

Peeking behind the Bars' invisible cloak (galactic Speakeasies)

© Judy Schmidt & JWST – NASA/ESA
Lee et al.

Phangs



Eric Emsellem

With big thanks to (and significant contributions from):

PHANGS Team, incl. Pierrick Verwilghen, Jessica Sutter, Ryan Shown, Tom Williams

Florent Renaud, Oscar Agertz

Extraordinary structures in nearby galaxies =

Physics

that drives, regulates, extinguishes Star Formation

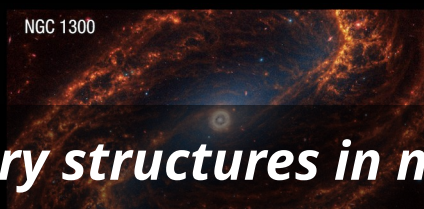
***operating together over
stellar, interstellar, galactic, circumgalactic scales***



NGC 5068



NGC 2835



NGC 1300



NGC 1566



NGC 1365



NGC 454



NGC 3627



NGC 1385



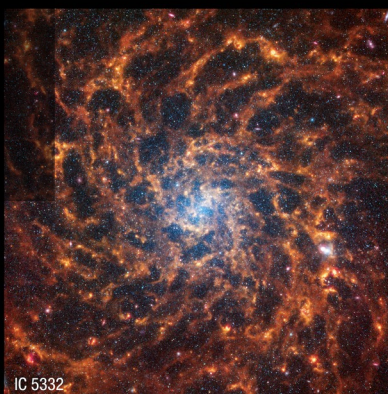
NGC 1512



NGC 1433



NGC 628



IC 5332



NGC 4321



NGC 4254



NGC 1672



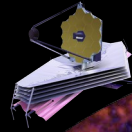
NGC 1087



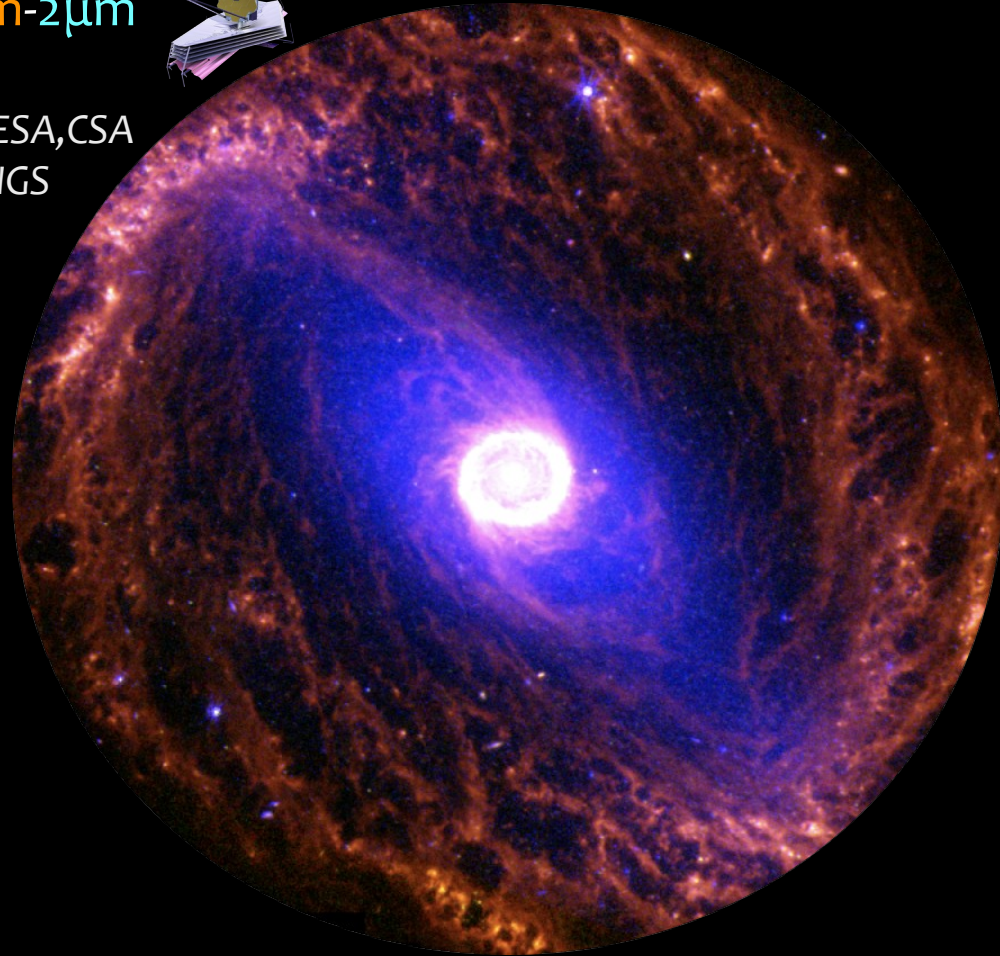
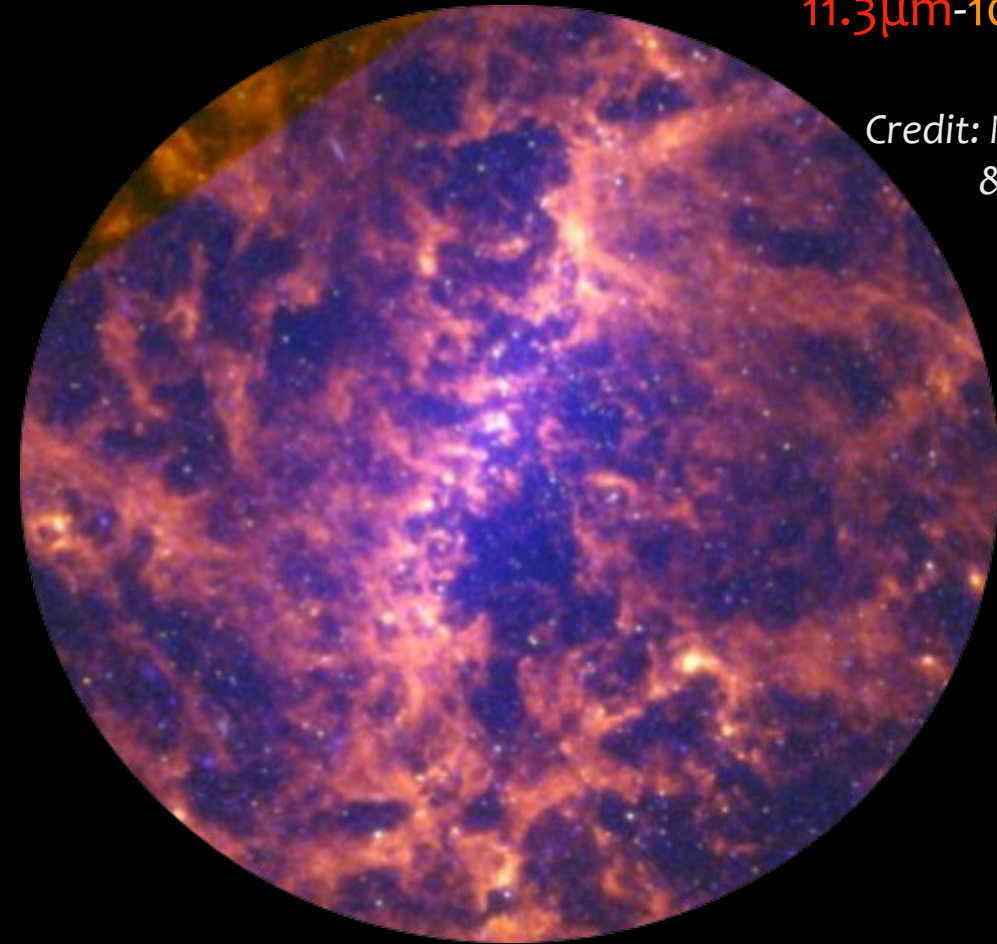
NGC 7496

PHANGS, JWST Jan 2024 DR & NASA PR
Depasquale, Pagan, OPO/STScI (Lee+23)

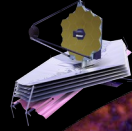
11.3 μm -10.0 μm -2 μm



Credit: NASA/ESA, CSA
& PHANGS



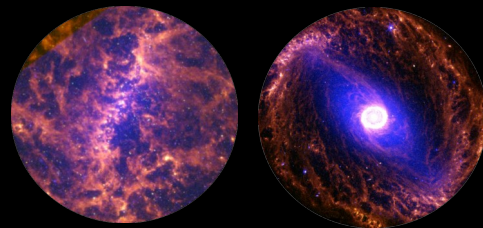
11.3 μm -10.0 μm -2 μm



Credit: NASA/ESA, CSA
& PHANGS

Can we establish a reference pathway for
- bar formation ?
- bar-driven evolution ?

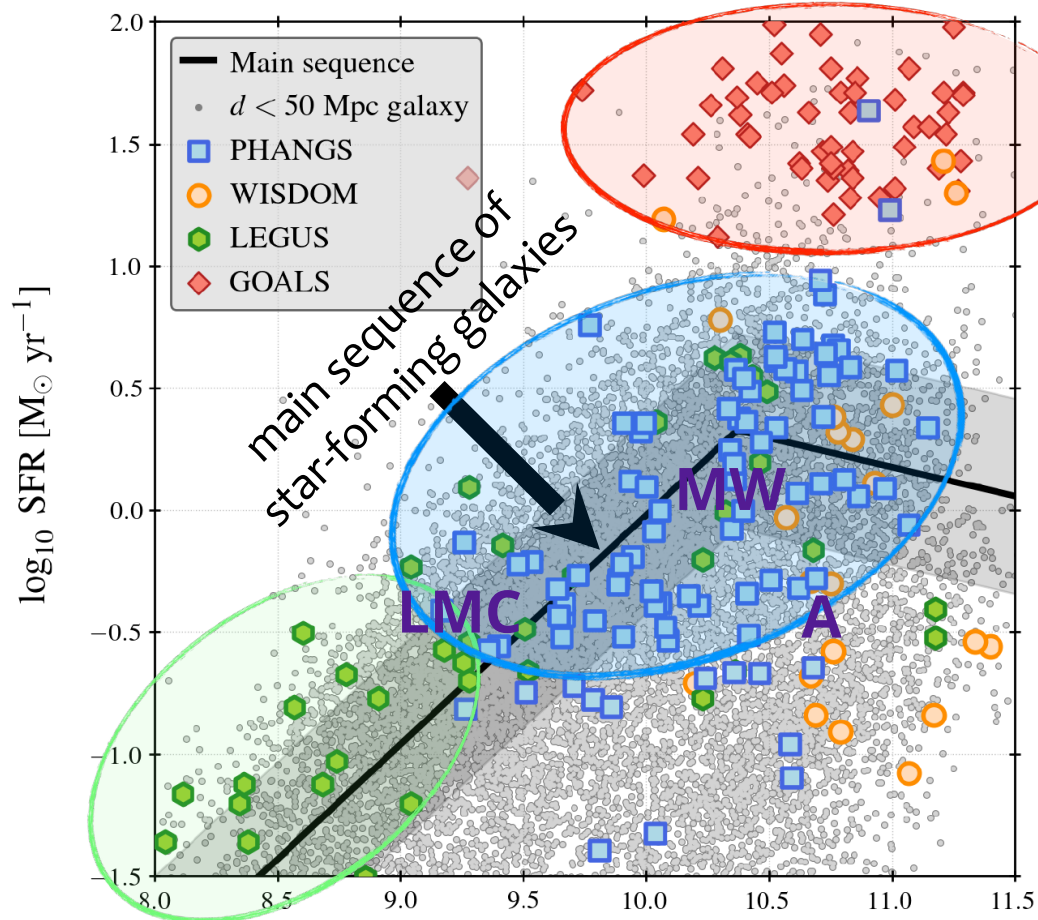




Time evolution

⇒ hydrodynamical simulations
(and Ramses)

Starburst galaxies



MW-like
galaxies

Most stars
form
In discs

dwarf
galaxies

$\log_{10} M_{\star} [M_{\odot}]$

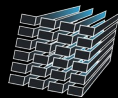
Large Magellanic Cloud
Milky Way
Andromeda



molecular gas
probing
~100,000 clouds
Leroy et al. (2021a)

90+ galaxies
Pis Schinnerer; Blanc; Leroy;
Faesi; Chevance

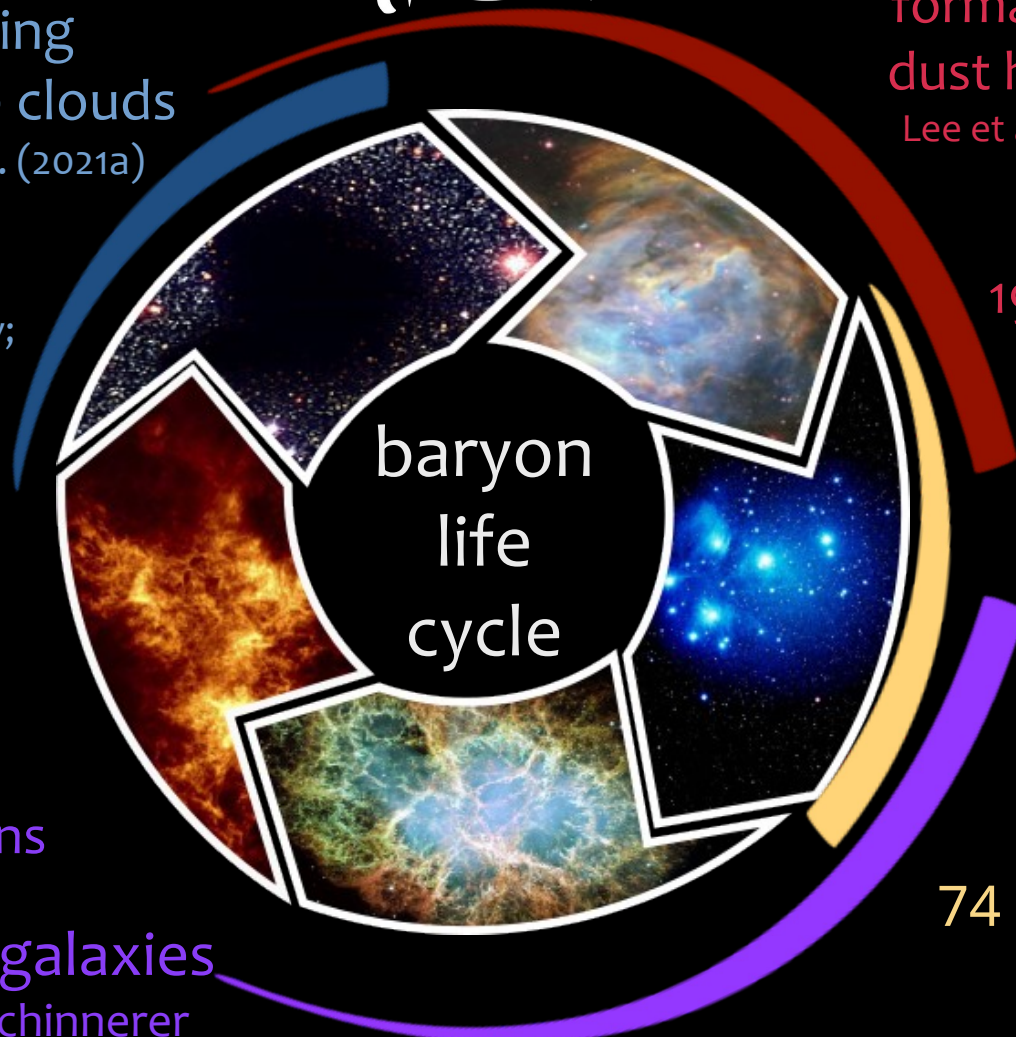
stellar feedback
probed by
~25,000 nebulae
+ stellar populations
Emsellem et al. (2022)



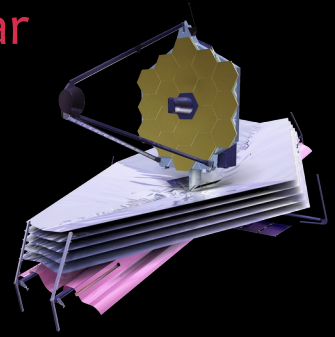
MUSE
multi unit spectroscopic explorer

19+ galaxies
PI Schinnerer

Phangs

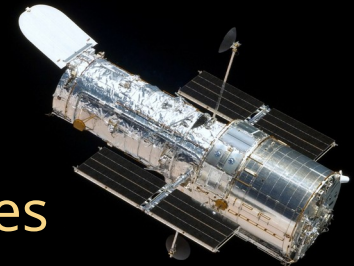


embedded star
formation &
dust heating
Lee et al. (2023)



19 + 55 galaxies
PI Lee + PI Leroy

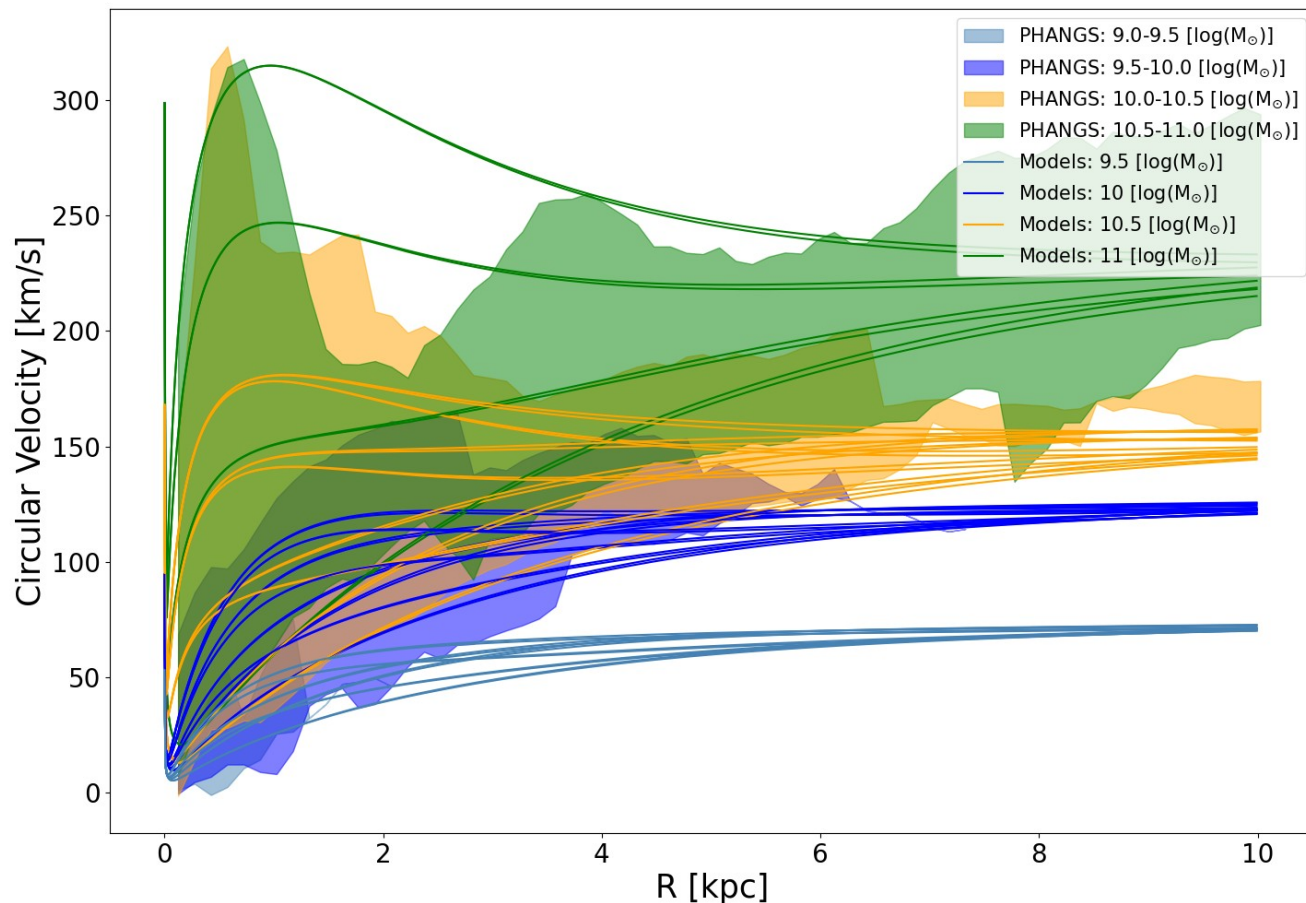
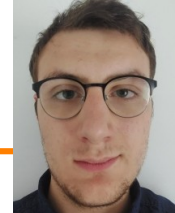
~80,000
stellar clusters
Lee et al. (2022)



74 galaxies
PI Lee

Generic Simulations of isolated discs

Verwilghen+ 2024



MGE ICs + AMR RAMSES

- ⇒ Gas, Stars, Dark Matter
- ⇒ Star formation, feedback winds, SNI
- ⇒ ~12 pc cells
- ⇒ 3 Gyr evolution

⇒ Grid of 54 models
spanning the
Phangs sample

M104

V band

Emsellem 1995
Baes et al. 2011

MGE model

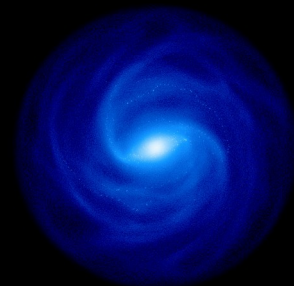
NGC1277

Emsellem 2015

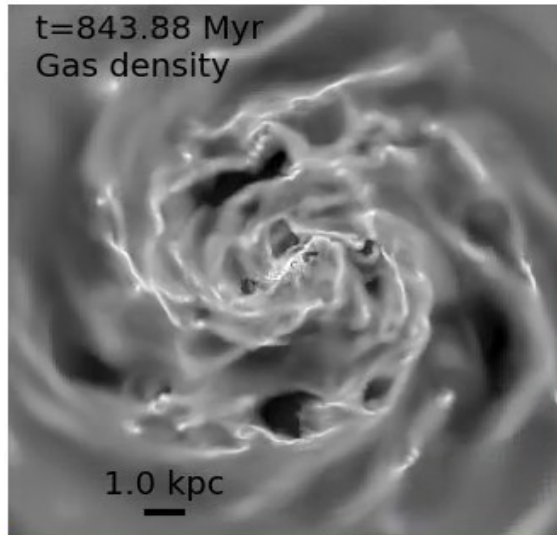
Parametric (1-3D) & profiles / images

3D Projection/deprojection
Gravitational Potential, density waves,
Generalised Jeans Equations

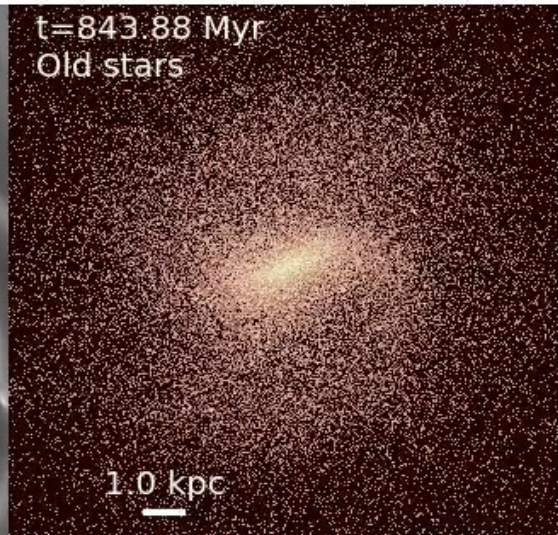
Stars + gas + DM
⇒ Gadget, Ramses



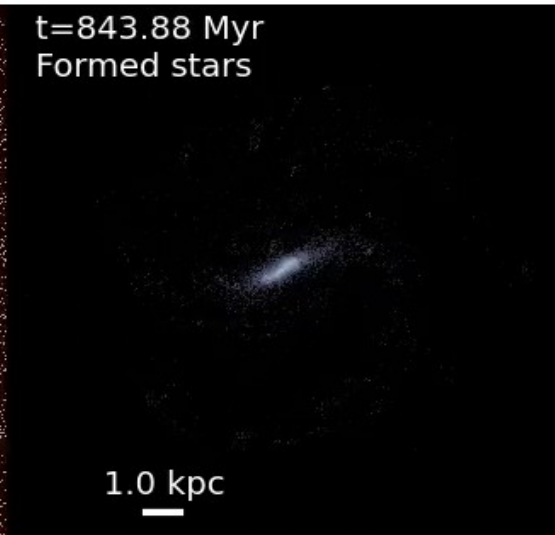
t=843.88 Myr
Gas density



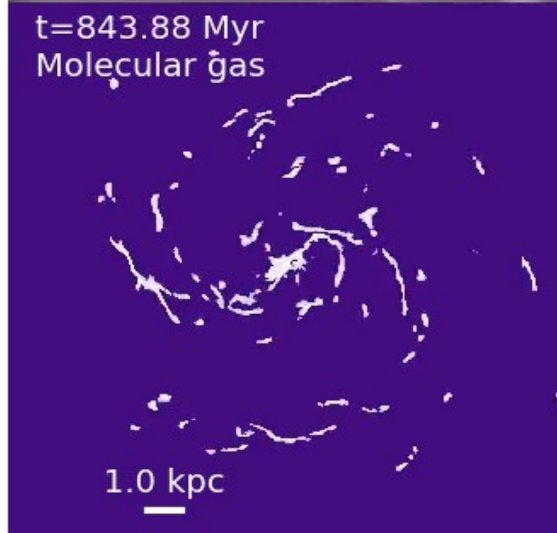
t=843.88 Myr
Old stars



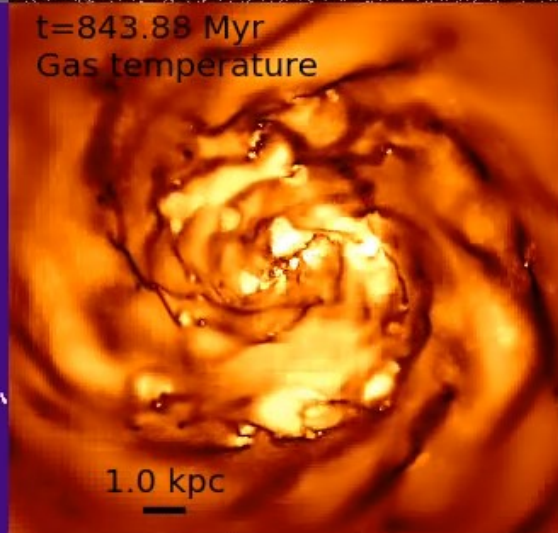
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Formed stars



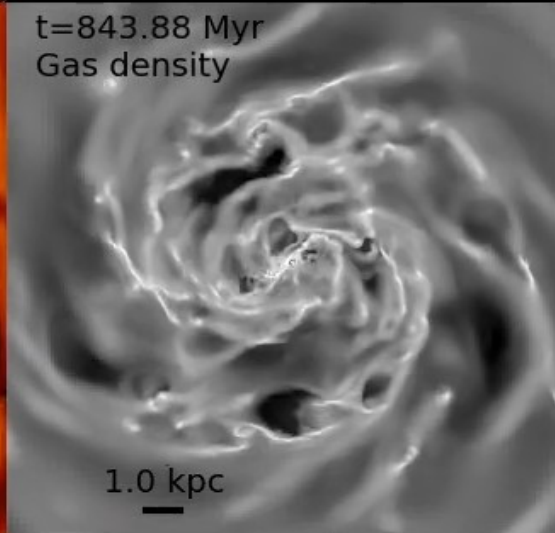
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Molecular gas



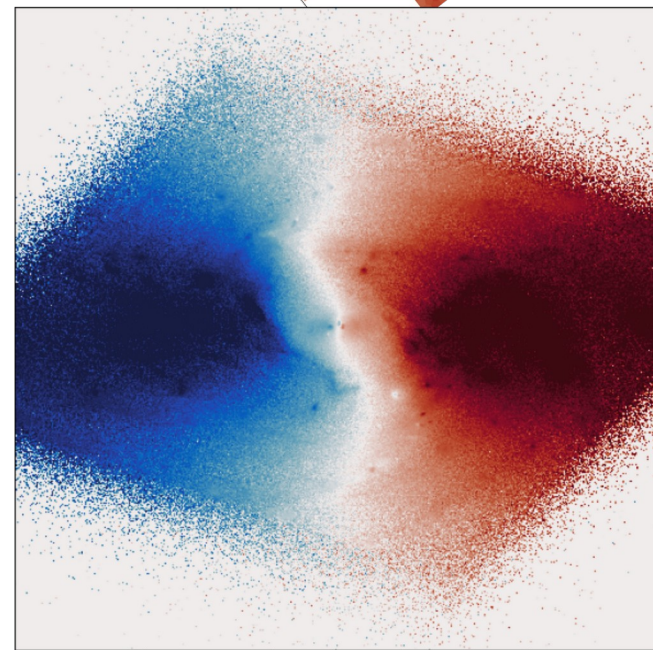
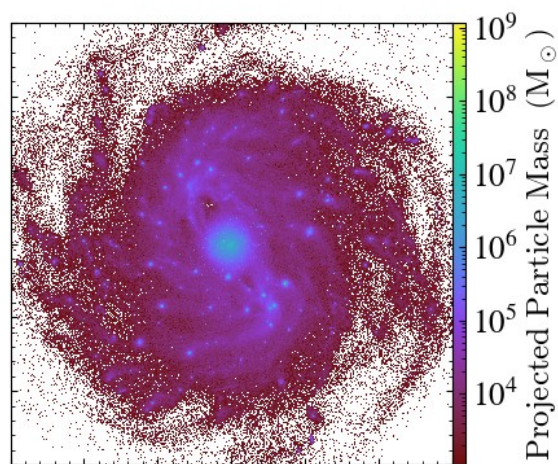
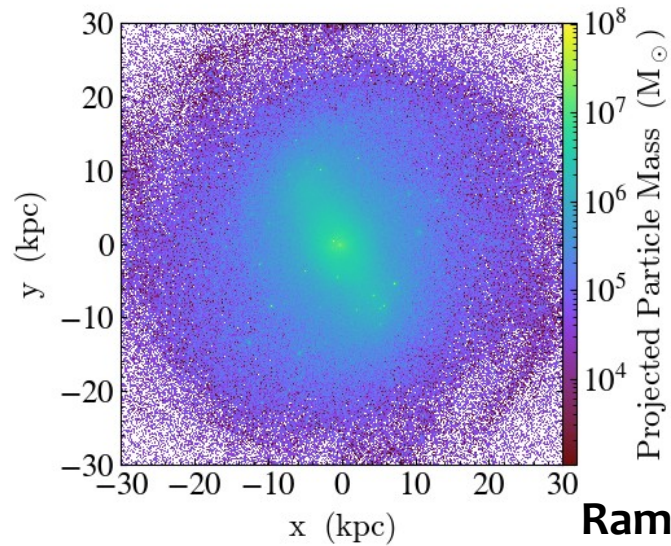
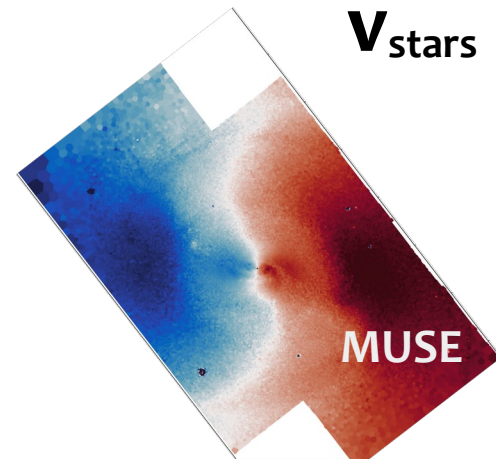
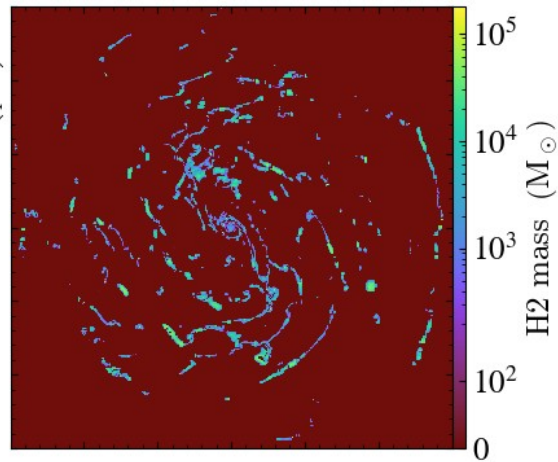
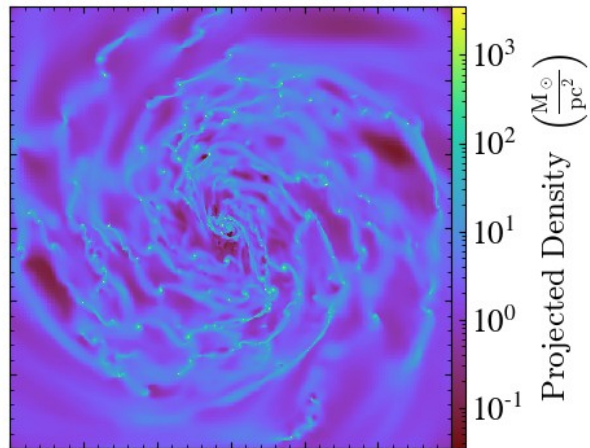
t=843.88 Myr
Gas temperature



t=843.88 Myr
Gas density



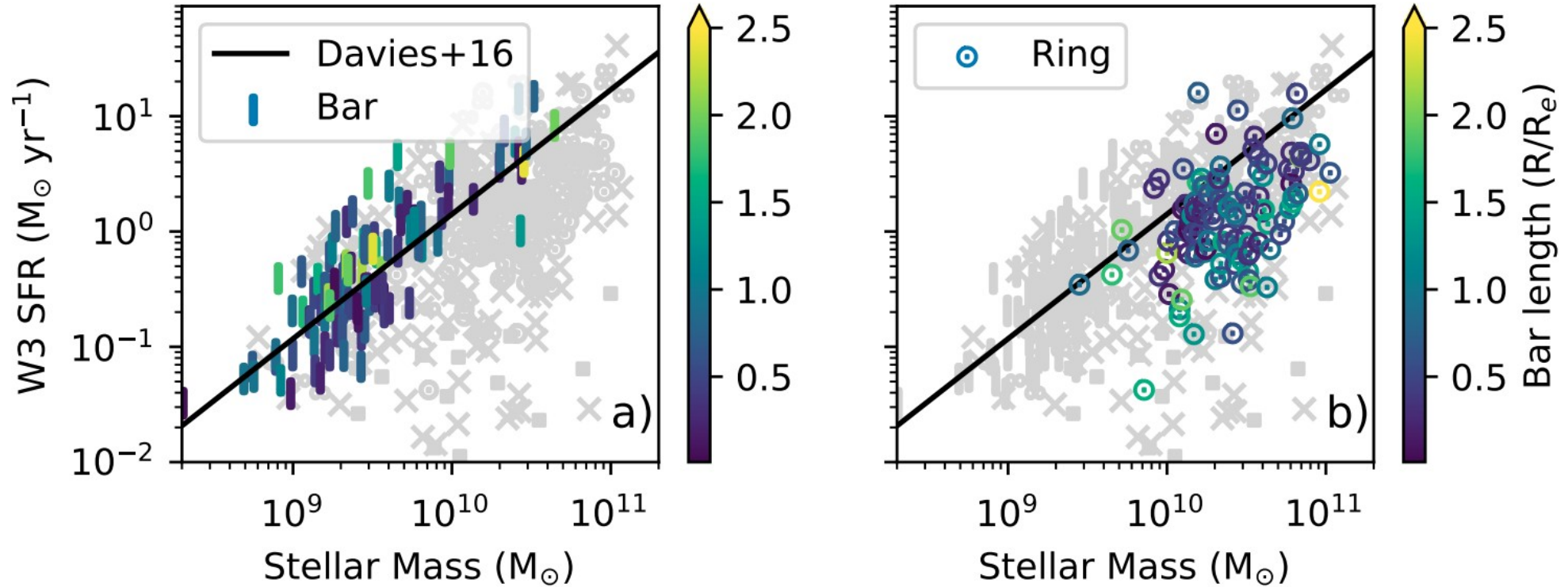
NGC 1365



Ramses hydro-dynamical simulation (Emsellem+ in prep)

Where do stars form & Why ?

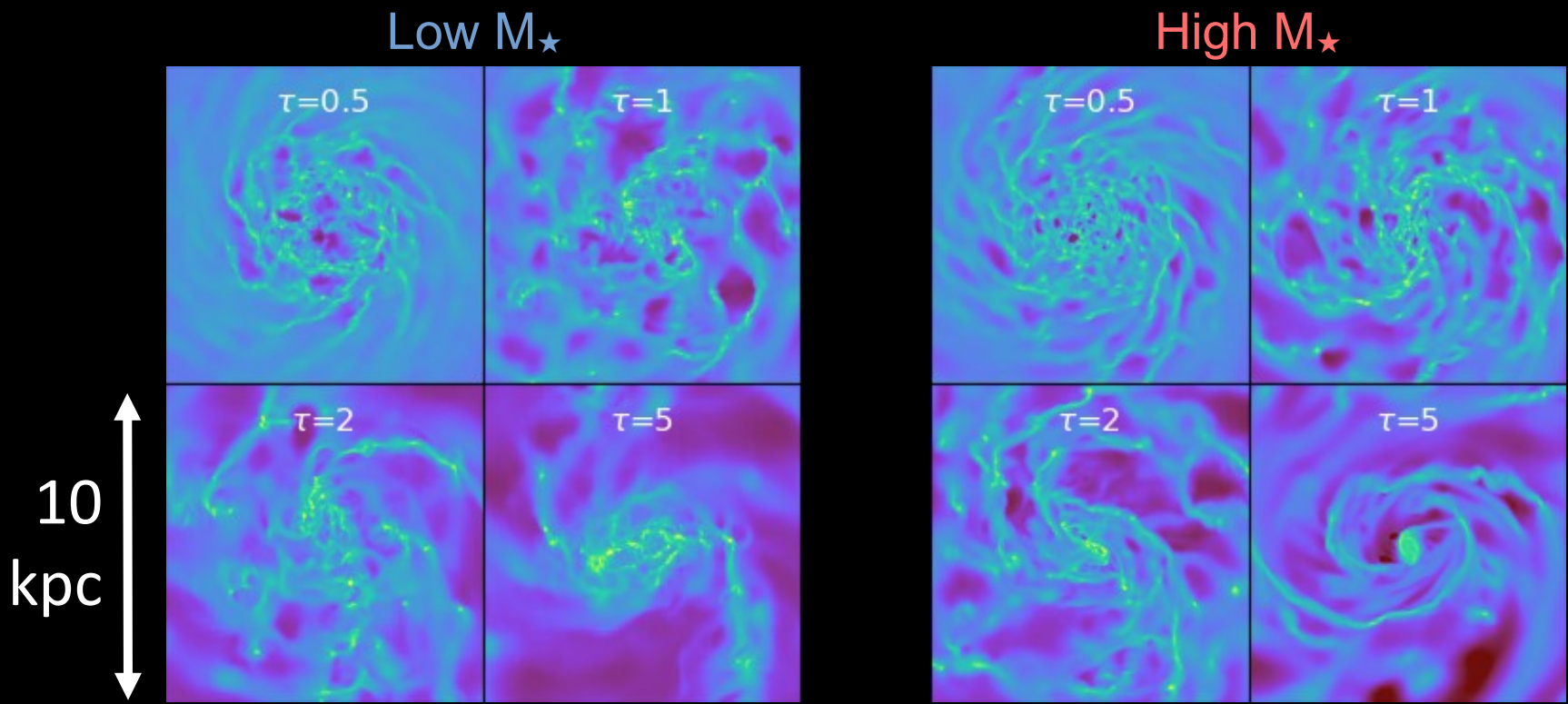
Fraser-McKelvie et al. 2020



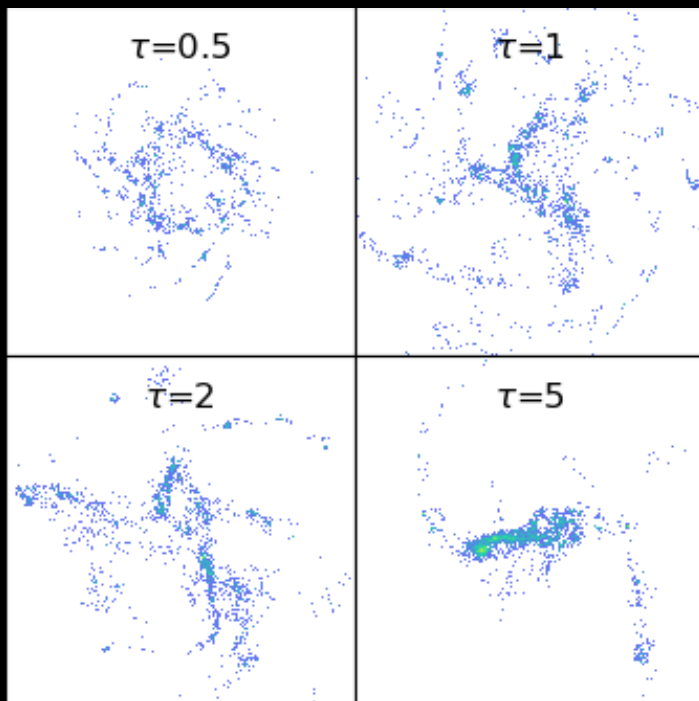
Dependence of SF on stellar mass

⇒ lower-mass = bar

⇒ higher mass = rings / central

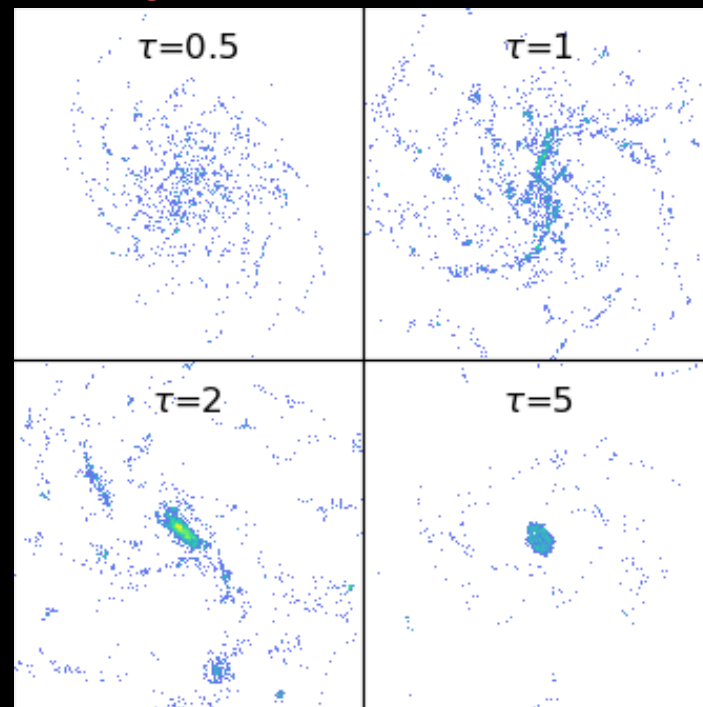


Low $M_{\star}$: Bar but no reservoir



SF along the bar

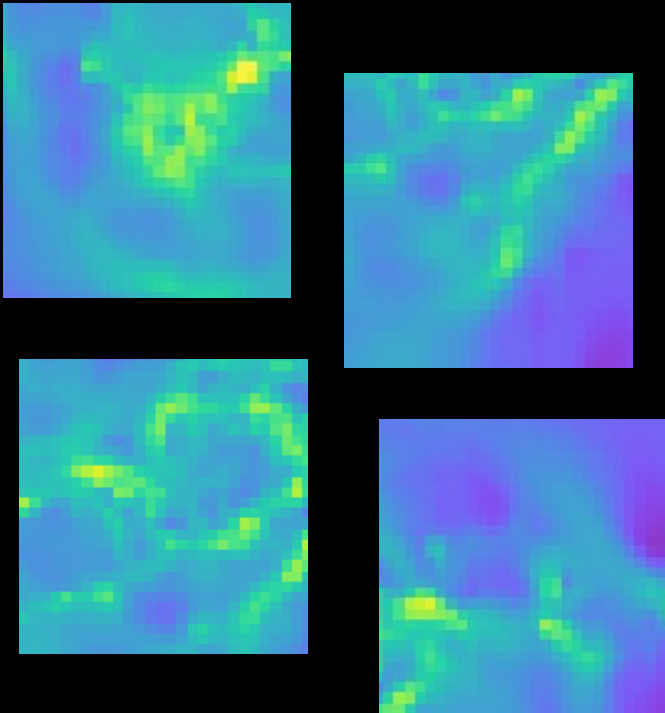
High $M_{\star}$: Bar + reservoir



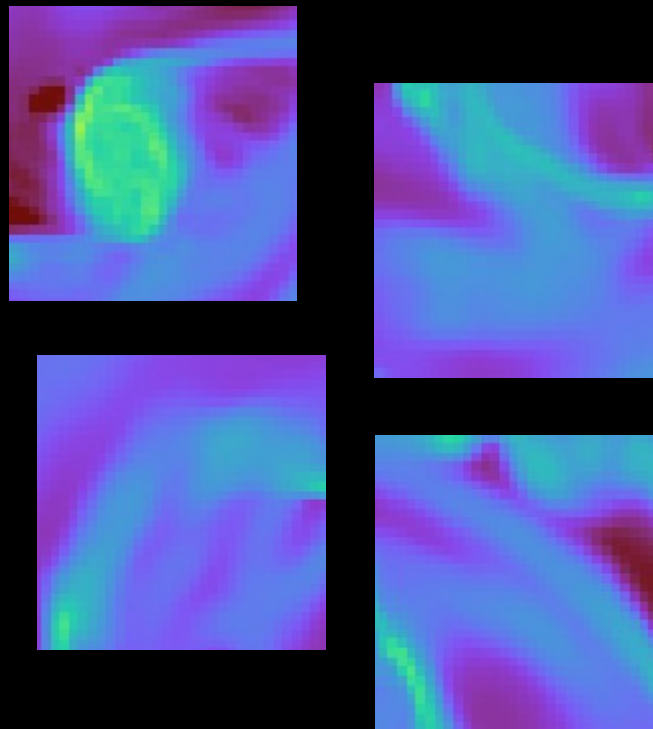
SF within the central reservoir

Consistent with Fraser-McKelvie+2020

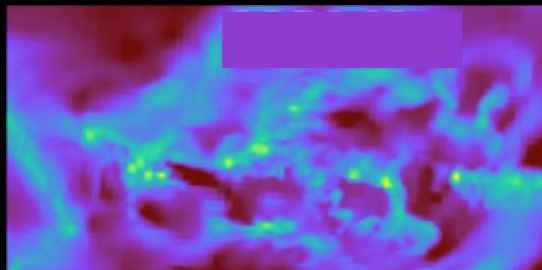
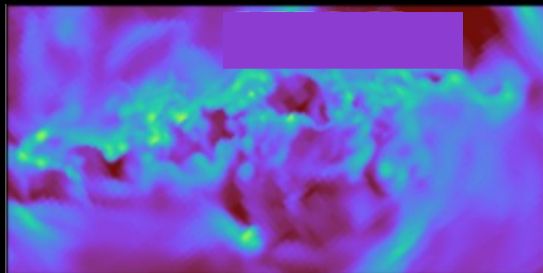
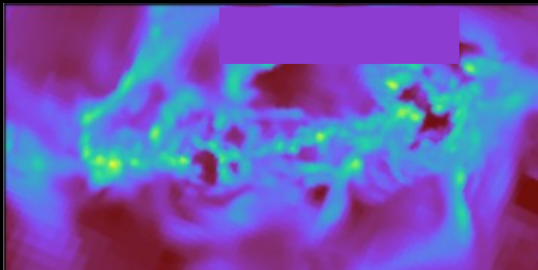
Low $M_{\star}$: where is the bar ?



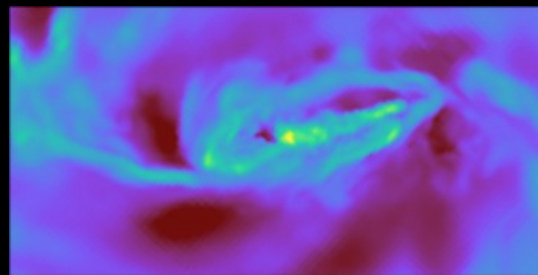
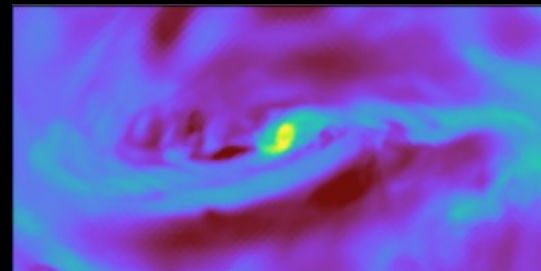
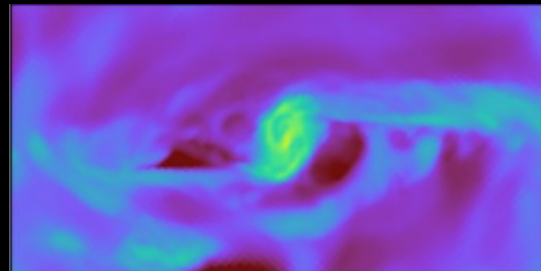
High $M_{\star}$: Bar structuring



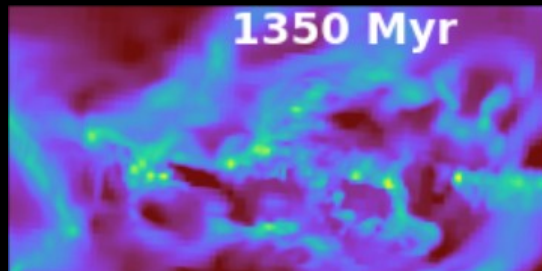
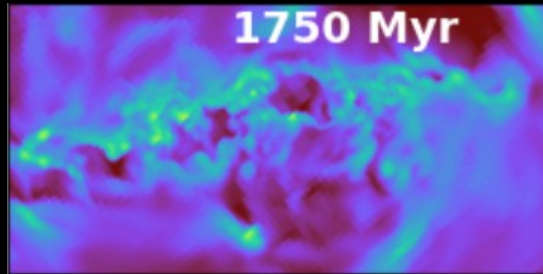
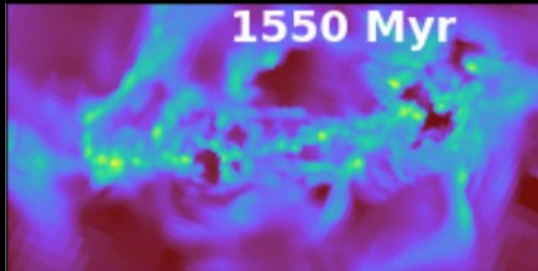
Low $M_{\star}$: evolution ?



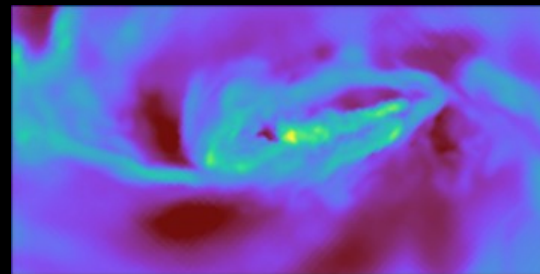
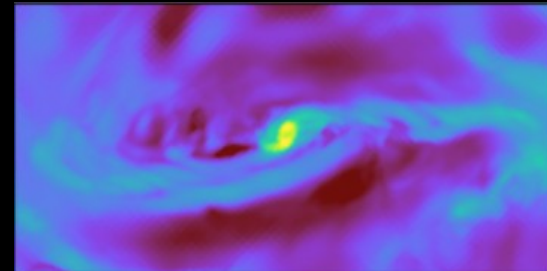
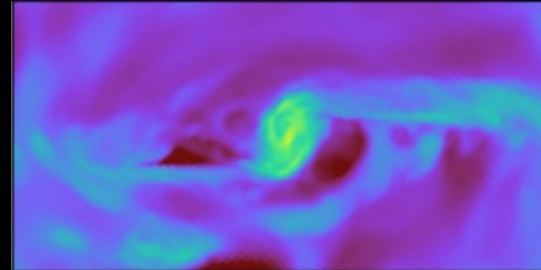
High $M_{\star}$: evolution !

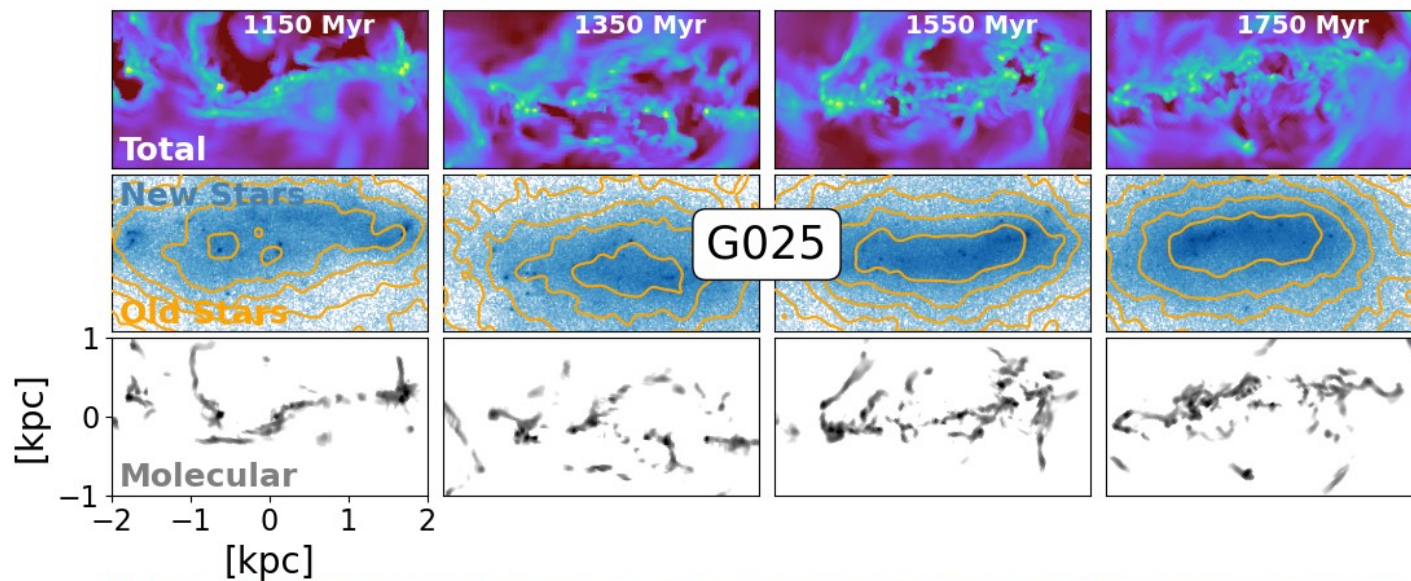


Low $M_{\star}$: evolution ?

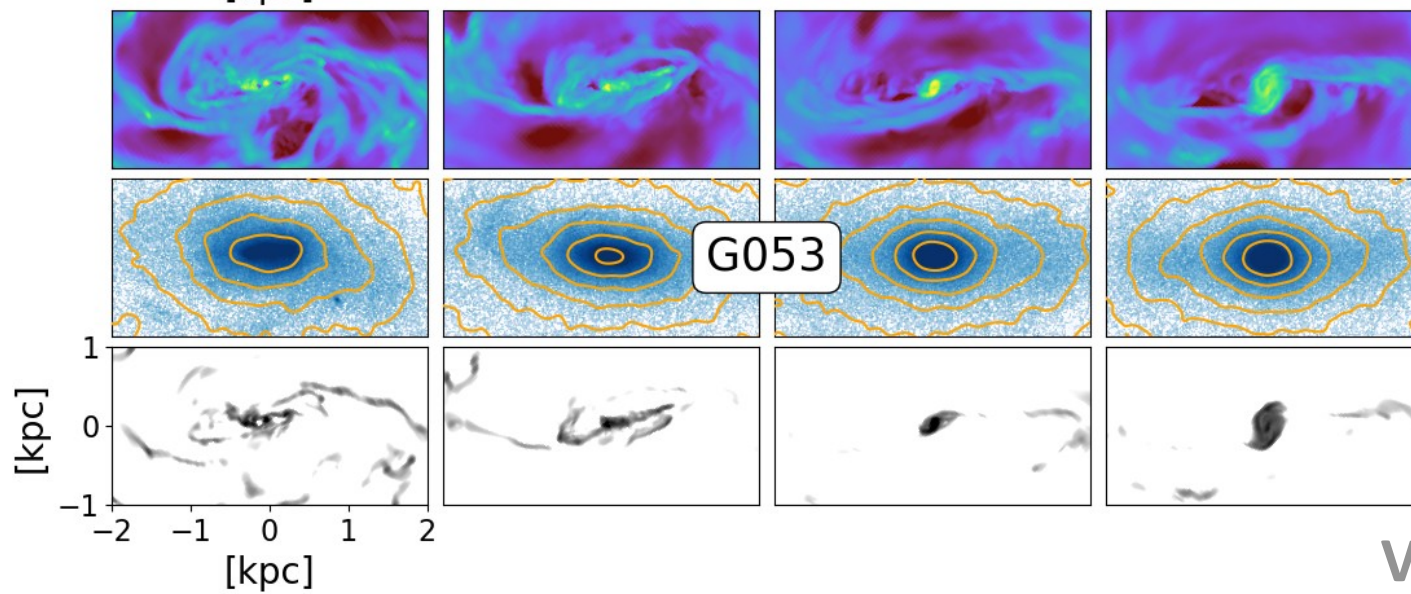


High $M_{\star}$: evolution !





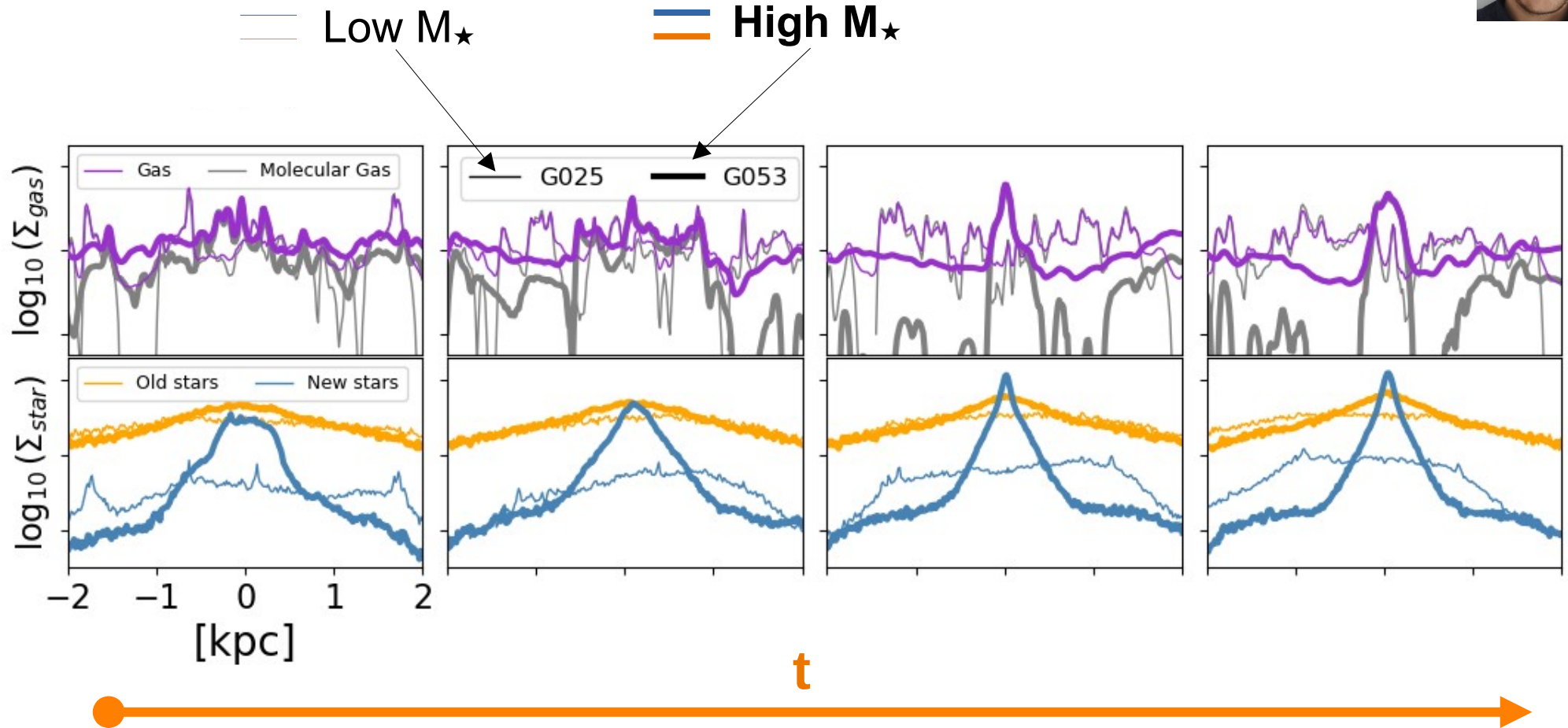
Low $M_\star$



High $M_\star$

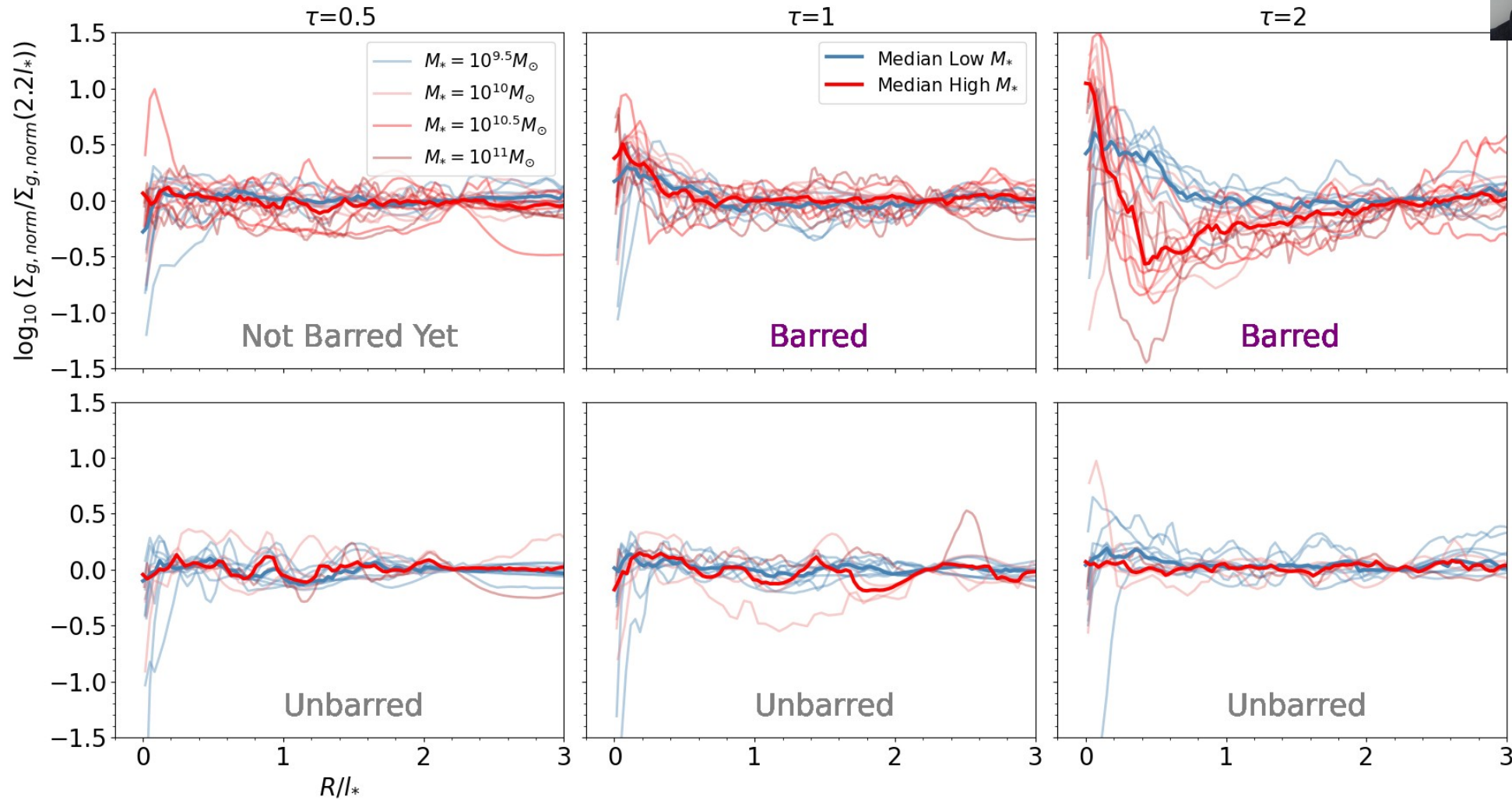
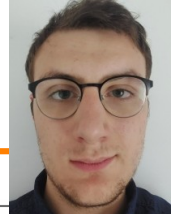
Building of inner discs

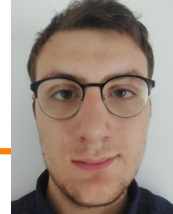
Verwilghen+ 2025



Bar-driven evolution: deserts & peaks

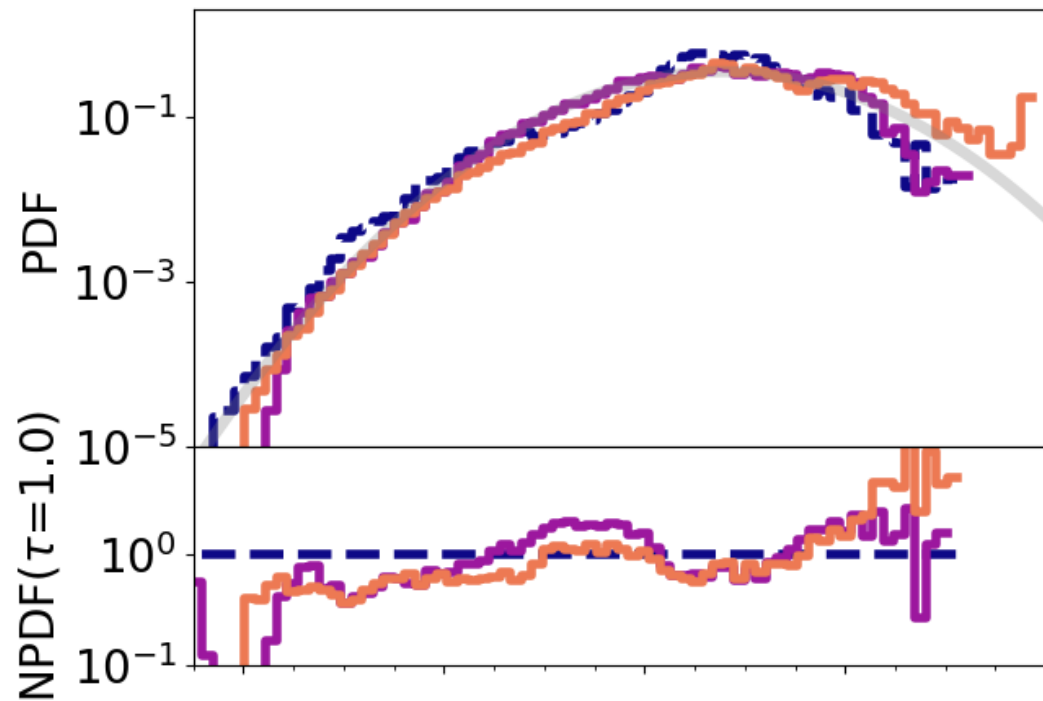
Verwilghen+ 2025





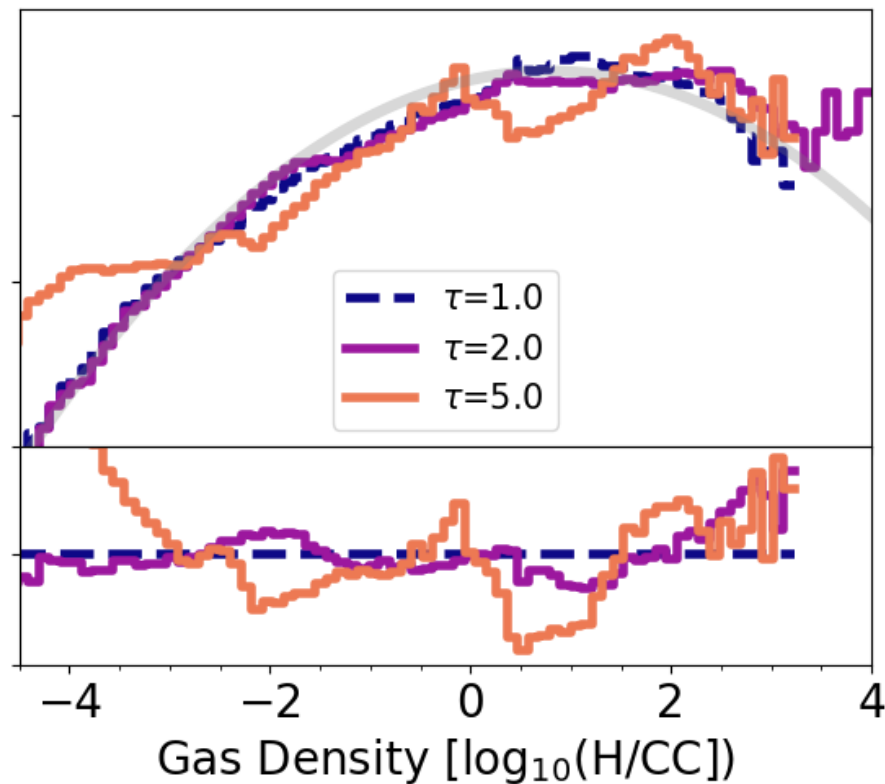
$10^{9.5} M_{\odot}$

G013M095F20L2B00



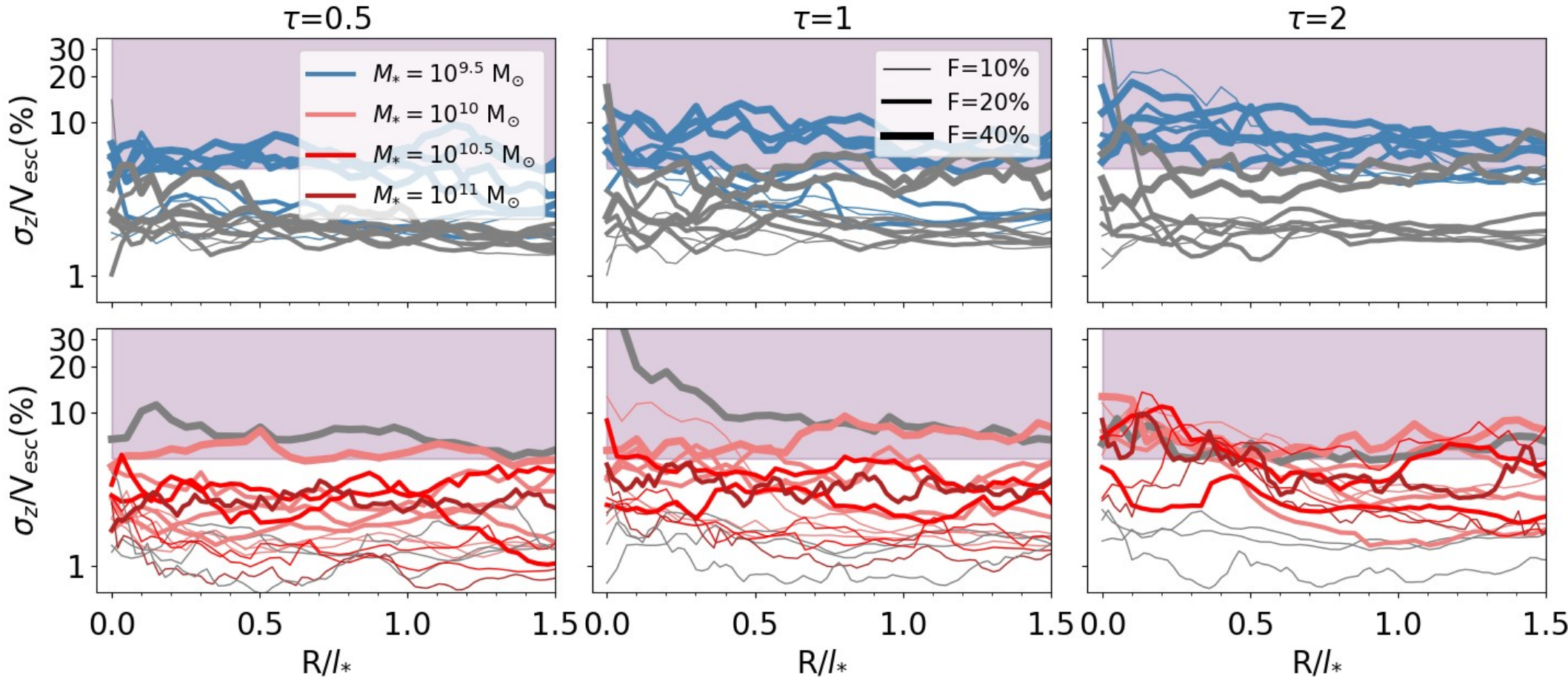
$10^{10} M_{\odot}$

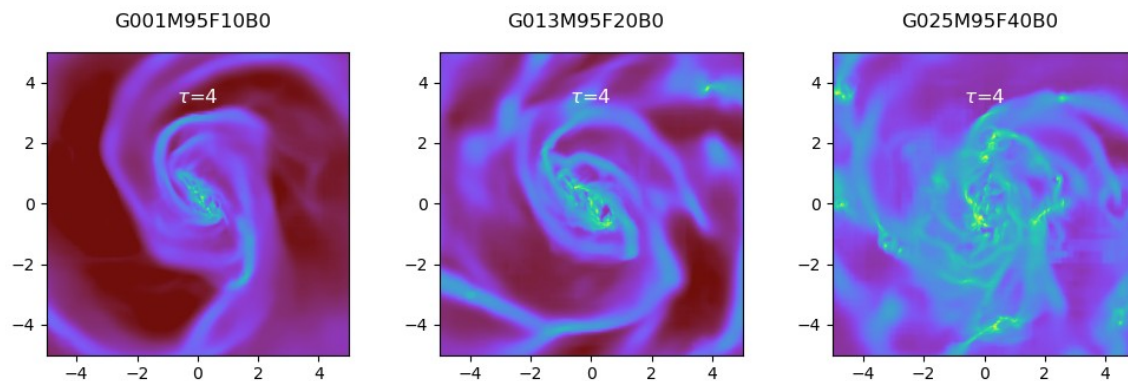
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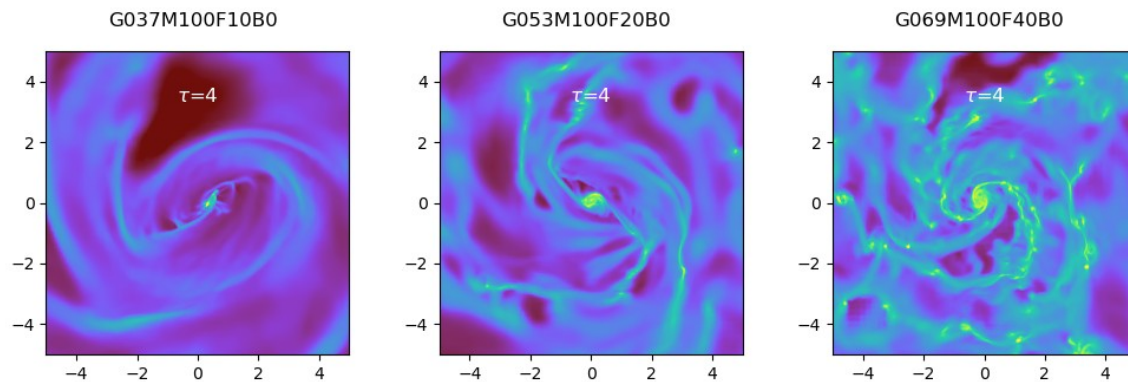
Feedback !

Verwilghen+ 2025

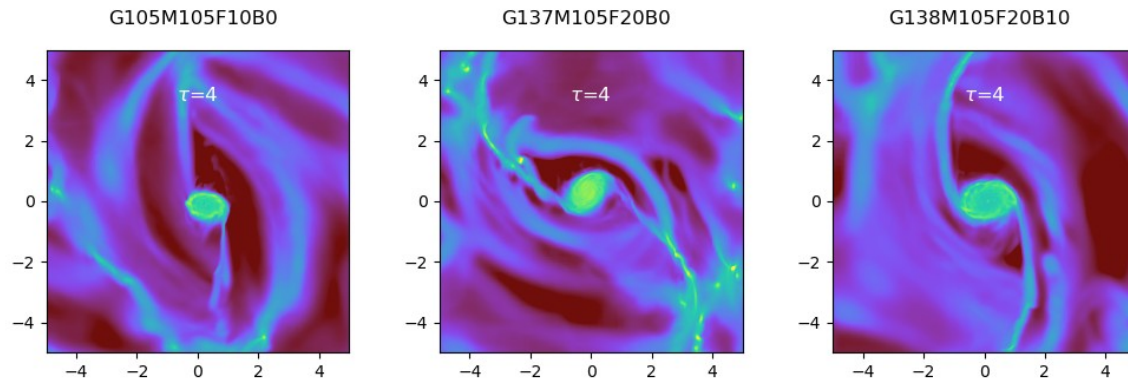




Low $M_\star$

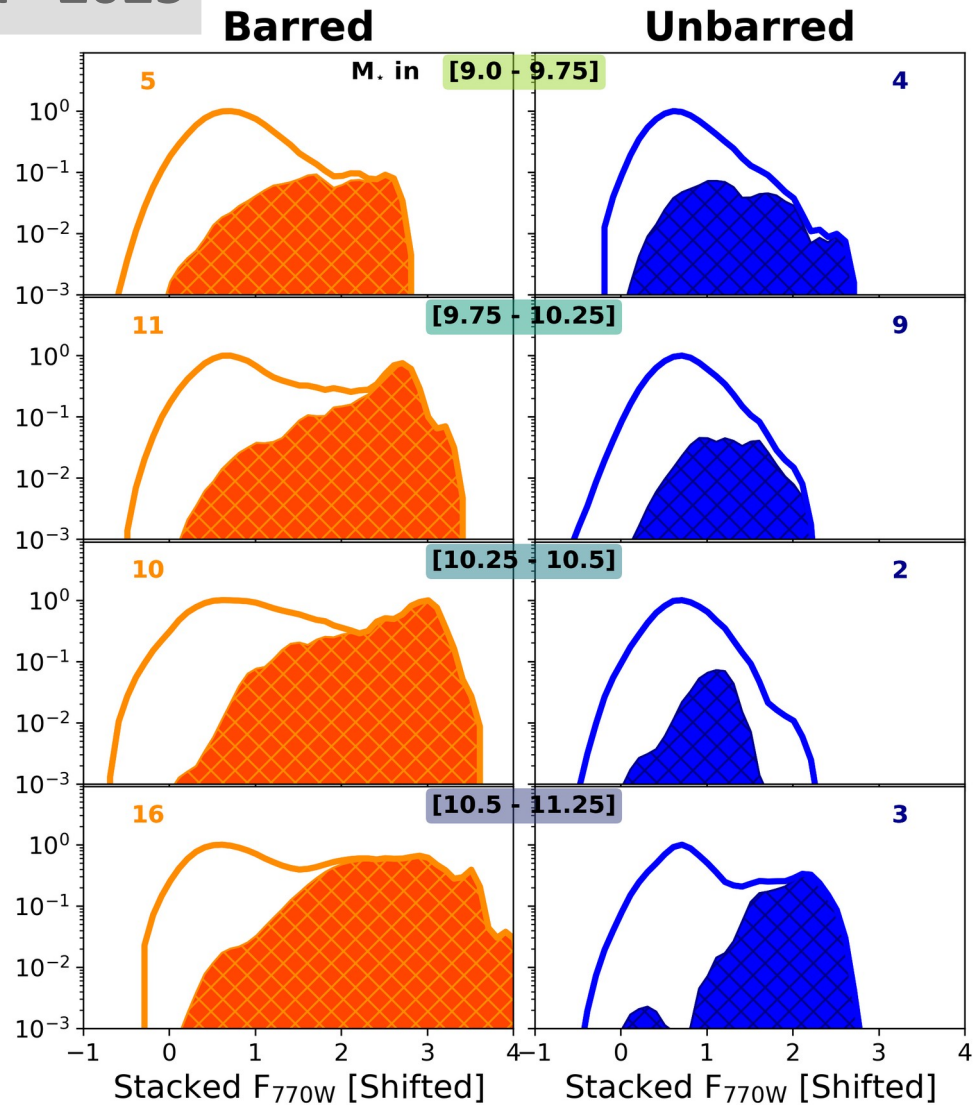
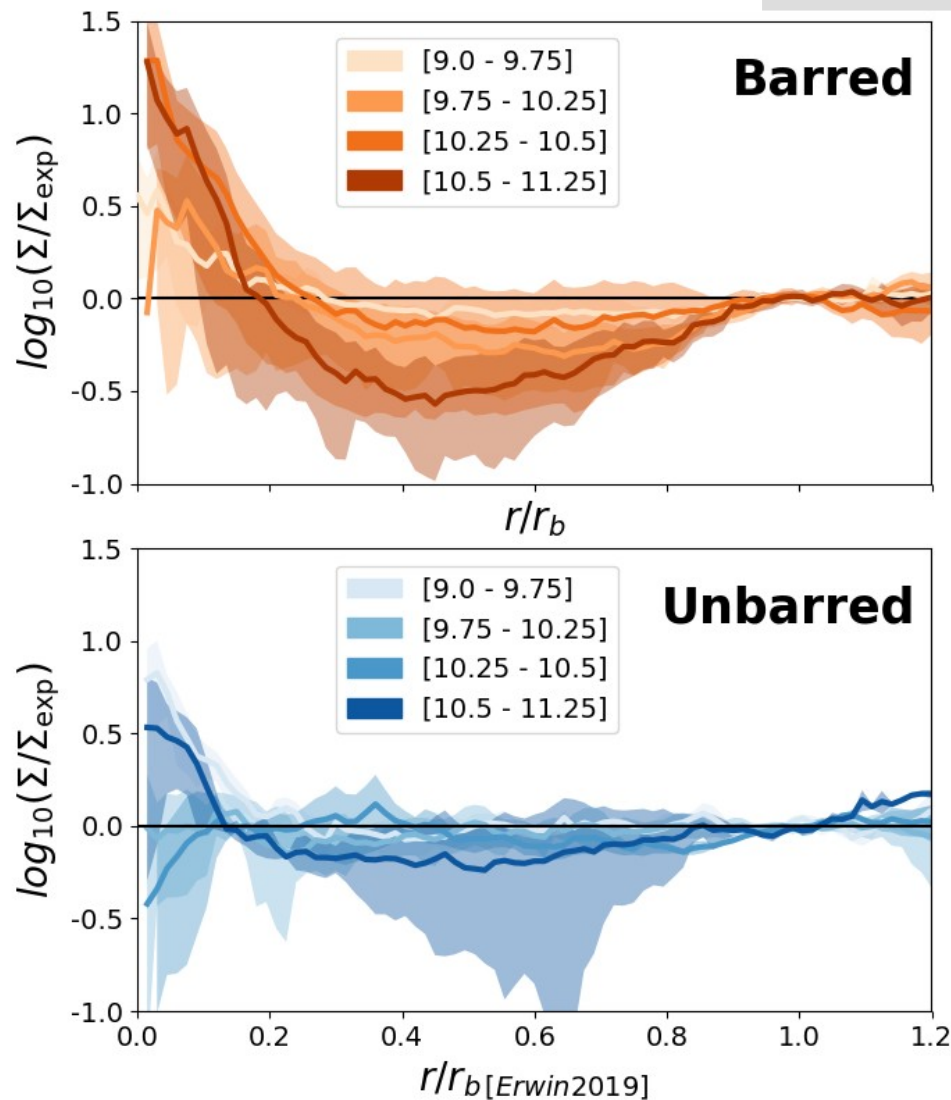


Mid $M_\star$

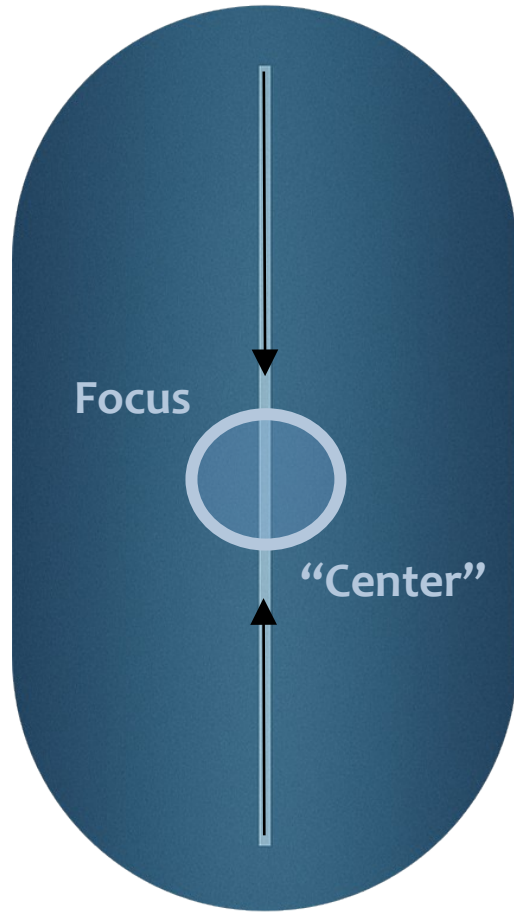


High $M_\star$

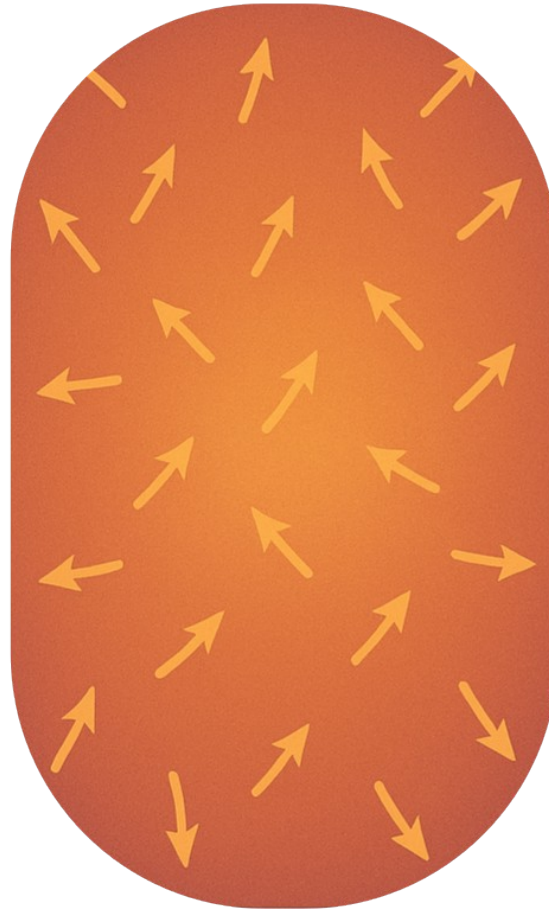
About
Timescales



Convergent
Laminar Inflow



Stellar Feedback
Perturbation



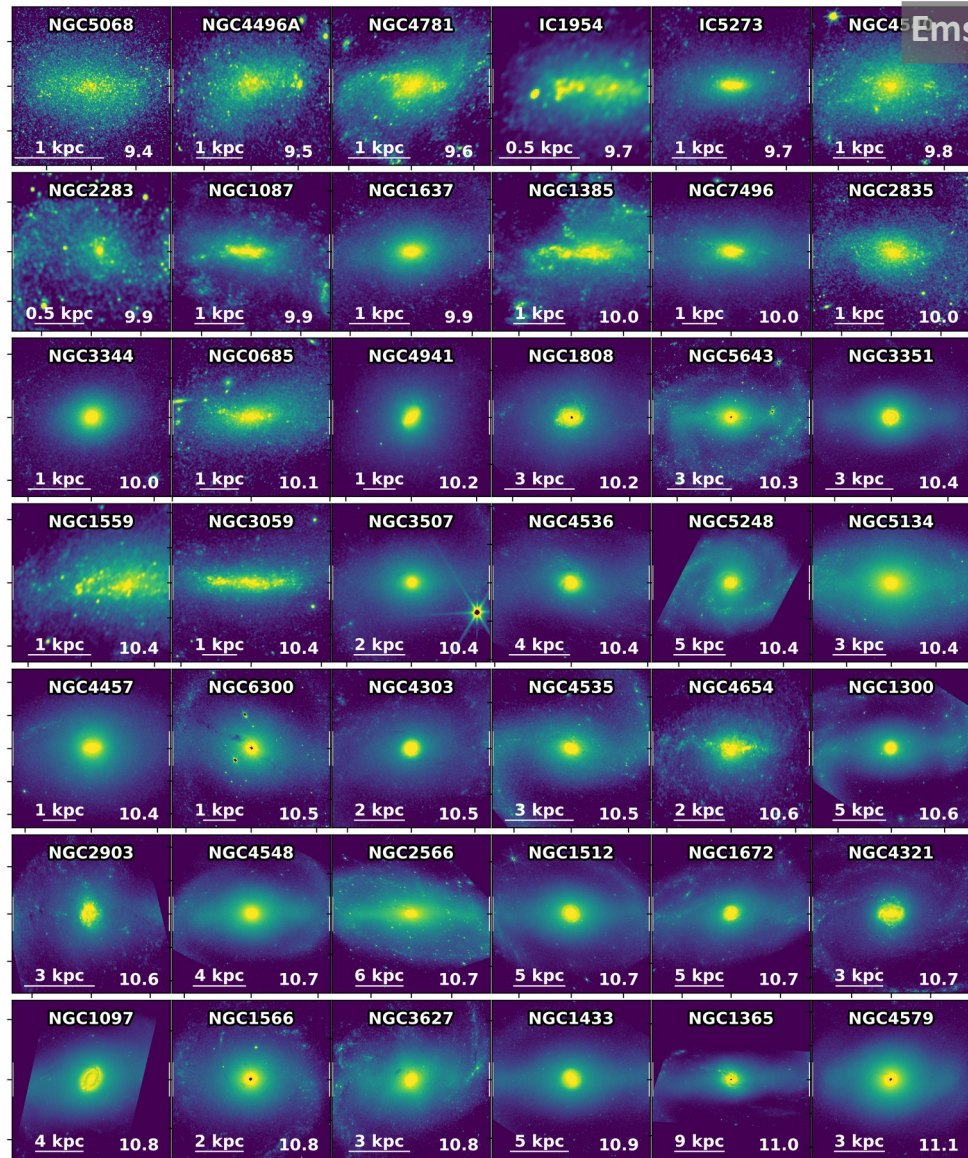
Turbulent,
Chaotic Flow



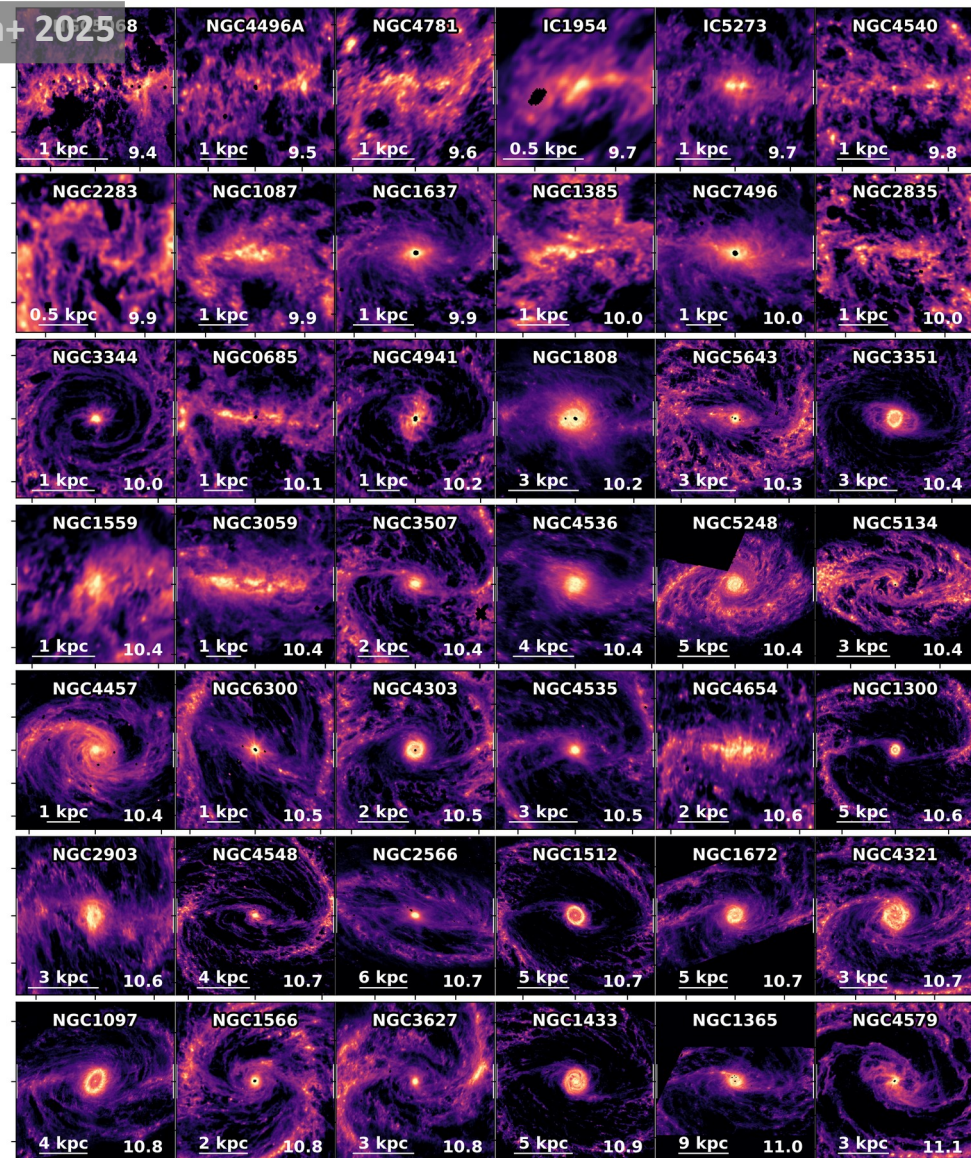
1D



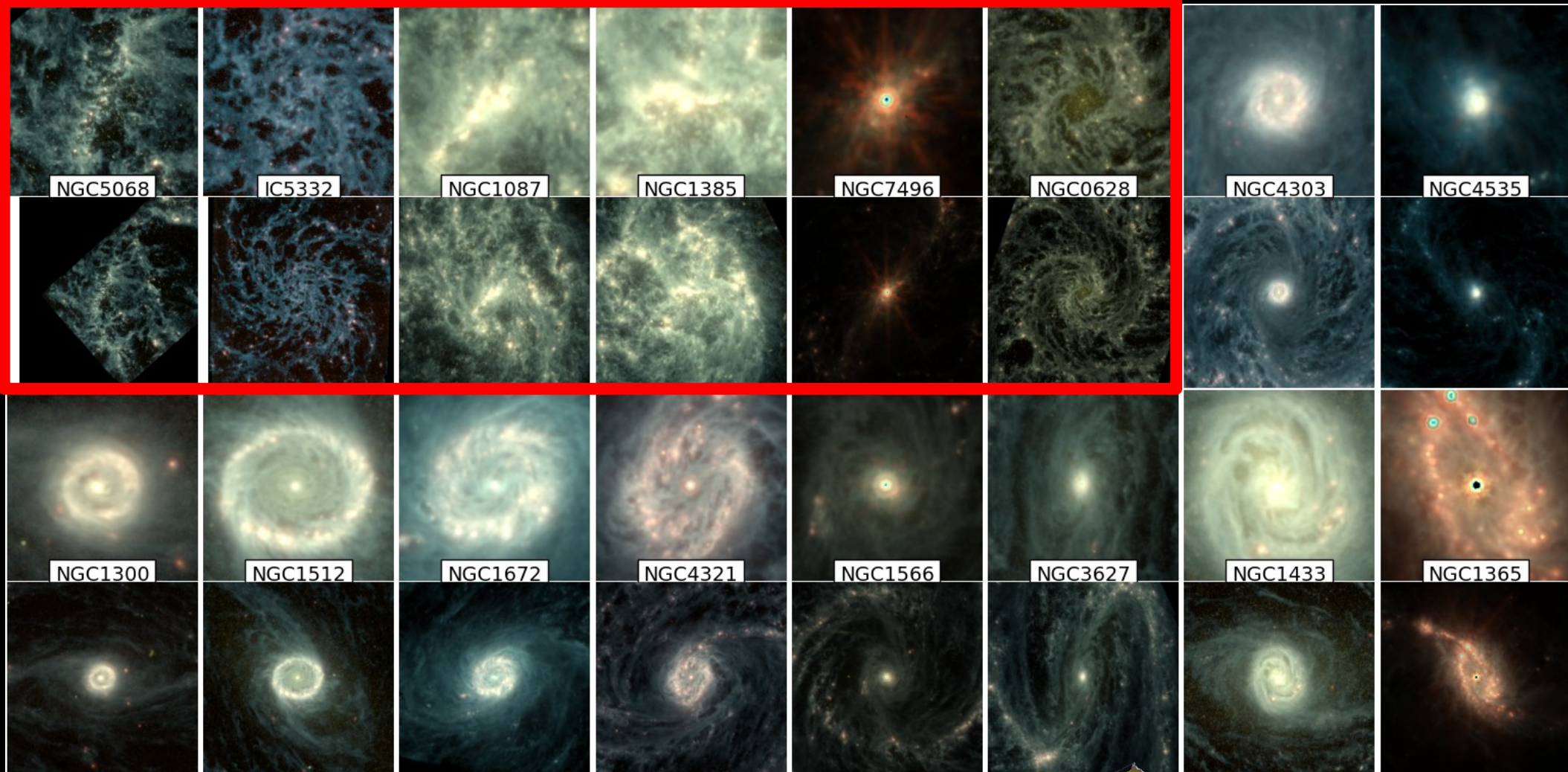
3D



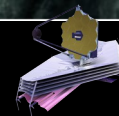
Emsellem+ 2025



Lower mass systems



Credit: NASA/ESA,CSA; PHANGS / Emsellem



21 μ m-10.0 μ m-3 μ m

Take home messages

Bars are hard to avoid in discs (if you have time + reasonable dynamics)

- **High-mass galaxies : key agents of disc evolution**
 - ▷ Gas and SF deserts + central rings and discs
- **Low-mass galaxies : ... in hiding**
 - ▷ SF regime, PDF, detection at high redshift ?

Relative imprint of gravity and feedback

- 1D flow versus 3D flow $\Rightarrow$ Central attractor
- $\Rightarrow$ requires high-resolution, involves varying timescales

Regime (mass-dependent) change and galaxy evolution

- What about high-er redshift galaxies ?

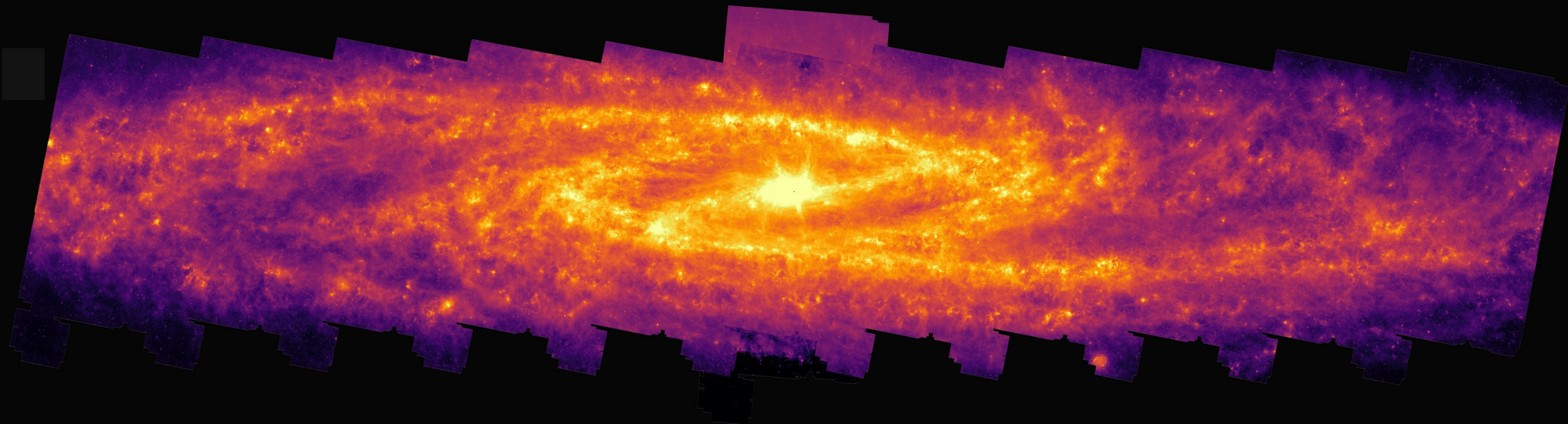
Serious issues

Bars = absence / morphology and size
(Differential) evolution



Full galaxy JWST 7.7 micron PAH mosaic

Erik Rosolowsky



NGC 253

15 million spectra
Reduced using pymusepipe
(github/emsellem)

100 MUSE pointings

H α [SII] [OIII]

Enrico Congiu

