

(how)  
can we constrain the  
impacts of *feedback*  
using galaxy SFHs?

Kartheik Iyer  
Hubble Symposium @ Caltech  
NHFP Hubble Fellow | Columbia University



 COLUMBIA UNIVERSITY  
IN THE CITY OF NEW YORK

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INSTITUTE  
Center for Computational  
Astrophysics



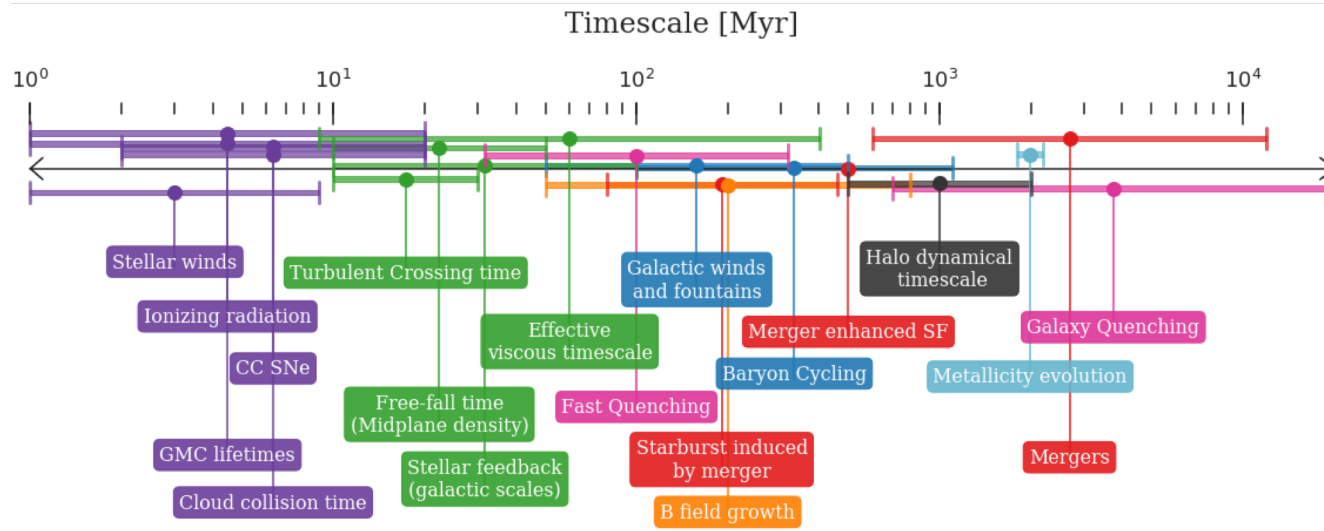
LEDA2046648 | ESA/Webb, NASA & CSA, A. Martel

**Galaxies are complex ecosystems**  
with physical processes spanning many scales  
regulating their formation & growth

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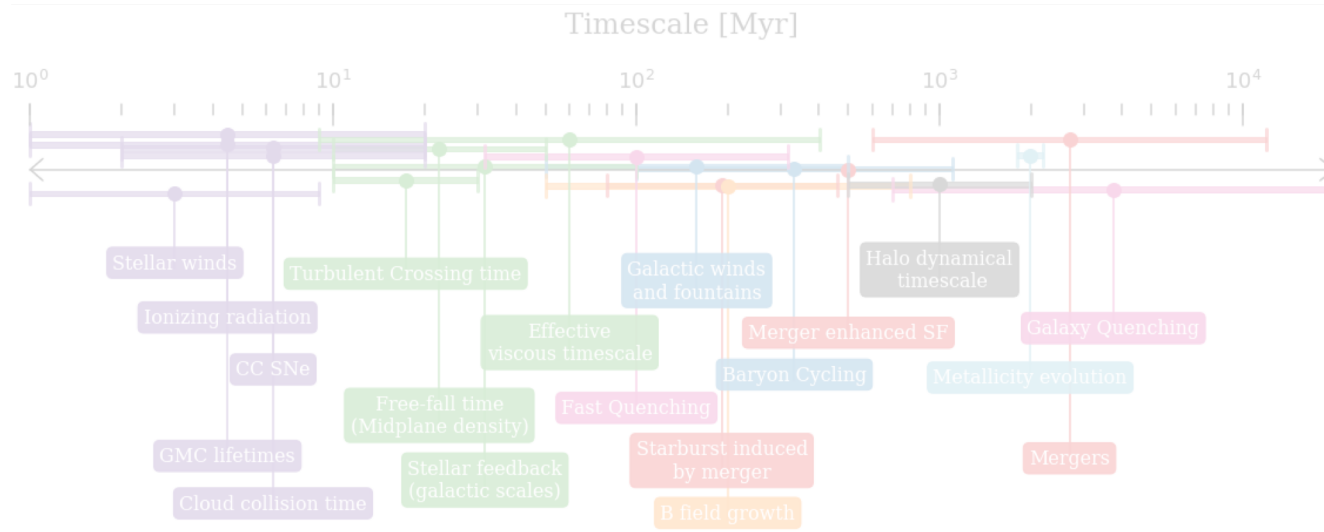
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< the scales of these processes often **overlap and interact** across both space and time  
Iyer et al. (2020)

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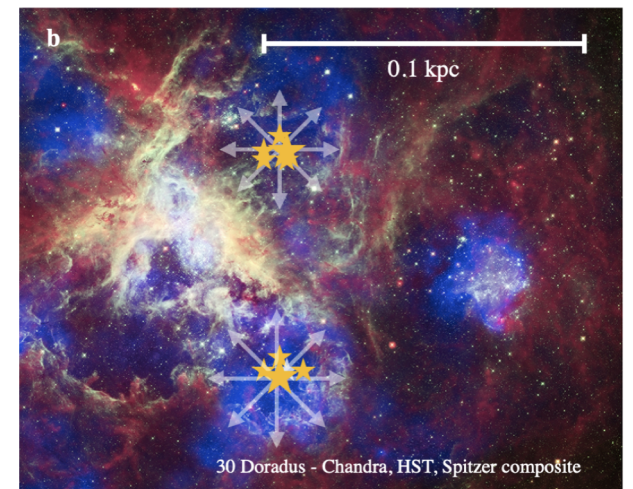


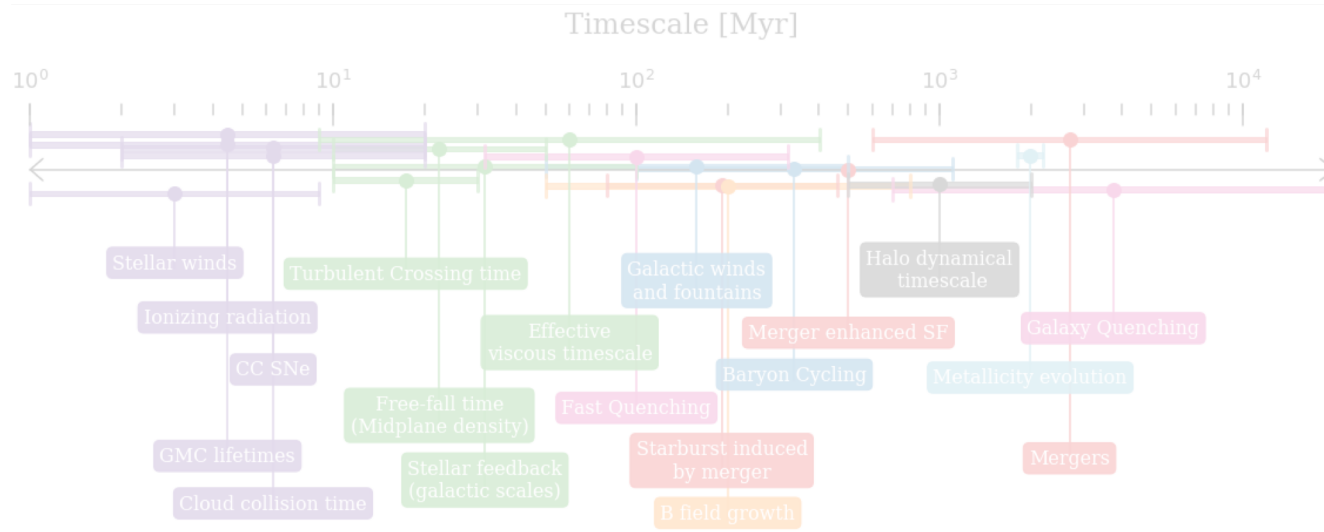


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**feedback is extensively > studied across a variety of spatial scales**

Galactic winds driven by star formation in 30 Doradus (Collins & Read 2022)

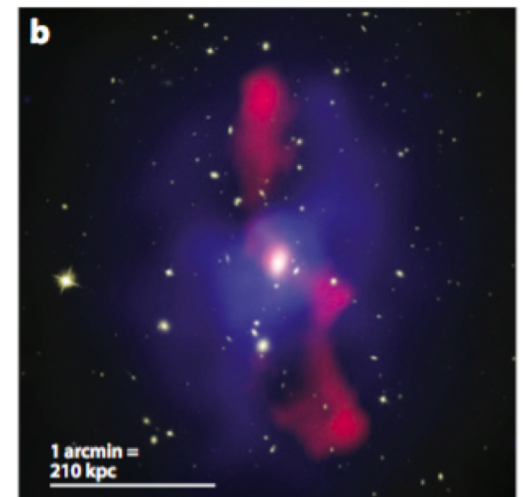
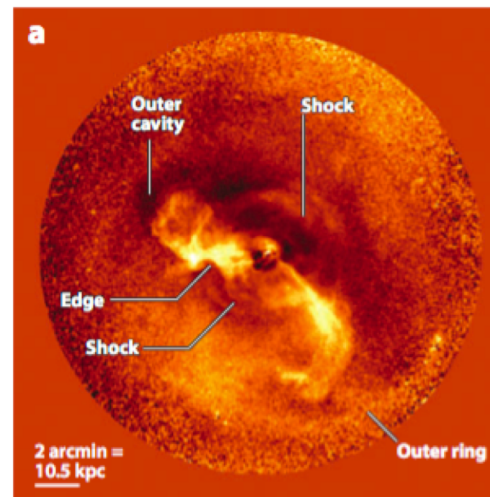


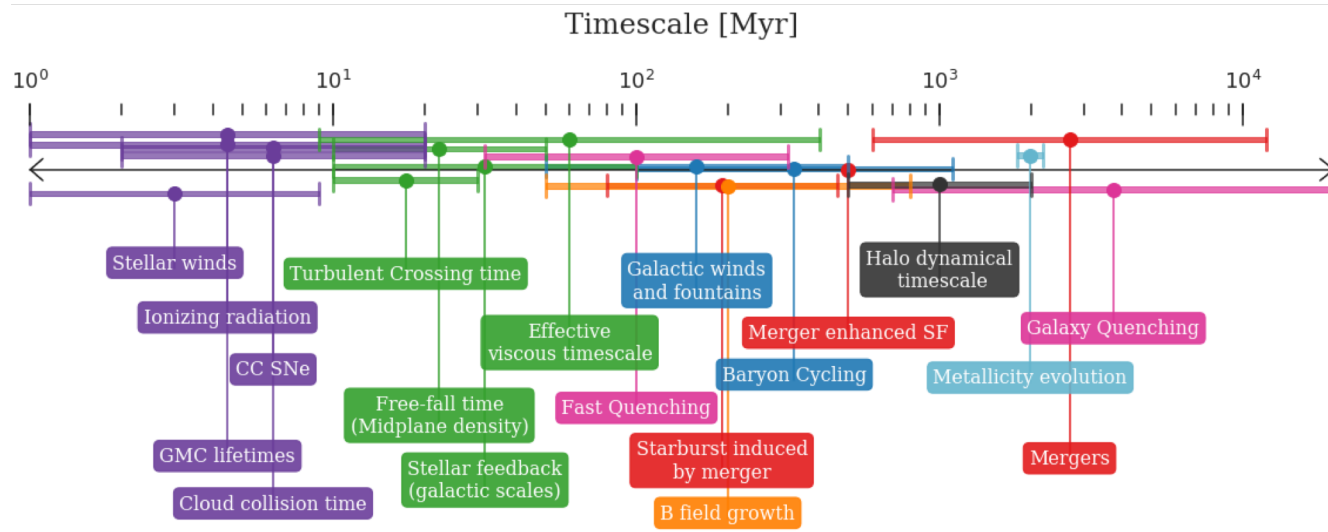


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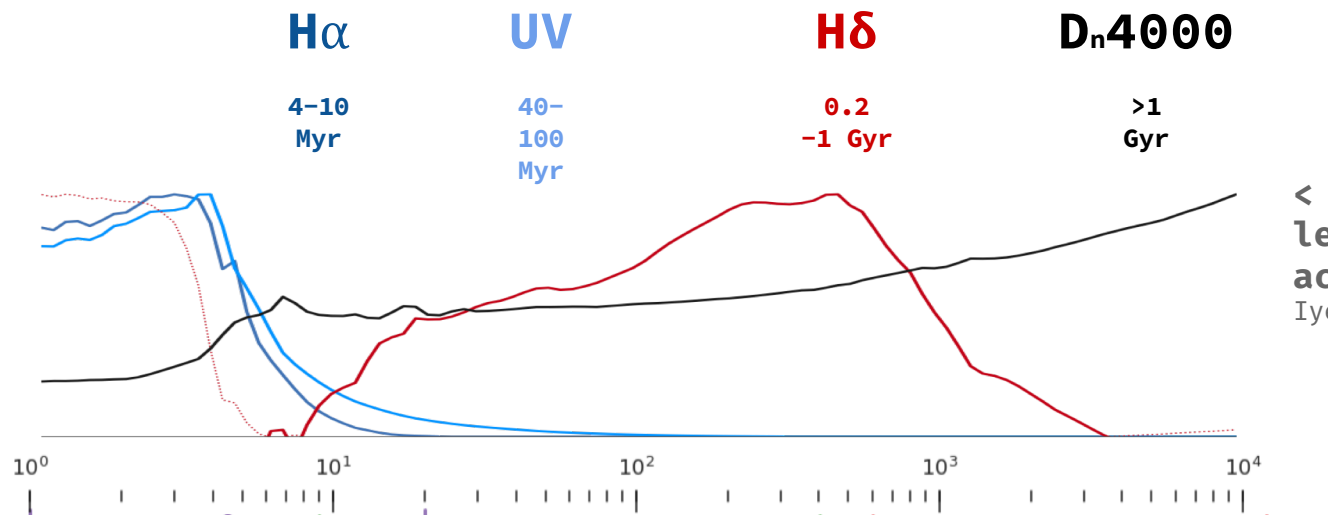
**feedback is extensively > studied across a variety of spatial scales**

M87's AGN jet shocking gas out to 100s of kpc (Fabian 2012)





< the scales of these processes often **overlap and interact** across both space and time  
Iyer et al. (2020)



< spectral features let us study star formation across a range of timescales  
Iyer & Speagle et al. (2024)

Spectral modeling tools like **dense basis** can be used to observationally constrain galaxy SFHs.

Suites of cosmological simulations like CAMELS can reveal the **SFH-feedback connection** for large populations of galaxies.

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**Serendipitous  
observations**

**Technical  
advances**

**Incredible  
students**

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Spectral modeling tools like **dense basis** can be used to observationally constrain galaxy SFHs.

High-z lensed galaxies like the **Firefly Sparkle** offer glimpses of resolved star formation as proto-galaxies assemble.

Interpretable ML tools like **Katachi** extend SFH inference to future telescopes & help build models of the SFH-morphology connection.

LLM-assisted literature survey tools like **pathfinder** help keep track of the ever-expanding astronomy literature & democratize research.

Suites of cosmological simulations like CAMELS can reveal the SFH-feedback connection for large populations of galaxies.



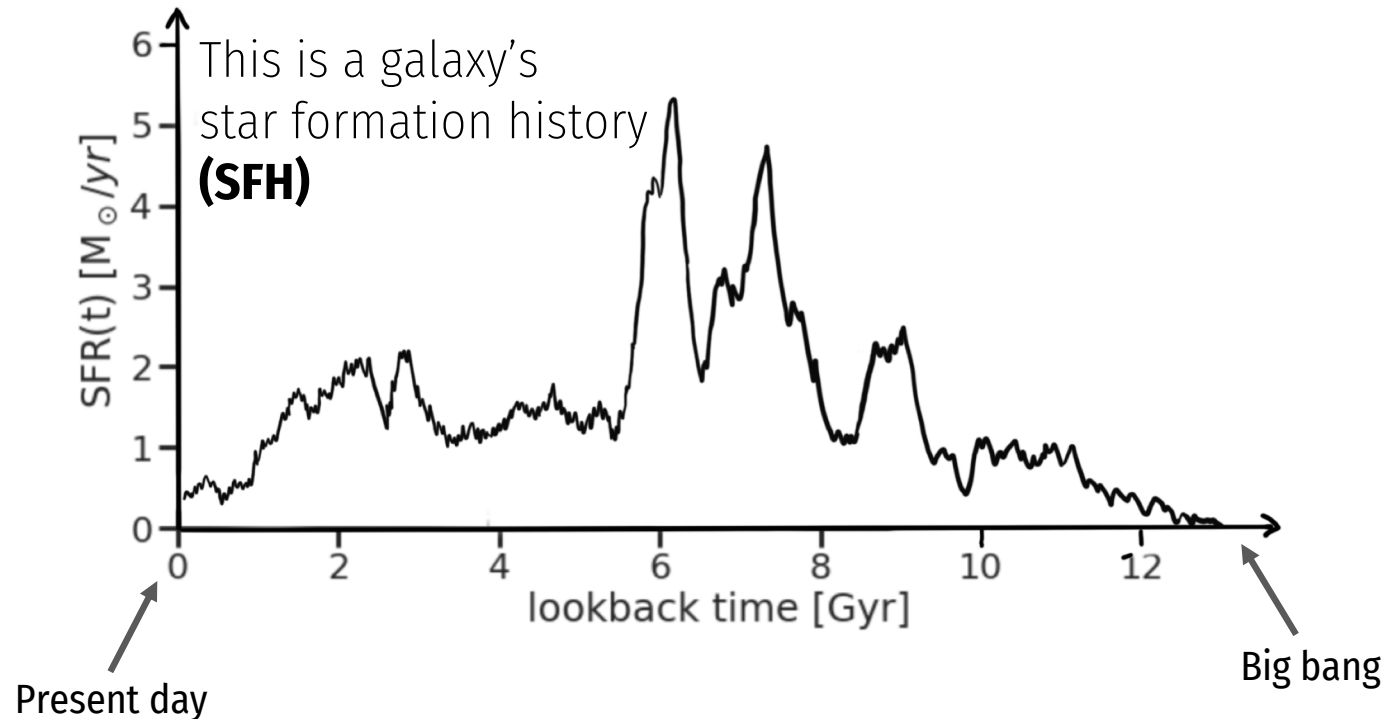
Spectral modeling tools like **dense basis** can be used to observationally constrain galaxy SFHs.

Iyer et al. (2019), [dense-basis.readthedocs.io](https://dense-basis.readthedocs.io)

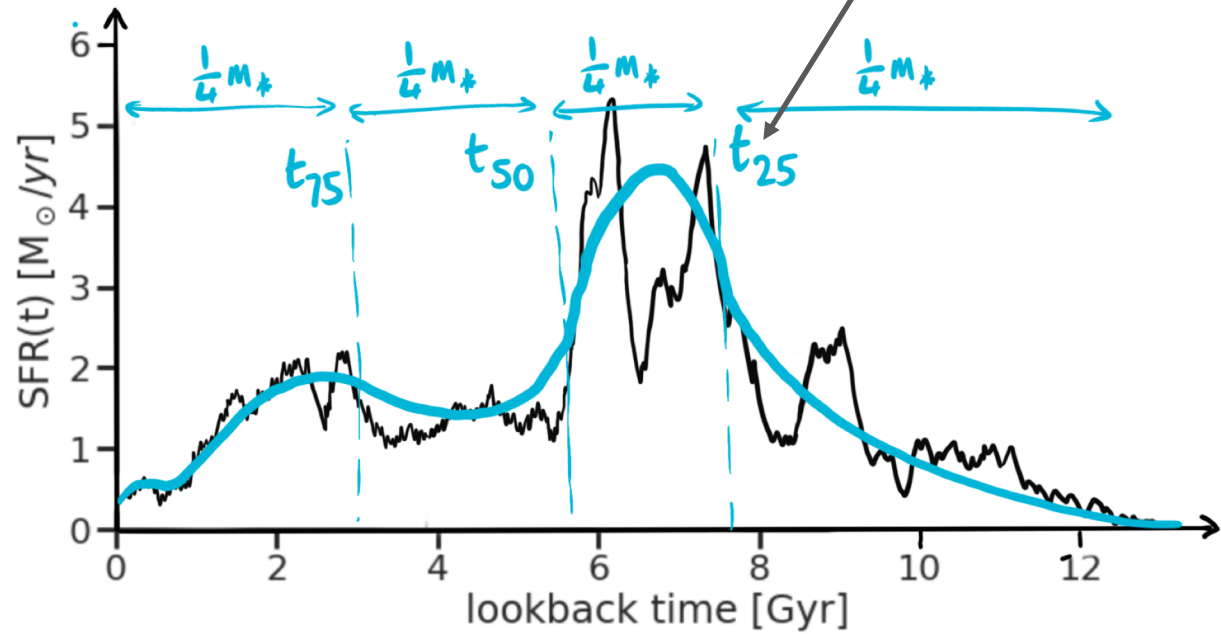


# How do we describe galaxy star formation histories (SFHs)?

(Heavens+00, Tojeiro+07, Dye '08, Pacifici+12, 15, 16, Simha+14, Kelson+14, Abramson+15, Iyer & Gawiser '17, Iyer+19, Leja+19b, Zhou+20, Jiminez-Lopez+21, Thorne+21, Cooray+23, Suess+22, Alarcon+24...)

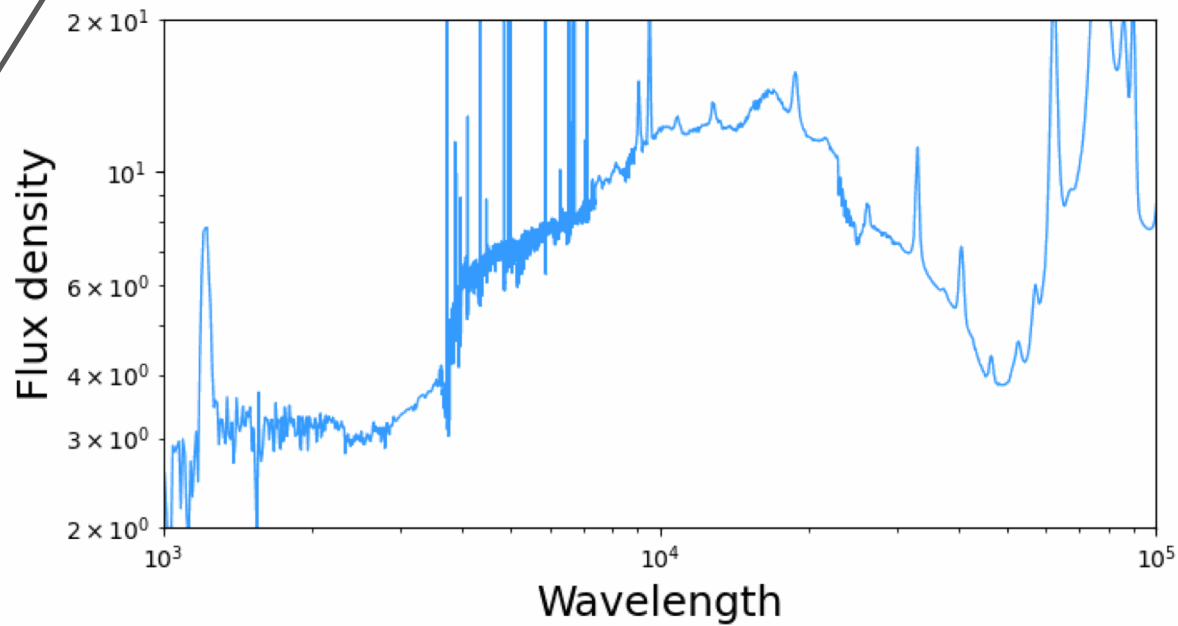
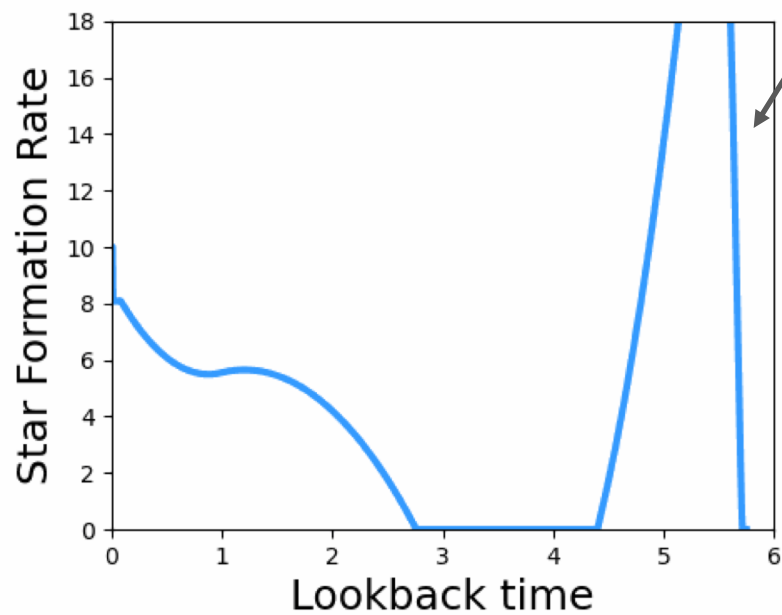


the Dense Basis method (Iyer+19)  
 $\text{SFH} = (M_*, \text{SFR}, \{t_x\})$



Sampling in  $\{t_x\}$  space  
(at fixed mass and SFR)

$$\text{SFH} = (M_*, \text{SFR}, \{t_x\})$$



# Interested in non-parametric SFHs?



Robust SFH recovery from multiwavelength observations: the Dense Basis method

> [pip install dense\\_basis](#)

on Github

> [kartheikiyer/dense\\_basis](#)

> in Bagpipes, piXedfit

Documentation + full examples  
[dense-basis.readthedocs.io](#)

papers using Dense Basis on ADS:  
[bit.ly/dbpapers](#)

The screenshot shows the documentation for the 'dense basis' package. The left sidebar contains navigation links for 'GENERAL USAGE' (Installation, Dependencies, Features), 'TUTORIALS' (The GP-SFH module), and 'A full SED-Fitting example'. The main content area is titled 'A full SED-Fitting example' and includes a paragraph explaining the method, a code block for prerequisites, and a code block for fitting. A small inset chart shows the number of papers published from 2017 to 2024, with a legend for 'Referred' (blue) and 'Non-referred' (green) papers. The chart shows a steady increase in referred papers, with a significant jump in 2024.

Docs » A full SED-Fitting example

### A full SED-Fitting example

This tutorial goes through the things that need to be done to fit the observed spectral energy distributions (SEDs) of galaxies. This is different from SED fitting codes that use a sampler while fitting to create their posteriors, in the sense that we pre-sample the prior volume prior to fitting, trading space for time complexity. This results in a moderately lengthy initialization period where the method generates an atlas of parameters drawn from the priors and SEDs corresponding to these parameters with a user-specified filter-set, which can then be used to fit any number of SEDs in an extremely short amount of time. (Further iterations of the code are also planned to include variants with live samplers for edge-cases and objects with pathological likelihood surfaces.)

The atlas essentially provides a coarse mapping from the galaxy's stellar population parameters (stellar mass, SFR, star formation history, dust attenuation, metallicity, and redshift) to their corresponding SEDs.

Instantiate the module, making sure you have all the prerequisite packages (especially python-fsps and george) installed. Don't worry if the initial import takes a few minutes, because it's initializing its FSPPS backend.

If you need to change any of the FSPPS parameters, do so using `db.mocksp.params['key'] = value`, consulting the [python-fsps](#) API for reference.

```
[1]: import numpy as np
import dense_basis as db

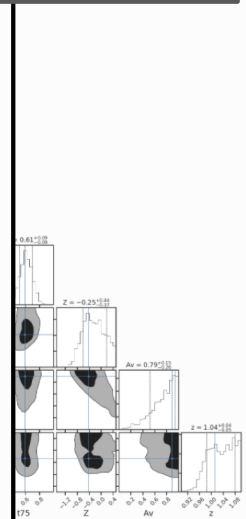
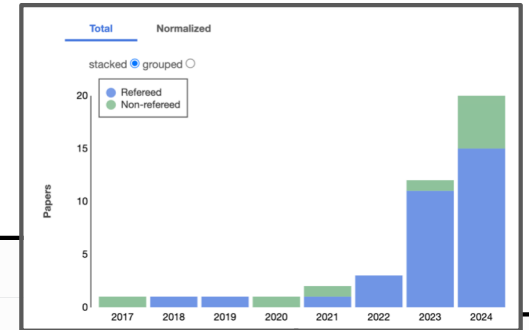
Starting dense_basis, please wait - a minute for the FSPPS backend to initialize.
Initialized stellar population with FSPPS.
```

### Prerequisites to fitting:

If you're fitting photometry, put your photometric filter transmission curves in a folder somewhere and make a list of filter curves with the paths to each filter. You'll need to pass `filter_list` and `filt_dir` as arguments to the code to generate SEDs corresponding to a given parameter set.

The `db.plot_filterset()` function can be used to visualize the set of filter curves used to make SEDs. Let's load a filter list corresponding to the CANDELS GOODS-South photometric catalog for now:

```
[2]: filter_list = 'filter_list_goods.dat'
filt_dir = 'internal' # path to directory containing filter list
db.plot_filterset(filter_list = filter_list, filt_dir = filt_dir)
```



compares to the true SFH:

(threshold = 0.9)

# ...or resolved non-parametric SFHs?

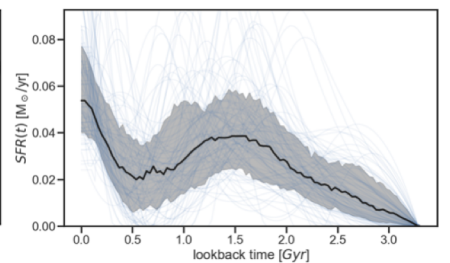
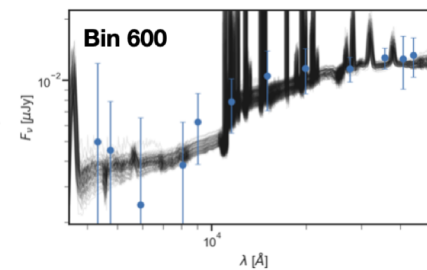
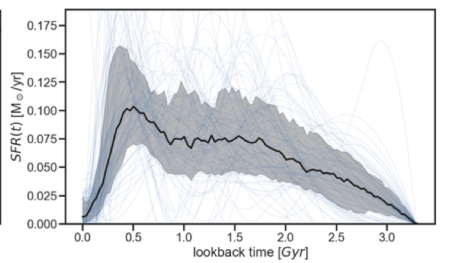
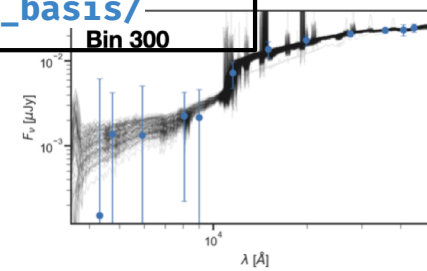
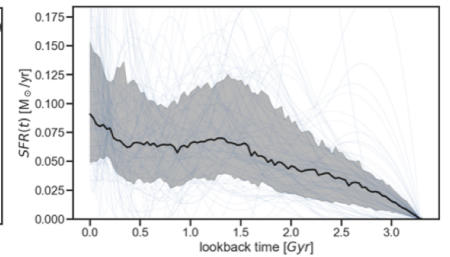
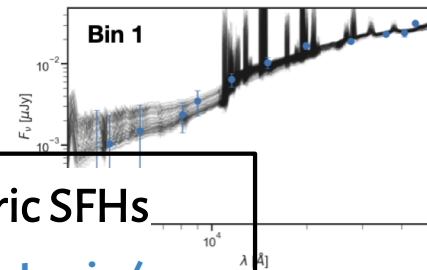
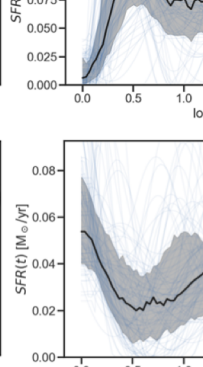
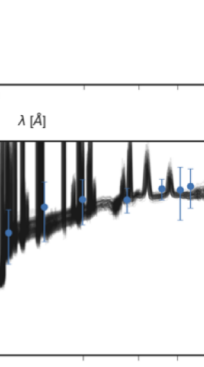
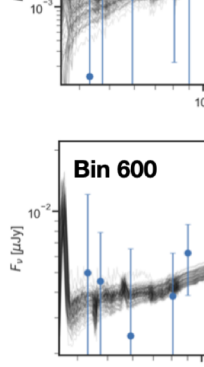
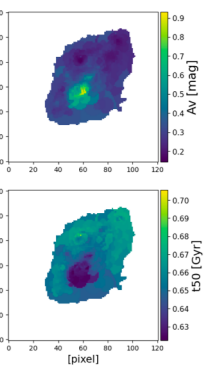
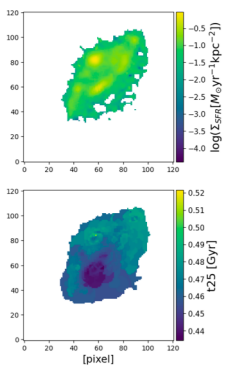
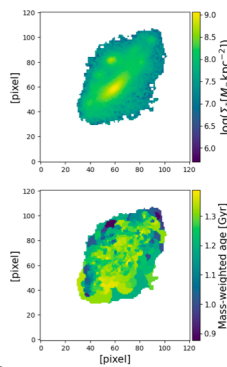
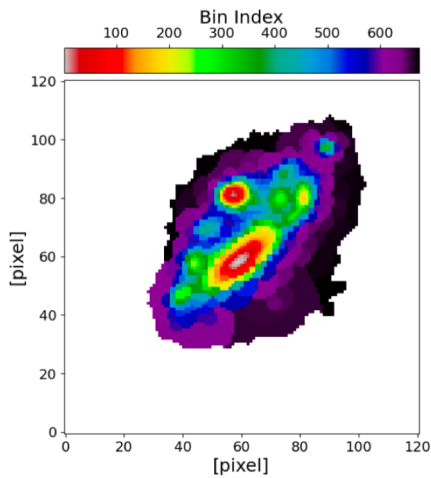


Dense Basis + piXedfit

> [github.com/aabdurrouf/piXedfit/](https://github.com/aabdurrouf/piXedfit/)

Fast resolved fitting with non-parametric SFHs

> [github.com/aabdurrouf/piXedfit-dense\\_basis/](https://github.com/aabdurrouf/piXedfit-dense_basis/)



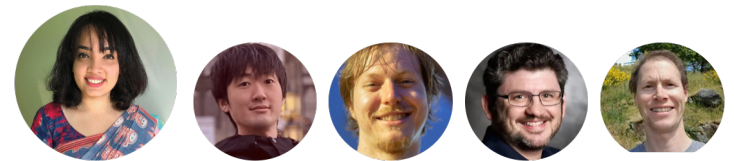




the **Firefly Sparkle**  
star formation on parsec scales at  $z=8.3$

# High- $z$ lensed galaxies like the **Firefly Sparkle** offer glimpses of resolved star formation as proto-galaxies assemble.

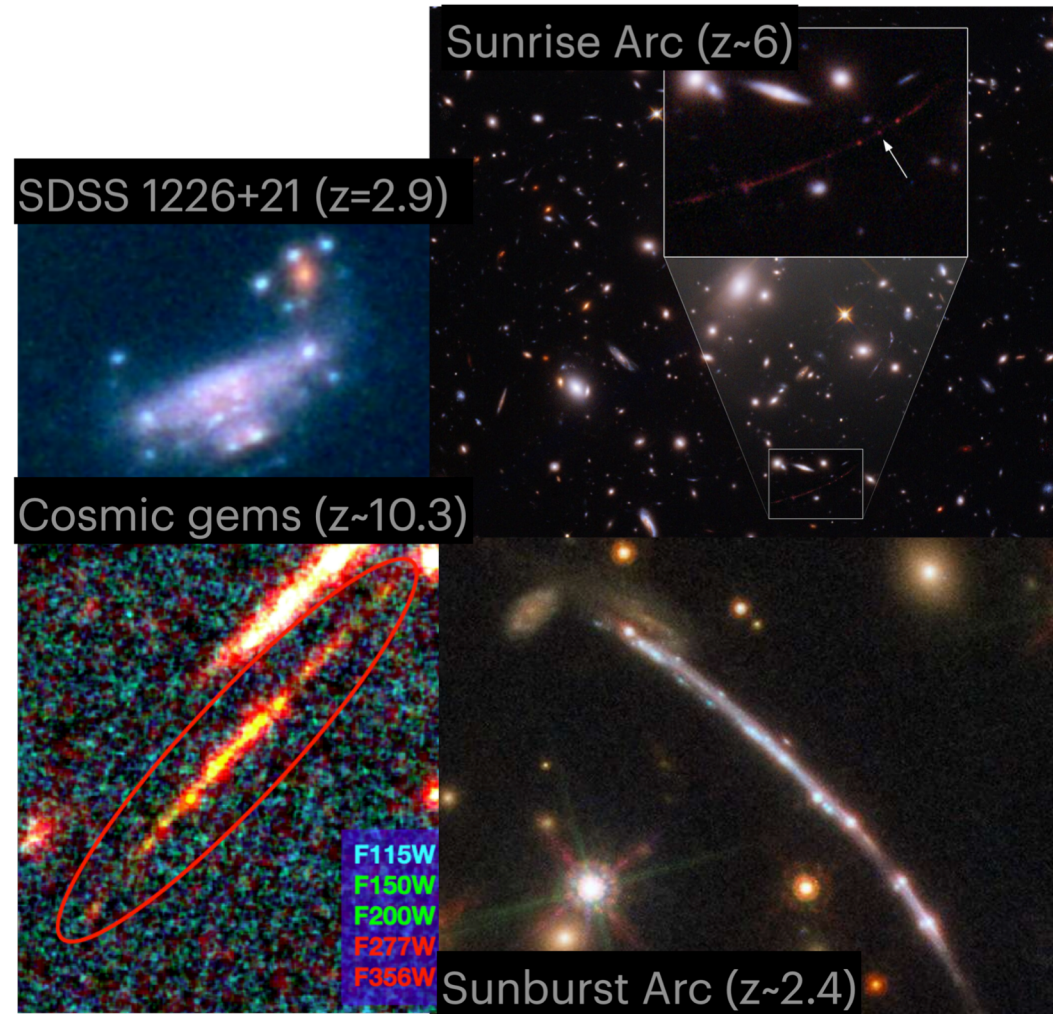
Mowla & Iyer et al. (2024) *accepted in Nature*



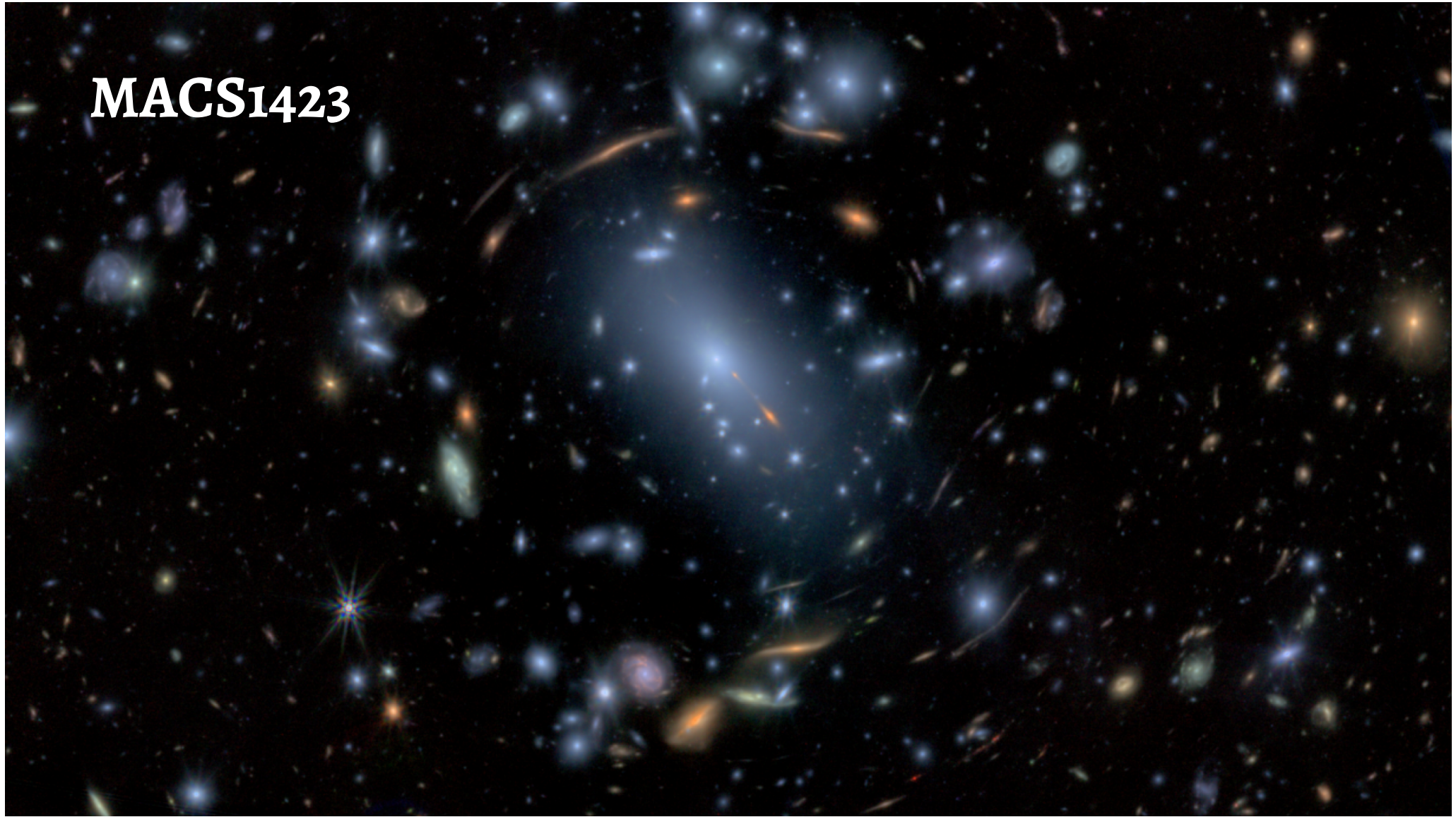
# Lensed Galaxies with Un(/semi)resolved Star Clusters

- Observe pc scale clumps at various stages of formation at various epochs, in rest-frame UV-NIR.
- Many candidates identified with HST, even more being discovered and followed up with JWST.

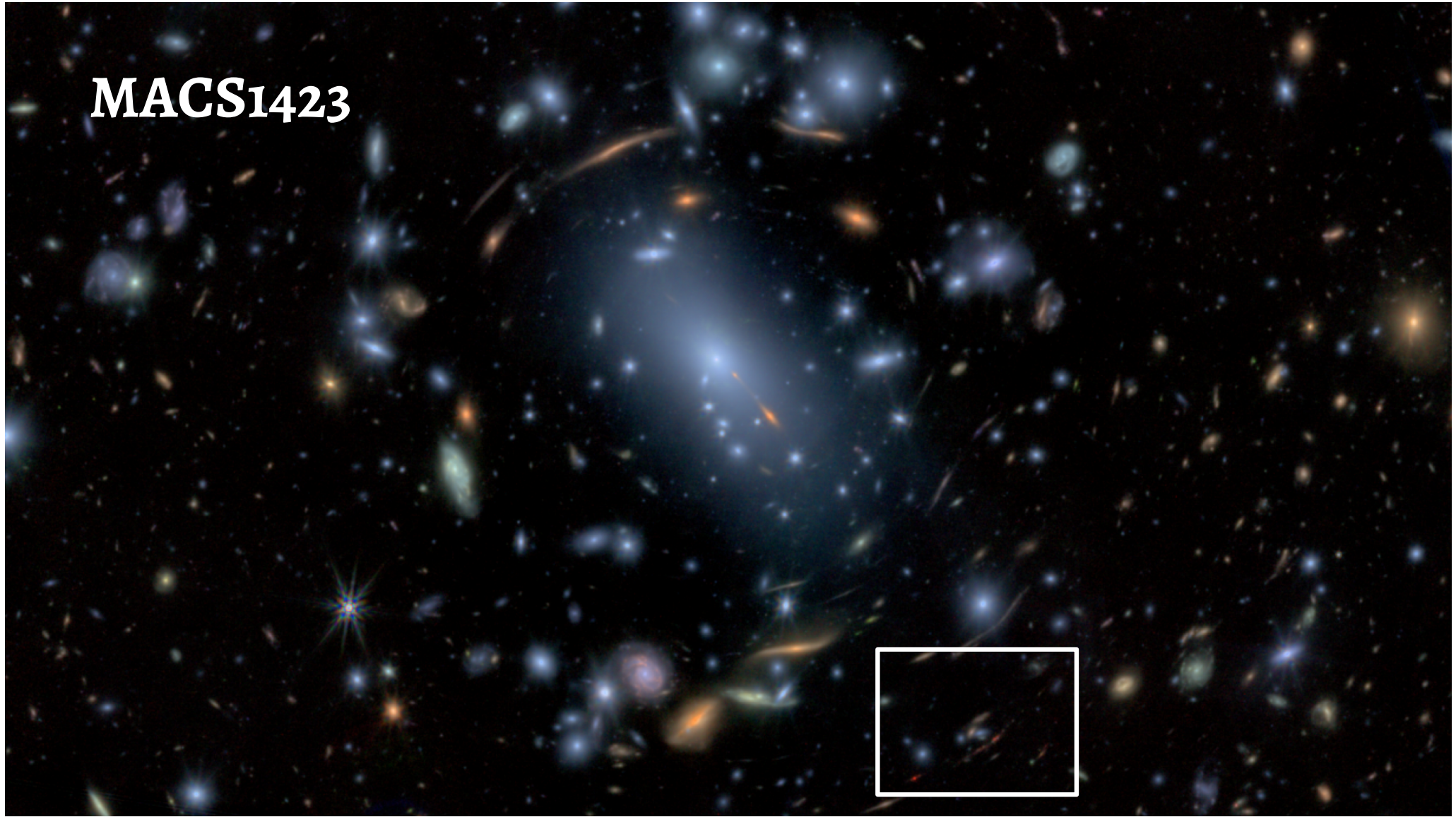
Also see Vanzella et al. 2019, 2022, Welch et al. 2023, Clayessens et al. 2023, 2024, Adamo et al. 2023, 2024, Sok et al. 2024, and many more for review



**MACS1423**

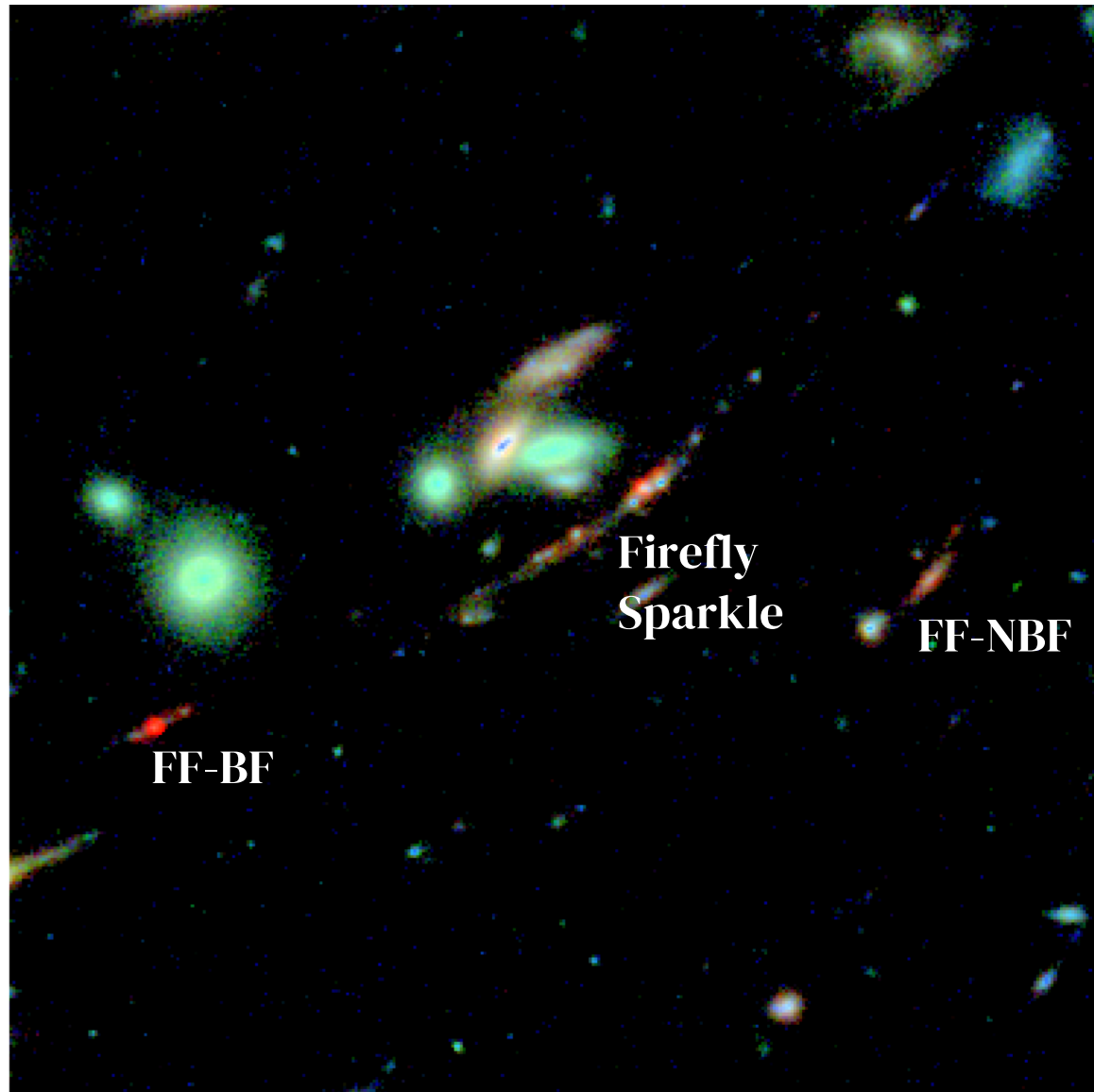


**MACS1423**



## Three galaxies in a ~600 Myr Old Universe

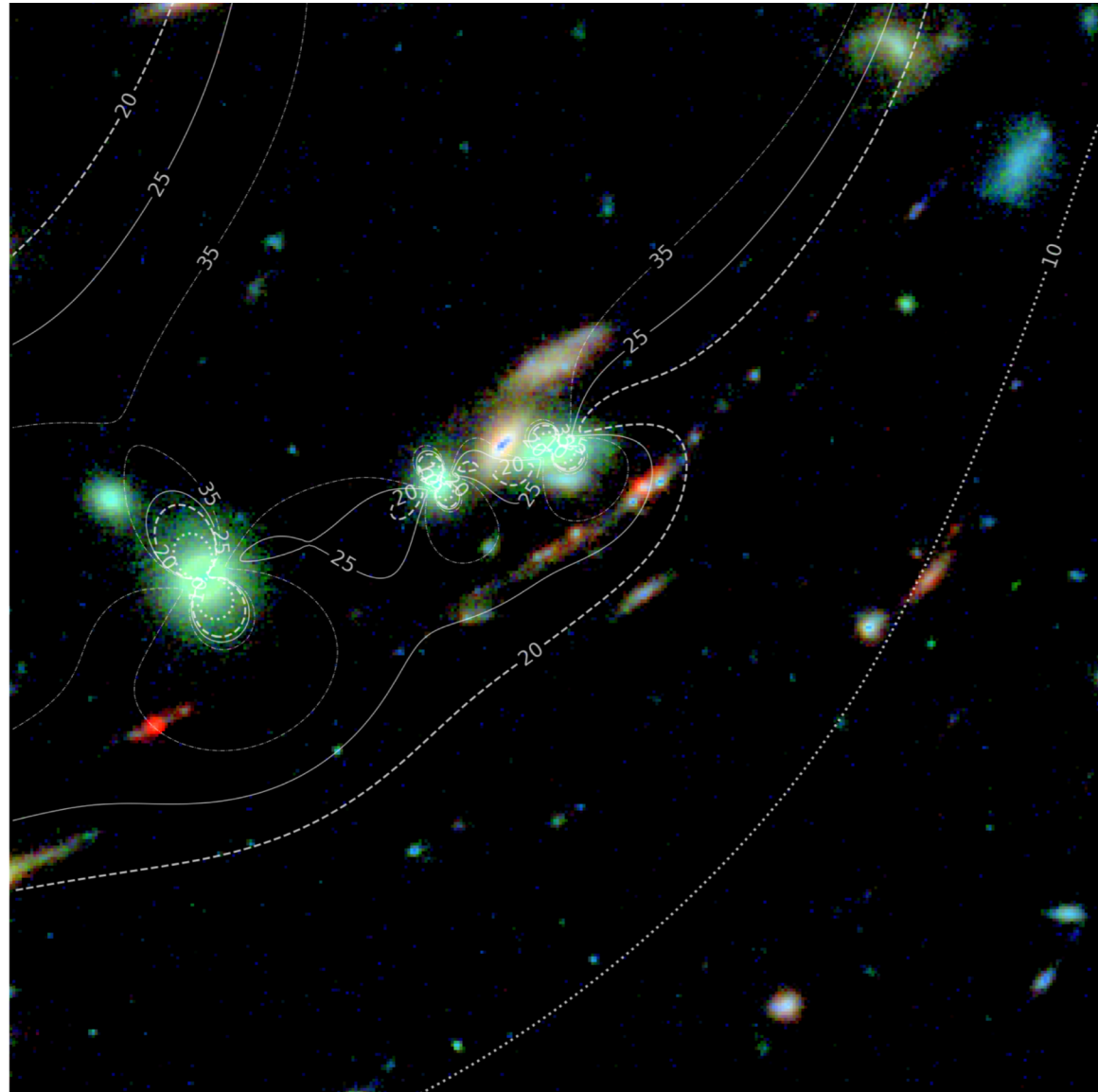
- Three galaxies at  $z_{\text{spec}} = 8.30$
- One galaxy fragmented into at least ten massive star clusters



Mowla and Iyer et al.  
(accepted in Nature; ArXiv:2402.08696)

## Three galaxies in a ~600 Myr Old Universe

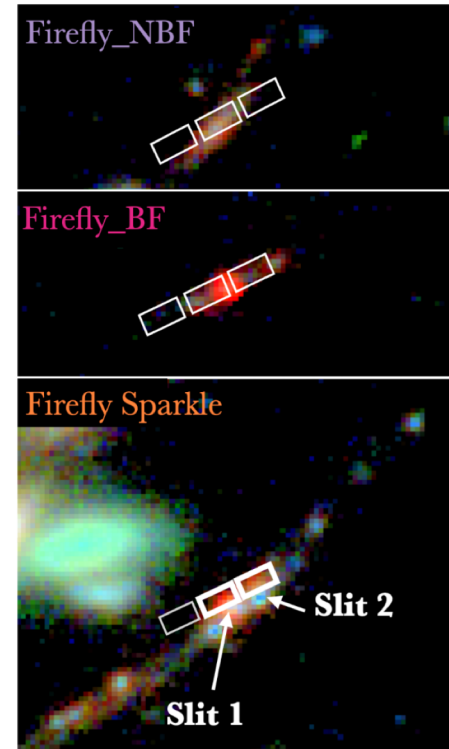
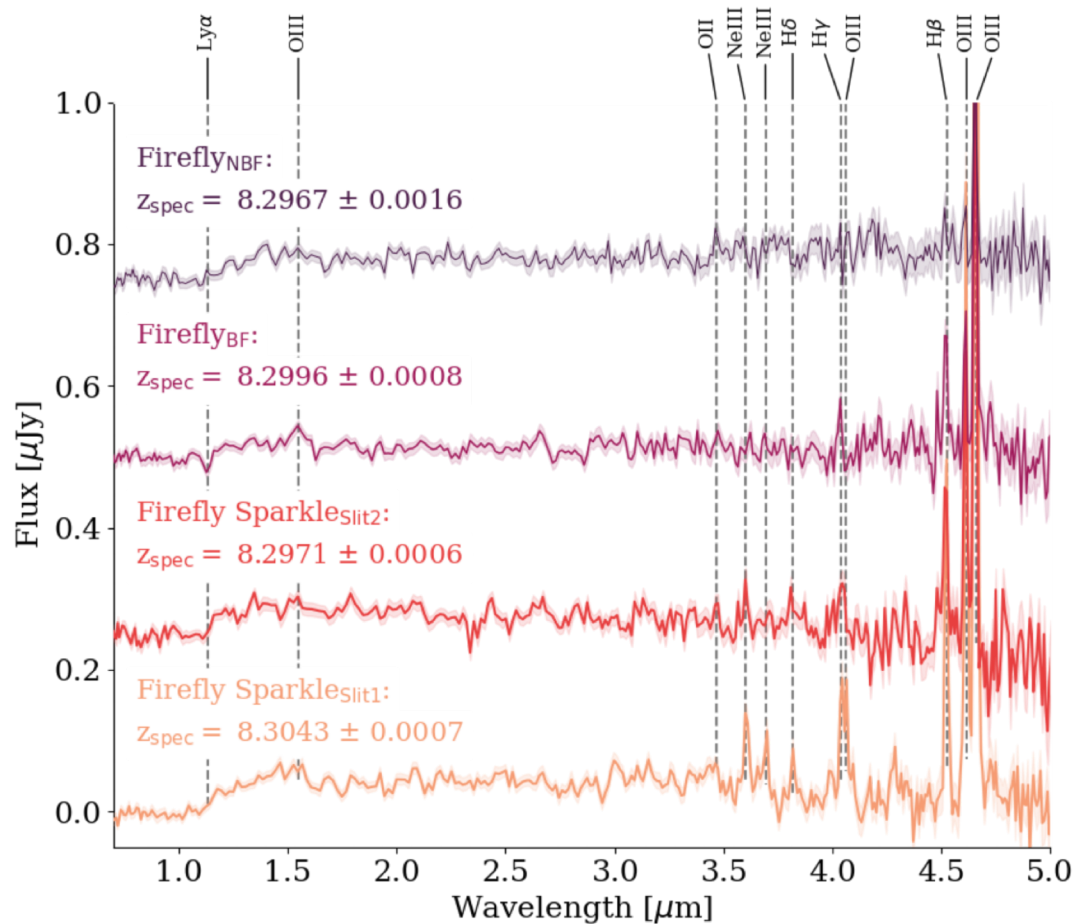
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- One galaxy fragmented into at least ten massive star clusters
- Magnification between 15-40x



Mowla and Iyer et al.  
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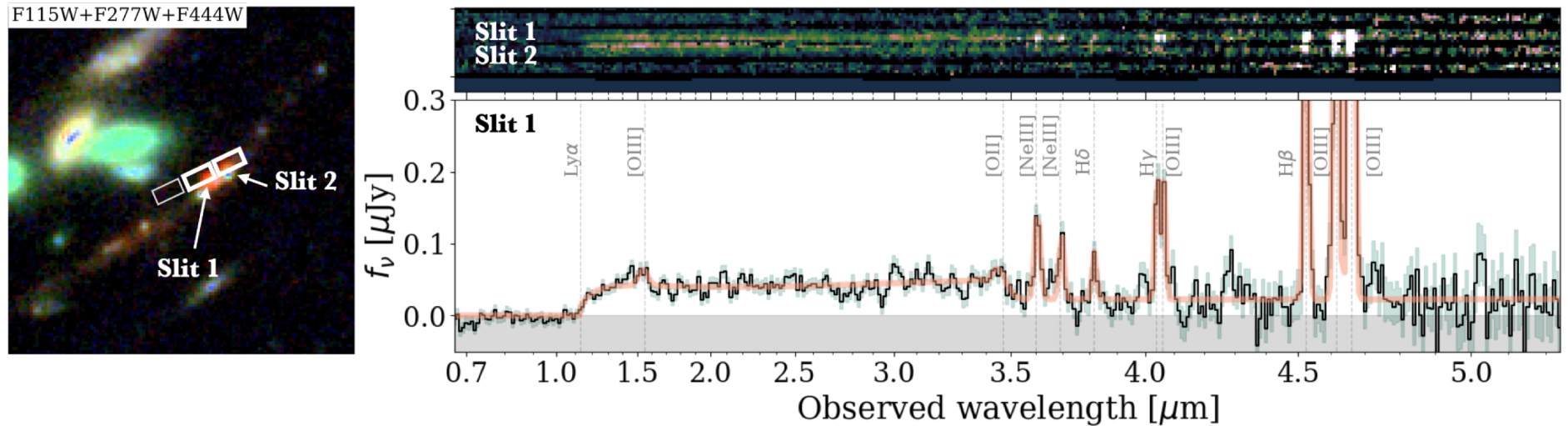
# the Firefly Sparkle: **NIRSpec Prism Follow Up**

- Spectroscopic redshift confirmation.
- Detection of OIII doublet in all three galaxies.



Mowla and Iyer et al. (accepted in Nature; ArXiv: 2402.08696)

## the Firefly Sparkle: **Two slits on the central four clusters**



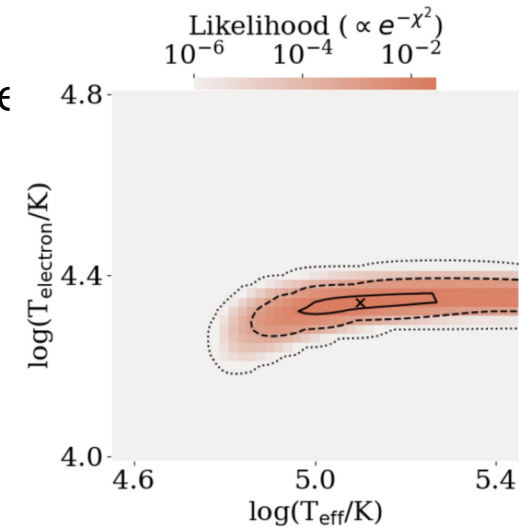
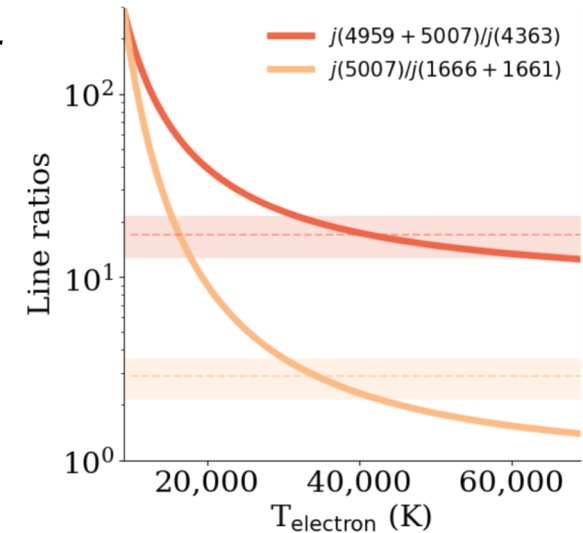
- Strong nebular continuum.
- Balmer decrement consistent with being dust free.
- Low metallicity ( $12+\log(\text{O}/\text{H}) = 7.02 \pm 0.25$ )

Mowla and Iyer et al. (accepted in Nature; ArXiv: 2402.08696)



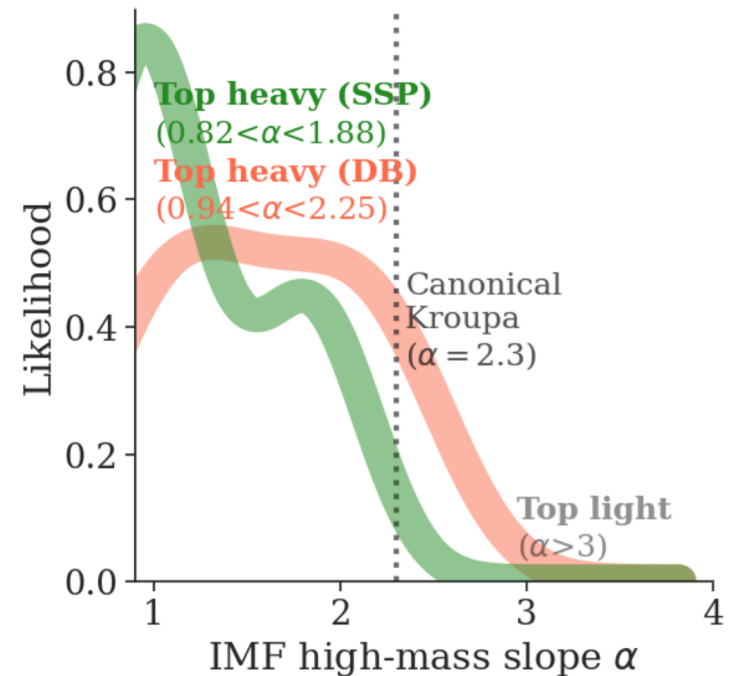
## the Firefly Sparkle: **High temperature and ionization**

- Ionizing source effective temperature  $> 40,000$  K.
- Temperature determined from:
  - Line ratios
  - Nebular continuum modeling
- Indication of a higher mass limit on the IMF from both:
  - The temperature of the ionizing source
  - The high-mass slope of the Kroupa IMF ( $\alpha < 2$ ) in the SED fits.



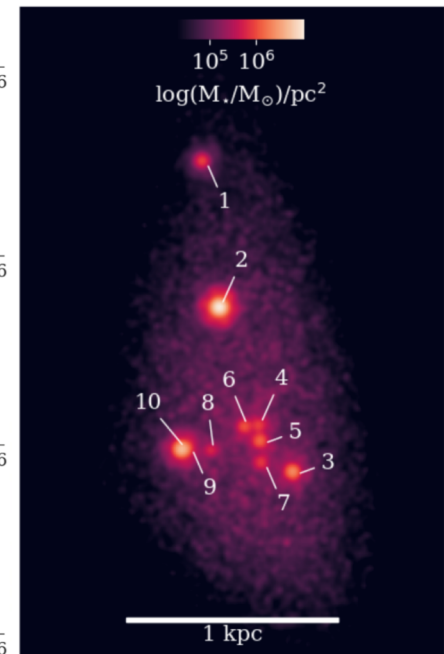
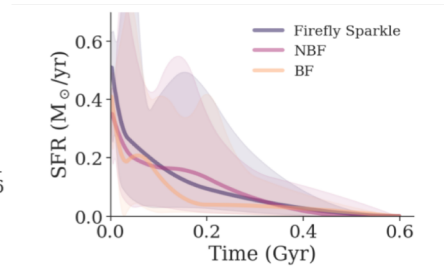
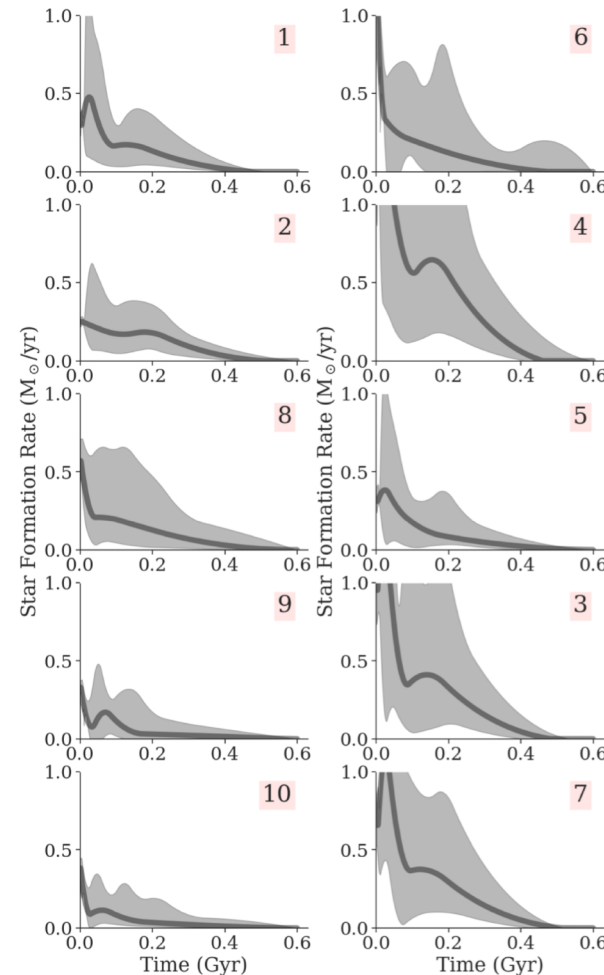
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# the Firefly Sparkle: **Age-dating the star clusters**

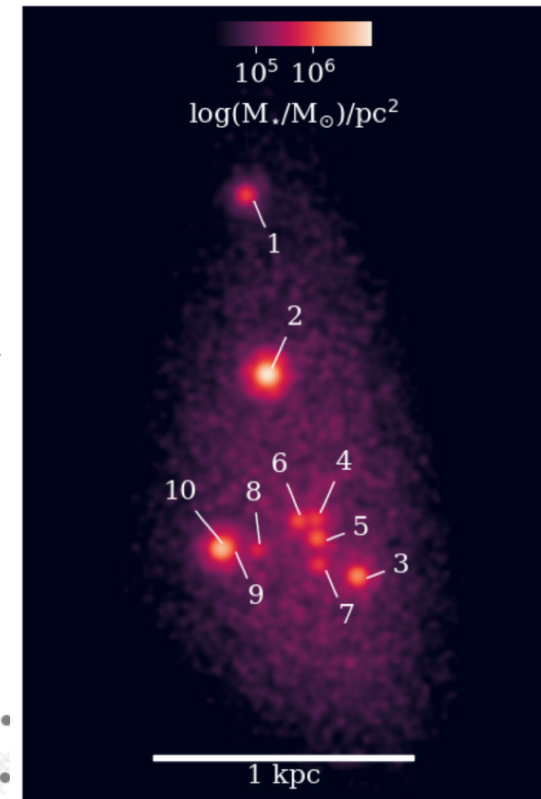
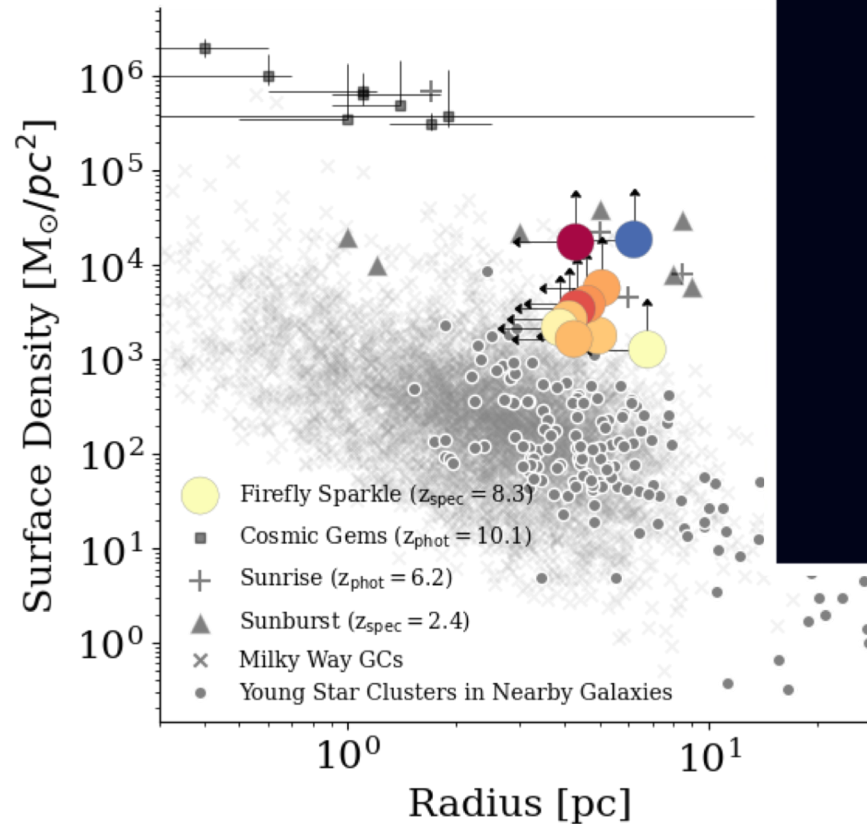
- We perform SED fits:
  - using the dense basis method (non-parametric SFH)
  - assuming single stellar populations (SSP)
- Majority of the stellar mass in the star clusters
- SSP fits give young ages of 3-10 Myr (less than a crossing time).
- DB fits give older ages with a recent burst of star formation.



Mowla and Iyer et al. (accepted in Nature; ArXiv: 2402.08696)

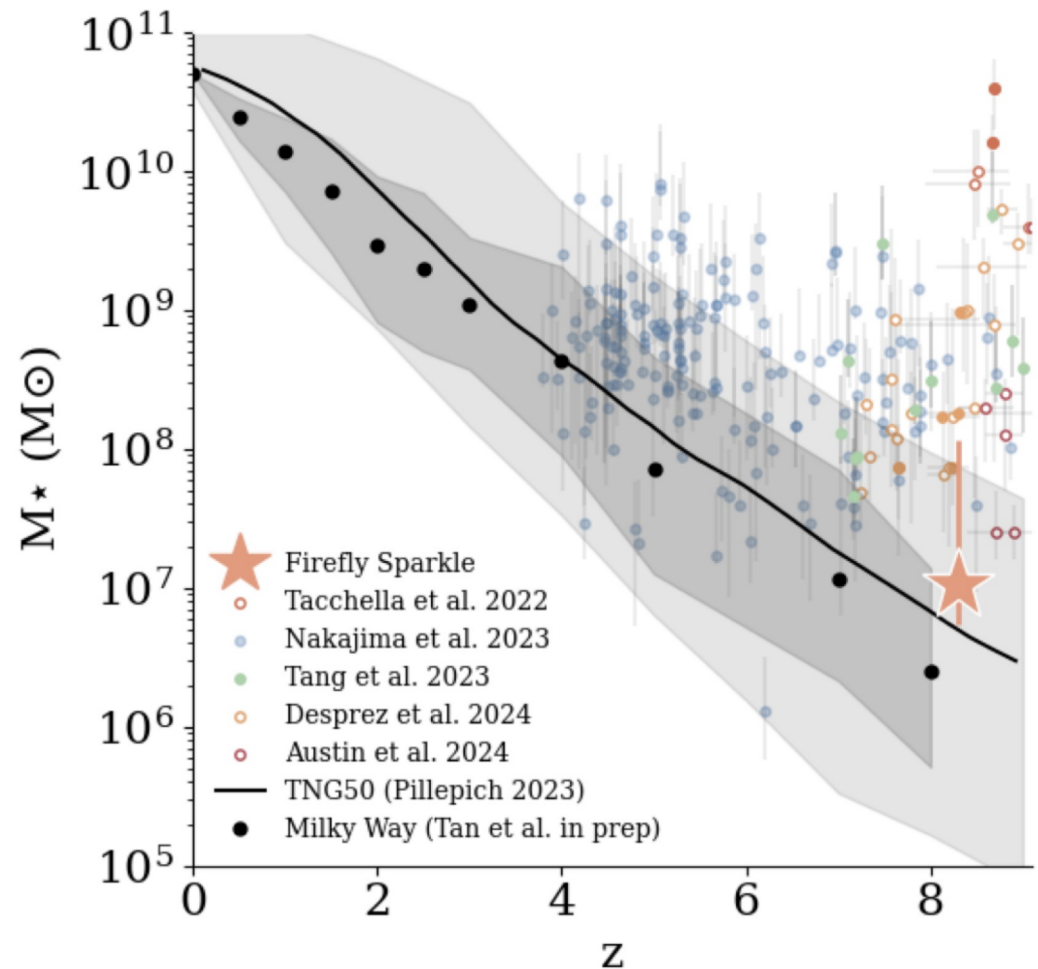
## the Firefly Sparkle: **Masses**

- Each star cluster  
 $\sim \log(M_*) = 5-6$
- High surface density with  $> 50\%$  of the stellar mass in the star clusters.
- Total demagnified mass  
 $\log(M) = 6.8 \pm 0.7$
- Assembly of a low mass galaxy which will likely evolve to a Milky Way mass galaxy.



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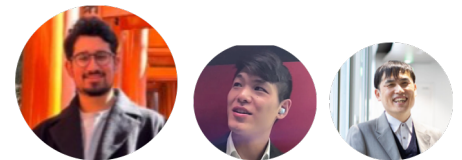
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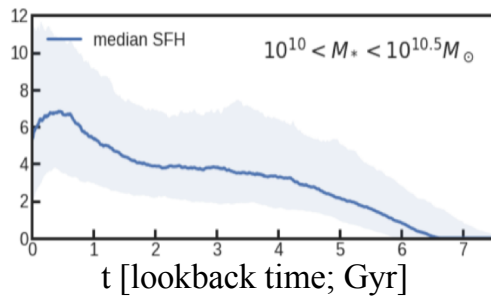
# Interpretable ML tools like Katachi extend SFH inference to future telescopes & help build models of the SFH-morphology connection.

Alfonzo, Iyer et al. (2024) *published in ApJ*

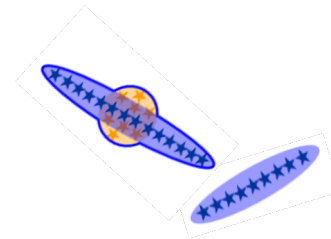
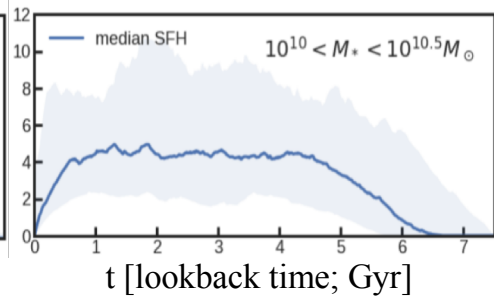




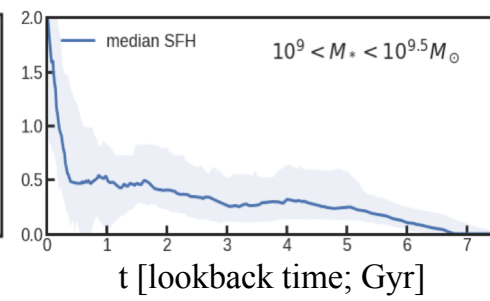
## Disks



## Spheroids



## Mergers

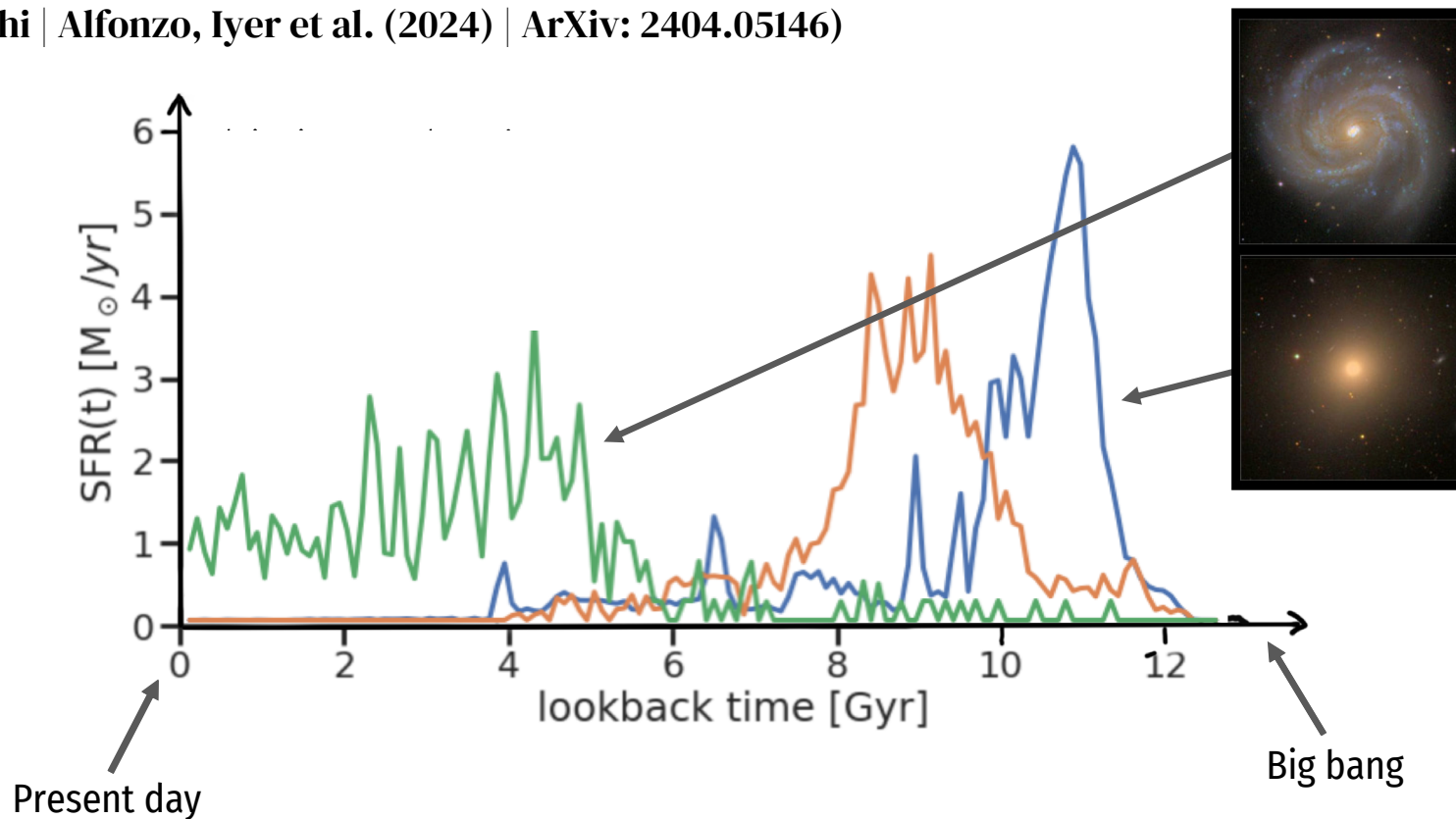


# What is the link between *how galaxies look and how they formed?*

(Katachi | Alfonzo, Iyer et al. (2024) | ArXiv: 2404.05146)

Juan Alfonzo (Tohoku U)

juanpabloalfonzo@astr.tohoku.ac.jp



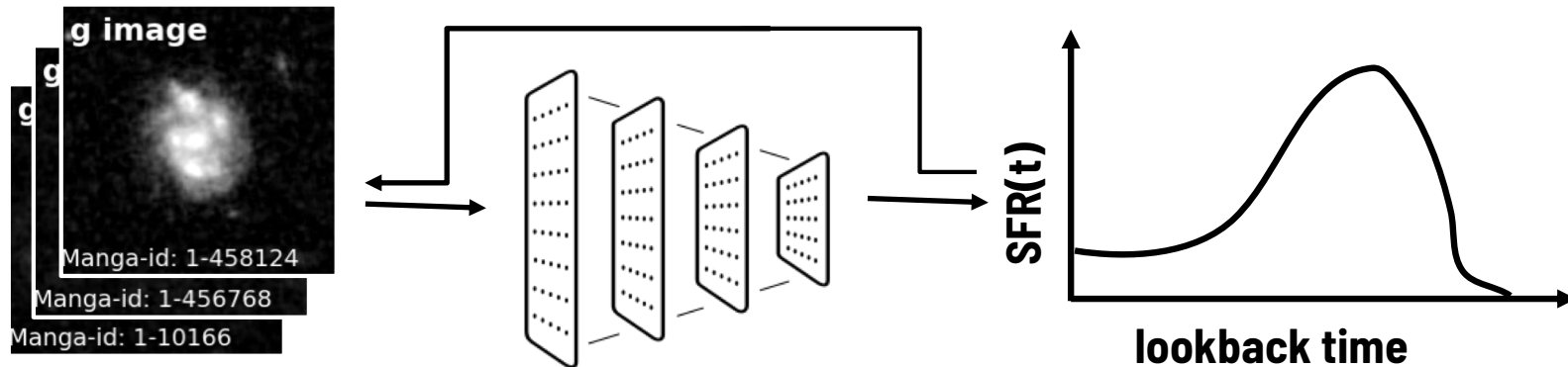


# What is the link between galaxy morphology and star formation histories?

(Katachi | Alfonzo, Iyer et al. (2024) | ArXiv: 2404.05146)

Juan Alfonzo (Tohoku U)

juanpabloalfonzo@astr.tohoku.ac.jp



→ Train a network to predict SFH parameters from images

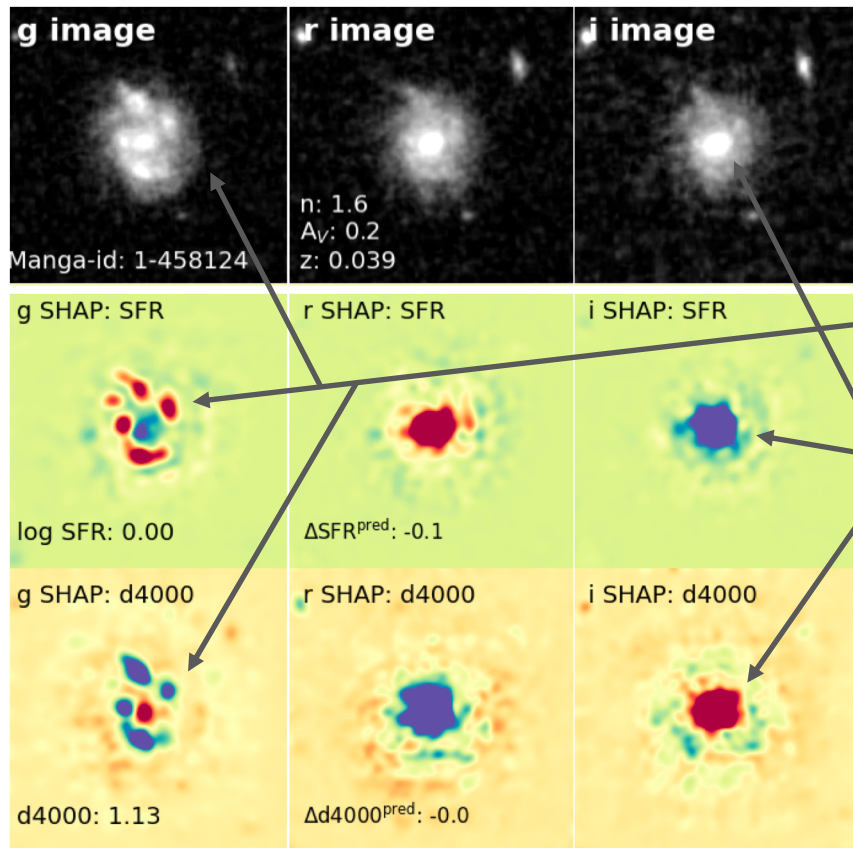
← Use XAI methods like SHAP to understand **which parts of the image drive the prediction**



Katachi

# decoding the *SFH-morphology connection* with SHAP

(Katachi | Alfonzo, Iyer et al. (2024) | ArXiv: 2404.05146)



**SHAP** - SHapley Additive Analysis (Lundberg & Lee '17)

**Red:** more flux here increases parameter estimate

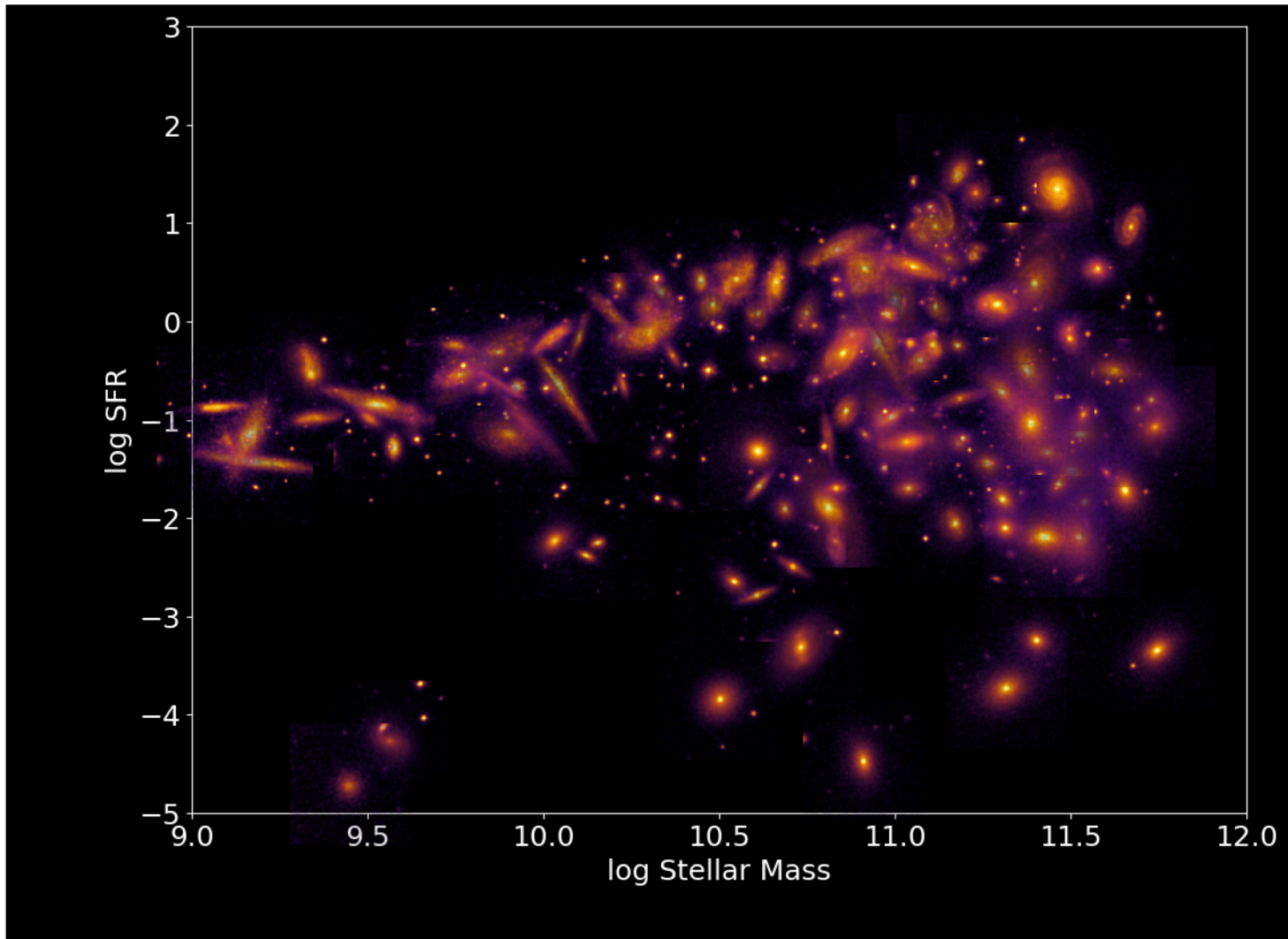
**Blue:** more flux here decreases parameter estimate

**Star forming clumps in the bluer band** drive the network to **higher SFR** and **lower t50** values

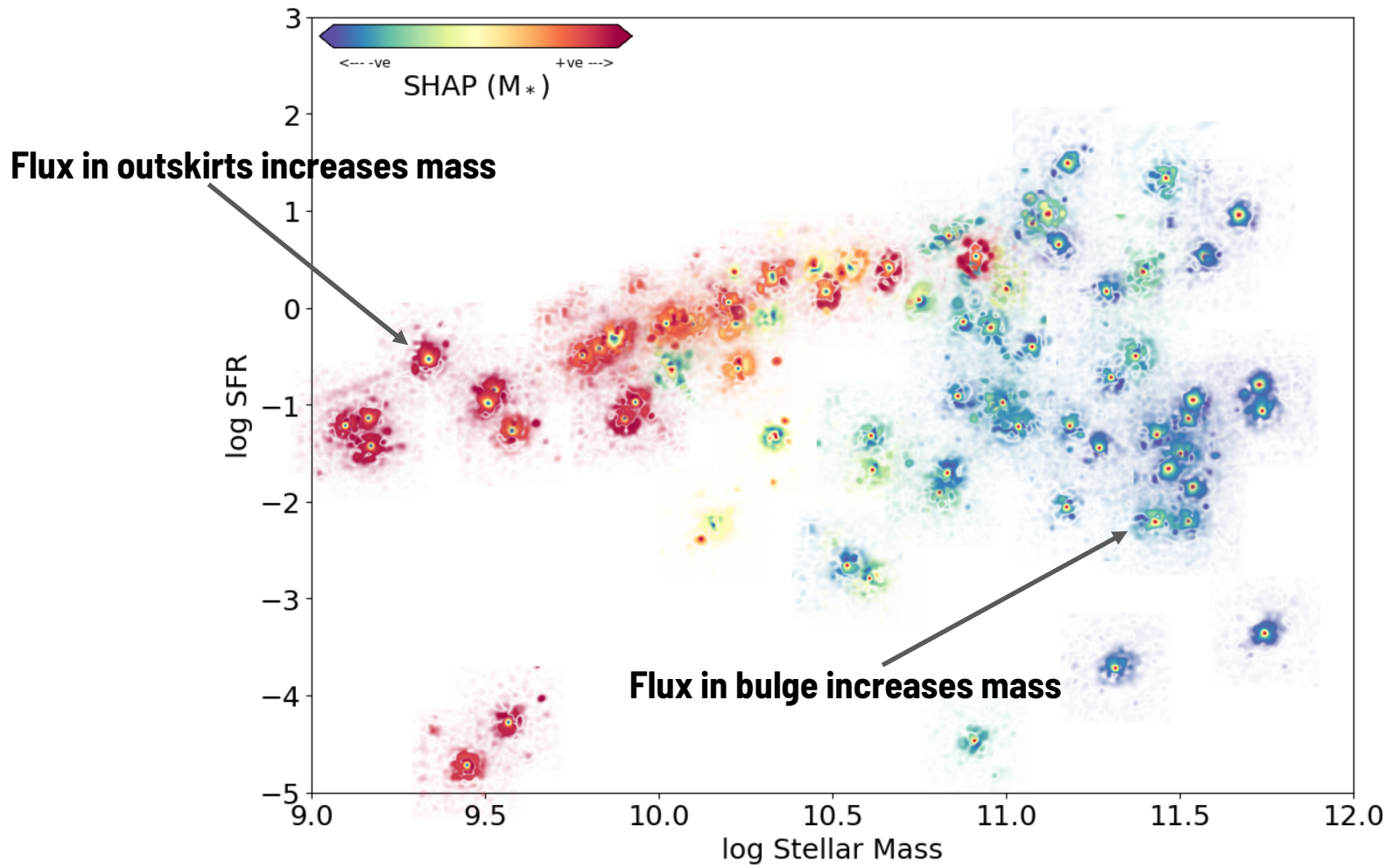
**Flux in the bulge in redder bands** reduce **SFR** and **increase t50** values



Alfonzo, KI et al. 2024 (ApJ) Katachi: <https://arxiv.org/abs/2404.05146>

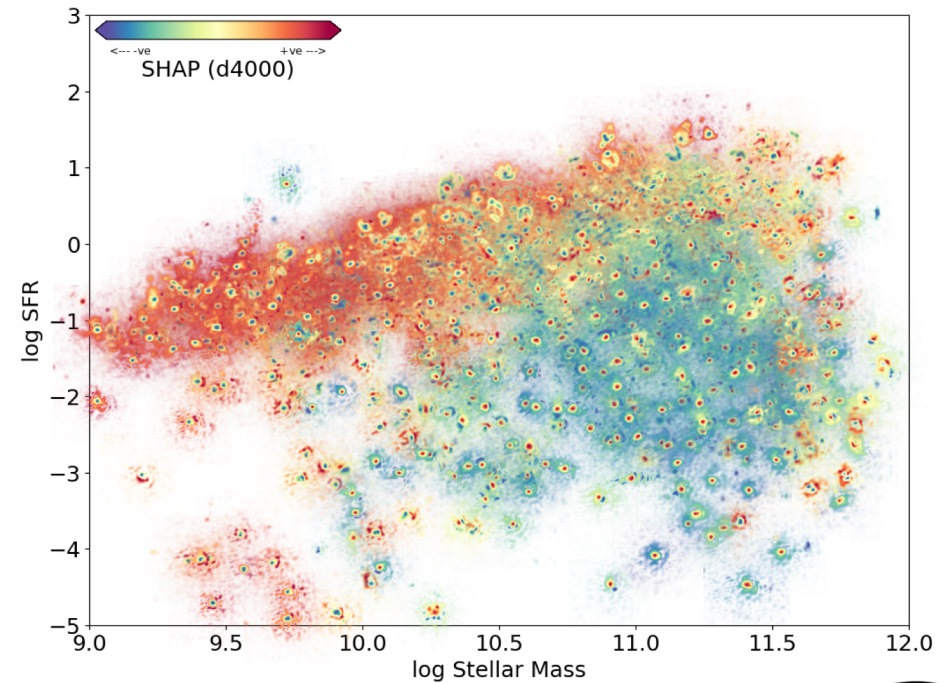
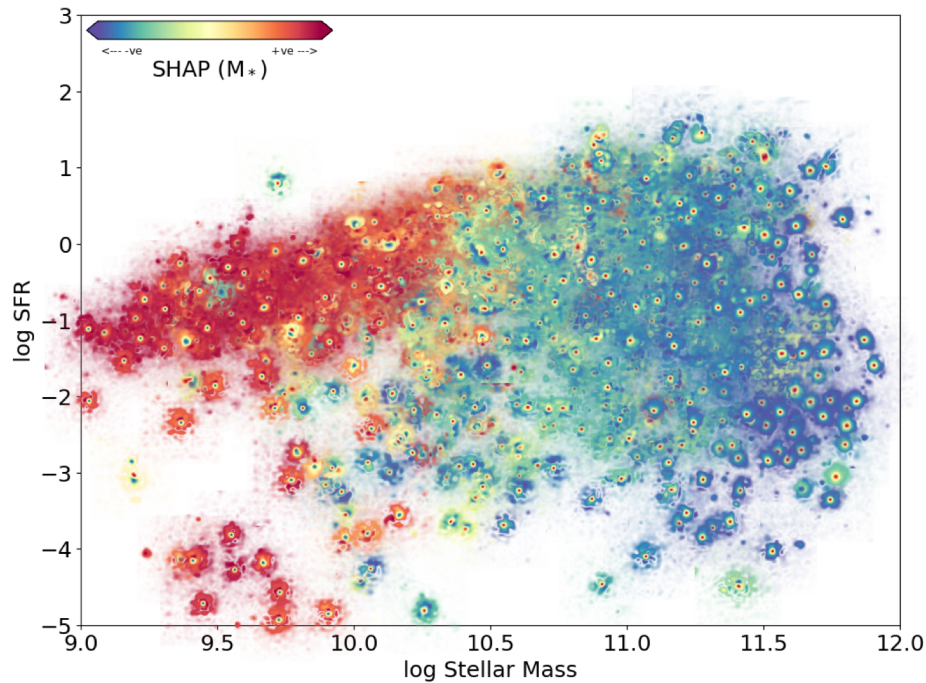


Alfonzo, KI et al. 2024 (ApJ) Katachi: <https://arxiv.org/abs/2404.05146>



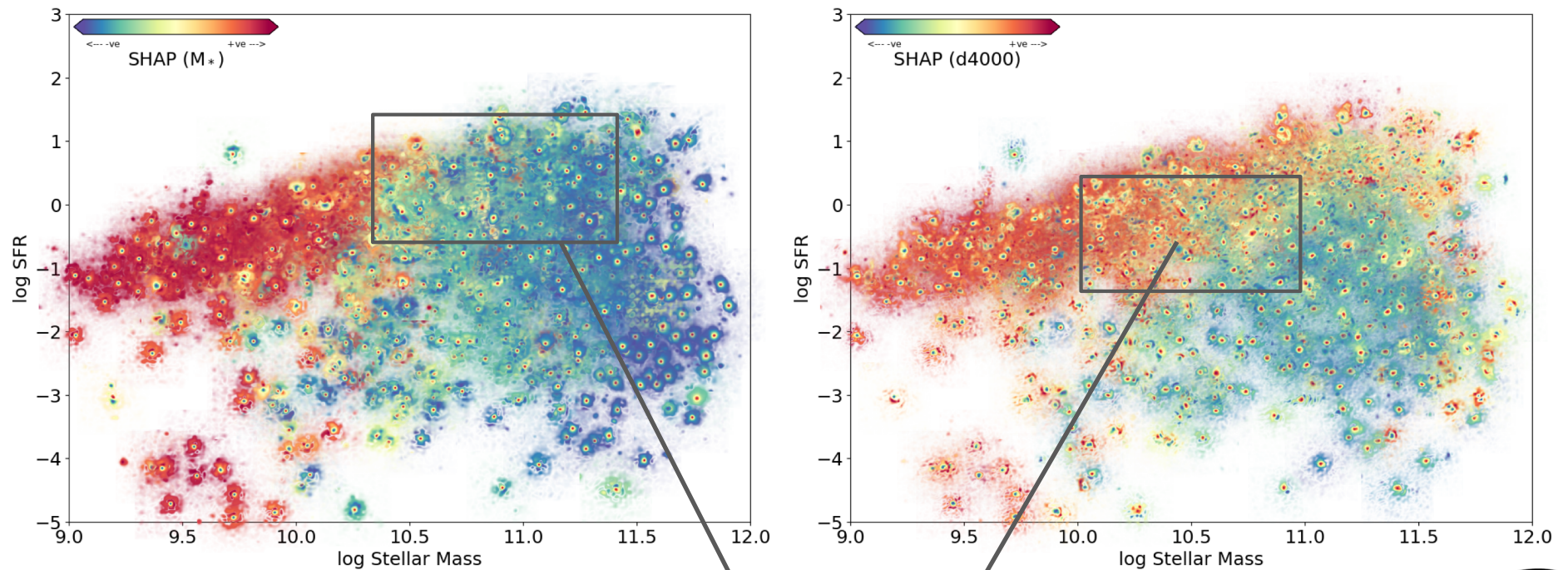
# decoding the *SFH-morphology connection* with SHAP

(Katachi | Alfonzo, Iyer et al. (2024) | ArXiv: 2404.05146)



# decoding the *SFH-morphology* connection with SHAP

(Katachi | Alfonzo, Iyer et al. (2024) | ArXiv: 2404.05146)



**Bulges that affect stellar mass but not age**

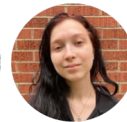




# LLM-assisted literature survey tools like Pathfinder help keep track of the ever-expanding astronomy literature & democratize research.

Iyer et al. (2024) *accepted in ApJS*, <https://pfd.r.app>

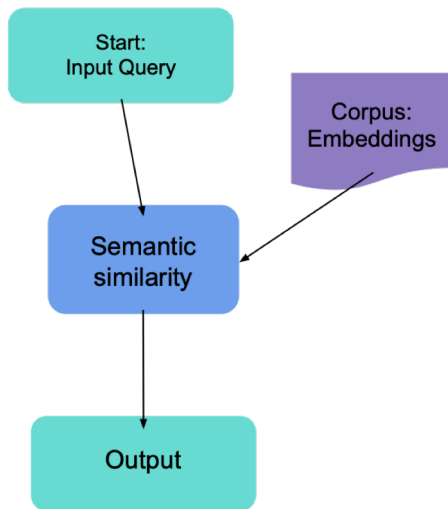
universeTED



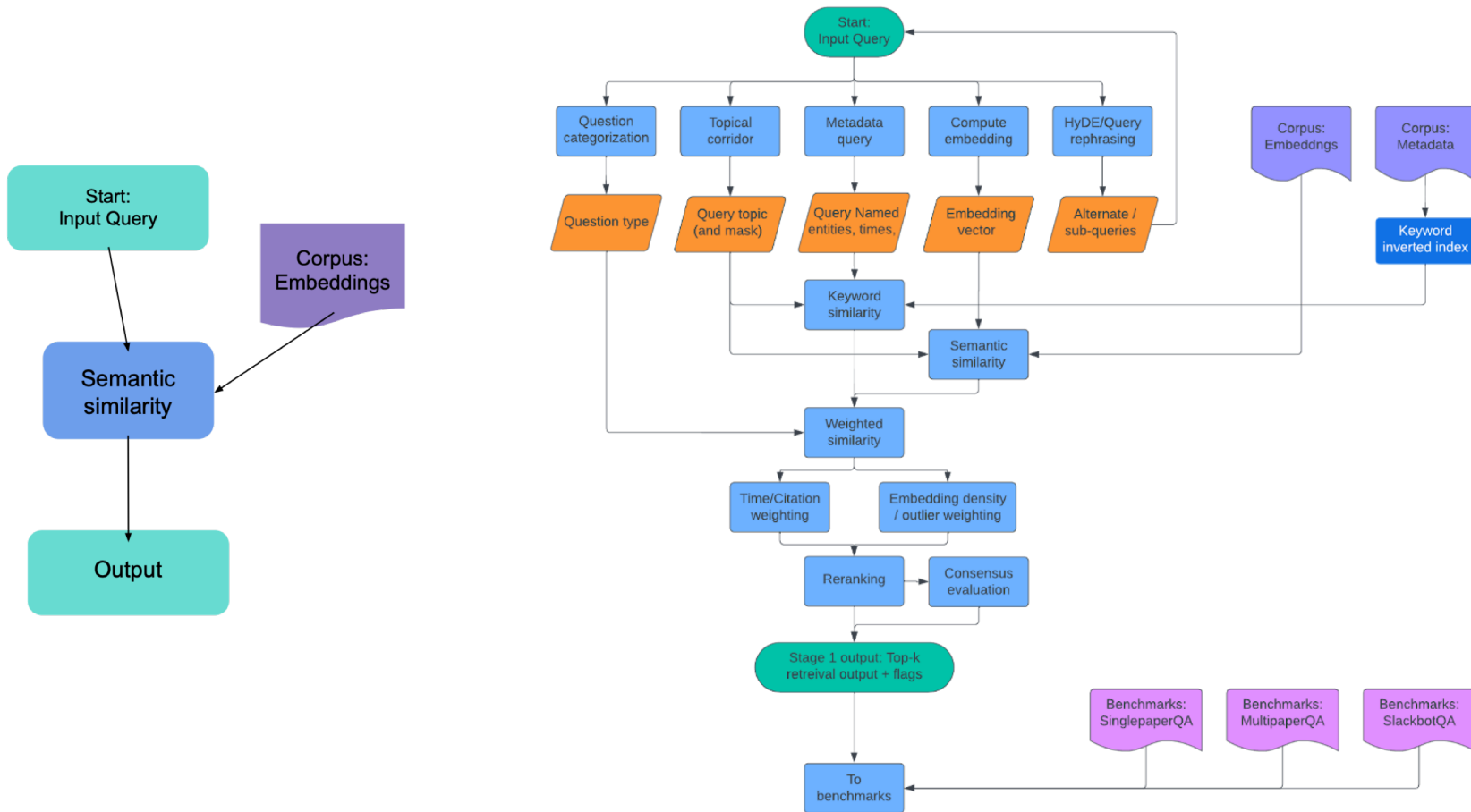
- > **citing everything relevant** is hard
- > **keeping track of new papers** is hard
- > **exploring new areas and jargon** is hard
- > **contextualizing new results with old** is hard
- > **synthesizing results across many papers** is hard
- > **finding a relevant reference for a specific statement** is hard



# What we had a year ago



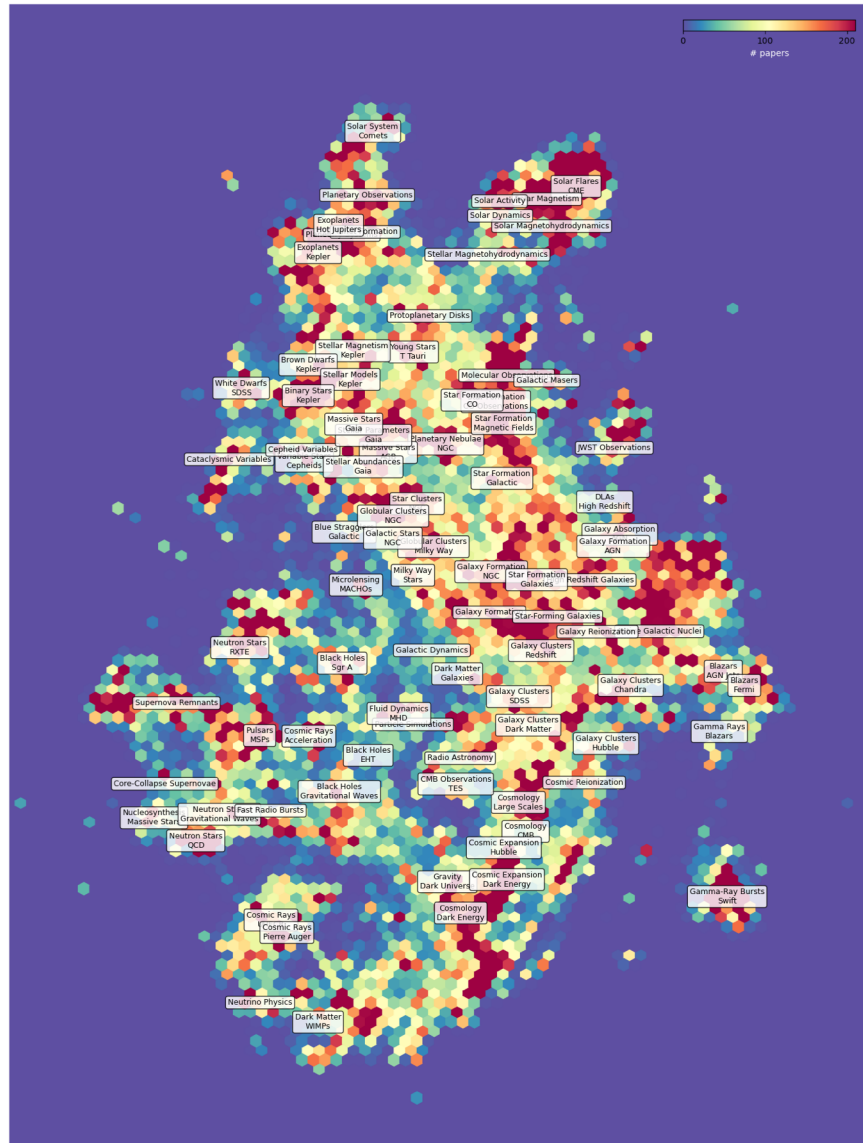
# ...and what we have now



# Building the corpus

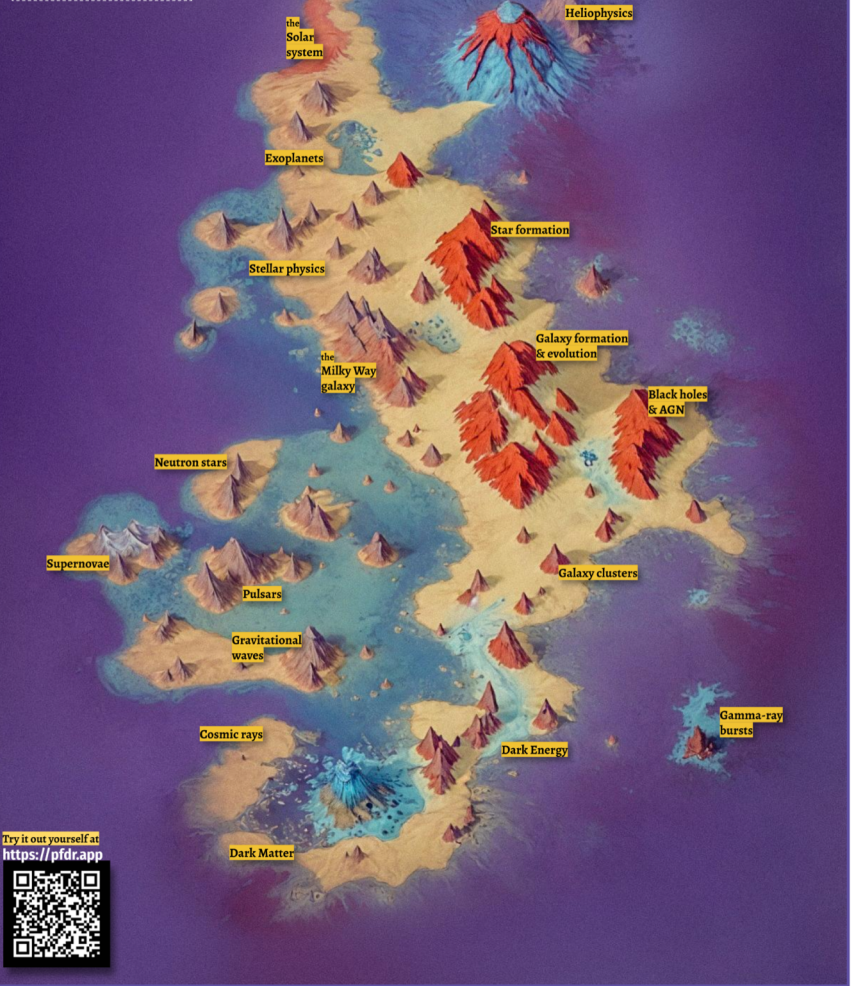
The screenshot shows the Hugging Face dataset viewer for 'kiyer/pathfinder\_arxiv\_data'. The browser address bar shows 'huggingface.co/datasets/kiyer/pathfinder\_arxiv\_data'. The page has tabs for 'Dataset card', 'Viewer', 'Files and versions', 'Community', and 'Settings'. The 'Dataset Viewer' section shows a split of 'train' with 352k rows. It includes a search bar and histograms for columns: 'ads\_id' (string, lengths 4-8), 'arxiv\_id' (string, lengths 8-25), 'title' (string, lengths 3-455), 'abstract' (string, lengths 1-9.28k), and 'embed' (sequence, lengths 1.54k-1.54k). A table of data rows is displayed with columns for 'ads\_id', 'arxiv\_id', 'title', 'abstract', and 'embed'. The right sidebar shows 'Downloads last month: 158', a 'Use this dataset' button, and statistics: 'Size of downloaded dataset files: 3.22 GB', 'Size of the auto-converted Parquet files: 3.22 GB', and 'Number of rows: 352,194'. A yellow callout box on the right contains the text: '~ 385k papers', 'Majority from specific journals (ApJ, MNRAS, A&A, ARAA, Nature), between 1990-Sep 2024'.

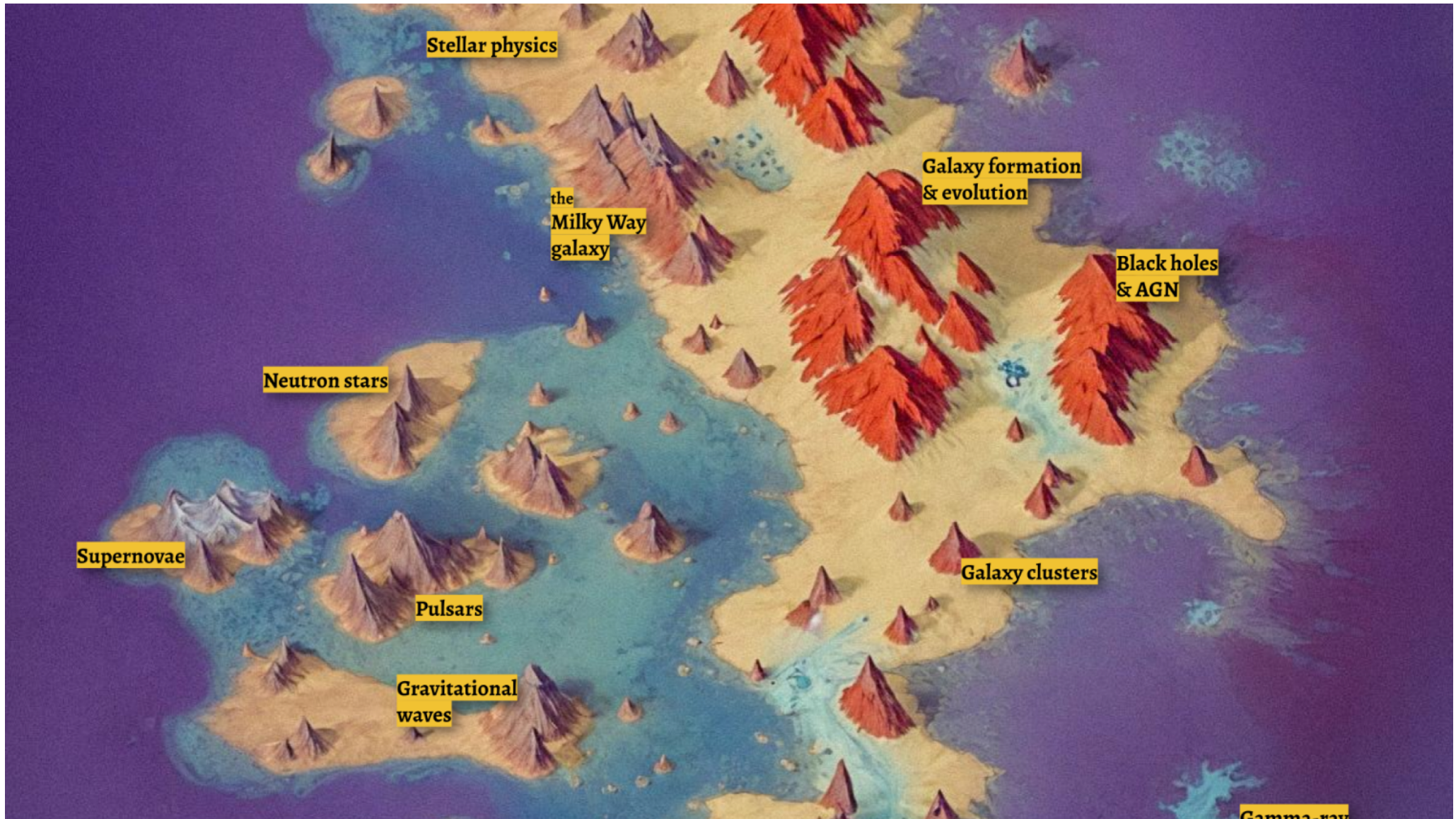
ads_id	arxiv_id	title	abstract	embed
12473133	1607.01526	Globular clusters as tracers of the...	The Fornax dwarf spheroidal galaxy is the most massive satellites of the Milky Way,...	[ 0.0 0.050]
5209849	1607.03009	Impacts of fragmented...	Context. The accretion process in classical T Tauri stars (CTTSs) can be studied...	[ 0.0 0.015]
12586989	1607.06240	Hybrid entropy stable HLL-type...	It is known that HLL-type schemes are more dissipative than schemes based on...	[ 0.0 0.020]
168897	1607.07246	Dynamics of Saturn's great...	Saturn's quasi-periodic planet-encircling storms are the largest convecting cumulus...	[ 0.0 0.020]
12408831	1607.07888	Observed Variability at 1...	We have monitored photometrically the Y0 brown dwarf WISEP J173835.52+273258.9...	[ -0.0 0.015]
12518466	1607.08820	"Dispersion by pulsars, magnetars...	"Our understanding of the universe relies mostly on electromagnetism. As photons are...	[ -0.0 16400]



# A map of the lands of astronomy papers

(astro-ph as on July 2024)  
Browse at <https://pfdi.app/>





Stellar physics

the  
Milky Way  
galaxy

Galaxy formation  
& evolution

Black holes  
& AGN

Neutron stars

Supernovae

Pulsars

Gravitational  
waves

Galaxy clusters

Gamma ray

Supernova

A map of the lands spanning  
galaxy evolution papers

© 2023 Phil G. et al. as on 27th June 2023  
https://arxiv.org/abs/2306.12345



Image: Farheit, Iyer & UniversitBD  
[https://img.galact.co/spaces/lyse/arxiv\\_gpr](https://img.galact.co/spaces/lyse/arxiv_gpr)

Pulsars

Gravitational waves

Galaxy formation & evolution

Black holes & AGN

Galaxy clusters

Gamma ray

# What can Pathfinder currently do?

Access pathfinder online at **pfd.r.app**

*Pathfinder: Papers in Astronomy Traced and Harnessed For INtelligent Discovery, Exploration, and Research?*

<https://arxiv.org/abs/2408.01556>

- > **Find similar papers** given a natural language query
- > **Synthesize information / answer questions** from paper abstracts
  - > **Fine tune search** by keywords/recency/citations
  - > **Explore** the landscape of astronomy literature
  - > **Translate, simplify and contextualize** results
- > **Quantify trends** in research, mission impact, and more





# Suites of cosmological simulations like CAMELS can reveal the **SFH-feedback connection** for large populations of galaxies.

Iyer et al. *in prep.* (for a really long time...)



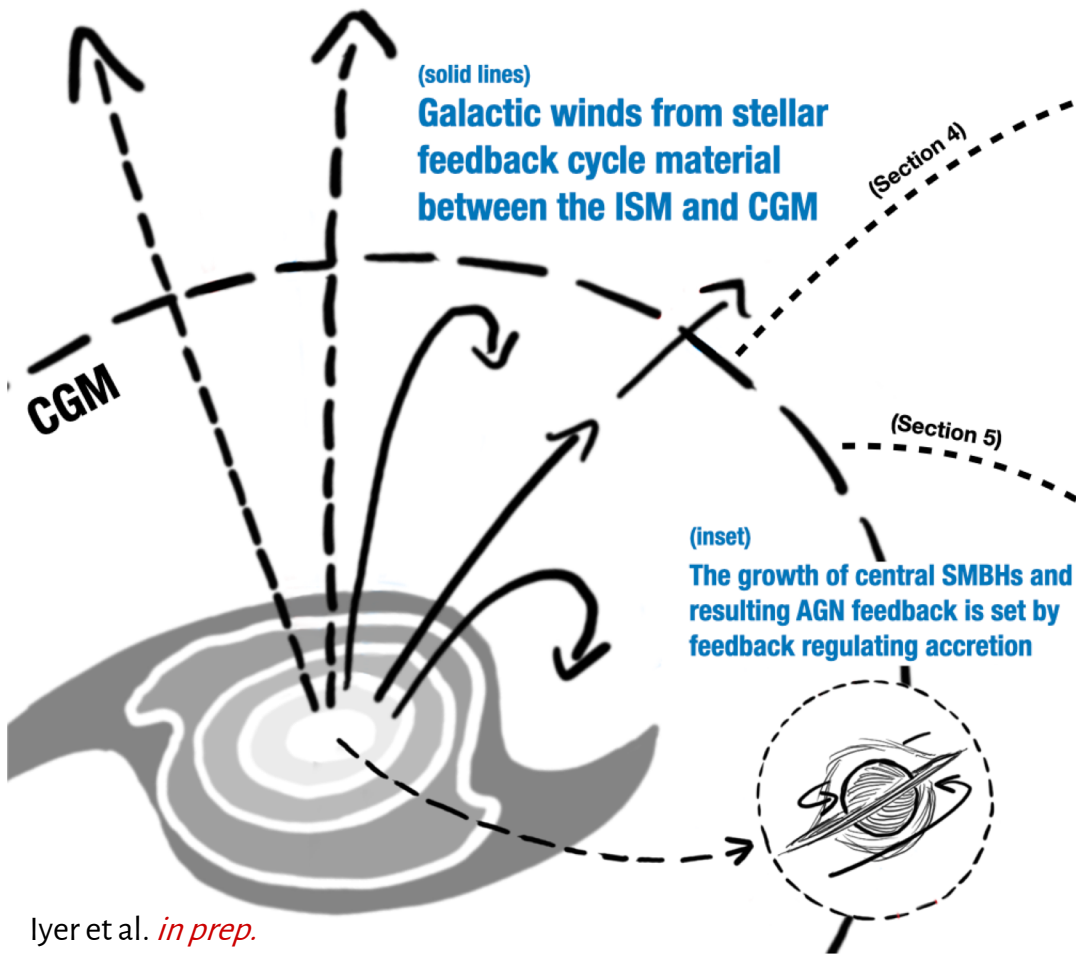
**CAMELS**



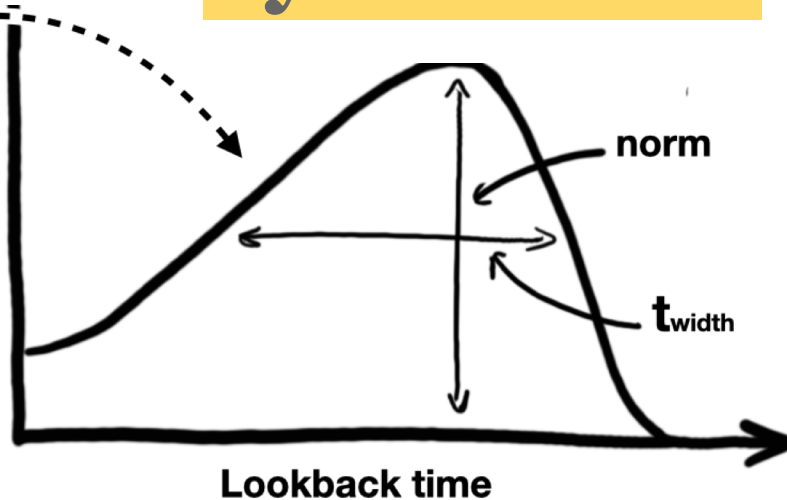
# how are SFHs affected by feedback?

(dotted lines)  
Extreme feedback from AGN jets  
drive material beyond the CGM

(solid lines)  
Galactic winds from stellar  
feedback cycle material  
between the ISM and CGM



Star formation rate



Baryon fraction  
(proxy for baryon cycling)

$M_{star}-M_{gas}$  ratio  
(proxy for SF efficiency)

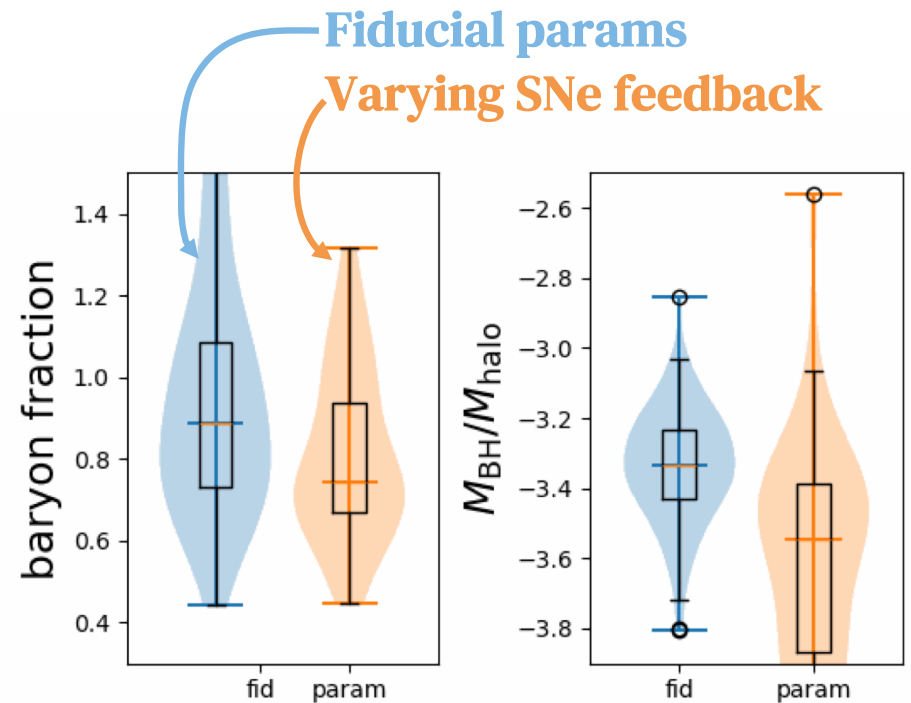
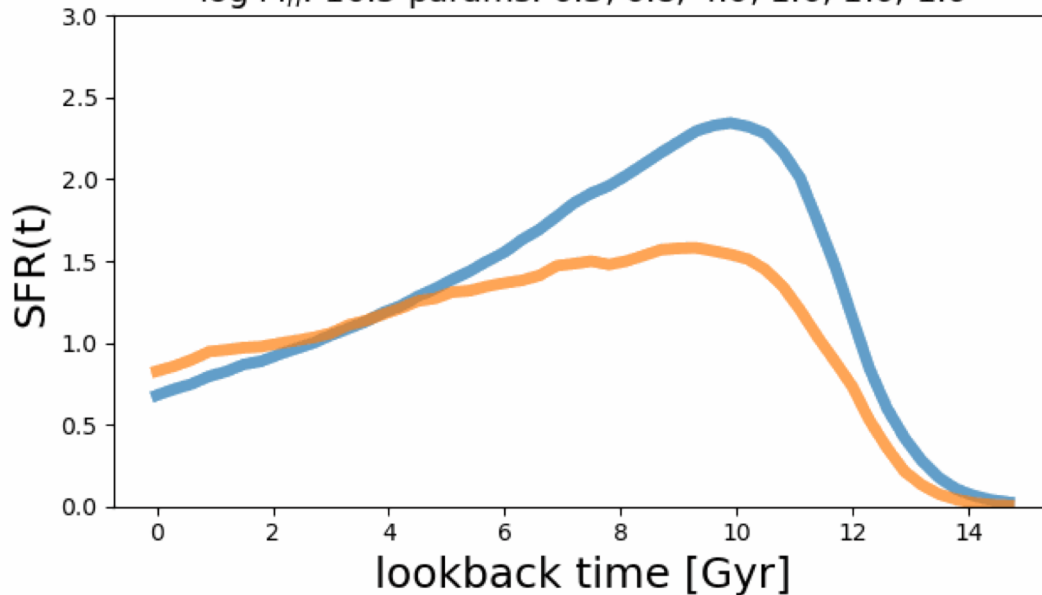
SMBH mass  
(proxy for BH growth)

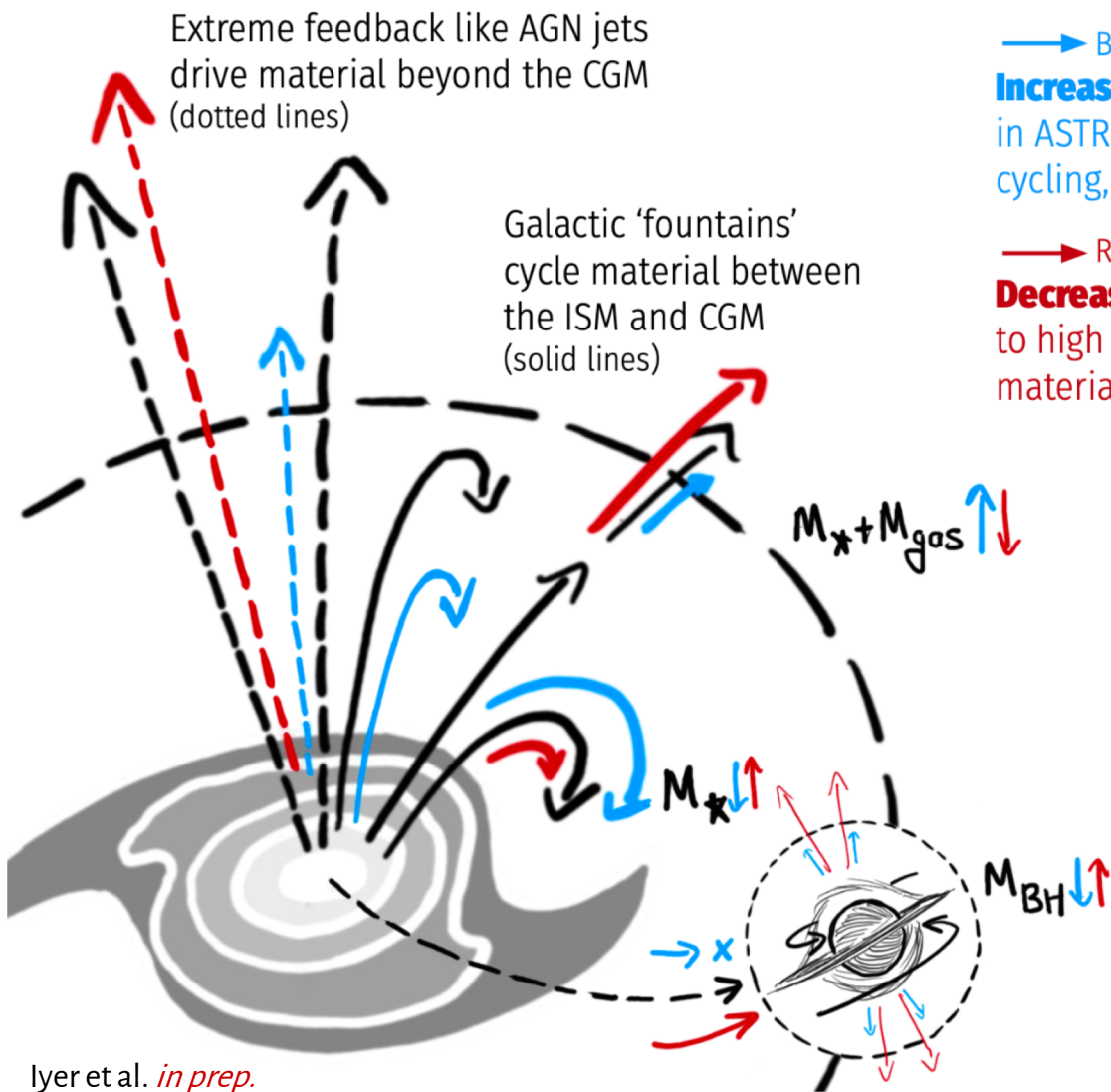
# case study: the impact of SNe *feedback*

(Iyer et al. *in prep.*, effect of feedback on the average CAMELS SFHs for galaxies with  $9.5 < \log M^* < 11.5$ )

CAMELS/TNG: Decreasing the amount of energy per unit SFR

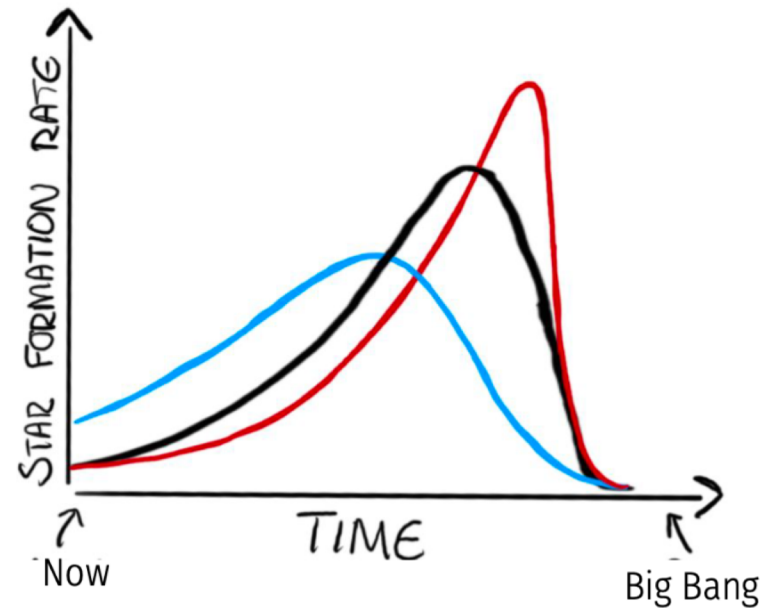
$\log M_h$ : 10.5 params: 0.3, 0.8, 4.0, 1.0, 1.0, 1.0





→ Blue arrows  
**Increasing** energy from feedback (e.g. higher  $ASN_1$  or  $AGN_2$  in ASTRID) can inhibit BH growth and promote baryon cycling, leading to lower SFR over extended periods of time

→ Red arrows  
**Decreasing** energy from feedback (e.g. lower  $ASN_1$ ) can lead to high SFR at early times and earlier SMBH growth, ejecting material from the CGM and quenching the galaxy earlier





Spectral modeling tools like **dense basis** can be used to observationally constrain galaxy SFHs.

Iyer et al. (2019), [dense-basis.readthedocs.io](https://dense-basis.readthedocs.io)



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star formation on parsec scales at  $z=8.3$

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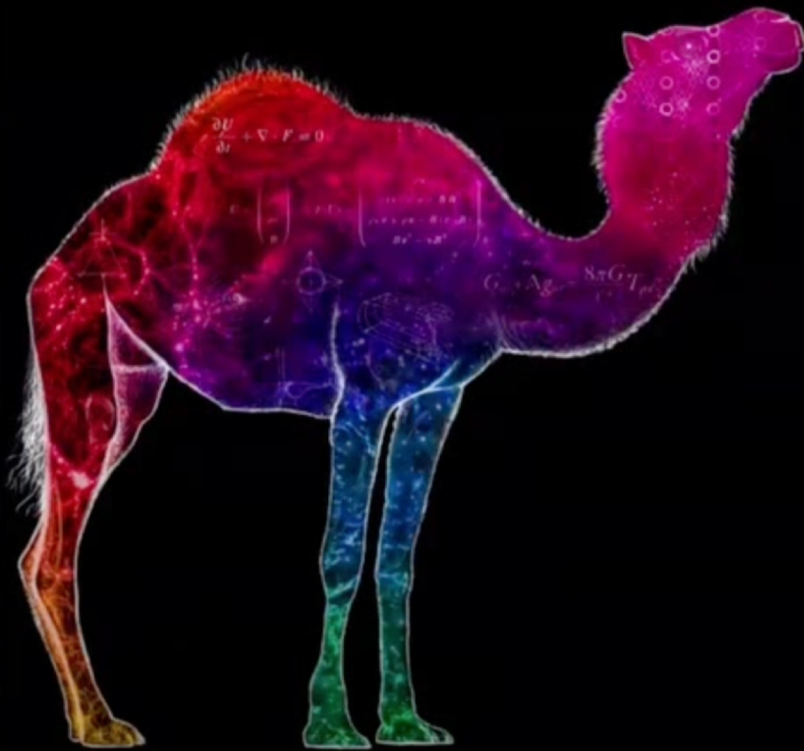
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Iyer et al. (*in prep.*)

✉ [kgi2103@columbia.edu](mailto:kgi2103@columbia.edu)  
🐙 [github.com/kartheikiyer](https://github.com/kartheikiyer)

# CAMELS

<https://www.camel-simulations.org>



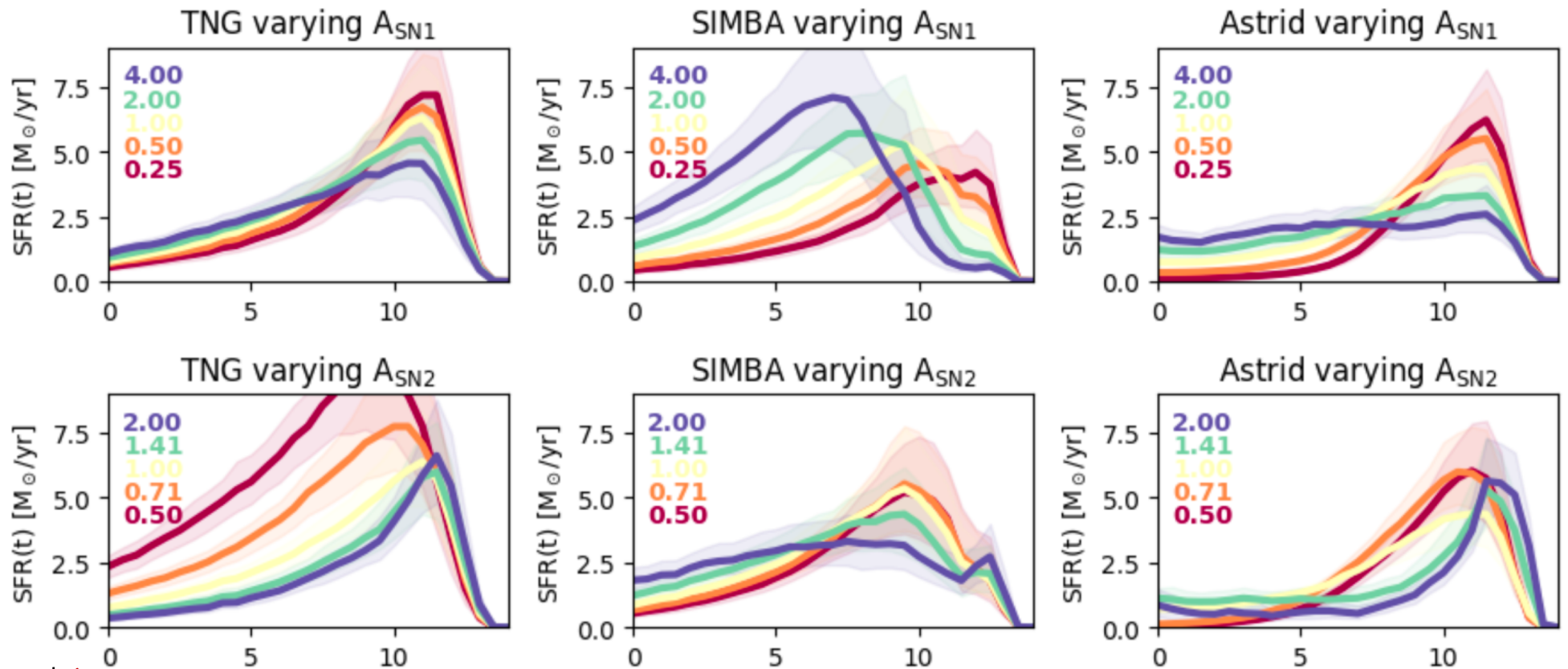
## Cosmology and Astrophysics with Machine Learning Simulations

- A suite of 4,233 simulations
- 2,049 N-body; Gadget-III
- 2,184 state-of-the-art (magneto-)hydrodynamic sims
- AREPO/IllustrisTNG + GIZMO/SIMBA
- 6 parameters:  $\{\Omega_m, \sigma_8, A_{SN1}, A_{SN2}, A_{AGN1}, A_{AGN2}\}$
- More than 100 billion resolution elements over combined volume of  $\sim(400 \text{ Mpc}/h)^3$
- More than 2,000 cosmologies & astrophysics models; more than 140,000 snapshots
- Designed for machine learning applications

Slide credit: Francisco Villaescusa-Navarro

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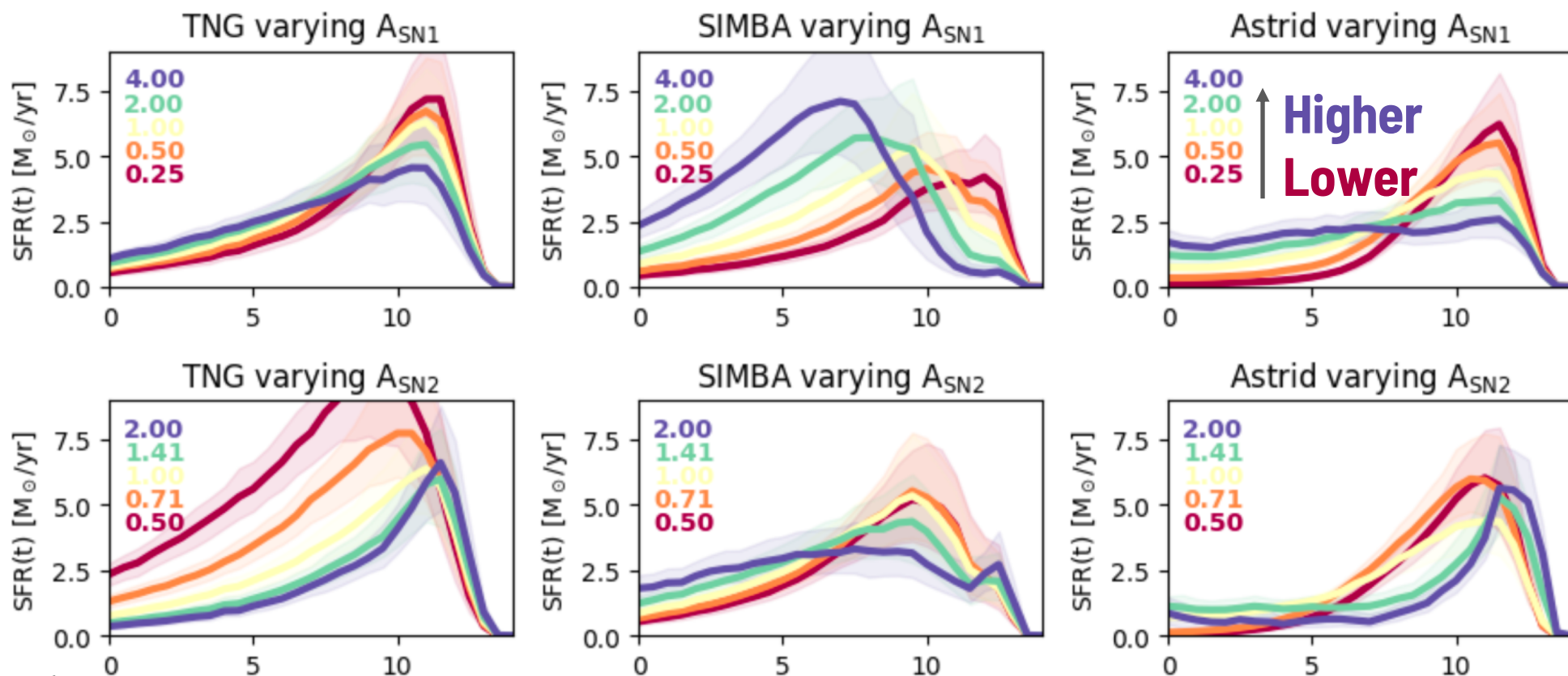


Iyer et al. *in prep.*



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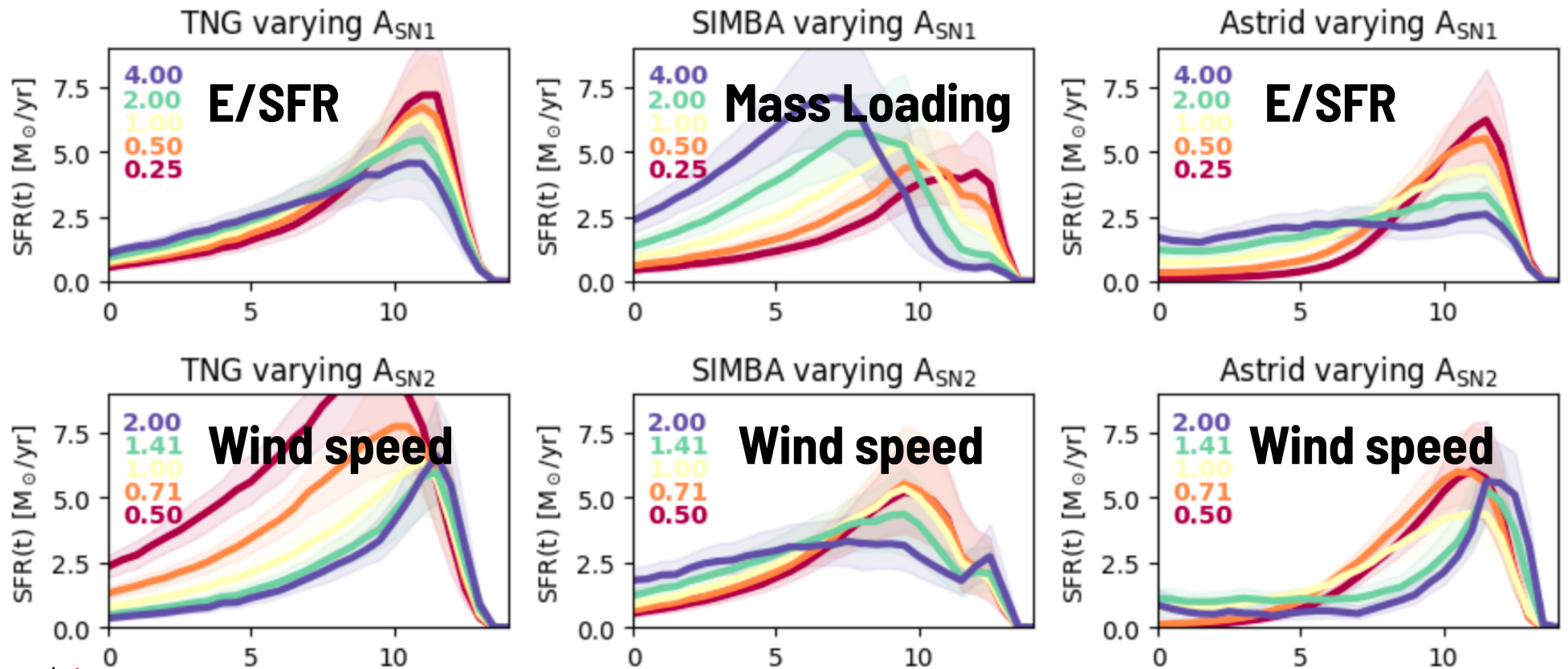
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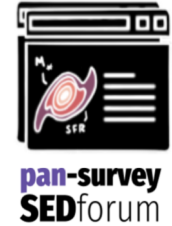


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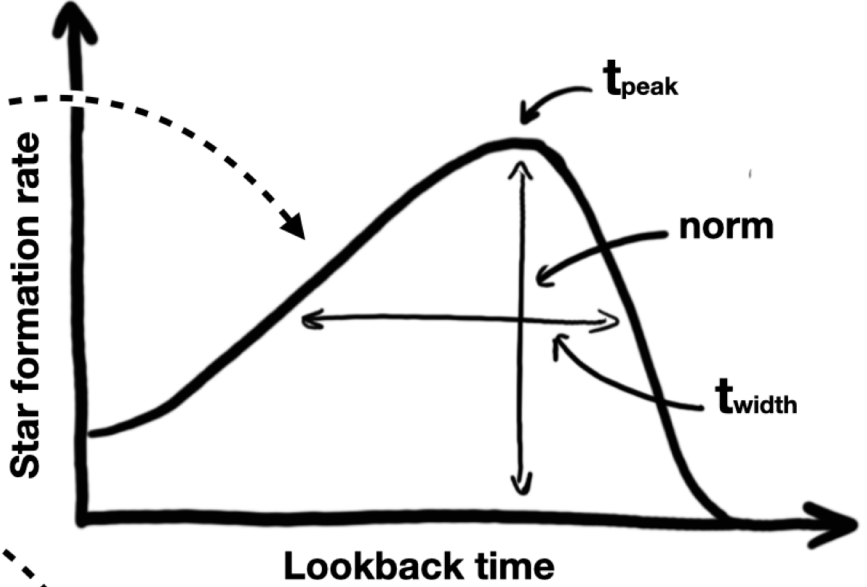
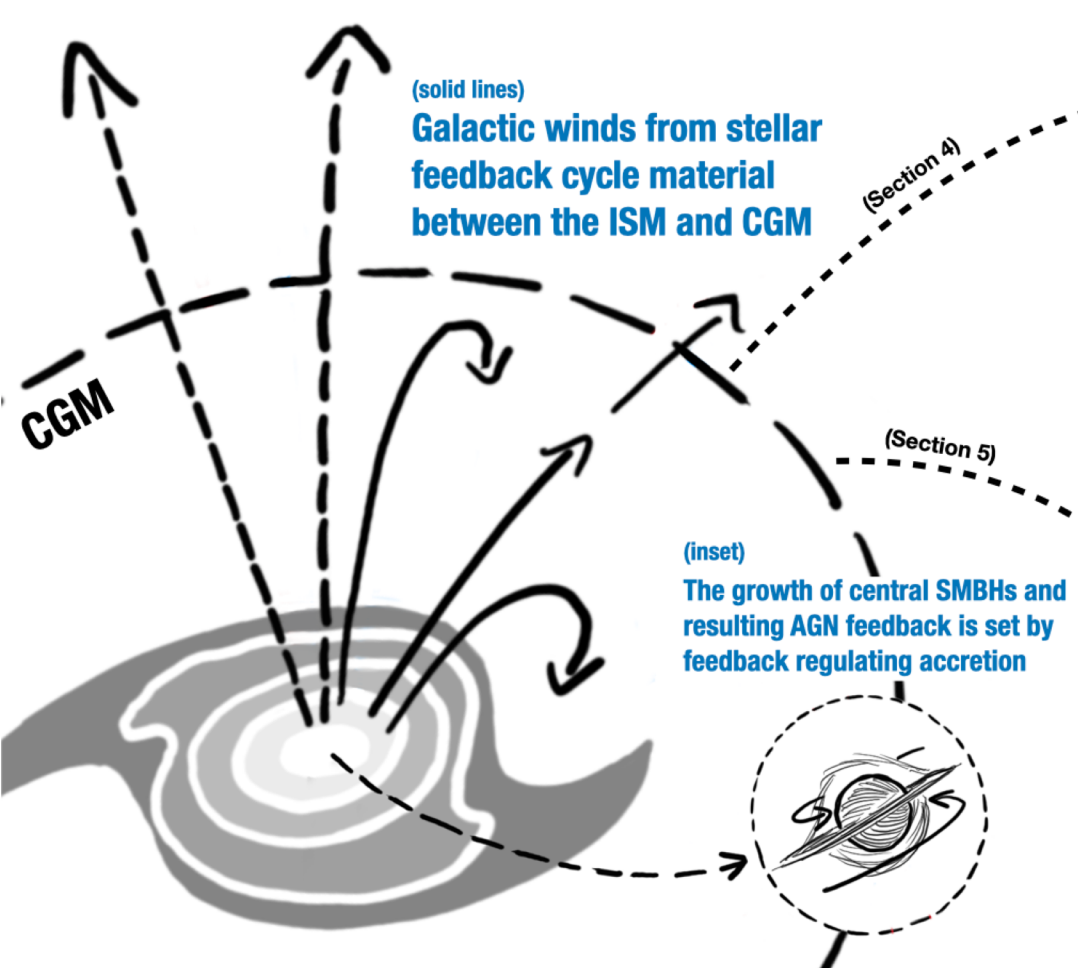
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# How does feedback affect galaxy SFHs?

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Extreme feedback from AGN jets  
drive material beyond the CGM

(solid lines)  
Galactic winds from stellar  
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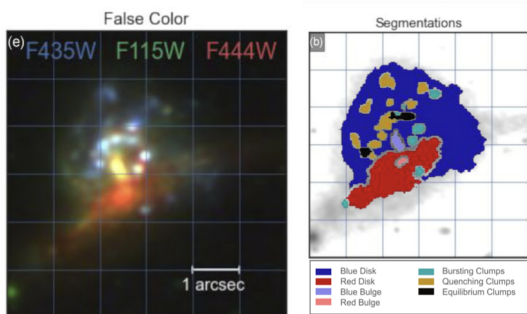
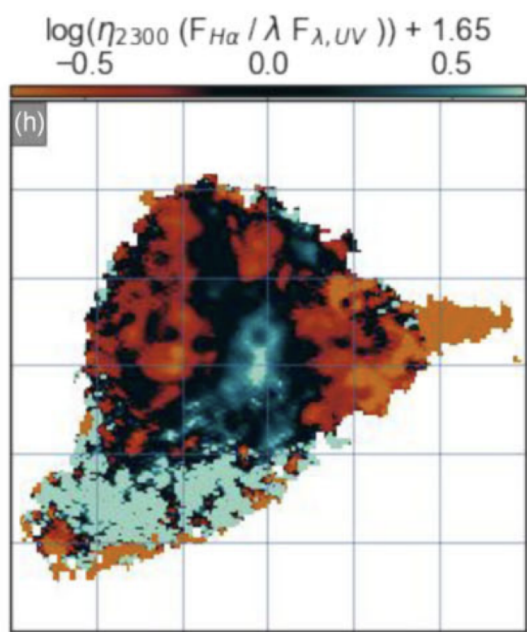
(inset)  
The growth of central SMBHs and  
resulting AGN feedback is set by  
feedback regulating accretion

Baryon fraction  
(proxy for baryon cycling)

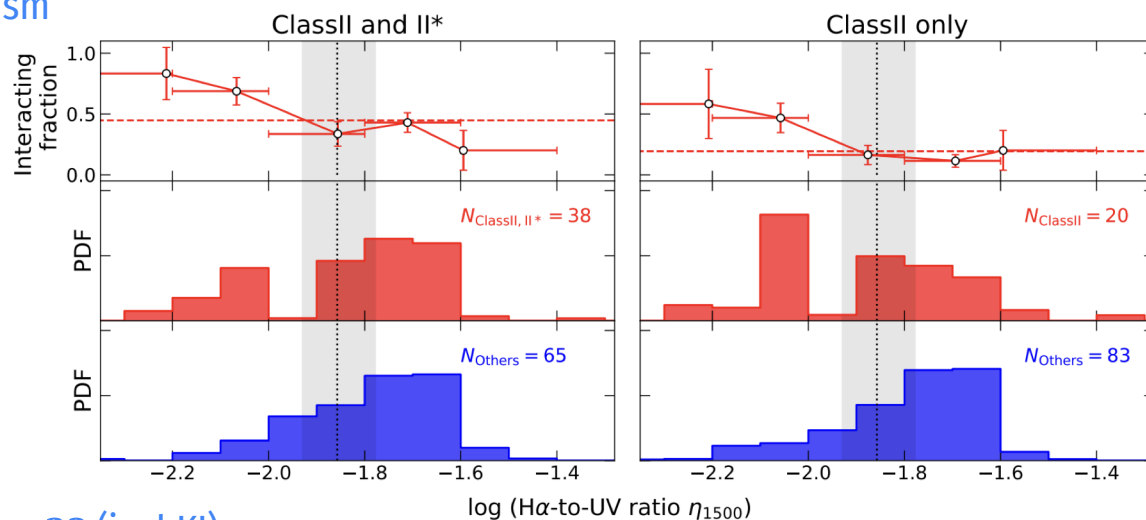
$M_{\text{star}}-M_{\text{gas}}$  ratio  
(proxy for SF efficiency)

SMBH mass  
(proxy for BH growth)

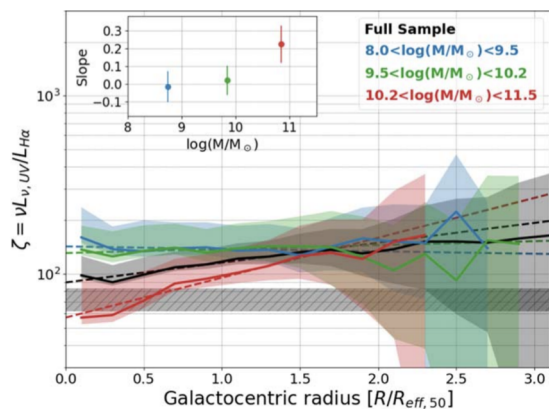
## Estrada-Carpenter+24 (incl KI) Spatially resolved burstiness with NIRISS Grism



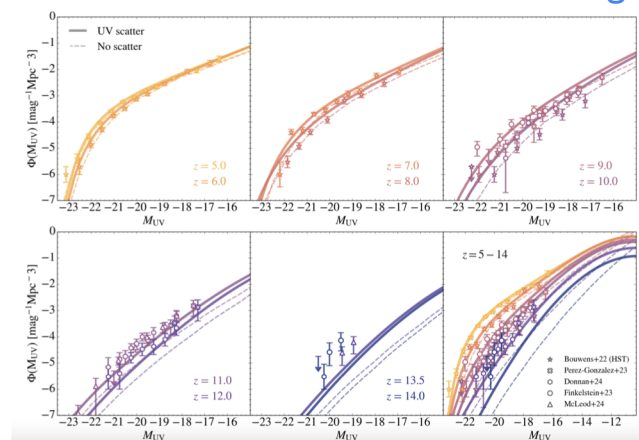
## Asada+23b (incl KI) Burstiness <-> Interactions in CANUCS



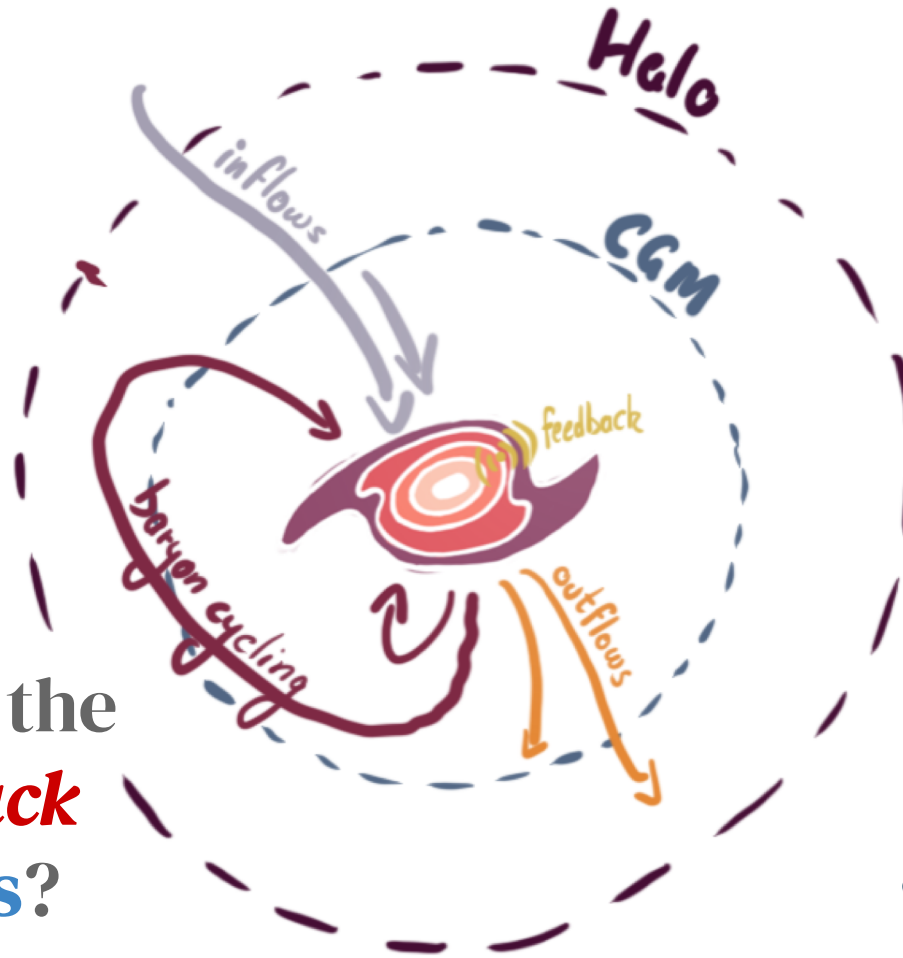
## Mehta+23 (incl KI) burstiness vs radius in UVCANDELS



## Gelli+24 burstiness -> UVLFs at high-z



(how)  
can we constrain the  
impacts of *feedback*  
using galaxy SFHs?



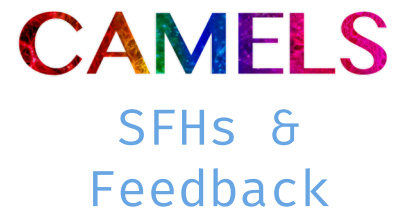
Kartheik Iyer @ Hubble Symposium @ Caltech  
NHFP Hubble Fellow | Columbia University

 COLUMBIA UNIVERSITY  
IN THE CITY OF NEW YORK



 FLATIRON  
INSTITUTE  
Center for Computational  
Astrophysics





clsp.jhu.edu/evaluating-llm-performance-in-research-astronomy/

JOHNS HOPKINS  
WHITING SCHOOL  
of ENGINEERING

CENTER FOR LANGUAGE  
AND SPEECH PROCESSING

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### Evaluating LLM Performance in Research Astronomy

Large language models (LLMs) are being used not only for common-knowledge information retrieval, but also for specialized disciplines such as cutting-edge astronomical research. However, in specialized domains, we lack robust, realistic, and user-oriented evaluations of LLM capabilities. Human evaluations are time-intensive, subjective, and difficult to reproduce, while automated metrics like perplexity or task benchmarks fail to reflect realistic performance. We seek to advance understanding of LLM capabilities for supporting scientific research through user-centric analysis and the development of robust evaluation standards; while we expect outputs from this workshop to be generalizable, we will focus on astronomy. Astronomy has open data and a vibrant and active community that is open to partnering in the design, experimentation, and evaluation processes. The primary goal of the workshop is to develop a quantifiable metric or objective function for evaluating LLMs in astronomy research, thereby taking humans out of the evaluation loop. A secondary goal is to understand how the evaluation criteria for a specialized use case (astronomy) compares to the evaluation criteria for typical English conversations. Our proposal will explore the first step toward a lofty goal: how can AI transform science for the better, by first evaluating what it means to be better.

Subscribe to the CLSP Seminars Mailing List

UPCOMING SEMINARS

SEP 6 Fri 12:00 pm Pengtao Xie (UCSD)  
"Foundation M... @ Hackerman Hall B17

Add View Calendar

Slide credit: JSALT team

# Design and data collection for evaluation

Slack chatbot experiment lasted 4.5 weeks, during which we collected some valuable user data from astronomers.

Paper to be submitted to *Machine Learning: Science & Technology (MLST)* and *NeurIPS EvalEval* workshop

Slide credit: JSALT team

**Thread** ai-agents

**John Wu** 10 days ago  
[@Ask astro-ph](#) How can compressed sensing be used for image deconvolution in radio interferometry?

2 replies

**Ask astro-ph** APP 10 days ago  
Compressed sensing (CS) can be used for image deconvolution in radio interferometry by leveraging its ability to reconstruct sparse or compressible signals from incomplete and noisy Fourier measurements. CS techniques involve formulating the deconvolution problem as a global minimization problem, which is then solved using convex or non-convex optimization methods. These methods can incorporate specific prior information about the signal, such as sparsity in a particular basis, to improve reconstruction quality. Recent advancements include joint calibration and imaging methods that account for direction-dependent effects, enhancing the fidelity of reconstructed images (e.g., [1701.03689](#), [1406.0359](#)).

2 1

# Understanding user-LLM interactions

## 37 Users (astronomers)

### 378 User queries

→ 269 in channel

→ 109 direct message

### 342 Emoji reactions

### 263 Feedback/comments

### 373 Retrievals

Conducted detailed interview study with astronomers

Writing paper to be submitted to *Conference on Human Factors in Computing Systems (CHI)*

Releasing anonymized user interaction data (Slack chatbot)

## RQ2: What features do scientists seek or expect in a ChatBot for interacting with academic literature?

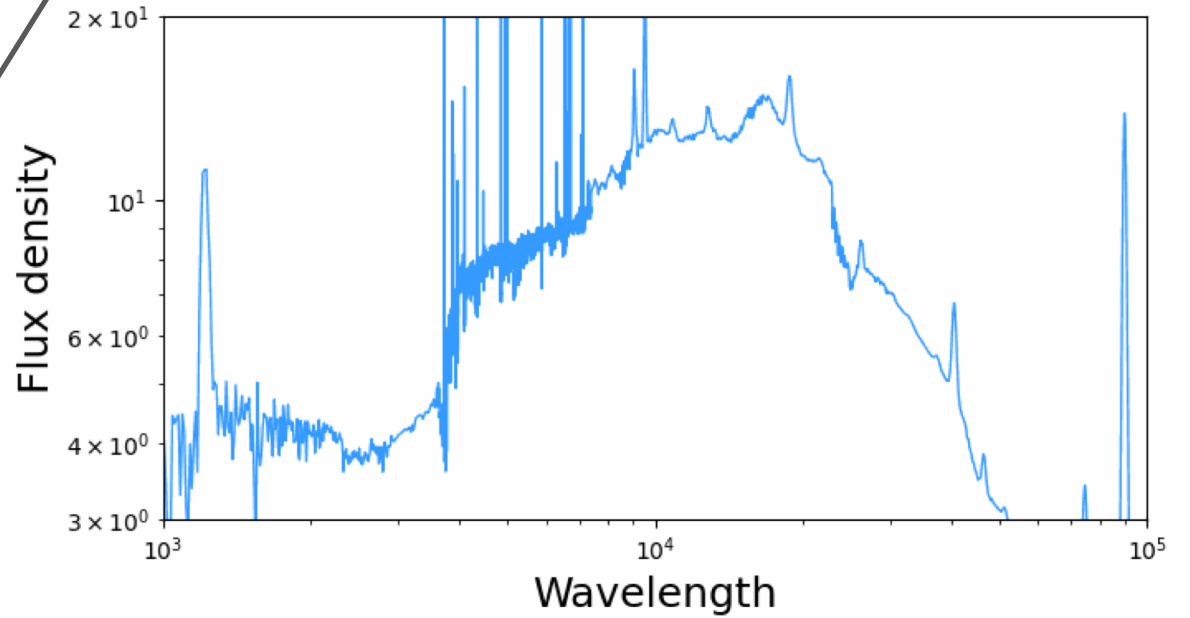
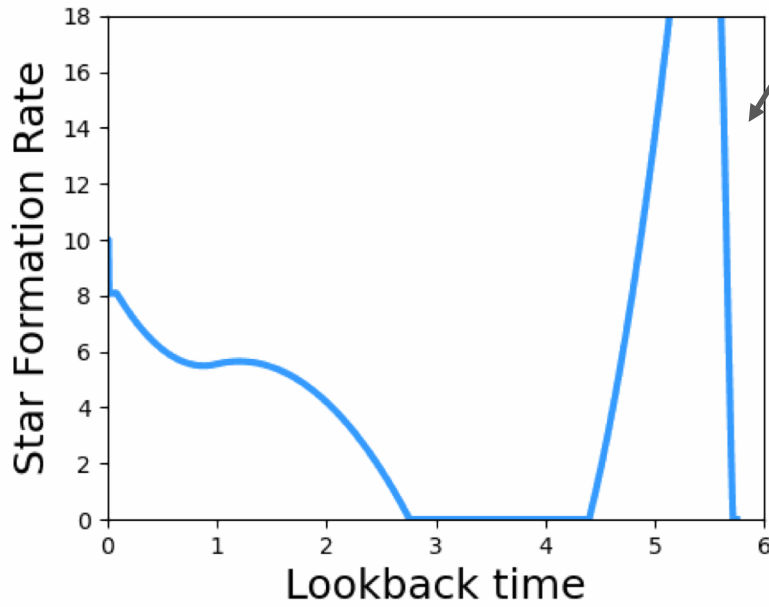
- Generation capabilities
  - **Specificity of answer**
  - Fluency of natural language
  - **Extra formatting capabilities (language translation, poems, rap)**
  - General correctness
  - **Interpret or synthesize knowledge**
  - **Critique**
  - **Graceful refusal**
  - **Expression of Confidence**
  - Personalization
  - Surprise Discovery Factor
  - Understanding different technical notations
  - Agent like capabilities
  - Chat with context (multi-turn)
- Retrieval capabilities
  - **Meta-data incorporation**
  - **Quality of retrieved citations**
  - **Completeness**

Maybe in the future?!

Beyond our intentions  
for this tool

Sampling in  $\{t_x\}$  space  
(at fixed mass and SFR)

$$\text{SFH} = (M_*, \text{SFR}, \{t_x\})$$

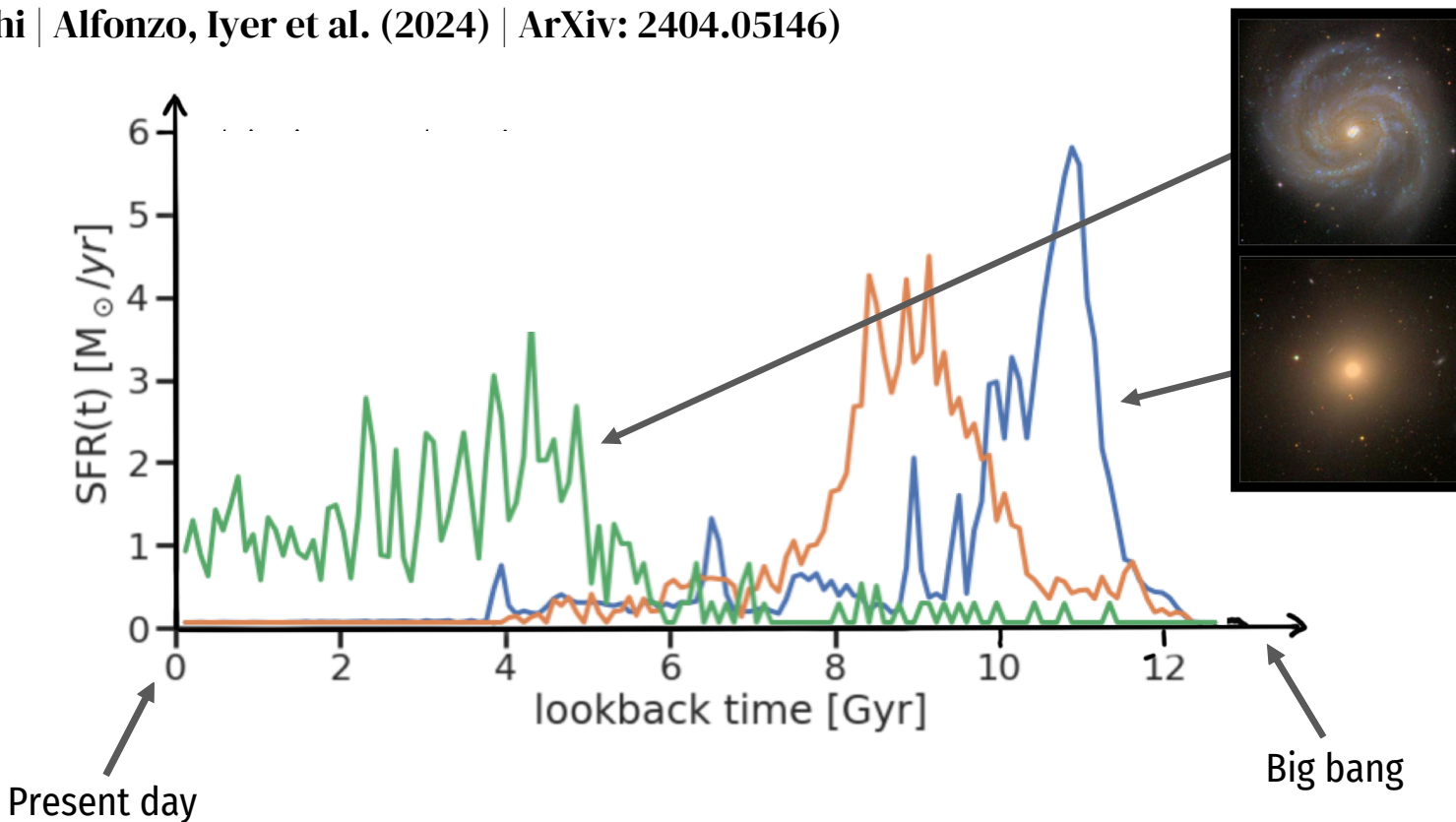


# What is the link between galaxy morphology and star formation histories?

(Katachi | Alfonzo, Iyer et al. (2024) | ArXiv: 2404.05146)

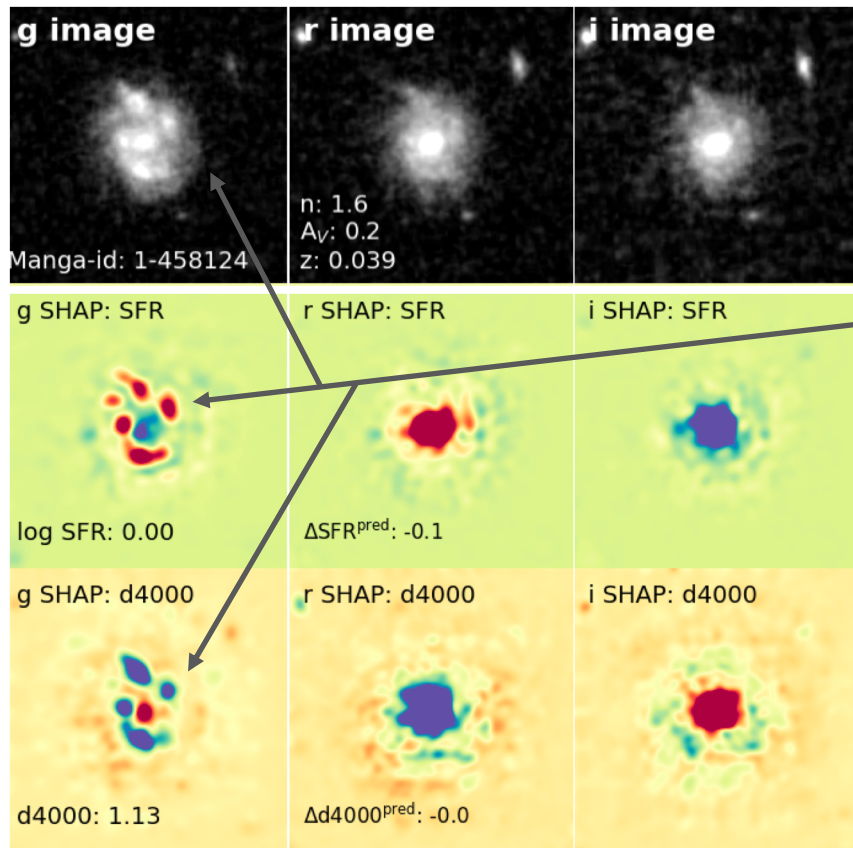
Juan Alfonzo (Tohoku U)

juanpabloalfonzo@astr.tohoku.ac.jp



# decoding the *SFH-morphology connection* with SHAP

(Katachi | Alfonzo, Iyer et al. (2024) | ArXiv: 2404.05146)



**SHAP** - SHapley Additive Analysis (Lundberg & Lee '17)

**Red:** more flux here increases parameter estimate

**Blue:** more flux here decreases parameter estimate

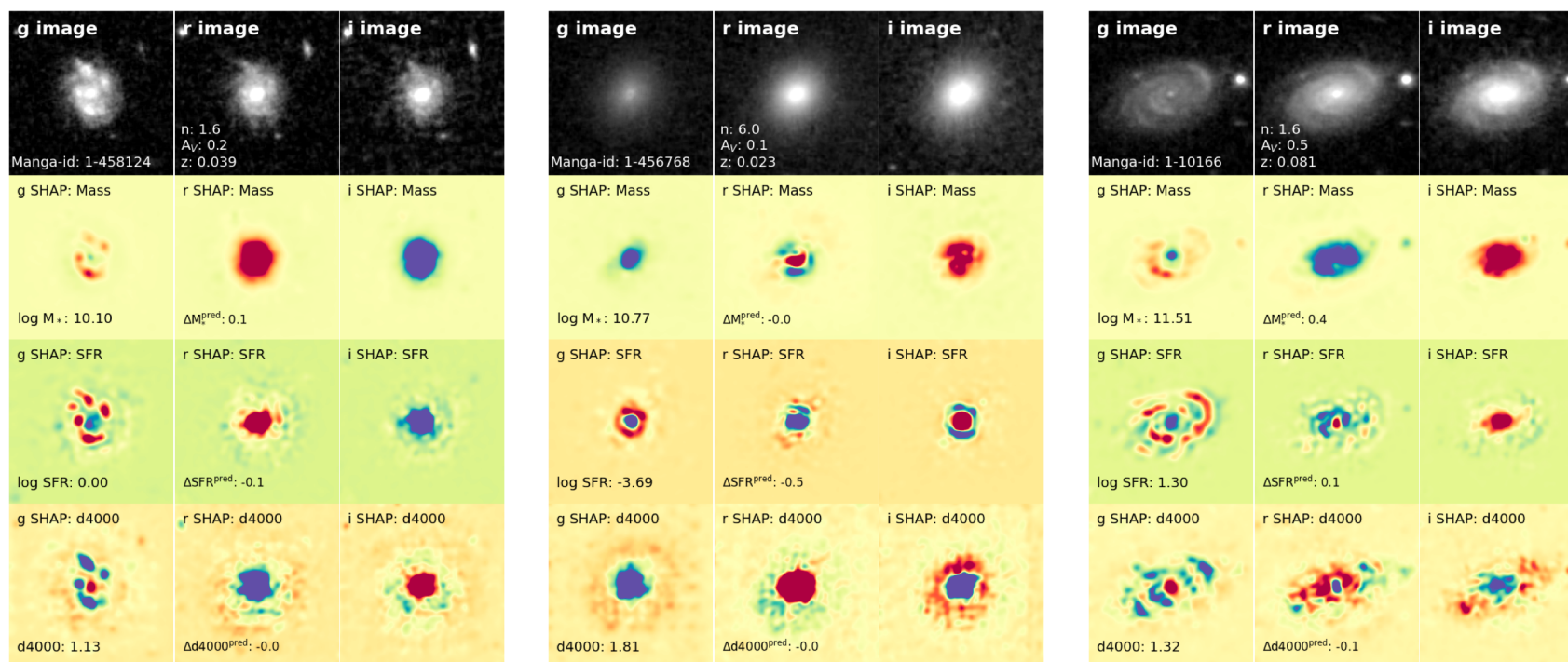
**Star forming clumps in the bluer band** drive the network to **higher SFR** and **lower t50** values





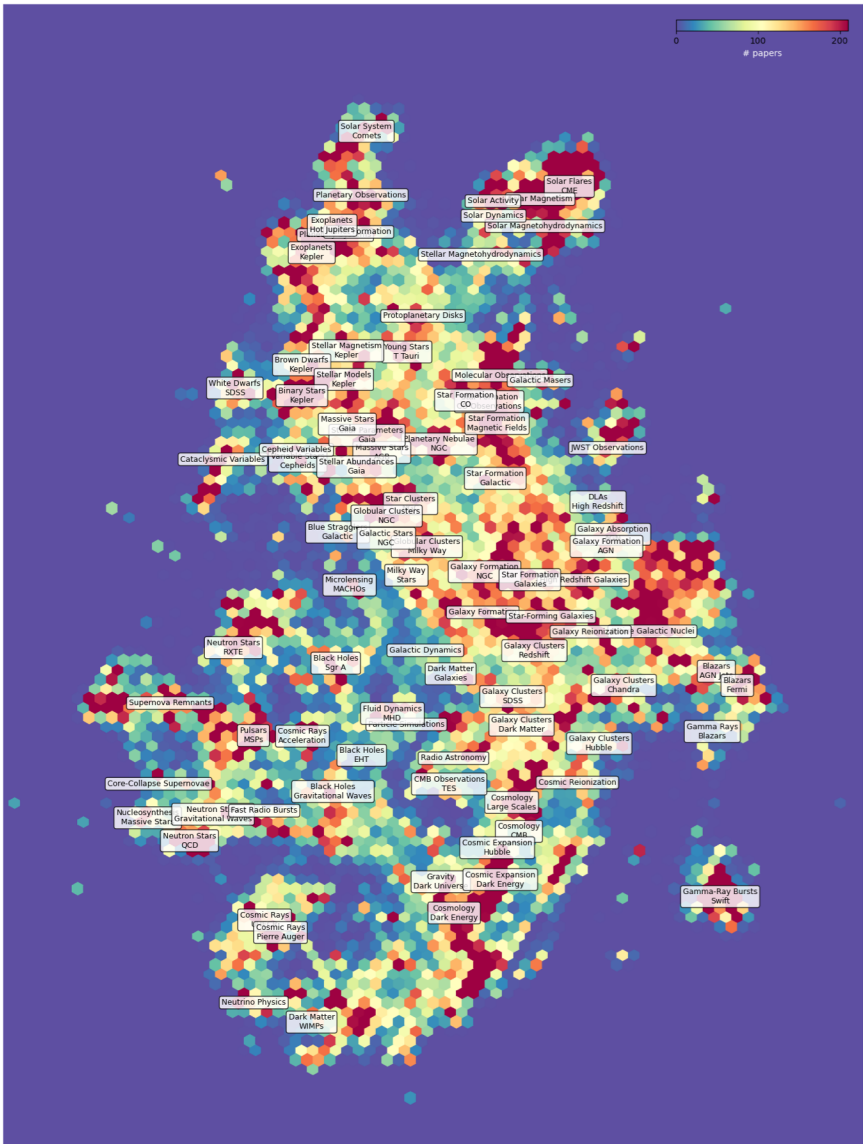
# generalizing across multiple galaxy types

(Katachi | Alfonzo, Iyer et al. (2024) | ArXiv: 2404.05146)



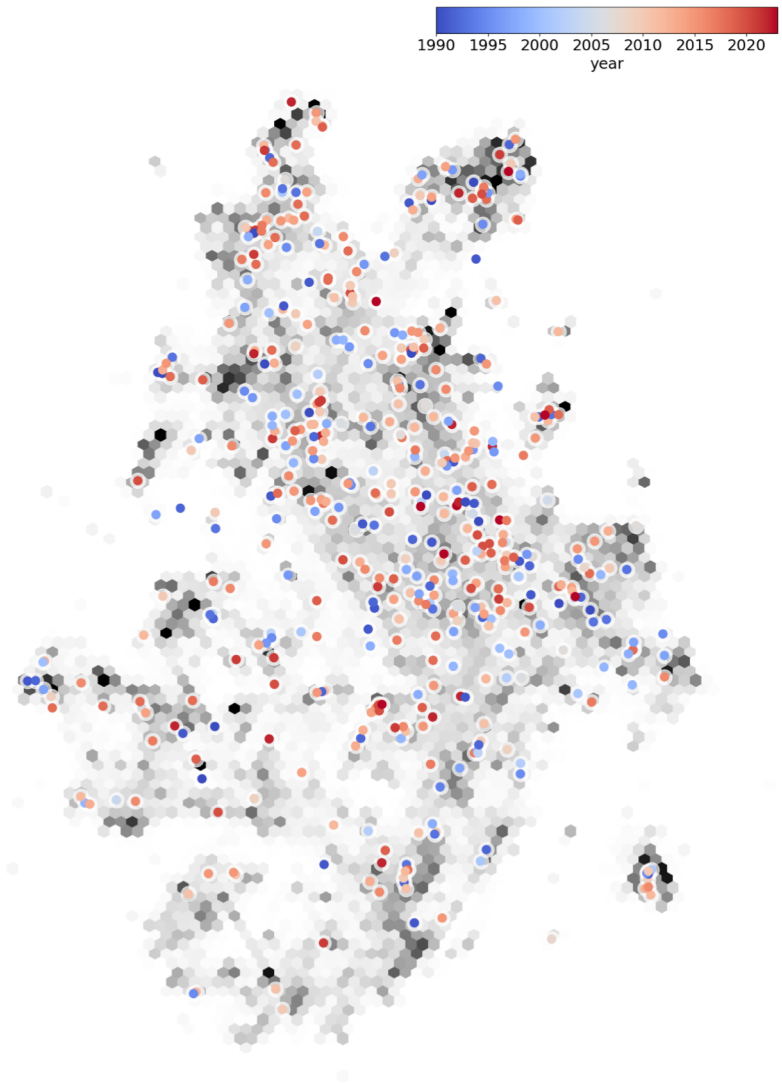
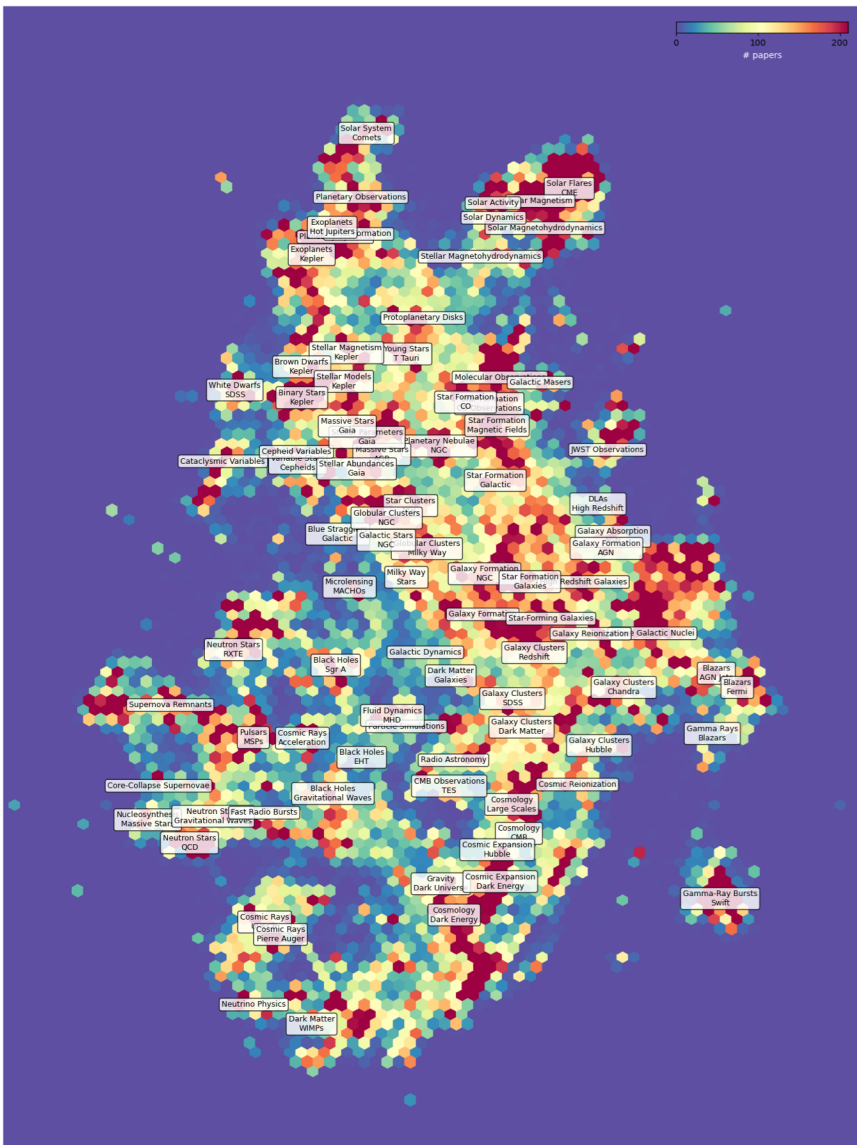
Katachi






- Juno(N: 12)
- SDO(N: 62)
- Parker(N: 49)
- Kepler(N: 442)
- Gaia(N: 330)
- Galex(N: 40)
- HST(N: 277)
- JWST(N: 90)
- Euclid(N: 66)
- Rubin(N: 21)
- Roman(N: 19)
- Keck(N: 195)
- Spitzer(N: 277)
- Herschel(N: 181)
- ALMA(N: 287)
- VLA(N: 161)
- SKA(N: 109)
- Arecibo(N: 45)
- Chandra(N: 527)
- XMM-Newton(N: 138)
- Fermi(N: 474)
- LIGO(N: 182)
- VIRGO(N: 196)
- LISA(N: 141)
- IceCube(N: 130)
- TESS(N: 196)
- WMAP(N: 157)
- Planck(N: 403)







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