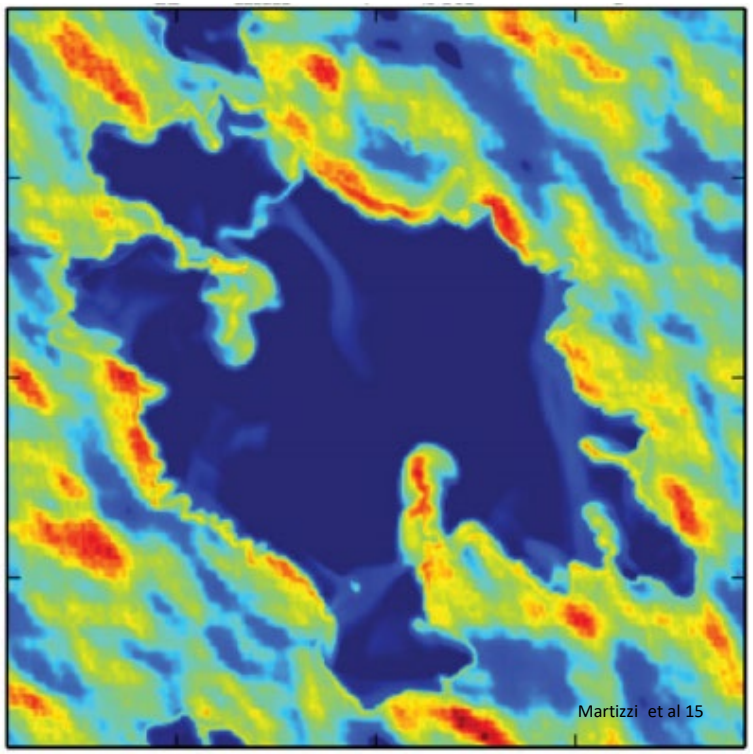

Observational constraints on momentum feedback from supernovae

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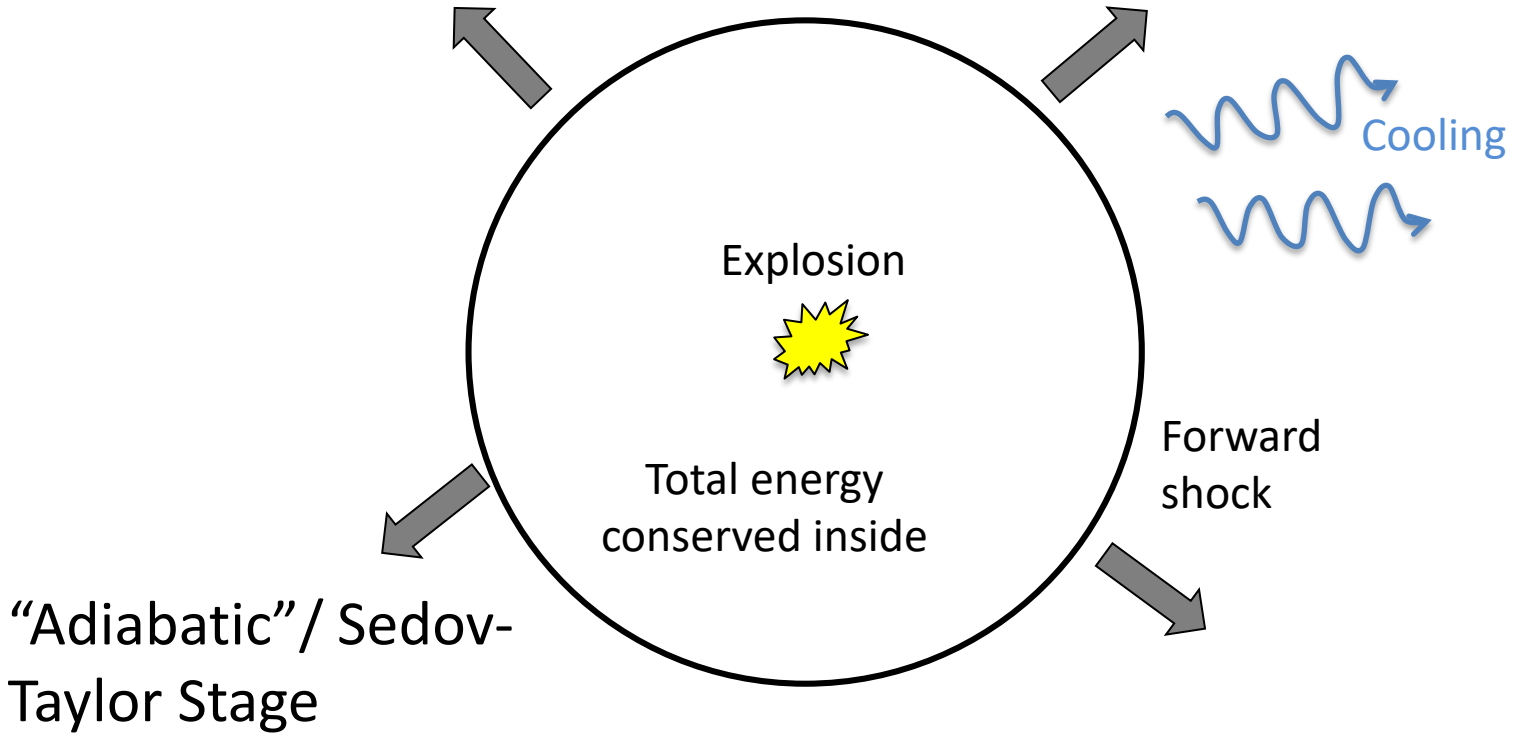
Michigan State University, USA

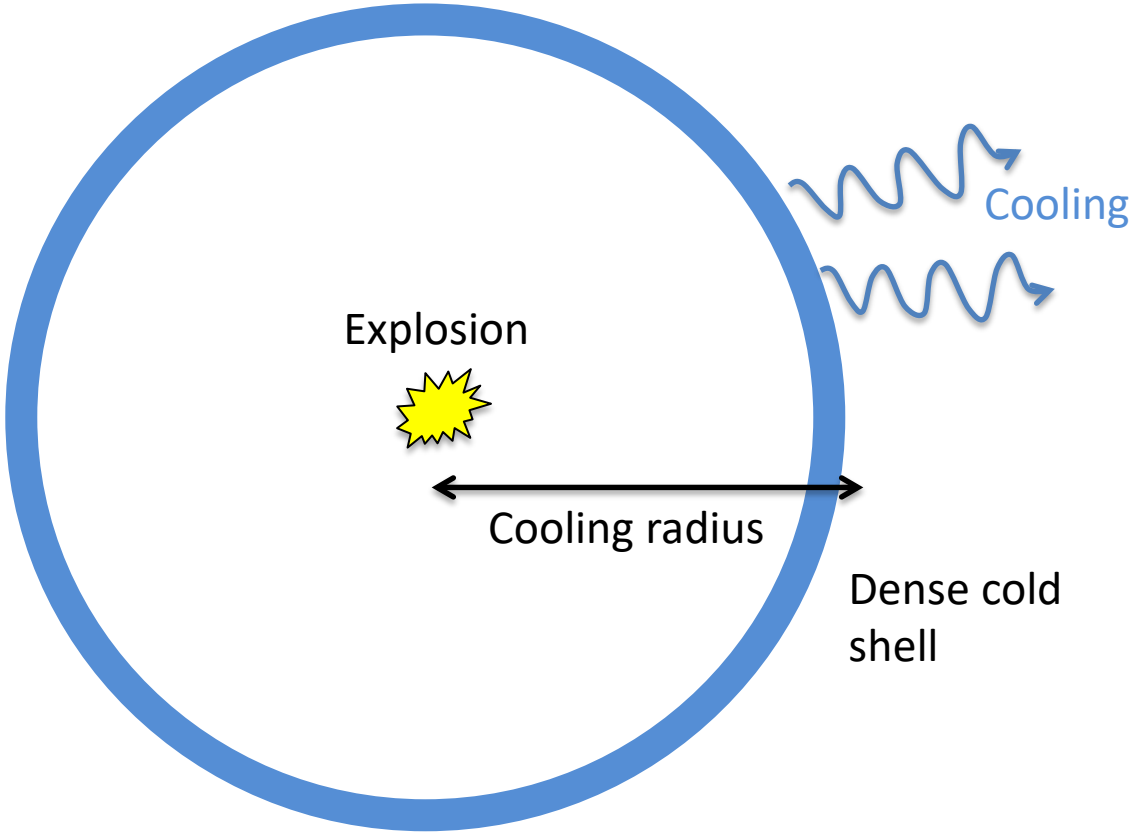
Collaborators: Davide Martizzi, Enrico Ramirez-Ruiz, Katie Auchettl, Carles Badenes

Feedback = return of energy/momentum from stars to the ISM

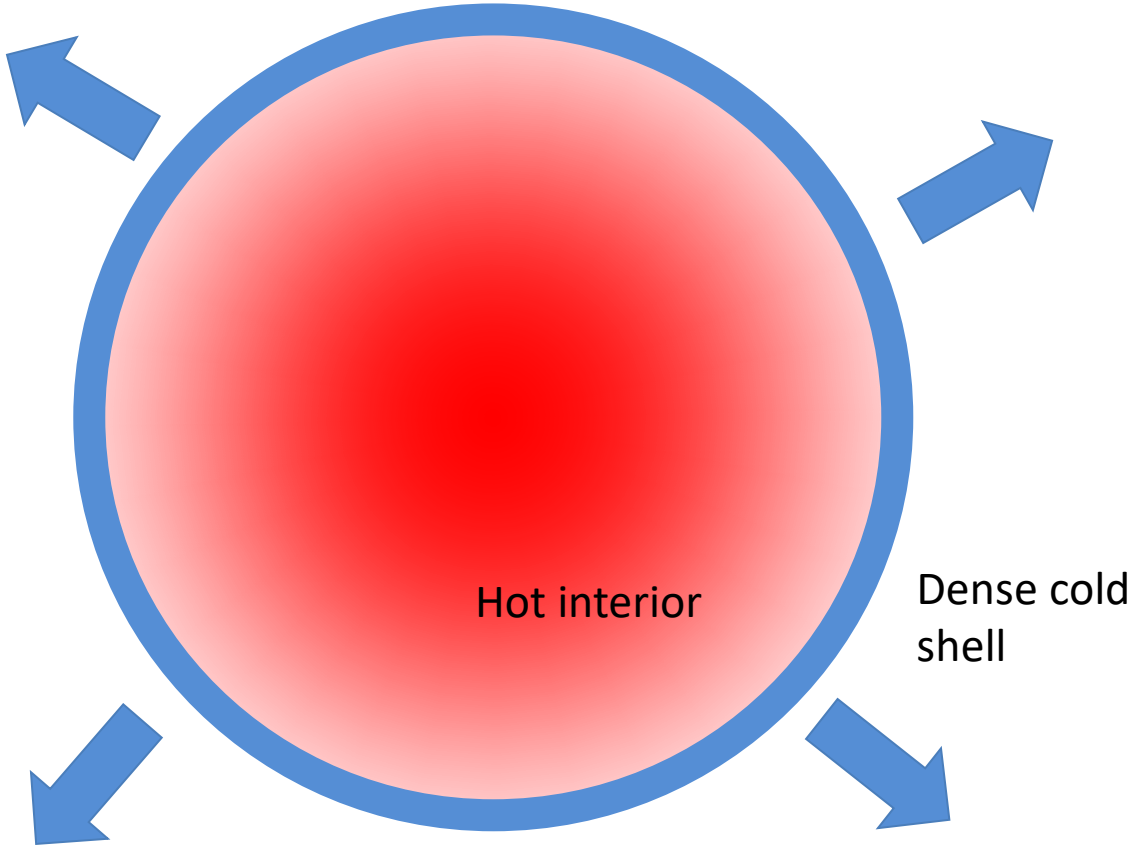
Feedback through the formation of supernova remnants



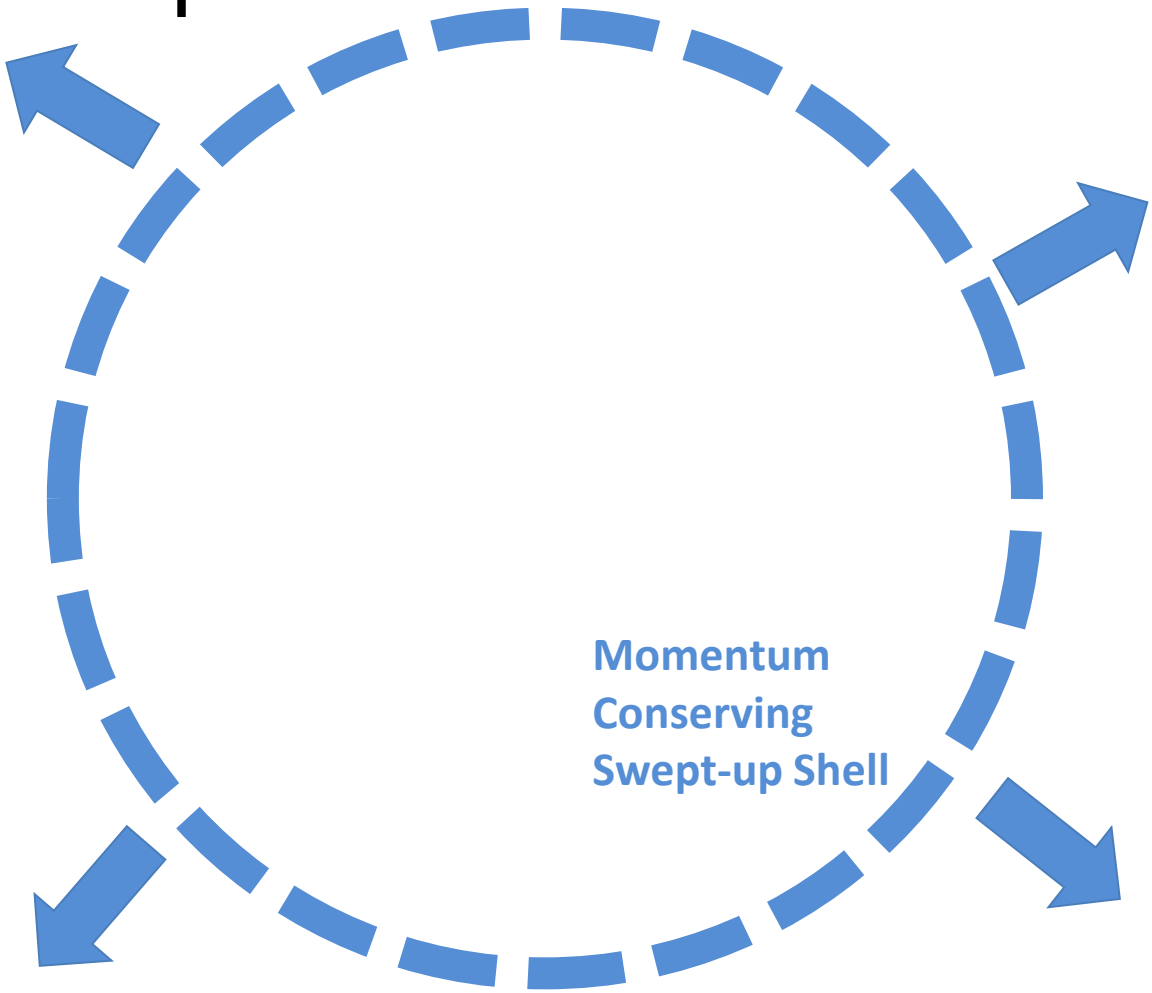
Feedback through the formation of supernova remnants



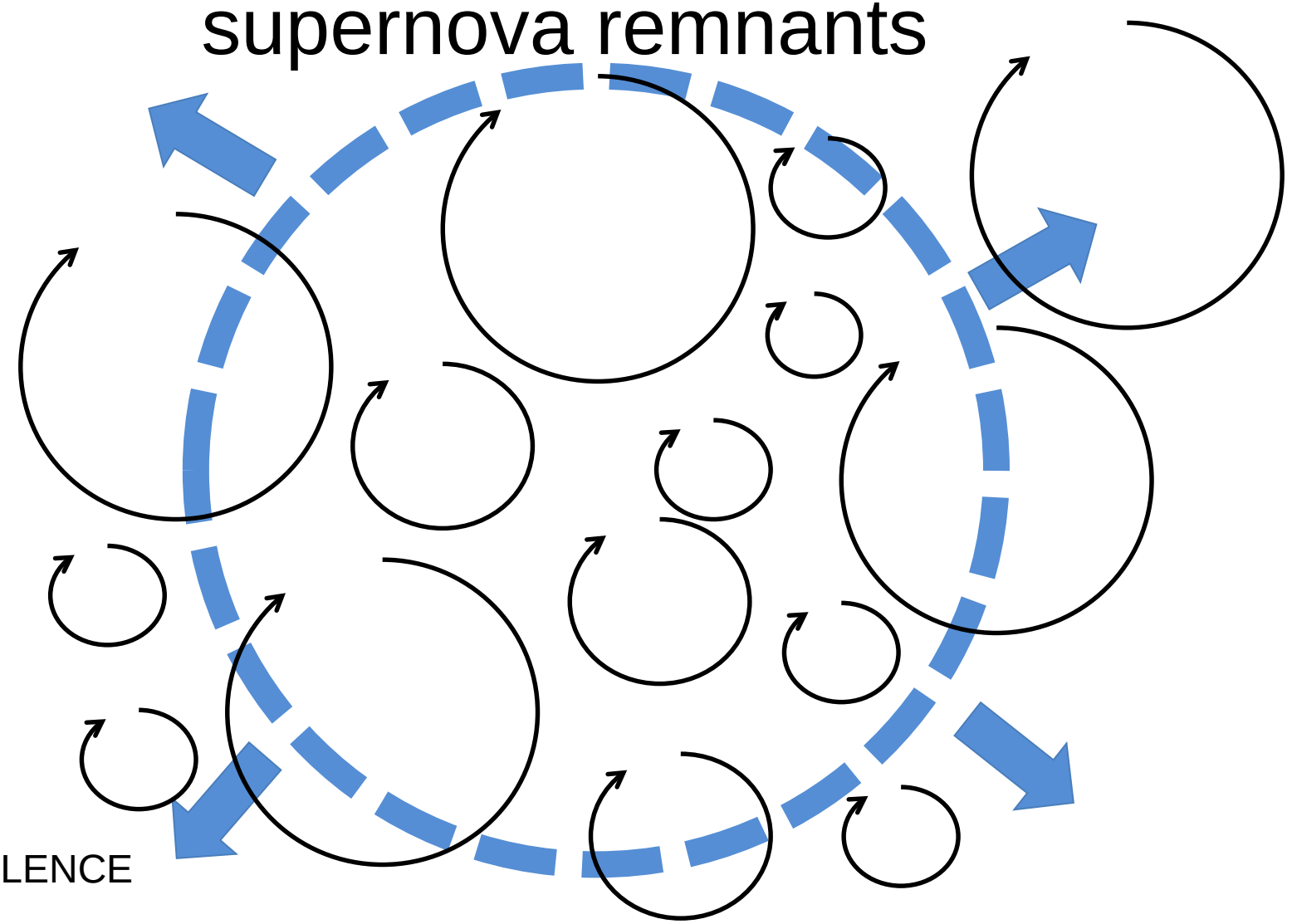
Feedback through the formation of supernova remnants



Feedback through the formation of supernova remnants

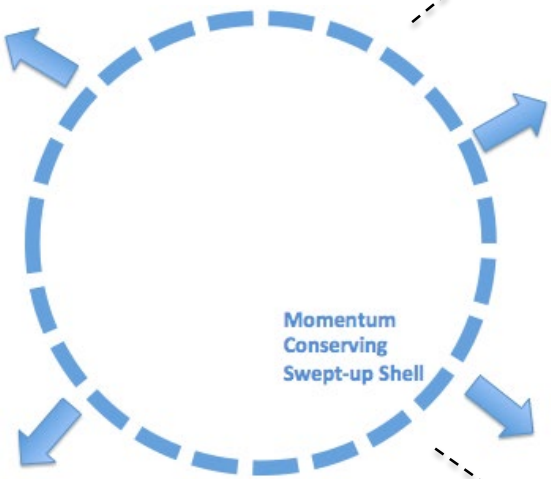


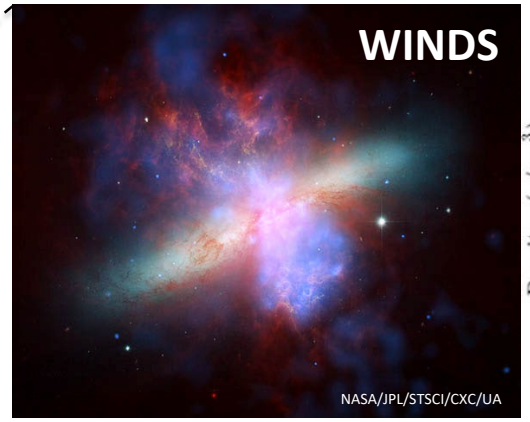
Feedback through the formation of supernova remnants

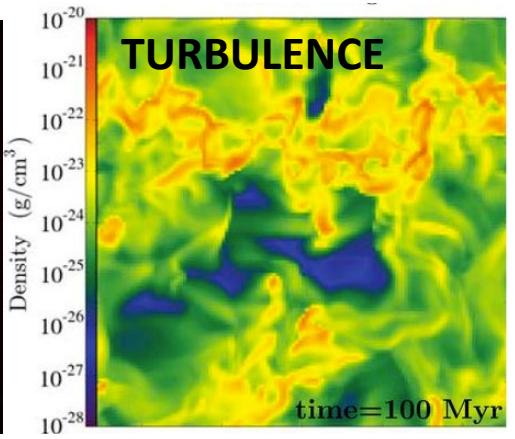


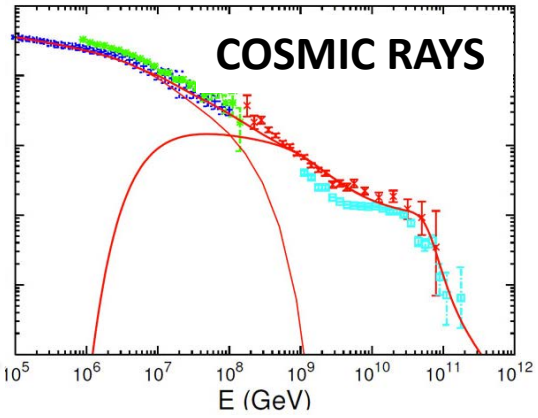
TURBULENCE

SN feedback regulates star-formation and ISM structure in galaxies

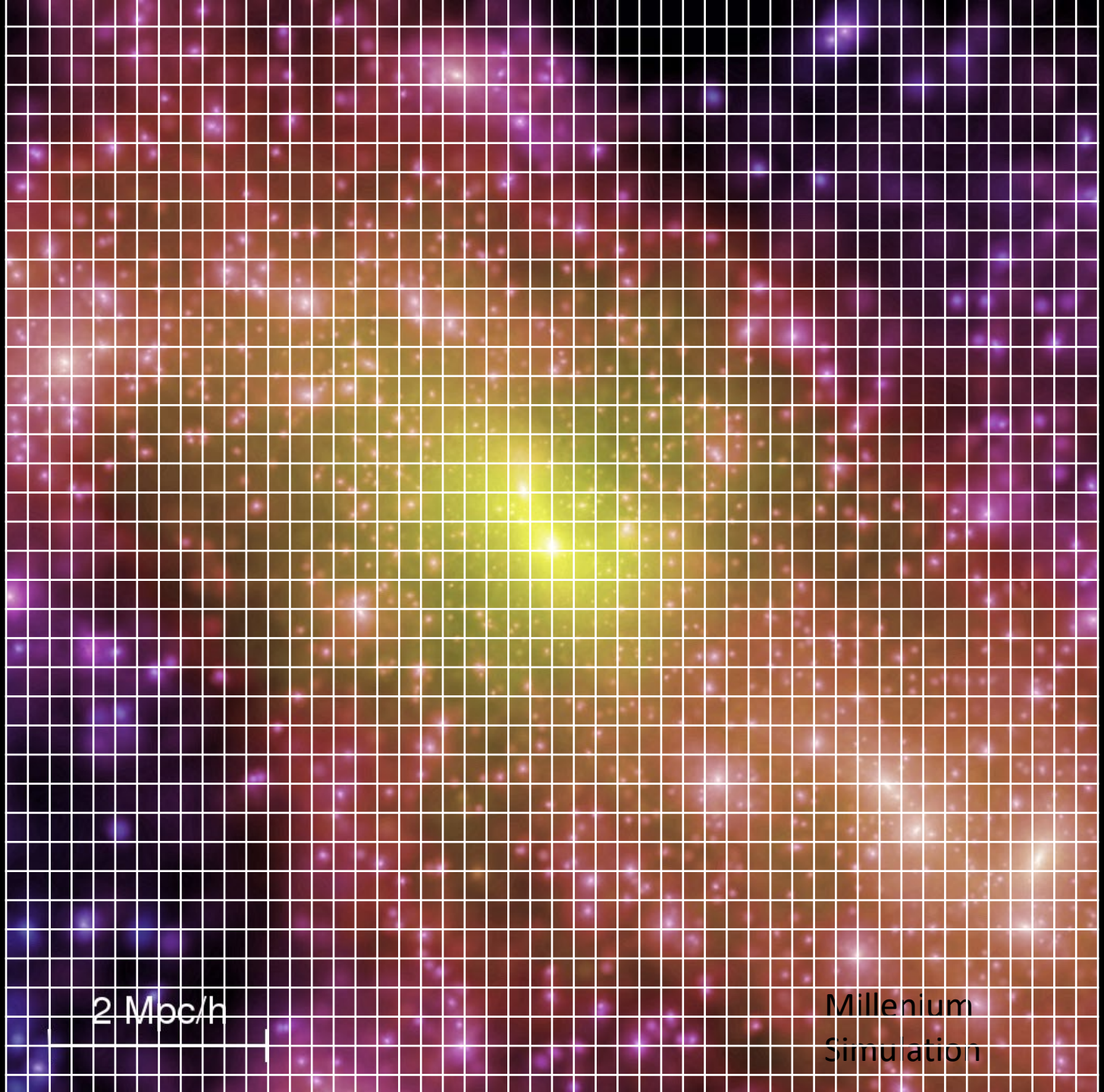


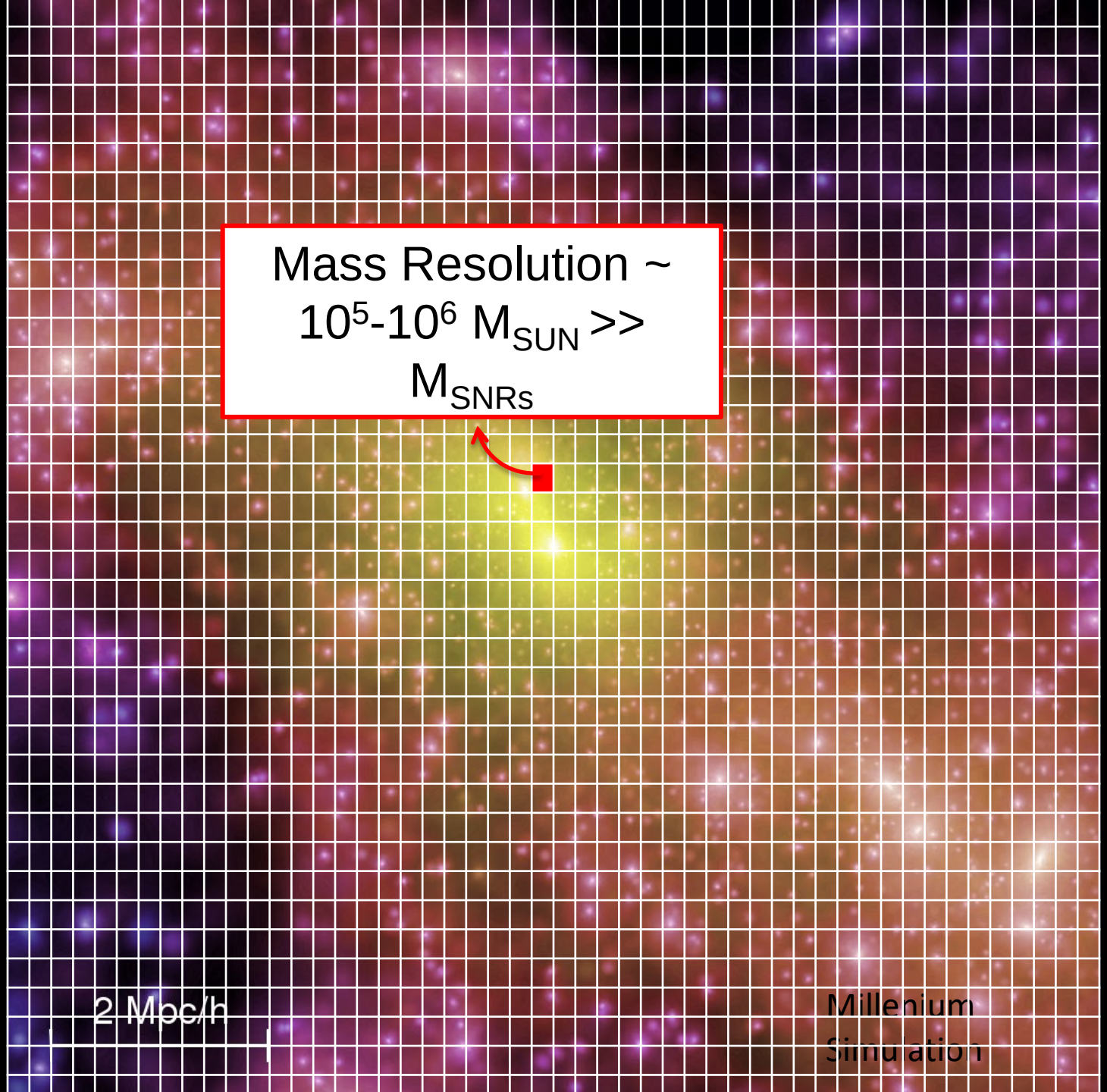


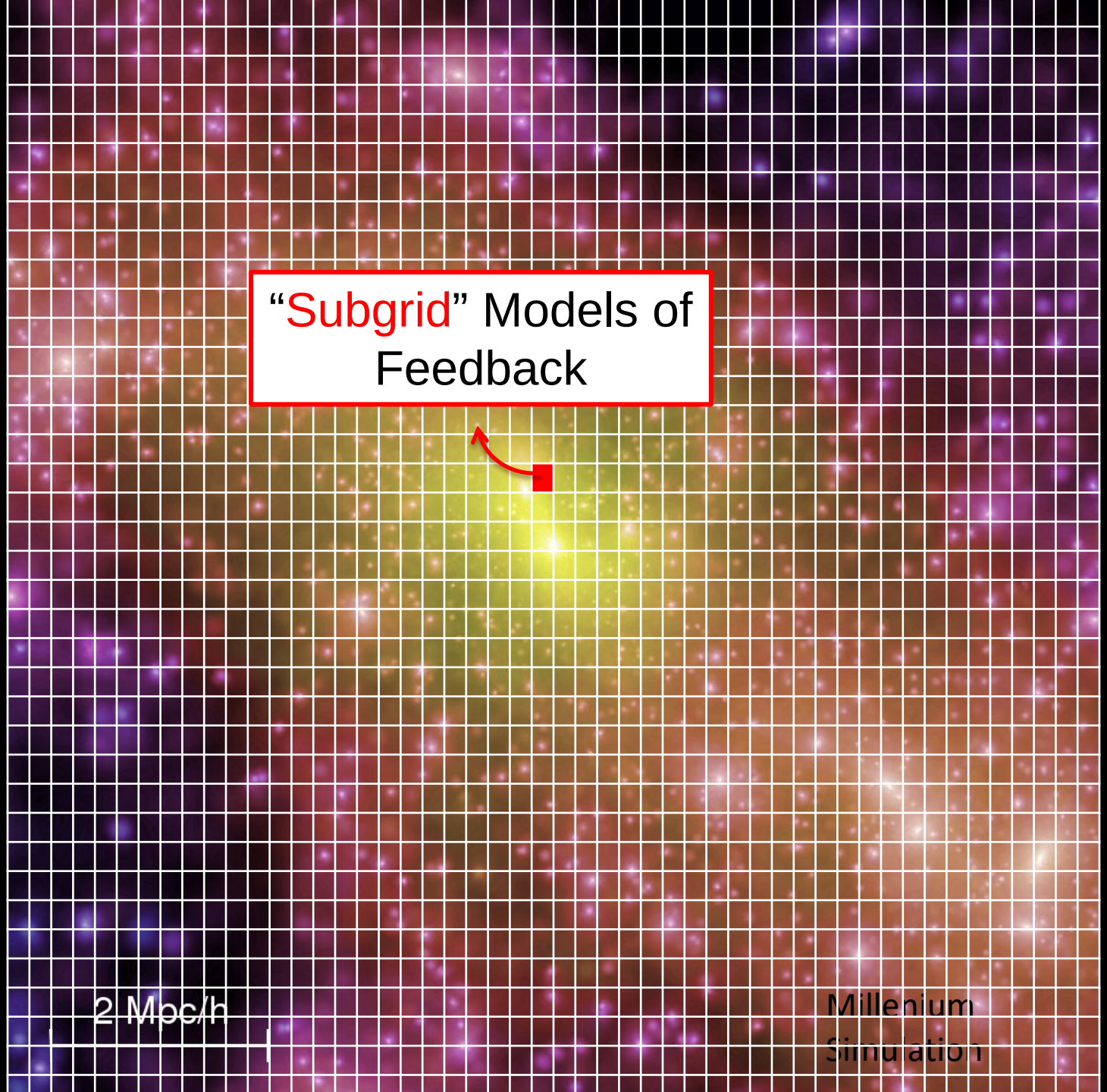





Millenium Simulation
2 Mpc/h


2 Mpc/h
Millenium
Simulation


Mass Resolution ~ 10^5-10^6 M_{SUN} >> M_{SNRs}
2 Mpc/h
Millenium Simulation


"Subgrid" Models of Feedback
2 Mpc/h
Millenium Simulation

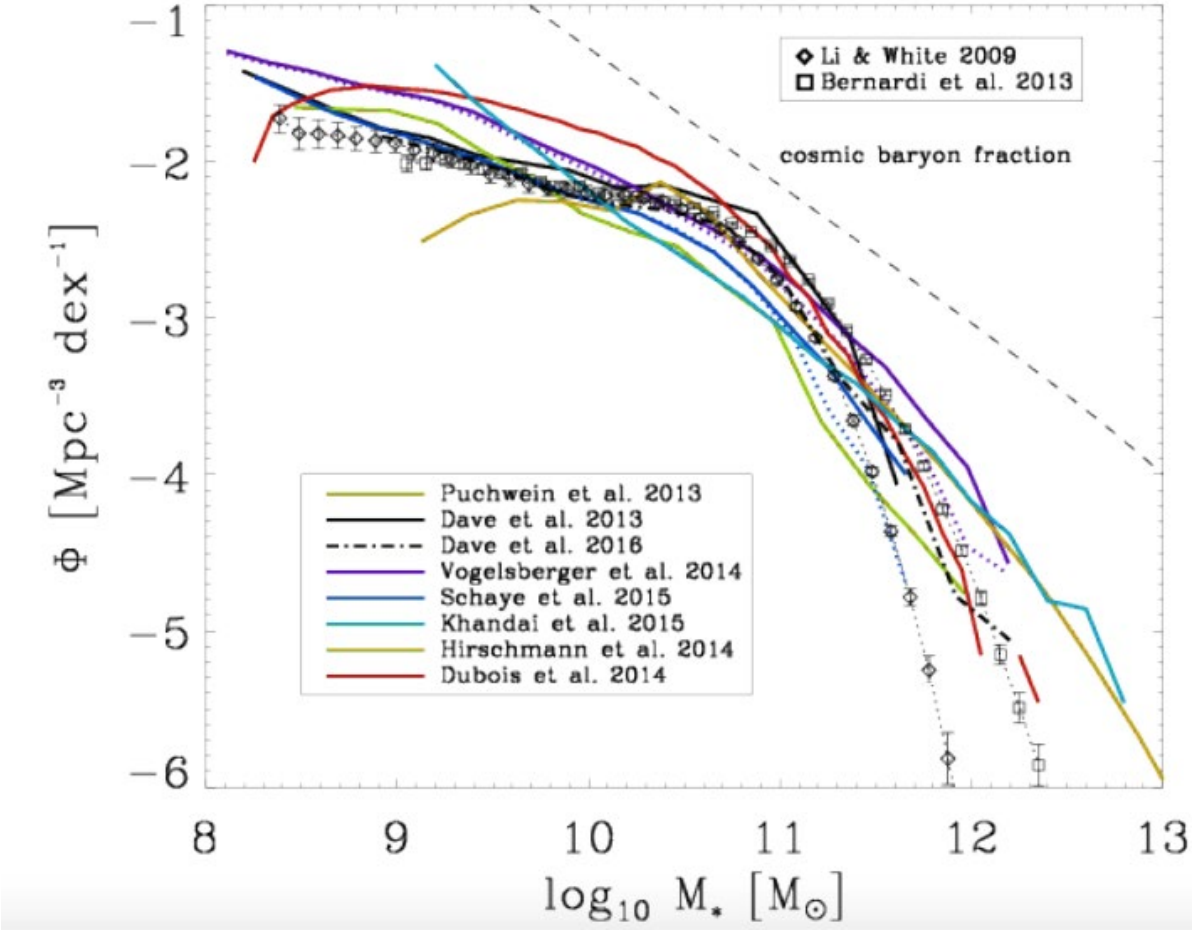
Many different sub-grid feedback models in the literature

(See Annual Review by Naab & Ostriker 2017 for a full review)

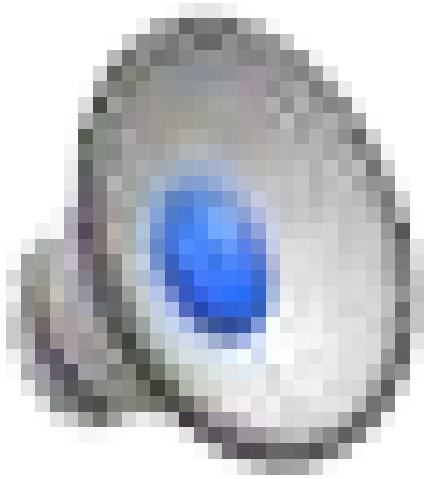
e.g. delayed-cooling, stochastic cooling, wind feedback

not always physically accurate

Subgrid models are often tuned to the statistical properties of galaxies

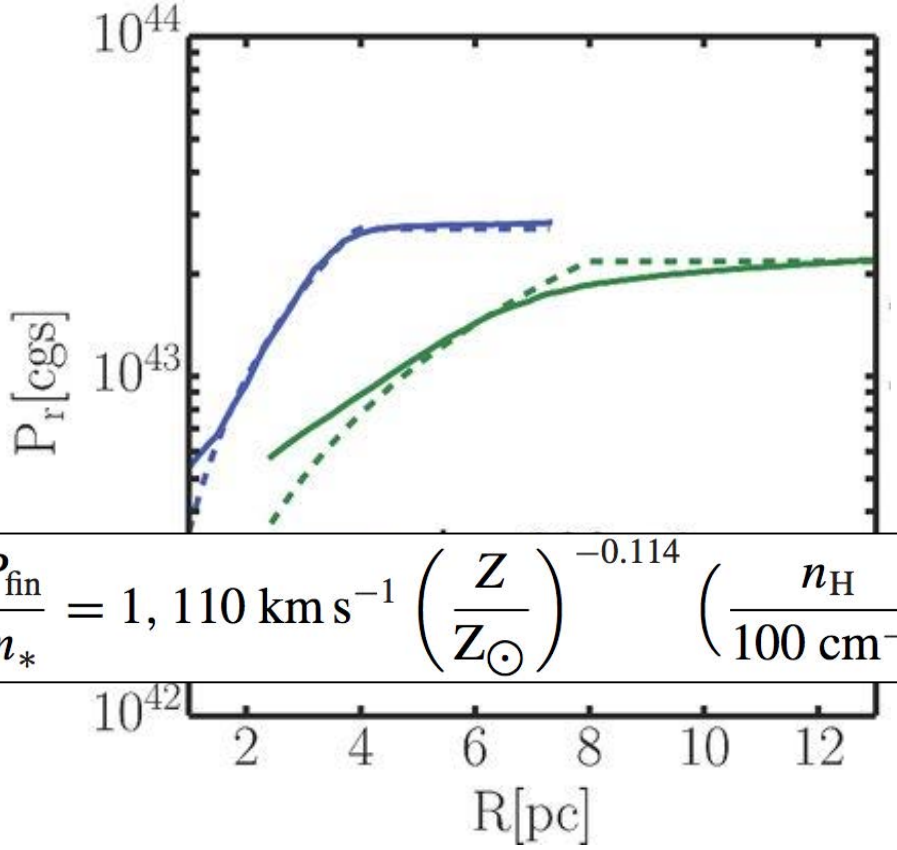


A different approach: making subgrid models from high-resolution simulations of Sedov SNRs



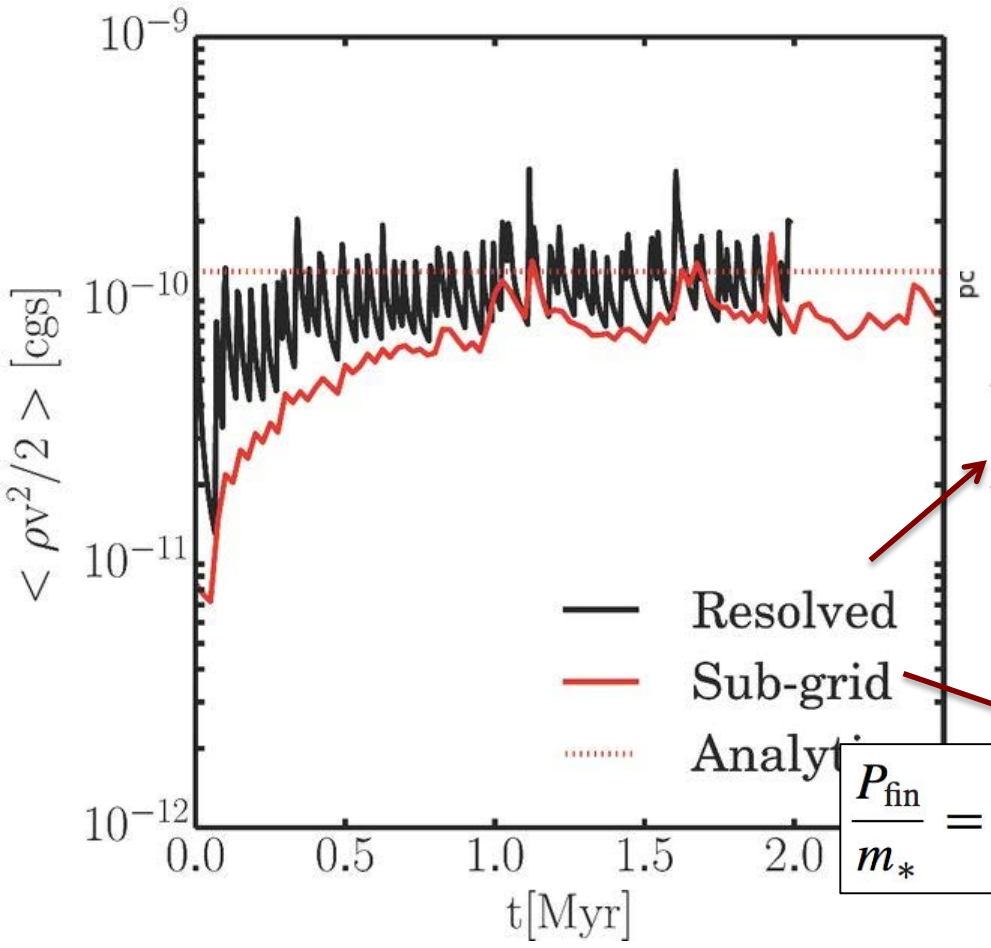
(Simulation by Martizzi, Faucher-Giguerre, & Quataert 2015)

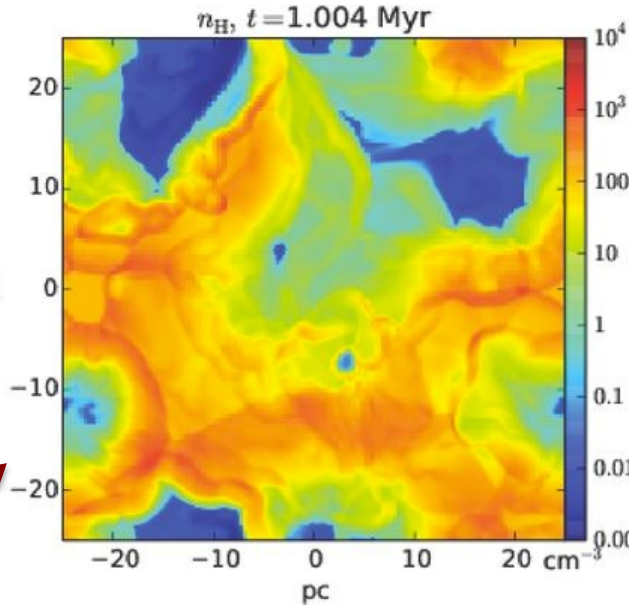
Inhomogenous ISM leads to 30% less momentum deposition at larger radii



$$\frac{P_{\rm fin}}{m_*} = 1,110\,{\rm km\,s^{-1}} \left(\frac{Z}{Z_\odot}\right)^{-0.114} \left(\frac{n_{\rm H}}{100\,{\rm cm^{-3}}}\right)^{-0.190}$$

Momentum subgrid model roughly consistent with numerical simulation

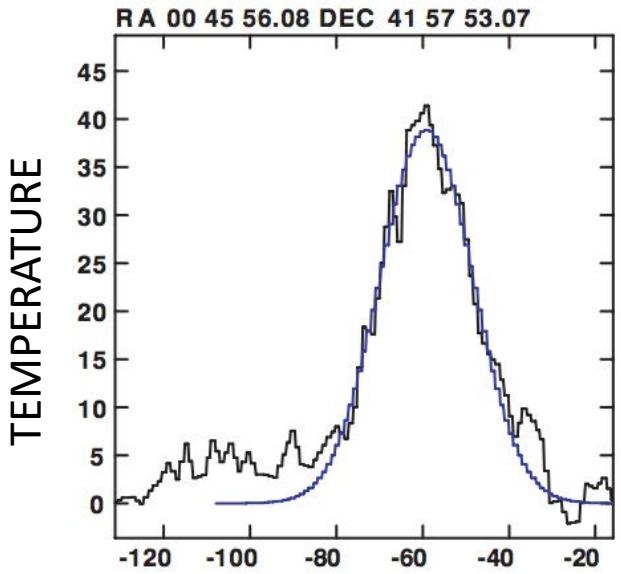


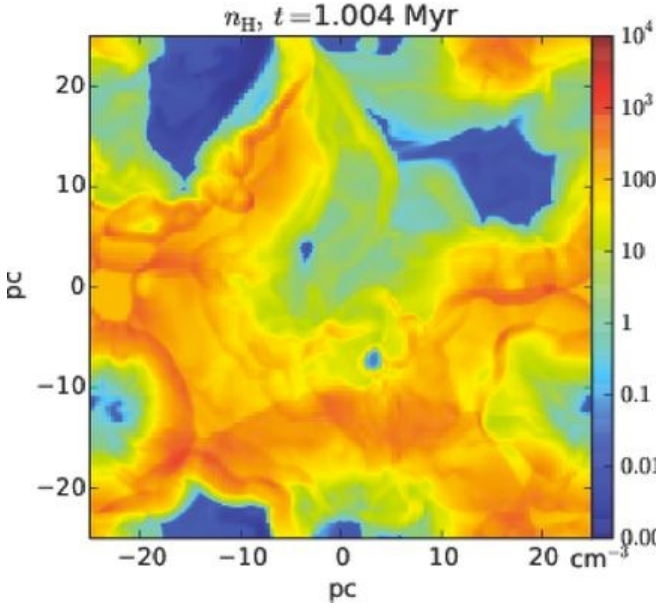


$$\frac{P_{\rm fin}}{m_*} = 1,110\,{\rm km\,s^{-1}} \left(\frac{Z}{Z_\odot}\right)^{-0.114} \left(\frac{n_{\rm H}}{100\,{\rm cm^{-3}}}\right)^{-0.1}$$

Is the momentum subgrid model consistent with observations of ISM?

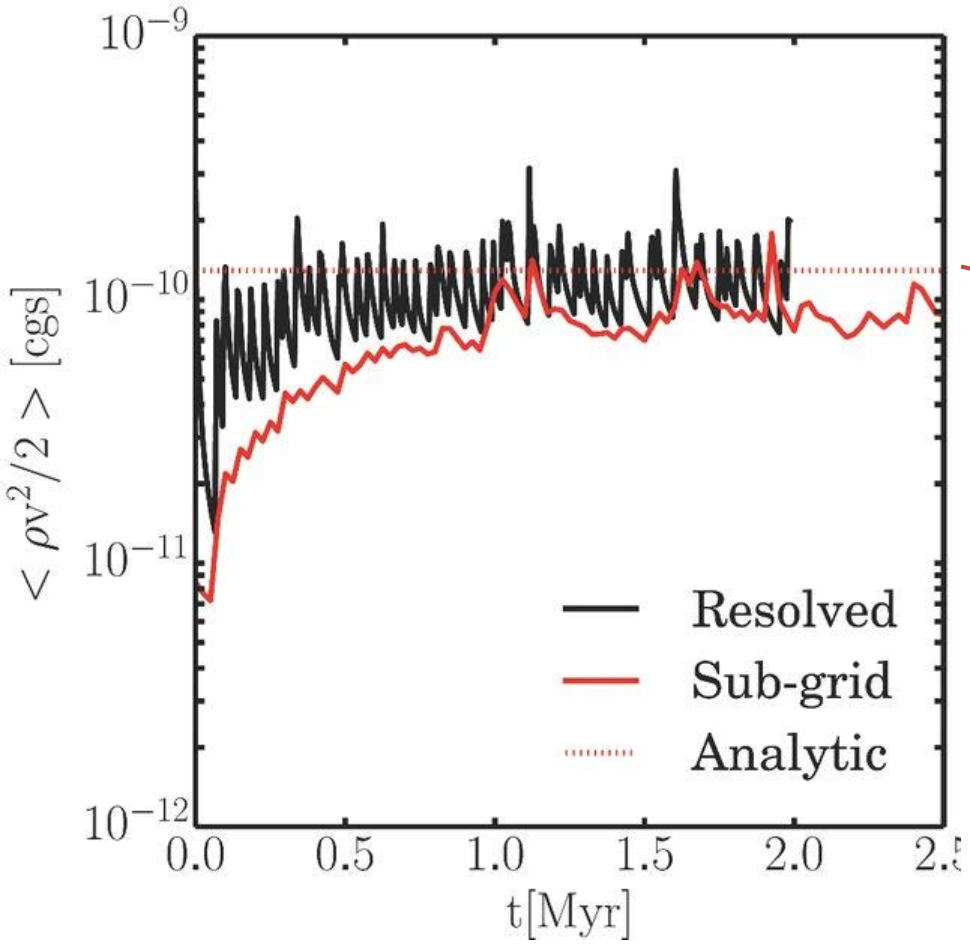
Broadening of lines indicate turbulence in ISM





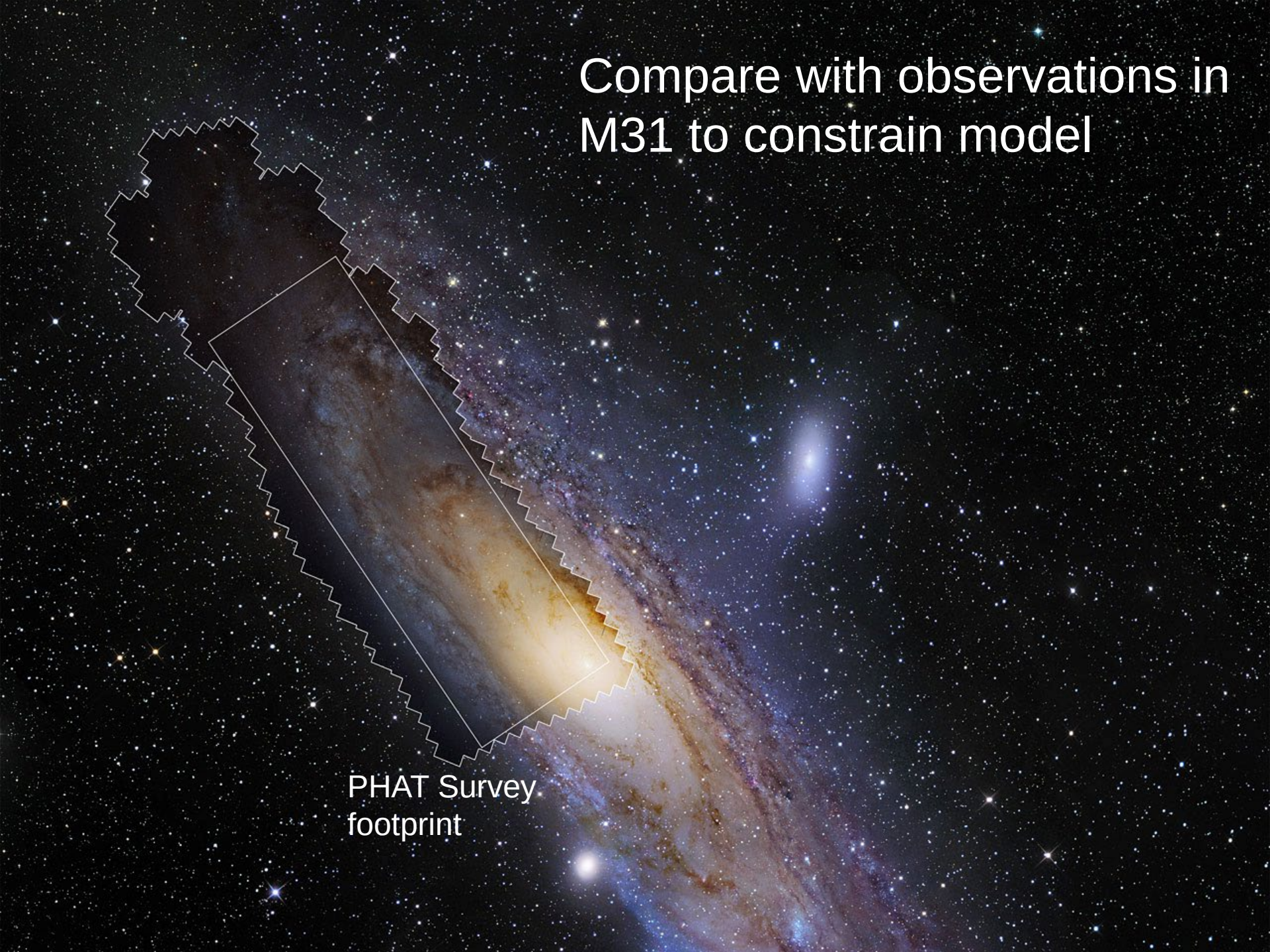
$< \rho v^2/2 > [\mathrm{cgs}]$

t[Myr]



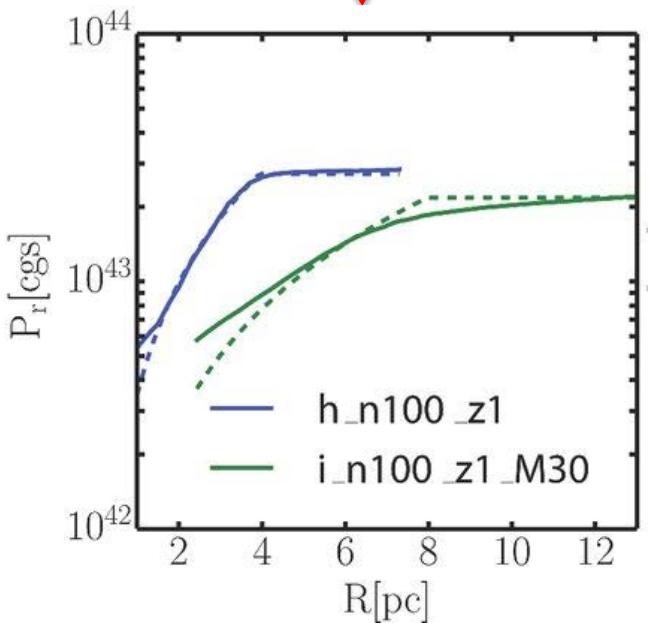
Rate of Turbulence Decay = Rate of Momentum Injection

$$\sigma \sim \left(\frac{P_{fin}}{\rho} \right)^{4/7} \dot{n}_{SN}^{3/7}$$

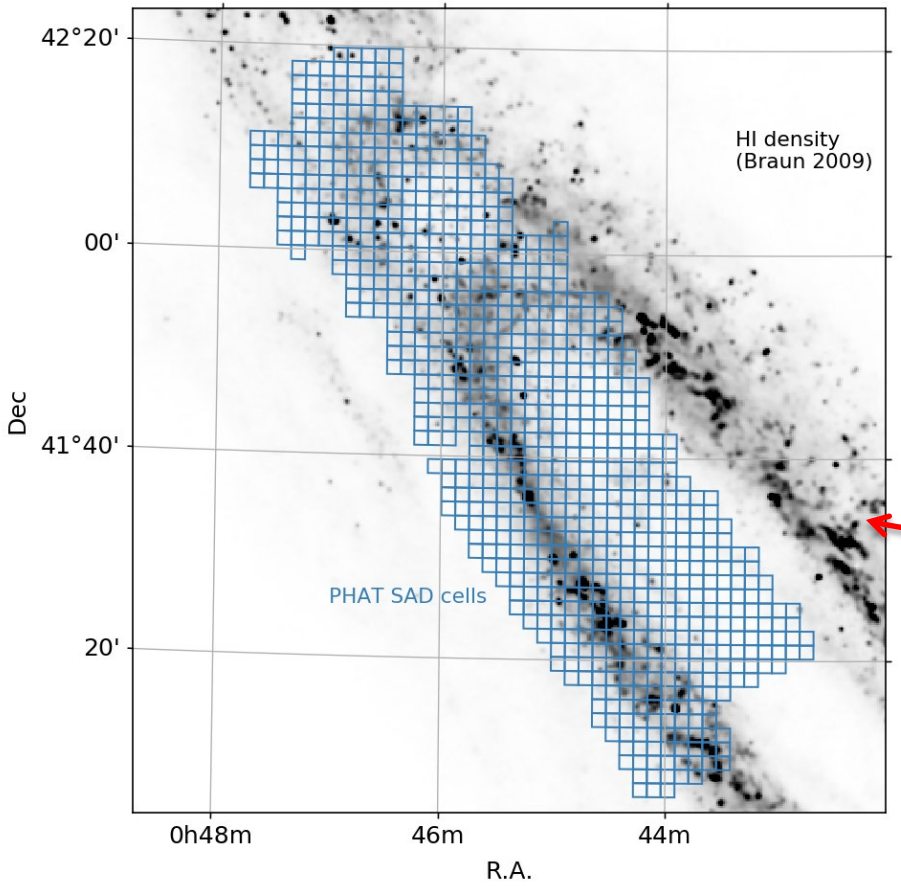

Compare with observations in M31 to constrain model
PHAT Survey footprint

Setting up the M31 model-observation comparison

$$\sigma \sim \left(\frac{P_{fin}}{\rho}\right)^{4/7} \dot{n}_{SN}^{3/7}$$

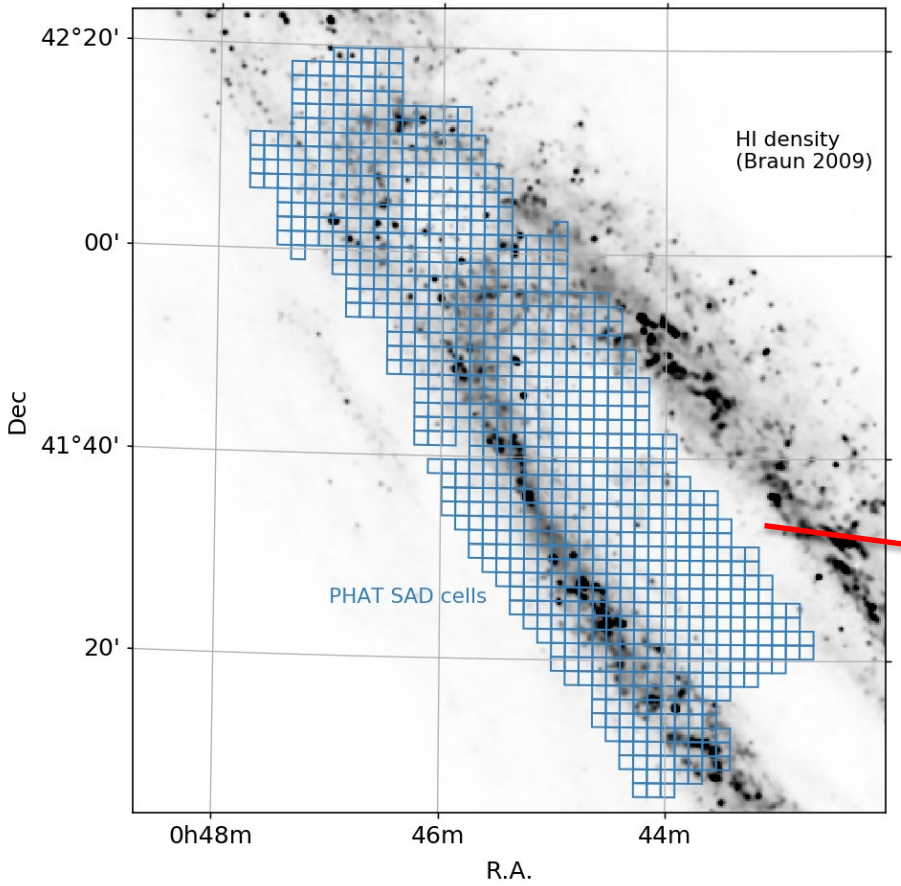


Setting up the M31 model-observation comparison



$$\sigma \sim \left(\frac{P_{fin}}{\rho} \right)^{4/7} \dot{n}_{SN}^{3/7}$$

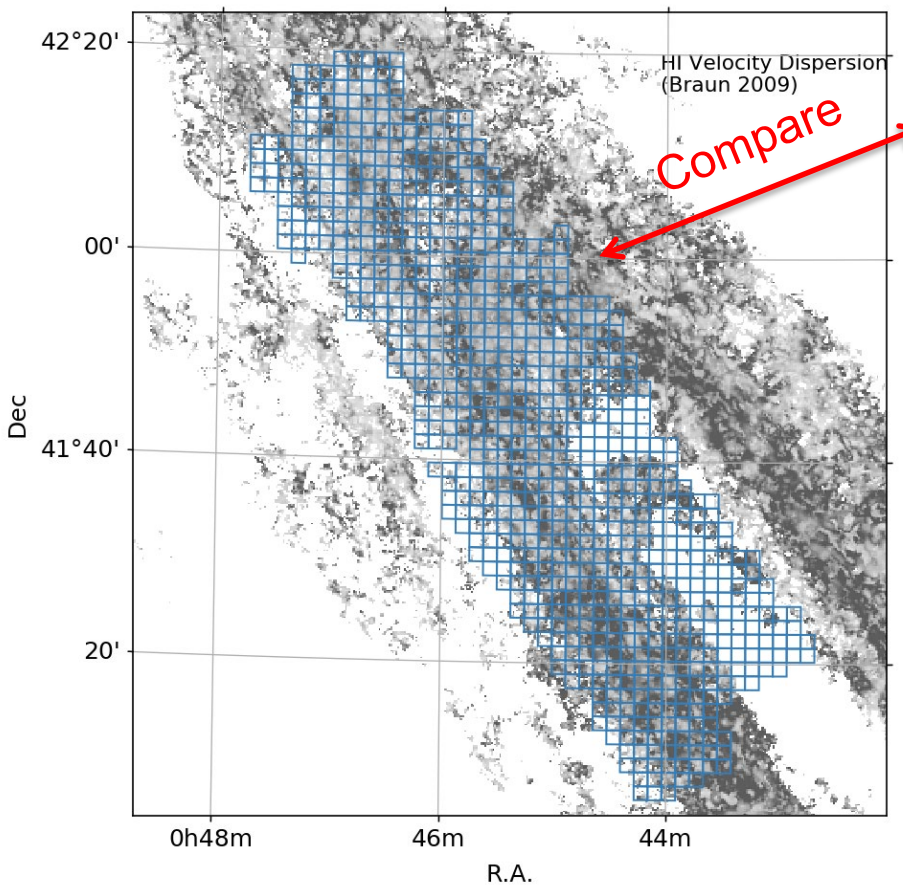
Setting up the M31 model-observation comparison



$$\sigma \sim \left(\frac{P_{fin}}{\rho}\right)^{4/7} \dot{n}_{SN}^{3/7}$$

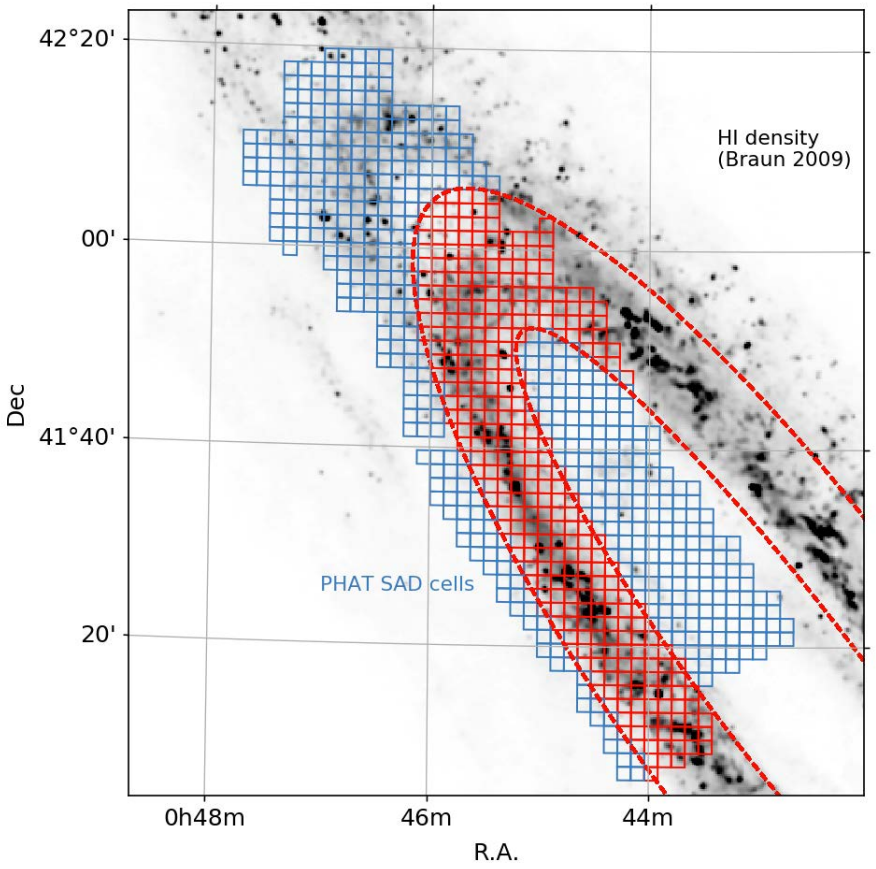
PHAT star-formation histories + SN delay-time distribution

Setting up the M31 model-observation comparison



$$\sigma \sim \left(\frac{P_{fin}}{\rho}\right)^{4/7} \dot{n}_{SN}^{3/7}$$

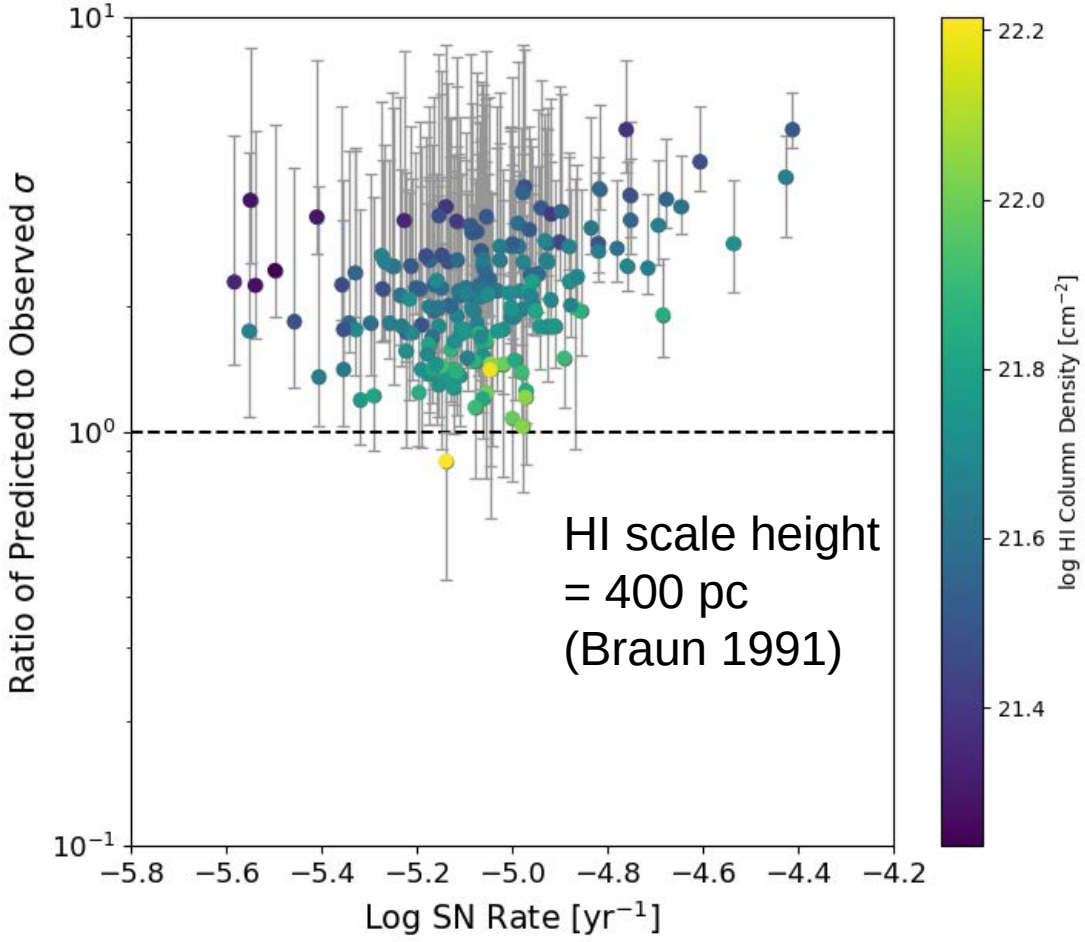
Setting up the M31 model-observation comparison



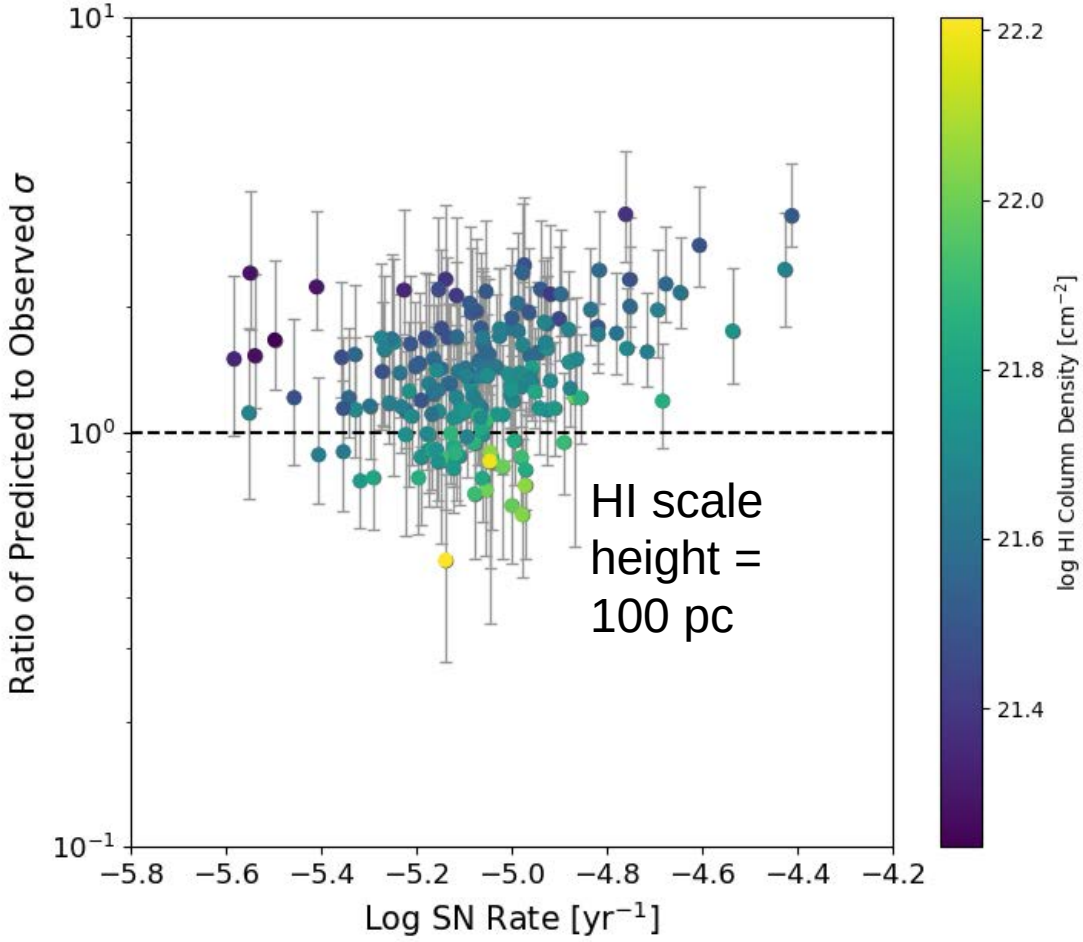
$$\sigma \sim \left(\frac{P_{fin}}{\rho}\right)^{4/7} \dot{n}_{SN}^{3/7}$$

Restrict analysis to the 10 kpc ring

Subgrid models overpredict the observed HI velocity dispersion in the ring



Subgrid models overpredict the observed HI velocity dispersion in the ring



Possible reasons for suppression of momentum

At high SN rates :-

- Overlapping of shocks?

At low densities

- SNRs merge before cooling (possible at lower densities)

Take-away Points

- Local Group is a powerful testbed for sub-grid models of supernova feedback.

- Comparison with M31’s ISM and PHAT data provided second-order corrections (e.g. overlapping shocks, merging before cooling) for momentum feedback models.