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OBSERVATIONS OF THE 30 MICRON FEATURE IN IRC +10216

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ABSTRACT

Infrared observations from 30 to 37 μm of IRC +10216 extend the wavelength coverage of the 30 μm feature found in four carbon stars and two planetary nebulae by Forrest, Houck, and McCarthy. The present data confirm the existence of this newly observed feature and determine its shape beyond 30 μm. The determination of the long-wavelength end of the spectral excess depends critically on the assumed underlying continuum. A combined spectrum of the excess is presented and shows the feature to extend to at least 37 μm.

Subject headings: infrared: sources — nebulae: planetary — stars: circumstellar shells

I. INTRODUCTION

The infrared source IRC +10216, CW Leo (Neugebauer and Leighton 1969), is a late-type variable star with a carbon-rich envelope that, due to its close proximity (290 pc; Herbig and Zappala 1970) and high luminosity ($> 10^4\ L_\odot$; Becklin *et al.* 1969), has been studied extensively at both infrared and millimeter wavelengths. Lunar occultation and interferometric measurements indicate that the dominant infrared emission comes from a region approximately 2″ in size (Toombs *et al.* 1972; McCarthy, Howell, and Low 1980), while the surrounding molecular envelope extends to about 2′ (Wannier *et al.* 1979). Numerous emission lines from carbon-rich molecules have been detected from the expanding envelope, including CO, CN, CS, and $HC_nN(n = 1, 3, 5, 7, 9)$ (cf. Morris 1975; Kuiper *et al.* 1976; and references in both), and indicate a mass loss rate of approximately $2 \times 10^{-5}\ M_\odot\ \mathrm{yr}^{-1}$ (Kwan and Hill 1977). It has been suggested that this object is evolving into a planetary nebula (Zuckerman *et al.* 1976).

Recently, Forrest, Houck, and McCarthy (1981, hereafter FHM) observed a 26–30 μm emission feature in four carbon-rich stars and two planetary nebulae. The feature is quite strong in IRC +10216. Unfortunately, their observations extended only to 30 μm where the spectrum showed no indication of returning to the underlying continuum level. FHM point out broad-band photometric evidence for the feature terminating at approximately 38 μm. In the planetary nebula IC 418 where the 30 μm feature is also seen, Moseley (1980) finds a 28–57 μm flux which is larger compared with longer wavelengths than for the other planetary nebulae he observed. FHM remark that this excess flux is consistent with the observed 30 μm excess extending to about 38 μm. However, as they point out, for the planetary nebula NGC 6572 where a 30 μm feature is observed, Moseley does not find excess flux in his 28–57 μm bandpass.

The current observations extend the available data on IRC +10216 to 36.5 μm. These new observations indicate that the feature extends to at least this wavelength. This should aid in an identification of the material responsible for the excess.

FHM have tentatively attributed the excess to a solid-state resonance in the circumstellar dust grains.

II. OBSERVATIONS

The observations reported here were made using the 91 cm telescope of the Kuiper Airborne Observatory (KAO). Flight altitude was in excess of 12.5 km with less than 10 μm of precipitable water vapor in the line of sight for both the source and the calibrators at the time of the observations. A liquid-helium–cooled grating spectrometer with a three-element Ge:Ga detector array was used. This spectrometer is an improved version of the one described by Houck and Ward (1979). The resolution of the spectrometer is $\Delta\lambda \approx 0.07$ μm (FWHM), and when used with the KAO, the beam size is approximately 26″ on the sky. The Moon and α Ori were used as calibrators, with the Moon being the primary one. The flux of α Ori at 33.43 μm as determined by comparison with the Moon is $1.8 \pm 0.1 \times 10^{-16}\ \mathrm{W\ cm^{-2}\ \mu m^{-1}}$ in good agreement with the flux of $2.2 \pm 0.6 \times 10^{-16}\ \mathrm{W\ cm^{-2}\ \mu m^{-1}}$ found by Forrest, McCarthy, and Houck (1979).

Nine data points spaced from each other by 0.03 μm (2 points per FWHM) were acquired at eight selected wavelength regions in the range from 29 to 37 μm. These wavelength regions were chosen to avoid telluric water vapor absorption. Each set of nine data points was averaged together to yield a synthesized resolution of $\Delta\lambda \approx 0.3$ μm. The resulting data are plotted in

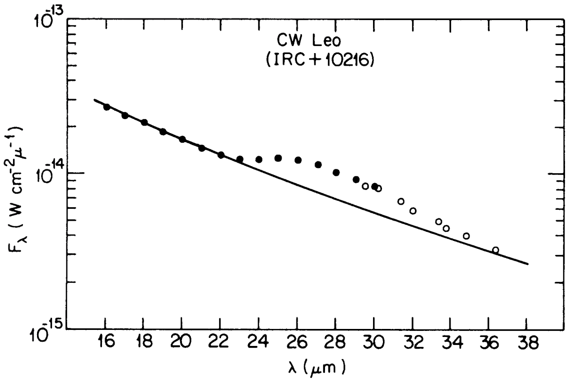

FIG. 1.—Spectrum of IRC +10216 from 16 to 37 μm. Present observations are given by the open circles, while the FHM data (given only at 1 μm intervals) are represented by the solid circles. The solid line represents a 300 K gray body fit to the 16–22 μm data by FHM. Error bars are shown only if they exceed the size of the point.

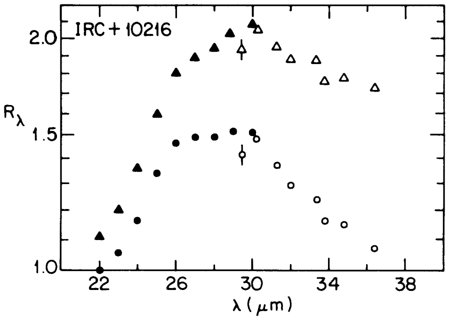

FIG. 2.—Observed emission divided by the blackbody fit of Fig. 1 for the 22–37 μm range (*circles*). Observed emission is divided by a fit with the λ^{-1} emissivity law which incorporates longer wavelength photometry (*triangles*). See text for details and interpretation.

Figure 1 along with the shorter wavelength data of FHM. The averaging was performed because the higher resolution data show some evidence for fine-scale structure in the feature. However, because there is incomplete wavelength coverage, the present data do not allow us to make any judgments concerning the possibility of small-scale structure at this time.

The statistical errors for the current data are better than a few percent, while the overall flux calibration is estimated to be ±15%. The uncertainty in the shape of the spectral distribution of IRC +10216 between 30 and 38 μm is mainly due to uncertainties in the spectral distribution of the calibrator. Under the assumption that the Moon is a gray body, the change in shape of the spectrum of IRC +10216 is less than 5% even for an extreme range of possible lunar temperatures. The agreement between the short-wavelength and long-wavelength data in the overlap region is excellent. Both the short-wavelength and long-wavelength data were taken at maxima of the 2.2 μm light curve (cf. Witteborn *et al.* 1980).

III. DISCUSSION

Represented in Figure 1 is the 300 K gray body fit of FHM to the 16–23 μm spectral region. It is evident that the 30 μm feature is returning to the continuum level at about 37 μm. Figure 2 displays R_λ which is defined to be the ratio of the observed flux to the gray body fit. Under the assumption of a uniform temperature for the emitting dust, the quantity R_λ is proportional to $(1 - e^{-\tau_\lambda})$. The observed 50% enhancement in R_λ between 22 μm and 29 μm then places a strong upper limit on the optical depth at 22 μm, $\tau(22\ \mu\text{m}) < 1.10$. This is consistent with the estimate $\tau(24\ \mu\text{m}) \approx 1$, based on the 24 μm flux and the 2″ source size.

The extrapolated gray body fit of the 16–23 μm spectral region is considerably higher than the long-wavelength broad-band observations at 53 μm and 61 μm (Fazio *et al.* 1980; Campbell *et al.* 1976). This probably results in an overestimate of the continuum level at $\lambda \sim 37$ μm and, therefore, in an underestimate at a lower limit of the strength of the feature. A good fit to the 16–23 μm data and the longer wavelength photometry is found by assuming an optically thin emission shell with an emissivity law varying as λ^{-1} and a dust temperature of 253 K. Using this to specify the underlying continuum, the derived values of R_λ are now considerably greater than for the gray body fit (Fig. 2). In this instance the feature extends considerably beyond 37 μm. Unfortunately, uncertainties in the calibration and the variability of the source make comparison of the current spectral data and the longer wavelength photometry difficult. Measurements of the entire 16–50 μm range made at the same time with the same instrument will greatly aid in determining the shape and extent of the feature.

The integrated flux from 22 to 37 μm is $\sim 6 \times 10^3$ $L_\odot$ if the source is the assumed distance of 290 pc. The 30 μm feature contributes a minimum of 22% more than would be expected from the gray body continuum emission alone or 40% more than a gray body with λ^{-1} emissivity.

The nature of the grain material causing the 30 μm feature is as yet unknown. FHM have suggested Fe_3C (iron carbide) and carbynes, while Goebel (1980) has proposed metallic sulfides, in particular MgS, as possible constituents causing this resonance. Unfortunately, at this time, measurements of the infrared properties of possible candidate materials are severely lacking.

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