The in-situ exploration of Jupiter's radiation belts

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Jupiter has the most energetic and complex radiation belts in our solar system. Their hazardous environment is the reason why so many spacecraft avoid rather than investigate them, and explains how they have kept many of their secrets so well hidden, despite having been studied for decades. We believe that these secrets are worth unveiling, as Jupiter’s radiation belts and the vast magnetosphere that encloses them constitute an unprecedented physical laboratory, suitable for both interdisciplinary and novel scientific investigations: From studying fundamental high energy plasma physics processes which operate throughout the universe, such as adiabatic charged particle acceleration and nonlinear wave-particle interactions; to exploiting the astrobiological consequences of energetic particle radiation. The in-situ exploration of the uninviting environment of Jupiter’s radiation belts presents us with many challenges in mission design, science planning, instrumentation and technology development. We address these challenges by reviewing the different options that exist for direct and indirect observation of this unique system. We stress the need for new instruments, the value of synergistic Earth and Jupiter-based remote sensing and in-situ investigations, and the vital importance of multi-spacecraft, in-situ measurements. While simultaneous, multi-point in-situ observations have long become the standard for exploring electromagnetic interactions in the inner solar system, they have never taken place at Jupiter or any strongly magnetized planet besides Earth. We conclude that a dedicated multi-spacecraft mission to Jupiter’s radiation belts is an essential and obvious way forward. Besides guaranteeing many discoveries and outstanding progress in our understanding of planetary radiation belts, it offers a number of opportunities for interdisciplinary science investigations. For all these reasons, the exploration of Jupiter’s radiation belts deserves to be given a high priority in the future exploration of our solar system. A White Paper on this subject was submitted in response to ESA’s Voyage 2050 call.