DEEP NARROW BAND IMAGERY OF THE DIFFUSE ISM IN M 33

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Very deep narrow band images have been obtained for several fields in the local group spiral galaxy M 33 using the "Wide Field PFUEI" reimaging CCD camera on the 1.5-m telescope at Palomar Observatory. The reimaging system uses a 306 mm collimator and a 58 mm camera lens to put a $16' \times 16'$ field onto a Texas Instruments 800×800 pixel CCD at a resolution of 1.2 arcseconds pixel^{-1}. The overall system is $f/1.65$. Images have been obtained in the light of Hα, [S II]$\lambda\lambda$6717, 6731, [O III]λ5007, and line-free continuum bands 100Å wide, centered at 6450Å and 5100Å. Assuming a distance of 600 kpc to M 33 (Humphreys 1980, *Ap. J.*, **241**, 587), this corresponds to a linear scale of 3.5 pc pixel^{-1}, and a field size of 2.8 kpc $\times$ 2.8 kpc. In the present abstract we discuss our Hα imagery of a field centered $\approx 8'$ NE of the nucleus, including the supergiant H II region complex NGC 604.

Two 2000 second Hα images and two 300 second red continuum images were obtained of two slightly offset fields. The fields were offset to allow for discrimination between real emission and possible artifacts in the images. All images were resampled to align them with one of the Hα frames. The continuum images were normalized to the line images using the results of aperture photometry on a grid of stars in the field, then the rescaled continuum data were directly subtracted from the line data. Figure 1 shows the resulting continuum subtracted Hα image with a logarithmic stretch. The data were calibrated by comparison with published Hα fluxes of H II regions in M 33 (Viallefond and Goss 1986, *Astron. Astrophys.*, **154**, 357; Searle 1971, *Ap. J.*, **168**, 327). The measured surface brighteness sensitivity in the continuum subtracted image is $S_{\mathrm{H}\alpha} = 5.2 \times 10^{-7}$ ergs cm^{-2} s^{-1} sr^{-1} (3σ in a 3".6 $\times$ 3".6 region), which corresponds to an emission measure of 6 cm^{-6} pc assuming $T = 10^4$ K. There is a zero point uncertainty in the sky subtraction because the galaxy more than fills the field. A sky value was taken from the lowest surface brightness region in the field, located in an interarm region north of the nucleus.

Hα emission structure can be seen throughout the galaxy ranging continuously from supergiant H II regions such as NGC 604 to faint features at the limits of detectability. The ubiquitous Hα background (*i.e.*, the emission not associated with well defined H II regions) is significantly brighter in the spiral arms than in the interarm regions. Morphologically, this emission consists of filaments embedded in a very low surface brightness diffuse component. In an arm region $\sim$ 800 pc west of NGC 604 the brightest filaments have

$S_{H\alpha} \approx 150 - 200$ cm^{-6} pc, while the surrounding nonfilamentary emission has $S_{H\alpha} \approx 20$ cm^{-6} pc. An average Hα emission measure for the region, excluding bright H II regions, is ~ 40 cm^{-6} pc. Assuming a disk thickness of ~ 300 pc and $\langle n_e^2 \rangle \approx 1$ cm^{-6} pc, this gives a local filling factor of $\sim 13\%$ for the warm ionized material. Assuming photoionization accounts for most of the Hα emission, this average brightness requires a conversion of $\sim 2.6 \times 10^{44}$ ioniziong photons pc^{-2} s^{-1}, or the total output of 1 O5 V star per 1.8×10^5 pc ^{2}. The average surface brightness of the diffuse background emission within ~ 450 pc of the nucleus is about a factor of 2 higher than the values given above.

The morphology of the Hα background emission indicates that the warm ionized material is distributed in large scale sheets or surfaces. Filaments are due to projection effects (*i.e.*, limb brightening) in these regions. This is especially apparent in numerous locations where multiple "filaments" merge into single structures which bound regions of nonfilamentary emission. This morphology may be important in explaining the excitation mechanism for the emission. Within our Galaxy, Reynolds has shown that while UV from O stars is the only mechanism energetically capable of explaining the excitation of the diffuse Hα background, this emission is often far removed from such stars. A structure such as that seen in M 33 would allow the warm gas to fill a substantial fraction of the volume of the galaxy while still permitting UV escaping from the immediate surroundings of O stars to have a substantial mean free path. The two dimensional Hα emitting structures could be either sheets within a low density matrix or illuminated surfaces of large denser structures, or both.

Numerous shells and partial shells are seen, including multiple shells around the outskirts of NGC 604. The largest complete shell in the field, located ~ 1 kpc south of NGC 604, is ~ 300 pc in diameter. These structures have been studied previously in M 33 and other galaxies in both ionized and neutral gas (see review by Tenorio-Tagle and Bodenheimer 1988, *Ann. Rev. Astron. Astrophys.*, **26**, 145). In the present images, most of the complete shells can be seen to be limb brightened, with diffuse emission filling their interiors. Hence most of these shells have not broken completely through the galactic disk, although many may have broken through on one side or the other. A possible exception is the large faint bubble south of NGC 604, which has a very low surface brightness in its interior.

There seems to be a continuum of structure ranging from well defined shells through partial shells through the sheets of emission that make up the ubiquitous background. This is especially apparent around NGC 604, where the bubbles around the periphery of the H II complex merge into the filamentary structure of the Hα background. These data appear to support a view that much of the warm ionized material found in the diffuse ISM occurs in sheets that were once part of such large shell-like structures. While this idea is far from new, the structure of the very low surface brightness Hα emission provides a compelling demonstation of the plausibility of this idea, at least for M 33.

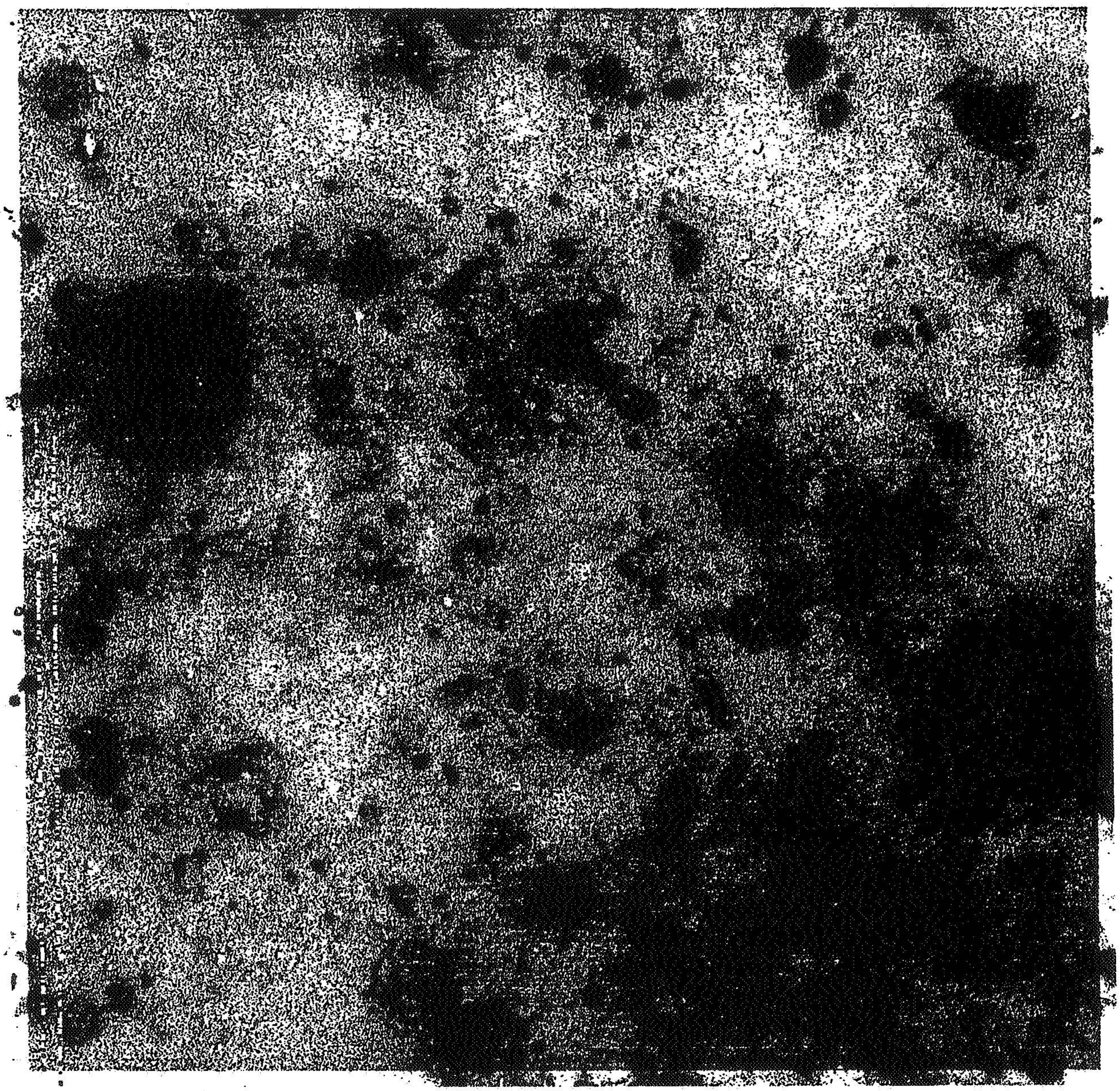

Figure 1. Continuum subtracted Hα image of a field to the NE of the nucleus of M 33. The field is 16' on a side. The data were obtained with a reimaging camera on the 1.5-m telescope at Palomar Observatory. The surface brightness sensitivity of the image corresponds to an emission measure of 6 cm^{-6} pc. The faintest structures discernable in this representation of the data have a surface brightness of $\sim$ 3 times that level. The dot density increases logarithmically with the surface brightness.