Bursting Bubbles: Feedback from Clustered SNe and the Trade-off Between Turbulence and Outflows

arXiv:2109.14626
arXiv:2109.14656

Our Galactic Ecosystem: Opportunities and Diagnostics in the Infrared and Beyond

March 1, 2022

Matt Orr

Physics & Astronomy | Rutgers University
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Orr+2022, ApJL 924 L28

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Feedback-regulation Often Means Constant-strength Feedback

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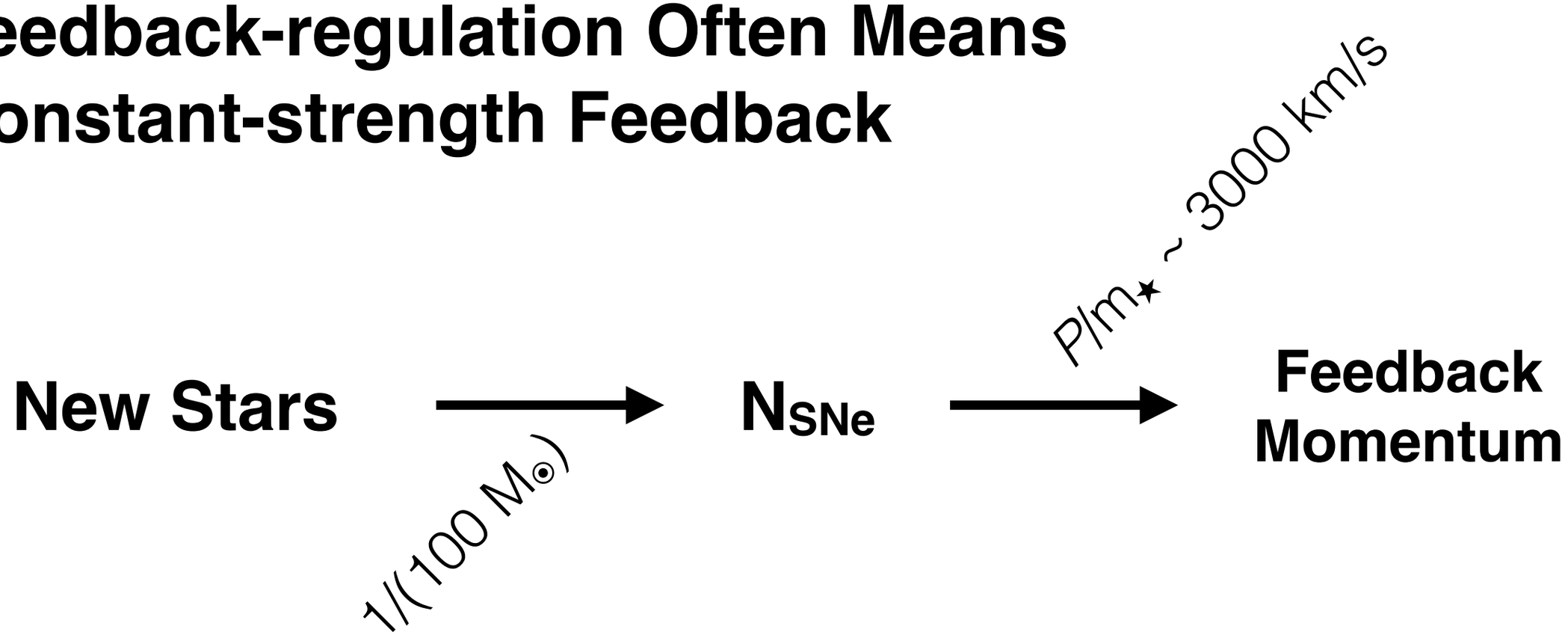

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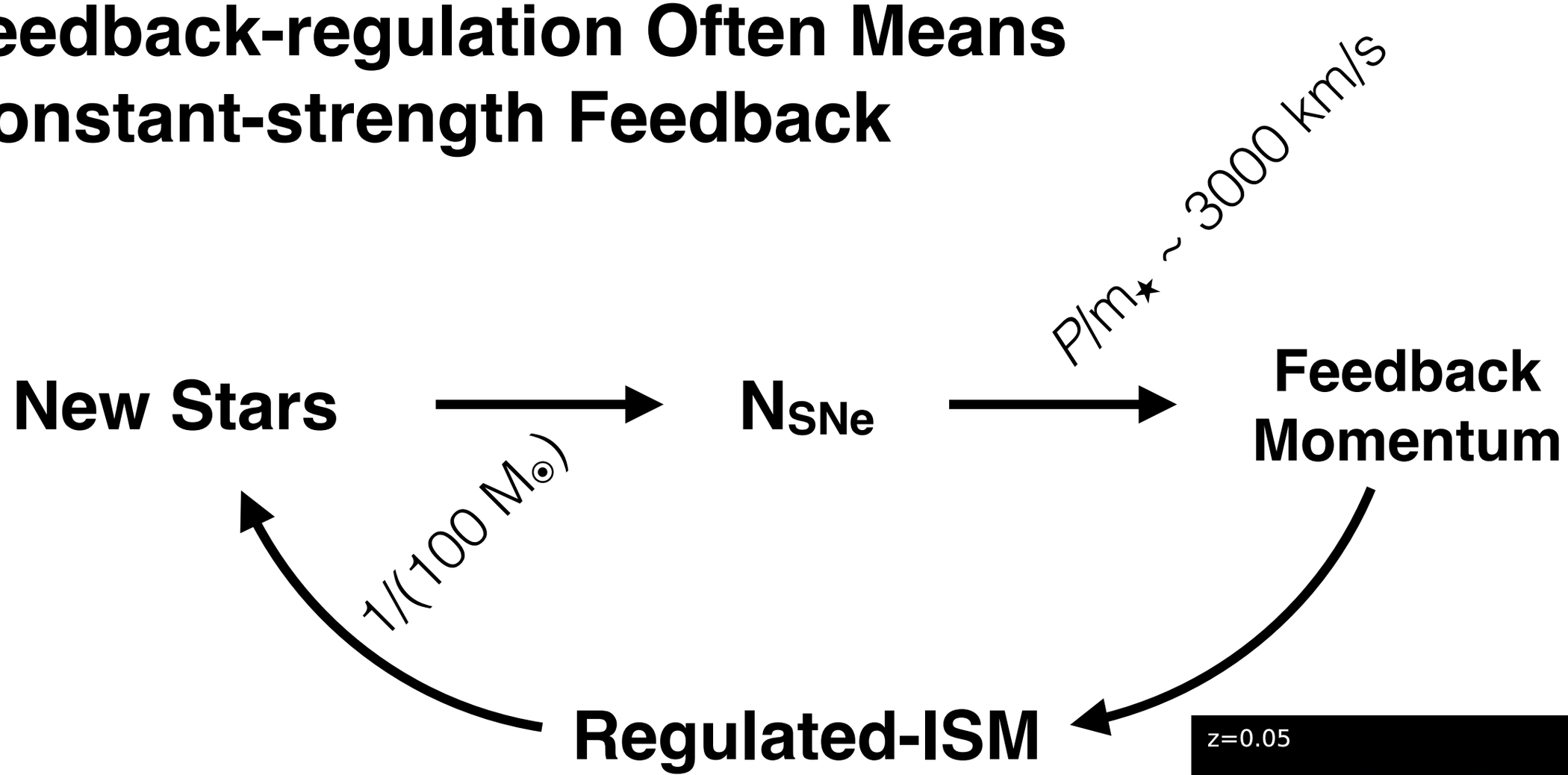
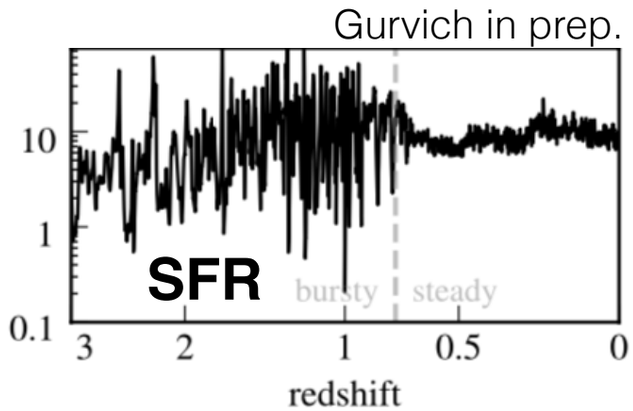
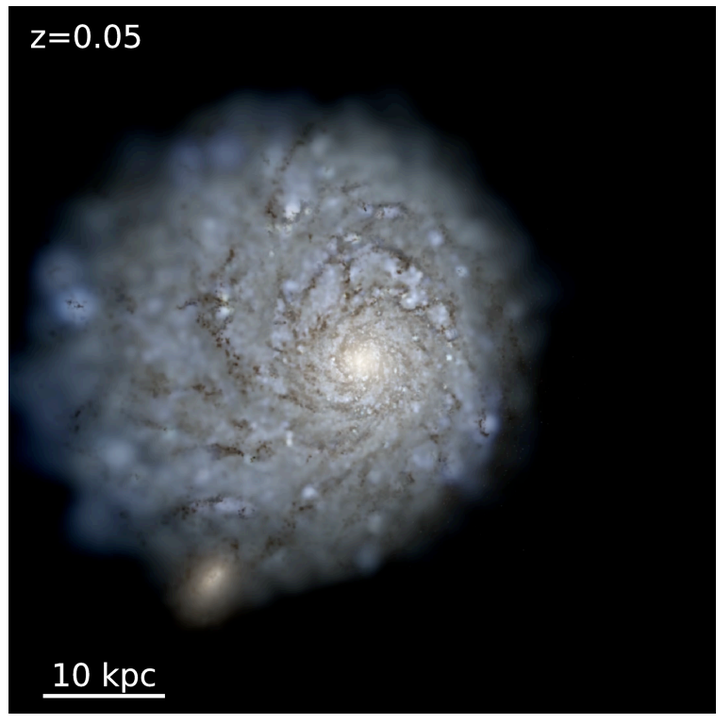


Gurvich in prep.





FIRE-2 **m12b** (Hopkins+2018)

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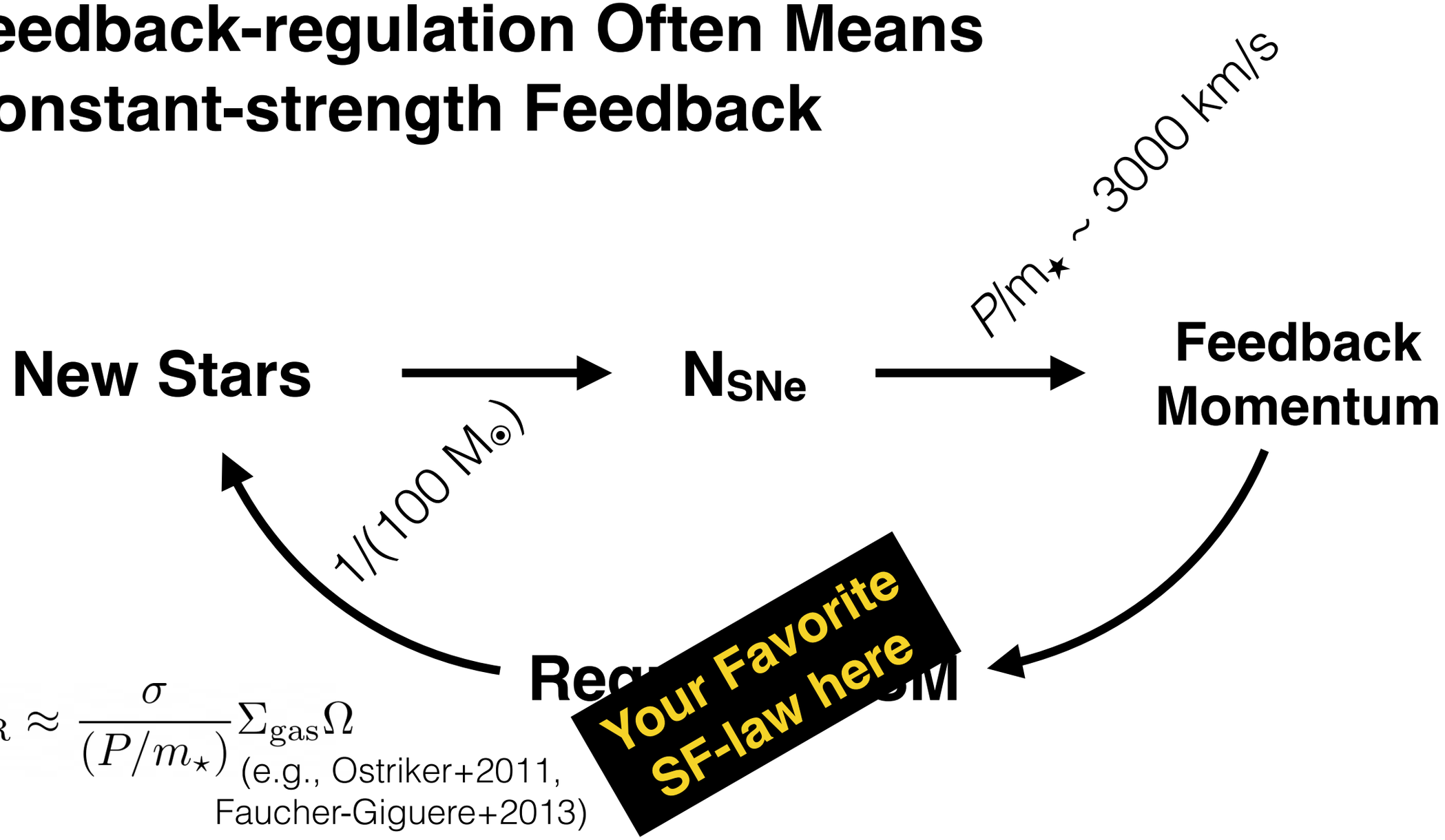

$$\Sigma_{\rm SFR} \approx \frac{\sigma}{(P/m_\star)} \Sigma_{\rm gas} \Omega$$

(e.g., Ostriker+2011, Faucher-Giguere+2013)

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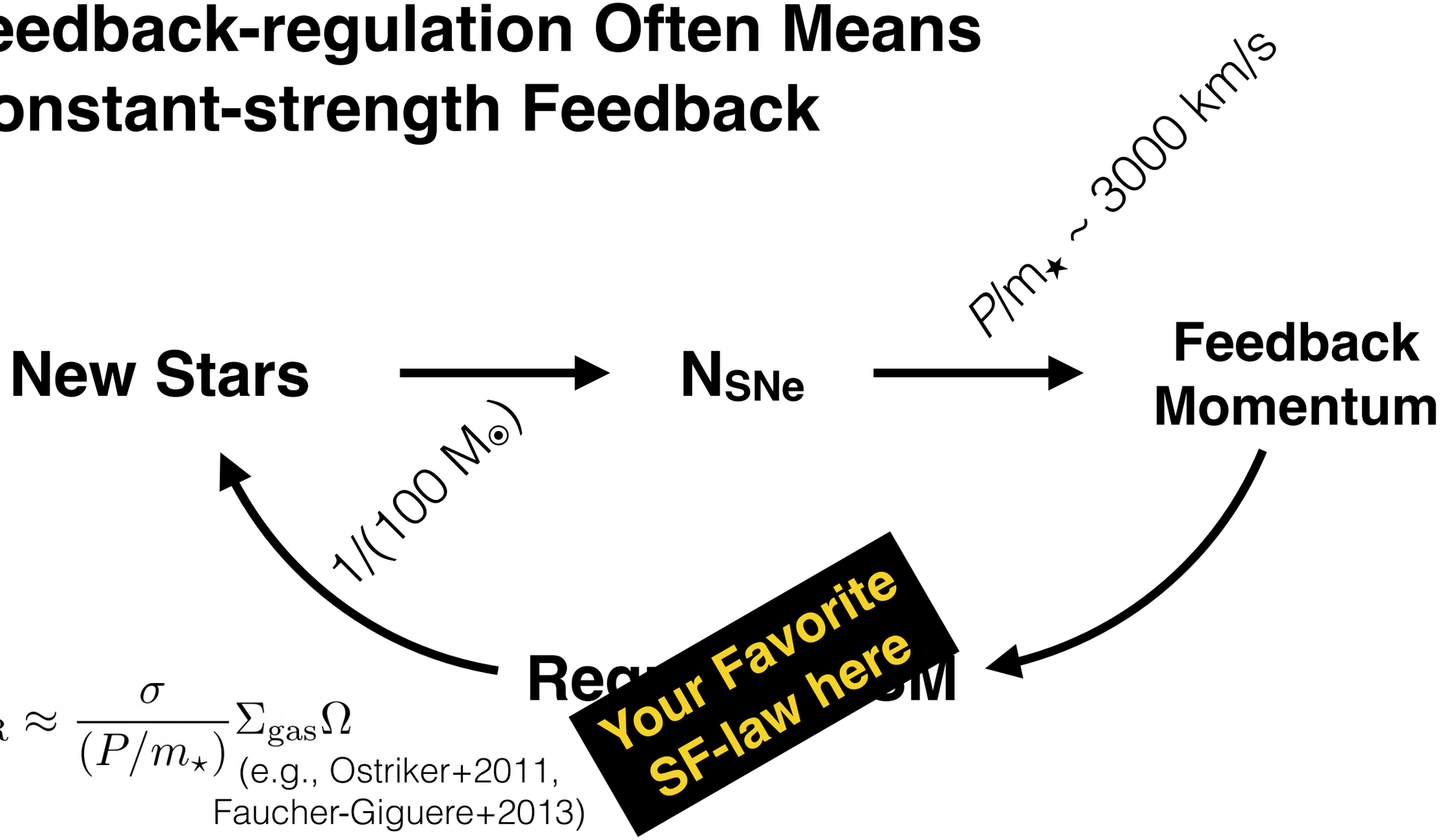

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E.g. HI->H2 transition, thermal or turbulent support, self-gravitating disks, etc.

(cf. Bigiel+2008, Leroy+2008)

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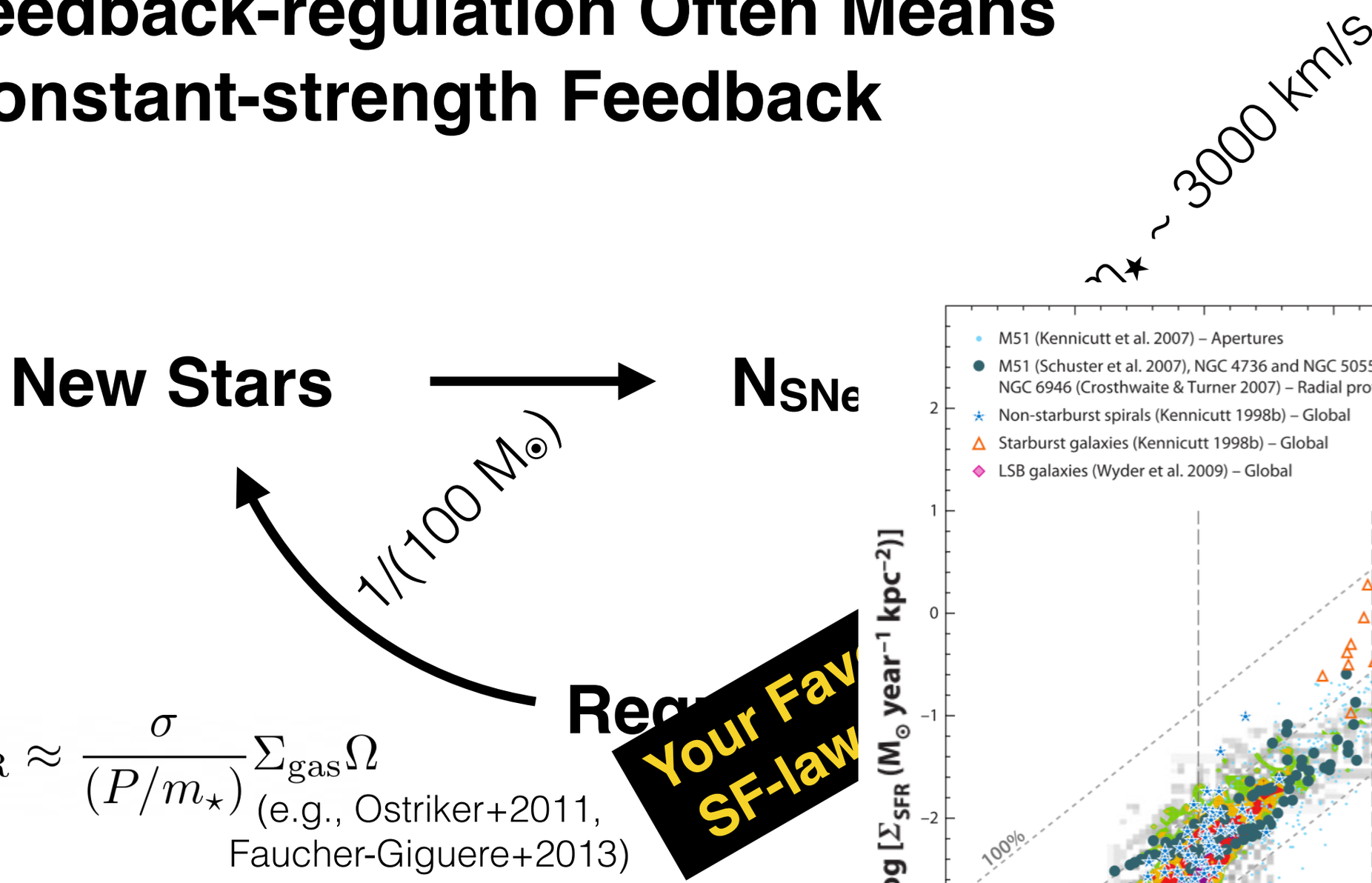

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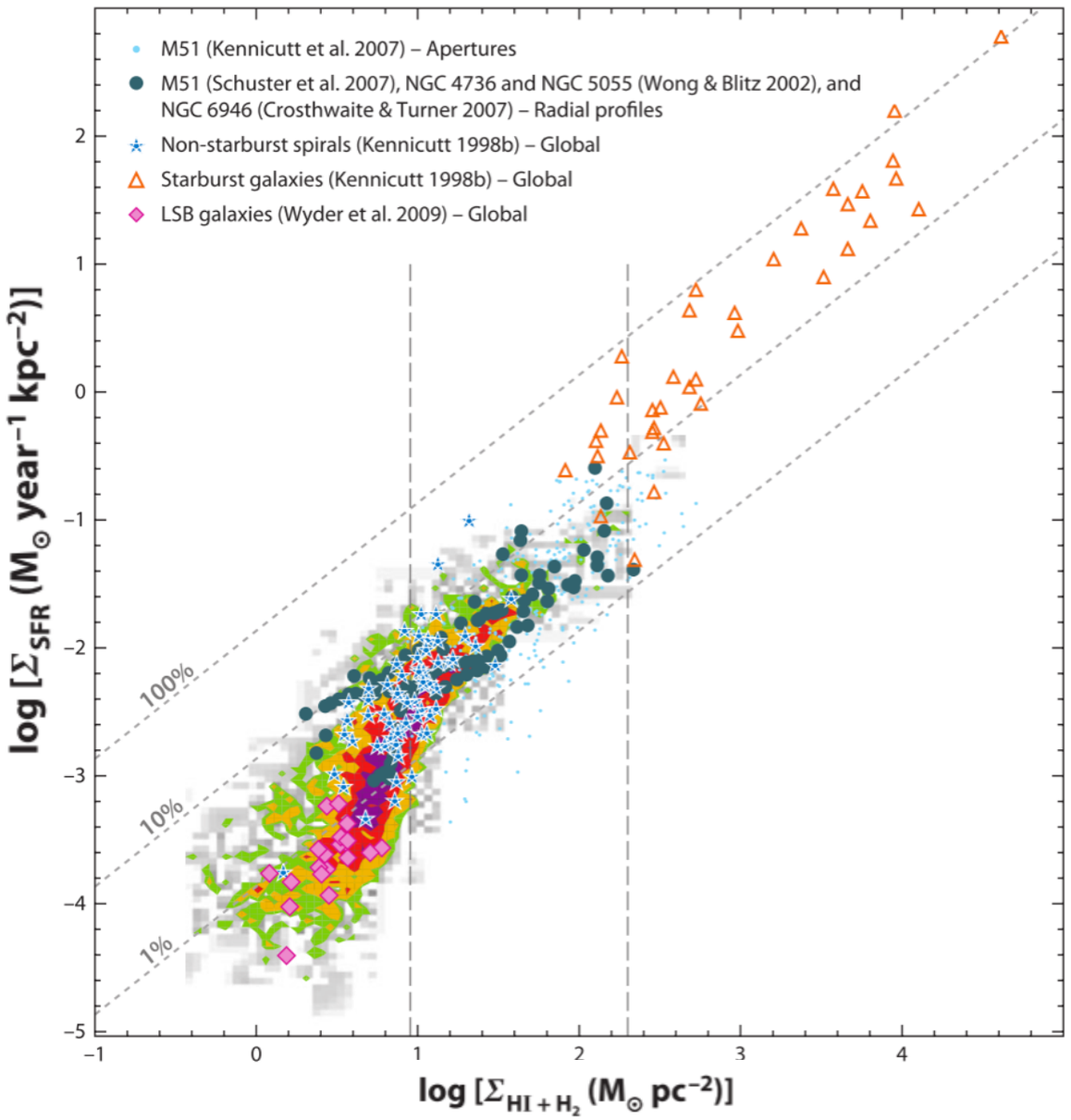

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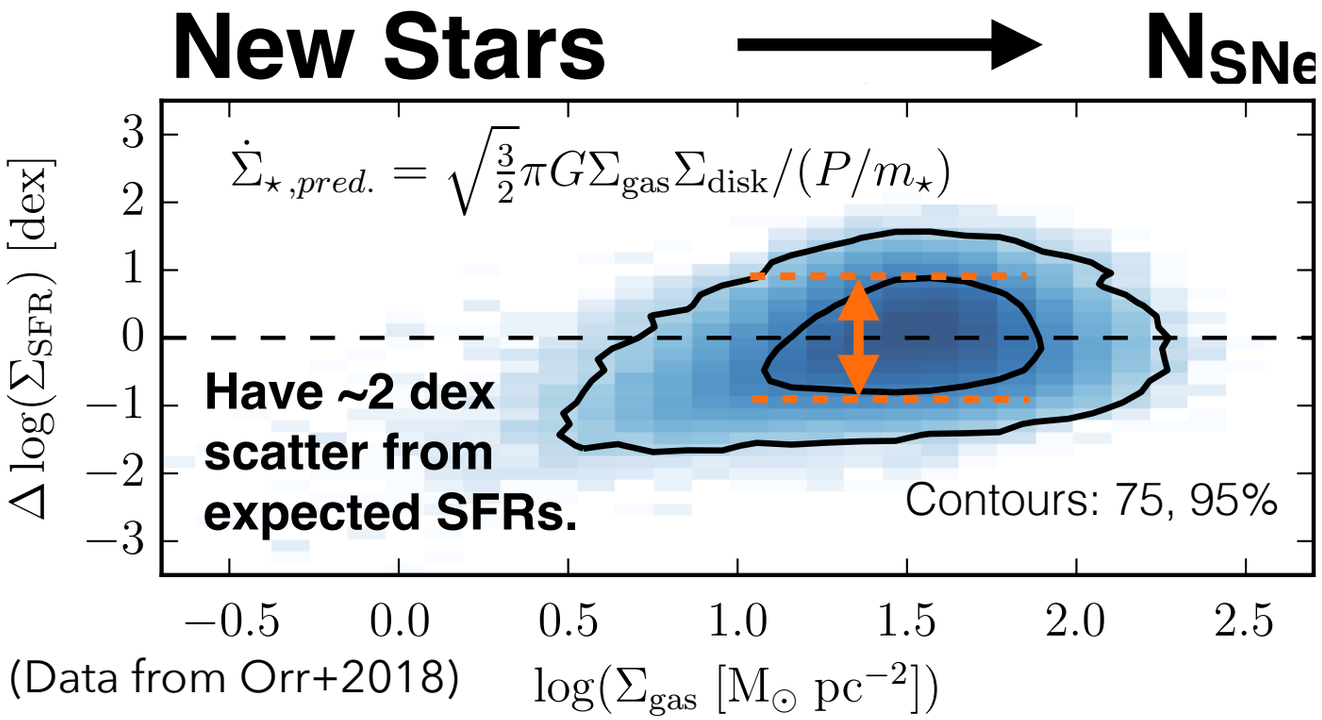

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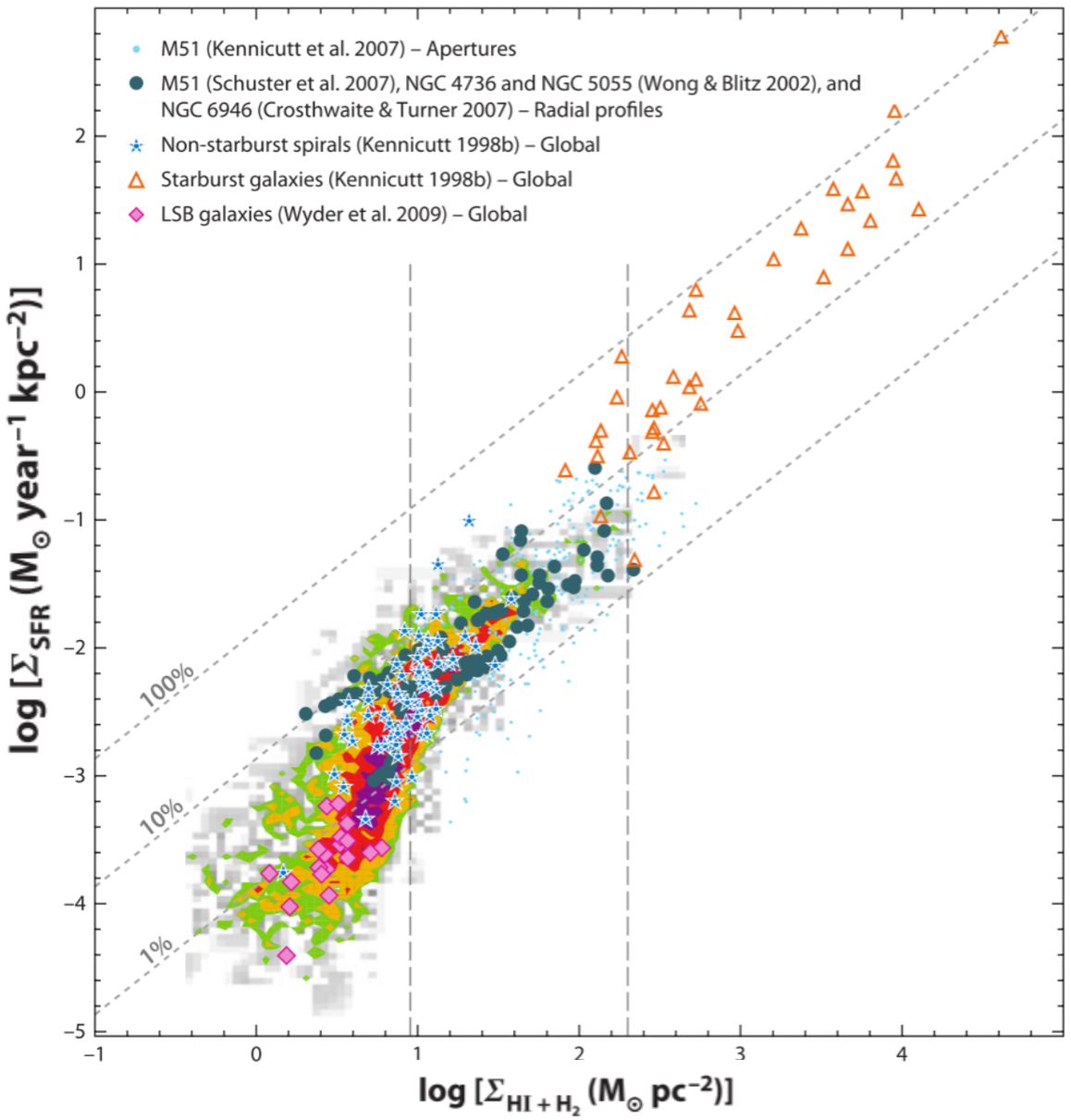

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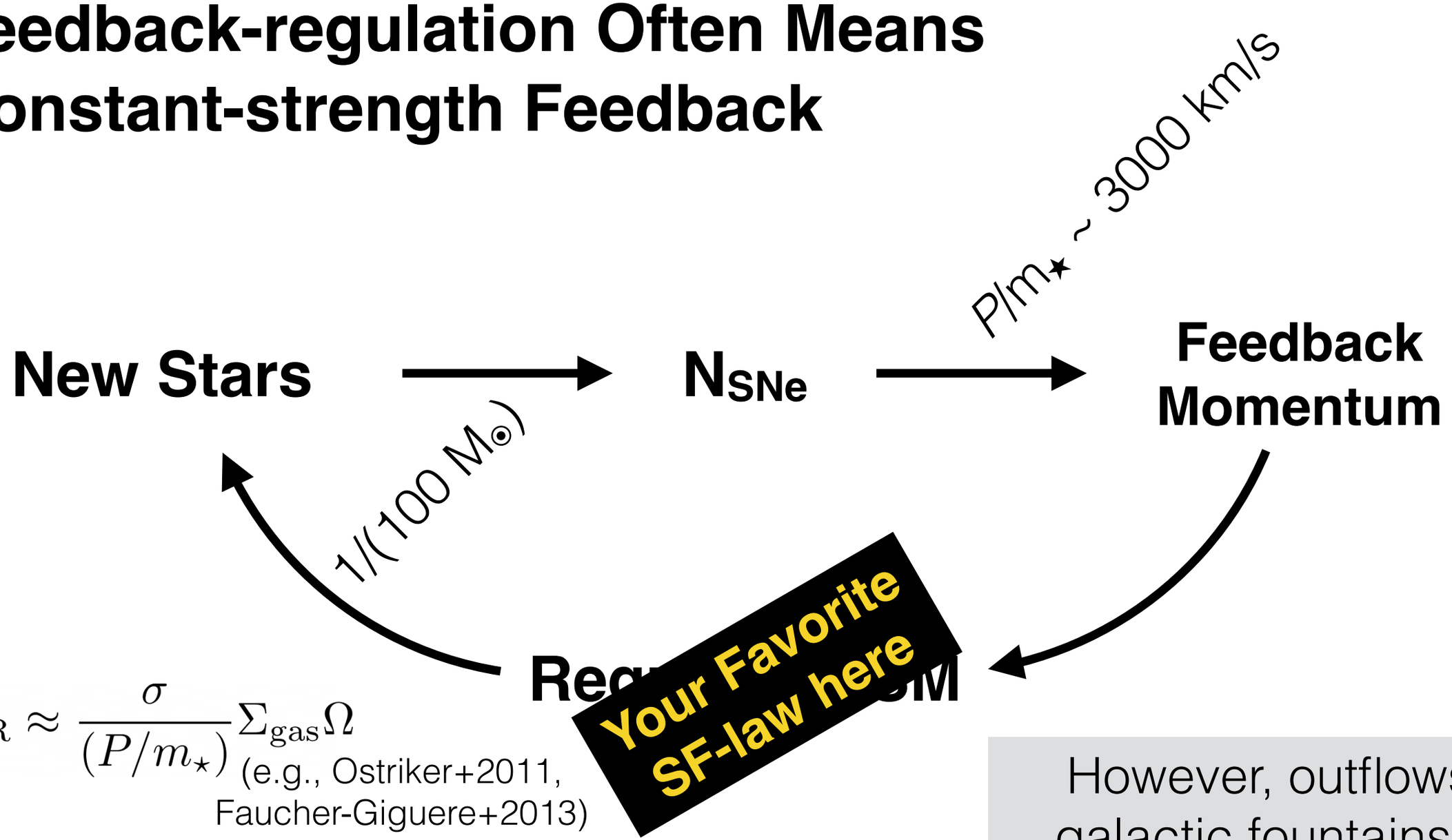

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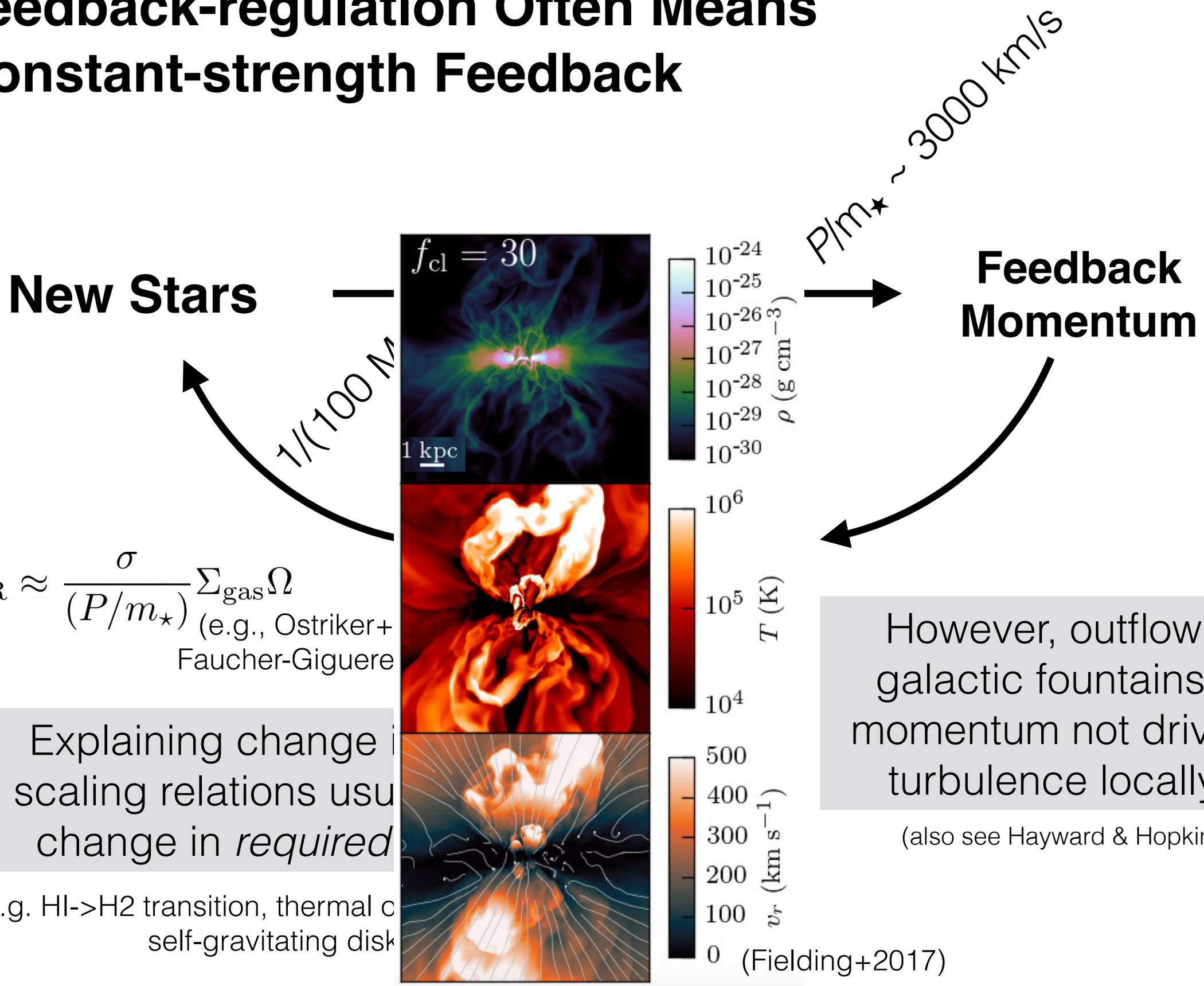

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Explaining change i
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E.g. HI->H2 transition, thermal c
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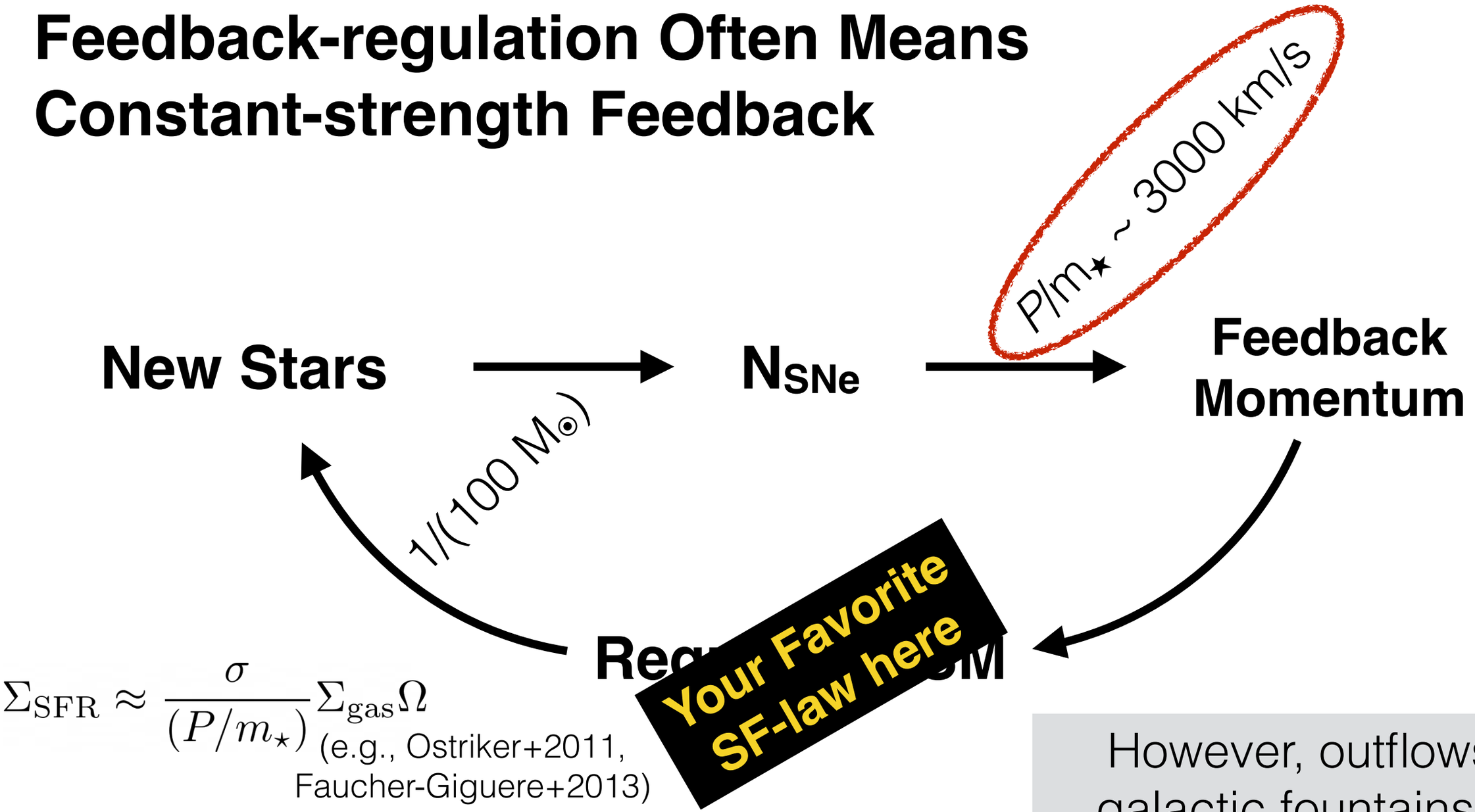
However, outflows/ galactic fountains = momentum not driving turbulence locally!

(also see Hayward & Hopkins 2017)

(Fielding+2017)

Feedback-regulation Often Means Constant-strength Feedback



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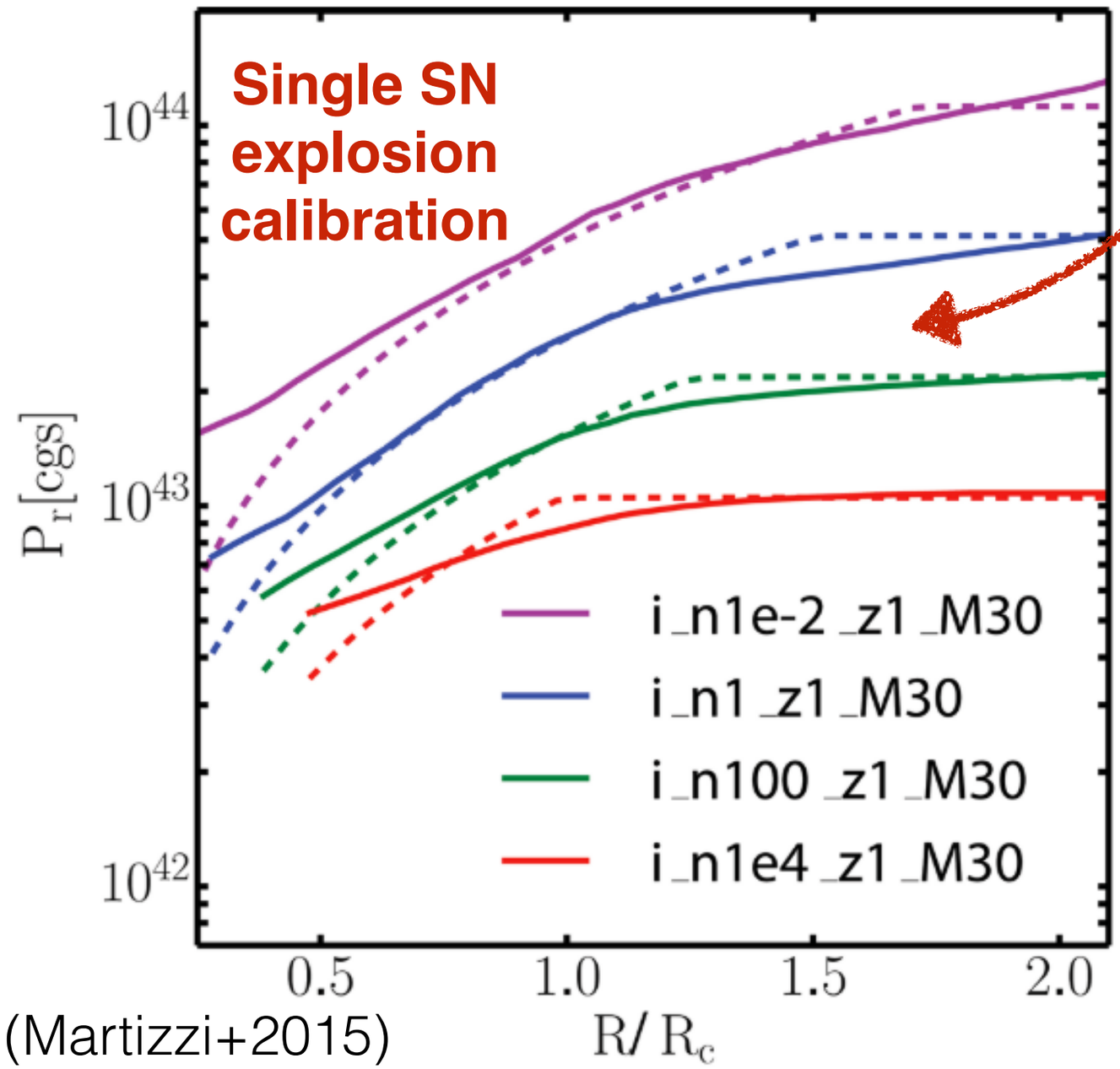
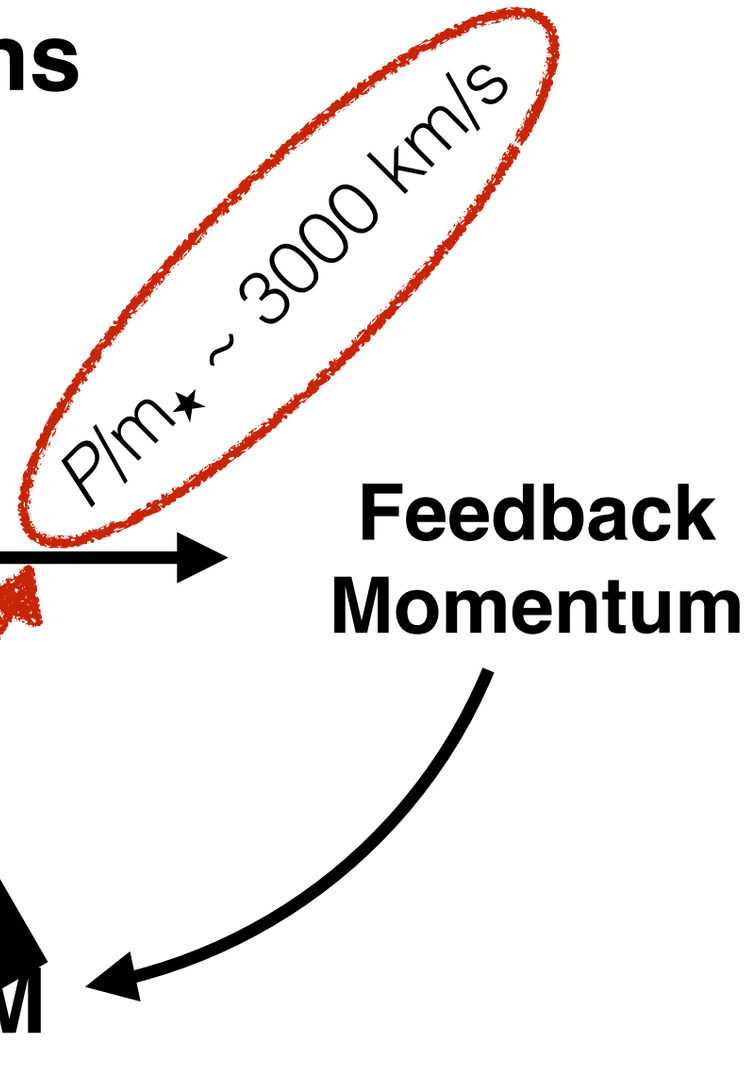


(Martizzi+2015)



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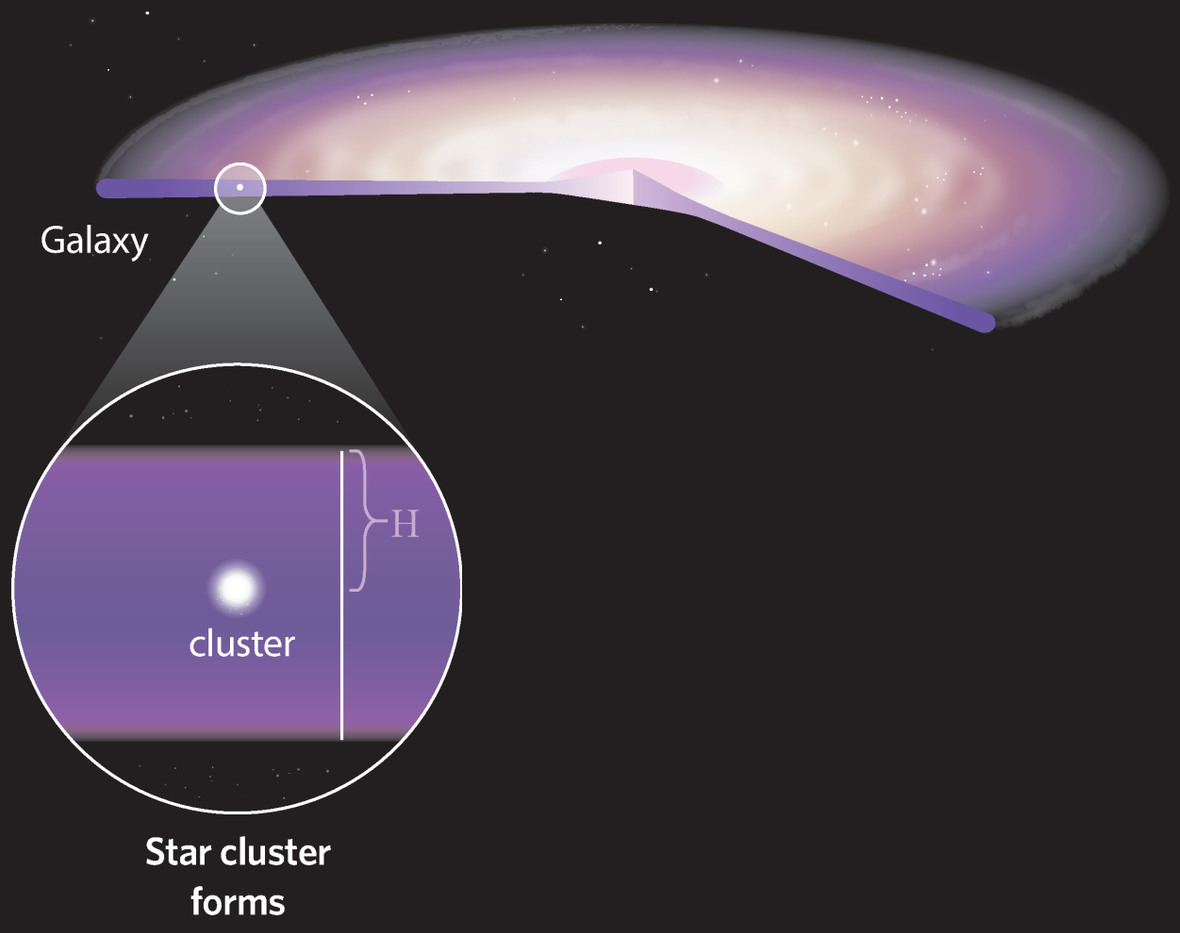
"Variable" strength of Feedback??

Stars formation is clustered

NASA APOD 11/04/17

Superbubble Model



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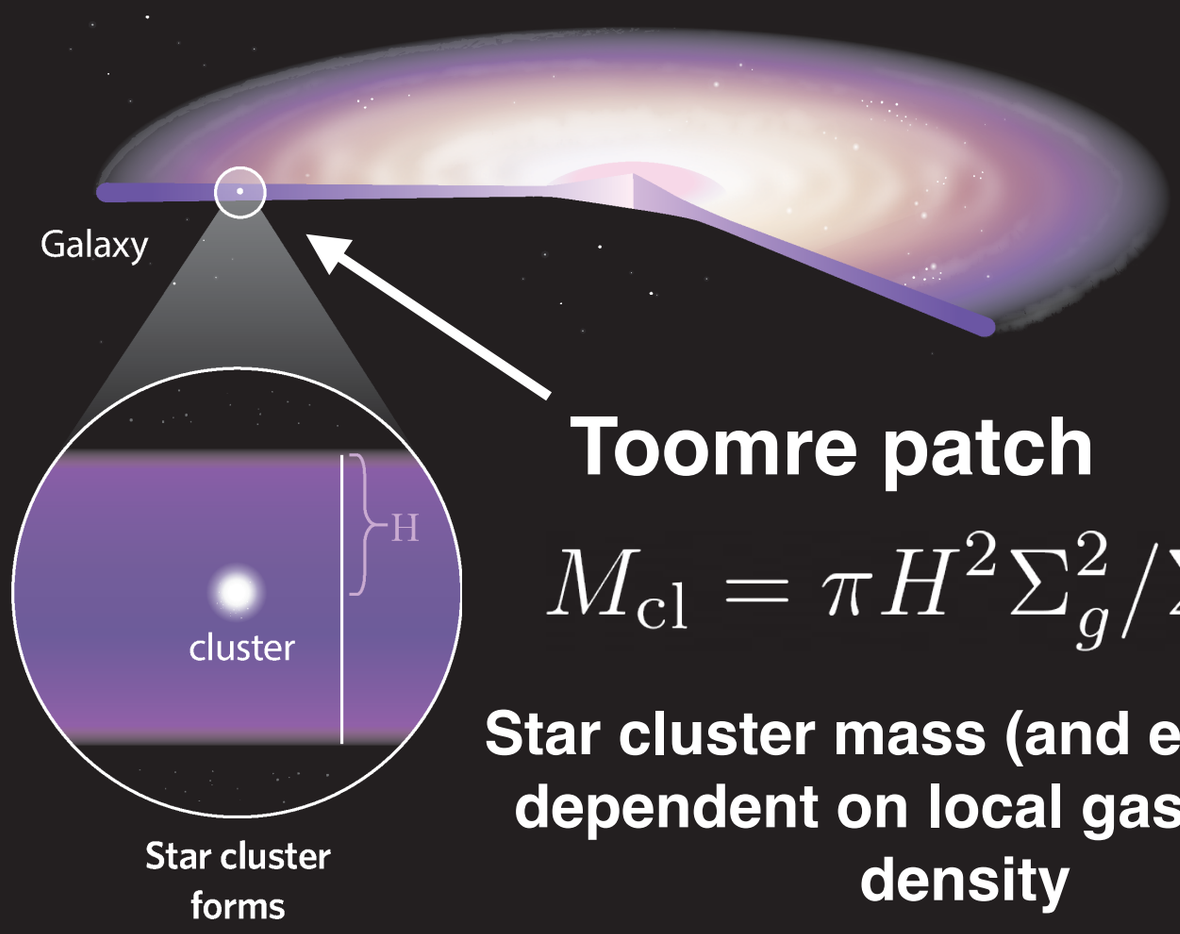
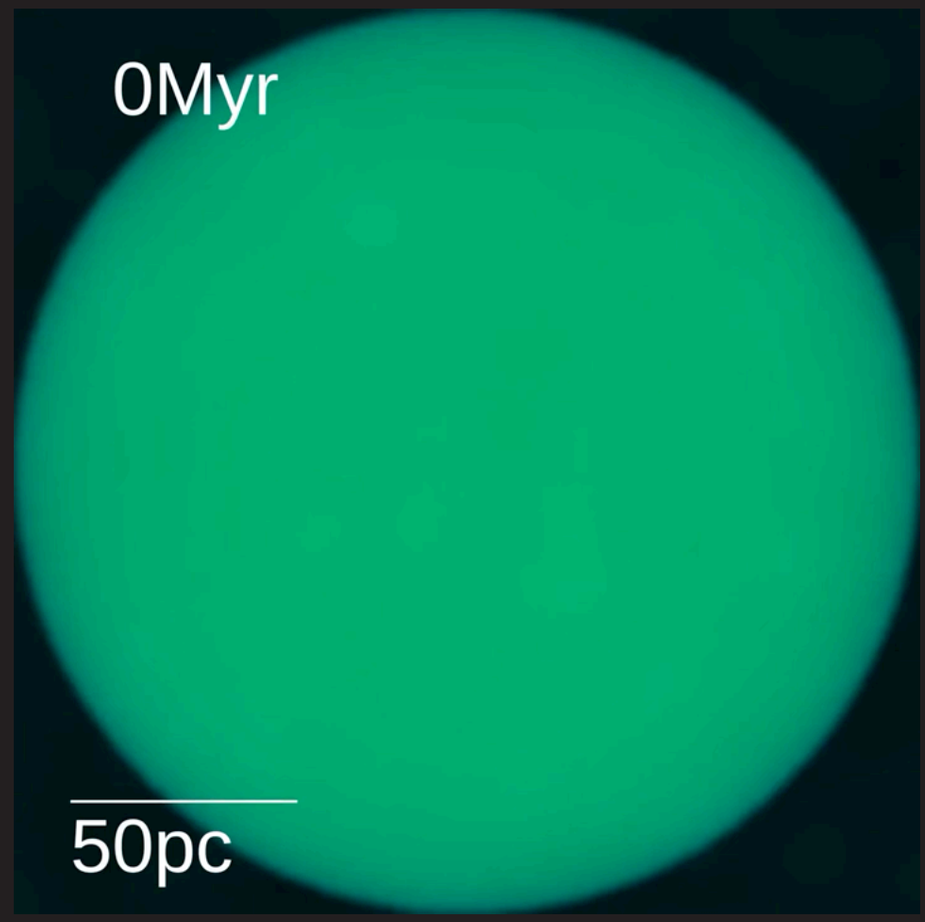


Toomre patch

$$M_{\rm cl} = \pi H^2 \Sigma_g^2 / \Sigma_{\rm crit}$$

Star cluster mass (and efficiency) dependent on local gas surface density

(Cluster formation efficiency from Grudic+18)



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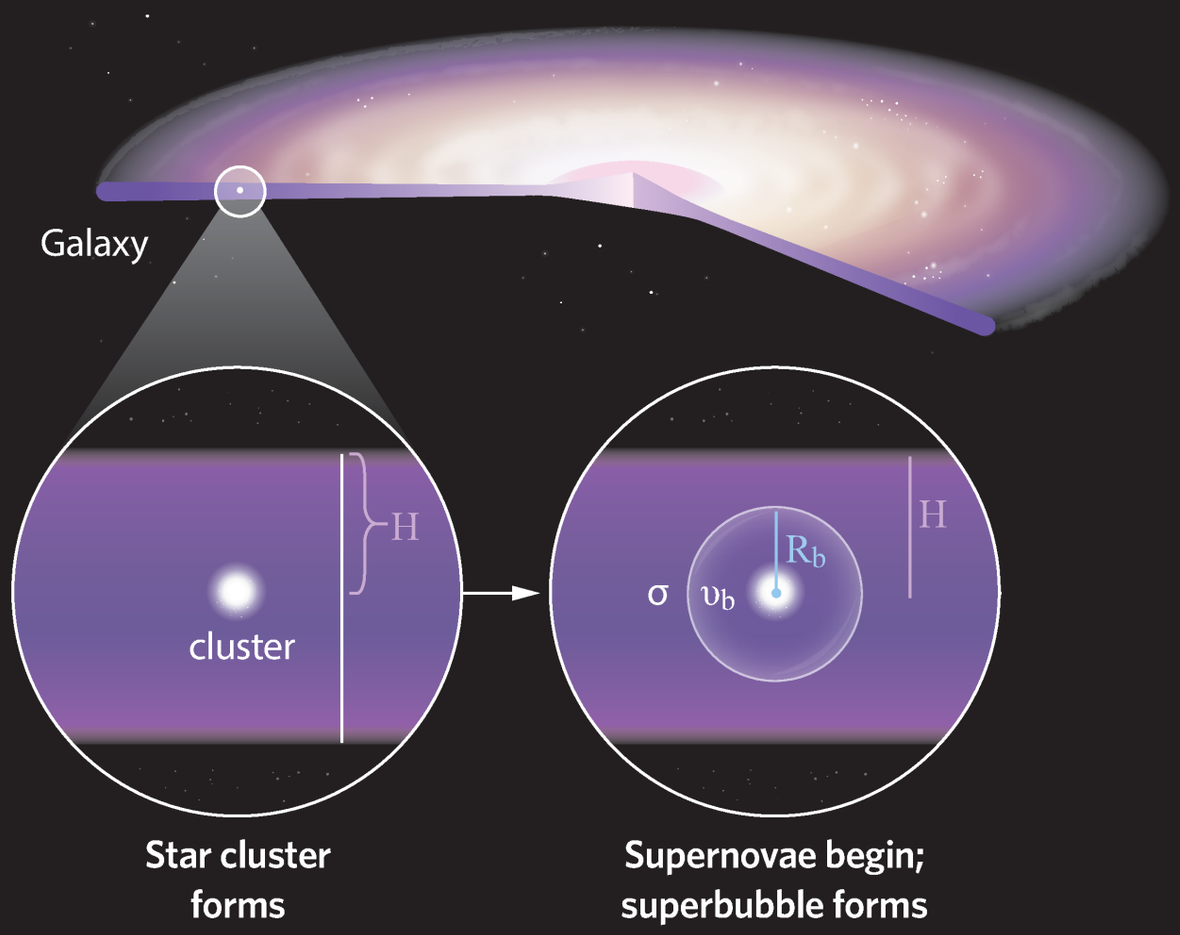

In the regime where time between SN is << lifetime of individual remnant

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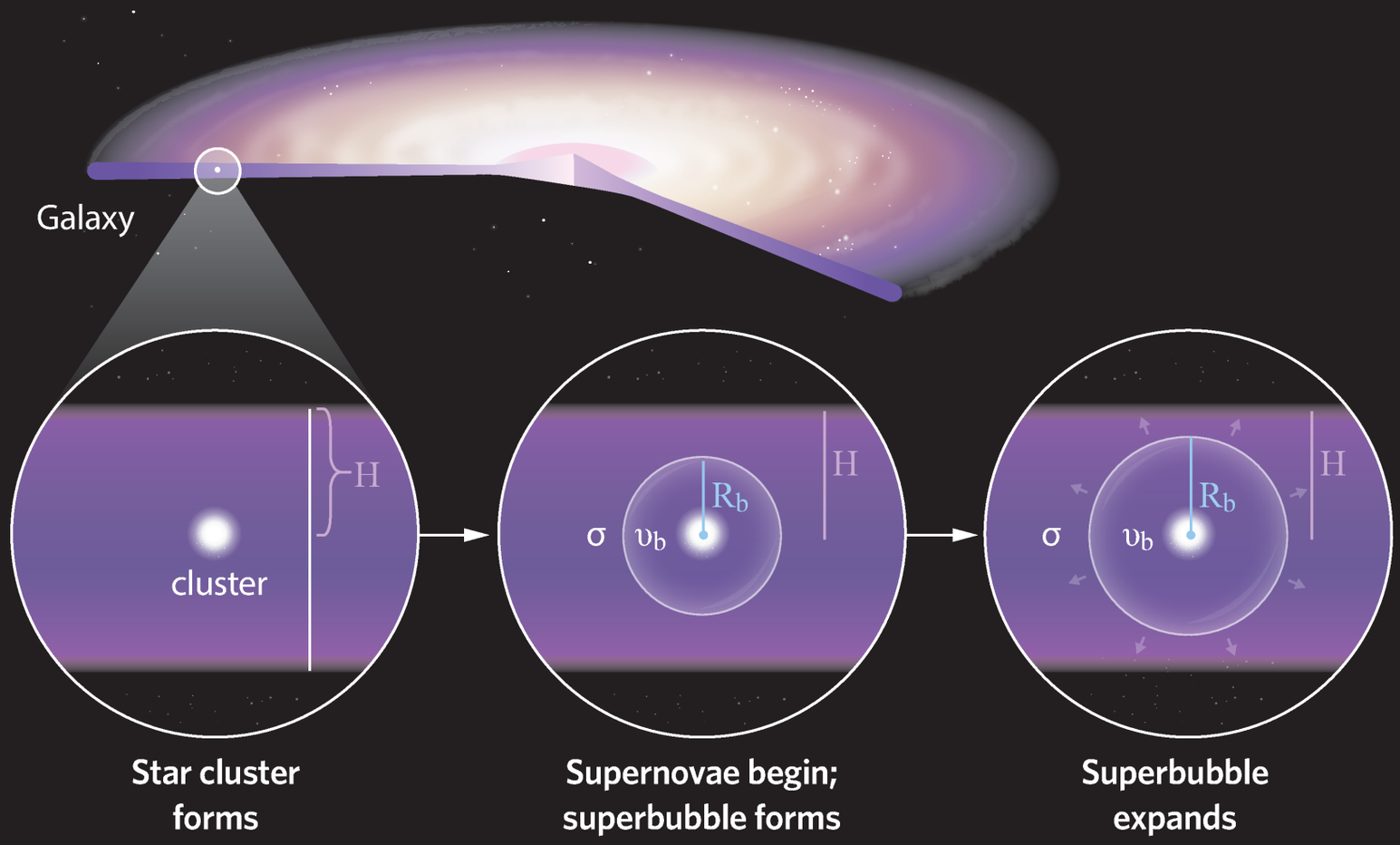
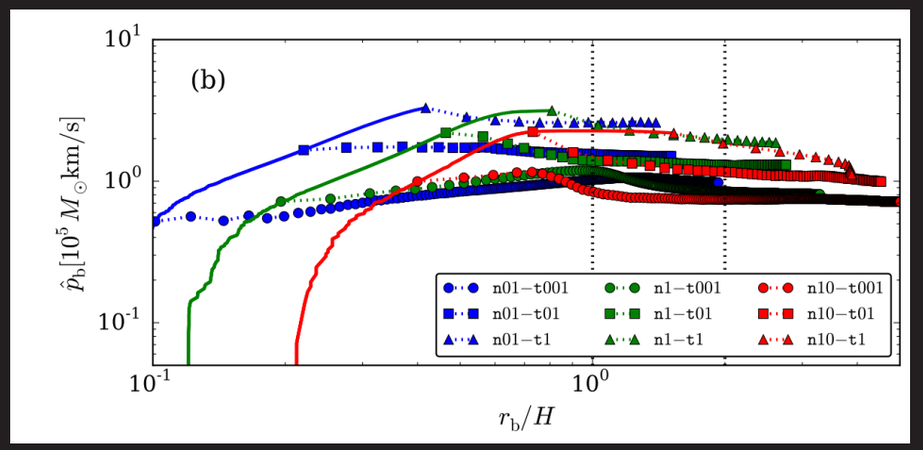
Superbubble Model



Kim+2016



Simulations show bubble momentum directly proportional to N_{SNe}

Balance momentum of the bubble with the integrated supernova momentum.

$$P_b = \frac{4}{3}\pi R_b^3 \rho_g v_b$$

$$P_{\mathrm{SNe}}(t) = M_{\mathrm{cl}} \left(\frac{P}{m_\star}\right)_0 \begin{cases} \left(\frac{t}{t_{\mathrm{SNe}}}\right)^{1-\alpha}, & 0 < t < t_{\mathrm{SNe}} \\ 1, & t > t_{\mathrm{SNe}} \ , \end{cases}$$

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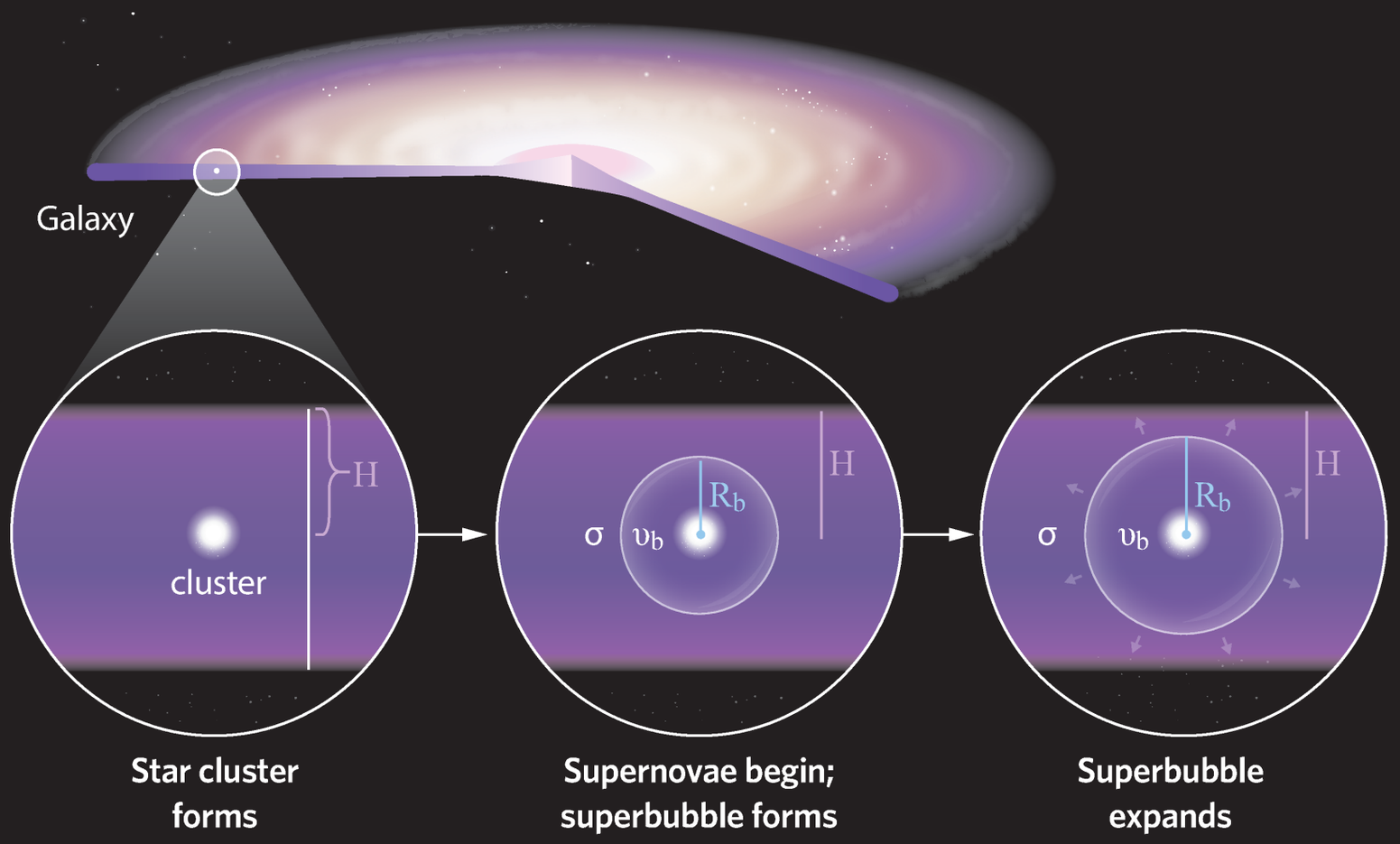

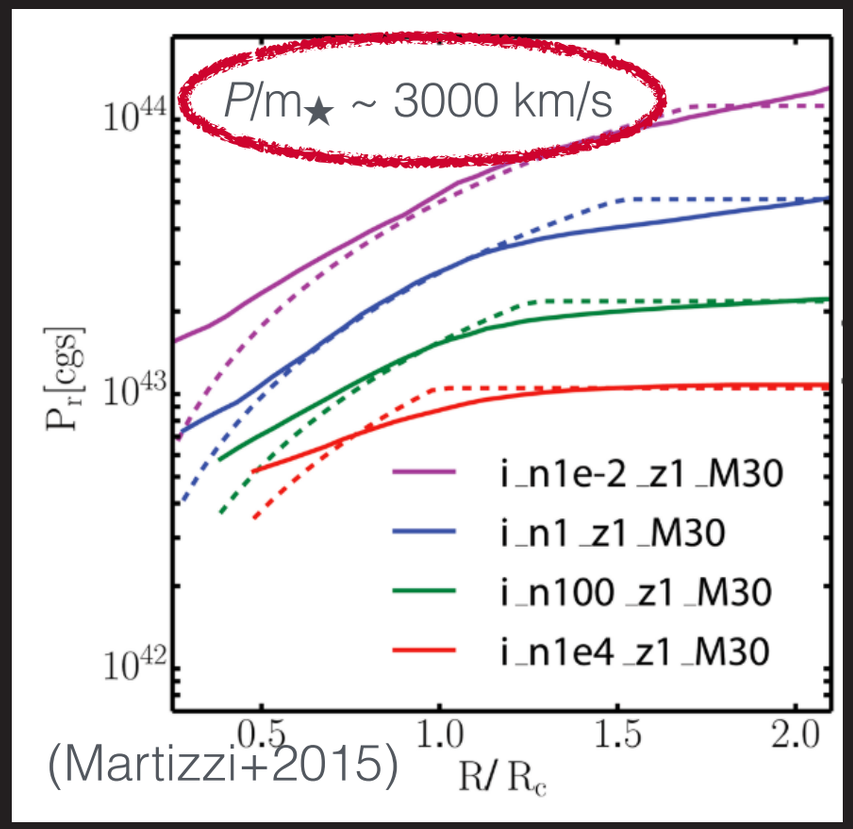

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Depends on IMF, stellar lifetimes

$\alpha \approx 0.46$

Time of last SN ~40 Myr

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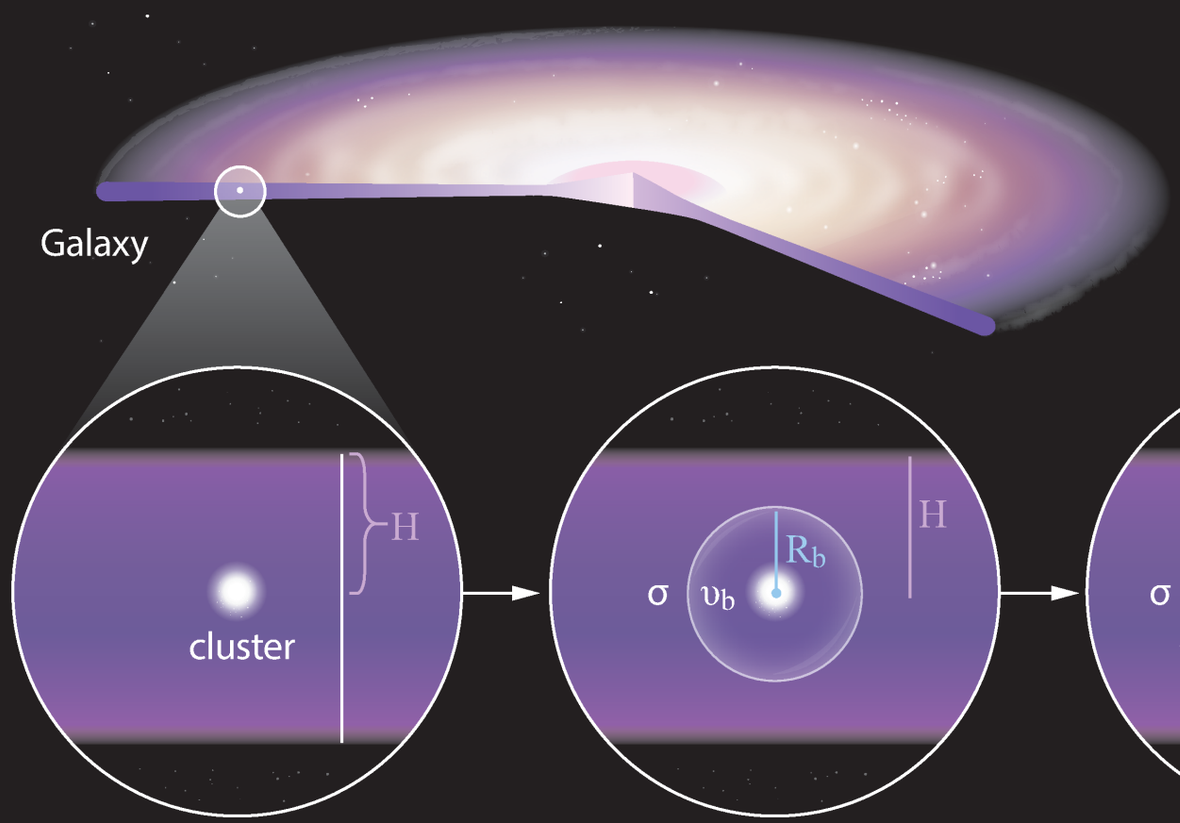

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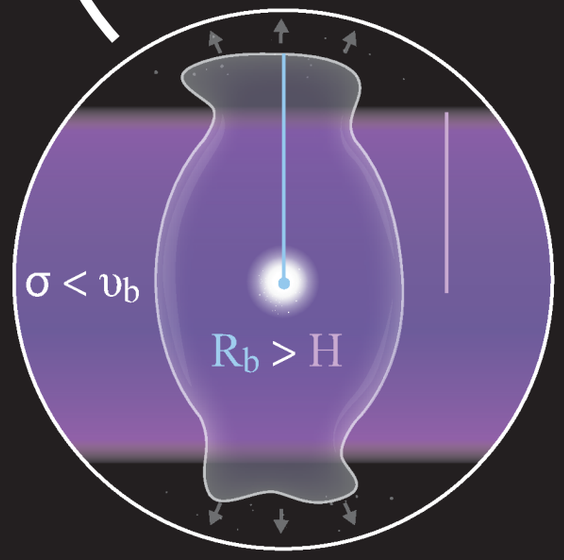
Bubble Outcomes

Fielding et al. 2017



Bubble reaches disk scale height before/after last supernova occurs.

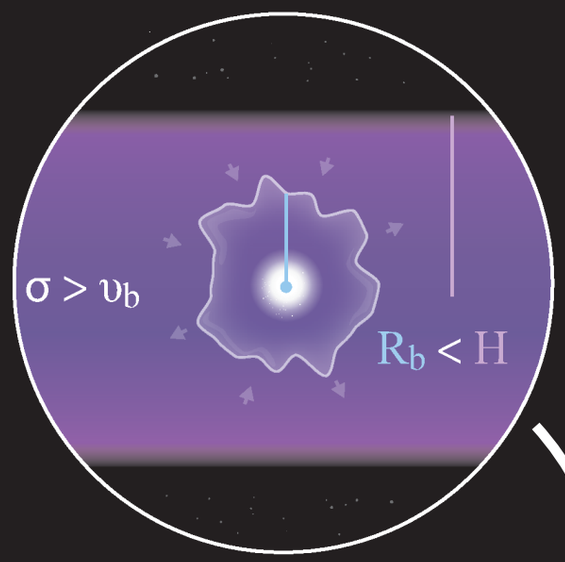
Powered Break-out (before)

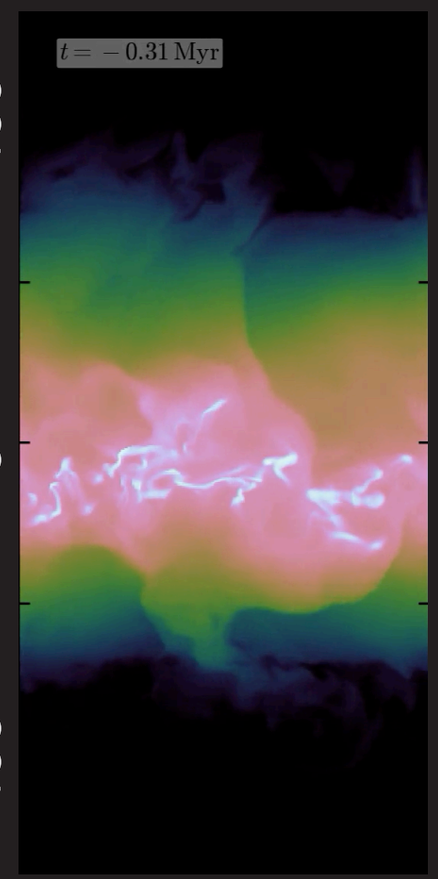
Coasting Break-ou (after)

Bubble stalls before or fragments after the last supernova occurs.

Powered Stall (before)

Coasting Fragmentation (after)





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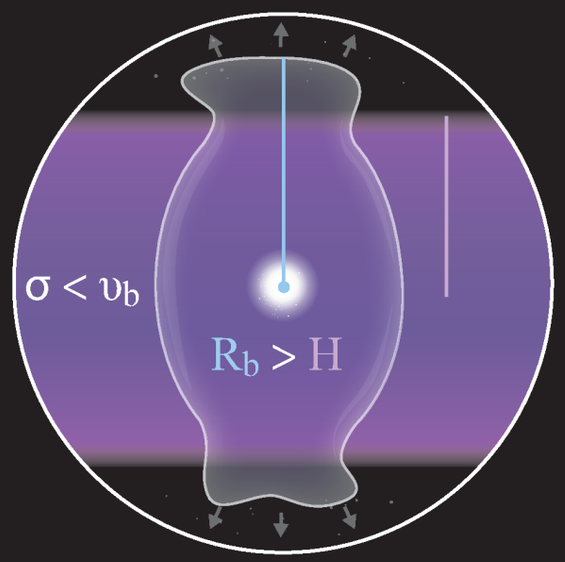
What determines break-out?

Momentum Balance

$$P_{\rm SNe}(t) = P_b(t)$$



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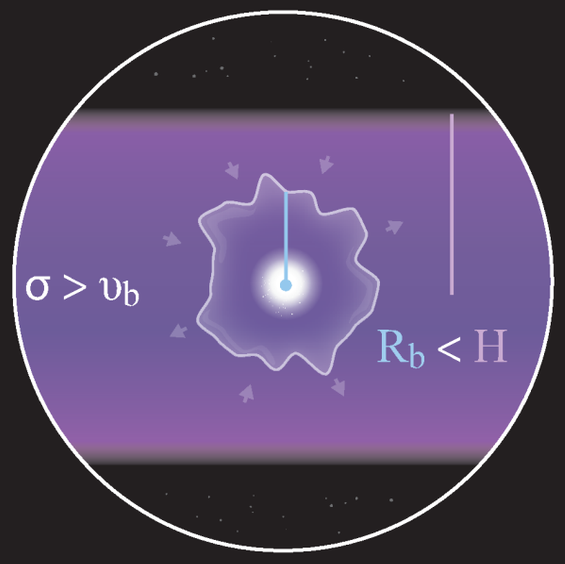

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Two conditions

$$R_b = H$$

$$v_b > \sigma$$

Also:

$$H = \sigma/\Omega \qquad \Omega = v_c/R$$

$$Q \approx 1$$

Can solve for R_b & v_b

In terms of f_g & Ω

+ some model parameters

When and where bubbles break out

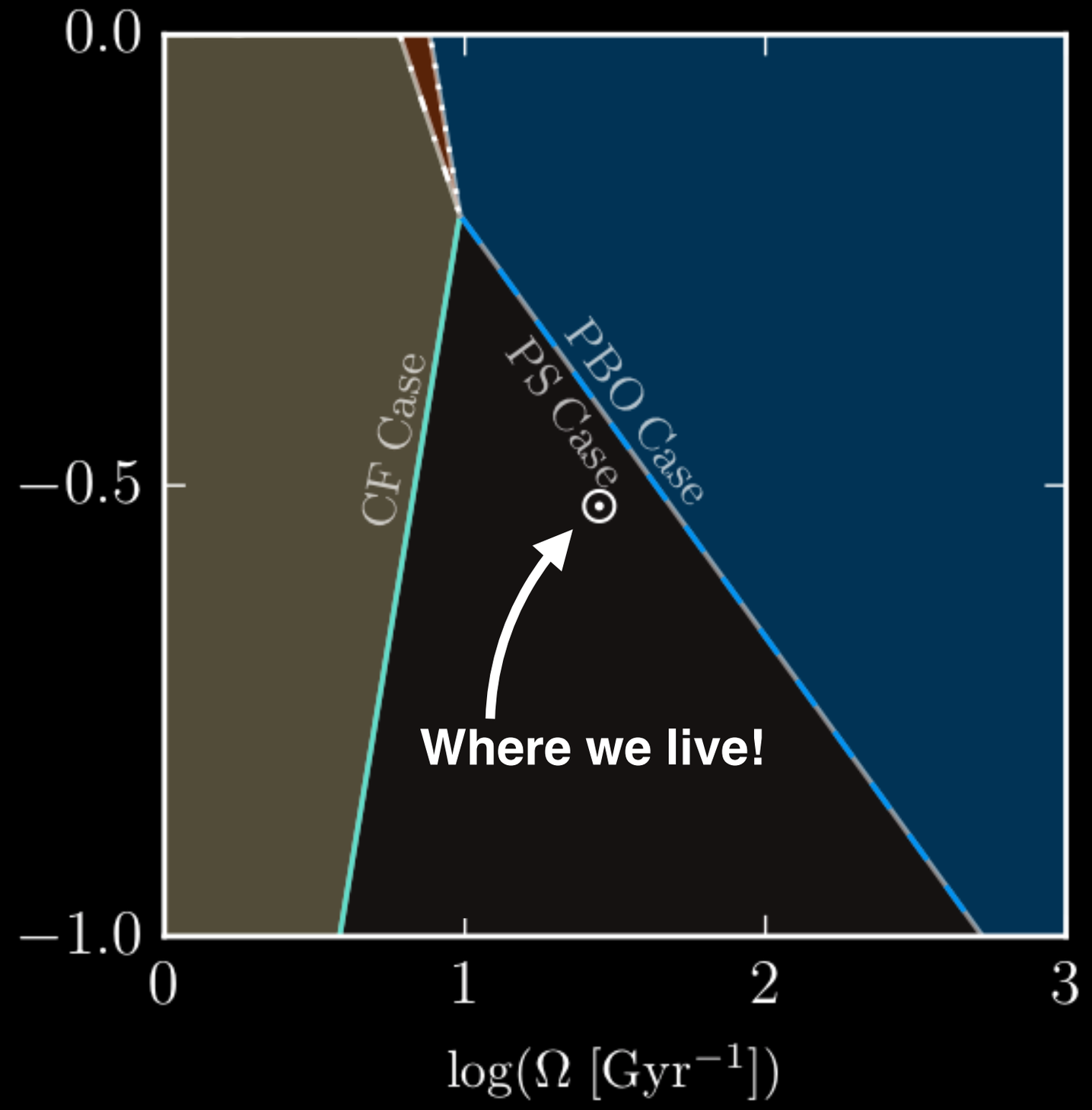
Four cases, by name:

PBO*: Powered Break out*

PS*: Powered Stall*

CBO*: Coasting Break out*

CF*: Coasting Fragmentation*



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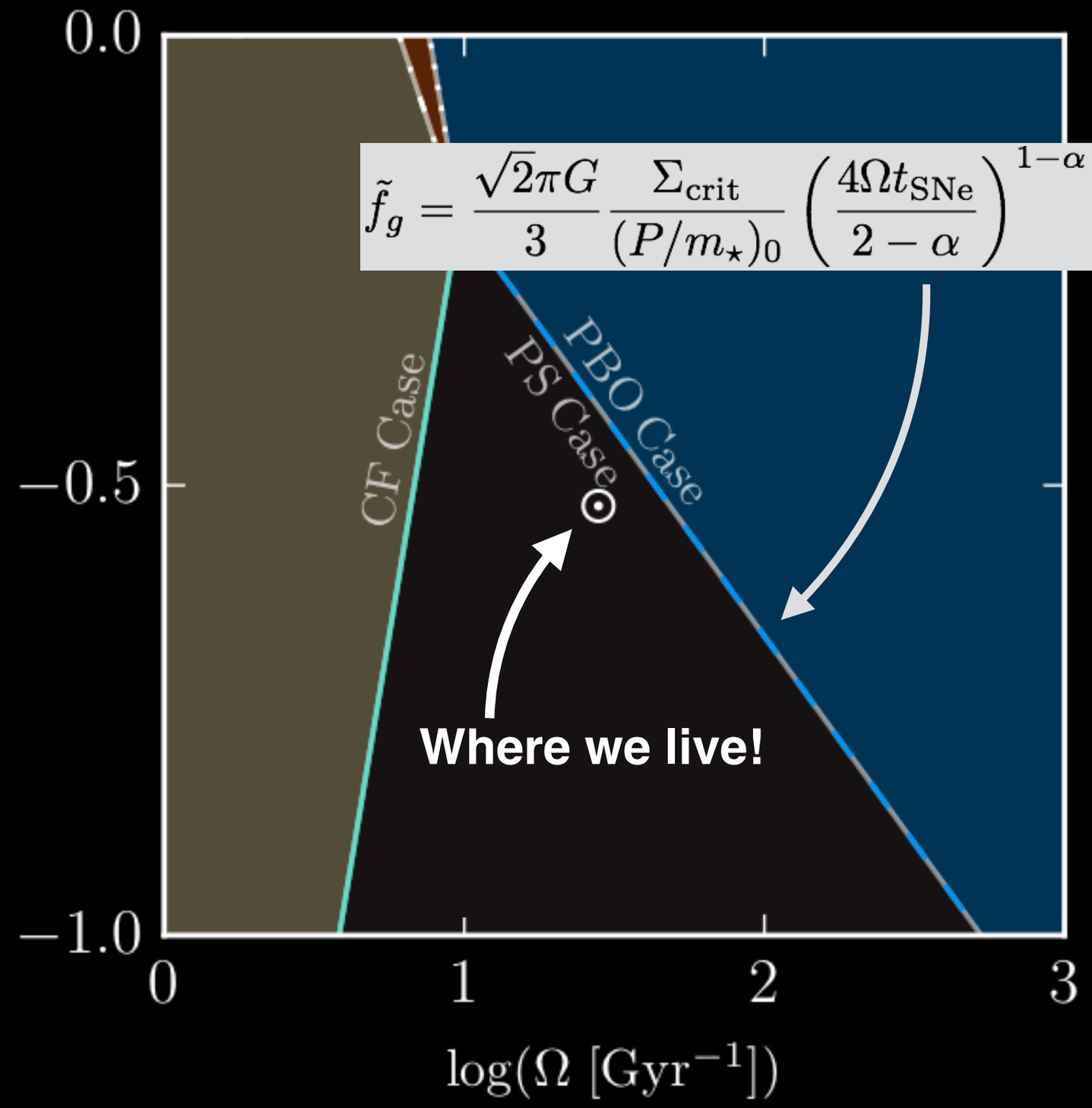

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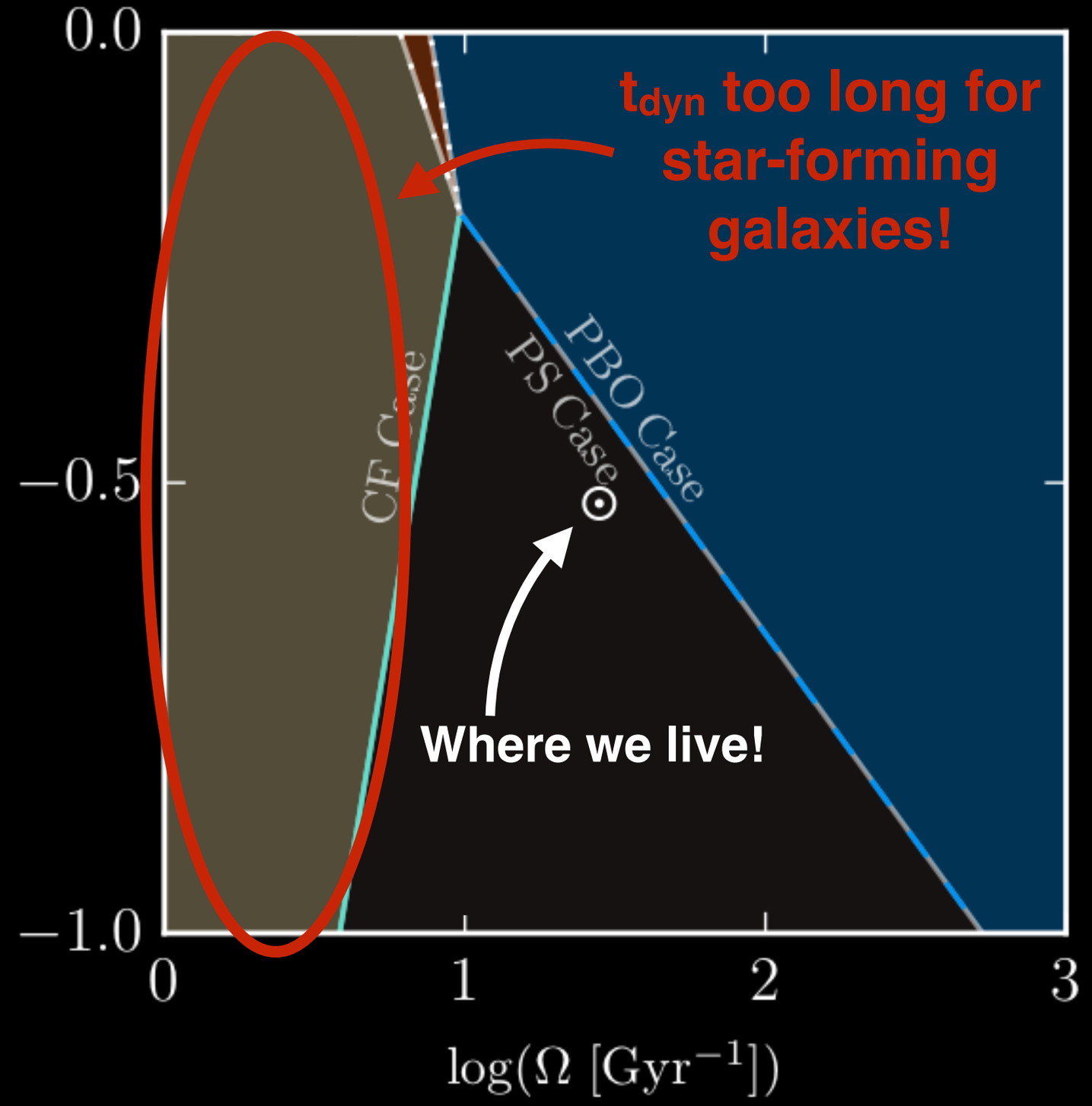

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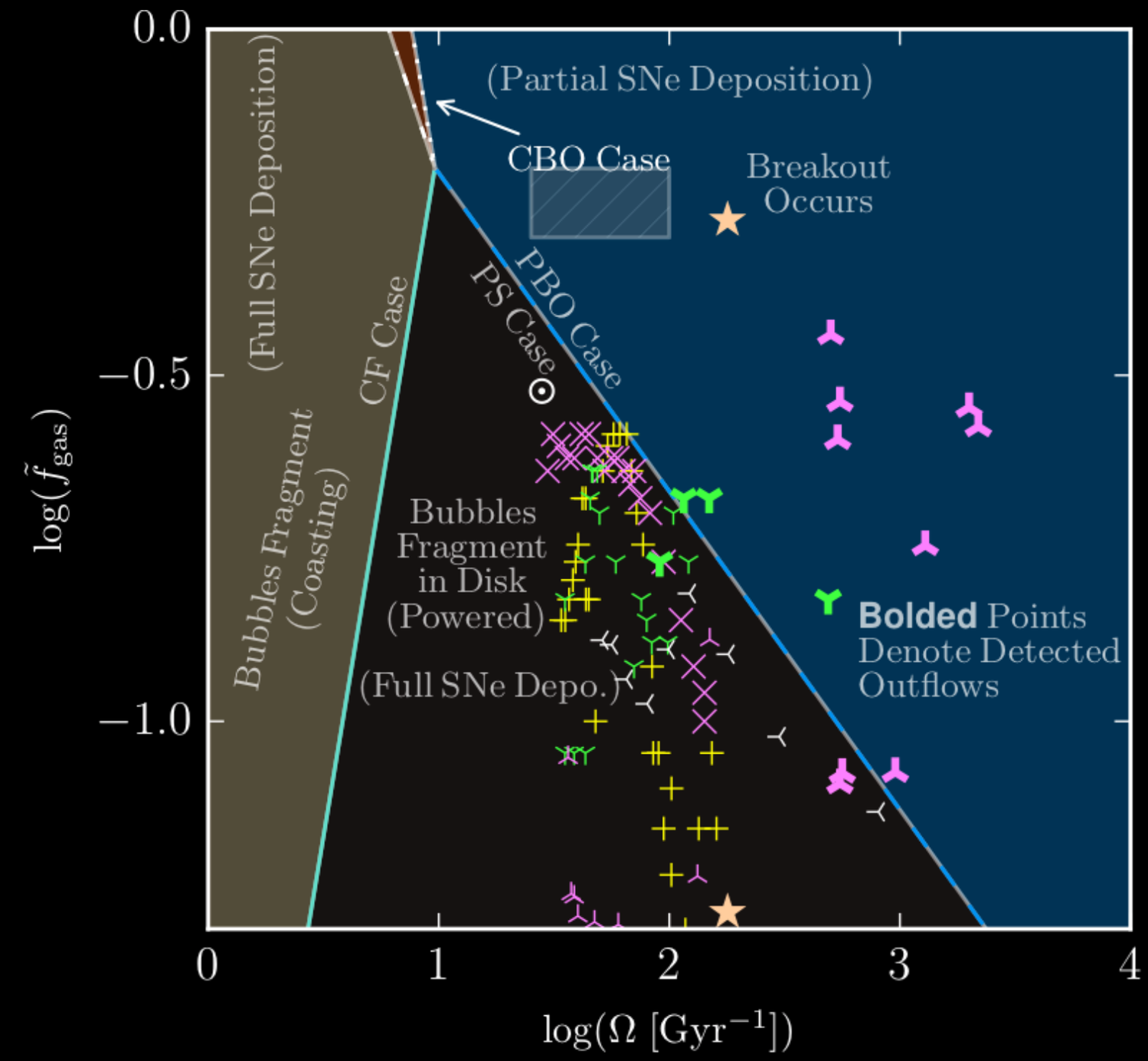
When and where bubbles break out

Out in the Universe, we can see that most superbubbles break up *inside* their galaxies.



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But our prediction for where they break *out* seems to explain the super-winds that we see!

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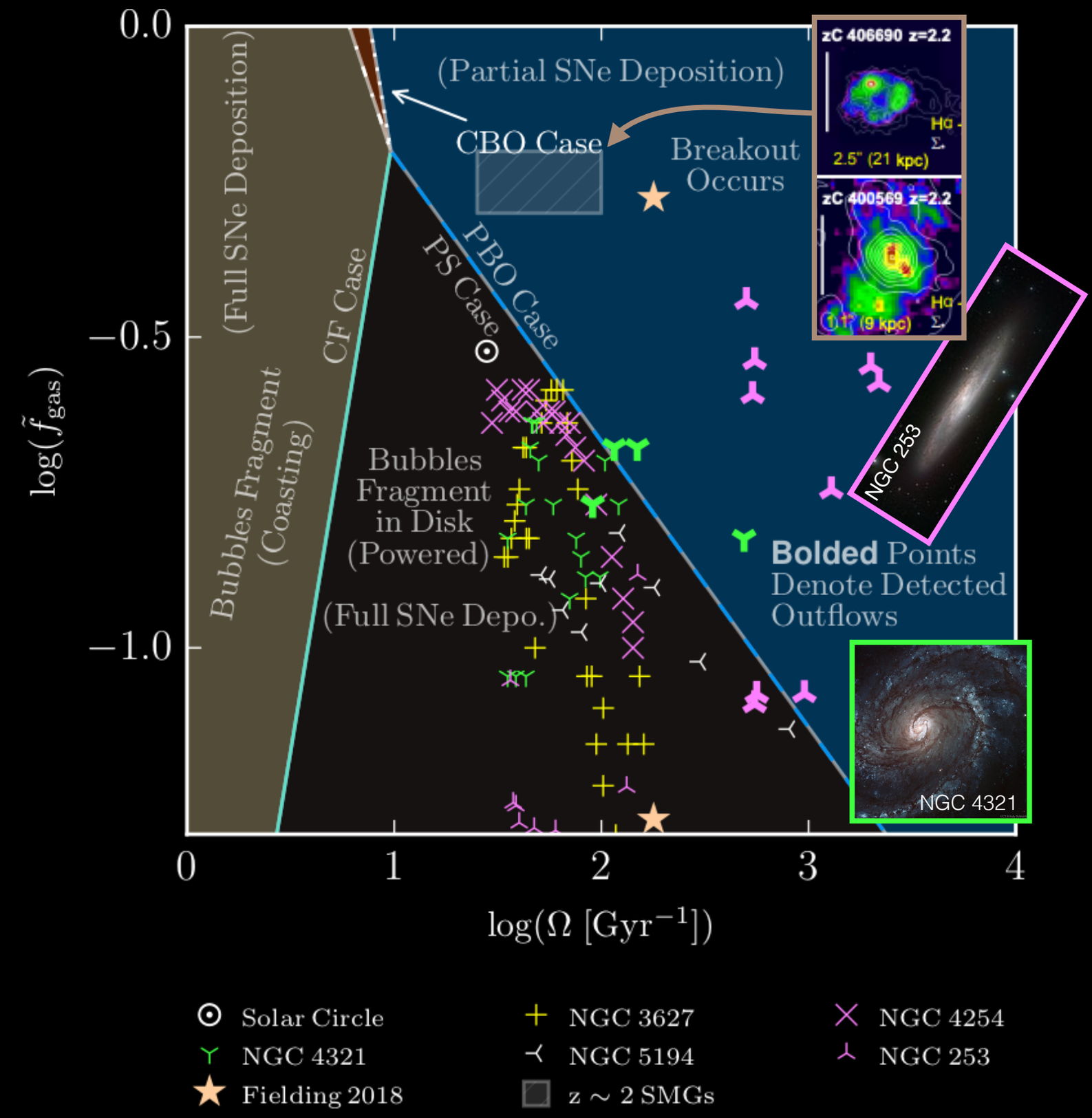

Effective Strength of Feedback

When superbubbles break out, less momentum is deposited into the ISM vs. CGM

Less momentum contained at shorter dynamical times

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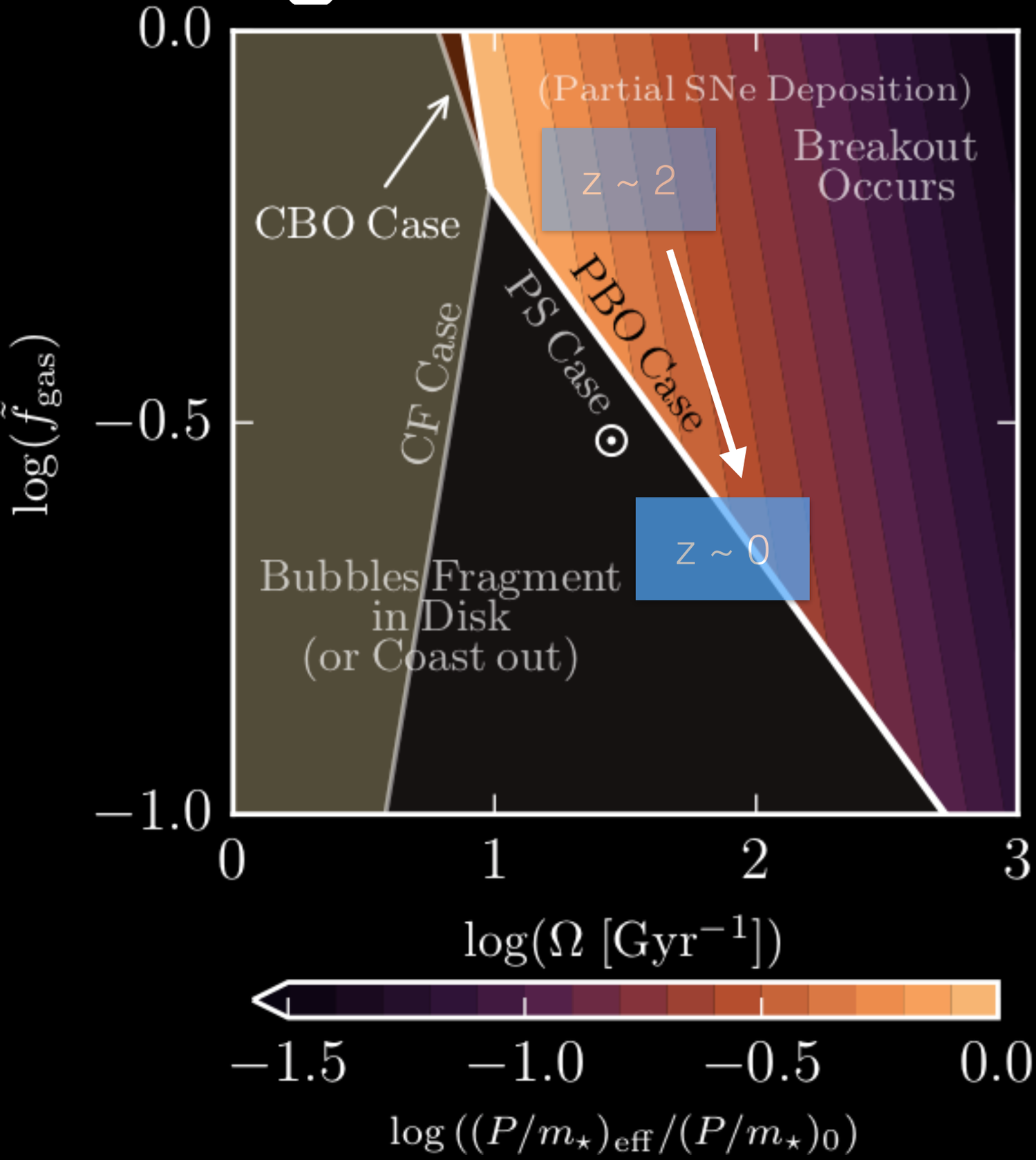

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containe
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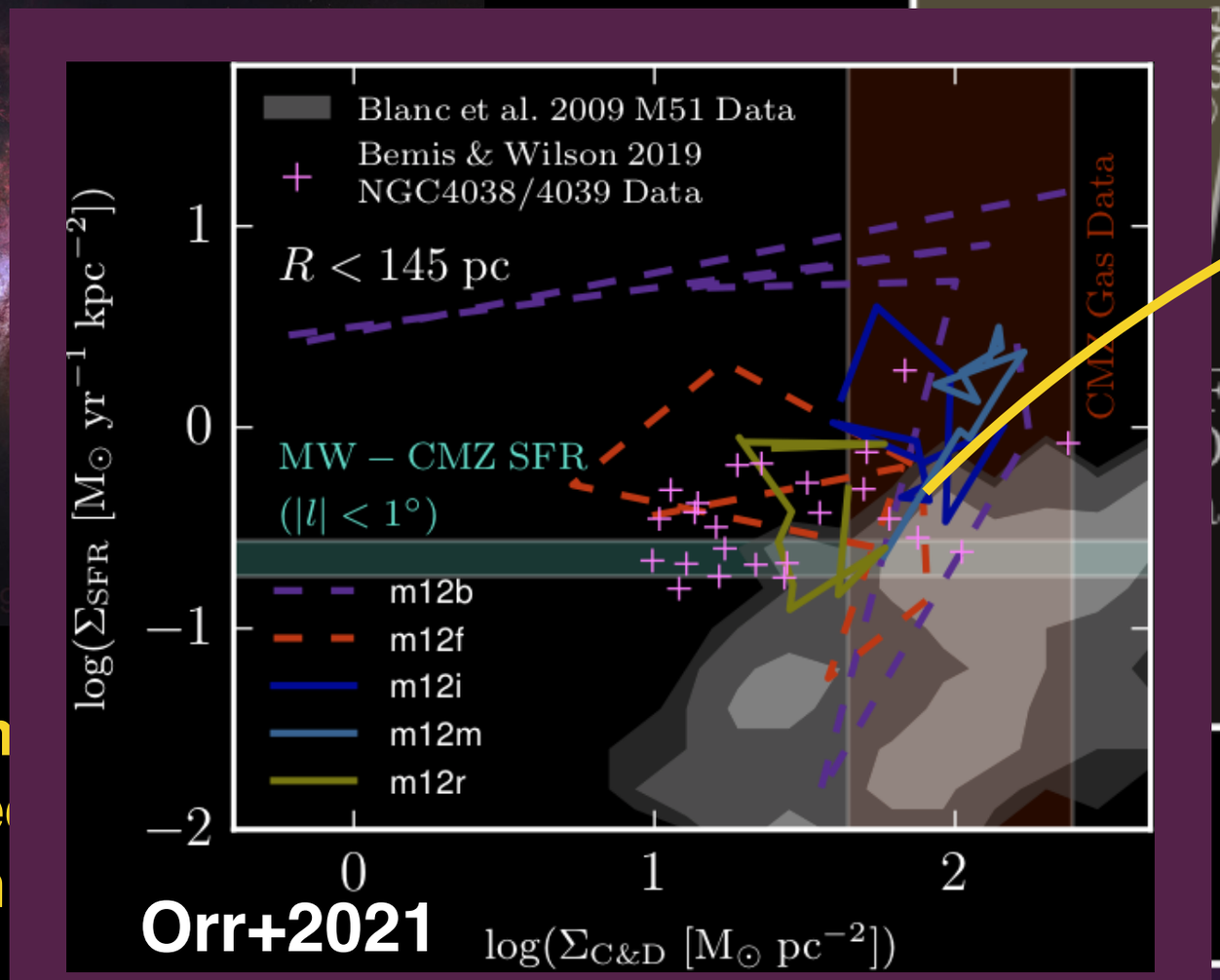

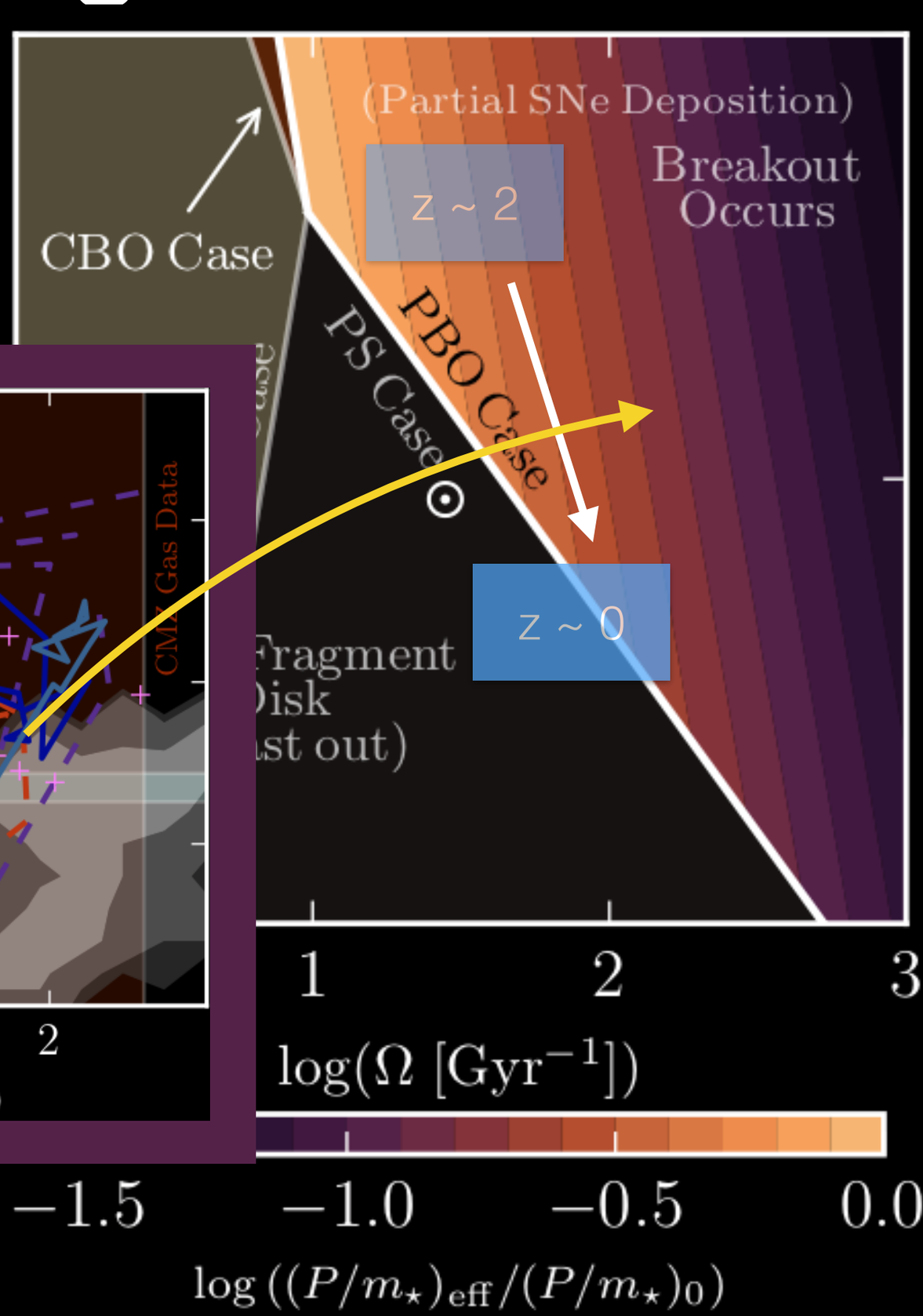

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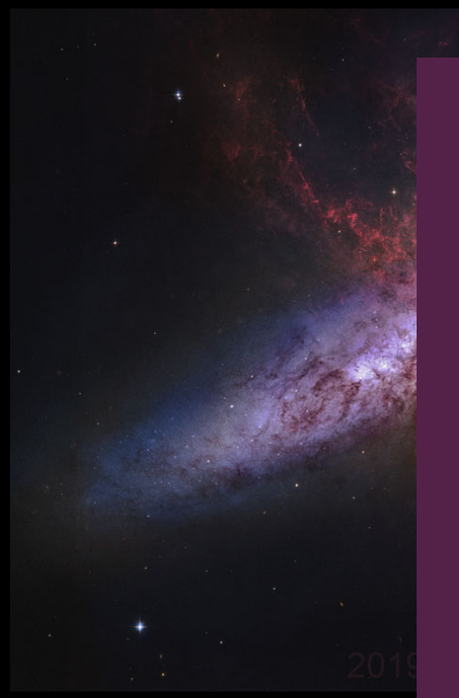
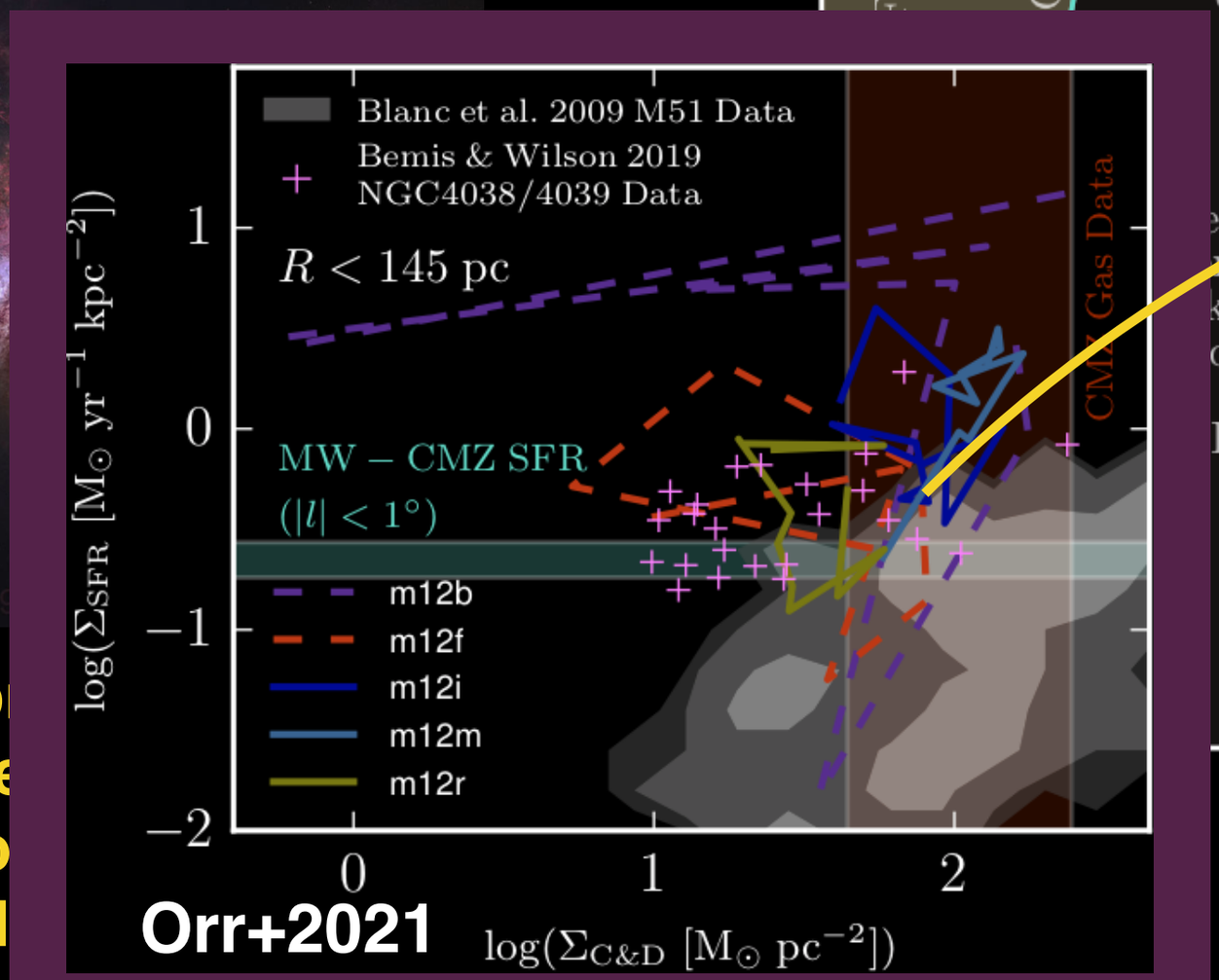
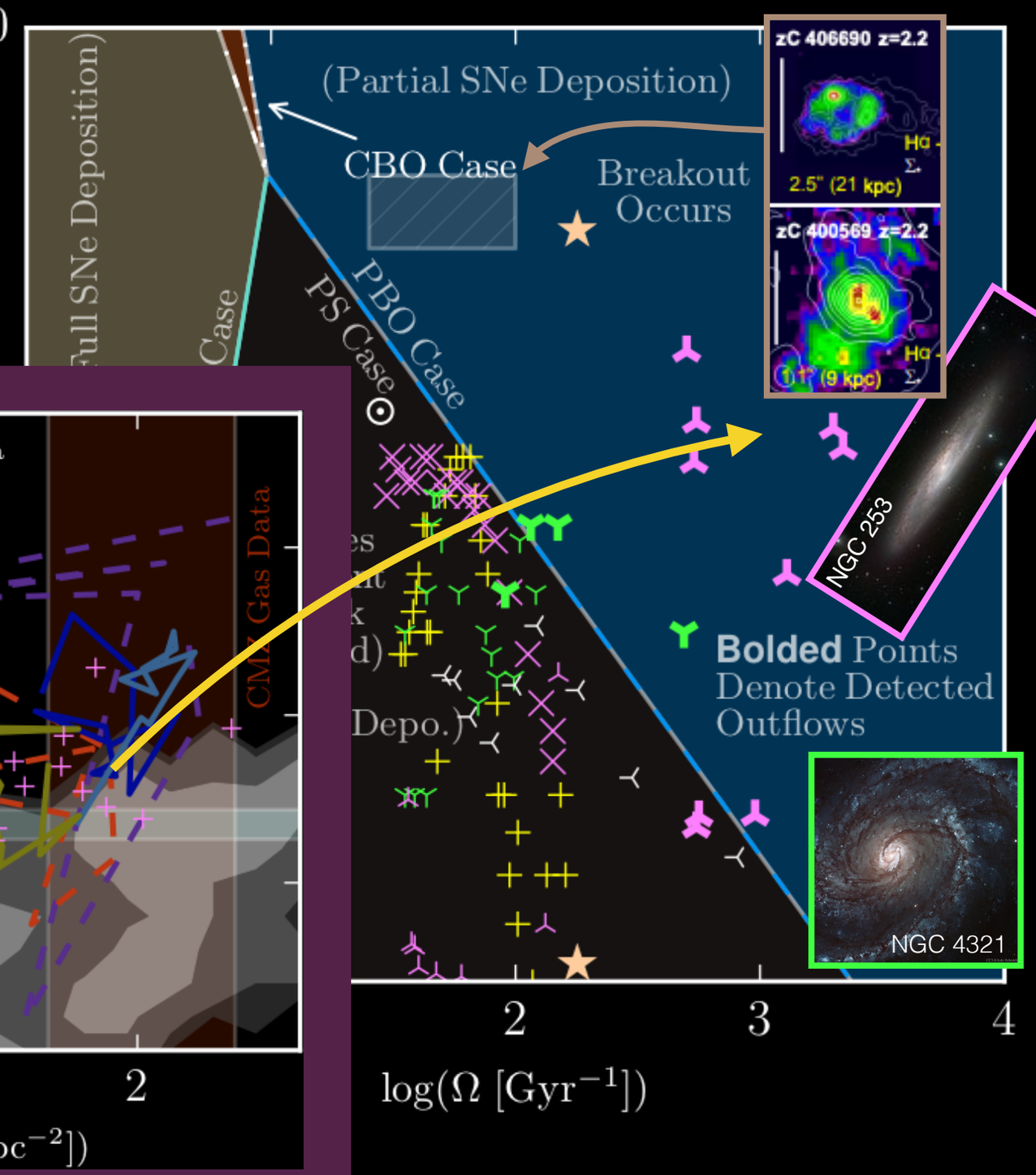


But our p
where the
seems to
super-wind





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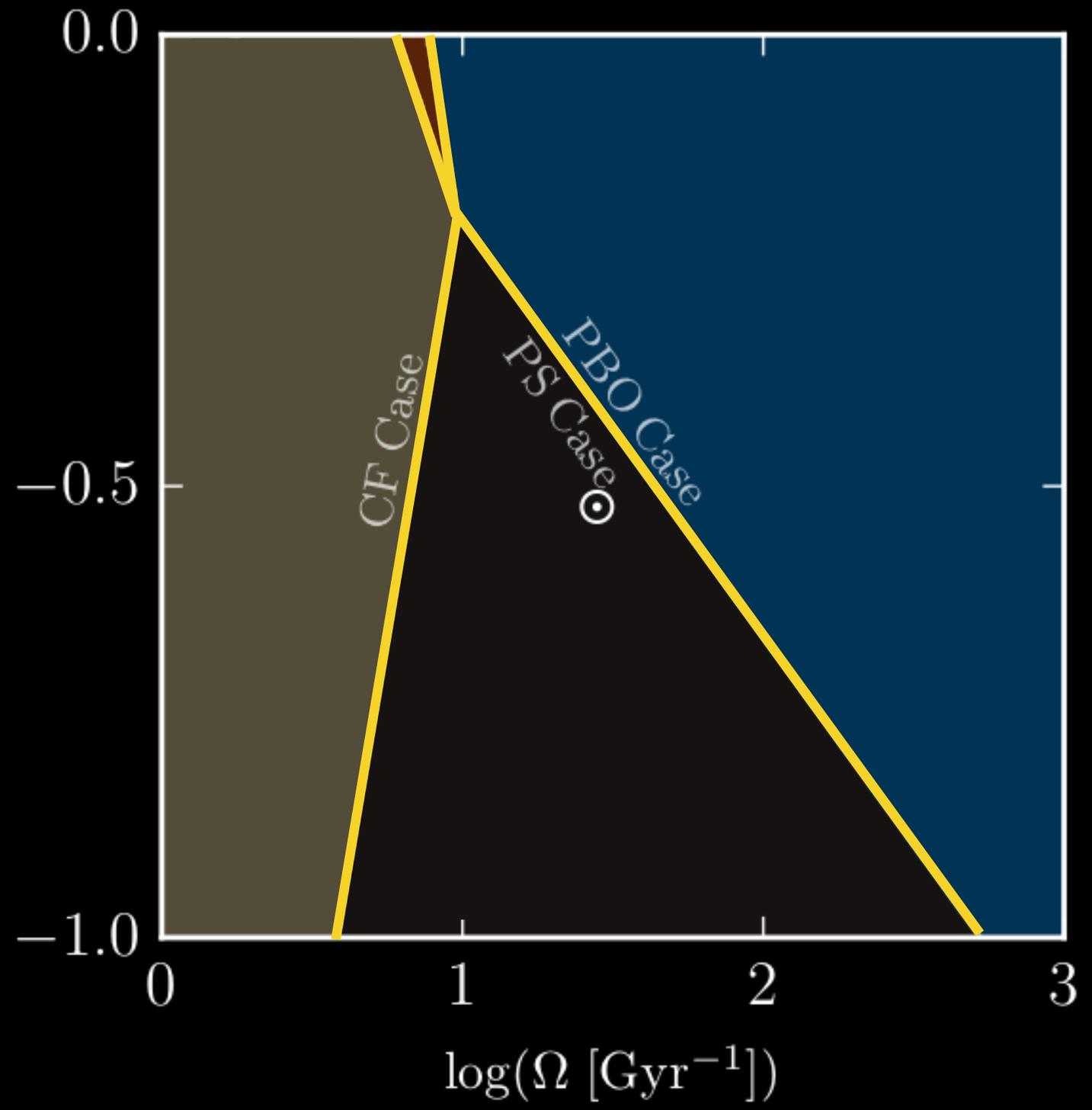

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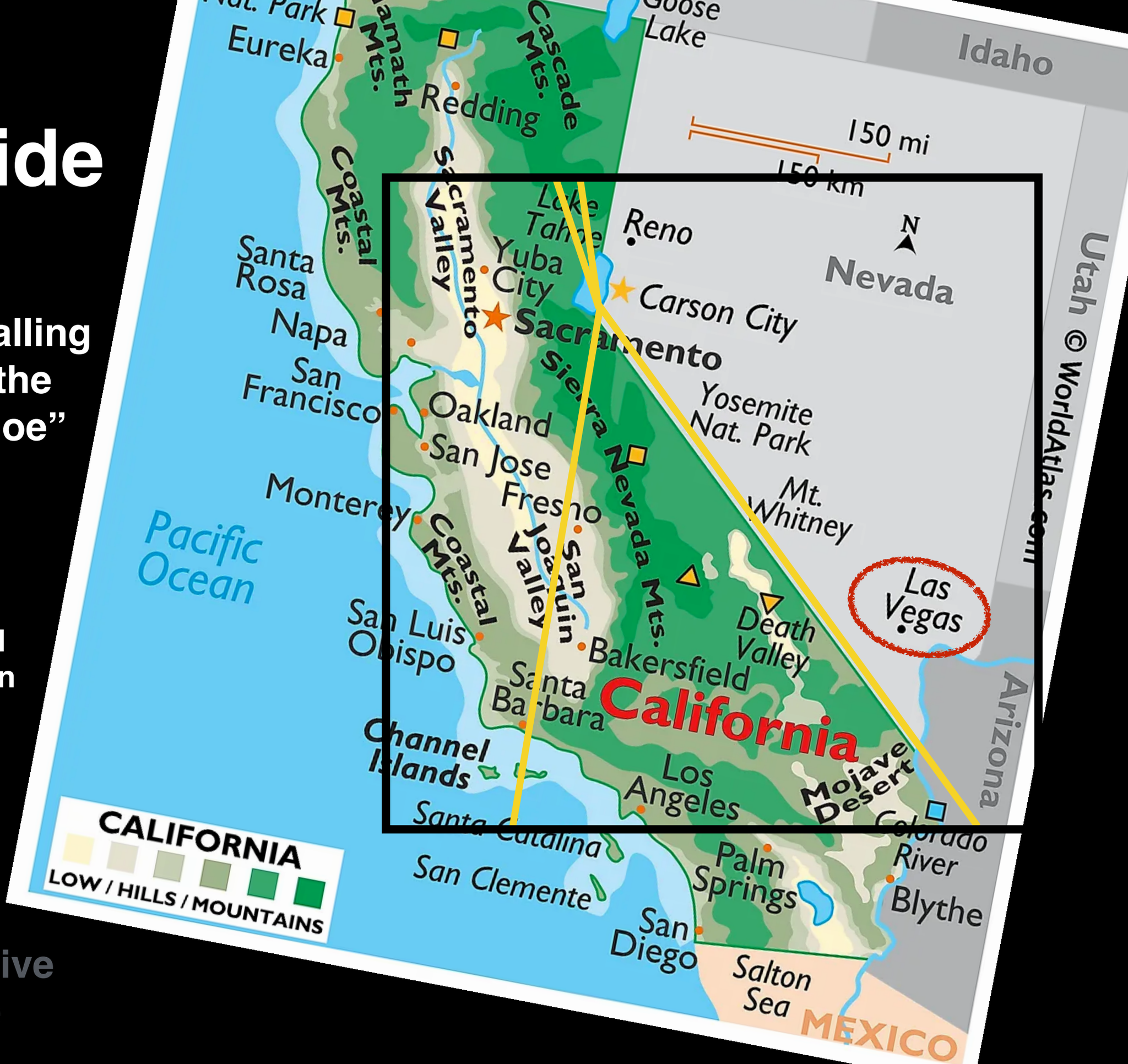

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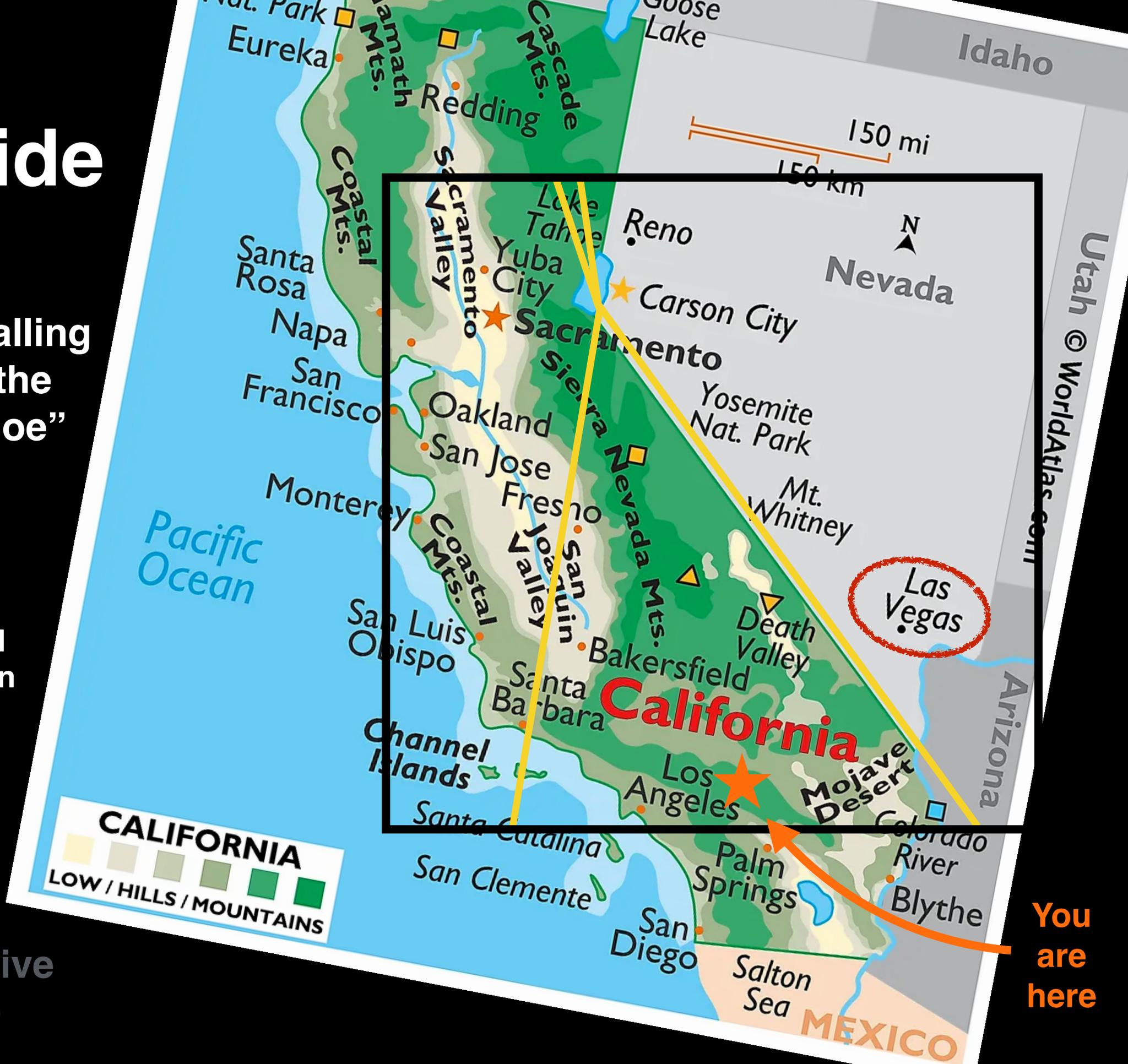
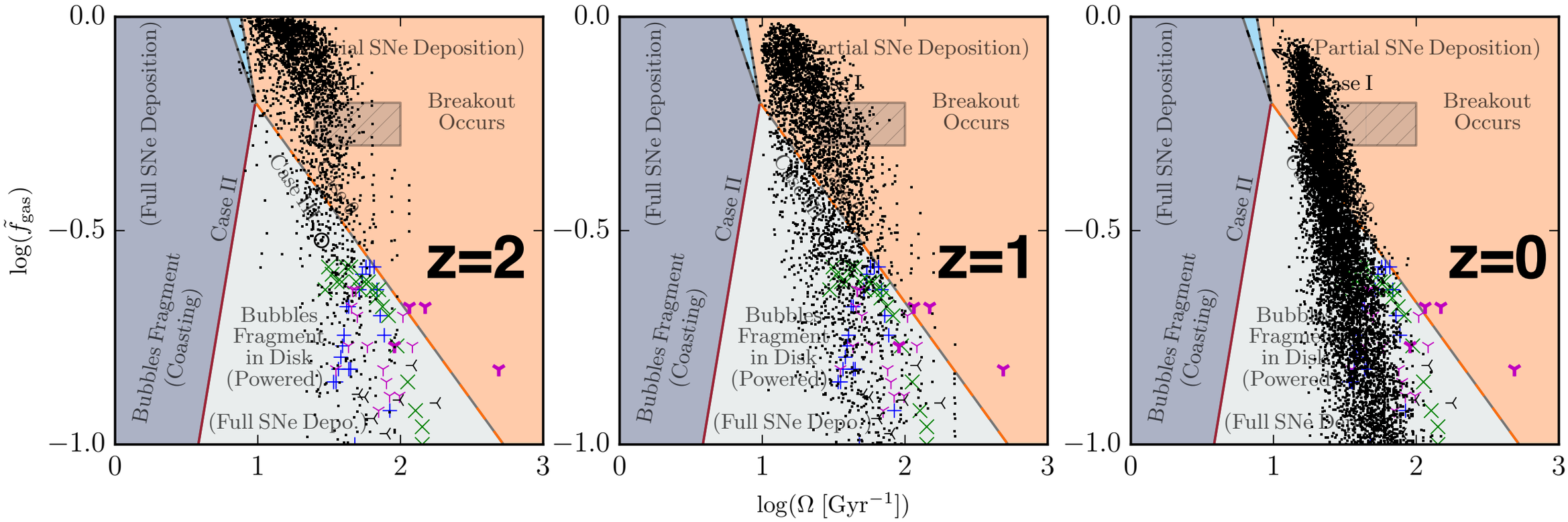


Redshift Evolution

Future Directions



Sites of star formation have lower gas fraction through time
(dynamical times don't change all that much)

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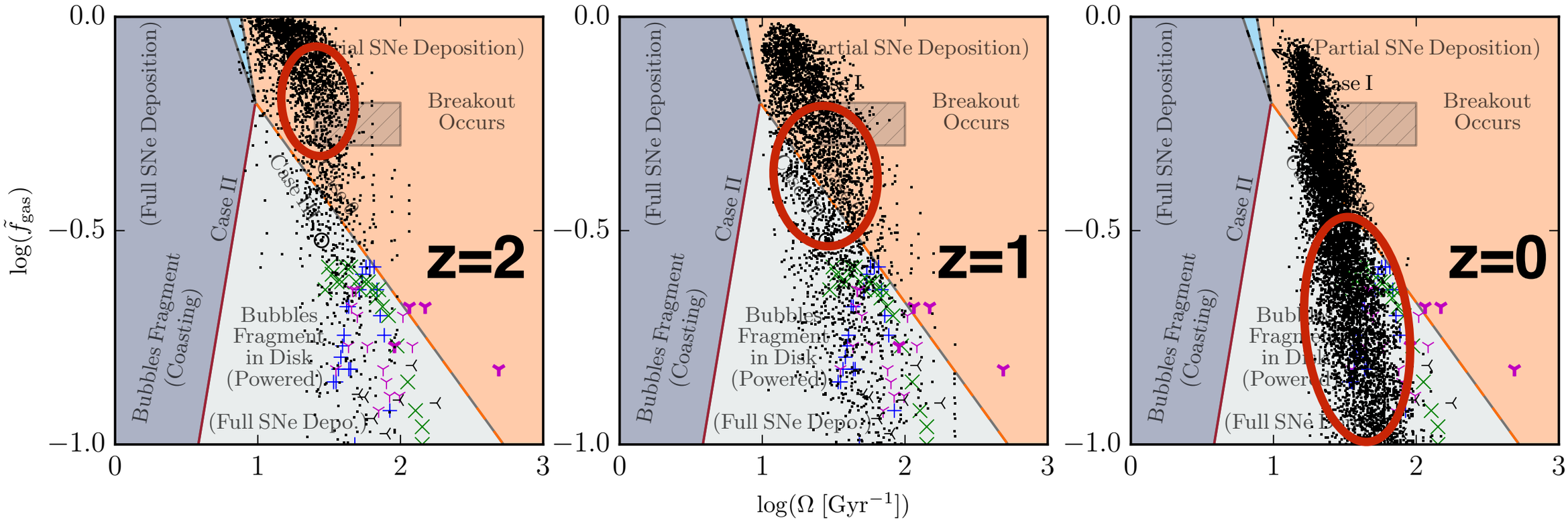

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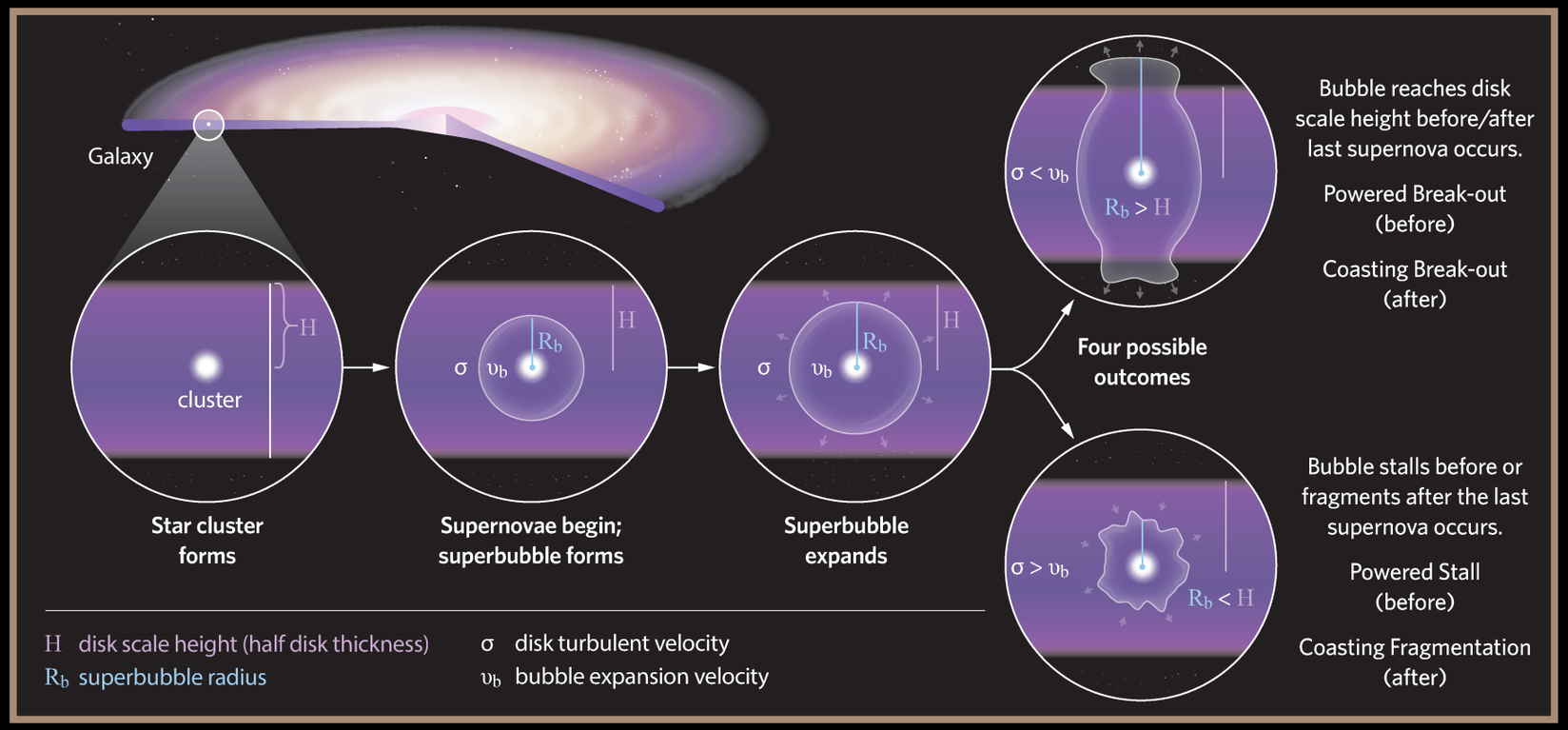
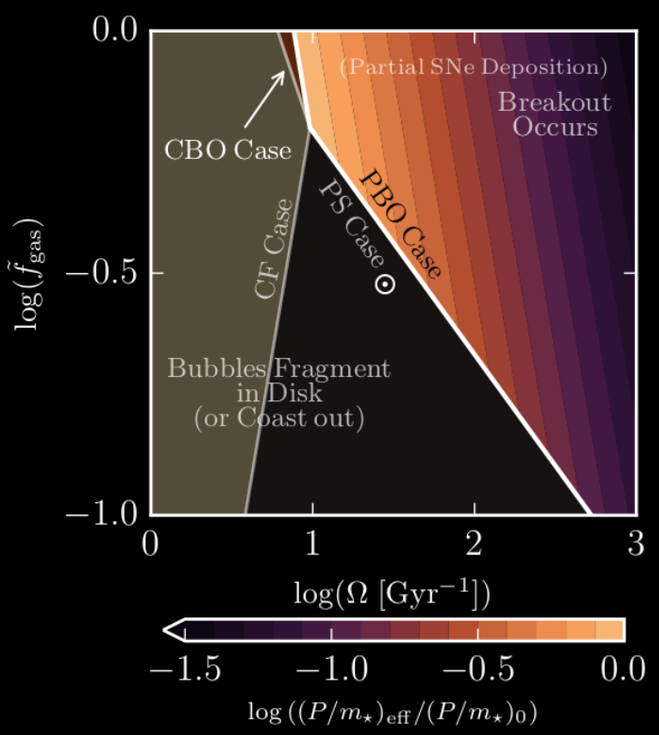
This evolution could be tied to disk settling: no longer does *every* star formation event produce a bubble that can break out of the ISM

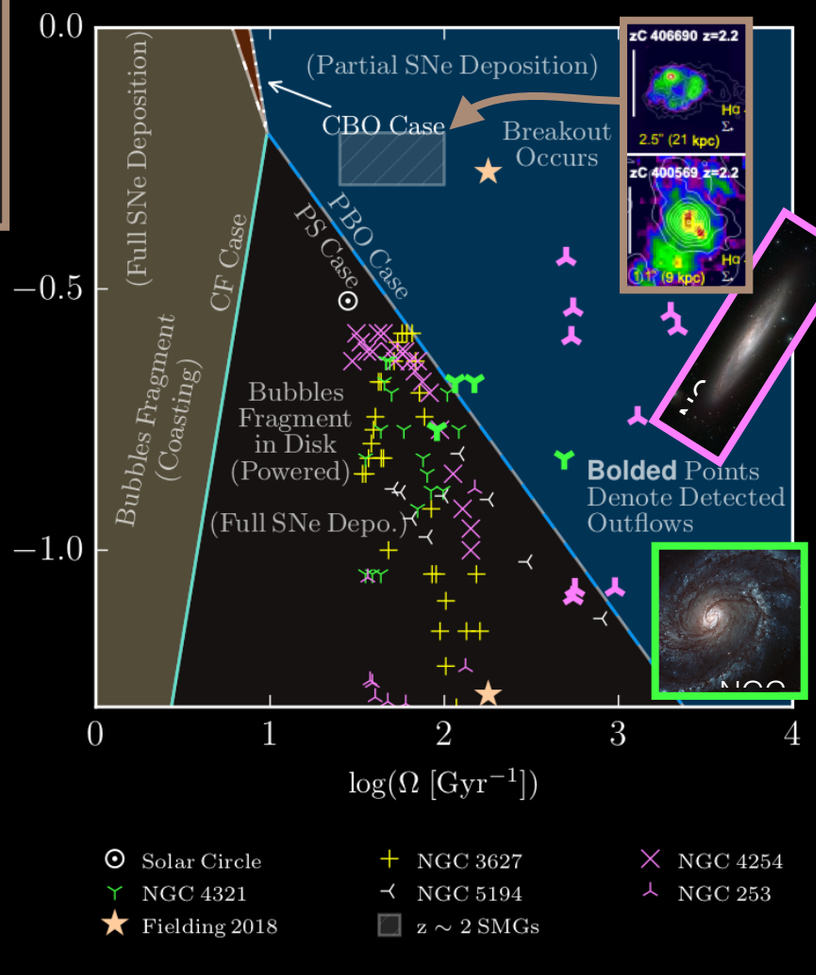
Summary



We develop a simple model for superbubbles to understand when and where outflows likely occur, and how clustered SNe affect the effective strength of feedback



Parameterized in local gas fraction and dynamical time!



Qualitatively agrees with local (spatially resolved) and high redshift observations of outflow hosts

On arXiv now!
arXiv:2109.14656
arXiv:2109.14626