Stellar populations of nine passive spiral galaxies from the CALIFA survey: are they progenitors of S0s

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STELLAR POPULATIONS OF NINE PASSIVE SPIRAL GALAXIES FROM THE CALIFA SURVEY: ARE THEY PROGENITORS OF S0s?

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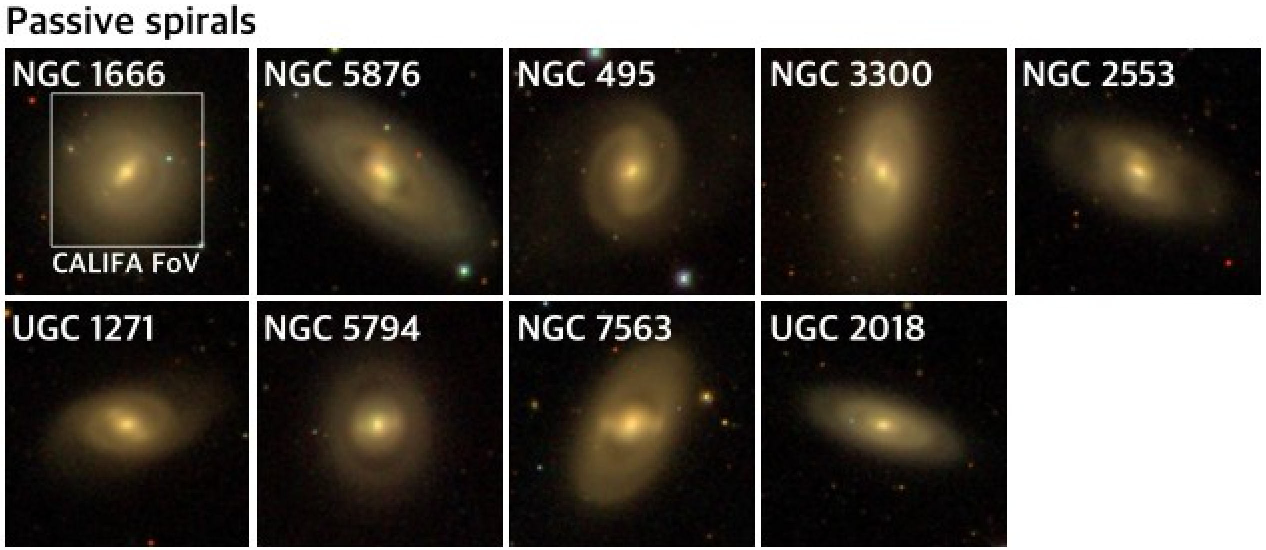
ABSTRACT

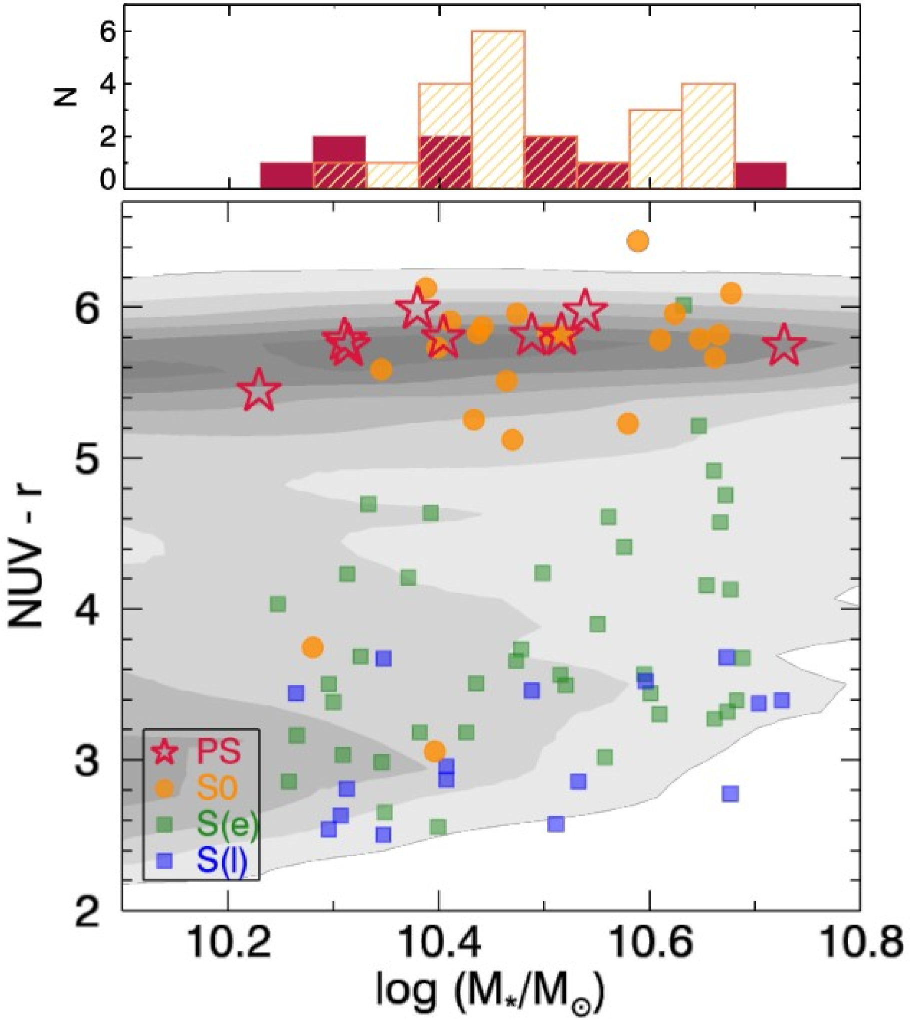
We investigate the stellar population properties of passive spiral galaxies in the CALIFA survey. Nine spiral galaxies that have NUV−r > 5 and no/weak nebular emission lines in their spectra are selected as passive spirals. Our passive spirals lie in the redshift range of $0.001 < z < 0.021$ and have stellar mass range of $10.2 < \log(M_\star/M_\odot) < 10.8$. They clearly lie in the domain of early-type galaxies in the WISE IR color-color diagram. We analyze the stellar populations out to two effective radius, using the best-fitting model to the measured absorption line-strength indices in the Lick/IDS system. We find that stellar populations of the passive spirals span a wide range, even in their centers, and hardly show any common trend amongst themselves either. We compare the passive spirals with S0s selected in the same mass range. S0s cover a wide range in age, metallicity, and [α/Fe], and stellar populations of the passive spirals are encompassed in the spread of the S0 properties. However, the distribution of passive spirals are skewed toward higher values of metallicity, lower [α/Fe], and younger ages at all radii. These results show that passive spirals are possibly related to S0s in their stellar populations. We infer that the diversity in the stellar populations of S0s may result from different evolutionary pathways of S0 formation, and passive spirals may be one of the possible channels.

Subject headings: galaxies: evolution

What is passive spiral ?

- Little or no star formation activity despite their obvious spiral structure





Evolution of passive spirals

- Evolutionary pathways: spiral→passive spiral → S0
- Mechanisms:

  Low mass: cluster environmental effects

  High mass: secular evolution as a result of bars

The origins and evolutionary pathways of passive spirals are still under debate.

Purpose of this work

- Better understanding the **evolution** of passive spiral galaxies by investigating their **spatially resolved stellar populations**, using the CALIFA survey

The **first study** of spatially resolved stellar populations for passive spirals

Sample selection

- Classification: using the SDSS g−, r−, and i−band composite color images and the spectra
- Passive spirals:

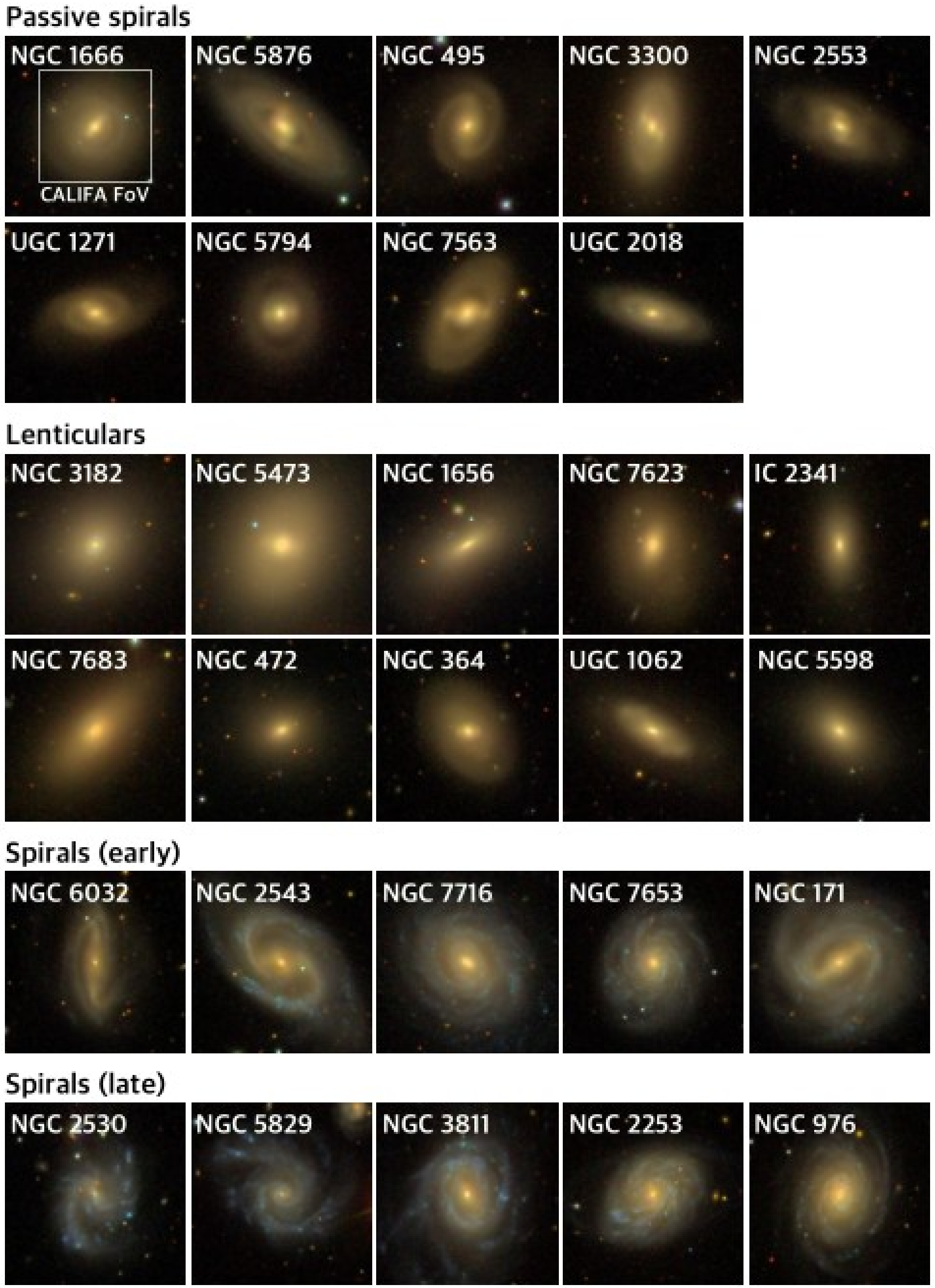
  spirals with red optical color and without nebular emission

  NUV−r colors >5

  stellar masses: $10.23 \leqslant \log(M_*/M_\odot) \leqslant 10.8$

  edge-on galaxies, shell galaxies, and galaxies with ongoing mergers or strong tidal interactions with neighbors are excluded

Sample selection



Sample selection

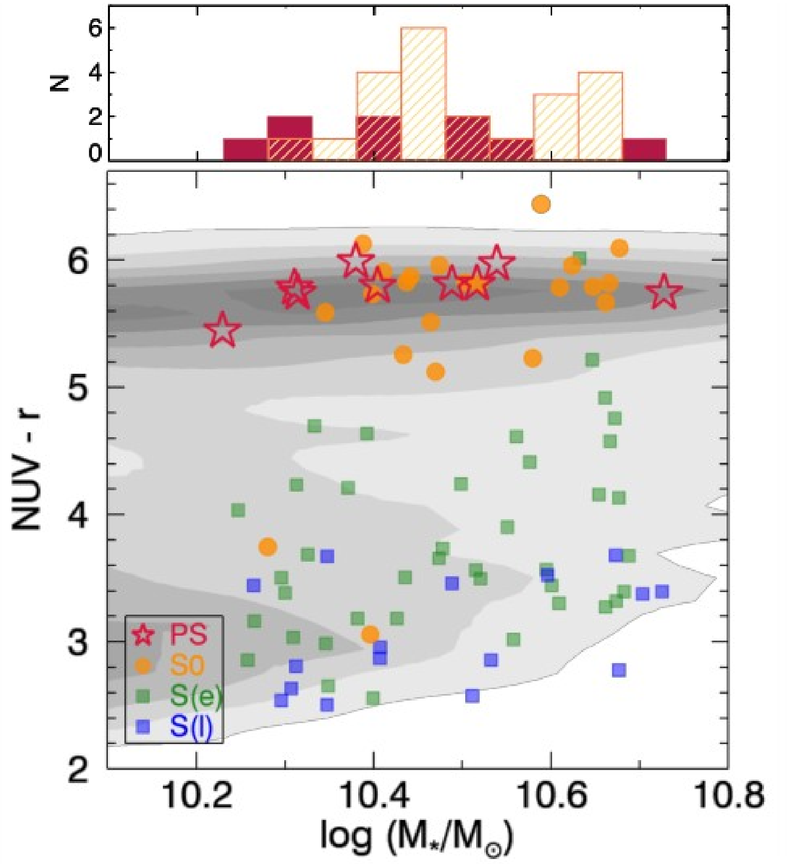


FIG. 2.— NUV−r vs. log ($M_\star/M_\odot$) for passive spirals and S0s. Red stars (and red in histogram) are 9 passive spirals and orange circles (and orange hatched in histogram) are 21 S0s. The green and blue squares indicate early- and late-type star-forming spiral galaxies. The distribution of galaxies from the NSA catalog is overlaid as contours.

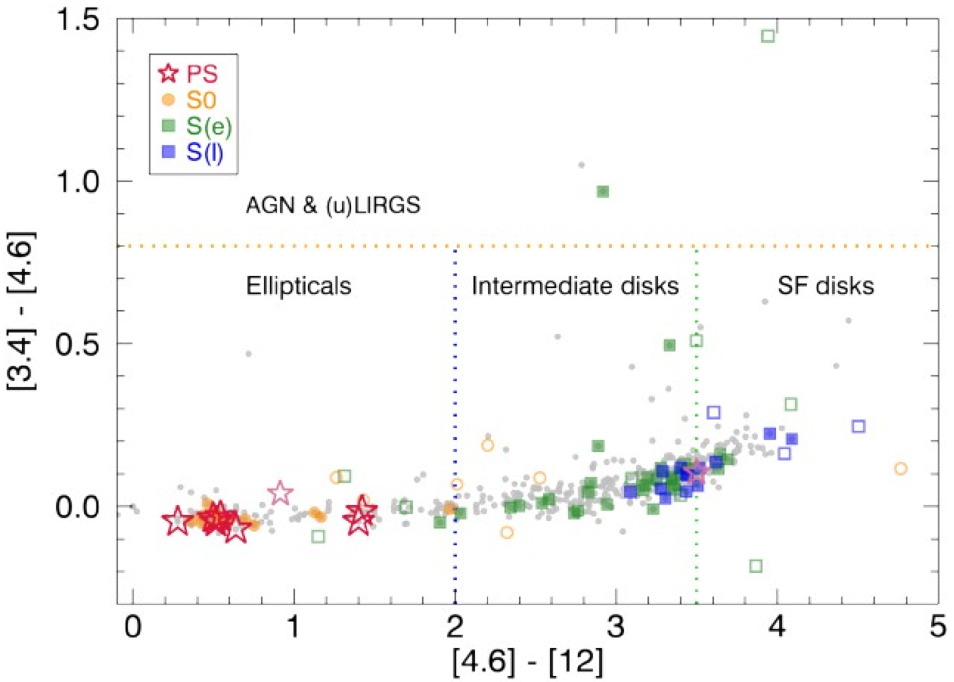


FIG. 3.— WISE color-color diagram for all CALIFA galaxies. The spheroidal (early-type), intermediate disk (disk), and star forming (SF) disk (late-type disk) galaxies are divided by dotted lines based on the schematic diagram from Jarrett et al. (2017). Symbols are the same as those in Figure 2. We use the magnitudes in the WISE catalog extracted using elliptical aperture photometry. When the elliptical-aperture magnitude is not available, we use the instrumental profile-fit photometry magnitude (light red stars for passive spirals, orange open circles for S0s, green and blue open squares for early- and late-type spirals, respectively).

Data

- CALIFA (FoF:74” × 64”):

  Use the V500 data cube with a nominal resolution (λ/Δλ) of 850 at 5000 Å (FWHM ～6 Å) and a wavelength range from 3745 to 7500 Å

  9 passive spirals

  21 S0s and 57 spirals as a comparison sample (in the same stellar mass range)

Analysis

- stellar velocity (v star) and velocity dispersion (σ) from pPXF +absorption line fitting:
- Hβ, Mgb, Fe5270 and Fe5335, taken from the Lick/IDS system

Results

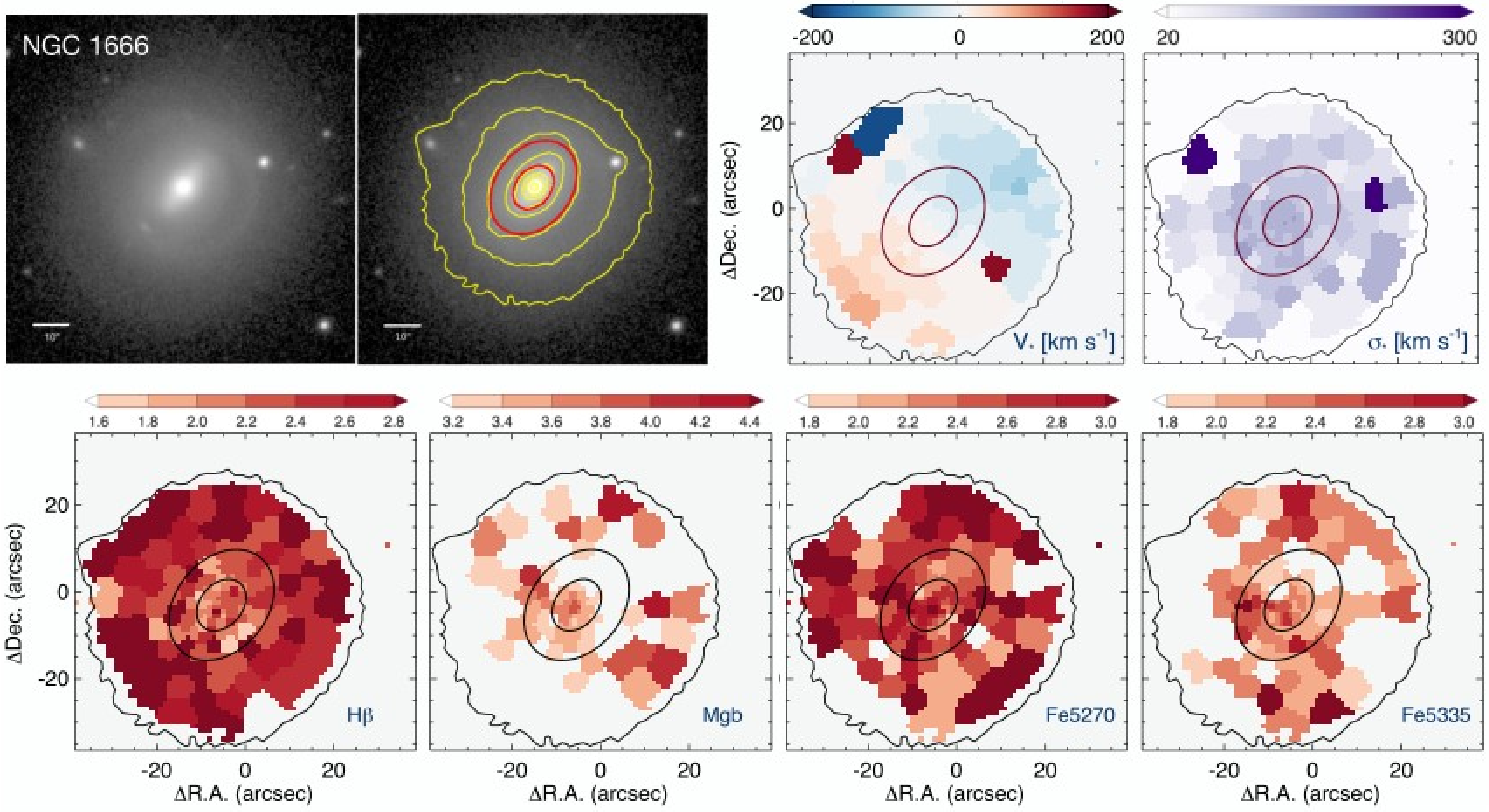
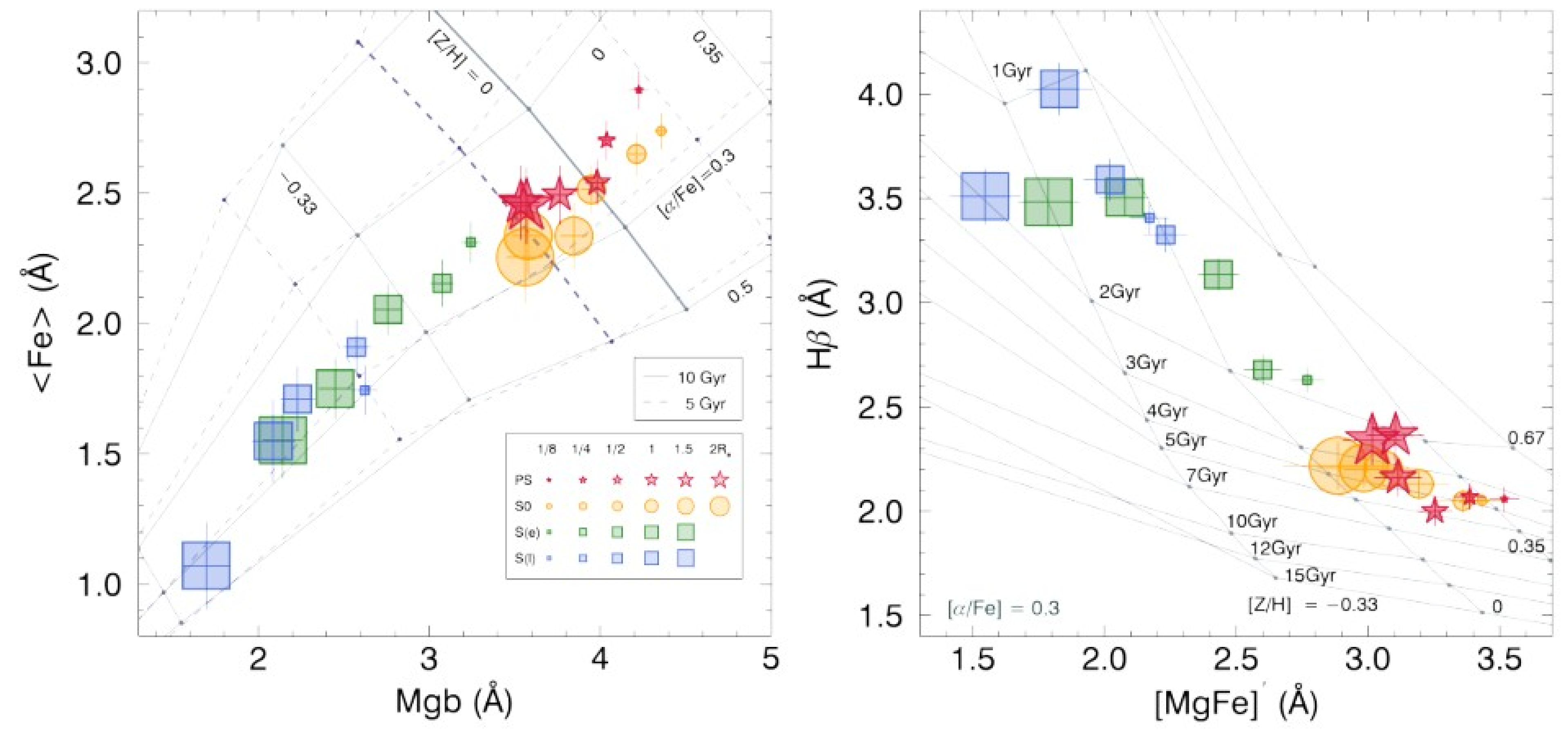


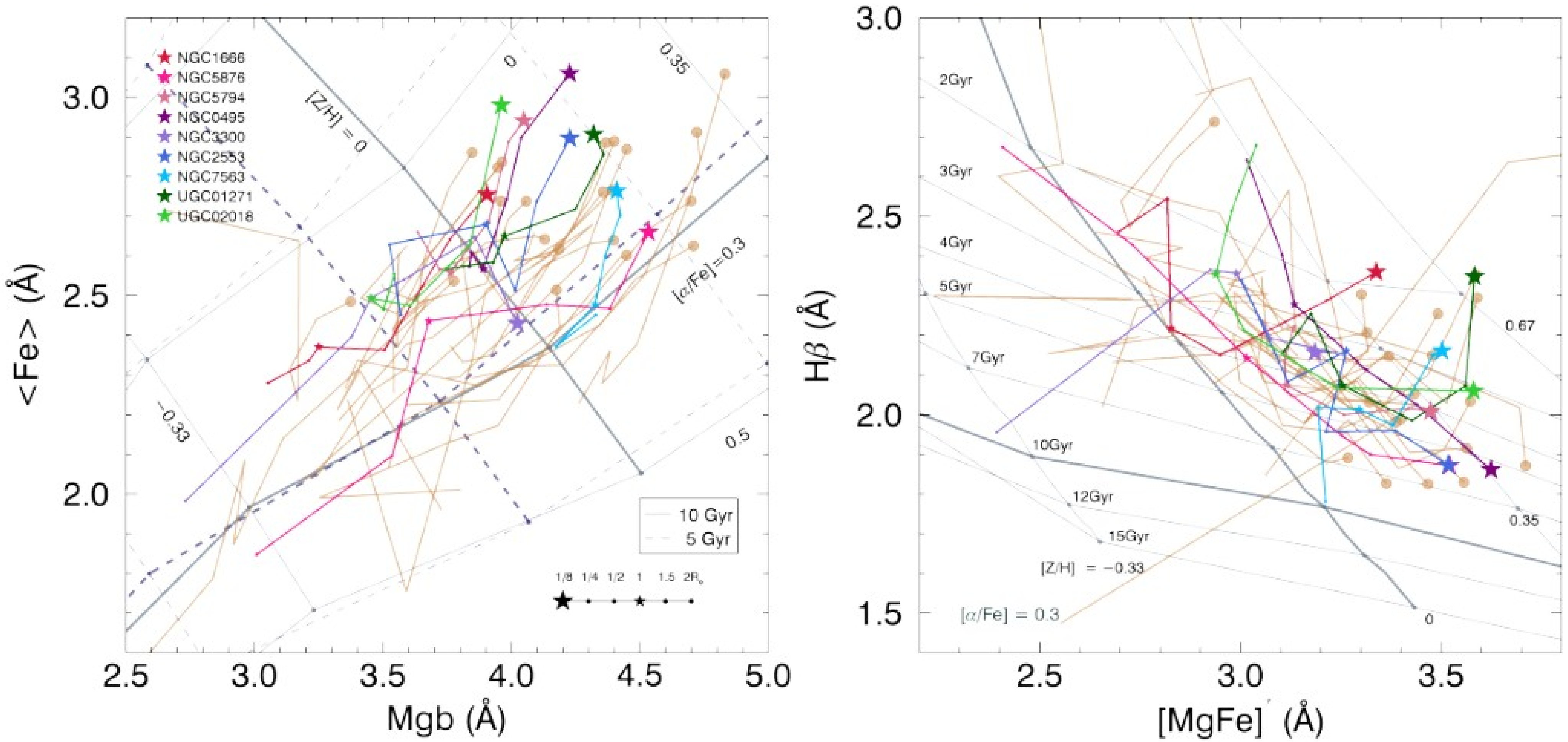
FIG. 4.— The SDSS optical images and maps of the derived parameters of the 9 passive spirals in the CALIFA sample, ordered by increasing stellar mass from the NSA catalog. In the upper row, from left to right we show the SDSS r-band image, the SDSS r-band image with surface brightness contours (in yellow) and the one and two effective radius (ellipses), the stellar velocity map, and the velocity dispersion map. The velocity is normalized relative to the velocity of the brightest pixel. In the bottom row, we present the Hβ, Mgb, Fe5270 and Fe5335 maps. We mark the outermost of the surface brightness contour and the one and two effective radius (ellipses) on the parameter maps. In order to easily compare between galaxies, the range of the color bars is fixed for each parameter.

Results



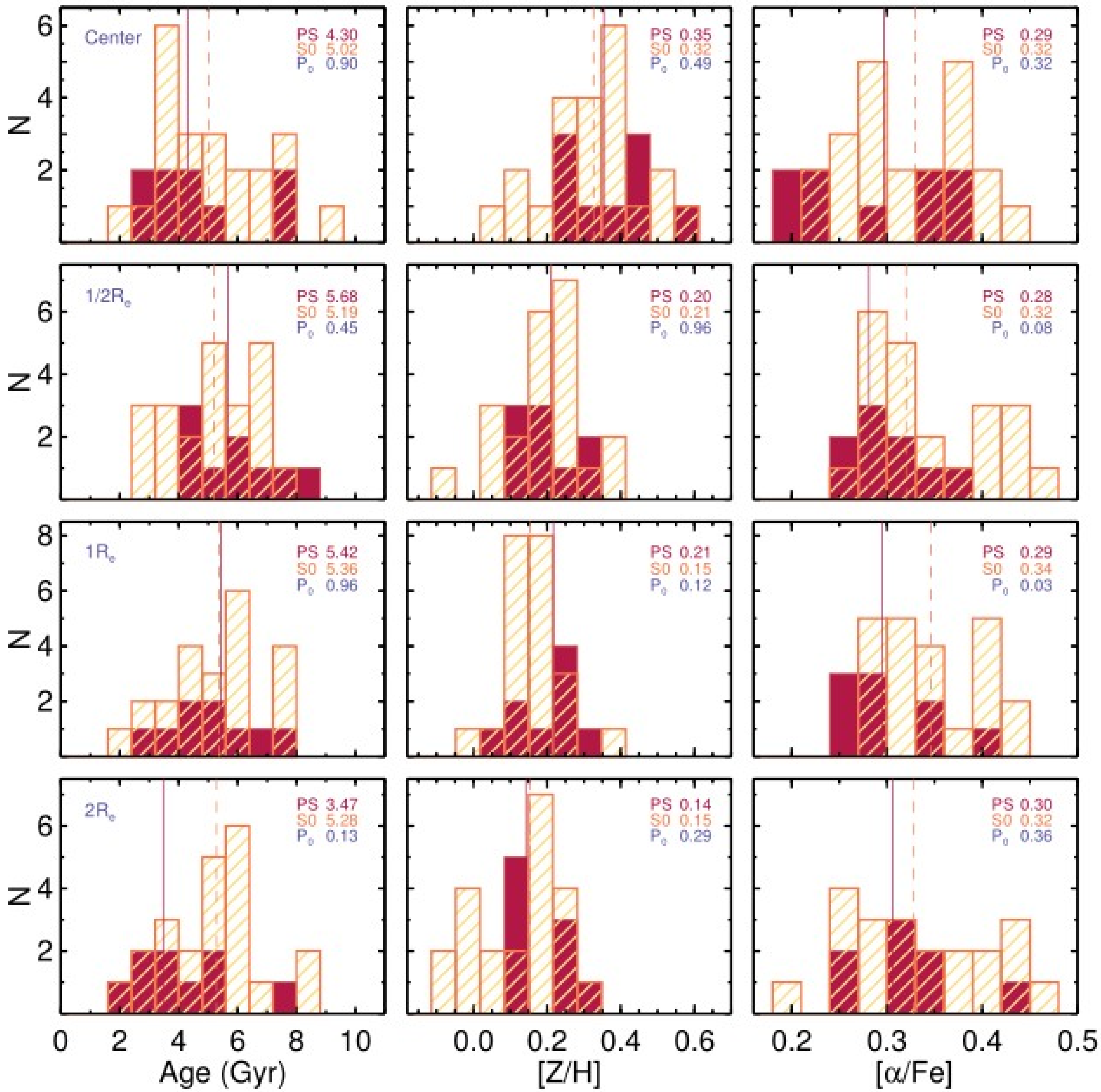
3.0
2.5
2.0
1.5
1.0
<Fe> (Å)
2
3
4
5
Mgb (Å)
[Z/H] = 0
0
0.35
−0.33
[α/Fe]=0.3
0.5
10 Gyr
5 Gyr
1/8 1/4 1/2 1 1.5 2R
PS
S0
S(e)
S(l)
4.0
3.5
3.0
2.5
2.0
1.5
Hβ (Å)
1.5
2.0
2.5
3.0
3.5
[MgFe]' (Å)
1Gyr
2Gyr
3Gyr
4Gyr
5Gyr
7Gyr
10Gyr
12Gyr
15Gyr
0.67
0.35
0
[α/Fe] = 0.3
[Z/H] = −0.33

Results



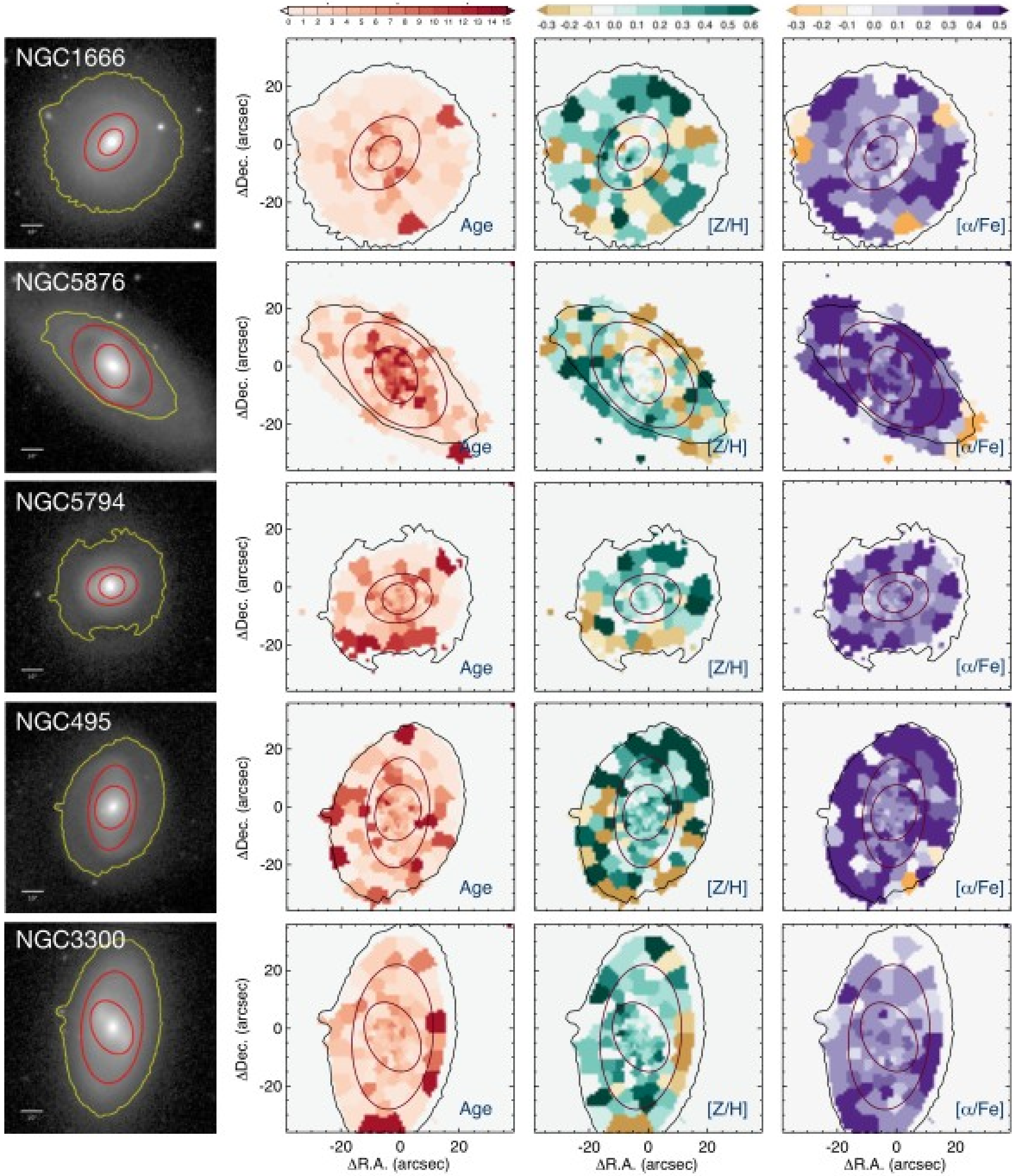
NGC1666
NGC5876
NGC5794
NGC0495
NGC3300
NGC2553
NGC7563
UGC01271
UGC02018
[Z/H] = 0
[α/Fe]=0.3
0
0.35
−0.33
0.5
10 Gyr
5 Gyr
1/8 1/4 1/2 1 1.5 2R_e
<Fe> (Å)
Mgb (Å)
2Gyr
3Gyr
4Gyr
5Gyr
7Gyr
10Gyr
12Gyr
15Gyr
0.67
0.35
[Z/H] = −0.33
[α/Fe] = 0.3
Hβ (Å)
[MgFe]′ (Å)

Results



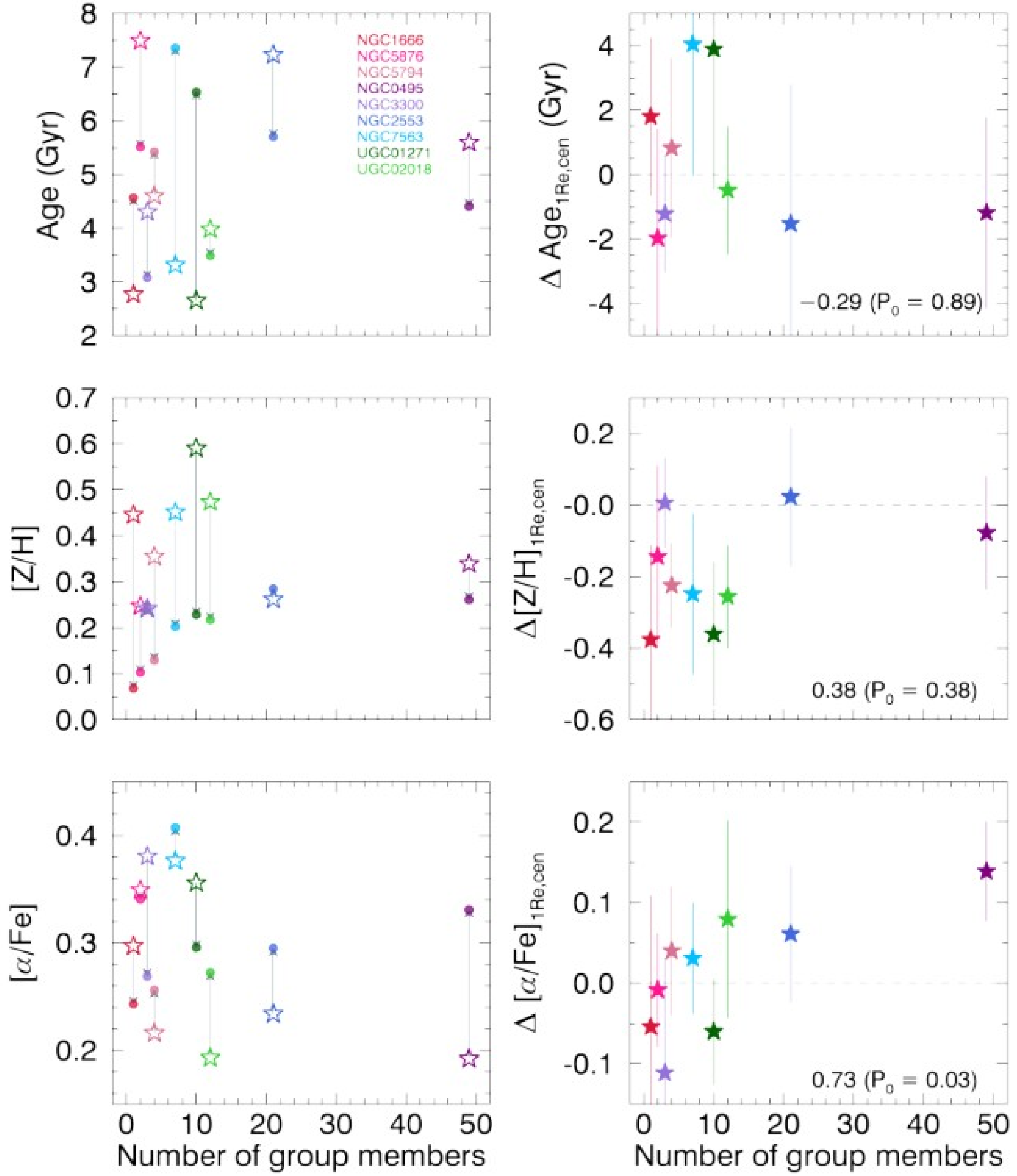
Center
PS 4.30
S0 5.02
P0 0.90
PS 0.35
S0 0.32
P0 0.49
PS 0.29
S0 0.32
P0 0.32
1/2Re
PS 5.68
S0 5.19
P0 0.45
PS 0.20
S0 0.21
P0 0.96
PS 0.28
S0 0.32
P0 0.08
1Re
PS 5.42
S0 5.36
P0 0.96
PS 0.21
S0 0.15
P0 0.12
PS 0.29
S0 0.34
P0 0.03
2Re
PS 3.47
S0 5.28
P0 0.13
PS 0.14
S0 0.15
P0 0.29
PS 0.30
S0 0.32
P0 0.36
N
Age (Gyr)
[Z/H]
[α/Fe]

Results



NGC1666
NGC5876
NGC5794
NGC495
NGC3300
Age
[Z/H]
[α/Fe]
ΔDec. (arcsec)
ΔR.A. (arcsec)

Results


NGC1666
NGC5876
NGC5794
NGC0495
NGC3300
NGC2553
NGC7563
UGC01271
UGC02018
Age (Gyr)
Δ Age1Re,cen (Gyr)
−0.29 (P0 = 0.89)
[Z/H]
Δ[Z/H]1Re,cen
0.38 (P0 = 0.38)
[α/Fe]
Δ [α/Fe]1Re,cen
0.73 (P0 = 0.03)
Number of group members
Number of group members

Conclusions

- (1) Passive spirals in isolation or low density regions might be just old spirals that have exhausted their fuel. Such gas consumption may have been accelerated by internal processes related with bar structure.
- (2) In denser environments, neighbor interactions or group/cluster mechanisms can help strip the gas away predominantly in the halo and outer disks, but still secular evolution by a bar could accelerate quenching. Both scenarios may explain the cessation of star forming activity without destroying the spiral structure.