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Direct imaging of molten protoplanets in nearby young stellar associations

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During their formation and early evolution, rocky planets undergo multiple global melting events due to accretionary collisions with other protoplanets. The detection and characterization of their post-collision afterglows (magma oceans) can yield important clues about the origin and evolution of the solar and extrasolar planet population. Here, we quantitatively assess the observational prospects to detect the radiative signature of forming planets covered by such collision-induced magma oceans in nearby young stellar associations with future direct imaging facilities. We have compared performance estimates for near- and mid-infrared instruments to be installed at ESO's Extremely Large Telescope (ELT), and a potential space-based mission called Large Interferometer for Exoplanets (LIFE). We modelled the frequency and timing of energetic collisions using N-body models of planet formation for different stellar types, and determine the cooling of the resulting magma oceans with an insulating atmosphere. We find that the probability of detecting at least one magma ocean planet depends on the observing duration and the distribution of atmospheric properties among rocky protoplanets. However, the prospects for detection significantly increase for young and close stellar targets, which show the highest frequencies of giant impacts. For intensive reconnaissance with a K band (2.2 μm) ELT filter or a 5.6 μm LIFE filter, the β Pictoris, Columba, TW Hydrae, and Tucana-Horologium associations represent promising candidates for detecting a molten protoplanet. Our results motivate the exploration of magma ocean planets using the ELT and underline the importance of space-based direct imaging facilities to investigate and characterize planet formation and evolution in the solar vicinity. Direct imaging of magma oceans will advance our understanding of the early interior, surface and atmospheric properties of terrestrial worlds.