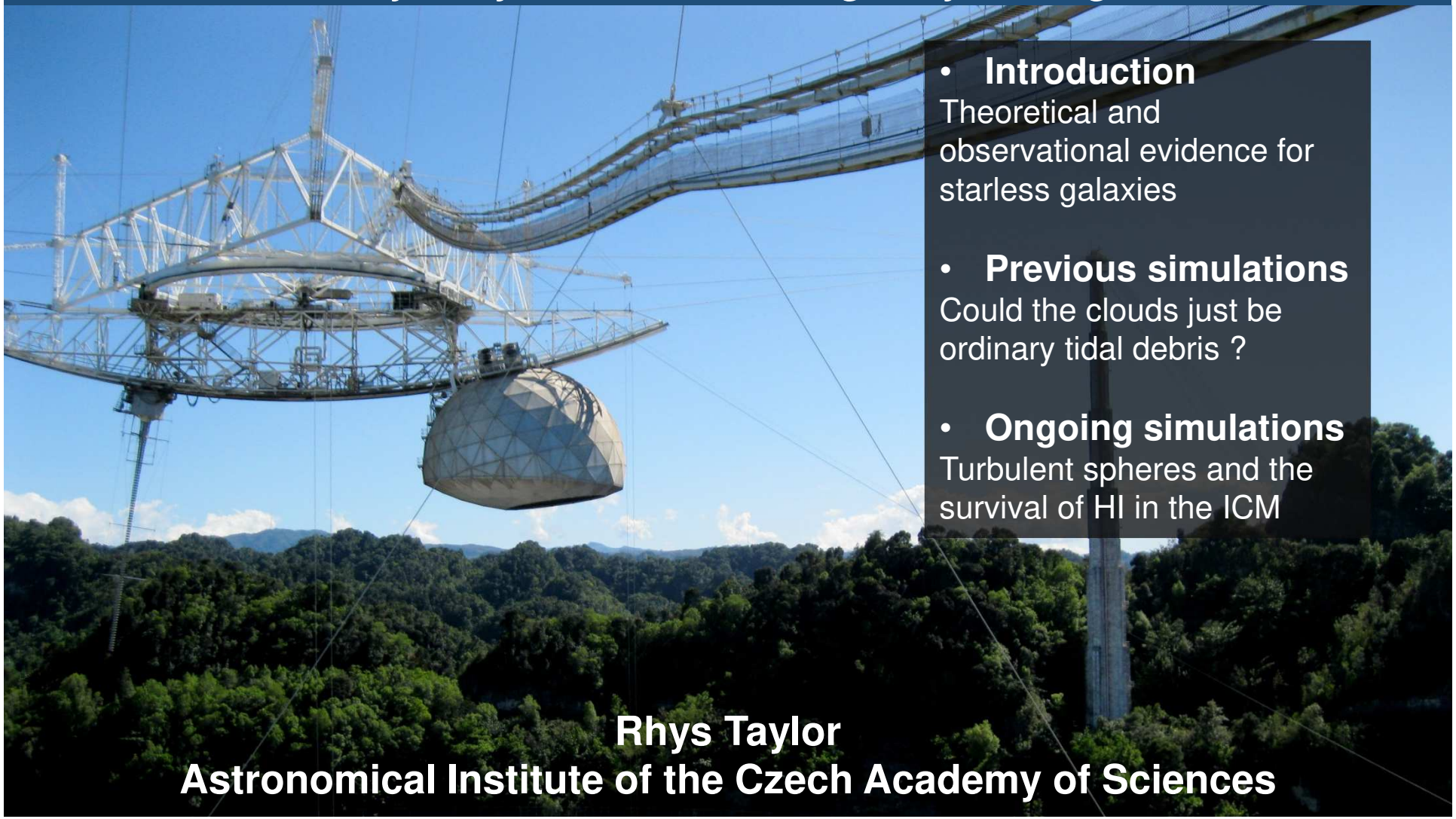
Hydrogen Clouds That Don't Do Anything

…and why they're not as boring as you might think



- **Introduction**
  Theoretical and observational evidence for starless galaxies
- **Previous simulations**
  Could the clouds just be ordinary tidal debris ?
- **Ongoing simulations**
  Turbulent spheres and the survival of HI in the ICM

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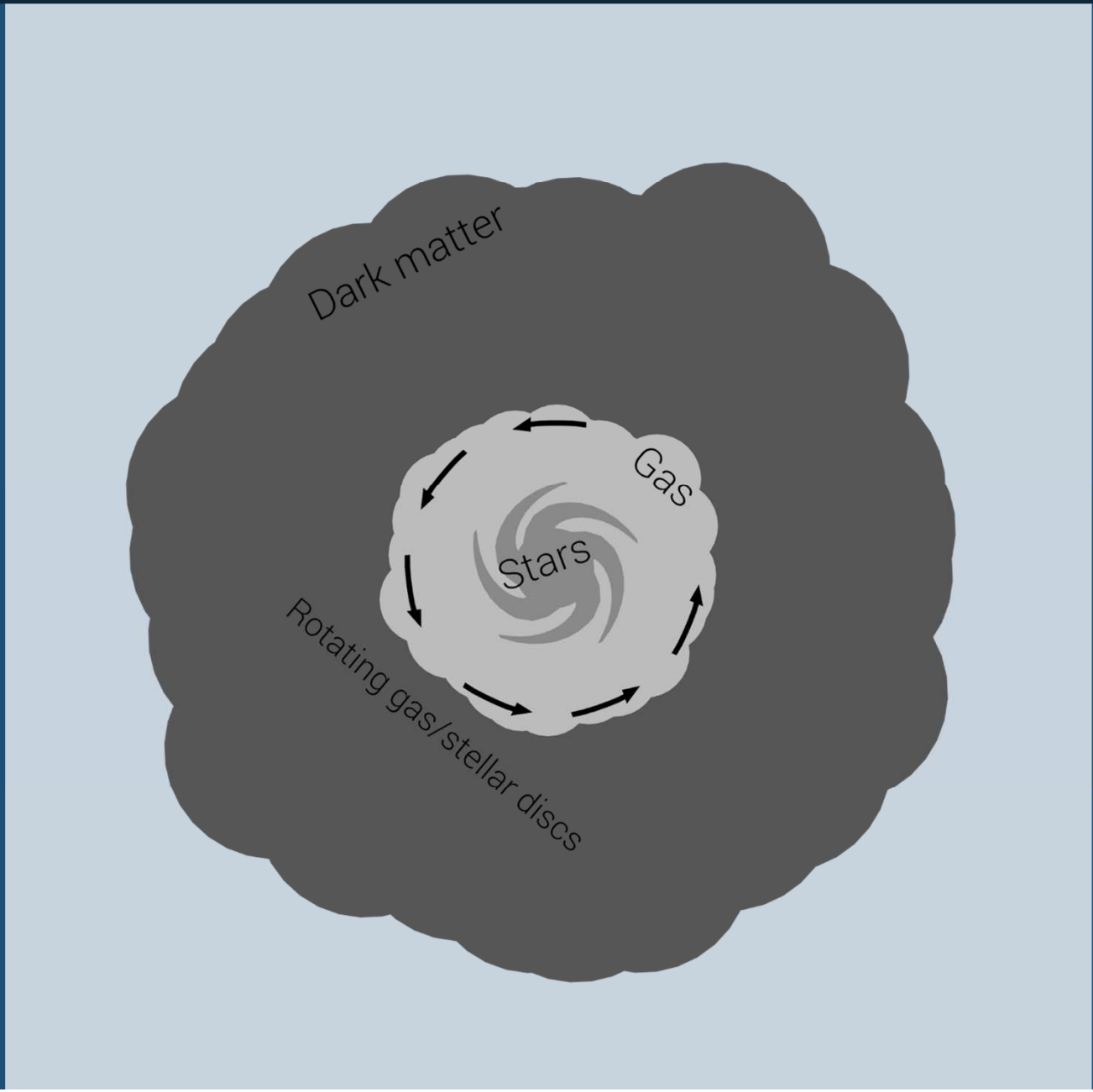
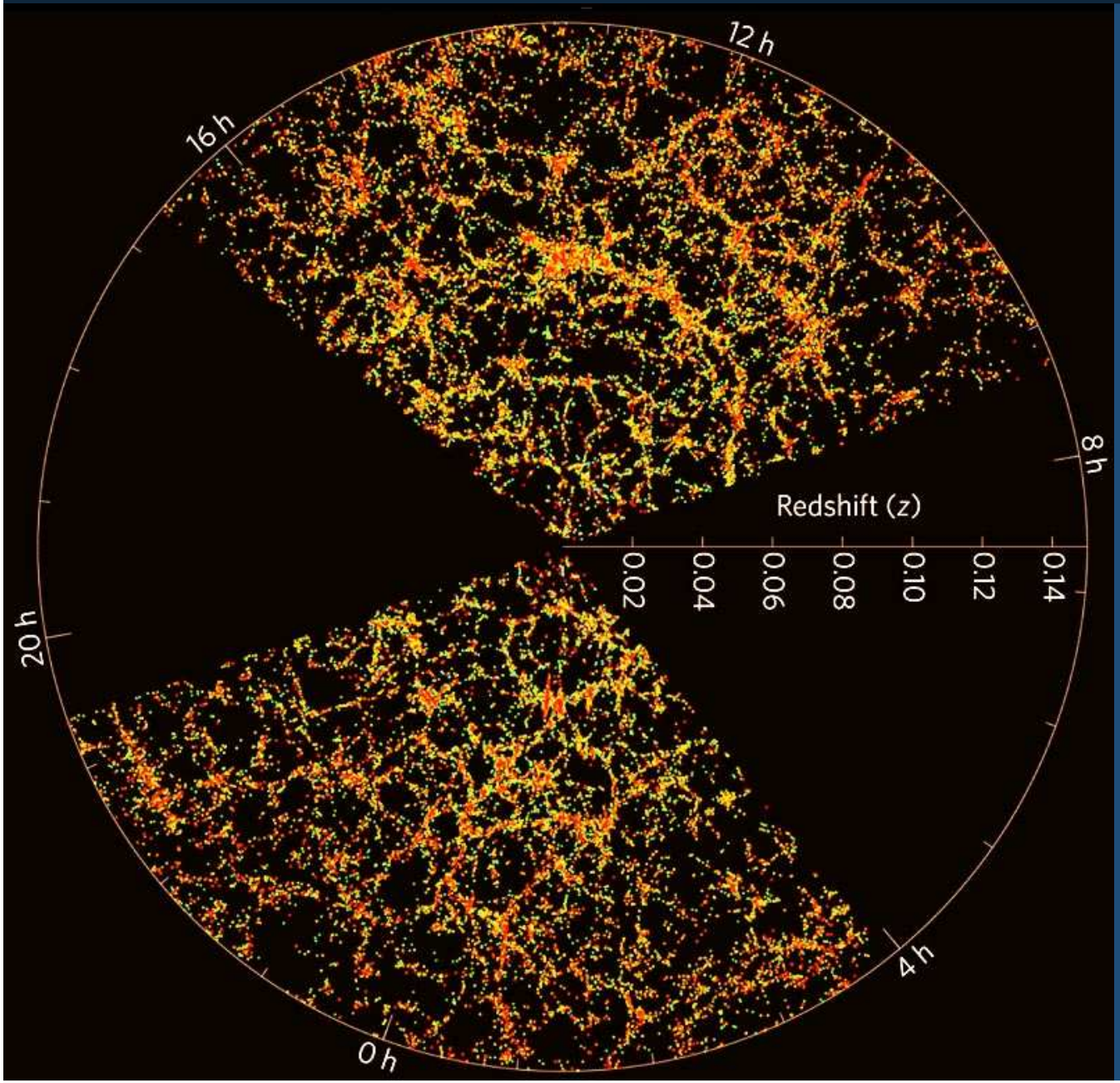
A basic galaxy

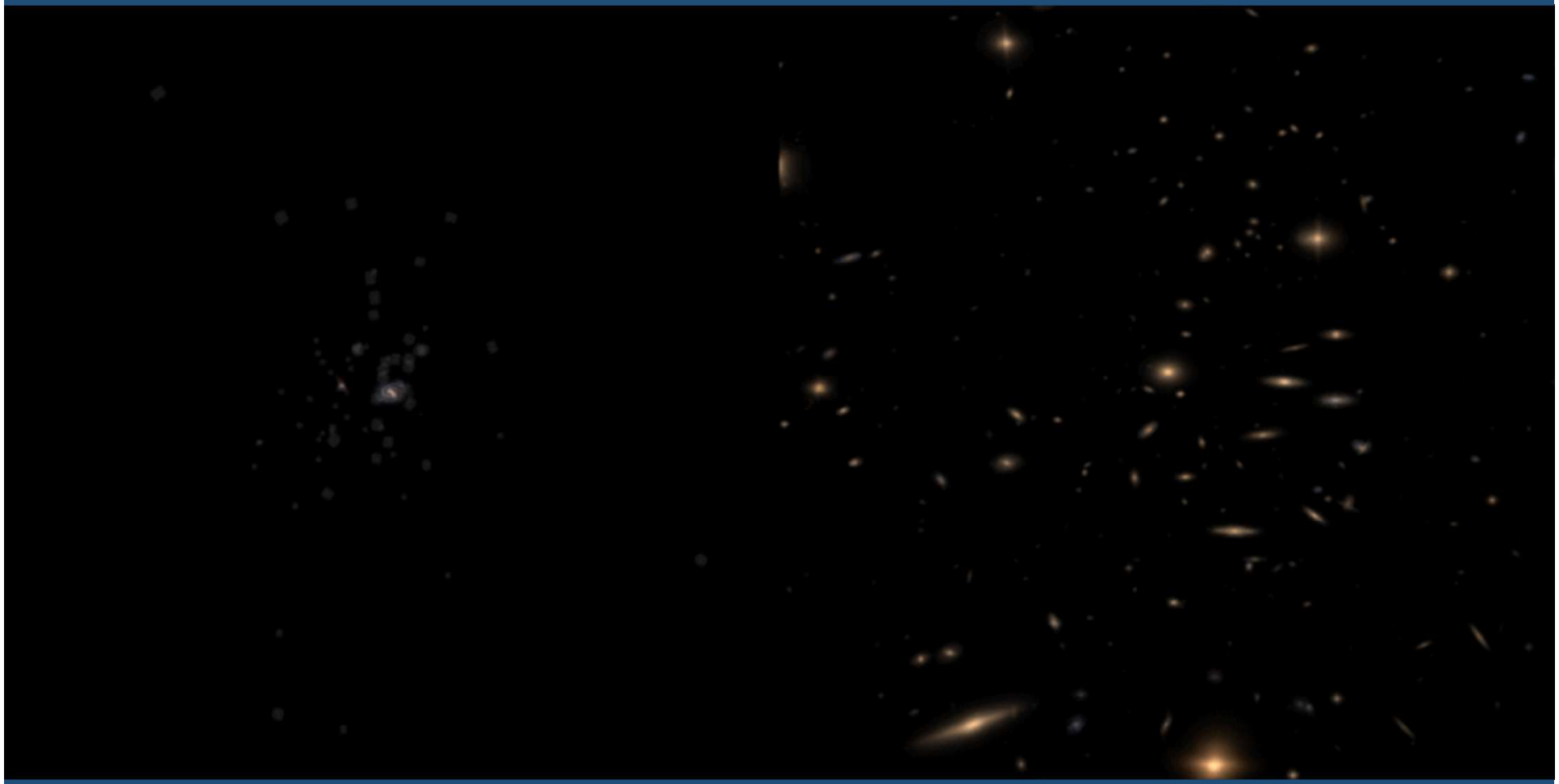


We can predict the big stuff….



- Most matter in the Universe thought to be cold dark matter
- Can model as collisionless particles, computationally cheap
- Gives excellent agreement with observations on very large scales
- … but results on small scales are lousy !

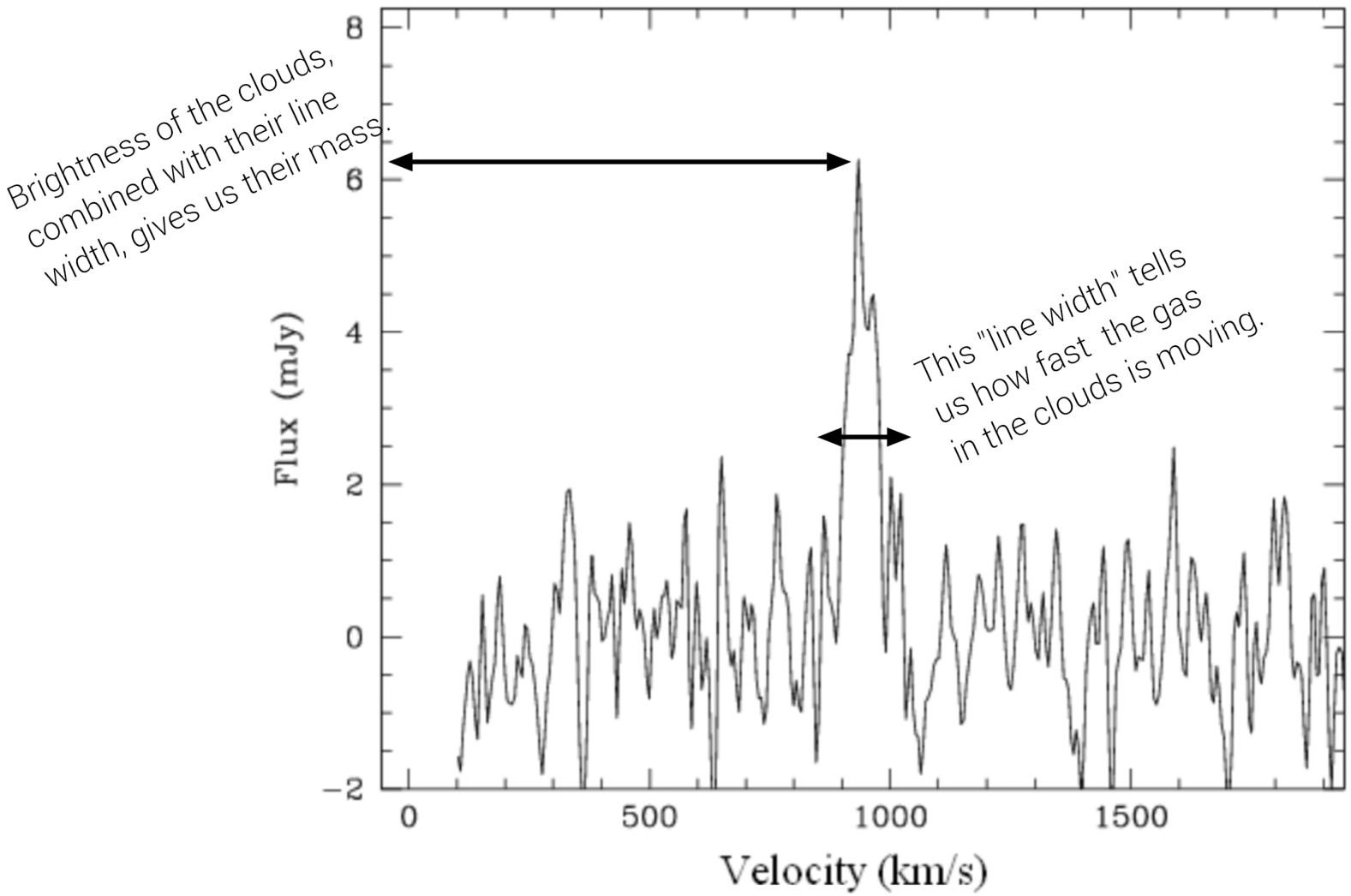
… but not the small stuff



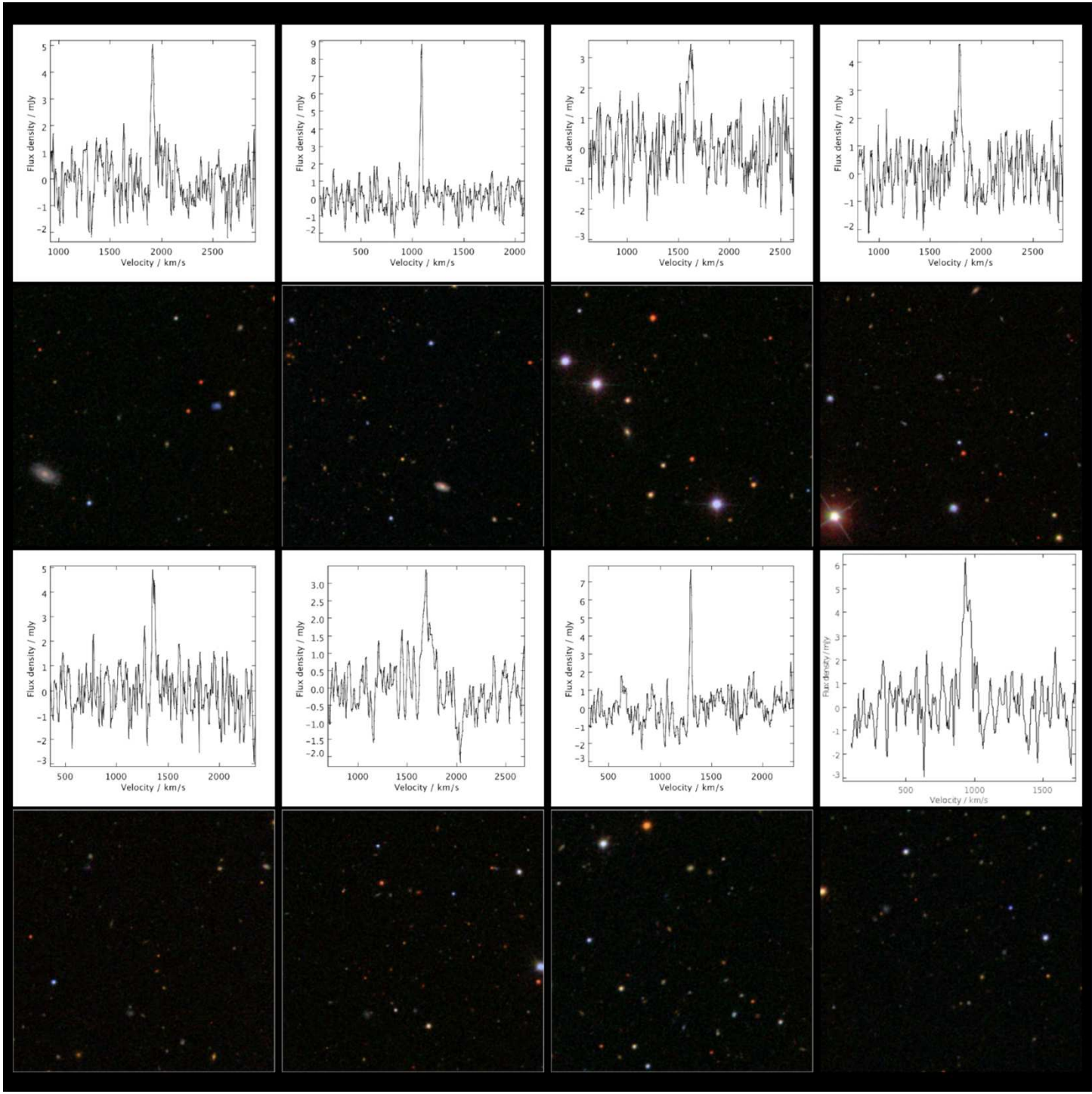
Local Group

Virgo Cluster

HI observations



The typical, "systemtic" velocity of the clouds lets us estimate their distance away from us.

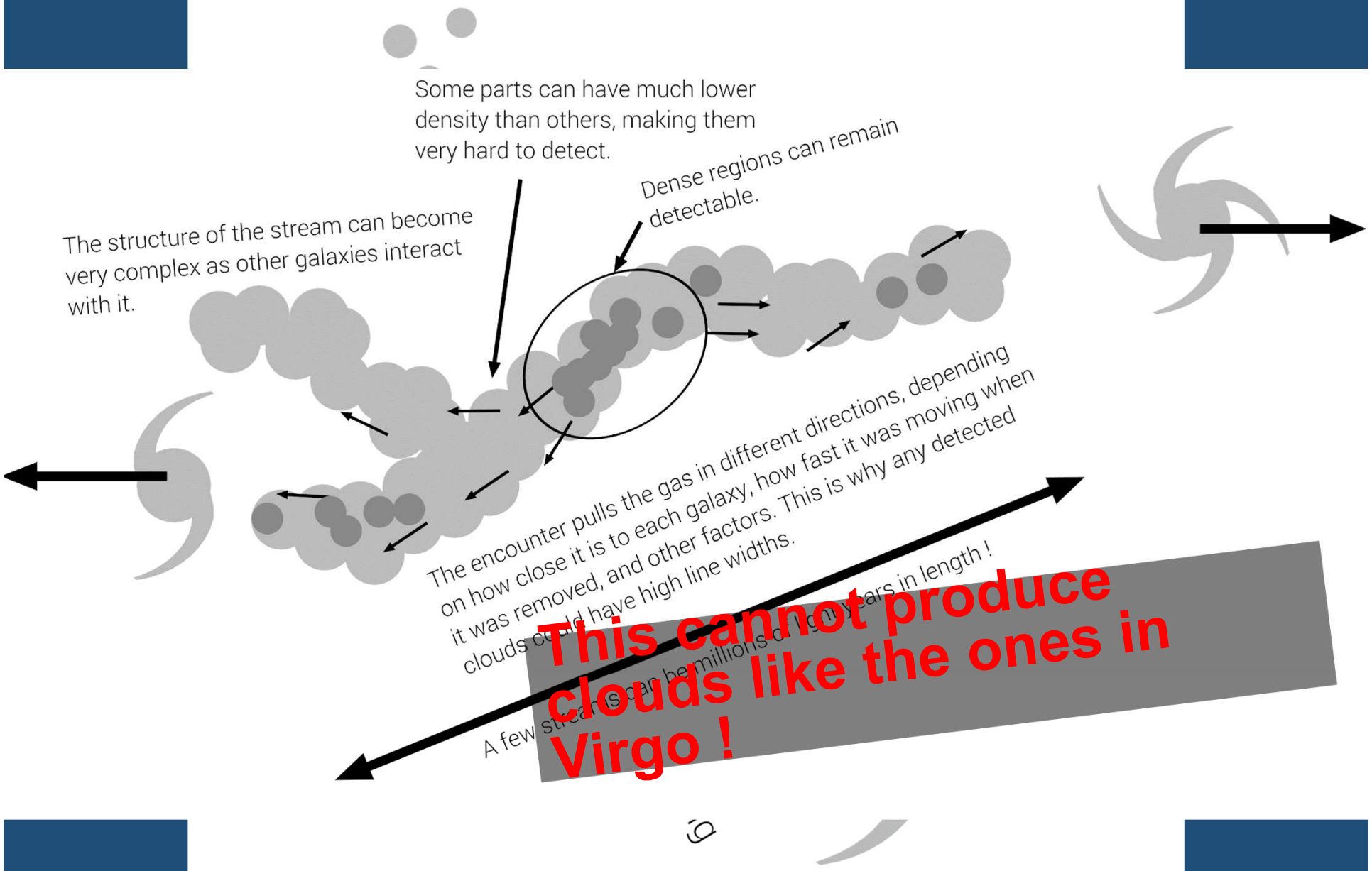


Dark galaxy candidates

- Eight candidates in the Virgo cluster
- Optically dark
- Low HI mass
- Up to 180 km/s line widths

2012MNRAS.423..787T
2013MNRAS.428..459T

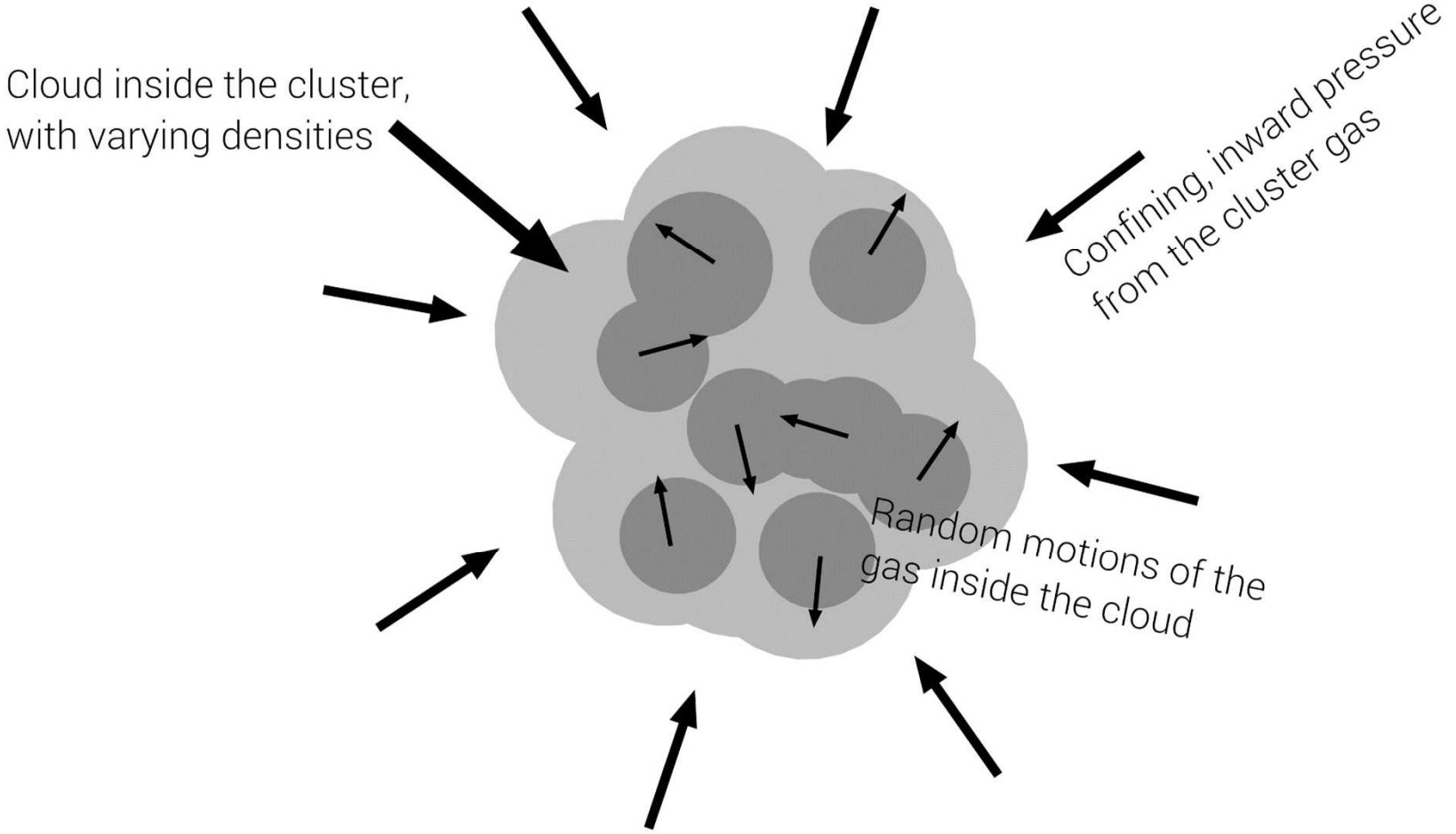
Traditional explanation : tidal debris



Are dark galaxies plausible ?

Dark galaxies can be stable and survive tidal encounters in the cluster

New explanation : it's the environment



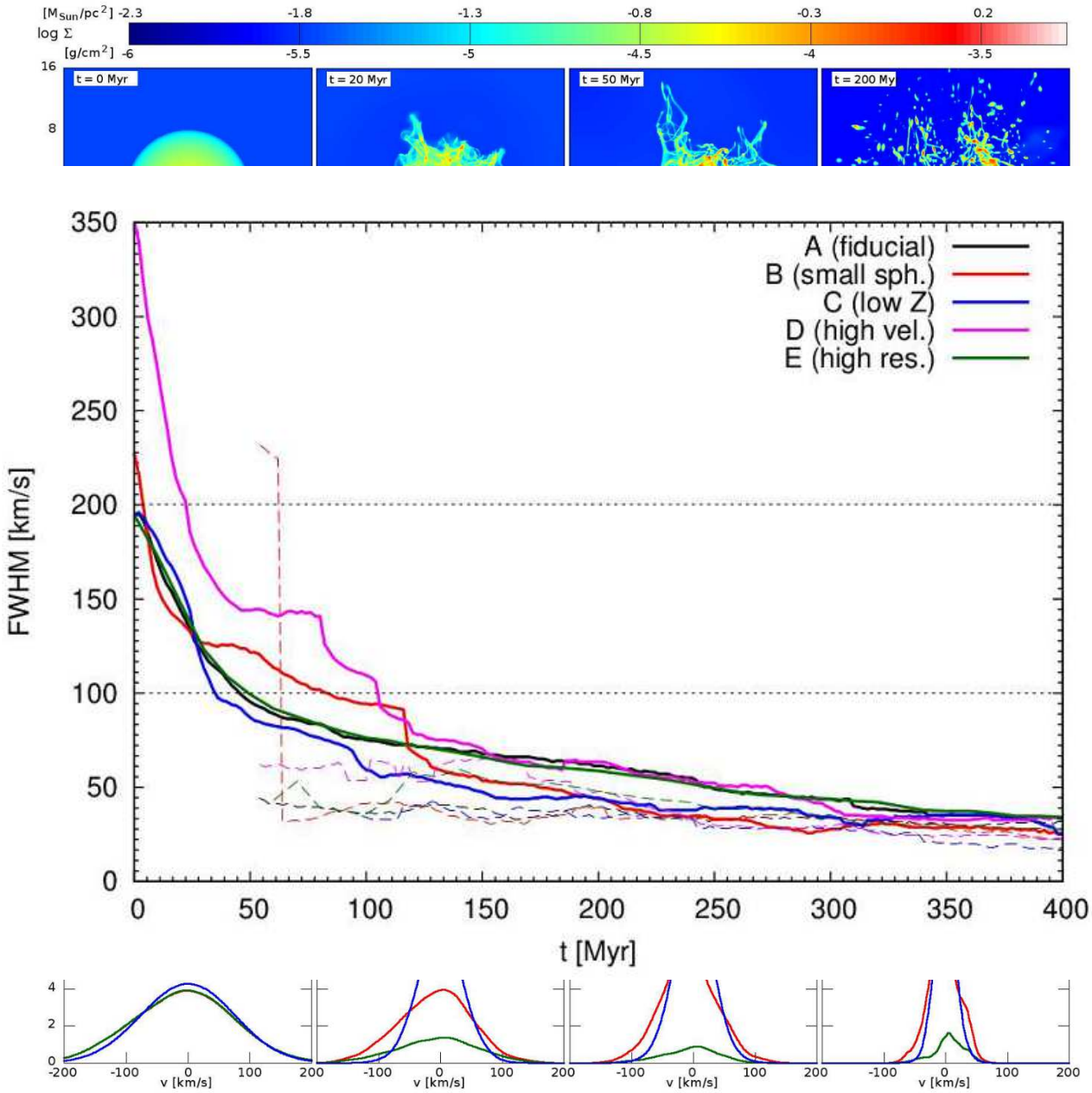
Model of Burkhart & Loeb 2016 predicts size of the clouds

$$r = \sqrt[3]{\frac{M_{HI}(W50/2.35)^2}{\frac{4}{3}\pi P_{ICM}}}$$

Will no-one rid me of this turbulent sphere ?

- FLASH grid code
- Warm gas representing HI surrounded by hot, thin ICM
- Initial Gaussian sphere of HI matching observed mass and line width
- ICM from standard model of Vollmer et al. 2001
- Have tried varying size of HI, structure of velocity field
- Heating, cooling
- No motion through the ICM, magnetic fields, driving of turbulence, chemistry

No, that doesn't work either



We found three modes of behavior :

1) Dispersal
2) Heating
3) Collapse

- None match the observations for longer than 100 Myr : the high line width is hard to sustain

Summary

We found eight optically dark, isolated HI clouds in the Virgo cluster with high line widths. We tested three scenarios to explain them.

TIDAL DEBRIS

- Works very well for low width clouds
- Can produ… high line width clouds w… …eam
- Pretty much fails entirely for isolated high width clouds

TURBULENT S…

- Demonstrate… and the ICM…
- Quickly re… width fe…re
- Pretty much … isolated high…

But the impact of the ICM is not…