

# Exploring the Role of AGN Feedback in Galaxy Formation

Rebekka Bieri

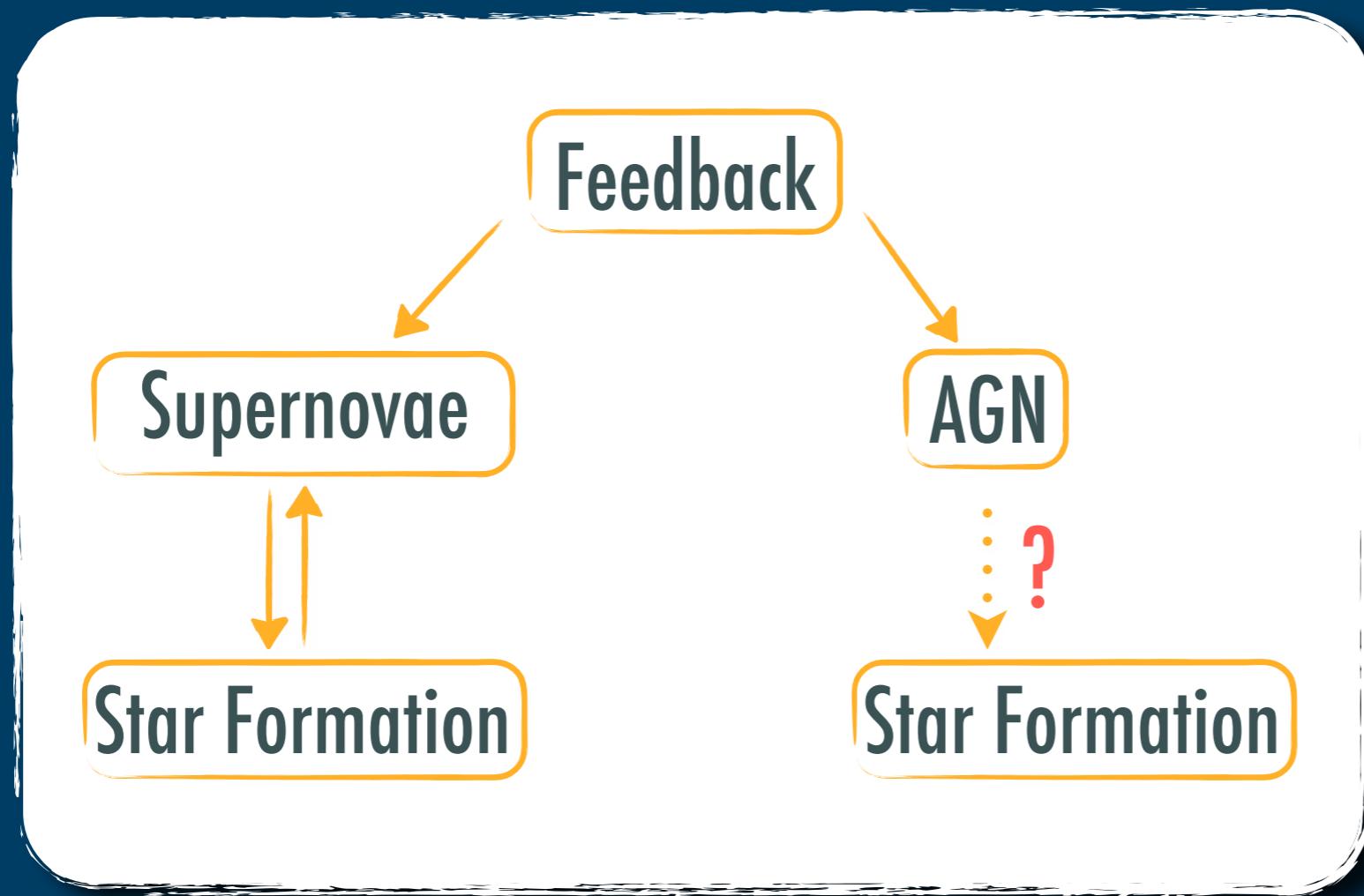
Joe Silk

Yohan Dubois

Gary Mamon

IAP

# Outline



# History of the whole wide Universe

SMALL PERTURBATIONS



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SMALL PERTURBATIONS



# History of the whole wide Universe

GROW



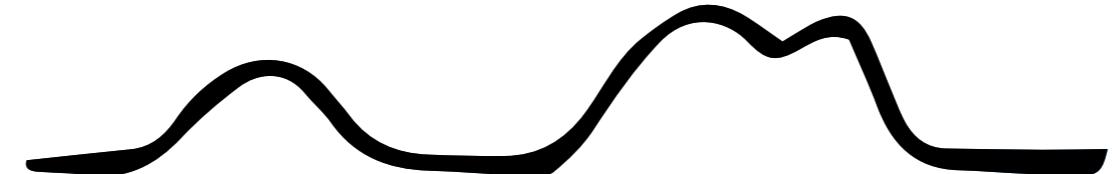
# History of the whole wide Universe

Awo grow



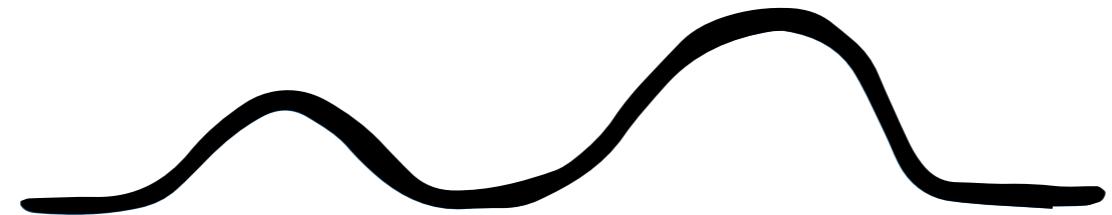
# History of the whole wide Universe

And...



# History of the whole wide Universe

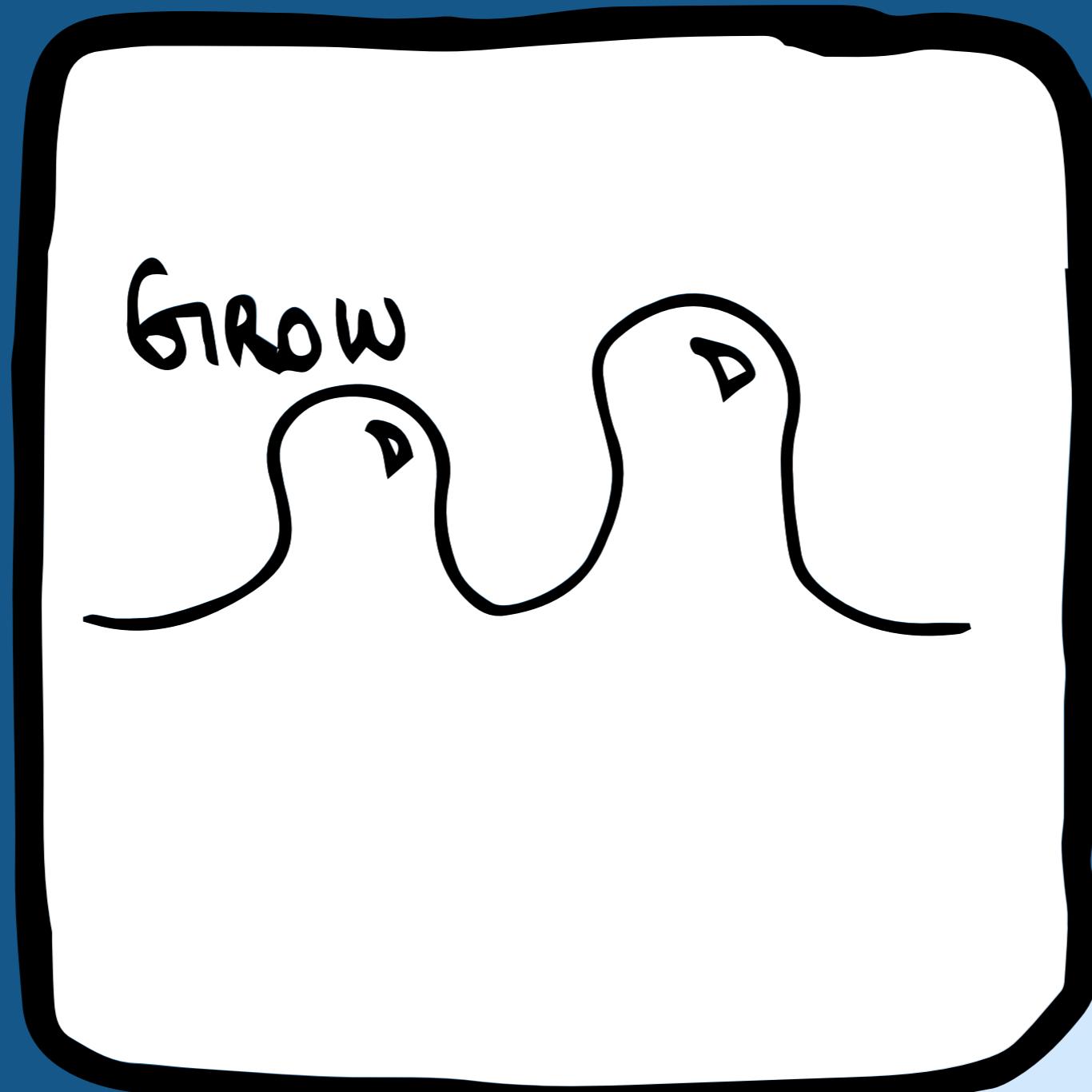
MEROE



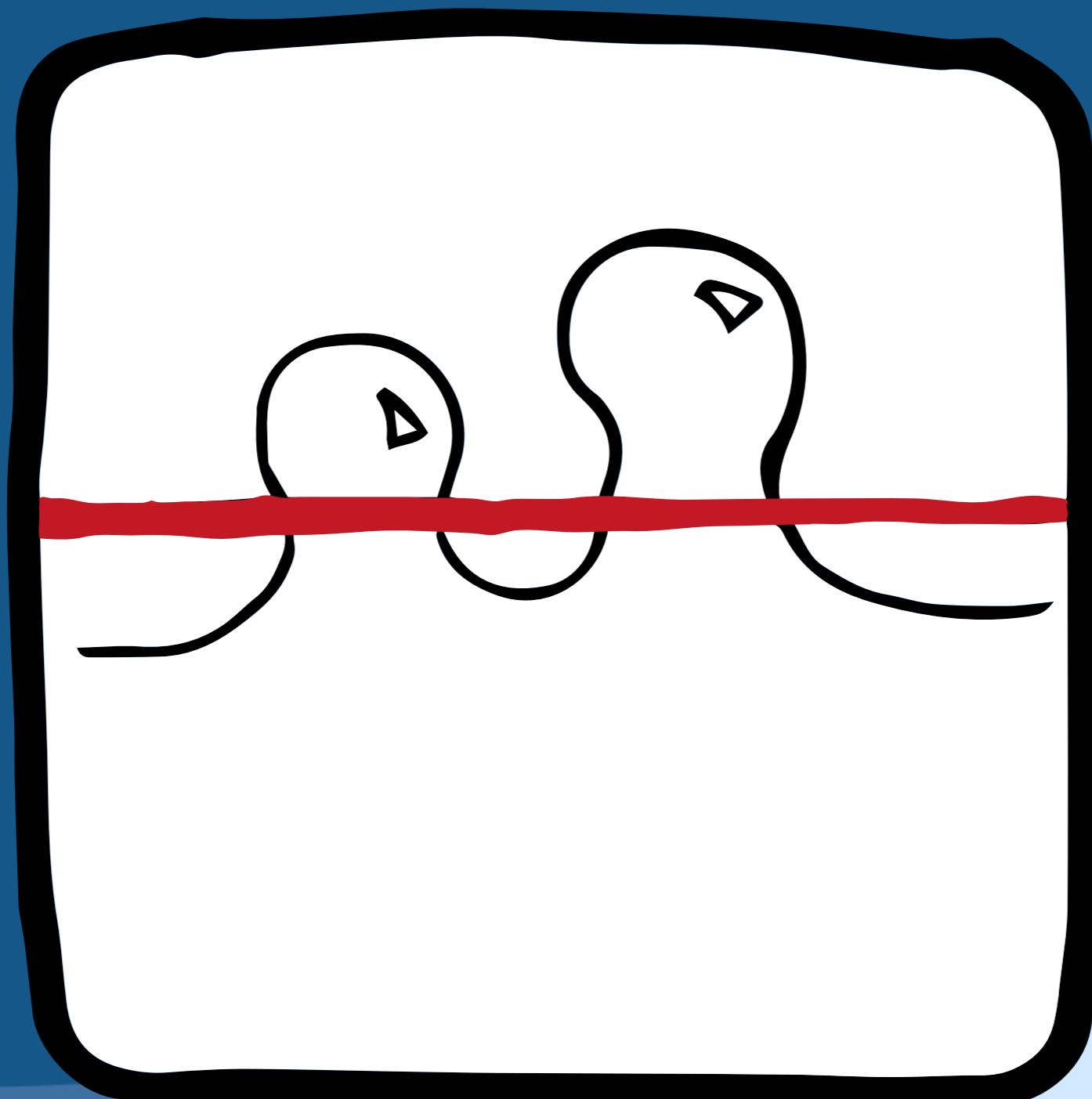
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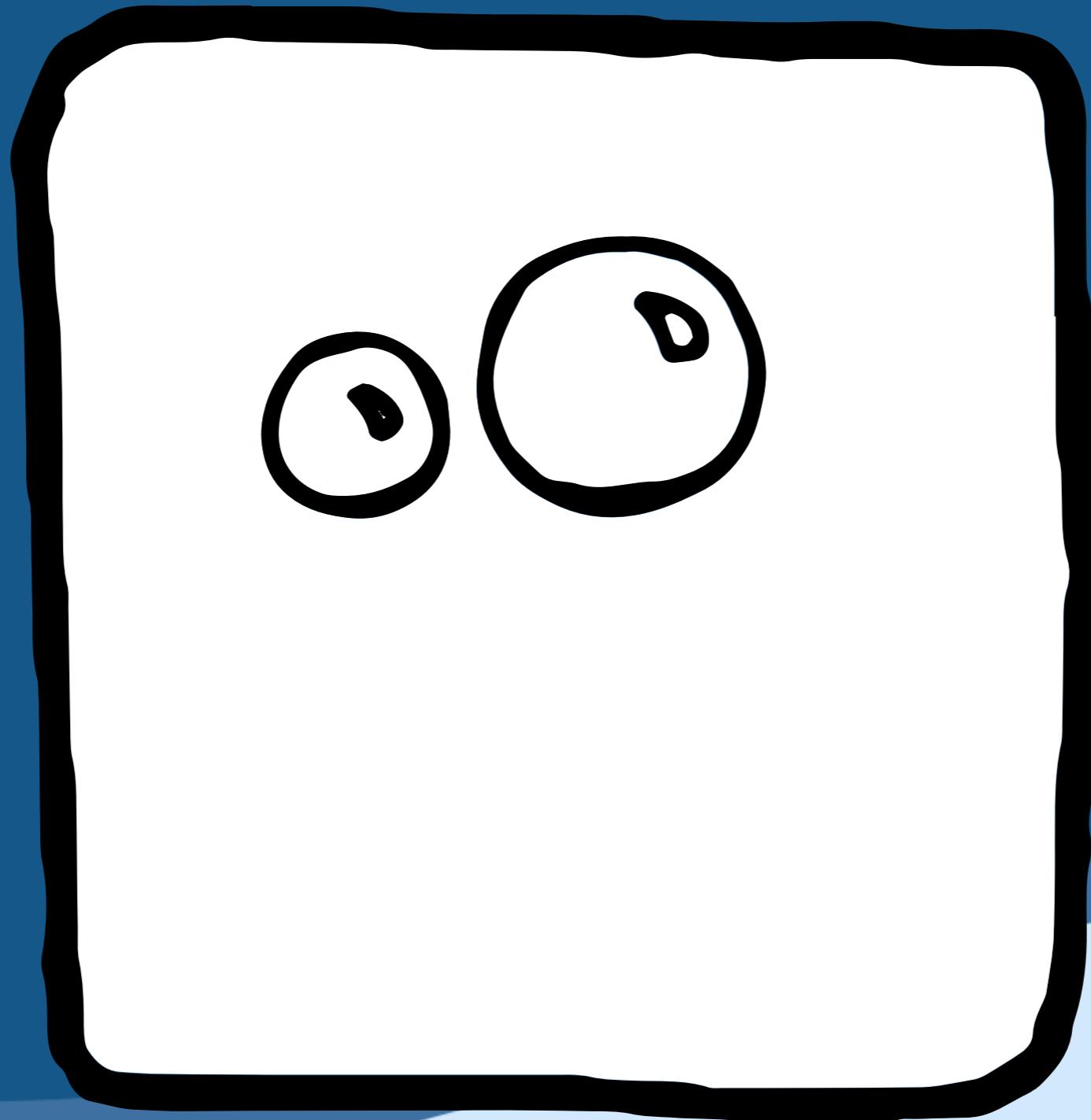
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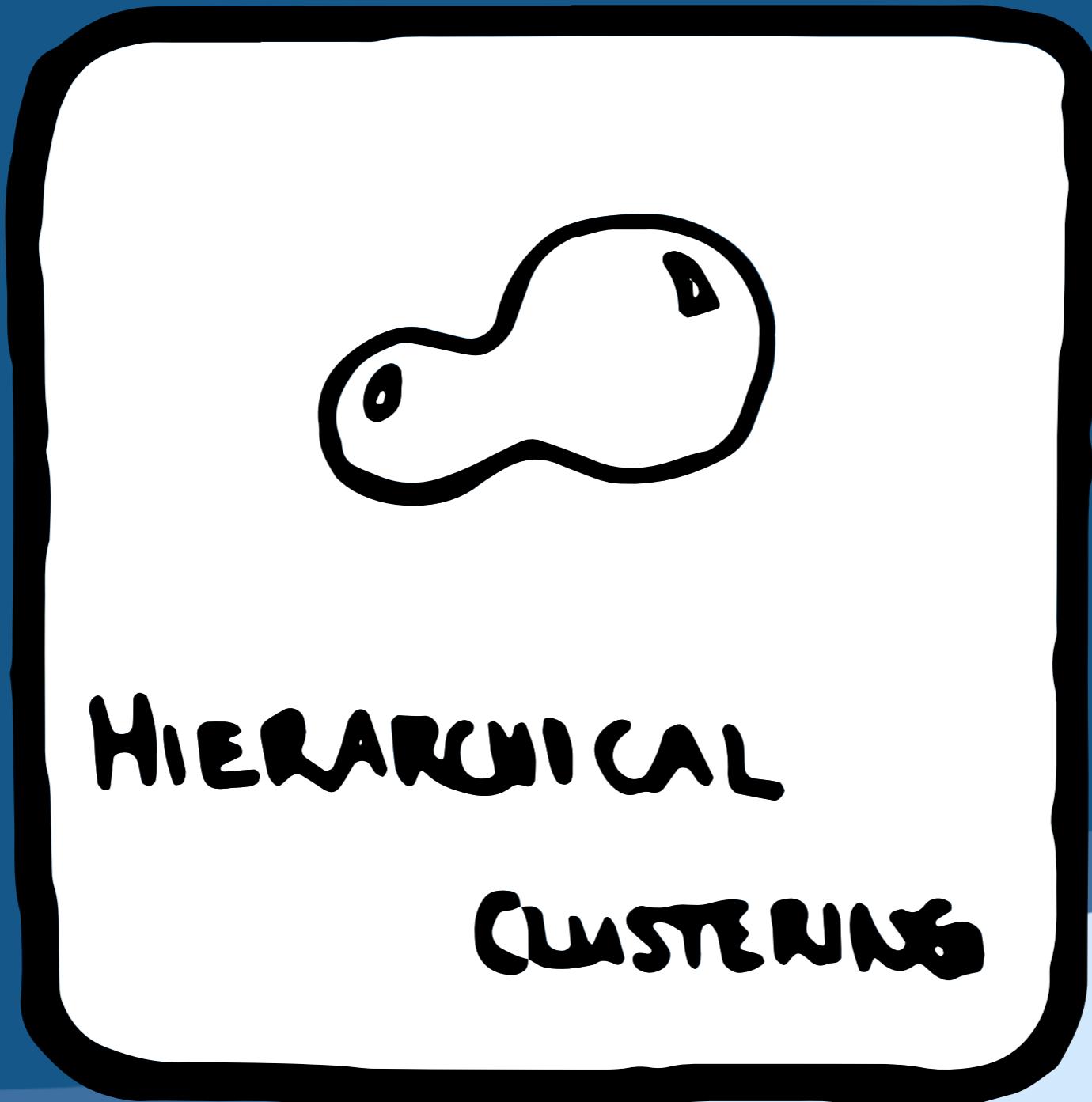
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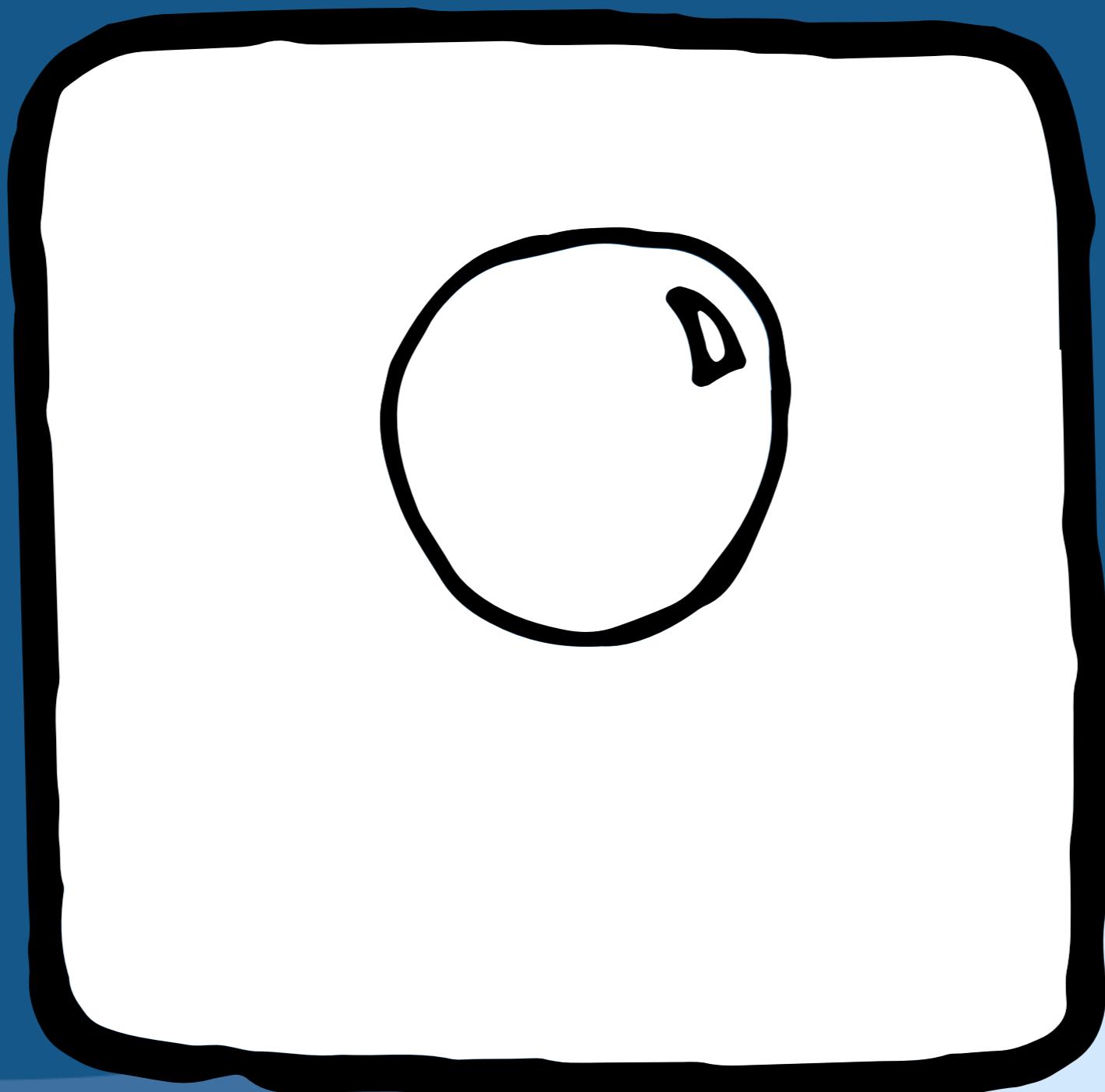
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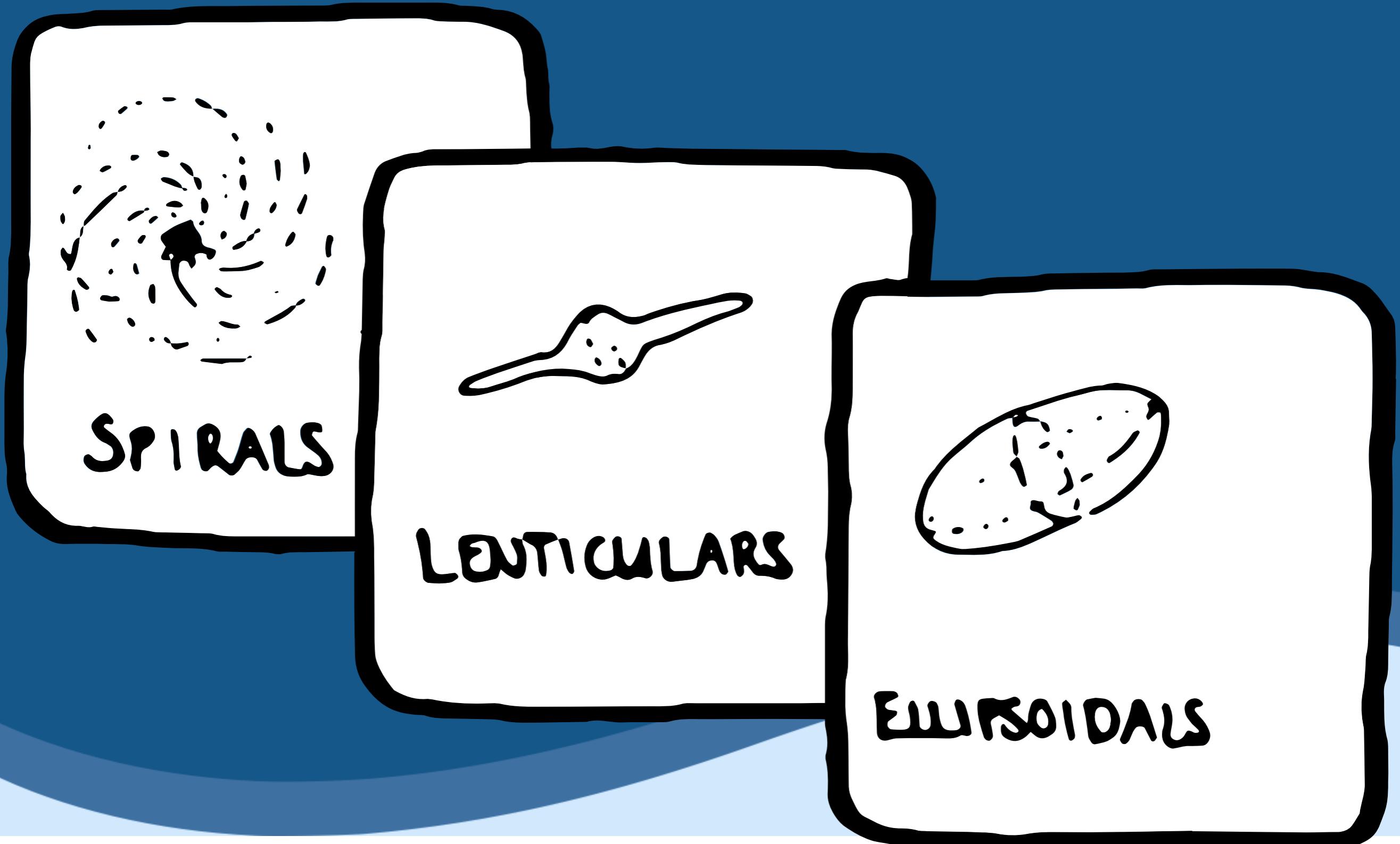
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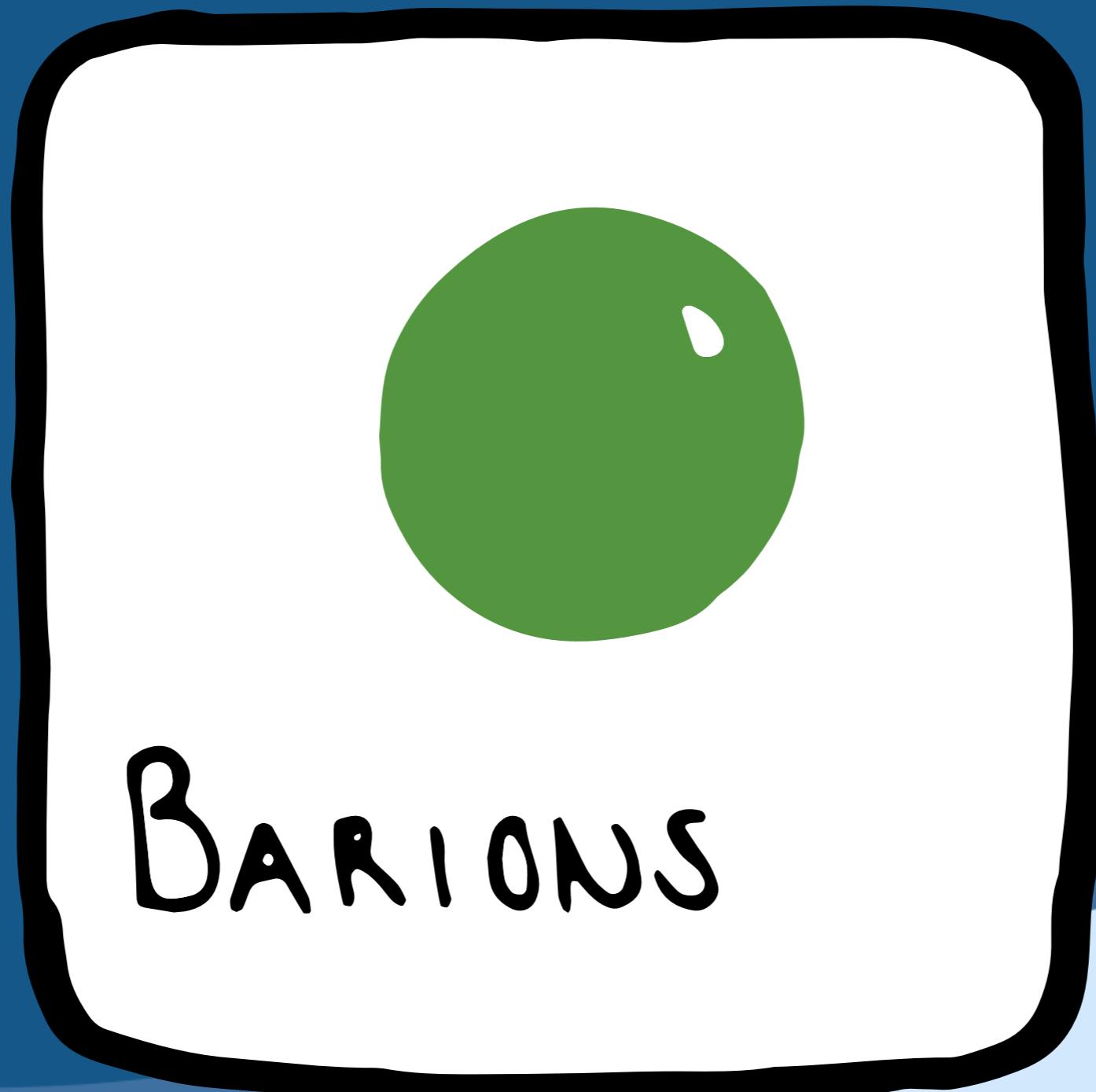
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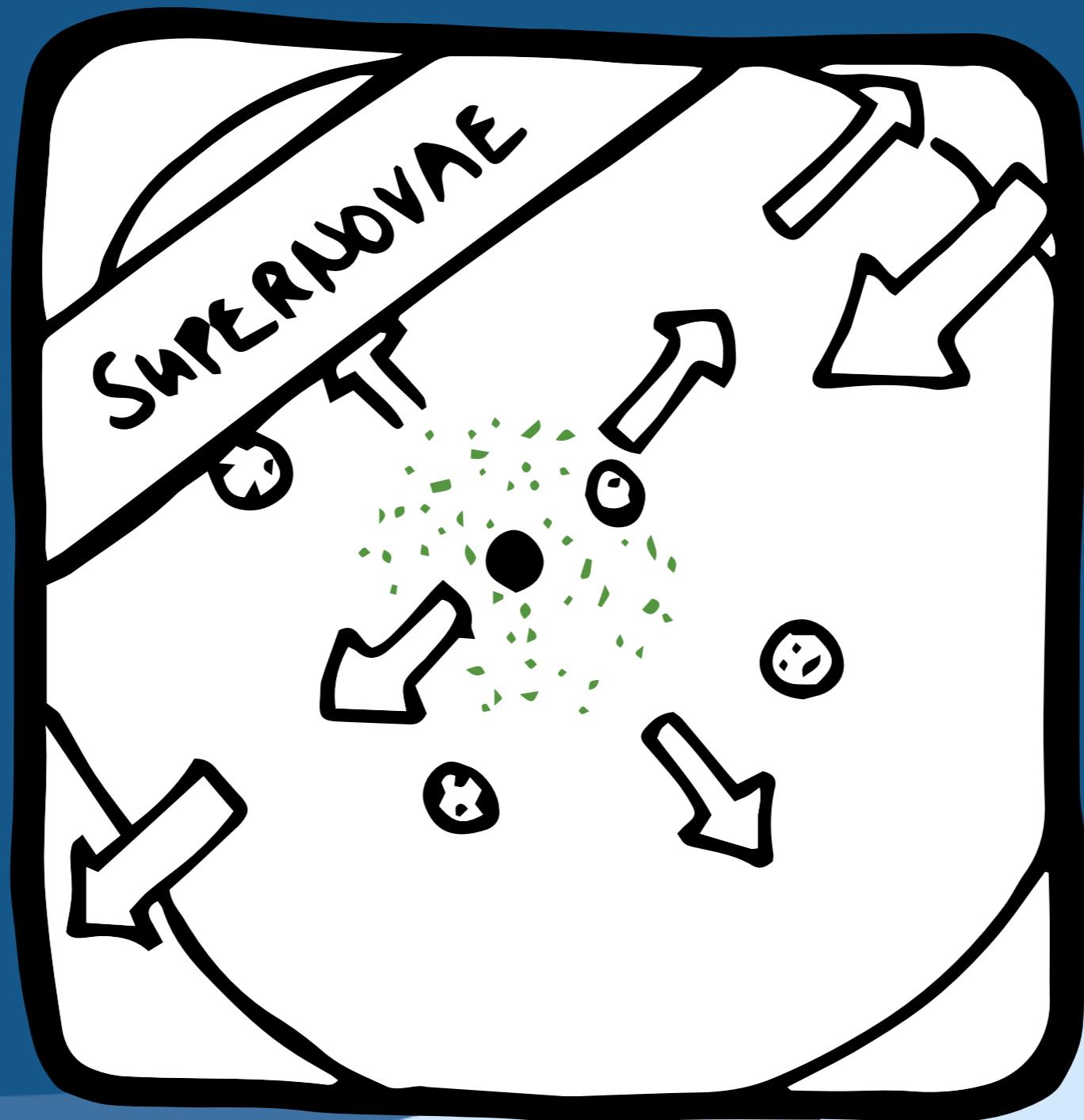
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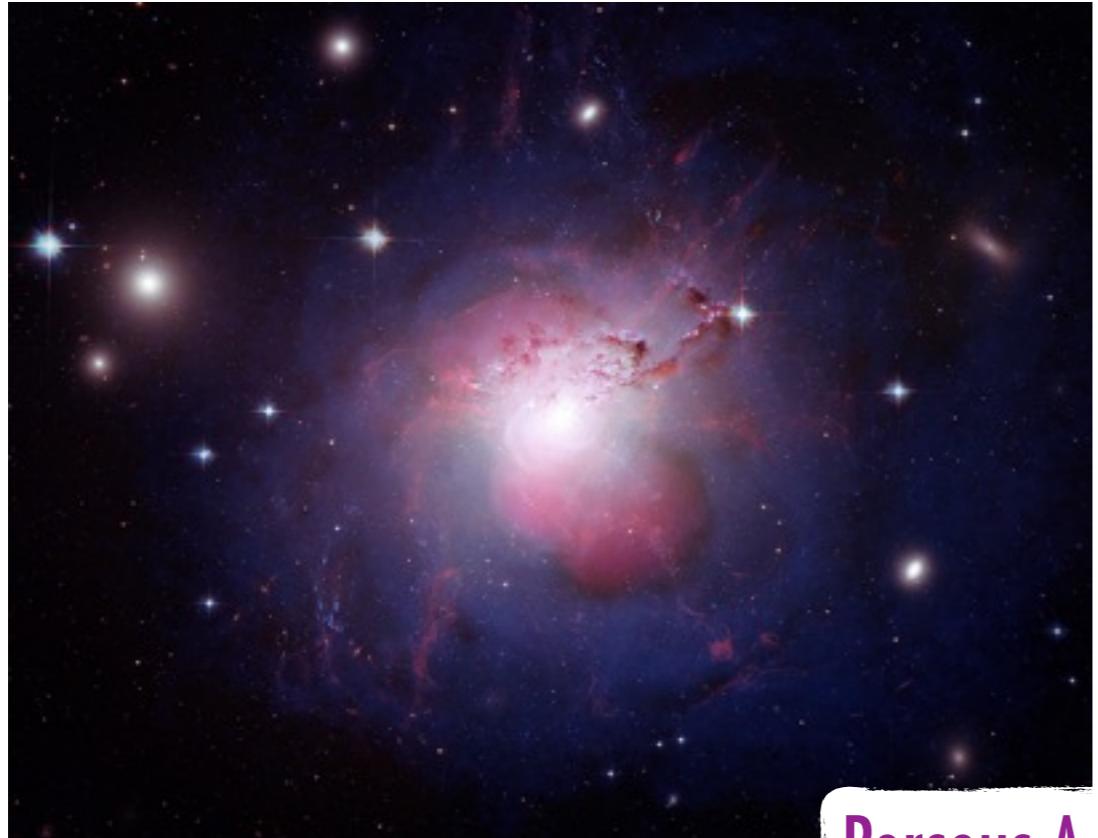


# History of the whole wide Universe



# Why is feedback important?

Shuts off Cooling in Clusters



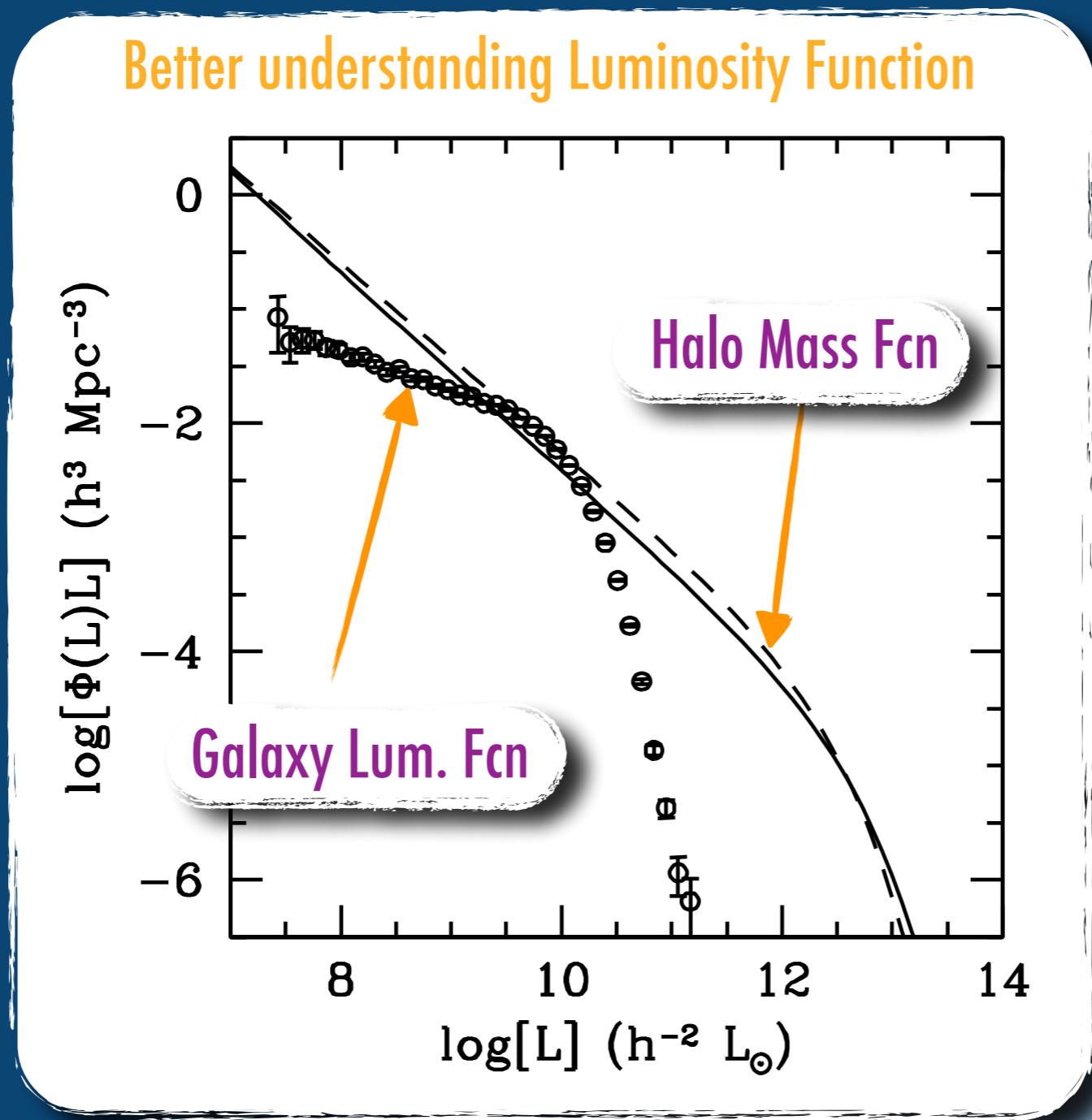
Perseus A

Ejects gas/metals out of a galaxy



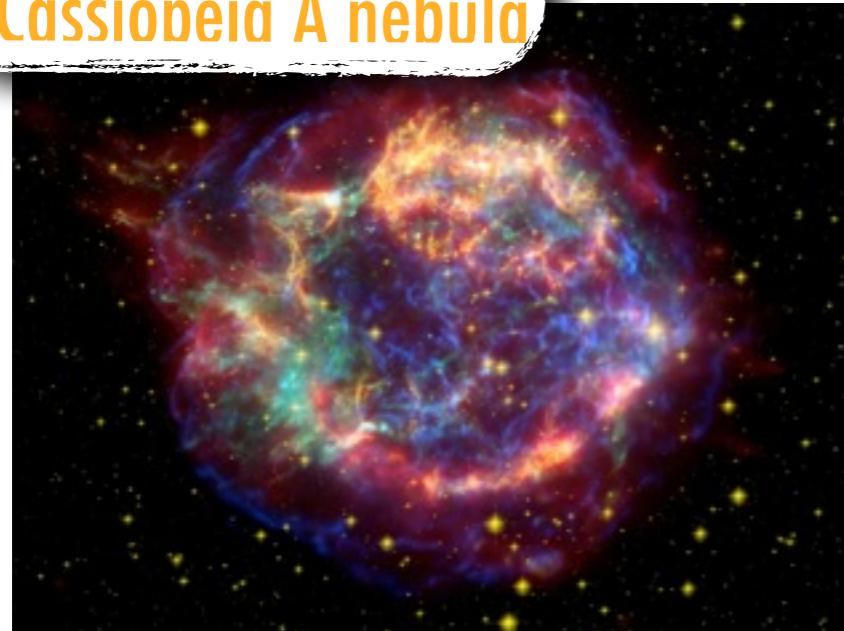
NGC 3079 (HST)

# Why is it important?



# Supernovae

## Cassiopeia A nebula

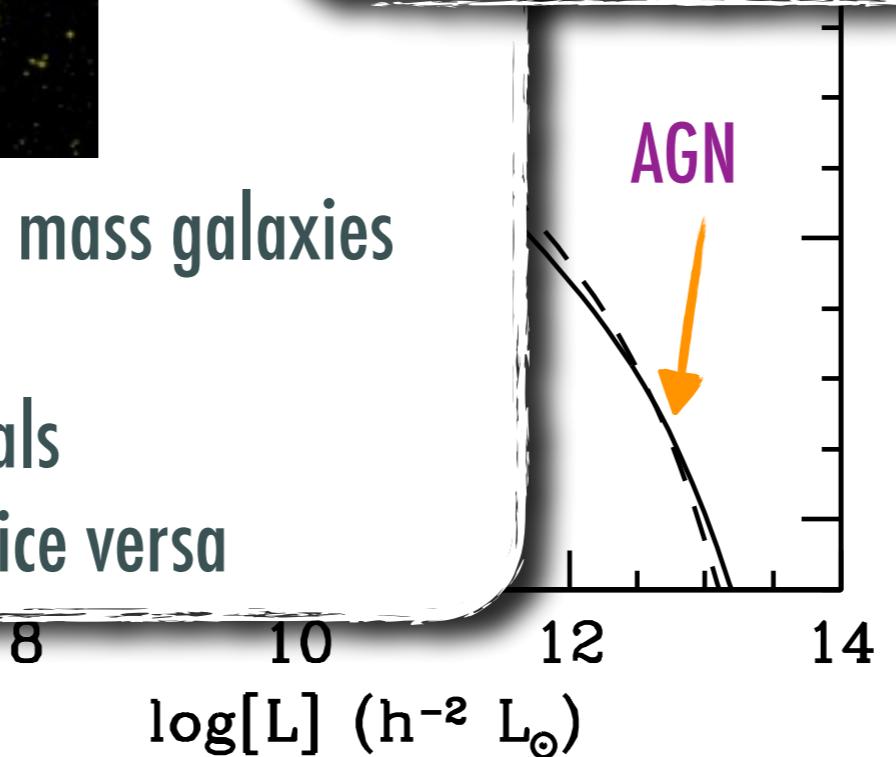


- Drives evolution of low mass galaxies
- Expel baryons
- Enriches IGM with metals
- Influenced by SF and vice versa

## Simulations

- SNe-driven winds limit accretion/SF?
- Sufficient mass outflow rate?

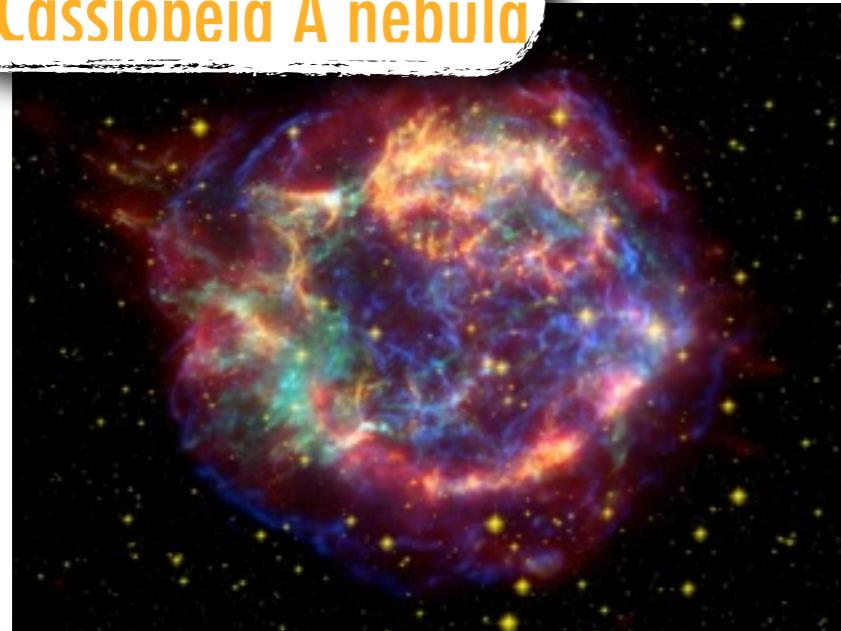
Powell+ (2010), Governato+ (2007), Scannapieco+ (2009), Agertz+ (2010)



Yang et al. 2003

# Supernovae

Cassiopeia A nebula

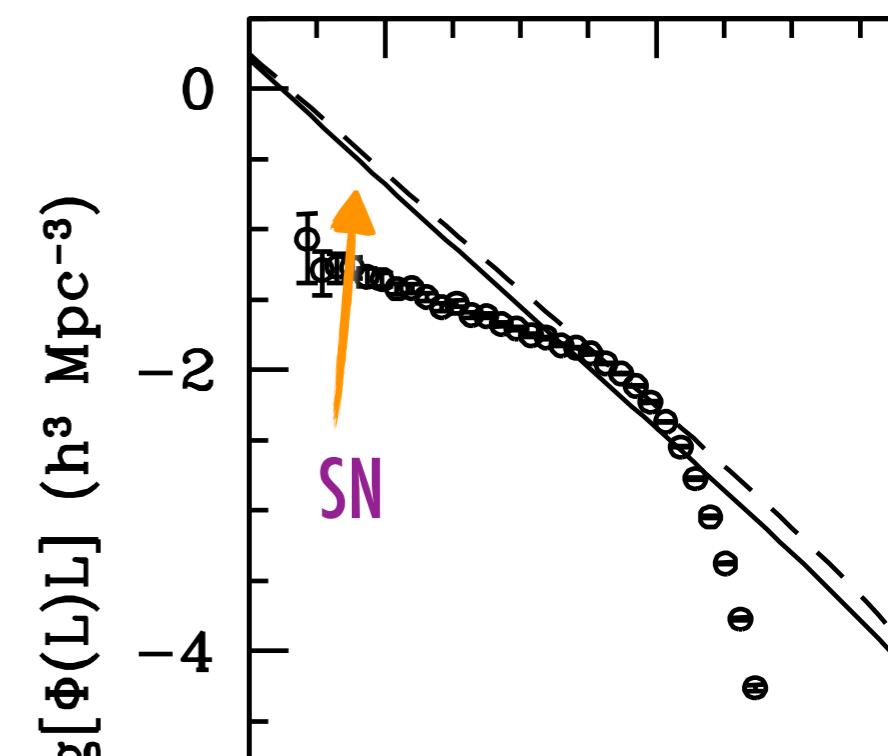


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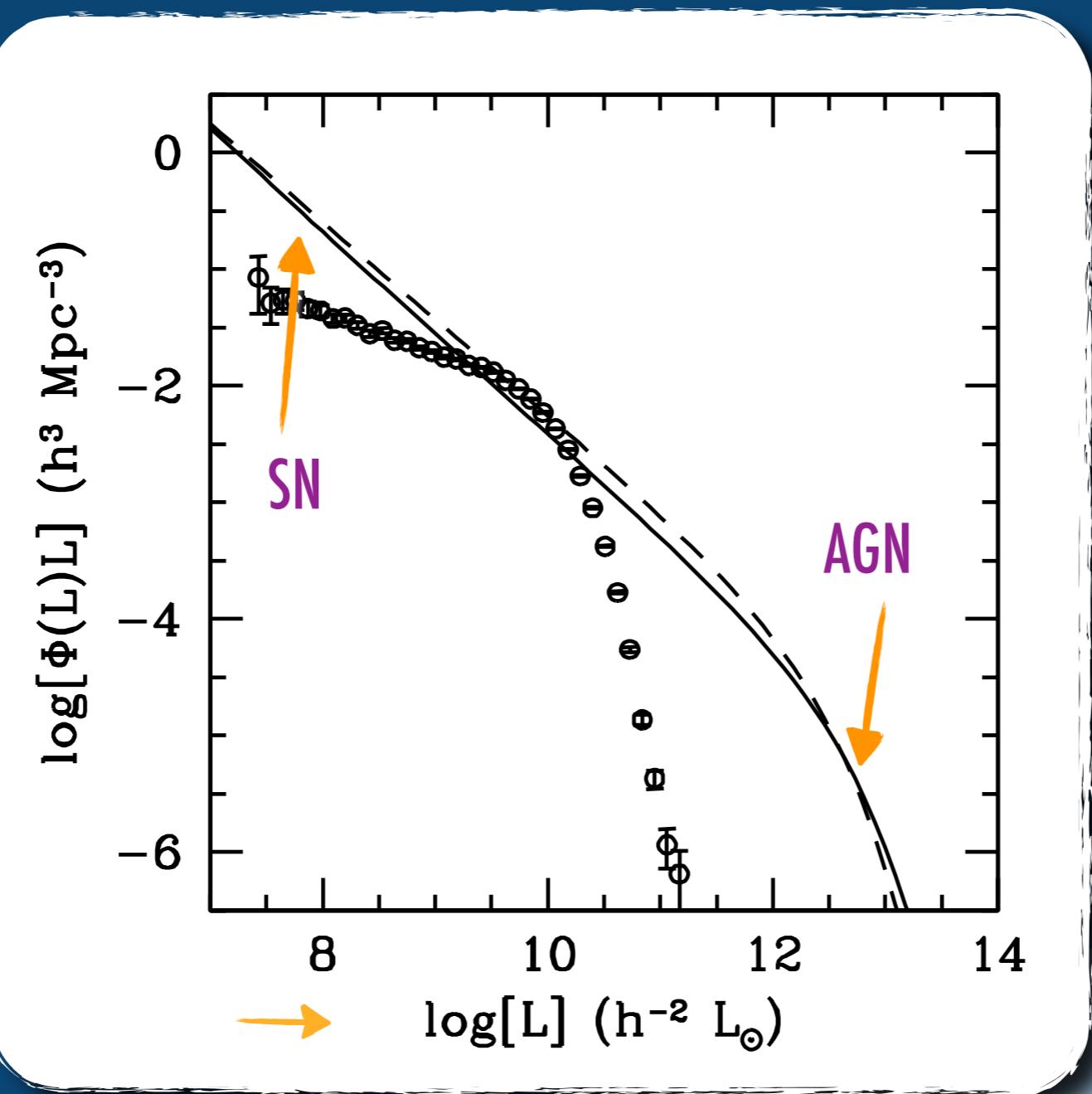
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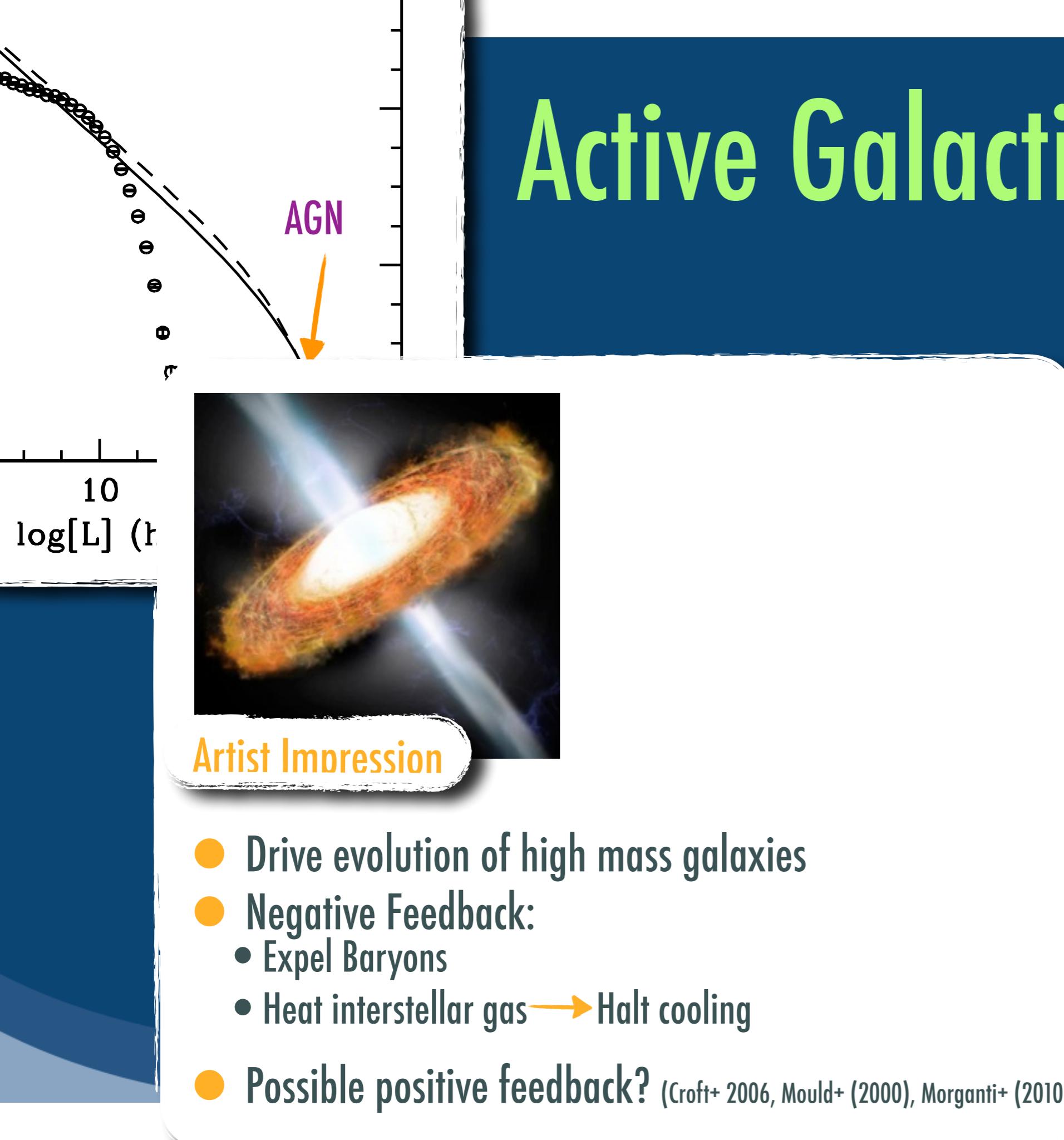


# Active Galactic Nuclei

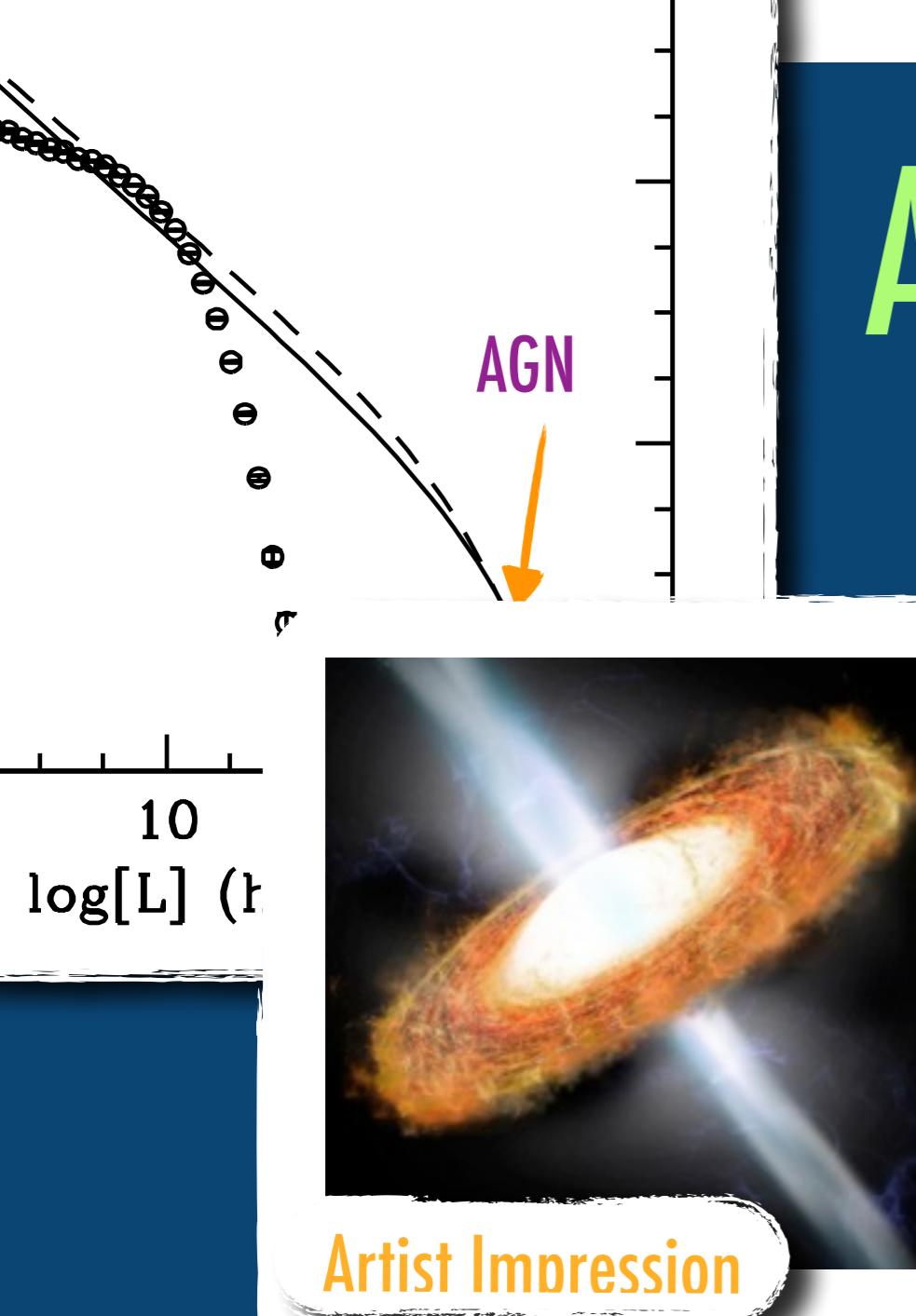


Yang et al. 2003

# Active Galactic Nuclei



# Active Galactic Nuclei



Artist Impression

- Drive evolution of high mass galaxies
- Negative Feedback:
  - Expel Baryons
  - Heat interstellar gas  $\rightarrow$  Halt cooling
- Possible positive feedback? (Croft+ 2006, Mould+ (2000), Morganti+ (2010))

## Simulations

- Able to quench cooling flows in clusters
- May also show positive feedback? (Gaibler+ 2012)

Dubois+ (2011+), Martizzi+ (2012+), Springel+ (2005), Di Matteo+ (2005+)

# Star Formation in Simulations

- Models impose 'local Schmidt-law':  $\dot{\rho}_* = \epsilon_* \frac{\rho_{\text{gas}}}{t_{ff}}$
- Some additional criteria or restrictions are included:
  - **Density threshold** ( $n > 0.1 \text{cm}^{-3}$ ) (most common, RAMSES)
  - Restricting star-formation to gas below some temp
  - Jeans unstable
  - Convergent flows
  - Short gas cooling time
  - Molecular criteria (restricting SF to the 'molecular gas')
  - Turbulence criteria
  - Other possibilities?

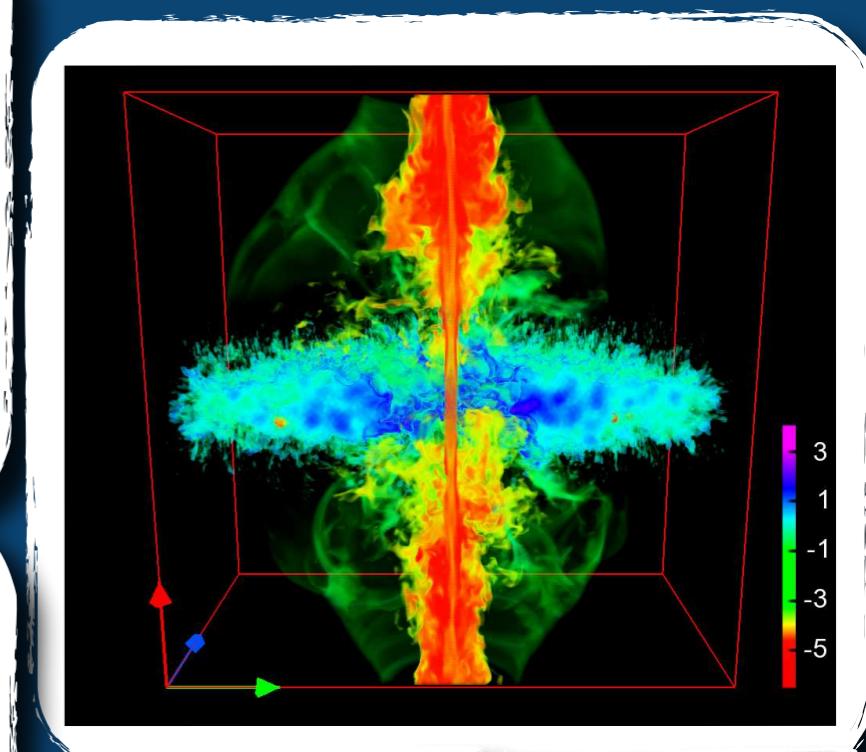
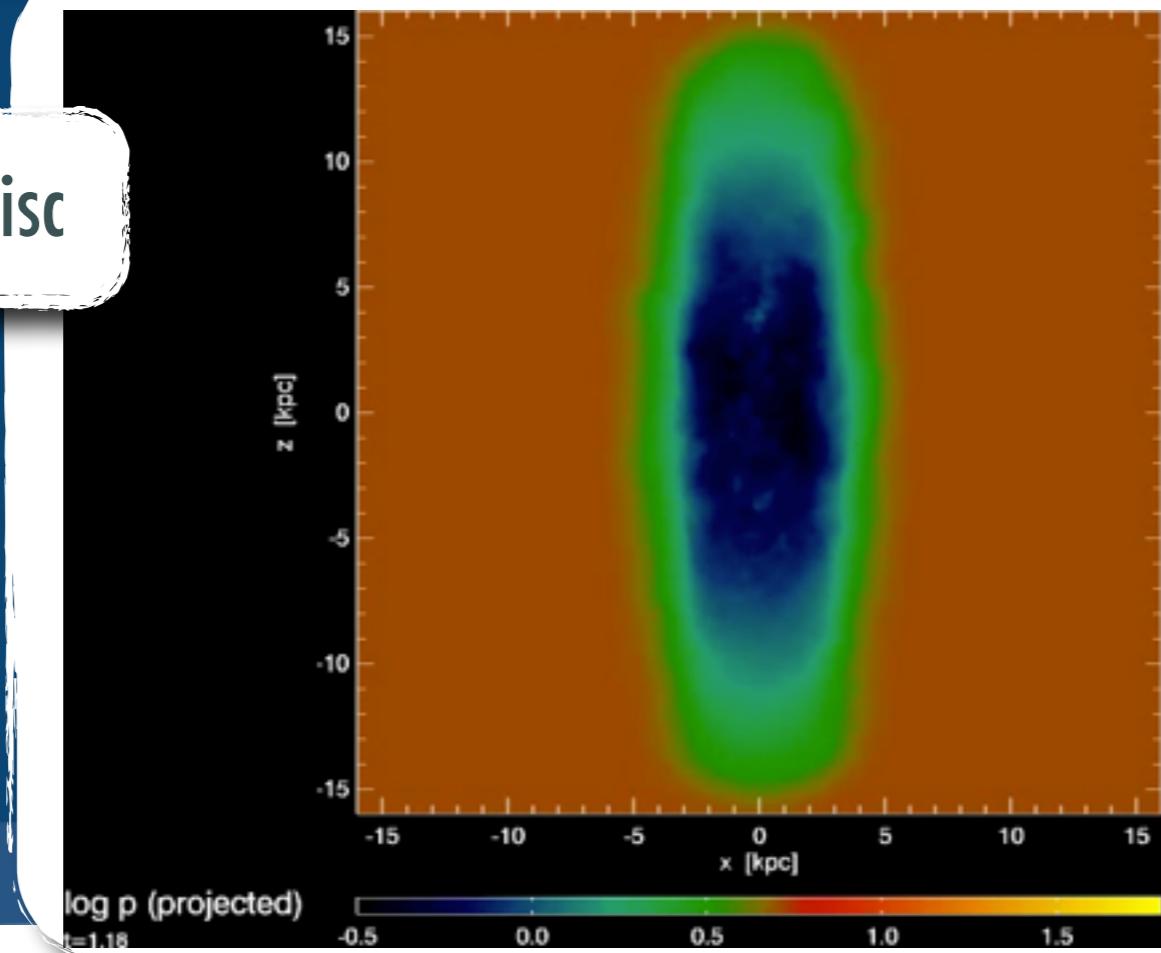
Physical interpretation depends on resolved dynamic range of simulation and the mean properties of the galaxy

# Positive Feedback?

## Feedback influences Star Formation

Supernovae (SNe bubbles)  $\leftrightarrow$  Star Formation  
AGN  $\rightarrow$  Star Formation (jet induced)?

- Jet pressurises disc



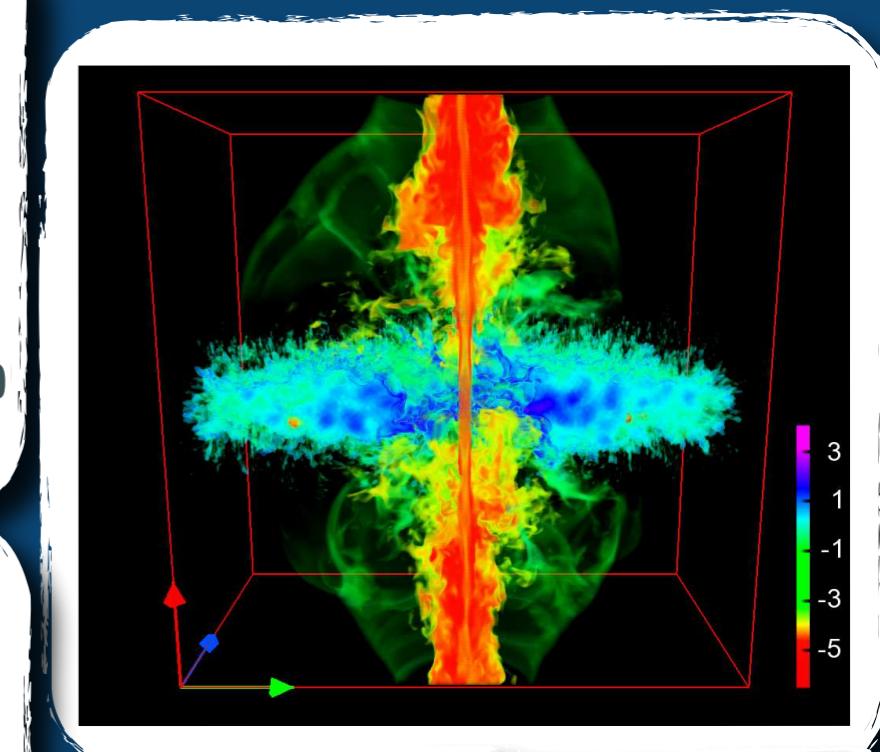
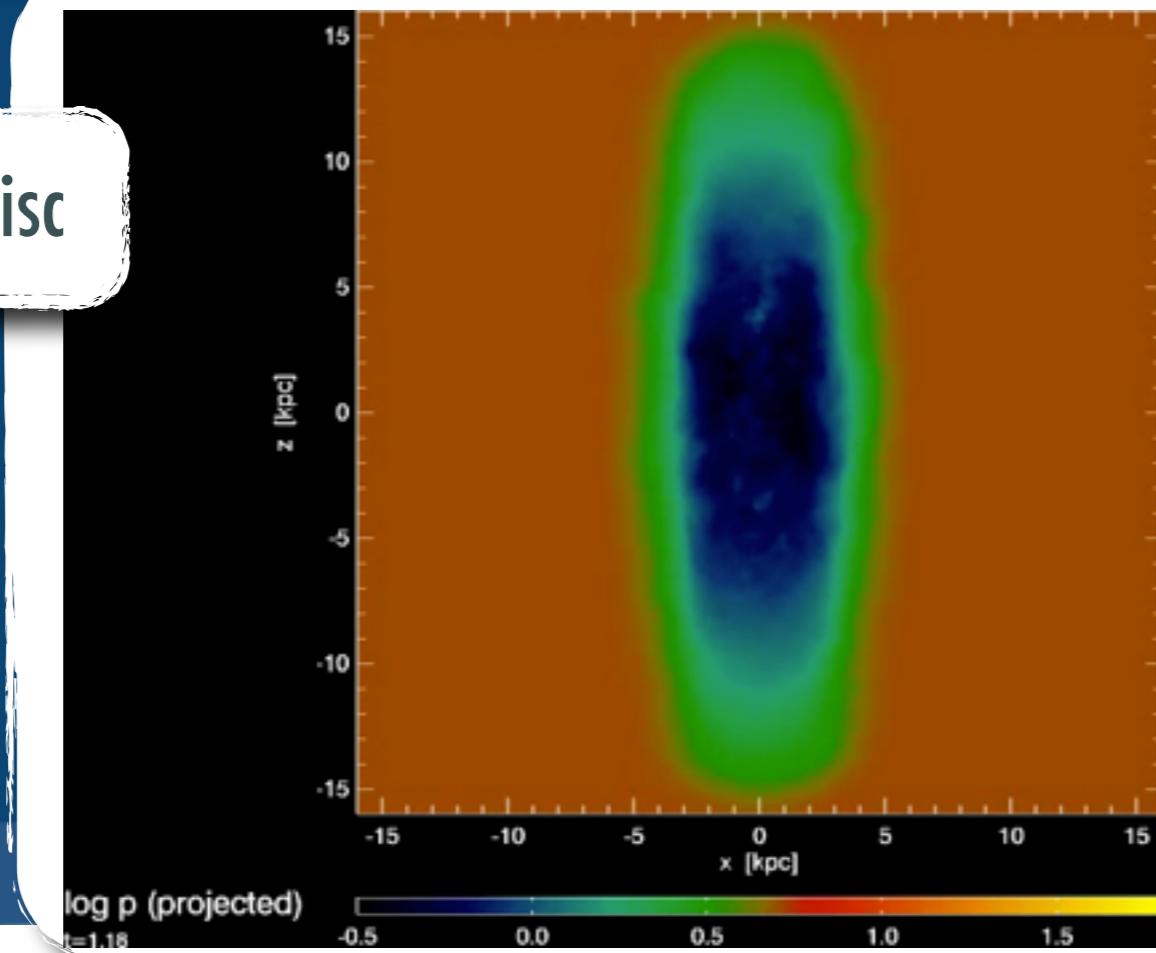
Gaibler+ (2012)

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Gaibler+ (2012)

# Pressurised Disk - Simulations

## Simulations:

- Runs with **RAMSES** code, 40/10 pc resolution:

- Pure adiabatic hydrostatic case (Teyssier 2002)
- Pure cooling and star formation
- Stellar feedback (Teyssier+ 2013)

Identifier	$M_{200}$	$v_{200}$ [km/s]	$r_s$ [kpc]	$f_g$ [%]
disc_ad	$1.1 \times 10^{11}$	70	3.43543	10
disc_ad2	$1.1 \times 10^{11}$	70	3.43543	50

# Pressurised Disk - Sim

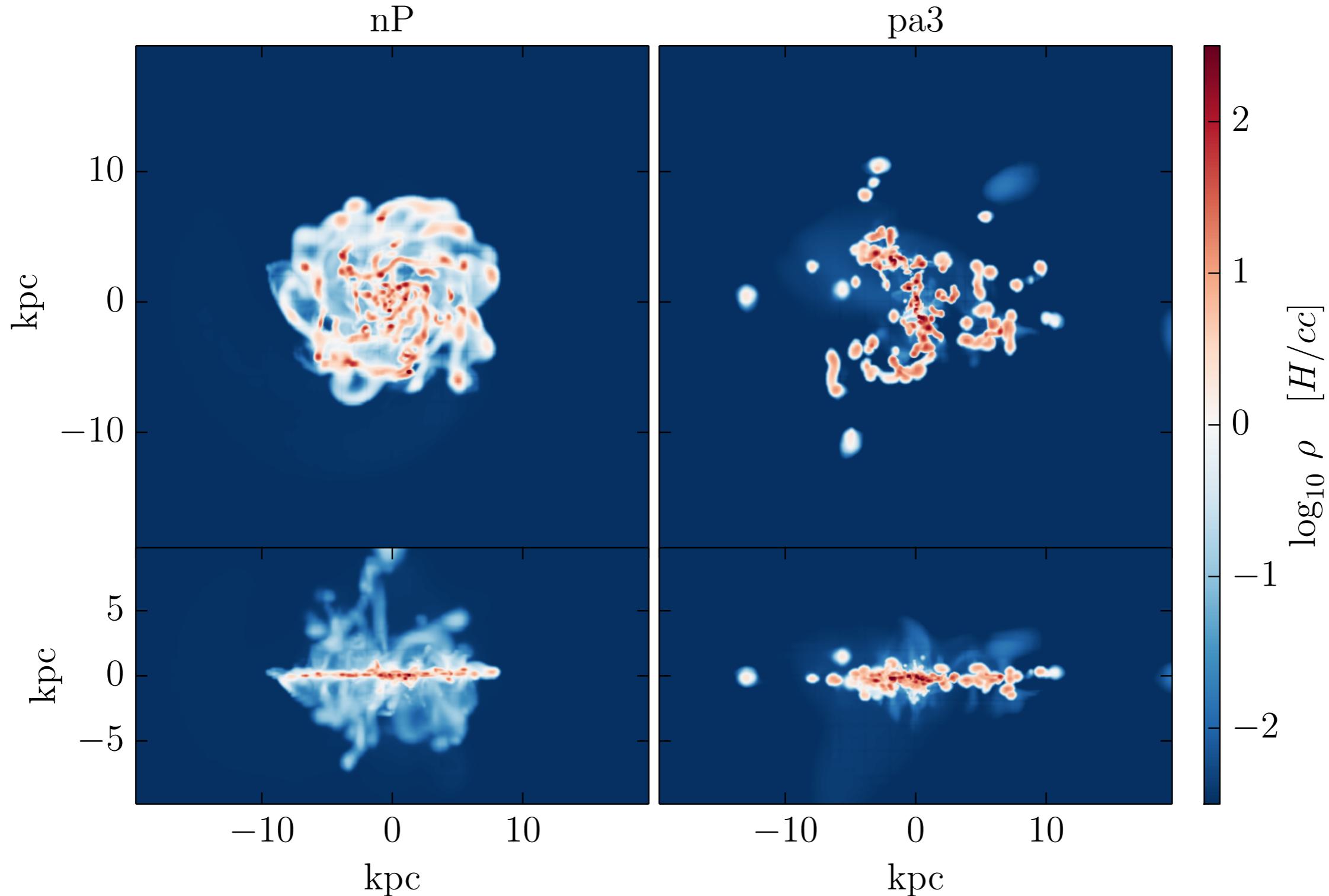
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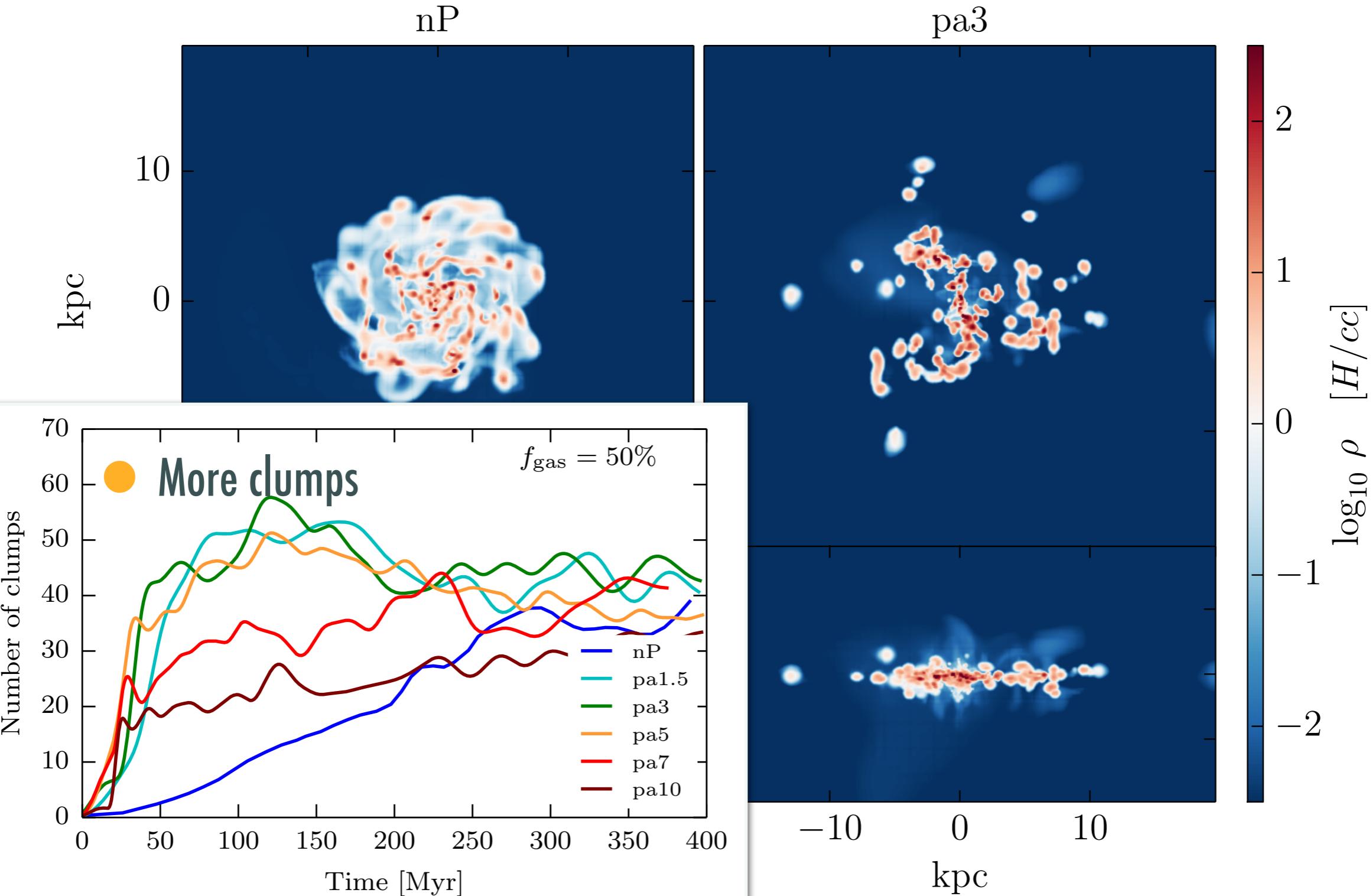
Identifier	base	amp
fb_nP	disc_ad	0
fb_pa1_2		1_2
fb_pa1_5		1_5
fb_pa3		3
fb_pa5		5
fb_pa7		7
fb_pa10		10
fb2_nP	disc_ad2	0
fb2_pa1_2		1.2
fb2_pa1_5		1.5
fb2_pa2		2
fb2_pa3		3
fb2_pa5		5
fb2_pa7		7
fb2_pa10		10

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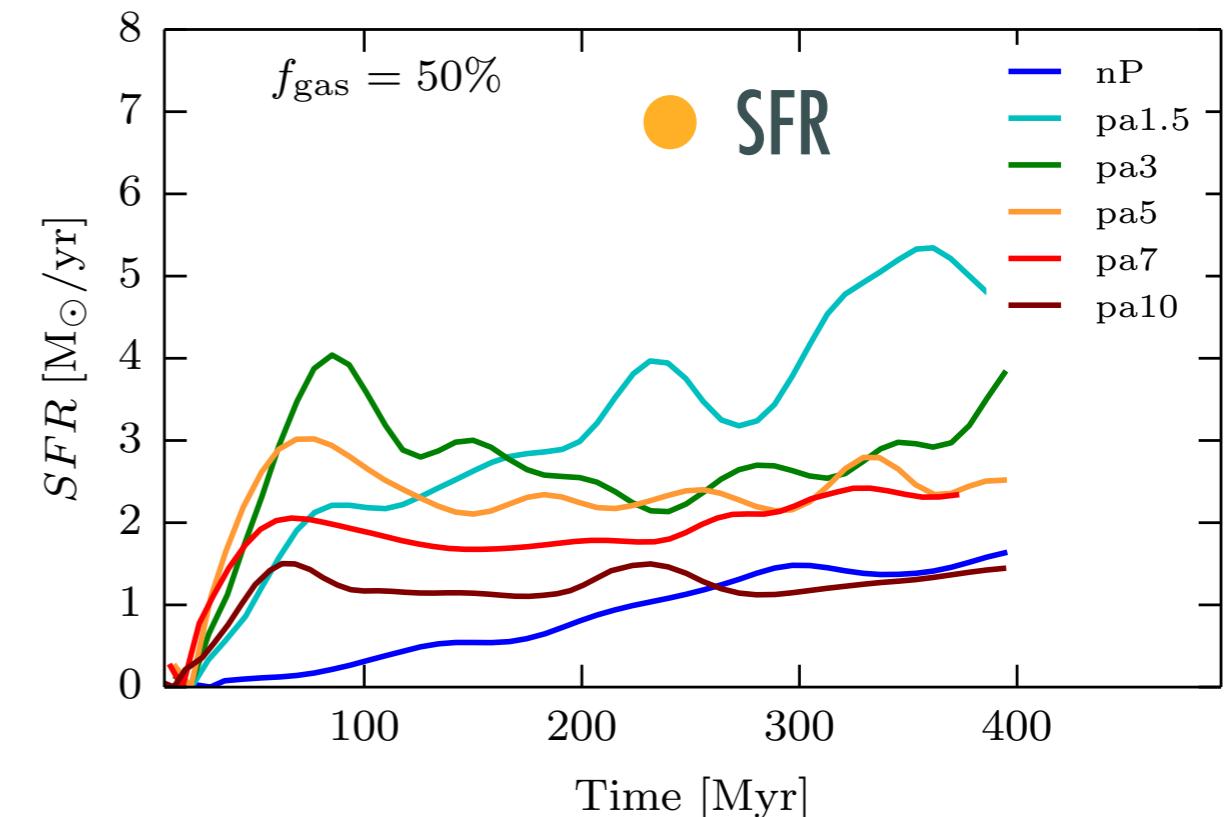
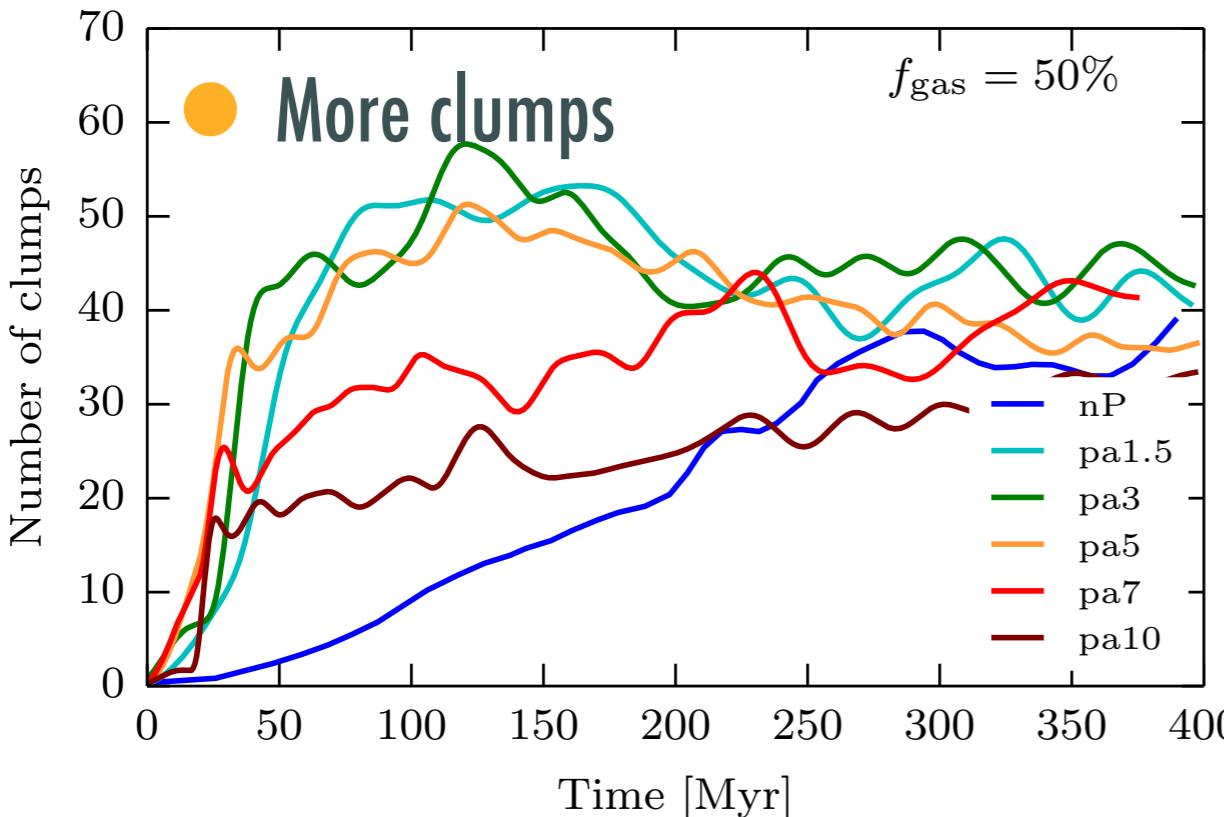
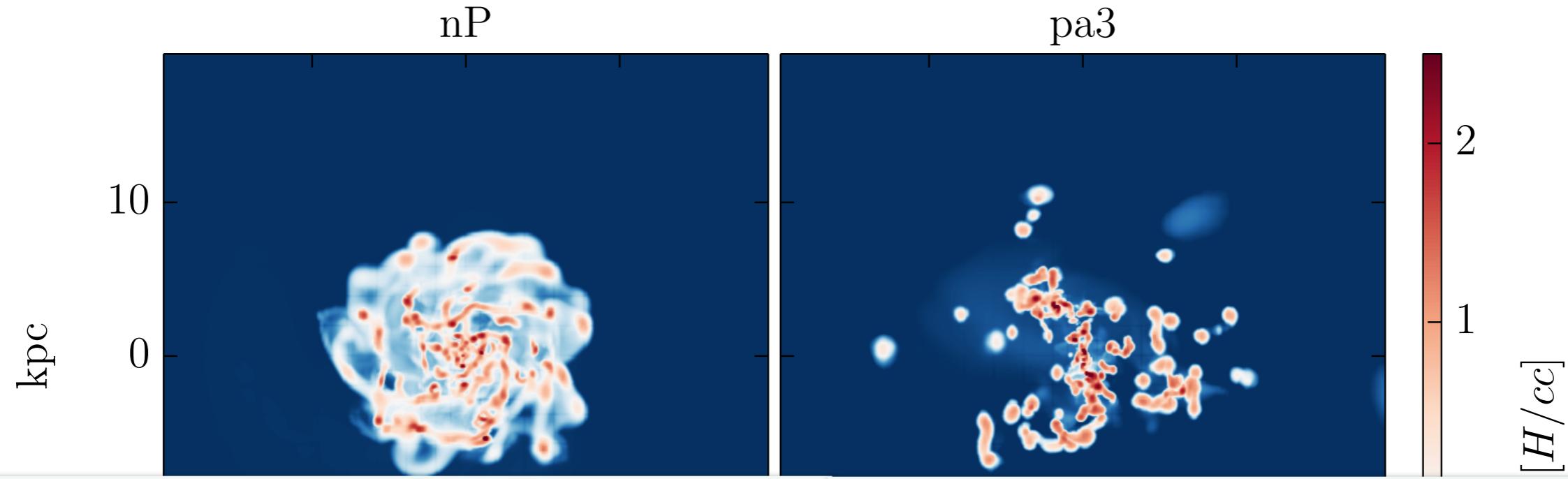
# Pressurised Disk - Movie



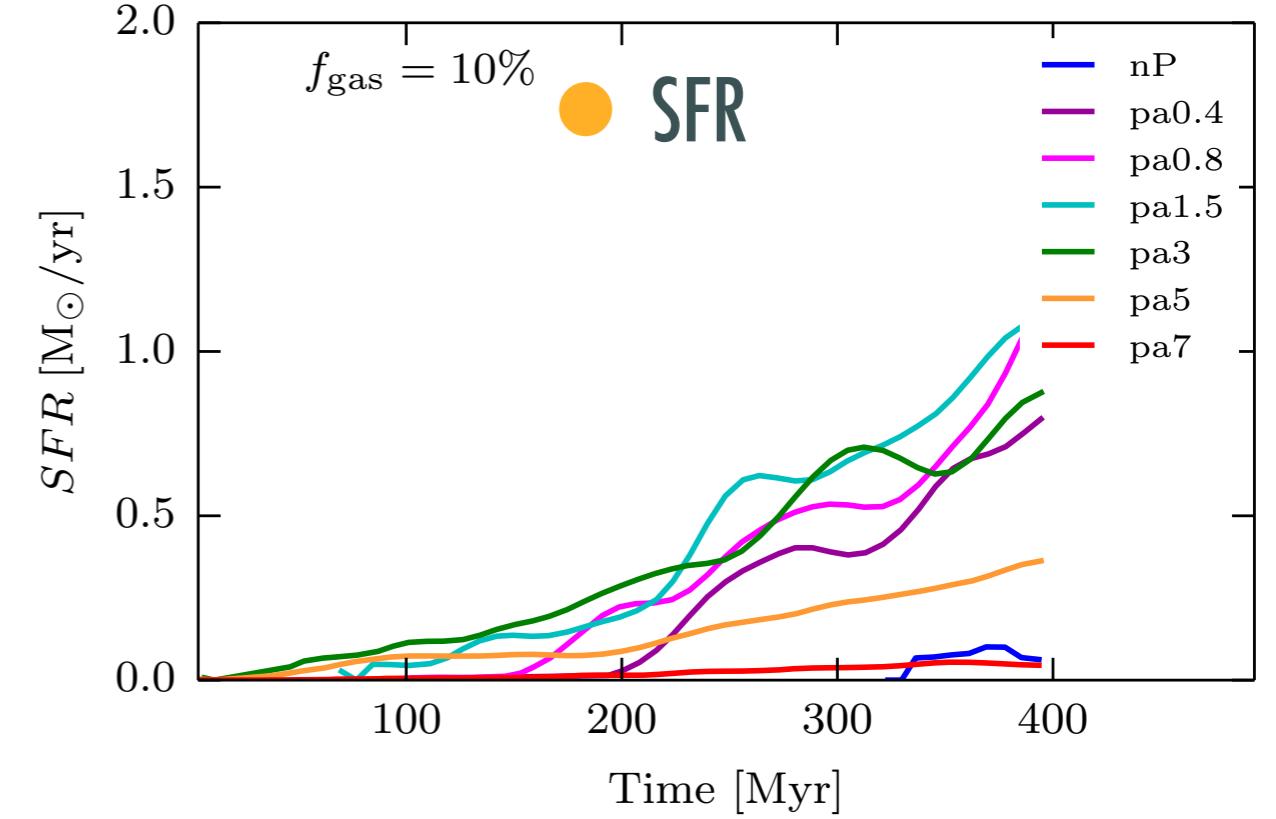
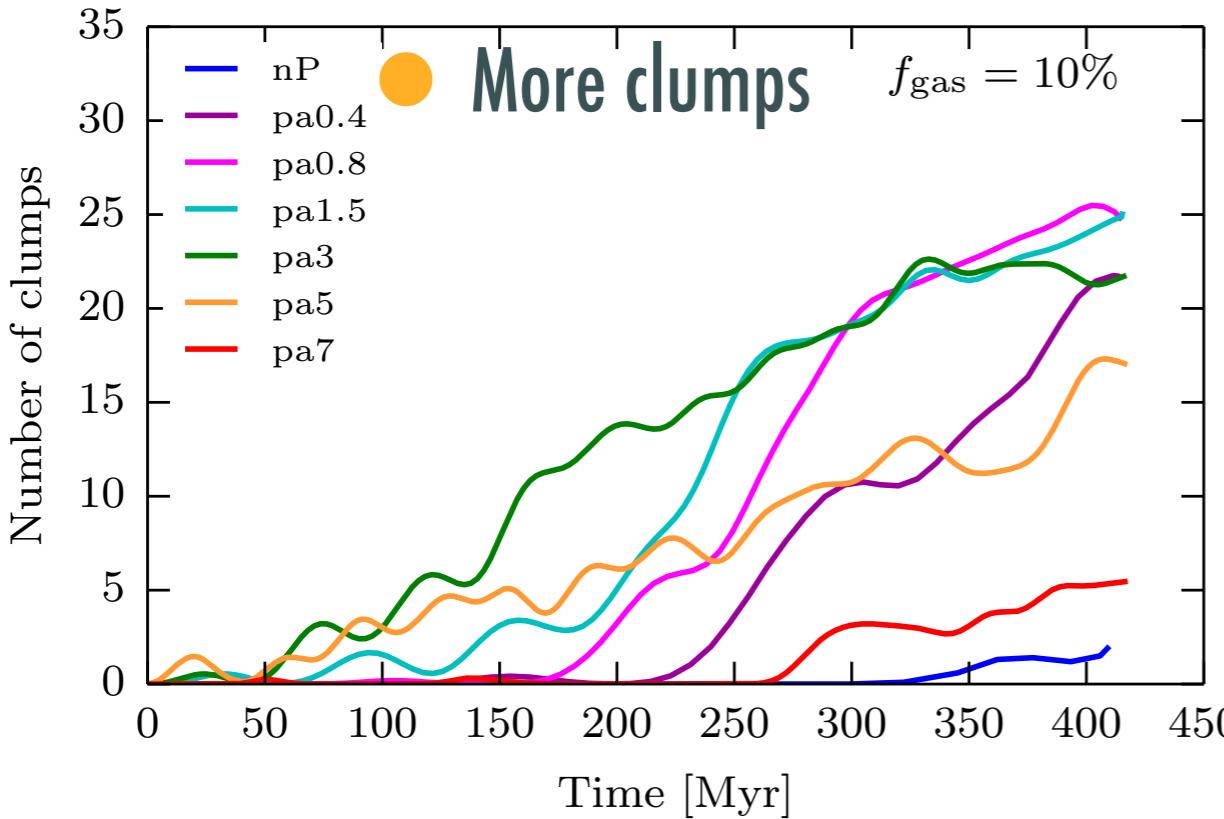
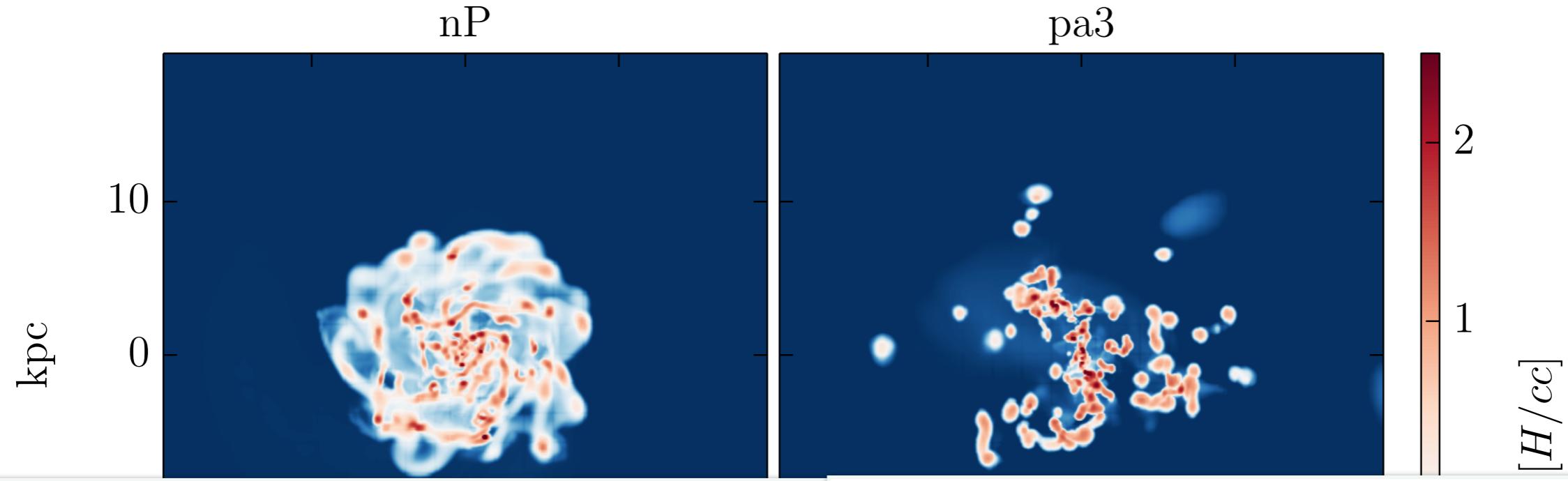
# Pressurised Disk - Clump Formation



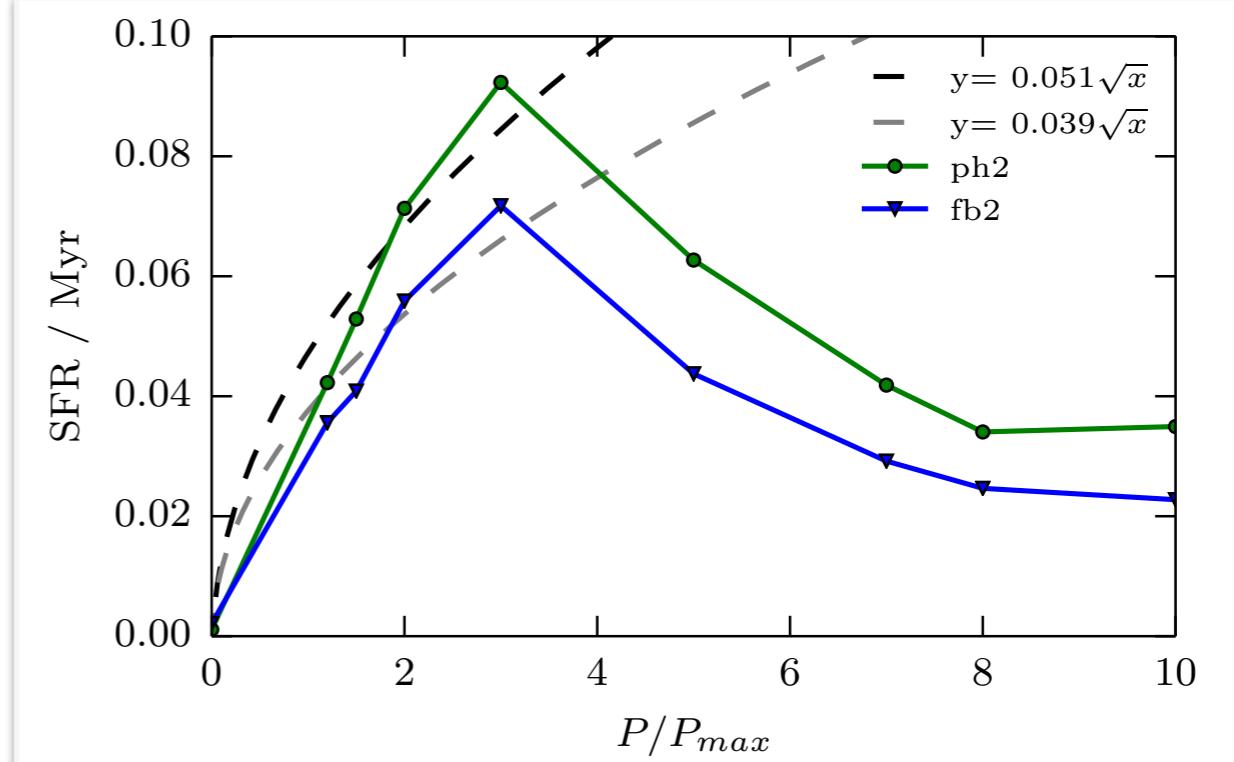
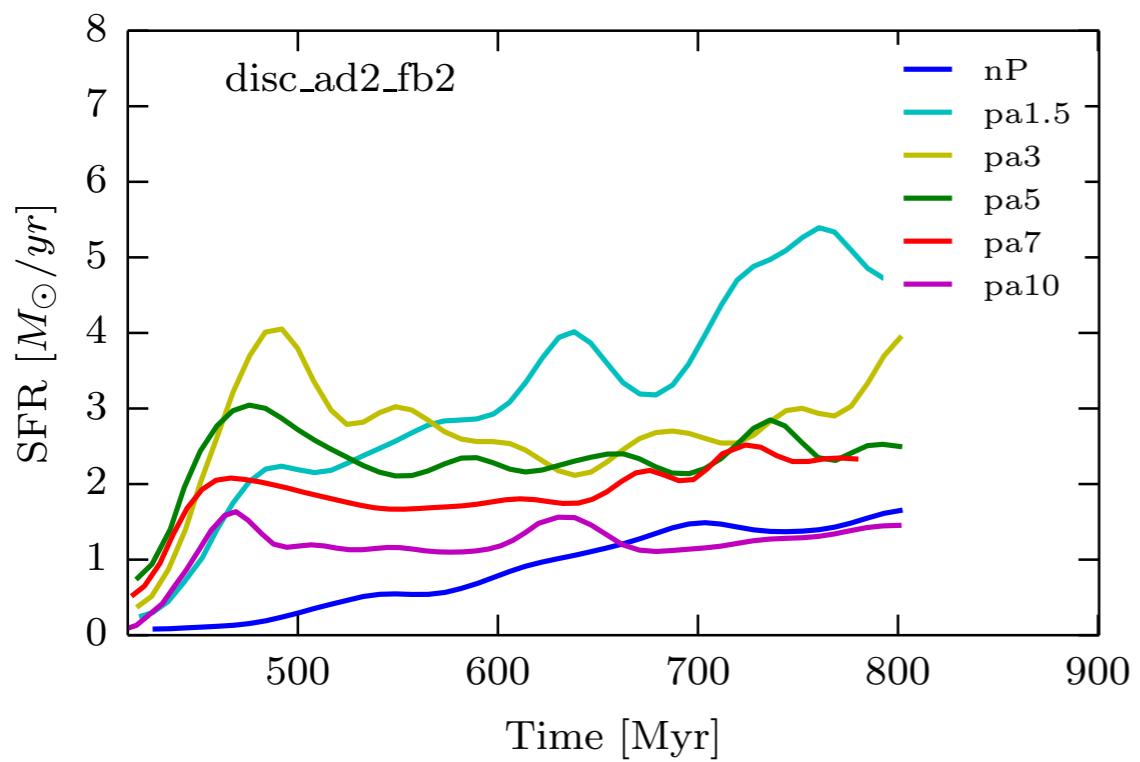
# Pressurised Disk - Star Formation



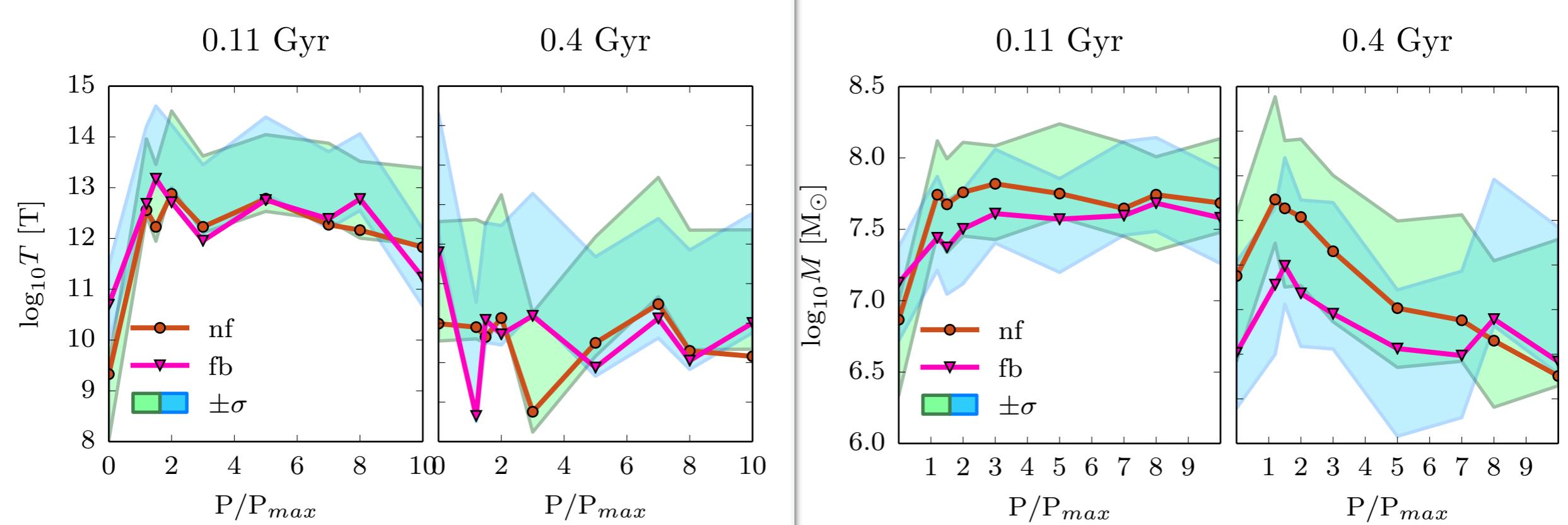
# Pressurised Disk - Low Gas Fraction



# Pressurised Disk - SFR



# Pressurised Disk - Clump Properties



# Merci pour votre attention

