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Determining the beaming of Io decametric emissions, a remote diagnostic to probe the Io-Jupiter interaction

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We investigate the beaming of 11 Io-Jupiter decametric (Io-DAM) emissions observed by Juno/Waves, the Nançay Decameter Array and NenuFAR. Using an up-to-date magnetic field model and three different methods to position the active Io Flux Tube (IFT), we accurately locate the radiosources and determined their emission angle theta from the local magnetic field vector. These methods rely on (i) updated models of the equatorial lead angle, (ii) ultraviolet (UV) images of Jupiter's aurorae from the Hubble Space Telescope simultaneous with radio data and (iii) multi-point radio measurements. The kinetic energy E(e-) of source electrons is then inferred from theta in the framework of the Cyclotron Maser Instability. The precise position of the active IFT obtained from methods (ii) or (iii), when compared to (i), can be used to test of the effective torus plasma density. Simultaneous radio and UV observations reveal that multiple Io-DAM arcs are associated with multiple UV spots and provide the first direct evidence of an Io-DAM arc associated with a trans-hemispheric beam UV spot. Multi-point radio observations alternately probe the Io-DAM sources at various altitudes, times and hemispheres. Overall, theta decreases from ~75-80° to ~70-75° over 10-40 MHz and varies both as a function of frequency (altitude) and time (longitude of Io). Its uncertainty of a few degrees is dominated by that on the longitude of the active IFT. The inferred values of E(e-), also depending on altitude and time, vary between 3 and 16 keV, in agreement with Juno in situ measurements.