We present results of a comprehensive study of a low-mass star-forming region, L1251B, at wavelengths from the near-infrared to the millimeter. L1251B, where only one protostar, IRAS 22376+7455 was known previously, has been revealed as a small group of three or more protostars based on observations with the Spitzer Space Telescope (Figure 1 and Figure 2). The most luminous source of L1251B is located 5 arcseconds north of the IRAS position. A near-infrared bipolar nebula, which is not associated with the brightest object and located at the SE corner of L1251B, has been detected in IRAC bands.

The submillimeter continuum observations with single-dish telescopes and the $N_2H^+$ interferometric observations (Figure 3) suggest that the brightest object and the NIR bipolar nebula source in L1251B are a possible proto-binary system within a rapid rotating envelope. In molecular line observations, L1251B shows very complex kinematics including infall, rotation, and outflow. The known large CO outflow of L1251B may be the combined feature of two or more outflows. The molecular observations also support recent theoretical studies of the chemistry after the formation of central protostellar objects. Once a central heating source forms and the dust temperature is high enough, the evaporated CO destroys $N_2H^+$ to produce a hole in the $N_2H^+$ emission around the central heating source (Figure 3). However, H$_2$CO is enhanced due to the evaporation of CO or the evaporation of itself (Figure 4).

Interestingly, the direction of the rotational velocity gradient calculated for the inner denser region of L1251B is opposite to that of the extended surroundings, indicative of magnetic braking or magnetic de-coupling. Outside of the small group, many protostellar objects have been detected over a larger region of 12$''$ × 12$''$. Extended emission to the east of L1251B has been detected at 850 micron (Figure 5); therefore, this region might also be a potential site for future star formation since CS and HCN lines show infall signatures even though no object has been detected with IRAC or MIPS. This region is, therefore, a possible example of low mass cluster formation, which contains a small group of protostars, L1251B, and a large pre-protostellar core.
Figure 1: The IRAC band 1 image around L1251B with source identification numbers.

Figure 2: Color-color diagram for sources in the IRAC bands ([$3.6 \pm 4.5$] vs. [8.0]). The numbers present source identification numbers marked in Figure 1. The blue boxes delineate the approximate domains of Class 0/I, Class II, and Class III sources based on Allen et al. (2004). An extinction vector, which is calculated from Weingartner and Draine (2001) model with $A_v = 5.5$, is shown for $A_v = 30$ mag.

Figure 3: The integrated intensities of HCO$^+$ 1–0 (thin contours) and $N_2$H$^+$ 1–0 (thick contours) with the continuum intensity at 3.0 mm (grays). The contour starts at $2\sigma$ and increases in step of $1\sigma$ (0.35 and 0.45 Jy beam$^{-1}$ km s$^{-1}$ for $N_2$H$^+$ and HCO$^+$ 1–0, respectively), and the gray ranges starts at $1\sigma$ and goes to $4\sigma$. In the edge of the $N_2$H$^+$ distribution, the stronger and weaker peaks of the 3 mm continuum correspond to source 1 and 2, respectively. The smaller beam is for $N_2$H$^+$ 1–0, and the larger beam is for HCO$^+$ 1–0.

Figure 4: The integrated intensity of the $^{12}$CO 3–2 line (contours) and the continuum intensity at 1.3 mm (grays). The contour starts at $2\sigma$ and increases in step of $2\sigma$, and $1\sigma$ is 0.13 Jy beam$^{-1}$ km s$^{-1}$. The gray ranges starts at $1\sigma$ and goes to $5\sigma$.

Figure 5: The extended 850 micron emission (contours) on top of the MIPS 24 micron image. The 850 micron emission has been smoothed by 3 pixels. The contours begin at $2\sigma$ and increase by $1\sigma$. Only 5 contours are used in order to avoid confusion inside L1251B where dust emission is very strong and three sources are detected in 24 micron. This figure covers the region used in the analysis of colors and magnitudes of sources in Figure 2. The red X denotes the position of IRAS 22376+7455, and open red circles indicate the positions of other IRAS point sources shown in Figure 3 of Sato et al. (1994). The red open box presents the source that is not detected in any IRAC band.