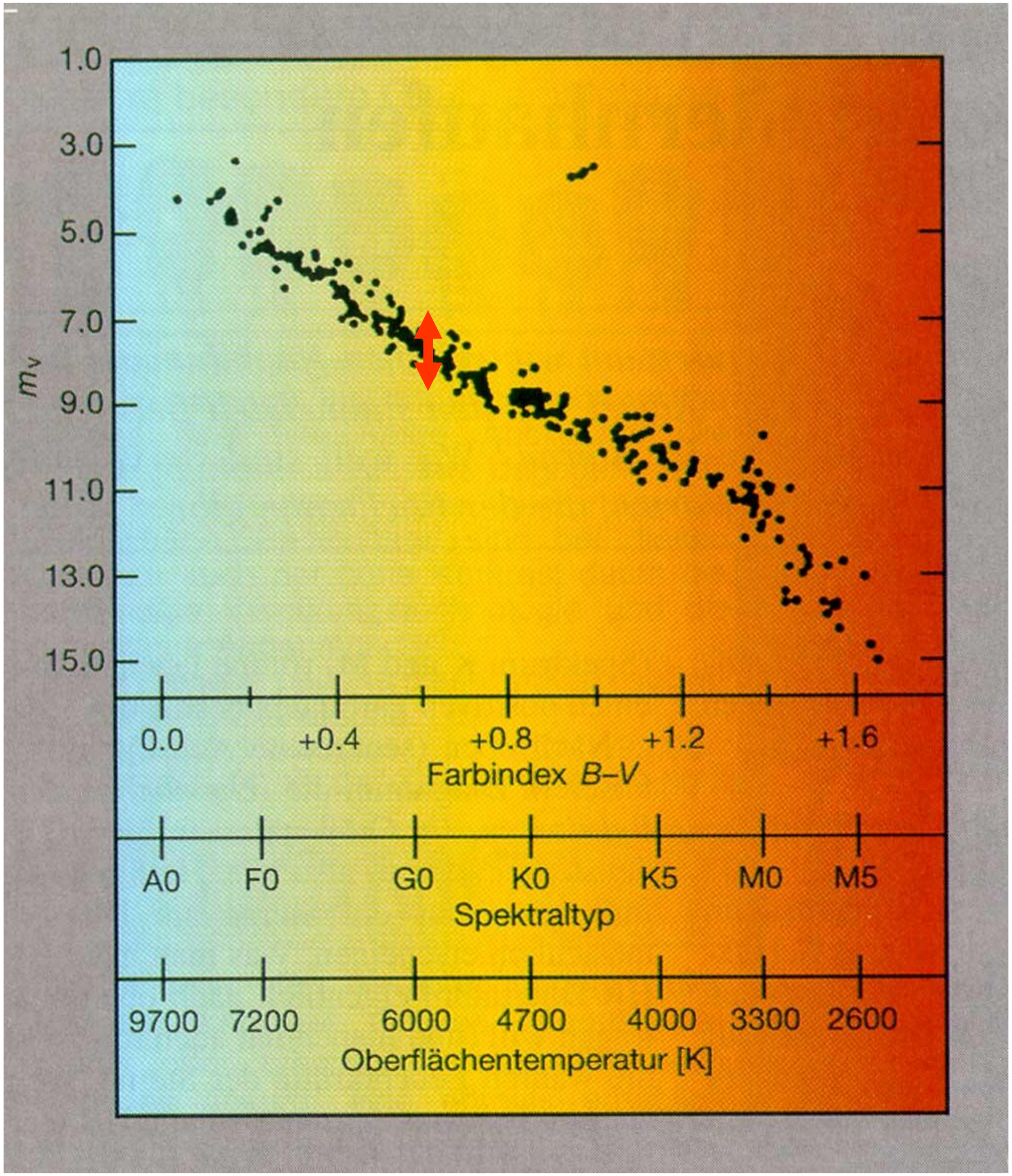


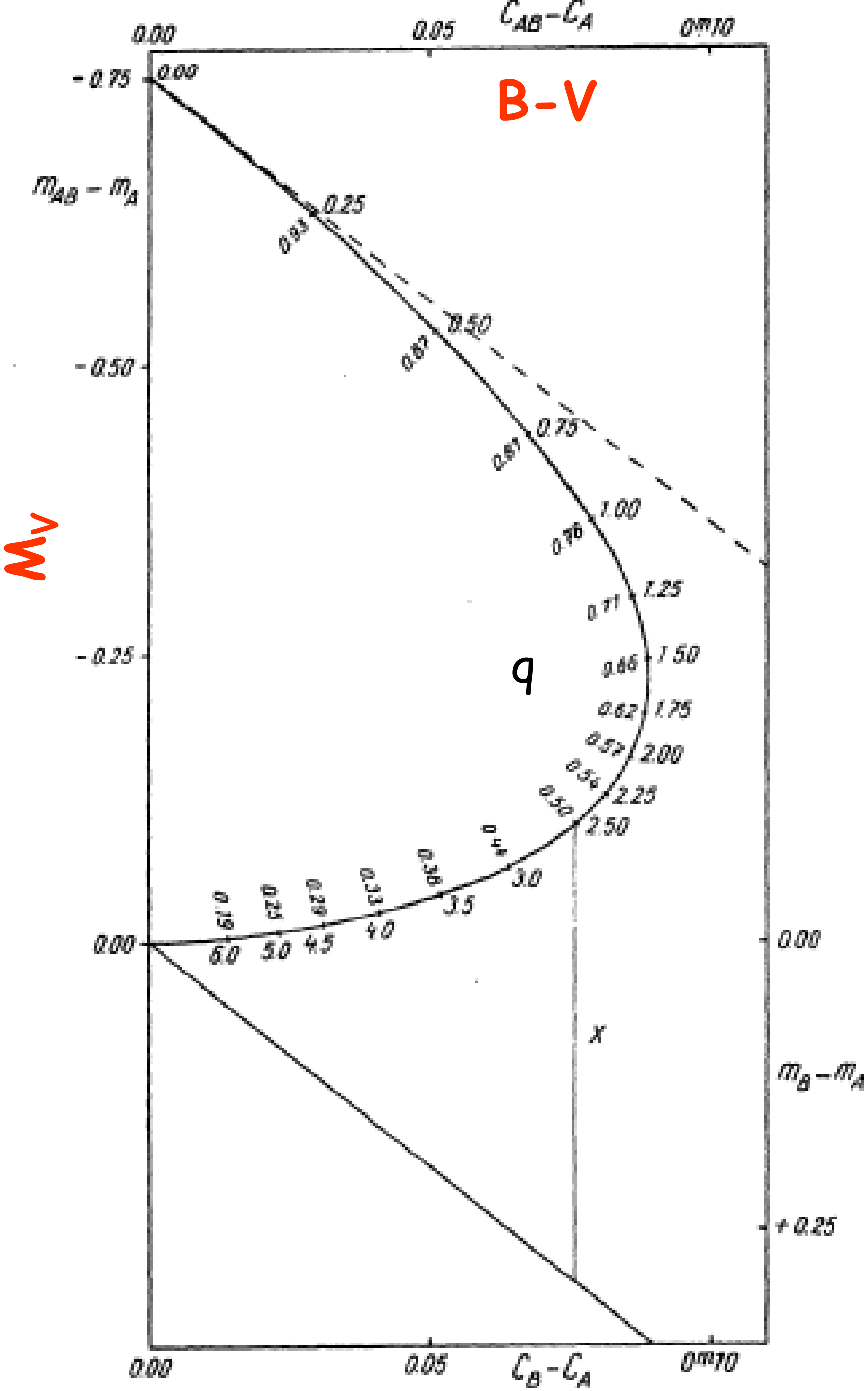
Hyades

log t = 8.90
d = 45 pc
[Fe/H] = +0.17 dex

↕ Width of Main Sequence about 1.8 mag in M_V

NO
Observational error

What are the reasons?



Vertical distance from the main sequence

$$x = a(C_{AB} - C_A) + V_A - V_{AB}$$

Absolute magnitude:

$$M_V = -2.5 \log (L_1 + L_2)$$

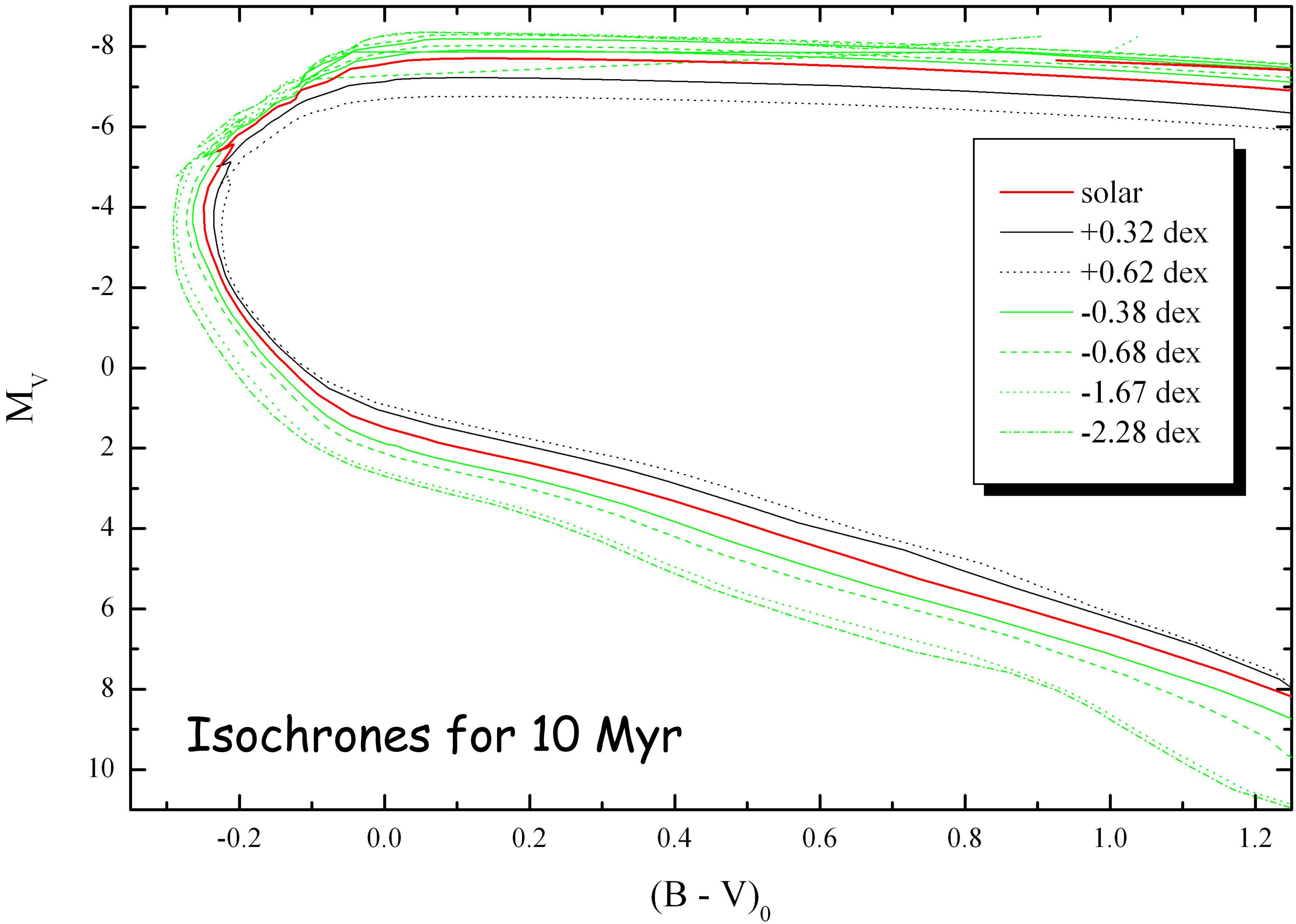
Maximum at $L_1 = L_2$ =>

$$M_V = -0.753 \text{ mag}$$

The maximal width of the main sequence due to binary systems is 0.753 mag

Haffner & Heckmann, 1937, VeGeo, 55, 77

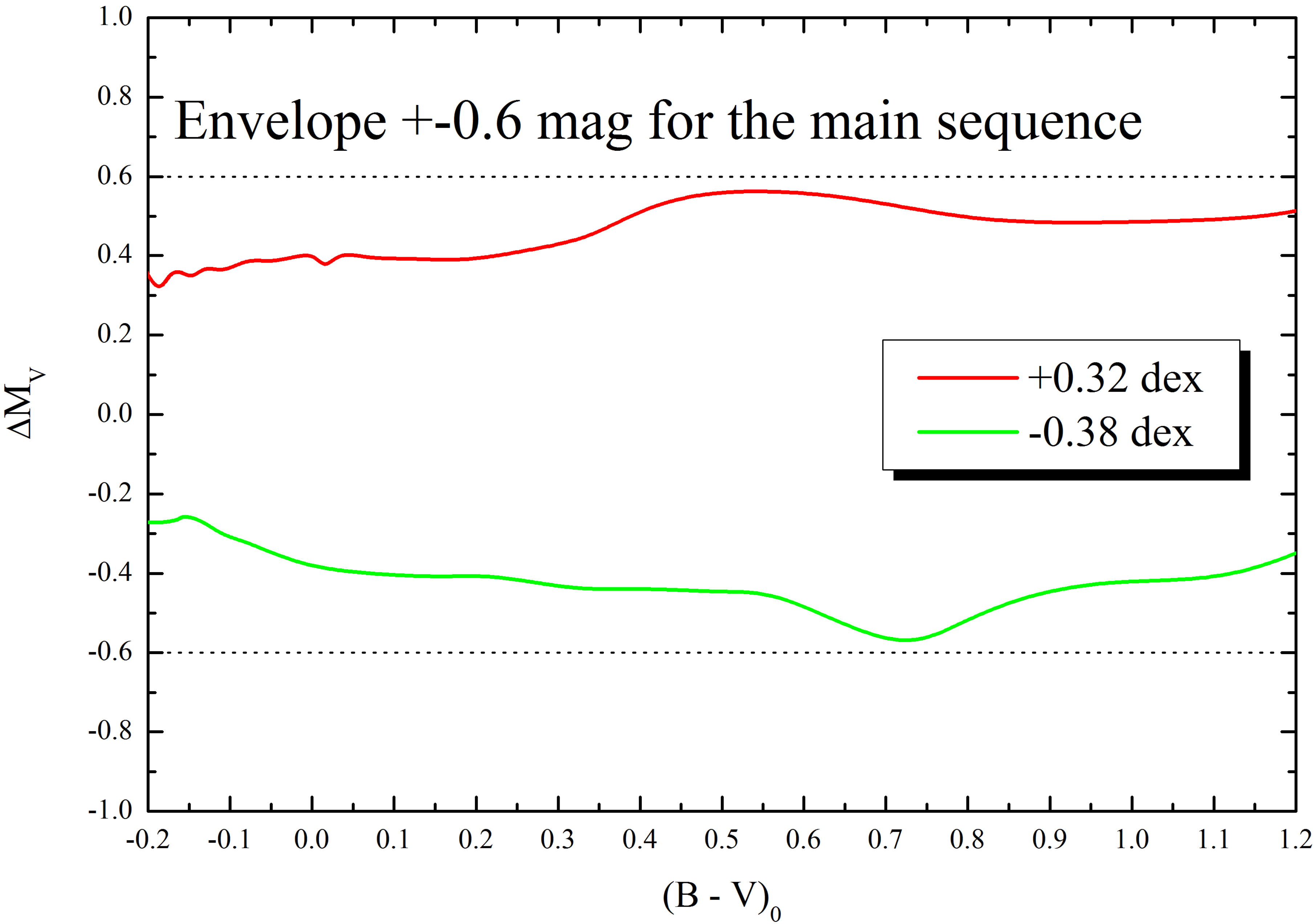
Metallicity => different opacity

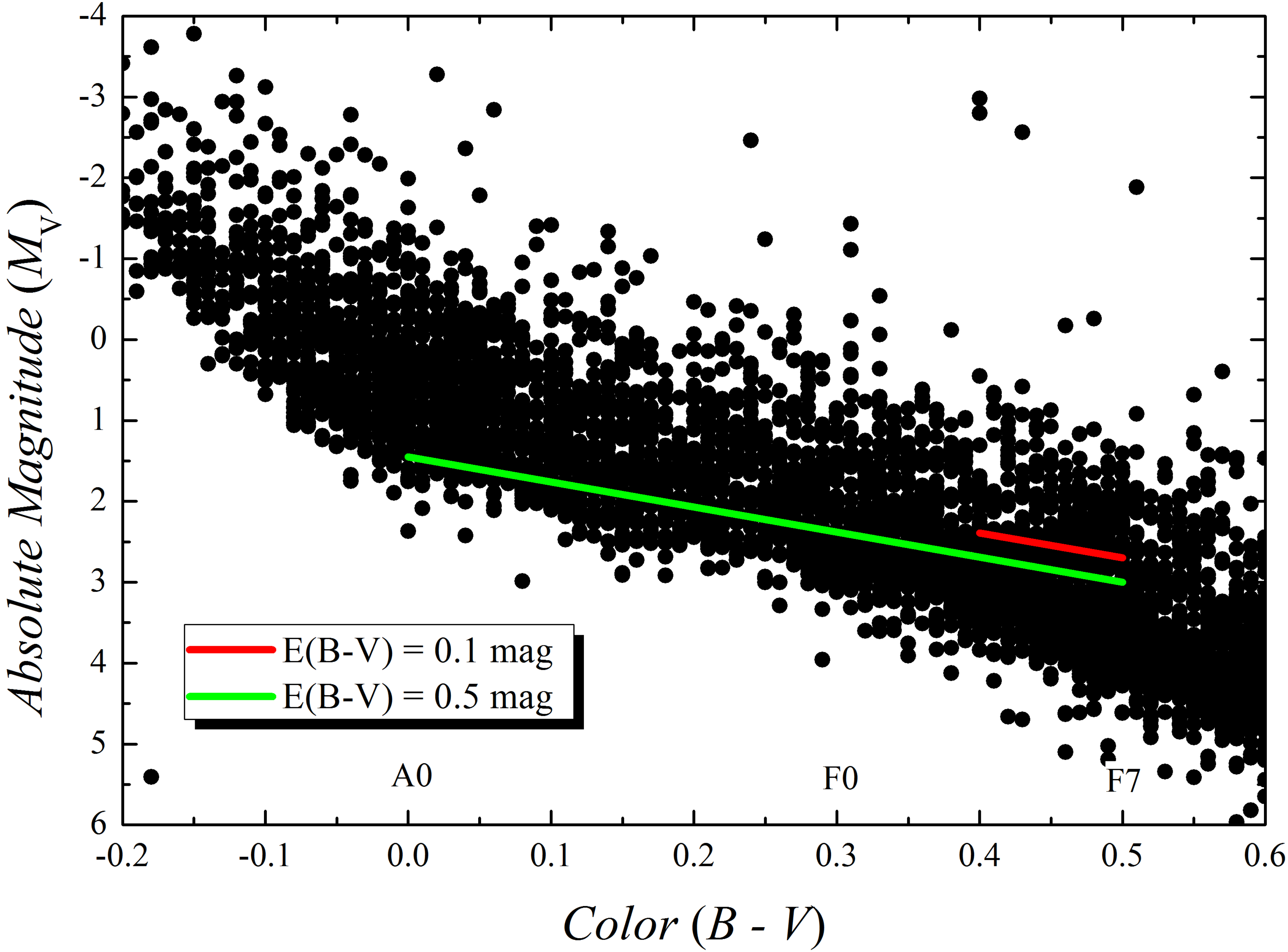


Praesepe: Fossati et al., 2008, *A&A*, 483, 891

					"Normal" A–type stars					Solar
At.N.	Element	HD 72846	HD 73345	HD 73450	HD 73574	HD 74028	HD 74050	HD 74587	HD 74718	Abundances
3	Li	< −8.08(−; 1)	< −8.33(−; 1)	< −8.70(−; 1)	< −8.38(−; 1)			< −8.41(−; 1)	< −8.26(−; 1)	−10.99
6	C	−3.58(−; 1)	−3.44(12; 3)	−3.27(−; 1)	−3.36(18; 2)	−3.39(08; 2)	−3.52(−; 1)	−3.49(01; 2)	−3.51(04; 2)	−3.65
8	O	−3.18(−; 1)	−3.22(01; 2)				−3.70(−; 1)	−3.30(−; 1)		−3.38
11	Na	−5.44(01; 2)	−5.37(01; 2)	−6.28(−; 1)	−5.57(02; 2)	−5.98(−; 1)	−5.64(13; 2)	−5.61(02; 2)	−5.70(14; 2)	−5.87
12	Mg	−4.18(08; 3)	−4.18(02; 3)	−5.02(18; 2)	−4.37(04; 3)	−4.86(08; 3)	−4.22(05; 4)	−4.56(08; 3)	−4.52(01; 2)	−4.51
14	Si	−4.62(16; 2)	−4.67(−; 1)	−4.13(−; 1)	−4.19(−; 1)	−4.17(−; 1)	−4.37(−; 1)	−4.16(−; 1)	−4.25(−; 1)	−4.53
16	S	−4.71(04; 2)	−4.44(03; 4)	−4.35(−; 1)	−4.61(02; 2)	−4.26(01; 2)		−4.50(04; 2)	−4.28(11; 2)	−4.90
20	Ca	−5.17(−; 1)	−5.39(09; 6)	−5.95(06; 4)	−5.86(16; 5)	−5.37(16; 2)	−6.13(06; 2)	−5.49(15; 6)	−5.68(02; 3)	−5.73
21	Sc	−8.88(−; 1)	−8.63(07; 3)	−8.57(14; 3)	−8.89(02; 3)	−8.35(−; 1)	−8.96(27; 3)	−8.56(−; 1)	−8.69(14; 2)	−8.99
22	Ti	−6.88(03; 5)	−6.95(06; 6)	−7.30(11; 5)	−6.98(09; 5)	−6.78(−; 1)	−7.08(15; 5)	−6.83(16; 3)	−6.93(10; 5)	−7.14
24	Cr	−6.23(06; 3)	−6.22(08; 2)	−6.56(08; 3)	−6.19(16; 3)	−6.23(12; 4)	−6.48(10; 3)	−6.05(13; 4)	−6.44(20; 5)	−6.40
25	Mn		−6.37(−; 1)	−6.88(−; 1)	−6.52(02; 2)	−6.77(−; 1)	−6.61(−; 1)	−6.62(04; 2)	−6.71(−; 1)	−6.65
26	Fe	−4.55(18; 42)	−4.33(11; 61)	−4.62(09; 15)	−4.49(10; 30)	−4.50(09; 18)	−4.44(13; 16)	−4.28(10; 33)	−4.61(11; 26)	−4.59
28	Ni	−5.70(18; 2)	−5.58(11; 4)	−5.82(16; 2)	−5.62(08; 4)	−5.93(14; 3)	−5.60(15; 3)	−5.84(−; 1)	−5.68(02; 3)	−5.81
39	Y	−9.75(−; 1)	−9.46(−; 1)	−9.83(−; 1)	−9.20(−; 1)	−9.56(−; 1)	−9.26(−; 1)	−9.13(−; 1)	−9.10(−; 1)	−9.83
56	Ba	−9.48(−; 1)	−9.30(06; 2)	−9.50(02; 2)	−8.98(04; 2)	−9.65(−; 1)	−9.52(01; 2)	−8.96(25; 2)	−9.15(−; 1)	−9.87
	$T_{\rm eff}$	8045	7993	7270	7662	7750	7872	7500	7600	
	$\log g$	3.50	3.96	4.20	4.00	4.50	3.66	4.20	4.00	
	$\upsilon_{\rm mic}$	2.5	2.6	2.7	2.6	2.6	2.6	2.7	2.7	
	$\upsilon \sin i$	119	85	138	102	150	188	90	155	

Fe: -4.28 to -4.62dex; 0.34 dex

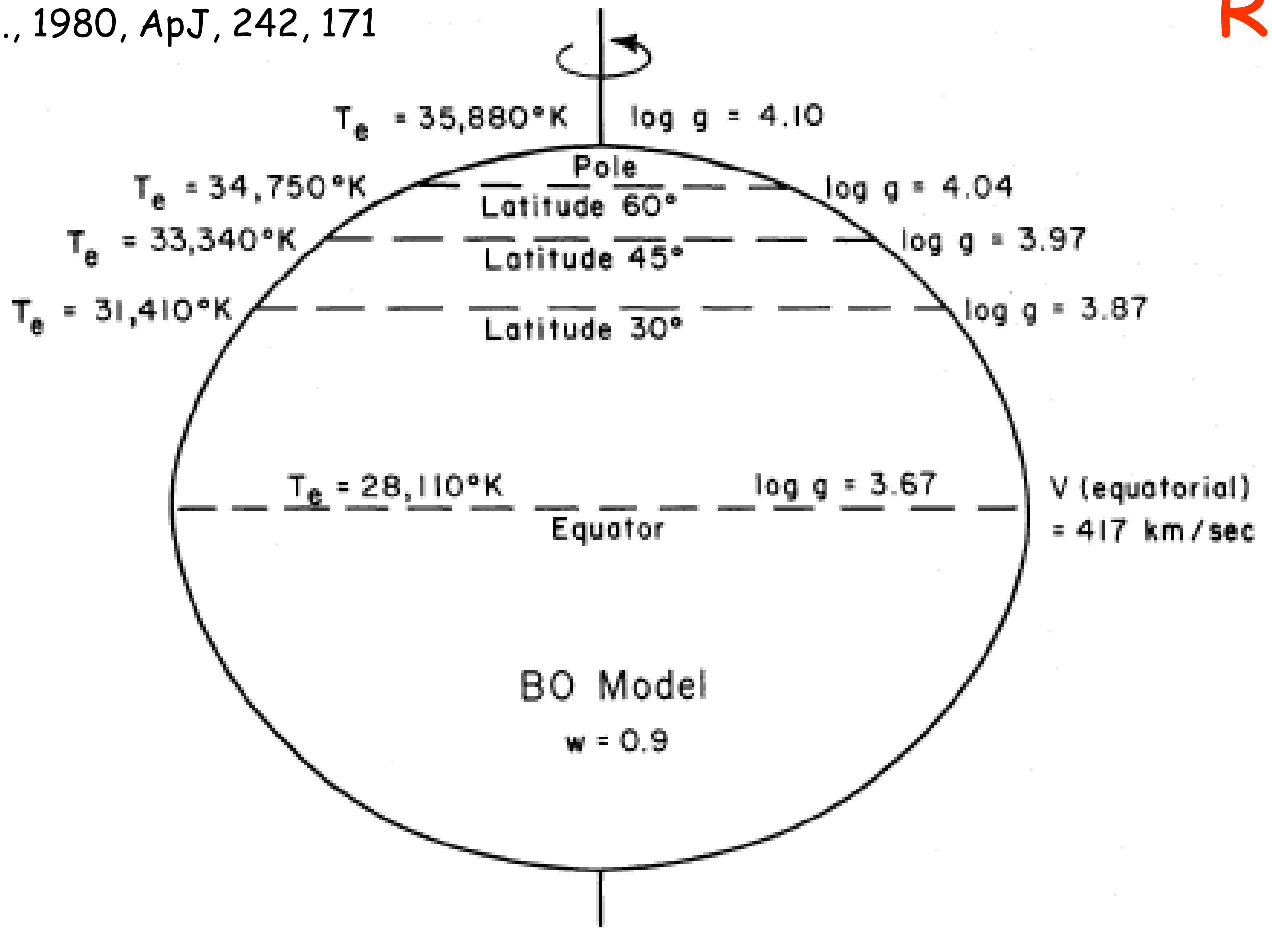

Envelope +-0.6 mag for the main sequence
+0.32 dex
-0.38 dex
ΔM_V
(B - V)_0
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2



Absolute Magnitude (M_V)
Color (B - V)
E(B-V) = 0.1 mag
E(B-V) = 0.5 mag
A0
F0
F7
-4
-3
-2
-1
0
1
2
3
4
5
6
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6

Rotation

Slettebak et al., 1980, ApJ, 242, 171



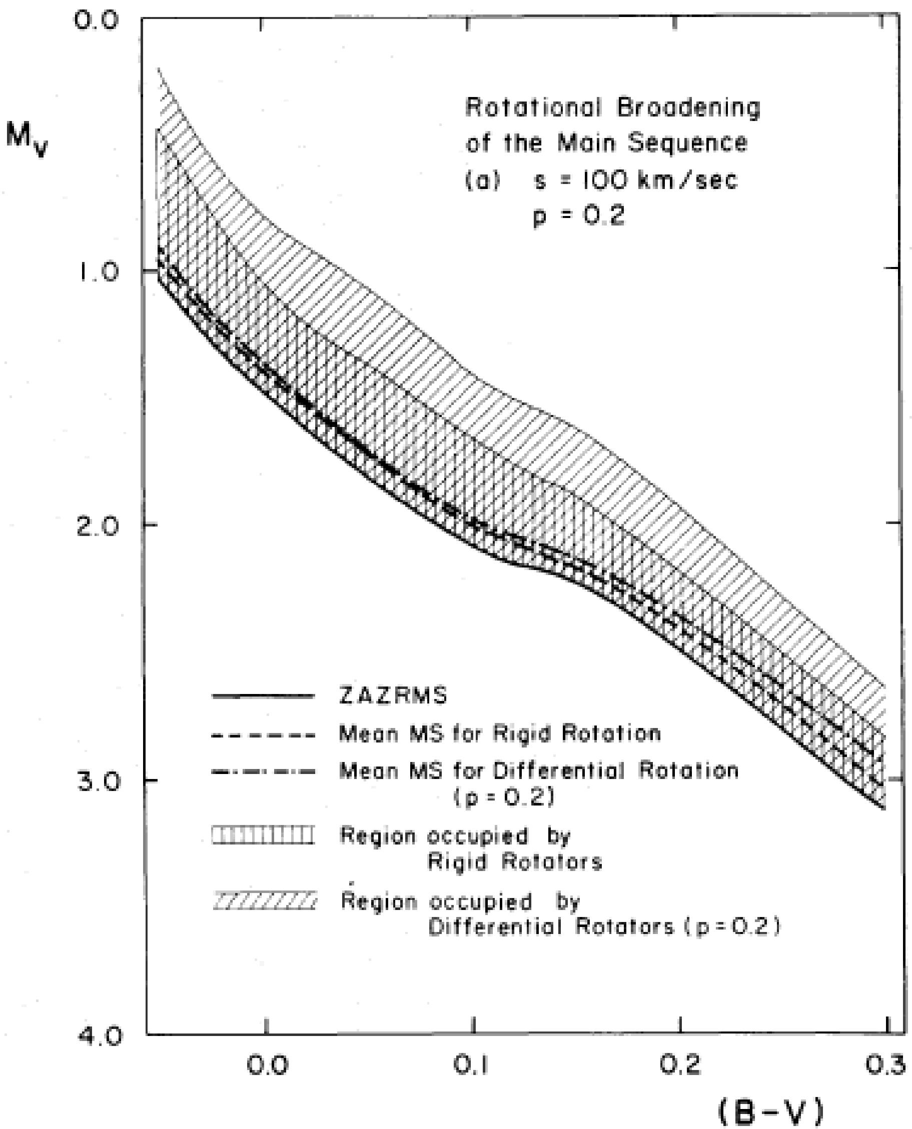
Energy generation rate

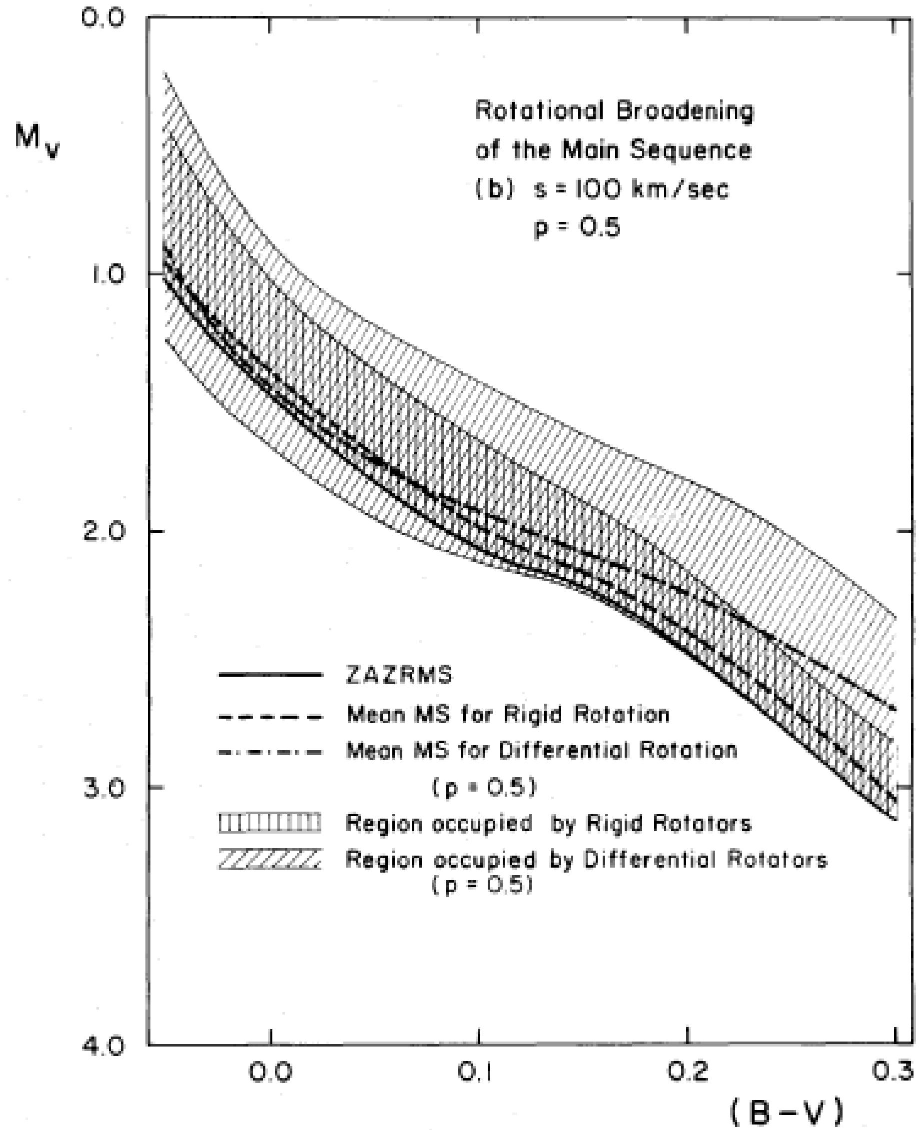
$$\epsilon = (\text{const})\left(1 - \frac{\omega^2}{2\pi G\rho}\right)$$

Von Zeipel Theorem (1924)

From the rotational velocity => ε => T_{eff} and L (log g)

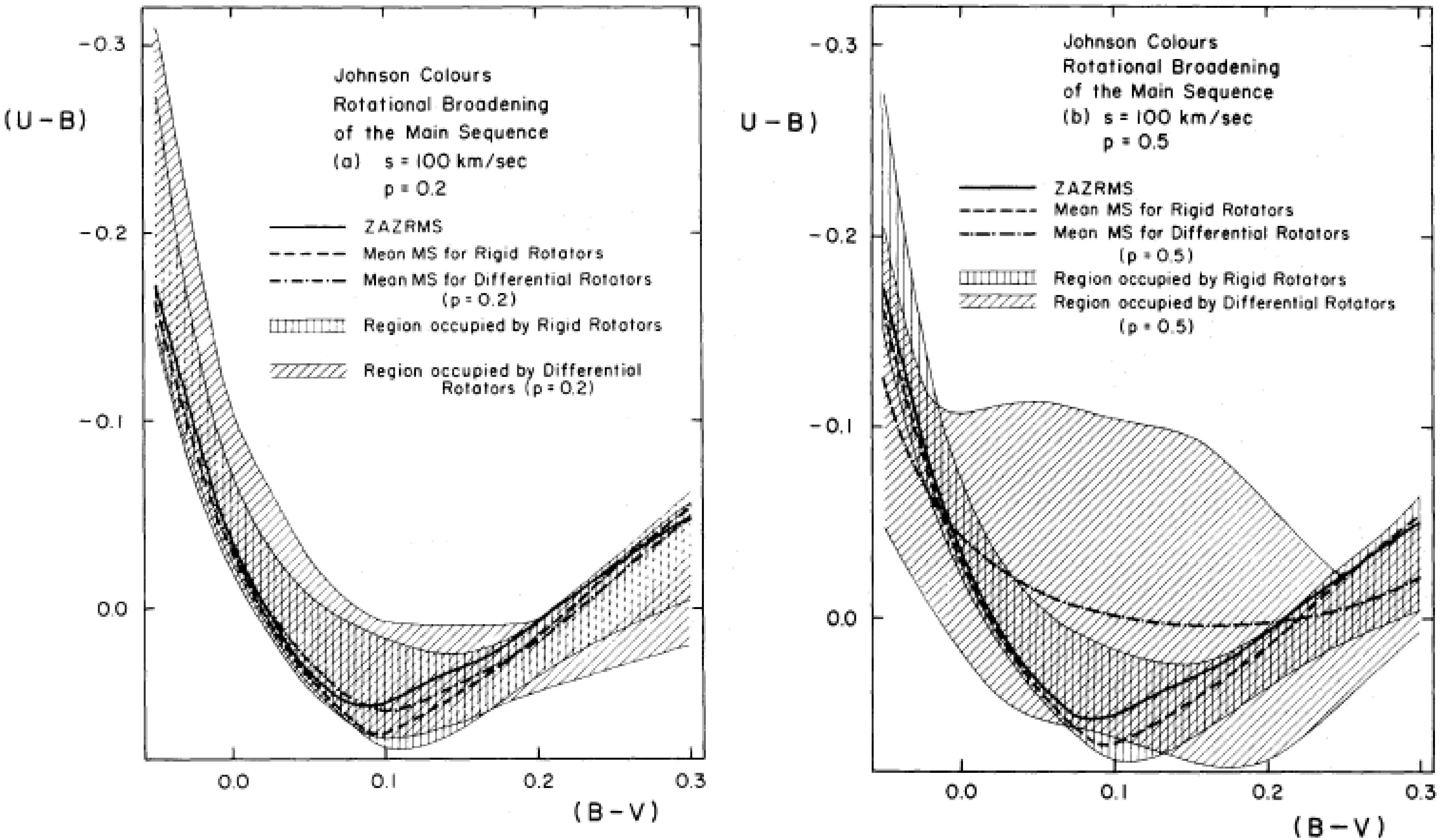
Collins & Smith, 1985, MNRAS, 213, 519





p … Degree of differential rotation

Collins & Smith, 1985, MNRAS, 213, 519



Conclusions – Width of the Main Sequence

- Differential reddening: $k \cdot \Delta E(B-V)$
- Spectroscopic Binaries: 0.753 mag
- Metallicity: up to 1.2 mag for M_V, but only 0.2 mag for (U – B) versus (B – V)
- Rotation: 1 mag for M_V, 0.2 (?) mag for (U – B) versus (B – V)

Stellar Associations

- Stellar associations have different characteristics than star cluster, two different types
  1. OB Associations: Stars of spectral types O and B, but also T Tauris
  2. T (Tauri) Associations : PMS objects with masses lower than two solar masses
- Stellar associations are also found in other Galaxies (IC 1613, NGC 330)

Characteristics

- The stars are born together from GMC
- Not gravitational bound
- No common kinematics
- Very young, $\log t < 7.5$
- Diameters up to 200 pc

Blaauw, 1964, AR&A, 2, 213

GENERAL PROPERTIES OF THE ASSOCIATIONS AND O-B2 CLUSTERS WITHIN 1000 PC

1. Designation Morgan, Whitford & Code (19) [=Markarian (18)]	2. Approximate position l^{II}	3. Approximate position b^{II}	4. Distance (pc)	4. Distance (Ref.)	5. Z (pc)	6. Largest overall projected diameter (pc)	7. Number of O-B2 stars	8. Number of stars between limits of M_v: −7 −3	−3 −2	−2 −1	−1 0	0 +1	9. Estimated total mass (10^3) 10^3
IC 2602	289°.6	−4°.9	155	(99)	− 13	2.2	1	1	0	3	3	6	0.3
Scorpio-Centaurus						≥200							
Upper Scorpius (II Sco)	341° to 2°	+10° to +30°	170	(28)	+ 55		17	10	5	9	9	12	5.8
Upper Centaurus-Lupus	312 to 341	+10 to +25	170	(28)	+ 40		12	6	9	8			
Lower Centaurus-Crux	292 to 312	−10 to +15	160	(28)	+ 10		10	5	4	8			
II Perseus [=Perseus II]	156 to 165	−11 to −21	330	(62)	− 85	50	10	5	5	7			1.5
I Orion [=Orion I]	199 to 210	−12 to −21	460	(62)	−130	100	56	35	31	21			7.6
I Lacerta	92 to 107	− 7 to −20	600	(59)	−165	130	18	10	10				3.0
NGC 7160	104.0	+6.5	705	(36)	+ 80	2.5	1	2	1	3	4		0.4
II Monoceros (NGC 2264) [=Monoceros I?]	202.9	+2.2	715	(36)	+ 27	8	1	1	1	4	10	21	0.8
III Cepheus	109.3 to 111.7	+2.4 to +3.7	730	(43)	+ 37	23	28	15	11	5	6:		3.8
I Cepheus [=Cepheus II]	96 to 105	0 to 8	830	(73)	+ 73	120	≥34	≥29					10:
NGC 1502	143.6	+7.6	880	(36)	+116	3.8	5	2	9	7	6		0.8
NGC 2169	195.6	−2.3	930	(36)	− 37	2.3	2	1	1	3	2		0.4

In the same space volume we find about 350 star clusters

Probability of formation is very low

Subgroups

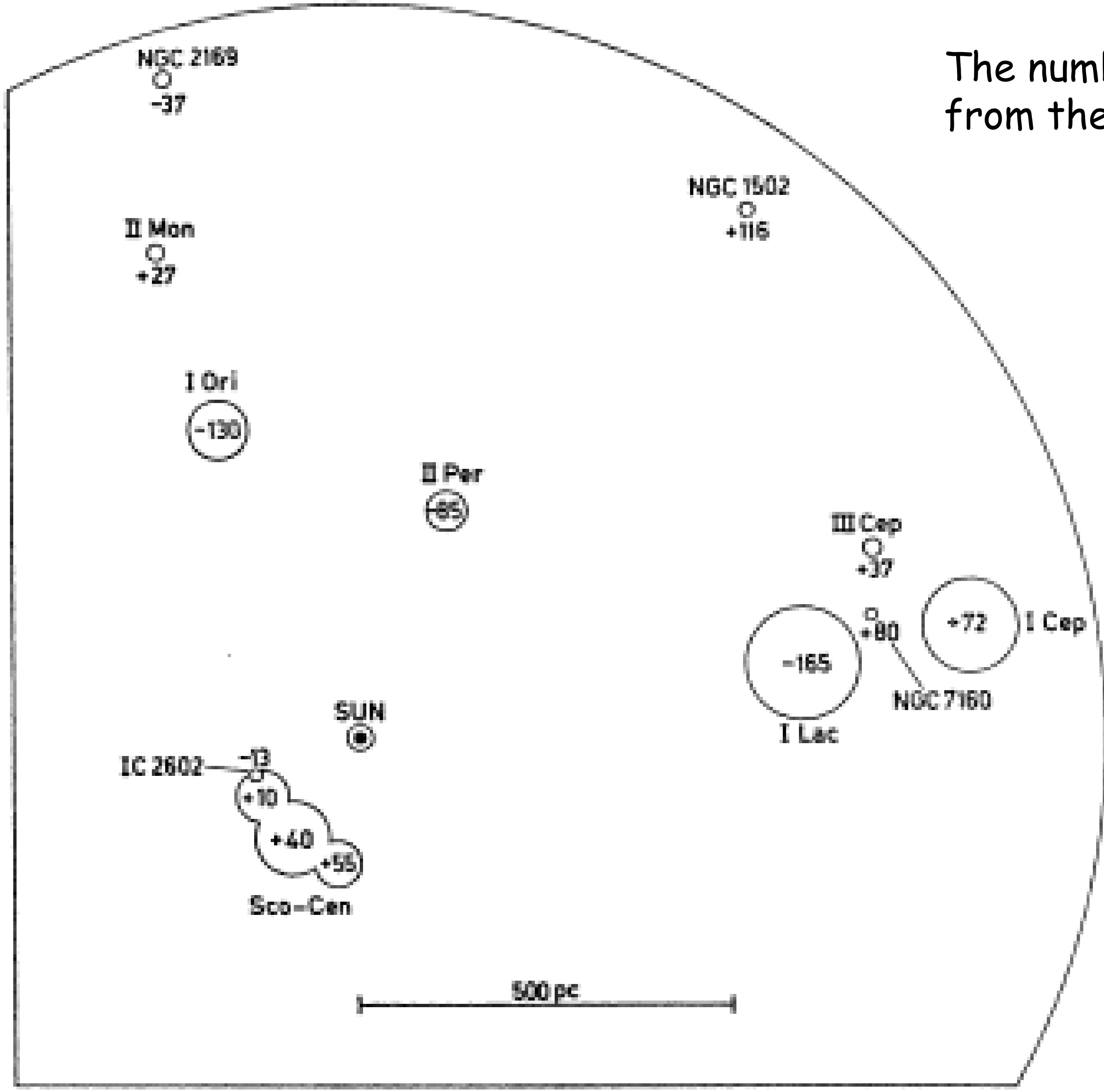
Some Properties of the Subgroups in Associations Within 1000 pc

1.	2.	3.	4.	5.	6.	7.	8.
				Estimated average age		Runaway stars	
Subgroup (see Fig. 4)	Largest projected dimension (pc)	Projected separation of centers (pc)	Number of stars B3 and earlier	from C-M diagrams (10^6 yr)	from kinematic data (10^6 yr)	Name	Kinematic age (10^6 yr)
Upper Centaurus-Lupus	80	65	18	14			
Upper Scorpius	45		16	10	20	ζ Oph	1.1
II Per	50		14	4	1.5	ξ Per	1.6
Ia Ori	50	25 (ab)	20	12		{ AE Aur	2.7
Ib Ori	20	25 (bc)	15	8		{ μ Col	2.2
Ic Ori	15		18	6		{ 53 Ari	4.9
Id Ori	2			47	0.3		
Ia Lac	100	70	10	16	77	{ HD 197149	10:
Ib Lac	30		11	12		{ HD 201910	3:
II Mon	8		4	1			
IIIa Cep	17	13	16	8			
IIIb Cep	10		15	4			
NGC 1502	4		9	47		α Cam	2.0

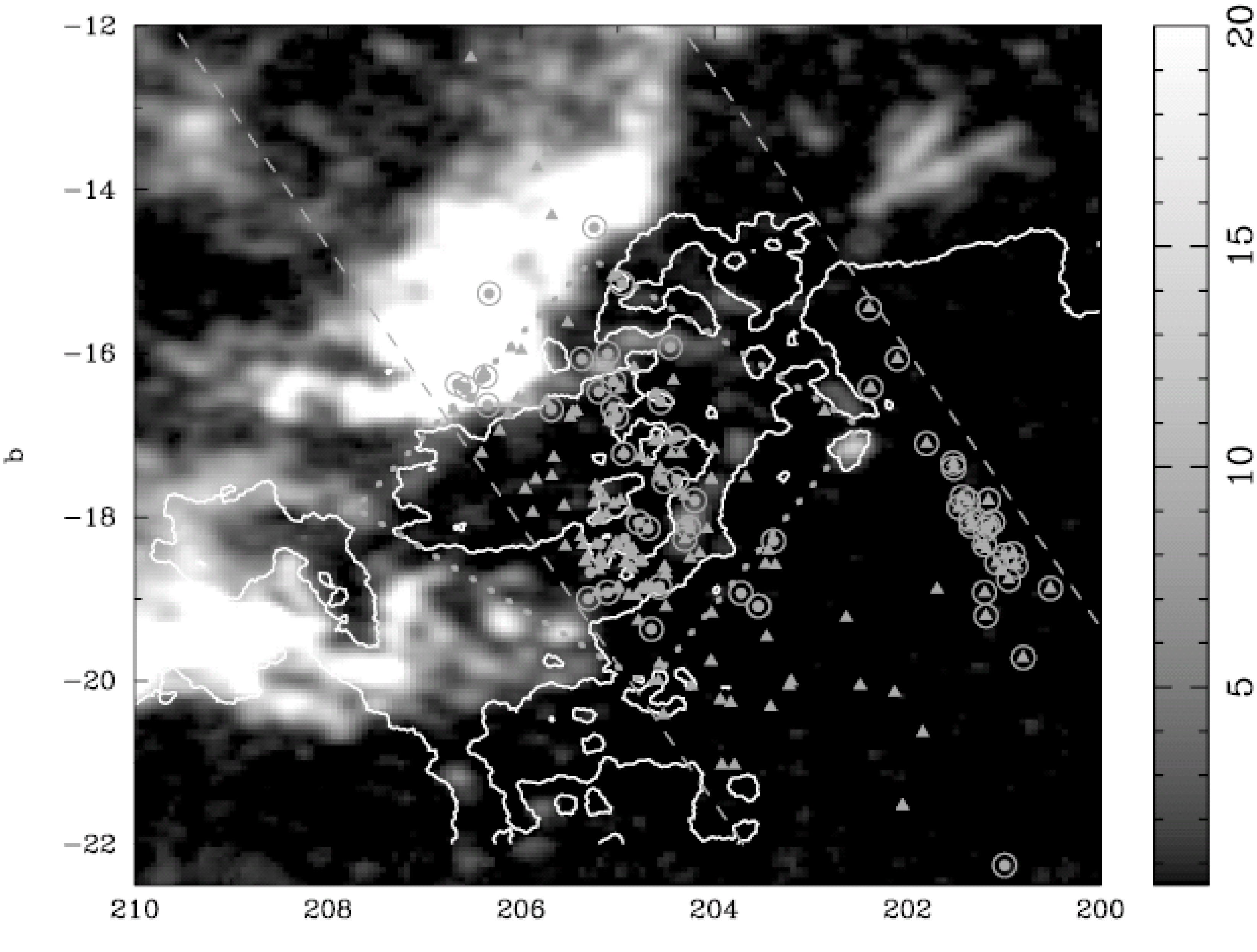
Blaauw, 1964, AR&A, 2, 213

10^6 10^6 10^6 yr

The numbers are the distance from the Galactic disk in [pc]



Blaauw, 1964, AR&A, 2, 213

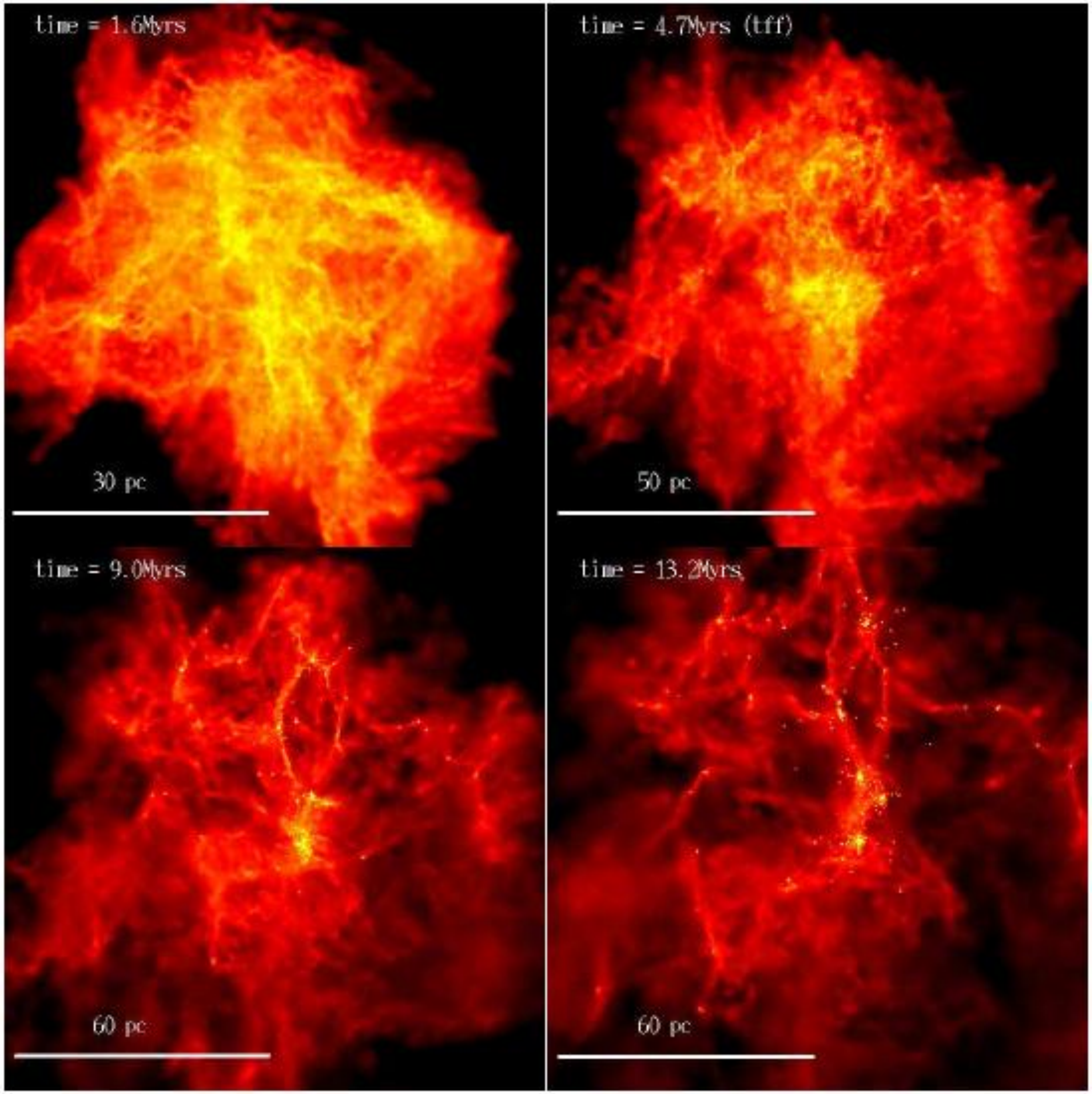


T Tauri stars in Orion OB1b, be aware of the gas- and dust distribution

Calvet et al., 2005, AJ, 129, 935

Formation

- Giant Molecular Cloud
- Supernova explosion(s)
- Gravitation too weak to bound stars together
- Formation in a gravitational unbound association
- Low probability
- Simulations by Clark et al., 2005, MNRAS, 359, 809



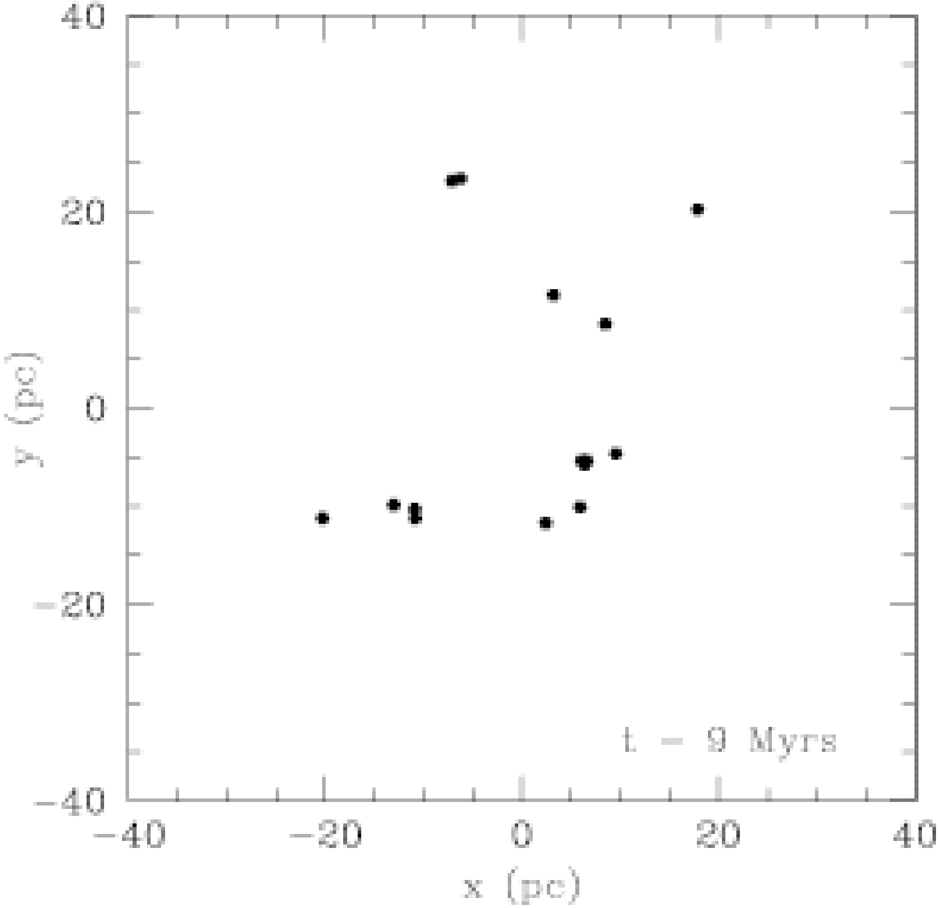
SFC No.	M_{SFC} ($M_\odot$)	ΔV (km s^{-1})	R pc	t_{cr} Myr
1	1763	3.27	0.71	0.42
2	761	2.68	0.45	0.33
3	706	3.24	0.29	0.17
4	624	2.24	0.53	0.46
5	455	2.37	0.35	0.29
6	362	1.77	0.50	0.55
7	338	1.77	0.46	0.51
8	329	2.88	0.17	0.12
9	305	1.68	0.46	0.54
10	212	2.31	0.17	0.14
11	174	1.37	0.39	0.56
12	151	1.95	0.17	0.17
13	150	1.95	0.17	0.17
14	144	1.91	0.17	0.17
15	141	1.63	0.23	0.27
16	140	1.39	0.31	0.44

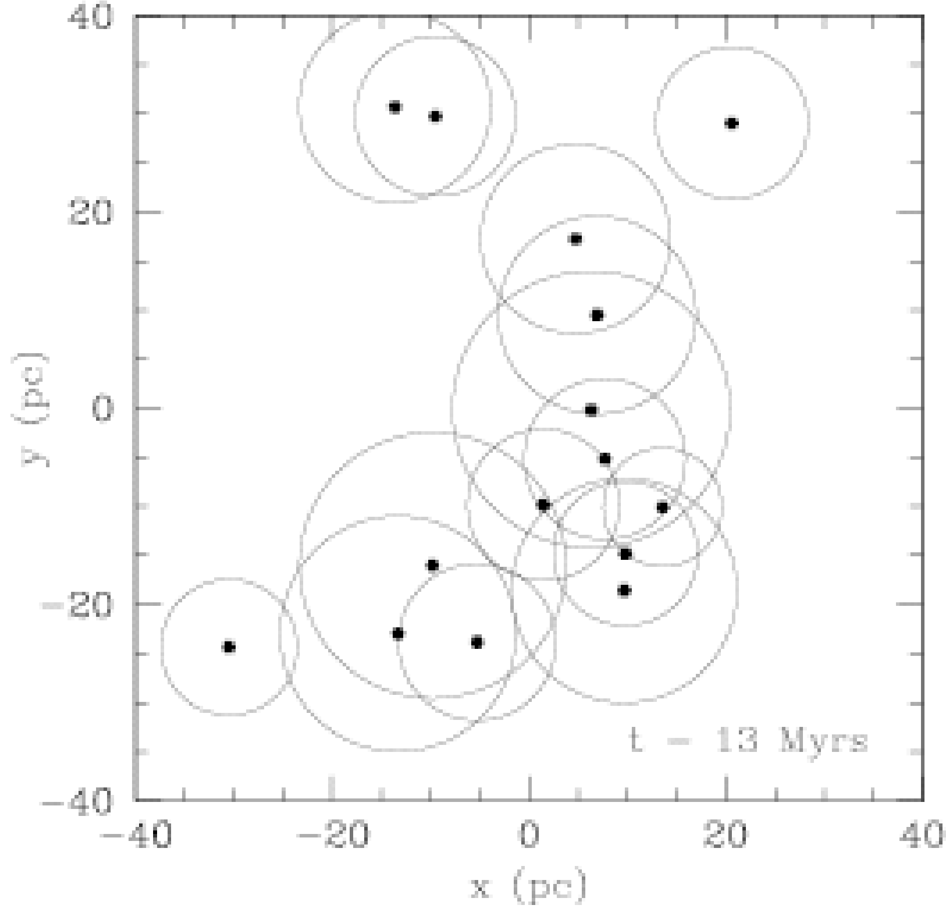
High masses

Low
Crossing time

Clark et al., 2005, MNRAS, 359, 809

Clark et al., 2005, MNRAS, 359, 809





Disintegration in small subgroups

„Gravitational spheres“

Expansion within 4 Myr

Moving Groups

- Group of stars which have identical kinematical characteristics. This is not depending on the galactic rotation.
- First detection by Richard A. Proctor (1869 !). He was also the first who discovered the common proper motions of the Hyades.
- Main researcher: Olin Eggen

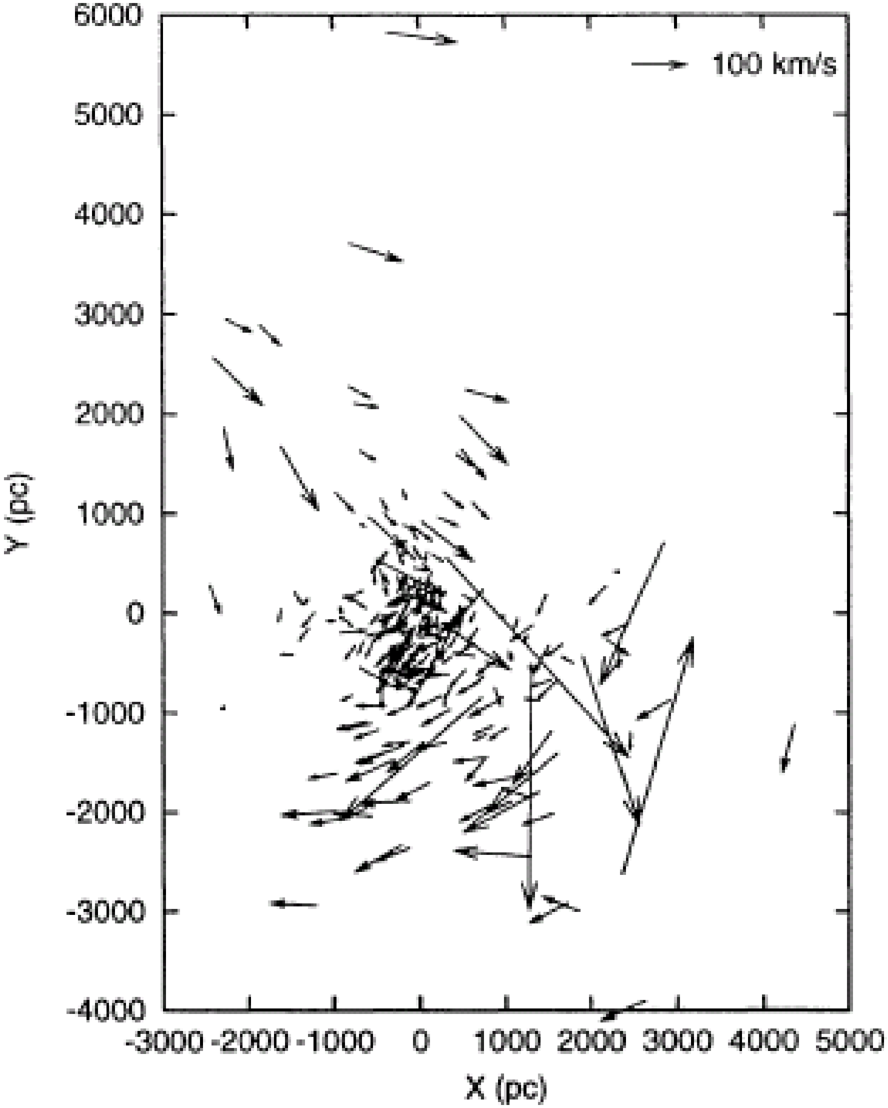
II. "Preliminary Paper on certain Drifting Motions of the Stars." By RICHARD A. PROCTOR, B.A., F.R.A.S. Communicated by WARREN DE LA RUE, V.P.R.S. Received October 26, 1869.

A careful examination of the proper motions of all the fixed stars in the catalogues published by Messrs. Main and Stone (Memoirs of the Royal Astronomical Society, vols. xxviii. and xxxiii.) has led me to a somewhat interesting result. I find that in parts of the heavens the stars exhibit a well-marked tendency to drift in a definite direction. In the catalogues of proper motions, owing to the way in which the stars are arranged, this tendency is masked; but when the proper motions are indicated in maps, by affixing to each star a small arrow whose length and direction indicate the magnitude and direction of the star's proper motion, the star-drift (as the phenomenon may be termed) becomes very evident.

Proctor, 1869, Proc. R. Soc. London, 18, 169

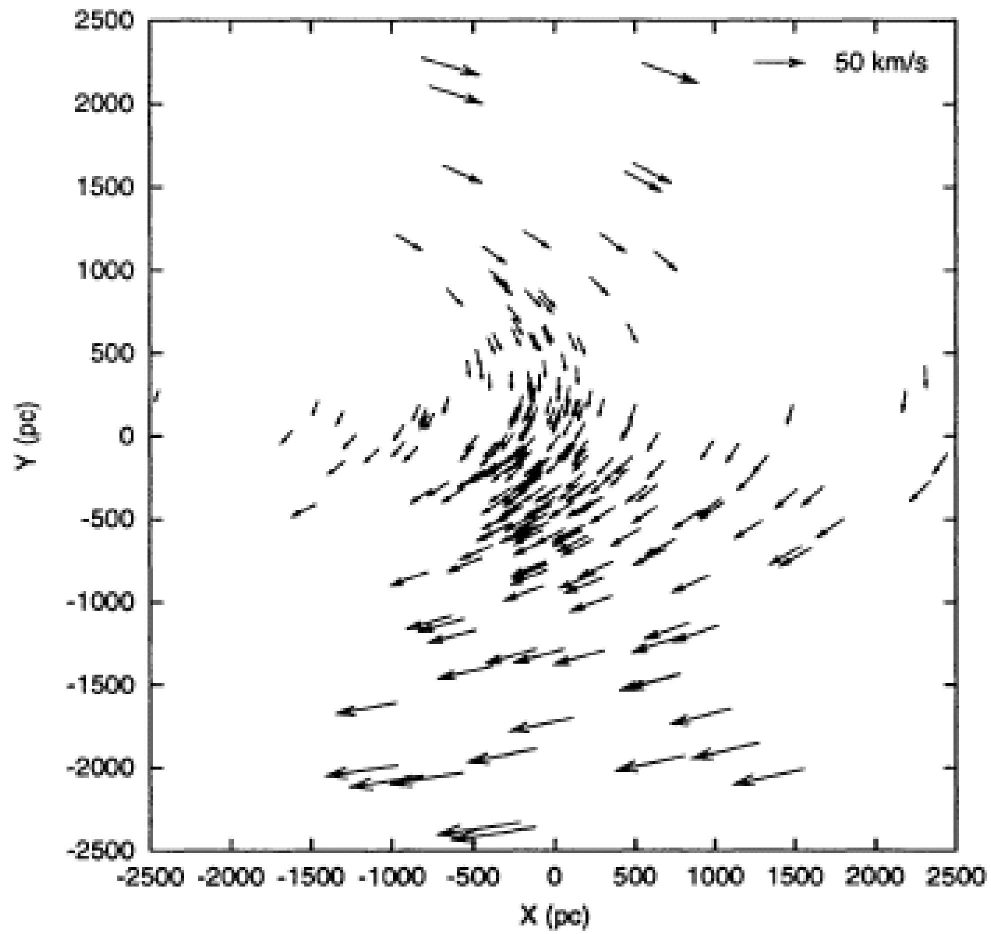
1964: Petrie, Hoyle, Sahade, Brownlee, Schwarzschild, McCrea, Herbig, Walker (2), Woolley, Sandage, van den Bergh, King, Eggen, Stromgren, Haffner

Observations of 243 O to B5 stars



After the correction of the Apex motion

Uemura et al., 2000, PASJ, 52, 143



Observations I

- Be aware: normally, there is no correction for the Apex Motion of the Sun!
- Apex Motion: (U,V,W) = (-10, +5, +7)
- If comparing values from the literature, always check for the correction
- For finding moving groups, the galactic rotation has to be accounted for

Observations II

- We need the proper motion [μ_α:μ_δ] and the radial velocity for each object
- Moving groups can only be detected
  1. The solar vicinity (μ_α and μ_δ significant)
  2. Far distances for very peculiar kinematical groups
- GAIA: 2011/2, Kinematical data for 10^7 stars with V = 15 mag

TABLE 1. Stellar kinematic groups.

Name	U	V	W	v(rad)
Ursa Major Group (Sirius Gr.)	+13	+1	−8	30
γ Leonis Group	−78	−4	−1	
Hyades Group	−40	−16	−3	44
Local Association (Pleiades Gr.)	−9	−27	−12	31
Wolf 630 Group	+25	−33	+13	
ε Indi Group	−78	−38	+4	88
ζ Her Group	−52	−47	−27	75
61 Cygni Group	−90	−53	−8	106
HR 1614 Group	−4	−58	−11	
σ Pup Group	−75	−88	−21	107
η Cephei Group	−33	−97	+10	
Arcturus Group	+25	−115	−3	
Groombridge 1830 Group	+277	−157	−14	304
Kapteyn's Star Group	+19	−288	−53	

Soderblom & Mayor, 1993, AJ, 105, 226

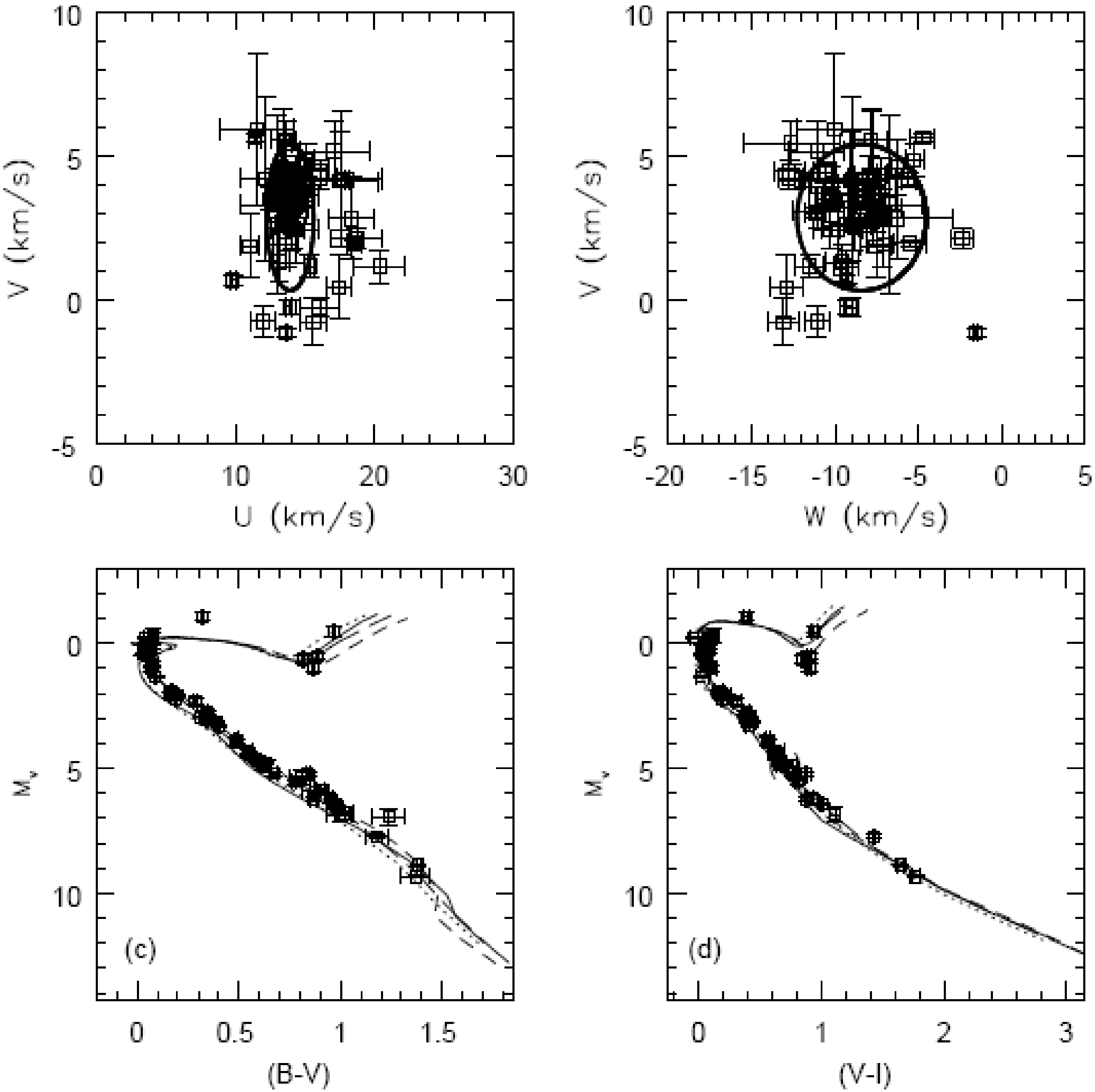
Star density: 10^{-4} to 10^{-3} stars per pc^3 (Sun: about 0.1)

„Age“ widely different, if possible to determine

„Theory“

- Moving groups are dissipating star clusters which explains the widely different ages
- There is a continuous transition with star clusters
- Punch line from Olin Eggen:

Each star cluster is a moving group, but not all moving groups are star clusters



Ursa Major
„Siriusgroup“

Diameter
about 150 pc

Isochrone for
600 Myr

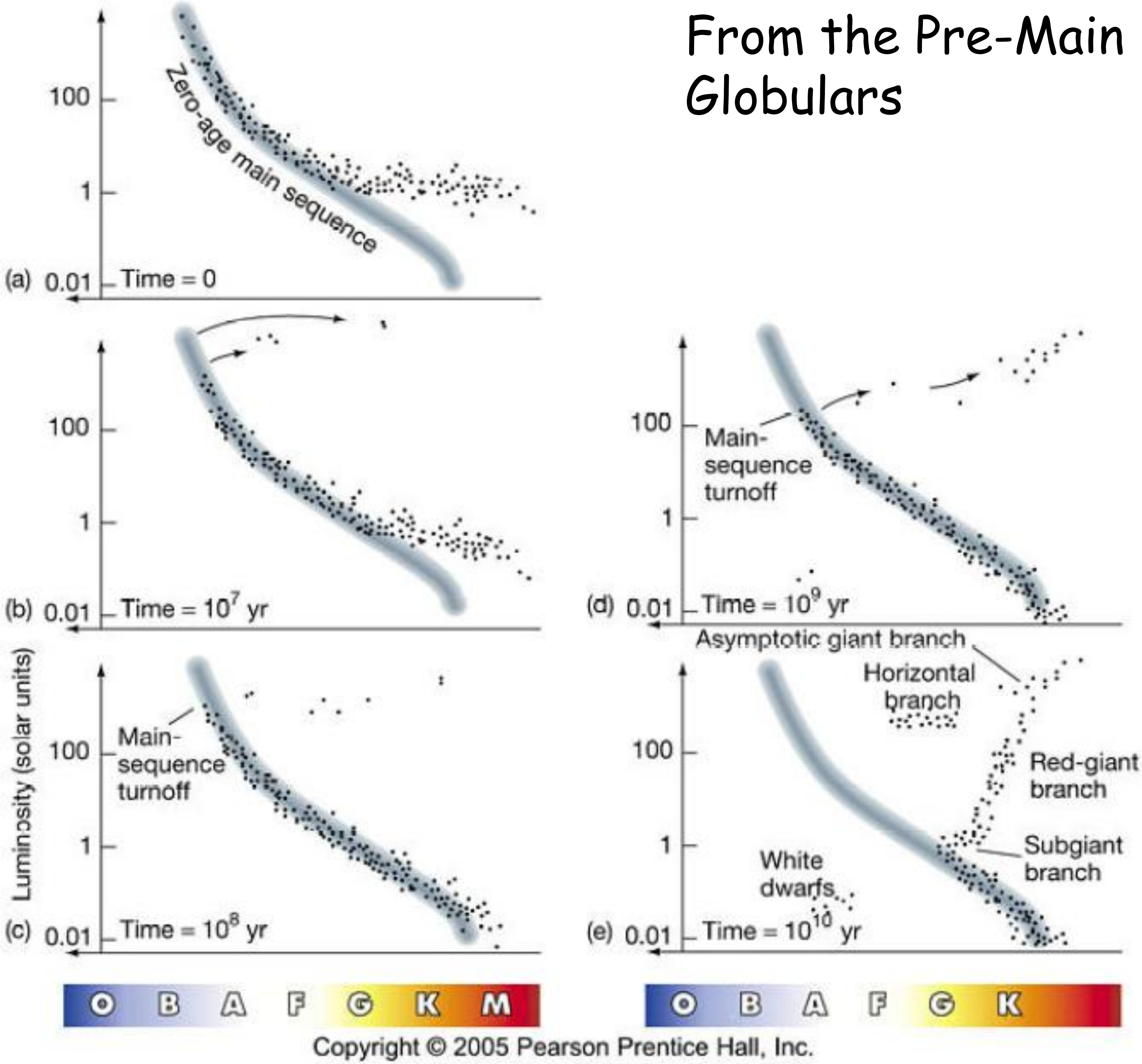
Any difference
to an open
cluster?

King et al., 2003, AJ, 125, 1980

Globular Clusters of the Milky Way

- Data base und links: http://venus.mporzio.astro.it/~marco/gc/
- Literature:
  1. Ashman & Zepf, Globular Cluster Systems, 1998, Cambridge Astrophysics, ISBN-10: 0521550572
  2. Piotto et al., New Horizons in Globular Cluster Astronomy, 2003, PASP Vol. 296
- In ADS there are 10934 hits for the key words „globular cluster“

From the Pre-Main Sequence to Globulars



(a) $t = 0$

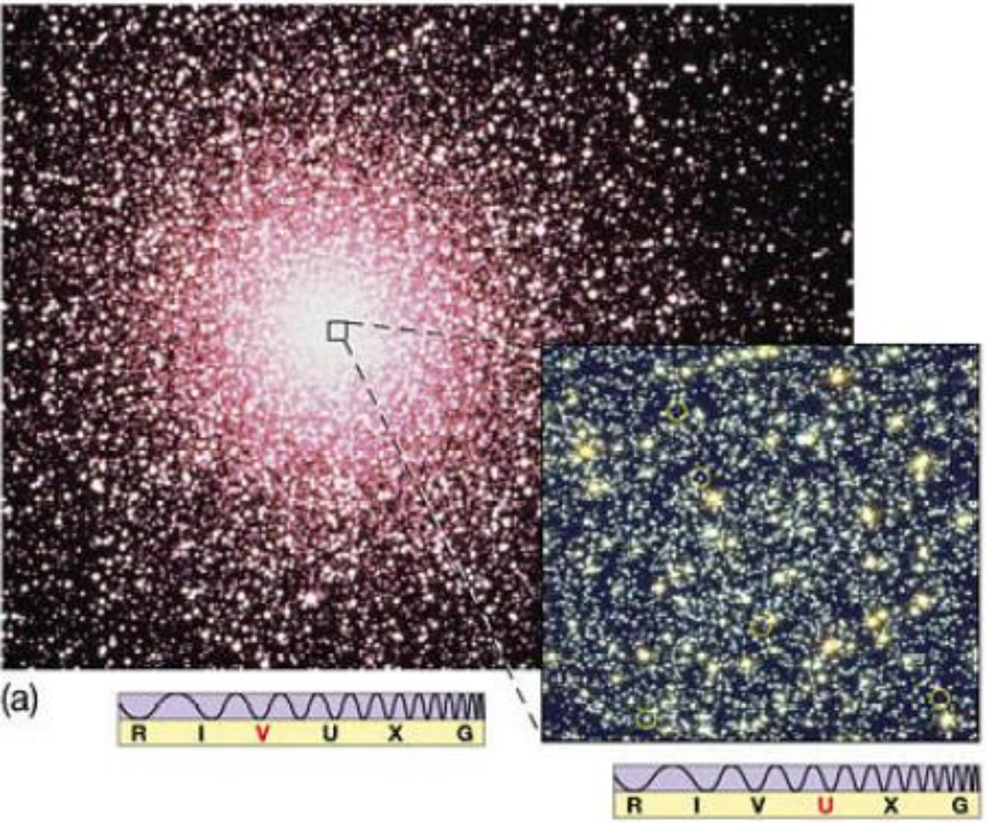
(b) $t = 10^7$yr

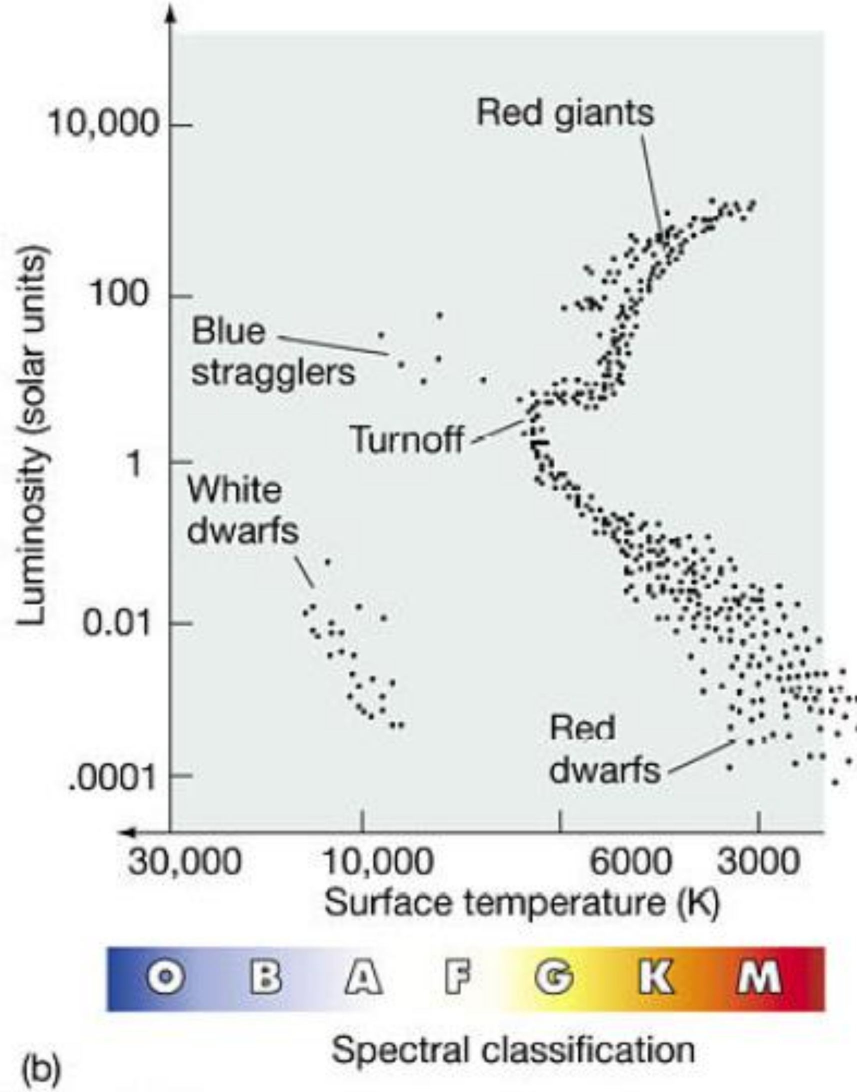
(c) $t = 10^8$yr

(d) $t = 10^9$yr

(e) $t = 10^{10}$yr

47 Tuc





NGC 104: d = 4500 pc, D = 31',
[Fe/H] = -0.76 dex, t = 12 Gyr,

M4

Mass: 10^4 to 10^6 M(Sun)

[Fe/H]: -2.5 to +0.5 dex

Age: 10 to 15 Gyr

Diameter: 5 to 100pc

Members: 10^4 to 10^8

Density: 10^4 Stars pc^{-3}

150 known in the Milky Way with a total mass of 10^8 M(Sun)

Classification of Globular Clusters: Shapley H. & Sawyer H.B., 1927, Harvard College Observatory Bulletin No. 849, pp.11-14

A Classification of Globular Clusters. — Notwithstanding a general similarity of globular clusters in size, form, content, and absolute brightness, some deviations from the average have been frequently noted in the course of past studies. Clusters such as Messier 19 and ω Centauri are conspicuously elongated; Messier 62 is strikingly non-symmetrical; N.G.C. 4147 is deficient in giant stars; and for nearly one third of the globular systems the brighter stars are so loosely arranged that from an ordinary examination, photographic or visual, we might place them with the galactic clusters and exclude them from their true class.

It was proposed some years ago (Mt. W. Contr. 161, 7, 1918) that N.G.C. 7492 might be taken as a type of a rather distinct subdivision, called the loose globular cluster, which would include among others Messier 4, Messier 72, N.G.C. 288, N.G.C. 3201, N.G.C. 5466, and I.C. 4499. That such systems are of the globular class is made certain by long exposure photographs which bring out the thousands of faint stars that are never present in even the richest of galactic clusters, and their identity is also often indicated by their high galactic latitude and by the discovery in several of them (M 4, 72, N.G.C. 3201) of many cluster type Cepheid variables.

A detailed examination of the globular clusters on good Bruce photographs, which are available in the Harvard collection for practically all the ninety-five systems now listed as globular, shows that many intermediate forms exist between the loosest and most concentrated clusters. Instead of classing the clusters, therefore, in the two or three broad and obvious categories, we arrange them in finer subdivisions, in a series of grades on the basis of central concentration.

Detailed star counts may or may not agree with our classification. The numerical concentration will certainly depend upon the magnitudes of the stars included in the counts, and because of crowding and Eberhard effect will always be of doubtful value except for the brightest stars. On the other hand, our estimated concentrations are slightly influenced by the quality of the plates and the total brightness and angular diameters of the clusters; but we believe that these factors are not of such consequence that they detract appreciably from the value of the classification.

For the accompanying tabulation, all of the ninety five globular clusters have been classified twice by two observers. Class I represents the highest concentration toward the center, and Class XII the least.

Asterisks with the N.G.C. numbers mark the clusters (usually bright) which have been chosen as representative of their respective classes. The objects marked with daggers are the eight whose identification as globular clusters is yet considered questionable (H.B. 848). The uncertainty of their classification and that of a few others is indicated by colons.

For the following clusters, superposed stars have interfered somewhat with

Classification of Globular Clusters

N.G.C.	Messier	Class	N.G.C.	Messier	Class	N.G.C.	Messier	Class
*104		III	5986		VII	6453		IV
*288		X	6093	80	II	6496		XII
362		III	6101		X	6517		IV
1261		II	6121	4	IX	†6535		XI:
†1651		VIII:	6139		II	†6539		X:
1783		VII	6144		XI	6541		III
1806		VI	6171		X	6553		XI
1831		V	6205	13	V	6569		VIII
1846		VIII	*6218		IX	6584		VIII
1851		II	6229		VII:	6624		VI
*1866		IV	6235		X	6626	28	IV
1904	79	V	6254	10	VII	6637	69	V
1978		VI	6266	62	IV	6638		VI
2298		VI	6273	19	VIII	6652		VI:
2419		VII	6284		IX:	*6656	22	VII
*2808		I	6287		VII	6681	70	V
3201		X	6293		IV	†6712		IX:
4147		IX	6304		VI	6715	54	III
4372		XII	6316		III	6723		VII
4590	68	X	6333	9	VIII	*6752		VI
4833		VIII	6341	92	IV	†6760		IX:
5024	53	V	6342		IV	6779	56	X
5139		VIII	†6352		XI:	*6809	55	XI
5272	3	VI	6356		II	6864	75	I
5286		V	6362		X	6934		VIII
5466		XII	6366		XI	6981	72	IX
5634		IV	6388		III	7006		I
I.C. 4499		XI	6397		IX	7078	15	IV
5897		XI	*6402	14	VIII	*7089	2	II
5904	5	V	†6426		IX:	*7099	30	V
5927		VIII	6440		V	*7492		XII
†5946		IX:	6441		III			

- **Class I, II, III:** Visible high stellar density at their core. With a halo around decreasing in luminosity as a function of the distance from the core.

M75 is a globular cluster of class I in Sagittarius.

- **Class IV, V, VI:** The core stellar density is still visible, but is more spread out and not as dense.

M62 is a globular cluster of class IV

- **Class VII, VIII, IX:** The cluster stellar density is more homogeneous and less contrasted.

M22 is a globular cluster of class VII in Sagittarius

- **Class X, XI, and XII:** The cluster surface luminosity is completely homogeneous with no increase in stellar density visible at the core.

M55 is a globular cluster of class XI in Sagittarius

The smaller the number of stars, the higher the core's stellar density.

Definition - Radii

- **Core Radius**: Distance at which the apparent surface luminosity has dropped by half
- **Half-Light Radius**: Distance from the core within which half the total luminosity from the cluster is received
- **Half-Mass Radius**: The radius from the core that contains half the total mass
- **Tidal Radius**: Distance from the center at which the external gravitation of the galaxy has more influence over the stars in the cluster than does the cluster itself

Density – Profile (King Profile)

- Heuristic description of the density law of star clusters (open and globular) by Ivan King (1962, AJ, 67, 471):

$$f = f_1[(1/r - 1/r_t)^2]$$

f … Stars per square unit; f_1 … Constant; r_t … Radius f(r) = 0

- General formula:

$$f = k\left\{\frac{1}{[1+(r/r_c)^2]^{\frac{1}{2}}} - \frac{1}{[1+(r_t/r_c)^2]^{\frac{1}{2}}}\right\}^2$$

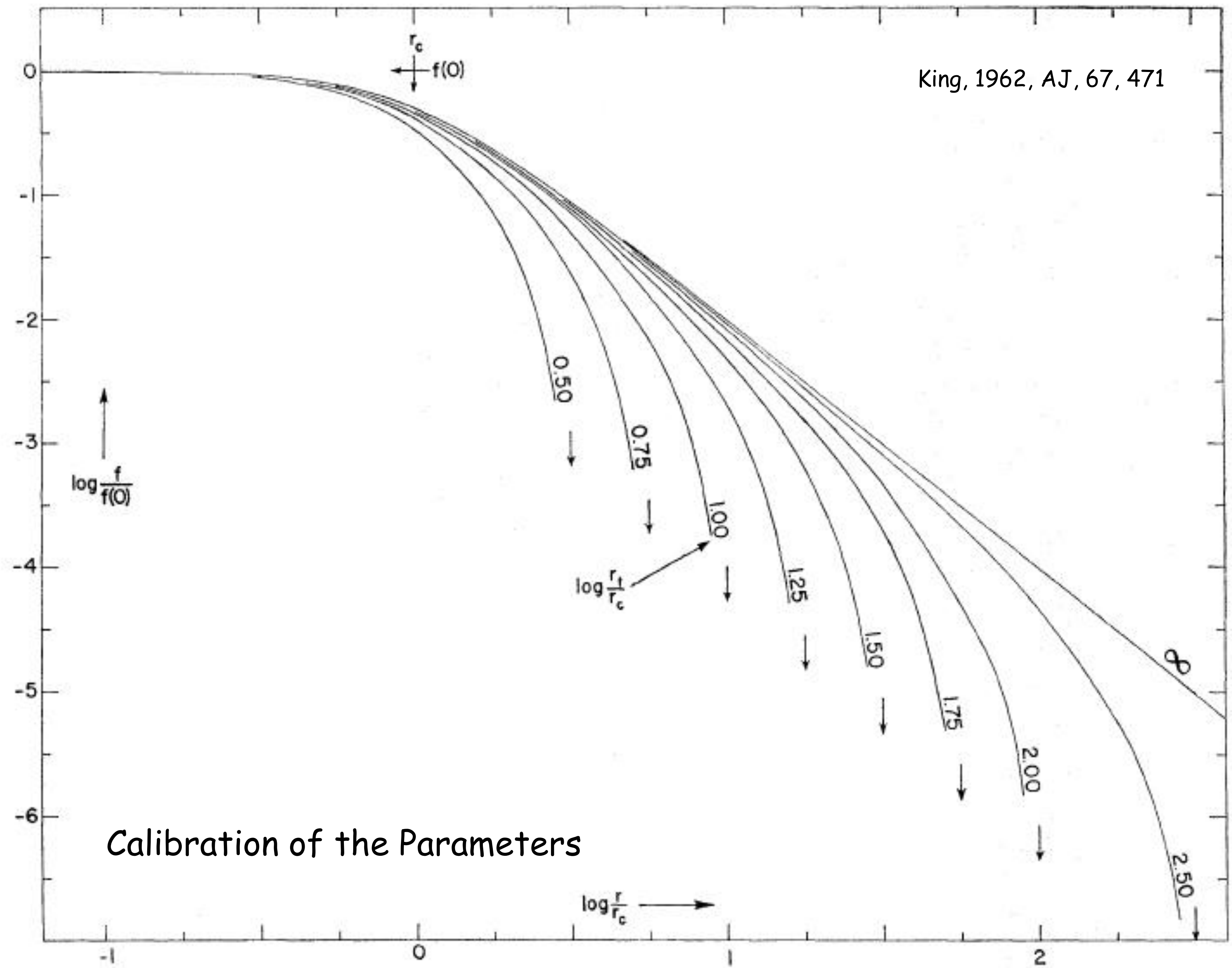
k … Constant; r_c … core radius

Density – Profile (King Profile)

- Typical Globular Cluster:
  1. $r_t/r_c \sim 30$
  2. Unit for k is V = 10 mag per square arc minute
- The parameters r_t and r_c can be treated within numerical simulations and can be converted into an „astrophysical quantity“, for example:

$$r_t = R(M/2M_g)^{\frac{1}{3}}$$

R … Distance from the galactic center; M … Mass of the Globular Cluster; M_g … Mass of the Milky Way



Calibration of the Parameters

Ellipticity

Goodwin, 1997, MNRAS, 286, L39

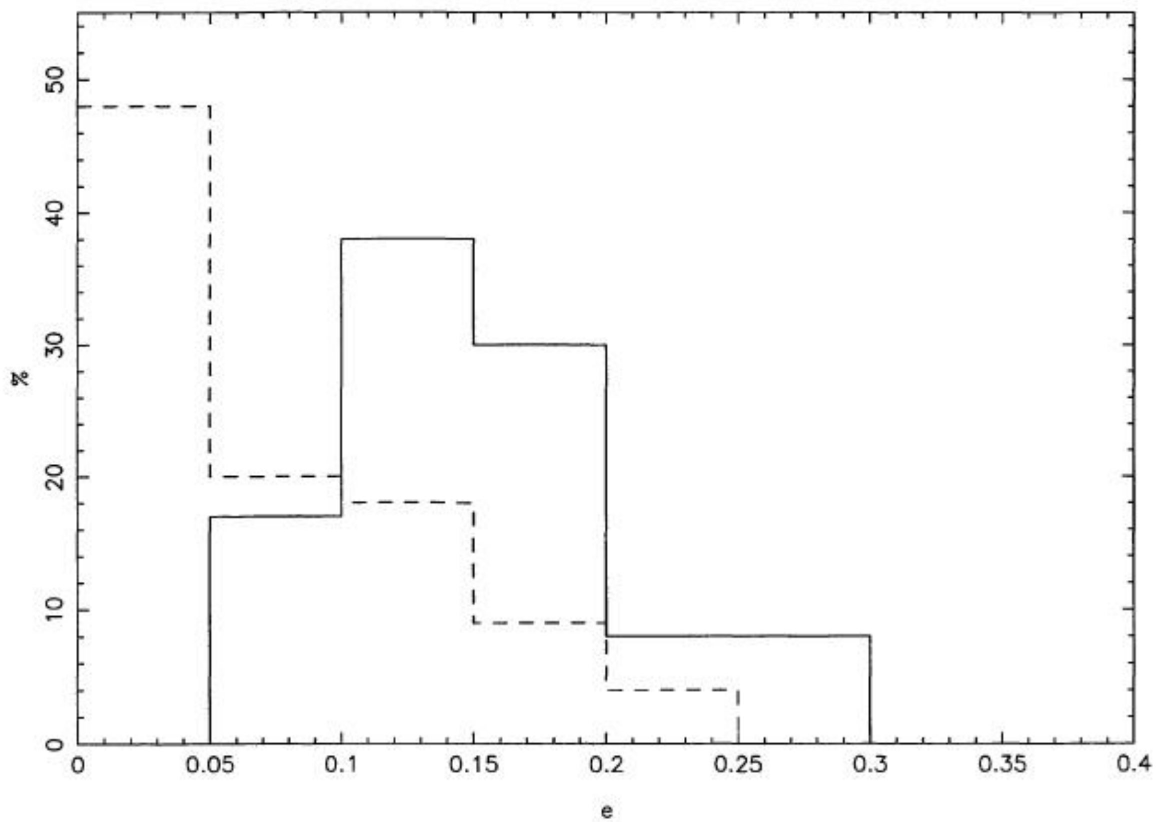
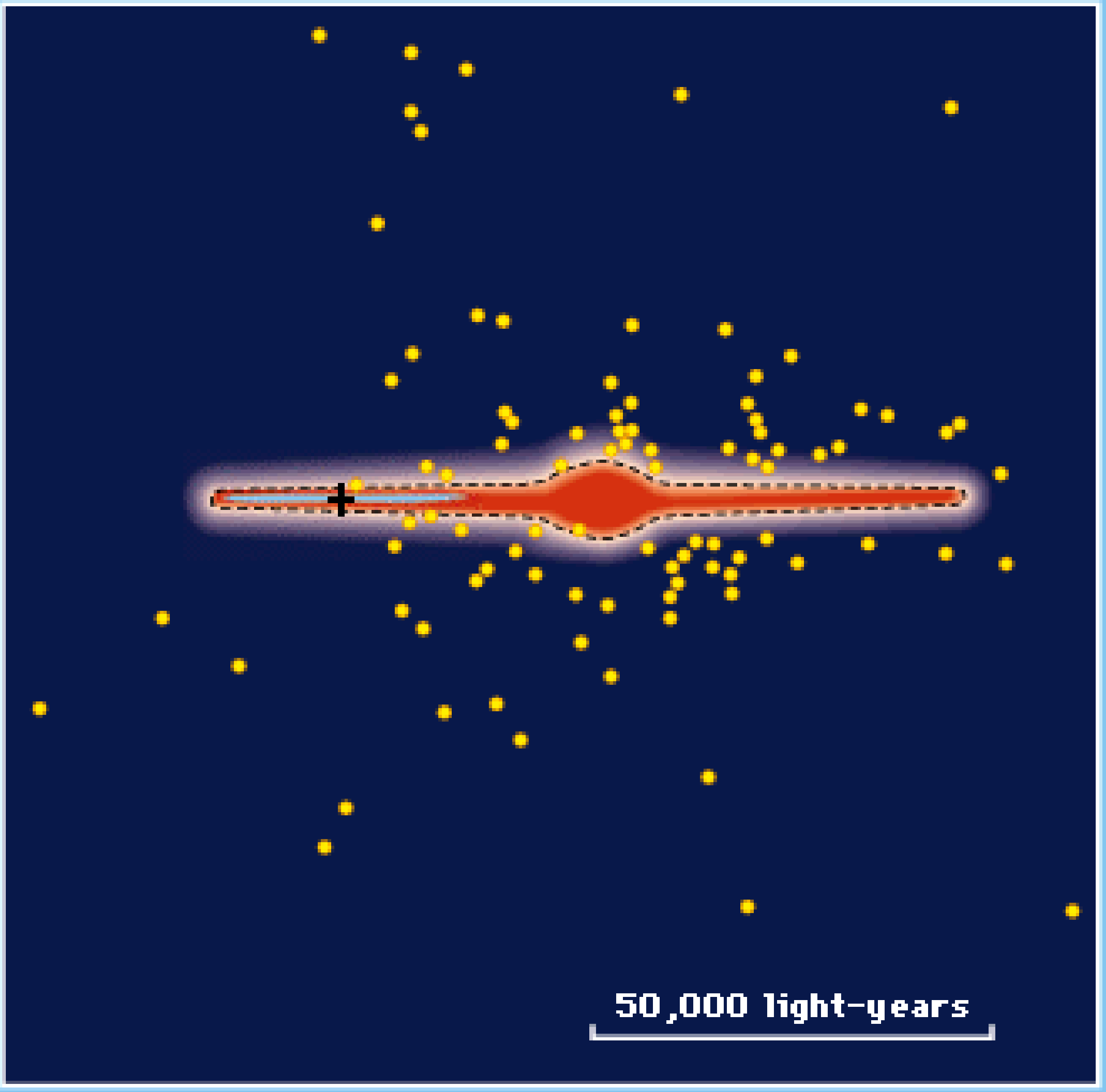


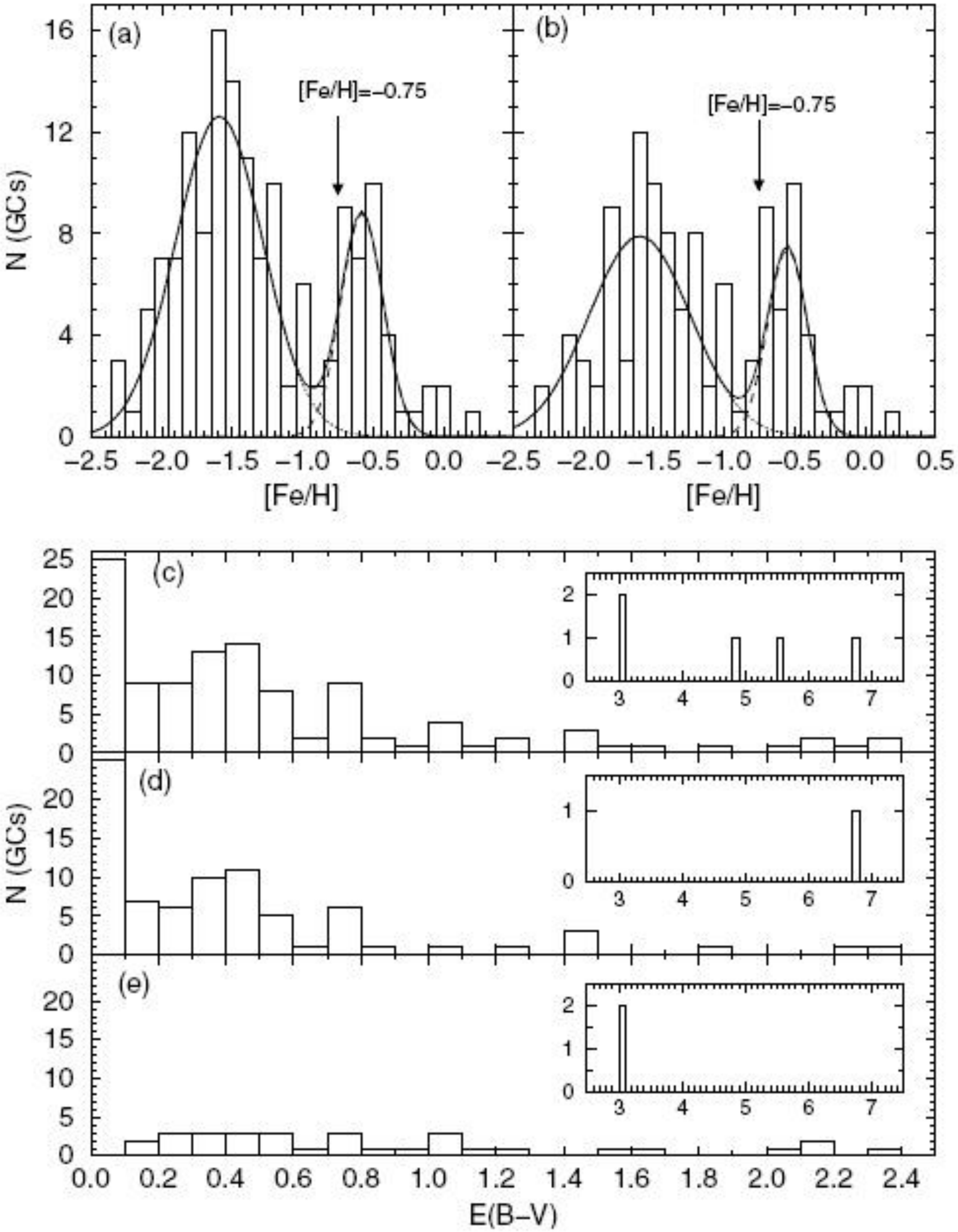
Figure 1. The ellipticity distributions of globular clusters in the LMC (full line) and the Galaxy (dashed line) from data in White & Shawl (1987) and Kontizas et al. (1989).



Dotted line indicates probable outline of the galaxy, a flat-tened lens-shaped system formed by the stars, as seen edgewise from outside. Eccentric position of the Sun is shown by a cross. Some of the known open star clusters are scattered among the stars in shaded region. Small circles repre-sent globular clusters.

Two „external Populations“

- Halopopulation:
  - Spherical around the center of the Milky Way
  - Very much extended (Halo)
  - $-2.5 < [Fe/H] < -1$ dex
  - $10 <$ Age < 15 Gyr
- Diskpopulation:
  - More concentrated around the center of the Milky Way
  - $-0.7 < [Fe/H] < +0.5$ dex
  - Age about 10 Gyr
- Continuous transitions!



Bica et al., 2006, A&A, 450, 105

153 Globulars, no age listed

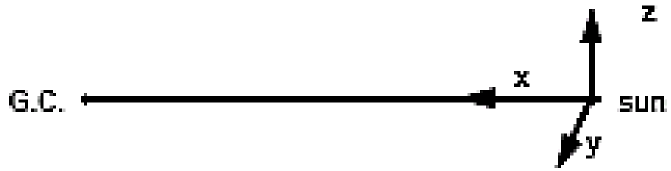
Two Populations

Reddening

Although the large distance, no Reddening, Halo

New Globulars with large reddening And large distance detected

Galactic Components



- coordinates:
  - x: l = 0 b = 0 (Galactic Centre)
  - y: l = 90 b = 0 (Cygnus) direction of disc rotation
  - z: b = 90 (North Galactic Pole)

- star positions:
  - x = r cos b cos l
  - y = r cos b sin l
  - z = r sin b

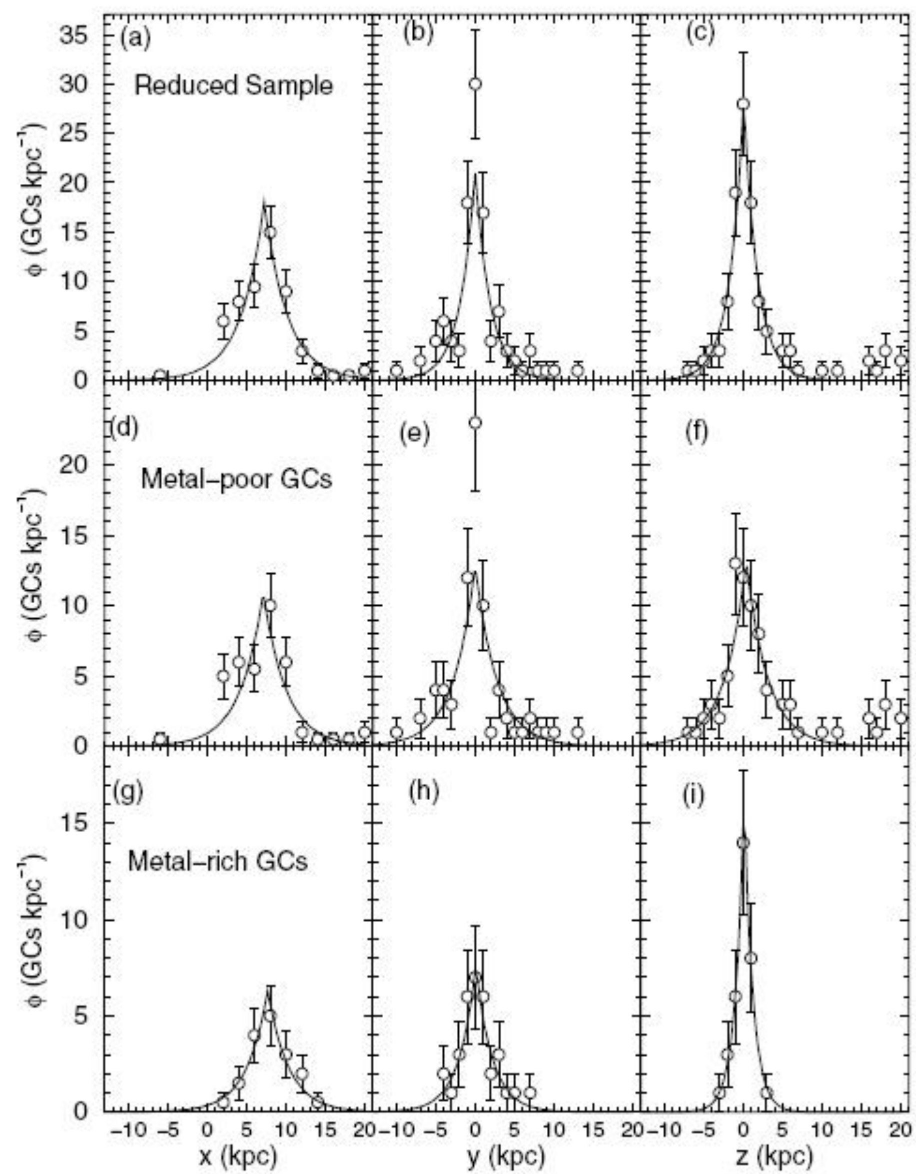
$$r = \sqrt{x^2 + y^2 + z^2}$$

distance from sun to star

- star velocities: $u, v, w \equiv \dot{x}, \dot{y}, \dot{z}$

	Reduced sample GCs		
	All	Metal-poor	Metal-rich
(1)	(2)	(3)	(4)
x_o (kpc)	7.2 ± 0.3	7.1 ± 0.5	7.7 ± 0.3
x_h (kpc)	2.9 ± 0.4	2.9 ± 0.6	2.7 ± 0.4
y_o (kpc)	0.0 ± 0.3	0.0 ± 0.4	0.1 ± 0.3
y_h (kpc)	1.9 ± 0.4	2.8 ± 0.5	2.1 ± 0.4
z_o (kpc)	0.1 ± 0.2	0.4 ± 0.3	0.1 ± 0.1
z_h (kpc)	1.8 ± 0.2	2.7 ± 0.5	1.1 ± 0.1
x_h/y_h	1.5 ± 0.4	1.0 ± 0.3	1.3 ± 0.3
x_h/z_h	1.6 ± 0.3	1.1 ± 0.3	2.4 ± 0.4
y_h/z_h	1.1 ± 0.3	1.0 ± 0.2	1.9 ± 0.4

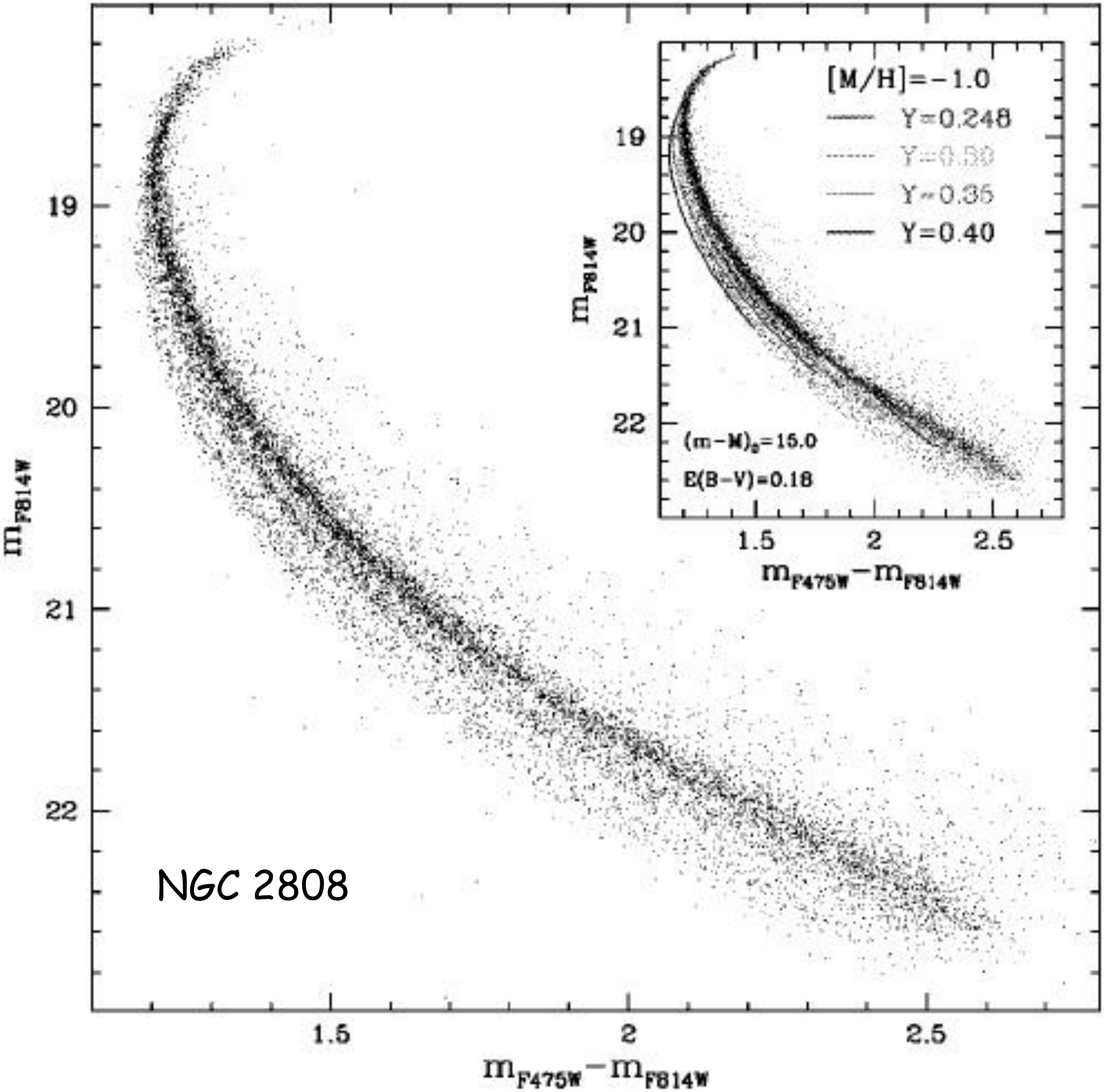
Bica et al., 2006, A&A, 450, 105



Dimensions:
- ~12 kpc × 11 kpc × 5 kpc (Disk)
- ~35 kpc × 36 kpc × 30 kpc (Halo)

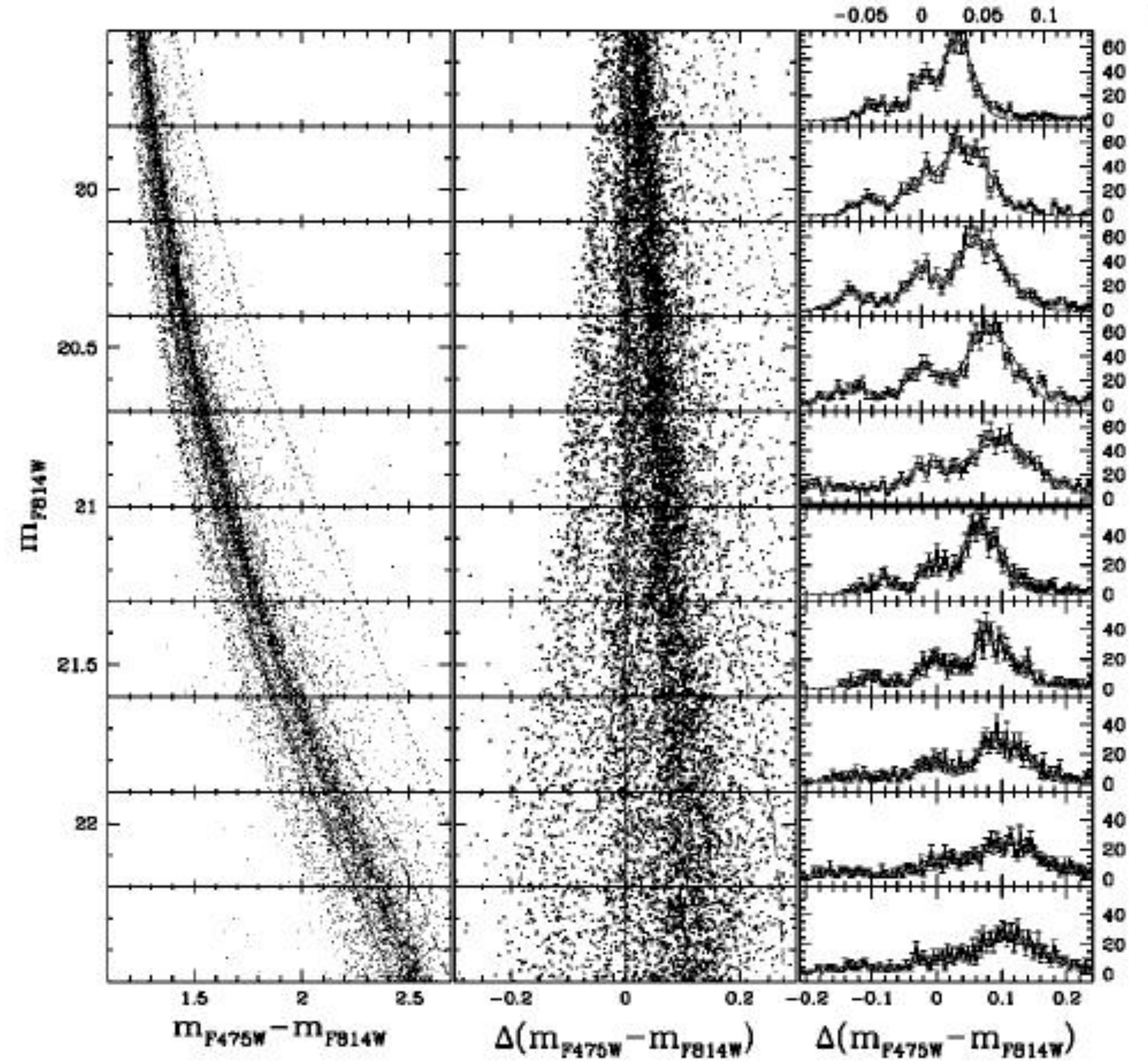
Multiple „ internal Populations“

- Multiple Main, AGB and HB Sequences within one Globular were found
- Not for all Globulars although same observational quality
- No clear morphology detected yet
- Also indications for the oldest OCLs
- HST data

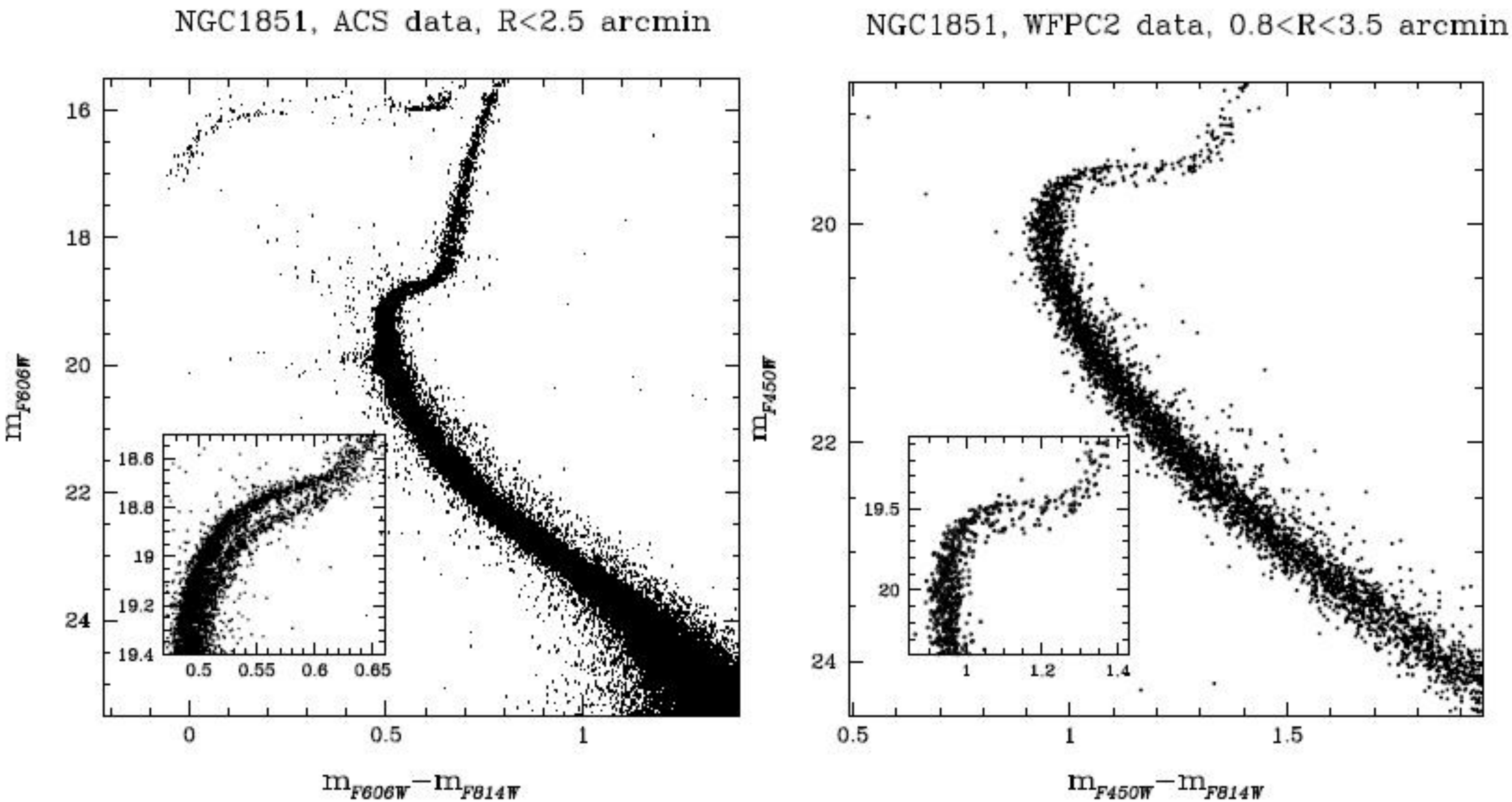


Piotto et al., 2007, ApJ, 661, L53

Different He content can explain the Multiple MS

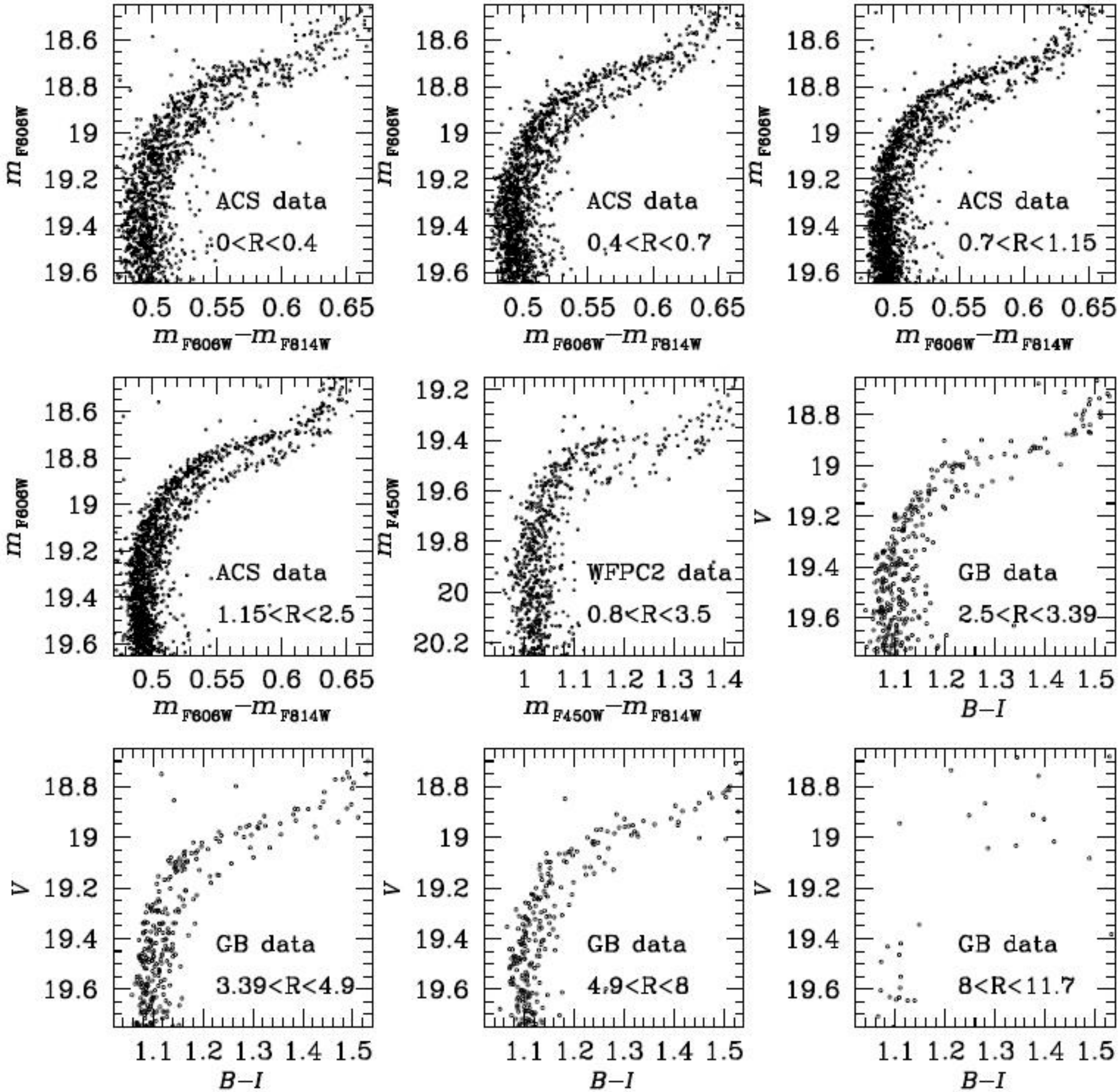


Piotto et al., 2007, ApJ, 661, L53



Double sub-giant branch but no double Main Sequence

Milone et al., 2009, A&A, 503, 755



No "location" effect