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Mapping Dark Matter in the Milky Way using Normalizing Flows and Gaia DR3

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We present a novel, data-driven analysis of Galactic dynamics, using unsupervised machine learning – in the form of density estimation with normalizing flows – to learn the underlying phase space distribution of 6 million nearby stars from the Gaia DR3 catalog. Solving the collisionless Boltzmann equation with the assumption of approximate equilibrium, we calculate – for the first time ever – a model-free, unbinned, fully 3D map of the local acceleration and mass density fields within a 3 kpc sphere around the Sun. We find clear evidence for dark matter throughout the analyzed volume. Assuming spherical symmetry and averaging mass density measurements, we find a local dark matter density of 0.47±0.05 GeV/cm3. We fit our results to a generalized NFW, and find a profile broadly consistent with other recent analyses.

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