Evidence Against an Edge-On Disk around the Extrasolar Planet, 2MASS 1207 b and a New Thick-Cloud Explanation for its Underluminosity

Andrew Skemer[1], Laird Close[1], László Szűcs[2,3], Dániel Apai[3], Ilaria Pascucci[3], Beth Biller[4]
([1]University of Arizona, [2]University of Szeged, [3]STScI, [4]MPIA)

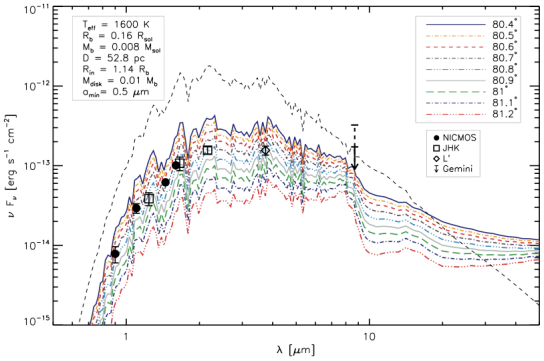
2M1207 b, the first directly imaged planetary-mass companion, has an infrared spectrum that is well-fit by an AMES-Dusty 1600 K atmosphere. However, given its well-known age and distance, 2M1207 b appears to by "underluminous" by ~2.5 magnitudes compared to evolutionary models.

Is 2M1207 b "underluminous" because…

…of an edge-on disk of gray-extincting dust?

We model an edge-on disk around 2M1207 b where we assume 2M1207 b is a 1600 K AMES-Dusty brown dwarf with a radius set by evolutionary models. In this configuration, the edge-on disk must create 2.5 magnitudes of approximately gray extinction to explain the photometry of 2M1207 b. We find the following:

1) Small non-axisymmetric structures (approximated by inclination changes), which are thought to be present in most if not all young objects, would cause wild photometric variability that has not been observed.



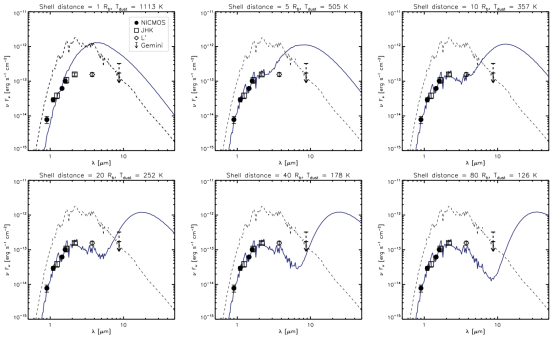
2) The disk inclination must be tuned in a way that is, a priori, very unlikely. This relates to our 3rd point.
3) Other young, low-mass objects (such as the HR 8799 planets) have been found that also appear to be underluminous. They cannot all be explained by edge-on disks.

Unlikely

…of an isotropic shell of gray-extincting dust?

We model an isotropic dust shell around 2M1207 b where we assume 2M1207 b is a 1600 K AMES-Dusty brown dwarf with a radius set by evolutionary models. In this configuration, the isotropic shell must create 2.5 magnitudes of approximately gray extinction to explain the photometry of 2M1207 b. We find the following:

1) Dust shells near the surface of the brown dwarf would emit blackbody radiation in the near-infrared at a level that is ruled out by near-infrared photometry.
2) Dust shells further from the surface would emit blackbody radiation in the mid-infrared at a level that is ruled out by our new Gemini 8.7 micron photometric upper-limit. This rules out dust shells at $R < 20\ R_b$ and $T > 250$ K.



No

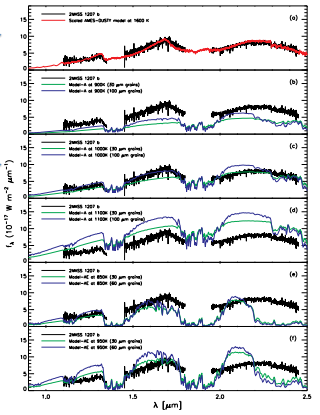
…it is cooler than originally thought?

We investigate the possibility that 2M1207 b is not a 1600 K object, despite the fact that its near-infrared spectrum is well fit by a 1600 K AMES-Dusty model scaled to a lower luminosity. Thick cloud models from Madhusudhan et al. (2011), might be able to reproduce the SED and near-infrared spectrum of 2M1207 b without an unphysical radius scaling. We find the following:

1) The 1000 K Madhusudhan A-models are able to reproduce 2M1207 b's low-luminosity, while mostly reproducing its near-infrared spectrum. With some tuning of non-equilibrium chemistry and gravity, these models might be able to explain 2M207 b's appearance, along with other objects in itsclass such as the HR 8799 planets.

Good fit with an unphysical radius →

Reasonable fit with a physical radius →



Maybe