

## THE KINEMATICS OF THE SNR G292.0+1.8

R. Braun<sup>1</sup>, W.M. Goss<sup>2</sup>, I.J. Danziger<sup>3</sup>, A. Boksenberg<sup>4</sup>.

<sup>1</sup>Sterrewacht Leiden, The Netherlands

<sup>2</sup>Kapteyn Astronomical Institute, Groningen, The Netherlands

<sup>3</sup>European Southern Observatory, Garching bei München, F.R.G.

<sup>4</sup>Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, U.K.

## ABSTRACT

Optical velocity field mapping of G292.0+1.8 in the  $[OIII] \lambda 5007 \text{ \AA}$  line has been carried out using the IPCS with the 3.6 m ESO telescope at La Silla. Our data are not consistent with the suggestion that the  $[OIII]$  emitting material in the western portion of this remnant is concentrated in an expanding ring. The existing data on G292.0+1.8 suggests that only the brightest portion of a thick shell of ejecta with high velocity spurs is observed. The expansion centroid, size, velocity and age of this SNR are derived.

## INTRODUCTION

The SNR G292.0+1.8 was first found to be center-filled on the basis of radio observations at 21 cm (Lockhart et al. 1977), and similar structure has been recently observed at 843 MHz by Caswell (private communication) using the MOST telescope with an angular resolution of  $43''$  arc. Optical nebulosity was found in its vicinity (Goss et al. 1979) which showed strong oxygen and neon lines but virtually none of hydrogen, sulfur or nitrogen. Together with the high velocity dispersion ( $> 2000 \text{ km s}^{-1}$ ) of this material (Murdin and Clark 1979) a young SNR was indicated in which the optical emission was dominated by ejecta which had not yet experienced appreciable contamination by the ISM. To better understand the nature of this source optical velocity field mapping was carried out using the 3.6 m ESO telescope. Since this work began, the Einstein SSS spectrum (Clark et al. 1980) has suggested that the X-ray emission also arises within ejecta, while the HRI image (Tuohy et al. 1982) has been interpreted as evidence for an expanding ring of ejecta.

## OBSERVATIONS

A total of 15 spectra were obtained on 14-15 March 1980 using the IPCS detector with the 3.6 m ESO telescope and Boller and Chivens spectro-

graph at La Silla. The spectra were centered on  $[\text{OIII}] \lambda 5007 \text{ \AA}$  with resolution  $170 \text{ km s}^{-1}$  determined by the  $2''$  arc slit width. The slit had length  $2.9$  arc with a pixel separation of  $2.06$  arc. The slit orientation was east-west and each of the 15 spectra was displaced in declination (separation  $10'' - 20''$  arc) to define a grid containing most of the conspicuous emission features. The calibrated spectra were aligned into a 'data cube' (on the basis of stellar images and night sky lines) from which maps at fixed velocity were produced after subtracting the stellar images. Absolute velocities are accurate to within about  $\pm 20 \text{ km s}^{-1}$  and positions within about  $\pm 2''$  arc.

Three prominent features are apparent in these maps. The first is a fairly smooth component extending over the entire mapped field. This is centered at  $V_{\text{LSR}} \approx 0 \text{ km s}^{-1}$  and corresponds to the feature described by Murdin and Clark (1979). Secondly, an arc of emission is prominent at all velocities between about  $-700$  to  $+700 \text{ km s}^{-1}$  extending from the NE to the west central portion of the field. This feature is illustrated by the maps at  $V_{\text{LSR}} = -570$  and  $+285 \text{ km s}^{-1}$  shown in Figures 1a and 1b. Finally a southern spur is prominent at large positive velocities between about  $+700$  and  $+1200 \text{ km s}^{-1}$ . This feature is illustrated by the map at  $V_{\text{LSR}} = +850 \text{ km s}^{-1}$  in Figure 1c.

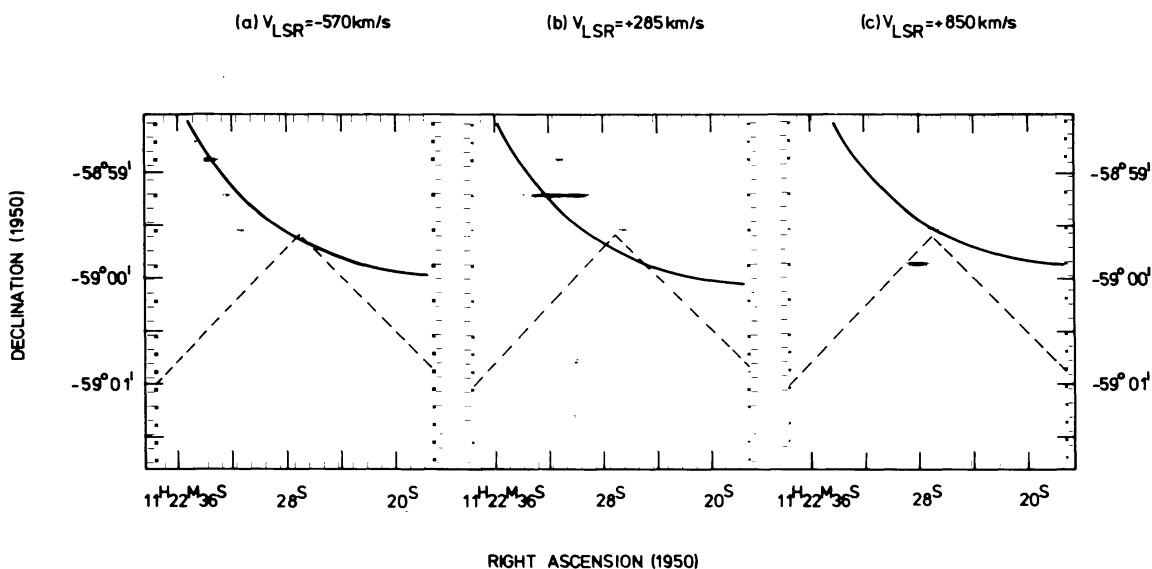


Figure 1.  $[\text{OIII}] \lambda 5007 \text{ \AA}$  emission maps of a portion of G292.0+1.8 in a  $142 \text{ km s}^{-1}$  interval centered at the indicated velocity. Shaded squares along the right and left hand edges indicate the positions of the spectra. The grey-scale is linear beginning from the  $5\sigma$  level. The curves are discussed in the text.

## DISCUSSION

To understand the significance of these features it is instructive to consider the  $[\text{OII}] \lambda 3727 \text{ \AA}$  interference filter photograph of this region obtained at the prime focus of the AAT (Murdin, private communication) shown in Figure 2. A portion of the same photograph also appears in Tuohy et al. (1982). Extended emission is indeed apparent over a large region. This emission is not centered on the SNR and may well not be physically related. The arc of emission sampled in our spectra is also prominent but is seen to have an extension to the west beyond the region sampled. This feature curves to the north again before disappearing. There are also weak filaments up to  $3.5'$  arc north of this 'southern rim' as well as a suggested extension of the rim to the NE. The southern spur is also apparent and is seen to extend to about  $4'$  arc south of the rim.

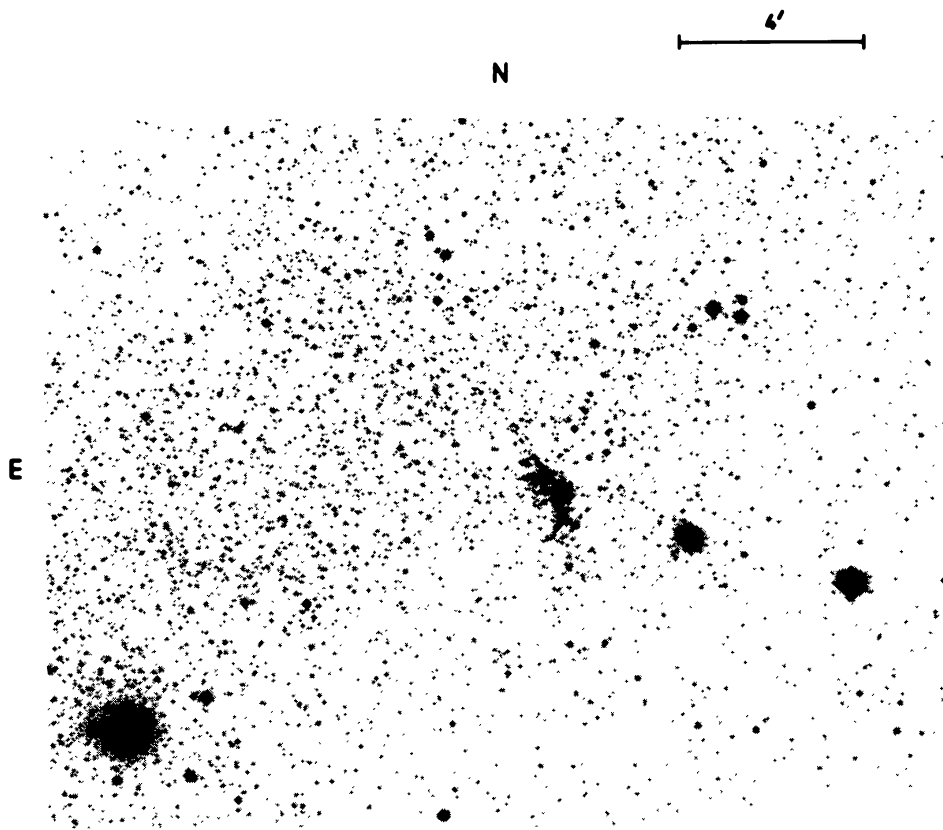


Figure 2.  $[\text{OII}] \lambda 3727 \text{ \AA}$  interference filter photograph of the region of G292.0+1.8 obtained at the prime focus of the AAT. The rectangle indicates the field of our velocity mapping study while the cross indicates the assumed expansion center.

Another valuable comparison is that with the X-ray image of Tuohy et al. (1982). The southern rim of oxygen line emission coincides with a series of prominent X-ray hot spots and these extend symmetrically even farther to the NW. (The radio map of Lockhart et al. (1977) also shows a weak extension at this position.) Other X-ray features include a weak counterpart to the optical southern spur and a prominent spur extending to the SW. It is perhaps noteworthy that the center of curvature of the southern rim is easily compatible with a radial extrapolation from the X-ray spurs.

What type of physical entity could give rise to the observed structure? The suggestion that the oxygen-rich material is concentrated in an expanding ring is not compatible with the kinematic data. The [OIII] emission features along the NE segment of the southern rim seen in Figures 1a and 1b clearly show that both strong red and blue-shifted emission are observed, contrary to what one would expect from the approaching or receding edge of a ring. However, the continuous southern rim feature is very suggestive of a portion of an expanding shell; while the two spurs appear to be instances of prominent breakout of high velocity ejecta beyond this region of more orderly expansion.

To investigate this possibility, all of our data excluding the region of the southern optical spur (indicated by the dashed line in Figures 1a,b and c) were used to model the expanding shell. A spheroid was fitted to the data (by least squares) to represent the positional and velocity information. The expansion center was fixed in position by the center of curvature of the southern rim as determined from both the [OII] emission of Figure 2 and the X-ray map of Tuohy et al. (1982) giving  $\alpha(1950) = 11^{\text{h}}22^{\text{m}}18^{\text{s}} \pm 2^{\text{s}}$ ,  $\delta(1950) = -58^{\circ}57'25'' \pm 15''$ . This position is indicated in Figure 2. The rest velocity was fixed at  $V_{\text{LSR}} = 0 \text{ km s}^{-1}$  since line-of-sight velocities at  $\ell^{\text{II}} = 292^{\circ}$  are within  $0 \pm 25 \text{ km s}^{-1}$  out to distances,  $d$  of 10 kpc. The derived radius and expansion velocity with respect to this center are  $R = 2.6 \text{ arc}$  and  $V = 2200 \text{ km s}^{-1}$ . If we assume a distance of 5.4 kpc (Goss et al. 1979) this corresponds to a radius  $R = 4.2 (d/5.4 \text{ kpc}) \text{ pc}$ . If the further assumption is made that the physical dimension along the line of sight is similar to that in the plane of the sky, the age of the remnant can be determined. Since negligible contamination of the ejecta has taken place (as indicated by the spectrum), it is appropriate to consider this material in free expansion, i.e.  $R = VT$ ; giving an age of about  $T = 1800 (d/5.4 \text{ kpc}) \text{ yr}$ .

The compatibility of the model with the data is illustrated by the histogram in Figure 3a, where volume emissivity  $E_v$  (defined as the number of observed samples in a spheroidal shell divided by the volume of the partial shell which was sampled) is plotted against normalized distance ( $D_n = 1$  corresponds to a sample lying on the solution spheroid). A single well-defined peak is observed with a halfwidth of about 0.9 ( $d/5.4 \text{ kpc}$ ) pc as opposed to the flat curve expected for data samples distributed randomly in position and velocity. The distribution of the southern spur emission features with respect to the model is illustrated in the same way in Figure 3b. A significant component is found associated with the

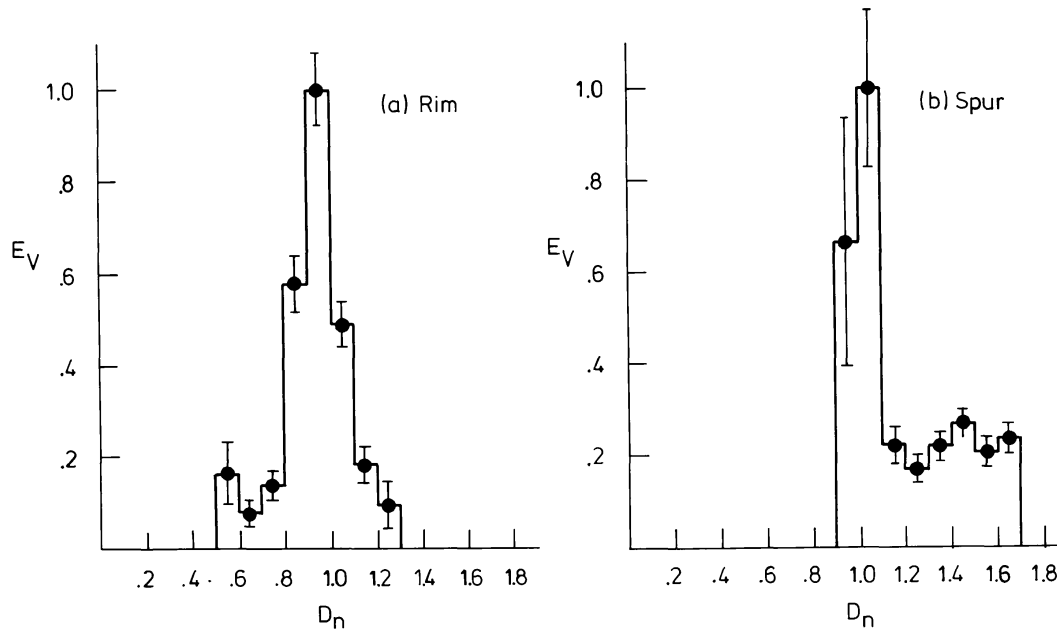


Figure 3. Histogram of volume emissivity as a function of normalized distance from the assumed expansion center for  $[\text{OIII}] \lambda 5007 \text{ \AA}$  emission features.

shell as well as the expected high velocity component which shows quite uniform filling. The model spheroid is also included as the solid curve in Figures 1a,b and c for direct comparison with the data.

This kinematic model is limited by the incomplete sampling. Future observations of the fainter features shown in Figure 2 would lead to a better determination of the expansion center as well as to a more precise knowledge of the total extent of the SNR. However, it is doubtful that the estimated age of the remnant would change dramatically since experimentation with movement of the assumed expansion center has shown that the inferred age of the remnant remains fixed to within about 10% of the quoted value.

The degree of consistency of this interpretation with the kinematic data gives strong support to its applicability. The implication is that there is a northern portion of this more extended remnant that remains to be studied. This explains in a natural way the peculiar radio and X-ray morphology observed.

Such asymmetry in brightness of opposite sides of a SNR is certainly not uncommon. In radio SNR it is quite common to encounter asymmetries of a factor of 10 or more. In particular, a remnant as young as Kepler's SNR ( $T=380 \text{ yr}$ ) shows a northern rim which is more than 10 times brighter in both the radio (Gull, 1975) and the X-ray (White and Long, 1982) than

the southern counterpart. A similar degree of asymmetry would be sufficient to explain the absence of corresponding structure in the present radio and X-ray observations of G292.0+1.8.

#### CONCLUSION

A consistent interpretation of the SNR G292.0+1.8 is possible if the 'southern rim' feature seen in [OII], [OIII], X-ray and radio observations is identified with part of an expanding shell of ejecta of finite thickness and the two spurs with high velocity ejecta which has broken out of this region of more orderly expansion. While this interpretation is suggested by the morphology, it receives strong support from the systematic velocities of the [OIII] emitting material discussed here. The center of curvature of this rim corresponds to  $\alpha(1950) = 11^{\text{h}}22^{\text{m}}18^{\text{s}} \pm 2^{\text{s}}$ ,  $\delta(1950) = -58^{\circ}57'25'' \pm 15''$ , while the derived parameters of a least-squares-fit spheroid with respect to this center are velocity  $V=2200 \text{ km s}^{-1}$ , radius  $R=4.2$  (d/5.4 kpc) pc halfwidth  $\Delta R=0.9$  (d/5.4 kpc) pc and age  $T=1800$  (d/5.4 kpc) yr.

#### ACKNOWLEDGEMENTS

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#### DISCUSSION

DOPITA: The oxygen rich SNR in the SMC shows evidence for a highly distorted expanding ring. Your analysis covers only part of the SNR and you have rejected a portion of the data. Can you therefore firmly reject the hypothesis of an expanding twisted ring to explain the dynamics?

BRAUN: Any form of simple expanding ring is ruled out by our observations. It is of course usually possible to construct an arbitrarily complex variation of some preferred model to explain an observation. This does not seem justified in this case where a reasonable and simple alternate explanation is sufficient.