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Study of the emission line spectra and the stellar populations of starburst galaxies

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Abstract. Based on the optical-NIR spectra, we discuss the nebular properties and stellar populations of starburst nuclei. Starbursts are found to have higher electron densities and higher excitations compared to HII nuclei. We find evidence for a composite population of young, ionizing massive stars (less than 3 Myr old) co-existing with the evolved RSG populations (about 5 to 7 Myr old) in most of our sample starburst nuclei.

Key words : Starburst galaxies, HII nuclei, emission lines

1. Introduction

Starburst galaxies have very bright nuclei and are characterized by H_α luminosities of 10^{40} to 10^{42} erg s^{-1}. The nebular spectra emitted by star - forming regions serve as powerful tools to study the physical properties of HII regions like, electron densities and temperatures, ionization parameter, and nebular abundances. As the embedded stellar cluster evolves beyond 3 Myrs, the massive stars evolve off the main sequence towards the Red Supergiant (RSG) phase. This results in a decrease of ionizing photons and the Balmer lines can no longer be used to estimate the age of the ionizing cluster. Age determination of a burst population (around 10 Myr old) that has evolved beyond the early nebular phase, would require the study of stellar absorption features that are indicative of an evolved population (Mayya, 1997; Garcia - Vargas et al, 1998).

2. Observations and reductions

Our sample consists of starburst galaxies from Devereux (1987) along with other well-known starburst galaxies like NGC 972, NGC 1808, and NGC 3310. Spectra were obtained using the 2.34−m Vainu Bappu Telescope at the Vainu Bappu Observatory (VBO, Kavalur, India) with the OMR spectrograph using 600 lines/mm grating. The wavelength range covered was from λ 4500 to λ 9100 Å, with a spectral resolution of 5.2 Å and the typical exposure times were 1800s to 2400s. Image scale along the spatial direction is 1.06 arcsec/pixel. Reduction of spectra were done using IRAF software package. One- dimensional spectra were extracted using apertures of 2″ x 6″ which corresponds to projected areas of 200 x 600 square parsecs at the average distance of the galaxies.

3. Emission line properties

Starburst nuclei have mean [SII]λ6717/[SII]λ6731 ratio = 1.05 ± 0.08 which implies high electron densities with $n_e \approx 500 \pm 170$ cm^{-3}. For normal disk HII regions this is an order of magnitude lesser with $n_e \approx 70 - 80$ cm^{-3}, while HII nuclei have intermediate densities of $n_e \approx 180$ cm^{-3}. We used the [SII] and [SIII] line ratios to obtain the ionization parameter U and find that the value of $\log U$ ranges from –2.4 to –2.9 for our sample. This is similar to the ionization parameters found in Seyfert 2 nuclei. The mean oxygen abundance for our sample Starburst nuclei is 1.6 ± 0.6, which implies lower metal abundance compared to HII nuclei whose mean metallicities are above twice solar (Ho et al., 1997). The low ionization emission lines like [NII] and [SII] are considerably enhanced in starbursts, compared to HII nuclei and disk HII regions. The enhancement can be attributed to the modification of thermal properties of the nebula by dust in high density, high metallicity star-forming regions. The presence of weak AGN activity or shock excitation also appear to be a likely alternative for explaining the enhancement of low-ionization lines.

4. Star formation properties

The Ca II triplet (λλ 8498, 8542, 8662 Å) equivalent width which is defined using the two strong lines at λ8542 Å and λ8662 Å, were measured with respect to the defined pseudo-continum (as in Terlevich et al., 1990). Evolutionary synthesis models predict the time evolution of equivalent widths of Ca II triplet lines for different metallicities, different IMFs and different star formation scenarios (Instantaneous Burst, IB or Continuous Star Formation, CSF). According to these models, the EW (Ca T) shows a clear maximum with values higher than 7Å at ages of about 10 Myrs for solar and higher metallicities, indicating the presence of RSGs. Mayya (1997) describe the use of diagnostic diagrams with EW (Ca T) versus EW(H_α) (in emission) for determining the ages of starbursts. Our values of more than 7Å for EW (Ca T) for the starburst nuclei imply the presence of RSGs and metallicities higher than solar. We infer ages of 5 – 7 Myrs for the RSG population. However, the high H_α luminosities can only be accounted for by the presence of a very young burst, which is less than 3 Myr old, containing large number of massive OB stars. Thus we infer a composite population in most of these starburst nuclei.

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