THE ARCHES CLUSTER MASS FUNCTION

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ABSTRACT

We have analyzed $H$ and $K_s$-band images of the Arches cluster obtained using the NIRC2 instrument on Keck with the laser guide star adaptive optics (LGS AO) system. With the help of the LGS AO system, we were able to obtain the deepest ever photometry for this cluster and its neighborhood, and derive the background-subtracted present-day mass function (PDMF) down to $1.3 M_\odot$ for the 5"-9" annulus of the cluster. We find that the previously reported turnover at $6 M_\odot$ is simply due to a local bump in the mass function (MF), and that the MF continues to increase down to our 50% completeness limit ($1.3 M_\odot$) with a power-law exponent of $\Gamma = -0.91$ for the mass range of $1.3 < M / M_\odot < 50$. Our numerical calculations for the evolution of the Arches cluster show that the $\Gamma$ values for our annulus increase by 0.1-0.2 during the lifetime of the cluster, and thus suggest that the Arches cluster initially had $\Gamma$ of $-1.0 \sim -1.1$, which is only slightly shallower than the Salpeter value.

Key words: Galaxy: center — open clusters and stellar associations: general — stars: luminosity function, mass function — celestial mechanics, stellar dynamics

I. INTRODUCTION

The stellar initial mass function (IMF) is the most primary product of the star formation process. With this one relation, it is possible to directly probe the crucial predictions of star formation models. Surprisingly, the IMF is approximately universal, following the Salpeter law (Salpeter 1955) for masses between 1 and 120 $M_\odot$ (Kroupa 2002). On the low mass end, there appears to be a universal rollover around 0.8 $M_\odot$, and the high mass end seems to be truncated by a sharp cutoff near 150 $M_\odot$ (Weidner & Kroupa 2004; Figer 2005).

However, star formation theories predict that the lower mass cutoff ($m_l$) should be a function of environmental parameters, i.e. magnetic field strength and cloud temperature (e.g., Bonnell, Larson, & Zinnecker 2006). In the extreme environment of the Galactic center (GC), some of these models predict an elevated lower mass cutoff/rollover with respect to that observed in the disk (Morris 1993). If this prediction is true, then the GC should have an abnormally bright lower mass cutoff, something that has not been directly observed anywhere in the Universe.

The best places to trace the IMF near the GC are the two young star clusters therein: the Arches and Quintuplet clusters (see Figer et al. 1999 for findings and early studies on these clusters). These clusters are very young (2-4 Myr), compact ($\lesssim 1$ pc), and only 20-30 parsecs away from the GC in projection, while they appear to be as massive as the smallest Galactic globular clusters ($\sim 2 \times 10^4 M_\odot$; Kim et al. 2000). Of the two clusters, the Arches is preferred for studies of the low-end mass function (MF) as the Quintuplet is significantly more dispersed.

Earlier observational studies on the mass function of the Arches cluster include Figer et al. (1999), Yang et al. (2002), Stolte et al. (2002), and Stolte et al. (2005). In the present Proceedings paper, we present the Keck/NIRC2 laser guide star (LGS) AO observations of the Arches cluster and its nearby background populations, which were reported in Kim et al. (2006).

II. OBSERVATIONS

The images were obtained using the Keck/NIRC2 LGS AO system on 2006 May 4 & 5. The Arches cluster ($\alpha = 17^h 45^m 50^s.59$, $\delta = -28^\circ 49' 20''.3$; J2000) was observed with the medium ($20'' \times 20''$, 0''.0198 pixel$^{-1}$) and wide ($40'' \times 40''$, 0''.0397 pixel$^{-1}$) field cameras, and three nearby control fields, separated $\sim 60''$ from the cluster center, were imaged with the medium field camera in order to sample the background population. All fields were imaged in $H$ and $K_s$ bands in a 9-point dither pattern with a leg size of 2''. The multiple correlated double sampling (MCDS) mode was used with 10 coadds and a 10 s integration time per coadd, giving a total exposure time of 900 s per field. Obtained Strehl ratios for the $K_s (H)$ images are 0.17 (0.08),
0.19 (0.08), 0.25 (0.06), 0.13 (0.06), and 0.12 (0.06) for the medium cluster field, control fields A, B, C, and wide cluster field, respectively, resulting in FWHMs of 70–100 mas for $K_s$, and 61–98 mas for $H$. Detailed descriptions on the data reduction are given in Kim et al. (2006).

### III. THE MASS FUNCTION

We convert the apparent magnitudes into masses using the Geneva models. Here, we only use $K_s$-band data as they provide deeper photometry. Figure 1 shows our completeness-corrected MF for the cluster intermediate region after background subtraction, along with the MF from Stolte et al. (2005) that is also completeness-corrected, but not background-subtracted; both are scaled to an area of $5''$–$9''$ annulus. The MF of Stolte et al. (2005) shows a global turnover below $\log M/M_\odot \simeq 0.35$ ($M \simeq 2.3 M_\odot$), which is also their 50% completeness limit, but our cluster MF, whose 50% completeness limit is at $\log M/M_\odot = 0.1$ ($M \simeq 1.3 M_\odot$), still has a significant amount of stars below $M = 2.3 M_\odot$ and keeps increasing at least down to $M = 1 M_\odot$. Note that our MF increases even below our 50% completeness limit.

Stolte et al. (2005) claim that there may be a turnover near $\log M/M_\odot \simeq 0.8$ ($M \simeq 6.3 M_\odot$) in their MF and that this might indicate a global decrease of the background-subtracted MF below that mass. However, our data, which have a quarter dex lower completeness limit in mass, indicate that the MF globally increases down to our completeness limit even after background subtraction. Therefore, we presume that the turnover around $M = 6.3 M_\odot$ claimed by Stolte et al. (2005) is in fact a local bump in the MF as seen in Figure 1. Eisenhauer et al. (1998) find a similar bump in their LF of the Galactic starburst template NGC 3603, and show that such a bump is an indication of the young age ($\lesssim 3$ Myr) using the evolutionary pre-main-sequence tracks by Palli & Stahler (1993).

When fit to a single power-law relation, our cluster MF gives a power-law exponent of $\Gamma = -0.91 \pm 0.08$ (the Sapleton slope is $\Gamma = -1.35$) for the mass range of $\log M/M_\odot = 0.1$–1.7. This is slightly steeper than the exponent for massive stars only ($\log M/M_\odot = 0.7$–1.7), $\Gamma = -0.71 \pm 0.15$.

We have performed several Fokker-Planck calculations (for $m_1 = 0.1$ & $1 M_\odot$) and $N$-body simulations (for $m_1 = 1 M_\odot$) targeted for the Arches cluster with initial cluster conditions similar to those used in Kim, Morris, & Lee (1999) and Kim et al. (2000), one of which is no initial mass segregation. We find that the $\Gamma$ values for the projected annulus of $5''$–$9''$ increase by 0.1–0.2 during the lifetime of the Arches cluster, 2–2.5 Myr.* Therefore, our results suggest that the IMF of the cluster has $\Gamma = -1.0 \sim -1.1$. Figure 1 shows two MFs for our annulus from our Fokker-Planck calculations that best match the observed MF at 2 Myr. These two calculations have considerably different $m_1$'s (0.1 & $1 M_\odot$), but result in nearly identical MFs for the annulus. Thus our estimate for the IMF from the simulations does not sensitively depend on the choice of $m_1$.

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*These calculations consider internal dynamics of the cluster such as mass segregation and tidal evaporation among others; see the references for model details.
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