

Supernova and AGN outflows in an isolated cooling halo: dynamics and feedback

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Outline

- Supermassive black holes in the nucleus?
- Hand-in-hand with supernovas
- Launching the outflows

New AGN in RAMSES

- seeding with a watershed clump finder (used first for star formation simulations, Bleuler+15)
- modified Bondi accretion - boosting accretion!

$$\dot{M}_{\text{BH}} = 4\pi\rho_{\infty}r_{\text{B}}^2v_{\text{B}} \quad r_{\text{B}} = \frac{G(M_{\text{sink}} + M_{\text{gas}})}{v_{\text{B}}} \quad v_{\text{B}} = \left[(c_{\text{s}}\alpha^{-1/3})^2 + v_{\text{rel}}^2 \right]^{1/2}$$

- under the hood improvements to accretion and feedback
- direct N-body solver and a new, fully momentum-conserving drag

Drag - full redesign

- Redesigned drag - fully momentum conserving from gas due to accretion
- Mass weighted **accretion** on the sink with (boosted) **Bondi rate** and volume weighted '**decretion**' from the sink of the difference of (**Bondi - Eddington**) rates



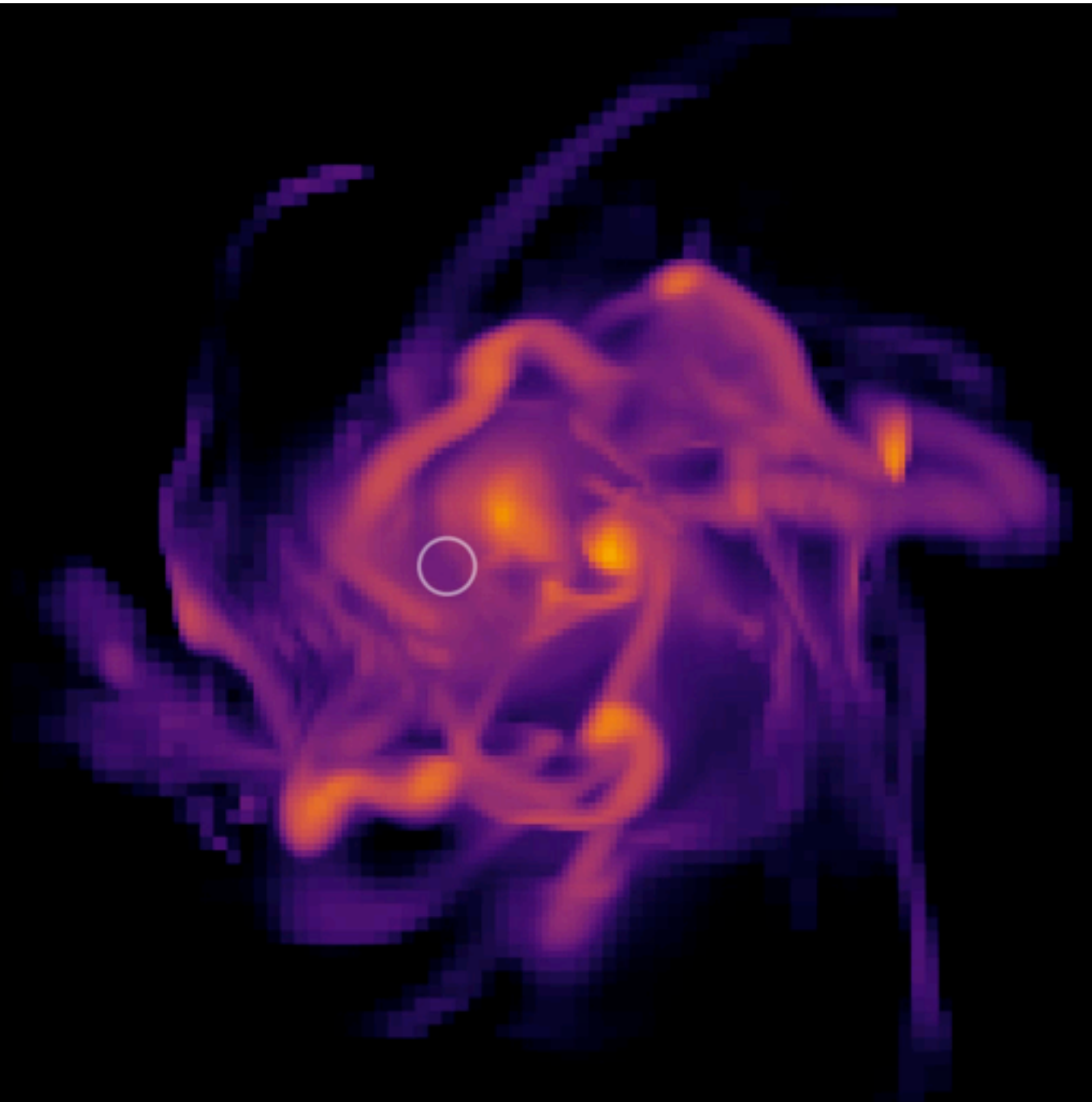
Isolated cooling halo

- RAMSES AMR
- **gas rich**, low metallicity, slowly rotating halo
- gas mass resolution of $10^4 M_{\text{sun}}$
- dark matter halo of $2 \times 10^{12} M_{\text{sun}}$ - probed with one million particles
- spatial resolution: **~80 pc**

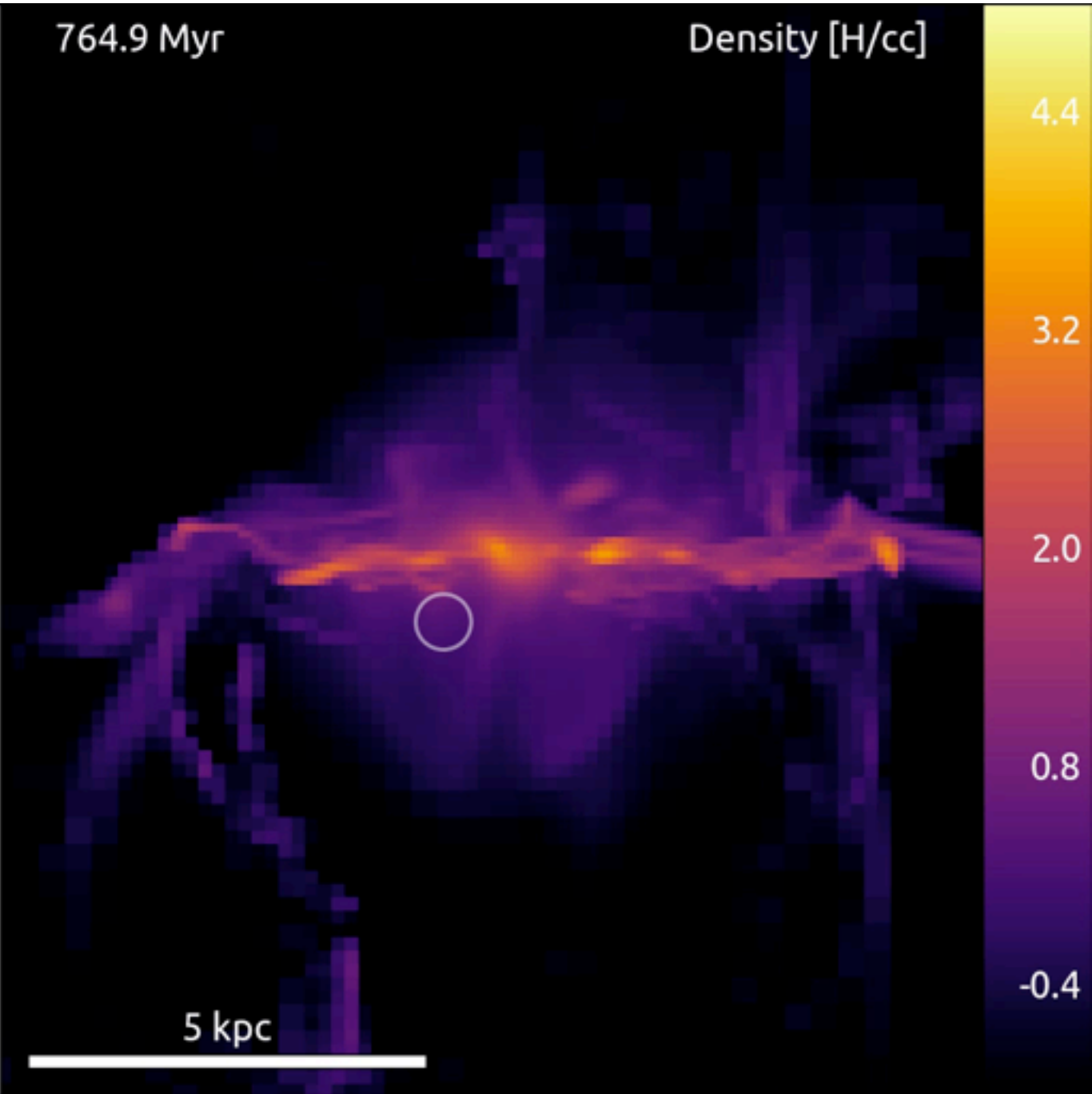
- supernova feedback
 - ▶ thermal blast, 10% efficiency, yield of 0.1
 - ▶ **delayed cooling** on the scale of 10 Myr
 - ▶ exploding in **GMCs of $5 \times 10^8 M_{\text{sun}}$** (Teyssier+13)

- AGN feedback (Teyssier+11, Dubois+12, Martizzi+14)
 - ▶ seeding on the fly with clump/halo finder
 - ▶ energy released every fine timestep
 - ▶ blast if gas temperature criterion met
 - ▶ feedback as a classical **thermal dump w/ $T_{\text{AGN}} = 0.15 \times 10^{12} \text{ K}$**

Face-on



Edge-on

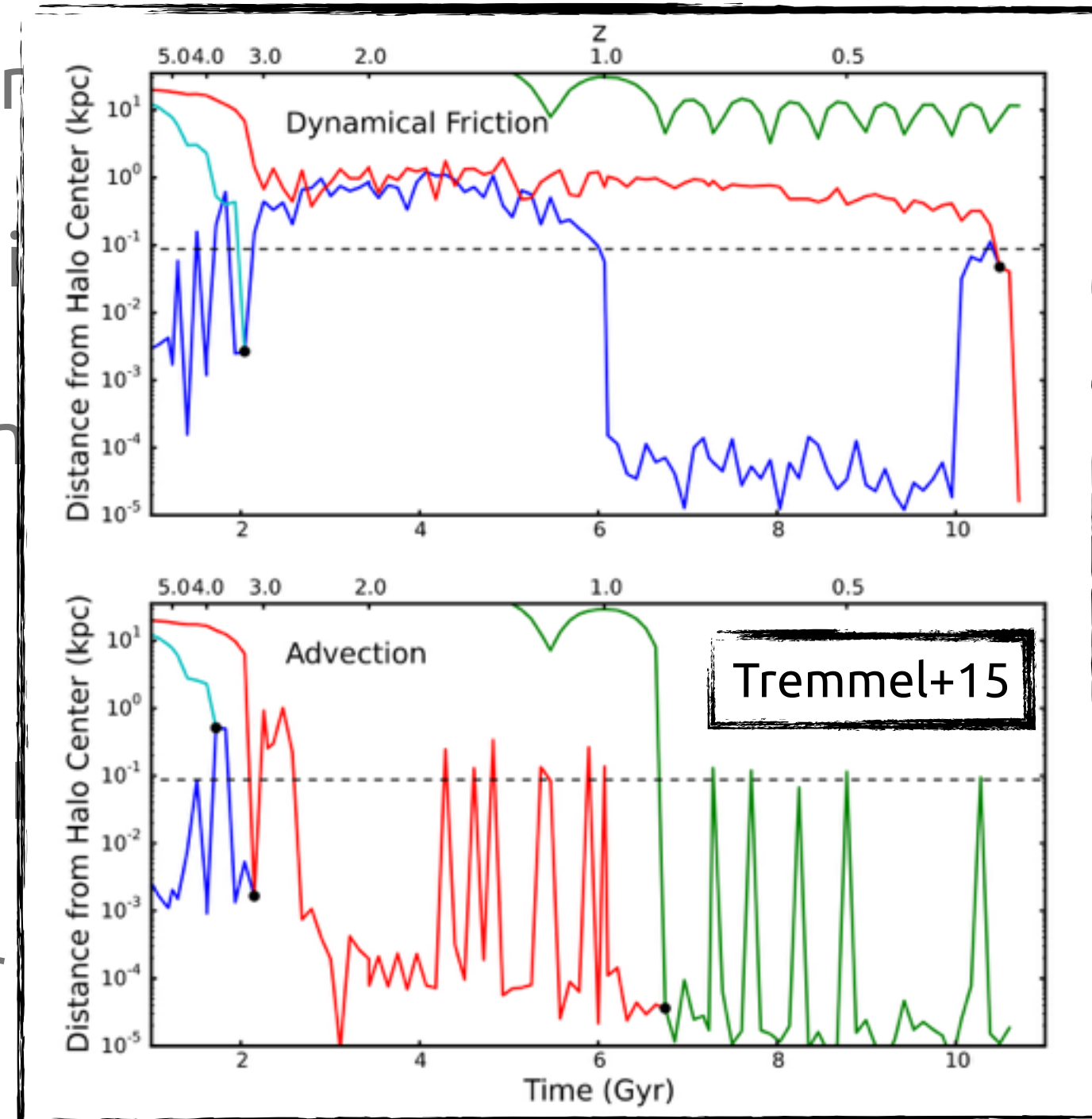


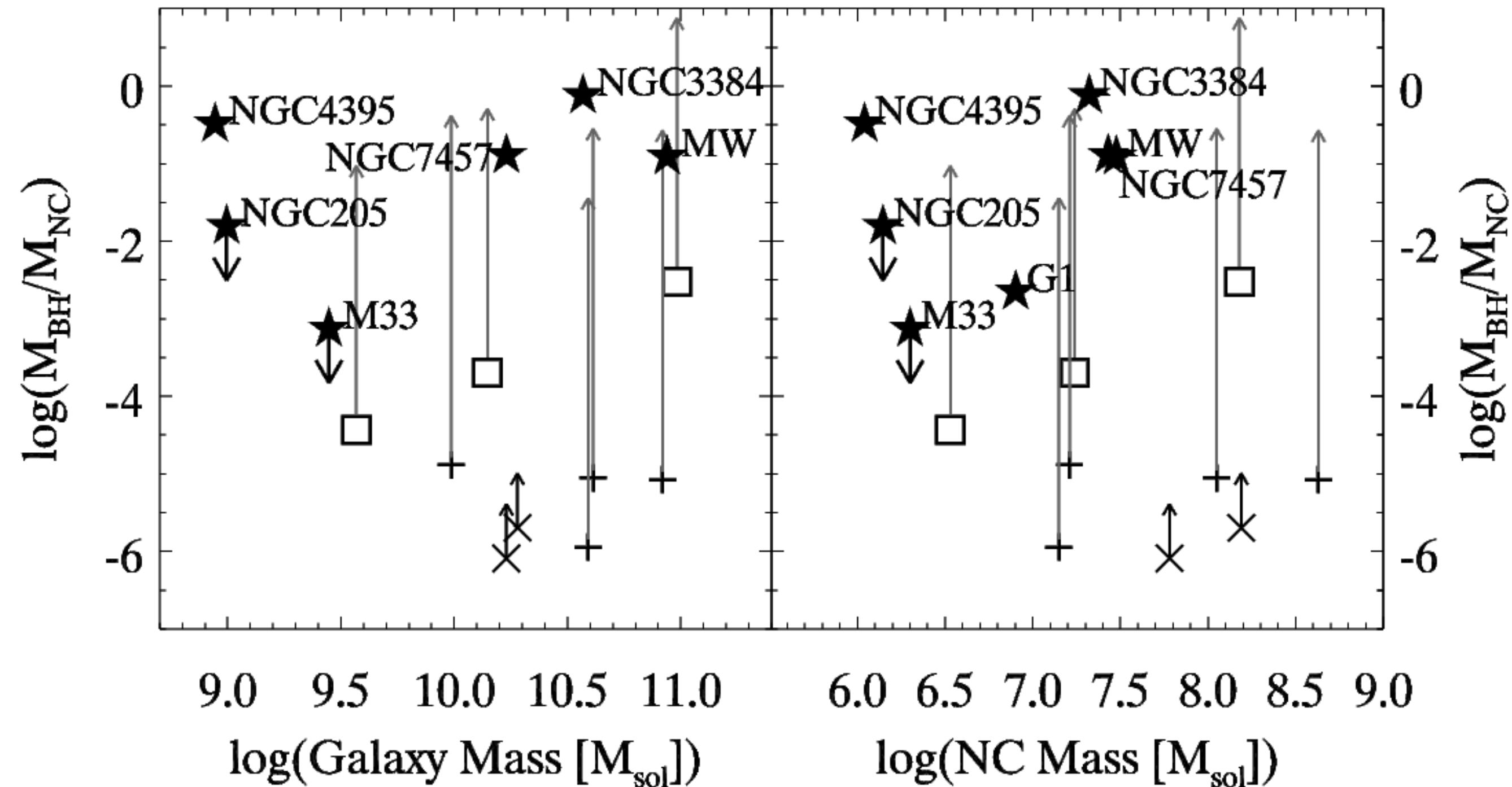
Here is where problems start

Circle - sink's probing/feedback zone

What can we do to keep the SMBH in the centre?

- do not evolve the position
- reposition the sink when it
- push the sink to the minimum
- but how strongly?
- fudge the dynamic mass,
- swipe the problem under



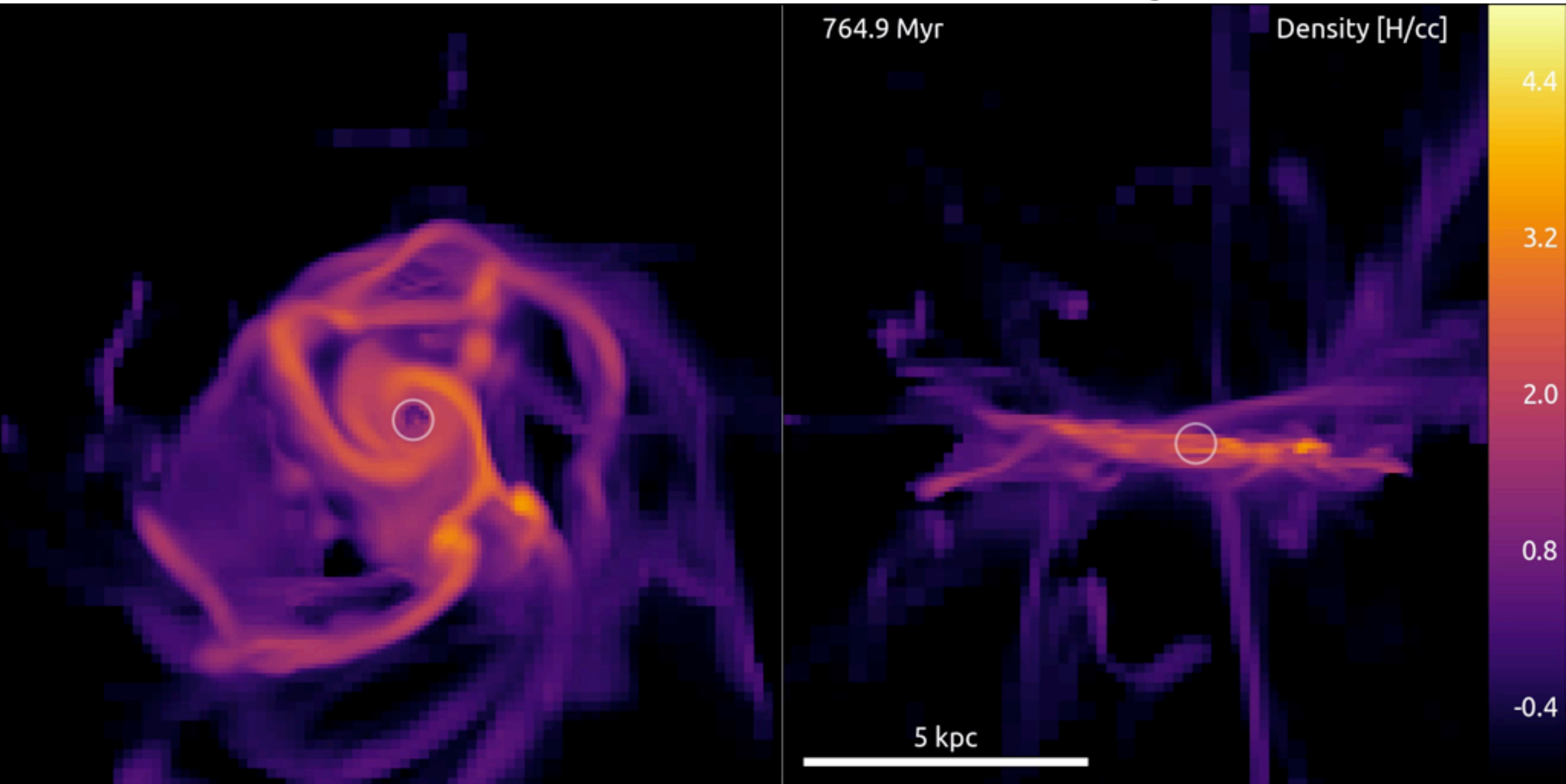


SMBH is not alone

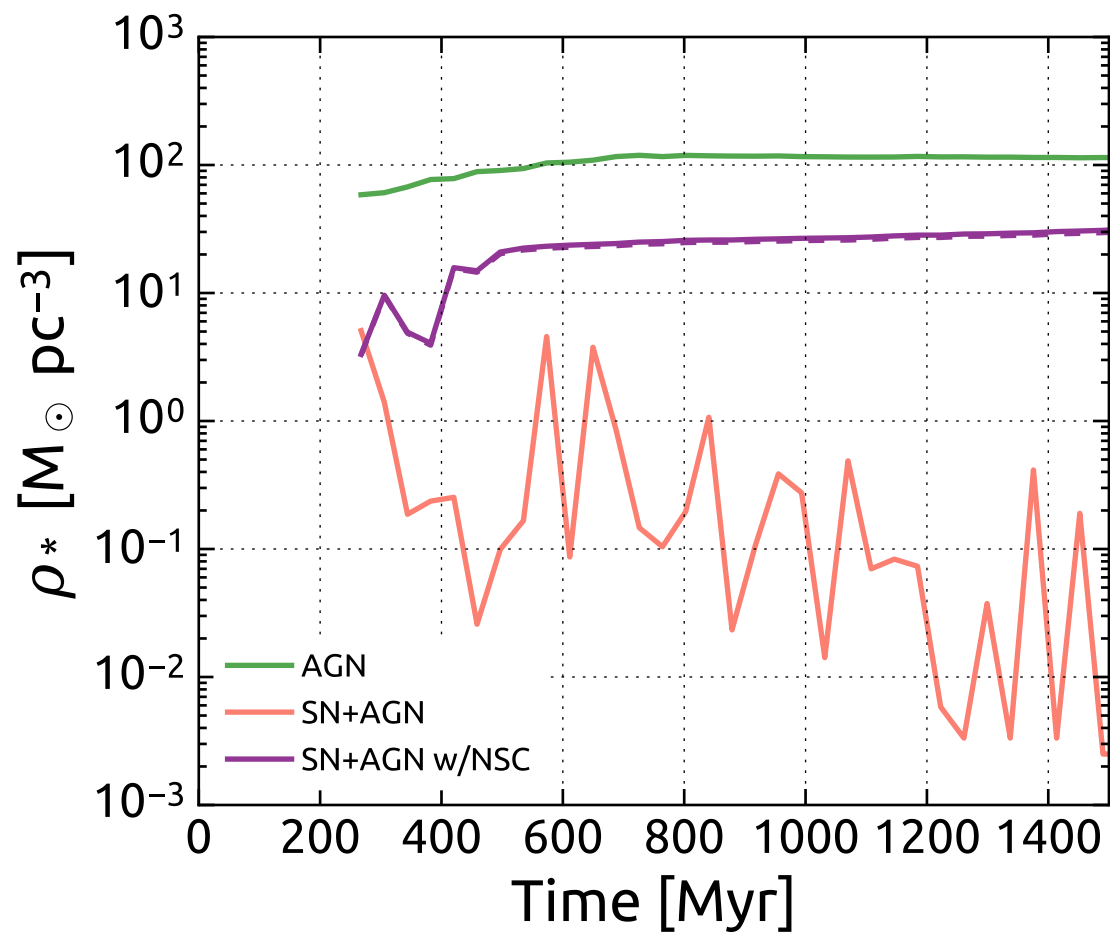
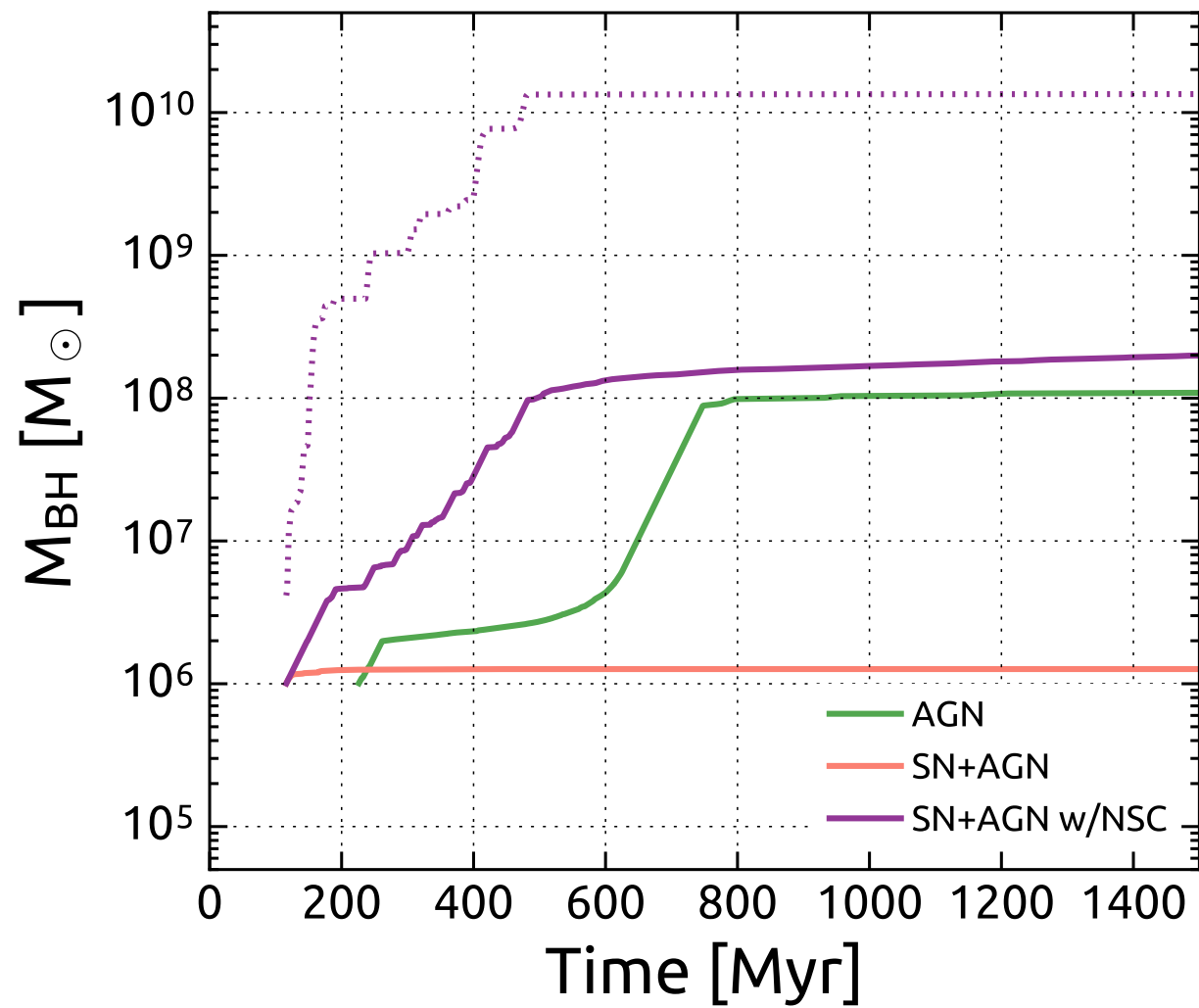
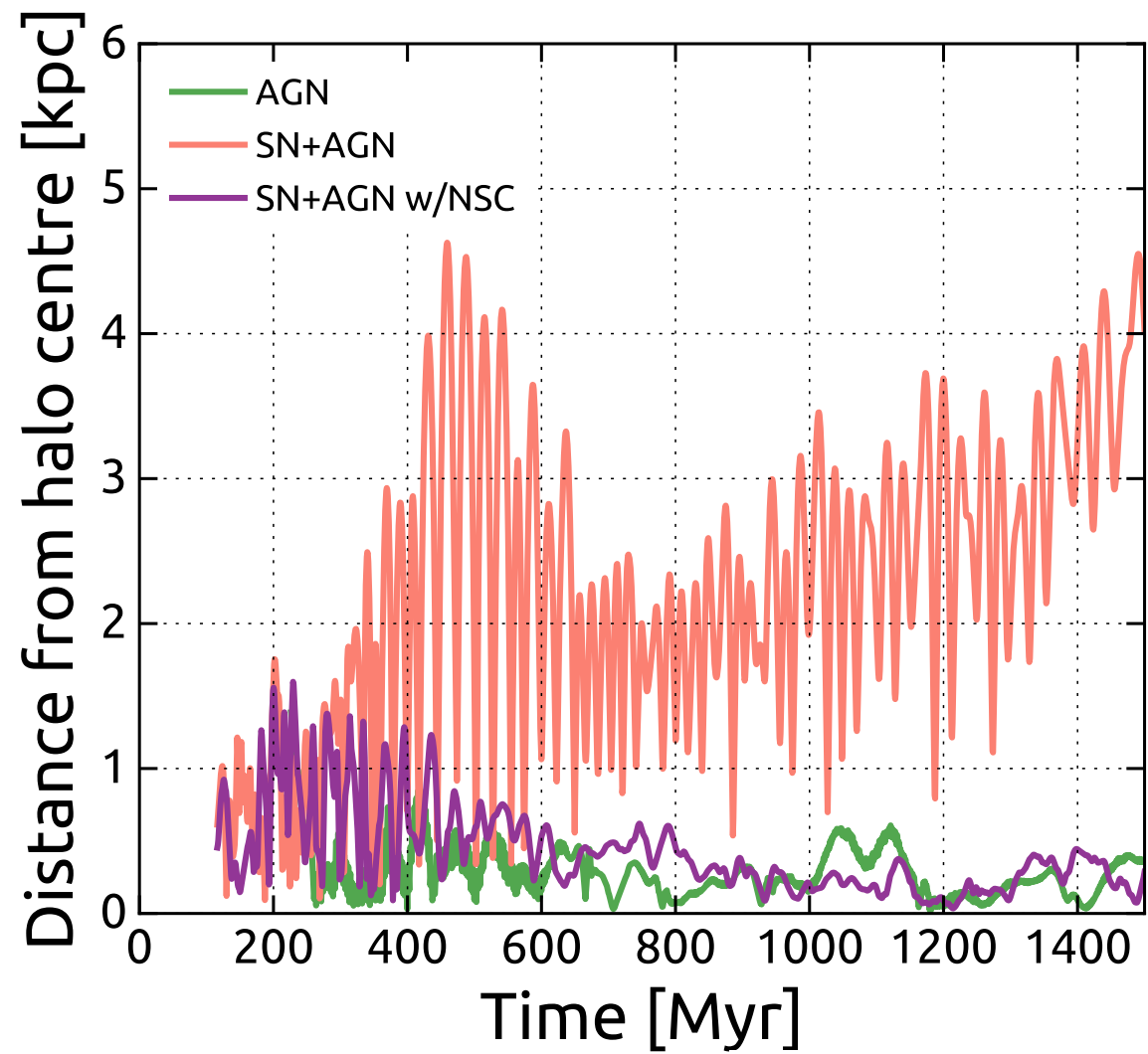
Seth et al. 2008

Face-on

Edge-on

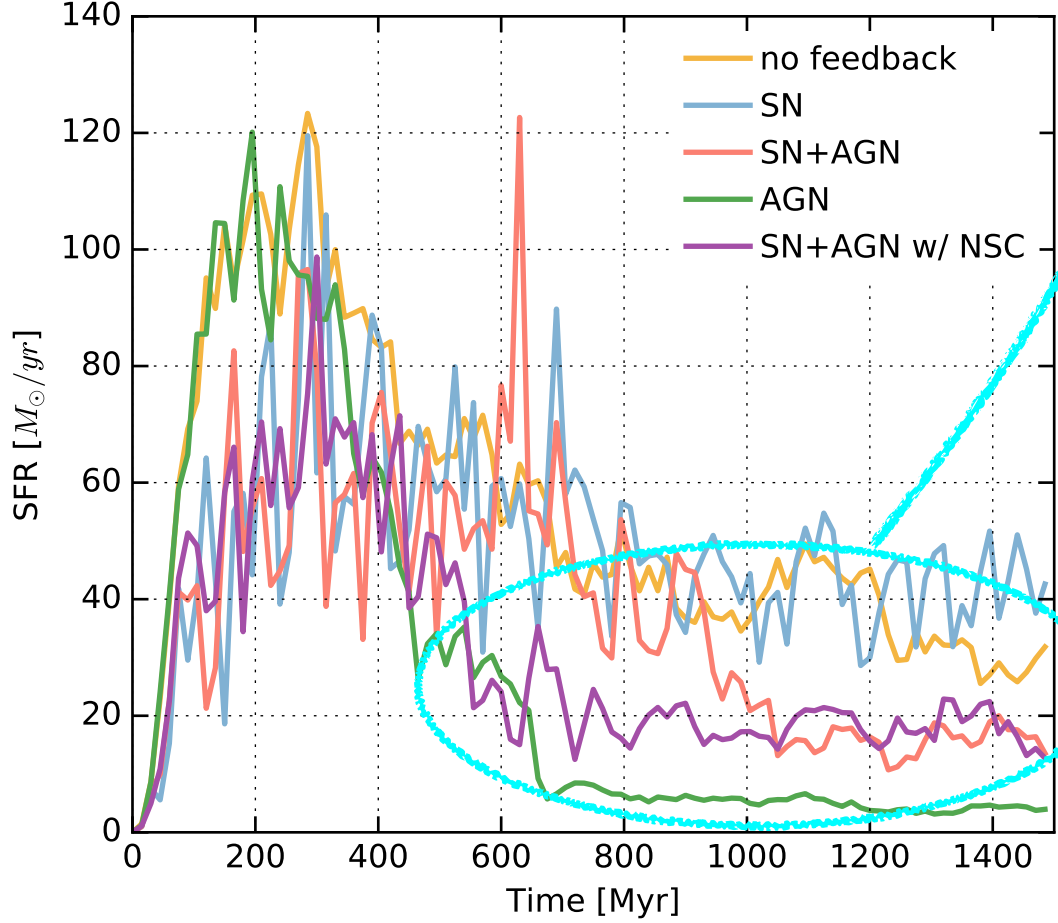


Nuclear Star Cluster
comes to rescue!

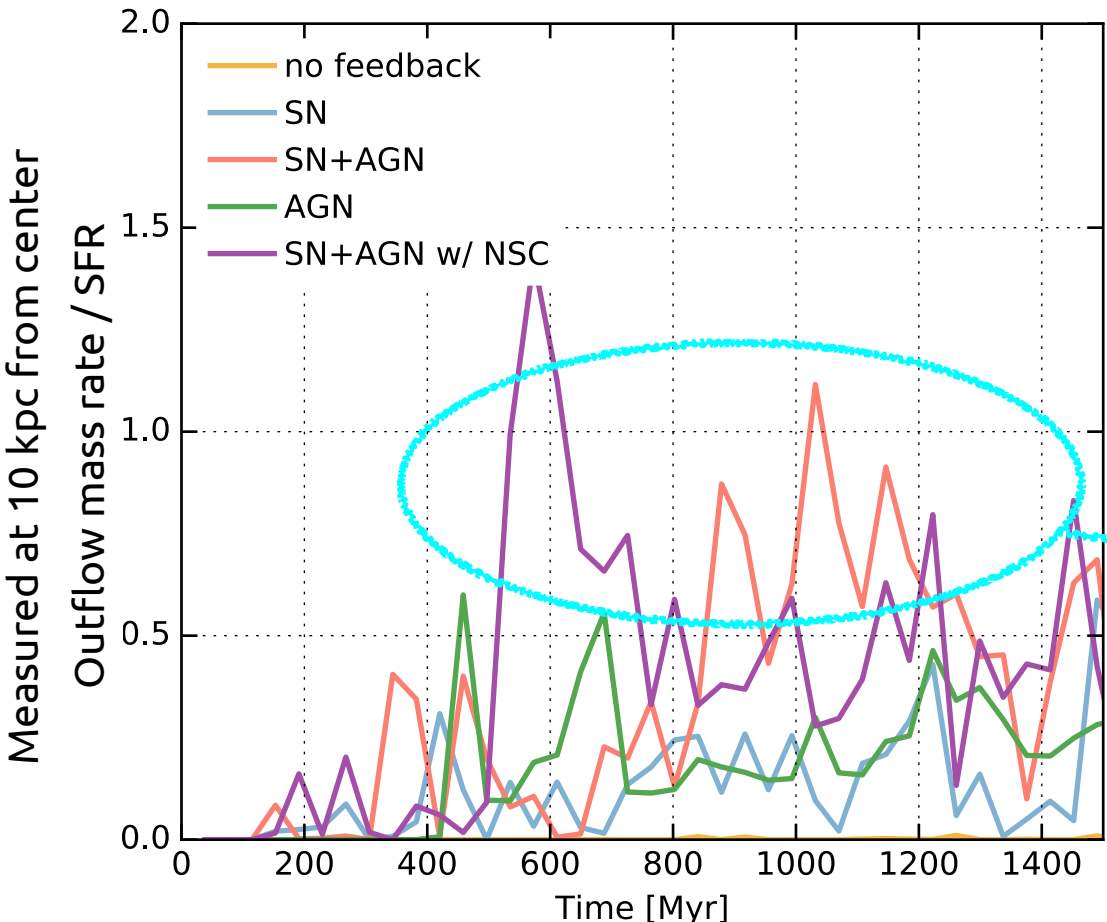
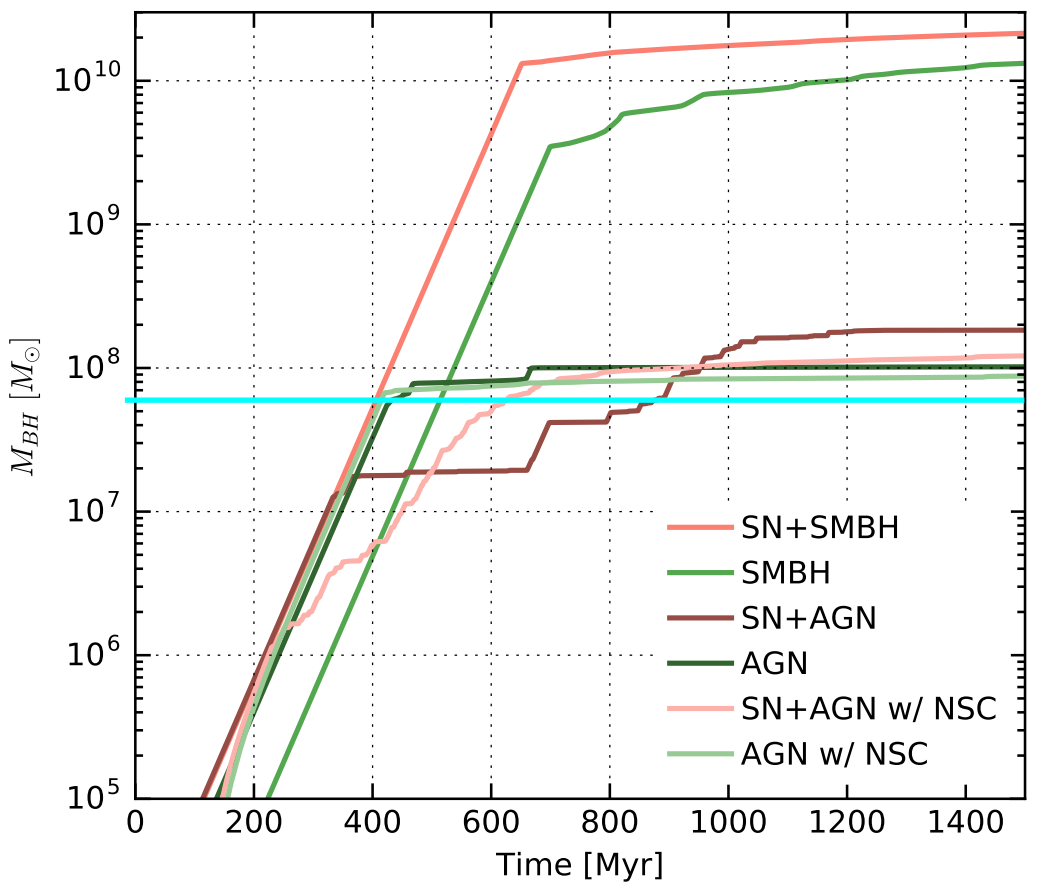


What about the feedback?

AGN quenches the SFR...

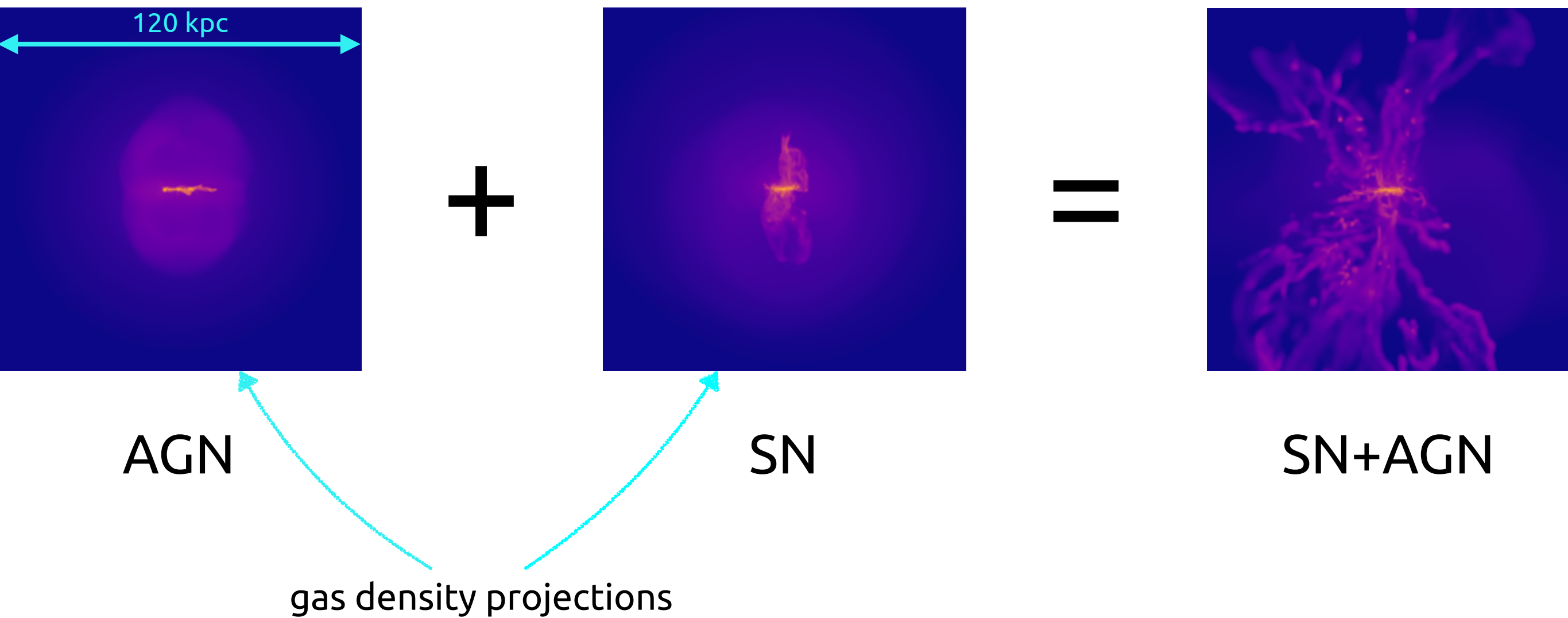


... when it self-regulates

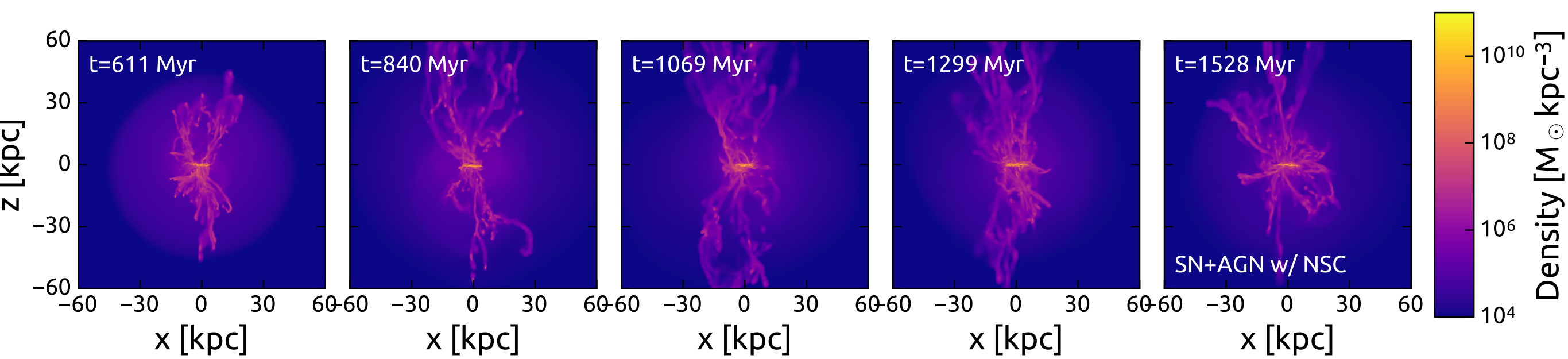
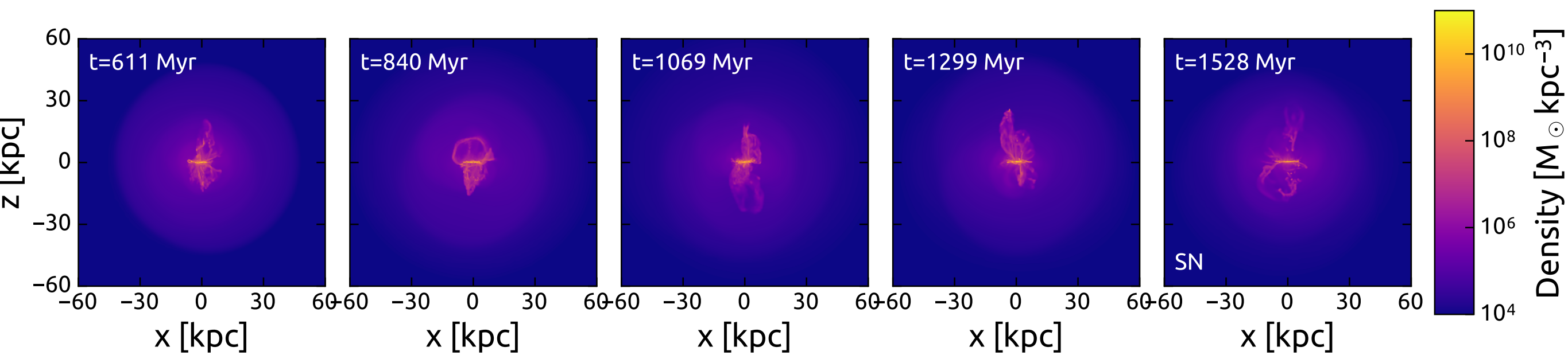
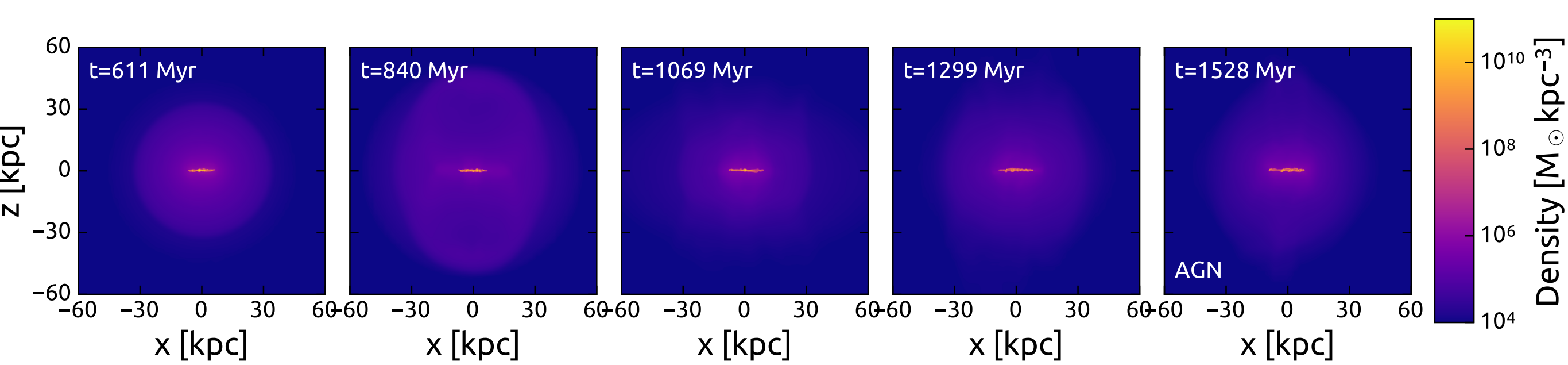


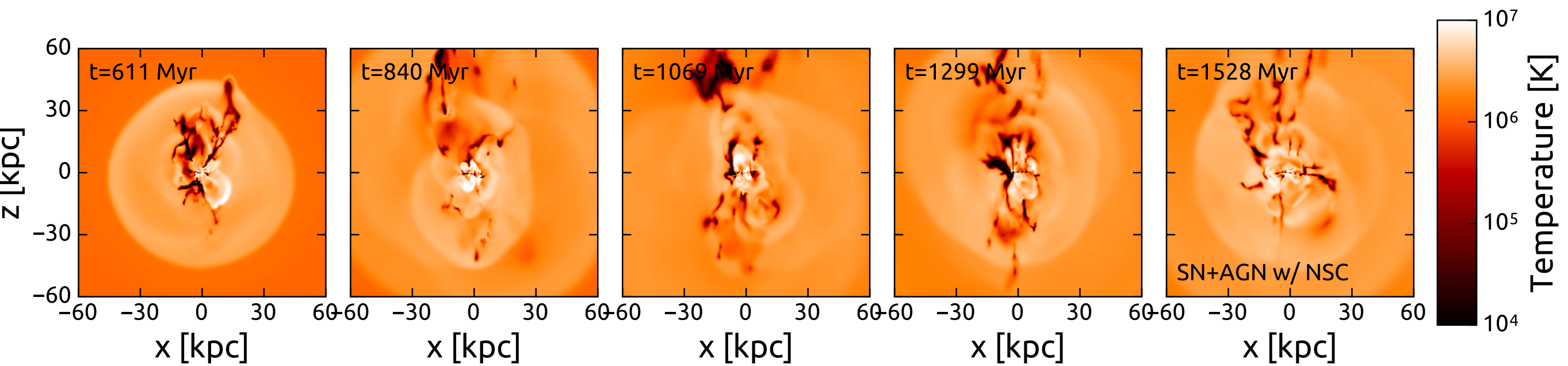
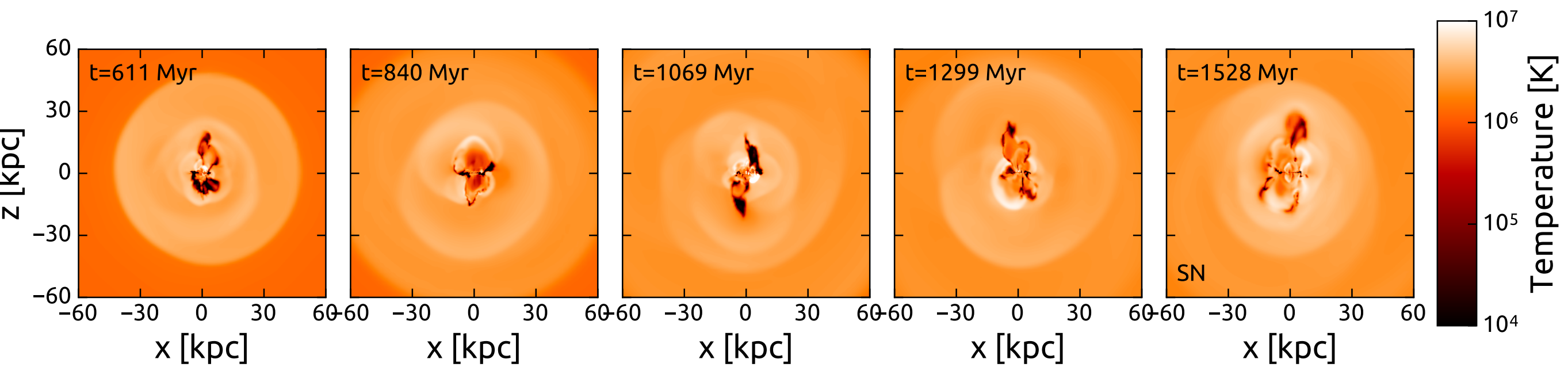
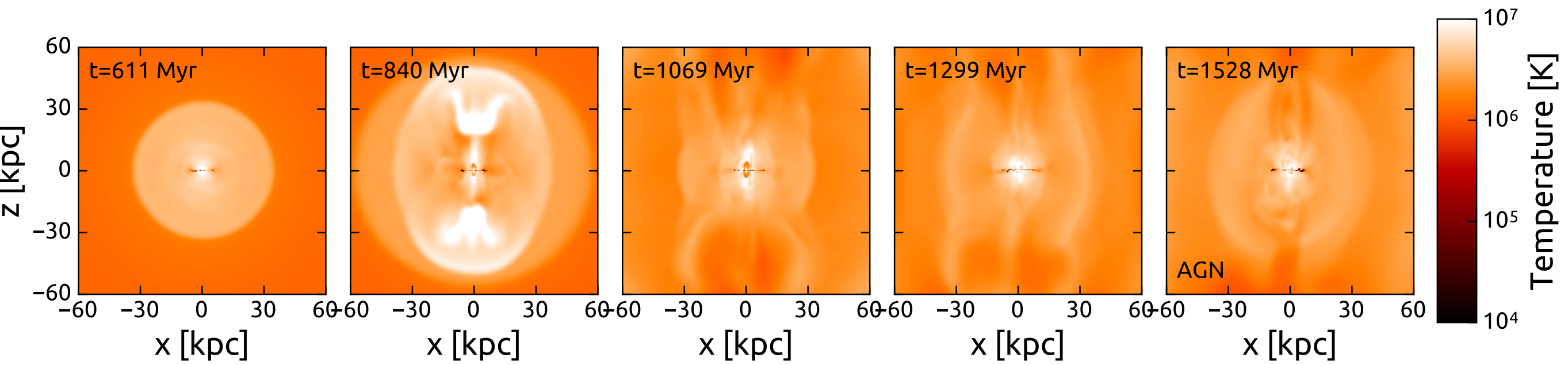
More lasting outflows

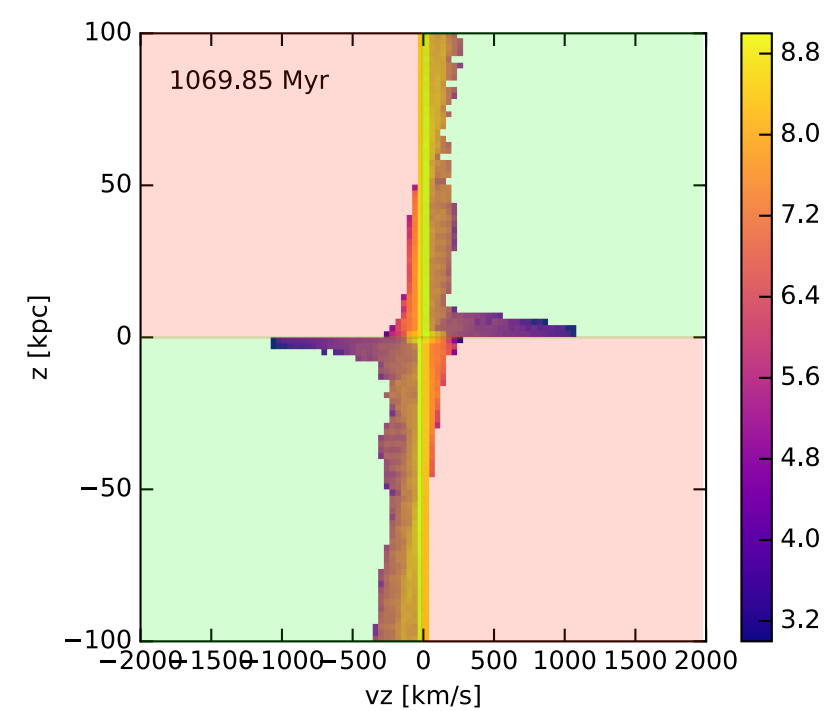
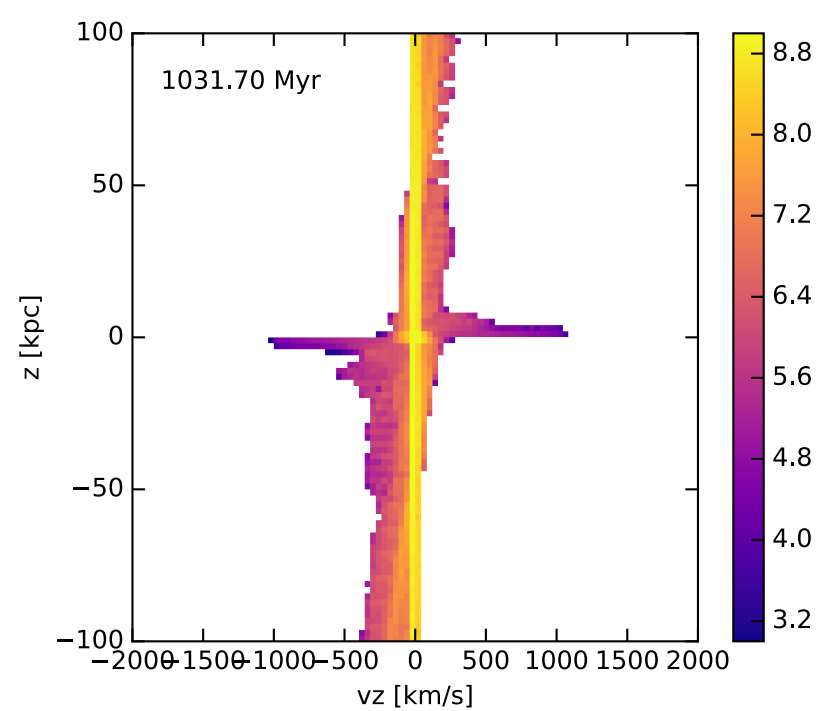
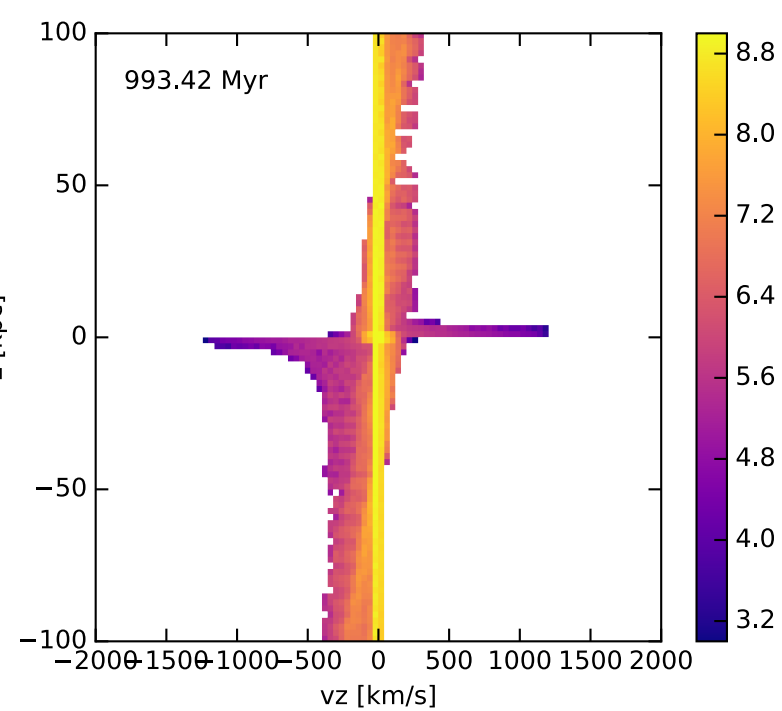
Let's mix the ingredients...



As seen in observations of Chapman et al., in prep.





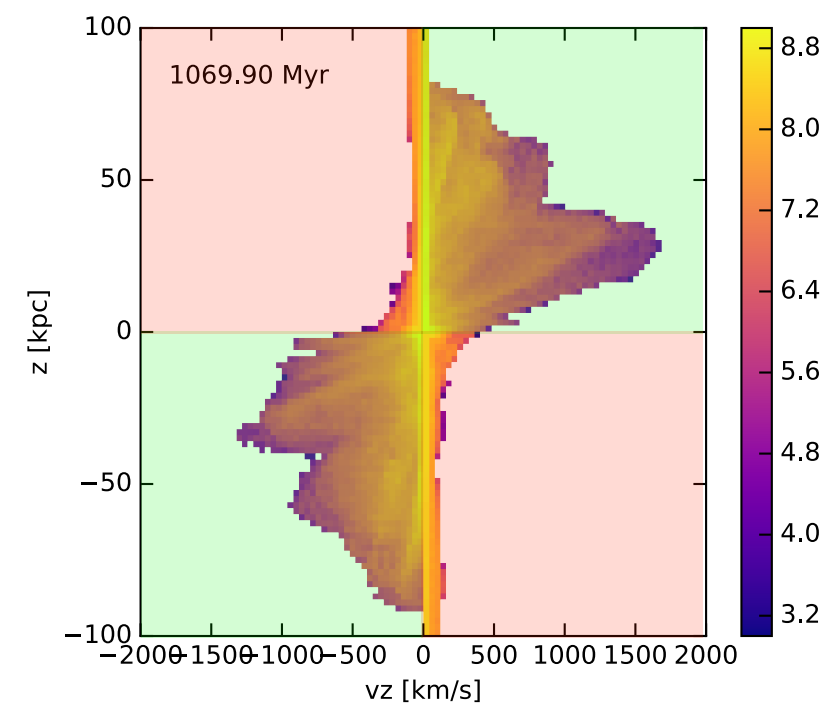
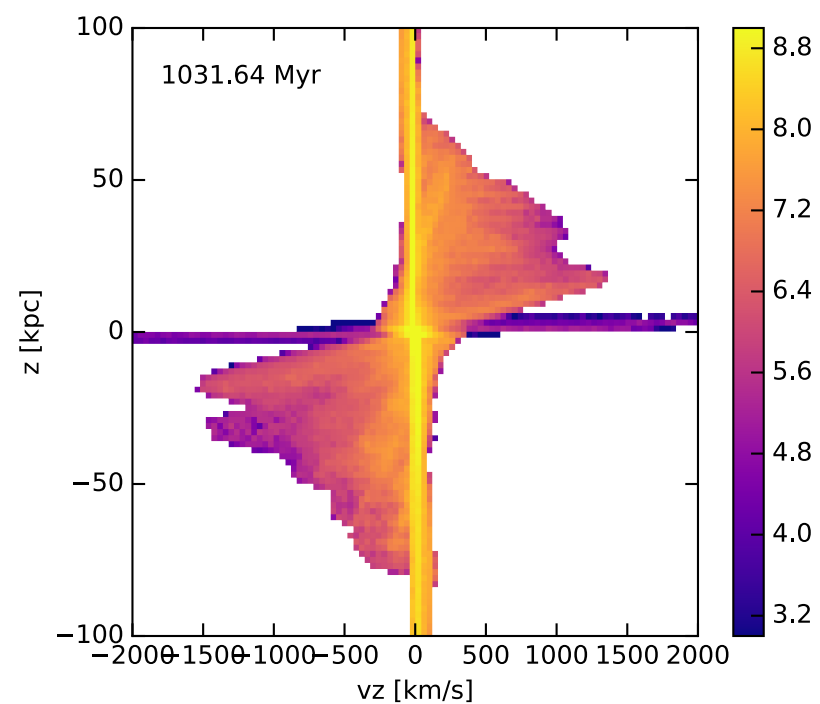
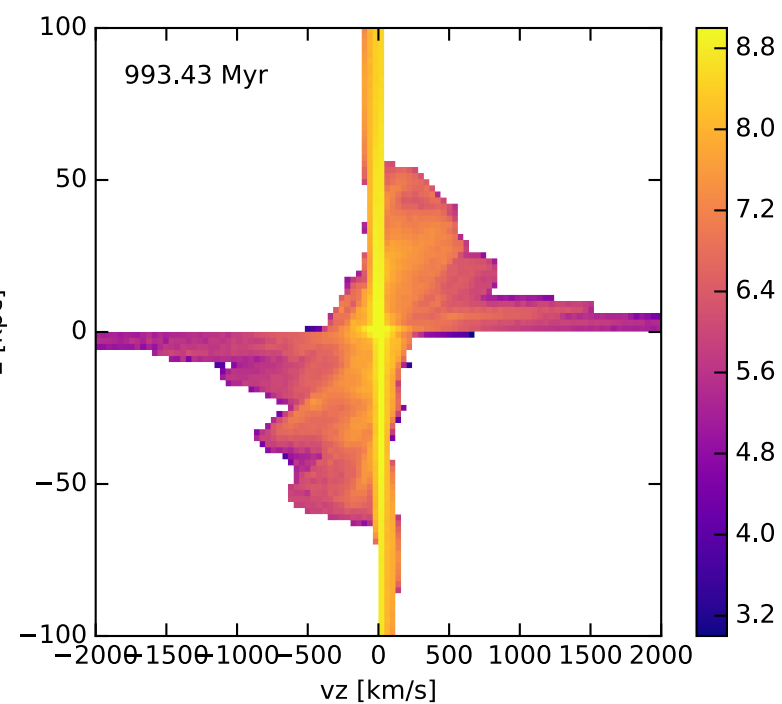


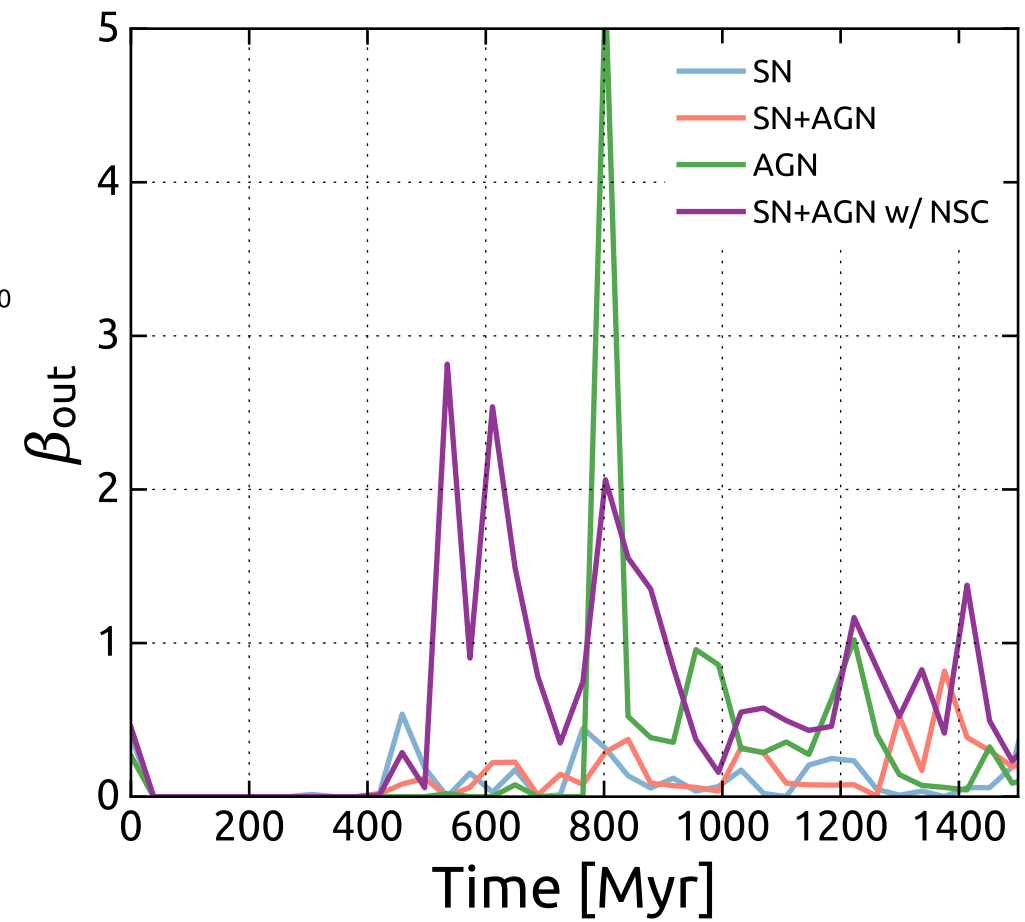
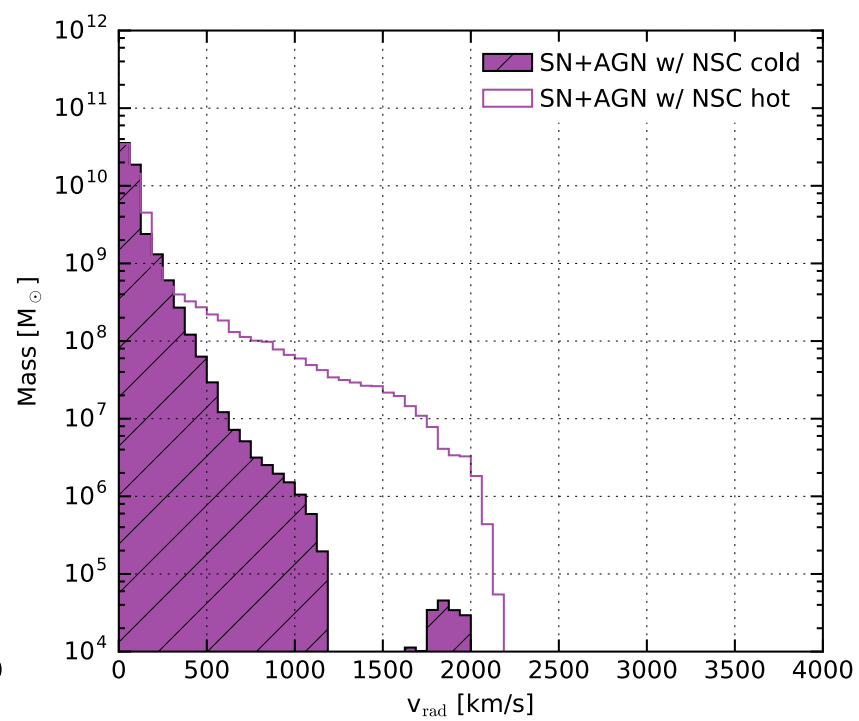
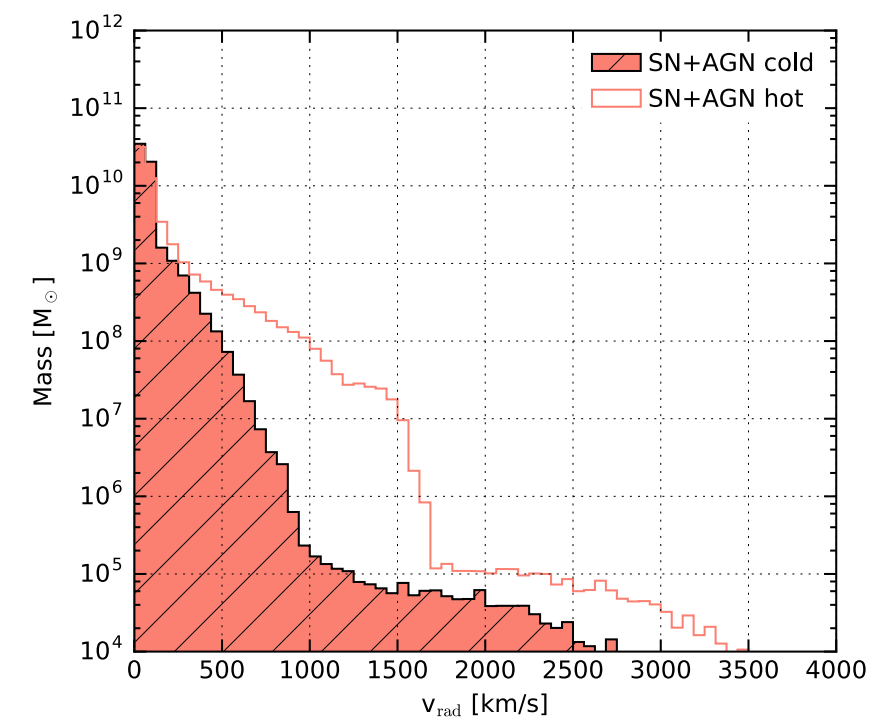
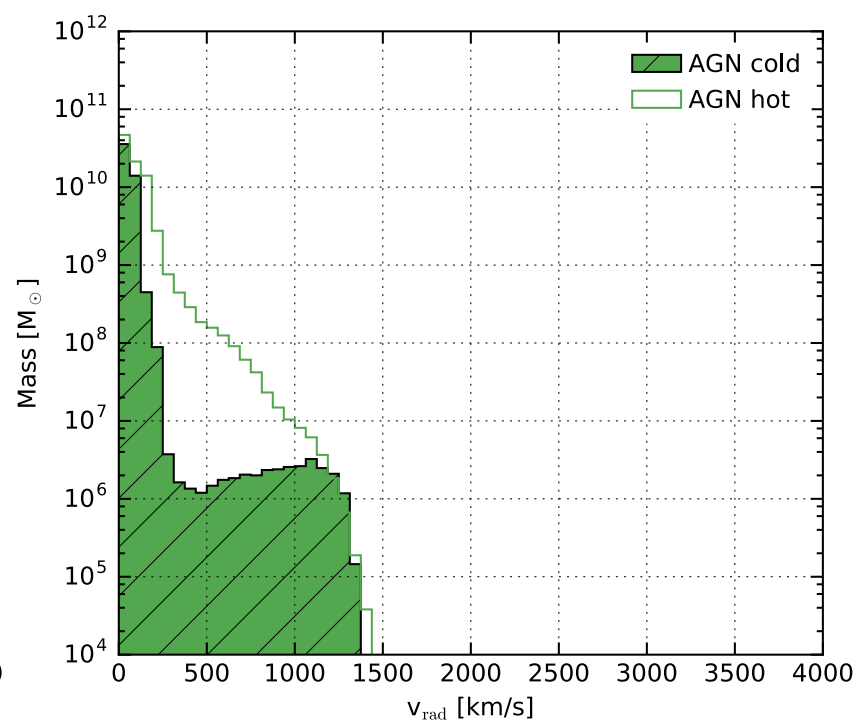
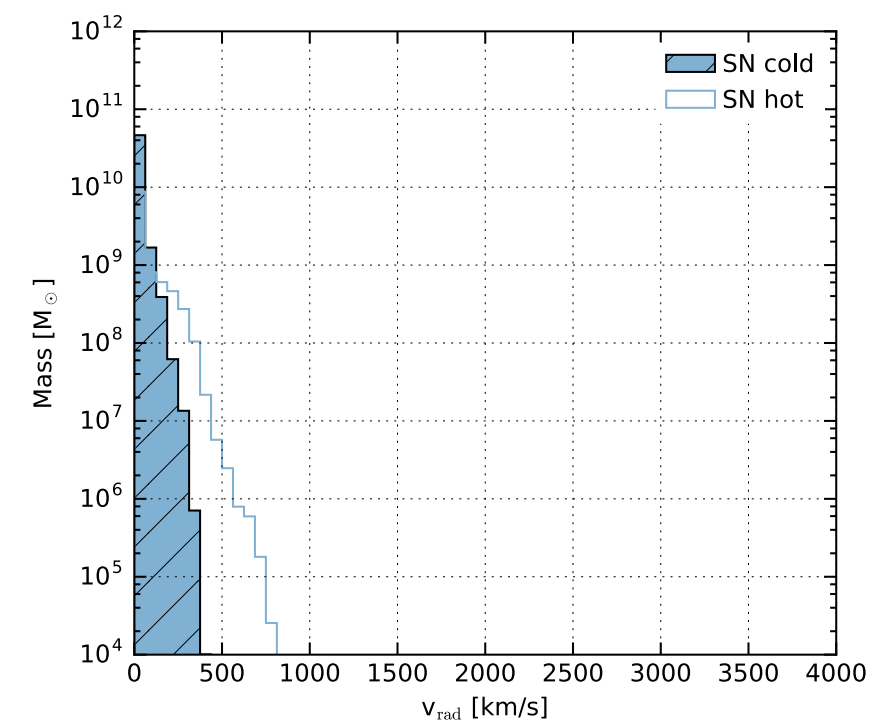
SN feedback only

Inflow

Outflow

SN+AGN feedbacks





In agreement with hot and cold outflows of Costa+15

Take home message

- SMBH dynamics in a clumpy galaxy seems to point towards the need for NSC and SMBH co-evolution
- Resolved ISM and AGN feedback can be the origin of fast cold outflows
- AGN feedback provides necessary energy to push/unbind the gas residing in the galactic corona
- Do you want to easily make cool movies?
See RAMSES Animation Maker:
<https://bitbucket.org/biernacki/ram>