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/S1743921323000376

A UVIT Look at Star Formation in Nearby Interacting/Merging Galaxies

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Abstract. The interactions and mergers of gas rich galaxies are known to produce star formation which often leads to nuclear activity as well. The star formation is ideally mapped using FUV and NUV emission, since UV traces star formation for longer timescales compared to Hα emission. It is also emitted over a broader range of stellar masses in galaxies. In this study we present FUV and NUV observations of merging and interacting galaxies in our nearby universe conducted using the UVIT. We present the example of a merging system MRK212 that has dual AGN and the triple AGN system NGC7733-7734. The UV emission is associated with the tidal arms, individual nuclei, resonance rings, nuclear spirals as well as AGN/stellar feedback. We also find that radio emission is often closely associated with the UV emission, arising from both star formation as well as AGN activity, and perhaps kpc-scale AGN feedback. We find that a comparison of optical IFU imaging with FUV in NGC7733-7734 reveals unique properties associated with the interaction including the third AGN buried in a tidal arm.

Keywords. galaxies: spiral, galaxies: interacting, galaxies: active, galaxies: UV

1. Introduction

Galaxy interactions and mergers cause enormous changes in the gravitational potential of galaxies, even if the interactions are distant and at separations of tens of kpc. The change in potential results in cloud collisions and hence star formation resulting in the formation of very bright merger remnants. The tidal interaction also causes the formation of extended tidal arms and rings, both of which may host star forming complexes (SFCs). As the galaxies come closer, there is usually gas infall to the nuclear regions, often resulting in nuclear starburst activity and the triggering of active galactic nuclear (AGN) activity. Both star formation and AGN emit copiously at UV wavelengths. Hence, both FUV and NUV are ideal wavelengths to trace galaxy evolution via star formation and AGN activity. In this paper we present a variety of UV observations of closely interacting and merging galaxies. Our aim is to examine the star formation on kpc scales in the form of SFCs and understand how they are related to the merging process. Details of the projects are given in some recent papers (Yadav et al. 2021).

2. Observations

The observations were conducted mainly in the far-UV (FUV) band (1300–1800 A) with the Ultraviolet Imaging Telescope (UVIT), on board the AstroSat Satellite. The details of the filters and instrument are briefly described in (Das et al. 2021). The advantage of using the UVIT is that it has a wide field of view of approximately 28′ and a spatial resolution $\sim 1.5''$, which is good enough to resolve the large star forming clusters

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https://doi.org/10.1017/S1743921323000376 Published online by Cambridge University Press

in nearby galaxies. Our UVIT observations of the galaxies presented in this paper have observing times of 15Ks and 6Ks. The data analysis was done with the standard UVIT pipeline. The UV emission arises from massive stars that give out FUV and NUV emission as well as Hα emission. But FUV and NUV trace star formation for upto 10^8 years whereas Hα traces for it for 10^6 to 10^7 years only. So UV can detect star formation for longer duration in galaxies. Also, for good spatial resolution such as that in UVIT, the FUV and NUV emission can detect individual star forming clusters. The UV emission also arises from AGN activity i.e. mainly from the accretion disk and makes the nucleus appear as a compact, bright source in the centers of galaxies.

3. UVIT observations Dual AGN in MRK212

During mergers, as the galaxies come closer they eventually become gravitationally bound. When their bulges are at separations of few to several kpc their supermassive black holes (SMBHs) can start accreting mass. Then they often become AGN and their nuclei become very luminous. When both nuclei are AGN and are at separations of approx 1-10 kpc they form dual AGN (DAGN). DAGN are very rare and are mainly detected using radio observations and X-ray observations Rubinur et al. (2019). Alternatively the nuclei can be mixed starburst-AGN pairs or starforming nuclei pairs, both of which are bright at UV wavelengths. The luminosity can be due to star formation or it can be associated with the gas outflows due to starburst and/or AGN activity consituting stellar or AGN feedback. There will be negative feedback due to the outflows pushing out the infalling gas, but there may also be positive feedback caused by to star formation in the shocked gas falling back onto the disk. There can also be interaction between the outflows if the nuclei are close enough. Such activity will trigger star formation and lead to the growth of hot gas around galaxies.

A good example is the study of the dual nuclei in the galaxy MRK212, which we have studied using radio observations (EVLA and uGMRT), FUV (UVIT) observations and optical spectroscopy (Himalayan Chandra Telescope) (Rubinur et al. 2021). The galaxy is a major merger and nearly face-on in orientation. Both nuclei are bright in FIRST radio images. The HCT spectra of the 2 nuclei confirmed that they fall in the star forming and AGN class in the BPT plot and so this is a DAGN system. Figure 1 shows the UVIT FUV observations of MRK212. The star forming knots are clearly detected along spiral or tidal arms. They may represent super star clusters that have formed due to the merger. There must be gas collected between the two bulges which has given rise to star formation between the two nuclei. Such gas has been detected in ALMA observations of similar mergers (e.g. NGC6240) and here we are seeing the star formation associated with that gas. The S2 nucleus has 2 knots of star formation that coincide with the 2 radio lobes detected in radio EVLA 8.5 GHz observations. The outflows from the AGN in S2 could have triggered the star formation and so this could be a signature of AGN feedback on kpc scales. We may also be seeing signatures of AGN wind triggered star formation i.e. positive AGN feedback in the knots 3 and 4 which coincide with the radio lobes associated with nucleus S2.

4. The Triple AGN in NGC7733-7734

As part of a study of interacting galaxies, we observed the southern interacting galaxy pair NGC7733 and NGC7734 in the JHK band using the near infrared 1.5m telescope IRSF in the South Africam Astronomical Observatory (SAAO). The northern knot in NGC773 was previously identified as a star forming region, but is clearly a bulge in the NIR images. The nature of the nuclei can be determined using the empirical plot called the BPT plot, which is based on the ratio of the emission lines [OIII], [NII], Hα and Hβ.

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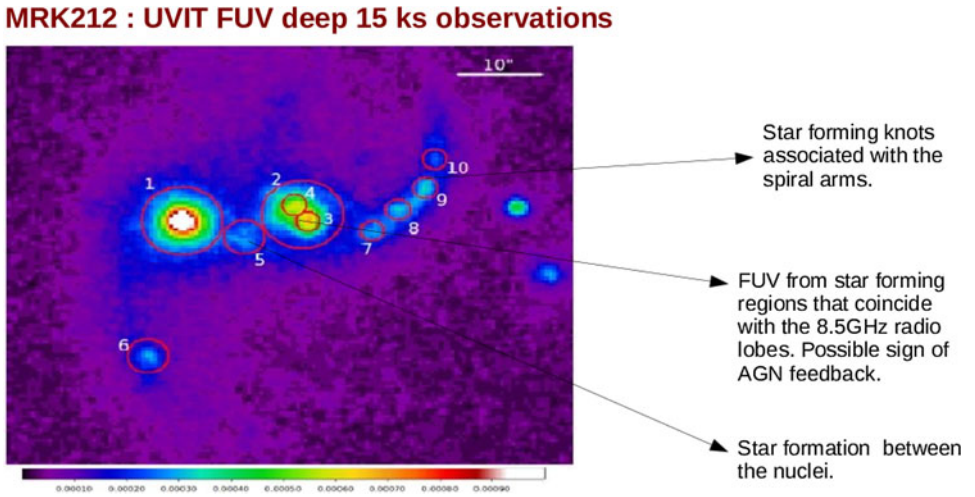

Figure 1. The FUV image of MRK212 had 15ks of observing time. The S2 nucleus has 2 knots of star formation that coincide with the 2 radio lobes detected at 8.5 GHz radio observations. The outflows from the AGN in S2 could have triggered the star formation and could be a signature of AGN feedback on kpc scales. Details are given in Rubinur et al. (2021).

We aslo used the MUSE archival data of the interacting pair. MUSE gives the spectra of the spaxels and so the BPT position of the individual pixels can be determined. It is clear that NGC7733 nucleus and NGC7733N are both Seyfert type whereas NGC7734 is a LINER type nucleus. Both NGC7733 and NGC7734 show extensive star formation in the spiral arms, but it is stronger in NGC7733. So the small group can be considered as a triple AGN system, although all 3 nuclei are not really within a common envelope. The nuclear SMBH mass in NGC733 and NGC7734 are few times 10^8 solar mass, whereas NGC7733N has the least massive SMBH mass of a few times 10^7 solar mass. The galaxy NGC7733 shows emission from an extended narrow line region (ENLR) which is due to the photionized gas around the AGN. It extends out to 18 kpc from the nucleus of NGC7733. Apart from the triple AGN, the FUV image shows many rings of star formation associated with the two galaxies, and especially with the northern galaxy NGC7734. There is also star formation along the bar of the latter galaxy as seen in the FUV image. Details are given in Yadav et al. (2021).

5. Conclusions

UV studies can offer us new insights into the star formation and nuclear activity in nearby interacting galaxies. This is mainly because UV traces star formation for longer timescales compared to Hα. So it can detect fainter star formation in tidal arms, diffuse disks and in extended tidal tails. When the UV is combined with optical integral field spectroscopy (IFS) data such as MUSE or SDSS-MANGA it can reveal hidden nuclear activity and star formation processes.

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