VOL. 3, NO. 12, December 2013 ISSN 2225-7217
ARPN Journal of Science and Technology

http://www.ejournalofscience.org

Measuring the Star Formation Rate of Nearby Galaxy – M83

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ABSTRACT

The Star Formation Rate (SFR) of M83 galaxy was investigated. The first hand photometry data using R, B, V and H_α filters was collected using 1.0m telescope for two nights. IRAF, Python and Sextractor software were used during data reduction and analysis. A scaling factor for R-band to H_α band counts was derived to be 0.043 while count/sec was found to be 2.98 x 10^{-20}ergs^{-1}cm^{-2} $\dot{A}^{-1}$. The Sextractor was used to identify the HII regions at the South-West (S-W) portion of the galaxy with a total of 1198.57 counts. This yielded a total of $6.44\times10^{-1} ergcm^{-2}\dot{A}^{-1}$ H_α-flux per year. The derived total H_α luminosity for the same portion (S-W) is $1.21\times10^{4} ergs^{-1}$, which gave SFR of 0.95$M_\odot$yr^{-1} and Dust Mass (DM) of (1.21 ± 0.02) x 10^7 M_o. The complete galaxy images observed with R-, V- and B- band filters were used for image reconstruction. The H_α luminosity, H_α SFR and DM presented here is suggested to be lower limits since they were not corrected for air mass and dust extinction.

Keywords: *Galaxy; M83 galaxy; Star Formation Rate*

1. INTRODUCTION

The M83 galaxy is one of the brightest barred spiral galaxy in the local universe, visible with simple binoculars. This starburst galaxy lies at a distance of about 4.5Mpc [1]. The total infrared luminosity of M83 galaxy is 4 x 10^9L_o [2], making it fall within starburst galaxies whose activity is known to be triggered by galactic interactions. However, there is a controversy as to the cause of increased star formation (SF) in this object. One of the leading theories is the possibility of a tidal encounter between this galaxy and its neighbor NGC5253 at about 1-2Gyrs ago e.g. [3]. The other group cites possibility of interaction with its dwarf companion such as KK208 e.g. [4].

Multi wavelength studies of the center of this galaxy have been conducted with the result suggesting an increased star forming activity during the last 10Myrs e.g. [5]. The activity in the center of this galaxy combined with the high level of SFR in the disk indicated that the galaxy is actively forming stars e.g. [6]. Armed with this fact, it becomes ideal to study difference rate at which star is formed at various portions of the galaxy.

Moreover, the mean SFR per unit area of this galaxy is 0.04$M_o$yr^{-1}Kpc^{-2} and the total SFR is about 5$M_o$yr^{-1} [7] though the results of [7] is for the entire galaxy. In this study, we concentrated on the S-W portion of M83 to examine if the rate of SF is evenly distributed. However, due to the scarcity of the telescope time coupled observation time lag at Sutherland and unstable weather condition during the period, we could only study the S-W portion of the galaxy.

2. OBSERVATIONS AND DATA REDUCTION

2.1 The Target

The target object was M83 galaxy (Ra 13 37 0.9, Dec -29 51 57) at a distance of about 4.5Mpc with total IR luminosity of 4 x 10^9L_o.

2.2 Photometry

The photometry observations presented in this paper were obtained with 1.0m (Elizabeth) telescope situated at Sutherland, South Africa on 15th and 19th February 2012 during the 34th ISYA 2012 summer school. During the data collection, the R-band and H_α-band images were obtained for the S-W portion while R-, B- and V-band images for the entire galaxy was taken for image color reconstruction.

The back illuminated 1024 X 1024 pixel CCD (designated STE4) with a read out noise of 6.5 electrons was used. Throughout the data collection, 1 pixel corresponded to 1Mpc and the exposure time was 600sec for R-, B- and V–band images and 300sec for H_α. The standard stars used for absolute flux calibration of the object were E4106 (mag 11.28) and BD +082015 (mag 9.9). The seeing during the observations was in the range of 1".0 to 1".7.

2.3 Data Reduction

The FITs file data from each CCD were trimmed and over-scan subtracted, sky flat fielded and bias subtracted using SALT IRAF package. The cosmic ray correction was done using XZAP task in IRAF XDIMSUM package. The images (H_α and R-band images) were aligned separately using IMALIGN task in

IRAF IMMATCH package and later combined separately using IMCOMBINE task. With both H_α and R-band calibrated, R-band image was aligned to H_α image in order to subtract R-band image from H_α-band image thereby making the stars in the foreground of the image to disappear and the HII regions to stand out giving a pure H_α image of the galaxy (Fig. 3).

The Sextractor software was set to detection threshold of 10, Deblend-minimum count of 0.5, magnitude zero point as 22.34 and background size of 128. This enabled it to identify 12 star forming regions with a total count of 1198.57 (Fig.2).

3. ANALYSIS

3.1 Magnitude and Flux Determination

The absolute magnitude M determination was derived using the relation

$$M = -2.5\log\left(\frac{counts}{time}\right) + M_o, \quad (1)$$

while the scaling factor used to relate R-band counts to H_α counts was derived using the relation

$$K \times C_R = C_{H\alpha}\ , \quad (2)$$

where K is the conversion factor found to be 0.043, C_R is the counts in R-band and $C_{H\alpha}$ is counts in H_α- band, M_o the solar magnitude.

The Sextractor identified 12 HII regions with a total of 1198.57 counts, while the total BD+082015 were 1085. From equation (1), the total flux for the standard star was found to be 1.02 x 10^{-17} and its count/sec was $2.98x10^{-20}$ergs^{-1}cm^{-2} $\dot{A}^{-1}$. The total H_α flux/sec for the 12 HII regions was derived to be 2.04 x 10^{-18}ergs^{-1}cm^{-2} $\dot{A}^{-1}$ while H_α flux/yr is 6.44 x 10^{-11}ergcm^{-2} $\dot{A}^{-1}$

3.2 Luminosity Determination

From the inverse square law, flux F received from a sphere at a distance R is given by

$$F = \frac{L}{4\pi R^2}\ , \quad (3)$$

The Hα luminosity can therefore be derived as

$$L(H_\alpha) = 4\pi\left(3.086x10^{24}\, x4.56 D_{Mpc}\right)^2 xF(H_\alpha), \quad (4)$$

where $L(H_\alpha)$ is the total H_α luminosity and $F(H_\alpha)$ is the total H_α flux per year

3.3 Recombination Line and SFR

The nebular lines effectively re-emit the integrated stellar luminosity of galaxies short of the Lyman limit; so they provide a direct, sensitive probe of the young massive stellar population. Most application of this method has been based on measurement of the H_α counts. The conversion factor between ionizing flux and SFR is derived using equation (5) below. Basically, only stars with mass up to$10M_o$ and lifetimes < 20Myrs contribute significantly to the integrated ionizing flux [7], therefore, this can be used as a measure of the SFR, independent of previous star formation history. For solar abundances and the same Salpeter IMF (0.1 – $100M_o$) and the calibrations of Kennicutt et al. (1998) and Madau et al. (1998) yields;

$$SFR\left(M_o yr^{-1}\right) = 7.9\text{X}10^{-42} L(H_\alpha)\left(ergs^{-1}\right) \quad (5)$$

The main advantages of this method are; it's high sensitivity, and the direct coupling between the nebular flux and the massive SFR. The main limitations of the method are; its sensitivity to the uncertainties in the extinction, and the IMF, and the assumption that all of the massive star formation is traced by ionization.

3.4 Dust Content Estimation

There exists a very strong relationship between the dust mass M_d and the rate of star formation in a galaxy. The dust estimation was derived from the SFR as;

$$M_d = (1.28 \pm 0.02)\times 10^7 (SFR)^{1.11\pm0.01} M_o \quad (6)$$

4. DISCUSSION

4.1 Hα Luminosity and Hα SFR

The total H_α luminosity derived in this paper using the equation (4) was found to be 1.21 x $10^4$1ergs^{-1}. This result we suggest is an under estimation because the images were not corrected for both air mass and dust extinction. The SFR was derived using the equation (5). The obtained SFR for the S-W region of the galaxy was $0.95M_oyr^{-1}$ which can be generalized to be $3.8M_oyr^{-1}$(assuming the SFR is even for the entire galaxy). This value is lower than the total SFR of $5M_oyr^{-1}$ recorded by [7] which is attributed to the uncorrected air mass and dust extinction effects which tend to lower the SFR. Moreover, the SFR calculated was purely from the spiral arms and hence failed to account for the starburst caused by the gas inflow into the center of this galaxy. However, if both air mass and dust extinction are corrected with the result agreeing with this, it then means that the rate at which star is formed in this galaxy is not evenly distributed.

4.2 Dust Content

The dust content derived from the H_α SFR of the galaxy as given by equation (6) also confirms that the DM given is a lower estimate of the dust content. The obtained value is (1.21 ± 0.02) x 10^7 M_o

5. CONCLUSION

The obtained total H_α luminosity, SFR and Dust mass estimates presented in this paper were lower limits to the actual values. Besides, the H_α luminosity values

must be missing some or even much of the H_α luminosity of the galaxy because the S-W region of the galaxy avoided the bright central part which is holding a star burst.

ACKNOWLEDGMENT

The successful completion of this study was possible because of the help offered by the entire 34th ISYA2012 group, of which the group supervisors Dr. Petri Vaisanen and Dr. Hannah Worters deserves to be noted for their guidance, support and constant availability for consultations. We also recognize Zarah and Abiy for contributions during data reduction. Also, we thank IAU, UCT and, SAAO for the funding and lectures.

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APPENDIX

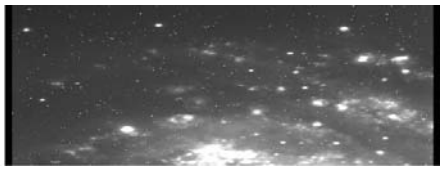

Fig 1: South-West portion of M83 galaxy as observed in H filter

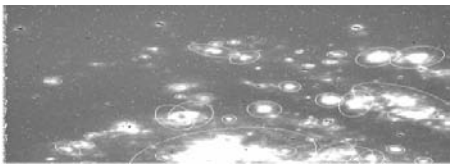

Fig 2: Sxtracor image used in the study of SFR giving a total of 1198.57 counts

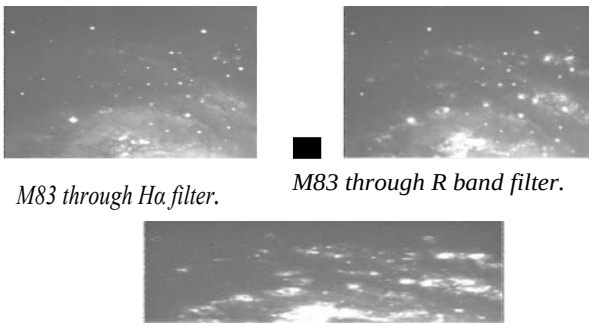

Fig 3: Obtaining HII region of M83