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THE UNUSUAL INFRARED OBJECT IRC+10216*

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ABSTRACT

IRC+10216 is an extended object located out of the galactic plane in an unreddened region. At 5 μ it is the brightest source observed outside the solar system; at 2.2 μ it varies by as much as 2 mag, with a time scale on the order of 600 days. Its energy distribution resembles that of a 650° K blackbody, and no spectral features have been observed in the wavelength range from 1.5 to 14 μ. The object is interpreted as being consistent with a galactic source surrounded by an optically thick dust shell.

INTRODUCTION

In a continuing study of objects selected from a 2.2-μ sky survey (Neugebauer and Leighton 1969), one object, IRC+10216, which is located out of the galactic plane in an unreddened region, has been found to be extremely red and bright at 5, 10, and 20 μ. Although it is visually fainter than eighteenth magnitude, its observed 5-μ flux is greater than that of any known object outside the solar system. Its brightness, location, unusual optical appearance, and infrared spectroscopic properties merit special attention.

OBSERVATIONS

IRC+10216 has been observed regularly at 2.2 μ since 1965 with the 62-inch infrared-survey telescope. These observations are shown in Figure 1; they indicate that the 2.2-μ magnitude of IRC+10216 varies on a time scale of about 600 days over a range of at least 2 mag.

Infrared photometry of IRC+10216 was carried out during the spring of 1969 at wavelengths from 1 to 20 μ. Table 1 and Figure 2 contain a summary of the photometric data obtained in 1969 April. From Figure 1 it is seen that IRC+10216 was near its maximum 2.2-μ brightness. The photometer and photometric system have been described by Becklin and Neugebauer (1968*a*) and by Hyland *et al.* (1969).

In addition to the photometry, spectra of IRC+10216 have been obtained in each of the atmospheric-transmission windows from 1.5 to 14 μ. The spectra near 1.6, 2.2, and 3.5 μ were obtained with a 0.5-meter Ebert-Fastie spectrometer (McCammon, Münch, and Neugebauer 1967) at resolutions of 32.5, 32.5, and 65 Å, respectively. Spectra in the 5- and 10-μ regions were obtained with 1.5 percent band-pass circular filter wheels used in conjunction with the photometer.

The spectra, with atmospheric and instrumental effects removed, are shown in Figures 2 and 3. A comparison with the spectra of the hot stars α Lyr and α CMa, in which all the features except for the Brackett lines can be attributed to terrestrial atmospheric

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TABLE 1

INFRARED PHOTOMETRY OF IRC+10216, 1969 APRIL 10 AND 11

$\lambda_{eff}(\mu)$	Magnitude	F_λ (10^{-14} W cm^{-2} μ^{-1})	$\lambda_{eff}(\mu)$	Magnitude	F_λ (10^{-14} W cm^{-2} μ^{-1})
1.25.....	+6.55±0.15	0.01	4.8.....	−5.0±0.1	25.0
1.65.....	+2.94±0.07	0.77	10.1.....	−7.4±0.1	11.4
2.2.....	−0.06±0.07	4.23	19.5*....	−9.1±0.4	3.8
3.5.....	−3.44±0.07	17.2			

* The 19.5-μ magnitude was measured on 1969 April 10.

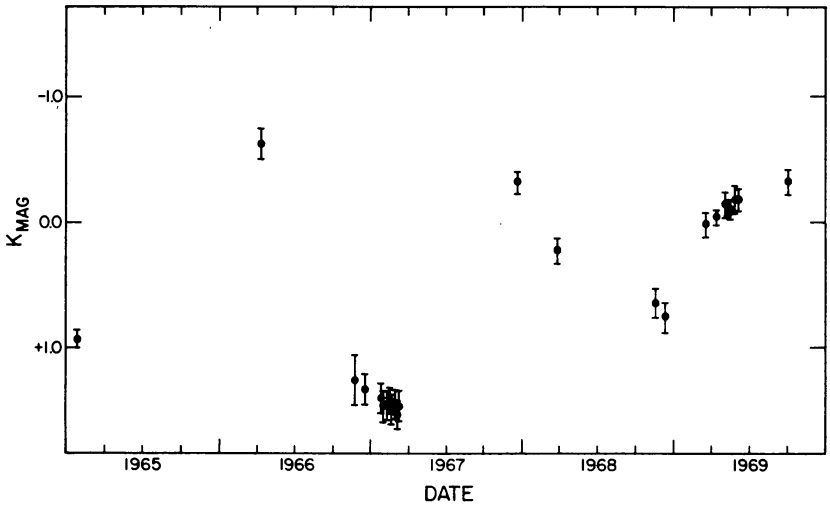

FIG. 1.—Observations of the 2.2-μ magnitude of IRC+10216 over the period 1965–1969

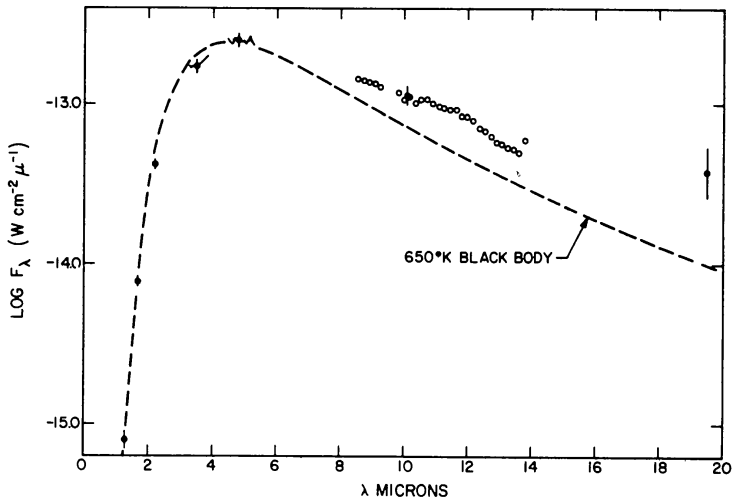

FIG. 2.—Spectrum of IRC+10216 from 1.25 to 19.5 μ compared with that of a 650° K blackbody. Filled circles represent the broad-band photometry of Table 1; error bars represent the statistical standard deviations of the measurement and do not include the calibration uncertainty. Continuous lines and open circles represent the narrow-band spectra obtained in the 3.5-, 5-, and 10-μ regions. The 3.5-μ spectrum was calibrated by assuming that the flux emitted by R Leo in this wavelength region follows the emission of a 2000° K blackbody. In the 4.5–5.5-μ region α Boo was assumed to approximate a 4000° K blackbody emitter, while from 8 to 14 μ the Moon was assumed to emit as a 350° K blackbody.

absorption, shows that the only definite features present in the spectrum of IRC+10216 from 1.5 to 2.5 μ are atmospheric in origin. The spectra at the longer wavelengths also show no features other than those attributable to atmospheric effects.

A 25-min 103aE+GG11 (5000–7000 Å) plate was taken of IRC+10216 by Dr. H. C. Arp at the prime focus of the 200-inch Hale reflector on 1969 May 11 (Fig. 4, Pl. L1). Inspection of an enlargement of this plate indicates that IRC+10216 is definitely nonstellar in this wavelength region. It is an extended elliptical object with major and minor axes of 6″ and 4″ as measured on the plate. Since the seeing was about 2″ as determined from star images on the plate, a lower limit to its visual size is 2″ × 4″. The extended nature of IRC+10216 is also apparent on the E plate of the *Palomar Sky Survey;* the object is not visible on the *Sky Survey* O plate. A 1-min exposure taken with the 48-inch Schmidt on an IN plate shows a starlike object in the wavelength region 7500–9000 Å.

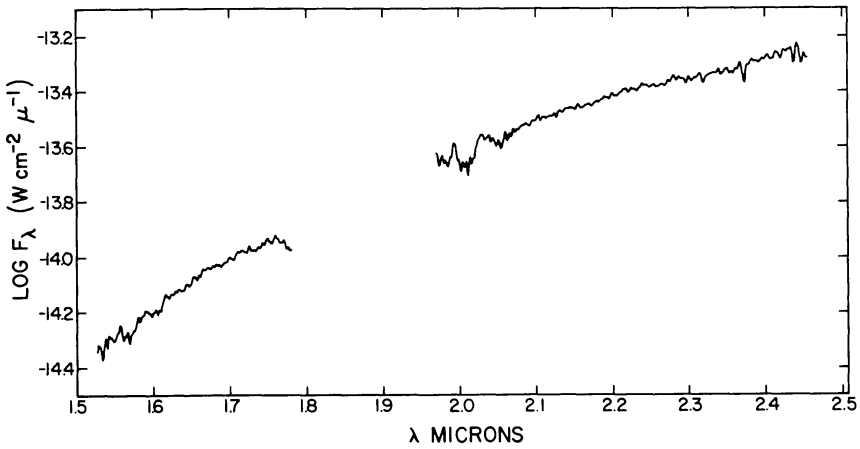

FIG. 3.—Spectrum of IRC+10216 from 1.5 to 2.5 μ, corrected for the effects of terrestrial atmospheric absorption. This spectrum was calibrated by using observations of α Lyr taken at a similar hour angle on the same night and assuming that the model atmosphere calculated by Gehlich (1968) gives a good representation of the infrared energy distribution of α Lyr. All features present can be attributed to incomplete correction for terrestrial absorption.

No definitive measurements of the size of the region (or regions) emitting the infrared radiation have been made. Observations under nonideal conditions, however, set an upper limit of 5″ on the size at 2.2 μ.

The identification of the infrared source IRC+10216 and its presumed optical counterpart was confirmed by measuring the positions of both with respect to the star marked *B* on Figure 4 (Plate L1). The two determinations of relative position agree within the assigned uncertainty of 5″. Furthermore, the estimated brightness of the optical object on an IN plate is in agreement with an extrapolation of the infrared photometry. The coordinates of IRC+10216, measured with respect to twenty-one nearby AGK 2 stars on a 48-inch Schmidt E plate, are $\alpha(1950) = 9^h45^m14^s.84 \pm 0^s.02$, $\delta(1950) = +13°30'40''.5 \pm 0''.3$. The corresponding galactic coordinates are $l^{II} = 221°$, $b^{II} = +44°$.

A lower limit for the distance to IRC+10216 can be estimated from its lack of proper motion. Measurements of the *Palomar Sky Survey* plate taken in 1954, and of a plate with the same center taken in 1969, show that the proper motion of IRC+10216 is less than 0″.03 per year. The absence of a secular parallax to this limit implies that the distance to IRC+10216 is probably greater than 100 pc.

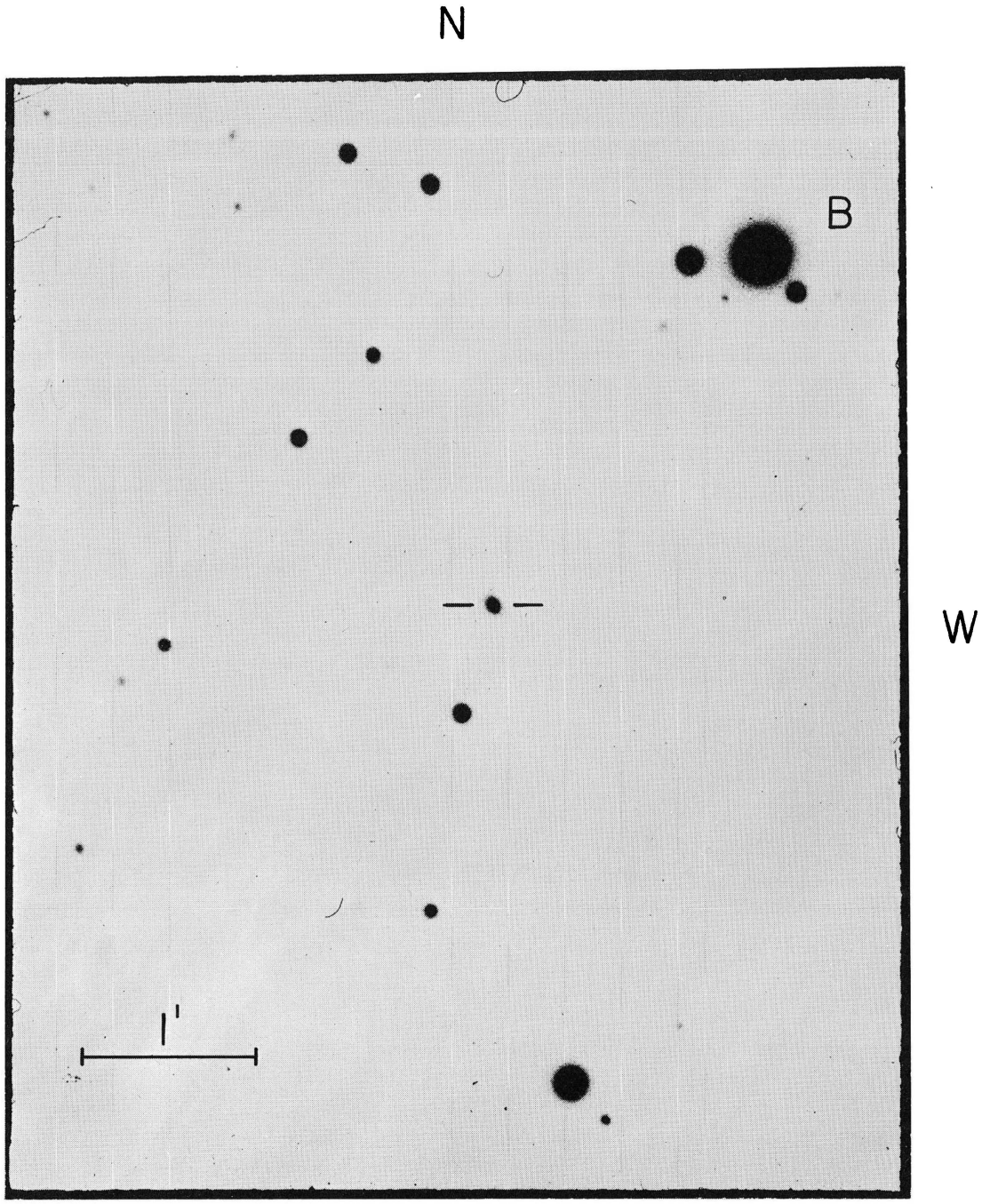

FIG. 4.—Enlargement of a portion of a 25-min 103aE+GG11 plate taken at the prime focus of the 200-inch Hale reflector by Dr. H. C. Arp on 1969 May 11. The diffuse object delineated by the tic marks is identified with the infrared source IRC+10216 as discussed in the text.

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DISCUSSION

The energy distribution of IRC+10216 from 1.2 to 5 μ closely follows that of a 650° K blackbody continuum (Fig. 2). The 10- and 20-μ fluxes and 8–14-μ spectra are indicative of a cooler radiation source at $\sim$500° K, although the calibration uncertainties at these wavelengths are quite large. If a 650° K blackbody is taken as a good representation of the entire spectrum, the total flux and angular diameter measured at the Earth are 1.7×10^{-8} W m^{-2} and 0".5, respectively. An extrapolation of a 650° K blackbody emission curve predicts an intensity of 0.01 flux unit at 3 cm, which is consistent with an upper limit of 0.3 flux unit observed by Muhleman (1969) at that wavelength.

The absolute luminosity calculated for IRC+10216 depends on its distance from the Earth; at present it is not even possible to say whether the object is galactic or extragalactic. Although we believe the object to be galactic, its optical appearance and location suggest the possibility that it could be extragalactic. If the radius were 10^{18} cm, the maximum allowed by the 600-day variation, the object would be at about 200 kpc. The luminosity at this distance then would be 10^{37} W, comparable to that of the Galaxy.

The proper-motion measurement discussed above sets an approximate lower limit of 100 pc for the distance of IRC+10216. If the object is at a typical galactic distance of 200 pc, its radius is about 10^{15} cm and its luminosity is 10^{31} W. This is comparable to an estimated luminosity of 5×10^{29} W for the infrared point source in the Orion Nebula (Becklin and Neugebauer 1967), 8×10^{30} W for VY CMa (Hyland *et al.* 1969), and 2×10^{30} W for long-period Mira variables (Smak 1966).

One current explanation of the nature of several galactic infrared objects is that of a dust shell surrounding a central source of energy (Low and Smith 1966; Johnson 1968; Woolf and Ney 1969; and Hyland *et al.* 1969). If it is assumed that IRC+10216 is galactic and that a similar model applies, the object is distinct from other infrared sources so far observed, in that it possesses both large-amplitude, long-period variability and a featureless spectrum in the spectral regions observed.

The variability of the source is strikingly similar to that observed in NML Tau and CIT 3. These objects have been identified as late-type Mira variables (Wing, Spinrad, and Kuhi 1967; Hyland *et al.* 1970); thus in this model the source of energy of IRC+10216 is possibly a long-period Mira star. The presumed shell would necessarily be opaque; long-period variable stars, even those with very large infrared excesses, show strong CO absorption bands and in many cases broad bands of hot water vapor in the 1.5–2.5-μ spectral region. Some cool carbon stars, furthermore, show the striking 1.8-μ Ballik-Ramsey band head of C_2 in addition to weak CO bands (McCammon *et al.* 1967; Johnson *et al.* 1968).

The broad emission feature in the 8–12-μ region which has been seen in several stars, including Mira variables (Woolf and Ney 1969), and has been attributed to silicates is not seen in IRC+10216. Although the absence of this feature may be due to the absence of silicates in IRC+10216, it is also consistent with the model of an optically thick shell.

It is interesting to discuss the possible evolutionary state of IRC+10216 in the context of a shell model. Some objects with presumed infrared-emitting shells are thought to be protostars (Low *et al.* 1970). In particular, the infrared point source in the Orion Nebula, which has many of the characteristics attributed to a protostar, has an energy distribution similar to that of IRC+10216 and a featureless spectrum between 2.0 and 2.5 μ (Hyland *et al.* 1970). IRC+10216 is, however, at a high galactic latitude in a region devoid of gas, dust, and young stars. Thus its position is not typical of that expected for a protostar. The large, long-period light variations exhibited by IRC+10216 have been neither observed in nor predicted for those objects widely believed to be protostars; indeed, the point source in the Orion Nebula has shown no variation at 2.2 μ (Becklin and Neugebauer 1968*b*; Lee 1969). Hyland *et al.* (1969, 1970) also give reasons for believing that VY CMa, NML Cyg, and CIT 3, infrared objects with similar energy

distributions, are more likely to be in an advanced than in a pre-main-sequence evolutionary state. Thus the similarity in the observed properties of the latter stars, IRC+10216, and the presumed protostars T Tau, R Mon, and the Orion point source may reflect a similar structure rather than a similar history.

The hypothesis just discussed—that of an evolved long-period star surrounded by an opaque dust shell—is so plausible that we believe that IRC+10216 is galactic rather than extragalactic.

If the central star is a Mira variable, the question must be raised whether the characteristics of IRC+10216 are common to only a few peculiar Mira stars. In view of the nebulosity associated with the object, the current ideas that planetary nebulae may evolve from Mira stars (Osterbrock 1964), and recent discoveries of strong infrared emission from planetaries (Gillett, Low, and Stein 1967; Gillett and Stein 1969; Woolf 1969), it is also interesting to speculate that IRC+10216 may be in a state immediately preceding that of a planetary nebula.

Further data to clarify the nature of IRC+10216 are clearly needed. Observations are being continued to determine the presence or absence of near-infrared spectral lines, to determine experimentally the extent of IRC+10216 in the infrared, and to study dependence of the color of IRC+10216 on its brightness.

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