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HOW DO BINARY CLUSTERS FORM?

What are binary clusters?

- Pairs
- More than chance [1]
- ~10 % [2]

Image credit: N.A.Sharp/NOAO/AURA/NSF

[1] Rozhavskii (1976) [2] de la Fuente Marcos & de la Fuente Marcos (2009)

Observations

- Young [1]
- Coeval [2]
  - Chance line ups
  - Capture [3]
- Even size ratios [4]
- Bridges [5] [6]

Image credit: N.A.Sharp/NOAO/AURA/NSF

[1] Palma+ (2016) [2] Pietrzynski & Udalski (2000) [3] Dehnen (1998)
[4] Bhatia+ (1991) [5] Dieball & Grebel (2000) [6] Minniti+ (2004)

Questions

- Know a bit about binary clusters
- How / Why?
- Observed in N-body papers [1] [2]
- Not the focus
- Is this how binary clusters form?

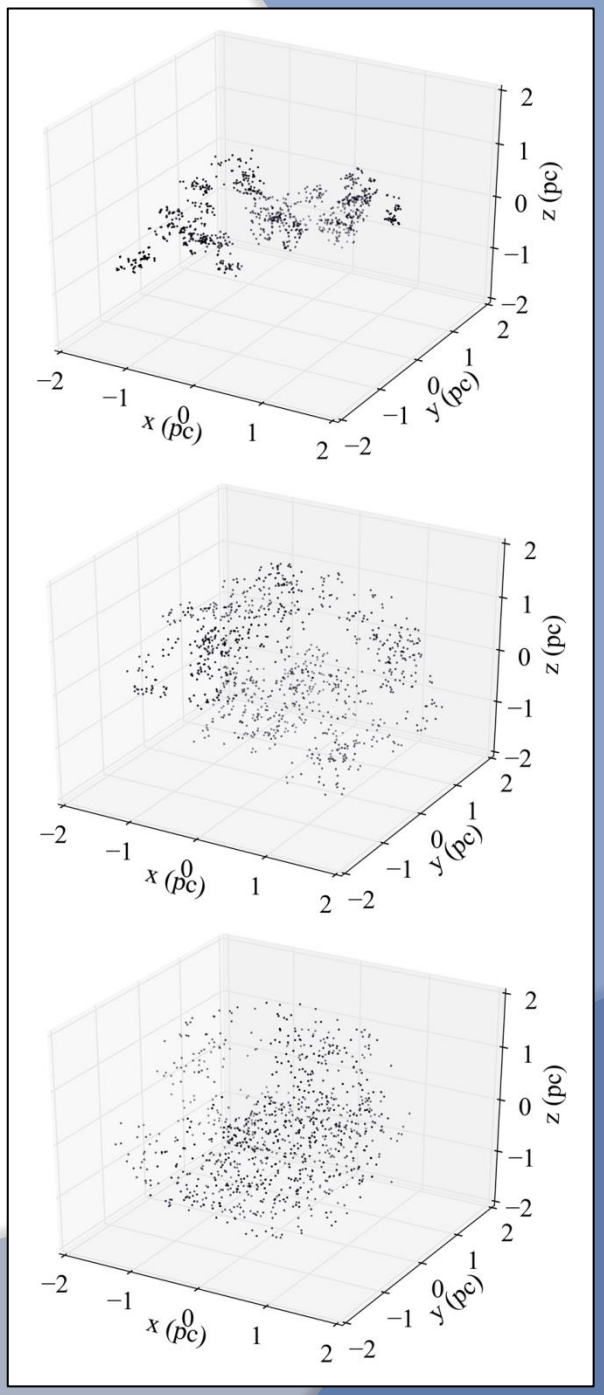
[1] Goodwin &Whitworth (2004) [2] Parker+ (2014)

Simulations

- Further N-body simulations
- Why use N-body?
  - Simple
  - Understand why
  - Numerical effects
  - Fast
  - ~10 Myr

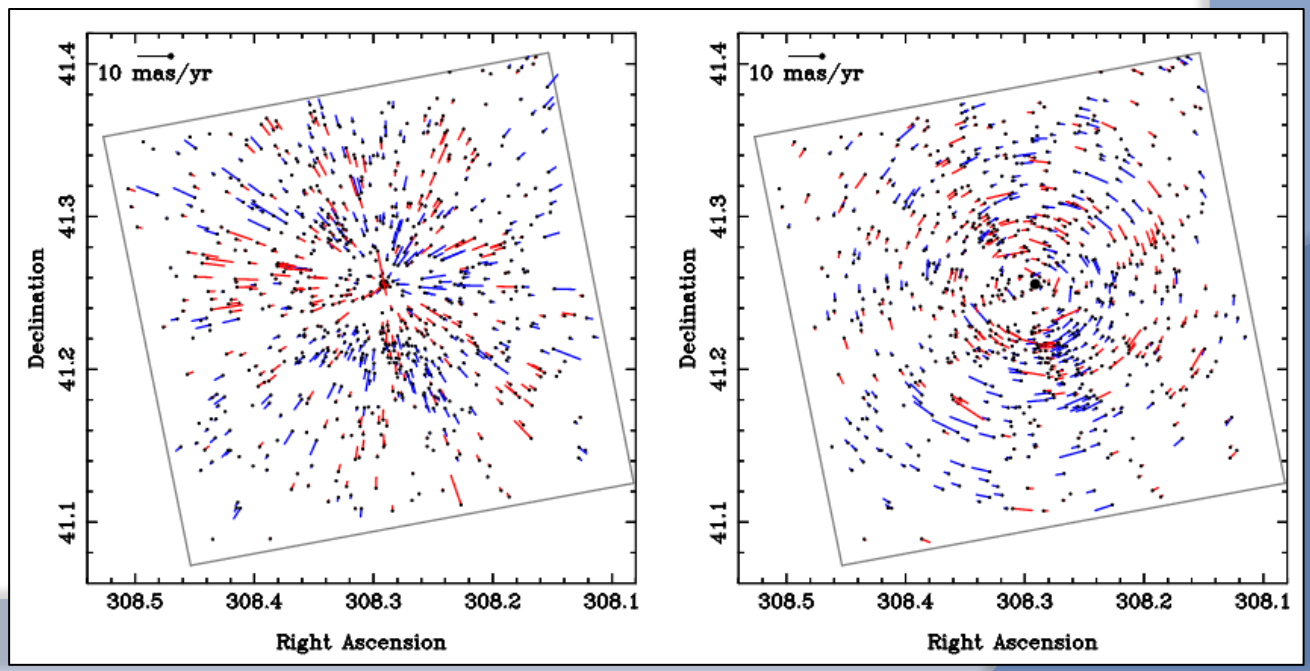
Initial conditions (Spatial)

- Fractals
- Control substructure



Initial conditions (Velocity)

- Less information
- Observations of velocity structure in young clusters [1] [2] [3] [4]
- Inherit
- Scale



[1] Wright+ (2016)

[2] Jefferies+ (2014)

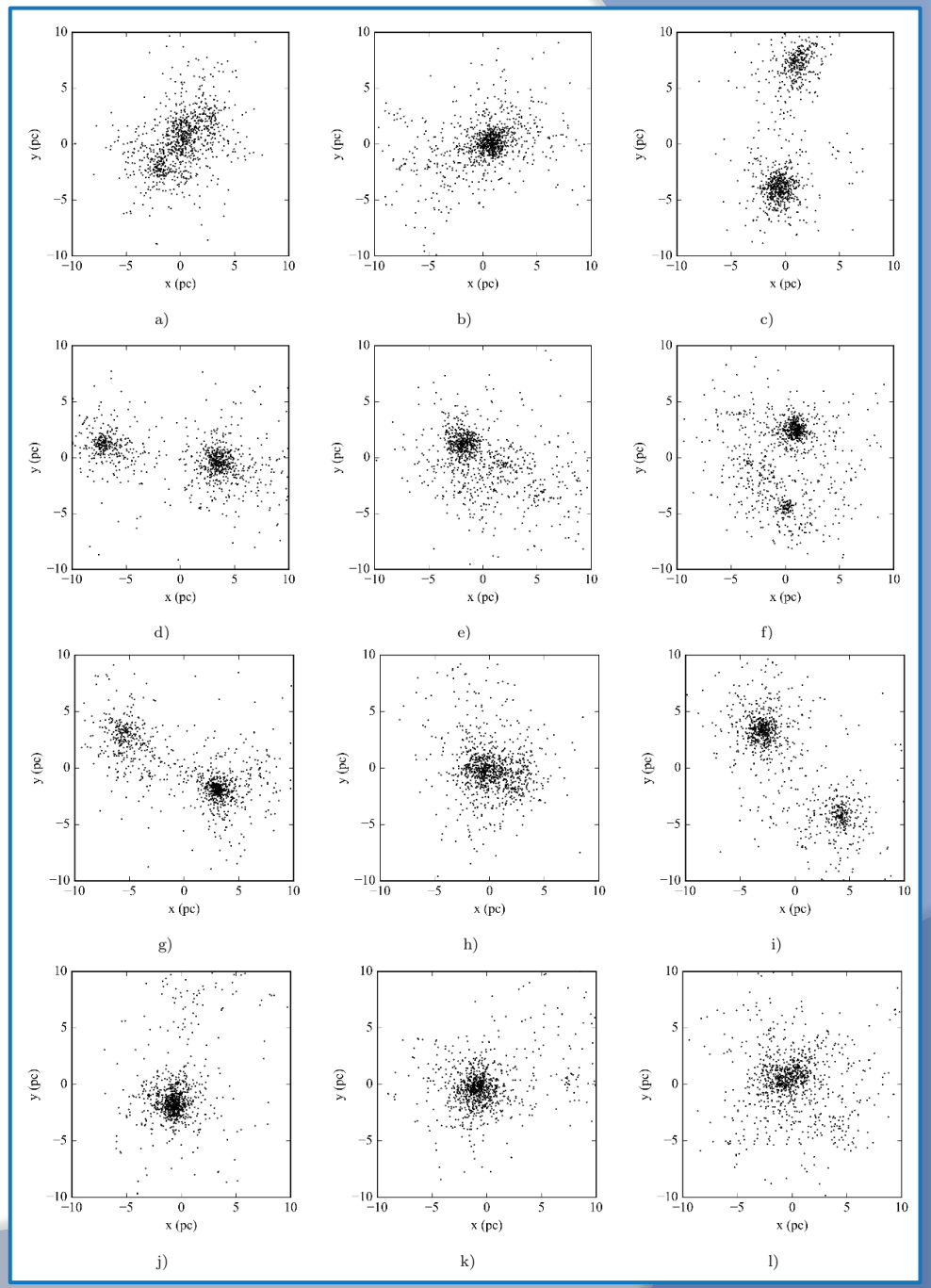
[3] Tobin+ 15

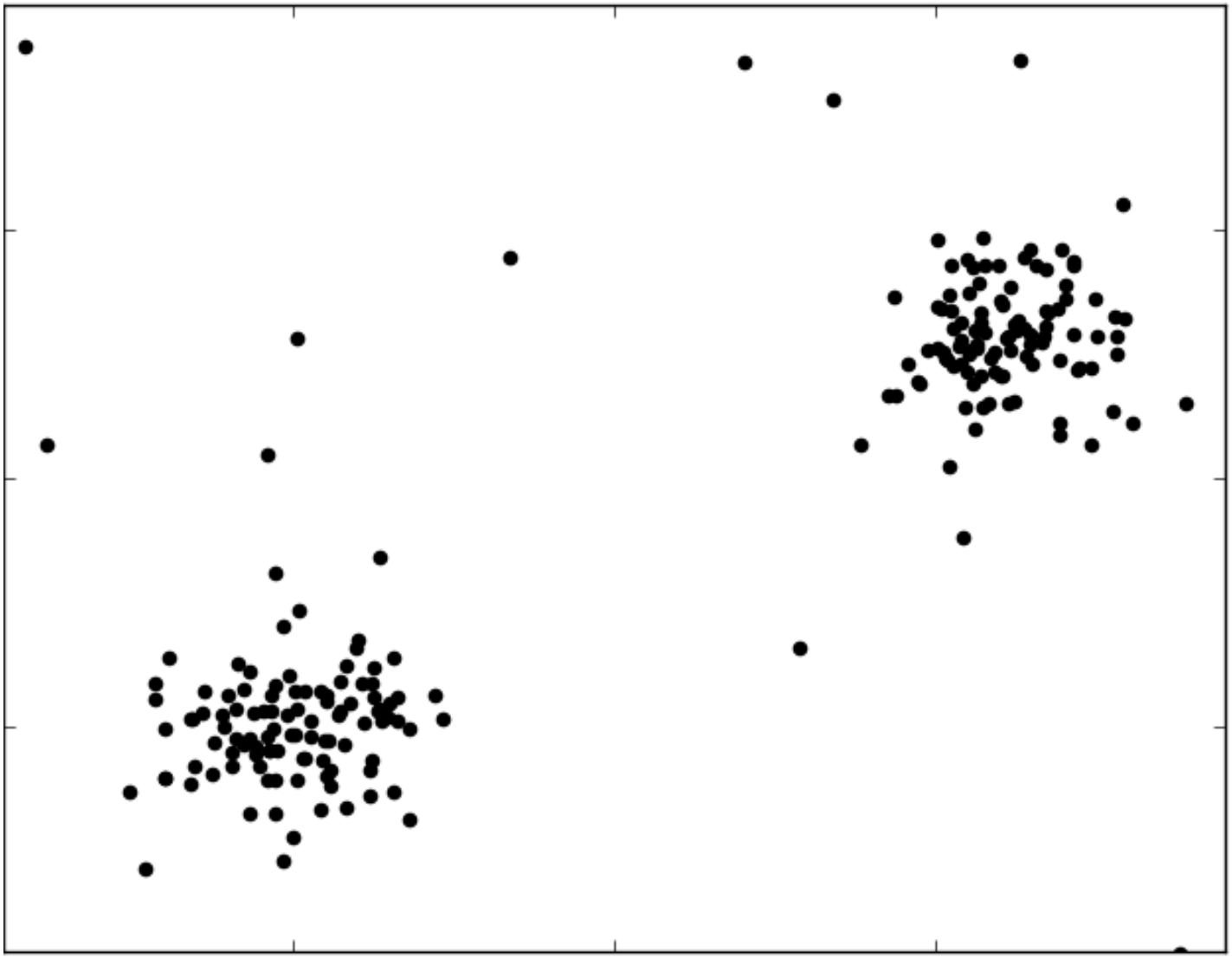
Key question:

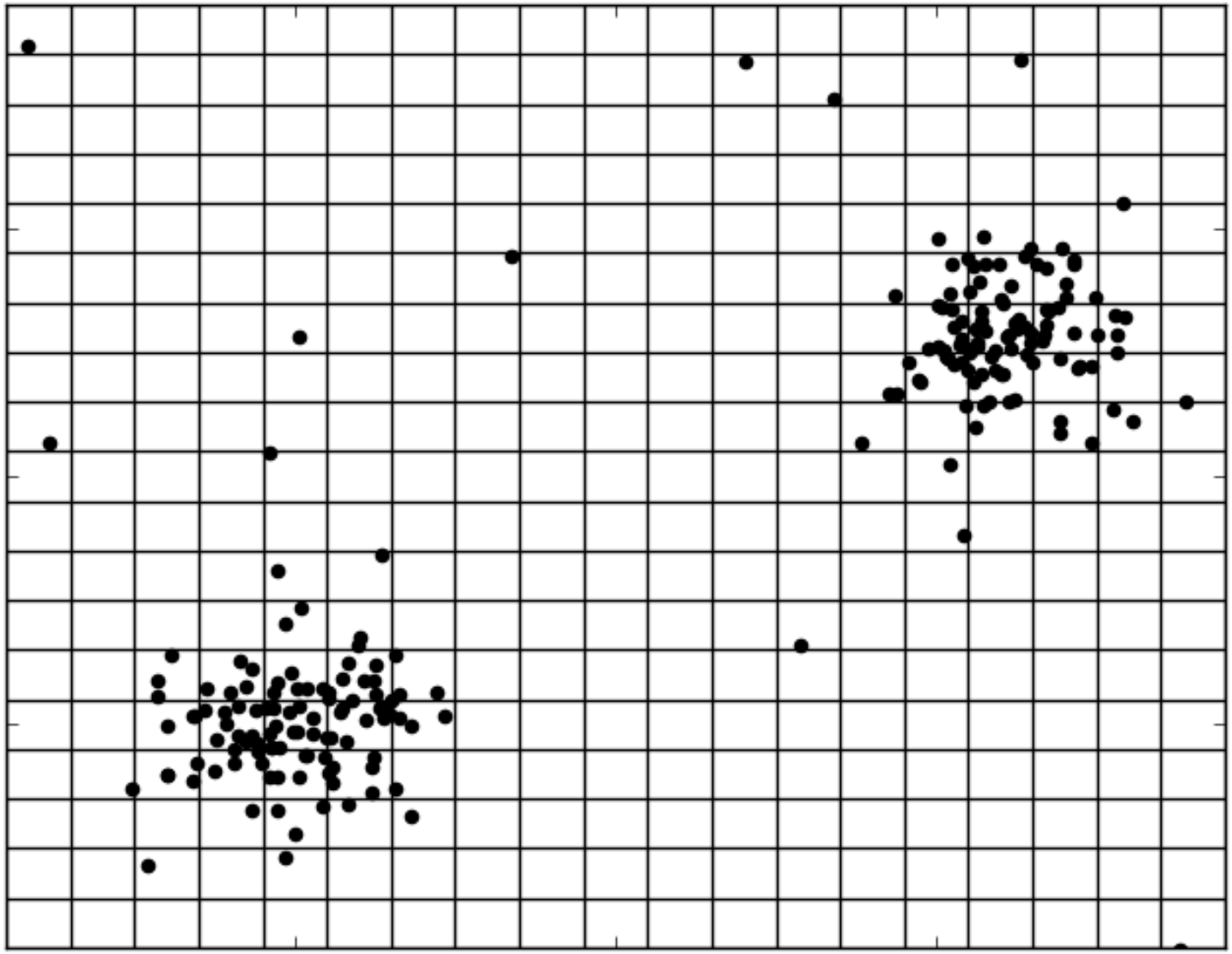
- Can binary clusters come from single star forming regions?
- Moderate substructure
- Virial ratio 0.7
- 1000 stars, 10 Myr
- 12 simulations

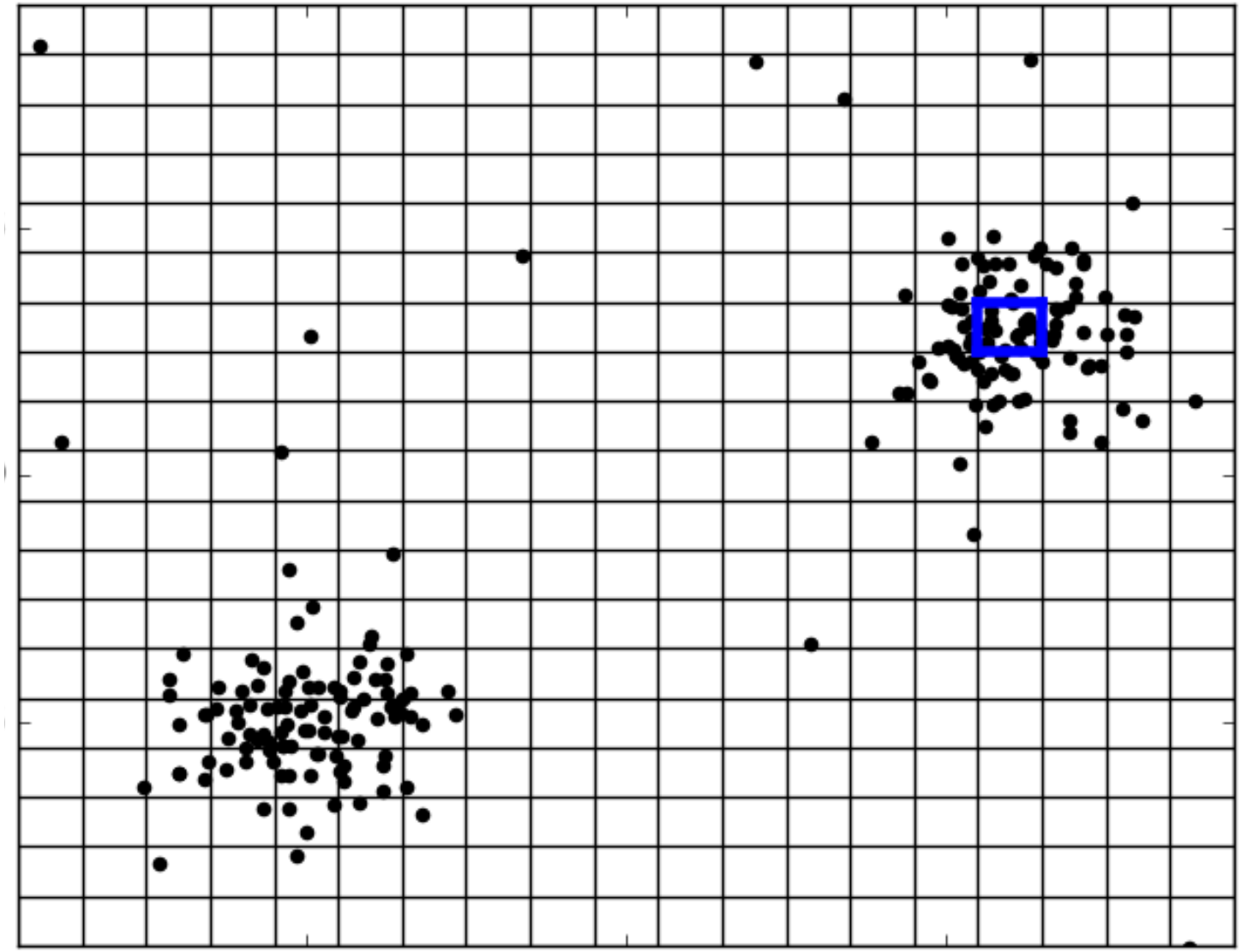
Results

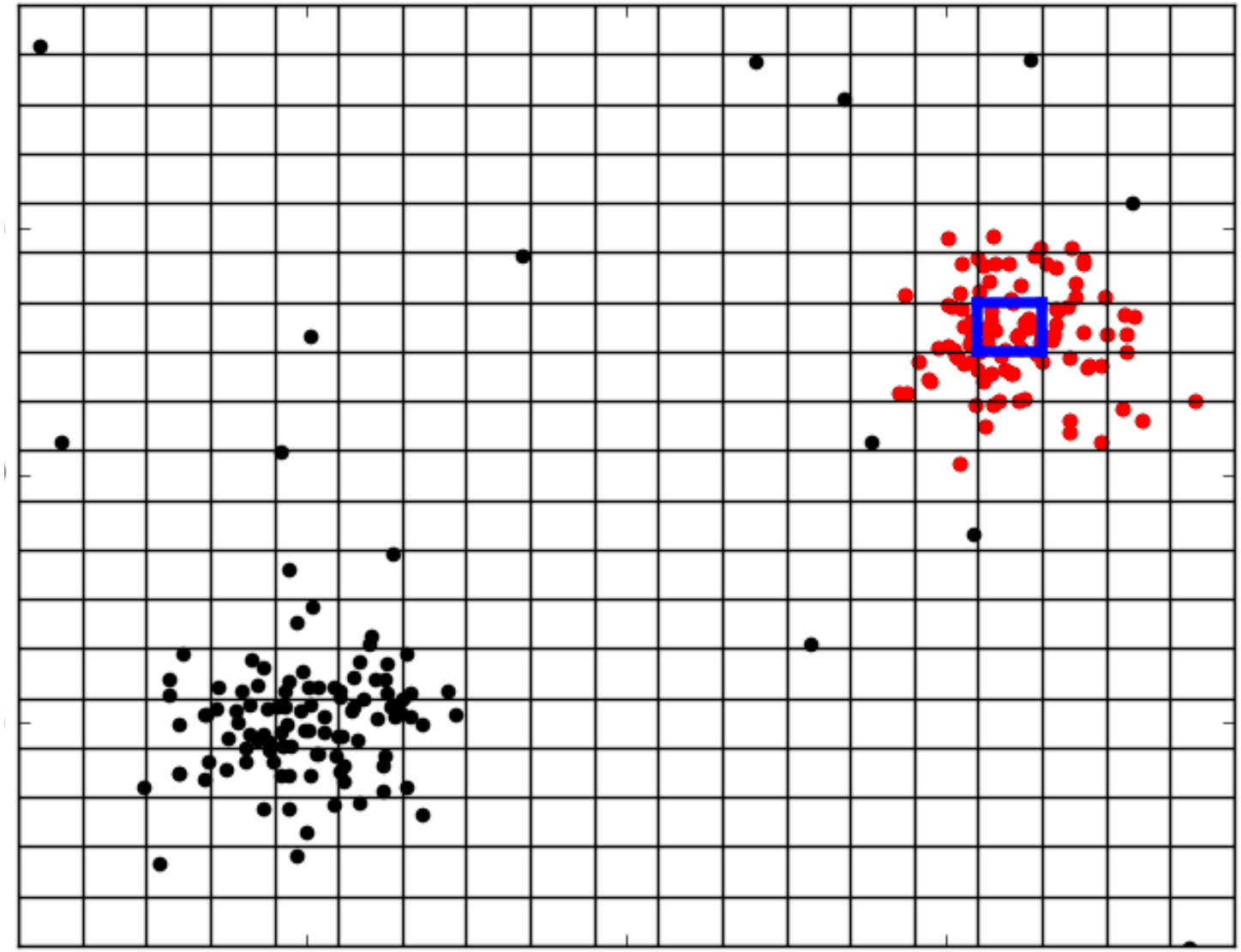
- Binaries!
- Some single
- Some messy
- Bridges

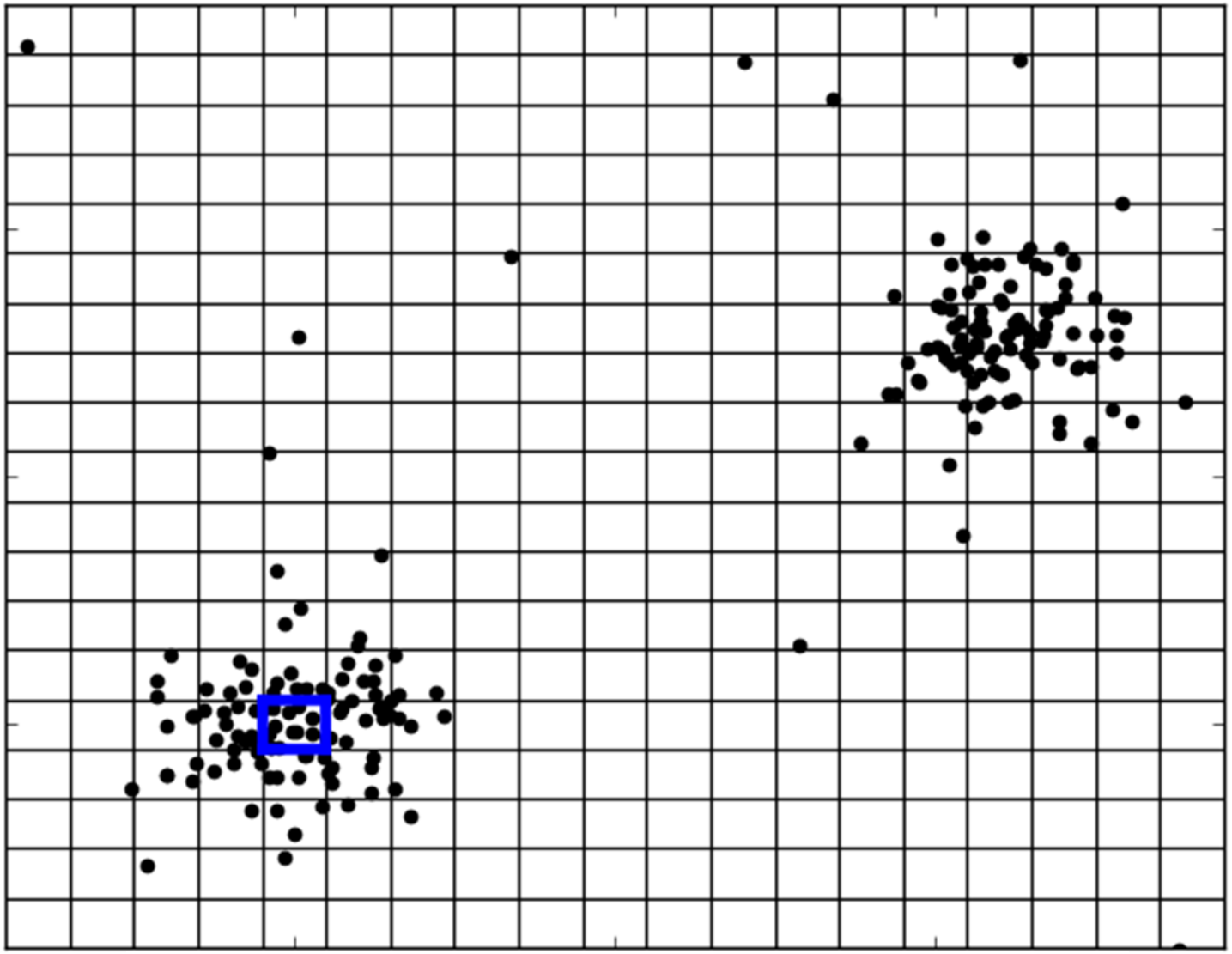


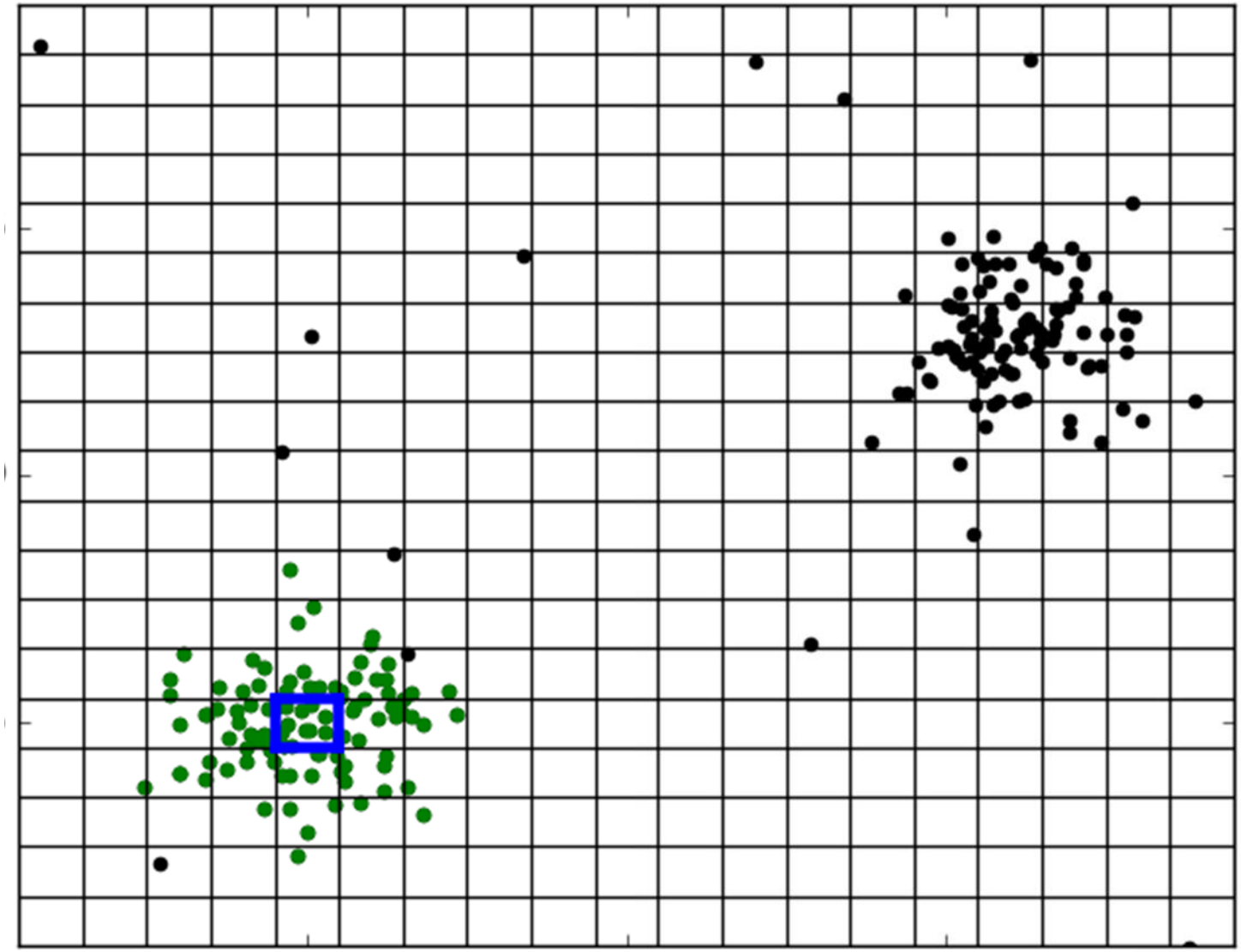


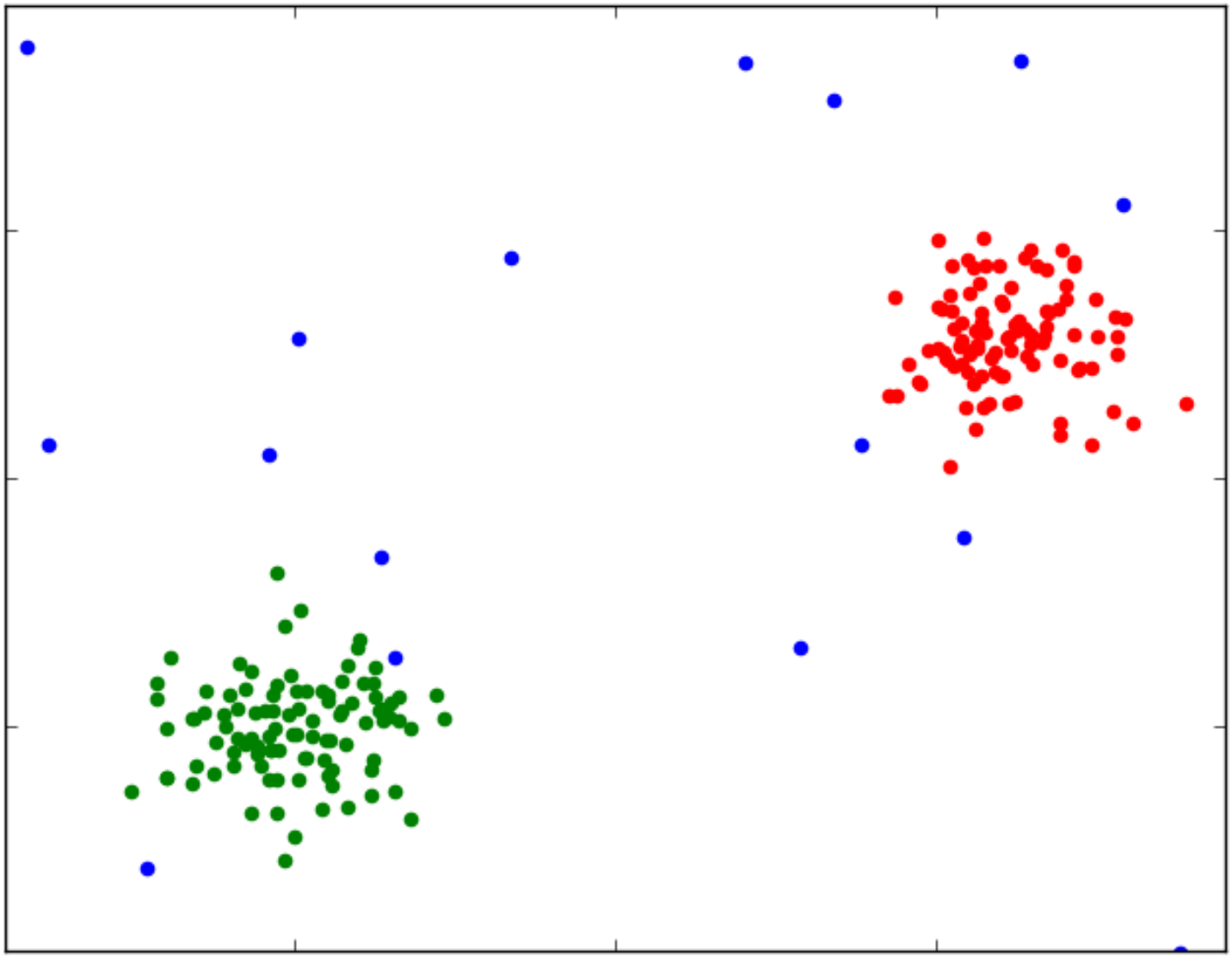


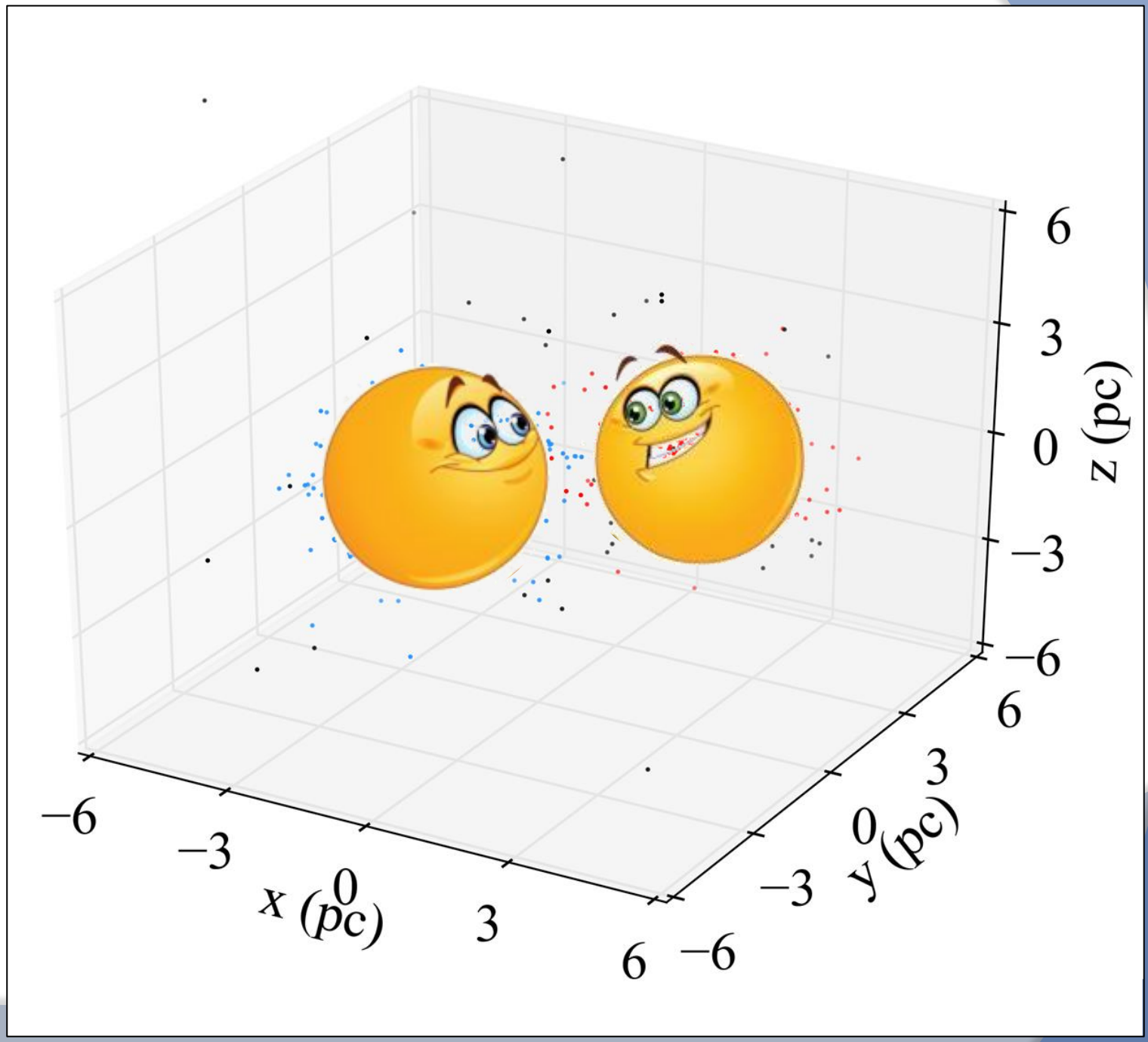








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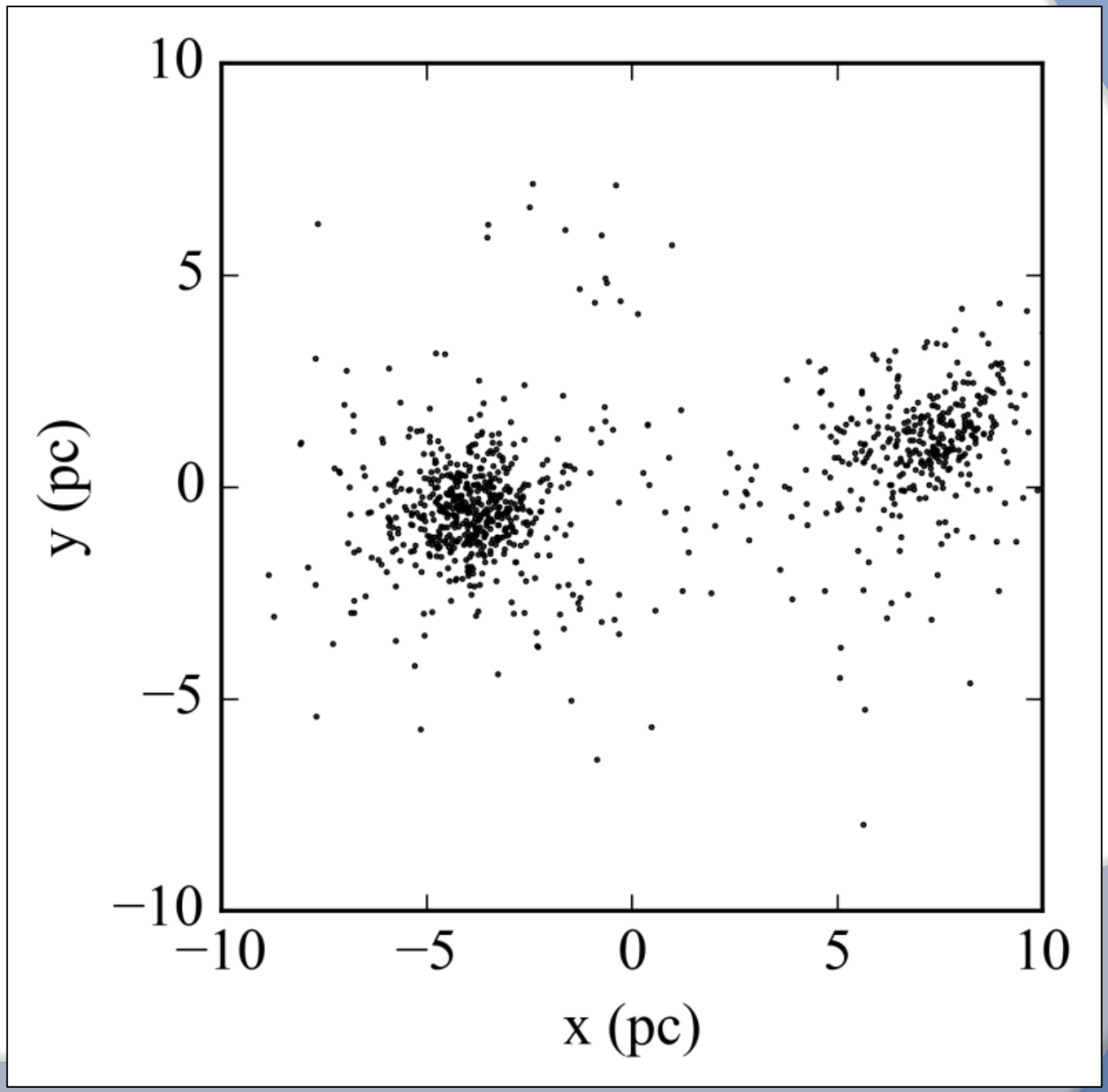
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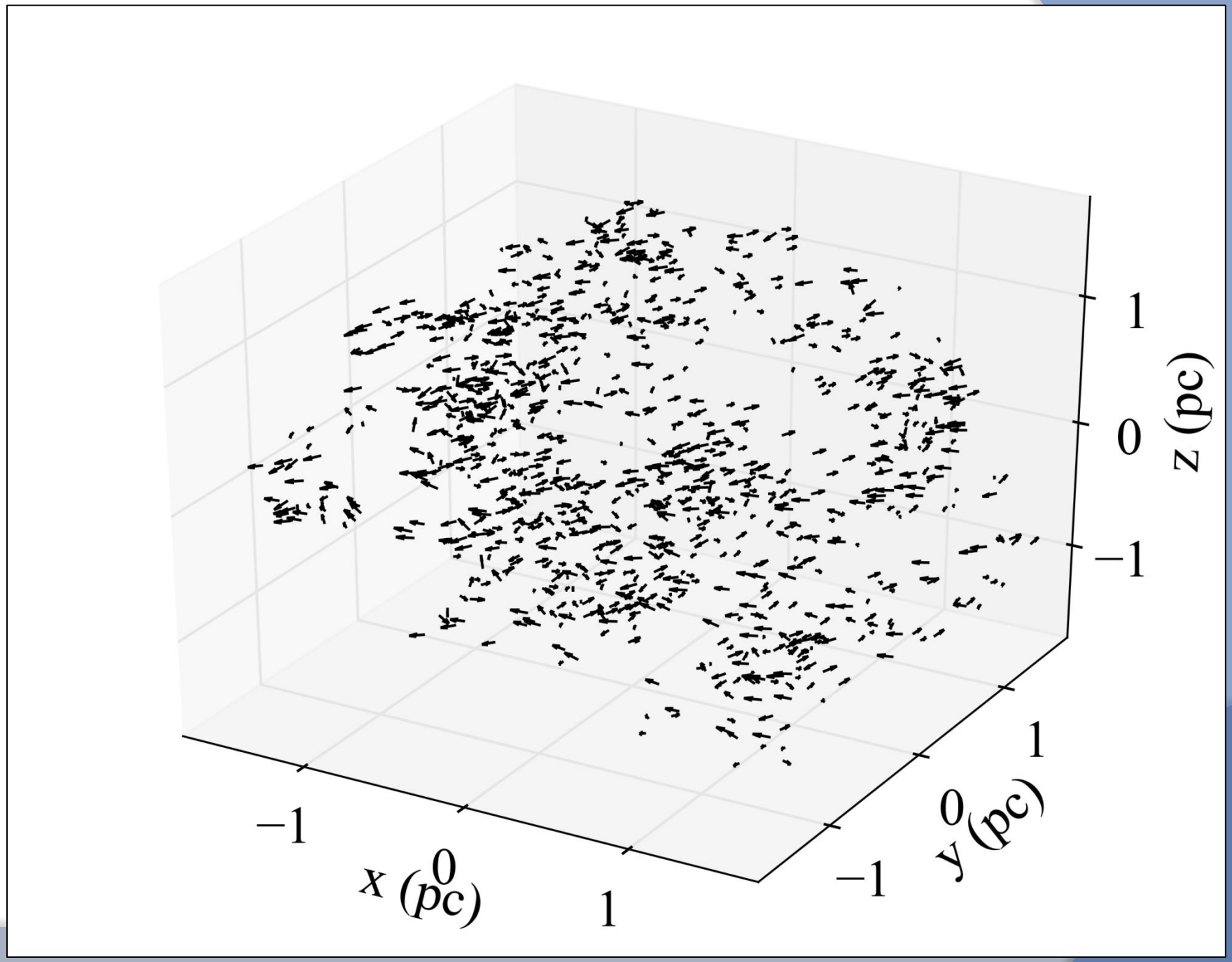
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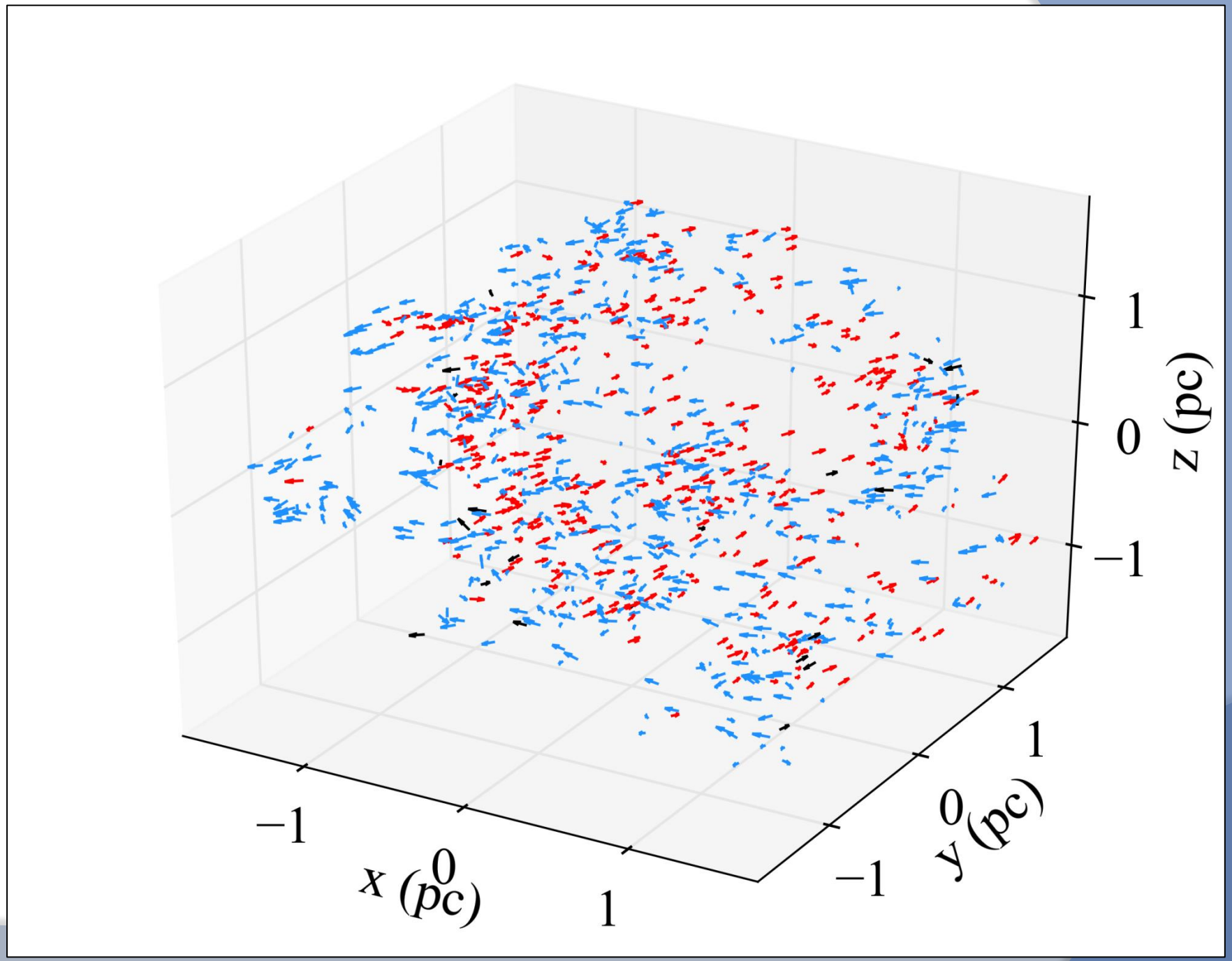
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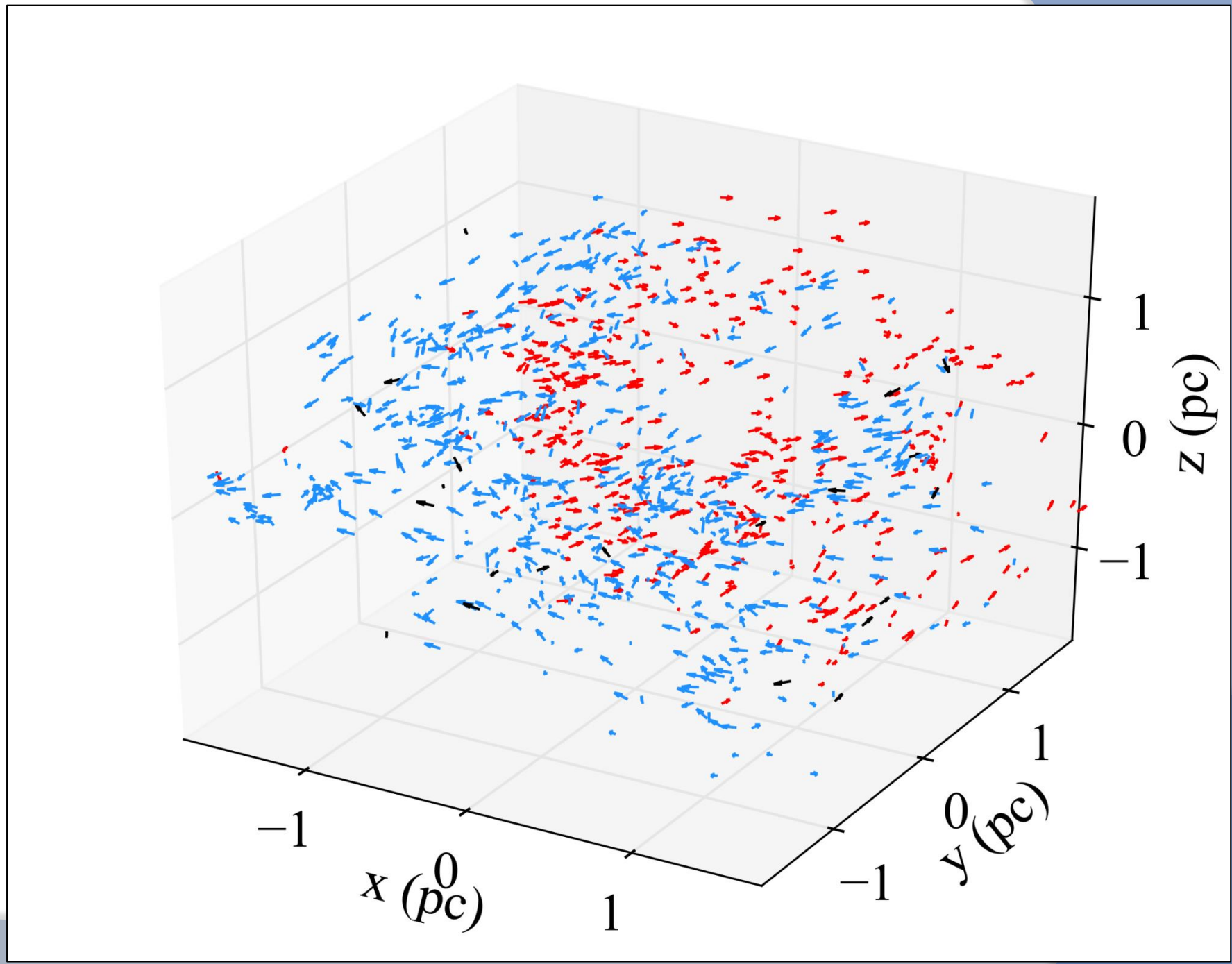
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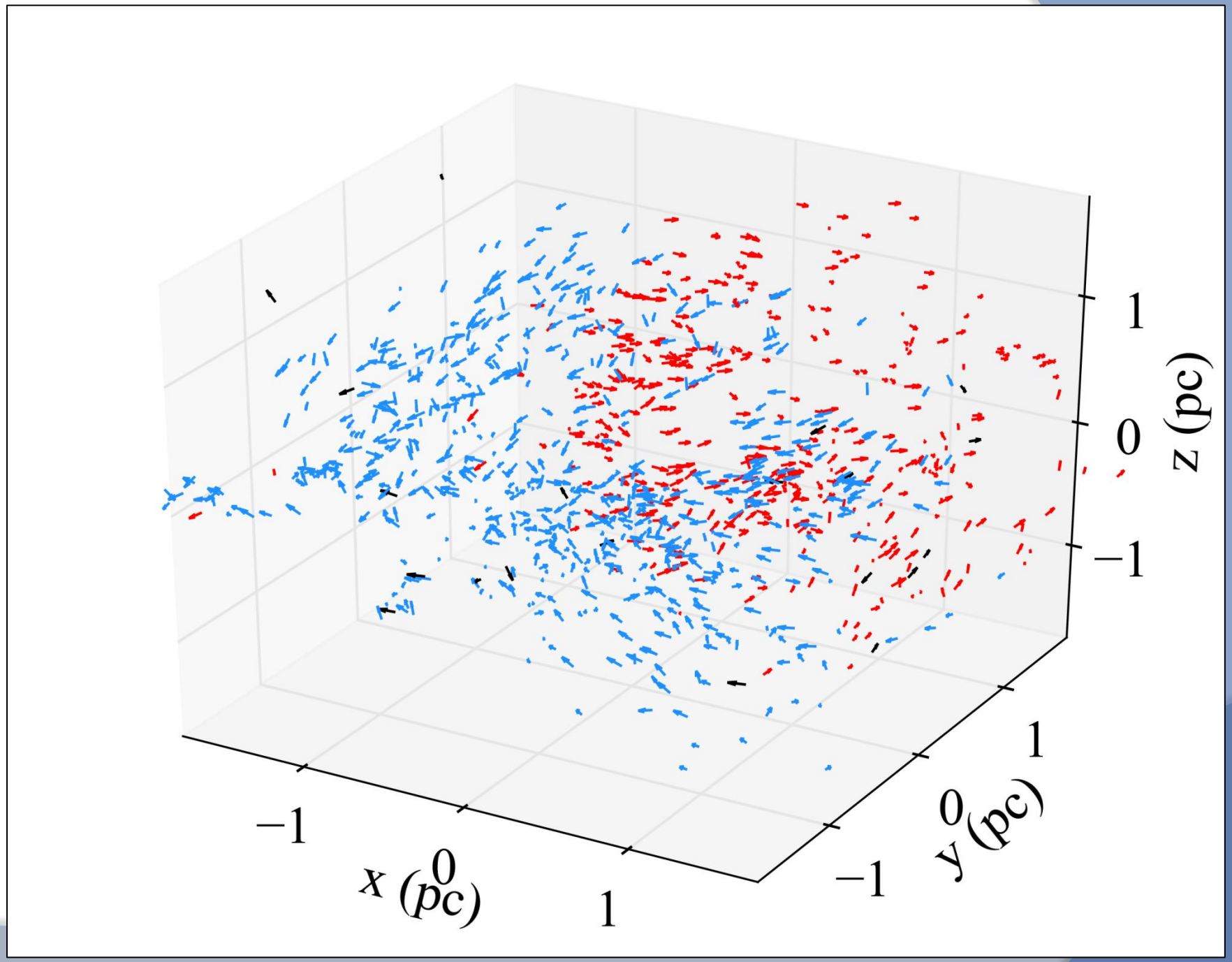
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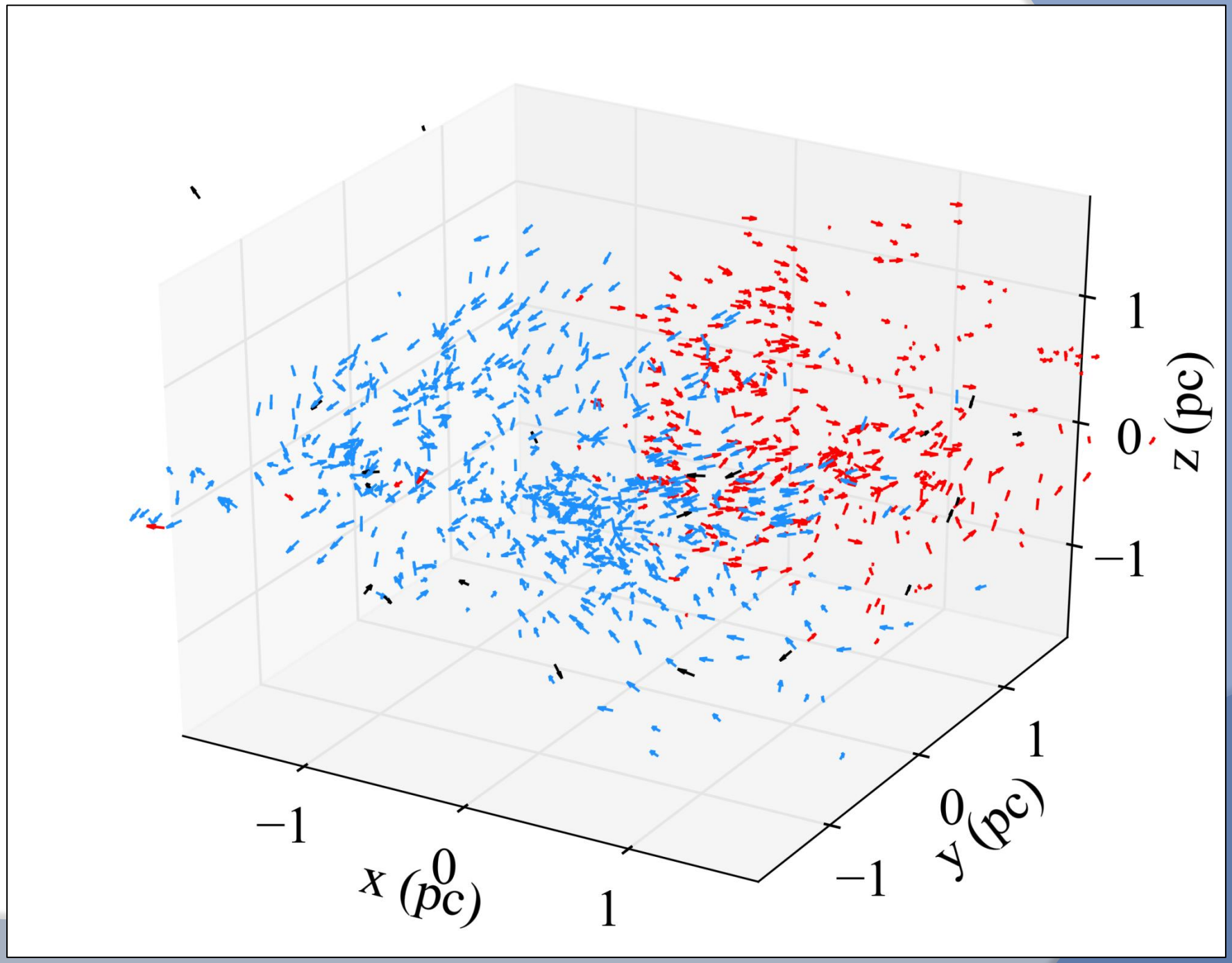
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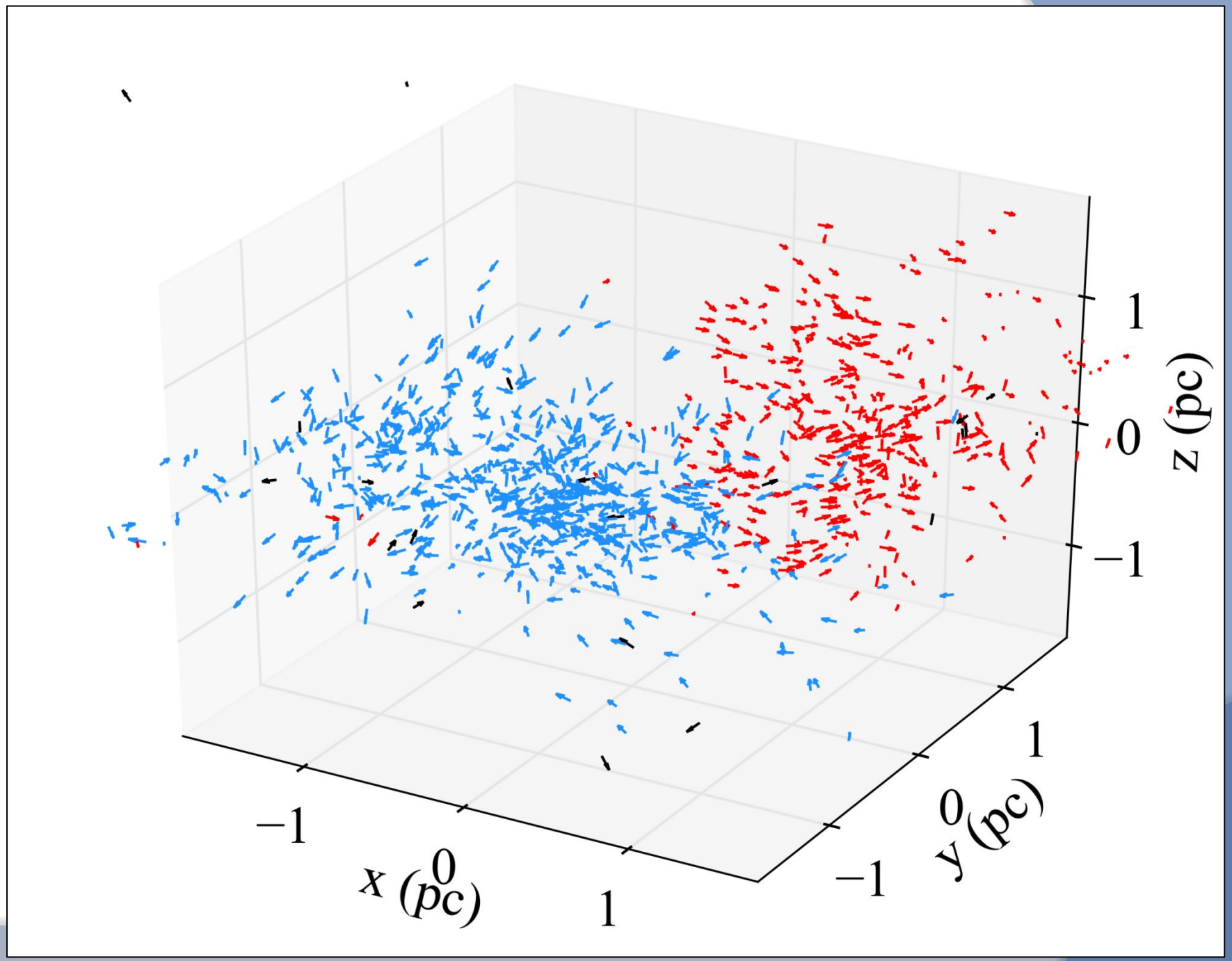
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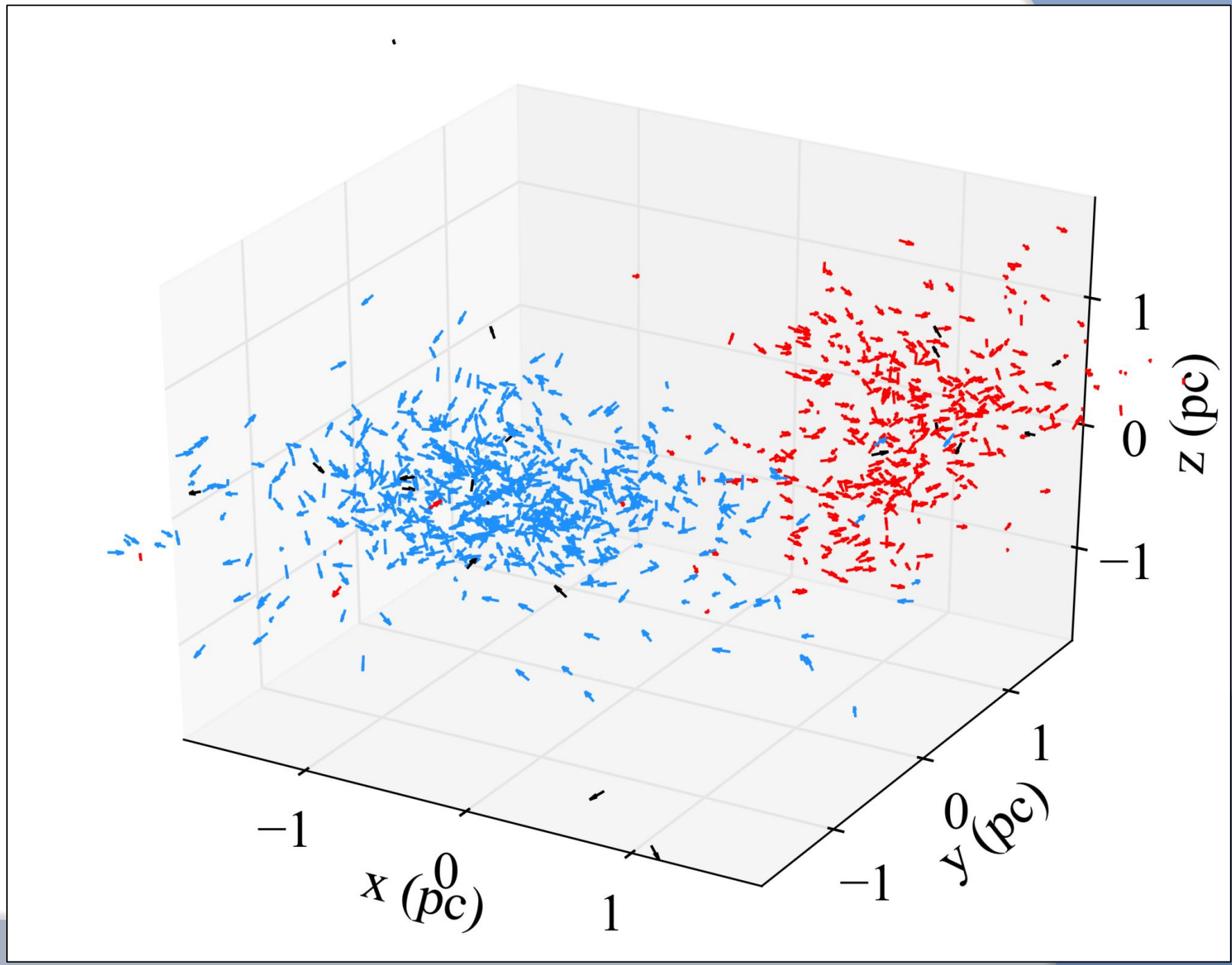
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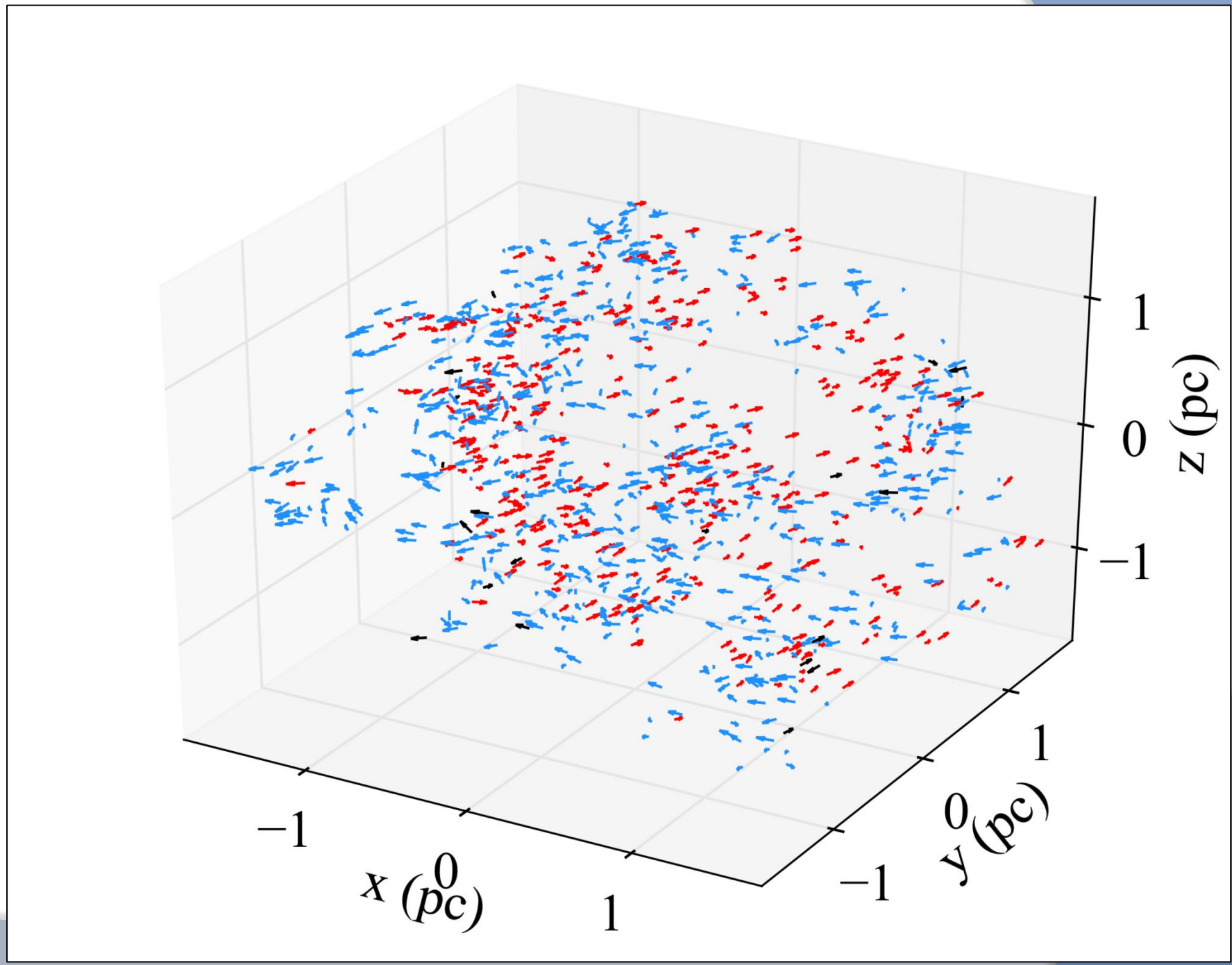
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Parameter space

- Only one set of initial conditions
- Substructure
- Virial ratio
- 50 of each
- Classify
  - Single
  - Binary merger
  - Binary

	Highly substructured	Moderately substructured	Smooth
Virial = 0.3			
Virial = 0.5			
Virial = 0.7			

Parameter space

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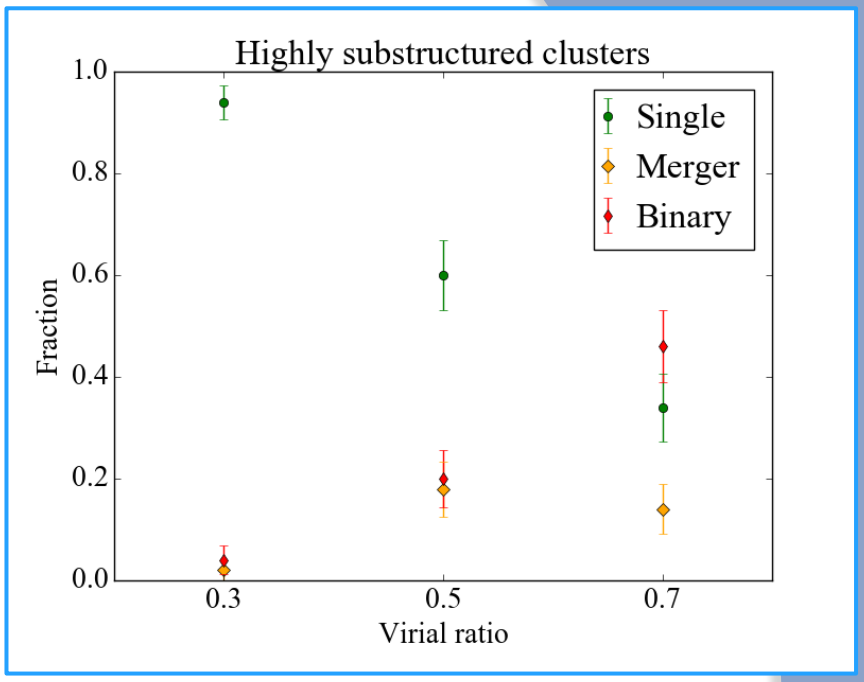
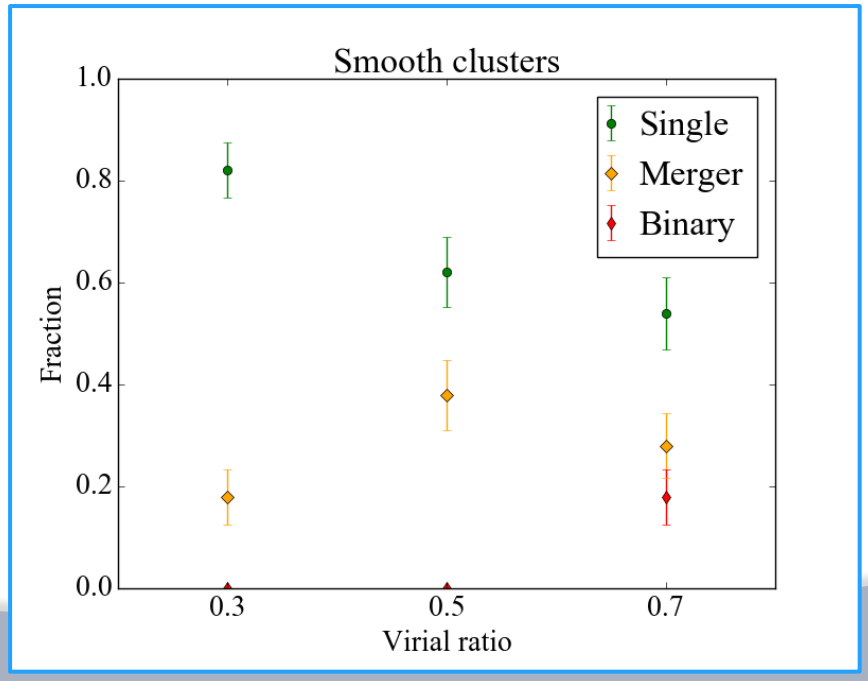
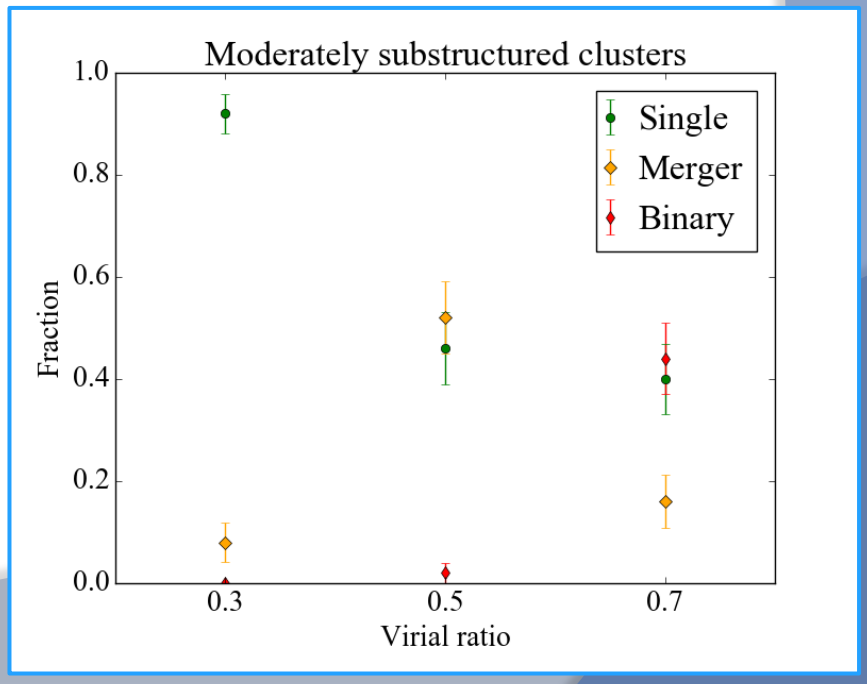
	Highly substructured	Moderately substructured	Smooth
Virial = 0.3	?	?	?
Virial = 0.5	?	?	?
Virial = 0.7	?	?	?

Results

- Binaries only if warm
- Mergers favour equilibrium







Conclusions

- ~ 10 % binary clusters
- Key question
  - Binary clusters may begin as single star forming regions
  - Velocity coherence
- Parameter space
  - Binary = (probably) initially high virial ratio
  - Merger = range