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ƆBSERVATIONS OF SUPERNOVA REMNANTS INTERACTING WITH H II REGIONS

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RESUMEN

Se presume que los grandes complejos nebulares, formados por asociaciones de estrellas OB, son lugares en los que han ocurrido explosiones de SN. En la mayoría de los casos la emisión característica de los remanentes de supernova (RSNs) resultantes es opacada por la emisión, mucho más intensa, de la región H II. En estos casos es necesario contar con otras técnicas de identificación de RSNs. En este trabajo se muestra la aplicación de una de estas técnicas (identificación cinemática) en la detección de varios RSNs dentro de las regiones H II N19 y N66 de la Nube Menor de Magallanes. Se proponen observaciones de nebulosas galácticas con propiedades similares.

ABSTRACT

Large H II regions formed by rich OB stellar associations are suspected to be sites of SN explosions. In most cases, the characteristic emission of the resulting supernova remnants (SNRs) is masked by the stronger H II region emission. In those cases, other SNR identification techniques are required. Here we present the application of one of these techniques (kinematic identification) to the detection of several SNRs inside the large H II regions N19 and N66 in the Small Magellanic Cloud. Similar observations are suggested for galactic nebulae of similar properties.

Key words: **ISM: SUPERNOVA REMNANTS — H II REGIONS — ISM: KINEMATICS AND DYNAMICS**

1. INTRODUCTION

It is now believed that massive stars are progenitors of supernovae (SN) of types Ib and II. On the other .and, massive stars tend to associate to form rich stellar clusters; thus we expect that: a) Several identified upernova remnants (SNRs) should be associated with large H II regions implying that the evolution of the ılast wave is taking place in a"modified" interstellar medium (ISM), with properties quite different from the SM used to describe the classical SNR evolution (homogeneous and isotropic). b) Many SNRs inside large I II regions remain to be discovered.

Conclusion a) has been amply exemplified from both the observational (Dufour 1994) and theoretical Franco 1994) points of view. Here, we would like to stress conclusion b) by showing two examples of the xistence of several SNRs inside large H II regions that have been recently discovered by new identification echniques.

2. SNRs IDENTIFICATION CRITERIA

2.1. Classical Criteria

In our Galaxy, SNRs are usually identified by their non-thermal radio emission. Several of the SNRs identified in this way have also extended soft X-ray emission (Seward 1990), some others also have optical counterparts which reveal large internal motions and/or an emission characteristic of radiative shocks.

The use of the radio discriminators in the Magellanic Clouds (MC's) is not an easy technique because of the low angular resolution of radio telescopes in the southern hemisphere which prevents the detection of small diameter SNRs (i.e., unresolved SNRs could be confused with background extragalactic sources such as radio galaxies).

In order to avoid misidentifications, a series of criteria in several spectral ranges have been adopted to identify SNRs in the MC's. The candidate must satisfy at least 2 of the following conditions: 1) be an extended soft X-ray source, 2) be a non-thermal radio source, 3) have optical emission with enhanced [S II]/Hα line-ratio

However, several SNRs inside large H II regions could remain undetected given that the characteristic SNR emission is masked by the stronger emission of the H II region. Thus, we need other means of identification of SNRs inside H II regions.

2.2. New Identification Methods

We list here three new methods of identification of SNRs that are highly recommended when some of the classical criteria fail:

1. The "kinematic method" (Rosado et al. 1993, 1994) consists of the detection of the suspected nebula in several velocity channels of a scanning Fabry-Perot (FP) interferometer. It is based on the fact that the radial velocity profiles of SNRs are complex and have widths of at least 200 km s^{-1} due to the presence of shocks.

2. The "scaled subtraction" method (Ye et al. 1991) uses the S($H\alpha$)/$S\nu$ ratio in a very local analysis avoiding the problems of extinction. The Hα intensity is very high in giant H II regions, and the variation of the S($H\alpha$)/$S\nu$ ratio within the region due to the presence of SNRs may be small. When the Hα map is scaled and subtracted from the radio map, the difference map reveals the presence of non-thermal sources.

3. The "IR" method is based on the [Fe II](1.6435μ)/Br γ line-ratio which traces shock emission (Oliva et al. 1989).

3. EXAMPLES OF SNRs INSIDE LARGE H II REGIONS

3.1. Optical Observations

We have performed scanning FP interferometry with special equipment at the European Southern Observatory (ESO). The description of the instrument, observations and data reductions can be found in Le Coarer et al. (1993). Here we only note that with this equipment we are able to obtain radial velocity profiles every 9 arcsec^2 in the sky over a field of 38 arcmin^2 at Hα and [S II](λ6717 A) with sampling spectral resolutions of 5 and 15 km s^{-1} and a limiting emission measure of 10 cm^{-6} pc, assuming that the gas is at 10^4 K and in Case B of photoionization.

3.2. The SNRs Inside the H II Region N19 in the SMC

The nebular complex N19 (Henize 1956) has linear dimensions of about 110 pc (assuming a distance to the SMC of 65 kpc) and is presumably formed by the rich OB stellar association H12 (Hodge 1985). Previous studies have shown that one SNR is located inside this nebula towards the western boundary (Mathewson & Clarke 1972). However, our kinematic data at Hα and [S II] reveal that there are two other SNRs inside the H II region and two other SNR candidates. We have obtained velocity profiles integrated over windows of 49 arcsec^2. We have analyzed the profiles and have identified several zones where the profiles are rather complex. In general, the radial velocity profiles are contaminated by the strong emission of the H II region. Nevertheless some of the profiles show in addition to the H II region emission high velocity wings which widen the profile up to velocity widths of hundredths of km s^{-1}. In Figure 1 we have marked the zones with complex velocity profiles on a [S II]/ Hα image of N19 (Zones A and B and the SNR 0045–73.4). These zones are separate entities, one of

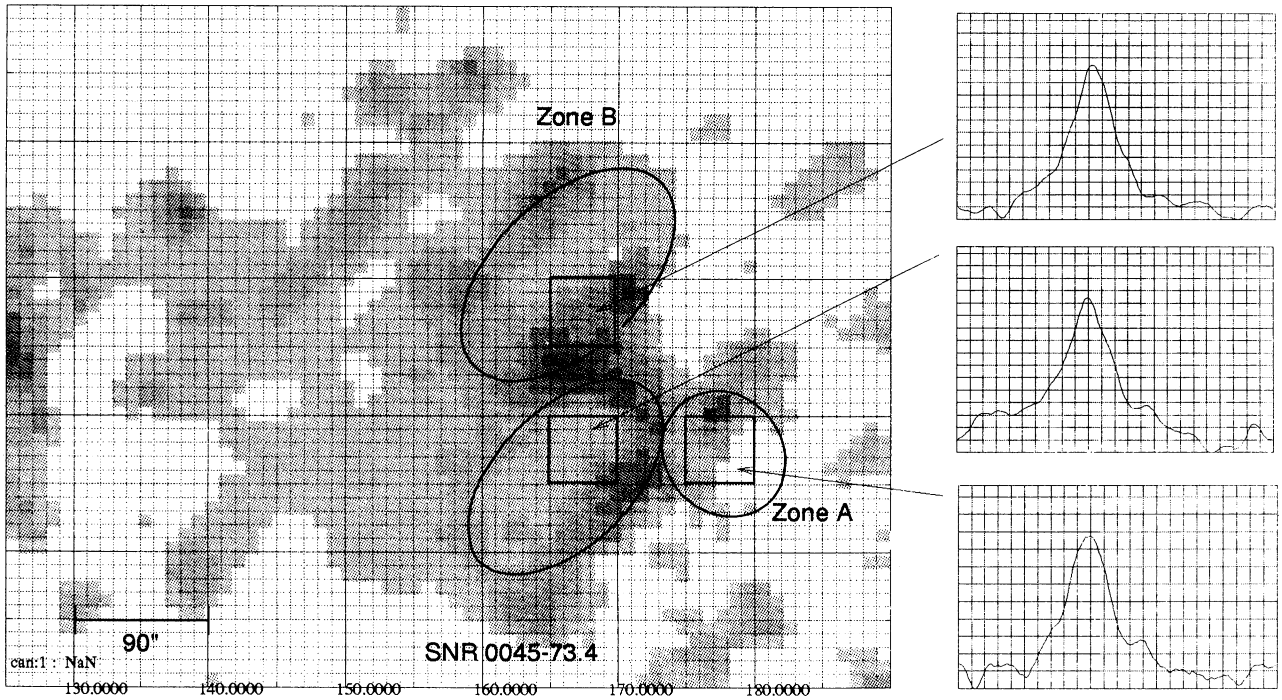

Fig. 1. [S II]/Hα 2D line-ratios of the N19 H II region. The profiles of zones with violent motions are displayed.

which coincides in morphology with the previously reported SNR 0045–73.4. However, there are other regions showing violent motions comparable to those of this SNR. In addition, from the [S II]/Hα line-ratios obtained from our data, we note that Zone B has a [S II]/Hα line-ratio comparable to that of the SNR 0045–73.4.

A bibliographical search has revealed that Zone A coincides with the position of an extended X-ray source (No. 15 in Wang & Wu 1992). Furthermore, these authors report two non-thermal radio sources whose approximate positions are in agreement with the positions of Zones A and B. Thus, we are rather confident that there are at least three SNRs mutually interacting inside this H II region.

3.3. The SNRs Associated With the H II Region N66 in the SMC

N66 (Henize 1956) is the largest and brightest H II region in the SMC. Its diameter is of about 250 pc and this nebula is excited by a rich cluster of very early-type stars.

Previous studies report one SNR identified by classical methods at the south-west boundary (SNR 0056–72.5) and an additional SNR located near the center, identified both by the "scaled subtraction" method and by its kinematics (Ye et al. 1991). The latter studies suggest another SNR candidate located at the western boundary.

Figure 2 shows the Hα image of N66 and the velocity profiles of the interesting zones mentioned before. While these results are preliminary, one can see from the examination of the profiles, that violent motions are present in the three nebulosities, revealed by the existence of high velocity wings superposed on a quite high H II region emission profile.

4. CONCLUSIONS

In this work we have presented two examples where large H II complexes have several SNRs and wind-blown bubbles inside them.

We have shown that in those cases SNR identification cannot be accomplished by classical methods. Instead, it is seen that the "kinematic method" (Rosado et al. 1993, 1994) and the "scaled subtraction method" (Ye et al. 1991) are useful tools in discriminating the SNR emission against stronger H II region emission.

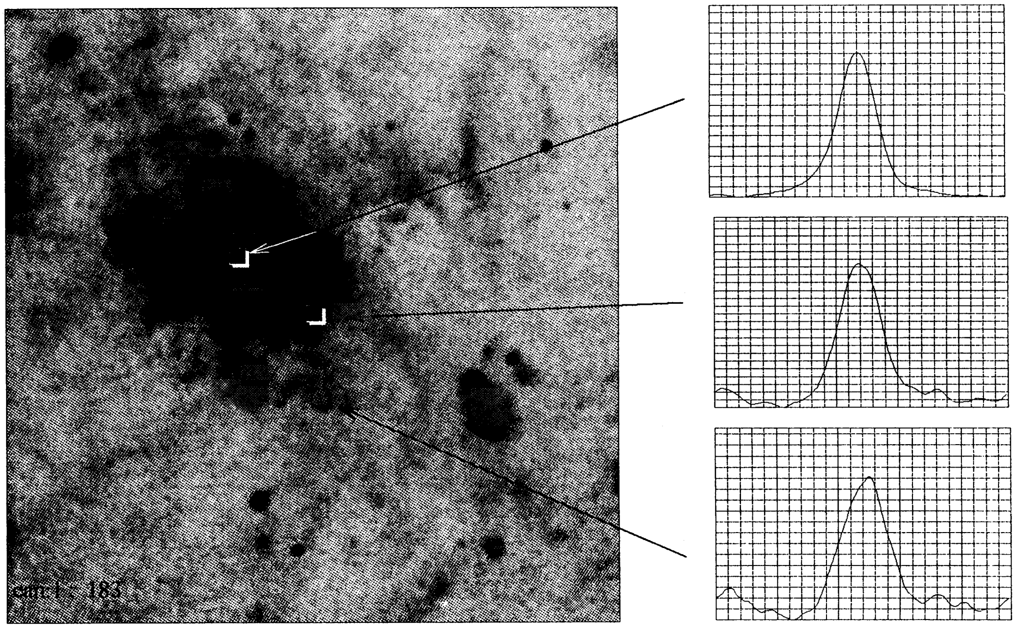

Fig. 2. Hα image of the N66 H II region. The profiles of zones with violent motions are also displayed.

These nebular complexes are excellent laboratories where SNR interactions can be studied. Besides, they will allow study of how the energy from the stars is liberated to the disks of galaxies.

In the two cases studied in this work, we have triplicated the number of SNRs detected. This implies that after a careful kinematic survey, complemented by radio and X-ray observations, the SN rates of irregular galaxies (and perhaps of spirals too) should be revised.

While the SMC offers the advantage of a moderate spatial resolution and the possibility of observing the overall interesting regions with wide field instruments, it is necessary to perform similar work in our own Galaxy. We have searched for H II regions having diameters larger than 100 pc and we propose the following nebulae which could be the galactic equivalent to the nebulae studied in this work (Rosado 1986): Sivan 10, the Gum Nebula and the Cygnus Superbubble. The Instituto de Astronomía-UNAM is developing a scanning FP interferometer to accomplish this type of kinematic observations (Bernal et al. 1994).

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DISCUSSION

Silich: a) What are the characteristic scales and ages of the H II regions? b) What are the positions of SNRs relative to the centre of the H II region?

Rosado: The diameter of N19 is about 110 pc. This H II region is formed by an association of B stars (Hodge 12) but surely it must contain undetected O stars. The SNRs are located to the western side of this H II region.

Arthur: How can you tell the difference between supernova remnants and stellar wind bubbles with your method?

Rosado: There are no means, at present, of differentiating between SNRs and wind-blown bubbles by the kinematic method I describe. This method identifies shocked nebulae. Thus it is necessary to have complementary information at other wavelengths and a knowledge of the stellar wind content. However, it has been found that nebulae with expansion velocities larger than about 200 km s^{-1} are more likely SNRs.

Herbig: It has been speculated that 2 or 3 runaway O-type stars are the result of ejection in supernova events in Orion several 10^6 years ago. I think it has been suggested that Barnard's Loop is a souvenir of such an event. In the light of your work, is this reasonable?

Rosado: The cases I have exemplified are much younger because while the H II region dimensions are similar, Barnards's Loop ($D \simeq 140$ pc), the dimensions of the SNRs inside are about 20 pc; thus, their ages are about 5×10^4 yr. It is possible that Barnard's Loop was formed by SN events but, given that those explosions occurred some 10^6 yr ago, it is very difficult to prove because at that age, a SNR has lost most of its characteristic signatures.

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