SEARCH FOR B[E] STARS IN YOUNG OPEN CLUSTERS

D. DE WINTER
Dpto. Física Teórica, C–XI, Universidad Autónoma de Madrid, Cantoblanco, 28049 Madrid, Spain

M.E. VAN DEN ANCKER
Astron. Inst. "Anton Pannekoek", University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands

AND

M.R. PÉREZ
Space Applications Corp., Suite 250, 9315 Largo Drive West, Largo, MD 20774, USA

Abstract. The properties and the stellar content of five young open clusters have been investigated to identify new B[e] stars. After a detailed analysis we conclude that none of the $\sim$ 260 relatively young early type stars can be identified as such. We propose that either the B[e] characteristic is not present in young stars or that due to the close proximity of other hot stars the circumstellar material can not hold sufficient amounts of material to show this spectroscopic property. After investigating the direct environment of well known galactic B[e] stars we find support for our hypothesis that the B[e] phenomenon is mostly seen in rather isolated sources. As many massive stars are located in clusters it explains the paucity of this spectral characteristic.

1. Introduction

The stellar population of five well-known galactic young open clusters has been studied: NGC 2244, 2264, 6383, 6530, 6611. The first goal was to find Herbig Ae/Be (HAeBe) type stars among the early type members of these young clusters. However, only relatively few were detected ($\sim$ 21).

For the majority of the bright visible stars (more than 250 objects) their observable properties (optical to near-IR photometry and low resolution spectroscopy), as well as other astrophysical parameters were studied in some detail. As the sample is obviously biased toward O- and B-type stars, it is also perfectly suited for the detection and identification of B[e] stars among these very young objects of unknown type.

The results of this study will be shown and discussed by presenting the characteristics of individual objects, as well as the general cluster properties. Finally, the results will be discussed in relation to known B[e] stars.

2. Description of the sample

An advantages of the use of young open clusters in these kind of studies is that no confusion exists about the distance and age of the cluster-members. This has been a major confusion for the classification of known B[e] stars, see several papers in these proceedings. Most of cluster-members are also bright enough for a wide range of observational work. Besides these advantages, there is a difficulty to discriminate between real cluster-members and field stars. For each of the clusters these problems are widely discussed and sample selections are carefully made in the studies mentioned in Table 1.

In general the selection of B[e] stars is made on the obvious spectroscopic properties, being spectral type B and the presence of emission lines of [Fe II] and [O I], and an indication of a near-infrared (NIR) or far-IR excess.

3. The observational results

We have obtained 4000–8000Å low resolution spectroscopy (LRS) and $UBVRI-JHK(LM)$ photometry of probable cluster members. IRAS data for cluster-members can not be derived, because of the low spatial resolution of the instrument and the strong background radiation. Spectral corrections for emission lines of bright nebulae in these clusters is not always easy as the emission can be intracluster rather than intrinsic.

The final spectra were studied and the spectral energy distributions (SEDs) were made and investigated. The observations and all results can be found in the original studies, see Table 1. In this table we have also summarized the properties for each cluster-sample and of each of the clusters its properties as derived in these studies.

The results as presented in Table 1 show that in none of the clusters, all very young, not even a single B[e] star was detected. Why?

4. The circumstellar environment of B[e] stars

We have seen that no B[e] stars were found in large samples of young early type stars in several very young ($\ll 10^7$ yrs) clusters. It is not an exceptional property of one of these clusters. We propose, therefore, that B[e] stars are

TABLE 1. Properties of early type stars in several YCOs. The abbreviations in the heading refer to the original studies: dW = de Winter et al. (1997); Hil = Hillenbrand et al. (1993); MP = Pérez et al. (1987, 1991); PT2 = Thé et al. (1985); PT2 = Thé et al. (1990); vdA = van den Ancker et al. (1997). For some cluster properties estimates are given with the error between parentheses.

NGC: − − −− > Characteristic	2244 MP	2264 MP	6383 PT1	6530 vdA	6611 dW+PT2	6611 Hil	Total
# Objects studied	104	80	14	132	87	332	749
LR spectra	21	22	14	80	57	67	261
Strong emission	1	1	1	7	18	20	48
Weak/possible emission	0	0	0	12	9	5	26
NIR data	21	22	14	26	49	28	160
NIR excess	1	9	5	9	12	7	43
HAeBes candidates	2	6	1	5	4	3	21
O & B stars with LRS:	21	22	5	54	37	57	196
Emission	1	1	0	13	22	19	56
NIR data	21	22	5	30	19	27	124
NIR excess	1	9	1	9	8	7	35
NIR excess & emission	0	1	0	3	6	3	13
B[e] Stars	0	0	0	0	0	0	0
Cluster properties:							
d [kpc]	1.67(1)	0.95(7)	1.5(2)	1.8(2)	2.6(3)	2.1(1)	–
interstellar $E(B-V)$	0.48(2)	0.06(1)	0.31(2)	0.30(2)	0.50(2)	0.4	–
$t_{\rm max}$ [Myr]	<4	<5	<6	<4	<6	<6	–
$t_{\rm ave}$ [Myr]			1.7(4)*	2(1)**	1–2	2(1)	–
$t_{\rm min}$ [Myr]			<0.3	0	0	0	–

Notes:
*) Taken from Luiken-Miller (1982). **) Taken from Sagar & Joshi (1978).

not extremely young ($\gg 10^7$ yrs), or that their CS material (disk?) survival time is $\ll 10^7$ yrs.

The latter is supported by the detection of Hester et al. (1996) that dusty regions in NGC 6611 suffer from erosion due to the intense UV radiation fields of nearby O & B stars. This might work also as disk erosion of young stars in such clusters (Pérez et al. 1998). In fact their calculations show that in these crowded regions the disk survival time is less than the pre-main sequence time of a few Myrs for the studied stars, which explains the lack of detected HAeBe stars, see Table 1.

Note that most well known HAeBes are found in relatively isolated positions. What about the known B[e] stars? We have studied this and found 41 early type (ET) stars (O, B and A) within a circle of 10′ around 28 known galactic B[e] stars (de Winter & Pérez, these proceedings). However 19 of these nearby ET stars are around only 4 B[e] objects, these are: CD$-42°$11721, HD 87643, He 2–14 and MWC 17. As 24 B[e] stars have only 22 ET neighbours within 10′ we conclude that the known galactic B[e] stars are isolated objects, a suggestion already proposed by Zickgraf & Schulte-Ladbeck (1989) for a few B[e] stars.

5. Conclusions

From the non-detection of B[e] stars among more than 250 well studied early type stars in 5 young open clusters and the investigation of the surroundings of 28 known galactic B[e] stars we summarize the main possibilities for the nature of B[e] stars:

- **B[e] stars are young and isolated.** In this case the disk material is young and the B[e] star will be clearly located in or near a SF region, possible examples are R Mon and V380 Ori (de Winter & Pérez, these proceedings).
- **B[e] stars are evolved objects with “young disks”.** The “disk” can be relatively young when it originates from mass loss. The star might be isolated or not. Examples of such objects are massive stars such as LBVs and B[e] supergiants in the MCs, and stars with recent mass-loss like post-AGB stars.
- **B[e] stars are evolved objects with “old disks”.** The disk survived a significant time of the stellar evolution for some reason. The B[e] star will be isolated and does not belong to the previously mentioned groups. Examples could be HD 45677 and HD 50138.

The final conclusion is that, as for HAeBes, the environments of B[e] stars might be very important to understand the presence and the rarity of the B[e] phenomenon, which is not detected in young open clusters.

Acknowledgements

D. de Winter is supported in part by Spanish grant DGICYT PB94-0165. M. van den Ancker acknowledges financial support through an NWO *Pionier* grant to L.B.F.M. Waters.

References

van den Ancker, M.E., Thé, P.S., Feinstein, A., Vázquez, R.A., de Winter, D., Pérez, M.R. 1997, A&AS 123, 63

Hester, J.J., Scowen, P.A., Sankrit, R., Lauer, T.R., Ajhar, E.A., Baum, W.A., Code, A., Currie, D.G., Danielson, G.E., Ewald, S.P., Faber, S.M., Grillmair, C.J., Groth, E.J., Holtzman, J.A., Hunter, D.A., Kristian, J., Light, R.M., Lynds, C.R., Monet, D.G., O'Neil, E.J., Shaya, E.J., Seidelmann, K.P., Westphal, J.A. 1996, AJ 111, 2349
Hillenbrand, L.A., Massey, P., Strom, S.E., Merrill, K.M. 1993, AJ 106, 1906
Luiken-Miller, M. 1982, Ph.D. thesis, University of Waterloo, Canada
Pérez, M.R. 1991, Rev. Mex. Astron. Astrof. 22, 99
Pérez, M.R., de Winter, D. , van den Ancker, M.E., Grady, C.A., Thé, P.S. 1998, A&A, to be submitted
Pérez, M.R., Thé, P.S., Westerlund, B.E. 1987, PASP 99, 1050
Sagar, R., Joshi, U.C. 1978, MNRAS 184, 467
Thé, P.S., Hageman, T., Westerlund, B.E., Tjin A Djie, H.R.E. 1985, A&A 151, 391
Thé, P.S., de Winter, D., Feinstein, A., Westerlund, B.E. 1990, A&AS 82, 319
de Winter, D., Koulis, C., Thé, P.S., van den Ancker, M.E., Pérez, M.R. Bibo, E.A. 1997, A&AS 121, 223
Zickgraf, F.-J., Schulte-Ladbeck, R.E. 1989, A&A 214, 274