HI and HII in NEARBY SPIRAL GALAXIES

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1. Introduction

Spiral arm properties varies widely from one galaxy to another. For this reason detailed observational studies of galaxies with different morphologies are critical for the understanding of the role, if any, of the spiral arms, in the formation of the complexes of HI clouds, molecular clouds and ultimately for the formation of the massive stars.
In the disk of galaxies the gas cycles through three major phases: the diffuse atomic HI phase, the molecular phase and the ionized phase. Some gas may also go through a hot (10^6K) and diffuse ($n \sim 10^{-3}$ cm^{-3}) phase via supernovae explosions; this is the coronal phase. The HI phase is characterized by cold dense filaments and sheets observed by the HI in absorption and by diffuse warm clouds (with typical densities around 1 cm^{-3}). The extragalactic observations reveal quasi exclusively the warm HI which can be accessed easily using the 21cm HI line in emission. The large scale distribution and abundance of the molecular H_2 phase is only indirectly accessed via the observation of the CO molecule which samples the cold dense molecular clouds ($n>10^3$ cm^{-3}). The warm ionized phase is associated to the HII regions and diffuse disk emission; it is best observed in the optical using e.g. the Hα line or in the radio continuum through its free-free emission. The spatial distribution for these phases is characterized by ridges of emission which are organized into grand design spiral structures; they are associated to star forming regions. However there is also in some cases vigorous star formation in interarm regions. Indeed this is not very surprising because we know that the Irregular galaxies are also able to form actively stars. A typical case is the well known region 30 Doradus in the Large Magellanic Cloud. The observations adress a number of questions:

1/ Is the spiral phenomenon only of minor importance for cloud and star formations; is it only something which structures galaxies tracing a sequence of events?
2/ Do spiral structures simply collect preexisting molecular clouds and/or do molecular clouds form in spiral arms from the compression of diffuse atomic gas?
3/ Is the HI distribution largely influenced by dissociated H_2?
4/ Are the HI concentrations the diffuse envelopes of molecular cloud complexes shielding them from the Inter-Stellar Radiation Field (ISRF)?
5/ Is there a threshold in the HI (surface) density for the formation of molecular clouds?

Obviously these different questions are not fully independent! In addition, it may be that, from an observational point of view, there is no way to get a unique answer. One of the most important problems

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is the fact that the H_2 phase is not observed directly. Furthermore, the observations must be used with extreme care! In many cases one observes only the top of the iceberg either because of sensitivity limitation (an important limitation at millimeter wavelength) and/or because of the inadequacy to measure low spatial frequencies when using the aperture synthesis technics solely.

This paper will restrict on a review of the observations of the HI and HII phases of the interstellar medium in the disks of a few nearby galaxies for which relatively extensive information has been or is being collected. An other requirement is that these galaxies must have sufficiently well known characteristics from the CO observations to properly study the relation between the molecular phase and the HI and HII phases. Although these conditions restrict severely the number of spiral galaxies to be reviewed this is already a difficult task because of the considerable amount of details in which some of them have been observed. The most instructive way to present data cubes which, in some cases, exceed 10^8 pixels would have been to present color images. Color images are also very useful tools to compare the spatial distribution of the different phases. It is unfortunately not possible to use such type of representation here; undoubtedly this review will not show all the richness available in the data! Furthermore, I have no doubt that part of the richness may still be hidden in the data, simply because it is not easy to handle large data bases obtained, in some cases, with very different technics.

In our Galaxy one observe associations between HI, HII and CO emission over a large range of scales from typically 10^4 to 10^7 M_o. For the extragalactic observations this full range of scales is currently accessible only for the two nearby spirals M31 and M33. For more distant galaxies only the upper part of this range of scales is accessible. Beyond M31 and M33, M51, M81, M83, and NGC6946 are the four best observed next spirals; they will be reviewed successively.

2. Our Galaxy

One would like to see our Galaxy from outside for a better comparison with the nearby galaxies. This is indeed not easy! On large scale the Galaxy is characterized by a "molecular ring" of about 3.5 kpc inner radius and a gradual decrease outside. This ring is known to coincide with active star formation as traced by the radial distribution of radio HII regions. On smaller scale the existence of HI superclouds and their associations with Giant Molecular Complexes (GMCs) has been very convincingly demonstrated by Elmegreen and Elmegreen (1987). These HI superclouds have typically 10^6 to 4 10^7 M_o of gas; they are distributed along ridges following the spiral structure. 40 to 70% of the HI is associated to these superclouds but they occupy only 4% of the volume in the disk. Most of the atomic mass is in the largest HI complexes as well as most of the molecular mass is in the largest CO complexes. The molecular mass fraction of these superclouds decreases from 70% to 5% from the inner to the outer part of the Galaxy. These HI superclouds are probably the result of gravitational instabilities of the ambient interstellar medium. These instabilities should be enhanced in spiral density waves because of the higher density and magnetic field strength but also because of lower shear. Molecular clouds could be agglomerations of smaller clouds formed elsewhere but collected just as for the HI gas.

3. M31

3.1. The HI phase

On large scale the Sb galaxy M31 is characterized by a large ring of about 11 kpc diameter. Major efforts have been spent during this last decade to study with considerable details the HI phase (Brinks, 1984, Braun, 1990). At a resolution of about 100 pc the distribution of HI is characterized by loops and filaments. Brinks and Bajaja (1986) compiled a list of 141 holes of sizes up to 1kpc, 10^3 to 10^7 M_o of swept away gas and with kinematical ages in the range 3 to 30 10^6 years. There is evidence for the holes of diameter smaller than about 300 pc to be spatially correlated with the OB associations and the HII

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regions; in contrast there is no correlation with the location of the SNRs. The filling factor of the M31 holes is only 1%, a value significantly smaller than the one expected by McKee and Ostriker (1977) for our Galaxy. The VLA survey obtained by Braun covers half of the galaxy with a resolution of 10" (~35 pc at the distance of M31) and 5 km s^{-1} and a detection limit of about 7K. Although these data have not yet been published some of the first results were presented at the Wyoming conference (Braun, 1989): there is a large number of narrow lines with high brightness temperature (T_b~160K) significantly higher than those observed in our Galaxy (T_b~125K) . There are also resolved contiguous structures of 100 pc x 10 km s^{-1}.

The HI phase is also observed indirectly in the far infrared with IRAS since a large fraction of the infrared emission results from dust associated with this phase that is heated by the ISRF (Walterbos and Schwering, 1987). The large scale distribution of the emission in the infrared is also characterized by a ring structure although there is in addition a prominent nuclear source not observed in HI (see e.g. the contour map presented at this Symposium by Dame et al.). There is a radial gradient in the infrared luminosity per HI atom which is interpreted partly by a gradient of the dust-to(atomic) gas ratio.

3.2. The HII phase

The distribution of Hα emission has been mapped by Pellet et al. (1978). On large scale the HII regions are distributed in the HI ring. At smaller scale (about 200pc) there is a clear tendency for the HII regions to lie in strings along HI segments (Unwin, 1980). From his continuum survey at 1412MHz with a resolution of about 100 pc and a sensitivity limit of about 0.2 mJy, Walterbos (1986) observed that the continuum ring is resolved into complexes which correlate very closely with the Hα sources.

Major efforts are currently spent to study in more details this HII phase in M31. A VLA radio continuum survey at 1.4 GHz (Braun, 1990) has been very recently published; the resolution is 5" (~20pc) and the detection limit 30 μJy. About 100 Hα sources from the optical catalog of Pellet et al. (*ibid.*) have been identified ; even the highest luminosity M31 HII regions are only a few hundreds of mJy. Major efforts are also currently spent to get a more quantitative optical data base. Braun and Walterbos are currently working on a survey consisting of 19 CCD fields in Hα, [SII], and the photometric bands R and B. A brightness sensitivity of about 1 pc cm^{-6} (expressed in emission measure) at 10" resolution is obtained in Hα. A catalog of about 1000 sources is in preparation including many new SNRs discriminated from the HII regions on the basis of their [SII]/ Hα ratio. They also used a Fabry-Perot interferometer to study the kinematics of 8 regions. High velocity HII outflows are observed around young associations with gas at ± 30 km s^{-1}. HII regions are also observed associated with OB associations (van den Bergh, 1964) and far UV sources (Deharveng et al. 1980). Although the HII regions must be also far infrared sources, because of their weakness and also because of the relatively poor angular resolution of the IRAS measurements leading to confusion with the M31 cirrus, they do not show up prominently on the far infrared images. Only 10% of the far infrared emission from M31 is associated to the young star forming regions i.e. the HII regions-OB associations (Walterbos and Schwering, *ibid*).

3.3. Molecular phase

From an ongoing sensitive complete CO survey of M31 (Dame et al. 1990) preliminary results already show the large-scale distribution of the CO emission. There is a good spatial correlation between the distribution of CO emission, the HI component and the infrared emission from dust at 100 μm. Because of the large angular size of M31 it is currently out of question to map entirely this galaxy in CO with the same degree of details as in HI, in the radio continuum or in the optical. However a number of specific regions have now been observed with relatively high angular resolution. The aperture synthesis observations of Vogel et al. (1987) provide strong evidence for the existence of GMCs in M31. At a resolution of 7" (25pc) these GMCs are resolved; their observed properties lie in the range observed for galactic GMCs; their mass is typically a few $10^5 M_o$. These GMCs do also coincide with HII regions. Several observations have also been reported at lower resolution (Ichikawa et al. 1985, Casoli et al., 1987, 1988, Lada et al. 1988, Beck 1990). In all cases the concentrations of CO emission are found to be

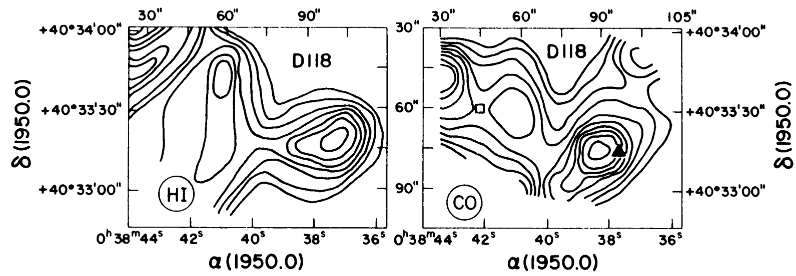

Figure 1. Distribution of the HI and CO emission from the D118 region in M31 (Lada et al, *ibid.*) at a common angular resolution. The position of two optical HII regions are also indicated on the CO map by a square and a triangle. HI contour levels are 2800, 3000, 3200 etc. K km s^{-1}. CO(1-0) contour values are 0.4, 0.8 1.2 etc. K km s^{-1} (in units of NRO antenna temperature).

associated with HII regions. The coordinated CO and HI observations of Lada et al. impressively demonstrate, at least for the region that they observed, the close association both in space and velocity of HI and CO emission (Fig. 1); the contrast between the peaks of emission and the background is considerably smaller for the HI emission than for the CO emission. The GMCs in M31, with typically a few $10^5 M_o$ of molecular hydrogen, contain about 30% of their total mass in atomic hydrogen. Lada et al. suggest a threshold $N_{HI} \sim 10^{21}$ at cm^{-2} for the formation of molecular hydrogen; they also suggest that the molecular clouds form from atomic hydrogen within a spiral on a relatively short time scale.

4. M33

4.1. The HI phase

The large scale distribution of the HI in M33 is characterized by a flat radial distribution with some deficiency of emission in the inner 2 kpc diameter region, a property typical for a Scd galaxy. Our view on the distribution and kinematics of the HI in M33 has considerably progressed with the Westerbork survey published by Deul and van der Hulst (1988). At the angular resolution of 12"x24" corresponding to 80 pc in the plane of M33 the HI structure consists of filaments forming loops or holes. Deul (1989) catalogued 148 holes. The mass of swept away gas ranges from 10^3 to 10^5 M_o requiring 10^{49} to 10^{51} erg of energy and the typical age for these structures is estimated as 10^7 years. The HI holes are best correlated with the OB associations (200 pc scale). Holes may be produced by stellar winds, supernova explosions or by collision between high velocity clouds . However the filling factor of holes do not exceed 40%, a value smaller than the one computed by McKee and Ostriker (*ibid.*) for our Galaxy. Actually van der Hulst and Viallefond (1990, unpublished) do not find the presence of high velocity HI gas in the direction of the SNRs. Because of a more favourable inclination angle of the disk of M33 as compared to the one for M31, it is more easy to study M33. The HI kinematics in M33 is still indeed dominated by the general rotation of the galaxy but when one removes this effect from the data cube a considerable amount of details appears. First of all there is no grand design pattern for non-circular motions associated with the spiral arm features. The only region where streaming motions are easily recognized corresponds to a portion of the main southern arm where, several years ago, Courtès and Dubout-Crillon (1971) were the first to propose from optical data the existence of a density wave.

The HI phase is also observed indirectly in the infrared from the emission of the dust in the diffuse HI clouds (Rice et al. 1990). As for M31 the global infrared spectrum of M33 is similar to the spectrum of a galactic cirrus. Similarly the infrared emission per HI atom also decreases with radial distance. Using observational constrains based on the distribution of the ultraviolet and optical light to determine the radial variation of the ISRF, Rice et al. succeeded to model the radial profile of the infrared emission by invoking a radial decrease of the abundance of dust.

4.2. The HII phase

During the last few years spectacular new results have also been obtained to reveal the HII phase in M33. Courtès et al. (1987) made a complete photographic Hα survey with a limiting surface brightness level of ~40 pc cm^{-6} at 1" angular resolution. 748 sources are identified. More spectacularly these photographs reveal a new appearance of the ionized gas in M33: the classical HII regions are observed bathing in a very chaotic background of Hα emission. Rings, loops, arc-shaped and filamentary structures are present all over the galaxy in and between the arms. Several new optical studies are currently in progress to measure more quantitatively the observational properties of the HII phase in M33. Most impressive is the wide field CCD observations in Hα, [SII] and in the red continuum from Hester and Kulkarni (1990). These high sensitivity observations reveal even more spectacularly the complex structure of the interstellar medium at a brightness level as low as a few pc cm^{-6} in emission measure.
The large scale distribution of the radio continuum emission at 10.7 GHz (Buczilowski and Beck, 1987, Buczilowski, 1988) gives an overall view of the distribution of the HII phase because at this frequency a large fraction of the emission is thermal. At higher angular resolution our view of M33 in the radio continuum is being to improve (Viallefond et al. 1991). The entire optical disk of M33 has been mapped at 5 and 1.4 GHz combining data from the VLA and the WSRT aperture synthesis telescopes. Maps have been produced at 5" resolution with a sensitivity limit of about 35 to 50 μJy. Diffuse emission is observed along the spiral arms. Hundreds of sources are also observed; most of them are identified with Hα sources. A few tens of these sources are identified (Duric et al. 1990) with optically confirmed or candidates SNRs (Long et al. 1990). It is the first time that a large sample of radio continuum - Hα sources has been measured at several radio frequencies and with such a sensitivity and resolution. Comparing the flux densities of the M33 sources between 5 and 1.4 GHz, interestingly one observe that a large fraction of the sources are contaminated by non thermal emission; this suggests the presence of small scale (« 40 pc) non-thermal structure in a number of the HII regions.

On a large scale there is a good correlation between the HI distribution and the location of the optical HII regions (Newton, 1980). However, on smaller scales, the HII regions in M33 tend to concentrate on the boundary of the large HI holes (Deul, *ibid*) or of HI concentrations along the spiral arms. HII regions are also in most cases displaced relative to molecular clouds. This displacement must be considered as real and not caused by extinction effects since the optical sources coincide very well with the radio sources (Viallefond et al. 1991).

Not surprisingly the HII regions are also bright sources in a new large-scale survey (resolution of about 15" to 20") of the ultraviolet emission at λ2000Å (Milliard 1990). At this wavelength the emission is dominated by the light from non-ionizing stars in the range 5 to 10 M_o. The massive stars responsible of the ionization do form together with lower mass stars. The HII regions are indeed also found to coincide with associations of blue stars (Humphreys and Sandage, 1980, Kunchev and Ivanov, 1984) although there are also associations with no HII regions. This can be interpreted by age effects. The M33 HII regions are observed in the infrared (Rice et al. *ibid*). There is a very strong correlation between distribution of HII regions and the structure on the 60-100μm color image of M33. The dust associated with the HII phase, hotter than the galaxy in average, contributes to about 50% of the total infrared luminosity of M33, a value much higher as for M31.

The luminosity function of the HII regions in the inner part of M33 has been determined by Viallefond and Goss (1985). NGC 604 is, and by far, the brightest HII nebula in M33; this nebula resembles 30 Dor in the LMC, it has been extensively observed in the ultraviolet, the optical, the infrared and the radio. The association of HII with the HI and CO emission for this nebula has been briefly discussed during this symposium (Viallefond et al. 1990).

4.3 Molecular phase

The large-scale distribution of the molecular phase in M33 is at present not yet observed. It would be highly desirable to perform a low resolution CO survey over all the optical disk of M33 of the type of the ongoing CfA survey of M31. The nuclear region has been mapped by Wilson and Scoville (1989) at a resolution of 55" (about 200 pc). Although there is no emission at the nucleus, several associations of GMCs are observed not very far away. These associations are neither tidally bound nor virially bound. The CO and HI emission are spatially correlated, but without an overall global pattern. There is no exponential radial decrease in the CO distribution. Provided that the standard galactic I_{CO}/N_{H2} ratio holds for the nuclear region of M33, the average column density of molecular hydrogen is about twice the average HI column density which would suggest no gas depletion in the inner part of M33. The CO contrast between these associations and their environment is greater than 7 i.e. at least twice the HI contrast. These associations observed at low resolution are now resolved into smaller scale structures with the OVRO interferometer and the IRAM 30m antenna. The first interferometric data have been obtained by Boulanger et al. (1988) and Wilson et al. (1988). Boulanger et al. observed in the direction of one bright radio HII region (VGHC 75, radio continuum nomenclature) in the main southern spiral arm as well as on the eastern side in NGC 604 (Fig. 2) which is located at the extremity of the main northern arm. With a resolution of 7" (about 25pc) they resolved one molecular cloud near VGHC 75 and two in NGC 604. These three clouds are bright and small compared to Orion. However they are exposed to a much intense ISRF than in the solar neighborhood. Viallefond et al. (1990) suggest that the metallicity deficiency compensates the very bright intensity of the radiation field to yield a I_{CO}/N_{H2} ratio close to the Galactic value. Wilson et al. detected three clouds in the nuclear region with a comparable resolution. The

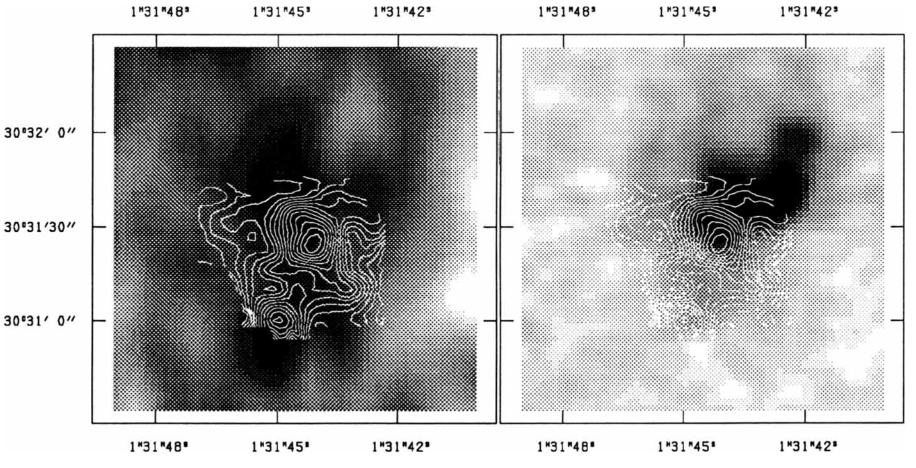

Figure 2. Comparison of the CO(2-1) total emission (solid contours from 1 to 15 K km s^{-1} (T_r^* units) with a constant step) with that of HI emission (left) and the radio free-free emission (right) on the eastern side of the M33 HII complex NGC 604 (Viallefond et al., in preparation). This CO map is at 12" angular resolution. Gray scale represents the HI distribution extracted from the M33 survey of Deul and van der Hulst (*ibid*) and the radio free-free emission extracted from a M33 WSRT-VLA survey at 5GHz (Viallefond et al. in preparation). The resolution is respectively 12" x 24" and 7" x 7" for these two components.

properties of these clouds are similar to GMCs in our Galaxy. Indeed it is highly dangerous to draw any general conclusion from this restricted and higly selective sample of six clouds! Two new surveys have been recently undertaken. Using the OVRO interferometer, Wilson and Scoville (1990,1991) mapped 19 fields in the inner 1 kpc of M33; the resolution corresponds to about 20pc; they discovered 38 molecular clouds and measured their physical properties. The summary of their results is given in a paper presented at this symposium; it will not be repeated here. Only very briefly 1/ these clouds have properties similar to the Galactic GMCs, 2/ the cloud mass spectrum is similar in M33 and our Galaxy although M33 seems to be deficient in clouds more massive than $10^5 M_o$and 3/ there is a close association between the molecular phase, the HII and the HI phase. The second ongoing survey (Boulanger et al. 1991) is based on measurements at 230 and 115 GHz with the IRAM 30m antenna. Hα-radio HII regions identified in the infrared (Rice et al. *ibid.*) have been mapped; at 230GHz the angular resolution corresponds to about 40pc. Most of these regions are at larger radial distance (up to 4.2 kpc) compared to the 38 molecular clouds of the interferometric survey. All the regions observed up to now have been detected. Preliminary results indicates that at 40 pc resolution most of them are extended; some are likely associations of GMCs. This survey also shows a close association between the molecular clouds, the HII regions and HI concentrations but the molecular complexes do not usually coincide with the maxima in the HI distribution. It will be interesting to compare the results of this survey with those from the interferometric survey because the physical conditions in the molecular phase may change as the metallicity decreases from the inner to the outer part of M33 (Vilchez et al. 1988). It is interesting to notice that the molecular clouds observed in the direction of NGC 604 are not particularly massive compared to other clouds in M33. A similar remark applies for the HI in NGC 604. The only spectacular aspect of NGC 604 in the neutral phase is the existence of molecular and atomic gas a high velocities which is unique in M33. Finally one should notice that near infrared H_2 lines have been detected in a few HII regions (Israel et al. 1990). It is shown that, at least for NGC 604, these lines arise from radiatively excited H_2.

5. M51

The purpose of this section is not to give a review on the HI and HII phases with the relations with the molecular phase in M51 since most of the information is already available in the recent review paper from Rand and Tilanus (1989). Furthermore several papers based on CO observations have been presented during this symposium (Garcia-Burillo and Guélin, Kuno et al. , Tosaki et al., Rand and Rydbeck et al.). Since 1988 the new major inputs are CO observations with angular resolutions in the range 2 to 4" (90 to 180 pc at a distance of 9.6 Mpc), a complete sensitive single-dish survey in CO and a high resolution HI survey. I would like to draw the attention only on a few points related to these new important observations. The most important characteristic of the M51 spiral arms is the association with streaming motions of very large amplitudes (60 to 90 km s^{-1} in the plane of the galaxy). Amongst the other important characteristics of the spiral arms in M51 is the finding that: 1) the ridges of non-thermal radio continuum emission along major portions of the spiral arms correspond closely the dust lanes, 2) the ridges of CO emission do also coincide with the dust lanes 3) the ridges of HI complexes and HII regions are 200 to 700 pc downstream from the dust lanes, 4) the HII regions tend to be on the edge of the HI complexes, and 5) the CO emission in the interarm regions, although of faint brightness, give a substantial fraction of the total CO emission in M51. The relative displacement between the dust lanes and the HI-HII ridges, actually originally observed in M83, prompted Allen et al. (1986) to suggest that the observed HI is H_2 dissociated by the newly formed stars. This suggestion has been reinforced with the subsequent discovery of the coincidence between the ridges of CO emission and the dust lanes in M51; it is also consistent with the observation of the substantial amount of CO emission in the interarm regions which indicates that a large fraction of the neutral gas is in the form of H_2. Although this suggestion is very attractive, the segregation between the different phases is more complex than originally thought. The high-resolution HI observations of Rots et al. (1990) show that the HI arms are broader than the CO arms; they partly overlap the dust lanes and CO arms. The single dish measurements (Garcia-Burillo and Guelin, *ibid*) show also that the CO arms may be somewhat broader than those observed with interferometers. Finally, the non-thermal radio emission, which is supposed to trace the compressed regions, tails upstream the dust lane (Tilanus, 1990).

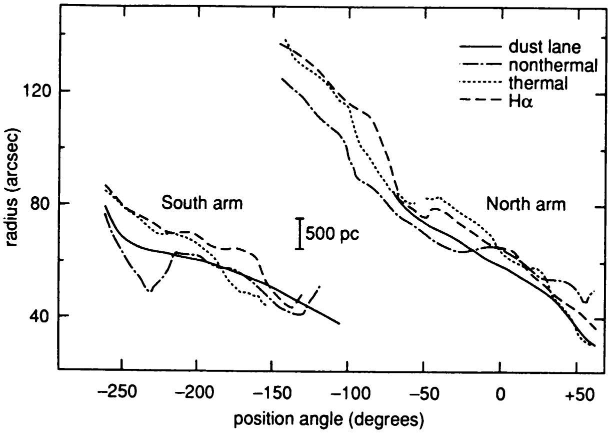

Figure 3. Loci of the centroids of various components of the northern and southern spiral arms of M51 (Tilanus, 1990)

6. M81

The Sab spiral M81 has been subject to detailed studies to compare the relative distribution of the HI gas, the HII regions, the radio continuum emission and the dust lanes. As very briefly summarized during this symposium (Bash, 1990) all these tracers are intermingled with no general tendency for one to lie upstream of the other; all lie downstream of the position of the HI shock as traced by the velocity discontinuity. A large portion of the optical disk of M81 has been observed in CO (Brouillet et al. 1988, Brouillet et al., 1990) with a resolution of 1' (1 kpc at the distance of 3.2 Mpc). The distribution is characterized by a central depletion. Only a small fraction of the neutral gas in M81 is in molecular form. Observations of CO(2-1) and CO(1-0) at resolutions of respectively 12 and 24" (Brouillet et al., 1990) suggests that the CO comes from an ensemble of more or less massive clouds distributed quite uniformly at a 300pc scale. There is no clear correlation between CO and the dust lanes or the giant radio HII regions. Kaufman et al. (1989) suggest that the more luminous HII regions are efficient either in dissociating the molecules or in pushing the molecular gas away. However CO emission is neither enhanced in the directions of highly obscured HII regions; this could be, for these regions, the result of a spatial coincidence and beam filling effects. Interferometric measurements are required to investigate this hypothesis.

7. M83

The HI distribution and kinematics of the Sc spiral M83 were observed using the VLA with a resolution of about 10" (450 pc at the distance of 8.9 Mpc) by Tilanus (1990). The large scale distribution is characterized by a flat distribution with a depression at radial distances below 5 kpc. This distribution is highly clumped. Bright HI complexes are observed in the spiral arms; they have typical masses of about 5 10^6 M_0. As in the case of M51, there is a good large-scale correspondence between the ridges of HI emission and of HII regions (Allen et al. *ibid*). These ridges are downstream from the dust lanes. By contrast the streaming motions in M83 are of much smaller amplitude compared to those in M51; they are not obvious in HI but are observed in the optical. From Fabry-Perot measurements using the Hβ line, Tilanus (1990) finds that their amplitude does not exceed 35 km s^{-1}. The detailed distribution of the HII regions was compiled by Rumstay and Kaufman (1983) using Hα observations. Again, as in the case of M51, on small scale there is a tendency for the HII regions to be on the edges of the HI complexes. Measurements in the radio continuum reveal a spiral structure (Harnett, 1984, Ondrechen, 1985, Sukumar et al. ,1987) composed of HII regions and extended nonthermal features associated with the dust lanes. The radio properties of the M83 HII regions are known only for a very few of them. These radio data tend to indicate at least for these few regions, as for M51 regions, that they are contaminated by non-thermal

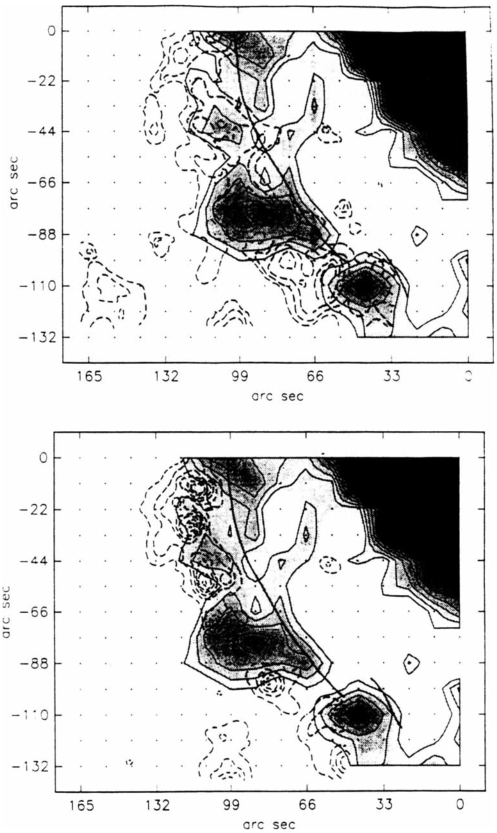

Figure 4. Comparison of the CO(1-0) (grey scale and solid contours) with that of HI emission (top) and Hβ (bottom) emission (Wiklind et al., *ibid*). The HI and Hβ data are taken from Allen et al. (*ibid*) and are represented with dashed contours. The CO contours are 6, 7, 8 etc. K km s^{-1} (T_{mb} units).

emission. This result must be considered as very uncertain because of the confusion of the HII regions with the large scale nonthermal disk. M83 lacks a sensitive high resolution multifrequency radio continuum survey. Contrary to M31 and M51 there is not yet a global large-scale view of the CO distribution in M83. The inner part of the galaxy was mapped by Lord et al. (1987) and Sofue et al,. (1987) at resolutions of respectively 20 and 45". Handa et al. (1990) reported on observations with the Nobeyama 45m antenna. Wiklind et al. (1990) observed the eastern arm in CO(1-0) (Fig. 4) and CO(2-1) with resolutions of respectively 24 and 48". They find a close correspondence between the HI, Hβ and CO emission, all three components being situated well away from the dust lane. In addition these CO observations also show relatively little molecular gas in the interarm region. These results differ remarkably from those for M51; this does not support the suggestion of Allen et al. (*ibid*). M83 is a strong arm galaxy. One interpretation would be, as proposed by Elmegreen (1987, 1989a,b), that these HI complexes (i.e. the superclouds) are the results of gravitational instabilities in the density wave spiral arms because of the increased density and magnetic field strength and the decreased tidal and shear forces there. The molecular clouds would be formed by secondary instabilities in the HI superclouds. In this scenario the interarm molecular material would be the result of superclouds disrupted either by star formation and/or by galactic forces.

8. NGC 6946

A detailed view at a resolution of 25" (1200pc at the distance of 10.1Mpc) of the HI and radio continuum emission in the Scd spiral NGC6946 is given by Boulanger and Viallefond (1990). The large-scale rotation derived from these HI data is analyzed by Carignan et al. (1990). The radial distribution of the HI emission is fairly flat. Within 5' from the center the distribution of HI emission is rather chaotic. The main optical arms lie within this region; they coincide with local maxima of HI emission but the arm-interam contrast does not exceed 2. Several prominent HI holes with sizes of 1 to 2 kpc and "missing masses" of about

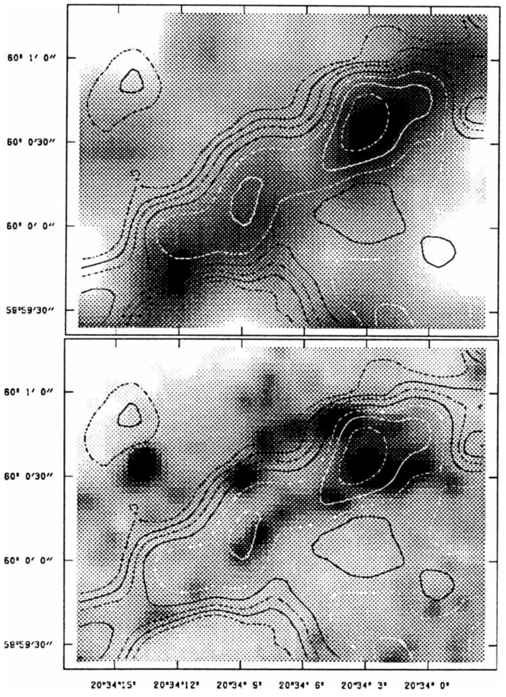

Figure 5. Comparison of the CO (solid an dashed alternated contours) with that of HI emission (top) and Hα (bottom) emission (Casoli et al. in preparation) for the main north-eastern spiral arm in NGC 6946. The HI and Hα data are taken from Boulanger and Viallefond (*ibid*); they are represented in grey scale with a linear transfert function. Contour levels are 1.5, 2.1, 2.8, 3.9, 5.3, 7.3 and 10 K km s^{-1} (T_r^* units); they are white from level 5.3 K km s^{-1}.

$10^7 M_o$ are also observed. In the outer part of the galaxy broad and highly contrasted HI arms can be traced over long distances. The arms are fragmented in HI clouds of a few to several $10^7 M_o$. Streaming motions are observed along the spiral arms; along the main optical arm north-east from the nucleus the amplitude is about 15 to 20 km s^{-1}. The optical distribution of the HII regions (Bonnarel, 1986, Bonnarel et al. 1986) and the kinematics, based on Fabry-Perot interferometric measurements (Bonnarel, 1986, Bonnarel et al. 1988), have been studied in details. Velocity perturbations across the main optical spiral arm are observed in Hα with an amplitude similar to the one from the HI data. The large scale distribution of the thermal radio emission has been determined by Klein et al. (1982) using observations at 10.7GHz. Boulanger and Viallefond (*ibid*) decomposed the radio continuum emission in three components: the disk, the arm and the HII complexes. At 1.4 GHz the emission from the spiral arms is mainly non-thermal. The brightest HII complexes are associated with HI concentrations; their radio emission is essentially thermal. NGC 6946 is bright in CO emission. With an angular resolution of 12 to 25", Casoli et al. (1990) observed a CO concentration 2.5' east of the nucleus which coincides fairly well with one bright HI-HII association. A more complete view of the distribution of the CO emission has been presented during this symposium by Clausset et al. (1990). The CO spiral structure is more contrasted than in HI. The molecular arms are also fragmented into massive molecular concentrations (with masses up to $10^8 M_o$ as for the atomic gas). There is a tight correlation between the distribution of this emission and the distribution of the HI clouds and the HII complexes. Although in many cases there are positional coincidences, in other cases there are relative displacements with a tendency to find the CO on the inner edge. There is not a one-to-one correlation between HI and CO: on the south-eastern part of the optical disk two CO concentrations are observed with only faint HI counterparts. It is a region in NGC 6946 where the optical spiral structure is rather chaotic. Along the main optical arm (Fig. 5) the ridges of HI emission and HII regions coincide fairly well; they are also very near the ridge of CO emission. These three ridges are located on the inner side of the optical arm as traced in the red light. On the inner side of this arm a few patches with dust obscuration are visible; neither in HI nor in CO is found the counterpart of these features. Although less well delineated , the nonthermal arm tends also to follow these ridges. On the outer part of this arm there is very little molecular gas while there is still significant HI and, more spectacularly, a second ridge of HII emission. The narrow structure of this molecular arm makes difficult to observe possible streaming motions in the CO data.

9. Conclusions

The morphology of the HI distribution in the nearby spirals appears more and more complex with improved resolution and sensitivity. It is characterized by filaments, loops, concentrations and holes over a wide range of scales. The filling factor of the HI holes in M31 and M33 does not fit well with the model of McKee and Ostriker; it is too small. Although the number of detected SNRs in the two galaxies increases rapidly owing to the increase in the quality of the radio and optical data, there is not yet clear sign of velocity pertubations associated with them in the HI phase. The HII regions seem quite frequently contaminated by non-thermal radio emission, although this statement is currently solid only for the spiral M33 and M51; more high-resolution sensitive radio continuum measurements in at least two frequencies are required. The relative contribution of the HI cirrus and the HII regions in the far infrared emission may vary widely from galaxy to galaxy and also within a galaxy with radial distance. The observations for M31 and M33 suggest a radial decrease of the dust to gas ratio. These results complicate significantly the interpretation of the infrared luminosity as a star formation efficiency indicator. At scales greater than 200 to 400 pc there is in all the reviewed nearby spirals a close association between the HI concentrations and the HII complexes. However, at this scale as well as at smaller scales the HII regions tend to be quite frequently on the edges of the HI clouds. At large scales the association of the molecular clouds with the HII regions is very common. At smaller scales there is not a unique picture prevailing for all the galaxies; a similar remark applies also between different regions within a spiral galaxy. The fraction of the mass of HI gas which results from dissociated H_2 may vary widely from place to place and is hardly predictible as illustrated by the predictions and successive observations of a strong spiral arm galaxy M83. This suggests that it will be always difficult to distinguish in many cases between the HI concentrations as the progenitors of the molecular clouds, as the companions and protectors of the molecular clouds or as the waste-products of dissociated molecular material. A final remark: I decided to ignore in this review the cases of IC 342 and M 101; this is partly because of lack of space. Spectacular observational progress are going on currently, at least to my knowledge for M101. In this respect I have less regrets since most of the results could have looked too preliminary!

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