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Shock Occurrence Rates in the Inner Heliosphere: Observations from 0.3 to 1 AU with Helios, MESSENGER, and STEREO

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The two major sources of collisionless shocks in the solar wind are interplanetary coronal mass ejections, whose leading edges generally travel faster than the ambient solar wind flows and stream interactions that become more compressed as they move outward from the Sun. Recent studies of shock formation in the solar wind indicate that nearly all shocks associated with stream interactions form between Venus and Earth or beyond. We examine the high-resolution magnetometer records from Helios 1 and 2 obtained between 0.3 and 1 AU from 1974 to 1981 to gain further insight as to where, and in what context, shocks are formed in the inner solar system. We find most of the shocks inside of the Venus orbit appear to be associated with ICMEs. These occur over the entire range of distances that Helios observed. The shock annual occurrence rate is fairly constant for different ranges of heliocentric distance, 19$\sim$26 per year. We compare the Helios results with MESSENGER magnetic field observations obtained over the same range of distances but for the most recent deep minimum in solar activity. We also compare MESSENGER and STEREO shocks at 1 AU for the same cycle activity. The shock rate is dramatically lower at solar minimum because ICME driven shocks were almost entirely absent during the 2008 deep solar activity minimum. The paucity of ICME-driven shocks allows the radial gradient in stream interaction driven shocks to be clearly observed. The rate increases by an order of magnitude from 0.4 to 1 AU, being only 2 per year at MESSENGER but 19 per year at STEREO.