Connecting the high-z surveys of quasars and their host galaxies with numerical simulations

via post-processed multiwavelength mock-images

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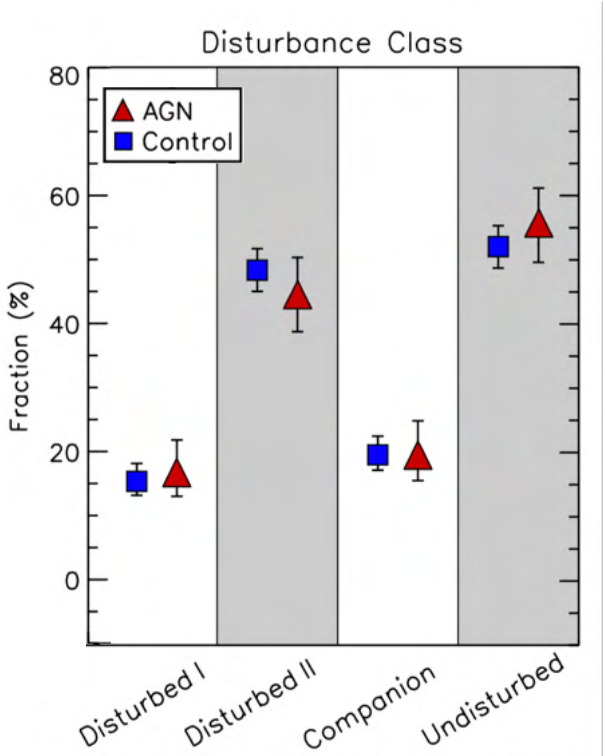
Galaxy Collisions: Simulation compared to Observations

Theory: "Galaxy Mergers can trigger AGNs"

- Mergers can effectively dissipate angular momentum and funnel gas to the center growing both BH and bulge.
- Isolated and idealized simulations of galaxy merger show AGN triggered by mergers. Springel+05, Hopkins+05,06
- AGN-Merger connection can easily explain the tight correlation between BH and bulge.
- AGN-Merger connection can also easily explain why only certain galaxies have ongoing AGN activity.

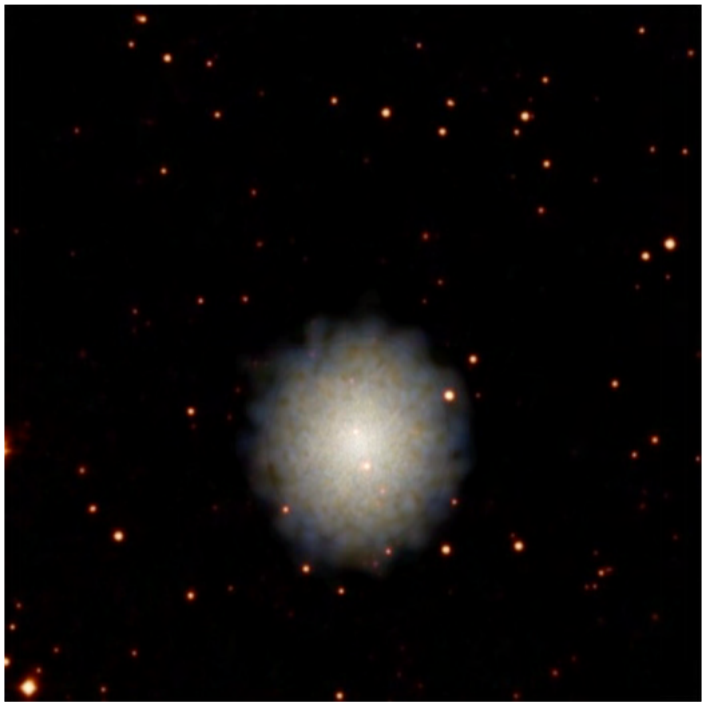
AGN surveys: "Not much connection btw AGN/galaxy merger"

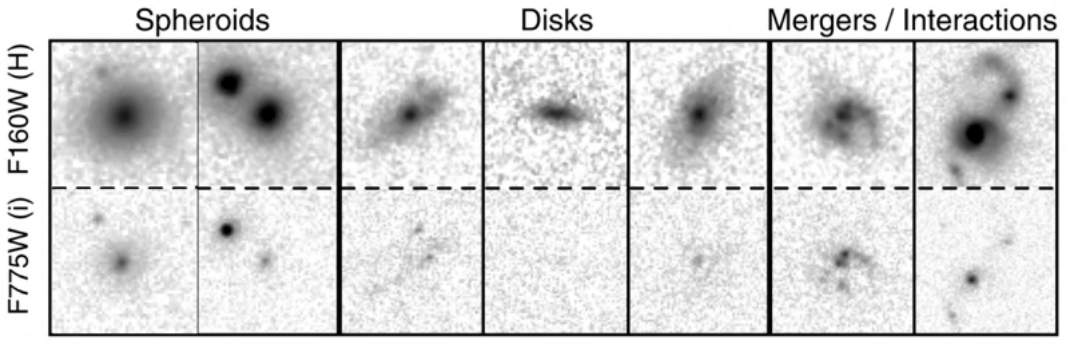
- Many surveys find **lack of connection between merger & AGN** (Pierce+07, Georgakakis+09, Cisternas+11, Kocevski+12, Marian+19) especially at z>1
- Fraction of disturbed galaxies in AGN sample vs.
  Fraction of undisturbed galaxies in non-AGN sample (control sample)
- The simulation should provide more realistic prediction can confront the current observations.



HST CANDELS at z~2; Kocevski+12

Simulations / Observations

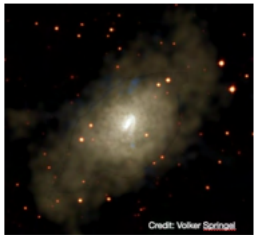




1. Sequence vs. Capturing the moment
2. Halo finder traced merger vs. image based merger definition (close companion, disturbed morphologies, etc.)

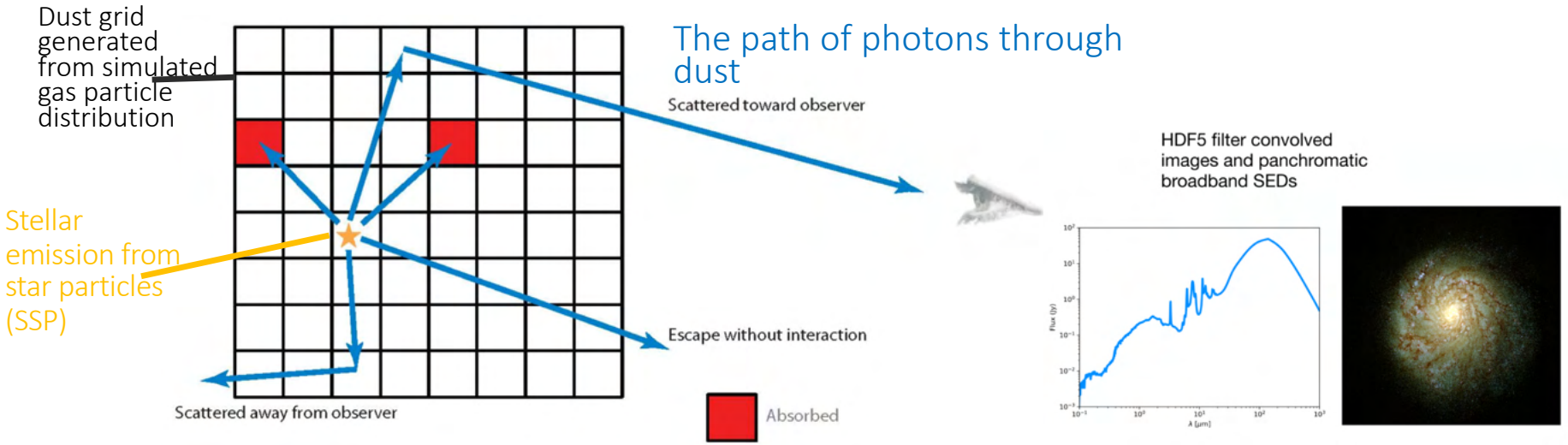
In simulation we see all time sequence.

But if we “capture” the moment.



Method (1) : Mock Observations via radiation transfer

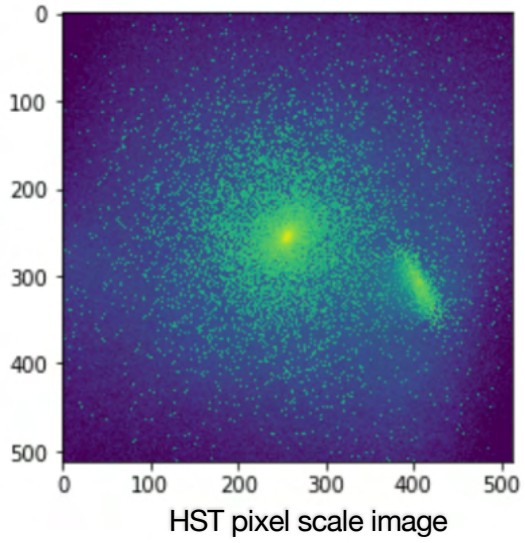
- Bridge the divide between simulations and observations.
- "**Powderday**": a dust radiative transfer package (Desika Narayanan, EC, et al. 2021)
- Process photon emission from star particles through the dusty ISM and generate filter convolved images

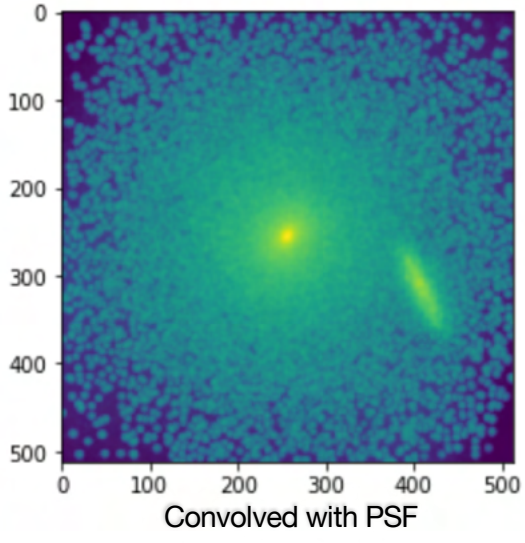


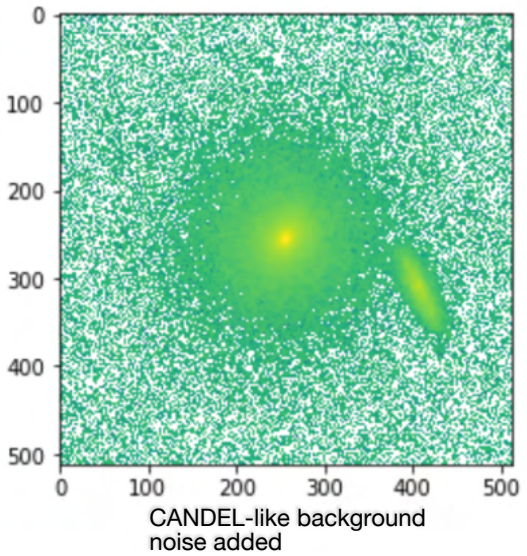
Method (2) : Mock Observations

adding observational effects

- 12,000 HST-WFC3 F160W images with a HST CANDELS pixel scale, PSF, and noise.
- A direct prediction for how our simulated galaxies would appear in HST CANDELS survey

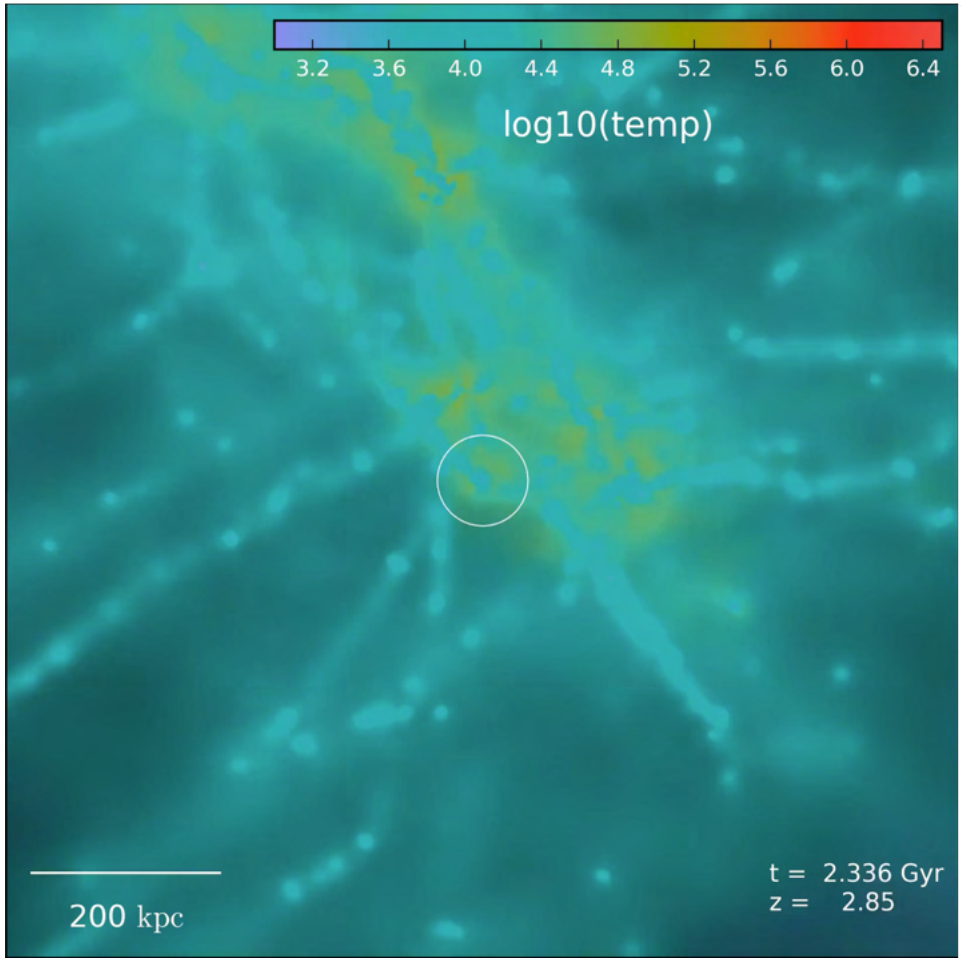






Method (3) : Cosmological simulations of massive galaxies (with AGN)

Choi+17



- Cosmological zoom-in simulations: Central galaxies with z=0 mass Mstel=10^{11} - 10^{12} M_{sun} Choi+17
- GADGET-3 Smoothed particle hydrodynamic simulations
- Momentum feedback from AGN (1. Winds and 2. Radiative heating/momentum) Choi+12/14/15
- SN wind feedback, Feedback from massive stars ('Early' feedback), AGB winds Núñez+17
- Metal enrichment and metal line cooling Aumer+13 / Modified SPH (SPHGal) Hu+15

Sample synthetic images

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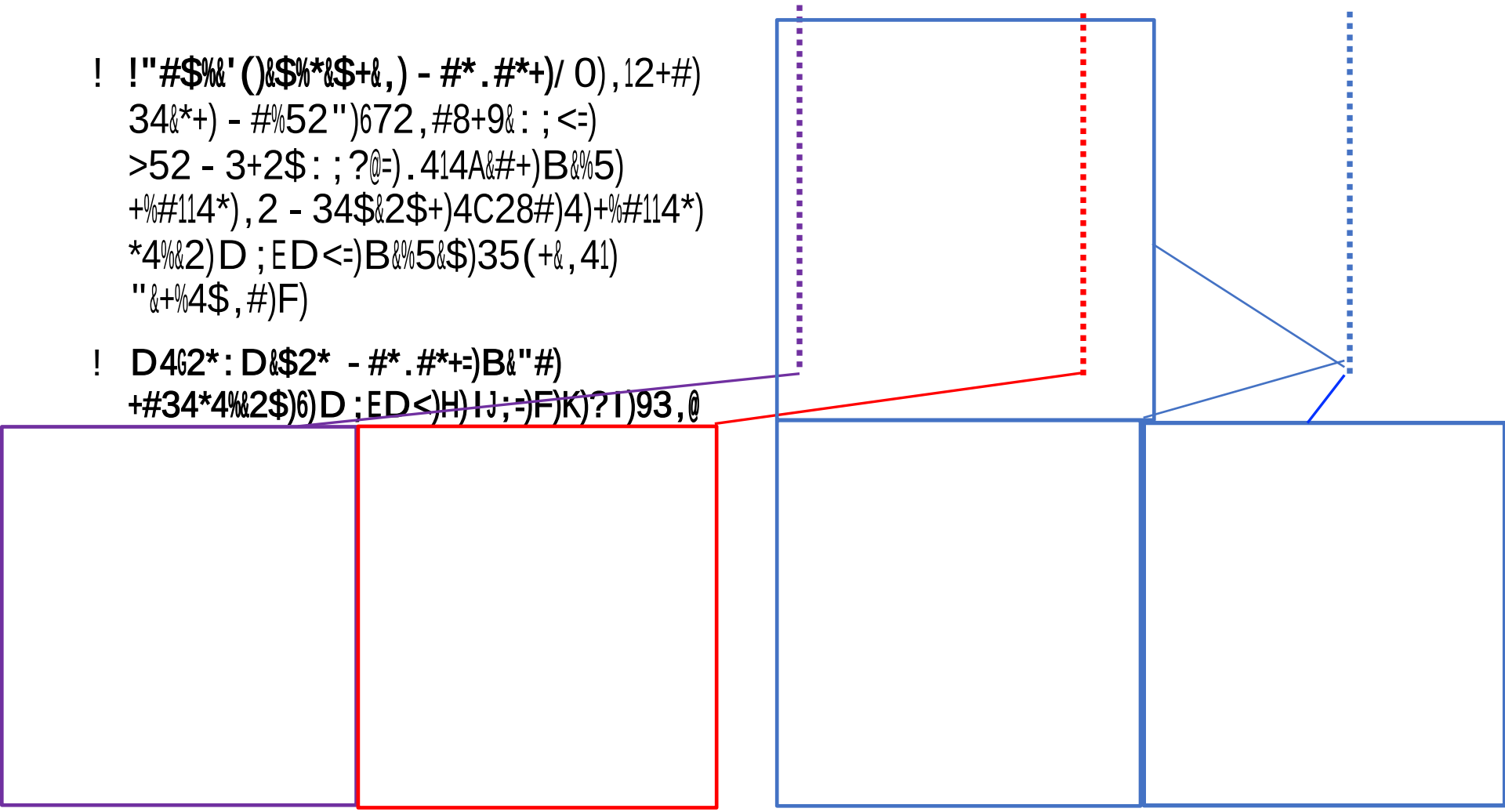


Merger fraction of AGN & control non-AGN galaxy sample in simulations and in observations

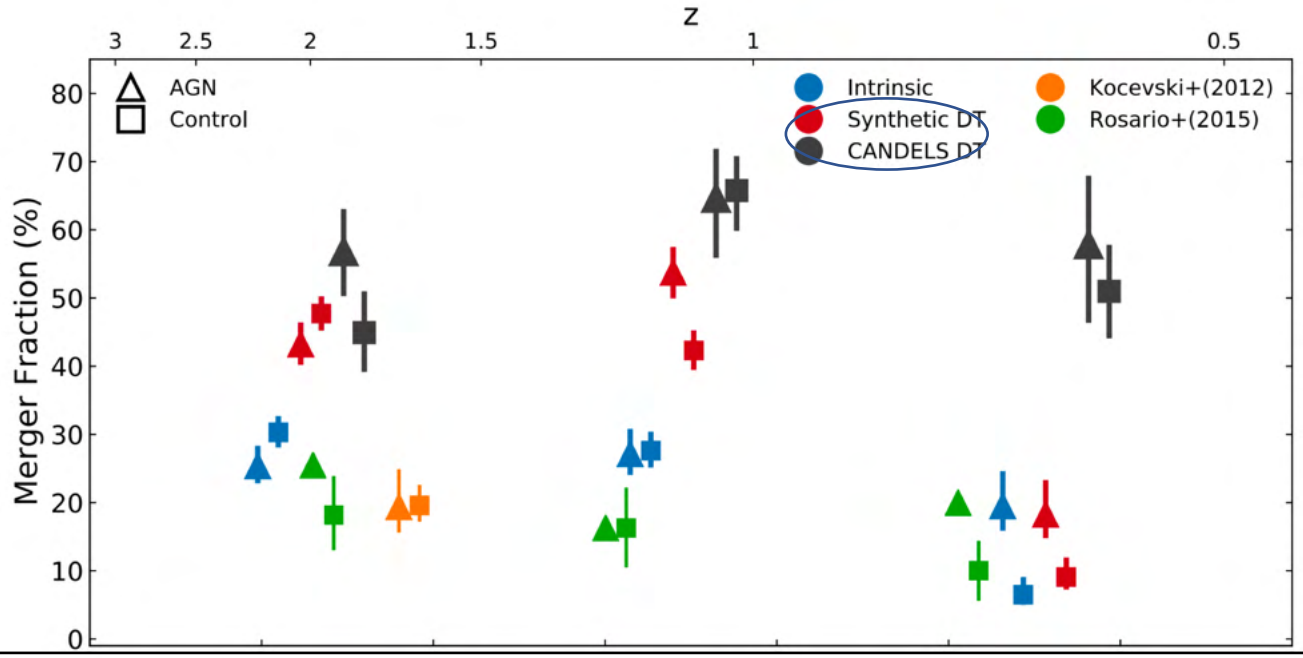
- **△ AGN :** $L_{bol}>10^{43}$ erg/s
- **☐ Control:** inactive, mass-matched control galaxy counterparts

Simulation:

Intrinsic merger

DT classifications applied to synthetic images

DT classifications applied to CANDELS observed images



Observation:

Visual inspected mergers for observed CANDELS galaxies

Kocevski: "companions" pair fraction

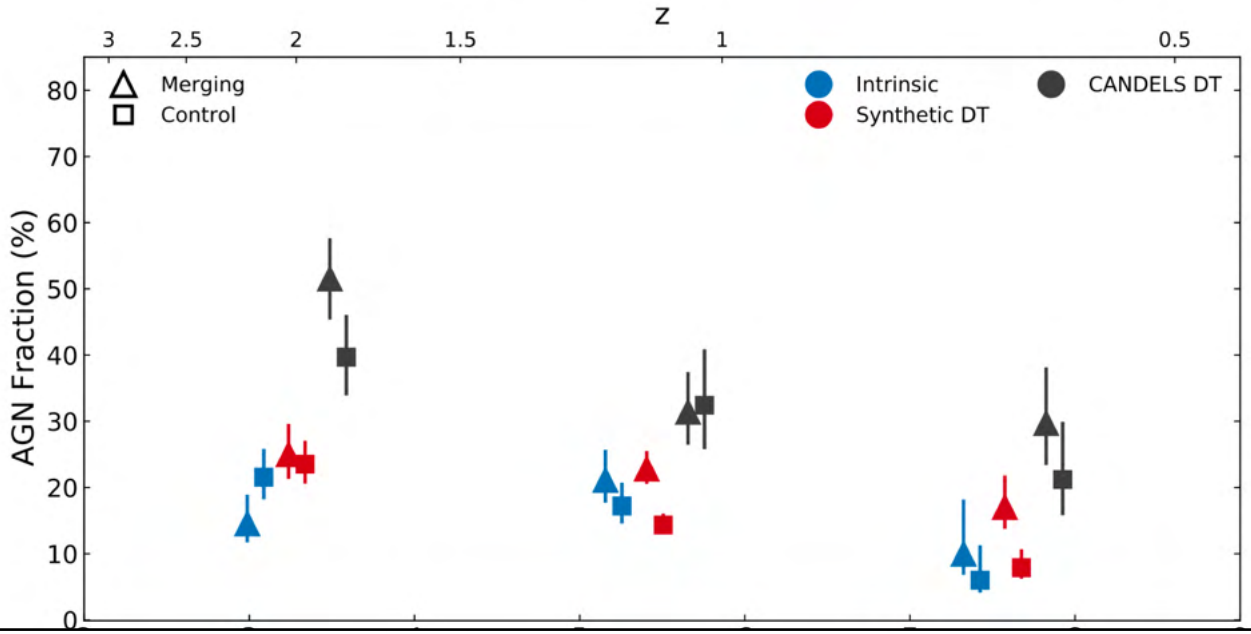
Rosario: the interaction fraction

Sharma, EC et al. 2021

The AGN samples do not show a statistically significant excess in merger fraction in mock-images (simulations) as well as in observations.

AGN fraction of merging & control non-merging galaxy samples in simulations

- △ Merging
- ☐ Control: non-merging mass-matched control galaxy counterparts



Sharma, EC et al. 2021

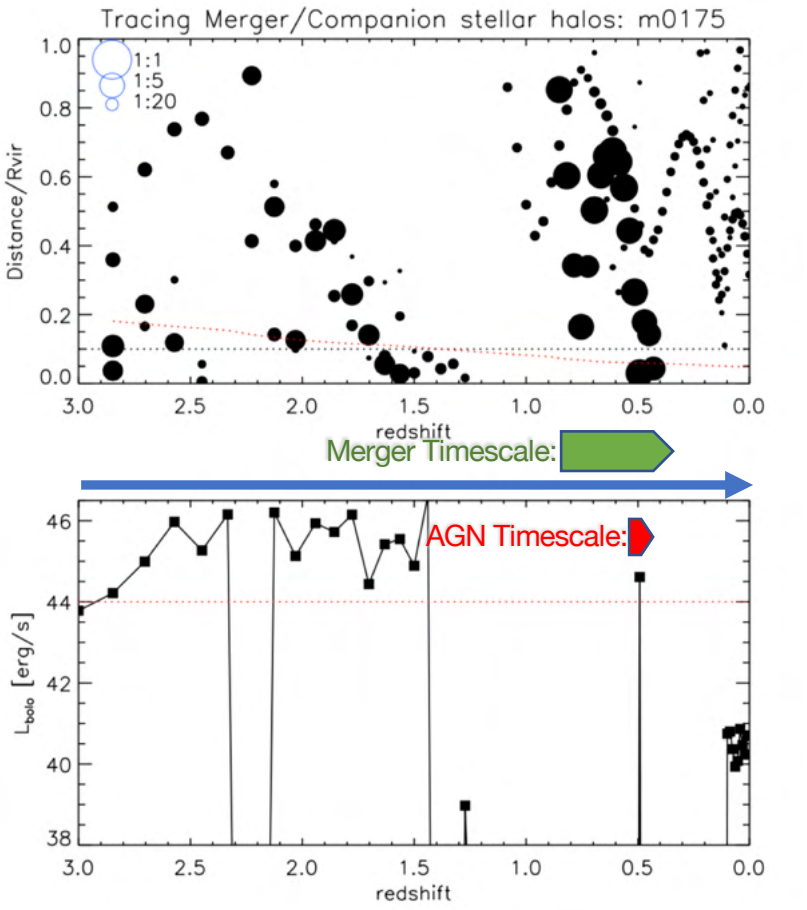
Merging systems do not show a significant enhancement of AGN activity than non-merging systems.

AGN do not appear to live in merging systems

"in mock images", because..

1. There is a significant time-lag between merging and AGN triggering.

2. Merger is not the primary fueling mechanism – not all AGNs are triggered by merger.



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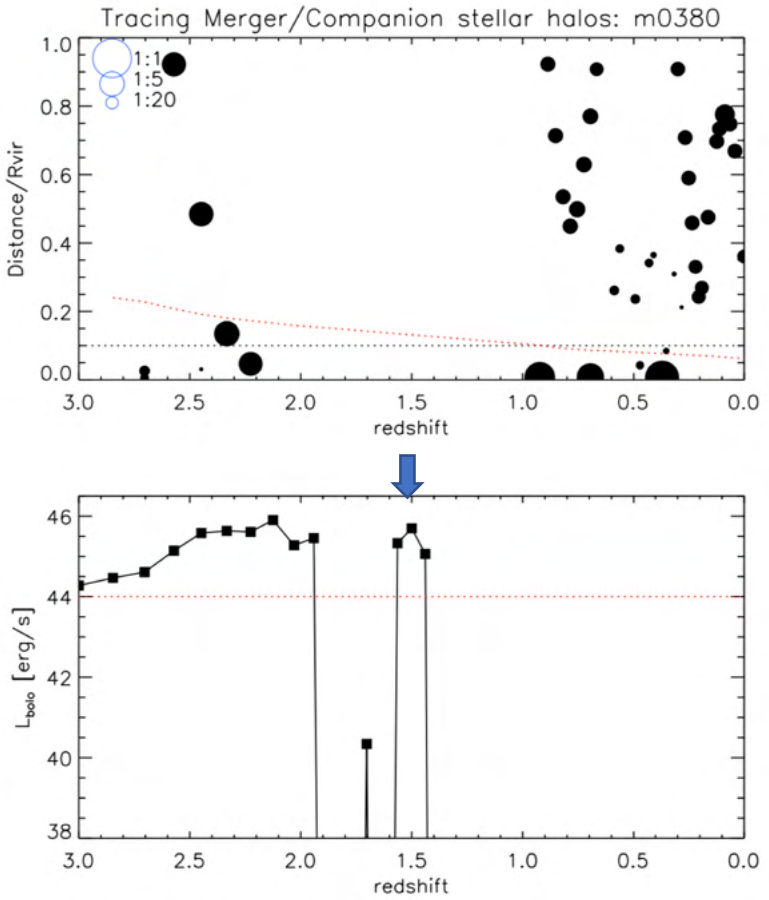
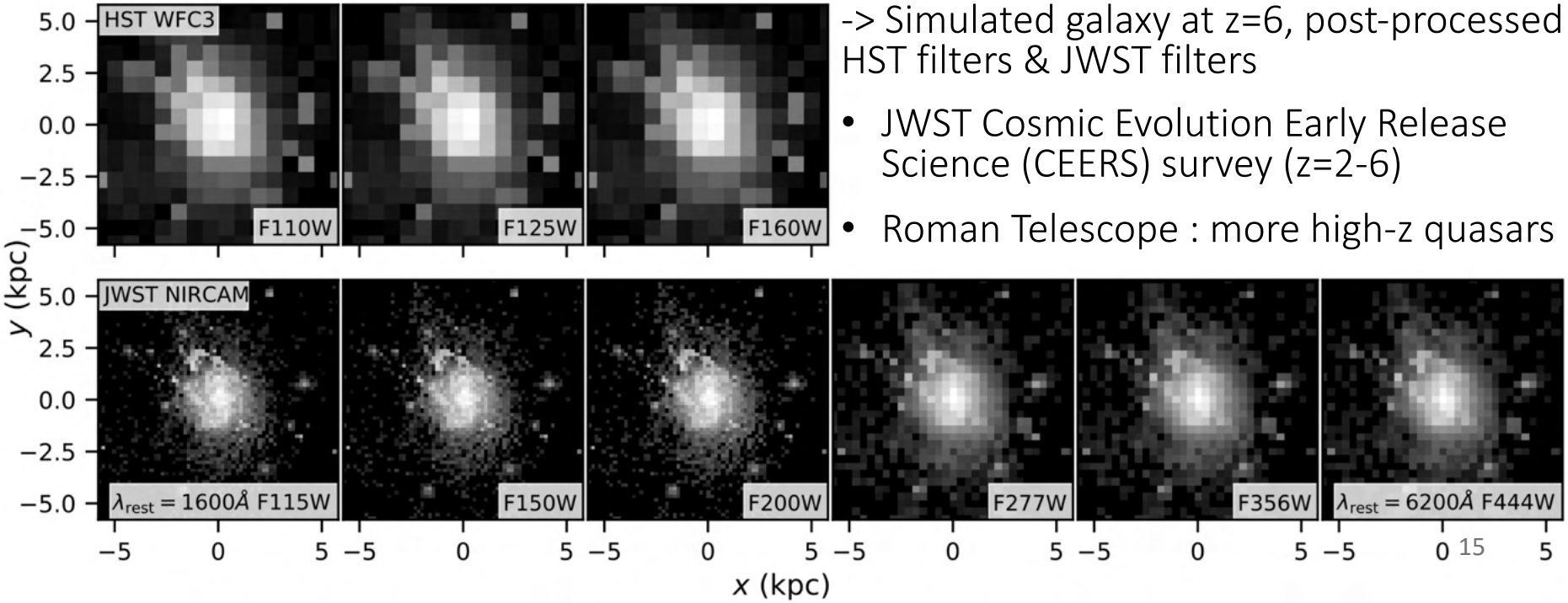


Summary

- We studied the AGN-merger connection in a set of cosmological simulations and in the HST CANDELS survey.
- We apply the same method to compare simulations and observation by generating mock images, and using the same merger classifier.
- How the merger fraction varies between AGN hosts and inactive galaxies:
  - AGN host do not exhibit higher close-pair fractions than inactive galaxies.
- How AGN fractions vary between merging and non-merging systems:
  - AGN fraction in merging systems is consistent with that in non-merging systems.
- Mergers may sometimes trigger observable AGN activity, but overall AGN do not appear to more preferentially live in merging systems due to:
  - time-lag between merging and AGN triggering
  - other mechanisms that play a role in fueling AGN

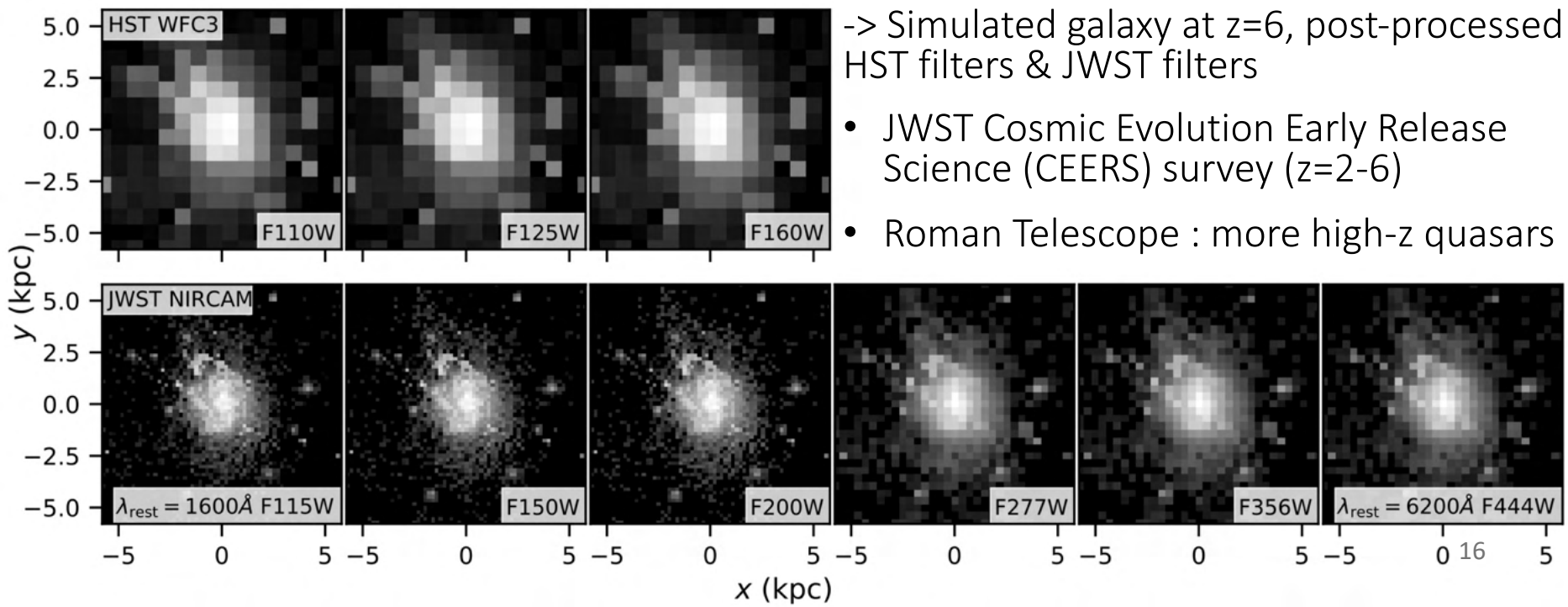
Upcoming JWST



-> Simulated galaxy at z=6, post-processed to HST filters & JWST filters

- JWST Cosmic Evolution Early Release Science (CEERS) survey (z=2-6)
- Roman Telescope : more high-z quasars

Upcoming JWST



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