2026 Helmholtz – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project:

Radiation Belt Dynamics at Jupiter and Saturn

Helmholtz Centre and/or institute:

GFZ Helmholtz Centre for Geosciences

Project leader:

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Description of the project (max. 1 page)**:**

The giant planets Jupiter and Saturn host the most powerful magnetospheres in the Solar System. Their radiation belts contain highly energetic electrons and ions with intensities far exceeding those at Earth, forming natural laboratories for extreme plasma physics. Unlike Earth's solar-wind-driven system, the magnetospheres of Jupiter and Saturn are predominantly rotation-dominated and internally mass-loaded, offering fundamentally different regimes of particle acceleration, transport, and loss. Understanding radiation belt dynamics in these environments is essential for comparative magnetospheric physics and provides insight into particle acceleration processes operating in astrophysical plasma systems beyond the Solar System.

This project aims to develop a comprehensive and comparative understanding of radiation belt dynamics at Jupiter and Saturn, integrating acceleration, radial transport, wave–particle interactions, and loss mechanisms into a unified framework. The study will exploit in-situ observations from the Juno mission at Jupiter and the Cassini–Huygens mission at Saturn, combined with advanced numerical modelling.

The scientific objectives are:

1. Quantify particle acceleration processes in rotation-dominated magnetospheres, including radial diffusion and wave-driven energization.

2. Characterize transport and variability, assessing the influence of internal plasma sources (e.g., moons and rings) and solar wind modulation.

3. Identify dominant loss pathways, including atmospheric precipitation, and ring absorption (Saturn).

4. Develop comparative scaling relationships between Jovian and Kronian systems to establish general principles of radiation belt physics in giant magnetospheres.

Methodologically, the project combines data analysis, physics-based modelling, and statistical approaches. Observational datasets of waves will be used to develop empirical models. The developed empirical wave models will be used to calculate diffusion coefficients to quantify the wave-particle interactions. Then the diffusion coefficients will be used in physics-based models to simulate the dynamics of the radiation belt particles.

The comparative approach is central: by systematically contrasting Jupiter's ultra-strong magnetic field and intense synchrotron-emitting belts with Saturn's weaker system but with rings, we aim to identify universal versus system-specific processes. The results will advance fundamental understanding of particle acceleration in strongly magnetized, rapidly rotating plasma systems and provide a foundation for interpreting magnetospheric environments of giant planets.

By positioning Jupiter and Saturn as complementary natural laboratories, this project establishes a forward-looking research framework that is scientifically ambitious, computationally innovative, and ideally suited for internationally competitive postdoctoral researchers in space plasma physics and planetary science. Strategically, the project is embedded within the Helmholtz research field Earth and Environment and strengthens Helmholtz expertise in space plasma physics and comparative planetary science. By connecting planetary magnetospheres with fundamental plasma processes relevant to astrophysical systems, the project enhances Helmholtz visibility in interdisciplinary space research at the interface of planetary science, plasma physics, and astrophysics.

Description of existing or sought Chinese collaboration partner institute (max. half page)**:**

The proposed project strengthens sustainable research collaboration between the Helmholtz Association and leading Chinese universities, in particular Wuhan University and Peking University. The partnership builds on long-standing scientific ties: Prof. Binbin Ni previously worked with Prof. Yuri Shprits as a postdoctoral researcher at UCLA and is now Dean of the School of Earth and Space Science and Technology and full professor in the Department of Space Physics at Wuhan University. Several PhD students from Wuhan University have conducted research visits in the GFZ space physics group. Likewise, Dr. Yixin Hao completed a postdoctoral fellowship with Prof. Yuri Shprits at GFZ and is now an assistant professor at Peking University. These academic trajectories demonstrate sustained bilateral mobility and durable institutional links.

Scientifically, the collaboration is strongly complementary. Wuhan University and Peking University have extensive expertise in analysing publicly available spacecraft data, including observations from Juno and Cassini–Huygens. GFZ contributes internationally recognized strengths in physics-based numerical modelling and radiation belt simulations. This combination of advanced data analysis in China and modelling expertise within Helmholtz creates a balanced framework for comparative studies of radiation belt dynamics.

With China planning future planetary missions, establishing a stable long-term collaboration will position the partners to jointly analyse publicly available data from upcoming spacecraft. Together, the partners will advance understanding of planetary magnetospheres; comparative studies of giant planets provide key insights into plasma processes that ultimately improve our understanding of Earth’s radiation belts. The project establishes a structured framework for postdoctoral exchange and co-supervision, ensuring a sustainable and mutually beneficial partnership.

Required qualification of the postdoc:

<Sample text below>

- PhD in Space Physics
- Experience with satellite wave and particle data analysis and modelling
- Additional skills in empirical model development
- Language requirement: fluent English communication; sufficient for academic presentation and documentation