1. Introduction

Massive stars play an important role in both the morphology and the chemical evolution of the interstellar medium (ISM), but their formation mechanism is still poorly understood. The formation of massive stars can be triggered by the action of H II regions. With the expansion of the H II regions, it may compress a pre-existing molecular cloud creating a compact clump, or sweep up the surrounding molecular material creating a dense molecular layer. The compact clump and dense molecular layer can be break apart and then may collapse to lead to the formation of new stars.

In the numerical study of star formation, the expanding H II regions can trigger star formation if the ambient molecular material is dense enough (Hosokawa & Inutsuka 2005; Dale et al. 2007). Collect and collapse (CC) and radiatively driven implosion (RDI) mechanisms may trigger star formation on the borders of H II regions (Elmegreen 1998). Several pieces of observational evidence have been found supporting these star formation mechanisms (e.g., Zavagno et al. 2007; Deharveng et al. 2008; Paron et al. 2009; Tibbs et al. 2012). Therefore, a detailed study of the star-forming regions at various wavebands is necessary to trace the star formation scenario of H II region environments.

Infrared dark clouds (IRDCs) are considered potential cluster and massive star formation regions (Menten et al. 2005). In this paper, we present results of an IRDC G38.95-0.47 with a distance of ∼2.9 kpc (Du & Yang 2008), located between H II regions G38.91-0.44 and G39.30-1.04. Because IR-dark clumps are absorption features against the mid-IR Galactic background emission, López-Sepulcre et al. (2010) suggested that IRDCs are absorption features against the mid-IR Galactic background emission. López-Sepulcre et al. (2010) suggested that IRDCs are large-scale clumps that are associated with young stellar objects (YSOs) associated this region, we used the GLIMPSE I catalog. The radio continuum, infrared, and CO molecular observations of infrared dark cloud (IRDC) G38.95-0.47 and its adjacent H II regions G38.91-0.44 (N74), G38.93-0.39 (N75), and G39.30-1.04. The Purple Mountain Observation (PMO) 13.7 m radio telescope was used to detect $^{12}$CO $J=1-0$, $^{13}$CO $J=1-0$ and C$^{18}$O $J=1-0$ lines. The carbon monoxide (CO) molecular observations can ensure the real association between the ionized gas and the neutral material observed nearby. To select young stellar objects (YSOs) associated this region, we used the GLIMPSE I catalog.

**Key words.** Stars: formation —Stars: early-type — ISM: H II regions — ISM: individual objects( G38.91-0.44, G38.93-0.39, G38.95-0.47, G39.30-1.04)

1. Introduction

Massive stars play an important role in both the morphology and the chemical evolution of the interstellar medium (ISM), but their formation mechanism is still poorly understood. The formation of massive stars can be triggered by the action of H II regions. With the expansion of the H II regions, it may compress a pre-existing molecular cloud creating a compact clump, or sweep up the surrounding molecular material creating a dense molecular layer. The compact clump and dense molecular layer can be break apart and then may collapse to lead to the formation of new stars.

In the numerical study of star formation, the expanding H II regions can trigger star formation if the ambient molecular material is dense enough (Hosokawa & Inutsuka 2005; Dale et al. 2007). Collect and collapse (CC) and radiatively driven implosion (RDI) mechanisms may trigger star formation on the borders of H II regions (Elmegreen 1998). Several pieces of observational evidence have been found supporting these star formation mechanisms (e.g., Zavagno et al. 2007; Deharveng et al. 2008; Paron et al. 2009; Tibbs et al. 2012). Therefore, a detailed study of the star-forming regions at various wavebands is necessary to trace the star formation scenario of H II region environments.

Infrared dark clouds (IRDCs) are considered potential cluster and massive star formation regions (Menten et al. 2005). In this paper, we present results of an IRDC G38.95-0.47 with a distance of ∼2.9 kpc (Du & Yang 2008), located between H II regions G38.91-0.44 and G39.30-1.04. Because IR-dark clumps are absorption features against the mid-IR Galactic background emission, López-Sepulcre et al. (2010) suggested that IRDCs are absorption features against the mid-IR Galactic background emission. López-Sepulcre et al. (2010) suggested that IRDCs are large-scale clumps that are associated with young stellar objects (YSOs) associated this region, we used the GLIMPSE I catalog. The radio continuum, infrared, and CO molecular observations of infrared dark cloud (IRDC) G38.95-0.47 and its adjacent H II regions G38.91-0.44 (N74), G38.93-0.39 (N75), and G39.30-1.04. The Purple Mountain Observation (PMO) 13.7 m radio telescope was used to detect $^{12}$CO $J=1-0$, $^{13}$CO $J=1-0$ and C$^{18}$O $J=1-0$ lines. The carbon monoxide (CO) molecular observations can ensure the real association between the ionized gas and the neutral material observed nearby. To select young stellar objects (YSOs) associated this region, we used the GLIMPSE I catalog.

**Key words.** Stars: formation —Stars: early-type — ISM: H II regions — ISM: individual objects( G38.91-0.44, G38.93-0.39, G38.95-0.47, G39.30-1.04)

1. Introduction

Massive stars play an important role in both the morphology and the chemical evolution of the interstellar medium (ISM), but their formation mechanism is still poorly understood. The formation of massive stars can be triggered by the action of H II regions. With the expansion of the H II regions, it may compress a pre-existing molecular cloud creating a compact clump, or sweep up the surrounding molecular material creating a dense molecular layer. The compact clump and dense molecular layer can be break apart and then may collapse to lead to the formation of new stars.

In the numerical study of star formation, the expanding H II regions can trigger star formation if the ambient molecular material is dense enough (Hosokawa & Inutsuka 2005; Dale et al. 2007). Collect and collapse (CC) and radiatively driven implosion (RDI) mechanisms may trigger star formation on the borders of H II regions (Elmegreen 1998). Several pieces of observational evidence have been found supporting these star formation mechanisms (e.g., Zavagno et al. 2007; Deharveng et al. 2008; Paron et al. 2009; Tibbs et al. 2012). Therefore, a detailed study of the star-forming regions at various wavebands is necessary to trace the star formation scenario of H II region environments.
J.-L. Xu et al.: Triggered massive and clustered stars formation by together H II regions G38.91-0.44 and G39.30-1.04

Fig. 1. $^{13}$CO $J=1-0$ integrated intensity contours (black) and 1.4 GHz radio continuum emission contours (blue) overlayed on the Spitzer-IRAC 8 $\mu$m emission map (color scale). The black contour levels are 30, 40, ..., 90% of the peak value (46.7 K km s$^{-1}$). The blue contour levels are 1.7, 3.3, 4.9, 6.5, and 8.1 mJy beam$^{-1}$. The letters A and B indicate the different cloud clumps. The green and red crosses indicate four millimeter continuum sources.

To look for signatures of star formation, we combined molecular, infrared, and radio continuum observations toward IRDC G38.95-0.47 and its adjacent H II regions.

2. Observations and data reduction

The mapping observations of IRDC G38.95-0.47 and its adjacent H II regions were performed in the $^{12}$CO $J=1-0$, $^{13}$CO $J=1-0$, and C$^{18}$O $J=1-0$ lines using the Purple Mountain Observation (PMO) 13.7 m radio telescope at De Ling Ha, China, in May 2012. The new 3$x$3 beam array receiver system in single-sideband (SSB) mode was used as front end. The back end is a fast Fourier transform spectrometer (FFTS) of 16384 channels with a bandwidth of 1 GHz, corresponding to a velocity resolution of 0.16 km s$^{-1}$ for $^{12}$CO $J=1-0$ and 0.17 km s$^{-1}$ for $^{13}$CO $J=1-0$ and C$^{18}$O $J=1-0$. $^{12}$CO $J=1-0$ was observed at upper sideband, while $^{13}$CO $J=1-0$ and C$^{18}$O $J=1-0$ were observed simultaneously at lower sideband. The half-power beam width (HPBW) was 53$''$ at 115 GHz and the main beam efficiency was 0.5. The pointing accuracy of the telescope was better than 5$''$. The system noise temperature (Tsys) in SSB mode varied between 150 K and 400 K. Mapping observations were centered at RA(J2000)=$19^h04^m30^s$, DEC(J2000)=$05^d08^m18.9''$ using on-the-fly (OTF) observing mode. The total mapping area is $20'\times20'$ in $^{12}$CO $J=1-0$, $^{13}$CO $J=1-0$, and C$^{18}$O $J=1-0$ with a $0.5'\times0.5'$ grid. The standard chopper wheel calibration technique is used to measure antenna temperature $T_A^*$ corrected for atmospheric absorption. The final data was recorded in brightness temperature scale of $T_{mb}$ (K). The data were reduced using the GILDAS/CLASS package. The 1.4 GHz radio continuum emission data were obtained from the NRAO VLA Sky Survey (Condon et al. [1998]).

3. Results

3.1. Radio continuum and infrared emission of H II regions

Figure 1 shows the 1.4 GHz continuum emission image (blue contours) superimposed on the Spitzer-IRAC emission at 8 $\mu$m (color scale). The Spitzer-IRAC 8 $\mu$m emission is attributed to polycyclic aromatic hydrocarbons (PAHs), which can be used to trace the photodissociated region (PDR) surrounding H II region. In Fig. 1, the PAH emission displays a ring-like shape for the H II region G38.91-0.44, which coincides with bubble N74 (Churchwell et al. [2006]; Deharveng et al. [2010]; Sherman [2012]). A small area of higher flux is situated at the center of the bubble, which could be a feature in the PDR on the far or near side of the bubble. Moreover, one compact and two weak radio continuum emissions (blue contours) are distributed along the PAH emission of G38.91-0.44. Anderson et al. [2011] determined that the hydrogen radio recombination line (RRL) velocity is 40 km s$^{-1}$.

1 http://www.iram.fr/IRAMFR/GILDAS/
km s\(^{-1}\) for G38.91-0.44. Hence, the triggered star formation is taking place in the molecular cloud at the periphery of PDR. There may be another new H II region to the east of G38.91-0.44, named G39.30-1.04 with RA(J2000)\(=19\)h\(04\)m\(19.0^\circ\) and DEC(J2000)\(=05^\circ06^\prime42.7^\prime\prime\). The 1.4 GHz continuum emission reveals the presence of the ionized gas of G39.30-1.04. The PAH emission of G39.30-1.04 with a higher surface brightness shows a comet-like morphology. Because the ionized gas of G39.30-1.04 is surrounded by the PAH emission, the PAH emission may be excited by radiation from G39.30-1.04. The H II region G38.93-0.39 associated with bubble N75 (Churchwell et al. 2006; Deharveng et al. 2010; Sherman 2012) is located at the northwest of G38.91-0.44. From Fig. 1, we can see that the PAH emission of G38.93-0.39 show an almost semi-ring shape with a cut towards the southwest. The dense continuum emission is filled in the PAH emission of G38.93-0.39.

### 3.2. Molecular line emission

To analyze in greater detail the morphology of molecular gas associated with H II regions, we use the optically thin \(^{13}\)CO \(J=1-0\) to trace the molecular gas. After a careful inspection of the CO component using the channel map (see Fig. 2), we find that only the CO component in intervals 37 ~ 47 km s\(^{-1}\) is associated with these H II regions. Using this velocity range, we make the integrated intensity map of \(^{13}\)CO \(J=1-0\) (Fig. 1). From Fig. 1 (black contours), we find two large cloud clumps, designated clumps A and B, respectively. Clump A covers the whole IRDC G38.95-0.47, which is located between H II region G38.91-0.44 and G39.30-1.04. In addition, four submillimeter continuum sources were detected in the clump A (Di Francesco et al. 2008). Only G038.95-00.47-M1 core (marked by a red cross in figures 1 and 4) has outflow and infall motions (López-Sepulcre et al. 2010). Moreover, \(^{13}\)CO \(J=1-0\) emission of clump A presents a triangle-like shape, and has an integrated intensity gradient along the direction of H II regions G38.91-0.44 and G39.30-1.04, suggesting that the shocks from the two H II regions have expanded into clump A, and have compressed it. Clump B shows a bow-like shape toward G38.93-0.39, the center of which has a small area of higher PAH emission. Mercer et al. (2005) detected a star cluster in clump B.

Figure 3 shows the average spectra of \(^{12}\)CO \(J=1-0\), \(^{13}\)CO \(J=1-0\), and \(^{18}\)O \(J=1-0\) over clumps A and B, respectively. From these spectra, we can see that the velocity components are mainly located in the velocity interval 30 to 50 km s\(^{-1}\). The velocity component in interval 10~20 km s\(^{-1}\) should belong to the foreground emission, while 50~90 km s\(^{-1}\) may belong to the background emission, as seen in Fig. 2. We perform Gaussian fits to the spectra of \(^{12}\)CO \(J=1-0\), \(^{13}\)CO \(J=1-0\), and \(^{18}\)O \(J=1-0\) in clumps A and B. The fitted results are summarized in Table 1. Hence, we derive systemic velocities of ~41.7 km s\(^{-1}\) and ~39.4 km s\(^{-1}\) in the \(^{18}\)O \(J=1-0\) lines for clumps A and B, respectively, which are well associated with the hydrogen RRL velocity of H II region G38.91-0.44.
Table 1. Observed parameters of each line

| Name     | \(^{12}\text{CO}~J=1-0\) | \(^{13}\text{CO}~J=1-0\) | \(^{18}\text{O}~J=1-0\) |
|----------|------------------------|------------------------|------------------------|
|          | \(T_{mb}\) (K) | FWHM (km s\(^{-1}\)) | \(V_{LSR}\) (km s\(^{-1}\)) | \(T_{mb}\) (K) | FWHM (km s\(^{-1}\)) | \(V_{LSR}\) (km s\(^{-1}\)) | \(T_{mb}\) (K) | FWHM (km s\(^{-1}\)) | \(V_{LSR}\) (km s\(^{-1}\)) |
| Clump A  | 18.8 | 4.3 (0.2) | 41.7 (0.2) | 8.6 | 2.9 (0.1) | 41.5 (0.2) | 1.6 | 2.1 (0.1) | 41.7 (0.1) |
| Clump B  | 20.3 | 4.6 (0.2) | 40.2 (0.1) | 6.3 | 3.6 (0.1) | 38.9 (0.1) | 0.5 | 3.7 (0.2) | 39.4 (0.1) |

Table 2. The physical parameters of the clumps in LTE.

| Name     | \(T_{ex}\) (K) | \(d\) (pc) | \(N_{H_2}\) (cm\(^{-2}\)) | \(n(H_2)\) (cm\(^{-3}\)) | \(M\) (10\(^3\)M\(_\odot\)) |
|----------|----------------|-------------|-----------------------|-----------------------|---------------------|
| Clump A  | 22.3           | 31.2        | 1.7 \times 10\(^2\)  | 0.9 \times 10\(^2\)  | 1.0                 |
| Clump B  | 23.7           | 34.8        | 1.6 \times 10\(^2\)  | 0.8 \times 10\(^2\)  | 1.1                 |

Fig. 3. Average spectra of \(^{12}\text{CO}~J=1-0\), \(^{13}\text{CO}~J=1-0\), and \(^{18}\text{O}~J=1-0\) over each clump.

Assuming local thermodynamical equilibrium (LTE) and using the optically thin \(^{13}\text{CO}~J=1-0\), the column densities of the clumps are determined by the Garden et al. (1991) equation

\[
N_{\text{vCO}} = 4.6 \times 10^{13} \left[ \frac{(T_{ex} + 0.89)}{\exp(-5.29/T_{ex})} \right] \int T_{mb} dv \text{cm}^{-2}, \quad (1)
\]

where \(T_{ex}\) is the excitation temperature in K, and dv is the velocity range in km s\(^{-1}\). We calculate \(T_{ex}\) following the equation \(T_{ex} = 5.53 / \ln[1 + 5.53 / (T_{mb} + 0.82)]\), where \(T_{mb}\) is the corrected main-beam temperature of \(^{12}\text{CO}~J=1-0\). Here we use the relation \(N_{H_2} \approx 5 \times 10^5 N_{\text{vCO}}\) (Simon et al. 2001). If the clumps are approximately spherical in shape, the mean number density of H\(_2\) is estimated to be \(n(H_2) = 1.62 \times 10^{-19} N_{H_2} / d\), where \(d\) is the averaged diameter of the clumps in parsecs (pc). Moreover, their mass is given by \(M_{H_2} = \frac{4\pi d^2}{3} n(H_2) m(H_2)\) (Garden et al. 1991), where \(m_c = 1.36\) is the mean atomic weight of the gas, and \(m(H_2)\) is the mass of a hydrogen molecule. The obtained column density, mean number density, and mass of each clump are all listed in Table 2.

3.3. Search for young stellar objects

To look for star formation toward IRDC G38.95-0.47 and its adjacent H II regions, we used the Spitzer/GLIMPSE I catalog. The GLIMPSE I survey observed the Galactic plane (65° < |l| < 10° for \(|b| < 5°\) with the four mid-IR bands (3.6, 4.5, 5.8, and 8.0 \(\mu\)m) of the Infrared Array Camera (Fazio et al. 2004). From the database, we extracted 9046 near-infrared sources within a circle of 10' in radius centered on R.A. = 19°04'07.5" (J2000), Dec = 05°08'18.9" (J2000). Based on the color selection criteria of YSOs (Allen et al. 2004; Robitaille et al. 2008), we only selected the 103 Class I sources that had been detected in the four Spitzer-IRAC bands. Class I sources are protostars with circumstellar envelopes that are expected to be YSOs with an age of \(< 10^3\) yr. Figure 4 presents the spatial distribution of Class I sources. From Fig. 4, we see that Class I sources are asymmetrically distributed across the whole selected region, and are mostly concentrated in IRDC G38.95-0.47 between H II regions G38.91-0.44 and G39.30-1.04. The existence of Class I sources may indicate star formation activity.

In addition, we found 13 IRAS sources using the IRAS Point Sources Catalog in this region. In Fig. 4, five IRAS sources may be associated with PAH emission. Because the fluxes of the five IRAS sources are only upper limits except for IRAS 19012+0505, we only calculate the parameters of IRAS 19012+0505. Infrared luminosity (Casoli et al. 1986) and dust temperature (Henning et al. 1992) are expressed respectively as,

\[
L_{IR} = (6.196 \times F_{12} + 2.261 \times F_{25} + 1.373 \times F_{60} + 0.529 \times F_{100}) \times D^2, \quad (2)
\]

\[
T_d = \frac{96}{(3 + \beta) \ln(100/60) - \ln(F_{60}/F_{100})}, \quad (3)
\]

where \(D\) is the distance from the sun in kpc, and \(F_{12}, F_{25}, F_{60}, \) and \(F_{100}\) are the infrared fluxes at four IRAS bands, 12 \(\mu\)m, 25 \(\mu\)m, 60 \(\mu\)m, and 100 \(\mu\)m, respectively. The emissivity index of dust particle (\(\beta\)) is assumed to be 2. In addition, we calculate the color index of each IRAS source. The calculated results are presented in Table 2.

4. DISCUSSION

The \(^{13}\text{CO}~J=1-0\) emission of IRDC G38.95-0.47 shows a triangle-like shape (see Figs. 1 and 4), and has a steep integrated-intensity gradient toward H II regions G38.91-0.44 and G39.30-1.04. We suggest that H II regions G38.91-0.44 and G39.30-1.04 have expanded into the IRDC G38.95-0.47. Four submillimeter continuum sources have been detected in the IRDC G38.95-0.47. Only source G038.95-00.47-M1 has outflow and infall motions, as well as a solar mass of \(117 M_\odot\), indicating indicating that it is a newly forming massive star. Both kinetic timescales
Fig. 4. Left: Class I sources are labeled as the blue dots. The red squares and triangle represent IRAS sources and Class II methanol maser (Deharveng et al. 2010), respectively. The green and red crosses indicate five smm continuum sources. The purple dashed circle outlines the Class I sources, which may be associated with IRDC G38.95-0.47. Right: the velocity-integrated intensity maps of $^{13}$CO $J = 1 - 0$ outflows (red and blue contours) overlaid with the $^{13}$CO $J = 1 - 0$ emission of each clump (gray scale). The red and blue contour levels are 30,...,100% of the peak value.

Table 3. Selected IR point sources associated with these H II regions: IR flux densities and the obtained parameters

| Name Source          | RA (h m s) | DEC ($\circ \arcmin \arcsec$) | $F_{12}$ [Jy] | $F_{25}$ [Jy] | $F_{60}$ [Jy] | $F_{100}$ [Jy] | log($F_{25}/F_{12}$) | log($F_{60}/F_{12}$) | $L_{IR}$ [$L_\odot$] | $T_d$ [K] |
|---------------------|------------|-------------------------------|--------------|--------------|--------------|---------------|----------------------|----------------------|---------------------|--------|
| IRAS 19012+0505     | 19 03 43.51| 05 09 48.91                   | 8.27         | 17.31        | 497.20       | 1156.00       | 0.32                 | 1.78                 | 11644.14            | 91.62  |

The velocity component of blueshifted emission is from 39.7 km s$^{-1}$ to 40.7 km s$^{-1}$, while the velocity component of redshifted emission is from 42.6 km s$^{-1}$ to 43.6 km s$^{-1}$ for G038.95-00.47-M1. In IRAS 19012+0505, the velocity component of blueshifted emission is from 36.5 km s$^{-1}$ to 38.2 km s$^{-1}$, while the velocity component of redshifted emission is from 40.2 km s$^{-1}$ to 41.0 km s$^{-1}$. In Fig. 4, the blueshifted and redshifted components are presented as blue and red contours. From Fig. 4 (right), we clearly see that clump B has a collimated outflow activity at the NE-SW direction. Moreover, there is also outflow motion in clump A consistent with G038.95-00.47-M1. However, the blueshifted lobe of clump A is weak, which may be disrupted by the expansion of the H II region G38.91-0.44. Adopting the angle of 90$^\circ$, the dynamic timescale of each outflow is estimated by equation $t = 9.78 \times 10^5 R/V$ (yr) (Goldsmith et al. 1984; Qin et al. 2008), where $V$ in km s$^{-1}$ is the maximum flow velocity relative to the cloud systemic velocity, and $R$ in pc is the outflow size defined by the length of the begin-to-end flow extension for each blueshifted and redshifted lobe. Because IRDC G38.95-0.47 is associated with H II regions G38.91-0.44 and G39.30-1.04, we also adopt a kinematic distance of 2.9 kpc in this paper. The average dynamical timescale of the outflow in clump A is 2.8$\times 10^5$ yr, which is roughly consistent with the value in HCO$^+$ $J=1-0$ line (López-Sepúlcre et al. 2010). For clump B, the outflow has the average dynamical timescale of 3.0$\times 10^5$ yr.

In addition, Class I sources are mostly concentrated in IRDC G38.95-0.47 between H II regions G38.91-0.44 and G39.30-1.04. Along the northeastern and eastern sides of N74 associated with G38.91-0.44, both Beaumont & Williams (2011) and Alexander et al. (2013) found a significant statistical overden-
sity of YSOs above the surrounding field. We do not know if all the selected sources seen in the direction of this region lie at the same distance as IRDC G38.95-0.47 relative to G38.91-0.44 and G39.30-1.04. However, the high density of YSOs located in the IRDC indicates that it is unlikely that they are all merely foreground and background stars. It is more likely that these YSOs are physically associated with IRDC G38.95-0.47, between H II regions G38.91-0.44 and G39.30-1.04.

The above analysis suggest that the triggered star formation have occurred in this region. The dynamical age of the H II region can also be used to decide whether YSOs are triggered by H II regions. Assuming an H II region expanding in a homogeneous medium, the dynamical age of the H II region can be estimated by the Dyson & Williams (1980) equation

$$t_{\text{d}} = 7.2 \times 10^4 \left( \frac{R_{\text{HII}}}{\text{pc}} \right)^{0.4} \left( \frac{Q_{\text{L}}}{10^{48} \text{ph s}^{-1}} \right)^{0.25} \left( \frac{n_i}{10^3 \text{cm}^{-3}} \right)^{-0.25} \text{yr},$$

where $R_{\text{HII}}$ is the radius of the H II region, $n_i$ is the initial number density of the gas, and $Q_{\text{L}}$ is the ionizing luminosity. In previous studies toward several H II regions (e.g., Zavagno et al. 2006; Deharveng et al. 2008; Paron et al. 2009, 2011; Pomarès et al. 2009; Dirienzo et al. 2012), an initial number density of $\sim 10^3 \text{cm}^{-3}$ was determined. Alexander et al. (2013) gave the ionizing luminosity of $1.2 \times 10^{46} \text{ph s}^{-1}$, $2.1 \times 10^{46} \text{ph s}^{-1}$, and $6.6 \times 10^{45} \text{ph s}^{-1}$ for G38.91-0.44, G38.93-0.39 and G39.30-1.04, respectively. Adopting the measured radius of H II regions G38.91-0.44 ($\sim 1.4$ pc), G38.93-0.39 ($\sim 0.8$ pc), and G39.30-1.04 ($\sim 1.4$ pc) obtained from Fig. 1, and assuming an initial number density of $\sim 10^3 \text{cm}^{-3}$, we derived that the ages of these H II regions are $6.1 \times 10^5 \text{yr}$, $2.5 \times 10^5 \text{yr}$, and $9.0 \times 10^4 \text{yr}$, respectively. Comparing the ages of these H II regions with YSOs (Class I sources and massive GO38.95-0.47-M1 source), we suggest that the YSOs located in IRDC G38.95-0.47 are likely to be triggered by G38.91-0.44 and G39.30-1.04 together. Deharveng et al. (2003) suggest that some dense fragments are regularly spaced along the H II region, providing strong evidence in favor of the CC model. In this picture, the shock fronts of G38.91-0.44 and G39.30-1.04 have driven into clump A, and have compressed some pre-existing cores in the IRDC G38.95-0.47. Furthermore, the PAH emission of G39.30-1.04 shows the first time that the triggered massive and clustered stars formation has occurred in the IRDC compressed by two H II regions.

We detected an outflow in clump B. Because the age of G38.93-0.39 is slightly smaller than that of the outflow, we conclude that the triggered star formation has not occurred in clump B, as we also did not find a significant statistical overdensity of YSOs ($10^4 \text{yr}$) surrounding G38.93-0.39. Clump B is consistent with a star cluster (Merce et al. 2005), hence the outflow may be driven by the cluster.

2. Four submillimeter continuum sources have been detected in the IRDC G38.95-0.47. Only the GO38.95-0.47-M1 source has outflow and infall motions. In addition, the selected young stellar objects (YSOs) (Class I sources) are concentrated in the IRDC G38.95-0.47, which appear to be sites of ongoing star formation. The obtained ages of the three H II regions are $6.1 \times 10^5 \text{yr}$, $2.5 \times 10^5 \text{yr}$, and $9.0 \times 10^4 \text{yr}$. Taking into account the age of H II regions and YSOs (Class I sources and massive GO38.95-0.47-M1 source), we suggest that YSOs may be triggered by the combined energy G38.91-0.44 and G39.30-1.04, supporting the radiatively driven implosion model. It may be the first time that the triggered star formation has occurred in the IRDC compressed by two H II regions.

3. We detected a new collimated outflow in the clump compressed by G38.93-0.39. The new detected outflow may be driven by a star cluster.