Connecting Jupiter's Auroral Pulsations with In-situ Measurements by Juno

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In 1979, the Voyager spacecraft arrived at Jupiter. Amongst their rich array of discoveries, they identified bright bursts of radio emission at kHz frequencies\(^1\), often called quasi-periodic (QP) bursts, and discovered Jupiter's ultraviolet (UV) aurora\(^2\) - the most powerful aurora in the Solar System\(^3\). The same year that the Voyager spacecraft explored the Jovian system, the Einstein X-ray Observatory took the first X-ray images of Jupiter\(^4\) and discovered that planets can also produce bright and dynamic X-ray aurora\(^5,6\). Over the subsequent decades, these distinct multi-waveband emissions have all been observed to pulse with quasi-periodic regularity\(^7–10\). Here, we combine simultaneous observations by the Juno spacecraft with the X-ray and UV observatories: XMM-Newton, Chandra and the Hubble Space Telescope. These observations show that the radio, UV and X-ray pulses are all synchronised, beating in time together. Further, they reveal that the X-ray and radio pulses share an identical 42.5 minute periodicity with simultaneously measured compression-mode Ultra Low Frequency (ULF) waves in Jupiter’s outer magnetosphere\(^11\). ULF waves are known to modulate wave-particle interactions that can cause electron and ion precipitation, providing a physically consistent explanation for the observed simultaneous ion and electron emissions. The unification of Jupiter’s X-ray, UV and radio pulsations and their connection to ULF waves provides fundamental and potentially universal insights into the redistribution of energy in magnetised space environments.