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

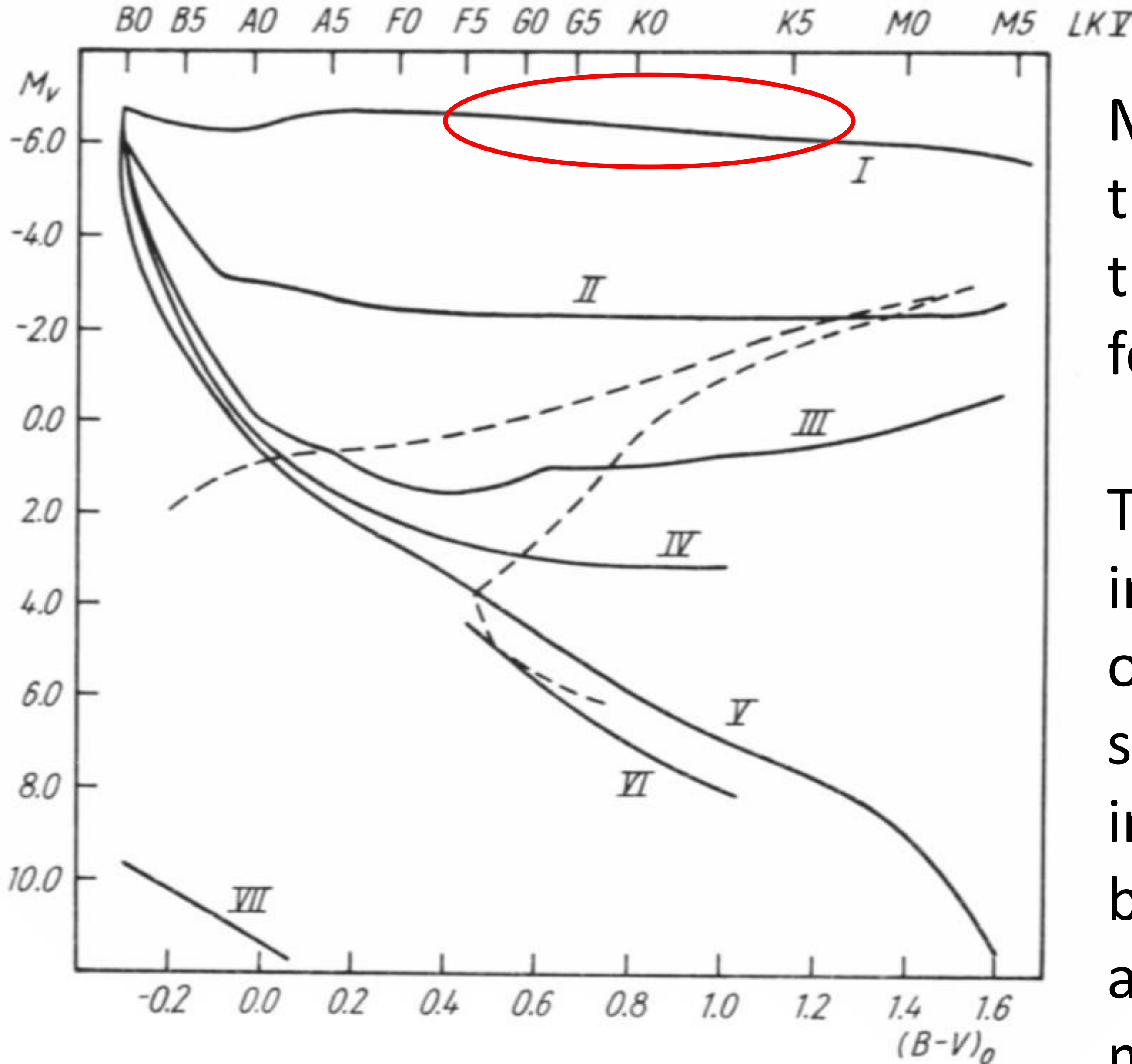
$$I(m) = -2.5 \ \log \left[\sum_i (10^{-0.4 m_i}) \right]$$

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

Lata et al., 2002, A&A, 388, 158

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

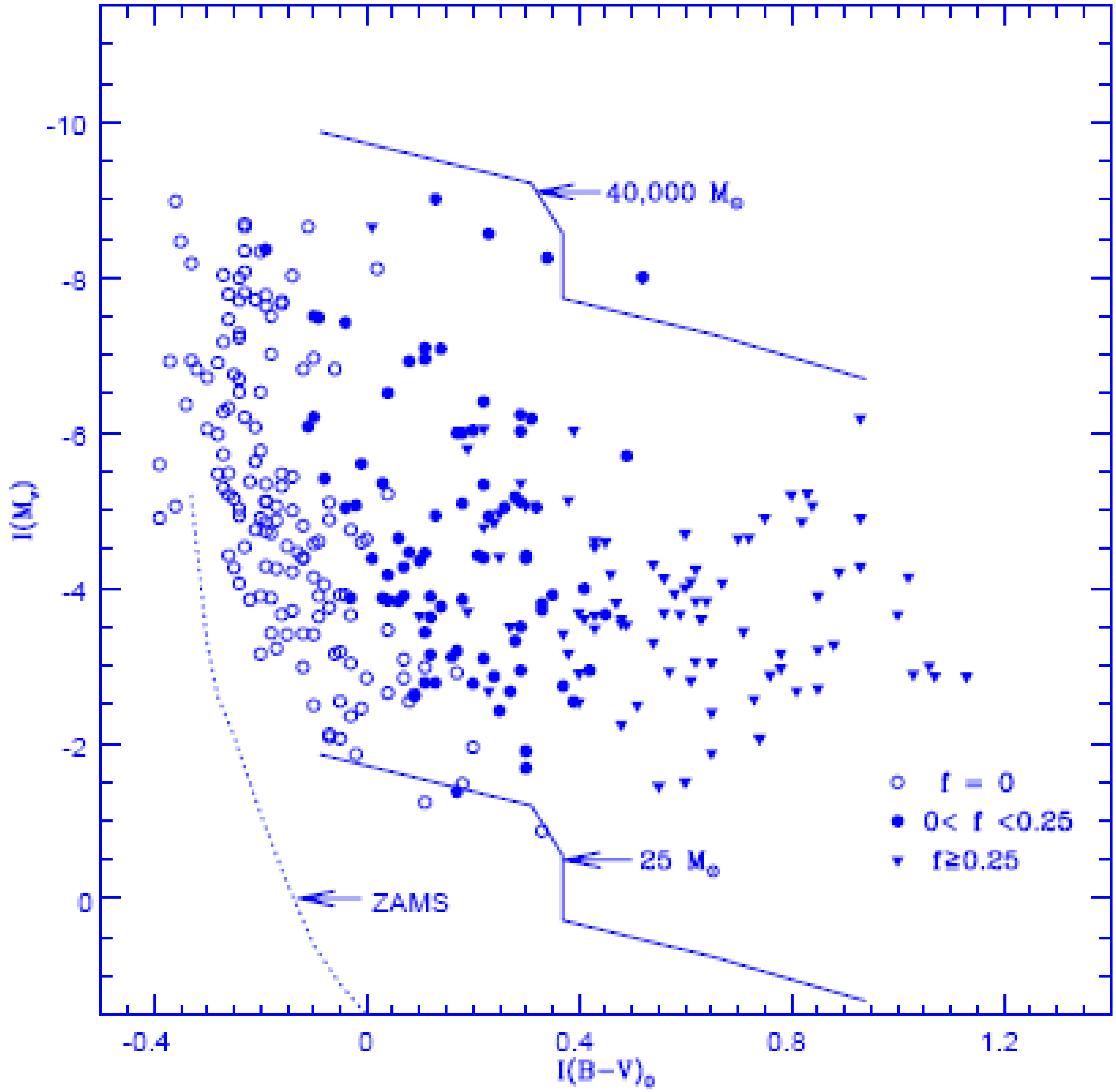


Fig. 2. The $I(M_V)$, $I(B-V)_0$ diagram. f is the fraction of red giants/supergiants in the open clusters.

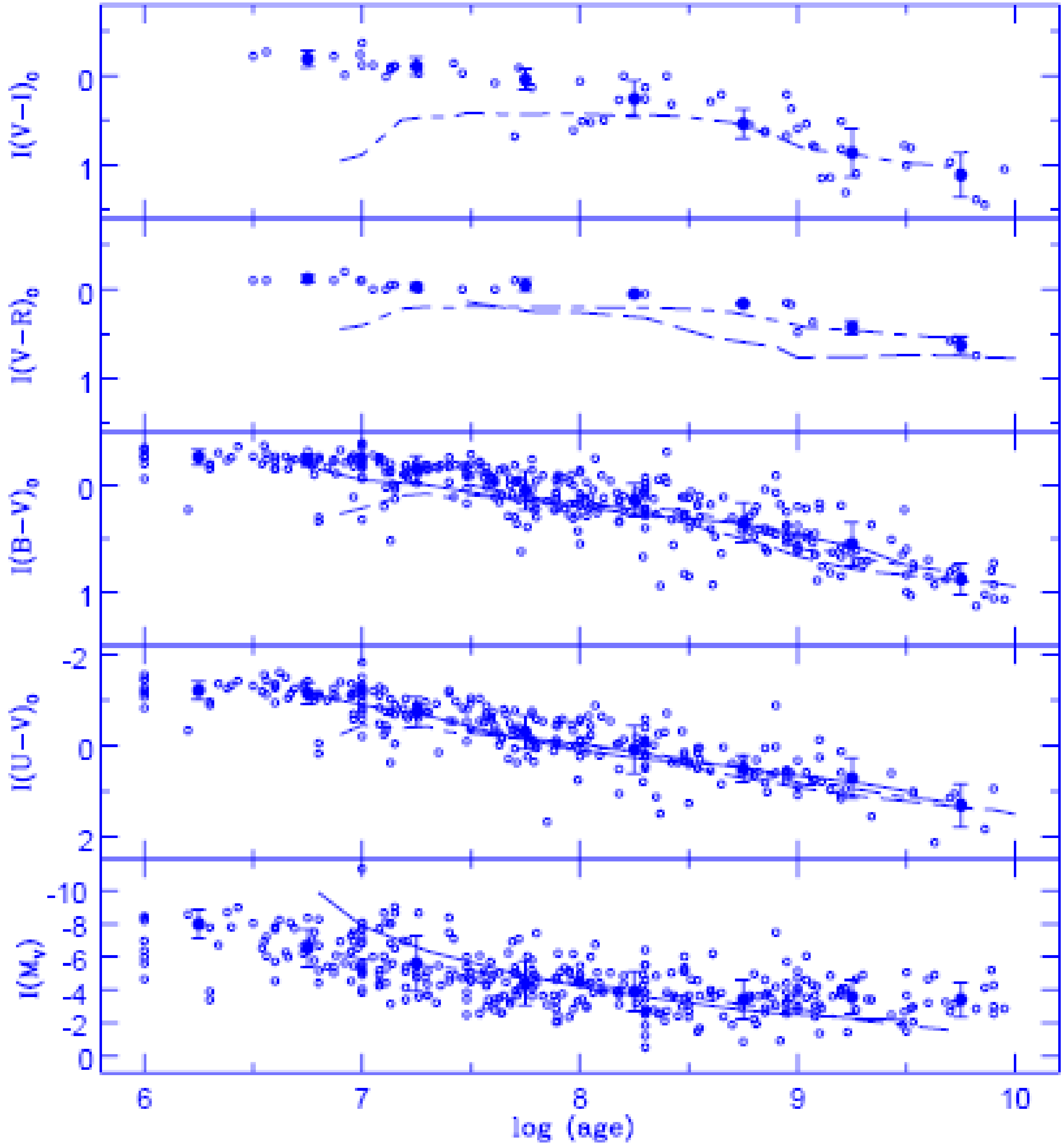
Lata et al., 2002, A&A, 388, 158

Relations for 352 galactic open clusters

The age and reddening were taken from the literature

Errors given by Lata et al. (2002):

$\sigma I(M_V) < 0.5$ mag
$\sigma I(\text{colors}) < 0.2$ mag



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

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

with $\chi^2 = 2.017$

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

with $\chi^2 = 0.171$

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

with $\chi^2 = 0.037$

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

with $\chi^2 = 0.011$

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

with $\chi^2 = 0.048$

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

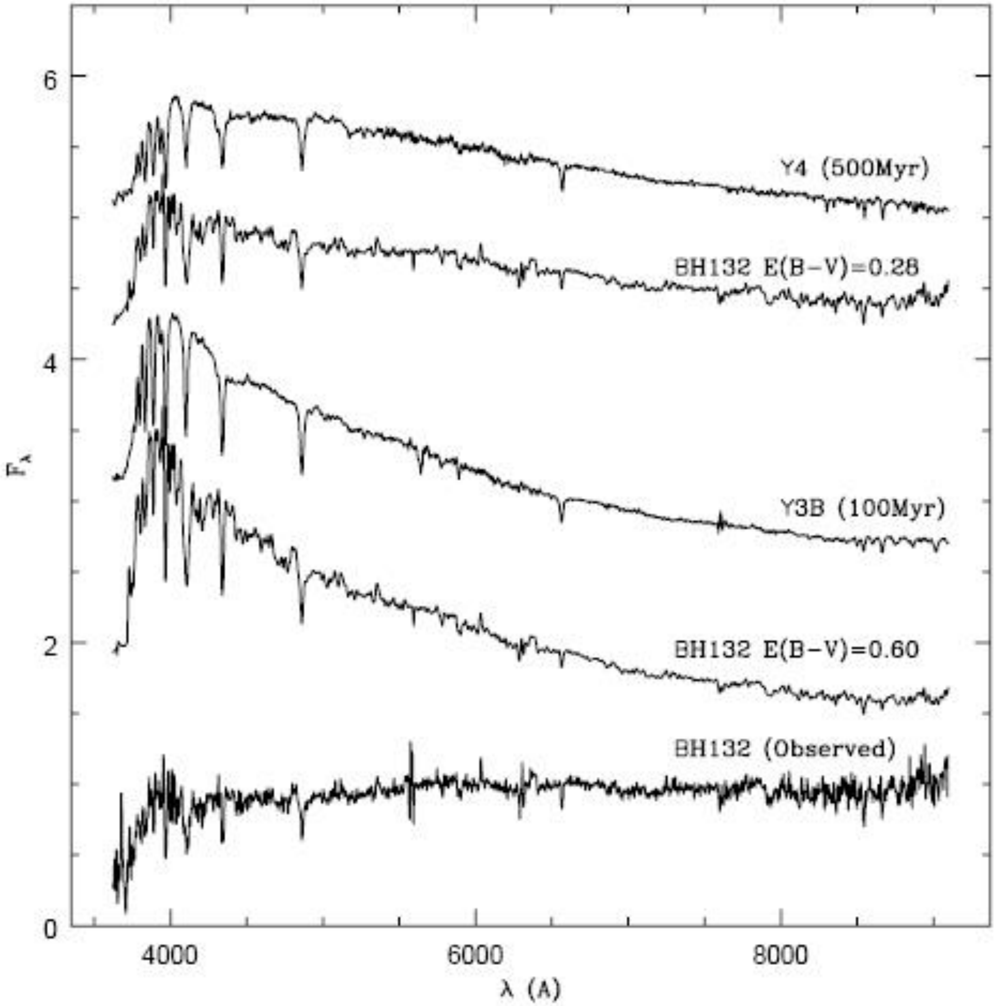
Integrated spectra of Star Clusters

- 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

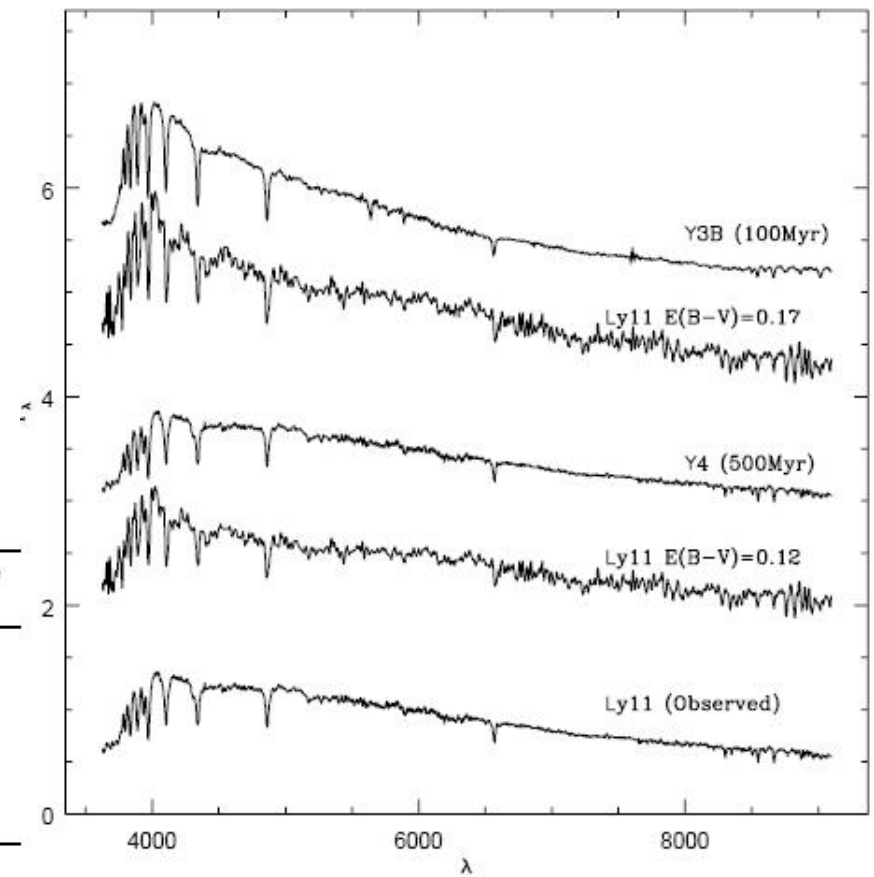
Integrated spectra of Star Clusters

- 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/

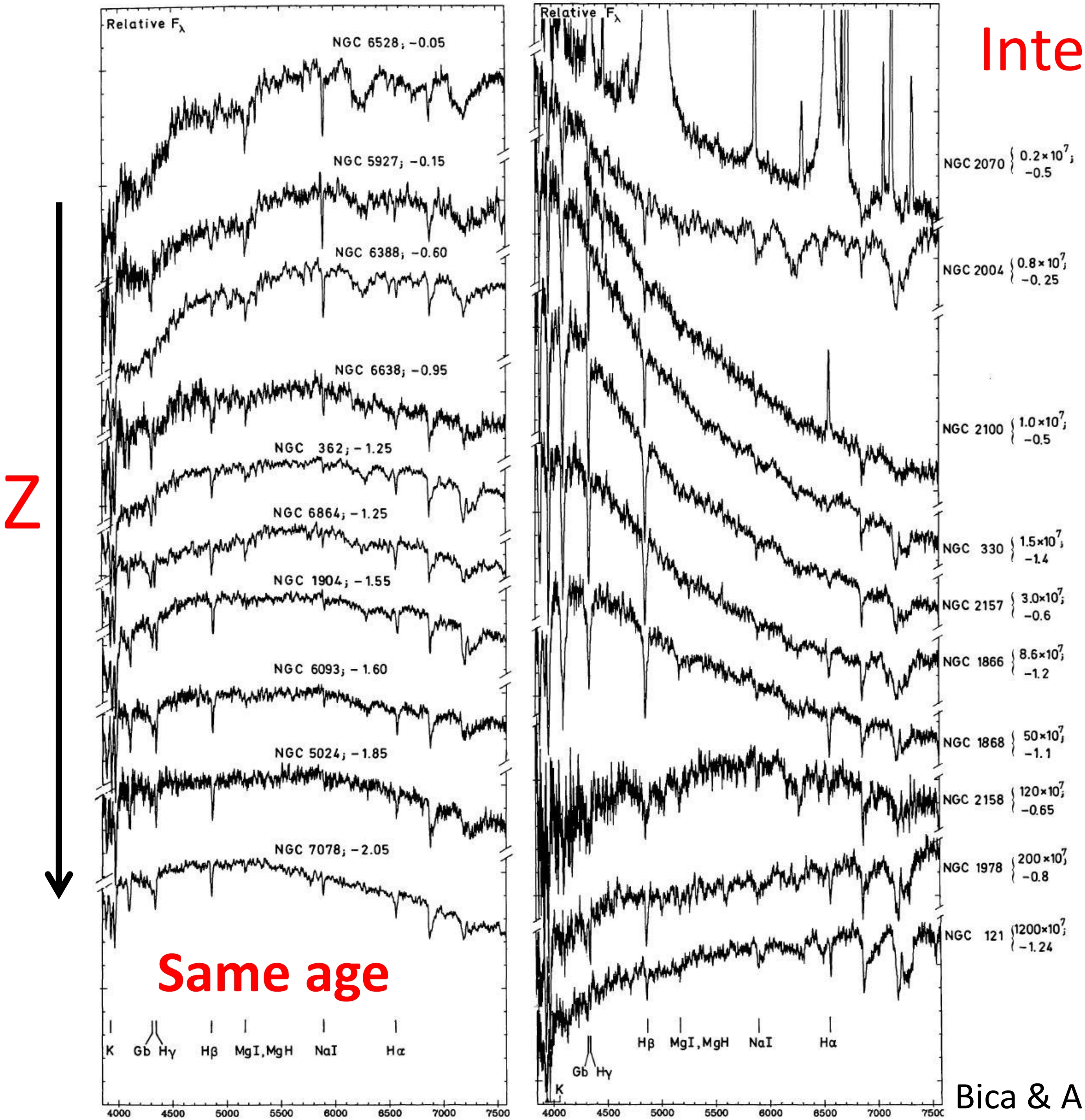
Ahumada et al., 2000, A&AS, 141, 79



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

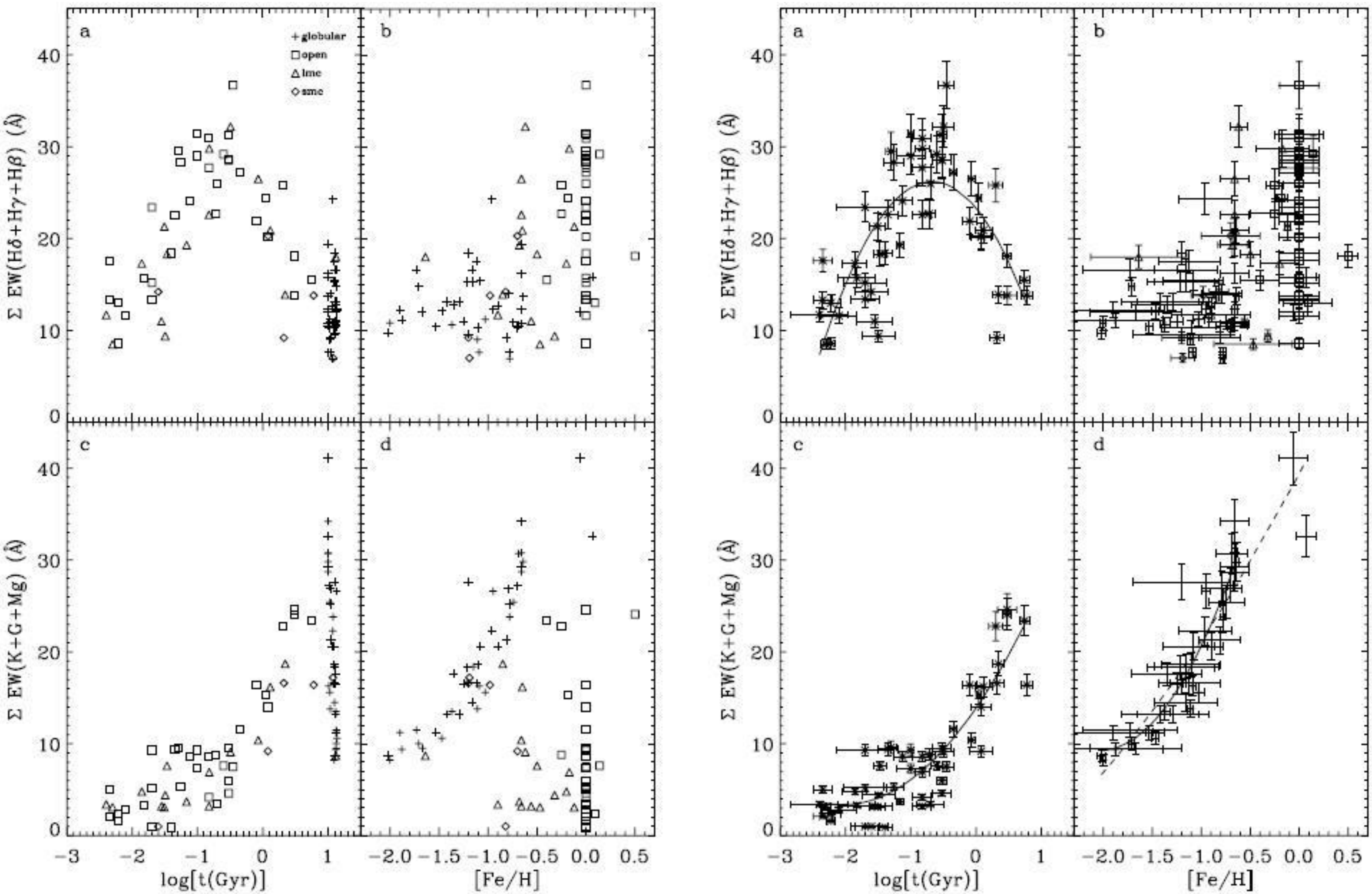


Integrated spectra



Age

Bica & Alloin, 1986, A&A, 162, 21



Santos & Piatti, 2004, A&A, 428, 79