Building up synthetic color-magnitude diagrams

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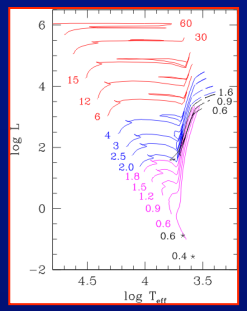
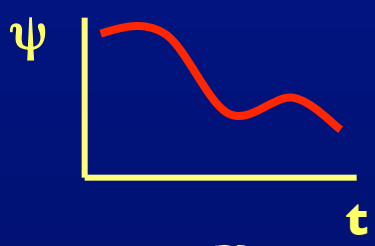
Computing a synthetic CMD

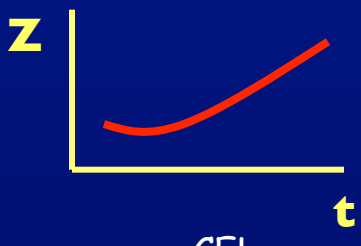
Ingredients



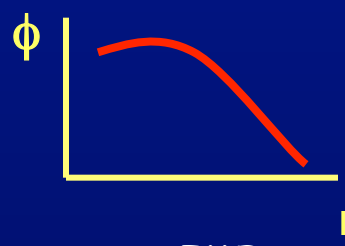
Stellar models



SFR



CEL



IMF

Binaries

Computing method

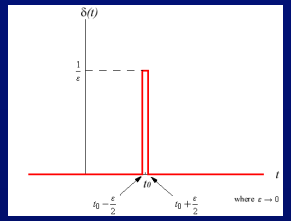
Montecarlo	→	**Age, metallicity and mass**
Interpolation in the stellar evolution library	→	Luminosity and effective temperature
Bolometric corrections	→	Magnitudes and colors

Let us start with the simplest case: a Simple Stellar Population

The stars must be coeval ⇒ **Single star formation burst**

⇓

Then the SFR function is represented by a Dirac delta function



The stars must be chemically homogenous ⇒ **All stars were BORN with the same chemical composition**

⇓

The metallicity is constant

Synthetic CMD for a SSP: setting the parameters

let us assume that we want to compute a CMD for a SSP with:

- ✓ Age = 10000Myr
- ✓ [Fe/H]=-1.3 ➔ Z=0.002 for an α-enhanced metal mixture
- ✓ He abundance Y=0.248
- ✓ Number of objects in the simulation = 100000
- ✓ Initial mass function: Salpeter power law
- ✓ No binaries
- ✓ Observational plane: ACS@HST photometric system

Synthetic CMD for a SSP: selecting the stellar model library

URL: http://www.oa-teramo.inaf.it/BASTI

1 - selecting the metal mixture & He abundance…

Stellar Evolutionary models

SCALED SOLAR:

- canonical
- non-canonical

α - ENHANCED:

- canonical
- non canonical

ADDITIONAL MODELS:

- He enhanced
- CNONa extreme
- White Dwarfs

Create Query on *BaSTI* DB

WEB TOOL:

- Isochrones - Tracks
- Luminosity Function
- Synthetic Color - Magnitude Diagrams
- Synthetic HB Generator

2 - selecting the metallicity…

Please choose tracks/isochrones for download from the following list of chemical compositions:

Z	Y	[Fe/H]	[M/H]	normal		AGB extended	
0.00001	0.245	-3.62	-3.27	η=0.4			
0.0001	0.245	-2.62	-2.27	η=0.2	η=0.4	η=0.2	η=0.4
0.0003	0.245	-2.14	-1.79	η=0.2	η=0.4	η=0.2	η=0.4
0.0006	0.246	-1.84	-1.49	η=0.2	η=0.4	η=0.2	η=0.4
0.001	0.246	-1.62	-1.27	η=0.2	η=0.4	η=0.2	η=0.4
0.002	0.248	-1.31	-0.96	η=0.2	η=0.4	η=0.2	η=0.4
0.004	0.251	-1.01	-0.66	η=0.2	η=0.4	η=0.2	η=0.4
0.008	0.256	-0.70	-0.35	η=0.2	η=0.4	η=0.2	η=0.4
0.01	0.259	-0.60	-0.25	η=0.2	η=0.4	η=0.2	η=0.4
0.0198	0.2734	-0.29	0.06	η=0.2	η=0.4	η=0.2	η=0.4
0.03	0.288	-0.09	0.26	η=0.2	η=0.4	η=0.2	η=0.4
0.04	0.303	0.05	0.40	η=0.2	η=0.4	η=0.2	η=0.4
0.05	0.316	0.16	0.51	η=0.4			

3 - selecting the type of models…

You are now in:
BASTI Home / Alpha Enhanced (F05) Models / Canonical Models / List of metallicities / Z=0.002

- Evolutionary models
- HB models
- Isochrones

4 - selecting the Photometric system…

3 - selecting the type of models…

You are now in:
BASTI Home / Alpha Enhanced (F05) Models / Canonical Models / List of metallicities / Z=0.002

- Evolutionary models
- HB models
- Isochrones

Y= 0.248, Z = 0.002 - Evolutionary models

M = 0.50 Mo	M = 0.55 Mo	M = 0.60 Mo	M = 0.70 Mo	M = 0.75 Mo
M = 0.78 Mo	M = 0.80 Mo	M = 0.90 Mo	M = 1.00 Mo	M = 1.10 Mo
M = 1.20 Mo	M = 1.30 Mo	M = 1.40 Mo	M = 1.50 Mo	M = 1.60 Mo
M = 1.70 Mo	M = 1.80 Mo	M = 1.90 Mo	M = 2.00 Mo	M = 2.20 Mo
M = 2.40 Mo	M = 2.60 Mo	M = 2.80 Mo	M = 3.00 Mo	M = 3.50 Mo
M = 4.00 Mo	M = 4.50 Mo	M = 5.00 Mo	M = 5.50 Mo	M = 6.00 Mo
M = 6.50 Mo	M = 7.00 Mo	M = 7.50 Mo	M = 8.00 Mo	M = 8.50 Mo
M = 9.00 Mo	M = 9.50 Mo	M = 10.00 Mo		

Download all tracks (as a single .tar.gz file)

UBVRIJKL bands | ACS HST bands
Stroemgren bands | Sloan bands
Walraven bands | WFC2 HST bands
WFC3 HST bands | WFC3-IR HST bands

4 - selecting the Photometric system…

The key points along the evolutionary track

```
# Evol. track by Pietrinferni - Cassisi - Salaris - Castelli 2008 ::: Standard Model
#=============================================================================================================
# Alpha-enhaced model & transformations for ACS (Castelli 2008)
#=============================================================================================================
#  Np= 1190   [M/H]=-0.963   Z= 0.0020   Y= 0.248   Mass=  1.000   normalized: 20 12 2014
#=============================================================================================================
#       log(age)         (M/Mo)     log(L/Lo)  logTe     F435W   F475W   F555W   F606W   F625W   F775W   F814W
#=============================================================================================================
    -9.00000000000   1.0000000000  0.18235  3.82844   4.7031  4.5760  4.3633  4.2445  4.1187  3.8701  3.8453
     7.16377092359   1.0000000000  0.18274  3.82845   4.7021  4.5750  4.3624  4.2435  4.1177  3.8691  3.8443
     7.46480091925   1.0000000000  0.18313  3.82845   4.7011  4.5740  4.3614  4.2425  4.1167  3.8681  3.8433
     7.64089217831   1.0000000000  0.18352  3.82845   4.7001  4.5730  4.3604  4.2415  4.1157  3.8672  3.8423
     7.76583091492   1.0000000000  0.18392  3.82845   4.6991  4.5720  4.3594  4.2405  4.1147  3.8662  3.8414
     7.86274092793   1.0000000000  0.18431  3.82845   4.6981  4.5710  4.3584  4.2395  4.1137  3.8652  3.8404
     7.94192217397   1.0000000000  0.18470  3.82845   4.6971  4.5700  4.3574  4.2385  4.1127  3.8642  3.8394
     8.00886896360   1.0000000000  0.18509  3.82846   4.6961  4.5690  4.3564  4.2375  4.1118  3.8632  3.8384
     8.06686091058   1.0000000000  0.18548  3.82846   4.6951  4.5680  4.3554  4.2365  4.1108  3.8623  3.8374
     8.11801343303   1.0000000000  0.18593  3.82846   4.6939  4.5668  4.3542  4.2354  4.1096  3.8611  3.8363
     8.16377092359   1.0000000000  0.18677  3.82849   4.6917  4.5646  4.3521  4.2333  4.1076  3.8591  3.8343
     8.20516360875   1.0000000000  0.18760  3.82852   4.6895  4.5624  4.3500  4.2312  4.1055  3.8571  3.8323
     8.24295216964   1.0000000000  0.18844  3.82855   4.6872  4.5602  4.3478  4.2291  4.1034  3.8551  3.8303
     8.27771427590   1.0000000000  0.18927  3.82859   4.6850  4.5580  4.3457  4.2270  4.1013  3.8531  3.8283
     8.30989895927   1.0000000000  0.19009  3.82862   4.6828  4.5559  4.3436  4.2249  4.0993  3.8511  3.8264
     8.33986218265   1.0000000000
     8.36789090625   1.0000000000
     8.39421984497   1.0000000000
     8.41904342869   1.0000000000
     8.44252452454   1.0000000000
     8.46480091925   1.0000000000
     8.48599021832   1.0000000000
     8.50619360441   1.0000000000
     8.52549875961   1.0000000000
     8.54398216530   1.0000000000
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     8.59513468775   1.0000000000
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     8.65513261742   1.0000000000
     8.66892090191   1.0000000000
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     8.70783896794   1.0000000000
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     8.73197264766   1.0000000000
     8.74355452021   1.0000000000
     8.75483553062   1.0000000000
     8.76583091492   1.0000000000
     8.77655478031   1.0000000000
     8.78702021399   1.0000000000
     8.79723937917   1.0000000000
     8.80722360008   1.0000000000
     8.81698343737   1.0000000000
     8.82652875527   1.0000000000
     8.83586878153   1.0000000000
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     8.85396700362   1.0000000000
     8.86274092793   1.0000000000
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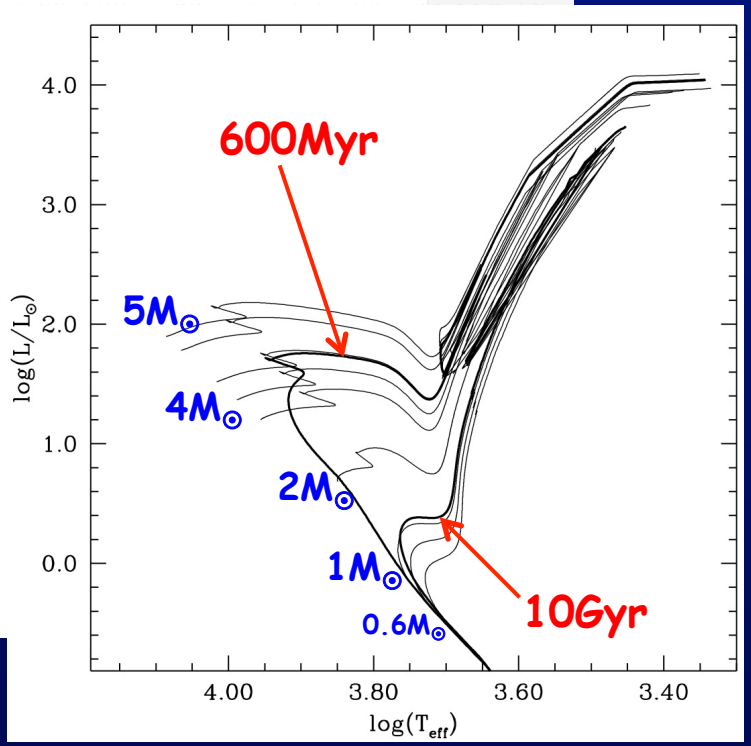

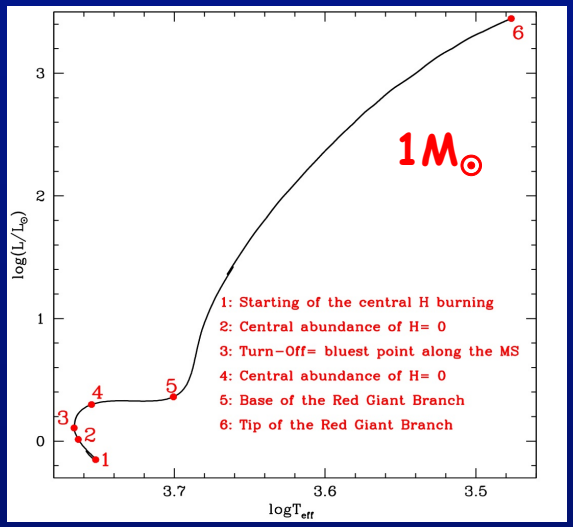

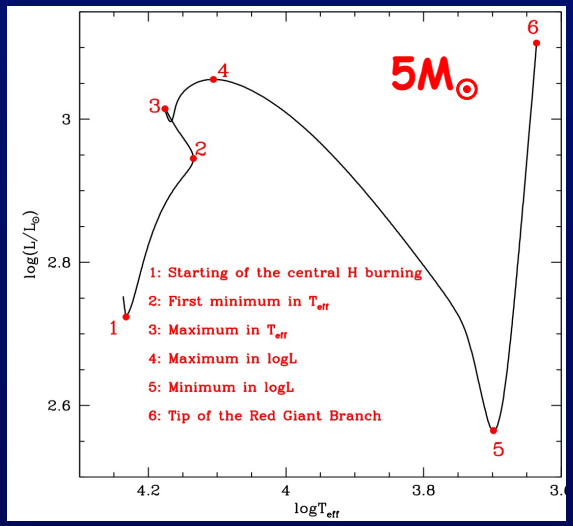

Building the stellar model library

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  0.7000      0070z203y248aes.nor_acs_hst
  0.7500      0075z203y248aes.nor_acs_hst
  0.8000      0080z203y248aes.nor_acs_hst
  0.9000      0090z203y248aes.nor_acs_hst
  1.0000      0100z203y248aes.nor_acs_hst
  1.1000      0110z203y248aes.nor_acs_hst
  1.2000      0120z203y248aes.nor_acs_hst
  1.3000      0130z203y248aes.nor_acs_hst
  1.4000      0140z203y248aes.nor_acs_hst
  1.5000      0150z203y248aes.nor_acs_hst
=======================================
  0.4885  0488m08z203y248aes.nor_acs_hst
  0.4890  0489m08z203y248aes.nor_acs_hst
  0.4900  0490m08z203y248aes.nor_acs_hst
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  0.5800  0580m08z203y248aes.nor_acs_hst
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 READING NOW ...      0150z203y248aes.nor_acs_hst
 SYNTESYS AVAILABLE IN THE RANGE   1583.8 -  17046.6  MYRS
```

```
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 Number of STAR  AGE
 N.BINARY N.of CROWDED ExpMF VLIM QSPREAD <M_HB> SIGMAMHB BINfl
 N.of error point  (m-M)
 V1 ERRV1 ERRBV1
 V2 ERRV2 ......
 ...............
 ...............

**********************************************************************
100000 10000
  00.0  00.0 2.35  5.00  0.0000 0.600 0.010 0.250
   1   0.0
 -4.000  0.000  0.000
 -3.000  0.000  0.000
 -2.000  0.000  0.000
 -1.000  0.000  0.000
  0.000  0.000  0.000
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  4.000  0.000  0.000
  5.000  0.000  0.000
```
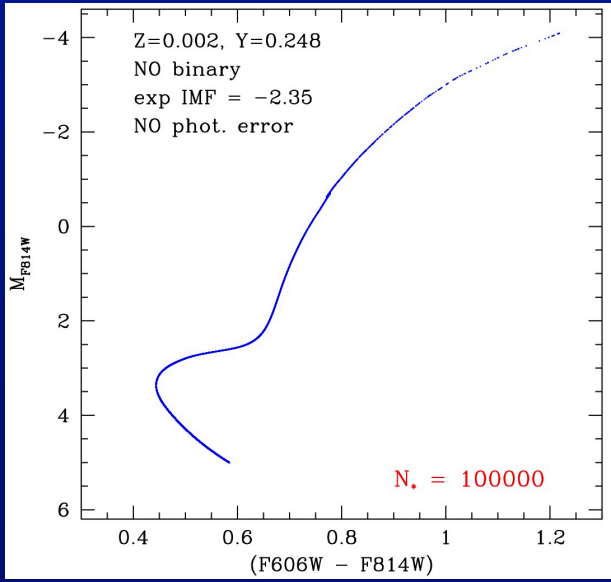
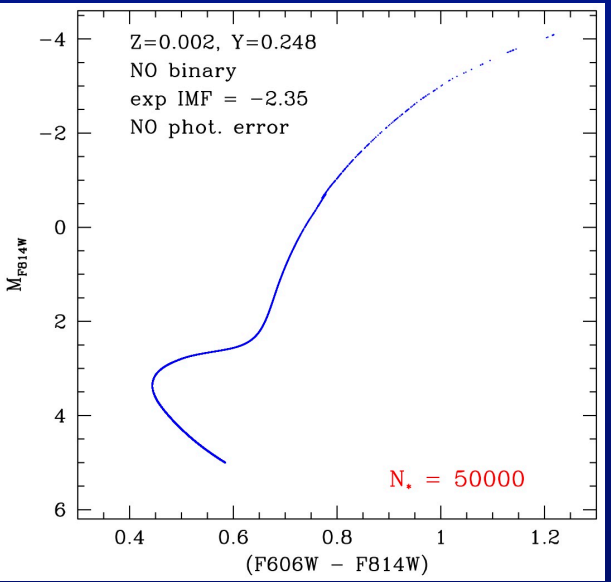
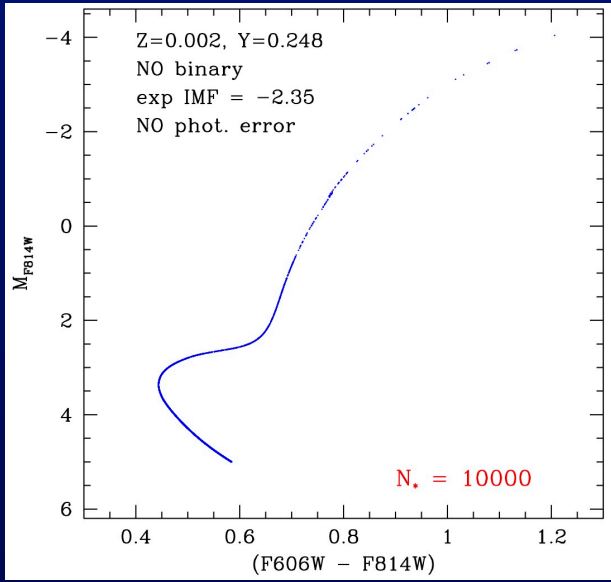
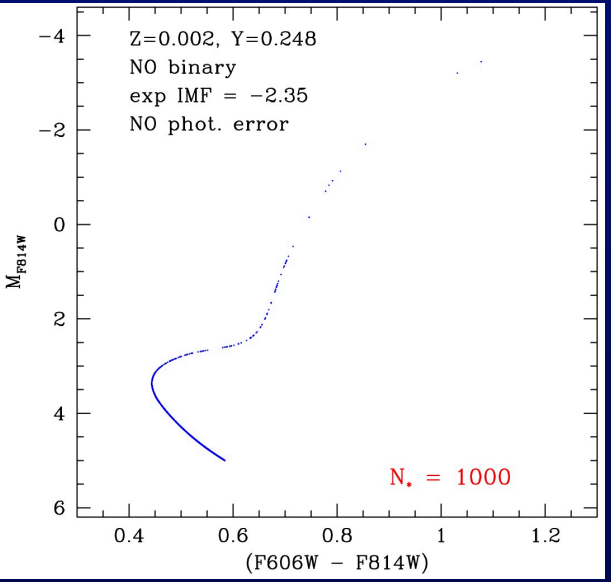

The effect of Statistical Sampling

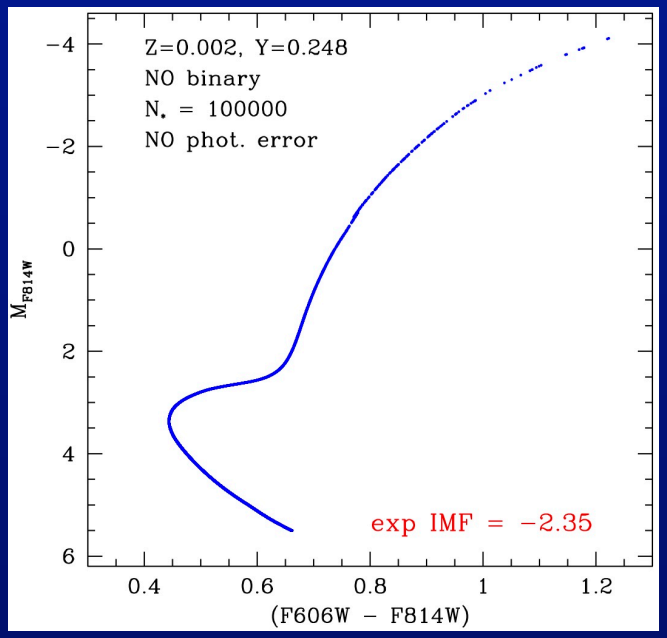


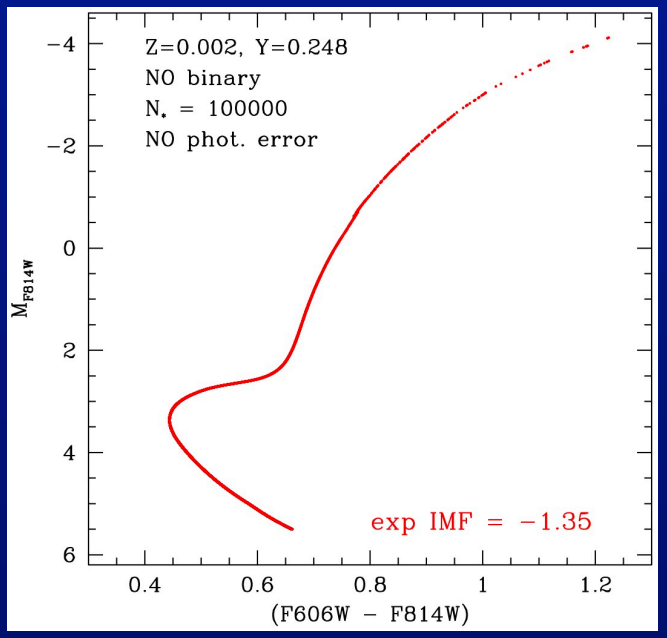


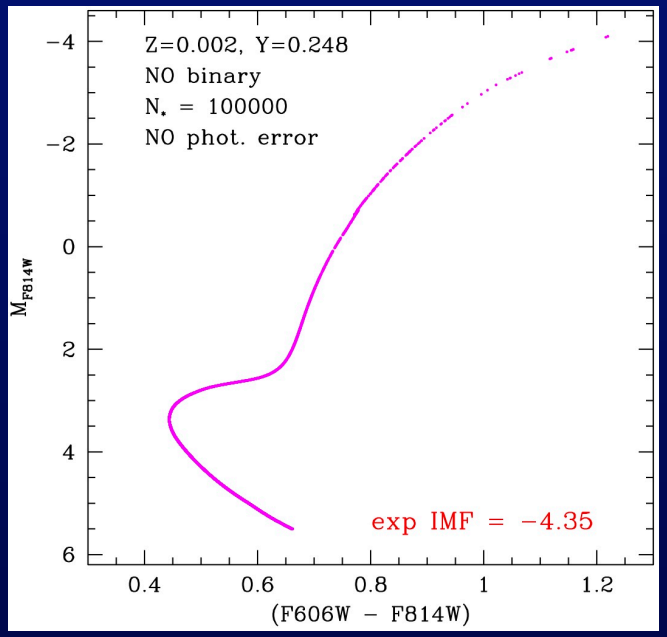


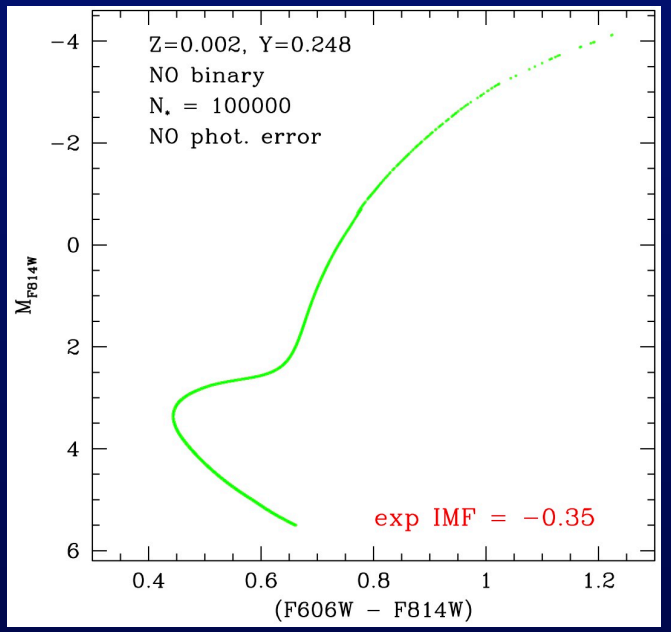


The effect of the Initial Mass Function

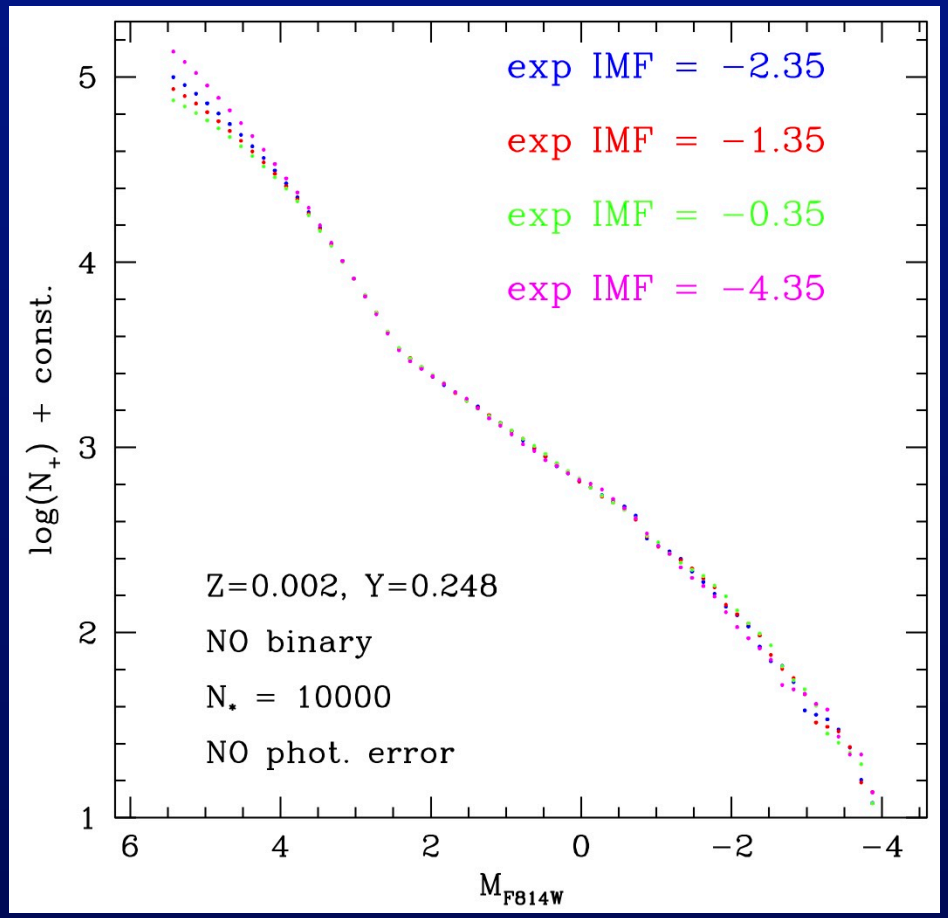






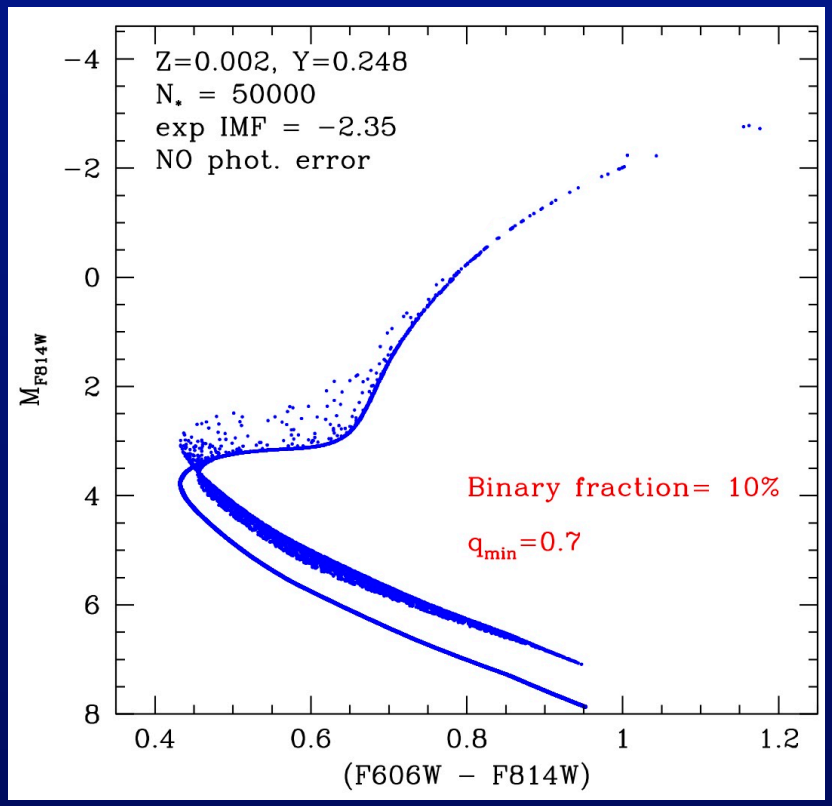


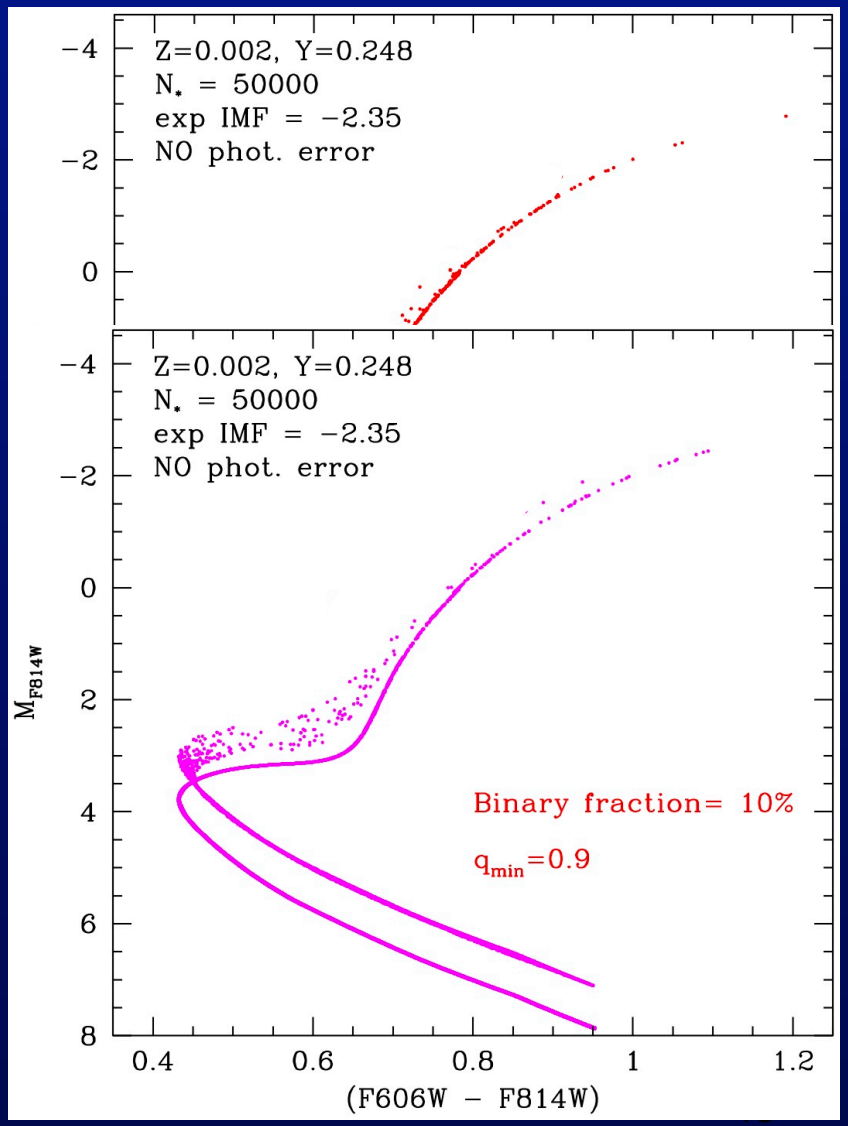
The Luminosity Function: IMF effects



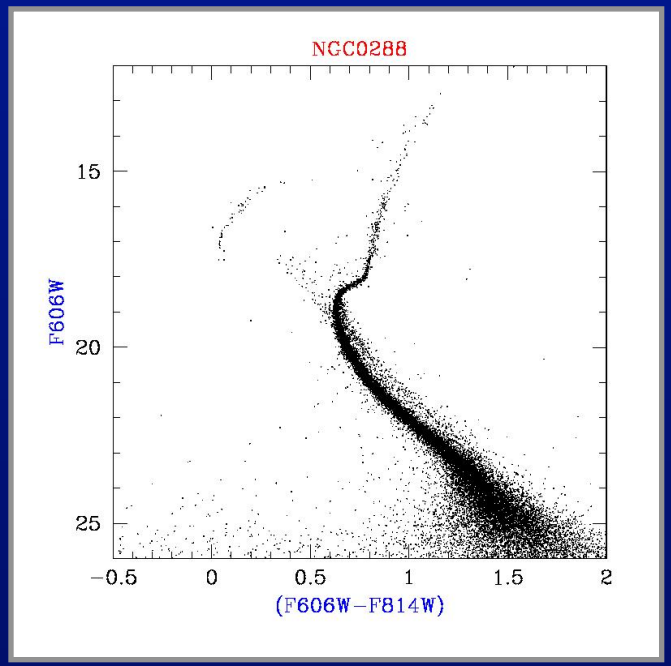
$$\frac{dN}{dm} \propto m^{\alpha}$$

The presence of binary

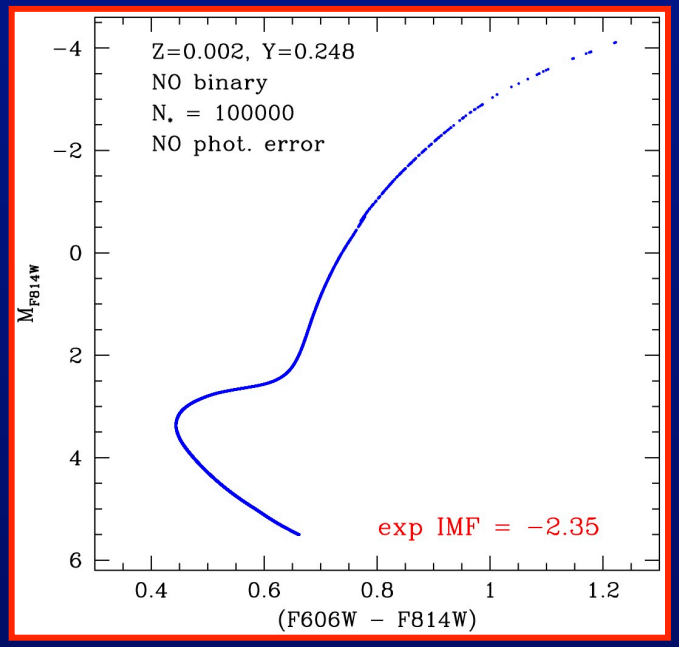




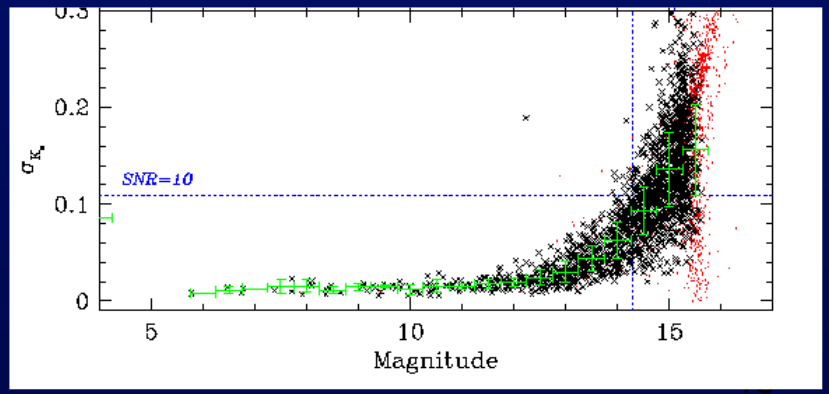
Real CMD



Theoretical CMD

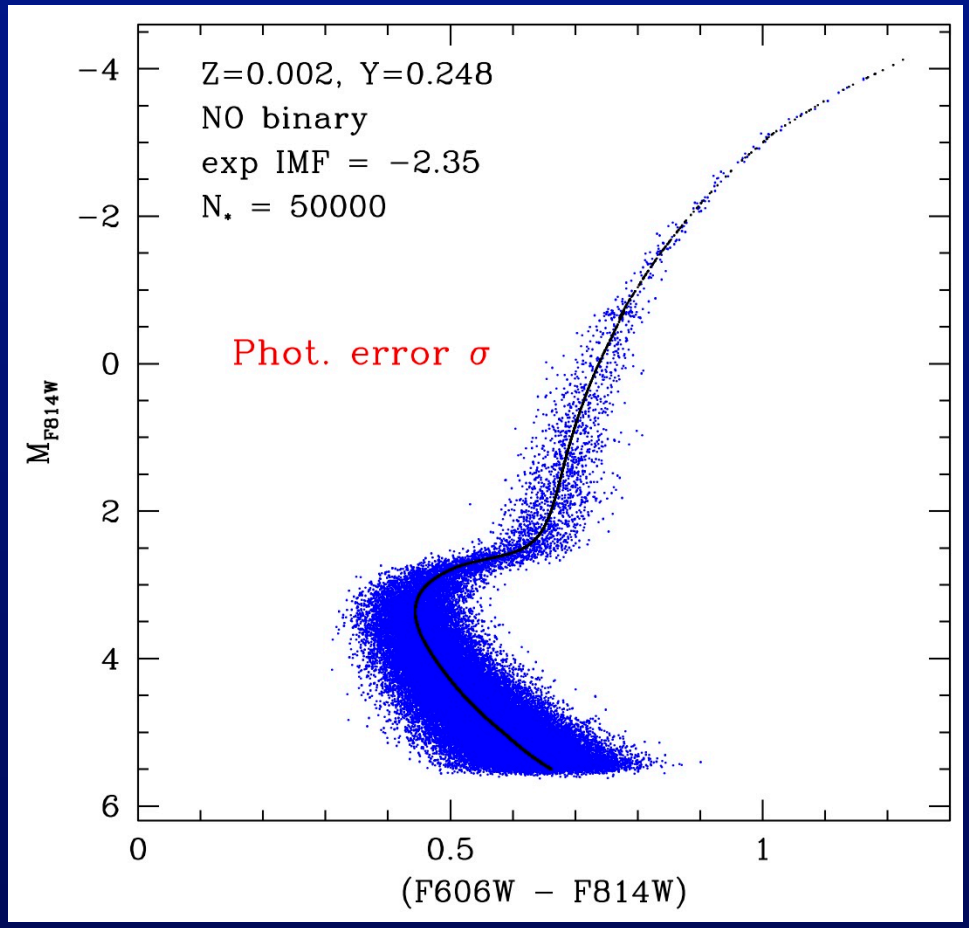


Photometric errors



Simulating the photometric errors…

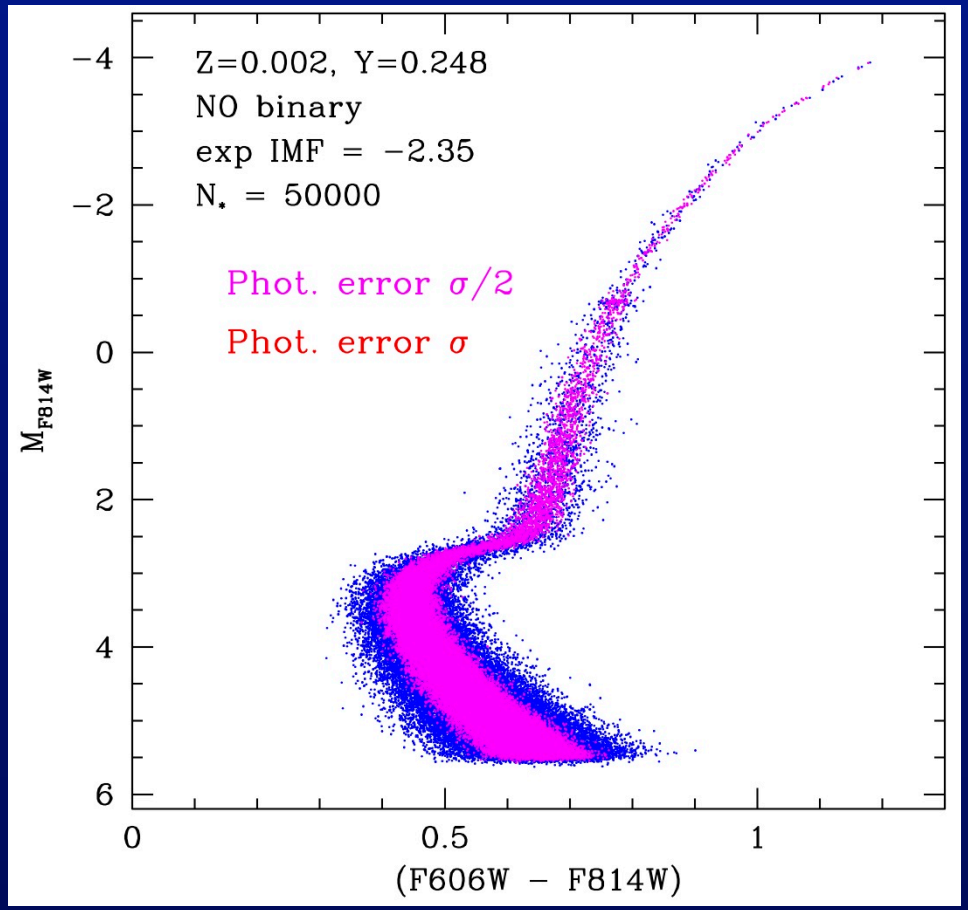
```
50000 10000
   0.0   00.0 2.35   5.50   0.0000 0.600 0.010 0.150
   9    0.0
 -4.000   0.001   0.001
 -3.000   0.006   0.008
 -2.000   0.008   0.011
 -1.000   0.010   0.014
  0.000   0.020   0.028
  2.000   0.025   0.035
  4.000   0.030   0.042
  5.000   0.040   0.056
  6.000   0.050   0.071
```



please remember the lecture by Monelli for a discussion on how to retrieve the "true" observational errors that have to be taken into account….

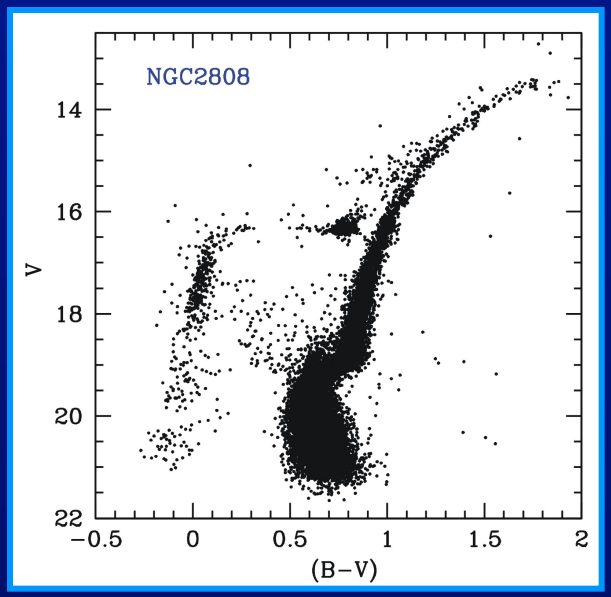
Simulating the photometric errors…

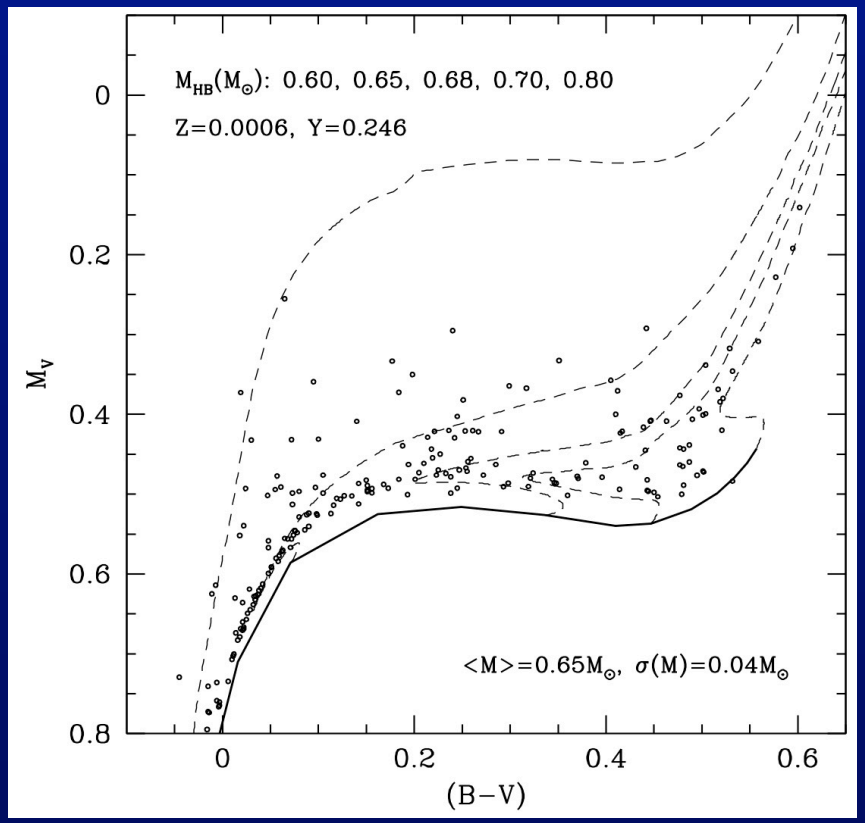
```
50000 10000
   0.0   00.0 2.35   5.50   0.0000 0.600 0.010 0.150
   9    0.0
 -4.000   0.001   0.001
 -3.000   0.006   0.008
 -2.000   0.008   0.011
 -1.000   0.010   0.014
  0.000   0.020   0.028
  2.000   0.025   0.035
  4.000   0.030   0.042
  5.000   0.040   0.056
  6.000   0.050   0.071
```



please remember the lecture by Monelli for a discussion on how to retrieve the "true" observational errors that have to be taken into account….

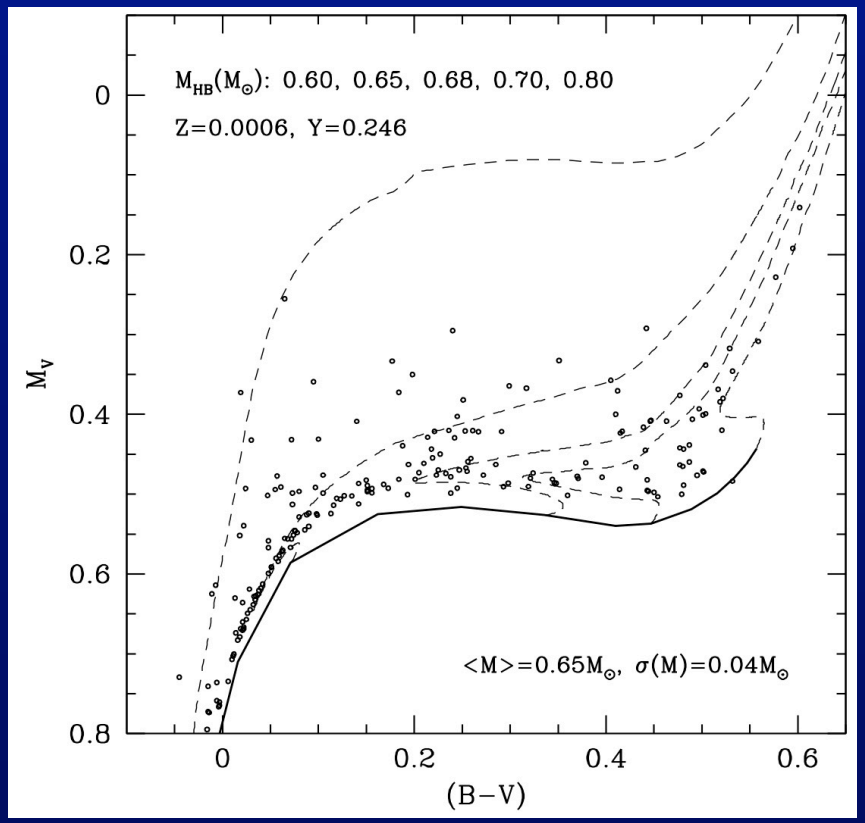
Simulating the HB stage…





Simulating the HB stage…

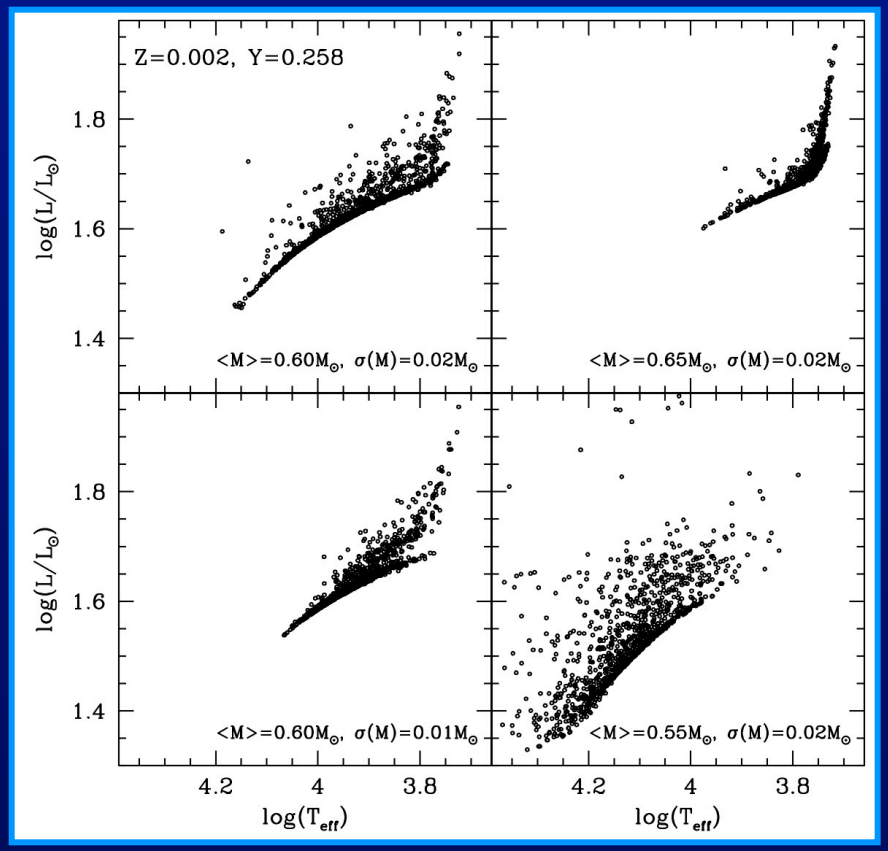
13	4	320 1190	7	35	900	7
0.5000		0050z203y248aes.nor_acs_hst				
0.5500		0055z203y248aes.nor_acs_hst				
0.6000		0060z203y248aes.nor_acs_hst				
0.7000		0070z203y248aes.nor_acs_hst				
0.7500		0075z203y248aes.nor_acs_hst				
0.8000		0080z203y248aes.nor_acs_hst				
0.9000		0090z203y248aes.nor_acs_hst				
1.0000		0100z203y248aes.nor_acs_hst				
1.1000		0110z203y248aes.nor_acs_hst				
1.2000		0120z203y248aes.nor_acs_hst				
1.3000		0130z203y248aes.nor_acs_hst				
1.4000		0140z203y248aes.nor_acs_hst				
1.5000		0150z203y248aes.nor_acs_hst				
0.4885		0488m08z203y248aes.nor_acs_hst				
0.4890		0489m08z203y248aes.nor_acs_hst				
0.4900		0490m08z203y248aes.nor_acs_hst				
0.4950		0495m08z203y248aes.nor_acs_hst				
0.5000		0500m08z203y248aes.nor_acs_hst				
0.5050		0505m08z203y248aes.nor_acs_hst				
0.5100		0510m08z203y248aes.nor_acs_hst				
0.5150		0515m08z203y248aes.nor_acs_hst				
0.5200		0520m08z203y248aes.nor_acs_hst				
0.5250		0525m08z203y248aes.nor_acs_hst				
0.5300		0530m08z203y248aes.nor_acs_hst				
0.5350		0535m08z203y248aes.nor_acs_hst				
0.5400		0540m08z203y248aes.nor_acs_hst				
0.5450		0545m08z203y248aes.nor_acs_hst				
0.5500		0550m08z203y248aes.nor_acs_hst				
0.5600		0560m08z203y248aes.nor_acs_hst				
0.5700		0570m08z203y248aes.nor_acs_hst				
0.5800		0580m08z203y248aes.nor_acs_hst				
0.5900		0590m08z203y248aes.nor_acs_hst				
0.6000		0600m08z203y248aes.nor_acs_hst				
0.6100		0610m08z203y248aes.nor_acs_hst				
0.6200		0620m08z203y248aes.nor_acs_hst				
0.6300		0630m08z203y248aes.nor_acs_hst				
0.6400		0640m08z203y248aes.nor_acs_hst				
0.6500		0650m08z203y248aes.nor_acs_hst				
0.6600		0660m08z203y248aes.nor_acs_hst				
0.6700		0670m08z203y248aes.nor_acs_hst				
0.6800		0680m08z203y248aes.nor_acs_hst				
0.6900		0690m08z203y248aes.nor_acs_hst				
0.7000		0700m08z203y248aes.nor_acs_hst				
0.7200		0720m08z203y248aes.nor_acs_hst				
0.7400		0740m08z203y248aes.nor_acs_hst				
0.7600		0760m08z203y248aes.nor_acs_hst				
0.7800		0780m08z203y248aes.nor_acs_hst				
0.8000		0800m08z203y248aes.nor_acs_hst				

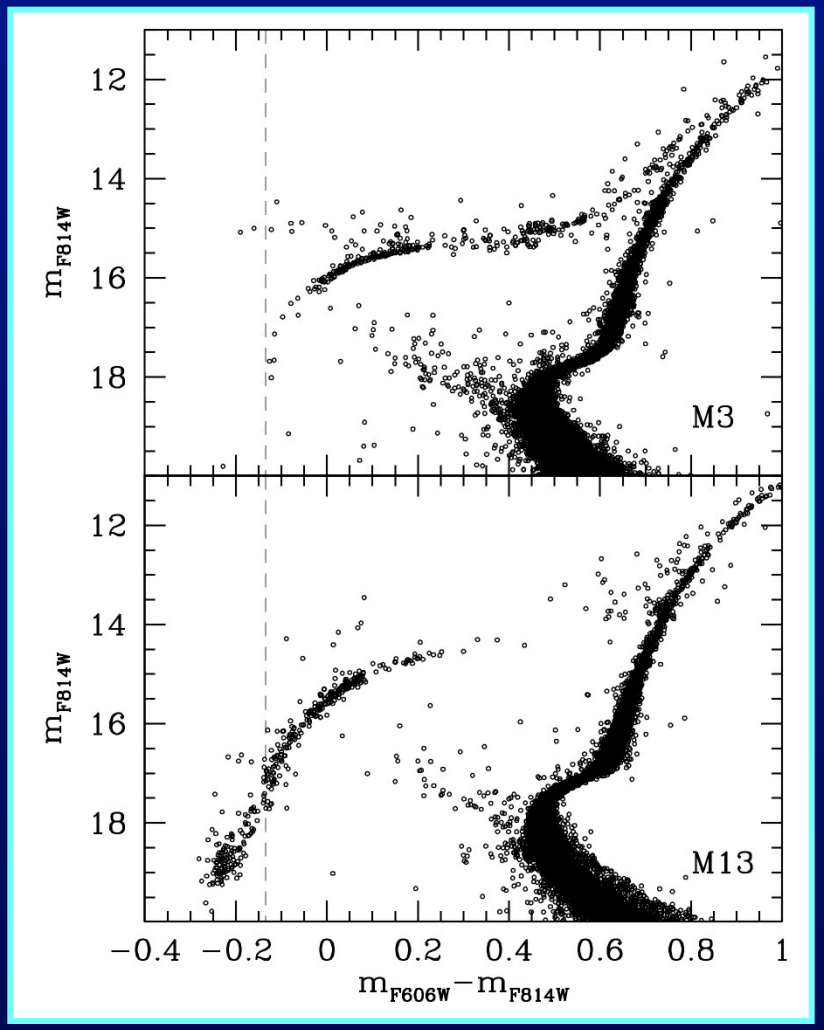


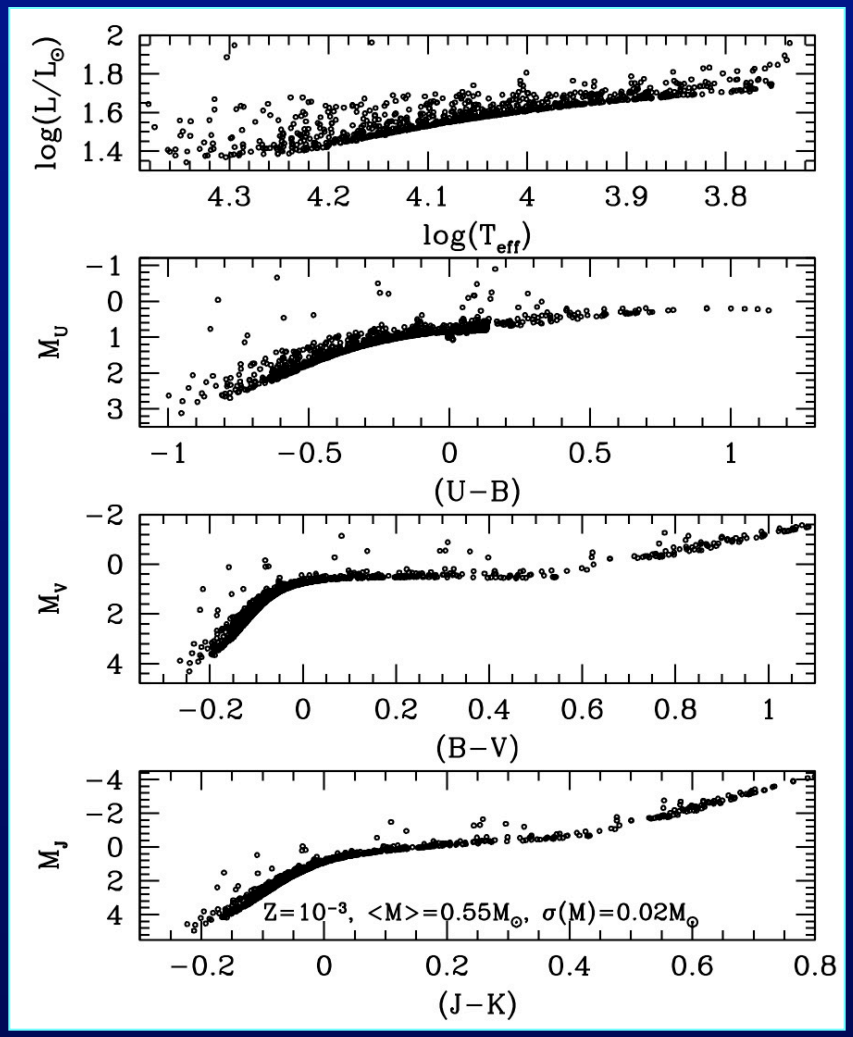
Average Mass on the HB: <M>

Mass dispersion along the HB: σ(M)

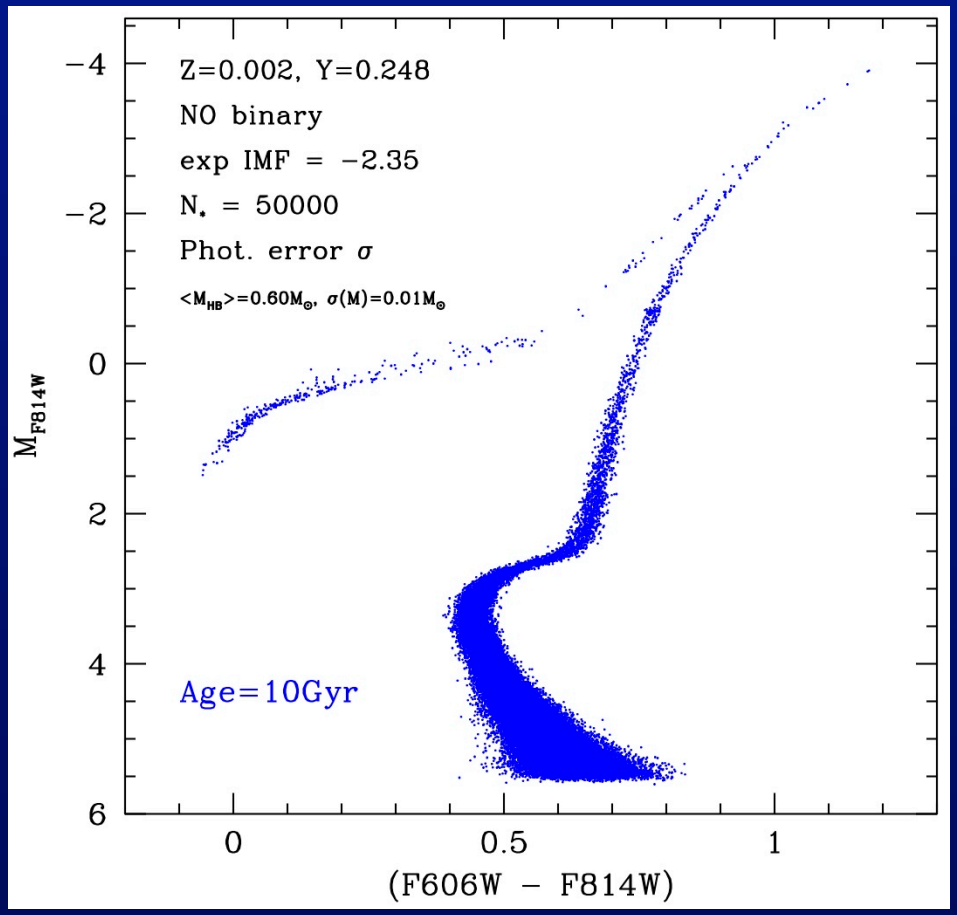
how do they affect the HB distribution?



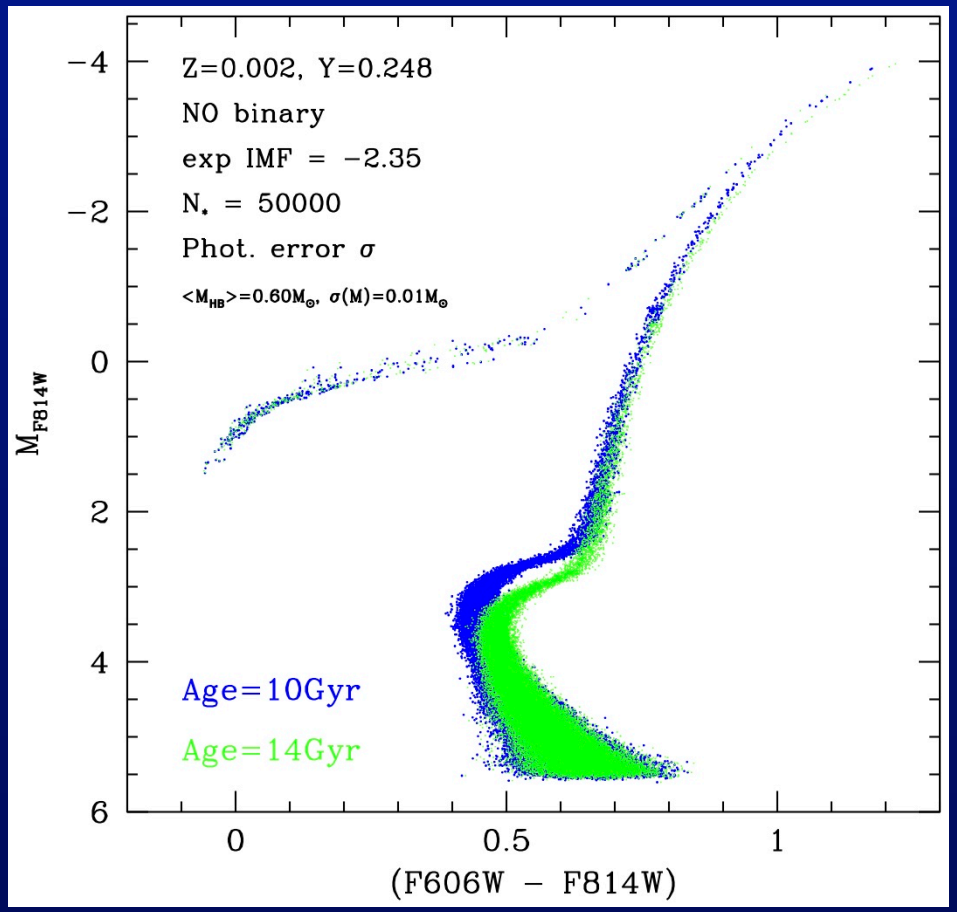


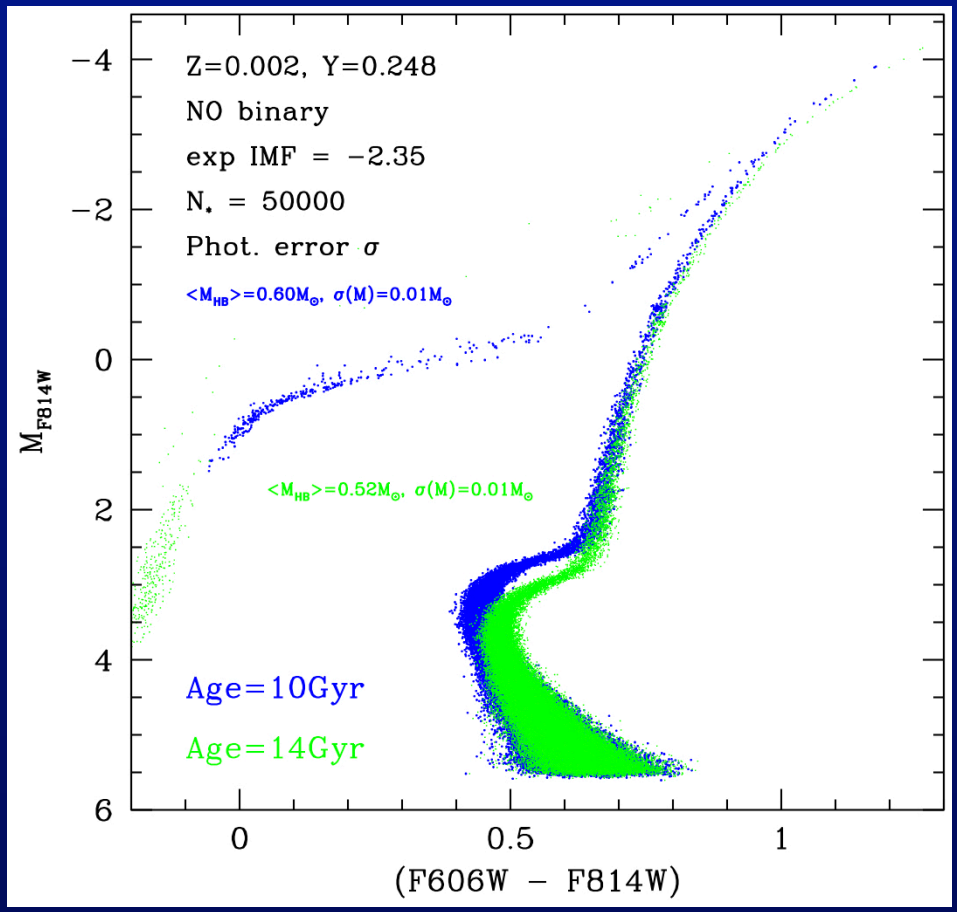

log(L/L⊙)
2
1.8
1.6
1.4
4.3
4.2
4.1
4
3.9
3.8
log(T_eff)
M_U
−1
0
1
2
3
−1
−0.5
0
0.5
1
(U−B)
M_V
−2
0
2
4
−0.2
0
0.2
0.4
0.6
0.8
1
(B−V)
M_J
−4
−2
0
2
4
Z=10⁻³, <M>=0.55M⊙, σ(M)=0.02M⊙
−0.2
0
0.2
0.4
0.6
0.8
(J−K)

The age effect

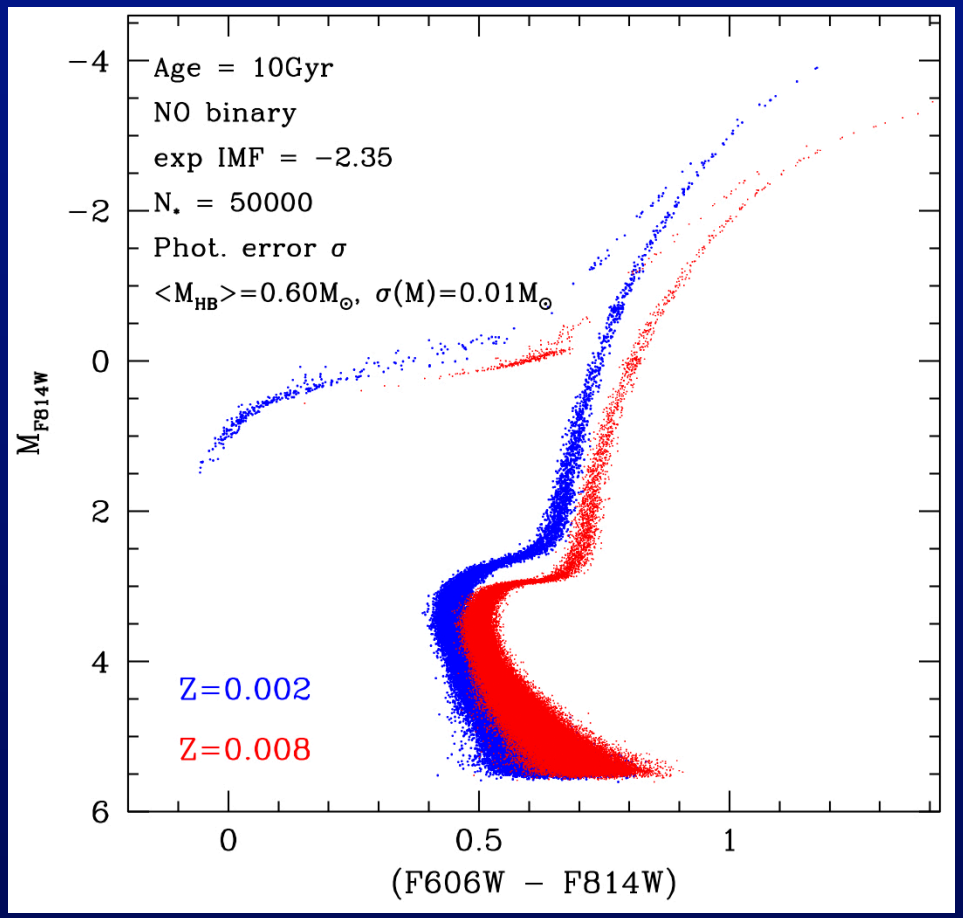


The age effect

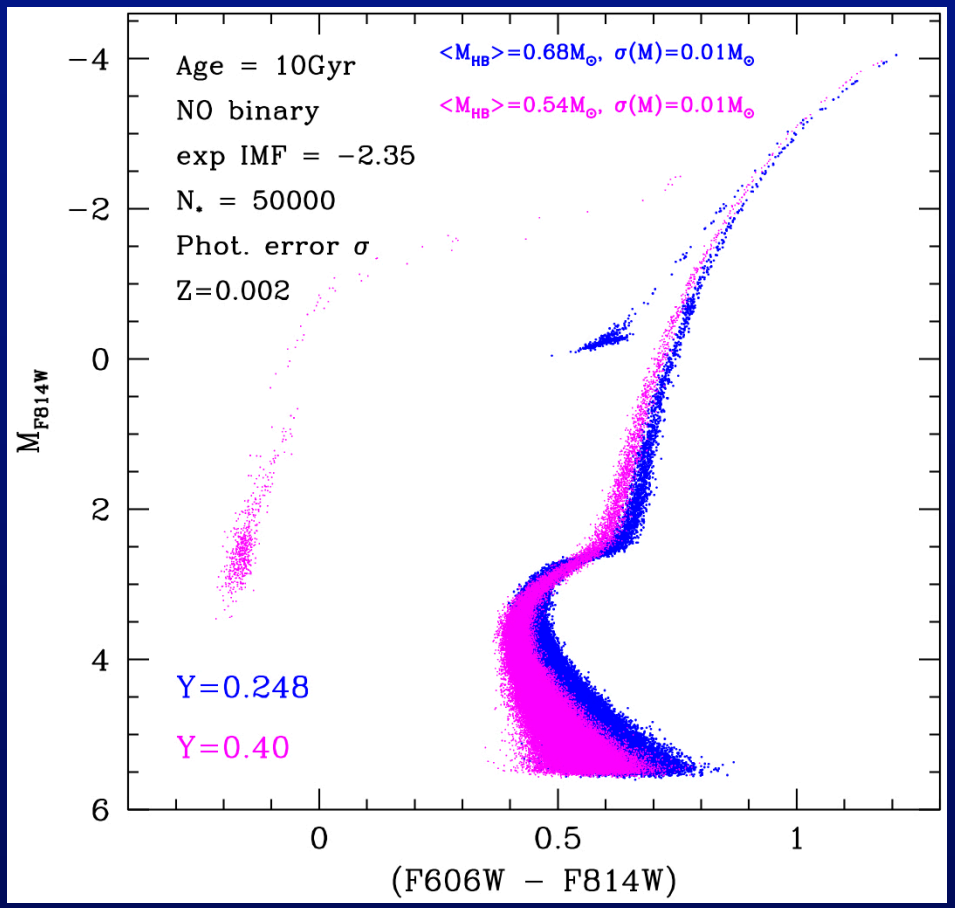




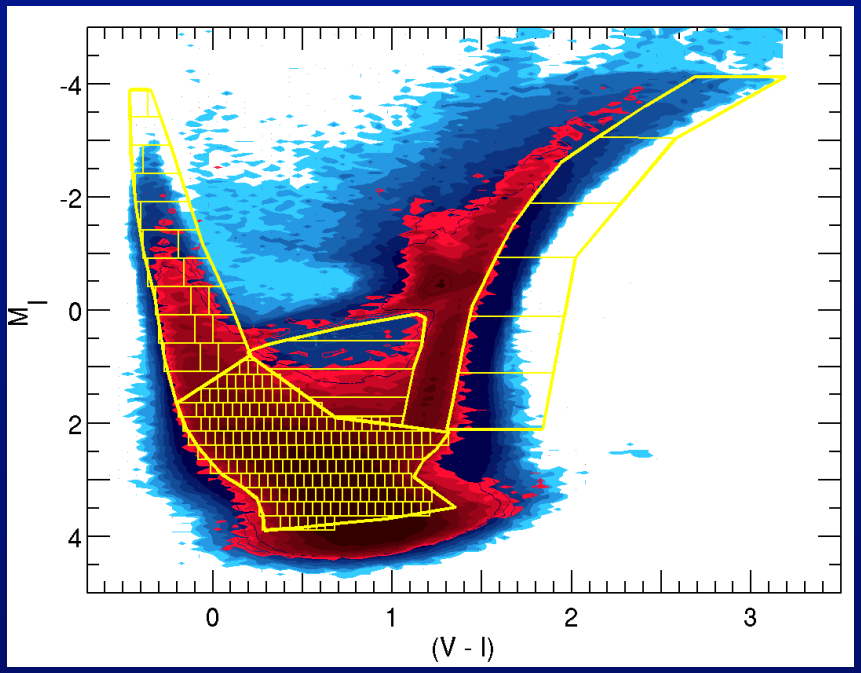
The chemical composition: metallicity effects

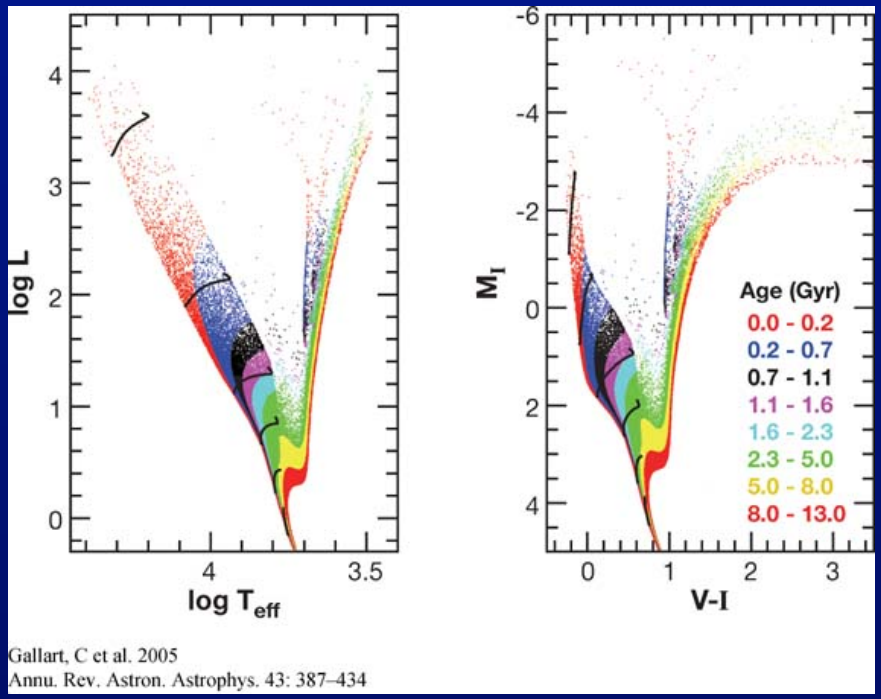


The chemical composition: Helium effects

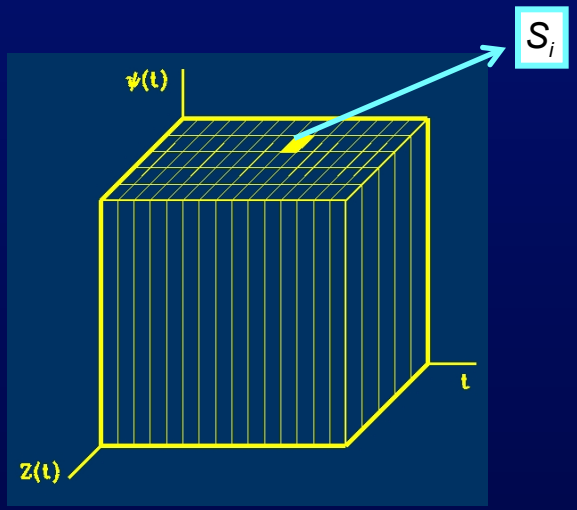


Playing with (synthetic) stars…

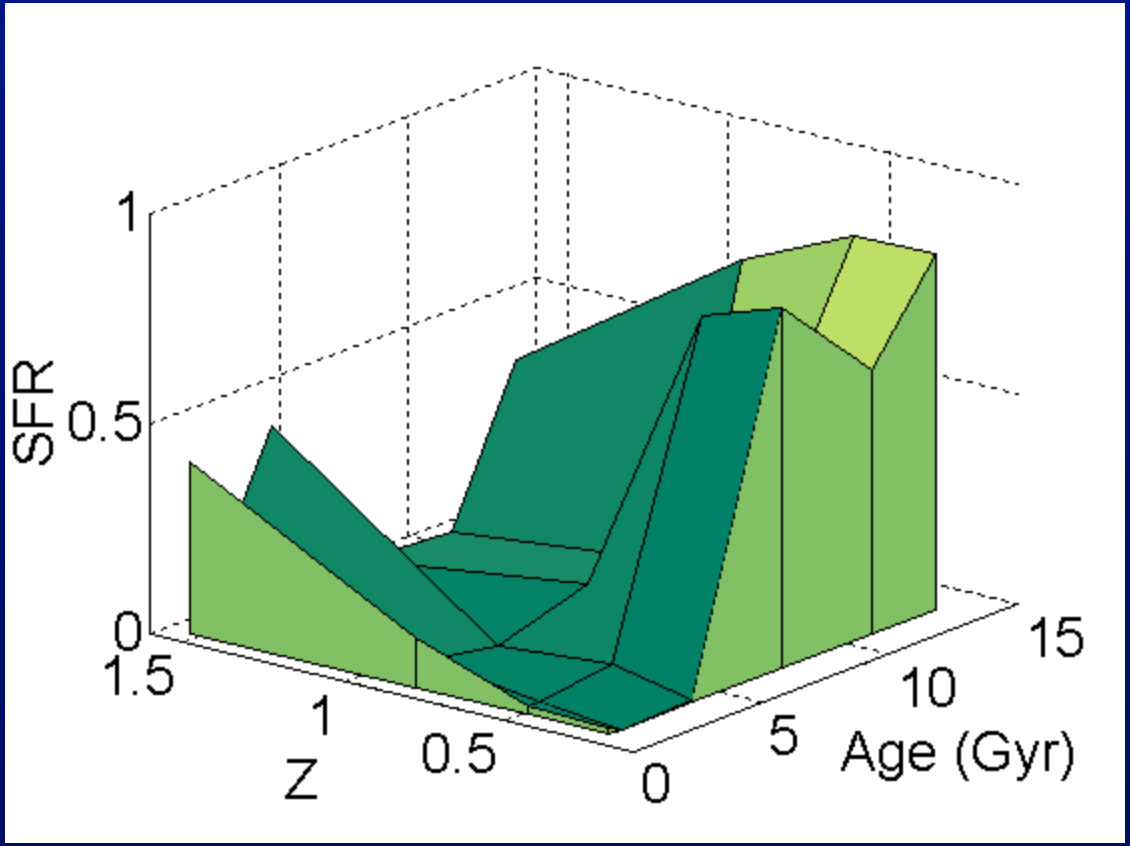




Gallart, C et al. 2005
Annu. Rev. Astron. Astrophys. 43: 387–434

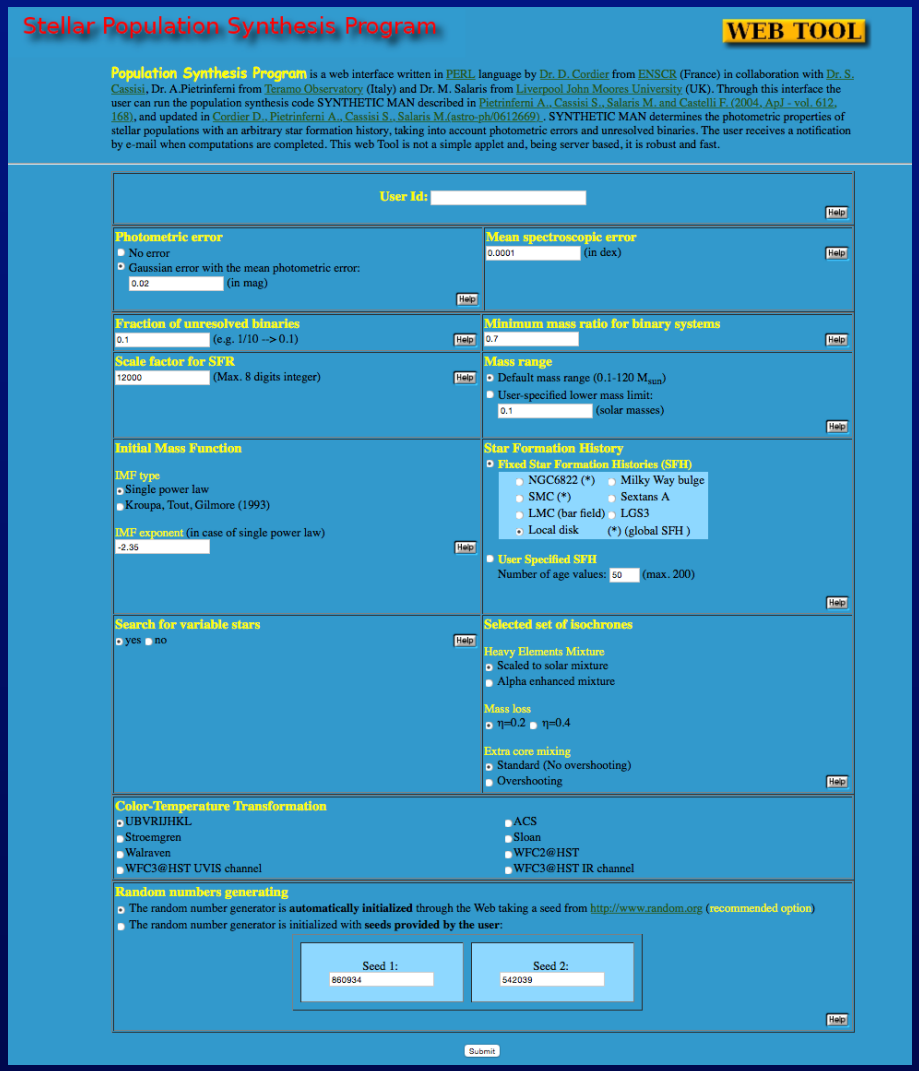


$$S(\psi, Z) = A \sum_i \alpha_i S_i$$


SFR
1
0.5
0
1.5
1
0.5
0
Z
5
10
15
Age (Gyr)

Synthetic CMD generator: BaSTI

http://193.204.1.62/BASTI/WEB_TOOLS/synth_pop2/



Stellar Population Synthesis Program

WEB TOOL

You have to choose your 4 age values, stellar formation rates, metallicity and metallicity spread. Please be careful when typing your data! After that click on the "submit" button at the bottom of this page, or type RETURN.

	Age (in years) (allowed range: 30 My to 14 Gy)	Star Formation Rate	The metallicity [Fe/H] (of the stars formed at that age)	The metallicity spread (Delta [Fe/H], in dex) at that age
1	12000000000	0.7000	-1.80	0.03
2	12000000000	0.0000	-1.90	0.03
3	3000000000	0.3000	-1.3	0.05
4	3000000000	0.0000	-1.3	0.05

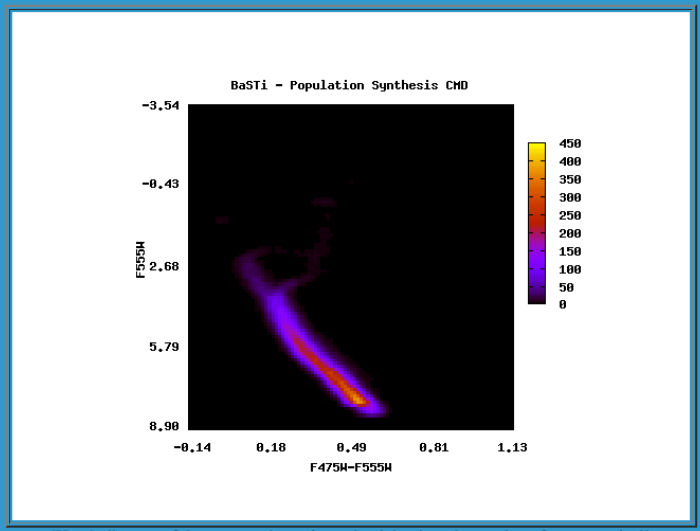
Submit

Stellar Population Synthesis Program

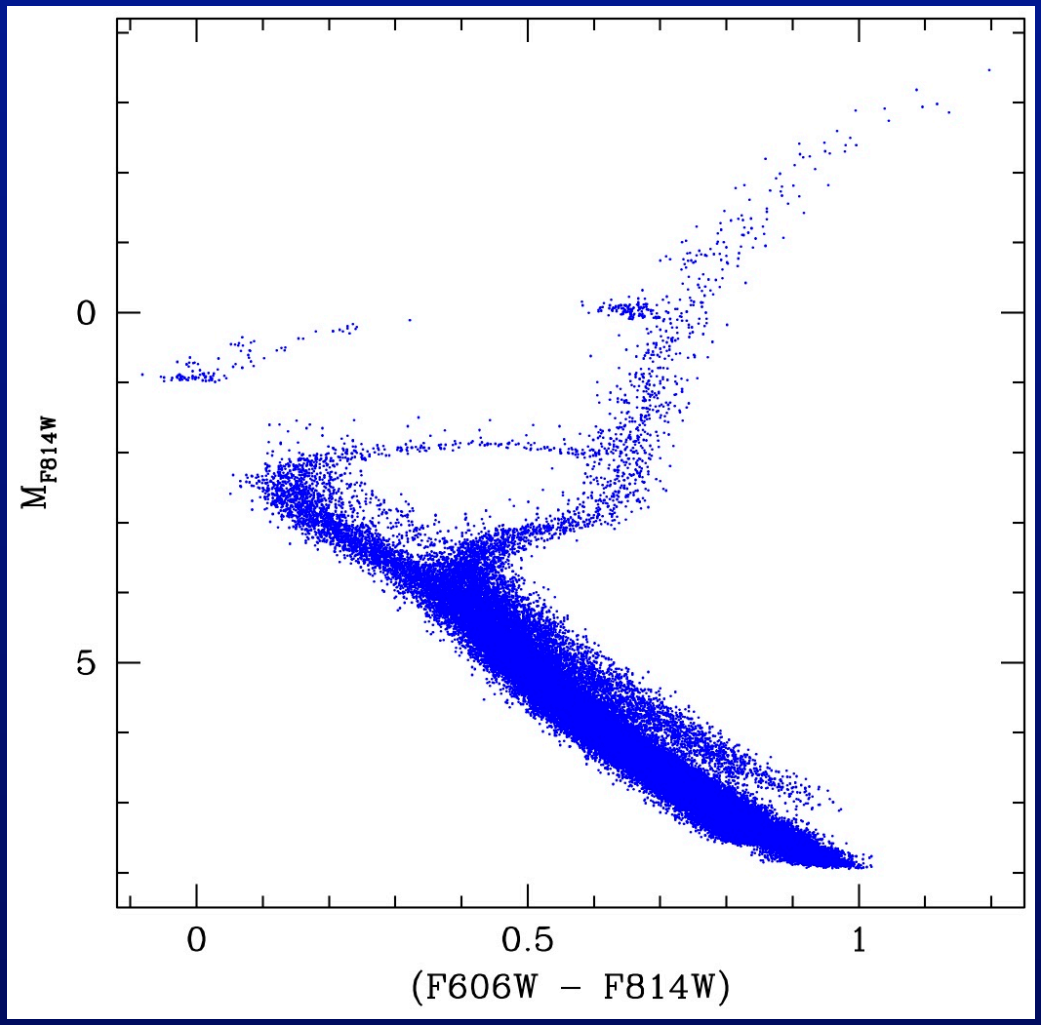
WEB TOOL

outputs "Synth_Pop__Sep_24_08.54.31_CEST_2015_" for cassisi--AT--oa-teramo.inaf.it:

- The parameters file: Synth_Pop__Sep_24_08.54.31_CEST_2015_user.in
- The Gzipped synthetic HRD file: Synth_Pop__Sep_24_08.54.31_CEST_2015_.HRD.gz **(size: 1.9MB)**
- The stellar formation history file used for this calculation: Synth_Pop__Sep_24_08.54.31_CEST_2015_.sfh
- The integrated colors file: Synth_Pop__Sep_24_08.54.31_CEST_2015_.INT_PROPERTIES



[Hess's diagram of the outputs, the scale on the right gives the number of stars per pixel]



if you want to perform your own game…
please ask for a user ID by sending an e_mail to:

cassisi@oa-teramo.inaf.it