Estimation and comparison of the SFRs of galaxies along the Hubble Sequence

Abstract

An estimation of the SFR is done for the different Hubble types using H_α fluxes measured via aperture photometry. The resultant values for the SFR and the SNR are mentioned below in Table2. The science goal for the analysis carried out requires the difference in the SFRs of the target galaxies to be ≥ 0. The evolution of the SFR along the Hubble sequence is investigated from comparison among the T-type galaxies. The source of the errors in the H_α fluxes are explored.

Introduction/Theory

Star formation rates act as a parameter for distinguishing between the galaxies along the Hubble sequence. Galaxies along the sequence vary in the young stellar content. The evolution of the star formation properties help in classifying the Hubble sequence. Estimating the gas content in the disks and other regions incorporate major uncertainties. Different properties such as the morphological type, gas content, bar structure and the dynamical environment hugely influence the global star formation rates of galaxies.

Earlier work done by Walter Baade on resolving young stellar populations acted as the seed for further research in the field of SFRs and galaxy evolution. Evolutionary synthesis models which involved analysing galaxy colors and spectra allowed for an initial estimation of SFRs (Tinsley 1968, 1972). This study confirmed the trends in the SFRs along the sequence. The trends in the SFR and the star formation properties along the Hubble sequence is investigated by observing the Halpha emission regions. Integrated light measurements, like analysing the nebular recombination lines (Halpha), the Far Infra-Red continuum and the UV continuum, provide most information on the star formation properties of galaxies. The nebular lines act as direct probe to the young stellar population in the galaxy. The integrated ionizing flux are dominated by stars with masses >10M_o and lifetimes <20Myr.

Using the Salpeter IMF(0.1-100 M_o) and solar abundances, a relation between the H-alpha flux, $F_{H\alpha}$ and the SFR is derived from the calibrations of Kennicutt et al (1994) and Madau et al (1998).

$$SFR[1] = 7.9 * 10^{-42} L(H_\alpha) \qquad \text{-(1)}$$

Where, $L(H_\alpha) -$ ionizing H_α flux (in $ergs\ s^{-1}$)
$SFR -$Star Formation Rate (in $M_o yr^{-1}$)

To carry out the analysis, different T-type galaxy targets are selected. Three targets, an elliptical, irregular and spiral galaxy were chosen allowing to investigate the different regions of the Hubble sequence. These targets vary in population of young stars and in HII regions.

Method

The targets for our analysis were chosen based on their availability in the night sky. Limits were set on the redshifts (z<0.5) which led to neglecting redshifted H_α lines. For the three galaxies, M87 (elliptical), NGC4449 (irregular) and M61(barred spiral), an estimation of the SFR is made from different papers as given in table 1. For determining the SFRs of the three targets, NGC6720, a planetary nebulae, was used as a calibrating object. The data for NGC6720 was taken from the other group due to the lack of observing time slots. The difference in SFR between two galaxies is linked to a Signal-to-Noise Ratio for the measurement. With the exposure times calculated from the SNRs estimated, significant observations were carried out to allow for more precision in our results.

Galaxy	RA[2] (J2000)	Dec [2](J2000)	Visible brightness[2] (in mag)	Star Formation Rate(in $M_o yr^{-1}$)
NGC 4449	12h 28m 11.1s	+44°05’37”	10.0	0.28 [3]
M61	12h 21m 54.9s	04°28’25”	10.18	14.0 [4]
M87	12h 30m 49.4s	12°23’28”	9.59	0.01 [4]

Table 1: SFR values searched in the literature.

Decent observing time was given to the targets to be observed using the pt5m telescope in La Palma. With the data obtained, reduction procedures were carried out followed by mean combining the CCD images. Subtraction of the H-alpha and the R-band images followed by performing aperture photometry, gave H_α fluxes for the targets.

The resultant SFRs were calculated from the H_α fluxes, leading to determining a value for the SNR for the measurement.

Results

For the various targets, aperture photometry gave an approximation of the number of counts from the source with an uncertainty. Due to the linear proportionality between the flux and the count rate, the H_{α} fluxes were measured. Using the values above, SFRs and the associated errors were determined using equation(1).

Galaxies	H_{α} flux (in $ergs\ cm^{-2}\ s^{-1}$)	SFR (in $M_{o}yr^{-1}$)	SNR
M87	0.00 ± 0.00	0.00 ± 0.00	0.0
M61	$(8.15 \pm 0.07) * 10^{-12}$	1.67 ± 1.18	118
NGC4449	$(1.53 \pm 0.11) * 10^{-11}$	0.22 ± 0.06	132

Table2: Calculated fluxes, SFRs and SNRs of the targets.

The sky background was estimated by placing different circular annuli around the galaxy. In comparison to the initially estimated SFRs, the calculated values lack in accuracy. For M87, each of the above values show zeroes due to the lack of counts from the apertures placed around the target. Being an elliptical galaxy, M87 has a very low young stellar population, thereby giving a lower H_{α} ionizing flux.

The SFRs determined agree with the science goal of the analysis. The difference in the SFRs of the target galaxies are not equal to zero with a confidence fractionally below 3σ.

Discussion

The calculated fluxes represent a reasonable value for the three target galaxies. From literature, the mean star formation rates lie in agreement with the calculated SFRs. The major uncertainties in the values came from the aperture photometry method where the count values of the target involved large errors.

The other source of error came from the normalization of the R-band images. From the subtraction of the H-alpha and R-band images, random errors emerged. The lack of target counts from M87 led to the above quantities to be approximately zero.

Conclusion

The SFRs for the three target galaxies were estimated using the H_α fluxes obtained from performing aperture photometry. The SFR values in table 2 lie in agreement to the literature values for the galaxies. The comparison of the SFR between the different galaxies supports the science goal mentioned before. For the different Hubble types, the difference in the SFR does not get to zero. With measured flux and its uncertainties, a target SNR was determined.

References

[1]- Kennicutt Jr, R.C., 1998. Star formation in galaxies along the Hubble sequence. Annual Review of Astronomy and Astrophysics, 36(1), pp.189-231.

[2]- NASA/IPAC Extragalactic Database

[3]- Karczewski, O.Ł., Barlow, M.J., Page, M.J., Kuin, N.P.M., Ferreras, I., Baes, M., Bendo, G.J., Boselli, A., Cooray, A., Cormier, D. and De Looze, I., 2013. A multiwavelength study of the Magellanic-type galaxy NGC 4449–I. Modelling the spectral energy distribution, the ionization structure and the star formation history. Monthly Notices of the Royal Astronomical Society, 431(3), pp.2493-2512

[4]- Gavazzi, G., Fumagalli, M., Galardo, V., Grossetti, F., Boselli, A., Giovanelli, R., Haynes, M.P. and Fabello, S., 2012. Hα3: an Hα imaging survey of HI selected galaxies from ALFALFA-I. Catalogue in the Local Supercluster. Astronomy & Astrophysics, 545, p.A16.

Appendix

Below is the code for normalizing the r-band data for NGC4449, followed by finding the residual between the h-alpha and r-band data.

```
#normalizing the r-band data
#factor = mean_h_data_4449/mean_r_data_4449
mean_normed_r_data_87 = 5*(mean_r_data_87/mean_r_data_87.mean())
#mean_r_data.sum(axis=1)[:,np.newaxis])
print('mean_normed_r_data:',mean_normed_r_data_87,'\n')

#subtraction of r-band image from the h-alpha
mean_residual_data_87 = (mean_h_data_87 - mean_normed_r_data_87)
print('mean_residual_data:',mean_residual_data_87,'\n')
#Mean_residual_data_87 = mean_residual_data_87
```