THE ASTROPHYSICAL JOURNAL, 182:L125–L129, 1973 June 15

THE H II REGION G333.6—0.2, A VERY POWERFUL 1–20 MICRON SOURCE

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Received 1973 March 19; revised 1973 April 16

ABSTRACT

G333.6—0.2 has been found to be one of the brightest 20-micron sources in the sky, and the most luminous H II region known in the wavelength range 1–25 μ. Despite its high luminosity it consists of only a single component with a diameter of 11″ (0.2 pc). The source appears to be a dust-filled compact H II region.

Subject headings: infrared sources — nebulae, individual

I. INTRODUCTION

G333.6—0.2 is one of the brightest radio sources studied by Goss and Shaver (1970) in their 4 arc min resolution observations of southern-hemisphere H II regions; at 5 GHz it emits 84 f.u. (1 f.u. = 10^{-26} W m^{-2}Hz^{-1}) and has a full width to half-maximum of 1.′1 (Shaver and Goss 1970). The H II region is totally obscured at optical wavelengths but is known to be associated with OH and H_2O radio line sources (Goss, Manchester, and Robinson 1970; Johnston *et al.* 1972). Assuming that the source is at a distance of 4 kpc (Goss *et al.* 1972), the radio flux density implies that one or more very early-type stars are necessary to ionize the region, and thus the source may be comparable in its physical properties to well-known northern H II regions like W3 (Wynn-Williams, Becklin, and Neugebauer 1972, hereinafter referred to as WBN).

II. OBSERVATIONS

All observations were made with the 1-m telescope of the Carnegie Institution of Washington at Las Campanas, Chile, in 1972 April and September. Those at 1.25, 1.65, 2.2, and 3.5 μ employed a PbS photoconductor, and those at 4.8, 10, and 20 μ were made with a Ge-Ga bolometer; both systems utilized cooled focal-plane apertures and filters.

Searches at 2.2 μ over an area 5′ × 5′ centered on the radio continuum position yielded only one source above a level of 0.1 f.u. Subsequent observations at other wavelengths with various aperture sizes (figs. 1 and 2) were confined to this source.

The position of the infrared source was measured by offsetting from nearby stars whose positions were subsequently determined relative to Smithsonian Astrophysical Observatory standard stars on plates from the Harvard College Observatory plate collection. As can be seen in table 1, the positions at 2.2 and 20 μ coincide to within the experimental error. The positions of the infrared and radio line and continuum sources also agree, although the radio determinations have low precision.

The size of the source was determined from scans across it with a slit 10″ wide at 10 and 20 μ, and from variable-aperture photometry at several wavelengths (see fig. 2) to be approximately 11″ in diameter (0.2 pc at 4 kpc).

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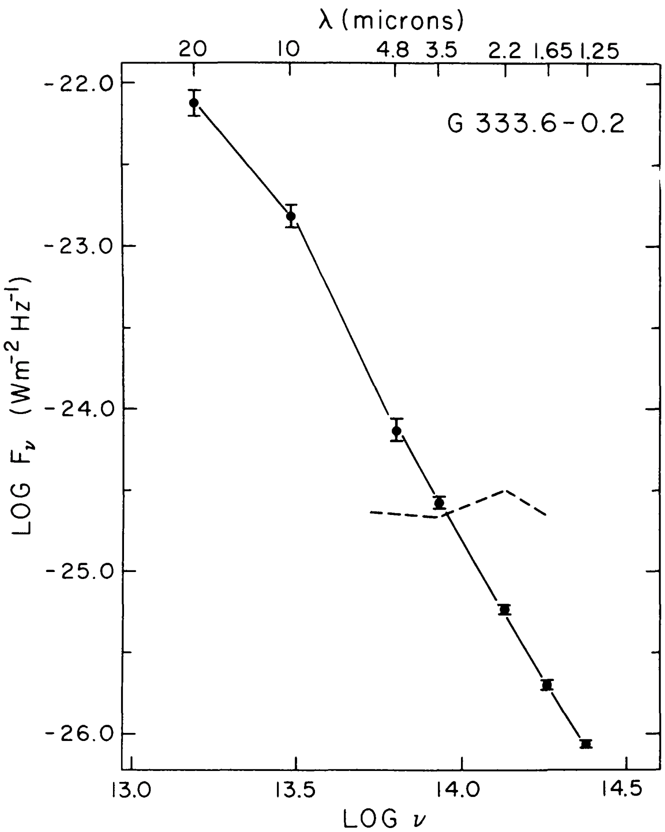

FIG. 1.—The infrared energy distribution of G333.6—0.2. The flux densities have been normalized to an aperture of 45″ diameter. The dashed line represents the fluxes expected in the various infrared bands from thermal emission from ionized hydrogen, assuming that there is no self-absorption at 5 GHz (from Willner, Becklin, and Visvanathan 1972).

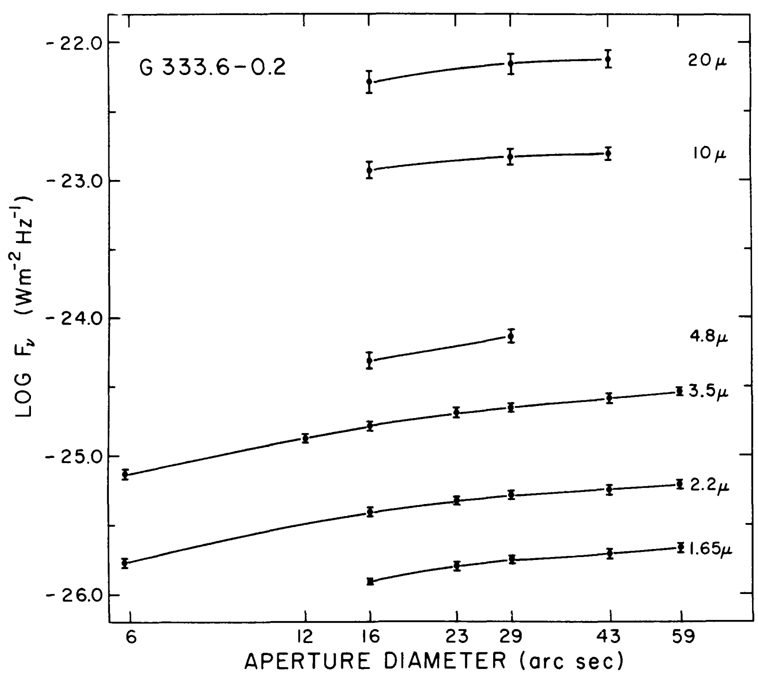

FIG. 2.—The flux density versus aperture diameter relations for G333.6—0.2.

TABLE 1

POSITIONS OF G333.6—0.2 (1950.0)

Type of Observation	R.A.	Decl.	Reference
2.2 μ	$16^h18^m27.1^s \pm 0.7^s$	$-49°58'52''.5 \pm 5''$	This paper
20 μ	16 18 27.1 ± 0.7	−49 58 54.0 ± 5″	This paper
5 GHz	16 18 26 ± 5	−49 58.9 ± 0′.5	Shaver and Goss 1970
OH	16 18 27 ± 13	−49 58.3 ± 2′	Goss *et al.* 1970
H_2O	16 18 27 ± 10	−50 00.0 ± 0′.5	Johnston *et al.* 1972

III. RESULTS

G333.6—0.2 is an exceptionally bright source at 20 microns; its observed flux density, which comes from a single compact region, is more than four times the total flux density of the compact sources in W3 (WBN).

a) The Energy Distribution of the Source

The infrared energy distribution of G333.6—0.2 (fig. 1) is qualitatively similar to that of other H II regions, such as W3, W49, and K3-50 (WBN; Becklin, Neugebauer, and Wynn-Williams 1973; Neugebauer and Garmire 1970); the flux density falls steeply from 20μ to 1.2 μ, the emission at the longer wavelengths being much greater than, and the emission at the shorter wavelengths much less than, that expected from thermal emission from ionized hydrogen. As in W3, we interpret the excess longward of 3 μ as being due to thermal emission from dust grains. Although the contribution from heated dust to the emission shortward of 3 μ is unknown, following WBN it may be deduced from the ratio of 1–3 μ to radio flux density that the extinction toward G333.6—0.2 is at least 15 magnitudes at visible wavelengths. Since the data of Georgelin and Georgelin (1970) show that for stars in the vicinity of G333.6—0.2 the visual extinction is not more than 4 mag, it is probable that a significant fraction of the obscuring matter is physically associated with, though exterior to, the H II region itself, as in W3.

The longer-wavelength fluxes have been used (table 2) to derive the mean brightness temperature and color temperature of the dust in the central 11″ of the source as a function of wavelength. The color temperature was calculated from the slope of the energy distribution at each wavelength, assuming gray-body emission. It can be seen that both the color and brightness temperatures vary strongly with wave-

TABLE 2

DERIVED PARAMETERS* OF G333.6—0.2

Effective λ(μ)	Brightness Temperature (°K)	Color Temperature (°K)
3.5	222	520
4.8	187	410
10	130	260
20	98	170

* The parameters, as a function of wavelength, were computed on the assumption that the emissivity of the dust does not change with wavelength. Forty percent of the observed 3.5-micron flux was attributed to recombination emission. All fluxes were corrected for absorption (15 mag in the visual), by using the van de Hulst no. 15 reddening law (Johnson 1968).

length, with the brightness temperature always much less than the color temperature. The optical depth at 20 μ is of the order of 0.05; a normal dust emissivity law would therefore imply an optical depth of order unity at visual wavelengths.

b) The Brightness Distribution of the Source

Spatial scans at 2.2, 10, and 20 μ show that G333.6—0.2 consists of a single extended component. The curves of flux density versus aperture (fig. 2) indicate that half of the infrared flux is emitted from an area only 11″ in diameter (0.2 pc), a result leading to the very high brightness temperatures derived for the source (table 2). Infrared observations of sources such as Orion A, W3, M17, and W49 (Ney and Allen 1969; WBN; Kleinmann 1973; Becklin *et al.* 1973) show that many H II regions consist of several components of comparable flux density. It is therefore of particular interest that such a powerful source as G333.6—0.2 contains, at least at infrared wavelengths, only a single component whose energy source must be either an extremely luminous star or a compact cluster of luminous stars.

The data in figure 2 also indicate that at all wavelengths observed, the infrared colors are independent of aperture diameter. In this respect G333.6—0.2 resembles W3(A)/IRS 1 (WBN) but is unlike fainter H II regions such as Sharpless 138, 152, and 270, in which the infrared colors become redder with increasing aperture (Frogel and Persson 1972). This result indicates that the dust temperature does not decrease appreciably with central distance in the nebula, as would be expected from simple models with radiative heating of the dust by a central star. The range in dust temperature indicated in table 2 probably arises as a result of a distribution of particle size within the nebula. If the emission shortward of 2 μ is dominated by thermal emission from ionized hydrogen, figure 2 indicates that the emission from the hot dust and the ionized gas have very similar spatial distributions. From the flux versus aperture distribution in figure 2 we conclude that there is a steep decline away from the center in both the dust and the gas emissivity per unit volume.

The fact that the half-width of the H II region at 2.2 μ is much less than that at radio wavelengths is probably due to the presence of an extended low-brightness envelope of ionized gas. At infrared wavelengths the contribution from this envelope would be underestimated as a result of beam-switching, whereas at 408 MHz, where the H II region has an apparent diameter of 3′.1 (Shaver and Goss 1970) the envelope would be more prominent as a result of self-absorption in the central high-emission measure region of the source.

c) The Luminosity of G333.6—0.2

Between 1 and 25 μ, G333.6—0.2 is the most luminous H II region known, radiating $5 \times 10^5\ L_\odot$ in this wavelength range. This value is significant because, if allowance is made for the probable emission longward of 25 μ, the luminosity of the source exceeds the $4 \times 10^5\ L_\odot$ available from the absorption by dust of resonantly scattered Lα radiation. This latter quantity is calculated from Rubin's (1968) formula and on the assumption that there is no self-absorption at 5 GHz. This result implies that the dust inside the H II region may be thick enough to absorb a significant fraction either of the visible radiation from the H II region or of the primary ionizing stellar radiation in the nebula. Further speculation as to the nature of this object is not warranted by the present observations; high angular resolution measurements of G333.6—0.2 at radio and far-infrared wavelengths are essential.

J.A.F. and S.E.P. thank Dr. H. W. Babcock for guest observer privileges at Las Campanas. We also acknowledge several interesting discussions with Drs. H. M. Johnson, T. de Jong, and M. Litvak. All of us greatly appreciate the assistance received from the staff at Las Campanas, and we especially thank our night assistant Sr. A. Zúñiga. Part of this work was performed under National Aeronautics and Space Administration grant NGL 05-002-207.

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