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HIDDEN MILKY WAY STAR CLUSTERS HOSTING WOLF-RAYET STARS

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RESUMEN

Una importante fracción de los cúmulos jovenes escondidos en polvo contiene estrellas O y WR, convertiéndolos en laboratorios perfectos para estudiar la evolución y el entorno de nacimiento de estas estrellas peculiares. En este trabajo reportamos el enrojecimiento, la distancia y una estimación de la edad de los cúmulos Glimpse 23 y Glimpse 30.

ABSTRACT

A noticeable fraction of the hidden young star clusters contain WR and O stars providing us with unique laboratories to study the evolution of these rare objects and their maternity places. We are reporting the reddening, the distance and age of two new members of the family of massive young Galactic clusters, hosting WR stars – Glimpse 23 and Glimpse 30.

Key Words: Galaxy: open clusters and associations — infrared: general — stars: formation — stars: early-type — stars: Wolf-Rayet

1. INTRODUCTION

During their formation and early evolution the stellar clusters are often only visible at the infrared wavelengths, being heavy obscured by dust. The *Spitzer Space Telescope* Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE, Benjamin et al. 2003) offers an excellent opportunity to carry out a deep census of such objects because of the lower extinction in the mid-IR.

Wolf-Rayet stars represent very short evolved phase of the most massive stellar population, and are characterized by high mass loss and fast dense stellar winds. The study of WRs *within* star clusters enables us to study a coeval population with uniform metallicity, where the main sequence turnoff mass can be accurately determined. In the optics, the Galactic Wolf-Rayet population is well studied, but there is a significant lack of information for a hidden one.

Mercer et al. (2005) carried a comprehensive search for clusters in the mid-IR. They used the point source catalog of GLIMPSE and reported 92 cluster candidates. Some of these objects are young clusters, just blowing-up the surrounding gas nebula and presenting significant population of massive young stars. We provide evidences that two of these clusters, Glimpse 23 (G23) and Glimpse 30 (G30), contain Wolf-Rayet stars. These are compact young clusters located near the Galactic plane (Figure 1). The presence of more than one WR star puts them into the family of WR rich clusters. Here we present the main results of our photometric and spectral analysis of the clusters and the newly discovered WRs.

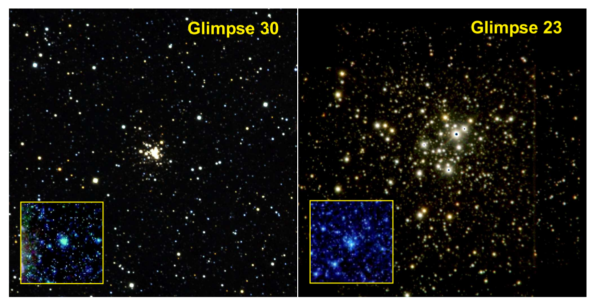

Fig. 1. Pseudo-true color images of G23 (right panel) and G30 (left panel) composed from J – blue, H – green and K_S – red. The small images for each cluster are composed from 3.6 μm – blue, 5.8 μm – green and 8.0 μm – red *Spitzer Space Telescope* images.

2. OBSERVATIONS

Deep $J_S H K_S$ imaging of G30 was carried out on April 15, 2006 with SofI/NTT within observing program 77.D-0089. The total integration time was 16 min in each filter. Deep JHK_S imaging of G23 was carried out on July 12 2006 with the near-IR

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TABLE 1

PHYSICAL PARAMETERS OF WR STARS

Star	$\log L$ $[L_\odot]$	$T_{\rm eff}$ [K]	$\log \dot{\mathcal{M}}$ $[\mathcal{M}_\odot/{\rm yr}]$	H/He	BC [mag]	M_K [mag]	$(K\text{-}M_K)_0$
GLIMPSE 23							
1	5.85	35560	−5.16	3.330	−3.4	−6.04	13.603
2	6.08	35460	−4.89	1.250	−3.8	−7.10	14.254
GLIMPSE 30							
1	6.04	37700	−4.91	1.000	−3.8	−6.55	15.065
2	5.91	38185	−5.12	1.030	−4.4	−5.62	14.134
4	5.81	36800	−5.30	1.015	−3.6	−6.18	13.625

imager PANIC at the 6.5 meter Baade telescope at the Las Campanas Observatory.

The stellar photometry of the final images was carried out with ALLSTAR in DAOPHOT II. The photometric calibration was performed by comparing our instrumental magnitudes with the 2 MASS measurements of about thousand stars, covering a wide range in magnitudes and colors.

All spectra were obtained with SofI on Apr 14, and August 10, 2006. They cover the region from $\sim$2.00 to $\sim$2.35 μm. For the spectroscopy we used a 1 arcsec slit and the medium-resolution grism. We obtained 16 images of 150 sec each, in one slit position for G30, and 8 images of 300 sec each, in one slit position for G23. We applied standard reduction process.

3. RESULTS

We used the color-color diagrams to determine the reddening to the clusters. We simply measured the color excesses of this locus on the color-color diagrams with respect to the sequences of unreddened MS stars (Schmidt-Kaler 1982), obtaining for G30: $A_{K_{\rm S}}$=1.12±0.08 mag (A_V=10.0±0.7 mag) and for G23: $A_{K_{\rm S}}$=0.82±0.07 mag (A_V=7.3±0.6 mag).

The WN luminosities (see below) allow us to obtain relatively good estimates of the distance. The bolometric corrections (BC) for WN stars were used to transform the luminosities to absolute $K_{\rm S}$ band magnitudes. The BCs and the distance moduli of WR stars are listed in Table 1. Averaging the individual estimates, we obtain for G30 $(K_{\rm S}-M_{K_{\rm S}})_0$=14.31±0.35 mag, corresponding to distance of d=7.2±0.9 kpc, and for G23 $(K_{\rm S}-M_{K_{\rm S}})_0$=13.82±0.35 mag, corresponding to distance of d=6.5±0.9 kpc.

The stellar evolutionary models with rotation predict the onset of red supergiants at $\sim$4.5−5 Myr. The lack of such stars in both clusters define this upper limit to the clusters age. The WR phase is very short lived and the presence of WR stars limits the maximal age of the cluster (Meynet & Maeder 2005). All known WR stars are of the WN6-8 subtype and the upper age limit of $4-4.5$ Myr can be set, independently of the exact metallicity and mass-loss scenario. The age of the PMS stars in both clusters, determined by theoretical PMS isochrones from Siess, Dufour, & Forestini (2000) and also, the fraction of stars with NIR-excess suggest an age of 3–4 Myr.

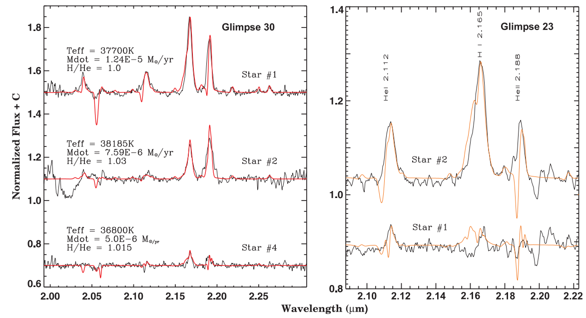

Fig. 2. CMFGEN model (Hillier & Miller 1998) fit to the observed spectra of WR stars in G23 and G30.

We used the CMFGEN model (Hillier & Miller 1998) to obtain synthetic line profiles of WR stars presented in Figure 2. We calculated a grid of models spanning a range of temperatures and mass loss rates. Initially, the luminosity of each star was set to $\log L/L_\odot$=6.0 and the terminal velocity to V_∞=1000 km s^{-1}, determined from the width of the spectral lines. The synthetic spectra were degraded to the resolution of the observed spectra, using the profile of the arc lamps as a measure of the instrumental profile. We apply the relation between modified wind momentum $\Pi=\dot{\mathcal{M}}\ V_\infty\ R_*^{0.5}$ and the luminosity (Kudritzki, Lenon, & Puls 1995) to determine the stellar luminosity (Table 1).

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