Rev. Mexicana Astron. Astrof., **14**, 474-478 (1987)

THE BIPOLAR H II REGION S 201

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RESUMEN. Nuevas observaciones ópticas e infrarrojas de S 201 nos permiten discutir su nauraleza, en términos de la interacción entre una región H II evolucionada y la nube molecular cercana. Asímismo discutimos la energética de la región y el papel que la formación estelar juega en ese área.

ABSTRACT. We discuss the nature of S 201 in the light of new optical and infrared observations, in terms of the interaction between an evolved H II region and a nearby molecular cloud. The energetics of the region and the role of star formation in that area are also briefly discussed.

Key words: INFRARED SOURCES — INTERFEROMETRY — NEBULAE-H II REGIONS

I. INTRODUCTION.

S201 is a small HII region (Fig. 1) at the eastern end of the chain of HII regions W3, W4 and W5, where star formation is still in progress. Earlier observations of this region in radio wavelengths (Felli and Harten 1981; Felli et al. 1986) and the infrared (Kleinmann et al. 1979; Thronson et al. 1983) have shown an interesting structure presumably due to the interaction between the HII region and the adjacent molecular cloud (Martin and Barrett 1978). The excitation sources are unknown.

In this work we report on new observations of S201 (Section II) and discuss them in Section III. In Section IV we present our conclusions.

II. OBSERVATIONS.

a) Optical interferometry: The Hα velocity field of S201 was determined using a photographic Fabry-Pérot interferometer attached to the 1.0 m telescope at Observatorio Nacional (Tonantzintla, México). The interferograms were calibrated, measured and reduced using standard techniques. Three regions of different velocity could be defined (see Fig. 2 and Table 1). Furthermore, the systemic velocity of all the 91 measured points, gave a V_{LSR} of -34.3 km s^{-1}, yielding thus a kinematic distance of 2.3 kpc and confirming its physical association with the W3, W4 and W5 complex.

TABLE 1. Average Heliocentric Radial Velocities of Subregions in S201.

Subregion	Radial velocity (Km s^{-1})	Number of points
A	-41.4	7
B	-36.4	79
C	-29.8	5

Note: Estimated total errors are about ±3 Km s^{-1}.

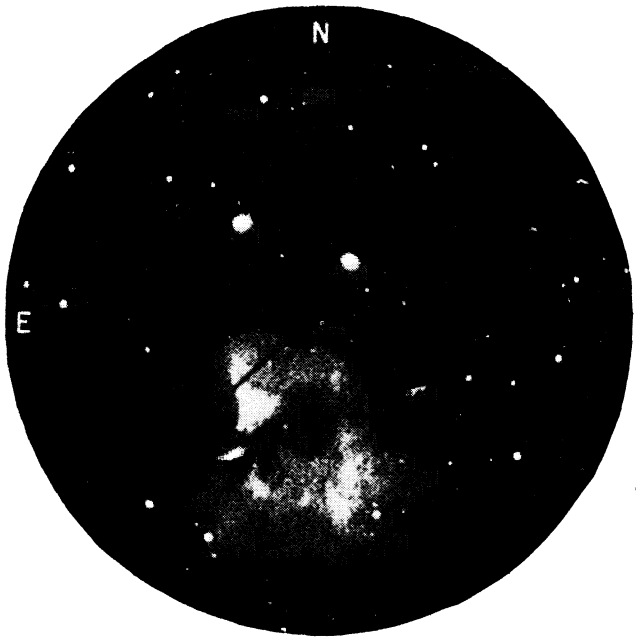

Fig. 1. Image of S201 in the [NII] 6584 Å line taken with the 2.1 telescope at San Pedro Mártir Observatory.

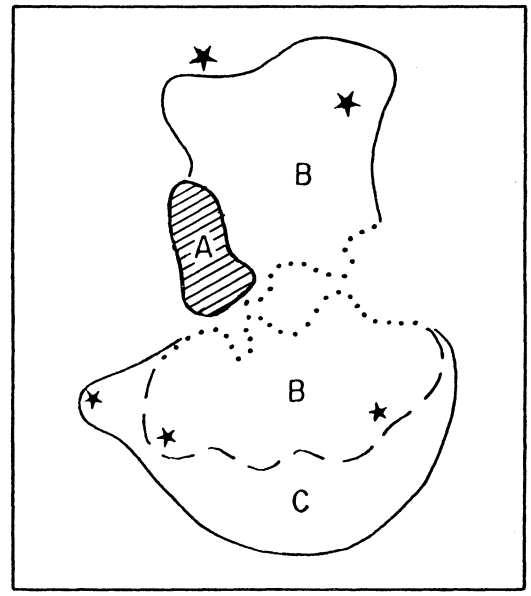

Fig. 2. Freehand sketch of the different subregions in S201, A, B and C, named in order of decreasing velocities.

b) Optical spectroscopy: We observed S201 with the IDS bidimensional spectrograph and IPCS detector at the 2.5 m INT telescope in the Observatorio del Roque de los Muchachos (La Palma, Spain), using a medium resolution (∿2Å/pixel) grating over a spectral range from 3500 to 7300 Å, enabling the study of 115 spectra (separated by 1 arcsec each) with the 1 arcsec slit oriented in the N-S direction and passing through the optical bright knot.

The seeing was typically 1 arcsec during the exposure.

c) Near infrared observations. S201 was observed with a standard JHKLM photometer (using an InSb detector cooled at 63 K) attached to the 1.5 m CSM telescope at the Observatorio del Teide (Tenerife, Spain). We mapped, in DC mode (i.e. without spatial chopping), an area of 90x128 arcsec in the H and K bands using a 15 arcsec circular aperture. Subsequent photometry of the two main NIR sources detected were performed with the same aperture and chopping throw of 22 arcsec in declination.

III. RESULTS AND DISCUSSION.

The optical spectra of S201 are typical of a low excitation HII region, with the [OIII] 4959, 5007 Å and the HeI 5876 Å lines not present, and consistent with a medium of large O/H abundance at low temperature (less than 6000 K) ionized by a star with a temperature of <35000 K (indicating an 09 ZAMS type or later (Panagia 1973)).

The density sensitive line ratio [SII] 6717/6731 shows a larger value (Fig. 3) at the position of the bright knot (region A in Fig. 2) indicating a density of ∿1500 cm^{-3} for this region. At the outer parts of the nebula, the density drops to a value $\lesssim$ 50 cm^{-3}, in agreement with the previous radio results (Felli and Harten 1981).

From the Balmer decrement we have estimated the visual extinction along the nebulae, finding that it varies between 3 and 5 mag, except in the central obscuring lane where it reaches a value of A_V >8 mag.

Our infrared K map (Fig. 4) of S201 shows an extended source (IRS1) towards the east, coincident with the bright knot A, and also, within the errors with the radio continuum

peak (Felli et al. 1986) as well as with the H_2O maser present in the region (Blair et al. 1980) and the associated IRAS source. Other four compact sources (IRS2 to IRS5) are also present within the scanned area of 3 square arcminutes.

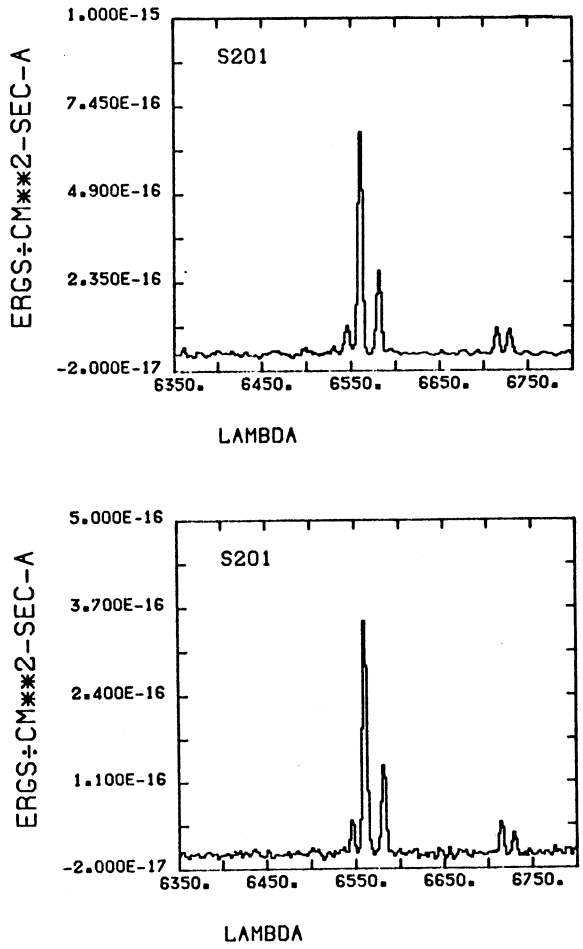

Fig. 3. Spectra of the bright optical north lobe (upper) and of the southern lobe (lower) of S201 in the zone of Hα. Note the difference in the relative ratio of the [SII] lines of the lobes.

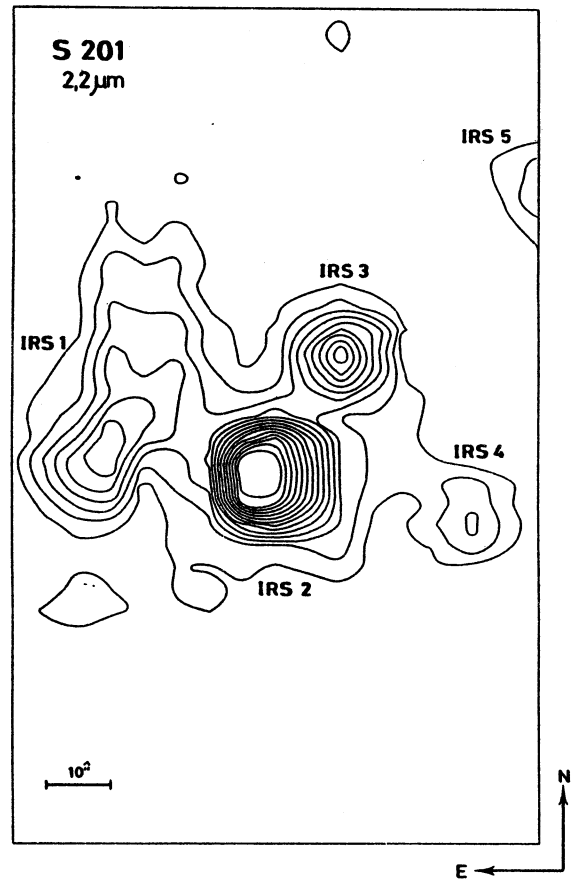

Fig. 4. 2.2 μm map of S201 showing the different sources discussed in the text.

In Fig. 5 we present 2.2 μm declination spatial scans of IRS1 and IRS2, exhibiting the extended nature of IRS1 and its asymmetric profile, with the southern side almost unresolved.

IRS2 has infrared colors typical of a deeply ($A_V \gtrsim 20$ mag) embedded star. At the distance of 2.3 kpc, its spectral type would be O9 ZAMS (to fit our 1.6 μm fluxes) in agreement with that expected for the exciting star. At wavelengths longer than 2 μm an infrared excess is apparent, indicating the presence of dust radiating at T∿600 K.

On the other hand, the H and K fluxes measured for IRS1, would be explained as infrared thermal emission of the ionized gas (extrapolated from the radio measurements) were it extinguished by $A_V \sim 9$ mag, a value which agrees with our optical estimation for the extinction in that position. At λ>3 μm the emission is dominated by dust radiating at a range of temperatures (30-300 K), which includes also the IRAS fluxes for this region.

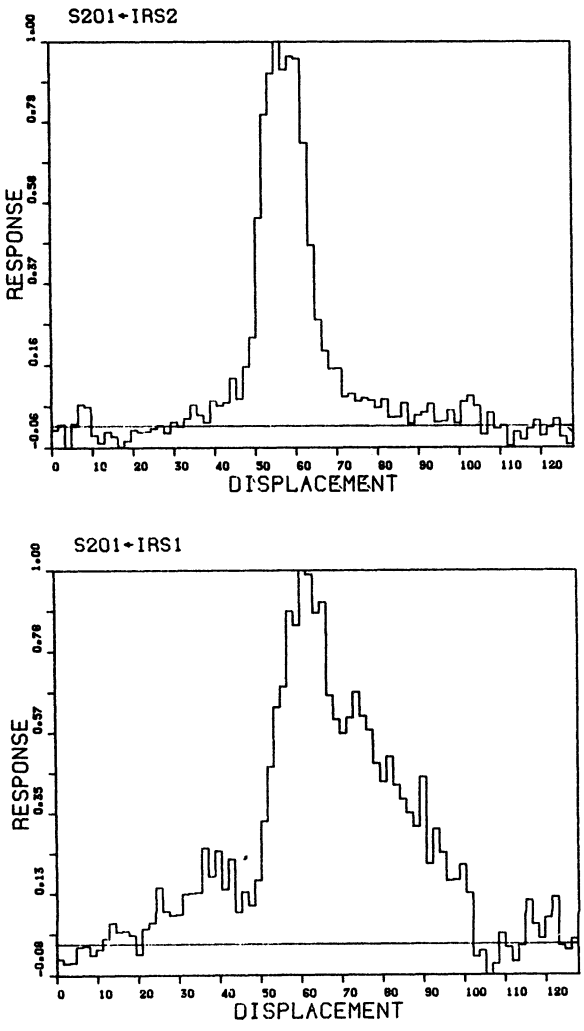

Fig. 5. Spatial scans through S201 IRS2 (upper) and IRS1 (lower) in 2.2 μm, showing the asymmetry of this latter source. The relative displacement (from S to N) is in units of arcsecs.

IV. CONCLUSIONS.

The observations reported in this work suggest a possible scenario for the bipolar HII region S201:

1) The optical nebula is a low density, low excitation HII region with a core of higher density, located at the position of the bright Hα knot (region A). Its distance is around 2.3 kpc.

2) The exciting source of S201 is likely to be the source detected in the infrared (source IRS2) which is deeply embedded in the dust lane that divides the nebula into two lobes.

3) This exciting star ionizes from the outside the bright knot A, producing the curved structure apparent in our infrared maps (source IRS1) and in the higher resolution radio continuum maps (Felli et al. 1986). Our velocity measurements support this interpretation of an outflow of material from this region.

4) Based upon the presence of the H_2O maser in IRS1, and the estimated total infrared luminosity of the region, we suggest that a young early-type star has recently been formed there, probably triggered by the expansion of the evolved HII region into the molecular cloud. If this were the case, we would have the exciting opportunity of studying the structure and evolution of the outer layers of a deeply embedded young star (or protostar) from the radio region through the optical, as it is in the process of being energized by the exciting central star of the main region.

ACKNOWLEDGEMENTS.

It is a pleasure to thank the ON, IAC and RGO staffs for their help during the observations. The 2.5 m Isaac Newton telescope is operated by the Royal Greenwich Observatory at the Spanish Observatorio del Roque de los Muchachos (La Palma) of the Instituto de Astrofísica de Canarias. The 1.5 m Carlos Sánchez Magro telescope is operated by IAC at the Spanish Observatorio del Teide (island of Tenerife).

A.M. wishes to thank the hospitality of the Instituto de Astronomía (UNAM) in Mexico during the preparation of this work and also many helpful discussions with L. Carrasco, M. Tapia and other members of the I.A. U.N.A.M.

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DISCUSSION

CARRASCO: Irene Cruz y yo hemos mapeado esta región en K y a magnitud superficial 19 mag arcsec^{-2} vemos una nebulosa de reflexión de 2'×4'.

MAMPASO: Nuestro mapa, sin embargo, está hecho en el modo DC lo que, aunque disminuye ligeramente la sensibilidad hasta ∿ 18 mag arcsec^{-2}, permite una interpretación directa y sin ambigüedades de los resultados. No es sorprendente, por otro lado, la existencia de una componente más extensa y débil más allá de los límites de nuestro mapa.

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