THE DIFFUSE IONIZED GAS PERPENDICULAR TO THE PLANE OF NGC 891

R.-J. DETTMAR[1], J.W. KEPPEL[2], M.S. ROBERTS[3], J.S. GALLAGHER[4]
(1) Radioastr. Inst. Uni. Bonn, Auf dem Hügel 71, D-5300 Bonn, FRG
(2) 603 Pauley Dr., Prescott, AZ 86301, USA
(3) NRAO, Edgemont Rd., Charlottesville, VA 22901, USA
(4) AURA Inc., 1625 Massachusetts Ave., Washington, DC 20036, USA

ABSTRACT. Hα images and long–slit spectra of NGC 891 show the presence of a thick layer of diffuse ionized gas (DIG) in this edge–on galaxy. Hα emission originating in the DIG of NGC 891 is detected out to several kpc above the midplane with a typical scale height for the electron density $n_e(z)$ of $h_e \sim 600$ pc. The distribution of the gas is very inhomogeneous with a large scale asymmetry and filamentary structure. Individual Hα emitting structures can be traced out to 4–5 kpc above the midplane. The emission line ratios of [NII] and [SII] to Hα vary with height above the disk. We compare these properties with the analogous gas phase in our Galaxy.

The distribution of the DIG is related to star formation in the underlying galactic disk and we conclude that in NGC 891 the interstellar medium is heavily effected by processes related to star formation.

1. INTRODUCTION

Under excellent seeing conditions the edge–on galaxy NGC 891 exhibits a very complex network of filamentary structures in the dust lane. Some of these dust filaments are almost perpendicular to the stellar disk and can be traced out to at least 1.5 kpc above the plane. NGC 891 also possesses a "thick" radio continuum emitting disk and it therefore is a very promising candidate for studies of the so–called "disk–halo–connection".

In an study of the structure and the properties of the diffuse ionized interstellar medium (DIG) perpendicular to the plane of disk galaxies we have obtained Hα images and long slit spectra of NGC 891.

2. OBSERVATIONS

Hα images were obtained with a 2:1 focal reducer at the 42–inch telescope at Lowell Observatory (Dettmar, 1990). Long slit spectra at intermediate resolution were

H. Bloemen (ed.), The Interstellar Disk-Halo Connection in Galaxies, 295–298.

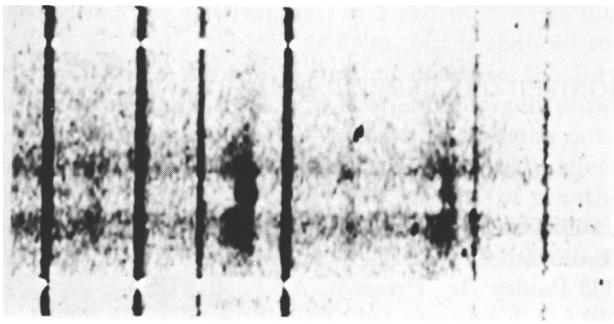

Figure 1. Hα and [NII] emission lines in the CCD–echelle–spectrum taken perpendicular to the plane of NGC 891 (PA 112°) 65″ NE of the nucleus. Night sky lines cover the slit length of 2.25′. The wavelength coverage is λ6540Å-λ6610Å and the binned pixel size 0.24Å×1.51″ resulting in a velocity resolution of ∼23 km sec^{-1}.

collected with the Cassegrain spectrographs at the KPNO 4–m Mayall telescope and the 72–inch Perkins telescope at Lowell Observatory. In addition spectra were obtained with the Echelle-spectrograph at the 4–m (see Fig. 1).

3. RESULTS

The most remarkable property of the Hα emission line in NGC 891 is its extent out of the plane of the galaxy: we are able to measure the Hα line out to more than 30″ (1.4 kpc, we use a distance of D=9.5 Mpc throughout this paper) from the midplane. Individual features can be traced out to ∼4.5 kpc above the plane.

The large z-extent of the ionized gas is confined to the inner half of the optical disk. In this inner region the Hα distribution also shows a filamentary structure of the diffuse ionized medium. These filaments, sticking out of the plane, originate in HII regions in the plane. Some of the filaments are correlated with dust features perpendicular to the plane. Typical linear dimensions for these structures are diameters of 300 pc and they reach out to ≥1 kpc.

The large scale distribution and the filamentary structure of the Hα emission is confirmed by similar imaging observations presented by Rand et al. (1990) but we definitely failed to detect the very extended component with a scale height of several kpc reported by them. As the dust obscures the emission near the midplane we have applied a correction for dust absorption before estimating the scale height of the DIG. A typical exponential scale height for the electron density $n_e(z)$ is $h_e \sim$ 600 pc. But in one outstanding region ∼2 arcmin NE of the nucleus this scale height is $h_e \sim 1$ kpc.

Our long slit spectra confirm the large scale distribution of the Hα–emitting ionized gas but they are not sensitive enough to probe the very extended Hα emitting component found by Rand et al. (1990). The [NII] (Fig. 1) and [SII]

https://doi.org/10.1017/S0074180900089191 Published online by Cambridge University Press

($\lambda\lambda$6816/31) to Hα emission line ratios vary with height above the plane in the sense that they become larger outside the HII regions of the central plane.

4. DISCUSSION

The scale height and the large scale distribution of the Hα emitting gas in NGC 891 is similar to the DIG observed by Reynolds (1990) in the Galaxy. The filamentary structures seen in the dust and Hα-emission may represent the "chimneys" in supernova–dominated models of the interstellar medium (e.g. Norman and Ikeuchi, 1990). Dust structures perpendicular to plane of the Galaxy, which would be comparable to those observed in NGC 891, have been identified from the *IRAS*–survey by Koo (1990). For the extended component in NGC 891 the Hα flux from the high z–component is $\sim$10% of the Hα flux emitted from the plane, a again ratio very similar to the Galactic value.

The observed changing emission line ratios exclude the possibility that the large scale height of the emission is due to scattering of disk emission by dust high above the plane. The line ratios rather vary in the same sense as they do in the "Reynolds–layer" of the Galaxy, indicating a low-excitation ionization by photons that can escape from the HII regions in the midplane (Mathis, 1986). From a detailed comparison of the line profiles in the high resolution spectra with the observed HI velocity field (Sancisi and Allen,

1979) we can rule out that the high z-extent of the Hα emitting gas is just due to geometrical effects, like warping of the disk. The measured velocities in the Cassegrain spectra and the line profiles of the high resolution spectra also show that the DIG at high z is corotating.

All the observed properties of the DIG in NGC 891 mentioned above are comparable with the analogous gas phase in the Galaxy. The main difference is that the surface density of the DIG in NGC 891 is about twice that of the solar neighbourhood.

The large extent of the DIG out of the plane in the region $\sim$2′ NE of the nucleus is most probably related to star formation activity in the underlying disk as can be shown by a comparison of star formation tracers with the Hα distribution (Dettmar and Dahlem, 1990). Also the polarized radio continuum intensity as deduced from new VLA observations at 1.49 GHz is surprisingly well correlated with the observed diffuse Hα–emission. Though Faraday depolarization effects are visible towards the midplane this indicates that the magnetic field structure in this region is very regular on scales of a few kiloparsec.

Additional long–slit spectra were taken perpendicular to the planes of several other edge–on galaxies with varying radio continuum properties (NGC 3628, NGC 4244, NGC 4631). This data allow to determine the scale heights of the diffuse ionized gas and show a possible relation of the extent of the DIG with the presence of a radio continuum emitting "thick" disk. The transport of relativistic electrons into the halo and the sources of ionization of the DIG both are related to actively star–forming regions in the underlying galactic disks. Most probably

these independent phenomena are coupled by the presence, orientation, and order of magnetic fields.

5. CONCLUSIONS

The inhomogeneous distribution and the filamentary structure of the diffuse ionized gas in NGC 891 are very different from the stratified layers in hydrostatic equilibrium models. This observational evidence rather supports a more dynamical view of the interstellar medium where the energy input from star forming processes strongly affects the gas phase and connects the interstellar medium in the disk to the galactic halo.

ACKNOWLEDGEMENTS

In the course of this work RJD was supported by the Deutsche Forschungsgemeinschaft (De 385/2–1), the Lowell Observatory Research Fund, and the MPIfR.

REFERENCES

Dettmar, R.-J. (1990) *Astron. Astrophys. Lett.* **232**, L15
Dettmar, R.-J., Dahlem, M. (1990) *this conference, Poster Proceedings*, ed. H. Bloemen, Sterrewacht Leiden, p. 41
Koo, B.-C., Heiles, C., Reach, W. T. (1990) *this conference*
Mathis, J. S. (1986) *Astrophys. J.* **301**, 423
Norman, C. A., Ikeuchi, S. (1990) *Astrophys. J* **345**, 372
Rand, R. J., Kulkarni, S. R., Hester, J. J. (1990) *Astrophys. J. Lett.* **352**, L1
Reynolds, R. (1990) in *IAU Symposium No. 139, Galactic and Extragalactic Background Radiation*, eds. S. Bowyer and C. Leinert.
Sancisi, R., Allen, R. J. (1979) *Astron. Astrophys.* **74**, 73