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The quest for discovery of planetary radiation belts: From Explorer 1 to MESSENGER (Jean Dominique Cassini Medal Lecture)

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May 1, 1958 was an exciting time in the Great Hall of the US National Academy of Sciences. An announcement was made that the Earth possessed radiation belts at high altitudes with intensities thousands of times greater than those of galactic cosmic rays (GCR) that were known to penetrate the atmosphere and produce secondaries detectable at ground level. The leading scientist at the time was James A. Van Allen, head of the Physics Department at the University of Iowa, who instrumented Explorer-1 and follow-on satellites with radiation detectors, and the press labeled the doughnut-shaped structures Van Allen Belts. Once the basic properties of what was subsequently named Earth' s Magnetosphere were established, the quest began to search for Van Allen Belts at other nearby planets, namely Venus and Mars. Mariner 2 was launched to Venus in 1962, but did not have radiation detectors, although a plasma instrument was used to firmly establish the properties of the solar wind. The Mariner 4 mission to Mars was properly instrumented and expectations were high that radiation belts were likely to be present. No planet-associated increase in radiation was measured, however, but use of scaling arguments with Earth' s magnetosphere established an upper limit to the ratio of magnetic moments of M_M/M_E <0.001 (Van Allen et al, 1965). Similarly, the Mariner 5 flyby of Venus produced an upper limit of the ratio of magnetic moments < 0.001 (Van Allen et al, 1967), dealing another blow to the expectation that all planetary bodies must possess significant radiation belts. Jupiter, however, came to the rescue with the discovery of Io-controlled decametric radio emissions in 1965, proving that at least that planet must have large intensities of trapped electrons and therefore radiation belts. Flybys of Jupiter by Pioneers 10, 11 in 1973 and 1974, respectively, measured a variety of energetic particles in Jupiter's magnetosphere and established the fact that it was rotationally modulated. A flyby of Mercury in 1974 by Mariner 10 established that the planet possessed a magnetic field but the presence of higher energy particles remained controversial until MESSENGER. The two Voyager missions, in addition to making the key discovery that an internal plasma source (Io) was populating Jupiter's magnetosphere, and that internal plasma rather than solar wind pressure played a dominant role, measured a variety of plasma waves, identified the Io plasma torus and measured the huge current connecting that satellite to the planet' s upper atmosphere. The flybys of Saturn revealed that the magnetosphere possessed its own internal plasma source(s) and high-energy radiation belts. The subsequent discoveries of Van Allen belts at Uranus and Neptune by Voyager 2, established beyond any doubt that radiation belts were the rule rather than the exception in planetary environments. Finally, we now know from the Voyagers and through Energetic Neutral Atom images from Cassini and IBEX that an intense energetic particle population surrounds the heliosphere. Thus, the reconnaissance of radiation belts of our solar system is now complete, some 54 years after the discovery of the Van Allen Belts.