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Lifetime and spectral evolution of a magma ocean with a steam atmosphere: its detectability by future direct imaging

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Theoretical studies predict that the final stage of terrestrial planet formation involves a series of giant impacts between protoplanets. In the aftermath of the last impact, the planets probably begin in a molten state. Detecting molten terrestrial planets in extrasolar systems is of great significance in testing the widely accepted view of their hot origins.

We present the thermal evolution and emergent spectra of solidifying terrestrial planets along with the formation of steam atmospheres. The lifetime of a magma ocean and its spectra through a steam atmosphere depends on the orbital distance of the planet from the host star. For a type-I planet, which is formed beyond a certain critical distance from the host star, the thermal emission declines on a timescale shorter than approximately 10^6 years. Therefore, young stars should be targets when searching for molten planets in this orbital region. In contrast, a type-II planet, which is formed inside the critical distance, will emit significant thermal radiation from near-infrared atmospheric windows during the entire lifetime of the magma ocean. The Ks and L bands will be favorable for future direct imaging because the planet-to-star contrasts of these bands are higher than approximately 10^{-7}-10^{-8}. Our model predicts that, in the type-II orbital region, molten planets would be present over the main sequence of the G-type host star if the initial bulk content of water exceeds approximately 1 wt%.

Keywords: Magma ocean, Steam atmosphere, direct imaging, thermal emission spectrum