The new estimates of the IMF in compact stellar systems

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A new method for new estimates

- We developed a new technique for the determination of the low-mass slope (α_1; $M_* < 0.5M_\odot$) of the present day stellar mass function (PDMF) using the pixel space fitting of integrated light spectra

- This technique can be used to constrain the IMF of stellar systems with relaxation timescales exceeding the Hubble time (e.g., globular clusters where a mass segregation have not yet finished)

An extension of NBURSTS

- Our technique was developed as an extension of the NBURSTS package (Chilingarian et al. 2007a,b) -- an approach to determine the parametrized line of-sight velocity distribution (LOSVD) and star formation history (SFH) of unresolved stellar populations by means of the full spectral fitting in the pixel space.

- Previously the NBURSTS technique was mostly used with simple stellar population (SSP) models (PEGASE.HR, Prugniel et al., 2007) characterized by only two parameters, age and metallicity of the instantaneous starburst event computed for a pre-defined IMF shape.

- We added an extra dimension to the grid of SSP models by varying the low-mass end slope α_1 of the Kroupa canonical IMF (Kroupa 2002) leaving the slope above $0.5M_\odot$ fixed ($\alpha_2 = 2.3$).

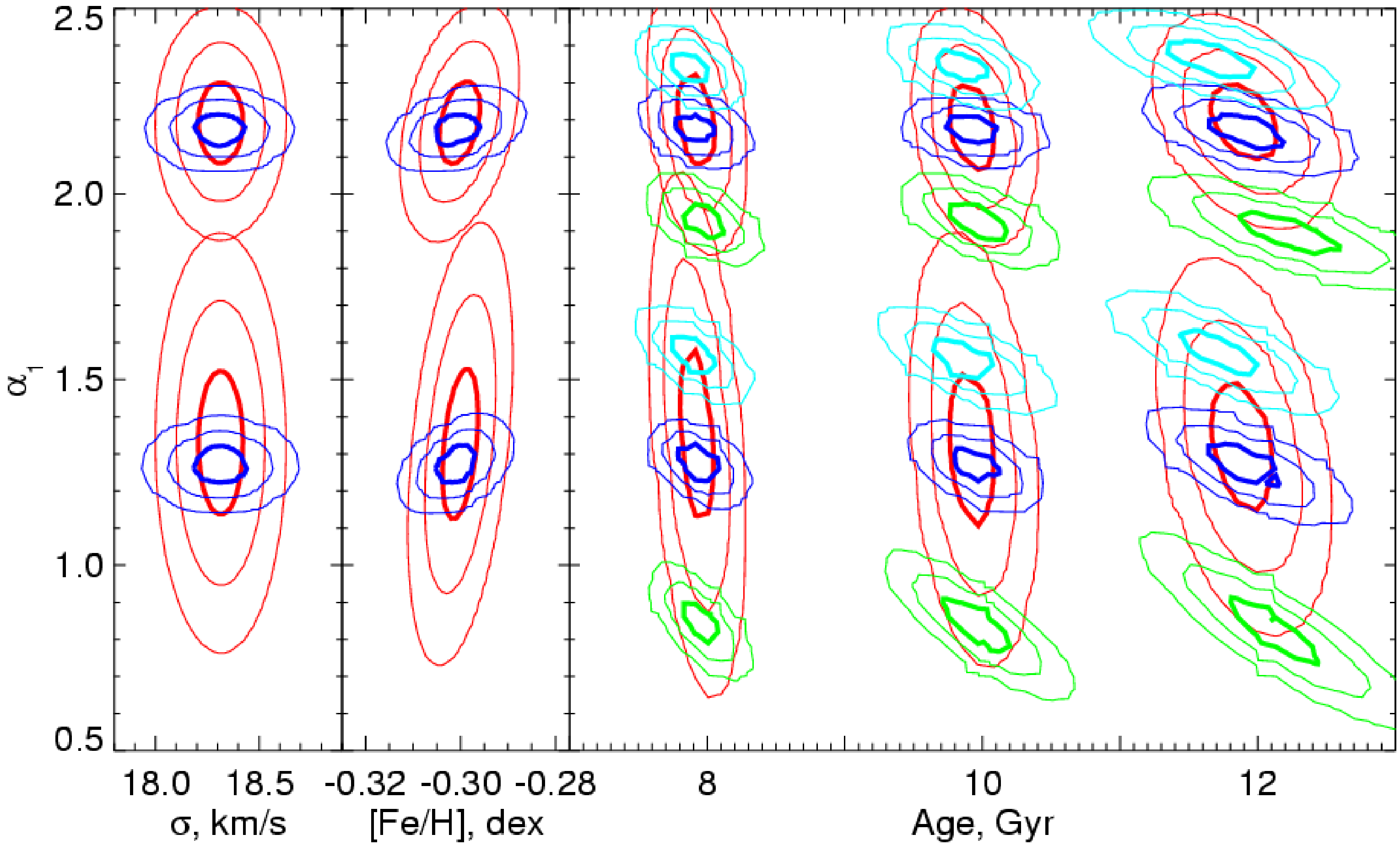
An extension of NBURST

We provide two versions of the technique:

(1) a fully unconstrained determination of the age, metallicity and α_1

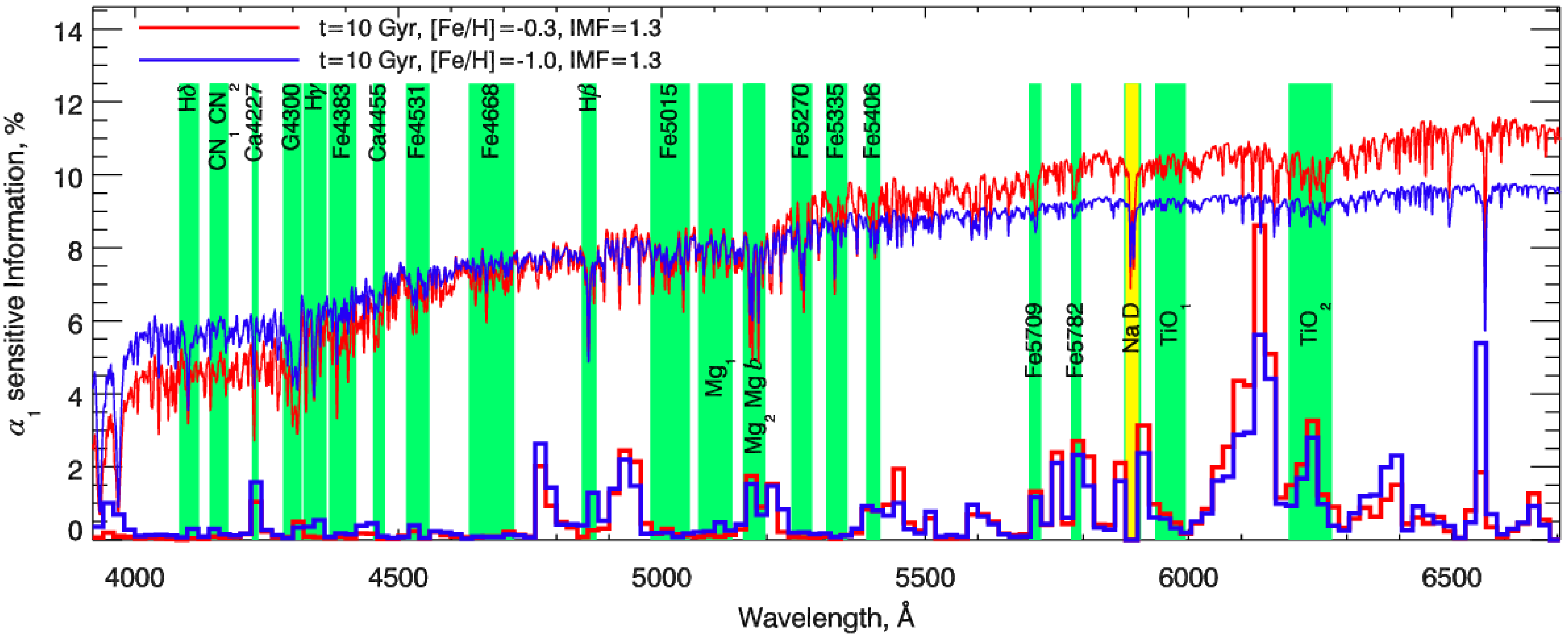
(2) a constrained fitting by imposing the externally determined mass-to-light ratio (M/L) of the stellar population.

Monte-Carlo simulation



(a) age, metallicity and α_1 can be precisely determined by applying the unconstrained version of the code to high signal-to-noise datasets (S/N=100, R = 7000 yield α_1~0.1);
(b) the M/L constraint significantly improves the precision and reduces the degeneracies, however its systematic errors will cause biased α_1 estimates

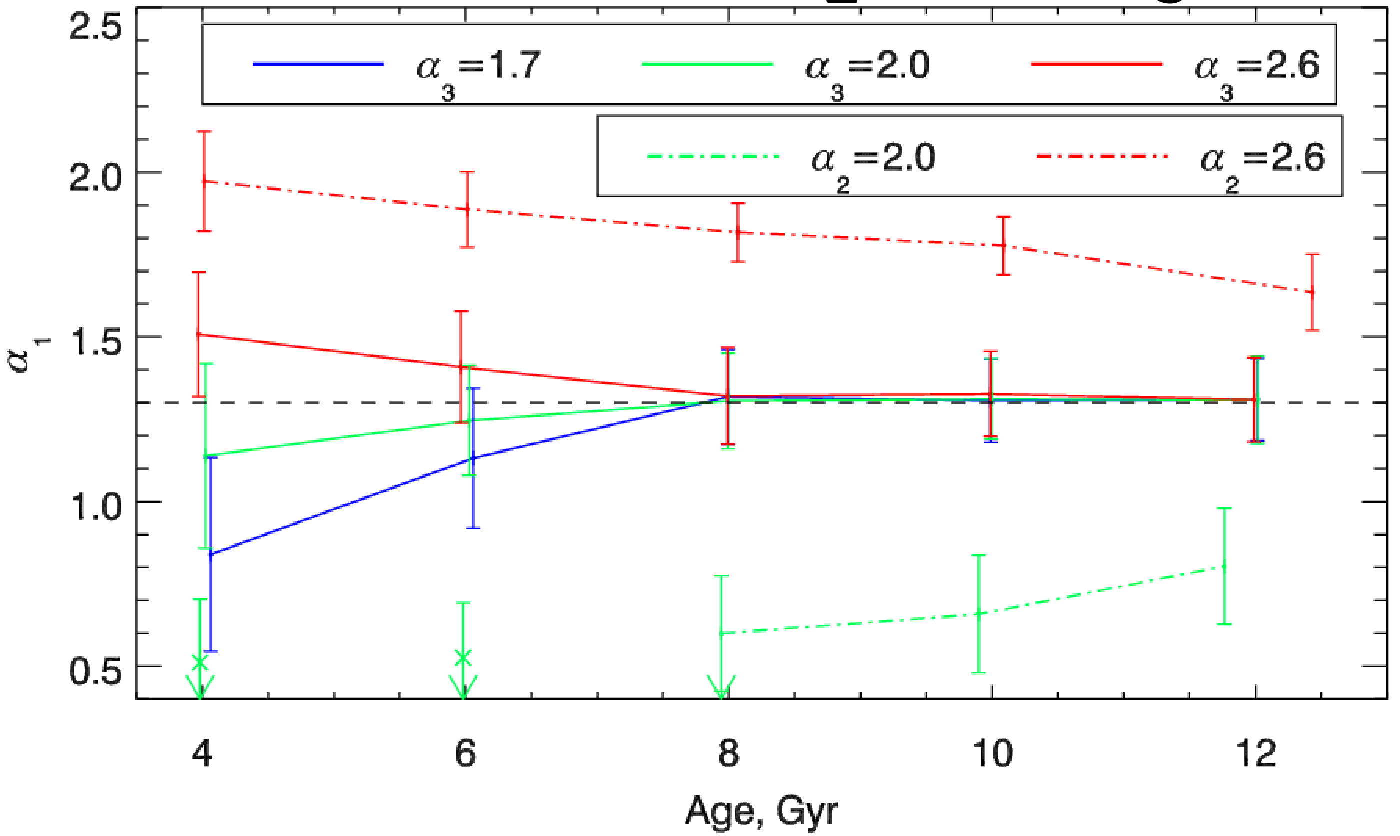
The distribution of α_1-sensitive information



IMF-sensitive information is not associated with Lick indices

Most of the IMF-sensitive spectral regions are those containing numerous but relatively faint absorption lines sensitive to the surface gravity in the atmospheres of late type (GKM) stars. These lines associated with CaI, VI, CoI, NiI and TiI absorption lines

Variation α_2 and α_3



α_3 : Any stellar system of the age of 8 Gyr or older can be analysed with our standard set of the SSP models with the fixed value of α_3=2.3 when using the first version of our IMF determination technique.

We see that α_2 variations introduce significant biases into the best-fitting α_1 values. However, we stress that according to recent studies there is no evidence for α_2 to vary

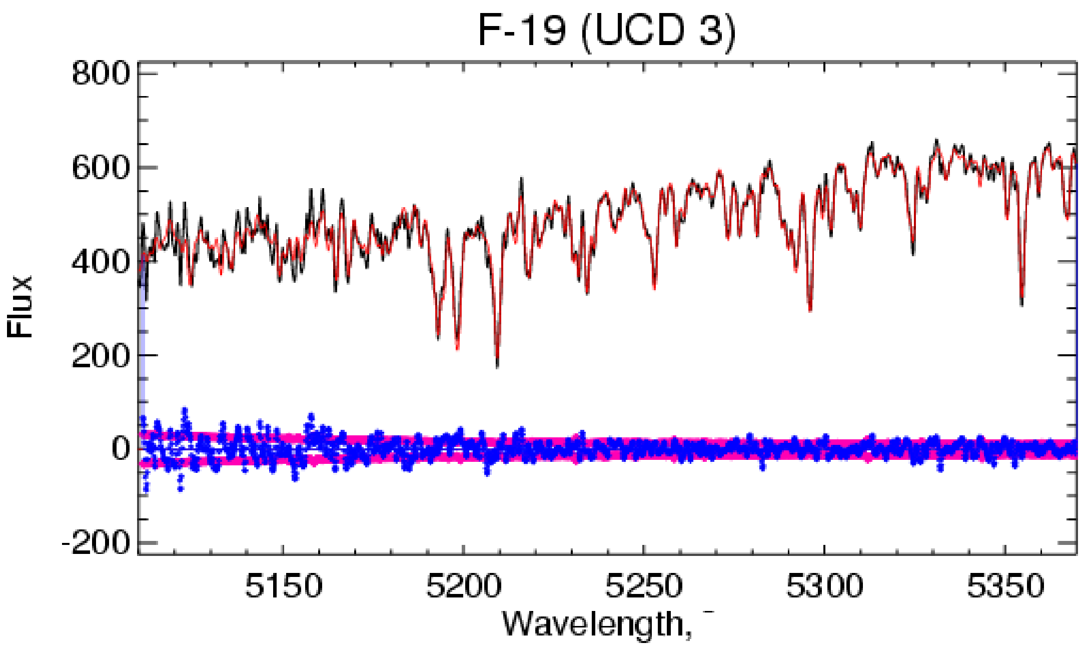
Real data: galactic GC

(1) intermediate resolution (R=1300) Galactic GC spectra from Schiavon et al. (2005) obtained at the 4 m Blanco telescope at CTIO in the wavelength range 3900< λ <6500 A

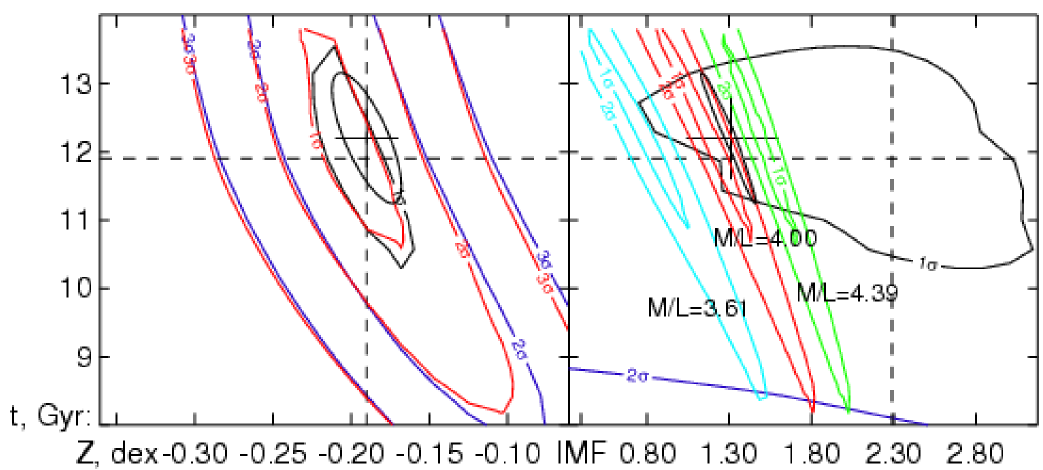
None of the clusters had t_{rel} > 4 Gyr, and those spectra were integrated and extracted only in the cluster core region.

We could not obtain any reliable estimates of α_1 values in these objects but only use them to evaluate statistical errors of the techniques for spectra of such a type. The statistical uncertainties of the first version of our technique turned to be about α_1~0.3–0.5. Fixing the M/L values reduced them down to 0.15.

Real data: UCD



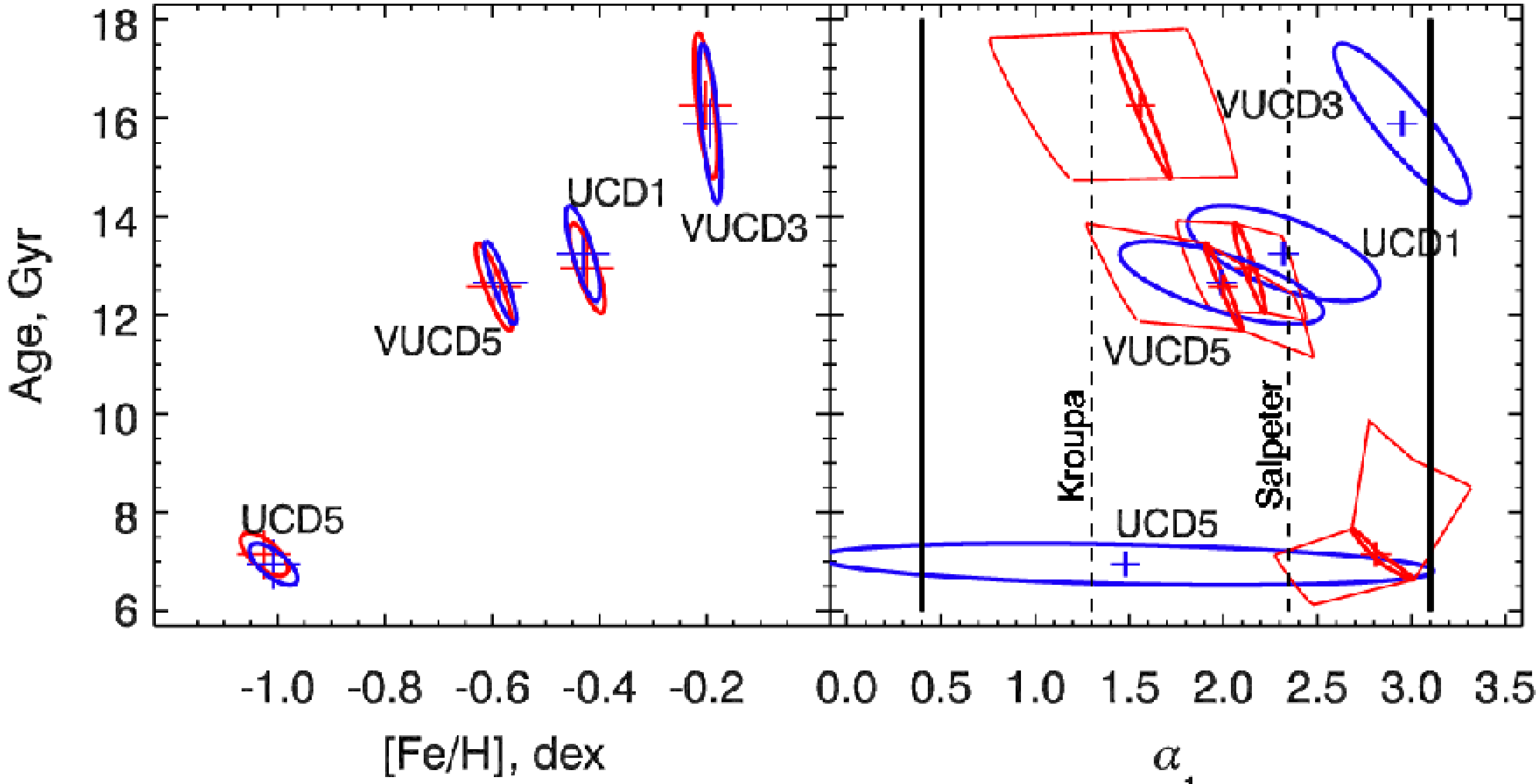
(2) high-resolution (R=17000) intermediate signal-to-noise spectra of UCDs in the Fornax cluster obtained at ESO VLT in narrow wavelength interval, 5120< λ <5450°A (Mieske et al. 2008; Chilingarian et al. 2011) downgraded to R=10000



Very short wavelength range not including any strong IMF sensitive features makes the α_1 determination impossible for the first unconstrained version of our technique bringing the statistical error to α_1 =0.8 even for the brightest object, UCD 3 (F 19 in Chilingarian et al. 2011).

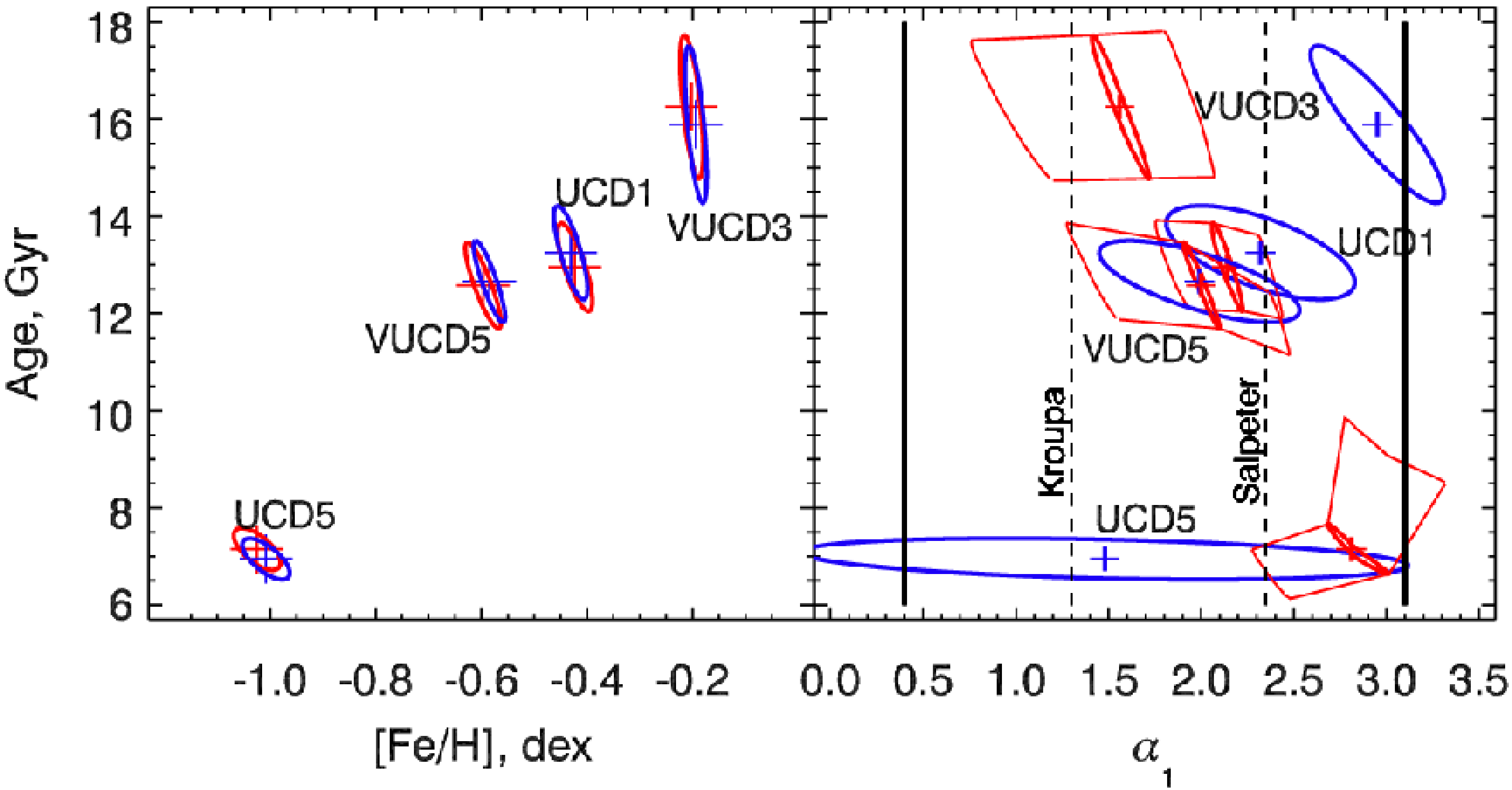
Real data: UCD

Intermediate resolution (R=1500–2000) high signal-to-noise ratio spectra (3900< λ <6800 A) of Fornax and Virgo cluster UCDs obtained with Gemini GMOS-N/GMOS-S



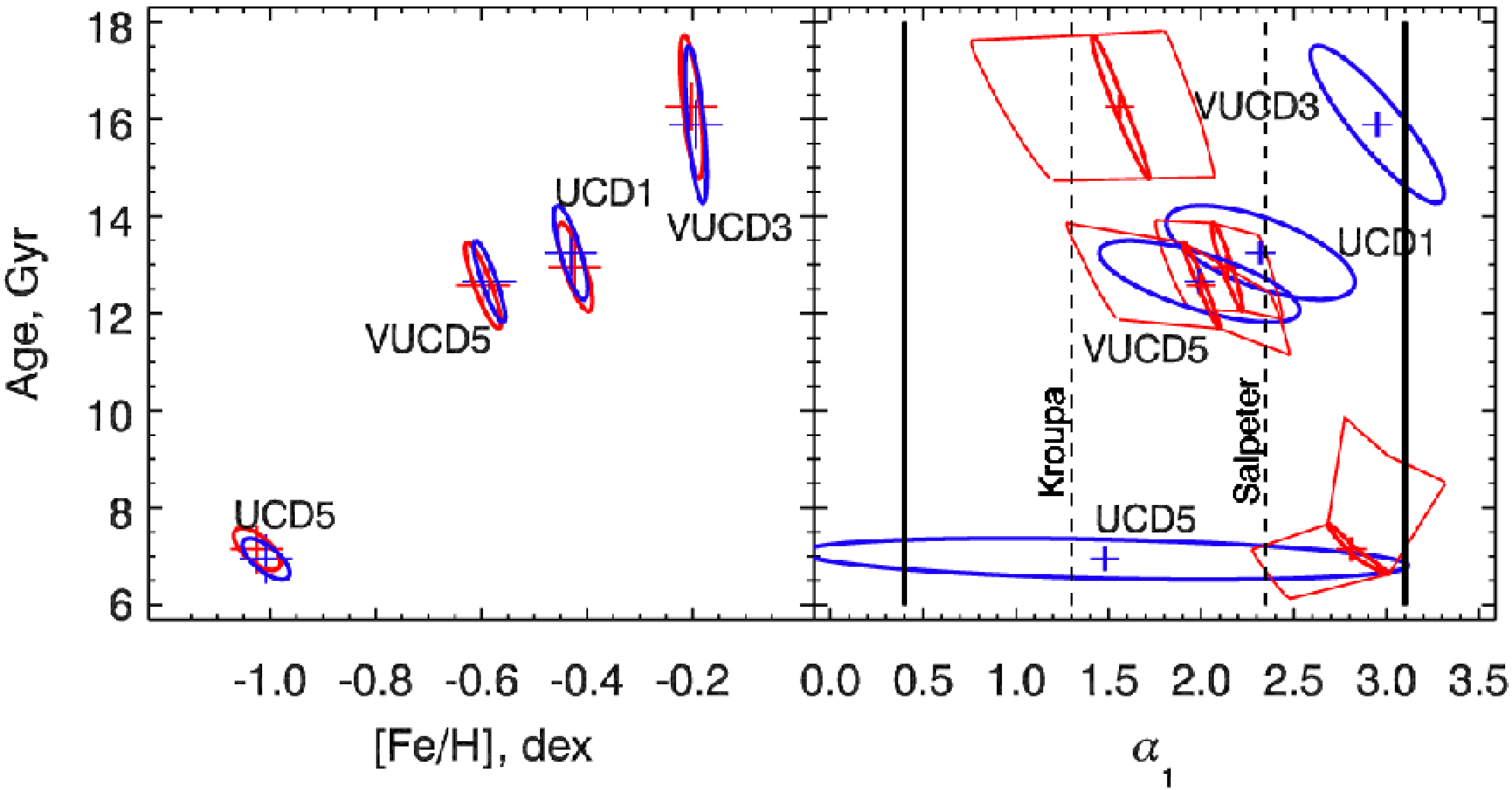
For UCD 1 and VUCD 5 both, fully unconstrained fitting and the M/L-imposed version of the technique agree well within the statistical uncertainties of the unconstrained fitting.

Real data: UCD



For UCD 5 having low metallicity and therefore much weaker absorption lines, the unconstrained fitting results in very large uncertainties while the adopted $(M/L)_V$ value puts it close to the edge of the model grid on the MF slope (2.8).

Real data: UCD



For VUCD 3 the situation is the opposite, the unconstrained fitting yields α_1~2.9, however one has to keep in mind that this object has extremely high value of the [α/Fe] chemical abundance ratio (Francis et al. 2012) resulting in the significant template mismatch, therefore the unconstrained measurements may get biased.

At present, we do not have models required to study the biases which may be introduced to the MF measurements from integrated light spectra by significantly non-solar abundance ratios.

Conclusion

- We present new estimates of the stellar initial mass function (IMF) in massive compact stellar systems which have not been affected by dynamical evolution. These estimates were made by new technique that determines low-mass end slope of the present day stellar mass function (PDMF) of unresolved stellar populations using pixel fitting of spectra integrated along line of sight.

- This method achieves precision of ~0.1 in MF slope value and hence outperforms classical IMF determination techniques which use direct star counts in open clusters and HII associations.

- We note that biases may be introduced to the MF measurements from integrated light spectra by significantly non-solar abundance ratios.

Perspectives

- Extragalactic GC systems where structural parameters of clusters are available from the Hubble Space Telescope data will have advantage over the Galactic GCs because the integrated velocity dispersion measurements of such systems are much easier to obtain for large samples of targets using multi-object spectroscopy.

- The unconstrained version can be applied to check whether the IMF is bottom heavy in massive elliptical galaxies where low-mass stars might have efficiently formed in cooling flows (Kroupa & Gilmore 1994)

- To check the IMF universality hypothesis.

Thank you for attention!

Podorvanyuk N., Chilingarian I., Katkov I., **A new technique for the determination of the initial mass function in unresolved stellar populations**. MNRAS, 2013, 432 (4): 2632-2638. arXiv:1303.0897