Ionization Parameter Mapping of BCD Galaxies in the Virgo Cluster

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Abstract

We imaged four Blue Compact Dwarf (BCD) galaxies in the Virgo Cluster using both narrowband and broadband filters, looking for possible triggering mechanisms of the starburst regions within these galaxies. We created ionization parameter maps (IPM) to locate the regions of high ionization within the galaxies, and analyzed and compared the trends indicative of mergers and ram pressure stripping (RPS) against our galaxies. Of the four galaxies, we found one candidate for an outflow, one candidate for a merger, one weak candidate for RPS, and an inconclusive candidate. Within the constraints of our small sample size, we conclude that BCD galaxies located in cluster environments undergo a diversity of interactions with their environments.

Results

VCC 144:

- Due to the presence of a highly ionized gas stream ejected from the galaxy, we believe there is a likelihood of a galactic outflow occurring, caused by winds present within the galaxy.
- There is a large neutral hydrogen (H I) envelope found by Brosch et al. (1997), that surrounds the southeastern part of the galaxy. This supports a blow-out scenario, as the escaping ionized gas is more likely to penetrate a region of the galaxy with less H I present (Zastrow et al. 2011).

VCC 324:

- There is a highly ionized companion object that lies in close visual proximity to our galaxy. Since the object does not disappear in the IPM, we conclude that it is at a similar redshift as our galaxy.
- There is another interesting region on the western half of VCC 324. An ejected stream of ionized gas appears to be the beginning of an outflow, possibly a result of the gravitational effects felt by VCC 324 from its companion object to the south.

VCC 428:

- Since a majority of VCC 428 is not highly ionized, we cannot say one way or another if there is evidence of a merger or RPS from our data.
- However, there is a definite comparison of the image of VCC 428 on SDSS to the jellyfish galaxy in Figure 1. According to the H I deficiency values calculated by Roegge and Pleau (2016), VCC 428 has the expected amount of H I gas present within the galaxy.
- Although nothing conclusive can be said about the nature of this starburst from our data, there is an outside possibility that this galaxy is undergoing the beginning stages of RPS.

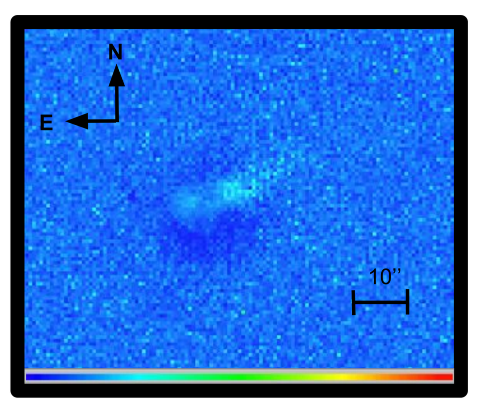
VCC 1313:

- This galaxy has a very uniform light that is centered on the nucleus. The galaxy is also very H I rich.
- There is a small potential companion that appears in close proximity to VCC 1313 in the IPM. Although there is a slight deformity towards that unknown object in the isophotal map of the IPM, the object itself disappears, since it is below 3 sigma from the background. This leaves the cause of the starburst inconclusive from our data.

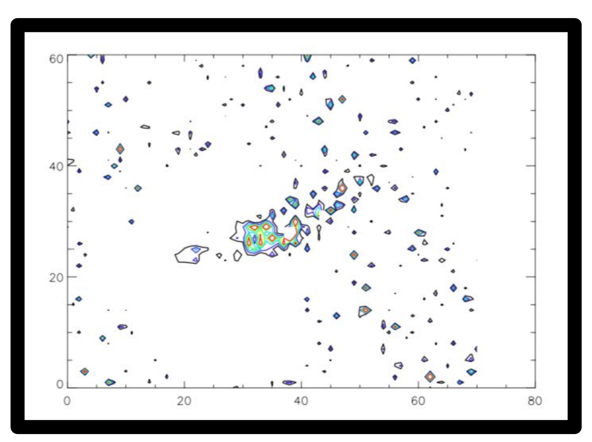
Motivation

- The mechanisms driving starbursts within blue compact dwarf galaxies is still a widely debated topic.
- The environment that a galaxy is located in plays a crucial role in its evolution and development (Ebeling et al., 2014). The four galaxies researched are in the Virgo Galaxy Cluster.
- Galaxies located in clusters can be affected by mergers with other objects in the galaxy cluster, as well as undergo ram pressure stripping (RPS).
- Ram pressure stripping occurs when a galaxy located in a cluster travels through the intracluster medium (ICM), and has its interstellar medium stripped away by the thick, pervasive ICM, which is much denser than the typical interstellar medium.
- Galaxies located in clusters can also have an effect on the environments that they reside in, via outflows from supernovae erupting within the galaxy. The outflows eject ionized gas into the ICM, which enriches it with gas and dust.

VCC 144

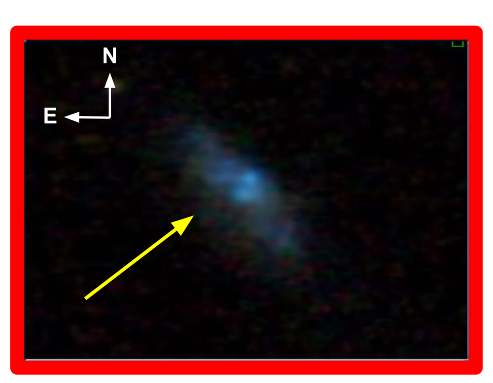


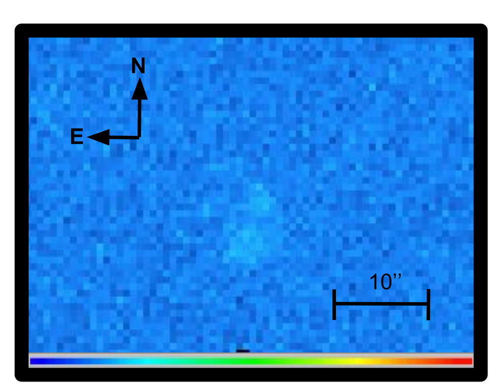
Left: The Ionization parameter mapping of VCC 144. Notice the high-ionization trending towards the north-western section of the image.

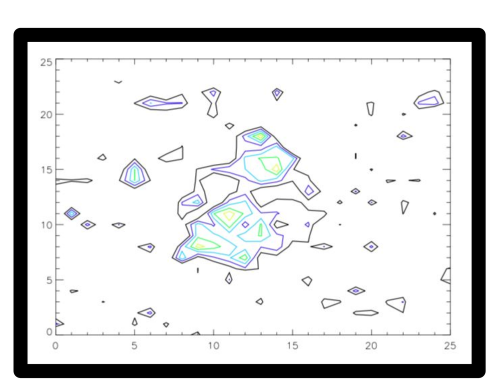


Right: The isophotal mapping of VCC 144. The image is oriented as above. The contours show 3 sigma above the mean background, with each isophotal line representing an increase of +3 sigma

VCC 428







From top left to bottom right: The SDSS image of VCC 428, its ionization mapping, and the isophotal map. Note the jellyfish structure in the southwestern region of the SDSS image, and the lack of high ionization in a majority of the galaxy

Motivation

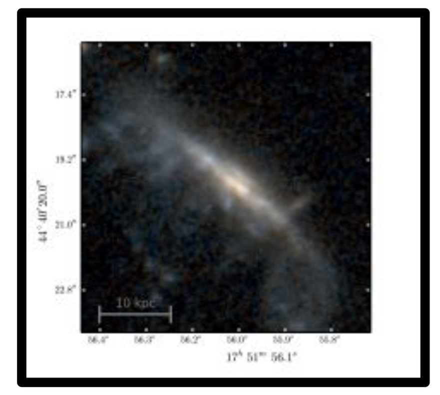


Figure 1: An example of a Jellyfish galaxy undergoing RPS (McPartland, 2015). Notice the ISM gas that is stripped off in the opposite direction of the motion of the galaxy through the ICM.

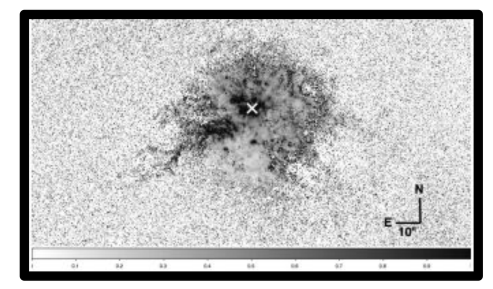


Figure 2: An example of of what an outflow looks like in the IPM of a galaxy (Zastrow et al., 2011). Ionized gas is ejected out of the southeastern portion of the galaxy and into the ICM.

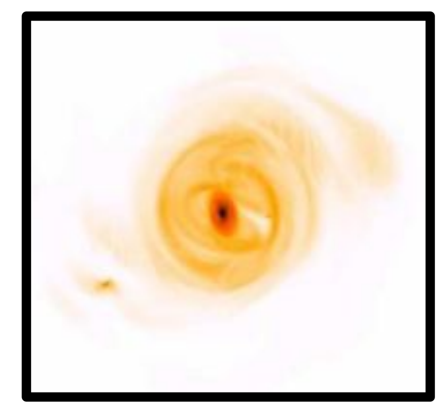
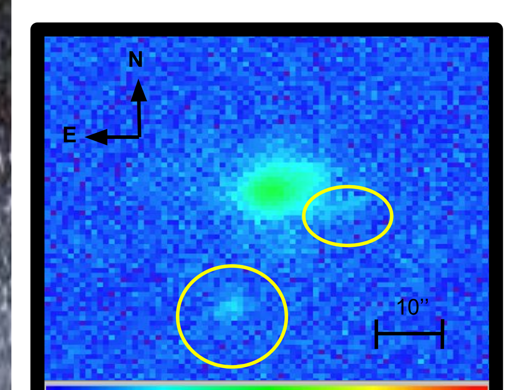
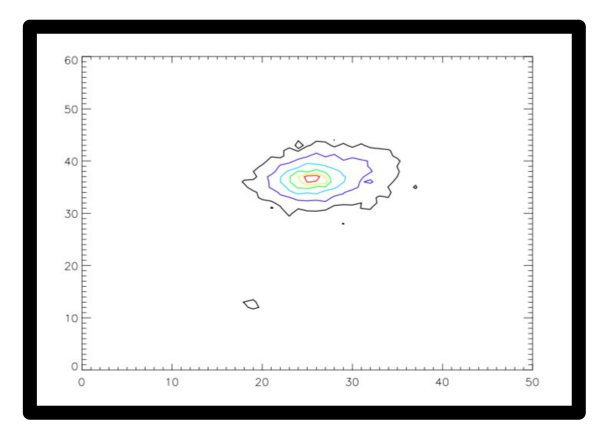


Figure 3: A visual example of what a merger may look like between two objects (Powell et al., 2013). Gravitational disturbances from a merger compresses the interstellar gas, triggering star formation, as well as possibly triggering outflows of gas into the ICM.

VCC 324

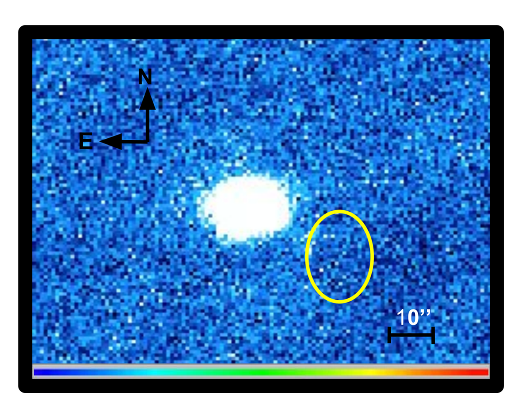


Left: The Ionization parameter mapping of VCC 324. There is one possible companion that lies to the south of the galaxy, as well as a possible outflow on the western edge of the galaxy.

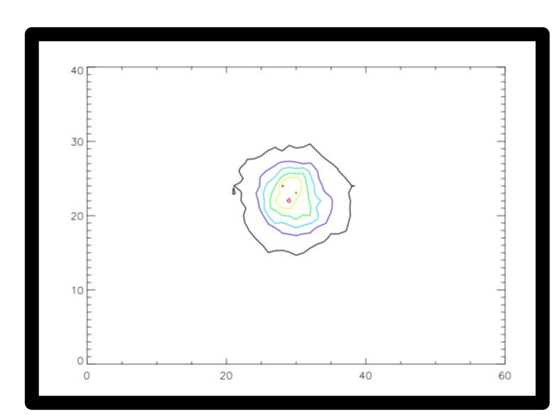


Right: The isophotal map of VCC 324. The image is oriented the same as above. There does not seem to be a connection between the galaxy and the object to the south. The threshold for the first isophote is +3 sigma above the mean background count, and each isophote after represents +3 sigma

VCC 1313



Left: The Ionization parameter mapping of VCC 1313. Note the possible companion that appears in the western section of the image.



Right: The Ionization parameter mapping of VCC 1313. The image is oriented as above. We are unable to draw any conclusions about the companion, since it is below the 3 sigma threshold of the mean background sky count.

Methods

- Data was obtained over an eight night observing run using the 0.9-meter WIYN telescope at Kitt Peak National Observatory in Tucson, Arizona.
- After reducing and calibrating the data, the continuum (U,V,R bands) was subtracted from the narrow band images ([OIII], [OII], [SII]), leaving images of only the regions of ionized gas within the images.
- Ionization Parameter Maps (IPM) were then created by taking the narrow-line ratios of [OIII]/[OII] and [OIII]/[SII]. These IPM show regions of thick optical depth, which are indicative of star formation and high ionization within the galaxy(Oey et al., 2014).
- In the IPM, we look for structural evidence of RPS that is consistent with Figure 1, outflows consistent with Figure 2, and evidence of mergers consistent with Figure 3.

Conclusions

Of the four galaxies we imaged, one is a likely candidate for an outflow of highly ionized gas into the ICM, although the cause of the starburst within the galaxy is still inconclusive (VCC 144). There is one galaxy that is a likely candidate for a merger, due to the nearby ionized companion that is also possibly affecting the shape of the galaxy gravitationally in the form of an outflow (VCC 324). We have one very weak candidate for RPS due to the optical jellyfish-like shape the galaxy has (VCC 428), but at this time the cause of the starburst is inconclusive from our data, until further observations can be made. Lastly, we have a very weak candidate for a merger (VCC 1313). There is a region of high ionization connected to the western edge of the galaxy that also appears to deform the isophotal map in that region. However, the ionized region is below the 3 sigma above the background threshold necessary to register on the isophotal map, so a strip of background noise cannot be ruled out, leaving our results for VCC 1313 inconclusive.

Overall, a fairly small sample of BCD galaxies was observed. There were potential candidates for all three scenarios of interactions galaxies located in clusters could have with their environments, albet ith varying strengths of conclusiveness. Although our sample size is rather small, it suggests that BCD galaxies in clusters have a diversity in their interactions with their ICM environment. Future research could include a larger, more diverse sample size of BCD galaxies in order to observe larger scale trends. Also, space based observations would allow for observations to more distant clusters of galaxies containing BCD galaxies.

References

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