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A zoomed view of molecular cloud evolution impacted by multiple supernovae

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Introduction

Previous works

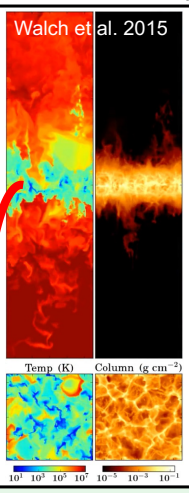
- ✓ The ISM is ubiquitously bubble-structured (e.g., PHANGS-JWST, Williams et al. 2024)
- ✓ Molecular clouds are compressed many times by supernovae during cloud lifetime, especially in star-burst env. (e.g., McKee & Ostriker 1977, Inutsuka et al. 2015, Padoan et al. 2016, Kobayashi et al. 2017, 2018, Chevance et al. 2020, Rathjen et al. 2023)
- ✓ Single shock from a neighboring supernova is not enough to sustain supersonic turbulence in clouds (Seifried et al. 2018)

Key questions

1. What **density and turbulence structures** emerge under shock compressions from **multiple supernovae?**
2. What **observational signatures** do we have to characterize the impact of multiple supernovae?

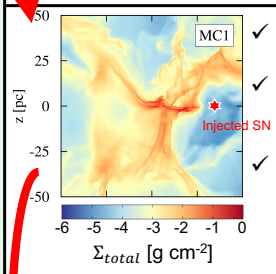
Setup

SILCC project (Walch et al. 2015)



- ✓ Galactic ISM simulation 500 pc x 500 pc x ± 5 kpc
- ✓ FLASH 4.3 for magnetohydrodynamics (Fryxell et al. 2000; Dubey et al. 2008)
- ✓ Supernova feedback (random driving)
- ✓ Basic chemical network H^+, H, H_2, C^+, CO, e^-, and O (Nelson & Langer 1997; Glover & Mac Low 2007; Glover et al. 2010)
- ✓ Initial total gas column density $\Sigma_{gas} = 10\ M_\odot$ pc^{-2}
- ✓ Resolution at mid-plane: 4 pc

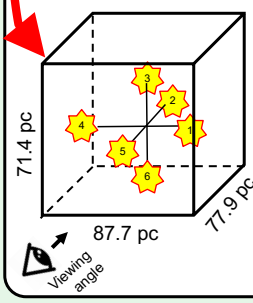
SILCC-"Zoom" (Seifried et al. 2018)



- ✓ Pick up a target cloud in SILCC
- ✓ Progressively increase the resolution up to 0.12 pc on 100 pc scale
- ✓ Inject "an" additional supernova with various distance to the cloud center

- ✓ Supernova at < 25 pc enhances the cloud turbulence
- ✓ However, that maintains only for a few 100 kyr

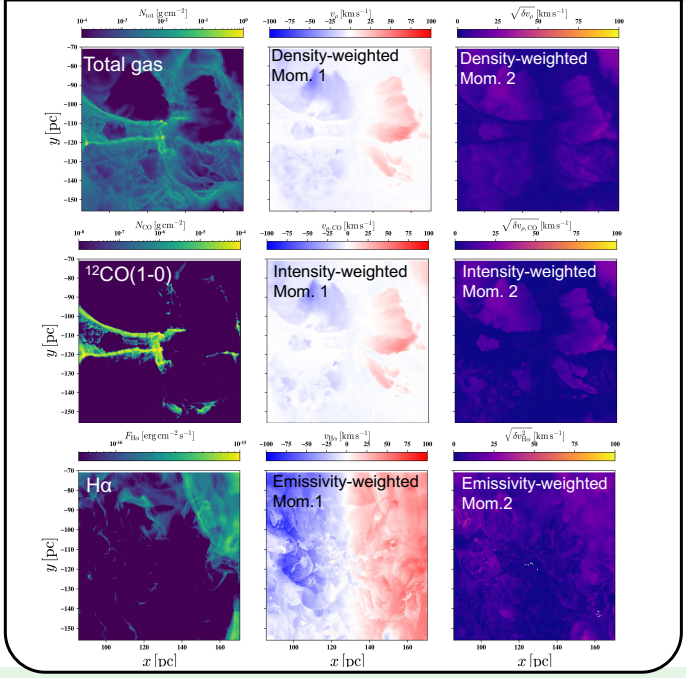
This work: Multiple supernovae injection



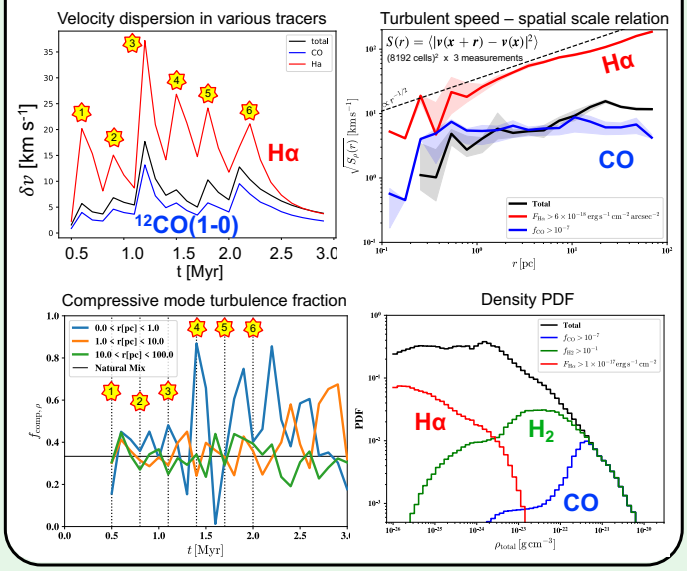
- ✓ Inject additional **6 supernovae**
- ✓ 0.3 Myr interval between explosions
- ✓ At 25 pc distance from the cloud mass center
- ✓ Synthetic observations:
  - ^{12}**CO(1-0)** in RADMC3D (Dullemond 2012)
  - **Hα** in MAPPINGS V (Sutherland & Dopita 2017)

Results

Moment maps (face-on view towards galactic mid-plane)



Turbulence & density structure



Key takeaway

- ✓ Supernovae **kinetic energy** is deposited more to **diffuse (Hα-bright) regions**, but not to dense (CO-bright) regions.
- ✓ Supernovae feedback significantly **widen the density PDF of diffuse but still H_2-bearing regions** (n < 100 cm^{-3}).
- ✓ Supernova explosions **enhance the compressive mode** turbulence from small to large scales as they expand, but this effect lasts **only <~ 0.3 Myr**.