Investigating Cold Gas Filaments in Cool-core Clusters

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Abstract

- **Aims.** Cold gas ($\mathrm{T}\sim10^4$ K) filamentary structures with $H\alpha$ emissions were found around central regions of some cool-core galaxy clusters. We wish to compare the results between observation of the Perseus cluster and our simulation in order to interpret velocity structures of observed filaments.
- **Methods.** We perform hydrodynamic simulations to trace gas motions in the Perseus cluster.
- **Results.** In our simulation, filaments with a chaotic velocity structure dominate the population, while those with a uniform velocity structure are secondary. The simulation also produces an overall low velocity dispersion.
- **Conclusions.** The cold gas motions present chaotic more often, whereas observations suggest an uniform structure. On the other hand, the velocity dispersion in the simulation is consistent with the observation results.

Introduction

- Galaxy clusters are composed of
  1) **Thousands of galaxies** within a massive **dark matter** halo,
  2) **Intracluster medium (ICM)**: diffuse and ionized hot gas emitting X-rays with a temperature around 10^7 to 10^8 K,
  3) **Cold gas**: $\mathrm{T}\sim10^4$ K, formed through hot gas radiative cooling and has high $H\alpha$ luminosity (McDonald et al, 2011).
- Recent observation has found that the velocity of filaments along the line-of-sight (LOS) is uniform, and the velocity dispersion of filaments is small along the filaments. (Fig. 1)

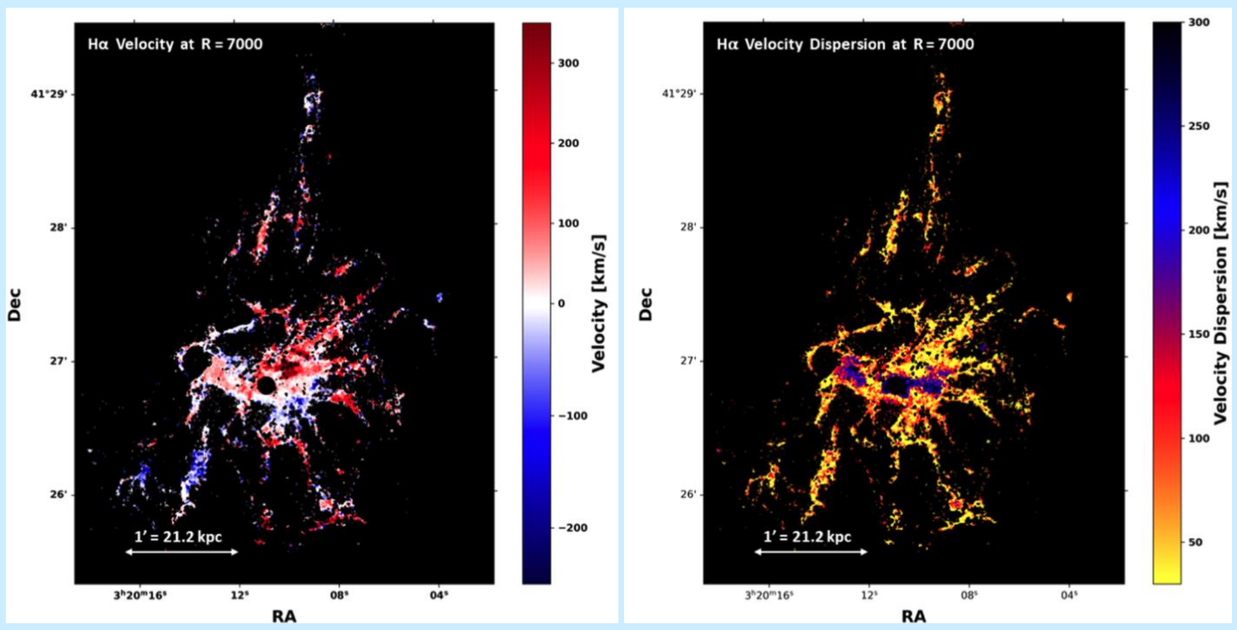

Figure 1. Observation results from Vigneron et al, 2024. The left panel shows the LOS velocity of the cold gas filaments in the central galaxy of the Perseus cluster. The right one shows the velocity dispersion.

Method

- Our simulation used the FLASH code with adaptive mesh refinement (AMR) with 1 Mpc simulation box and the initial condition of the Perseus cluster. (Wang & Yang, 2022)
- We analyzed the simulation data using the yt software and investigated the overall evolution of the cold gas filaments in the cluster.

Results

- LOS velocity analysis

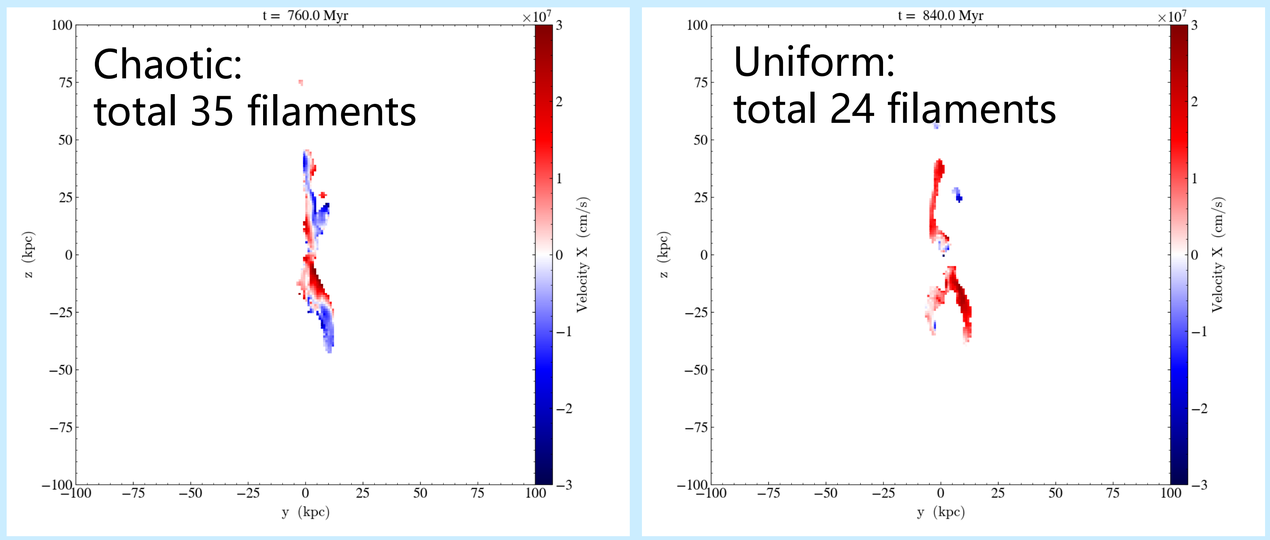

Figure 2. Snapshots at two different times in the simulation. The left panel shows one of the frames with chaotic cold gas motions. There are 35 filaments belonging to this category among all frames. The right one shows filaments with uniform velocity, which has 24 filaments in total. The observation result (left panel of Fig. 1) looks more similar to the uniform velocity structure.

- Velocity dispersion analysis

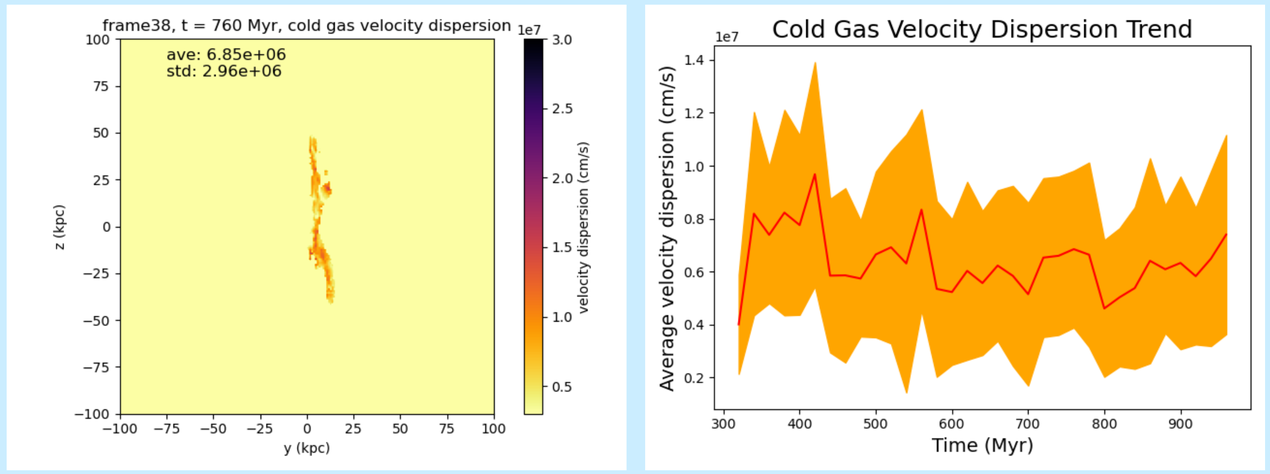

Figure 3. The left panel shows one of the snapshots of cold gas velocity dispersion, and the right one shows the evolution of velocity dispersion. The shaded region represents the standard deviation. The velocity dispersion averaged at 63.8 km/s, with the highest velocity dispersion 96.8 km/s, and the lowest 40.1 km/s. The averaged value is consistent with the observed value of 44 km/s (right panel of Fig. 1).

Conclusions

- In the simulation, most cold gas filaments exhibit chaotic motion. The uniform velocity profiles in the observational results likely correspond to a secondary population.
- The velocity dispersion remains low throughout the simulation, consistent with observational results.

References

[1] McDonald et al, 2011, ApJ, 734, 95
[2] Vigneron et al, 2024, ApJ, 962, 96
[3] Wang & Yang, 2022, MNRAS, 512, 5100