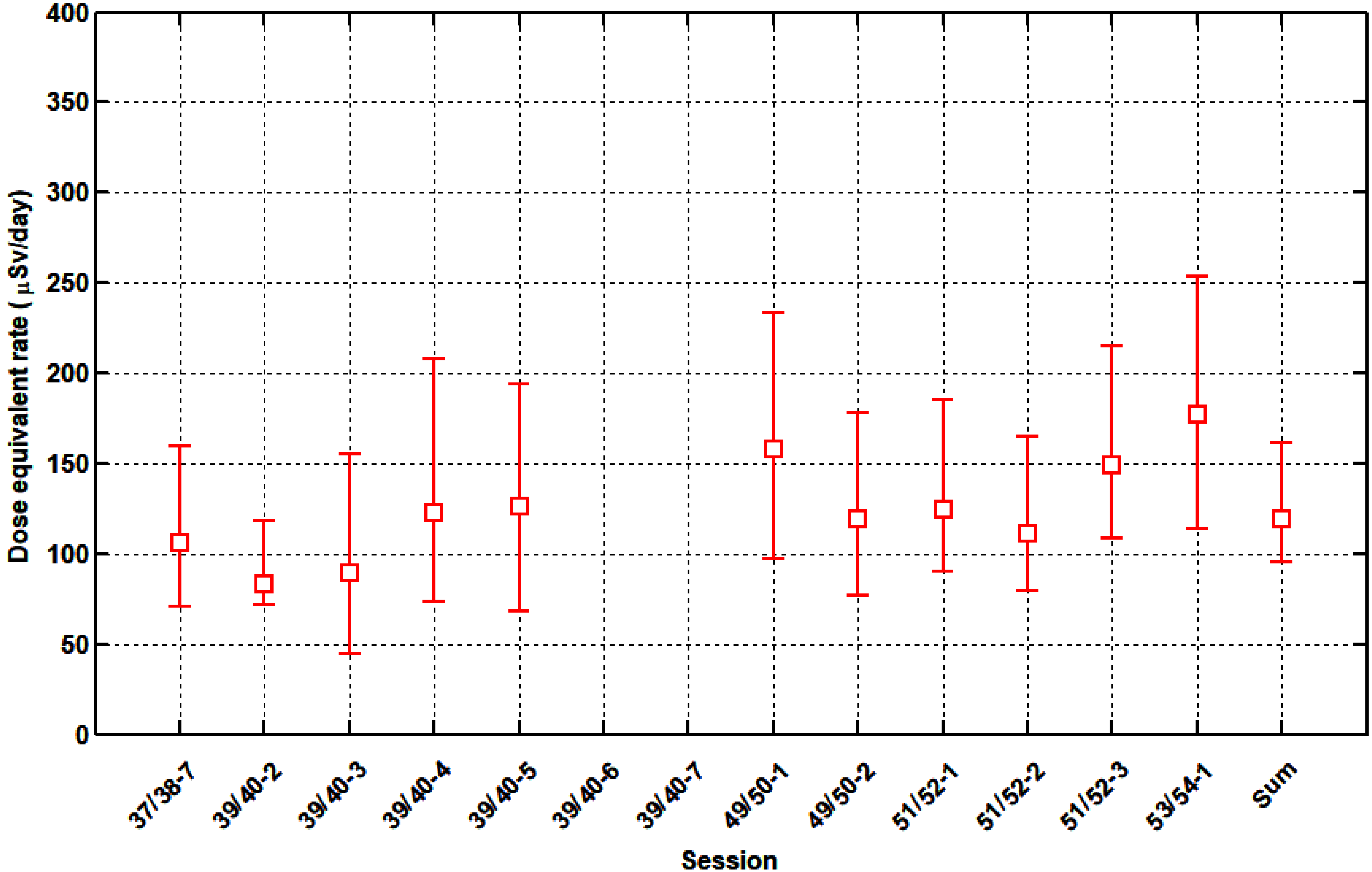
- For Matroshka-R, a total of nine week-long measurements were conducted during ISS-51/52 and ISS-53/54
- Three sessions were performed in MRM2
  - Detectors were located at handhold 6111
  - This was the location used for earlier measurements in MRM2 during ISS-37/38 and ISS-39/40
  - At that time, the neutron dose equivalent appeared lower than in USOS modules
  - This may be because of the lower mass of MRM2 (~4000 kg) compared to USOS modules (~15,000 kg)
- Five sessions were conducted in the Functional Cargo Block (FGB)
  - These are the first bubble-detector measurements in the FGB
  - Detectors were located on panel 426

MRM2: SBDS Data



MRM2: SPND Data

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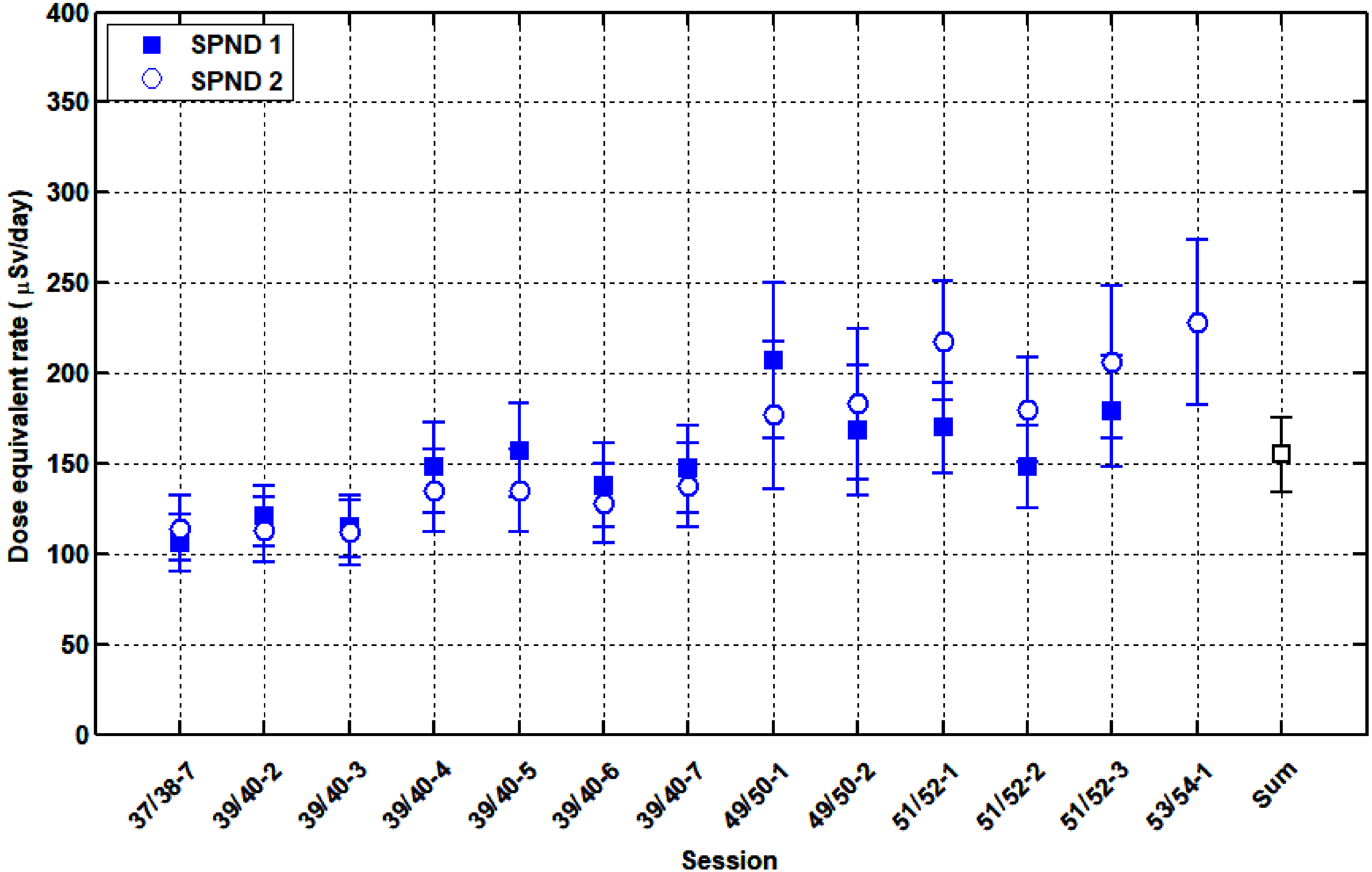
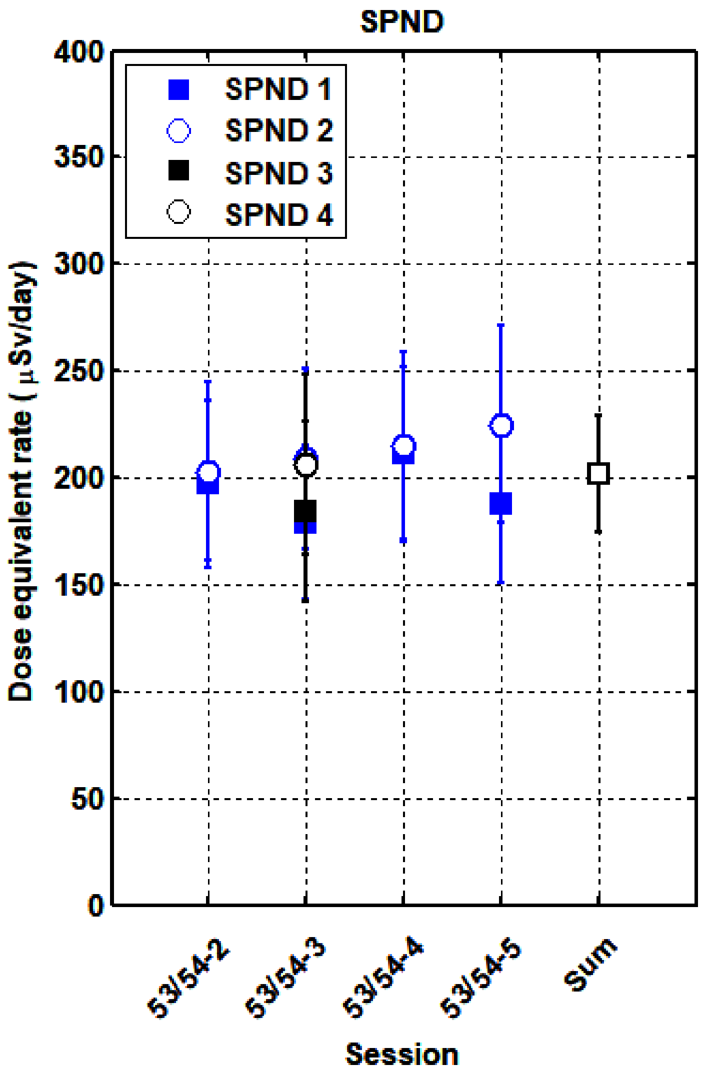
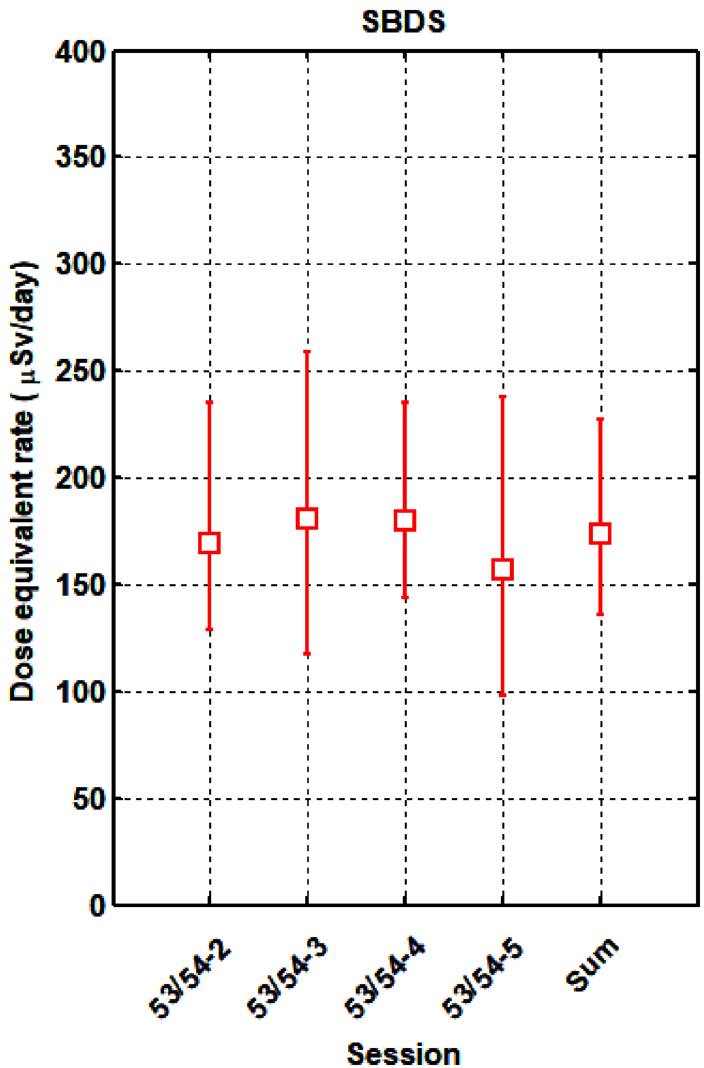


FGB: SPND and SBDS Data





ISS-55/56 Measurements

Session	Initialization Date	Retrieval Date	Prime Location	Back-Up Location
55/56-1	5 March 2018	12 March 2018	Node 3	FGB
55/56-2	9 April 2018	16 April 2018	Node 3	MRM1/phantom
55/56-3	8 May 2018	15 May 2018	US Lab	MRM1/phantom
55/56-4	12 June 2018	18 June 2018	JEM	FGB
55/56-5	19 July 2018	26 July 2018	Node 3	FGB
55/56-6	5 September 2018	12 September 2018	JEM	FGB

The Radi-N2 detectors were co-located with the ISS-RAD during Session 3 in the US Lab

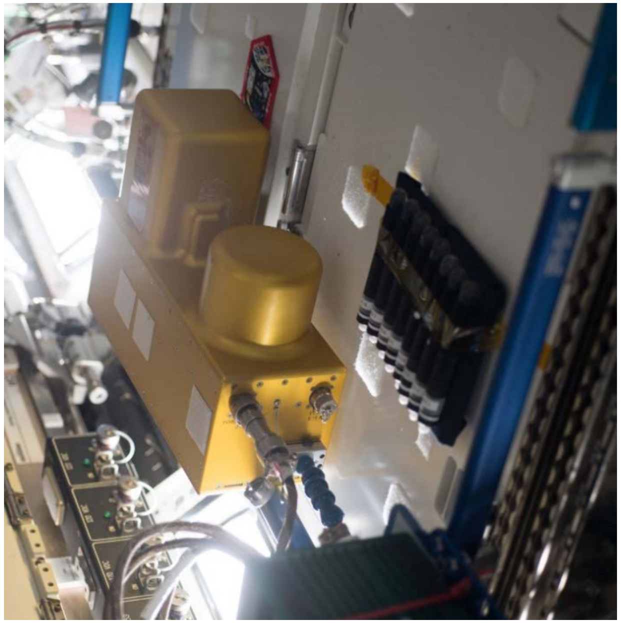
ISS-57/58 and ISS-59/60

- Planning for the upcoming ISS-57/58 and ISS-59/60 increments is in progress
- At least three sessions are expected during ISS-57/58
- Preliminary dates have been proposed in October 2018, January 2019, and February 2019
- Canadian astronaut David Saint-Jacques will be on board the ISS from December 2018 to July 2019 (ISS-58/59)
- He will repeat earlier measurements, carrying one bubble detector on his person and comparing to a detector located in his sleeping quarters

Image from the CSA: www.asc-csa.gc.ca

Summary

- Bubble-detector experiments have been performed on the ISS since 2006
- The Radi-N2 and Matroshka-R measurements continued during ISS-51/52 and ISS-53/54 (to January 2018)
- ISS-55/56 measurements are in progress and planning to 2020 (ISS-63/64) is ongoing
- Radi-N2 is nearing its goal of collecting ten weeks of data in each of the four initial locations (US Lab, Columbus, the JEM, and Node 2) and in Node 3
- Experiments up to 2020 will aim to extend Radi-N2 to other USOS modules (e.g., the Cupola and Bigelow Expandable Activity Module, BEAM) while continuing in the initial locations to assess a full solar cycle



Acknowledgements

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  - The astronauts and cosmonauts that performed the measurements
  - The CSA's Operational Space Medicine Group, the IBMP, and NASA's Space Radiation Analysis Group for supporting the experiments
  - The CSA and the Russian Space Agency for funding the work
- References for recent publications

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  - B.J. Lewis et al., Radiat. Prot. Dosim. 150(1), 1 – 21 (2012)
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