27th European Cosmic Ray Symposium - July 2022

The **cosmic rays** interstellar medium interplay.
In a simulated dwarf galaxy

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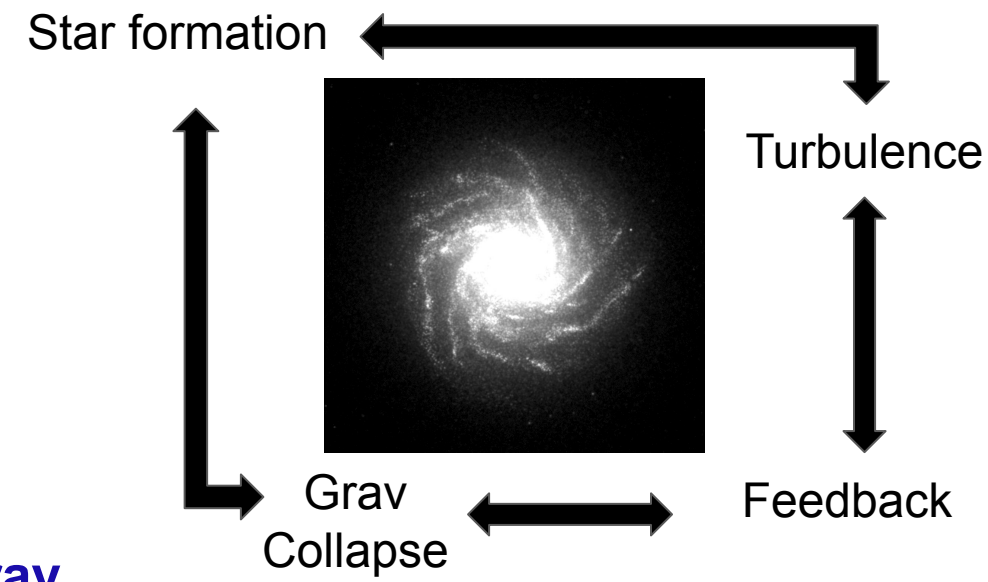
What we do

- Galaxy simulations with RAMSES (Teyssier 2002)
- AMR code
- MHD
- Gravity
- Subgrid physics
- Cosmic rays

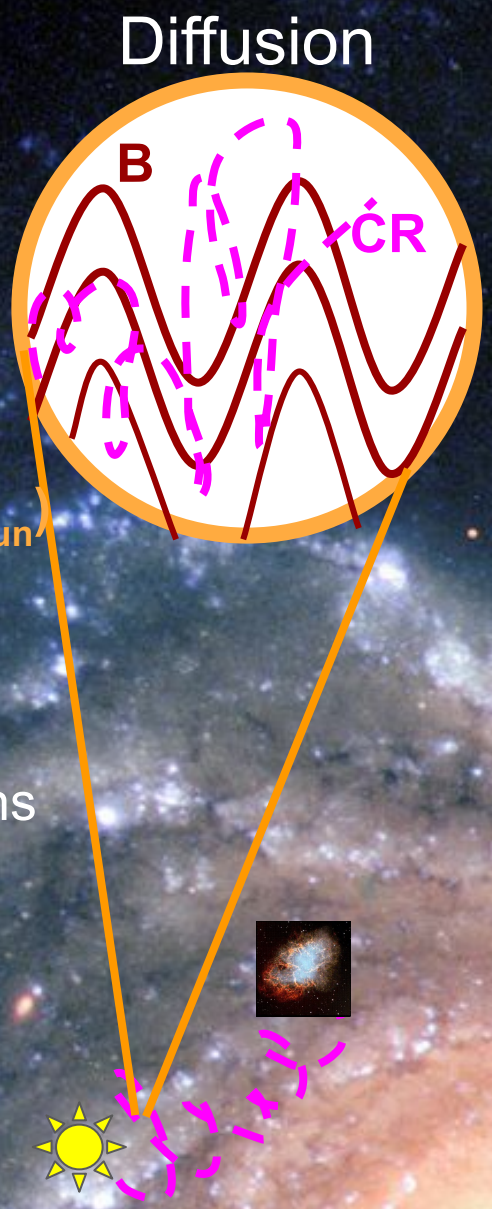


The **ISM** is a **complex** environment

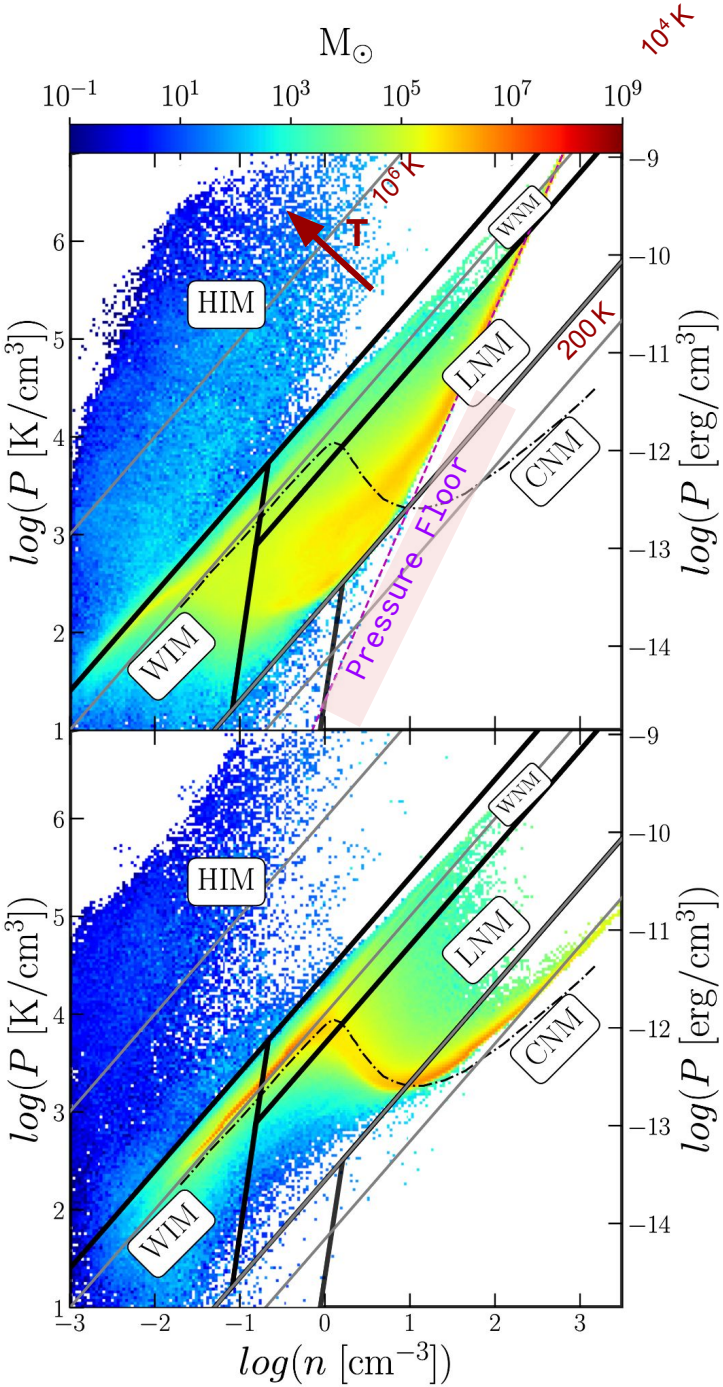
What is the impact of **cosmic-ray transport** on multi-scale and multi-phase **ISM** structures?

Why CR? In the local Milky Way environment pressure equipartition between **Cosmic rays** , thermal, magnetic and turbulent.

Galaxy Simulation



- **Dwarf galaxy M_{tot} 10^{11} M_{sun}(baryons ~$10^9 M_{sun}$)**
- **9 pc resolution r~6 kpc**
- Multiphasic ISM
- **GeV cosmic-ray** fluid (nuclei)
- Simple CR transport coupled to MHD equations
  - Uniform diffusion
  - $\kappa_{//}=0.01\kappa_{\perp} = \{3\times10^{27}, 3\times10^{28}, 1\times10^{29}\}$
  - Isotropic or Anisotropic
  - 10% SN energy into CR



Improved Gas thermal dynamics

The multiphase nature of the ISM is essential to this study

CNM: Cold Neutral Medium

LNM: Lukewarm Neutral Medium

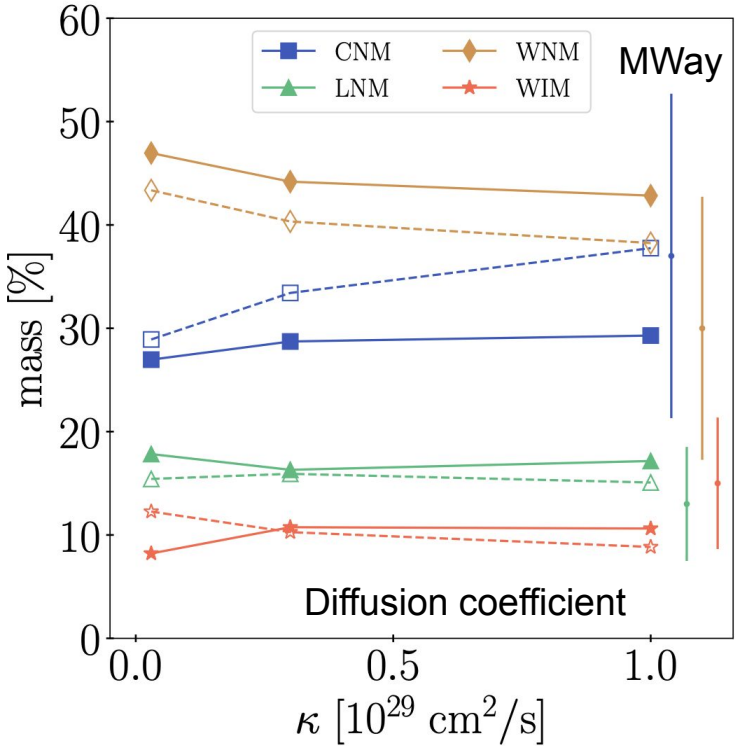
WNM: Warm Neutral Medium

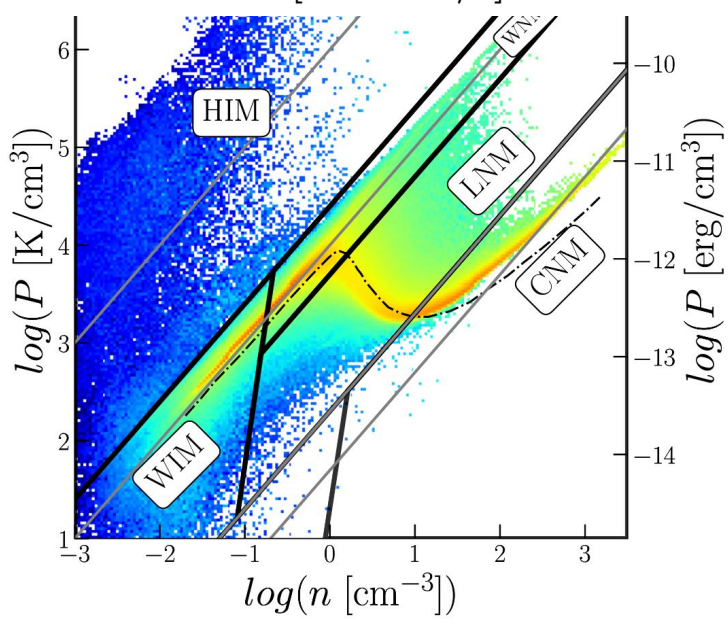
WIM: Warm Ionized Medium

HIM: Hot neutral medium

- Thermally stable gas (Wolfire 1993)
- Pressure floor (Truelove 1995)

From Dashyan & Dubois 2020, gas thermal physics *need to be updated* to resolve the ISM phases





Improved gas thermal dynamics

Phase mass fraction

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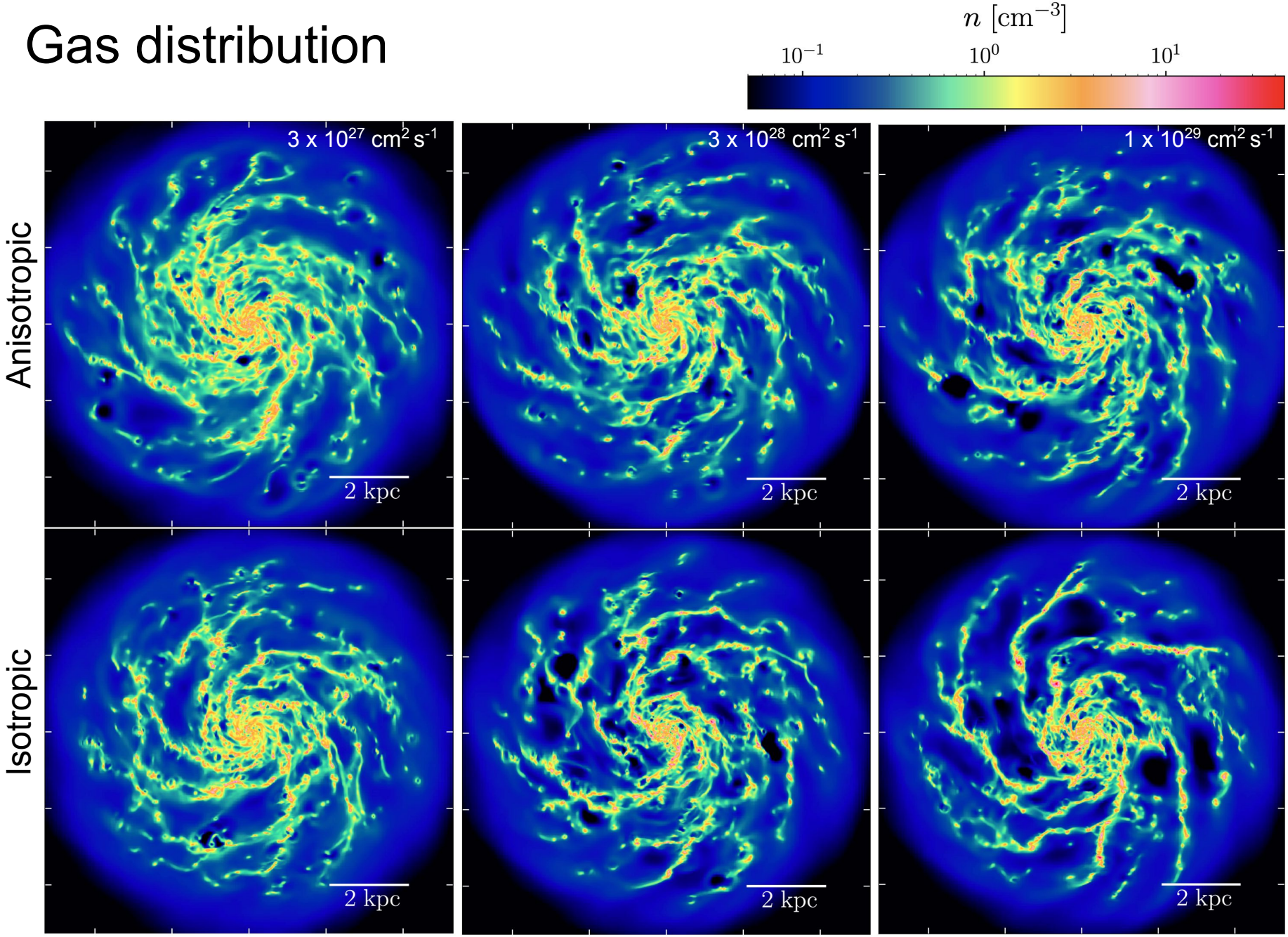
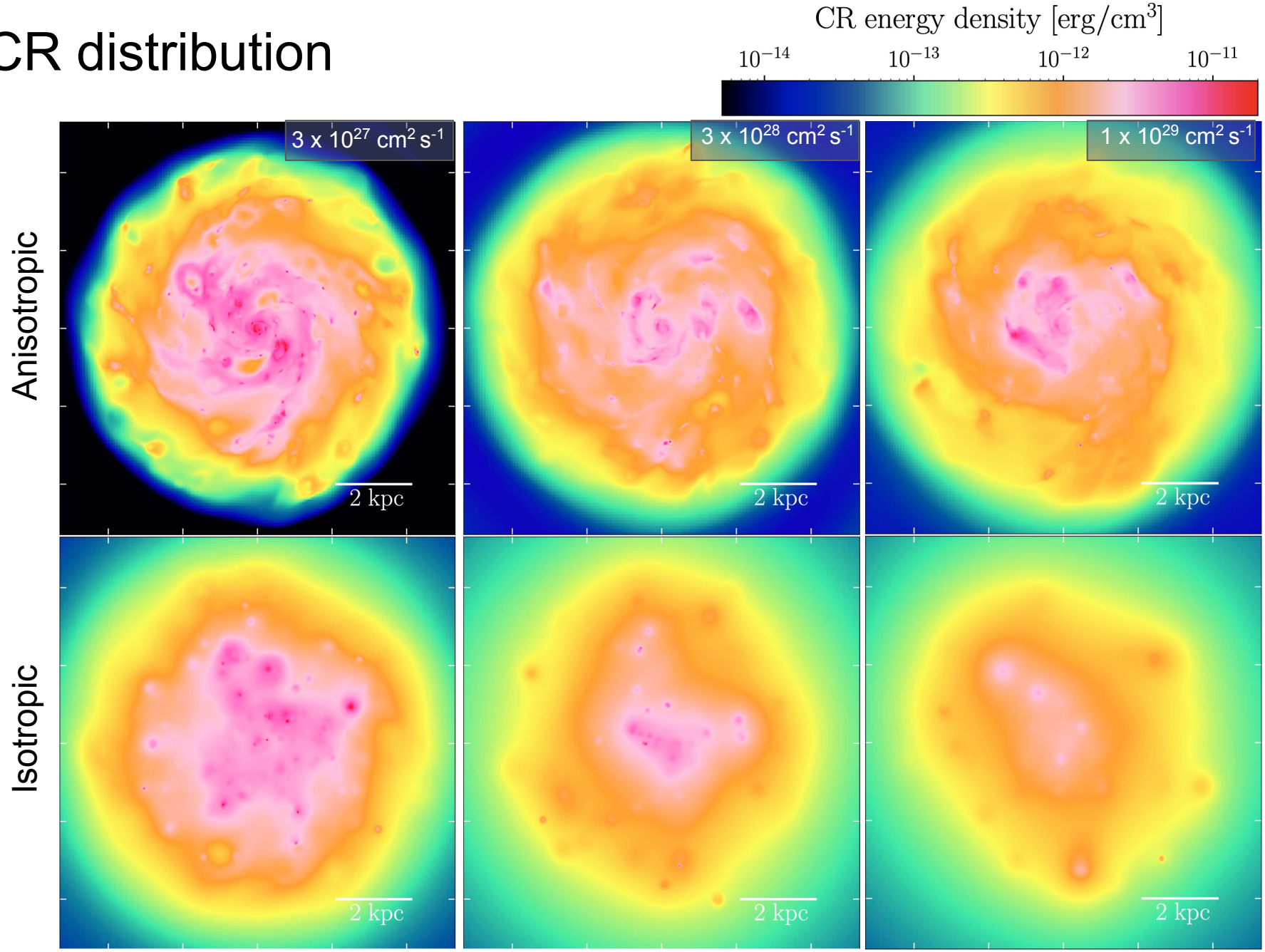
The results

Gas distribution



Nunez-Castineyra et al 2022 [submitted arxiv:2205.08163]

CR distribution



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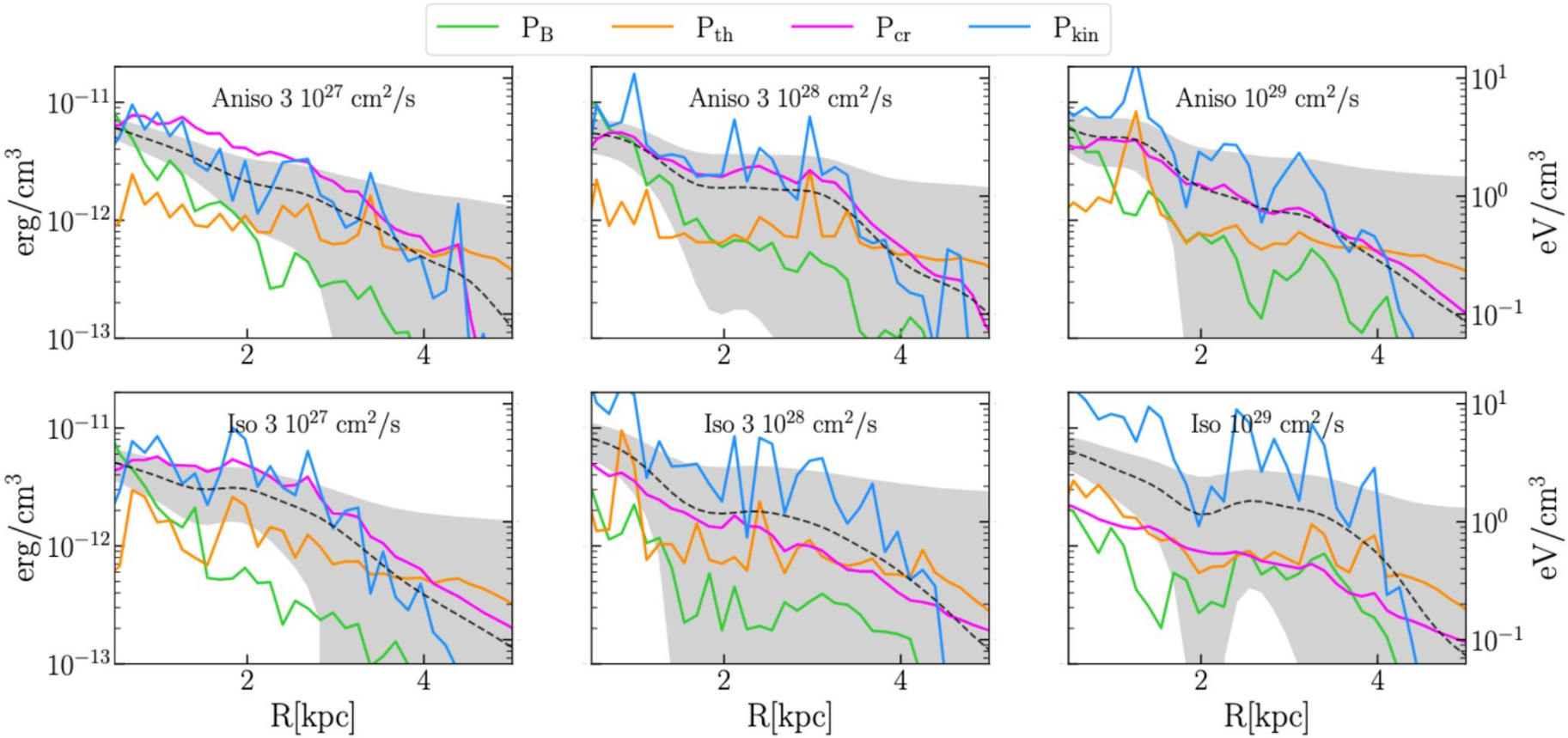
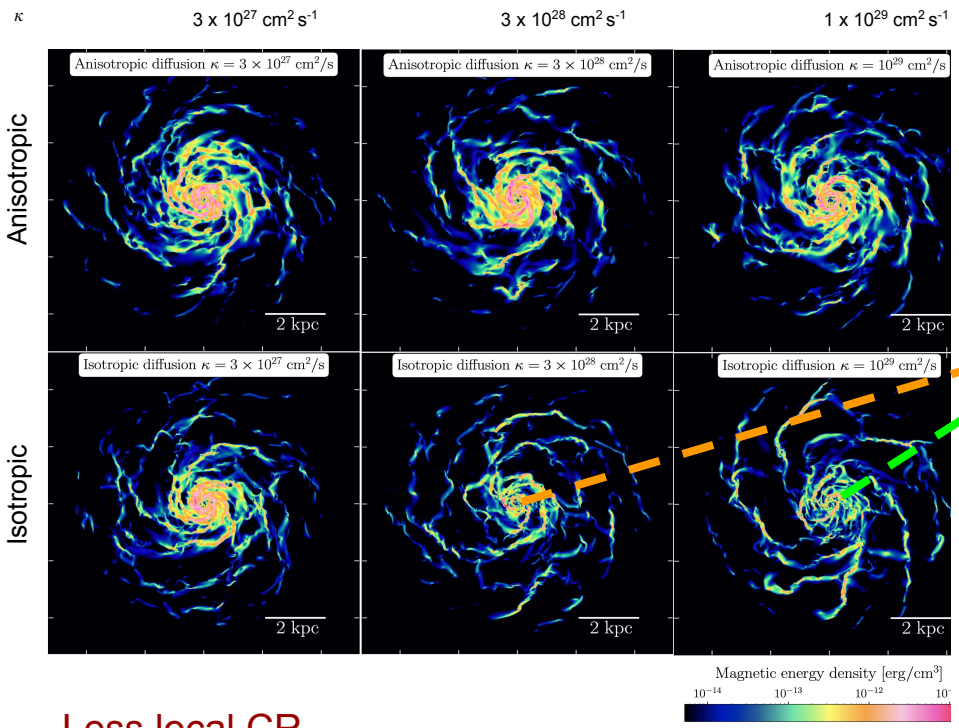
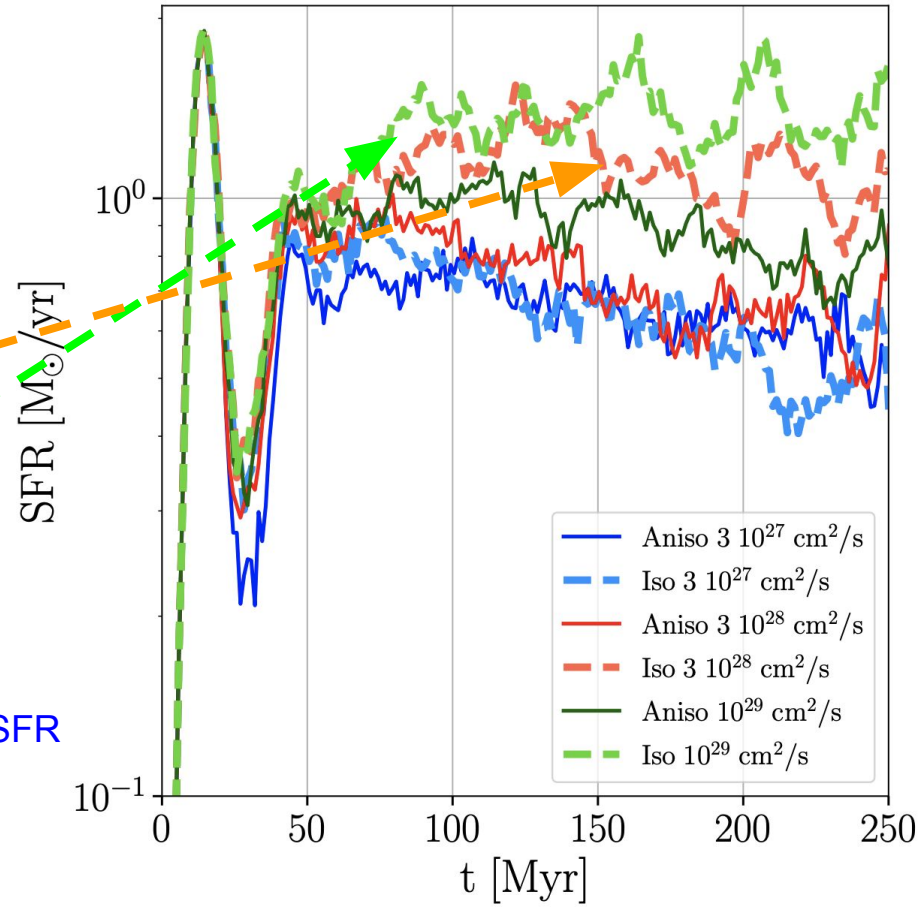
Close to pressure equipartition between
Cosmic rays , thermal, magnetic and turbulent.



Slow or Anisotropic CR transport favours magnetic amplification in the inner regions.

CR-induced magnetic amplification





Less local CR pressure → More SFR

If isotropic CR transport → Less B pressure

Slow or Anisotropic CRs transport →

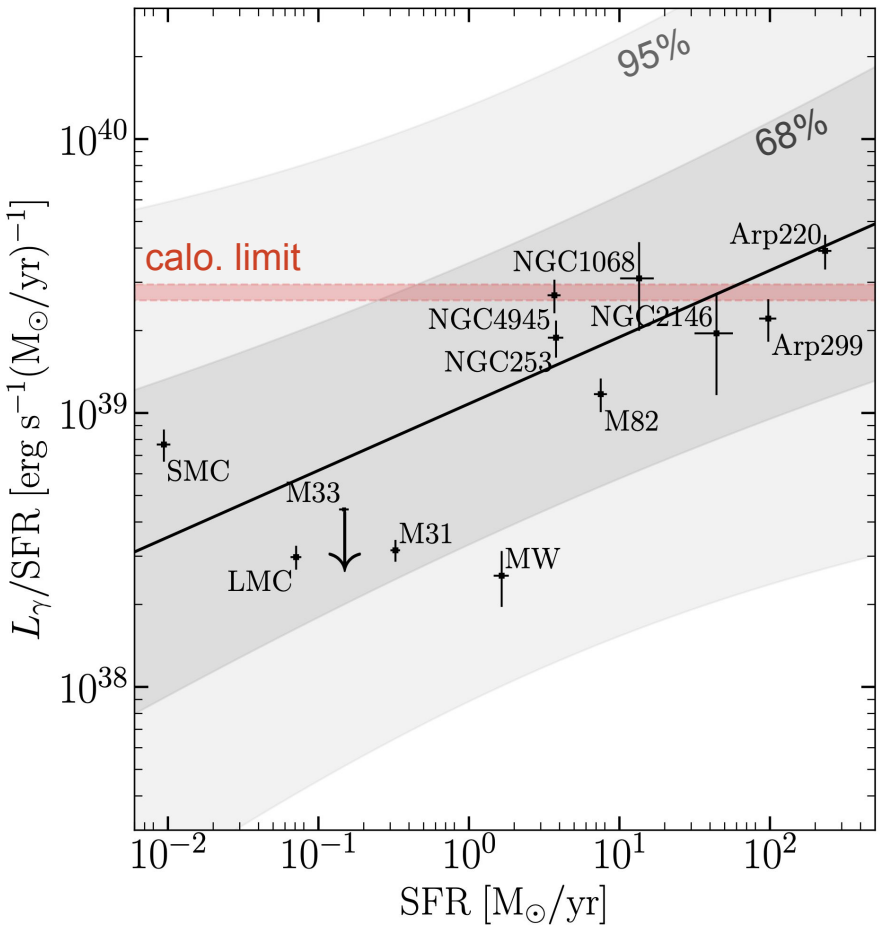
- more turbulent fields and stronger small-scale dynamo?
- More B compression?

Less SFR

(Pakmor et al 2016 and Buck et al 2020 found similar behaviors with different codes)

γ-ray luminosity vs SFR trend

Nunez-Castineyra et al 2022
[submitted arxiv:2205.08163]



γ-ray luminosity vs SFR trend

Consistent with observations

Slow isotropic 3e27

Anisotropic 3e27 3e28 1e29

Not so consistent with observations

Fast isotropic 1e29

Nunez-Castineyra et al 2022
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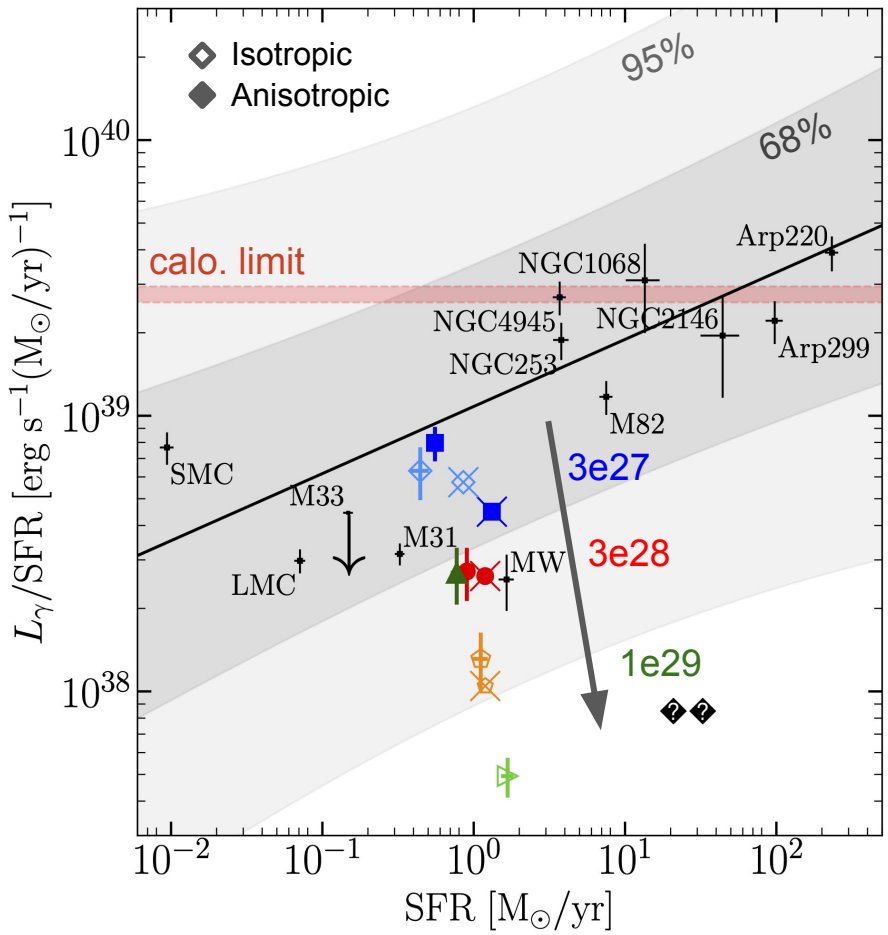

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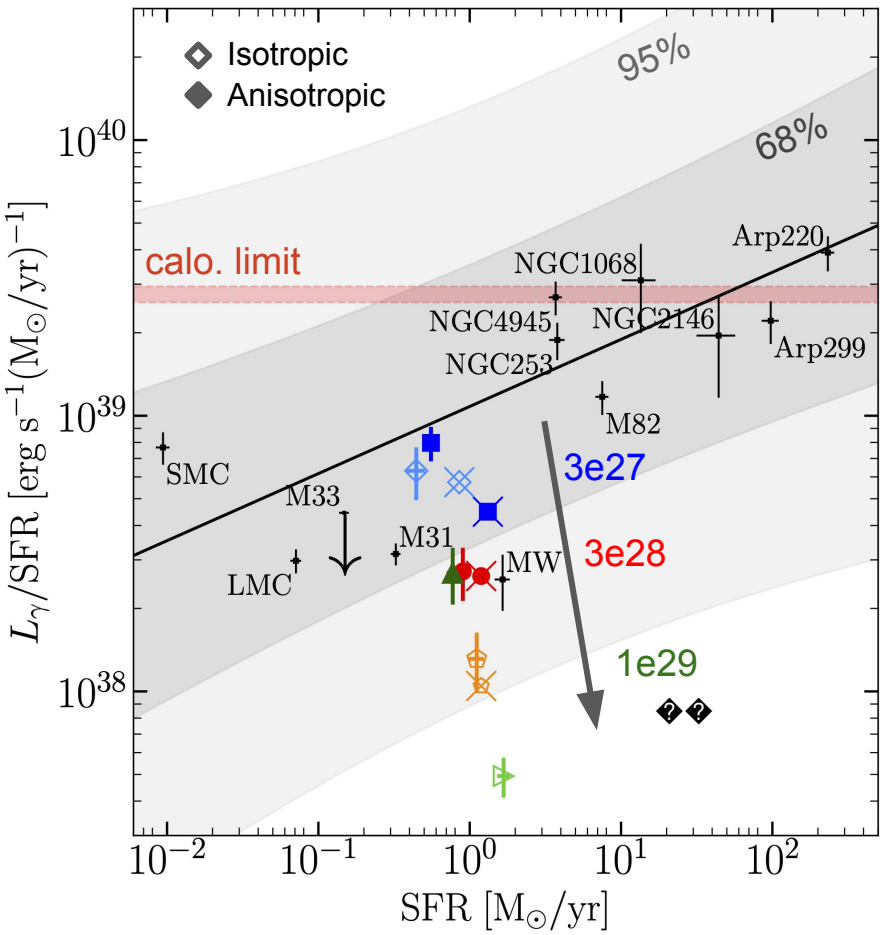
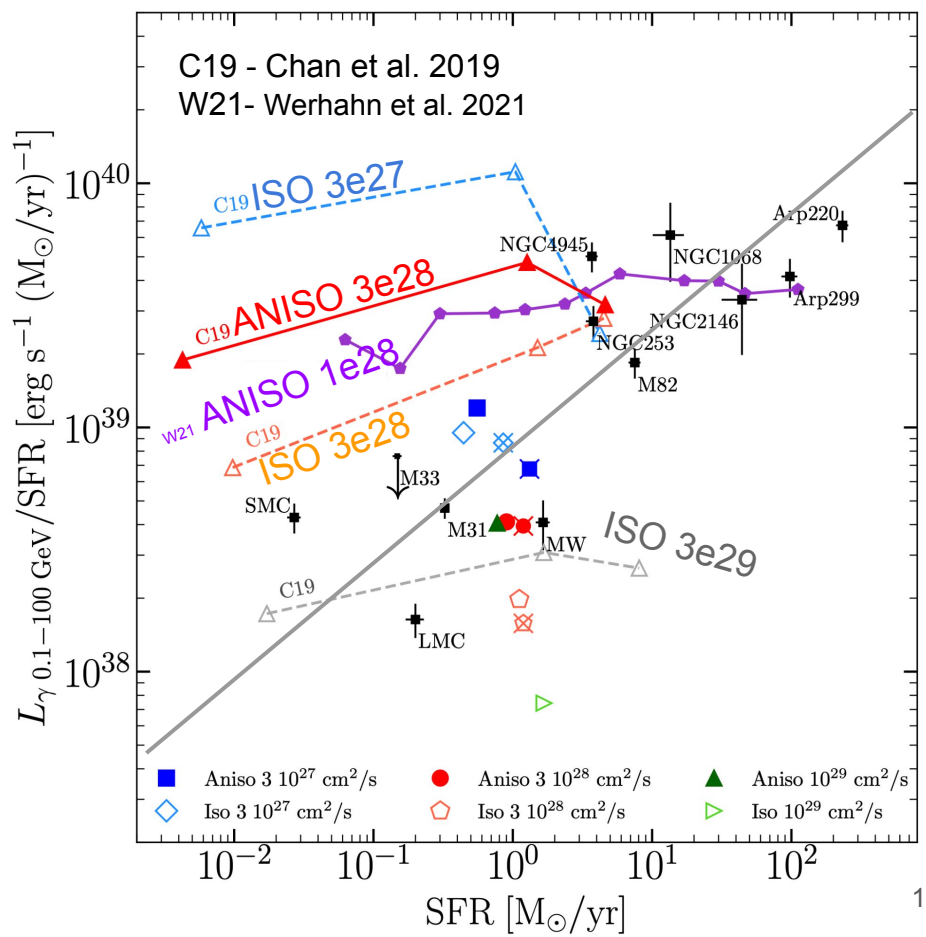


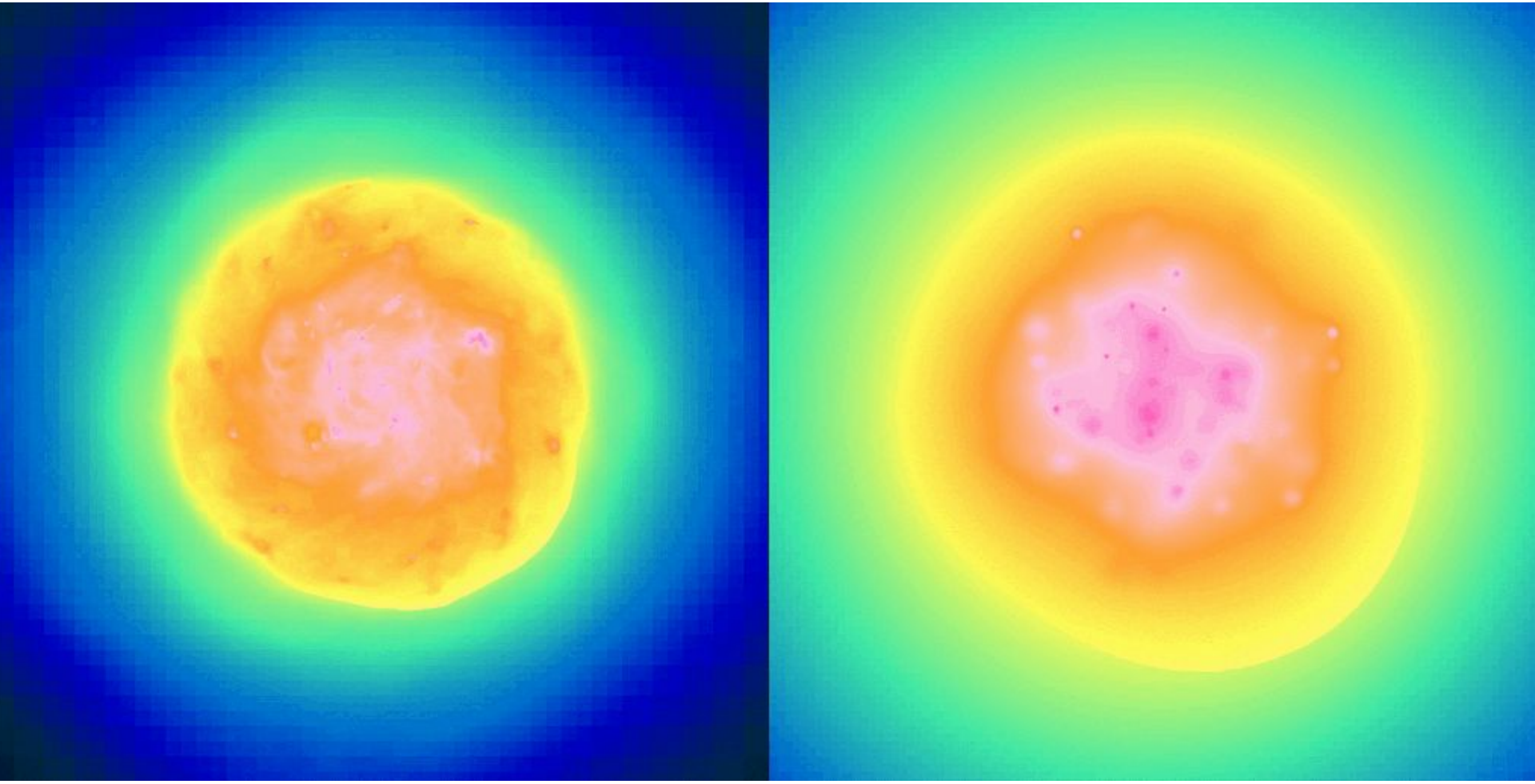


Conclusions

- Simple CR diffusion weakly modifies the large-scale spatial distribution of the gas in the galaxy
- The global mass fractions in the different gas phases varies little with CR transport and compares reasonably with estimates in the Milky Way
- CR transport modifies the large-scale magnetic field distribution in the galaxy, in particular in the inner regions for slow transport.
- CR transport has a dual impact on suppressing star formation:
  - directly through added CR pressure
  - indirectly by increasing the magnetic field pressure.
- Slow-isotropic or anisotropic CR diffusion is consistent by γ-ray vs SFR trend

Perspectives

- Small scales study
- New set of simulations with environment dependent diffusion coefficient



Thank you