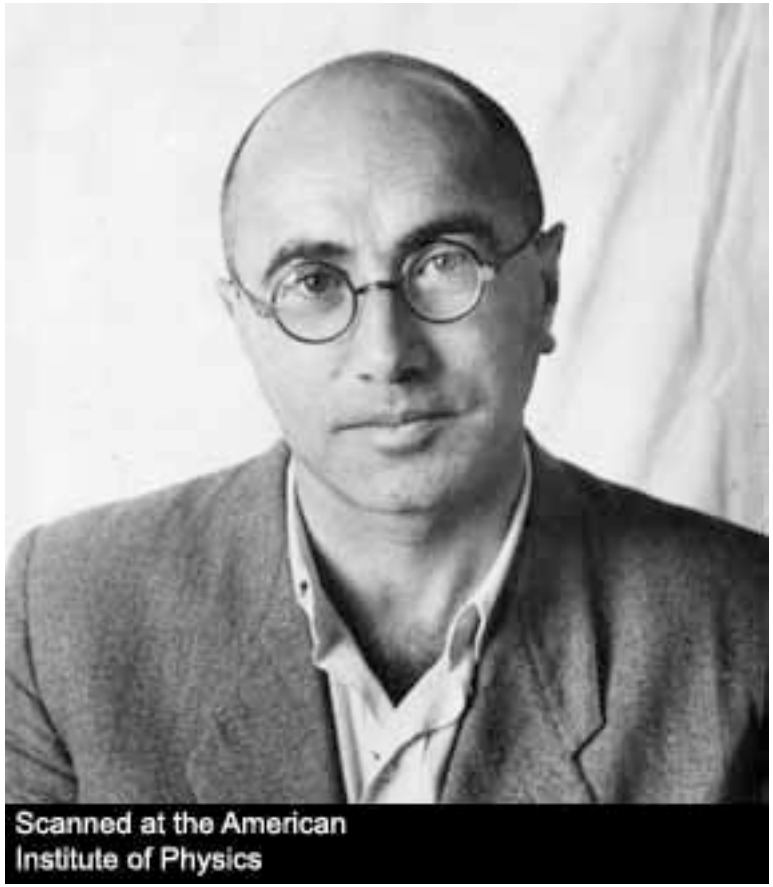
Pancakes in space

NBIA, aug 2014

Steen H. Hansen (DARK)



Yakov B. Zeldovich

Gravitational Instability: An Approximate Theory for Large Density Perturbations

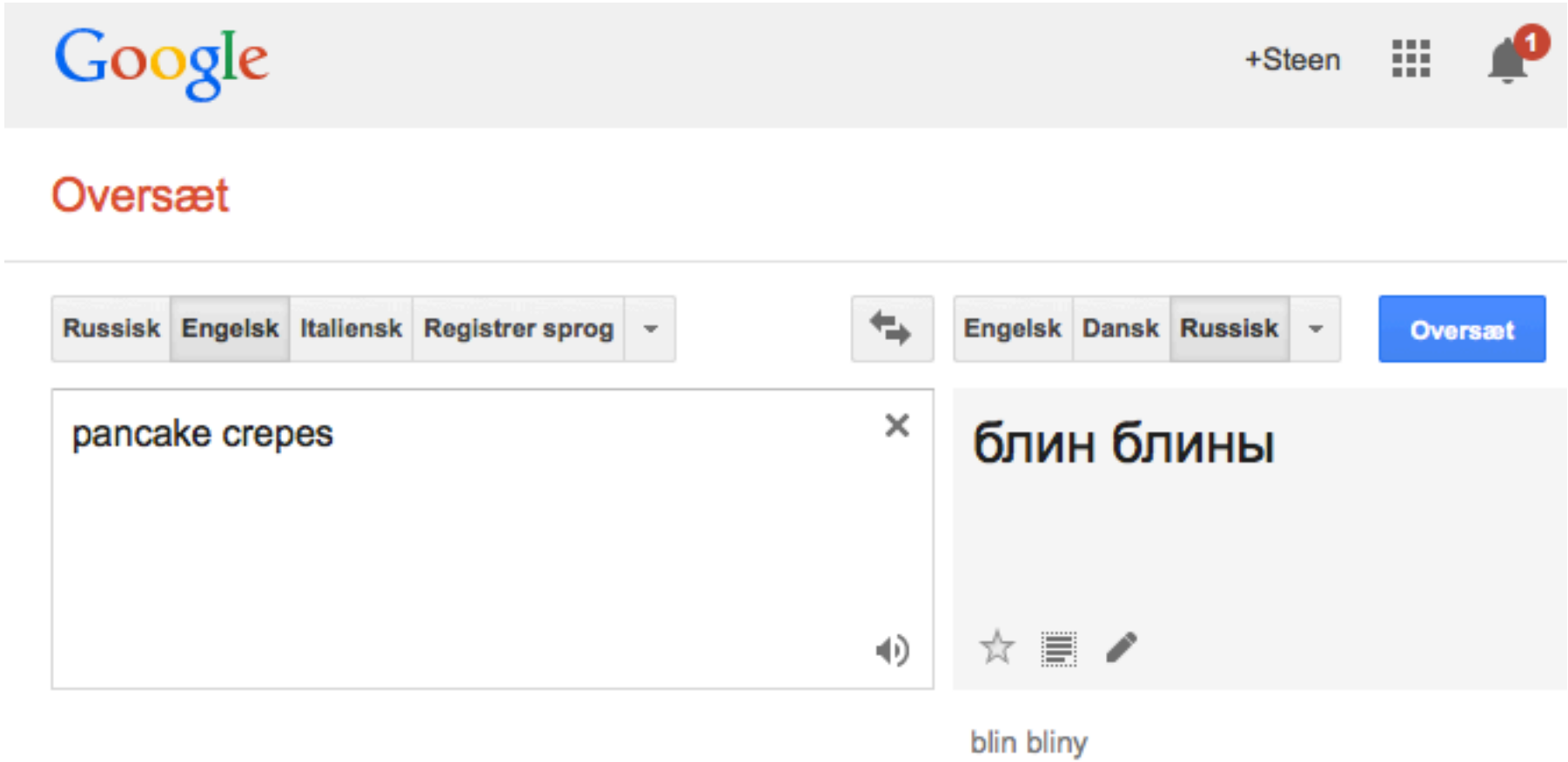
YA. B. ZELDOVICH
Institute of Applied Mathematics, Moscow

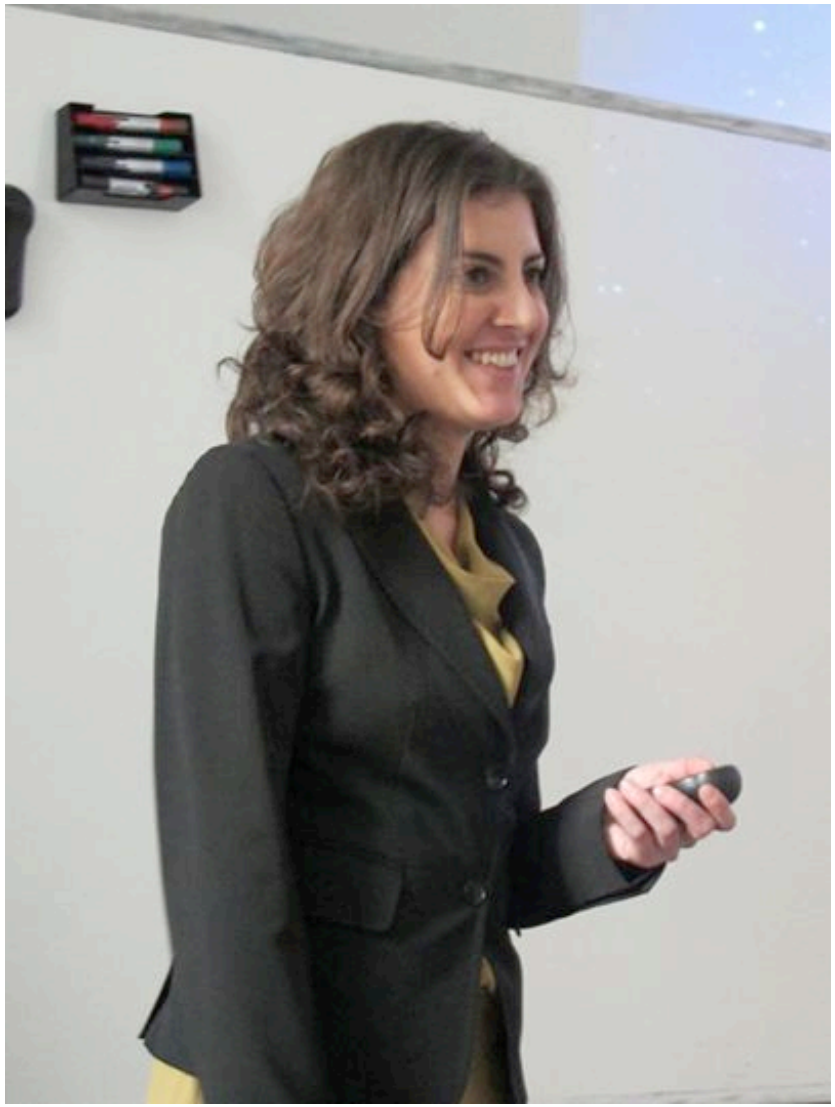
Received September 19, 1969

An approximate solution is given for the problem of the growth of perturbations during the expansion of matter without pressure. The solution is qualitatively correct even when the perturbations are not small. Infinite density is first obtained on disc-like surfaces by unilateral compression.

The following layers are compressed first adiabatically and then by a shock wave. Physical conditions in the compressed matter are analysed.

Key words: Galaxies formation — Cosmology — Gravitational instability

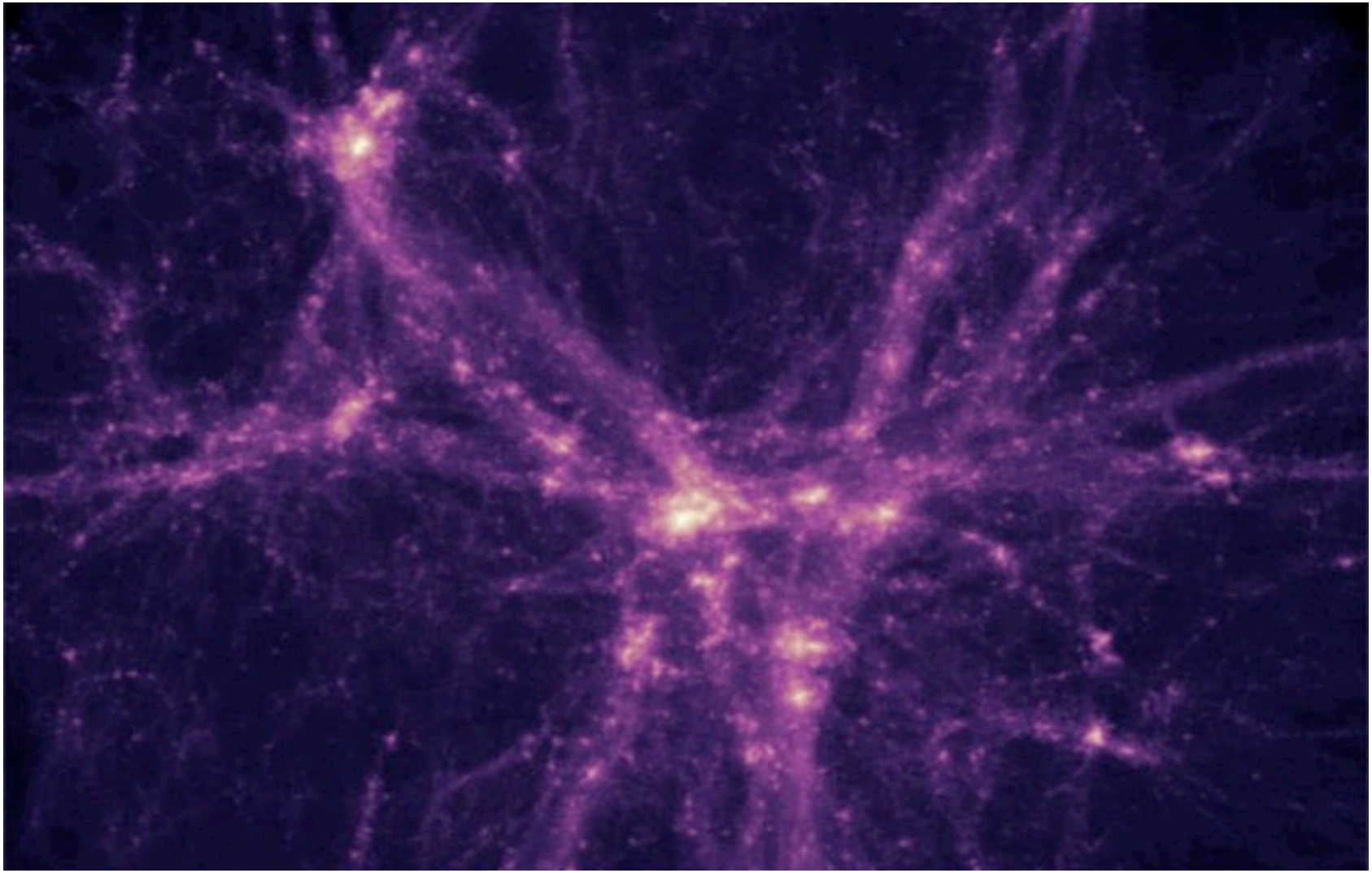

Google
+Steen
1
Oversæt
Russisk
Engelsk
Italiensk
Registrer sprog
Engelsk
Dansk
Russisk
Oversæt
pancake crepes
блин блины
blin bliny

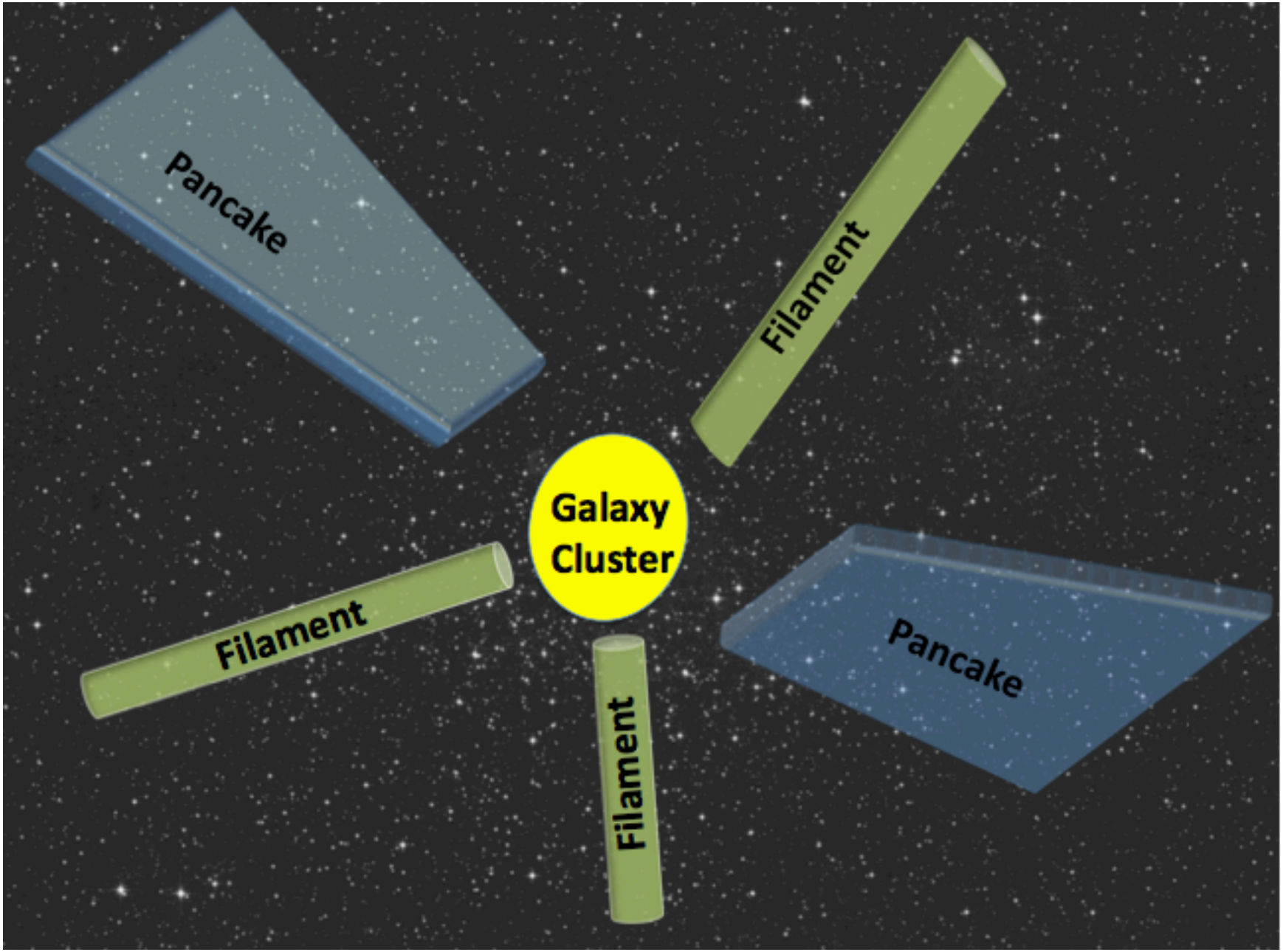


Martina Falco

Talk based on papers...

- Falco et al, 2014 (MNRAS)
- Brinckmann et al, 2014/15 (in prep)
- Wadekar et al, 2014/15 (in prep)
- Sacchi et al, 2015/16 (in prep)

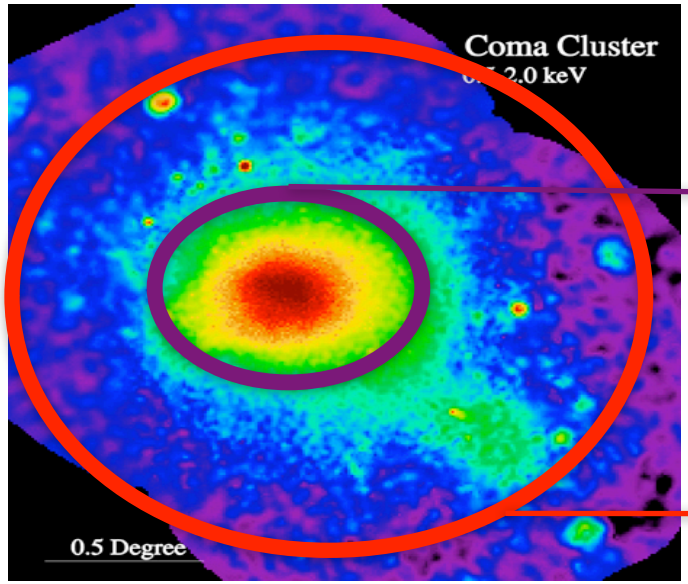



Pancake
Filament
Galaxy Cluster
Filament
Filament
Pancake

Dynamics of galaxy clusters

The inner core of clusters had the time to reach the virialization state : all the matter components are in equilibrium

The cluster outskirts still contain matter inflowing into the inner region : the matter is not set to dynamical equilibrium



Virial sphere:
equilibrium

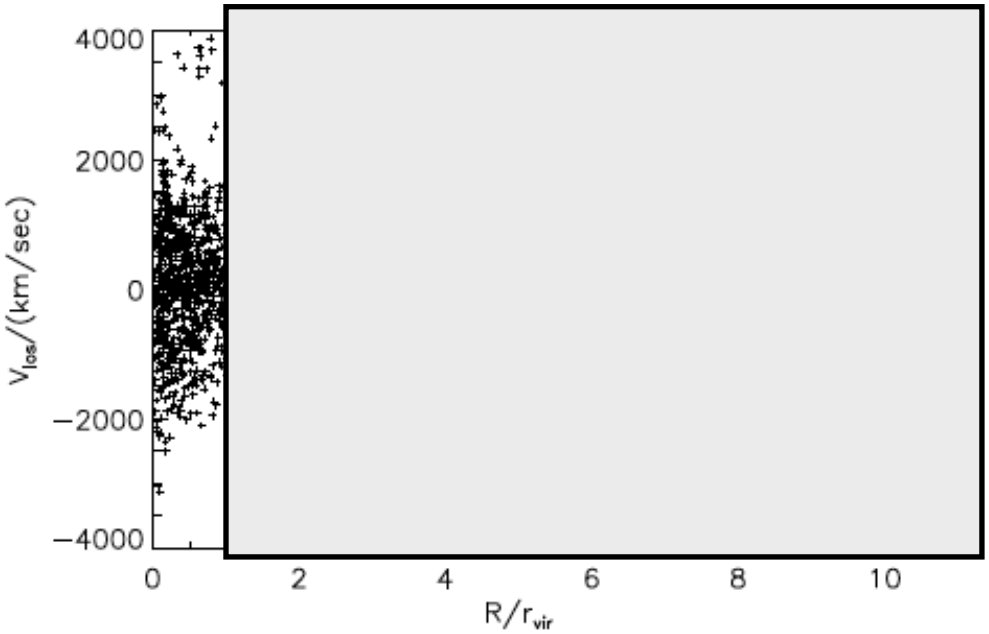
Outskirts:
non equilibrium

Dark Cosmology Centre

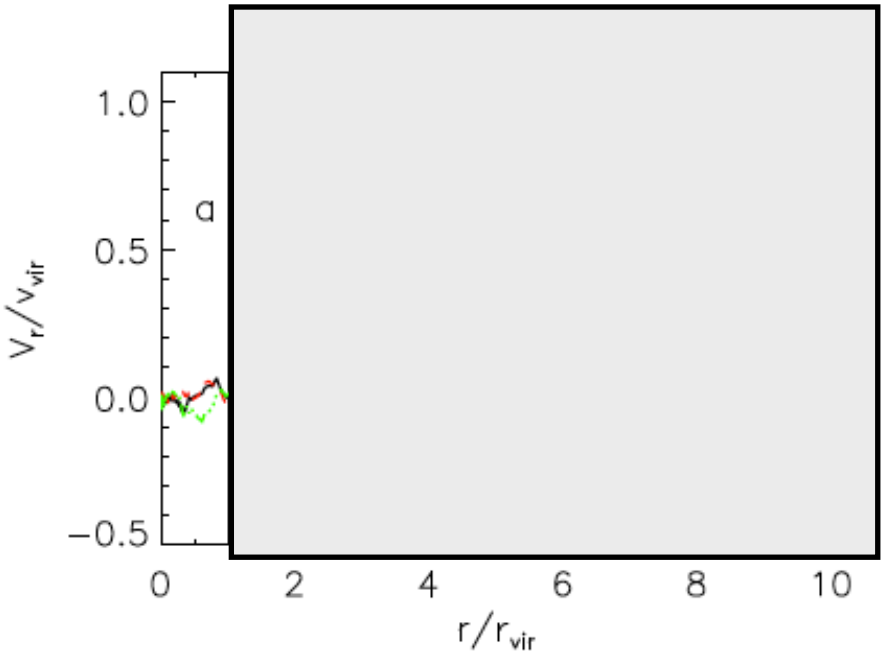
Cluster dynamics beyond virialization

Outskirts in the phase space

Observations of the Coma cluster:



Simulations:

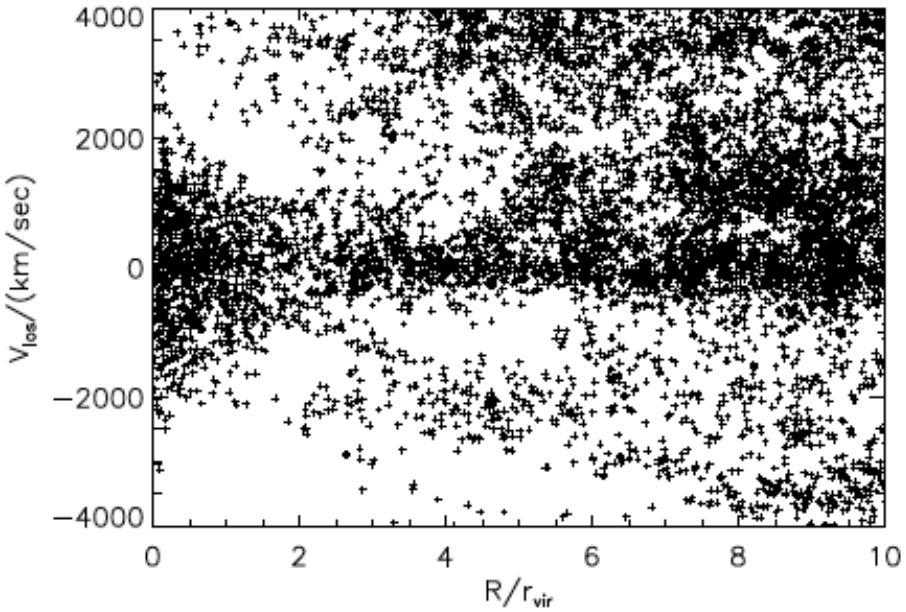


a) <1 r_v: Virialized cluster, matter in equilibrium

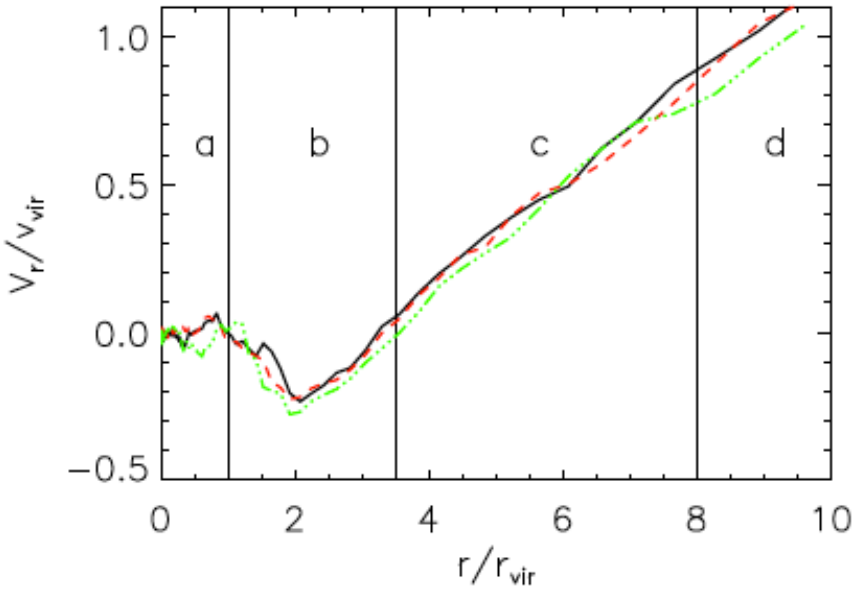
Cluster dynamics beyond virialization

Outskirts in the phase space

Observations of the Coma cluster:



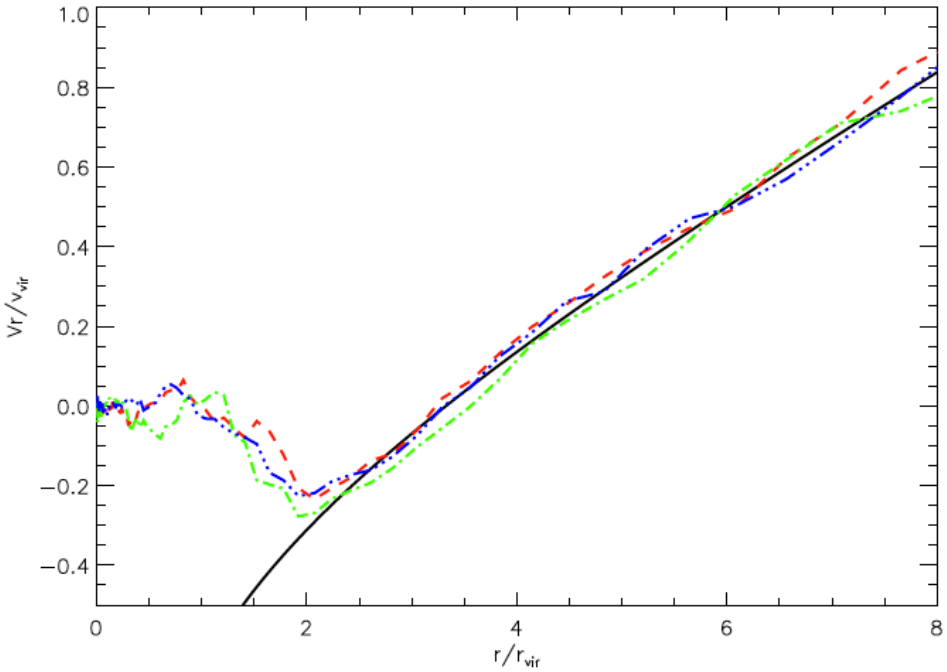
Simulations:



a) <1 r_v: Virialized cluster, matter in equilibrium
b) 1-4 r_v: Infall regime, matter falling towards the cluster center groups of galaxies, filaments)
c) 4-8 r_v: Transition region, matter still affected by the cluster mass (filaments and sheets)
d) > 8 r_v: Hubble regime,motion dominated by the Hubble flow

Virial mass from the outskirts

Velocity model from simulations



Quite universal trend for the radial velocity profile of cluster-size halos normalized to their virial velocities

$$\overline{v}_r(r, M_V) = Hr + \overline{v}_p(r, M_V) \longrightarrow v_{los}(R, \alpha, M_{virial})$$

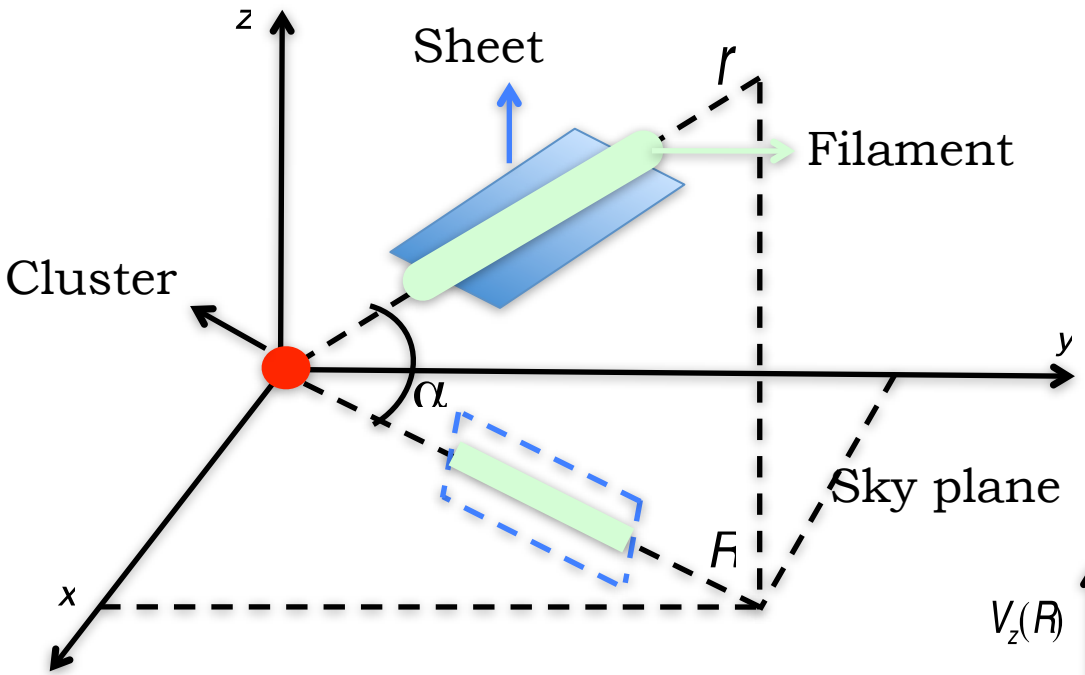
Hubble velocity

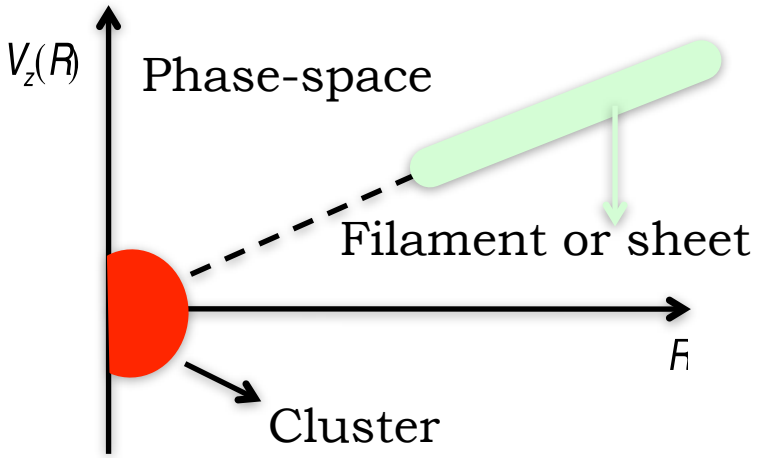
Peculiar velocity

Dark Cosmology Centre

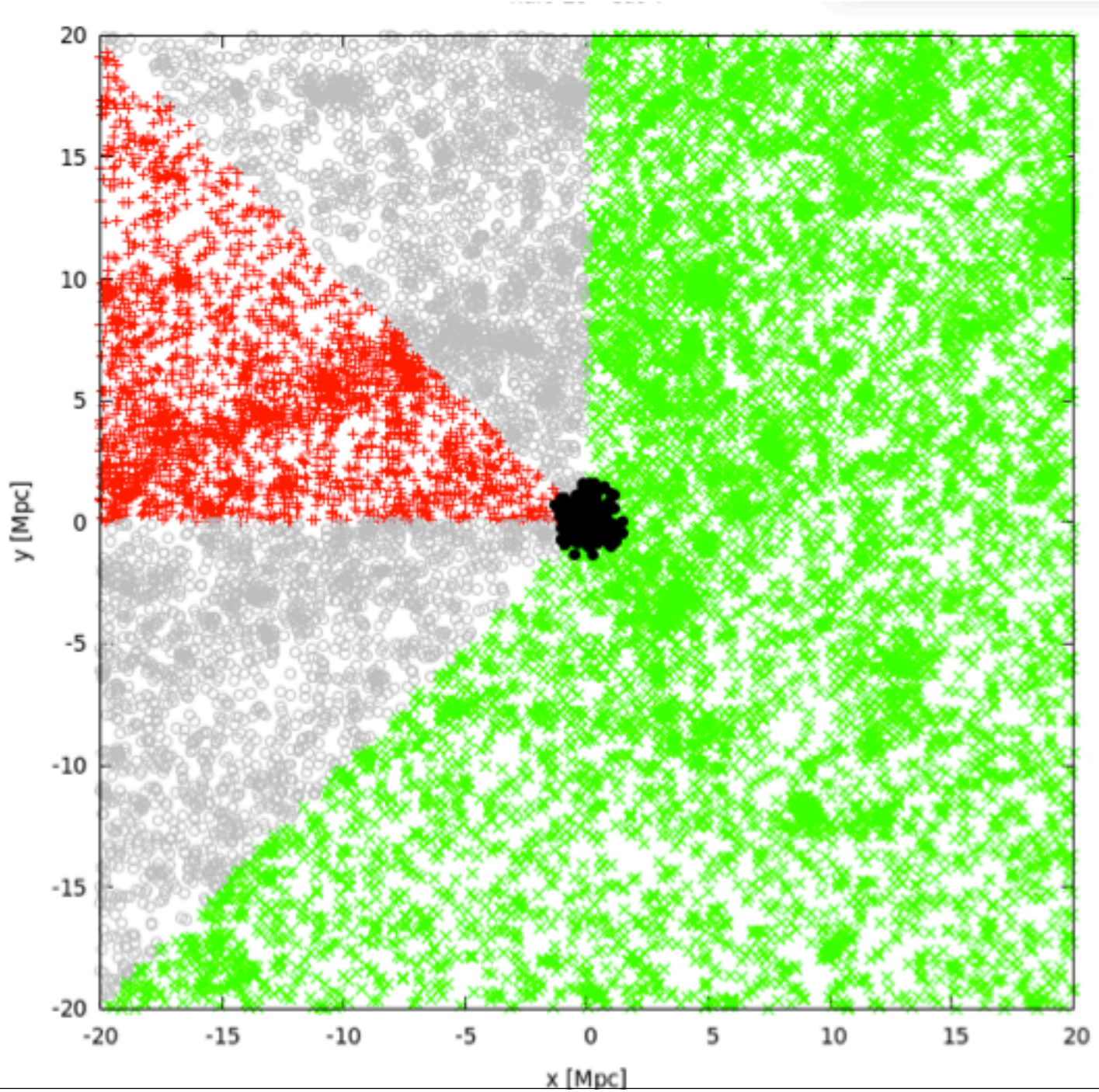
Virial mass from the outskirts

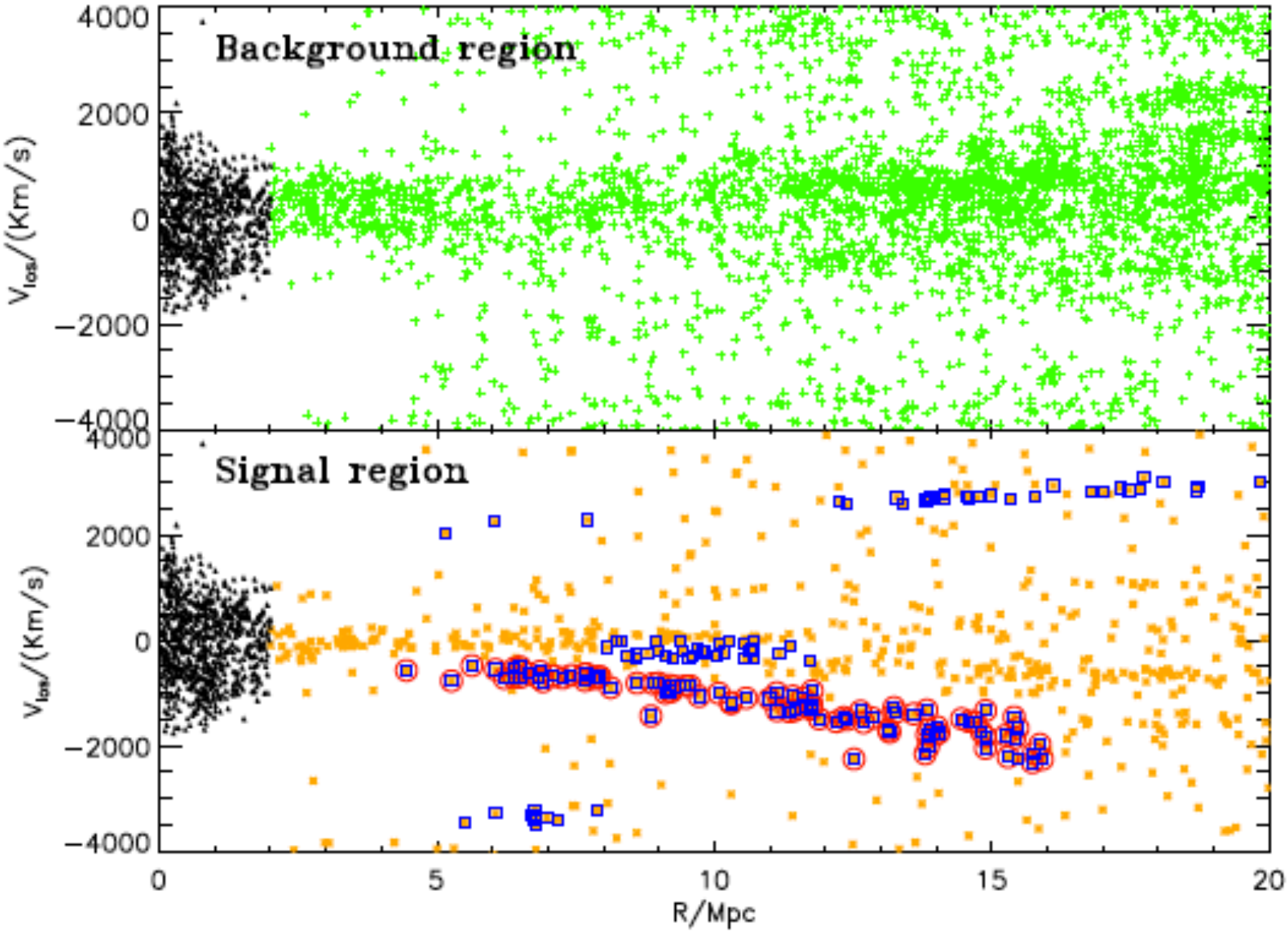
Finding filaments and sheets



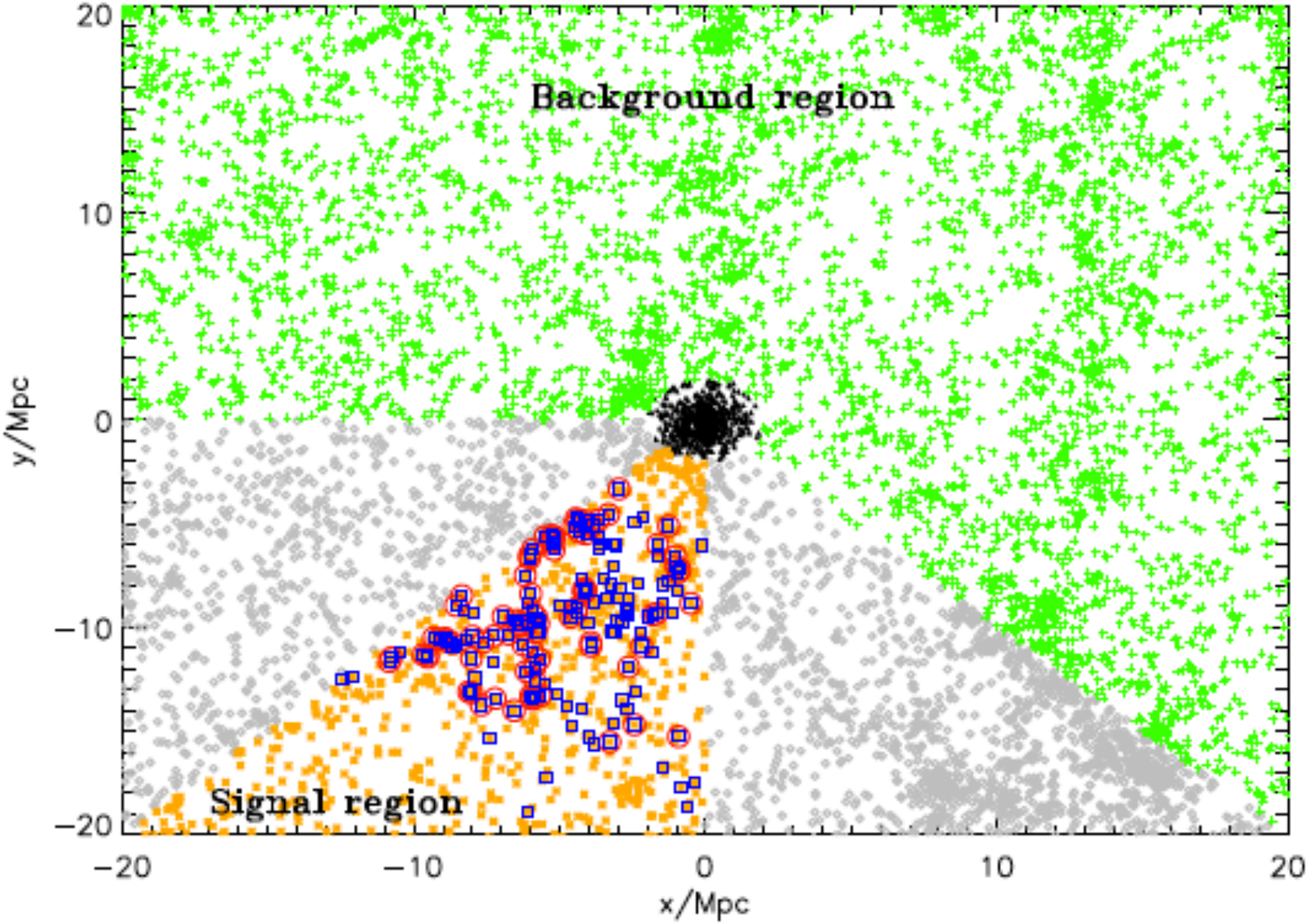


Dark Cosmology Centre


20
15
10
5
0
-5
-10
-15
-20
y [Mpc]
-20
-15
-10
-5
0
5
10
15
20
x [Mpc]

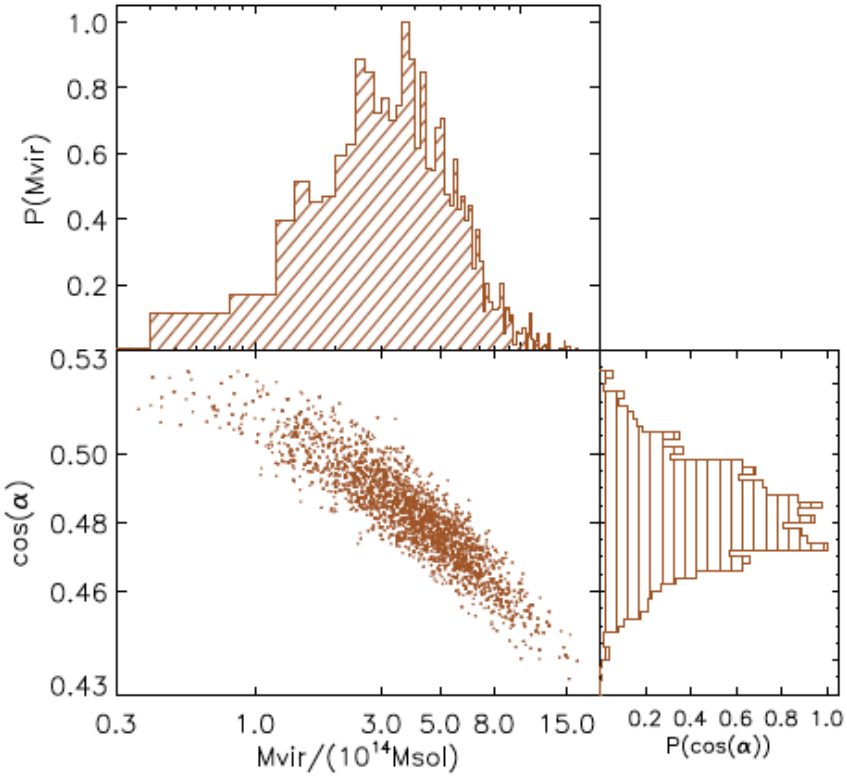


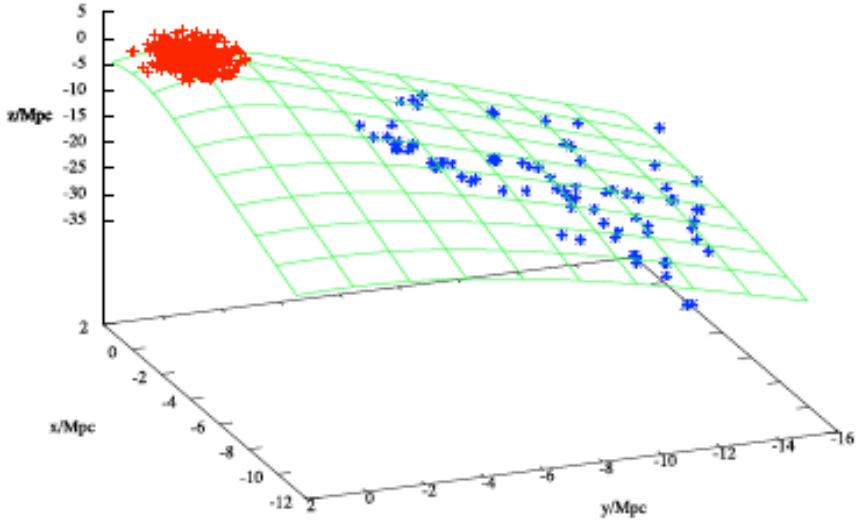
Dark Cosmology Centre


Background region
Signal region
20
10
0
−10
−20
−20
−10
0
10
20
y/Mpc
x/Mpc

Virial mass from the outskirts

Results - cosmological simulations





Best fit for the virial mass: $(4.3 \pm 2.2) \times 10^{14}\ M_{\odot}$

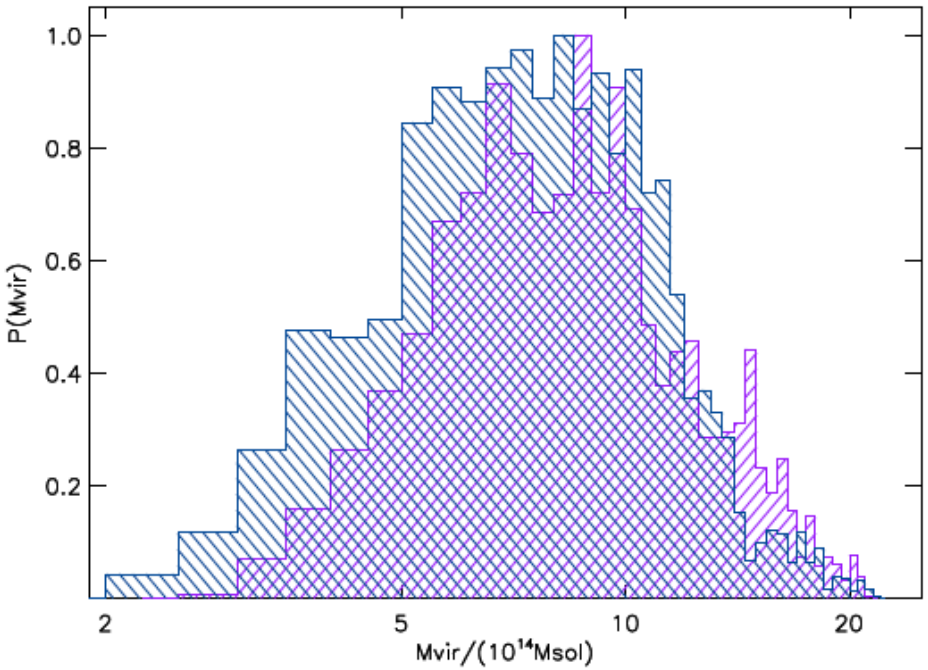
True virial mass: $4.7 \times 10^{14}\ M_{\odot}$

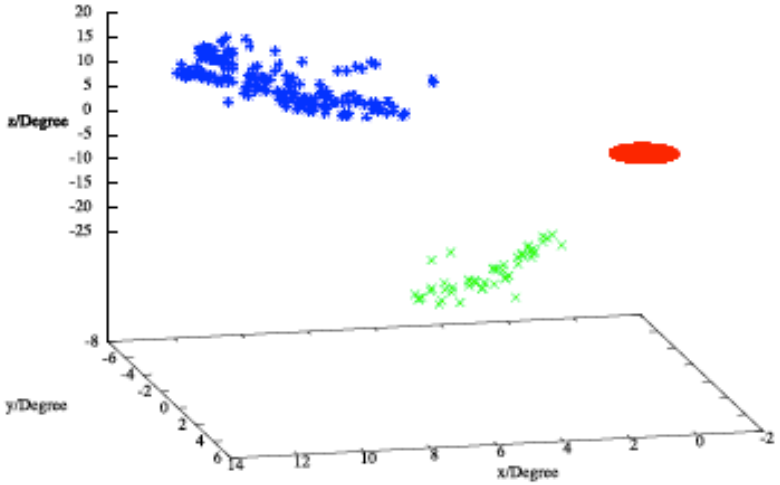
The best fit for the orientation angle of the sheet in 3D is compatible with the real one

Dark Cosmology Centre

Virial mass from the outskirts

The Coma cluster





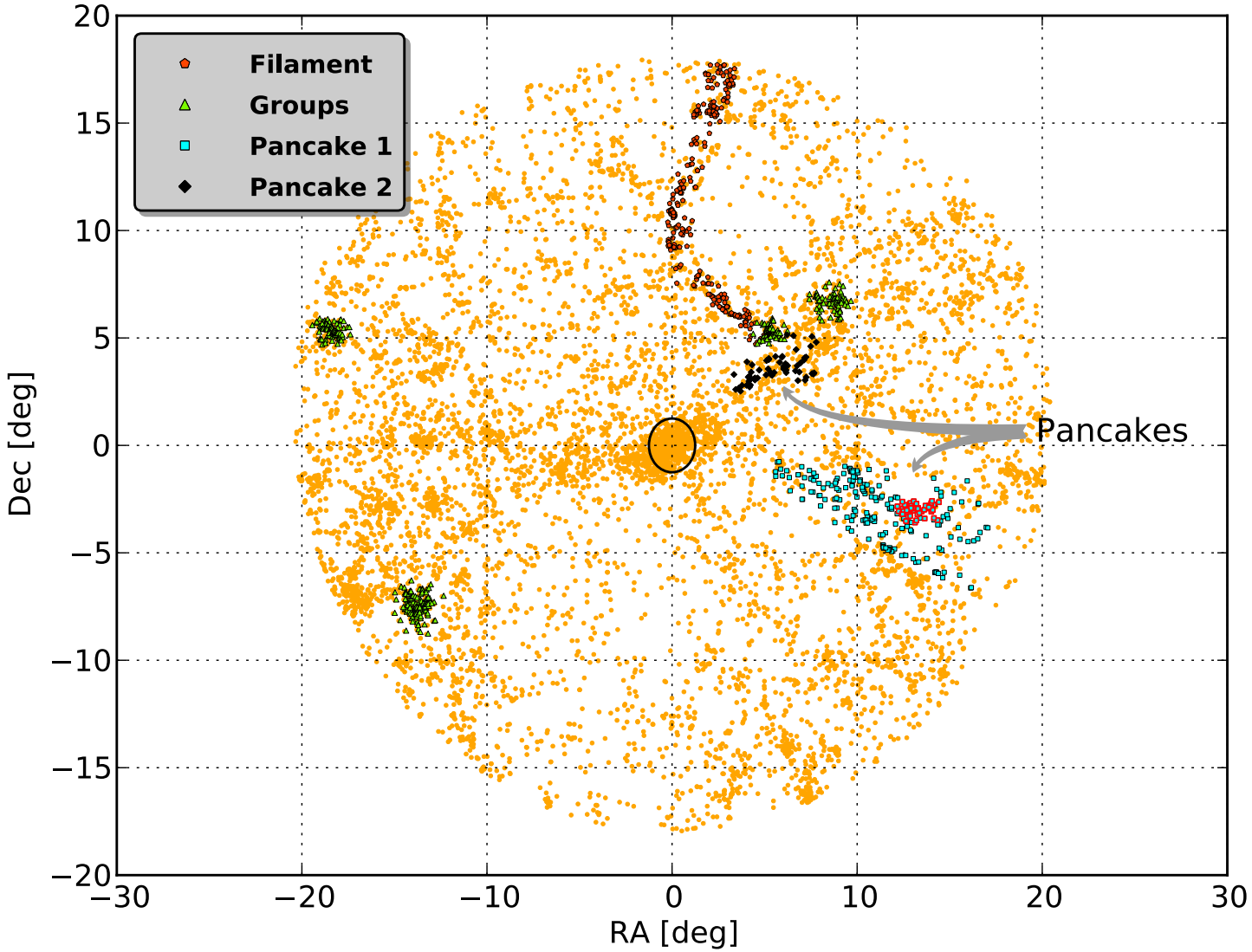
Best fit for the virial mass: $(9.2 \pm 2.4) \times 10^{14}\, M_{\otimes}$

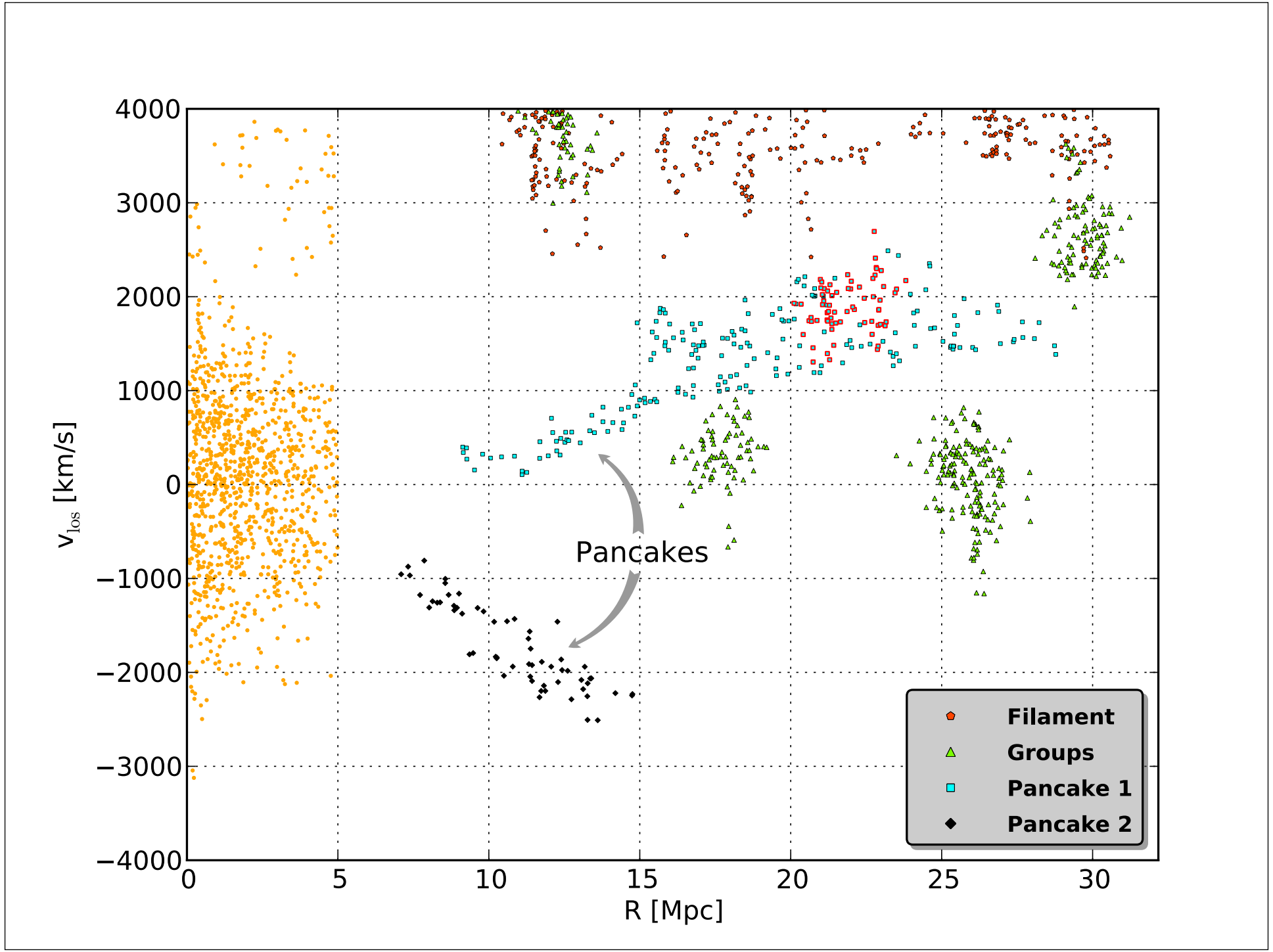
X ray: $(13 \pm 2) \times 10^{14}\, M_{\otimes}$

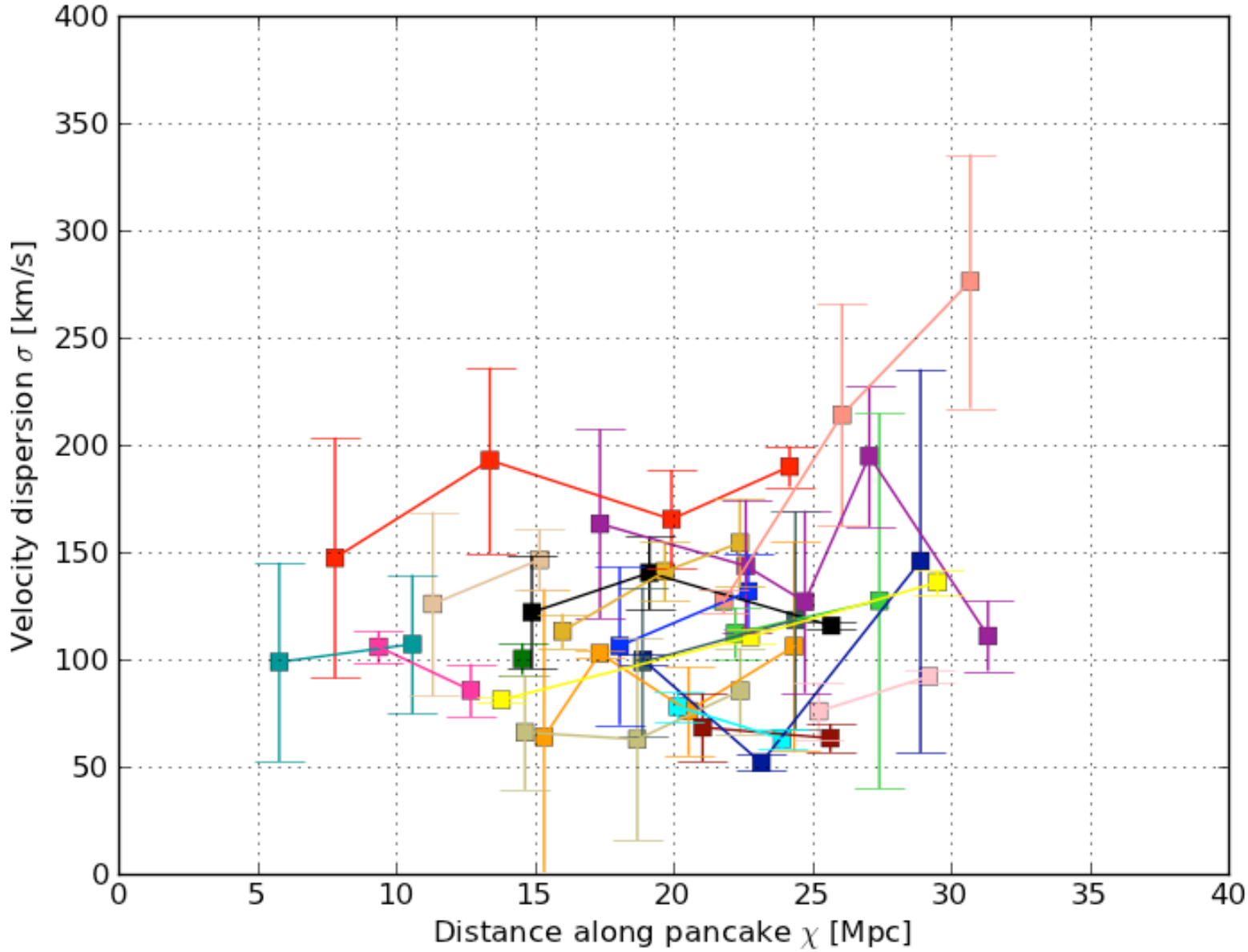
Jeans: $(15 \pm 4.5) \times 10^{14}\, M_{\otimes}$

We can reconstruct the 3D orientation of the sheets

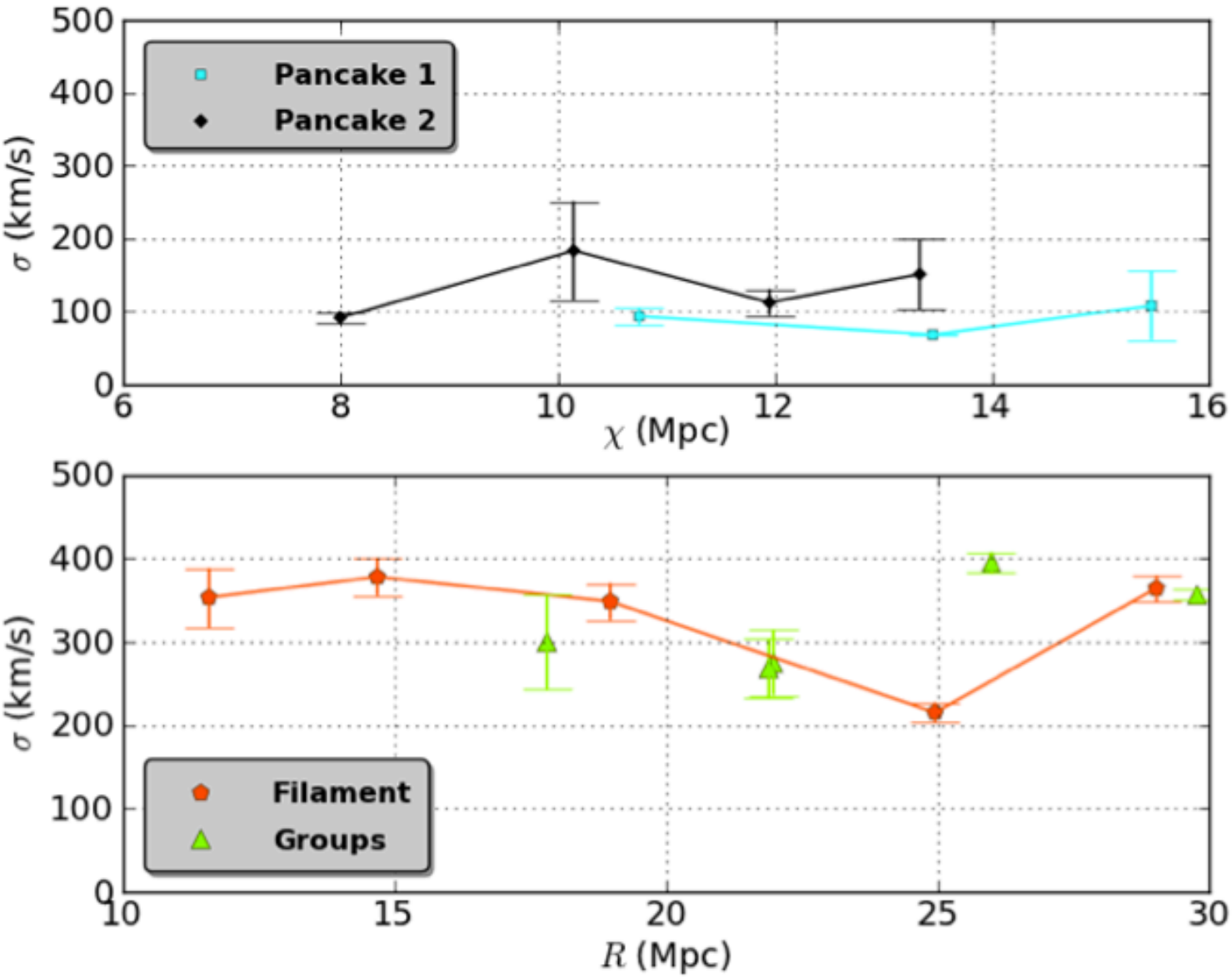
Dark Cosmology Centre

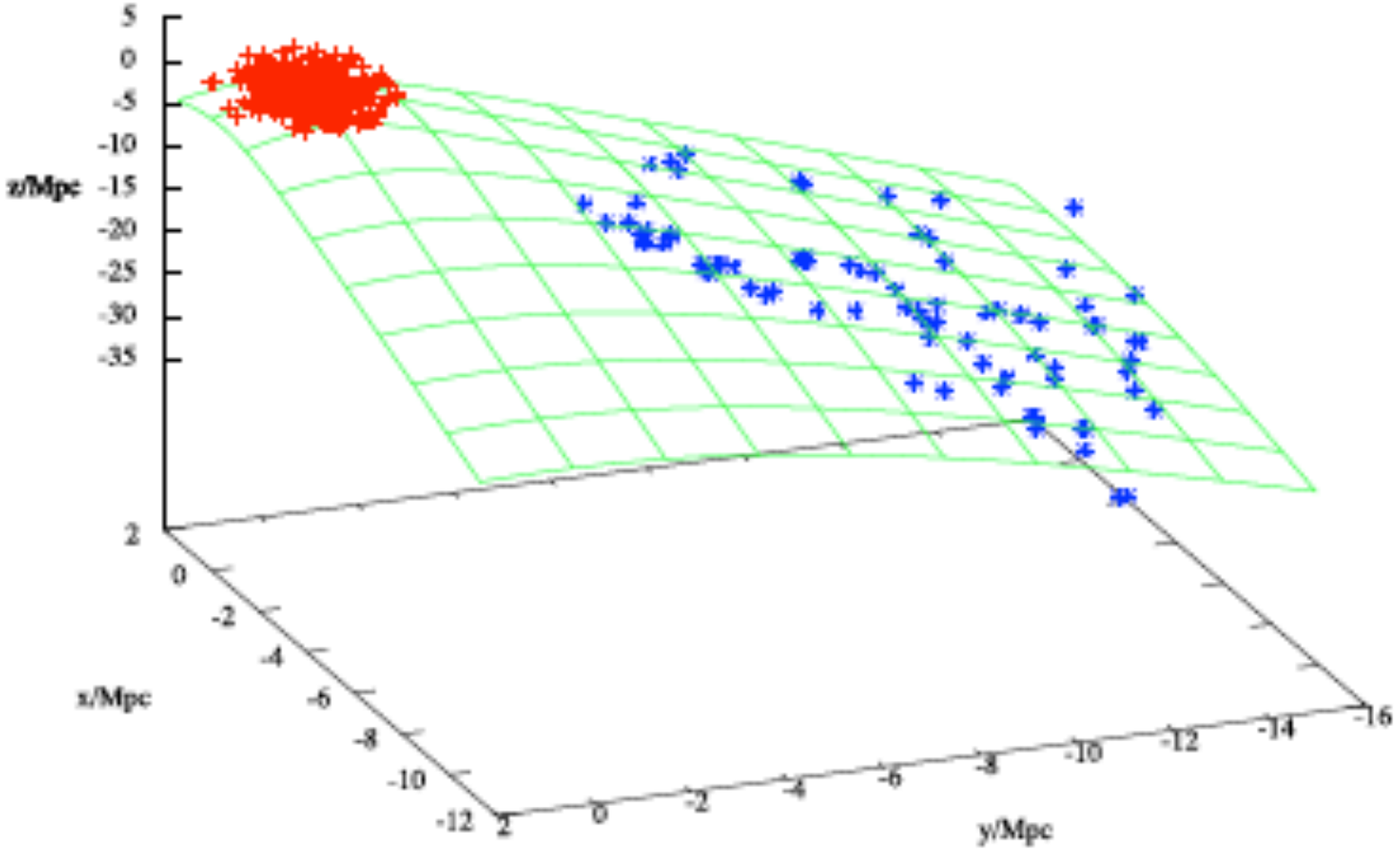

Filament
Groups
Pancake 1
Pancake 2
Pancakes
Dec [deg]
RA [deg]
20
15
10
5
0
−5
−10
−15
−20
−30
−20
−10
0
10
20
30

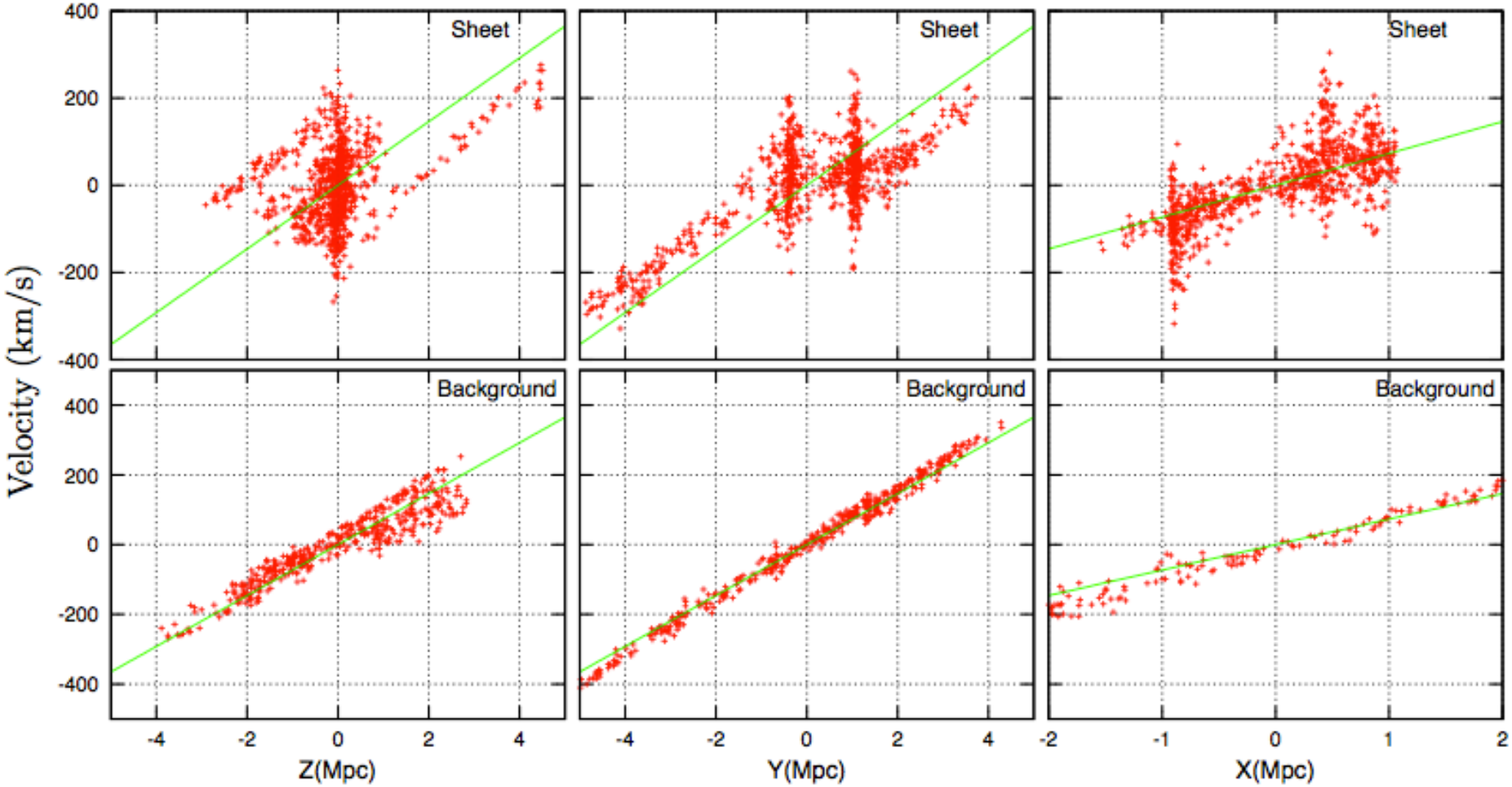

4000
3000
2000
1000
0
−1000
−2000
−3000
−4000
0
5
10
15
20
25
30
v_{los} [km/s]
R [Mpc]
Pancakes
Filament
Groups
Pancake 1
Pancake 2

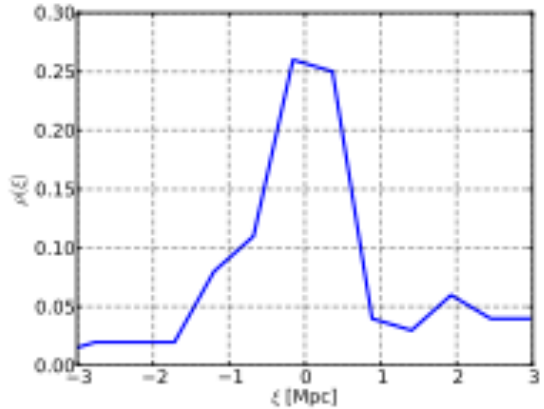

Velocity dispersion σ [km/s]
Distance along pancake χ [Mpc]
0
50
100
150
200
250
300
350
400
0
5
10
15
20
25
30
35
40

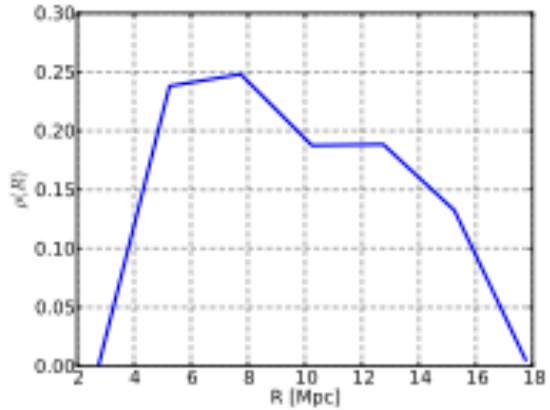
Really cold

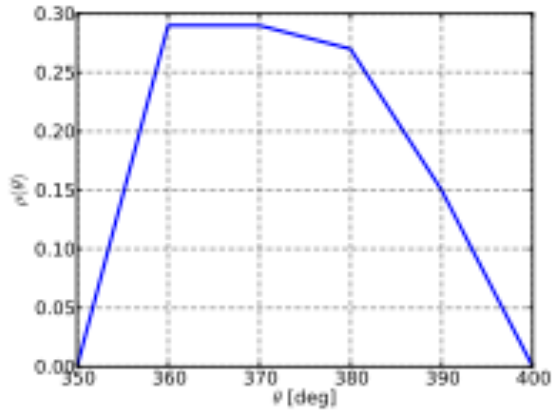

Pancake 1
Pancake 2
σ (km/s)
χ (Mpc)
Filament
Groups
σ (km/s)
R (Mpc)

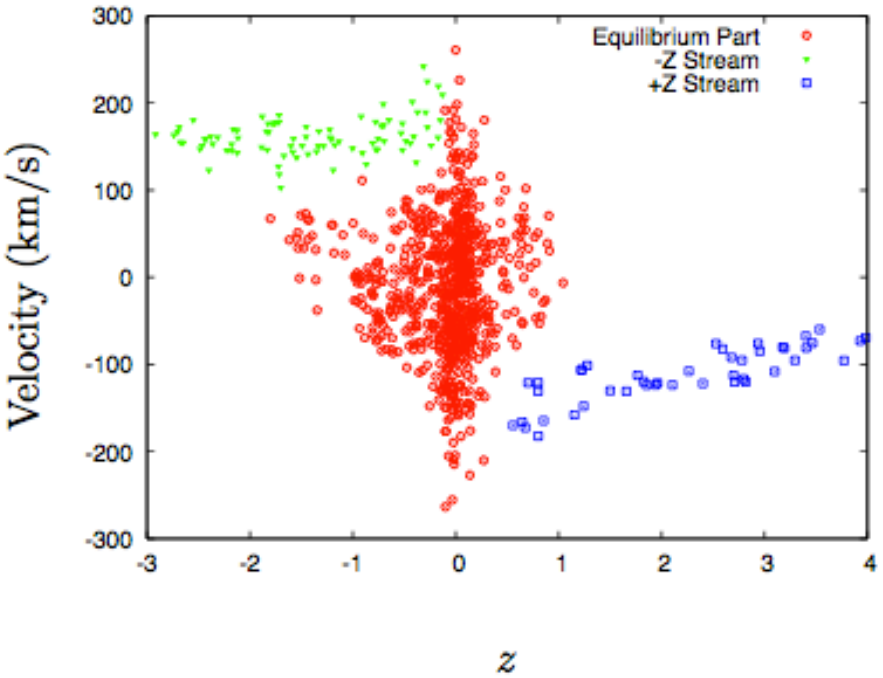

z/Mpc
5
0
-5
-10
-15
-20
-25
-30
-35
x/Mpc
2
0
-2
-4
-6
-8
-10
-12
y/Mpc
2
0
-2
-4
-6
-8
-10
-12
-14
-16

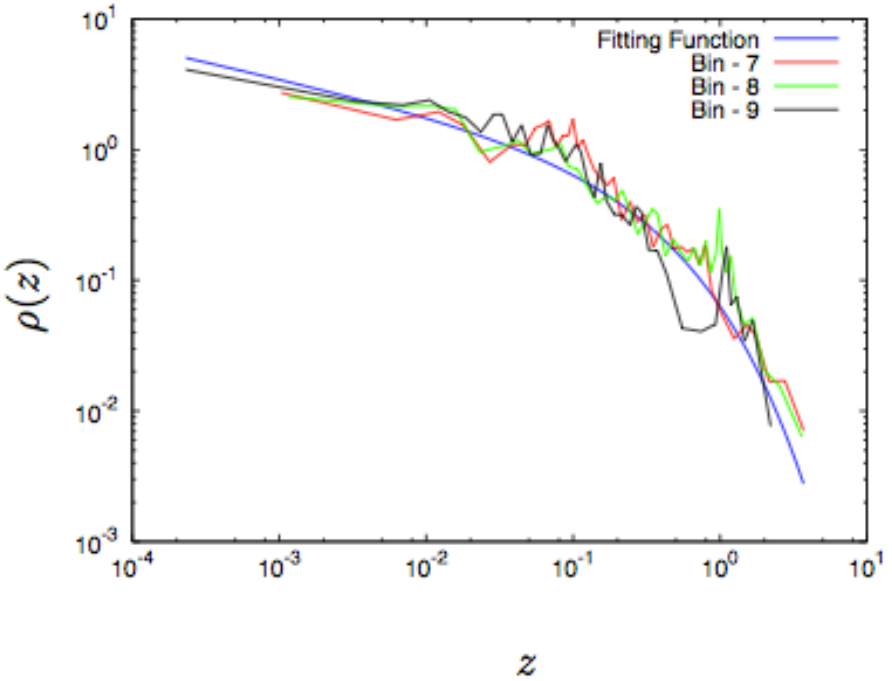

Sheet
Sheet
Sheet
Background
Background
Background
Velocity (km/s)
400
200
0
-200
-400
-4
-2
0
2
4
-2
-1
0
1
2
Z(Mpc)
Y(Mpc)
X(Mpc)


0.30
0.25
0.20
0.15
0.10
0.05
0.00
−3
−2
−1
0
1
2
3
ξ [Mpc]

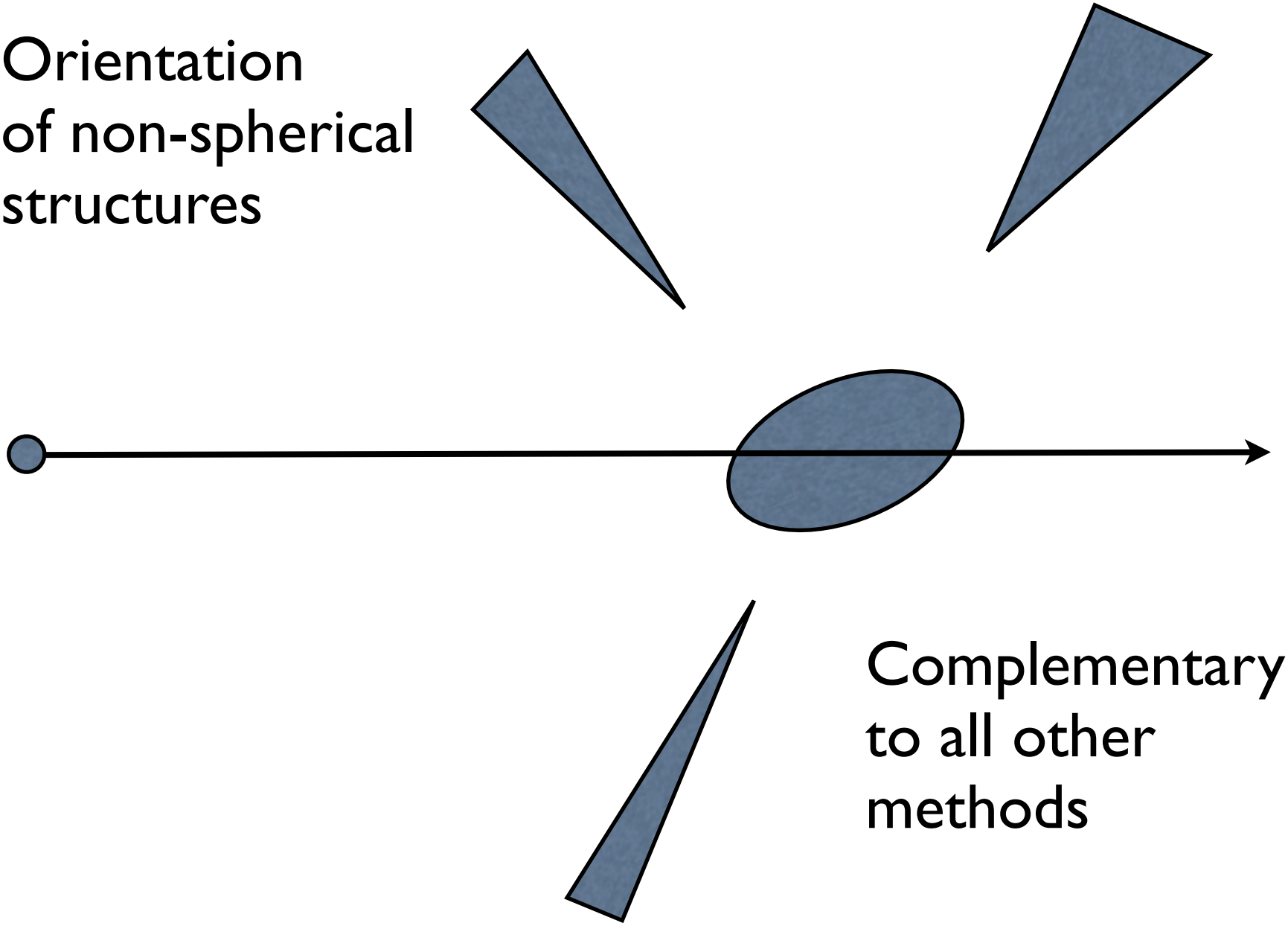

0.30
0.25
0.20
0.15
0.10
0.05
0.00
2
4
6
8
10
12
14
16
18
R [Mpc]


0.30
0.25
0.20
0.15
0.10
0.05
0.00
350
360
370
380
390
400
ν [deg]


Equilibrium Part
-Z Stream
+Z Stream
Velocity (km/s)
300
200
100
0
-100
-200
-300
-3
-2
-1
0
1
2
3
4
z


Fitting Function
Bin - 7
Bin - 8
Bin - 9
ρ(z)
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-3
10^-2
10^-1
10^0
10^1
z

Orientation
of non-spherical
structures



Complementary
to all other
methods

- the end...