Goal

The primary goal of this work is to study by which mechanisms and how galaxies can be pre-processed (Fujita 2004) in the filaments before they fall into the cluster. We have been carrying out an HI imaging study to look for signatures that galaxies are being affected by their surroundings. In particular, we search for the evidence that gas accretion or stripping from/by the intergalactic gas in the filaments.

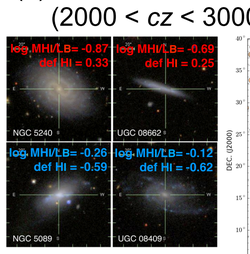
Sample and HI Observation

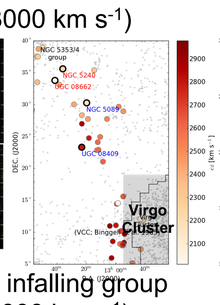
There are striking filamentary structures around the Virgo cluster (Tully 1982, Karachentsev & Nasonova 2013). First, we calculated HI mass, HI deficiency and HI mass-to-light ratio of the galaxies in three regions (Fig. 1) around Virgo using their HI fluxes in the archival data (e.g. HIPASS, ALFALFA and LEDA). Then, we have selected either extremely HI-rich or extremely HI-poor galaxies and observed them in HI (21cm) to find signatures that the galaxies being pre-processed in the cluster outskirts.

Table 1. Summary of HI observations

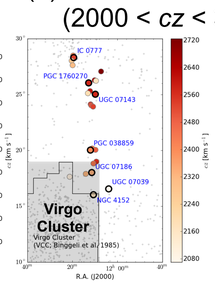
Region	Telescope (array)	Observing Date (month year)	Integration time (hr)	Bandwidth (MHz)	# of Channel	Theoretical rms (mJy beam^{-1})
North-eastern filament (4 galaxies)	JVLA (D-array)	July 2014	1.5 x 4	16.00	512	1.07
North-western filament (7 galaxies)	WSRT (72m)	Dec 2013 / Jan Apr May July 2014	12 x 7	20.00	1024	1.17
South-eastern infalling group (2 galaxies)	GMRT	Jan 2014	10 x 2	16.67	512	0.55

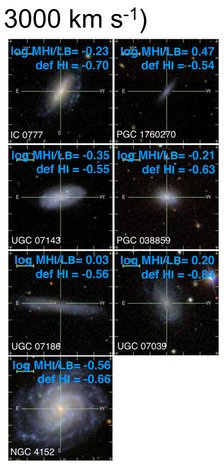
(a) North-eastern filament (2000 < *cz* < 3000 km s^{-1})



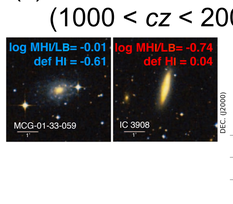


(b) North-western filament (2000 < *cz* < 3000 km s^{-1})





(c) South-eastern infalling group (1000 < *cz* < 2000 km s^{-1})



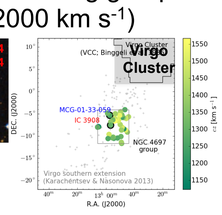
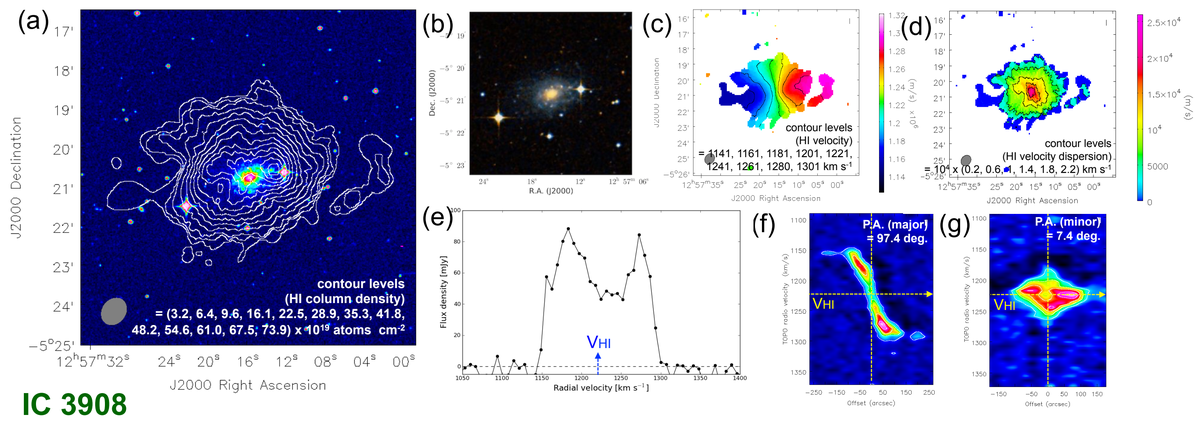


Figure 1. The distribution of three filamentary structures in the (a) NE, (b) NW and (c) SE of the Virgo cluster. These are identified based on their position and radial velocity. The SDSS/DSS optical images of member galaxies are shown next to each filament. HI-mass-to-light ratio (unit : M⊙/L⊙) and HI deficiency of the galaxies based on HI archival data are also presented.

HI Morphology and Kinematics

We present preliminary results of two galaxies, MCG-01-33-059 and IC 3908 selected from the infalling galaxy group in the south-east of Virgo. Both galaxies show peculiarities in their outer HI disk.

MCG-01-33-059



IC 3908

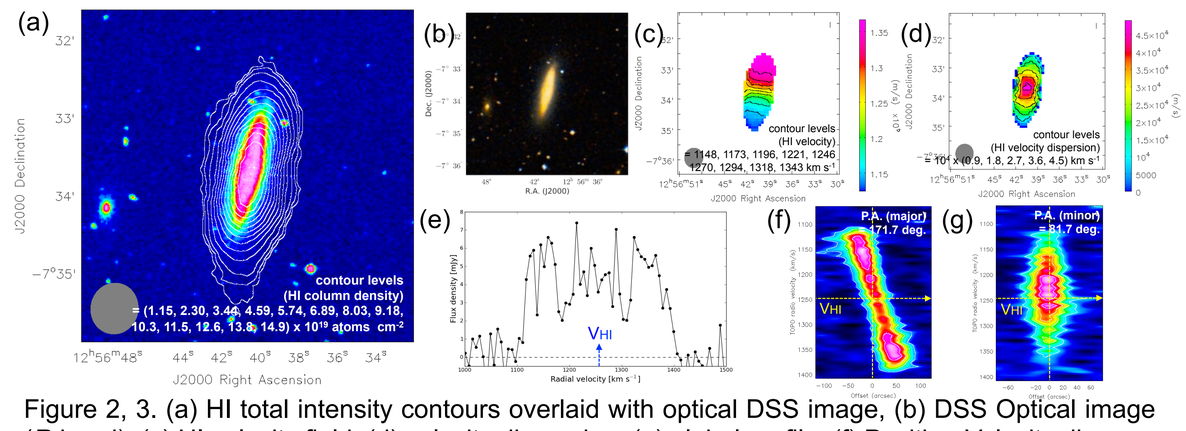


Figure 2, 3. (a) HI total intensity contours overlaid with optical DSS image, (b) DSS Optical image (*R*-band), (c) HI velocity field, (d) velocity dispersion, (e) global profile, (f) Position-Velocity diagram along the optical major axis, (g) Position-Velocity diagram along the optical minor axis.

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Pre-processing of Galaxies in the Filaments around the Virgo Cluster

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Abstract

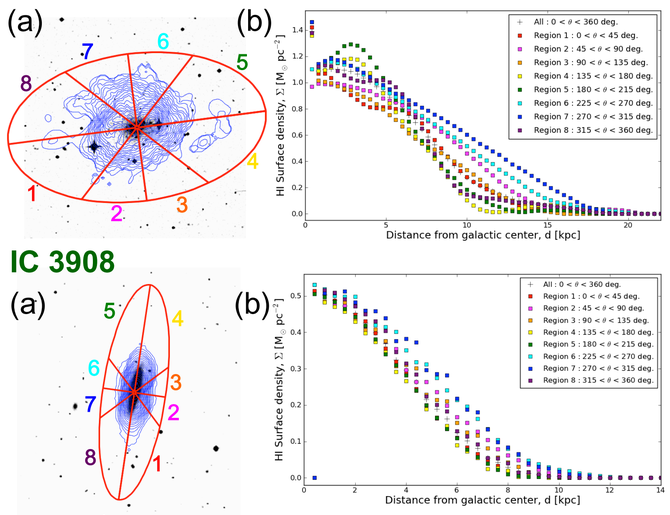
It has been suggested that galaxies can be "pre-processed" in the low-density outskirts of galaxy clusters. Indeed, galaxies may interact with the medium in the filaments or with other galaxies while falling into the cluster as a group. However, no consensus has been made yet on how early on galaxies get affected by their surroundings and how various mechanisms can change galaxy properties before they reach to the high-density cluster environments. In order to probe pre-processing mechanisms in detail, we are carrying out a neutral atomic hydrogen (HI) imaging study of a sample of galaxies selected from two filaments around the Virgo cluster. Our current sample consists of nine late-type galaxies, which are potentially interacting with their surroundings. The HI observations have been done using the Westerbork Synthesis Radio Telescope (WSRT) and the Giant Metrewave Radio Telescope (GMRT) with column density sensitivity of ~ 10^{19} cm^{-2}, which is low enough to detect faint HI features in the outer disks of the galaxies. We have examined the HI morphology and kinematics of the sample to probe the possible mechanism(s) responsible for any signs of pre-processing in the galaxies. We find evidence for gas-gas and/or tidal interactions, and discuss how the low-density environments can change the galaxy evolution.

HI Properties and Asymmetry

Table 2. Summary of HI properties of the galaxies

Galaxy	SHI (Jy km s^{-1})	MHI (10^8 M_{sun})	W20 (km s^{-1})	W50 (km s^{-1})	VHI (km s^{-1})	log(MHI/LB)	def HI
MCG-01-33-059	8.72	5.59	145	136	1221.75	-0.536	-0.079
IC 3908	1.27	0.81	285	256	1249.25	-1.741	1.037

MCG-01-33-059



IC 3908

Figure 4, 5. (a) Eight regions in HI disk. Each region covers 45 deg. (b) Surface density profile along the distance from the optical galactic center.

As one way to show the morphological peculiarity, we measure the HI surface density and extent in eight sectors of the HI disk which were divided using the optical major axis and inclination. Each pie covers 45 deg. of the HI disk. For MCG-01-33-059, both the surface density and the extent of Region 3 and 4 are very different from their counterpart, Region 7 and 8. For IC 3908, the surface density of each region is comparable to that of the counterpart. However, the gas tail present along the major axis makes the extent very distinct between 1 and 8, and 4 and 5.

Discussion

MCG-01-33-059

- The HI disk is larger than its stellar disk in size by a factor of ~4.
- It contains about 20% more HI gas compared to other field galaxies with a similar size.
- The HI disk is quite asymmetric and more extended to the north-east (Region 7).
- The HI peak is off from the optical center to the west by ~35 arcsec.
- Its HI mass and morphology are suggestive of gas accretion, which might be responsible for the star-forming regions found in the optical. No obvious companions are present around this galaxy, and it might be the gas in the filament that has been accreted (Sancisi et al. 2008).

IC 3908

- The HI disk is about twice bigger than the stellar disk and shows an one-sided gas tail in the south (Region 1 and 8).
- Compared to other field galaxies of similar size, this galaxy deficient in HI, containing 10% of the HI in field counterpart.
- Based on the HI deficiency, the gas tail is likely to be the gas being stripped not being accreted, which might be responsible for its unusually red optical color. It might be the case where a galaxy is being ram pressure stripped while crossing the gas filament.

References

- Binggeli, B., Sandage, A., & Tammann, G. A. 1985, AJ, 90, 395
- Fujita, Y. 2004, PASJ, 56, 29
- Karachentsev, I. D., Nasonova, O. G., 2013, MNRAS, 429, 2677
- Sancisi, R., Fraternali, F., Oosterloo, T., & van der Hulst, T. 2008, A&A Rev., 15, 189
- Tully, R. B. 1982, ApJ, 257, 389