Lucifer's Planet: Photolytic Hazes in the Atmosphere of 51 Eri b

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Abstract

We use a 1D model to address photochemistry and possible haze formation in the irradiated atmosphere of 51 Eri b (2016arXiv160407388Z). The intended focus was to have been on carbon and organic hazes, but sulfur photochemistry turns out to be interesting and possibly more important. The case for organic photochemical hazes is intriguing but falls short of being compelling. If organic hazes form abundantly, they are likeliest to do so if vertical mixing in 51 Eri b is weaker than in Jupiter, and they would be found below the altitudes where methane and water are photolyzed. The more novel result is that photochemistry turns H2S into elemental sulfur, here treated as S8. In the cooler models, S8 is predicted to condense in optically significant clouds of solid sulfur particles, whilst in the warmer models S8 remains a vapor along with several other sulfur allotropes that are both visually striking and potentially observable. For 51 Eri b, the division between models with and without condensed sulfur is at an effective temperature of 700 K, which is within error its actual effective temperature; the local temperature where sulfur condenses is between 280 and 320 K. The sulfur photochemistry we discuss is quite general and ought to be found in a wide variety of worlds over a broad temperature range, both colder and hotter than the 650-750 K range studied here, and we show that products of sulfur photochemistry will be nearly as abundant on planets where the UV irradiation is orders of magnitude weaker than it is on 51 Eri b.