Publ. Astron. Soc. Aust., 1998, 15, 9–13

Marseille Observatory Hα Survey of the Southern Galactic Plane and Magellanic Clouds

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Received 1997 August 1, accepted 1997 December 1

Abstract: The ionised gas regions, which are the main tracers of the spiral arms, can be used for the study and determination of the spiral structure of our Galaxy. Towards this goal, the Marseille Observatory elaborated and developed an instrument, using a scanning Fabry–Perot interferometer, particularly suited for the observation of extended objects. A survey of the southern Galactic plane then started at the beginning of 1990. The major instrumental aim is to obtain spectral information, and therefore the ionised gas kinematics, in each pixel of the observed fields. Already 300 fields of $38'\times38'$ have been observed in Hα with a spatial resolution of $9''\times9''$, covering almost the entire fourth quadrant of the Galactic plane, and numerous discrete HII regions have been detected, as well as diffuse emission which is widely distributed. Also, the Magellanic Clouds have been studied using the same instrument.

Keywords: ISM: HII regions, supernovae remnants, kinematics and dynamics — Galaxy: structure — Galaxies: individual (Large Magellanic Cloud, Small Magellanic Cloud)

1 Introduction

The Hα survey of the southern Galactic plane and Magellanic Clouds began in 1990 using a specific instrument elaborated and developed at the Marseille Observatory. Its characteristics, widely described in Amram et al. (1991) and Le Coarer et al. (1992), are summarised in Section 2. Such an instrument allows us to have spectral information, and hence kinematic information, continuously anywhere throughout the observed field (data cubes x, y, λ). The profiles obtained, extracted from the interesting zones, are the superposition of the different emission lines met along the line of sight. We have to analyse them to derive information about both systemic and internal velocities of the studied regions. Also, monochromatic images may be built up by the flux integration of each emission line.

2 The Instrument

The instrument, located at the Southern European Observatory in La Silla, uses a 36 cm telescope equipped with a focal reducer (final F/D = 3·3), a photon counting camera and a scanning Fabry–Perot interferometer, which provide the ideal characteristics for a systematic survey: large field ($38'\times38'$), high luminosity, high spectral resolution and limited spectral range centred on the Hα line. In practice we use two different Fabry–Perot interferometers depending on the expected velocity range of the object to observe. They offer free spectral ranges of 376 km s^{-1} and 115 km s^{-1} with respective spectrum samplings of 16 km s^{-1} and 5 km s^{-1}. For these interferometers the finesse is about 12 or 10, explaining why we scan through 24 scanning steps according to the common sampling criterion. A recent determination of the flux detection limit is about 0·2 Rayleigh (1 Rayleigh = $2\cdot4\times10^{-7}$ erg cm^{-2} s^{-1} sr^{-1} at Hα) for a typical observation time of two hours. This allows us to observe not only the individual HII regions but also the diffuse emission of the ionised gas.

The interpretation of the data requires splitting of the observed profiles into elementary components as is illustrated in Figure 1. The night-sky lines (geocoronal Hα and OH lines) and the nebular ones are modeled respectively by a pure instrumental profile, and an instrumental profile convolved with a gaussian (details are given in Georgelin et al. 1994).

3 Survey of the Galactic Plane

The aim of this survey is to give a more precise picture of the spiral structure traced by the star formation regions, especially the HII regions, and by the diffuse Hα emission. The method is to determine the ionised hydrogen spatial distribution by splitting the different Hα emissions met along the lines of sight from the velocity measurements.

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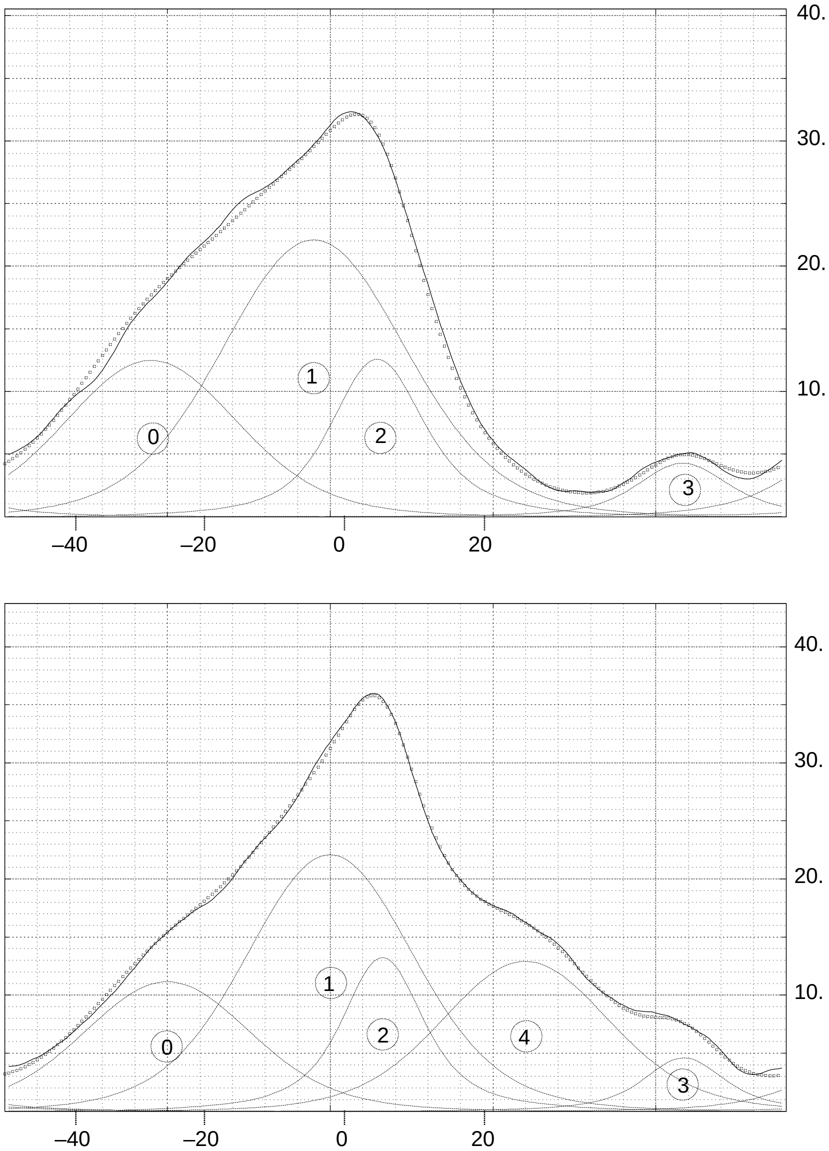

Figure 1—Hα profiles resulting from the addition of several pixel profiles covering an 'empty zone' (upper profile) and the HII region G296·593−0·975 (lower profile) in the direction $l = 298°$. The first profile is decomposed into two night-sky lines (components 2 and 3) and two nebular components (components 0 and 1) associated with diffuse emissions. In the second profile, one more emission line (component 4) appears at positive velocity, corresponding to the HII region.

The interpretation of the Hα data is helped by the use of other surveys at wavelengths not affected by absorption due to the presence of dust (e.g. continuum radio 5 GHz, Hα photographs, radio recombination lines, CO, IR). Indeed, HII regions are often grouped together at the edge of molecular clouds. It is then essential to use the Galactic plane surveys already performed in CO lines, radio recombination lines and radio continuum 5 GHz emission in order to separate the different HII region–molecular cloud complexes met along the line of sight by itemising the objects forming the same complex (e.g. molecular clouds, HII regions, OB stars) and to identify the dynamical motions inside HII regions (e.g. the champagne effect and bubble-like expansion) that we must take into account to determine their systemic velocities. When complexes are identified, we determine the kinematic distance from the systemic velocity (using a galactic rotation model) and/or the stellar distance when the exciting stars are identified. In general, the stellar distance, based on spectrophotometric data and hence free from kinematic biases, will be favoured instead of the kinematic one. But often we have only the kinematical information. In such a case, when the Hα emission exhibits deviations from circular rotation, the distance determination is impossible

To determine the spiral structure of our Galaxy we must perform such a study in numerous directions. Consequently about 300 fields ($38' \times 38'$)

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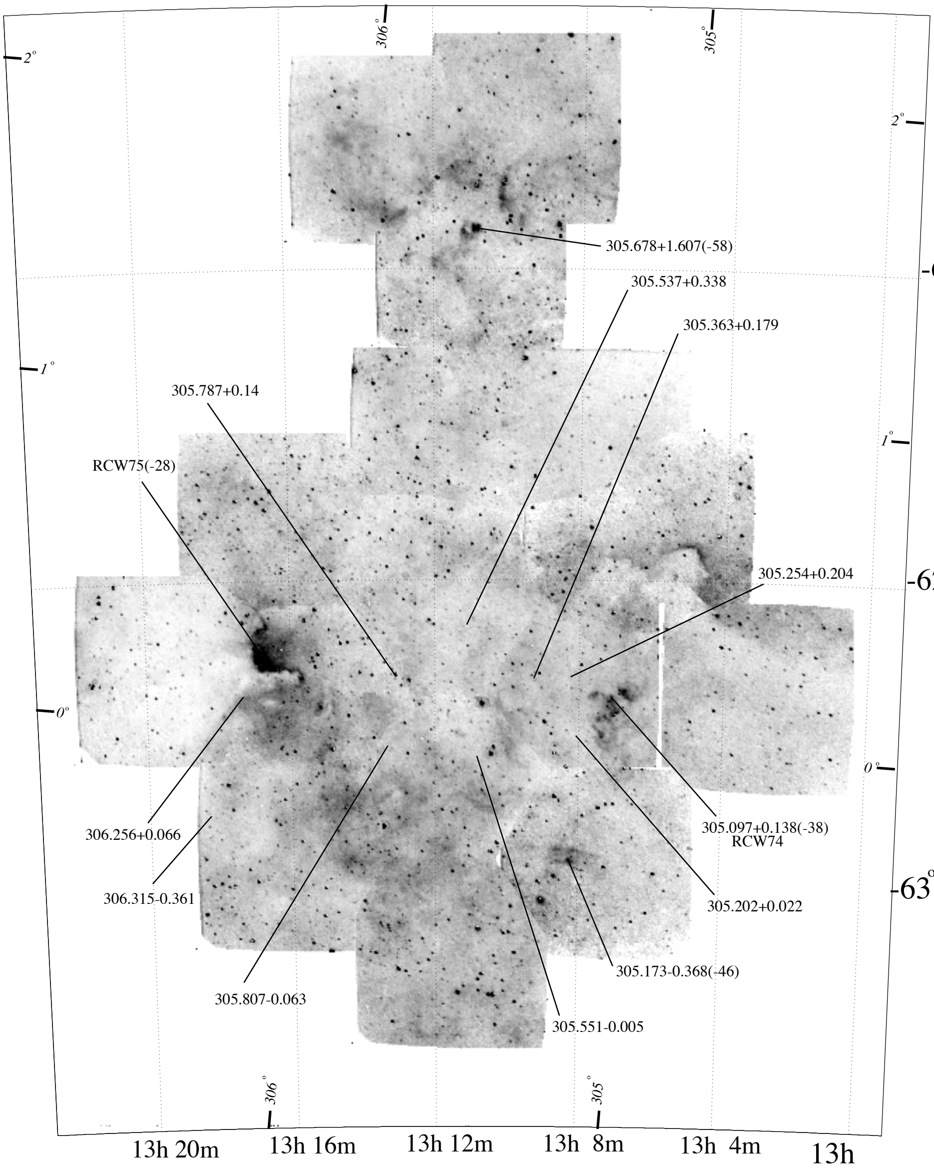

Figure 2—Hα mosaic of the observed fields in the 305° area. This image is obtained by adding λ maps over the whole free spectral range, flat fielding and then correcting for distortion. This is equivalent to a photograph obtained through a filter with a 2·4 Å bandwidth. The positions of radio sources and HII regions are shown with the corresponding Hα velocity values, when observed.

were observed, forming mosaics of 10 to 20 fields distributed along the galactic plane ($234° < l < 355°$ and $-2° < b < 2°$). An example of a mosaic is presented in Figure 2 with the corresponding velocities in Figure 3. The directions observed in Hα, which correspond to HII-region-rich zones and some strategic lines of sight in relation to the expected spiral structure (e.g. arm tangential directions), were selected on the basis of large scale photographic data (Georgelin & Georgelin 1970) and the 5 GHz radio emission survey (Haynes, Caswell & Simons 1978).

At the present stage of the survey eight directions are fully observed [298° (Russeil 1997), 301°, 305°, 308°, 313°, 320°, 328° (Georgelin et al. 1994) and 338° (Georgelin et al. 1996)], and four zones remain to be completed (283°, 290°, 332°, 350°). Although each direction is kinematically particular, common features can be noted: (1) The diffuse emission is always detected, even in 'empty' fields (see Figure 1, upper profile). Usually, it exhibits roughly the same velocities as the discrete HII regions, suggesting a physical link. Located in the arms the diffuse emission is sometimes the only tracer of the spiral structure, as it is evident in the 298° direction (Russeil 1997). (2) We observe a systematic local diffuse emission (~170 pc) which may be linked to the near molecular clouds (e.g. Coalsack, dark clouds) and the OB Sco-Cen stellar association. (3) We have collected a large number of HII regions newly detected in Hα. Let us cite for example the Hα detection of a clump of distant HII regions

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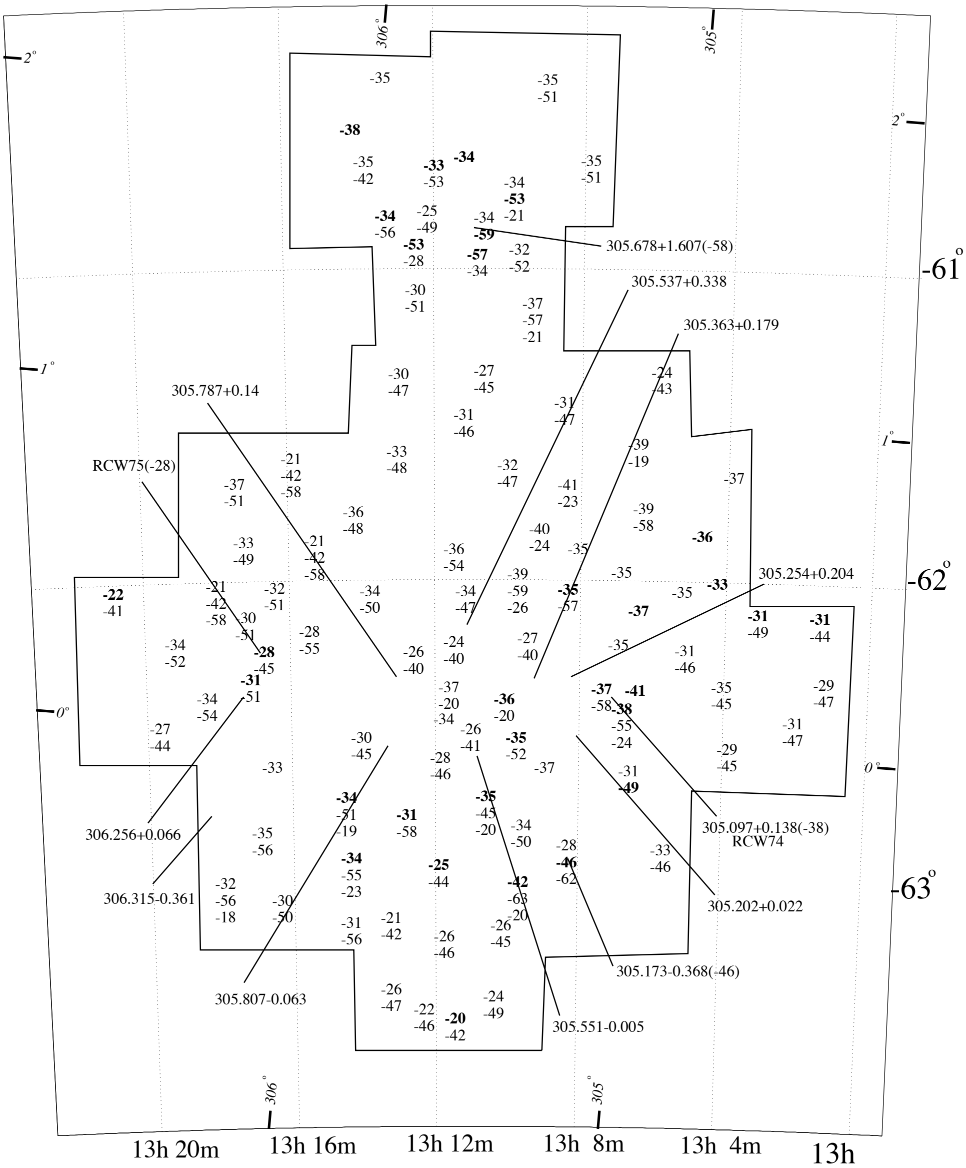

Figure 3—Spatial distribution of velocity components in the 305° area. Only the non-local components are indicated. Note that the velocities of the diffuse Hα emission, as well as those of the discrete HII regions, are shown at the points of measurement. Bold numbers correspond to Hα emission patches in the mosaic. Very closely placed numbers represent multiple components at one point of measurement.

located at 10 kpc (such as the HII region revealed by component 4 in the lower profile of Figure 1). (4) Several HII regions exhibit velocity departure from the circular rotation model making impossible the determination of their distance.

However, the four spiral arm structure, previously proposed by Georgelin & Georgelin (1976), is confirmed, but we have to wait for the complete survey to be precise about potential substructures. In parallel, we plan to compare the Hα observations with surveys carried out at other wavelengths to connect our different zones to larger scale observations, to quantify the absorption, to derive the physical conditions within the HII regions and to identify the nature of deeply embedded objects.

4 Survey of the Magellanic Clouds

Due to their close distance, the Magellanic Clouds are also observed with the same instrument. A kinematical map of the fast moving nebulae with their full extension (stellar wind driven bubbles and supernovae remnants) was obtained, and the energetic balance of the nebulae was established. Indeed, the spectral information interpretation and the flux calibration allow the determination of the expansion velocity and electron density of the objects. For this purpose the SMC was completely covered (30 fields), while for the LMC about 40 fields were observed, in both the Hα and [OIII] lines.

For the SMC a catalogue and the kinematics of the HII regions were established, the rotation curve

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was determined (Le Coarer et al. 1993) and several SNR were observed. More specifically, two new SNR candidates were identified inside the HII complex N19. For the LMC, the results are more specific to individual regions: detection of stellar wind driven bubbles inside the nebulae N120A, N11B (Rosado et al. 1996) and N59 (Rosado et al. 1998), detection of SNR candidates inside N103A (Ambroccio-Cruz et al. 1997) and N186E, and study of probable sequential stellar formation inside N11, N120, N105, and the supergiant bubbles LMC1 and LMC4.

Acknowledgments

We thank INSU for financial support of this survey. The authors are most grateful to J. Caplan for reading the manuscript.

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