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DUST EMISSION IN THE SAGITTARIUS B2 MOLECULAR CLOUD CORE

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ABSTRACT

We present a model for the dust emission from the Sagittarius B2 molecular cloud core which reproduces the observed spectrum between 30 μ and 1300 μ, as well as the distribution of the emission at 1300 μ. The model is based on the assumption that Sgr B2(N) continuum source is located behind the dust cloud associated with Sgr B2(M) continuum source. The fact that Sgr B2(N) is stronger at 1300 μ can be attributed to a local column density maximum at the position of this source. Absence of a 53 μ emission peak at the position of Sgr B2(N) suggests that the luminosity of the north source is lower than that of the middle source.

I. OBSERVATIONS

We have observed the 1300 μ continuum emission in the Sgr B2 molecular cloud core, using the 14 m FCRAO radome enclosed telescope at New Salem, Massachusetts. The receiver system comprised two cooled Schottky diode receivers sensitive to orthogonal linear polarizations with an IF bandwidth of approximately 500 MHz. The LO frequency of 230.2 GHz was selected to be free of any strong line emission. The data were taken on three days in February and March 1988 and consist of 45 positions with 15″ spacing and 16 positions with 20″ spacing centered at the position of Sgr B2(M) continuum source ($\alpha_{1950} = 17^h44^m10.5^s$, $\delta_{1950} = -28°22'05''$). The size of the mapped region is 1′ × 2′. The receivers were tuned for double sideband operation. A typical double sideband system temperature referred to above the Earth's atmosphere at the low elevation characteristic of Sgr B2 was 1900 K. A 4 minute integration time gave an observed r.m.s. fluctuation level of about 40 mK (1σ). Saturn was used for pointing and calibration. The FWHM beam size was measured to be 23″, and the beam efficiency was about 0.1 . The resulting conversion from the observed antenna temperature to the unpolarized flux density in 23″ beam is 185 Jy K^{-1}. A contour map of the emission, presented in Fig. 1, shows a qualitative agreement with the first data set obtained in 1986 (Goldsmith, Snell and Lis 1987), except of a small difference in declination of the peak of the emission. Each of the three data sets which are averaged in Fig. 1 shows the same distribution of the emission. The peak antenna temperature of 0.31 K (equivalent to the flux density of 58 Jy) is observed at the (0,40″) position corresponding approximately to the Sgr B2(N) continuum source. The antenna temperature observed at the position of the Sgr B2 (M) source is 0.24 K (equivalent to 45 Jy).

II. MODEL OF THE SOURCE

An acceptable model of the source should be able to reproduce the observed spectrum of the continuum emission, as well as to explain the absence of the 53 μ emission peak coincident with the maximum of the 1300 μ emission at the position of Sgr B2(N) (Harvey, Campbell, and Hoffmann 1977). We have modeled the source structure using the radiation transfer code of Egan, Leung, and Spagna (1988). We first find an equilibrium temperature distribution for Sgr B2(N) and Sgr B2(M) assuming spherical symmetry and no interaction between both sources. Then we compute the observed flux convolved with a Gaussian beam assuming that Sgr B2(N) is located behind the dust cloud associated with Sgr B2(M), and the emission from this source is therefore attenuated by cold foreground dust. The observations of the $J=1\rightarrow0$ transition of $C^{18}O$ (Lis and Goldsmith 1988) suggest that the molecular cloud associated with Sgr B2(M) has a radius of about 22.5 pc and consists of a constant density envelope with an H_2 density of about 2200 cm^{-3} surrounding a central region with a power law density distribution with an exponent of -2 extending inward to about 1.25 pc. The average density within inner 1.25 pc is about 5.7×10^4 cm^{-3}. We have used this as a starting point for our calculations. From the small source size at 1300 μ it is clear that the emission originates from a small high density core of the cloud. Due to small beam filling factor and high temperature this core does not show up in the $C^{18}O$ emission. We have assumed the core to be a Gaussian and have taken the FWHM size (D_N) and central density (n_N) as parameters of the model. For Sgr B2(N) we have assumed a simple Gaussian core and a constant density envelope of the same density as for Sgr B2(M). For simplicity we have assumed the same radii of the envelopes. Density distributions for

Fig. 1.

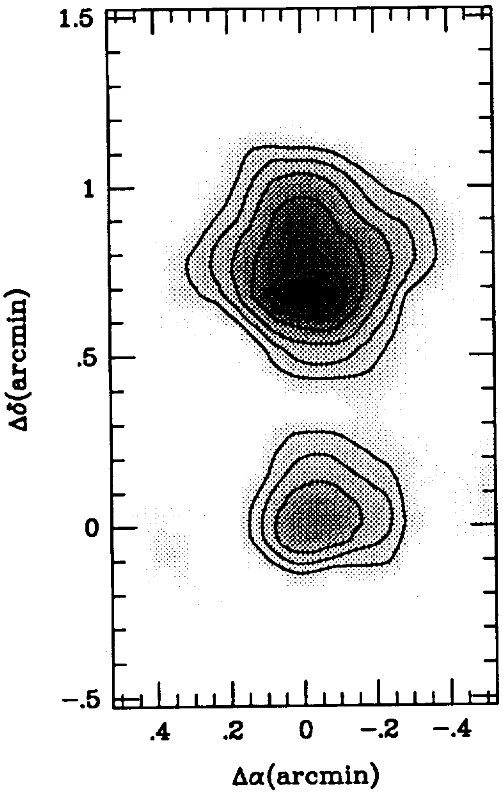


Fig. 2.

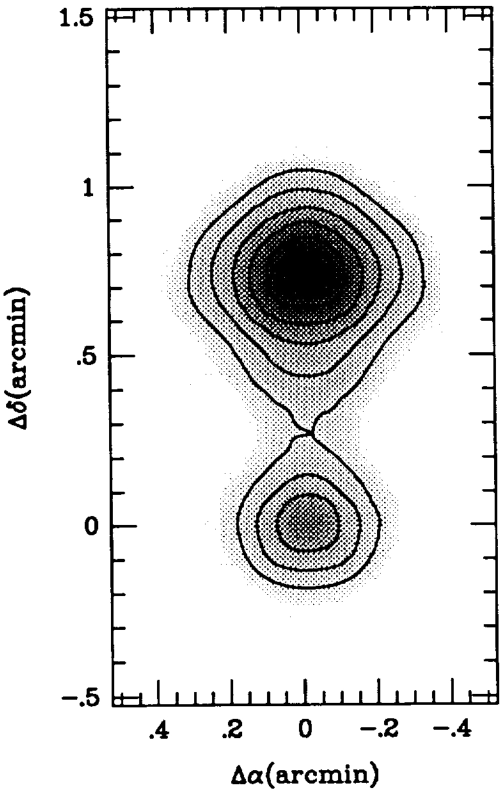
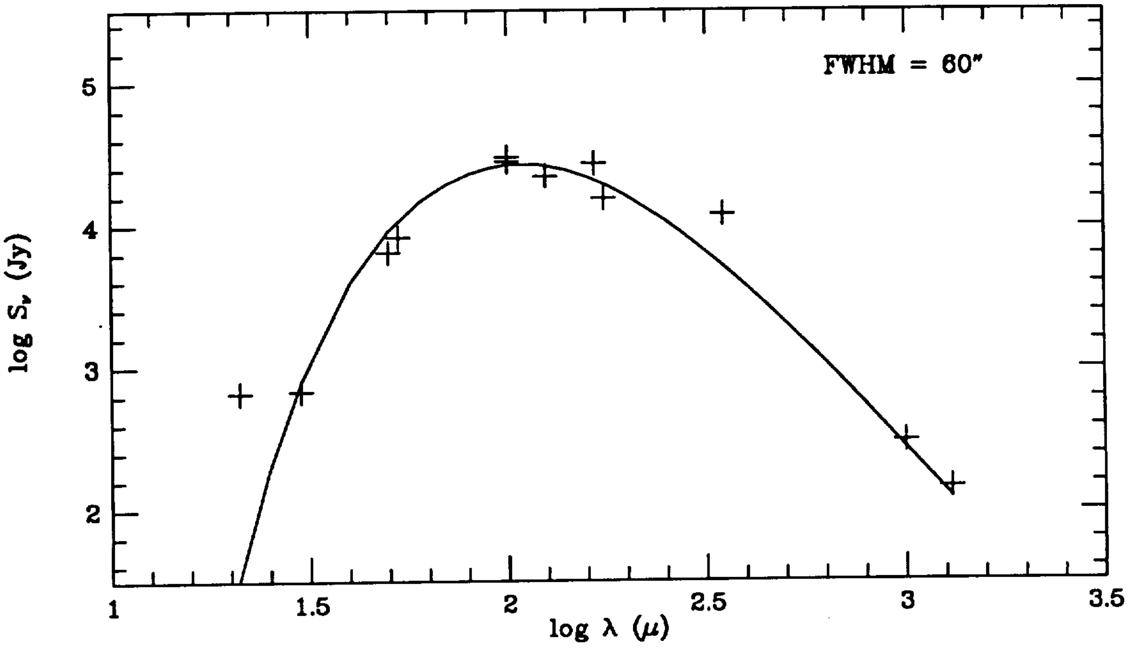


Fig. 3.



both sources as described above have been then scaled to give a required optical depth at 100 μ. Other important input parameters of the model are luminosities and temperatures of the central objects (L_N, L_M, T_N, T_M). We have used standard grain model with 0.1 μ radius and density of 3 g cm^{-3}. The grain emissivity varies as λ^{-1} between 0.1 and 100 μ and as λ^{α} for wavelengths longer than 100 μ, α being again a parameter varied in the computations. Based on a series of test runs we conclude that the wavelength of the peak of the convolved spectrum is sensitive mainly to the optical depth of the middle source (τ_M). The fact that the peak occurs at the wavelength of about 100 μ suggests that the optical depth at this frequency is relatively high. The flux at the peak is a function of the luminosity of the middle source. The 1300 μ flux is not very sensitive neither to the luminosity nor the temperature of the central star. It is mainly a function of the column density (or τ) and α. The 100 μ optical depth of the north source (τ_N) is, therefore, given by the optical depth of the middle source and the north-to-middle peak flux ratio at 1300 μ. The absence of the peak of the 53 μ emission at the position of Sgr B2(N) imposes an upper limit for the luminosity of the north source.

In this paper we present a model that successfully predicts distribution of the emission at 1300 μ, observed spectrum between 20 and 1300 μ and is consistent with the $C^{18}O$ data. The range of relevant parameters for which a good fit to the data is obtained has yet to be determined. The parameters of our model are presented in Table 1. Figure 2 presents distribution of the emission from our model cloud at 1300 μ, and Figure 3 the observed flux in 60″ beam as a function of wavelength.

III. CONCLUSION

We have presented a model for the dust emission from the Sgr B2 molecular cloud core. The model successfully predicts the observed spectrum of the continuum emission between 30 μ and 1300 μ and the observed distribution of the emission at 1300 μ. Sgr B2(N) is less luminous than Sgr B2(M) and the peak of the 1300 μ emission at the position of the north source is a result of a local column density maximum. This together with the fact that Sgr B2(N) is located behind the dust cloud associated with Sgr B2(M) continuum source explains why no peak of the 53 μ emission is detected at the position of Sgr B2(N). Observations of the 350 μ emission would be especially useful to test our model, because it predicts the peak fluxes from both sources to be approximately equal at this frequency.

Table 1. - Model parameters.

Parameter	M	N
$L(L_\odot)$[a]	1.0×10^7	5.1×10^6
$T(K)$[b]	$4. \times 10^4$	$4. \times 10^4$
$\tau_{100}(0'')$[c]	2.2	2.1
$\tau_{100}(23'')$	1.7	-
$\tau_{100}(60'')$	0.9	-
$D_{core}(pc)$[d]	0.5	1.1
$n_{grain}(cm^{-3})$[e]	7.0×10^{-6}	3.5×10^{-6}
$n_{H_2}(cm^{-3})$[f]	2.5×10^6	1.3×10^6
α[g]	1.4	1.4
$N_{H_2}(0'')$[h]	5.4×10^{24}	-
$N_{H_2}(23'')$	2.0×10^{24}	-
$N_{H_2}(60'')$	1.1×10^{24}	-
$N_{H_2}(core)$[i]	4.1×10^{24}	4.4×10^{24}

[a] Total luminosity of the central star.

[b] Temperature of the central star.

[c] 100 μ optical depth for different beam sizes.

[d] FWHM size of the core.

[e] Grain density at the center.

[f] H_2 density at the center assuming standard gas to dust ratio of 100 by mass.

[g] Grain emissivity law slope for $\lambda > 100\ \mu$.

[h] H_2 column density for different beam sizes.

[i] H_2 column density through the core.

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