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Prominence Formation by Levitation-Condensation at Extreme Resolutions

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We revisit the so-called levitation-condensation mechanism for the ab-inito formation of solar prominences: cool and dense clouds in the million-degree solar atmosphere. Levitation-condensation occurs following the formation of a flux rope in response to the deformation of a force-free coronal arcade by controlled magnetic footpoint motions and subsequent reconnection. Existing coronal plasma gets lifted within the forming rope, therein isolating a collection of matter now more dense than its immediate surroundings. This denser region ultimately suffers a thermal instability driven by radiative losses, and a prominence forms. We improve on various aspects that were left unanswered in the early work, by revisiting this model with our modern open-source grid- adaptive simulation code [amrvac.org]. Most notably, this tool enables a resolution of 5.6 km within a 24 Mm x 25 Mm domain size; the full global flux rope dynamics and local plasma dynamics are captured in unprecedented detail. Our 2.5D simulation (where the flux rope has realistic helical magnetic field lines) demonstrates that the thermal runaway condensation can happen at any location, not solely in the bottom part of the flux rope where the majority of prominence material is assumed to reside. Intricate thermodynamic evolution and shearing flows develop spontaneously, themselves inducing further fine-scale (magneto)hydrodynamic instabilities. Our analysis touches base with advanced linear magnetohydrodynamic stability theory, e.g. with the Convective Continuum Instability or CCI process as well as with in-situ thermal instability studies. We find that condensing prominence plasma evolves according to the internal pressure and density gradients as found previously for coronal rain condensations, but also misalignments therein suggesting the relevance of the Rayleigh-Taylor instability or RTI process in 3D. We also find evidence for resistively-driven dynamics in the prominence body, in close analogy with analytical predictions. These findings are relevant for modern studies of full 3D prominence formation and structuring. Most notably, we anticipate obtaining similar resolutions within a fully 3D setup. Such an achievement will afford us the exciting opportunity to offer crucial explanations as to the persistent discrepancy in prominence appearance when projected off- or on-disk.