Bayesian analysis of resolved stellar populations: The fossil galaxy Eridanus II

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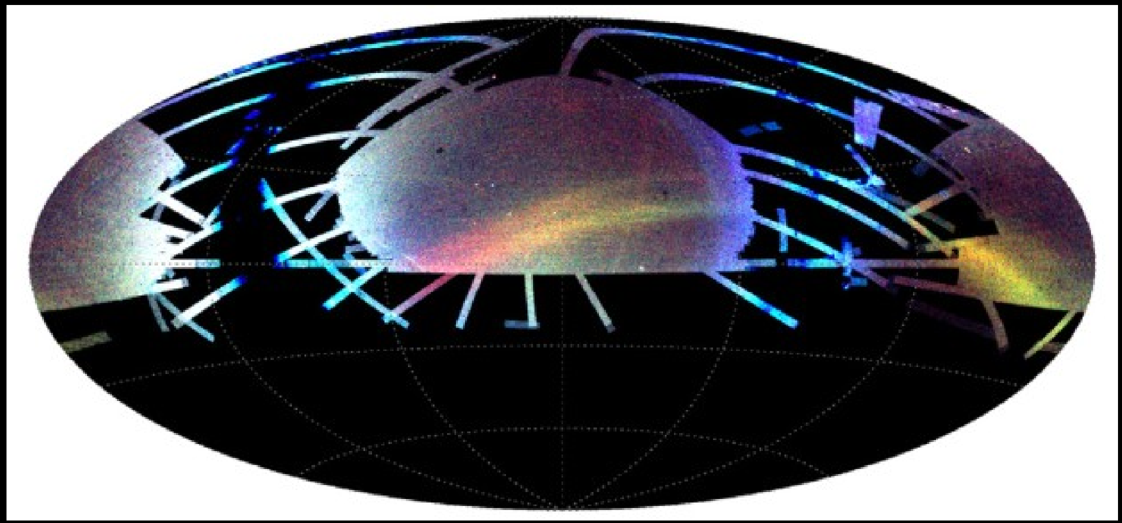
Fossil galaxies

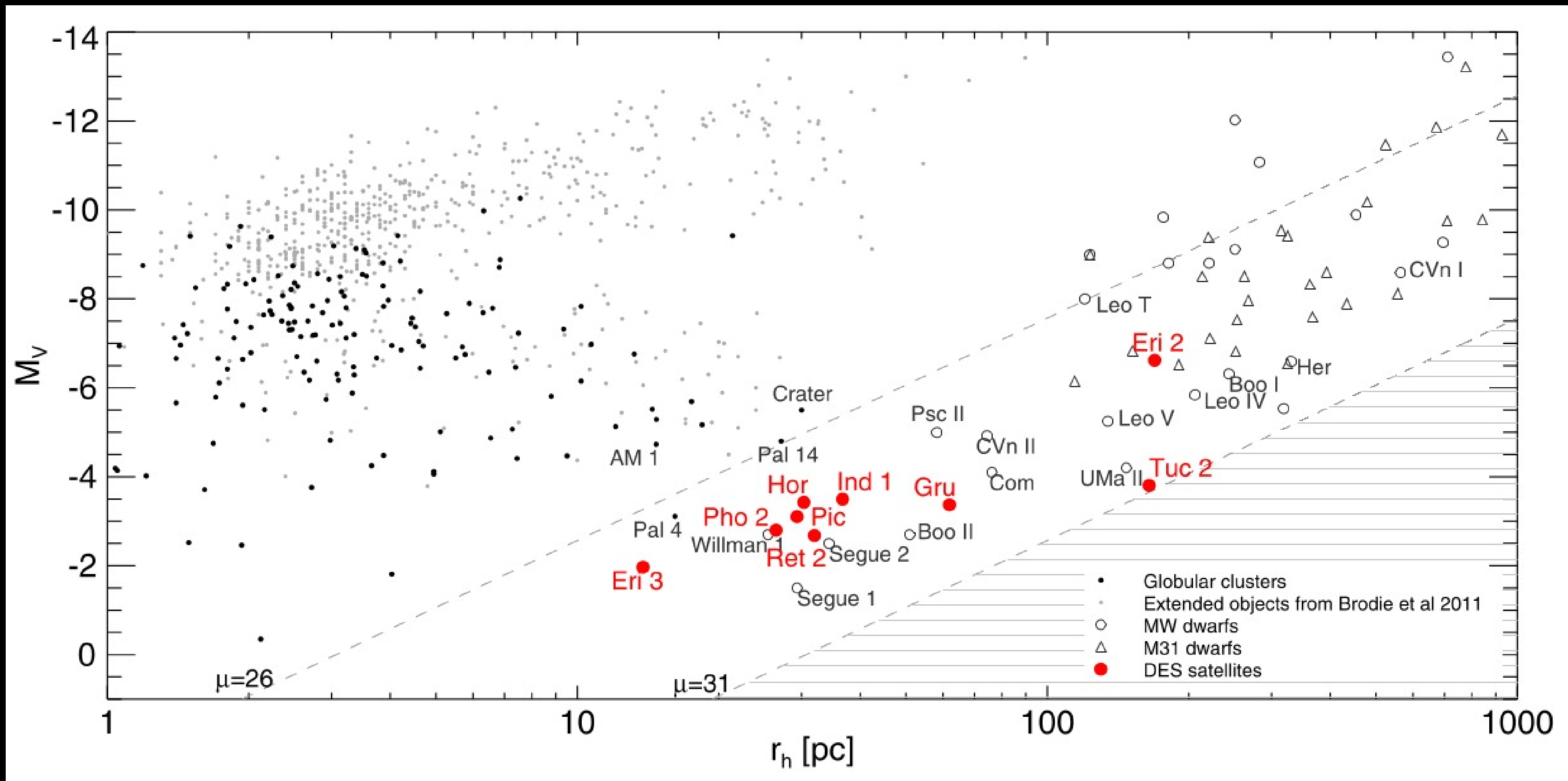
Lovell et al. (2012)

SDSS DR9



Belokurov (2013)

Dwarf galaxies



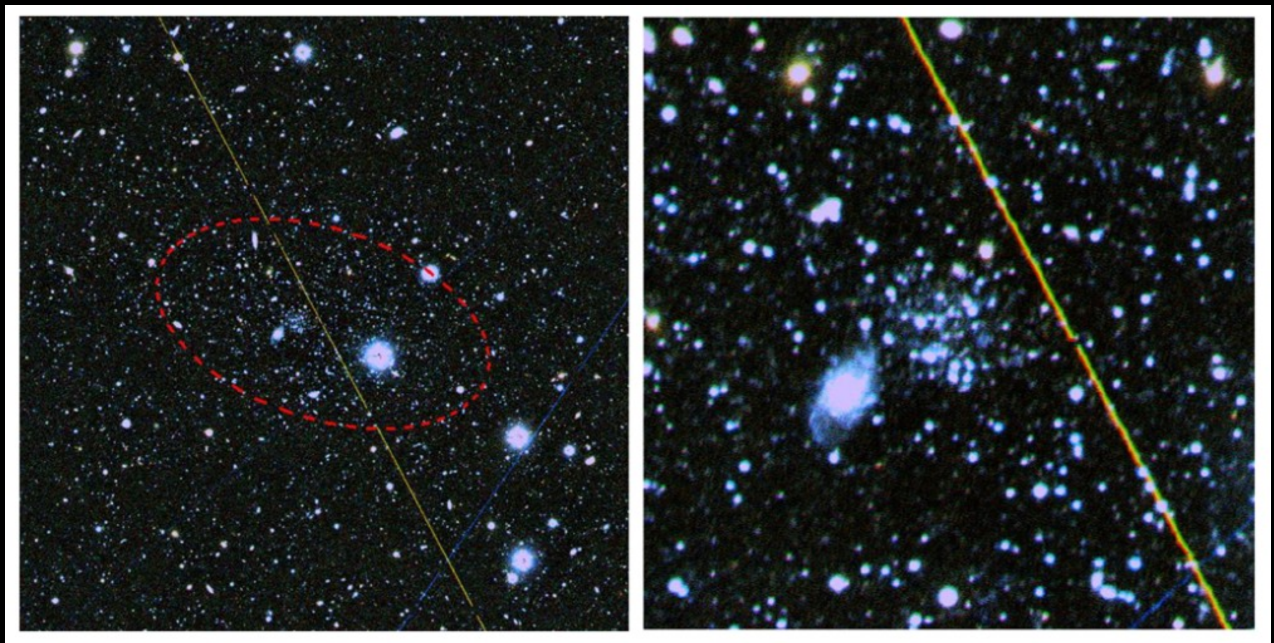
Koposov et al. (2015)

Dwarf spheroidal galaxy Eridanus II (Eri II)

Dark Energy Survey

Koposov et al. (2015)

Deep imaging of Eri II and its cluster



Megacam Imager
Maguellan Clay Telescope

Crnojevic et al. (2016)

Table 1
Properties of Eri II and Its Cluster

Parameter	Eri II	Cluster
R.A. (h:m:s)	03:44:20.1±10.″5	03:44:22.2 ± 1″
Decl. (d:m:s)	−43:32:01.7±5.″3	−43:31:59.2 ± 2″
$(m - M)_0$ (mag)	22.8 ± 0.1	···
D (kpc)	366 ± 17	···
ϵ	0.48 ± 0.04	···
PA (N to E; ^{o})	72.6 ± 3.3	···
r_h (arcmin)	2.31 ± 0.12	0.11 ± 0.01
r_h (pc)	277 ± 14	13 ± 1
n (Sérsic index)	1[a]	0.19 ± 0.05
$\mu_{V,0}$ (mag arcsec^{-2})	27.2 ± 0.3	25.7 ± 0.2
M_V (mag)	−7.1 ± 0.3	−3.5 ± 0.6
$\langle(g - r)_0\rangle$ (mag)	0.5 ± 0.3	0.4 ± 0.2
M_{HI}/L_V ($M_\odot/L_\odot$)	<0.036	···

Kinematical characterization of Eri II

IMACS spectrograph
Magellam Baade Telescope

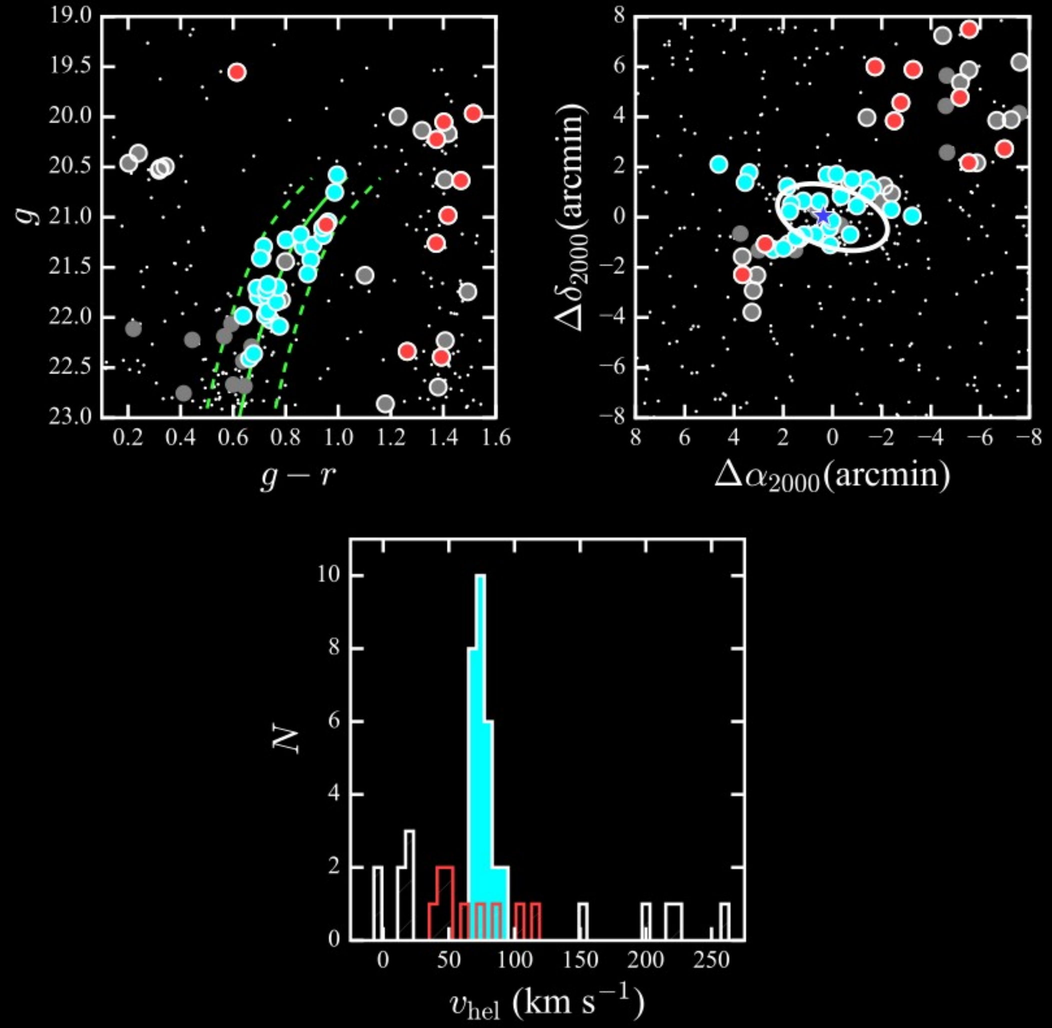
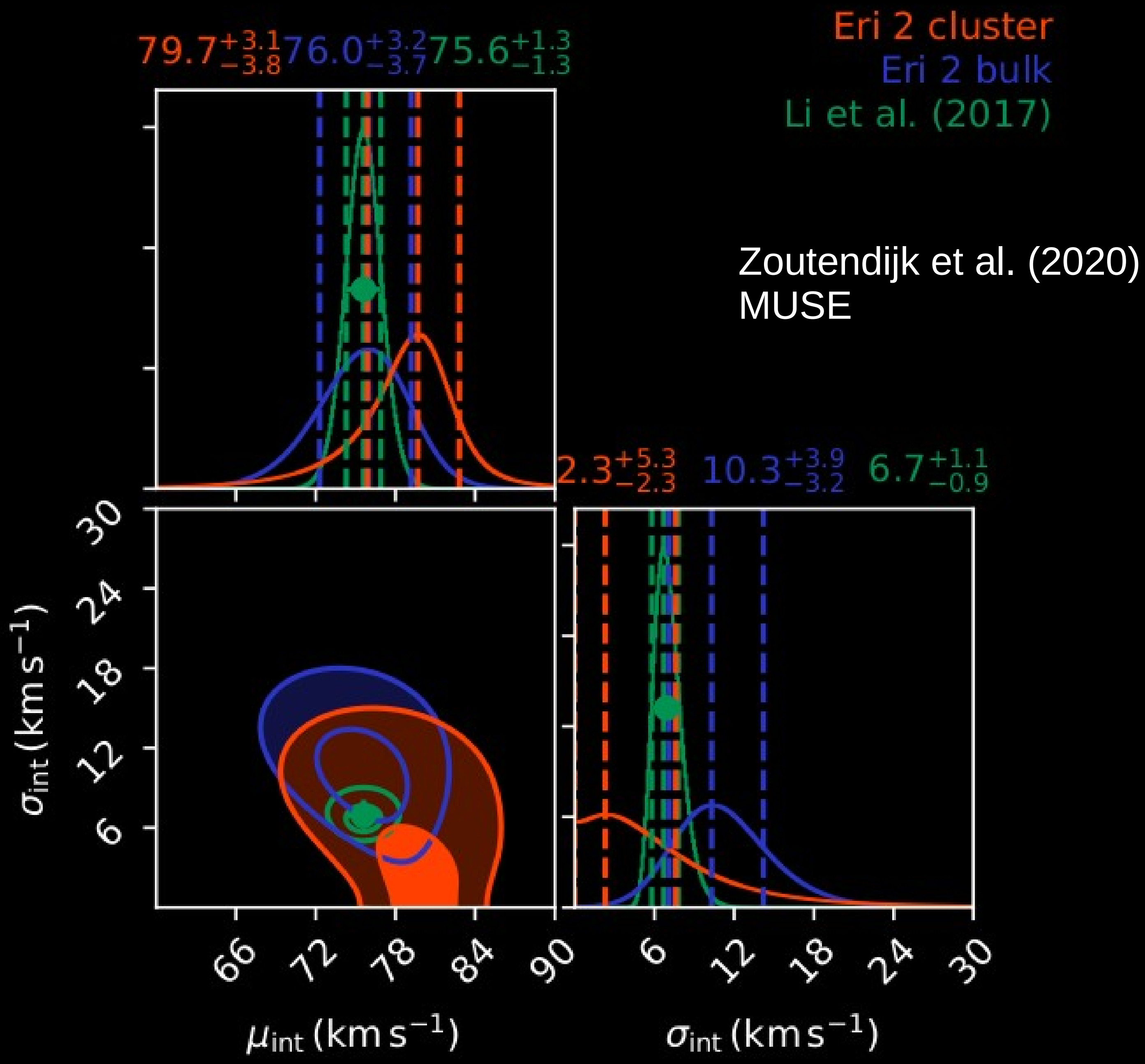


Table 1
Summary of the Properties of Eridanus II

Row	Quantity	Value
(11)	$v_{\rm hel}$ (km s^{-1})	$75.6 \pm 1.3 \pm 2.0$
(12)	$v_{\rm GSR}$ (km s^{-1})	-66.6
(13)	σ_v (km s^{-1})	$6.9^{+1.2}_{-0.9}$
(14)	$M_{\rm half}$ ($M_\odot$)	$1.2^{+0.4}_{-0.3} \times 10^7$
(15)	M/L_V ($M_\odot/L_\odot$)	420^{+210}_{-140}
(16)	$\frac{dv}{d\chi}$ (km s^{-1} arcmin^{-1})	0.1 ± 1.1
(17)	Mean metallicity	-2.38 ± 0.13
(18)	Metallicity dispersion (dex)	$0.47^{+0.12}_{-0.09}$

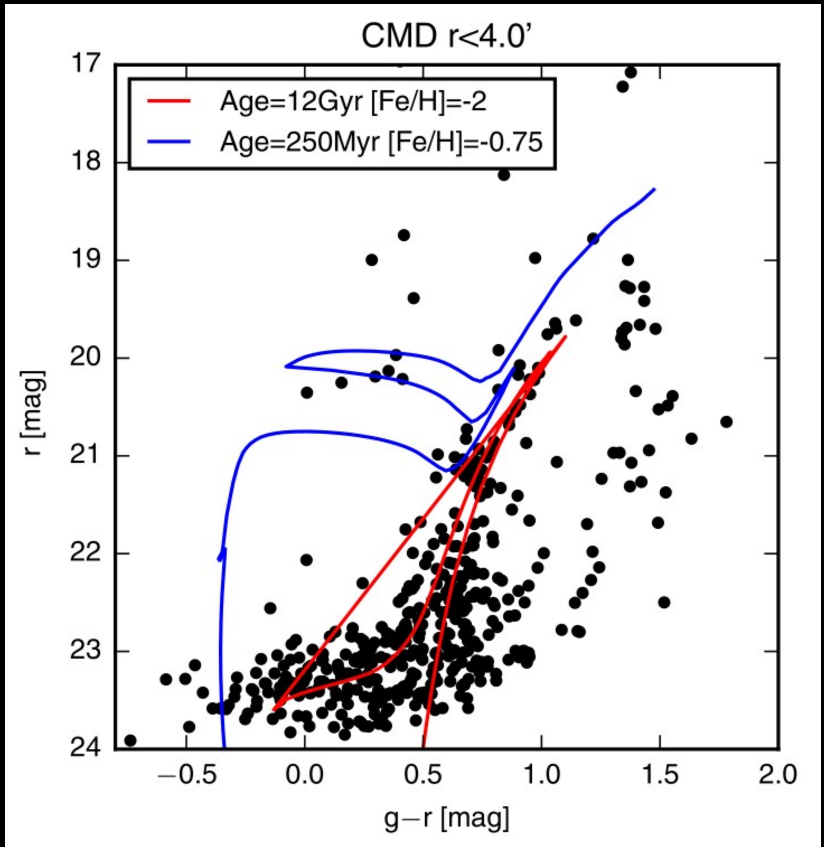
Li et al. (2017)

Kinematical characterization of its cluster

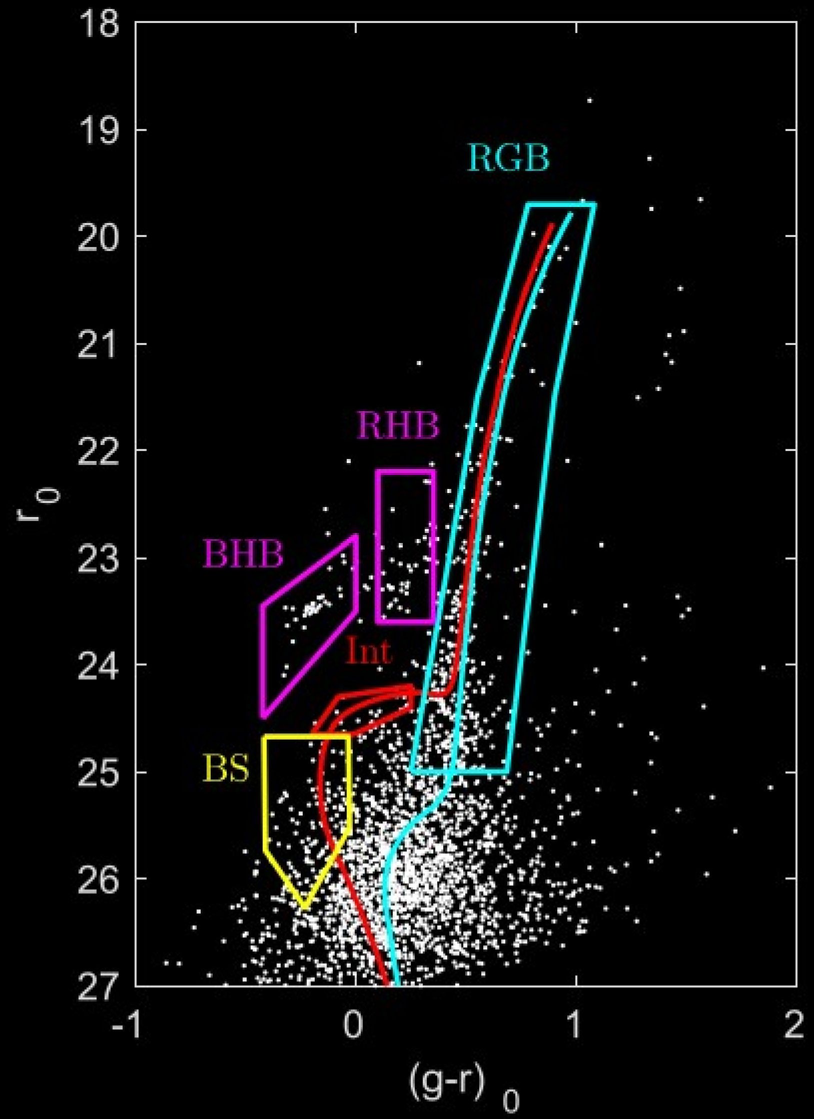


Zoutendijk et al. (2020)
MUSE

What is the star formation history of Eri II?



Koposov et al. (2015)



Crnojevic et al. (2016)

Zoutendijk et al. (2020)

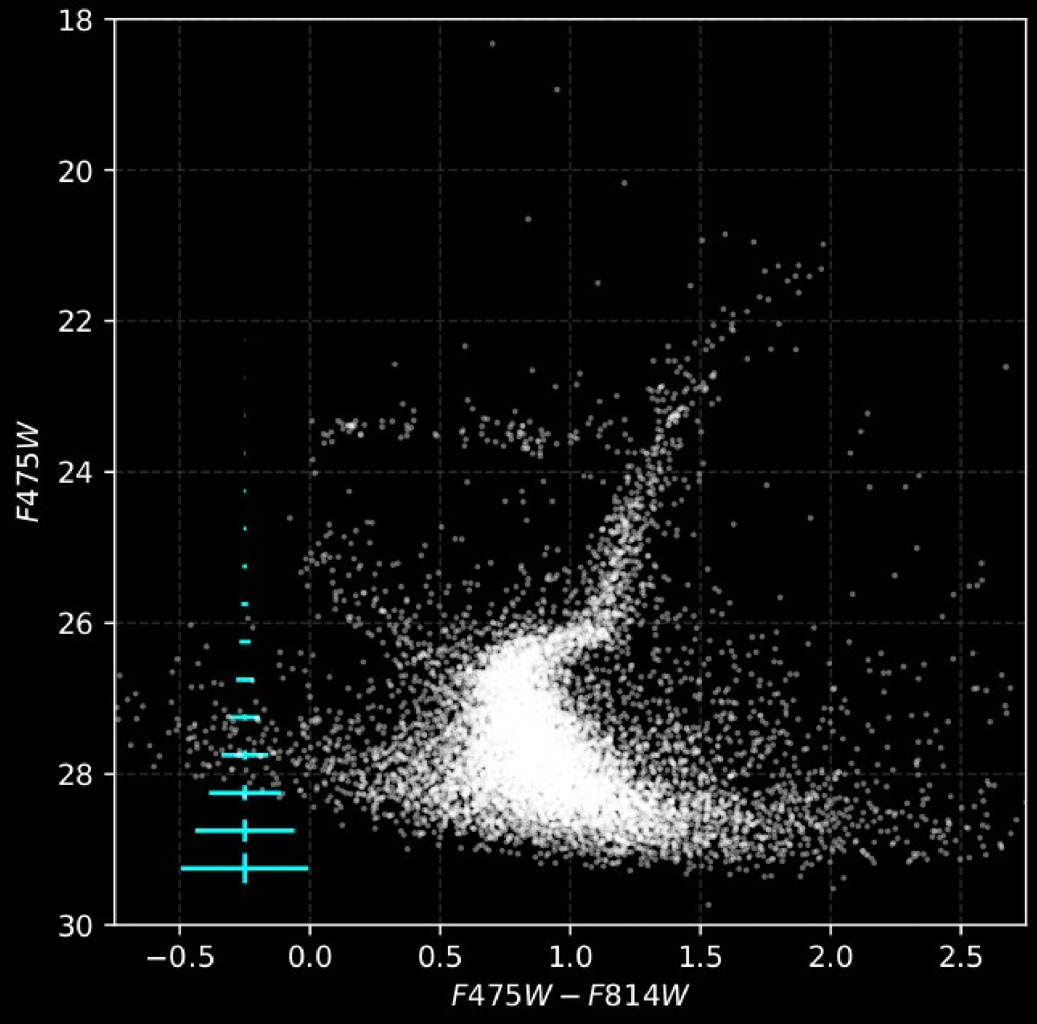
- Possible presence of carbon stars.

What is the star formation history of Eri II?

- How old is it?
- How long did it form stars?
- Are there two separated star formation episodes?
- Is there evidence of the presence of young or intermediate age population stars?
- What is the possible origin of the carbon stars?

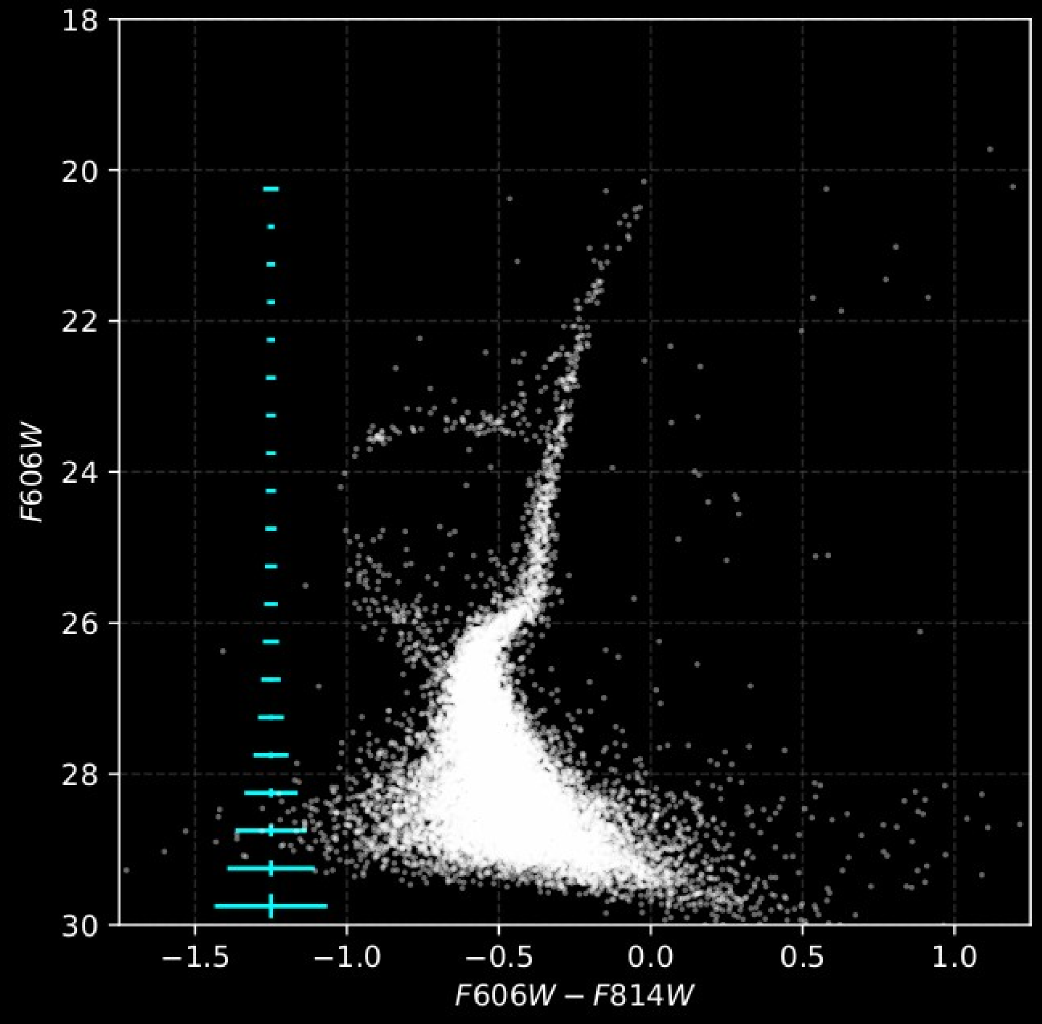
HST/ACS photometric data of Eri II

F475W/F814W Hubble Legacy Archive
P.I. D. 14224 Gallart 2016, G16 hereafter
F475W - 7644 s, F814W - 7900 s



90% comp. - F475W < 29 mag

F606W/F814W published photometry
Simon et al. (2021), S21 here after
F606W - 12830 s, F814W - 20682 s



90% comp. - F606W < 29.2

Inference of the star formation history

$$\mathrm{P}(\boldsymbol{a}|F_j^k) \propto \mathrm{P}(\boldsymbol{a}) \prod_{j=1}^{N_D} \int \frac{S(F_j^k)\mathrm{P}(F_j^k|F_{\mathrm{true}}^k)\ \mathrm{P}(M_j^k|\boldsymbol{a})}{\ell(\boldsymbol{a}, S)} dM_j^k,$$

- a Isochrone contribution (SFH) $\boldsymbol{a} = \{a_{i=1,\ldots,N_I}\},\ a_i > 0$ and $\sum_i a_i = 1$
- F_j apparent magnitude
- True apparent magnitude $F_{true}^k = M_j^k + \mu$

Model inputs

- Kroupa IMF

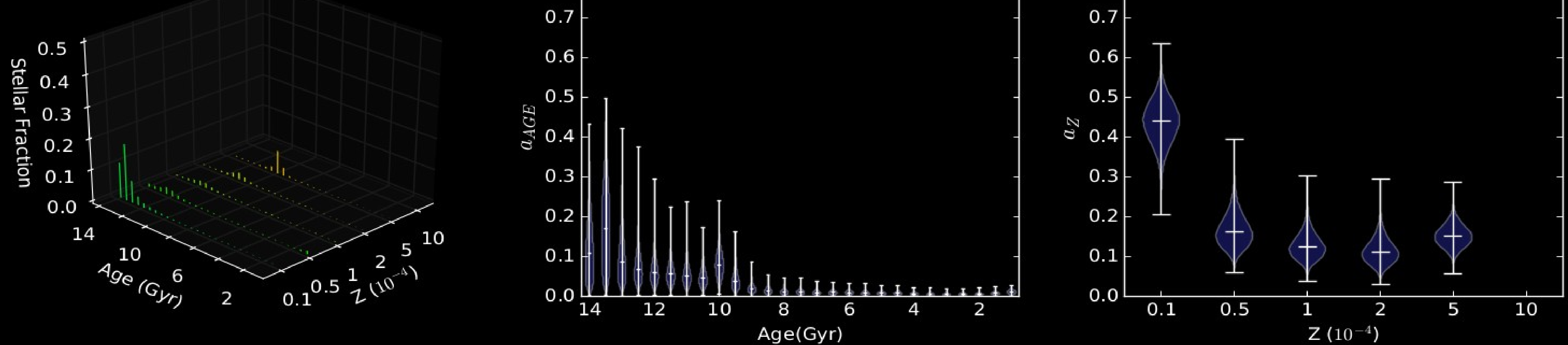
Grid	Isochrones	Age (Gyr)	Step (Gyr)	Z 0.00001	0.00005	0.0001	0.0002	0.0005	0.001	N_{iso}
A	BaSTI	[1,14]	0.5	✓	✓	✓	✓	✓		135
B	PARSEC	[1,14]	0.5			✓	✓	✓	✓	108

Alzate et al. (2021)

SFH Eri II: Grid A

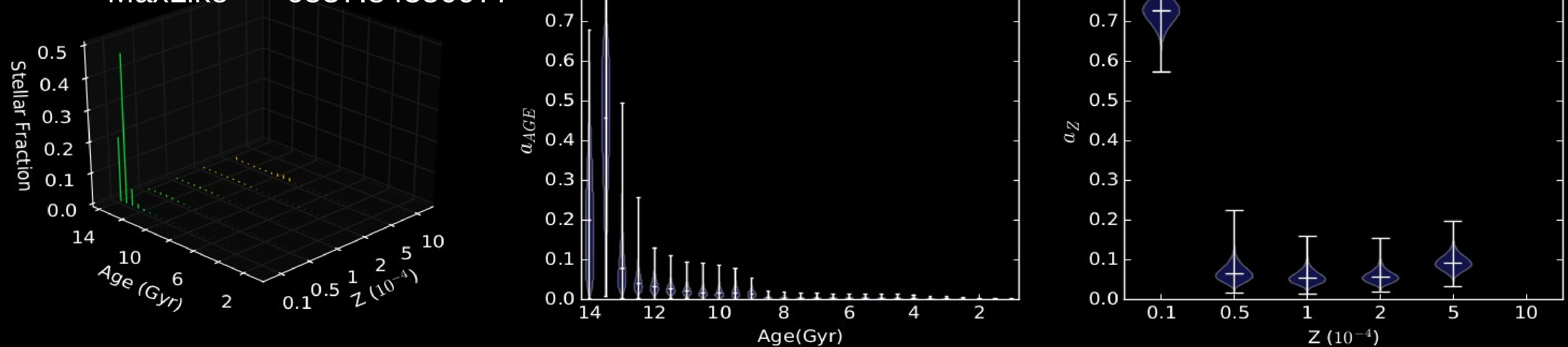
G16

MaxLike = -12669.4129984



S21

MaxLike = -6537.84350977

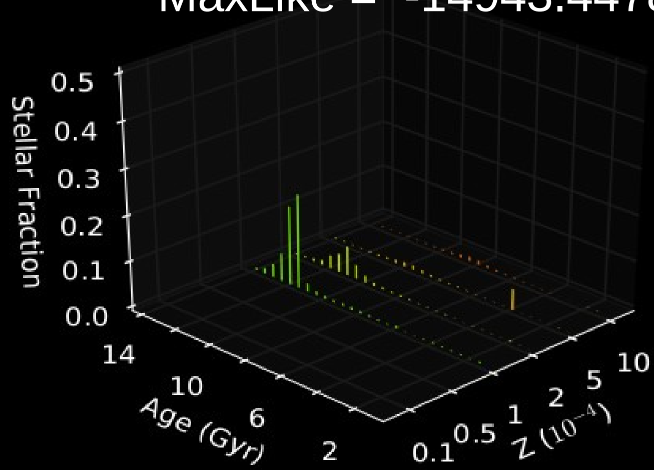


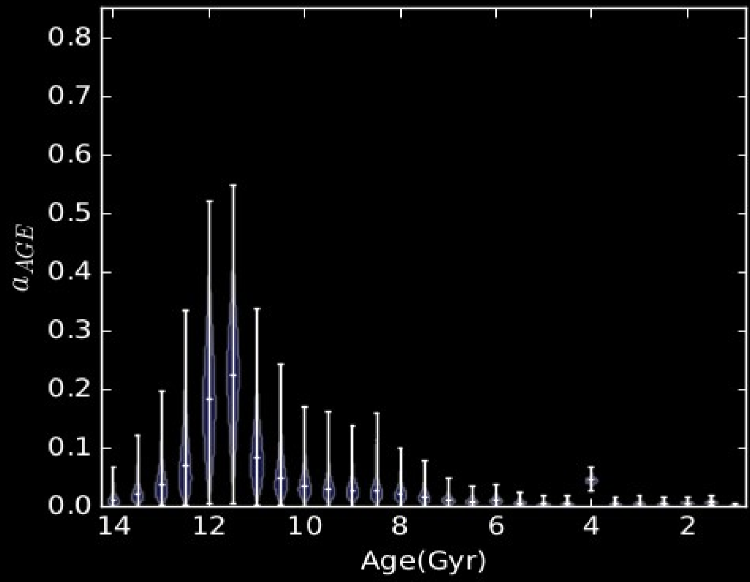
Alzate et al. (2021)

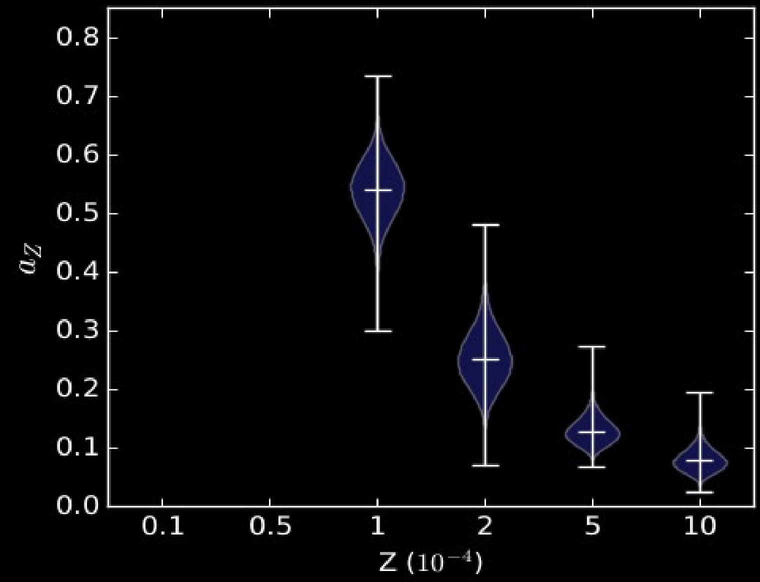
SFH Eri II: Grid B

G16

MaxLike = -14943.4478621

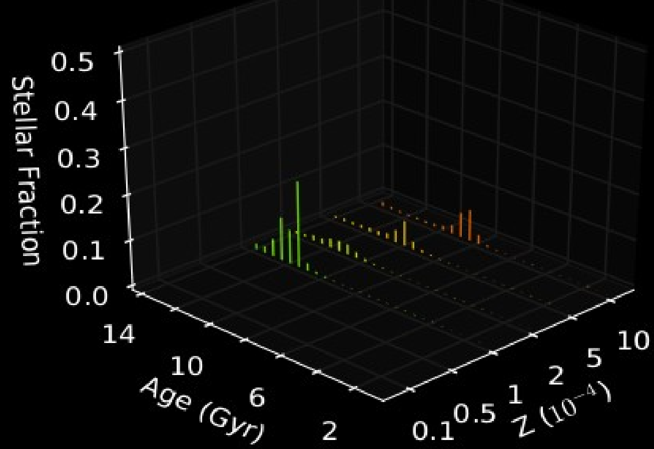


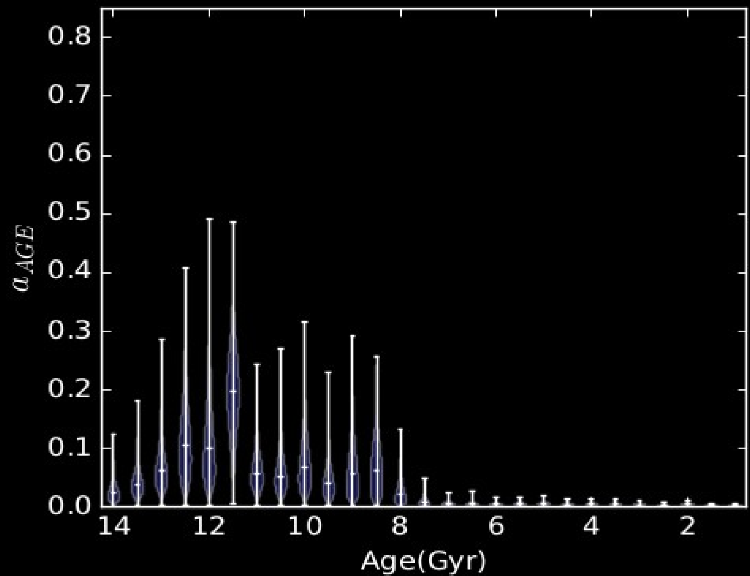


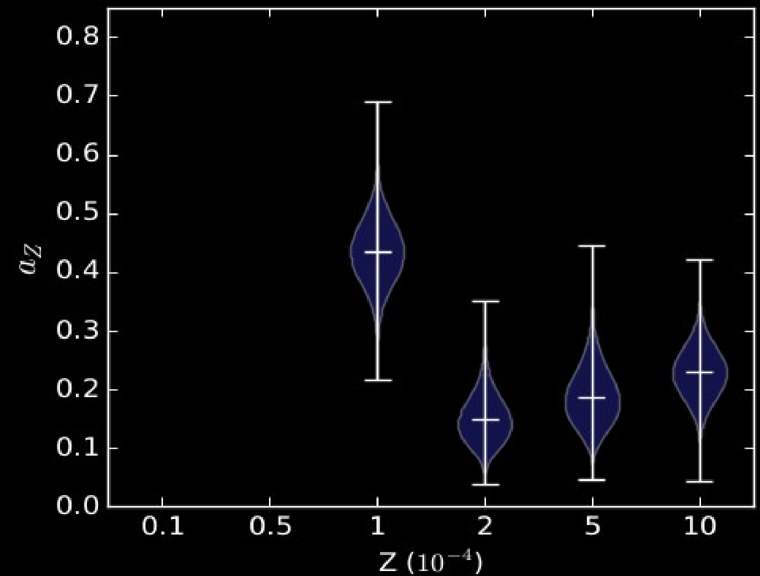


S21

MaxLike = -6970.84423787

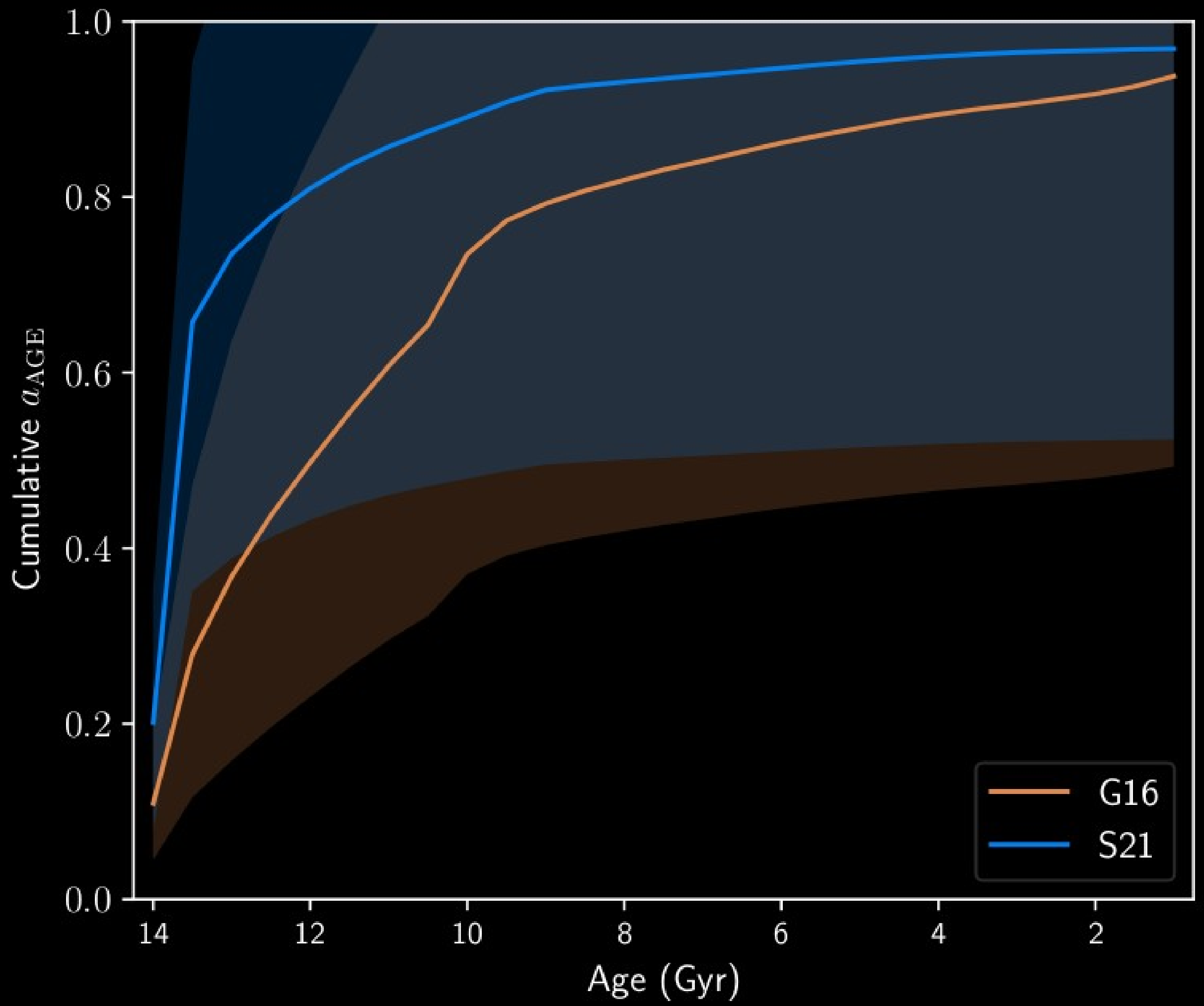






Alzate et al. (2021)

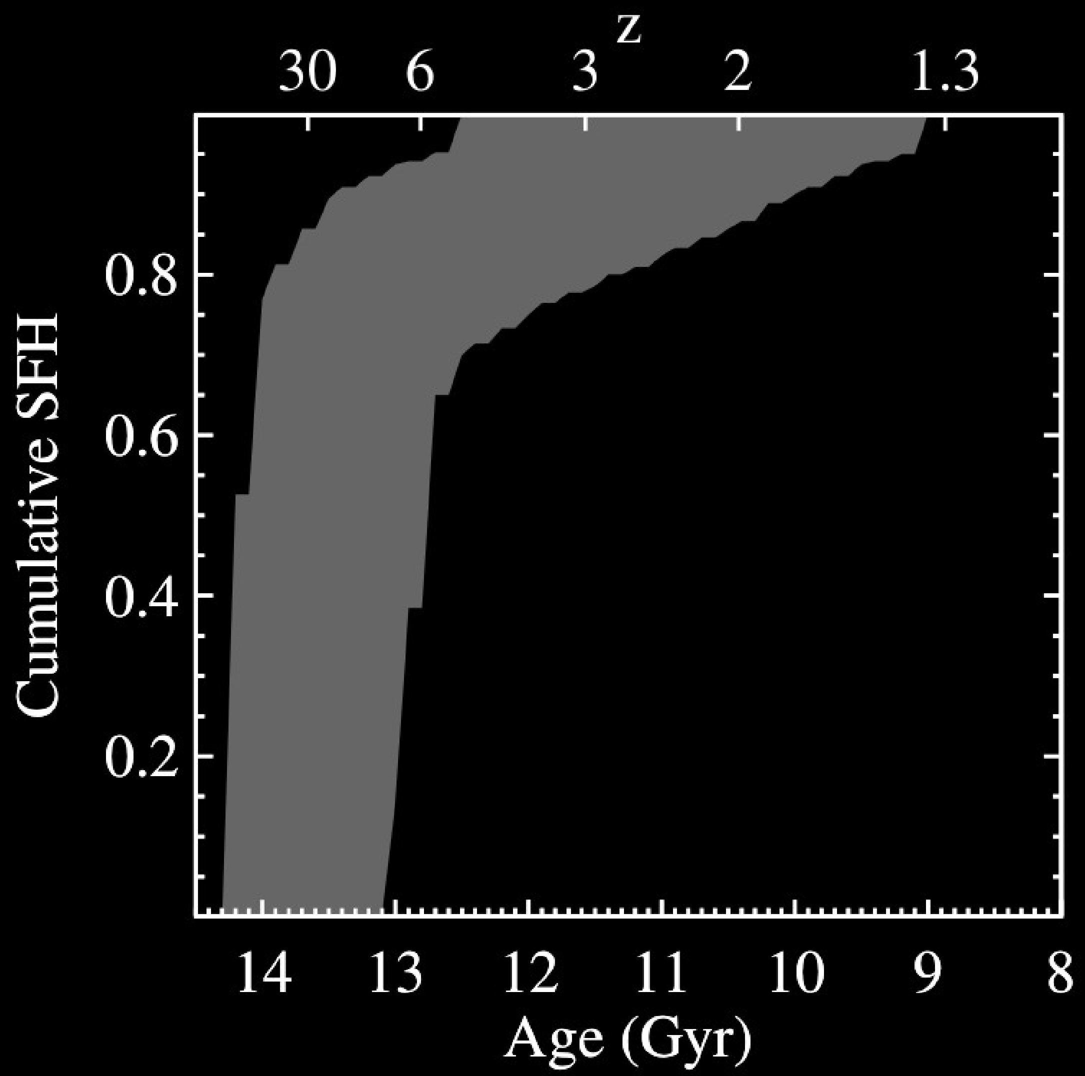
Cumulative SFH: GridA



- For G16 ~60% of the stars in Eri II are younger than 13 Gyr.
- For S21 ~ 75% of the stars in Eri II are older than 13 Gyr.
- The most statistically significant inference shows a star formation quenching 13 Gyr ago.

Alzate et al. (2021)

Quenching by reionization

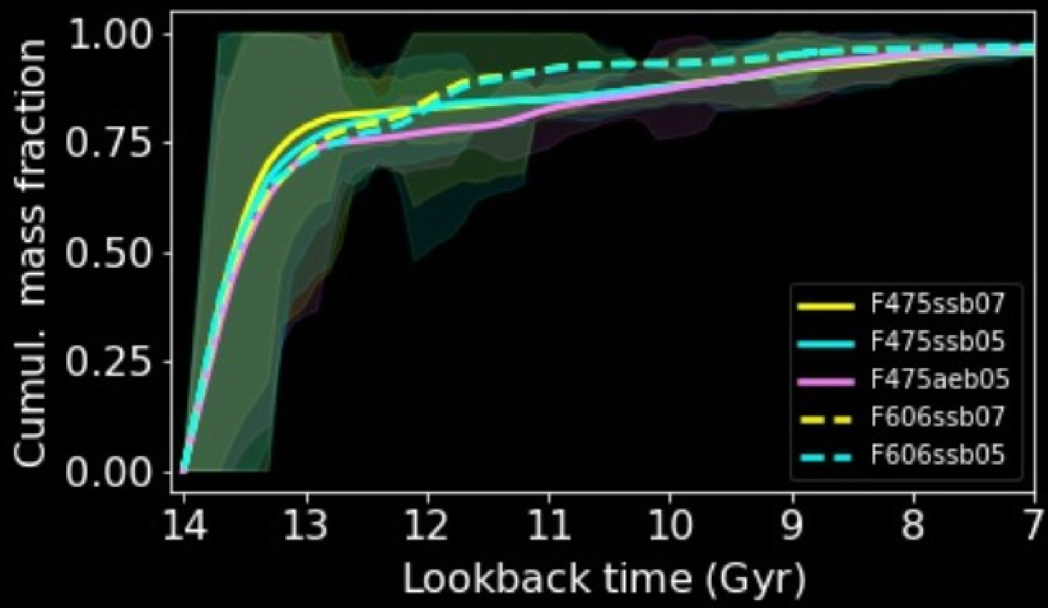


Simon et al. (2021)

From a statistical analysis of orbital information and comparing whit simulations (Garrison-Kimmel et al. 2014) they concluded:

- Eri II has not yet passed through its closest approach to MW.
- The reionization is then the most likely cause for the quenching of star formation in Eri II.

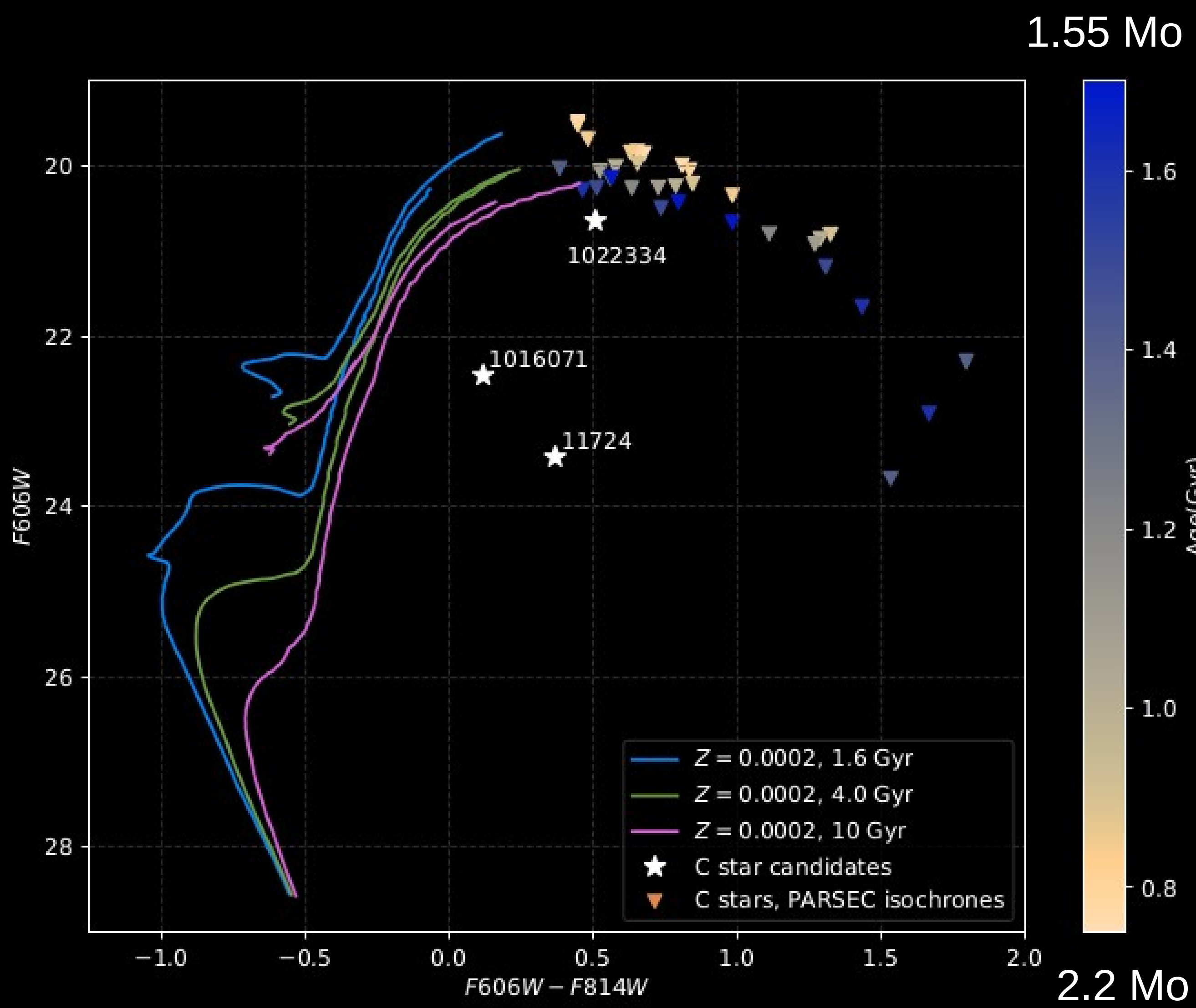
Quenching by stellar feedback



Gallart et al. (2021):

- Leo T is similar to Eri II and held the star formation beyond reionization times.
- The quenching of star formation in Eri II is due to stellar feedback.
- The energy injected by supernova events is enough to overcome the gravitational potential of Eri II.

Carbon stars in Eri II



- C stars from Zoutendijk et al. (2020) MUSE.
- Since we do no detect any residual star formation extending to ~2 Gyr, it is likely that C stars evolve from lower star mass progenitors that increased their mass through stellar fusions.

Alzate et al. (2021)

Conclusions

- We find convincing evidence that the bulk of the stars in Eri II are very old, with an age of $13.5^{+0.5}_{-1}$ Gyr and quite metal poor, with Z = 0.00001.
- In agreement with S21, we found that the 75% of the stars were formed 700 Myr after Big Bang. This result is consistent with the width at half maximum (∼500 Myr) of the derived star formation rate profile of G21.
- We did not succeed in determining the age of the star cluster as an independent entity.
- Nor we find any evidence of the presence of an intermediate age population.
- The lack of recent star formation implies that mass pumping of lower mass MS stars through blue-straggler fusions is responsible of forming the massive progenitors of the C stars seen today in Eri II.