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OPTICALLY THICK GIANT H II REGIONS WITH DECREASING DENSITY GRADIENTS IN THREE BARRED GALAXIES

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Franco, García-Barreto, & de la Fuente (2000, hereinafter FGF00) have re-analyzed the radio continuum emission at 2, 6 and 20 cm from the circumnuclear regions of the barred galaxies NGC 1022, 1326 and 4314. The angular resolution of the observations is approximately 3.7″, roughly equivalent to 200 parsecs. Here we summarize the results discussed in FGF00

With the spectral index analysis of the radio continuum emission of photoionized gas at short wavelengths, we can probe the density structure of an H II region. Generally, the best range to detect thermal emission is at wavelengths below 2 cm. Both thermal and non-thermal emission can be present at 6 cm, while 20‘cm measures the mainly non-thermal emission. The thermal radio continuum emission of an optically-thin photoionized plasma in H II regions has a relatively flat spectrum, $S_\nu \propto \nu^{-0.1}$, and it changes to $S_\nu \propto \nu^2$ when the region becomes optically thick. The optically thin non-thermal emission has a spectrum $S_\nu \propto \nu^\alpha$ with $\alpha \lesssim -0.2$. The typical spectral index for extragalactic non-thermal emission is $\alpha_6^{20} \sim -0.8$. In the circumnuclear zones of NGC 1022, 1326, and 4314, the spatial distributions of Hα and radio continuum are similar, suggesting the existence of several giant (~ 100 pc) H II regions (see Figs. 1 and 2 of FGF00). These giant extragalactic H II regions are most likely composed of a collection of individual ionized cores embedded in a lower brightness extended region (see sources labeled as FGF in Figs. 1, 3, and 4 of FGF00). We find that the average density stratifications of these H II regions can be approximated by a power law $n_\mathrm{e} \propto r^{-\omega}$, where $\omega = (0.5\alpha - 3.1)/(\alpha - 2)$ (Olnon 1975). In the case of barred galaxies, large cloud complexes are concentrated in circumnuclear structures, forming new massive stars. These structures are due to inner torques generated by the non-axisymmetric potential of the bar (Schwarz 1984), driving gas to the central regions, presumably near an Inner Lindblad Resonance. The radiation field of these newly formed stars creates giant H II regions in approximately a recombination time. In the initial stages of evolution, these H II regions reach pressures of 10^{-5} dyne cm^{-2} and expand. For decreasing density gradients with $\omega > 1.5$, the ionization front eventually overtakes the shock front and the entire cloud becomes ionized. The ionized gas is set into rapid motion by pressure gradients. All this, and the effects of dust and pressure in these H II regions are discussed briefly in Franco et al. (2000, 2001) and Kurtz et al. (2001). Reviews of nuclear rings and barred galaxies are given in Buta (1999) and Sellwood & Wilkinson (1993). In Figure 5 of FGF00, and Figure 1 of Franco et al. (2000), the radio continuum flux density vs. frequency of the three barred Galaxies is plotted; the position of sources FGF is displayed in those figures. The negative spectral indices from 20 cm (1.5 GHz) to 6 cm (5 GHz) are indicative of non-thermal (synchrotron) emission, most likely the result of supernova explosions. In contrast, the flat to positive spectral indices from 6 to 2 cm (15 GHz) is indicative of thermal bremsstrahlung emission dominating at these wavelengths ($\alpha_2^6 > -0.1$), mainly due to H II regions in massive star forming regions. Our data indicate an important thermal contribution at 6 cm. The positive spectral index between 6 and 2 cm is used to determine the density gradients. This behavior can be explained if the photoionized gas is optically thick (see the spectral indices behavior) and has a decreasing density structure with a power-law $n_\mathrm{e} \propto r^{-\omega}$, with $1.6 < \omega < 2.4$. These density gradients represent an "average" density stratification which may be different from the actual density profiles of the individual ionized cores.

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