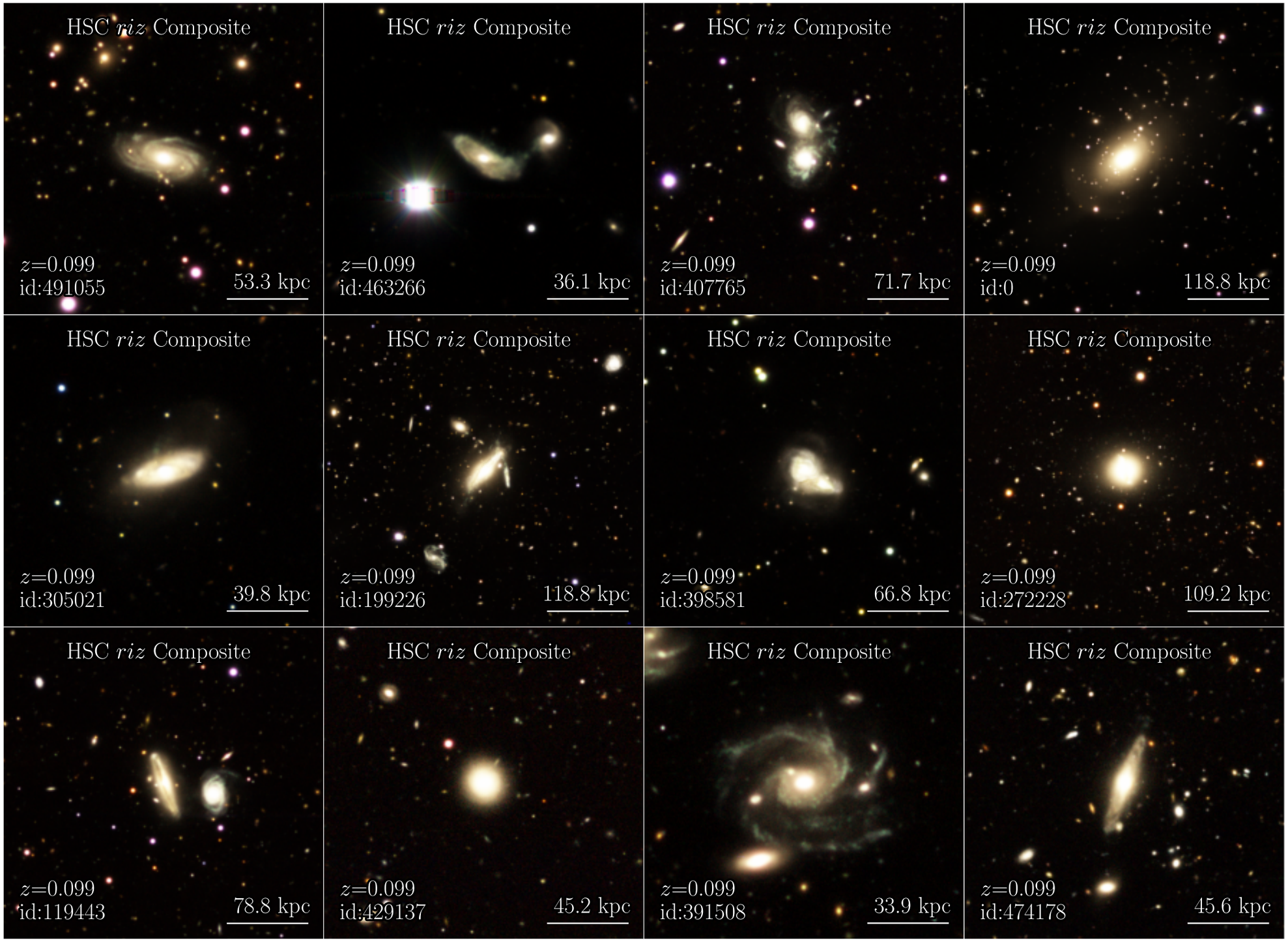
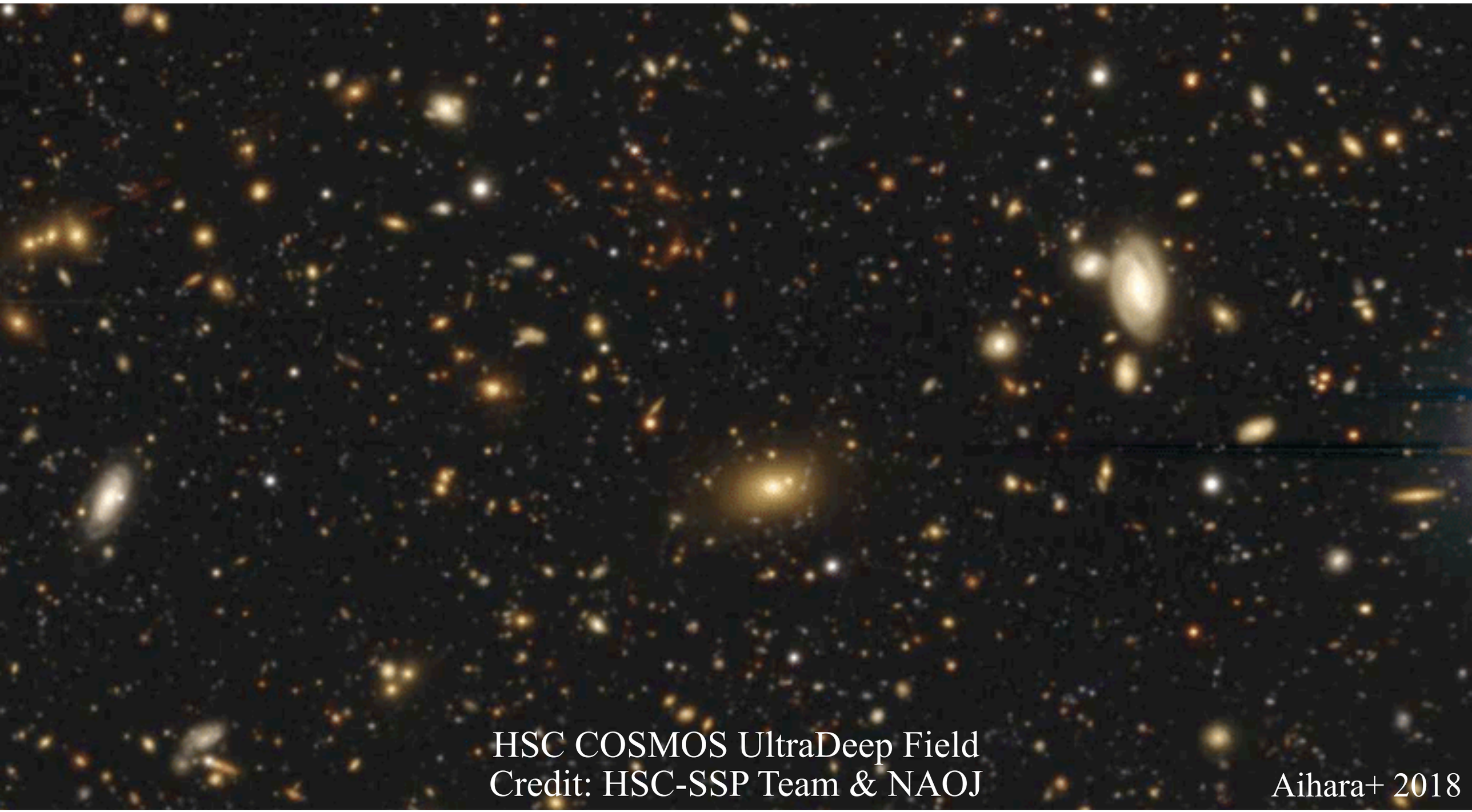
TNG50 Galaxies Observed in the HSC-SSP!

Connor Bottrell (Kavli IPMU | connor.bottrell@ipmu.jp)

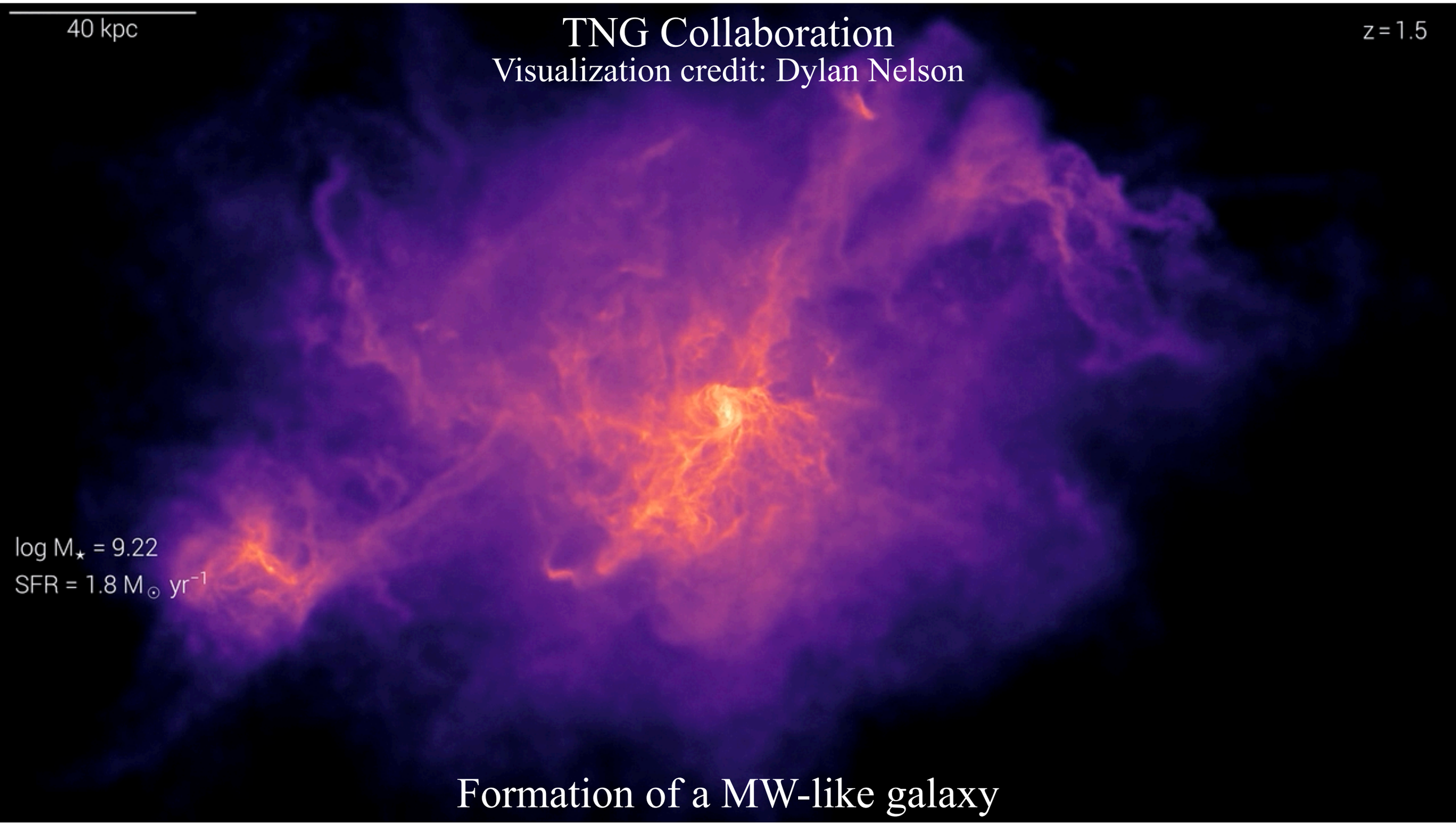


The observed morphologies of galaxies encode their highly non-linear formation scenarios and statistics



How can connections be established between these observed shapes and their formation scenarios if the histories of galaxies are not accessible observationally?

Numerical hydrodynamical simulations facilitates connections between *observables* and *non-observables*



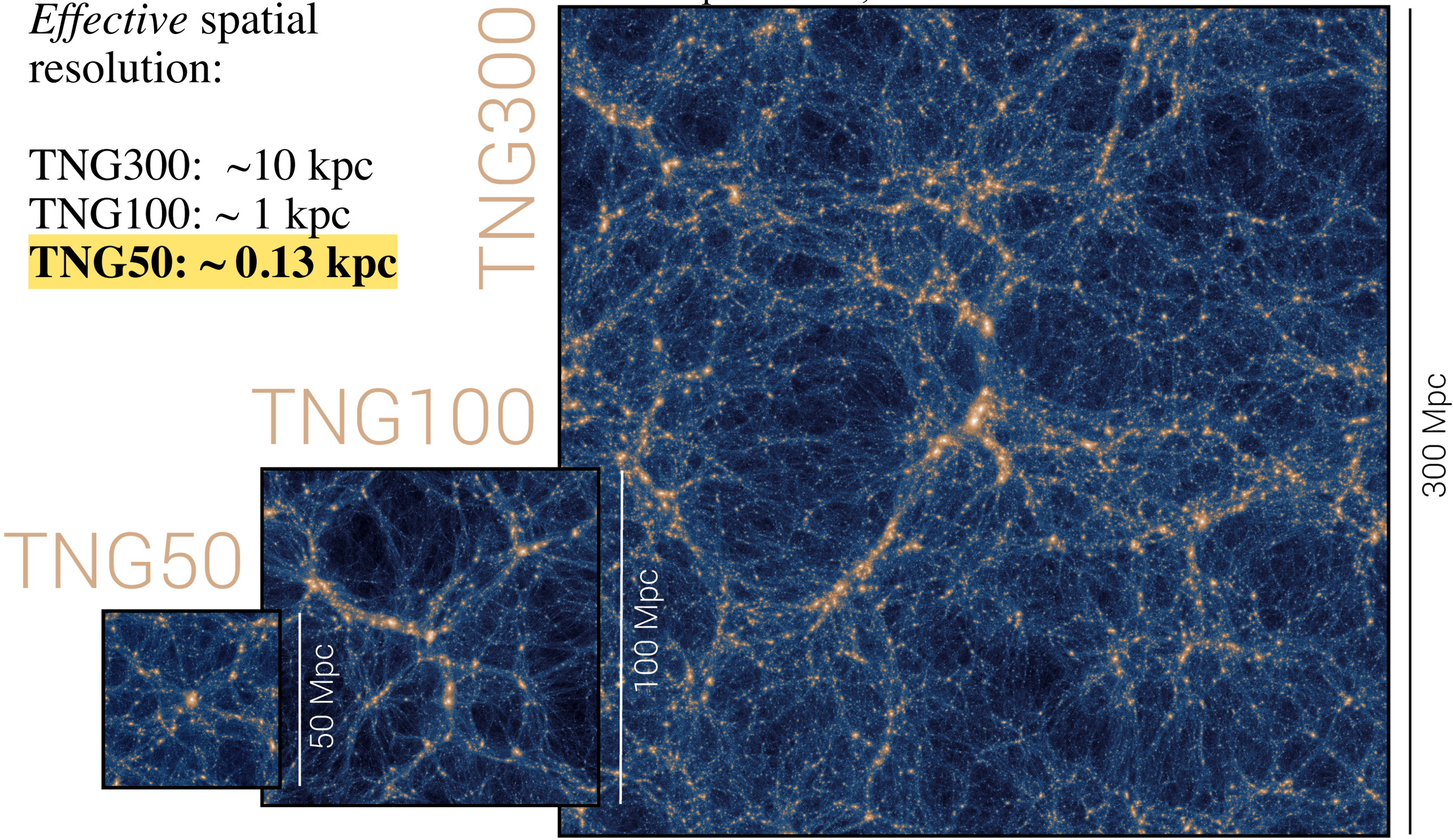
Observed shapes and morphologies can be tied to merger and star-formation histories but also halo properties such as mass and concentration.

Illustris-TNG: cosmological magneto-hydrodynamical simulations explicitly modelling the co-evolution of dark and baryonic matter

Intro: Pillepich+2019, Nelson+2019 TNG Collaboration

Effective spatial resolution:

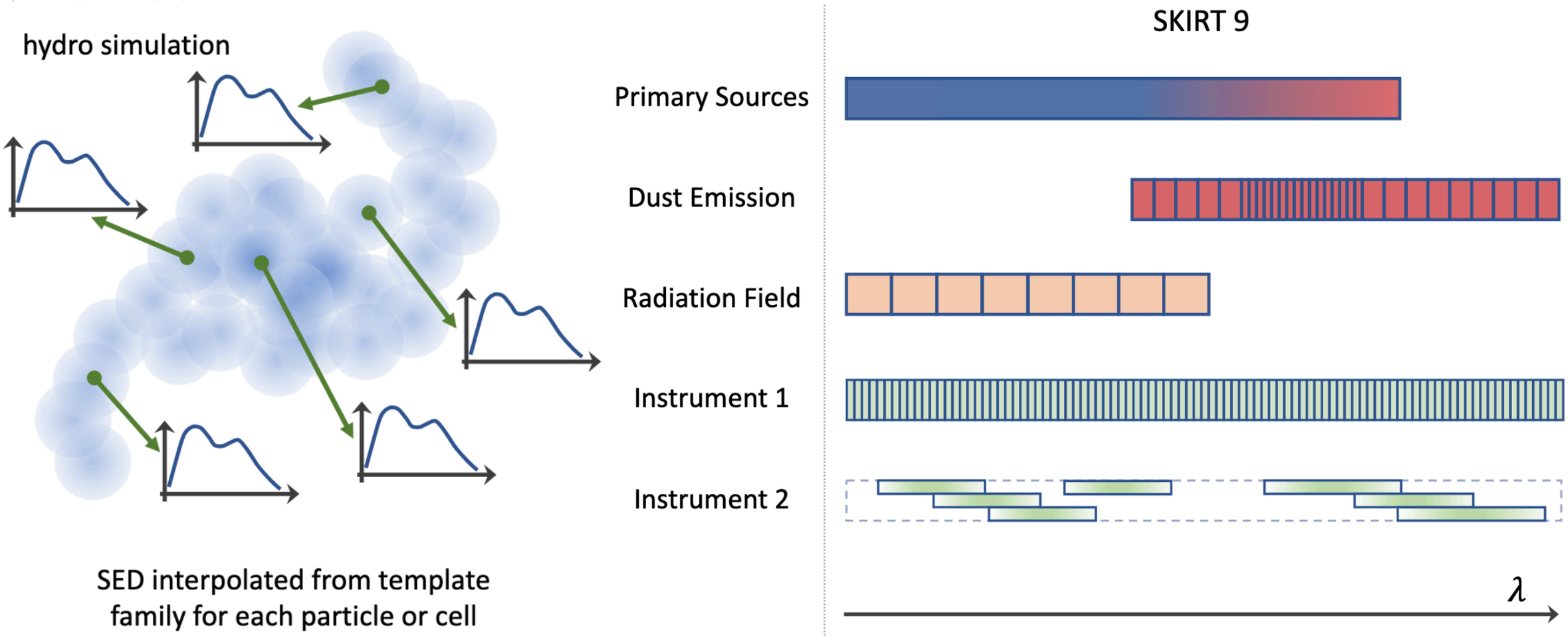
TNG300: ~10 kpc
TNG100: ~ 1 kpc
TNG50: ~ 0.13 kpc



From Simulations to Synthetic Observations via Dusty Radiative Transfer

The most *self-consistent* way to produce synthetic observables from a numerical simulation.

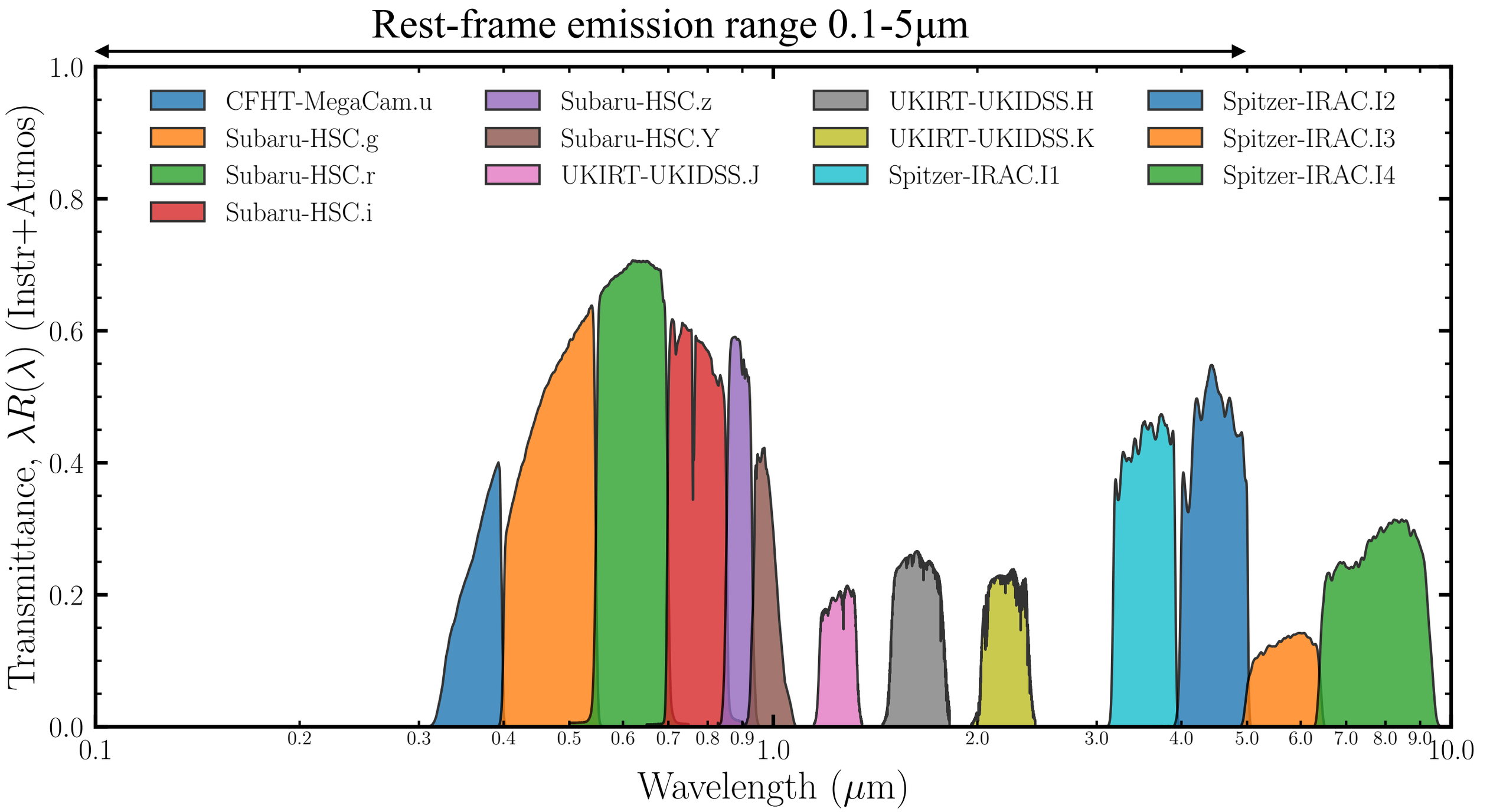
Camps & Baes 2020; Camps & Baes+ 2015; Baes+ 2011
(e.g. also SUNRISE: Jonsson, Groves, & Cox 2010)



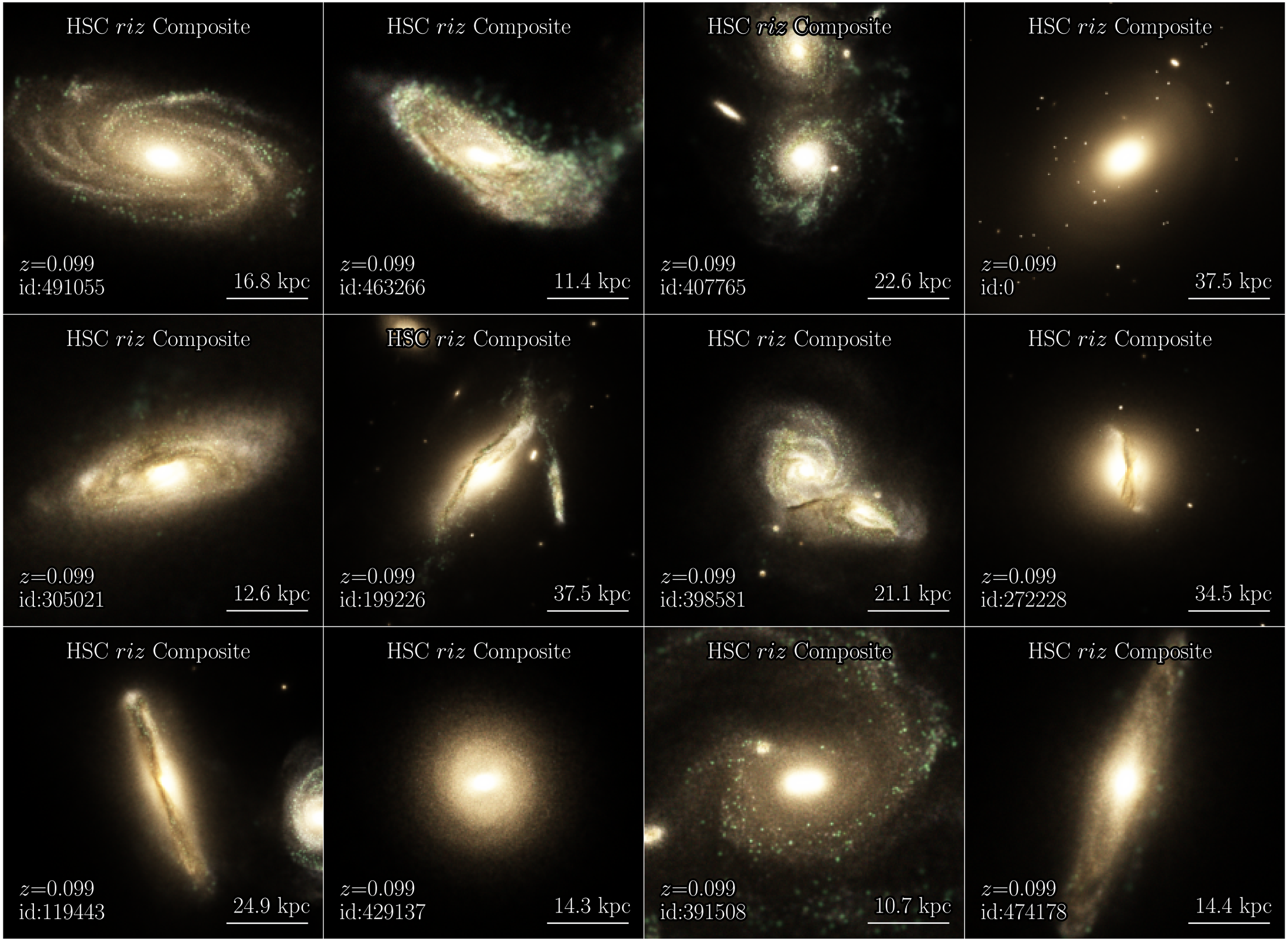
Spectra: old stellar populations (**Bruzual & Charlot 2003**); young stellar populations and birth clouds (**Groves et al. 2010**); dust absorption and scattering (**Popping et al. 2021**, **Remy-Ruyer et al. 2014**). No AGN spectra incorporated [in development by Xuejian Shen @ Caltech].

DP1: *Idealized* Synthetic HSC Joint Programme Images

Noiseless (but dusty), high-resolutions images spanning near-UV to IR.
Multi-Extension FITS files: 100 pc/pixel in AB surface brightness units (mag/arcsec^2).
Comprehensive headers.



Accounting for redshift and surface brightness dimming: $f_\lambda(z) = f_{\lambda,\mathrm{rest}} \times (1+z)^{-5}$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z=0.099
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z=0.099
id:474178
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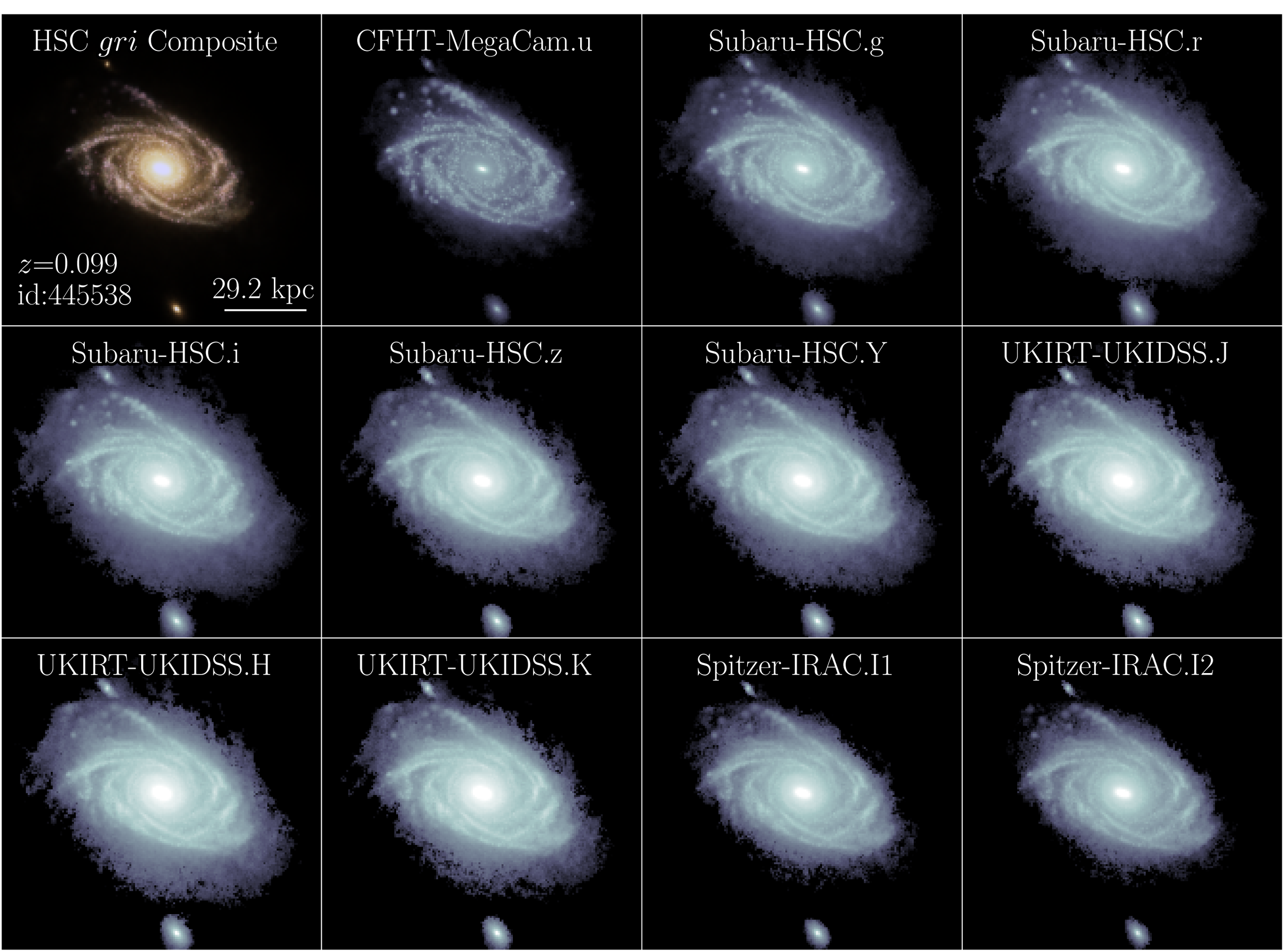
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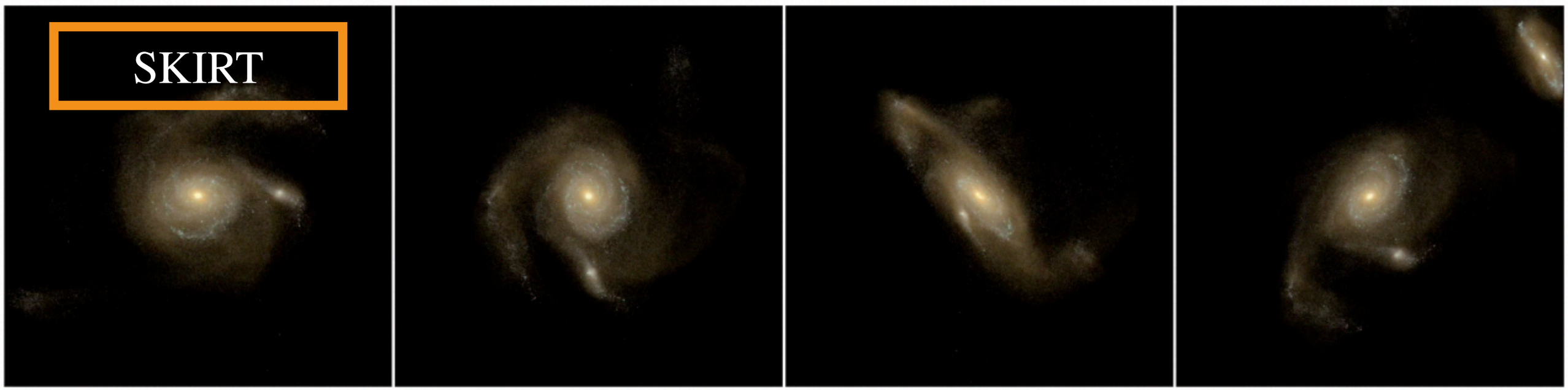
Subaru-HSC.i
Subaru-HSC.z
Subaru-HSC.Y
UKIRT-UKIDSS.J
UKIRT-UKIDSS.H
UKIRT-UKIDSS.K
Spitzer-IRAC.I1
Spitzer-IRAC.I2

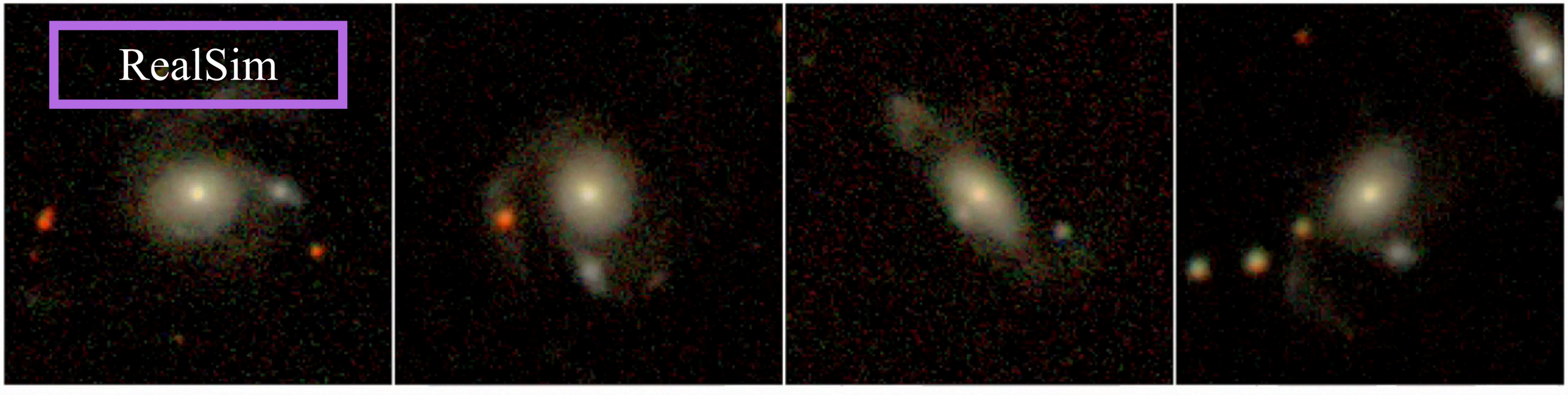
DP2: HSC-SSP *survey-realistic* synthetic *grizY* images

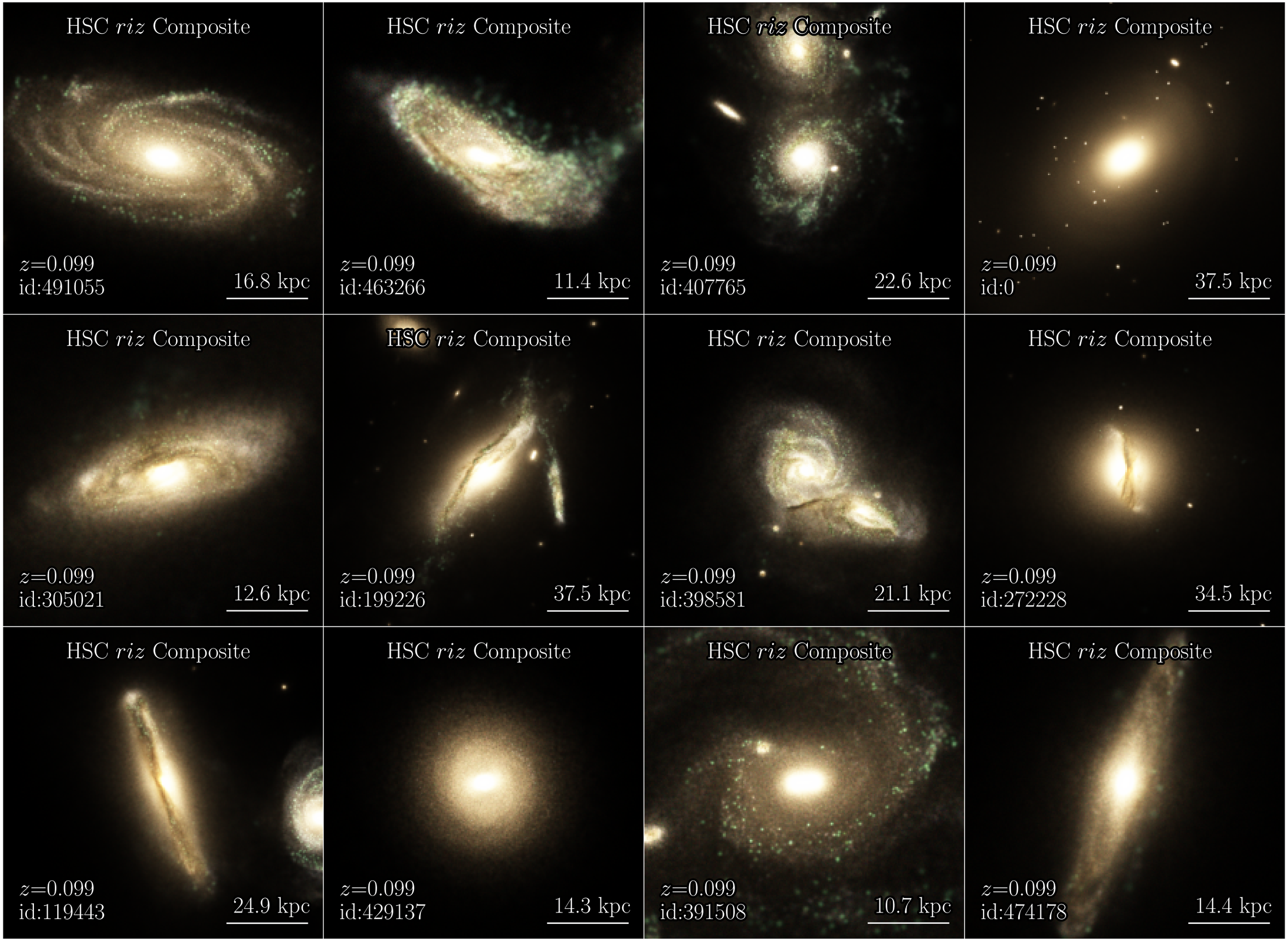
Statistical injection into real HSC cutouts with reconstructed HSC point-spread functions. Statistical matching of sky noise, atmospheric blurring, and crowding effects for real galaxies.



RealSim

Bottrell+ 2017ab, 2019b

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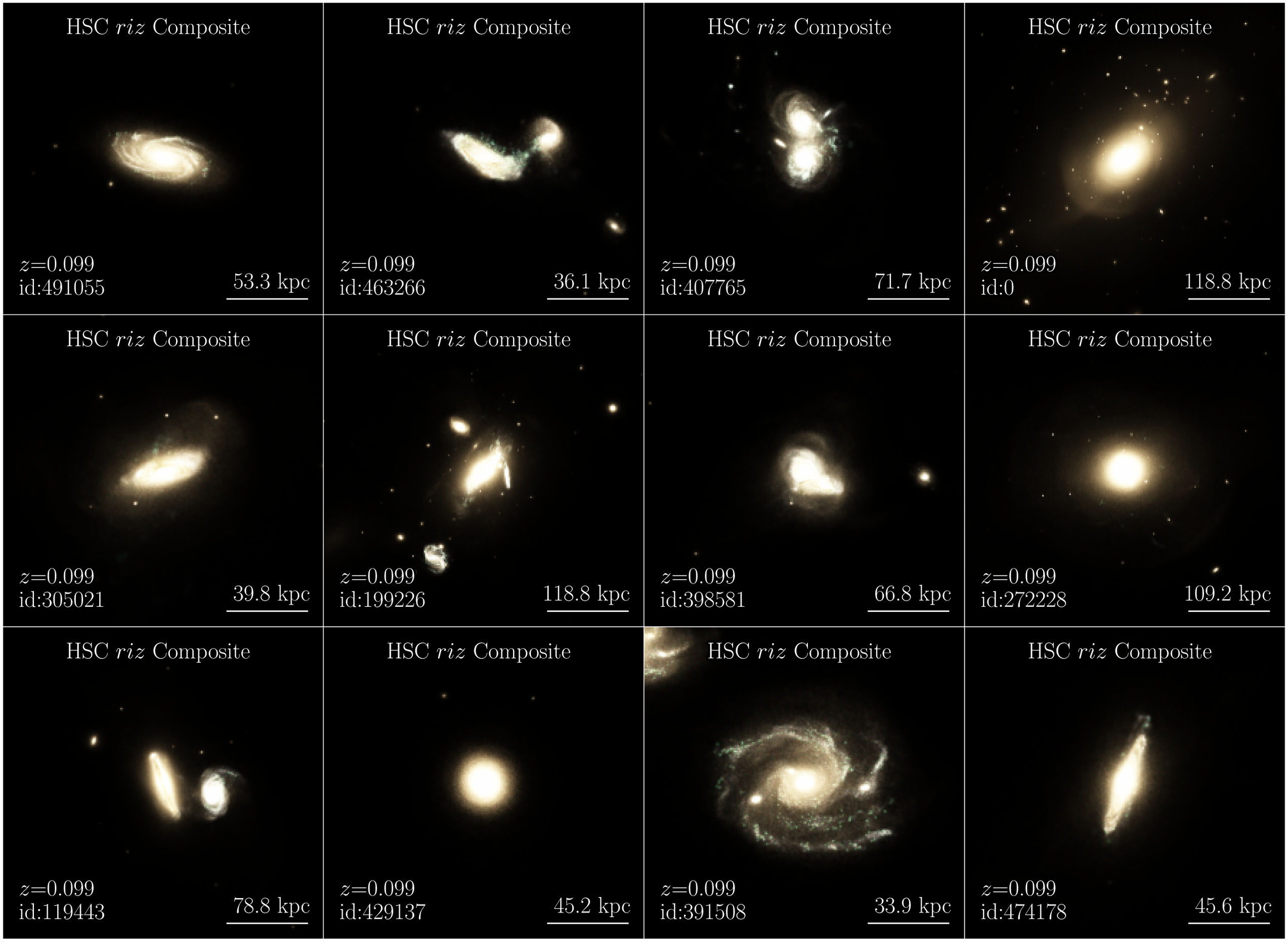
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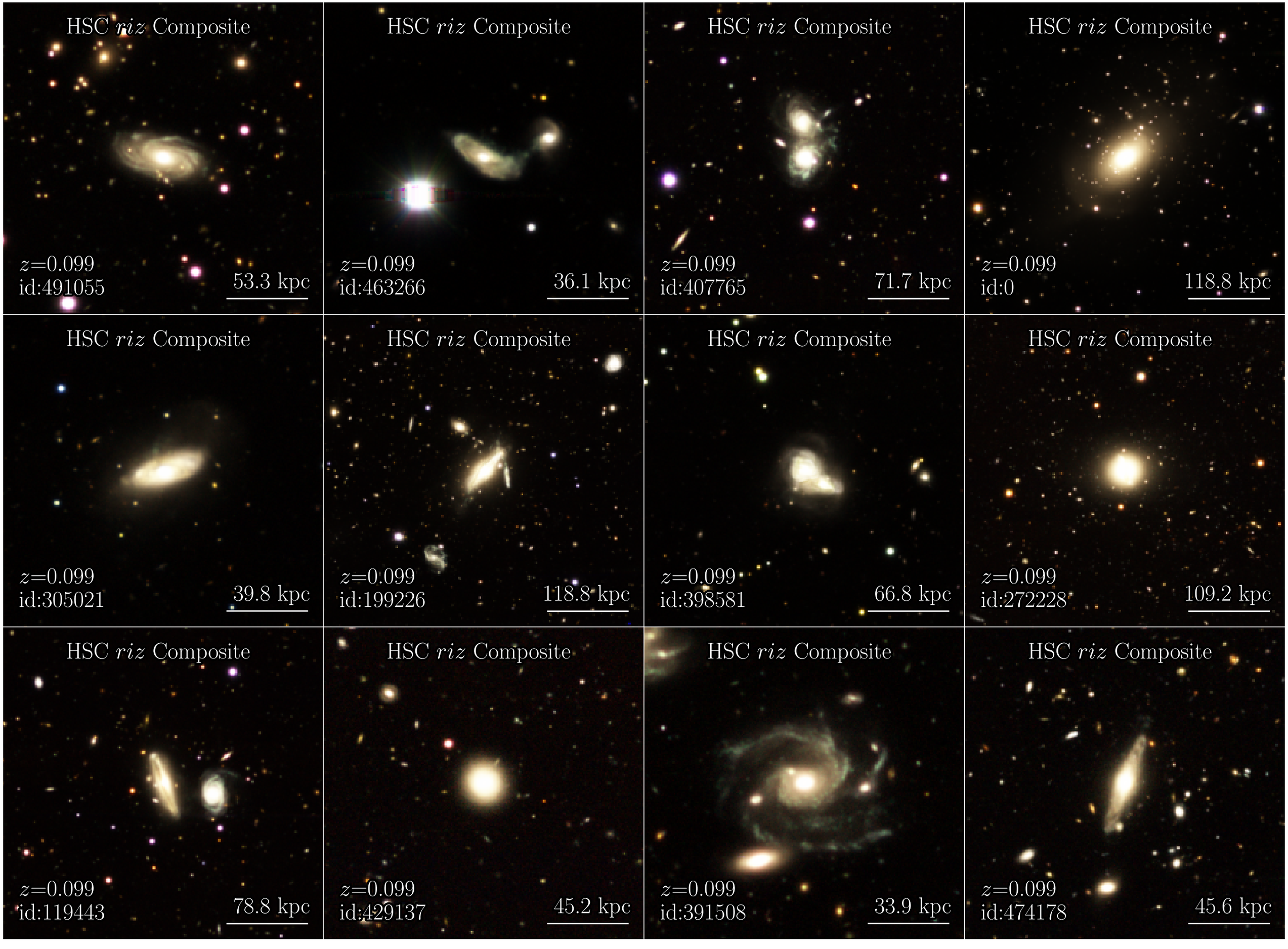
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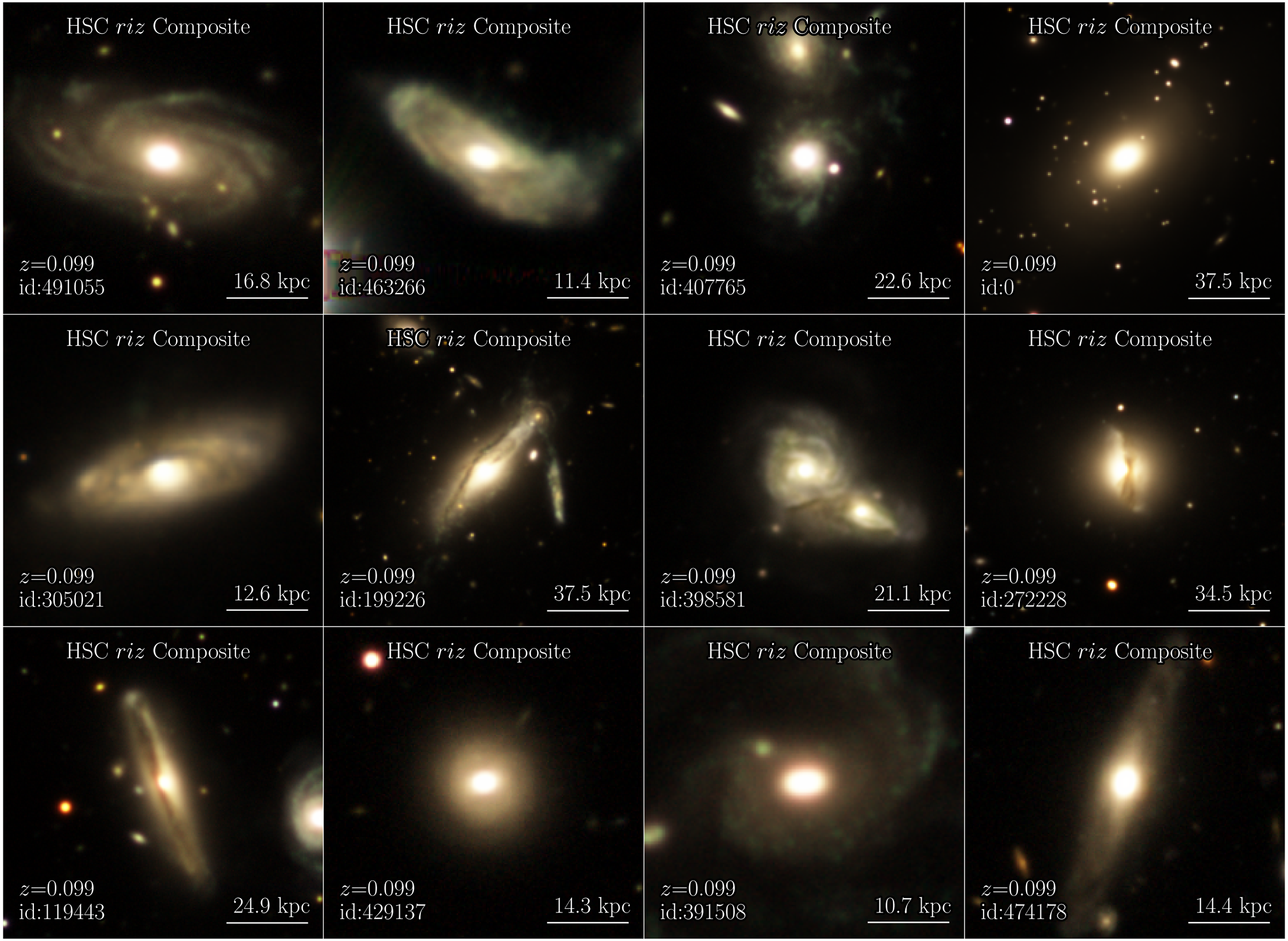
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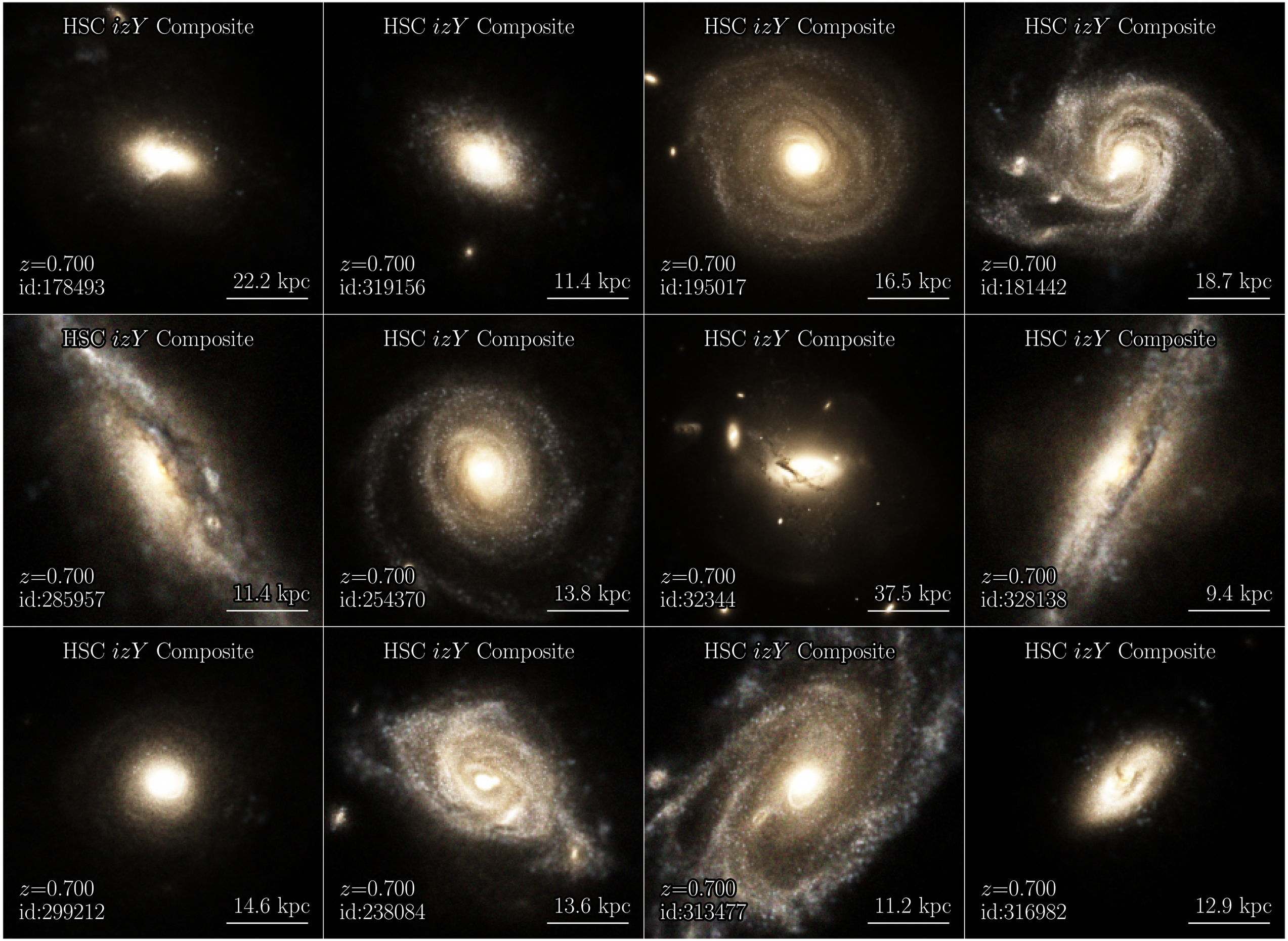
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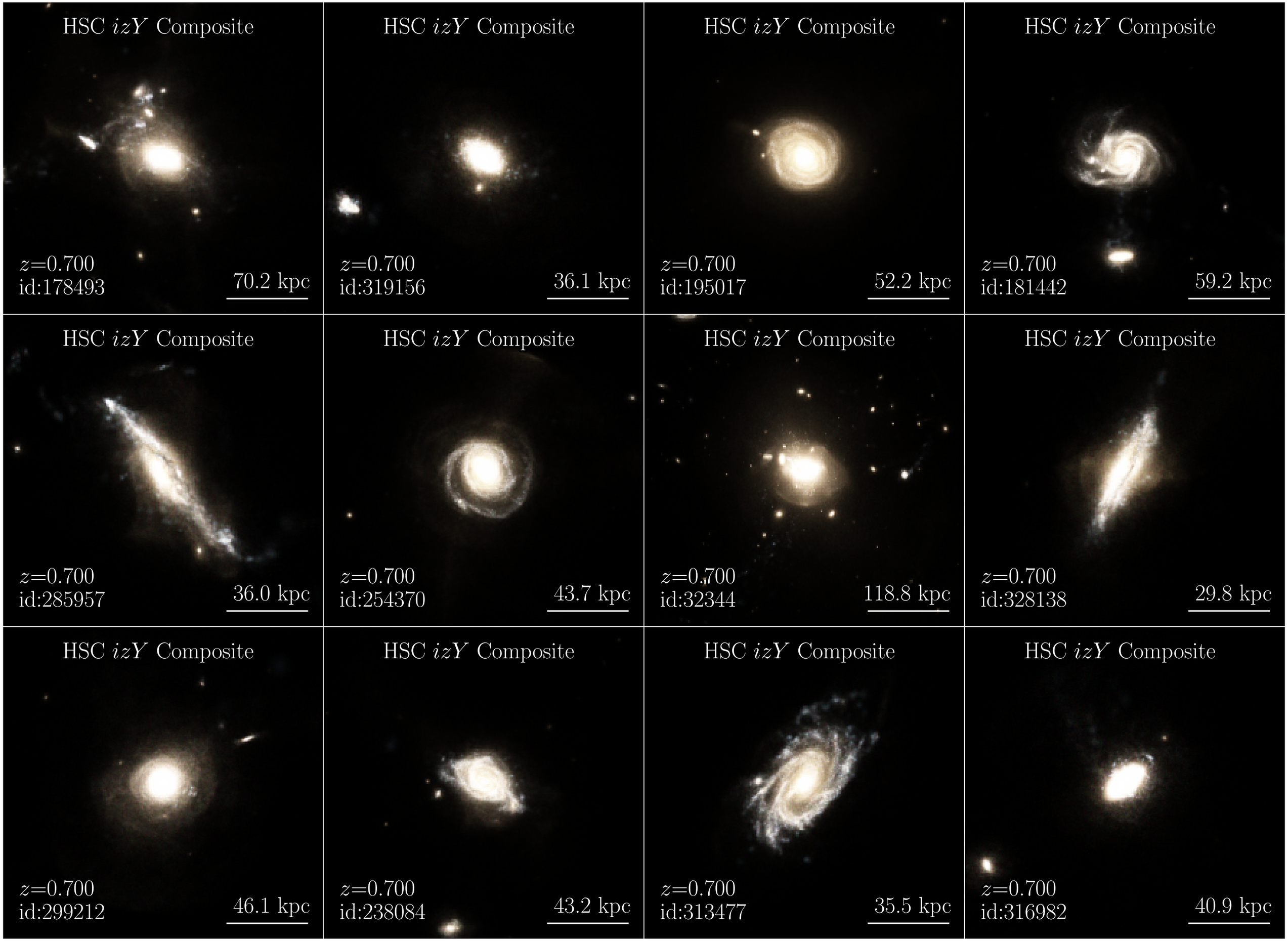
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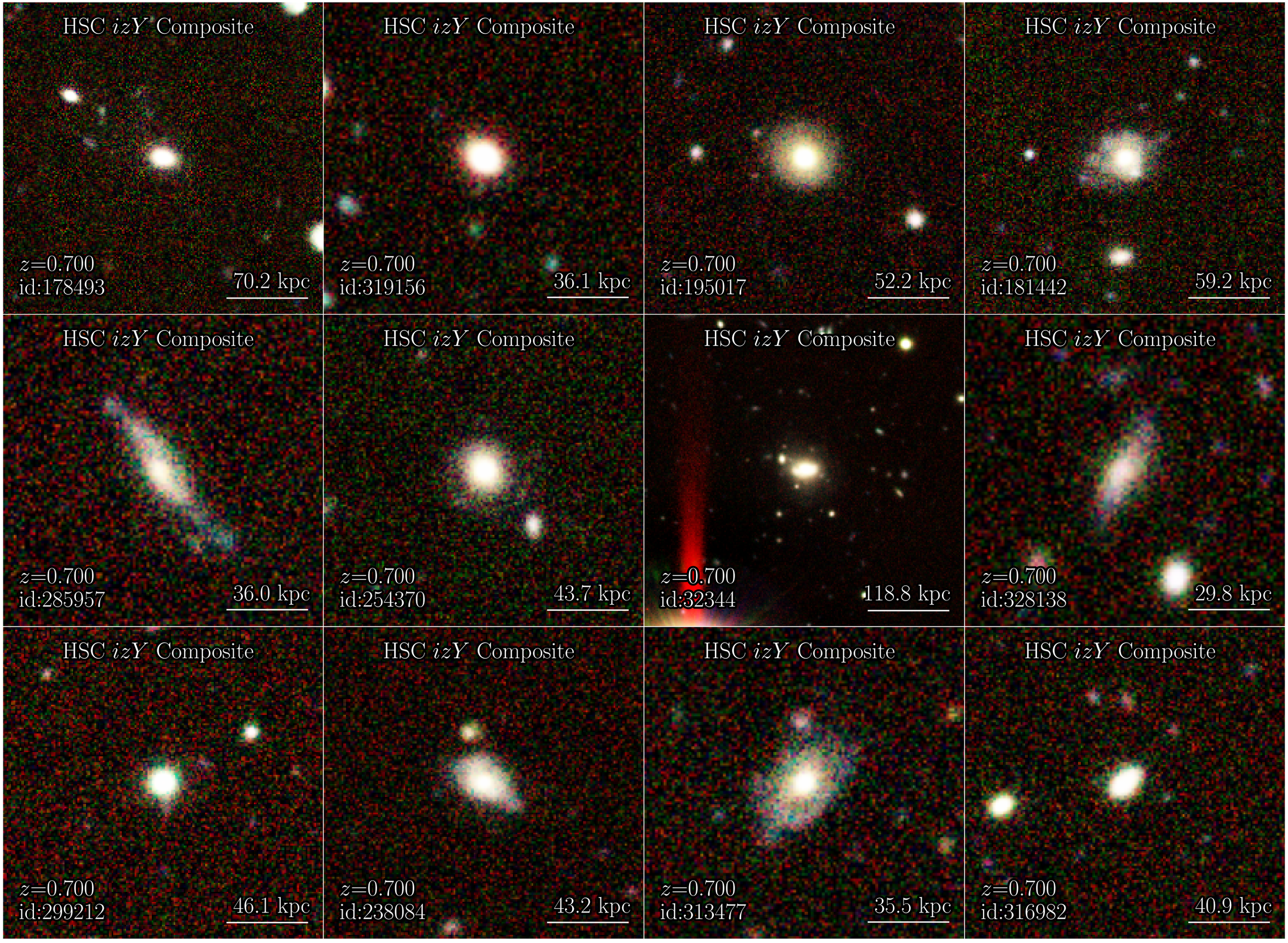
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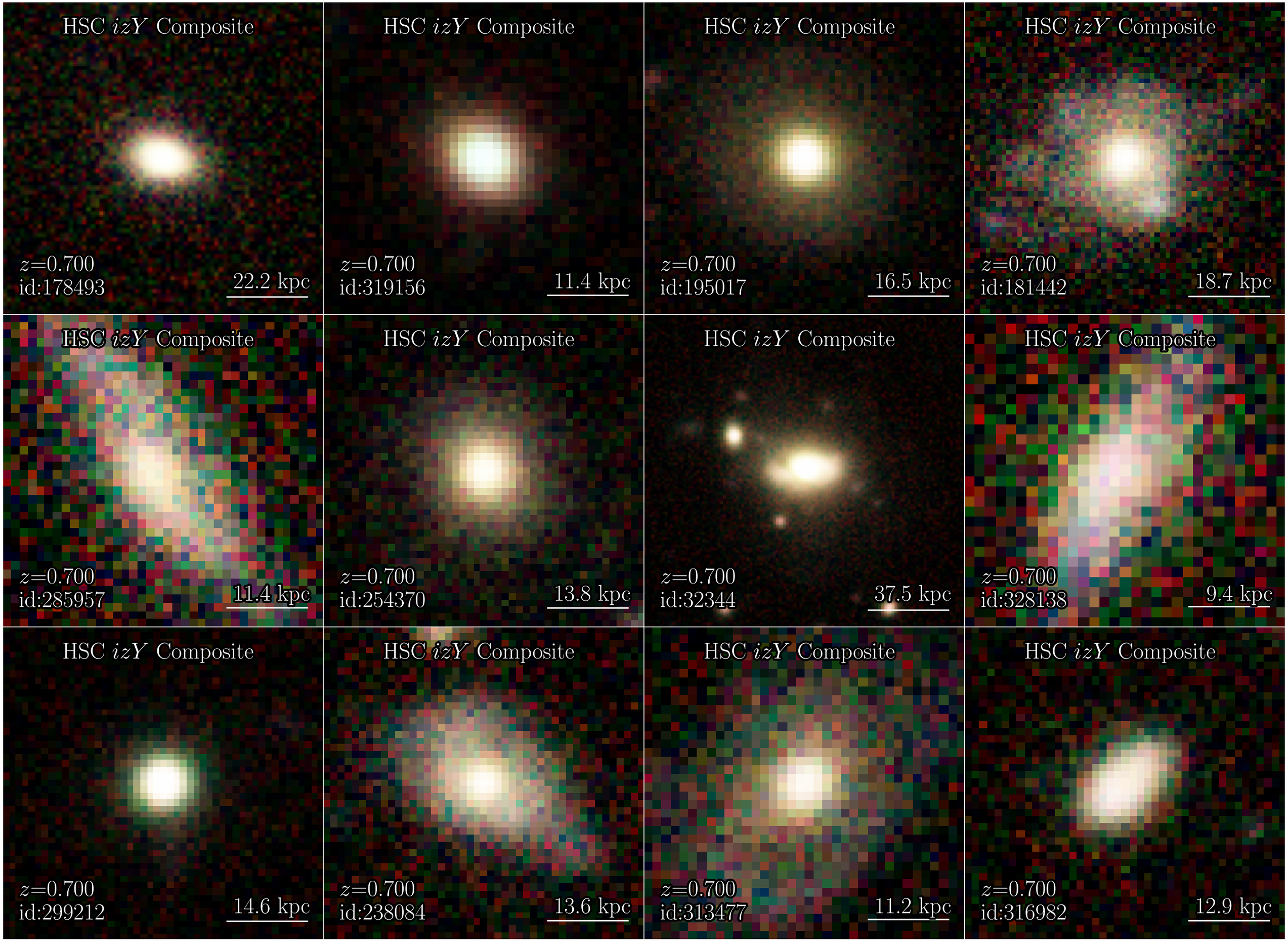
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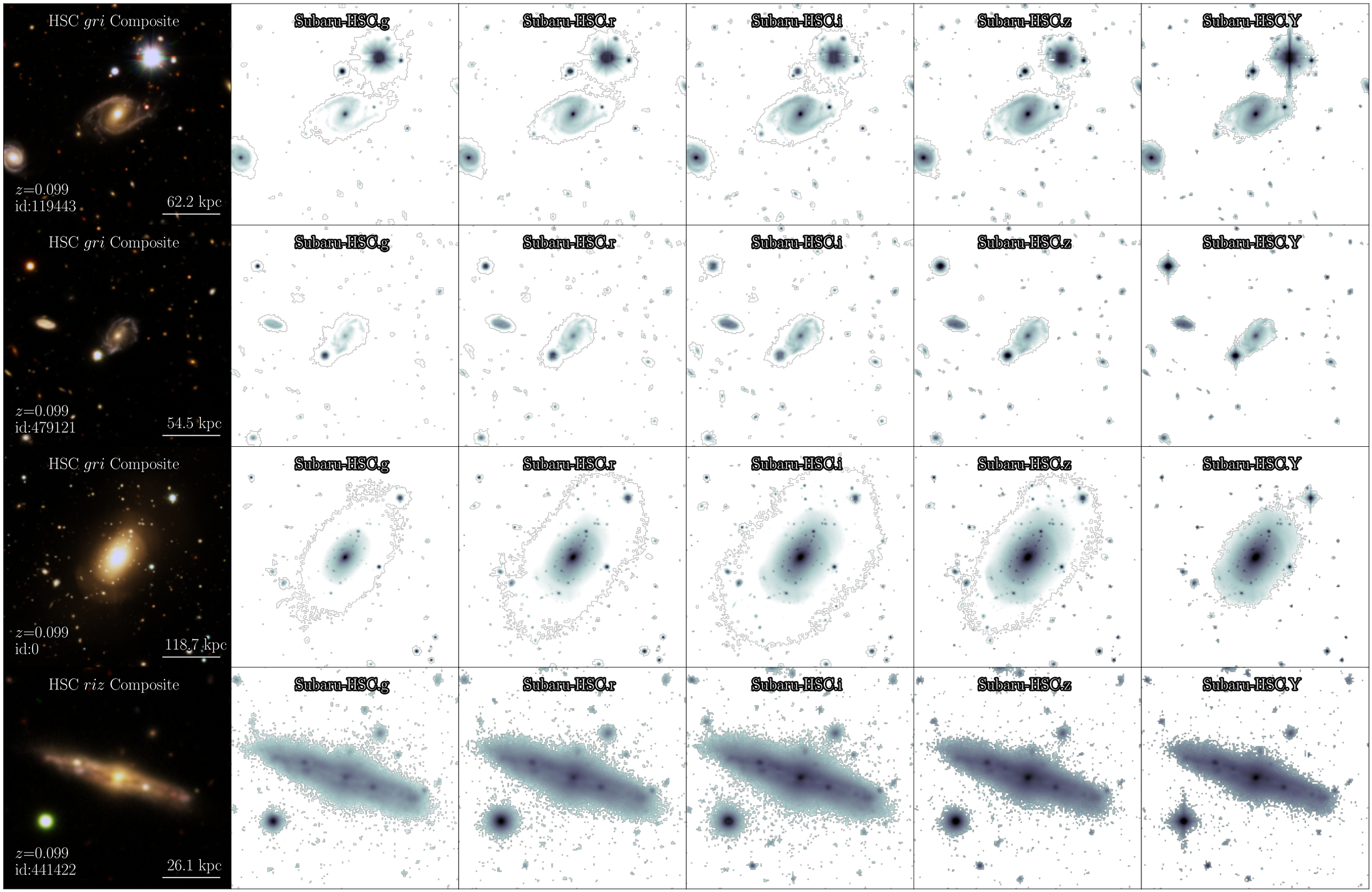
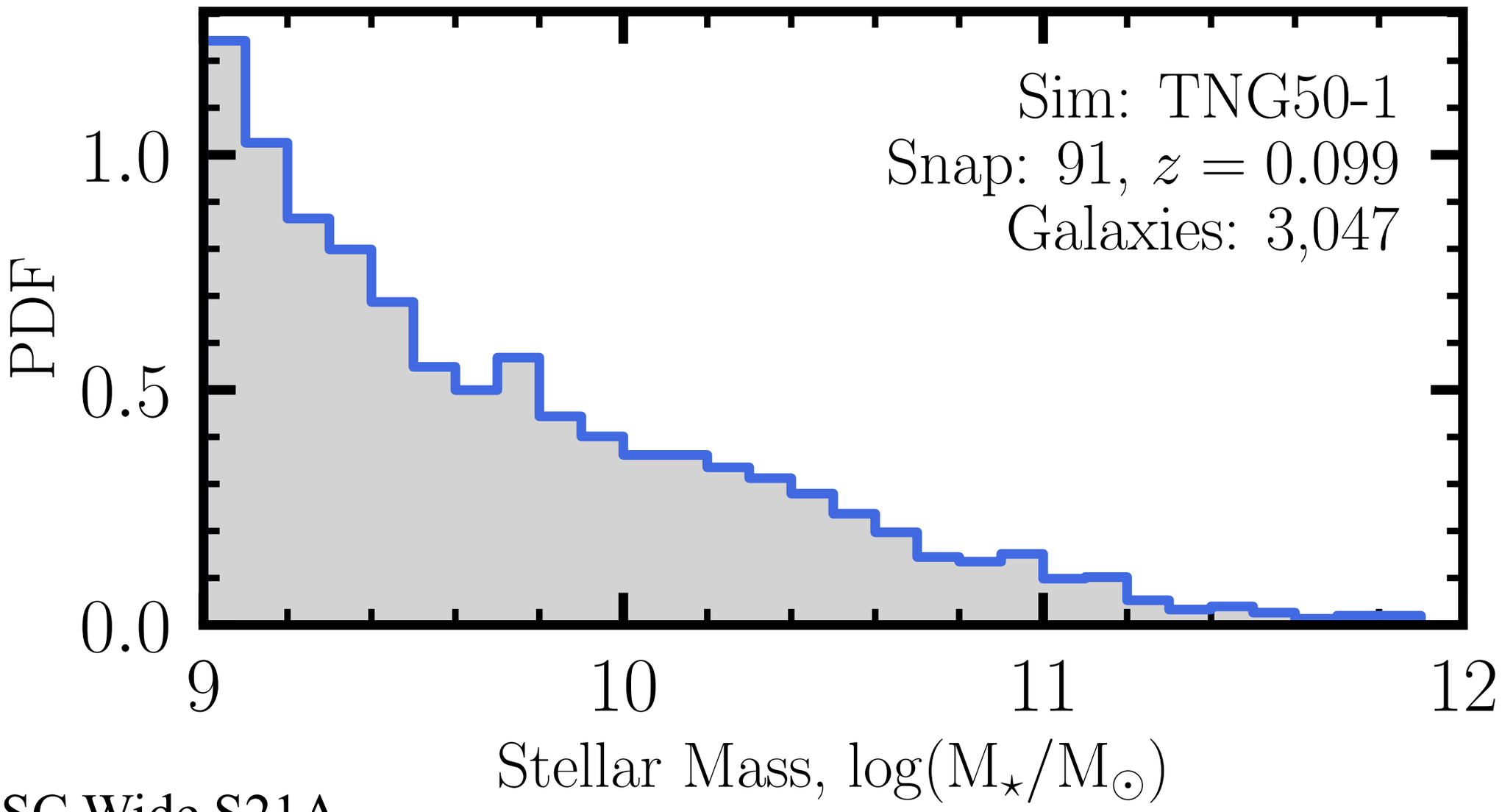
id:316982
12.9 kpc

DP2: HSC-SSP *survey-realistic* synthetic *grizY* images

Multi-Extension FITS files: Image + Variance + Mask for all 5 bands. Comprehensive headers including RA+Dec, measured sky statistics, and calibration info.



Selection and Specifications



HSC Wide S21A

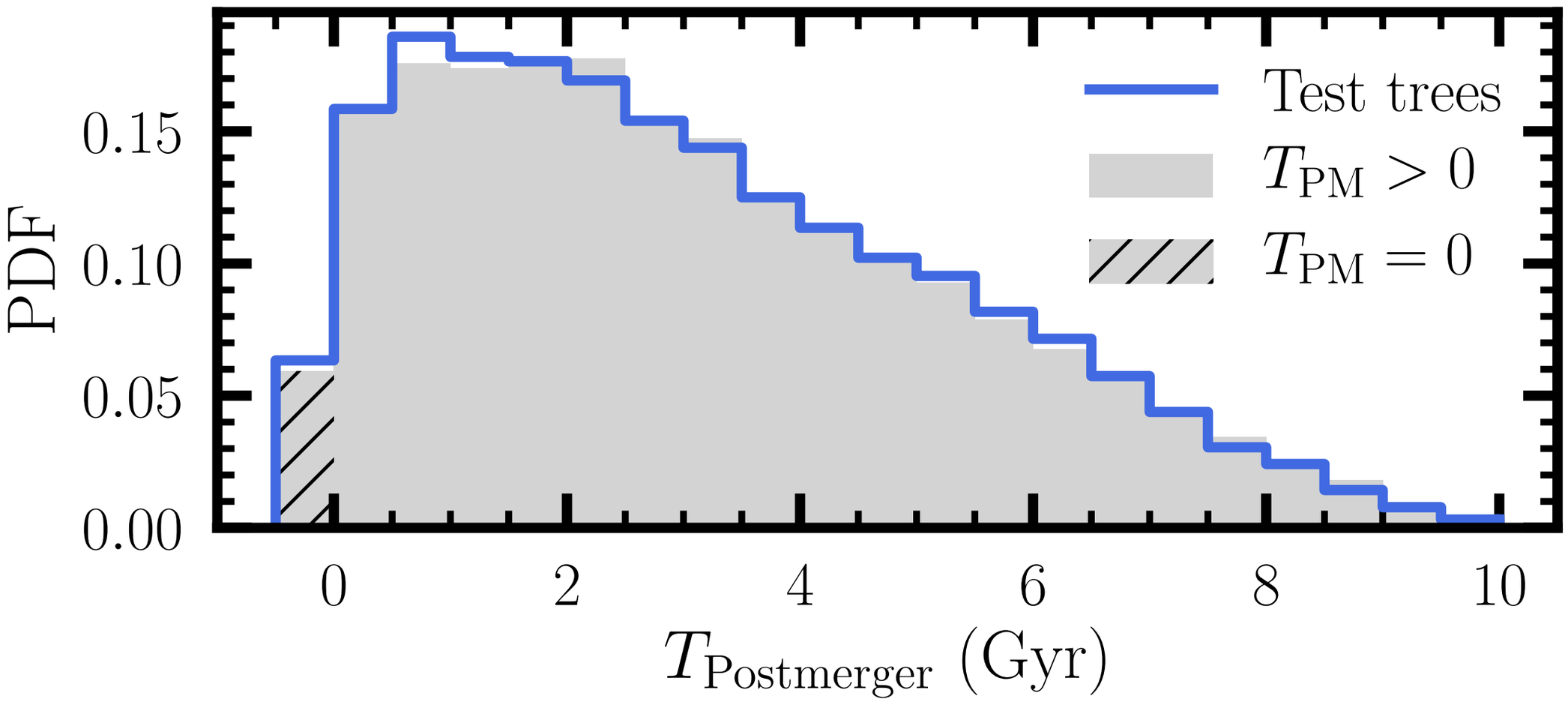
Redshifts: z = 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7 *Completed

Stellar Masses: $\log M_\star/M_\odot \geq 9.0$ (no SFR cuts)

Lines of Sight: 4 per galaxy (tetrahedron in simulation coordinates)

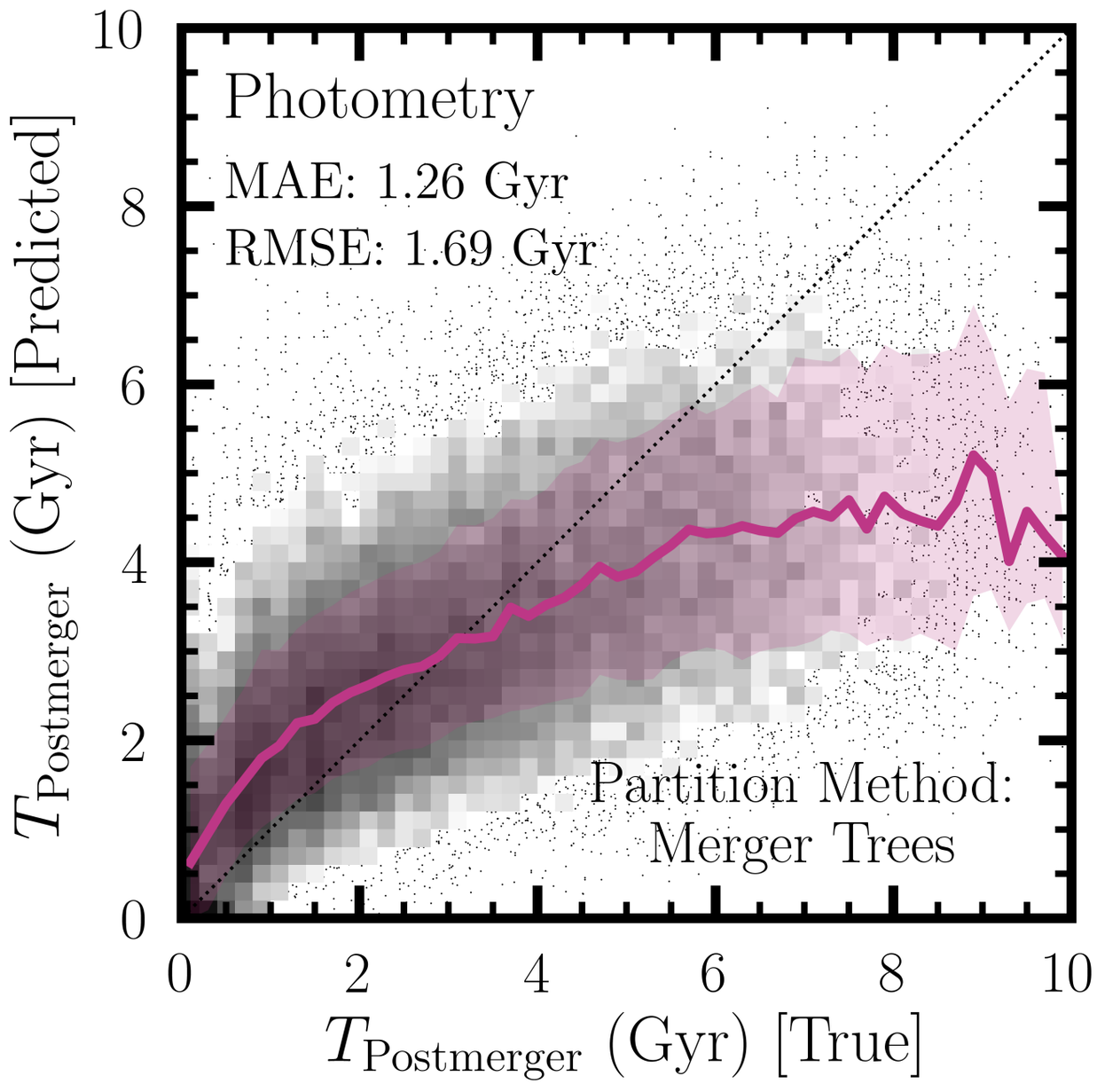
Example Application:
Connecting galaxy morphologies to their merger histories

Most galaxies have undergone a merger in the past. The time since a galaxy last merged with a massive companion cannot be known *a priori* in observations — but is known with certainty in simulations.



Non-linear models can be calibrated to connect the observed morphologies of galaxies to the time since they last merged.

The time since a galaxy last merged can be estimated with surprising accuracy using models calibrated on synthetic images.



Implication: an average galaxy's current morphology is strongly connected to its most recent merger event — even many Gigayears after the merger. The predictions then stagnate at larger time-since-merger values.

TNG50 Galaxies Observed in the HSC-SSP!

CONNOR BOTTRELL (KAVLI IPMU | connor.bottrell@ipmu.jp)

Scope of HSC Project 405

Structural evolution of galaxies: Roles of mergers, environment, and secular evolution in shaping the morphologies of galaxies.

Physical evolution of galaxies: Relations between morphology, star-formation, and quenching.

Intrinsic morphologies of AGN host galaxies: Direct comparison to recent observational results from ***Junyao Li et al.*** (arXiv:2105.06568).

***Galaxy merger properties in HSC-Deep*:** Predictions for the properties of galaxy mergers at $z > 1$. How do these square with observations?

Morphology-DM halo connection: Calibrate deep regression models to relate galaxy observables to host halo mass

Merger characterization: Calibrate deep regression/classification models to classify and characterize observed galaxy mergers.

…Your project here…

TNG50 Galaxies Observed in the HSC-SSP!

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Data Access

The images are currently hosted at IPMU on idark:
Base URL: http://idark.ipmu.jp/hsc405
Basic Catalogues: {Base URL}/Catalogues
Idealized Images: {Base URL}/SKIRT9/Photometry
HSC-SSP Images: {Base URL}/SKIRT9/HSC_SSP
Username: hsc405

The password will be made available upon request sent to connor.bottrell@ipmu.jp and silverman@ipmu.jp. The subject header should be "HSC 405: Project Proposal" and should include a project title, contributor list, and brief description of the project.

These measures are only so that we can keep track of the various projects being undertaken with the data and avoid overlaps.