

Young Stars and Clouds in Camelopardalis

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Abstract. Star formation in the Local spiral arm in the direction of the Galactic longitudes $132\text{--}158^\circ$ is reviewed. Recent star-forming activity in this Milky Way direction is evidenced by the presence here of the Cam OB1 association and dense dust and molecular clouds containing $H\alpha$ emission stars, young irregular variables and infrared stellar objects. The clouds of the Local arm concentrate in two layers at $150\text{--}300$ pc and ~ 900 pc from the Sun. The Perseus arm objects in this direction are at a distance of about 2 kpc.

1. Introduction

At the border of Cassiopeia and Camelopardalis the Milky Way loses its brightness and almost disappears at the Galactic longitude $\ell = 143^\circ$. Its brightness comes back only at $\ell = 170^\circ$, near the Auriga border. This Milky Way discontinuity most naturally can be explained as blocking of light of distant stars by interstellar dust clouds. The presence of dense dust and molecular clouds in the Local arm in the direction of Camelopardalis now is confirmed both by optical and radio observations which will be reported in the subsequent sections. We will also discuss star formation in Camelopardalis which is evidenced by the presence here of the Cam OB1 association at a distance of $0.9\text{--}1.0$ kpc and by other young objects.

The population of dust and molecular clouds, as well as of young stars, will be analyzed in the ranges of Galactic longitudes $132\text{--}158^\circ$ and latitudes $\pm 12^\circ$. These ranges are defined by the distribution of the supposed Cam OB1 association members. The region is located mainly in Camelopardalis, but also includes edges of Cassiopeia, Perseus and Auriga. Since our attention will be concentrated only on the objects related to star formation in the Local spiral arm, distant objects in the Perseus arm will be touched on only occasionally. Objects in the nearby areas of Cassiopeia are reviewed by Megeath et al. and by Kun in this book.

2. Nebulae and Clusters of the Local Arm

Figure 1 gives a map of the reported area in Galactic coordinates indicating some of the objects mentioned in this review. In comparison to Cassiopeia, the Camelopardalis section of the Milky Way is relatively poor in bright nebulae: here only a few faint emission and reflection nebulae are present. At $\ell, b = 140^\circ, +2.0^\circ$ the emission nebula Sh 2-202 of $\sim 2^\circ$ diameter is seen (Sharpless 1959). Located at a distance of 800 pc (Fich & Blitz 1984), the nebula is ionized by the nearby star HD 19820 (O8.5 III). A group of bright stars inside it is known as the open cluster Stock 23 with a blue nebula

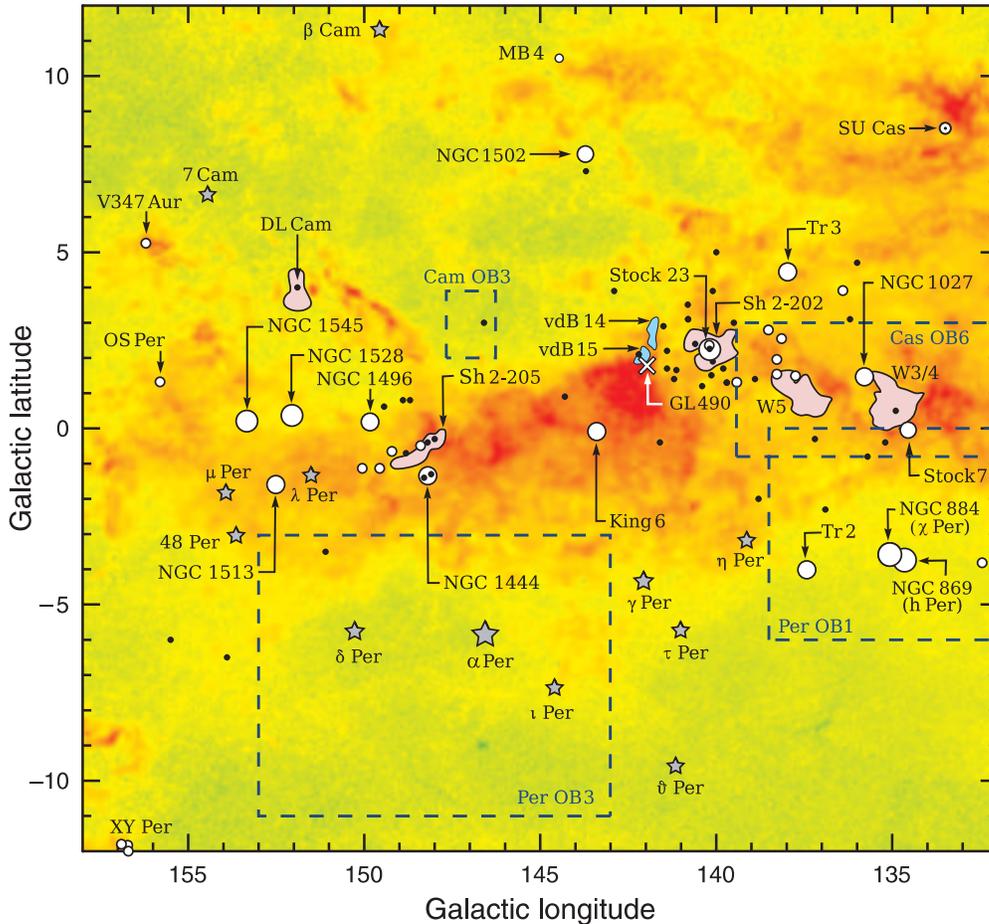


Figure 1. Dust clouds in Camelopardalis from Dobashi et al. (2005) plotted together with the clusters and nebulae and the known young objects. White large circles designate positions of 12 open clusters belonging to the Local arm and of the double cluster $h+\chi$ Per. The bright rosy patches designate the emission nebulae W3/4, W5, Sh 2-202, Sh 2-205 and DL Cam, the two small blue patches are the reflection nebulae vdB 14 and vdB 15. Black dots designate the association Cam OB1 members of spectral types O–B3 V–III and supergiants, small white circles designate young irregular variables and $H\alpha$ emission stars. The YSO GL 490 is shown as a white cross. Dashed lines delimit the areas of the associations Cas OB6, Per OB1, Cam OB3 and Per OB3. Star-like symbols designate the Camelopardalis and Perseus stars brighter than $V = 4$ mag.

around (Figure 2). According to Kharchenko et al. (2005), this cluster is not related to the nebula and is a foreground object at a distance of 380 pc. However, in the V vs. $B-V$ diagram stars of this group are so scattered that the cluster seems to be not real. One of these stars, HD 20134 (B2 IV), is in the list of the Cam OB1 association members.

The two elongated reflection nebulae, vdB 14 and vdB 15, each extending for $0.7\text{--}0.8^\circ$ in the N–S direction, are located at $\ell, b = 142^\circ, 1.8\text{--}3.0^\circ$ (Figure 3). They are illuminated by two supergiants, HD 21291 (B9 Ia) and HD 21389 (A0 Ia), respectively.



Figure 2. The emission nebula Sh 2-202 and the doubtful cluster Stock 23 in the center. North is up and east is left. The figure is $\sim 2.2^\circ$ high. Courtesy Dean Salman.

Racine (1968) suggested that these two stars, and three other young stars in the vicinity, form a separate association Cam R1. However, there is no ground to isolate these stars from other association Cam OB1 members.

At $\ell, b = 148\text{--}149^\circ, 0\text{--}1^\circ$ another oblong ($1.6 \times 0.3^\circ$) emission nebula, Sh 2-205, at a distance of 900 pc (Fich & Blitz 1984) is located. Its ionizing star is HD 24431 (O9 III). At its left edge a relatively small nebula Sh 2-206 is seen, this is an object of the Perseus arm. On deep exposures in an $H\alpha$ filter an emission nebula of about $1.5 \times 2^\circ$ is seen at $\ell, b = 152^\circ, +4^\circ$, around the star DL Cam (a triple system, the brightest component is of spectral type B0 III).

These nebulae and the surrounding areas exhibit evidence of recent star formation. The most evident confirmation of this process is the presence here of a group of numerous young and massive stars known as the Cam OB1 association located at a distance of ~ 1 kpc. Its members are scattered between 132° and 156° in longitude and between $+7.5^\circ$ and -4° in latitude. It contains more than 40 O–B3 luminosity V–III stars and a

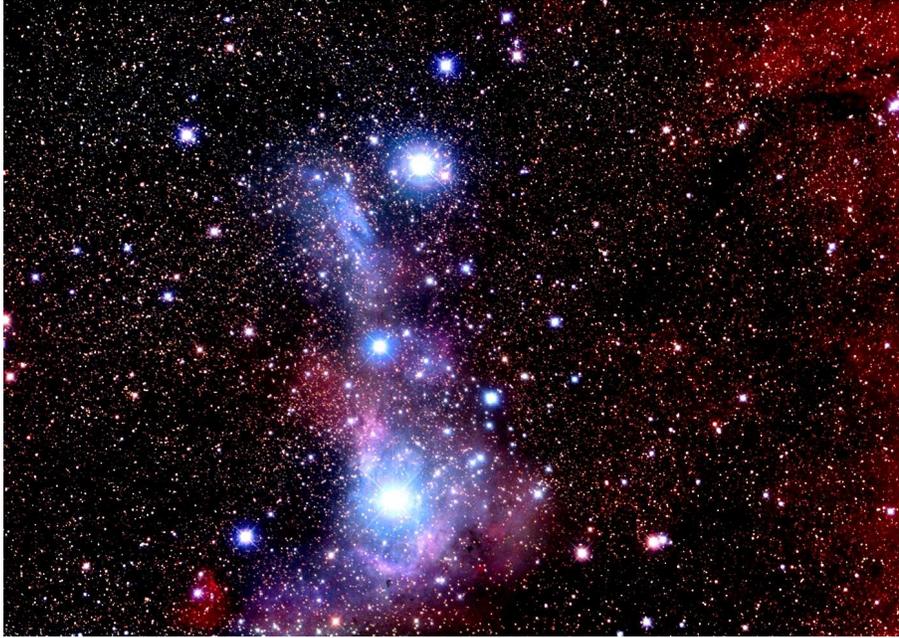


Figure 3. The reflection nebulae vdB 14 and vdB 15 at the center of the Cam OB1-A association. North is up, east is left. The figure is $\sim 2^\circ$ high. Courtesy Adam Block and Tim Puckett.

few supergiants (Humphreys 1978; Humphreys & McElroy 1984; Straižys & Laugalys 2007a), as well as the open cluster NGC 1502. For more about the association see Section 6.

The Cam OB1 association on its western side partly overlaps the associations Cas OB6 and Per OB1 with several well known objects – the H II regions W3/4/5 and the double cluster $h+\chi$ Per. The areas of these two associations overlap with Cam OB1 only in projection: in space they are much farther, in the Perseus arm. One more group of O and early B stars, seen in the far background (in or near the Outer arm), is the Cam OB3 association at $\ell, b = 146.3\text{--}147.7^\circ, +2.0\text{--}+3.9^\circ$. The Per OB3 association (with the brightest star α Per), located in the foreground of Cam OB1, is seen in the lower part of Figure 1.

Thirteen open clusters, belonging to the Local arm, are present in the area, their list is given in Straižys & Laugalys (2007a). In the context of this review the most important cluster is NGC 1502 located at $\ell, b = 143.7^\circ, +7.7^\circ$, in the upper part of Figure 1. In the first lists of associations, this cluster was considered as a separate association Cam II, since it has two stars of spectral classes B0 III (sometimes classified as O9). Blaauw (1961) suspects that the run-away star α Cam (O9.5 Ia) is also related: it has escaped from NGC 1502 about 2.0 million years ago. Later on, stars of this cluster were included into the list of the Cam OB1 members (Ruprecht 1964; Humphreys & McElroy 1984). The ages of both cluster and association are similar ($\leq 10^7$ yr) since the spectral types of the most massive stars are \sim O9 in both of them.

Another cluster, related to the Cam OB1 association, is NGC 1444 at $\ell, b = 148.1^\circ, -1.3^\circ$, in the vicinity of the Sh 2-205 nebula. Its appearance is dominated by two stars – HD 23675 and HD 23800 of 6.7 and 6.9 visual magnitudes and B0.5 III and B1 IV

spectral types. Both of them are in the list of the Cam OB1 members. Although Peña & Peniche (1994) find that the distances of the cluster and the association are close to each other, there are some doubts whether NGC 1444 is a real cluster.

A compact group of stars at the southern edge of the H II region W4 is known as the open cluster Stock 7. Its distance and age (700 pc and 16×10^6 yr) given in the Webda database ¹ are not very different from those of the Cam OB1 association. More details are given in Moffat & Vogt (1973).

Other clusters in the area having similar distances as the association probably are not related to it since their ages are between $(150\text{--}630) \times 10^6$ yr. Several clusters of infrared objects in the area were identified by Carpenter et al. (2000), Bica et al. (2003a,b) and Froebrich et al. (2007a): all of them belong to the Perseus arm.

3. Dark Clouds

During the last decade several detailed maps of dust distribution along the Galactic plane were published. The investigation of Schlegel et al. (1998) is based on the thermal dust emission survey at 100 μm by the IRAS and COBE satellites. The Dobashi et al. (2005) atlas is based on star counts in the Palomar DSS I database charts. The Froebrich et al. (2007b) maps are based on the average infrared color excesses in the 2MASS survey. In Straizys & Laugalys (2007a), we compared dust distributions given in these three surveys and found very similar dust cloud patterns in the area. The distribution of molecular clouds taken from the whole sky CO survey by Dame et al. (2001) is also in a good agreement. For a comparison of distributions of dust clouds and young stars we decided to use the Tokyo atlas (Dobashi et al. 2005), which better represents dust distribution in the Local arm. Cloud numbers of this atlas are designated by TGU, their identification chart is given in Straizys & Laugalys (2007a).

In Figure 1 dark clouds are shown as red areas of different density. The largest extinction is detected between the longitudes $142\text{--}143^\circ$ at the latitudes $0\text{--}2^\circ$, i.e., at the southern edge of the complex of the reflection nebulae vdB 14 and vdB 15 and about 2° southeast of the emission nebula Sh 2-202. Here (at $\ell, b = 142.1^\circ, +1.6^\circ$) is the clump P1 of the cloud TGU 942, in which a young massive stellar object (YSO), GL 490, is immersed (more about it see in Section 6). The cloud TGU 942 in the Tokyo atlas is split into 20 clumps numerated from P1 to P20 which extend from 142° to 148° at the Sh 2-205 nebula. While the densest clumps at the object GL 490 are at the same distance as the Cam OB1 association, the other clumps in TGU 942 belong to different cloud layers.

The dust clouds near the Galactic equator, located within $b = 0^\circ$ and $+2^\circ$ right of the Sh 2-202 nebula, belong to the Perseus arm at a distance of 2.0–2.2 kpc from the Sun. These clouds are related to the H II regions W3, W4 and W5 and the association Cas OB6. In the Tokyo atlas all these clouds are shown under one number TGU 879.

A dense cloud TGU 878 (LDN 1355/58) is seen in the right upper corner of Figure 1 at $\ell, b = 133^\circ, +9^\circ$. Its lower part belongs to the Gould Belt layer while the upper part to the Cam OB1 layer. The Gould Belt clouds at a distance of 260 pc are illuminated by several B8–A3 stars and the cepheid SU Cas (Turner & Evans 1984).

¹<http://www.univie.ac.at/webda>

At the longitudes $> 148^\circ$ dust clouds form the three possible configuration versions of ring-like structures described in Straizys & Laugalys (2007a). All of these versions include a curved chain of small dark clouds TGU 994. In the Lynds (1962) catalog this chain includes the clouds from LDN 1390 to LDN 1406. Most noticeable is the almost perfect ring (or bubble) with the center at $\ell, b = 152^\circ, +0.5^\circ$ (at the open cluster NGC 1528) and a diameter of $\sim 8^\circ$. This ring includes the following Tokyo clouds (counterclockwise): TGU 942 (clumps P7 and P8), TGU 994, TGU 1003, TGU 1036, TGU 1041, TGU 1027 (with μ Per in foreground), TGU 1014, TGU 1006 and TGU 989. According to radial velocities of the associated CO clouds, all these dust clouds belong to the Local arm, but probably are located in different layers. If these clouds form a real bubble, they should have peculiar motions additional to the Galactic rotation.

4. Interstellar Extinction from Photometry

Until 1996 the interstellar extinction in the Camelopardalis section of the Milky Way was investigated only scantily. Probably the first studies were published by Heeschen (1951), McCuskey (1952) and Kharadze (1952). The first of them was based on star counts and two-color photographic photometry, the next two were based on low-dispersion spectra and two-color photographic photometry. The conclusion was that the extinction starts rising at a distance of 100–200 pc. Rydström (1978) investigated the extinction in some Camelopardalis areas by a spectrophotometric method, and found zero extinction at 100 pc with a rise up to 2.0 mag at 1 kpc. However, the above methods were based on photographic techniques and, consequently, were of low accuracy.

Crude estimates of the extinction in large areas of Camelopardalis near the Galactic plane have been done by FitzGerald (1968) and Neckel & Klare (1980) applying *UBV* photometry data and MK spectral types collected from the literature. The extinction was found to grow up to 3.5 mag at 1 kpc with no increase at larger distances. Similar extinction values were obtained for several open clusters investigated by two- or three-color photometry.

Since 1996, several areas in Camelopardalis were investigated in the seven-color Vilnius photometric system determining spectral classes, luminosities and interstellar reddenings of stars with the help of interstellar reddening-free *Q*-parameters (Zdanavičius et al. 1996, 2001, 2002a,b, 2005a,b). Interstellar extinction was studied in four areas of different sizes using both photoelectric and CCD photometry of about 2000 stars down to 15.5 mag. Figure 4 shows the extinction A_V run with distance in a 1.5 square degree area at $\ell, b = 146^\circ, +2.6^\circ$ investigated by Zdanavičius et al. (2005b). A common property of all areas is the extinction rise after 120–150 pc reaching about 1.5–2.5 mag at 1 kpc. At larger distances the extinction values remain at this level in relatively transparent areas and reach 2.0–3.0 mag in the direction of dark clouds. However, the most reddened stars in these areas were too faint to be measured, consequently, there is a selection effect present. The listed investigations show that the front edge of the Camelopardalis clouds is almost at the same distance, or even closer, as the Taurus clouds.

The interstellar extinction law in the direction of Galactic longitudes 135–150° was investigated by Zdanavičius et al. (2002c): in the optical range (345–660 nm) it was found to be nearly normal, typical for the low density interstellar dust. In the

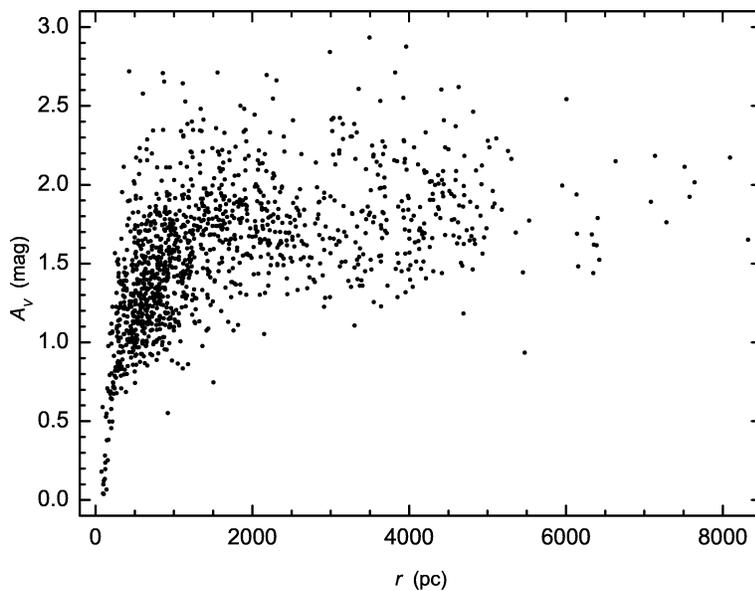


Figure 4. The dependence of interstellar extinction A_V on distance in the area at $\ell, b = 146^\circ, +2.6^\circ$ from Zdanavičius et al. (2005b).

ultraviolet wavelengths shorter than 330 nm the extinction is found to be slightly larger than the average. The ratio R is found to be ~ 2.9 , i.e., a little smaller than normal.

5. Molecular Clouds

The first CO survey of the distribution of molecular gas in the second quadrant of the Galaxy was published by Cohen et al. (1980), however, it ended near the Cassiopeia and Camelopardalis border. The first composite CO survey of the entire Milky Way by Dame et al. (1987) included all the area discussed in the present review but with a relatively low resolution. The next investigation was by Digel et al. (1996) with a higher resolution, but it included only the longitudes $132\text{--}144^\circ$ of those covered by the present review ($132\text{--}158^\circ$). In the following discussion we will use the combined results of Digel et al. and of a much broader CO survey but with lower resolution published in the second entire sky survey by Dame et al. (2001). One more high resolution CO survey was published by Heyer et al. (1998) and Brunt et al. (2003) but it covers only the longitudes $< 141.5^\circ$.

Digel et al. conclude that molecular clouds in the investigated direction are formed by three layers with different radial velocities: (1) the local layer with velocities between -5 and $+10$ km/s, (2) the Cam OB1 layer with velocities between -5 and -20 km/s, and (3) the Perseus arm with velocities between -30 and -60 km/s. The space between the Cam OB1 and the Perseus arm layers is nearly empty in all the investigated longitude range. The separation of the local (hereafter the Gould Belt layer) and the Cam OB1 layers is not so distinct. Radial velocities may be transformed to distances of the layers from the Sun using the Galactic rotation curve. Digel et al. accept the mean distance of the local layer ~ 200 pc and of the Cam OB1 layer ~ 800 pc. These distances are close to those determined from stellar photometry. For the Gould Belt

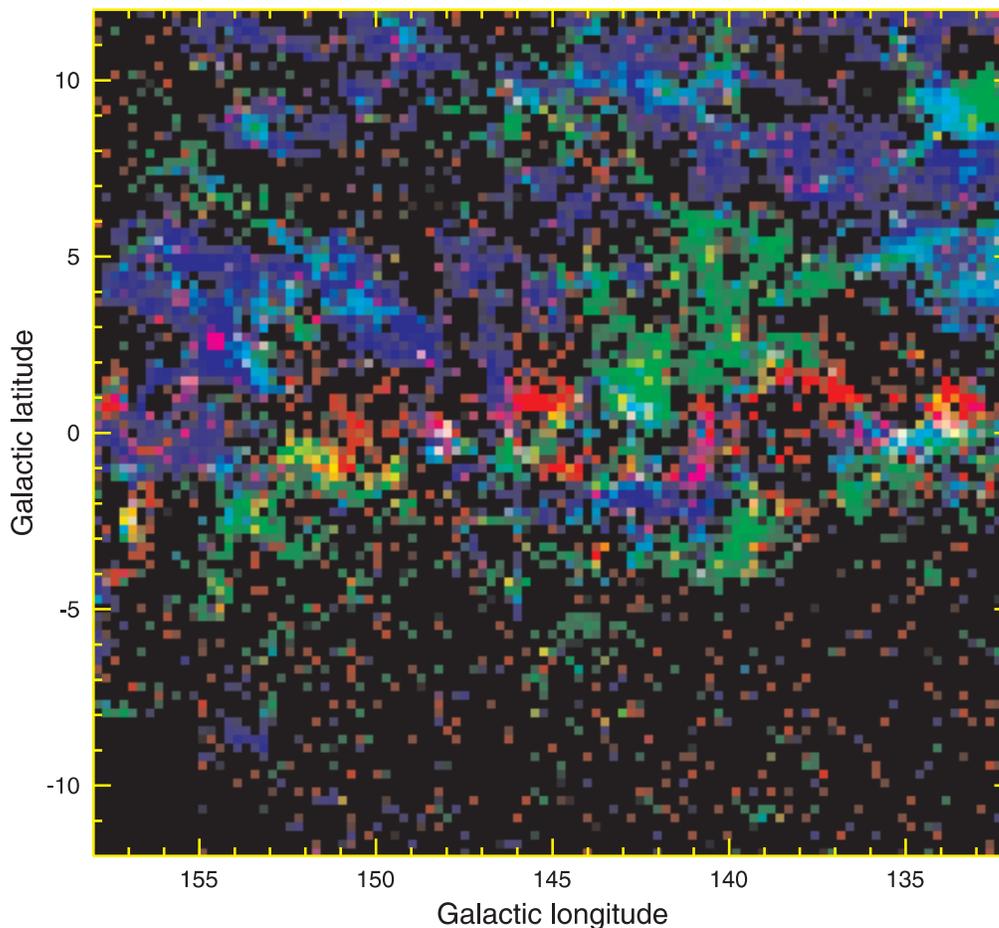


Figure 5. CO clouds from Dame et al. (2001). Clouds of the Gould Belt layer are shown in blue, of the Cam OB1 layer in green and of the Perseus arm in red. The format of the figure matches that of the extinction map in Figure 1.

layer it is more realistic to accept a distance range of 150–300 pc, in accordance with the optical cloud distances in Camelopardalis and nearby regions (Zdanavičius et al. 2005b; Straižys et al. 2001). For the second layer the range of distances 900–1000 pc would be in a better agreement with the optical distance of the Cam OB1 association (see the next Section). Both layers contain clouds of different sizes and densities covering a wide range of longitudes and latitudes. Many clouds extend up to $+12^\circ$ and some are even at $+24^\circ$ from the Galactic equator (Heithausen et al. 1993; Dame et al. 2001).

In order to assign clouds at larger longitudes to their proper layer, radial velocities from the Dame et al. (2001) data have been analyzed (Straižys & Laugalys 2007a). The resulting picture is shown in Figure 5. The clouds of the Gould Belt layer (150–300 pc) are shown in blue, of the Cam OB1 layer (900–1000 pc) in green and in the Perseus arm (> 2 kpc) in red. It is evident that most clouds seen in the area belong to the two layers of the Local arm. The Perseus arm clouds cover relatively small areas which concentrate near the Galactic equator.

6. The Cam OB1 Association

The association was first identified by Morgan et al. (1953) and appeared in the *Catalogue of Star Clusters and Associations* (Alter et al. 1958, 1970). The size of this association seems to be unusually large: its possible members are scattered within 24° in longitude and 12° in latitude. In Straizys & Laugalys (2007a) we have suggested that this association may consist of three unrelated groups: Cam OB1-A around the nebulae vdB 14, vdB 15 and Sh 2-202, Cam OB1-B around the nebula Sh 2-205, and Cam OB1-C, the NGC 1502 cluster. At a distance of 1 kpc the groups Cam OB1-A and Cam OB1-B would be of about 70–90 pc diameter which is a typical size for OB associations.

Humphreys & McElroy (1984) list 55 massive member stars of the Cam OB1 association (including two stars of the cluster NGC 1502). We have revised this list by estimating photometric distances of the stars from their MK spectral types and B, V photometry. The main source of distance errors are the accepted luminosity classes. On the other hand, some of the potential association stars possess spectral peculiarities (emission, duplicity, variability, etc.). Our revised list contains 43 stars plotted in Figure 1: two O8.5–O9 stars, 35 B0–B3 V–I stars and six A, G and K supergiants. About 15 O–B5 stars of the cluster NGC 1502 should be added. Almost a half of the loose association members are concentrated in Group A, and only 10 in Group B.

In the area of Group A we also find the Class I YSO GL 490, mentioned in Section 3 and shown in Figure 1. It is known to be a massive object ($8\text{--}10 M_\odot$) in a transition stage to Herbig Be stars. surrounded by a rotating disk and huge envelope, with a ~ 100 AU cavity inside (see Mitchell et al. 1995; Schreier et al. 2002, 2006). The dust envelope gives an extinction A_V of 35 ± 5 mag (Alonso-Costa & Kwan 1989).

The distance of the Cam OB1 association was estimated by taking the average of the distances of its members. For this purpose we chose stars with reliable MK classification, without peculiarities, and with BV photometry available. The calibration of MK spectral types in absolute magnitudes M_V was taken from the Straizys (1992) monograph. The ratio $R = A_V/E_{B-V} = 2.90$ was used (Zdanavičius et al. 2002c). For 26 selected stars the average distance is 1010 ± 210 pc. This value is in good agreement with the earlier determinations by Humphreys (1978, 1.0 kpc), Melnik & Efremov (1995, 0.98 kpc), Zeeuw et al. (1999, 0.9 kpc) and Lyder (2001, 0.98 kpc).

Lyder (2001) has attempted to identify Cam OB1 stars of lower masses (spectral classes B5–A0 V) in the area of our Group A using spectral, photometric and radial velocity data from the literature. He concluded that star formation in the association has been ongoing during 100 million years. However, the membership and the evolutionary stage of the selected stars should be verified by more accurate observations.

7. Low-mass Stars and Infrared Objects

The data on young low-mass stars in the Camelopardalis area are quite scarce. The Herbig & Bell (1988) catalog of emission-line stars of the Orion population lists only one $H\alpha$ emission star, IRAS 03134+5958 ($V \sim 14$), located near the questionable open cluster Stock 23, within the Sh 2-202 nebula. The same star, also known as HBC 336 or CPM 7, is in the list of YSO objects by Campbell et al. (1989).

More young low-mass stars in Camelopardalis have been suspected by Gahm (1990). In low-dispersion objective-prism spectra he identified 12 stars with emission

in $H\alpha$ in the vicinity of the Sh 2-205 nebula. In Straizys & Laugalys (2007a) we have shown that four of the Gahm stars in the $J-H$ vs. $H-K_s$ diagram are located near and above the intrinsic line of classical T Tauri (CTTS) and weak-line T Tauri (WTTS) stars. The position of the mentioned $H\alpha$ emission star IRAS 03134+5958 also confirms its relation to T Tauri-type objects. Two more $H\alpha$ emission stars satisfying the same criterion were found in the Kohoutek & Wehmeyer (1997) catalog. Eleven irregular variables of types IN and IS, selected from GCVS (Samus et al. 2004) and listed in Straizys & Laugalys (2007a), also lie in the same region of the diagram (Figure 6).

Many YSOs were identified in the Camelopardalis dark clouds using the available IRAS photometry. Clemens & Barvainis (1988) list seven globules in this area. Two of them, CB 17 (LDN 1389) and CB 26 (LDN 1439) are associated with the IRAS 04005+5647 and IRAS 04559+5200 sources and protostellar cores (Launhardt & Henning 1997; Launhardt & Sargent 2001; Stecklum et al. 2004). Benson & Myers (1989) identify 12 dense cores in the LDN 1400 cloud. Clark (1991) finds in them 32 IRAS objects. One of the Clark objects (IRAS 03233+5833) is close to GL 490. Stecklum et al. (2007) found that the source IRAS 04376+5413, partially embedded in the small cloud LDN 1415 and associated with the object HH 892, has brightened considerably in recent years, possibly indicating that it is an EXor or FUor. A large nebula surrounding the binary object IRAS 04261+6339 with a jetlike plume was discovered by McCall et al. (2004) at $\ell, b = 144.5^\circ, +10.5^\circ$ (see the object MB 4 in Figure 1). At the estimated distance of 2.0 ± 0.8 kpc, the object may belong to the Perseus arm. However, in this case its distance from the plane (about 370 pc) is unusually large for YSO. The object in the sky is quite close to the TGU 951 dust cloud which, according to the radial velocity of the associated CO cloud, is an object of the Local arm.

We have increased the number of suspected young stars in the area using infrared photometry from the 2MASS, IRAS and MSX surveys (Straizys & Laugalys 2007b, 2008). In the $J-H$ vs. $H-K_s$ diagram we isolated infrared objects having $H-K_s \geq 0.5$ and lying below the reddening line of O-type stars, which might be reddened YSOs of Classes I, II and III, see Lada (1987). From this sample the known M-type giants of the latest subclasses (including oxygen-rich long-period variables), OH/IR stars, carbon-rich stars of spectral type N, Be stars, galaxies and quasars were excluded. More stars, not related to star formation, were recognized and excluded according to their color indices based on IRAS and MSX photometry. The remaining 187 objects may be considered as potential YSOs. Evolutionary status was confirmed for 14 of the brightest objects from this list by obtaining their far red spectra (Corbally & Straizys 2008). More suspected YSOs were confirmed to be $H\alpha$ emission stars by the IPHAS survey (Witham et al. 2008).

The distribution of YSOs in the area exhibits evident clustering in the darkest dust clouds. Some groups of objects coincide with known star-forming regions (W3, W4, W5, LDN 1355/1358 at SU Cas), with the two centers of the Cam OB1 association (GL 490 and Sh 2-205), and with the infrared clusters described by Bica et al. (2003a,b) and Froebrich et al. (2007a). The grouping of objects within a few arcminutes around the object GL 490 in K -band images was first described by Hodapp (1990, 1994). However, clustering of infrared objects in the direction of dense dust clouds does not mean that we are observing a real cluster: distant heavily reddened K–M giants may imitate it as well (Straizys & Laugalys 2008).

The suspected YSOs were attributed to the Gould Belt, the Cam OB1 and the Perseus arm layers on the basis of radial velocities of the associated CO clouds. 42

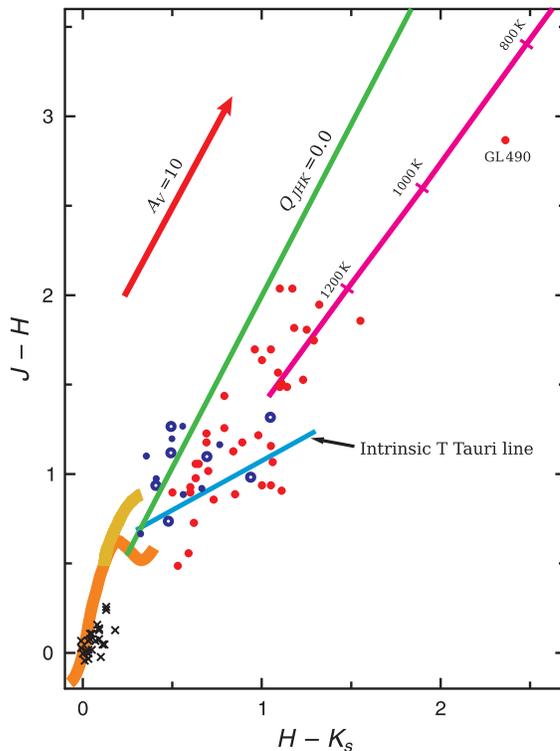


Figure 6. The $J-H$ vs. $H-K_s$ diagram for young stars of the Cam OB1 star-forming region. Crosses designate O–B3 stars of the Cam OB1 association, blue dots designate known irregular variables, blue open circles are $H\alpha$ emission stars and red dots are suspected YSOs. The intrinsic main-sequence and giant lines are shown in orange and yellow. The blue line designates the intrinsic locus of T Tauri stars (Meyer et al. 1997), the violet line is the locus of black bodies. The length of the reddening vector (in red) corresponds to the extinction in the V passband of 10 mag. Infrared YSOs were searched for in the region below the green line.

objects were found belonging to the Cam OB1 star-forming region in the Local arm. In Figure 6 these objects are plotted in a $J-H$ vs. $H-K_s$ diagram together with other young objects of the same SFR: O–B3 stars of Cam OB1, irregular variables and $H\alpha$ emission stars. In reality, more young objects are expected above the intrinsic T Tauri line but they are difficult to identify among thousands of other stars with only 2MASS photometry available. Photometric data in the mid- and far-infrared would be helpful.

The young objects for which fluxes have been measured in the 8–100 μm wavelength range, can be classified in the Lada (1987) classes or the Robitaille et al. (2006, 2007) evolutionary stages. We classified about 40 objects observed by IRAS and/or by MSX. The spectral energy distribution curves (SEDs) in the $\log \lambda F_\lambda$ vs. $\log \lambda$ coordinates were used (Straizys & Laugalys 2007b, 2008). The object GL 490 is the brightest among all, and its SED is typical for a Class I object with a maximum at 50–60 μm .

8. Conclusions

The Milky Way in Camelopardalis (including the nearby areas of Cassiopeia and Perseus) was until a decade ago among the least investigated regions. However, recently a number of important studies of stars and interstellar matter in this region have appeared. This paper is an attempt to put together the results related to star-forming processes in the Local spiral arm at the Galactic longitudes from 132° to 158° .

It is evident that this arm is populated by dust and molecular clouds of high density in which star formation takes place. The clouds may be divided into the Gould Belt layer at 150–300 pc distances from the Sun and the Cam OB1 association layer at ~ 900 pc distance. However, this division is somewhat ambiguous since in some directions

dust distribution across the arm is almost continuous. The largest density is observed in the Cam OB1 layer where some cloud clumps (like TGU 942 P1) reach an extinction A_V of up to 25 mag or more.

The presence in the area of tens of young massive stars of spectral classes O–B3 and of supergiants is evidence of a recent star-forming process which lasted about 10 million years. Probably this process continues up to now, since we have succeeded to find in the clouds tens of stars, which photometrically are similar to YSOs of Classes I–III. The most typical YSO of Class I is GL 490, a massive object in a protostellar evolutionary stage. The presence of young stars of lower masses in the clouds is also confirmed by identifying about 17 irregular variable and $H\alpha$ emission stars. Most probably, new spectral and photometric observations will reveal more T Tauri-type stars and related objects in the clouds. In the densest parts of the clouds more YSOs in early evolutionary stages are expected.

The Cam OB1 association sometimes is considered as unusual due to its enormous linear extent. However, the association may be split into three parts – Group A at the Sh 2-202 and vdB 14+15 nebulae, Group B at the Sh 2-205 nebula, and a third group formed by the cluster NGC 1502. Then both the A and B parts will become of normal sizes, 70–90 pc in diameter. Both groups contain O–B3 stars, supergiants, $H\alpha$ emission stars and suspected young infrared objects.

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