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G34.3 + 0.2: A "COMETARY" H II REGION

MARK J. REID AND PAUL T. P. HO[1]
Harvard-Smithsonian Center for Astrophysics
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ABSTRACT

Radio-frequency observations of the H II complex G34.3 + 0.2 made at 1″ resolution with the VLA indicate a component whose appearance resembles that of a comet, containing an ultracompact H II "head" and a diffuse "tail." This "cometary" H II region points (from tail through head) in the direction of the supernova remnant W44 which lies at a projected separation of 40 pc. The morphology of the cometary source might be explained as owing to the interaction of a newly formed O type star with a large (40 pc radius) shell. This shell is seen in both CO and H I and may have been driven outward from the center of W44 by a wind from the stellar precursor to the supernova.

Subject headings: interferometry — nebulae: H II regions — stars: winds

I. INTRODUCTION

Recently, continuum observations of H II regions with radio interferometers have revealed a class of ultracompact sources with diameters less than 0.1 pc and electron densities of 10^5 cm^{-3} and higher (cf. Habing and Israel 1979). When observed at high radio frequencies (e.g., > 15 GHz), shell-like structures are often found (Dreher and Welch 1981; Turner and Matthews 1984). Because of the high degree of excitation required to explain the observed emissions and because of the short dynamical time scale ($< 10^4$ yr) implied by the small observed sizes, these objects are thought to be the ionized envelopes surrounding very young O type stars.

Most published maps of ultracompact H II regions made at high radio frequencies can be qualitatively interpreted in terms of an energetic main-sequence star embedded in a comoving envelope of neutral material. However, as part of a recent study of ultracompact H II regions associated with OH masers, we have found at least one source, G34.3 + 0.2, which does not fit this picture. Instead, this source exhibits a well-defined asymmetric radio morphology that suggests relative motion between the exciting star and its environment.

II. OBSERVATIONS AND RESULTS

The source G34.3 + 0.2 was observed with the Very Large Array (VLA) of the National Radio Astronomy Observatory[2] on 1983 November 12. The array was in the A configuration which provides baselines up to about 35 km. The observing band was centered at 1627.5 MHz and covered 12.5 MHz. A total of about 20 minutes of observation time was obtained from six short integrations spaced between 17:30 and 00:30 local sidereal time. Instrumental amplitude and phase variations were monitored with observations of 1923 + 210, and the flux density scale was determined by assuming 2.35 Jy for 0212 + 735. Calibration was done in the usual manner, and maps were generated using the AIPS programs.

In Figure 1 we present a map of the continuum emission at 18 cm wavelength from G34.3 + 0.2 with an angular resolution of 1″.4. The map is complex and indicates emission from several structures. In the southeast there is a low brightness arc, which seems to be a part of a 1′ diameter ring centered near R.A. (1950) = $18^h50^m49^s.5$ and decl. (1950) = 01°10′40″. Projected on the northwest edge of this arc there appears to be a brighter 20″ diameter source. Farther toward the northwest at R.A. = $18^h50^m45^s.5$ and decl. = 01°11′10″, there is an elongated source with a bright "head" toward the east and a "tail" trailing off toward the west.

The first two sources just described will not be discussed further in this *Letter*; instead we will focus discussion on the elongated source. The radio spectrum of the "head" component (based on our data and those of Garay, Reid, and Moran 1985 and Benson and Johnston 1984) is consistent with that of a compact H II region which is optically thick up to about 15 GHz. The "tail" component, however, appears to be optically thin even at 1.6 GHz. Because this source appears to be radiating via thermal bremsstrahlung and has a comet-like appearance, we will refer to it as a "cometary" H II region throughout this *Letter*.

III. DISCUSSION

The cometary H II region appears to be dominated by one ionizing source—the head component. The flux density of the head component measured at 1.3 cm wavelength (Garay, Reid, and Moran 1985) can be accounted for with an ionizing source of about 10^{49} Ly_c s^{-1}, approximately that of an O7 star, assuming a distance of 3.8 kpc. Other stars of lower mass may be present but difficult to detect. In fact, two faint sources just to the east of the head component (labeled A and B in Fig. 1) are seen clearly in the 2 cm wavelength VLA map of Rodríguez (1984) and may be later O type or early B type stars. Hydroxyl (OH) masers are found in two clumps (Garay,

[1]Alfred P. Sloan Foundation Fellow.

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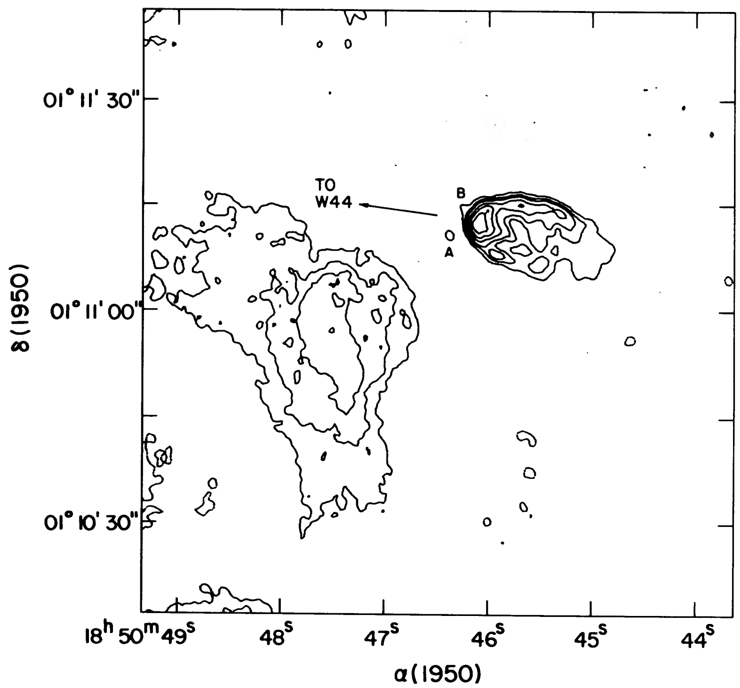

FIG. 1.—Map of the cometary H II region G34.3 + 0.2 and its surroundings at 18 cm wavelength with 1''.4 resolution. Contour levels are −10, 10, 20, 30, 50, 70, and 90% of the peak brightness of 32 mJy per beam. The arrow labeled "to W44" indicates the direction of the center of the W44 supernova remnant about 40′ away. Two faint sources labeled A and B are discussed in the text.

Reid, and Moran 1985), one on the eastern edge of the head component and the other near the faint source B.

The tail component has a characteristic brightness temperature of about 2000 K and a size of about 0.3 pc. This emission is barely visible at about the 200 K level in the VLA map of Benson and Johnston (1984) at 4.9 GHz. These results suggest optically thin emission from electrons at a density of about 3000 cm^{-3}, assuming an electron temperature near 10^4 K and a line-of-sight depth of 0.15 pc. Under these conditions, the hydrogen recombination time is roughly 40 yr, which is about three orders of magnitude shorter than a dynamical time of 30,000 yr (i.e., 0.3 pc per 10 km s^{-1}). Therefore, the tail is not a fossil envelope; it must be actively ionized, most likely by an O type star (or stars) in the head component.

The Strömgren ionization radius for an electron density of 3000 cm^{-3} and an O7 star is about 0.3 pc. This is close to the observed size of the tail which suggests that photoionization is the dominant source of excitation. Were an O star to form on the edge of a cloud with a steep density gradient, it would be possible to form an elongated "Strömgren sphere" with some of the characteristics of G34.3 + 0.2. However, such a structure probably would not have the limb-brightened appearance that is apparent in this source.

The observed morphology of an ionizing star at the head of a "bow-shock"-like structure suggests relative motion of the star with respect to its surroundings. A newly formed star might decouple from its surrounding material which can be constrained by gas and magnetic pressures (e.g., Elmegreen 1981). A relative velocity of 3 km s^{-1} would result in a motion equal to the (projected) length of the tail in about 10^5 yr, which is much less than the main-sequence lifetime of the O star. Weaver *et al.* (1977) consider the case of a star with a strong stellar wind driving a bubble in the interstellar medium. Specifically, they discuss the effects of stellar motions on the shape of the bubble and conclude that a parabolic shell-like structure, similar to that seen in G34.3 + 0.2, might result.

An examination of the area surrounding G34.3 + 0.2 suggests an origin for the relative motion. The supernova remnant (SNR) W44 lies at a projected distance of only 40 pc from the cometary H II region. Distance estimates for W44 based on both the surface brightness–diameter relationship for shell-like SNRs (Milne 1979) and OH and H I absorption studies (Goss, Caswell, and Robinson 1971; Radhakrishnan *et al.* 1972) are about 3 kpc. This is reasonably close to the near kinematic distance of 3.8 kpc for G34.3 + 0.2, and we assume that the two sources are at approximately the same distance.

The center of W44 is offset from G34.3 + 0.2 along a position angle of about 80° east of north. Thus, the cometary H II region points (from tail through the head) almost directly at the SNR. This is morphologically similar to comets in our solar system whose tails are swept back by the solar wind and suggests an interaction between W44 and G34.3 + 0.2. Further evidence for an association of the cometary H II region with W44 can be found in H I (Knapp and Kerr 1974) and CO (Dame 1984) observations which indicate that G34.3 + 0.2 is embedded in a 10^6 $M_\odot$ shell at a radius of about 40 pc from the center of W44.

Interaction between W44 and the G34.3 + 0.2 region is not likely to be a result of the supernova event. The SNR shell extends only 25 pc in radius, and so its mechanical energy is not yet available at the distance of G34.3 + 0.2 and the 10^6 $M_\odot$ CO/H I shell. Also, the initial burst of radiant energy which precedes the SNR does not seem to have sufficient energy to sweep up 10^6 $M_\odot$ of interstellar material in the 40 pc radius shell in the $< 10^6$ yr since the event. A possible interaction between W44 and G34.3 + 0.2 might be via a wind from the stellar precursor to the supernova. For example, an O star with a stellar wind of 10^{-6} $M_\odot$ yr^{-1} flowing at 2000 km s^{-1} for 3×10^6 yr could provide sufficient energy to drive a 10^6 $M_\odot$ shell outward at 3 km s^{-1}. Spectroscopic observations of the molecular shell in the vicinity of the cometary H II region might clarify the nature of such interactions. Clearly, angular resolution of better than 10″ will be needed to address this problem.

The model outlined in the preceding discussion assumes energetic winds from the SNR precursor, to sweep up the 40 pc CO/H I shell, and from the G34.3 + 0.2 O star, to support the cometary H II "bubble." Observations of O stars outside of dense molecular environments support such an assumption. However, it may still be possible to explain the 40 pc shell and the cometary H II region without invoking winds. For example, it is possible that another supernova (or other supernovae) preceded the W44 event in the same region. In this case, the 40 pc shell could be the remnant of the earlier supernova. The ram pressure from this shell could blow back a tail around a clump of neutral material out of which the G34.3 + 0.2 O star formed, stripping off gas down to a density of roughly 10^5 cm^{-3}. When this O star reached the main sequence, its ultraviolet photons would ionize the circumstellar material, yielding the cometary H II region we observe. This scenario requires that the cometary H II region be younger than about 10^3–10^4 yr so that it would have retained its structure once ionized.

IV. CONCLUSIONS

The cometary appearance of the ultracompact H II region G34.3 + 0.2 probably is due to the relative motion of the exciting star and its surroundings. The direction of motion suggests a connection with the supernova which formed the W44 remnant. One possible interaction might have been through a stellar wind from the precursor star which was responsible for the supernova event. However, the case for this association is circumstantial, and more ultracompact H II regions near SNRs should be examined for cometary structure aligned in the direction of the SNR. If other cases are found with a similar morphology to the G34.3 + 0.2/W44 case, the observations might constitute direct evidence for mass loss associated with a supernova precursor or for multiple supernova events in the same region.

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PAUL T. P. HO and MARK J. REID: Center for Astrophysics, 60 Garden Street, Cambridge MA 02138