CSIRO Publishing

Publications of the Astronomical Society of Australia

VOLUME 18, 2001

An international journal of astronomy and astrophysics

For editorial enquiries and manuscripts, please contact:
The Editor, PASA,
ATNF, CSIRO,
PO Box 76,
Epping, NSW 1710, Australia
Telephone: +61 2 9372 4590
Fax: +61 2 9372 4310
Email: Michelle.Storey@atnf.csiro.au

For general enquiries and subscriptions, please contact:
CSIRO Publishing
PO Box 1139 (150 Oxford St)
Collingwood, Vic. 3066, Australia
Telephone: +61 3 9662 7666
Fax: +61 3 9662 7555
Email: pasa@publish.csiro.au

CSIRO PUBLISHING

Published by CSIRO Publishing
for the Astronomical Society of Australia

www.publish.csiro.au/journals/pasa

Publ. Astron. Soc. Aust., 2001, 18, 259–266

Filamentary Shell Structures from the AAO/UKST Hα Survey

A. J. Walker[1], W. J. Zealey[1] and Q. A. Parker[2]

[1]Department of Engineering Physics, University of Wollongong, Northfields Avenue, Wollongong, NSW 2522, Australia
ajw01@uow.edu.au, b.zealey@uow.edu.au
[2]Institute for Astronomy, University of Edinburgh, Blackford Hill, Edinburgh EH9 3HJ, United Kingdom
qap@roe.ac.uk

Received 1999 April 21, accepted 2001 September 12

Abstract: Here we present the first results of a search for new optical supernova remnant candidates and other filamentary objects on films produced by the Anglo-Australian Observatory/UK Schmidt Telescope Hα Survey. Sixty-one fields, or 26% of the Galactic plane survey fields, have been visually examined. This has resulted in the detection of four new large diameter filamentary structures, and the discovery of extensive new optical emission in two previously known optical supernova remnant candidates.

Keywords: surveys — ISM: general — supernova remnants — [H II] regions

1 Introduction

Extensive radio surveys within our Galaxy have led to the discovery of 225 supernova remnants as of August 2000 (Green 2000). Of these a small number, including the Crab and Vela remnants, optically present us with a beautiful and complex picture of how the shock wave of a supernova interacts with the surrounding interstellar medium. By examining closely the relationships between the emission seen in different wavelengths, we can obtain a good picture of the processes occurring within the remnant. Most SNRs have been detected through their radio emission; optical counterparts are hard to find because of extinction.

Hα emission from gas in our Galaxy provides us with a picture of how the interstellar medium is being influenced by stars. This gas may be excited in a number of ways, chiefly by the radiation from hot stars, or the passage of shock waves from supernova explosions or strong stellar winds. The nebulae observed in Hα emission have a wide variety of morphologies. The emission may be diffuse, as seen in the Rosette Nebula, or filamentary, as seen in the Vela SNR. Partial or full shell structures are also often seen. Filamentary shell structures, the focus of this work, may be produced by Wolf–Rayet stars, Of and O(f) stars, the central stars of planetary nebulae, and by supernova explosions.

All known optical SNRs, apart from the oxygen rich class (Weiler & Sramek 1988), emit in the Hα line, as well as the [N II] 6548, 6583 Å lines. These are produced in regions behind the shock front, due to post shock cooling of the excited gas. The Hα survey will cover these lines and is well suited for SNR searches.

The AAO/UKST Hα Survey (Parker, Phillips & Morgan 1999) has the potential to reveal fainter filamentary emission at a higher resolution than previously possible in a wide-field survey. This will improve our knowledge and understanding of optical SNRs and other filamentary structures such as Wolf–Rayet shells by increasing the number and variety available for further study. We have recently commenced two projects. The first, the subject of this paper, is to visually examine survey films to discover new objects classifiable as SNR candidates based on their optical morphology, along with other shell structures. The second is to examine fields of known radio SNRs for optical emission (Walker & Zealey 1998).

Previous SNR searches have concentrated on known objects identified in other wavebands. This work covers the entire southern Galactic plane out to $|b| = 10°$ for the first time optically. The use of Tech Pan film and the Hα interference filter allows the detection of finer and fainter detail than any previous large area search (Parker & Phillips 1998).

In order to ensure completeness of any SNR survey, future optical and radio searches will need higher sensitivities, and will need to be responsive to a wide range of angular scales, from sub arcsecond to several tens of degrees. The Hα survey goes some way to meeting these requirements for our local region out to 4–5 kpc. Optical detections combined with radio observations will provide a more detailed picture of the nature of these objects.

1.1 Wind-blown Shells and Planetary Nebulae

Two hundred and twenty-seven Wolf–Rayet stars are known within the Galaxy (van der Hucht 2000). These hot, massive young stars have broad emission lines in their spectra from He I and He II, along with various lines from excited states of carbon, oxygen and nitrogen. Of and O(f) stars are massive O stars which also exhibit a range of broad and narrow emission lines. Both of these types have strong stellar winds, typically $v_w = 10^3 - 4 \times 10^3\,\mathrm{km\,s^{-1}}$ and $\dot{M} = 10^{-6} - 10^{-4} \mathrm{M}_\odot\,\mathrm{yr}^{-1}$ (Lozinskaya 1992). The stellar wind interacts with the surrounding ISM, which will include matter previously ejected by the star. Optical ring structures resulting from this interaction

10.1071/AS01063 1323-3580/01/03259$05.00

have been observed around many of these stars. Details on searches around Wolf–Rayet stars can be found in Heckathorn, Bruchweiler & Gull (1982), Miller & Chu (1993), Marston, Chu & Garcia-Segura (1994a), Marston et al. (1994b), and Marston (1997), in which it is concluded that more than one-third of Galactic Wolf–Rayet stars are associated with nebulae. A study of nebulae associated with Of stars (Lozinskaya 1992 and references therein) discovered ring nebulae associated with 12 stars.

Driven by the stellar wind, these nebulae may expand to over 100 pc in size. Those observed in our Galaxy are mainly between 5 and 20 pc in size (Chu 1992). Their angular diameters vary from a few arcminutes to a few degrees.

Planetary nebulae may also exhibit filamentary structure. Some of their main properties of relevance here are widely varied morphologies; spectra similar to H II regions; hot, low mass central stars, mainly early O-type stars, Of stars, and Wolf–Rayet stars; and a size of ~0.8 pc (Kaler 1985; Kitchin 1987). Their progenitors are normally evolved asymptotic giant branch stars.

The largest known planetary nebula, the Helix Nebula, is $15'$ in diameter. However, the majority of those known are under $1'$ in size. All of the objects presented in this work are of a larger size and are not planetary nebula.

A search for planetary nebulae using an Hα survey is being undertaken by Parker et al. (1999) in the Galactic plane. So far they have discovered over 700 candidates from 50% of the survey. Confirmatory spectroscopy has already been obtained for over 300 of these.

1.2 Supernova Remnants

Supernovae result from the core collapse of stars more massive than $\sim 3M_\odot$ (types Ib, II), or the explosion of a white dwarf due to accretion leading to the star exceeding the Chandrasekhar limit (type Ia). Material in the surrounding ISM is heated by the expanding shock wave producing filamentary shell structures in optical emission. They may be visible for a few times 10^5 years. The largest of these are over 100 pc in size. A summary of the physical parameters of several well studied optical SNRs in our Galaxy is given in Lozinskaya (1992).

The optical morphology and spectra of known SNRs shows a great variety of types which depend on:

- the type of supernova outburst
- the influence of any stellar remnant
- the nature of the surrounding ISM
- a contribution from circumstellar material from the progenitor star
- the evolutionary stage of the remnant

Mathewson et al. (1983) have shown from a study of SNRs in the Magellanic Clouds that they can be separated into four classes: Balmer-dominated, oxygen-rich, plerionic-composite, and evolved, that we detail below. Weiler & Sramek (1988) propose a fifth class, centrally-influenced. Details on individual objects may be found in Lozinskaya (1992) and Green (2000).

The Balmer-dominated remnants of Tycho, Kepler, and SN 1006 are believed to result from type Ia supernova, however the Ib class cannot be ruled out. Their spectra are strong in the hydrogen Balmer lines, but weaker in [S II], [N II], and [O III] than the typical evolved case. This results from a non-radiative shock meeting partially neutral gas (Chevalier & Raymond 1978).

Oxygen-rich remnants are distinguished by the presence of filaments with strong [O III] lines and, in many cases, lines of neon, argon, and sulphur. The most studied example is Cassiopeia A; the spectra of its fast moving knots vary widely from feature to feature (Chevalier & Kirshner 1979). This material is ejecta from the explosion of a massive star, most probably within the last 2000 years (Lozinskaya 1992). Other examples are G292.0+1.8, Puppis A; N132D and 0540-69.3 in the LMC; 1E 0102.2-7219 in the SMC; and an unresolved source in NGC 4449.

Plerionic and plerionic-composite remnants are classified as having filled-centre radio emission with a flat spectral index. Plerion-composite remnants have in addition an outer shell with a steeper spectral index (e.g. Weiler 1983; Weiler & Sramek 1988). The main examples of the plerion class are the Crab Nebula and 3C 58 (SN 1181). Vela XYZ and W 28 are plerionic-composites. Many of these have been shown to be strongly influenced by a pulsar, which may be true for the class as a whole. Optically these two classes display extended and filamentary emission throughout their centre.

The evolved remnants encompass the majority of known SNRs and may represent the final state of the other younger classes. They exhibit clear shell structure in the optical and radio, and their optical spectra are dominated by Hα, [S II], and [N II] emission, produced by cooling behind the shock front. One of the best studied objects of this class is the Cygnus Loop.

1.2.1 Previous Optical SNR Searches

The most recent catalogue of Galactic SNRs (Green 2000) presents information on 225 SNRs. Of these 156 are located in the southern sky. Optically, 20 of these SNRs have been detected in the southern sky compared with 31 in the northern sky. The smaller ratio in the southern sky is due to greater obscuration. By making deeper observations a greater proportion of these southern SNRs should be optically visible.

The first known SNRs were the brighter and closer objects such as the Crab and Vela remnants, of which several had obvious optical counterparts. Great advances in the sensitivity and resolution of radio surveys, especially in the late 1960s and more recently using interferometers, e.g. the Molongolo Observatory Synthesis Telescope (MOST) (Whiteoak & Green 1996), has resulted in most objects now being discovered by their radio emission.

Searches have been made to detect optical emission from radio SNRs. The earliest comprehensive work was by van den Berg, Marscher & Terzian (1973) where the 24

https://doi.org/10.1071/AS01063 Published online by Cambridge University Press

then optically identified SNRs are detailed. Further identifications were made by van den Bergh from the late 1970s (van den Bergh 1976, 1978, 1979, 1980). Another search from 1977 onwards, using UKST IIIaF and IIIaJ plates (Zealey, Elliot & Malin 1979), resulted in the first optical detection of many southern SNRs. Since then several other remnants have been optically identified, primarily through narrow band CCD imaging. References to these can be found in Green (2000).

1.3 Discrimination between Formation Mechanisms

1.3.1 Optical Morphology as a Discriminator

Optical morphology can provide clues to the origin of filamentary structure, but it is only a guide. The presence of small knots and condensations, for instance, suggests ejected material associated with an oxygen-rich SNR, but this morphology may also be seen in Wolf–Rayet shells and planetary nebulae. The presence of filaments and diffuse emission throughout the centre may possibly indicate a plerionic object. Objects seen as partial or complete shell structures with a large angular size strongly suggest an evolved remnant. The effects of differing extinction levels and ISM structure from object to object makes classification from optical morphology alone impossible. In general optical spectroscopy, narrow-band imaging, and a radio spectral index are needed to reveal the true nature of filamentary objects.

1.3.2 Spectral Discrimination

In parallel with morphology, spectral information from radio and infrared observations can also be used to discriminate between the possible sources of the observed emission. The radio emission of SNRs is produced by the synchrotron emission of relativistic electrons. This is nonthermal, and can be fitted by a power law $S_\nu \propto \nu^\alpha$, with $-0.8 \le \alpha \le 0$ (Lozinskaya 1992). H II regions have a thermal spectrum, with $\alpha \sim 0$. Separation of the two processes can be made by direct measurement of the spectral index α. Linear polarisation also indicates that the radio emission is synchrotron.

Better discrimination can often be made by comparing the 60 μm and radio emission from shells. Broadbent, Osborne & Haslam (1989) have shown a correlation between IRAS 60 μm emission from the Galaxy and radio continuum emission. From this it has been shown that the 60 μm to radio flux density ratio is high for H II regions and low for SNRs, with both types being well separated. This method has been used with great success (e.g. Whiteoak & Green 1996) to identify SNR candidates.

2 The UKST Hα Survey

The Hα survey began in July 1997 on the UKST. Using 4° fields, 233 fields will cover the southern Galactic plane to a latitude of $|b| \le 10°$, and 40 will be used for the Magellanic Clouds. Each exposure uses a 356 × 356 mm glass Hα interference filter with a central wavelength of 6590 Å and a FWHM bandpass of 70 Å. Although 6.5° × 6.5° is imaged on each film, the filter is optimal within a circular diameter of 5.5°, and hence the usual 5° fields would not provide full coverage in the survey area. The three-hour exposures are taken on Tech Pan film, which offers improved sensitivity at the Hα wavelength and improved resolution in comparison with previous UKST R band surveys which used IIIaF emulsion. Further details of the survey and film are given Parker & Phillips (1998). The filter is described in Parker & Bland-Hawthorn (1998).

In February 1998 we began a systematic search of films produced by the Hα survey. Films badly affected by trailing, poor focus, weather or other factors have not been closely examined as they will be repeated at a later date.

After an initial quick look to identify obvious large emission features, each film was visually scanned using a wide angle magnifying lens. This involved scanning horizontally across the film, working from the bottom of the field to the top, and ensuring that each strip overlapped so that no area was missed.

A wide variety of non-stellar objects are imaged on each film, primarily galaxies, planetary nebulae, and diffuse H II regions. SNRs and Wolf–Rayet shells optically have a filamentary appearance, and so can in general easily be distinguished from the above.

Digitised images of each object were then obtained, using an HP desktop scanner with transparency attachment. Approximate x–y positions of each object were measured off the film. These were entered into the UKST program PLADAT to obtain rough RA and Dec values. Using STScI Digitised Sky Survey images and the Karma program (Gooch 1996), each digitised image had a J2000 coordinate system attached to it. From this accurate positions were obtained for each object's centre and sizes were determined.

3 Discoveries

The most interesting class of objects identified are those over 30′ in extent, with a filamentary appearance and a partially annular structure. At 5 kpc these objects would have diameters in excess of 40 pc. The larger of these are more likely to be identifiable as SNRs, Wolf–Rayet or stellar wind shells, to be relatively close, and to be identifiable in other surveys.

From the fields examined so far, six such large objects have been identified. Two of these have been previously identified as SNR candidates from their optical emission, however they have been poorly studied and the Hα survey has revealed far more extensive emission than previously recognised. A summary of these objects is presented in Table 1.

In addition we have identified many faint, isolated filaments under 10′ in extent. Very few are identifiable with known objects. Unless identified as thermal through a large infrared flux or their radio spectral index, the best way of identifying these objects will be through

https://doi.org/10.1071/AS01063 Published online by Cambridge University Press

Table 1. Filamentary structures

Object	R.A. (2000.0)	Dec. (2000.0)	Approximate size	Comments
G245.9+0.9	$08^h00.5^m$	$-28°30'$	$1°20'$	New WR shell
G296.2−2.8	11^h47^m	$-64°50'$	$1°$	–
G304.7−3.1	13^h08^m	$-65°56'$	$1°$	θ Mus
G310.2−2.8	14^h00^m	$-64°45'$	$1° \times 1°30'$	–
G340.5+0.7	16^h46^m	$-44°25'$	$20'$	Possible SNR
Kes 45	16^h56^m	$-43°45'$	$1°30'$	Possible SNR

Positions given are geometric centres of the observed emission.

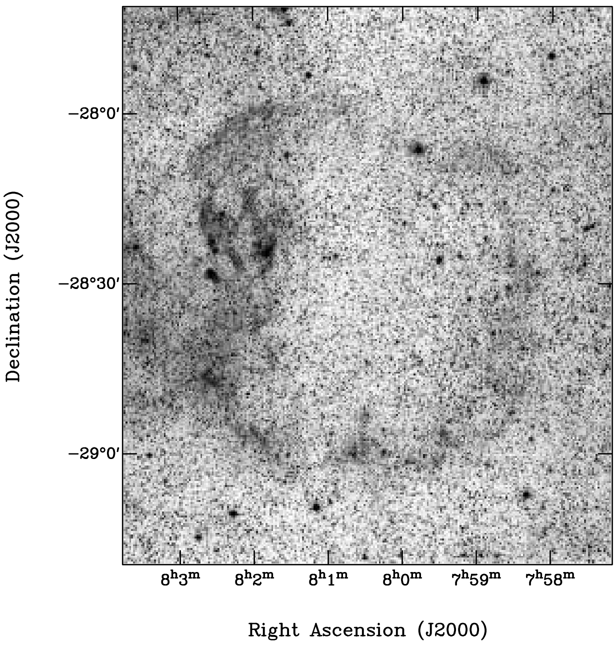

Figure 1 G245.9+0.9.

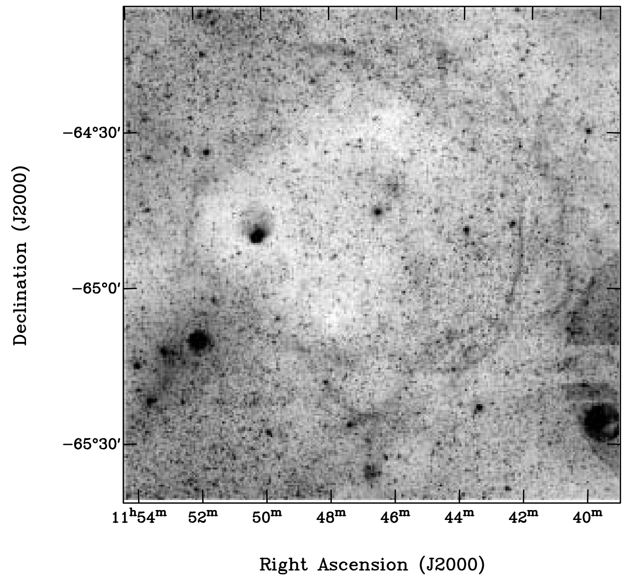

Figure 2 G296.2−2.8.

deep imaging to reveal their full extent followed up with spectroscopy.

3.1 G245.9+0.9

This object is very faint on the original film. Computer enhancement shows a large amount of filamentary structure forming a full shell 1° in diameter (Figure 1). The emission is stronger towards the east. Radio continuum observations with the MOST at 843 MHz with resolution $43'' \times 43''$ cosec$|\delta|$ detected no significant radio emission from the object. However, it is visible, though faint and fragmentary, in 60 μm images from IRAS (Beichman et al. 1985). From this there is a strong likelihood that the object is an H II region.

The Wolf–Rayet star HD 65865 lies interior to the shell at $7^h59^m46^s$, $-28°44'$ (J2000), which is about $20'$ from the shell's geometrical centre. It has the spectral type WN5 and a distance of 4.61 kpc (van der Hucht 2000). This would imply a shell diameter of 107 pc if the shell is produced by this star, which lies within the range of shell diameters expected for Wolf–Rayet stars given by Marston (1997), from 1.3 pc to 180 pc.

3.2 G296.2−2.8

Here a nearly complete shell structure over 1° in diameter is visible (Figure 2). Some very fine and extended filaments exist along its western edge. A large amount of obscuration is evident interior to the shell. The bright nebula IC 2966 is also located within the shell at $11^h50^m15^s$, $-64°51'$ (J2000). Brand et al. (1986) list the nebula as BBW 374 in their catalogue. From CO measurements (Brand et al. 1987; Brand et al. 1993), the distance to IC 2966 is 3.28 kpc. Inside the nebula is the star VBH 56a (van den Bergh & Herbst 1975). It is of spectral type B0.5V, $V_0 = 11.47$, $V_0 - M_V \sim 12.7$, giving d $\sim$ 3.5 kpc. This indicates the star may be exciting IC 2966 but probably not the larger surrounding shell. If an association is real, using the distance to IC 2966 gives a size of ~60 pc for G296.2−2.8.

A number of possible scenarios may explain the nature of this object:

1. The interaction of an SNR in the line of sight of the dark cloud and the cloud could produce a ring of filamentary emission.

https://doi.org/10.1071/AS01063 Published online by Cambridge University Press

2. The filamentary emission may represent a photodissociation region produced as the cloud is exposed to ionising radiation from a nearby source.
3. The filamentary shell may be the result of an SNR associated with the dark cloud.
4. The star VBH56a may be responsible for the bright nebula IC 2966 and the larger 1° shell, though the energetics make this unlikely.

A similar, but much closer object that may be compared with G296.2−2.8 is the Coalsack Loop (Walker & Zealey 1998), where a 10° ring of Hα emitting nebulosity surrounds the Coalsack Nebula. This loop is estimated to be between 33 pc and 43 pc in diameter. In this case weak radio emission has been identified with the shell, but there is again no obvious exciting source of the shell.

3.3 G304.7−3.1

G304.7−3.1 is an arc of filamentary emission (Figure 3) about 1° in size. The brightest of its filaments are towards the southwest, additional faint filaments can be seen extending outside the figure to the northeast. These appear to be part of the northern edge of a larger diffuse emission feature which is clearly visible both optically and in the Parkes-MIT-NRAO (PMN) 4850 MHz survey (Griffith & Wright 1993). This diffuse optical emission directly overlays the radio emission which forms the 9° radio/Hα shell G303.5+0 surrounding the Coalsack (Duncan et al. 1995; Walker & Zealey 1998). The sharp filaments lie just inside this shell and may be part of the same shell.

These filaments have been associated with the WC6 type Wolf–Rayet star θ Mus (HD 113904) (Heckathorn et al. 1982) which lies about 30′ to the north. Its distance has been measured as 2.27 kpc (van der Hucht 2000). Imaging and spectroscopy (Giménez de Castro & Niemela 1998) show the filaments to be bright in Hα and [O III] while weak in [S II], and to have line ratios consistent with H II regions.

As the visible structure forms only a small part of a possible shell, an association with θ Mus must remain uncertain.

3.4 G310.2−2.8

The extensive isolated emission of this object is the most unusual in our sample. A main body of faint filamentary emission is seen to extend for ∼1.5°, along with two small patches of emission separated from this by ∼20′ (Figure 4). This object is visible in the PMN radio survey, one of the small Hα filaments corresponding with bright extended radio emission at $13^{h}55.5^{m}$, −64°35′ (J2000). The filament appears projected on the large 2.7° × 3.5° radio shell G310.5−3.5 (Duncan et al. 1997), and so we may be seeing optical emission from the front or back edge of the shell. In addition images taken with Mike Bessell's wide field imaging equipment at Siding Spring Observatory (Buxton, Bessell & Watson 1998) clearly show the optical emission in Hα and [S II] (6716 Å, 6731 Å), indicating the presence of shock excited material. This region has been imaged with the Australia Telescope Compact Array (ATCA) (Roy Duncan 1998, private communication), showing the presence of polarised and non-thermal emission.

A radio image of the region, centred on $13^{h}57^{m}31^{s}$, −63°54′ (J2000), has also been obtained on 3 April 1997, using MOST (Figure 5) at a frequency of 843 MHz in its wide-field mode. In this mode the field size is 163′ × 163′ cosec $|\delta|$, the rms noise level is 1–2 mJy beam^{-1}, and the resolution (FWHM) is 43″ × 43″ cosec$|\delta|$. Further details of the MOST telescope and its operating modes are given in Bock, Large & Sadler (1999) and references therein. Diffuse emission is visible over about 10′ diameter at the same location as seen in the PMN radio survey, peaking at ∼5–7 mJy beam^{-1}. A faint arc of emission is visible just north of this at declination −64°20′. This image structure is very similar to that seen with the ATCA. The lines across

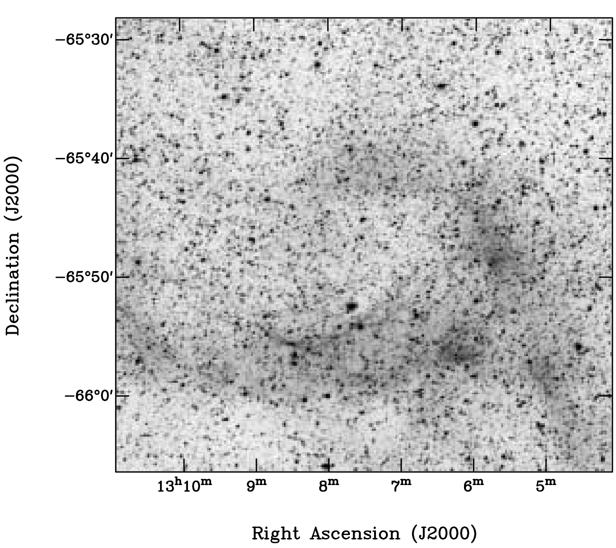

Figure 3 G304.7−3.1.

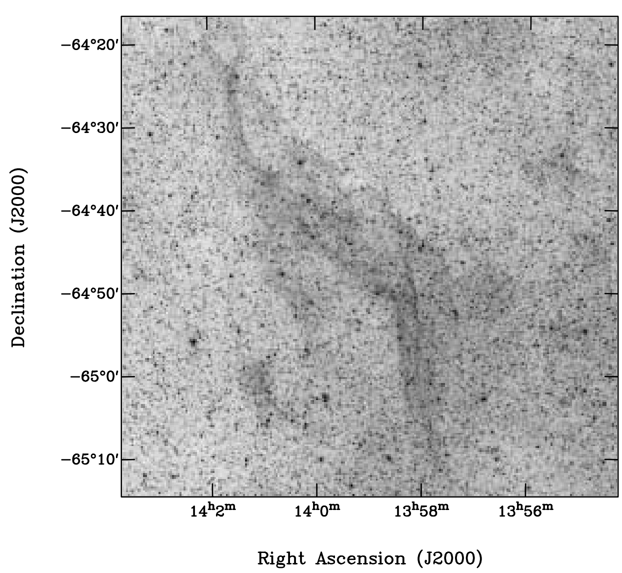

Figure 4 G310.2−2.8.

https://doi.org/10.1071/AS01063 Published online by Cambridge University Press

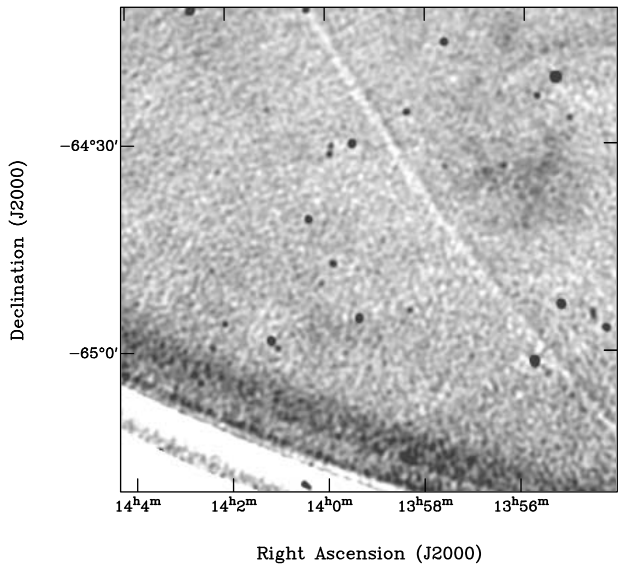

Figure 5 MOST image of G310.2−2.8.

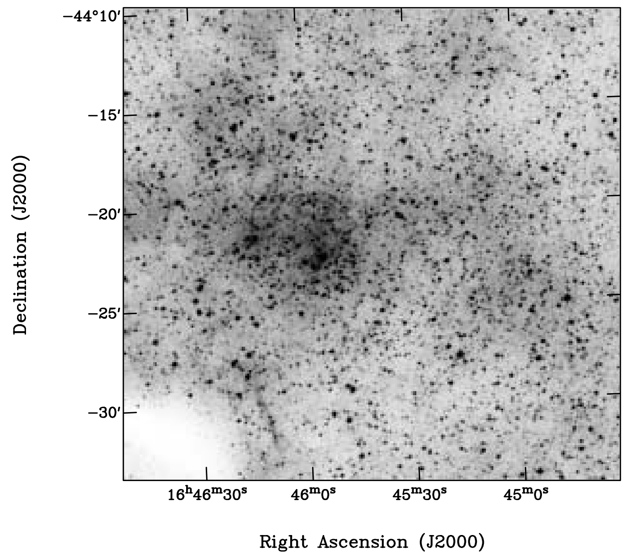

Figure 6 G340.5+0.7.

the middle and along the bottom are grating ring artifacts from bright radio sources.

The general impression is that the diffuse optical emission matches radio features at $13^{h}55.5^{m}$, $-64°35'$ and possibly at $14^{h}00^{m}$, $-65°$. However the crisp filamentary structure visible optically has no counterpart in the radio. Further work on this object will be needed with improved sensitivity and resolution in order to detect its full extent and to establish a link between the optical and radio emission. While it is clear that we are seeing an SNR in radio emission, a physical link with the optical emission needs to be established.

3.5 G340.5+0.7

Zealey et al. (1979) noted the presence of optical filaments west and northwest of the teardrop shaped globule Barnard 235 near the SNR G340.4+0.4. An image of this region obtained for the Hα survey shows very clearly this brighter filament, whose shape closely matches the shape of the edge of the globule, and fainter filaments to the northwest of this filament (Figures 6 and 7). Additional filaments are located to the north of the bright filament in a region of enhanced emission (Figure 8). Some very faint features below this emission region can only be seen on the film.

The arc of emission close to the globule could be due to photoionisation by a nearby source or a supernova shock. The associated filamentary emission to the north, well away from the globule, makes a supernova shock more likely. It is possible that we are seeing extended emission from the western edge of a shell structure $\sim 20'$ in size. Unfortunately no related emission is visible in available radio surveys or IRAS data.

3.6 Kes 45

Kes 45 (G342.1+0.1, MSH 16-48, MHR 58) is a $30'$ diameter radio source located at $16^{h}53^{m}46^{s}$, $-43°35'$ (J2000).

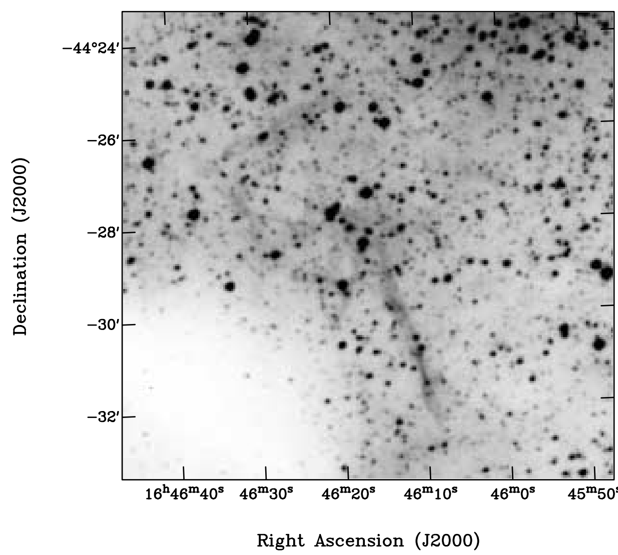

Figure 7 Closeup of southeast quadrant of G340.5+0.7.

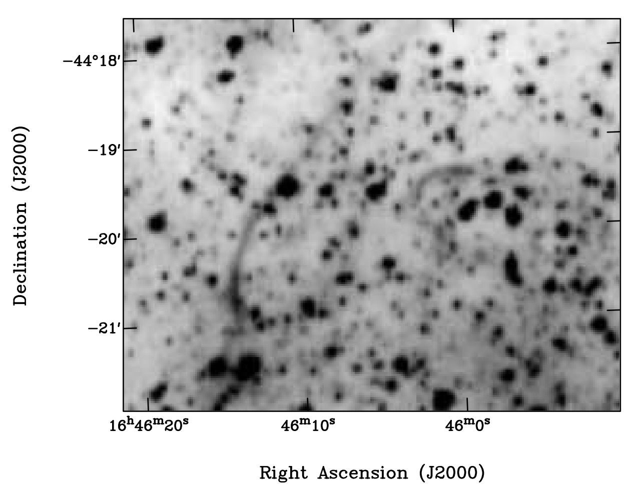

Figure 8 Closeup of northeast quadrant of G340.5+0.7.

https://doi.org/10.1071/AS01063 Published online by Cambridge University Press

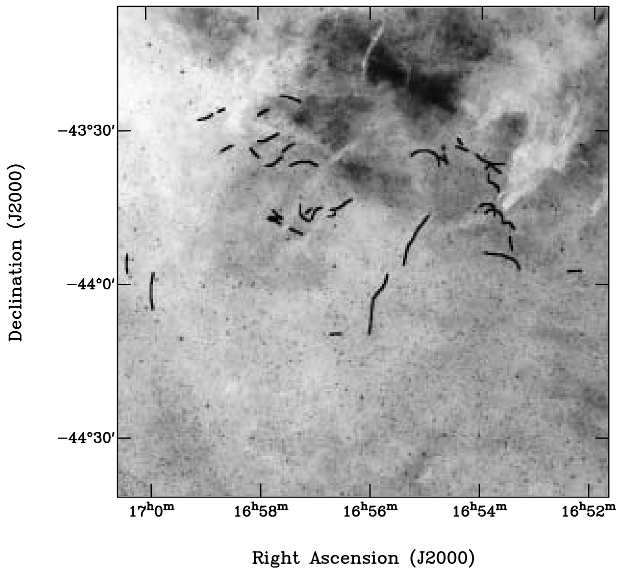

Figure 9 Diagram showing major filamentary structures in the Kes 45 region.

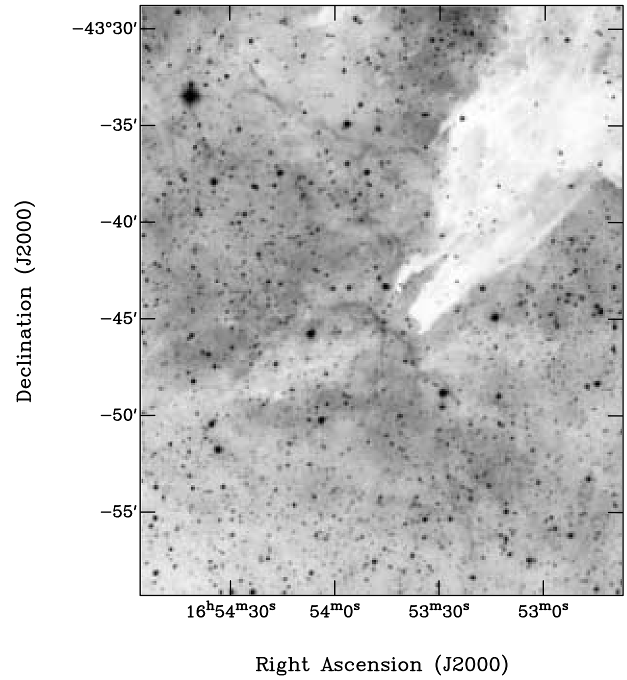

Figure 10 Closeup of central western section of Kes 45.

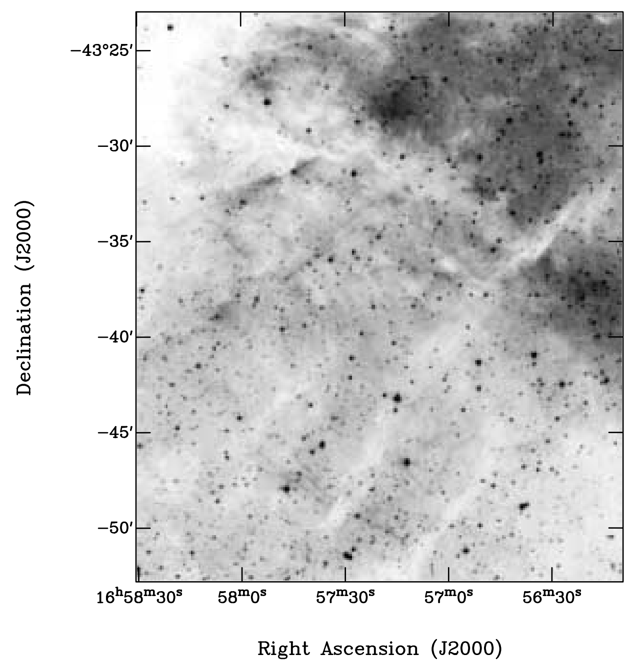

Figure 11 Closeup of northeast quadrant of Kes 45.

It has been considered an SNR based on its spectral index $\alpha = -0.50$ at 1 GHz (Milne 1970), although subsequently it has been lost from SNR catalogues.

Improved resolution radio observations (Caswell & Clark 1975) resolved several sources in this region. Two of these, G341.9−0.3 and G342.0−0.2, are now known to be SNRs. However, as noted, the low frequency flux density of these sources is much less than the MSH flux density (Mills, Slee & Hill 1960), so an extended object is likely to be present.

Optically, images of the region show a network of filaments over an area 30′ in diameter (van den Bergh et al. 1973; Zealey et al. 1979) interacting with elephant trunk structures (Frieman 1954), instabilities that can form in expanding shock and ionisation fronts. Spectra in the visible region (Danziger & Dennefeld 1974; Danziger & Dennefeld 1976) indicate enhanced [S II] emission relative to Hα and weak [O III] 5007 Å emission, but the underlying H II region makes any interpretation very difficult.

Hα survey images show filamentary emission covering an area 1.5° in diameter. The main features are indicated in Figure 9. In Figure 10 a closeup is shown of the western group of filaments identified by van den Bergh et al. (1973). These filaments indicate an association with a dark cloud in the shell of NGC 6231. New features include two filaments to the east located near $17^{h}00^{m}$, $-44°00'$ (J2000), and a large number of filaments to the northeast, a section of which is shown in Figure 11.

If these optical filaments represent a single object, then the diameter, assuming an association with the NGC 6231 H II region to the north (Zealey et al. 1979), becomes 36 pc.

The combination of size, extensive optical emission and low radio flux indicate that Kes 45 is in an advanced state of evolution.

4 Conclusions

Using films from the AAO/UKST Hα Survey we have identified four large filamentary shell structures, one of these a new possible Wolf–Rayet shell, and new optical emission in two known SNR candidates. These objects are:

- G245.9+0.9, a faint 1°20′ optical shell surrounding the Wolf–Rayet star HD 65865

- G296.2−2.8, a 1° optical shell with interior absorption, possibly associated with the star VBH 56a
- G304.7−3.1, an arc of filamentary emission on the edge of a larger shell structure, and likely associated with θ Mus
- G310.2−2.8, a filamentary structure with an unusual morphology and associated radio emission
- G340.5+0.7, a small patch of optical filaments
- Kes 45, a system of optical filaments 1.5° in diameter, which has long been suspected as an SNR

Techpan film used with the new Hα filter is detecting fainter and more distant filamentary structures in comparison with previous photographic surveys, due to the improved spatial resolution, red sensitivity of the film, and narrow bandpass of the filter.

Based on the discovery rate and survey completion, we expect that 16 or more large filamentary structures may be discovered by this survey.

Acknowledgments

We would like to thank the UKST staff for obtaining and making available the films used in this work, and providing the opportunity for A. Walker to observe at the UKST during the first half of 1998. We would also like to thank the referees whose helpful comments greatly improved this paper. The Digitised Sky Surveys were produced at the Space Telescope Science Institute under US Government grant NAG W-2166 based on photographic data obtained using the Orsin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. The UK Schmidt Telescope was operated by the Royal Observatory Edinburgh, with funding from the UK Science and Engineering Research Council until 1988 June, and thereafter by the Anglo-Australian Observatory. The MOST is operated by the University of Sydney with support from the Australian Research Council and the Science Foundation for Physics within the University of Sydney.

References

Beichman, C. A., Neugebauer, G., Habing, H. J., Clegg, P. E., & Chester, T. J. 1985, IRAS Explanatory Supplement (Pasadena: Jet Propulsion Laboratory)
Bock, D. C.-J., Large, M. I., & Sadler, E. M. 1999, AJ, 117, 1578
Brand, J., & Blitz, L. 1993, A&A, 275, 67
Brand, J., Blitz, L., Kerr, F. J., & Wouterloot, J. G. A. 1987, A&AS, 68, 1
Brand, J., Blitz, L., & Wouterloot, J. G. A. 1986, A&AS, 65, 537
Broadbent, A., Osborne, J. L., & Haslam, C. G. T. 1989, MNRAS, 237, 381
Buxton, M., Bessell, M., & Watson, B. 1998, PASA, 15, 24
Caswell, J. L., & Clark, D. H. 1975, Aust. J. Phys. Astrophys. Suppl., 37, 57
Chevalier, R. A., & Kirshner, R. P. 1979, ApJ, 233, 154
Chevalier, R. A., & Raymond, J. C. 1978, ApJ, 225, L27
Chu, Y.-H. 1992, in The Astronomy and Astrophysics Encyclopedia, ed. S. P. Maran (New York: Cambridge University Press), 244
Danziger, I. J., & Dennefeld, M. 1974, A&A, 36, 149
Danziger, I. J., & Dennefeld, M. 1976, PASP, 88, 44
Duncan, A. R., Stewart, R. T., Haynes, R. F., & Jones, K. L. 1995, MNRAS, 277, 36
Duncan, A. R., Stewart, R. T., Haynes, R. F., & Jones, K. L. 1997, MNRAS, 287, 722
Frieman, E. A. 1954, ApJ, 120, 18
Giménez de Castro, C. G., & Niemela, V. S. 1998, MNRAS, 297, 1060
Gooch, R. E. 1996, PASA, 14, 106
Green D. A. 2000, A Catalogue of Galactic Supernova Remnants (2000 August version), Mullard Radio Astronomy Observatory, Cavendish Laboratory, Cambridge, United Kingdom (http://www.mrao.cam.ac.uk/surveys/snrs)
Griffith, M. R., & Wright, A. E. 1993, AJ, 105, 1666
Heckathorn, J. N., Bruchweiler, F. C., & Gull, T. R. 1982, ApJ, 252, 230
Kaler, J. B. 1985, ARA&A, 23, 89
Kitchin, C. R. 1987, Stars, Nebulae and the Interstellar Medium (Bristol: IOP)
Lozinskaya, T. A. 1992, Supernovae and Stellar Winds in the Interstellar Medium (Chicago: AIP)
Marston, A. P. 1997, ApJ, 475, 188
Marston, A. P., Chu, Y.-H., & Garcia-Segura, G. 1994a, ApJS, 93, 229
Marston, A. P., Yocum, D. R., Garcia-Segura, G., & Chu, Y.-H. 1994b, ApJS, 95, 151
Mathewson, D. S., Ford, V. L., Dopita, M. A., Tuohy, I. R., Long, K. S., & Helfand, D. J. 1983, in Supernova Remnants and their X-ray Emission, IAU Colloquium 101, ed. J. Danziger, & P. Gorenstein (Dordrecht: Reidel), 541
Miller, G. J., & Chu, Y.-H. 1993, ApJS, 85, 137
Mills, B. Y., Slee, O. B., & Hill, E. R. 1960, Aust. J. Phys., 13, 676
Milne, D. K. 1970, Aust. J. Phys., 23, 425
Parker, Q. A., & Bland-Hawthorn, J. 1998, PASA, 15, 33
Parker, Q. A., & Phillipps, S. 1998, PASA, 15, 28
Parker, Q. A., Phillipps, S., & Morgan, D. H. 1999, in New Perspectives on the Interstellar Medium, ASP Conference Series, 168, ed. A. R. Taylor, T. L. Landecker, & G. Joncas, 126
van den Bergh, S. 1976, ApJ, 208, L17
van den Bergh, S. 1978, ApJ, 220, L9
van den Bergh, S. 1979, ApJ, 227, 497
van den Bergh, S. 1980, ApJ, 236, L23
van den Bergh, S., Marscher, A. P., & Terzian, Y. 1973, ApJS, 26, 19
van den Bergh, S., & Herbst, W. 1975, AJ, 80, 208
van der Hucht, K. A. 2000, New Astronomy Reviews, submitted
Walker, A. J., & Zealey, W. J. 1998, PASA, 15, 79
Weiler, K. W. 1983, in Supernova Remnants and their X-ray Emission, IAU Colloquium 101, ed. J. Danziger, & P. Gorenstein (Dordrecht: Reidel), 299
Weiler, K. W., & Sramek, R. A. 1988, ARA&A, 26, 295
Whiteoak, J. B. Z., & Green, A. J. 1996, A&AS, 118, 329
Zealey, W. J., Elliot, K. H., & Malin, D. F. 1979, A&AS, 38, 39