The Emergence of Spiral Galaxy Structure at Cosmic Noon

A science case for SHARP

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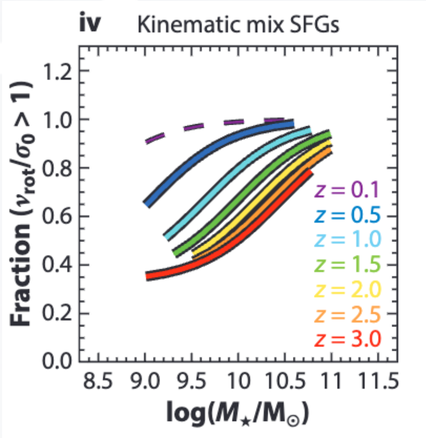
Unveiling the Universe with SHARP: a Spectrograph Proposal for MORFEO@ELT
Monday 30th September - Wednesday 2nd October 2024 Sala Bassetti - Palazzo Brera, Milano

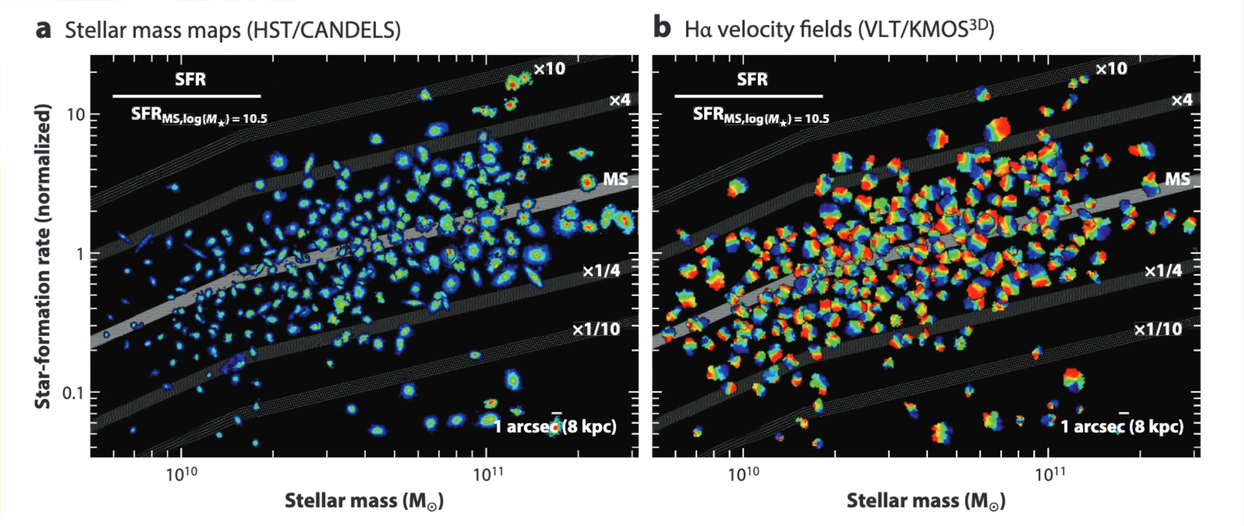
Spiral galaxies at Cosmic Noon

What we know

- **Cosmic noon**: 1.5<z<3 peak of the cosmic SFH
- The majority of **SFGs** around the MS and $M_* > 10^9 M_\odot$ are ***exponential disks***, increasing with mass and time (KMOS —> SINFONI, see Förster-Schreiber & Wuyts 2020 review and refs therein)
- The overall **structure** from rest-optical/UV light and colors correlates with **location in the M–SFR plane**, with most star formation happening in disks, while quiescent galaxies feature cuspier profiles.
- **Hubble sequence** (morphology↔stellar populations) in place already ***since z~2.5***



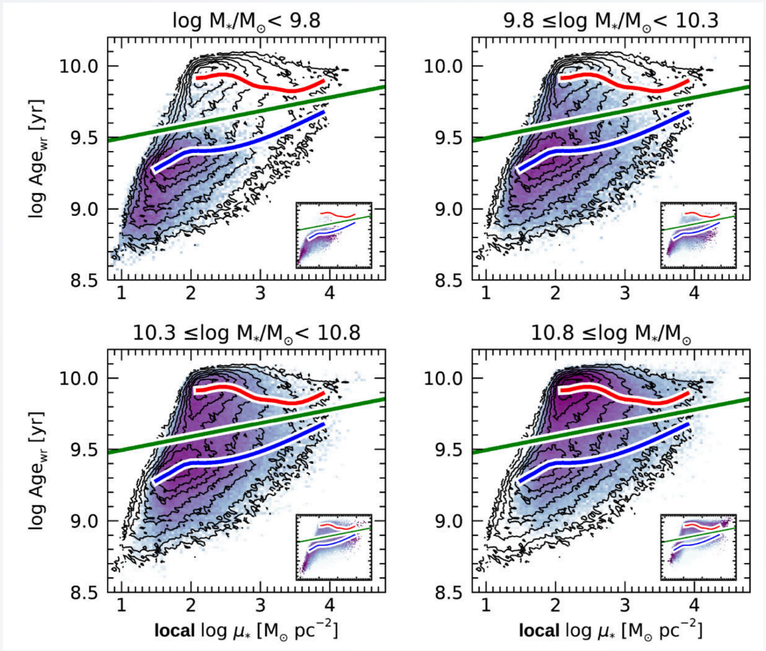
- What is the **link** between **structure/morphology and SF suppression**?
- How is this reflected in the **chemical enrichment**?



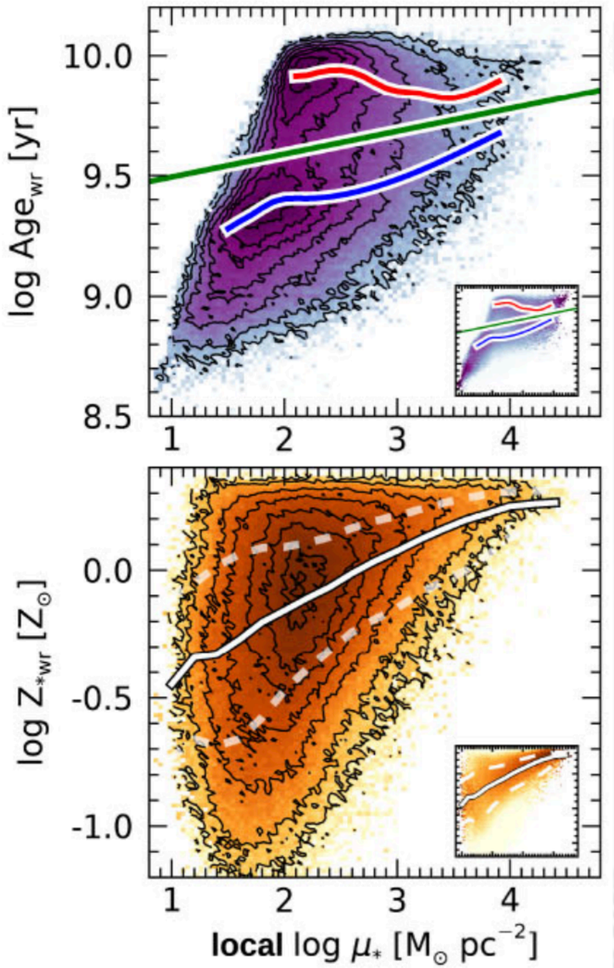
Structure evolution and SF/Chemical enrichment go hand in hand

Hints from local spatially resolved archaeological studies

- Fundamental relations between **stellar age and metallicity** with **stellar mass surface density**



Resolved regions ~1 kpc



Zibetti & Gallazzi (2022)

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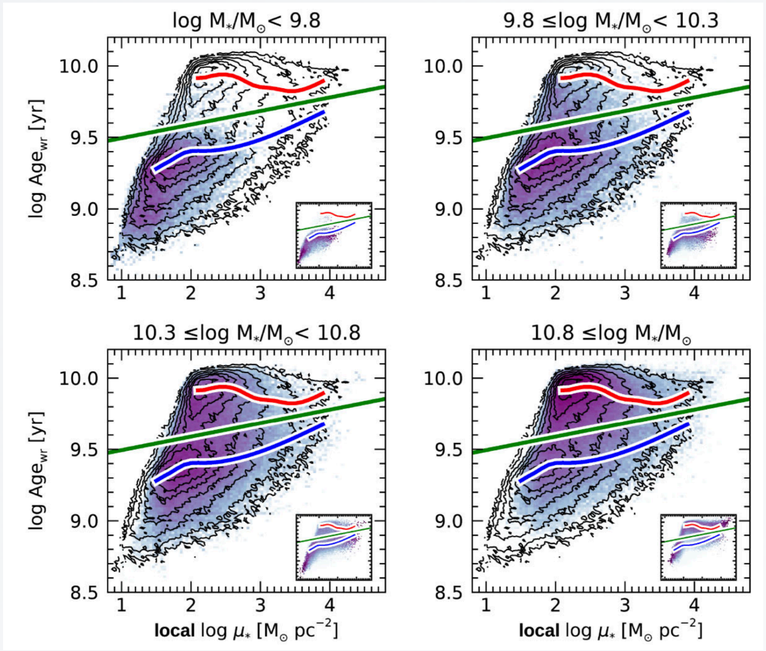

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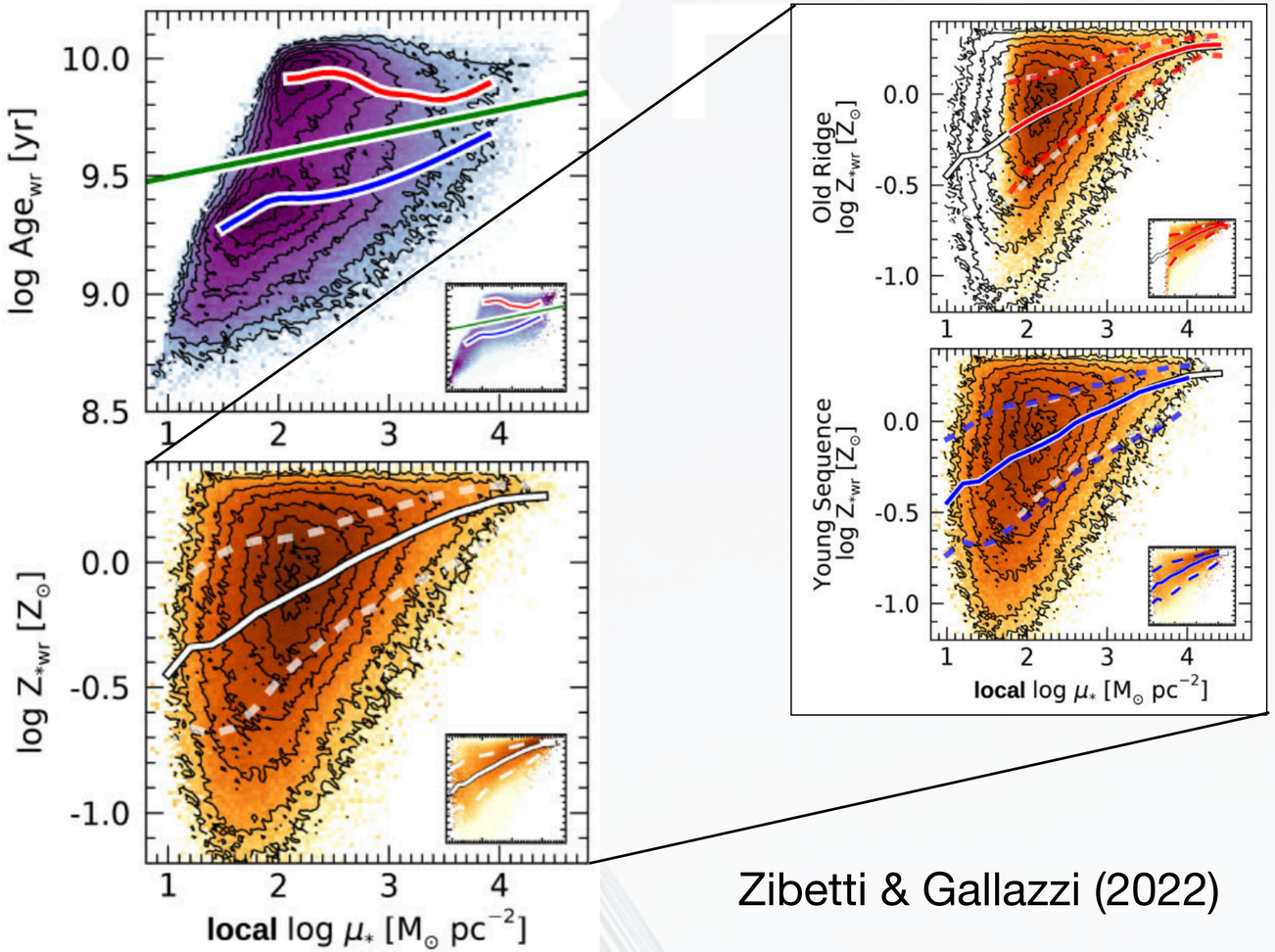

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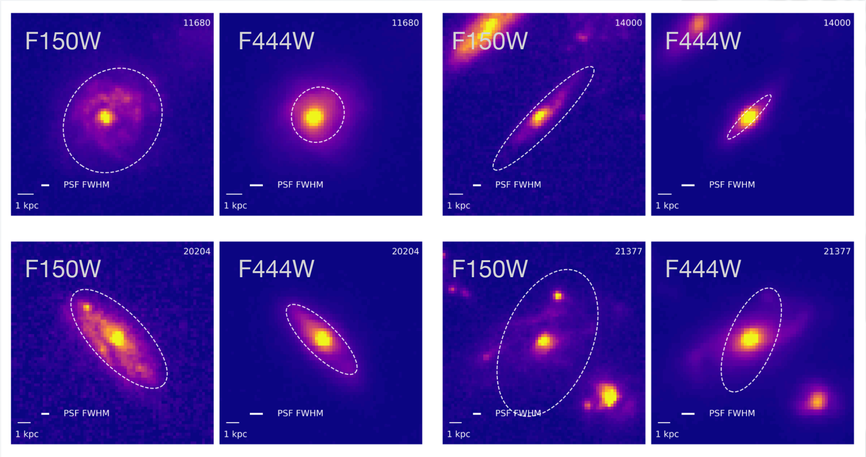
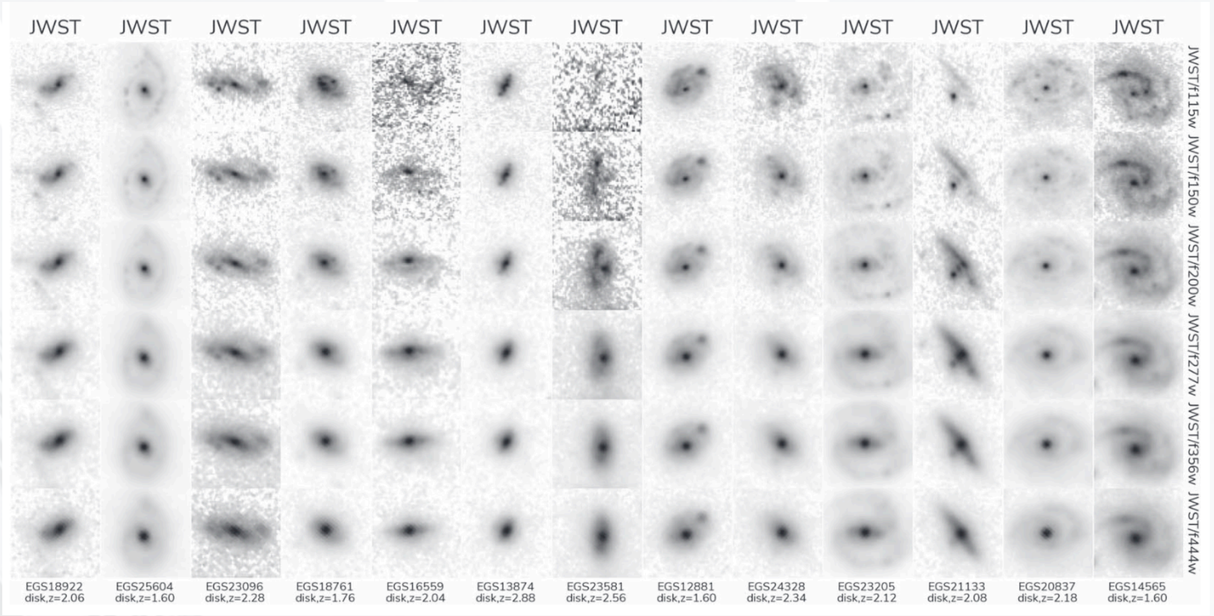
Spiral galaxies at Cosmic Noon

What we (are going to) know with current facilities (JWST)

- Many more **morphological/structural details** only available in the r.f. ***optical***
  - **Spirals** (and **bars**) in SFing disks
  - **Bulges**



Benton+2024

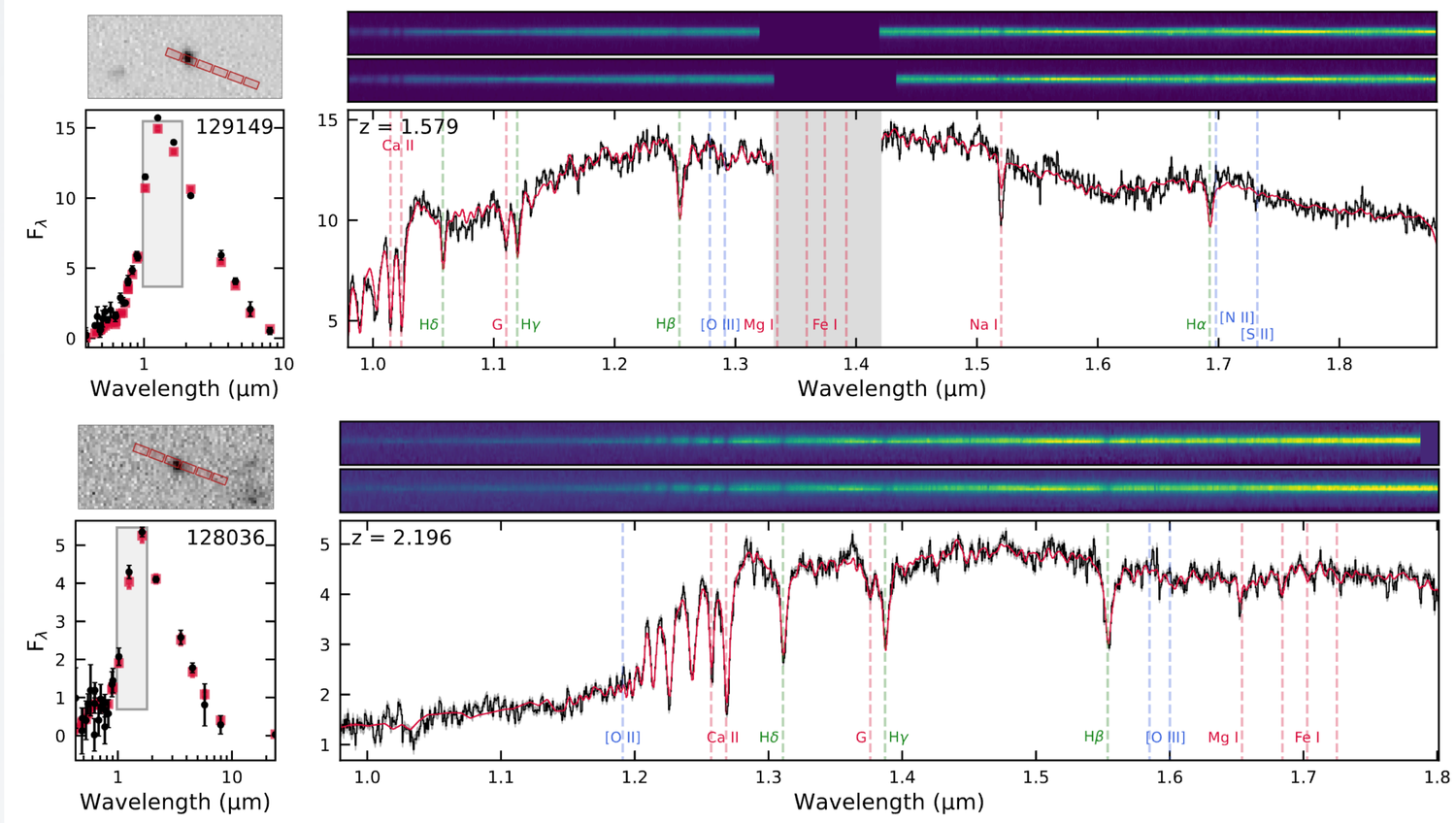


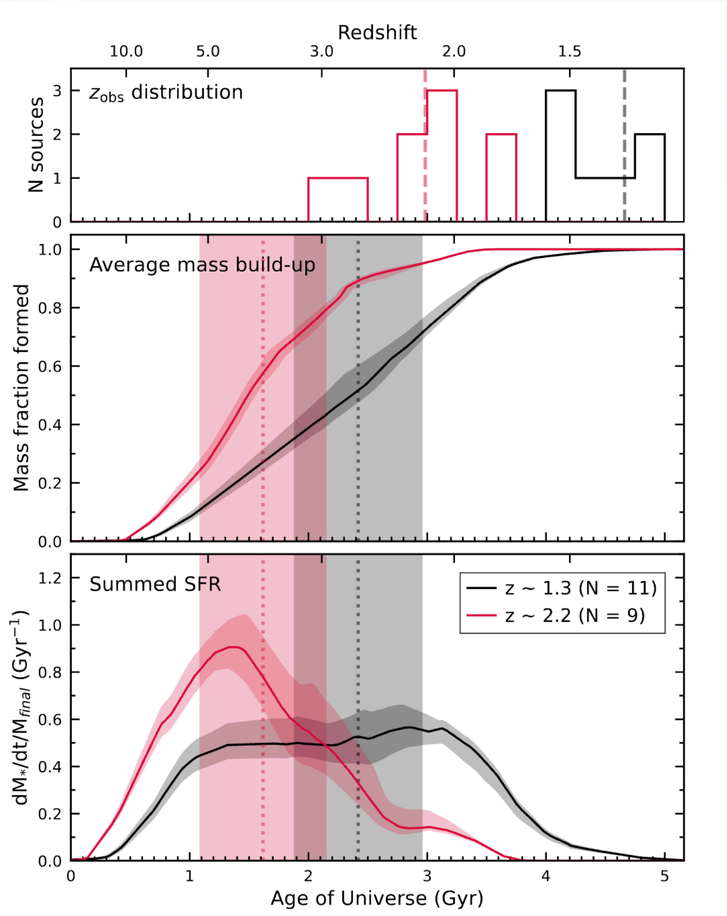
Ferreira+2023

- **Spatially resolved SEDs**
- **Emission line maps and gas kinematics** at much higher resolution

What JWST can deliver today

JWST **SUSPENSE**: 16.4hrs of NIRSpec,
on 20 targets $H \sim 20 - 23$ $\mathrm{mag_{AB}}$





Slob+2024

Spiral galaxies at Cosmic Noon

What we would like to know and we need SHARP for

- ***Questions***
  - Which/how many bulges originate from disks via ***dynamical evolution***? (*"pseudo-bulges"*)
    - What is the role of ***secular processes and bars***?
    - What is the role of ***external interactions***?
  - Which/how many **bulges** are **pristine**? (*"classical bulges"*)
  - How often are **disks (re)grown** around a pre-existing bulge?
  - Is the *growth of a bulge* a "verdict" of **quenching**? Or slow **reduction of SFE**?

- ***How to answer***
  - **Date** different **structural components**, possibly characterize their SFH
  - Determine their **chemical enrichment**
  - Map the **kinematics** of the **stellar** component
  - Find signatures of **mergers/interactions**

Observations needed in integral field spectroscopy

- **Targets**: SFing galaxies at 1.5<z<3, $M_* \gtrsim 10^{9.5}\mathrm{M}_\odot$
- **Optical rest-frame spectroscopy** (see Gallazzi+2005 … Zibetti+2017, 2024 for our methodology)
  - Across the 4000Å break, up to ~5500Å to cover Mg and red Fe complexes (better up to Halpha, SII …)
  - R>~2500
  - “High” SNR ~10-20 per r.f. Å

➡ Average stellar population properties (mean age, Z, main abundance ratios $[\alpha/\mathrm{Fe}]$), dust attenuation

➡ Basic characterization of the SFH

➡ Basic stellar (+gas) kinematics: velocity and velocity dispersion (higher moments?)

- **Spatial resolution** to characterize different structural components:
  - Effective radii ~2 kpc (e.g. Martorano+2024), bulge sizes <~1 kpc: ~0.2”, bulges <~0.1” @z~2
- **Statistics**: >~100 galaxies to capture diversity and variety of mechanisms at work

Why SHARP?

VESPER multi-IFU

- **Wavelength coverage**:
  NIR coverage enables detection of **Hα up to z~2.6 and Mg absorption features up to z~3.6**
  - To have full spectral coverage from $3800\text{Å} \rightarrow z > 2.15$
- **Sensitivity**:
  in 4hr-integration SNR~15 per observed Å (i.e., ~25 per rest-frame Å at z~2) for $H_{AB} = 24$ (point-like), corresponding to $M_* \sim 10^{9.5-10}\text{M}_\odot$ at z~2 (according to P. Franzetti's ETC).
- **Spatial resolution**: 31 mas/spax probes well below kpc scales, allowing to trace bulges, bars and even spiral arms (*note JWST-NIRSpec* has 100mas/spax, *~3 times worse*)
- **IFU** spatial coverage captures **disk perturbations** at ~6 kpc >~3 Re
- **Multiplexing**: ~10 galaxies brighter than $H_{AB} = 24$ per field, to match 12 IFUs
  - Note: this science case makes good use of the proposed instrument multiplexing

Segmenting galaxies according to structure becomes feasible!

Conclusions

- SHARP (VESPER) ideal instrument to study the emergence of structure in star forming disks at cosmic noon: ***unique features*** that make it **superior** to any present or planned facility
  - Better spatial resolution than ***JWST***
  - 2D spatial resolution and multiplexing advantage over ***MICADO***
  - Multiplexing advantage over ***HARMONI***
  - More spectral coverage in the NIR than ***MOSAIC***
- *Complementarity* with SHARP-NEXUS: spatial resolution along one axis only, but gain in multiplexing (~3x)
- Complementary to studies of passive galaxies (normal and compact)