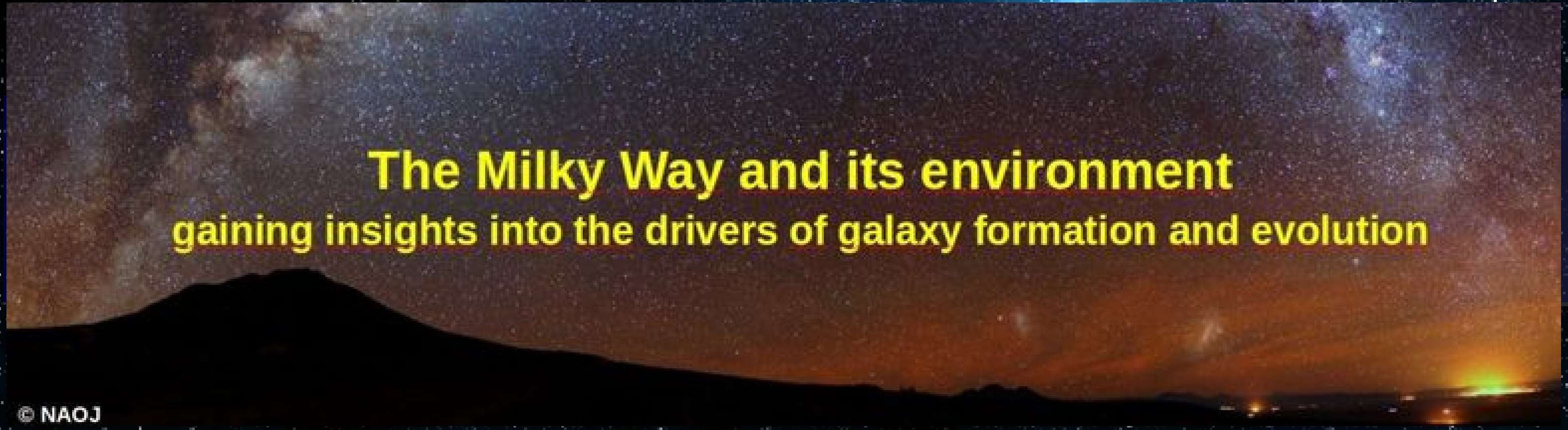
The Art of Deriving SFHs: From Dwarf Galaxies to the Milky Way.

Sebastián L. Hidalgo – Instituto de Astrofísica de Canarias
shidalgo@iac.es



IAP – September 2016

The Art of Deriving SFHs:
From Dwarf Galaxies to the Milky Way.

Outline

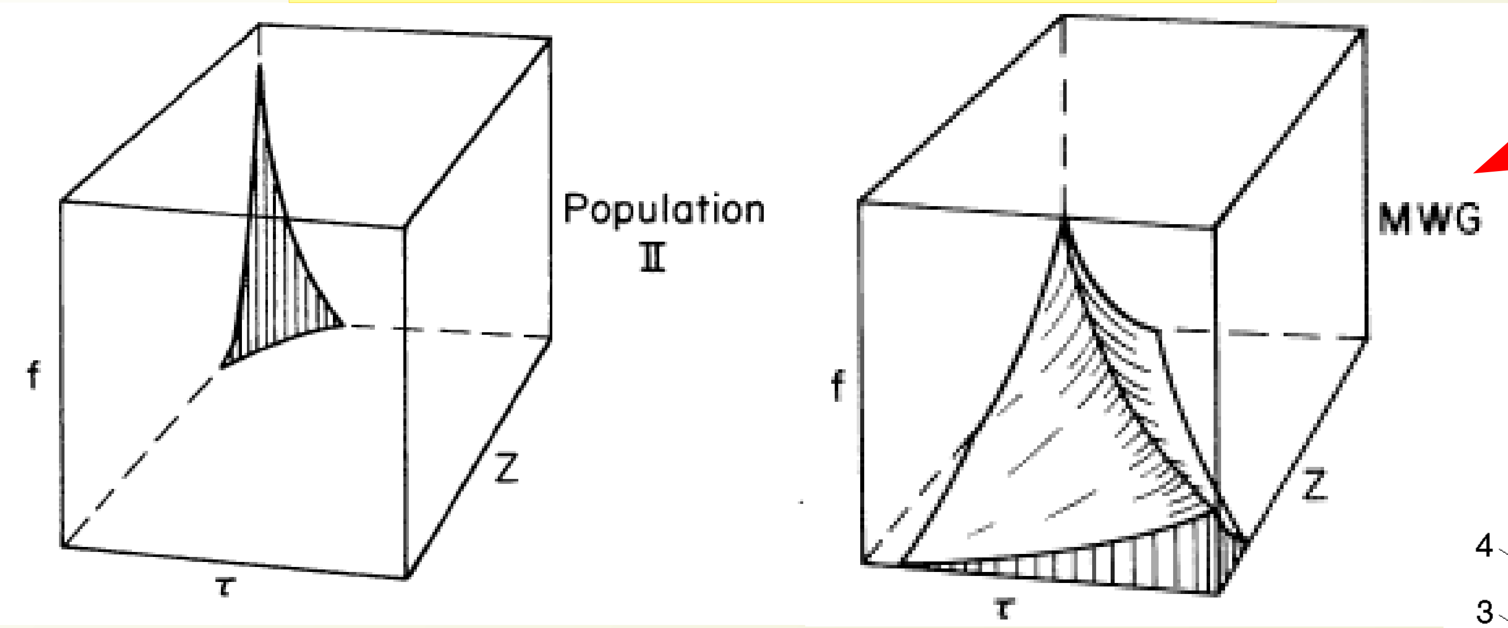
1. Computing a reliable SFH.
2. Results from the Local Group dwarf galaxies.
3. Project: The SFH of the Galactic bulge and disk using the ESO-VVV survey

Star Formation History : distribution of the age and metallicity of the stars in a stellar system.

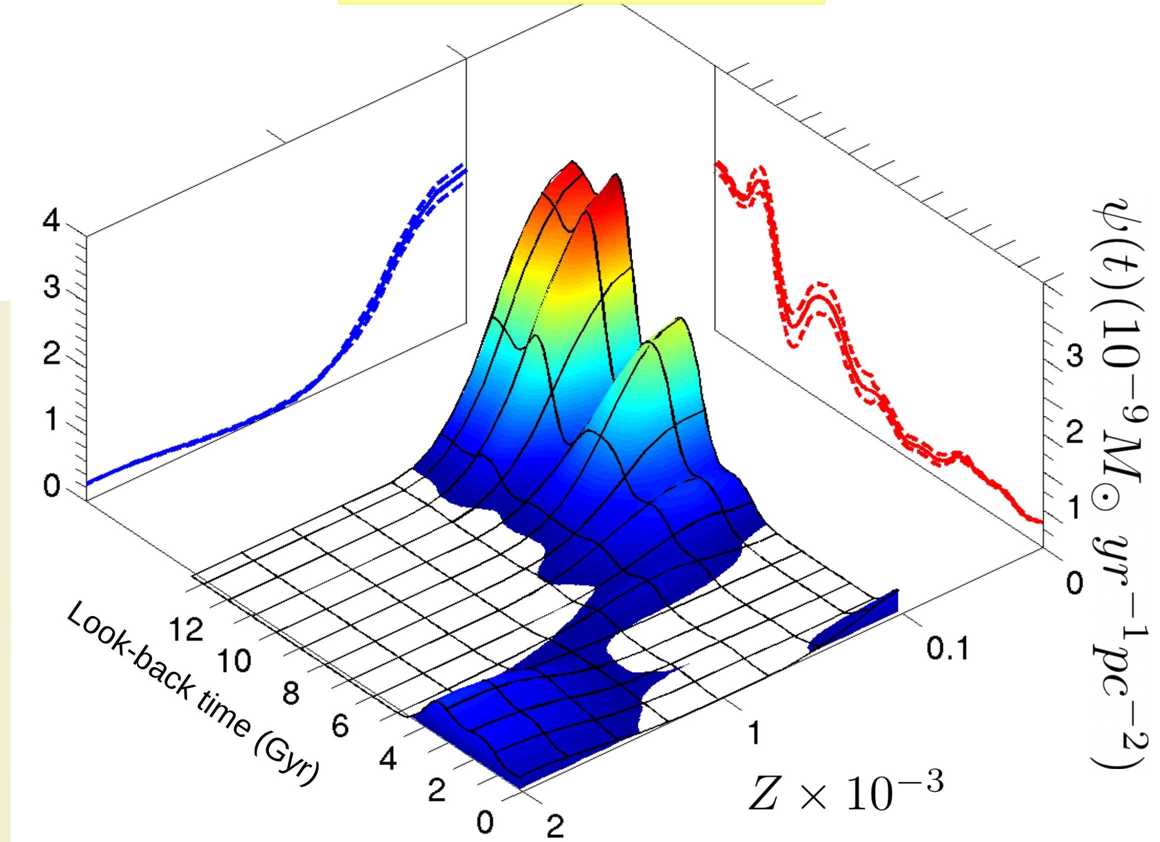
Population box

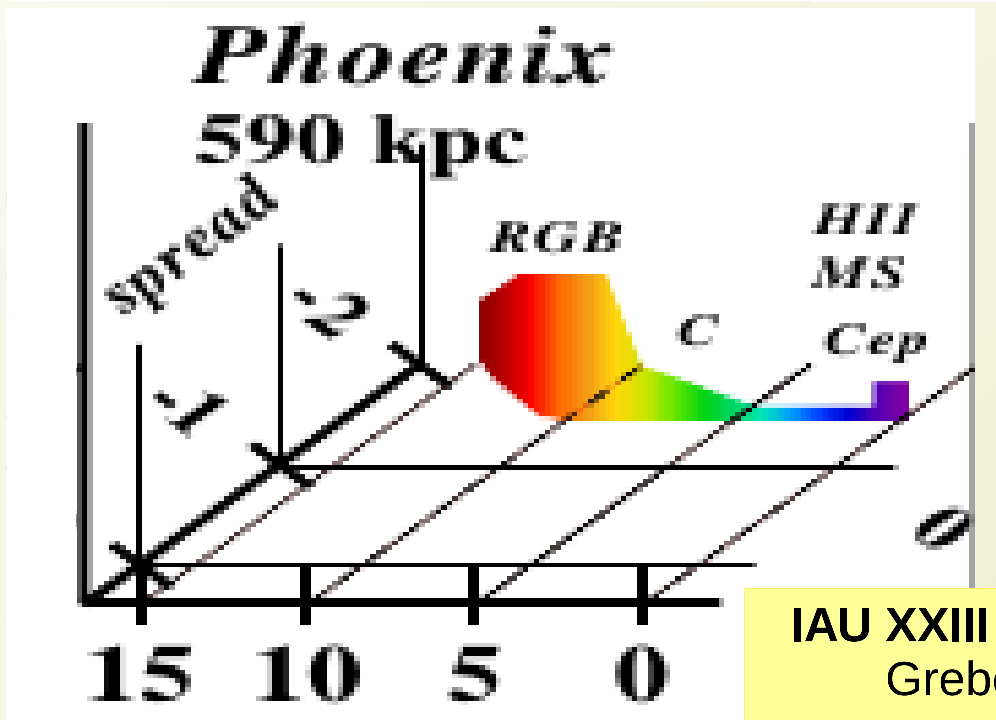
A very convenient tool to represent SFHs

"Populations in Local Group galaxies"
Hodge 1989 ARA&A, 27, 139



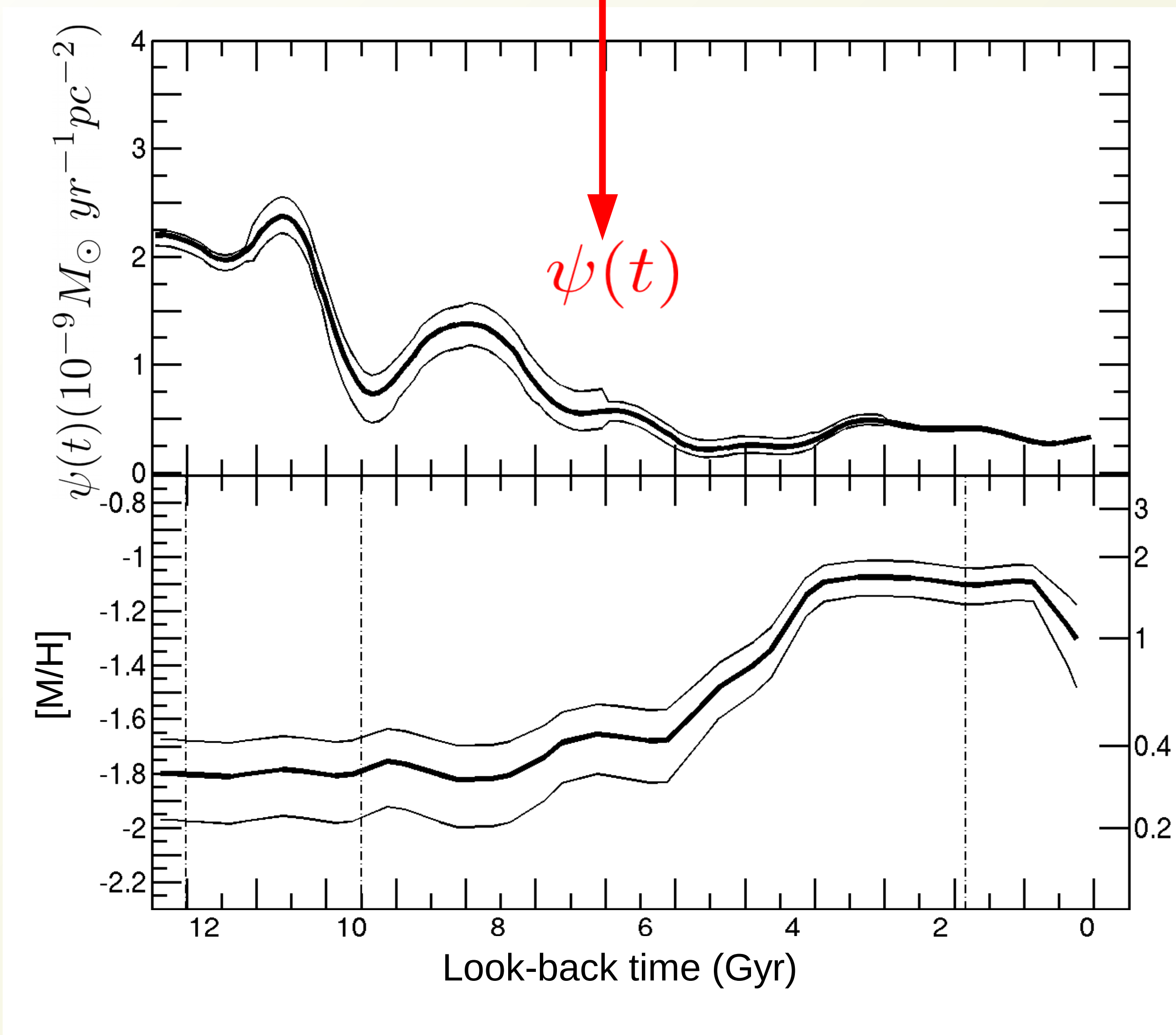
Hidalgo et al. 2009

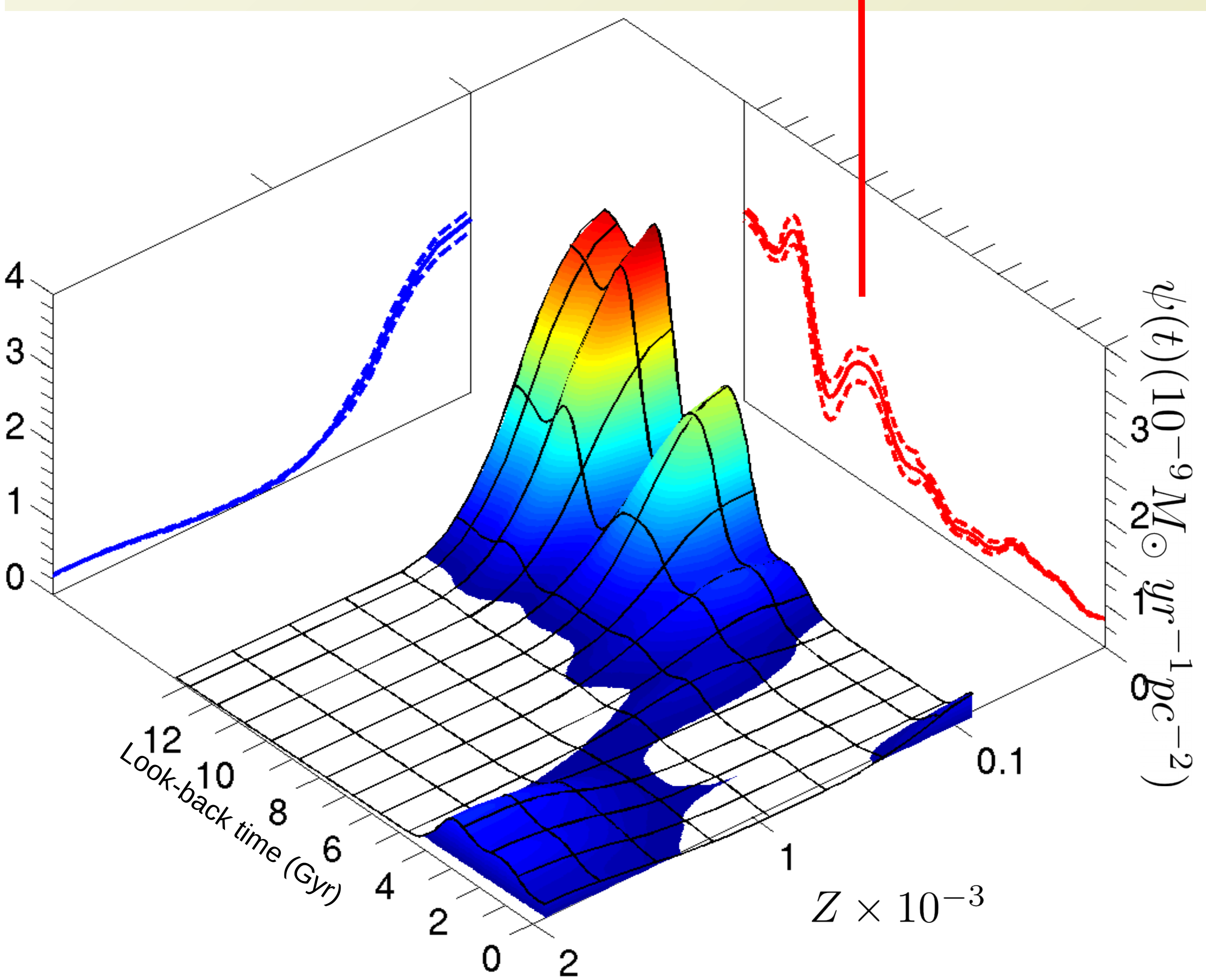




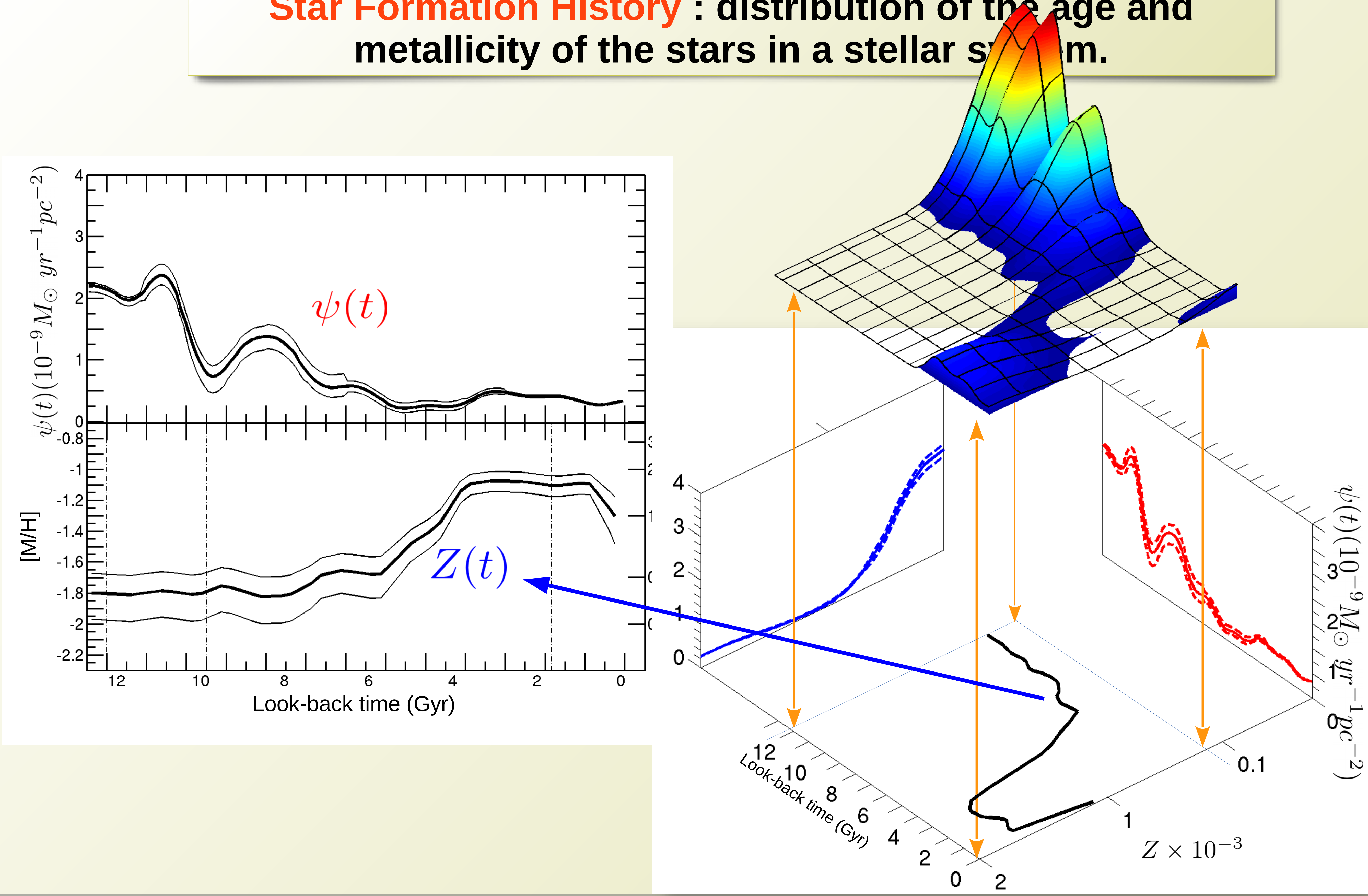
IAU XXIII General Assembly, 1997
Grebel 1998 HiA, 11, 125

Star Formation History : distribution of the age and metallicity of the stars in a stellar system.

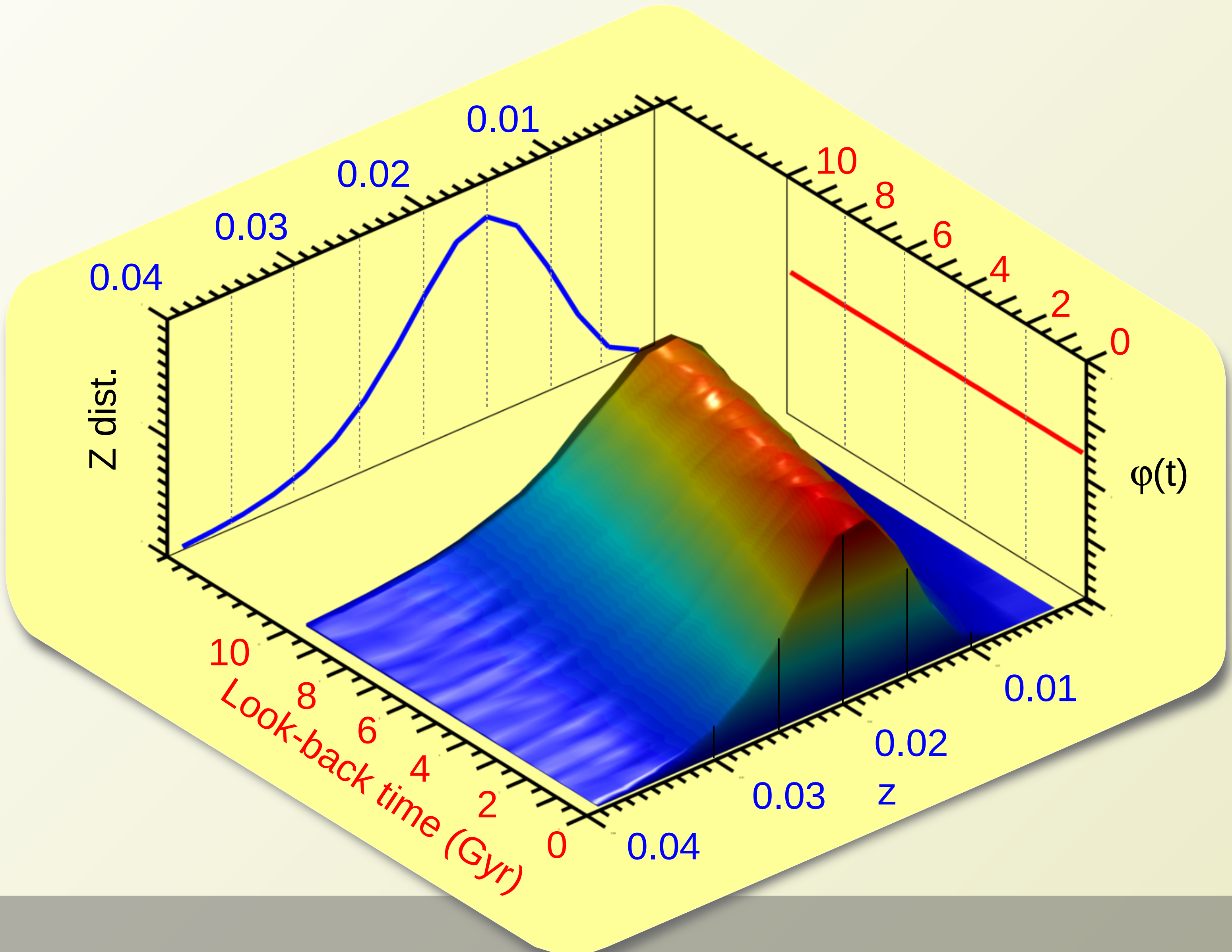




Star Formation History : distribution of the age and metallicity of the stars in a stellar system.



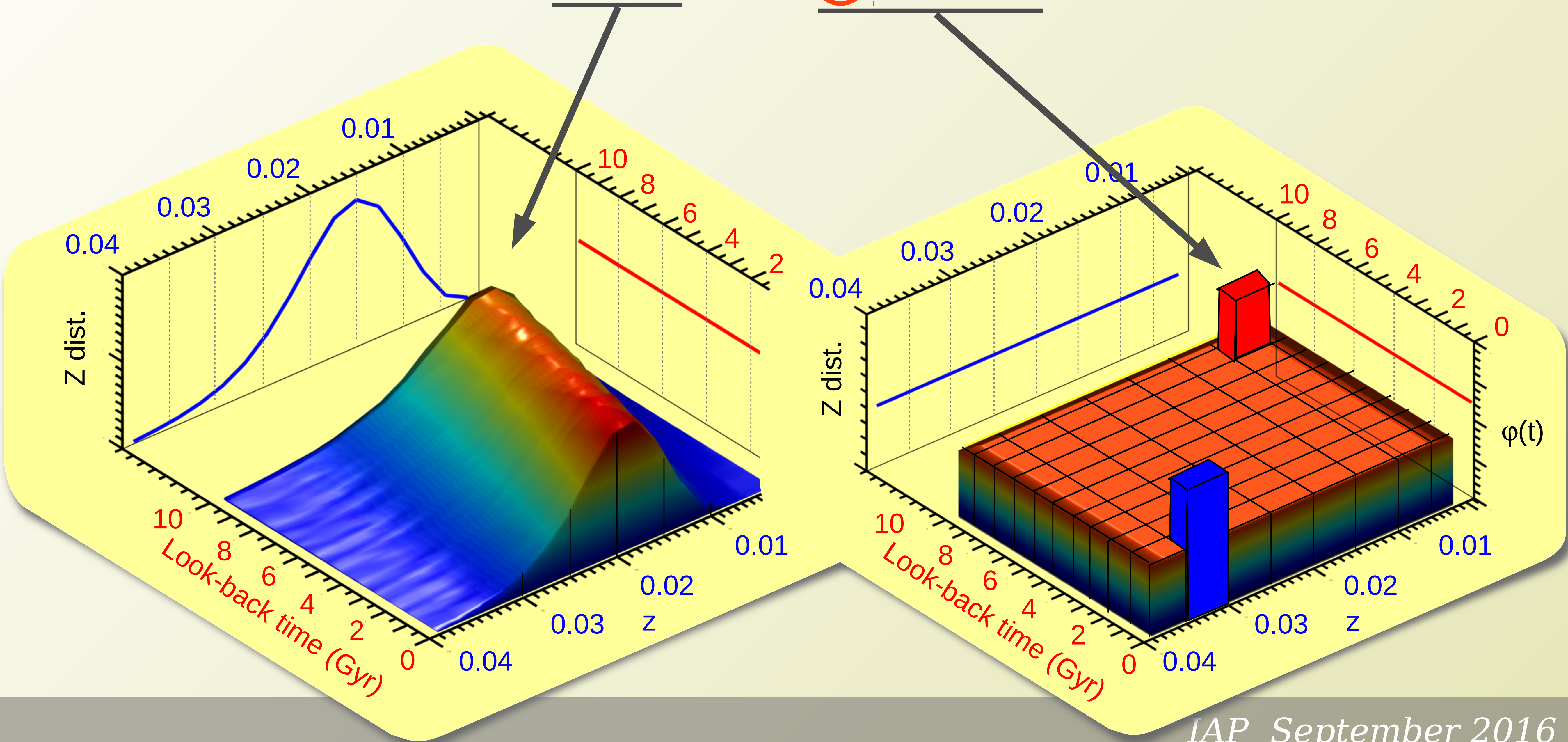
We assume the Star Formation History as a function of two independent variables: AGE and METALLICITY



We assume the Star Formation History as a function of two independent variables: AGE and METALLICITY

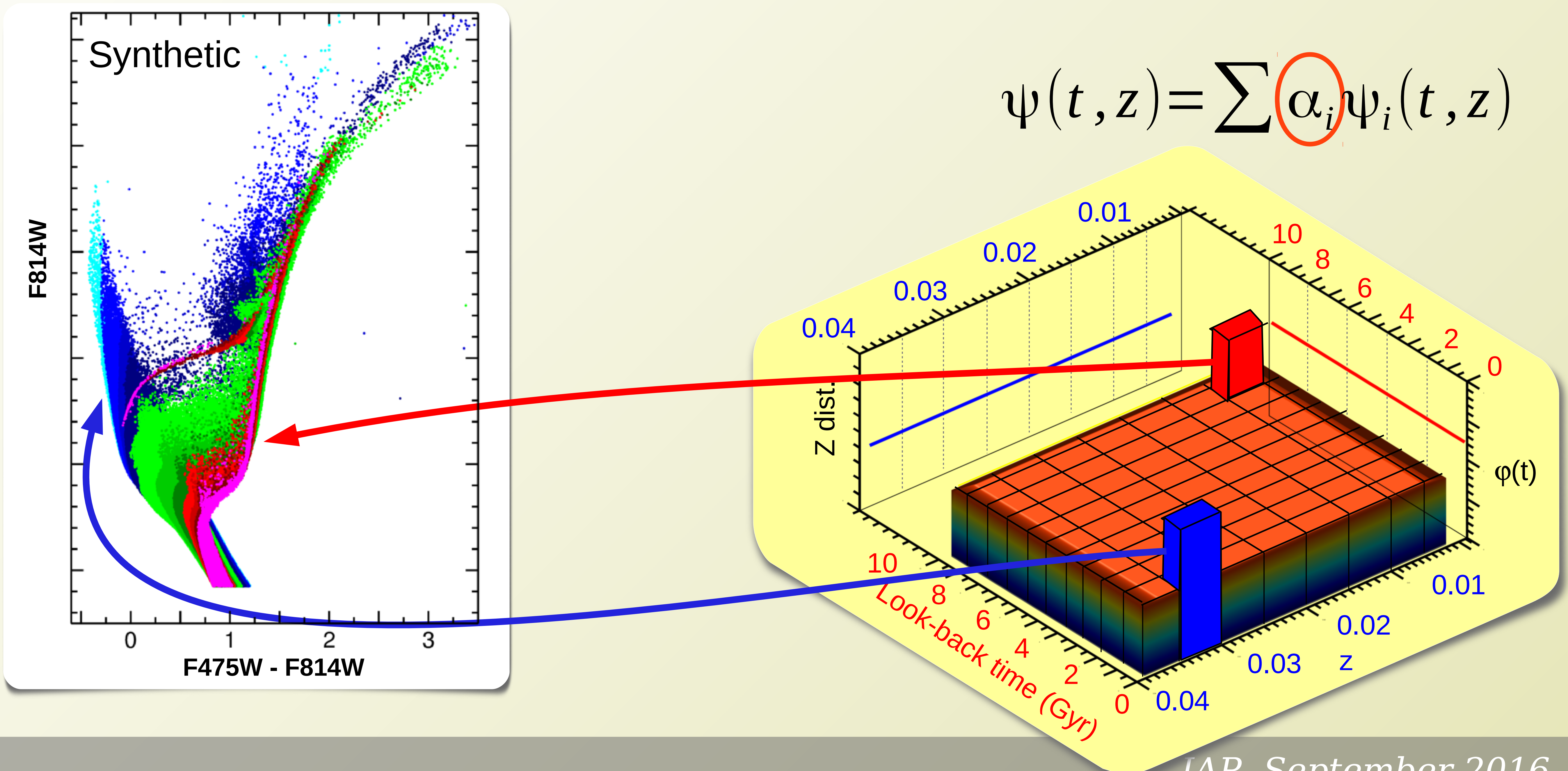
Any SFH can be represented as a linear combination of SSPs:

$$\psi(t,z) = \sum \alpha_i \psi_i(t,z)$$



SSPs distribute differently in a CMD according their ages and metallicities

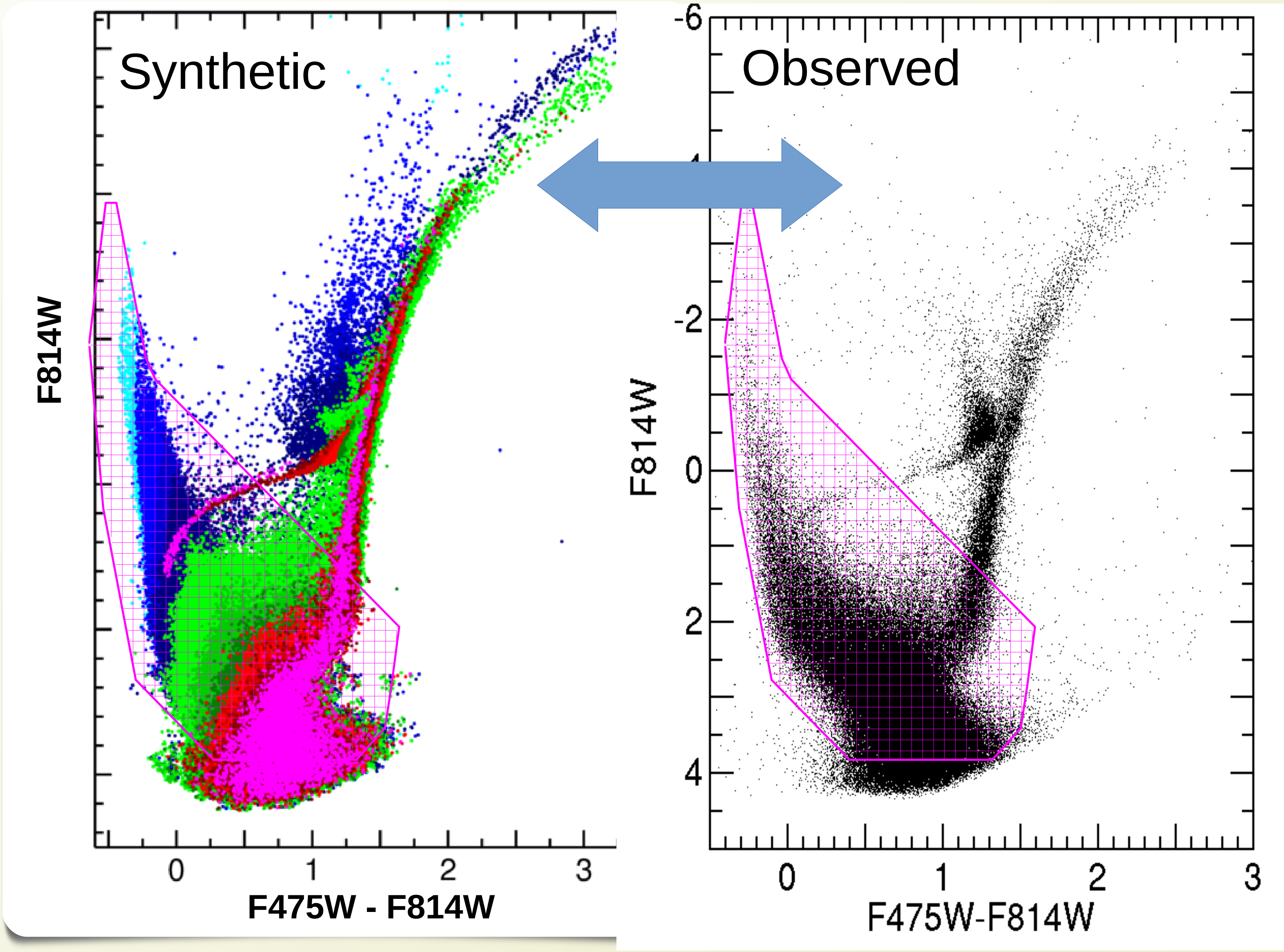
$$\psi(t,z)=\sum \alpha_i \psi_i(t,z)$$



Both CMDs are sampled by dividing them in boxes. The number of stars in each box of the oberved CMD is compared with the number of star for each SSP in the same box in the model CMD.

IAC-star/IAC-pop/MinnIAC

Aparicio & Gallart (2004)
Aparicio & Hidalgo (2009)
Hidalgo+ (2011)



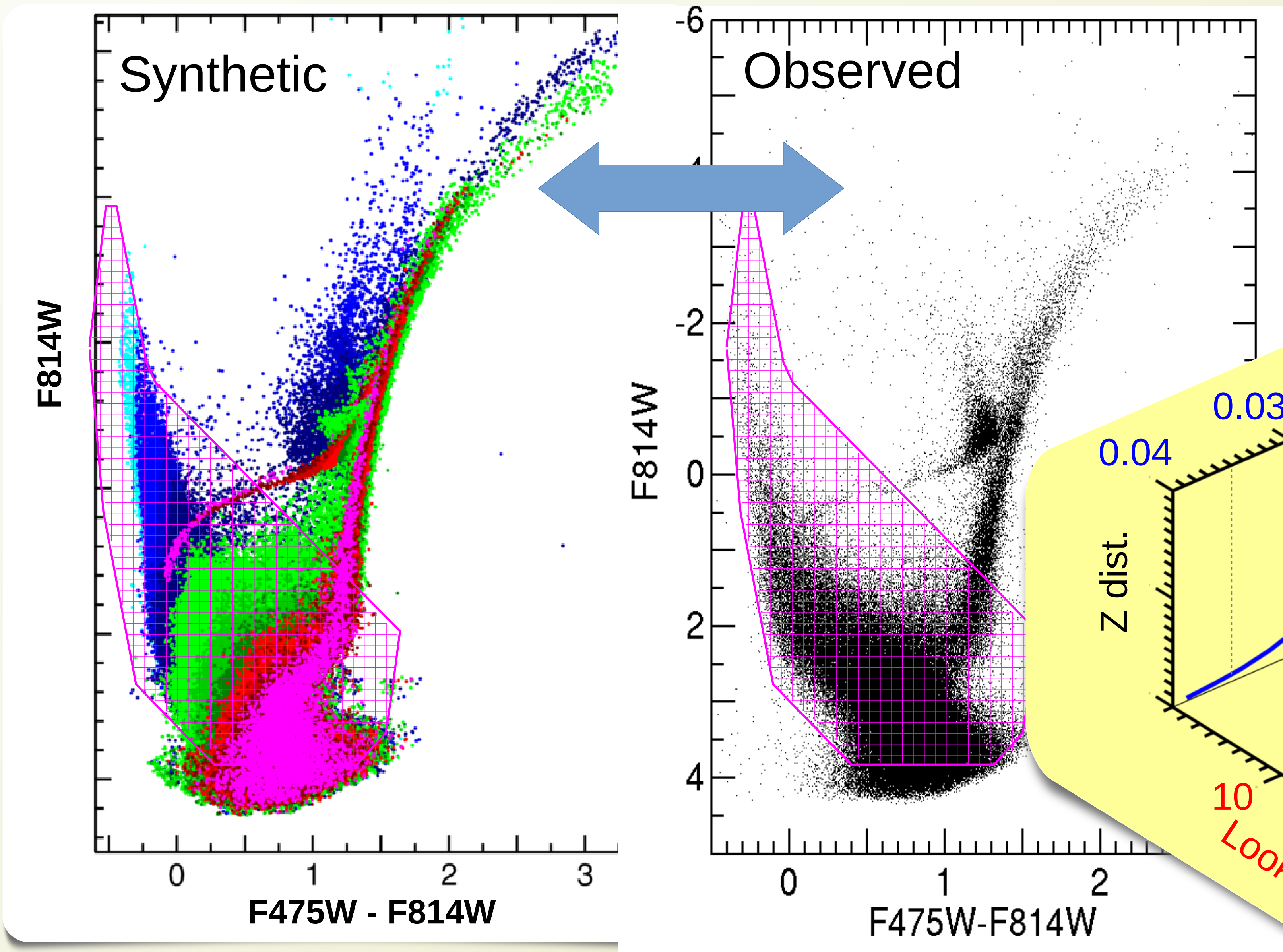
$$\psi(t,z)=\sum \alpha_i \psi_i(t,z)$$

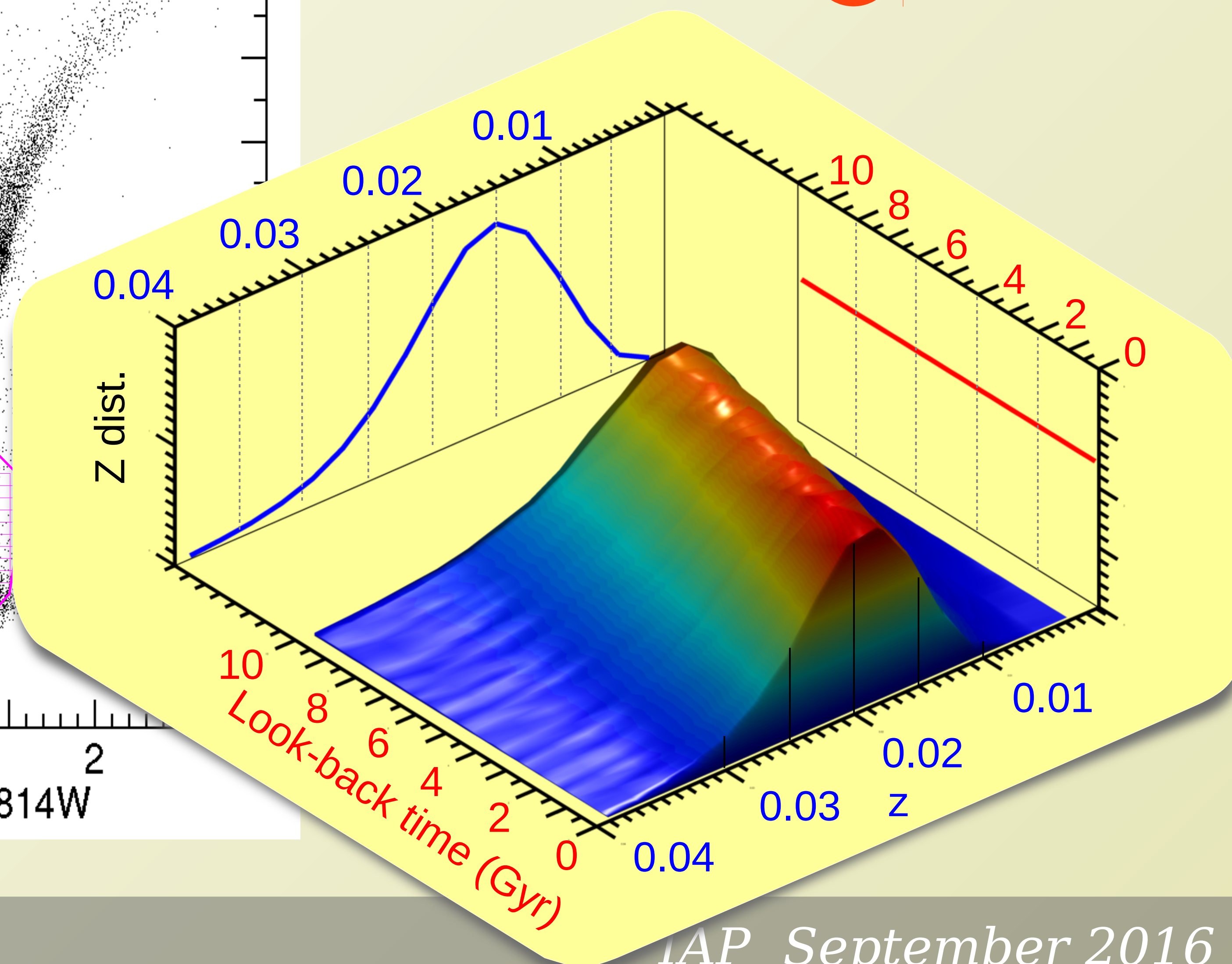
By using a merit function, we can select those coefficients which best reproduce an observed CMD to obtain the SFH of the stellar system.

IAC-star/IAC-pop/MinnIAC

Aparicio & Gallart (2004)
Aparicio & Hidalgo (2009)
Hidalgo+ (2011)

$$\psi(t,z)=\sum \alpha_i \psi_i(t,z)$$





Deriving a reliable SFH

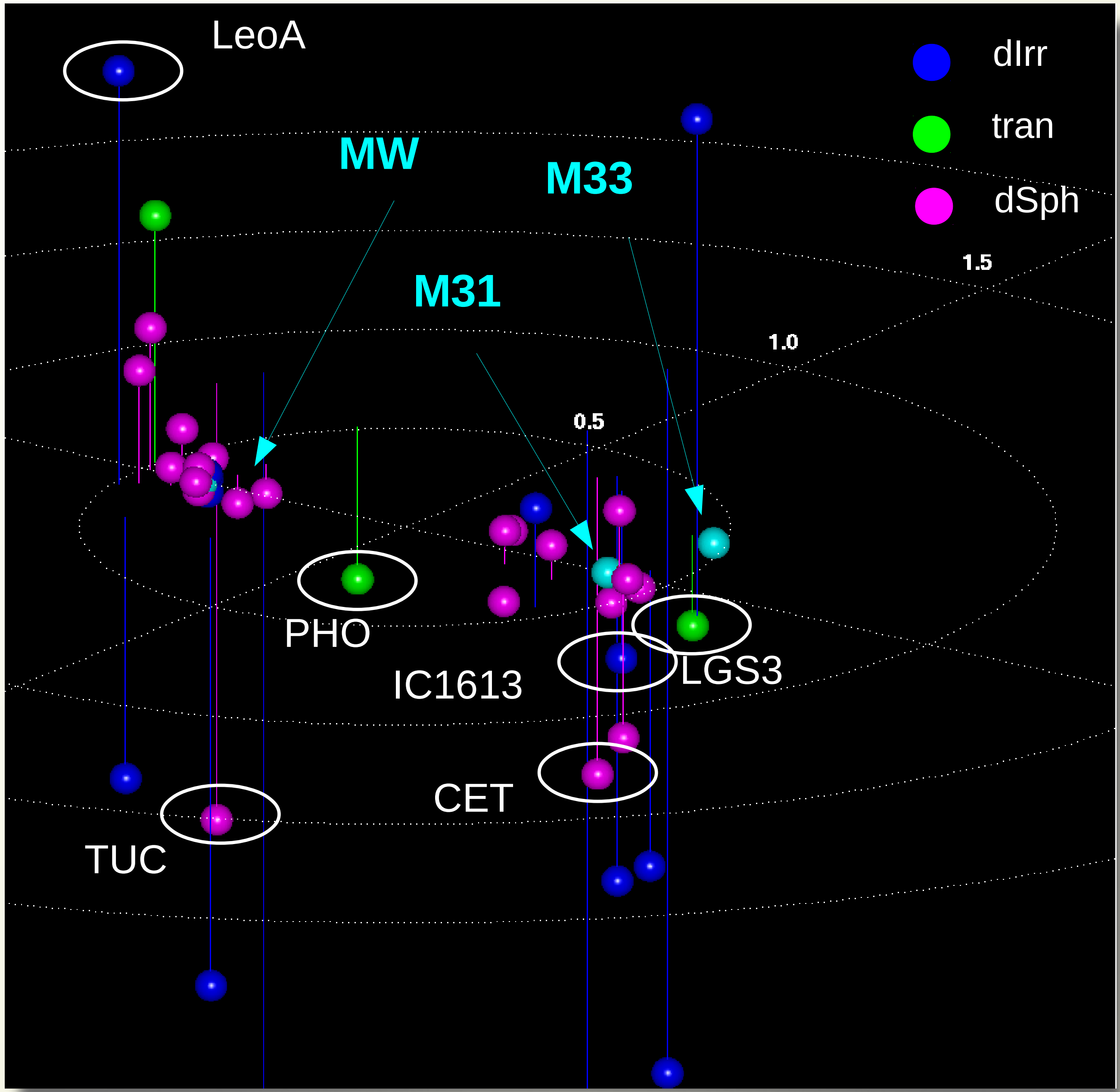
- Testing different stellar evolution libraries.
- Constraining the initial mass function
- Constraining the number of binaries stars.

Affect to the model

- Distance
- Reddening
- Completeness

Affect to observations

Local Cosmology from Isolated Dwarfs (LCID)



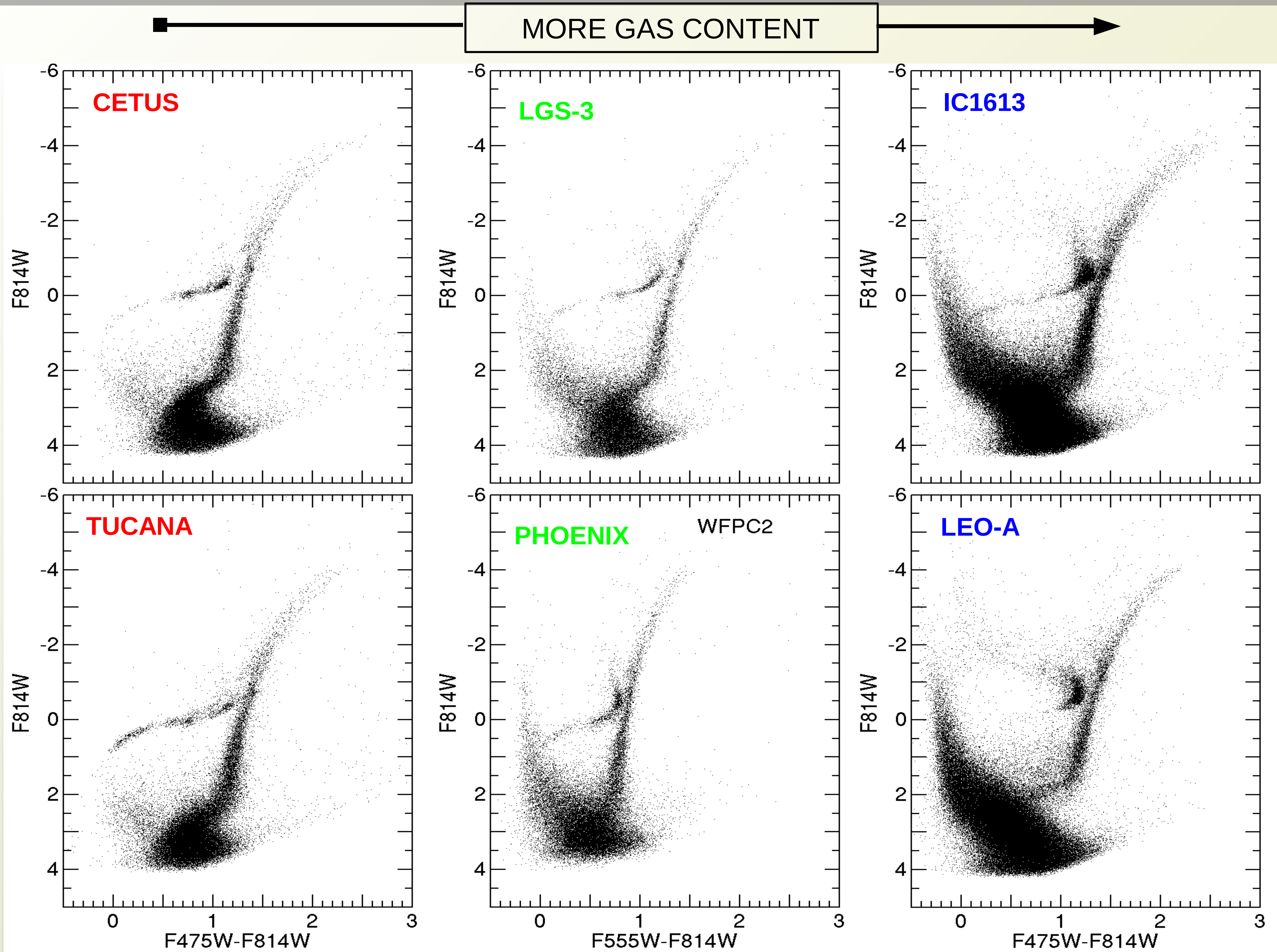
HST data

Galaxy	Type	$(m-M)_0$	D(kpc) MW / M31	# Orbit
IC1613	dIrr	24.41	769 / 520	24
Leo A	dIrr	24.50	794 / 1180	16
LGS3	dTran	23.98	625 / 270	12
Phoenix	dTran	23.30	457 / 610	24_{wfpc2}
Cetus	dSph	24.39	755 / 680	25
Tucana	dSph	24.77	899 / 1340	32

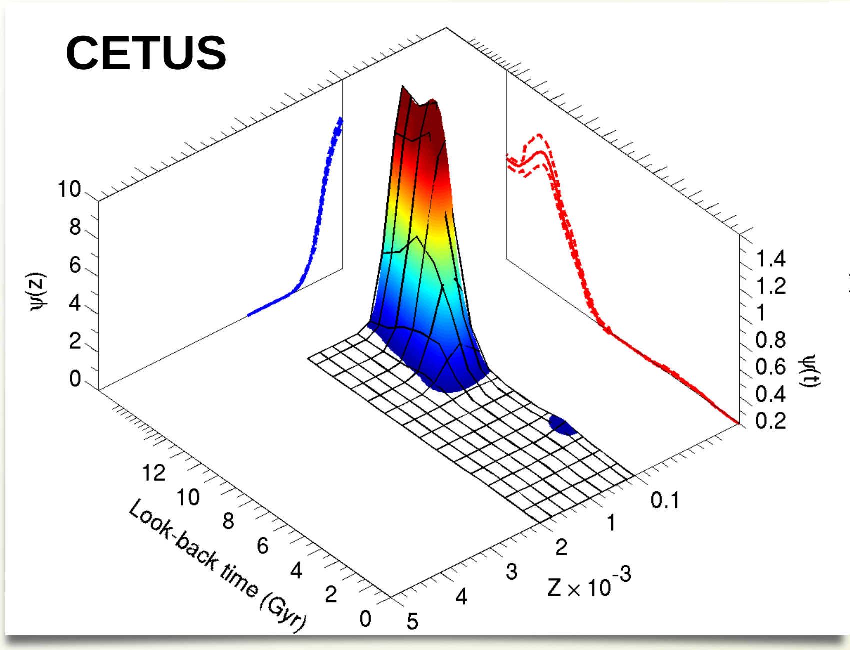
Project team

P.I.: **Gallart, Aparicio** (IAC), **Cole** (U. Tasmania)

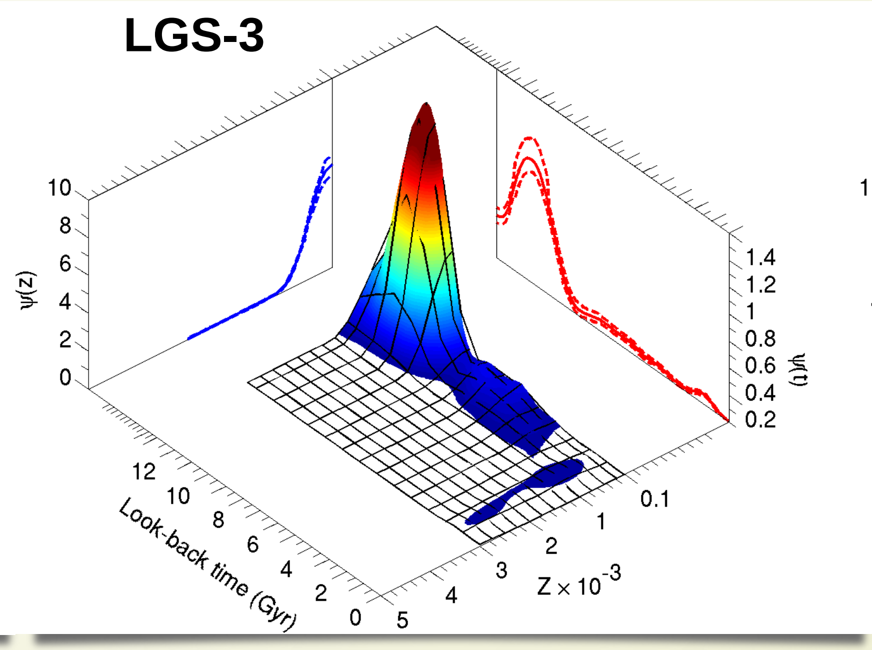
Co-I: **Bernard** (IAC)**, Drozdovsky** (IAC), **Hidalgo** (IAC), **Monelli** (IAC),. **Bertelli** (U. Padova), S. **Cassisi** (INAF-OA-Teramo), P. **Demarque**, (U. Yale), H.C. **Ferguson** (STScI), A. **Dolphin** (U. Arizona), J. **Gallagher** (U. Wisconsin), **Mayer** (U. Zurich), M. **Mateo** (U. Michigan), J. **Navarro** (U. Victoria), E. **Skillman, D. Weisz** (U. Minnesota), P.B. **Stetson** (DAO), **E.Tolstoy** (Kapteyn).


MORE GAS CONTENT
CETUS
LGS-3
IC1613
TUCANA
PHOENIX
WFPC2
LEO-A
F814W
F475W-F814W
F555W-F814W

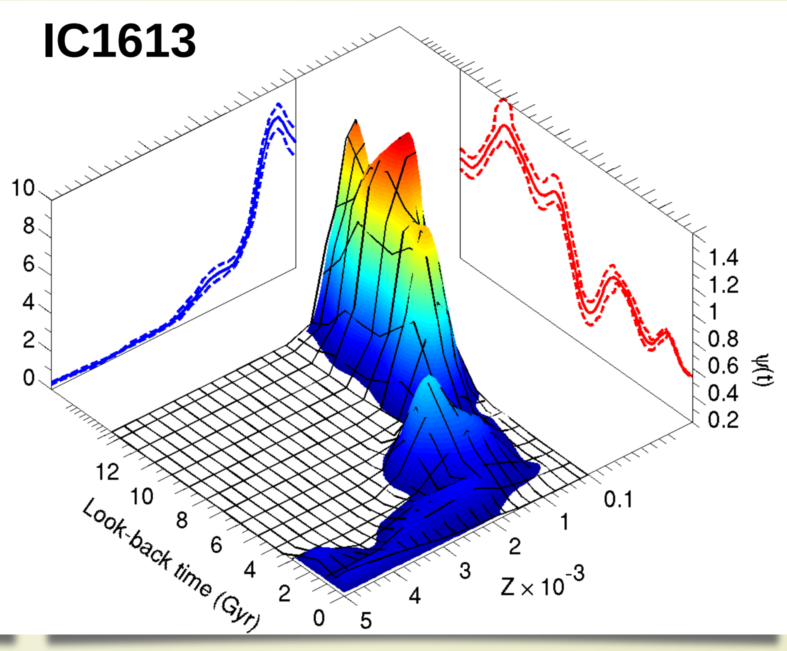
MORE GAS CONTENT



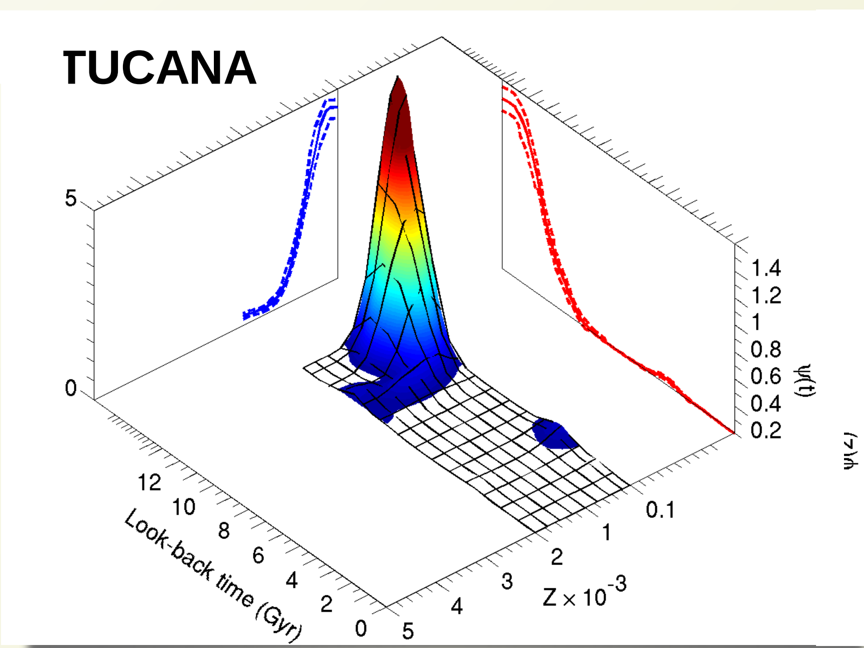
Monelli+ (2010)



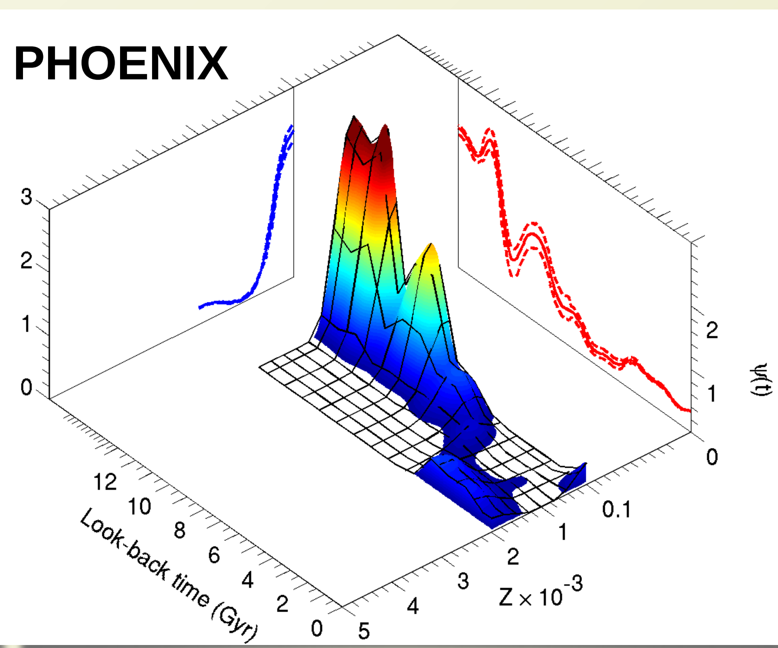
Hidalgo+ (2011)



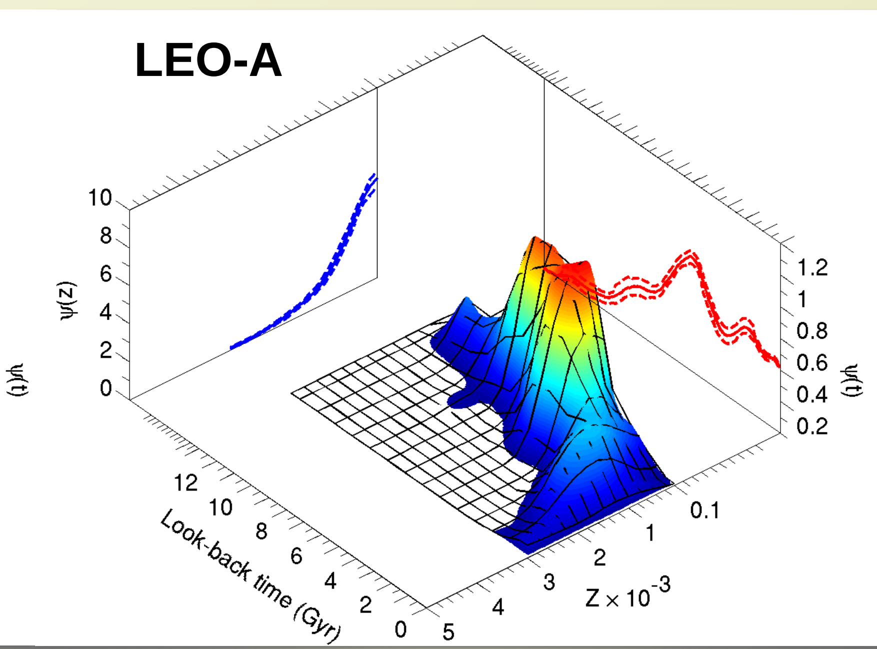
Skillman+ (2014)



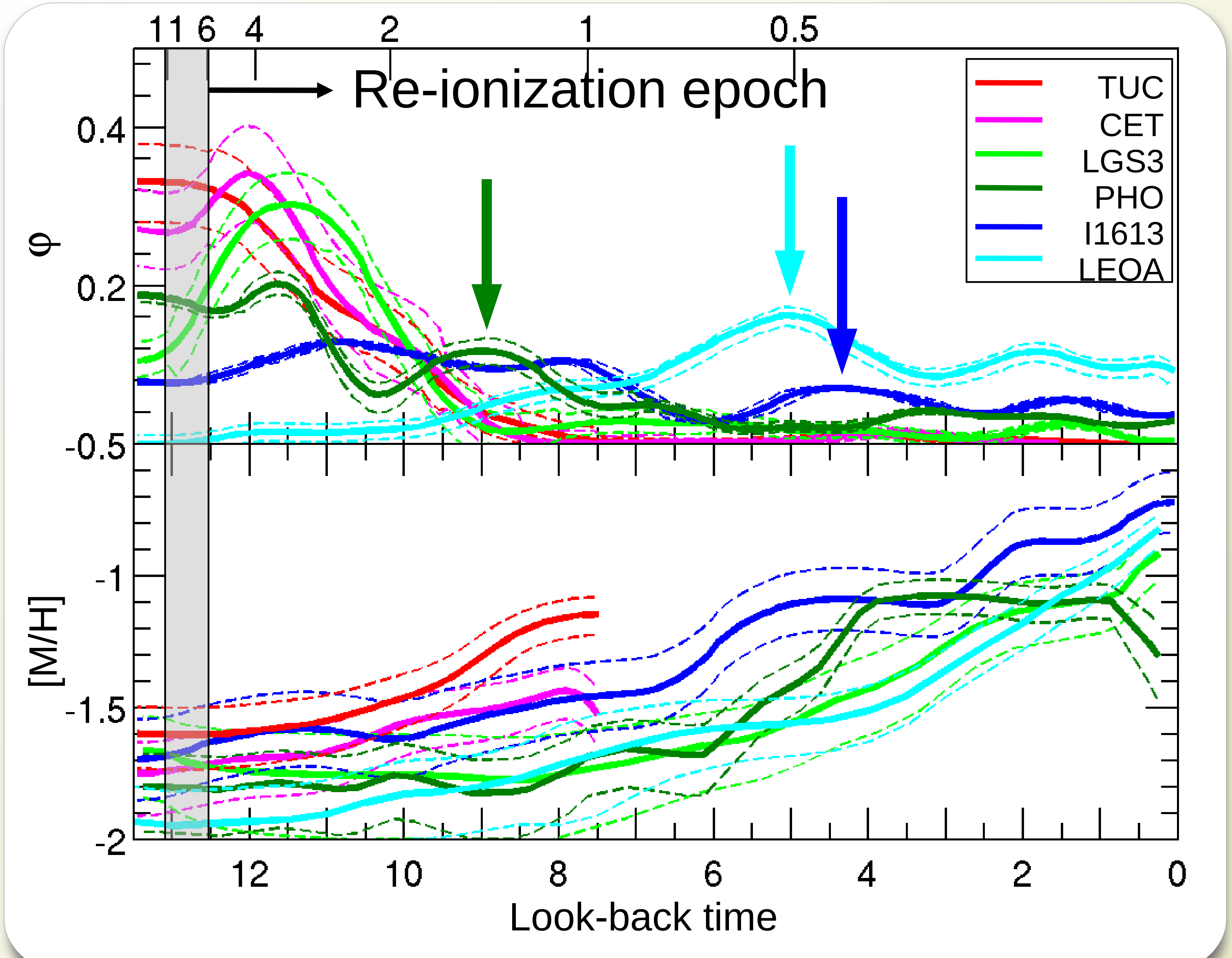
Monelli+ (2010)



Hidalgo+ (2009)



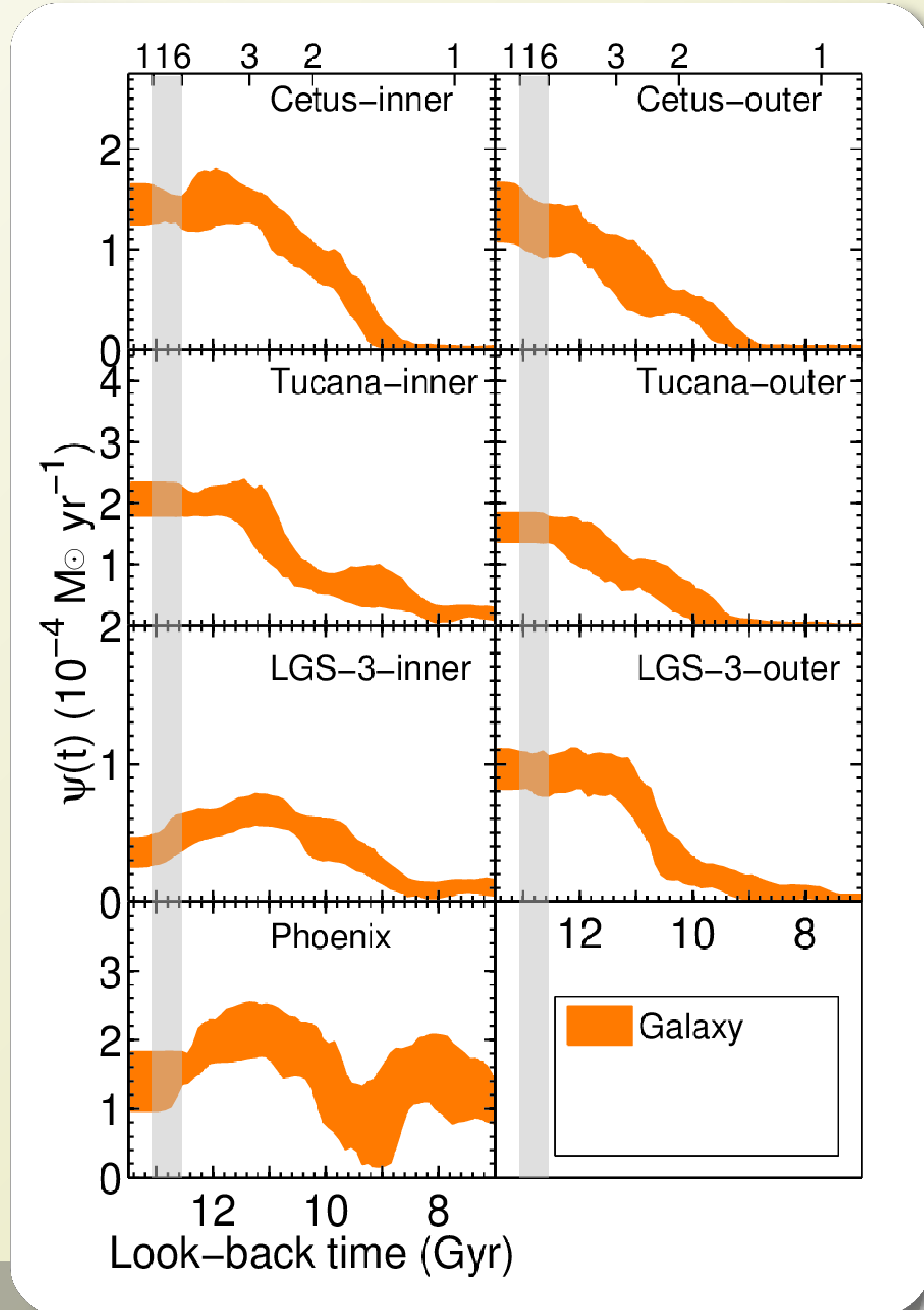
Hidalgo+ (in prep)
Cole+ (2009)



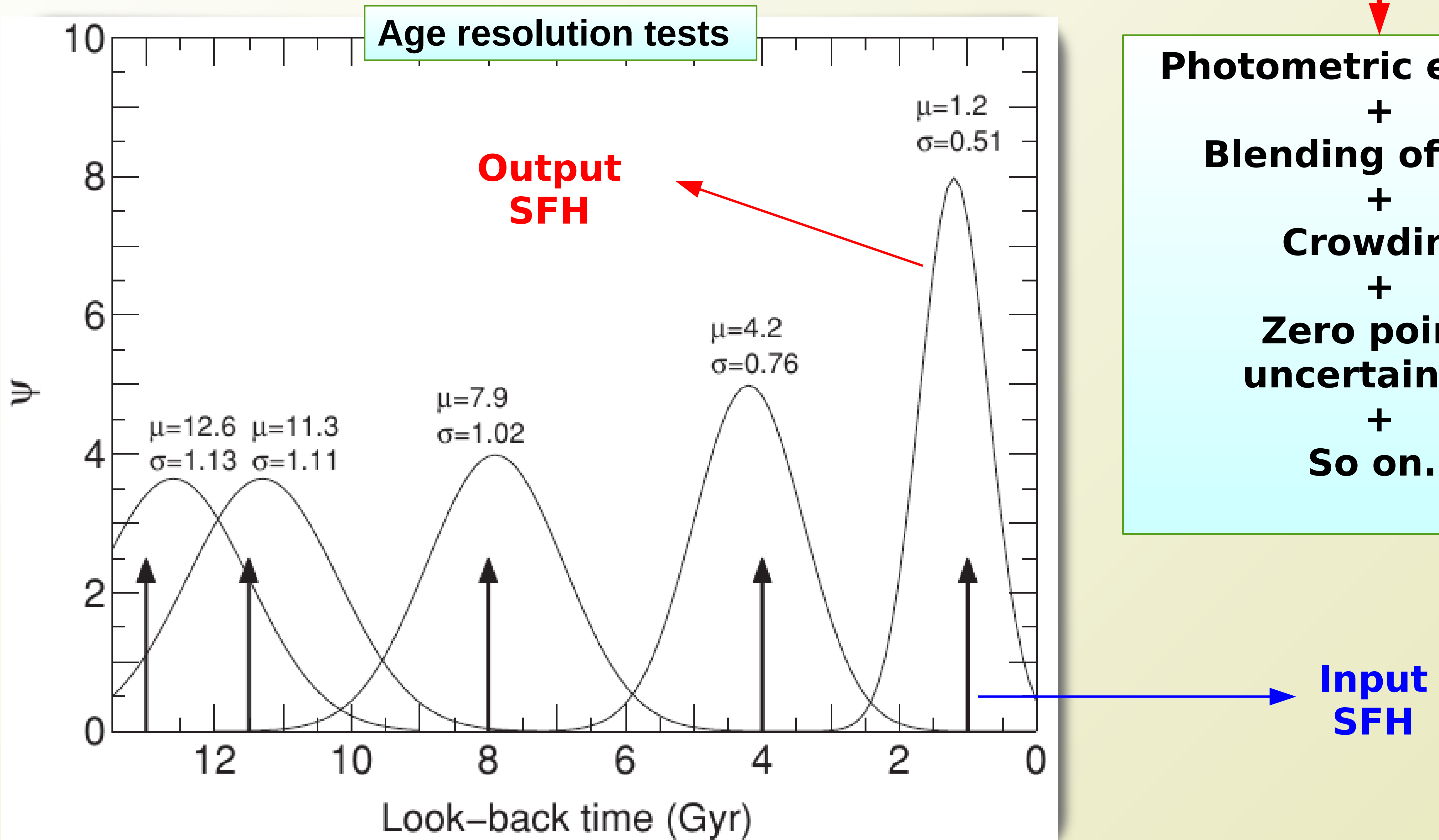
Reionization seems to have not stopped the star formation in any of these galaxies.

Phoenix, Leo-A, and IC1613 have a medium-to-high star formation rate clearly located after the EoR

(1)	M_* $(10^6 M_\odot)$ (2)	L_V $(10^6 L_\odot)$ (3)	σ (kms^{-1}) (4)
Cetus	7.17	2.58	17.0 ± 2.0
Tucana	1.66	0.54	$15.8^{+4.1}_{-3.1}$
LGS-3	2.08	0.94	$7.9^{+3.2}_{-2.4}$
Phoenix	1.29	0.78	...



How do affect the observational effects to the age resolution?

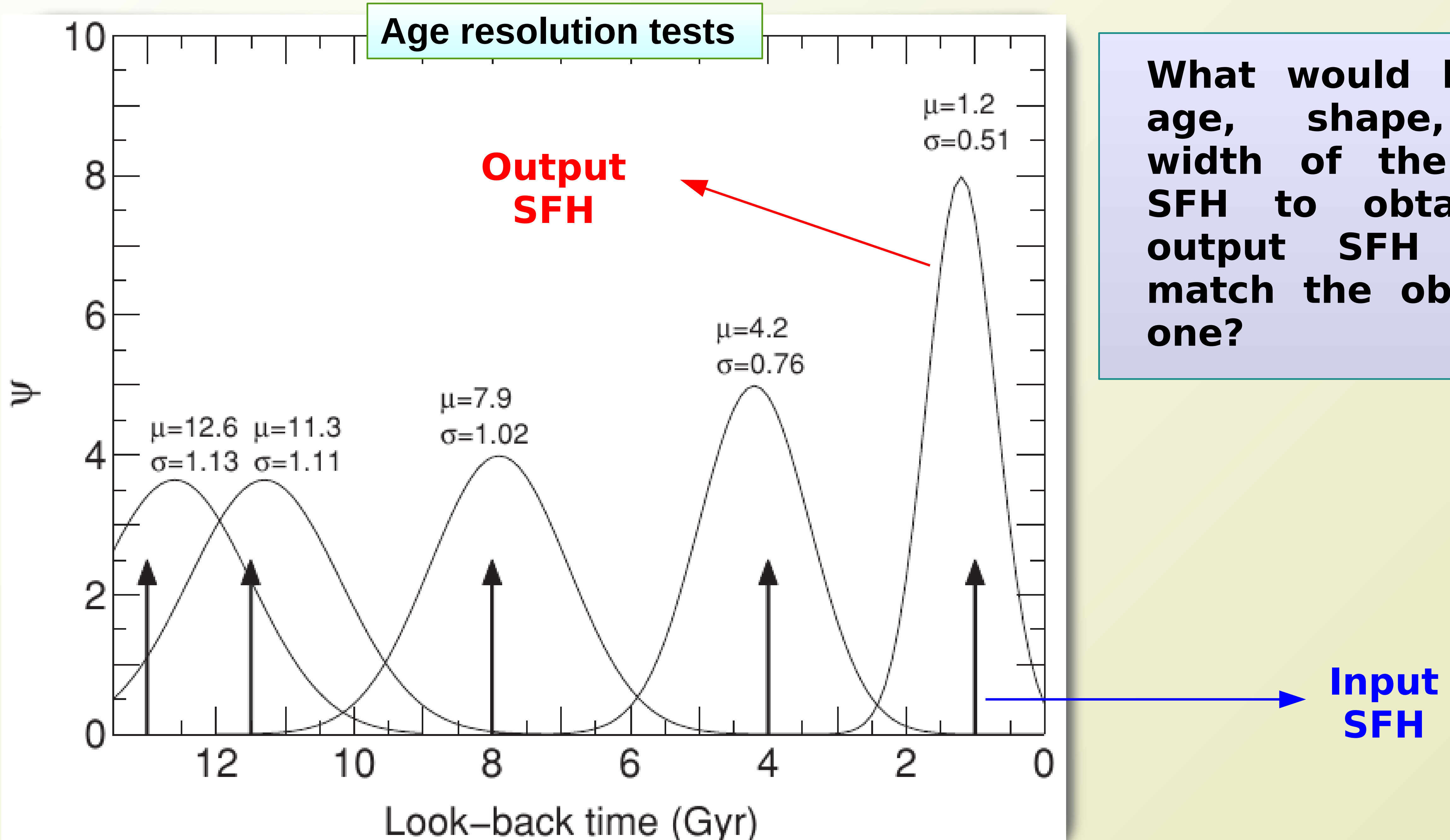


Photometric errors
+
Blending of stars
+
Crowding
+
Zero points uncertainties
+
So on..

Hidalgo+ (2011)

How do affect the observational effects to the age resolution?

Age resolution tests



What would be the age, shape, and width of the input SFH to obtain an output SFH which match the observed one?

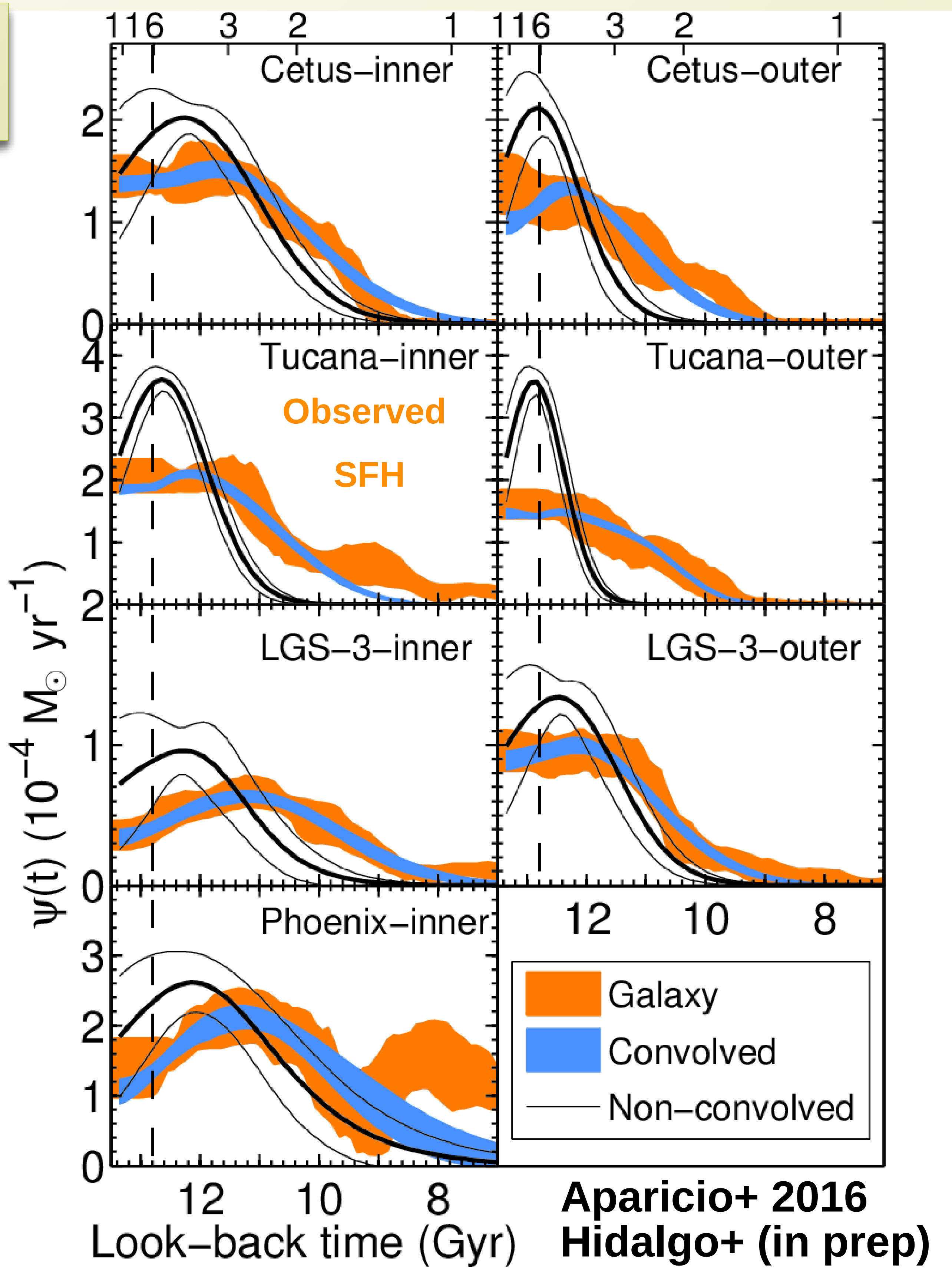
Hidalgo+ (2011)

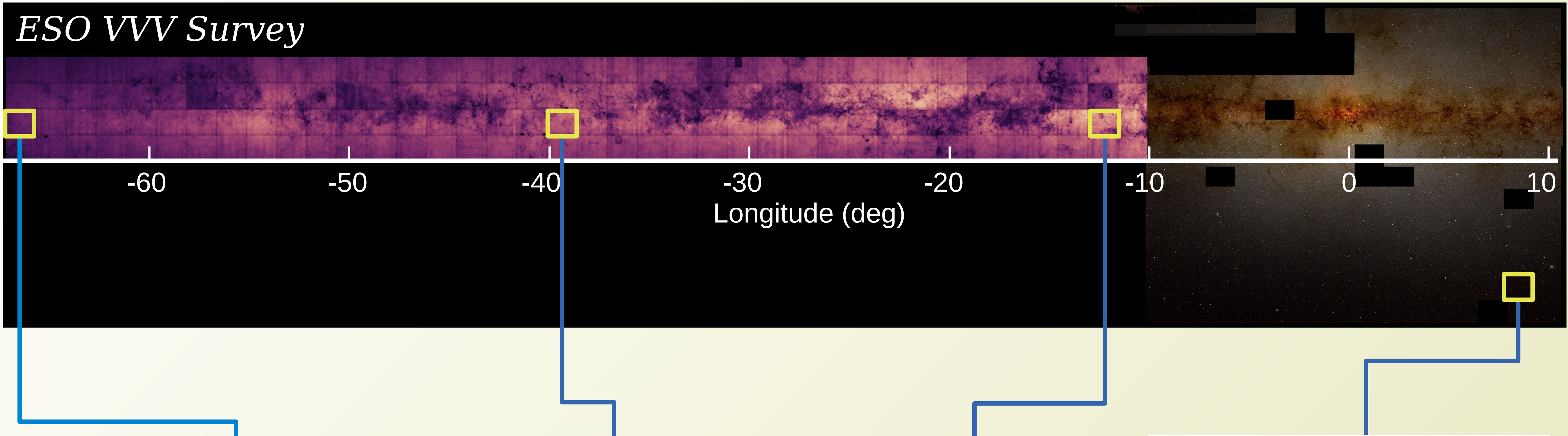
True fossils from the pre-reionization era: $\Psi(t) = 0.7$ at the EoR t ~ 12.7 Gyr. (Bovill & Ricotti 2011)

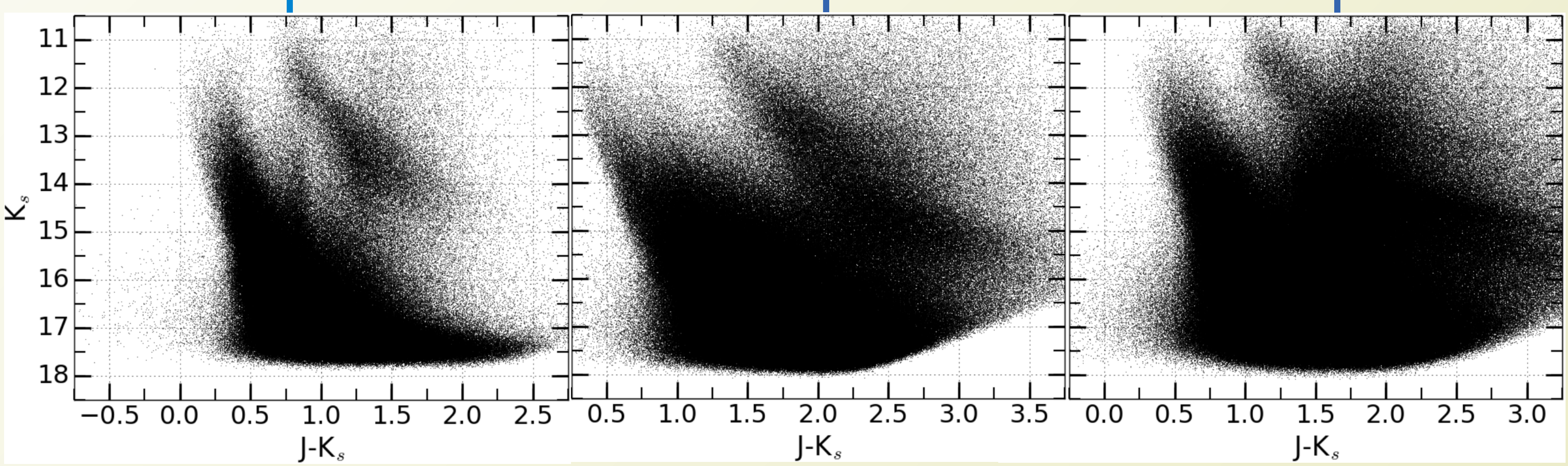
Galaxy field	Age for $\Psi(t)$=0.7 Observational	Age for $\Psi(t)$=0.7 Non-convolved
Cetus inner	$10.9^{+0.2}_{-0.2}$	$11.6^{+0.3}_{-0.4}$
Cetus outer	$11.3^{+0.3}_{-0.6}$	$12.4^{+0.2}_{-0.3}$
Tucana inner	$10.8^{+0.7}_{-0.3}$	$12.1^{+0.1}_{-0.1}$
Tucana outer	$11.5^{+0.4}_{-0.3}$	$12.6^{+0.0}_{-0.1}$
LGS-3 inner	$9.4^{+0.3}_{-0.5}$	$11.4^{+0.4}_{-0.4}$
LGS-3 outer	$11.2^{+0.3}_{-0.2}$	$11.9^{+0.3}_{-0.2}$
Phoenix inner	$7.3^{+0.3}_{-0.2}$	$9.1^{+0.3}_{-0.2}$

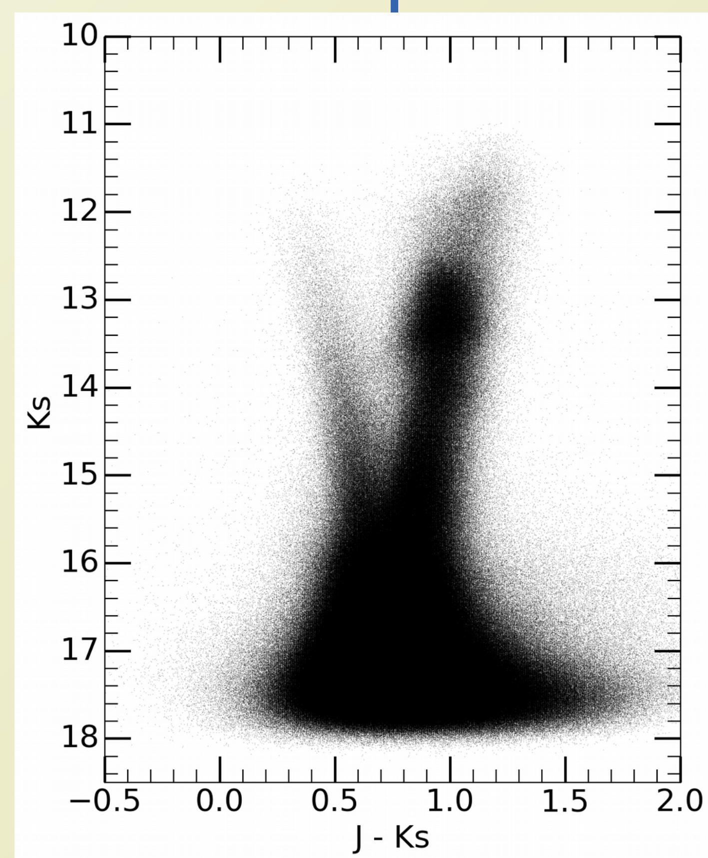
The age of the 0.7 percentile of the mass is shifted towards older ages:

Δt = 1.25 Gyr ~ 40% of the Universe age









- Efşan Sökmen (Sup. Hidalgo & Aparicio, disk)
- Francisco Surot (Sup.: Valenti, bulge)

Where we are now

- Photometry: PSF, DoPHOT+DAOPHOT,
  Alonso-García ,J.; Hidalgo, S.

  DISK: ~300 millions of stars
  BULGE: ~600 millions of stars

- Completeness: On the way, several millions.

  DISK: E. Sökmen (IAC)
  BULGE: F. Surot (ESO-Garching)

- Models for distance and extinction.

  - Hard work to do!

- New stellar evolution library IAC-BaSTI:

  - Wide range in stellar masses and metallicities.
  - New solar abundances (Caffau 2011).
  - Additional alpha enhancement and depleted set of models.
  - Updated physics.

COLLABORATORS

====================================

- Efşan Sökmen (PhD, IAC)
- Antonio Aparicio (IAC-Tenerife)
- Santi Cassisi (INAF-Teramo)
- J. Alonso-García (UAU-Antof.)
- Manuela Zoccali (PUC-Santiago)
- Elena Valenti (ESO-Garching)
- Francisco Surot (PhD, Garching)

SUMMARY

IAC-pop/MinnIAC: a SFH code for multipopulation CMD-fitting

- Recover the age and metallicity distribution of a stellar system using a CMD.

- No constrains in age and metallicity relations are imposed.

The LG is a laboratory to study the formation and evolution of galaxies. By using their SFHs we can analyze:

- The effect of the UV-background in dwarf galaxies: may have affected differently to inner and outer regions.

- But be careful with observational effects...

Bulge + Disk SFH by the eyes of the ESO-VVV survey

- More than 900 millions of stars to analyze.

- The impresive FOV will allow us to search for radial gradients.

- A precise SFH that combined with the GCs and variable stars results would shed light on the formation and evolution of the MW.