A DYNAMICAL STUDY OF THE YOUNG OXYGEN-RICH SUPERNOVA REMNANT IN THE SMALL MAGELLANIC CLOUD

Ian R. Tuohy & Michael A. Dopita

Mount Stromlo and Siding Spring Observatories
Australian National University

We present a velocity map of the young oxygen-rich supernova remnant (1E0102.2-7219) in the Small Magellanic Cloud, obtained with the Anglo-Australian Telescope. The velocity structure is complex, and implies a high degree of asymmetry during the Type II supernova explosion. Our data can be modelled geometrically in terms of a severely distorted ring of oxygen-rich ejecta. This result, together with the evidence for expanding rings in similar remnants, suggests non-spherical ejection to be an intrinsic characteristic of Type II supernovae. We have also obtained two-dimensional spectroscopy of the diffuse halo of emission which partially surrounds 1E0102.2-7219. The halo exhibits the high excitation line of HeII λ4686, and is either a fossil HII region created by a UV flash accompanying the supernova, or alternately, is being excited by intense UV radiation from the remnant itself. It is the first clear association of a high excitation region with a supernova remnant.

1. INTRODUCTION

In a recent X-ray survey of the Small Magellanic Cloud (SMC), Seward and Mitchell (1981) reported the discovery of an intense soft X-ray emitting supernova remnant, 1E0102.2-7219. The optical counterpart was found by Dopita, Tuohy and Mathewson (1981) and consists of a series of filaments (~ 24 arcsec diam.) emitting only in the forbidden lines of oxygen and neon. A faint outer halo, separated from the filaments by a dark annular region, partially surrounds the remnant. In this paper we report the results of a detailed two-dimensional spectroscopic study of both the oxygen-rich filaments and the diffuse outer halo. A more complete discussion of this work is given by Tuohy and Dopita (1982).

2. OBSERVATIONS AND RESULTS

The observations were made in June 1981 using the RGO spectrograph on the Anglo-Australian Telescope. A total of 11 long slit spectra were taken over the full area of the SNR and part of the halo, resulting in a

J. Danziger and P. Gorenstein (eds.), Supernova Remnants and their X-Ray Emission, 165–169.

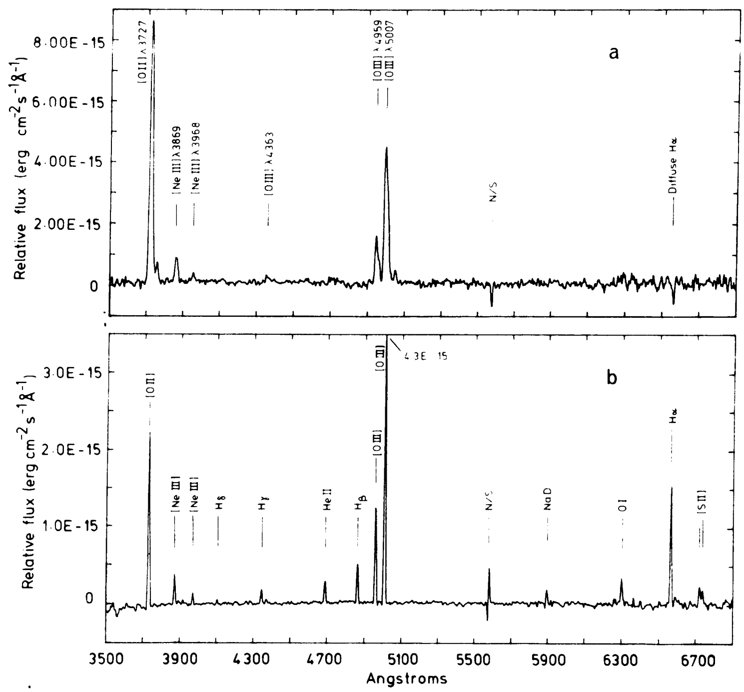

Fig. 1 (a) A representative sky-subtracted and calibrated spectrum of a filament in 1E0102.2-7219.

(b) Spectrum of the diffuse halo which partially surrounds 1E0102.2-7219. Note the He II λ4686 line.

data set consisting of a spatial grid of 58 x 11 pixels, each with 2040 spectral elements spanning the wavelength range 3000 to 7000 Å (resolution ~ 8 Å FWHM). A typical spectrum of a single filament is shown in Figure 1a.

2.1 Velocity Structure

The velocity of the oxygen-rich material ranges from -2500 to +4000 km s^{-1}, relative to the local SMC standard of rest. Narrow band images have been constructed from the spatial grid of spectra by summing wavelength elements over velocity intervals centered on the [OII] λ3727 line (the [OIII] λ5007 line was not suitable because of velocity overlap from the λ4959 component). The total [OII] emission from the remnant in the velocity range -2500 to +4000 km s^{-1} is shown in Figure 2a. The [OII] image agrees well with the [OIII] discovery image which covers a restricted velocity interval, but has higher angular resolution (Tuohy and Dopita 1982).

Figure 3 depicts a mosaic of 12 narrow band images, each equivalent to a velocity range of 520 km s^{-1}. Comparison of the individual images

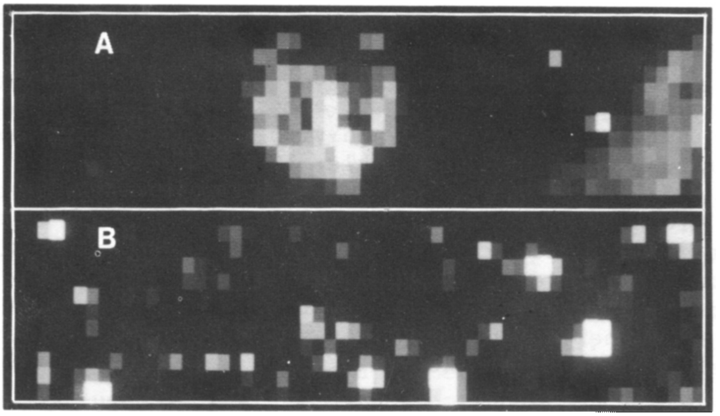

Fig. 2 An [OII] image of 1E0102.2-7219 (and N76 to the west) obtained by summing emission in the velocity range -2500 to +4000 km s^{-1}. A continuum image (b) centered near 4000 Å has been subtracted to cancel the stellar component. Individual pixels measure 3.0 arcsec (N-S) and 2.3 arcsec (E-W).

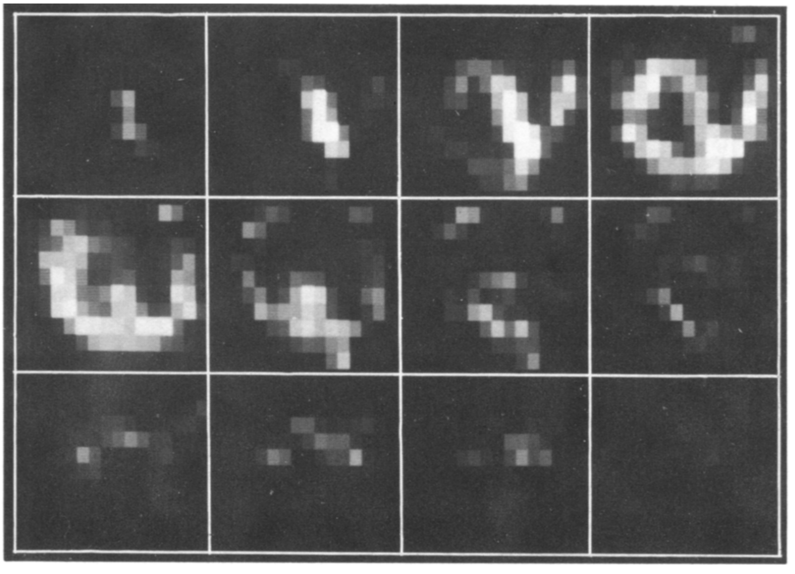

Fig. 3 A mosaic of 12 images, each corresponding to a velocity range of 520 km s^{-1}. The sequence begins at -2600 km s^{-1} (top left) and ends at +3640 km s^{-1} (bottom right). The stellar component (Figure 2b) has been subtracted. Pixel sizes are the same as Figure 2.

https://doi.org/10.1017/S0074180900033830 Published online by Cambridge University Press

shows that the velocity structure of the SNR is both highly ordered and complex. In particular, it is not consistent with a simple expanding shell of material. We have attempted to model the complex motions of the filaments in terms of an expanding ring of ejecta. Evidence for such rings has been found in three other oxygen-rich SNRs: N132D (Lasker 1980), Cas A (Markert, Canizares and Winkler 1981) and G292.0+1.8 (Tuohy, Clark and Burton 1982, Clark and Tuohy 1983). For 1E0102.2-7219 however,, the ring must be grossly distorted. We have allowed for this distortion by applying a sin 3θ deformation of varying amplitude to a simple planar ring, as summarized in Figure 4. While our mathematical model is idealized, approximate, and the uniqueness of the solution is not established, we find nevertheless that it gives an acceptable representation of the gross properties of the data.

The complex velocity structure of 1E0102.2-7219 provides compelling evidence for a high degree of asymmetry during the supernova explosion (assuming that the oxygen emission does in fact trace out the ejection pattern). As noted above, similar evidence has been found for three other members of the class (N132D, Cas A and G292.0+1.8), suggesting that

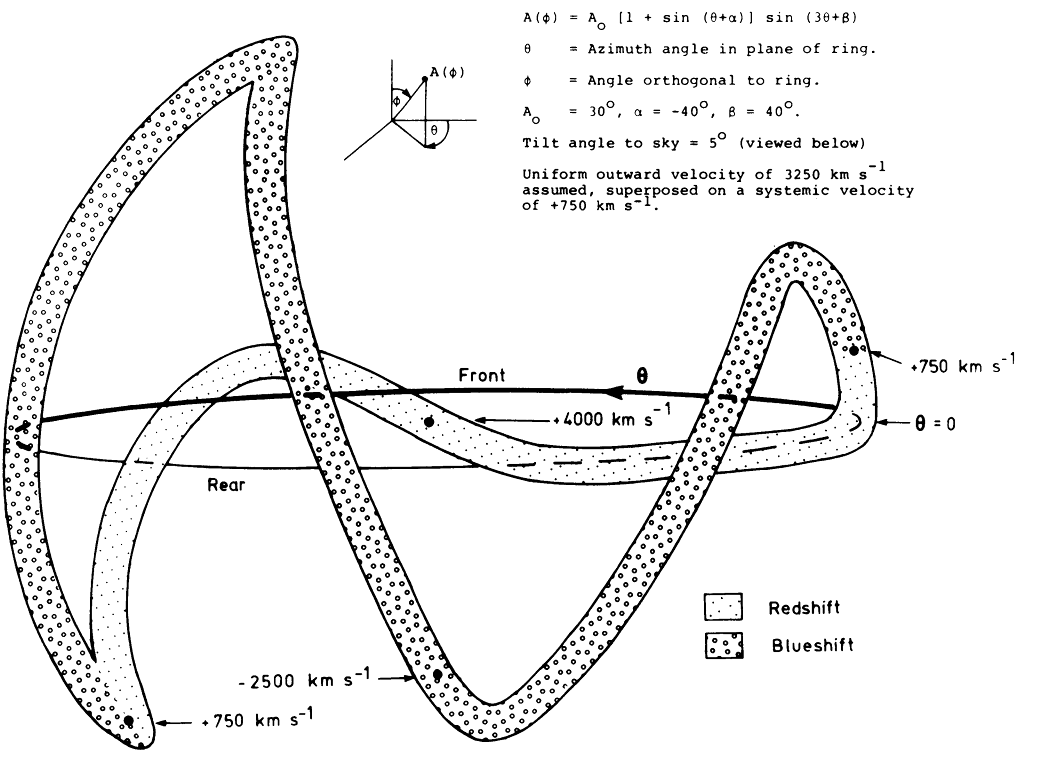

Fig. 4 A schematic representation of the distorted ring model of 1E0102.2-7219.

https://doi.org/10.1017/S0074180900033830 Published online by Cambridge University Press

non-spherical ejection may be an intrinsic property of Type II supernovae. We note that the ejection of a planar ring of oxygen-rich material can be understood in terms of the collapse of a massive (~25 $M_\odot$) rotating pre-supernova star (Bodenheimer and Woosley 1980, Woosley and Weaver 1982). The ejection of a distorted ring (if our modelling of 1E0102.2-7219 is valid) would appear to require an extension of this model; e.g., allowance for magnetized plasma instabilities.

2.2 The Halo Emission Region

A sky-subtracted spectrum was also obtained of the diffuse halo which is prominent to the east of 1E0102.2-7219. The halo spectrum (Figure 1b) has a typical Case B Balmer decrement of Hα:Hβ = 2.9:1.0, but the most unusual feature is the presence of the high excitation He II λ4686 line. There are two possible explanations for this unique association of a high excitation halo with an SNR. First, the halo may be a fossil HII region created by a UV flash accompanying the supernova. Second, modelling of radiative shocks in the oxygen-rich filaments by Dopita, Binette and Tuohy (1982) shows that a sufficient specific intensity of UV radiation (principally [OVI] λ150.1) can escape from the SNR itself and ionize the surrounding medium. We note in conclusion that HII regions have been detected in the vicinity of other oxygen-rich SNRs (Tuohy and Dopita 1982), suggesting that these may also be associated with the supernova events (or remnants).

REFERENCES

Bodenheimer, P.B., and Woosley, S.E.: 1980, Bull. Am. Astron. Soc., 12, 833.
Clark, D.H., and Tuohy, I.R.: 1983, this volume, p. 153.
Dopita, M.A., Tuohy, I.R., and Mathewson, D.S.: 1981, Astrophys. J. (Letters), 248, L105.
Dopita, M.A., Binette, L., and Tuohy, I.R.: 1982, in preparation.
Gull, S.F., and Daniell, G.J.: 1978, Nature, 272, 686.
Lasker, B.M.: 1980, Astrophys. J., 237, 765.
Markert, T.H., Canizares, C.R., and Winkler, P.F.: 1981, Talk presented at Colgate University, April 1981.
Seward, F.D., and Mitchell, M.: 1981, Astrophys. J., 243, 736.
Tuohy, I.R., Clark, D.H., and Burton, W.M.: 1982, Astrophys. J. (Letters) 260, L65.
Tuohy, I.R., and Dopita, M.A.: 1982, Astrophys. J. (Letters), in press.
Woosley, S.E., and Weaver, T.A.: 1982, Proc. NATO Advanced Study Institute on Supernovae, R. Stoneham and M. Rees, Cambridge, England, June-July, 1981, p. 791.