PASJ: Publ. Astron. Soc. Japan **59**, 199–204, 2007 February 25

Age Sequence in Small Clusters Associated with Bright-Rimmed Clouds

Katsuo OGURA,[1] Neelam CHAUHAN,[2] Anil K. PANDEY,[2] Bhuwan C. BHATT,[3] Devendra OJHA,[4]
and Yoichi ITOH[5]
[1]*Kokugakuin University, Higashi, Shibuya-ku, Tokyo 150-8440*
ogura@kokugakuin.ac.jp
[2]*Aryabhatta Research Institute of Observational Sciences, Manora Peak, Naini Tal - 263 129, India*
[3]*CREST, Indian Institute of Astrophysics, Shidlaghatta Road, Hosakote - 562 114, India*
[4]*Tata Institute of Fundamental Research, Homi Bhabha Road, Colaba, Mumbai - 400 005, India*
[5]*Graduate School of Science and Technology, Kobe University, 1-1 Rokkodai, Nada, Kobe, Hyogo 657-8501*

(Received 2006 October 10; accepted 2006 November 16)

Abstract

Bright-rimmed clouds (BRCs) found in H II regions are probable sites of triggered star formation due to compression by ionization/shock fronts, and it is hypothesized that star formation proceeds from the exciting star(s) side outward of the H II region ("*small-scale sequential star formation*"). In order to quantitatively test this hypothesis we undertook $BVI_{\rm c}$ photometry of four BRC aggregates. The amounts of interstellar extinction and reddening for each star were estimated by using $JHK_{\rm s}$ photometry. We then constructed reddening-corrected $V/V-I_{\rm c}$ color–magnitude diagrams, where the age of each star was derived. All of the stars turned out to be a few tenths to a few Myr old. Although the scatters were large and the numbers of the sample stars are small, we found a clear trend that the stars inside or in the immediate vicinity of the bright rim are younger than those outside it in all four aggregates, confirming the hypothesis in question.

Key words: Galaxy: open clusters and associations: general — ISM: globules — ISM: H II regions — stars: formation — stars: pre-main sequence

1. Introduction

Bright-rimmed clouds (BRCs), or cometary globules, correspond to relatively dense clumps in a giant molecular cloud left unionized during the course of expansion of the H II region. They are therefore a sort of remnants of star-formation activity in giant molecular clouds. However, at the same time, they are current sites of star formation. Theoretically, triggered star formation caused by the compression of gas due to shock is expected to take place in such a pre-existing dense clump in an H II region. This phenomenon is called radiation-driven implosion (RDI), and detailed model calculations were carried out by several authors (e.g., Bertoldi 1989, Lefloch & Lazareff 1994, Miao et al. 2006). Many molecular line and radio continuum observations of BRCs (Lefloch & Lazareff 1995, Lefloch et al. 1997, De Vries et al. 2002, Thompson et al. 2004a, 2004b, Thompson & White 2004, Morgan et al. 2004, Urquhart et al. 2006) show that the overall morphology and some of their physical properties are consistent with those of the RDI models.

Actually, many BRCs are associated with signposts of recent and ongoing star formation, such as Herbig–Haro objects and IRAS point sources of low temperature that meet the YSO criteria of, e.g., Carpenter, Heyer, and Snell (2000). Sugitani, Fukui, and Ogura (1991) and Sugitani and Ogura (1994) compiled catalogs (the so-called SFO Catalog) of altogether 90 BRCs associated with such IRAS point sources for the northern and southern skies, respectively. Subsequent near-IR (*JHK*) imaging observations of many of the BRCs in the above-mentioned catalogs revealed that an elongated, small cluster or aggregate of YSOs is often associated with them (Sugitani et al. 1995). Interestingly, "redder" stars tend to be located inside the BRC and closer to the IRAS source, which corresponds to the reddest source and lies at the innermost end of the aggregate; "bluer" stars tend to lie outside the cloud on the side of the O star(s) exciting the H II region. These results led them to advocate the "small-scale sequential star-formation (hereafter, S^4F) hypothesis" that a BRC undergoes a few or several star-formation events due to RDI always at its head part, which is located closer to the exciting stars(s) first, but then recedes outward in the H II region as the star formation proceeds, leaving a group of stars aligned in an age sequence.

With the aim to strengthen the S^4F hypothesis, Ogura, Sugitani, and Pickles (2002) conducted grism surveys of 24 BRCs for Hα emission stars. Altogether 460 Hα emission stars and 12 Herbig–Haro objects have been detected in their vicinities. Presumably, these Hα emission stars are mostly T Tauri stars (TTSs), although practically no follow-up observations have yet been made for them. These objects are found to be concentrated toward the head, or just outside of, BRCs on the side of the exciting star(s). One may suspect that there might be just as many such stars farther inside the BRCs, but concealed by the higher extinction. However, this does not appear to be likely, because, as we show in section 4, the A_V values of the Hα emission stars inside, e.g., BRC 14, are not much larger than those outside of it. In addition in figures 1a to 1z of Ogura, Sugitani, and Pickles (2002) we have not found many faint (Hα emission) stars inside BRCs. We thus think that the observed concentration of Hα emitters toward the heads of the BRCs supports the S^4F hypothesis, although it may be exag-

Table 1. Log of observations.

BRC	Date of obs.	Exposure times (sec) × No. of frames
11NE	05/9/27	I_c: 60×4 V: 120×4 B: 300×4
12	05/9/27	I_c: 60×4 V: 100×4 B: 240×4
14	05/9/27	I_c: 50×4 V: 120×4 B: 300×4
37	05/9/25	I_c: 60×6 V: 200×6 B: 300×6

gerated to some extent by the opacity effect. (Here we also add that as for the very rich AFGL 4029 IR cluster embedded in a somewhat eastern part of BRC 14 (e.g., Deharveng et al. 1997), we believe that it formed spontaneously, not as a result of RDI; it is located too far away from the head of the BRC 14 for the effects of RDI to propagate.) Recently, Matsuyanagi et al. (2006) analyzed their deep *JHK* photometry of the BRC 14 region and showed that three indicators of star formation, i.e., the fraction of YSO candidates, the amount of extinction of all sources, and near-IR excesses of the YSO candidates, all showed a clear sequence from outside to inside of the bright rim. This result further strengthens the S^4F hypothesis.

The best way to quantitatively testify the hypothesis is to estimate the ages of the aggregate members and to compare them between different regions with respect to the bright rim. We thus undertook BVI_c photometry of BRC aggregates. The problems associated with this attempt, in contrast to the case of ordinary open clusters, are membership selection and reddening correction. We overcame these difficulties as described in section 3, and constructed reddening-corrected color–magnitude diagrams (CMDs) for each BRC aggregate. The age of each star has been determined on the $V_0/(V-I_c)_0$ CMDs, and its spatial distribution has been examined. The result seems to confirm the S^4F hypothesis.

2. Observations and Data Reduction

Imaging observations of the four BRCs in the BVI_c bands were carried out on the 2.0-m Himalayan Chandra Telescope (HCT) of the Indian Astronomical Observatory. HCT is located at Mt. Saraswati (altitude 4500 m above sea level) in the Himalayan region, but is remotely operated from CREST, Hosakote near Bangalore, via a satellite link. The instrument used was HFOSC in the imaging mode. The details of the site, HCT and HFOSC can be found at the HCT website.[1] The observations were made on 2005 September 25 and 27 and a log of the observations is given in table 1. The sky conditions at the time of the observations were satisfactory with a seeing size of about 1.″5.

Data reduction was carried out at Aryabhatta Research Institute of Observational Sciences (ARIES), India. The initial processing of the data frames was made using the IRAF data-reduction package. Photometric measurements were made using DAOPHOT II (Stetson 1987). The point-spread function (psf) was obtained for each frame using several uncontaminated stars. The photometric accuracies depend on the brightness of the stars, and the typical DAOPHOT errors of our target stars ($V\sim 18$ mag) are: 0.003 mag in I_c, 0.005 mag in V, and 0.007 mag in B for BRCs 11NE, 12, and 37. However, they are slightly larger for BRC 14: 0.005, 0.005, and 0.007, respectively. The standard deviation of the residuals of the transformed V magnitude, $B-V$ and $V-I_c$ colors of the standard stars were 0.010, 0.005, and 0.012, respectively. Near the limiting magnitude of $V\sim 20.5$, the DAOPHOT errors increase to ~ 0.03 in all color bands.

3. Star Selection and Reddening Correction

BRC aggregates are very loose and composed of a small number of stars. In addition, their Galactic latitudes are low, so there can be many field stars, although some of them may be associated with the H II region to which the BRC belongs. Therefore, we selected the targets from such BRCs that the associated aggregate contains relatively many stars. BRCs 11NE, 12 and 14 belong to the H II region IC 1848 and BRC 37 to IC 1396. For each BRC the Hα emission stars of Ogura, Sugitani, and Pickles (2002) were selected as member stars. In the case of BRC 11NE and BRC 37, however, only a few Hα stars are available. But, as one can see in figures 1f and 1p of Ogura, Sugitani, and Pickles (2002), a relatively clear aggregate of stars can be noticed that appears to be associated with the BRCs; these aggregates show up more prominently in the 2MASS images. We, therefore, have added stars having 2MASS counterparts from the aggregates, and are indicated by "A" (*additional stars*) in the finding charts, figure 1. In BRCs 12 and 14, because we deal only with the Hα stars of Ogura, Sugitani, and Pickles (2002), we can see the finding charts therein.

Another difficulty is extinction correction. The target stars must have different amounts of extinction caused by the dust in the BRC and/or H II regions. Moreover, they are thought to be pre-main sequence stars, and so can have peculiar color indices, particularly, $U-B$ ("UV excess"). Therefore the ordinary technique of the $U-B/B-V$ two-color diagram (2CD) to estimate the amount of reddening in open clusters cannot be used. $B-V$ and $V-I_c$ are less peculiar in TTSs, but a new problem emerges: in the $B-V/V-I_c$ 2CD the intrinsic line is nearly parallel to the reddening vector in the part for late-type stars, so this 2CD is practically not usable to estimate the amount of reddening.

In order to overcome this difficulty we used the $J-H/H-K_s$ 2CD, where the A_V value for each star was measured by tracing back to the intrinsic lines along the reddening vector found in Meyer, Calvet, and Hillenbrand (1997). We adopted the intrinsic line of TTSs given by Meyer, Calvet, and Hillenbrand (1997) and that of dwarfs of Bessell and Brett (1988). The former is used for Hα stars. The latter, used for non-emission stars, was converted into the CIT JHK_s system according to equations given in Bessell and Brett (1988). For BRCs 11NE, 12 and 37 the JHK_s data were taken from the 2MASS catalog and converted into the CIT JHK_s system according to relations given on the 2MASS web site.[2] Only stars with photometric qualities 'AAA' were adopted. For BRC 14 we have adopted the JHK_s data used in Matsuyanagi et al.

1 ⟨http://www.crest.ernet.in/iia/iao/iao.html⟩.

2 ⟨http://www.astro.caltech.edu/%7Ejmc/2mass/v3/transformations⟩.

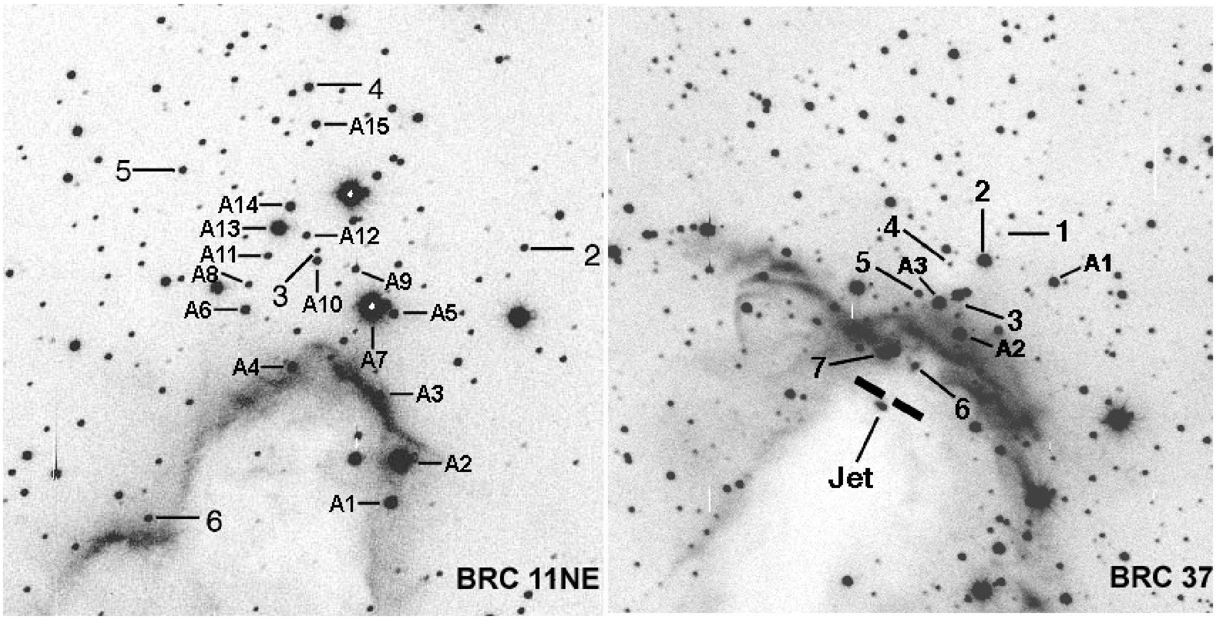

Fig. 1. Finding charts for stars in BRC 11NE and BRC 37. Stars with prefix "A" are non-Hα emission stars, and those without the prefix are Hα emitters of Ogura, Sugitani, and Pickles (2002). They are reproduced from their figures 1f and 1p, and are 2.′5 by 2.′5 wide each with north up and east to the left. In BRC 37 "jet" is part of the Herbig–Haro object HH 588 (see, Ogura et al. 2002) and the pair of thick tick marks indicate the nominal IRAS position. BRC 11NE does not harbor any IRAS point sources.

(2006), which were obtained with the infrared camera SIRIUS on the University of Hawaii 2.2-m telescope atop Mauna Kea. Identifications of the target stars between the HCT data and the 2MASS catalog or the SIRIUS data were made on the basis of the J2000.0 coordinates within an accuracy of 2″. From the thus-obtained A_V values, we calculated the color excesses, E_{V-I_c} and E_{B-V}, according to the ratios given by Munari and Carraro (1996).

4. Results

The photometric results for each star in each BRC aggregate are given in table 2. The second, third, and fourth columns give the extinction-corrected V magnitude, $B-V$ and $V-I_c$ colors, respectively. The last column gives the location of the star with respect to the bright rim. Note that "outside/inside BR" (BR stands for bright rim) are the inside/outside of the H II region. We cannot tell the accuracies of the values in table 2, since the amounts of reddening corrections depend on several factors, whose reliability is difficult to quantify. For each BRC, a $V_0/(V-I_c)_0$ CMD was constructed, where overlaid are the isochrones of Siess, Dufour, and Forestini (2000) with $Z = 0.02$ and no overshooting, which are corrected for the distance given in table 2. These distances are taken from the SFO Catalog (Sugitani et al. 1991). The age of each star was determined according to these isochrones. In view of the limited page space, we show as an example the $V_0/(V-I_c)_0$ CMD for BRC 14 in figure 2. There are many stars that lie above the youngest isochrone of 1 Myr, and their ages are estimated by extrapolation. The resultant ages appear to be reasonable, ranging from 0.1 to a few Myr (with only a few exceptions), which compare well with TTSs' lifetime of a few tenths to a few Myr. From this we would say that all of the stars in our sample are probably aggregate members with practically no foreground/background stars mixed-in. The masses of the stars range from ~ 0.3 to $\sim 2\,M_\odot$(for the 1 Myr isochrone), which is again reasonable. With these ages and masses, the TTS nature of the Hα emission stars is almost confirmed. $V_0/(B-V)_0$ CMDs yield similar results.

In each aggregate the locations of the stars with respect to the bright rim are grouped into two or three (only in the case of BRC 14) regions. The grouping is chosen so that there are at least four stars in each region, with the exception of BRC 37, where we have altogether only six stars. The mean age and A_V of the stars in each region are summarized in table 3. It shows that the mean age of the stars inside or on the bright rim is *always* younger than that outside of it, although the scatter is very large. The age difference is particularly significant in BRCs 12 and 14, where we have some stars inside the bright rim. Moreover, in BRC 14 the mean age constantly decreases from outside to inside of the bright rim. Therefore, our results appear to confirm the S^4F hypothesis.

From table 3 we can see that stars inside the bright rim have larger A_V values than those outside of it in the case of BRCs 12 and 14, although the scatters are large again. This confirms the result of Matsuyanagi et al. (2006) for BRC 14 (but with a smaller difference between the regions in our case). It is natural in view of the above general trend of the stellar ages. In the case of BRCs 11NE and 37, however, no difference is found between the two regions.

5. Discussion and Conclusion

Lee et al. (2005) argued that the presence of TTSs only near and/or outside the surface of BRCs would clearly indicate evidence for triggered star formation, and in their study of BRCs

Table 2. Results of dereddening and age estimation.

Star	V_0	$(V-I_c)_0$	$(B-V)_0$	A_V (mag)	Age (Myr)	Location
BRC 11NE	(1.9 kpc)					
Hα-6	17.99	1.84	1.23	1.46	1.7	on BR
A1	15.45	1.57	1.22	1.41	0.3	″
A2	14.56	1,57	1.41	0.00	0.1	″
A3	17.44	2.00	1.40	0.71	0.7	″
A4	16.25	1.34	0.80	2.26	1.5	″
A5	17.91	1.75	−0.21	0.69	1.9	outside BR
A6	17.01	1.67	1.29	0.78	1.0	″
A7	13.13	0.85	0.53	0.00	1.0	″
A8	19.13	2.24	1.65	0.78	1.9	″
A9	17.27	1.61	−0.65	2.16	1.8	″
A10	15.56	1.58	1.06	3.09	0.3	″
A11	17.92	1.8	1.32	1.55	1.8	″
A12	16.84	1.45	1.11	2.29	1.9	″
A13	15.52	1.54	1.30	0.00	0.3	″
A14	16.26	1.63	1.21	1.42	0.6	″
Hα-5	18.32	2.08	1.52	0.73	1.4	″
A15	17.24	1.82	1.35	1.38	0.8	″
Hα-4	18.09	2.05	1.37	0.61	1.2	″
BRC 12	(1.9 kpc)					
Hα-1	16.19	1.61	1.06	2.61	0.6	outside BR
Hα-5	17.88	1.52	1.09	0.00	6.0	″
Hα-10	19.79	2.22	0.97	0.00	4.0	″
Hα-17	17.96	1.88	1.29	1.06	1.6	″
Hα-19	16.34	1.70	1.09	0.94	0.35	″
Hα-9	16.34	1.95	1.18	1.62	0.17	on BR
Hα-11	17.18	2.10		2.36	0.35	″
Hα-14	14.81	1.57	0.99	1.73	0.1	″
Hα-16	16.9	1.83	1.13	1.41	0.4	″
Hα-20	15.24	1.29	0.64	3.54	0.5	inside BR
BRC 14	(1.9 kpc)					
Hα-5	16.99	1.84	1.50	2.18	0.5	outside BR
Hα-12	16.51	1.46	1.35	3.40	1.3	″
Hα-16	17.85	1.85		3.37	1.5	″
Hα-18	19.07	2.11		2.42	2.5	″
Hα-20	17.29	1.62		3.14	1.7	″
Hα-23	16.94	1.39		3.23	3.0	″
Hα-24	18.93	2.55		2.14	1.0	″
Hα-32	15.2	1.36	1.15	3.22	0.4	on BR
Hα-33	17.87	1.77		2.87	1.9	″
Hα-35	16.76	1.82	1.47	2.70	0.4	″
Hα-31	15.6	1.39		3.99	0.5	″
Hα-34	16.46	1.39	0.88	4.17	1.7	″
Hα-38	17.68	1.97		2.65	0.8	inside BR
Hα-39	17.22	1.89		2.87	0.5	″
Hα-40	15.04	1.37		5.47	0.3	″
Hα-42	17.14	1.95		3.04	0.4	″
BRC 37	(0.75 kpc)					
A1	16.07	1.63	1.23	2.04	4.5	outside BR
Hα-2	14,10	1.49	1.12	2.27	0.6	″
Hα-3	14.13	1.46		3.71	0.7	″
A2	14.65	2.00	1.01	2.52	0.25	near BR
A3	15.11	1.62	1.20	2.07	1.5	″
Hα-7	14.39	1.49	0.68	3.21	1.0	on BR

in the Orion region they actually found TTSs only between the BRCs and the OB stars. In the present study we located some probable TTSs inside the bright rim. However, their A_V values show that they are not deeply embedded in the BRC. Therefore, their apparent location may be due to a projection effect, and they may actually be located near to the front surface of the BRC, so in reality similar to the "on BR" stars. The difference between the result by Lee et al. (2005) and ours is probably due to the fact that our study is deeper and more small-scaled.

The regions in each BRC aggregate show big scatters of the ages of the member stars in spite of a clear trend of the mean

Table 3. Summary of results.

BRC	Region	No. of stars	Mean age ±st dev (Myr)	Mean A_V ±st dev (mag)
11NE	outside BR	13	1.26 ± 0.60	1.21 ± 0.88
	on BR	5	0.86 ± 0.71	1.17 ± 0.85
12	outside BR	5	2.51 ± 2.43	0.93 ± 1.07
	inside & on BR	5	0.30 ± 0.17	2.13 ± 0.86
14	outside BR	7	1.64 ± 0.86	2.84 ± 0.57
	on BR	5	0.98 ± 0.75	3.39 ± 0.66
	inside BR	4	0.50 ± 0.22	3.51 ± 1.32
37	outside BR	3	1.93 ± 2.22	2.67 ± 0.91
	on & near BR	3	0.92 ± 0.63	2.60 ± 0.57

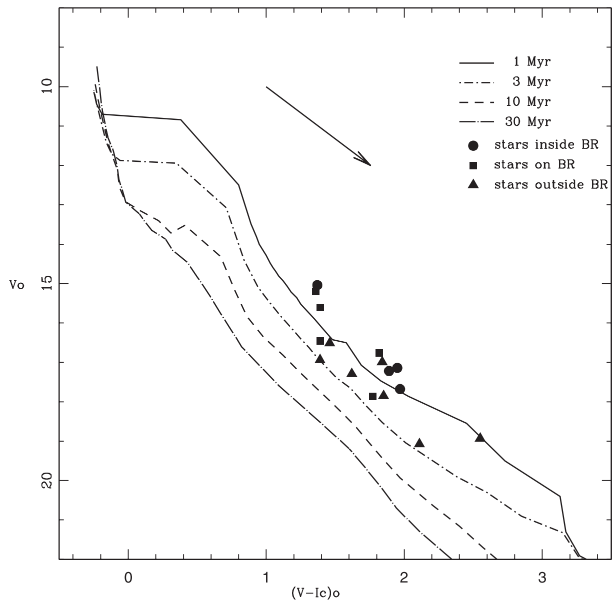

Fig. 2. $V_0/(V-I_c)_0$ CMD for the BRC 14 aggregate. Stars, which are all Hα emitters in this case, are plotted with different symbols according to their locations with respect to the bright rim. The isochrones of Siess, Dufour, and Forestini (2000) with $Z = 0.02$ and no overshooting are drawn with a correction for a distance of 1.9 kpc. The arrow indicates the reddening vector.

ages. The reason for this is not clear, but we suspect that it is caused by the proper motions of newly born stars. Jones and Herbig (1979) showed that young stars in the Taurus molecular cloud have velocity dispersions of 1–2 km s^{-1} in one coordinate. If this value is applicable to BRC aggregates, the stars must have moved 2 pc or so (in projection) from their birth place in 1 Myr. Since the size of the BRC aggregates is ∼ 0.2 pc (BRC 37) to ∼ 2 pc (BRC 12), this is sufficiently large for some of the stars that formed 1 Myr ago to move into the (projected) present bright rim. We suspect that many stars in H II regions have thier origin in already dispersed BRC aggregates, except for the case where a rich cluster exists.

The stars outside a BRC (i.e., inside the H II region) have similar ages irrespective of the (projected) distance from the bright rim. It is our position that they essentially formed there inside the BRC, which has since retreated to its present position. Then, the above fact suggests that they were formed in the (first) collapse phase of the evolution of BRCs (Lefloch & Lazareff 1994). Presumably BRCs may have a second (or, even more) collapse phase due to their clumpiness, or as the exciting O star(s) evolve(s) and increase(s) its (their) UV photon emission, or somehow they give birth to stars after this phase (i.e., in the cometary phase); also, stars on, or near to, the bright rim, which generally are younger, may correspond to such an origin. It is interesting to note that among the aggregate regions given in table 3, those having the youngest mean age (i.e., inside/on BR of BRCs 12 and 14) show the smallest age scatter.

The age estimate from CMDs depends on the adopted distance; if we use a larger distance we get younger ages. For some BRCs in the SFO Catalog the distances are not well determined. However, since the results given in tables 2 and 3 are in a reasonable range, and do not show any systematic differences between the BRCs, the distances adopted here do not have a big error, presumably. In any case, what is important in the present study is the relative ages among the stars in a BRC, and they are not changed by the error of the adopted distance. Another factor that affects the age estimation is the duplicity of stars. On a CMD, an unresolved binary star can be placed at an elevated position (by up to 0.75 mag), which results in a younger age. Some of the stars that fall above the 1 Myr isochrone (see figure 2) might be like this. However, unresolved binaries must not be limited to this location, but can exist among all of the stars more or less equally on the CMDs. Therefore, our main conclusion remains unchanged by this effect. We conclude that our photometry of the BRC aggregates confirms the S^4F hypothesis, although some problems remain.

We thank the TAC and staff of HCT for the time allotment and for supporting the observations, respectively. Our thanks are also due to I. Matsuyanagi and the SIRIUS team for providing the JHK_s data on BRC 14. We are grateful to the referee Dr. G.H. Herbig for his helpful comments. K.O. and A.K.P. acknowledge JSPS (Japan) and DST (India) for the financial supports. Y.I. is supported by "The 21st Century COE Program: The Origin and Evolution of Planetary System" of MEXT.

References

Bertoldi, F. 1989, ApJ, 346, 735
Bessell, M. S., & Brett, J. M. 1988, PASP, 100, 1134
Carpenter, J. M., Heyer, M. H., & Snell, R. L. 2000, ApJS, 130, 381
Deharveng, L., Zavagno, A., Cruz-Gonzalez, I., Salas, L., Caplan, J., & Carrasco, L. 1997, A&A, 317, 459
De Vries, C. H., Narayanan, G., & Snell, R. L. 2002, ApJ, 577, 798
Jones, B. F., & Herbig, G. H. 1979, AJ, 84, 1872
Lee, H.-T., Chen, W. P., Zhang, Z.-W., & Hu, J.-H. 2005, ApJ, 624, 808
Lefloch, B., & Lazareff, B. 1994, A&A, 289, 559
Lefloch, B., & Lazareff, B. 1995, A&A, 301, 522
Lefloch, B., Lazareff, B., & Castets, A. 1997, A&A, 324, 249
Matsuyanagi, I., Itoh, Y., Sugitani, K., Oasa, Y., Mukai, T., & Tamura, M. 2006, PASJ, 58, L29
Meyer, M. R., Calvet, N., & Hillenbrand, L. A. 1997, AJ, 114, 288
Miao, J., White, G. J., Nelson, R., Thompson, M., & Morgan, L. 2006, MNRAS, 369, 143
Morgan, L. K., Thompson, M. A., Urquhart, J. S., White, G. J., & Miao, J. 2004, A&A, 426, 535
Munari, U., & Carraro, G. 1996, A&A, 314, 108
Ogura, K., Sugitani, K., & Pickles, A. 2002, AJ, 123, 2597
Siess, L., Dufour, E., & Forestini, M. 2000, A&A, 358, 593
Stetson, P. B. 1987, PASP, 99, 191
Sugitani, K., Fukui, Y., & Ogura, K. 1991, ApJS, 77, 59
Sugitani, K., & Ogura, K. 1994, ApJS, 92, 163
Sugitani, K., Tamura, M., & Ogura, K. 1995, ApJ, 455, L39
Thompson, M. A., & White, G. J. 2004, A&A, 419, 599
Thompson, M. A., Urquhart, J. S., & White, G. J. 2004, A&A, 415, 627
Thompson, M. A., White, G. J., Morgan, L. K., Miao, J., Fridlund, C. V. M., & Huldtgren-White, M. 2004, A&A, 414, 1017
Urquhart, J. S., Thompson, M. A., Morgan, L. K., & White, G. J. 2006, A&A, 450, 625