Handbook of Star Forming Regions
ASP Conference Series, Vol. ..., 2007
Bo Reipurth, ed.

The Lacerta OB1 Association

W. P. Chen[1] and H. T. Lee[1,2]

[1]*Institute of Astronomy and Department of Physics, National Central University, 300 Jhongda Road, Jhongli 32054, Taiwan*

[2]*Institute of Astronomy and Astrophysics, Academia Sinica, P.O. Box 23–141, Taipei 10617, Taiwan*

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 Strömgren 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 Hβ 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 $\sim$ 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 = $22^{\rm h}35^{\rm m}$ and Decl = $+43\overset{\circ}{.}3$, 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 $(\ell, b) = (97\overset{\circ}{.}0, -15\overset{\circ}{.}5)$, 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* members 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 for Lac OB1 of the following parameters: (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: $\mu_\ell \cos b = -2.3\pm0.1$ mas yr^{-1}, and $\mu_b = -3.4\pm0.1$ mas yr^{-1}. (3) Radial velocity: Bijaoui, Lacoarret & Granes (1981) obtained the peak around $v_{\rm rad}$(LSR) ~ -15 km s^{-1}, whereas the *Hipparcos* Input Catalogue gave an average of $v_{\rm rad} = -13.3$ km s^{-1}. (4) Expansion age: 2.5±0.5 Myr (Lesh 1969). (5) Stellar rotation: Abt & Hunter (1962). (6) Photometric (e.g., *uvby*, Crawford & Warren 1976) and spectroscopic (e.g., Coyne et al. 1969, Levato & Abt 1976, Guetter 1976) studies. Also useful is the review by Garmany (1994) on the physical properties and dynamical evolution of OB associations, including Lac OB1.

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 LkHα 233 (= V375 Lac), a Herbig Ae star (Hernández et al. 2004) showing Hα, [O I] 6300 Å, and [S II] 6717 Å emission lines in the spectrum (Lee & Chen 2007). LkHα 233 was noticed by Herbig (1960) to be an Ae/Be star associated with nebulosity that was later resolved by near-infrared speckle interferometry to be $\sim$ 1000 AU in size (Leinert, Haas, & Weitzel 1993). Given $m_{\rm V} = +13.8$ and assuming a luminosity class V (which is not appropriate for a PMS star), hence $M_{\rm V} = +2.3$, Odenwald (1988) estimated a distance 140–860 pc to LkHα 233, depending on the adopted

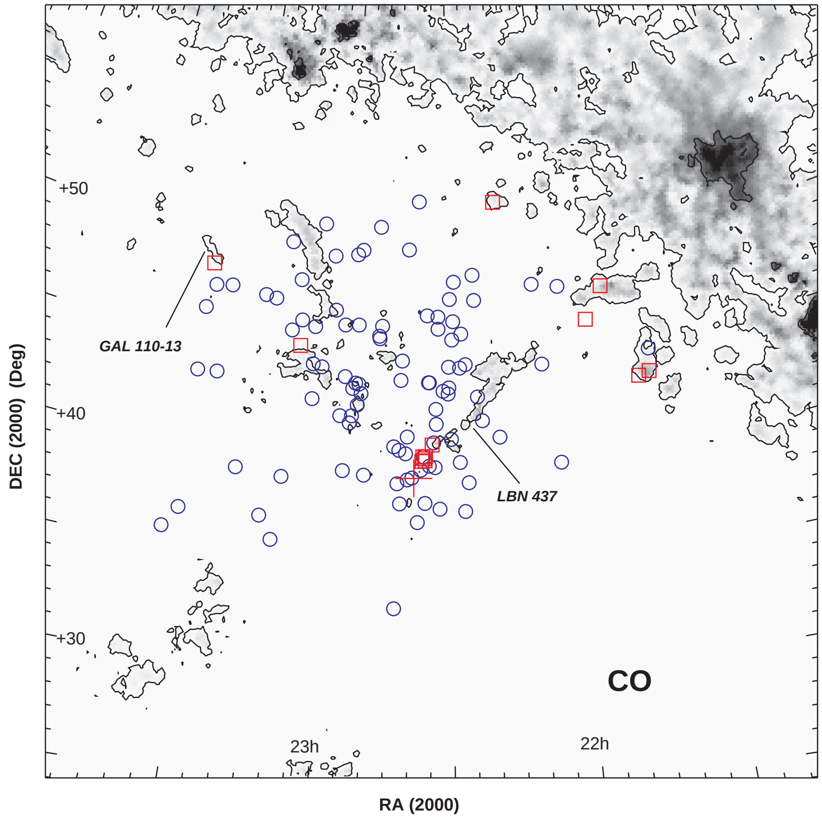

Figure 1. CO emission in Lac OB1 (Dame et al. 2001). The circles mark the positions of *Hipparcos* member stars (de Zeeuw et al. 1999), and the boxes represent CTTSs and Herbig Ae/Be stars (Lee & Chen 2007). The O star 10 Lac is indicated by a cross. The Galactic plane is seen on the upper right. The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

value of optical extinction. Fig. 3 shows the region around LKHα 233 and other fainter emission-line stars LkHα 230, LkHα 231, LkHα 232, and the luminous star HD 213976 (Herbig 1960). The association of LkHα 233 with Lac OB1, however, should be taken with caution because of the very different proper motions of LkHα 233 $(\mu_\alpha \cos\delta, \mu_\delta) = (-18, 13)$ mas yr^{-1} (Ducourant et al. 2005), from those of 10 Lac $(0, -8)$, or of Lac OB1b $(0, -5)$ (Lee & Chen 2007) (see Table 1.)

LkHα 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 $\sim 65°/245°$ (McGroarty et al. 2004, see Fig. 4). Note that McGroarty et al. (2004) adopted a distance of 880 pc to LkHα 233, apparently taken from Calvet & Cohen (1978) based on the inference that the B1.5 V star HD 213976, with $m_{\rm V} = 7.0$ and a distance modulus of 9.6, has a negligible extinction $A_{\rm V} \sim 0.42$ (Aspin, McLean, & McCaughrean 1985), so it should be in front of the dark cloud. In such a case, the cloud, and hence

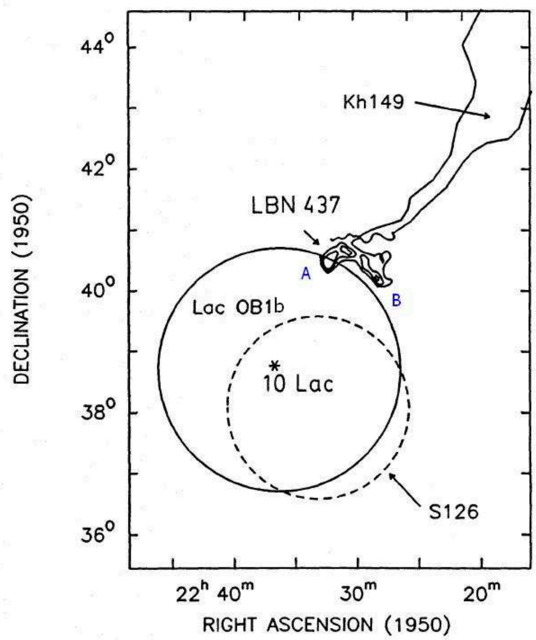

Figure 2. Schematic of Lac OB1 near the LBN 437 cloud (modified from Olano et al. 1994). Condensations A and B at the southern end of LBN 437 are marked.

LkHα 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 LkHα 233 outflows derived by McGroarty et al. (2004) should be considerably shorter—but still on parsec scales. Most HH outflows are excited by low-mass PMS stars, so the ones associated with LkHα 233 (mass $\sim 4M_\odot$, Perrin & Graham 2007) are among the rarities to be related to intermediate-mass PMS stars (McGroarty et al. 2004). LkHα 233 is among the Herbig Ae/Be stars that show the 10-μm silicate feature in absorption (Hanner, Brooke, & Tokunaga 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 LkHα 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 $\lesssim 0\farcs1$, yielded physical parameters, such as electron density, temperature, and ionization fraction in the bipolar jet of LkHα 233 that are scaled up from those in T Tauri stars (Melnikov et al. 2007). LkHα 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). LkHα 233 is located near the edge of LBN 437 and, being the exciting source of Herbig-Haro objects, conceivably should be among

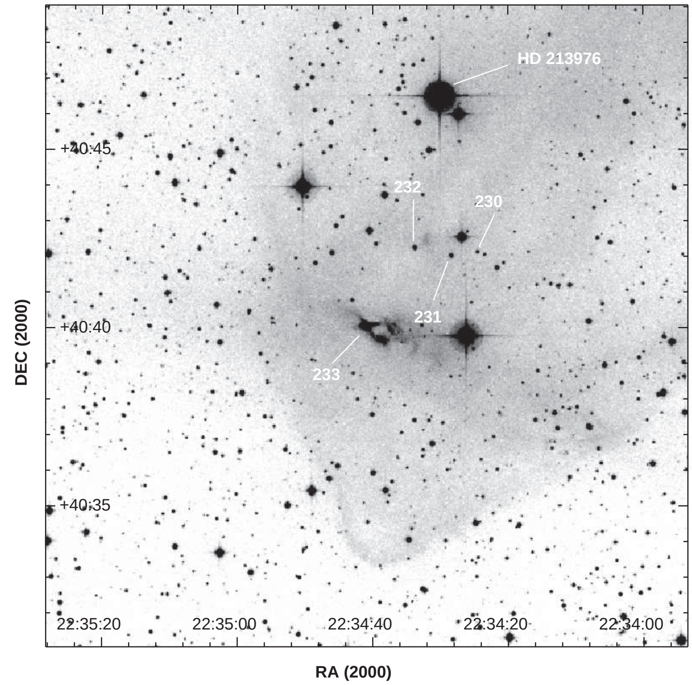

Figure 3. DSS-2 red image of the region around LkHα 233 and other emission-line stars, each labeled with its LkHα number, and the luminous star HD 213976.

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 (Bertoldi 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 = $23^{\rm h}37^{\rm m}38\overset{\rm s}{.}5$, Decl = $+48^\circ24'12''$, 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 ($\sim$ 440 pc, Aveni & Hunter 1969), cloud radial velocity ($\sim$ 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.

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

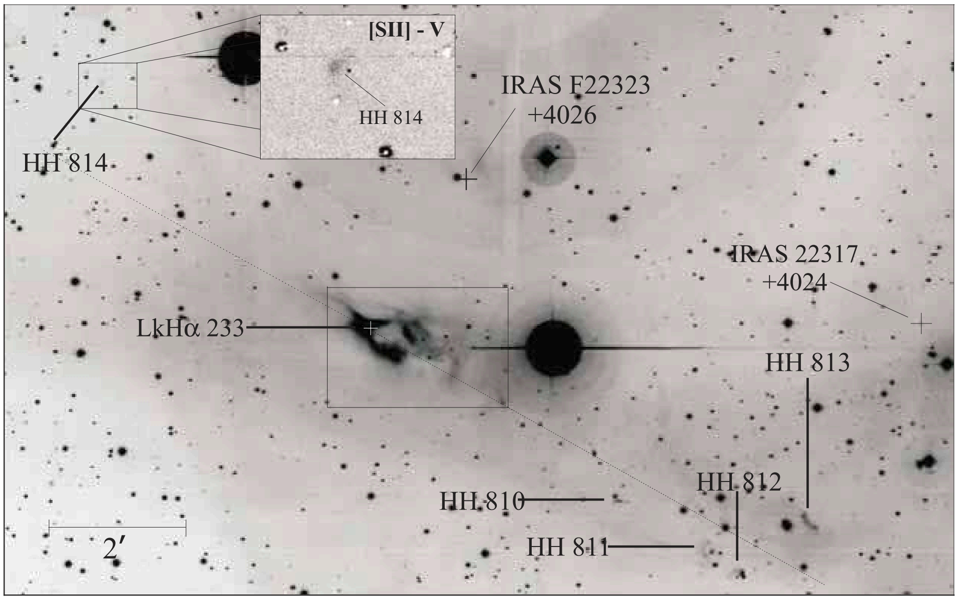

Figure 4. [S II] image of the LkHα 233 region, taken from McGroarty et al. (2004). Herbig-Haro objects and IRAS sources are labeled. The straight line depicts the major axis of the outflow at 62°. The inset shows the continuum subtracted ([S II]-V) image of HH 814.

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).

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 Hα 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 $\sim$ 3.6 Myr for 10 Lac (Schaerer & de Koter 1997) and the typical age of a few Myr for the CTTSs 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

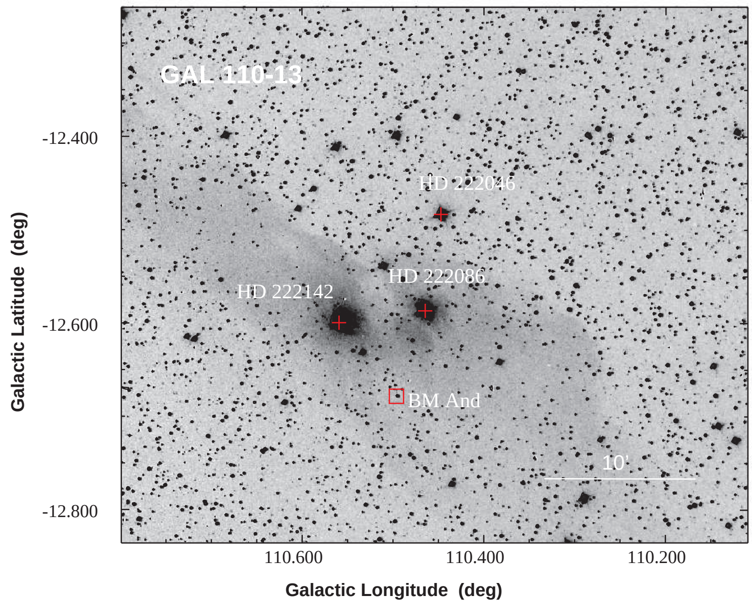

Figure 5. DSS blue image of GAL 110−13, shown in Galactic coordinates. BM And and three late-B stars are marked.

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 H I gas around S 126 where 10 Lac and other luminous stars are located (Cappa de Nicolau & Olano 1990). On the other hand, Lac OB1a, if it is a real association, seems to contain some PMS stars and therefore represents a generation of stars younger than—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

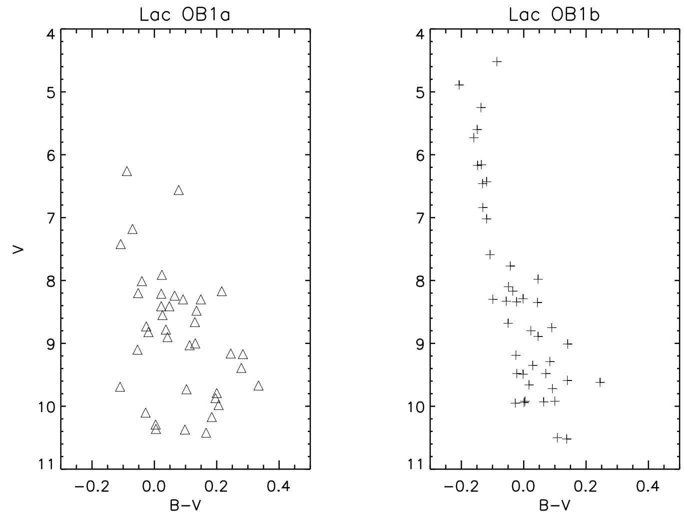

Figure 6. Color-magnitude diagrams for the subgroups Lac OB1a and Lac OB1b reconstructed from de Zeeuw et al. (1999) for stars having $B-V <$ 0.4 mag.

(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 away, the triggering appears to have far-reaching influence. The Lac OB1 association, with much of cloud material already dissipated, is clearly ending its star-formation activity, and stages an interesting case of starbirth sequence in an OB association.

Acknowledgments. We thank Carlos Olano for very useful comments that much improved the quality of the article. This work has made use of the NASA's Astrophysics Data System, and of the SIMBAD database, operated at CDS, Strasbourg, France. The grant NSC-95-2745-M-008-002 is acknowledged.

References

Abt, H. A., & Hunter, J. H. 1962, ApJ, 136, 381
Aspin, C., McLean, I. S., & McCaughrean, M. J. 1985, A&A, 144, 220
Aveni, A. F. & Hunter, J. H. 1969, AJ, 74, 1021
Bertoldi, F. 1989, ApJ, 346, 735
Bertoldi, F. & McKee, C. F. 1990, ApJ, 354, 529
Bijaoui, A., Lacoarret, M., & Granes, P. 1981, A&AS, 45, 483
Blaauw, A. 1958, AJ, 63, 186
Blaauw, A. 1961, Bull. Astron. Inst. Netherlands, 15, 265
Blaauw, A. 1964, ARA&A, 2, 213
Blaauw, A. 1991, in *The Physics of Star Formation and Early Stellar Evolution*, eds. C. J. Lada & N. D. Kylafis (Dordrecht:Kluwer), 125
Blaauw, A. & Morgan, W. W. 1953, ApJ, 117, 256
Bowey, J. E., Adamson, A. J., & Yates, J. A. 2003, MNRAS, 340, 1173
Calvet, N. & Cohen, M. 1978, MNRAS, 182, 687

Cappa de Nicolau, C. & Olano, C. A. 1990, Rev. Mex. Astron. Astrof., 21, 269
Chen, W. P., Lee, H. T., & Sanchawala, K. 2007, in *Triggered Star Formation in a Turbulent ISM*, eds. B. G. Elmegreen & J. Palous, IAU Symposium 237, p. 278
Clark, P. C., Bonnell, I. A., Zinnecker, H. & Bate, M. R. 2005, MNRAS, 359, 809
Corcoran, M., & Ray, T. P. 1998, A&A, 336, 535
Coyne, G., Berley-Mead, J. & Kaufman, M. 1969, AJ, 74, 103 (see also NASA Technical Note D-5060)
Crawford, D. L. 1961, ApJ, 133, 860
Crawford, D. L. & Warren, W. H. 1976, PASP, 88, 930
Dame, T. M., Hartmann, Dap, Thaddeus, P. 2001, ApJ, 547, 792
de Zeeuw, P. T., Hoogerwerf, R., de Bruijne, J. H. J., Brown, A. G. A. & Blaauw, A. 1999, AJ, 117, 354
Dieter, N. H. 1960, ApJ, 132, 49
Ducourant, C., Teixeira, R., Périé, J. P., Lecampion, J. F., Guibert, J., & Sartori, M. J. 2005, A&A, 438, 768
Finkbeiner, D. P. 2003, ApJS, 146, 407
Garmany, C. D. 1994, PASP, 106, 25
Gies, D. R. & Bolton, C. T. 1986, ApJS, 61, 419
Guetter, H. H. 1976, AJ, 81, 1120
Hanner, M. S., Brooke, T. Y., & Tokunaga, A. T. 1998, ApJ, 502, 871
Herbig, G. H. 1960, ApJS, 4, 337
Hernández, J., Calvet, N., Briceño, C., Hartmann, L., & Berlind, P. 2004, AJ, 127, 1682
Hernández, J., Calvet, N., Hartmann, L., Briceno, C., Sicilia-Aguilar, A., & Berlind, P. 2005, AJ, 129, 856
Hester, J. J. & Desch, S. J. 2005, in *Chondrites and the Protoplanetary Disk*, eds. Alexander N. Krot, Edward R. D. Scott, & Bo Reipurth, ASP Conf. Ser. 341, 107
Howard, W. E. 1958, AJ, 63, 50
Khavtassi, J. 1960, *Atlas of Galactic Dark Nebulae* (Abastumani, USSR: Abastumani Astrophysical Observatory)
Lee, H.-T., Chen, W. P., Zhang, Z. W. & Hu, J. Y. 2005, ApJ, 624, 808
Lee, H.-T. & Chen, W. P. 2007, ApJ, 657, 884
Leinert, Ch., Haas, M., & Weitzel, N. 1993, A&A, 271, 535
Lesh, J. R. 1969, AJ, 74, 891
Levato, H. & Abt, H. A. 1976, PASP, 88, 141
Lindblad, P. O., Grape, K., Sandqvist, A., & Schober, J. 1973, A&A, 24, 309
Lynds, B. T. 1965, ApJS, 12, 163
McGroarty, F., Ray, T. P. & Bally, J. 2004, A&A, 415, 189
Melnikov, S., Woitas, J., Eislöffel, J., Bacciotti, F., Locatelli, U., & Ray, T. P. 2007, A&A, in press.
Odenwald, S. F. 1988, ApJ, 325, 320
Odenwald, S., Fischer, J., Lockman, F. J. & Stemwedel, S. 1992, ApJ, 397, 174
Olano, C. A. 1982, A&A, 112, 195
Olano, C. A., Walmsley, C. M. & Wilson, T. L. 1994, A&A, 290, 235
Perrin, M. D., & Graham, J. R. 2007, astro-ph 0707.2394
Raimond, E. 1957, Bull. Astron. Inst. Netherlands, 13, 269
Schaerer, D. & de Koter, A. 1997, A&A, 322, 598
Shapless, S. 1959, ApJS, 4, 257
Strömgren, B. 1952, AJ, 57, 196 (Yerkes Observatory Report)
Sugitani, K., Fukui, Y., & Ogura, K. 1991, ApJS, 77, 59
van den Bergh, S. 1957, ApJ, 126, 323
White, G. J., Casali, M. M. & Eiroa, C. 1995, A&A, 298, 594
Whitney, B. S. 1949, ApJ, 109, 540

Table 1. Kinematic Members of Lac OB1

ID	RA (J2000) h m s	Decl. (J2000) ° ′ ″	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 22 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 (J2000) h m s	Decl. (J2000) ° ′ ″	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+40 4771
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+48 3697
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+46 3676
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+45 3940
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+40 4831
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+42 4429
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	Ap	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+40 4852
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+51 3434, 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+36 4896
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+38 4834
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	$\mu_\alpha \cos\delta$ 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