Variability in the UVLF : Connecting Stellar Feedback and Bright Galaxies

Arghyadeep Basu
Max Planck Institute for Astrophysics (MPA), Garching

- With **Aniket Bhagwat, Benedetta Ciardi, Tiago Costa** -

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Potsdam Thinkshop - July 2025

MAX PLANCK INSTITUTE
FOR ASTROPHYSICS

IMPRS

Thanks to everyone of you 👊

For discussing about cosmic ray, impact of feedbacks, turbulence... and **many** more xD

How did our Universe look like in the past?

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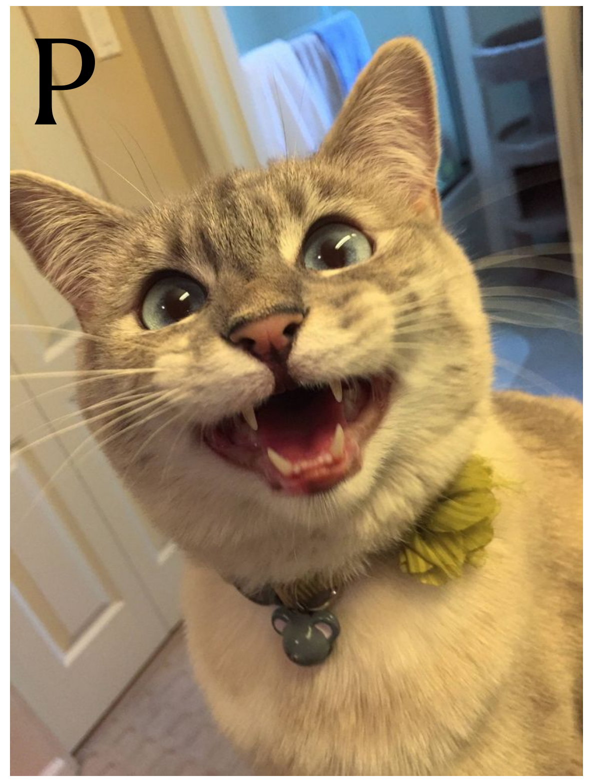

Illustration: NASA

How did our Universe look like in the past?

Observations of UV-bright galaxies with JWST at $z \geq 10$

A highly magnified candidate for a young galaxy seen when the Universe was 500 Myrs old

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A Long Time Ago in a Galaxy Far, Far Away: A Candidate $z \sim 12$ Galaxy in Early JWST CEERS Imaging

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and…

JWST/MIRI photometric detection a… in a galaxy at $z > 14$

Jakob M. Helton[1*], George H. Rieke[1], Stacey…
Zihao Wu[2], Daniel J. Eisenstein[2], Kevin N. …
Stefano Carniani[3], Zhiyuan Ji[1], William M. Baker[4,5],
Rachana Bhatawdekar[6], Andrew J. Bunker[7], Phillip A. Cargile[2],
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Jan Scholtz[4,5], Irene Shivaei[10], Feng…
Sandro Tacchella[4,5], Lily Whitler[1], Christin…
Christopher N. A. Willmer[1], Chris Willott[13], …
Yongda Zhu[1]

Revealing galaxy candidates out to $z \sim 16$ with JWST observations of the lensing cluster SMACS0723

Hakim Atek[1★], Marko Shuntov,[1] Lukas J. Furtak[2], Johan Richard[3], Jean-Paul Kneib,[4] Guillaume Mahler[5], Adi Zitrin[2], H. J. McCracken,[1] Stéphane Charlot,[1] Jacopo Chevallard[6] and Iryna Chemerynska[1]

Early Results from GLASS-JWST. III. Galaxy Candidates at $z \sim 9$–15*

Marco Castellano[1], Adriano Fontana[1], Tommaso Treu[2], Paola Santini[1], Emiliano Merlin[1], Nicha Leethochawalit[3,4,5], Michele Trenti[3,4], Eros Vanzella[6], Uros Mestric[6], Andrea Bonchi[7], Davide Belfiori[1], Mario Nonino[8], Diego Paris[1], …anluca Polenta[7], Guido Roberts-Borsani[2], Kristan Boyett[3,4], Maruša Bradač[9,10], Antonello Calabrò[1], …Karl Glazebrook[11], Claudio Grillo[12,13], Sara Mascia[1], Charlotte Mason[14,15], Amata Mercurio[16], …iro Morishita[17], Themiya Nanayakkara[11], Laura Pentericci[1], Piero Rosati[18,19], Benedetta Vulcani[20], Xin Wang[21], and Lilan Yang[22]

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Two Remarkably Luminous Galaxy Candidates at $z \approx 10$–12 Revealed by JWST

Rohan P. Naidu[1,2,26], Pascal A. Oesch[3,4], Pieter van Dokkum[5], Erica J. Nelson[6], Katherine A. Suess[7,8], Gabriel Brammer[4], Katherine E. Whitaker[9,10], Garth Illingworth[11], Rychard Bouwens[12], Sandro Tacchella[13,14], Jorryt Matthee[15], Natalie Allen[4], Rachel Bezanson[16], Charlie Conroy[1], Ivo Labbe[17], Joel Leja[18,19,20], Ecaterina Leonova[21], Dan Magee[22], Sedona H. Price[23], David J. Setton[16], Victoria Strait[4], Mauro Stefanon[24,25], Sune Toft[4], John R. Weaver[9], and Andrea Weibel[3]

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Why so many UV bright galaxies in these early times?

Possible arguments to explain the ‘over-abundance’ of UV bright galaxies

- Massive objects - high stellar mass -

- High star formation efficiency -

- Top heavy IMF -

- Exotic Dark Matter scenario (WDM, fuzzy DM etc.) -

- Primordial Non-gaussianity -

- Modified primordial matter power spectrum -

- UV Luminosity function (UVLF) variability -

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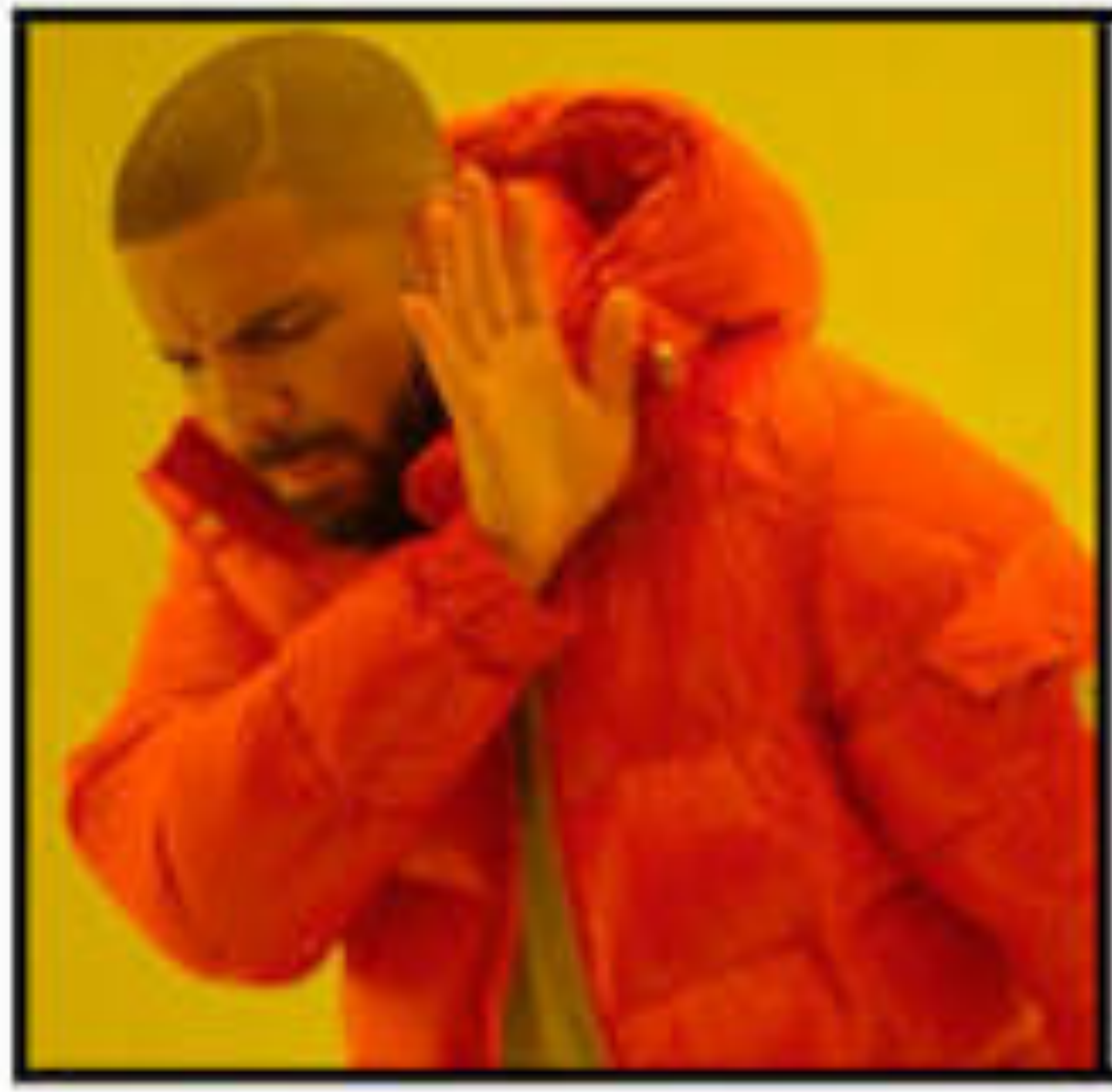

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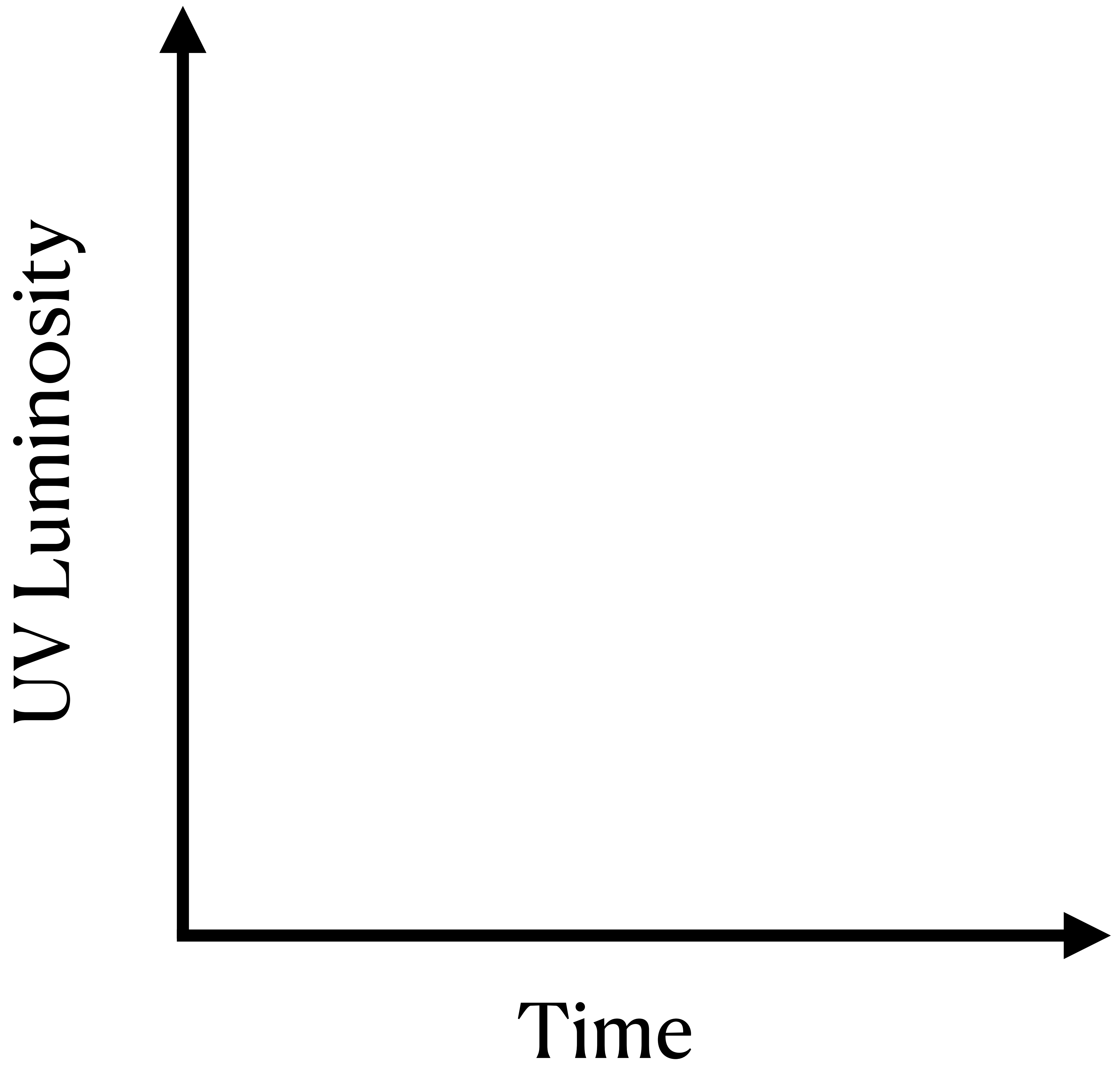
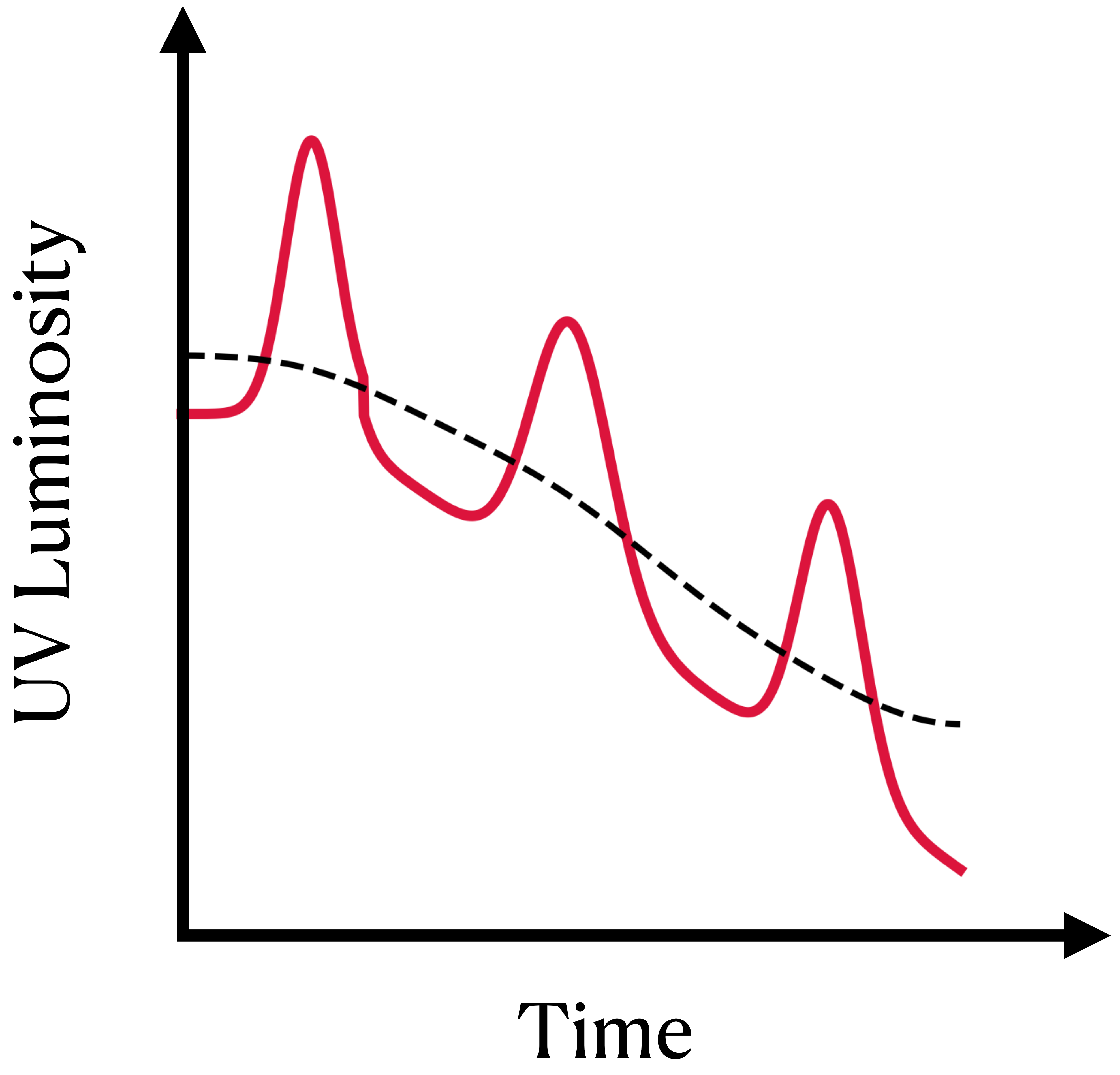
‘over-abundance’ of UV bright galaxies - UVLF variability

What do I mean by UVLF variability?



‘over-abundance’ of UV bright galaxies - UVLF variability

What do I mean by UVLF variability?



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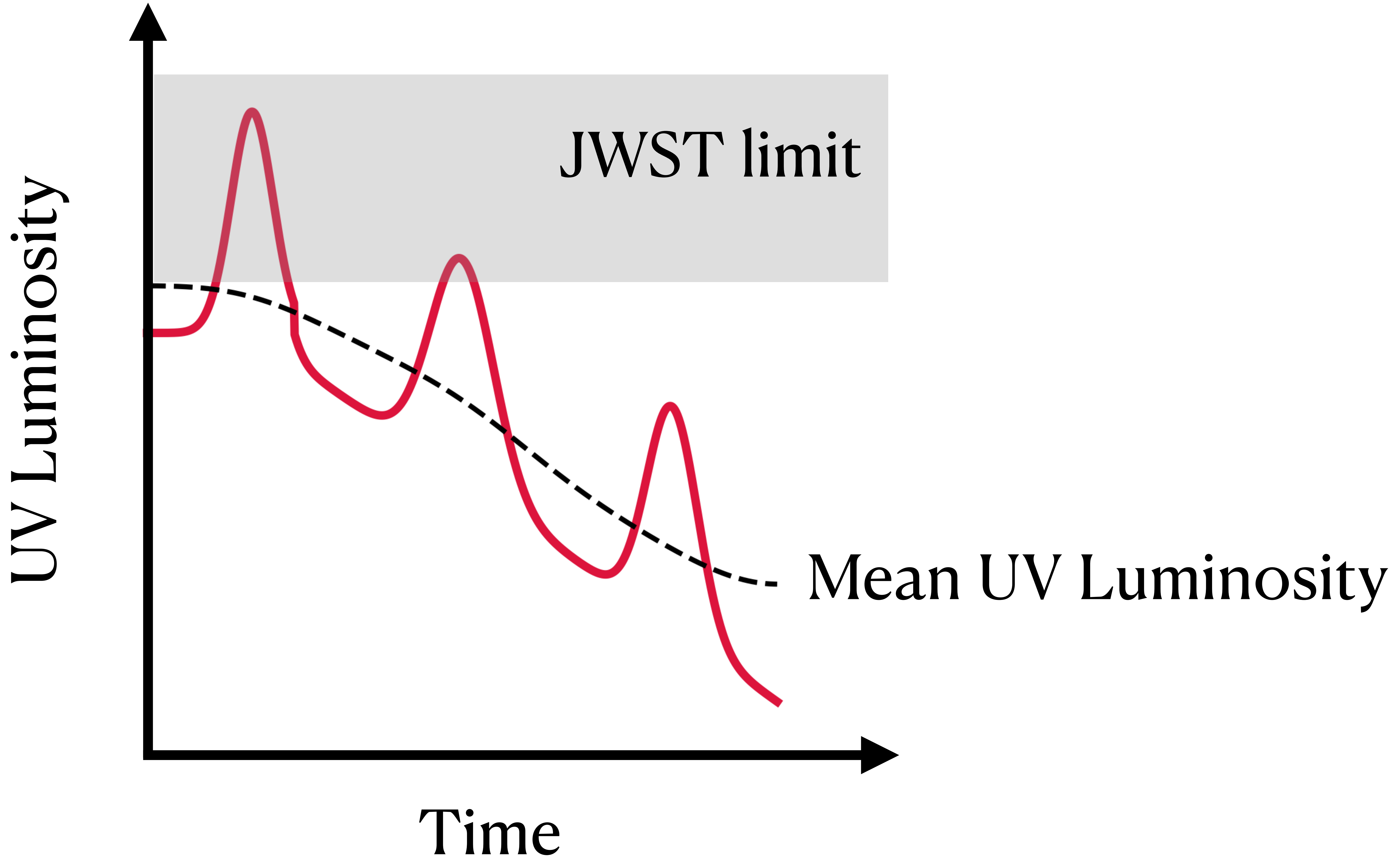

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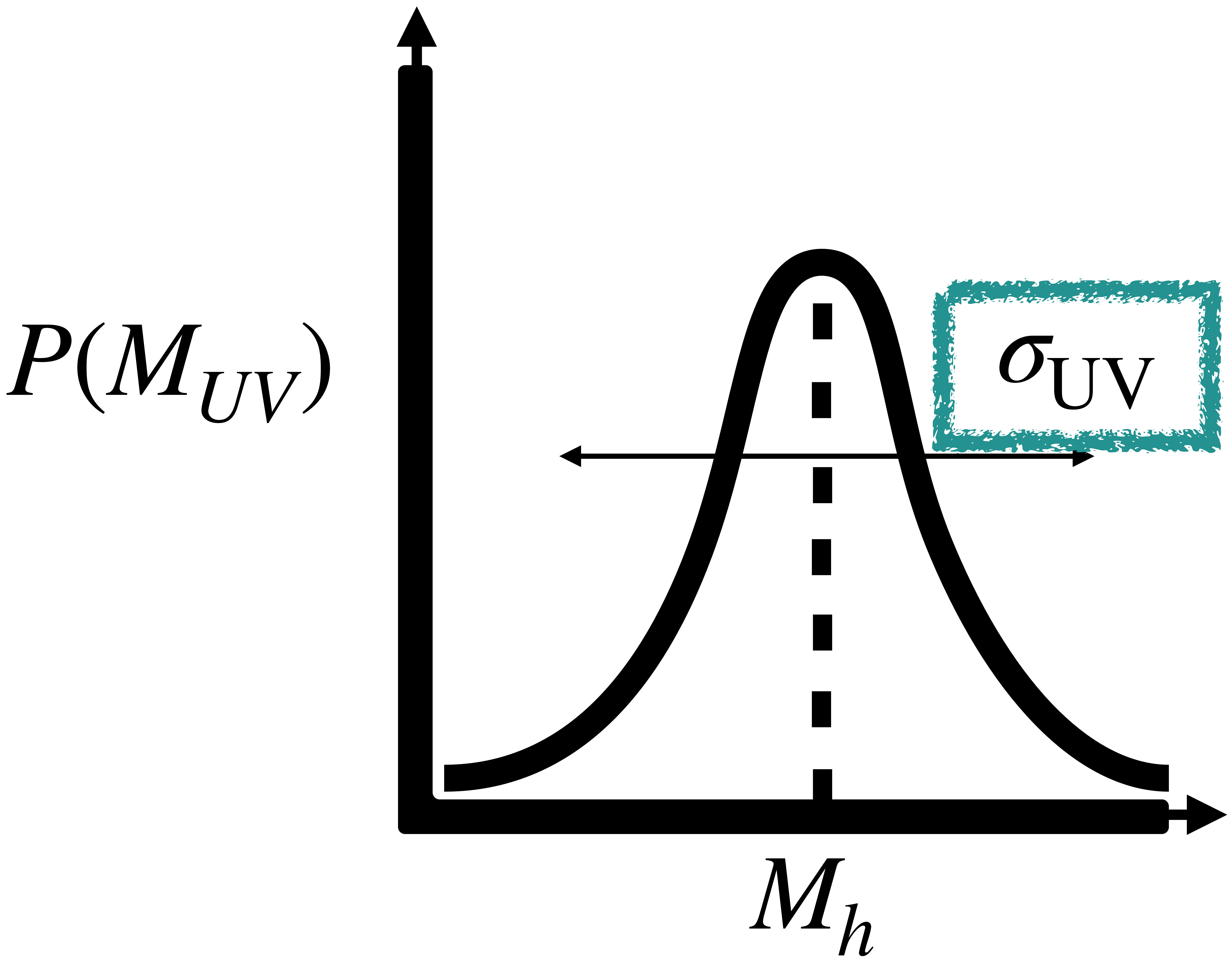
What do I mean by UVLF variability?

Halo mass function → UVLF



‘over-abundance’ of UV bright galaxies - UVLF variability

Stochastic star formation in early galaxies: JWST implications

A. Pallottini [1,⋆] and A. Ferrara [1]

The impact of UV variability on the abundance of bright galaxies at $z \geq 9$

Xuejian Shen,[1,2⋆] Mark Vogelsberger,[2] Michael Boylan-Kolchin,[3] Sandro Tacchella,[4,5] and Rahul Kannan[6]

Identification of a transition from stochastic to secular star formation around $z = 9$ with JWST

L. Ciesla[1], D. Elbaz[2], O. Ilbert[1], V. Buat[1,3], B. Magnelli[2], D. Narayanan[4,5], E. Daddi[2], C. Gómez-Guijarro[2], and R. Arango-Toro[1]

The brightest galaxies at Cosmic Dawn

Charlotte A. Mason[1,2⋆], Michele Trenti[3,4] and Tommaso Treu[5]

The Impact of Mass-dependent Stochasticity at Cosmic Dawn

Viola Gelli[1,2], Charlotte Mason[1,2], and Christopher C. Hayward[3]
[1] Cosmic Dawn Center (DAWN), Denmark; viola.gelli@nbi.ku.dk
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‘over-abundance’ of UV bright galaxies - UVLF variability

UVLF
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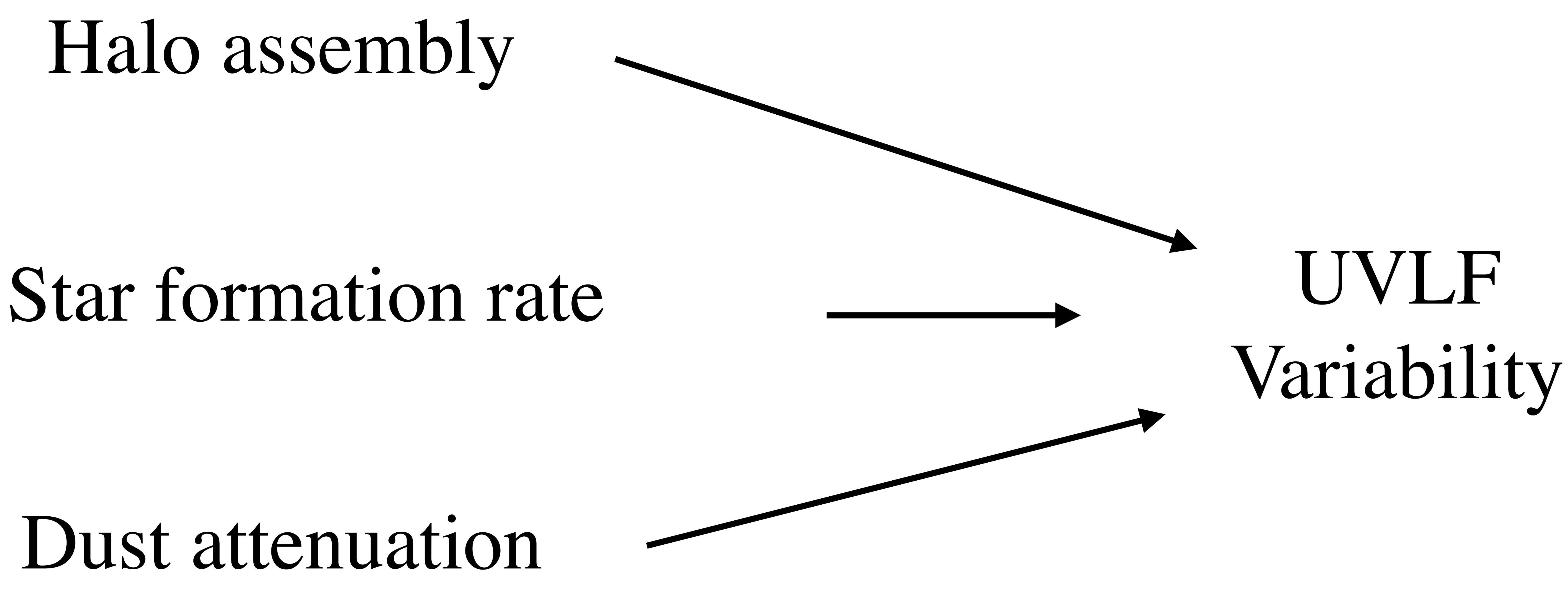

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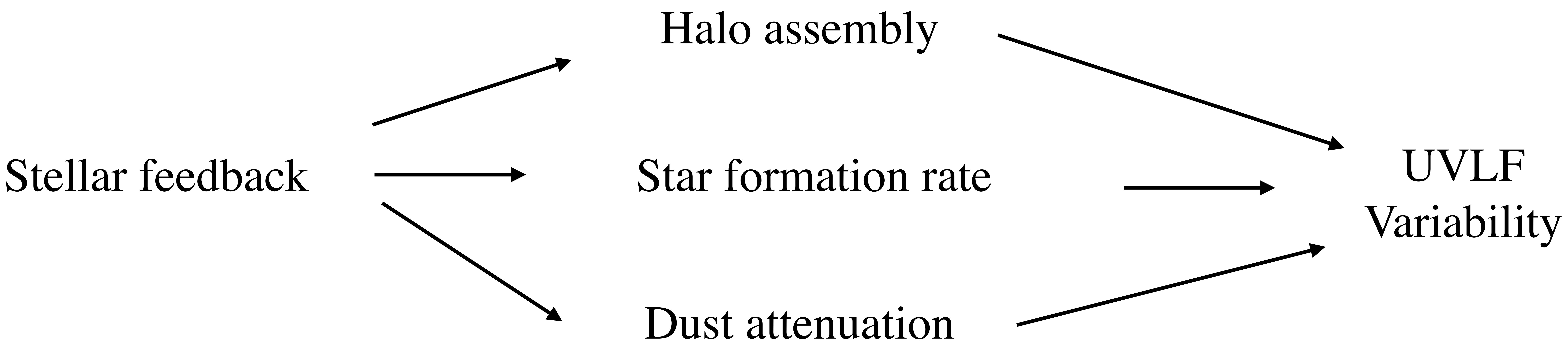


‘over-abundance’ of UV bright galaxies - UVLF variability

Stellar feedback → UVLF Variability

‘over-abundance’ of UV bright galaxies - UVLF variability

Supernova (SN) driven

Stellar feedback

UVLF
Variability

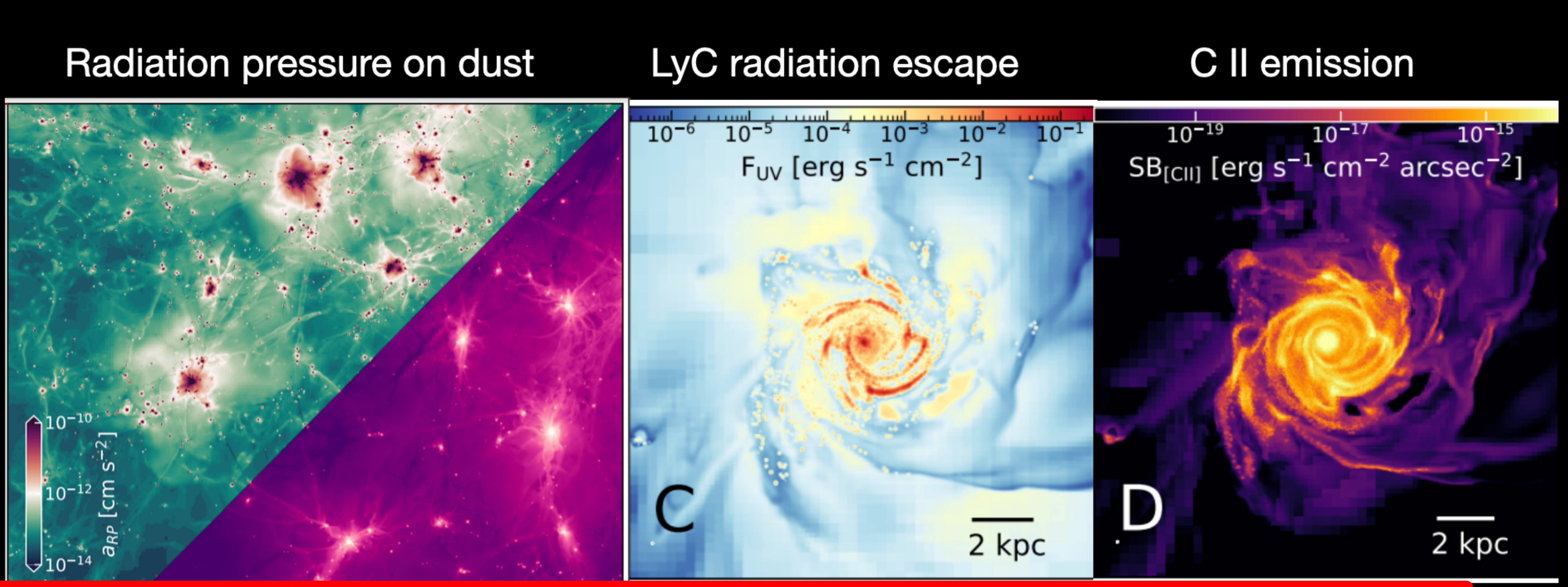
Need to validate this with high resolution simulation

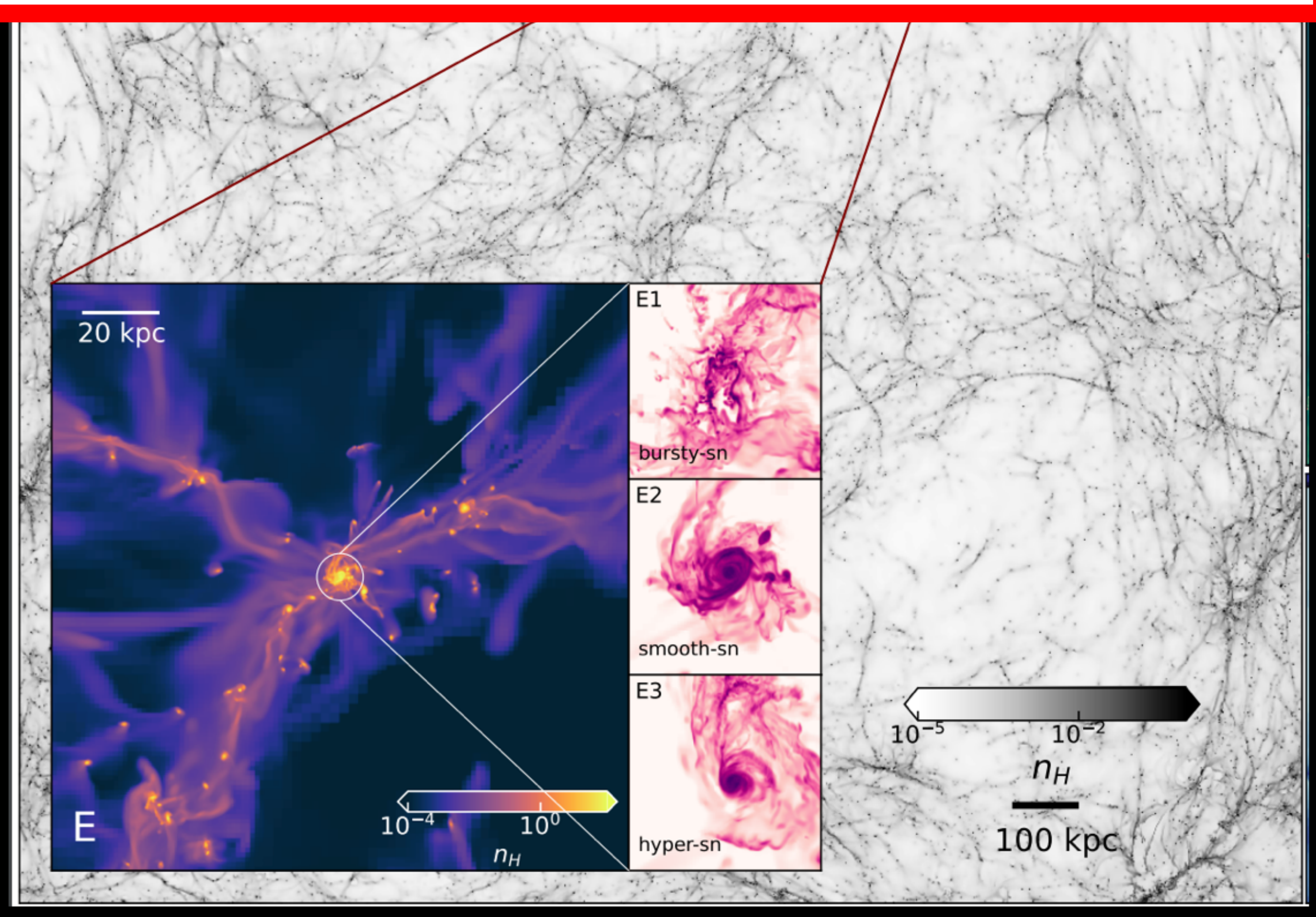
SPICE simulations

Code: *RAMSES-RT*
Side: 10 cMpc/h
Max resolution: 28(15) pc at z = 5(10)

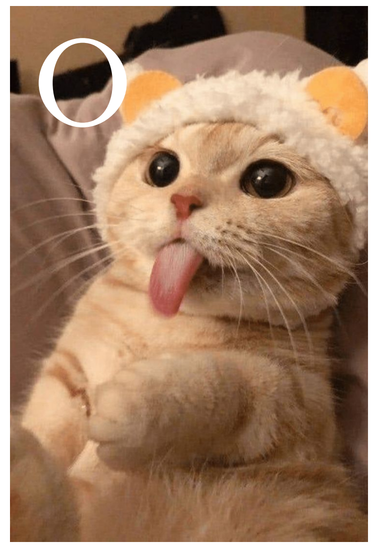
3 SN driven feedbacks models

- Radiative feedback channels;
- …





Bhagwat et al. 24



Slides from Benedetta Casavecchia (MPA)

Supernova feedback variations

Bursty

Time: 10 Myr

Energy: 2×10^{51} erg

Smooth

Time: 3-40 Myr

Energy: 2×10^{51} erg

Hyper(novae)

Time: 3-40 Myr

Energy: $10^{50} - 2 \times 10^{51}$ erg (SN) + 10^{52} erg (HN)

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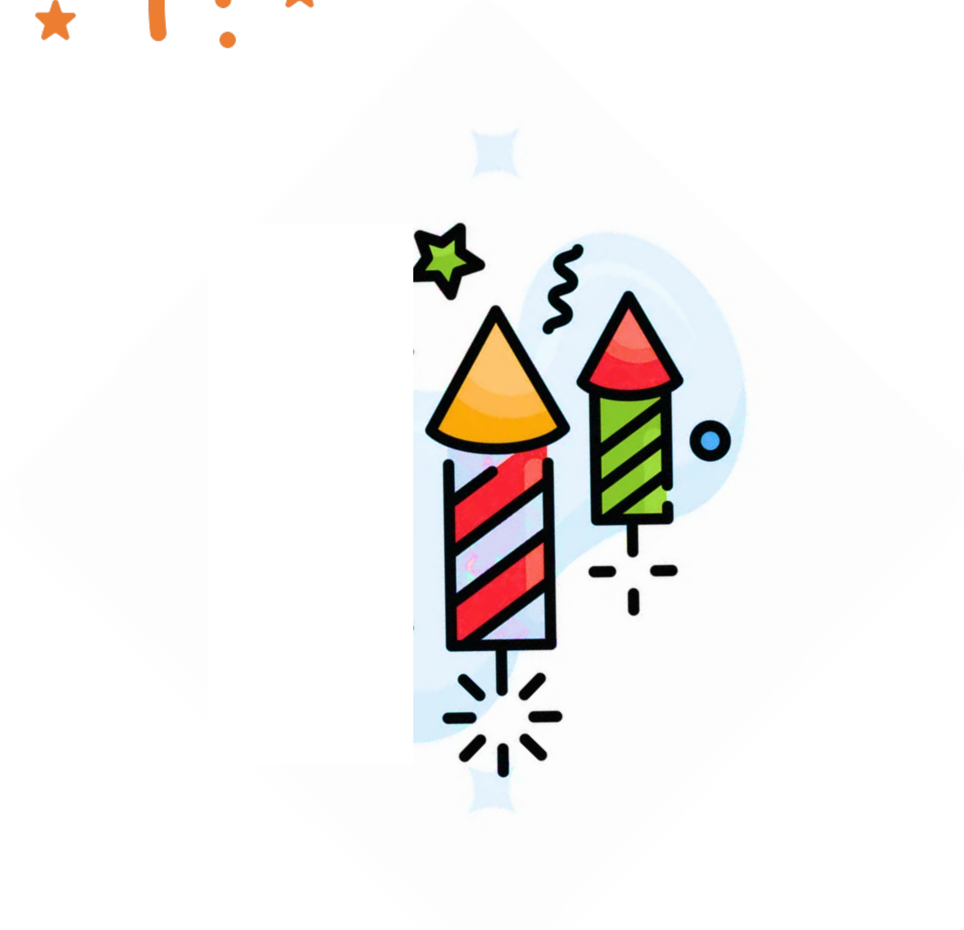

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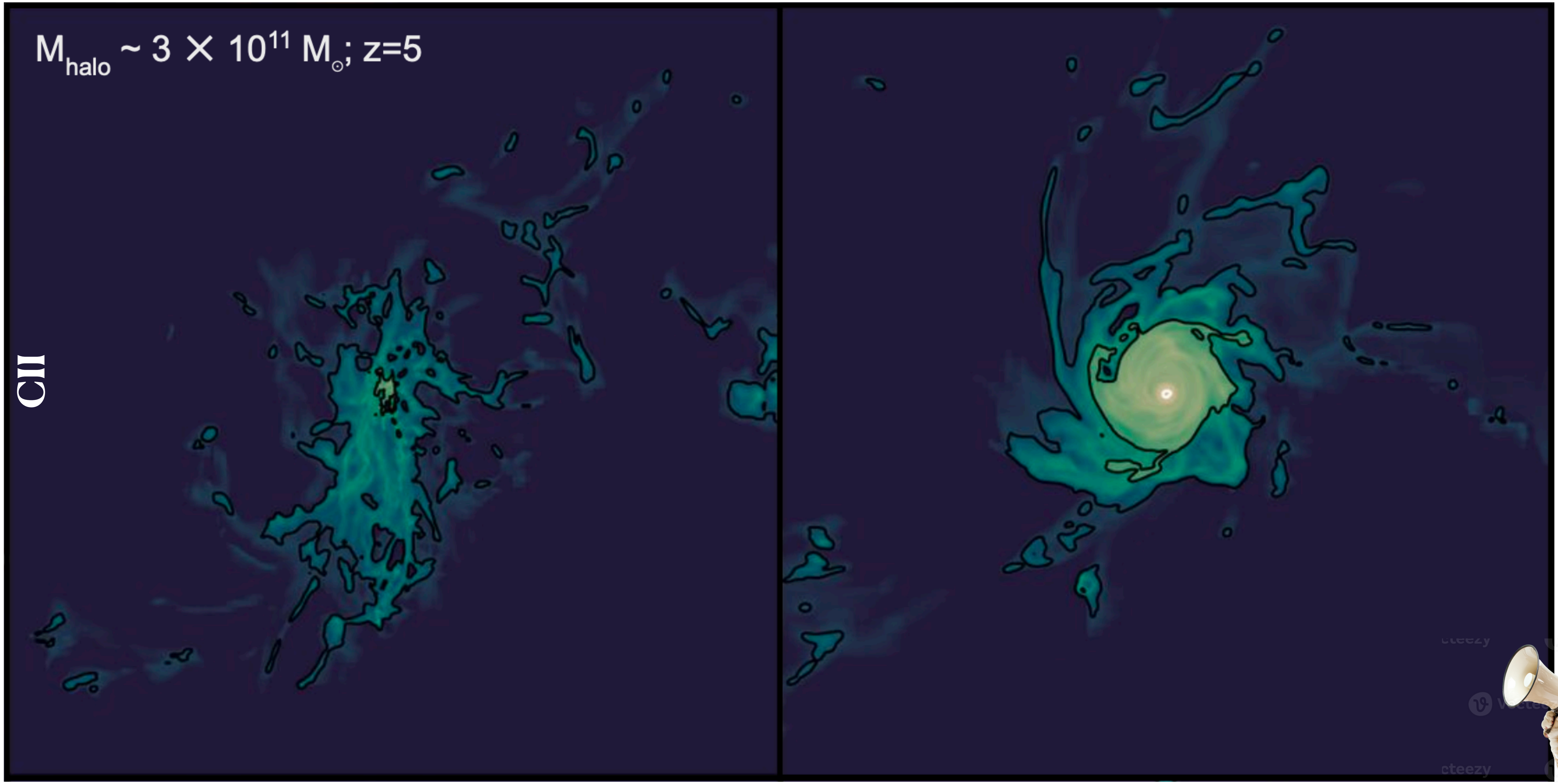
SPICE simulations

- from Katyayani Trivedi's poster
Connecting CII and OI in SPICE



bursty-sn smooth-sn

T

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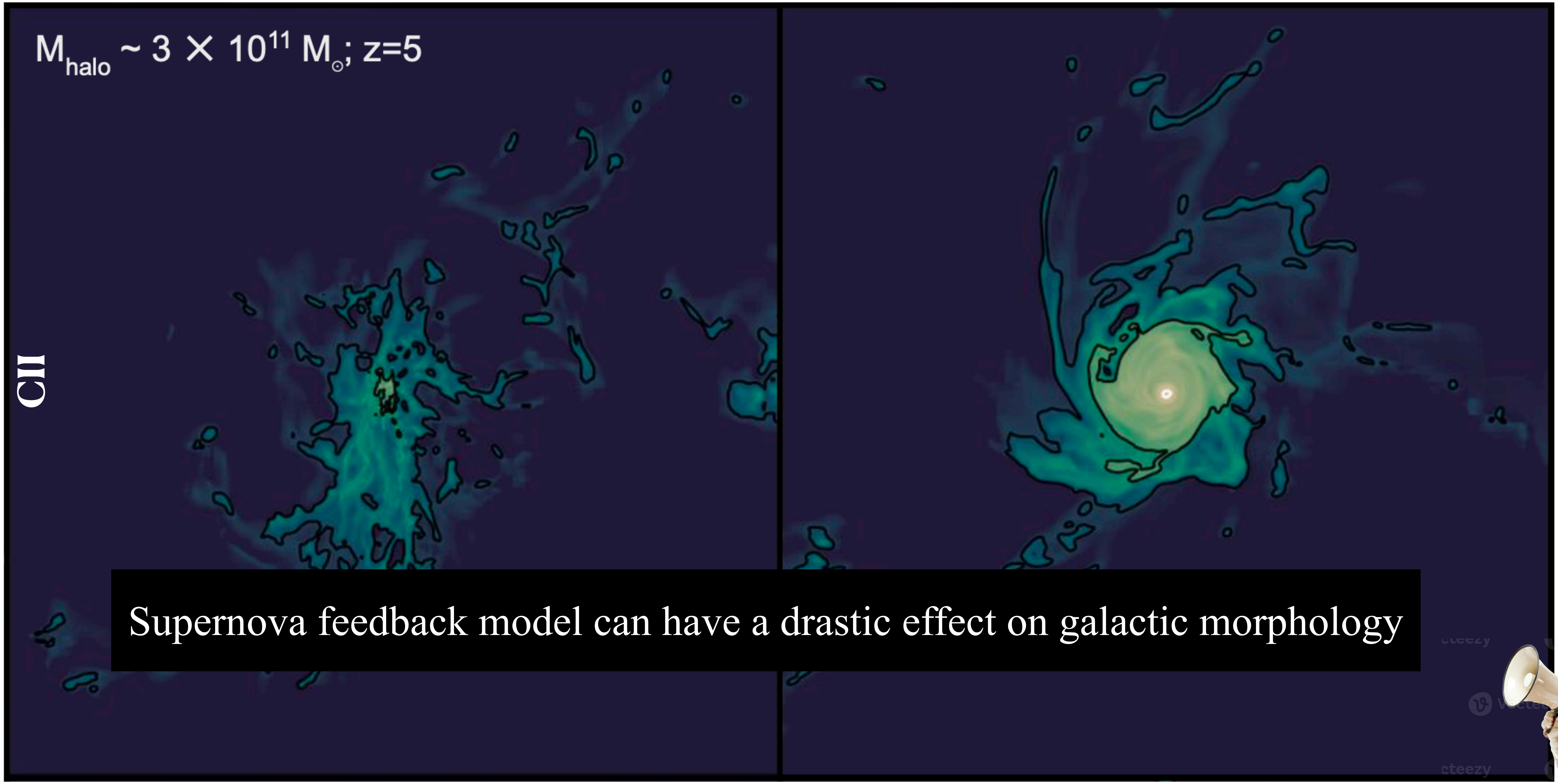
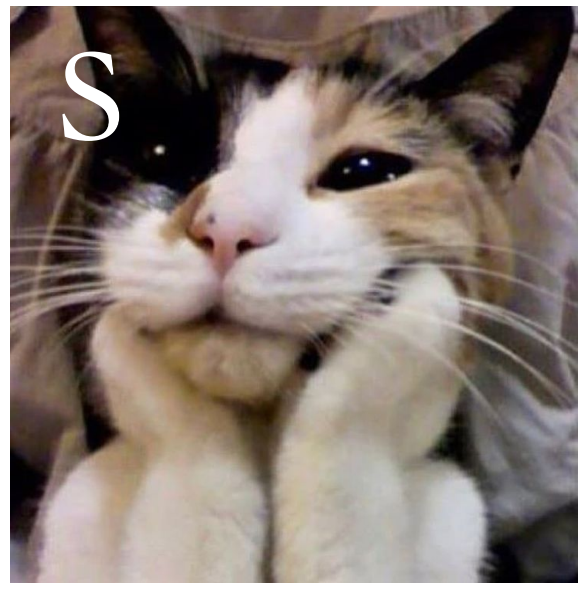


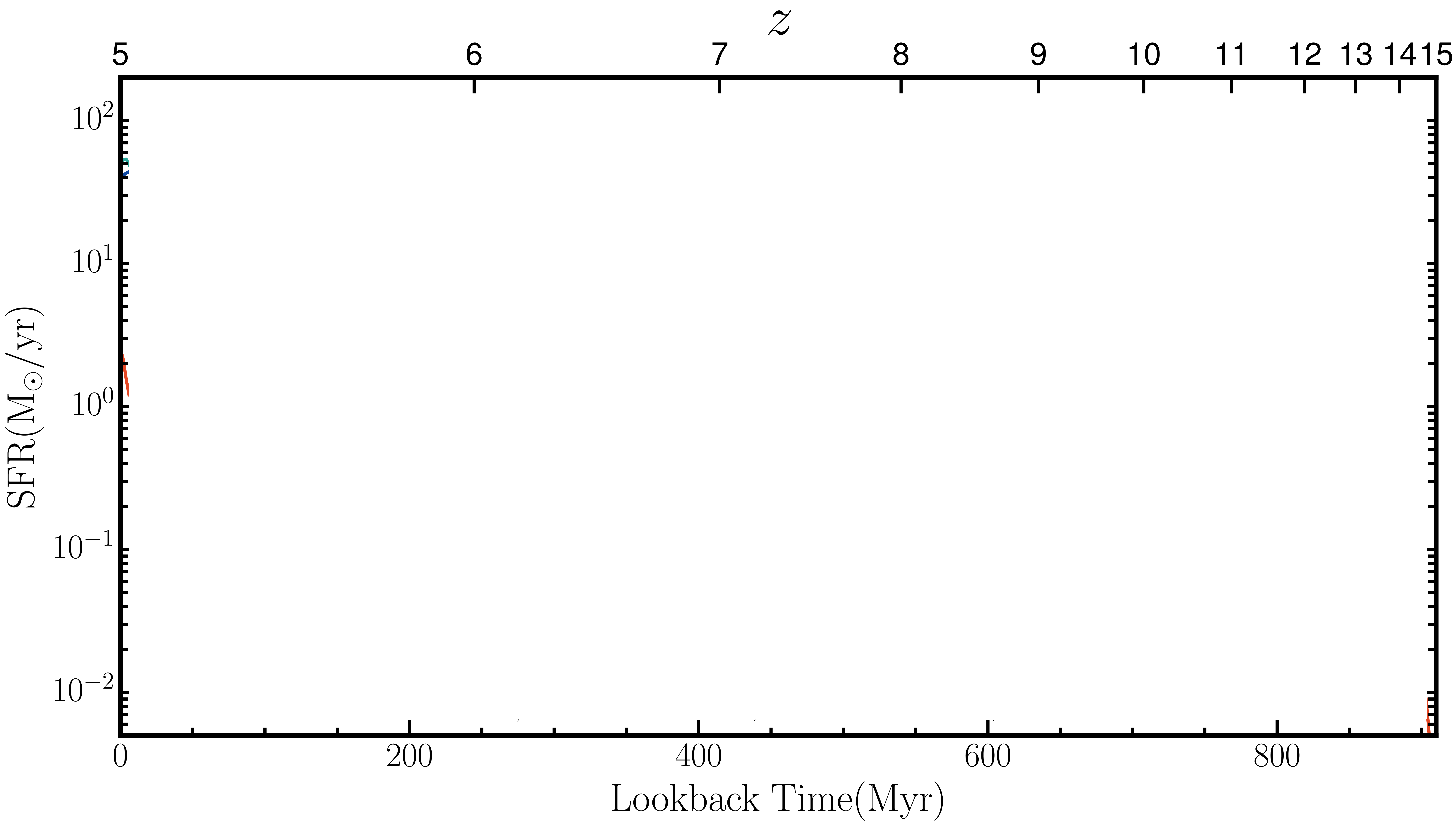
Supernova feedback model can have a drastic effect on galactic morphology

bursty-sn smooth-sn

Connecting UVLF variability with stellar feedback



Star formation history for the most massive haloes in each model



Basu et. al. 2025 (in review)

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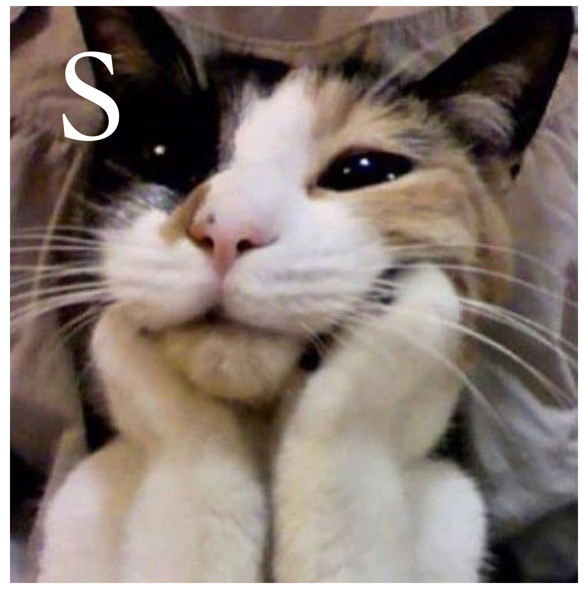

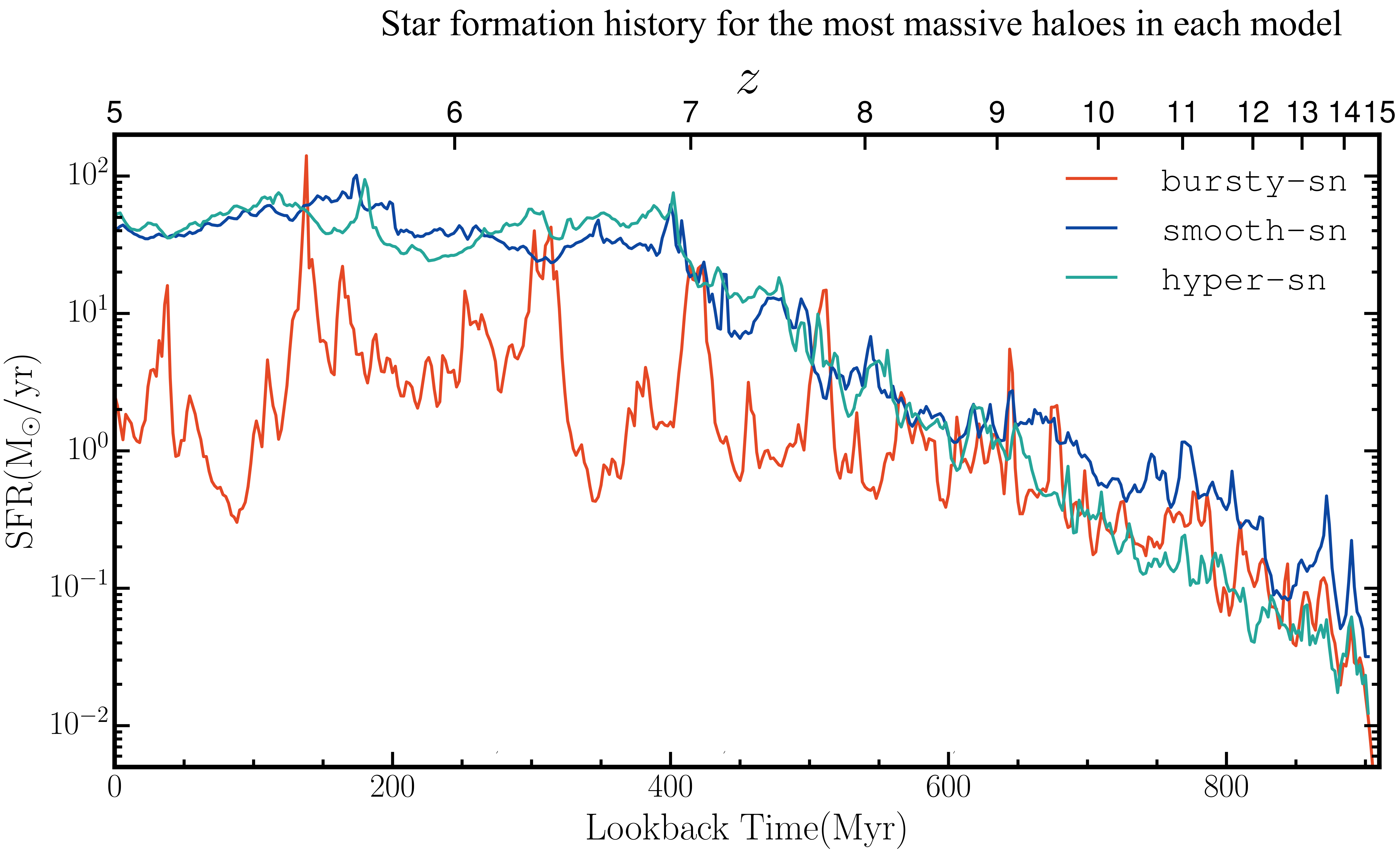

Basu et. al. 2025 (in review)

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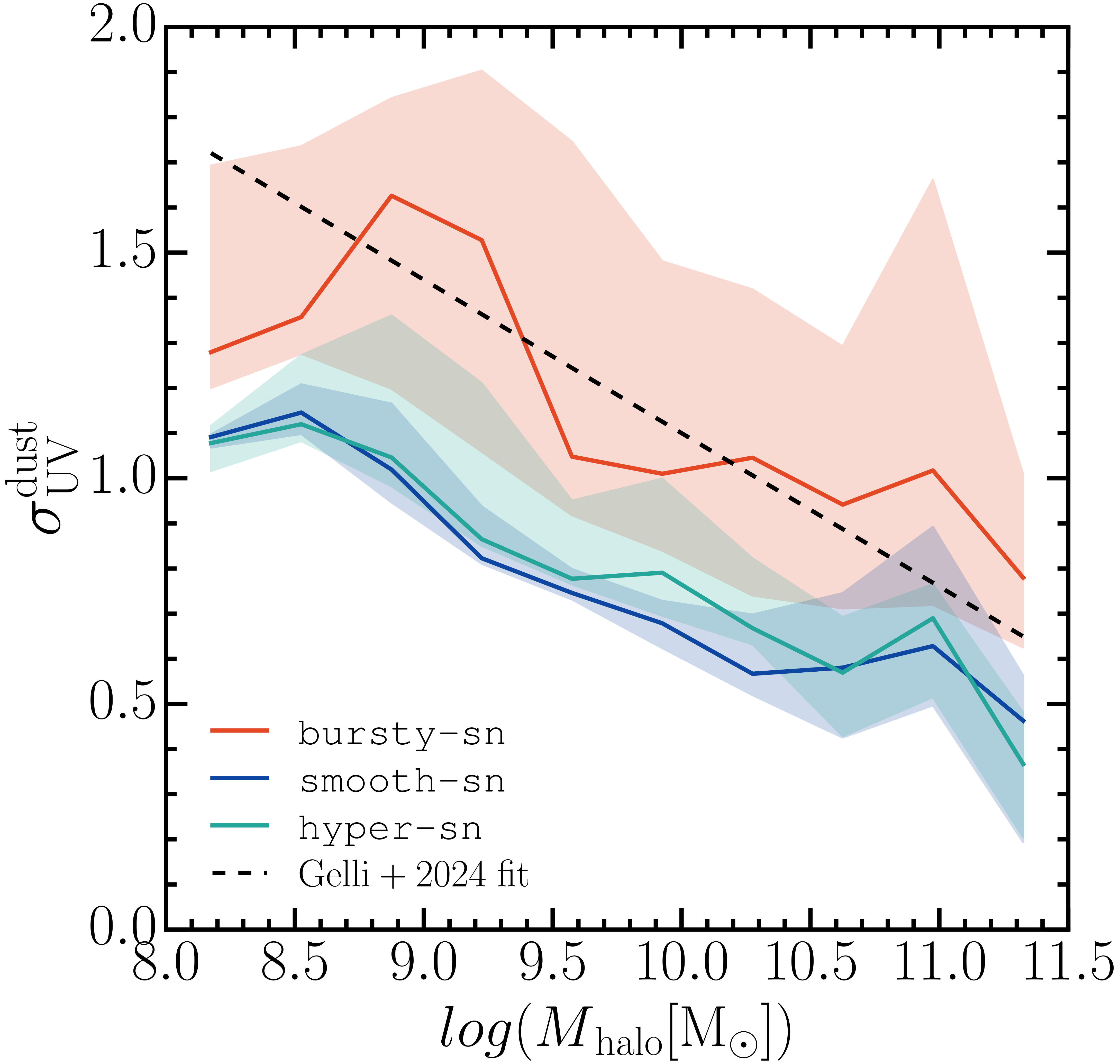

Mass dependence of $\sigma_{\mathrm{UV}}^{\mathrm{dust}}$

all models exhibit a similar slope, confirming that **lower mass halos are more sensitive to feedback** effects, producing more fluctuations compared to massive halos.

'bursty-sn' model produces **highest amplitude and highest scatter** - wider range of variability

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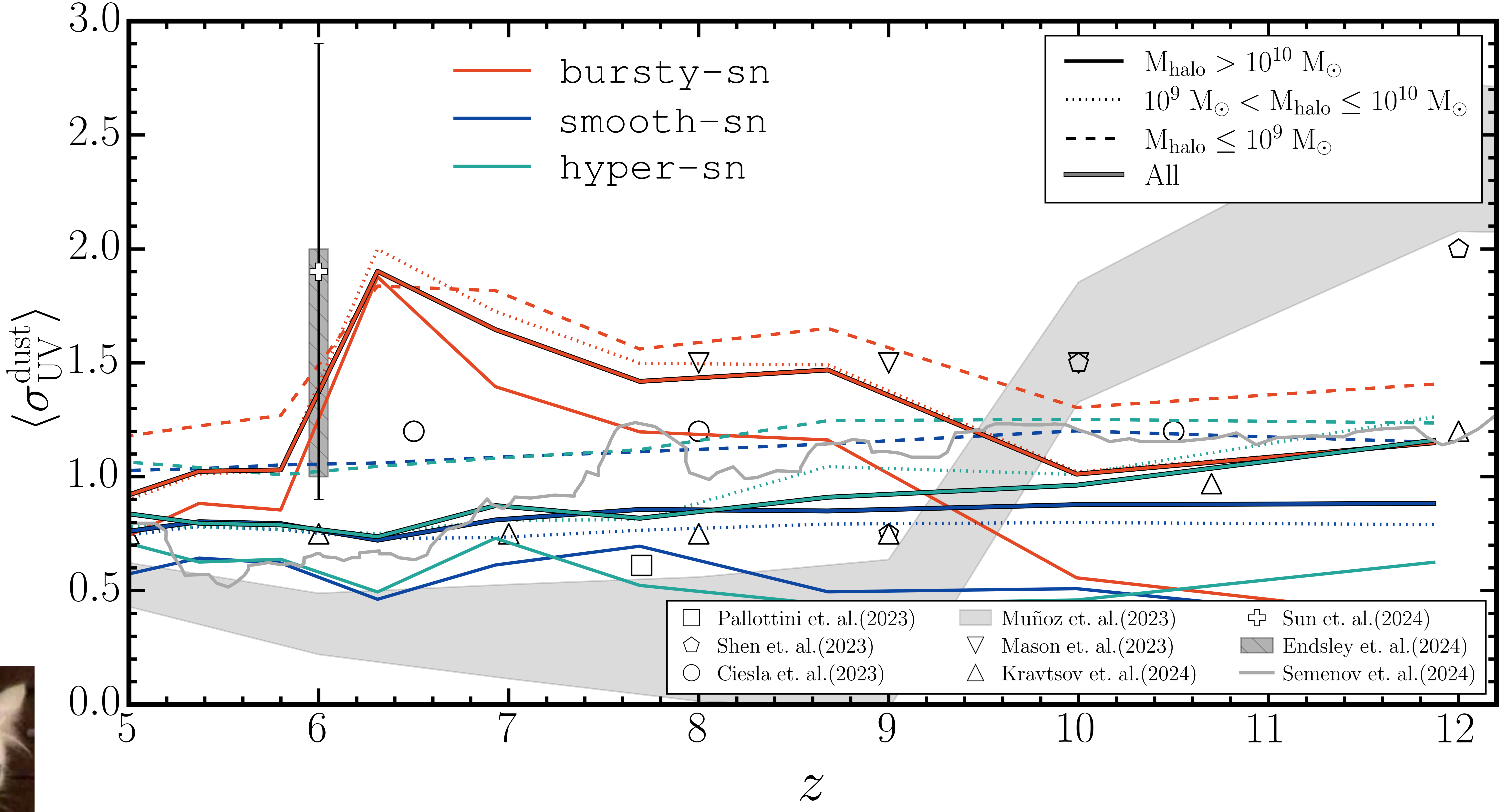
Redshift dependence of σ_{UV}^{dust}



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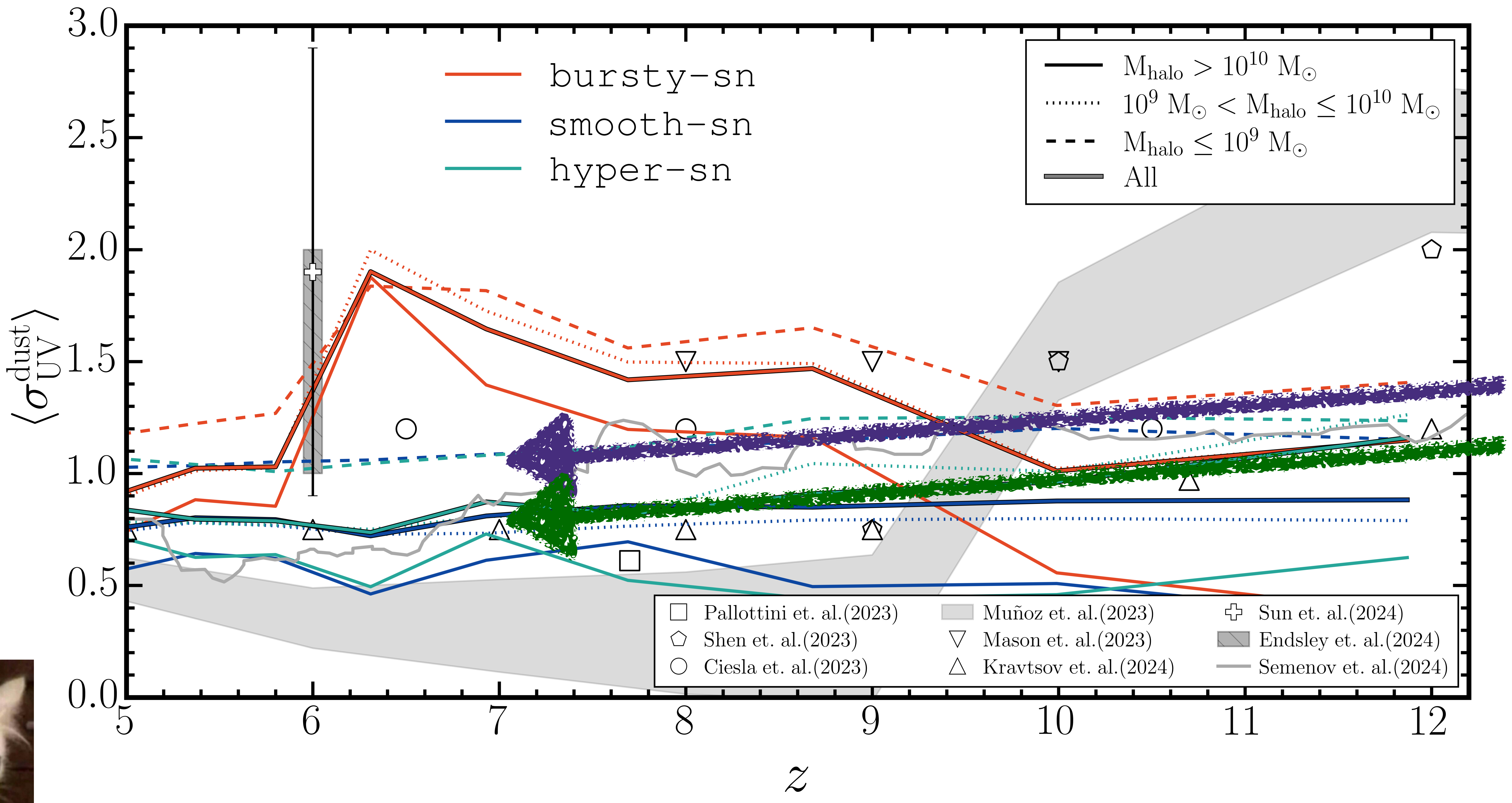

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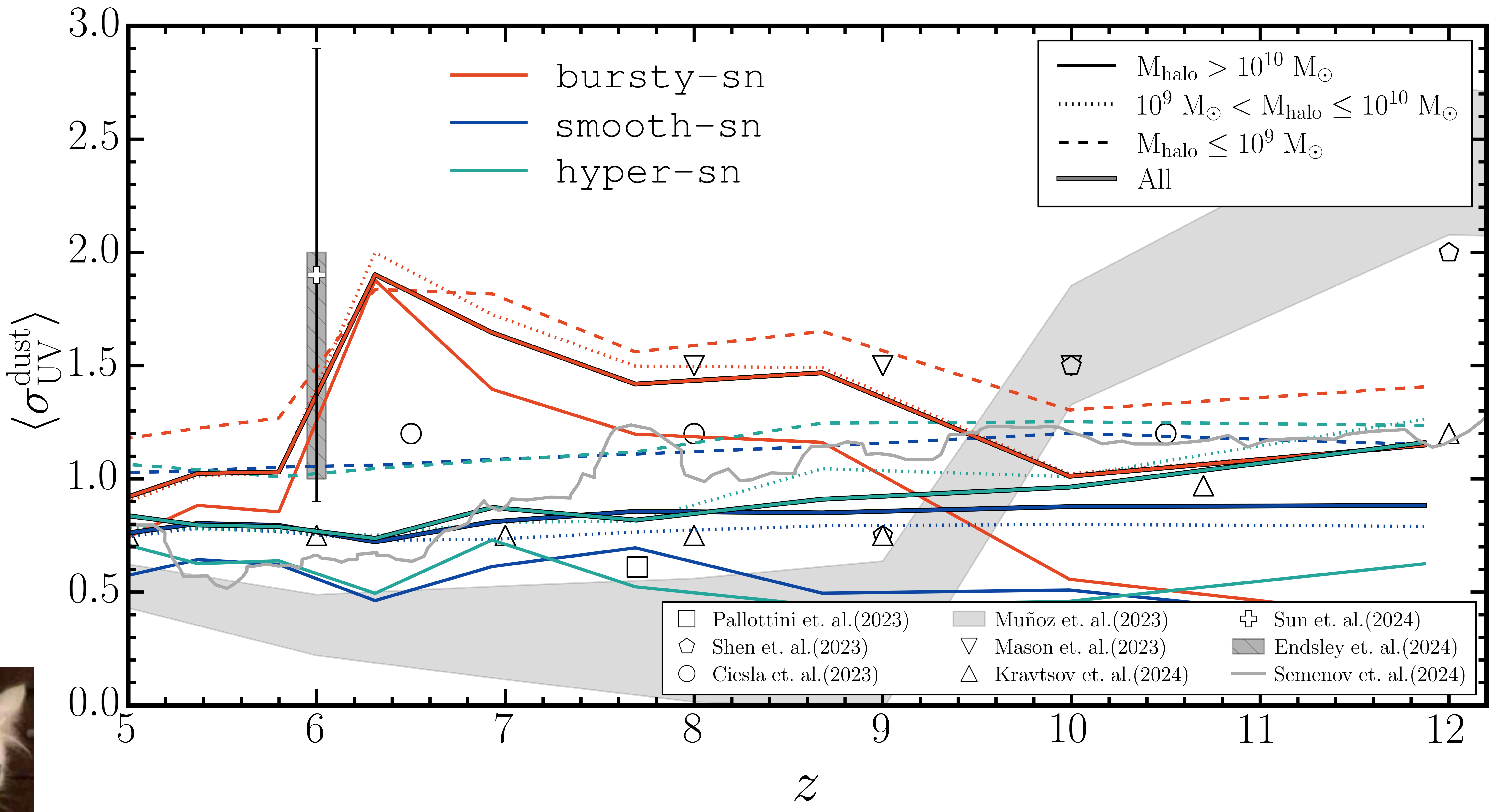

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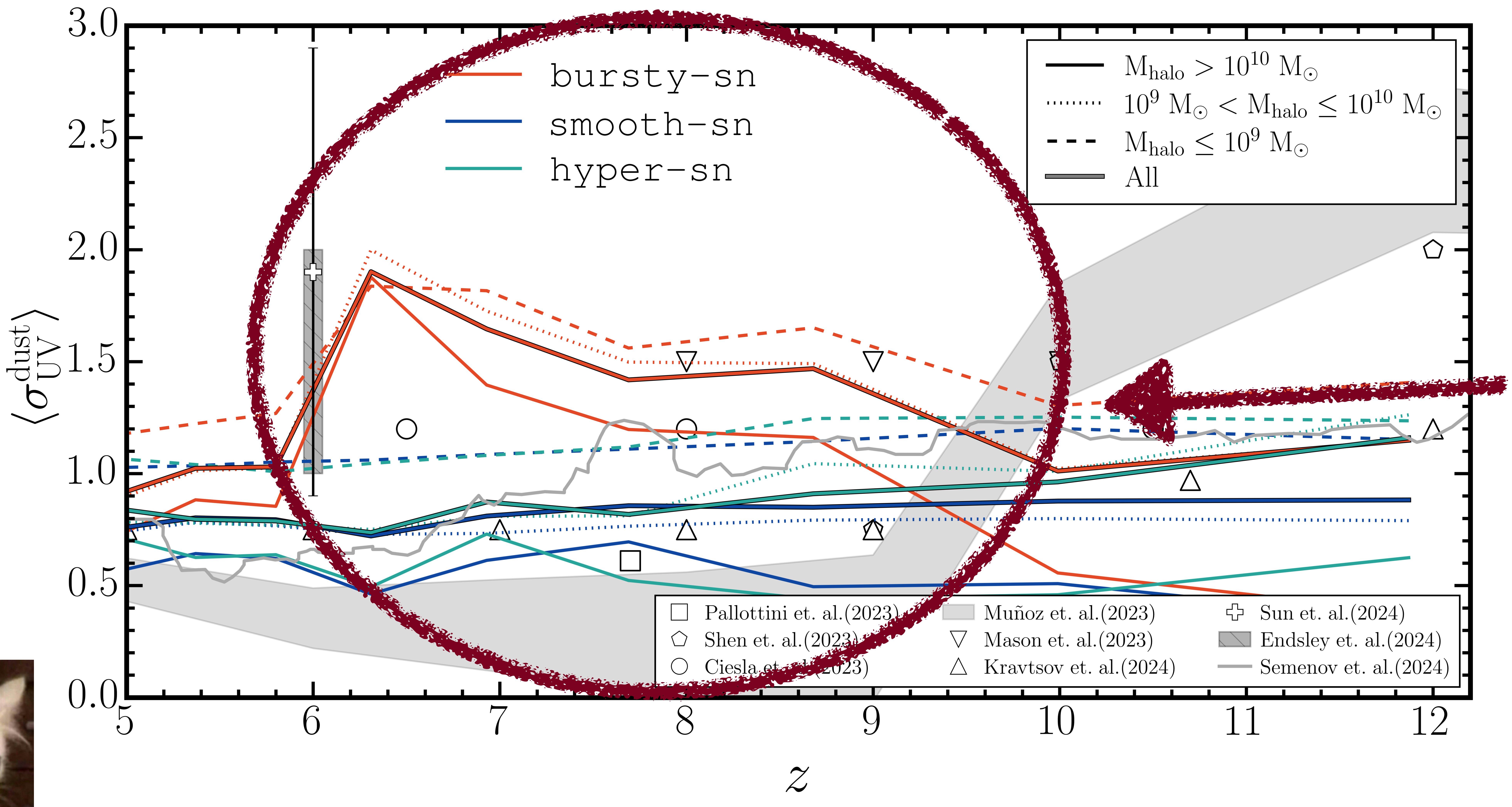


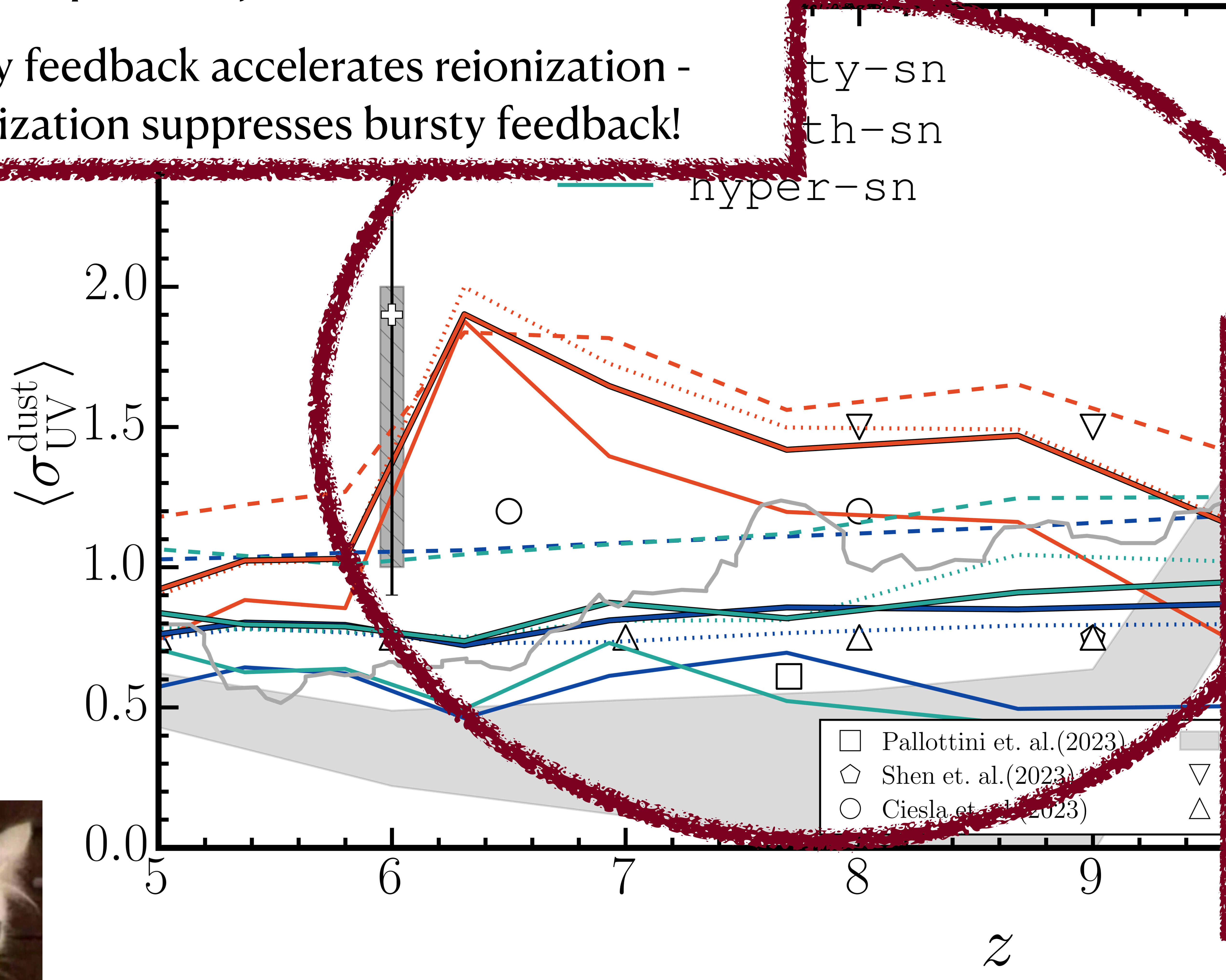
Basu et. al. 2025 (in review)

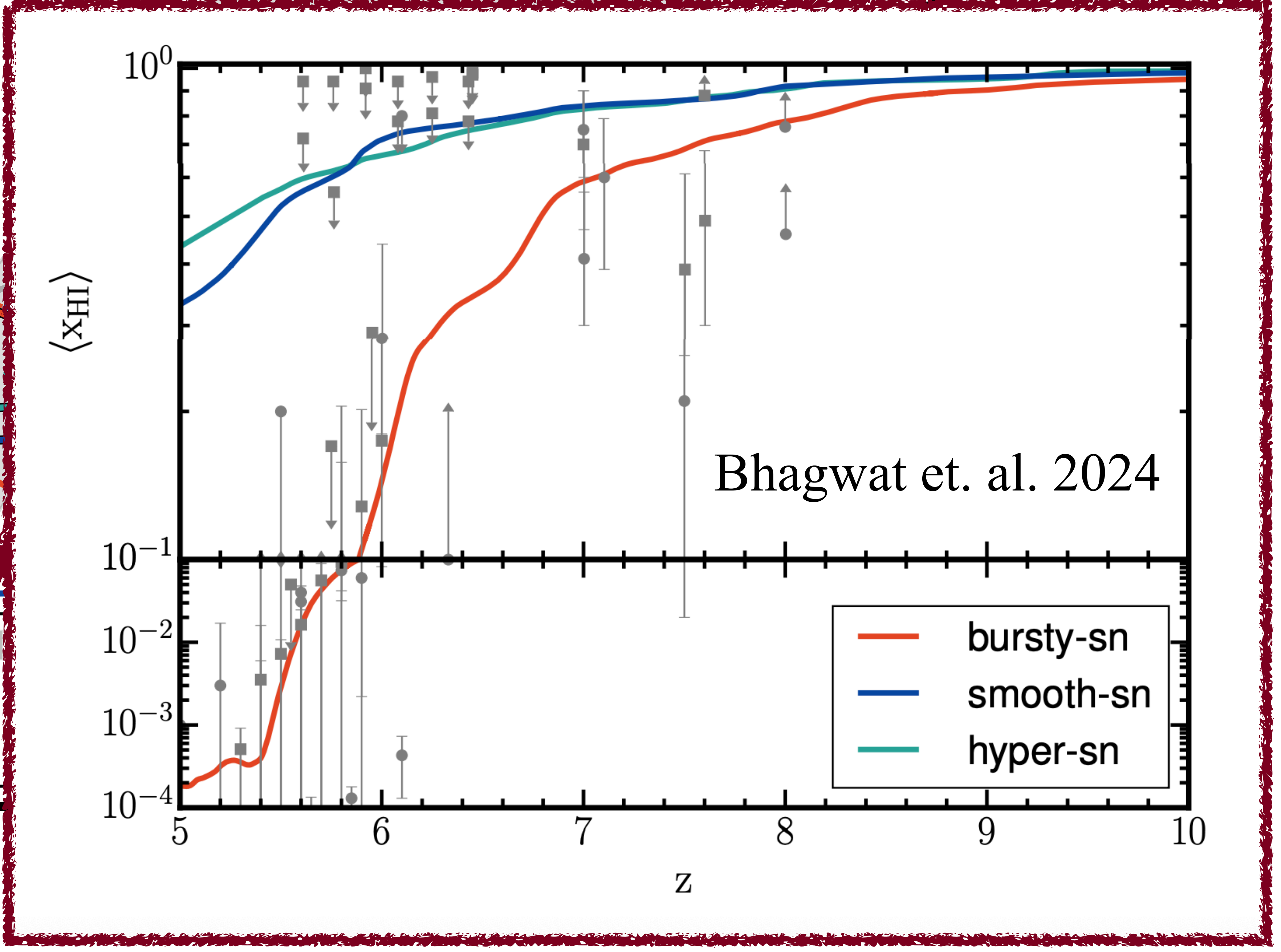
Connecting UVLF variability with stellar feedback

Redshift dependence of $\sigma_{\rm UV}^{\rm dust}$

Impacted by the rise of UVB

Bursty feedback accelerates reionization - reionization suppresses bursty feedback!





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Connecting UVL

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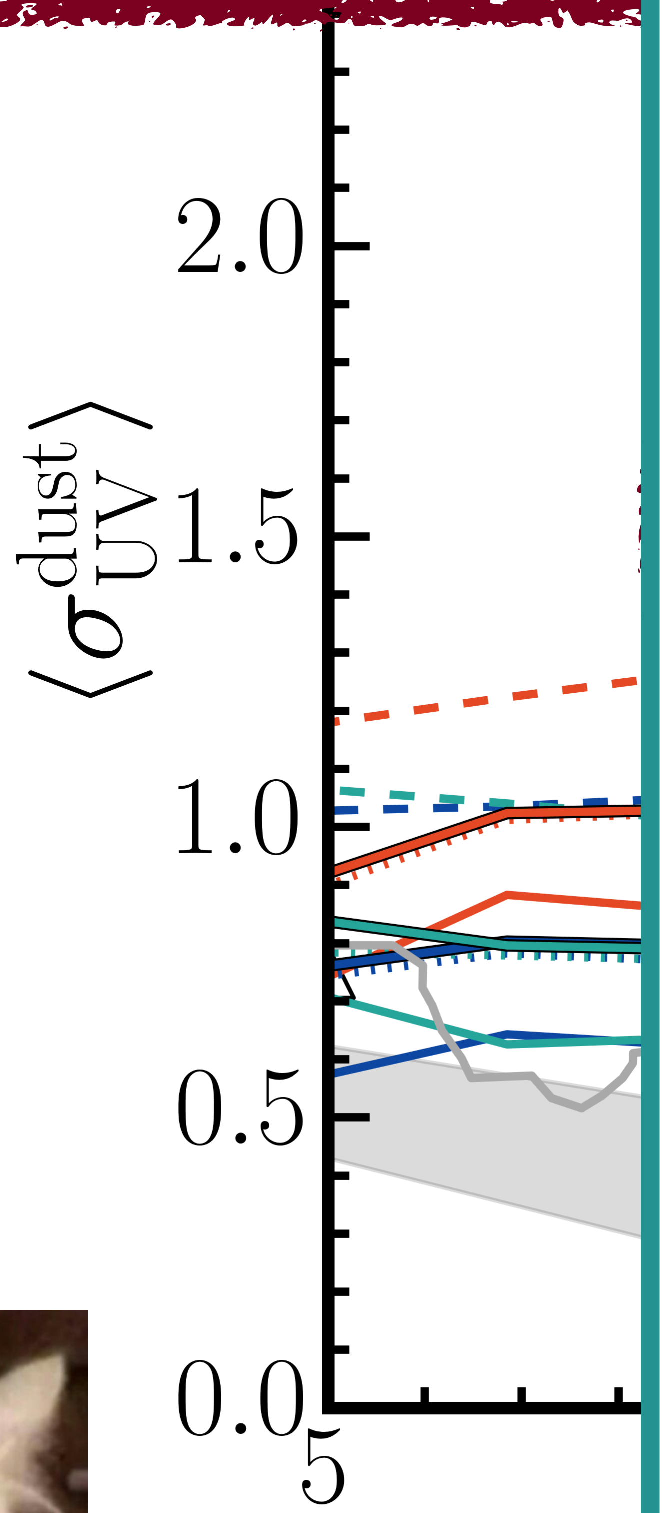

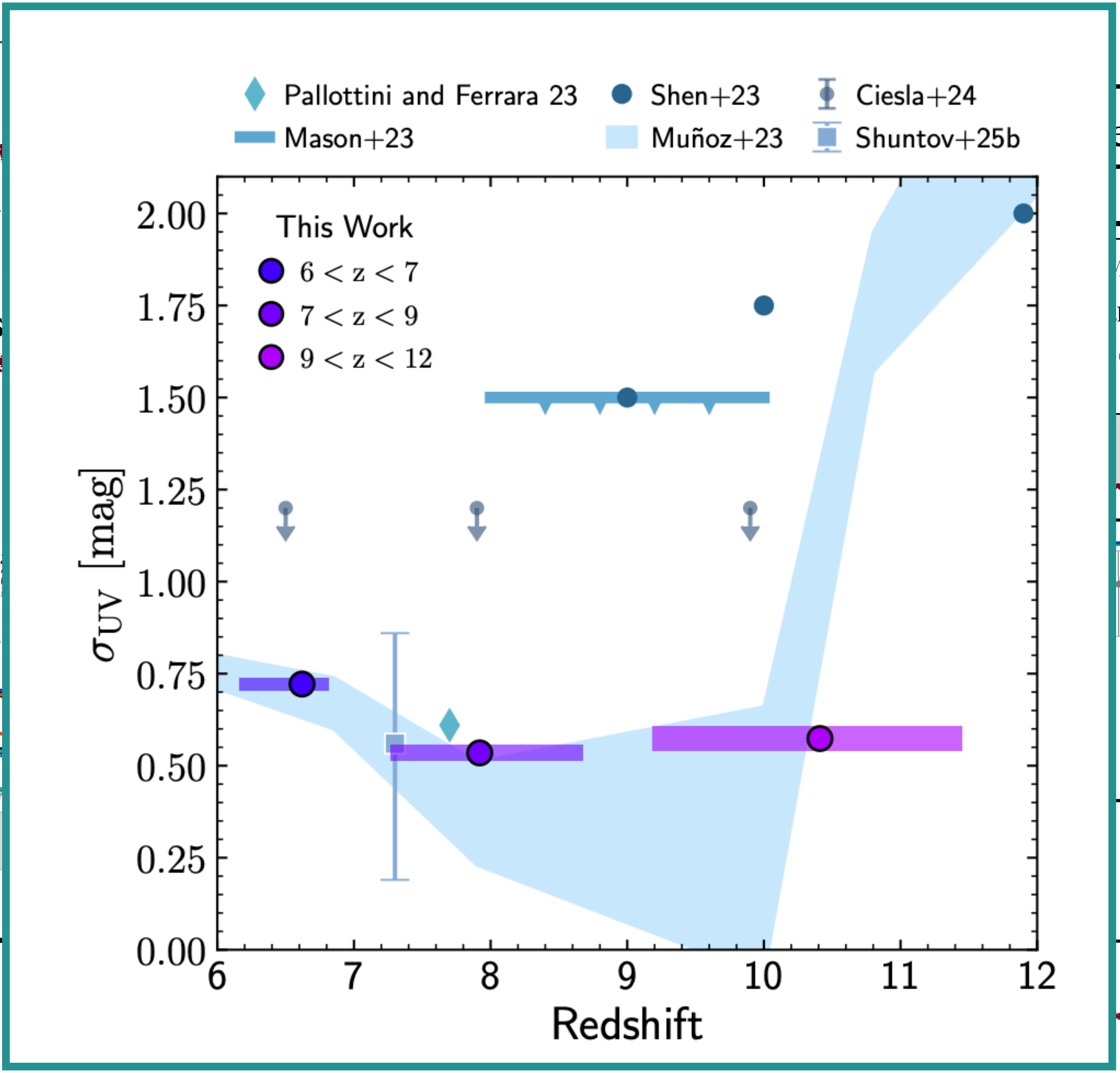

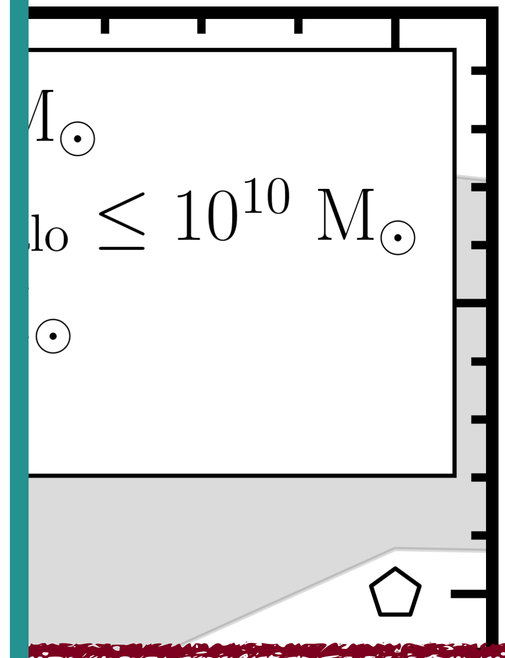

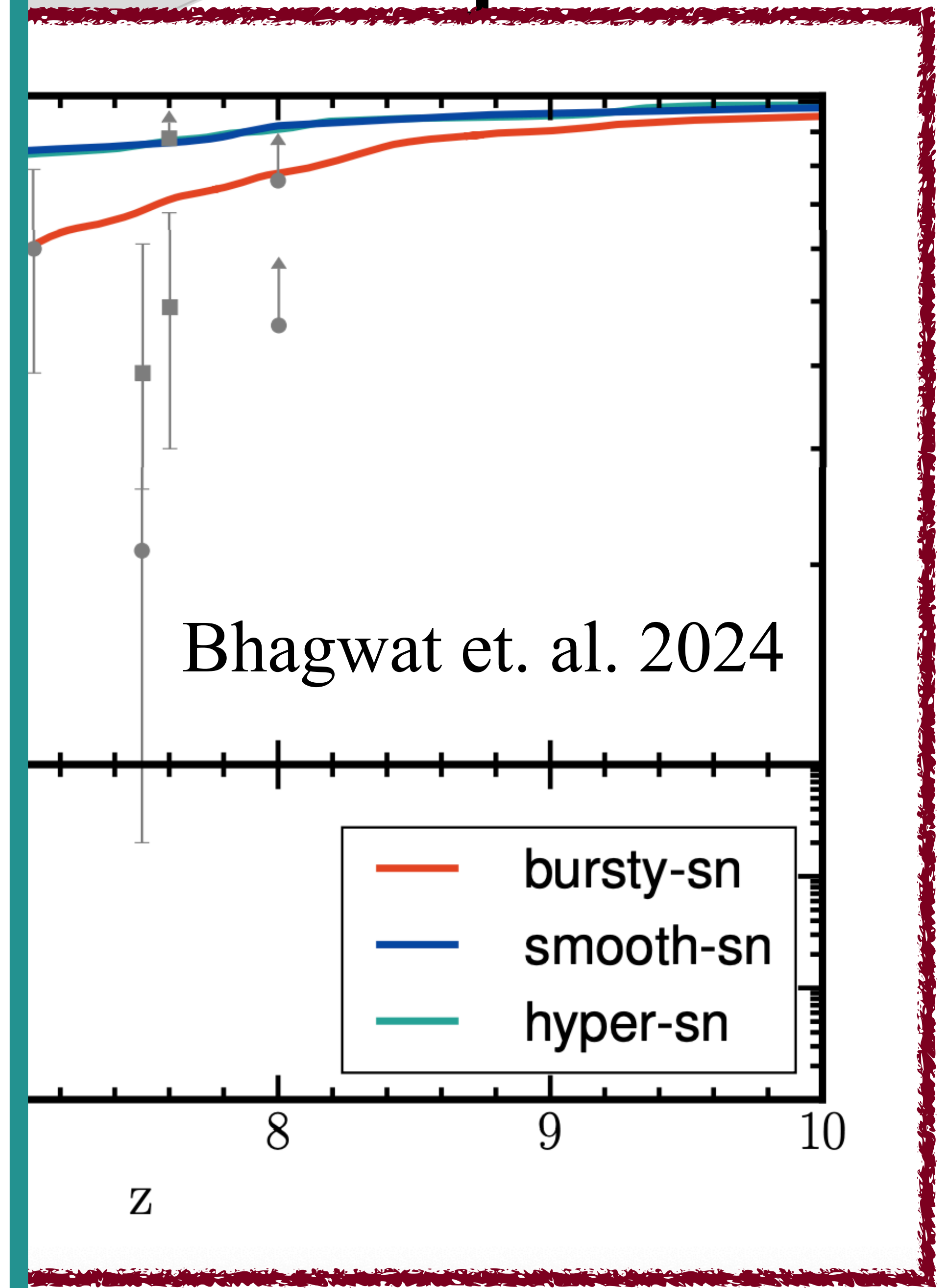

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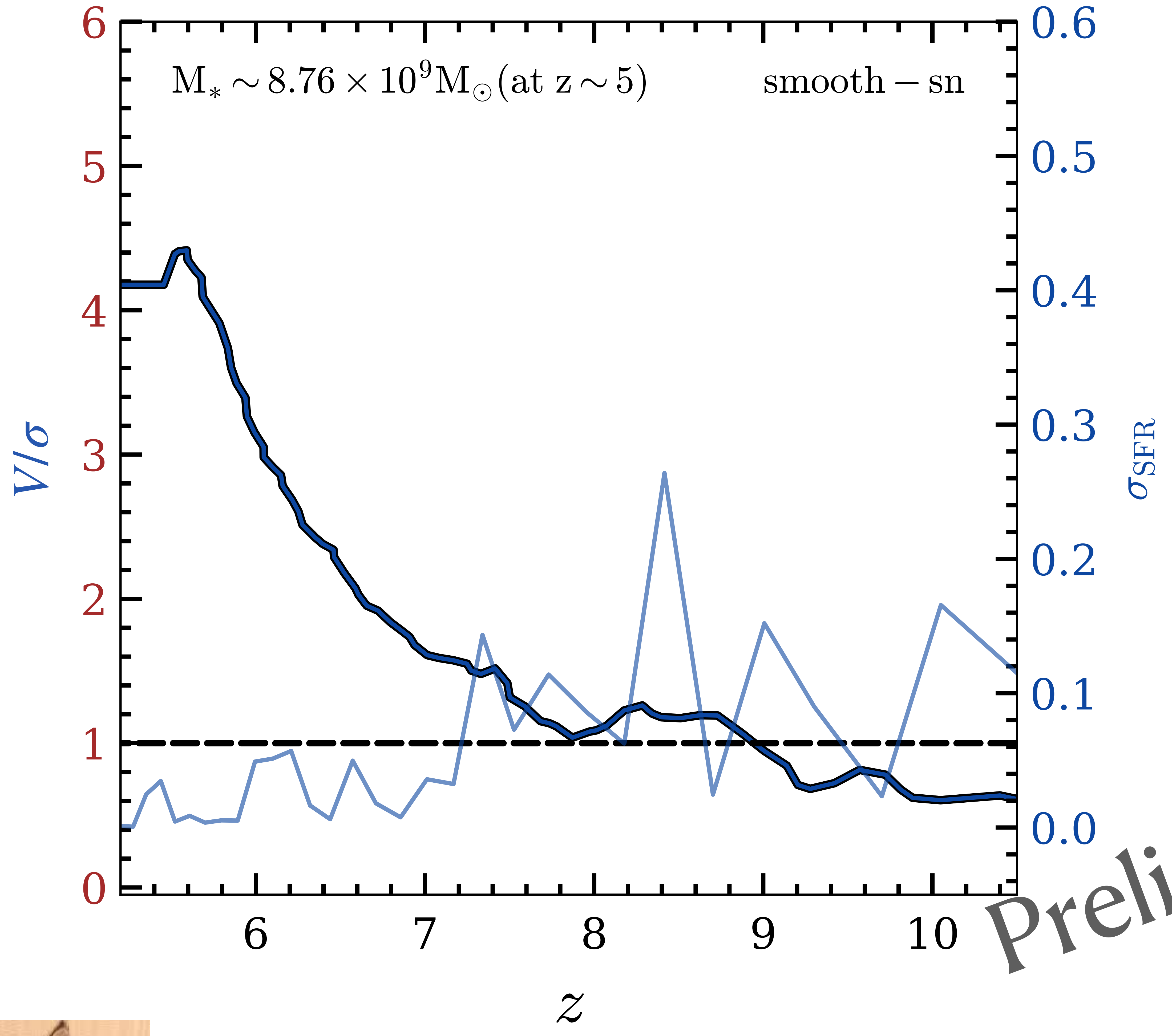
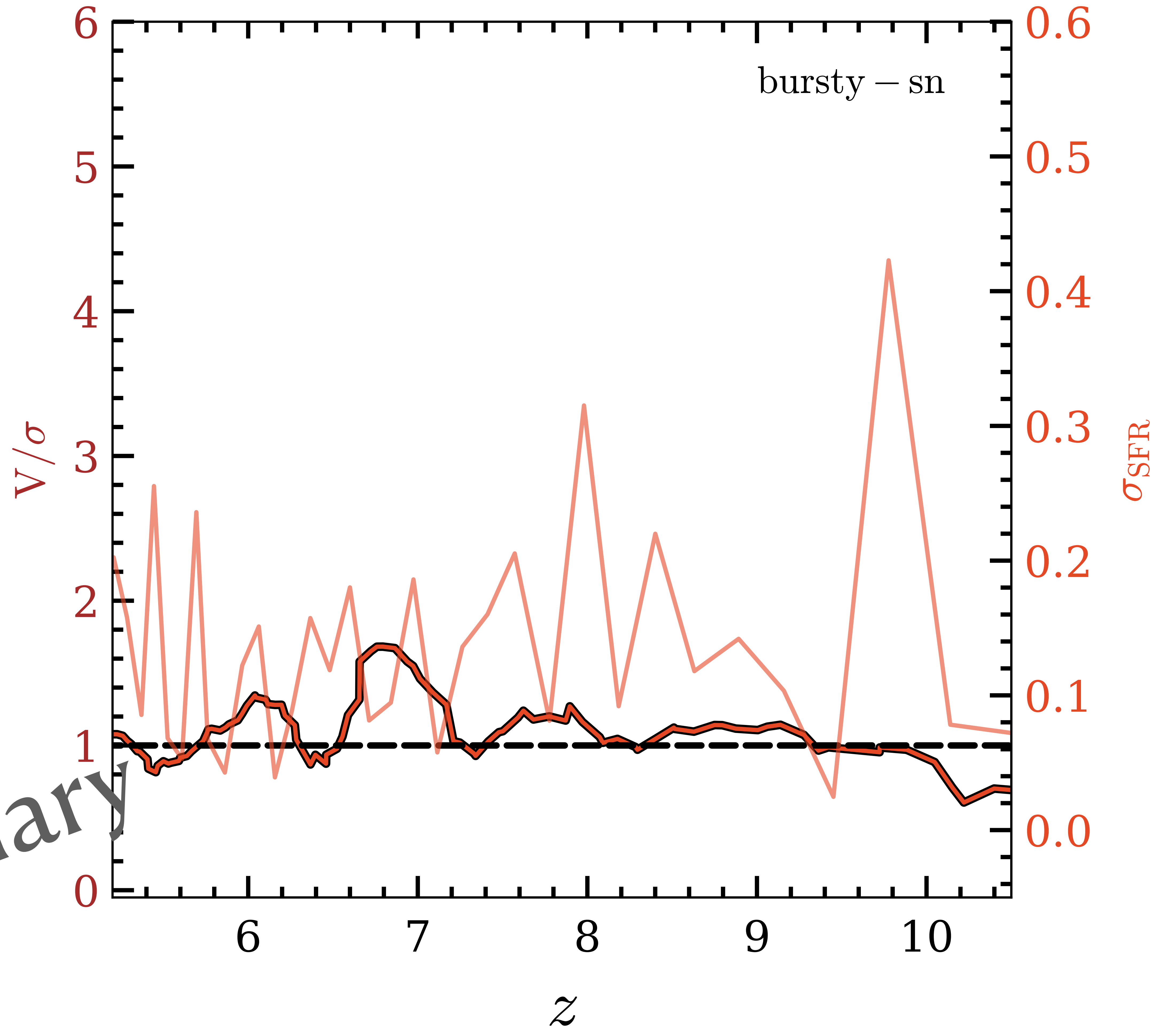
Impact on galaxy morphology





Preliminary

Can we connect UVLF variability with disk formation ?

Take Home Messages

Reach me at : basu.arghyadeep@yahoo.in
Or Facebook, Instagram, LinkedIn… I am here, there and everywhere :D

Also, I am moving to Lyon in October - will work with Joki Rosdahl - you can find me there as well xD

Variability is impacted by the rise of UVB

Variability is mass and redshift dependent

Feedback accelerates Reionization - - Reionization suppresses feedback

Variability might impact the disk formation ?

Catch me if you can

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Cheers to POTSDAM ! Thank you :D

Disclaimer : No cats are harmed and I am also not harmed by any cat