Ancient stellar populations in the outskirts of nearby grand-design spirals: Investigation of their star formation histories

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Received date / Accepted date

ABSTRACT

Context. The main sequence (MS) of star-forming galaxies (SFGs) is the tight relation between the galaxy stellar mass ($M_\star$) and its star formation rate (SFR) and was observed up to $z \sim 6$. The MS relation can be used as a reference for understanding the differences among galaxies, which are characterised by different rates of stellar production (starbursts, SFGs, and passive galaxies), and those inside a galaxy that is made up of different components (bulge, disk, and halo). To investigate peculiar features found in our sample galaxies in more depth, we focus here on their star formation history (SFH).
Aims. The SFHs are a fundamental tool for revealing the galaxy path from the earlier stages of formation to the present time. The various phases of galaxy evolution are imprinted on the source spectrum globally and locally. Thus, we are able to interpret the dynamical origin of the spirals quantitatively and distinguish between in situ or ex situ formation processes.
Methods. We performed a spectral energy distribution fitting procedure that accounted for the energetic balance between UV (observed) and far-IR (optically obscured) radiation on a sample of eight nearby face-on grand-design spiral galaxies from the DustPedia sample. This approach allowed us to study the spatially resolved MS of the sample and to recover the past SFH by accounting for attenuation due to the presence of dust. By exploiting the BAGPIPES code, we constrained the SFHs for each galaxy with a delayed exponentially declining model to derive their mass-weighted age (t_{MW}).
Results. The spiral galaxies in our sample have similar radial t_{MW} trends overall. A central old region (t_{MW} up to $\sim$ 7Gyr, consistent with the presence of a bulge for various systems) is followed by younger regions in which the disks are still forming stars ($t_{MW} \sim$ 4Gyr). At larger distances from the centre of the galaxies, t_{MW} increases mildly in general. Strikingly, in two galaxies (NGC4321 and NGC5194), we found a steep increase in t_{MW} that reached levels similar to those of the bulge. These old stellar populations in the very galaxy outskirts, which are also detectable as "quenched rings" below the spatially resolved MS, is unexpected. We discuss their potential origin by considering the different gas phases (HI and H_2) of the source with the most prominent quenched ring, NGC4321, and argue for two main possibilities: 1) some environmental effect (e.g. starvation) could affect the outer edge of the galaxies or 2) the circumgalactic medium of sources outside of high-density clusters might have stopped to supply pristine gas to the galaxy (e.g. if its specific angular moment is too high for being accreted).

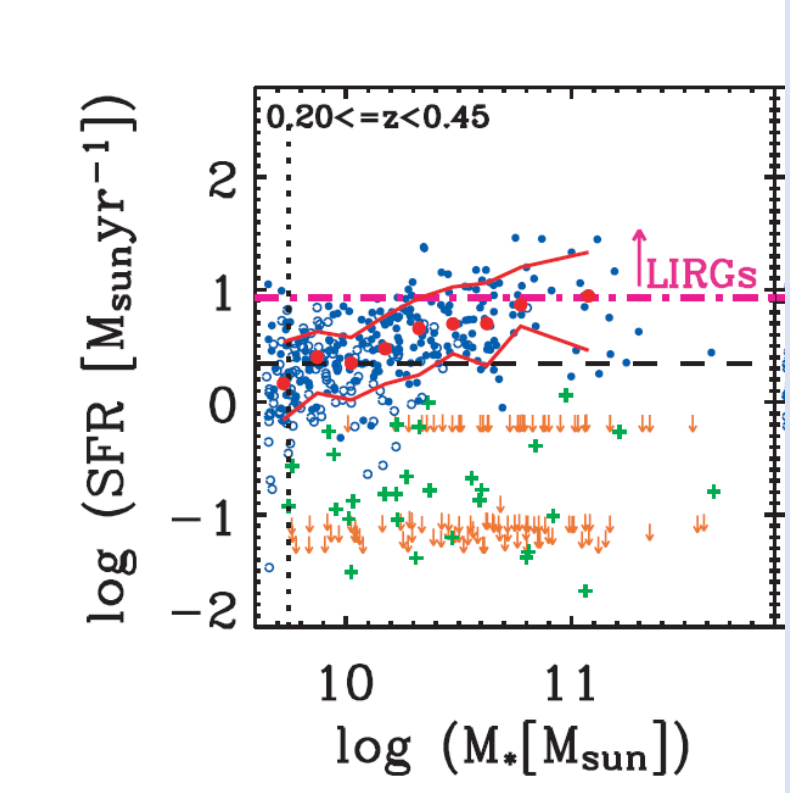
Key words. galaxies: spirals – galaxies: Star Formation History – galaxies: mass-weighted age

1. Introduction

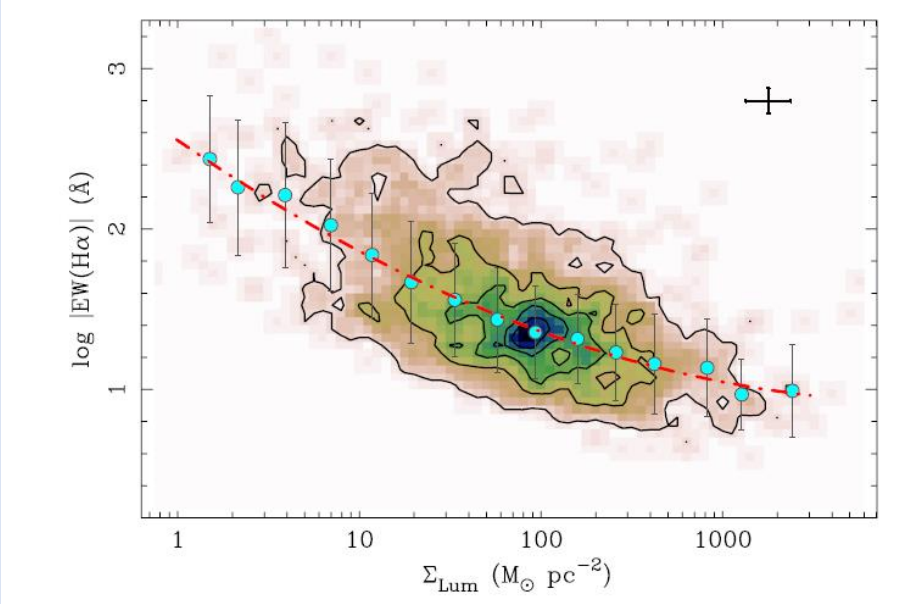
et al. 2015; Saintonge et al. 2016). The tight relation between stellar mass surface density ($\Sigma_\star$) and SFR surface density (Σ_{SFR}

История:

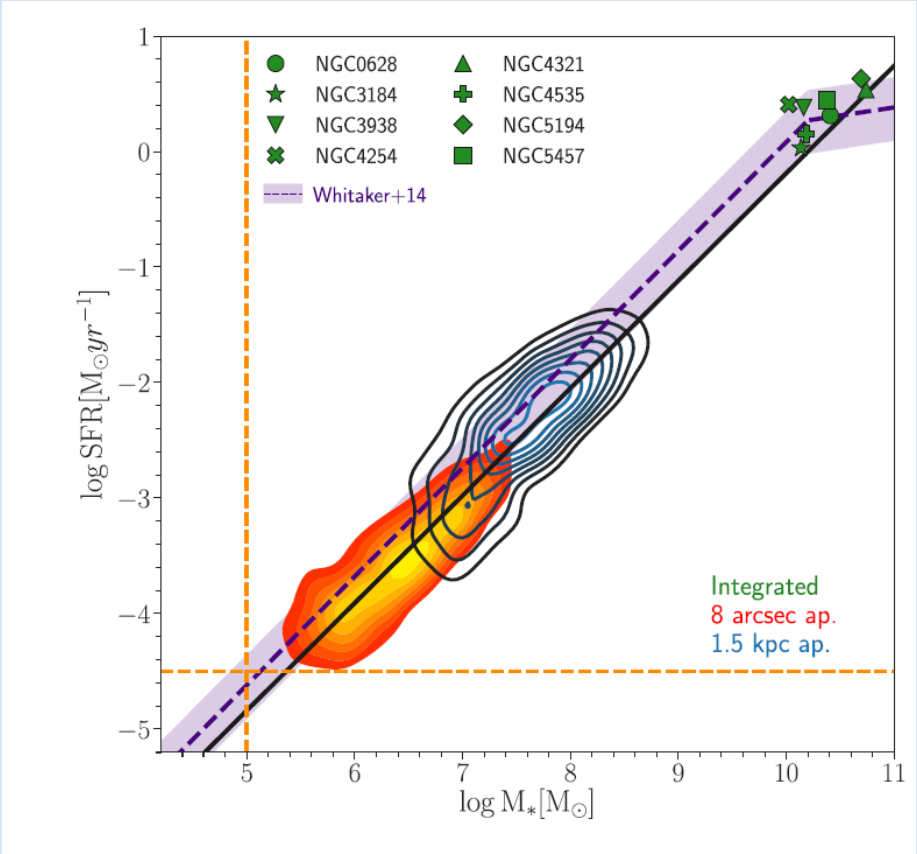
Noeske et al 2007



Rosales-Ortega etal 2012



- Предыдущая работа:
- A panchromatic spatially resolved analysis of nearby galaxies – I. Sub-kpc-scale main sequence in grand-design spirals
- Eina et al., 2020



However, individual galaxies show specific variations around the ΣSFR-Σ∗ relation, indicating that a comprehensive analysis of a larger sample is required.

- The motivation of our work is understanding the origin of the significant deviations from the average MS that were observed in the sample presented in Enia et al. (2020)

- Работа использует архивные данные DustPedia - a research project to characterize the dust in the local Universe. It contains the imagery and multiwavelength photometry study of 875 nearby galaxies.
- Базы данных GALEX, SDSS, 2MASS, WISE, SPITZER, HERSHEL, PLANCK.
- Данные HI (VLA) и CO (HERACLES Survey)
- Рассматривается 8 галактик: NGC0628, NGC3184, NGC3938,

NGC4254, NGC4321, NGC4535, NGC5194, and NGC5457.

ЦЕЛЬ: вычисление mass-weighted ages на различном расстоянии от центра галактик.

$$t_{\mathrm{MW}} = \frac{\int_0^{t_{\mathrm{obs}}} tSFR(t)dt}{\int_0^{t_{\mathrm{obs}}} SFR(t)dt},$$

where $SFR(t)$ is the SFH, and $t_{\mathrm{obs}} = t(z_{\mathrm{obs}})$.

Методы:

- Звездная масса – по SED, учет ослабление пылью
- SFR = SFR(UV) + SFR(8-1000мкм).

ИСТОРИЯ:

$$SFR(t) \propto \begin{cases} (t - T_0)\, exp\,(-\frac{t-T_0}{\tau}) & t > T_0 \\ 0 & t < T_0 \end{cases} \quad (1)$$

, where t is the time since the Big Bang, T_0 is the time when star formation starts, and τ is the timescale of the exponentially declining star formation.

The total mass formed over the whole history (in log10(M⋆/M⊙)) spanning from 1 to 15, and metallicities varying between 0 and 2.5 Z⊙

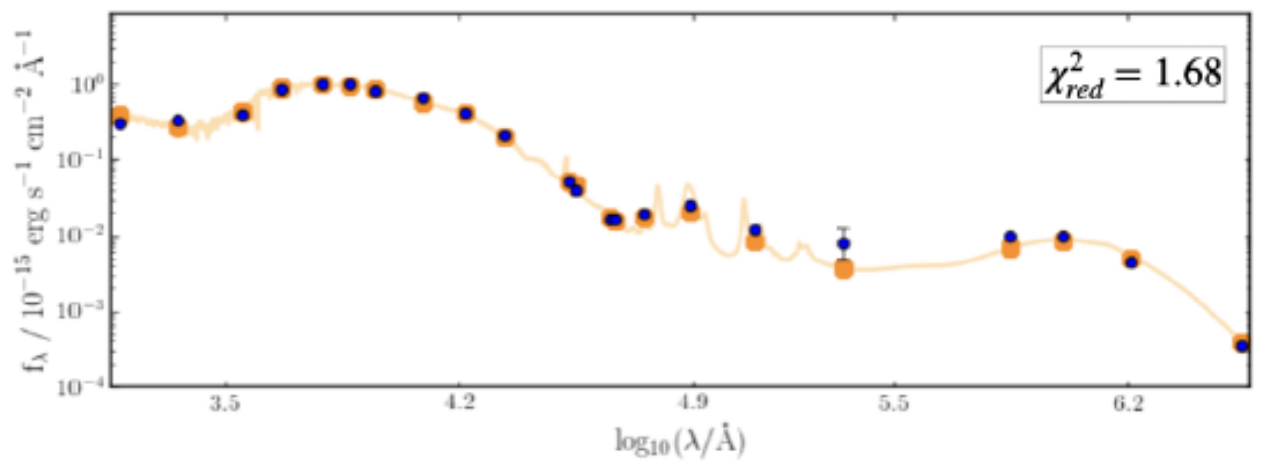


Fig. A.2. Same as A.1 for an aperture located at $0.5R_{25}$ of NGC4321 (aperture B in 1).

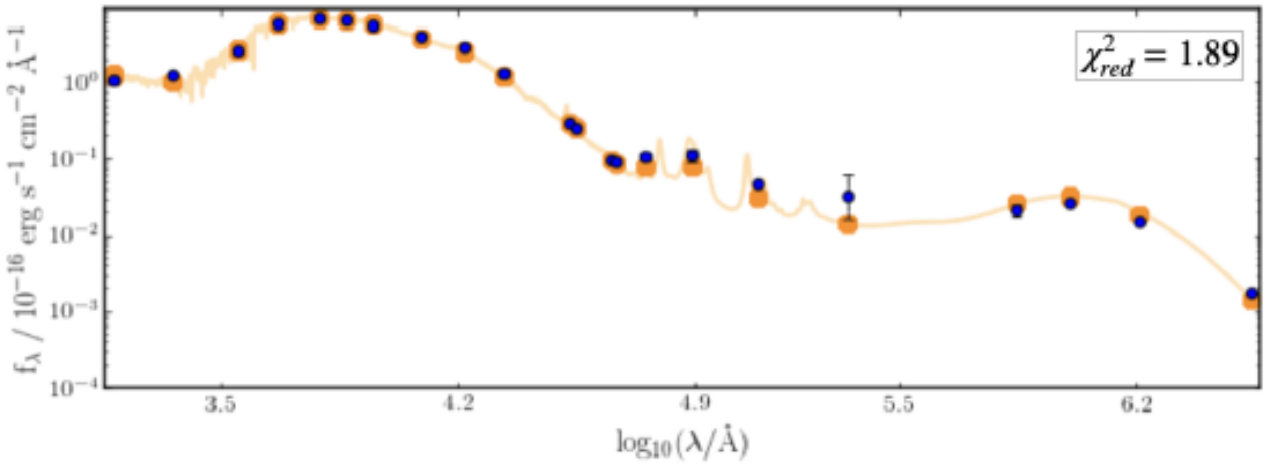


Fig. A.3. Same as A.1 for an aperture located at R_{25} of NGC4321 (aperture C in 1).

- Пример: NGC 4321

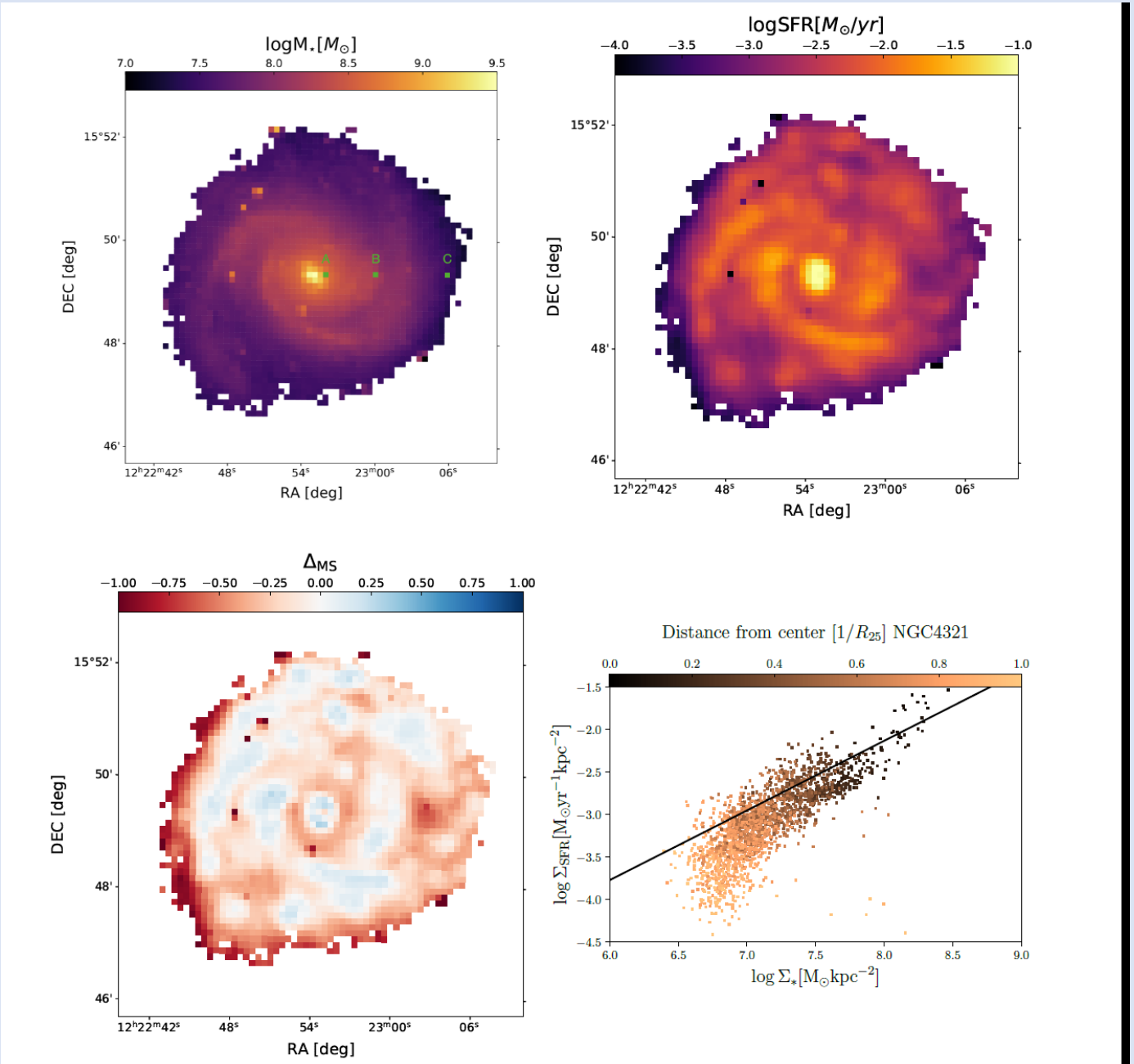
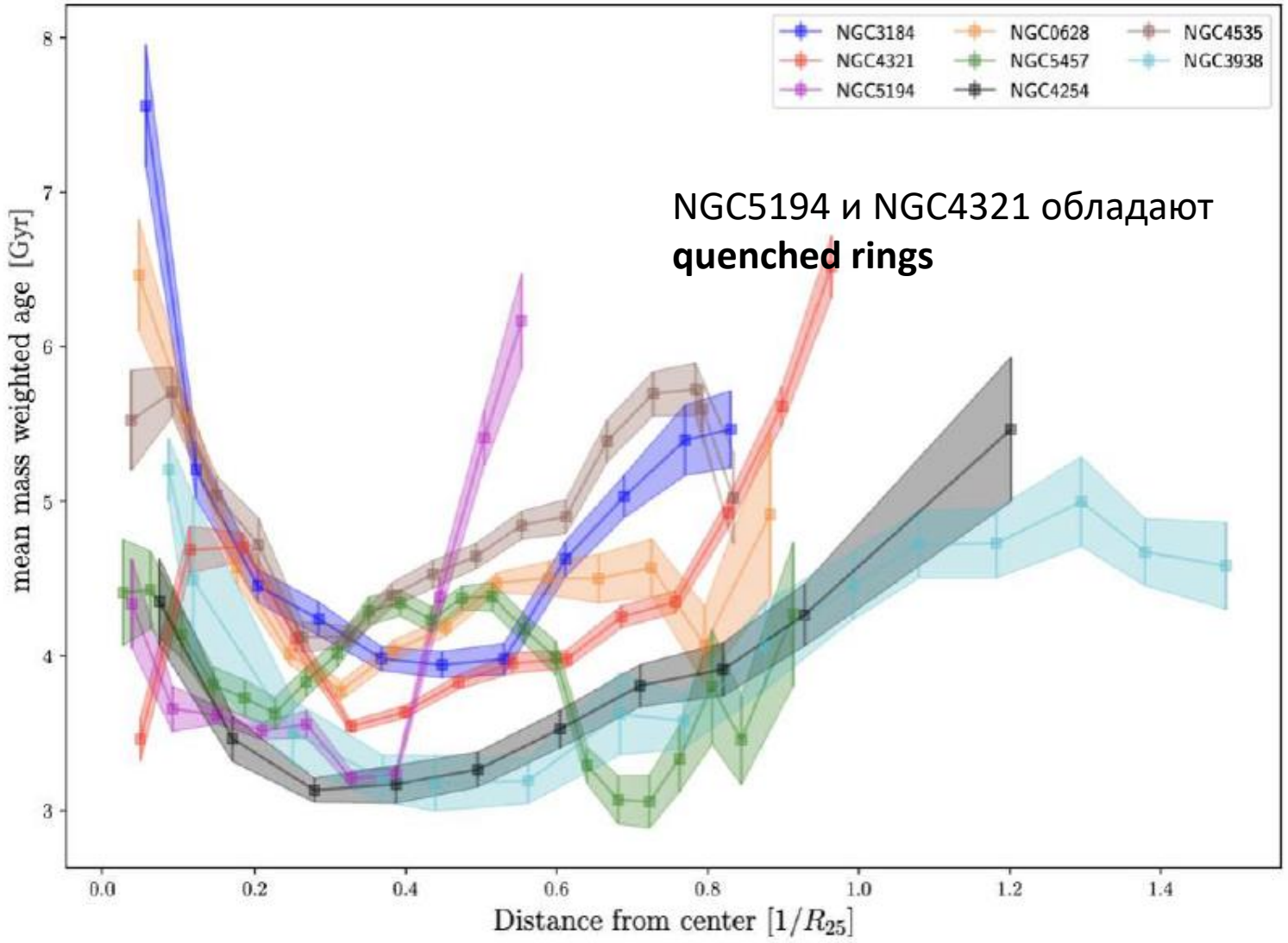


Fig. 1. Summary plot for NGC4321. The panels are organised as follows: stellar mass surface density (*upper left*), SFR surface density (*upper right*), distance from the MS (*bottom left*), and spatially resolved MS (*bottom right*). The solid black line shows the spatially resolved main sequence by Enia et al. (2020), and each point is colour-coded by the cell distance from the galaxy centre. In the first panel, three apertures (A, B, andC) are highlighted. The corresponding SED plot for each is reported in Appendix A.



NGC5194 и NGC4321 обладают **quenched rings**

Fig. 2. Average radial distribution of the mass weighted age of the eight galaxies of our sample. The distance from the center is normalised to their R_{25} radius. As regards the uncertainties computation, see Sec. 3.2

РЕЗУЛЬТАТ:

The stellar populations in the outermost regions of the disk that are probed by our photometric measurements are older (up to 2 - 3 Gyr) on average than those of the same disk component at intermediate galactocentric distances (where they are not contaminated by the bulge component). We note that the rise is steeper for at least two sources, NGC5194 and NGC4321. The former has an interacting companion (NGC5195), and the latter shows a more extended and dead disk (from 0.8 up to R=R25).

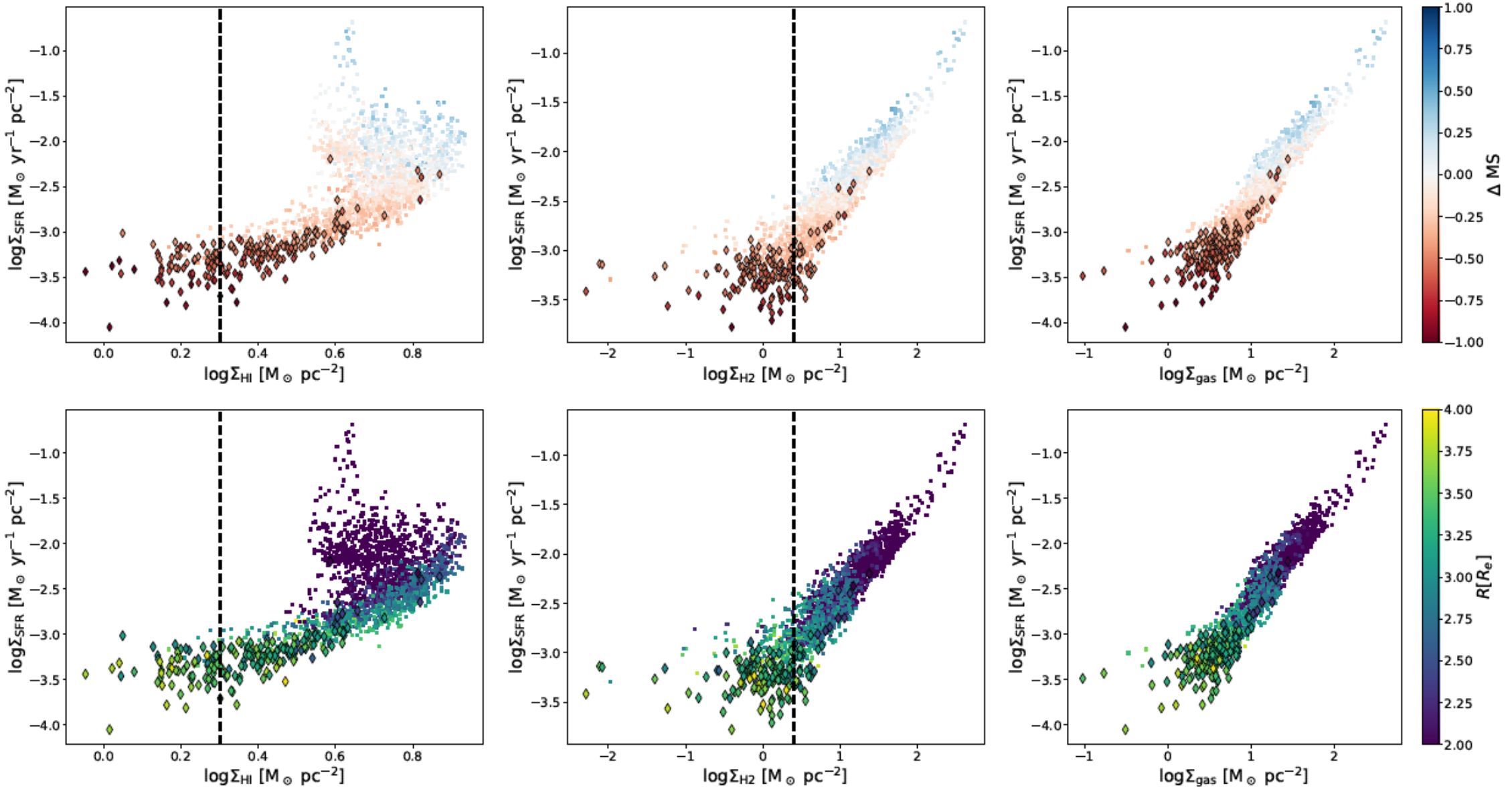


Fig. 5. Spatially resolved Kennicutt-Schimdt relation for NGC4321. The surface density of SFR (Σ_{SFR}) is reported as a function of Σ_{HI} (left panel), Σ_{H2} (central panel), and the total (HI+H2) gas surface density (right panel). The three upper panels are colour-coded as a function of the distance to the MS. The lower panels indicate the galacto-centric distance of each physical galaxy cell. Diamonds correspond to regions associated with the quenched ring.

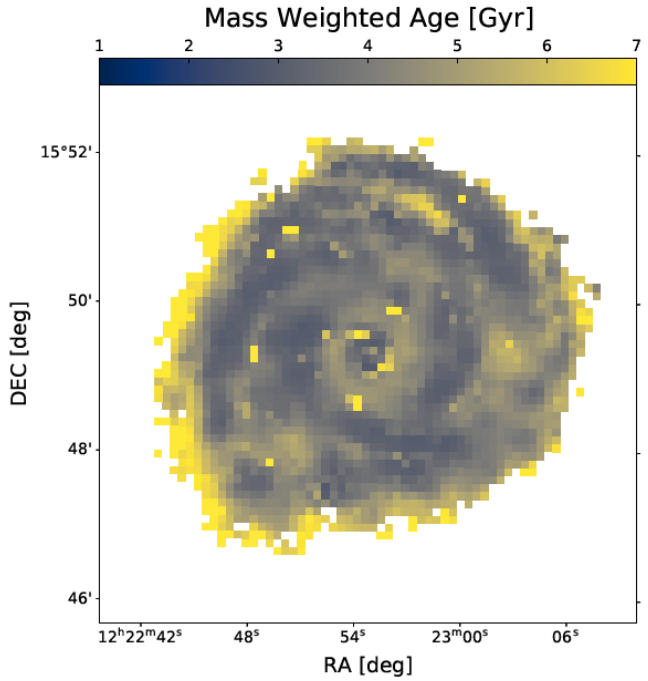


Fig. 3. Spatial distribution of the mass weighted age for NGC4321.

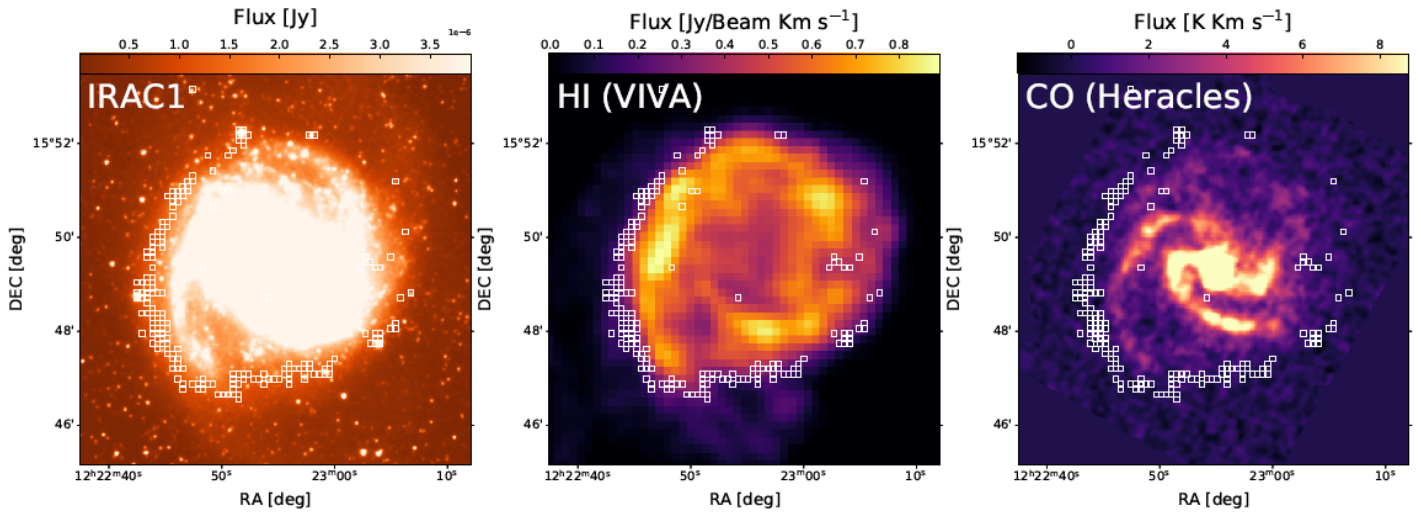


Fig. 4. Spatially resolveed properties of the face-on galaxy NGC4321 *Left panel:* IRAC/Spitzer view of NGC4321. The map at 3.6μm highlights the diffuse stellar emission around the disk and shows the structure of the spiral arms. *Central panel:* HI emission from the public VIVA database. The maps are reported in the same astrometric system. The open squares mark the position of the galaxy cells building the quenched ring, and they have a size of 8"×8". *Right panel:* The H2 gas phase for NGC4321 is traced by the CO emission from the Heracles survey. Each image is presented at the native angular resolution (*Spitzer* = 1.6", HI = 15", CO = 11").

A low Σ_{HI} like this, associated with a paucity of H_2, in addition to a distribution of an old stellar population, indicates that "starvation" has started at the outer edge of the galaxy as a result of insufficient gas supply, whereas star formation is sill going on in the inner regions.

Либо газ выдут из периферийных областей, либо израсходован на звездообразование.
Последнее не проходит для N5194.

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