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Comparison of Discrete Sources in Radio and Hα Surveys of the Magellanic Clouds and the Potential for the New Hα Survey

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Abstract: We present a comparison between the latest Parkes radio surveys (Filipović et al. 1995, 1996, 1997) and Hα surveys of the Magellanic Clouds (Kennicutt & Hodge 1986). We have found 180 discrete sources in common for the Large Magellanic Cloud (LMC) and 40 in the field of the Small Magellanic Cloud (SMC). Most of these sources (95%) are HII regions and supernova remnants (SNRs). A comparison of the radio and Hα flux densities shows a very good correlation and we note that many of the Magellanic Clouds SNRs are embedded in HII regions.

Keywords: galaxies: Magellanic Clouds—radio continuum: galaxies—ISM: HII regions — ISM: supernova remnants

1 Introduction

Galactic studies give us a close look at many of the important manifestations of star formation and evolution. In the Magellanic Clouds (MCs) we have the opportunity of seeing these factors at work nearby, but on a much larger scale and in a different galactic environment to that of our own Galaxy. The MCs are irregular dwarf galaxies, interacting with each other and with our Galaxy, a fortunate circumstance allowing us to study such interactions close at hand by using the powerful combination of radio and Hα surveys.

In this paper we compare sources common to the Parkes radio and the Hα surveys using primarily the radio results of Filipović et al. (1995; hereafter Paper IV), Filipović et al. (1996; hereafter Paper IVa), Filipović et al. (1997a; hereafter Paper V) and the Hα catalogues of Kennicutt & Hodge (1986). We classify each source as either an HII region, SNR or background object. Also, we compare source radio and Hα flux densities.

2 Discrete Sources towards the Magellanic Clouds

2·1 Radio Data

Catalogues of discrete radio sources towards the LMC at six radio frequencies are presented in Papers IV and IVa. The total number of catalogued radio sources is 483. The common area of the radio and Hα surveys (∼100 square degrees) lies between RA (B1950) = 04″23″ to 06″14″ and Dec(B1950) = −64° to −74°.

The new catalogues of radio sources in the SMC at five radio frequencies are given in Paper V. There is a total of 224 radio sources towards the SMC in a region of ∼42 square degrees between (B1950) = 00″12″ to 01″38″ and Dec(B1950) = −69°40′ to −76°20′.

As clear radio detections, we listed only radio sources that are stronger than 5σ or seen in at least two frequencies.

2·2 Hα Data

The Hα investigation of the MCs started with the Henize (1956) catalogue of emission nebulae. These observations provided a remarkable database for investigating discrete sources, star-formation regions and dust properties in the MCs. This is because the Hα emission from galaxies, such as the MCs, is mostly due to thermal radiation, a process which is believed to be associated with HII regions.

Since Henize's pioneering work, a number of other Hα catalogues of sources in the MCs have been published. Some of them, such as the DEM catalogue (Davies, Elliott & Meaburn 1976), have a significant importance even today. For the comparison with radio data, we used the Kennicutt & Hodge (1986) catalogue of Hα objects in the field of the MCs. This catalogue consists of 235 objects in the field

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of the LMC and 99 in the SMC. Along with the positions and source extensions, they listed the Hα flux density for each catalogued source.

3 Radio-to-Hα Comparison of the Sources towards the Large Magellanic Cloud

The comparison of the radio and Hα surveys resulted in the discovery of 180 sources common to both surveys. The basic criterion for positive source identification is that a source must lie within $2{\cdot}5'$ of its counterpart. Using the common area of the radio and Hα surveys and the search criterion, we expect not more than six sources to have positional coincidence by chance alignment. The most accurate radio positions available are from the highest radio-frequency survey on which the source appears. These positions were compared with Hα positions listed in Kennicutt & Hodge (1986).

Positional comparisons were undertaken for all 180 sources common to the radio and Hα surveys of the LMC. The mean difference in RA is $17''{\pm}5''$ (radio − Hα) with a standard deviation (SD) of $52''$. The difference in Dec is $7''{\pm}5''$ (SD = $50''$). This uncertainty is consistent with the combined positional uncertainties for the radio (defined in Paper IV) and the Hα sources, and retrospectively justifies the initial identification criterion of $2{\cdot}5'$ (which is equivalent to $2{\cdot}8\sigma$ in both RA and Dec).

4 Radio-to-Hα Comparison of the Sources towards the Small Magellanic Cloud

In the same manner as for the LMC, radio and Hα surveys of the SMC have been compared, resulting in the identification of 40 sources common to both surveys. Each radio source and Hα counterpart lie within $2{\cdot}5'$ of each other. This criterion was chosen according to the upper limit of positional uncertainties at our $1{\cdot}42$ GHz survey (Paper V). Based on the common area of the two surveys and on the number of sources at each observing frequency (radio and Hα), we expect that not more than two sources will be found as a result of positional chance coincidence.

Positions for all 40 SMC sources common to the radio and Hα surveys have been compared in the same way as for the LMC. The mean differences are $-5''{\pm}9''$ (radio − Hα) in RA with SD = $51''$ and $-8''{\pm}10''$ in Dec with SD = $65''$. This uncertainty is also consistent with the combined positional uncertainties for the radio (defined in Paper V) and the Hα sources, and justifies the initial identification criterion of $2{\cdot}5''$ (which is equivalent to $2{\cdot}7\sigma$ in RA and $2{\cdot}2\sigma$ in Dec).

5 Classification and Analysis of Discrete Sources in Common to the Radio and Hα Surveys

Out of the 180 sources common to the radio and Hα surveys of the LMC (Section 3), 88 (49%) have been previously classified (Filipović et al. 1997b and references therein). Most are HII regions (53) and SNRs (34). Only one source common to both surveys towards the LMC is listed as a background object.

Similarly, from 40 sources common to the radio and Hα surveys of the SMC 27 (68%) have been classified in previous investigations (Filipović et al. 1997b). Again, most of these sources are intrinsic to the SMC (14 HII regions and 12 SNRs embedded in HII regions). There is one radio/Hα source behind the SMC.

5.1 Source Classifications

The majority of the MC HII regions (and SNRs embedded in HII regions) have been detected in Hα surveys. Some 95% of HII regions in the LMC (53 out of 56) and 88% in the SMC (14 out of 16) appear as Hα sources. This is not surprising, as Hα emission is due to emission from the thermal surroundings of the MC sources. Only five radio HII regions are not detected in Hα surveys, probably due to confusion. The similarity of broad-scale structure between radio, IR and Hα emission from the MCs has been reported by Xu et al. (1992).

The relative number of background objects seen in both radio and Hα surveys is small (just 2). Therefore, we conclude that the rest of the unclassified sources (92 in the LMC and 13 in the SMC) are more likely to be intrinsic, i.e. HII regions. However, there is the possibility that some of these unclassified sources are indeed background objects.

Applying this criterion to the LMC, 85 out of 92 previously unclassified (radio to Hα) sources are suggested to be intrinsic. The other 7 sources common to radio and Hα surveys remain ambiguous. Similarly, from 13 unclassified radio and Hα sources in the SMC, 11 are suggested to be HII region candidates (or SNR candidates), and 2 sources remain ambiguous.

6 Radio-to-Hα Source Flux Density Comparison

The Hα and the radio continuum images of the MCs are found to be closely correlated, in the sense of an overall coincidence of peaks in the two surveys and a strong resemblance around giant star formation regions such as 30 Doradus. Here we will concentrate on the discrete source flux density comparison between surveys from these two wavelengths.

The comparison between the source radio flux density at the $4{\cdot}75$ GHz survey ($4{\cdot}85$ GHz survey for the SMC) and the Hα survey is shown in Figures 1a and 1b. All classified HII regions and SNRs embedded in HII regions appear in both the radio and Hα surveys.

An overlap between HII regions and SNRs is noted; the reason for this is that most of the Hα

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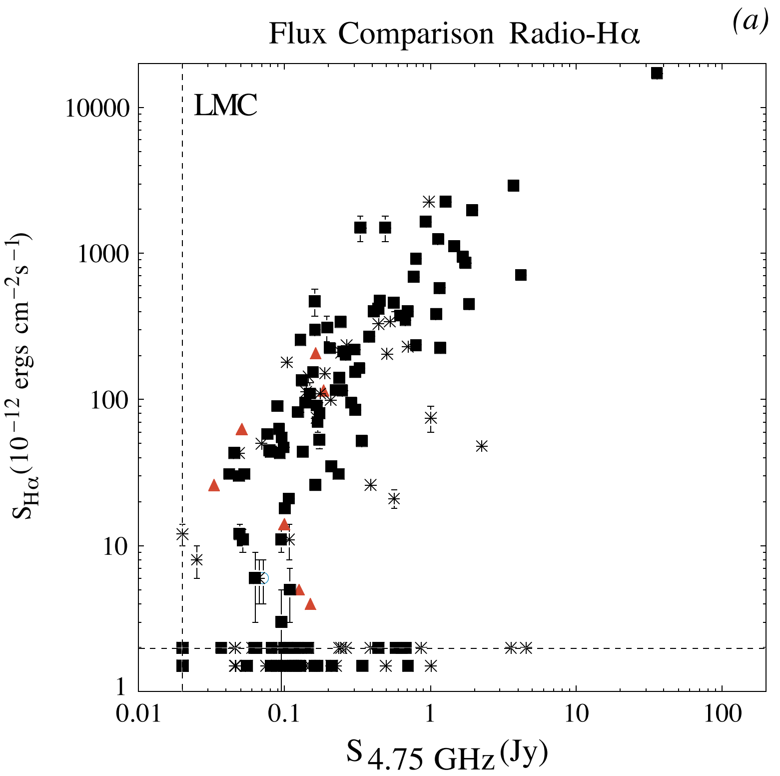

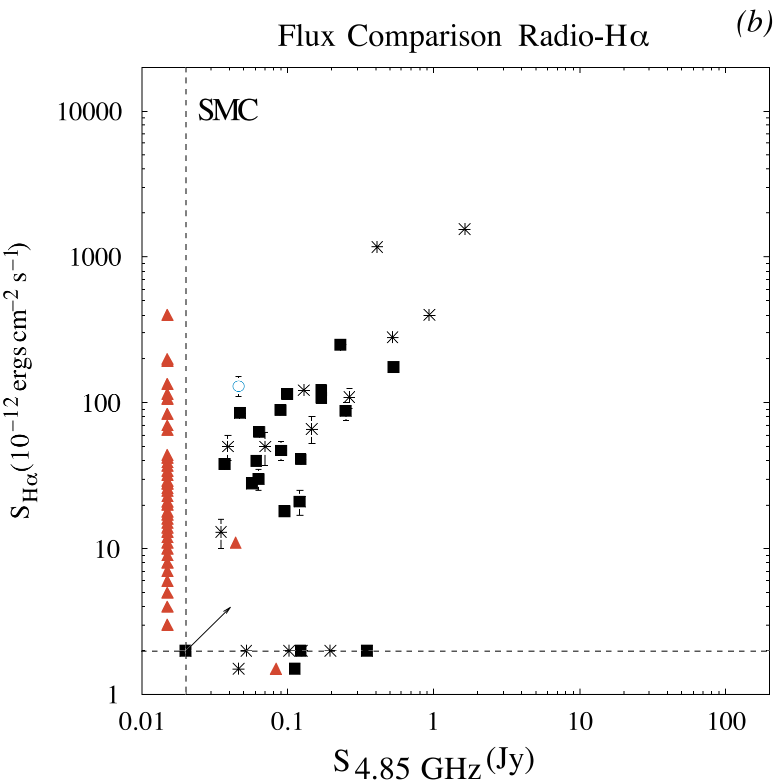

Figure 1—Comparison of Hα and radio flux density at 4·75 GHz (4·85 GHz for the SMC) for different classes of sources towards (a) the LMC and (b) the SMC. Asterisks represent SNRs; filled squares, HII regions; open circles, background sources; and filled triangles, unclassified sources. The dotted line represents the approximate threshold of the radio survey. Sources below the dotted lines represent non-detections.

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bright SNRs are embedded in HII regions. The majority of background radio sources towards the MCs are not detected in the Hα surveys.

7 Conclusions and the Potential for the New Hα Survey

The comparison of Parkes radio surveys with the Hα surveys showed 180 and 40 sources in common to the LMC and SMC respectively. Most of these sources (~95%) are intrinsic to the MCs as HII regions and SNRs. Some 61 sources in the LMC and 7 sources in the SMC are classified on this basis as HII region candidates. Along with other criteria, such as X-ray detection, another 24 sources in the LMC and 4 in the SMC are classified as SNR candidates. A flux density comparison of the sources in common for the radio and Hα surveys shows very good correlation for the sources intrinsic to the MCs.

Because these galaxies are relatively dust-free and the objects within them are at a well defined distance, many of the problems that beset Galactic studies of large structures are greatly simplified. Hα images have already been very useful in studying nebulae in the MCs, revealing in particular old supergiant shells up to 1 kpc across, which appear to be associated with areas of recent star formation (Meaburn 1980; Hunter 1994). Furthermore, hundreds of HII regions and planetary nebulae have also been detected. A sensitive method has been found to search for, identify and separate SNRs from giant HII regions by a comparison of the Hα and radio continuum data (Ye et al. 1991). The new narrowband of the Hα filters will exclude most background sources by virtue of the redshift. Another major use of an Hα survey of the MCs lies in its ability to locate sources more usually detected using objective prism spectroscopy, for example planetary nebulae, symbiotic and emission-line stars.

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