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Little Red Dots: Rapidly Growing Black Holes Reddened by Extended Dusty Flows

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The James Webb Space Telescope (JWST) observations have revolutionized extragalactic research, particularly with the discovery of little red dots (LRD), which have been discovered as a popula- tion of dust-reddened broad-line active galactic nuclei. Their unique v-shape spectral feature, which appears blue in the rest-frame UV and red in the optical, as observed through JWST/NIRCam, challenges us to discern the relative contributions of the galaxy and AGN. We study a spectral energy distribution (SED) model for LRDs from rest-frame UV to infrared bands. We hypothesize that the incident radiation from an AGN, characterized by a typical SED, is embedded in an extended dusty medium with an extinction law similar to those seen in dense regions such as Orion Nebula or certain AGN environments. The UV-optical spectrum is described by dust-attenuated AGN emission, featuring a red optical continuum at $\lambda > 4000$ AA and a flat UV spectral shape established through a gray extinction curve at $\lambda < 3000$ AA, due to the absence of small-size grains. There is no need for additional stellar emission or AGN scattered light. In the infrared, the SED is shaped by an extended dust and gas distribution, which allows relatively cool dust temperatures to dominate the radiation, thereby shifting the rest-frame energy peak from near- to mid-infrared bands, which corresponds to the observed-frame wavelength changing from JWST/MIRI to Hershel coverage. This model, unlike the typical AGN hot torus models, can produce an infrared SED flattening that is consistent with LRD observations through JWST MIRI. Such a density structure can arise from the coexistence of inflows and outflows during the early assembly of galactic nuclei. This might be the reason why LRDs emerge preferentially in the high-redshift universe younger than one billion years.

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