HI content of galaxies in groups

by

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Certificate:

This is to certify that the thesis entitled "HI content of galaxies in groups" submitted by Chandreyee Sengupta for the award of the degree of Doctor of Philosophy of Jawaharlal Nehru University is her original work. This has not been published or submitted to any other University for any other Degree or Diploma.

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Declaration:

I hereby declare that the work reported in this thesis is entirely original. This thesis is composed independently by me at Raman Research Institute under the supervision of Dr. Ramesh Balasubramanyam. I further declare that the subject matter presented in this thesis has not previously formed the basis for the award of any degree, diploma, membership, associateship, fellowship or any other similar title of any university or institution.

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Dedicated To

The Taxpayers of India

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I was quite nervous about writing this section as I was told by my seniors that this is the first and probably the only section most people will read in this thesis. During my six years of stay in Bangalore, I have made the acquaintance of a large number of people each of whom in their own way have contributed towards the completion of this thesis. I take this opportunity to express my gratitude and thanks to each and every one of them and my sincere apologies to those whose names I might have missed out.

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Contents

Synopsis

Cold gas in galaxies evolve, i.e either the gas gets converted to stars or is lost to the medium around it. This gas loss can be due to either internal processes to the galaxy like star formation, supernovae and galactic winds or external processes like tidal interaction with another galaxy, ram pressure stripping by the medium where the galaxy resides or evaporation by thermal conduction. In this thesis, we investigate the effects of the X-ray emitting hot gas internal and external to the galaxy on its cold gas content in low density environments (loose groups of galaxies). Therefore this thesis comprises of two parts. In the first part (which consists of CHAPTERS TWO, THREE and FOUR), we study the effect of the hot gas external to the galaxy (intra-group medium) on its H I content. In the second part (CHAPTER FIVE) we study the relation of the hot gas internal to the galaxy to its H I content. *CHAPTER ONE* of this thesis is a brief introduction to the topics covered in this thesis and discusses the motivation behind taking up this study.

Cold gas evolution in cluster spirals is a well studied subject. A wealth of information exists about studies related to H I deficiency (a term used to measure H I loss from a galaxy; this will be explained in detail in the chapters to follow) in cluster spirals and the processes responsible for it. Members in groups may also lose gas to the intra-group medium (IGM) and become relatively deficient in H I . Galaxies in the Hickson compact groups have been reported to be gas deficient [155]. Relatively less observational evidence exists about gas deficiency in loose group environment. For the first time, H I deficiency by a factor more than 1.6 was reported in some members of a non-compact group in the Puppis region [29]. In some of the loose groups, the IGM was found to have enhanced metalicity, suggesting recent gas removal from the member galaxies [39]. Thus, investigating gas removal processes operating in loose groups was timely and important. Two mechanisms have been considered important for gas removal in group or cluster environment: tidal interaction and ram-pressure stripping. Ram pressure stripping [58] is effective when the H I surface mass density is less than $\rho_0 v^2/(2\pi G\sigma_*)$, where σ_* is the stellar surface mass density. Clearly, larger the ICM or IGM density, ρ_0, and galaxy velocity dispersion, v, the more effective is this stripping. Clusters satisfy these requirements and ram-pressure stripping has been considered an effective process in them. In groups, though, both these quantities are lower, especially dispersion by a factor of 10 and therefore ram pressure stripping was considered ineffective. Tidal interactions on the other hand, involve gravitational interaction between two or more galaxies as they pass by each other. The lower relative velocities in groups allow larger interaction timescales making tidal stripping the likely process for gas removal. This, in a larger sense, includes galaxy 'harassment', where the tidal stripping is caused by the overall gravitational potential of the group. However, a significant number of loose groups have been found to have hot gas in them emitting diffuse X-rays [97]. In such cases, ram pressure assistance cannot be ruled out, making X-ray bright groups more H I deficient than non X-ray bright groups.

We studied in detail the H I content of galaxies in groups with and without X-ray detection, covering a wide-range in X-ray luminosity. Here, in this thesis, in *CHAPTER TWO*, we report the first part of our study, viz. a comparative analysis of H I content in small loose groups based on HIPASS and other existing single dish data. We find that the galaxies in non X-ray groups are not deficient in HI with respect to the field galaxies. The galaxies in X-ray groups are clearly deficient in HI and have lost more gas compared to those in non X-ray groups. On average, the galaxies in X-ray groups show a HI deficiency of 0.28 ±0.04 compared to an insignificant deficiency of 0.09 ±0.03 in non X-ray group galaxies. No systematic dependence of the H I deficiency with L_x is found. *Tidal aided ram pressure stripping* and *evaporation* are the possible mechanisms leading to the excess gas loss found in galaxies in X-ray groups.

The work mentioned above, established that the galaxies in X-ray bright groups are on an average more HI deficient than galaxies in non X-ray groups. The next step was to investigate the gas removal process responsible for this excess deficiency. Thirteen galaxies from four

X-ray bright groups (NGC720, NGC5044, NGC1550, IC1459) were imaged in H I with the Giant Metrewave Radio Telescope (GMRT). This work is described in detail in *CHAPTER THREE*. The aim of this work was to study the morphology of H I in these galaxies and to see if the H I distribution has any signatures of IGM assisted gas stripping. Our estimates on these galaxies show that ram pressure by itself or tidal aided ram pressure can be important gas removal mechanism in groups with hot IGM. That such processes may play a vital role is also evident from the analysis of the H I data on these galaxies. We find on an average the HI disks of these galaxies are shrunk compared to field and normal group galaxies. Average H I diameter to optical diameter ratio for these galaxies is 1.1 compared to 1.7±0.05 seen in both field and group spirals. This indicates either direct ram pressure or tidal assisted ram pressure has contributed in gas loss from these galaxies.

Continuing with the topic of gas evolution in group galaxies, in *CHAPTER FOUR*, we present a study about the gas content in 2 intermediate redshift (z ~0.06) groups. It is part of a multi-wavelength survey of a statistical sample of groups chosen from the 2dF galaxy survey. The primary aim of the project is to understand the nature and evolution of the galaxy population in groups, and the role played by cold gas (radio) and hot gas (X-ray) in their history in relatively higher redshifts. However in this chapter, we study only the cold gas content of these two groups, both of which have been detected to have hot X-ray emitting IGM. The groups were observed with the GMRT in 21 cm H I line. We have detected H I from one galaxy in one of the groups, which has relatively cooler IGM amongst the two groups. We did not detect any H I from the galaxies in these groups (apart from the single detection), even if, in several cases the expected H I masses in the galaxies were well above our sensitivity limits, suggesting the galaxies in these groups to be H I deficient. This study, is in confirmation with our results of CHAPTER 2 and CHAPTER 3, but extended to higher redshift groups than the ones studies in the previous chapters.

Having studied the effects of the environment (IGM) on the H I content of galaxies, the next step was to understand the relation of the X-ray emitting hot inter stellar medium (ISM) on the cold gas content of a galaxy. This is what is investigated in the *CHAPTER FIVE* of this thesis. This project is a comparative study of the diffuse hot X-ray gas in a sample of spiral galaxies, mostly in group environment. The sample includes normal, AGN hosts and starburst galaxies. Archived data for 34 galaxies targeted with the 'Chandra' have been analysed in an uniform manner to do this comparative study. The aim of this study was to address issues of the origin of hot gas in spirals, its relation to the star formation in the galaxy and the relation of the hot gas to the H I content of the galaxy. There exists only two previous statistical studies probing the origin of hot gas in spirals. The first study of this nature was carried out by Read & Ponman in 2001, with a sample of 17 galaxies, with ROSAT-PSPC data [116]. Their main conclusions were that the hot gas found in spiral galaxies is closely related to the star formation activity in the galaxies, especially for starburst galaxies. For normal galaxies, where there is less of current star formation, the gas which was once heated by a previous burst of star formation is held back to the galaxy by the virtue of the mass of the galaxy [116]. Similar tight correlation of X-ray gas content and star formation rate was found in the second study carried out with a modest sample of 10 Chandra observed spiral galaxies by Strickland et al.[138]. However the problem needed a revisit to understand the issue with better certainty as the first study suffered from the poor resolution of ROSAT and the second study was based on a small sample of 10 galaxies, with mostly starburst galaxies. In this chapter, we present our results from a quantitative comparative study of 34 spiral galaxies. Our study of the origin of the hot gas in spirals, confirms the results of Read & Ponman (2001). Our next interest was to study the relation of the hot gas and cold gas in the spiral galaxies. There has been no previous study of this kind. However, there were observational evidence of the validity of the Schmidt law for cold gas and star formation in spiral galaxies. In the first part of this study we establish that the hot gas in a galaxy is related to its star formation rate and therefore we expect a relation between the hot gas and H I content of a galaxy. We do find this relation in normal galaxies. We find galaxies show decrease in star formation and thereby decrease in hot gas content with increasing H I deficiency. However, for galaxies that host AGNs, the relation changes. In these galaxies, we note a marginal rise in the H I deficiency with increase in X-ray luminosity and star formation rate. We infer, that this excess deficiency can be merger or interaction related. Previous studies indicate higher probability of occurrence of AGNs in interacting or merging galaxies [161], [3]– these interactions and mergers can induce starburst in a galaxy, making it X-ray luminous and at the same time is capable of stripping gas from the galaxies making them H I deficient. This picture explains why we find the normal galaxies without AGNs to follow the pattern expected from the Schmidt law–to have higher gas content for higher star forming galaxies, and for AGN host galaxies to follow a different pattern–to have an excess H I deficiency for higher star forming galaxies.