SNR – Open Clusters

Kumar, 1978, ApJ, 219, L13

COINCIDENT SUPERNOVA REMNANTS AND OPEN CLUSTERS

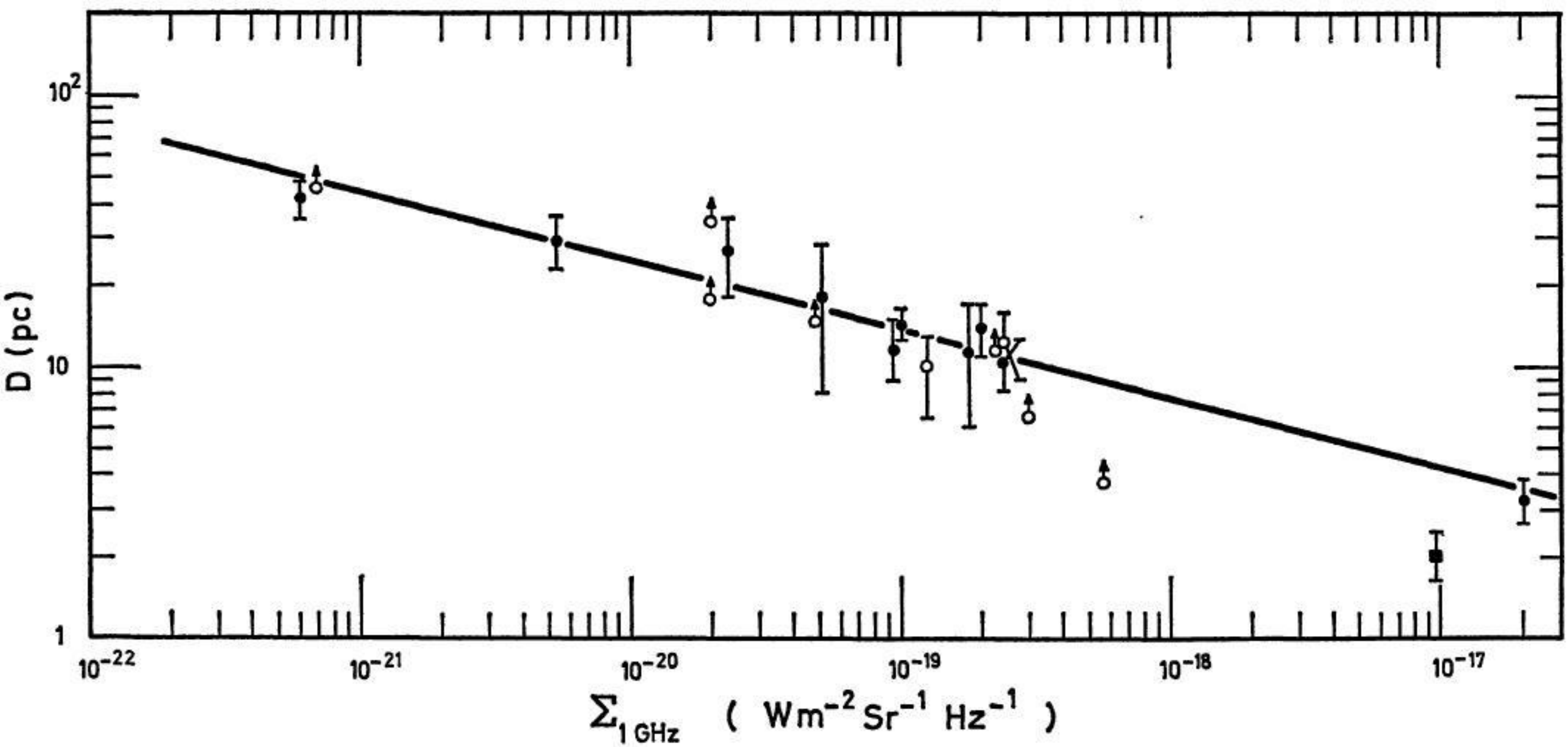
PARAMETER	OPEN CLUSTER*		SNR†	
	Tr 18	Tr 21	G291.0 – 0.1	G307.6 – 0.3
α(1950)	$11^h09^m.3$	$13^h28^m.8$	$11^h09^m.8$	$13^h29^m.1$
δ(1950)	−60°24′	−62°33′	−60°22′	−62°32′
Diameter (arcmin)	12	5	5	4
Spectral type‡	B5 V	B4 V	...	...
Turnoff mass ($M_\odot$)	~6	7	...	...
Distance (kpc)	1.28‡	1.11‡	6.8,§ 0.9–1.4‖	10.7§

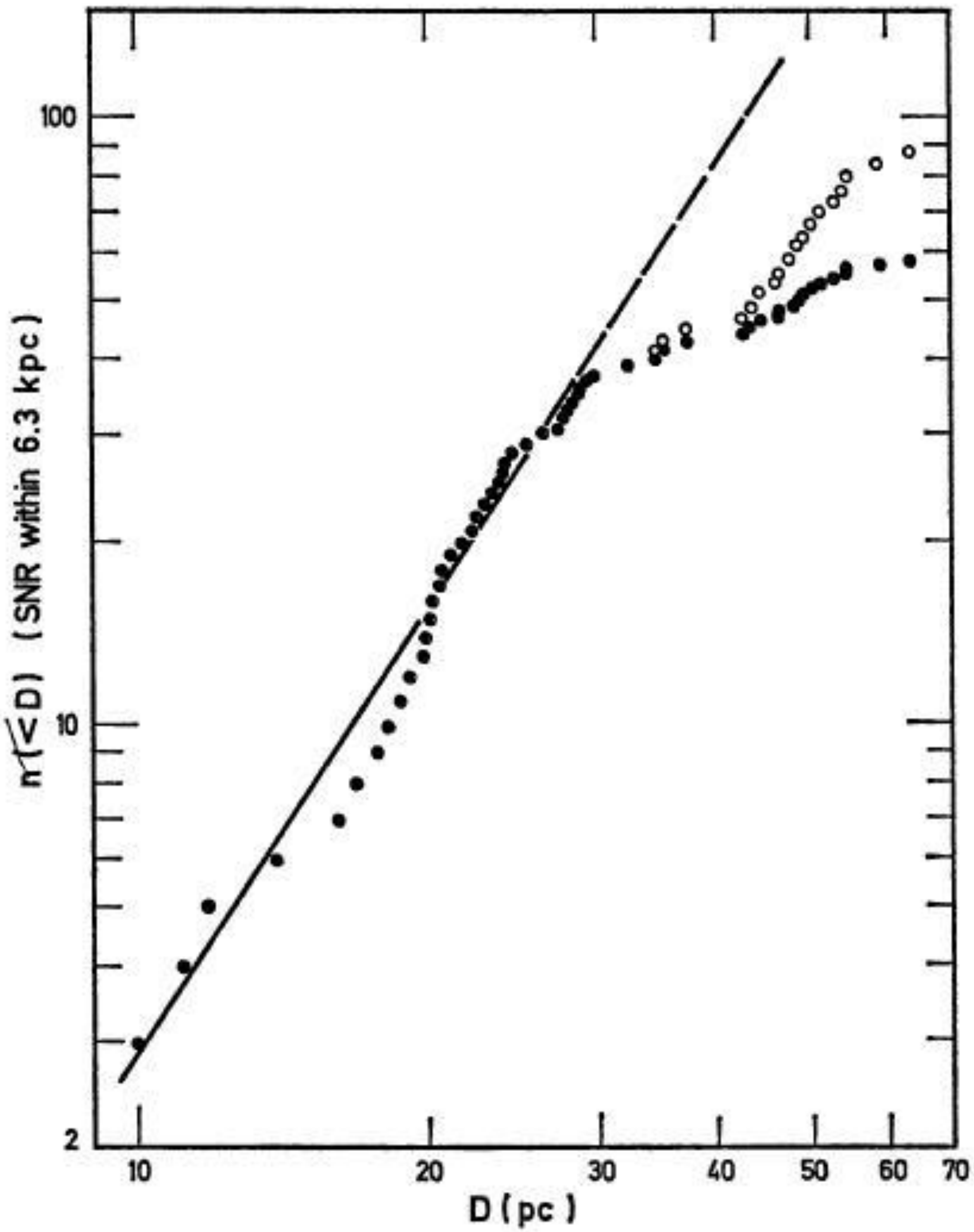
* Hogg 1959.
† Lang 1974.
‡ Moffat and Vogt 1973, 1975.
§ Σ–D distance, from Ilovaisky and Lequeux 1972.
‖ Distance from 21 cm observations.

Distances to SNR

- HI, H_2CO, OH measurements, absorption features can be correlated with distance
- Radial velocities and proper motions from filaments
- Surface brightness in GHz region
- Linear diameter is correlated with GHz surface flux
- Linear Diameter is correlated with the distance

Ilovaisky & Lequeux, 1972, A&A, 18, 169





100
10
2
10
20
30
40
50
60
70
D (pc)
n (<D) (SNR within 6.3 kpc)

The free parameters

1. Reddening
2. Distance modulus
3. Age
4. Metallicity

Determination in the order: Reddening, age, distance modulus simultaneously, metallicity with possible iterations

Different photometric indices

Several different indices et al. are available (very much incomplete):

- Sensitive to temperature:
  1. Johnson: B-V, V-I, R-I, V-K, …
  2. Strömgren: b-y, u-b, β
  3. Geneva: B2-V1, …
  4. 2MASS: H-K, J-K and H-J
- „Mixture":
  1. Johnson: U-B
  2. Strömgren: c_1, m_1, …
  3. Geneva: d, Δ, m_2, …

Data bases and sources

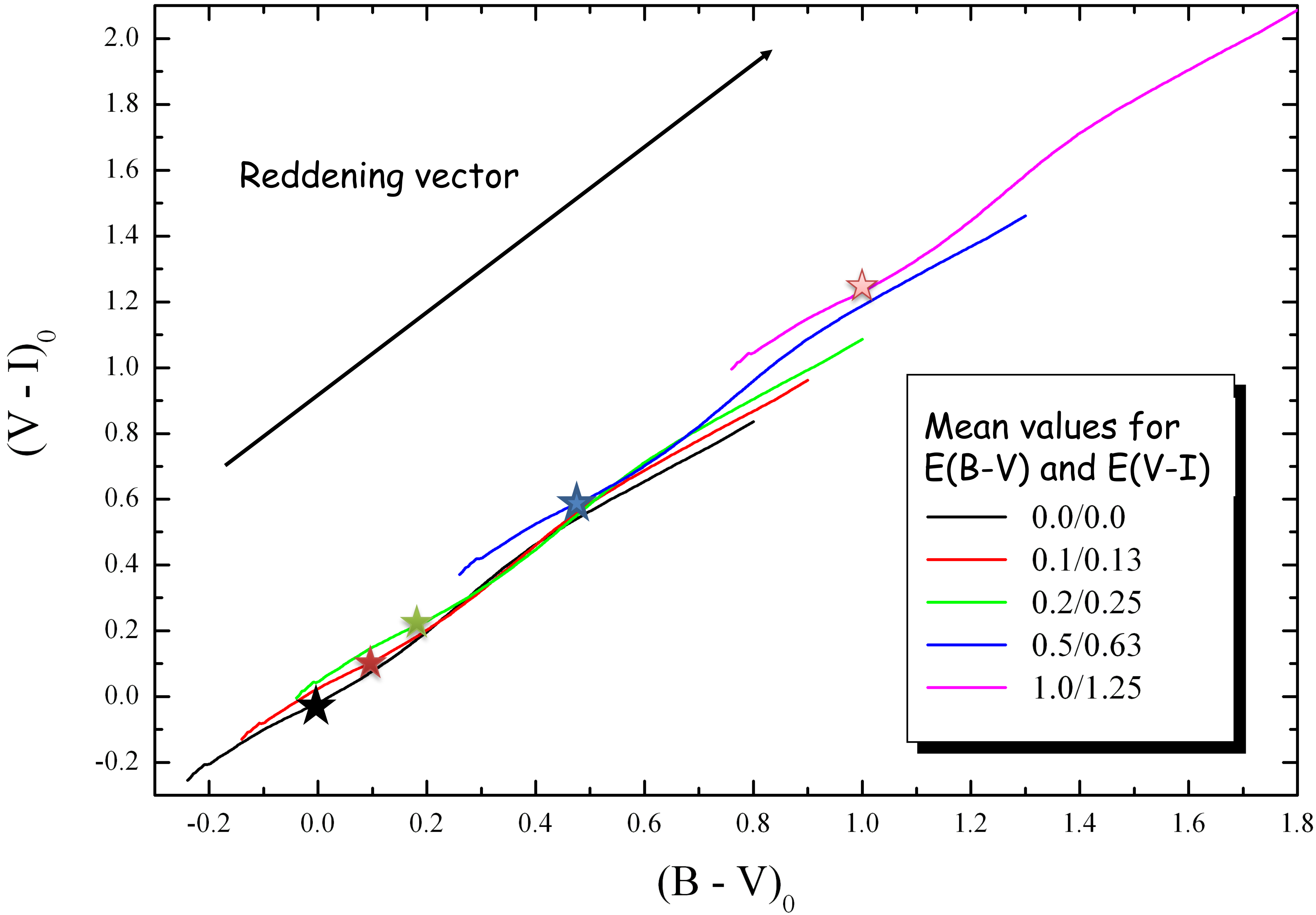
- The Asiago Database on Photometric Systems
  http://ulisse.pd.astro.it/Astro/ADPS/Systems/index.html
- The General Catalogue of Photometric Data
  http://obswww.unige.ch/gcpd/gcpd.html
- WEBDA
  http://www.univie.ac.at/webda/
- CDS/SIMBAD/VizieR
  http://vizier.u-strasbg.fr/cgi-bin/VizieR

How to derive cluster parameters?

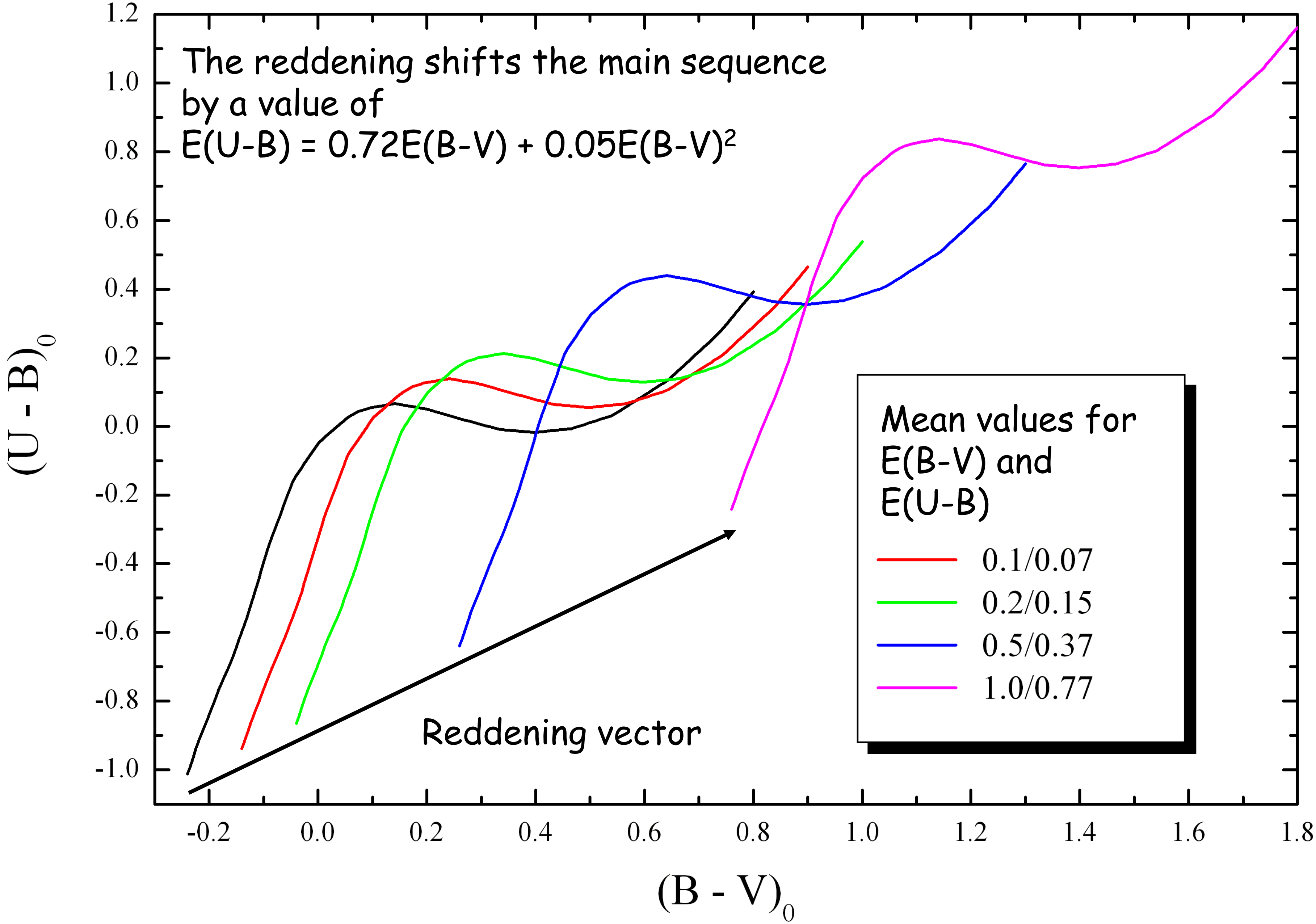
- Program „HR – Trace“, very good for training: http://xoomer.virgilio.it/waphil/
- Use as much as possible available indices
- Check the literature for published values as least as a starting point
- First try it with a “standard set” of data

Determination of the reddening

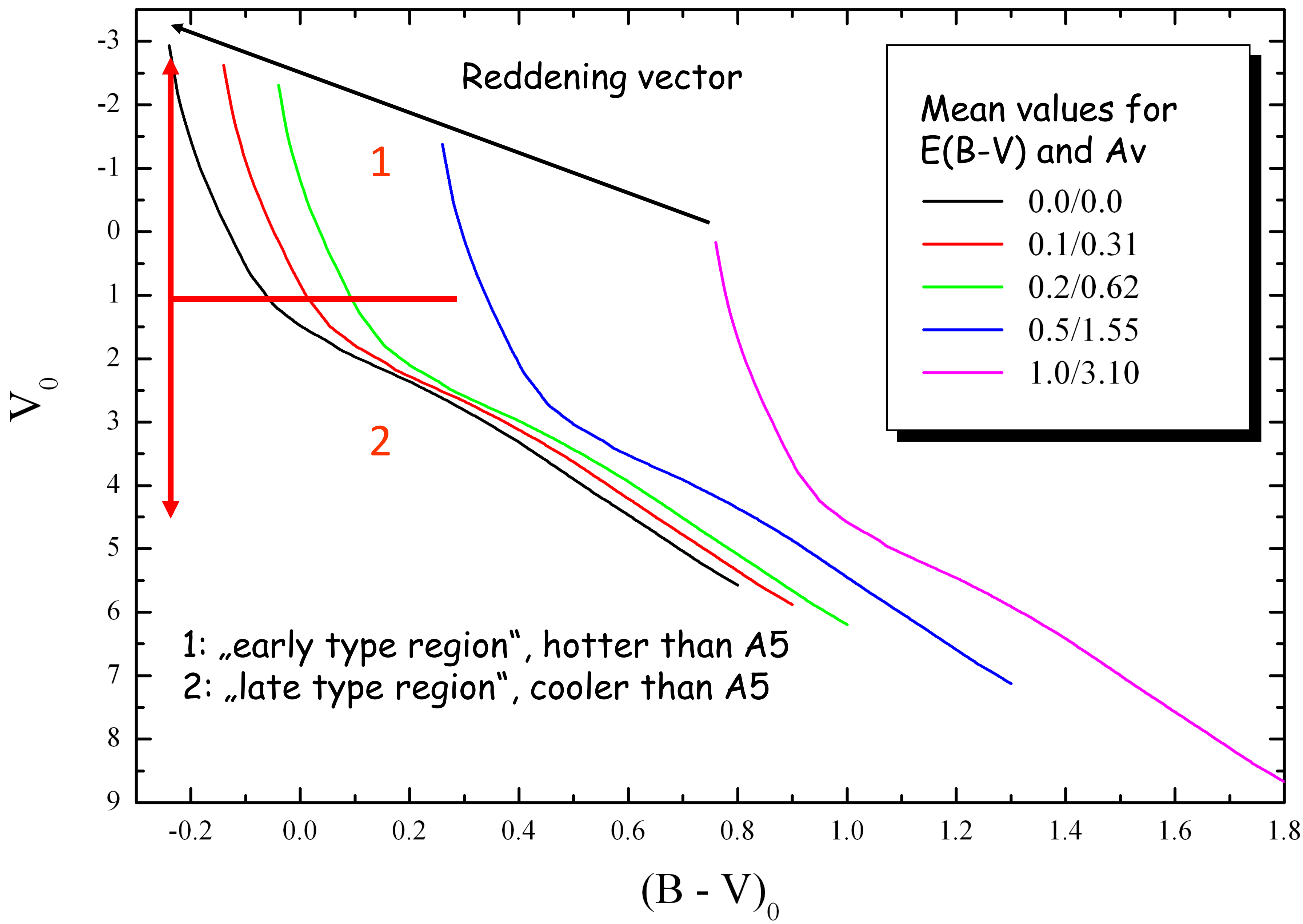
- From two temperature sensitive parameters, the determination of the reddening is not possible
- You need one “other” observational index
- First choices: (U – B), (u – b), [X], β
- Normally, you only have V, J, H, K, and so on



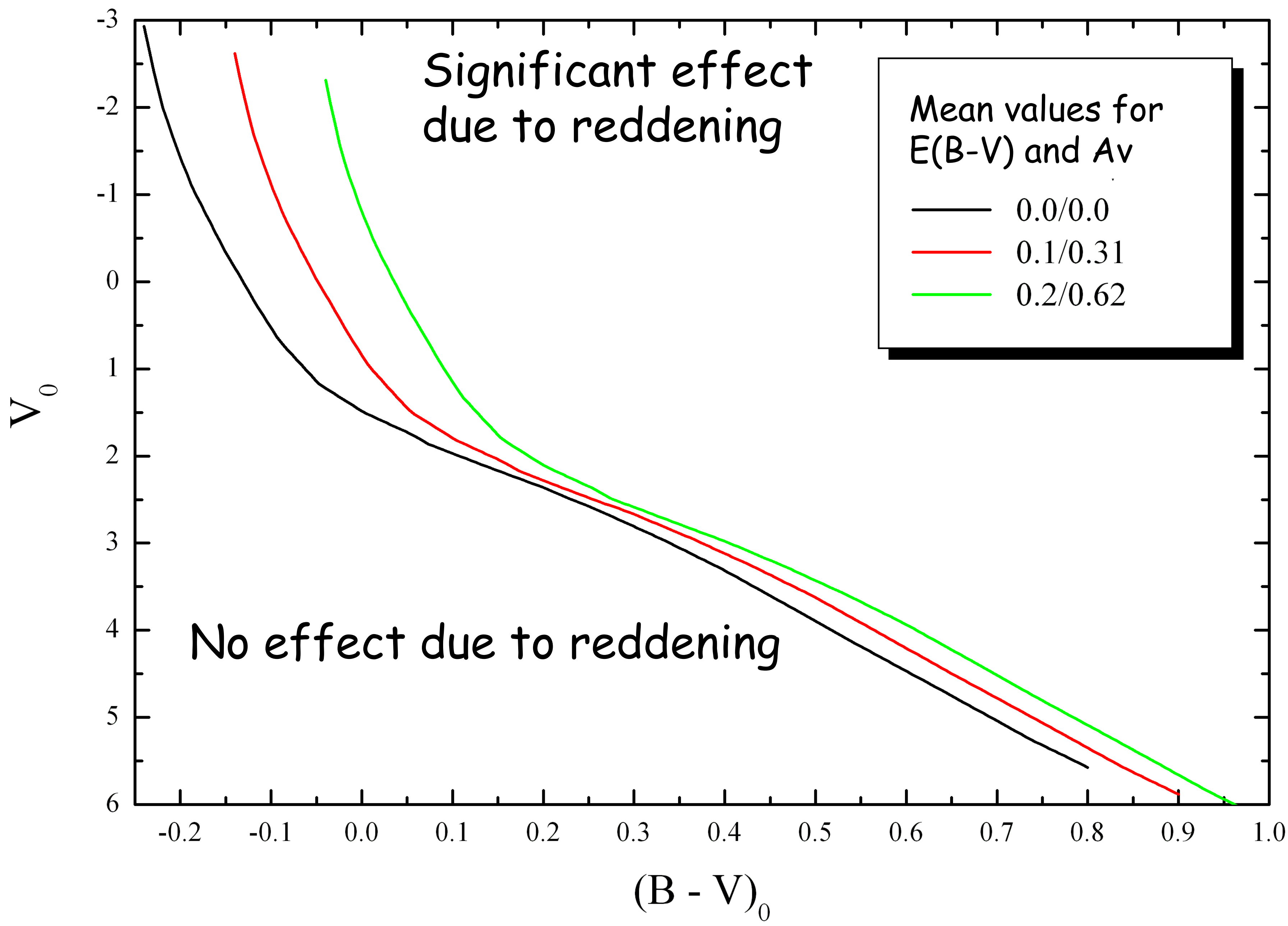
You would need a spectral information



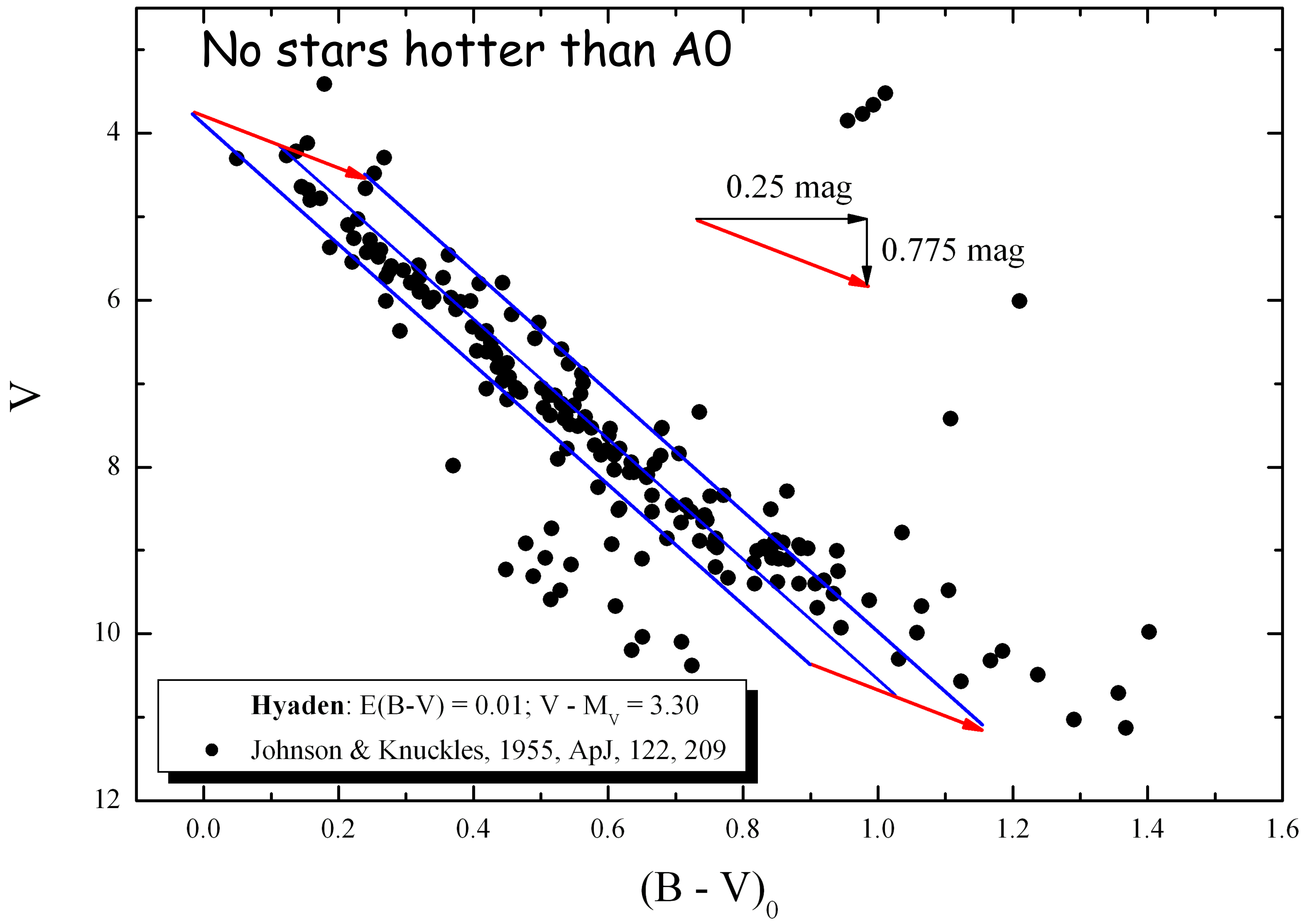
The reddening shifts the main sequence
by a value of
E(U-B) = 0.72E(B-V) + 0.05E(B-V)²
Mean values for
E(B-V) and
E(U-B)
0.1/0.07
0.2/0.15
0.5/0.37
1.0/0.77
Reddening vector
(U - B)0
(B - V)0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8



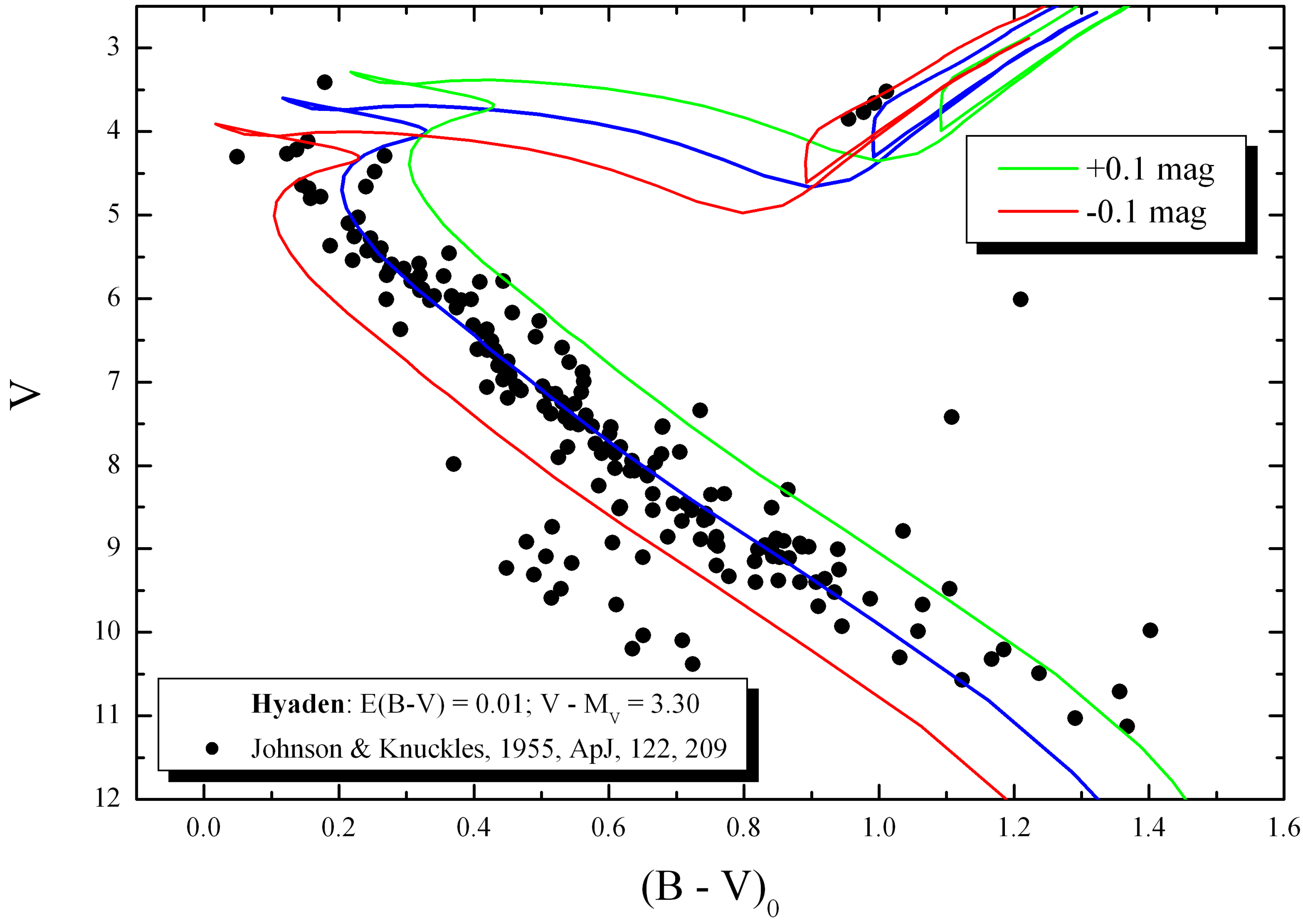
Reddening vector
1
2
Mean values for
E(B-V) and Av
0.0/0.0
0.1/0.31
0.2/0.62
0.5/1.55
1.0/3.10
1: „early type region", hotter than A5
2: „late type region", cooler than A5
V_0
$(B - V)_0$
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8



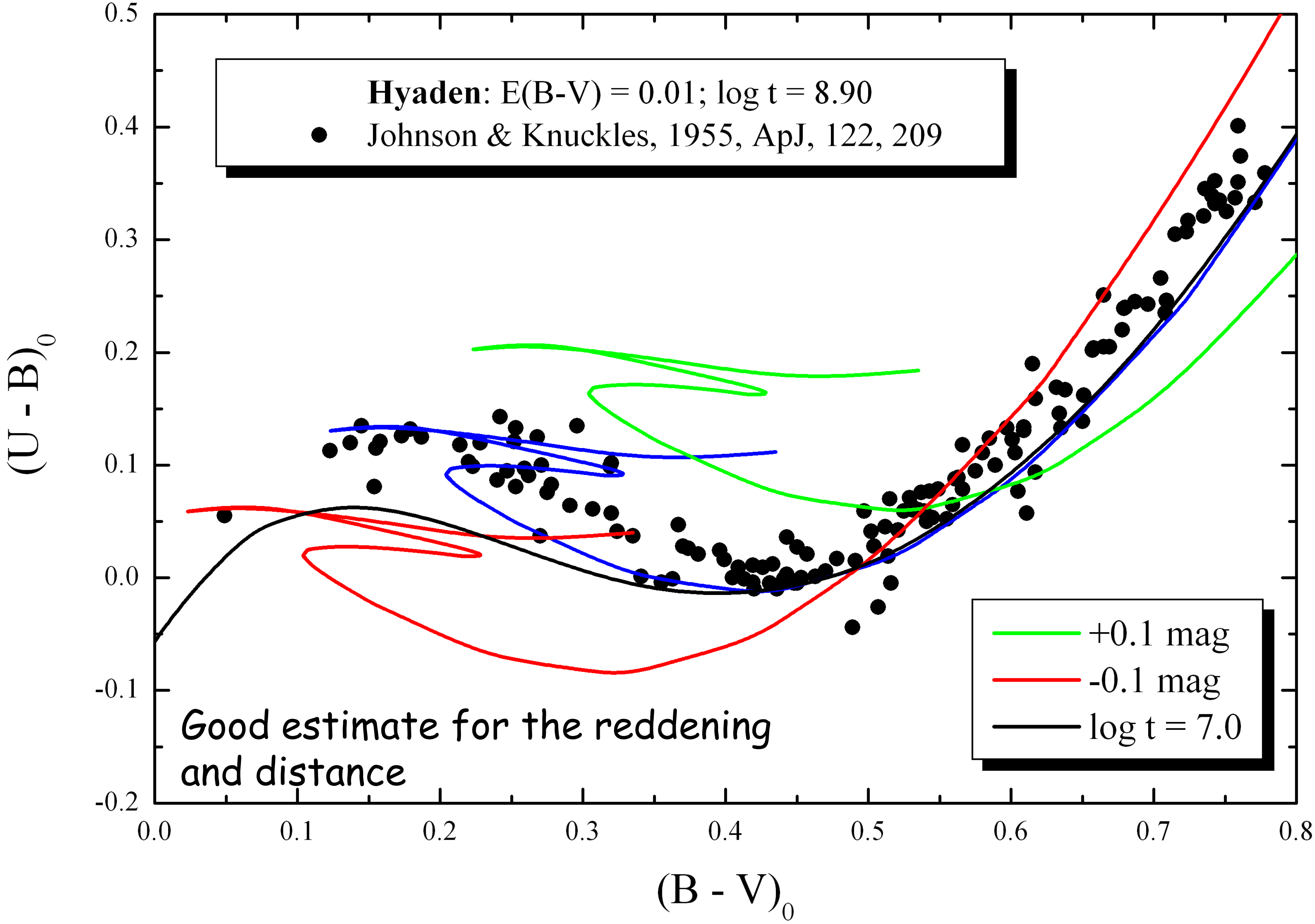
Significant effect due to reddening
No effect due to reddening
Mean values for E(B-V) and Av
0.0/0.0
0.1/0.31
0.2/0.62
V_0
$(B - V)_0$
-3
-2
-1
0
1
2
3
4
5
6
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0



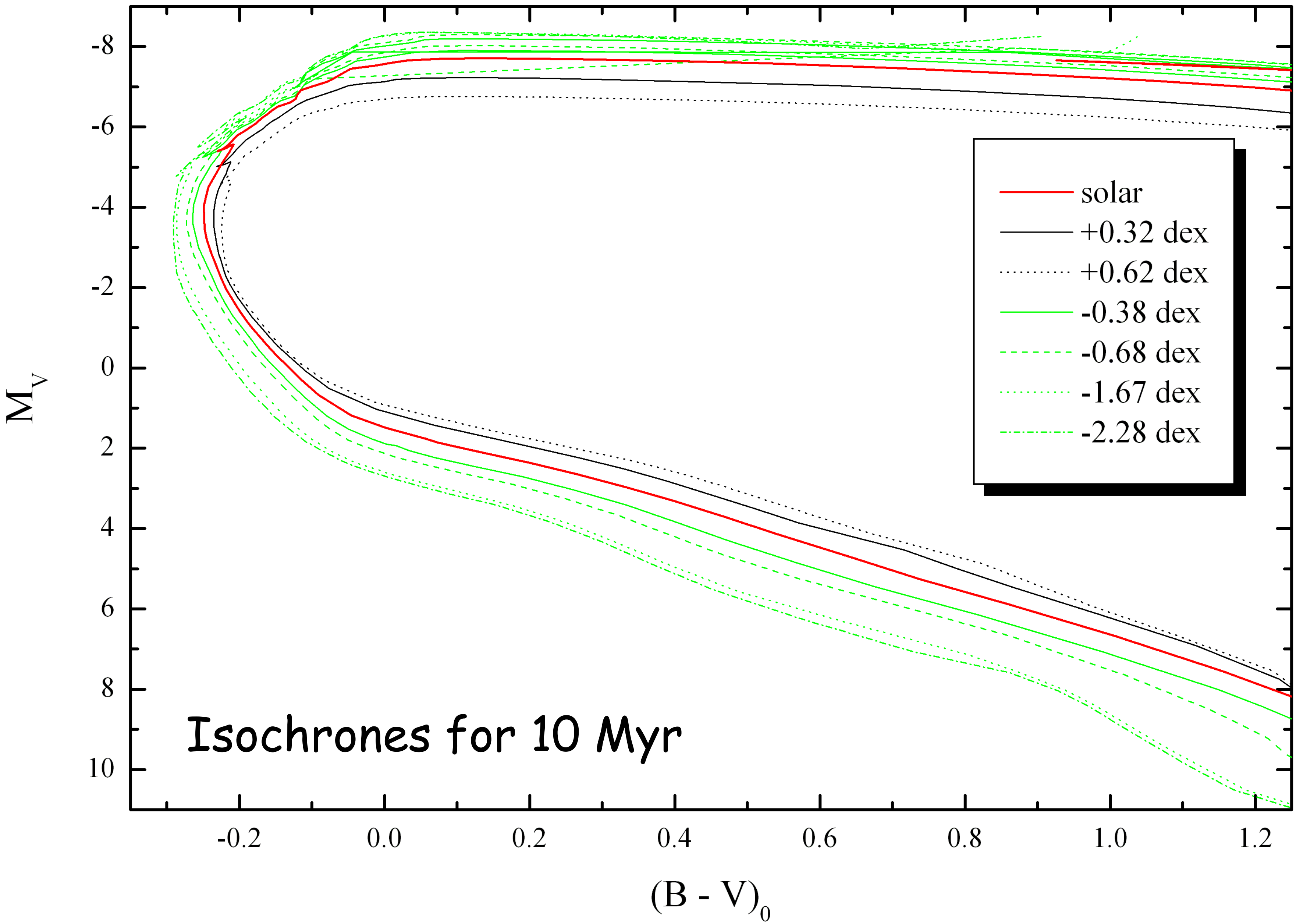
No stars hotter than A0
0.25 mag
0.775 mag
Hyaden: E(B-V) = 0.01; V - M_V = 3.30
Johnson & Knuckles, 1955, ApJ, 122, 209
V
(B - V)_0
4
6
8
10
12
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

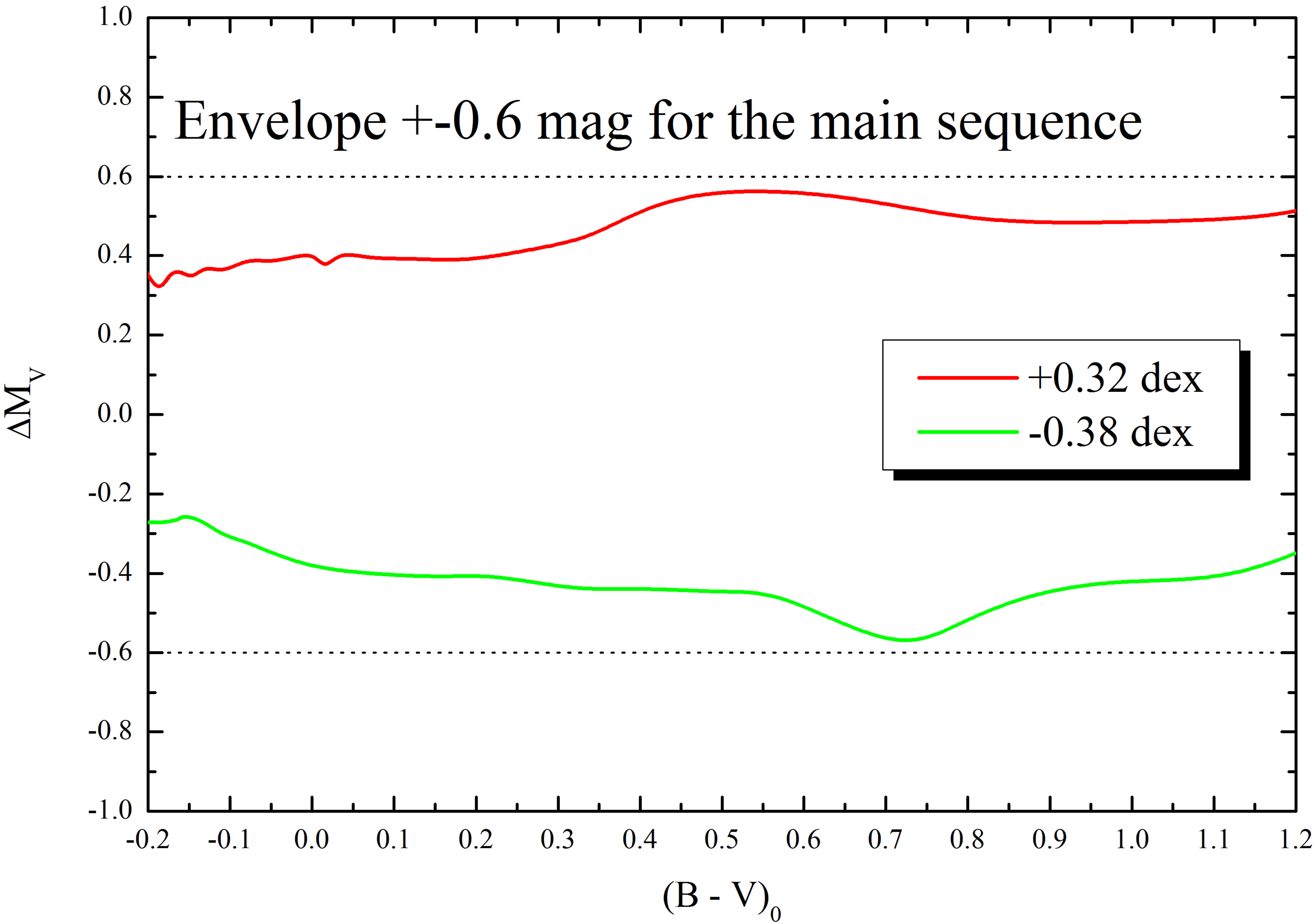


V
3
4
5
6
7
8
9
10
11
12
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
(B - V)0
+0.1 mag
-0.1 mag
Hyaden: E(B-V) = 0.01; V - MV = 3.30
Johnson & Knuckles, 1955, ApJ, 122, 209

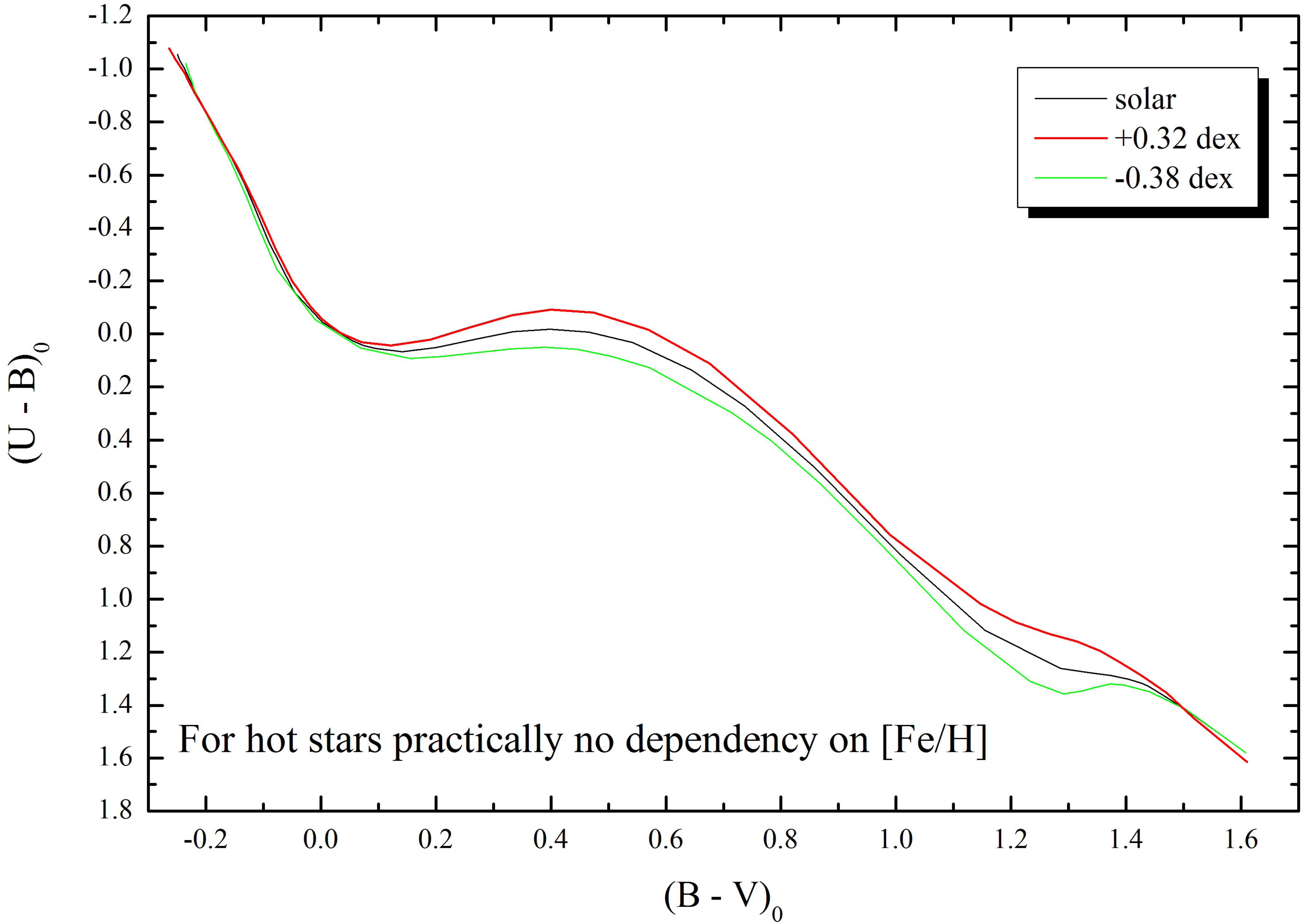

Hyaden: E(B-V) = 0.01; log t = 8.90
Johnson & Knuckles, 1955, ApJ, 122, 209
+0.1 mag
-0.1 mag
log t = 7.0
Good estimate for the reddening
and distance
(U - B)0
(B - V)0
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

Metallicity => different opacity

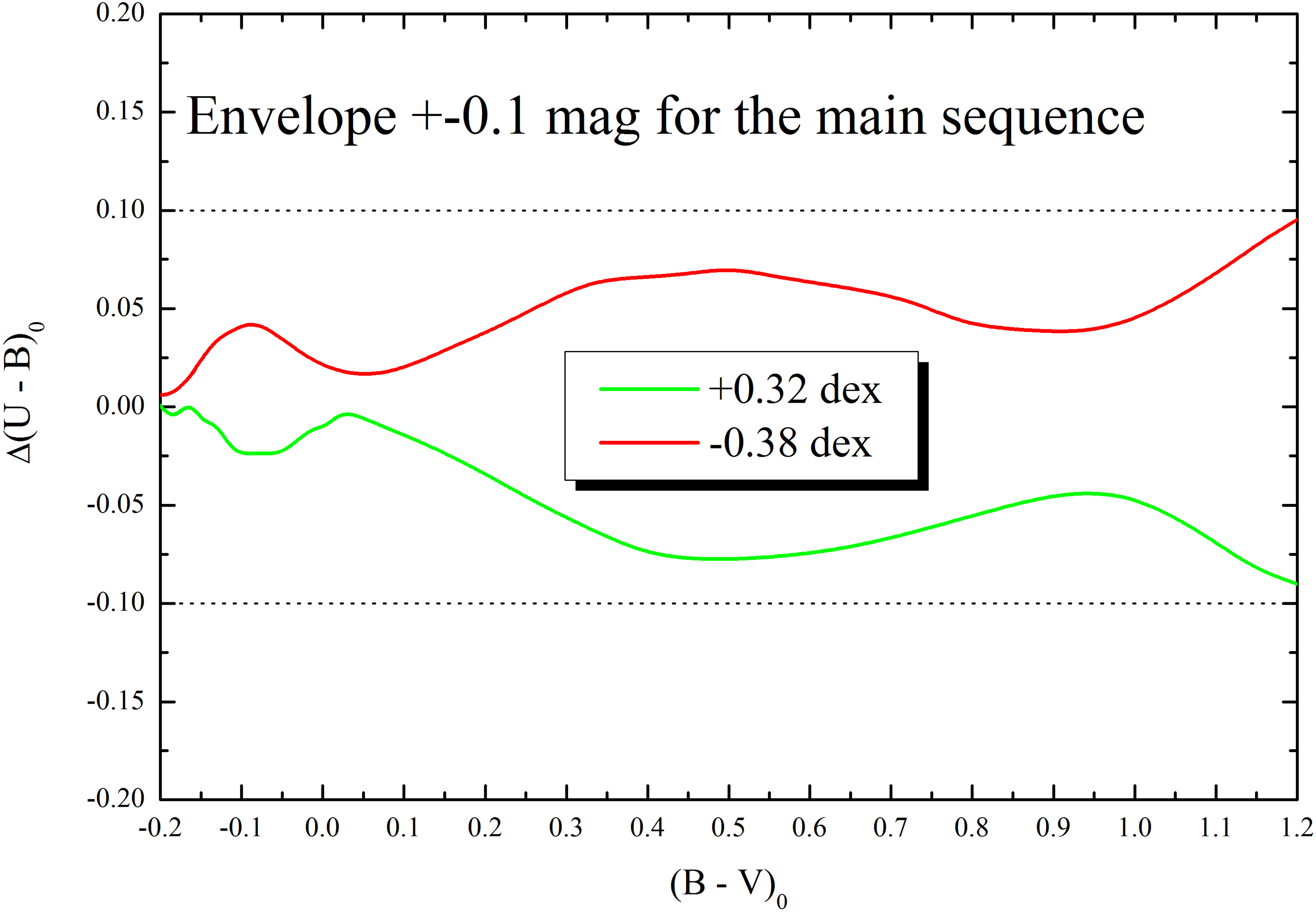




Envelope +-0.6 mag for the main sequence
+0.32 dex
-0.38 dex
ΔM_V
$(B - V)_0$
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-0.2 -0.1 0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2



solar
+0.32 dex
-0.38 dex
For hot stars practically no dependency on [Fe/H]
(U - B)0
(B - V)0
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6


Envelope +-0.1 mag for the main sequence
+0.32 dex
-0.38 dex
Δ(U - B)0
(B - V)0
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-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

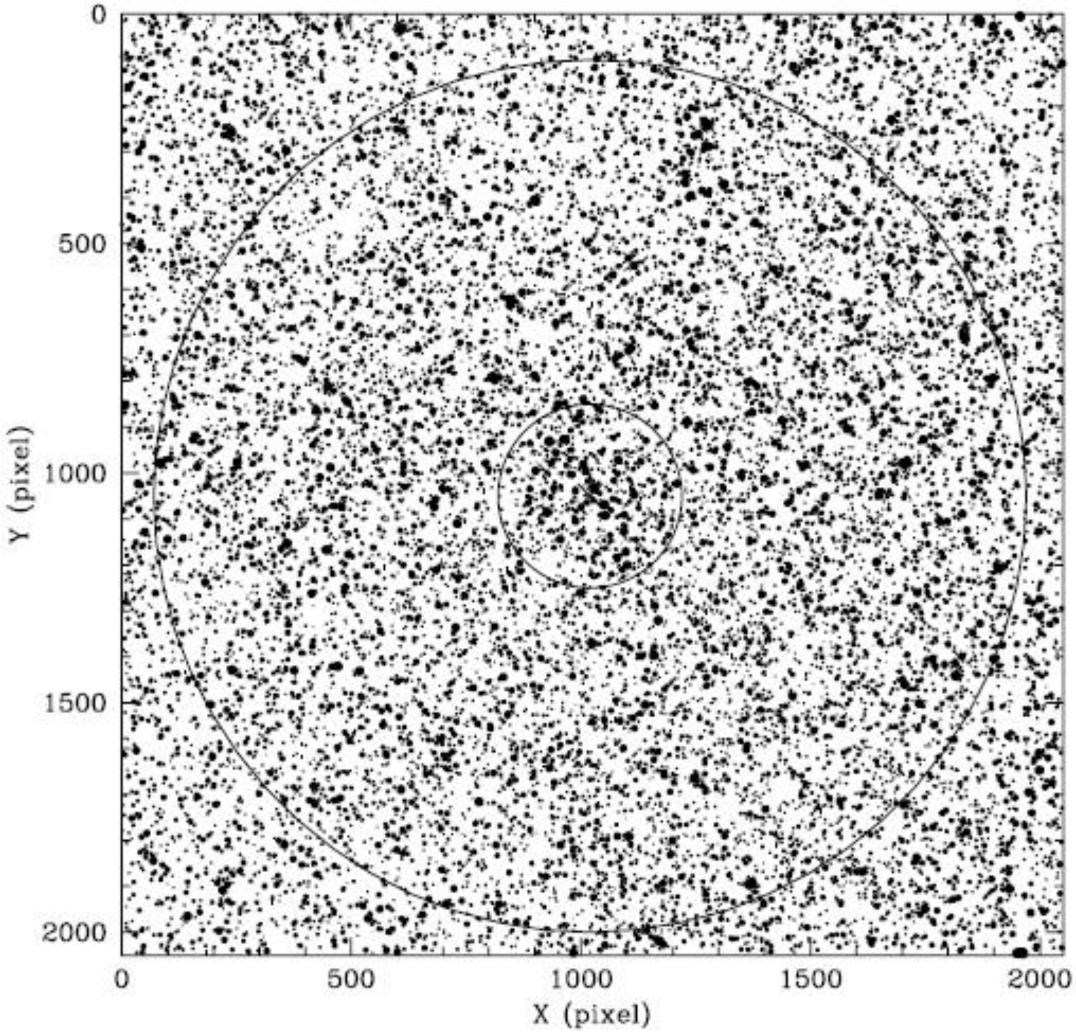
A typical example

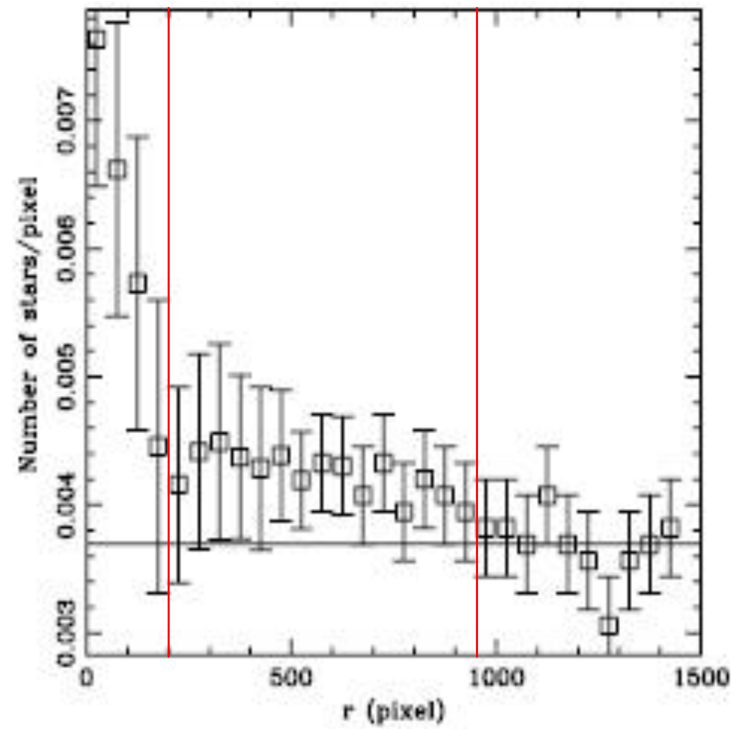
One typical example from the literature about how the free parameters are derived:

Piatti et al., 2006, MNRAS, 367, 599: ***First estimates of the fundamental parameters of the relatively bright Galactic open cluster NGC 5288***

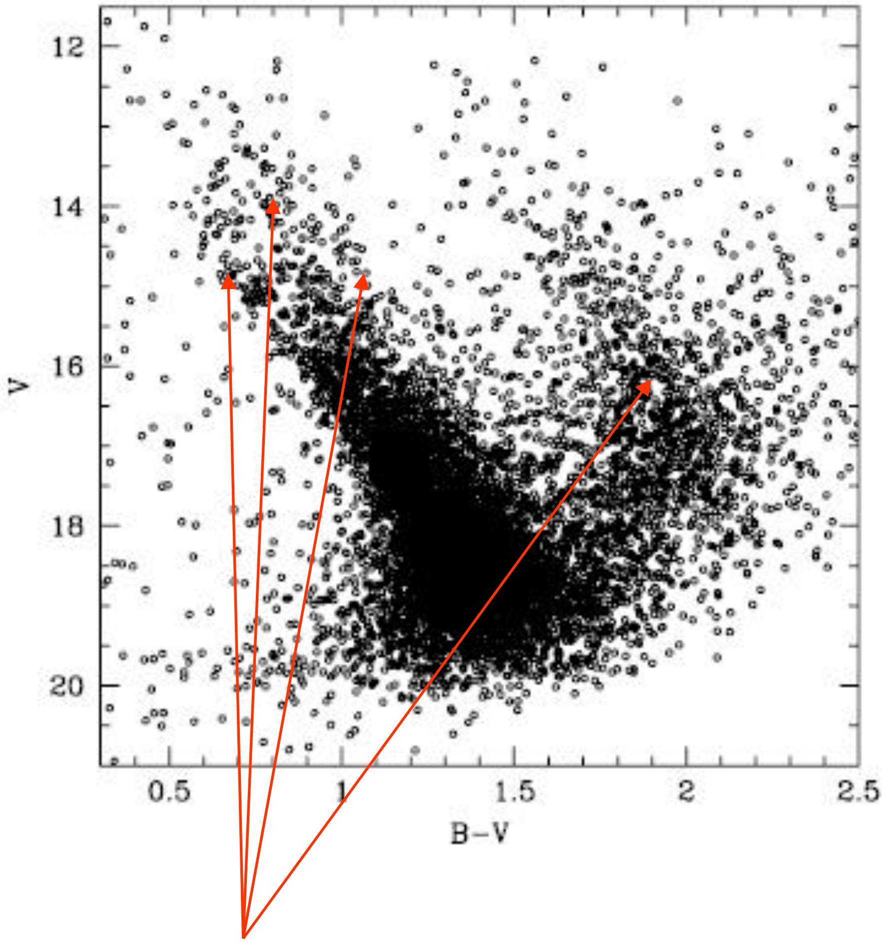
CCD BVI Photometry, 1 Pixel = 0.4´´, 13.6x13.6´ field,
NO information about the integration time and number of observations

No other observations available for this open cluster



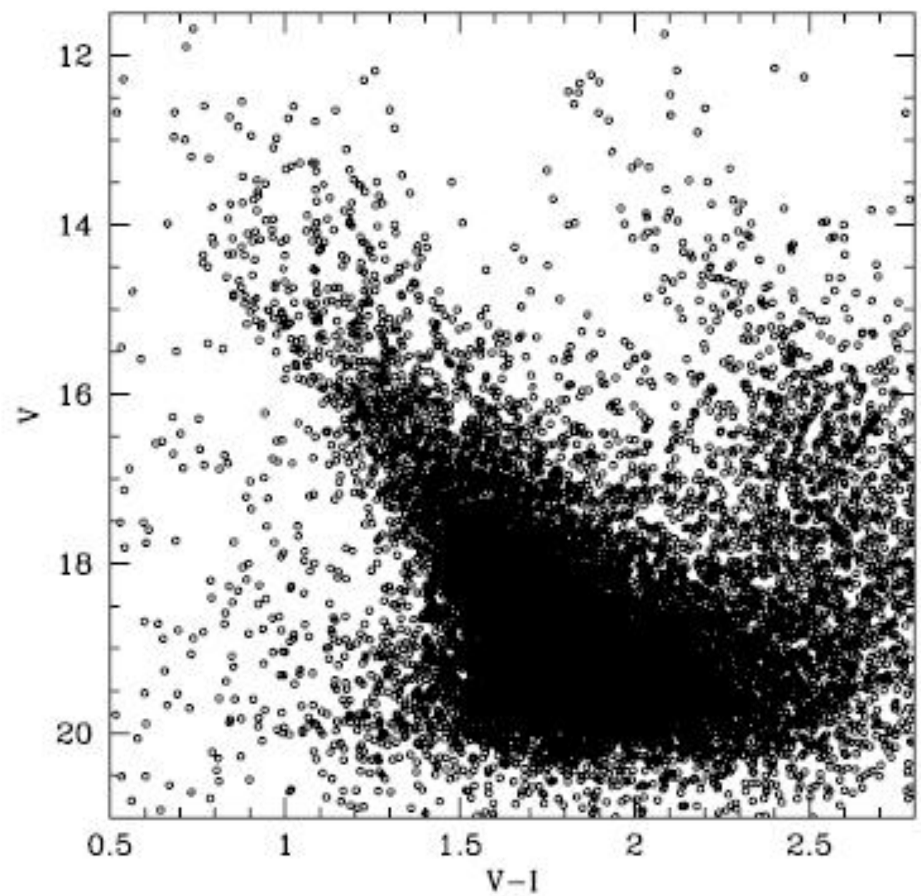


Center assumed and star counting applied => radius; Core of 200 pixels, total radius 950+-50 Pixel



Different „main sequences" due to fore- and background populations

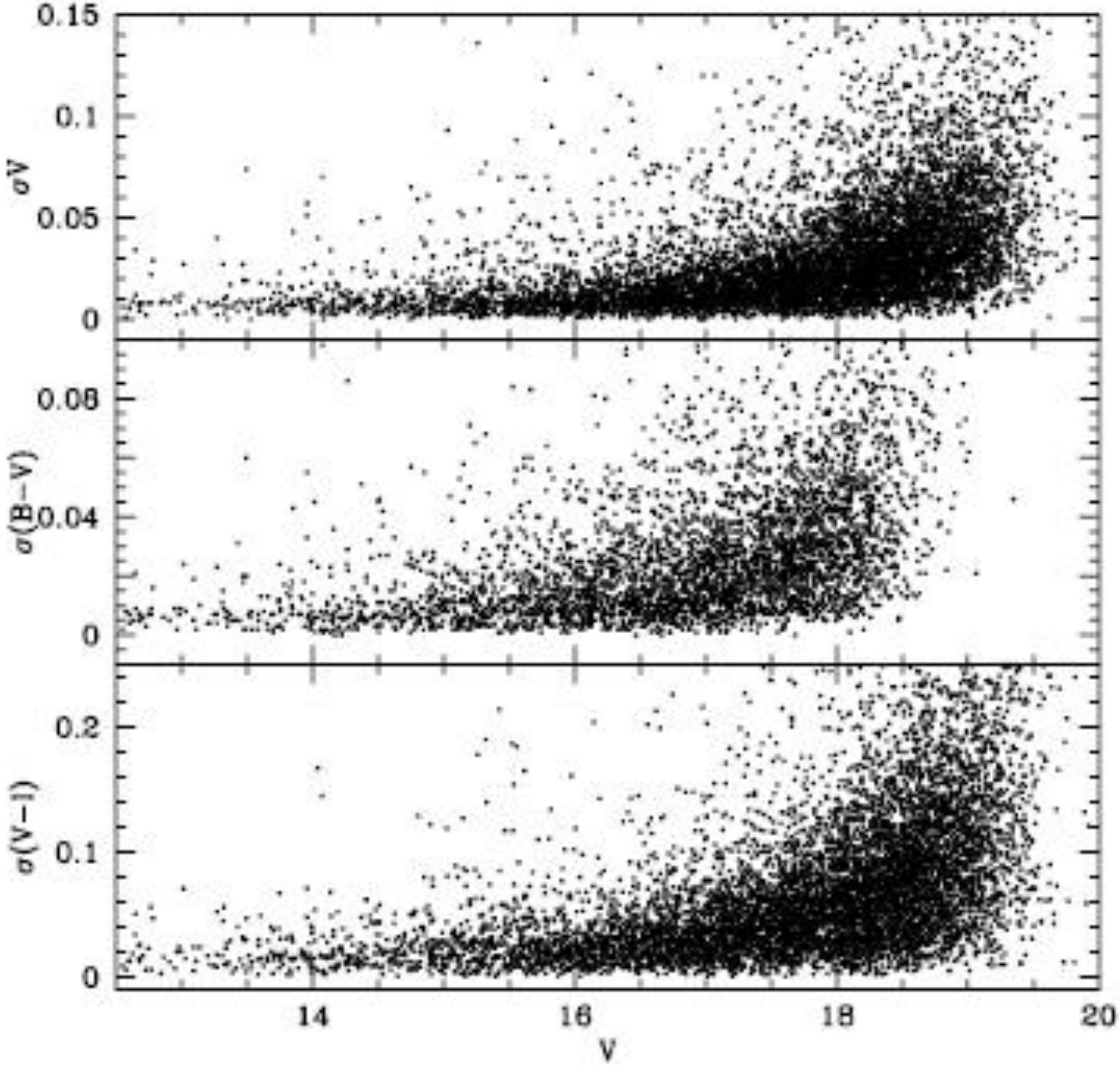
15688 stars in the complete field



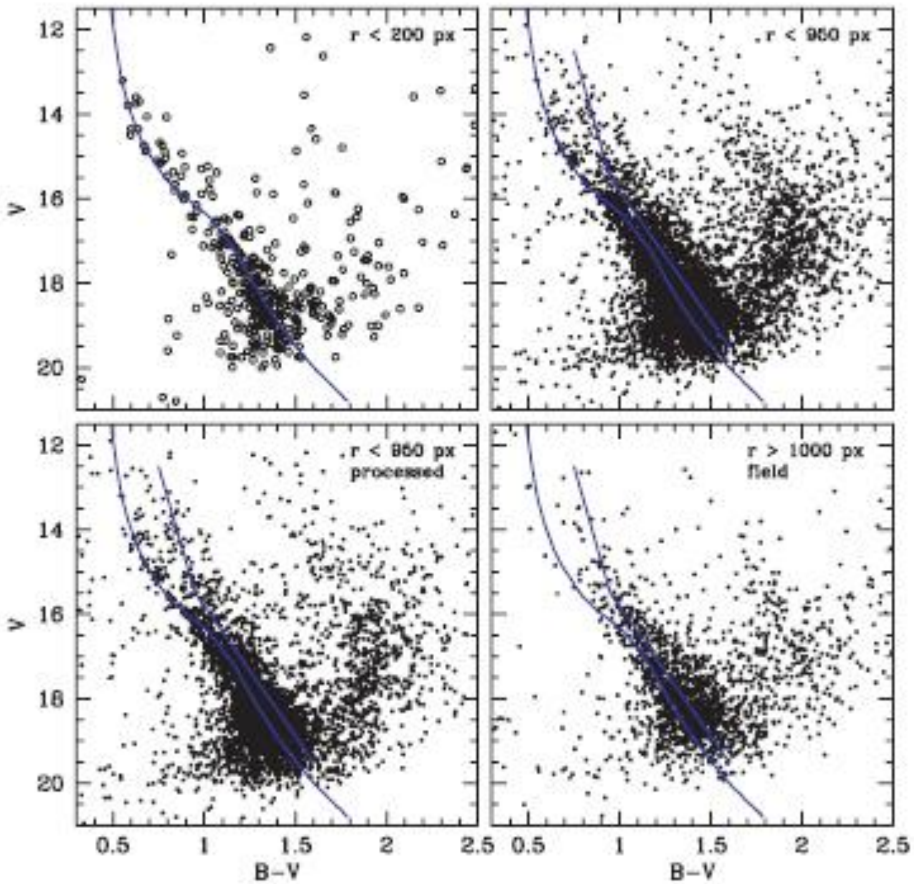
Error in correlation with the magnitude

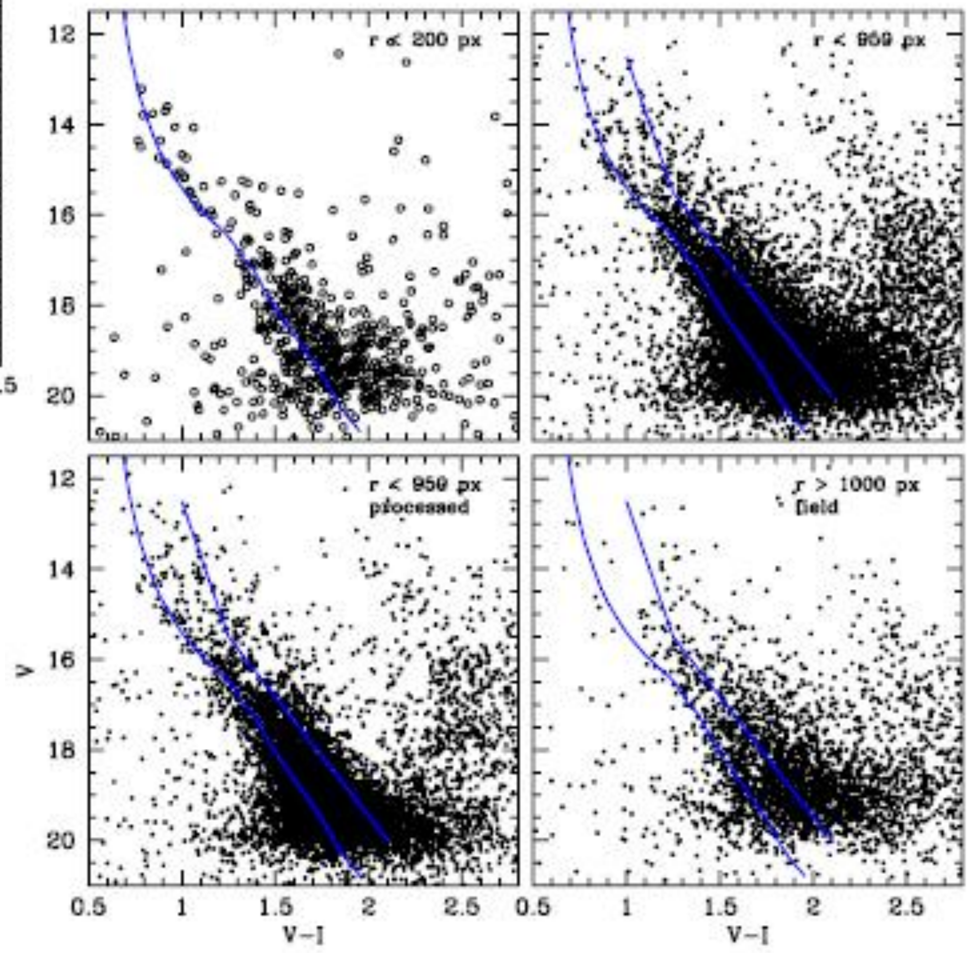
Photonnoise = Square root (Number of Photons)

Very important to evaluate the quality of the data

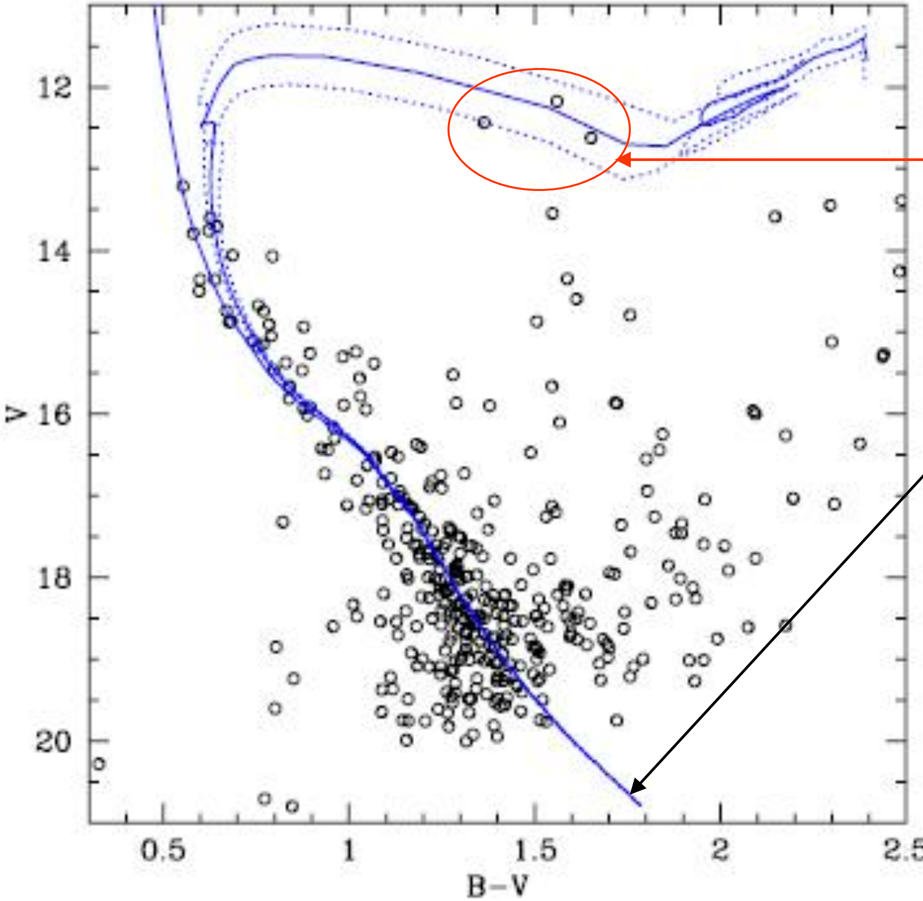


Only stars within 200 Pixel are used



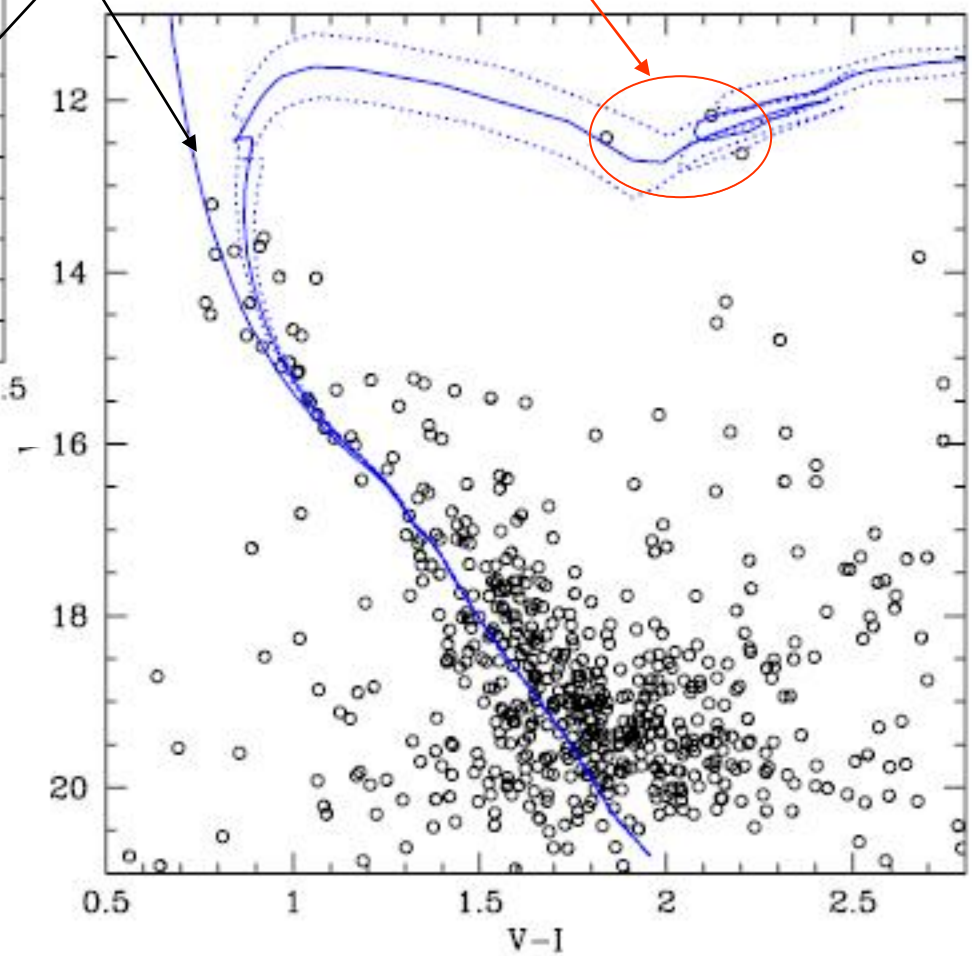


The authors claim that the isochrone with [Z] = 0.040 „fits best“, however no plot is given with [Z] = 0.019



Age determination ONLY based on these three stars

log t = **7.0**



Isochrones for [Z] = 0.040 and log t = 8.0, 8.1 und 8.2

Result: $t = 130^{+40}_{-30}$ Myr

E(B-V) = 0.75(5) mag

$V - M_V$ = 14.00(25) mag

Automatic Methods

Jorgensen & Lindegren, 2005, A&A, 436, 127

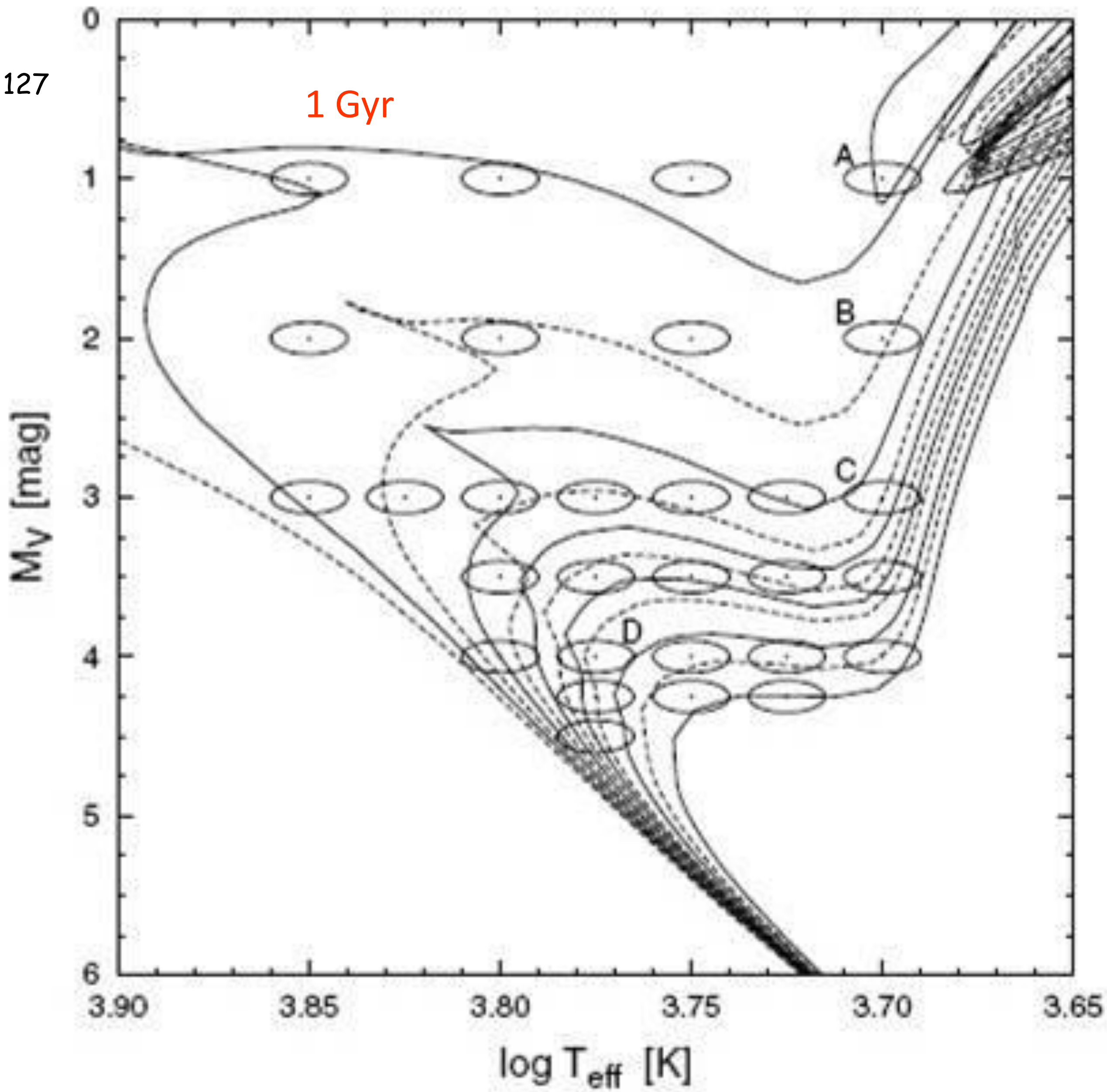
Definition of different „important" areas (Box) in the CMD. Do this allocation as you like.

Turn-off point, location of the red giant clump, and so on

Count the number of stars in each box

Warning: you always „lose" stars because of discrete boxes

Only for t > 300 Myr



Other methods

- An et al., 2007, ApJ, 655, 233
- Frayn & Gilmore, 2003, MNRAS, 339, 887
- Kharchenko et al., 2005, A&A, 438, 1136
- Monteiro et al., 2010, http://arxiv.org/abs/1003.4230
- Pinsonneault et al., 2003, ApJ, 598, 588

Calculation of Isochrones

The calculation of theoretical isochrone (= lines of equal age) is done with stellar atmospheres

Free parameter : Metallicity [X, Y, Z]

1. Zero Age Main Sequence $[T_{eff}, L]_0$
2. Chemical and gravitational evolution
3. $[T_{eff}, L](t)$
4. Adequate stellar atmosphere = **PHYSICS**
5. Absolute fluxes
6. Folding with filter curves
7. Colors, absolute magnitudes and so on

Which astrophysical "parameters" are important?

- Equations of State
- Opacities
- Model of convection
- Rotation
- Mass loss
- Magnetic field
- Core Overshooting
- Abundance of helium

A zoo of isochrones

- „Padua": http://pleiadi.pd.astro.it/
- Baraffe: http://cdsweb.u-strasbg.fr/viz-bin/Cat?J/A%2bA/337/403
- „Genf": http://obswww.unige.ch/~mowlavi/evol/stev_database.html
- Y^2: http://www.astro.yale.edu/demarque/yyiso.html
- Siess: http://www-astro.ulb.ac.be/~siess/database.html
- „Granada": http://www.iaa.es/~claret/

Tipp: contact the groups directly

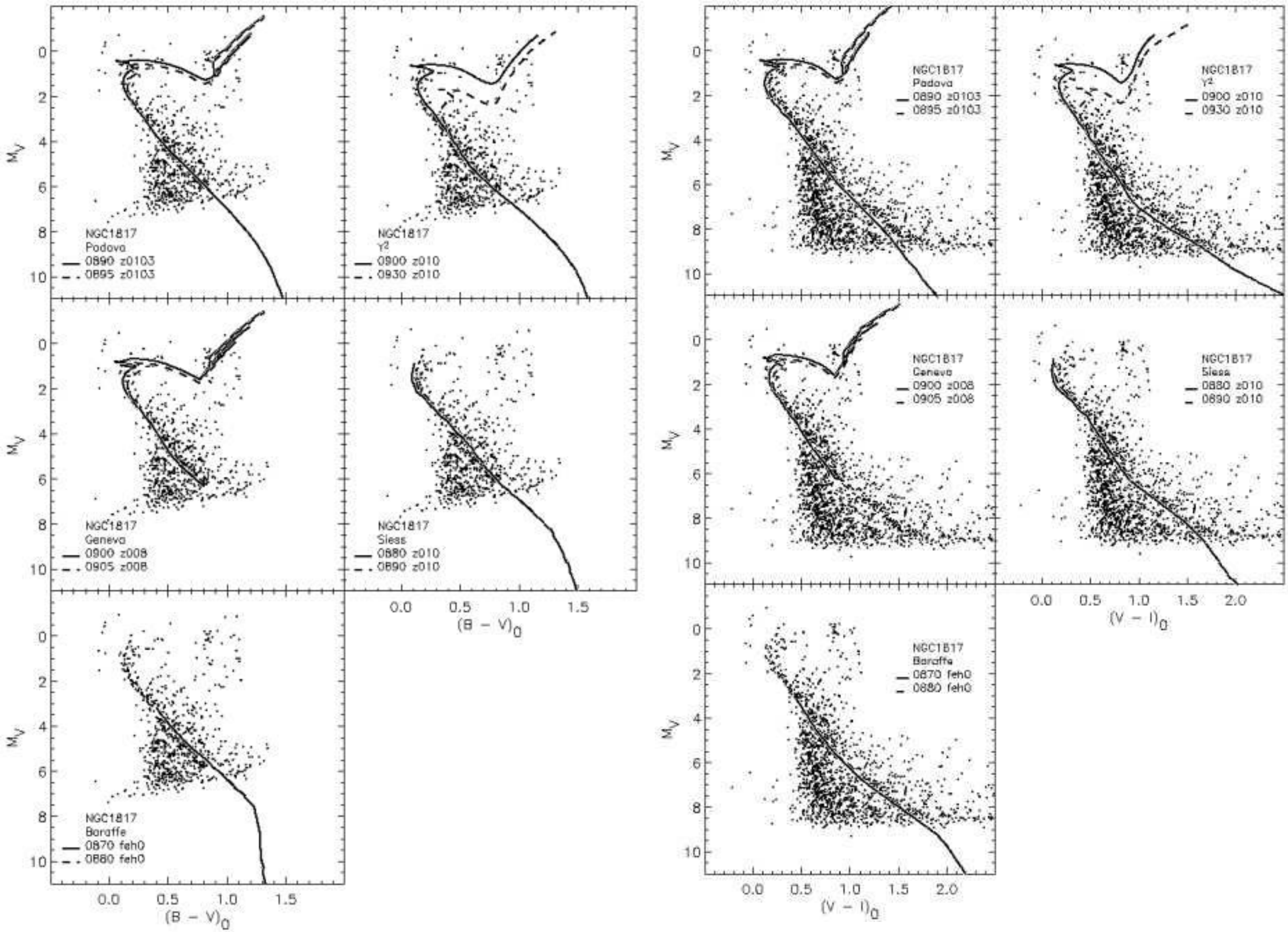
A comparison of the isochrones

- Grocholski & Sarajedini, 2003, MNRAS, 345, 1015 compared the following isochrones:
    1. "Padua": Girardi et al., 2002, A&A, 391, 195
    2. Baraffe: Baraffe et al., 1998, A&A, 337, 403
    3. "Genf": Lejeune & Schaerer, 2001, A&A, 366, 538
    4. Y^2: Yi et al., 2001, ApJS, 136, 417
    5. Siess: Siess et al., 2000, A&A, 358, 593

Grocholski & Sarajedini, 2003, MNRAS, 345, 1015

	Padova	Baraffe	Geneva	Y^2	Siess
Opacity	OPAL (1993)[a]	OPAL (1996)[b]	OPAL (?)[c]	OPAL (1996)[b]	OPAL (1996)[b]
Low temperature opacity	AF94	AF94	AF94, Kurucz (1991)	AF94	AF94
Equation of state	$T > 10^7$: Kippenhahn[d] $T < 10^7$: MHD[e]	SCVH[f]	Maeder & Meynet (1989)	OPAL (1996)[b]	based on Pols et al. (1995)
Core overshoot	$0.25H_p$ for $M \geq 1.5M_\odot$	none	$0.2H_p$ for $M \geq 1.5M_\odot$	$0.2H_p$ for $age \leq 2Gyr$	$0.2H_p$ for $Z = 0.02$ (all others = 0)
Mixing length, α	1.68	1.9	1.6	1.7431	1.605
He abundance	$Y_p = 0.23$	$Y_{solar} = 0.282$	$Y_p = 0.24$	$Y_p = 0.23$	$Y_p = 0.235$
He enrichment, $\frac{\Delta Y}{\Delta Z}$	2.25	n/a	2.5 for $Z > 0.02$ 3 for $Z \leq 0.02$	2.0	2.0
Synthetic photometry	ATLAS9[g] DUSTY99[h] Fluks et al. (1994)	NextGen[i]	BaSeL-2.2[j]	BaSeL-2.2[j]	Siess et al. (1997)

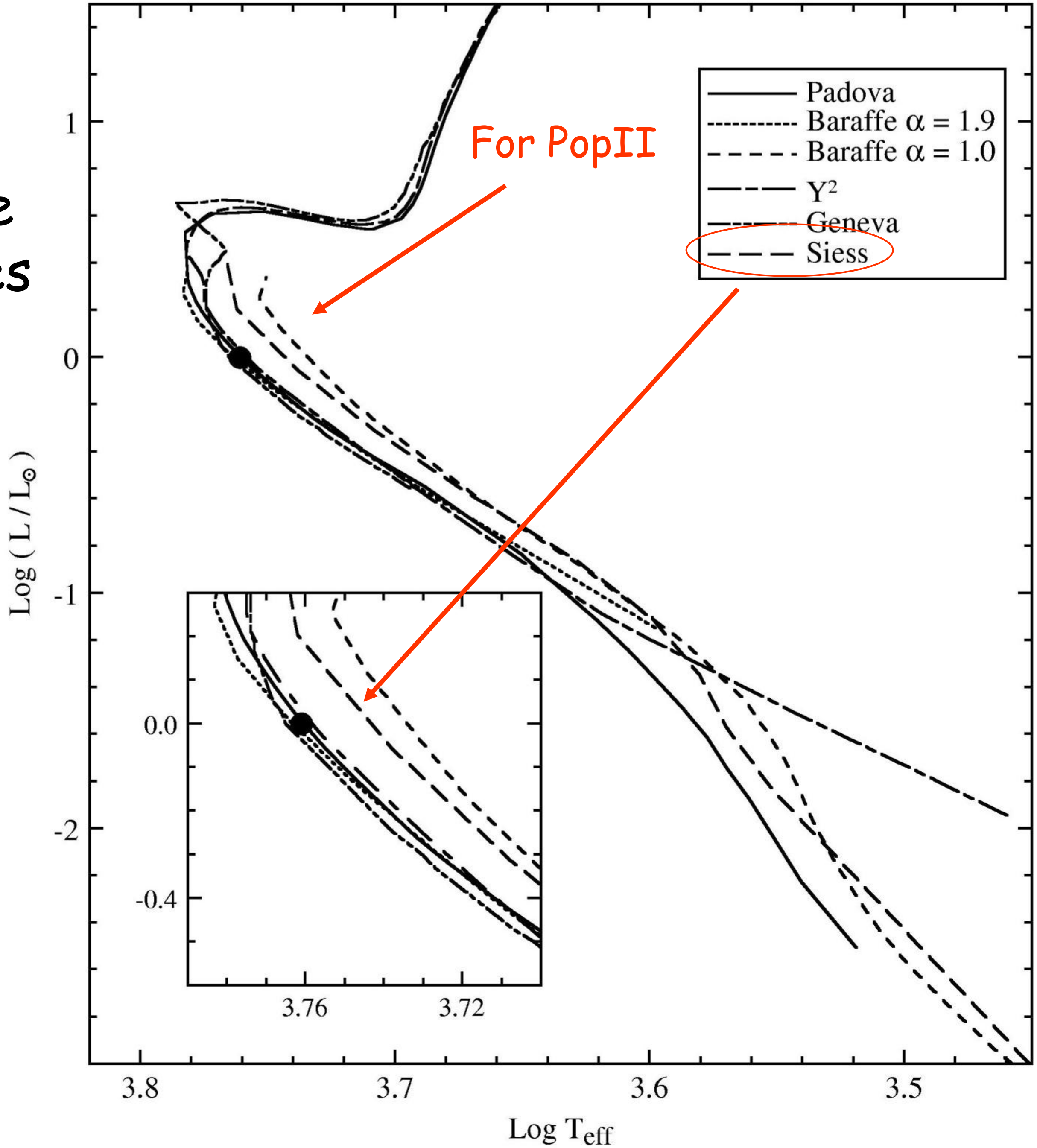
A permutation of models and parameters



Grocholski & Sarajedini, 2003, MNRAS, 345, 1015

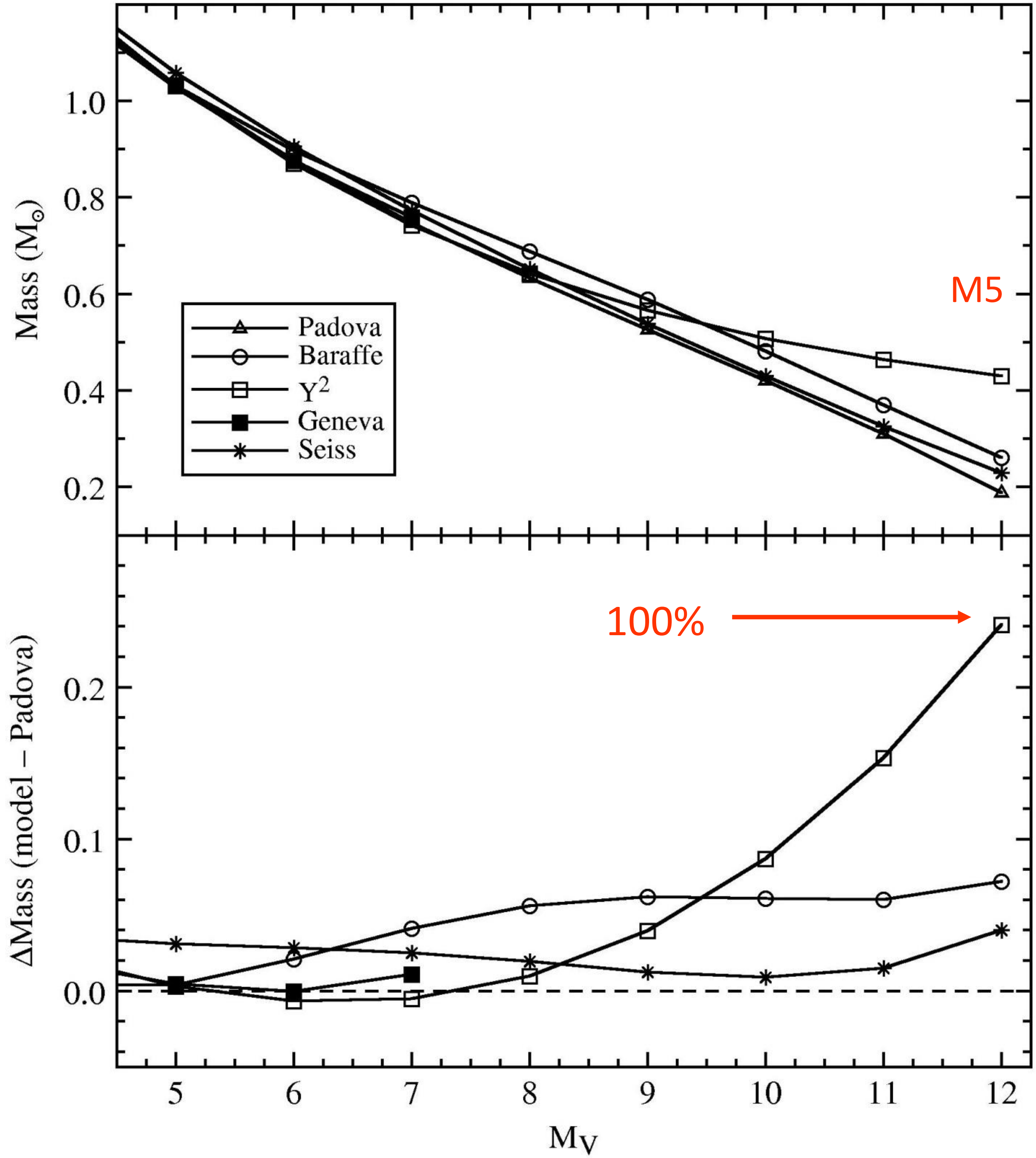
The location of the Sun with isochrones of 5 Gyr

Isochrones by Siess et al. (1997) seem “to have a problem”



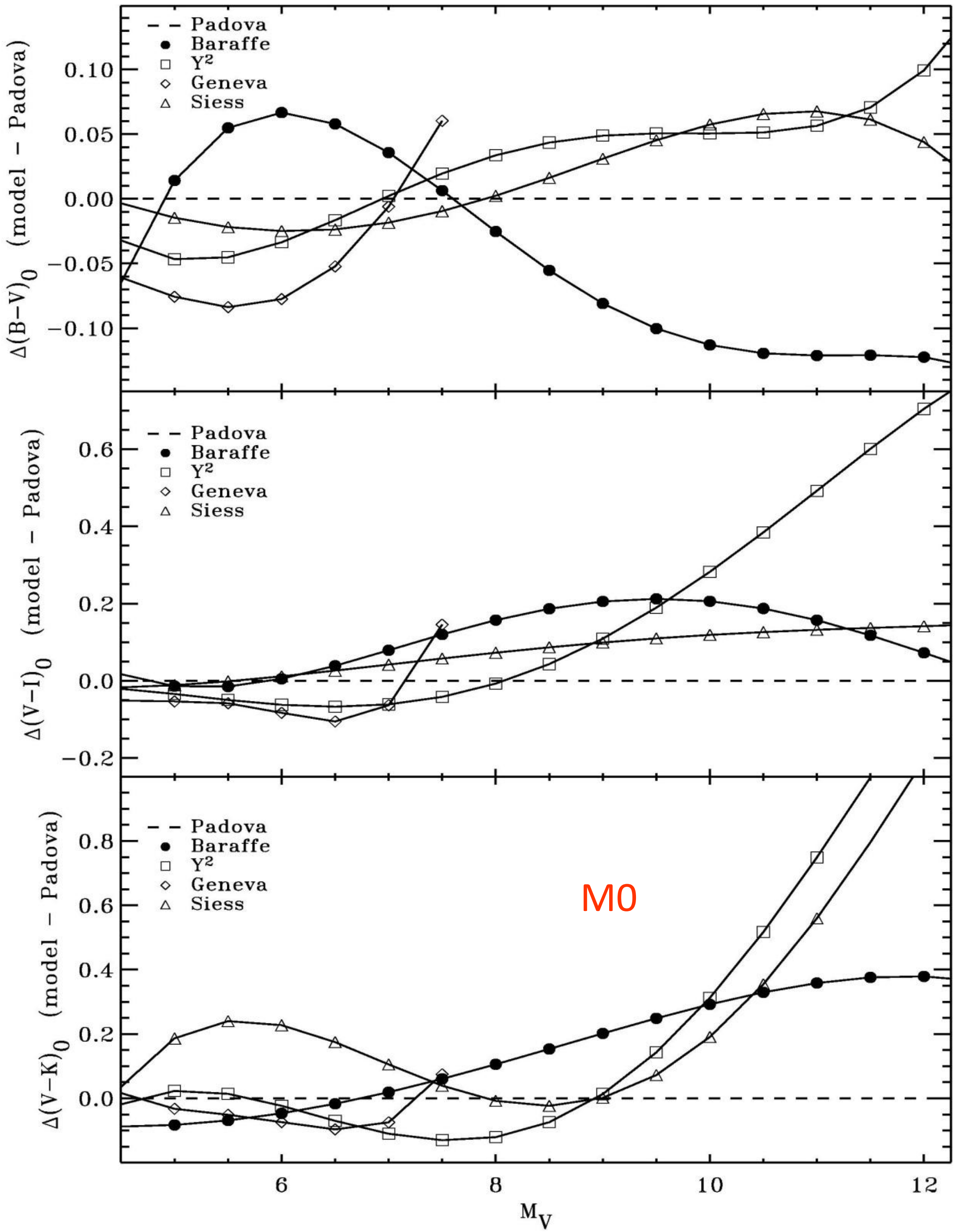
Comparison of different masses for a constant M_V

Zero line is the isochrone of the Padua group



Comparison of different color indices for a constant M_V

Zero line is the isochrone of the Padua group



Name	Available Photometry	Log Age	$E(B-V)$	[Fe/H]
M 35 (NGC 2168)	$UBVRIJHK_S$	8.17	0.19	−0.160
M 37 (NGC 2099)	$...BV.....JHK_S$	8.73	0.27	0.089
NGC 1817	$...BVRIJHK_S$	8.80	0.26	−0.268
NGC 2477	$UBV...IJHK_S$	9.04	0.23	0.019
NGC 2420	$...BVRIJHK_S$	9.24	0.05	−0.266
M 67 (NGC 2682)	$UBVRIJHK_S$	9.60	0.04	0.000

Used Photometry

Parameters from the literature

Cluster	Padova	Baraffe	Geneva	Y^2	Siess	Twarog et al.
M 35 (NGC 2168)	10.16	10.41	9.81	9.91	9.96	10.30
M 37 (NGC 2099)	11.55	11.40	11.50	11.35	11.75	11.55
NGC 1817	12.10	12.30	11.90	11.85	12.00	12.15
NGC 2477	11.55	11.60	11.30	11.15	11.45	11.55
NGC 2420	12.12	12.45	11.95	11.90	12.07	12.10
M 67 (NGC 2682)	9.80	9.80	9.60	9.45	9.65	9.80

log t, E(B-V) and [Fe/H] fixed, only Distance modulus determined

Value from the literature

Cluster	Padova	Baraffe	Geneva	Y^2	Siess	Twarog et al.
M 35 (NGC 2168)	10.16	10.41	9.81	9.91	9.96	10.30
M 37 (NGC 2099)	11.55	11.40	11.50	11.35	11.75	11.55
NGC 1817	12.10	12.30	11.90	11.85	12.00	12.15
NGC 2477	11.55	11.60	11.30	11.15	11.45	11.55
NGC 2420	12.12	12.45	11.95	11.90	12.07	12.10
M 67 (NGC 2682)	9.80	9.80	9.60	9.45	9.65	9.80

Transformation in distances [pc]

- M35: 1148 [916,1208]; -20% +5%
- M37: 2042 [1905,2239]; -7% +10%
- NGC 1817: 2692 [2344,2884]; -13% +7%
- NGC 2477: 2042 [1698,2089]; -17% +2%
- NGC 2420: 2630 [2399,3090]; -9% +17%
- M67: 912 [776,912]; -15% +0%
- Mean values: -13(5)% +7(6)%, for one free parameter!

Grocholski & Sarajedini, 2003, MNRAS, 345, 1015

Cluster	Padova	Baraffe	Geneva	Y^2	Siess	Twarog et al.
M 35 (NGC 2168)	10.16	10.41	9.81	9.91	9.96	10.30
M 37 (NGC 2099)	11.55	11.40	11.50	11.35	11.75	11.55
NGC 1817	12.10	12.30	11.90	11.85	12.00	12.15
NGC 2477	11.55	11.60	11.30	11.15	11.45	11.55
NGC 2420	12.12	12.45	11.95	11.90	12.07	12.10
M 67 (NGC 2682)	9.80	9.80	9.60	9.45	9.65	9.80

In a statistical point-of-view: significant

For a given reddening, metallicity and age, the isochrones by Baraffe et al. yield significantly brighter and Yi et al. significantly fainter absolute magnitudes .

In addition, the isochrones by Siess et al. do not reproduce the location of the Sun correctly.