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Exploration of the Kinked Jet in the Crab Nebula with Scaled Laboratory Experiments[1]

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X-ray images from the Chandra X-ray Observatory show that the South-East jet in the Crab nebula changes direction every few years. This remarkable phenomenon is also frequently observed for jets in other pulsar-wind nebulae and in other astrophysical objects. Numerical simulations suggest that it may be a consequence of current-driven, magnetohydrodynamic (MHD) instabilities taking place in the jet, yet that is just a hypothesis without verification in controlled experiments. To that end, we recently conducted scaled laboratory experiments that reproduced this phenomenon. In these experiments, a supersonic plasma jet was generated in the collision of two laser-produced plasma plumes, and this jet was radiographed from the side using 15-MeV and 3-MeV protons. It was observed that if self-generated toroidal magnetic fields around the jet were strong enough, they triggered plasma instabilities that caused substantial deflections throughout the jet propagation, mimicking the kinked jet structure seen in the Crab Nebula. We have modeled these laboratory experiments with comprehensive two- and three-dimensional numerical simulations, which in conjunction with the experiments provide compelling evidence that we have an accurate model of the most important physics of magnetic fields and MHD instabilities in the observed jet in the Crab Nebula.

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