

# The galaxy n cycle as seen WST

**Francesco Belfic**

Research Scientist  
INAF – Arcetri Astrophysical O  
Florence, Italy

WST Italian Worksh  
11 March 2025



INAF



Part I

## Introduction

Cosmic Ecosystems

Part II

## The WST Extragalactic Science Case

Part III

## The small-scale matter cycle

With current multi-wavelength facilities

# The galaxy matter cycle as seen by WST

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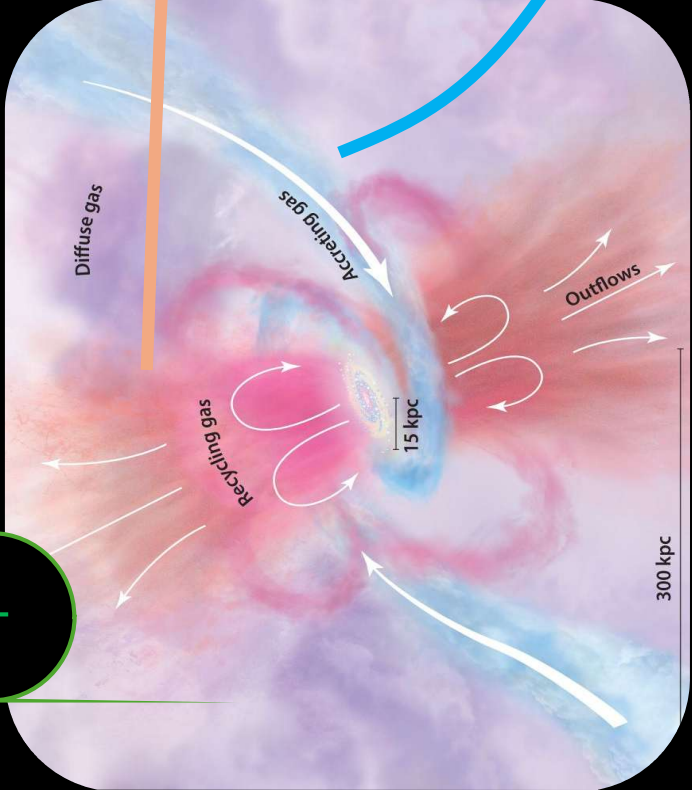
WST Italian Workshop  
11 March 2025



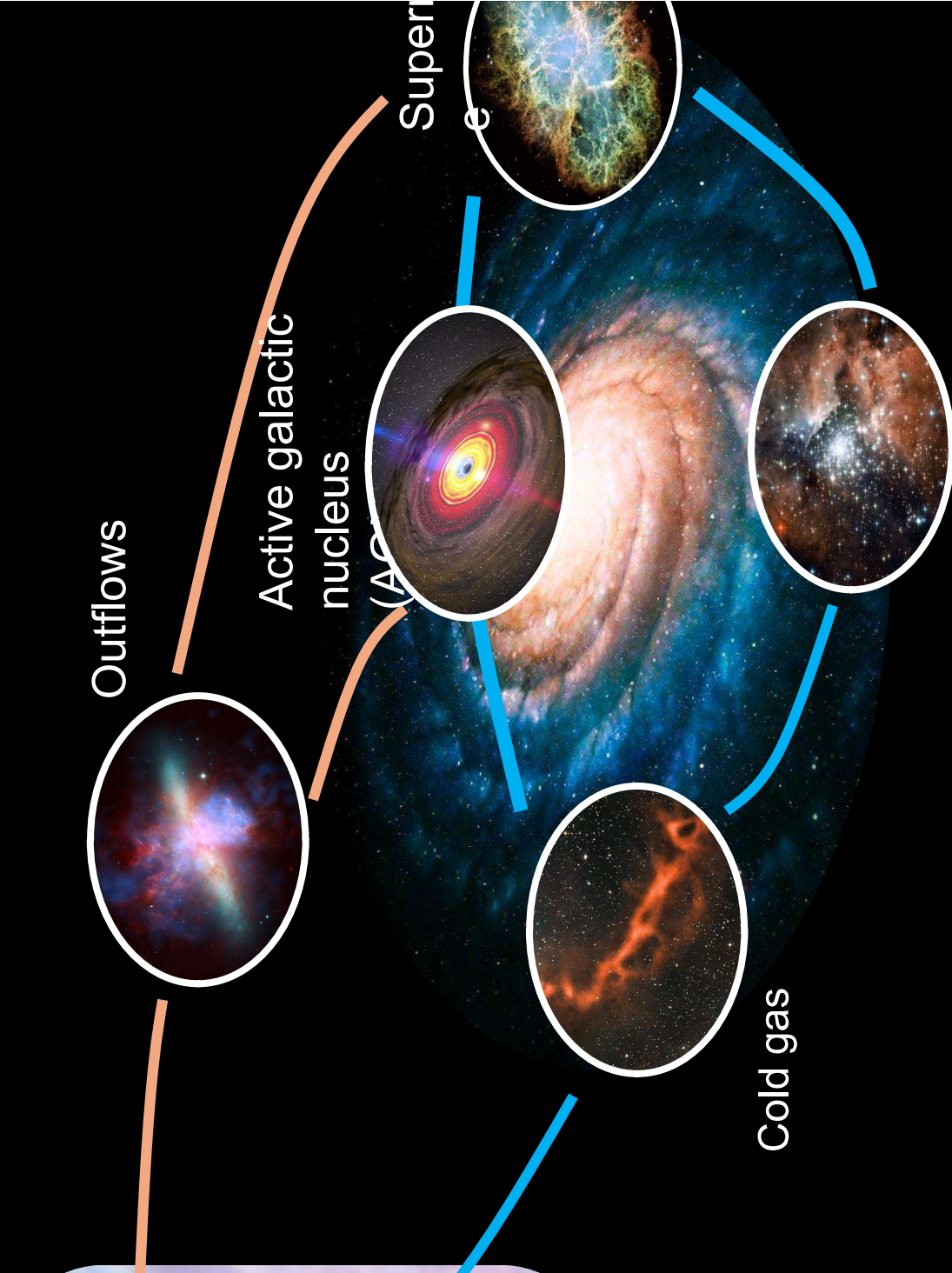
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# The Cosmic Ecosystem

1



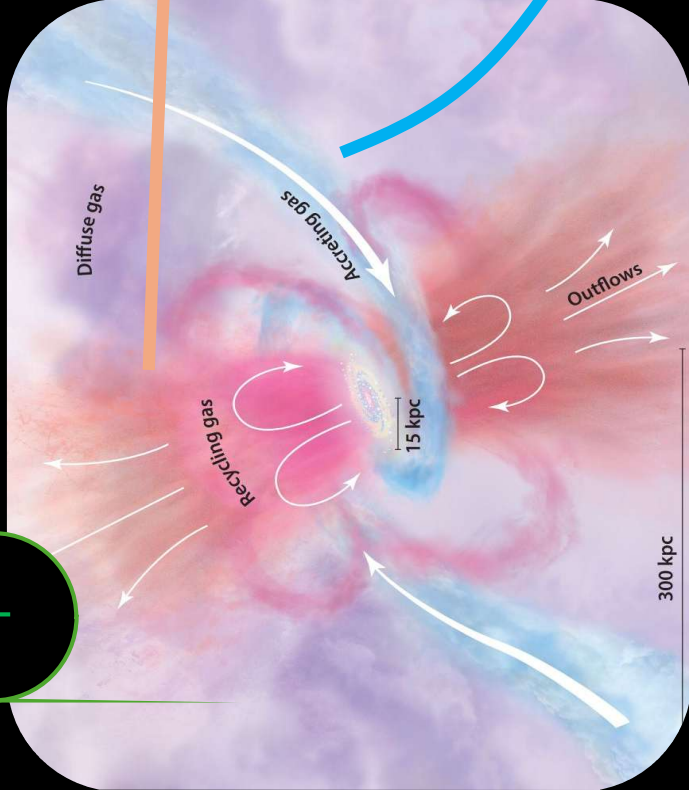
Credit:  
Tumlinson+2017



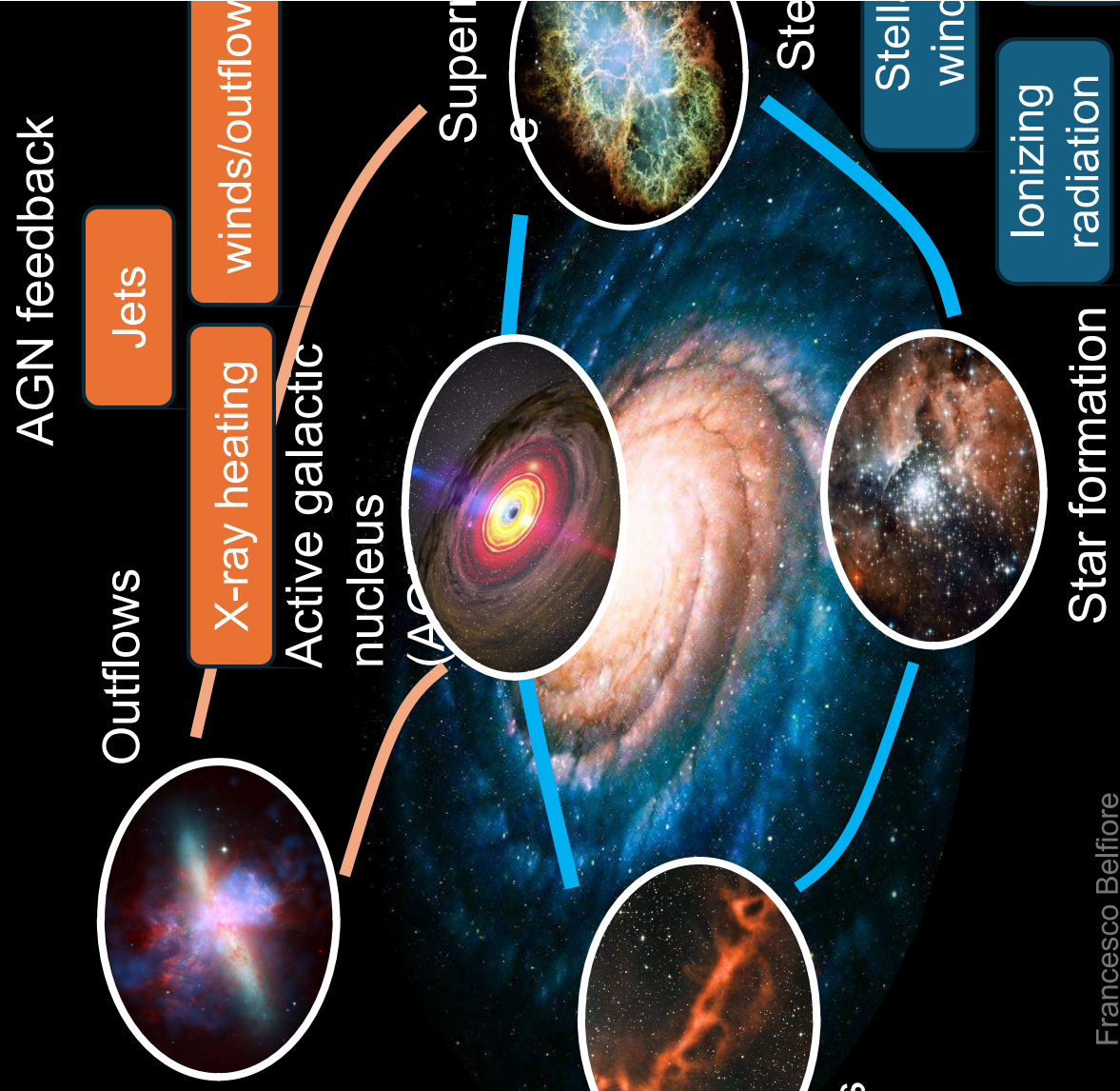
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# The Cosmic Ecosystem

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Credit:  
Tumlinson+2017



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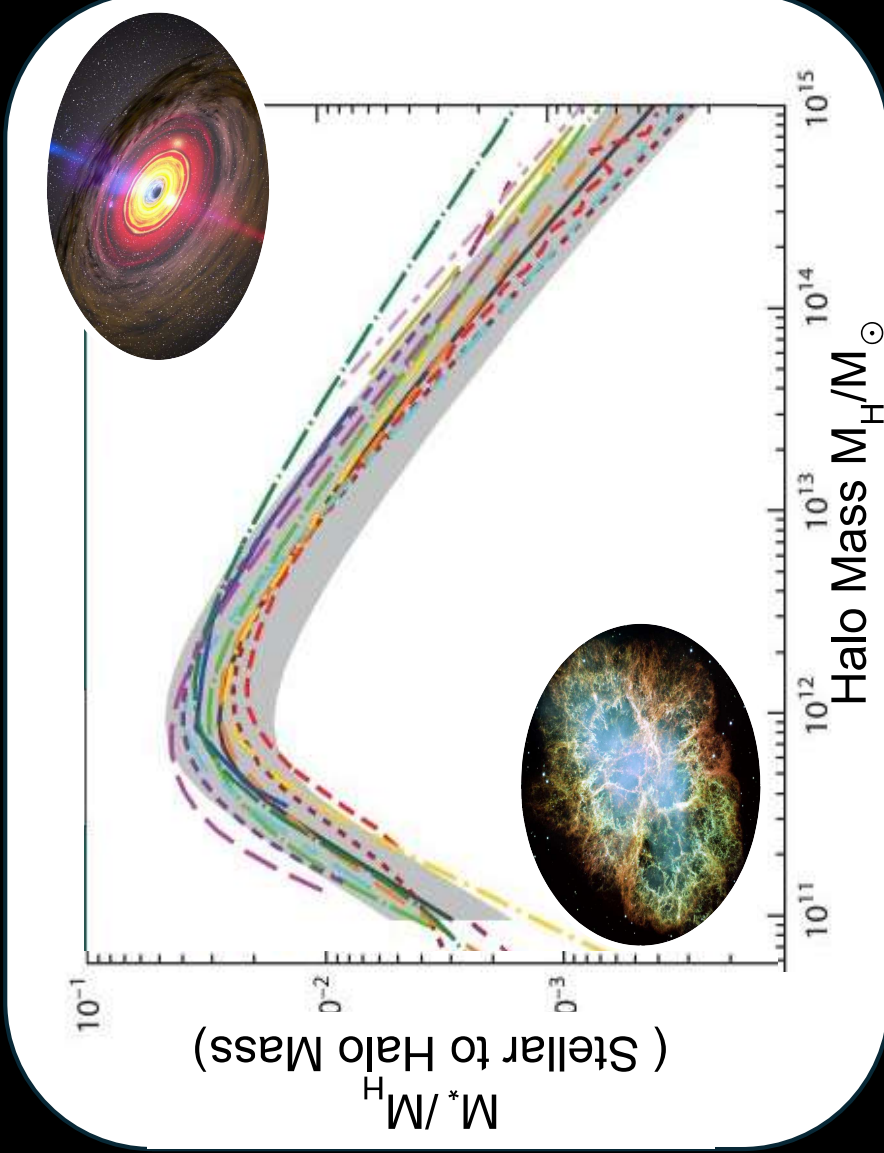
How does feedback determine the star formation efficiency (globally and locally) in galaxies?

# What determines the “star formation efficiency

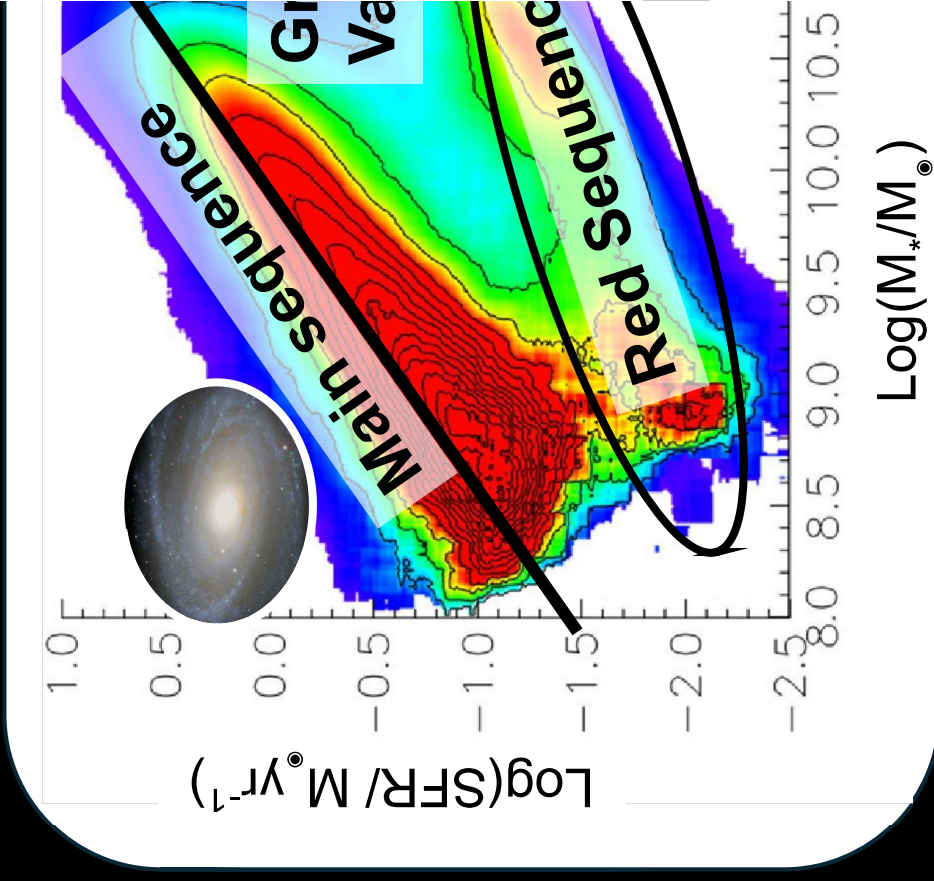
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## Globally in galaxies

Stellar-to-halo mass relation



Main Sequence of star formation i



Wechsler & Tinker 2018

Francesco Belfiore

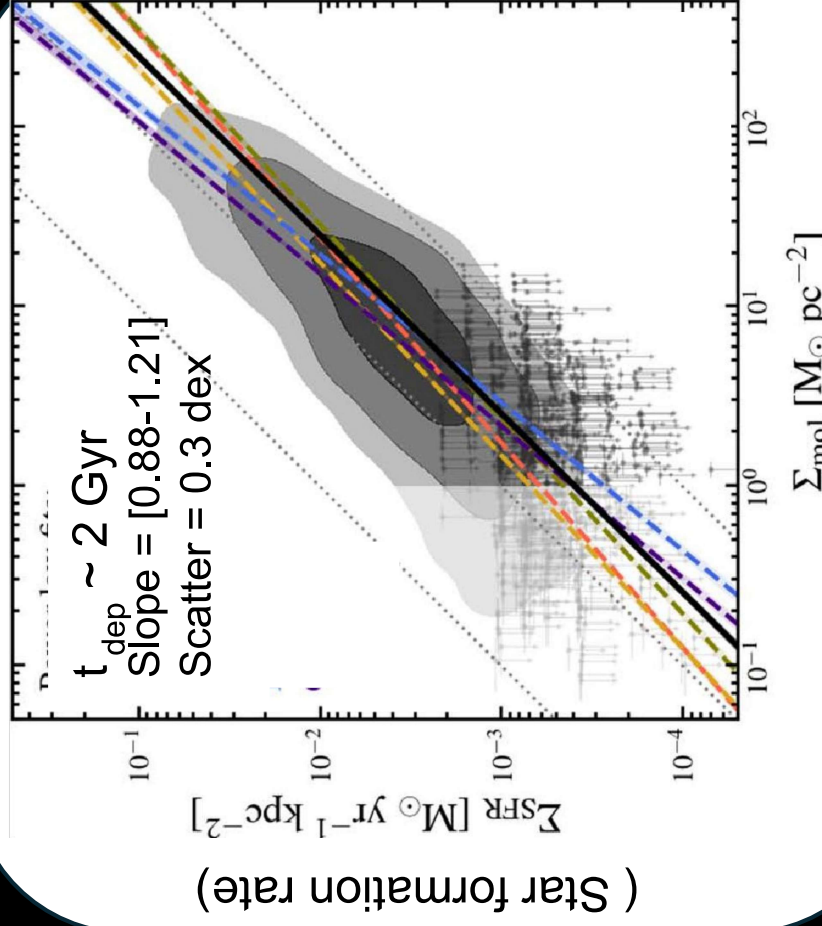
Renzini & F

# What determines the “star formation efficiency

1

## Locally in galaxies

Schmidt-Kennicutt star formation law on kpc scales



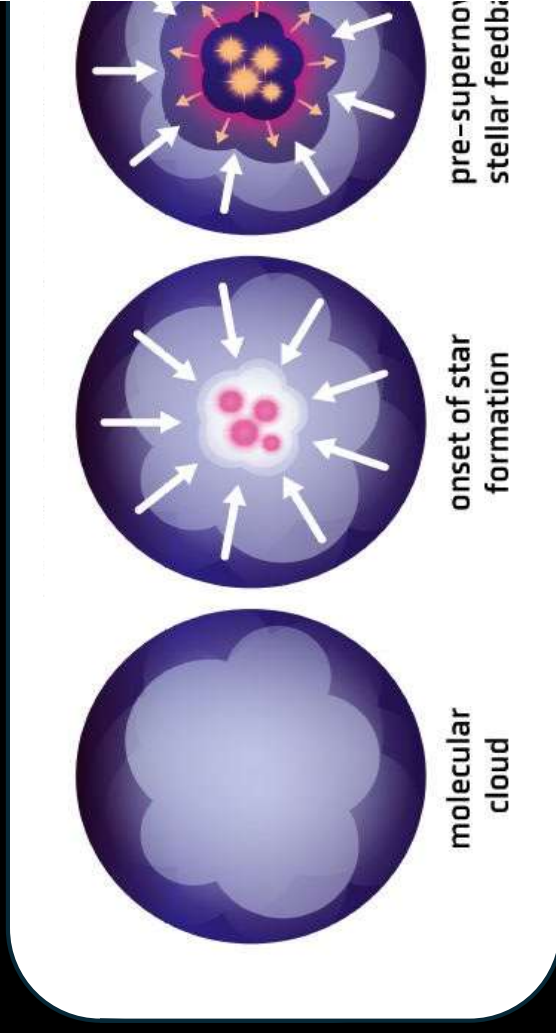
Star formation in individual clouds is disrupted by early feedback

Quiescent phase

$t = 4\text{-}20 \text{ Myr}$

Fast feedback phase

$t = 1\text{-}6 \text{ Myr}$



Sun, +FB 2023

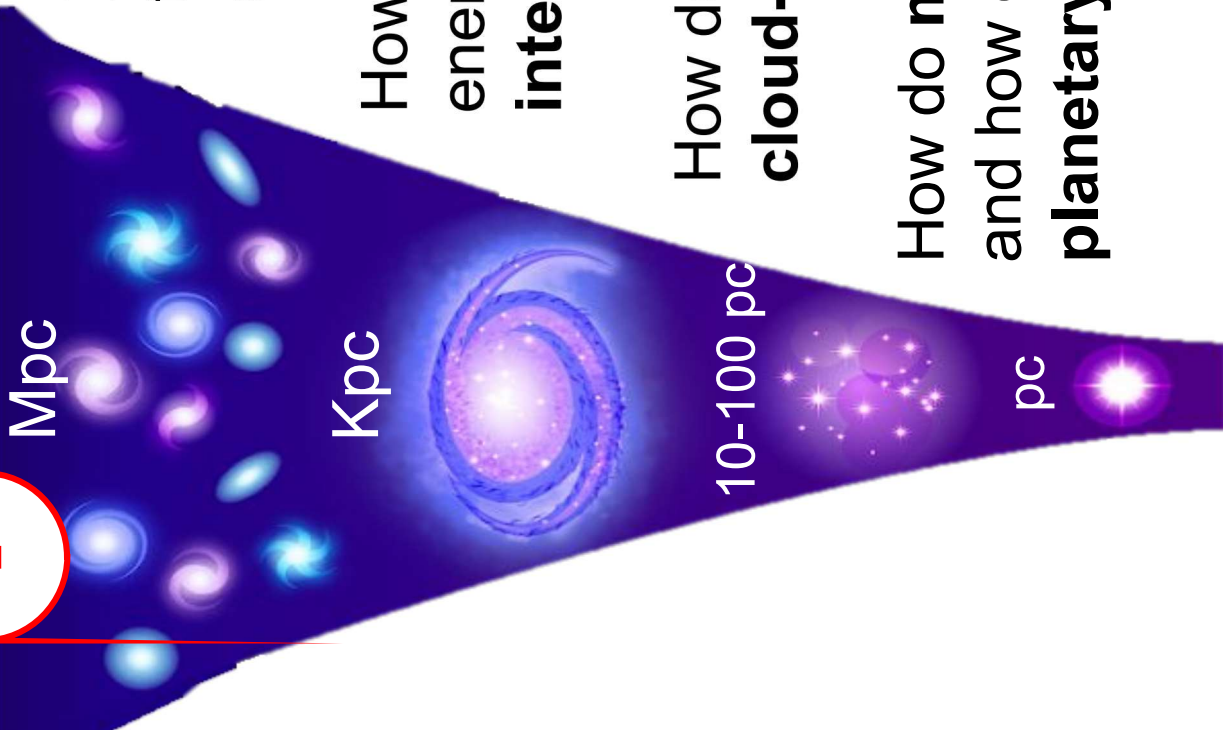
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Schinnerer



# The WST Science case is

## multi-scale

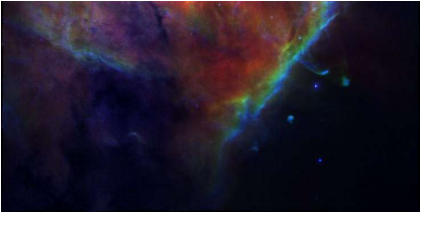
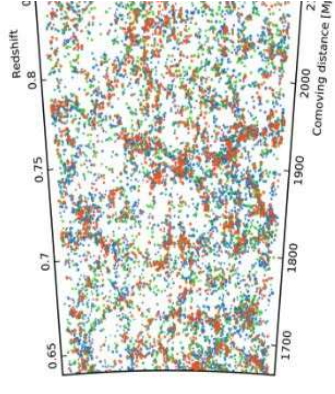


How does the **Cosmic Web** impact the evolution of galaxies from the peak epoch of star formation to now?

How do galaxies exchange matter and energy with the **circum- and intergalactic** medium?

How does feedback set the state of the ISM & **cloud-scale** efficiency of star formation?

How do **massive stars** shape their local environment and how does feedback affect the formation of **planetary systems**?





# The WST Science case is

## Multi-scale WST Extragalactic WP

Richard Ellis & FB

Mpc

Kpc

10-100 pc

pc

Cosmic Dawn, galaxies  
the Epoch of Reionization

The Cosmic Web survey: galaxy  
within the large-scale structure

ZS1 Deep galaxy & IFS  
survey

Nearby Galaxies Reference survey

WST Resolved stellar  
Populations WP

Martin Roth & Anna McLeod

Massive Stars in the Local Group

Stellar Evolution and Binarity  
star clusters

Francesco Belfiore

See WST White Paper





# The WST Science case is

## Multi-scale WST Extragalactic WP

Mpc

Cosmic Dawn, galaxies  
the Epoch of Reionization

Richard Ellis & FB

Kpc

The Cosmic Web survey: galaxy  
within the large-scale structure

*Tonotti*  
*Cucciati*  
*Ditrani*  
*Marasco*

ZS1 Deep galaxy & IFS  
SURVEY

10-100 pc

Nearby Galaxies Reference survey

## WST Resolved stellar Populations WP

Martin Roth & Anna McLeod

Massive Stars in the Local Group

Stellar Evolution and Binarity  
star clusters

pc



# We need your science case!



## Upgrade Plan

- IR for the MOS-I resolution
- Ground layer ACIFS
- IFU mini-bundles

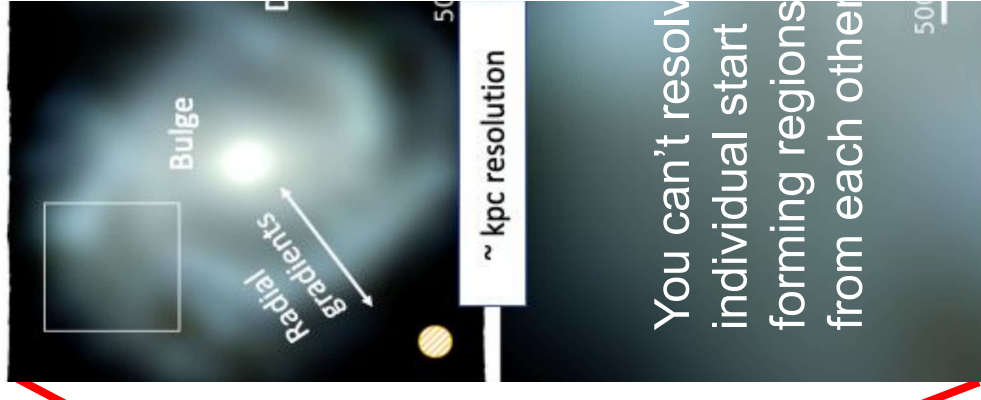
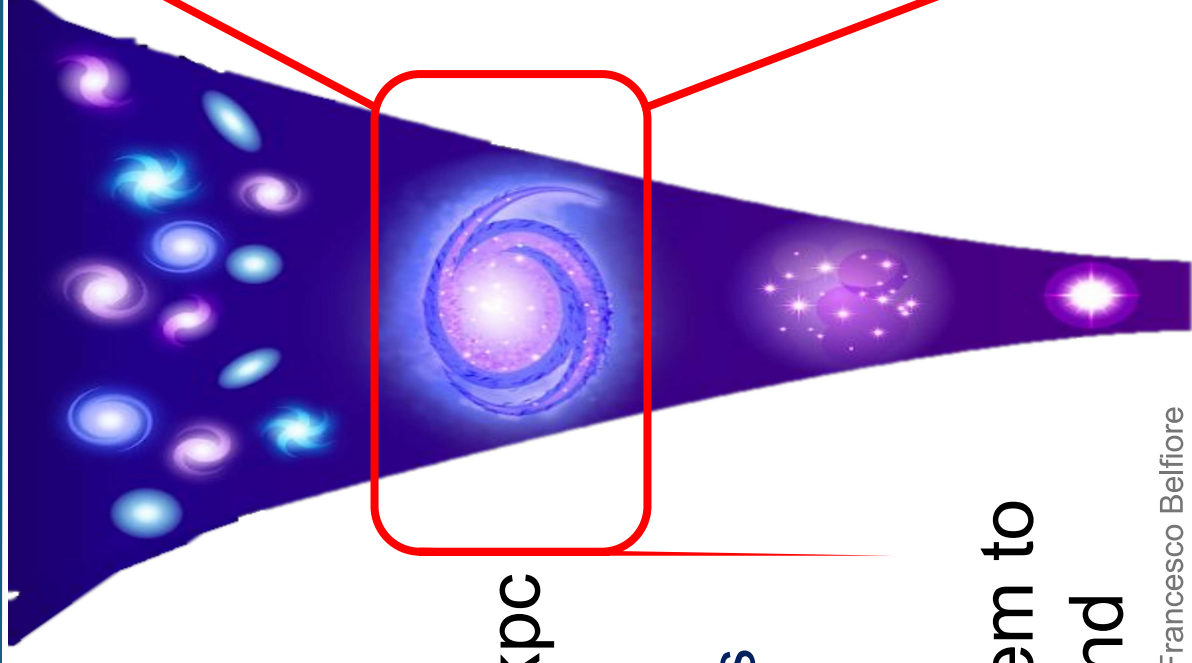


# Studying the galaxy population on kpc scales

3

- Large (representative) IFS surveys (MaNGA, CALIFA etc),  $10^{3-4}$  galaxies, good sampling of cosmological environments
- ~kpc resolution, resolve bulges from discs, radial gradients but not individual star-forming

Goal: Map star forming and quiescent regions and relate them to the global effects of feedback and quenching



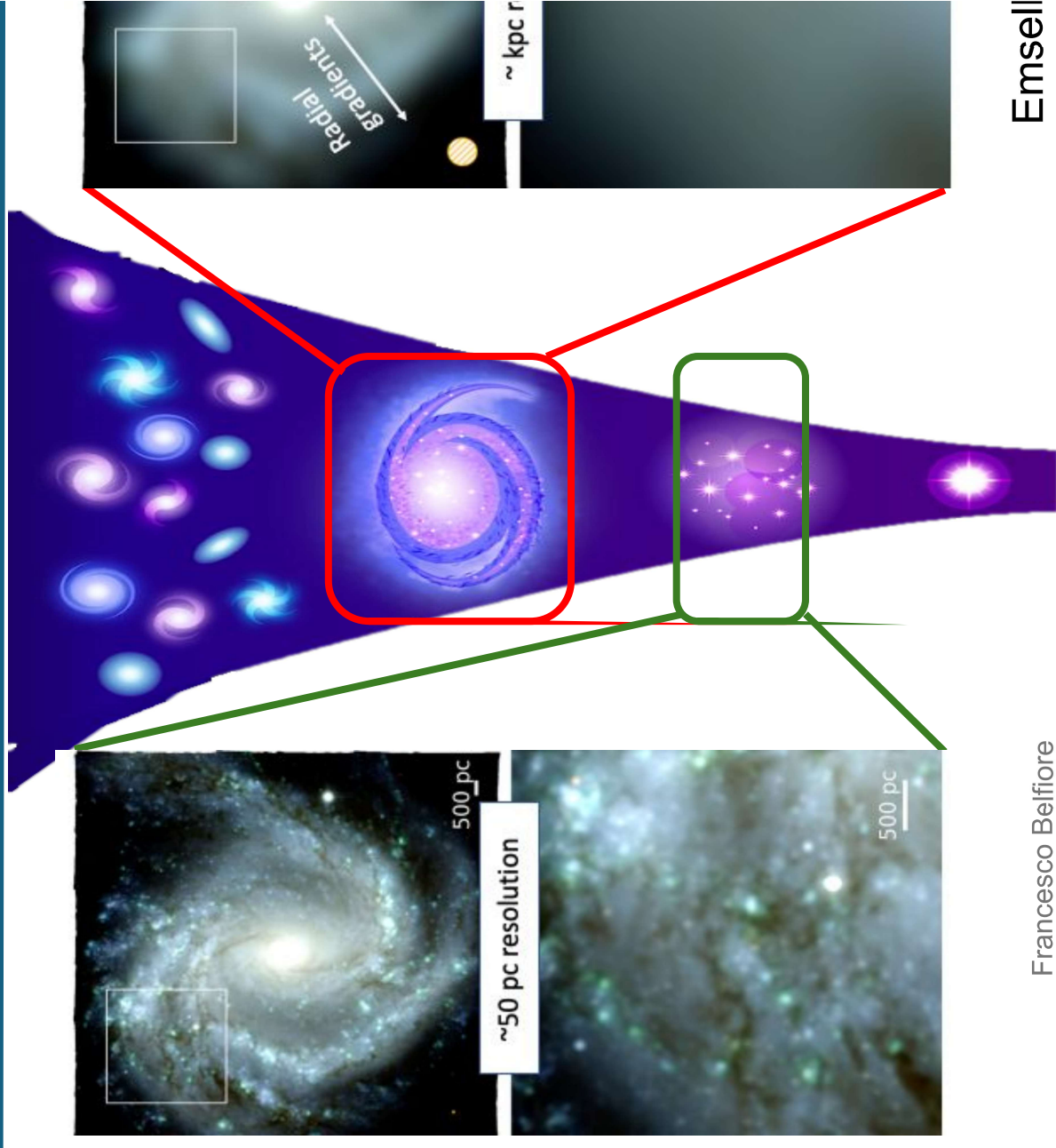
# Moving to the “cloud scale”

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## PHANGS

- ~50-100 pc resolution, resolves the fundamental units of the star-formation cycle
- Multi-wavelength, MUSE, ALMA, HST, JWST
- Small (~20) sample of main sequence galaxies

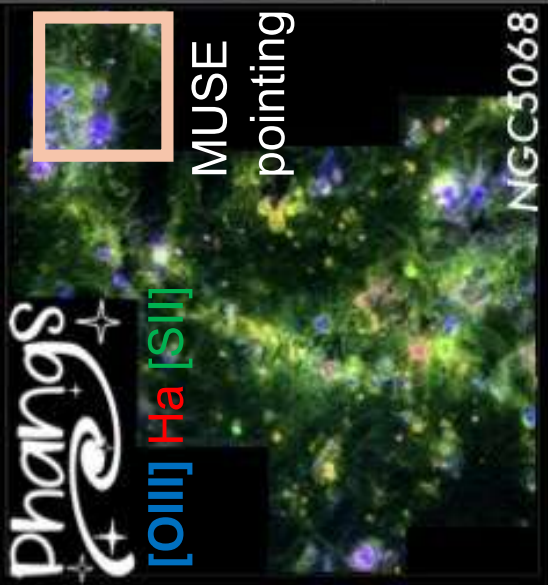
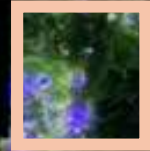
Goal: Study the physics and timescales of stellar feedback



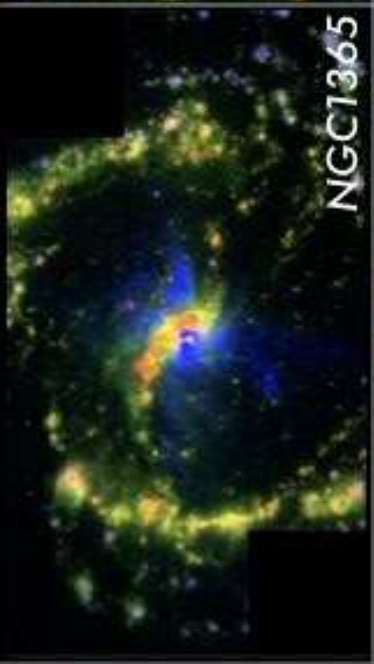
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Embell

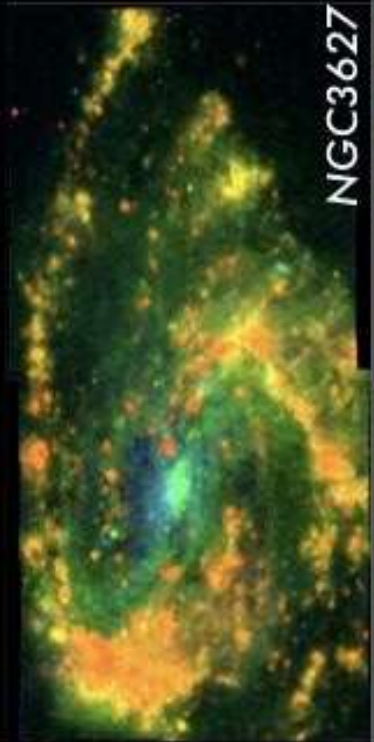
MUSE  
pointing



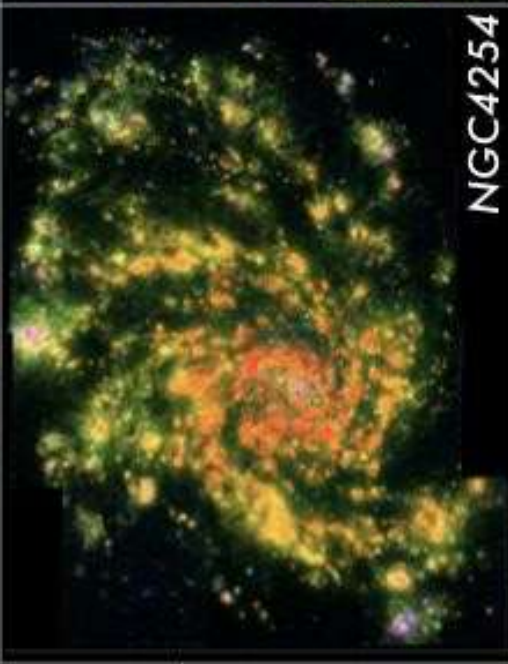
NGC5068



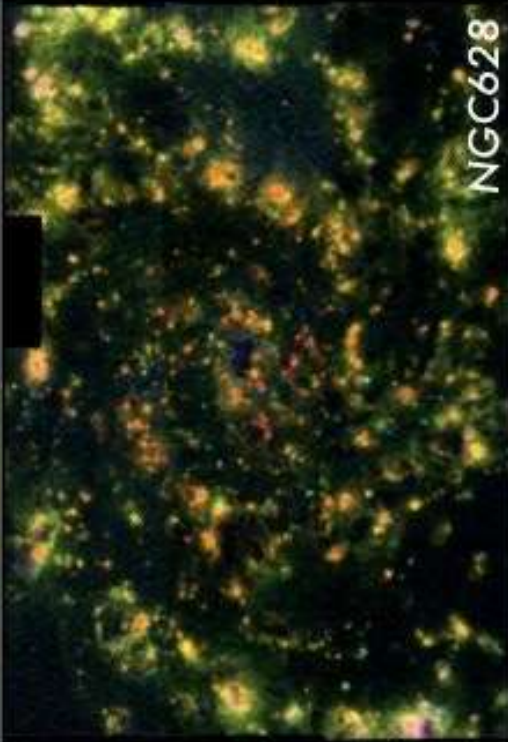
NGC1365



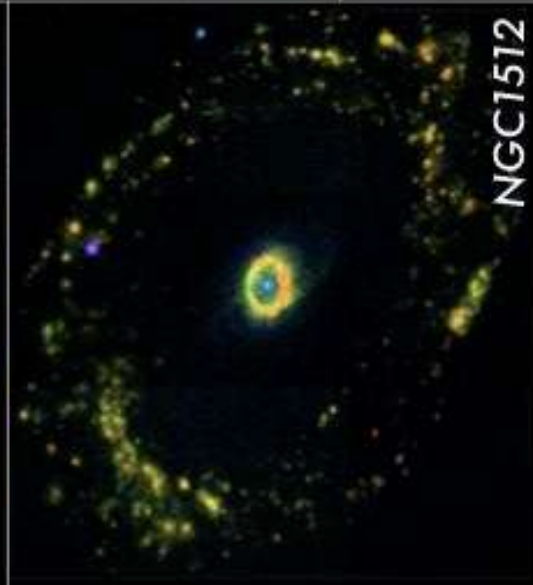
NGC3627



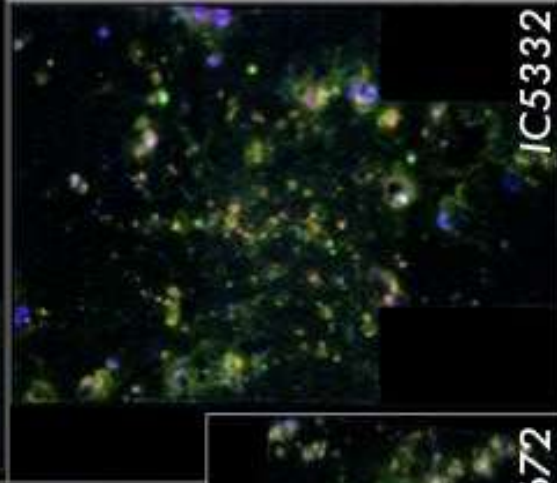
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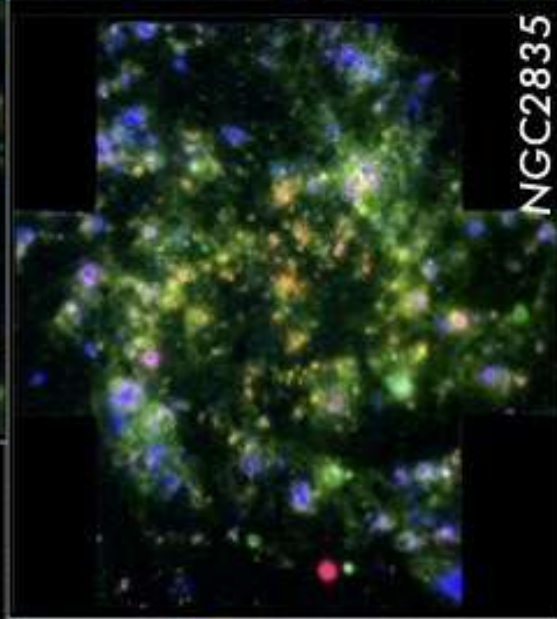
NGC628



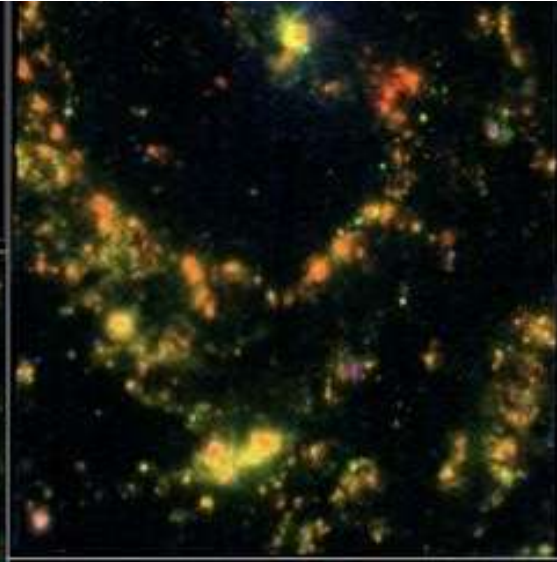
NGC1512



IC5332



NGC2835

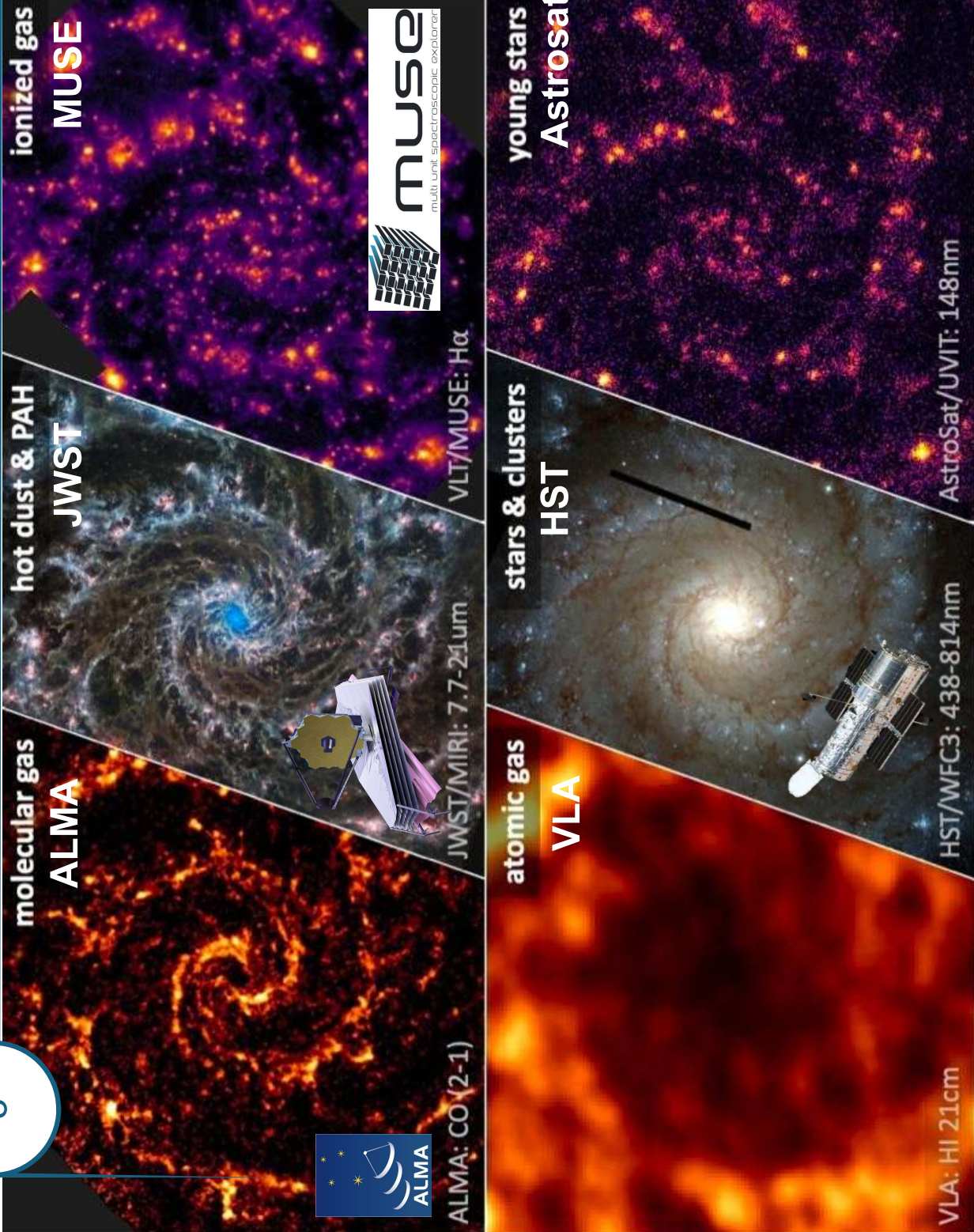


NGC1672

Credit: FB+ F

# Leveraging a multi-wavelength view

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Resolve the fundamental  
the star formation cycle  
**HII regions, star clus**

How does local (dyna  
environment affect star fo  
e.g. Querejeta+2021, Pessa+

How do ionising rad  
and feedback shap  
e.g. Belfiore+22, ~~SM~~ Barnes  
Congiu+23, Groves+23

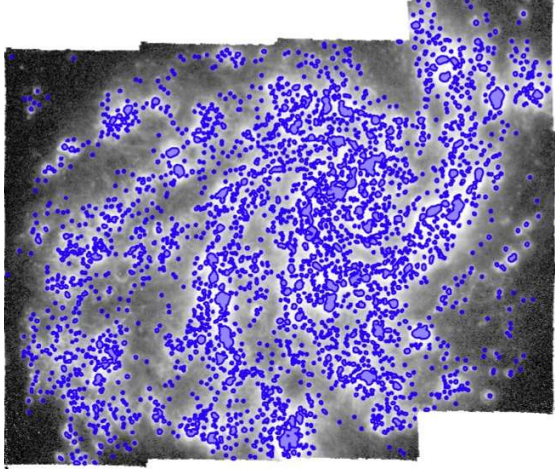
How do metals cyc  
galaxy discs?  
e.g. Kreckel+2020, Williams-  
Brazzini+24

# A few highlights from PHANGS

How do ionising radiation and feedback shape the ionized ISM?

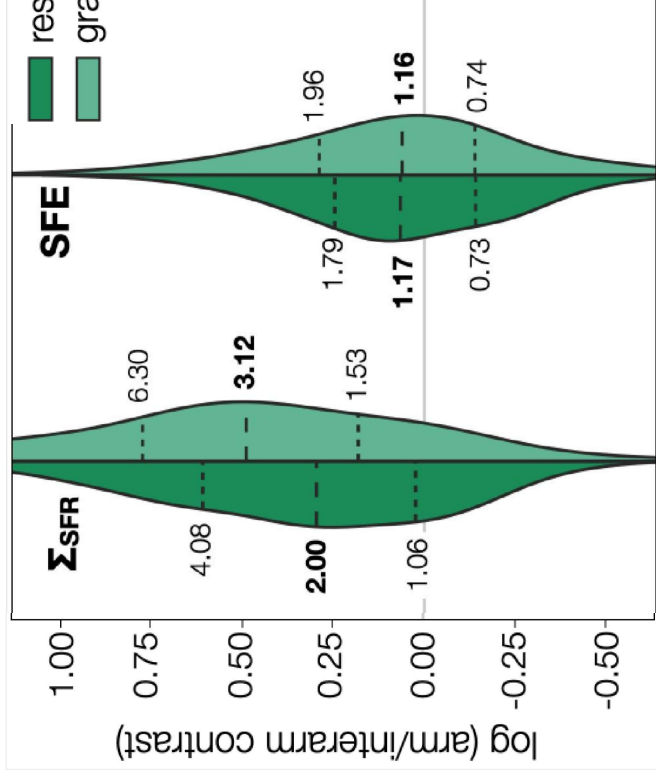
**How much ionizing radiation escapes from HII regions?**

- $40 \pm 20\%$  of the ionizing photons escape HII regions
- The mean free path of ionizing photons is 1-2 kpc



ISM?

**Are spiral arms more efficient at forming**



- Spirals are more efficient at forming molecular gas
- The increase in SFR in spiral arms is modest
- The increase in SFE in spiral arms is not dependent on galaxy morphology

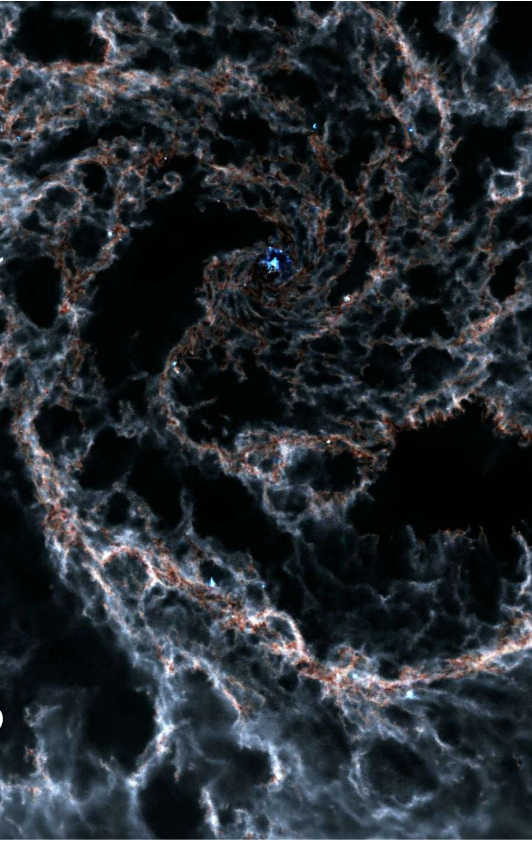
# JWST opens a new window in the ISM

**NIRCam** resolves individual (and highly attenuated) star clusters

**MIRI** sees diffuse dust resolves into compact sources and filaments

Most of the science requires a multi-wavelength approach

Image Credit: R. Tress (ITA, Heide

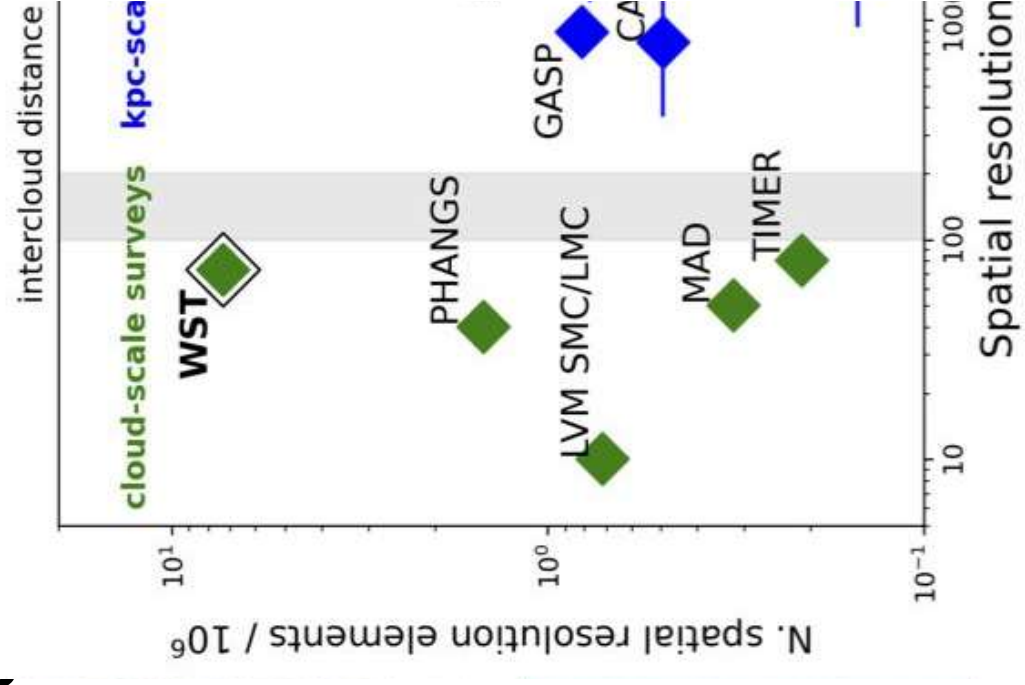
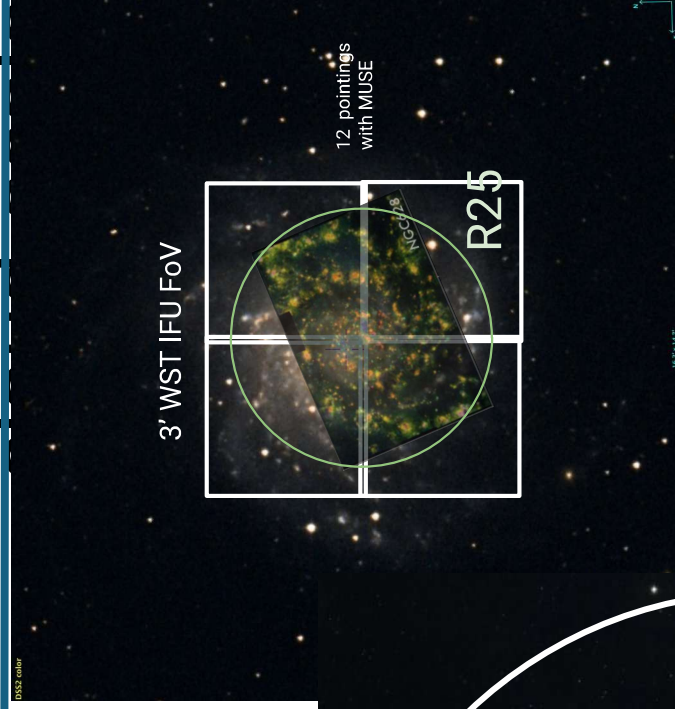


Hydrodynamical simulation



# A reference survey of nearby galaxies on

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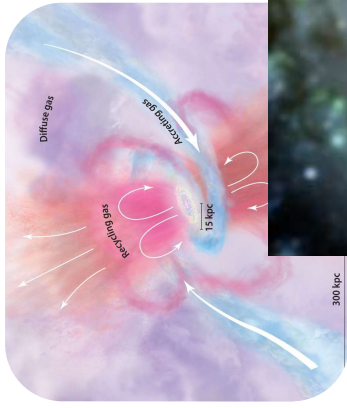


Adapted from Emseller

Francesco Bellio

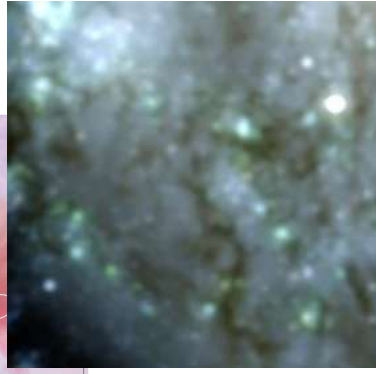
# Take home

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The **Cosmic Matter Cycle** is driven by feedback and shapes the ability of galaxies to form stars both globally and locally.

**Cloud-scale observations** enable measurements of the physics and timescales of the small-scale matter cycle.



The WST Extragalactic science case is truly **multi scale**.

A WST **reference survey of nearby galaxies** will enable unprecedented statistics needed to tease out the environmental dependences of feedback.

**We need your help to refine the Science Case**