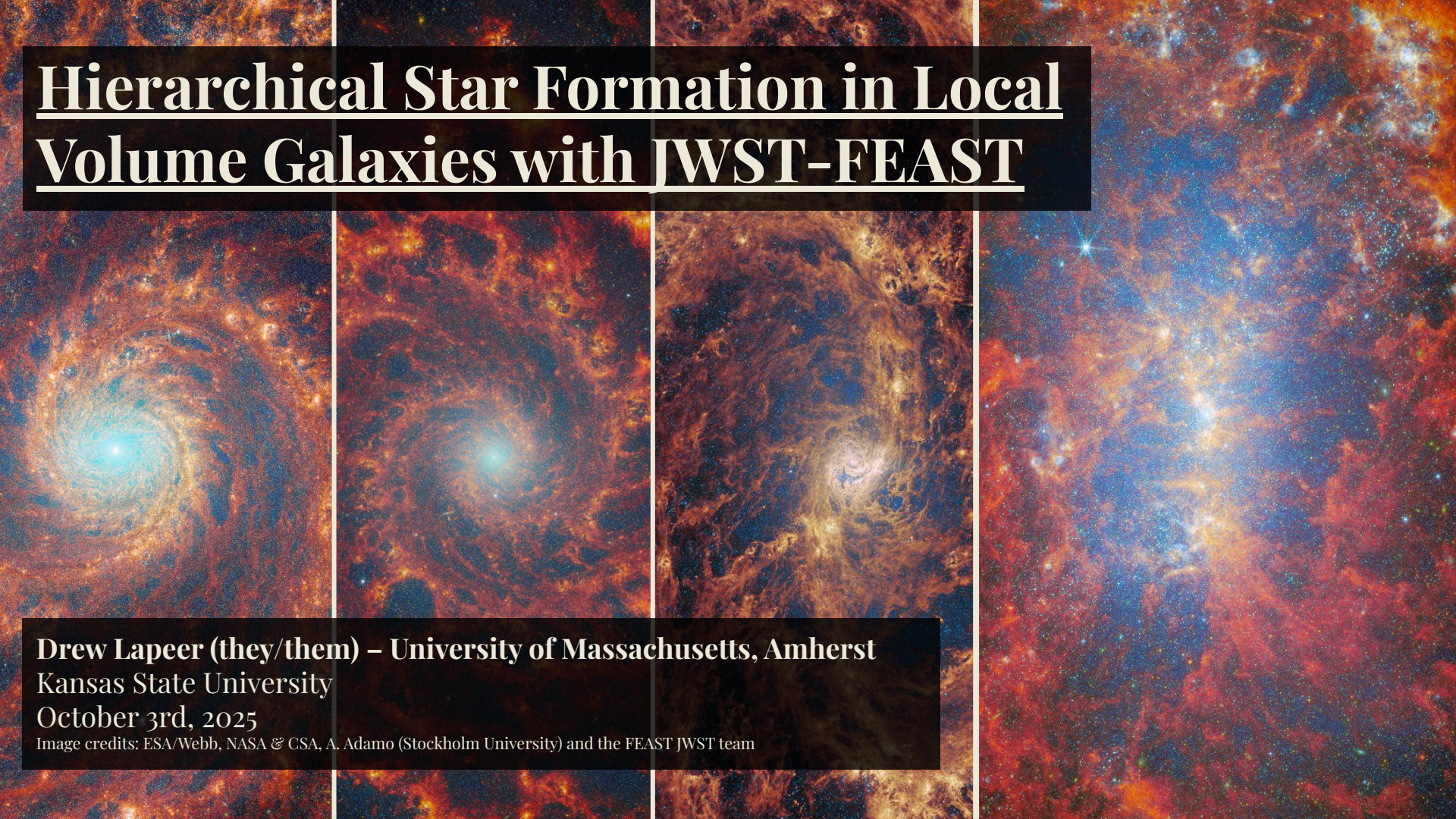
Hierarchical Star Formation in Local Volume Galaxies with JWST-FEAST



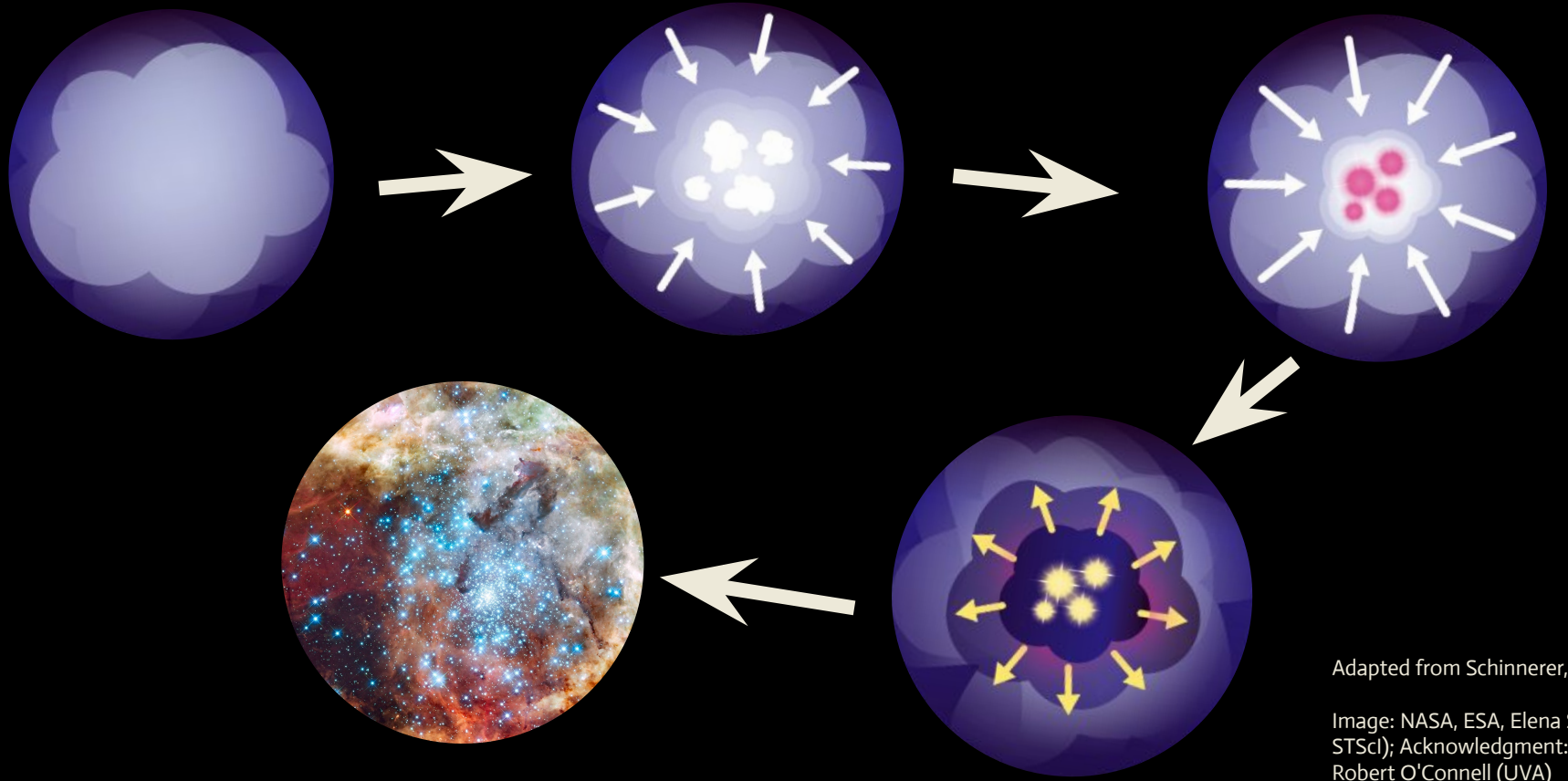
Drew Lapeer (they/them) – University of Massachusetts, Amherst

Kansas State University

October 3rd, 2025

Image credits: ESA/Webb, NASA & CSA, A. Adamo (Stockholm University) and the FEAST JWST team

Cloud-Scale Star Formation: A Broad Overview



Adapted from Schinnerer, Leroy 2024

Image: NASA, ESA, Elena Sabbi (ESA, STScI); Acknowledgment: SOC-WFC3, Robert O'Connell (UVA)

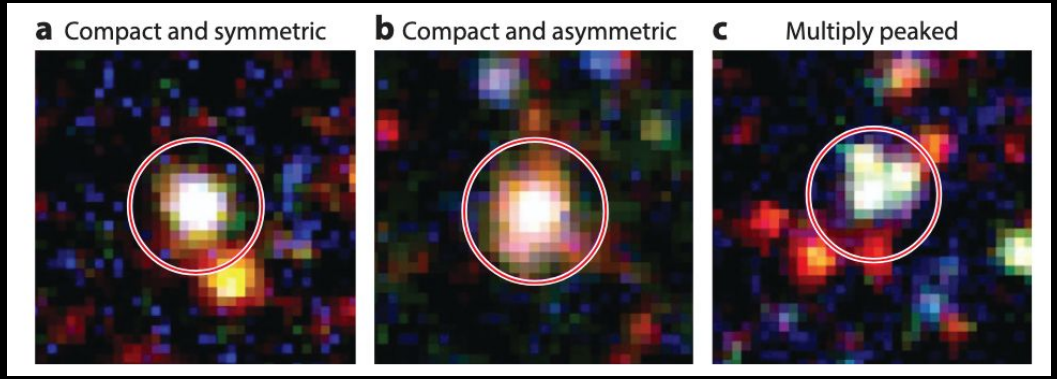
Cloud-Scale Star Formation: A Broad Overview

Credit:
David Guszejnov et al.
2020, STARFORGE

Star Clusters: Why Do We Care?

Star clusters are the 'building blocks' of galaxies

With JWST, survey populations in other galaxies!



Krumholz+2019, Adamo+2017

FEAST: Feedback in Emerging extrAgalactic Star clusTers

- JWST Cycle 1 program (GO 1783, PI Angela Adamo, U. Stockholm)

- Revolutionize understanding of star formation & feedback across a range of environments

- JWST NIRCam, MIRI…
  - NGC 628
  - M51
  - M83
  - NGC 4449
  - NGC 4485/4490

- Local (D < 11 Mpc)
  - High spatial resolution
- Diverse range of SF environments
  - Nuclear starburst + molecular rings, dwarfs, interacting galaxies

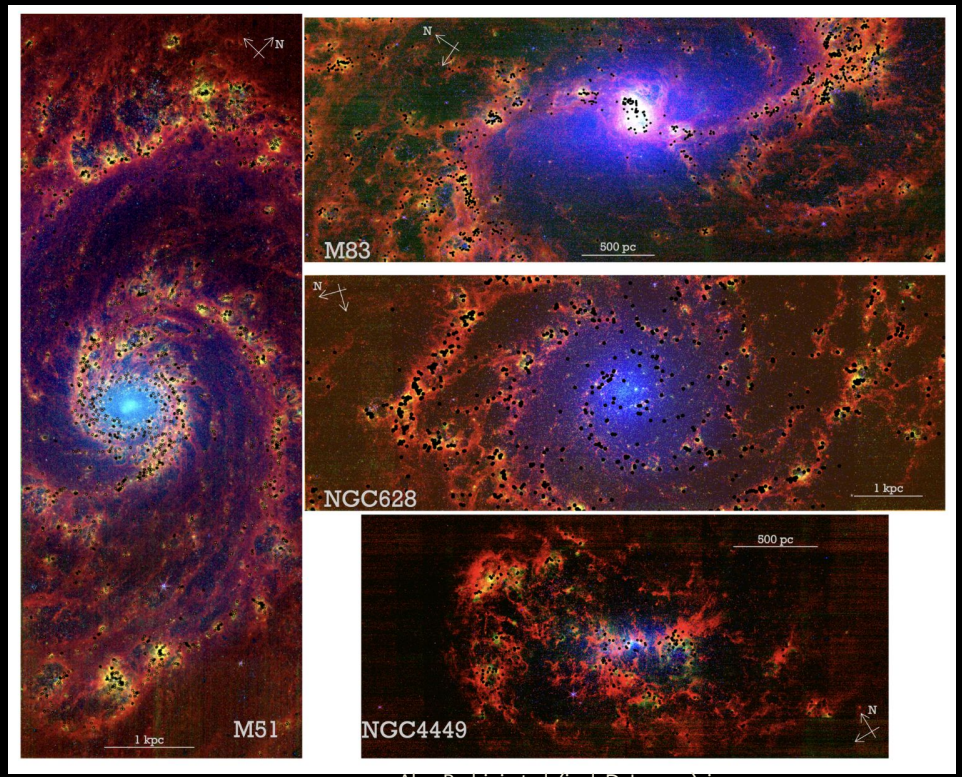
FEAST Website!

https://feast-survey.github.io/

Image Credit: ESA/Webb, NASA & CSA, A. Adamo (Stockholm University) and the FEAST JWST team

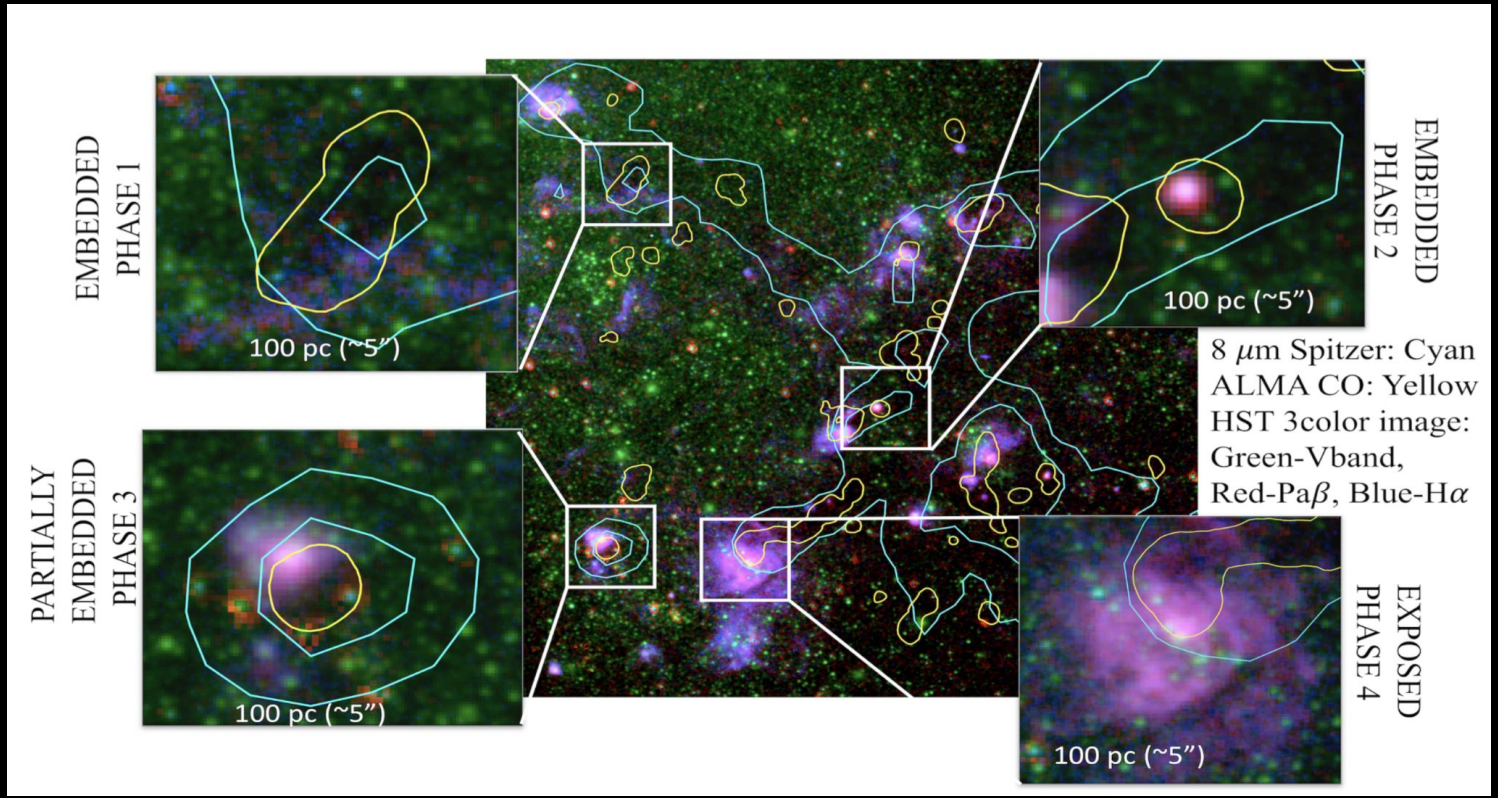
One of the Science Objectives: Tracing Emerging Phase of Star Clusters

~60% missed by HST (M. Messa+21) (!!)



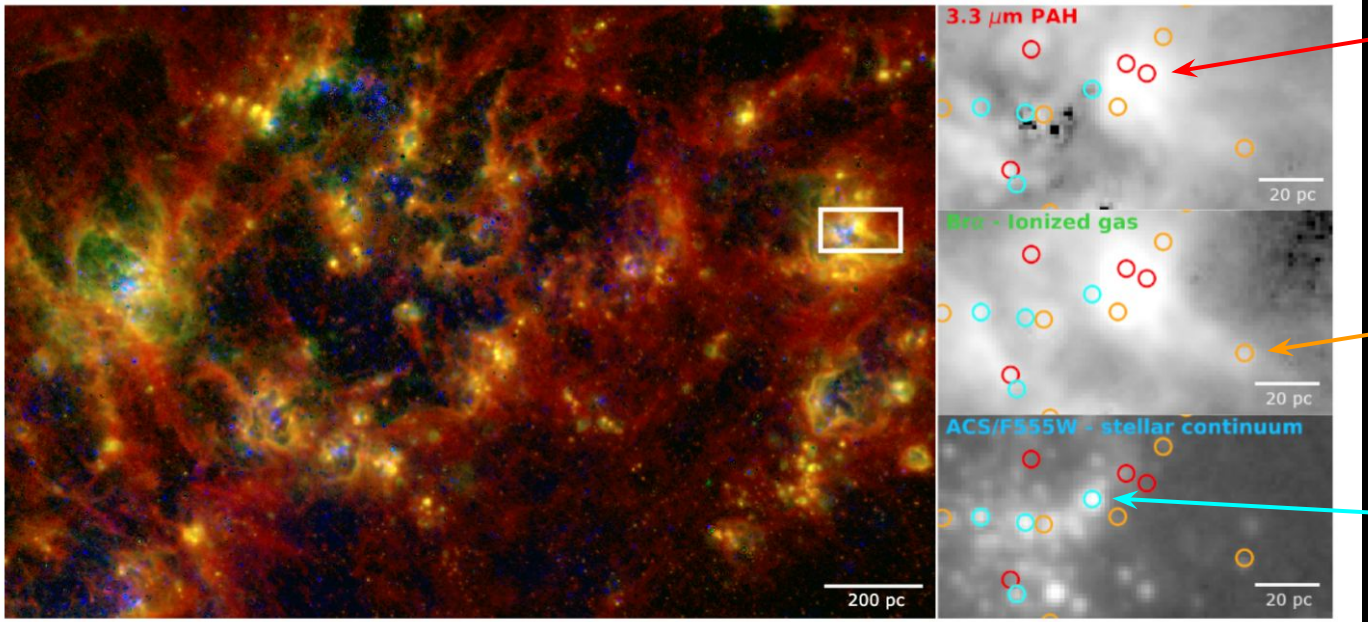
Alex Pedrini et al. (incl. D. Lapeer), in press. 2025

Tracing Emerging Phase of Star Clusters



A. Adamo 2021, priv. comm

Emerging Phase of Star Clusters

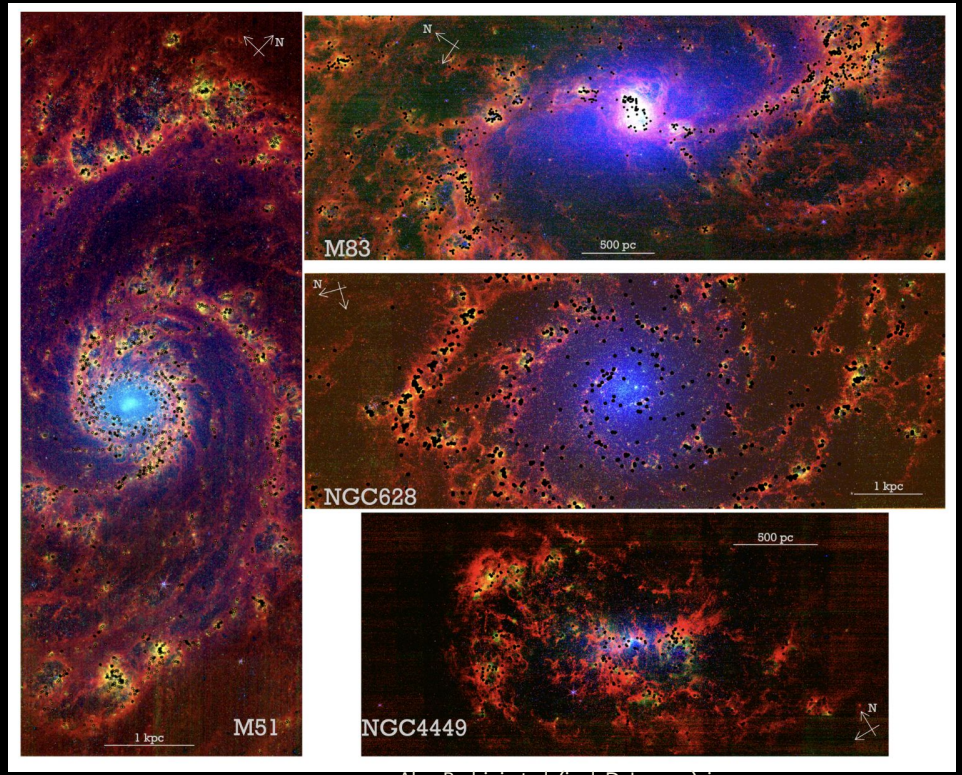


A. Pedrini et al. (incl. D. Lapeer), in prep.

One of the Science Objectives: Tracing Emerging Phase of Star Clusters

~60% missed by HST (M. Messa+21) (!!)

eYSCs are <u>powerful</u> tool for studying star formation and stellar feedback

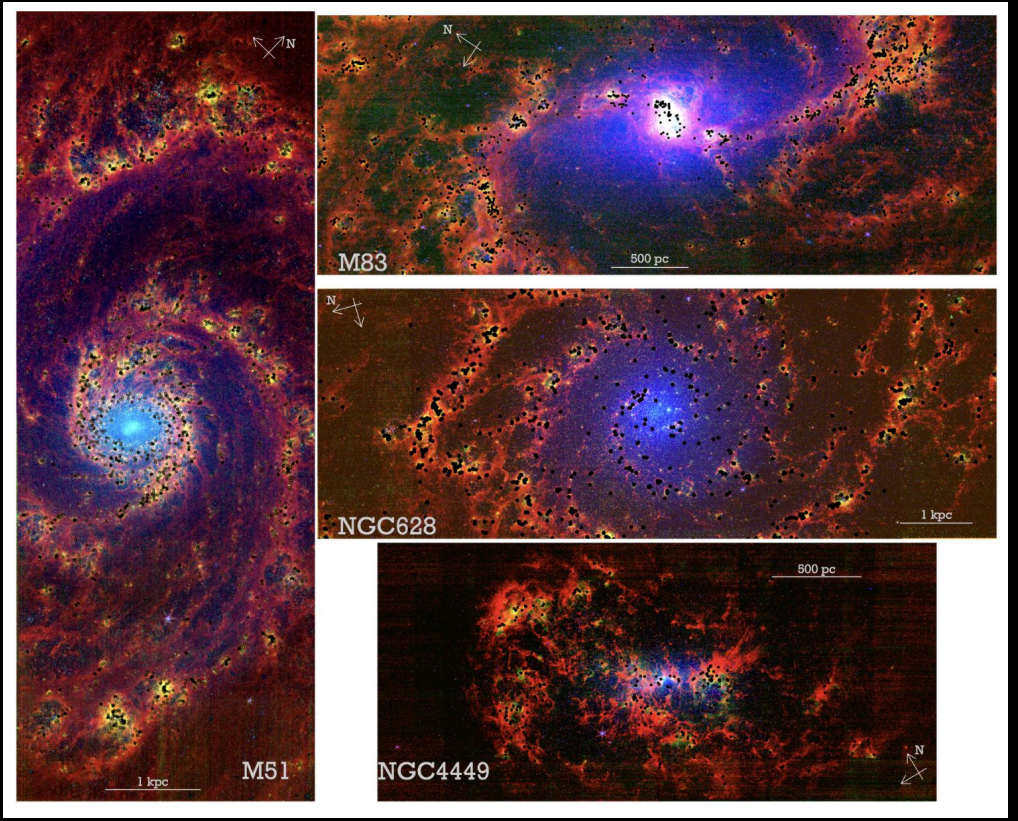


Alex Pedrini et al. (incl. D. Lapeer), in press. 2025

Young Star Clusters as Tracers of Hierarchical Structuring

How do you quantitatively study the spatial distributions of YSC populations?

Two-point correlation function!



Angular Two-Point Correlation Function (TPCF): The Basics

TPCF quantifies spatial correlation across scales in comparison to random distribution

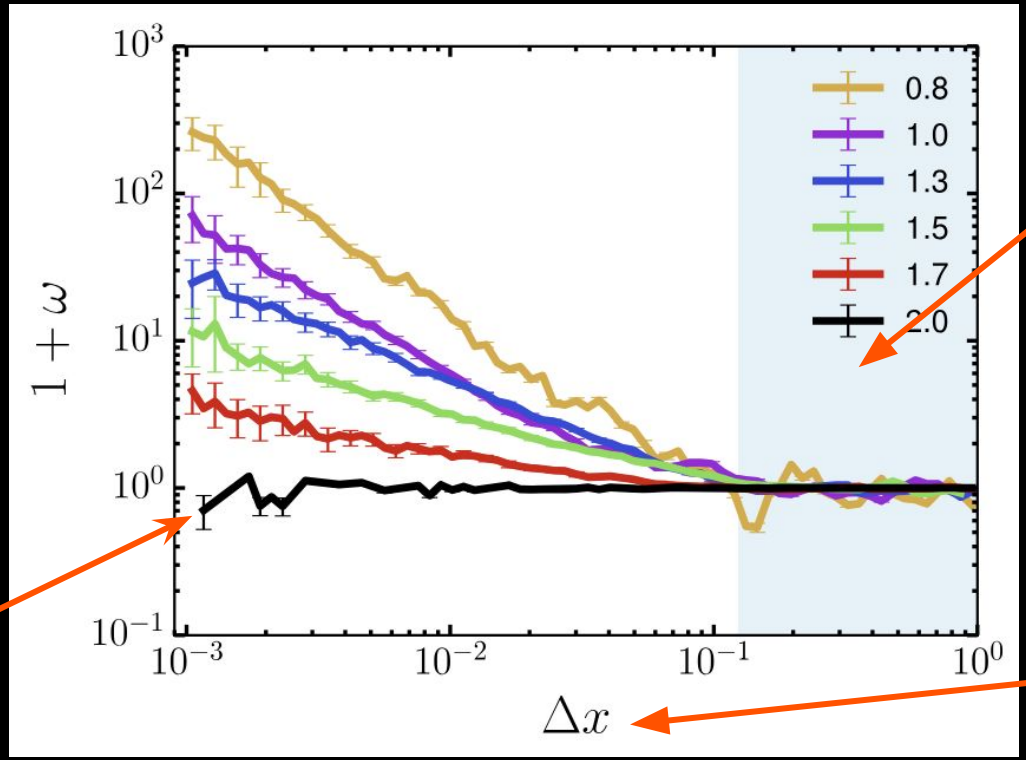
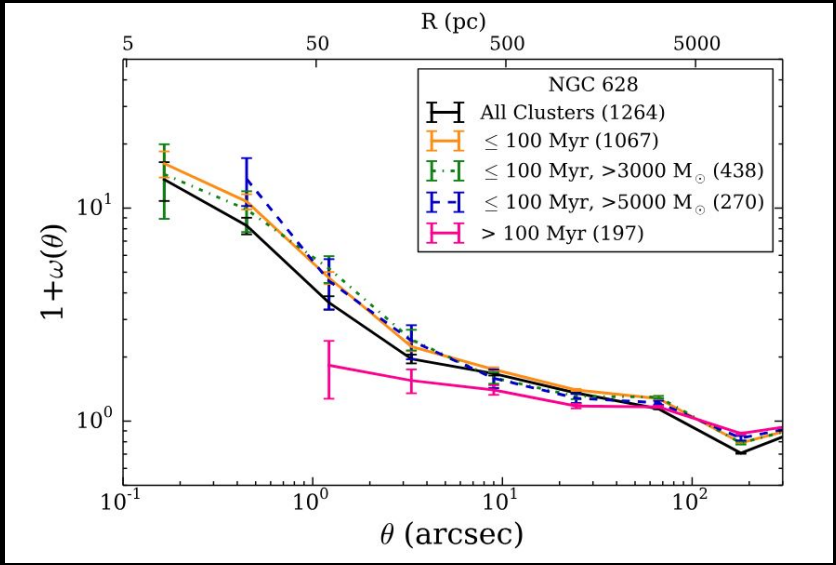
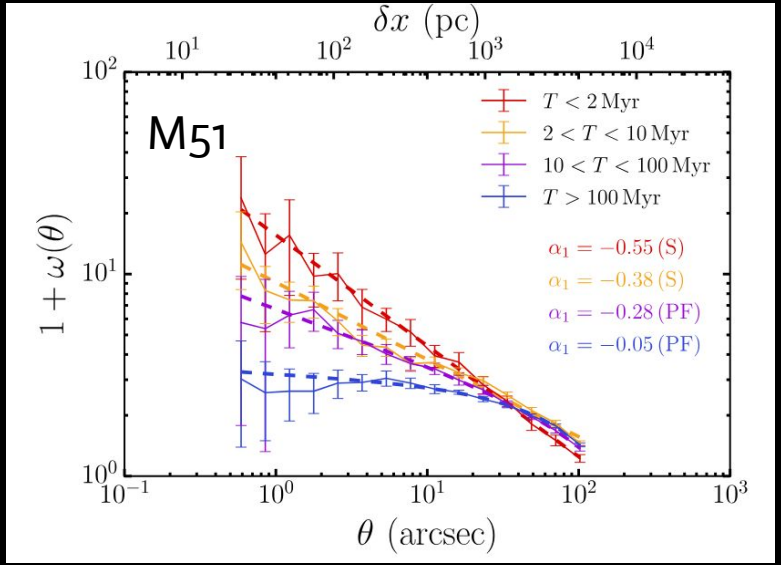


Figure adapted from S. Menon+21

Previous Findings Using LEGUS (HST UV-Opt YSCs)



K. Grasha et al. 2017, 6 LEGUS galaxies



S. Menon et al. 2021, 12 LEGUS galaxies

Missing so much information! (eYSCs)

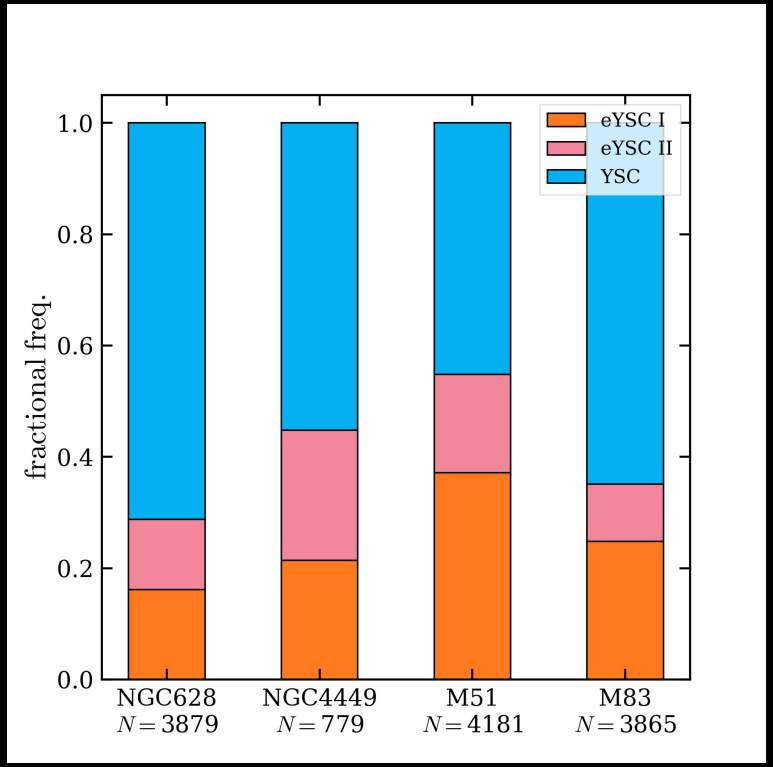
New Findings with FEAST-JWST

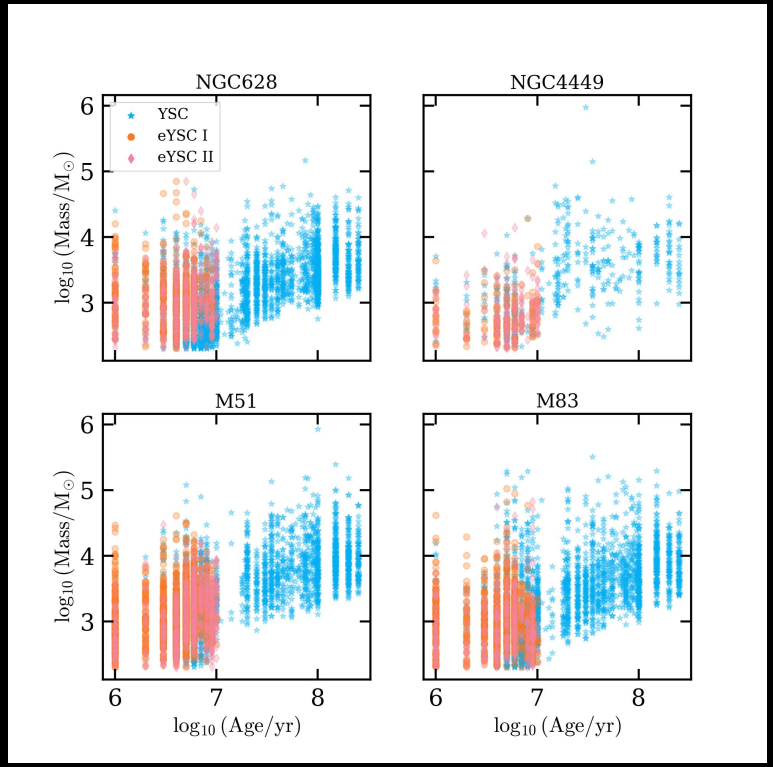
FEAST: Probing Hierarchical Star Formation with the Spatial Distributions of Young Star Clusters

Drew Lapeer [1], Daniela Calzetti [1], Kathryn Grasha [2,*], Angela Adamo [3], Bruce G. Elmegreen [4], Arjan Bik [3], Giacomo Bortolini [5], Anne Buckner [6], Michele Cignoni [7,8,9], Matteo Correnti [10,11], Debra Meloy Elmegreen [12], H. Faustino Vieira [13], Max Hamilton [14], Kelsey Johnson [15], Thomas S.-Y. Lai [16], Sean T. Linden [17], Subhransu Maji [14], Matteo Messa [18], Göran Östlin [19], Alex Pedrini [20], E. Sabbi [21] and Linda J. Smith [22]

D. Lapeer et al. (subm. ApJ 2025)
Pre-print available upon request

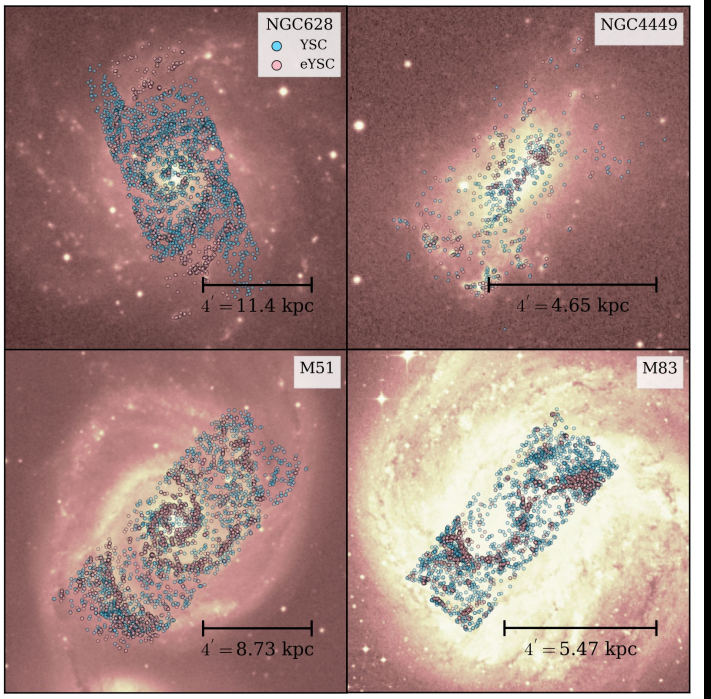
The Sample – eYSCs, oYSCs, and everything else

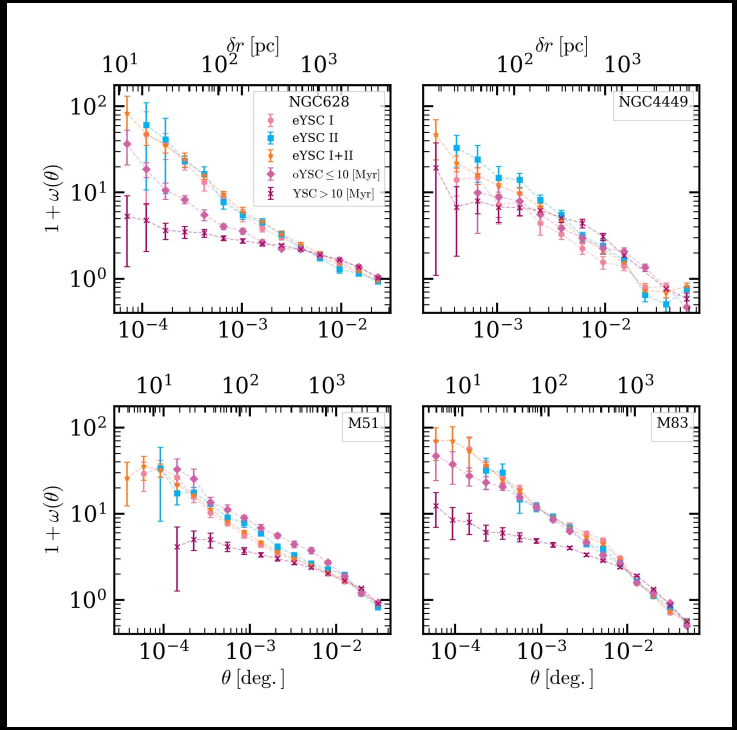




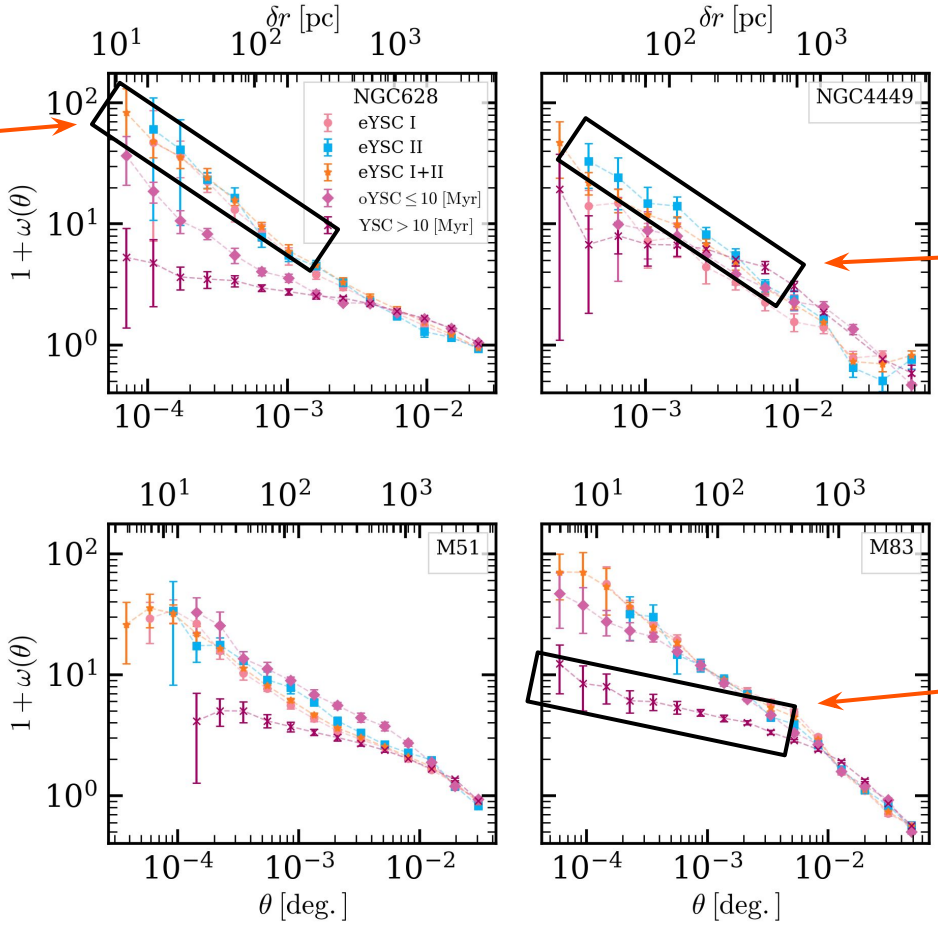
Ages+Masses from CIGALE (M. Boquien et al. 2019), see A. Pedrini+2025 (incl. D.Lapeer)

The TPCFs of (e)YSCs in 4 FEAST Galaxies





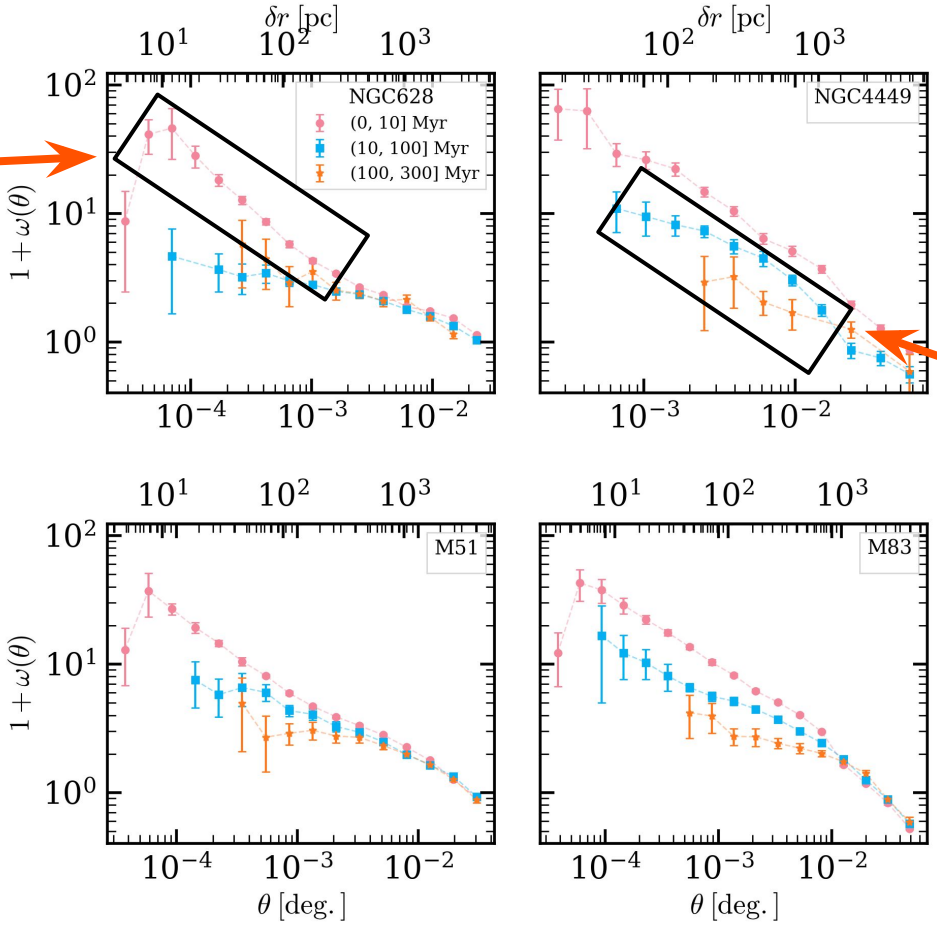
Minimal differences



oYSCs align well with eYSCs, except in NGC 628

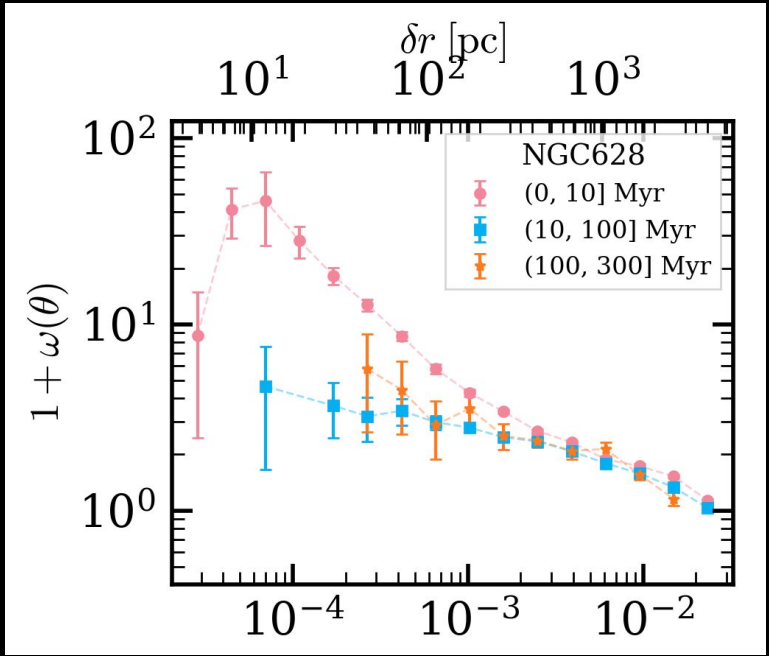
Mostly random at ~10 Myr+

Clear hierarchical structuring



Still structuring at 10-100 Myr...*and* at 100-300 Myr?

What Are TPCFs Telling Us?

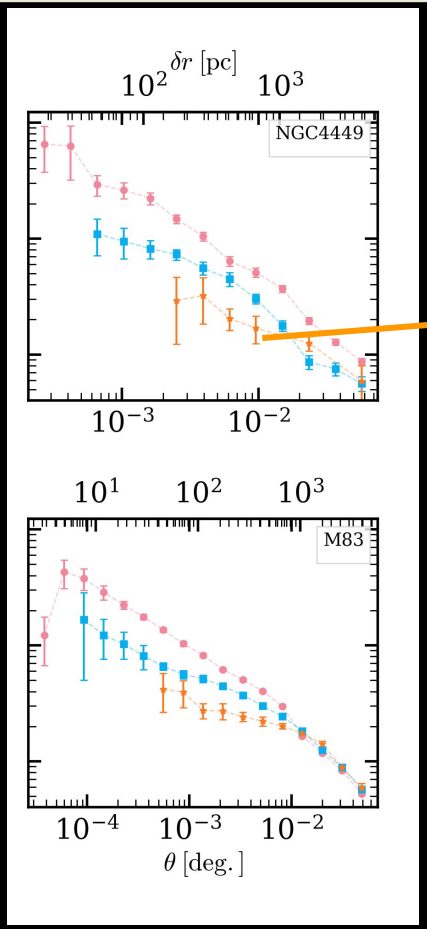


In NGC 628, shorter randomization timescale (~10-100 Myr) compared to other galaxies

Only 'normal' galaxy [no bar-induced effects (M83), no active merger (M51), standard spiral (unlike NGC 4449)]

Without additional influence, SCs spatially decouple from ISM on <~ 100 Myr timescales

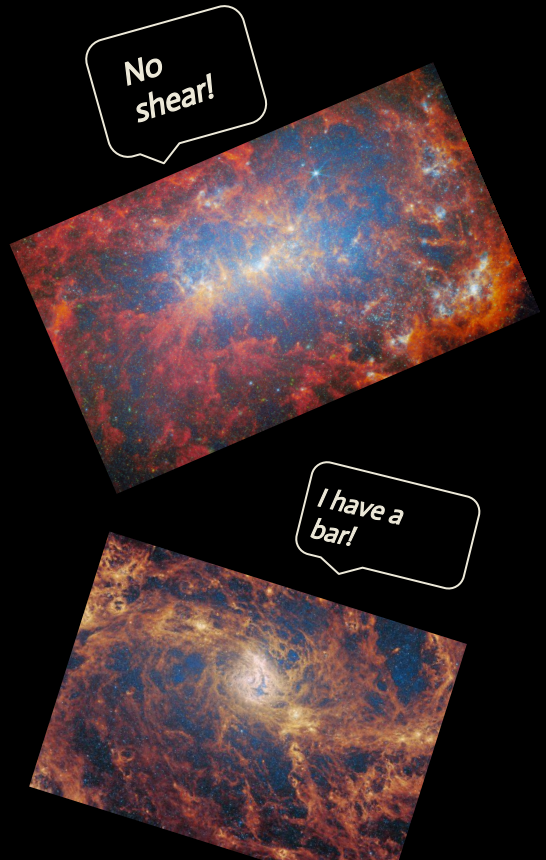
What Are TPCFs Telling Us?



In NGC 4449, M83, clear hierarchical structuring at (100-300] Myr

NGC 4449: Dwarf, minimal/no shear, SCs retain information about natal gas for longer

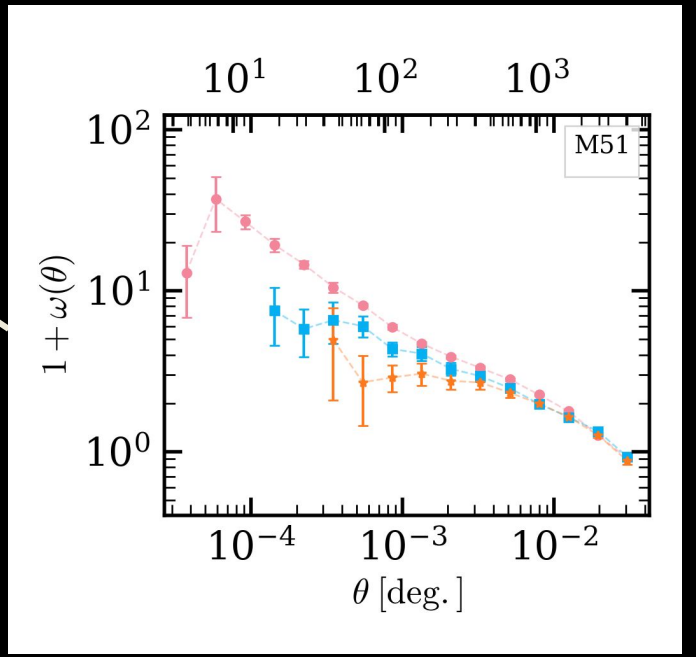
M83: Bar-driven shear inhibits SF (T. Kim+24), explains longer timescales



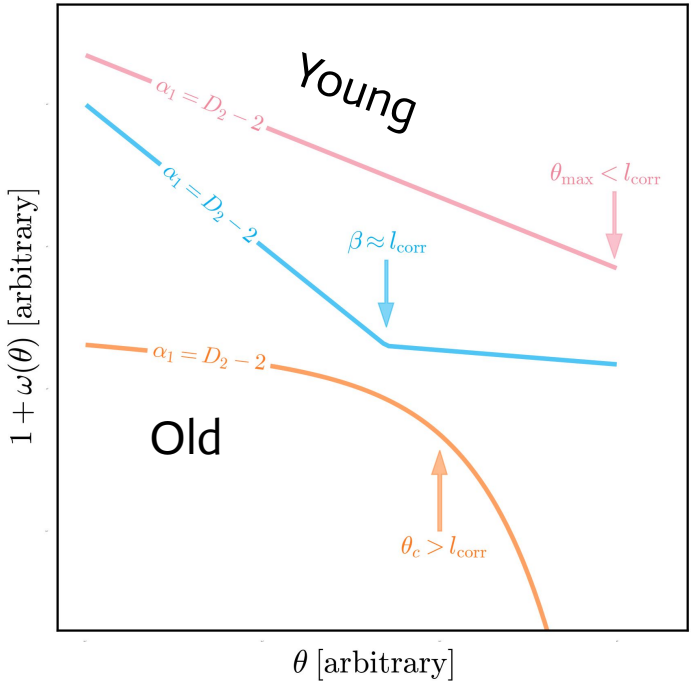
What Are TPCFs Telling Us?

M51: Slightly longer randomization timescales, randomized at ~100-300 Myr

Active interaction with companion may also be extending randomization timescales in M51



Further Quantifying Results – Functional Forms with MCMC



$$\alpha_1 = D_2 - 2$$

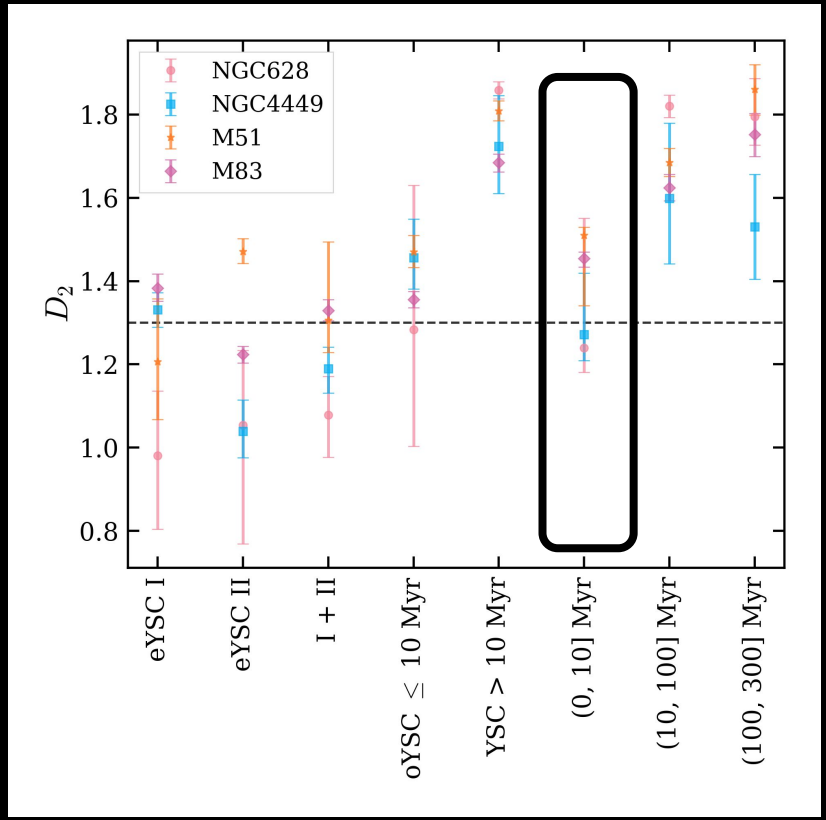
D_2 is ***fullness of fractal distribution***

Universal SF process, D_2 ~ 1.3 **always** (see B.G. Elmegreen, J. Scalo 2004)

D_2~1.3 -> SF set by turbulence, grav. instability

Evidence for Universal Star Formation Process

We find consistent D_2 ~ 1.3 across our entire sample!



Previous studies find varying D_2 (e.g., S. Menon+21, G.Shashank+25), but worse data

Summary – Thank you! :-)

FEAST targets 6 local, SF galaxies. Range of environments, powerful science.

TPCF provides insight into SF, nature of ISM. FEAST catalogs enable most comprehensive study to date.

dlapeer@umass.edu
https://giantmolecular.cloud

Evidence for...

- Clear hierarchical structuring
- Environment-dependent randomization timescales
- Universal star formation

Thanks to...
Daniela Calzetti (UMass, Advisor)
Katie Grasha (ANU, Mentor/Collaborator)
Angela Adamo (U.Stockholm, FEAST PI)
Bruce Elmegreen (Collaborator)
FEAST Team