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IONIZED INTERSTELLAR FROTH IN IRREGULAR GALAXIES

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Introduction

The warm interstellar medium of galaxies is a complicated place. It is often full of holes, neutral and ionized loops and shells, and diffuse ionized gas (cf. Monnet 1971, Sivan 1974, Heiles 1979, Sabbadin and Bianchini 1979, Ogden and Reynolds 1985). Deep Hα images of Magellanic-type irregular galaxies also reveal complex spatial structures consisting of loops and filaments in the interstellar gas outside of the boundaries of traditional HII regions (cf. Meaburn 1980). We refer to these ionized structures as "froth". Such structures could mark paths over which newly produced heavy elements are dispersed in irregular galaxies, and they could be the signatures of a feedback process related to star formation (cf. Dopita *et al.* 1985, McCray and Kafatos 1987). In order to investigate the physical nature of the froth we have obtained narrow-band images and high and low dispersion spectra from KPNO and deep blue-passband plates from the CFHT.

Description

Characteristics of typical filaments and loops are as follows: a) Dimensions: 0.5–1 kpc $\times$ 15–150 pc; b) Hα Surface Brightness: 6×10^{-16} ergs/cm^2/s/arcsec^2; EM $\sim$ 230 cm^{-6} pc; c) Fraction of Total Hα: 15–20%; d) Emission-line Ratios: [OII]/[OIII] $\sim$ 3.5 (HII: $\sim$ 1.5); [SII]/Hα $\sim$ 0.5 (HII: $\sim$ 0.25); [NII]/Hα $\sim$ 0.2 (HII: $\sim$ 0.1); [OI]/Hα $\leq$ 0.05; e) Kinematics: FWHM(Hα) $\sim$ 40–140 km/s; Δv(loops) $\sim$ 0–20 km/s.

We have superimposed the filamentary structures on prints of the CFHT plates in order to compare their locations to that of OB associations. We see that only one structure is centered around a young OB cluster. The loop around the giant HII region NGC 2363 in the dwarf irregular NGC 2366 has a similar structure, as does the outer structure of the 30 Doradus giant HII region in the LMC. In all other cases, including apparently coherent ionized loops, there is no stellar group of particular interest located *within* the feature.

In all cases, however, we find that the frothy structures are associated with HII regions. The loops and filaments appear to emanate from the HII regions with the filaments extending radially away and the loops being connected to the same HII complex on both footprints. Thus, while frothy ionized structures are associated with the presence of young, massive OB stars, their structures are inconsistent with simple models in which such features mark bubbles blown in the surrounding interstellar matter by stellar winds, supernovae explosions, and HII regions (Tenorio-Tagle and Bodenheimer 1988).

We have also compared the locations of the filaments with the distribution of the HI in the two galaxies for which high resolution maps exist (van Gorkom and Hunter, unpublished; Skillman *et al.* 1988). In NGC 4449 we see that the froth is generally located on the edges of HI complexes. None of the features is located within a cloud complex. In Sex A this general trend continues. The filaments extend from the eastern HII region and HI peak further west towards the HI hole.

Ionization and Pressure

The problem of ionization of interstellar froth in irregular galaxies parallels that of understanding the source of ionization for diffuse Hα emitting gas in the Milky Way (e.g. Reynolds 1984,1985; Sivan *et al.* 1986): (1) Interstellar froth in irregulars has lower excitation than classical HII regions in the same galaxies, although the excitation is higher than in the Milky Way diffuse ionized gas (e.g. much higher [OIII])/Hβ; c.f. Reynolds 1985; Sivan *et al.* 1986). Froth therefore cannot be due to light reflected from HII regions by interstellar dust. (2) Frothy matter shows large local velocity widths, and a shock-excited component therefore may also be present. (3) The higher surface brightnesses of the ionized froth in irregulars compared to that in the Milky Way exacerbates the problem of finding a suitable local ionization source as compared with the local Galactic disk (Reynolds 1984). A best model at present, therefore, appears to be the combined shock and photoionization interpretation proposed by Sivan *et al.* (1986). Shocks could produce enhanced emission from [S II], while photoionization contributes to the higher ionization species and depresses the amount of [O I] emission.

The pressures inferred in frothy structures studied here are 3–10 times *greater* than the estimated pressure in the local Galactic disk cloud layer (Kulkarni and Heiles 1988). We see no obvious reason why the mean pressure in the outer regions of an irregular galaxy with significantly lower surface mass density than the local Galactic disk should exceed the local value by a large factor. We therefore conclude that either (1) higher surface brightness (denser) ionized frothy structures in irregulars are not in pressure equilibrium with the surrounding interstellar medium, or (2) magnetic fields provide an additional confining force for these structures.

Preliminary Conclusions

Frothy features in irregular galaxies show that the influence of young stellar systems extends beyond the production of supershell bubbles around luminous OB associations. The origin of filaments extending out from HII regions is currently unclear, but these structures involve dynamic processes which produce comparatively large line velocity widths. Froth may possibly be produced from old supershells, in which case star formation must be spatially correlated to explain the proximity of HII regions and ionized froth. Alternatively, some form of magnetic structuring of gas is possible. That these features are more readily found in the ionized gas of irregulars than in spirals could reflect the high UV stellar output and small diffferential rotation in the irregulars.

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