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A REMARKABLE LOW-MASS X-RAY BINARY WITHIN 0.1 PARSECS OF THE GALACTIC CENTER

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ABSTRACT

Recent X-ray and radio observations by Muno et al. and Bower et al. have identified a transient low-mass X-ray binary (LMXB) located only 0.1 pc in projection from the Galactic center, CXOGC J174540.0−290031. In this paper, we report the detailed analysis of X-ray and infrared observations of the transient and its surroundings. *Chandra* observations detect the source at a flux of $F_X = 2 \times 10^{-12}$ ergs cm^{-2} s^{-1} (2–8 keV). After accounting for absorption both in the interstellar medium (ISM) and in material local to the source, the implied luminosity of the source is only $L_X = 4 \times 10^{34}$ ergs s^{-1} (2–8 keV; $D = 8$ kpc). However, the diffuse X-ray emission near the source also brightened by a factor of 2. The enhanced diffuse X-ray emission lies on top of a known ridge of dust and ionized gas that is visible in infrared images. We interpret the X-ray emission as scattered flux from the outburst and determine that the peak luminosity of CXOGC J174540.0−290031 was $L_X \gtrsim 2 \times 10^{36}$ ergs s^{-1}. We suggest that the relatively small observed flux results from the fact that the system is observed nearly edge-on, so that the accretion disk intercepts most of the flux emitted along our line of sight. We compare the inferred peak X-ray luminosity to that of the radio jet. The ratio of the X-ray to radio luminosities, $L_X/L_R \lesssim 10^4$, is considerably smaller than in other known LMXBs ($\gtrsim 10^5$). This is probably because the jets are radiating with unusually high efficiency at the point where they impact the surrounding ISM. This hypothesis is supported by a comparison with mid-infrared images of the surrounding dust. Finally, we find that the minimum power required to produce the jet, $L_{\rm jet} \sim 10^{37}$ ergs s^{-1}, is comparable to the inferred peak X-ray luminosity. This is the most direct evidence yet obtained that LMXBs accreting at low rates release about half of their energy as jets.

Subject headings: accretion, accretion disks — Galaxy: center — X-rays: binaries

1. INTRODUCTION

Black holes and neutron stars accreting from binary companions are often identified as transient X-ray, radio, optical, and infrared sources. Most of the identifications have occurred first at X-ray wavelengths, thanks to a series space-based observatories that were designed to monitor large portions of the sky (e.g., Levine et al. 1996; Jager et al. 1997). However, the sensitivities of these instruments are only $\simeq 10^{-10}$ ergs cm^{-2} s^{-1}, which at the Galactic center distance corresponds to $\simeq 10^{36}$ ergs s^{-1} ($D = 8$ kpc; see Reid et al. 1999).

The *Chandra X-Ray Observatory* and *XMM-Newton* are several orders of magnitude more sensitive than previous wide-field X-ray instruments. Their observations of large concentrations of stars in our Galaxy, such as globular clusters and the Galactic center, have revealed several faint X-ray transients with $L_X \sim 10^{34}$–10^{35} ergs s^{-1} (e.g., Heinke et al. 2003; Sakano et al. 2005; Muno et al. 2005). Studies of these faint X-ray transients provide the best means of understanding the physics of accretion at luminosities between the more well-examined regimes of outburst ($L_X > 10^{36}$ ergs s^{-1}) and quiescence ($L_X < 10^{33}$ ergs s^{-1}).

In 2004 July, *Chandra* observations of the Galactic center revealed a new transient X-ray source, CXOGC J174540.0−290031, that was located only 0.1 pc in projection from the supermassive black hole Sgr A*. The close proximity of the source to Sgr A* has important implications for understanding stellar dynamics at the Galactic center, which have been discussed in Muno et al. (2005). In that paper, we also reported a candidate 7.9 hr orbital modulation in the X-ray light curve and an upper limit on the magnitude of any infrared counterpart of $K < 16$ in Keck observations. These facts demonstrated that the source is a low-mass X-ray binary (LMXB). This source also was detected with *XMM-Newton* in 2004 March and August, as discussed in Bélanger et al. (2005) and Porquet et al. (2005). Finally, CXOGC J174540.0−290031 was detected as a radio transient with the Very Large Array (VLA) during a series of observations between 2004 March and 2005 January. A detailed analysis of the radio emission is presented in Bower et al. (2005).

In this paper, we provide the details of our analysis of the *Chandra* and Keck observations. We also report that the diffuse X-ray emission within 3″ of CXOGC J174540.0−290031 has brightened. We interpret this diffuse feature as a light echo from the transient, which allows us to constrain the peak luminosity of the outburst. Finally, we compare the energetics of the X-ray and radio outburst in order to understand how accretion proceeds in this remarkable example of a faint X-ray transient.

2. X-RAY OBSERVATIONS

The *Chandra X-Ray Observatory* has observed the inner 10′ of the Galaxy with the Advanced CCD Imaging Spectrometer imaging array (ACIS-I; Weisskopf et al. 2002) at least once a year between 1999 and 2004 (Table 1; Baganoff et al. 2003; Muno et al. 2003, 2005). As mentioned in Muno et al. (2005), a new transient source, CXOGC J174540.0−290031, was identified 2.″9 south of Sgr A* during 99 ks of observations on 2004 July 5–7 (Fig. 1) and during 5 ks of director's discretionary observations on 2004 August 28. We obtained another 5 ks observation of the field on 2005 February 27, which we report here for the first time.

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TABLE 1
Observations of the Inner 20 pc of the Galaxy

Start Time (UT)	Sequence	Exposure (s)	Aim Point (deg) R.A. (J2000.0)	Aim Point (deg) Decl. (J2000.0)	Roll (deg)
1999 Sep 21 02:43:00	0242	40,872	266.41382	−29.0130	268
2000 Oct 26 18:15:11	1561	35,705	266.41344	−29.0128	265
2001 Jul 14 01:51:10	1561	13,504	266.41344	−29.0128	265
2002 Feb 19 14:27:32	2951	12,370	266.41867	−29.0033	91
2002 Mar 23 12:25:04	2952	11,859	266.41897	−29.0034	88
2002 Apr 19 10:39:01	2953	11,632	266.41923	−29.0034	85
2002 May 7 09:25:07	2954	12,455	266.41938	−29.0037	82
2002 May 22 22:59:15	2943	34,651	266.41991	−29.0041	76
2002 May 24 11:50:13	3663	37,959	266.41993	−29.0041	76
2002 May 25 15:16:03	3392	166,690	266.41992	−29.0041	76
2002 May 28 05:34:44	3393	158,026	266.41992	−29.0041	76
2002 Jun 3 01:24:37	3665	89,928	266.41992	−29.0041	76
2003 Jun 19 18:28:55	3549	24,791	266.42092	−29.0105	347
2004 Jul 5 22:33:11	4683	49,524	266.41605	−29.0124	286
2004 Jul 6 22:29:57	4684	49,527	266.41597	−29.0124	285
2004 Aug 28 12:03:59	5630	5,106	266.41477	−29.0121	271
2005 Feb 27 06:26:04	6113	4,855	266.41870	−29.0035	91

Each observation has been processed using the techniques described in Muno et al. (2003). In brief, for each observation we corrected the pulse heights of the events for position-dependent charge-transfer inefficiency (Townsley et al. 2002a), excluded events that did not pass the standard ASCA grade filters and *Chandra* X-ray Center (CXC) good-time filters, and removed intervals during which the background rate flared to $\geq 3\ \sigma$ above the mean level. Finally, we applied a correction to the absolute astrometry of each pointing using three Tycho sources detected strongly in each *Chandra* observation (Baganoff et al. 2003). We estimated combined accuracy of our astrometric frame and of the positions of the individual X-ray sources by comparing the offsets between 36 foreground X-ray sources that were located within 5′ of Sgr A* (Muno et al. 2003) and their counterparts from the

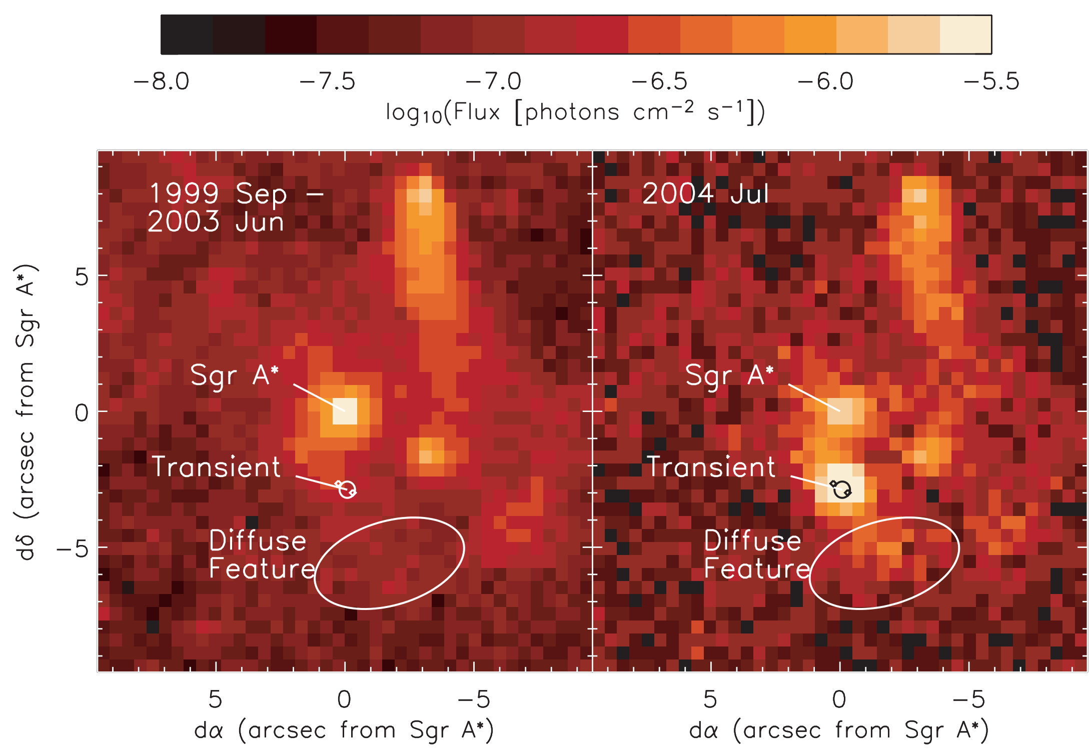

Fig. 1.—Images of the 10″ around the super-massive black hole Sgr A*, which illustrate the appearance of CXOGC J174540.0−290031. *Left*: Image created from the average of 13 observations (650 ks exposure) taken between 1999 September and 2003 June, demonstrating the quiescent state of the region. *Right*: Image created from 2 observations (99 ks) taken on 2004 July 5–7, in which a new transient X-ray source is evident 2.″5 south of Sgr A* (*circle*). The location of twin lobes of the radio transient identified with the VLA are indicated by diamonds. Finally, a portion of the diffuse emission brightened coincident with the transient outburst (*ellipse*). Both images are displayed at the 0.″5 resolution of the detector. They were generated from the raw counts and then scaled to correct for the relative exposures and the spatially varying effective area of the detector.

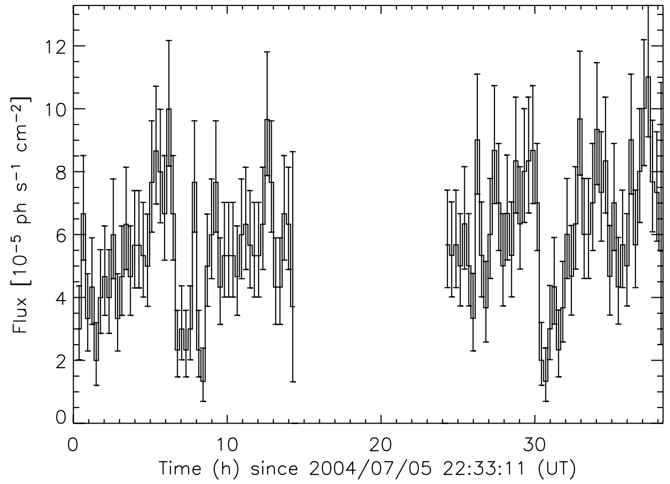

FIG. 2.—Flux, in units of photons $\mathrm{cm^{-2}\,s^{-1}}$, as a function of time from CXOGC J174540.0−290031 on 2004 July 5–7. The source is clearly variable, with three minima in the flux at about 0, 8, and 31 hr. A Fourier analysis indicates that these minima occur with a period of 7.9 hr.

2MASS catalog. The rms dispersion in the offsets was 0.″25. We conclude that the positions of individual X-ray sources are accurate to 0.″3 with 90% confidence.

The image of the $20'' \times 20''$ around Sgr A* is displayed in Figure 1. The location of CXOGC J174540.0−290031 is $\alpha = 266\overset{\circ}{.}41680$, $\delta = -29\overset{\circ}{.}00861$ ($\pm0.''3$; J2000.0). Inspection of the figure reveals that the appearance of the transient was accompanied by a factor of 2 increase in the flux of the diffuse X-ray emission 2″ south of the transient. The region is indicated by the white ellipse.

2.1. *Transient Properties*

In order to understand the nature of CXOGC J174540.0−290031, we analyzed the light curve and spectrum for CXOGC J174540.0−290031 in the 0.5–8.0 keV band using the `acis_extract` routine from the Tools for X-Ray Analysis (TARA)[5] and CIAO version 3.0.2. From each observation, we first extracted events associated with the source from a circular region that enclosed 90% of the point spread function (PSF). The region had a radius of $\approx 1''$. Then we extracted background event lists for each observation from larger circular regions centered on CXOGC J174540.0−290031, excluding from the event list the point sources and discrete filamentary features in the field. We chose the size of the background region to include $\approx$1400 total counts from the full set of observations.

In Figure 2, we display the flux as a function of time during the observations on 2004 July 5–7. Three minima are evident in the light curve at about 0, 8, and 31 hr. As reported in Muno et al. (2005), we searched these observations for periodic variability using the Rayleigh statistic (Z_1^2; Buccheri et al. 1983). The power spectrum contains a strong signal with a period of 7.9 hr and $Z_1^2 = 175$, and its first harmonic with $Z_1^2 = 120$. The exact significance of this signal is uncertain, because there may be red noise in the power spectrum. However, *XMM-Newton* observations in 2004 August detected similar dips with the same 7.9 hr period (Bélanger et al. 2005; Porquet et al. 2005), making us confident that this signal represents a stable periodicity in the source, such as its orbital period.

[5] At http://www.astro.psu.edu/xray/docs/TARA.

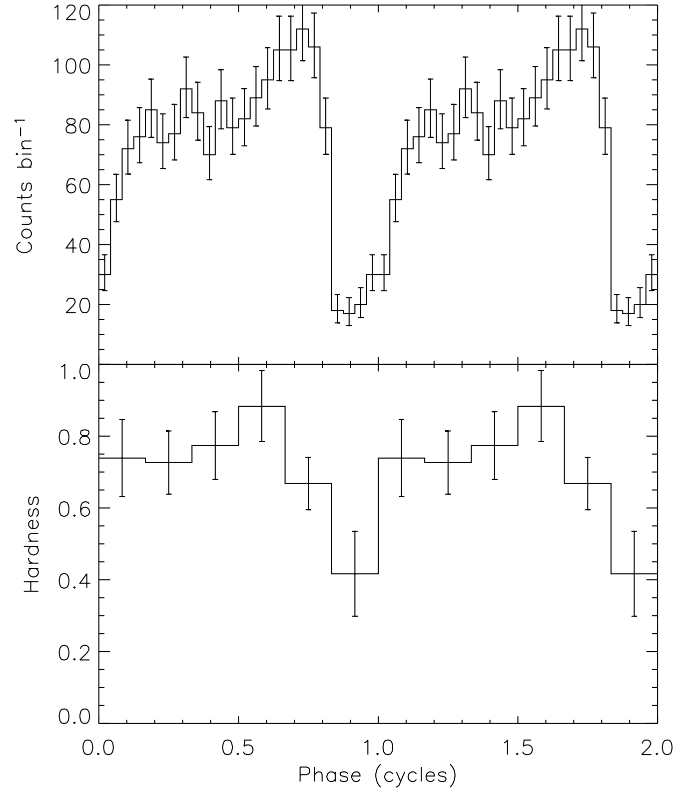

FIG. 3.—Folded profile of the 7.9 hr modulation in the X-ray light curve (*top*), along with the variation in the hardness ratio throughout the cycle (*bottom*). We have repeated a single cycle twice in both panels. The hardness is defined as the ratio of counts in the 2–6 and 6–8 keV energy bands. The softening of the spectrum at the time of the dip in the light curve is only significant at the 93% confidence level and should be confirmed by more sensitive observations.

In order to further explore the nature of the modulation, in the top panel of Figure 3 we display the 2–8 keV count rate folded about the 7.9 hr period. The most obvious feature in the folded profile is the dip mentioned above, during which the flux drops by 75%. We also computed the ratio of counts in the 2–6 and 6–8 keV energy bands, which is displayed in the bottom panel of Figure 3. This dip appears to be accompanied by a slight softening of the spectrum, although a χ^2 test only allows us to reject the hypothesis that the hardness is constant at the 93% confidence level. As we discuss in § 4, the dips in the light curve of CXOGC J174540.0−290031 probably result from structures in the outer accretion disk that obscure the central X-ray–emitting region.

Next, we extracted and modeled the spectrum of CXOGC J174540.0−290031. We produced source and background spectra from the respective event lists by computing the histogram over pulse height (energy). We then computed the effective area function at the position of CXOGC J174540.0−290031 for each observation. This was corrected to account for the fraction of the PSF enclosed by the extraction region. Finally, we estimated the detector response for the source in each observation using position-dependent response files that accounted for the corrections we made to undo partially the charge-transfer inefficiency (Townsley et al. 2002b). The mean flux did not change between the two observations on 2004 July 5–7, so we summed the source spectra and computed the average effective area and response functions weighted by the number of counts from the two observations.

We obtained enough photons to model the spectra from the observations on 2004 July 5–7 (1740 total counts) and 2004 August 28 (306 total counts). We subtracted the same background

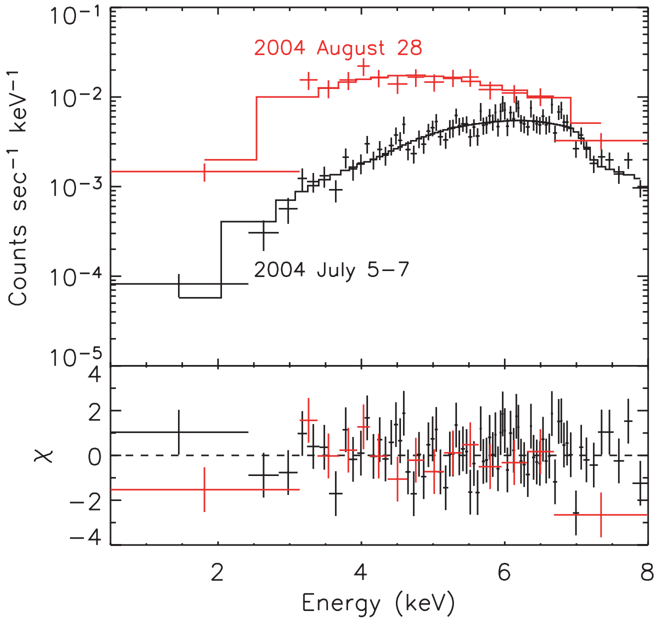

FIG. 4.—Spectra of CXOGC J174540.0−290031 obtained on 2004 July 5–7 and August 28. *Top:* Observed detector counts as a function of energy (*crosses*), so that the shape of the intrinsic spectrum is convolved with the instrument response. The solid lines indicate the detector counts predicted by the best-fit model. The flux between 7–8 keV is very similar in both observations; however, the slope at lower energies is dramatically different. The smaller flux at low energy in the July observations probably results from excess absorbing material that is located within the binary system. *Bottom:* Difference between the counts observed and those predicted by the best-fit model, in units of residuals divided by the uncertainties.

spectrum from the 2004 July and August spectra. The background contributed <3% to the total flux. We grouped the source spectra so that each energy bin had at least 20 counts. The spectra are displayed in Figure 4. We modeled the spectra using XSPEC version 11.3.1 (Arnaud 1996). We initially modeled the spectrum a power law absorbed by interstellar gas and dust. However, we found that for the longer observation, this model did not reproduce the 0.5–2.0 keV part of the spectrum and left residuals near the photoelectric edge of Fe at 7 keV. Therefore, we added a second absorption component that only affected a fraction of the emitting region. The free parameters in this model were the column of interstellar gas ($N_{\rm H,ISM}$), the column of the partial-covering absorber ($N_{\rm H,pc}$) and the fraction of the emitting region covered by this absorber ($f_{\rm pc}$), the photon index (Γ), and normalization (N_Γ) of the power law. The optical depth of dust was set to $\tau = 0.485 N_{\rm H}/(10^{22}\ {\rm cm}^{-2})$, and the halo area to 100 times that of the PSF (Baganoff et al. 2003). The best-fit spectral parameters for the two epochs are listed in Table 2. We found that the interstellar absorption in the 2004 July spectrum is consistent with the value toward Sgr A*, 6×10^{22} cm^{-2}. There was not enough signal in the 2004 August observation to constrain all of the parameters, so we fixed the interstellar absorption to this value.

The change in the spectrum in Figure 4 is the result of an order-of-magnitude decrease in the column depth of the partial-covering absorber between 2004 July and August (Table 2). In contrast, the values of the photon indices from the two observations are consistent within their 2 σ uncertainties, so the intrinsic spectrum appears to change very little. Likewise, after accounting for the interstellar and partial-covering absorption, the inferred luminosity of CXOGC J174540.0−290031, changes by only 10% between 2004 July and August. Finally, we note that the assumption that the absorption components are constant and that only

TABLE 2
SPECTRAL PROPERTIES OF CXOGC J174540.0−290031

PARAMETER	VALUE	
	2004 Jul	2004 Aug
$N_{\rm H}$ (10^{22} cm^{-2})	6^{+2}_{-1}	$6^{\rm a}$
$f_{\rm pc}$	$0.92^{+0.01}_{-0.02}$	>0.5
$N_{\rm H,pc}$ (10^{22} cm^{-2})	59^{+9}_{-8}	5^{+4}_{-2}
Γ	$0.0^{+0.6}_{-0.2}$	$1.2^{+0.8}_{-0.4}$
N_Γ ($\times 10^{-4}$ ph cm^{-1} s^{-1} keV^{-1})	$1.0^{+2.5}_{-0.5}$	6^{+20}_{-3}
χ^2_ν	76/72	8/11
$F_{\rm X}$ (10^{-12} ergs cm^{-2} s^{-1})	0.9	2.2
$uF_{\rm X}$ (10^{-12} ergs cm^{-2} s^{-1})[b]	1.2	3.3
$L_{\rm X}$ (10^{34} ergs s^{-1})[c]	3.7	3.4

NOTE.—Uncertainties are 1 σ for a single parameter of interest ($\Delta\chi^2 = 1$). We report the 2–8 keV fluxes and luminosities because this is the band in which most of the flux is observed. The bolometric values are probably less than a factor of 2 higher.

[a] The column density for the 2004 August observation was set to the value toward Sgr A*.

[b] We define $uF_{\rm X}$ as the deabsorbed flux after correcting for interstellar absorption.

[c] We define $L_{\rm X}$ as the luminosity after correcting for both interstellar and local absorption.

the slope of the continuum varies is not sufficient to reproduce the changes in the spectrum.

Finally, in order to determine the quiescent luminosity of CXOGC J174540.0−290031, we extracted the counts from the *Chandra* observations during 1999–2003 and during 2005 February. During 1999–2003, the region contained 485 total counts, of which the expected background contribution was 371 counts. Although this excess flux could represent the quiescent emission from CXOGC J174540.0−290031, two young, emission-line stars also lie within the 1″ extraction region (IRS 33N and IRS 33E), and these may be X-ray sources. If we assume a $\Gamma = 1.5$ power-law spectrum (typical for a quiescent LMXB; e.g., Kong et al. 2002) absorbed by 6×10^{22} cm^{-2} of gas and dust, we can place a rough upper limit to the quiescent luminosity of CXOGC J174540.0−290031 using the observed net count rate of 1.8×10^{-4} count s^{-1} during 1999–2003. We find that the quiescent luminosity is $L_{\rm X} \lesssim 7 \times 10^{31}$ ergs s^{-1} (2–8 keV).

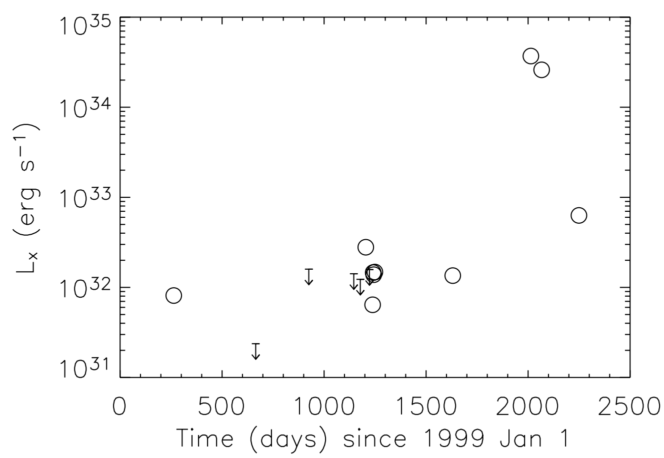

FIG. 5.—Luminosity of CXOGC J174540.0−290031 as determined from observations with *Chandra*. Prior to 2004, the source was no brighter than 3×10^{32} ergs s^{-1}. Observations in 2004 July and August reveal that the source has varied by a factor of ≈2 about a mean luminosity of 5×10^{34} ergs s^{-1}. *XMM-Newton* observations in 2004 March and August reveal the source at a similar luminosity (Bélanger et al. 2005; Porquet et al. 2005).

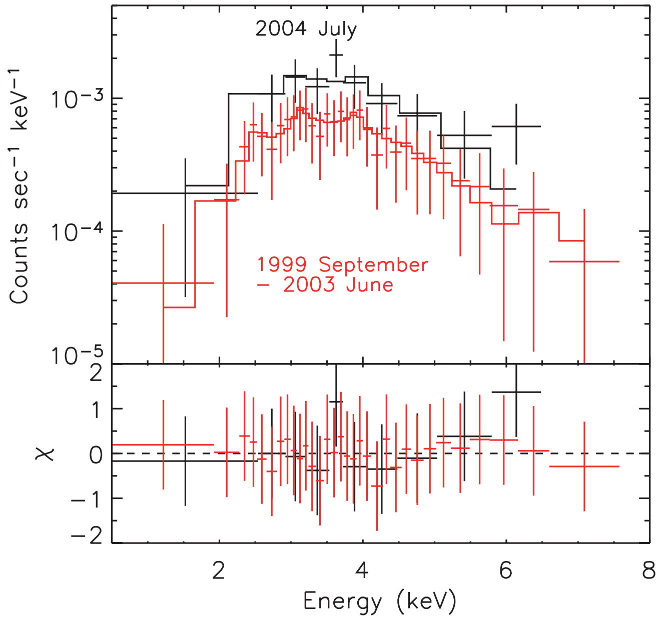

FIG. 6.—*Top:* Spectra of the diffuse emission southwest of CXOGC J174540.0−290031 obtained 1999 September through 2003 June (*red*) and 2004 July 5–7 (*black*). The intensity of the diffuse emission clearly increases. However, there is not enough signal in the spectrum to determine what physical changes in the emitting region produced the brightening. *Bottom:* Residuals from the fits to both spectra, with 1999 September through 2003 June in red and 2004 July 5–7 in black.

During the 2005 February observation, we received only 13 counts from the location of CXOGC J174540.0−290031, 5 of which should be background. If the total count rate were the same as that before the outburst, 8×10^{-4} count s^{-1}, the chance probability of receiving at least 13 counts in 5 ks from a Poisson distribution is only 5×10^{-5}. Therefore, X-rays continued to be produced by the outburst through 2005 February. The corresponding luminosity is $L_X \approx 6 \times 10^{32}$ ergs s^{-1}. The history of the luminosity of CXOGC J174540.0−290031 is displayed in Figure 5.

2.2. *Diffuse Feature*

In order to study the properties of the diffuse X-ray emission that brightened coincident with the outburst of CXOGC J174540.0−290031, we have defined an ellipse that encloses the excess counts seen during 2004 July. This ellipse is displayed in Figure 1. It is centered at $\alpha = 266\overset{\circ}{.}41629$, $\delta = -29\overset{\circ}{.}00936$ (1″.6 east and 2″.7 south of CXOGC J174540.0−290031), and its semimajor and semiminor axes are, respectively, 3″.0 and 1″.6. The ellipse is somewhat larger than the extent of the most obvious brightening of the diffuse flux because we wanted to include photons in the wings of the *Chandra* PSF, which extends a factor of ≈4 beyond its 0″.5 core.

We judged the significances of the changes in flux by assuming that the numbers of counts follow a Poisson distribution. We found that the count rate increased between 1999–2003 and 2004 July, from $(2.08 \pm 0.05) \times 10^{-3}$ counts s^{-1} to $(4.1 \pm 0.2) \times 10^{-3}$ counts s^{-1}. The increase in flux is significant at the ≈10 σ level. The count rate in 2004 August, $(5 \pm 1) \times 10^{-3}$ counts s^{-1}, was consistent with that in 2004 July and 3 σ larger than during 1999–2003. Finally, in 2005 February, the flux appeared to return to its value in 1999–2003, with a count rate of $(2.1 \pm 0.7) \times 10^{-3}$ counts s^{-1}.

Next we attempted to determine what physical changes occurred when the region brightened. We extracted the spectra of the diffuse emission within the elliptical region from each observation prior to 2005, obtained the appropriate instrument response files (Townsley et al. 2002b), and computed effective area functions weighted by the number of counts in each pixel. We then computed the summed spectra and count-weighted average responses for two intervals, 1999 September–2003 June and 2004 July–August. For the background subtraction, we used the spectrum of the diffuse emission extracted from the "close" region 4′ south of Sgr A* in Muno et al. (2004). The background contributed <3% to the total spectrum. We grouped the spectra to have a minimum of 40 counts bin^{-1} between 0.5 and 8 keV. The spectra are displayed in Figure 6.

We modeled the spectra as a thermal plasma (Mewe et al. 1986) absorbed by interstellar gas and dust. The free parameters of the model were the absorption N_H, temperature kT, and normalization (proportional to the emission measure $K_{EM} = \int n_e n_H \, dV$). We found that the differences in the two spectra were consistent with changes in either kT or K_{EM}. We list the best-fit parameters for both hypotheses in Table 3. If we assume that both kT and K_{EM} vary, an F-test suggests that the change in χ^2 has at least a 10% chance of representing a random variation.

Unfortunately, beyond identifying a brightening in the diffuse emission, there is not enough signal to determine unambiguously what physical change occurred in the region to produce the enhanced emission. The above model is useful for constraining the energy required under the assumption that a change has occurred in the properties of the plasma responsible for the diffuse emission. In § 4.2, we suggest an alternative explanation, that the excess diffuse emission detected in 2004 as scattered light from the outburst of CXOGC J174540.0−290031. This latter model

TABLE 3
SPECTRAL PROPERTIES OF THE DIFFUSE EMISSION

Date	N_H (10^{22} cm^{-2})	kT (keV)	K_{EM} (cm^{-6} pc)	F_X (2–8 keV) (ergs cm^{-2} s^{-1})	L_X (2–8 keV) (ergs s^{-1})
		Varying kT			
1999 Sep–2003 Jun	8^{+2}_{-2}	$1.5^{+0.6}_{-0.4}$	$9^{+13}_{-4} \times 10^{-3}$	0.5×10^{-13}	1.1×10^{33}
2004 Jul–Aug	8[a]	3^{+3}_{-1}	9×10^{-3}[a]	1.0×10^{-13}	2.3×10^{33}
		Varying K_{EM}			
1999 Sep–2003 Jun	8^{+2}_{-2}	$1.7^{+0.8}_{-0.4}$	$8^{+10}_{-5} \times 10^{-3}$	0.5×10^{-13}	1.1×10^{33}
2004 Jul–Aug	8[a]	1.7[a]	$16^{+21}_{-10} \times 10^{-3}$	1.0×10^{-13}	2.3×10^{33}

[a] These parameters were tied together in the two spectral fits. The values of reduced χ^2 for each joint fit were $\chi^2_\nu = 6/37$ when allowing kT to vary and $\chi^2_\nu = 6/38$ when allowing K_{EM} to vary.

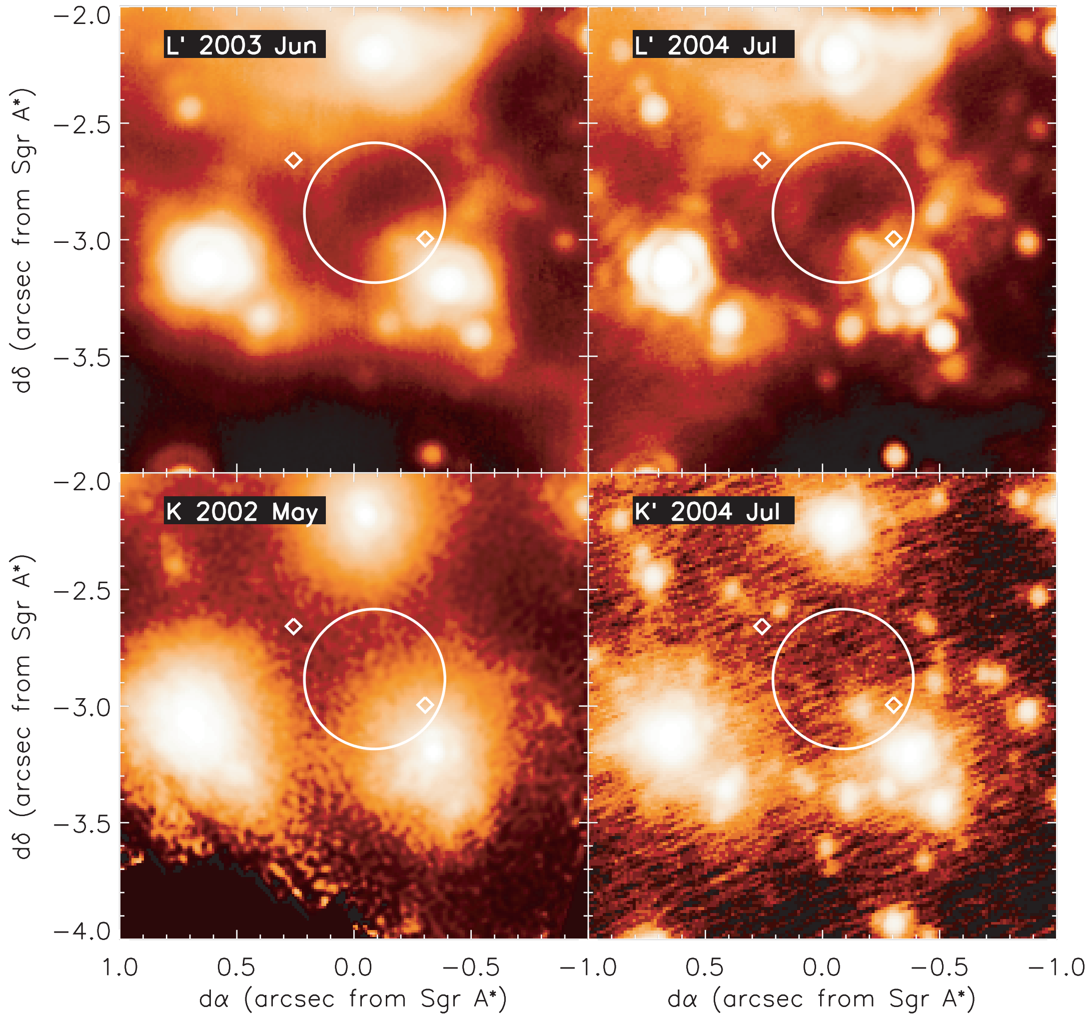

FIG. 7.—L' (*top*) and K/K' (*bottom*) images of the $2'' \times 2''$ field around CXOGC J174540.0−290031 taken in 2003 (*left*) and 2004 (*right*) with Keck (see text for details). The position of the transient X-ray source is indicated with the circle of 0.″3 radius, and the mean positions of the two radio features are indicated with diamonds. Several stars are present within the error circle of the transient, although only the K' image from 2004 July is sensitive enough to see all of them. Therefore, we cannot identify the true infrared counterpart of CXOGC J174540.0−290031. The faintest stars in the images have $L' \sim 15$ and $K' \sim 17$, which we take as the upper limits to the magnitude of the counterpart.

is equally consistent with the spectra in Figure 6, although there are too few excess photons above the already-bright diffuse emission to obtain a useful spectral constraint on the putative scattered emission.

3. INFRARED OBSERVATIONS

We searched for an infrared counterpart to CXOGC J174540.0−290031 using observations taken at the Keck Observatory. For each observation, we calculated the astrometry using the positions of known maser sources in the field, so the coordinates are accurate to 10 mas (Ghez et al. 2005).

To search for the transient in outburst, we used images at L' and K' that were taken in 2004 July using the NIRC-2 camera behind the newly commissioned laser guide star adaptive optics system. To establish whether there were variable infrared sources within the error circle of CXOGC J174540.0−290031, we compared these images from to a K speckle image taken in 2002 May with NIRC-1 and an L' image taken in 2003 July with NIRC-2 behind natural guide star adaptive optics. Unfortunately, these earlier images did not benefit from the increase in quality afforded by the laser guide star system and are not as sensitive as the images taken in 2004 July. The $2'' \times 2''$ field around the transient from each image is illustrated in Figure 7. In both images, the position of CXOGC J174540.0−290031 is indicated with a 0.″3 circle (90% confidence), and the average locations of the two lobes of the radio jet are illustrated with diamonds (Bower et al. 2005).

There are clearly several faint infrared sources within the 90% error circle of CXOGC J174540.0−290031 in the images taken in 2004 July (Fig. 7, *right panels*). The brightest of these, at the southwest edge, has $K' = 15.3$ and $L' = 13.3$. Although the K image from 2003 is not sensitive enough to reveal this source, it does appear to be present at the same intensity in L' in 2003. There may also be several fainter sources near the detection threshold of $K' \sim 17$ in the K' image from 2004 July. Again, the K images from 2003 are not sensitive enough to determine whether any of these brightened. Therefore, we are not able to unambiguously identify the infrared counterpart to CXOGC J174540.0−290031, but we can rule out with 90% confidence that its infrared counterpart has $K < 15$.

Finally, we note that the K' and L' images extend no more than $4''$ south of Sgr A* and do not cover the region where the diffuse X-ray emission brightened. Therefore, we have obtained images with wider fields of view in order to search for gas and dust that might have contributed to the brightening of the diffuse emission.

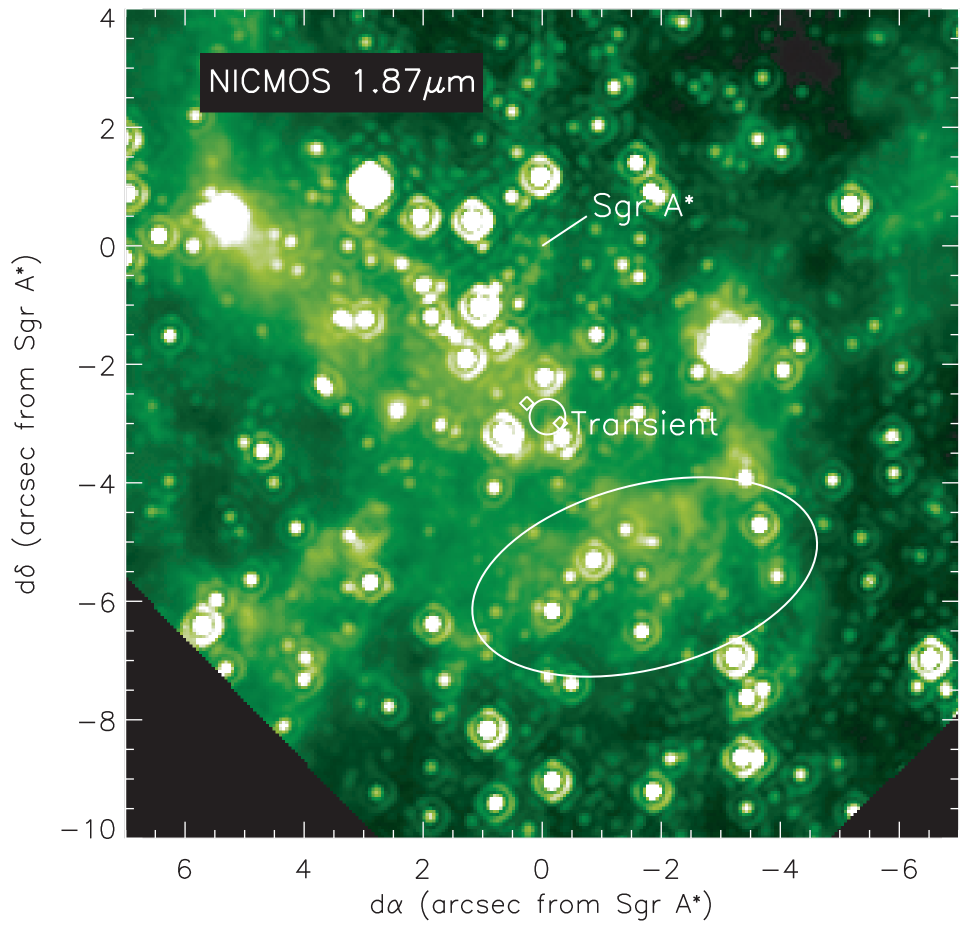

FIG. 8.—*HST* NICMOS image taken in 1998 with the narrow 1.87 μm filter. The filter is sensitive to Paα emission from hydrogen, which is evident in this image as bands of diffuse emission. We have marked the relative locations of Sgr A*, the transient, the two radio features (*diamonds*), and the region of enhanced diffuse X-ray emission (*ellipse*). The region of enhanced diffuse X-ray emission is coincident with a dense region of ionized gas that is evident by its hydrogen emission lines.

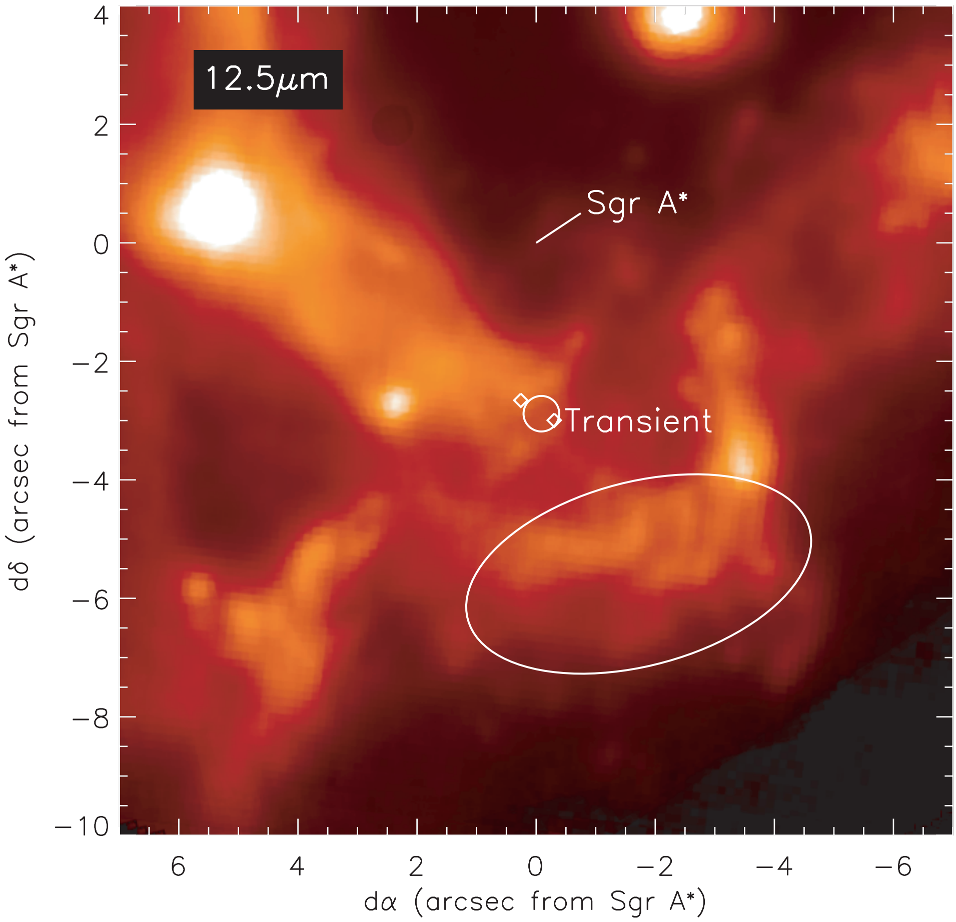

FIG. 9.—Mid-infrared (12.5 μm) image of the Galactic center taken with the MIRLIN camera on Keck I in 1998. The image is dominated by thermal emission from dust. We have marked the relative locations of Sgr A*, the transient, the two radio features (*diamonds*), and the region of enhanced diffuse X-ray emission (*ellipse*). Two things are notable. First, dust emission to the east of the transient is particularly strong, coincident with the brighter of the two radio features. This suggests that the radio feature is produced where a jet interacts with the ISM. Second, as in the Paα image, the region of enhanced diffuse X-ray emission, lies on a bright section of dust emission.

In Figure 8, we present a 1.87 μm image of the Galactic center taken in 1998 August with the Near-Infrared Camera and Multi-Object Spectrometer (NICMOS) aboard the *Hubble Space Telescope* (Scoville et al. 2003). The astrometry was registered to 0\farcs1 by matching the brightest stars to sources in the 2MASS catalog. The filter used is sensitive to Paα emission from hydrogen, which can be seen as bands of diffuse emission in the image. We also present a 12.5 μm image taken with the MIRLIN camera on Keck II during 1998 June. We computed the astrometry using the positions of IRS 3, IRS 7, and IRS 22 in Genzel et al. (2000) and estimate that the positional uncertainty is also about 0\farcs1. This image is dominated by thermal emission from dust.

In both images, the ellipse denotes the region that brightened in X-rays. It is clearly coincident with bright emission from ionized gas and dust. The diamonds denote the two lobes of the jet (Bower et al. 2005). The brighter, eastern lobe is coincident with prominent dust emission in Figure 9. The same appears to be true for the ionized gas in Figure 8, although the prominence of the stars in the 1.87 μm image makes this much less obvious.

4. DISCUSSION

As stated in Muno et al. (2005), our X-ray and infrared observations of CXOGC J174540.0−290031 suggest that it is an LMXB that is viewed nearly edge-on. Now that we have described the X-ray and infrared observations in greater detail, it is worth discussing how this conclusion was reached.

First, the partial-covering absorption in the spectrum and the 7.9 hr modulation in the light curve suggests that we observe CXOGC J174540.0−290031 nearly edge-on (e.g., Parmar et al. 1986). The geometric arrangement that leads to the partial-covering absorption is as follows. Most of the X-ray emission originates in a region a few tens of kilometers across, consisting of the inner accretion disk and for neutron star systems, a boundary layer where the accretion flow is halted. The total radius of the accretion disk is $\gtrsim 10^5$ km, and at a minimum (i.e., ignoring radiation-induced warping, etc.) the thickness of the accretion disk should increase as $H \approx \alpha R$, where $\alpha \sim 10^{-3}$ to 0.1 (e.g., Frank et al. 2002). Therefore, the outer accretion disk has $H \gtrsim 10^2$ km and is easily thick enough to obscure the main X-ray–emitting region for a system with an inclination $>75°$. A fraction of the X-ray emission also originates in a corona of hot plasma above the accretion disk. The scale height of this emission is large enough that part of it is visible even from systems observed nearly edge-on, as is thought to be the case for several LMXBs that are referred to as accretion disk corona sources (Parmar et al. 2000; Kallman et al. 2003). If only a fraction of the corona is absorbed by the outer disk in CXOGC J174540.0−290031, it would explain the partial-covering absorption in the spectrum (Fig. 4 and Table 2).

Dips, similar to those seen in Figure 2, are caused by discrete structures that rise above the outer accretion disk and obscure the X-ray emission for a small fraction of the binary orbit. Such structures form, for example, at the point where the material lost by the companion star first impacts the accretion disk. Since most of the absorption results from the incident X-rays photoionizing the intervening material, the dips should be most prominent at low energies. This is the case in about half of all edge-on LMXBs (Balucinska-Church et al. 1999; Homan et al. 2003; Uno et al. 1997). However, in the other half the depths of the dips are independent of energy (White et al. 1984; Parmar et al. 1999; Iaria et al. 2001), as in Figure 3. This is probably because either (1) the dips result from energy-independent electron scattering by highly ionized or metal-deficient material or (2) the mean energy of the X-rays emitted from the corona decreases as a function of height, so that much of the cooler flux remains unobscured during the dips. Should the evidence that we find for softening during the dips in Figure 3 be confirmed, some combination of these options could be constructed to reproduce the spectral evolution of the dip.

The fact that CXOGC J174540.0−290031 is a compact object accreting from a low-mass companion is indicated by the 7.9 hr orbital period of the binary (Fig. 2) and by the faintness of the infrared companion (Fig. 7). The short orbital period can accommodate a mass donor with a radius of $\approx 0.8\ R_\odot$ (Frank et al. 2002, eq. [4.10]). The only high-mass stars that are this compact are in the Wolf-Rayet phase. For $D = 8$ kpc and $A_K = 3.2$ (Reid et al. 1999; Tan & Draine 2003) a Wolf-Rayet star would have $K =$ 9–14 and would have been easily detectable in our Keck images. In contrast, if the few LMXBs that have been monitored in the infrared during their outbursts were placed at the Galactic center, they would have had peak intensities of $K \approx 15$–17 (Jain et al. 2001; Chaty et al. 2003; Buxton & Bailyn 2004). The fainter LMXBs would have been barely detectable in our 2003 Keck images. Therefore, the short orbital period and the lack of a counterpart with $K < 15$ in Figure 7 indicates that the mass donor in CXOGC J174540.0−290031 is a low-mass star that overfills its Roche lobe.

The nature of the compact object is not yet clear. We did not observe either thermonuclear bursts from the surface of the compact object or coherent pulsations that can be naturally associated with a spin period. Either of these would indicate that the source is a neutron star. However, the lack of these signals is not surprising, because the recurrence times of bursts are often longer than 100 ks and the time resolution of the ACIS data was too coarse to detect pulsations faster than 10 s. On the other hand, bright radio emission is much more common from black hole LMXBs than from neutron star ones (Fender & Kuulkers 2001), which suggests that the primary in CXOGC J174540.0−290031 could be a black hole.

4.1. *A Faint X-Ray Transient*

One unusual aspect of the outburst from CXOGC J174540.0−290031 is that it is quite faint. The history of its X-ray luminosity between 1999 and 2004 is displayed in Figure 5. During 1999–2003, *Chandra* detected a marginally significant excess in the source counts within $1''$ of CXOGC J174540.0−290031, with an average luminosity of $\sim 10^{32}$ ergs s^{-1}. This emission is probably from nearby young, emission-line stars. Therefore, we consider 10^{32} ergs s^{-1} as the upper limit to the luminosity of CXOGC J174540.0−290031 during that time period. This is typical for an LMXB in quiescence. In contrast, the highest luminosity observed from CXOGC J174540.0−290031 with *Chandra* was only 4×10^{34} ergs s^{-1}. This luminosity is well below that at which transient LMXBs are typically detected in outburst (e.g., Campana et al. 1998). The low luminosity is surprising in the context of the disk-instability models that are typically used to explain the outbursts of LMXBs, which predict that most of the disk is accreted onto the compact object, leading to an outburst with $L_X > 10^{37}$ ergs s^{-1} (e.g., King & Ritter 1998). However, three observational selection effects could contribute to the low peak luminosity of CXOGC J174540.0−290031.

First, transient LMXBs have traditionally been identified with wide-field monitoring instruments that only have sensitivities of $\gtrsim 10^{-10}$ ergs cm^{-2} s^{-1} (Levine et al. 1996; Jager et al. 1997), or 10^{36} ergs s^{-1} for the Galactic center distance. There are few accreting black holes and neutron stars within 2 kpc of Earth, so there is a strong selection effect against finding transients this faint.

Second, only a few sensitive X-ray observations of the Galactic center have been obtained within the last year, so we may have missed the peak of the outburst. The first observation of the source in outburst was taken by *XMM-Newton* in 2004 March by Bélanger et al. (2005) and Porquet et al. (2005). They report that the source had a comparable luminosity to that at which we detected the source with *Chandra* in 2004 July and August. In between, the *Rossi X-Ray Timing Explorer* (*RXTE*) carried out scanning observations of the Galactic center with the Proportional Counter Array (PCA; Markwardt et al. 2002). These allow us to put an upper limit of 3×10^{36} ergs s^{-1} on the intensity of the source during 2005. This upper limit is at the low end of the luminosities of outbursts often seen from LMXBs.

Finally, as mentioned above, we observe CXOGC J174540.0−290031 along the plane of its binary orbit, so it is likely that the outer accretion disk obscures most of the X-ray–emitting region. These facts motivate us to search for an independent constraint on the X-ray luminosity of the transient outburst. Fortunately, the apparent detection of scattered X-ray emission from the transient outburst in Figure 1 provides us with just such a constraint.

4.2. *The Light Echo*

The enhancement in the diffuse X-ray emission is coincident with part of a well-known ridge of dust and ionized gas, referred to as the "minispiral" (Figs. 9 and 8). Although the brightening in diffuse X-rays could represent either scattered X-rays or a mechanical outflow shocking against the surrounding interstellar medium (ISM), the morphology and energetics of the observed X-rays makes the first mechanism appear more likely. First, the diffuse region is separated from the central source by at least 4 light-months and the outburst of CXOGC J174540.0−290031 started after 2003 June, so any material that impacted the minispiral must have been traveling faster than $0.3c$. Second, if we interpret the brightening of the diffuse X-rays as an increase in the density of the emitting plasma, then the implied energy input is $\Delta U = (\Delta n)kT \sim 10^{42}$ ergs (Table 3). Therefore, the power required over 6 months is 10^{35} ergs s^{-1}. Both of these conditions could be fulfilled by a radio jet (see § 4.2 and Bower et al. 2005). However, the axis of the observed jet is oriented about 45° from the center of the brightening of the diffuse emission. Moreover, the diffuse emission has an extent of $\approx 3''$, which is vastly more extended than the radio features. These facts make it seem unlikely that the jet is responsible for the diffuse X-ray emission. Instead, we propose that the enhancement in the diffuse emission is produced by X-rays from CXOGC J174540.0−290031 that are scattered by electrons in the minispiral.

The ionized gas from this ridge has been extensively studied in radio continuum at 13 mm (Zhao & Goss 1998) and 6 cm (Lo & Claussen 1983); hydrogen emission from the H92α (3.6 cm; Roberts & Goss 1993), Paα (1.87 μm; Scoville et al. 2003), and Brγ (2.16 μm; Paumard et al. 2004) electronic transitions; and [Ne II] emission (12.8 μm; Lacy et al. 1991; Vollmer & Duschl 2000). The ridge is obviously more extended than the brightening of the diffuse emission (Fig. 8), which raises the question of why only a small fraction of it has been illuminated. Careful studies of the velocity of the gas in the minispiral have indicated that it is composed of several kinematic features (Vollmer & Duschl 2000; Paumard et al. 2004). Although the complexity of the region precludes any conclusive associations, the enhancement in X-ray flux is coincident with a section of the northern arm that has a high velocity toward us (200 km s^{-1}; see Paumard et al. 2004). We suggest that this is the only region that has brightened because it is closest to CXOGC J174540.0−290031.

The scattered flux ($F_{\rm scat}$) associated with the outburst of CXOGC J174540.0−290031 depends on the luminosity ($L_{\rm X}$) and distance (D) of the source, the solid angle (Ω) and optical depth (τ) of the scattering region, and the angle (θ) through which photons are scattered:

$$F_{\rm scat} = L_{\rm X}\frac{f(\theta)}{4\pi D^2}(1-e^{-\tau})\frac{\Omega}{4\pi}. \quad (1)$$

The function $f(\theta)$ depends on the scattering process; for Thompson scattering $f(\theta) = 0.75(1+\cos^2\theta)$. The solid angle Ω depends on the distance between the source and the scattering region and the size of the scatterer. The projected separation between the two is $\approx 2''$, so if θ is the angle between our line of sight and the line connecting the source and the scatterer, the true distance is $d \approx 0.1(\sin\theta)^{-1}$ pc. The brightening of the diffuse flux is contained in a roughly elliptical region no larger than $3''.0 \times 1''.6$, so we estimate that the projected area of the scattering region with respect to the source is $A \lesssim 0.02$ pc^2. Therefore, the solid angle of the scatterer is $\Omega/4\pi = A/(4\pi d^2) \approx 0.2\sin^2\theta$.

The scattering is most likely caused by electrons.[6] The electron density in the region of enhanced diffuse X-ray emission has not been measured directly, but the average electron density has been determined over the entire northern arm by Scoville et al. (2003) by comparing the Paα and H92α fluxes. We use their value of $n_e \sim 10^4$ cm^{-3} to estimate the optical depth to electron scattering. Assuming that the depth of the scattering region is similar to its major axis length, $l \approx 0.2$ pc, the column density is $N_e = n_e l \approx 6\times10^{21}$ cm^{-2}. The optical depth to Thompson scattering is then $\tau_{\rm T} = \sigma_{\rm T} N_{\rm e} \approx 0.004$.

We have measured the scattered flux, $L_{\rm scat} = 1.6\times10^{-13}$ ergs cm^{-2} s^{-1} (2–8 keV; Table 3), so we can solve for the intrinsic luminosity of CXOGC J174540.0−290031 using equation (1). If we assume $\theta = 90°$, we find $L_{\rm X} \approx 2\times10^{36}$ ergs s^{-1}. We consider this to be a conservative estimate of the intrinsic luminosity, because choosing a smaller value for θ or assuming a smaller depth and projected area for the scattering region would result in an inferred luminosity that is a factor of several higher, up to $L_{\rm X} \sim 10^{37}$ ergs s^{-1}.

Therefore, the peak luminosity of CXOGC J174540.0−290031 must have been at least $\sim$100 times larger than the values observed with *Chandra* (Table 2 and Fig. 5). As mentioned above, *RXTE* PCA observations would have detected an outburst larger than 3×10^{36} ergs s^{-1} and therefore conceivably could have missed CXOGC J174540.0−290031 at its peak luminosity. However, the timing and morphology of the diffuse emission argue that the peak of the outburst should have been detected with *XMM-Newton*. The region of diffuse X-ray emission remained bright for at least 2 months between 2004 July 5 and August 28 (§ 2.2), so the luminous portion of the outburst must have lasted at least this long. The peak of the outburst had to have occurred $d/c \approx 4\sin^{-1}\theta$ months prior to the *Chandra* observations. This places the peak of the outburst during 2004 March and April, when *XMM-Newton* observed the source. At that time the flux was similar to that in our *Chandra* observations (Porquet et al. 2005; Bélanger et al. 2005).

Therefore, it seems likely that the flux measured from the location of CXOGC J174540.0−290031 by *Chandra* and *XMM-Newton* is only a small fraction of its total output. Indeed, observations of edge-on LMXBs often suggest that their intrinsic luminosities are significantly larger than would be inferred from their observed X-ray fluxes. For instance, based on the strength of oxygen emission lines in the *XMM-Newton* Reflection Grating Spectrometer and *Chandra* High-Energy Transmission Grating spectra of 2S 0921-63, Kallman et al. (2003) suggest that only $\sim$30% of its total X-ray flux is transmitted toward the observer. Similarly, based on the low observed X-ray to optical flux of the accretion disk corona source X 1822−731, Parmar et al. (2000) suggest that we observe only 5% of its total flux. Our measurements of CXOGC J174540.0−290031 suggest that an even smaller fraction, $\sim$1%, of the total flux is observed.

If indeed the vast majority of the flux from CXOGC J174540.0−290031 is obscured by the accretion disk, then it could help explain the fact noted by Narayan & McClintock (2005) that no confirmed black hole LMXB is known with an inclination larger than 75°.[7] If only 1% of the total flux can be detected from a black hole LMXB observed edge-on, then almost all of the black hole transients in Fender & Kuulkers (2001) would have apparent $L_{\rm X} \lesssim 10^{36}$ ergs s^{-1} and would have been almost undetectable by the all-sky monitors on *BeppoSAX* and *RXTE* (Levine et al. 1996; Jager et al. 1997). If CXOGC J174540.0−290031 contains a black hole primary, then it could be the first such system to be observed edge-on.

4.3. *Radio Jets from a Faint X-Ray Transient*

VLA observations by Bower et al. (2005) revealed two new radio sources that appeared coincident with the X-ray outburst of CXOGC J174540.0−290031. The X-ray source was located on the line between the two radio features, which suggests that they are produced by synchrotron emission from a jet launched by the X-ray source. The peak intensity was observed in 2004 March, with $S_\nu = 90$ mJy, or $L_R \approx 4\pi D^2 \nu S_\nu \approx 2\times10^{32}$ ergs s^{-1} at 43 GHz. In 2004 July only the eastern feature was detected, with a flux density of $\approx$45 mJy at 43 GHz, or $L_R \approx 1\times10^{32}$ ergs s^{-1}. The intensity varied by $\approx$20% from day to day. The spectrum of the emission is uncertain, because even when measurements were made at multiple frequencies, VLBI observations revealed that the sources were resolved, and therefore each frequency samples a different spatial scale from the jet. It is also noteworthy that unlike the relativistically expanding jets often seen from LMXBs (Fender 2004), there was no proper motion of the radio sources along the jet axis (although there was some perpendicular to that axis; see Bower et al. 2005 for further discussion). Therefore, the radio features probably formed where the jet impacted the ISM. Indeed, the mid-infrared image in Figure 9 reveals a significant amount of dust that is near in projection to

[6] Dust only scatters photons by a few arcminutes, so the hypothesis that the diffuse X-rays are scattered by dust and would require CXOGC J174540.0−290031 lie $\sim$100 pc from the minispiral, which in turn would imply that its intrinsic luminosity is $L \sim 10^{42}$ergs s^{-1}. We also see no evidence for fluorescent emission from metals, but this could result from the poor signal-to-noise in the spectrum of the diffuse emission.

[7] It has been proposed that 4U 1755−33 is a black hole with $i > 75°$ (White et al. 1984), although no mass function has yet been measured to confirm the nature of the compact object.

CXOGC J174540.0−290031, particularly at the location of the brighter, eastern radio feature.

The radio luminosity of CXOGC J174540.0−290031 is unusually large compared to the X-ray luminosity that we infer from the light echo, $L_X \approx 2 \times 10^{36}$ ergs s^{-1}. First, LMXBs typically are observed to produce extended radio jets only during outbursts with peak luminosities of $L_X \gtrsim 10^{37}$ ergs s^{-1} (e.g., Fender & Kuulkers 2001). The only sources fainter than this that produced radio outbursts are SAX J1808.4-3658 ($L_X = 5 \times 10^{36}$ ergs s^{-1}) and XTE J1118+480 (6×10^{35} ergs s^{-1}), and in neither case was a jet resolved. Second, the ratio of the peak X-ray to radio luminosities for LMXBs in Fender & Kuulkers (2001) is typically $L_X/L_R > 10^6$, whereas that from CXOGC J174540.0−290031 is $\lesssim 10^4$. For comparison, the three LMXBs in Fender & Kuulkers (2001) with the brightest radio emission relative to their X-ray emission are XTE J1748−288 [$\log(L_R/L_X) = 5.8$], GRO J1655−40 [$\log(L_R/L_X) = 5.4$], and Cir X-1 in the 1970s [$\log(L_R/L_X) = 5.3$]. The unexpectedly bright radio emission from CXOGC J174540.0−290031 probably results from the fact that the jet radiated with unusually high efficiently when it impacted the surrounding ISM.

Finally, we can compute a lower limit to the power required to produce the radio-emitting jet by assuming that it contains only electrons and positrons, that these particles are in equipartition with the magnetic field, and that the volume (V) of the emitting region is related to the timescale on which the jet is produced (Δt) by $V = 4\pi(c\Delta t)^3$ (Fender et al. 2004). If we assume that the slope of the radio spectrum is $\alpha = -0.75$, the minimum energy is given by

$$L_{\rm jet} = 2 \times 10^{35} \left(\Delta t_{\rm day}\right)^{2/7} \nu_{\rm GHz}^{2/7} S_\nu^{4/7} D_{\rm 8kpc}^{8/7} \text{ ergs s}^{-1}, \quad (2)$$

where $\Delta t_{\rm day}$ is the time over which the jet was launched in days, $\nu_{\rm GHz}$ is the lowest frequency at which the radio emission was observed, S_ν is the flux density in millijanskys at that frequency, and D is the distance in units of 8 kpc (Longair 1994, eq. [19.29]). Using the peak radio flux of $S_\nu = 90$ mJy at $\nu_{\rm GHz} = 43$ GHz and assuming a timescale of 1 day, we find that $L_{\rm jet} \approx 10^{37}$ ergs s^{-1}. This power is comparable to the X-ray luminosity inferred from the diffuse X-ray light echo, which suggests that about half of the accretion energy is channeled into launching the radio jet.

It is often argued that LMXBs accreting at low rates release much of their energy as a jet, both based on theoretical models for flat-spectrum radio through infrared emission (e.g., Markoff et al. 2001; Malzac et al. 2004; Fender et al. 2004) and recently based on observations of an Hα nebula that appears to have been energized by the jet from Cyg X-1 over the course of many tens of years (Gallo et al. 2005). Our observations strengthen this hypothesis in two regards. First, our derivation of the jet power is relatively model independent, because our assumption of equipartition yields the minimum energy required to produce the radio emission and our conversion to a power relies on the reasonable assumption that the jet was launched on a timescale of days. Second, once one accounts for the time delay implicit in our derivation of L_X from the light echo, our measurements of the radio and X-ray luminosities are nearly contemporaneous. Therefore, these observations of CXOGC J174540.0−290031 provide the most direct evidence yet that when LMXBs accrete near 1% of the Eddington level, they release much of that energy as jets.

5. CONCLUSIONS

We have presented *Chandra* and Keck observations of a new transient X-ray source, CXOGC J174540.0−290031, which is located only 0.1 pc from Sgr A* (Fig. 1). The presence of dips in the X-ray light curve that recur at the 7.9 hr binary orbital period (Fig. 2) and the lack of any infrared counterpart with $K' < 15$ (Fig. 7) indicates that this source is a low-mass X-ray binary. The peak flux from the transient is $F_X = 4 \times 10^{-12}$ ergs cm^{-2} s^{-1} (2–8 keV, deabsorbed), which would imply a luminosity of only $L_X = 3 \times 10^{34}$ ergs s^{-1} (Fig. 5). However, the diffuse X-ray emission within 4 light-months of the source has also brightened (Fig. 1), probably because electrons in the ridge of gas and dust referred to as the minispiral (Figs. 8 and 9) have scattered light from the outburst. The intensity of the scattered flux suggests that the intrinsic luminosity is $L_X \gtrsim 2 \times 10^{36}$ ergs s^{-1}.

We have compared the energetics of the X-ray emission with those of transient radio jets that were identified with the VLA (Bower et al. 2005). The brightness of the radio flux relative to the X-ray flux suggests that the radio jets from CXOGC J174540.0−290031 radiate with unusually high efficiency, probably because electrons are accelerated as the jet impacts the surrounding ISM. Moreover, we find that the X-ray luminosity is similar to the minimum energy required to power the radio jets, which provides the most direct evidence yet that LMXBs accreting at low rates release most of their energy in the form of jets.

Future observations of this transient are important for several reasons. First, such faint outbursts cannot be monitored with all-sky instruments like that on *RXTE*. Therefore, the only way to learn about the duty cycles of such faint systems is to observe dense concentrations of LMXBs, such as those at the Galactic center and in globular clusters, with *Chandra* and *XMM-Newton*. Second, *Chandra* may be able to identify further brightening in the diffuse X-ray emission as the flux from the outburst encounters more distant sections of the minispiral. Finally, *Chandra* observations could reveal extended X-ray emission as the radio jet impacts dense regions in the ISM.

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