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IRAS 18059–3211: OPTICALLY KNOWN AS "GOMEZ'S HAMBURGER"

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ABSTRACT

Spectra, polarimetry, and infrared and visual photometry of this recently discovered object are discussed. A scenario of an A0 III type star embedded in a torus of hot dust surrounded by a cloud of colder dust is suggested. The object is believed to be at an advanced evolutionary stage possibly related to the formation of a planetary nebula.

Subject headings: nebulae: individual (IRAS 18059–3211) — nebulae: reflection — photometry — polarization — spectrophotometry

I. INTRODUCTION

In 1985 May one of us (A. G.) discovered a nonstellar fuzzy object about 3″.5 by 5″.5 in size, on a plate taken with the 1.5 m telescope at CTIO. Due to its morphology, namely a bunlike shape with an equatorial absorption band (see Fig. 3*b*), the object became known as "Gomez's Hamburger." The discovery plate was taken as part of a survey for RR Lyrae stars in the Galactic bulge near $l = 0°$, $b = -5°.8$. The area was selected for having low reddening; the globular cluster NGC 6558, less than 30′ from "Gomez's Hamburger" has an $E(B - V) = 0.41$ (Zinn 1980). The area of the sky covered by the plate, about one square degree, is a "window" through the galactic plane, free of emission regions and dark clouds, where there is a uniform distribution of stars belonging to the Galactic bulge. A fuzzy object like this, in a gas- and dust-free window, seems very peculiar. The coordinates for the object are $\alpha(1950.0) = 18^h05^m57^s.5$ and $\delta(1950.0) = -32°11'20''.6$; $l = 359°.7$ and $b = -6°.0$; Figure 1 (Plate L2) is a finding chart.

The coordinates correspond exactly with the *IRAS* point source 18059–3211.

II. OBSERVATIONS

a) *Spectroscopy*

Blue and red spectrograms of the object were obtained using the 4 m and 1.5 m telescopes at CTIO. At the 4 m telescope we used the RC spectrograph, with the 2D-Frutti as detector, to cover the spectral range from 3600 to 6600 Å with 4 Å resolution. The slit was 2″ by 50″ in size oriented E-W. A second spectrum covering the wavelength range from 6000 Å to 9400 Å with 16 Å resolution was obtained using the Cassegrain spectrograph attached to the 1.5 m telescope with a GEC CCD as a detector; the slit oriented E-W was 4″ by 3′.5 in size.

The spectrum shows strong Balmer absorption lines and no narrow emission lines or broader molecular features are evident. The wavelengths of the line centers are consistent with a zero radial velocity.

Figure 2*a* shows a composite spectrum of the object in which the blue and red spectra described above have been combined by rebinning the blue spectrum to the resolution of the red one and scaling its flux to match over the region of overlap. Because of the different apertures used to obtain the two spectra, colors from Figure 2*a* will be inaccurate if there is substantial color gradient across the object. Figure 2*b* shows the blue end of the blue spectrogram described above at full resolution.

b) *Photometry*

In 1985 September *UBVRI* photoelectric photometry of the object was obtained at the CTIO 1 m telescope, equipped with a standard photometer, a dry-ice cooled Hamamatsu Ga-As photomultiplier, and the standard Tololo set of *UBVRI* filters described by Graham (1982). Standard stars were also selected from the list published by Graham (1982). Table 1 gives the average and the mean deviation of four observations of the object made through an aperture of 16″.9, completely containing the object (3″.5 by 5″.5 in size).

Infrared photometry was obtained in 1985 July with the D3 InSb system attached to the CTIO 1.5 m telescope. An $f/30$ chopping secondary, with N-S 30″ beam-switching, was used. The aperture was 13″.7 in diameter. The IR photometric results given in Table 2 are on the CIT/CTIO photometric system defined by Elias *et al.* (1982).

c) *Polarimetry*

We obtained nine direct RCA CCD images on 1986 September at the Cassegrain focus (f/13.5) of the CTIO 1.5 m telescope; the scale was 0″.3 per pixel. The frames were taken using a combination of *V* filter and polarizing sheets oriented at 0°, 45° and 90°. Three images were taken at each orienta-

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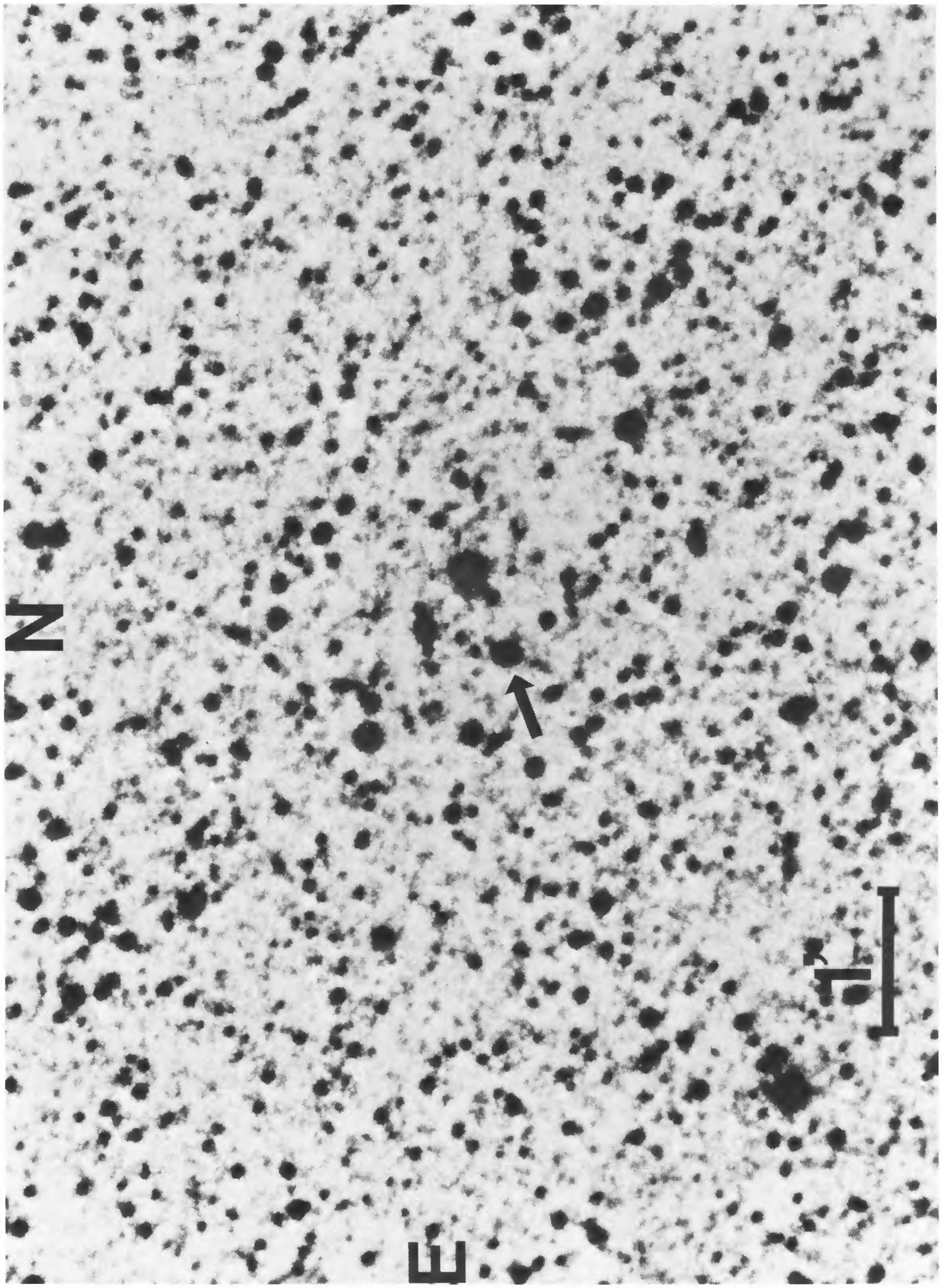

FIG. 1.—The position of the object is indicated on a reproduction of the ESO (B) survey plate

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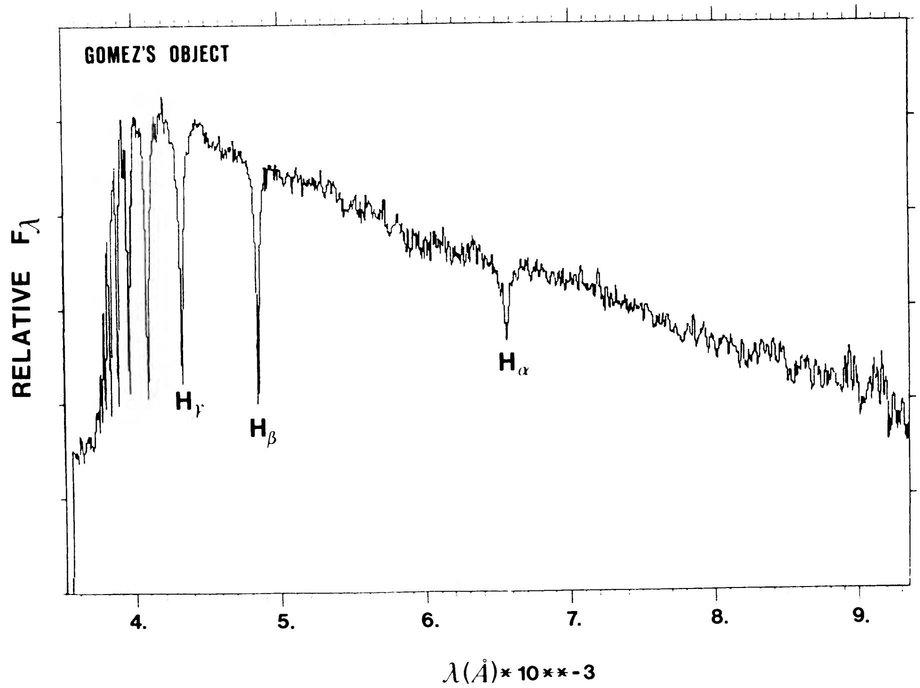

FIG. 2*a*

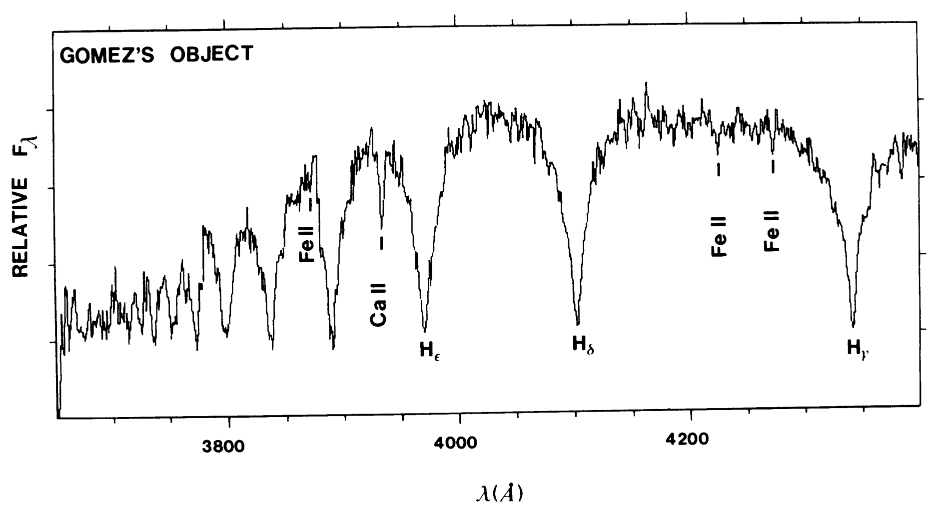

FIG. 2*b*

FIG. 2.—(*a*) Composite/spectrum (2D-Frutti plus CCD spectra combined) of Gomez's object. The resolution is 16 Å. (*b*) Blue end of the spectrum taken with the CTIO 4 m telescope and a 2D-Frutti detector at 4 Å resolution.

TABLE 1

UBVRI PHOTOMETRY

Color	Value
V...........	14.44 ± 0.01
$U - B$.......	0.43 ± 0.02
$B - V$.......	0.54 ± 0.02
$V - R$.......	0.41 ± 0.02
$R - I$.......	0.38 ± 0.02

TABLE 2

IR PHOTOMETRY

Parameter	Value
K..........	11.87 ± 0.04
$J - K$......	1.22 ± 0.005
$H - K$	0.66 ± 0.03
CO	0.24 ± 0.06

tion. Each group of three images was carefully combined and cosmic rays removed. The resultant images were shifted, convolved with appropriate Gaussians to match the seeing profiles, and scaled in intensity using three stars as reference images. Therefore, the three final images are coincident and of comparable seeing and are adjusted in intensity so that the sky and reference stars show no polarization. From these three images we constructed normalized Q and U maps, from which the percent polarization p and position angle θ (relative to some arbitrary zero point) could be determined. The polarization p was corrected at low signal-to-noise ratio using an approximation to the formula given by Wardle and Kronberg (1974). The results are shown in Figure 3 (Plate L3). The figures of the polarization and relative position angle have been masked at twice the sky level to suppress the spurious polarization values in the sky.

The polarization is small near the center of the object and increases smoothly away from the center. The maximum measured polarization in the SW lobe of the object is 21.4% ± 1.5% averaged over one square arcsecond. To the SE, the polarization increases to the edge of the mask, indicating that the region of maximum polarization may not have been detected.

The position angle map (Fig. 3*c*) shows radial symmetry about a point near the center of the object, implying scattered light from a central illuminating source.

III. DISCUSSION

The absence of He absorption lines in the spectrum of "Gomez's Hamburger" suggests the spectral type of the embedded star cannot be earlier than B9, while the small Ca II K line compared to Hε indicates a spectral type no later than A1. We conclude that a spectra type A0 is the best match to the observed spectra.

In the higher resolution spectra of the object one can identify lines of Fe II in absorption of the type seen in giants and supergiants suggesting that the central star is not a main-sequence star.

If we assume the star to be a supergiant we get $E(B-V) = 0.56$ and $E(U-B) = 0.77$ implying $E(U-B)/E(B-V) = 1.38$ (Schmidt-Kaler 1965); such a ratio so far from the canonical value 0.72 would require the presence of very peculiar dust (Martin 1978). On the other hand assuming the star to be a giant, we get $E(B-V) = 0.56$, $E(U-B) = 0.46$, and $E(U-B)/E(B-V) = 0.82$, consistent with normal reddening. This result is consistent with Racine's finding that scattered *UBV* light in reflection nebulae follows the standard reddening line (Racine 1971). Nonetheless one should be aware of the fact that the above argument fails if the reddening is abnormal, a possibility that cannot be excluded given the peculiar nature of this object.

Thus, the spectroscopic constraints indicate that the central object is not a main-sequence star, while the photometric argument given above suggests that it is also unlikely to be a supergiant. We therefore favor the hypothesis that the embedded star is an A0 III, which implies an $M_v = -0.6$ (Corbally and Garrison 1984).

Fluxes have been computed using Bessell's calibration of *UBVRI* magnitudes in W m^{-2} Hz^{-1} units (Bessell 1979); they are given in Table 3 and plotted in Figure 4 together with the corresponding fluxes for HD 44179 and M1-92 obtained from Cohen *et al.* (1975), Herbig (1975), and the *IRAS* Point Source Catalogue. Clearly "Gomez's Hamburger" is very similar to the other two objects, namely an early-type star embedded in a torus-like distribution of dust. The close resemblance between the optical flux distribution from HD 44179 and "Gomez's Hamburger" suggests that their central stars might be similar. Cohen *et al.* (1975) concluded that in

TABLE 3

FLUXES (10^{-26} W m^{-2} Hz^{-1})

λ (μm)	F
0.36 (*U*)	0.0012
0.44 (*B*)	0.0043
0.55 (*V*)	0.0061
0.64 (*R*)	0.0075
0.79 (*I*)	0.0088
1.25 (*J*)	0.0100
2.20 (*K*)	0.0110
12.00	0.6200
15.00	1.6100
60.00	17.7700
100.00	14.2600

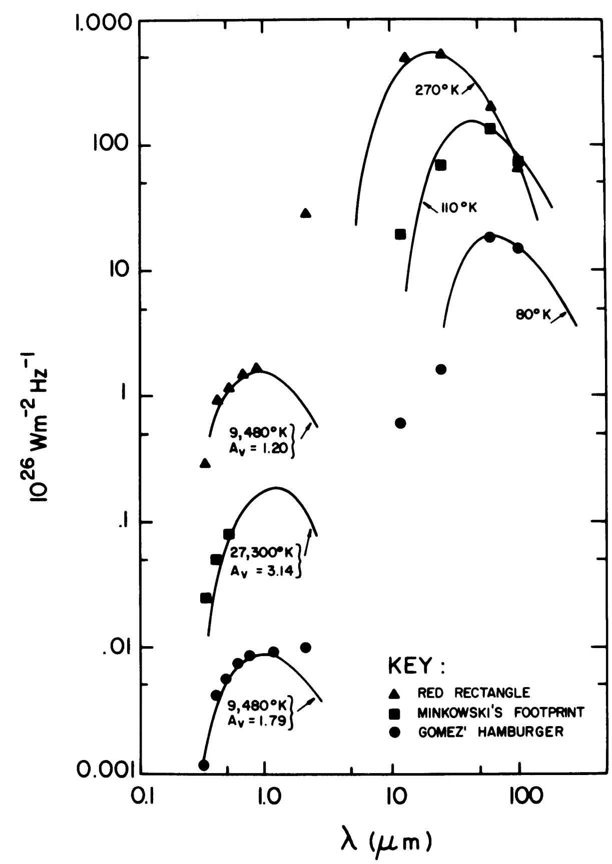

FIG. 4.—Flux distribution for "Gomez's Hamburger" shown along with those for the Red Rectangle and Minkowski's Footprint. Blackbodies have been fitted to their optical and infrared fluxes.

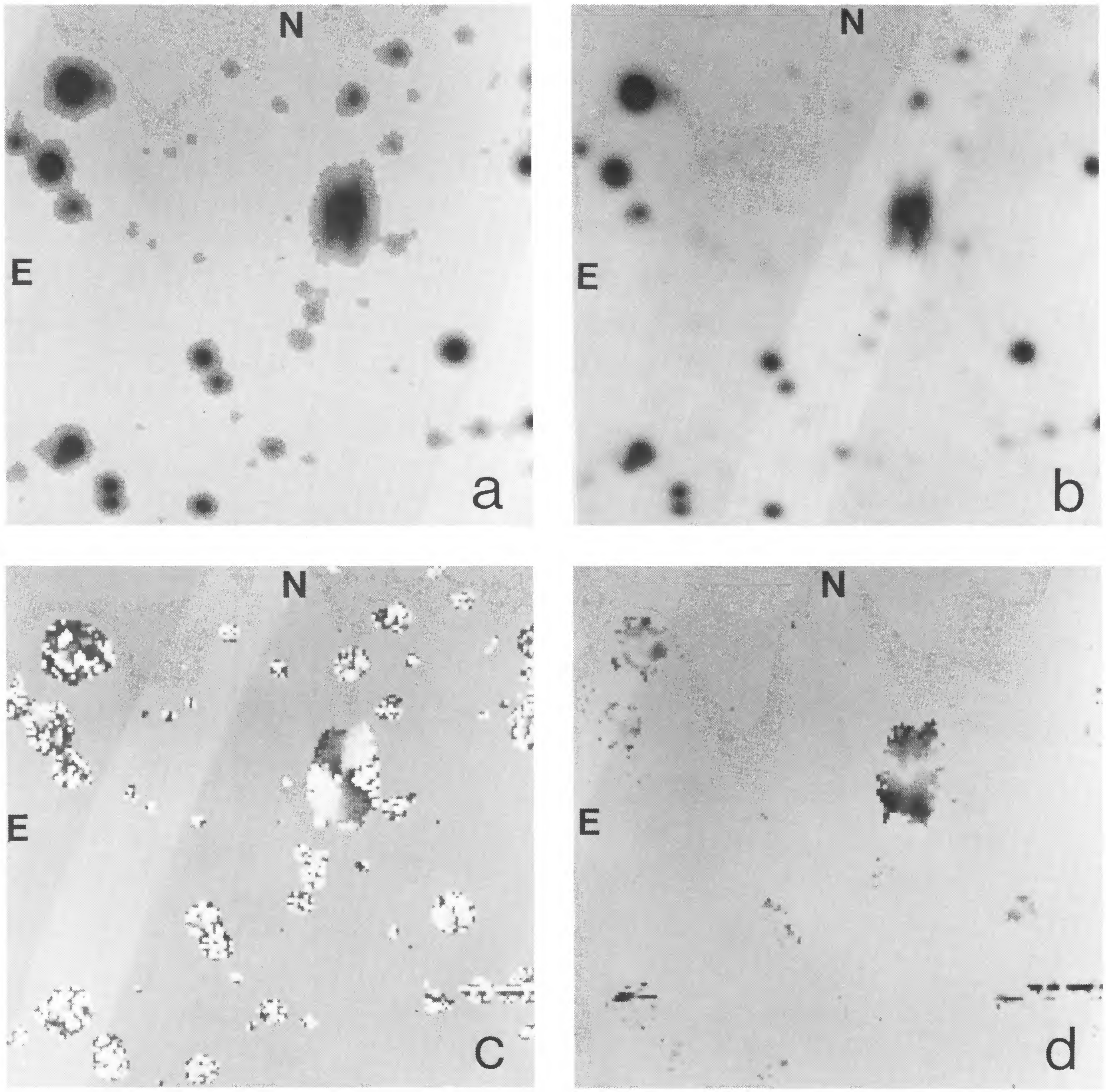

FIG. 3.—(a) and (b) CCD frames taken through a V filter. Fig. 3a is the same as Fig. 3b but with a mask of twice the sky level. The same mask has been used in Figs. 3c and 3d. (c) Position angle map, relative to some arbitrary zero point. Maximum black represents $-90°$, white $+90°$, and background gray 0°. The map shows radial symmetry about a point at the center of the object. (d) Polarization map. The polarization is small near the center increasing smoothly towards the edges. The maximum value was measured in the SW lobe and amounts to 21.4%, while in the SE lobe the polarization increases to the edge of the mask where it reaches a value of about 30%.

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HD 44179 the central star (or stars) was type B9 to A0 III. This is consistent with the spectral type we estimated for the central star in Gomez's.

In Figure 4 we fitted the optical and near-infrared fluxes of Gomez's object to a blackbody of $T = 9480$ K, corresponding to an A0 III star (Böhm-Vitense 1981), allowing for a reddening corresponding to $E(B - V) = 0.56$. The same has been done for the Red Rectangle but in this case $E(B - V) = 0.39$ (Cohen *et al.* 1981). For Minkowski's Footprint, Herbig (1975) finds the central star to be class B0.5 V and $E(B - V) = 0.98$; in this case a $T = 27{,}300$ K blackbody was fitted to the observed fluxes in Figure 4.

Differences between observed fluxes and the blackbody fluxes can be due to errors in the assumed temperatures, in the estimates of the interstellar visual absorption, and to departures from the standard interstellar extinction. In the case of Gomez's object, the excess flux observed between $2.2 < \lambda < 12$ μm could be due to dust at about 300 to 800 K.

Blackbody curves were also fitted to the observed *IRAS* fluxes (Fig. 4); emission by dust at $T = 80$ K may explain the far-infrared fluxes $\lambda > 12$ μm of Gomez's object.

A rough estimate of the distance to the object can be made by integrating its flux distribution from Figure 4. The total flux thus obtained, corresponding to its apparent bolometric luminosity, is 1.1×10^{-9} ergs cm^{-2} s^{-1}, which in turn is equal to $(R/d)^2 \sigma T^4$, where R is the star radius, d is the distance, T is the effective temperature, and σ is the Stefan-Boltzmann constant. Taking the radius for an A0 III star to be $R = 4.39 \times 10^{11}$ cm and the effective temperature $T =$ 9480 K we get a distance to the object $d = 2.9$ kpc implying a size for the optical object of 0.08 pc by 0.05 pc approximately.

Considering the arguments given above and taking into account that (a) the object is in an area of the sky free of the dust and gas which are typical of star-forming regions; (b) the high polarization of the object and the symmetry of its position angle with respect to a central source are entirely consistent with the observed properties of other bipolar nebulae (see, for example, Perkins *et al.* 1981); and (c) the spectrum, *UBVRIJHK* photometry as well as the far-infrared fluxes measured by *IRAS* can be explained by a scenario consisting of an evolved central star surrounded by a torus of warm dust embedded in a cloud of colder dust, a model that has also been suggested for HD 44179 (Cohen *et al.* 1975), CRL 2688 (Ney *et al.* 1975; Crampton, Cowley, and Humphreys 1975) and M1-92 (Herbig 1975); we therefore believe there is sufficient evidence to sustain the argument that Gomez's Hamburger is an evolved object in the stage of proto–planetary nebula as has been suggested for the bipolar reflection nebulae mentioned above (Zuckerman *et al.* 1976).

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