*Stellar Populations as Building Blocks of Galaxies*
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# Planetary Nebulae in Extragalactic Young Star Clusters

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**Abstract.** We have recently obtained optical spectra for a large sample of young and intermediate-age star clusters in several nearby galaxies. The main aim of this programme is to carry out a detailed test of photometric and spectroscopic age- and metallicity indicators, but a first inspection of the data has also revealed emission lines in 3 clusters with ages of 30 Myrs or older. We identify these three objects as likely Planetary Nebula (PN) candidates and discuss their properties. Based on the cluster ages, the progenitor stars had initial masses in the range 3 to 7 $M_\odot$, while the PN central stal luminosities and temperatures (estimated from emission line fluxes) are consistent with current masses close to 0.60 $M_\odot$. These objects represent a rare opportunity to study PNe whose progenitor stars are known to be of intermediate masses, although detailed analysis is challenging because of the strong underlying stellar continuum from the cluster stars. Detection of 3 PNe in our sample appears consistent with expectations from stellar evolutionary theory.

**Keywords.** stars: AGB and post-AGB, galaxies: star clusters

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It is notoriously difficult to determine the masses of planetary nebula (PN) progenitor stars. Star clusters offer a possible way out of this problem, since the progenitor mass of any PN associated with a cluster can be assumed to be very similar to the current main sequence turn-off mass. However, the number of PNe known to be associated with star clusters is small: Only a couple of handfuls of such objects have been identified in Milky Way open and globular clusters (Pedreros 1987; 1989; O'Dell 1963; Jacoby *et al.* 1997).

We have recently obtained spectra for 80 star clusters in several nearby star-forming galaxies. 52 of these have ages between 30 Myr and 1 Gyr, corresponding to main sequence turn-off masses less than 8 $M_\odot$. Three of the clusters display [O III] ($\lambda 4959, 5007$Å) and [N II] ($\lambda 6548, 6584$Å) emission lines, a strong indication that they host planetary nebulae. Basic properties of the clusters and the candidate PNe are listed in Table 1. Cluster ages were derived from $UBVI$ broad-band colours ($\log(\mathrm{age/yr})_{\mathrm{phot}}$) and by matching model SSP spectra from the library of González-Delgado *et al.* (2005) to our observed EMMI spectra ($\log(\mathrm{age/yr})_{\mathrm{spec}}$). The table lists both age estimates, together with the corresponding total cluster masses and the main sequence turn-off masses ($M_{\mathrm{TO}}$).

Dopita *et al.* (1992) provide a model grid which allows determination of effective temperature and luminosity for PN central stars from their Balmer and [O III] emission line fluxes. In our case, accurate measurements of the Balmer lines are complicated by the underlying strong absorption lines from A-type stars in the clusters, but by subtracting the best-fitting SSP models from our observed spectra we were able to obtain rough estimates of the H$\alpha$ emission line fluxes for two of the clusters. Combined with the [O III] fluxes, this yielded the $T_{\mathrm{eff}}$ and $\log L_{\mathrm{cs}}$ estimates given in Table 1. These are consistent with post-AGB model calculations for central stars with a mass of about 0.60 $M_\odot$ (Vassiliadis & Wood 1994). The small masses inferred for the PN central stars are some-



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**Table 1.** Properties of PN candidates and their host star clusters. $M_{\rm cl}$ and $M_{\rm TO}$ are the total cluster masses and main sequence turn-off masses. $T_{\rm eff}$ and $L_{\rm cs}$ are the estimated effective temperatures and luminosities of the PN central stars.

| | N5236-254 | N5236-487 | N3621-1106 |
|---|---|---|---|
| $\log(\mathrm{age/yr})_{\rm phot}$ | $8.56 \pm 0.03$ | $7.81 \pm 0.24$ | $8.21 \pm 0.45$ |
| $\log(\mathrm{age/yr})_{\rm spec}$ | 8.45 | 7.50 | 7.70 |
| $M_{\rm cl}/10^3 M_\odot$ | 376–495 | 29–51 | 94–187 |
| $M_{\rm TO}/M_\odot$ | 3.2–3.6 | 6.6–9.0 | 4.5–7.3 |
| L ([O III]) | 6.11±0.99 | 5.10±0.84 | 18.7±4.49 |
| $\mathrm{M}_{5007}$ | $-3.01 \pm 0.18$ | $-2.82 \pm 0.18$ | $-4.23 \pm 0.26$ |
| $\log T_{\rm eff}$ [K] | 4.66±0.02 | 4.65±0.02 | - |
| $\log L_{\rm cs}/L_\odot$ | 3.79±0.08 | 3.73±0.08 | - |

what surprising in light of the relatively high masses for the progenitor stars: although the initial-final mass relation may be nearly flat for $M_{\rm initial} < 3 - 4$ $\mathrm{M}_\odot$, most current evidence suggests that a star with an initial mass $> 6M_\odot$ is more likely to produce a $\sim 0.8 - 1.0$ $\mathrm{M}_\odot$ remnant (e.g. Ferrario *et al.* 2005; Weidemann 2000).

It is interesting to ask whether the observed number of PN candidates is consistent with naive expectations based on stellar evolution. Using stellar lifetimes from Salasnich *et al.* (2000) evolutionary tracks and assuming that PNe remain observable for $10^4$ years, we estimate a total of 6 PNe in our full cluster sample. This number is a factor of two higher than our observations, but the lifetimes for PNe with massive progenitor stars might well be shorter than our assumed $10^4$ years (Schönberner & Blöcker 1996). Since the predicted number of PNe scales linearly with the observable lifetime, we therefore conclude that the observed number of PNe is in good agreement with theoretical expectations.

A search for PNe in a larger sample of young star clusters might prove rewarding and a detailed follow-up study of the properties of the candidates (e.g. with high-dispersion spectroscopy) would allow better constraints on the physical properties of the nebulae and their central stars. For a full discussion of our results, the reader is referred to Larsen & Richtler (2006).

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