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Star formation in giant extragalactic H II regions*

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Abstract. Star formation properties in Giant Extragalactic H II Regions (GEHRs) are investigated using the optical photometry and evolutionary population synthesis models. We find it necessary to have differential extinction between embedded cluster stars and the surrounding nebulosity in GEHRs, with about 50% of the cluster photons escaping the nebula unattenuated. GEHRs are found to contain hot massive stars and evolved red supergiants simultaneously, implying more than one event of star formation in the last 10 Myr. We have identified some regions on our images which may be examples of young and old regions spatially separated by 40-100 pc. Extended duration of star formation in GEHRs may be as a result of a trigger from the earlier star formation event.

Key words : Galaxies : H II regions—star formation

1. Introduction

Giant extragalactic H II regions are the major sites of star formation in external galaxies. In this study, we investigate the star formation (SF) properties of GEHRs for an assumed Initial Mass Function (IMF). GEHRs are found to contain massive and hence young stars and it is interesting to see whether they contain more than one generation of stars. It is not known whether star formation in GEHRs takes place continuously over a period of time or in the form of bursts. The present study is an attempt in understanding these using optically derived quantities, by minimizing the errors due to uncertainties in interstellar extinction, aperture sizes and distance.

2. Data and method of analysis

The photometric data on GEHRs in Hα emission line and *BVR* continuum is obtained by synthetic aperture photometry on CCD images. Published spectroscopic data on these regions is used to estimate the metallicity, reddening and gaseous contribution within the broad *BVR* bands, which are used to obtain pure cluster $B - V$ and $V - R$ colours. Quantity ϕ/L_B defined as the ratio of $H\beta$ to B band luminosity is computed from observed $H\alpha$ and B band fluxes. This ratio resembles $H\beta$ equivalent width, which is the ratio of Hβ flux to the underlying continuum flux. All the derived quantities are distance independent.

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An evolutionary population synthesis model is developed to compute the quantities obtained from our optical study. This is done using the stellar evolutionary models of Maeder (1990) and stellar atmosphere models of Kurucz (1979). In the model, embedded cluster is defined by an IMF, age, metallicity and total mass. IMF has three parameters namely m_l and m_u, the lower and upper cut-off masses, and α, the slope. Quantities $B - V$, $V - R$ and ϕ/L_B are computed for a range of values of the above parameters. All the stars assumed to be formed in an instantaneous burst and the cluster is evolved up to 14 Myr. Additionally models with continuous star formation and multiple bursts are also considered.

3. Discussion

Comparing observed quantities with population synthesis models, it is shown that dereddening $B - V$ colours using Balmer decrement overcorrects the cluster colours, implying that cluster stars are not experiencing the same amount of extinction as the ionized gas. In addition observed values of ϕ/L_B are lower by an order of magnitude compared to models with Salpeter's IMF. We adopt a new prescription for correction to interstellar extinction, which assumes that a fraction of stellar light escapes without attenuation. This fraction is found to be close to 50%. It is shown that a similar fraction of ionizing radiation either escapes the H II region or escapes detection through absorption of Balmer radiation by dense clouds. This partly explains the observed low values of ϕ/L_B. The colours of embedded clusters show evidence of red supergiants which belong to an earlier burst of age greater than 6 Myr. The older population contributes significantly to the optical continuum, thus explaining the low observed values of ϕ/L_B. This contribution increases at longer wavelengths. The younger population supplies the ionizing photons, and in the observed regions it is younger than 5 Myr (see figure 1). From three colour images of some galaxies in BV Hα bands, we infer

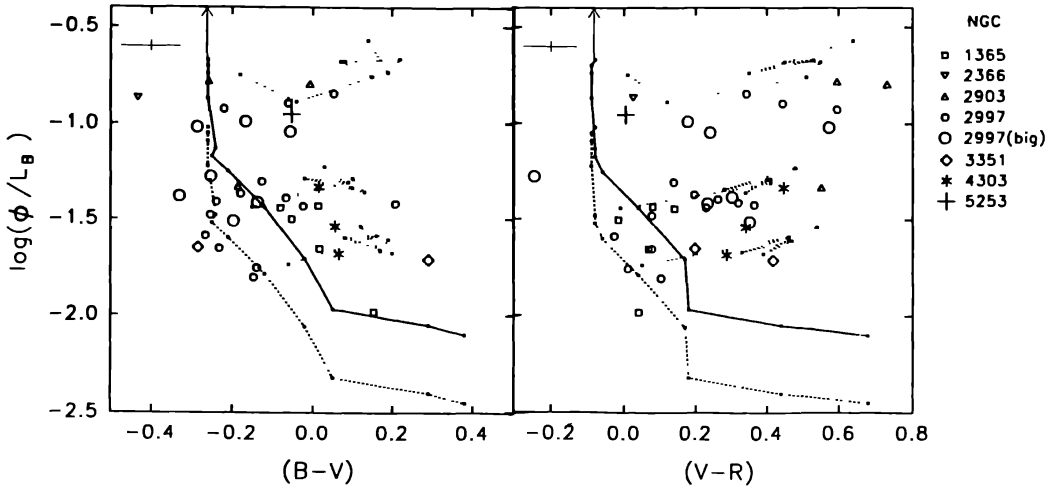

Figure 1. Extinction corrected regions in log (ϕ/L_B) vs $B - V$ and $V - R$ plane. Maximum rms errors on the observed quantities are shown by the cross at the top left corner. The evolution of a cluster with $m_u = 60$ and $\alpha = 2.5$ is shown by the thick line. The dots on the line are spaced 0.5 Myr apart with the dot at the bottom right being at 7 Myr. The dashed line is the model represented by thick line, with 55% of the ionizing photons escaping the nebula. A model with $m_u = 120$ and no escape of Lyman photons begins at the tip of the arrow. Sequence with dotted lines correspond to composite models with the younger population at 0 (top), 3.5 (middle) and 5 (bottom) Myr superposed on an older population. The leftmost point on these curves represents older population at 5, 6, 6 Myr respectively. Further points are placed at increments of 1 Myr. Note that the observed regions imply the existence of two populations.

the presence of two clusters of differing age situated at separations 40-100 pc. If the younger burst is due to a trigger from the older one the inferred speed of propagation of the trigger is 4-10 km s^{-1}. The average mass of each cluster is ~ 10^5 $M_\odot$. It may be noted that Hyland *et al.* (1992) have found direct evidence for the existence of two populations in 30 Dor from infrared photometry, which supports our results.

The low values of ϕ/L_B found from our observations are consistent with the published Hβ equivalent widths of GEHRs. In the absence of any other constraints such as colours, the low Hβ equivalent widths are interpreted to be as a result of evolution inferring ages greater than 5 Myr. Apart from the difficulties in explaining the absence of younger regions, this picture infers too much mass (> 10^6 $M_\odot$) in newly formed stars for reasonable IMF parameters. With the usage of colours in addition to ϕ/L_B we were able to infer the existence of a second population, thus solving the age and mass problems. The range of Hβ equivalent widths of GEHRs and HII galaxies (Terlevich *et al.* 1991) are similar and hence our results can be tentatively extended to these bigger systems as well.

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