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Dynamically Constraining the PDS 70 Planet Masses

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Hot- and cold-start planet formation models predict differing luminosities for the young, bright planets that direct imaging surveys are most sensitive to. However, precise mass estimates are required to distinguish between these models observationally. The presence of two directly imaged planets, PDS 70 b and c, in the PDS 70 protoplanetary disk provides us a unique opportunity for dynamical mass measurement, since the masses for these planets are currently poorly constrained. Fitting orbital parameters to new astrometry of these planets, taken with VLTI/GRAVITY in the K¯band, we find 95% confidence dynamical upper mass limits of 6.9 Jupiter masses for b and 15.4 Jupiter masses for c. Adding astrometry from the newly proposed planet candidate PDS 70 d into our model, we determine 95% confidence dynamical upper mass limits of 4.9, 11.3 and 4.5 Jupiter masses for b, c, and d respectively. Using these mass limits we rule out the coldest-start formation models for b, calculating a minimum post-formation entropy of 9.57 k_B/baryon. Using the mass limits from our 3-planet fit to b, c and d we also rule out the coldest-start formation models for c, calculating a minimum post-formation entropy of 8.54 k_B/baryon. This places PDS 70 b and c on the growing list of directly-imaged planets inconsistent with cold-start formation.

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