The effects of cosmic ray feedback on Milky Way-like galaxies in cosmological simulations

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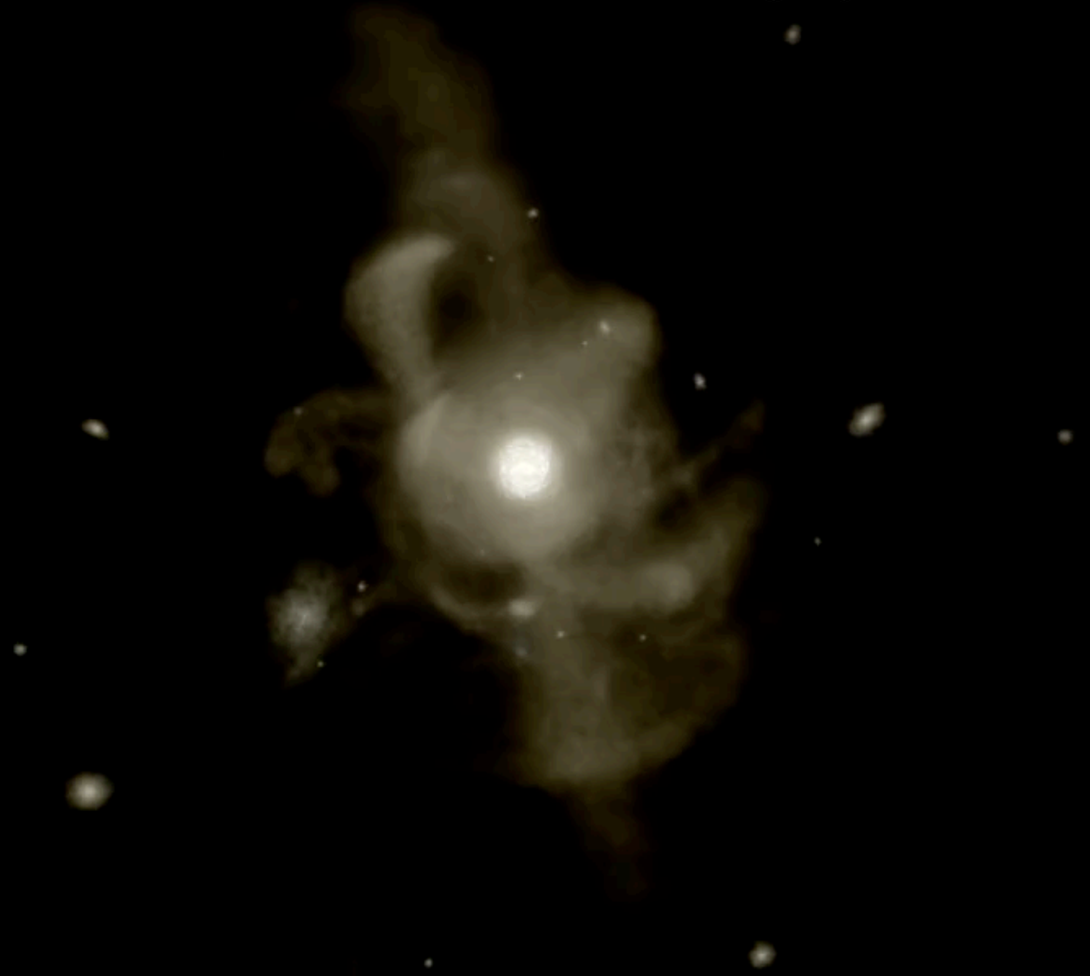

AIP

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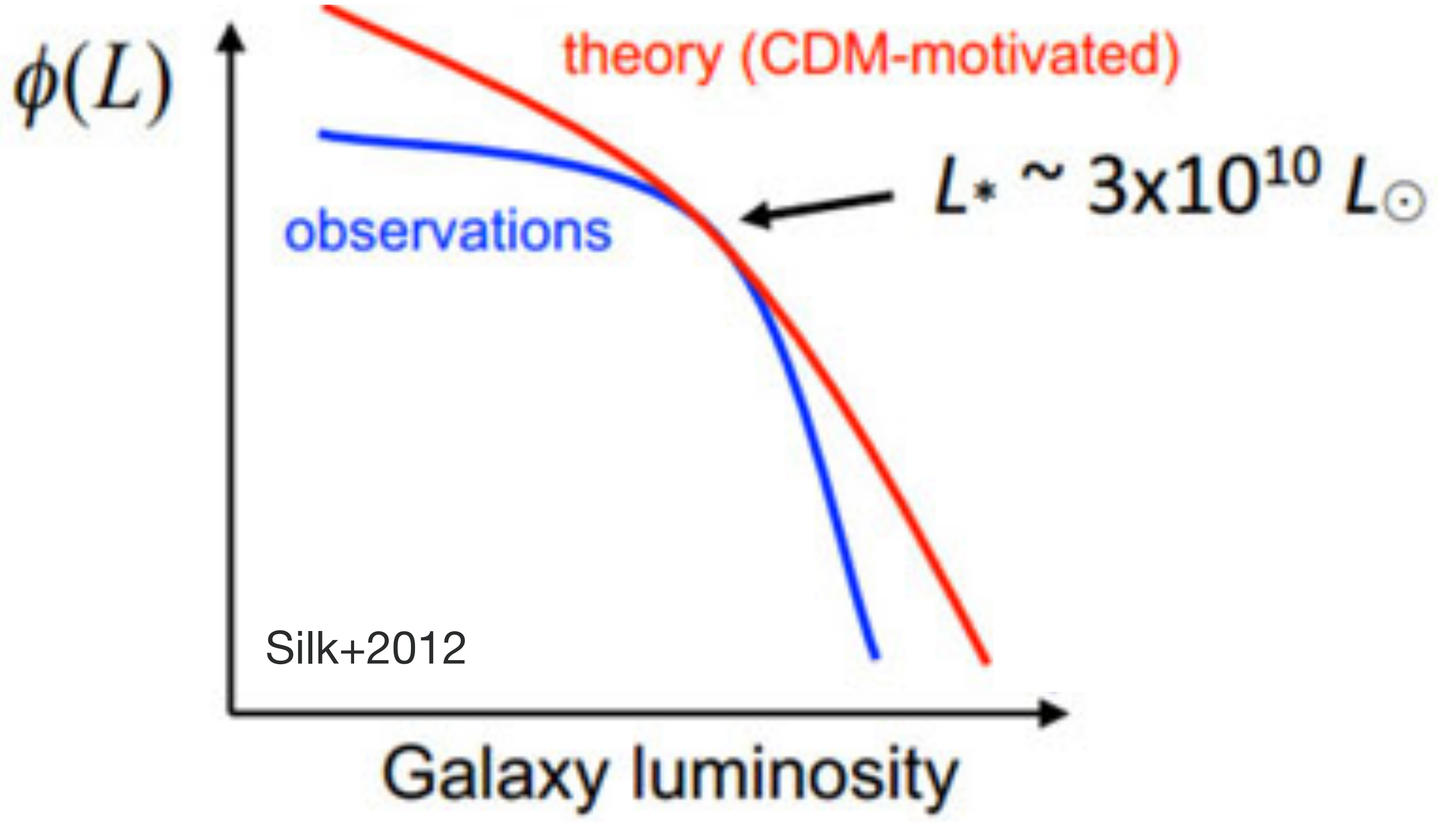
Key ingredient in galaxy formation: Feedback



LCDM and observed luminosity functions show different shapes

—> necessity of feedback

from T. Buck’s PhD Thesis

Sources of (stellar) feedback still unclear

M82: NASA/JPL-Caltech/STScI/CXC/UofA

Galactic outflows powered by:

- thermal pressure
- radiation pressure and photoionisation
- cosmic ray pressure and Alfvén wave heating

Cosmological simulations of CR feedback

- simulation setup: Cosmological sims as part of AURIGA

- properties of the stellar and gaseous disks

- properties of the CGM

The Auriga simulations: cosmological "zoom" simulations for the formation of Milky Way mass galaxies (Grand et al. 2017)

Galaxy formation model

Reionisation:
- *spatially uniform UV background (Faucher-Giguere 2009)*
- *completes at z=6*

Star formation and ISM:
- *cold clouds in a warm ambient medium (Springel & Hernquist 2003)*
- *density threshold crit (>0.13/cc)*

Cooling:
- *primordial*
- *metal line*

Black holes:
- *seeded at ~10^5 Msun*
- *growth (Bondi accretion)*

Energetic feedback:
- *SNII winds (non-local, thermal+kinetic)*
- *AGN (Radio+quasar)*

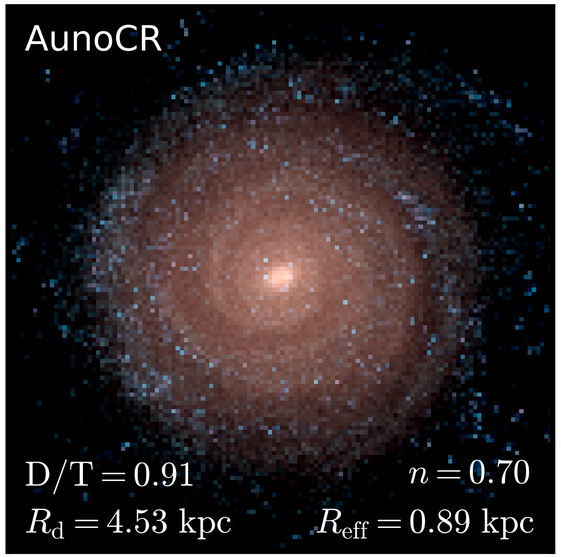
Mass & Metal enrichment:
- *SN Ia & AGB (local,isotropic)*

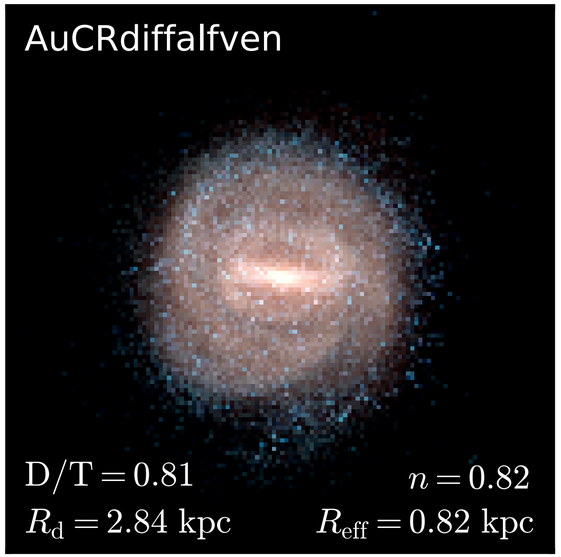
Magnetic fields seeded at 10^{-10}cG at z=128

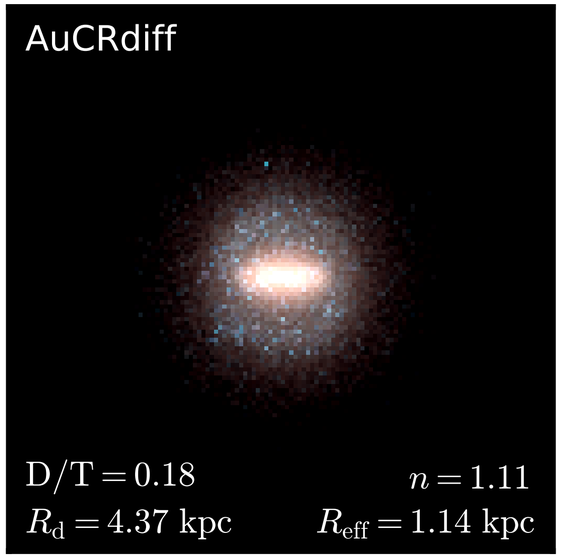
thanks to Rob Grand for providing the slide

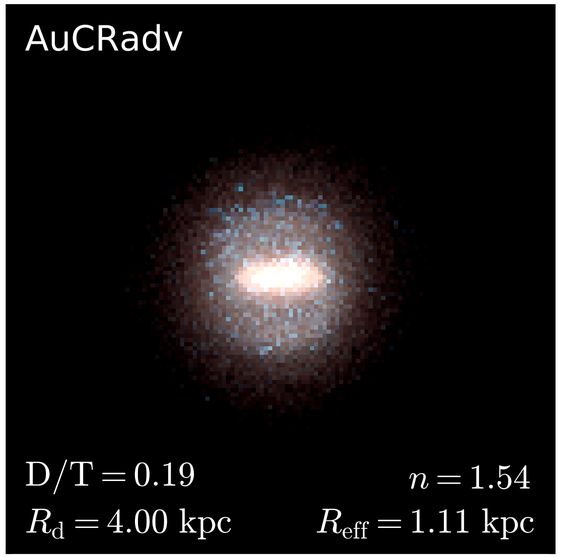
8 Cosmological sims as part of AURIGA

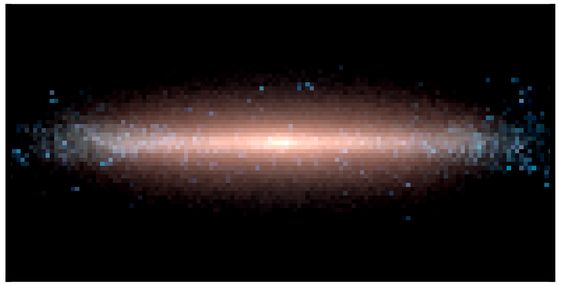
- 2 haloes with 4 different physical feedback models:

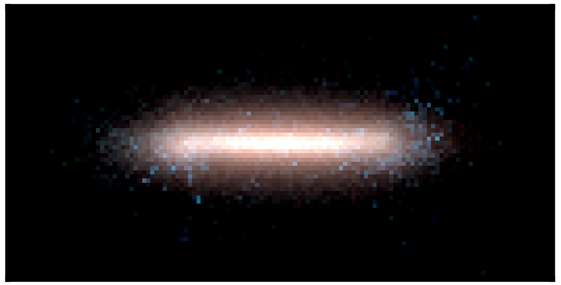


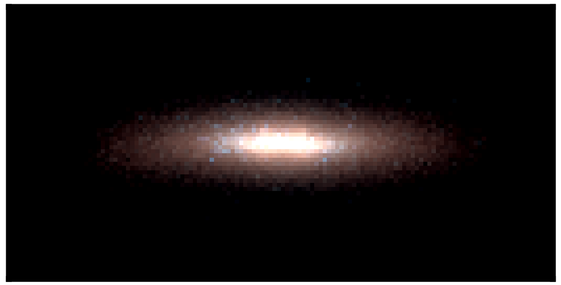


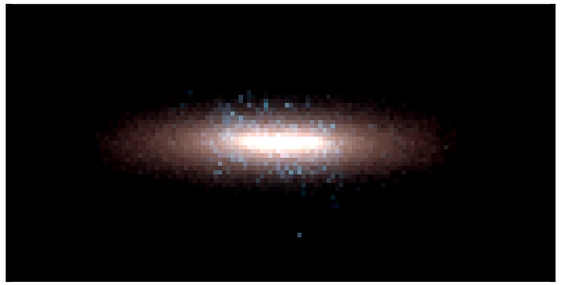




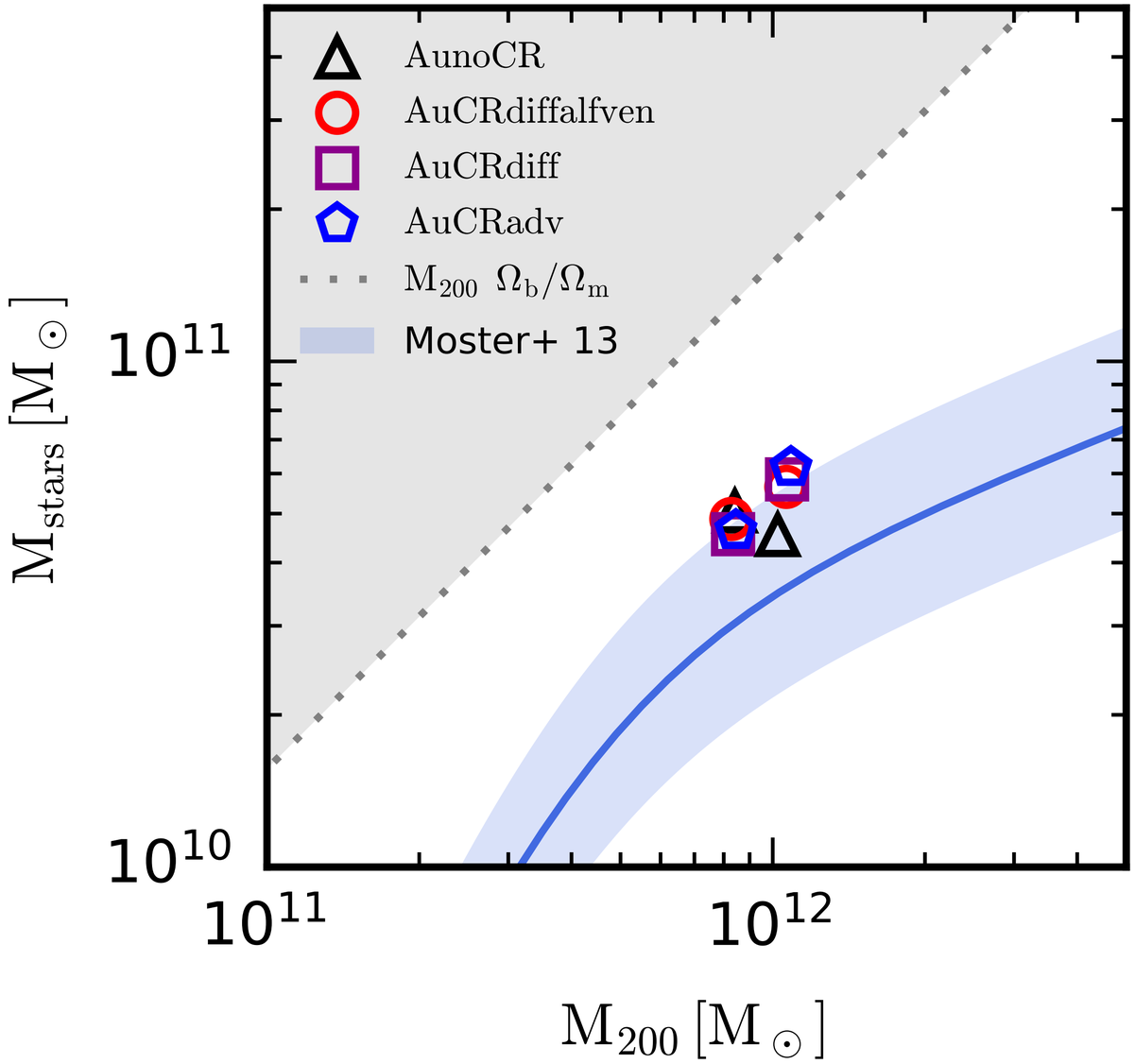




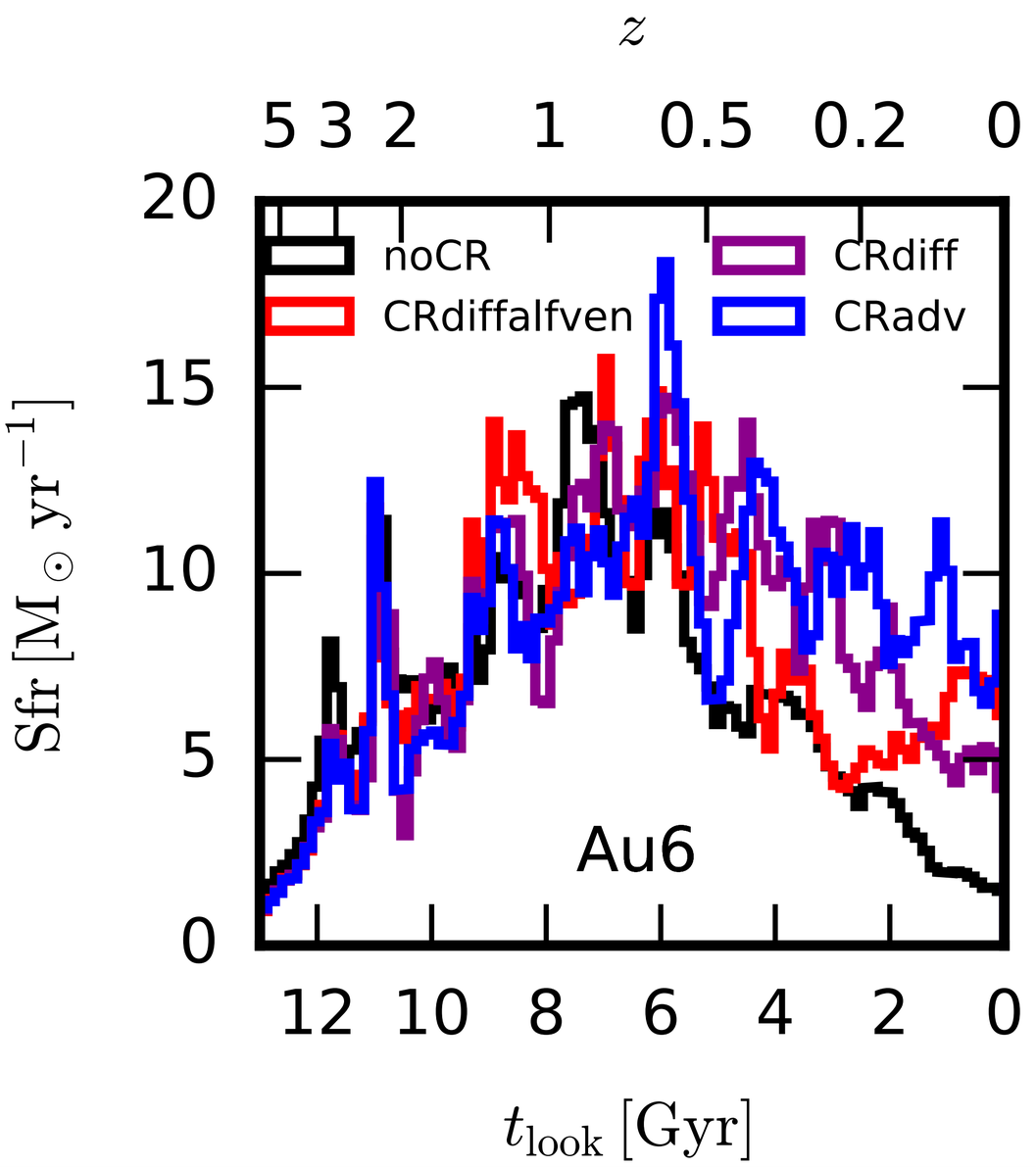


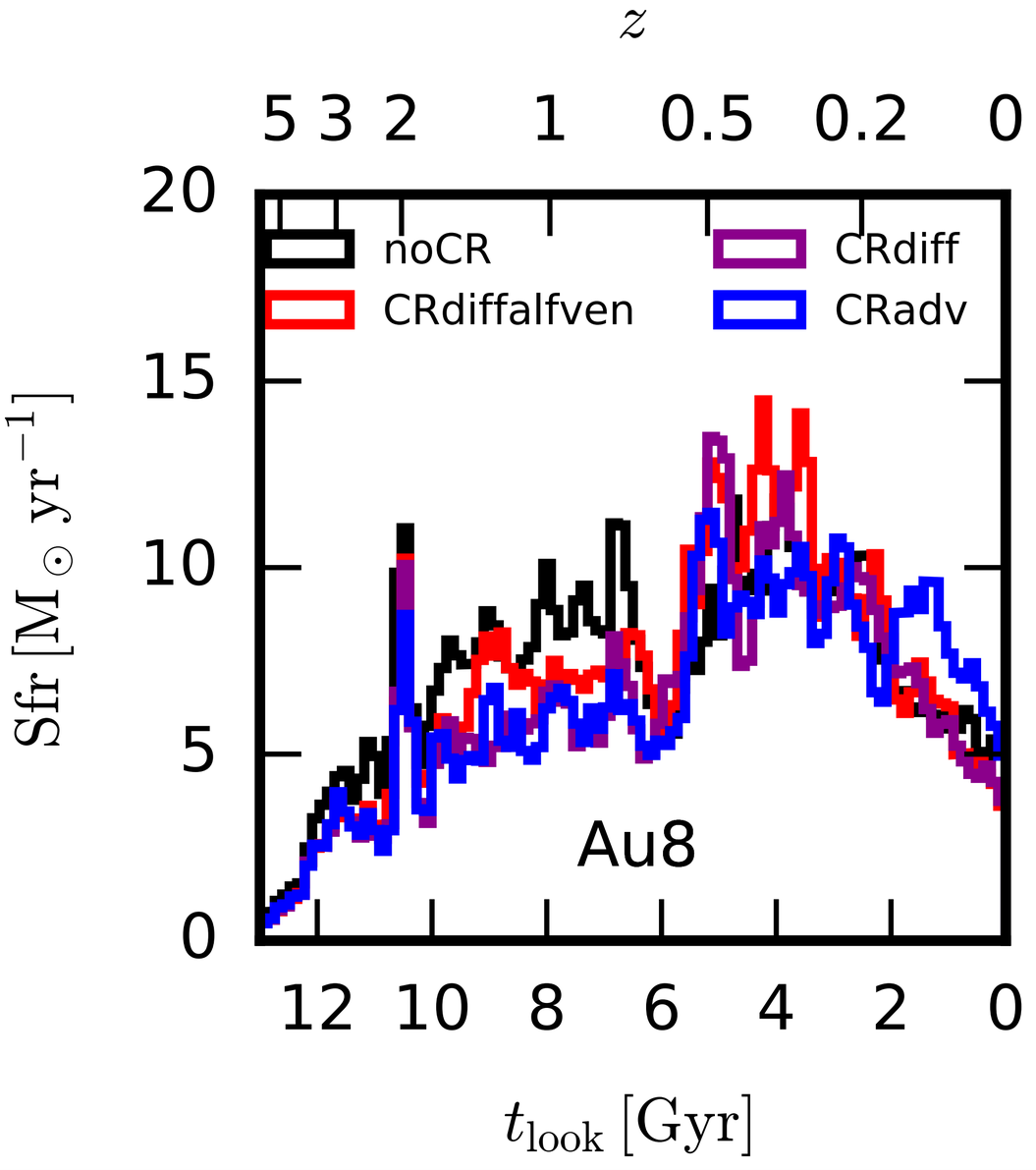


Stellar masses are robust!

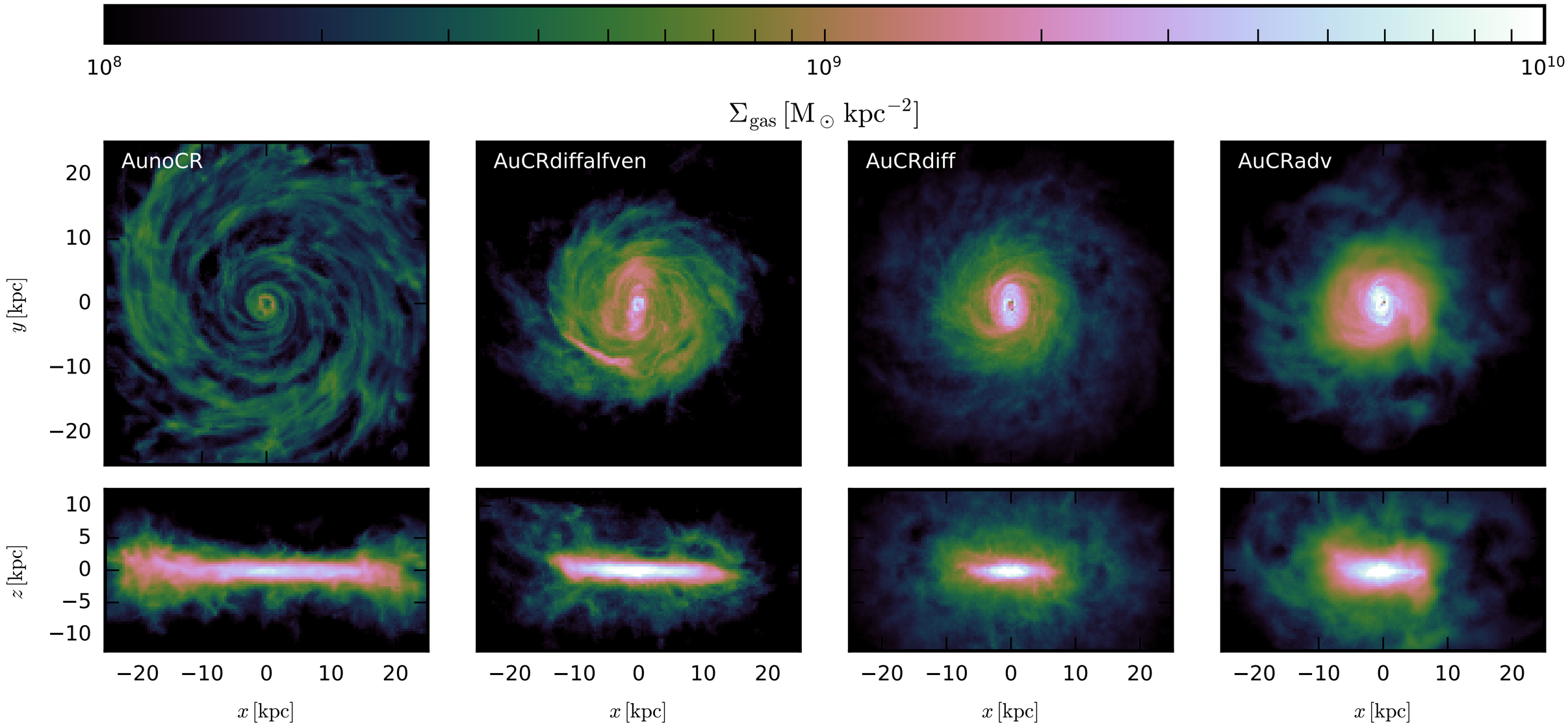


SFRs are robust!

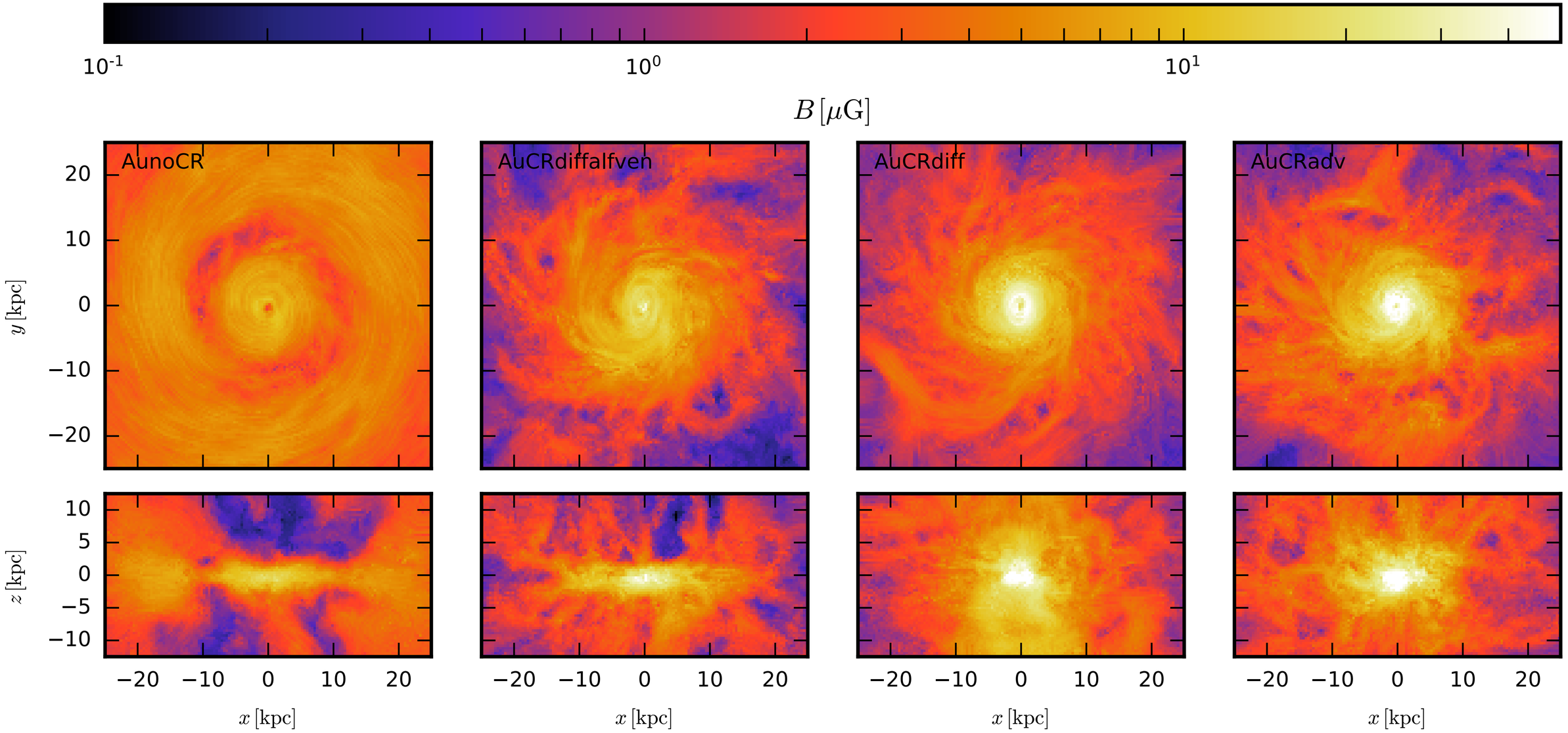




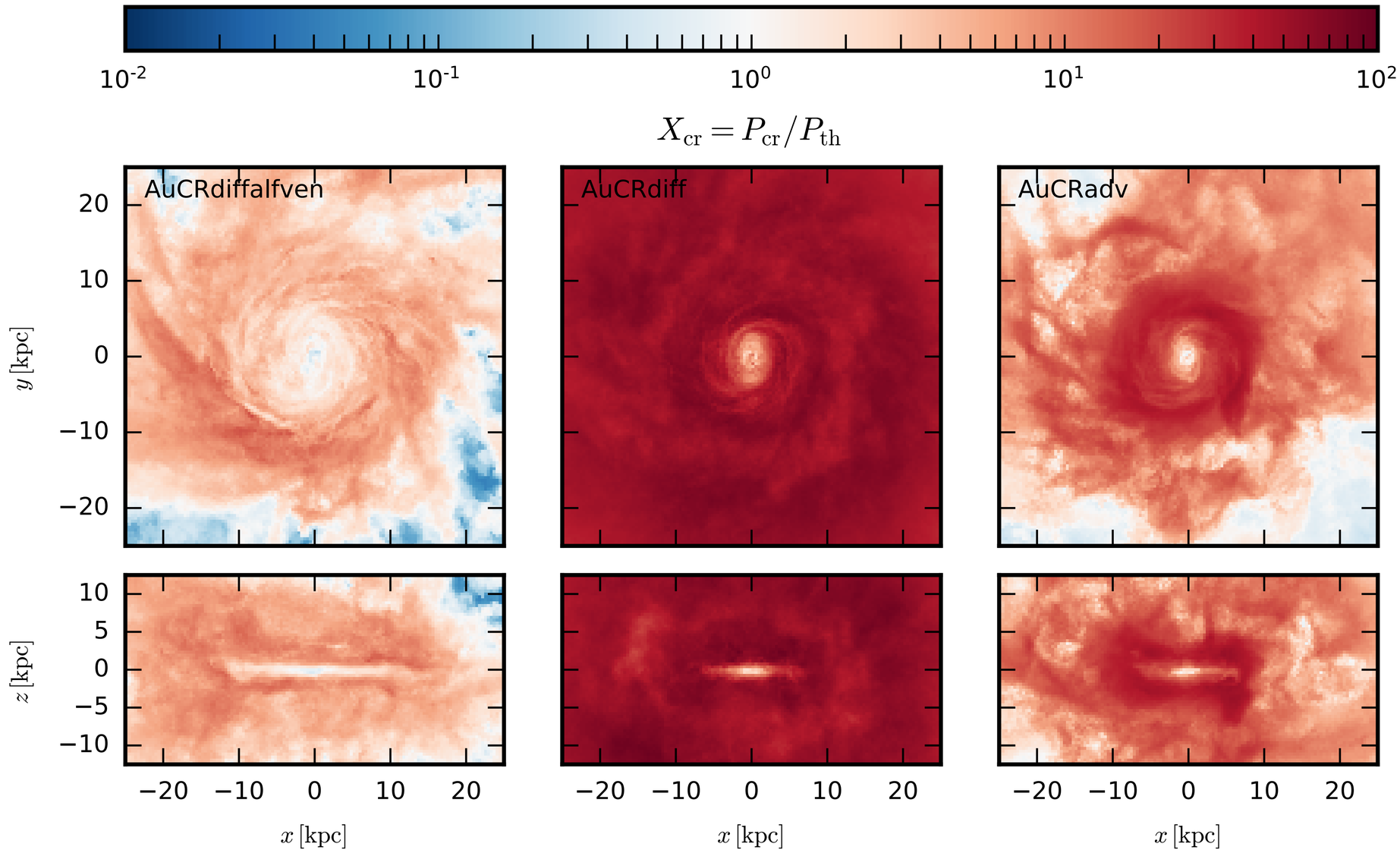
CRs have a strong impact on the gas disk



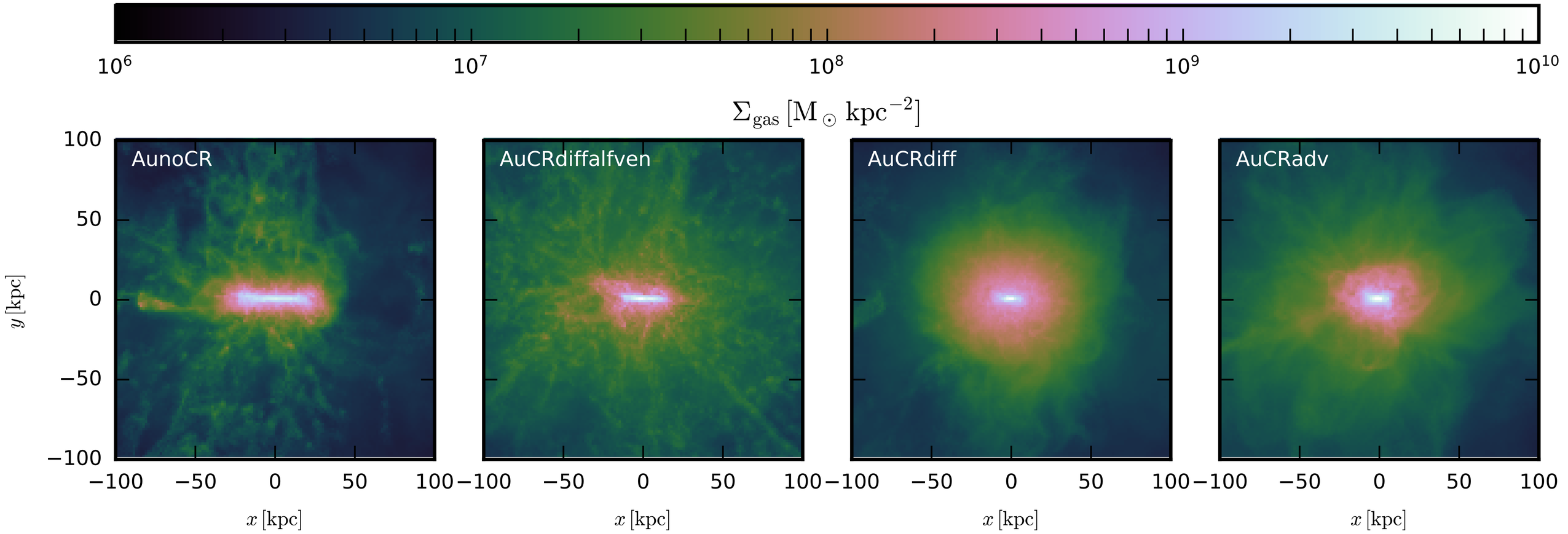
Galaxy disk properties: The B-field



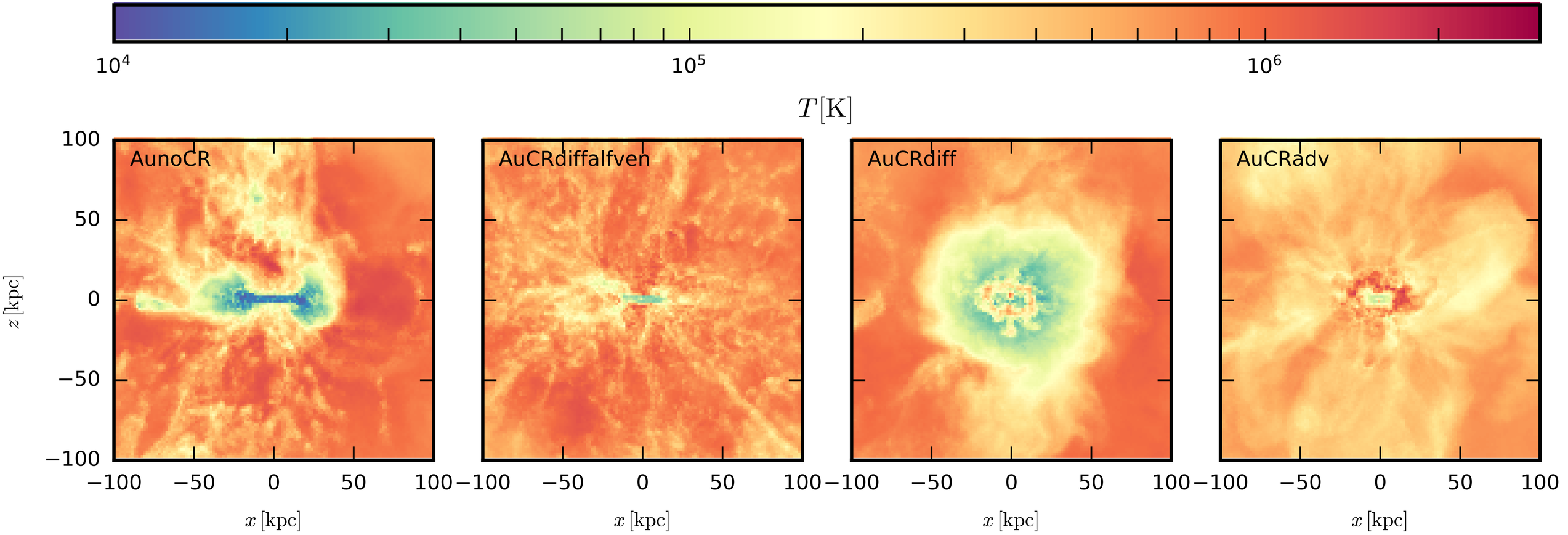
CRs provide additional pressure support



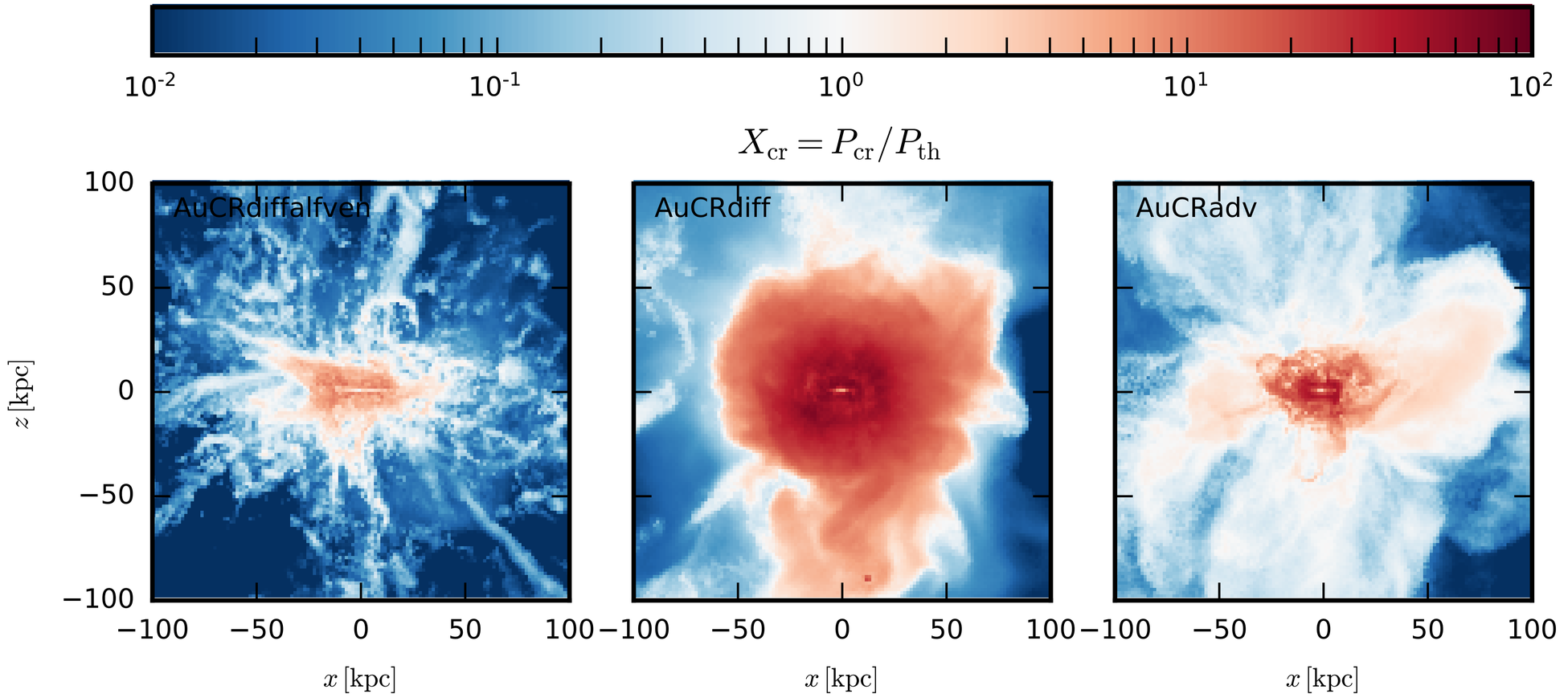
Gas density in the CGM is strongly influenced



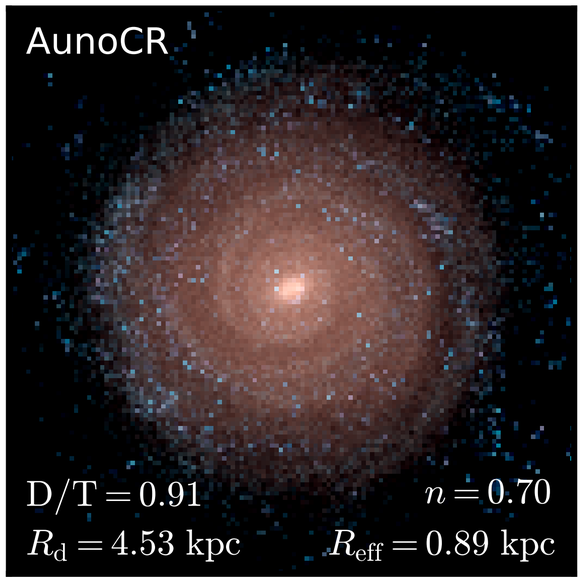
CRs leave a strong impact on the CGM temperature

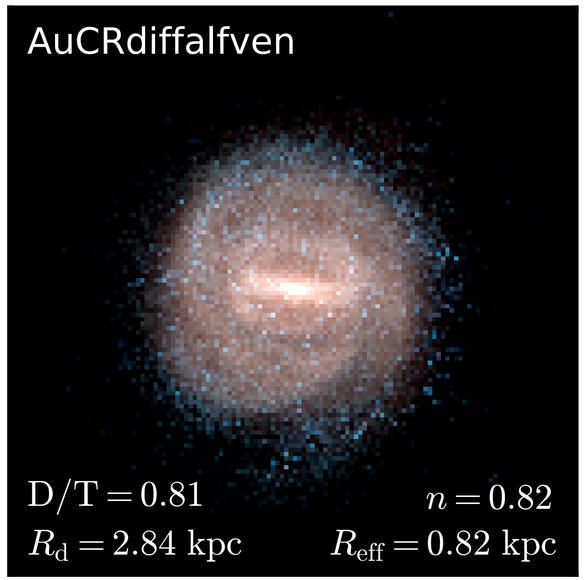


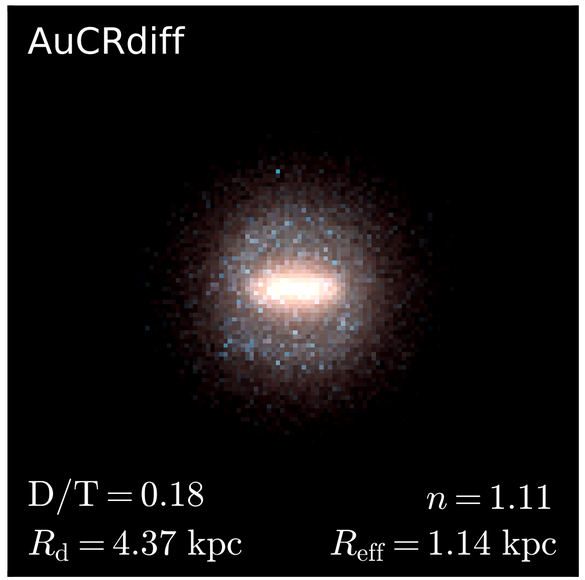
CR pressure dominated CGM

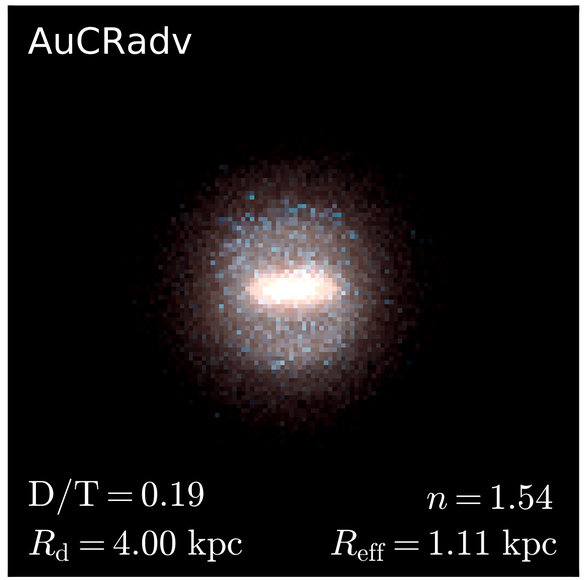


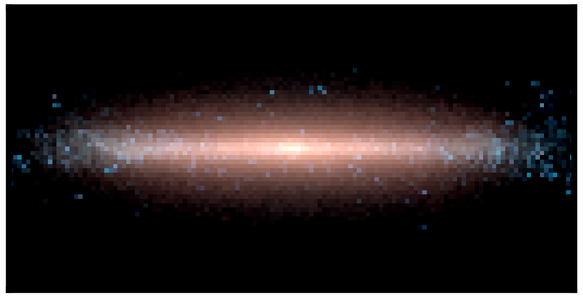
Stellar disk sizes are reduced by CRs

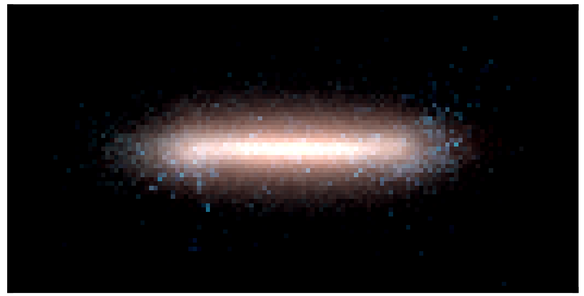


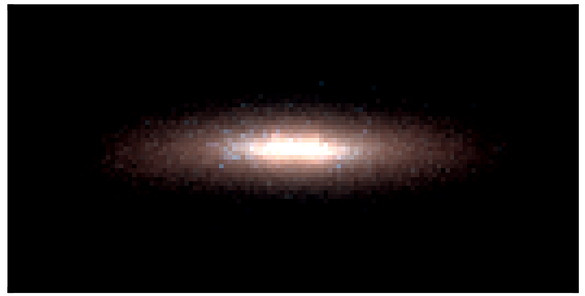


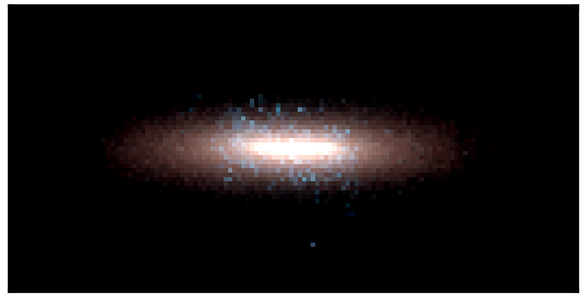




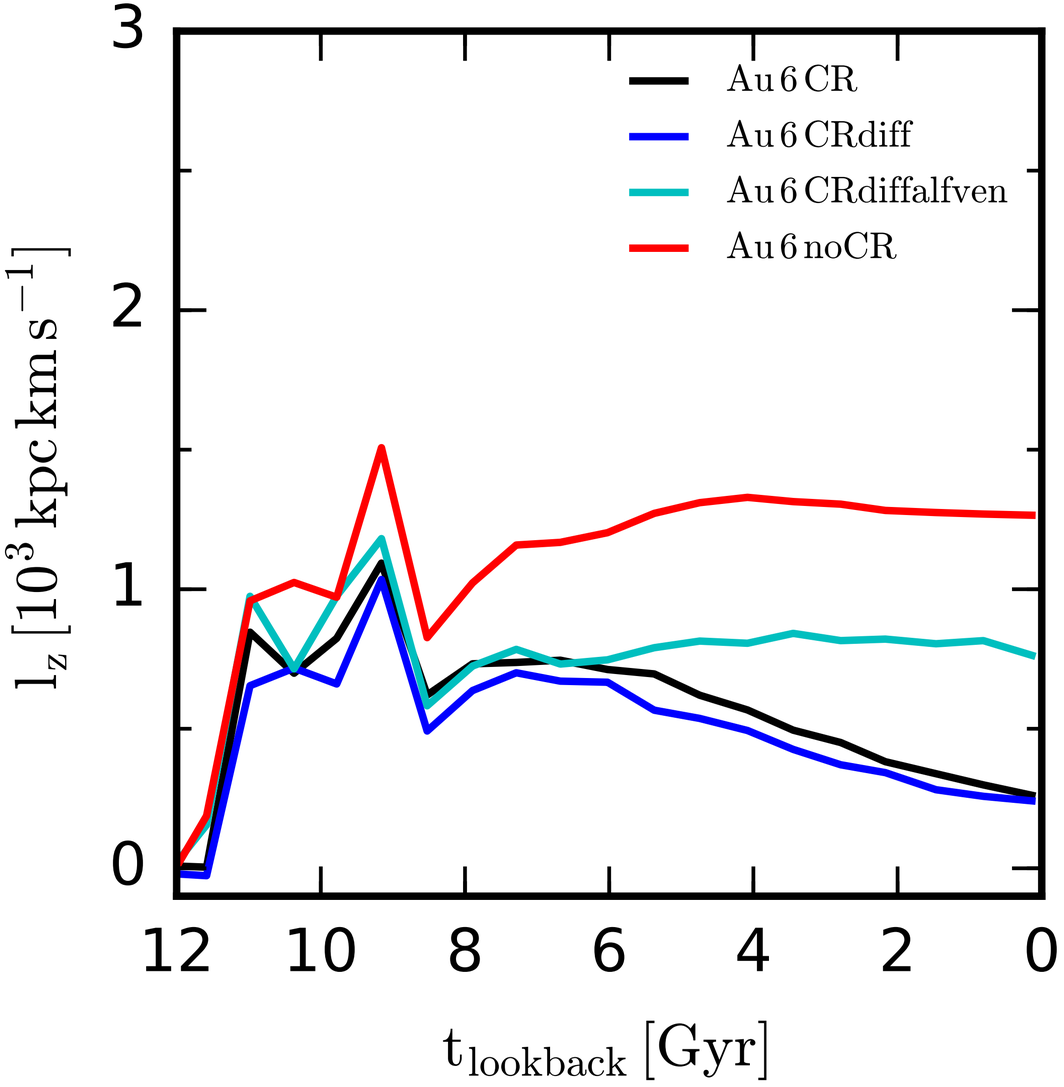


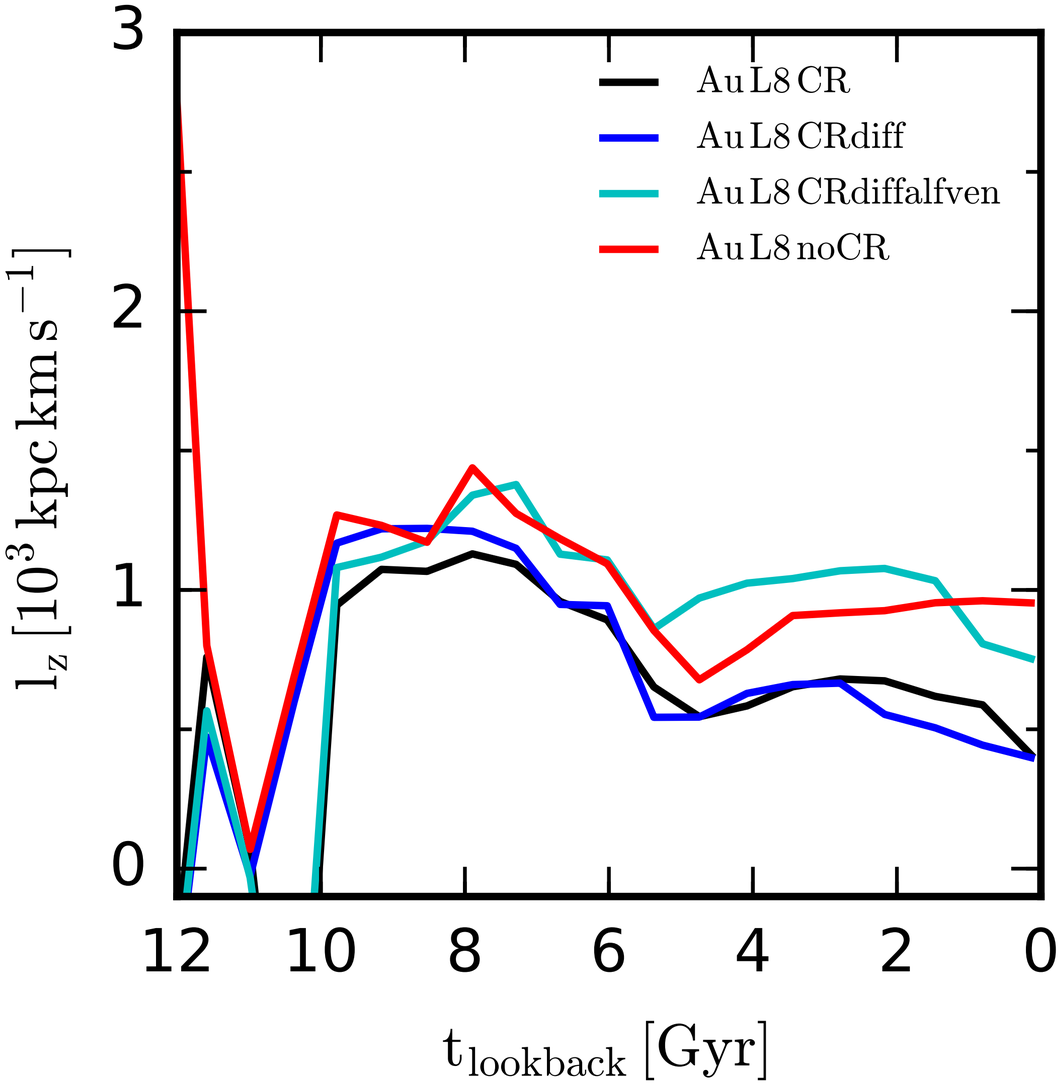






Angular momentum acquisition

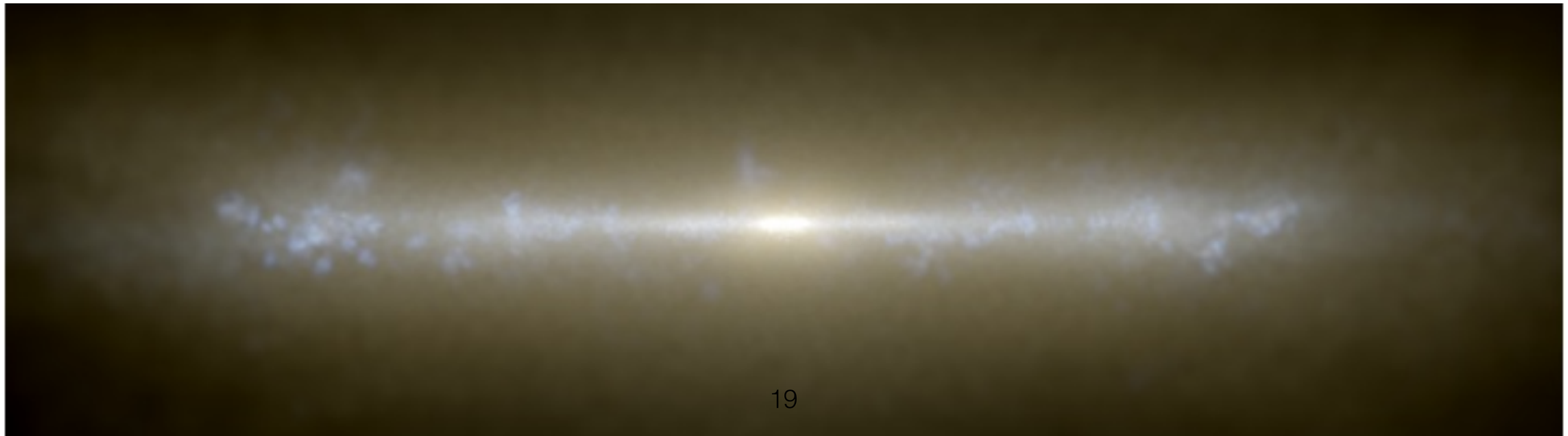




Effects of CRs in cosmological simulations of MW-like galaxies

- We test three different physics implementation of CR feedback within the AURIGA setup
- bulk galaxy properties like stellar mass and SFR are robust among different models
- morphology and CGM properties are strongly affected
  - CRs reduce the stellar disk size
  - CRs produce a hotter and smoother CGM

Extra Material



CGM properties