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Neutral and Ionised Hydrogen in NGC 4214

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Abstract: It is not clear at present how the diffuse ionised gas (DIG) component in galaxies is ionised. The leading hypothesis is that ultraviolet photons from star clusters are responsible, but this requires a rather porous interstellar medium if the photons are to travel the large distances ($\geq$ 1 kpc) between the bright clusters and diffuse-emission regions. To examine this hypothesis, we present high-resolution VLA observations of the neutral hydrogen in the Magellanic galaxy NGC 4214, and compare them with an Hα image. The data appear consistent with the idea that enough UV photons escape from supergiant H II regions to ionise the DIG.

Keywords: ISM: bubbles — galaxies: star clusters — galaxies: individual (NGC 4214)

1 Background

Ionised gas forms an important component of the interstellar medium in late-type galaxies. The bulk of the emission comes from H II regions, but a significant fraction comes from regions far removed from these ionising clusters. This emission is distributed in loops and filamentary structures, and a component that appears diffuse.

Spectroscopy of the filamentary and diffuse components in other galaxies (Hunter, Hawley & Gallagher 1993; Ferguson et al. 1996; Hunter & Gallagher 1997; Martin & Kennicutt 1997) shows this emission is predominantly photoionised, and the most likely source of ionisation is the UV continuum from bright starforming regions, even though the projected pathlengths are of order 1 kpc. This implies that the giant H II regions are not ionisation-bound, and that the interstellar medium beyond the H II region environs must be rather porous. How porous the ISM must be depends on the (unknown) location of the ionised emission relative to the disk.

The diffuse emission is likely akin to the Reynolds layer in our own galaxy, where many small holes are sufficient for radiation escaping the midplane to keep the gas at large scale heights ionised (Miller & Cox 1993; Dove & Shull 1994).

The loops and filaments can be divided into two classes, one where the structures at least partially encircle young clusters, and another where the filament size scale is often large (∼kpc) and there is no clear association with an ionising cluster [Hunter & Gallagher (1997) call these 'superfilaments']. The former are probably within the disk plane and can be understood as classical expanding shells with the interior largely cleared of H I by the expansion and heating processes, and the filamentary ionised emission coming from the interior of the shell wall. For the latter class, the emission might be part of an expanding-shell shock front, or an ionisation front on a relatively stationary H I structure. If we assume these superfilaments to be photoionised, and if they lie within the host's disk, the column density along the path between the emission region and ionising cluster must be rather low. The H I deficit should be visible in radio synthesis observations. If the emission comes from gas above the disk plane, the radiation transport problem is similar to that of the diffuse gas, and the the disk may appear more nearly uniform.

In images[1] I present comparisons of ionised and neutral gas morphology with the aim of understanding the origin of the large-scale filaments in NGC 4214, and discuss the neutral hydrogen distribution around the most UV-luminous cluster in the galaxy, NGC 4214#1.

2 NGC 4214#1

This bright cluster (diameter 5″) contains ∼400 OB stars which lie inside a 10″ ring of Hα emission. HST imaging and spectra appear to show four to eight times more UV flux than can be accounted for by the Hα emission. Hβ equivalent width (normally well correlated with UV flux) is lower than expected for the observed UV flux (Leitherer et al. 1996).

[1]Space does not permit reproduction of the images, but copies are available from the author, upon request.

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Is the Hα emission density-bounded? H I data are consistent with this, but any swept-out region must be small or incompletely cleared. Local H I surface density is 2×10^{21} cm^{-3}. For gaussian disk profile, the corresponding mean density is $2\cdot6$ cm^{-3}. The Hα emission implies a local ionised gas density of 2–3 cm^{-3}.

For a uniform density of $2\cdot5$ cm^{-3}, the UV flux of NGC 4214#1 would produce a Strömgren sphere 260 pc ($13''$) in diameter. Since this is comparable to the scale height, the ionised volume should be even larger. But no signature of an H I hole is visible in column density or position-velocity maps. The two most likely interpretations of this are: (a) there is neutral gas in self-shielding filaments or clumps or (b) some coincidence of viewing geometry.

Self-shielding is consistent with the presence of CO emission nearby (Becker et al. 1995), and with the observations of dense filaments (Kim et al. 1996) and cold absorbing clouds (Dickey et al. 1994) near 30 Dor.

Luks & Rohlfs (1992) made observations of the LMC with spatial resolution comparable to the data shown here, and found no evidence of a hole around the central cluster of 30 Dor. They speculated that the cluster lies in front of or behind the main disk of the galaxy. A similar model for NGC 4214#1 cannot be easily ruled out, but seems improbable given the cluster's central location.

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