MAPPING GALAXY EVOLUTION WITH MULTIPLE TRACERS

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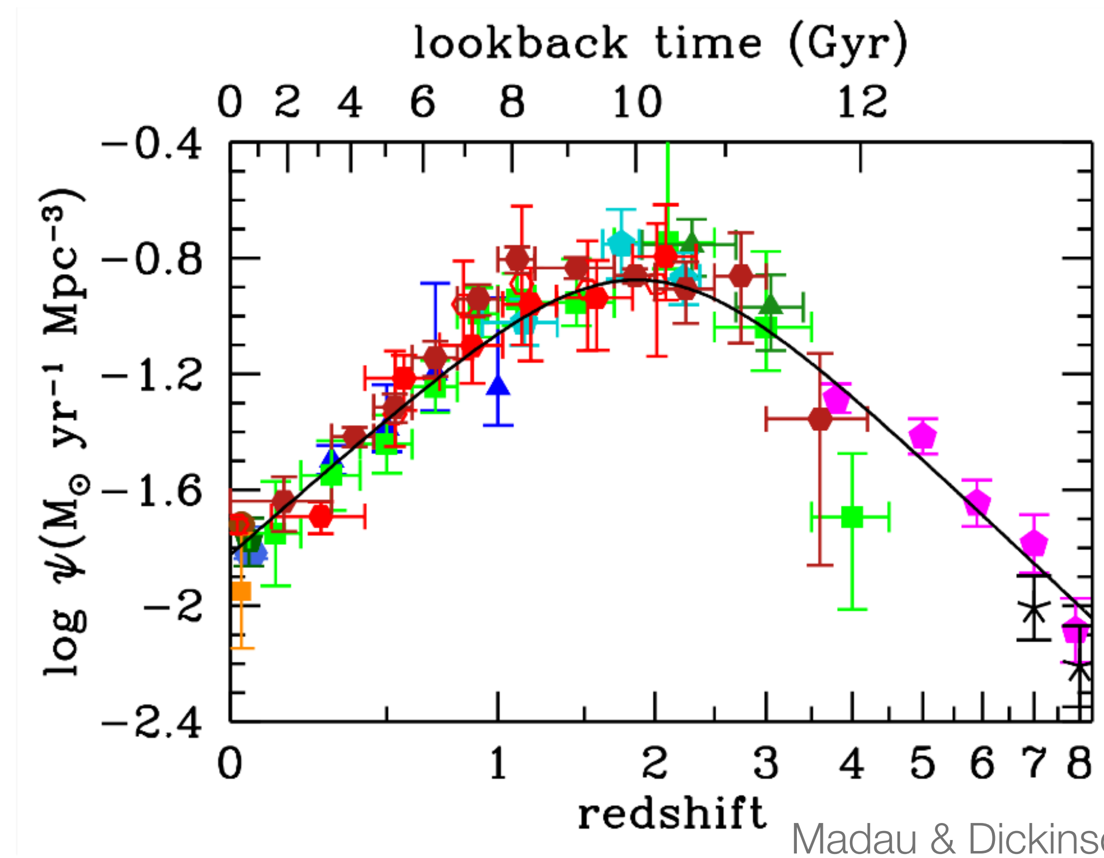
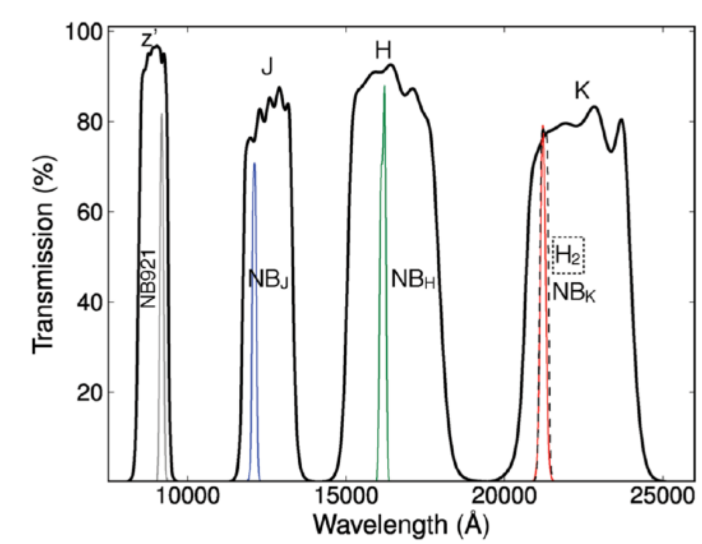
Overview of PhD work with HiZELS

HiZELS (High-Redshift(z) Emission Line Survey) is a narrow-band survey used to characterise the properties of high redshift galaxies.

- Use a single indicator, Hα, to identify large samples of star-forming galaxies across the peak and fall of the volume-averaged star formation rate density.
- Large, unbiased samples of SFGs.
- Probe fields with good multi-wavelength coverage: COSMOS, UDS, SA22. Total coverage is several square degrees.

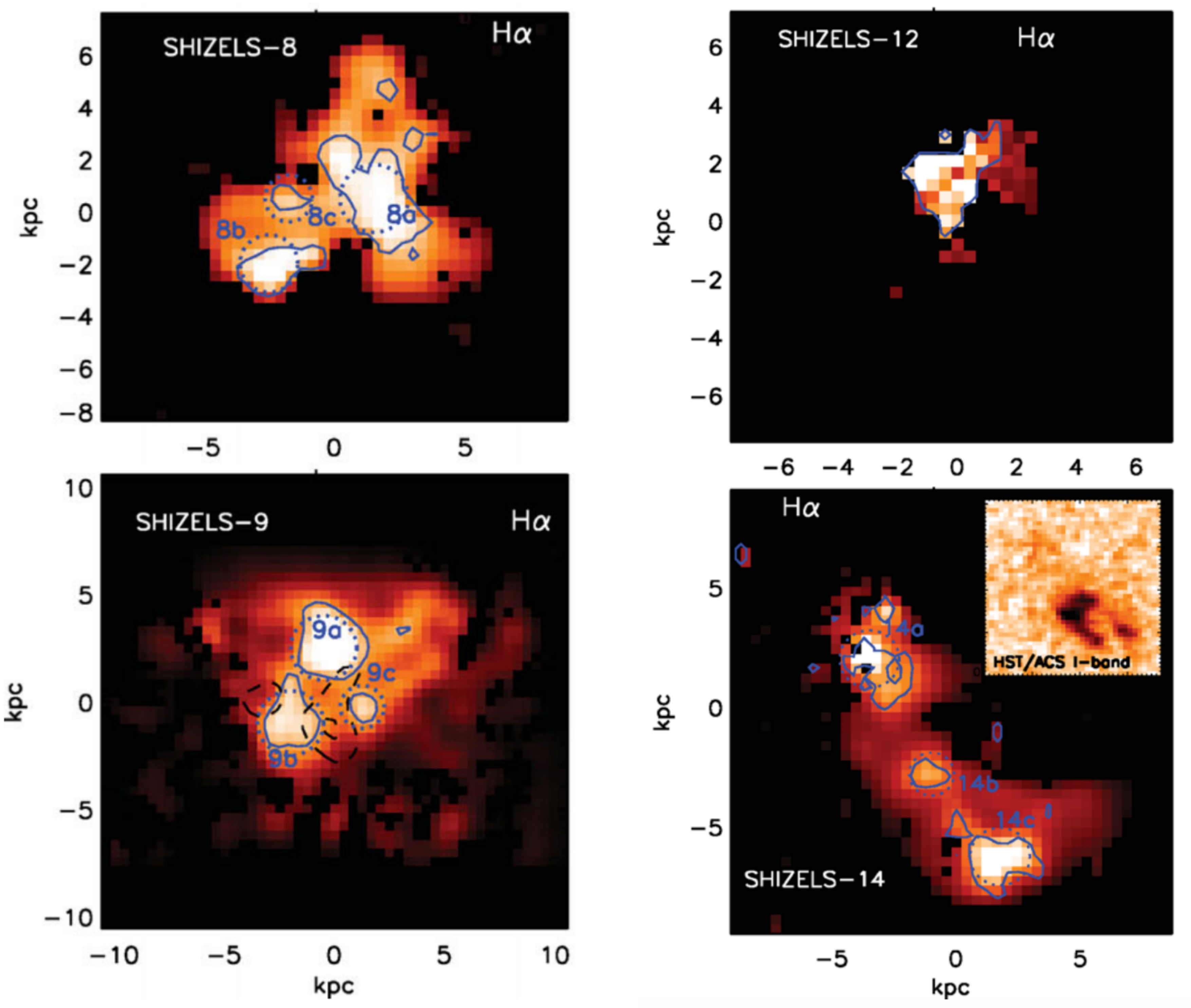


Madau & Dickinson 2014



Sobral et al. 2013

Resolving star formation at high redshift

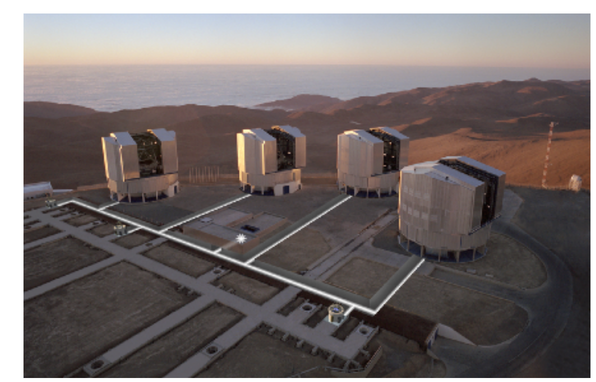


Swinbank et al. 2012.

HiZELS

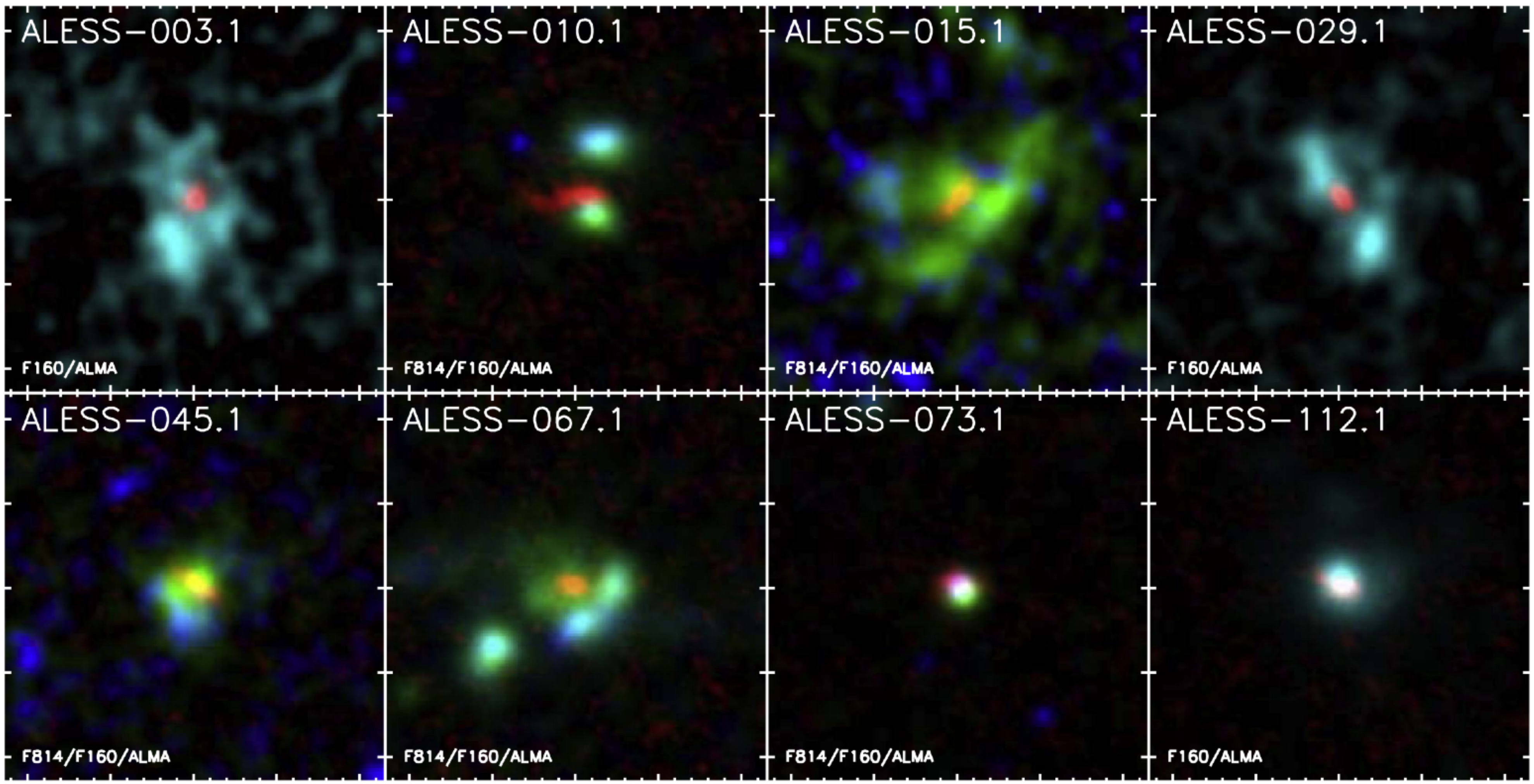
↓

SHiZELS



spatially-resolved Hα maps

ALMA observations indicate that dust continuum emission of high-redshift galaxies is compact



ALMA imaging of ALESS galaxies at z~2.5 (Hodge+16). At ~0.15” resolution, the 870-micron emission appears smooth and compact, whereas the rest-frame optical structures mapped by HST tend to be more extended.

SHiZELS: Spatially-resolved observations of HiZELS galaxies

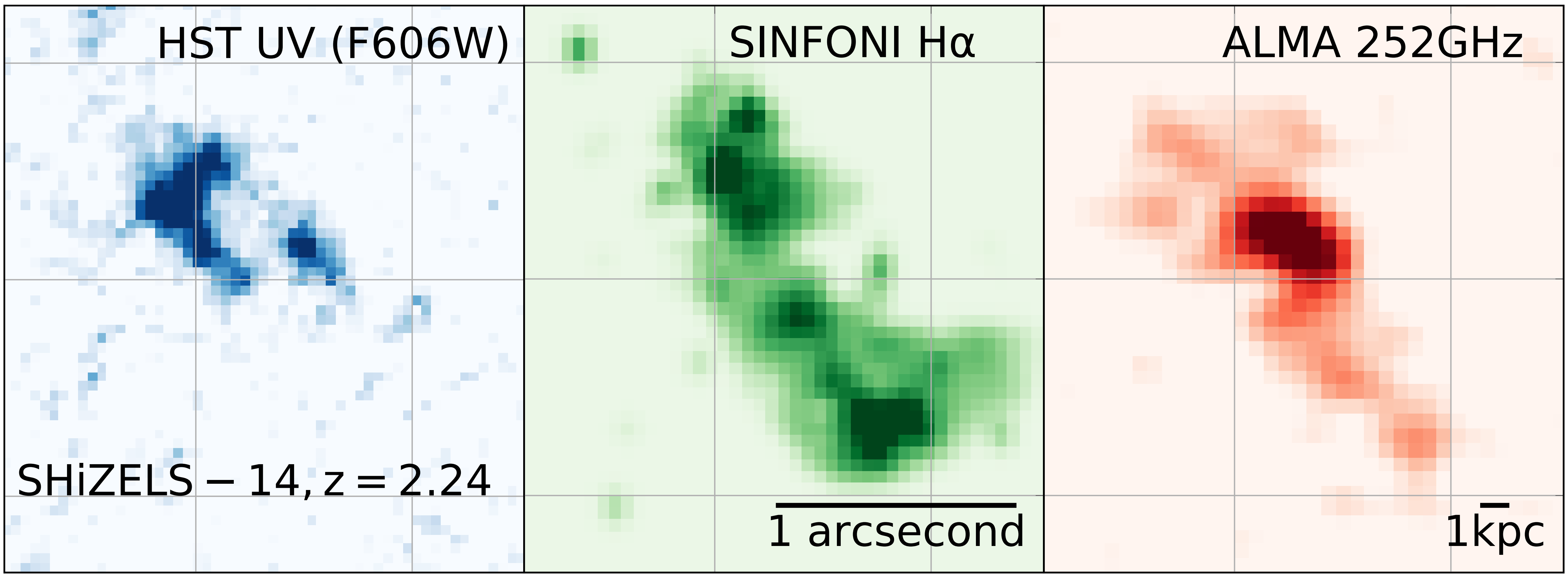
HST

SINFONI/VLT

ALMA

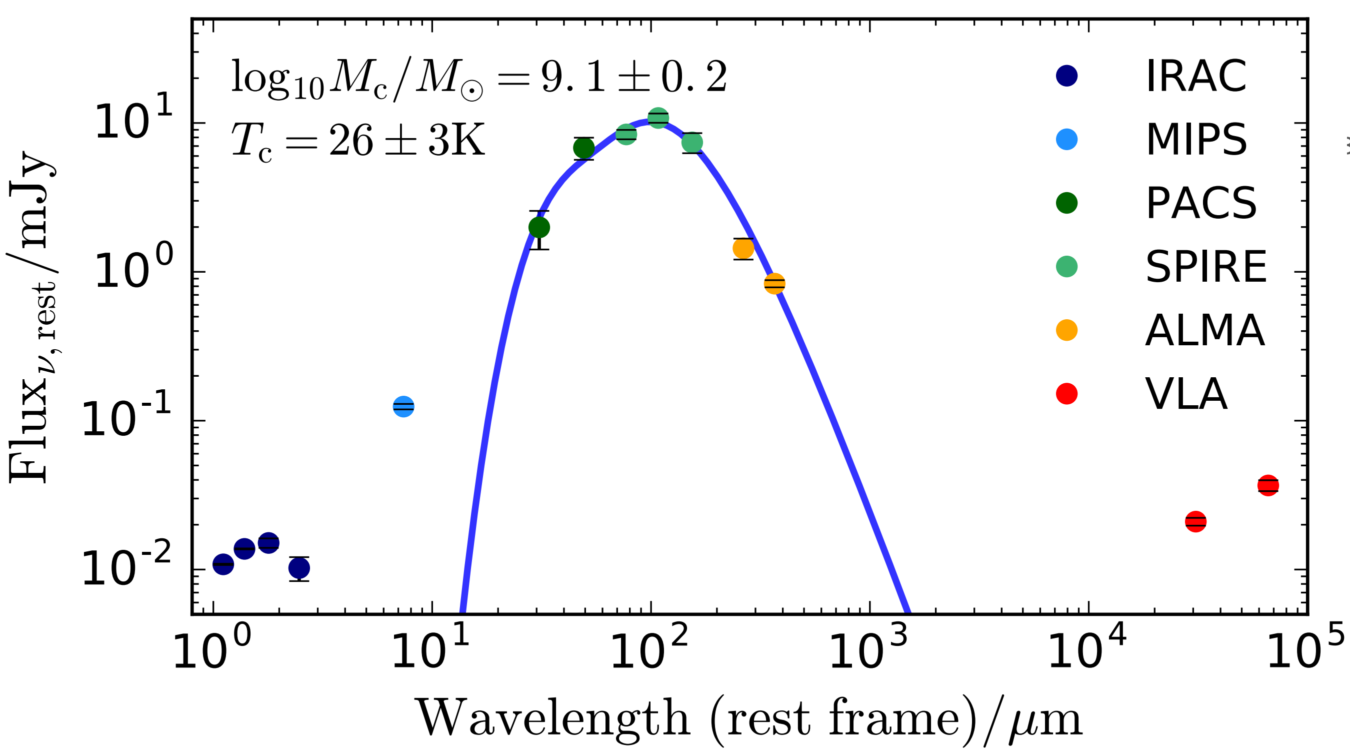
0.15''-resolution imaging in three different widely used tracers of star formation: UV continuum (from HST), the Hα emission line (from SINFONI/VLT), and the far-infrared (from ALMA)

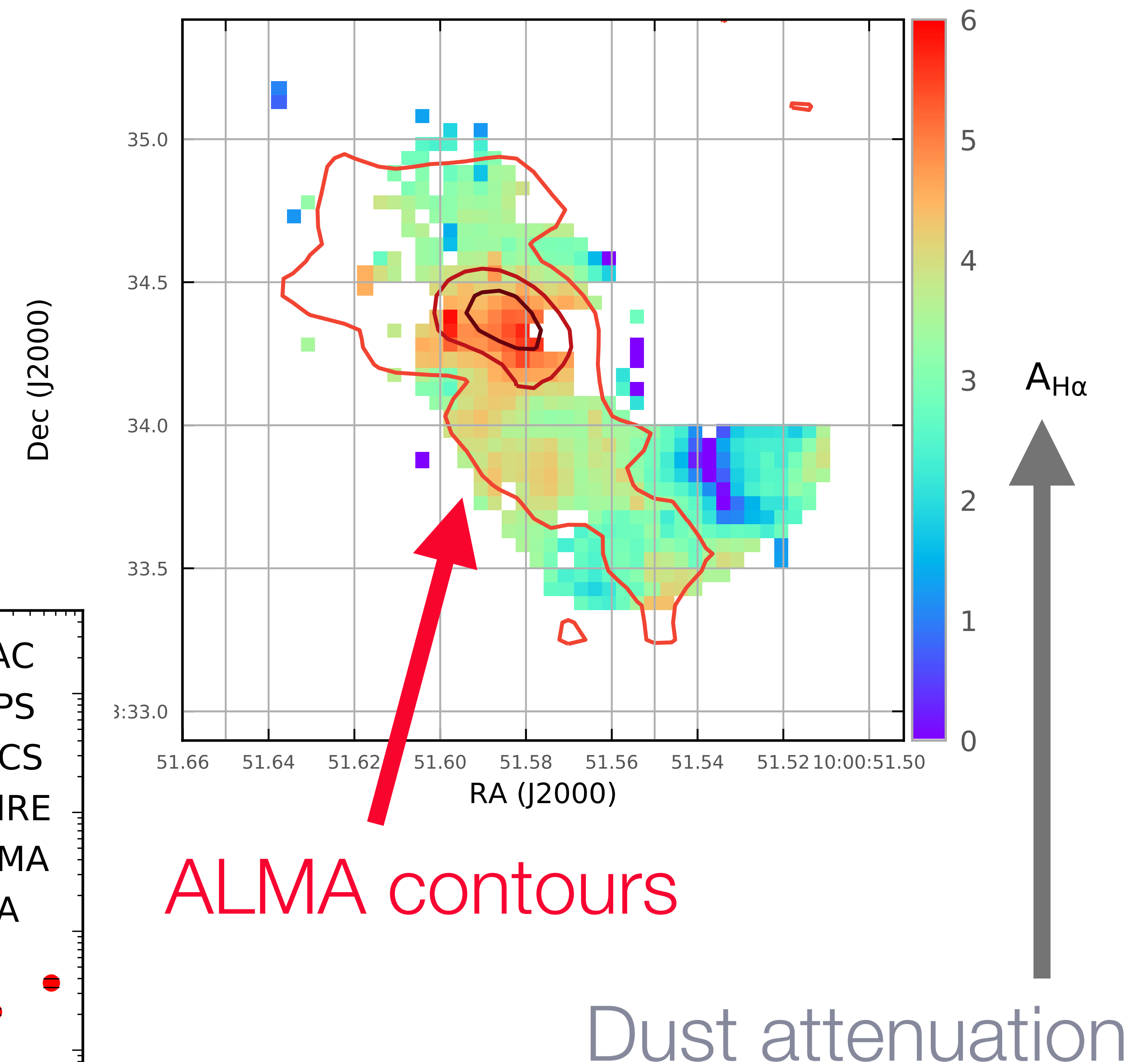
SHiZELS-14: wildly different morphologies



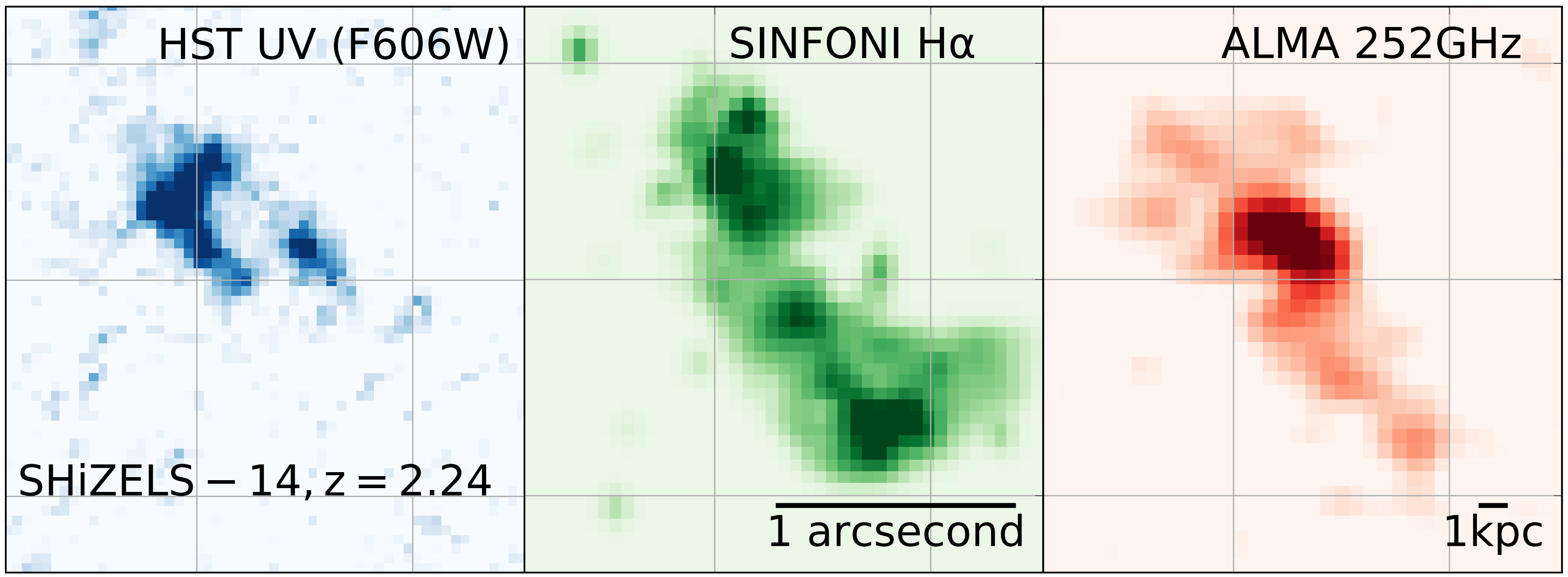
0.15''-resolution imaging in three different widely used tracers of star formation: UV continuum (from HST), the Hα emission line (from SINFONI/VLT), and the far-infrared (from ALMA)

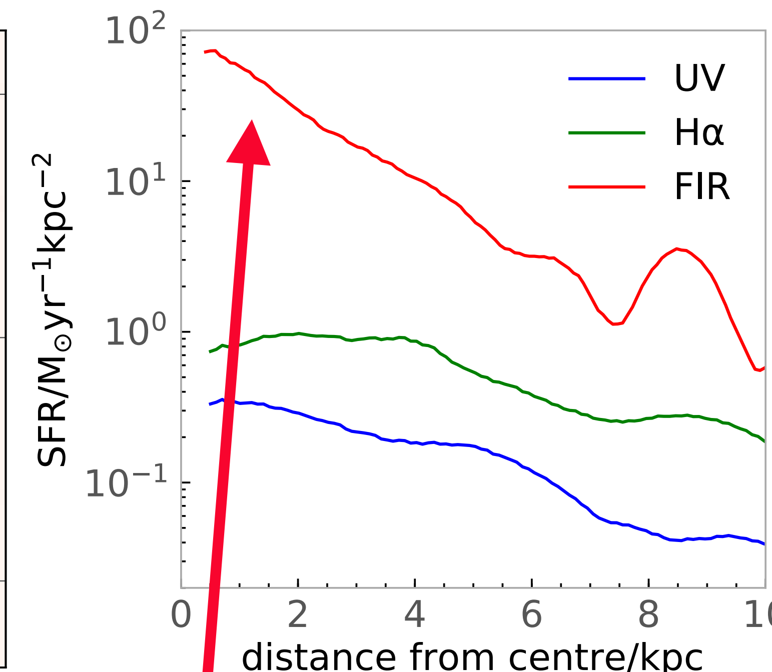
SHiZELS-14: an extremely dusty galaxy





Commonly-used SFR calibrations break down





UV: 13 M⊙/yr

Hα: 33 M⊙/yr

Hα ($A_{Hα}$=1): 82 M⊙/yr

concentrated central star-formation

TIR luminosity =>
SFR ~ 1000 M⊙/yr

Using the FIRE-2 simulations to interpret observations

- State-of-the-art in hydrodynamical cosmological zoom-in simulations.
- Resolves the formation of giant molecular clouds on ~10pc scales.

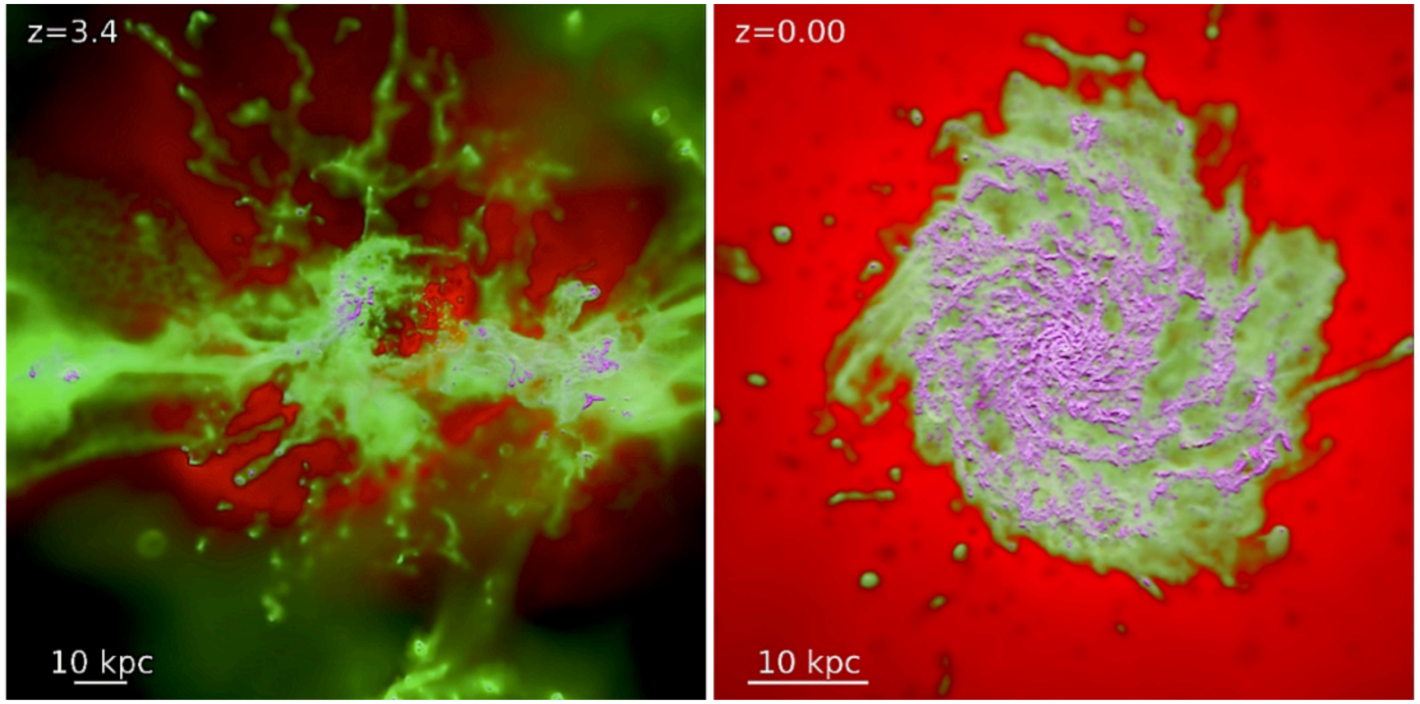
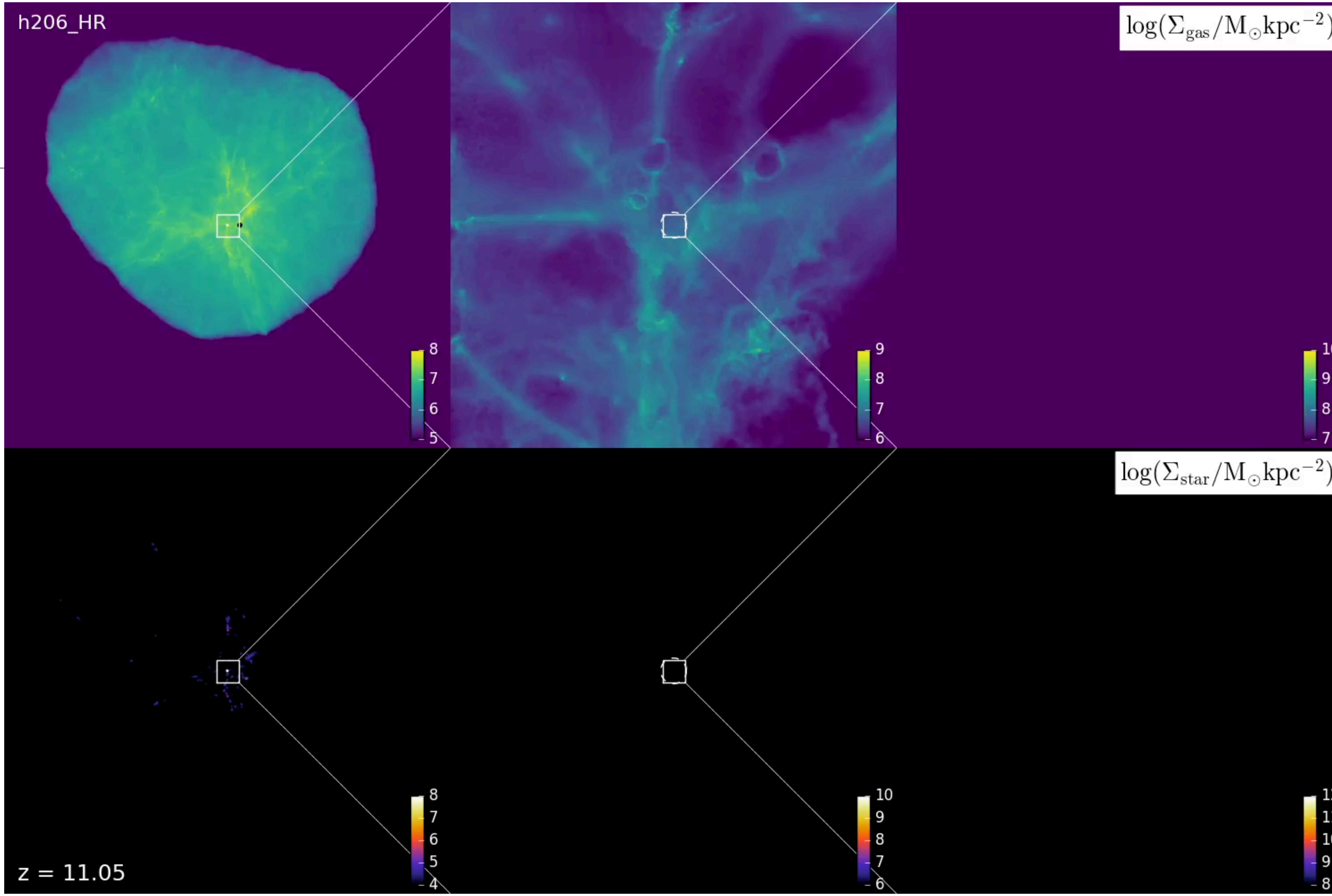


Figure from a MW-like galaxy in the main FIRE-2 simulations (Hopkins+17). The gas density distribution at high and low redshift.

Our sample: 4 central galaxies (A1, A2, A4, A8) that reach Milky Way masses by z~2. Gas and star particles at 600 redshift snapshots.



Credit: Daniel Anglés-Alcázar

Using the FIRE-2 simulations to interpret observations

Identify galaxies/snapshots likely to have high FIR fluxes using dust mass and SFR.

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Run radiative transfer modelling on these snapshots to derive predicted emission maps in different wavebands.

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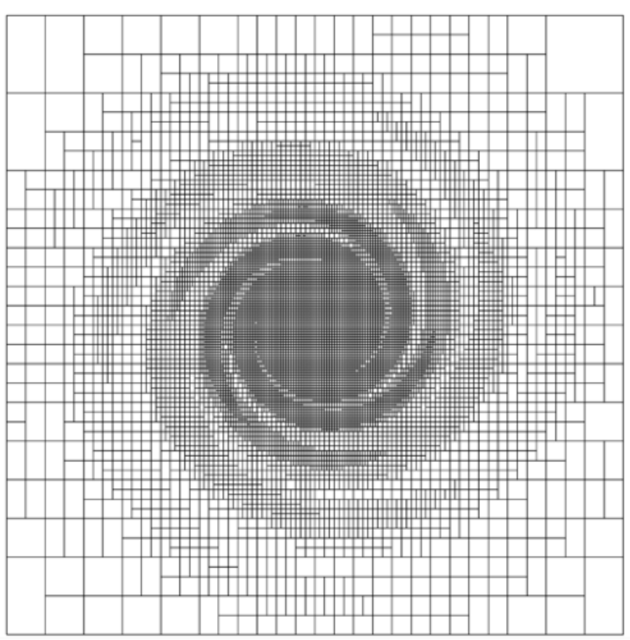
Look at the spatial distribution of the dust continuum emission, and how this compares to other physical quantities.

SKIRT uses Monte Carlo techniques to simulate the scattering, absorption and emission of photons by dust particles

Camps & Baes 2014

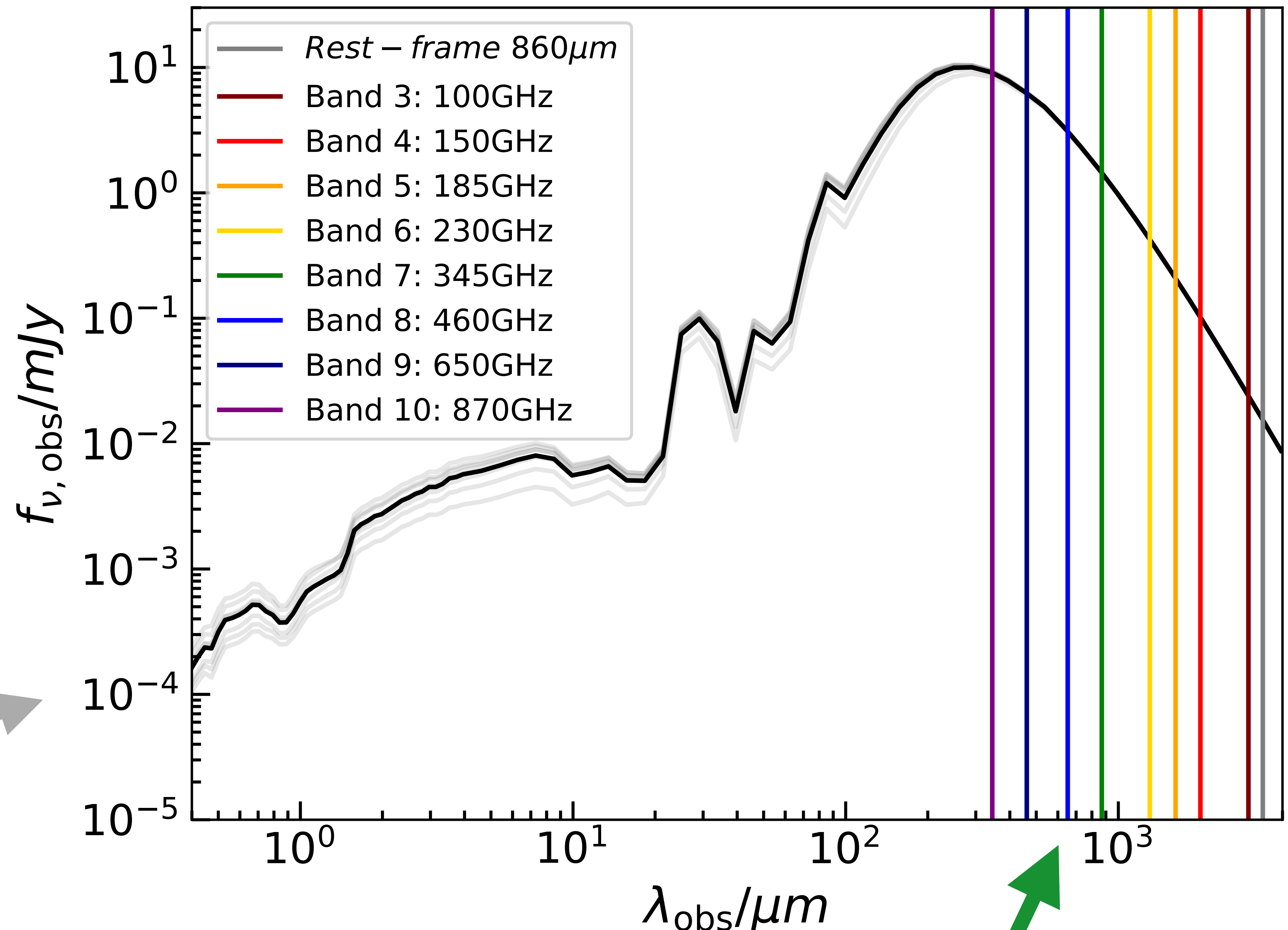
Simulating galaxy SEDs using the SKIRT radiative transfer code



We used an octree grid. Cell sizes are adjusted according to the dust density distribution.

- Gas and star particle positions for a given snapshot
- Every star particle is treated as a single stellar population with known mass, age, and metallicity. SEDs come from stellar evolution models of Bruzual & Charlot, assuming a Kroupa IMF
- dust prescription: a mixture of graphite, silicate and PAH grains (Weingartner and Draine 2001)
- dust grid (octree)
- a wavelength grid (resolve emission from UV to mm wavelengths)
- detectors placed at z=0 (7 inclinations)

Galaxy A2,
z=2.95



Grey lines show the SED at different inclinations

flux~1.5mJy

SED output from SKIRT

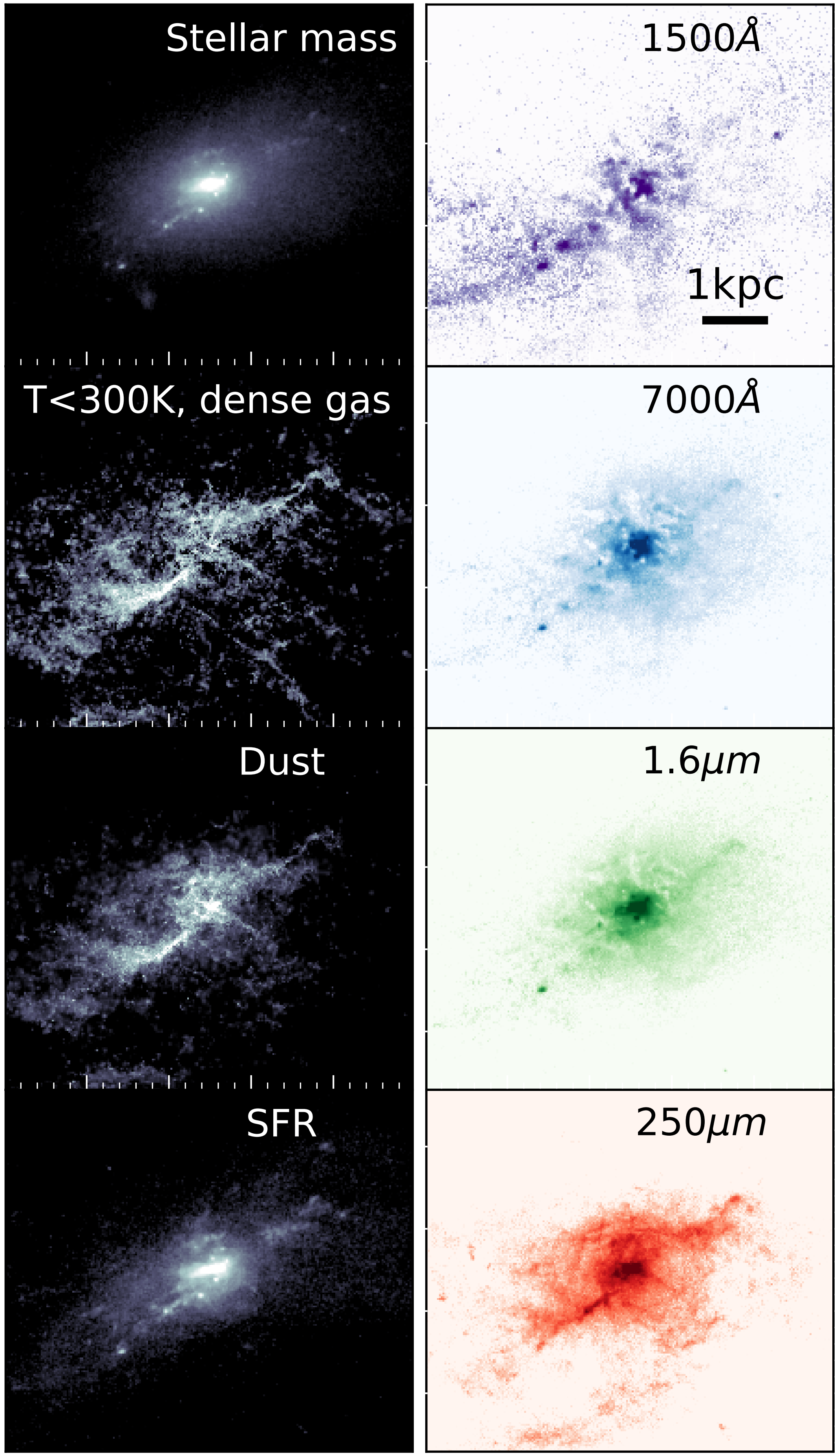
The typical ALMA waveband used to probe rest-frame FIR emission at high-z is shown by the green line

The UV emission is clumpy and extended.

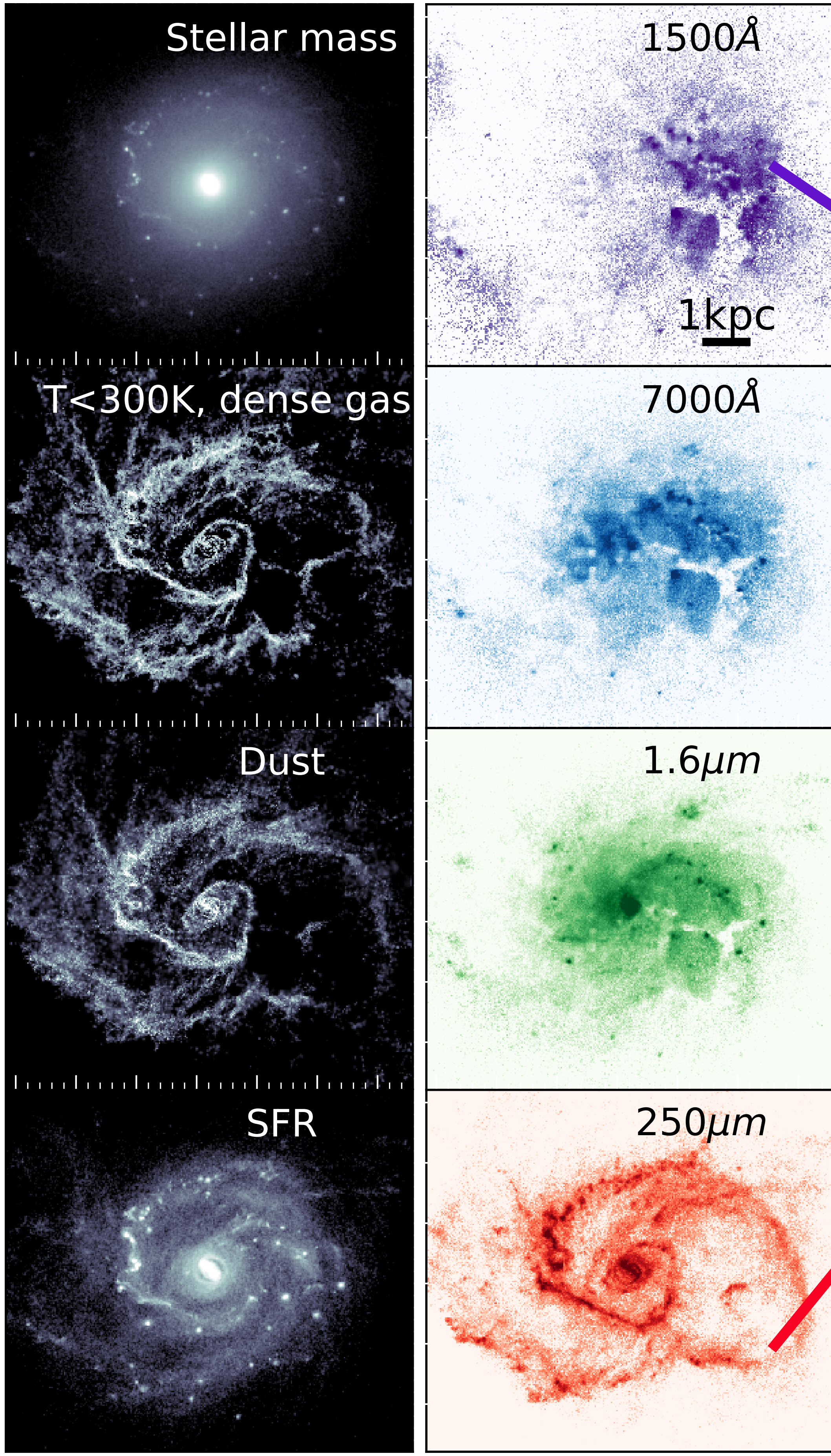
We see clear morphological differences between wavebands (rest-frame emission shown)

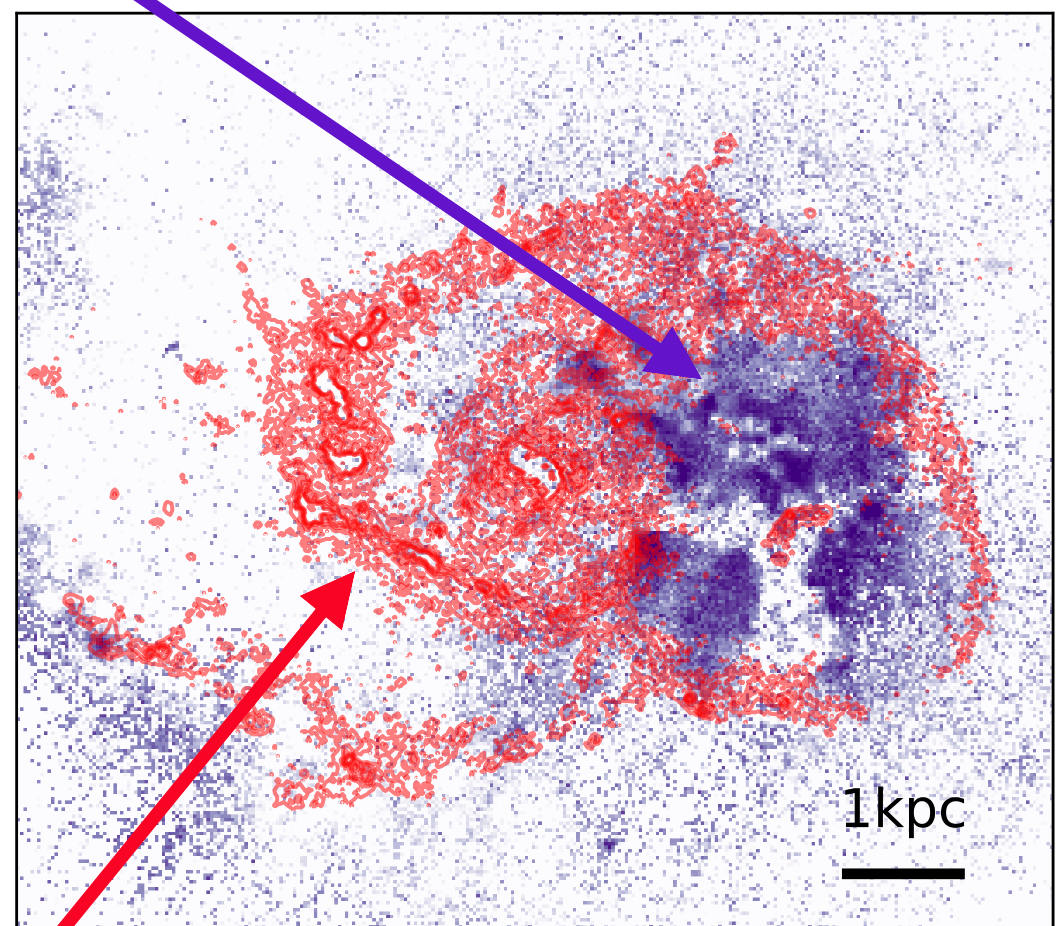
Galaxy A1, z=4.4

The FIR emission appears smoother and more compact.



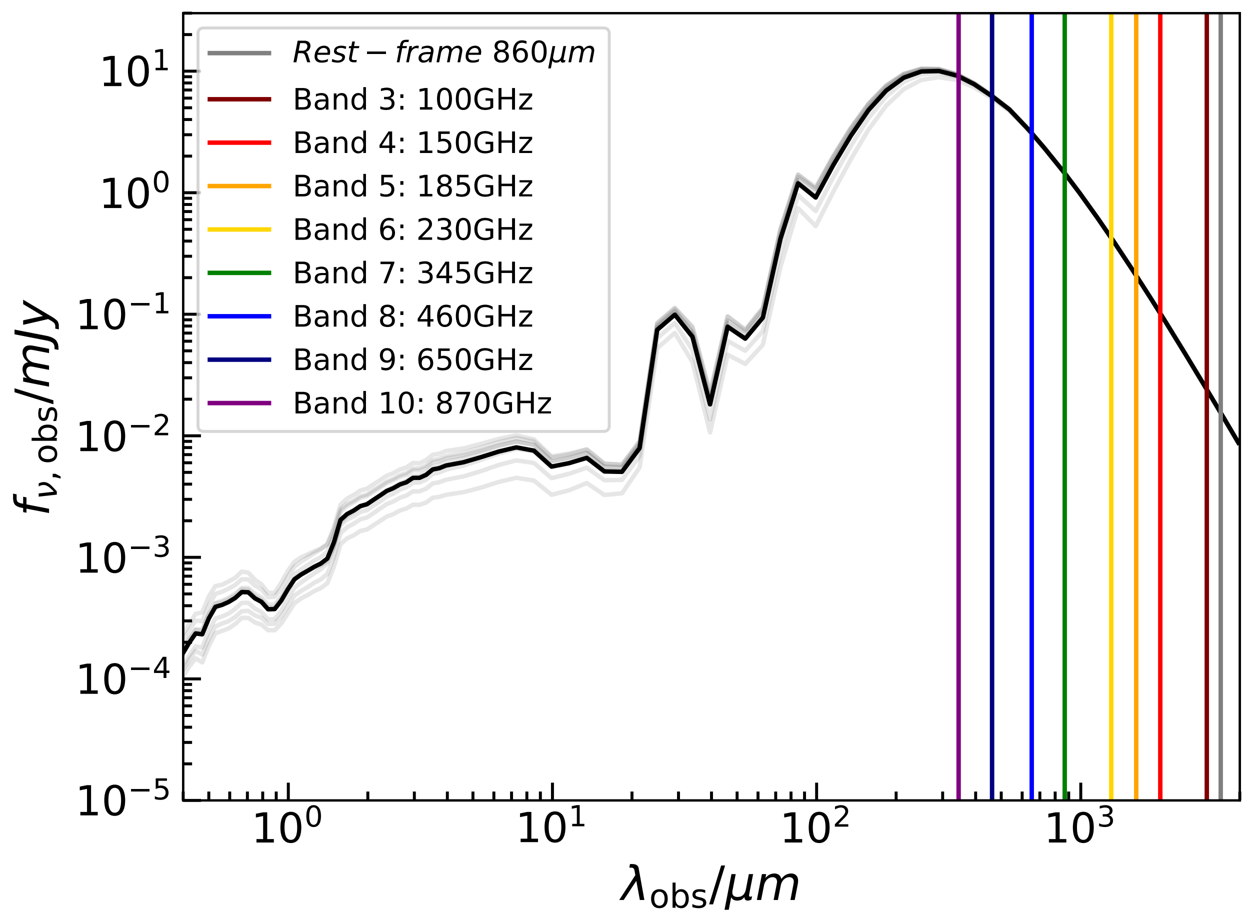
Offsets between short and long-wavelength emission, in line with our observations



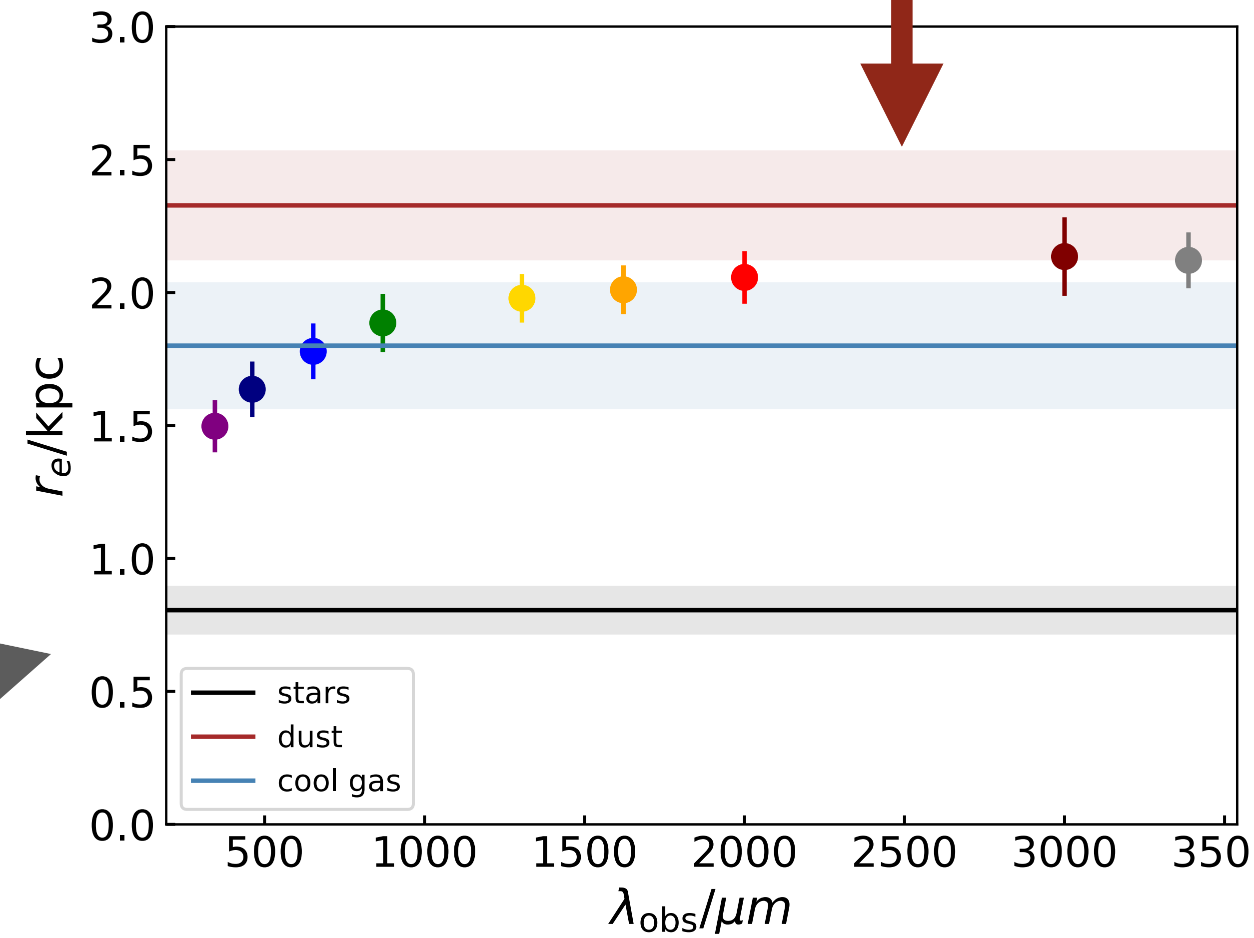


Galaxy A2 at z=2.95

How does the predicted dust continuum emission trace other physical quantities?

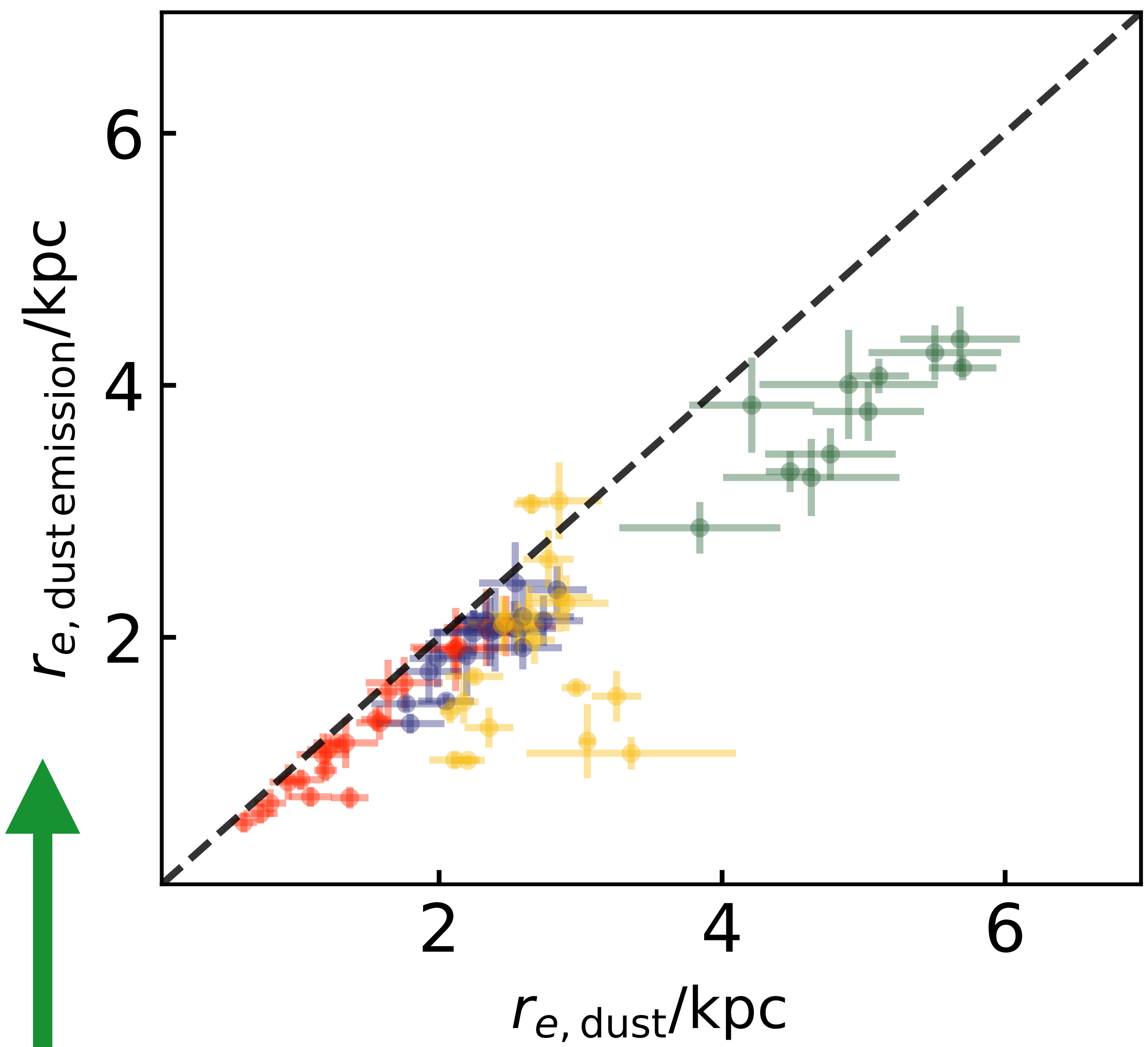


Emission at FIR wavelengths is smaller in extent than the intrinsic dust distribution



But more extended than the total stellar mass

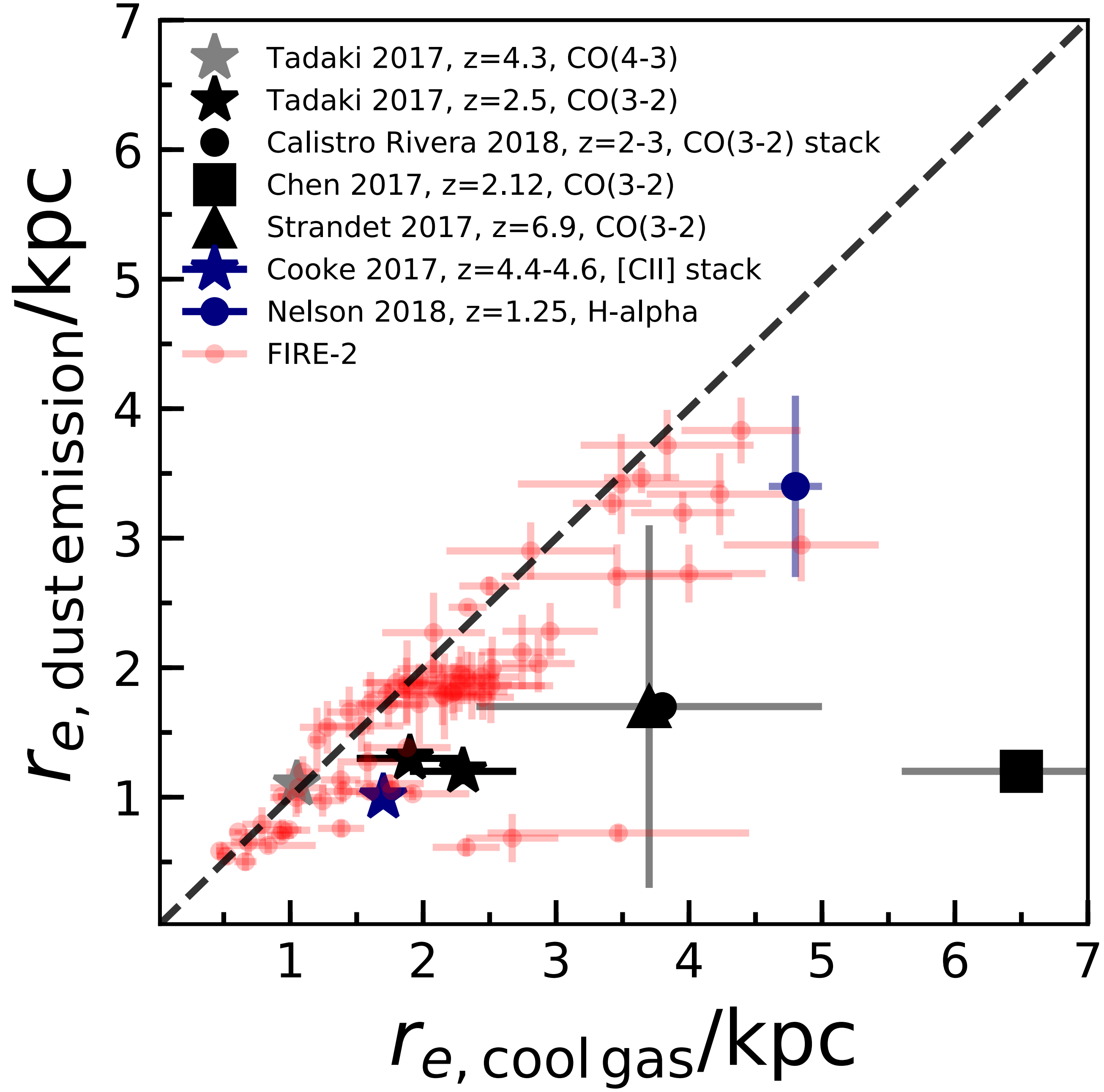
Spatial distribution of dust emission



The dust continuum emission tends to be more compact than the dust mass.

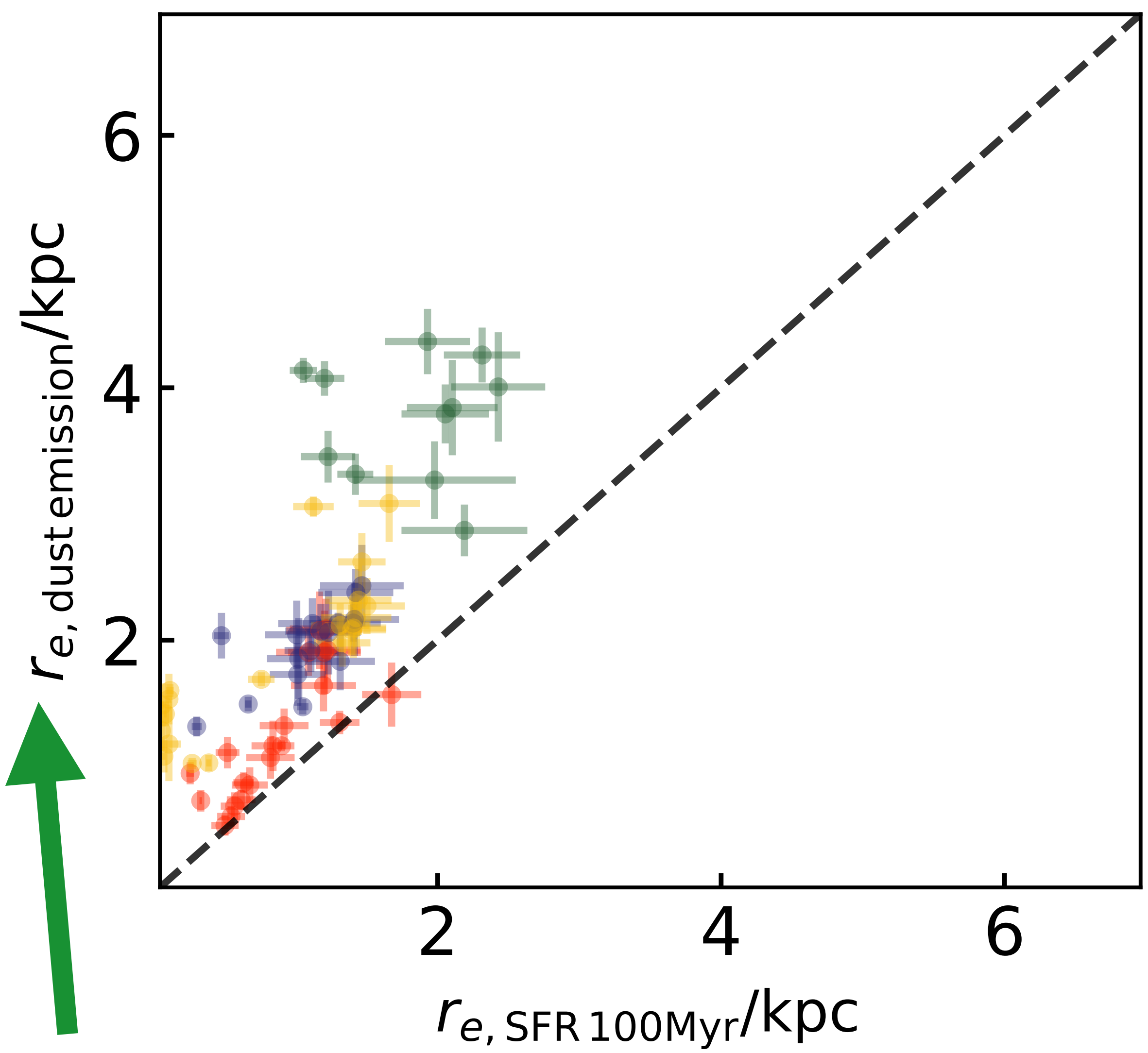
observed-frame wavelength of ALMA band 7

Derived radii are consistent with observations



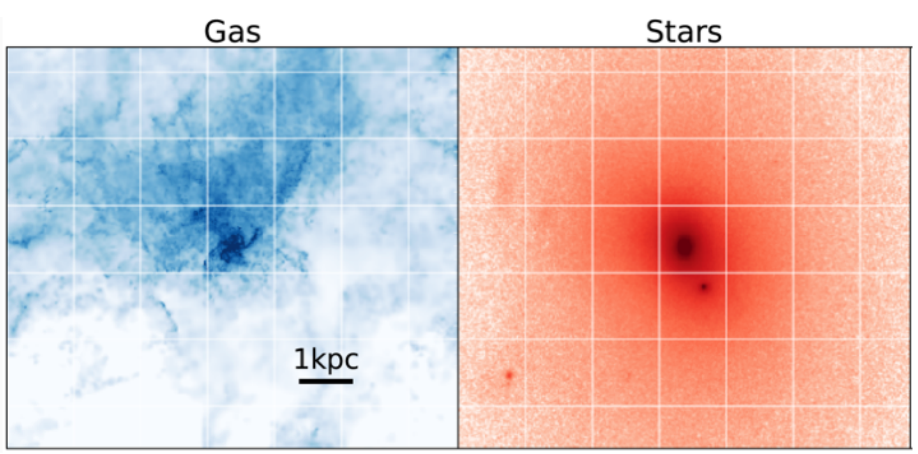
Effective radius of dust continuum emission is ~0.5-4kpc, in line with observations of high redshift galaxies

The role of recent (<100Myr) star-formation



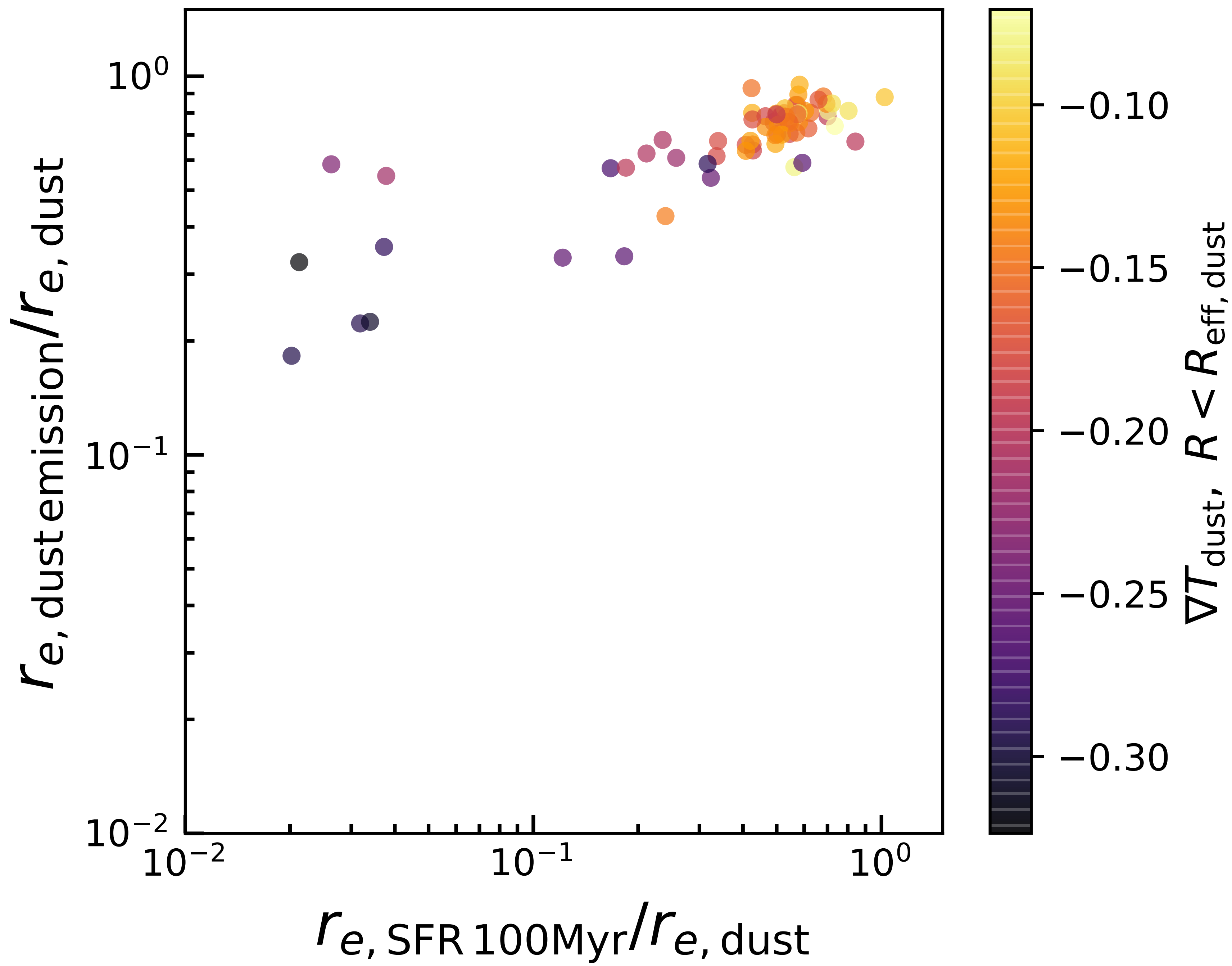
observed-frame wavelength of ALMA band 7

A4, z=2.2



Some galaxies show extremely compact recent star formation, on the scale of <0.5kpc. These galaxies also have very compact dust emission.

The role of recent (<100Myr) star-formation



Summary

- We identify a population of FIRE-2 galaxies with ~1-3mJy FIR fluxes at z~1-5.

- These galaxies display compact dust emission (~0.5-4kpc), consistent with observations.

- The dust continuum emission in simulated galaxies is more compact than the dust itself.

- A small number of galaxies have extremely compact dust emission (~0.5kpc). These also have recent SF of similar extent. Where the star formation is centrally concentrated, dust in the inner regions is heated most.