LATE-TYPE GIANTS AND SUPERGIANTS IN THE GALACTIC CENTER

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ABSTRACT

An absorption feature at 2.3 μ attributed to CO molecules in stellar atmospheres has been found in some, but not all, of the infrared sources within 20″ of the galactic center. The absorption is characteristic of that found in M-type giant and supergiant stars. The infrared source coincident with the sub-arcssecond nonthermal radio source does not show CO absorption.

Subject headings: galaxies: nuclei — galaxies: Milky Way — infrared: sources — stars: late-type — stars: supergiants

I. INTRODUCTION

The central 30″ of the galactic center contains a variety of compact infrared sources (Becklin and Neugebauer 1975, hereafter referred to as BN). Some of these sources have absolute magnitudes and infrared colors which suggest that they could be giant and supergiant M or K stars. If this is the case, then these objects should show a broad absorption band in the wavelength range 2.30–2.45 μ due to carbon monoxide (see, e.g., Baldwin, Frogel, and Persson 1975). In this Letter we describe new observations of several of the galactic center sources with a 1.2 percent resolution filter-wheel spectrometer. The observations covered the range 2.10–2.45 μ and so include the short-wavelength edge of the carbon monoxide band, and also the Brackett-γ line (n = 7 to n = 4) of atomic hydrogen at 2.17 μ. The observations were made primarily with the intent of observing the CO absorption and thus data were not taken at frequent enough intervals to delineate weak By features.

II. OBSERVATIONS

All observations were made at the f/16 Cassegrain focus of the Palomar 5 m telescope on the nights of 1975 August 22–24. The spectrometer consists of a cooled variable filter wheel in front of an indium antimonide photovoltaic detector. The spectral resolution over the wavelength range 2.10–2.45 μ was 0.02 μ. Observations were made with a 5″ diaphragm chopped in the focal plane by a distance of 15″ in the north-south direction.

The observations were normalized by observing ζ Cap, an unreddened 4.1 mag F5 V star at about the same declination and zenith angle. The star was assumed to have a Rayleigh-Jeans distribution over the relevant wavelength range except at the 2.17 μ wavelength of the By line. Measurements of several later type stars indicate that a 3 percent correction was necessary to the channel which included the By line.

The data were corrected for the extinction of the Earth’s atmosphere at each point in the spectrum. The correction ranges from ~0.05 to 0.2 mag per air mass but is less than ~0.1 mag per air mass for wavelengths between 2.1 and 2.35 μ. The variation of atmospheric attenuation with wavelength was further checked each night by observing spectra of IRS 7 at different zenith angles. Although there is some indication of systematic

![Graph](https://example.com/graph.png)

**Fig. 1.**—Spectra of five galactic center sources. Instrumental effects were removed by normalizing the spectra with respect to ζ Cap (F5 V) whose spectrum, taken at 2.0 air masses, was assumed to follow the Rayleigh-Jeans approximation to a blackbody spectrum. The constant in the ordinate is different for each source. The spectrum of IRS 12 is of marginal significance because of the high air mass; the air mass of each observation is designated by η. The spectra of IRS 7 and IRS 1 were obtained on 1975 August 23, the remaining were obtained on 1975 August 24.
variations in the air-mass correction across the band, these variations are small and smooth and show no narrow-band effects which can be confused with spectral features in the sources. Differences in the error in the flux due to the air mass correction should be less than 0.03 mag between adjacent spectral points and 0.15 mag across the whole band.

III. RESULTS

Measurements were made on the sources designated IRS 1, 7, 11, 12 and 16 by BN. IRS 1 and IRS 7 were measured at a total of 19 equally spaced wavelengths, the other objects approximately half as often; see Figure 1. IRS 7 was scanned once on each night; three scans are illustrated in Figure 2 to give an indication of the consistency of the data. One additional scan of IRS 7 was made at an air mass of ~3.5 and is not shown in the figure; even though the data are of a very poor quality, the CO absorption edge is still clearly seen. A scan of the M3 III star 3 Aqr, which was observed in order to check the wavelength dependence of the CO absorption, is shown on Figure 3 along with scans of γ Sgr, a KO III type star, and Vega, and A0 V star.

Very clear indications of CO absorption are seen in IRS 7, IRS 11, and IRS 12, and little or none in IRS 1 and IRS 16. The absorption appears as the sharp decrease in the continuum level for wavelengths longward of 2.28 μ. The slopes of the continuum shortward of 2.28 μ and longward of 2.35 μ are characteristic of reddened objects. The interstellar extinction towards these and neighboring galactic center sources will be discussed in a future paper (Becklin, Willner, and Neugebauer 1976). Signs of a By emission line are seen in IRS 12 and IRS 16. It should be noted that IRS 12 was observed only at a very large air mass and the results are uncertain because of the extinction correction and the effects of seeing. CO absorption has been independently detected in IRS 7 by Gillett (1975).

IV. DISCUSSION

Before drawing any general conclusions, each source will be described separately:

![Figure 2](https://example.com/fig2.png)

Fig. 2.—Spectra of IRS 7 taken on the three nights of observations. For clarity of presentation, the ordinate scale is 0.08 in log $F_x$. The spectra were reduced in the same manner as those of Fig. 1.

![Figure 3](https://example.com/fig3.png)

Fig. 3.—Spectra of Vega (A0 V), γ Sgr (K0 III), and 3 Aqr (M3 III) are shown along with mean air masses at which spectra were obtained. The spectra were reduced as discussed for Fig. 1. The constant in the ordinate is different for each source. The CO absorption is prominent in 3 Aqr at wavelengths greater than 2.3 μ; the dashed line represents the Rayleigh-Jeans approximation to a blackbody spectrum. All were taken on 1974 Aug 22.

IRS 1.—This is the brightest object in the galactic center at 10 μ. The absence of significant CO absorption supports the suggestion of BN that the infrared emission of this source is from heated dust, possibly associated with ionized gas. The weakness or absence of a By line means that recombination radiation is not the main source of emission at 2.2 μ; for recombination radiation at 10,000 K the By line has an equivalent width of ~0.05 μ (Hilgemann 1970) and would be detectable with the present observations.

IRS 7.—This is the bright 2.2 μ object in the galactic center region, and was designated the "2.2-μ source" by Becklin and Neugebauer (1968). If, as argued below, the CO absorption is intrinsic to IRS 7, the presence and strength of the CO absorption feature supports the hypothesis, based on its absolute magnitude and infrared color, that IRS 7 is a late-type supergiant star (BN).

IRS 11.—This object has the strongest CO absorption of any of those measured in the galactic center region in this program; it is presumably a late-type star. The depth of the absorption, about 0.6 mag, is comparable to that seen in the M7 stars W And and T Cas (Froehlich 1971). The fact that this object appears extended on the 2.2 μ map presented by BN is probably the result of confusion by another object. IRS 11 is not evident as a discrete source on the 10 μ map of BN.

IRS 12.—This object, for which the data are of
poorer quality than the other sources, appears to have both CO absorption and Brγ emission. The latter is consistent with being flux from a background H II region in the 5" aperture used, while the CO absorption is indicative of the presence of a late-type star.

IRS 16.—This object, which is not seen as a discrete source at 10 µ, is within 2" of a very compact radio source (Balick and Brown 1974; Lo et al. 1975). The absence of the CO absorption indicates that IRS 16 is probably not a late-type giant star. The presence of the Brγ line in emission suggests that the radiation at 2.2 µ within the 5" aperture may be partially recombination radiation in the source. If IRS 16 is an H II region, it is unusual in having no localized 10 µ emission from associated heated dust; see the maps with 2" resolution of BN. Alternatively, the 5" aperture may be including recombination radiation from the background H II region which is not a part of IRS 16. The nature of IRS 16 is open to much speculation; Thorne and Braginsky (1976), for example, have discussed the possibility that IRS 16 is a cluster of M dwarfs, which do not show CO absorption, associated with a black hole.

General Discussion.—The presence of CO absorption in some, but not all, sources indicates that the CO molecules are local to each source rather than being a property of the intervening material. The fact that IRS 7 and IRS 11 have such different depths of absorption is weak evidence that each consists of a single dominant stellar object rather than a cluster of fainter stars.

It is premature to attempt to assess the spectral subclass of these objects on the basis of the depths of their CO feature as measured at this resolution. The unexpected strength of the absorption, especially in IRS 11, would suggest, however, that they are of later rather than earlier M-type. The absolute 2.2 µ magnitude of IRS 7 is −11 if the extinction is 2.7 mag at that wavelength, and if IRS 7 is at the galactic center at a distance of 10 kpc (Becklin and Neugebauer 1968). The brightest late-type giant stars known to the authors have absolute 2.2 µ magnitudes of ~ −9 (Hyland et al. 1972; Becklin et al. 1971); thus IRS 7 can be classified as a supergiant. IRS 11 and 12 have absolute 2.2 µ magnitudes ~ −9 and thus could be either very red giants or supergiants.

Type M supergiants are generally assumed to have evolved from O or B stars. The detection of at least one supergiant within 10" or 0.5 pc of the galactic center indicates that this region possibly contains a rapidly evolving cluster of young stars. The O stars in this cluster would not be seen on BN’s 2.2 µ map since the absolute 2.2 µ magnitude of the brightest O stars is −6 (Conti and Ascherl 1971; Johnson 1966), 5 mag fainter than IRS 7. Several of the O stars in the cluster would presumably provide the 2 × 10^10 Lyman continuum photons which ionize the 40" diameter radio component Sgr A West (Ekers et al. 1975); approximately five O5 main-sequence stars would be needed.

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