

The Lacerta OB1 Association

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Abstract. Lac OB1 is a nearby OB association in its final stage of star formation. While the member stars suggest an expansion time scale of tens of Myr, the latest star formation episode, as manifested by the existence of massive and pre-main sequence stars, took place no more than a few Myr ago. The remnant molecular clouds in the region provide evidence of starbirth triggered by massive stars.

1. Introduction

The Lacerta OB1 (I Lacertae) association was discovered by Blaauw & Morgan (1953, reported earlier by Strömberg 1952) as an aggregate of dispersing early-type stars, with an expansion time scale of a couple of million years. In the review article on nearby O associations, Blaauw (1964) listed a distance of 600 pc for Lac OB1, estimated by means of $H\beta$ photometry by Crawford (1961), which had quite a large uncertainty because of the presence of pre-main sequence (PMS) objects, and a possible age spread among member stars. A relatively recent distance determination by de Zeeuw et al. (1999), derived from *Hipparcos* data, yielded an average distance of ~ 370 pc. A noticeable distance range is obviously expected for a nearby association, which by itself has a typical extent of a few hundred parsecs. With a distance less than 400 pc, Lac OB1 ranks among the nearest OB associations in the solar neighborhood, and forms a part of the Gould belt system. The interstellar matter associated with the Gould belt is organized into a giant expanding ring, called the Lindblad ring (Lindblad et al. 1973), in whose periphery lie the local stellar associations, including Lac OB1 (Olano 1982). Early radio observations of Lac OB1 in the 21 cm line of neutral hydrogen were carried out by Raimond (1957), Howard (1958), and Dieter (1960).

Blaauw (1958) divided Lac OB1 into two subgroups, Lac OB1a and Lac OB1b, on the basis of stellar proper motions and radial velocities. The entire Lac OB1 is centered around $RA = 22^h35^m$ and $Decl = +43^\circ3'$, and covers the large sky region $90^\circ \lesssim \ell \lesssim 110^\circ$ and $-5^\circ \lesssim b \lesssim -25^\circ$ (de Zeeuw et al. 1999). The subgroup Lac OB1b has been considered younger and more concentrated, distributed within a $\sim 5^\circ$ radius centered around $(\ell, b) = (97.0, -15.5)$, whereas the presumably older Lac OB1a extends over the remaining region. Blaauw (1958) listed 15 stars for Lac OB1a, and 11 stars for Lac OB1b. The Lac OB1b harbors the only O star in the region, 10 Lac (O9 V; HIP 111841). De Zeeuw et al. (1999) identified a total of 96 *Hipparcos* mem-

bers for Lac OB1, including 1 O, 35 B, 46 A, 1 F, 8 K, 3 M-type stars, 1 carbon star (HIP 116681) and 1 star without spectral information (HIP 111762). Table 1 lists these 96 stars together with their 2MASS JHKs photometry. The first column is the *Hipparcos* number, followed by (2) and (3) the star's coordinates, (4) apparent *V* magnitude, (5) *B*−*V* color, (6) parallax and (7) proper motions. Columns (8), (9), and (10) are 2MASS magnitudes. Column (11) gives the spectral type, and the last column (12) provides some information gathered from SIMBAD.

De Zeeuw et al. (1999) gave a comprehensive list of references on the following parameters for Lac OB1: (1) Distance: For instance, Lesh (1969) estimated 368 pc and 603 pc, while Crawford & Warren (1976) obtained 417 pc and 479 pc for the subgroups Lac OB1a and Lac OB1b, respectively. (2) Proper motions: $\mu_\ell \cos b = -2.3 \pm 0.1$ mas yr^{−1}, and $\mu_b = -3.4 \pm 0.1$ mas yr^{−1}. (3) Radial velocity: Bijaoui, Lacoarret & Granes (1981) obtained the peak around $v_{\text{rad}}(\text{LSR}) \sim -15$ km s^{−1}, whereas the *Hipparcos* Input Catalogue gave an average of $v_{\text{rad}} = -13.3$ km s^{−1}. (4) Expansion age: 2.5 ± 0.5 Myr (Lesh 1969). (5) Stellar rotation: Abt & Hunter (1962). (6) Photometric studies (e.g., *uvby*, Crawford & Warren 1976) and spectroscopic (e.g., Coyne et al. 1969, Levato & Abt 1976, Guetter 1976). Also useful is the review by Garmany (1994) on the physical properties and dynamical evolution of OB associations, including Lac OB1.

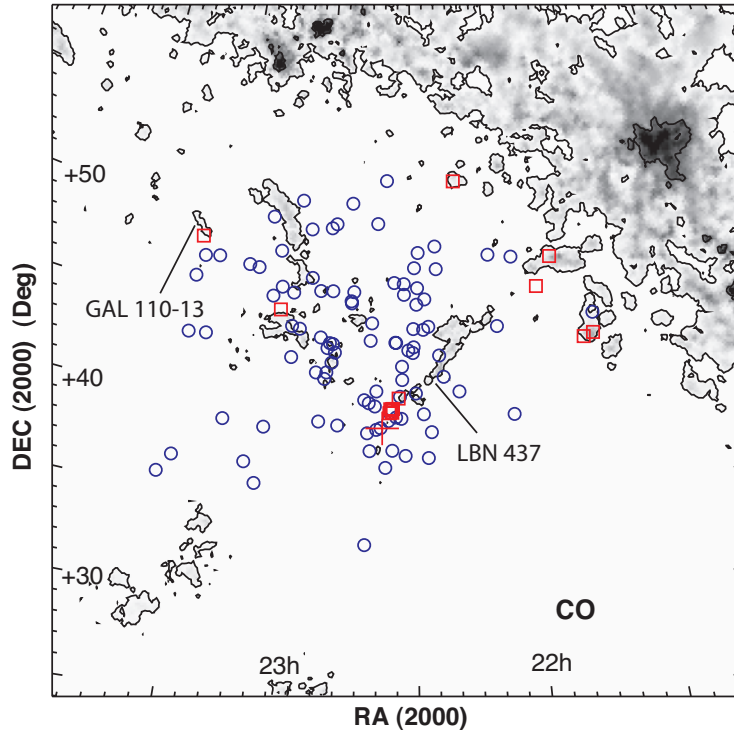


Figure 1. CO emission in Lac OB1 (Dame et al. 2001). The circles mark the positions of *Hipparcos* member stars (de Zeeuw et al. 1999), and the boxes represent CTTSs and Herbig Ae/Be stars (Lee & Chen 2007). The O star 10 Lac is indicated by a cross. The Galactic plane is seen on the upper right. The figure covers roughly the Galactic coordinates from $\ell \sim 75^\circ$ to $\sim 120^\circ$ and from $b \sim +10^\circ$ to $\sim -35^\circ$.

2. Sites of Recent Star Formation in Lac OB1

Despite a considerable number of fairly massive member stars, Lac OB1 is relatively devoid of cloud material. Two regions—both being remnant molecular clouds—are known to have had recent star-forming activities, namely the bright-rimmed cloud LBN 437 (Lynds 1965) and the comet-shaped cloud GAL 110–13 (Whitney 1949). Figure 1 shows the molecular CO emission (Dame et al. 2001), along with *Hipparcos* members (de Zeeuw et al. 1999), Herbig Ae/Be and classical T Tauri stars (CTTSs) (Lee & Chen 2007) in the Lac OB1 region.

2.1. LBN 437

LBN 437 is at the edge of an elongated molecular cloud complex Kh 149 (Khavtassi 1960), also known as GAL 96–15 (Odenwald 1988), and on the border of the H II region S 126 (Sharpless 1959) excited by 10 Lac (see Fig. 2). The southern end of LBN 437 is forked into two condensations sharing the same mean radial velocity. Condensation A contains a cold, elliptical dense core traced by NH_3 emission, and is associated with an optical reflection nebula and luminous young stars, whereas the less massive Condensation B appears not associated with any optical stars (Olano et al. 1994).

Stars associated with Condensation A include LkH α 233 (= V375 Lac), a Herbig Ae star (Hernández et al. 2004) showing H α , [O I] 6300 Å, and [S II] 6717 Å emission lines in the spectrum (Lee & Chen 2007). LkH α 233 was found by Herbig (1960) to

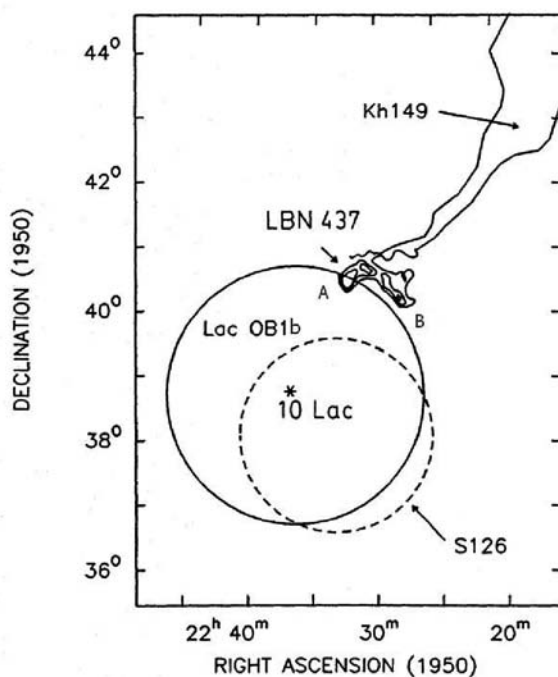


Figure 2. Schematic of Lac OB1 near the LBN 437 cloud (modified from Olano et al. 1994). Condensations A and B at the southern end of LBN 437 are marked.

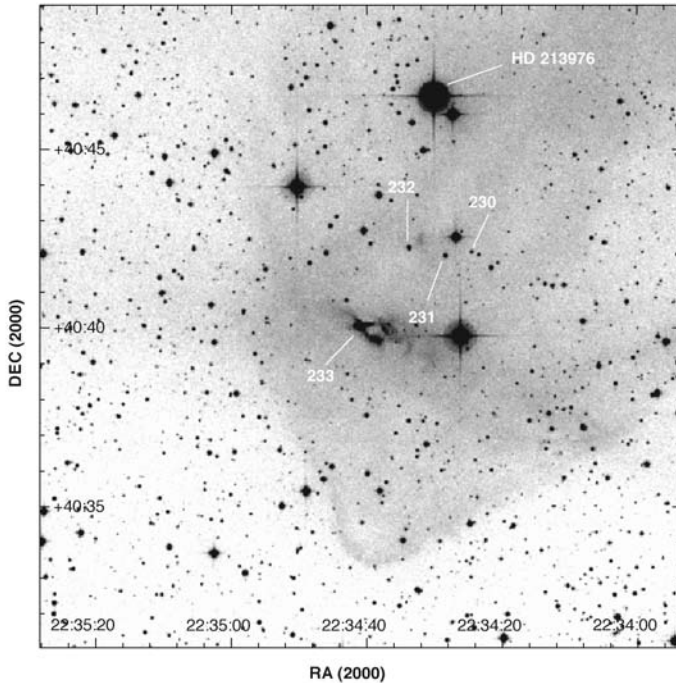


Figure 3. DSS-2 red image of the region around LkH α 233 and other emission-line stars, each labeled with its LkH α number, and the luminous star HD 213976.

be an Ae/Be star associated with nebulosity that was later resolved by near-infrared speckle interferometry to be ~ 1000 AU in size (Leinert, Haas, & Weitzel 1993). Given $m_V = +13.8$ and assuming a luminosity class V (which is not appropriate for a PMS star), hence $M_V = +2.3$, Odenwald (1988) estimated a distance 140–860 pc to LkH α 233, depending on the adopted value of optical extinction. Fig. 3 shows the region around LkH α 233 and other fainter emission-line stars LkH α 230, LkH α 231, LkH α 232, and the luminous star HD 213976 (Herbig 1960). The association of LkH α 233 with Lac OB1, however, should be taken with caution because of the very different proper motions of LkH α 233 $(\mu_\alpha \cos \delta, \mu_\delta) = (-18, 13)$ mas yr $^{-1}$ (Duchêne et al. 2005), from those of 10 Lac $(0, -8)$, or of Lac OB1b $(0, -5)$ (Lee & Chen 2007) (see Table 1.)

LkH α 233 is the exciting source of a series of bipolar Herbig-Haro objects (Corcoran & Ray 1998), including HH 398 and HH 808 through HH 814, that stretch a few parsecs along the direction of $\sim 65^\circ/245^\circ$ (McGroarty et al. 2004, see Fig. 4). Note that McGroarty et al. (2004) adopted a distance of 880 pc to LkH α 233, apparently taken from Calvet & Cohen (1978) based on the inference that the B1.5 V star HD 213976, with $m_V = 7.0$ and a distance modulus of 9.6, has a negligible extinction $A_V \sim 0.42$ (Aspin, McLean, & McCaughrean 1985), so it should be in front of the dark cloud. In such a case, the cloud, and hence LkH α 233, should be at least 880 pc away. This inferred distance is, however, much farther than the recent *Hipparcos* value of 370 pc (de Zeeuw et al. 1999), thus the linear dimensions of the LkH α 233 outflows derived by McGroarty et al. (2004) should be considerably shorter—but still on parsec scales.

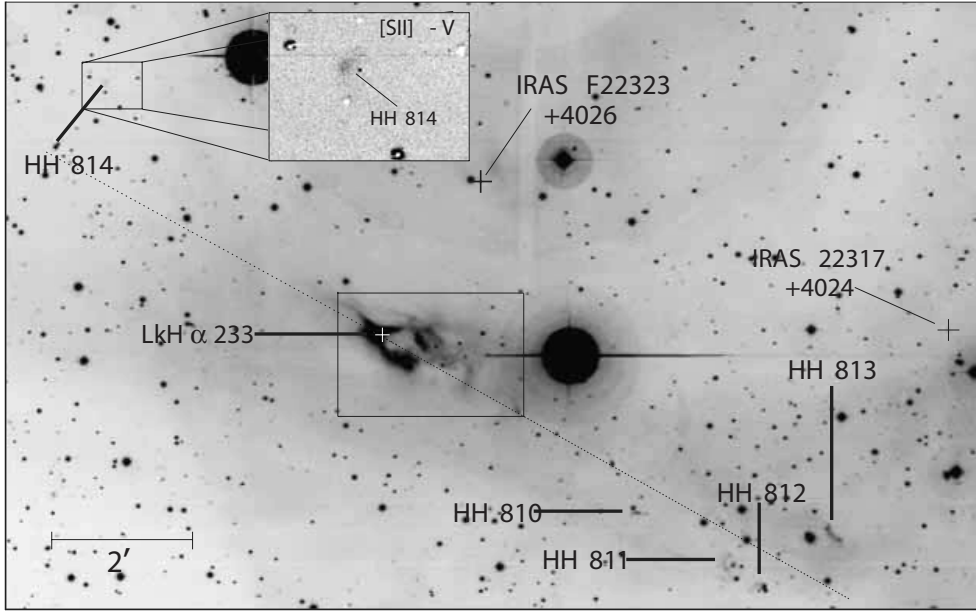


Figure 4. [S II] image of the LkH α 233 region, taken from McGroarty et al. (2004). Herbig-Haro objects and IRAS sources are labeled. The straight line depicts the major axis of the outflow at 62°. The inset shows the continuum subtracted ([S II]-V) image of HH 814.

Most HH outflows are excited by low-mass PMS stars, so the ones associated with LkH α 233 (mass $\sim 4M_{\odot}$, Perrin & Graham 2007) are among the rarities to be related to intermediate-mass PMS stars (McGroarty et al. 2004). LkH α 233 is among the Herbig Ae/Be stars that show the 10 μ m silicate feature in absorption (Han et al. 1998; Bowey, Adamson, & Yates 2003). Optical polarimetric imaging revealed a circumstellar disk roughly perpendicular to the outflows (Aspin, McLean, & McCaughrean 1985). High angular resolution imaging by Keck adaptive optics indicated that the bipolar jet of LkH α 233, redshifted in the position angle of 69° and blueshifted in 249°, is highly collimated, with an opening angle less than 10°, suggestive of an early accretion phase (Perrin & Graham 2007). Recent HST observations, with a spatial resolution $\lesssim 0''.1$, yielded physical parameters, such as electron density, temperature, and ionization fraction, in the bipolar jet of LkH α 233 that are scaled up from those in T Tauri stars (Melnikov et al. 2008). LkH α 233 presents thus an interesting case for young stellar outflows intermediate in stellar mass between T Tauri stars and massive young stars.

Between 10 Lac and LBN 437 there is a group of PMS stars spanning some 24' (about 2.6 pc) across, most of which exhibit forbidden lines, indicative of youth (Lee & Chen 2007). LkH α 233 is located near the edge of LBN 437 and, being the exciting source of Herbig-Haro objects, conceivably should be among the youngest. There are otherwise no CTTSs or Herbig Ae/Be stars known inside the cloud (Lee & Chen 2007). The formation of this chain of young stars lying between 10 Lac and the LBN 437 cloud complex might be triggered by the radiation-driven implosion mechanism (Bertout 1989, Bertoldi & McKee 1990, Hester & Desch 2005), in which the UV photons from a luminous star evaporate and compress a nearby molecular cloud. As a result, the cloud

is shaped into a pillar, being illuminated as a bright-rimmed cloud, and star formation may be taking place at the surface layer of the cloud.

2.2. GAL 110–13

GAL 110–13 is an isolated, elongated cloud (Whitney 1949). The CTTS BM And (RA = 23^h37^m38^s.5, Decl = +48°24′12″, J2000), and three B-type stars associated with the cloud, namely HD 222142 (which illuminates the nebula vdB 158, van den Bergh 1957), HD 222046, and HD 222086, all share common proper motions, suggesting a physical group (Lee & Chen 2007). This cloud was not included in the study by de Zeeuw et al. (1999), but given its distance (~ 440 pc, Aveni & Hunter 1969), cloud radial velocity (~ 8 km s⁻¹, Odenwald et al. 1992), and the proper motions of associated young stars (Lee & Chen 2007), it is likely a part of Lac OB1 (see Fig. 5).

Odenwald et al. (1992) attributed the morphology and high star formation efficiency (30%) in GAL 110–13 to compression by a recent cloud collision. The cloud points to the central part of Lac OB1 where 10 Lac is located, similar to LBN 437 and other cloud filaments in the region (see Fig. 1). An alternative to a cloud collision is shock interaction from a supernova in Lac OB1b which shaped GAL 110–13 and prompted the formation of stars in the cloud. Evidence in support of this supernova scenario comes from the B5V star HD 201910, a possible runaway star from a binary system in Lac OB1b when one of the component stars became a supernova (Blaauw 1961, Gies & Bolton 1986).

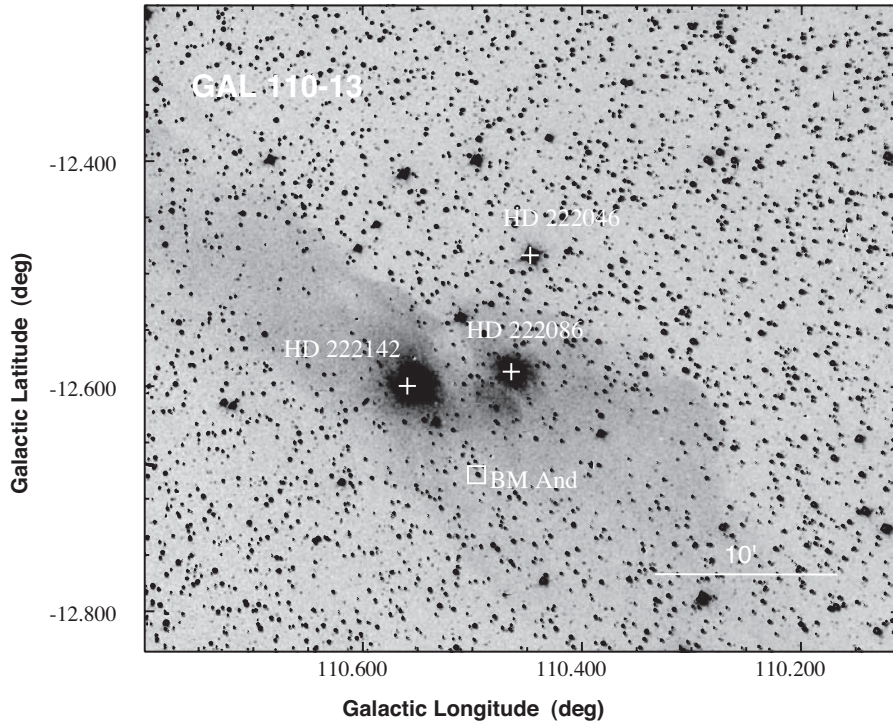


Figure 5. DSS blue image of GAL 110–13, shown in Galactic coordinates. BM And and three late-B stars are marked.

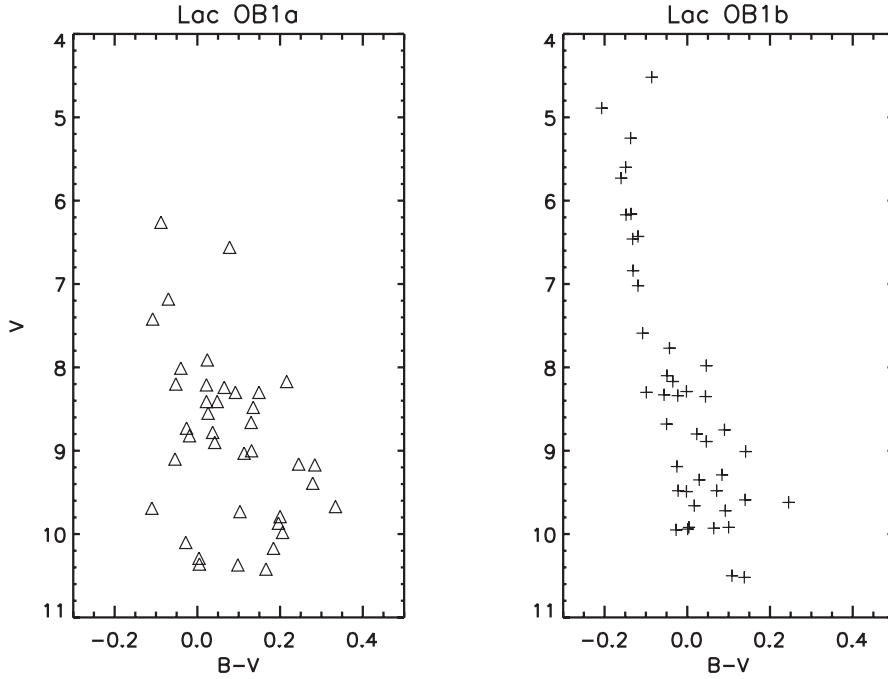


Figure 6. Color-magnitude diagrams for the subgroups Lac OB1a and Lac OB1b reconstructed from de Zeeuw et al. (1999) for stars having $B-V < 0.4$ mag.

3. Star Formation History in Lac OB1

Blaauw (1958) and Blaauw (1964, 1991) derived an expansion age of 16–25 Myr for Lac OB1a and 12–16 Myr for Lac OB1b, on the basis of stellar proper motions and radial velocities. The majority of the Lac OB1 members indeed was thought to be an evolved population; e.g., Hernández et al. (2005) failed to find *bright* Herbig Ae/Be stars in the region, and all the H α emission-line stars these authors studied turned out to be classical Be stars, i.e., on the verge of turning off the main sequence. The kinematic ages of tens of Myr, however, are much longer than the main sequence lifetime of ~ 3.6 Myr for 10 Lac (Schwartz, Burton & Herrmann 1997) and the typical age of a few Myr for the CTTs in the region.

Star formation in Lac OB1 therefore appears not coeval, with the latest episode occurring no more than a few Myr ago. Kinematic ages of OB associations are often a factor of 2 less than those derived photometrically based on stellar evolution models (Garmany 1994). Subgroups in an OB association may originate in a gravitationally unbound giant molecular cloud (Clark et al. 2005). Likewise, members in a subgroup may be formed out of dispersing cloud fragments, or as a consequence of triggered star formation by an expanding ionization front. Figure 6 shows the color-magnitude diagram for Lac OB1a and for Lac OB1b. It is seen that the stars in the subgroup Lac OB1b form a clear main sequence, whereas those in Lac OB1a are much more scattered. De Zeeuw et al. (1999) suspected that Lac OB1a might not be a physical group. In any case, care should be exercised when doing photometric dating; the scattering could be attributed partly to the distance spread among members, as Lac OB1a is nearby and occupies a large volume in space. It may be that the more compact Lac OB1b is actually more

evolved, as evidenced by a smaller color excess of its stars (Crawford & Warren 1976) and the deficiency of HI gas around S 126 where 10 Lac and other luminous stars are located (Cappa de Nicolau & Olano 1990). Lac OB1a, if it is a real association, seems to contain some PMS stars and therefore could represent a generation of stars younger than—and perhaps triggered by—those in Lac OB1b. Eventually the sequence of star formation reached GAL 110–13, as we now witness.

Both LBN 437 and GAL 110–13 have low dust extinction, similar to the bright-rimmed clouds in Ori OB1 (Lee et al. 2005), as is expected for remnant clouds (Sugitani et al. 1991). Such a low density condition is unfavorable for spontaneous, global cloud collapse. The ablation of molecular clouds also gives rise to a seemingly high star-formation efficiency, e.g., 30% for GAL 110–13 (Odenwald et al. 1992), to be compared with a few percent typical in star-forming regions (White et al. 1995). The cloud morphology, age sequence, and spatial distribution of young stars in the vicinity of clouds suggest sequential star formation by stellar radiation, supernova shocks or cloud collision. In particular, if GAL 110–13 is indeed related to Lac OB1, which has a projected distance of some 100 pc, the triggering appears to have had far-reaching influence. The Lac OB1 association, with much of the cloud material already dissipated, is clearly ending its star-formation activity, and stages an interesting case of a starbirth sequence in an OB association.

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Table 1. Kinematic Members of Lac OB1

ID	RA ₂₀₀₀ h m s	Dec ₂₀₀₀ ° ' "	V mag	B - V mag	π mas	$\mu_\alpha \cos \delta$ mas/yr	μ_δ mas/yr	J mag	H mag	K mag	Sp Type	Remarks
HIP 108508	21 58 56.6	47 59 00	8.82	-0.019	1.32 (0.87)	-2.07	-3.38	8.66	8.70	8.69	B3V	MR Cyg, sp. binary
HIP 109082	22 05 51.2	48 13 53	6.26	-0.088	1.66 (0.53)	-1.62	-4.33	6.36	6.50	6.48	B2V	V365 Lac, sp. binary
HIP 110476	22 02 41.4	42 57 04	9.29	0.084	1.91 (1.15)	-0.27	-6.32	8.91	8.87	8.76	B8	BD+42 4370
HIP 110790	22 26 45.6	37 26 37	6.46	-0.132	1.69 (0.95)	-0.82	-5.20	6.70	6.84	6.87	B2V	double star
HIP 110835	22 27 17.3	44 22 46	9.92	0.004	2.68 (1.45)	-0.38	-4.18	9.86	9.86	9.87	B8	BD+43 4205
HIP 110849	22 27 26.5	39 48 36	6.16	-0.136	2.39 (0.71)	-0.53	-6.09	6.41	6.54	6.53	B2V	HD 212978, double/multiple
HIP 110953	22 28 47.7	46 37 51	9.10	-0.054	2.25 (1.17)	0.17	-3.67	9.15	9.21	9.21	B9	HD 213190
HIP 111080	22 30 12.3	44 26 18	8.89	0.046	1.52 (1.11)	0.99	-2.21	8.65	8.65	8.64	B9	HD 213390
HIP 111104	22 30 29.3	43 07 24	4.52	-0.086	2.38 (0.64)	-2.05	-5.76	4.99	4.70	4.75	B2IV	HD 213420, sp. binary
HIP 111139	22 30 54.4	43 25 40	8.29	-0.002	1.19 (1.00)	0.63	-3.39	8.22	8.27	8.27	B9	HD 213484
HIP 111308	22 32 58.6	37 34 32	10.52	0.138	5.45 (1.81)	-0.79	-3.39	8.67	8.21	8.13	B9	BD+36 4868
HIP 111337	22 33 23.5	39 34 31	8.17	-0.035	2.35 (1.13)	-1.53	-4.29	8.18	8.23	8.26	B9V	HD 213801, double/multiple
HIP 111429	22 34 30.2	40 46 30	7.02	-0.119	3.45 (0.90)	-0.68	-3.45	7.19	7.27	7.29	B1.5V	HD 213976, double
HIP 111491	22 35 18.1	43 40 52	8.33	-0.056	3.92 (0.93)	-0.10	-3.22	8.42	8.46	8.50	B8	HD 214098
HIP 111546	22 35 52.3	39 38 04	5.73	-0.160	5.10 (1.79)	1.11	-4.39	5.78	5.85	5.70	B2Ve	HD 214167
HIP 111576	22 36 16.7	40 05 20	8.30	-0.099	3.07 (1.01)	0.94	-3.22	8.50	8.58	8.59	B6IV	HD 214243
HIP 111589	22 36 22.3	37 50 32	6.84	-0.131	2.92 (0.72)	-0.89	-5.34	7.12	7.23	7.25	B2V	HD 214263
HIP 111683	22 37 28.7	39 26 20	7.59	-0.108	3.07 (0.79)	-0.34	-5.04	7.74	7.83	7.85	B3V	HD 214432
HIP 111841	22 39 15.7	39 03 01	4.89	-0.207	3.08 (0.62)	-0.29	-5.70	5.30	5.44	5.50	O9V	10 Lac, HD 214680, double
HIP 112031	22 41 28.7	40 13 32	5.25	-0.137	2.34 (0.62)	-0.75	-5.90	5.48	5.58	5.62	B2III	12 Lac, HD 214993, β Cep var.
HIP 112144	22 42 55.4	37 48 10	6.43	-0.119	2.71 (0.79)	-1.12	-5.30	6.61	6.67	6.67	B1V	HD 215191
HIP 112148	22 42 57.3	44 43 18	8.75	0.090	3.90 (1.34)	-2.82	-3.16	8.23	8.13	7.88	B5:ne	HD 215227
HIP 112167	22 43 03.4	38 46 07	8.68	-0.050	1.80 (1.13)	0.67	-4.97	8.73	8.78	8.81	B8V	HD 215211
HIP 112293	22 44 43.3	40 33 16	9.93	0.064	3.30 (1.61)	-1.66	-5.41	9.71	9.63	9.62	B8	BD+39 4920
HIP 112906	22 51 50.2	39 08 42	9.49	-0.002	2.19 (1.41)	0.30	-5.12	9.44	9.49	9.48	B8	BD+38 4883
HIP 113003	22 53 07.3	43 03 21	8.80	0.023	2.85 (1.12)	-0.18	-6.00	8.63	8.72	8.69	B9	HD 216537
HIP 113110	22 54 21.2	43 31 43	7.77	-0.043	3.18 (0.85)	0.09	-4.79	7.76	7.87	7.85	B8V	HD 216684
HIP 113226	22 55 47.1	43 33 33	7.98	0.046	4.01 (1.61)	-0.33	-4.29	7.67	7.61	7.46	B3V:n	V423 Lac, HD 216851
HIP 113281	22 56 23.6	41 36 14	5.60	-0.149	2.71 (0.69)	-0.99	-4.25	5.88	6.01	6.03	B2IV	16 Lac, HD 216916, β Cep var.
HIP 113371	22 57 40.7	39 18 32	6.17	-0.148	2.39 (0.66)	0.46	-5.13	6.46	6.61	6.64	B2IV/V	HD 217101
HIP 113469	22 58 45.7	43 50 20	7.18	-0.070	2.74 (0.72)	0.67	-5.75	7.25	7.31	7.33	B2:V	HD 217227
HIP 113835	23 03 08.3	49 35 10	9.69	-0.110	3.14 (1.37)	-2.33	-1.53	9.64	9.68	9.67	B8	BD+48 3916

Table 1. Kinematic Members of Lac OB1 (continued)

ID	RA ₂₀₀₀ h m s	Dec ₂₀₀₀ ° ′ ″	V mag	B-V mag	π mas	$\mu_{\alpha} \cos \delta$ mas/yr	μ_{δ} mas/yr	J mag	H mag	K mag	Sp Type	Remarks
HIP 114097	23 06 32.2	51 04 38	7.42	-0.108	2.41 (0.67)	-0.28 -4.13	7.63	7.73	7.76	B2V		HD 218344
HIP 114106	23 06 37.1	42 39 27	8.01	-0.040	4.57 (0.87)	-1.81 -4.54	8.06	8.10	8.16	B9		V380 And, HD 218326
HIP 115067	23 18 23.6	47 15 42	8.66	0.130	3.77 (1.52)	-1.85 -2.62	8.54	8.57	8.64	B9II		HD 219813, double
HIP 115334	23 21 38.7	47 21 04	8.41	0.048	3.28 (0.90)	-0.93 -5.50	8.21	8.17	8.14	B9		HD 220210
HIP 106656	21 36 11.4	44 25 38	8.90	0.042	2.53 (0.95)	1.02 -3.46	8.77	8.80	8.79	A0		HD 205742
HIP 108841	22 02 54.6	39 33 46	8.21	0.022	1.71 (1.50)	-1.07 -2.91	8.08	8.09	8.10	A0		HD 209483, double
HIP 108933	22 04 06.7	44 20 42	6.56	0.078	5.72 (0.67)	-0.53 -2.90	6.29	6.31	6.27	A2		HD 209679
HIP 110033	22 17 12.0	40 58 05	9.48	0.071	1.80 (1.25)	0.96 -3.41	9.36	9.39	9.38	A0		BD+404771
HIP 110373	22 21 21.1	41 47 48	8.34	-0.023	3.25 (1.11)	-2.23 -5.81	8.36	8.42	8.42	A0		HD 212153, double/multiple
HIP 110448	22 22 17.9	48 50 25	8.39	1.172	1.89 (0.79)	-2.02 -2.48	6.30	5.79	5.63	K0		BD+483697
HIP 110473	22 22 38.5	47 37 56	9.98	0.206	2.33 (1.92)	0.12 -4.51	9.62	9.55	9.51	A0		BD+463676
HIP 110664	22 25 06.0	44 32 19	8.10	-0.049	1.87 (0.82)	-1.85 -5.22	8.19	8.28	8.26	A0		HD 212668
HIP 110700	22 25 43.7	38 49 26	9.48	-0.022	5.20 (1.37)	-0.16 -6.18	9.45	9.51	9.51	A0		HD 212732
HIP 110804	22 26 58.3	46 01 49	10.29	0.004	2.79 (1.32)	-2.01 -3.57	10.12	10.15	10.17	A0		BD+453940
HIP 110929	22 28 29.3	48 32 34	7.84	1.800	2.09 (1.02)	-1.82 -4.17	5.26	4.62	4.39	K0III:		HD 213141, double
HIP 111022	22 29 31.8	47 42 25	4.34	1.679	2.80 (0.50)	-0.60 -3.37	1.32	0.41	0.27	M0II:		5 Lac, HD 213310/213311
HIP 111038	22 29 42.7	40 55 19	9.62	0.245	1.87 (1.57)	0.52 -2.45	9.04	8.98	8.94	A5		BD+404831
HIP 111055	22 29 52.6	45 44 41	7.80	1.334	1.73 (0.87)	1.41 -2.34	5.42	4.82	4.64	K2		HD 213354
HIP 111207	22 31 45.3	43 16 52	9.95	-0.027	1.71 (1.50)	-2.12 -3.00	9.87	9.88	9.88	A0		BD+424429
HIP 111292	22 32 43.1	46 16 21	10.10	-0.028	2.19 (1.50)	1.40 -5.29	10.01	10.05	10.08	A0		HD 213732
HIP 111329	22 33 19.9	42 23 42	9.19	-0.025	3.20 (1.26)	0.48 -3.63	9.14	9.17	9.14	A0		HD 213800
HIP 111340	22 33 25.1	46 51 27	9.39	0.279	1.38 (1.21)	-1.02 -4.08	8.69	8.57	8.53	A2		HD 213833
HIP 111375	22 33 48.1	41 40 28	9.94	0.001	2.07 (2.51)	0.41 -5.11	9.94	10.01	9.99	A0		BD+404852
HIP 111552	22 35 54.5	43 41 26	9.66	0.017	2.36 (1.42)	-0.58 -4.08	9.57	9.59	9.58	A0		HD 214179
HIP 111591	22 36 25.0	46 55 39	10.37	0.098	2.15 (1.67)	-0.31 -3.88	10.18	10.20	10.19	A0		HD 214311
HIP 111762	22 38 22.2	52 22 06	9.98	1.363	8.98 (3.27)	-0.85 -5.59	7.26	6.53	6.34	-		BD+513434, double/multiple
HIP 111814	22 38 54.9	36 55 42	9.72	0.092	4.06 (1.41)	-2.83 -4.82	9.42	9.42	9.41	A2		BD+364896
HIP 111916	22 40 12.5	38 58 25	9.59	0.140	2.79 (1.47)	-2.07 -6.15	9.27	9.25	9.22	A2		BD+384834
HIP 112016	22 41 22.9	50 05 33	7.91	0.024	2.38 (0.74)	0.10 -2.74	7.78	7.81	7.80	A0		HD 215025
HIP 112017	22 41 23.7	41 02 16	9.35	0.029	2.27 (1.33)	-1.04 -5.40	9.29	9.28	9.28	A2		HD 214977
HIP 112182	22 43 15.2	43 46 25	10.50	0.108	3.77 (1.64)	-1.02 -5.11	10.14	10.15	10.10	A0		HD 215271

Table 1. Kinematic Members of Lac OB1 (continued)

ID	RA (J2000) h m s	Decl. (J2000) ° ′ ″	V mag	B−V mag	π mas	μ _α cos δ mas/yr	μ _δ mas/yr	J mag	H mag	K mag	Sp Type	Remarks
HIP 112212	22 43 35.3	32 49 19	7.27	1.628	1.92 (0.81)	-1.00 -3.11	4.14	3.31	2.90		M0III	QU Peg, HD 215290
HIP 112213	22 43 36.7	40 23 06	9.92	0.100	4.63 (1.67)	-2.60 -5.55	9.54	9.45	9.43	A2		BD+39 4917
HIP 112639	22 48 47.2	46 22 11	9.03	0.113	2.31 (1.18)	0.61 -1.98	8.75	8.73	8.72	A0		HD 216037
HIP 112700	22 49 21.6	45 53 50	8.48	0.135	2.02 (1.04)	0.72 -2.33	8.13	8.13	8.10	A0		HD 216107
HIP 112710	22 49 29.4	45 46 59	9.87	0.196	2.13 (1.55)	0.40 -3.25	9.45	9.44	9.44	A2		HD 216117
HIP 112805	22 50 40.5	51 06 58	8.30	0.149	2.00 (1.70)	-1.12 -6.07	8.06	8.09	8.05	A0		HD 216255, double/multiple
HIP 113145	22 54 43.9	42 30 39	7.83	0.520	3.74 (0.84)	1.50 -2.53	6.54	6.37	6.25	A2		HD 216733
HIP 113187	22 55 13.8	46 22 20	8.30	0.092	1.91 (0.88)	1.34 -2.92	8.02	8.02	8.03	A0		HD 216797
HIP 113188	22 55 14.1	49 58 42	8.78	0.037	1.59 (1.08)	-1.97 -3.50	8.64	8.68	8.67	A2		HD 216795
HIP 113208	22 55 31.5	43 17 36	8.35	0.044	2.99 (1.03)	0.01 -3.65	8.20	8.21	8.26	A2		HD 216815
HIP 113237	22 55 52.9	41 58 32	8.13	1.312	2.21 (0.96)	-0.68 -4.78	5.66	5.00	4.84	K2		HD 216853
HIP 113288	22 56 26.0	49 44 01	4.99	1.778	1.74 (0.58)	0.05 -2.87	1.79	0.96	0.72	K5Ib:		V424 Lac, HD 216946
HIP 113411	22 58 06.7	41 56 04	9.01	0.141	2.96 (1.78)	0.41 -3.98	9.06	9.12	9.07	A2		HD 217161, double
HIP 113474	22 58 49.6	46 19 38	8.24	0.065	1.83 (0.89)	-0.01 -3.92	7.99	8.05	8.06	A0		HD 217262
HIP 113731	23 01 58.4	47 01 00	8.41	0.022	1.81 (1.03)	-1.47 -2.48	8.21	8.23	8.24	A2		HD 217713
HIP 113950	23 04 35.5	44 13 10	10.36	0.005	4.35 (2.67)	-0.06 -3.28	9.99	10.00	9.95	A0		BD+43 4383
HIP 114134	23 06 54.0	44 19 26	8.55	0.026	2.58 (1.00)	0.92 -4.19	8.46	8.53	8.52	A0		HD 218364
HIP 114153	23 07 05.6	46 07 47	10.17	0.184	2.13 (1.34)	-0.22 -4.95	9.82	9.78	9.79	A0		BD+45 4144
HIP 114441	23 10 37.7	46 22 40	8.20	-0.052	2.22 (0.90)	0.27 -3.76	8.24	8.27	8.30	A0		HD 218844
HIP 114554	23 12 15.0	38 46 59	9.16	0.245	4.17 (1.46)	-2.40 -5.09	8.64	8.57	8.55	A5		HD 219016
HIP 114593	23 12 52.4	48 17 01	9.73	0.103	2.25 (1.38)	0.04 -5.32	9.57	9.60	9.56	A0		BD+47 4075
HIP 114625	23 13 15.1	45 50 25	10.42	0.166	2.41 (1.83)	-1.81 -3.19	10.17	10.20	10.18	A2		BD+45 4171
HIP 114642	23 13 26.7	35 45 43	8.65	1.100	4.72 (1.26)	-1.06 -6.02	6.79	6.29	6.19	K0		BD+34 4870
HIP 114890	23 16 19.0	50 01 41	9.17	0.284	2.48 (1.04)	-0.73 -2.65	8.69	8.65	8.58	A0		HD 219574
HIP 114909	23 16 31.1	36 50 13	9.67	0.334	2.07 (1.42)	1.46 -3.79	8.94	8.87	8.79	F0		BD+36 5034
HIP 115441	23 23 00.4	38 59 57	9.00	0.131	2.36 (1.14)	-0.89 -3.50	8.68	8.67	8.65	A2		BD+38 4988
HIP 116088	23 31 23.3	43 22 24	8.17	0.216	6.96 (0.94)	-1.97 -5.62	7.81	7.75	7.73	A0		HD 221379
HIP 116135	23 31 53.1	47 32 52	9.79	0.200	2.24 (1.48)	1.70 -2.58	9.47	9.48	9.41	A2		BD+46 4070
HIP 116411	23 35 24.2	36 44 54	9.19	1.628	3.19 (1.19)	1.69 -2.50	4.85	3.88	3.59	M2		V391 And, BD+35 5056
HIP 116457	23 35 50.9	47 25 39	8.73	1.071	1.52 (1.11)	1.54 -2.04	6.83	6.33	6.22	K0		BD+46 4089
HIP 116522	23 36 51.8	43 18 32	7.81	1.198	2.02 (0.88)	0.66 -5.07	5.79	5.18	5.09	K2		HD 222018
HIP 116540	23 37 05.9	46 17 15	8.73	-0.026	2.17 (1.13)	1.06 -3.15	8.68	8.72	8.75	A0		HD 222064
HIP 116681	23 38 45.1	35 46 21	9.74	2.100	5.50 (2.83)	1.58 -3.66	4.83	3.94	3.10	C		ST And, HD 222241, carbon star

Star Forming Regions in Cepheus

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Abstract. The northern Milky Way in the constellation of Cepheus ($100^\circ \leq l \leq 120^\circ$; $0^\circ \leq b \leq 20^\circ$) contains several star forming regions. The molecular clouds of the Cepheus Flare region at $b > 10^\circ$, are sites of low and intermediate mass star formation located between 200 and 450 pc from the Sun. Three nearby OB associations, Cep OB2, Cep OB3, Cep OB4, located at 600–800 pc, are each involved in forming stars, like the well known high mass star forming region S 140 at 900 pc. The reflection nebula NGC 7129 around 1 kpc harbors young, compact clusters of low and intermediate mass stars. The giant star forming complex NGC 7538 and the young open cluster NGC 7380, associated with the Perseus arm, are located at $d > 2$ kpc.

1. Overview

In this chapter we describe the star forming regions of the constellation of Cepheus. A large scale map of the constellation, with the boundaries defined by IAU overlaid, and the most prominent star forming regions indicated, is shown in Fig. 1. This huge area of the sky, stretching between the Galactic latitudes of about 0° and $+30^\circ$, contains several giant star forming molecular cloud complexes located at various distances from the Sun. According to their distance they can be ranged into three large groups:

- (1) Clouds nearer than 500 pc located mainly at $b \geq 10^\circ$, in the Cepheus Flare.
- (2) Three OB associations, Cep OB 2, Cep OB 3 and Cep OB 4 between 600–900 pc.
- (3) Star forming regions associated with the Perseus spiral arm at 2–3 kpc.

In the following we discuss the first two of these groups.

Fig. 2 shows the distribution of dark clouds perpendicular to the Galactic plane (Dobashi et al. 2005), with the outlines of the major star forming complexes overplotted.

The large-scale ^{13}CO observations performed by Yonekura et al. (1997) led to a refinement of division of the clouds into complexes. The groups listed in Table 2,

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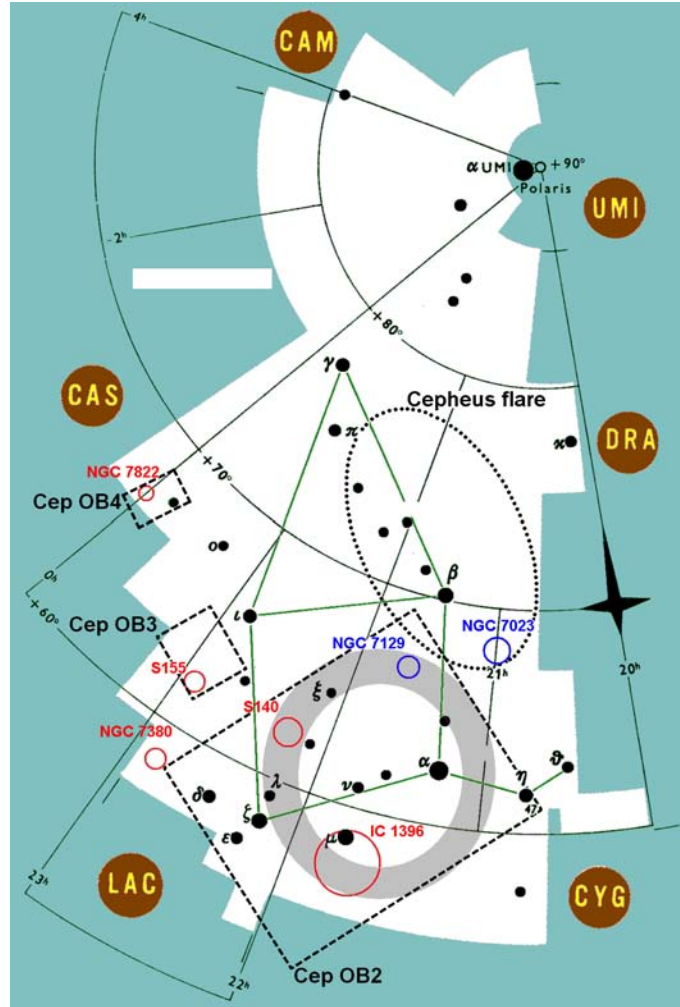


Figure 1. Positions of the major star forming regions of Cepheus, overplotted on a schematic drawing of the constellation.

adopted from Yonekura et al. (1997), were defined on the basis of their positions, radial velocities, and distances, where distance data were available.

Table 1 lists the dark clouds identified in the Cepheus region from Barnard (1927) to the Tokyo Gakugei University (TGU) Survey (Dobashi et al. 2005), and the molecular clouds, mostly revealed by the millimeter emission by various isotopes of the carbon monoxide (Dobashi et al. 1994; Yonekura et al. 1997). The cloud name in the first column is the LDN (Lynds 1962) name where it exists, otherwise the first appearance of the cloud in the literature. Equatorial (J2000) and Galactic coordinates are listed in columns (2)–(5), and the area of the cloud in square degrees in column (6). Column (7) shows the radial velocity of the cloud with respect to the Local Standard of Rest. The number of associated young stellar objects is given in column (8), and the alternative names, following the system of designations by *SIMBAD*, are listed in column (9). We

note that the LDN coordinates, derived from visual examination of the POSS plates, may be uncertain in several cases.

Figure 3 shows the distribution of the pre-main sequence stars and candidates over the whole Cepheus region.

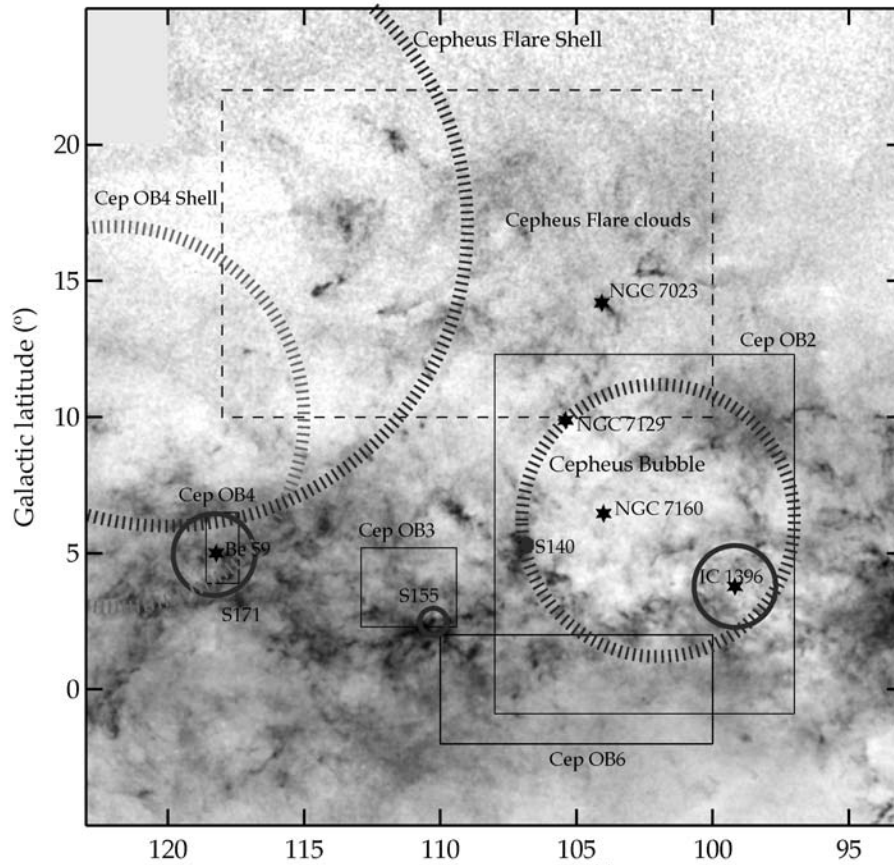


Figure 2. Distribution of the visual extinction in the Cepheus region in the $[I, b]$ plane (Dobashi et al. 2005) with outlines of the major star forming regions, discussed in this chapter, overplotted. Solid rectangles indicate the nominal boundaries of the OB associations (Humphreys 1978; de Zeeuw et al. 1999), and the dashed rectangle shows the Cepheus Flare cloud complex; giant HII regions are marked by solid grey circles, and star symbols indicate young open clusters. Three large circles, drawn by radial dashes, show giant shell-like structures in the interstellar medium. The Cepheus Flare Shell (Olano et al. 2006) belongs to the nearby Cepheus Flare complex, and the Cepheus Bubble (Kun et al. 1987) is associated with the association Cep OB2, and the Cepheus OB4 Shell (Olano et al. 2006) is associated with Cep OB4.

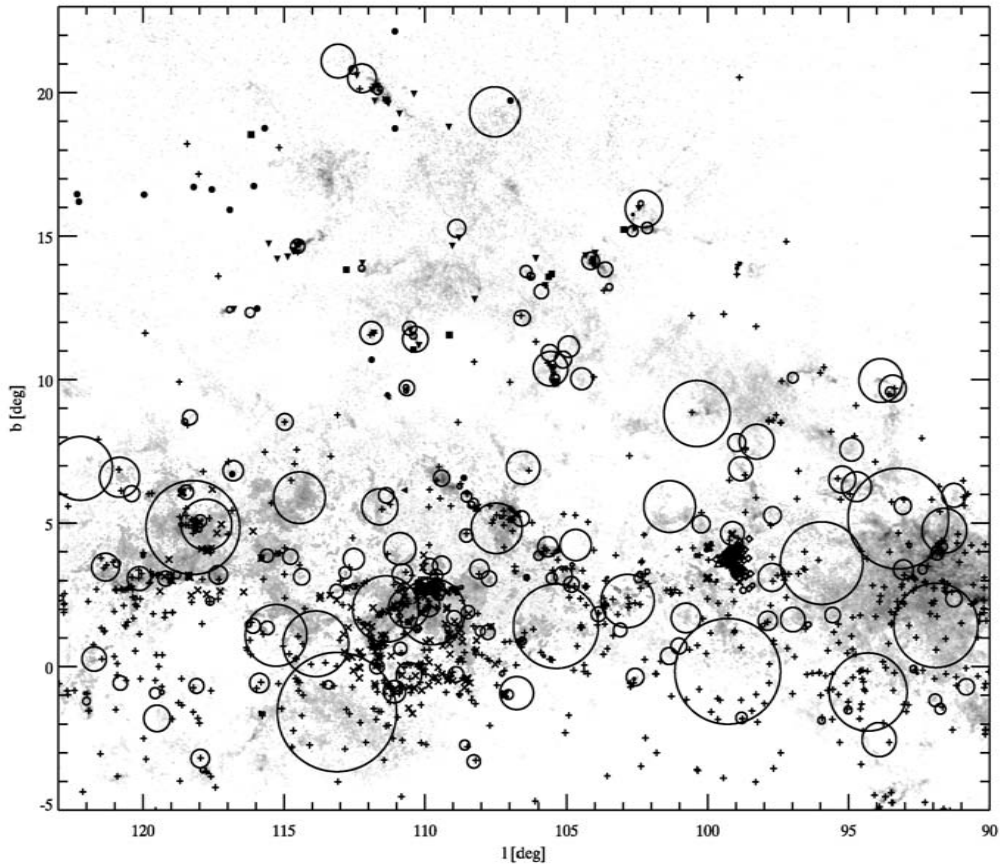


Figure 3. Pre-main sequence stars and candidates in the Cepheus region overlaid on the map of visual extinction obtained from 2MASS data based on interstellar reddening using the NICER method (Lombardi & Alves 2001). Large circles denote those clouds from Table 1 which have been associated with young stars. The meaning of different symbols are as follows: Filled triangles - T Tauri stars; Filled squares - Herbig Ae/Be stars; Filled circles - Weak-line T Tauri stars; Diamonds - Tr 37 ROSAT X-ray sources; Open triangles - PMS members of Tr 37; Open squares - Candidate and possible PMS members of Cep OB3b; X - $H\alpha$ emission stars; + - T Tauri candidates selected from a 2MASS color-color diagram.

Table 1.: List of clouds catalogued in Cepheus.

Cloud name	RA(2000) (h m)	Dec(2000) ($^{\circ}$ ')	l ($^{\circ}$)	b ($^{\circ}$)	Area (sq.deg.)	v_{LSR} (km s $^{-1}$)	n_{star}	Alternative names
LDN 1122	20 32.7	+65 20.3	99.97	+14.81	0.041	4.8	0	YMD CO 1, TGU 597
LDN 1089	20 32.8	+63 30.3	98.40	+13.78	0.244	-2.4	0	TDS 366, TGU 586
LDN 1094	20 32.8	+64 00.3	98.83	+14.06	0.002	0.1	1	CB 222
TGU 667	20 33.9	+73 51.6	107.53	+19.33	2.460		1	[KTK2006] G107.1+19.3, [KTK2006] G107.5+19.8, [KTK2006] G107.9+18.9
LDN 1152	20 34.4	+68 00.4	102.37	+16.14	0.025	2.9	0	YMD CO 8
CB 223	20 34.7	+64 10.7	99.10	+13.98	0.003	-2.7	0	
LDN 1100	20 34.8	+64 00.4	98.96	+13.88	0.007	-2.7	1	CB 224
LDN 1033	20 37.2	+57 10.5	93.44	+9.69	0.714	-2.4	0	TDS 343, TDS 345, TDS 346, TGU 549, DBY 093.1+09.6, DBY 093.5+09.4
LDN 1036	20 38.2	+57 10.6	93.52	+9.58	0.088	-2.1	1	DBY 093.5+09.4
LDN 1041	20 38.2	+57 30.6	93.79	+9.78	0.022	-2.1	0	DBY 093.5+09.4
LDN 1157	20 39.5	+68 00.7	102.65	+15.75	0.005	2.9	1	[DE95] LDN 1157 A1, YMD CO 8, TGU 619
LDN 1147	20 40.5	+67 20.8	102.14	+15.29	0.127	2.9	0	YMD CO 8, TDS 379, TGU 619, JWT Core 36, [LM99] 340, [BM89] 1-99, [LM99] 344
LDN 1148	20 40.5	+67 20.8	102.14	+15.29	0.015	2.9	1	YMD CO 8, TGU 619
LDN 1044	20 41.2	+57 20.8	93.90	+9.35	0.006	-2.1	0	DBY 093.5+09.4
LDN 1049	20 42.2	+57 30.8	94.12	+9.35	0.005	0.6	0	DBY 094.1+09.4
LDN 1039	20 42.3	+56 50.8	93.58	+8.94	0.079	-2.1	0	DBY 093.5+09.4
LDN 1051	20 42.7	+57 30.9	94.16	+9.29	0.010	0.6	0	DBY 094.1+09.4
LDN 1155	20 43.5	+67 40.9	102.60	+15.25	0.006	2.9	0	YMD CO 8, TGU 619
LDN 1158	20 44.5	+67 41.0	102.66	+15.17	0.111	0.9	0	TDS 388, [BM89] 1-100, [LM99] 346, TGU 619
LDN 1038	20 46.3	+56 21.0	93.53	+8.20	0.660	-2.1	0	[BM89] 1-102, [BM89] 1-103, [LM99] 348
LDN 1076	20 49.3	+59 51.2	96.57	+10.04	0.008	-2.2	0	DBY 096.8+10.2
LDN 1082	20 51.1	+60 11.3	96.98	+10.07	0.111	-2.6	8	Barnard 150, GF 9, TDS 362, [LM99] 350, DBY 097.1+10.1, [BM89] 1-105, [LM99] 351
LDN 1171	20 53.5	+68 19.5	103.71	+14.88	0.002	3.4	0	CB 229
LDN 1037	20 54.4	+55 26.5	93.53	+6.75	0.591		0	TGU 551
LDN 1168	20 56.6	+67 36.6	103.31	+14.21	0.003		0	

Table 1.: Continued.

Cloud name	RA(2000) (h m)	Dec(2000) (° ′)	l (°)	b (°)	Area (sq.deg.)	v_{LSR} (km s ⁻¹)	n_{star}	Alternative names
LDN 1061	20 58.3	+57 21.7	95.36	+7.56	0.618	-2.1	0	DBY 095.2+07.4, DBY 095.2+07.4
LDN 1071	20 58.3	+58 11.7	96.00	+8.10	0.092	-0.4	0	Barnard 354, DBY 096.0+08.1, TGU 569
LDN 1056	20 58.4	+56 01.7	94.35	+6.69	0.036		0	
TGU 730	20 58.8	+78 11.8	112.23	+20.50	0.803	-8.0	3	[BM89] 1-108, [BM89] 1-109, [B77] 48, [BM89] 1-112, GN 21.00.4, RNO 129
LDN 1228	20 59.0	+77 31.8	111.67	+20.10	0.086	-7.6	4	YMD CO 66, MBM 162, TGU 718
LDN 1170	21 01.7	+67 36.9	103.63	+13.84	0.215	2.8	0	TDS 392, TGU 629, GSH 093+07+9
LDN 1058	21 02.4	+56 01.9	94.72	+6.27	0.869	-1.1	1	[LM99] 359, [LM99] 361
LDN 1174	21 02.6	+68 11.9	104.15	+14.14	0.294	2.8	$\gtrsim 15$	TDS 354, TGU 558 TDS 393, [LM99] 358, [BM89] 1-110, [B77] 39, [BM89] 1-113, [LM99] 360, [BM89] 1-114, [BM89] 3B- 9, [BM89] 1-111, PP 100, [BM89] 1-115 Ced 187, GN 21.01.0, YMD CO 14
LDN 1172	21 02.7	+67 41.9	103.76	+13.82	0.010	2.7	$\gtrsim 4$	YMD CO 14, TGU 629
LDN 1167	21 03.7	+67 02.0	103.30	+13.32	0.062	2.8	0	YMD CO 11
LDN 1173	21 04.7	+67 42.0	103.88	+13.67	0.006	2.7	0	YMD CO 14
LDN 1068	21 06.3	+57 07.1	95.89	+6.59	0.027	0.2	0	Barnard 359, DBY 095.9+06.6, TGU 570
LDN 1063	21 07.4	+56 22.2	95.44	+5.97	0.025	0.3	0	Barnard 151, Barnard 360, DBY 095.5+06.5, TGU 561
LDN 1065	21 07.4	+56 32.2	95.56	+6.09	0.023	0.3	0	DBY 095.5+06.5, TGU 568
LDN 1069	21 08.4	+56 52.2	95.90	+6.21	0.018	0.3	0	DBY 095.5+06.5
LDN 1067	21 09.4	+56 42.3	95.87	+6.00	0.012	0.3	0	DBY 095.5+06.5, TGU 568
Sh 2-129	21 11.3	+59 42.3	98.26	+7.84	1.190	3.7	2	DBY 097.3+08.5, BFS 9
LDN 1060	21 11.5	+55 17.4	95.02	+4.82	0.031	-0.9	0	DBY 090.5+02.4
LDN 1119	21 13.2	+61 42.4	99.91	+9.03	0.010	2.5	0	DBY 100.1+09.3, TGU 598
LDN 1062	21 13.5	+55 32.4	95.40	+4.79	0.003	-0.9	0	DBY 090.5+02.4
LDN 1064	21 13.5	+55 37.4	95.46	+4.85	0.001	-0.9	0	DBY 090.5+02.4
LDN 1125	21 14.7	+61 42.5	100.04	+8.90	0.010	2.5	1	Barnard 152, TDS 376, [LM99] 365, DBY 100.1+09.3, TGU 598
LDN 1072	21 16.5	+56 12.6	96.18	+4.95	1.510	-0.6	0	Barnard 153, TDS 358, TGU 574, DBY 096.3+05.2
LDN 1177	21 18.8	+68 15.7	105.22	+13.06	0.005	2.9	2	CB 230, TGU 641

Table 1.: Continued.

Cloud name	RA(2000) (h m)	Dec(2000) (° ′)	l (°)	b (°)	Area (sq.deg.)	v_{LSR} (km s ⁻¹)	n_{star}	Alternative names
TGU 589	21 19.7	+59 27.7	98.83	+6.90	0.560		2	
LDN 1162	21 20.0	+65 02.8	102.92	+10.76	0.004		0	
LDN 1080	21 21.5	+56 32.8	96.91	+4.69	0.001		0	Barnard 154
YMD CO 23	21 22.2	+69 22.6	106.27	+13.60	0.056	-9.4	2	TGU 656
LDN 1108	21 26.4	+59 33.1	99.49	+6.37	0.046		0	
DBY 098.4+05.2	21 26.8	+57 55.9	98.40	+5.17	0.107	1.0	0	
LDN 1086	21 28.5	+57 33.2	98.30	+4.74	0.095	-4.6	18	DBY 098.8+04.2, TGU 584, [PGS95] 2, IC 1396 W, FSE 1
LDN 1176	21 31.0	+66 43.3	104.93	+11.15	0.446	-10.4	0	YMD CO 17, TGU 634, JWT Core 44, GAL 104.9+11.2
LDN 1145	21 31.3	+62 43.3	102.14	+8.24	0.183		0	TGU 622, [PGH98b] Cloud 11
LDN 1146	21 31.3	+62 43.3	102.14	+8.24	0.183		0	
LDN 1096	21 31.5	+58 03.3	98.93	+4.83	0.001		0	TGU 590
LDN 1102	21 32.5	+58 03.3	99.03	+4.74	0.008		0	
LDN 1085	21 33.3	+56 44.6	98.23	+3.69	0.010	3.4	0	WWC 156
LDN 1093	21 33.5	+57 38.4	98.85	+4.34	0.034	-4.6	20	DBY 098.8+04.2, TGU 587, FSE 3 [PGS95] 8
LDN 1083	21 33.6	+55 58.0	97.72	+3.11	0.761	8.7		WCC 178-179
LDN 1098	21 34.5	+57 38.0	98.95	+4.25	0.025	-4.6	20	DBY 098.8+04.2, FSE 3
Barnard 365	21 34.9	+56 43.0	98.36	+3.53	0.010	7.6		WWC 140
TGU 639	21 35.5	+66 32.0	105.13	+10.70	0.280		1	[KTK2006] G105.0+10.7
LDN 1087	21 35.6	+56 33.5	98.32	+3.35	0.013	7.4	2	TDS 364
LDN 1090	21 35.6	+56 43.5	98.43	+3.48	0.028		0	Barnard 365
LDN 1199	21 35.9	+68 33.5	106.57	+12.15	0.235	-11.5	1	TDS 398, TGU 653
								[KTK2006] G106.4+12.0, [KTK2006] G106.7+12.3
LDN 1099	21 36.5	+57 23.5	98.98	+3.88	0.008	-8.0	22	DBY 099.1+04.0, FSE 5
LDN 1116	21 36.5	+58 33.5	99.76	+4.75	0.034		3	[IS94] 7, [PGS95] 16, [IS94] 14, SFO 35, [G85] 5, [PGS95] 17, [PGS95] 19, FSE 6
LDN 1105	21 37.1	+57 33.5	99.15	+3.95	0.008	-8.0	22	TDS 369, [B77] 37, DBY 099.1+04.0, FSE 5
YMD CO 19	21 37.3	+67 01.2	105.60	+10.93	0.279	-10.2	1	TGU 642, [KTK2006] G105.5+10.8, [KTK2006] G105.7+10.8
LDN 1092	21 37.6	+56 58.5	98.81	+3.48	0.014		1	

Table 1.: Continued.

Cloud name	RA(2000) (h m)	Dec(2000) (° ′)	l (°)	b (°)	Area (sq.deg.)	v_{LSR} (km s ⁻¹)	n_{star}	Alternative names
LDN 1112	21 38.5	+58 03.6	99.63	+4.20	0.013	-0.3	0	DBY 099.7+04.1
LDN 1117	21 38.5	+58 18.6	99.79	+4.39	0.004	-0.7	0	WWC 114-116
LDN 1088	21 38.6	+56 13.6	98.41	+2.83	0.019	7.2	2	Barnard 160, TGU 585, DBY 098.4+02.9
LDN 1135	21 39.4	+60 38.6	101.44	+6.06	0.054		0	
LDN 1110	21 39.5	+57 53.6	99.62	+3.99	0.007	-0.3	2	DBY 099.7+04.1
LDN 1111	21 39.5	+57 53.6	99.62	+3.99	0.002	-0.3	2	Barnard 161, DBY 099.7+04.1, CB 233
LDN 1123	21 39.5	+58 28.6	100.00	+4.43	0.003		0	
LDN 1126	21 39.5	+58 33.6	100.06	+4.49	0.006		0	
LDN 1101	21 39.6	+56 58.6	99.01	+3.30	0.095		0	
LDN 1131	21 40.0	+59 33.7	100.77	+5.20	0.046	-0.4	0	Barnard 366, TDS 378, DBY 100.9+05.3, TGU 609
LDN 1140	21 40.4	+60 53.7	101.70	+6.16	0.240		0	
LDN 1121	21 40.5	+58 16.7	99.97	+4.19	0.008	-0.2	$\gtrsim 25$	DBY 100.0+04.2, [IS94] 5, [G85] 14, [LM99] 379, [IS94] 17, IC 1396 N, SFO 38, [PGS95] 24, FSE 19, TGU 599
CB 234	21 40.5	+70 18.6	108.09	+13.15	0.044	-5.0	0	TGU 599
LDN 1127	21 40.9	+58 33.7	100.20	+4.37	0.004		0	[KTK2006] G105.5+10.3, YMD CO 18
TDS 395	21 40.9	+66 35.7	105.57	+10.38	0.161	-10.8	1	DBY 100.0+4.2, IC 1396 N
LDN 1124	21 41.5	+58 13.7	100.04	+4.07	0.015	-0.2	20	TGU 599, WWC 117
LDN 1128	21 41.5	+58 33.7	100.26	+4.32	0.015	1.2	0	[PGH98b] Cloud 19, DBY 100.9+05.3, [PGH98b] Cloud 21, DBY 101.7+05.0
LDN 1134	21 41.5	+60 13.7	101.35	+5.58	2.630	-0.4	0	
LDN 1103	21 41.7	+56 43.7	99.07	+2.92	0.003		0	Barnard 163, TDS 371, WWC 184, [G85] 17, [LM99] 381
LDN 1104	21 42.1	+56 43.7	99.11	+2.89	0.006	4.1	2	YMD CO 18, TGU 645
LDN 1181	21 42.1	+66 08.7	105.36	+9.97	0.008	-9.9	0	Ced 196, GM 1-57, [B77] 40, TDS 395, [FMS2001] NGC 7129,
LDN 1183	21 42.1	+66 13.7	105.42	+10.03	0.090	-9.9	>84	[MPR2003] HI Ring, [MPR2003] HI Knot, BFS 11, JWT Core 46
LDN 1095	21 42.6	+56 18.8	98.89	+2.52	0.012		0	

Table 1.: Continued.

Cloud name	RA(2000) (h m)	Dec(2000) (° ′)	l (°)	b (°)	Area (sq.deg.)	v_{LSR} (km s ⁻¹)	n_{star}	Alternative names
LDN 1106	21 42.6	+56 53.8	99.27	+2.97	0.009	-0.4	0	[PGS95] 28
LDN 1113	21 44.6	+57 11.8	99.67	+3.02	0.002	4.5	1	Barnard 367, WWC 186
LDN 1130	21 44.6	+58 18.8	100.40	+3.87	0.012	-3.0	8	TGU 604, [PGS95] 32, FSE 8
LDN 1136	21 45.5	+59 58.9	101.57	+5.06	0.012	-2.9	0	DBY 101.7+05.0
DBY 100.0+03.0	21 46.3	+57 25.1	100.00	+3.03	0.015	-1.9	16	IC 1396 E, SFO 39, FSE 9
LDN 1115	21 46.6	+56 58.9	99.74	+2.68	0.002		0	
LDN 1118	21 46.6	+57 12.9	99.89	+2.86	0.001	-2.1	0	SFO 42, [PGS95] 38
LDN 1129	21 46.6	+57 53.9	100.33	+3.38	0.041	-2.1	0	[PGS95] 36, DBY 100.4+03.4, WWC 40-42
LDN 1132	21 46.6	+58 43.9	100.87	+4.02	0.003		0	
LDN 1120	21 47.6	+57 09.0	99.96	+2.72	0.001		0	
LDN 1114	21 49.7	+56 24.0	99.69	+1.96	0.016	-1.8	0	TDS 375, DBY 099.9+01.8
LDN 1241	21 50.0	+76 44.1	113.08	+17.48	1.380	-3.7	0	YMD CO 72, YMD CO 75, TGU 728, TGU 739
LDN 1144	21 50.5	+60 07.1	102.14	+4.77	0.027	-2.2	1	Barnard 166, DBY 102.1+04.8
LDN 1137	21 51.6	+59 04.1	101.58	+3.87	0.018	-10.5	0	[G85] 31, DBY 101.5+03.8
LDN 1138	21 51.6	+59 04.1	101.58	+3.87	0.018	-10.5	0	DBY 101.5+03.8
LDN 1109	21 51.7	+55 49.1	99.55	+1.33	0.150	-1.5	0	DBY 099.5+01.2
Barnard 167	21 52.0	+60 04.0	102.25	+4.61	0.005		1	
LDN 1139	21 55.6	+58 34.3	101.68	+3.15	0.015	0.1	15	Barnard 169, DBY 101.3+03.00, TGU 620, [LM99] 386, [PGH98b] Cloud 27, FSE 10
LDN 1141	21 55.6	+58 44.3	101.78	+3.28	0.010	0.1	0	Barnard 171, DBY 101.3+03.00,
LDN 1142	21 56.6	+59 04.3	102.09	+3.47	0.002	0.1	0	CB 235, DBY 101.3+03.00
LDN 1143	21 57.6	+58 59.3	102.14	+3.32	0.020	0.1	1	Barnard 170, TDS 380, DBY 101.3+03.00
LDN 1149	21 57.6	+59 07.3	102.22	+3.43	0.015	0.1	0	DBY 101.3+03.00
LDN 1151	21 59.6	+59 04.4	102.40	+3.23	0.027	0.1	0	DBY 101.3+03.00
LDN 1153	22 00.6	+58 59.5	102.45	+3.09	0.079	0.1	0	TDS 383, DBY 101.3+03.00
LDN 1133	22 02.7	+56 14.5	101.02	+0.72	0.248		0	
LDN 1160	22 04.7	+58 59.6	102.87	+2.78	0.019	0.1	0	DBY 101.3+03.00
LDN 1166	22 05.7	+59 34.6	103.32	+3.18	0.001	-3.0	0	CB 236
LDN 1159	22 06.7	+58 34.7	102.84	+2.29	2.790	-1.0	17	Barnard 174, TDS 384, TDS 391, [LM99] 389, [GA90] 3-36, DSH J2206.2+5819, DBY 102.9+02.4, [G85] 32, DBY 102.8+02.1, DBY 103.3+02.8,

Table 1.: Continued.

Cloud name	RA(2000) (h m)	Dec(2000) (° ')	l (°)	b (°)	Area (sq.deg.)	v_{LSR} (km s ⁻¹)	n_{star}	Alternative names
LDN 1164	22 06.7	+59 09.7	103.18	+2.76	0.019	-2.2	36	DBY 103.2+01.8, [PGH98b] Cloud 30,
LDN 1165	22 07.2	+59 04.7	103.18	+2.66	0.019	-2.2	1	DBY 103.5+02.0, GSH 103+02-66
LDN 1169	22 07.2	+59 44.7	103.57	+3.20	0.004	-3.2	0	DBY 103.3+02.8, FSE 11
TGU 659	22 09.0	+64 29.7	106.53	+6.93	1.070		1	DBY 103.3+02.8
LDN 1178	22 09.1	+62 19.8	105.27	+5.16	0.005		0	CB 237
LDN 1243	22 10.6	+75 20.0	113.16	+15.61	0.081	-2.9	0	[KTK2006] G106.9+07.1
LDN 1219	22 11.6	+70 59.9	110.58	+12.06	0.003	-4.6	1	YMD CO 74
LDN 1182	22 13.1	+61 54.9	105.42	+4.55	0.004		0	Barnard 175, TDS 414, YMD CO 57
LDN 1217	22 13.1	+70 44.9	110.54	+11.79	0.186	-4.6	1	Ced 201, YMD CO 57, TDS 414, TGU 696
LDN 1186	22 13.6	+62 07.9	105.59	+4.70	0.005		0	TGU 649
LDN 1175	22 13.7	+60 44.9	104.81	+3.55	0.015		0	TGU 635
LDN 1191	22 14.1	+62 24.9	105.80	+4.90	0.004		0	
LDN 1193	22 14.6	+62 24.9	105.85	+4.87	0.002		0	
LDN 1235	22 14.9	+73 25.0	112.24	+13.88	0.037	-4.0	4	YMD CO 69, TDS 426, HCL 1F,
TGU 627	22 15.2	+58 47.6	103.87	+1.83	0.210		3	TGU 725, [BM89] 1-117, [LM99] 390
LDN 1150	22 15.8	+56 00.0	102.37	-0.53	0.007	-6.9	0	Barnard 369, TDS 385, TGU 621
LDN 1188	22 16.7	+61 45.0	105.67	+4.18	0.398	-10.6	$\gtrsim 20$	YMD CO 21, TGU 652,
LDN 1154	22 16.8	+56 13.0	102.61	-0.43	0.007		0	[PGH98b] Cloud 33, [ADM95] 3,
TGU 636	22 16.9	+60 11.6	104.83	+2.87	0.240		2	[ADM95] 4, [ADM95] 5, [ADM95] 7,
TGU 640	22 17.6	+60 36.5	105.13	+3.17	0.330		2	[ADM95] 13, [ADM95] 8, GN 22.15.0
LDN 1156	22 19.9	+55 45.1	102.71	-1.05	0.043		0	DG 181, DG 182, GN 22.14.9
LDN 1161	22 19.9	+56 08.1	102.92	-0.73	0.006		0	[KC97c] G102.9-00.7
YMD CO 29	22 20.2	+63 53.1	107.20	+5.73	0.018	-11.0	13	Sh2-145, SFO 44
LDN 1184	22 20.7	+60 45.1	105.53	+3.08	0.124		0	TGU 643, TGU 644
LDN 1247	22 20.8	+75 15.2	113.66	+15.17	0.167	-5.1	0	TDS 430, TGU 742
LDN 1163	22 20.9	+56 10.1	103.05	-0.78	0.007		0	
LDN 1201	22 23.6	+63 30.2	107.31	+5.21	0.009		0	TGU 661

Table 1.: Continued.

Cloud name	RA(2000) (h m)	Dec(2000) ($^{\circ}$ ')	l ($^{\circ}$)	b ($^{\circ}$)	Area (sq.deg.)	v_{LSR} (km s $^{-1}$)	n_{star}	Alternative names
LDN 1202	22 26.7	+63 05.3	107.38	+4.67	0.004		0	TGU 661
LDN 1204	22 26.7	+63 15.3	107.47	+4.82	2.500	-7.6	$\gtrsim 100$	YMD CO 27, TDS 399, TDS 401, TDS 403, TDS 404, TDS 405, [KC97c], [PGH98b] Cloud 32, [PGH98b] Cloud 37, [PGH98b] Cloud 38, [G84b] 12, DG 185, [PGH98b] Cloud 36, Sh2-140, GSH 108+05-46, GN 22.21.5, TGU 661
LDN 1180	22 26.8	+59 15.3	105.37	+1.41	7.000	-3.6	19	YMD CO 20, YMD CO 24, TDS 396, TDS 397, CB 240, TGU 631, TGU 638, TGU 655, TGU 658, Min 2-72, [PGH98b] Cloud 34, [KC97c] G104.6+01.4, KR 47, [LM99] 394, [KC97c] G105.6+00.4, Sh2-138, [GSL2002] 109, [GSL2002] 110, [P85b] 18, [LM99] 396, DSH J2222.5+5918B, TGU 657, [B77] 42, [LM99] 391, GN 22.24.9
LDN 1195	22 26.8	+61 15.3	106.42	+3.11	0.017		1	
LDN 1196	22 26.8	+61 15.3	106.42	+3.11	0.029		1	
LDN 1179	22 27.3	+59 02.3	105.31	+1.19	0.002		0	TGU 661
LDN 1203	22 27.7	+63 00.3	107.43	+4.54	0.016		0	
TGU 719	22 27.8	+71 21.4	111.90	+11.63	0.510		3	
LDN 1221	22 28.4	+69 00.4	110.67	+9.61	0.020	-4.9	3	TDS 416, [KTK2006] G110.6+09.6, [LM99] 392, TGU 702
LDN 1206	22 28.7	+64 25.4	108.27	+5.70	0.083		0	TGU 673, [PGH98b] Cloud 35
LDN 1185	22 29.3	+59 05.4	105.56	+1.10	0.006		0	
LDN 1207	22 29.7	+64 25.4	108.36	+5.64	0.047		0	
LDN 1209	22 29.7	+64 45.4	108.53	+5.93	0.111	-8.8	3	Sh2-150, TGU 680
LDN 1208	22 30.7	+64 25.4	108.46	+5.58	0.018		0	
LDN 1190	22 30.9	+59 08.4	105.75	+1.04	0.004		0	
LDN 1242	22 31.2	+73 15.4	113.15	+13.11	0.793		0	
LDN 1213	22 31.6	+65 25.5	109.06	+6.39	0.006	-9.2	0	YMD CO 48, TGU 686, Sh2-150
LDN 1194	22 32.9	+59 05.5	105.95	+0.87	0.009		0	
LDN 1214	22 33.6	+65 45.5	109.41	+6.57	0.256	-8.5	1	TDS 407, YMD CO 48, Sh2-150
LDN 1192	22 33.9	+58 35.5	105.81	+0.37	0.007	-3.6	0	CB 240

Table 1.: Continued.

Cloud name	RA(2000) (h m)	Dec(2000) (° ′)	l (°)	b (°)	Area (sq.deg.)	v_{LSR} (km s ⁻¹)	n_{star}	Alternative names
TDS 417	22 35.5	+69 13.1	111.33	+9.47	0.014	-7.2	1	YMD CO 65, [B77] 46, GN 22.33.6 [KTK2006] G101.9+15.8
TGU 679	22 35.9	+63 35.2	108.53	+4.57	0.170		1	
LDN 1251	22 36.1	+75 15.6	114.51	+14.65	0.195	-3.8	$\gtrsim 20$	YMD CO 79, TGU 750, [SMN94] B, HCL 1A, [SMN94] C, [SMN94] D, [LM99] 397, [NJH2003] 5, [TW96] H2, [SMN94] E, [TW96] H1, [KTK2006] G114.4+14.6
LDN 1198	22 36.9	+59 25.6	106.57	+0.90	0.054	-11.91	2	
TGU 672	22 37.5	+62 20.6	108.07	+3.40	0.360		1	
LDN 1197	22 37.9	+58 55.6	106.43	+0.40	0.009		0	
LDN 1187	22 38.0	+57 15.6	105.62	-1.06	0.145		0	
LDN 1189	22 39.0	+57 15.6	105.74	-1.12	0.473		0	
TGU 671	22 44.1	+60 16.1	107.77	+1.20	0.200		2	
LDN 1210	22 44.9	+62 05.8	108.70	+2.77	0.011	-10.0	0	YMD CO 40, TGU 699
Sh 2-142	22 45.0	+57 55.8	106.76	-0.92	1.063	-41.0	14	Ced 206, GM 2-42, TGU 663, SFO 43, [KC97c] G107.2-01.0, [KC97c] G107.3-00.9
LDN 1205	22 45.9	+60 25.8	108.04	+1.24	0.095		0	
LDN 1200	22 46.0	+58 45.8	107.27	-0.24	0.020	-3.7	3	YMD CO 28, TDS 402, TGU 665
TGU 678	22 46.5	+61 12.8	108.47	+1.90	0.170		1	
LDN 1211	22 46.9	+62 10.8	108.95	+2.74	0.011	-11.1	4	YMD CO 40, TGU 699
LDN 1212	22 47.9	+62 12.9	109.07	+2.71	0.014	-10.0	0	YMD CO 40, TGU 699
TGU 689	22 50.2	+62 51.5	109.60	+3.17	0.160		2	
TGU 692	22 50.7	+63 15.4	109.83	+3.50	0.240		2	
YMD CO 38	22 51.1	+60 51.6	108.80	+1.33	0.028	-8.5	1	TGU 606, [KTK2006] G100.6+16.2
YMD CO 49	22 51.1	+62 38.9	109.60	+2.93	0.014	-9.6	1	TGU 690
LDN 1215	22 51.9	+62 06.0	109.44	+2.40	0.021		0	TGU 699
LDN 1216	22 51.9	+62 16.0	109.52	+2.55	0.142	-9.5	11	Cep F, TDS 408, GN 22.51.3, TGU 699
LDN 1236	22 52.7	+68 56.0	112.56	+8.49	0.044	-5.0	0	YMD CO 73, TGU 729
YMD CO 51	22 56.2	+62 02.7	109.87	+2.13	0.489	-10.2	$\gtrsim 15$	Cep A
LDN 1223	22 56.9	+64 16.1	110.89	+4.11	1.010		1	TGU 703, [BKP2003] 455 GN 22.58.2, GSH 111+04-105

Table 1.: Continued.

Cloud name	RA(2000) (h m)	Dec(2000) (° ')	l (°)	b (°)	Area (sq.deg.)	v_{LSR} (km s ⁻¹)	n_{star}	Alternative names
TGU 715	22 57.0	+65 53.5	111.60	+5.57	1.280		0	
TGU 684	22 57.4	+59 27.5	108.90	-0.27	0.230	-47.0	6	[KC97c] G109.1-00.3, [G82a] 13
TGU 705	22 59.5	+63 26.0	110.80	+3.23	0.410		2	
LDN 1218	23 02.0	+62 16.2	110.58	+2.05	1.590	-5.1	>400	YMD CO 53, YMD CO 51 YMD CO 56, YMD CO 58, YMD CO 59, YMD CO 62, YMD CO 63, TDS 418, Cep A, Cep A west, [THR85] Cep A-3, GAL 109.88+02.11, [HW84] 7d, [B77] 44, [TOH95] Ridge, [TOH95] C, [TOH95] B, [TOH95] A, Cep B, GN 22.55.2, [KC97c] G110.2+02.5, Cep E, Cep E South, Cep E North, [YNF96] a, [YNF96] b, TGU 699
YMD CO 55	23 02.1	+61 29.2	110.27	+1.33	0.056	-7.3	2	
LDN 1224	23 04.0	+63 46.2	111.39	+3.33	0.016		0	
LDN 1220	23 04.1	+61 51.2	110.63	+1.57	0.006	-10.1	1	YMD CO 58, Cep E
LDN 1222	23 05.1	+61 46.2	110.70	+1.45	0.002	-10.1	0	YMD CO 58, Cep E, TGU 699
TGU 707	23 09.0	+61 04.8	110.87	+0.63	0.160		1	
TGU 700	23 09.7	+60 06.4	110.57	-0.30	0.650	-52.8	10	BFS 18
LDN 1226	23 10.1	+62 16.3	111.44	+1.68	0.009	-10.7	0	YMD CO 63, TGU 699
LDN 1227	23 10.1	+62 19.3	111.46	+1.73	0.008	-10.7	0	YMD CO 63, TGU 699
LDN 1240	23 11.0	+66 26.3	113.12	+5.50	0.126		0	
LDN 1225	23 12.1	+61 36.3	111.41	+0.97	0.036	-10.9	4	TDS 419, CB 242, TGU 699
LDN 1239	23 12.3	+66 04.3	113.11	+5.11	0.005	-7.6	0	CB 241
NGC 7538	23 14.1	+61 29.4	111.58	+0.77	0.011	-57.0	~2000	[KSH92] CS 5, [KSH92] CS 4, [M73] C, [KSH92] CS 3, Ced 209, [WAM82] 111.543+0.7, [M73] B, [M73] A, [KSH92] CS 2, Sh2-158 GAL 111.53+00.82, [WC89] 111.54+0.78, [KSH92] CS 1 Cep D, TGU 699 Cep D, TGU 699 Cep D YMD CO 68, TGU 699
LDN 1229	23 14.1	+61 59.4	111.78	+1.24	0.004	-10.0	0	
LDN 1230	23 14.1	+62 01.4	111.79	+1.27	0.002	-10.0	0	
LDN 1233	23 16.5	+62 20.4	112.15	+1.47	0.001	-10.0	0	
LDN 1232	23 17.2	+61 46.4	112.03	+0.91	0.004	-10.6	0	
LDN 1234	23 17.2	+62 24.4	112.25	+1.51	0.004		0	
TGU 717	23 17.3	+60 48.1	111.70	0.00	0.200	-30.1	≥ 9	

Table 1.: Continued.

Cloud name	RA(2000) (h m)	Dec(2000) (° ′)	l (°)	b (°)	Area (sq.deg.)	v_{LSR} (km s ⁻¹)	n_{star}	Alternative names
TGU 757	23 17.3	+69 56.0	114.97	+8.53	0.270		1	
LDN 1231	23 18.2	+61 16.4	111.97	+0.40	0.013	-11.2	0	TDS 424
LDN 1250	23 22.1	+67 16.5	114.45	+5.89	2.630	-8.6	1	YMD CO 78, YMD CO 80, TDS 432, TGU 747 GSH 114+06-47
LDN 1259	23 22.9	+74 16.5	116.93	+12.44	0.035	3.9	0	YMD CO 101, TGU 772
LDN 1244	23 25.2	+62 46.5	113.25	+1.53	0.007		0	
LDN 1246	23 25.2	+63 36.5	113.52	+2.32	0.002	-11.1	0	CB 243, [GA90] 3-40, [LM99] 400
LDN 1261	23 27.0	+74 16.5	117.20	+12.35	0.030	3.9	2	YMD CO 101, TDS 447, TGU 772, TDS 448, CB 244, [LM99] 401 [BM89] 3B-10, [BM89] 1-119, TGU 772
LDN 1262	23 27.0	+74 16.5	117.20	+12.35	0.066	3.9	2	
YMD CO 85	23 32.6	+67 02.0	115.33	+5.33	0.084	-5.4	0	
YMD CO 86	23 35.8	+66 26.2	115.47	+4.67	0.056	-7.0	0	
YMD CO 87	23 39.3	+65 42.4	115.60	+3.87	0.168	-25.3	2	
TGU 767	23 42.9	+68 52.9	116.80	+6.83	0.400		2	
LDN 1264	23 52.5	+68 16.7	117.50	+6.03	0.102		0	
LDN 1266	23 57.5	+67 16.7	117.75	+4.95	2.540	-6.8	14	YMD CO 103, YMD CO 104, YMD CO 105, YMD CO 108, YMD CO 111, TDS 449, TDS 451, TGU 774, [LM99] 404, [YF92] C1, [LM99] 405, [YF92] C2, GN 23.56.1, [KC97c] G118.1+05.0, [LM99] 406, [GA90] 1-1, [GA90] 1-1a, [LM99] 1, [KC97c] G118.4+04.7, DG 1, [GA90] 3-41, [GA90] 3-42, SFO 1, SFO 3, DSH J2359.6+6741
LDN 1274	23 57.5	+70 56.7	118.52	+8.54	0.032	-2.5	0	YMD CO 109
LDN 1268	23 59.5	+67 26.7	117.97	+5.07	0.158	-6.2	3	Sh2-171, YMD CO 104, TGU 774
LDN 1269	00 00.6	+67 09.7	118.01	+4.78	0.025		0	TGU 774
LDN 1270	00 01.6	+67 09.7	118.11	+4.76	0.009		2	TGU 774
LDN 1271	00 01.6	+67 16.7	118.13	+4.87	0.010	-15.1	0	YMD CO 108, TGU 774
LDN 1272	00 02.6	+67 16.7	118.23	+4.85	8.690	-6.3	23	YMD CO 97, YMD CO 98, YMD CO 110, YMD CO 112, YMD CO 113, YMD CO 114, YMD CO 116, TGU 779, SFO 2, [GA90] 3-1, [GA90] 1-1b, GSH 1119+05-74

Table 1.: Continued.

Cloud name	RA(2000) (h m)	Dec(2000) (° ′)	l (°)	b (°)	Area (sq.deg.)	v_{LSR} (km s ⁻¹)	n_{star}	Alternative names
LDN 1273	00 02.6	+68 31.7	118.46	+6.08	0.199	-8.8	4	YMD CO 114
LDN 1275	00 06.6	+67 26.7	118.64	+4.95	0.020		0	TGU 781

References: [ADM95] – Ábrahám et al. (1995); Barnard – Barnard (1927); [B77] – Bernes (1977); [BKP2003] – Brunt et al. (2003); [BM89] – Benson & Myers (1989); BFS – Blitz et al. (1982); CB – Clemens & Barvainis (1988); Ced – Cederblad (1946) DBY – Dobashi et al. (1994); [DE95] – Davis & Eislöffel (1995); DG – Dorschner & Gürtler (1964); DSH – Kronberger et al. (2006); [ETM94] – Eiroa et al. (1994); [FMS2001] – Font et al. (2001); FSE – Froeblich et al. (2005); [G82a] – Gyulbudaghian (1982) [G85] – Gyulbudaghian (1985); [GA90] – Gyulbudaghian & Akopyan (1990); GAL – Kerber et al. (1996); GF – Schneider & Elmegreen (1979); GM – Magakian (2003); GN – Magakian (2003); GSH – Ehlerova & Palous (2005); [GSL2002] – Giveon et al. (2002) HCL – Heiles (1967); [HW84] – Hughes & Wouterloot (1984); [IS94] – Indrani & Sridharan (1994); JWT Core – Jessop & Ward-Thompson (2000); [KC97c] – Kuchar & Clark (1997); KR – Kallias & Reich (1980); [KSH92] – Kawabe et al. (1992); [KTK2006] – Kiss et al. (2006); LDN – Lynds (1962); [LM99] – Lee & Myers (1999); [M73] – Martin (1973); MBM – Magnani et al. (1985); Min – Minkowski (1947); [MPR2003] – Matthews et al. (2003); [NIH2003] – Nikolić et al. (2003); [P85b] – Petrossian (1985) [PGH98b] Cloud – Patel et al. (1998); [PGS95] – Patel et al. (1995); PP – Parsamian & Petrossian (1979); RNO – Cohen (1980) SFO – Sugitani et al. (1991); Sh 2- – Sharpless (1959); [SMN94] – Sato et al. (1994); TDS – Taylor, Dickman, & Scoville (1987); TGU – Dobashi et al. (2005); [THR85] – Torrelles et al. (1985); [TOH95] – Testi et al. (1995); [TW96] – Tóth & Walmsley (1996); [WAM82] – Wink, Altenhoff & Mezger (1982); [WC89] – Wood & Churchwell (1989); WWC – Weikard et al. (1996); YMD CO – Yonekura et al. (1997); [YF92] – Yang & Fukui (1992); [YNF96] – Yü et al. (1996).

2. The Cepheus Flare

2.1. Large-scale Studies of the Cepheus Flare

The term ‘Cepheus flare’ was first used by Hubble (1934) who recognized that the zone of avoidance of external galaxies, confined to the Galactic plane, extended to higher latitudes at certain segments of the plane, suggesting significant obscuration outside the main Galactic belt. He called these wide segments for Galactic disk *flares*. The Cepheus Flare can be found at $100^\circ \leq l \leq 120^\circ$: there is a large amount of dense ISM above $b \geq 10^\circ$ (Lynds 1962; Taylor, Dickman, & Scoville 1987; Clemens & Barvainis 1988; Dobashi et al. 2005).

Heiles’ (1967) study of the HI distribution in the region revealed two kinematically separate sheets of interstellar gas in the Galactic latitude interval $+13^\circ \leq b \leq +17^\circ$, moving at a velocity of $\sim 15 \text{ km s}^{-1}$ relative to each other. Heiles speculated that the two sheets probably represent an expanding or colliding system at a distance interval of 300–500 pc. Berkhuijsen (1973) found a giant radio continuum region *Loop III* centered on $l=124 \pm 2^\circ$, $b=+15.5 \pm 3^\circ$ and stretching across 65° , and suggested that it was a result of multiple supernova explosions. The HI shell reported by Hu (1981) at $l=105^\circ$, $b=+17^\circ$ and $v_{\text{centr}}=+3 \text{ km s}^{-1}$ also indicates that the interstellar medium in this region is in a state of energetic motion. The wide range in the velocity thus may reflect disturbances from various shocks.

Lebrun’s (1986) low-resolution CO survey revealed that, in this region, the clouds constitute a coherent giant molecular cloud complex. Based on Racine’s (1968) study of reflection nebulae, Lebrun placed the Cepheus Flare molecular clouds between 300 and 500 pc. Grenier et al. (1989) extended the CO survey to a region of 490 deg^2 in Cepheus–Cassiopeia above $b=+10^\circ$. They found that the clouds could be divided into two kinematically well separated subsystems around the radial velocities of $v_{\text{LSR}} \sim 0 \text{ km s}^{-1}$ and -10 km s^{-1} , respectively. They also detected CO emission around $v_{\text{LSR}} \sim 0 \text{ km s}^{-1}$ at higher longitudes ($124^\circ < l < 140^\circ$) in Cassiopeia, and found an area free of CO emission at $118^\circ < l < 124^\circ$. They suggested that the void between the Cepheus and Cassiopeia clouds is a supernova bubble. They estimated the age of the bubble as 4×10^4 years, and proposed that it may result from a Type I supernova.

Yonekura et al. (1997) conducted a large-scale ^{13}CO survey of the Cepheus–Cassiopeia region at an 8-arcmin grid spacing and with 2.7 beam size. Out of the 188 molecular clouds found in the whole surveyed region 51 fall in the Cepheus Flare region. Their surface distribution, adopted from Yonekura et al. (1997), is shown in Fig. 4.

These clouds, distributed over the velocity interval of $(-15, +6) \text{ km s}^{-1}$, were classified into three kinematically different components by Yonekura et al. (see Table 2). The high latitude part of the molecular complex is included in Magnani et al.’s (1985) catalog of high latitude molecular clouds. Ammonia observations of dense cores have been reported by Benson & Myers (1989) and Tóth & Walmsley (1996). In addition to the two major catalogs of dark clouds (Lynds 1962; Dobashi et al. 2005), dark cloud cores were catalogued by Lee & Myers (1999).

Kun (1998) determined cloud distances using Wolf diagrams, and presented a list of candidate YSOs found during an objective prism $\text{H}\alpha$ survey, and selected from the IRAS Catalogs.

Kiss et al. (2006) performed a complex study of the visual and infrared properties of the ISM in the Cepheus Flare region using USNO, 2MASS, DIRBE, IRAS, and

Table 2. Cloud groups in Cepheus, classified by Yonekura et al. (1997).

N	Longitude		Latitude		V_{LSR}		D (pc)	M ($M_{\odot}$)	Associated objects	Ref.
	l_l ($^{\circ}$)	l_u ($^{\circ}$)	b_l ($^{\circ}$)	b_u ($^{\circ}$)	V_l (km s^{-1})	V_u (km s^{-1})				
Close Group										
1	99	105	13	18	1	5	440	3900	NGC 7023, L1157	1, 2
2	102	104	16	18	-4	-1	300	90		3
3	105	110	-1	1	-4	-1	300	110	L1200	3
4	106	116	13	19	-8	-1	300	3600	Cepheus Flare	4
5	110	116	4	12	-9	-3	300	730	L1221, L1250	3
6	110	117	19	21	-9	-4	300	680	L1228	3
7	115	117	-4	-1	-4	-1	140	20	L1253, L1257	5
8	116	118	12	13	3	5	200	26	L1262	6
9	117	124	6	10	-3	-1	300	200	L1304	3
Distant Group										
10*	95	99	3	7	-8	2	624	4000	IC 1396	17
13	103	111	9	15	-21	-8	1000	12000	NGC 7129	7, 8
14	105	110	0	7	-14	-6	910	11000	S 140	9
15	108	117	0	4	-17	-4	730	15000	Cep OB3	10
16	115	116	3	5	-26	-23	1000	1400	M115.5+4.0	11
17	116	124	-2	7	-22	-2	850	27000	Cep OB4	12
Clouds in Perseus Arm										
22	111	112	-1	1	-31	-30	2200	2500	MWC1080	13, 14
23	112	113	-3	-2	-37	-34	3000	5400	Cas A	15
24	123	124	-7	-6	-32	-30	2100	2000	NGC 281	16

References. (1) Viotti (1969); (2) Shevchenko et al. (1989); (3) Grenier et al. (1989); (4) Kun & Prusti (1993); (5) Snell et al. (1990); (6) Myers & Benson (1983); (7) Racine (1968); (8) Shevchenko & Yakubov (1989); (9) Crampton & Fisher (1974); (10) Crawford & Barnes (1970); (11) Yang (1990); (12) MacConnell (1968); (13) Levreault (1985); (14) p (0); (15) Ungerechts & Thaddeus (1989); (16) Hogg (1959); (17) de Zeeuw et al. (1999).

* The ^{13}CO clouds in the region of IC 1396 are included in Dobashi et al. (1994), not in Yonekura et al. (1997).

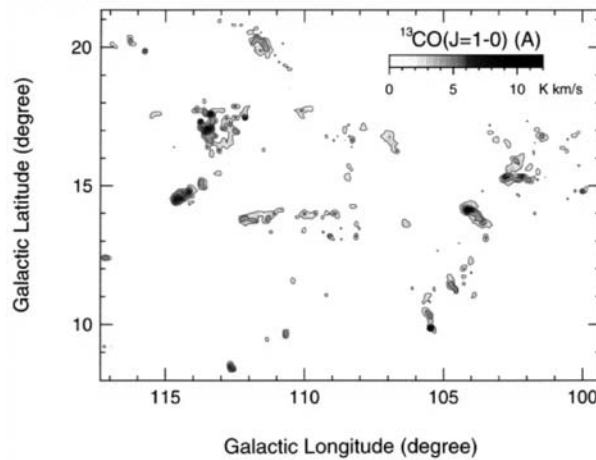


Figure 4. Distribution of ^{13}CO clouds in the Cepheus Flare (adopted from Yonekura et al. 1997)

ISO data. Based on the distribution of visual extinction they identified 208 clouds, and divided them into 8 complexes. They examined the morphology of clouds, and established several empirical relationships between various properties of the clouds.

Olano et al. (2006) studied the space distribution and kinematics of the interstellar matter in Cepheus and Cassiopeia, using the Leiden–Dwingeloo HI data and the Columbia Survey CO data. They found that the broad and often double-peaked spectral line profiles suggest that the Cepheus Flare forms part of a big expanding shell that encloses an old supernova remnant. Assuming a distance of 300 pc for the center of the shell, located at $(l, b) \approx (120^\circ, +17^\circ)$, they derived a radius of approximately 50 pc, expansion velocity of 4 km s^{-1} , and HI mass of $1.3 \times 10^4 M_\odot$ for the Cepheus Flare Shell. The supernova bubble proposed by Grenier et al. (1989), the radio continuum structure Loop III (Berkhuijsen 1973), and the Cepheus Flare Shell are various observable aspects of the supernova explosion(s) that shaped the structure of the interstellar medium and triggered star formation in the Cepheus Flare during the past few million years.

2.2. Distance to the Cepheus Flare Clouds

Spectroscopic and photometric studies of stars illuminating reflection nebulae in the Cepheus Flare (Racine 1968) indicated, long before the discovery of the molecular cloud complex, that interstellar dust can be found at several distances along the line of sight in this region. The presence of clouds at different velocities also suggests that there are clouds at various distances (Grenier et al. 1989).

At the low Galactic latitude boundary of the Cepheus Flare we find the associations Cep OB2 and Cep OB3 at a distance of ~ 800 pc. Therefore Grenier et al. (1989) propose that the negative velocity component of the Cepheus flare clouds ($v_{\text{LSR}} \sim -10 \text{ km s}^{-1}$) is an extension of these local arm features, while the more positive ($v_{\text{LSR}} \sim 0 \text{ km s}^{-1}$) velocity component corresponds to a nearby cloud complex at a distance of 300 pc.

Table 2 suggests a more complicated pattern of cloud distances. Both the close and the distant components are composed of several complexes, probably located at different distances. Other distance determinations found in the literature support this suggestion. Below we list some results and problems related to the distance of Cepheus Flare clouds.

Distances of individual clouds can reliably be derived by studying the effects of the clouds on the light of associated stars. Racine (1968), in a spectroscopic and photometric study of stars in reflection nebulae, obtained a distance of 400 ± 80 pc for the Cepheus R2 association above the latitude $+10^\circ$. Both velocity components are represented among the clouds being illuminated by the stars of Cep R2.

A prominent object of the distant component, in addition to the possible outer parts of Cep OB2 and Cep OB3, is NGC 7129. Though Kun, Balázs & Tóth (1987) and Ábrahám, Balázs & Kun (2000) proposed that NGC 7129 may be associated with the Cepheus Bubble, and thus with Cep OB2, other observations suggest that NGC 7129 may be farther than Cep OB2. Racine (1968) investigated three member stars, and derived $m - M \approx 12.2$ for BD+65°1637, and 10.0 for both BD+65°1638 and LkH α 234, and labeled each value as uncertain. Shevchenko & Yakubov (1989), based on an A_V vs. distance diagram, derived 1250 pc for NGC 7129. Yonekura et al. (1997) found a group of clouds at $l \sim 107^\circ - 111^\circ$, $b \sim +13^\circ$ at similar velocity, and regarded them as an extension of the NGC 7129 clouds to the northeast (group 13 in Table 2).

Table 3. Distance measured for the clouds within the Cepheus Flare region together with their probable lower and upper limits and the method of determination.

Cloud	l (°)	b (°)	d (Δ d) (pc)	Method	Ref.
L1147/L1158	102.0	15.0	325 ± 13	A_V vs. distance	4
L1167/L1174	104.0	15.0	440 ± 100	spectroscopy & photometry of HD 200775	1
L1167/L1174	104.0	15.0	288 ± 25	A_V vs. distance	4
L1167/L1174	104.0	15.0	430^{+160}_{-90}	<i>Hipparcos</i> parallax of HD 200775	10
L1177	105.14	13.12	300 ± 30	Wolf diagram	6
L1199	106.50	12.21	500 ± 100	Wolf diagram	6
L1199	106.50	12.21	800	spectroscopy & photometry of HD 206135	2
TDS400	107.01	16.78	300^{+50}_{-10}	Wolf diagram	6
CB 234	108.10	13.15	300^{+50}_{-10}	Wolf diagram	6
TDS406	108.50	18.15	300^{+50}_{-20}	Wolf diagram	6
L1217	110.34	11.41	400^{+50}_{-20}	Wolf diagram	6
L1219	110.60	11.96	400^{+50}_{-20}	Wolf diagram	6
L1219	110.60	11.96	400	spectroscopy & photometry of BD+69 1231	2, 8
TDS420	111.57	14.25	300^{+50}_{-10}	Wolf diagram	6
L1228	111.63	20.14	200^{+100}_{-20}	Wolf diagram	6
L1228	111.63	20.14	180^{+30}_{-10}	spectroscopy & photometry of BD+76 825	
TDS421	111.71	13.80	250^{+30}_{-10}	Wolf diagram	6
L1235	112.22	13.86	200	A_V vs. distance	3
L1235	112.22	13.86	300^{+50}_{-10}	Wolf diagram	6
L1235	112.22	13.86	400 ± 80	spectroscopy & photometry of HD 210806	2, 8
L1235	112.22	13.86	300^{+80}_{-40}	<i>Hipparcos</i> parallax of HD 210806	7
L1241	113.03	17.51	300^{+50}_{-10}	Wolf diagram	6
L1242	113.08	13.14	300^{+30}_{-10}	Wolf diagram	6
L1243	113.10	15.64	300^{+50}_{-10}	Wolf diagram	6
L1247	113.60	15.20	300^{+50}_{-10}	Wolf diagram	6
L1251	114.45	14.68	300 ± 50	A_V vs. distance	5
L1251	114.45	14.68	300^{+50}_{-10}	Wolf diagram	6
L1251	114.45	14.68	337 ± 50	star count analysis	9
MBM163–165	116.00	20.25	200^{+100}_{-20}	Wolf diagram	6
L1259–1262	117.00	12.40	180^{+40}_{-20}	Wolf diagram	6

References: (1) Viotti (1969); (2) Racine (1968); (3) Snell et al. (1990); (4) Straizys et al. (1992); (5) Kun & Prusti (1993); (6) Kun (1998); (7) ESA (1997); (8) Kun et al. (2000); (9) Balázs et al. (2004); (10) van den Ancker et al. (1997)

This result suggests that a considerable part of the Cepheus Flare clouds is located at about 1 kpc. The situation is, however, far from clear. Simonson & van Someren Greve (1976) found a large HI cloud coinciding both in position and velocity with the molecular clouds of Yonekura et al.'s group 13. They associated this cloud not with NGC 7129, but with the reflection nebulae of Cep R2 (Racine 1968) at a distance of some 400 pc. The Wolf diagrams constructed by Kun (1998) show two layers of extinction towards $b \sim +11^\circ - +13^\circ$, at 300 pc and ~ 450 pc, respectively, thus it is tempting to identify the two velocity components with these two layers.

Another direct distance determination within the area of the Cepheus Flare is that of Viotti (1969), who derived 440 ± 100 pc for the reflection nebula NGC 7023, based on high resolution spectroscopy and UBV photometry of its illuminating star, HD 200775.

In spite of the large uncertainty of this value, this is the most frequently cited distance of NGC 7023. Alecian et al. (2008) pointed out that HD 200775 is a spectroscopic binary with two nearly identical components, thus its observed luminosity has to be partitioned on both components, which suggests a distance of about 350 pc. The distance from the *Hipparcos* parallax of HD 200775, 430^{+160}_{-90} pc (van den Ancker et al. 1997) has to be treated with some caution, since part of the measured displacement of the star resulted from its orbital motion. The projected separation of the components, estimated by Alecian et al. (2008), 16 ± 9 mas, commensurates with the measured parallax, and the orbital period of 1412 days suggests that *Hipparcos* might have measured the position of the star at any point of the orbit.

Straizys et al. (1992) determined the visual extinction A_V vs. distance using photometric measurements of 79 stars in the Vilnius photometric system for the L1147/1158 and NGC 7023 (L 1167/1174) regions. They obtained a distance 288 ± 25 pc for NGC 7023, and the same method resulted in 325 ± 13 pc for the L1147/L1158 group.

Snell et al. (1990) studied the interstellar reddening towards L 1235 and pointed out the presence of an absorbing layer at a distance of 200 pc. This value is frequently assumed to be the distance of several other clouds in the region as well (e.g. Benson & Myers 1989).

Kun & Prusti (1993) found a distance of 300 ± 50 pc for L 1251 by examining the interstellar reddening as a function of distance moduli of field stars. Kun (1998) determined distances of dark clouds over the whole area of the Cepheus Flare using Wolf diagrams. The Wolf diagrams indicated that the interstellar matter in the Cepheus Flare is concentrated at three characteristic distances: 200, 300 and 450 pc. The three components, though partly overlapping, can be separated along the Galactic latitude. The three absorbing layers can be identified with Yonekura et al.'s (1997) groups 6, 4, and 1, respectively. The overlap of the layers makes the distance determination of some dark clouds ambiguous. For instance, both the 300 pc and 200 pc layers can be recognized towards L 1228. However, L 1228 differs in radial velocity from the other clouds of the 300 pc component. Moreover, the star BD+76°825 (*spectral type*: F2 V, $B=11.21$, $V=10.62$) is projected within a compact group of pre-main sequence stars of L 1228 and illuminates a faint reflection nebula (Padgett et al. 2004). Thus the photometric distance of this star, 180 pc, is a good estimate of the distance of L 1228. The Cepheus Flare shell, proposed by Olano et al. (2006), may explain the existence of dark clouds at both 200 and 300 pc (see Fig. 5). Table 3 summarizes the results of distance determinations in the Cepheus Flare region. The group of clouds whose distance remains controversial is associated with the negative velocity component at $l \sim 107^\circ - 111^\circ$, $b \sim +13^\circ$.

2.3. Star Formation in the Cepheus Flare

Star formation takes place in dense cores of molecular clouds. Dense cores within dark clouds are usually designated with letters appended to the name of the cloud, e.g. L 1082 A, L 1251 E. Several dense cores and IRAS sources of the Cepheus Flare clouds have been included in large molecular surveys aimed at studying their various properties and the associated young stellar objects. Below we list some major survey papers including key data for Cepheus Flare clouds, cores, and IRAS sources.

Myers et al. (1983) – CO observations (L1152, L1155 H, L1155 D, L1082 C, L1082 A, L1082 B, L1174, L1172 D, L1172 B, L1262 A);

Clemens & Barvainis (1988) – positions, radial velocities, and IRAS associations of

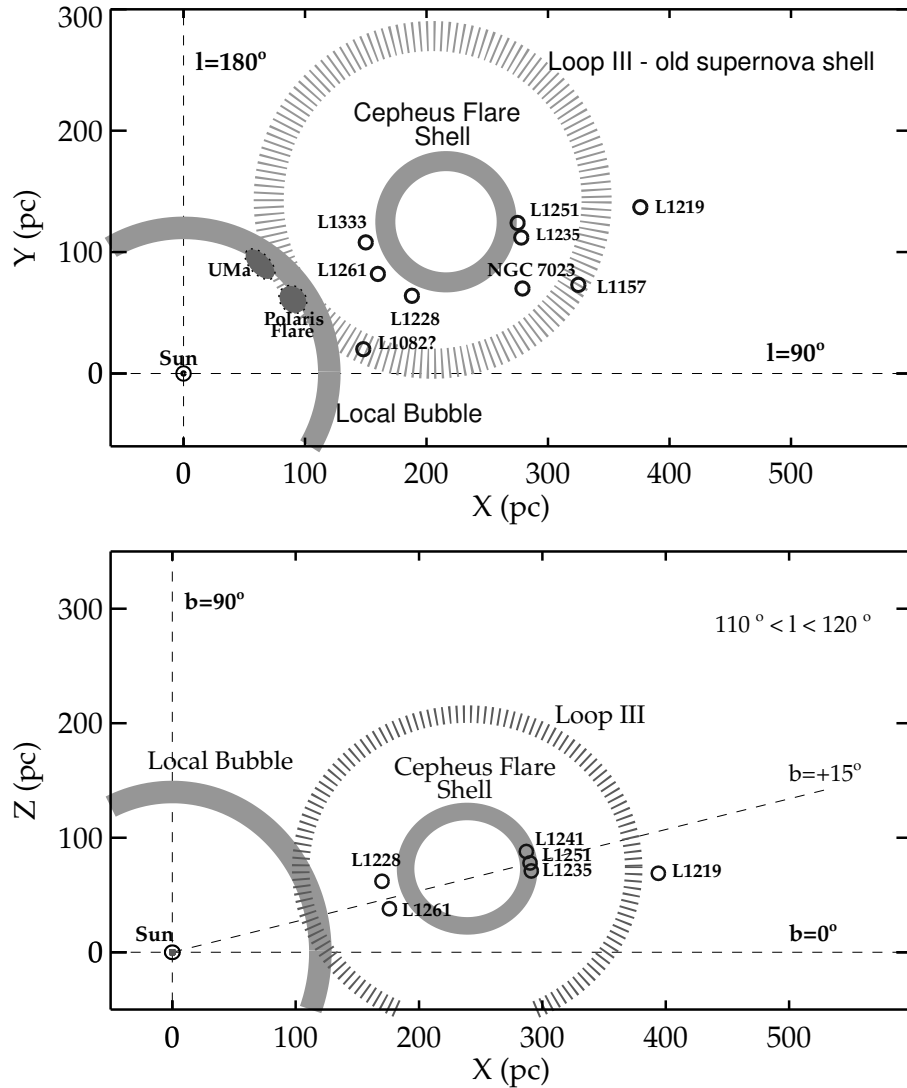


Figure 5. Upper panel: Distribution of the most prominent molecular clouds of the Cepheus Flare and nearby interstellar shells, projected on the Galactic plane, and viewed from the direction of the North Galactic pole. Lower panel: the same objects projected onto a plane perpendicular to the Galactic equator.

small, optically selected molecular clouds (CB 222, CB 224, CB 229 (L1171), CB 230, CB 232, CB 244);

Benson & Myers (1989) – NH_3 observations (L1152, L1155 B, L1155 C, L1155 D, L1155 G, L1158, L1082 C, L1082 A, L1174, L1174 B, L1172 D, L1172 A, L1172 B, L1228 C, L1228 B, L1235, L1251 A, L1262 A);

Goodman et al. (1993) – velocity gradients (L1152, L1082 A, L1082 B, L1082 C, L1174, L1172 A, L1251 A, L1251 E, L1262 A);

Benson et al. (1998) – N_2H^+ , C_3H_2 , and CCS observations (L1155, L1152, L1152 (IR), L1082 A, L1082 C, L1174, L1172 A, L1228, L1228 D, L1221, L1251 A, L1251 E,

L1262);

Myers et al. (1988) – search for outflows (L1152, L1082 A, L1174, L1172 D, L1262);
Fukui (1989) – search for outflows (PV Cep, L1228, L1172, NGC 7129, LkH α 234, L1221, L1251 A, L1251 B, L1262);

Furuya et al. (2003) – search for H₂O masers (L1082, L1082 A, L1082 B, L1228, L1174, L1172 D, L1221, L1251 A, L1251 B, L1262);

Mardones et al. (1997) – search for protostellar infall (IRAS 20353+6742, IRAS 20386+6751, IRAS 21017+6742, IRAS 22343+7501, IRAS 22376+7455, IRAS 23238+7401).

Table 4. Molecular outflows and sources in the Cepheus Flare.

Cloud	RA(2000)	Dec(2000)	Source	References
L 1157	20 39 06	+68 02 13	IRAS 20386+6751	5,17
L 1157	20 45 54	+67 57 39	PV Cep	5,10,12
L 1082	20 47 56.6	+60 04 14	IRAS 20468+5953	22
L 1082	20 51 30.1	+60 18 39	GF9–2	22,23
L 1082	20 53 13.6	+60 14 40	IRAS 20520+6003	22
L 1228 A	20 57 13	+77 35 47	IRAS 20582+7724	5,7,9
L 1228 B	20 57 06	+77 36 56	HH 200 IRS	9
L 1174 A	21 00 22	+68 12 52	L 1174 A	21
L 1172	21 02 24	+67 54 27	IRAS 21017+6742	2, 5,13,
L 1174	21 03 02	+68 06 57	RNO 131A	1,3,20
L 1177	21 17 40	+68 17 32	IRAS 21169+6804	19, 21
L 1183	21 42 57	+66 04 47	RNO 138	1,3,24
L 1183	21 43 01	+66 03 37	NGC 7129 FIRS 2	4,5,8,10
L 1183	21 43 02	+66 06 29	LkH α 234	4,5,8,10
L 1183	21 43 00	+66 11 28	V350 Cep	24
L 1219	22 14 08	+70 15 05	IRAS 22129+7000	14,25
L 1221	22 28 03	+69 01 13	IRAS 22266+6845	6,11,18
TDS 417	22 35 06	+69 10 53	IRAS 22336+6855	6
L 1251 A	22 35 24	+75 17 06	IRAS 22343+7501	5,15
L 1251 B	22 38 47	+75 11 29	IRAS 22376+7455	5,15,16
L 1262	23 25 46	+74 17 33	IRAS 23238+7401	5,17,20

References. 1: Armstrong (1989); 2: Beichman, Myers & Emerson (1986); 3: Cohen (1980); 4: Edwards & Snell (1983); 5: Fukui (1989); 6: Haikala & Dietrich (1989); 7: Haikala & Laureijs (1989); 8: Harvey, Wilking & Joy (1984); 9: Bally et al. (1995); 10: Lada (1985); 11: Lee et al. (2002); 12: Leveault (1984); 13: Myers et al. (1988); 14: Nikolić & Kun (2004); 15: Sato & Fukui (1989); 16: Sato et al. (1994); 17: Terebey et al. (1989); 18: Umemoto et al. (1991); 19: Wang et al. (1995); 20: Wu et al. (1992); 21: Yun & Clemens (1992); 22: Wiesemeyer et al. (1999); 23: Furuya et al. (2006); 24: Liseau & Sandell (1983); 25: Goicoechea et al. (2008).

The Cepheus Flare cloud cores can be found among the targets of infrared, submillimeter and millimeter continuum surveys of embedded low mass young stellar objects as well:

Connelley et al. (2007) – a K-band atlas of reflection nebulae (IRAS 20353+6742, IRAS 20453+6746, IRAS 21017+6742, IRAS 22266+6845, IRAS 22376+7455);

Young et al. (2006) – submillimeter (450 and 850 μ m) survey of cores included in the Spitzer c2d project (L 1152, CB 224, L 1157, L 1082 C, L 1082 A, L 1228, L 1177 (CB 230), L 1221, L 1251 C, L 1251 E, L 1155 C);

Rodríguez & Reipurth (1998) – VLA observations of HH exciting sources (L 1152, L 1157, L 1221).

We find these objects in statistical studies of dense cores and young stellar objects: Fuller & Myers (1992) – line width–size relations (L 1152, L 1262); Myers et al. (1991) – shapes of cores (L 1152, L 1251, L 1262); Wu et al. (2004) – properties of outflows (L 1152, L 1155, L 1082, L 1174, L 1172, L 1228, L 1177, L 1221, L 1251, L 1262); Wu et al. (2007) – submm (350 μ m) survey of cores included in the Spitzer c2d project (L 1152, L 1157, L 1148, L 1177, L 1228, RNO 129, L 1221, L 1251).

The molecular outflows discovered in the Cepheus Flare and their driving sources are listed in Table 4, and the Herbig–Haro objects and driving sources can be found in Table 5.

Figure 3 shows the surface distribution of pre-main sequence stars and candidates in the Cepheus Flare. Apparently star formation occurs in small aggregates, especially along the boundaries of the complex. The central part of the cloud complex contains clouds of low density and is avoided by known signposts of star formation.

The samples of T Tauri stars, displayed in Fig. 3, result from several surveys for H α emission stars conducted in the region of Cepheus Flare. Only 10 pre-main sequence objects are catalogued in the Herbig–Bell Catalog (Herbig & Bell 1988, hereinafter HBC). Ogura & Sato (1990) reported on 69 detected and 49 suspected H α emission stars in a wide environment of L 1228. Kun (1998) reported 142 H α emission stars, distributed over the whole area of the Cepheus Flare, identified on objective prism photographic Schmidt plates and 128 IRAS sources as possible YSOs. Spectroscopic follow up observations of both samples are underway (Kun et al., in preparation). We show in Fig. 3 and list in Table 6 those stars from these two surveys whose pre-main sequence nature has already been confirmed. The known Herbig Ae/Be stars are also listed in Table 6.

Tachihara et al.’s (2005) spectroscopic observations toward the ROSAT X-ray sources resulted in detecting 16 Li-rich stars, representing weak line T Tauri stars. The main properties of these WTTSs are listed in Table 6.

The distribution of the WTTSs in the Cepheus Flare differs from that of other YSOs. In the CO void found by Grenier et al. (1989), a group of WTTSs is separated from the ^{13}CO cloud by $\gtrsim 10$ pc. The cloud-to-WTTS separations are significantly larger in Cepheus than in other nearby SFRs such as Chamaeleon. Because of their grouping, Tachihara et al. propose the in-situ formation model for them. From the total mass of the group of TTSs, a $\sim 800 M_{\odot}$ molecular cloud might have formed them, while only $\sim 200 M_{\odot}$ molecular gas remained in their vicinity. An external disturbance might have dissipated the molecular cloud within several 10^5 yr. As the distances to the WTTSs are unknown, Tachihara et al. suggest two possible scenarios for the history of the formation of the WTTS sample isolated from the cloud complex: (1) The WTTSs in the CO void were formed at 300 pc and affected by the supernova shock discussed by Grenier et al. (1989); or (2) They are at 200 pc and an unknown supernova explosion has the responsibility for the parent cloud dissipation. Radial velocity measurements might help to find the relationship between the stars and the cloud complex. Taking into account the picture of the Cepheus Flare Shell, the same supernova might have triggered star formation at both 200 and 300 pc.

Table 5. Herbig–Haro objects and their sources in the Cepheus Flare.

Name	RA(2000)	Dec(2000)	Source	Cloud	D(pc)	Reference
HH 376B	20 35 06.1	+67 48 47	IRAS 20359+6745	L1152	440	11,13
HH 376A	20 36 02.4	+67 54 28	IRAS 20359+6745	L1152	440	11,13
HH 376	20 36 55.3	+67 59 28	IRAS 20359+6745	L1152	440	15,19
HH 375	20 39 06.2	+68 02 15	IRAS 20386+6751	L1157	440	2,18,19
HH 315C	20 45 06.9	+68 04 50	PV Cep	L1158	500	2,8,13
HH 315	20 45 34.0	+68 03 25	PV Cep	L1158	500	2,8,13
HH 315B	20 45 34.0	+68 03 25	PV Cep	L1158	500	2,8,13
HH 315A	20 45 38.4	+68 00 55	PV Cep	L1158	500	2,8,13
HH 215	20 45 53.8	+67 57 39	PV Cep	L1158	500	10,12,13
HH 415	20 46 04.6	+68 00 28		L1158	500	8,11,16
HH 315D	20 46 06.4	+67 54 13	PV Cep	L1158	500	2,8,13
HH 315E	20 46 28.1	+67 52 20	PV Cep	L1158	500	2,8,13
HH 315F	20 47 09.9	+67 50 05	PV Cep	L1158	500	2,8,13
HHL 65	20 53 06.0	+67 10 00			300	7
HH 199R3	20 54 49.1	+77 32 16	IRAS 20582+7724	L1228	200	4
HH 199R2	20 54 56.2	+77 32 21	IRAS 20582+7724	L1228	200	4
HH 200B6	20 55 09.4	+77 31 20	HH 200 IRS	L1228	200	4
HH 199R1	20 55 12.2	+77 33 11	IRAS 20582+7724	L1228	200	4
HH 200B5	20 55 22.5	+77 32 17	HH 200 IRS	L1228	200	4
HH 200B4	20 55 33.9	+77 33 07	HH 200 IRS	L1228	200	4
HH 200B4a	20 56 11.0	+77 34 18	HH 200 IRS	L1228	200	4
HH 200B3	20 56 22.2	+77 35 01	HH 200 IRS	L1228	200	4
HH 200B2	20 56 35.9	+77 35 34	HH 200 IRS	L1228	200	4
HH 200B1	20 56 51.2	+77 36 21	HH 200 IRS	L1228	200	4
HH 199B1	20 57 27.2	+77 35 38	IRAS 20582+7724	L1228	200	4
HH 199B2	20 57 31.0	+77 35 44	IRAS 20582+7724	L1228	200	4
HH 199B3	20 57 34.1	+77 35 53	IRAS 20582+7724	L1228	200	4
HH 199B4	20 58 21.7	+77 37 42	IRAS 20582+7724	L1228	200	4
HH 199B5	20 59 08.0	+77 39 25	IRAS 20582+7724	L1228	200	4
HH 198	20 59 09.7	+78 22 48	IRAS 21004+7811	L1228	200	4,14,16,17
HH 200R1	20 59 48.2	+77 43 50	HH 200 IRS	L1228	200	4
HH 199B6	21 00 27.4	+77 40 54	IRAS 20582+7724	L1228	200	4
HHL 67	21 05 00.0	+66 47 00			300	7
HH 450	22 14 24.1	+70 14 26	IRAS 22129+7000	L1219	400	5
HH 450X	22 14 50.1	+70 13 47		L1219	400	5
HH 363	22 27 46.7	+69 00 38	IRAS 22266+6845	L1221	200	1,9
HH 149	22 35 24.2	+75 17 06	IRAS 22343+7501	L1251	300	3,13
HH 373	22 37 00.0	+75 15 16		L1251	300	16
HH 374	22 37 39.1	+75 07 31		L1251	300	16
HH 374A	22 37 39.2	+75 07 31		L1251	300	1
HH 374B	22 37 50.0	+75 08 13		L1251	300	1
HH 364	22 38 19.2	+75 13 07		L1251	300	16
HH 189C	22 38 39.4	+75 09 49		L1251	300	6
HH 189	22 38 39.9	+75 10 41	IRAS 22376+7455?	L1251	300	6
HH 189B	22 38 40.0	+75 10 40	KP 44?	L1251	300	6
HH 189E	22 38 40.3	+75 13 52		L1251	300	1
HH 189A	22 38 40.4	+75 10 53		L1251	300	6
HH 189D	22 38 44.2	+75 13 28		L1251	300	1
HH 358	23 24 39.0	+74 12 35		L1262	180	1,16
HH 359	23 26 29.0	+74 22 28		L1262	180	1,16

References. 1: Alten et al. (1997); 2: Arce & Goodman (2002); 3: Balázs et al. (1992); 4: Bally et al. (1995); 5: Bally & Reipurth (2001); 6: Eiroa et al. (1994); 7: Gyulbudaghian et al. (1987); 8: Gómez et al. (1997); 9: Lee et al. (2002); 10: Moreno-Corral et al. (1995); 11: Movsessian et al. (2004); 12: Neckel et al. (1987); 13: Reipurth, Bally, & Devine (1997); 14: Movsessian & Magakian (2004); 15: Rodríguez & Reipurth (1998); 16: Wu et al. (1992); 17: Brugel & Fesen (1990); 18: Devine, Reipurth & Bally (1997); 19: Davis & Eislöffel (1995).

2.4. Notes on Individual Objects

L 1147/L 1158 The cloud group often referred to as the *L 1147/L 1158 complex* consists of the clouds Lynds 1147, 1148, 1152, 1155, 1157, and 1158. L 1157 harbors a Class 0 object, L 1157-mm, with $L_{\text{bol}} \sim 11 L_{\odot}$. It coincides with IRAS 20386+6751 and drives a spectacular outflow. The L 1157 outflow has been studied in detail through many molecular lines, such as CO (Umemoto et al. 1992; Gueth, Guilloteau & Bachiller 1996; Bachiller & Pérez Gutiérrez 1997; Hirano & Taniguchi 2001), SiO (Mikami et al. 1992; Zhang et al. 1995; Gueth, Guilloteau & Bachiller 1998; Zhang, Ho & Wright 2000; Bachiller et al. 2001), H₂ (Hodapp 1994; Davis & Eislöffel 1995), NH₃ (Bachiller et al. 2001; Tafalla & Bachiller 1995; Umemoto et al. 1999), and CH₃OH (Bachiller et al. 1995, 2001; Avery & Chiao 1996). Many other lines have been detected (Bachiller & Pérez Gutiérrez 1997; Bachiller et al. 2001; Beltrán et al. 2004; Benedettini et al. 2007; Arce et al. 2008), making L 1157 the prototype of chemically active outflows. Gas phase shock chemistry models have been used by Amin (2001) to study the production of the observed species in the L 1157 outflow. Arce & Sargent (2006) studied the outflow–envelope interaction on a 10^4 AU scale using high angular resolution multi-line observations. Velusamy et al. (2002) detected spatially resolved methanol emission at 1 mm from L 1157. Their results indicate the presence of a warm gas layer in the infall–disk interface, consistent with an accretion shock. Regarding the protostar itself, dust continuum observations have been carried out at 2.7 mm (Gueth et al. 1996, 1997; Beltrán et al. 2004), 1.3 mm (Shirley et al. 2000; Chini et al. 2001; Gueth, Bachiller & Tafalla 2003; Beltrán et al. 2004), 850 μm (Shirley et al. 2000; Chini et al. 2001; Young et al. 2006), 450 μm (Chini et al. 2001), as well as 60, 100, 160, and 200 μm (Froebrich et al. 2003). Using the VLA, Rodríguez & Reipurth (1998) detected the protostar as a radio continuum source at 3.6 cm. Froebrich et al. (2003) obtained a far-infrared spectrum of the L 1157 protostar using the LWS on board ISO. Deep Spitzer *IRAC* images of L 1157 reveal many details of the outflow and the circumstellar environment of the protostar. Looney et al. (2007) report on the detection of a flattened structure seen in absorption at 8 μm against the background emission. The structure is perpendicular to the outflow and is extended to a diameter of 2 arcmin. This structure is the first clear detection of a flattened circumstellar envelope or pseudo-disk around a Class 0 protostar.

The K' image of the outflow source, presented by Hodapp (1994), is dominated by nebulosity of bipolar morphology, indicative of an in-plane bipolar outflow. Knots of nebulosity extend to the north and south of the outflow position. Both the northern and the southern lobes contain bow shock fronts.

X-ray observations of L 1157, performed by the ASCA satellite, have been published by Furusho et al. (2000).

The molecular cloud L 1155 was mapped by Harjunpää & Mattila (1991) in the lines of C¹⁸O, HCO⁺, and NH₃. The observations revealed that L 1155 consists of two separate clumps, L 1155 C1 and L 1155 C2. The optically visible pre-main sequence star associated with L 1152 is HBC 695 (RNO 124), studied in detail by Movsessian et al. (2004).

Recently Kauffmann et al. (2005), using the data base of the Spitzer Space Telescope Legacy Program *From Molecular Cores to Planet Forming Disks* (c2d, Evans et al. 2003) found a candidate sub-stellar ($M \ll 0.1 M_{\odot}$) mass protostellar object in L 1148. The object L 1148–IRS coincides with IRAS F20404+6712.

Table 6. Weak-line T Tauri stars in the Cepheus Flare (Tachihara et al. 2005)

ID	GSC	RA(2000)	Dec(2000)	Sp. Type	V	$V - I_C$	$M^1(M_\odot)$	Age(My ¹)
4c1	0450001478	00 38 05.4	+79 03 21	K1	10.43	0.92	1.6	2
4c2		00 38 05.4	+79 03 21	K7	13.86	1.77	0.8	15
5c1	0450001549	00 39 06.1	+79 19 10	K6	12.18	1.52	0.6	1
5c2		00 39 06.1	+79 19 10	M2 ²	14.12	2.10	0.4	1
19	0458901101	20 20 29.3	+78 07 22	G8	10.39	0.82	1.6	6
20	0445900083	20 25 15.4	+73 36 33	K0	10.62	0.84	1.6	4
28	0458601090	21 11 29.4	+76 14 29	G8	11.66	0.81	1.0	25
34	0460801986	22 11 11.0	+79 18 00	K7	13.09	1.55	0.7	3
36c1	0427200174	22 27 05.3	+65 21 31	K4	12.92	1.13	0.9	20
36c2		22 27 05.3	+65 21 31	M4 ²	15.55	2.50	0.2	0.2
37c1	0448000917	22 33 44.9	+70 33 18	K3	11.63	1.65	1.0	0.4
38	0460400743	22 39 58.1	+77 49 40	K2	11.88	1.03	1.2	8
40	0460502733	23 00 44.4	+77 28 38	K0	10.98	0.88	1.4	6
41	0460500268	23 05 36.1	+78 22 39	K6	13.19	1.59	0.8	7
43c1	0448900036	23 09 43.4	+73 57 15	K7	13.21	1.86	0.3	4
43c2		23 09 43.4	+73 57 15	M3 ²	15.55	2.50	0.7	3
44	0460500170	23 16 18.1	+78 41 56	K4	11.77	1.24	1.0	2
45	0447900348	23 43 41.9	+68 46 27	K2	12.64	1.00	0.9	25
46	0461001318	23 51 10.0	+78 58 05	K1	11.34	0.93	1.3	6

¹Derived from the evolutionary tracks by D’Antona & Mazzitelli (1994).

²Derived only from the $V - I_C$ color.

PV Cep The highly variable pre-main sequence star PV Cep lies near the northeastern edge of the dark cloud complex L 1147/L 1158. It is a bright IRAS source, and has been detected in radio continuum (Anglada et al. 1992). It illuminates a reflection nebula, known as GM–29 (Gyulbudaghian & Magakian 1977) and RNO 125 (Cohen 1980). A dramatic brightening of the star (an EXor-like outburst) was observed in the period 1976–1978, and at the same time the shape of the associated nebula changed drastically (Cohen, Kuhl & Harlan 1977).

The stellar parameters of PV Cep are somewhat uncertain. Most of its optical spectrograms available show no photospheric absorption features. Cohen et al. (1977), based on measurements of narrow-band continuum indices, estimated a spectral type about A5. Cohen et al. (1981) found the same spectral type based on the strength of the H δ absorption line, apparent in two blue spectra. They note, however, that the hydrogen features probably represent merely a shell spectrum. Magakian & Movsessian (2001) estimated a spectral type of G8–K0, based on a spectrum taken in July 1978, when the star was some 2 magnitudes fainter than during the outburst. No other estimate of spectral type can be found in the literature (see Hernández et al. 2004, for a review). The spectral type of F, quoted by Staude (1986) and Neckel et al. (1987) is also based on the spectral information presented by Cohen et al. (1981).

Cohen et al. (1981) found a distance of about 500 pc for PV Cep. Their estimate was based on three independent arguments. (1) PV Cep is probably related to NGC 7023. The spectroscopic and photometric data of its illuminating star, HD 200775, suggest a distance of 520 pc. (2) The spectroscopic and photometric data of the nebulous star RNO 124, located in the same cloud complex as PV Cep, suggest the same distance. (3) A similar distance can be obtained from the light travel time from the star to a nebular spike which brightened about a year after the outburst of the star. On the contrary, Straizys et al. (1992) obtained a distance of 325 pc for the L 1147/L 1158 dark cloud complex (see Table 3).

The environment of the star shows a bipolar and rapidly changing optical morphology (Cohen et al. 1981; Neckel & Staude 1984; Staude 1986; Neckel et al. 1987; Levreault & Opal 1987; Scarrott et al. 1991a,b), as well as a bipolar CO outflow parallel to the symmetry axis of the reflection nebula (Levreault 1984). Neckel et al. (1987) detected several HH-knots, known as HH 215, emanating from PV Cep. Reipurth, Bally, & Devine (1997) and Gómez, Kenyon & Whitney (1997) discovered a giant (~ 2.3 pc long) Herbig-Haro flow, HH 315, consisting of 23 knots. HH 215 is also part of this giant flow. Reipurth, Bally, & Devine (1997) detected a further small knot, HH 415, located north-east of PV Cep, but this may be a dwarf galaxy with $H\alpha$ redshifted into the [SII] passband (Bally, priv. comm.). Near-infrared spectroscopy of PV Cep is presented by Hamann & Persson (1994) and Greene & Lada (1996), and optical spectroscopy by Corcoran & Ray (1997).

Far-infrared data obtained by ISOPHOT (Ábrahám et al. 2000) indicate the presence of an extended dust component on arcminute scale around PV Cep. The existence of a dust core close to PV Cep is also supported by the ^{13}CO ($J=1-0$) mapping of the region by Fuente et al. (1998b), who found a molecular core with a size of some $60''$.



Figure 6. Optical image of a field of $36' \times 24'$ of L 1082, obtained by Giovanni Benintende (<http://www.astrogb.com/>).

L 1082 is a remarkable filamentary cloud (see Fig. 6), first catalogued by E. E. Barnard (1927) as Barnard 150. It appears as GF 9 in the catalog of globular filaments by Schneider & Elmegreen (1979). Several dense cores, namely L 1082 A,B,C (Myers et al. 1983), and LM99 349, 350, 351 ($\equiv$ L 1082 C), 352 (Lee & Myers 1999), as well as four IRAS sources, IRAS 20468+5953, 20503+6006, 20520+6003, and 20526+5958 are found along the filament. A finding chart for the objects in L 1082 is given in Figure 7.

No distance determination is available in the literature for L 1082. Several authors assume that L 1082 is close to NGC 7023 not only on the sky, but also in space, and thus accept 440 pc as its distance (e.g. Ciardi et al. 1998). We note that the angular separation of 10° between NGC 7023 and L 1082 corresponds to 70 pc at the distance of NGC 7023. If both objects belong to the same complex, a similar difference can be expected between their distances. Wiesemeyer et al. (1997), based on statistical arguments, assume a distance of 100 ± 50 pc. Furuya et al. (2003) refer to 150 pc, and Furuya et al. (2006) derive the physical parameters of GF 9–2 using 200 pc. Kun (2007) speculates that L 1082 may lie at the interaction region of the Local Bubble and Loop III (Cepheus Flare Shell). In this case its likely distance is about 150 pc.

Ciardi et al. (1998) performed near-infrared observations of a core and a filament region within GF 9 (GF 9-Core and GF 9-Fila, see Fig. 7). They found that neither the core nor the filament contains a Class I or Class II YSO. The extinction maps of the two $7' \times 7'$ fields observed reveal masses 26 and $22 M_\odot$ in the core and the filament, respectively (at a distance of 440 pc). The core contains a centrally condensed extinction maximum that appears to be associated with IRAS 20503+6006, whereas GF 9-Fila does not show centrally peaked dust distribution.

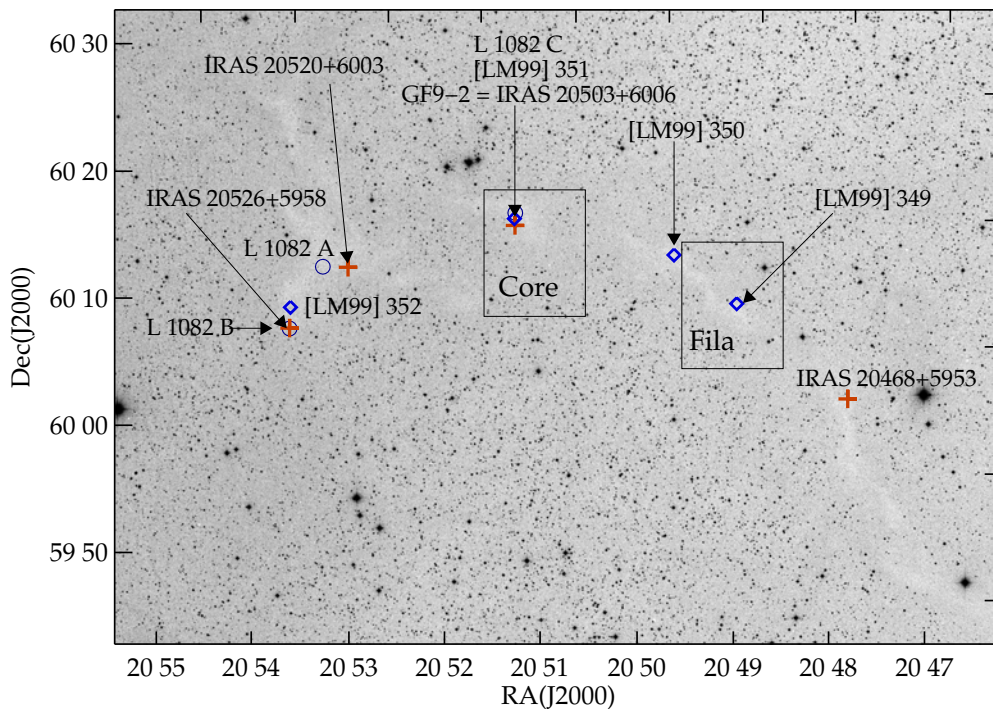


Figure 7. Finding chart for the structure of L 1082, based on Poidevin & Bastien's (2006) Fig. 1 and Wiesemeyer et al.'s (1998) Fig. 1. Crosses indicate the positions of the IRAS and ISOCAM point sources, open circles mark the dense cores L 1082 A, B, and C (Benson & Myers 1989), diamonds show the dense cores catalogued by Lee & Myers (1999). Two rectangles show the regions GF 9 Core and GF 9 Fila, studied in detail by Ciardi et al. (1998; 2000). The size of the underlying DSS red image is $70' \times 50'$.

Wiesemeyer et al. (1998) presented mid-infrared ISOCAM observations of L 1082. They identified 9 sources along the filament, and designated them as GF 9–1, 2, 3a, 3b, 4, 5, 6, I6, and 7. The designations probably follow Mezger (1994) who labeled dense cores along the filament by the same numbers. GF 9–2 coincides in position with IRAS 20503+6006, GF 9–3b with IRAS 20520+6003, GF 9–I6 with IRAS 20468+5953, and GF 9–4 lies at 12'' west of IRAS 20526+5958. They find that these latter two sources are Class 0 protostars, both associated with CO outflows, whereas GF 9–6 and GF 9–7 are most likely reddened background stars. They speculate that the other ISOCAM sources, not associated with outflows, may be transitional objects between prestellar (Class –1) and Class 0 evolutionary stages. Wiesemeyer et al. (1999) presented far-infrared ISOPHOT and millimeter continuum measurements for GF 9–2, GF 9–3a/3b, and GF 9–4.

Ciardi et al. (2000) performed CO, ^{13}CO , and CS observations of the GF 9–Core and GF 9–Fila regions, determined excitation temperatures, densities and masses. The CS observations reveal that both regions contain centrally condensed, high-density gas cores. The temperatures and masses of the two regions and of the cores contained within the regions are similar, but the densities in GF 9–Core are twice those of GF 9–Fila.

De Gregorio Monsalvo et al. (2006) detected CCS emission from GF 9–2. The structure of the magnetic field associated with GF 9 was studied by Jones (2003) and Poidevin & Bastien (2006).

Furuya et al. (2003) detected H_2O maser emission from GF 9–2. Furuya et al. (2006) studied in detail the spatial and velocity structure of GF 9–2, using several molecular transitions obtained by single-dish and interferometric radio observations and 350 μm continuum data. The observations revealed a dense core with a diameter of ~ 0.08 pc and mass of $\sim 3 M_\odot$. Within the core a protostellar envelope with a size of ~ 4500 AU and mass of $\sim 0.6 M_\odot$ could be identified. The radial column density profile of the core can be well fitted by a power-law form of $\rho(r) \propto r^{-2}$ for the $0.003 < r/\text{pc} < 0.08$ region. The power-law index of -2 agrees with the expectation for an outer part of the gravitationally collapsing core. They found no jet-like outflow, but a compact, low-velocity outflow may have formed at the center. They discovered a potential protobinary system with a projected separation of ~ 1200 AU, embedded in a circumbinary disk-like structure with ~ 2000 AU radius at the core center. The binary consists of a very young protostar and a pre-protostellar condensation. The studies led to the conclusion that GF 9–2 is very likely at an extremely early stage of low-mass star formation before arriving at its most active outflow phase.

Stecklum, Meusinger & Froebrich (2007) discovered 14 Herbig–Haro objects in the GF 9 region which apparently belong to at least three large HH-flows. Five HH-objects and GF 9–2 are linearly aligned, suggesting that they constitute an HH-flow driven by IRAS 20503+6006. Its overall length amounts to 43.5 arcmin, which corresponds to 2.3 pc for an assumed distance of 200 pc. The presence of a well-developed, parsec-scale outflow from GF 9–2 indicates a more advanced evolutionary stage of this source than previously believed.

Furuya et al. (2008) mapped GF 9 in the NH_3 (1,1) and (2,2) inversion lines, using the Nobeyama 45-m telescope, with an angular resolution of 73''. The large-scale map reveal that the filament contains at least 7 dense cores, as well as 3 candidates, located at regular intervals of ~ 0.9 pc (at an assumed distance of 200 pc). The cores have kinetic temperatures of $\lesssim 10$ K and LTE-masses of $1.8 - 8.2 M_\odot$, making them typical

sites of low-mass star formation, probably formed via the gravitational fragmentation of the natal filamentary cloud.

NGC 7023 is a reflection nebula, illuminated by the young massive star HD 200775 and a group of fainter stars. It was discovered by William Herschel in 1794. HD 200775 (also known as V380 Cep and HBC 726) is a Herbig Be star that has been extensively studied (e.g. Herbig 1960; Altamore et al. 1980; Pogodin et al. 2004; Alecian et al. 2008). The surrounding reflection nebula has been observed in detail (e.g. Slipher 1918; Witt & Cottrell 1980; Witt et al. 1982; Rogers et al. 1995; Laureijs et al. 1996; Fuente et al. 2000; Werner et al. 2004; Berné et al. 2008). Figure 8 shows an optical image of the reflection nebula.



Figure 8. Optical image of NGC 7023, illuminated by the Herbig Be star HD 200775. The size of the field is about $30' \times 20'$. Courtesy of Richard Gilbert of the Star Shadows Remote Observatory.

Weston (1953) found that, centered on the reflection nebula, there is a small cluster consisting of stars which are variable and show $H\alpha$ line in emission. Some two dozens of variable stars of the region were studied by Rosino & Romano (1962). Nevertheless, the HBC lists only four of these stars (HBC 726, 304, 306, 307, see Table 6) as confirmed T Tauri type stars. Recently Goodman & Arce (2004) speculated that the young Herbig Ae star PV Cep, located more than 10 pc to the west of the cluster, might have been ejected from NGC 7023 at least 100,000 years ago. HD 200775 is located at the northern edge of an elongated molecular cloud, corresponding to the dark clouds L 1167, 1168, 1170, 1171, 1172, 1173 and 1174, referred to as the *L 1167/L 1174 complex*. The cloud complex has been mapped in CO by Elmegreen & Elmegreen (1978). They found that the size of the cloud is $0.5^\circ \times 1.0^\circ$, or $3.9 \text{ pc} \times 7.7 \text{ pc}$, and the mass of the molecular hydrogen is some $600 M_\odot$.