Formation, evolution, and survival of massive star clusters
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Mid-infrared [NeII] Imaging of Young Massive Star Clusters Near Galactic Nuclei

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Abstract. We investigate the formation of young massive clusters near the nuclei in NGC 6946, IC 342, Maffei II, and NGC 7714, using ground-based mid-infrared [NeII] imaging. We derive the cluster formation efficiency and cluster mass function, and the results suggest that environmental effects on YMC formation may not be significant.

Keywords. Star Clusters, Nearby Galaxies, Infrared

Young massive clusters (YMCs) are common (> 50%) near galactic nuclei of all Hubble types (Böker *et al.* 2002). Galactic nuclei are ideal test beds to examine the impact of extreme environments on YMC formation, because conventional star formation processes do not necessarily operate in such environments. *Is cluster formation efficiency universal?* Cluster formation efficiency (CFE) is the fraction of stars formed in bound clusters, it is also a key parameter in numerical simulations of star cluster assembly histories. Observationally, empirical CFEs were derived using optically-visible, relatively older clusters (> 10 Myr) (Bastian 2008, Adamo *et al.* 2011). These works suggest that CFE is universal ∼10%. Theoretical work (Kruijssen 2012), however, suggests that CFE should depend on the host galaxy's environment, from 1% in low surface gas density ($\Sigma_{\rm gas}$) galaxies, to 70% in very high $\Sigma_{\rm gas}$ environments. *Does cluster mass assembly depend on the environment?* While observations suggest that cluster mass assembly is independent of galactic environments and cluster mass function is universal (Dowell *et al.* 2008), theories suggest otherwise, that high shear environments impede cluster formation (Weidner *et al.* 2010), thus cluster mass function should vary in different environments.

Extremely young YMCs are very obscured even in the near-infrared wavelengths (A_K > 3, Tsai *et al.* 2013). Extinction is almost absent at wavelengths > 10 μm, and mid-infrared observations on a 8-m telescope deliver diffraction limited, sub-arcsecond angular resolution, which is required to resolve the size of YMCs (a few pc) at a distance of few tens of Mpc. Such observations also simultaneously recover extended emission associated with unbound, field star formation, which allows us to derive CFE, while radio interferometric observations cannot recover extended emission. Our work is based on data taken in 2013 and 2014 using Cooled Mid-Infrared Camera and Spectrometer (COMICS) on Subaru Telescope. We mapped the nuclear regions of NGC 6946, IC 342, Maffei II, and NGC

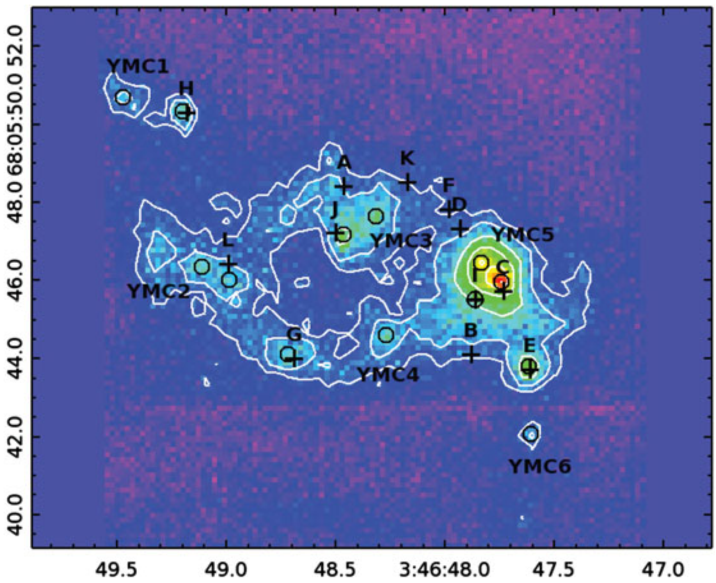

Figure 1. IC 342 [NeII] 12.8 μm image with 0.4" resolution. Lowest contours mark 3-σ detections. YMCs are marked in black circles, and their radio continuum counterparts are marked by crosses. The YMCs have no counterparts in the optical wavelengths.

7714, using the [NeII] 12.81 μm emission line, a direct tracer of massive star formation (Ho & Keto 2007) and much brighter than any hydrogen recombination lines. We detected 30 YMCs with estimated masses of 10^4 to 10^6 $M_\odot$, as well as extended [NeII] emission, which presumably is associated with unbound field star formation. Fig. 1 shows an example of the [NeII] images. *CFE Universality*: The derived CFEs in our sample galaxies are 12% to 22%, which disagree with theoretical predictions (Kruijssen 2012) of CFEs in extreme environments (> 50%), and they crudely agree with the empirical value of 10% found in exposed star clusters (Bastian 2008) in other galactic environments. This may suggest a universal cluster formation efficiency independent of the natal galactic environment. *CMF vs. Galactic Environments*: The CMF derived from our YMC sample has a power law index of -2.2. Taken into account the uncertainties, this agrees the YMC HII region luminosity function index of -2.2 (Tsai *et al.* 2006), and the cluster mass function index of -2 derived from older clusters in other galactic environments (Chandar *et al.* 2010). This perhaps also suggests that the environmental effects of YMC mass assembly is insignificant.

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