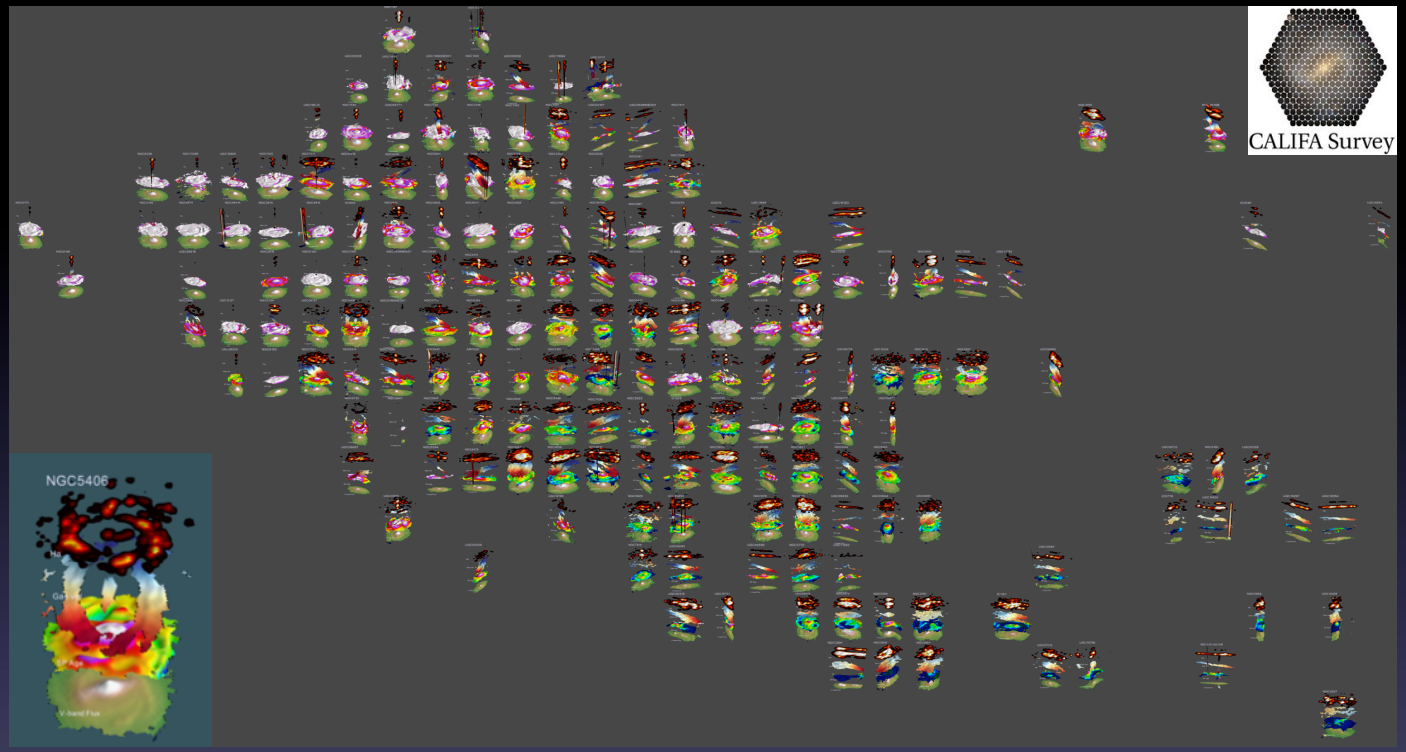
ESTUDIO MULTI-FRECUENCIA DE LAS HISTORIAS DE FORMACIÓN ESTELAR ESPACIALMENTE RESUELTAS DE GALAXIAS EN EL CARTOGRAFIADO DE CAMPO INTEGRAL CALIFA



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Rosa María González Delgado
Roberto Cid Fernandes

Granada – Junio 2013

1

- El proyecto CALIFA

2

- Síntesis evolutiva
- Índices de Lick
- Starlight
- Comparación de ambos métodos

3

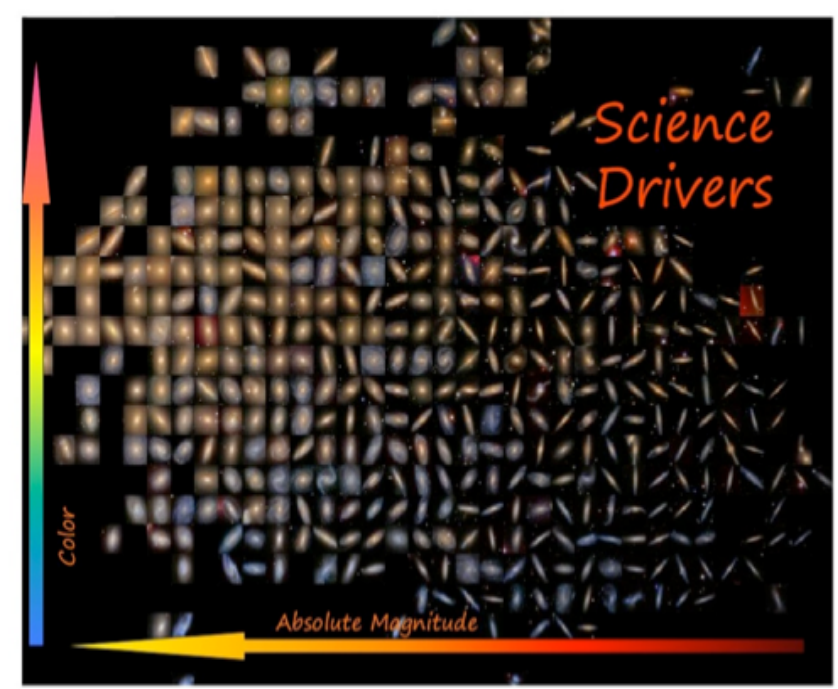
- GALEX: Fotometría

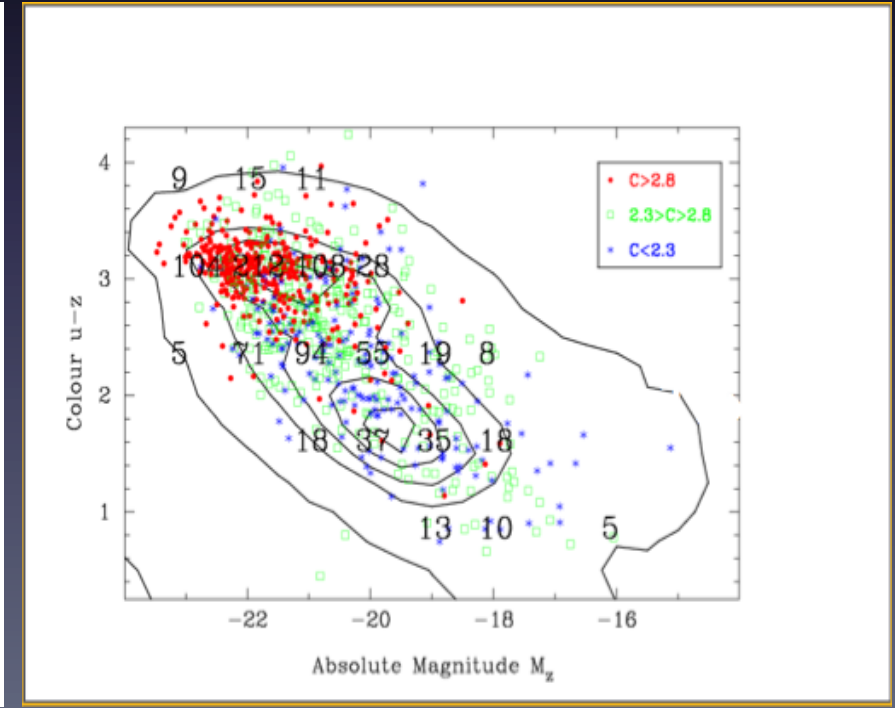
1

- El proyecto CALIFA

CALIFA

- Cartografiado de 600 galaxias
- 0.005 < z < 0.03
- IFS; Instrumento PMAS/PPak en el telescopio de 3.5 m de Calar Alto
- V500 (3745 a 7000 Å; 6 Å (FWHM)); V1200 (3650 a 4840 Å; 2.3 Å (FWHM))
- 331 fibras
- Tamaño de la fibra 2.7 arcsec = 0.5 – 1 kpc
- 3-fold dithering: muestreo final de 1 arcsec (200-300 pc)
- FoV = 74 x 65 arcsec





Objetivos científicos del proyecto:

1. Las poblaciones estelares en galaxias
2. Las propiedades químicas del gas ionizado
3. Las propiedades cinemáticas del gas y las estrellas

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CALIFA, the Calar Alto Legacy Integral Field Area survey:

II. First public data release⋆

B. Husemann[1], S. F. Sánchez[2,3], K. Jahnke[4], D. Barrado-Navascues[3], S. Bekeraité[1], A. Castillo-Morales[5], C. Catalán-Torrecilla[5], R. Cid Fernandes[6], J. Falcón-Barroso[7,8], R. García Benito[2], R. M. González Delgado[2], J. Iglesias-Páramo[2,3], B. D. Johnson[9], D. Kupko[1], R. López-Fernandez[2], M. Lyubenova[4], R. A. Marino[10], D. Mast[3], A. Miskolczi[11], A. Monreal-Ibero[2], A. Gil de Paz[5], E. Pérez[2], I. Pérez[12,13], F. F. Rosales-Ortega[16], T. Ruiz-Lara[12], U. Schilling[11], G. van de Ven[4], J. Walcher[1], J. Alves[14], A. L. de Amorim[6], N. Backsmann[1], J. K. Barrera-Ballesteros[7], J. Bland-Hawthorn[17], D. J. Bomans[11,15], R.-J. Dettmar[11], M. Demleitner[18], A. I. Díaz[16], H. Enke[1], E. Florido[12,13], L. Galbany[19], A. Gallazzi[20], B. García-Lorenzo[7,8], J. M. Gomes[21], N. Gruel[22], T. Haines[23], L. Holmes[24], C. Kehrig[2], R. C. Kennicutt Jr[25], J. Klar[1], M. D. Lehnert[26], A. de Lorenzo-Cáceres[8], E. Mármol-Queraltó[7,8], I. Márquez[2], J. Mendez-Abreu[7,8], M. Mollá[10], A. del Olmo[2], S. E. Meidt[4], P. Papaderos[21], J. Puschnig[14], A. Quirrenbach[27], M. M. Roth[1], P. Sánchez-Blázquez[16], K. Spekkens[24], R. Singh[4], V. Stanishev[19], S. C. Trager[28], J. M. Vilchez[2], V. Wild[29], L. Wisotzki[1], S. Zibetti[30], and B. Ziegler[14]

(Affiliations can be found after the references)

October 13, 2012

ABSTRACT

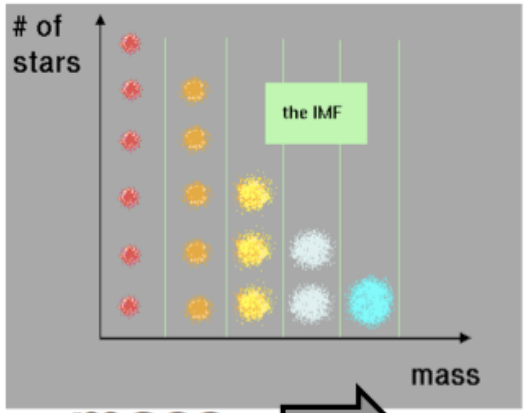
We present the first public data release (DR1) of the Calar Alto Legacy Integral Field Area (CALIFA) survey. It consists of science-grade validated optical datacubes for the first 100 of eventually 600 nearby ($0.005 < z < 0.03$) galaxies, obtained with the integral-field spectrograph PMAS/PPak mounted on the 3.5m telescope at the Calar Alto observatory. The galaxies in DR1 already cover a wide range of properties across the color-magnitude diagram, in morphological type, in stellar mass, and gas ionization conditions. This offers the potential to tackle a variety of open questions in the galaxy evolution framework using spatially resolved spectroscopy. Two different spectral setups are available for each galaxy, (i) a low-resolution V500 setup covering the nominal wavelength range 3745–7500Å with a spectral resolution of 6.0Å (FWHM), and (ii) a medium-resolution V1200 setup covering the nominal wavelength range 3650–4840Å with a spectral resolution of 2.3Å (FWHM). We present the characteristics and data structure of CALIFA datasets that should be taken into account for proper scientific exploitation of the data, in particular the effects of vignetting, bad pixels and spatially correlated noise. **The data quality test for all 100 galaxies showed that we reach a median limiting continuum sensitivity of** 1.0 **and** 2.2×10^{-18} erg s^{-1} cm^{-2} Å^{-1} arcsec^{-2} **at 5635Å for the V500 and at 4500Å for the V1200 setup, respectively, which corresponds to a limiting** *r* **and** *g* **band surface brightness of** 23.6 mag arcsec^{-2} **and** 23.4 mag arcsec^{-2} **or an unresolved emission-line flux detection limit of roughly** 1×10^{-17}, erg s^{-1} cm^{-2} arcsec^{-2} **and** 0.6×10^{-17}, erg s^{-1} cm^{-2} arcsec^{-2}**. The median spatial resolution is 3.″7 in the median, and the mean spectrophotometric calibration is accurate to better than 15%.** Finally, we also describe the available interfaces and tools that allow easy access to this first public CALIFA survey data at `http://califa.caha.es/DR1`.

Key words. techniques: spectroscopic - galaxies: general - surveys

2

- Síntesis evolutiva

Stellar populations are modeled with synthesis models



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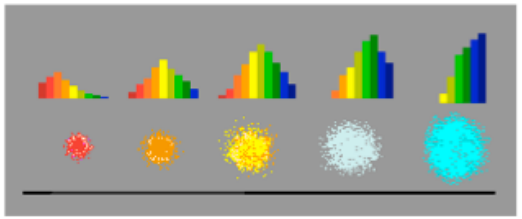

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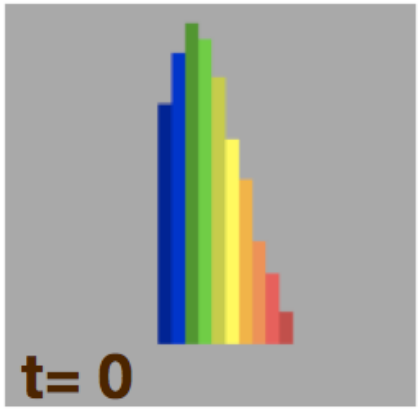
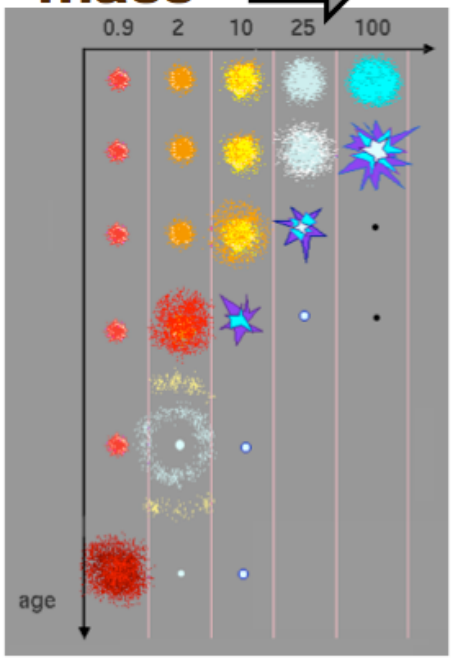


mass



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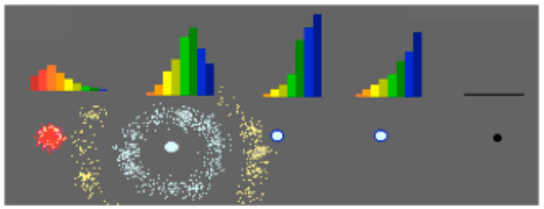

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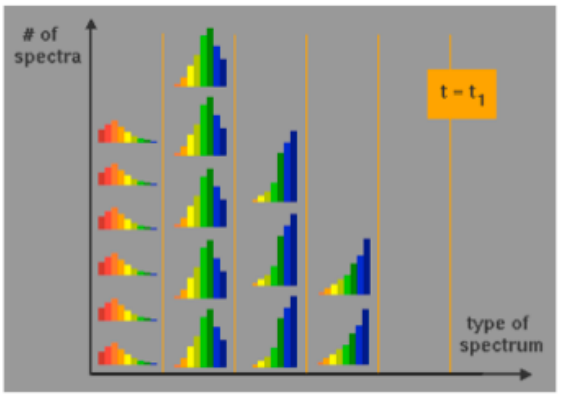
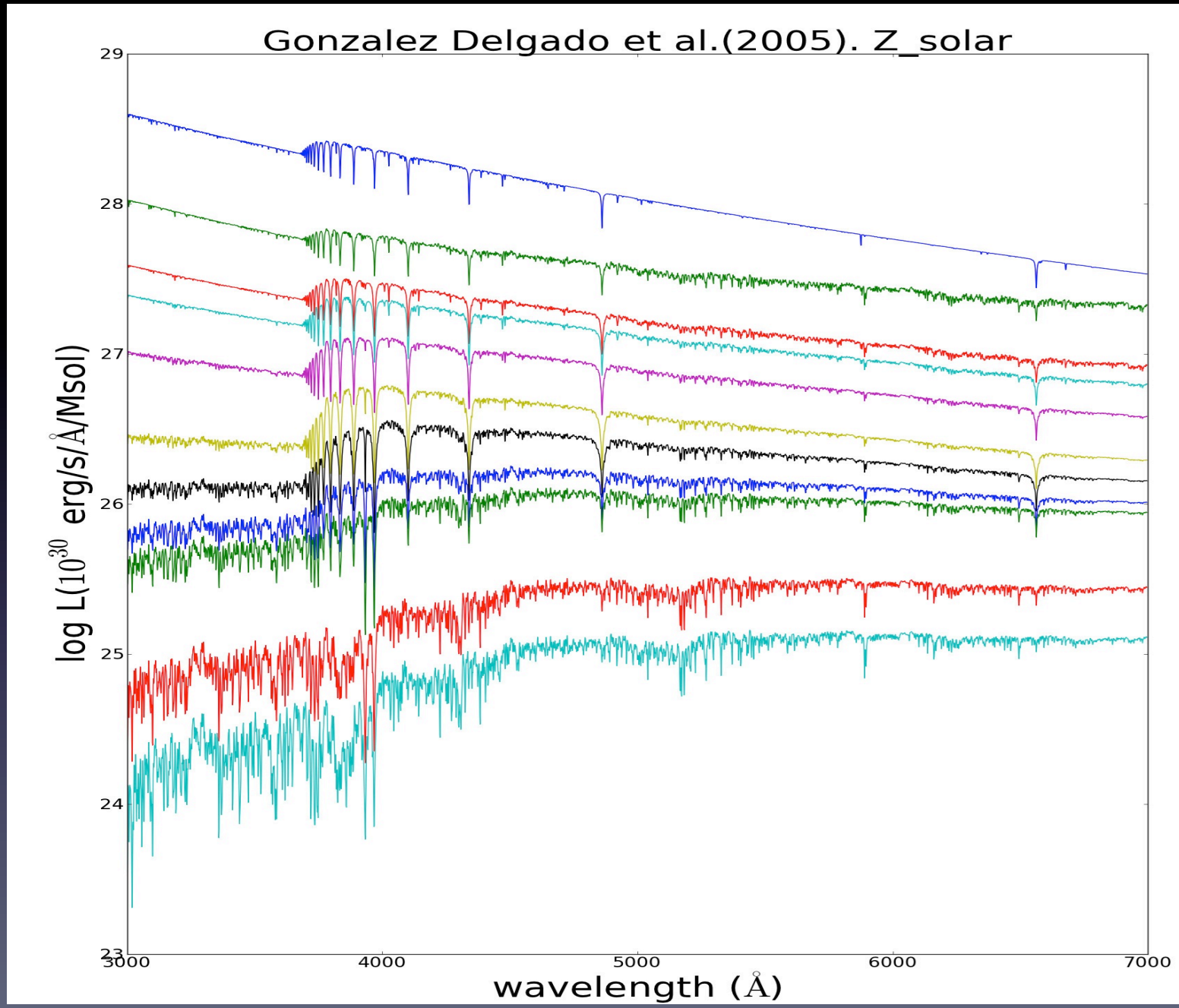


SSP = function (IMF, tracks, stellar libraries...)

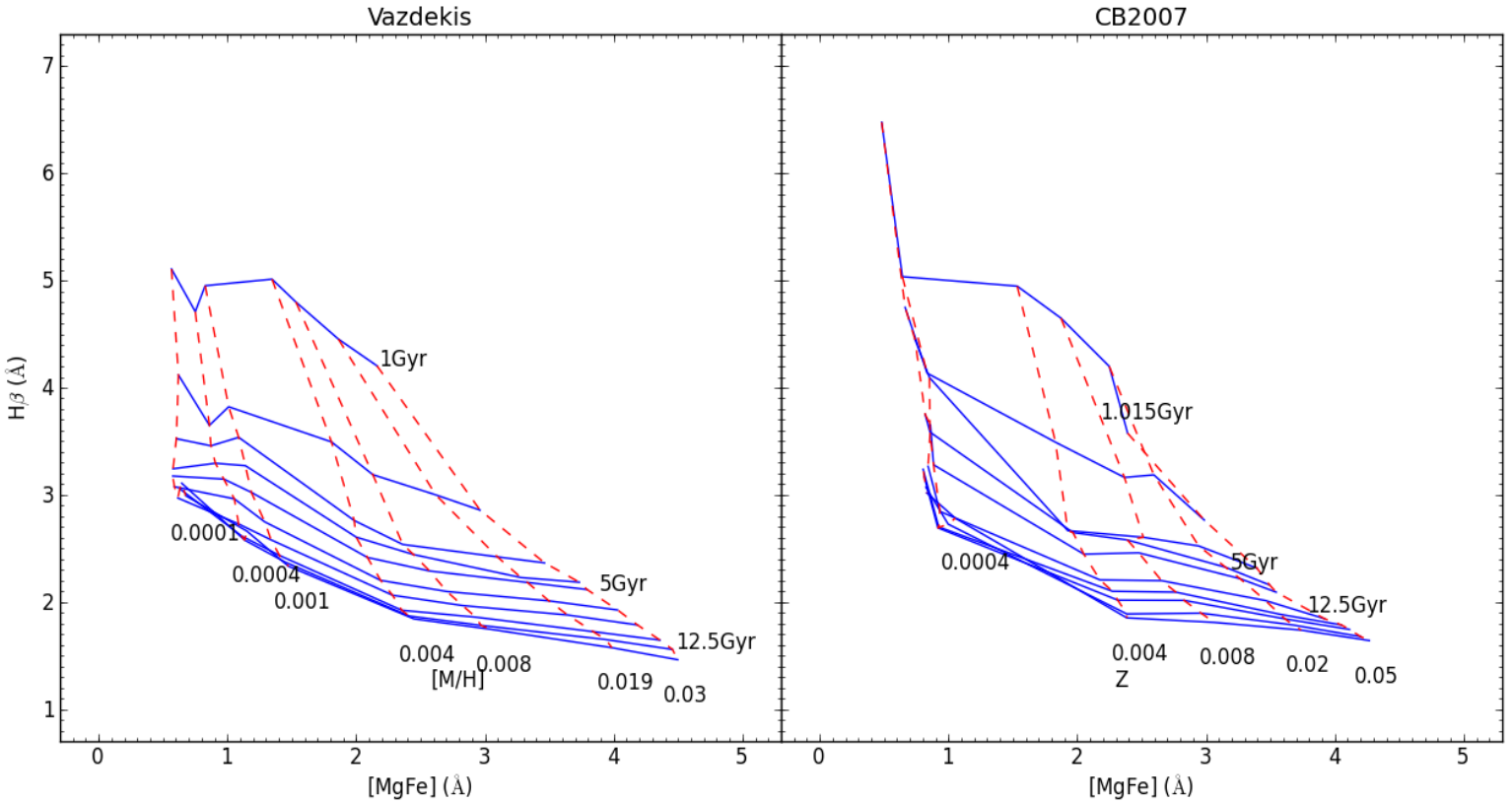
@Luridiana & Cerviño

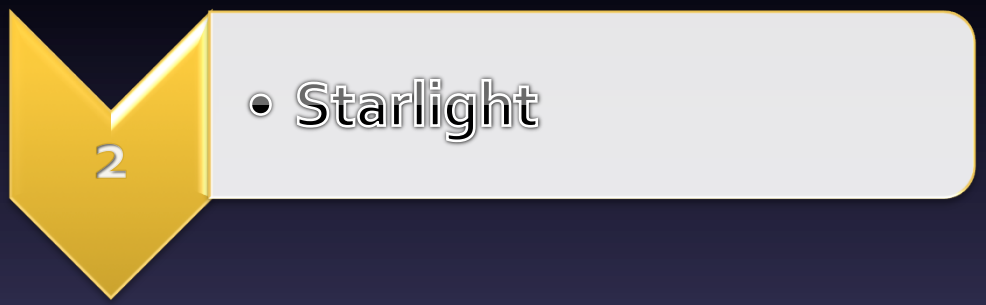

Gonzalez Delgado et al.(2005). Z_solar
log L(10^30 erg/s/Å/Msol)
wavelength (Å)
29
28
27
26
25
24
23
3000
4000
5000
6000
7000

2

- Índices de Lick

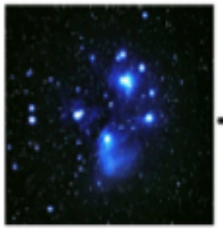
Índices que se utilizan tradicionalmente: Hb y MgFe




2
• Starlight

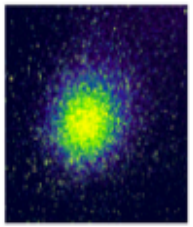
'Fossil record'

$= M_1$



$+ M_2$

$+ M_3$



$+ \ldots$

$$L_{gal}(\lambda) = \sum_{t,Z} M_{SSP}(t,Z) \times SSP(\lambda ; t,Z)$$

☺ ***Observables***

Full spectrum or indices

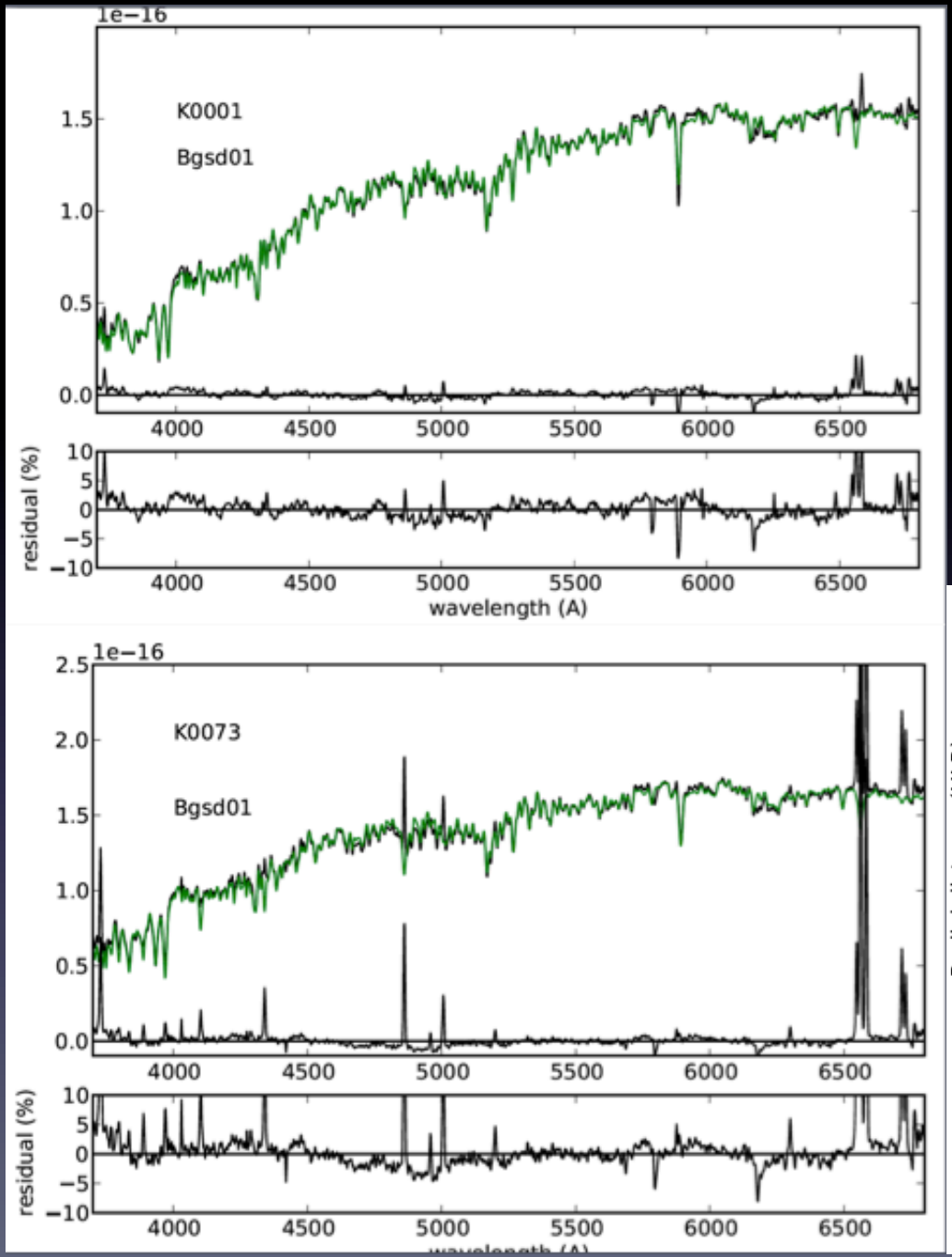
(F_λ, B-V, Mg_2 ...)

Star Formation History + Chemical Evolution (inversion methods)

☺ ***Spectral Base***

Model or Observed SSPs / star-clusters

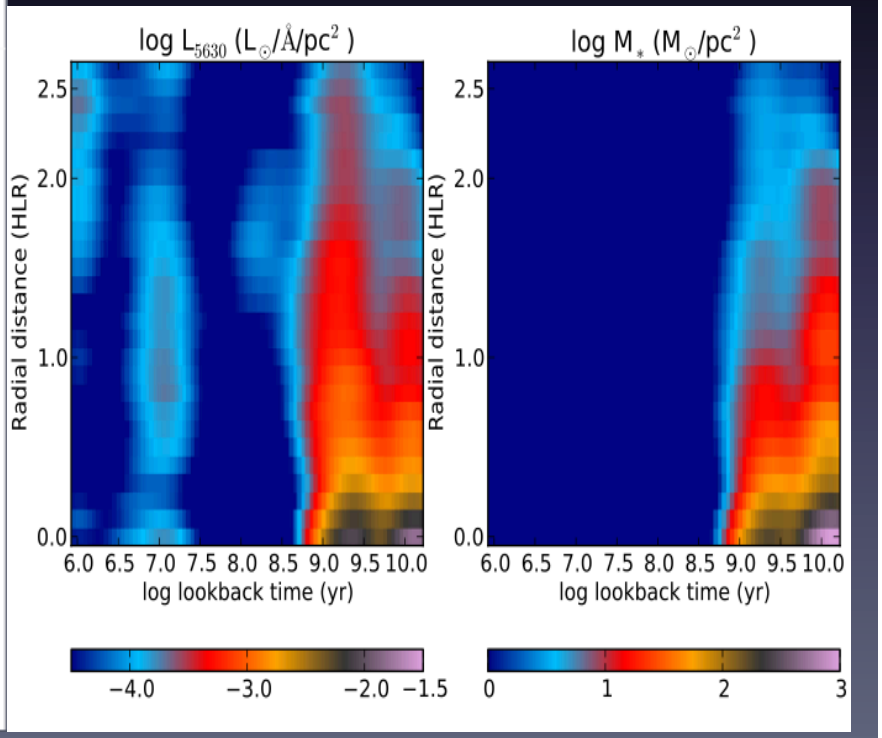
(BC03, SED@,...)

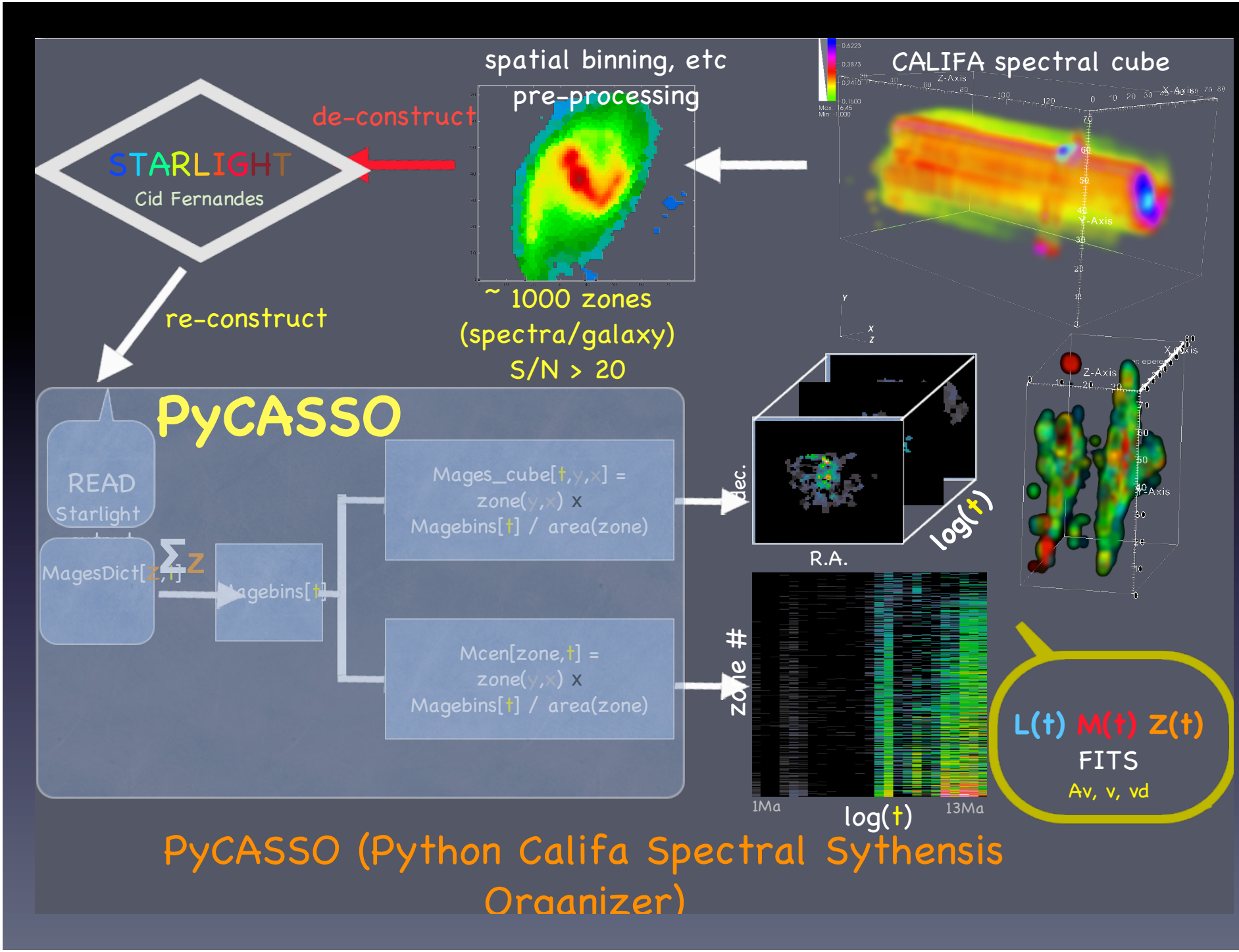


STARLIGHT – para ajustar el continuo estelar
(Cid Fernandes et al. 2005)

Salida de STARLIGHT: SFH

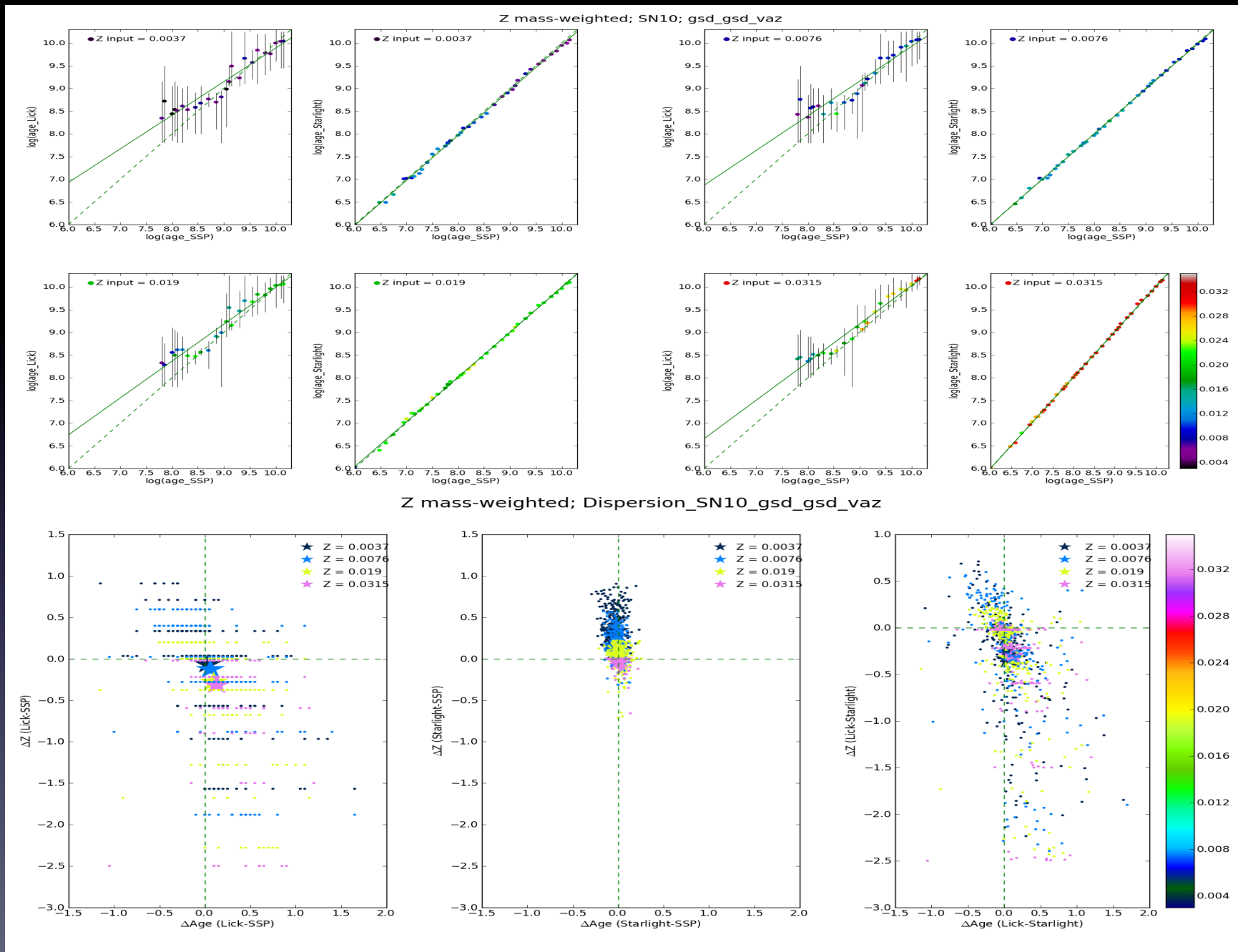
- Fracción de masa
- Fracción de luz
- Edades
- Metalicidades
- Extinción estelar, Av




spatial binning, etc
pre-processing
CALIFA spectral cube
de-construct
STARLIGHT
Cid Fernandes
~ 1000 zones
(spectra/galaxy)
S/N > 20
re-construct
PyCASSO
READ
Starlight
MagesDict[z,t]
Σz
Magebins[t]
Mages_cube[t,y,x] =
zone(y,x) x
Magebins[t] / area(zone)
Mcen[zone,t] =
zone(y,x) x
Magebins[t] / area(zone)
dec.
R.A.
log(t)
zone #
1Ma
log(t)
13Ma
L(t) M(t) Z(t)
FITS
Av, v, vd
PyCASSO (Python Califa Spectral Sythensis
Oraanizer)

2

- Comparación de ambos métodos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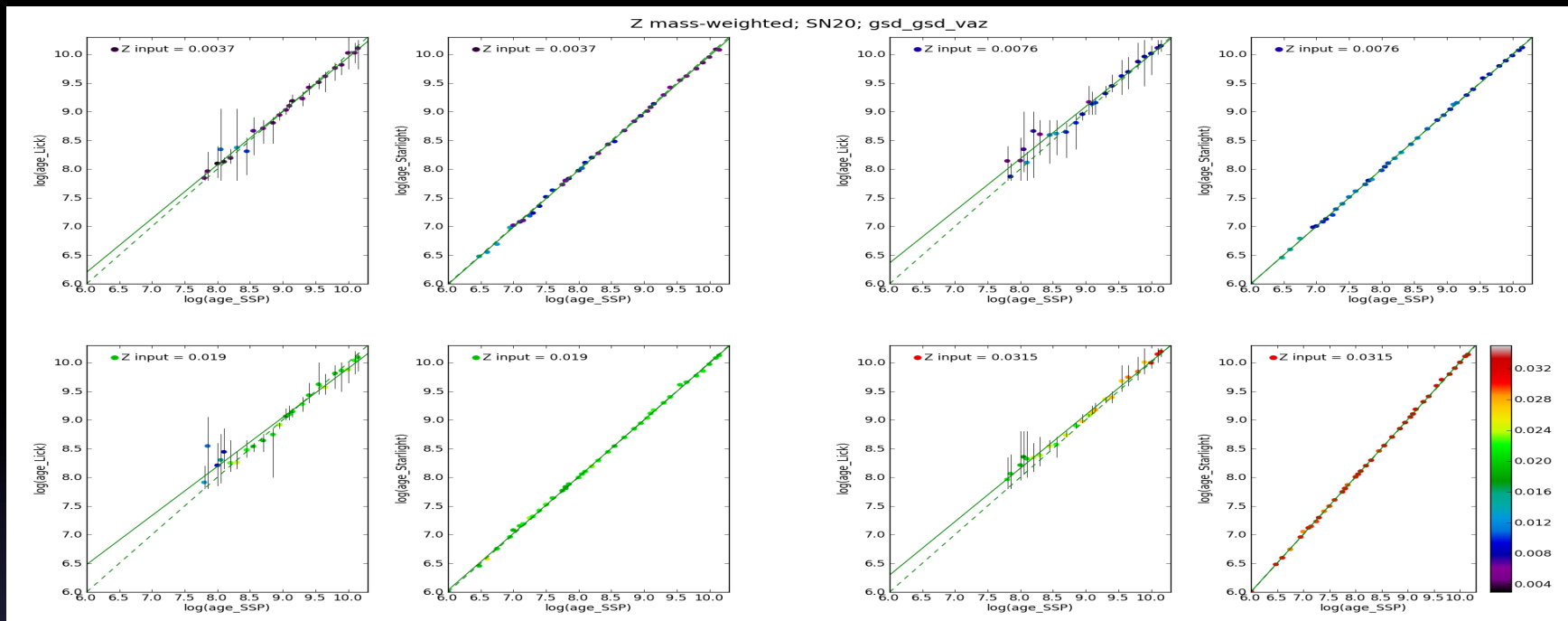
Z input = 0.0037
Z input = 0.0037
Z input = 0.0076
Z input = 0.0076
Z input = 0.019
Z input = 0.019
Z input = 0.0315
Z input = 0.0315
log(age_Lick)
log(age_Starlight)
log(age_SSP)
Z mass-weighted; Dispersion_SN10_gsd_gsd_vaz
Z = 0.0037
Z = 0.0076
Z = 0.019
Z = 0.0315
ΔZ (Lick-SSP)
ΔAge (Lick-SSP)
ΔZ (Starlight-SSP)
ΔAge (Starlight-SSP)
ΔZ (Lick-Starlight)
ΔAge (Lick-Starlight)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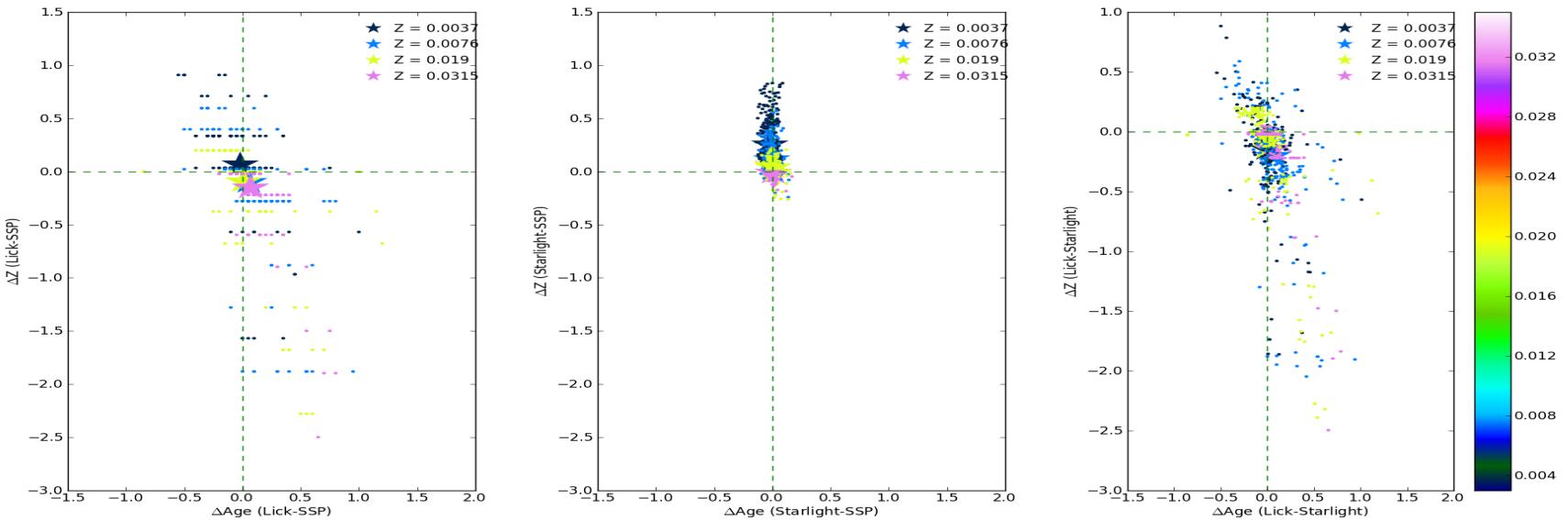
Z input = 0.0076
Z input = 0.0076
Z input = 0.019
Z input = 0.019
Z input = 0.0315
Z input = 0.0315
log(age_Lick)
log(age_Starlight)
log(age_SSP)


Z mass-weighted; Dispersion_SN20_gsd_gsd_vaz
Z = 0.0037
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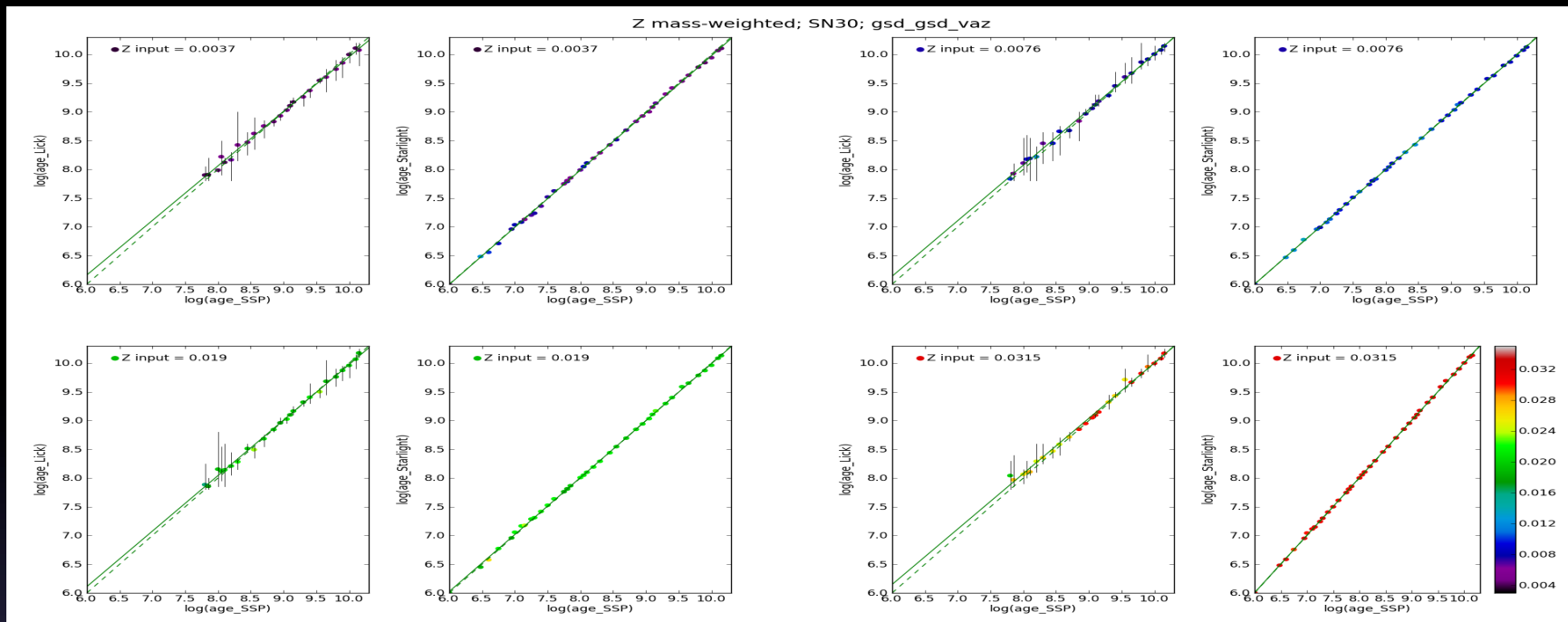
Z = 0.019
Z = 0.0315
ΔZ (Lick-SSP)
ΔAge (Lick-SSP)
ΔZ (Starlight-SSP)
ΔAge (Starlight-SSP)
ΔZ (Lick-Starlight)
ΔAge (Lick-Starlight)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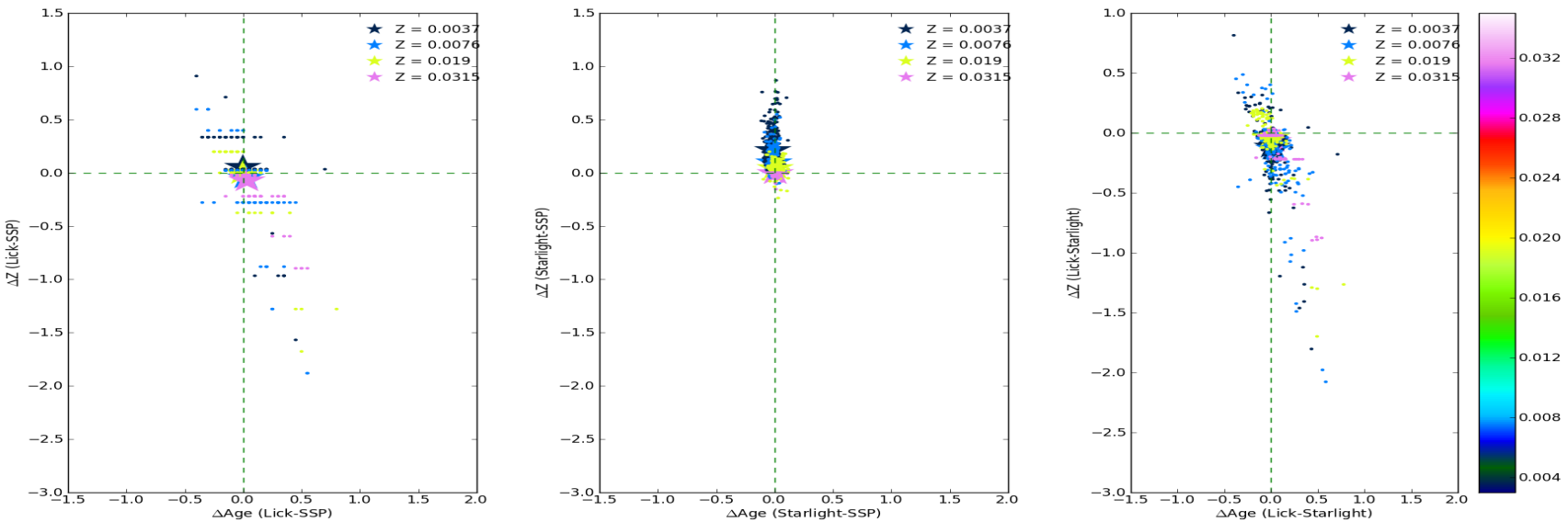
Z input = 0.0315
log(age_Lick)
log(age_Starlight)
log(age_SSP)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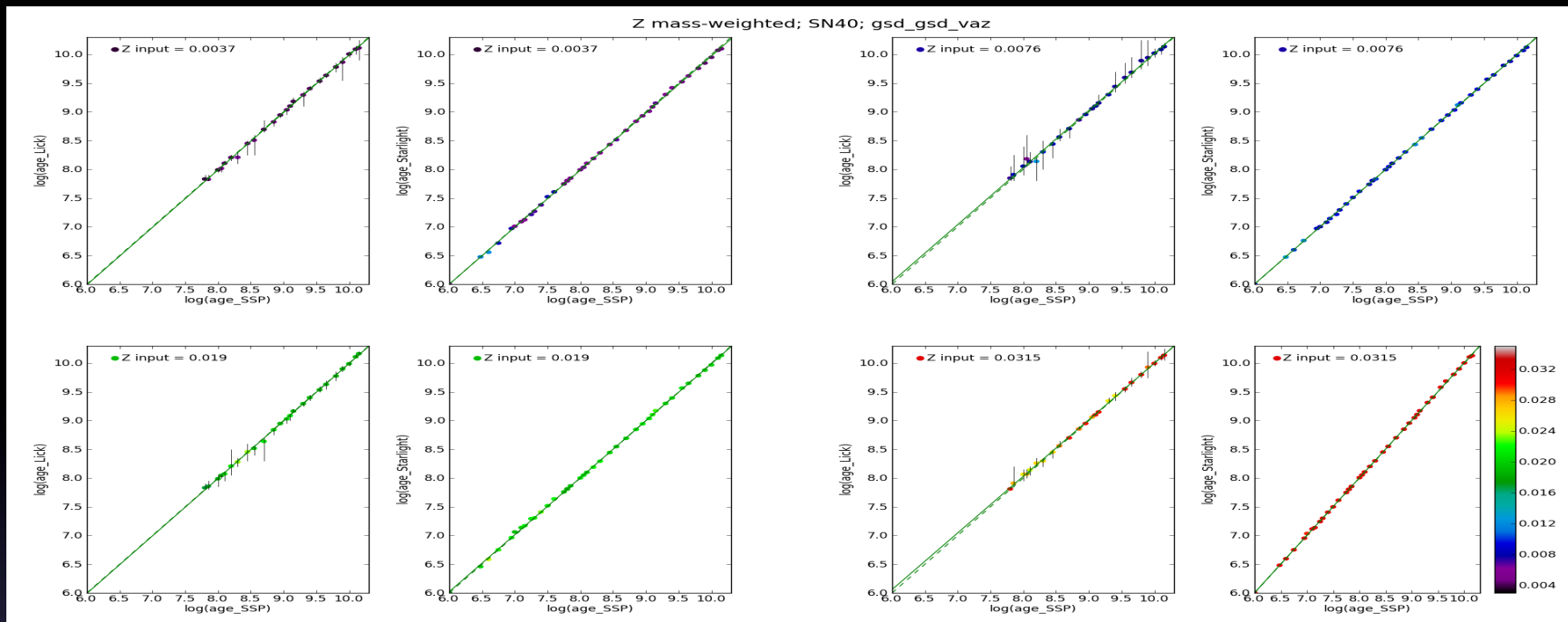
Z = 0.0315
ΔZ (Lick-SSP)
ΔAge (Lick-SSP)
ΔZ (Starlight-SSP)
ΔAge (Starlight-SSP)
ΔZ (Lick-Starlight)
ΔAge (Lick-Starlight)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Z input = 0.0076
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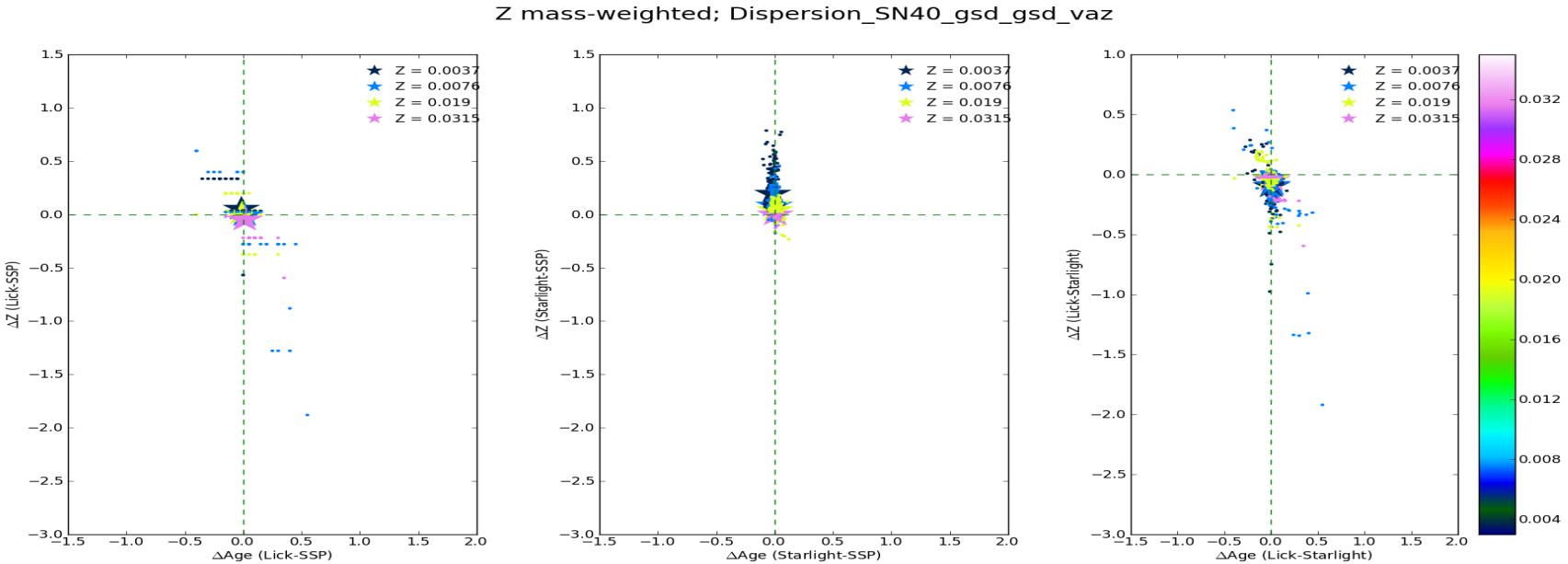
Z input = 0.0315
Z input = 0.0315
log(age_Lick)
log(age_Starlight)
log(age_SSP)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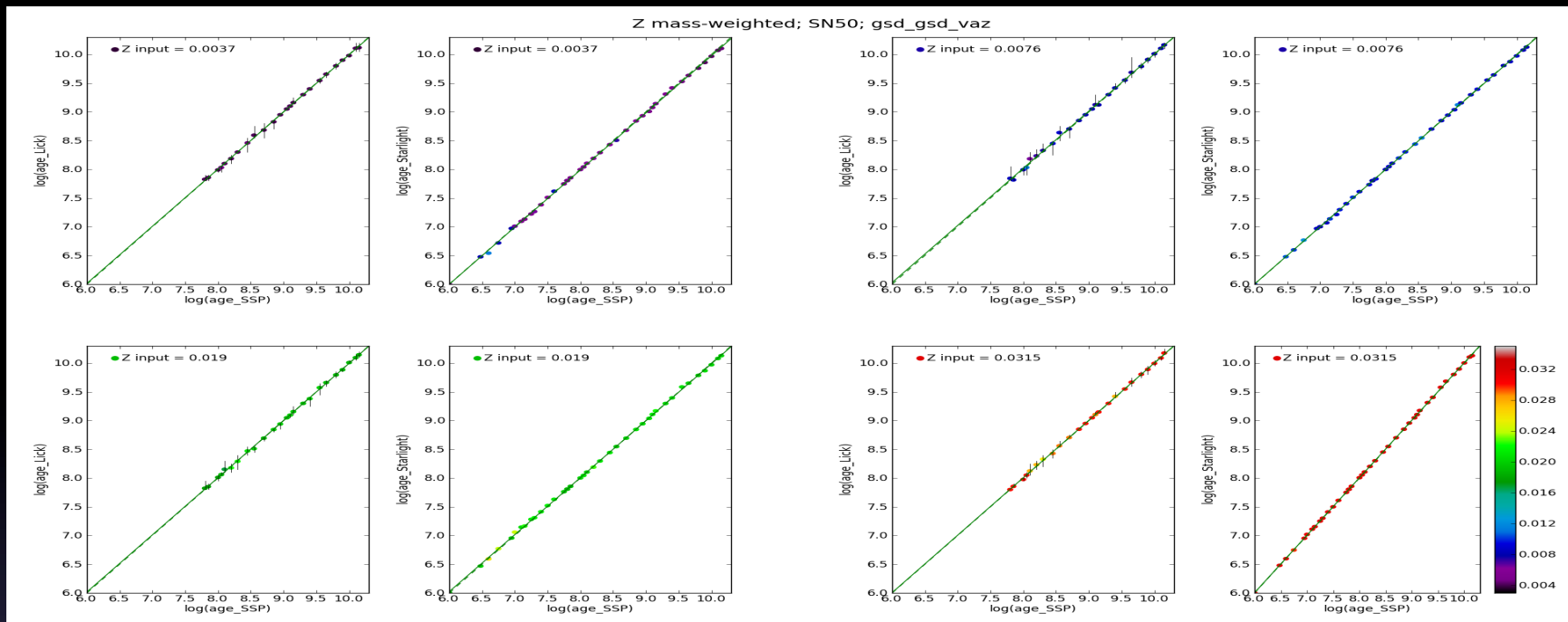
Z = 0.0076
Z = 0.019
Z = 0.0315
ΔZ (Lick-SSP)
ΔAge (Lick-SSP)
ΔZ (Starlight-SSP)
ΔAge (Starlight-SSP)
ΔZ (Lick-Starlight)
ΔAge (Lick-Starlight)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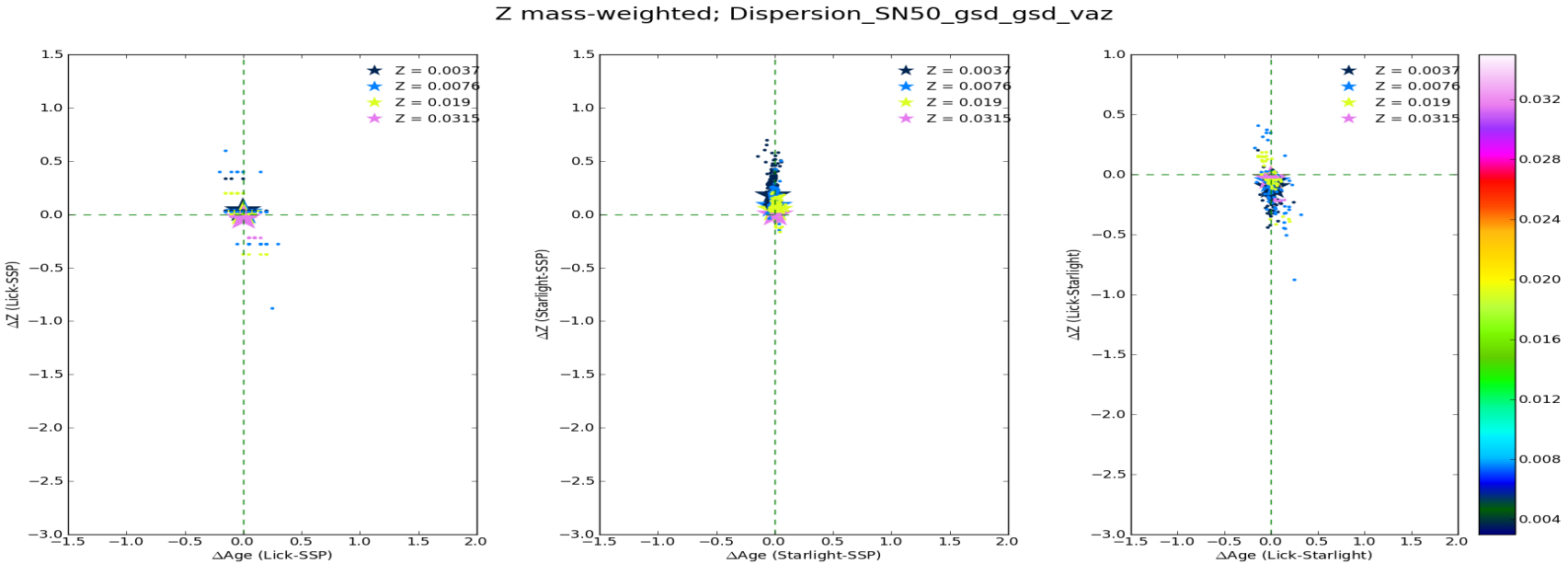
Z input = 0.0076
Z input = 0.0076
Z input = 0.019
Z input = 0.019
Z input = 0.0315
Z input = 0.0315
log(age_Lick)
log(age_Starlight)
log(age_SSP)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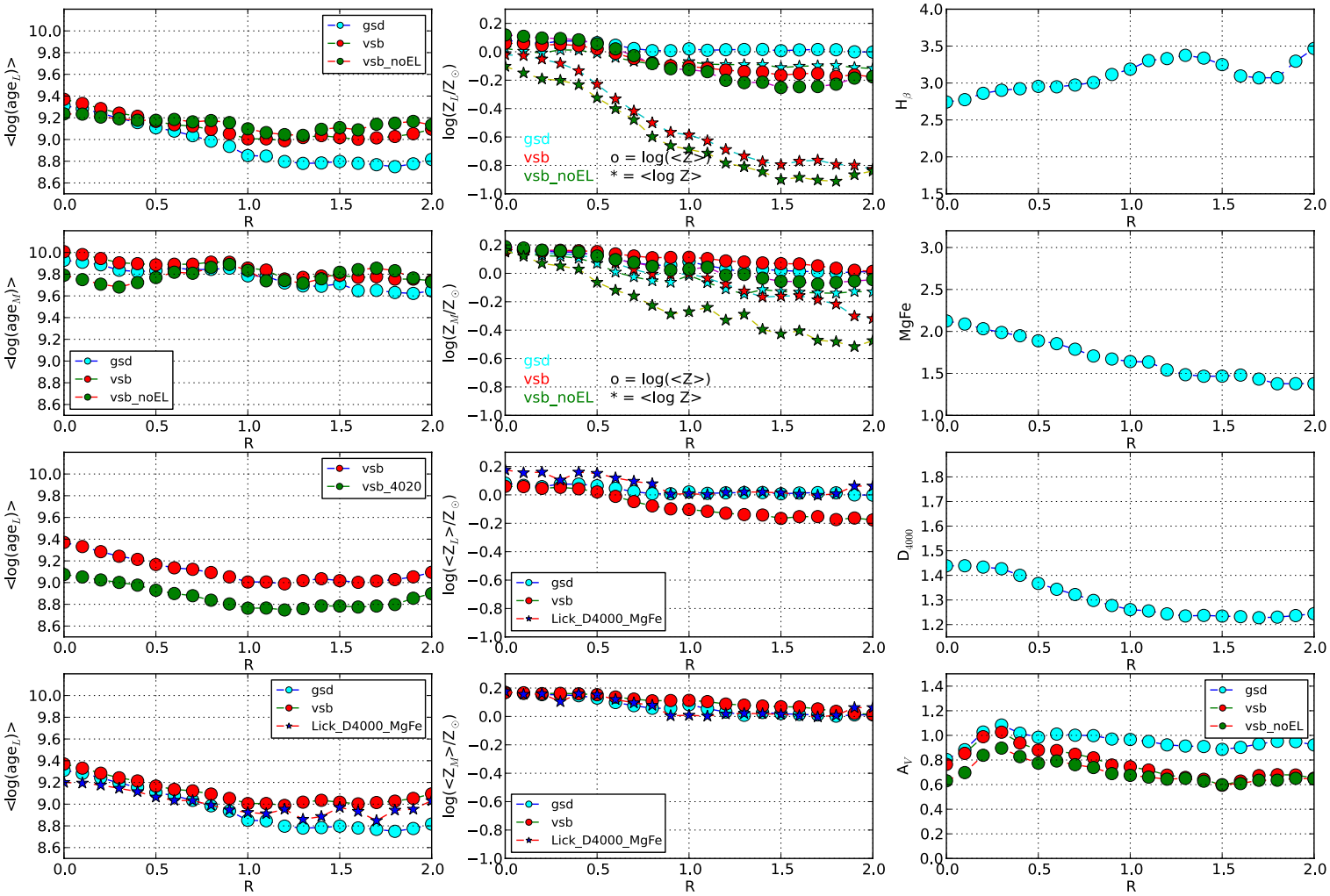
Z = 0.019
Z = 0.0315
ΔZ (Lick-SSP)
ΔAge (Lick-SSP)
ΔZ (Starlight-SSP)
ΔAge (Starlight-SSP)
ΔZ (Lick-Starlight)
ΔAge (Lick-Starlight)

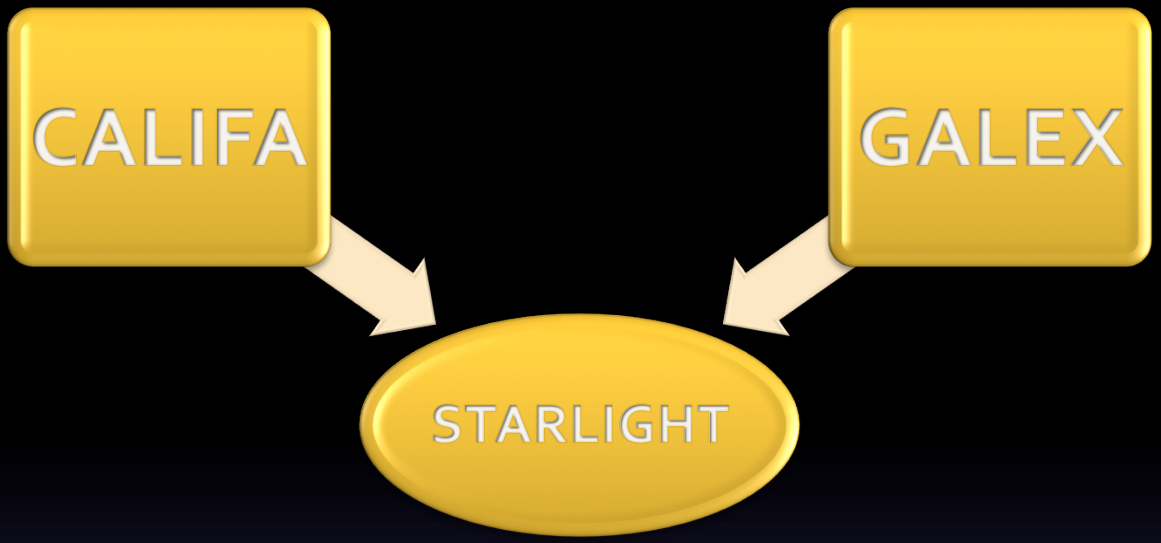
Spiral

K0008



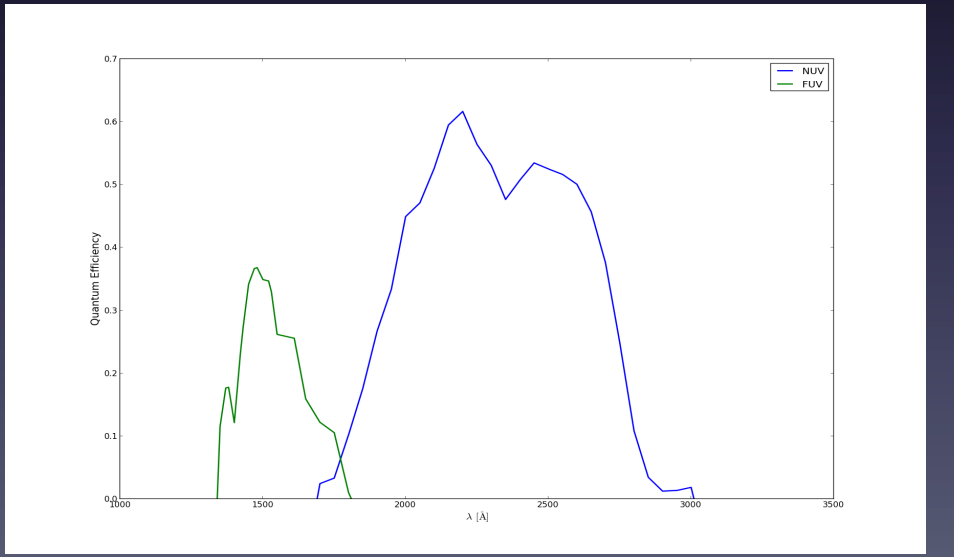
3

- GALEX: Fotometría



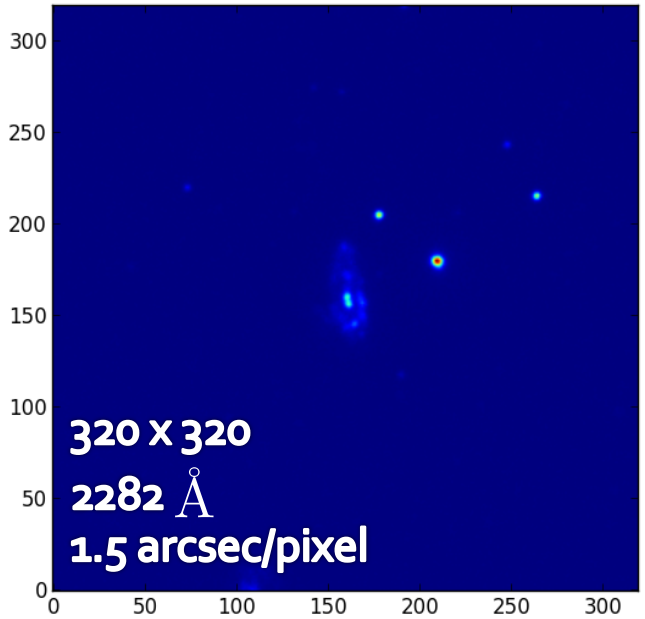
GALAXY EVOLUTION EXPLORER:

- Telescopio espacial de la NASA dedicado a observar galaxias en longitudes de onda ultravioleta.
- Se lanzó el 28 de abril de 2003.
- Pesa 280 kg. Mide 2 m de largo por 2.8 m de ancho.
- FoV: 1.2 grados
- Dos filtros: FUV y NUV

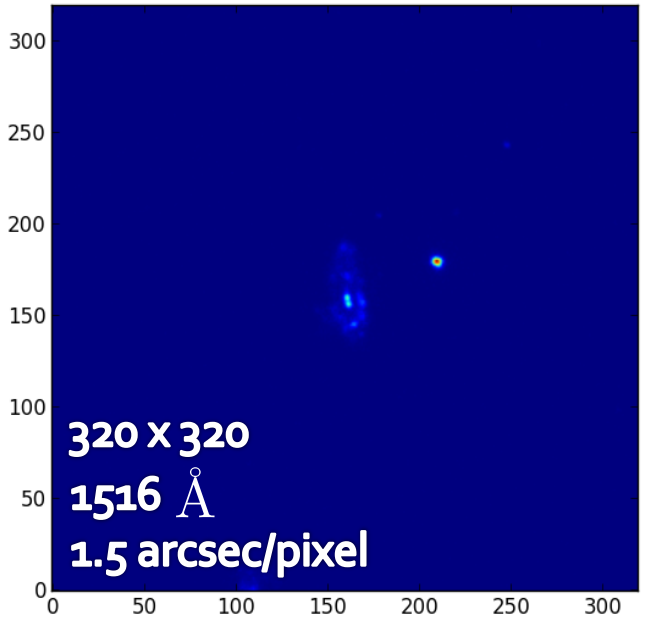


K0014

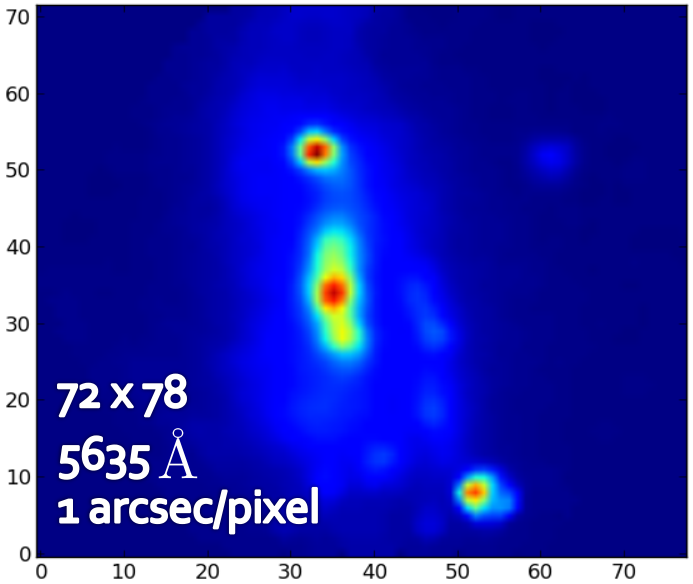
NUV



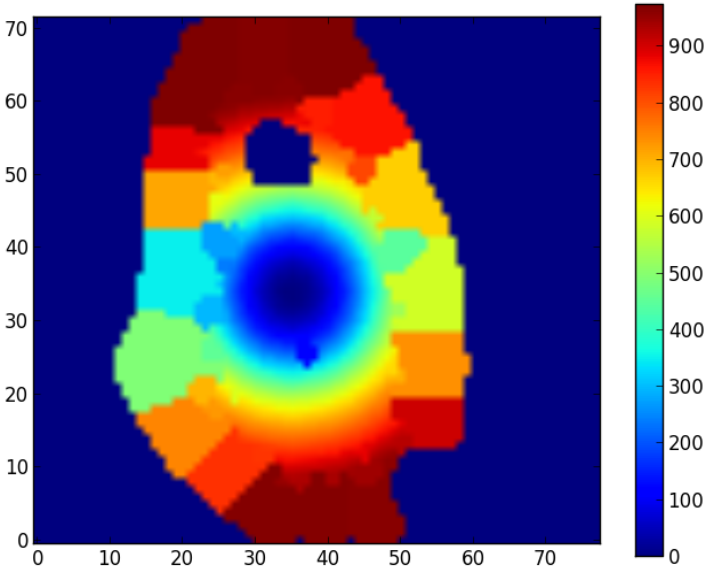
FUV



CALIFA



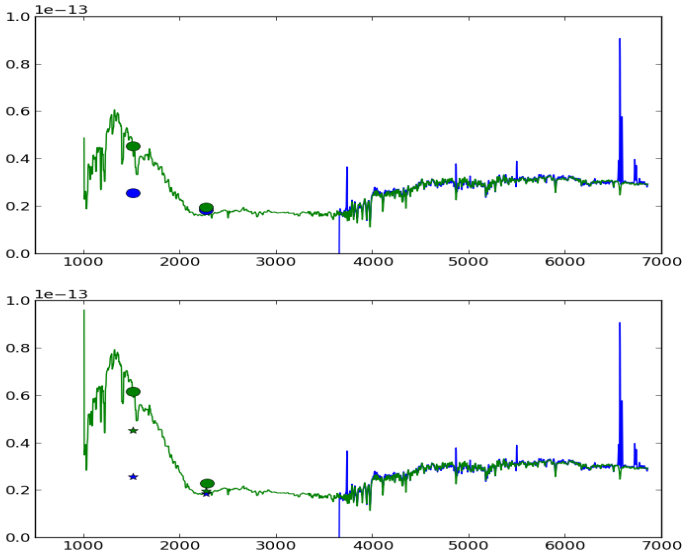
ZONES



K0073 Integrated_voronoi Spectrum

PHO-FIT	Extinction law = CCM	
logY_obs_NUV = 6.3493	ModlogY_NUV = 6.3761	ErrlogY_NUV = 0.5825
logY_obs_FUV = 6.4941	ModlogY_FUV = 6.7416	ErrlogY_FUV = 0.84
A_V = 0.6101	log_age = 8.8756	Z = 0.0403
Q(H)_ha = 4.805e+53	SFR_Oti(Ha) = 5.747	SFR_Kennicutt(Ha) = 3.829
Q(H)_syn = 1.564E+53	SFR_Oti(syn) = 2.522	

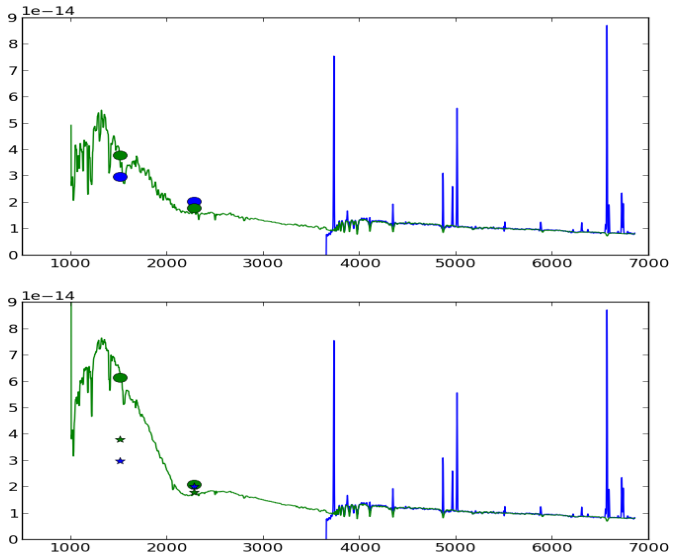
OPT-FIT	Extinction law = CCM	
A_V = 0.6519	log_age = 8.8263	Z = 0.0456
NUV = 6.4443	ModlogY_NUV = 6.3761	
FUV = 6.8764	ModlogY_FUV = 6.7416	
Q(H)_ha = 4.805e+53	SFR_Oti(Ha) = 5.747	SFR_Kennicutt(Ha) = 3.828
Q(H)_syn = 3.419E+54	SFR_Oti(syn) = 55.139	



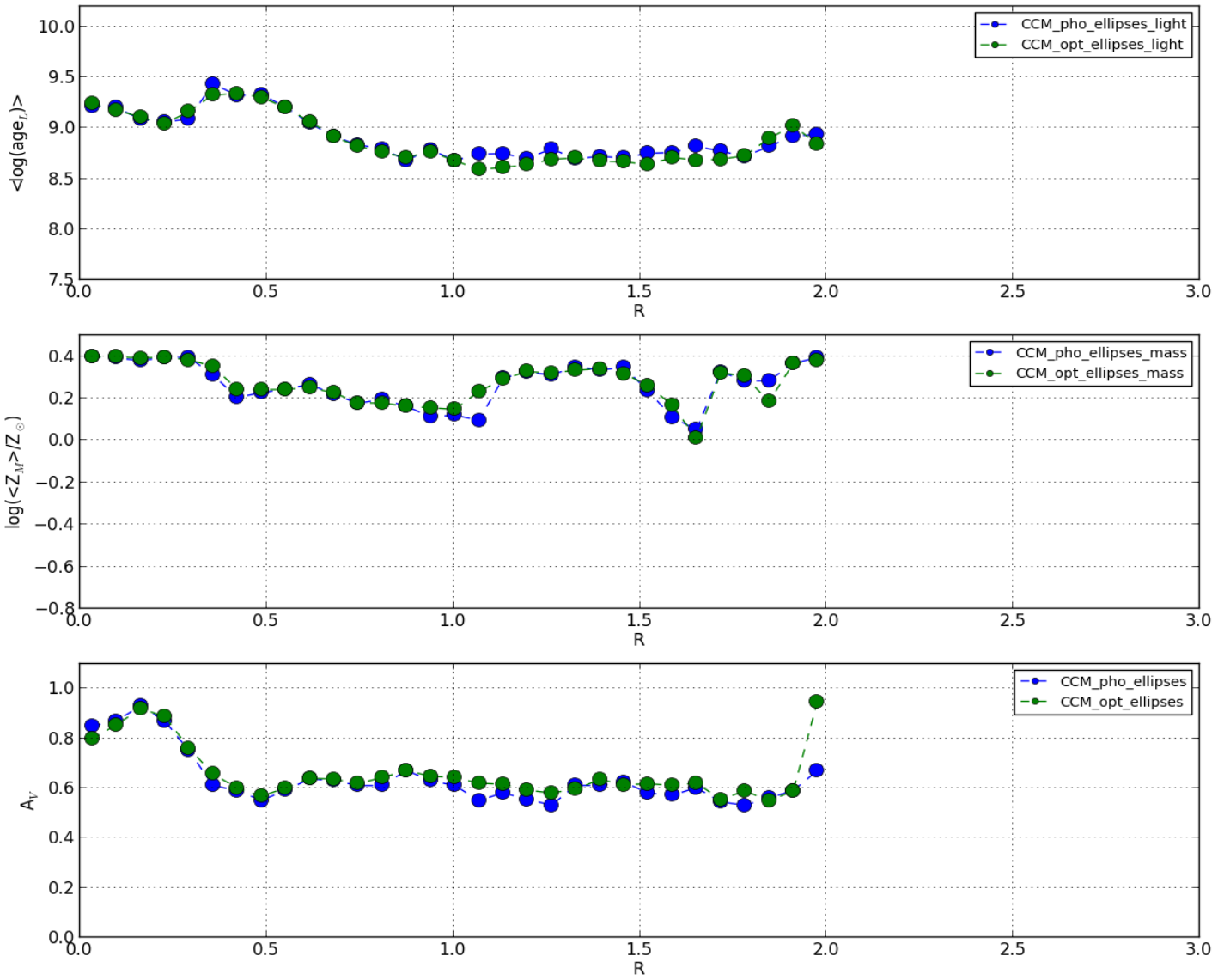
K0014 Integrated_voronoi Spectrum

PHO-FIT	Extinction law = CCM	
logY_obs_NUV = 6.3207	ModlogY_NUV = 6.2641	ErrlogY_NUV = 0.0843
logY_obs_FUV = 6.4891	ModlogY_FUV = 6.5942	ErrlogY_FUV = 0.1505
A_V = 0.43	log_age = 8.4238	Z = 0.0066
Q(H)_ha = 4.497e+53	SFR_Oti(Ha) = 5.379	SFR_Kennicutt(Ha) = 3.583
Q(H)_syn = 6.779e+52	SFR_Oti(syn) = 1.093	

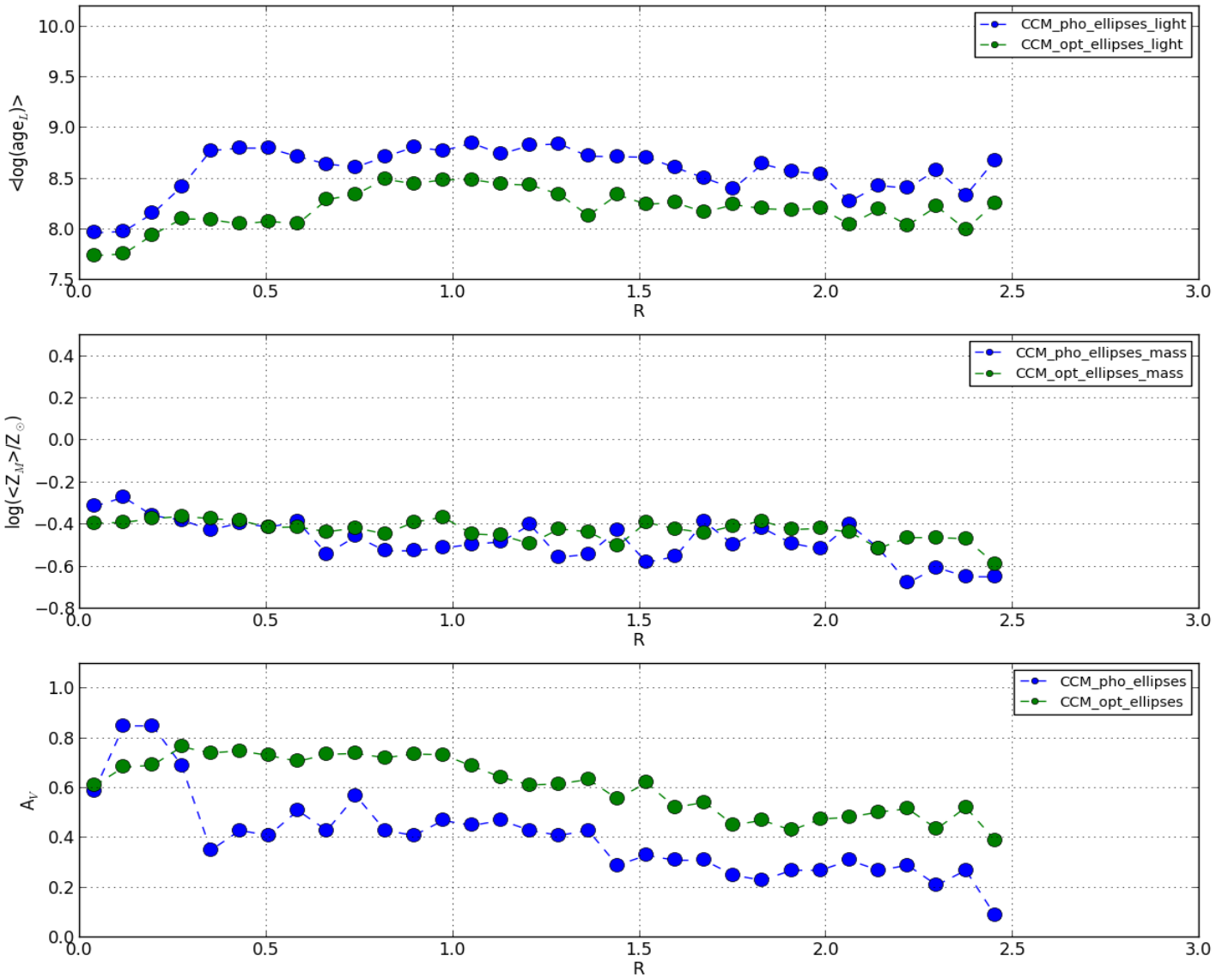
OPT-FIT	Extinction law = CCM	
A_V = 0.6432	log_age = 8.1812	Z = 0.0086
NUV = 6.3343	ModlogY_NUV = 6.2641	
FUV = 6.8033	ModlogY_FUV = 6.5942	
Q(H)_ha = 4.407e+53	SFR_Oti(Ha) = 5.271	SFR_Kennicutt(Ha) = 3.511
Q(H)_syn = 3.696e+54	SFR_Oti(syn) = 59.603	

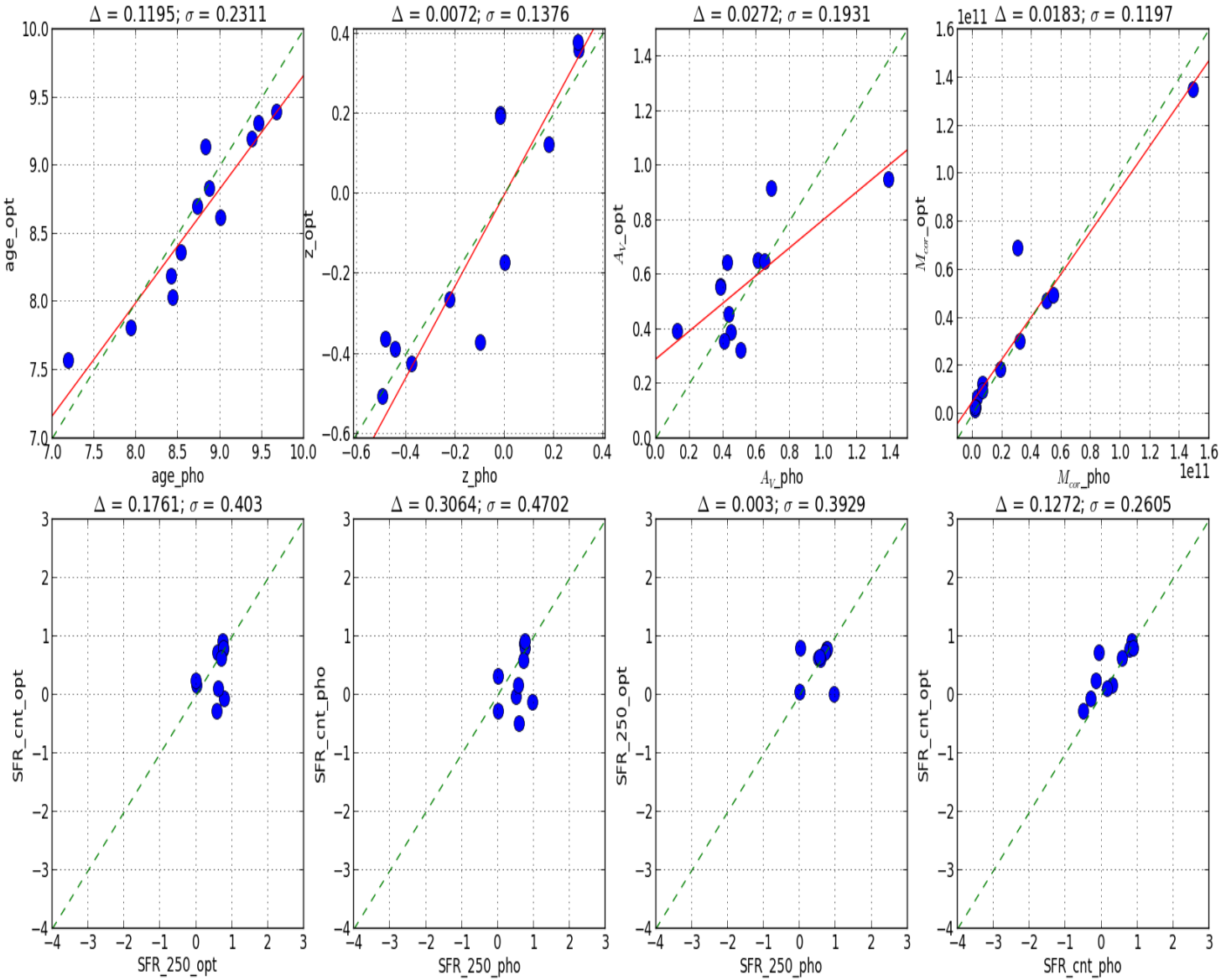


K0073


CCM_pho_ellipses_light
CCM_opt_ellipses_light
<log(age_L)>
R
CCM_pho_ellipses_mass
CCM_opt_ellipses_mass
log(<Z_M>/Z_⊙)
R
CCM_pho_ellipses
CCM_opt_ellipses
A_V
R

K0014

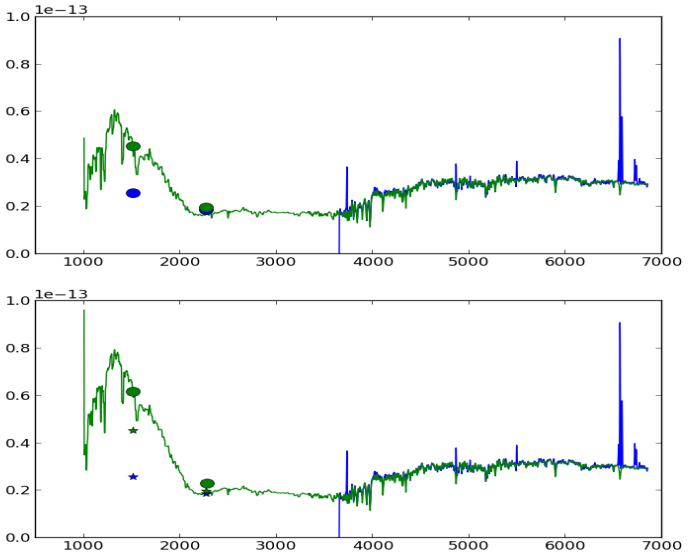

CCM_pho_ellipses_light
CCM_opt_ellipses_light
<log(age_L)>
R
CCM_pho_ellipses_mass
CCM_opt_ellipses_mass
log(<Z_M>/Z_⊙)
R
CCM_pho_ellipses
CCM_opt_ellipses
A_V
R


Δ = 0.1195; σ = 0.2311
age_opt
age_pho
Δ = 0.0072; σ = 0.1376
z_opt
z_pho
Δ = 0.0272; σ = 0.1931
A_V_opt
A_V_pho
1e11 Δ = 0.0183; σ = 0.1197
M_{cor}_opt
M_{cor}_pho
1e11
Δ = 0.1761; σ = 0.403
SFR_cnt_opt
SFR_250_opt
Δ = 0.3064; σ = 0.4702
SFR_cnt_pho
SFR_250_pho
Δ = 0.003; σ = 0.3929
SFR_250_opt
SFR_250_pho
Δ = 0.1272; σ = 0.2605
SFR_cnt_opt
SFR_cnt_pho

K0073 Integrated_voronoi Spectrum

PHO-FIT	Extinction law = CCM	
logY_obs_NUV = 6.3493	ModlogY_NUV = 6.3761	ErrlogY_NUV = 0.5825
logY_obs_FUV = 6.4941	ModlogY_FUV = 6.7416	ErrlogY_FUV = 0.84
A_V = 0.6101	log_age = 8.8756	Z = 0.0403
Q(H)_ha = 4.805e+53	SFR_Oti(Ha) = 5.747	SFR_Kennicutt(Ha) = 3.829
Q(H)_syn = 1.564E+53	SFR_Oti(syn) = 2.522	

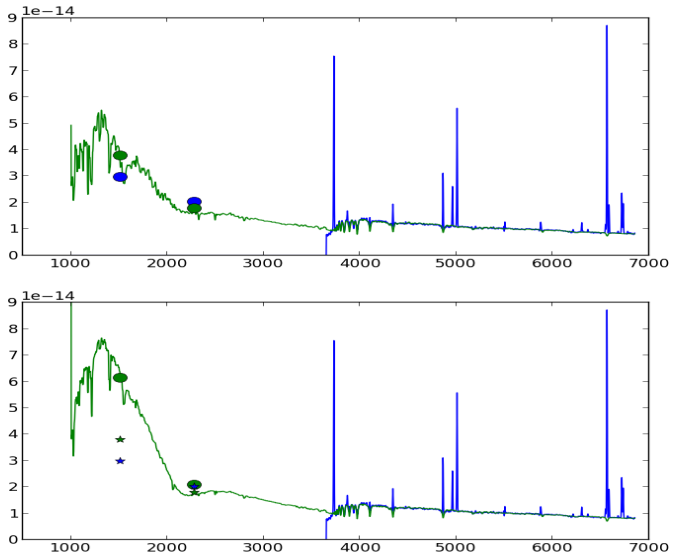
OPT-FIT	Extinction law = CCM	
A_V = 0.6519	log_age = 8.8263	Z = 0.0456
NUV = 6.4443	ModlogY_NUV = 6.3761	
FUV = 6.8764	ModlogY_FUV = 6.7416	
Q(H)_ha = 4.805e+53	SFR_Oti(Ha) = 5.747	SFR_Kennicutt(Ha) = 3.828
Q(H)_syn = 3.419E+54	SFR_Oti(syn) = 55.139	



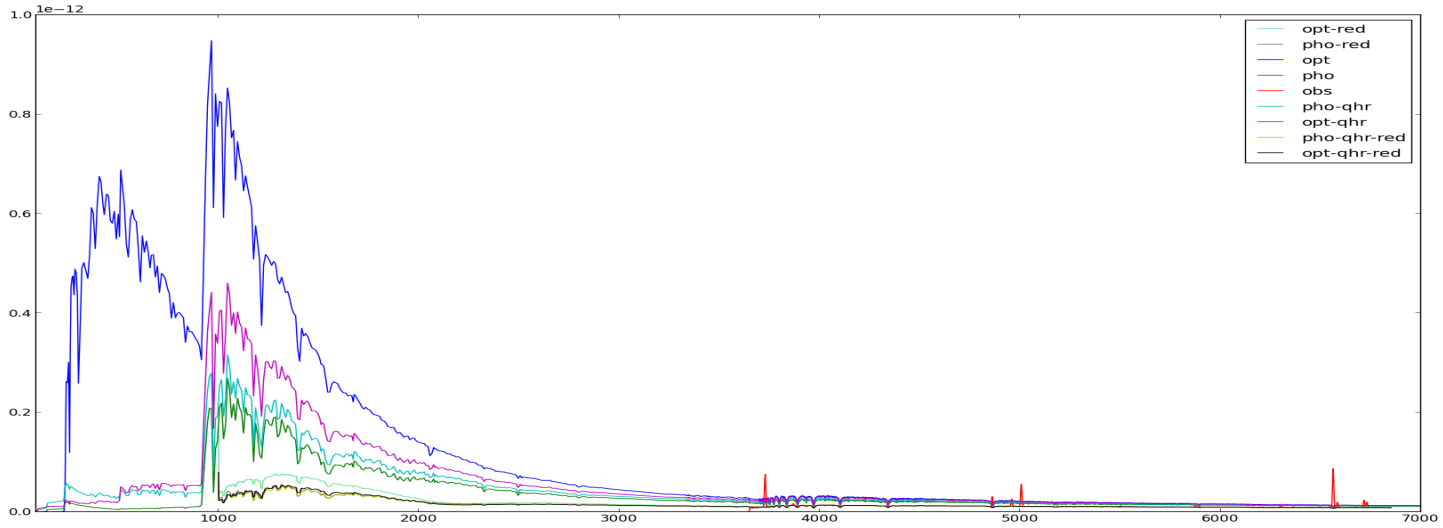
K0014 Integrated_voronoi Spectrum

PHO-FIT	Extinction law = CCM	
logY_obs_NUV = 6.3207	ModlogY_NUV = 6.2641	ErrlogY_NUV = 0.0843
logY_obs_FUV = 6.4891	ModlogY_FUV = 6.5942	ErrlogY_FUV = 0.1505
A_V = 0.43	log_age = 8.4238	Z = 0.0066
Q(H)_ha = 4.497e+53	SFR_Oti(Ha) = 5.379	SFR_Kennicutt(Ha) = 3.583
Q(H)_syn = 6.779e+52	SFR_Oti(syn) = 1.093	

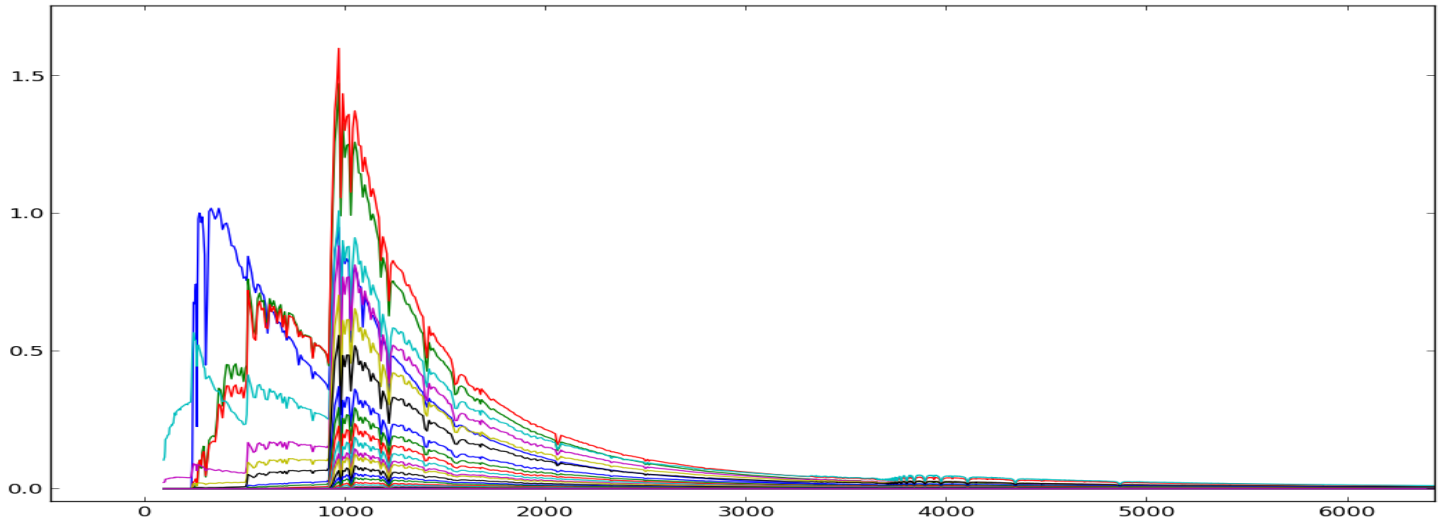
OPT-FIT	Extinction law = CCM	
A_V = 0.6432	log_age = 8.1812	Z = 0.0086
NUV = 6.3343	ModlogY_NUV = 6.2641	
FUV = 6.8033	ModlogY_FUV = 6.5942	
Q(H)_ha = 4.407e+53	SFR_Oti(Ha) = 5.271	SFR_Kennicutt(Ha) = 3.511
Q(H)_syn = 3.696e+54	SFR_Oti(syn) = 59.603	



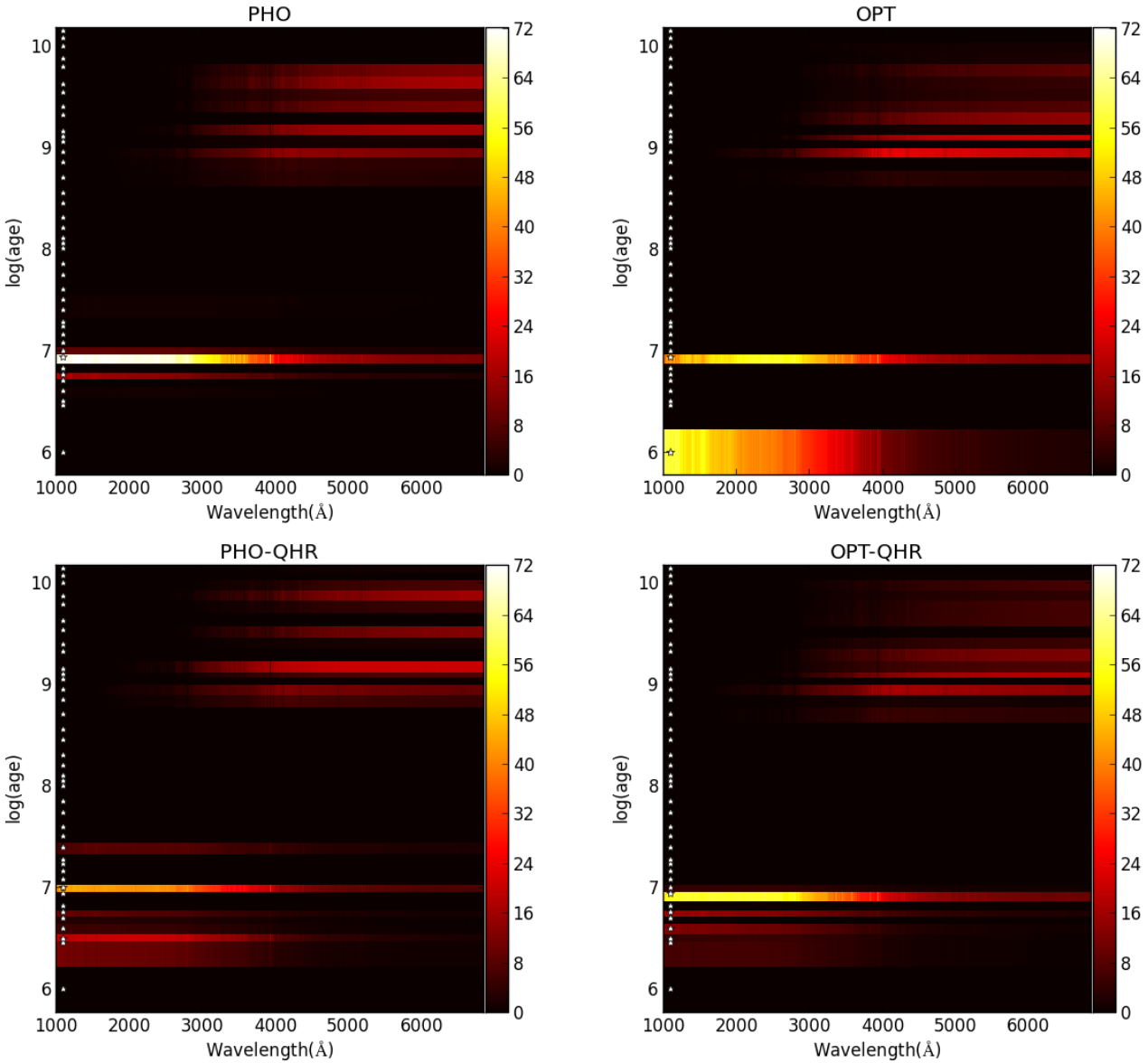
K0014 INTEGRADO



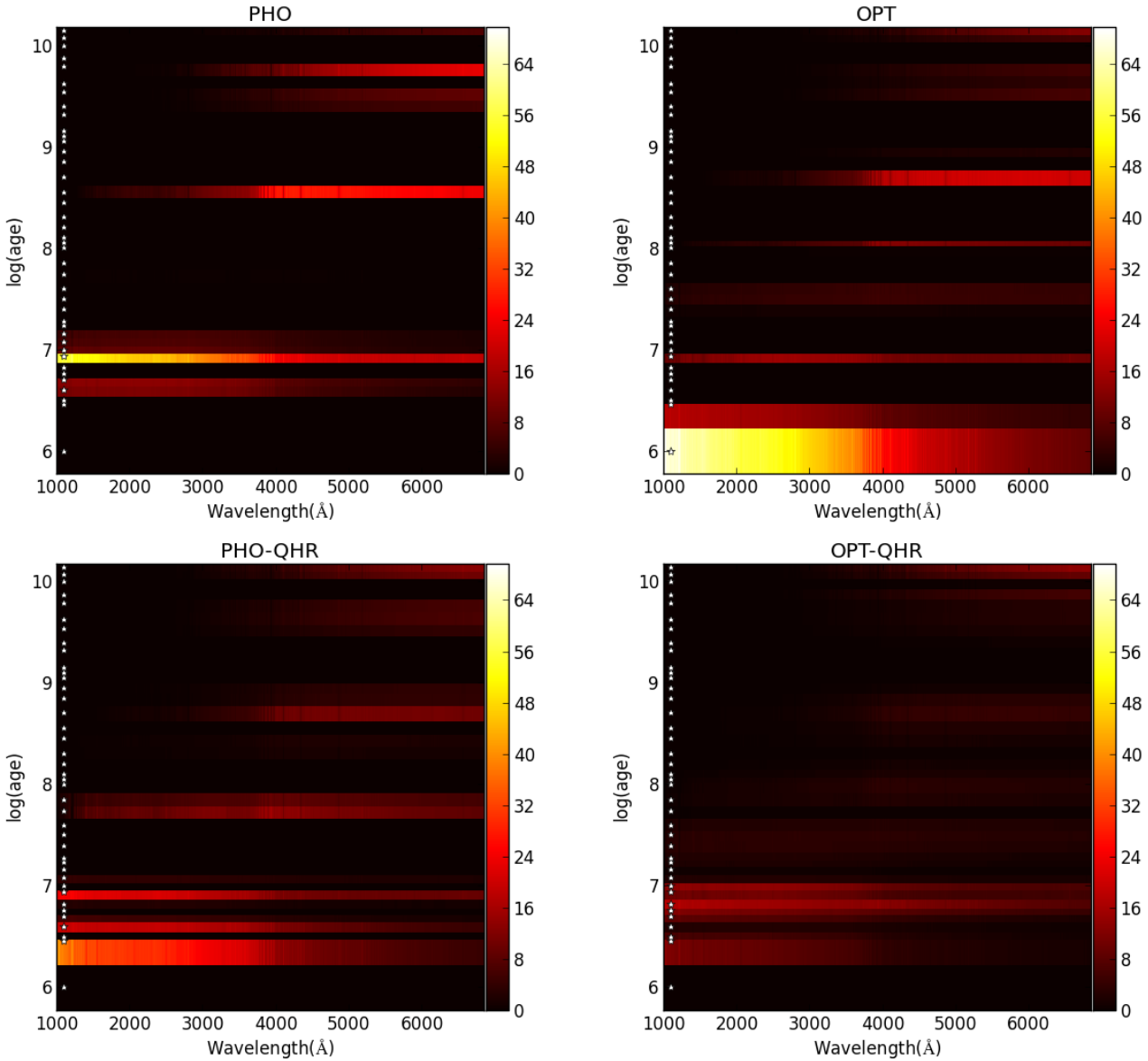
BASE ZCA01

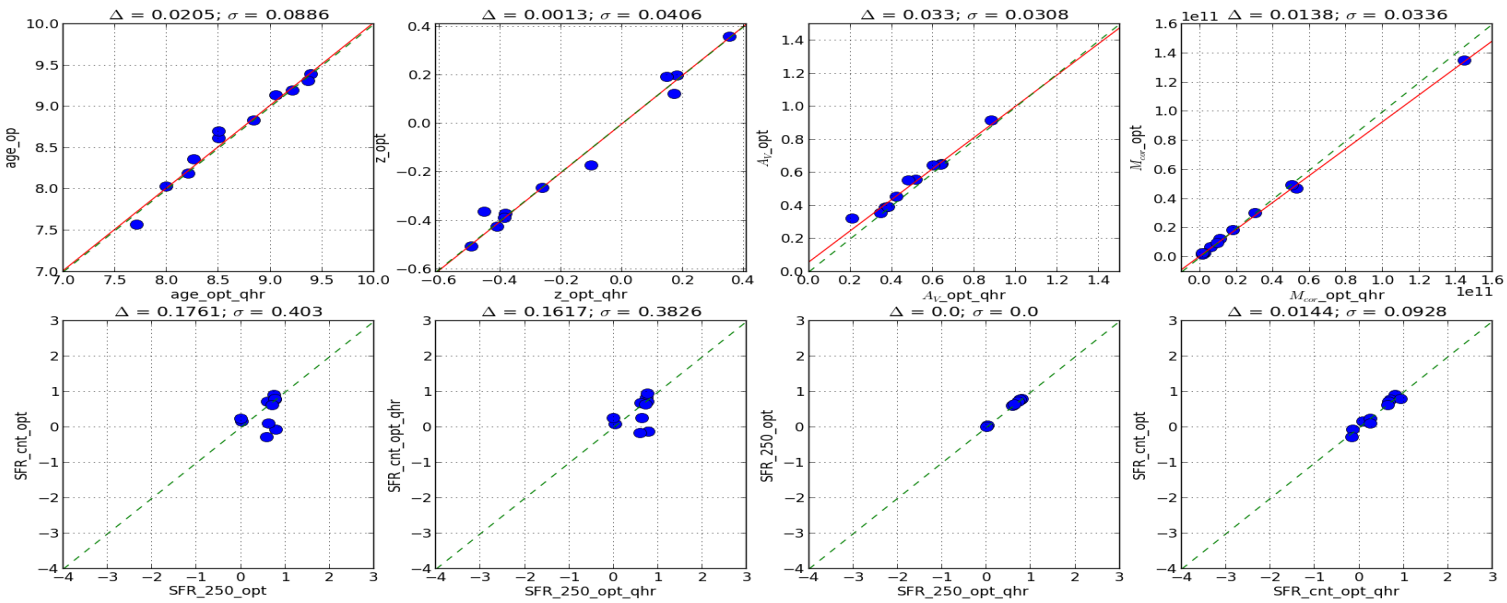


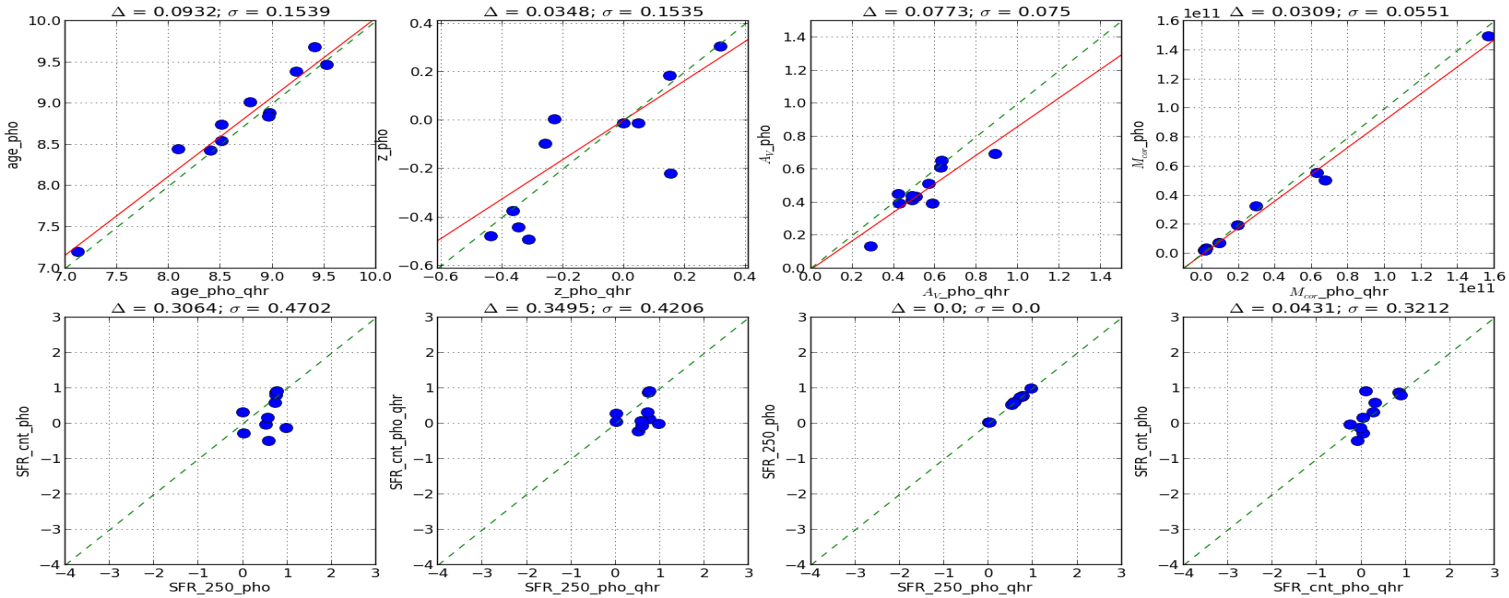
K0073 Integrated spectrum



K0014 Integrated spectrum



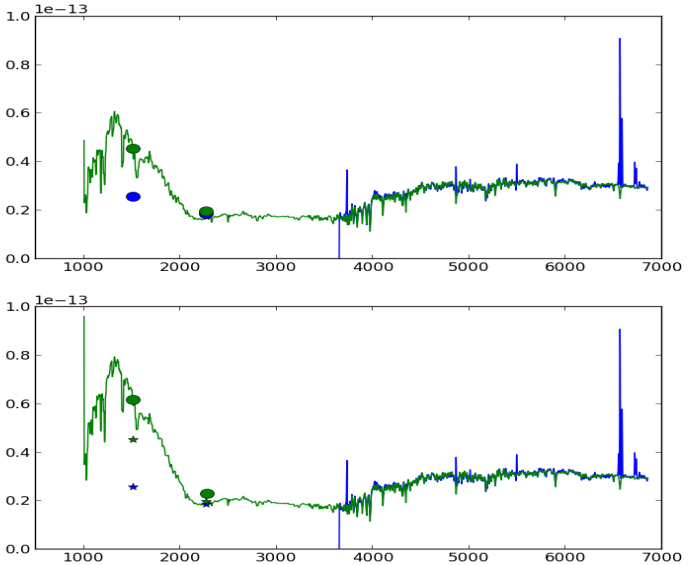

Δ = 0.0205; σ = 0.0886
age_op
age_opt_qhr
Δ = 0.0013; σ = 0.0406
z_opt
z_opt_qhr
Δ = 0.033; σ = 0.0308
A_{V}_opt
A_{V}_opt_qhr
1e11 Δ = 0.0138; σ = 0.0336
M_{star}_opt
M_{star}_opt_qhr
1e11
Δ = 0.1761; σ = 0.403
SFR_cnt_opt
SFR_250_opt
Δ = 0.1617; σ = 0.3826
SFR_cnt_opt_qhr
SFR_250_opt_qhr
Δ = 0.0; σ = 0.0
SFR_250_opt
SFR_250_opt_qhr
Δ = 0.0144; σ = 0.0928
SFR_cnt_opt
SFR_cnt_opt_qhr


Δ = 0.0932; σ = 0.1539
age_pho
age_pho_qhr
Δ = 0.0348; σ = 0.1535
z_pho
z_pho_qhr
Δ = 0.0773; σ = 0.075
A_{V}_pho
A_{V}_pho_qhr
1e11 Δ = 0.0309; σ = 0.0551
M_{star}_pho
M_{star}_pho_qhr
1e11
Δ = 0.3064; σ = 0.4702
SFR_cnt_pho
SFR_250_pho
Δ = 0.3495; σ = 0.4206
SFR_cnt_pho_qhr
SFR_250_pho_qhr
Δ = 0.0; σ = 0.0
SFR_250_pho
SFR_250_pho_qhr
Δ = 0.0431; σ = 0.3212
SFR_cnt_pho
SFR_cnt_pho_qhr

K0073 Integrated_voronoi Spectrum

PHO-FIT	Extinction law = CCM	
logY_obs_NUV = 6.3493	ModlogY_NUV = 6.3761	ErrlogY_NUV = 0.5825
logY_obs_FUV = 6.4941	ModlogY_FUV = 6.7416	ErrlogY_FUV = 0.84
A_V = 0.6101	log_age = 8.8756	Z = 0.0403
Q(H)_ha = 4.805e+53	SFR_Oti(Ha) = 5.747	SFR_Kennicutt(Ha) = 3.829
Q(H)_syn = 1.564E+53	SFR_Oti(syn) = 2.522	

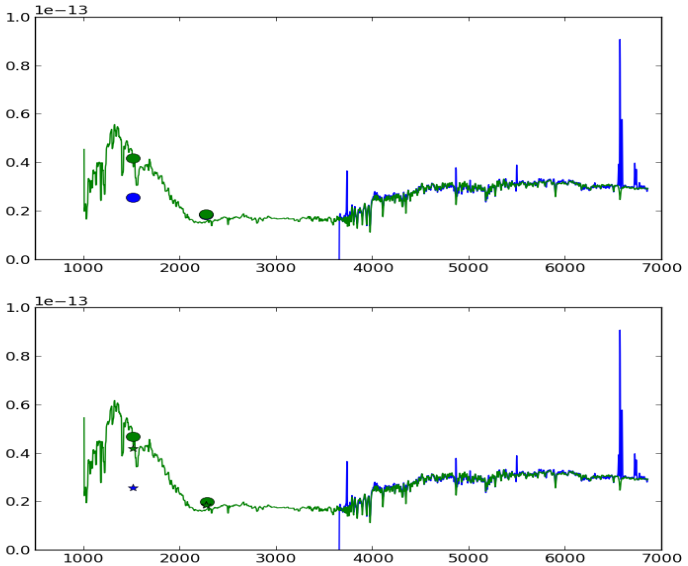
OPT-FIT	Extinction law = CCM	
A_V = 0.6519	log_age = 8.8263	Z = 0.0456
NUV = 6.4443	ModlogY_NUV = 6.3761	
FUV = 6.8764	ModlogY_FUV = 6.7416	
Q(H)_ha = 4.805e+53	SFR_Oti(Ha) = 5.747	SFR_Kennicutt(Ha) = 3.828
Q(H)_syn = 3.419E+54	SFR_Oti(syn) = 55.139	



K0073 Integrated_voronoi Spectrum_QHR

PHO-QHR-FIT	Extinction law = CCM	
logY_obs_NUV = 6.3493	ModlogY_NUV = 6.3535	ErrlogY_NUV = 0.5825
logY_obs_FUV = 6.4941	ModlogY_FUV = 6.7084	ErrlogY_FUV = 0.84
A_V = 0.6301	log_age = 8.9799	Z = 0.0415
Q(H)_ha = 4.805e+53	SFR_Oti(Ha) = 5.747	SFR_Kennicutt(Ha) = 3.829
Q(H)_syn = 4.168E+53	SFR_Oti(syn) = 6.721	

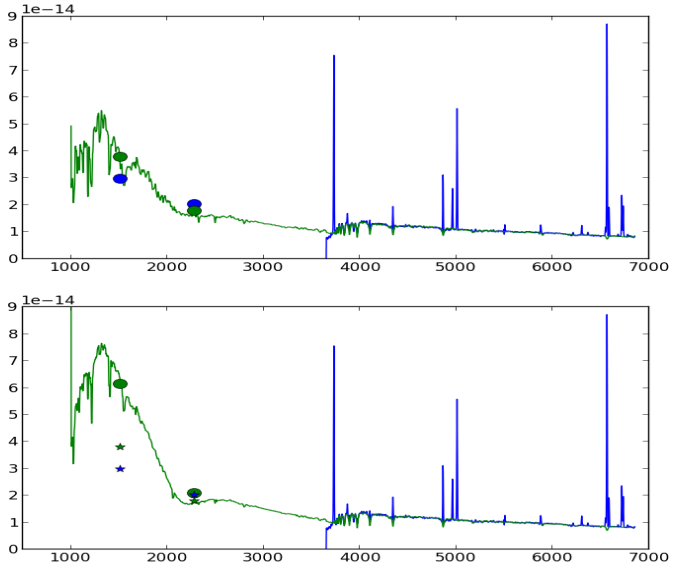
OPT-QHR-FIT	Extinction law = CCM	
A_V = 0.6417	log_age = 8.8455	Z = 0.0452
NUV = 6.3836	ModlogY_NUV = 6.3535	
FUV = 6.7566	ModlogY_FUV = 6.7084	
Q(H)_ha = 4.805e+53	SFR_Oti(Ha) = 5.747	SFR_Kennicutt(Ha) = 3.828
Q(H)_syn = 4.126E+53	SFR_Oti(syn) = 6.653	



K0014 Integrated_voronoi Spectrum

PHO-FIT	Extinction law = CCM	
logY_obs_NUV = 6.3207	ModlogY_NUV = 6.2641	ErrlogY_NUV = 0.0843
logY_obs_FUV = 6.4891	ModlogY_FUV = 6.5942	ErrlogY_FUV = 0.1505
A_V = 0.43	log_age = 8.4238	Z = 0.0066
Q(H)_ha = 4.497e+53	SFR_Oti(Ha) = 5.379	SFR_Kennicutt(Ha) = 3.583
Q(H)_syn = 6.779e+52	SFR_Oti(syn) = 1.093	

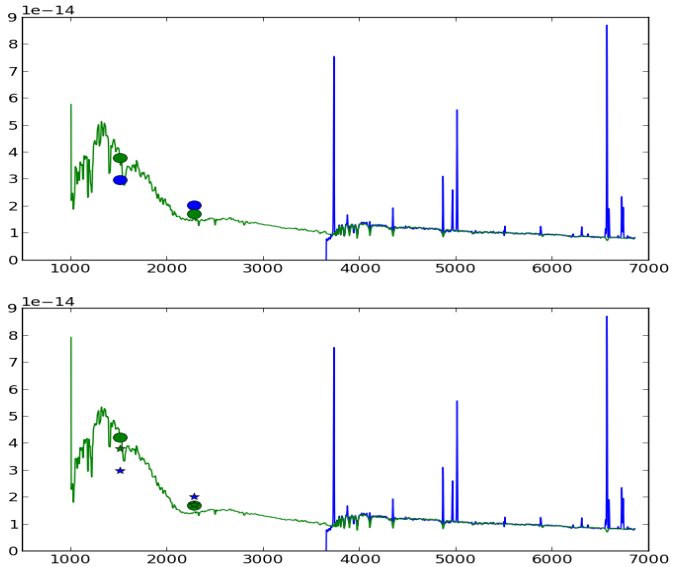
OPT-FIT	Extinction law = CCM	
A_V = 0.6432	log_age = 8.1812	Z = 0.0086
NUV = 6.3343	ModlogY_NUV = 6.2641	
FUV = 6.8033	ModlogY_FUV = 6.5942	
Q(H)_ha = 4.407e+53	SFR_Oti(Ha) = 5.271	SFR_Kennicutt(Ha) = 3.511
Q(H)_syn = 3.696e+54	SFR_Oti(syn) = 59.603	



K0014 Integrated_voronoi Spectrum_QHR

PHO-QHR-FIT	Extinction law = CCM	
logY_obs_NUV = 6.3207	ModlogY_NUV = 6.2465	ErrlogY_NUV = 0.0843
logY_obs_FUV = 6.4891	ModlogY_FUV = 6.5946	ErrlogY_FUV = 0.1505
A_V = 0.5106	log_age = 8.405	Z = 0.0074
Q(H)_ha = 4.497e+53	SFR_Oti(Ha) = 5.379	SFR_Kennicutt(Ha) = 3.583
Q(H)_syn = 3.076e+53	SFR_Oti(syn) = 4.962	

OPT-QHR-FIT	Extinction law = CCM	
A_V = 0.6005	log_age = 8.2065	Z = 0.0071
NUV = 6.2422	ModlogY_NUV = 6.2465	
FUV = 6.6408	ModlogY_FUV = 6.5946	
Q(H)_ha = 4.407e+53	SFR_Oti(Ha) = 5.271	SFR_Kennicutt(Ha) = 3.511
Q(H)_syn = 3.41e+53	SFR_Oti(syn) = 5.499	



Trabajo que estamos realizando:

- Hemos ampliado la muestra de estudio para abarcar galaxias en todo el rango de masas.

- Estamos estudiando la diferencia entre las diferentes extracciones para el análisis de las galaxias espacialmente resueltas: zonas de Voronoi y elipses.

- Estamos estudiando el efecto de Hα en los ajustes al realizar el análisis de las galaxias resueltas.

¡Muchas gracias!