The Galactic Center: A Window to the Nuclear Environment of Disk Galaxies
ASP Conference Series, Vol. 439, © 2011
M. R. Morris, Q. D. Wang, and F. Yuan, eds.

First Spectroscopic Identification of Massive Young Stellar Objects in the Galactic Center

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Abstract. We report the detection of several molecular gas-phase and ice absorption features in three photometrically-selected young stellar object (YSO) candidates in the central 280 pc of the Milky Way. Our spectra, obtained with the Infrared Spectrograph (IRS) onboard the *Spitzer Space Telescope*, reveal gas-phase absorption from CO_2 (15.0 μm), C_2H_2 (13.7 μm) and HCN (14.0 μm). We attribute this absorption to warm, dense gas in massive YSOs. We also detect strong and broad 15 μm CO_2 ice absorption features, with a remarkable double-peaked structure. The prominent long-wavelength peak is due to CH_3OH-rich ice grains, and is similar to those found in other known massive YSOs. Our IRS observations demonstrate the youth of these objects, and provide the first spectroscopic identification of massive YSOs in the Galactic Center.

1. Introduction

Evidence is mounting that conditions for star formation in the Central Molecular Zone (CMZ) are significantly different from those in the Galactic disk. The CMZ provides several signposts of *in situ* star formation, such as H_2O masers, (ultra-)compact HII regions, young OB stars, and young supernova remnants. However, young stellar objects (YSOs), which are the direct tracers of current star formation, have so far eluded detection in the CMZ. They have been inferred to be present based on infrared photometry (e.g., Yusef-Zadeh et al. 2009), but spectroscopic observations are required to confirm their status as a YSO. This is because evolved stars can look like YSOs in broad-band photometry, if they

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are heavily dust attenuated (e.g., Schultheis et al. 2003), a problem toward the Galactic Center (GC), where $A_V \approx 30$.

Here we present the evidence for the first spectroscopic identification of massive YSOs in the CMZ, using the Infrared Spectrograph (IRS; Houck et al. 2004) onboard the *Spitzer Space Telescope* (Werner et al. 2004). A full description of the method and our results can be found in An et al. (2009). Here we only discuss the highlights.

2. IRS Observations

Our YSO candidates were photometrically selected from the point source catalog (Ramírez et al. 2008), which was extracted from images of the CMZ (Stolovy et al. 2006) made using the Infrared Array Camera (IRAC; Fazio et al. 2004). We obtained spectroscopic data for 107 YSO candidates using the four IRS modules in May and October 2008. Because the GC exhibits strong, spatially variable background, we observed multiple off-source measurements to derive backgrounds near each of our YSO candidates. We made an interpolation of a plane in three dimensional space (positions on the IRAC map and wavelength) to obtain a background spectrum at the source position.

3. Results

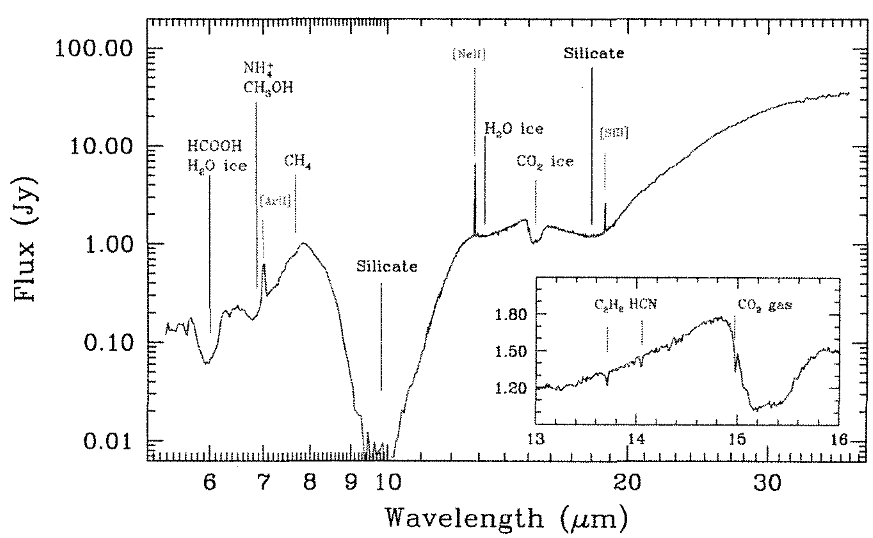

Figure 1. Composite IRS spectrum of SSTGC 797384.

For this initial analysis, we selected three targets (SSTGC 524665, SSTGC 797384, and SSTGC 803187) from among those showing characteristic spectral features of massive YSOs (see below). Figure 1 displays background-subtracted spectra of SSTGC 797384.

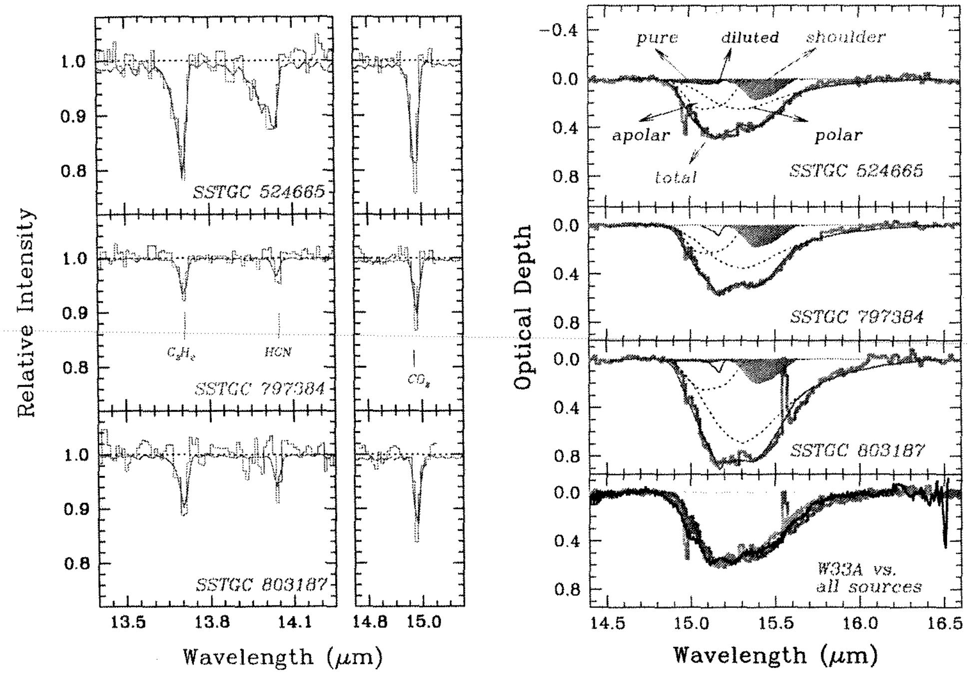

Figure 2. *Left:* Gas-phase molecular absorptions from C_2H_2 (13.71 μm), HCN (14.05 μm), and CO_2 (14.97 μm). Best-fitting models are shown in solid lines. *Right:* Optical depth spectra of solid-phase absorption from the CO_2 ice bending mode. Best-fitting CO_2 ice models and individual CO_2 ice components are shown for each target: polar (dotted line, centered at $\sim$ 15.3 μm), apolar (dotted line, centered at $\sim$ 15.1 μm), pure (shaded, centered at $\sim$ 15.1 μm), diluted (solid line), 15.4 μm shoulder (shaded), and the sum of these absorption components (solid line). The bottom panel shows a comparison of the ice absorption profile between our sources (grey) and massive YSO W33A (black). The optical depths for our targets were scaled in the bottom panel for comparison.

The left panel in Figure 2 shows gas-phase molecular absorptions at 13.71 μm (C_2H_2 $\nu_5 = 1-0$), 14.05 μm (HCN $\nu_2 = 1-0$), and 14.97 μm (CO_2 $\nu_2 = 1-0$), detected in three YSO candidates. These gaseous bandheads have been detected in absorption toward YSOs, tracing the warm and dense gas in the circumstellar disk and/or envelopes (e.g., Lahuis & van Dishoeck 2000; Boonman et al. 2003; Knez et al. 2009). Our derived abundances relative to H_2 are $\sim 10^{-7}$–10^{-6} for C_2H_2 and HCN, which are comparable to those found for massive YSOs (Lahuis & van Dishoeck 2000; Knez et al. 2009). Intervening molecular clouds in the line of sight to the GC are less likely the main cause of these absorptions, because the average HCN abundance of 2.5×10^{-8} (Greaves & Nyman 1996) towards Sgr B2(M) is an order of magnitude lower than our measurements.

The right panel in Figure 2 shows optical depth spectra of our sources at $\sim$ 15.2 μm. We followed the prescription in Pontoppidan et al. (2008) to decompose the absorption profile with five laboratory spectral components (polar, apolar, pure, deluted, and shoulder ice profiles). The strength of the 15.4 μm peak is similar to that of the well-studied embedded massive YSO W33A (Gerakines et al. 1999), which have a high CH_3OH abundance: 5%–22% relative to solid H_2O (Dartois et al. 1999b). Two other YSOs (AFGL 7009S, AFGL 2136) show a prominent 15.4 μm peak, and indeed these sources have high CH_3OH abundances (Dartois et al. 1999b; Gibb et al. 2004). Although the origin of the large quantities of CH_3OH in the previously studied massive YSOs is not fully understood, so far all lines of sight with high solid CH_3OH abundances are associated with star formation, strengthening the idea that the sources studied are indeed YSOs.

Both SSTGC 797384 and SSTGC 803187 have higher A_V values inferred from the 9.7 μm silicate absorption than the average for field stars (Schultheis et al. 2009). This implies that a significant fraction of the attenuation is intrinsic to the source. Both SSTGC 797384 and SSTGC 803187 are associated with a relatively weak radio continuum source (SGR B2(P) and SGR B2(R), respectively; Mehringer et al. 1993). We derived stellar masses of $10M_\odot$–$20M_\odot$ for these objects, by using a grid of YSO models (Robitaille et al. 2006, 2007).

Acknowledgments. This work is based on observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under a contract with NASA. Support for this work was provided by NASA through an award issued by JPL/Caltech.

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