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Kinematical Study of Old HII Regions and Optical Counterpart to the DRAO Canadian Galactic Plane Survey

Steve Godbout, Gilles Joncas and Laurent Drissen

Département de Physique, Observatoire du Mont-Mégantic,
Université Laval, Québec G1K 7P4, Canada
godbout@phy.ulaval.ca

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Abstract: This project aims to tackle a few unresolved problems related to the interstellar medium (ISM) by acting as an optical counterpart to the Canadian Galactic Plane Survey (CGPS). We have three main objectives: (1) the study of large/old HII regions; (2) observations of targets-of-opportunity that may be found by the CGPS; (3) comparison of the kinematics of extragalactic (M33) and galactic HII regions. (1) Old HII regions having large spatial extents will be observed to establish their kinematical structure when almost no molecular material is left to produce photodissociated flows. Does turbulence play a role in these objects as for younger nebulae? (2) Ionised nebulae observed by the CGPS that are peculiar, either morphologically or by special association with neutral hydrogen, will also be observed. (3) The kinematical behaviour of old HII regions in M33 will be compared with that of galactic HII regions. With both data sets in hand we will check if HII regions, like supernovae, dump energy into the neutral ISM. The instrument used as well as some very preliminary data are presented.

Keywords: HII regions — instrumentation: interferometers

1 Introduction: The Project

Radial velocity maps of HII regions (whether from young compact radio objects or optically visible nebulae close to a million years old) have shown the presence of large-scale velocity gradients and of small-scale velocity fluctuations. In most objects, large-scale motions are attributable to a birth and expansion scenario of the Champagne type (Tenorio-Tagle 1979). In other cases, a photodissociated/photoionised flow could be invoked (Hester et al. 1996; Hester 1991) to explain the observed velocity fields. Many observers have shown that turbulence is also present within the aforementioned HII regions. However, statistical velocity analysis fails to find any turbulent cell having a size greater than about $\sim 0 \cdot 1$ pc (Miville-Deschênes, Joncas & Durand 1995; Joncas & Boily 1997).

Old HII regions ($>1 \times 10^6$ years) have seldom been studied to a point where their dynamics are well explained. Therefore, a few questions come to mind. First, what happens to the large- and small-scale motions once the parent molecular cloud has been eroded away by the ionising flux from young and massive star associations? Second, turbulence being a dissipative process, it should not be present within this category of objects, since nothing is left to feed dynamical energy to the gas. If it were, one would have to explain the source of energy input into this gas by some other means than the 'classical' HII region/molecular cloud picture. Third, does the associated HI gas (recombined H^+ or diffuse HI that just happened to be around) retain an imprint of the ionised gas flow? After some time, the ionised gas should have had time to recombine and residuals of the large-scale motions should be observable within the colder local neutral hydrogen. Lastly, because of their low surface brightness, there are few observable old HII regions in the northern Milky Way. Therefore we will use spectral data cubes of the southern half of M33 to increase the number of objects. Velocity fields of the oldest HII regions will be extracted, taking care to avoid very active sites like Giant Extragalactic HII Regions. One has to wonder first if the 'normal' HII regions seen in many spiral galaxies behave in the same manner as the large galactic ones do. If so we can then tackle the broader question: is there an energy exchange between older/larger HII regions and the colder, neutral, interstellar medium in spiral galaxies and, if so, on what scales?

To probe these plausible interactions, observations will be made using the *Université Laval Wide Field Fabry–Perot Camera*. This camera is actually made from the addition of a custom-made Hα filter and Fabry–Perot interferometer to an already existing focal reducer at the Observatoire Astronomique du Mont-Mégantic (OMM). Such observations will provide a first step towards answering the questions mentioned above and, we hope, more. The *DRAO Canadian Galactic Plane Survey (CGPS)* (see English

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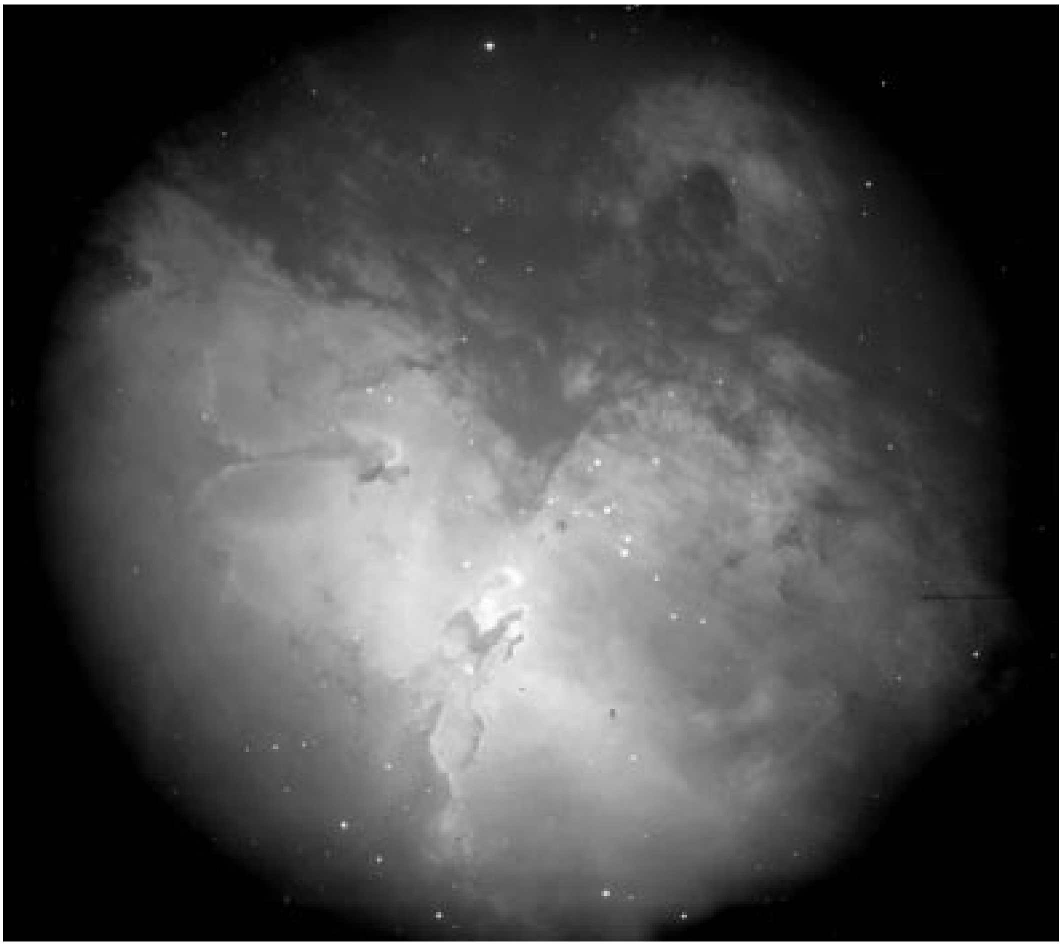

Figure 1—Hα image of M16 taken with PANORAMIX and Goliath. The field of view is ∼32′ in diameter. North is up and east is to the left.

et al. 1998, present issue p. 56, for a description) will provide the velocity field of the HI gas. Our sample of old galactic HII regions is located within the area covered by the survey. In addition, the OMM project will act as an optical counterpart to the CGPS in such a way that objects pointed out by the CGPS and categorised as peculiar, either by their radio morphology or unusual association with neutral gas, will be observed [e.g. the W4 chimney (Normandeau, Taylor & Dewdney 1996)]. The M33 Hα data consist of Fabry–Perot cubes from the Canada–France–Hawaii Telescope (CFHT).

2 The Instruments

Our project requires a large commitment from an observational facility. We have been guaranteed 6 weeks of observing time per year by the OMM. The OMM is equipped with a $1\cdot6$ m telescope of *Ritchey–Chrétien* design. Two secondary mirrors are available, allowing two focal ratios (f/8 and f/15). The f/8 configuration will be used throughout this project to maximise the field of view since the spatial extent of old HII regions is often larger than a square degree. With the addition of a focal reducer, this telescope becomes a very efficient instrument in the study of extended, low surface brightness objects.

2.1 PANORAMIX Focal Reducer

This focal reducer is primarily made of adapted and recycled parts from an old focal reducer used at the CFHT. Using the f/8 secondary configuration, PANORAMIX brings the effective focal ratio down to $f/2\cdot06$. With a suitably large field lens, the overall usable field is of about 38 arcmin in diameter, with approximately 22 arcmin totally unaffected by vignetting. PANORAMIX has very good optical components. Even with 19 optical elements in the light path, the transmission remains at 90% from 5000 to 10000 Å. Since PANORAMIX'S optics were designed for the CFHT, we are left with aberration corrections which are not fitted to the OMM telescope. Nevertheless, the coma, astigmatism and field curvature are matched with the site's seeing. The mean seeing at the OMM is $1\cdot2''$. To maximise field coverage, a Loral $2k\times2k\times15\ \mu$m CCD is used with PANORAMIX. The spatial scale is $0\cdot93''$ pixel^{-1}.

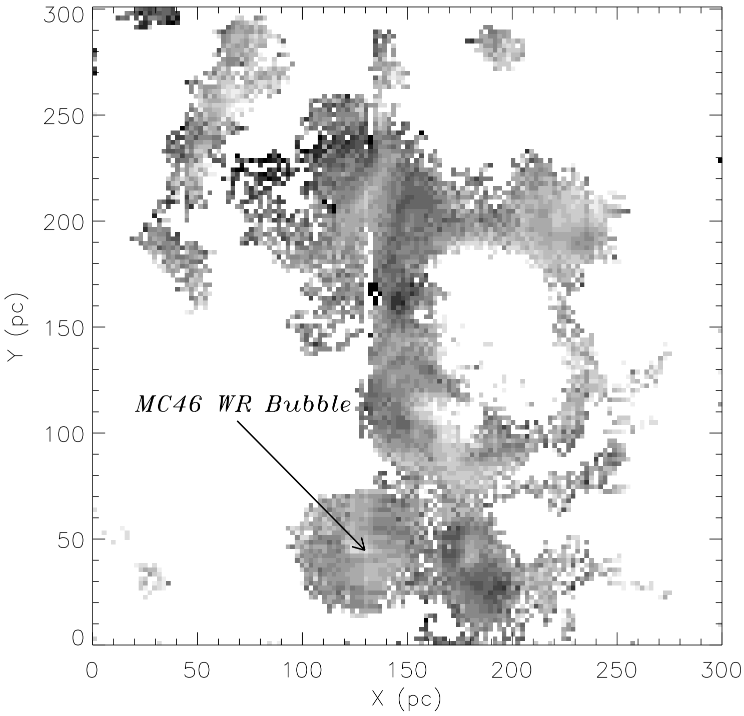

Figure 2 —Velocity field of the ionised gas in the region near Wolf–Rayet star MC46 in M33. Lighter shades indicate receding gas. Velocities range from 10 to 45 km s^{-1} in M33's frame of reference. North is up and east is left.

2.2 Goliath Hα Interference Filter and the Fabry–Perot Interferometer

In order to use the whole field of view, we contracted Andover Corporation to provide us with a custom-made circular filter with a diameter of 140 mm. From the manufacturer's benchmark testings at f/8, the peak transmission is 76·7% and is centred at λ6568·8 Å with a bandwith of 12·5 Å. This filter's specifications were optimised for observations where temperatures may range from −30° to 20°C. An image of M16, shown in Figure 1, was obtained on a commissioning run and gives a good idea of the available field of view (see, for example, the images in Hester et al. 1996 for a comparison). The observations were done under poor seeing conditions (cirrus clouds) and contained tracking errors, which prevented analysis of the image quality across the filter.

The spectroscopy is done with a scanning Fabry–Perot interferometer of Queensgate Instruments design, which is optimised to work within the 4600–6800 Å range. The interferometer has a free spectral range of 392·4 km s^{-1} at Hα and a spectral resolution of 11·3 km s^{-1}. The end result of observations with this system is a Fabry–Perot data cube $(\alpha, \delta, V_{LSR})$ spanning a 32′ field of view and yielding over 2 million spectra per field.

3 Conclusion

Throughout this project, many ionised nebulae will be studied using the instruments described above. Our first target is the W4/W5 complex. A total of 10 data cubes is needed to cover the object. The CGPS will cover an extremely large area of the Galactic plane, and obviously a 32′ field will not be enough to cover the same spatial extent. Eastern Canada's weather provides us with around 90 clear nights per year. This is why our project will be limited to peculiar and interesting objects. It is hard to know exactly how many of these will be observed, as they have to be catalogued by the CGPS consortium first. However, within the guidelines established earlier, two more old HII regions are already on our list, bringing the total number of expected data cubes to 28. Weather permitting, two cubes per observing night should be acquired but a more conservative estimate, for a 6 week/year period, is a total of about 14 cubes/year. We expect to have, on completion of the project five years from now, the most complete and detailed pictures and models for HII region dynamics and their interactions with the local neutral gas. To emphasise the type of data we will get from these studies, we include in Figure 2, a preliminary, grey level coded, velocity field for the ionised gas in the region of the Wolf–Rayet star MC46 from the already available M33 data.

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