YOUNG STARS IN THE CAMELOPARDALIS DUST AND MOLECULAR CLOUDS. II. INFRARED OBJECTS

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Abstract. Using infrared photometric data extracted from the 2MASS, IRAS and MSX databases, 142 suspected young stellar objects (YSOs) are selected from about 2 million stars in the Camelopardalis segment of the Milky Way limited by Galactic coordinates $\ell, b = 132–158^\circ, \pm 12^\circ$. According to radial velocities of the associated CO clouds, the objects are attributed to three molecular and dust cloud layers at 150–300 pc, $\sim 900$ pc and 2.2 kpc distances from the Sun. These objects concentrate into dust and molecular clouds and exhibit extremely large reddenings ($A_V$ up to 25 mag) which can be caused by the dust in foreground clouds and circumstellar envelopes or disks. In the $J–H$ vs. $H–K$ diagram these objects lie above the intrinsic line of T Tauri variables, roughly along the black-body line. Among the identified objects, some already known YSOs are present, including the well investigated massive object GL 490. The spectral energy distributions between 700 nm and 100 $\mu$m suggest that the objects may be YSOs of classes I, II and III. However, we do not exclude the possibility that a small fraction of the objects, especially those without IRAS and MSX photometry, may be unrecognized heavily reddened OB-stars, late-type AGB stars or even galaxies.

Key words: stars: formation – stars: pre-main-sequence – infrared: stars – ISM: dust, extinction, clouds

1. INTRODUCTION

In the previous paper (Stražys & Laugalys 2007, Paper I) we have shown that the star-forming process in the Camelopardalis segment of the Local spiral arm is still active. This was testified by the presence in the area of more than 40 stars of the Cam OB1 association and of about 20 young stars of lower masses exhibiting emission in H$\alpha$ or belonging to irregular variable stars of types IN and IS. A high-mass young stellar object, GL 490, embedded in the densest part of the dust cloud DoH 942 (Dobashi et al. 2005), has been identified by Snell et al. (1984) and investigated in many subsequent papers.

Trying to find more young stellar objects (hereafter YSOs) of different masses in the area limited by the Galactic coordinates $\ell, b = 132–158^\circ, \pm 12^\circ$ we have analyzed the infrared objects measured in the 2MASS, IRAS and MSX surveys.
2. IDENTIFICATION OF PRE-MAIN-SEQUENCE OBJECTS

Figure 1 shows the $J-H$ vs. $H-K_s$ diagram for about $2 \times 10^6$ stars measured in the 2MASS survey with the errors $\leq 0.05$ mag (Cutri et al. 2003; Skrutskie et al. 2006). In the comet-like crowding of dots the orange line designates the intrinsic main sequence, the yellow line K-M giants and the blue line the intrinsic locus of T Tauri-type stars from Meyer et al. (1997). The red line is the interstellar reddening vector; its length corresponds to the extinction $A_V = 10$ mag in the $V$ passband. The violet line shows the black-body locus. The ‘comet head’ is composed mostly of normal stars of different spectral classes and luminosities with little or no interstellar reddening. The upper rich ‘tail 1’ of the ‘comet’ is composed of normal reddened background stars, mostly of K and M giants. This ‘tail’ extends up to $H-K_s \approx 1.5$, i.e., some of the stars exhibit an extinction $A_V$ of 20–25 mag.

The lower tail (hereafter ‘tail 2’) is much longer, reaching $H-K_s \approx 3.0$ and running more or less along the black-body line. In this part of the diagram we expect to find a variety of reddened stars in early and late stages of evolution and extragalactic objects: M-type giants of the latest subclasses, including oxygen-rich and carbon-rich long-period variables (Whitelock et al. 1994, 2000), OH/IR stars (Sevenster 2002, Lewis et al. 2004, Jiménez-Esteban et al. 2005, 2006), carbon-rich stars of spectral type N (Whitelock et al. 2006), T Tauri-type stars with dense disks (Lada & Adams 1992, Kenyon & Hartmann 1995), young stellar objects surrounded by gas and dust envelopes (Persson & Campbell 1987, 1988; Campbell et al. 1989), Ae/Be stars (Lada & Adams 1992, Hillenbrand et al. 1992), Be stars (Dougherty et al. 1994), galaxies and quasars (Finlator et al. 2000, Ivezić et al. 2002). Unfortunately, $JHK$ photometry is not a sufficient tool for the identification of young stars among such a variety of other objects. Therefore, either spectroscopic or infrared photometric observations at longer wavelengths are essential.

For further analysis we isolated about 300 objects of ‘tail 2’ by two intersecting lines (green lines in Figure 1). The lower vertical line runs along $H-K_s = 1.0$ and the upper line is the interstellar reddening vector corresponding to

$$Q_{JHK} = (J - H) - 1.85(H - K_s) = 0.0.$$  

With this undertaking we have excluded the majority of normal stars of various temperatures, luminosities and reddenings (except reddened O–B stars and the coolest M giants and dwarfs). The known M- and N-type variables of the asymptotic giant branch (including the OH/IR objects), Be stars, quasars and galaxies were identified in the available catalogs and removed from the list. About ten objects at Galactic latitudes $> 5^\circ$, lying outside the dense interstellar clouds, were also excluded. Some galaxies were recognized and excluded by inspecting their images in the SkyView database. For the classification of the remaining objects we have used color indices from the IRAS catalog of point sources (Beichman et al. 1988).

The IRAS 12, 25 and 60 $\mu$m fluxes of reasonable accuracy ($\sigma$ of the flux $< 20\%$) are available for about 1/3 of the objects in the remaining list. For the identification of T Tauri stars and other YSOs, the two-color diagram $[12] - [25]$ vs. $[25] - [60]$ shown in Figure 2 was used. Here, the IRAS color indices (as defined by Walker & Cohen 1988) are:

$$[12] - [25] = 1.56 - 2.5 \log F_{12}/F_{25},$$
Fig. 1. The $J - H$ vs. $H - K_s$ diagram for 2 million stars in the investigated area. The intrinsic main-sequence and K–M giant lines are shown in orange and yellow, respectively. The blue line designates the intrinsic locus of T Tauri stars, the violet line is the locus of black bodies. The length of the reddening vector (shown in red) corresponds to the extinction in the $V$ passband of 10 mag. The two green intersecting lines separate the region where the presence of young stellar objects was investigated.

$$[25] - [60] = 1.88 - 2.5 \log F_{25}/F_{60}.$$  

In this diagram the ‘occupation zones’ for a broad range of known stellar and non-stellar sources were shown by Walker & Cohen (1988) and Walker et al. (1989). More literature sources have been used to define the zones of M- and N-type stars (Hacking et al. 1985; Kwok et al. 1997), infrared LPVs and OH/IR sources (van der Veen & Habing 1988; Kwok et al. 1997; Sevenster 2002; Jiménez-Esteban et al. 2006) and infrared galaxies (Emerson 1987; Magnani et al. 1995). The zone of T Tauri stars was taken from Harris et al. (1988): $[12] - [25]$ between 1.64 and 3.00, and $[25] - [60]$ between 1.23 and 2.90. The zone of infrared YSOs was based on the investigations of Persson & Campbell (1987, 1988), Campbell et al. (1989) and Kenyon et al. (1990). The zones of these types of stars, plotted in
Figure 2, were used to identify and reject the remaining carbon stars, infrared LPVs and other types of objects unrelated to star forming. However, even IRAS colors are insufficient to separate young stellar objects from galaxies, quasars and the coolest OH/IR sources. Almost all IRAS galaxies are of spiral type with active star formation and possess a large amount of dust. Their emission in the far infrared is mostly due to thermal radiation from interstellar dust grains heated by stars.

The stars falling into the IRAS diagram boxes of young stars (T Tauri and YSO zones) were included in the list of potential young objects. We also were able to identify a few young stars having the color index [12]–[25] of good accuracy but with inaccurate [25]–[60] and vice versa. The stars without IRAS observations (or with the IRAS data of poor quality) were also included in the list: their belonging to YSOs was based only on the $J-H$ vs. $H-K_s$ diagram and the concentration to molecular/dust clouds. The final list of 142 suspected YSOs is presented in Table 1. Its explanation is given in the next section.
| SL | ℓ   deg | b    deg | F    mag | J    mag | H    mag | Ks   mag | J−H  mag | H−Ks mag | QjHK mag | Cloud layer | Associated objects and notes |
|----|--------|--------|-------|--------|-------|--------|--------|--------|--------|----------|-----------------------------|
| 1  | 132.015 | 1.215  | 18.02 | 14.46  | 13.09 | 11.93  | 1.37   | 1.16   | −0.76  | −        |                             |
| 2  | 132.124 | 8.884  | 18.17 | 14.28  | 12.87 | 11.80  | 1.41   | 1.07   | −0.58  | Cam      | T878                        |
| 3  | 132.241 | 8.931  | 18.37 | 14.94  | 13.08 | 11.52  | 1.86   | 1.55   | −1.01  | Cam      | T878                        |
| 4  | 132.399 | 9.239  | 18.17 | 13.54  | 11.73 | 10.48  | 1.81   | 1.25   | −0.51  | Cam      | T878                        |
| 5  | 132.824 | 8.944  | 17.31 | 14.44  | 12.74 | 11.70  | 1.70   | 1.05   | −0.24  | Cam      | T878                        |
| 6  | 132.956 | 8.515  | 18.60 | 14.69  | 13.01 | 11.47  | 1.69   | 1.53   | −1.15  | Cam      | T878                        |
| 7  | 133.070 | −0.039 | 20.01 | 15.10  | 13.43 | 12.02  | 1.67   | 1.41   | −0.94  | Per      | T879                        |
| 8  | 133.281 | 8.813  | 18.55 | 14.48  | 12.52 | 11.21  | 1.95   | 1.32   | −0.48  | Cam      | T878                        |
| 9  | 133.320 | 0.475  | 16.11 | 12.99  | 11.90 | 10.86  | 1.10   | 1.04   | −0.82  | Per      | T879, [1]                   |
| 10 | 133.480 | 0.038  |       | 14.36  | 12.41 | 11.04  | 1.95   | 1.37   | −0.58  | Per      | T879, KR 140 [2]            |
| 11 | 133.411 | 0.446  | 19.48 | 14.49  | 12.64 | 11.28  | 1.85   | 1.36   | −0.67  | Per      | [1]                         |
| 12 | 133.411 | 1.195  |       | 14.70  | 12.91 | 11.56  | 1.79   | 1.35   | −0.71  | Per      | T879, W3                    |
| 13 | 133.432 | 1.098  | 18.83 | 14.75  | 13.43 | 12.35  | 1.32   | 1.08   | −0.69  | Per      | T879, W3, [1]               |
| 14 | 133.455 | 8.987  | 19.91 | 14.54  | 12.79 | 11.50  | 1.75   | 1.29   | −0.64  | Cam      | T878                        |
| 15 | 133.474 | 0.998  | 19.50 | 13.92  | 12.12 | 11.10  | 1.80   | 1.02   | −0.09  | Per      | T879, W3, [3]               |
| 16 | 133.548 | 0.091  |       | 15.38  | 13.14 | 11.32  | 2.24   | 1.82   | −1.12  | Per      | T879, KR 140 [2]            |
| 17 | 133.572 | 1.087  |       | 15.13  | 13.29 | 12.17  | 1.84   | 1.12   | −0.23  | Per      | T879, W3                    |
| 18 | 133.604 | 1.240  | 17.89 | 14.05  | 12.67 | 11.60  | 1.39   | 1.07   | −0.59  | Per      | T879, W3, IC1795            |
| 19 | 133.679 | 0.925  | 18.29 | 14.80  | 13.62 | 12.51  | 1.17   | 1.11   | −0.88  | Per      | T879, W3, [3]               |
| 20 | 133.683 | 1.095  |       | 14.98  | 12.67 | 10.91  | 2.31   | 1.75   | −0.93  | Per      | T879, W3                    |
| 21 | 133.688 | 0.490  | 15.14 | 12.56  | 11.15 | 9.97   | 1.42   | 1.18   | −0.76  | Per      | T879, [1]                   |
| 22 | 133.695 | 1.194  |       | 14.37  | 12.61 | 11.59  | 1.76   | 1.02   | −0.12  | Per      | T879, W3, IC1795            |
| 23 | 133.702 | 1.240  |       | 12.86  | 11.08 | 9.62   | 1.78   | 1.46   | −0.91  | Per      | T879, W3, IC1795, [3]       |
| 24 | 133.705 | 1.199  |       | 13.96  | 11.78 | 10.54  | 2.18   | 1.24   | −0.10  | Per      | T879, W3, IC1795, [3]       |
| 25 | 133.710 | 1.320  | 19.29 | 14.24  | 12.76 | 11.63  | 1.47   | 1.14   | −0.63  | Per      | T879, W3, IC1795            |
| 26 | 133.715 | 1.175  |       | 15.03  | 13.10 | 11.99  | 1.94   | 1.11   | −0.11  | Per      | T879, W3, IC1795            |

**Table 1.** Suspected YSOs in the area with \( \ell, b = 132–158^\circ, \pm 12^\circ \) and \( H−K_s \geq 1.00 \). Abbreviations: ‘Gou’ means the Gould Belt layer, ‘Cam’ means the Cam OB1 layer and ‘Per’ means the Perseus arm.
| SL | \( \ell \) | \( b \) | \( F \) | \( J \) | \( H \) | \( K_s \) | \( J-H \) | \( H-K_s \) | \( Q_{JHK} \) | Cloud layer | Associated objects and notes |
|----|-------|------|------|------|------|------|------|------|------|-----------|-------------------|
| 27 | 133.720 | 1.223 | 12.06 | 10.04 | 8.84 | 2.02 | 1.19 | -0.18 | Per | T879, W3, IC 1795, [3] |
| 28 | 133.723 | 1.259 | 20.02 | 15.20 | 13.63 | 12.60 | 1.57 | 1.03 | -0.34 | Per | T879, W3, IC 1795 |
| 29 | 133.739 | 1.228 | 14.14 | 11.63 | 9.90 | 2.51 | 1.73 | -0.68 | Per | T879, W3, IC 1795 |
| 30 | 133.749 | 1.078 | 15.10 | 13.35 | 12.24 | 1.75 | 1.11 | -0.30 | Per | T879, W3 |
| 31 | 133.766 | 1.320 | 14.55 | 12.79 | 11.35 | 1.76 | 1.44 | -0.90 | Per | T879, W3, IC 1795, [3] |
| 32 | 133.802 | 1.199 | 15.50 | 13.88 | 12.81 | 1.62 | 1.07 | -0.35 | Per | T879, W3, IC 1795, [1] |
| 33 | 133.805 | 1.161 | 15.47 | 13.92 | 12.84 | 1.55 | 1.08 | -0.45 | Per | T879, W3, IC 1795 |
| 34 | 133.809 | 1.217 | 11.12 | 8.31 | 6.73 | 2.81 | 1.59 | -0.13 | Per | T879, W3, IC 1795 |
| 35 | 133.811 | 1.362 | 14.27 | 12.70 | 11.60 | 1.56 | 1.10 | -0.47 | Per | T879, W3, IC 1795, [1] |
| 36 | 133.893 | 1.057 | 15.21 | 12.94 | 11.60 | 2.28 | 1.33 | -0.19 | Per | T879, W3, IC 1795 |
| 37 | 133.919 | 1.204 | 13.31 | 9.70 | 8.60 | 7.58 | 1.11 | 1.02 | -0.77 | Per | T879, W3, IC 1795 |
| 38 | 133.994 | 0.520 | 15.28 | 13.11 | 11.78 | 2.16 | 1.33 | -0.30 | Per | T879, [1], [4] |
| 39 | 134.049 | 0.698 | 19.61 | 14.23 | 12.61 | 11.59 | 1.62 | 1.02 | -0.26 | Per | T879, LBN 134.05+00.75 |
| 40 | 134.055 | 0.832 | 12.94 | 11.51 | 10.49 | 1.43 | 1.02 | -0.47 | Per | W4, [3] |
| 41 | 134.081 | 0.144 | 18.43 | 14.44 | 12.96 | 11.87 | 1.48 | 1.10 | -0.55 | Per | [1] |
| 42 | 134.086 | 0.794 | 20.12 | 15.00 | 13.48 | 12.45 | 1.52 | 1.03 | -0.40 | Per | W4 |
| 43 | 134.220 | 0.780 | 14.27 | 12.57 | 11.55 | 1.70 | 1.02 | -0.18 | Per | W4, [1,3] |
| 44 | 134.234 | 0.751 | 13.68 | 11.42 | 10.00 | 2.26 | 1.42 | -0.37 | Per | W4, [1,6] |
| 45 | 134.258 | -1.865 | 16.35 | 13.77 | 12.46 | 11.32 | 1.31 | 1.13 | -0.79 | Per | [6] |
| 46 | 134.849 | -1.467 | 17.77 | 14.82 | 13.53 | 12.41 | 1.28 | 1.13 | -0.80 | Cam |
| 47 | 135.053 | 1.663 | 16.68 | 14.75 | 13.50 | 12.31 | 1.26 | 1.18 | -0.93 | Per | W4 |
| 48 | 135.517 | 0.255 | 12.99 | 11.44 | 10.25 | 1.55 | 1.19 | -0.66 | Per | W4, [1,6] |
| 49 | 136.447 | 2.469 | 16.37 | 13.41 | 11.67 | 10.26 | 1.74 | 1.41 | -0.87 | Per | [1] |
| 50 | 136.472 | 1.252 | 19.29 | 14.63 | 12.24 | 10.39 | 2.40 | 1.84 | -1.02 | Per | T879-B5, W5, [1,5] |
| 51 | 136.519 | 0.850 | 18.73 | 14.74 | 13.18 | 12.12 | 1.55 | 1.06 | -0.41 | Per | T879-P5, W5 |
| 52 | 136.673 | 1.207 | 14.21 | 10.66 | 8.38 | 3.54 | 2.29 | -0.69 | Per | T879-P5, W5, [4,5,6] |
| 53 | 136.796 | 1.083 | 18.41 | 14.67 | 13.34 | 12.22 | 1.34 | 1.11 | -0.71 | Per | T879-P5, W5 |
| SL | $\ell$ deg | $b$ deg | $F$ mag | $J$ mag | $H$ mag | $K_s$ mag | $J-H$ mag | $H-K_s$ mag | $Q_{JHK}$ mag | Cloud layer | Associated objects and notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 54 | 136.846 | 1.150 | 17.20 | 11.13 | 8.95 | 7.24 | 2.18 | 1.71 | -0.98 | Per | T879-P5, W5, [1,4] |
| 55 | 136.849 | 1.106 | 15.75 | 13.16 | 12.11 | 11.05 | 1.05 | 1.03 | -0.86 | Per | T879-P5, W5 |
| 56 | 136.917 | 1.085 | 12.75 | 9.19 | 6.55 | 3.56 | 2.63 | 1.31 | -0.31 | Per | W5, [1,4,6] |
| 57 | 137.025 | 1.034 | 19.85 | 14.51 | 13.06 | 11.99 | 1.46 | 1.07 | -0.52 | Per | W5 |
| 58* | 137.114 | 3.120 | 17.82 | 14.39 | 12.70 | 11.56 | 1.69 | 1.13 | -0.41 | Per | |
| 59 | 137.364 | 0.636 | 17.57 | 14.61 | 13.14 | 12.10 | 1.47 | 1.05 | -0.47 | Per | W5 |
| 60 | 137.393 | 0.610 | 16.97 | 13.00 | 11.52 | 10.45 | 1.48 | 1.08 | -0.51 | Per | W5 |
| 61 | 137.506 | 1.391 | 14.38 | 11.91 | 10.23 | 12.47 | 1.68 | -0.64 | Per | W5 |
| 62 | 137.657 | 1.667 | 19.07 | 14.07 | 12.18 | 11.78 | 1.26 | 1.03 | -0.65 | Per | W5, [1] |
| 63* | 137.749 | 1.492 | 16.41 | 12.49 | 11.09 | 10.03 | 1.40 | 1.06 | -0.57 | Per | W5, [1], BDSB 58 [7] |
| 64 | 137.791 | 1.457 | 20.04 | 13.80 | 12.04 | 10.84 | 1.76 | 1.20 | -0.46 | Per | W5, BDSB 58 [7] |
| 65 | 137.920 | 1.924 | 18.63 | 14.74 | 12.94 | 11.59 | 1.79 | 1.35 | -0.71 | Per | W5, [1] |
| 66 | 138.294 | 1.559 | 15.40 | 12.92 | 11.38 | 11.69 | 1.86 | 1.54 | -0.37 | Per | T912, W5, [4,6] |
| 67 | 138.315 | -0.030 | 16.55 | 14.43 | 12.91 | 11.65 | 1.51 | 1.27 | -0.83 | Per | |
| 68* | 138.405 | 3.784 | 14.02 | 13.11 | 12.00 | 0.91 | 1.11 | -1.15 | Cam | [1] |
| 69 | 138.461 | 1.622 | 13.75 | 11.84 | 10.40 | 1.91 | 1.44 | -0.76 | Per | T912, Sh 2-201 |
| 70 | 138.488 | 1.641 | 14.02 | 11.96 | 10.60 | 2.06 | 1.36 | -0.46 | Per | T912, W5 |
| 71 | 138.490 | 1.667 | 14.23 | 13.05 | 11.85 | 1.18 | 1.20 | -1.04 | Per | T912, W5 |
| 72 | 138.495 | 1.639 | 14.30 | 11.69 | 10.24 | 2.61 | 1.46 | -0.08 | Per | T912, W5, [6] |
| 73 | 138.524 | 1.660 | 20.00 | 15.39 | 13.30 | 11.82 | 2.10 | 1.48 | -0.64 | Per | T912, W5 |
| 74 | 138.533 | 2.059 | 18.93 | 14.53 | 12.84 | 11.74 | 1.69 | 1.10 | -0.35 | Per | |
| 75 | 138.550 | 1.580 | 14.18 | 11.67 | 10.06 | 8.83 | 1.60 | 1.23 | -0.68 | Per | T912, W5 |
| 76 | 138.891 | 5.403 | 19.67 | 15.03 | 13.37 | 12.33 | 1.66 | 1.04 | -0.26 | Cam | T910 |
| 77 | 139.320 | -3.306 | 16.74 | 14.97 | 13.40 | 12.11 | 1.58 | 1.28 | -0.79 | Per | |
| 78 | 139.369 | -3.283 | 13.10 | 11.15 | 10.08 | 9.02 | 1.07 | 1.06 | -0.88 | Cam | |
| 79* | 139.788 | 1.269 | 15.12 | 12.82 | 11.75 | 10.65 | 1.07 | 1.10 | -0.97 | Per | LBN 140.07+1.64, [1,5] |
| 80 | 139.911 | 0.196 | 12.76 | 10.88 | 9.52 | 1.88 | 1.36 | -0.64 | Per | LBN 140.07+1.64, [5,6] |
| SL | $\ell$ | $b$ | $F$ | $J$ | $H$ | $K_s$ | $J-H$ | $H-K_s$ | $Q_{JHK}$ | Cloud layer | Associated objects and notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81 | 140.032 | 2.051 | 19.92 | 13.94 | 12.12 | 10.94 | 1.82 | 1.18 | -0.38 | Cam | Sh 2-202, LBN 139.57+2.70, [5] |
| 82* | 140.160 | 2.268 | 9.31 | 9.64 | 8.32 | 7.27 | 1.32 | 1.05 | -0.62 | Cam | Sh 2-202, LBN 139.57+2.70 [5] |
| 83 | 140.592 | 1.086 | 19.06 | 13.47 | 11.25 | 9.70 | 2.22 | 1.55 | -0.65 | Per | LBN 140.07+1.64, [1,5] |
| 84 | 140.600 | 1.122 | 17.21 | 14.77 | 13.47 | 12.38 | 1.30 | 1.09 | -0.72 | Per | LBN 140.07+1.64, [5] |
| 85* | 140.749 | 4.172 | 19.16 | 13.55 | 11.91 | 10.90 | 1.64 | 1.00 | -0.21 | Cam | T942 |
| 86 | 140.768 | 0.199 | 18.91 | 12.63 | 10.78 | 9.64 | 1.84 | 1.14 | -0.28 | Per | LBN 140.07+1.64, [1,5] |
| 87* | 140.914 | -1.164 | 14.82 | 13.03 | 11.88 | 1.79 | 1.16 | -0.34 | Cam | T942 |
| 88 | 141.068 | -1.582 | 17.42 | 13.78 | 12.28 | 11.14 | 1.50 | 1.14 | -0.60 | Per | LBN 140.77-1.42, [1,5] |
| 89 | 141.926 | 1.738 | 19.16 | 13.55 | 11.91 | 10.90 | 1.64 | 1.00 | -0.21 | Cam | T942 |
| 90 | 141.972 | 0.581 | 14.82 | 13.03 | 11.88 | 1.79 | 1.16 | -0.34 | Cam | T942 |
| 91 | 141.974 | 1.078 | 15.30 | 13.65 | 12.58 | 1.65 | 1.08 | -0.34 | Cam | T942 |
| 92 | 141.979 | 1.691 | 15.39 | 13.65 | 12.50 | 1.74 | 1.15 | -0.39 | Cam | T942 |
| 93 | 141.982 | 1.760 | 15.06 | 13.02 | 11.86 | 2.04 | 1.17 | -0.12 | Cam | T942 |
| 94 | 141.986 | 1.827 | 18.24 | 13.39 | 11.61 | 10.28 | 1.78 | 1.33 | -0.69 | Cam | T942 |
| 95* | 142.000 | 1.820 | 17.67 | 10.95 | 8.08 | 5.72 | 2.87 | 2.36 | -1.51 | Cam | T942, GL 490 |
| 96 | 142.013 | 1.607 | 14.94 | 12.99 | 11.76 | 1.96 | 1.23 | -0.31 | Cam | T942 |
| 97 | 142.040 | 1.850 | 14.78 | 13.02 | 12.00 | 1.77 | 1.01 | -0.11 | Cam | T942 |
| 98 | 142.343 | 1.354 | 18.01 | 13.20 | 11.88 | 10.77 | 1.32 | 1.10 | -0.72 | Cam | T942 |
| 99* | 142.688 | 1.817 | 15.09 | 13.50 | 12.11 | 11.11 | 1.39 | 1.00 | -0.47 | Cam | T942 |
| 100 | 142.772 | 1.476 | 17.79 | 13.72 | 12.06 | 10.91 | 1.65 | 1.15 | -0.48 | Cam | T942 |
| 101 | 143.152 | 0.479 | 14.90 | 11.71 | 9.77 | 0.94 | 1.00 | -0.90 | Cam | T942 |
| 102 | 143.273 | 1.226 | 18.80 | 13.85 | 12.36 | 11.26 | 1.49 | 1.10 | -0.53 | Cam | T942 |
| 103 | 143.324 | 1.762 | 14.35 | 12.94 | 11.93 | 1.41 | 1.01 | -0.46 | Cam | T942 |
| 104 | 143.511 | -1.646 | 19.14 | 14.70 | 13.27 | 12.12 | 1.42 | 1.15 | -0.70 | Per | Sh 2-203, BDSB 59 [7] |
| 105 | 143.638 | -1.589 | 18.20 | 15.18 | 13.98 | 12.97 | 1.20 | 1.00 | -0.66 | Per | Sh 2-203, BDSB 59 [7] |
| 106 | 143.737 | -1.715 | 15.62 | 13.39 | 11.75 | 10.56 | 1.64 | 1.19 | -0.56 | Per | Sh 2-203, BDSB 59 [7] |
| 107 | 143.803 | 0.767 | 20.46 | 15.21 | 13.70 | 12.59 | 1.51 | 1.11 | -0.55 | – | – |
| SL  | $\ell$   | $b$   | $F$    | $J$    | $H$    | $K_s$   | $J-H$  | $H-K_s$ | $Q_{JHK}$ | Cloud layer | Associated objects and notes |
|-----|---------|-------|--------|--------|--------|---------|--------|---------|-----------|--------------|-------------------------------|
| 108 | 143.845 | −1.573| 17.64  | 14.20  | 12.52  | 11.19   | 1.68   | 1.33    | −0.78     | Per          | Sh 2-203, BDSB 59 [7]          |
| 109*| 144.668 | −0.713| 17.12  | 13.16  | 11.57  | 10.25   | 1.59   | 1.32    | −0.84     | Per          |                               |
| 110 | 144.784 | −1.042| 18.46  | 14.63  | 13.40  | 12.22   | 1.23   | 1.18    | −0.95     | Per          |                               |
| 111 | 145.306 | −0.732| 18.59  | 13.75  | 12.04  | 10.79   | 1.71   | 1.26    | −0.61     | Per          |                               |
| 112 | 146.199 | −1.365| 15.45  | 12.54  | 11.60  | 10.55   | 0.94   | 1.05    | −1.00     | Cam          |                               |
| 113 | 146.839 | 0.109 | 17.14  | 13.69  | 12.53  | 11.48   | 1.16   | 1.05    | −0.79     |              |                               |
| 114 | 147.882 | −0.541| 17.50  | 13.96  | 12.94  | 11.91   | 1.02   | 1.03    | −0.89     | Per          |                               |
| 115 | 148.081 | 0.215 | 17.35  | 13.92  | 12.48  | 10.82   | 1.44   | 1.66    | −1.63     | Per          | FSR 655 [8]                      |
| 116 | 148.105 | 0.139 | 17.44  | 12.55  | 10.92  | 9.65    | 1.63   | 1.27    | −0.71     | Per          | FSR 655 [8]                      |
| 117 | 148.128 | 0.231 | 17.85  | 14.51  | 13.32  | 12.29   | 1.19   | 1.04    | −0.73     | Per          | FSR 655 [8]                      |
| 118 | 148.613 | 2.413 | 14.75  | 12.46  | 10.80  | 2.29    | 1.65   | 0.76    | −0.78     | Gou          |                               |
| 119 | 148.683 | 1.562 | 17.93  | 14.95  | 13.82  | 12.79   | 1.13   | 1.04    | −0.78     | Gou          |                               |
| 120 | 148.856 | 2.021 | 15.23  | 13.35  | 11.90  | 1.88    | 1.44   | 0.78    | −0.78     | Gou          |                               |
| 121 | 150.340 | 2.914 | 17.51  | 13.05  | 11.63  | 10.53   | 1.42   | 1.10    | −0.62     | Gou          |                               |
| 122 | 150.525 | −0.935| 18.00  | 14.66  | 13.12  | 12.04   | 1.54   | 1.08    | −0.45     | Per          | Sh 2-206, BDSB 61 [7]           |
| 123 | 150.593 | −0.844| 11.02  | 8.53   | 7.16   | 2.49    | 1.36   | 0.04    | −0.04     | Per          | Sh 2-206, BDSB 61 [7]           |
| 124*| 150.687 | −0.689| 15.24  | 11.70  | 10.32  | 9.08    | 1.38   | 1.24    | −0.92     | Per          | Sh 2-206, BDSB 63 [7]           |
| 125 | 151.229 | 1.026 | 18.04  | 14.26  | 12.55  | 11.43   | 1.72   | 1.12    | −0.35     | Per          |                               |
| 126 | 151.371 | 1.879 | 16.01  | 14.54  | 13.28  | 12.24   | 1.26   | 1.04    | −0.67     |              |                               |
| 127 | 151.392 | 1.287 | 16.47  | 14.26  | 12.88  | 11.77   | 1.37   | 1.12    | −0.69     | Per          |                               |
| 128 | 151.439 | −0.493| 14.87  | 13.21  | 11.94  | 1.66    | 1.27   | 0.70    | −0.70     | Per          | Sh 2-209, BDSB 65 [7]           |
| 129 | 151.609 | −0.222| 15.17  | 13.71  | 12.56  | 1.46    | 1.14   | 0.65    | −0.65     | Per          | Sh 2-209, BDSB 65 [7]           |
| 130*| 151.612 | −0.458| 15.83  | 10.92  | 8.90   | 7.12    | 2.02   | 1.79    | −1.28     | Per          | Sh 2-209, BDSB 65 [7]           |
| 131*| 151.725 | −1.292| 14.00  | 11.30  | 9.77   | 8.54    | 1.53   | 1.23    | −0.74     | Cam          |                               |
| 132 | 151.740 | −0.972| 17.03  | 9.50   | 7.45   | 6.35    | 2.04   | 1.10    | 0.01      | Cam          | T1000                      |
| 133 | 153.448 | −1.122| 19.67  | 15.29  | 13.51  | 12.42   | 1.78   | 1.09    | −0.25     | Per          |                               |
| 134 | 154.306 | −0.180| 18.46  | 14.42  | 12.85  | 11.76   | 1.57   | 1.09    | −0.44     | Cam          |                               |

Table 1. Continued
| SL | $\ell$ | $b$ | $F$ | $J$ | $H$ | $K_s$ | $J-H$ | $H-K_s$ | $Q_{JHK}$ | Cloud layer | Associated objects and notes |
|----|-------|-----|----|----|----|------|------|--------|--------|-------------|-----------------------------|
| 135 | 154.588 | 2.047 | 18.93 | 14.88 | 13.69 | 12.66 | 1.19 | 1.03 | -0.72 | Gou | T1036 |
| 136 | 155.432 | 0.635 | 14.72 | 12.84 | 11.72 | 10.67 | 1.12 | 1.05 | -0.82 | Gou | |
| 137 | 155.633 | -0.617 | 18.53 | 14.40 | 13.04 | 11.86 | 1.37 | 1.18 | -0.81 | Gou | |
| 138 | 156.556 | -1.623 | 17.71 | 14.37 | 13.20 | 12.18 | 1.17 | 1.02 | -0.71 | Per | |
| 139 | 156.873 | -2.172 | 18.60 | 14.48 | 12.98 | 11.84 | 1.49 | 1.14 | -0.62 | Per: | |
| 140 | 156.899 | -2.175 | 15.48 | 13.21 | 12.07 | 11.03 | 1.13 | 1.04 | -0.80 | Per: | |
| 141* | 157.551 | -4.058 | 18.12 | 15.32 | 13.83 | 12.80 | 1.49 | 1.03 | -0.41 | Per | |
| 142 | 157.555 | -8.977 | 16.91 | 11.67 | 9.51 | 7.87 | 2.16 | 1.64 | -0.88 | Cam | T1054 |

Notes (for the stars marked by asterisks):
[1]: CO and IRAS sources, Kerton & Brunt (2003)
[2]: submm and IRAS sources, Kerton et al. (2001)
[3]: embedded IR sources, Elmegreen (1980)
[4]: infrared clusters, Carpenter et al. (2000)
[5]: objects related to bright nebulae at W5 and Sh 2-202, Karr & Martin (2003a,b)
[6]: infrared clusters and groups, Bica et al. (2003a)
[7]: infrared clusters, Bica et al. (2003b), BDSB numbers
[8]: infrared clusters, Froebrich et al. (2007), FSR numbers

SL 63. L W Cas, IRAS 02534+6029, INA variable
SL 82. CPM 7, IRAS 03134+5958, YSO, Herbig & Bell (1988), Campbell et al. (1989)
SL 95. GL 490, IRAS 03236+5836, classical YSO
SL 109. CPM 8, IRAS 03293+5500, YSO, Campbell et al. (1989)
SL 124. GLMP 49, IRAS 04010+5118, T Tauri star, García-Lario et al. (1997)
SL 130. CPM 12, IRAS 04064+5052, YSO, Campbell et al. (1989)
SL 141. GLMP 61, IRAS 04172+4411, T Tauri star, García-Lario et al. (1997)
SL 58, 68, 79, 85, 87, 99, 124 and 131: binaries in R color (SkyView), the distance between components < 10''.
Table 2. IRAS and MSX data for the suspected YSOs in the investigated area with \( H-K_s \geq 1.00 \), supposed to be the Local arm objects. Fluxes are given in Janskys.

| SL  | IRAS          | \( F'(12) \) | \( F'(25) \) | \( F'(60) \) | \( F'(100) \) | \( F'(8.3) \) |
|-----|---------------|--------------|--------------|--------------|--------------|-------------|
| 3   | 02371+6934    | <0.27        | 0.24         | <0.49        | <12.37       |             |
| 4   | 02402+6947    | <0.31        | 0.25         | 0.42         | <16.71       |             |
| 5   | 02432+6919    | <0.37        | <0.25        | 0.55         | <17.04       |             |
| 8   | 02470+6901    | <0.25        | 0.64         | 1.35         | 7.41         | 14          |
| 68  | 03074+6211    | <0.25        | <0.50        | <0.40        | 4.46         | 0.15        |
| 78  |               |              |              |              |              | 0.19        |
| 81  | 03116+5951    | 0.39         | 0.54         | <2.77        | 27.90        | 0.15        |
| 82  | 03134+5958    | 1.91         | 2.10         | 9.33         | 37.13        | 1.34        |
| 89  | 03228+5834    | 0.24         | 1.06         | <4.04        | <27.71       |             |
| 93* | 03233+5833    | 0.44         | 2.13         | 23.3         | 40:          |             |
| 95* | 03236+5836    | 90.5         | 290          | 715          | 1156         | 54.73       |
| 101 |               |              |              |              |              | 0.11        |
| 102 | 03290+5724    | <0.26        | 0.17         | <0.75        | <44.76       |             |
| 107 | 03303+5643    | <0.39        | <0.25        | 0.69         | <5.80        |             |
| 108 | 03211+5446    | 12.67        | 43.09        | 496.5        | 854.3        |             |
| 112 | 03353+5333    | 0.28         | <0.57        | <0.40        | <18.18       | 0.15        |
| 113 | 03447+5422    | <0.26        | 0.31         | 0.46         | <12.64       |             |
| 118 | 04044+5500    | <0.25        | 0.55         | 2.02         | <11.02       | 0.25        |
| 120 | 04038+5433    | 0.37         | 0.48         | 1.19         | <5.37        |             |
| 126 | 04156+5244    | <0.35        | 0.40         | 1.49         | <25.57       | <0.08       |
| 131 | 04034+5010    | 1.93         | 2.89         | 5.50         | 19.23        | 1.30        |
| 134 | 04198+4912    | <0.75        | <0.42        | 0.57         | <3.12        |             |
| 135 | 04308+5033    | 0.28         | 0.48         | 2.53         | <14.19       |             |
| 137 | 04235+4757    | <0.35        | 0.67         | 2.00         | <5.49        |             |
| 142 | 03591+4034    | 1.30         | <0.40        | <0.40        | <7.70        |             |

Notes:
Stars 93 and 95: IRAS data are from Clark (1991).

3. ATTRIBUTION OF YSOs TO DIFFERENT CLOUD LAYERS

In Paper I we divided molecular/dust clouds in the area by their CO radial velocities (from Dame et al. 2001) to the following three layers: the Gould Belt layer at 150–300 pc from the Sun, the Cam OB1 association layer at 800–900 pc and the Perseus arm at 2–3 kpc (see the \( \ell, b \) map in Fig. 6 of Paper I). The objects from Table 1 were plotted on this map to attribute them to the listed dust layers. Most of the selected YSOs (68 objects) located within the longitudes 132–140\(^\circ\) and latitudes \( \pm \)2\(^\circ\) depend to the Perseus arm and coincide with the dust clouds DoH 879 and 912 related to the H II regions W3, W4 and W5 and the Cas OB6 association (the identification of the Dobashi cloud numbers is given in Paper I, Fig. 2). Additional 26 objects are assigned to the Perseus arm at larger longitudes.

Our attribution of YSOs to certain molecular/dust cloud layers was confirmed by inspection of the LSR radial velocities of the associated CO clouds presented by Wouterloot & Brand (1989), Wouterloot et al. (1993) and Kerton & Brunt (2003).
Table 1 for each object gives the serial number, Galactic coordinates, the $F$ magnitudes (close to $R$) taken from the GSC 2.3.2 catalog available at the CDS, the 2MASS $J$, $H$ and $K_s$ magnitudes, color indices and $Q_{JHK}$ parameters, belonging to the assigned dust/gas layer (Per, Cam or Gou, see the Table head for explanation) and the associated dark or bright clouds and clusters. The Cam OB1 layer contains 35 objects, 16 of them are concentrated in the cloud DoH 942 (clumps P1, P2 and P3) and seven in the cloud DoH 878 at $133^\circ$, $+9^\circ$. The Gould Belt layer contains only seven objects, all located between $\ell = 148^\circ$ and $156^\circ$. For a few objects we could not assign a single layer due to overlapping of the clouds.

In Figure 3 the objects from Table 1 are plotted in Galactic coordinates, together with the Dobashi dark clouds (Dobashi et al. 2005). Here we see an obvious grouping of the suspected YSOs to the darkest dust clouds, and this is one of the indications that these objects may be young. Some of the YSOs are projected close to the infrared open clusters identified by Carpenter et al. (2000), Bica et al. (2003a,b) and Froebrich et al. (2007): five objects near the Bica et al. cluster No. 59, four objects near the clusters Bica et al. No. 61 and Froebrich et al. No. 665 (in the direction of the HII region Sh 2-206), and three objects near the cluster Bica et al. No. 65 (in the direction of Sh 2-209).

All objects in Table 1 were inspected in the red plates of the POSS as well as in the 2MASS passbands, presented in the SkyView site of NASA (http://skyview.gsfc.nasa.gov). Notes on the double or oblong images are given at the end of Table 1.

In further analysis we will consider only the Local arm objects. YSOs in the Cassiopeia section of the Perseus arm were already investigated in many papers: Elmegreen (1980), Megeath et al. (1996), Deharveng et al. (1997), Carpenter et al. (2000), Ogura et al. (2002), Karr & Martin (2003a,b), Ojha et al. (2004), Ruch et al. (2007), Saito et al. (2007), etc.

In Table 2 we list only 27 YSOs belonging to the Local arm and matched with the IRAS and/or MSX point sources. For them we give IRAS numbers and fluxes in Jansysks in the 12, 25, 60 and 100 $\mu$m passbands, collected from the Simbad database. For some of the objects the fluxes in the 8.3 $\mu$m passband of MSX (Egan et al. 2003) are given too. In other MSX passbands the fluxes for most objects are of lower accuracy and have not been used.

The objects of the Local arm listed in Table 1 are plotted in the $J$–$H$ vs. $H$–$K_s$ diagram (Figure 4) as red dots. Other young objects of the area: O–B3 stars of Cam OB1 (black dots), irregular variables (blue dots) and H$\alpha$ emission stars (blue circles), are also plotted taking their data from Paper I. The star LW Cas was excluded as it belongs to the Perseus arm. The sharp edge of the red dots is the result of the selection criterion ($H-K_s \geq 1.0$). In reality, more young objects are expected within $H-K_s$ between 0.4 and 1.0 but it is difficult to identify them among thousands of other stars lying in the same area of the diagram. The distribution of the suspected YSOs in the $J$–$H$ vs. $H$–$K_s$ diagram for Camelopardalis is quite similar to that in other star-forming regions (see, e.g., Lada & Adams 1992; Gomez et al. 1994 and Kenyon & Hartmann 1995 for pre-main-sequence stars in Taurus).
Fig. 3. The suspected YSOs from Table 1 (black dots) plotted together with the dust clouds from Dabashi et al. (2005), nebulae and open clusters belonging to the Local arm (plus the h+χ Per cluster). The object GL 490 is shown as the white cross (and the white arrow). The four rectangles are boundaries of the associations Cas OB6 and Per OB1, located in the Perseus arm, Cam OB3 in the Outer arm and Per OB3 in the foreground of Cam OB1. The stars of Cam OB1 are scattered over the whole area, see Paper I.

4. SPECTRAL ENERGY DISTRIBUTIONS

In the $J-H$ vs. $H-K_s$ diagram the YSO sequence contains pre-main-sequence stars at various stages of evolution and having various physical parameters. Lada (1987) has suggested a scheme of classification for pre-main-sequence stars in three classes, based on their far-infrared spectral energy distribution (SED) curves in the log ($\lambda F_{\lambda}$) vs. log $\lambda$ plane. Class I sources exhibit SEDs with a steep rise in the near infrared (up to 10 $\mu$m) and a slower rise up to 100 $\mu$m. Class II sources exhibit broad SEDs with a steep rise up to $\sim 2 \mu$m and a shallow falling-off up to 100 $\mu$m. Class III objects have SEDs with maxima at $\sim 2 \mu$m, and their shape is similar to heavily reddened SEDs of normal stars or black bodies. Additional Class 0 (zero) was introduced by André et al. (1993) to designate extremely young submm continuum objects or protostars. Evolutionary interpretation of
Fig. 4. The same as in Figure 1, but only with real and suspected young objects belonging to the Local arm, i.e., to the ‘Cam’ and ‘Gou’ cloud layers (red dots). Black dots designate O–B3 stars of the Cam OB1 association, blue dots designate known irregular variables and blue open circles the Hα emission stars (see Paper I).

these classes, given by Adams et al. (1987), is still valid, but now we have much more complete observational data and a better theoretical understanding of early stages of stellar evolution.

Whitney et al. (2003a,b, 2004) and Robitaille et al. (2006, 2007) have calculated a three-dimensional grid of YSO models covering a wide range of stellar masses, evolutionary stages and viewing angles. Their Stage I objects have significant infalling envelopes and possibly disks, Stage II objects have optically thick disks (and possible remains of tenuous infalling envelope), and Stage III objects have optically thin disks. Typical Stage II objects are classical T Tauri-type stars with strong emission lines (CTTS), and typical Stage III objects are weak-lined T Tauri stars (WTTS). Since YSOs of Stages II and III have their own names (CTTS and WTTS), the term YSO in many times is used to designate only the
objects of Stage I of Robitaille et al. (2006) or the objects of Classes I and 0 of Lada (1987) and André et al. (1993). In this paper we use the term YSO for all pre-main-sequence objects.

The distribution of YSO models in the $J$–$H$ vs. $H$–$K$ diagram (Robitaille et al. 2006) shows close resemblance to the diagrams based on observations of YSOs in star-forming regions, including our Figure 4. Stage I objects tend to be located at the cool end of the sequence, with $H$–$K > 1$. GL 490 in Camelopardalis is one of such objects. Most of the YSOs with central stars of high temperatures ($> 10^4$ K) also have colors redder than those of low-mass objects. However, in the presence of different and unknown interstellar and circumstellar reddening, identification of YSOs in different stages of evolution using only the $J$–$H$ vs. $H$–$K_s$ diagram is quite complicated.

SEDs in the infrared are the most reliable tools for separating YSOs from normal (and, partly, from AGB) stars. The photospheres of normal and AGB stars having no dense envelopes of low temperatures exhibit black-body like curves in the plot $\log \lambda F(\lambda)$ vs. $\log \lambda$, with sharp maxima at $\sim 2 \mu$m and almost a linear drop of the flux with increasing wavelength; see Figure 5, where SEDs for intrinsic and heavily reddened K0 III, M0 III and M5 III stars are given. Interstellar reddening shifts the flux maximum towards longer wavelengths making the long-wave slope of SED curves steeper. This means that normal stars even with extremely heavy reddening remain only near infrared sources. The flat or rising up SED at the wavelengths longer than $2 \mu$m argues for the presence of a circumstellar disk or envelope.

Oxygen-rich AGB stars with thick dust envelopes (infrared miras and OH/IR sources) also exhibit excess radiation in the far-infrared, but their SEDs are quite different from YSOs – they resemble to SEDs of black bodies of very low temperatures ($< 300$ K) with the maximum flux density between 5 and 50 $\mu$m and the narrow $9.8 \mu$m and $20 \mu$m absorption bands of silicates (see Habing 1996). In thick dust envelopes of carbon miras, a SiC band at $11.2 \mu$m is observed. However, all these bands cannot be discerned in broad-band photometric data.

To construct SEDs from the available data of IR surveys, we calculated $\log \lambda F_\lambda$ quantities for the Table 2 stars using the following equations:

$$\log \lambda F_\lambda = \log (10^{-m/2.5} \times \lambda \times F^m_\lambda = 0)$$

for the $R$, $J$, $H$ and $K_s$ magnitudes and

$$\log \lambda F_\lambda = \log (3 \times 10^{-9} \times \lambda^{-1} \times F_\nu).$$

Fig. 5. Spectral energy distributions of K0 III, M0 III and M5 III stars: thick lines are for the unreddened stars and thin lines are for the same stars reddened by the interstellar dust up to the extinction of 15 mag in the $V$ passband. The SEDs are obtained from the intrinsic color indices in the $VRI$-$JHKLMN$ system and normalized at 550 nm ($\log \lambda = -0.26$).
for the [8.3], [12], [25], [60] and [100] fluxes. Here $\lambda$ is in $\mu$m, $F_\nu$ in Jy and $F_\lambda$ in erg cm$^{-2}$ s$^{-1}$ $\mu$m$^{-1}$. The following values of $F_\lambda$ for $m = 0$ were taken: $1.66 \times 10^{-5}$ for $R$, $3.03 \times 10^{-6}$ for $J$, $1.26 \times 10^{-6}$ for $H$ and $4.06 \times 10^{-7}$ for $K_s$ (Campins et al. 1985; Straižys 1992). For the $R$, $J$, $H$ and $K_s$ magnitudes the mean wavelengths 0.71, 1.26, 1.60 and 2.2 $\mu$m were taken.

Although IRAS measurements are available for 23 objects, in many cases only the upper limit of the flux is given. Consequently, we were not able to construct SEDs from 1.26 to 100 $\mu$m containing all the IRAS points. For 10 objects the MSX fluxes at 8.3 $\mu$m were helpful.

Figures 6–8 present SEDs only for 16 objects for which reliable fluxes are available at least at some of the IRAS or MSX passbands. For all the objects in Figures 6 and 7 the ratio of $F_{12}/F_{25}$ is lower than 1.0 or $[12]−[25] > 1.56$, and this indicates that radiation of their photospheres is modified by the circumstellar dust. We have attempted to differentiate the objects by the form of their SEDs. Although in the figures we joined the dots by rounded curves, the waves in most cases are not real, probably they are a consequence of the scatter of points due to measurement errors or other reasons. In many cases YSOs are not dot-like objects, and the measured fluxes depend on the size of photometer’s aperture used. The IRAS dots at 60 and 100 $\mu$m are affected by strong thermal dust emission since most of the YSOs are immersed in dense dust clouds.

In Figure 6 the YSOs, most similar to the Class I objects, are displayed. Here the most outstanding object is GL 490 with extremely steep flux distribution curve in the near infrared, a small dip near 10 $\mu$m and the maximum at 50–60 $\mu$m. This means that we are observing a typical Class I object with dominant thermal radiation from the envelope heated by a source of high temperature and having a small inclination of its rotational axis (see models in Fig. 3 of Whitney et al. 2004). The curves of other YSOs in Figure 6 are similar to the model curves of the Taurus SFR stars IRAS 04169+2702 and IRAS 04181+2654 (see Fig. 7 of Kenyon et al. 1993 and Fig. 1 of Robitaille et al. 2007). The model SEDs correspond to rotationally flattened infalling envelope and a flared disk with small inclination. In some cases we should take into account the strong interstellar reddening in front of the object, which may considerably reduce the radiation shorter than 1.0 $\mu$m, leaving the radiation longer than 10 $\mu$m not affected. This can reduce considerably the required opacity in the circumstellar envelope.

Figure 7 shows the SEDs for six objects supposed to belong to Class II. They exhibit a moderate decline of the shortward wing and a more or less flat spectrum longward of 2–3 $\mu$m. In YSOs of Class II either direct radiation from the photosphere or its scattered radiation by the thick disk should be observed. Thus, their SEDs should extend into the optical spectrum (see Whitney et al. 2003b; Robitaille et al. 2006, 2007). In Figure 7 we see a very faint intensity in the optical spectrum and no maximum at 1–2 $\mu$m predicted by models. Both optical spectrum and the maximum in the near infrared probably are cut down by strong interstellar reddening.

Figure 8 shows the SEDs for three objects, which are quite similar to photospheric spectra. These objects may be either normal stars affected by heavy reddening or post-T Tauri stars having no optically detectable circumstellar disk.

In Figure 9 we show the SEDs for five objects belonging to the Perseus arm, whose dependence to the YSO category is generally recognized. These objects are CPM 8 and 12 (Campbell et al. 1989), GLMP 49 and 61 (García-Lario et al.
Fig. 6. Spectral energy distributions for seven objects of Table 2 which are most similar to the Class I YSOs.

Fig. 7. Spectral energy distributions for six objects of Table 2 which are most similar to the Class II YSOs.
Fig. 8. Spectral energy distributions for three objects of Table 2 which are most similar to the Class III YSOs.

Fig. 9. Spectral energy distributions for five objects of Table 1 belonging to the Perseus spiral arm. All these objects are confirmed YSOs.
1997), and IRAS 03045+5612 (Kerton & Brunt 2003). The SEDs show that all five objects belong either to Class I or are intermediate between Classes I and II. The curve of CPM 12 at $\lambda > 2 \mu m$ is quite similar that of GL 490 (Figure 6).

We cannot exclude the possibility that some of the objects described can be unidentified spiral galaxies (or quasars) with heavy reddening by dust clouds in our Galaxy. Many of such galaxies have been already found behind the Milky Way (see, e.g., Takata et al. 1994; Saurer et al. 1997). A higher probability is to find some reddened galaxies among the fainter objects of Table 1, for which no reliable IRAS and MSX data are available. Fortunately, the number density of bright galaxies and quasars is relatively low. Also, many galaxies are not point sources and could be recognized in the SkyView images, especially in the optical passbands. Probably most (if not all) the SEDs shown in Figures 6–8 belong to young stellar objects.

5. CONCLUSIONS

In the Camelopardalis section of the Milky Way, including the nearby regions of Cassiopeia, Perseus and Auriga, we have identified 142 infrared objects suspected to be in the pre-main-sequence stage of evolution. The criteria for the attribution to YSOs are their positions in the $J–H$ vs. $H–K_\text{s}$ and $[12]–[25]$ vs. $[25]–[60]$ diagrams, the similarity of the observed and the model infrared energy distributions and their concentration in the densest parts of interstellar molecular and dust clouds. Approximate distances of the objects are estimated by radial velocities of the associated CO clouds. The majority of the identified objects belong to the Perseus arm and reside in the star-forming region associated with the complex of emission nebulae W3/W4/W5 and the Cas OB6 association. Many of these infrared objects are already known as YSOs from earlier investigations based on the IRAS, MSX, 2MASS and Spitzer surveys.

42 YSOs are found to belong to the Local arm: 35 objects are related to the Cam OB1 association CO layer at a distance of about 1 kpc and seven to the local CO layer related to the Gould Belt. About half of the identified objects of the Cam OB1 layer are concentrated in the dust cloud DoH 942 (clumps P1, P2 and P3), in the center of the association. The brightest among them is GL 490, a well known pre-stellar object of Class I, which has had numerous investigations in optical, infrared and radio wavelengths. Other groups of the detected objects concentrate either in other dark clouds or in the infrared clusters discovered recently through 2MASS photometry and infrared imaging surveys.

We do not exclude, however, that some of the objects, suspected to be in the pre-main-sequence stage, in reality are heavily reddened OB stars (including Be stars), AGB stars or even distant galaxies and quasars since $J, H, K$ photometry is not sufficient to differentiate these objects. Although IRAS and MSX photometry is helpful in rejecting reddened OB, Be stars and most of the late-type AGB objects, the dusty spiral galaxies and quasars remain mixed with YSOs.

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Errata. In the printed version of the description of Figure 1 (Section 2) and in Figure 1 caption the blue and green line colors should be interchanged. In the arXiv version the text is corrected.