The symphony of AGN and stellar feedback

Dark Matters
Birthday Conference for Joe Silk

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Overview

Learn to walk before you try to run

Overview

Learn to walk before you try to run

Study how AGN interacts with Molecular Clouds

Step 1 : Jet versus Radiatively driven Winds

Cielo, Bieri et al. 2017, submitted

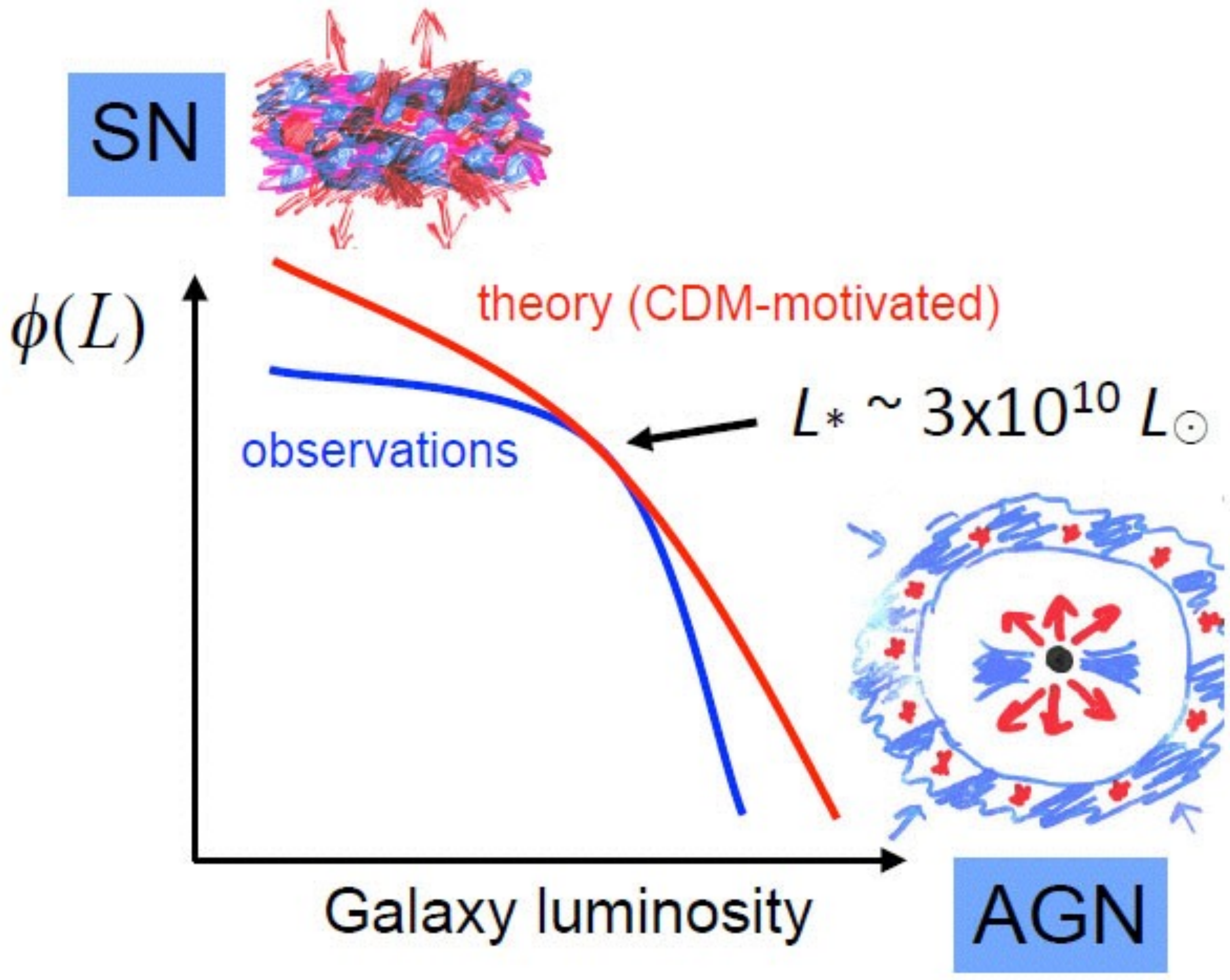
Step 2 : AGN outflow shocks on Molecular Clouds

Dugan, Gaibler, Bieri et al. arXiv:1608.04280

Step 3: AGN outflows colliding with Molecular Clouds

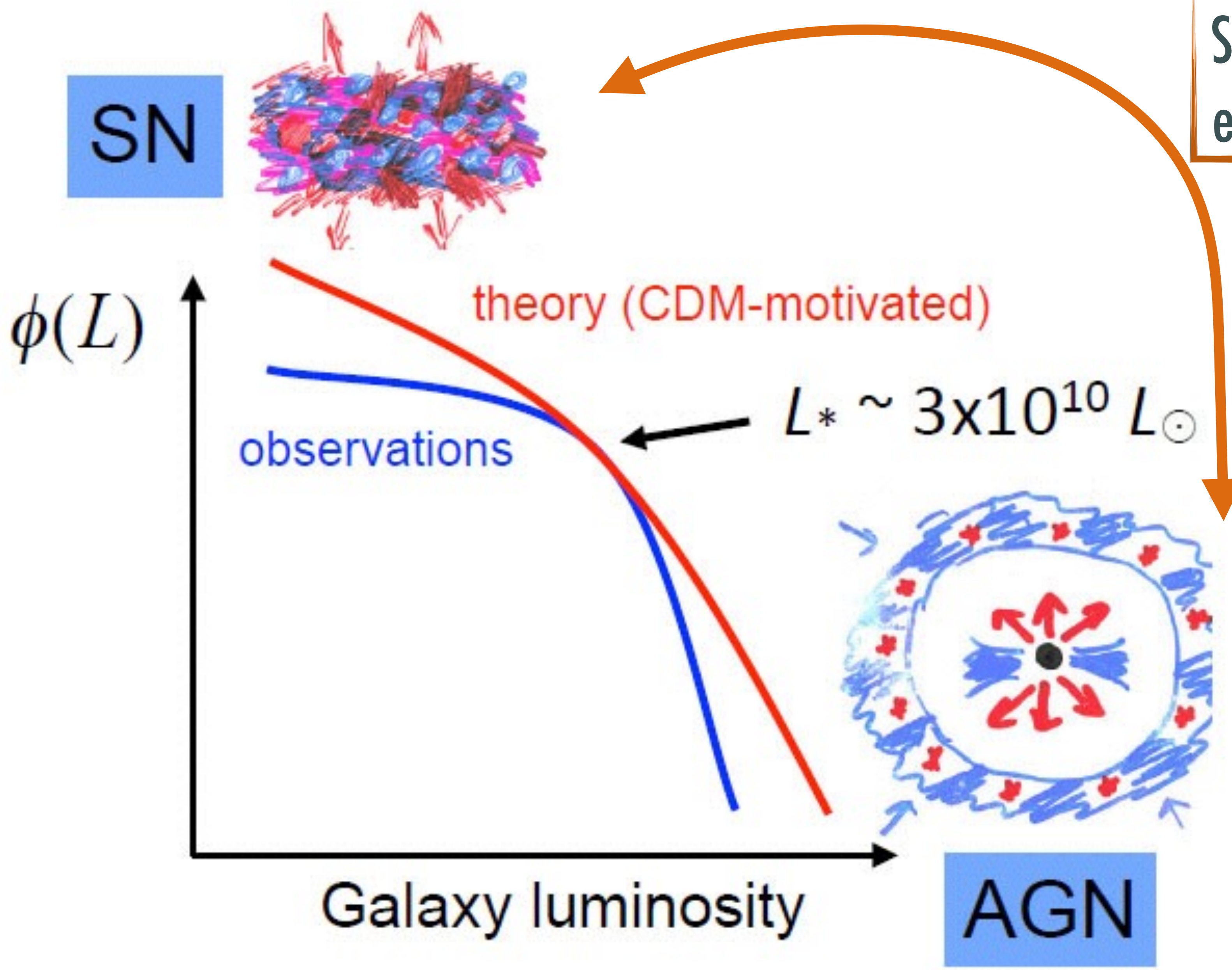
Bieri, Geen et al., in prep.

Comparing Models with Observations



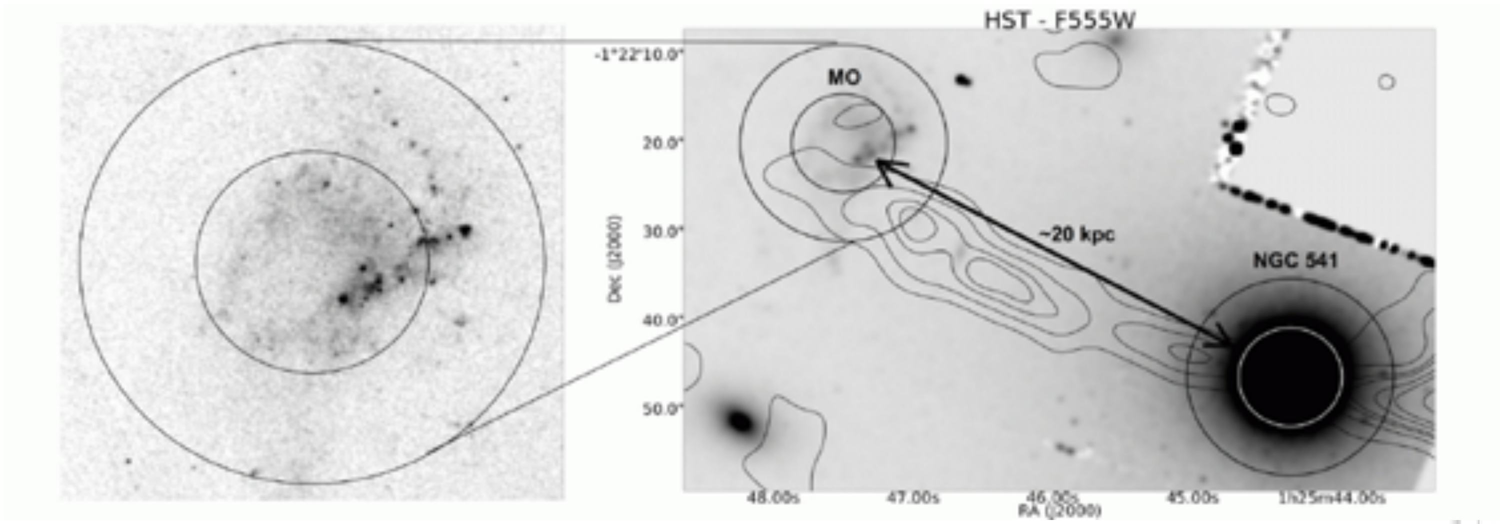
Comparing Models with Observations

Stellar feedback influences efficiency of AGN feedback



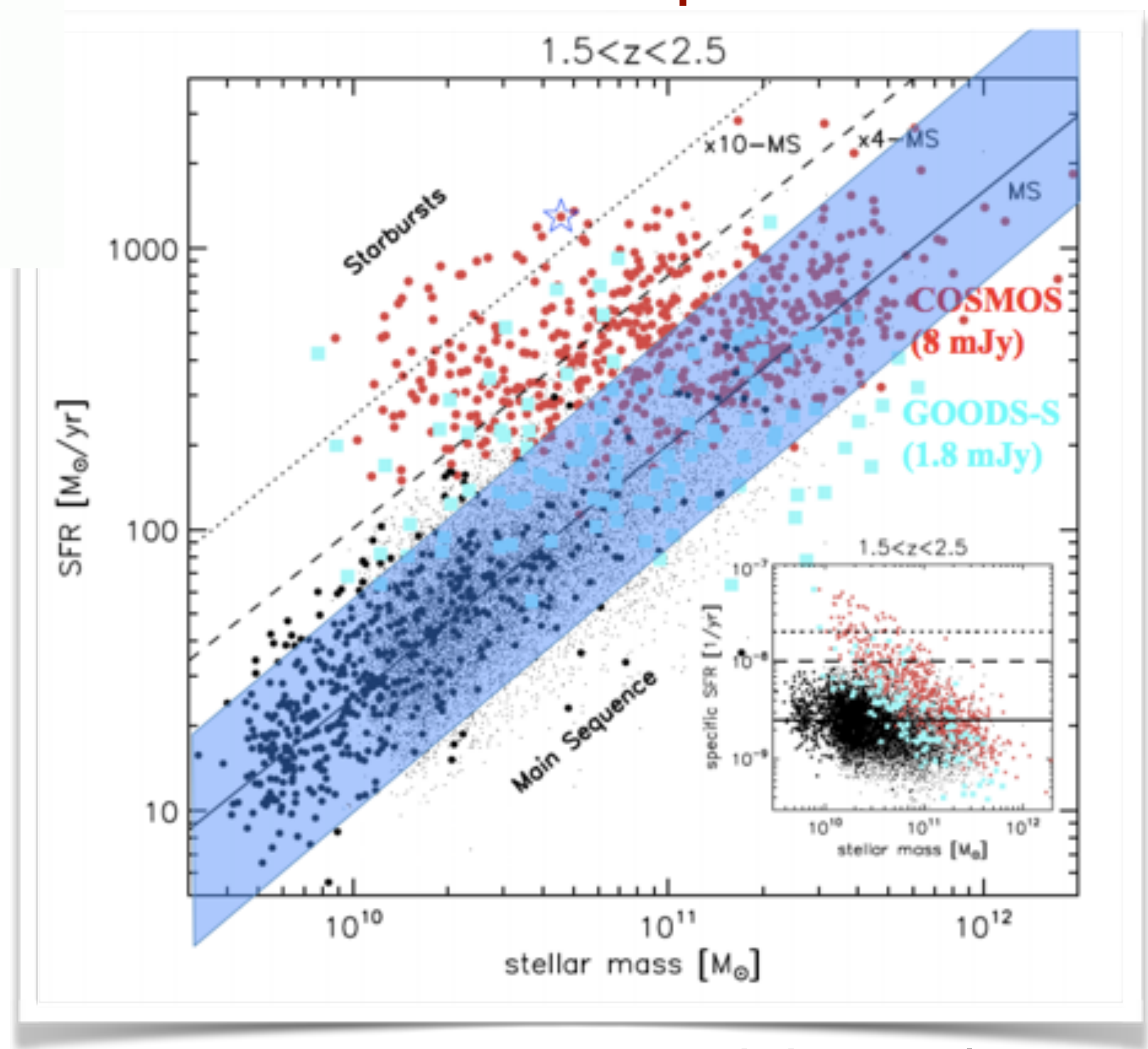
Positive Feedback from AGN?

Contour map of the eastern lobe of NGC 541 overlaid on a slightly smoothed stellar continuum image



Salomé et al. 2014

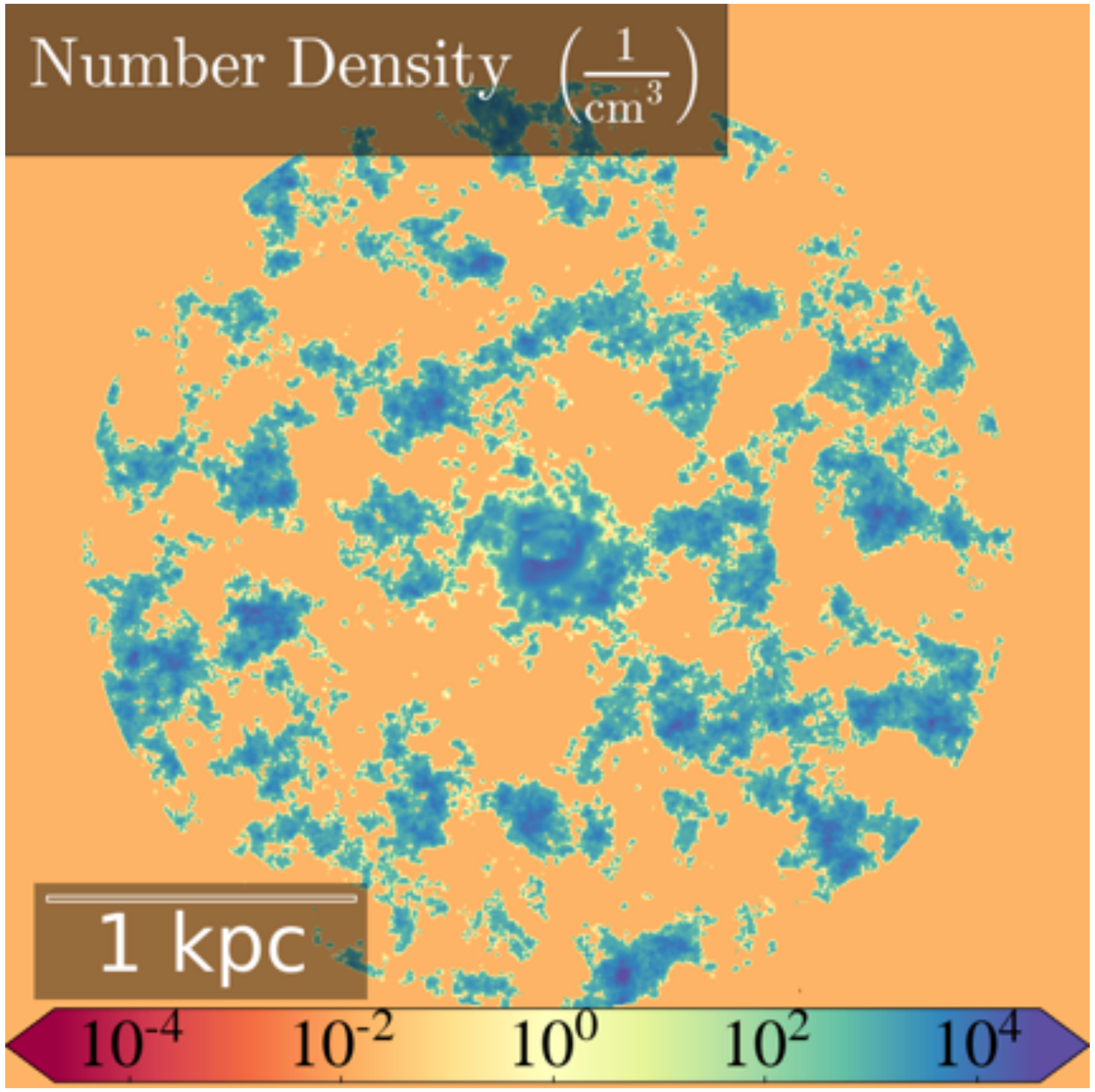
Starbursts unexplained



Rodighiero et al. 2011

Jet versus Radiatively driven Winds

- RAMSES : Grid based hydrodynamic solver with mesh refinement (Teyssier 2002)
- Turbulent, inhomogeneous **multi-phase** interstellar medium of a gas-rich high-redshift galaxy in terms of density structure and clump size (Wagner + Bicknell 2011)
- Caveats: No gravity, no cooling



Jet versus Radiatively driven Winds

Jet:

- Hydro source term, cylindrical base, orientation can be chosen
- **Steady density/momentum/energy flux**
- $\rho_{\text{jet}} = 0.01\rho_{\text{ambient}}$
- Straight beam that is self-collimated by internal shocks

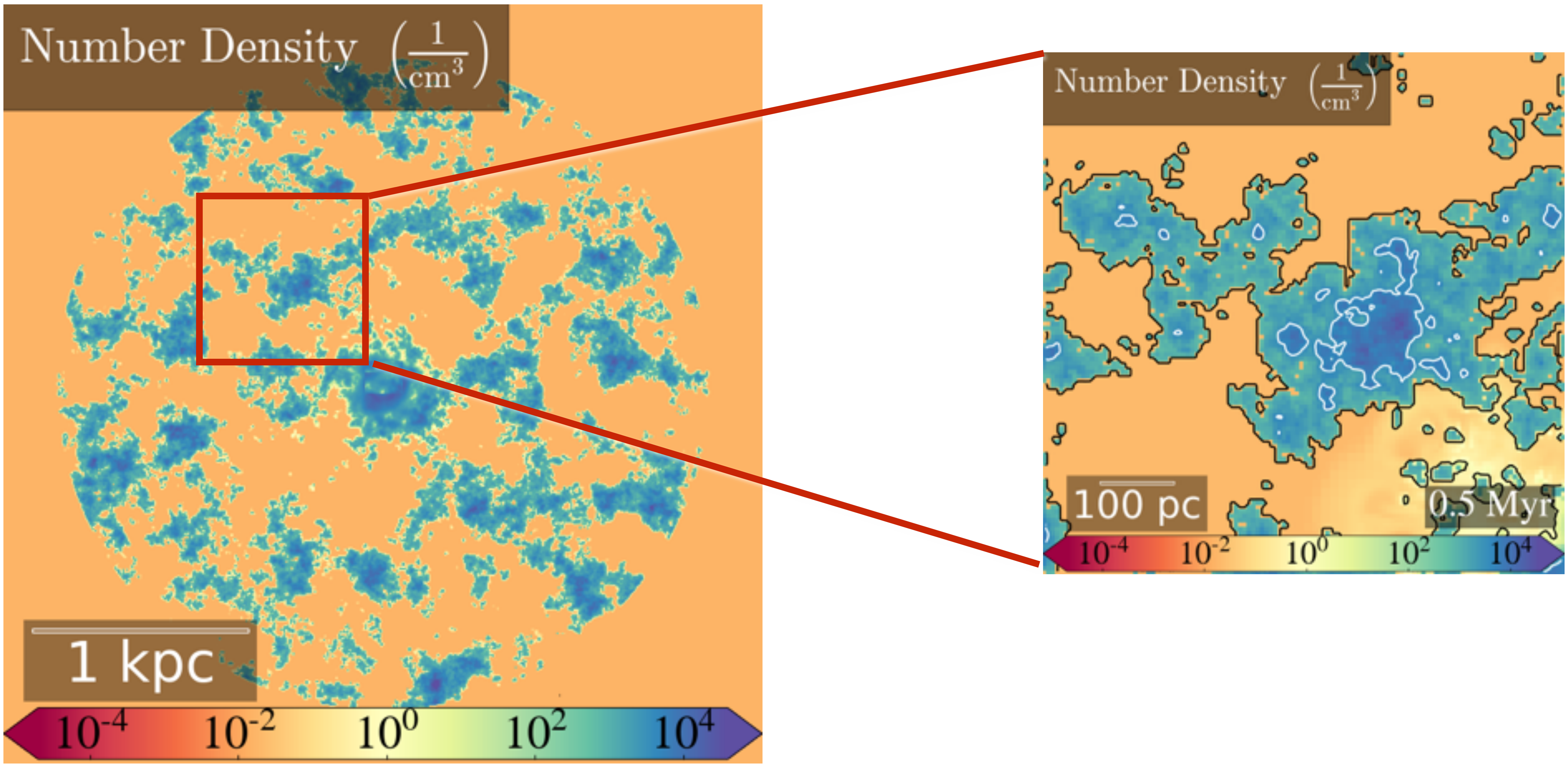
Radiation:

- RAMSES-RT: Uses moment method to solve **radiative transfer** in RAMSES

(Rosdahl et al. 2013, Rosdahl & Teyssier 2015)

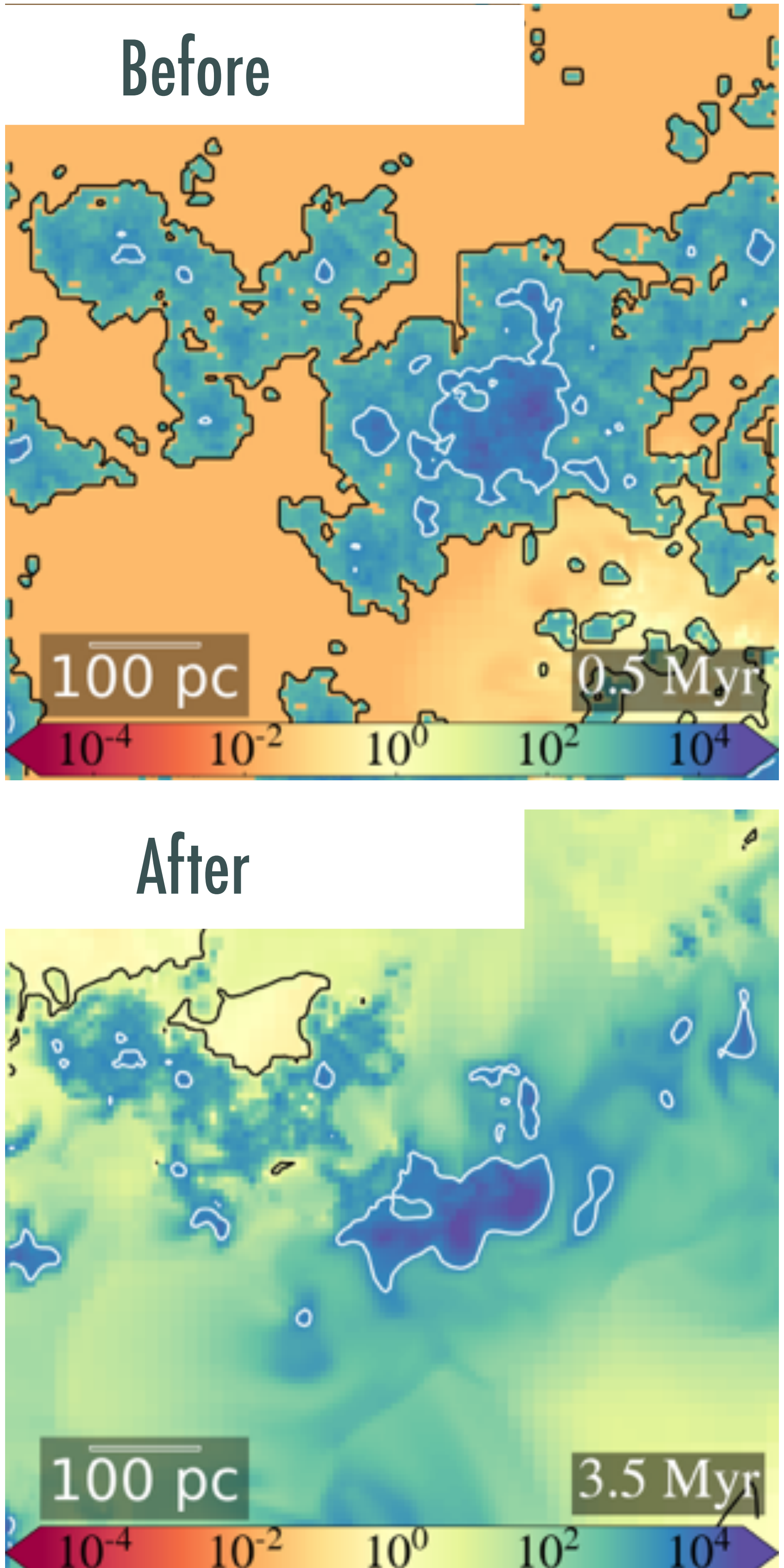
- Solves non-equilibrium evolution of ionisation fractions of HII, HeII, HeIII
- **Radiation pressure** + diffusion of multi-scattering IR radiation included
- AGN SED with 5 photon groups, IR $\longrightarrow$ UV

Cloud Evolution in different AGN feedback

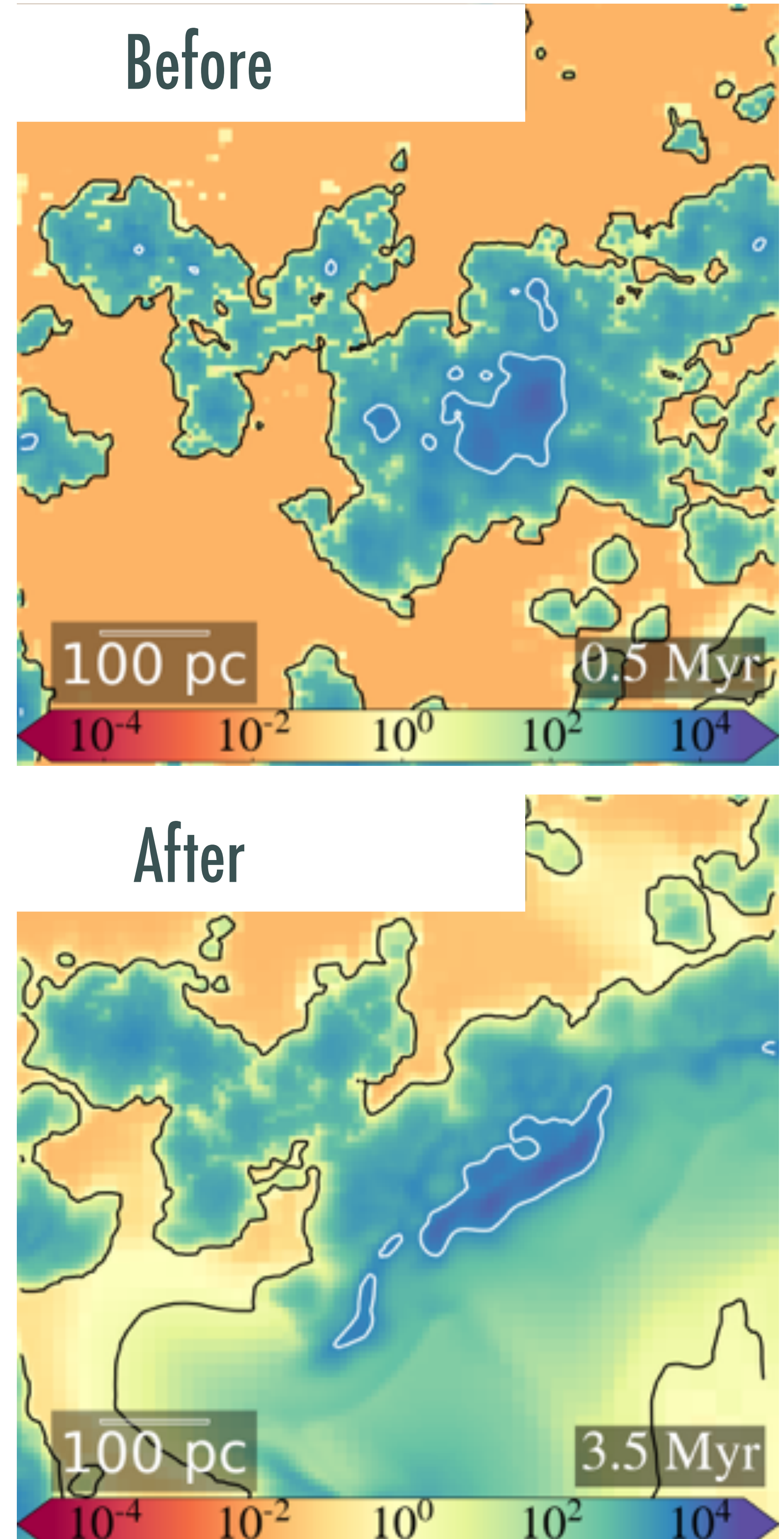


Cloud Evolution in different AGN feedback

Jet:

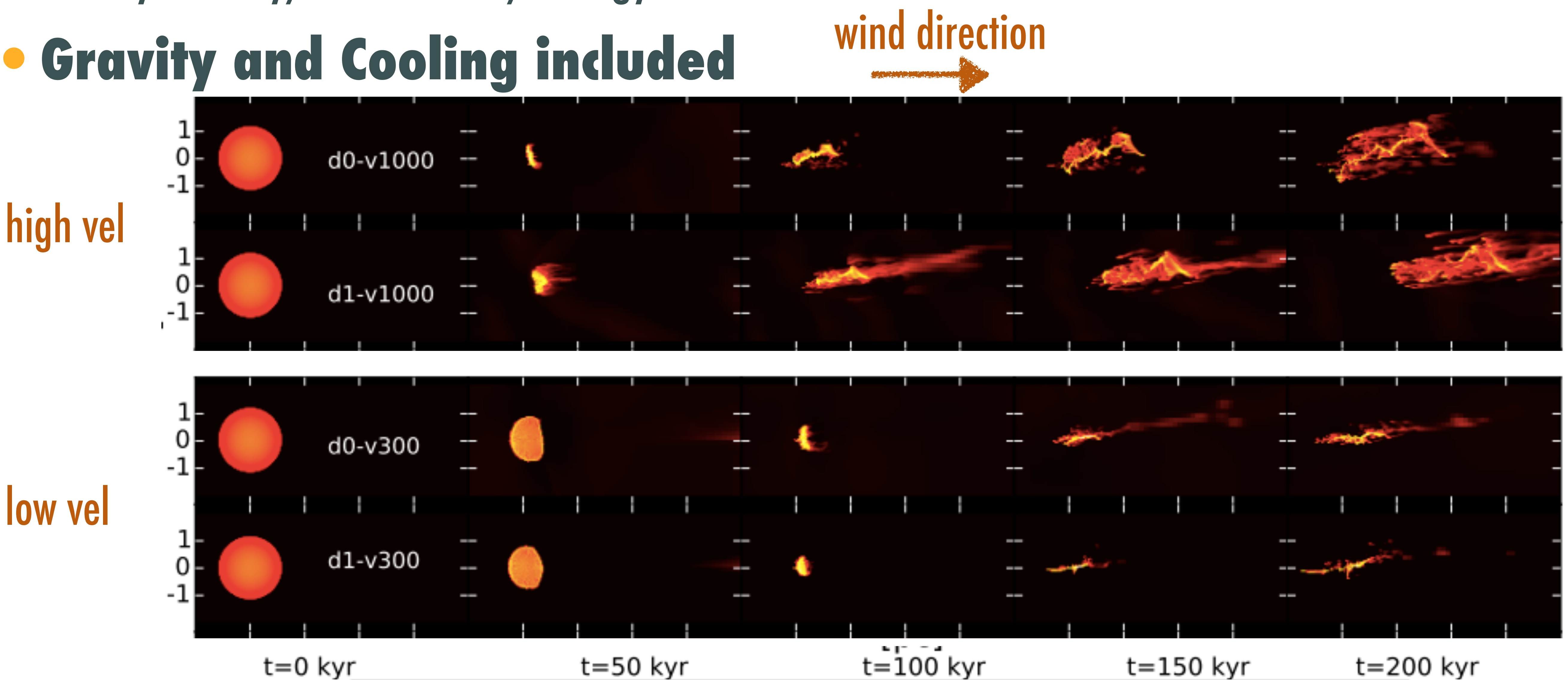


Radiation:



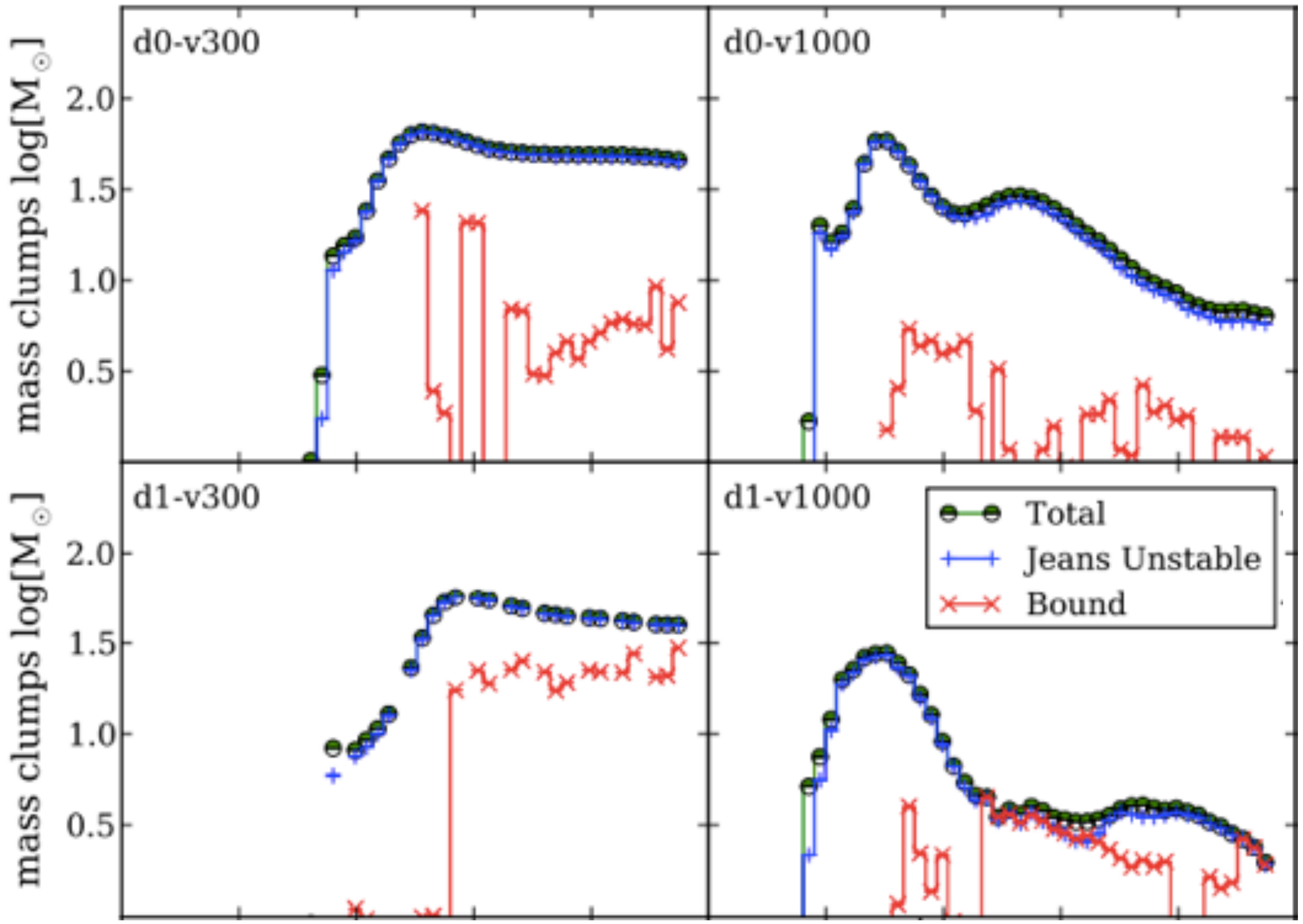
AGN Outflow shocks on Molecular Clouds

- **Bonnort-Ebert Spheres**: non-uniform density profile; pressure balance with ambient medium → more realistic description for dense clumps of MC
- Various wind velocities/densities, highly pressurised
- Steady density/momentum/energy flux
- **Gravity and Cooling included**



AGN Outflow shocks on Molecular Clouds

- **Ram pressure** is most important factor determining fate of MC
- High ram pressure : - increased fragmentation and decreased SF
  - SF on shorter timescale
  - Increased velocities of newly formed stars
- Ram pressure threshold above which no stars are formed



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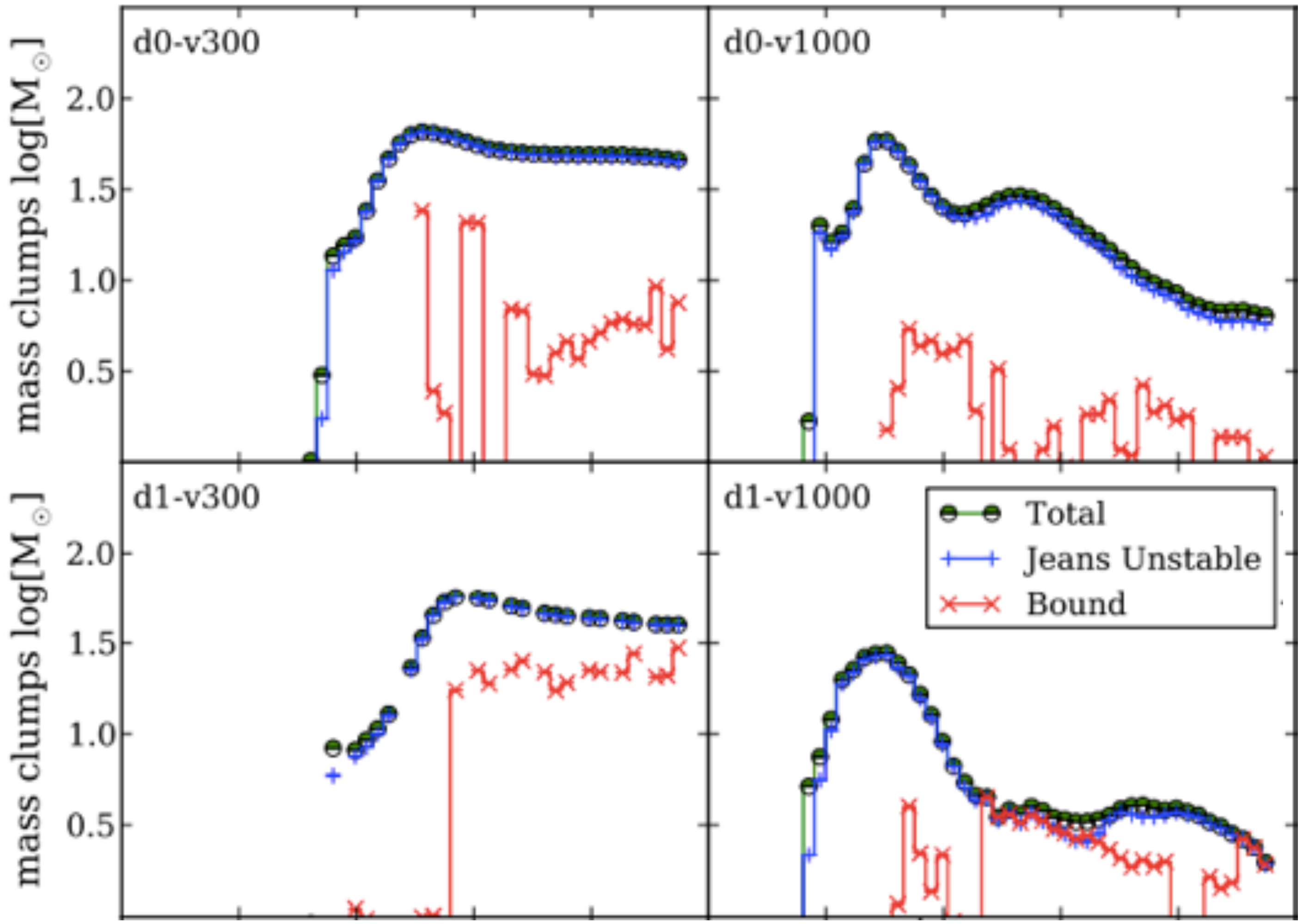
Caveats:

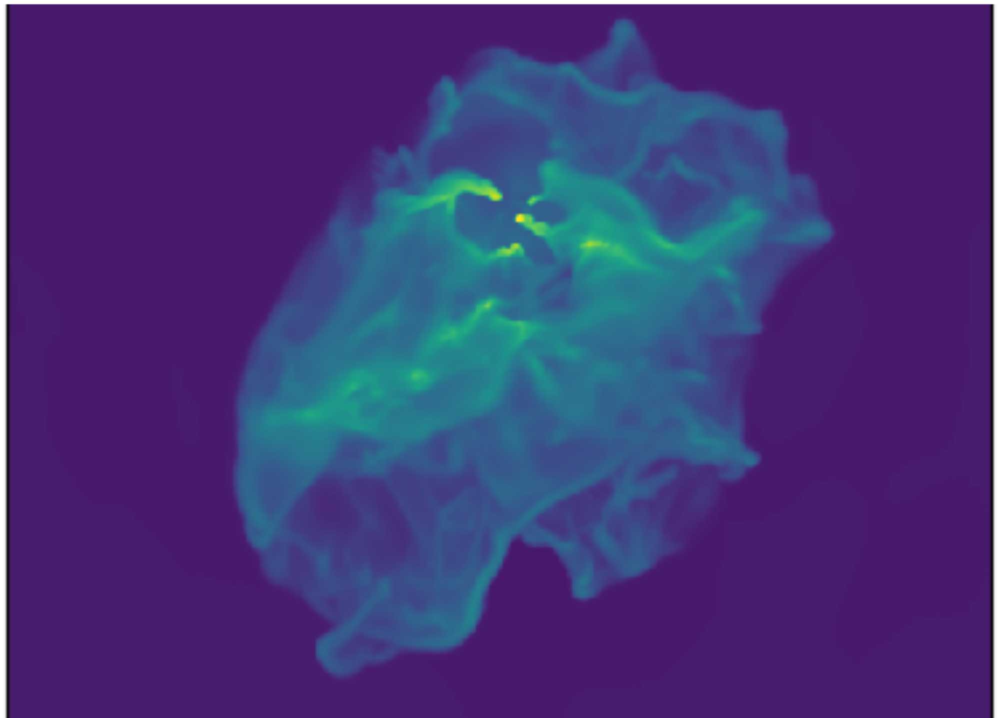
- Molecular Clouds are turbulent supported.
- Stars emit radiation, eject winds, and explode in a SNe.



AGN Outflows colliding with Molecular Clouds

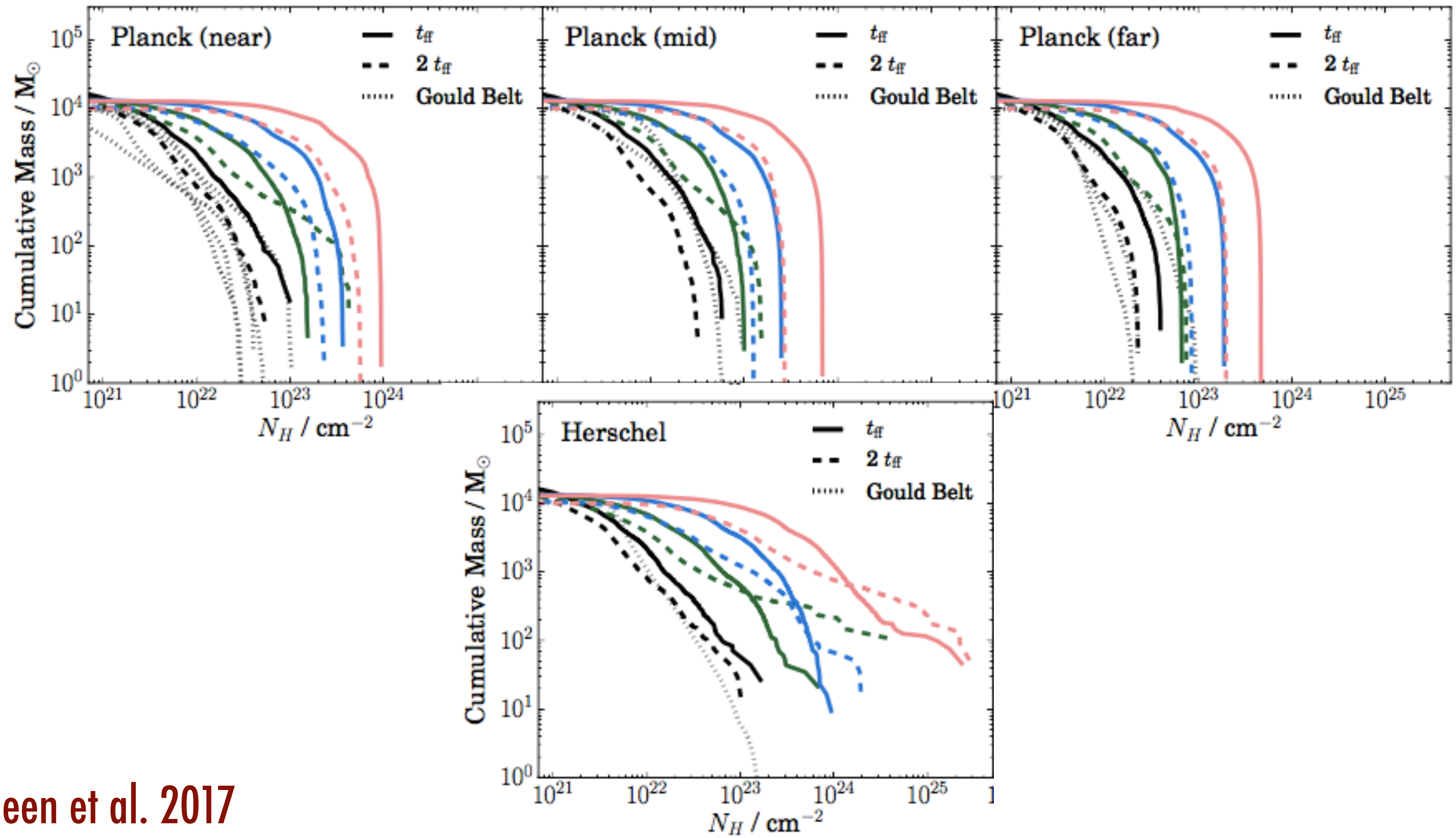
Clouds are turbulent and present large density contrasts and a complex structure induced by supersonic turbulence

- Radiative magnetohydrodynamics simulations (RAMSES-RT)
- Cloud in initial **thermal equilibrium** and surrounded by warm neutral medium
- Considering spherical cloud with profile $\rho = \rho0/(1 + (r/r_0)^2)$
- Thermal to gravitational energy is initially 1%
- Velocity field presents a **Kolmogorov power spectrum** with random phase
- Kinetic energy is about 100% of gravitational energy
  ⟶ **Turbulence supported MC**
- **Sink particles** representing clusters of stars
- Emitting **radiation** into 5 groups (UV/optical/IR)
- **Wind** ejections and **SNe** explosions



AGN Outflows colliding with Molecular Clouds

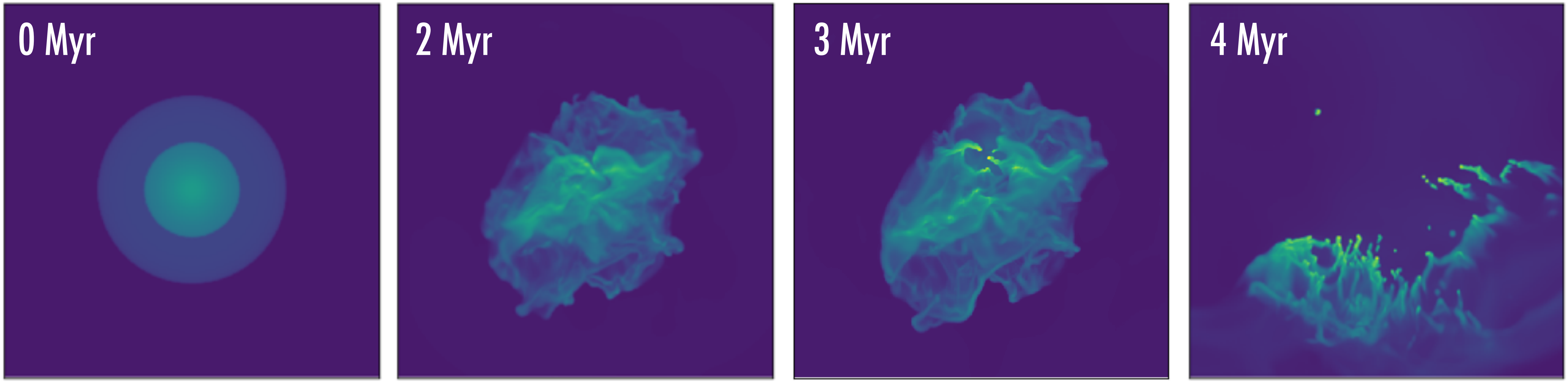
- Cloud used represents observed clouds in the Milky Way
- Tested by comparing cumulative PDF of Planck and Herschel data



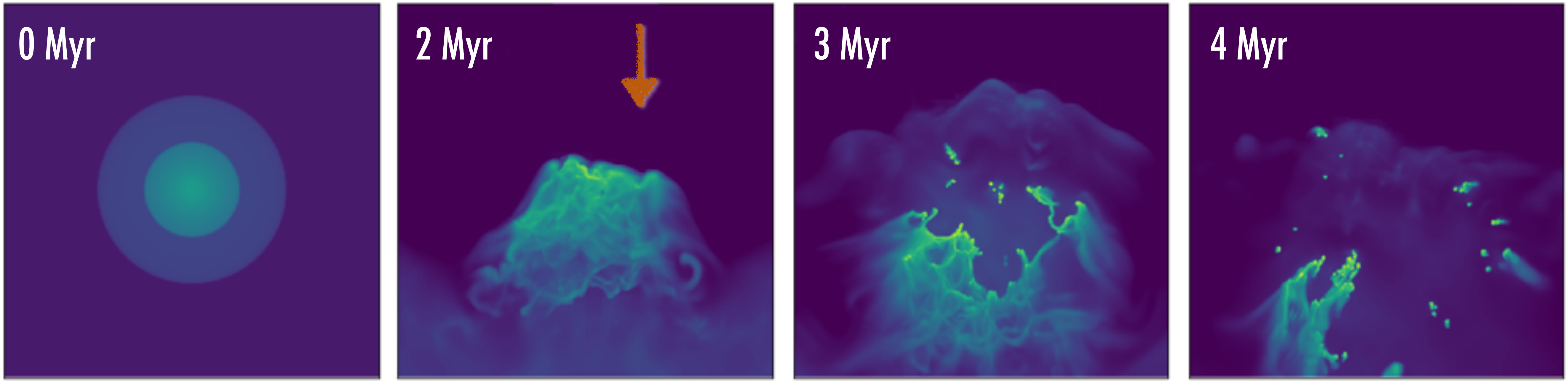
Geen et al. 2017

AGN Outflows colliding with Molecular Clouds

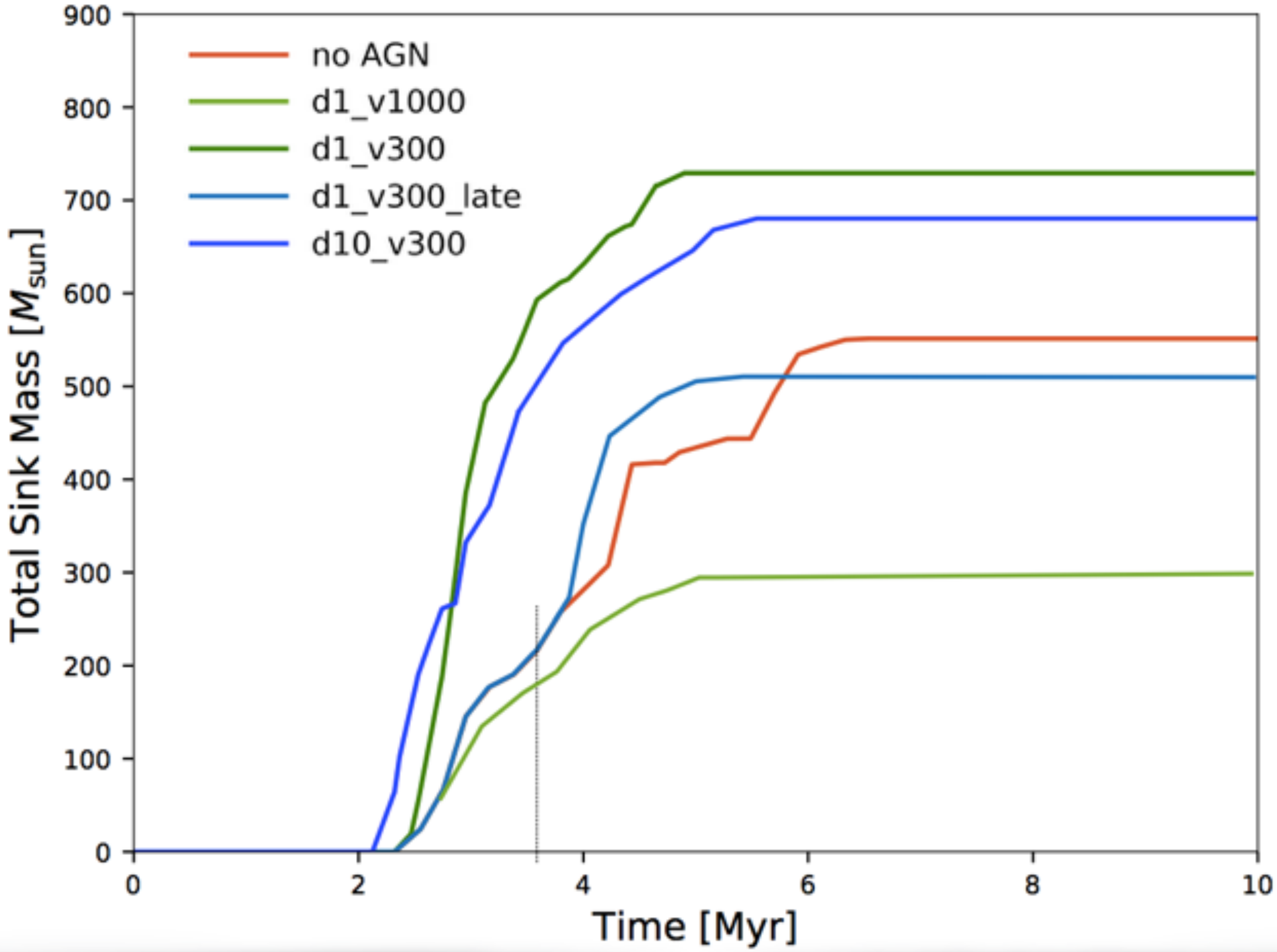
No AGN jet



AGN jet/wind (1 H/cc, 300 km/s) wind direction



AGN Outflows colliding with Molecular Clouds



- High ram pressure: Sinks can form quicker → Wind/radiation feedback also starts earlier
- Interplay between timing of AGN wind arrival and first star formation
- Similar to previous studies higher ram pressure leads to less stars formed

Conclusion

- Jet/Wind feedback leads more likely to positive feedback in MC
- Ram pressure of AGN jet/wind important in defining fate of MC
- Stellar feedback important in determining effect AGN jet/wind has on MC
- Stellar feedback is needed to define how efficient AGN feedback can be

If it exists in the real Universe

you should be able to simulate it

Thank you Joe