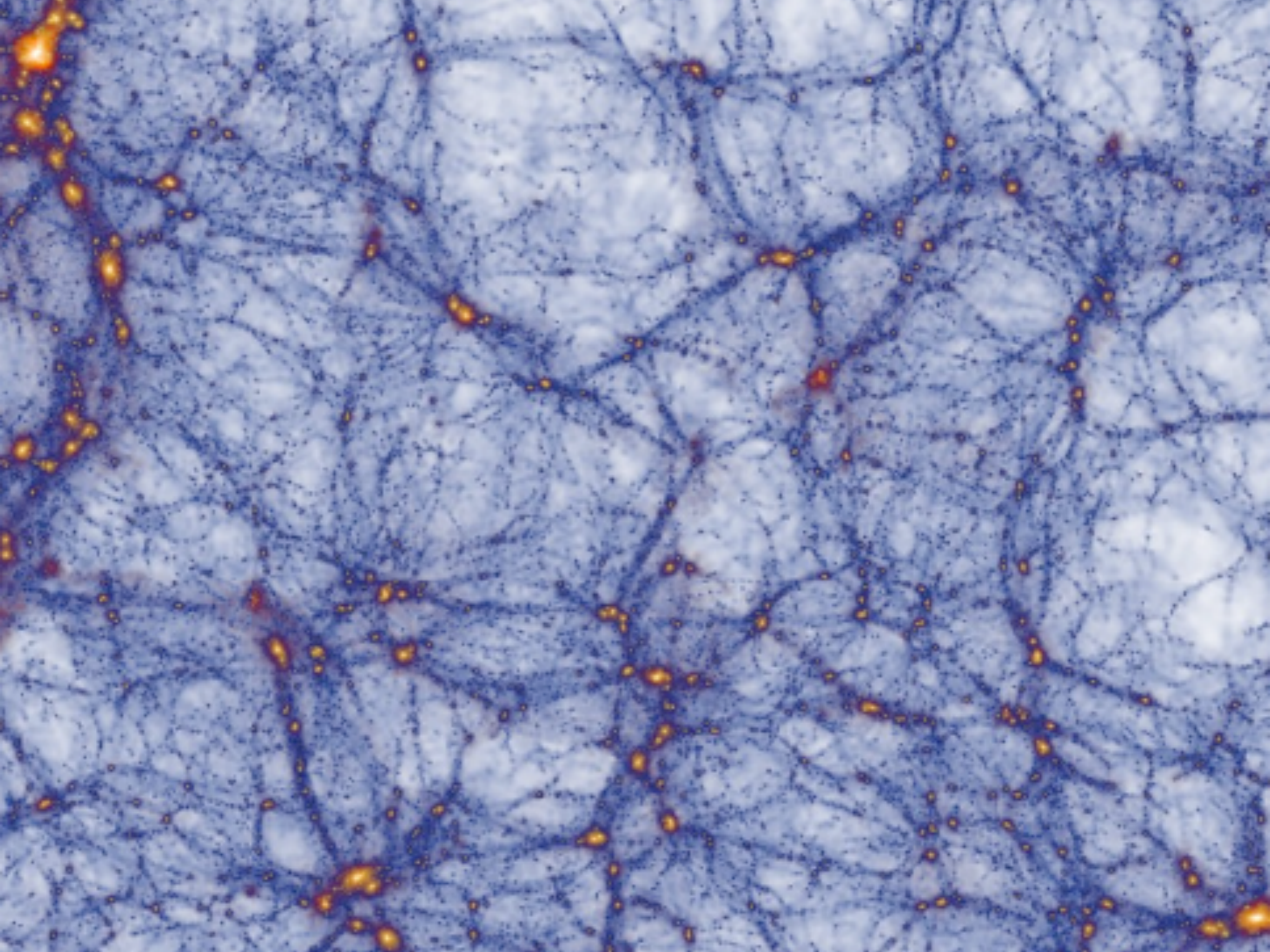
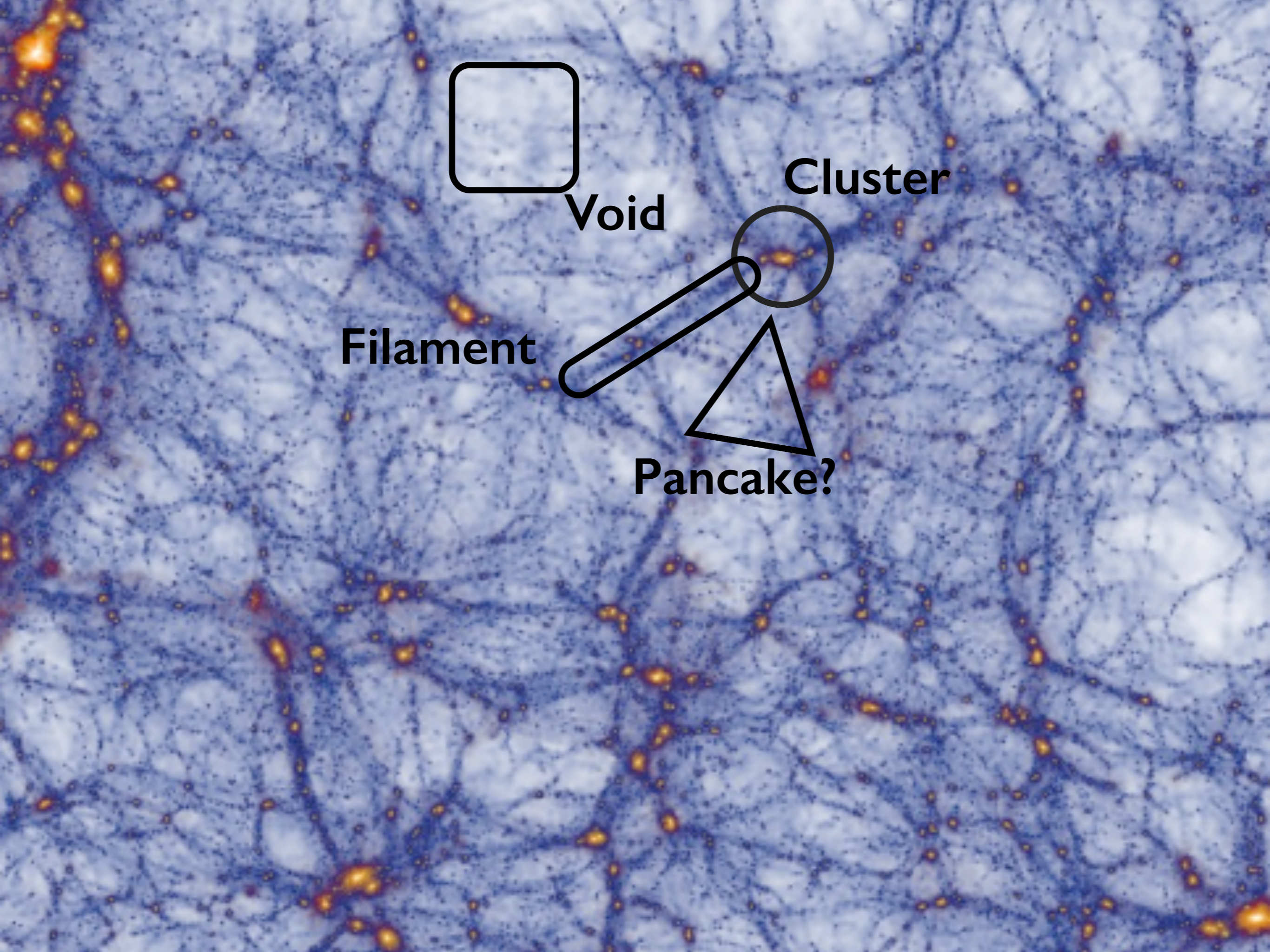


# Pancakes in Space

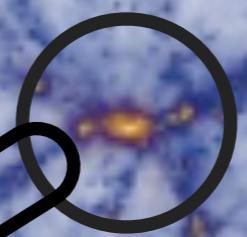
Steen H. Hansen,  
Dark Cosmology Centre,  
Copenhagen, Denmark

Brinkmann et al. JCAP 2016,  
Wadekar & Hansen MNRAS 2015,  
Falco et al. MNRAS 2014

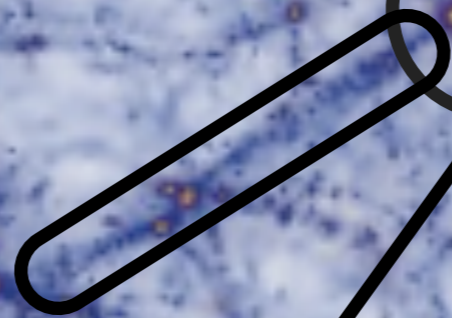




**Void**



**Cluster**

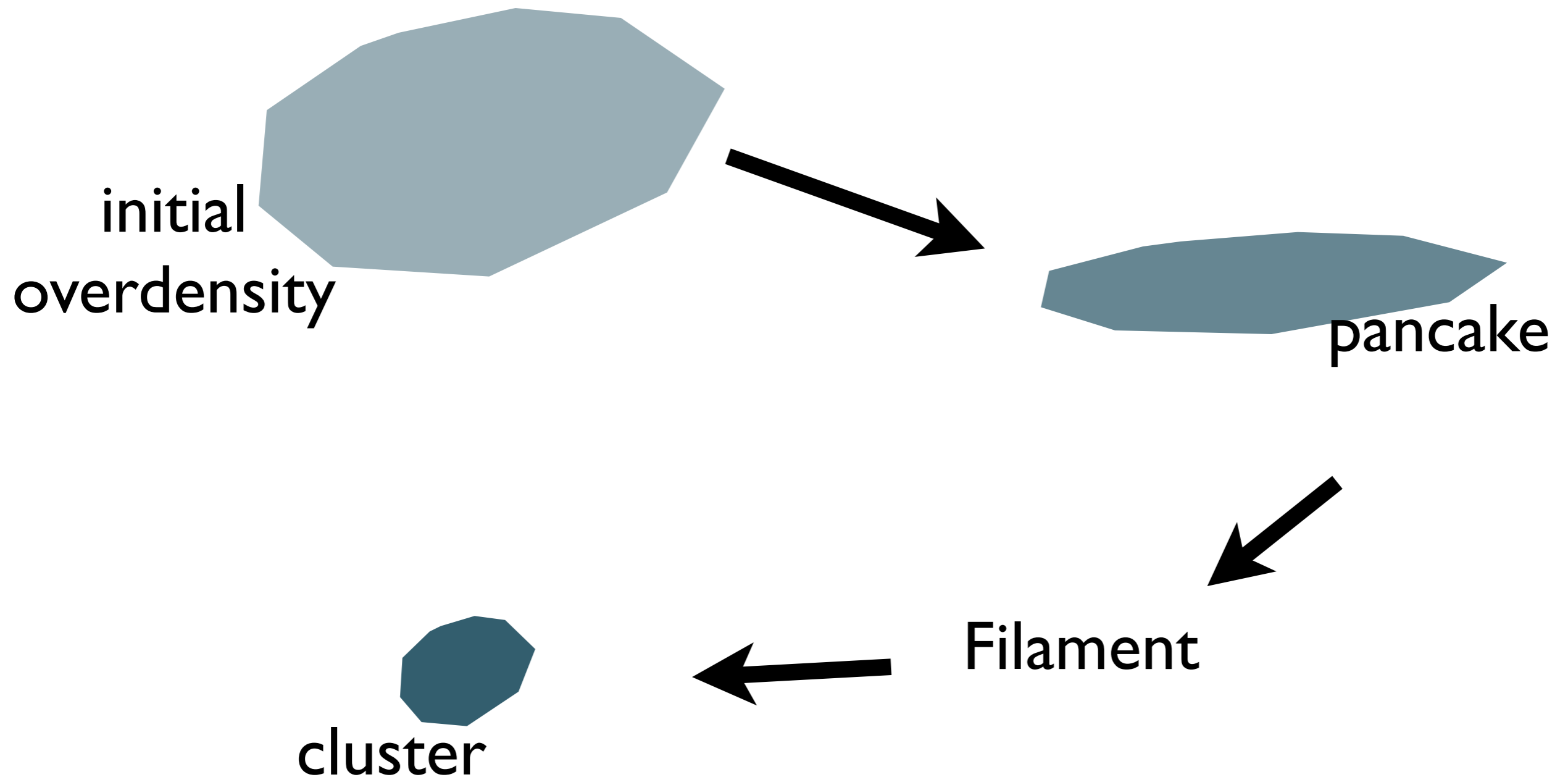


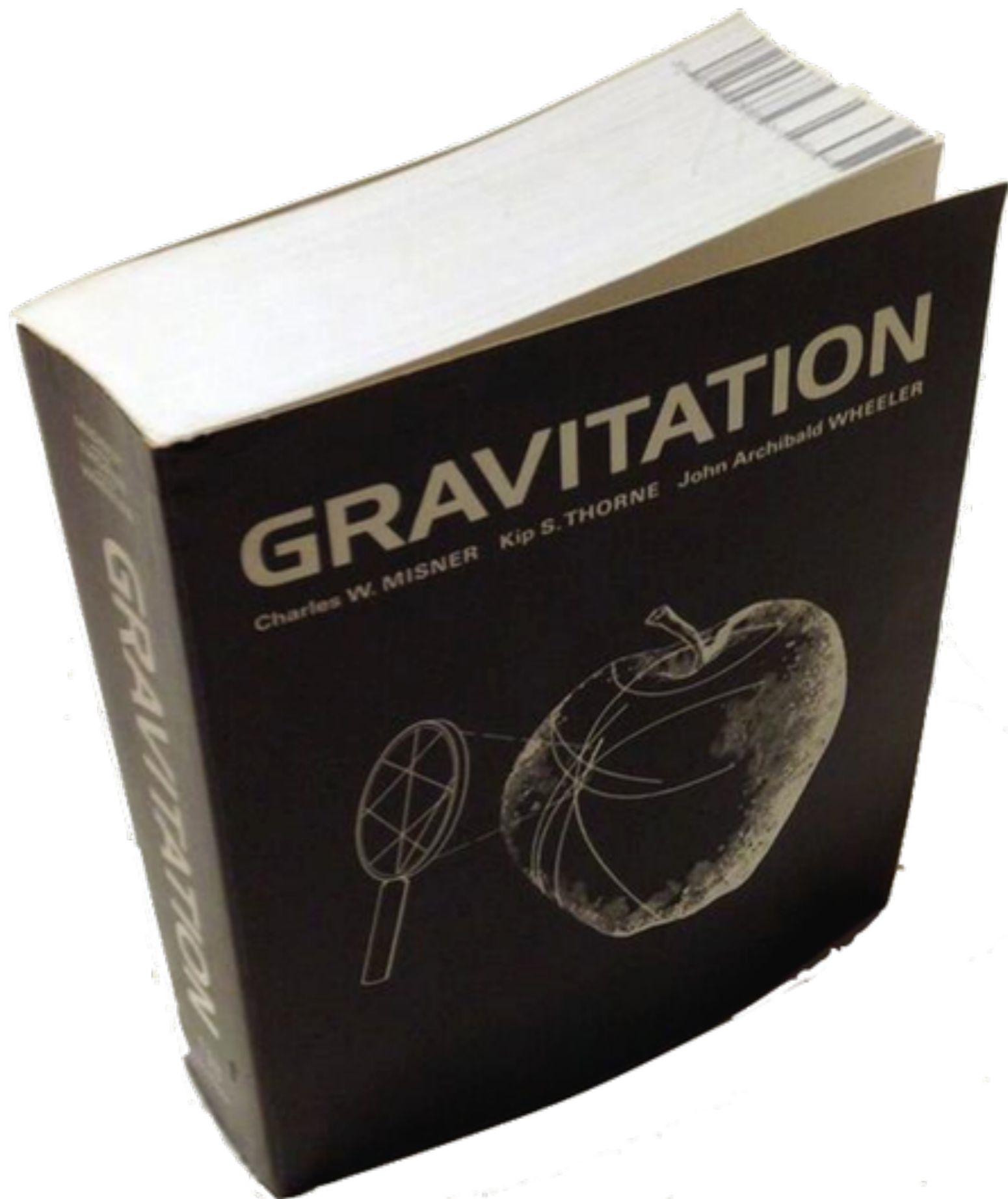
**Filament**



**Pancake?**

# Pancakes have only collapsed along one direction





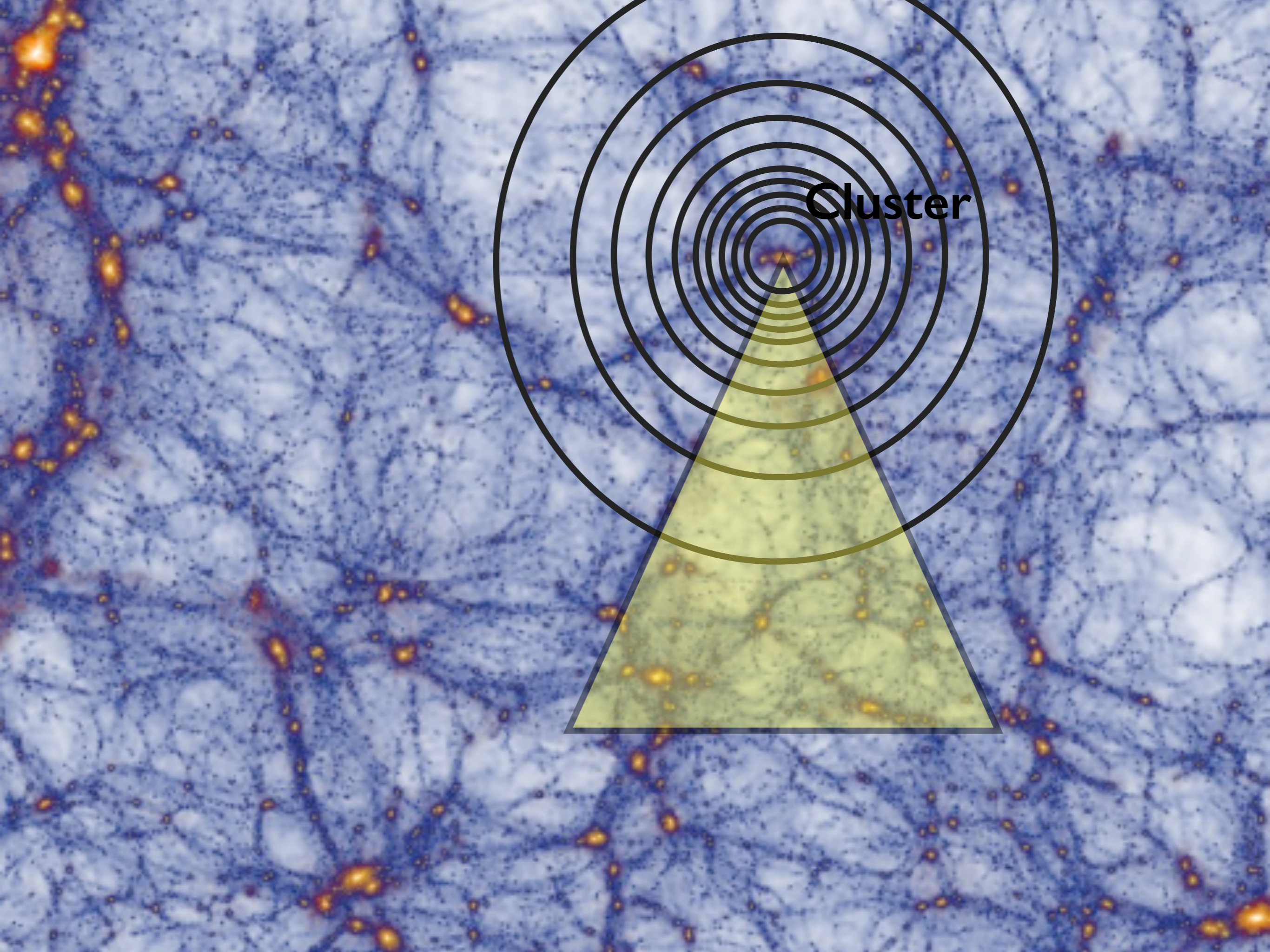
# GRAVITATION

Charles W. MISNER Kip S. THORNE John Archibald WHEELER

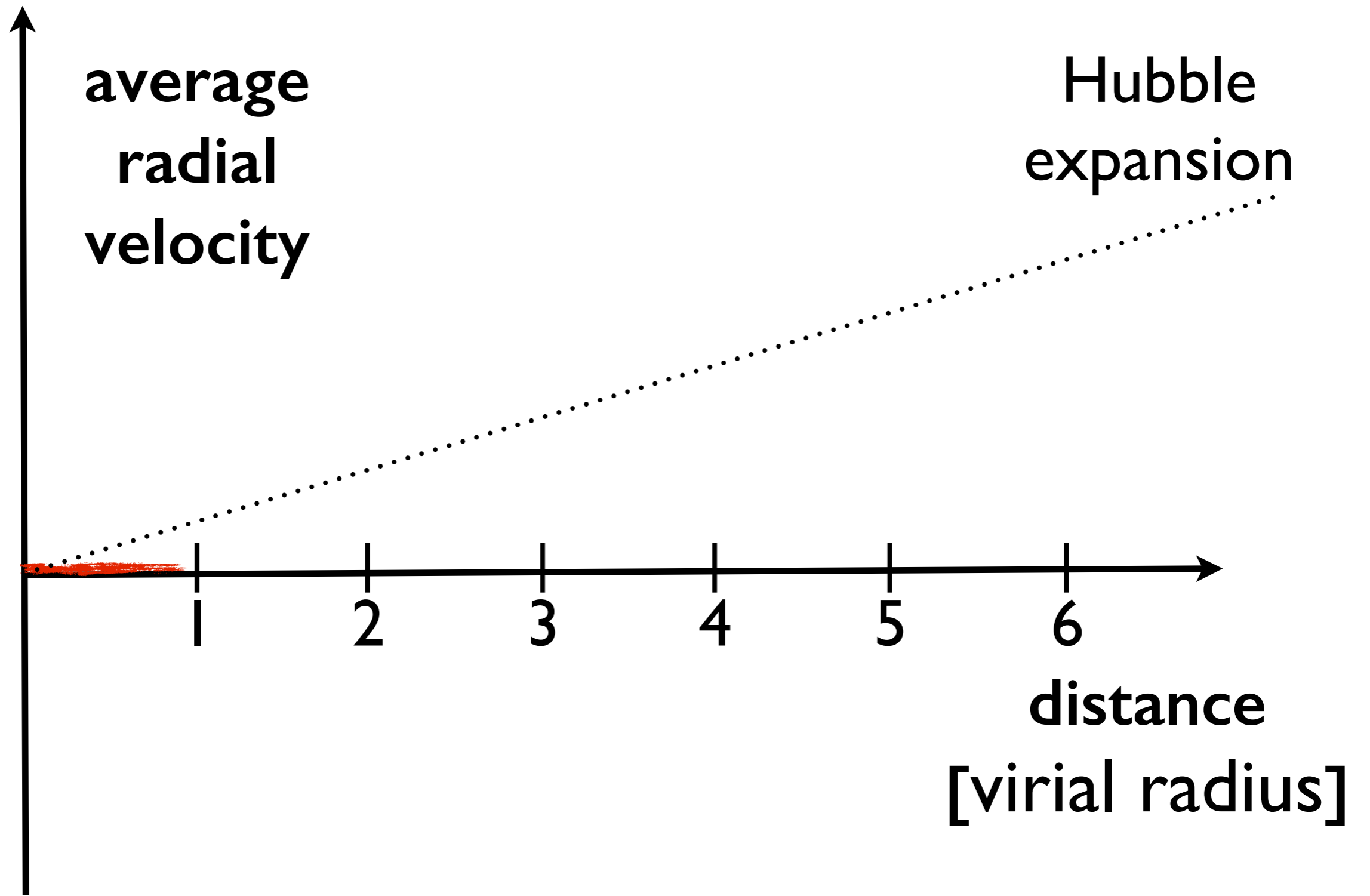


GRAVITATION

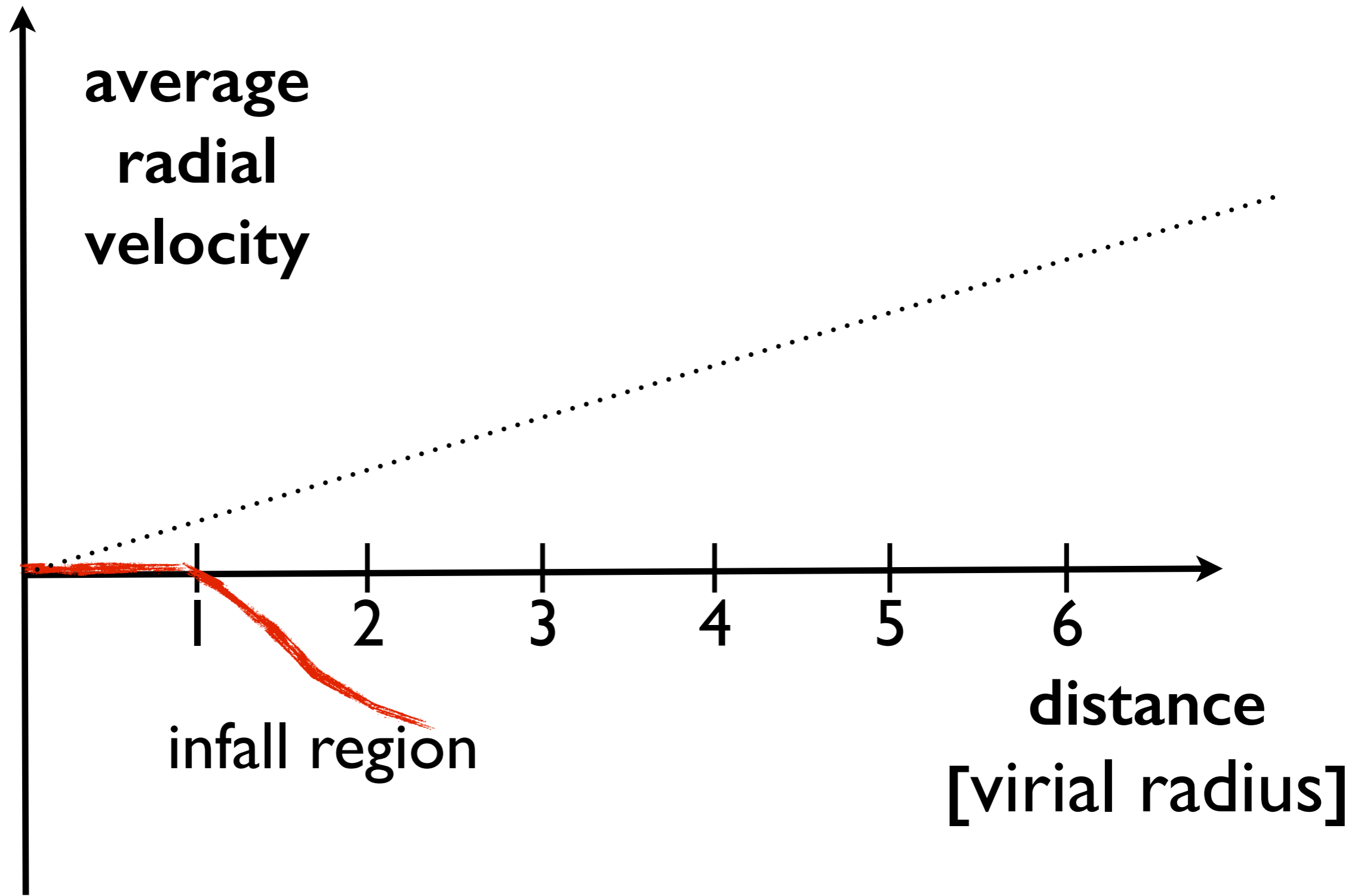
**How to find pancakes**

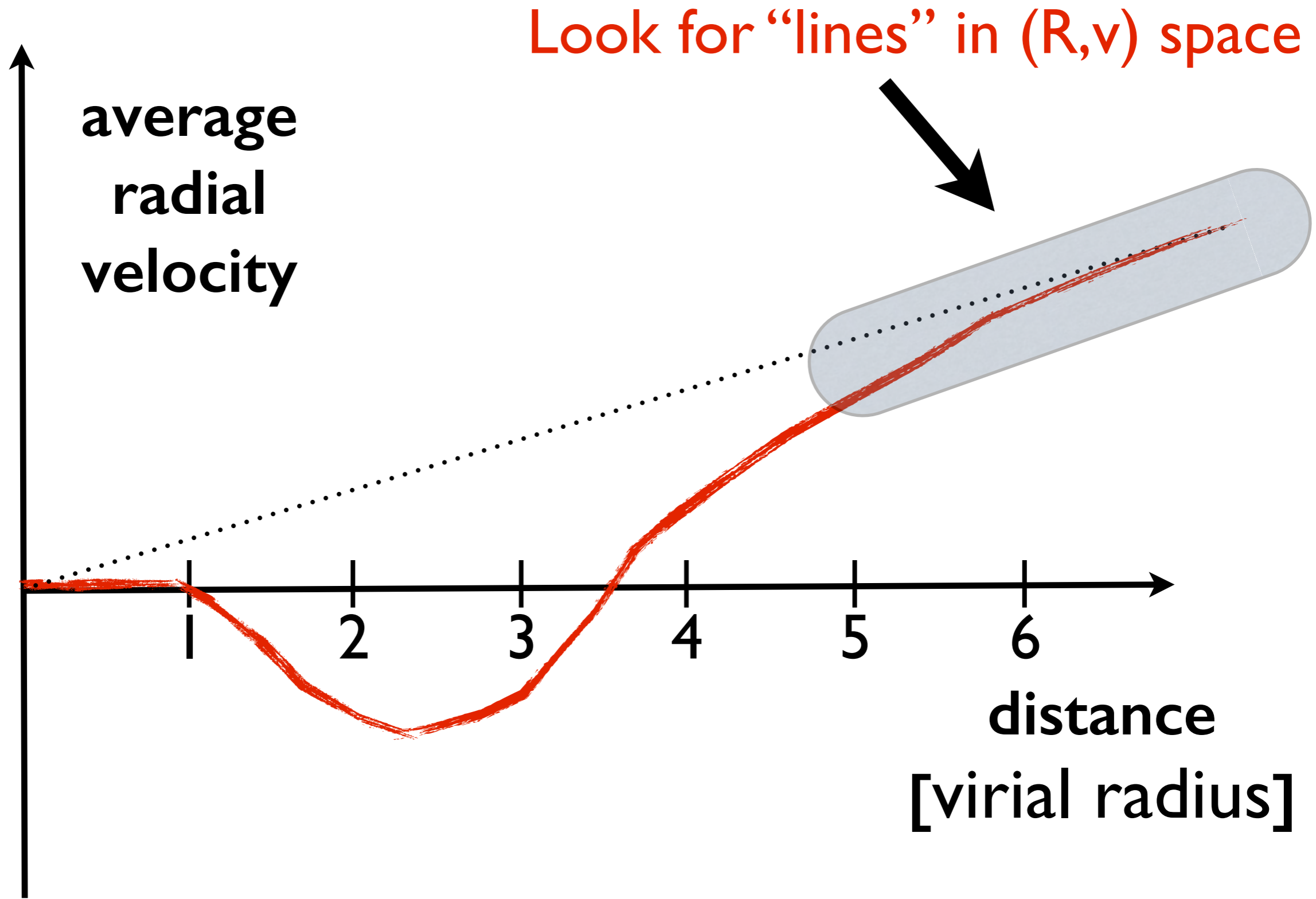


Cluster







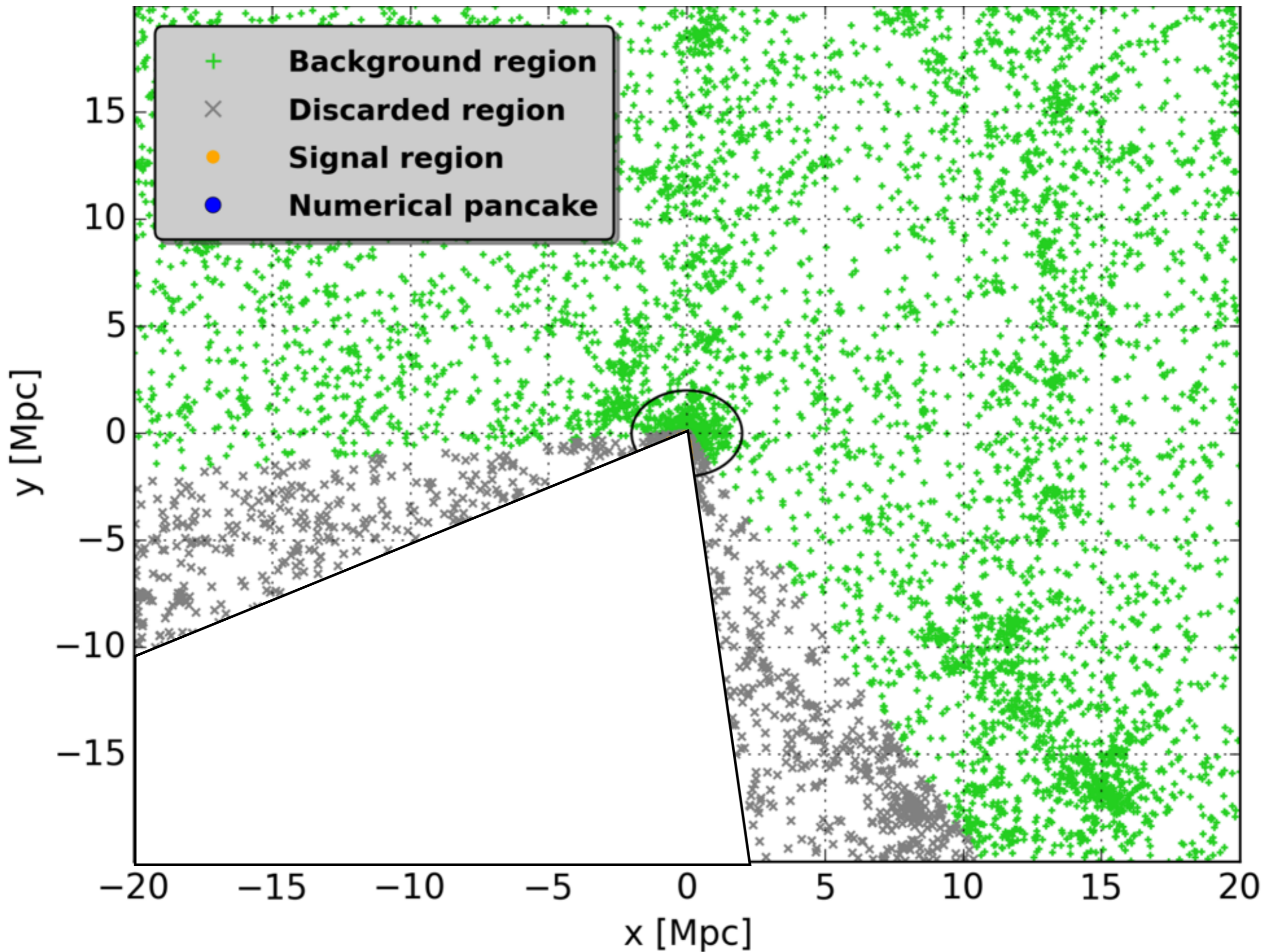


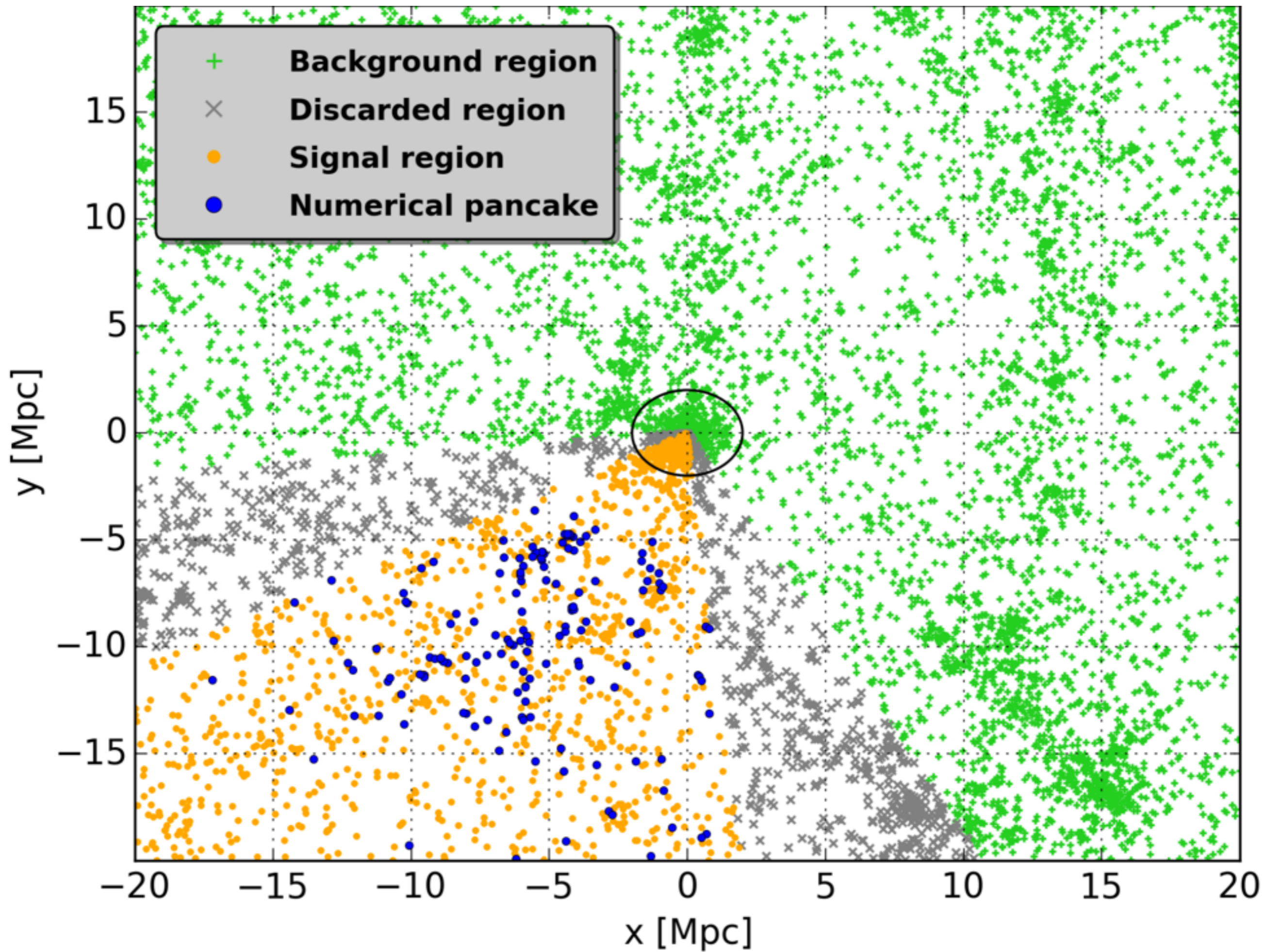
Look for "lines" in (R,v) space

average  
radial  
velocity

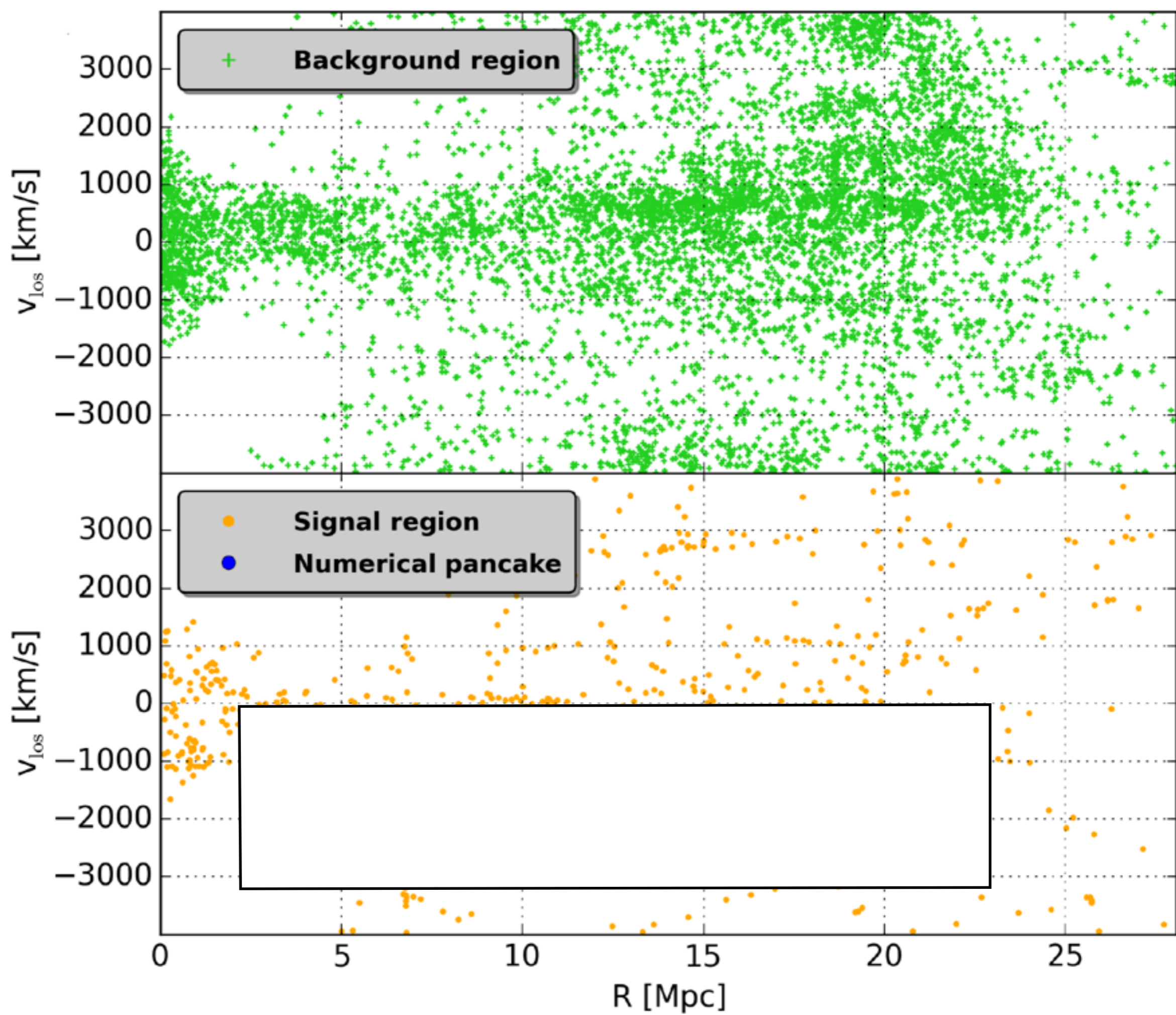
distance  
[virial radius]

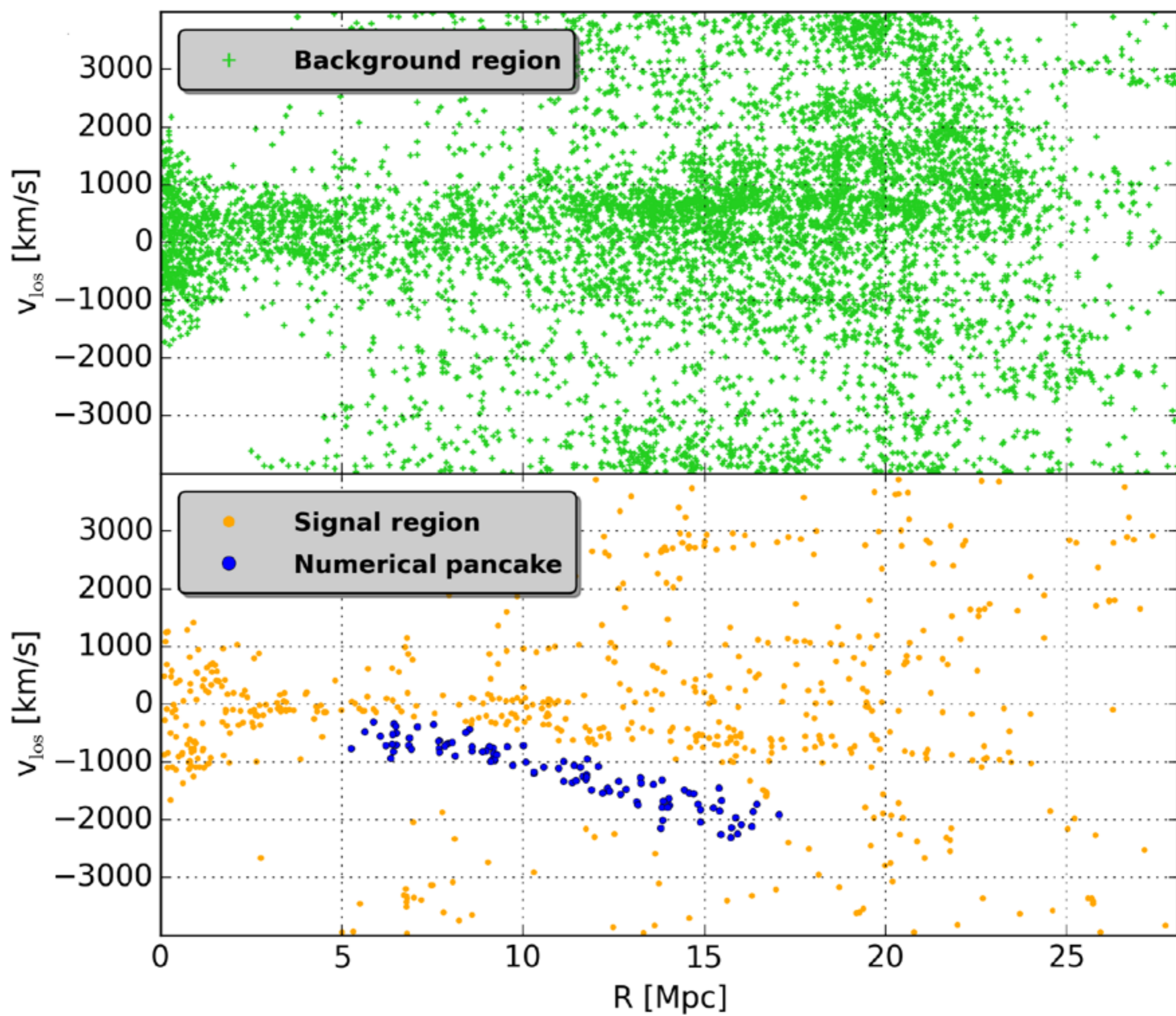
In real space





In phase-space

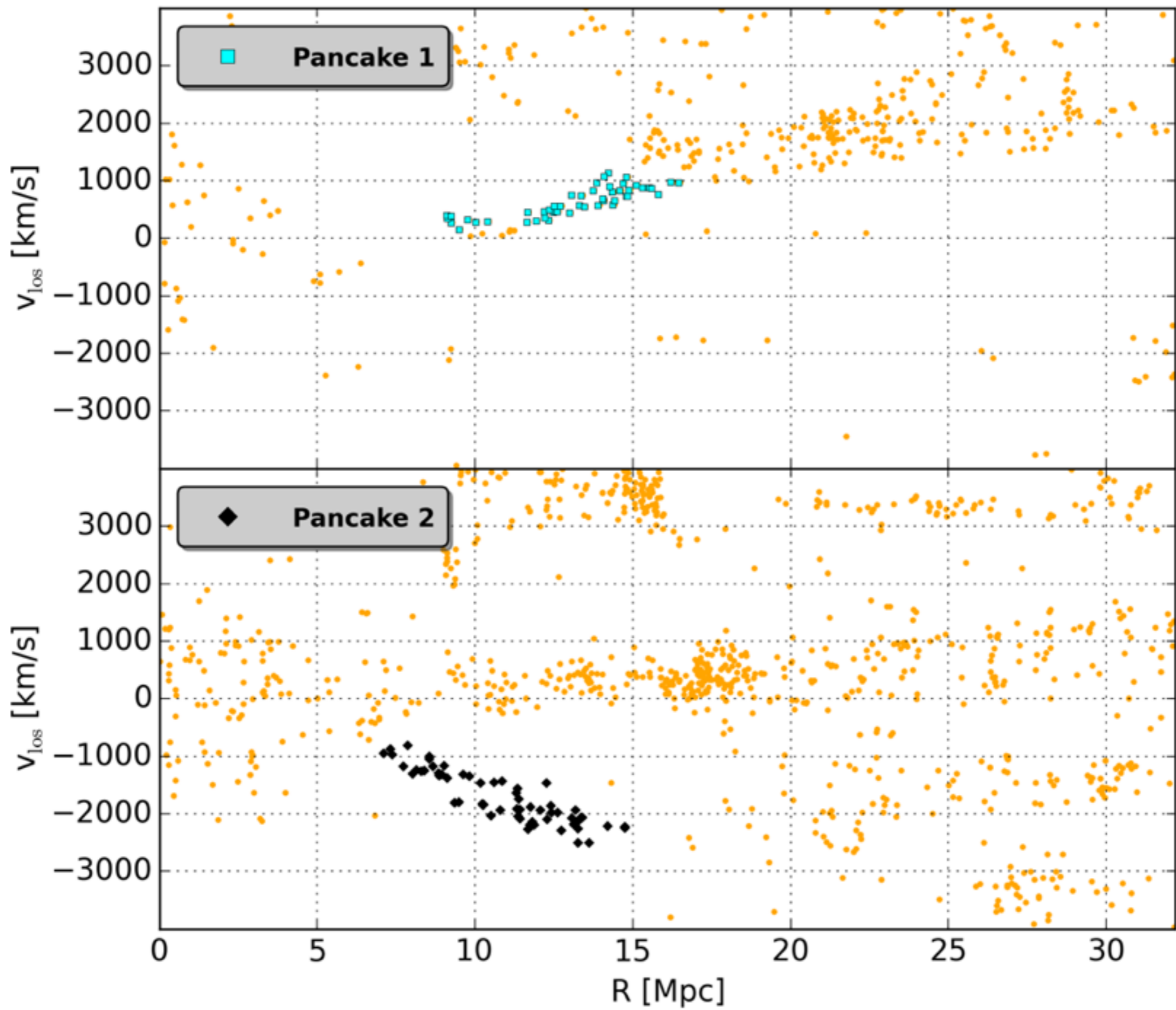






# Coma

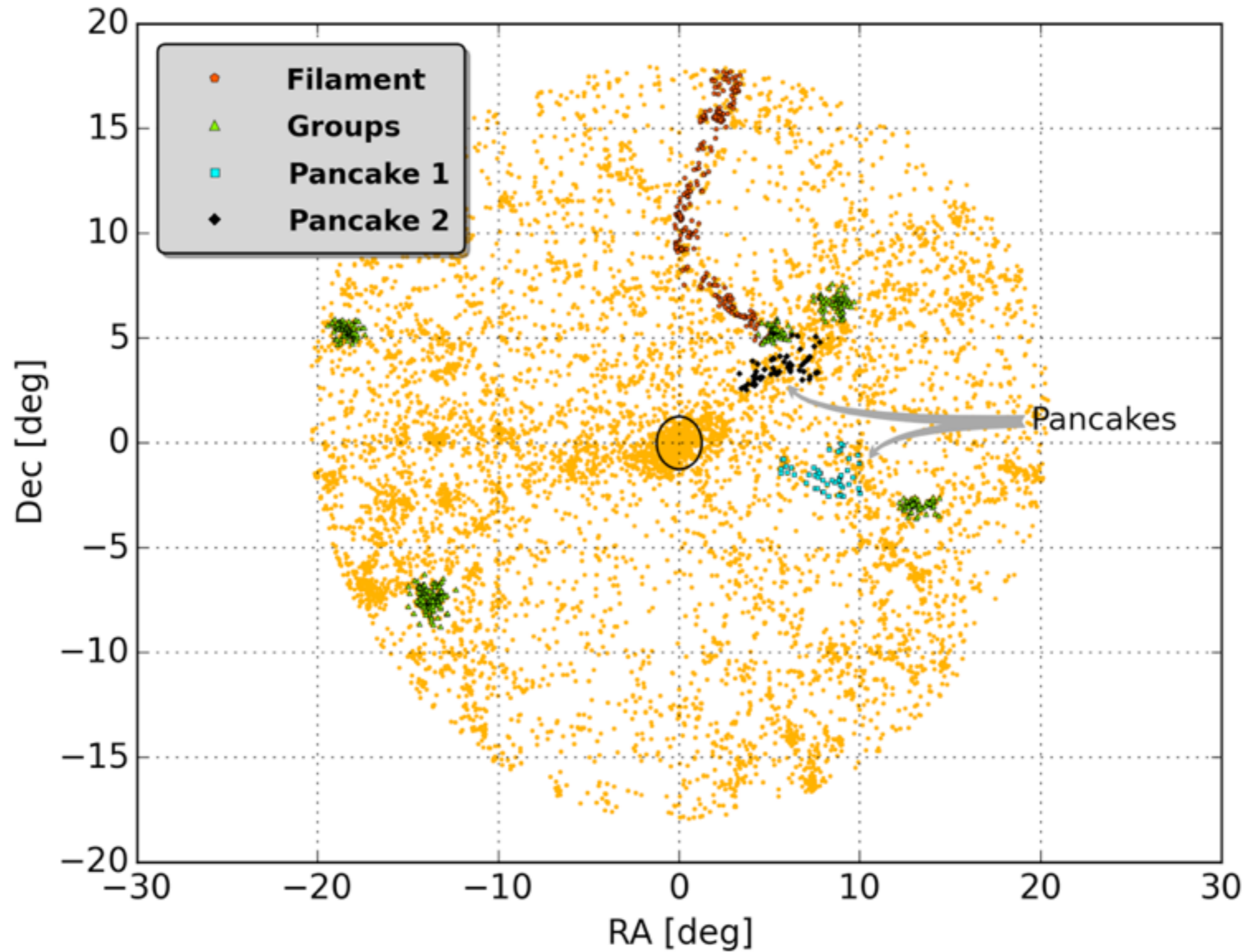
In phase space

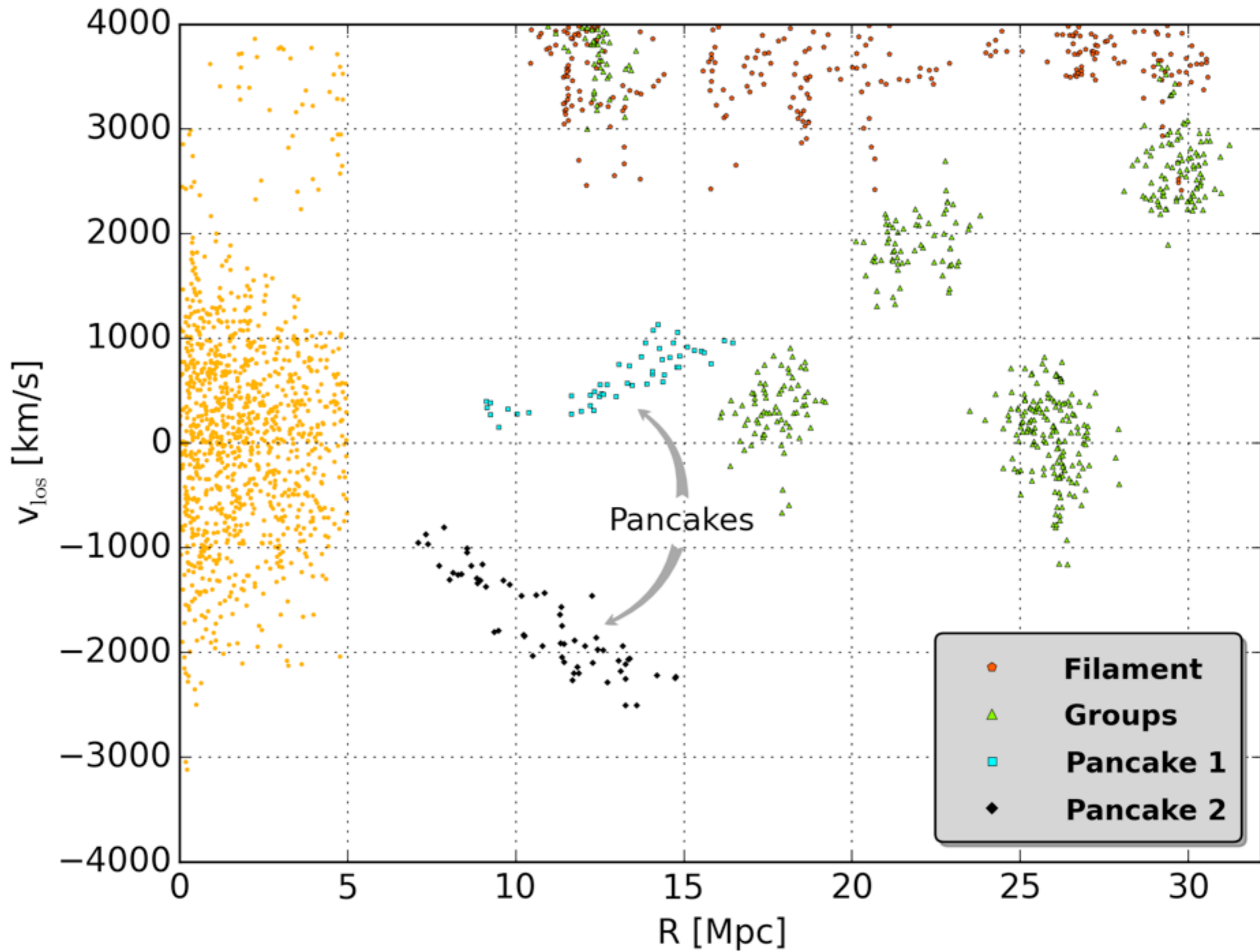


# Coma

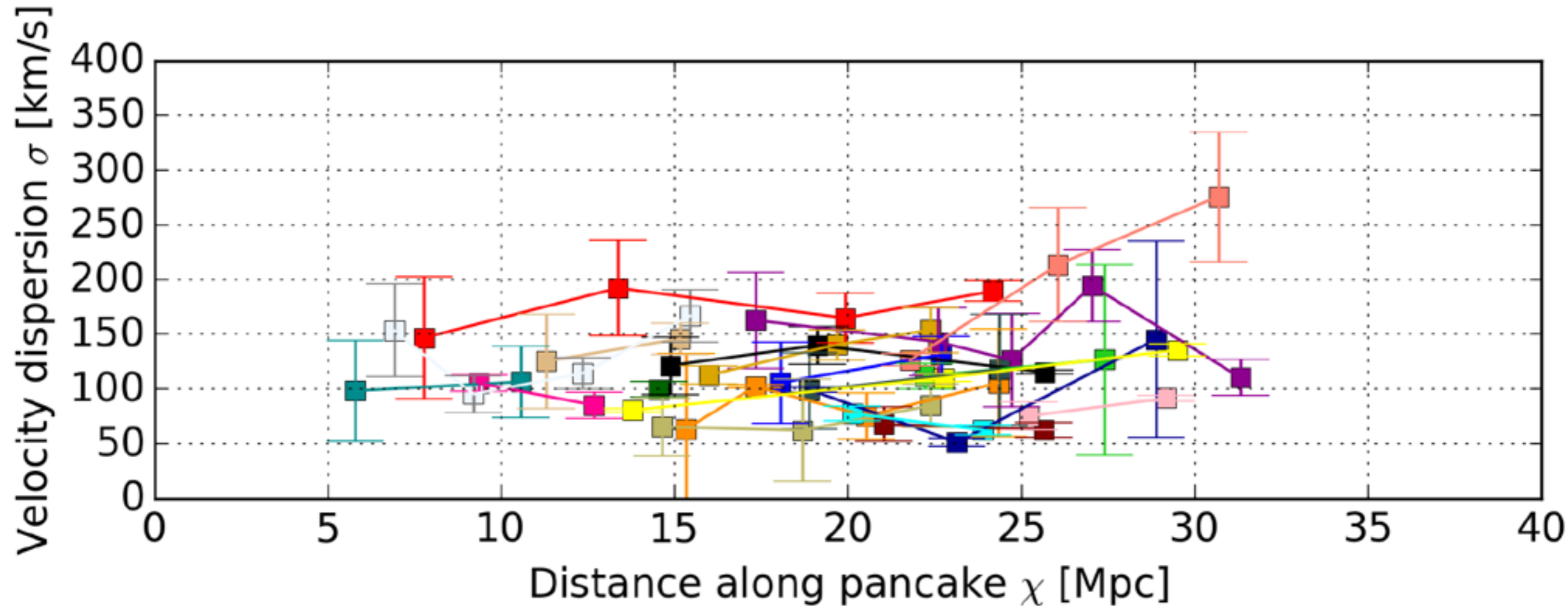
In real space

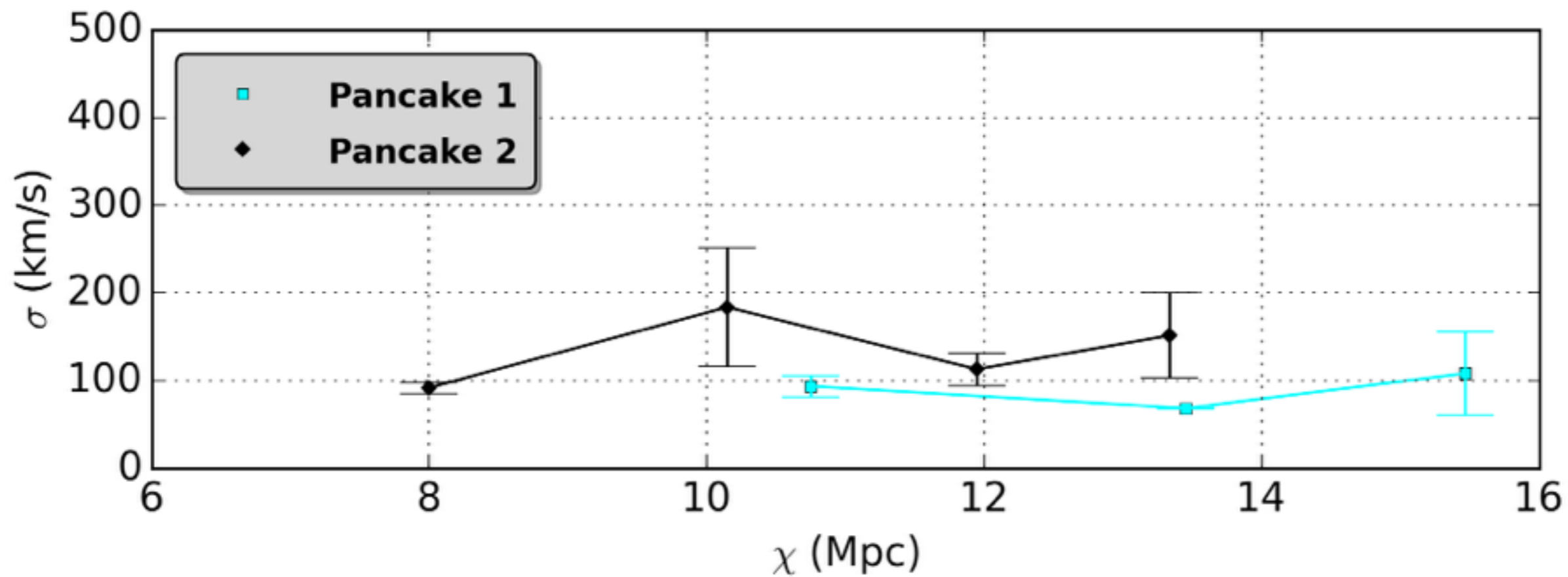
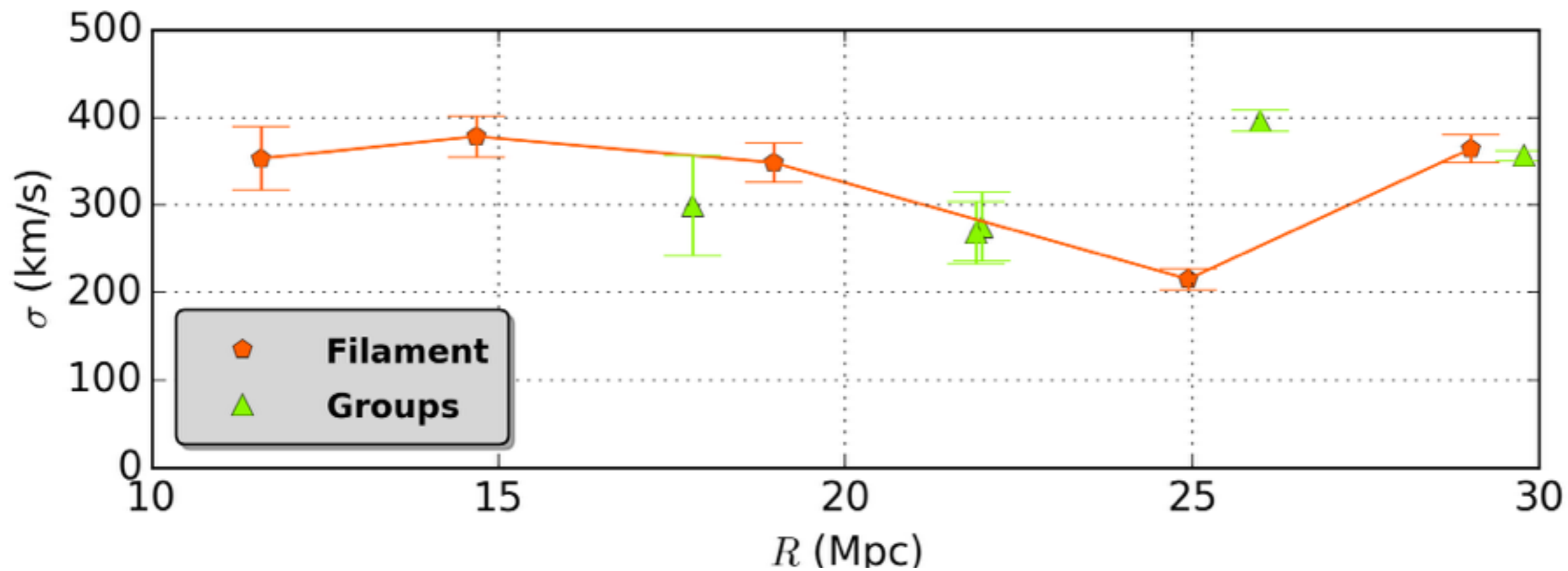
# Coma





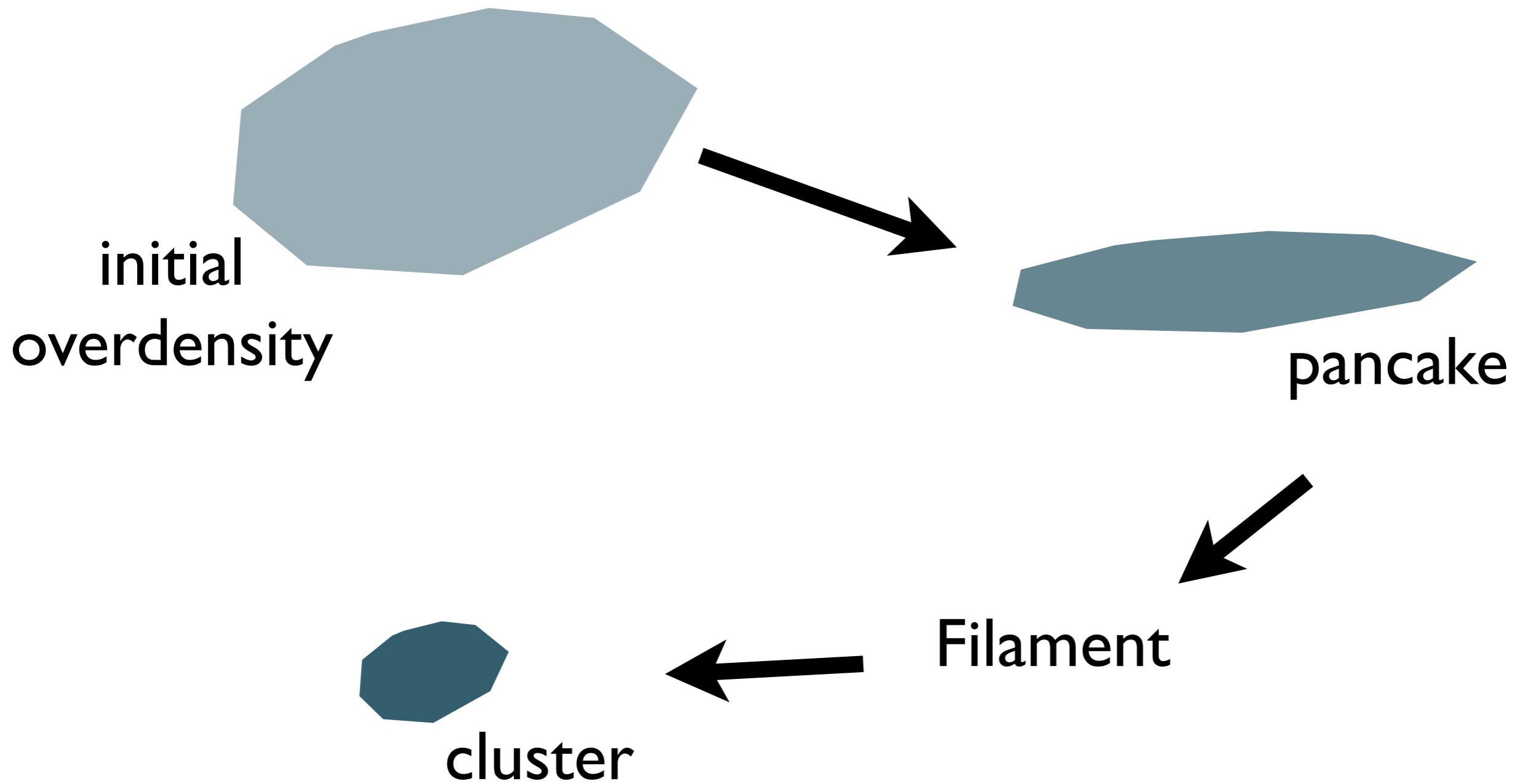
# Numerical simulations



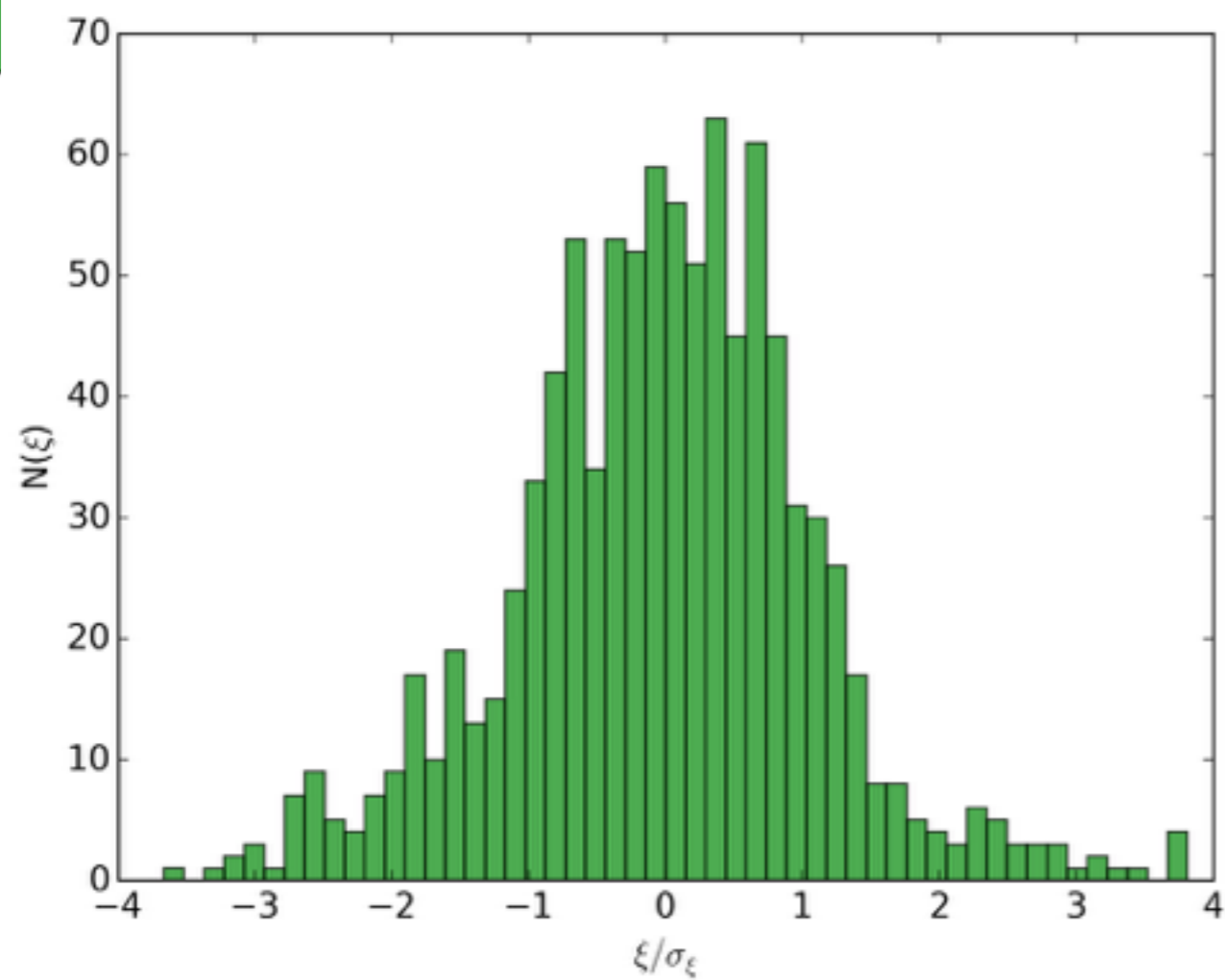
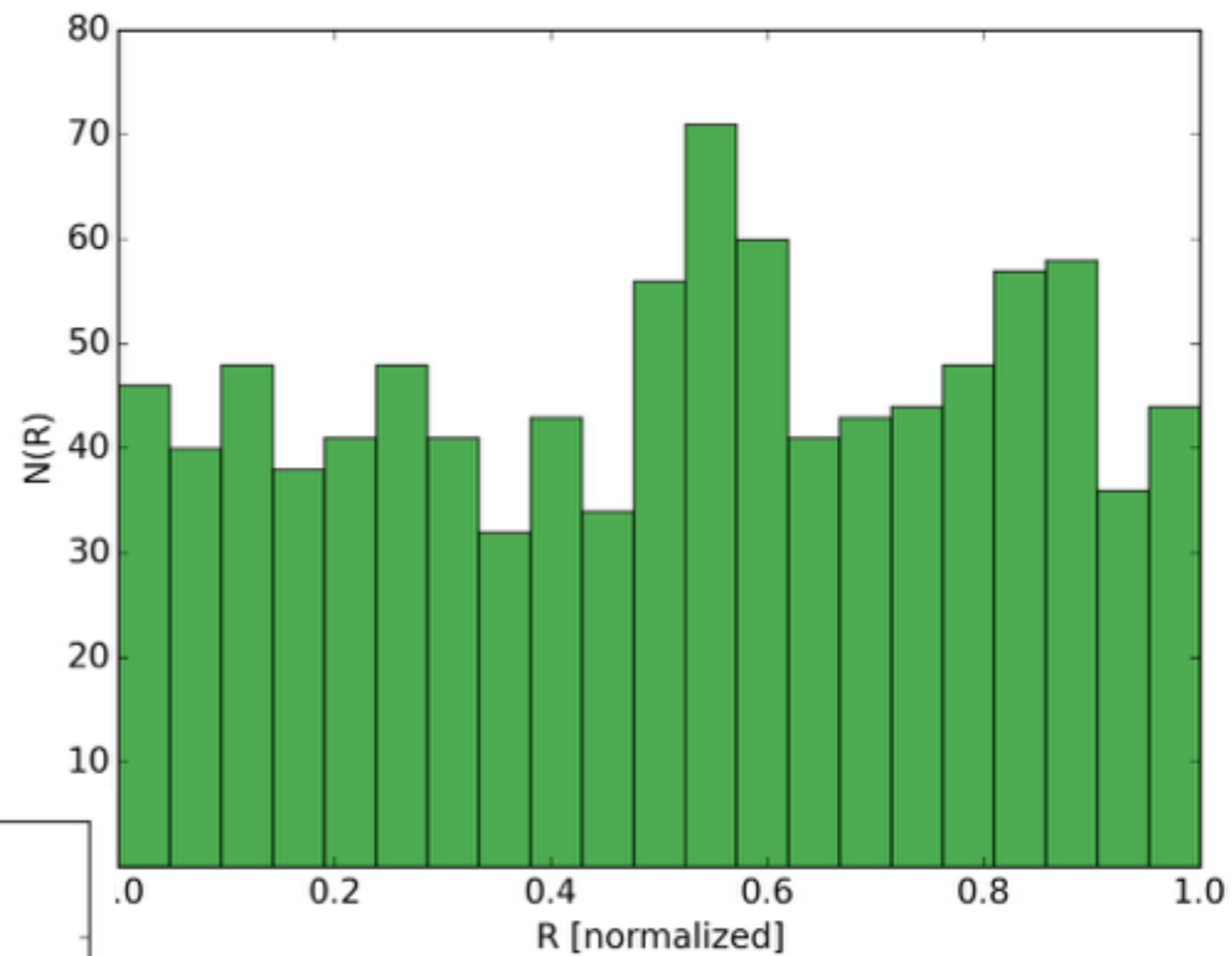
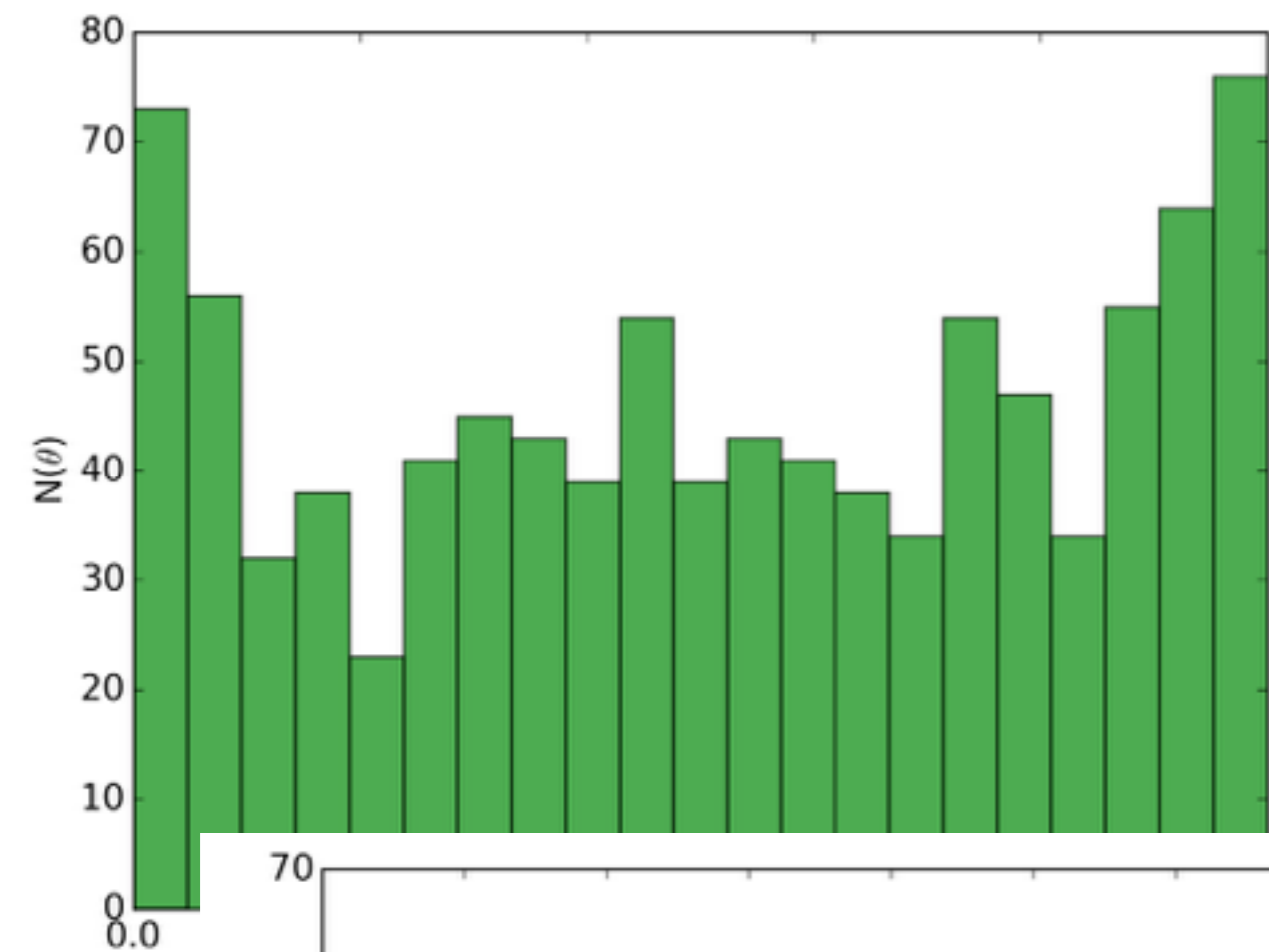


**Pancakes are cold !!**

# Pancakes have only collapsed along one direction

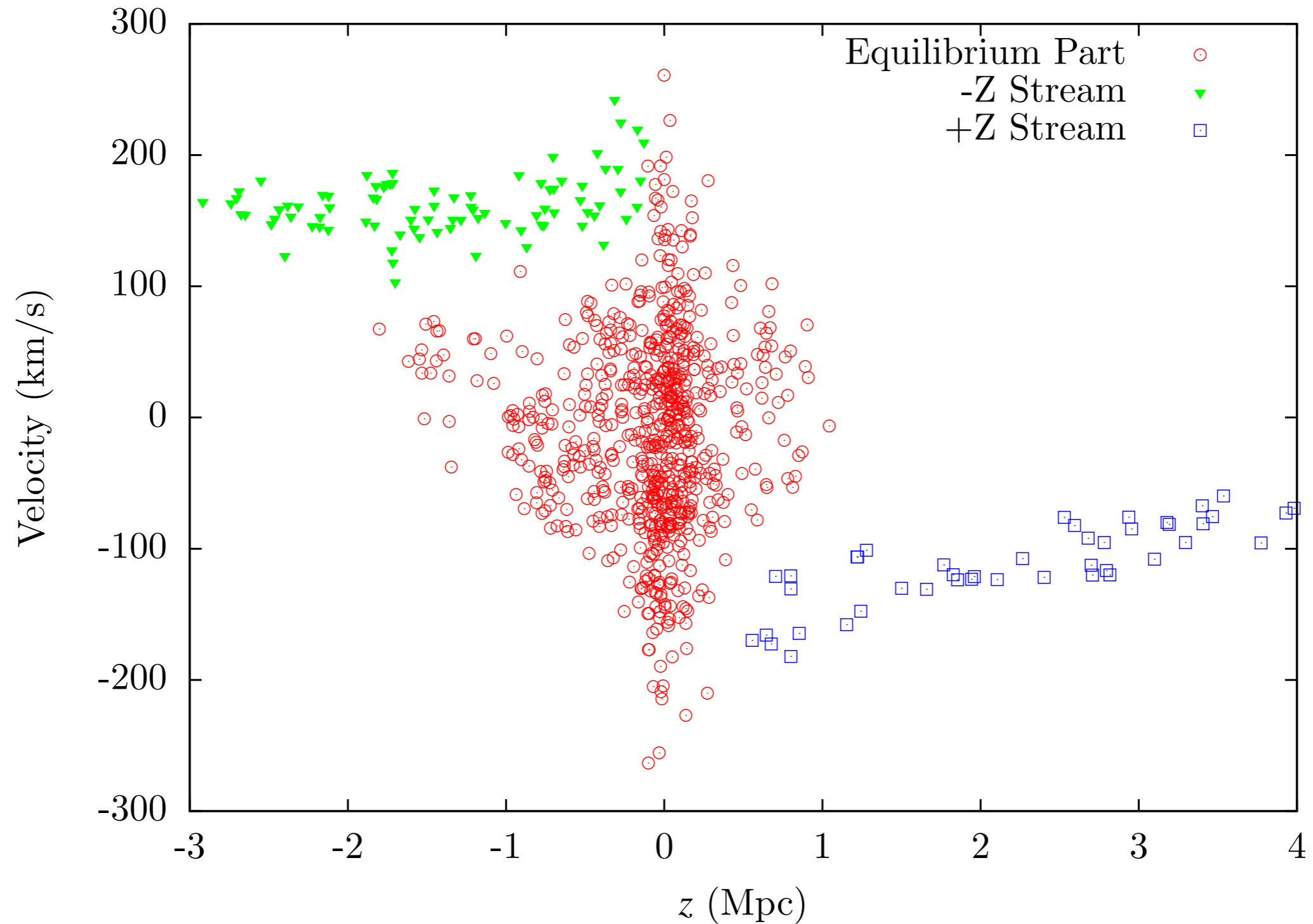




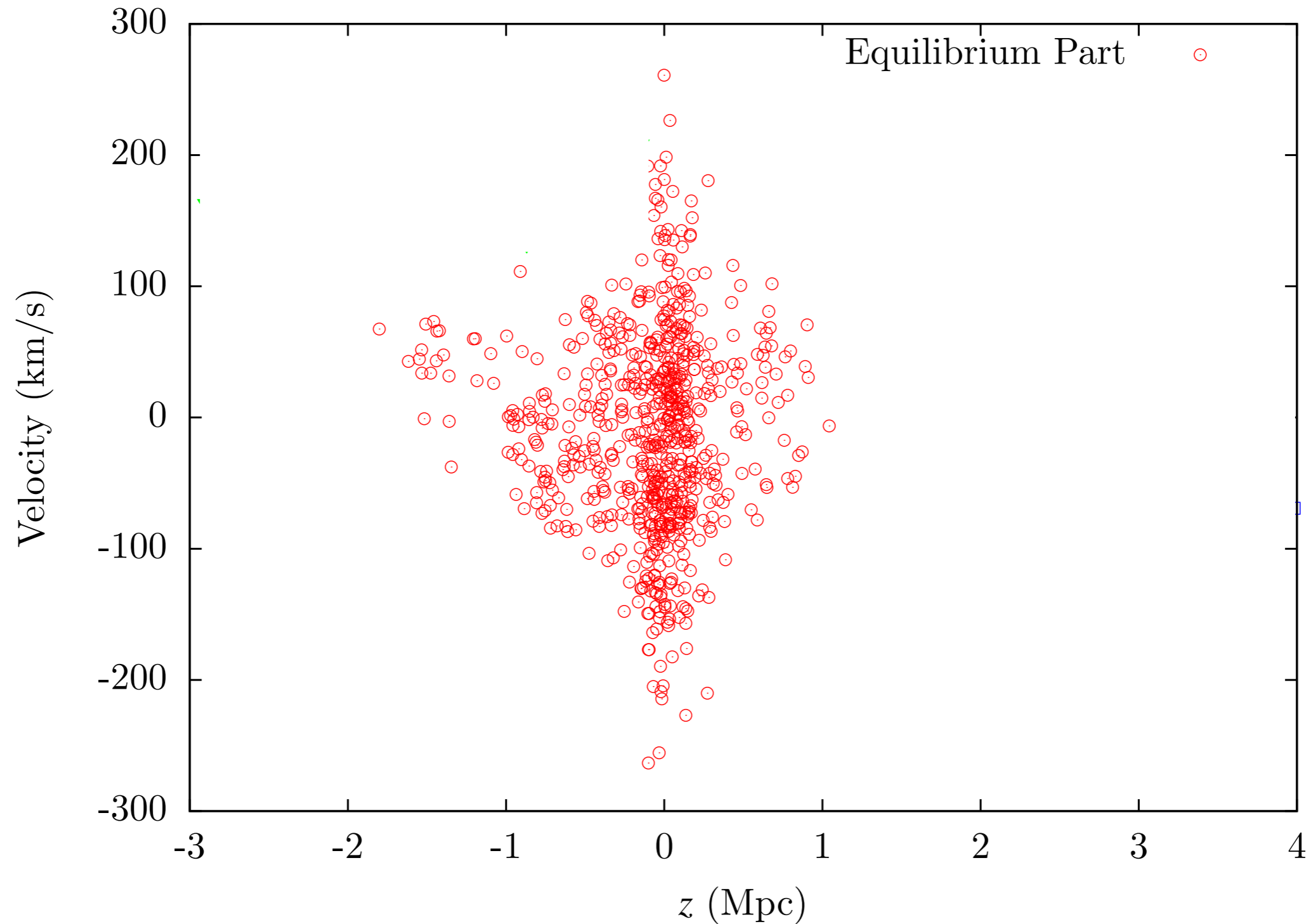


Yes, the pancakes have indeed collapsed only along one dimension !

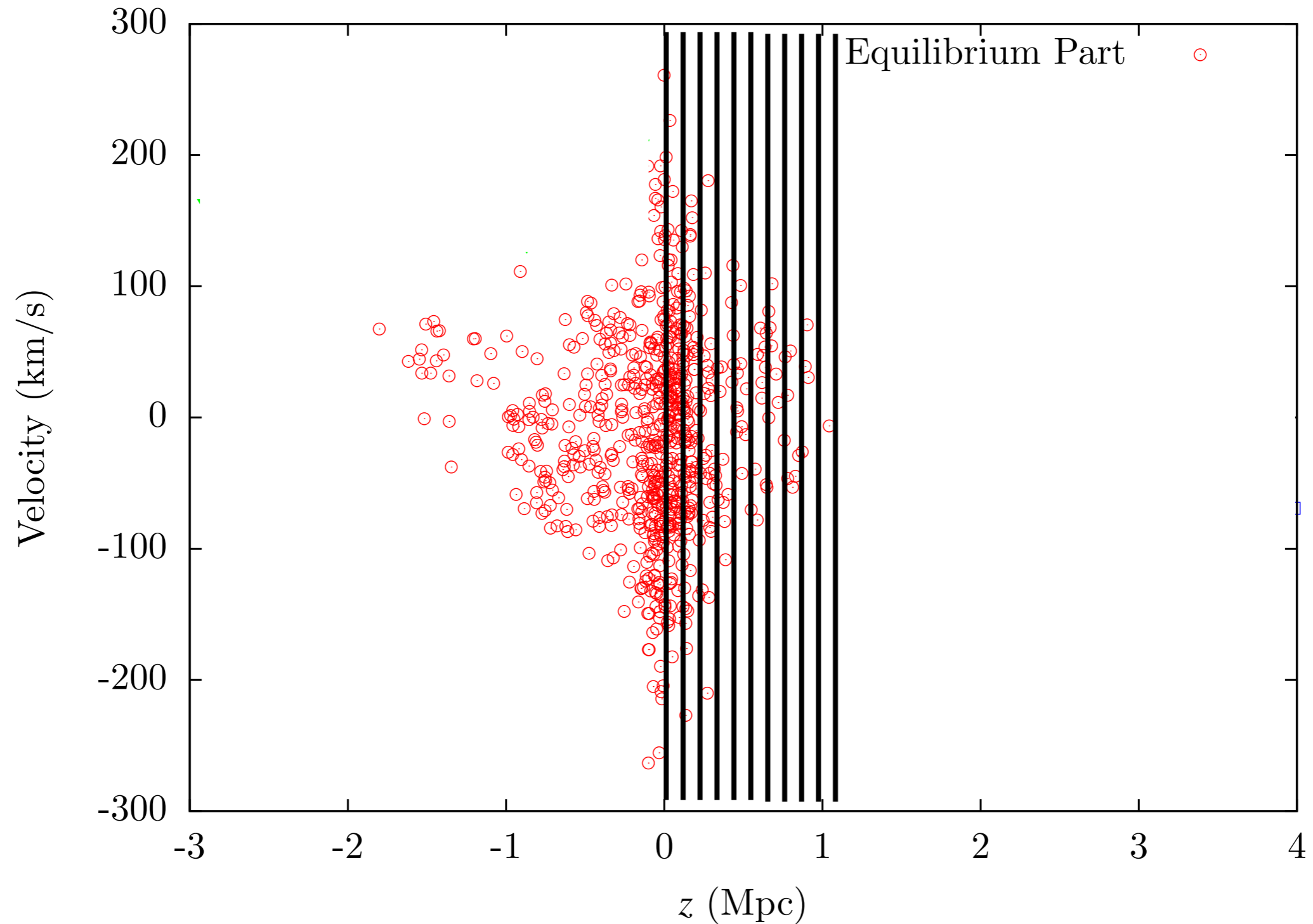
# Details of a numerical pancake



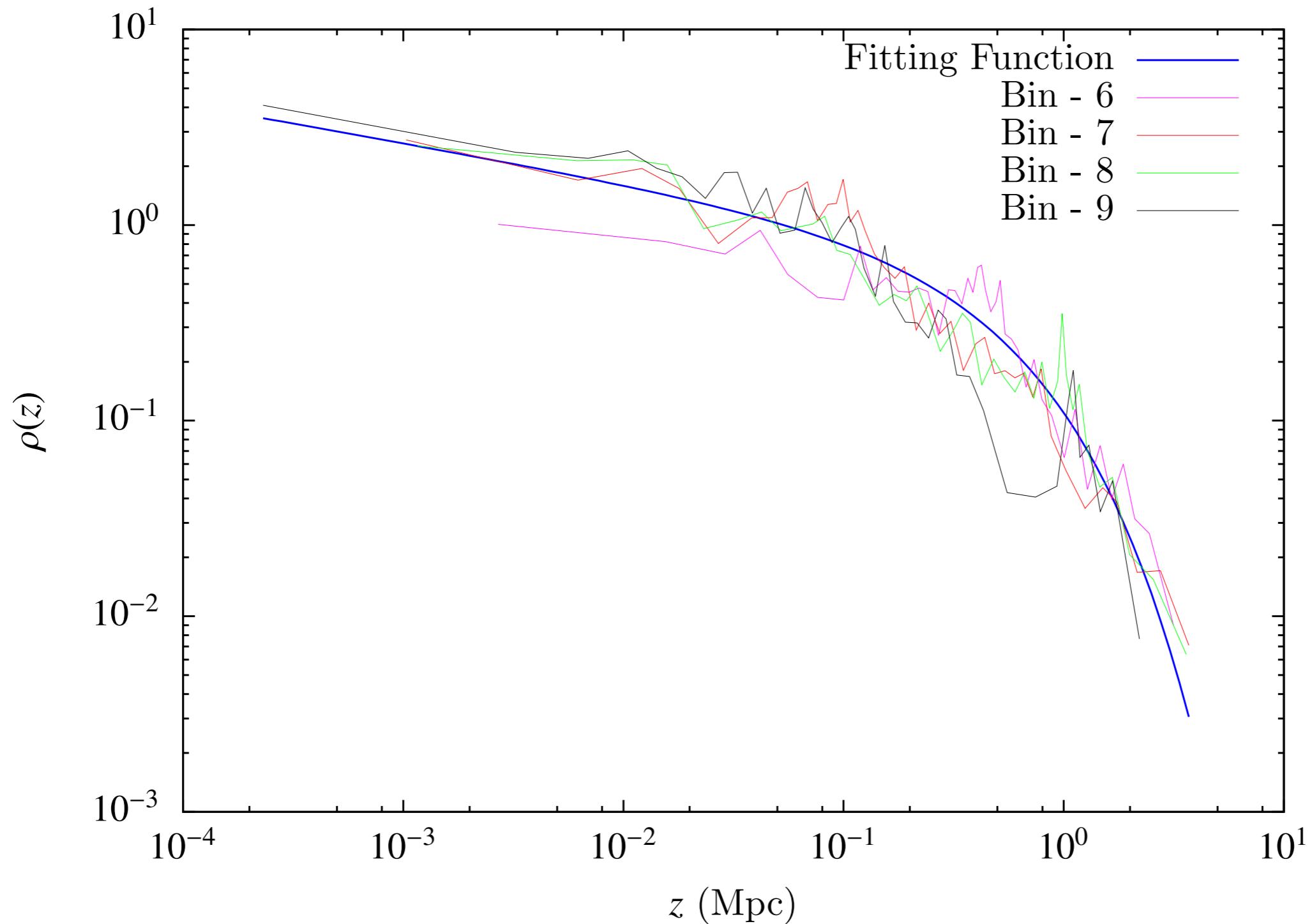
# Details of a numerical pancake



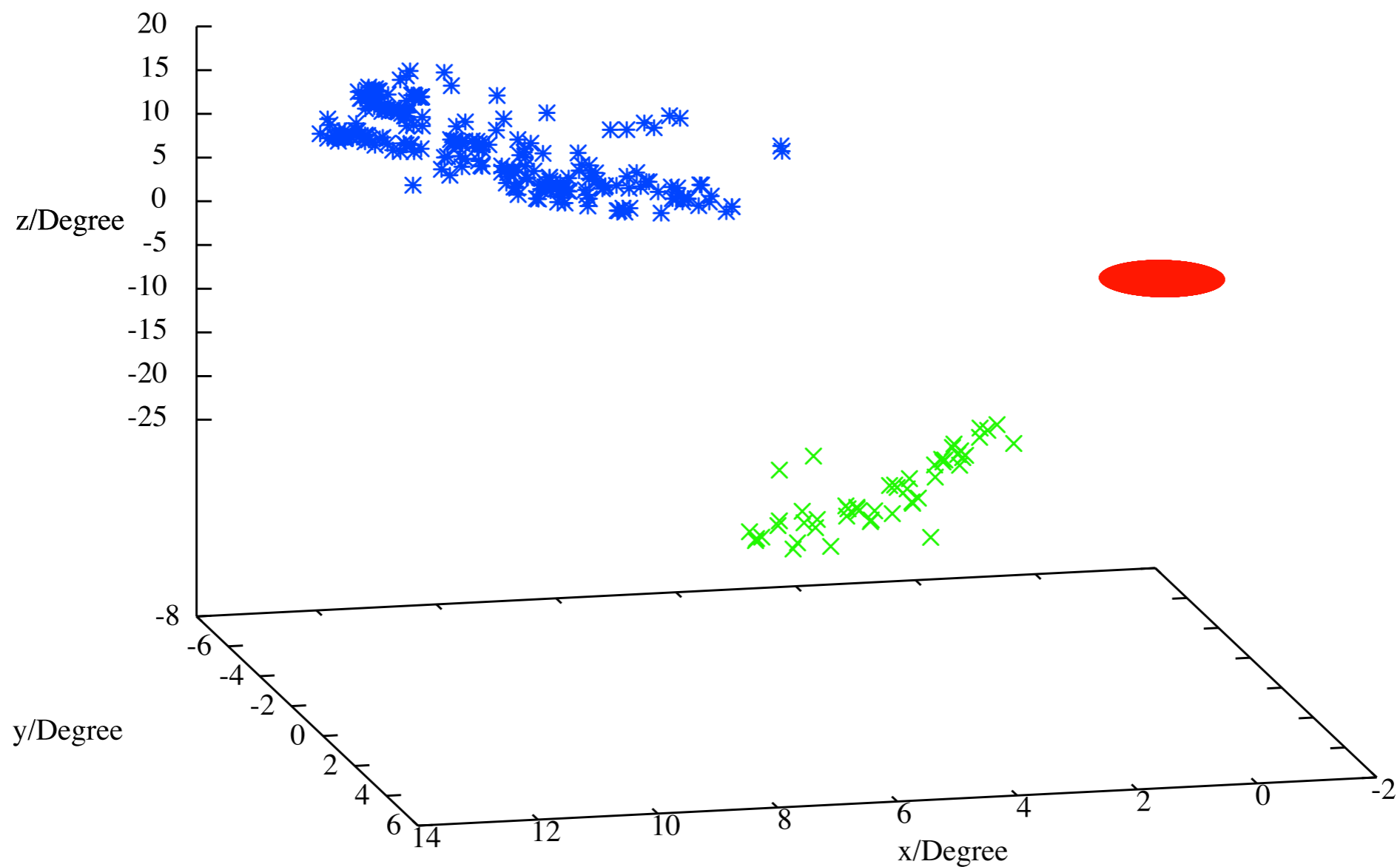
# Details of a numerical pancake



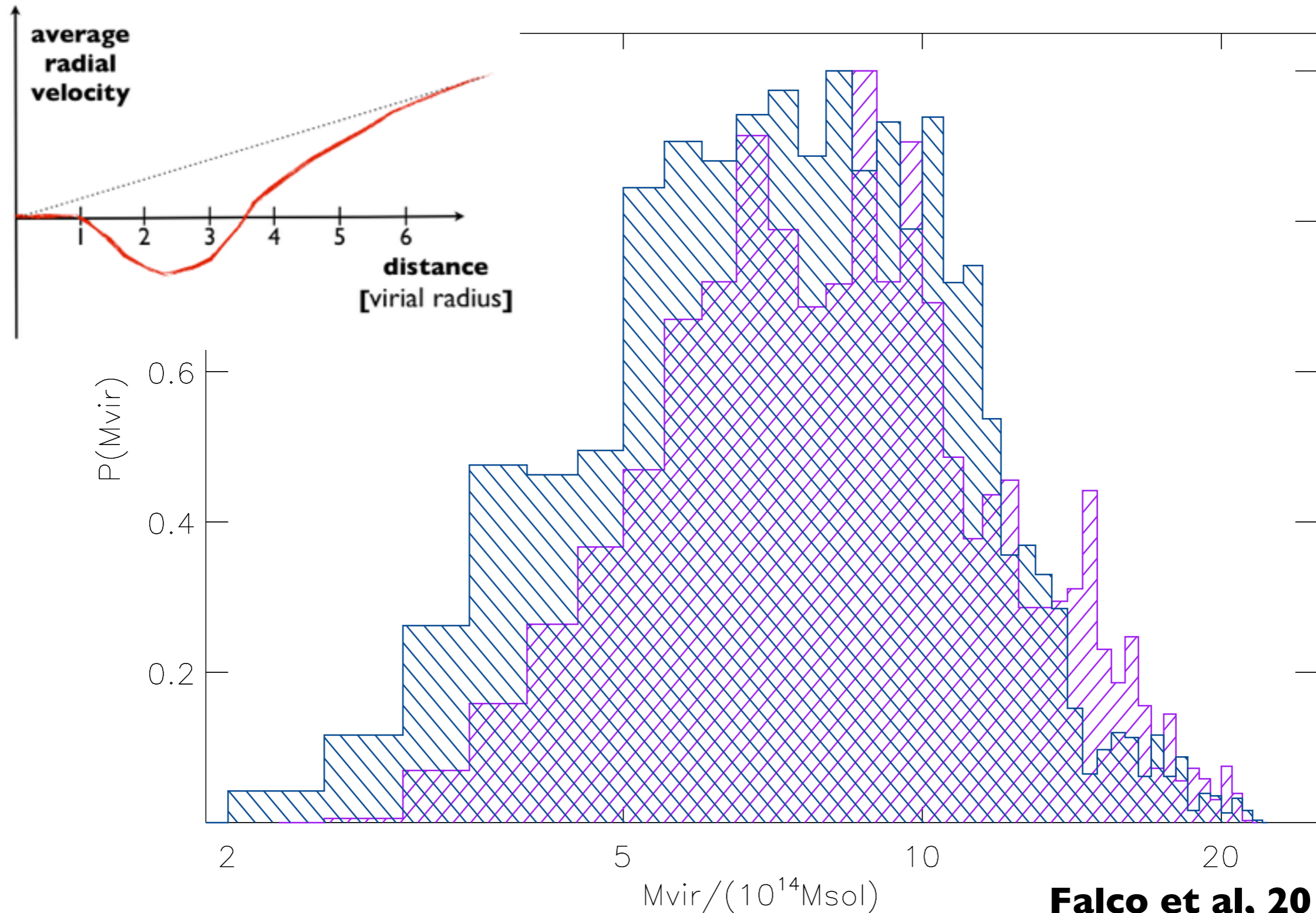
# Density profiles



# What are pancakes useful for?



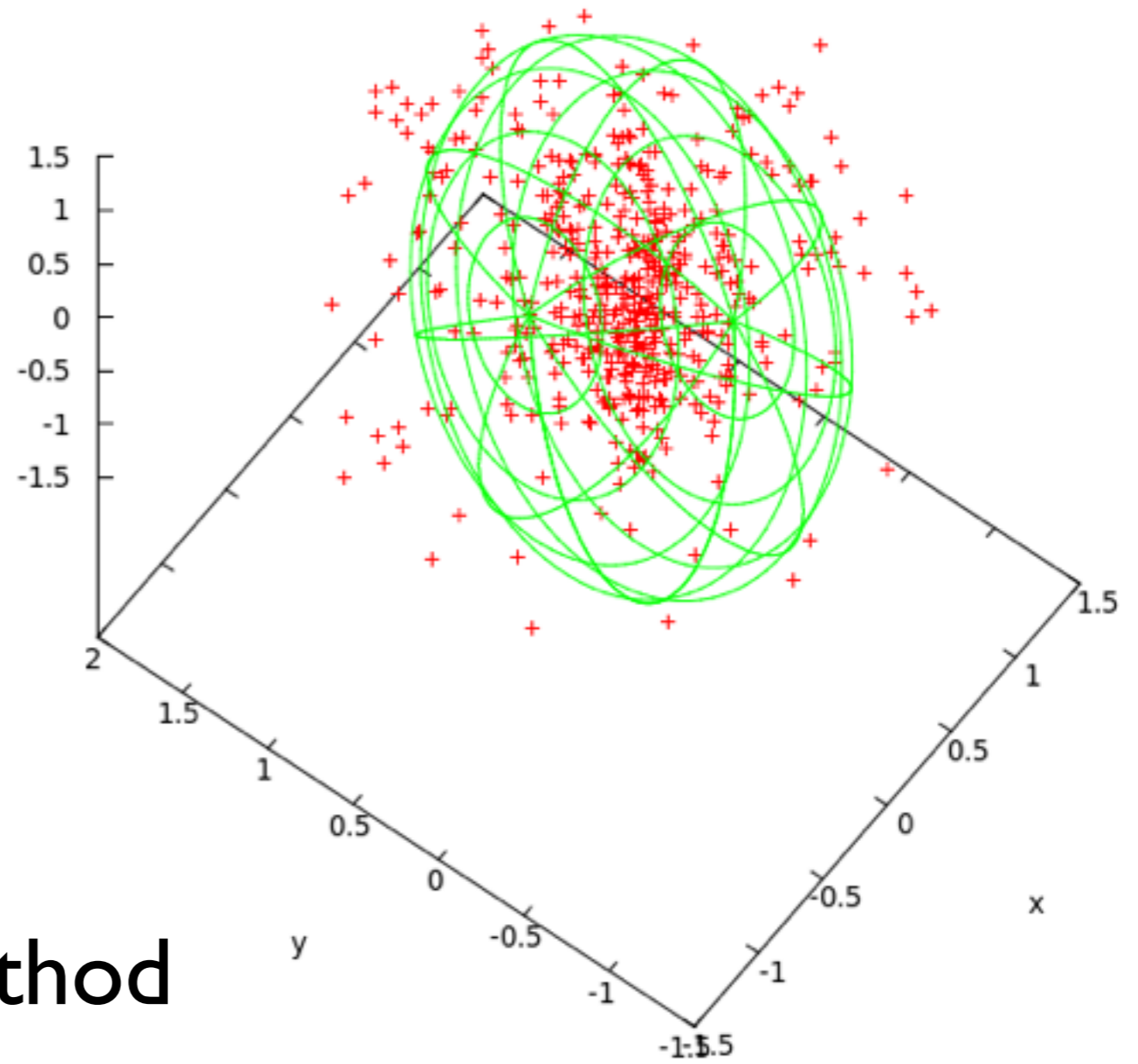
# Get the mass of Coma



**Falco et al, 2014**

# What may pancakes be useful for in the future?

Clusters are not spherical

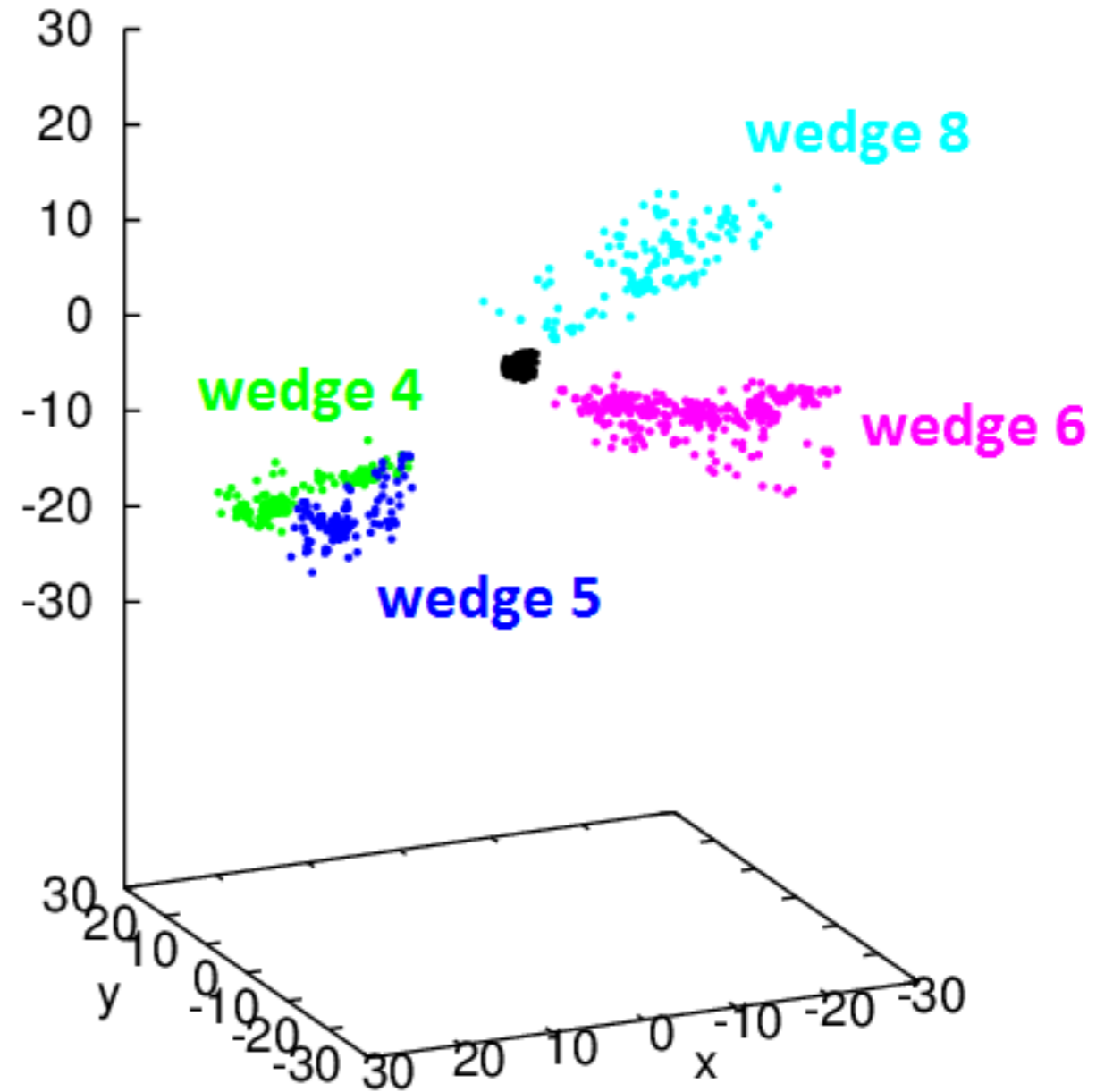
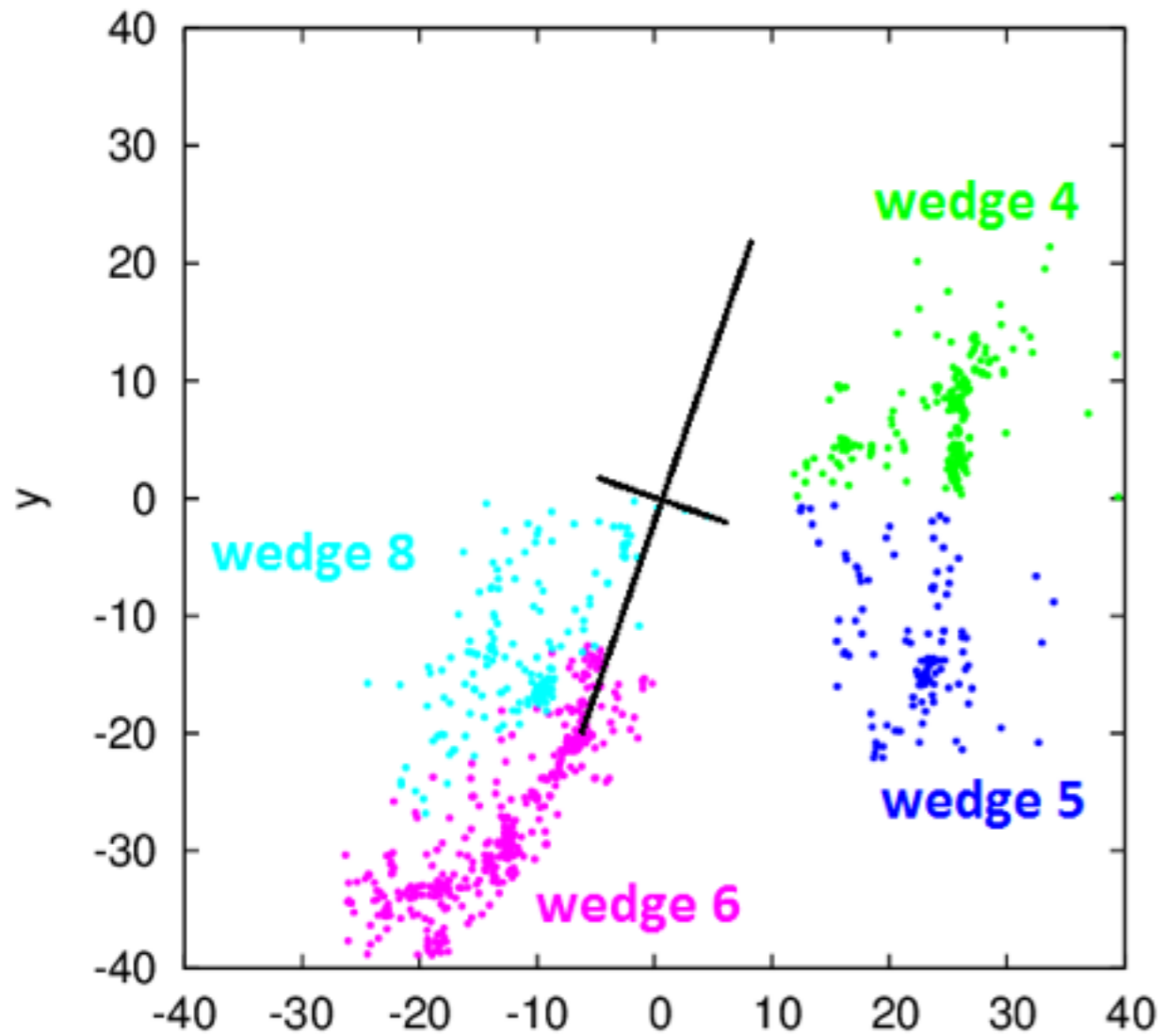


Our new  
mass-measurement-method  
depends on orientation



If we find several pancakes near a cluster, then we can measure its orientation

z



**A master student et al, in prep**

# Conclusions

- We have found the first 2 pancakes in space
- The pancakes are cold (100 km/sec)
- They are very dark matter dominated ( $10^{-4}$ )
- Pancakes are useful to measure masses
- The future - we can use the pancakes to find the absolute orientation of clusters

***The end***