ANALYSIS OF MULTIWAVELENGTH OBSERVATIONS OF IC443

M.L. McCollough[1,2] and S.L. Mufson[2]

[1]Physics Department, Oklahoma State University
[2]Astronomy Department, Indiana University

Abstract: High resolution observations at radio, infrared, optical and X-ray wavelengths have been made (Mufson et al. 1986). The infrared spectrum determined from the IRAS observations has been fitted with models which include shock heated dust, infrared line emission, and radiatively heated dust emission. Numerical simulations of a supernova expanding into a uniform medium, which describe the X-ray and large scale radio emission, are presented.

Introduction: Recent observations have shown that IC443 is expanding into a complex region of the ISM. The appearance and nature of emission at various wavelengths is very strongly governed by the components of the ISM with which the SNR is interacting. Details of the observations and their analysis are presented in Mufson et al. (1986).

IR Spectrum: Integrated and color corrected infrared flux densities for IC443 in the four IRAS bands are shown in Table 1. In modeling these infrared data three major sources of emission are considered: shock-heated dust (BB), IR line emission (lines) and radiation-heated dust (RHD). The method used to fit the data and the results of calculations for $I_{H\beta}= 2.85\times10^{-4}$ erg/cm^{2}s sr are given in Mufson et al. (1986). Suggestions have been made (R. Braun, private communication) that the average H_β intensity in the IC443 region used in these fits may be substantially lower. We have therefore investigated the effect of using an average H_β intensity which is a factor of 10 lower. The results of these calculations are shown in Table 2. From both sets of fits it is apparent that IR

Table 1. Measured Flux Densities

IRAS Band	S_ν
12μ	58 ± 17 Jy
25μ	90 ± 27 Jy
60μ	1330 ± 266 Jy
100μ	1810 ± 360 Jy

https://doi.org/10.1017/S025292110010274X Published online by Cambridge University Press

Table 2(a). Percentage of flux in the four IRAS bandpasses. $N_H = 10^{21}$ cm^{-2}

IRAS Band	BB(%)	Lines(%)	RHD(%)
12μ	*	*	*
25μ	65	10	25
60μ	91	4	5
100μ	77	0	23

T = 57 K * not well fitted by the model

$\tau = 1.4 \times 10^{-6}$ (n = o), $\tau = 1.9 \times 10^{-8}$ (n = 1)

$I_{H\beta} = 2.85 \times 10^{-5}$ ergs/cm^2 s sr

Table 2(b) Percentage of flux in the four IRAS bandpasses. N_H allowed to vary

IRAS Band	BB(%)	Lines(%)	RHD(%)
12μ	*	*	*
25μ	37	9	54
60μ	76	4	20
100μ	44	0	56

T = 53 K * not well fitted by the model

$\tau = 1.2 \times 10^{-8}$ (n = 1), $N_H = .3\text{-}3 \times 20^{21}$ cm^{-2}

$I_{H\beta} = 2.85 \times 10^{-5}$ ergs/cm^2 s sr

Table 3. SN Model Parameters

$E_o = 3 \times 10^{50}$ ergs

n_o (NE) = 0.11 cm^{-3}

n_o (SW) = 0.01 cm^{-3}

$M_{ejecta} = 8M_\odot$

$B_{ISM} = 15\mu G$

$T_{ISM} = 10^4 K$

https://doi.org/10.1017/S025292110010274X Published online by Cambridge University Press

line emission and radiatively heated dust play an important role in the IR spectrum of IC443. It should be noted that in the case of lower line intensities the 12μ flux density is not well fitted by the three components alone. But as noted by Dwek (1986), the presence of small dust grains in the shock-heated dust leads to an enhancement of the short wavelength flux density. This effect can account for the missing 12μ flux density.

Models of X-Ray and Large Scale Radio Emission: In order to get an approximation to the X-ray and radio emission, 1-D numerical models of the structure of a SNR expanding into a uniform density ISM have been made. The hydrodynamics code used is a version of SOLA-STAR (Cloutman 1980) modified to handle transient fluid flows in the ISM (Wolff 1986). To this code magnetic field and cosmic rays have been added. The parameters used in the code are shown in Table 3. A density difference of a factor of 10 is needed to explain the difference between the size of IC443 in the NE to its size in the SW.

The radio emission is taken to be synchrotron emission from the swept up magnetic field and cosmic rays. For an initial field of 3μG with equipartition in energy between the field and cosmic rays, the radio flux density from the models falls two orders of magnitude short of what is observed. An enhancement of a factor of 5 in the B field is required to reproduce the observed flux density. In Fig. 1 we show a plot of synchrotron emission as a function of radius for the NE region.

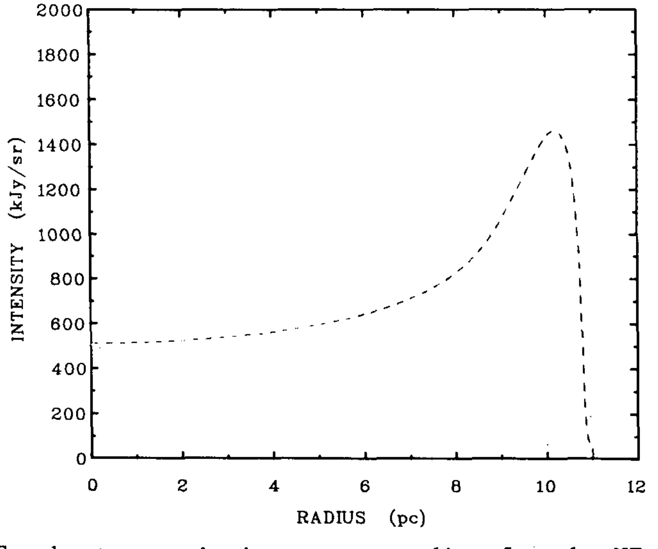

Fig. 1: Synchrotron emission versus radius for the NE region.

https://doi.org/10.1017/S025292110010274X Published online by Cambridge University Press

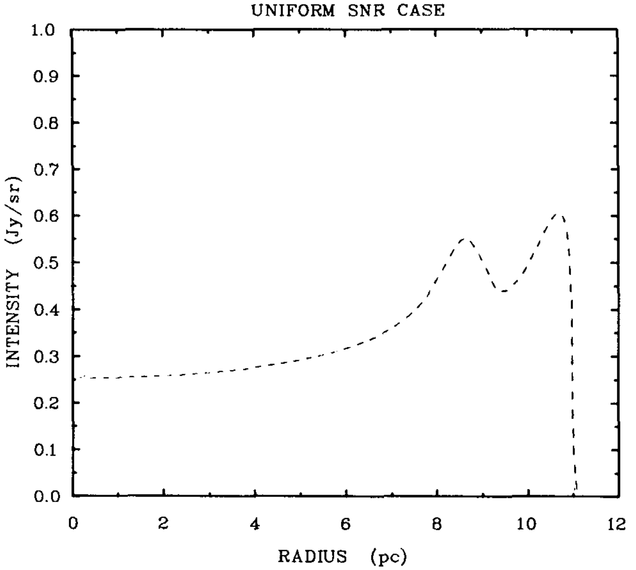

Fig. 2: X-ray emission versus radius for the NE region.

The X-ray emission from a uniform case arises from two sources, the SN ejecta and the swept-up ISM. In younger SNR models with ejecta of several solar masses, the reverse shock traversing the ejecta can be a strong source of X-rays. Later when the SNR has swept-up many times the mass of the ejecta, the model approximates a Sedov solution as it should. In fitting our models to IC443 we find it has not yet evolved to the Sedov phase. In this stage of its evolution, IC443 does not appear as a limb-brightened source. Fig. 2 shows the X-ray emission as a function of radius for the NE. This clumpy double peaked picture is more consistant with what is observed in the NE of IC443. However, care must be taken in interpreting IC443 with uniform models, since the region in which IC443 is evolving is very nonuniform.

References

Cloutman, L.D. 1980, Los Alamos Scientific Laboratory Informal Report. LA-8452-MS.

Dwek, E. 1986. Ap.J. 302, 363.

Mufson, S.L., McCollough, M.L., Dickel, J.R., Petre, R., White, R., and Chevalier, R. 1986. A.J. 92, 1349.

Wolff, M.J., 1986. Ph.D. Dissertation, Indiana University.

https://doi.org/10.1017/S025292110010274X Published online by Cambridge University Press