ON THE RELATIONSHIP BETWEEN THE INFRARED SOURCE CRL 2591 (UOA-27)
AND ITS RADIO AND H₂O COUNTERPARTS

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ABSTRACT

New radio, infrared, and H₂O maser observations show that there is a 7" angular separation between the protostar-like infrared source CRL 2591 and the compact H II region which has until now been identified with it, while the H₂O maser coincides with the infrared source. This result, together with an extension of photometric measurements to 20 μm and a much improved upper limit to its angular size, reinforces the apparent similarity of CRL 2591 to the BN object in Orion and to W3/IR5.5.

Subject headings: infrared: sources — masers — nebulae: individual — stars: formation

I. INTRODUCTION

The infrared source CRL 2591 was first described under another name¹ by Merrill and Soifer (1974). They showed that the object has an energy distribution between 2.8 and 14 μm which resembles that of the Becklin-Neugebauer point source in the Orion Nebula in its strength, in its overall shape, and in the depths of its 3.1 and 9.7 μm absorption features. Subsequently, Wendker and Baars (1974) found a faint H II region which they identified with the infrared source and which Brown (1974) estimated to have a width of 270 ± 10μ, while maser H₂O emission was found from the vicinity of CRL 2591 by Bale et al. (1975).

There has been much interest in CRL 2591 in the context of star formation theories since it was thought that it might represent an example of an object in an evolutionary stage intermediate between an infrared protostar and a conventional compact H II region. The new observations described in this Letter show that this cannot be the case since the two objects are separated in space.

II. INFRARED OBSERVATIONS

The position of the infrared source at 3.5 μm was measured using the Hale 5 m telescope and an f/16 Cassegrain photometer with a focal plane chopper. The location of the infrared peak was determined relative to six nearby field stars whose positions were determined relative to AGK2 standards using a Sky Survey plate. The position of the 3.5 μm peak (Table I) is accurate to about ±2". A second measurement, this time at 20 μm, was made using the 2.2 m telescope at Mauna Kea Observatory in Hawaii. Although the precision of this measurement is only about ±5", it agrees well with that made at Palomar (Table I). The new position lies just outside Kleiennmann and Lebofsky’s (1975) error box, and is 7" displaced from the radio position.

The diameter of CRL 2591 was measured at 12.5 μm (ΔΔ = 1.0 μm) by scanning across it with a 0.7 × 4" slit, and comparing the resultant profile with that from a standard star convolved with a Gaussian source profile in the manner described by Becklin et al. (1973). From a total of four scans a size of 0.5 ± 0.3 was obtained for the north-south diameter of the source, measured as the full width at half-maximum of a Gaussian model.

The 20 μm density of CRL 2591 was measured at Mauna Kea with a 9" aperture to be 660 ± 160 Jy [(20 μm) = −4.5 mag]. This extension of the measured energy distribution to longer wavelengths permits a broader comparison of this object with the BN source in Orion (Becklin, Neugebauer, and Wynn-Williams 1973). When combined with the data of Merrill and Soifer (1974), the new measurement shows that the energy distribution of the two objects are almost identical over the range 2.8 to 20 μm except for the fact that CRL 2591 appears about 60% brighter.

III. RADIO CONTINUUM OBSERVATIONS

The region around CRL 2591 was observed at both 5 GHz and 15 GHz with the Cambridge 5 km telescope. From the 5 GHz observations it is possible to set an upper limit (3 σ) of about 15 mJy to the flux density of a point source at the infrared position.

Measurements of the nearby radio source generally confirm previously published results. The position of the source is in very good agreement with those of Wendker and Baars (1974) and Brown (1974). Its diameter was determined by fitting the visibility function at 5 GHz to a model of a uniform density optically thin spherical H II region, and also by direct measurement of the 15 GHz map. At both frequencies the diameter of the source is about 2", in agreement with Brown’s (1974) measurement. The flux density of the radio source at both 5 GHz and 15 GHz is 110 ± 20 mJy, so there is no evidence for self-absorption at
these frequencies. This conclusion is corroborated by the fairly low values for the peak of brightness temperature of the source, namely 700 K at 5 GHz and 170 K at 15 GHz.

IV. H2O OBSERVATIONS

The position of the H2O maser source was measured with the Hat Creek interferometer during 1976 February. A description of the instrument is given by Welch et al. (1976). The interferometer baseline was determined to a fractional accuracy of about 10^{-4} by observations of several quasars whose positions are accurately known. At the time of observation, the strongest feature in the H2O spectrum had an intensity of 600 Jy and a velocity of −21.6 km s^{-1} (LSR). A slightly weaker feature at −23.6 km s^{-1} gave the same position within the accuracy of measurement of about ±0.5″. The source position is given in Table 1 and agrees with the 3.5 μm position within the errors.

V. DISCUSSION

The difference in position between the infrared source and the radio source is several times larger than the errors of measurement, and several times larger than the measured size of either object. We therefore conclude that the radio source and the infrared source are two separate objects, with the H2O maser source being coincident with the infrared source. Nevertheless, the proximity of the infrared source and radio source is probably not a coincidence; most compact H II regions occur in groups, as do many infrared sources. The molecular line data of Morris et al. (1974) and the 350 μm continuum observations of Rieke et al. (1973) indicate that the objects are probably embedded in a molecular cloud; they may therefore be manifestations of two recently formed stars, perhaps of different ages, perhaps of different masses. A study at various wavelengths of a larger area around CRL 2591 might well disclose evidence of other newly formed stars.

The absence of radio emission, the compact size, the energy distribution, and the coincidence with an H2O maser all strengthen the apparent similarity of CRL 2591 to the BN source in Orion. The main differences are first that whereas the BN object is one of a group of somewhat similar infrared sources, no infrared companions have yet been reported for CRL 2591, and second that its luminosity is probably several times larger than the BN source since its distance may be of the order of 1.5 kpc (Wendker and Baars 1974) as opposed to 0.5 kpc for Orion. There is also a very strong resemblance of CRL 2591 to the cooler and more luminous protostar W3/IRS 5 (Wynn-Williams, Becklin, and Neugebauer 1972) especially in the association of an H2O maser with an infrared source but no radio continuum emission.

Two other powerful, compact infrared sources with properties similar to CRL 2591 have been identified with very compact H II regions, namely W3 (OH) and NGC 7538-IRS 1 (Wynn-Williams, Becklin, and Neugebauer 1972, 1974). Although in both cases the radio source and infrared source coincide to within 3″, the possibility that the emission originates from two physically distinct objects should perhaps be taken more seriously in view of the results discussed in this Letter.

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TABLE 1
Positions (1950) of the Infrared Source CRL 2591, the H2O Maser, and the Nearby Radio Source

<table>
<thead>
<tr>
<th>Spectral Region</th>
<th>Right Ascension</th>
<th>Declination</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5 μm</td>
<td>20°27′35″9 +00′2″</td>
<td>40°01′16″7 ±2″</td>
</tr>
<tr>
<td>20 μm</td>
<td>20 27 35.9 ± 0.5</td>
<td>40 01 16 ± 5</td>
</tr>
<tr>
<td>H2O</td>
<td>20 27 35.9 ± 0.03</td>
<td>40 01 16 ± 0.5</td>
</tr>
<tr>
<td>Radio</td>
<td>20 27 35.6 ± 0.1</td>
<td>40 01 10 ± 1</td>
</tr>
</tbody>
</table>

REFERENCES


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