The Ultracompact HII-Region G45.07+0.13: An Ionized Bipolar Outflow?

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Abstract

We present continuum and hydrogen recombination line observations of the ultracompact HII-region G45.07+0.13 at cm-wavelengths with the VLA, as well as molecular line observations of the surrounding neutral gas at 3 mm with the BIMA-array. We show that the bright inner region of G45.07+0.13 has a bipolar structure, which is well aligned with and has a velocity gradient in the same sense as the larger-scale bipolar molecular outflow seen in 12CO. We discuss the possibility that G45.07+0.13 is an ionized bipolar outflow. The bipolar structure may reflect the preferential expansion of an ionized stellar wind or the stellar UV ionisation front along the less dense polar direction of the surrounding molecular gas core, partially or nearly entirely evacuated in this direction by the passage of a bipolar outflow. Alternatively, the stellar UV may be lighting up a genuine, ongoing bipolar outflow.

1 Introduction

The Ultracompact HII-region G45.07+0.13 was observed at high angular-resolution (∼0′′1) with the VLA in A-array by Turner & Matthews (1984). They report a shell structure with an outer diameter of ∼0′′6 at 2 cm, which at a distance of 8.3 kpc (Hunter et al. 1997) corresponds to a linear size of ∼0.02 pc. Garay et al. (1986) observed G45.07+0.13 in the H76α hydrogen recombination line (also at 2 cm) with the VLA in B-array (angular resolution of ∼0′′4), where the source was barely resolved. The report a full width at half power for the H76α line of nearly 50 km s⁻¹ (integrated over the source), and a shift in the line centroid from the southeast to the north-west with increasing velocity. Comparing the observed kinematic structure with the spatial structure observed at higher angular resolution by Turner & Matthews (1984), Garay et al. (1986) concluded that the UC-HII region delineates an expanding ionized ring or torus seen nearly face-on. They further suggest that this toroidal structure corresponds to the inner ionized walls of a (otherwise neutral) disk surrounding the central young, massive star.

2 Observations with the BIMA-array

Motivated by the interpretation of Garay et al. (1986), we observed G45.07+0.13 with the BIMA-array in several molecular transitions to search for the predicted neutral disk surrounding the UC-HII region. Instead, we discovered a bipolar molecular outflow from G45.07+0.13, as was discovered independently and imaged by Hunter et al. (1997) in the optically thick transition of CS J = 2 → 1 at 3 mm with the OVRO. In Figure 1, we show the bipolar molecular outflow as imaged with the BIMA-array in 12CO J = 1 → 0, which is optically thin except for line of sights close to and against the UC-HII region. This transition better traces the kinematic structure of the bipolar outflow (especially close to the UC-HII region), which has a polar axis at a position angle of approximately −30° (positive indicates anti-clockwise from north) similar to that measured by Hunter et al. (1997).

3 Reanalysis of archival VLA data

Motivated by a desire to superpose our BIMA-array images with the above-mentioned VLA continuum and recombination-line images, we reanalyzed the VLA data taken by Turner & Matthews (1984) and Garay et al. (1986). Contrary to the shell structure reported by Turner & Matthews (1984), our analysis reveals that the UC-HII region has a bright inner bipolar structure surrounded by more diffuse and more spherically symmetric emission, as shown in Figure 2. The polar axis of the bright inner bipolar structure has a position angle of approximately −30°, similar to that of the larger-scale bipolar molecular outflow. It is instructive to compare our image with that reported by Turner & Matthews (1984) (their Fig. 2), and to note where the two images differ. We found and discarded many obviously bad data points in the dataset. Unlike Turner & Matthews (1984), we also self-calibrated our image, although we emphasize that the image made before self-calibration already shows the same basic features as those seen in (our) Figure 2.

Figure 1: A bipolar molecular outflow from the UC-HII region G45.07+0.13 as imaged in 12CO J = 1 → 0 with the BIMA-array. The position of the UC-HII region is marked by an asterisk. The dotted contours correspond to the blueshifted part of the outflow spanning velocities 53–55 km s⁻¹, and the solid contours correspond to the redshifted part of the outflow spanning velocities 61–63 km s⁻¹. The polar axis of the bipolar molecular outflow is oriented at a position angle of approximately −30°, similar to that found by Hunter et al. (1997) in the CS J = 2 → 1 molecular line. The synthesized beam of the observation is shown in the lower left corner.

Figure 2: The 2-cm continuum image of G45.07+0.13 made from a reanalysis of archival VLA A-array data originally taken by Turner & Matthews (1984). The UC-HII region has a bright inner bipolar structure, surrounded by more diffuse and more spherically symmetric emission. The polar axis of the bright inner bipolar feature is oriented at a position angle of approximately −30°, similar to that of the larger-scale bipolar molecular outflow shown in Figure 1. The synthesized beam of the observation is shown in the lower right corner.
Our reanalysis of the H76α hydrogen recombination line data taken by Garay et al. (1986) with the VLA in B-array is shown in Figure 3, superposed on the high-resolution continuum image shown in Figure 2. Our results are essentially identical to that of Garay et al. (1986), although of higher image quality owing to the application of self-calibration. Recall, as described above, that Garay et al. (1986) saw a shift in the centroid of the line emission from the south-east to the north-west with increasing radial velocity (see their Fig. 5), identical to that seen in our (slightly improved) image of Figure 3. Based on the shell structure reported by Turner & Matthews (1984) for the UC-HII region, Garay et al. (1986) interpreted the observed velocity structure in terms of an expanding toroidal structure. From Figure 3, however, the spatial and kinematic structure of G45.07+0.13 are more naturally interpreted as an ionized bipolar outflow, which is aligned with the larger-scale bipolar molecular outflow.

4 Discussion

The total flux density of G45.07+0.13 rises with frequency to a peak at a turnover frequency of ~15 GHz (2 cm), and thereafter flattens out at shorter centimeter wavelengths (see Garay et al. 1986). Because measurements at different wavelengths were made with different telescopes or the same telescope but at different angular resolutions, the derived total flux density spectrum needs to be confirmed; furthermore, the spectrum of the bright inner bipolar structure may be different from the total flux density spectrum. Nevertheless, if the flux density spectrum is representative of the spectrum in the bright inner bipolar region of G45.07+0.13, it argues against the likelihood that this structure is actually a collimated mass outflow with a high mass-outflow rate. If that was the case, the resulting high density of the ionized gas would likely make the outflow optically thick throughout the centimeter-wavelength range, and thus show a rising flux curve. Clearly, spatially-resolved observations of the spectrum of G45.07+0.13 is highly desirable. Observations with higher angular resolution in hydrogen recombination line (i.e., A-array at 2 cm) also is desirable to better understand the ionized gas kinematics.

Instead, the bipolar structure of G45.07+0.13 could result from the faster expansion of an ionized stellar wind or the stellar UV ionization front along the less dense polar direction of the surrounding natal molecular gas. Indeed, our molecular line observations with the BIMA-array, especially in the higher critical density H3+CO+ transition, reveal a toroidal molecular core around G45.07+0.13 with a polar axis in the north-south direction, slightly tilted from the polar axis of the larger-scale bipolar molecular outflow. The preferential expansion of the ionization front along the polar axis of the bipolar molecular outflow, rather than the polar direction of the surrounding molecular core, may reflect the partial evacuation of gas in the direction of the bipolar molecular outflow, the ionization front is simply lighting up the walls of a cavity almost completely evacuated by the bipolar molecular outflow.

An intriguing possibility, which cannot be ruled out at this stage, is that the stellar UV may be lighting up an ongoing bipolar outflow which may be partly, or mostly, neutral, thereby accounting for the relatively low turnover frequency of the ionized gas component. If this is the case, then because the bipolar outflow traced in ionized gas has much higher velocities than the large-scale bipolar molecular outflow traced in 12CO, the latter may simply represent entrained material. More detailed observations of G45.07+0.13, especially at high angular resolution at cm-wavelengths, are required to fully unravel the nature of this UC-HII region.

References


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