Resolving the Rise and Fall of Star Formation in Galaxies
Proceedings IAU Symposium No. 373, 2023
T. Wong & W.-T. Kim, eds.
doi:10.1017/S1743921322004161

Recovering the origin of star formation in the central region of I Zw 81

Divya Pandey[1], Kanak Saha[2] and Ananta C. Pradhan[1]

[1]Department of Physics and Astronomy, National Institute of Technology, Rourkela, Odisha 769008, India

[2]Inter-University Centre for Astronomy & Astrophysics, Postbag 4, Ganeshkhind, Pune 411007, India

Abstract. We have studied the star formation properties of a massive void galaxy - I Zw 81. We performed 2D structural decomposition on *Canada France Hawaii Telescope (CFHT)* g- and r-band observation of I Zw 81 using GALFIT. The galaxy consists of an unresolved small bulge, a bar, an inner ring, and a truncated disk. We have used far-ultraviolet (FUV) and near-UV (NUV) observation of Ultraviolet Imaging Telescope (UVIT) onboard *AstroSat* for our analysis. The NUV−r color map of the lenticular galaxy illustrates a shallow positive color gradient in the profile, implying that the bar and inner ring are more star-forming than the outer disk. The FUV emission is mainly concentrated in the central region of the galaxy. A tidal tail-like feature is detected in the CFHT observations. We infer that bar and minor mergers-like interactions enhance the gas inflow and drive star formation in the center of I Zw 81.

Keywords. galaxies: elliptical and lenticular, ultraviolet: galaxies, galaxies: interactions

1. Introduction

Local galaxies disparate themselves into distinct classes, i.e., star-forming and quiescent (Kauffmann et al. 2003; Baldry et al. 2004). This separation is an outcome of various physical transformation processes that act on galaxies over their cosmic lifetime. It is well established that the environment and stellar mass play crucial role in determining the properties of galaxies (Peng et al. 2010). The low-mass galaxies are affected mainly by their surrounding environment, while at the high stellar mass range, several mass quenching mechanisms get activated that cause star formation cessation in galaxies (Alpaslan et al. 2015; Peng et al. 2010).

We are interested in studying the properties of a massive ($M_\star \approx 10^{10.9}$ $M_\odot$) early-type galaxy, I Zw 81 present in the Bootes void (Kirshner et al. 1987). Our previous analysis using Ultraviolet Imaging Telescope (UVIT) data reveals that the I Zw 81 is star-forming, shows blue color and strong ultraviolet (UV) emission (Pandey et al. 2021). The relatively rare class of massive blue early-type galaxies similar to I Zw 81 are thought to be an outcome of major merger events (Kannappan et al. 2009). However, such interactions are improbable in voids (Penny et al. 2015). In this work, we have attempted to understand the physical mechanisms responsible for the present state of massive void galaxy, I Zw 81.

2. Central star formation and FUV emission in bar

We have primarily used *Canada France Huwaii Telescope (CFHT)* g- and r-band and UVIT near-UV (NUV) and far-UV (FUV) imaging data to study the star formation and perform the structural analysis of I Zw 81. We performed the structural decomposition

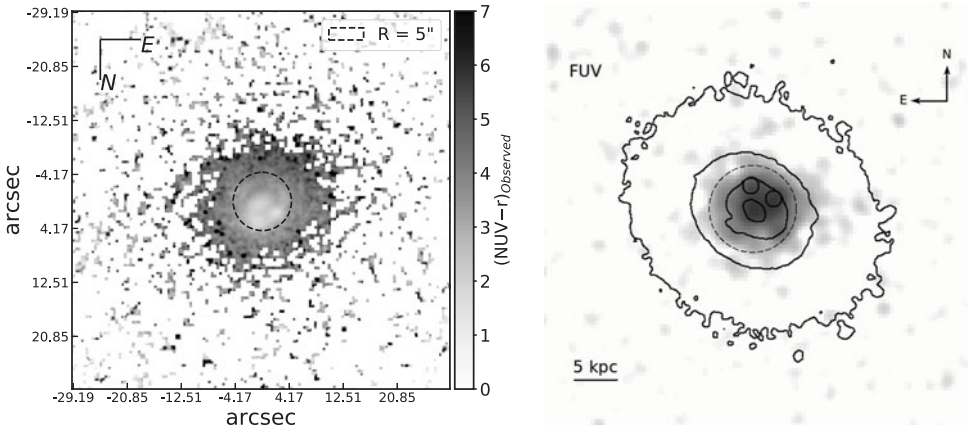

Figure 1. Left panel: NUV−r color map of I Zw 81; Right panel: FUV observation of I Zw 81. The *CFHT*-g band contours shown by black solid lines are overlayed. The contour comprises of 5 surface brightness levels = [17.37, 19.24, 21.11, 22.94, 24.58] mag/arcsec^2. The star-forming clumps are shown in black circles on the second contour. The black dashed circles (r = 5″) shown in both panels enclose the bar and ring.

of I Zw 81 using GALFIT (Peng et al. 2002) on *CFHT* observation, and found that the galaxy consists of an unresolved small bulge, a bar, an inner ring, and a truncated disk.

We studied the mass assembly of the galaxy using the NUV−r color map shown in the left panel of Figure 1. The central region comprising the bar and inner ring is represented by a dashed black circle of radius = 5″. Note that the point source function (PSF) matching on *CFHT* r-band data was performed prior to the color map construction. The color map shows that the central region of the galaxy is bluer than its outskirts. The shallow positive gradient displayed by I Zw 81 is generally observed in low-mass galaxies and is thought to be the product of environmental disturbances (Pan et al. 2015). The right panel of Figure 1 shows FUV observation of the galaxy with *CFHT* g-band contours overlayed on the image. The FUV emission traces recent star formation in a galaxy averaged to a timescale of 100 Myr (Kennicutt et al. 1998). We found that the FUV emission is localized in the central region of the galaxy enclosing the bar. The FUV emission in the bar region of I Zw 81 is similar to that reported by Saha et al. 2021 in the Malin 1 galaxy whose central region resembles lenticular morphology.

The bar generally transfers the gas from galactic outskirts to the inner region. As a result, shock waves and gravitation torque rise inside the bar which lead to decrease the ongoing star formation activity (Khoperskov et al. 2018). Massive lenticular galaxies similar to I Zw 81 show FUV emission only in the nuclear region of bars (Diaz-Garcia et al. 2020). On the other hand, the FUV emission in I Zw 81 is spread across the entire bar and the inner ring implying that galaxy is sufficiently gas-rich. We investigate the source of the gas supply and observed star formation in the next section.

3. Role of mergers and interactions

Mergers and interactions between galaxies strongly influence their star formation properties (Alonso et al. 2012; Kaviraj 2014). Since the galaxies present in voids are unlikely to go through major merger interaction in their lifetime (Penny et al. 2015), we only discuss the effect of minor mergers and tidal interactions on I Zw 81. We used deep *CFHT* g-band observation to look for any signatures of interactions. We found a tidal tail-like feature in the galactic outskirt shown in Figure 2. We detect a companion galaxy WISEA

https://doi.org/10.1017/S1743921322004161 Published online by Cambridge University Press

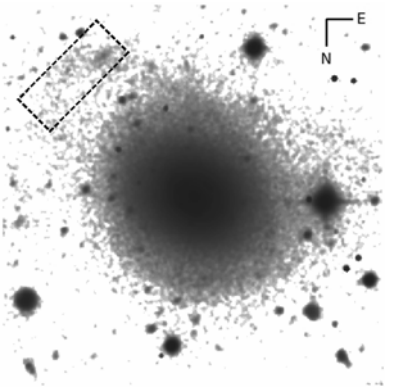

Figure 2. The black dashed rectangular box highlights the tidal tail-like feature observed in *CFHT*-g band image of the galaxy.

J140811.38+485344.2 at a distance of 120 kpc from I Zw 81. The galaxy is not massive enough to enhance the ongoing star formation in I Zw 81 via tidal interaction or flyby.

Minor merger interactions in the past seem to be the most favorable scenario to explain the rapid star formation. Such interactions can ignite star formation activity in the galaxies by supplying fresh gas to the systems (Bournaud et al. 2007). Galaxies in voids can sustain their gas supplies for longer time due to secular evolution. Hence, the low-density environment of I Zw 81 may play a part in enhancing the star formation induced by the interactions. The bar transfers the available gas to the galactic center which lead to the observed star formation. The results are explained in detail in (Pandey et al. 2022).

References

Alonso, S., Mesa, V., Padilla, N., et al. 2012, *AAP*, 539, A46
Alpaslan, M., Driver, S., Robotham, A. S. G., et al. 2015, *MNRAS*, 451, 3249
Baldry, I. K., Glazebrook, K., Brinkmann, J., et al. 2004, *ApJ*, 600, 681
Bournaud, F., Jog, C. J., & Combes, F. 2007, *AAP*, 476, 1179
Diaz-Garcia, S., Moyano, F. D., Comerón, S., et al. 2020, 896, *A&A*, 644, A38
Kannappan, S. J., Guie, J. M., & Baker, A. J. 2009, *AJ*, 138, 579
Kauffmann, G., Heckman, T. M., White, S. D. M., et al. 2003, *MNRAS*, 341, 33
Kaviraj, S. 2014, *MNRAS*, 440, 2944
Kennicutt, R. C. 1998, *AARA*, 36, 189
Khoperskov, S., Haywood, M., Di Matteo, P., Lehnert,932 M. D., & Combes, F. 2018, *A&A*, 609, A60
Kirshner, R. P., Oemler, A., Schechter, P. L., et al. 1987, *ApJ*, 314, 493
Pan, Z., Li, J., Lin, W., et al. 2015, *ApJL*, 804, L42
Pandey, D., Saha, K., & Pradhan, A. C. 2021, *APJ*, 919, 101
Pandey, D., Saha, K., Pradhan, A. C., & Kaviraj, S. 2022, *APJ*, 941, 128
Peimbert, M. & Torres-Peimbert, S. 1992, *AAP*, 253, 349
Peng, C. Y., Ho, L. C., Impey, C. D., & Rix, H.W. 2002, 973, *AJ*, 124, 266
Peng, Y.-. jie., Lilly, S. J., Kovač, K., et al. 2010, *ApJ*, 721, 193
Penny, S. J., Brown, M. J. I., Pimbblet, K. A., et al. 2015, *MNRAS*, 453, 3519
Saha, K., Dhiwar, S., Barway, S., et al. 2021, *JApA*, 42, 59

https://doi.org/10.1017/S1743921322004161 Published online by Cambridge University Press