RevMexAA (Serie de Conferencias), **2**, 23-25 (1995)

OBSERVATIONS OF CONTINUUM AND RECOMBINATION-LINE EMISSION FROM η CARINAE AT A WAVELENGTH OF 3 CM

R.A. Duncan[1], S.M. White[2], J. Lim[3], G.J. Nelson[4]
S.A. Drake[5], M.R. Kundu[2]

RESUMEN

Hemos obtenido imágenes de η Car en continuo de radio de 3 cm y en las líneas de recombinación H90α y H91α con resolución de $1''$. Las imágenes de continuo muestran una fuente con dimensiones de $10'' \times 8''$ cuyo centro coincide con la estrella, y cuyos ejes de simetría se alinean aproximadamente, pero no exactamente, con los del Homunculus óptico. La forma de la imagen se parece mucho a imágenes IR obtenidas por otros autores. La emisión de radio no es polarizada, y no apoya a los modelos que invocan estrellas degeneradas u objetos más exóticos dentro del núcleo de η Car. En cambio, es consistente con emisión térmica proveniente del gas que fluye desde una estrella LBV. El espectro obtenido de la observación de líneas de recombinación muestra dos máximos intensos: uno a -35 y el otro a -240 km s^{-1}. El primero está cercano a la velocidad sistémica de η Car, el segundo debe provenir del flujo gaseoso. Las imágenes muestran que la emisión de estas líneas surge de dos pequeñas áreas, desplazadas $0.5''$ y $1''$ respectivamente al NO de η Car.

ABSTRACT

We have made $1''$ resolution images of η Carinae in both the 3 cm radio continuum and in the H90α and H91α hydrogen recombination lines. The continuum image shows a source with dimensions $10'' \times 8''$ whose centre coincides with the star, and whose axes of symmetry align approximately, but not exactly, with those of the optical Homunculus. In shape, the image closely resembles infrared images obtained by other authors. The radio emission is unpolarized, and offers no support to models which invoke degenerate stars or more exotic objects within the core of η Carinae. Instead it is consistent with thermal emission from gas flowing away from a 'Luminous Blue Variable' star. The spectrum obtained from the recombination line observations shows two strong peaks, one at -35 km s^{-1}, and the other at -240 km s^{-1}. The former is close to the systemic velocity of η Carinae, the latter must arise from outflowing gas. Imaging shows that these line emissions arise from two small areas, displaced $0.5''$ and $1''$ respectively, NW of η Carinae.

Key words: **RADIO CONTINUUM: INTERSTELLAR — RADIO LINES: INTERSTELLAR — STARS: INDIVIDUAL: (η CAR)**

---

[1] Australia Telescope National Facility, P.O. Box 76, Epping NSW 2121, Australia.
[2] Department of Astronomy, University of Maryland, College Park, MD 20742 USA.
[3] Solar Astronomy 264-33, Caltech, Pasadena, CA 91125 USA.
[4] ATNF/Paul Wild Observatory, P.O. Box 94, Narrabri, NSW 2390 Australia.
[5] Lab. for High Energy Astrophysics, NASA/GSFC, Greenbelt, MD 20771 USA.

1. INTRODUCTION

η Carinae is an extraordinary star, and for this reason, as I am sure we shall hear this week, it has been intensively observed at wavelengths ranging infra–red to x–rays. Observations at radio wavelengths are clearly important because of their ability to penetrate the dust shells surrounding the star and reveal the ionized gas below it, yet this is one of the few wavelength ranges at which η Carinae has received relatively little attention. This has been because of the lack of a southern Hemisphere radio telescope capable of the arc–second resolution necessary to adequately resolve the source.

Of course η Carinae does not appear in the Parkes catalogue, because a single dish telescope is unable to detect it against the general emission of the galaxy. The first radio image of the region, and perhaps still the best published image, was obtained by Retallack (1983) using the Fleurs synthesis telescope (near Sydney) at 1.4 GHz. This image has a spatial resolution of 50″, and shows η Carinae as a compact source of 0.9 Jy. More recently, Jones (1985) has observed η Carinae at 843 MHz with the Molonglo Observatory Synthesis telescope (near Canberra); this has a resolution of about 45″ and measured a flux of 1.1 Jy.

The observations to be reported here were made at a wavelength of 3 cm with the new Australia Telescope. This synthesis array is at Narrabri, about 420 km north-west of Sydney, and has a maximum baseline of 6 km, which gives it a resolving power of 1″. It observes simultaneously at two wavelengths. Two kinds of observations have been made, continuum and hydrogen recombination lines.

2. CONTINUUM

Synthesis telescope, being unfilled apertures, have very large diffraction fringes, or in radio jargon sidelobes, and for this reason before studying a small area with high resolution it is prudent to first check the surrounding field for sources whose sidelobes could confuse the results. This is especially true in a region as complex as the Carinae nebula. Hence our first observations, in April 1992, were made with a maximum baseline of 375 m, that is over a wide (5′) field at low (13″) resolution. These observations showed that the field was dominated by an 0.7 Jy source at the position of η Carinae, and although there was weak extended nebular emission to the NW, this was not of a nature which would significantly contaminate a high resolution image of the immediate vicinity of η Carinae.

In June 1992 therefore, we observed η Carinae at frequencies of 8128 MHz and 9024 MHz and a maximum baseline of 6000 m. This yielded a resolution of 1″.0. The two images resulting from these observations were virtually identical. We found the emission to be highly concentrated to a central region with a FWHM of 1″.6. This is significantly larger than our resolution, so we can be sure that the emission is not stellar; at the distance of η Carinae (2.5 kpc) it corresponds to a radius of .012 pc or 2500 AU. The position of the radio peak differed from the optical position by 0″.6, but antenna positions were poorly determined at the time so that this difference is not significant. The brightness temperature of this central peak, if it was resolved, was 3000 K. Much fainter emission lies outside this peak. The overall dimension of the radio source around η Carinae is 10″ × 8″, with the major axis in the direction of the major axis of the Homunculus, but only about half the dimension of the optical Homunculus. In comparison with the inner peak, the outer structures are very faint; at the outer edge, the radio brightness temperature has fallen to 10 K.

The outer structure is remarkably similar to some infra-red images (e.g., Hackwell, Gehrz, & Grasdalen 1986; Hyland et al. 1983; Russell et al. 1987; Allen 1989). However we see no sign of the double peak seen by many infrared observers, including Robert Smith who is with us this week. Overall the image shows less than 0.05% polarization. The highest measured polarization is 0.3% circular at the location of the central peak, but this is not significant: the AT is most accurate when measuring linear polarization. The spectrum between 8GHz and 9GHz is flat to within 10%.

Although we cannot rule out the possibility that intrinsic polarization is destroyed by Faraday rotation, as the radiation propagates through the dense ionized medium around the star, taken together, the apparent lack of polarization and the flat or slightly falling spectrum, appear to rule out non–thermal emission, or at least optically–thick synchrotron emission in an ordered magnetic field. Instead both the lack of polarization and the flat spectrum suggest thermal emission; that is a compact H II region. Because η Carinae is a mature star, any primordial gas cloud must have long since been swept away by the stellar wind. Instead, the gas must have come from the star. If we interpret the emission from the strong 1″.6 radius central peak, to be thermal emission from an optically–thick stellar wind, we find a mass–loss rate of $3 \times 10^{-4}\ M_{\odot}/\mathrm{yr}$. The radio emission in the outer regions, from 2″ to 5″ from the star, must arise from residual material from past ejections. That sufficient UV can reach and heat and ionize this outer region, strongly suggests that the gas and dust is clumpy.

The similarity between the radio and infra-red images might suggest that the radio emission in the outer region arises as thermal emission from the dust. However the flat spectrum appears to rule out this possibility; dust emission would be expected to give a steeply rising spectrum.

Therefore in summary we believe that the radio emission from the vicinity of η Carinae arises thermally from hot ionized gas, that is, that η Carinae is an ultra-compact H II region.

3. RECOMBINATION LINES

The H90α and H91α hydrogen recombination lines were observed in September 1993. These observations covered the relatively broad bandwidth of 64 MHz, and so in addition yielded further observations of the continuum.

They showed two pronounced peaks, a smaller peak at a velocity of -36 km s^{-1}, that is, at the systemic velocity of η Carinae, and a larger peak from gas approaching us at 240 km s^{-1}. This spectral emission arose from small areas about $0''.5$ and $1''.0$ respectively NW of the peak of the continuum emission.

These spectral line observations are difficult to understand. First, recombination line emission should arise from the whole area of the continuum emission, yet it was observed to come only from two small areas. Second, the spectral line observations also yielded continuum maps, and the maps derived from observations in 1992 and 1993 were markedly different. Thus the observations suggested that the continuum emission is time variable, but astrophysically this would be surprising; the observed size of the radio source together with a stellar wind velocity of 500 km s^{-1}, gives a time scale of approximately 10 years. It was notable that the 1993 image, by comparison with the 1992 image, seemed to be enhanced in the very area from which the line emission was observed.

We will be observing η Carinae again in the new year in an attempt to resolve this question. Until these observations have been made and analysed, it is perhaps premature to try to interpret the recombination line observations.

REFERENCES

Allen, D.A. 1989, MNRAS, 241, 195.
Hackwell, J.A., Gehrz, R.D., & Grasdalen, G.L. 1986, ApJ, 311, 380.
Hyland, A.R., Robinson, G., Mitchell, R.M., Thomas, J.A., & Becklin, E.E. 1983, ApJ, 233, 145.
Jones, P.A. 1985, MNRAS, 216, 613.
Retallack D.S. 1983, MNRAS, 204, 669.
Russell, R.W., Lynch, D.K., Hackwell, J.A., Rudy, R.J., Rosano, G.S., & Castelaz, M.W. 1987, ApJ, 321, 937.