

# Integrated Colors

As for distant Galaxies, we are able to observe integrated colors  $I(m)$  of star clusters. We are able to estimate the **age** and **total mass**.

Techniques:

1. “Aperture photometry” for distant star clusters
2. Sum up colors of members for resolved star clusters

$$I(m) = -2.5 \log \left[ \sum_i (10^{-0.4m_i}) \right]$$

Starting point are the dereddened colors and absolute magnitudes. For the dereddening, here are the relations from Lata et al. (2002, A&A, 388, 158) for the Johnson-Cousins UBVRI system:

$$E(U - B) = 0.72E(B - V) + 0.05E(B - V)^2$$

$$E(U - V) = 1.72E(B - V)$$

$$E(V - R) = 0.60E(B - V)$$

$$E(V - I) = 1.25E(B - V)$$

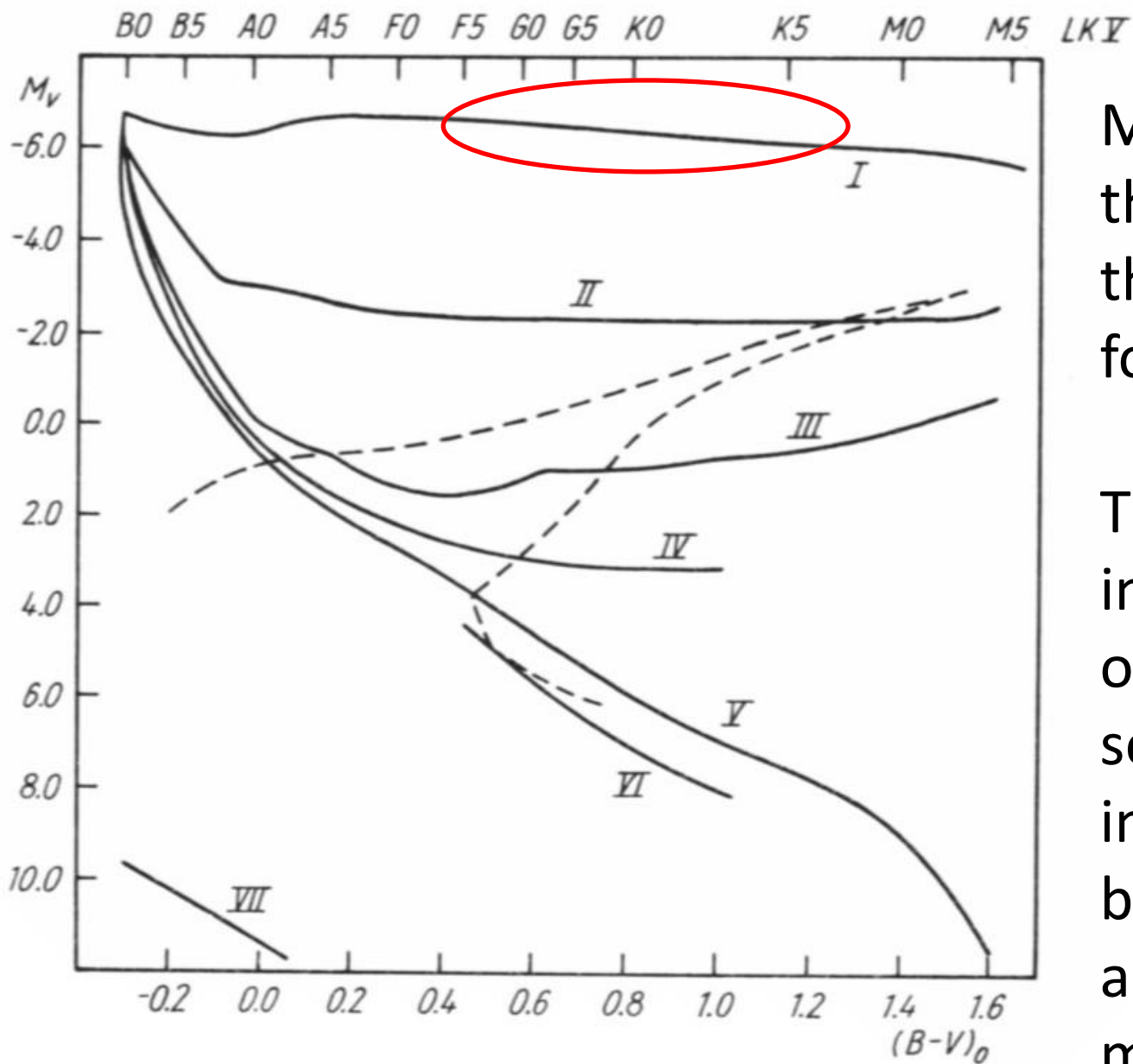
For the integrated colors we get:

$$I(B - V) = I(B) - I(V)$$

$$I(U - B) = I(U) - I(B)$$

$$I(V - R) = I(V) - I(R)$$

$$I(V - I) = I(V) - I(I)$$



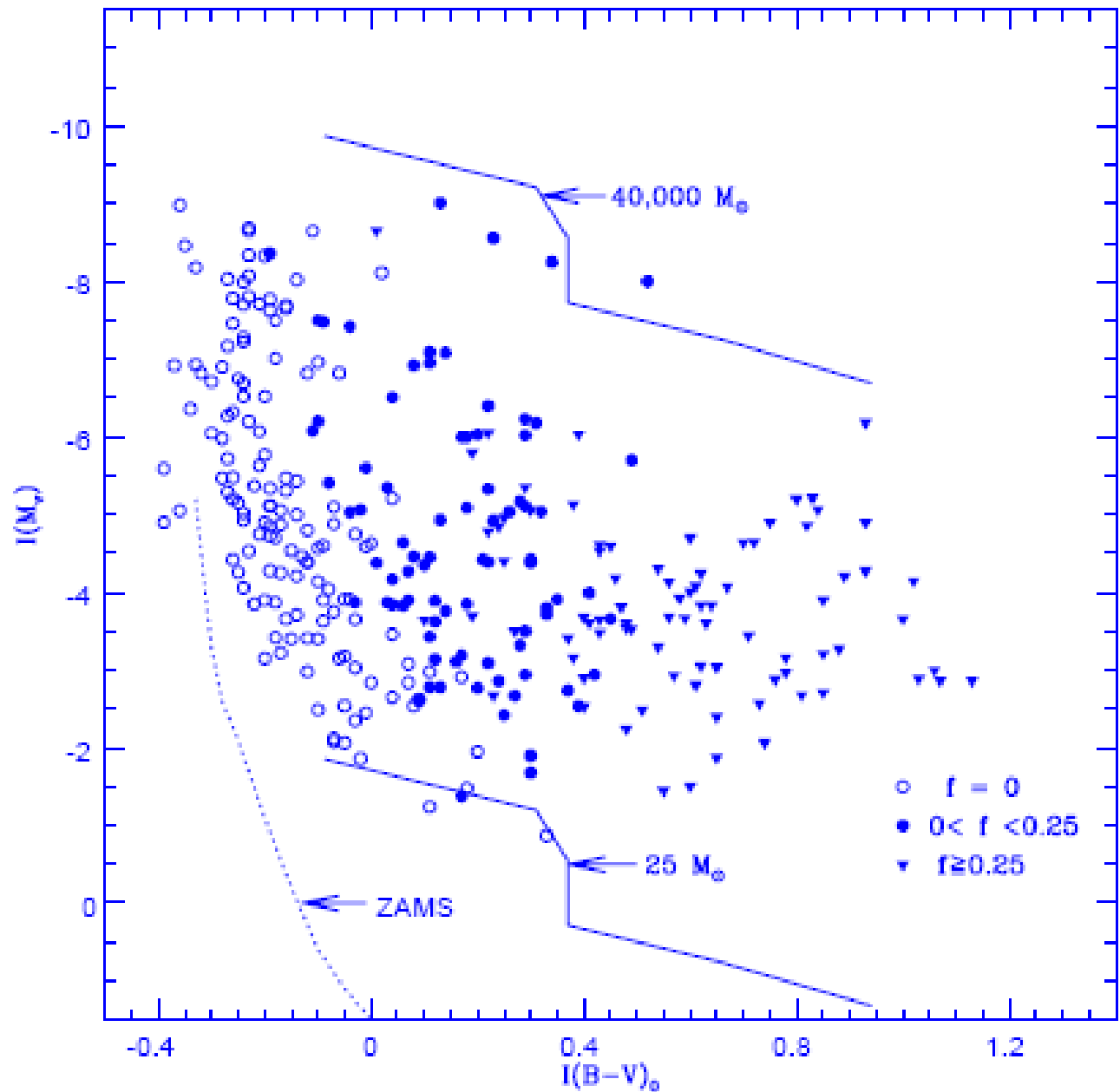
Most important is the knowledge of the membership for giants

The incompleteness of the lower main sequence is not important because of low absolute magnitudes

Clearly defined  
upper and lower  
mass limits

“Standard lines”  
for total masses  
from isochrones  
and population  
synthesis codes

González Delgado  
et al., 2005,  
MNRAS, 357,  
945



**Fig. 2.** The  $I(M_V)$ ,  $I(B-V)_0$  diagram.  $f$  is the fraction of red giants/supergiants in the open clusters.

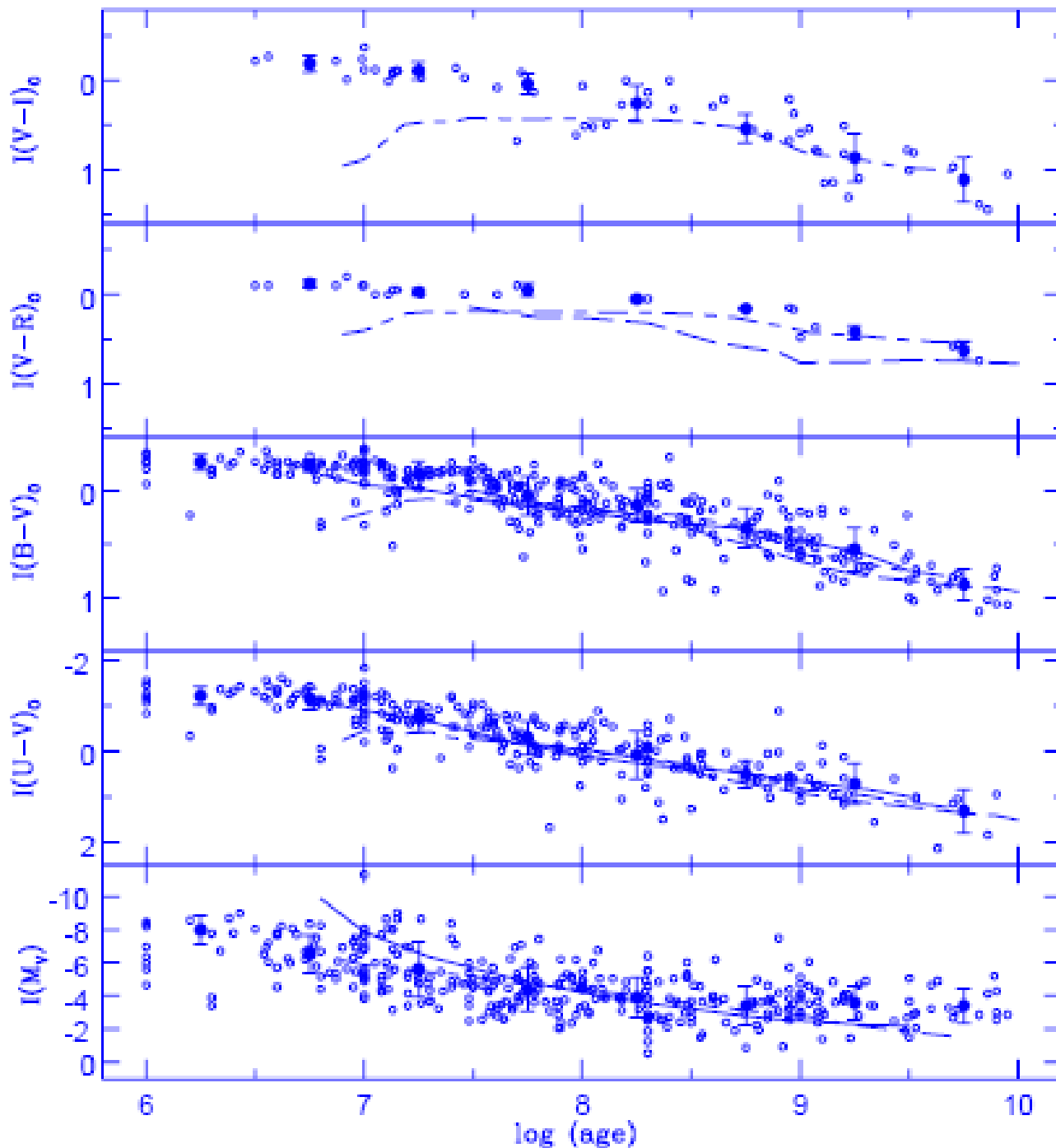
Relations for  
352 galactic open  
clusters

The age and  
reddening were  
taken from the  
literature

Errors given by Lata  
et al. (2002):

$\sigma(M_v) < 0.5$  mag

$\sigma(\text{colors}) < 0.2$  mag



Results from Lata et al. (2002, A&A, 388, 158), important are the **errors** for the determination of the uncertainties in log  $t$ :

$$I(M_V) = (1.20 \pm 0.08)(\log t) + (-14.12 \pm 0.66)$$

$$\text{with } \chi^2 = 2.017$$

$$I(U - V)_0 = (0.74 \pm 0.03)(\log t) + (-6.07 \pm 0.23)$$

$$\text{with } \chi^2 = 0.171$$

$$I(B - V)_0 = (0.31 \pm 0.01)(\log t) + (-2.36 \pm 0.09)$$

$$\text{with } \chi^2 = 0.037$$

$$I(V - R)_0 = (0.22 \pm 0.02)(\log t) + (-1.65 \pm 0.17)$$

$$\text{with } \chi^2 = 0.011$$

$$I(V - I)_0 = (0.44 \pm 0.03)(\log t) + (-3.25 \pm 0.25)$$

$$\text{with } \chi^2 = 0.048$$

where  $t$  is the age (in years) of the cluster.

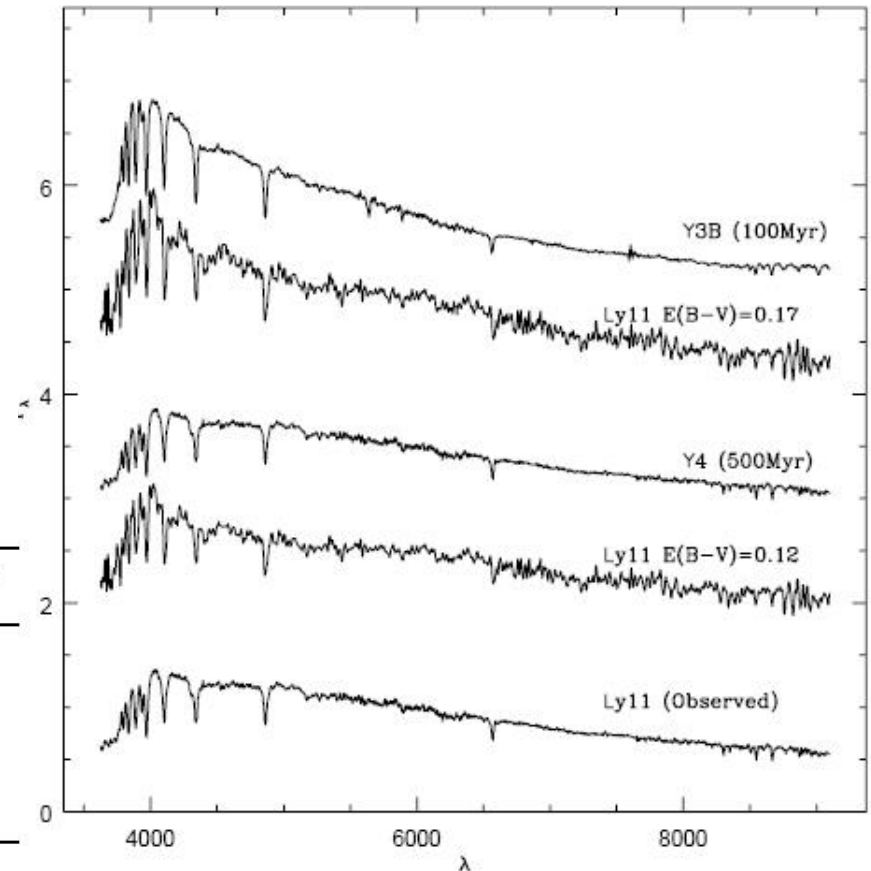
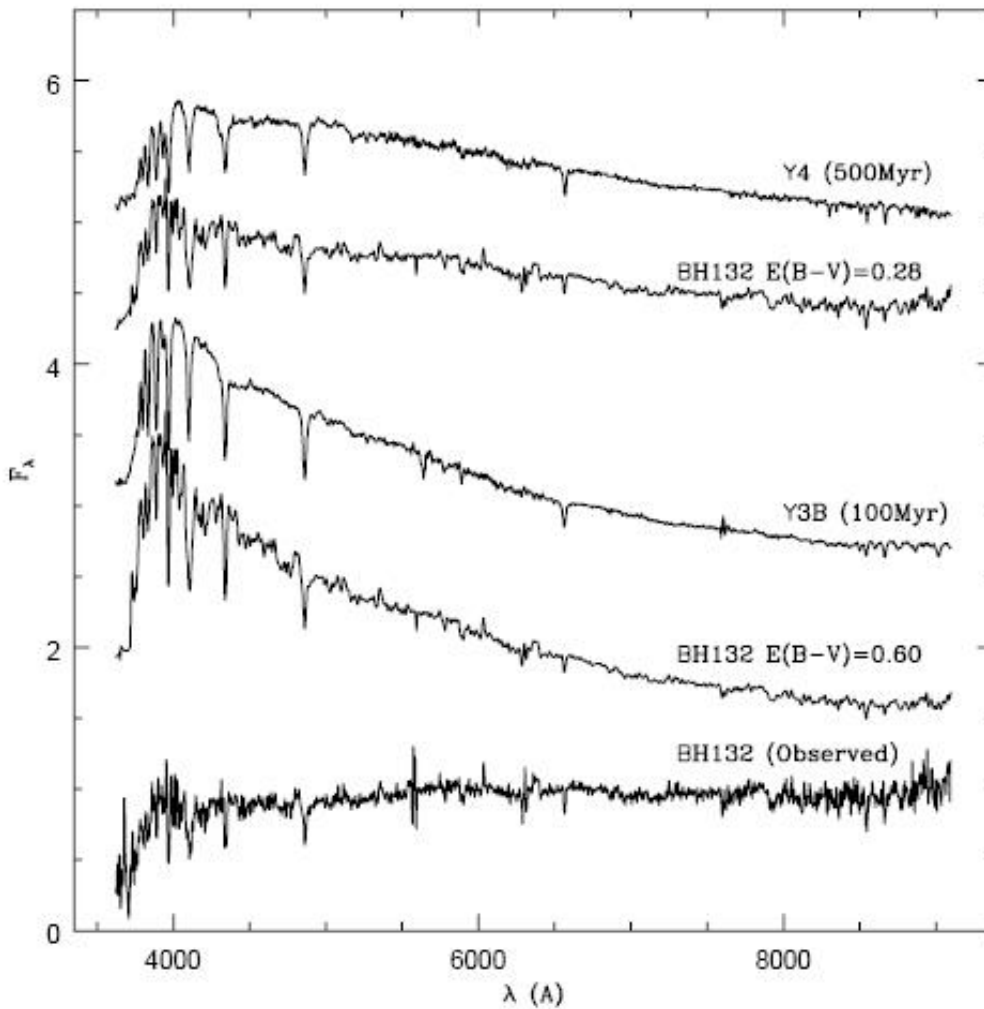
# Integrated spectra of Star Clusters

- Idea: clusters of different ages have different stellar content
- Example: old clusters ( $\log t > 100$  Myr) will not have any very hot (O and B) type stars any more as members because they have evolved
- Technique: slit spectrum over cluster => integrated spectrum of all members
- Assumption: slit covers a representative sample for the cluster

# Integrated spectra of Star Clusters

- How to get a standard library?
  1. Use isochrones together with IMF
  2. Let the cluster evolve
  3. Calculate an integrated spectrum of „what’s left“ in the cluster taking into account the luminosity of a star.
  4. Do this for a wide variety of ages and metallicities
- Library for Globular clusters:  
<https://www.noao.edu/ggclib/>

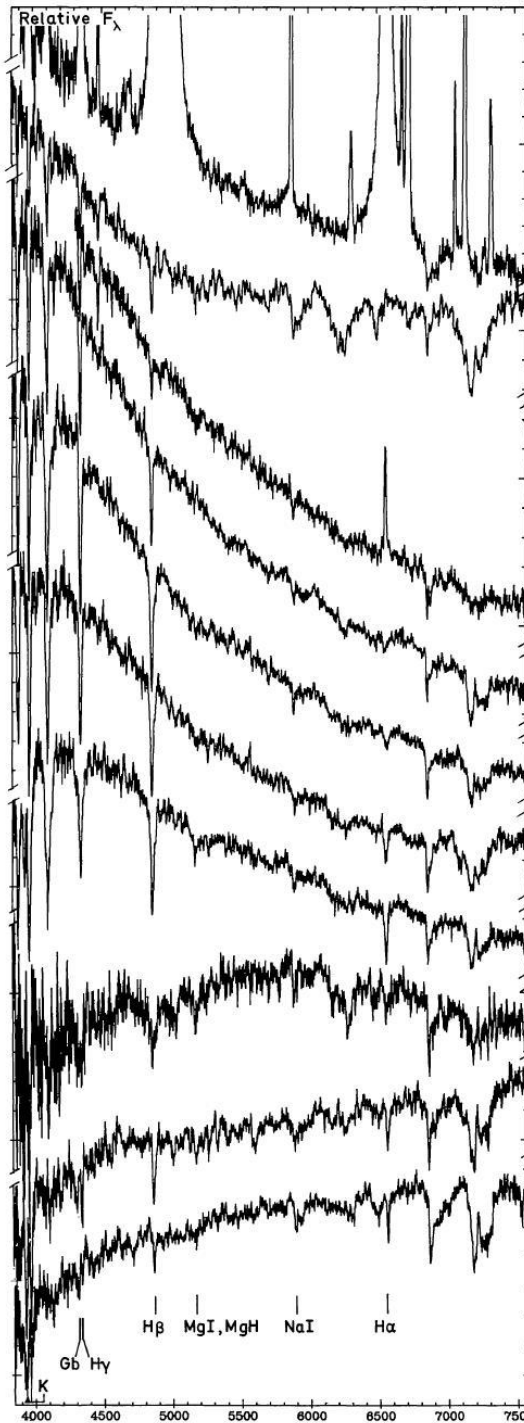
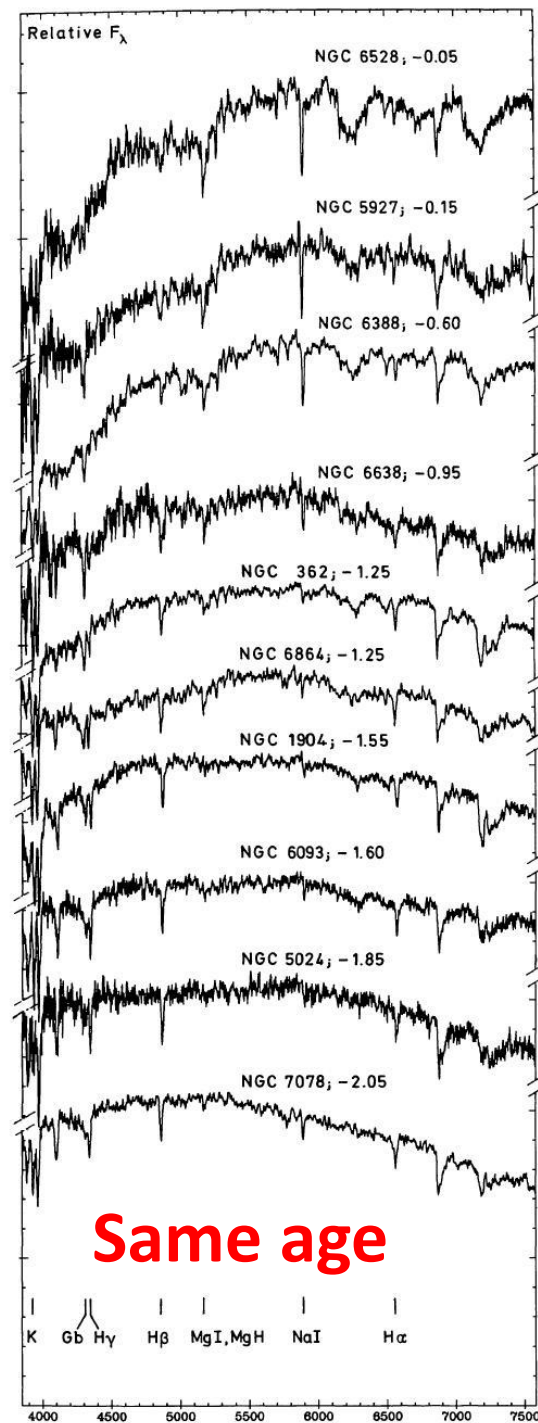




Cluster	$E(B - V)$	Age (Balmer) (Myr)	Age (template match) (Myr)	Adopted age (Myr)
Ruprecht 144	$0.32 \pm 0.02$	200	100	$150 \pm 50$
Melotte 105	$0.31 \pm 0.02$	300	100	$200 \pm 100$
BH 132	$0.60 \pm 0.05$	200	100	$150 \pm 50$
Hogg 15 <sup>a</sup>	$1.05 \pm 0.05$	30	3-6	$5 \pm 2$
Pismis 21	$1.50 \pm 0.03$	110	50	$80 \pm 30$
Lyngå 11	$0.12 \pm 0.03$	400	500	$450 \pm 50$
BH 217	$0.80 \pm 0.03$	20	50	$35 \pm 15$

# Integrated spectra

Z



Age

