Impact of cosmic rays (CRs) on thermal and dynamical evolution of a galaxy

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Collaborators

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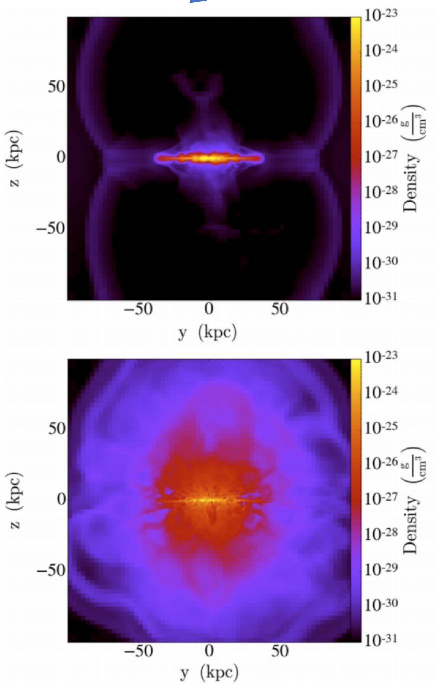
Evolution of a galaxy

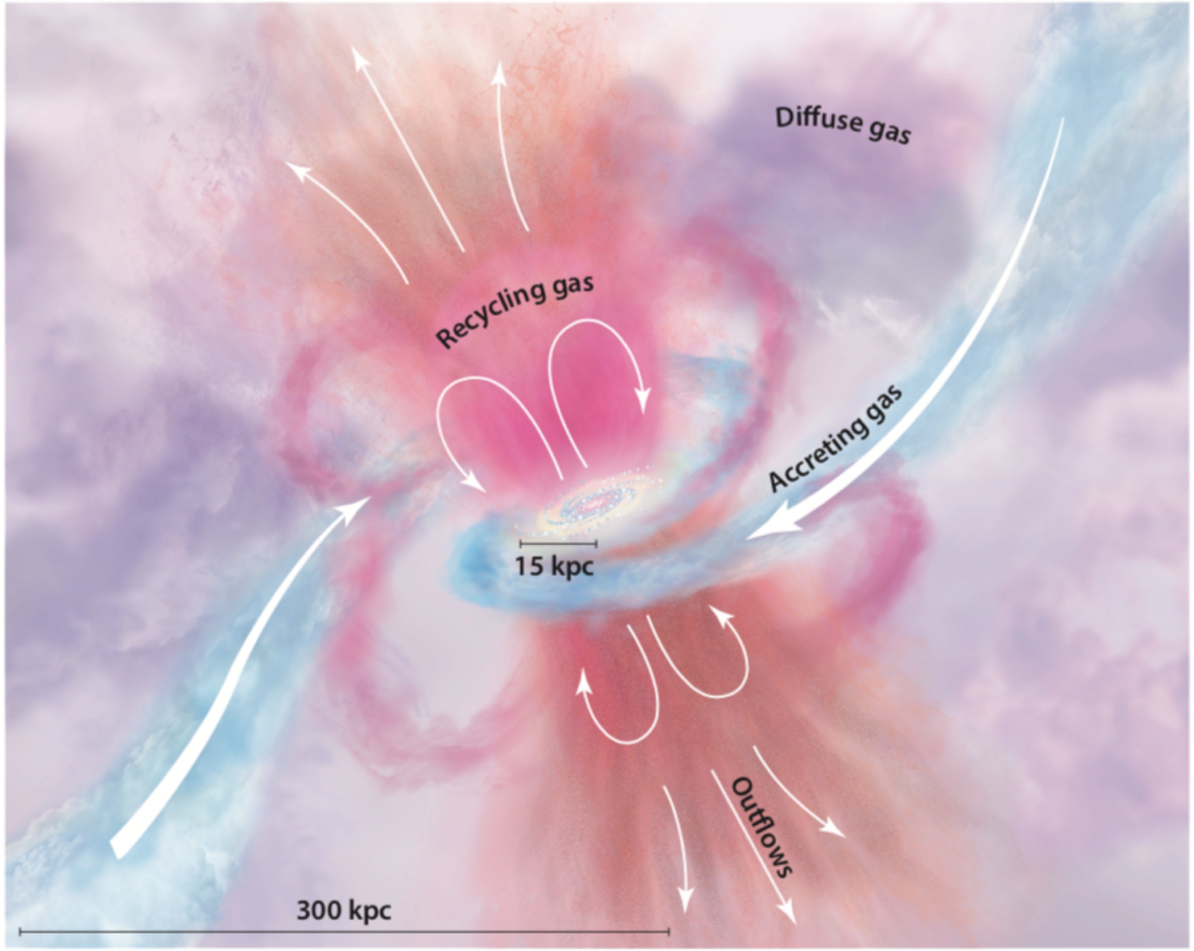
Gas density

No CRs



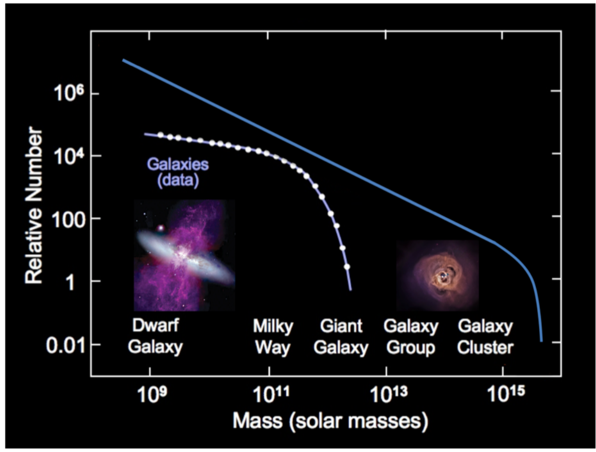
With CRs

Ruszkowski et al. 2017



Tumlinson et al. 2017

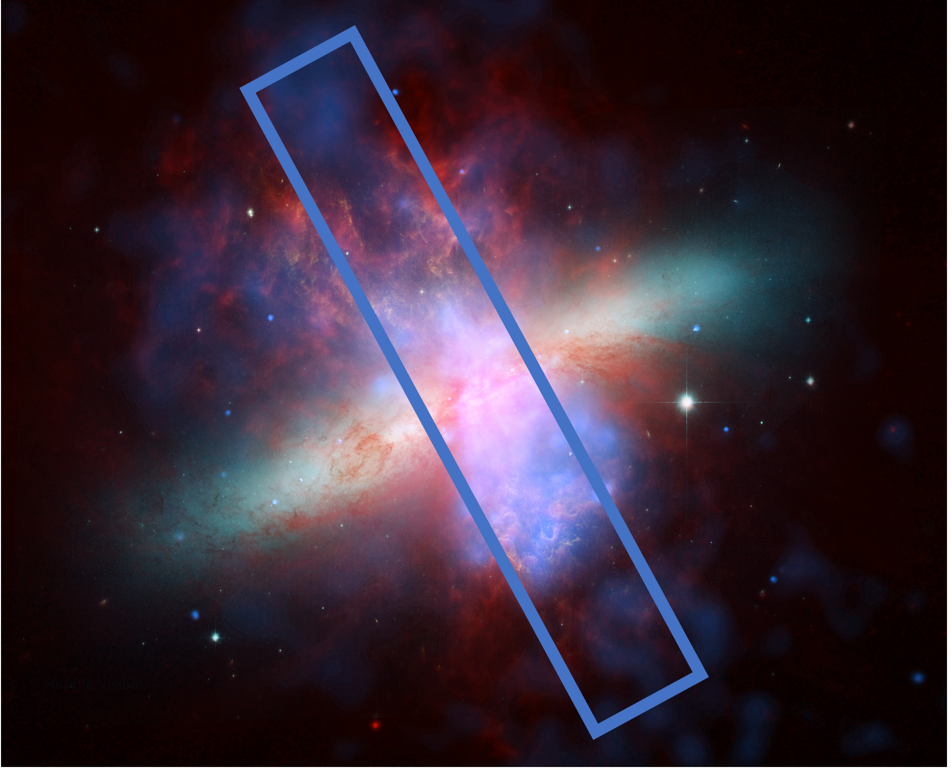
Influence of galactic feedback processes

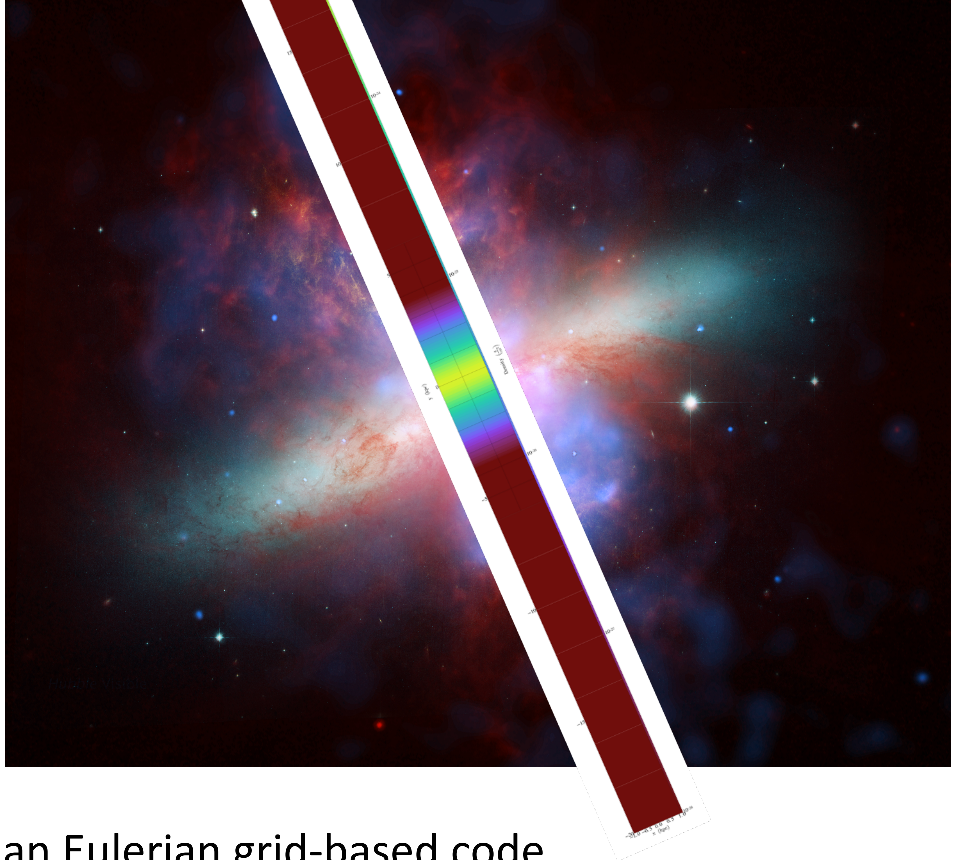


Blue line is expected number vs. total mass

Yellow dots is the observed line

Less baryons found at a given mass due to expulsion by feedback





- MHD-coupled CR fluid equations
  - Gas hydrodynamics with self-gravity
  - Magnetic fields
  - CR evolved as separate diffusive fluid coupled to gas
- Feedback
  - Stellar population particles
  - Supernovae and radiation
  - Radiative cooling/heating

FLASH, an Eulerian grid-based code

Resolution up to 15 pc

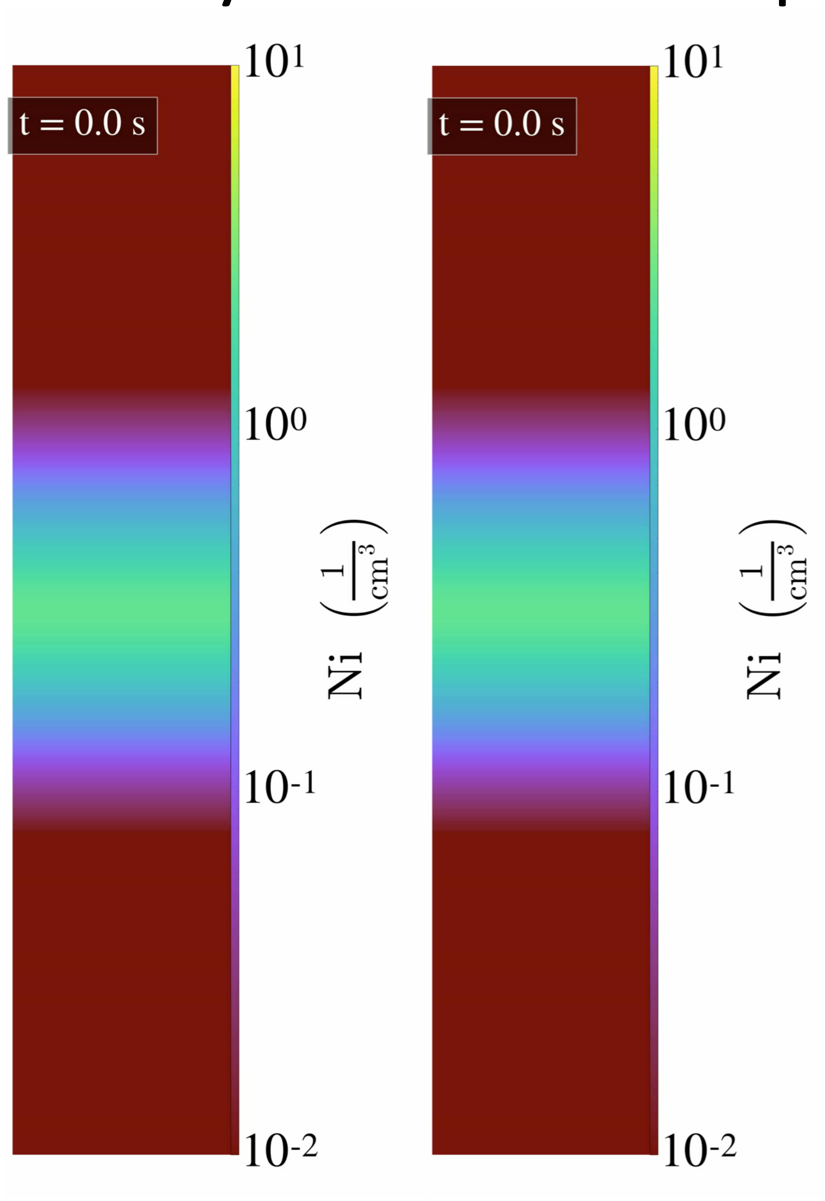
120 cores

BH Tree N-body gravity solver for particles

Timestep is limited by CR diffusion (slow simulation compared to simulations without CRs)

Simulations have been completed on Nasa Pleiades and Comet

Dynamical impact of CRs and turbulence

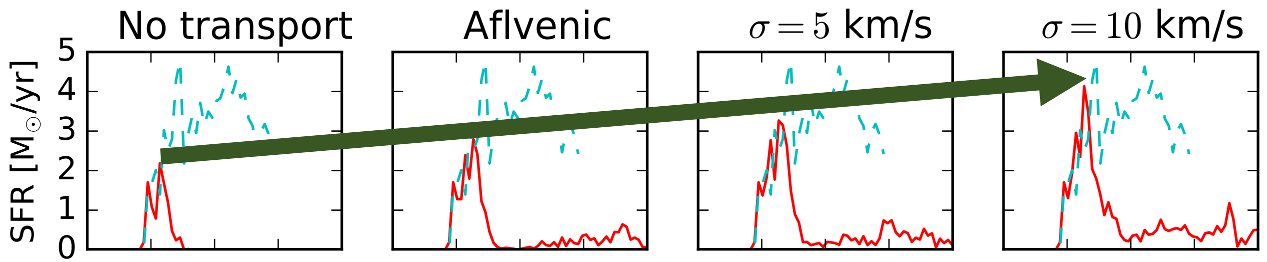


No turbulence

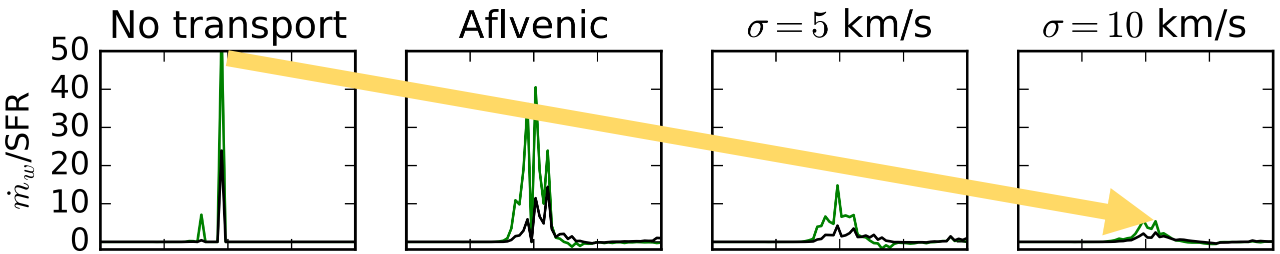
Stronger Turbulence

With stronger turbulence (measured by velocity dispersion sigma):

Higher peak SFR



Suppressed peak mass loading

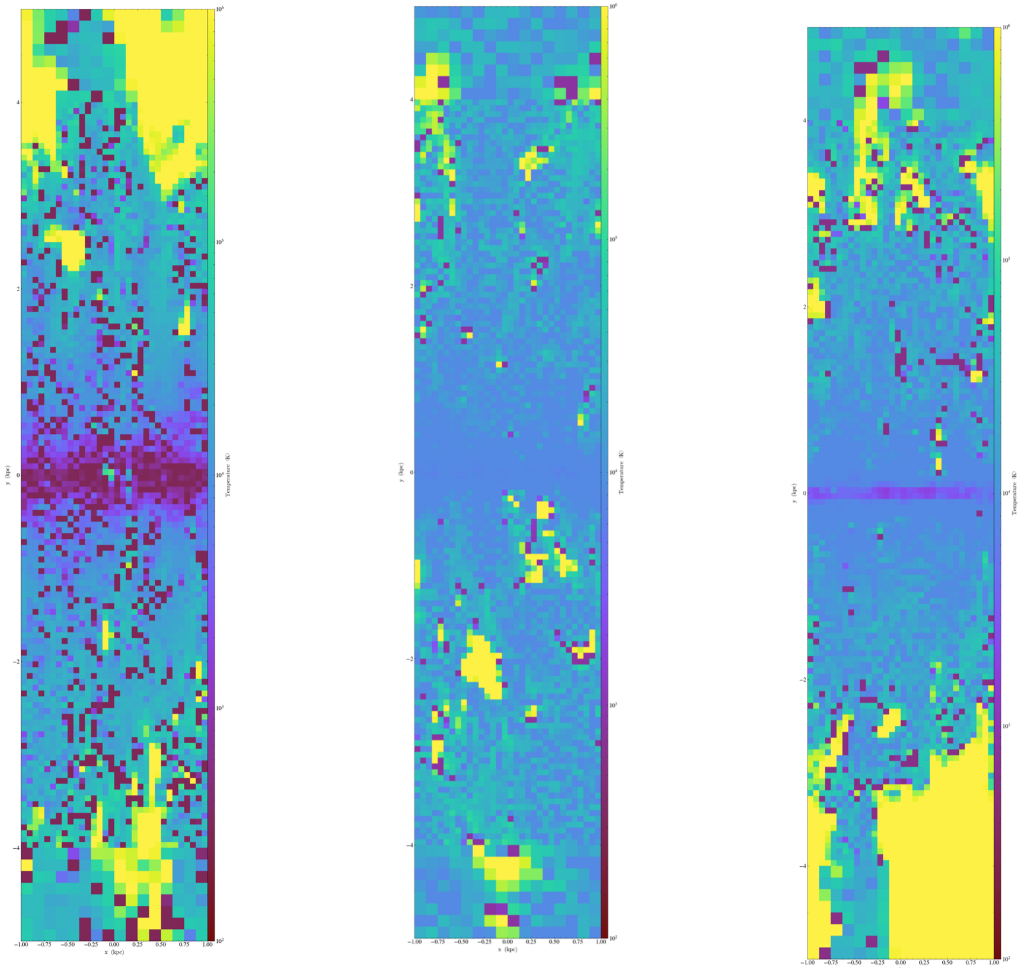


Regions above galactic midplane systematically slightly denser
CR spatial distribution is much more extended

Holguin et al. 2018 (submitted to MNRAS, under review)

Thermal impact of CRs and radiation (in progress)

Temperature slice of simulation



No radiation heating

Photoionization Heating

Photoelectric Heating

Purple: Cold gas ($T < 10^3$); Blue: Warm ($T = 10^4$ K); Yellow: Hot ($T = 10^6$ K)

- In order to study the thermal state of a galaxy, we need to account for all sources of thermal energy
  - Supernovae shock heating and CRs (done prev.)
  - Photoionization heating (hydrogen)
    - Extreme ultraviolet radiation
  - Photoelectric heating (interstellar dust)
    - Far infrared radiation
- Simulations with radiation heating included are hotter in regions around galactic disk
- Use simulation to produce estimates of metal (heavier than H, He) ionization state and abundance, and compare with observations

Future work

- Implementing global simulations with more sophisticated feedback will require more efficient code to minimize computational cost
- Use/learn new HPC techniques
  - Implement more efficient CR transport code
  - Produce observable predictions (spectra)