Simulations results of a possible ring around the young brown dwarf G196-3B

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Overview

The origin of the very red optical and infrared colours of intermediate-age (∼50–500 Myr) L-type dwarfs remains unknown. It has been suggested that low-gravity atmospheres containing large amounts of dust may account for the observed reddish nature. We explored an alternative scenario by simulating protoplanetary and debris discs around G 196-3 B, which is an L3 young brown dwarf with a mass of ∼ 15-M_{Jup} and an age in the interval 20–300 Myr. The best-fit solution to G 196-3 B's photometric spectral energy distribution from optical wavelengths through 24 μm corresponds to the combination of an unreddened L3 atmosphere ($T_{\rm eff} \approx 1870$ K) and a warm (≈ 1270 K), narrow (≈ 0.01–0.13 $R_\odot$) debris disc located at very close distances (≈ 0.12–1.77 $R_\odot$) from the central brown dwarf (see Figures 1 and 2). The best-fit parameters and their error bars are indicated in Table 1. This putative inner dusty belt, whose presence is compatible with the relatively young system age, would have a mass of about 4×10^{-11} $M_\oplus$ comprised of sub-micron characteristic dusty particles with temperatures close to the sublimation threshold of silicates, but below the sublimation temperature of carbon particles. Considering the derived global properties of the belt and the disc-to-brown dwarf mass ratio, the dusty ring around G 196-3 B may resemble the rings of Neptune and Jupiter, except for its high temperature and thick vertical height ($\approx 10^4$ km). Our inferred debris disc model is able to reproduce G 196-3 B's spectral energy distribution to a satisfactory level of achievement except for the data at the longest wavelengths, where the one-ring fiducial simulation predicts less flux than the observations. This may suggest the existence of additional, exterior, colder rings in the system (see Figure 3). With current data, some parameters, like the surface density profile and the inclination angle of the disc, can not be properly constrained (see Figure 4).

Table 1. Best-fit face-on disc parameters.

Model	$R_{in}{}^a$ ($R_\odot$)	R_{out} ($R_\odot$)	T_d (K)	L_d ($\times10^{-5}$ $L_\odot$)	χ^2 (W m^{-2} μm^{-1})
Chiang & Goldreich protoplanetary disc	0.12	$0.60^{+0.01}_{-0.01}$	790^{+5}_{-10}	$3.95^{+0.20}_{-0.20}$	8.65×10^{-16}
Andrews & Williams protoplanetary disc	0.12	$0.35^{+0.01}_{-0.01}$	930^{+4}_{-4}	$5.74^{+0.16}_{-0.16}$	3.88×10^{-16}
Hughes et al. debris disc[b]	$0.35^{+0.18}_{-0.23}$	$0.37^{+0.22}_{-0.24}$	1270^{+10}_{-33}	$6.86^{+0.30}_{-0.01}$	3.07×10^{-17}

[a] The smallest possible inner radius is fixed at 0.12 $R_\odot$ in all computations (see Zakhozhay et al. (2015) for details).
[b] Dust particle size of 0.2 μm.

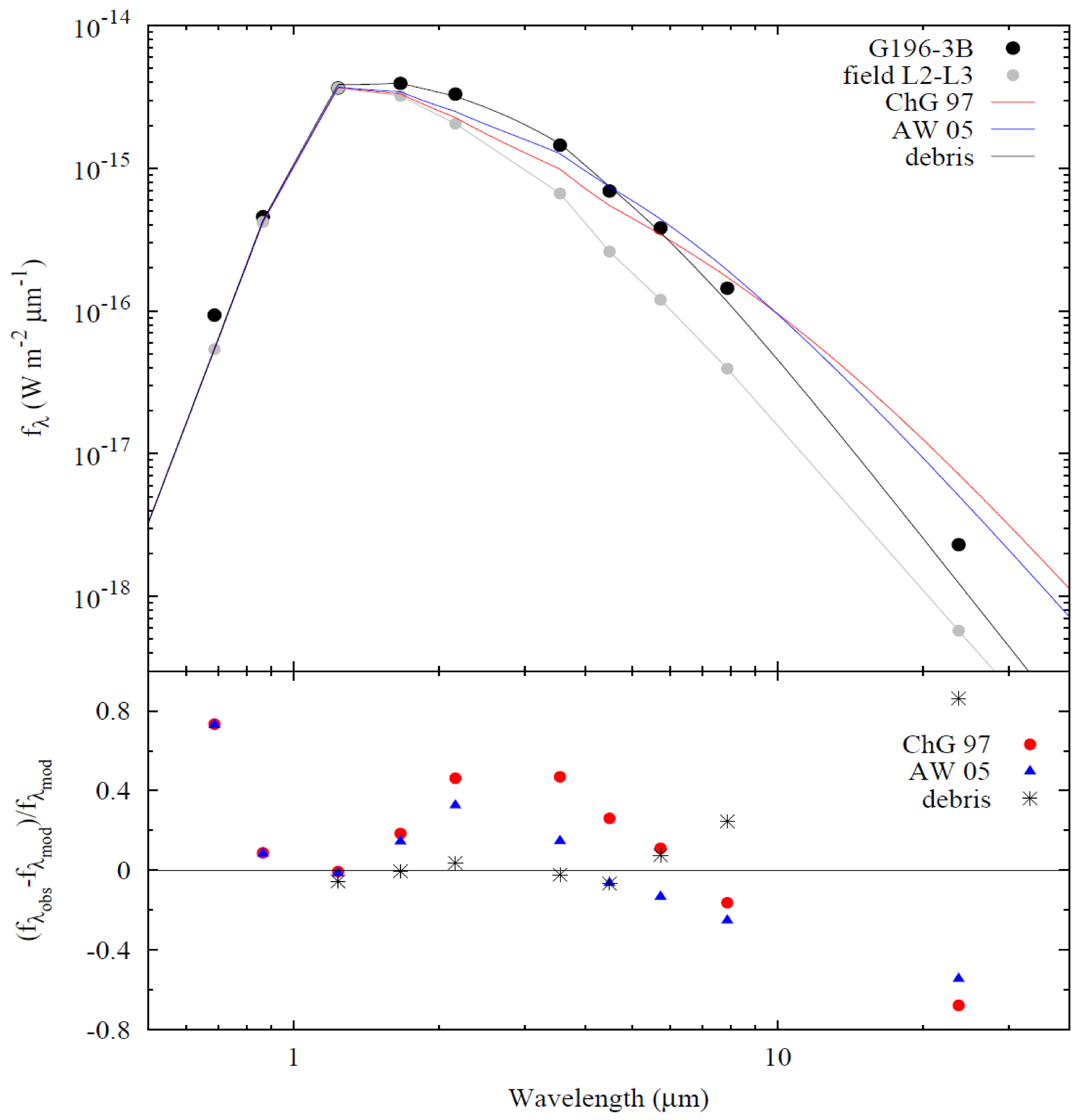

Figure 1. *(Top.)* The observed photometric SED of G 196-3 B (black dots, Zapatero Osorio et al. 2010) is shown in comparison with the best-fit face-on models: Hughes et al. (2011) debris disc (black solid line), Chiang & Goldreich (1997) primordial disc (red line), and Andrews & Williams (2005) protoplanetry disc (blue line). The photospheric emission of field L2–L3 dwarfs normalized to the J-band (1.25 μm) of the target is depicted by the gray dots and solid line. *(Bottom.)* Normalized residuals as a function of wavelength: debris disc (black asterisks), Chiang & Goldreich (1997) primordial disc (red circles), and Andrews & Williams (2005) protoplanetry disc (blue triangles).

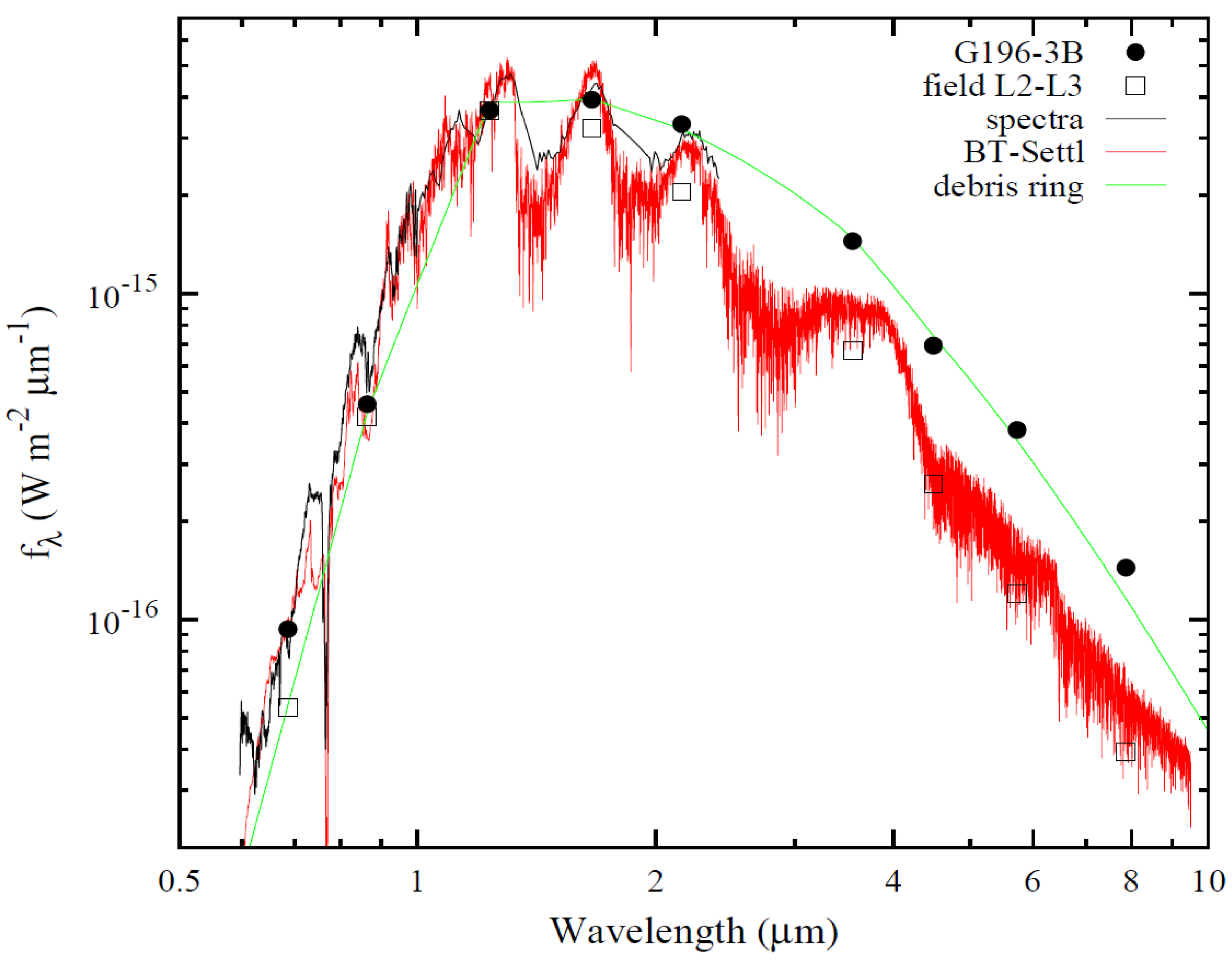

Figure 2. Spectral and photometric energy distribution of the L3 dwarf G 196-3 B (black solid line and dots) is compared with the BT-Settl spectrum (red line) of solar metallicity, $\log g = 4.5$ [g cm^{-2}], and $T_* = 1800$ K (Allard et al. 2003, 2012)) normalized to the J-band of the observations. The photospheric emission of field L2–L3 dwarfs is shown with open squares. The green line denotes our best fit solution provided by the debris ring model.

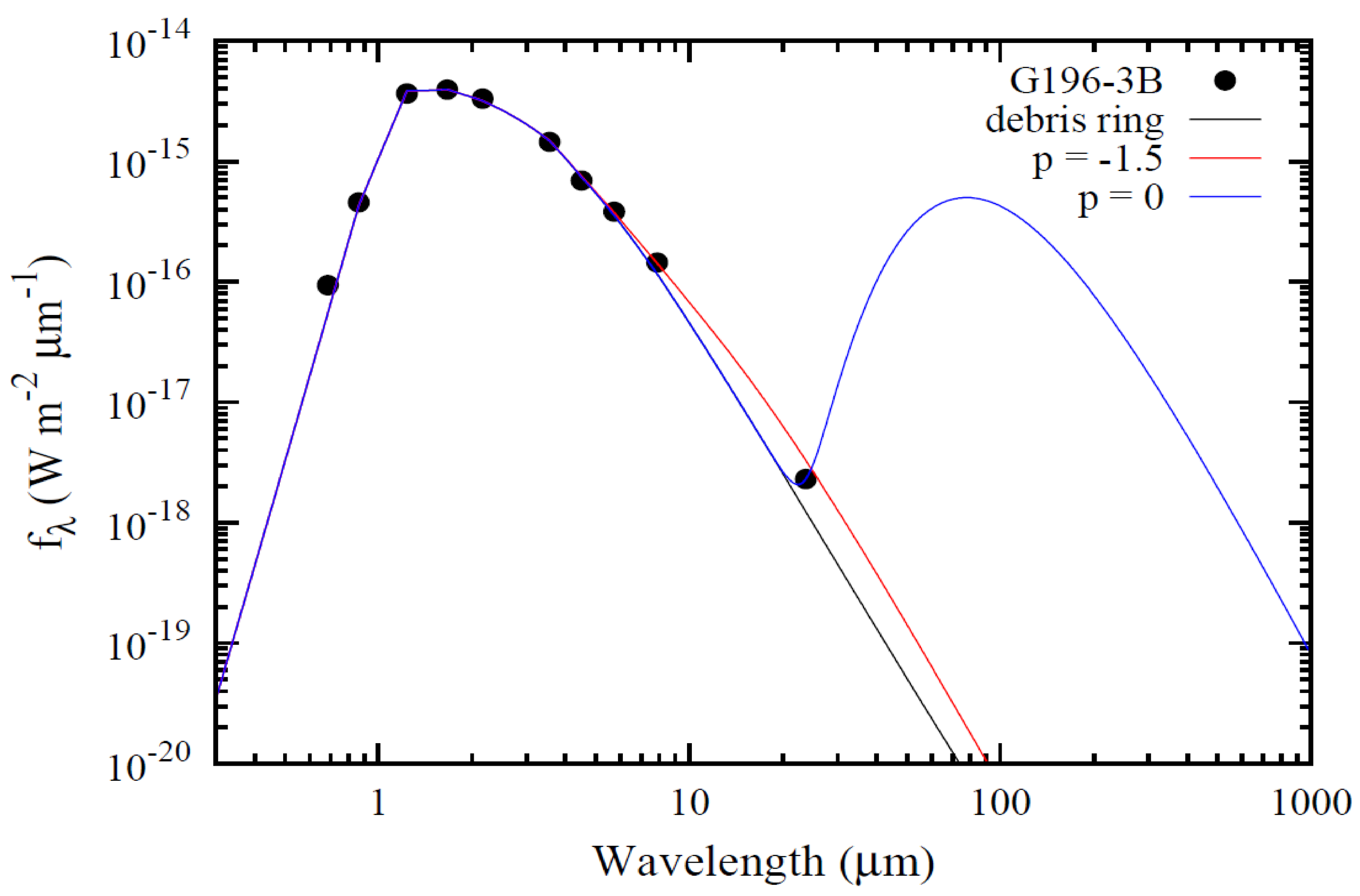

Figure 3. The photometric SED of G 196-3 B (dots) is compared with computations including one inner ring (black line, Table 1) and a combined inner ring and an outer disc of different surface density exponents p (blue and red lines).

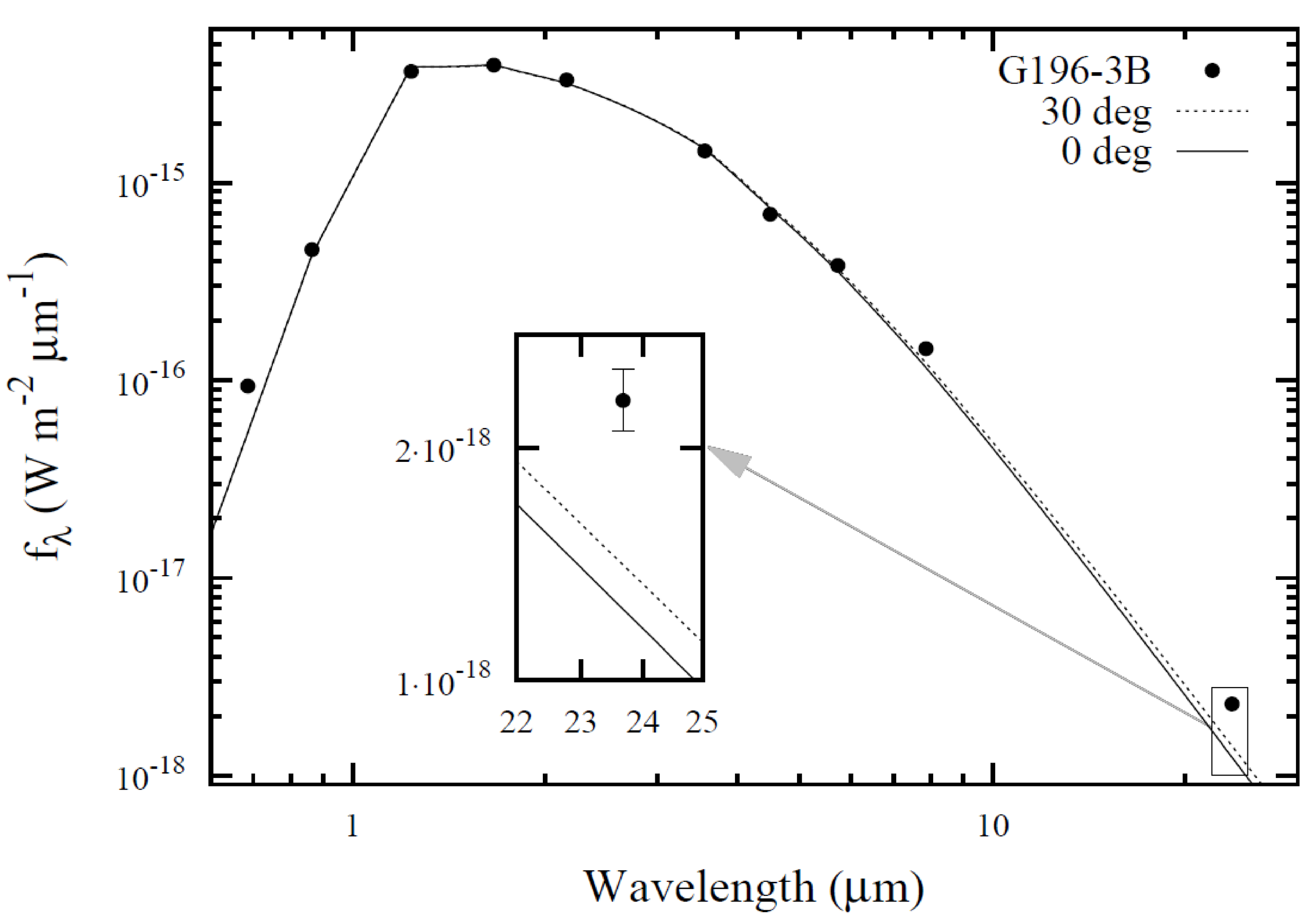

Figure 4. The SED of G 196-3 B is depicted (black dots) along with the best-fit computations according to the Hughes et al. (2011) debris disc model with face-on orientation (solid curve) and with inclination angle $i = 30°$ (dotted curve). The inner and outer belt radii are 0.35 and 0.37 $R_\odot$, the disc half thickness is 0.007 $R_\odot$, and the characteristic particle size is 0.2 μm.

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