A Catalog of Blue Stragglers in Open Clusters

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BSs in open clusters since the Fifties

THE COLOR-MAGNITUDE DIAGRAM FOR THE GALACTIC CLUSTER NGC 7789*

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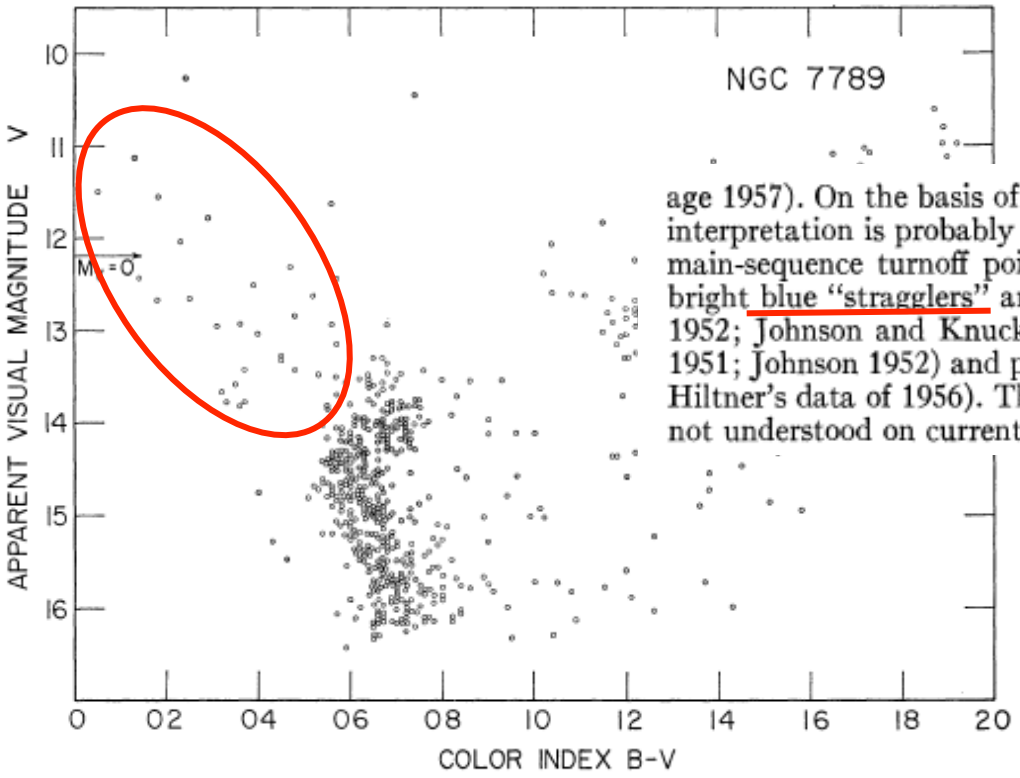


FIG. 5.—The color-magnitude diagram for NGC 7789 from the data of Tables 3 and 4

age 1957). On the basis of our present results in NGC 7789, we now conclude that this interpretation is probably not correct. M3 also has many blue stars brighter than the main-sequence turnoff point (Sandage 1953; Johnson and Sandage 1956). Additional bright blue "stragglers" are known in the Coma Berenices cluster (17 Comae: Weaver 1952; Johnson and Knuckles 1955), and in Praesepe (Klein Wassink No. 265: Eggen 1951; Johnson 1952) and possibly in h and χ Persei (Masevich 1957, using Johnson and Hiltner's data of 1956). The point is of interest because these bright blue stragglers are not understood on current ideas of stellar evolution.

Some antecedents (before 1992)

- Partial lists of BSs: Strom & Strom (1970), Hintzen et al. (1974), Hrivnak (1977), Mermilliod (1982), Peterson et al. (1984), Stryker & Hrivnak (1984), Twarog & Tyson (1985), Abt (1985), Eggen & Iben (1988, 1989), Mathys (1991), Pritchet & Glaspey (1991), Milone (1991), etc.

- A few statistical studies: Wheeler (1979), Mermilliod (1982), Morales & Sabau (1987), etc.

The idea

McCrea (1964)

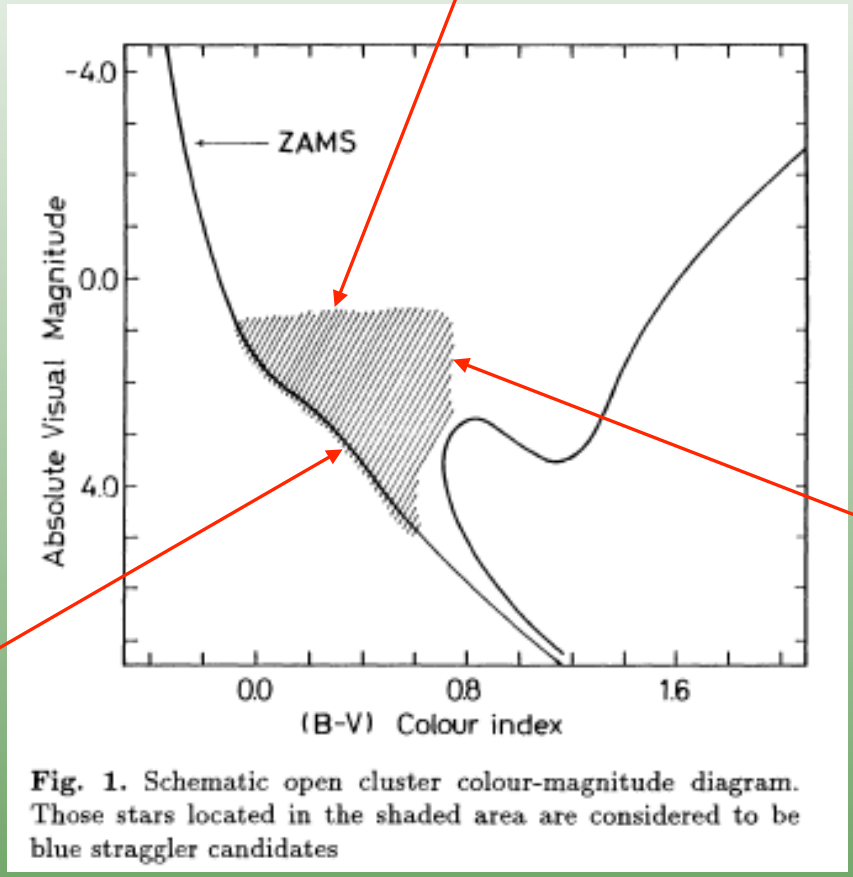


Fig. 1. Schematic open cluster colour-magnitude diagram. Those stars located in the shaded area are considered to be blue straggler candidates

turnoff color

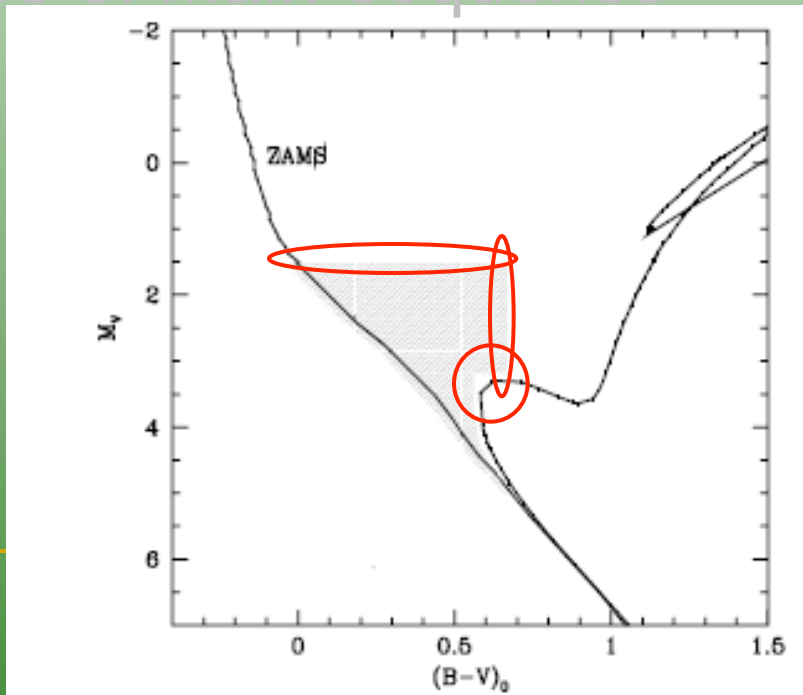
ZAMS

Heroic times: the selection

- Clusters from Lyngå's (1987) catalog
- Search through A&A Abstracts
- *UBV* photometry preferred
- Accuracy and completeness of the photometry
- Quality of the color-magnitude and color-color diagrams

An attempt to classify the BSs into three categories using:

- Membership probabilities: proper motions, radial velocities, photometric criteria, central position in the cluster
- Spectra consistent with those of main-sequence or slightly-evolved stars
- Mentions by other authors
- Position on certain parts of the area



The first catalog (1995)

Astron. Astrophys. Suppl. Ser. **109,** 375-382 (1995)

Catalogue of blue stragglers in open clusters*

J. Ahumada[1,2] and E. Lapasset[1,3]

- 959 stars in 39
- Percentage of

King 4	02 35.7	+59 00	0.86	7.
Trumpler 2	02 37.3	+55 59	0.32	8.
Berkeley 65	02 39.0	+60 25	1.12	7.
NGC 1039	02 42.1	+42 46	0.07	8.
NGC 1027	02 42.7	+61 36	0.33	8.
Czernik 13	02 44.7	+62 21	0.76	6.
IC 1848	02 51.2	+60 26	0.60	6.
Berkeley 66	03 04.3	+58 46	1.25	9.

NGC	King 5	273	0273	2
NGC	King 5	710	0710	2
NGC	King 5	801	0801	2
King	King 5	890	0890	2
NGC	NGC 1245	689	0146	2
Melo	NGC 1245	3005	0007	2
King	NGC 1245	3014	0512	2
NGC	NGC 1245	3021	0011	2
NGC	NGC 1245	3027	0507	2
IC 3	NGC 1245	3036	0071	2
Plei	Melotte 20	HD 22928		2
NGC	King 6	133	0133	2
King	NGC 1342	2	0002	2
NGC	NGC 1342	4	0004	2
NGC	NGC 1348	645	0645	2
	Pleiades	1432	1432	2
	NGC 1444	3	0003	2
	NGC 1444	5	0028	2
	King 7	40	0040	2
	King 7	317	0317	2
	King 7	431	0431	2
	King 7	519	0519	2
	King 7	584	0584	2
	King 7	602	0602	2
	Hyades	56	0056	1
	Berkeley 12	727	0727	2
	Berkeley 12	967	0967	2
	Berkeley 12	1069	1069	2

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Harvard 8      = Collinder 268.  Star 2 is cited as a blue straggler in (293).
Harvard 8   Adopted cluster centre: star 12 of (293).
Hogg 10        The apparent cluster diameter was taken from (71).
Hogg 17        Star 1 appears as a straggler but is a non-member according
Hogg 17           to (248).
Hyades         Star 56 is a cluster member acording to the proper motion and
Hyades          radial velocity study (409).  Adopted cluster centre: star 57
Hyades            of the same reference.  References (1) and (281) cite star 56
Hyades          as a blue straggler.  Star 56=68 Tauri=HD 27962 has a spectrum
Hyades          A3V and an optical companion of magnitude 9 (55).  The blue
Hyades            straggler does not show anomalous lithium abundances (50).
Hyades            In (1) this star is given a spectrum Am(K/H/M=A2/A3:/A5) and
Hyades          a projected velocity v.sin i=18km/s.  It has been suggested
Hyades          (303) that the white dwarf component of the binary V471 Tauri
Hyades            in this cluster descends from a blue straggler.  The selected
Hyades          angular diameter in (259) is listed.
IC 166             The cluster is given E(B-V)=0.80 and an age between those of
IC 166            NGC 752 and NGC 7789 in (51).  Star 459 could not be identified
IC 166            in the chart.
IC 1311        Several possible blue and red stragglers are pointed out in (10).
IC 1369        Adopted cluster centre: star 57 (ref. 160).  All the blue
IC 1369     stragglers lie on the periphery of the cluster, but they are
IC 1369           members according to (169).  In particular, note the close
IC 1369           group of stars 155-156-157.
IC 1805        The dereddened colour-magnitude diagram of (188) was examined.
IC 2488        Diagrams in (311) were also examined.  Adopted cluster centre:
IC 2488           star 28 in (311).  Star 99=HD 302225(B8) is cited as a blue
IC 2488     straggler in (311), and is a probable cluster member (85).
IC 2581        The dereddened colour-magnitude diagram in (392) was examined.
IC 2602        Star 18=Theta Carinae=HD 93030 is a well known blue straggler.
IC 2602         In (177) this star is given the following: v=2.78, (b-y)=-0.094,
IC 2602         m1=0.063, c1=-0.078, beta=2.603, spectrum: B0Vp.  Reference
IC 2602         (281) gives it a projected velocity v.sin i=195km/s.  Theta Car
IC 2602         is a spectroscopic binary of period 1.77 days and eccentricity
IC 2602         0.446 (423), thought to be the result of a mass transfer event
IC 2602         in a close binary: an account of this interpretation can be
IC 2602         found in (117).
IC 2714        Star 98, which also appears as a blue straggler, is a non-member
IC 2714           according to (83).
IC 2944        Star 21=HD 101545 has a spectrum B0III (184).
IC 4651        The colour-magnitude diagrams in (18) and (111) were examined.
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Some results

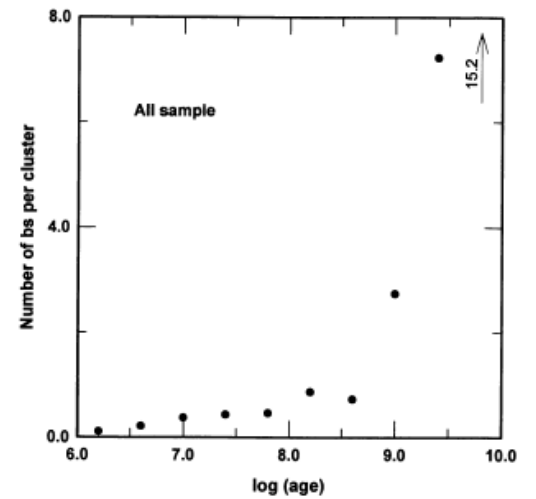


Fig. 2. Mean number of blue stragglers per open cluster and per logarithm of cluster age interval

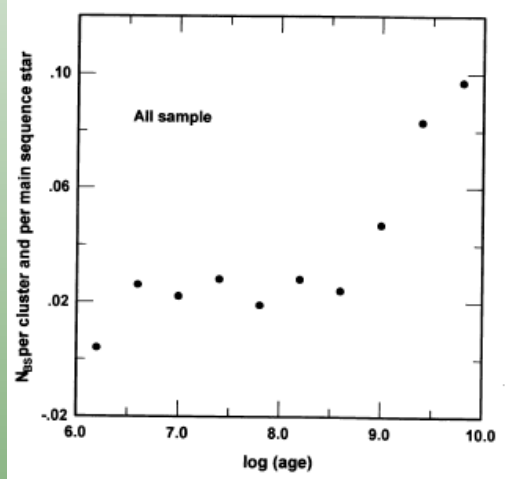


Fig. 4. Mean number of blue stragglers per open cluster, relative to the number of main sequence stars on the two magnitudes below the turnoff, vs. logarithm of cluster age interval

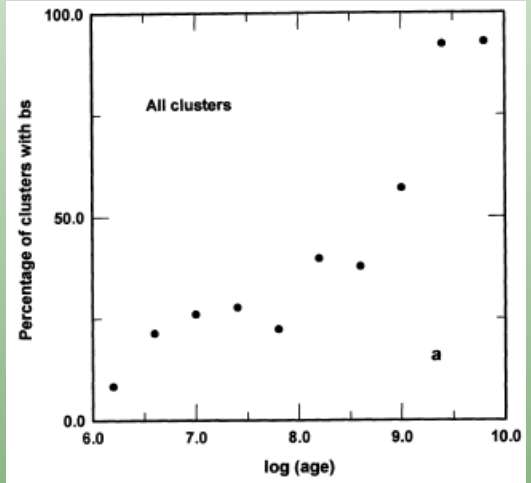


Fig. 3. a) Percentage of open clusters with blue stragglers, per logarithm of cluster age interval. Clusters in the whole range of richness are included

On the problem of the limits

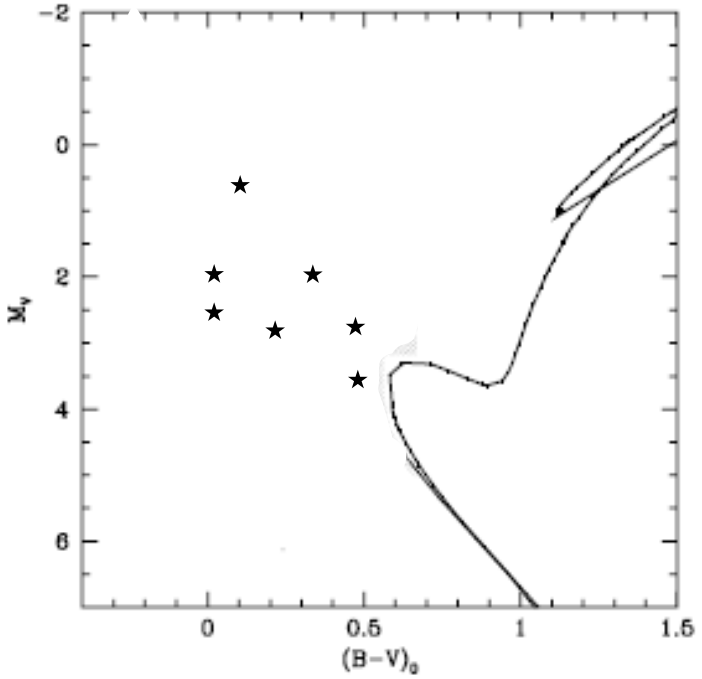


Fig. 1. Schematic colour–magnitude diagram for an old open cluster: the isochrone corresponds to log(age) = 9.8. The blue straggler area is shaded.

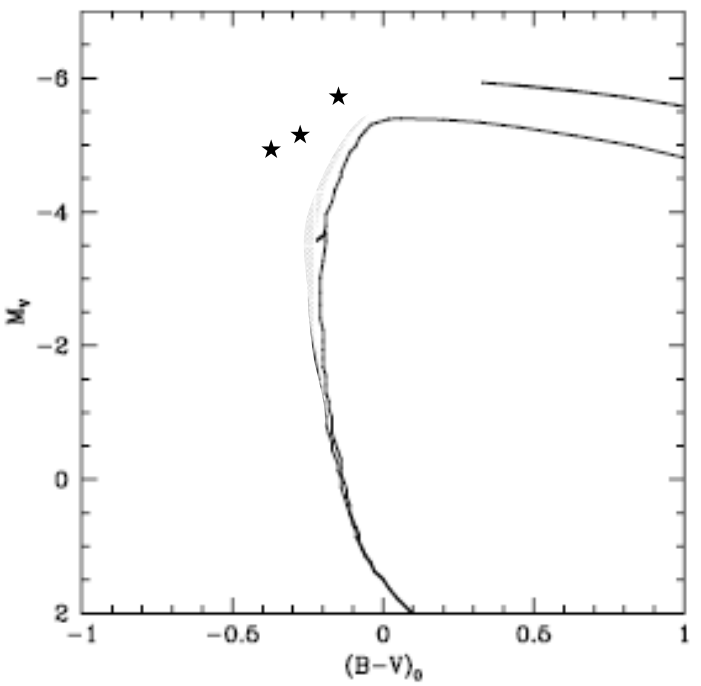


Fig. 2. Schematic colour–magnitude diagram for a young open cluster: the isochrone corresponds to log(age) = 7.5. The blue straggler area is shaded.

Ten years passed by…

- New clusters ✓
- Better photometry ✓
- More membership studies ✓…
- More spectroscopic information ✓…

Melotte 66

Hawarden (1976) **Kassis et al. (1997)**

Here we go again: the selection

- Search through the WEBDA for cluster and star data
- *UBVI* photometry preferred
- Accuracy and completeness of the photometry

C-M and color-color diagrams

again in all clusters for

of procedure

Table 1. Open clusters with entries in AL95 but not included in the present catalogue.

Basel 1	Basel 4	Basel 5	Basel 7
Basel 11a	Basel 11b	Basel 18	Berkeley 94
Bochum 4	Bochum 5	Bochum 11	Bochum 12
Bochum 13	Bochum 15	Collinder 173	Collinder 197
Collinder 240	Collinder 285	Collinder 347	Collinder 469
CV Mon	Czernik 29	Haffner 15	Haffner 20
IC 1442	Lyngå 14	Markarian 6	NGC 189
NGC 1605	NGC 2254	NGC 2286	NGC 2395
NGC 2423	NGC 2579	NGC 2925	NGC 3330
NGC 6208	NGC 6546	NGC 6683	NGC 6802
NGC 7031	NGC 7062	NGC 7226	NGC 7245
NGC 7762	Pismis 17	Ruprecht 18	Ruprecht 92
Ruprecht 93	Ruprecht 97	Ruprecht 108	Sher 1
Trumpler 22	Trumpler 31	Trumpler 33	Trumpler 35
Waterloo 6			

The procedure: now, isochrones

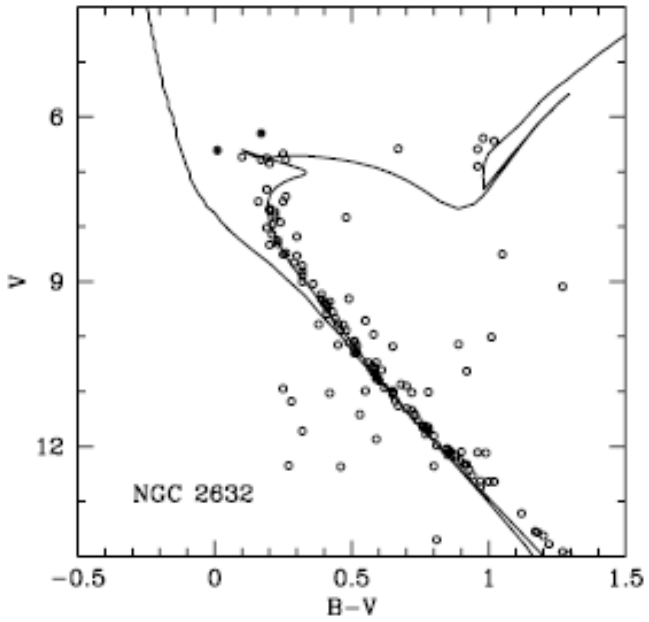


Fig. 3. Colour–magnitude diagram of NGC 2632. The photoelectric data of Johnson (1952) are plotted. The ZAMS from Bertelli et al. (1994) and the isochrone of solar metallicity and log(age) = 8.9 by Girardi et al. (2000) are set at $E(B-V) = 0.00$ and $(m-M)_0 = 6.25$. The two catalogued blue stragglers (solid circles) and the blue hook are seen clearly.

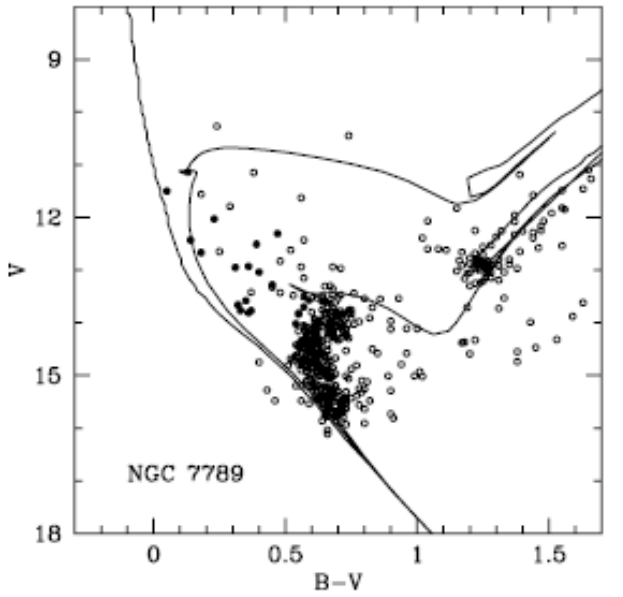
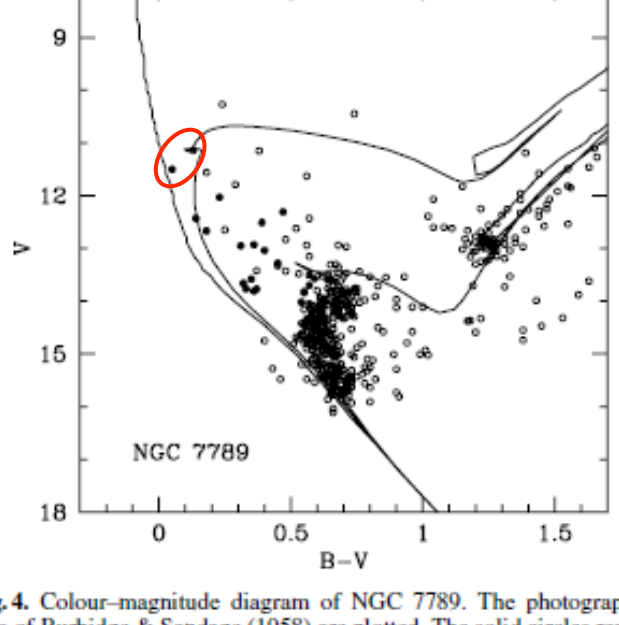
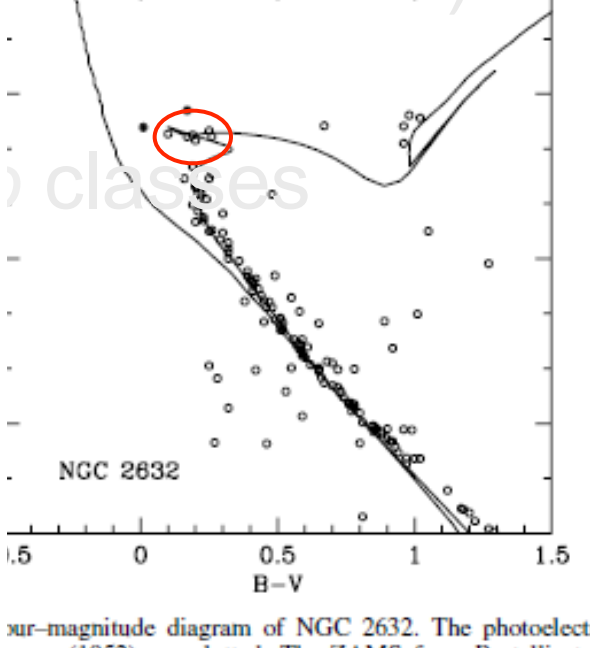


Fig. 4. Colour–magnitude diagram of NGC 7789. The photographic data of Burbidge & Sandage (1958) are plotted. The solid circles represent the stragglers listed in our catalogue. From left to right, we show the solar-metallicity ZAMS of Bertelli et al. (1994) and the isochrones of Girardi et al. (2000) for log(age) = 8.45 and 9.15; the curves are set at $E(B-V) = 0.20$ and $(m-M)_0 = 11.42$. The massive stragglers are the two brightest.

More differences

- Superior limit of the BS area not fixed: identification of massive stragglers
- Stellar models used (i.e., Padova isochrones) are involved
- Classificatio classes





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l. (2000) are set at $E(B-V) = 0.00$ and $(m-M)_0 = 6.2$
alogued blue stragglers (solid circles) and the blue hook

The second catalog (2007)

Astronomy & Astrophysics manuscript no. aa4590-05
December 22, 2006

New catalogue of blue stragglers in open clusters*

J. A. Ahumada and E. Lapasset

- 1887 stars in 427 open clusters of all ages
- Percentage of clusters with at least 1 BS candidate: 46.6%
- Percentage of BS classified as 1: 10.6% (200)
- Two tables, notes, and references, like the first catalog

Some results

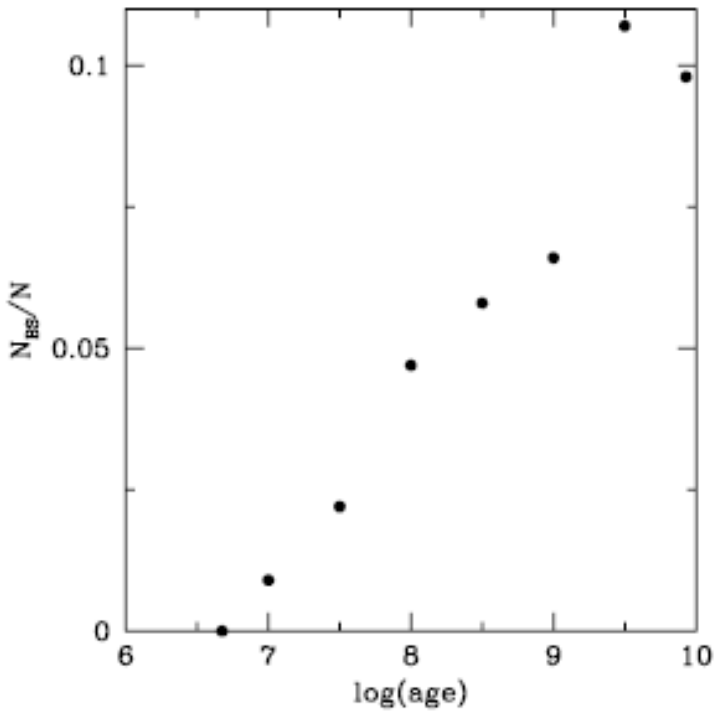


Fig. 5. Average number of blue stragglers, per main-sequence star and cluster.

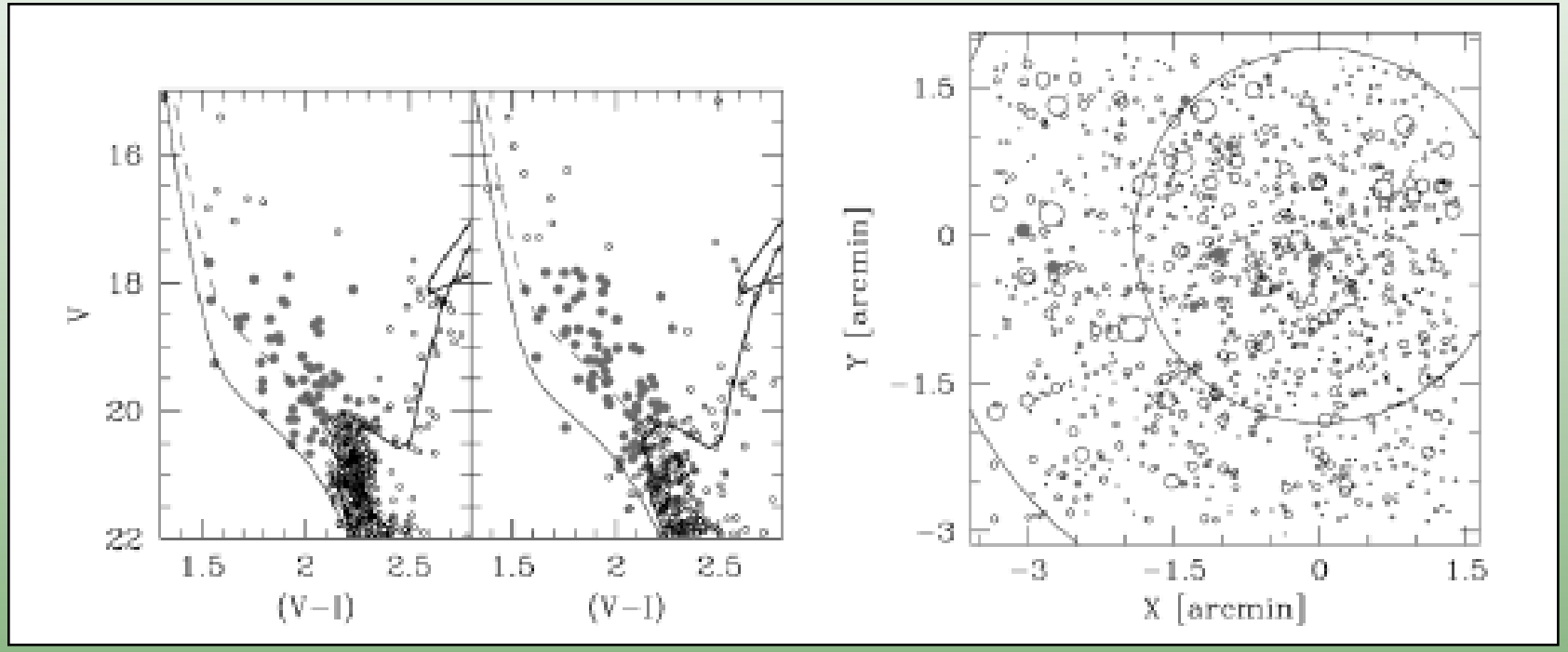
Table 4. Peculiar blue stragglers (for the references, see the notes of the catalogue).

Cluster	Stragglers
Berkeley 39	Four eclipsing binaries and a δ Sct variable.
Collinder 261	Ten eclipsing binaries.
Hyades	An Am star.
IC 2602	The spectroscopic binary θ Car has a period 1.77 days and a spectrum Bp.
IC 4651	Two probable binaries, one of them is an X-ray source.
IC 4725	A Be straggler.
IC 4756	An Ap straggler.
Melotte 111	An α CVn variable, of spectrum Ap.
NGC 188	A W UMa binary.
NGC 752	An X-ray source.
NGC 884	An Op straggler.
NGC 1342	An Ap straggler.
NGC 2251	An Ap straggler.
NGC 2281	An Ap straggler.
NGC 2287	A Bp straggler.
NGC 2354	An Algol, eclipsing binary.
NGC 2422	A Be straggler.
NGC 2516	V374 Car is a binary of spectrum Be.
NGC 2546	An Ap straggler.
NGC 2632	An Ap straggler; another Am and binary.
NGC 2682	Several binaries, X-sources, and δ Sct stars.
NGC 3532	A Bp straggler.
NGC 4755	A β Cep variable.
NGC 6025	A Be straggler.
NGC 6231	An Op straggler.
NGC 6425	A Be straggler.
NGC 6475	A spectroscopic binary.
NGC 6633	A Bp straggler.
NGC 6705	A Bp straggler.
NGC 6791	An EW variable.
NGC 6871	A WR binary.
NGC 7243	An Ap straggler.
NGC 7789	An Ap star, and a δ Sct variable.

Table 7. Clusters with the largest relative populations of blue stragglers ($N_{BS}/N \geq 0.1$).

Cluster	log (age)	N_{BS}/N	Cluster	log (age)	N_{BS}/N
Ruprecht 46	9.6	0.26	King 11	9.1	0.13
Berkeley 70	9.7	0.22	NGC 188	9.6	0.13
NGC 7142	9.3	0.21	Pismis 3	9.0	0.13
Berkeley 66	9.7	0.19	Berkeley 21	9.3	0.12
Berkeley 14	9.2	0.17	King 2	9.8	0.12
NGC 2682	9.4	0.17	NGC 2112	9.3	0.12
NGC 7789	9.2	0.17	NGC 2627	9.3	0.11
Berkeley 17	10.1	0.16	Pismis 2	9.1	0.10
Berkeley 32	9.5	0.16	Berkeley 81	9.0	0.10
NGC 6005	9.1	0.16			

On the problem of membership (1)

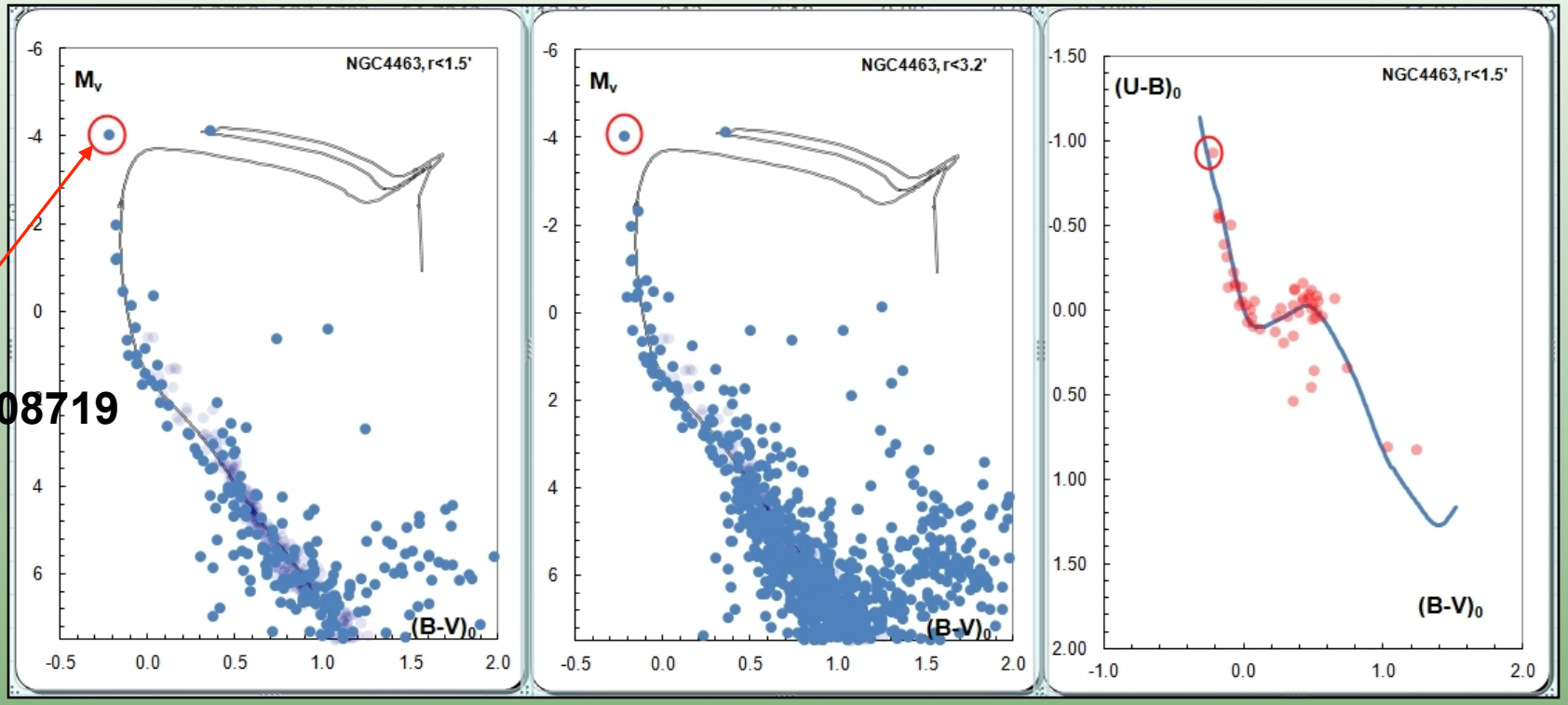


Berkeley 66, log(age) ~ 9.7 (Carraro et al. 2008)

Table 3. Rich open clusters with many stragglers.

Berkeley 12	Berkeley 14	Berkeley 17	Berkeley 18
Berkeley 21	Berkeley 22	Berkeley 31	Berkeley 39
Berkeley 66	Berkeley 70	Berkeley 99	Collinder 110
Collinder 261	King 2	King 11	NGC 1193
NGC 2141	NGC 2158	NGC 2194	NGC 6253
Pismis 2	Pismis 3	Ruprecht 46	Trumpler 5

On the problem of membership (2)



NGC 4463, log(age) ~ 7.85

(Majaess et al., in preparation)