Extragalactic Star Clusters
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Star Clusters in Giant Extragalactic HII Regions

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Abstract. In this paper we study the relationship between the star formation efficiency and luminosity of H_α emission, Lyman continuum radiation, and H_β emission on 35 giant extragalactic HII regions in seven galaxies. Using the observational results we obtain the relationship, and find that the star formation efficiency is correlation with H_{alpha} luminocity, and Lyman continuum luminosity, and H_β lumonosity, respectively.
Key words: external galaxy–giant HII region–star cluster

1. Introduction

Galaxies exist in diverse environments, with a wide range of morphologies, luminosities, sizes, and unique appearances. Understanding the origin of the diversity of properties found among galaxies is a primary goal of extragalactic studies and provides key input and constaints for theories of galaxy formation and evolution. One of the most definitive ways to describe the current epoch star formation in a galaxy is through the comparison of the current star formation efficiency with the mass of gas a valuable to form stars. This yield of young stars per unit mass of molecular gas is what we call the star formation efficiency(SFE). Previous studies of the global star formation efficiency in spiral galaxies of differing morphology indicate that there is no variation in the mean SFE based on $L(H_\alpha)/M(H_2)$ as a function of Hubble type for morphological types S_a through S_c. For spiral galaxies of types S_a, S_b, and S_c. Thus, even though the galaxies have deverse morphologies and bulge sizes, the observed constancy of the mean SFE with spiral type indicates a remarkable similarity in the global star fromation process in the disks of these galaxies.

The most significant enhancement in the global star formation efficiency is found among merging and strongly interacting galaxies, where the SFE is observed to be elevated by a factor of $\sim$ 5-20 relative to isolated galaxies. Furthermore, this enhancement in the SFE is found to be independent of weather one uses star formation efficiency traced by H_{alpha} emission or by the far-IR emission observed by IRAS.

In this paper we study the relationship between SFE and luminosity of H_α emission, H_β emission, and Lyman continuum radiation on 35 giant extragalactic HII regions(GEHRs) in seven galaxies, respectively.

2. GIANT EXTRAGALACTIC HII REGIONS

Giant extragalactic HII regions(GEHRs) are sites of current star formation activity in galactic disks. A detailed investigation of star formation in these relatively simpler systems is important towards understanding star formation in more complex star-forming systems such as blue compact galaxies and star burst systems.

GEHRs in an individual galaxy are known to differ from one another in many of the observational properties, but still have several properties in common. The common properties such as the constancy of luminosity and diameter of the brighest (also largest) HII regions have been used earlier for estimating the distances to galaxies as well as differences between different HII regions in order to make use of GEHRs as reliable distance indicators or traces of star formation rates in galaxies.

Initial mass function(IMF), age, history, metallicity, extinction, mass or luminosity are among the most important parameters determining the properties of GEHRs. In recent year, there have been several attempts to investigate the IMF parameters under a variety of conditions. Investigations based on the integrated properties of GEHRs have so far remained inconclusive on the exact value of IMF slope and the lower and upper cut off masses. It is however important to take into account the effects of (i) interstellar extinction, (ii) metallicity and (iii) nebular contributions on the observable quantities, before these quantities can be compared with the synthetic models. Interstellar extinction is coventionally derived using the observed ratio of Balmer lines. Balmer decrements as well as metallicities and nebular contributions can be derived from spectroscopic data on individual regions. The $BVRH_\alpha$ data of only these 35 GEHRs from Mayya(1994), and Mayya & Prabhu(1996) are used. The data, after applying corrections for extinction and nebular contribution, are compared with evolutionary populations synthesis model to investigate the properties of star formation in the sample regions.

All the observed quatities have to be corrected for interstellar extinction before comparing with the models. Total extinction towards extragalactic HII regions consists of three parts: (i) extinction from the interstellar medium(ISM) of our galaxy, (ii) extinction from the ISM of the parent galaxy outside the HII region, and (iii) extiction due to the dust mixed with the gas within the HII region.

Lyman continuum luminosities using

$$\frac{N_L}{phs^{-1}} = 7.32 \times 10^{11} \frac{H_\alpha}{ergs^{-1}}, \tag{1}$$

Which assumes an ionization bounded case B nebula. The expected H_β luminosity (ϕ) is computed from this using

$$\frac{\phi}{ergs^{-1}} = 4.78 \times 10^{-13} \frac{N_L}{phs^{-1}} \tag{2}$$

The estimated nebular luminosities are subtracted from extinction corrected broad band luminosities to obtain pure cluster quantities. These quantities are reddened back to obtain the observationally expected values without any contamination from the surrounding nebula.

The metallicity differences affect the cluster evolution significantly. Metal-poor models are particularly important for the study the star formation in blue compact galaxies.

For an assumed IMF, the mass of the star-forming complexes can be estimated based on the observed Lyman continuum luminisity of the regions. Corrections for the decrease in ionizing luminosity due to evolution, destruction by dust and possible escape of photons have to be made in order to obtain the total ionizing luminosity emitted from the cluster. The total mass (M_T) is thus given by,

$$log(M_T) = log(\phi)_{obs} - log f - log(\phi)_{mod}(t), \tag{3}$$

where $(\phi)_{mod}$(t) is the ionizing luminosity per unit mass of the cluster at an age t, as derived from the model for an assumed IMF. The factor f takes care of the loss of ionizing photons with an estimated value between 0.65 and 1.0. The masses is derived. The derived properties of 35 GEHRs are shown in the Table 1, where we take f=0.9.

3. STAR FORMATION EFFICIENCY

The cluster is defined by an initial mass function, age, metallicity, and the total mass in stars. Recent determinations of the SFE in hundreds of galaxies have shown that similar results are obtained on average, indendent of whether one uses star formation efficiency traced by H_α emission or by the far-IR emission observed by IRAS.

Since the earliest investigations of the star formation efficiency in interacting galaxies, it have been known that both the SFE and the dust temperature are elevated in these systems in relation to isolated galaxies. The increase of the

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SFE with dust in molecular clouds is heated by young star, and as the luminosity in young stars per unit mass of molecular gas (i.e. the SFE) increases, the resulting increase in the energy density of the radiation field heats the dust to higher temperatures.

Using the Table 1 we maps of the relationship between SFE and H_α, SFE and ϕ, and SFE and N_L, respectively. Using the maps we have obtained the relationship between SFE and H_α, SFE and N_L, and SFE and ϕ, and we have found that the star formation efficiency is correlation with H_α luminosity, Lyman continuum luminosity, and H_β luminosity, respectively. With linear fitting wethod (y=ax+b) in the maps we have obtained

$$logSFE = 4.5logN_L - 233logSFE = 4.5logN_\alpha - 179logSFE = 4.5log\phi - 177. \quad (4)$$

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References

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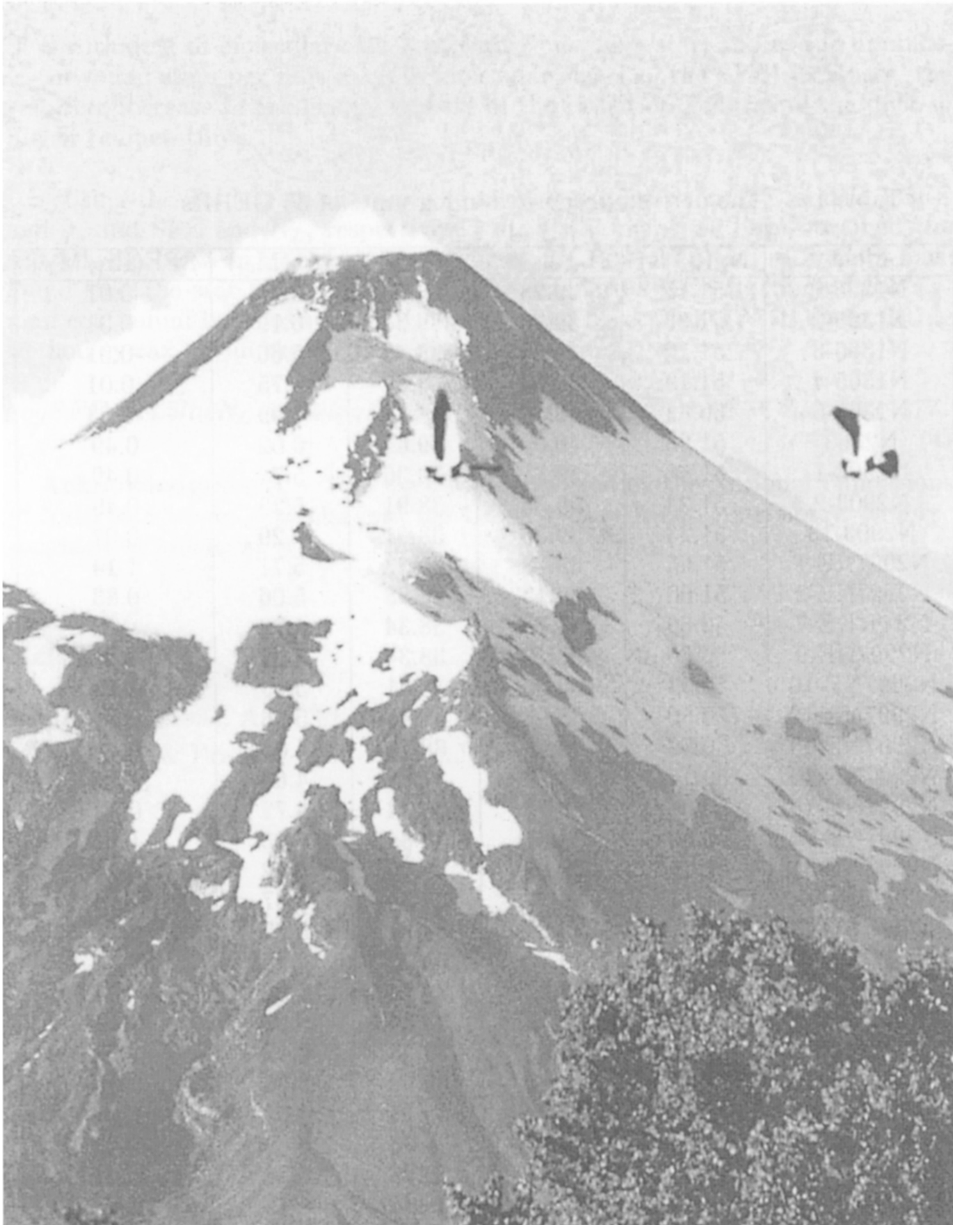
Table 1. The derived properties in log units of 35 GEHRs

Ident	N_L(ph/s)	H_α(erg/s)	ϕ(erg/s)	$M_T(M_\odot)$	SFE($H\alpha/M_T$)
N1365-1	51.15	39.28	38.83	5.71	-0.01
N1365-2	51.63	39.76	39.31	6.19	-0.01
N1365-3	51.10	39.23	38.78	5.66	-0.01
N1365-4	51.19	39.32	38.87	5.75	-0.01
N1365-5	50.83	38.96	38.51	5.99	-0.63
N2363	51.96	40.09	39.64	6.02	0.49
N2903-1	51.68	39.81	39.36	5.74	0.49
N2903-2	51.23	39.36	38.91	5.29	0.49
N2903-13	51.23	39.36	38.91	5.29	0.07
N2997NE-1	51.65	39.78	39.33	5.71	1.14
N2997NE-2	51.00	39.13	38.68	5.06	0.83
N2997NE-7	50.66	38.79	38.34	4.72	-0.01
N2997NE-9	50.66	38.79	38.34	5.22	-0.28
N2997NE-10	50.93	39.06	38.61	5.49	0.12
N2997NE-12	50.80	38.93	38.48	5.36	0.71
N2997NE-13	50.50	38.63	38.18	4.56	0.41
N2997NE-14	50.14	38.27	37.82	4.64	-0.03
N2997NE-15	50.66	38.79	38.34	4.72	0.13
N2997NE-24	50.52	38.65	38.84	5.08	-0.65
N2997NE-34	51.16	39.29	38.79	5.72	0.04
N2997SW-1	51.11	39.24	39.39	5.67	-0.11
N2997SW-2	51.71	39.84	39.27	5.77	0.11
N2997SW-3	51.59	39.72	39.33	6.15	1.34
N3351-1	50.74	38.87	39.74	4.80	-0.92
N3351-2	51.65	40.19	39.54	6.21	0.49
N4303-4	52.06	39.87	39.24	6.12	-0.01
N4303-9	51.74	39.65	39.90	6.30	0.01
N4303-24	51.52	40.35	39.18	6.06	1.15
N5253-1	51.56	39.63	38.96	5.62	-0.23
N2997NE-G1	52.22	39.02	39.23	6.28	-0.01
N2997NE-G2	51.50	39.68	39.85	5.45	0.49
N2997NE-G3	50.89	39.07	39.30	5.61	0.15
N2997NE-G4	51.55	39.73	39.90	5.91	0.06
N2997NE-G5	51.49	39.62	39.79	5.55	0.49
N2997NE-G8	51.56	39.74	39.91	6.12	-0.01



Two classic elements of Chile's natural beauty are combined in this photo of condors circling in front of a smoldering Volcan Villarica.