We present the serendipitous discovery of a young stellar cluster in the Galactic disk at $l = 12^\circ$. Using Keck/NIRSPEC, we obtained high- and low-resolution spectroscopy of several stars in the cluster, and we identified one red supergiant and two blue supergiants. The radial velocity of the red supergiant provides a kinematic cluster distance of $4.7 \pm 0.4$ kpc, implying luminosities of the stars consistent with their spectral types. Together with the known Wolf-Rayet star located 2.4' from the cluster center, the presence of the red supergiant and the blue supergiants suggests a cluster age of 6–8 Myr and an initial mass of $\approx2000 M_\odot$. Several stars in the cluster are coincident with X-ray sources, including the blue supergiants and the Wolf-Rayet star. This is indicative of a high binary fraction and is reminiscent of the massive young cluster Westerlund 1. The cluster is coincident with two supernova remnants, SNR G12.72–0.0 and G12.82–0.02, and the highly magnetized pulsar associated with the TeV $\gamma$-ray source HESS J1813–178. The mixture of spectral types suggests that the progenitors of these objects had initial masses of 20–30 $M_\odot$.

Subject headings: infrared: stars — stars: evolution — supernovae: general — X-rays: stars

Online material: color figure

1. INTRODUCTION

Young stellar clusters are important tools for investigating the structure, the chemical enrichment, and the current star formation of a galaxy. Furthermore, they are natural laboratories to study the evolution of massive stars. Massive stars explode as supernovae, creating neutron stars and black holes, and are believed to be sources of $\gamma$-ray bursts, which are the most energetic explosions in the universe. Because of their short lifespans, massive stars are rare and predominantly observed in young (few Myr) massive ($\sim 10^4$) clusters. Only a handful of massive stellar clusters are known in the Galaxy; important examples include Arches, Quintuplet, Westerlund 1, and Westerlund 2 (Figer 2008). As these clusters lie in the plane, their detection is hampered both by interstellar extinction and by the relatively low numbers of member stars. Indeed, the census is severely incomplete, as demonstrated by the recent discovery of two other massive clusters (RSGC 1 and RSGC 2; Figer et al. 2003; Davies et al. 2007).

We have serendipitously discovered a new stellar cluster at R.A. = 18°13′24.31′′, decl. = –17°53′30.83′′ (J2000.0). Previously undetected, this cluster clearly appears as a stellar overdensity at infrared wavelengths (Fig. 1) and is also visible at optical wavelength. It is located adjacent to the star-forming region W33 in an extremely rich and complex region. Two supernovae remnants (SNRs), G12.82–0.02 and G12.72–0.0 (Brogan et al. 2006); a $\gamma$-ray source, HESS J1813–178 (Aharonian et al. 2006); and numerous X-ray sources (Funk et al. 2007; Helfand et al. 2007) have been detected in its surrounding area.

In this Letter, we present near-infrared spectra of four cluster members, of which three are identified as early B-type stars and one as a red supergiant (RSG). Also, we analyze existing photometric infrared data and X-ray data and find that several bright cluster members are associated with an X-ray source, one of which is a known Wolf-Rayet (WR) star (Hadfield et al. 2007). From these results, we estimate the age and distance of the cluster, which appears associated with the star-forming region W33 and the high-energy source HESS J1813–178.

2. OBSERVATIONS AND DATA

Spectroscopic observations of several candidate cluster members (see Table 1) were performed at the Keck Observatory on 2008 April 19 using NIRSPEC (McLean et al. 1998) under program U050NS (PI R. M. Rich). A spectrum of star 1 ($K_p = 3.7$ mag) was obtained with the NIRSPEC-7 filter and the 0.57′′ × 24″ slit, covering 1.99–2.35 μm at a resolution of $R = 17,000$ with two nodded exposures of 10 s each. Low-resolution spectra of sources 2 and 3 were taken with the $K$ filter and a 0.57″ slit width, covering 1.9–2.35 μm at a resolution of $R = 1700$. Data reduction was performed as described in Figer et al. (2003). We subtracted pairs of nodded frames and flat-fielded them. The distorted 2-D spectral traces were rectified onto a linear grid, using arc and etalon frames for wavelength calibration. Atmospheric absorption and instrumental response were removed by dividing each extracted target spectrum by the spectrum of a B1 V telluric standard (HD 164581).

Photometric measurements of stellar point sources covering the cluster region were obtained from the VizieR database. We cross-correlated 2MASS near-infrared measurements (Cutri et al. 2003),5 Spitzer/GLIMPSE mid-infrared data (Benjamin et al. 2003), as well as optical data from the astrometric catalog NOMAD (Zacharias et al. 2004).

The region surrounding the cluster was observed with Chandra by Helfand et al. (2007), who detected 75 X-ray sources. We cross-identified the Chandra sources with the 2MASS and GLIMPSE catalog using a radius of 1.5″ and found 44 matches.

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5 The 2MASS All Sky Catalog of Point Sources can be found at http://irsa.ipac.caltech.edu/applications/Gator/.
3. SPECTRAL AND PHOTOMETRIC ANALYSIS

In order to confirm that the observed overdensity is an actual stellar cluster, we analyzed the photometric properties of stellar point sources from the 2MASS and GLIMPSE surveys. As an example, a \((J - K_s)\) versus \(K_s\) diagram of 2MASS point sources within 3.5 \(\arcmin\) from the peak of overdensity is shown in Figure 2. A well-defined cluster sequence appears in the infrared color-magnitude diagram (CMD) at about \(J - K_s = 1.5\) mag and \(K_s = 4-12\) mag. Its red color and bright magnitude distinguish the cluster sequence from a foreground component.

An interstellar extinction of \(A_{K_s} = 0.83 \pm 0.2\) mag (\(A_v = 9.1\) mag) is estimated by matching the colors of the observed star with \(A_v\) \(= 3.5\) mag brighter than other cluster members, dominates the infrared cluster surface brightness. Its high-resolution spectrum presents CO bands in absorption as shown in Figure 3. A radial velocity \(V_{\text{rot}} = +62 \pm 4\) km s\(^{-1}\) was measured by cross-correlating its spectrum with that of Arcturus after rebinning the latter at the same resolution. A determination of the spectral type was obtained by comparing the CO equivalent width with that of other template stars, as explained in Davies et al. (2007). The resulting CO equivalent width is consistent with that of a new RSG star, a WR star, and several BSGs.

![Image](image-url)

**Fig. 1.** \(K_s\)-band image of the cluster from 2MASS, with overlaid contours of 90 cm data (White et al. 2005). Contours levels, in mJy beam\(^{-1}\), are 40, 60, 80, 100, 120, 140, 160, 200. The beam size is 24\(\arcsec\) \(\times\) 18\(\arcsec\), FWHM, and the position angle of the major axis is along the north-south direction. Stellar identification numbers are from Table 1. [See the electronic edition of the Journal for a color version of this figure.]

**Table 1**

| ID   | R.A.     | Decl. | B   | V   | R   | J   | H   | \(K_s\) | [3.6] | [4.5] | [5.8] | [8.0] | ID\(_x\) | \(L_x\) | Spectral Type |
|------|----------|-------|-----|-----|-----|-----|-----|--------|-------|-------|-------|-------|----------|--------|--------------|
| 01   | 18 13 22.255 | -17 54 15.55 | 14.74 | 13.68 | 12.73 | 5.46 | 4.23 | 3.79 | 5.07 | 4.05 | 3.57 | ... | ... | ... | K2 I |
| 02   | 18 13 23.256 | -17 53 26.54 | 20.08 | 15.03 | 14.50 | 8.64 | 7.72 | 7.22 | 6.94 | 6.78 | 6.63 | 6.68 | 6.39 | 4.1 | B0.5–B2 I |
| 03   | 18 13 24.431 | -17 52 56.75 | 20.42 | 15.74 | 14.68 | 9.20 | 8.25 | 7.79 | 7.47 | 7.38 | 7.30 | 7.30 | 4.3 | 4.8 | B0.5–B2 I |
| 04   | 18 13 14.188 | -17 53 43.60 | 20.48 | 17.37 | 15.20 | 9.62 | 8.60 | 7.94 | 7.34 | 6.93 | 6.70 | 6.35 | 24 | 80.5 | WN7b |
| 05   | 18 13 23.711 | -17 50 40.41 | 19.51 | 16.41 | 14.94 | 9.96 | 9.06 | 8.56 | 8.23 | 8.10 | 7.99 | 8.06 | 41 | 63.4 | ... |
| 06   | 18 13 33.817 | -17 51 48.89 | ... | ... | ... | 16.12 | 10.29 | 9.15 | 8.57 | 8.00 | 7.90 | 7.75 | 7.58 | 58 | 4.0 | ... |
| 07   | 18 13 22.519 | -17 53 50.14 | 18.63 | 15.60 | 16.57 | 10.30 | 9.27 | 8.66 | 8.03 | 7.70 | 7.49 | 7.30 | 37 | 10.3 | ... |
| 08   | 18 13 14.494 | -17 54 01.77 | 19.91 | 15.47 | 15.71 | 9.86 | 9.12 | 8.75 | 8.43 | 8.33 | 8.31 | 8.31 | 27 | 3.8 | ... |
| 09   | 18 13 21.911 | -17 51 55.91 | 21.17 | ... | 16.24 | 10.74 | 9.80 | 9.34 | 8.95 | 8.90 | 8.83 | 8.91 | 36 | 2.8 | ... |
| 10   | 18 13 47.561 | -17 57 01.43 | 15.32 | ... | 13.64 | 10.76 | 9.89 | 9.60 | 9.31 | 9.34 | 9.22 | 9.20 | 71 | 21 | 70 |
| 11   | 18 13 23.620 | -17 53 24.50 | ... | ... | 11.74 | 10.85 | 9.59 | 10.16 | 10.32 | 10.02 | ... | ... | ... | B0.5–B2 |

**Note.**—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. For each star, number designations and coordinates (J2000.0) are followed by magnitudes measured in different bands. \(J, H,\) and \(K_s\) measurements are from 2MASS, while the magnitudes at 3.6, 4.5, 5.8, and 8 \(\mu\)m are from GLIMPSE. \(B, V,\) and \(R\) associations are taken from the astrometric catalog NOMAD. For sources with X-ray associations, number designations (ID\(_x\)) are taken from Helfand et al. (2007). Estimates of \(L_x\) are obtained for a distance of 4.7 kpc, by assuming \(M(H) = 1.6 \times 10^5\) cm\(^{-2}\), a power-law model, and a photon index of 1.5 (Townsley et al. 2006). X-ray luminosities \(L_x\) are given in units of \(10^{35}\) erg s\(^{-1}\).
K3 I star (Davies et al. 2008) is also shown (dashed line) and Bibby et al. (2008) and consider extinction laws and bolometric corrections given by Crowther et al. (2005).}

The 2MASS photometric measurements of stars 2 and 3

4. MAJOR WINDS AND DISTANCE

From the radial velocity of star 1, we derive a kinematic heliocentric distance of 4.7 ± 0.4 kpc by using the rotation curve of Brand & Blitz (1993) and a solar Galactocentric distance of 7.6 kpc (Kohles & Dougherty 2007). Since the far distance (10.3 kpc) would make the stars1 overltorous, we consider only the near distance. A spectrophotometric distance of 0.9 or 4.4 kpc is inferred when assuming an M4 giant or an early K RSG, respectively, together with the absolute infrared magnitudes of Wainscoat et al. (1992). An interstellar extinction $A_V$ of 0.48 mag is derived. We conclude that this bright star is a K2 I RSG star. Star 1 is 0.9′ from the center.

By assuming a distance of 4.7 kpc, as calculated for the RSG star, and an intrinsic $H - K_s$ from 0.11 to 0.27 mag (Crowther et al. 2006a) and using the extinction law by Messineo et al. (2005), we derive for the WN7b star an $A_K$ from 0.83 to 0.59 mag and an absolute magnitude $M_K$ from −6.0 to −6.2. This value of $M_K$ is consistent with those of similar WN7 stars in Westerlund 1 (Crowther et al. 2006a). The 2MASS colors and magnitudes are consistent with being a cluster member. A bolometric correction of −3.5 (Crowther et al. 2006a) yields a bolometric magnitude of −9.6. Star 4 is 2.4′ from the center.

The 2MASS photometric measurements of stars 2 and 3 support either early nearby B dwarfs or early B supergiants at a distance of 3.7 ± 1.7 kpc. We assume the absolute magnitudes and bolometric corrections given by Crowther et al. (2006b) and Bibby et al. (2008) and consider extinction laws by both Messineo et al. (2005) and Indebetouw et al. (2005). Star 2 has $A_K = 0.87$ mag and star 3 has $A_K = 0.81$ mag (Messineo et al. 2005). However, they have the same interstellar extinction as the WR star; they are located in the same region of the CMDs, and most likely they are B0–B2 supergiants, as well as members of the cluster. They are within 0.6′ from the center. Star 11 has poor 2MASS photometry; with $K_p = 9.59$ mag and an extinction $A_K = 1.2$ mag, it is consistent with being an early B dwarf.

We conclude from the CMDs and distance estimates that the RSG, the WR star, and the BSGs are all part of the same stellar cluster. The average spectrophotometric distance of 3.7 ± 1.7 kpc is consistent with the kinematic distance of 4.7 ± 0.4 kpc within uncertainties. We assume the kinematic distance.

5. THE X-RAY ASSOCIATIONS AND ENERGETICS

The 2MASS CMD (Fig. 2) shows two distinct populations of Chandra sources. One is associated with a blue foreground main-sequence population, while the other is associated with redder and brighter stars that have colors and magnitudes consistent with a cluster membership. X-ray sources with a bright 2MASS counterpart ($K_p < 9.6$ mag), such as candidate massive members of the stellar cluster, are more spatially concentrated; except for one, they are within 3.5′, while the other X-ray detections are within 12′ from the cluster center. The nine candidate massive members with an X-ray association are included in Table 1. Star 4, the WR star (star 8 in Hadfield et al. 2007), is associated with the Chandra source 24 (Helfand et al. 2007), coinciding with the XMM source 2 of Funk et al. (2007).

Massive stars can emit X-rays. Single OB stars with shocked stellar winds can emit with a typical X-ray luminosity $L_X$ of $10^{31}$–$10^{32}$ erg s$^{-1}$ (Pollock 1987). Shocks between the colliding winds of OB+OB or OB+WR binaries can generate a $L_X$ of $10^{32}$–$10^{33}$ ergs s$^{-1}$ (Clark et al. 2008).

To estimate the X-ray fluxes of the nine bright infrared stars associated with an X-ray source, we used an interstellar extinction of $A_V = 9.1$ mag, which was estimated from the CMDs, as well as the relationship between extinction and total hydrogen column density $N(H)_{[}cm^{-2]} = A_V[mag] 	imes 1.8 	imes 10^{21}$. Count rates were estimated from the Chandra/ACIS-I counts (in the band 2–10 kev) that were given by Helfand et al. (2007). We converted them into X-ray–unabsorbed fluxes by using PIMMS version 3.9d, an ACIS count estimator, with a power-law model and a photon index of 1.5 (Townsley et al. 2006). Fluxes were converted into X-ray luminosities $L_X$ by assuming a distance of 4.7 kpc. Six of the sources have $L_X = (2–10) \times 10^{31}$ ergs s$^{-1}$. The three remaining sources (stars 4, 5, and 10) are an order of magnitude brighter ($[2–8] \times 10^{32}$ ergs s$^{-1}$); the brightest, star 4, is the WR star (Hadfield et al. 2007). The ratio between the X-ray and bolometric luminosities was found to be $3.8 \times 10^7$ for the WR star but about 10 times fainter ($0.4 \times 10^7$) for stars 2 and 3, as expected for stars with spectral type later than B1 (Cohen 1996; Waldron & Cassinelli 2007). We conclude from the X-ray energetics that these bright infrared stars are likely to be massive stars. The WR is most likely a colliding wind binary (Portegies Zwart et al. 2002).

6. AGE AND MASS

The large variety of evolved objects—one WR, one RSG, two BSGs, and several X-ray emitters—allows us to constrain the age and mass of the stellar cluster by assuming coevality. The nonrotating Geneva models with solar abundance predict...
the onset of RSG stars at an approximate age greater than 6–7 Myr (Lejeune & Schaerer 2001). In a population of 6 Myr, the most massive stars have initial masses \(M_{\text{initial}}\) of approximately 29 \(M_\odot\) (Lejeune & Schaerer 2001). In contrast, WR stars are present in populations younger than 7.9 Myr. The X-ray emission associated with our WR star suggests a high-energy source (Jeffries et al. 2007). By analyzing the X-ray flux, the authors concluded that the SNR is associated with the star-forming region W33. Similar conclusions were also obtained with the XMM data by Funk et al. (2007). No stellar counterpart to the PWN was found in the 2MASS or Spitzer/GLIMPSE images by Helfand et al. (2007).

Dean & Hill (2008) assumed a distance of 4.5 kpc and an age of 300 yr and found the putative pulsar to have an extremely strong magnetic field \((B = 1.28 \times 10^{14} \text{ G})\). Funk et al. (2007) detected six other XMM sources in addition to the PWN, AX J1813–178, and Helfand et al. (2007) detected a total of 75 Chandra sources in the region surrounding the two SNRs (Fig. 1).

The new stellar cluster is coincident (to within 1.6') with the radio shell of SN G12.72−0.00, which suggests its association with the supernova progenitor. The kinematic cluster distance of 4.7 kpc is consistent with the distance to the high-energy source HESS J1813−178, as inferred from the hydrogen column density by Funk et al. (2007) and Helfand et al. (2007). Massive members of this cluster were most likely the progenitors of the two supernovae and of the pulsar associated with HESS J1813−178. The progenitors of these objects had likely an initial mass similar to that of the RSG and WR stars (20–30 \(M_\odot\)).

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7. SUPERNOVAE REMNANTS

The cluster core is about 4.5' away from HESS J1813−178. Several studies have recently been carried out in order to unveil the nature of the HESS \(\gamma\)-ray source. As a result, numerous radio and high-energy sources have been detected (see Fig. 1). Two nonthermal radio shells, G12.82−0.02 and G12.72−0.00, were identified on the 90 cm VLA survey (Brogan et al. 2006), a few arcminutes one from another (see Fig. 1). Very little is known about the SNR G12.72−0.00. The other SNR was associated with the HESS J1813−178 source by Helfand et al. (2005). A pulsar wind nebula (PWN) was detected by Chandra within this SN radio shell less than 1' from the maximum probability centroid of the HESS source (Helfand et al. 2007; Funk et al. 2007). By analyzing the X-ray flux, the authors concluded that the SN G12.82−0.02, the HESS J1813−178 source, and the PWN lie at or just beyond 4 kpc and might be associated with the star-forming region W33. Similar conclusions were also obtained with the XMM data by Funk et al. (2007).

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