Evidences of feedback processes in the Superwind galaxy NGC1482?

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We present new HI-study with the GMRT+VLA of the superwind galaxy NGC1482. While blue-shifted multi-component HI-absorption line demonstrate the affect of the outflow, HI emission maps of large tidal tails express that interaction with other group members might have triggered the central starburst producing the galactic wind. As an example of feedback process the shockwave from the superwind creating an expanding ring of compressed gas has possibly triggered a recent (few million years) burst of starformation in the cool gas associated with the dust-lane is seen as an arc of strong UV emission.

1 Introduction

Galaxy interaction is an important process by which galaxies evolve. Interaction is known to fuel a central starburst or an AGN activity (Sanders et al. 1998). Galactic wind (Superwind) from the central starburst not only supply metals and energy to the inter-galactic medium but also affects the host galaxy in various ways, known as feedback processes. It can control the fueling of the AGN, regulate blackhole growth and can control the starformation (Veilleux et al. 2005, Combes 2001). We have observed a nearby early-type (SA0/a) galaxy NGC1482 (Fig. 1) with a prominent galactic wind observed both in optical emission line imaging and in x-ray imaging (Fig. 2). A young galactic wind such as in NGC1482 (having 6 million year dynamical age) can serve as an promising candidate to study cause and affect issues related to the outflow. We present here new results from a combined radio continuum and HI study of this galaxy with the VLA and GMRT. We have used available multi-wavelength data (x-ray, Hα and UV) for a better and global understanding of this galaxy (Hota & Saikia 2005, Hota et al. 2008).

2 Results

NGC1482, at a distance of nearly 24.7 Mpc is a member of the Eridanus group of galaxies. It shows a prominent dust-lane (Fig. 1) and very faint stellar emission to the north-east and north-west. We have anslysed the archival HI-data taken with the VLA in CD-configuration. The tapered imaging has a resolution of $45''$. The total intensity HI map shows strong HI emission on both the eastern and western ends, eastern blob being brighter than the western (Fig. 3). The central region also show HI-absorption near the V_{sys} (1850 km s^{-1}). The image displays two long HI tails towards north of NGC1482. The north-eastern and north-western tails extend up to 65 and 58 kpc respectively, from NGC1482 (assuming it to be at the same distance as NGC1482 where $1' \sim 7.2$ kpc)

The intensity weighted velocity field of HI (Fig. 3) shows that the emission blobs on the east and west of NGC1482 are blue (1720 km s^{-1}) and red-shifted (1920 km s^{-1}) w.r.t. the V_{sys}. Gas in the tidal tails have velocities in the range of 1730 to 1840 km s^{-1} so to say line of sight velocity lower than the V_{sys}. Point to notice that tail on the north-west do not connect in velocity space with the HI-blob on the west of the galaxy and hence lack direct connection to the galaxy. At the end of the north-eastern tail an HI-rich late-type (Sc) face-on galaxy (ESO 549− G 035) is seen which has a V_{sys} of 1778 km s^{-1}. On the otherhand an HI-faint early-type (SA0) galaxy (NGC1481) having a V_{sys} of 1730 km s^{-1} is present at the end of the north-western tail. As these two galaxies are spectrally and spatially close enough to the HI-tails it is possible that the early type galaxy may have interacted with NGC1482 and the late-type galaxy may have supplied cold gas to NGC1482 for its bright starburst activity. While the dynamical time scale of the galactic wind outflow is very small, nearly 6 million years these long HI-tails suggest that this gas reservoir will be available to feed the central starburst for nearly 100 million years.

We have imaged the central starburst region of NGC1482 at 5GHz in radio continuum with the VLA in A-configuration (Fig. 4). Apart from it's high resolution ($\sim 0''.47$) it is free from dust obscuration. The radio image shows a central peak coinciding with the peak of infrared emission and probably defines the centre of the galaxy. This peak radio emission is surrounded by fainter emission, due to massive starforming regions or supernova remnants. Indeed this starburst region ($12''$ (1.4 kpc) wide in east-west direction) traced by 5GHz radio continuum is at the geometrical base of the bi-conical outflow seen in Hα emission line image (Fig. 5). This is expected if, stellar wind and supernovae from this region is driving the galactic wind. It is interesting to note that although the galaxy is an early type system the bi-conical outflow is well collimated and suggest presence of dense gas at the base to collimate the wind. No molecular gas imaging has been available so far. To investigate the affect of the wind outflow on the gaseous ISM (or the vice versa) we present below higher resolution ($2''$ to $6''$) HI-observations with the GMRT.

Integrated total intensity HI taken with the GMRT, shows two HI-emission blobs on both the eastern and western ends of NGC1482, similar to that seen in the low resolution VLA images (Fig. 6). These two blobs (150 and 135 million $M_\odot$ of HI mass) contains nearly 20% of the total HI in the system. These compact blobs show diffuse HI on the side away from the centre. These compact blobs also coincide with the Hα emission knots seen in Fig. 5. This display that the dense gas is either collimating the wind or being eroded by the wind and show signatures of ionised gas emitting Hα.

Against the central $12''$ region bright in radio continuum, we also detect multi-component HI-absorption (Fig. 7). While velocity of the emission blobs suggest rotation of HI-gas around the galaxy absorption line traces the rotating gas and also kinematic affects from the outflow. A component of HI-absorption is seen to be blue shifted by nearly 160km/s w.r.t. V_{sys}. Also the absorption line shows a blue-asymmetric by $\sim$70 km/s. This is suggestive of the effects of the wind outflow on the surrounding rotating HI gas in the galaxy. Apart from the affect of the outflow seen in absorption, components of HI emission on the east and west side, at velocities near the V_{sys} are also seen in the channel maps and emission spectra. This can be explained by a model where the gas on both the HI-emission blobs receive momentum from the outflow perpendicular to the line of sight similar to a ring of expanding HI. Detailed multi-wavelength gas velocity field analysis can disentangle affects of rotation and affects of the outflow.

Recently an Ultra-Violate image of this galaxy taken with the GALEX is available (Fig. 8). Although no detailed analysis is done so far, the on-line image display nicely the central starformation associated wind out flow and a brilliant arc roughly coinciding with the dust-lane seen in optical images. This Arc is also noticeable to some extent in the N[II] and Hα images but not discernible in the optical continuum images. Thus this arc traces regions of recent (few million years) and massive star formation dominated by O and B type stars. Hence it is likely that the galactic wind outflow (dynamical age of 6 million years) is not only compressing the surrounding gas and driving outward but also has triggered a recent burst starformation in it. Also since the HI-tails suggest that gas reservoir is available to fuel the central activity for nearly 100 million years, the cumulative affect of the feedback processes from the central activity seems substantial in deciding the evolution of this galaxy NGC1482.

3 Summary

We have studied a nearby galactic wind galaxy NGC1482 with both the VLA and GMRT in HI and radio continuum. With the help of multi-wavelength data like x-ray, Hα and UV imagings we have tried to understand its evolutionary history. Here we summarise our observational findings.

1. With the VLA in CD-configuration we imaged the HI-distribution and velocity field of gas in and around NGC1482. Two HI-tails extending up to 58 and 65 kpc from NGC1482 with gas velocities all blue-shifted w.r.t. V_{sys} are found. At the ends of each HI-tails two galaxies one early-type and the other late-type are seen with velocities similar to the HI-tail. This interaction has probably supplied the gas and triggered the central activity in NGC1482.

2. We have imaged the central starburst region at 5 GHz in radio continuum with the VLA in A-configuration. This starburst region is at the geometrical base of the well defined bi-conical ionised gas outflow seen in Hα imagings. This well collimated wind suggest dense gas surrounding the outflow base.

3. Higher resolution HI imaging with the GMRT, reveals dense cool gas on both the ends of the central starforming region roughly at the edges of the prominent dust-lane. These HI-blobs are possibly associated with the dense gas collimating the wind and being affected by the outward momentum of the wind outflow.

4. Against the central radio continuum source of starburst region we detect multi-component broad (250 km/s) blue-asymmetric (by 90 km/s) HI-absorption. This absorption line also has a line component blue-shifted by 160 km/s from the Vsys. This suggest that the HI-gas rotating around the galaxy also has been affected by the outward momentum from the wind outflow.

5. A recent image from GALEX suggest a prominent arc of UV emission roughly coinciding with the dust-lane and small emission knots in Hα and N[II]. This UV arc suggest dominance of young (few million years) massive starformation in the cool gas associated with the dust-lane possibly triggered by the wind outflow (of a dynamical age 6 million years).

Our study tries to cover a complete picture of the nearby superwind galaxy NGC1482 where we see the galaxy interaction traced by long HI-tails and signatures of central galactic wind outflow (superwind) driven by starburst to affect the surrounding ISM and triggering possible burst of young starformation in the surrounding cool gas.

4 References

[**1**] Hota A. & Saikia D.J., 2005, MNRAS, 356, 998 [**2**] Hota et al. 2008 (in preparation) [**3**] Combes, F. 2001, ASPC, 249, 475 [**4**] Sanders et al. 1988, ApJ, 325, 74 [**5**] Veilleux S. & Rupke D.S., 2002, ApJ, 565L, 63 [**6**] Veilleux S., Cecil G., Bland-Hawthorn J., 2005, ARA&A, 43, 769

Figure 1: Composite (B(blue)+R(green)+I(red)) optical image of NGC1482. [from NASA/IPAC Science Infrared Archive (SINGS survey)]

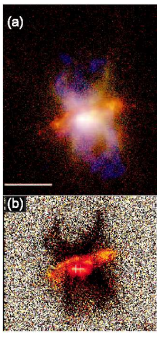

Figure 2: NGC1482 composite image: X-ray emission from Chandra is seen in blue, while Hα is seen in red and and N[II] is in green (top panel). The bottom panel show N[II]/Hα flux ratio, where darker region with ratio greater than unity suggest shock-ionisation (by the galactic wind outflow) and rest in orange representing star forming regions.[from Veilleux et al. 2005, ARAA, 43, 769]

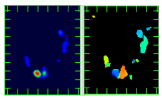

Figure 3: Left panel: Total intensity HI image from VLA in CD-configuration. The optical galaxy is bottom of the image in between the blobs. Each tick mark corre sponds to $1'$ in Dec. and 5 seconds in R.A.. Right panel shows the corresponding HI velocity field.

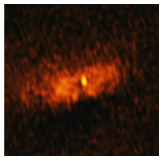

Figure 4: 5GHz radio continuum image of the central region of NGC1482 taken with the VLA in A configuration.

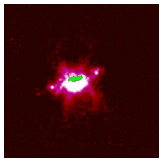

Figure 5: false colour optical emission line Hα image of NGC1482 showing the bi-conical galactic wind outflow in the north-south direction with the central starburst region traced by the 5GHz radio continuum image marked by green colour.

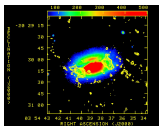

Figure 6: The high resolution ($6''$) GMRT image of the total intensity HI (in yellow contours) superimposed on the false colour optical image from DSS.

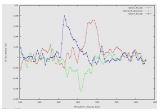

Figure 7: Superimposed HI spectra from both the HI-emission clumps seen with the GMRT and HI-absorption spectrum (in green) seen against the central radio continuum emission.

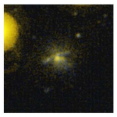

Figure 8: Composite near UV and far-UV image of NGC1482 taken with the GALEX.