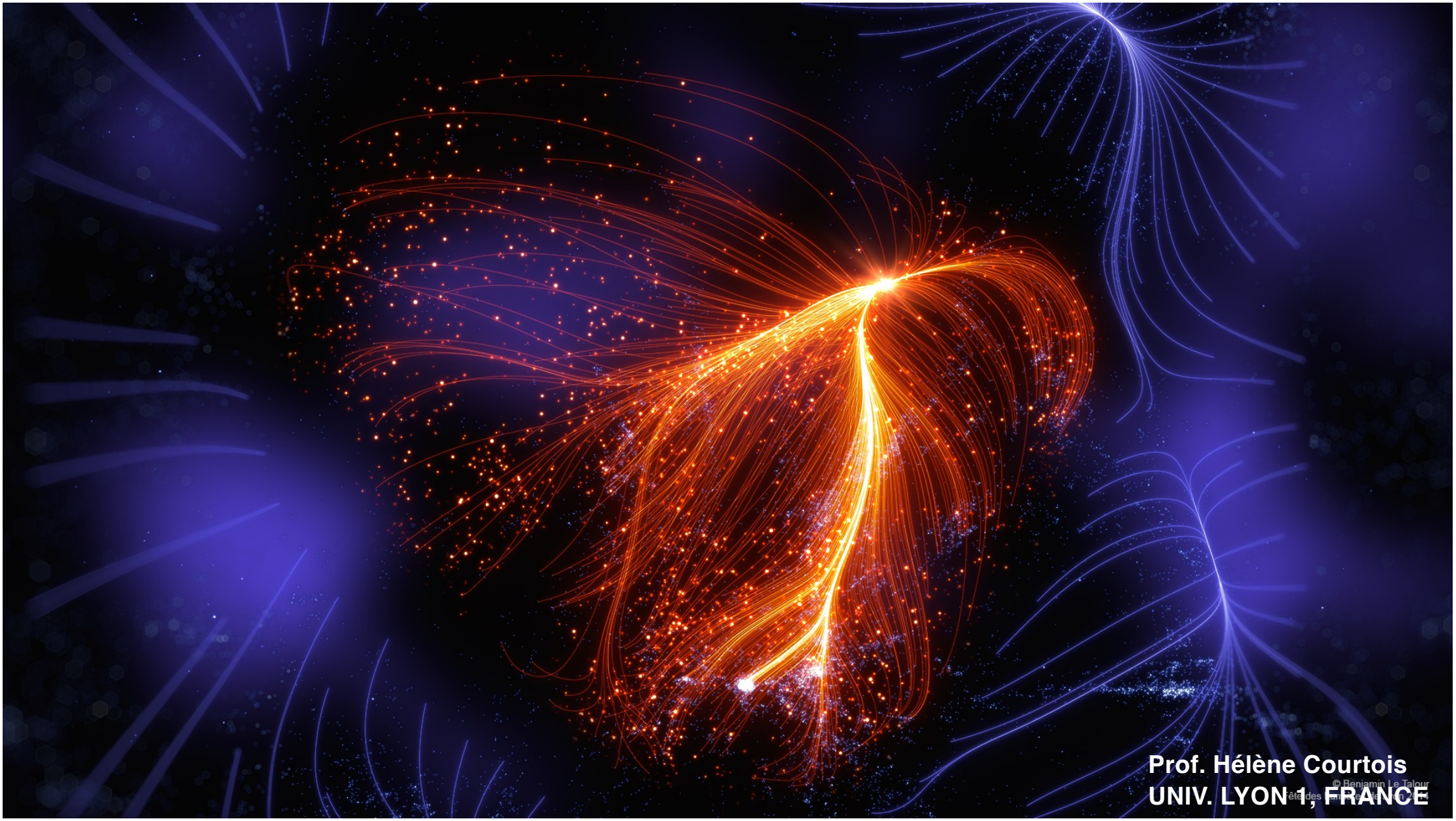

Prof. Hélène Courtois
UNIV. LYON 1, FRANCE
© Benjamin Le Talour

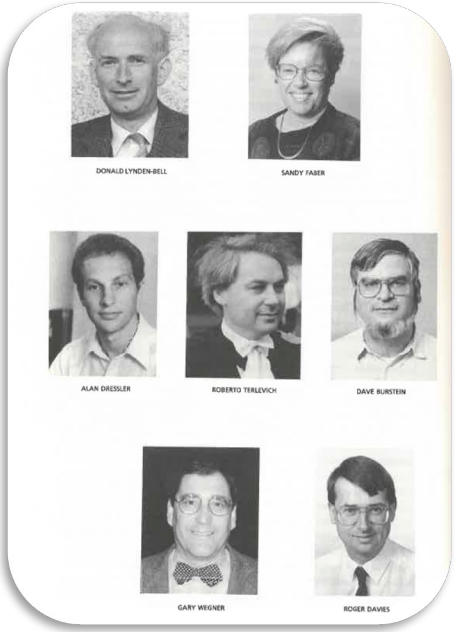
CosmicFlows, 20 years : probing the dynamics on large scales

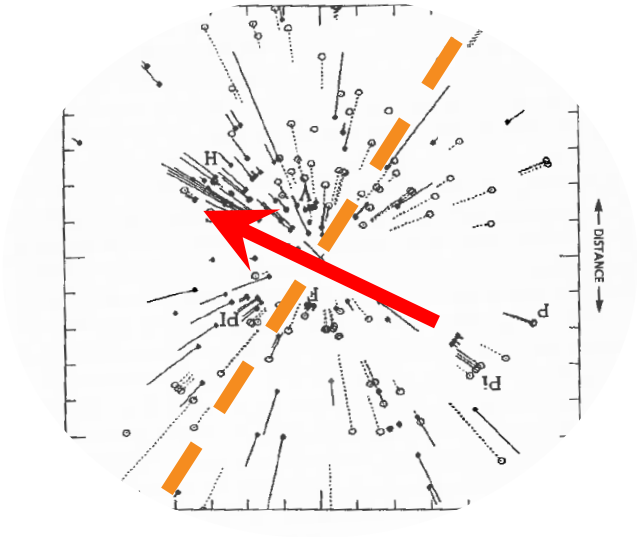
H. Courtois, A. Dupuy, A. Hollinger (Lyon / KIAS)
and collaborators : J. Mould, M. Colless, R. Kraan-Korteweg, P. Boubel

The idea is : on large scales the motions of galaxies are exclusively due to expansion and gravitation.

The methodology :

- *we can observe only the radial part of these motions,*
- *we can observe them in different environments : empty, medium, dense,*
- *we can observe them at different epochs.*

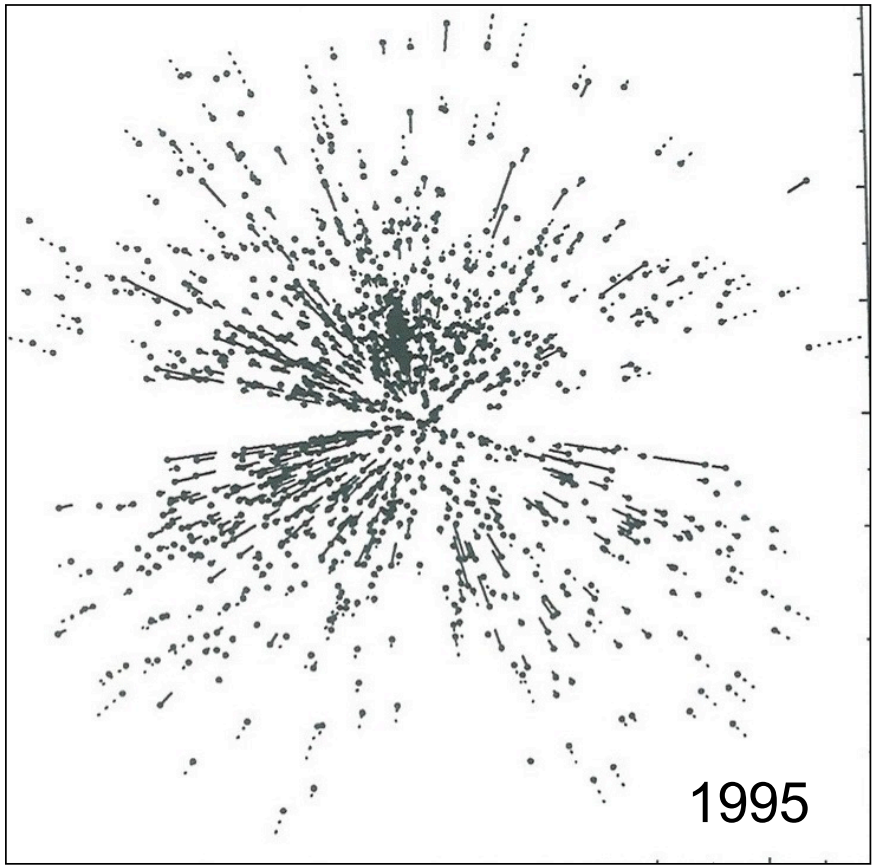




Sandra Faber and Donald Linden-Bell 1986









Obtaining datasets

1995→2005 death of the field









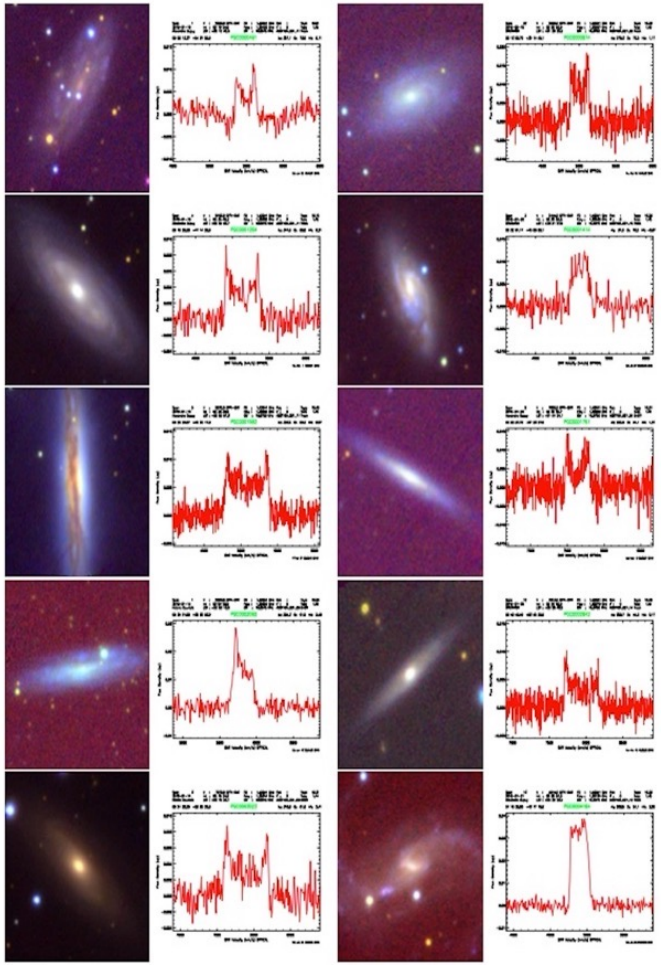




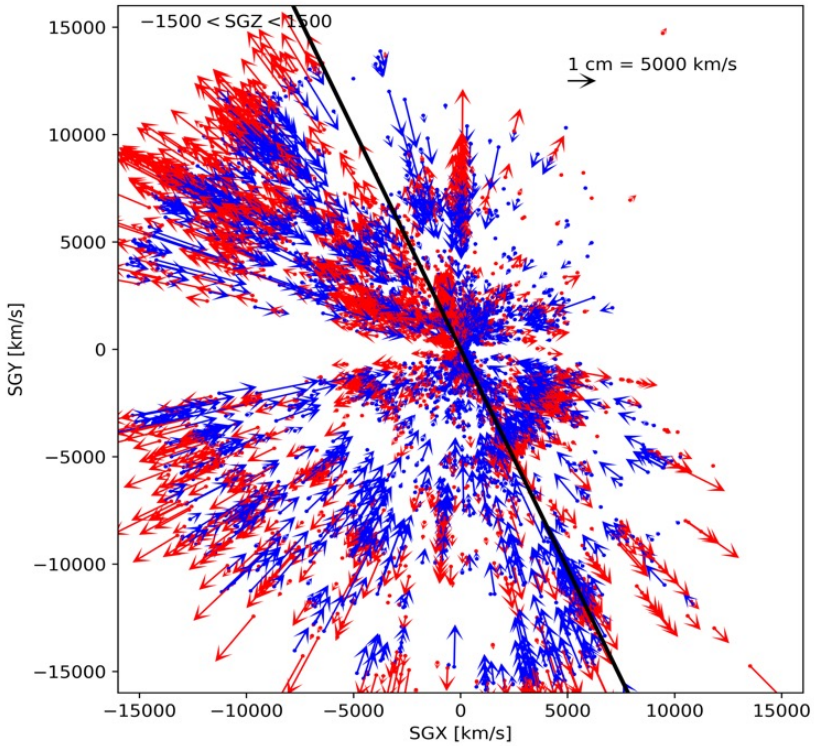




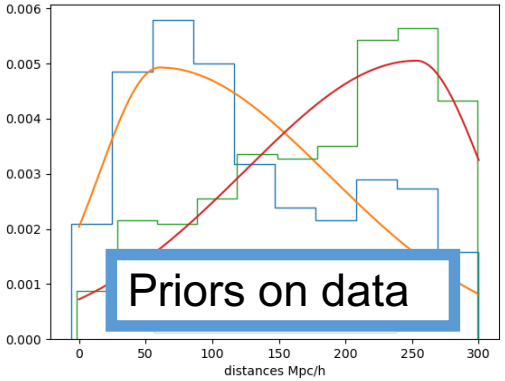
Observed distance moduli to estimated radial peculiar velocities in distorted redshift space



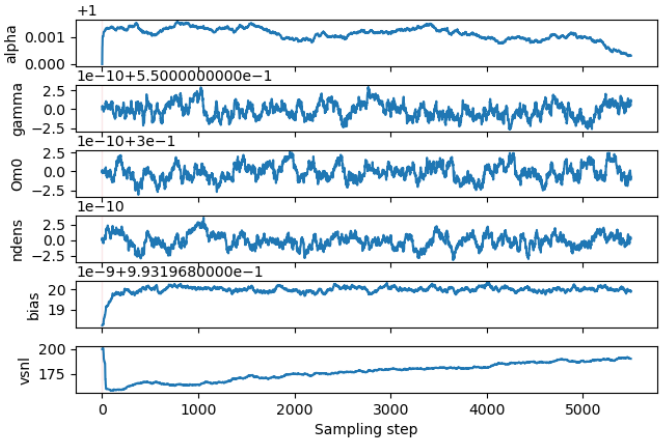
$$v^r \sim cz - H_0 d_L$$



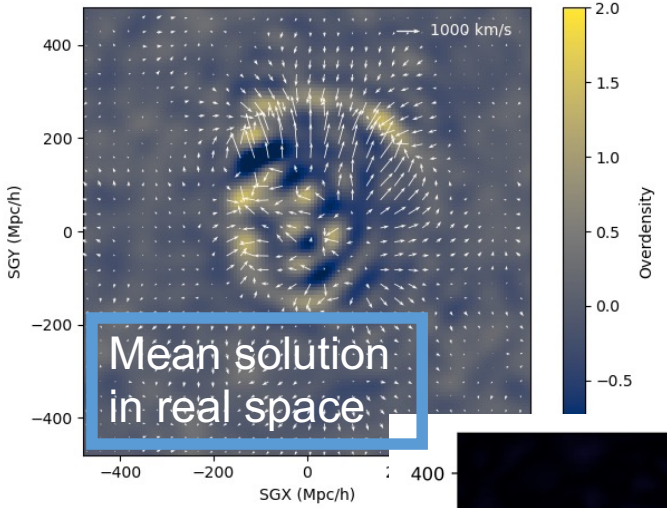
LCDM Hamiltonian Monte Carlo forward modeling of the observational dataset to compute a 3 dimensional reconstruction of the gravitational velocity field



Priors on data

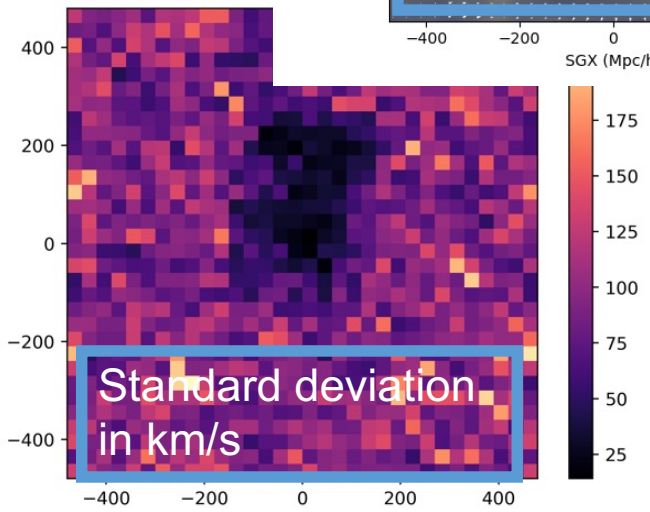


HMC steps exploration

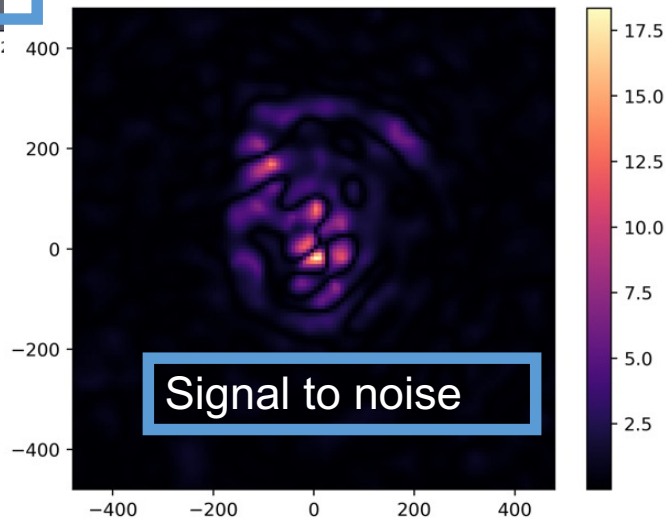


Mean solution in real space

$$\nabla . \boldsymbol{v}_m = -aHf(\Omega_m)\delta_m(\mathbf{x}, t)$$



Standard deviation in km/s



Signal to noise

Courtois et al. 2023 A&A...670L..15C

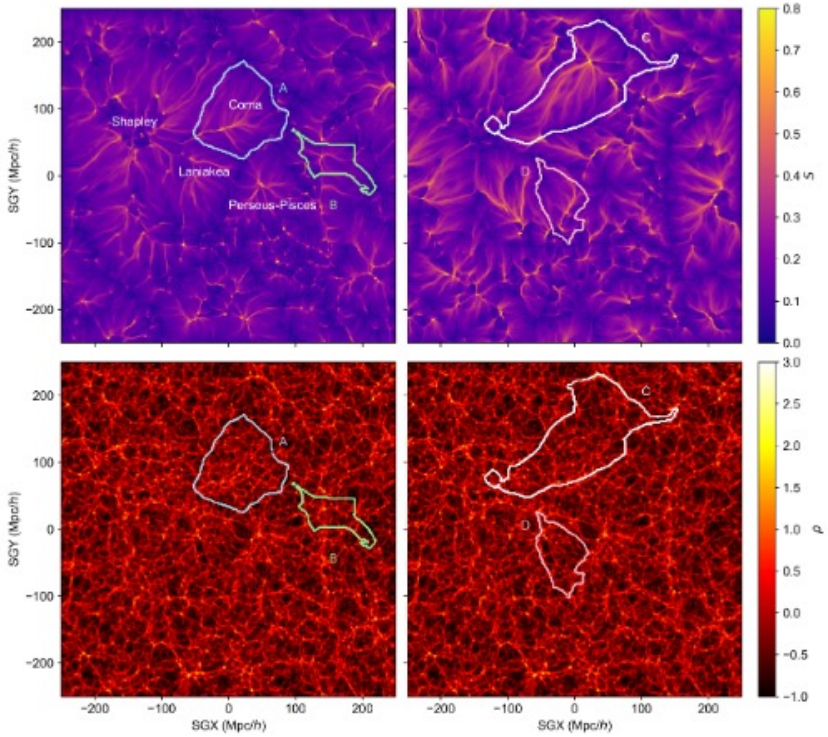
Testing gravitation using matter homogenity and growth rate of structures

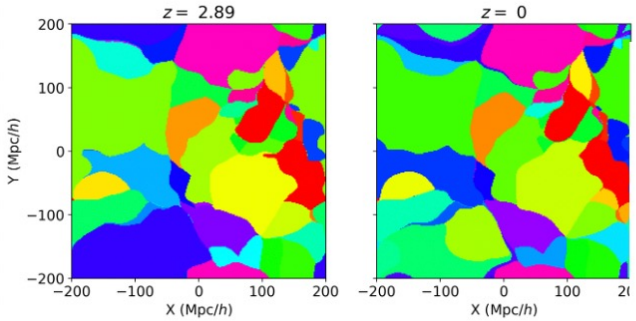
the questions we try to answer are :

- Do we find a scale at which the universe is homogeneous : no more large tidal flow due to large gravitational instabilities ?

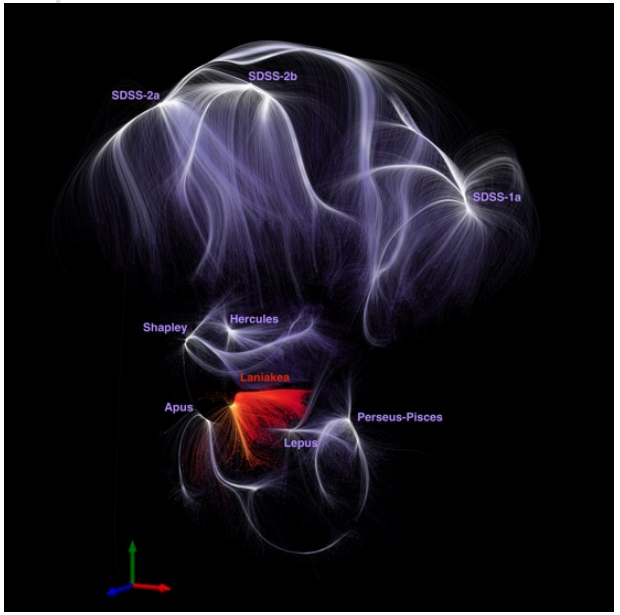
- How fast does gravitation pull galaxy structures together ?

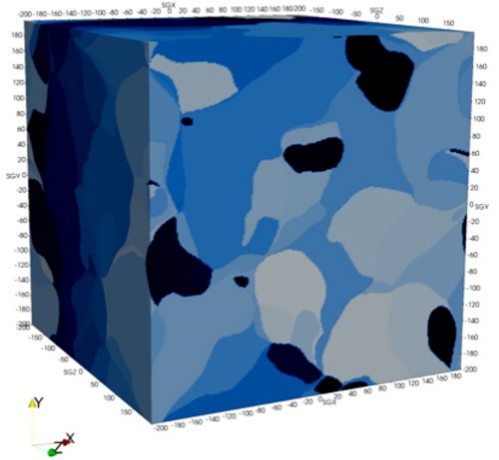
Watersheds → bulk flow, growth rate



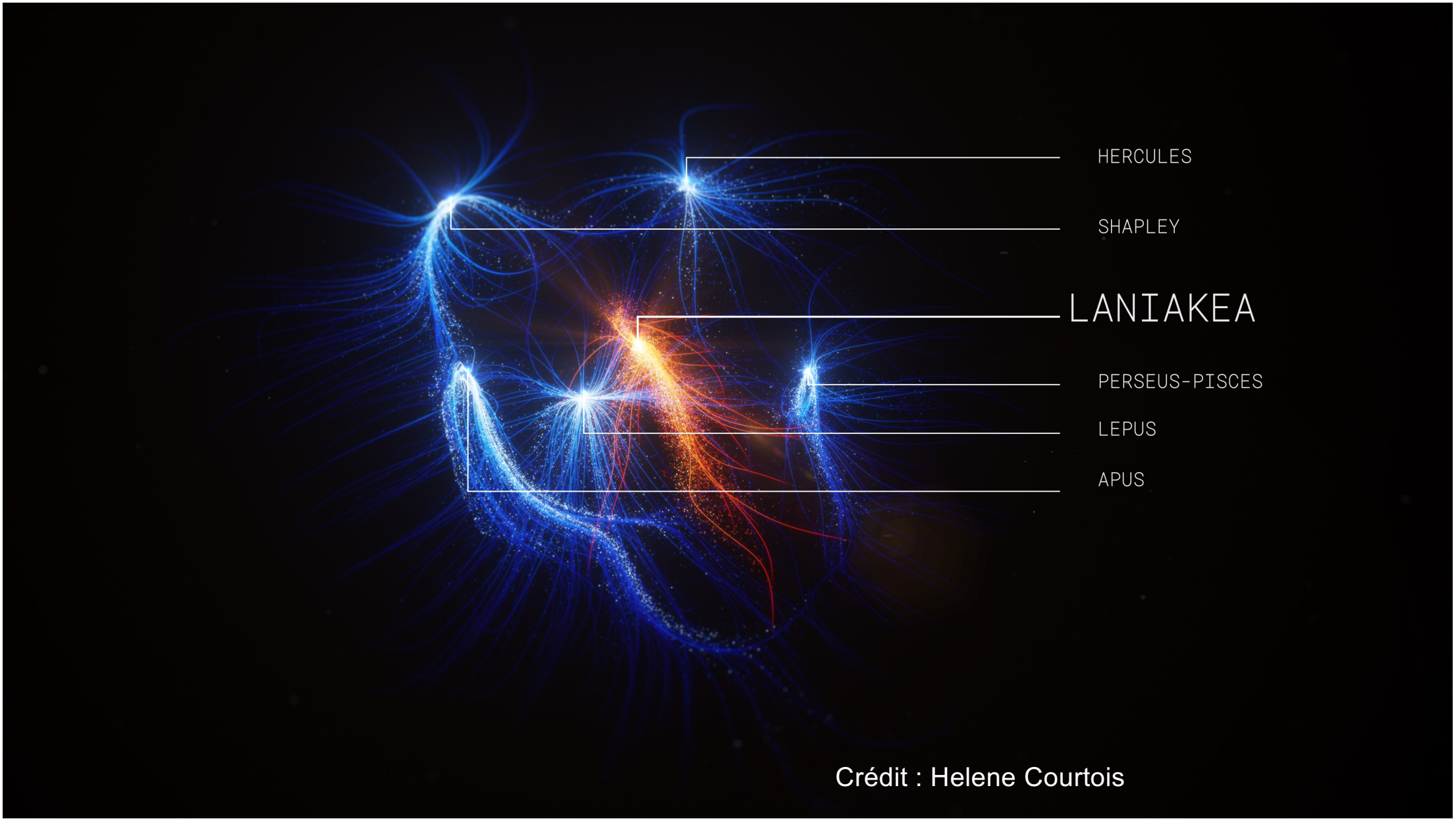


Evolution in time of the gravitational watersheds in a simulated universe at 2 billions years and today 13,7 b.years





Dupuy et al. 2020 MNRAS 493, 3513
Dupuy & Courtois 2023A&A...678A.176D



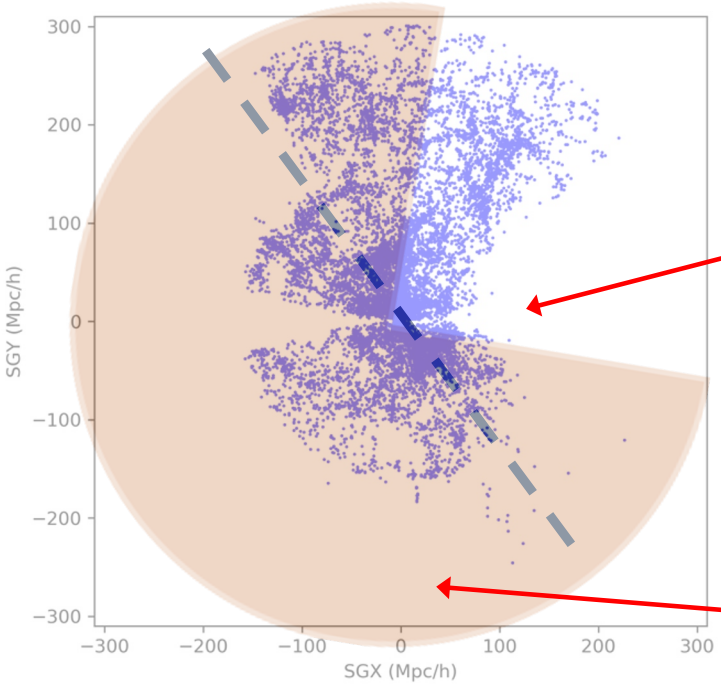
Crédit : Helene Courtois

Wallaby pilot phase : 2022-2023
start of the full survey in 2024

the question we try to answer is :

Today : a new technology : sensitivity of interferometric multi-antennas radio-telescope (how far, how good) ?

Today : new radio technologies : SKA (square kilometer array)



MeerKAT :
Obscuration zone

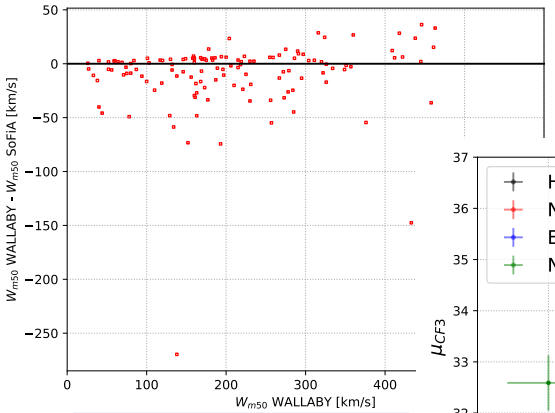


WALLABY :
+200,000 galaxies

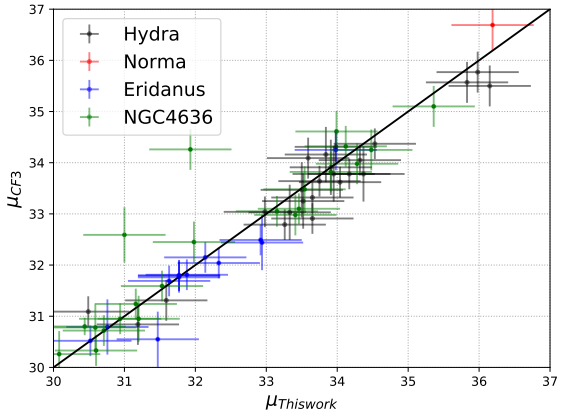


WALLABY Pilot Survey :
from radio HI linewidth algorithms pipeline and space near-infrared photometry
to distance moduli using in 8 test fields

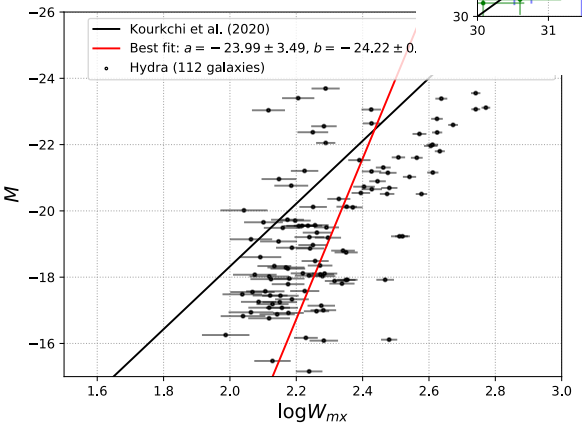
radio

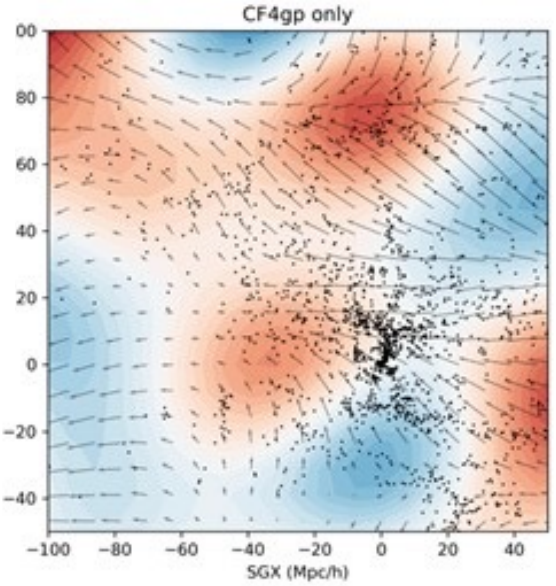


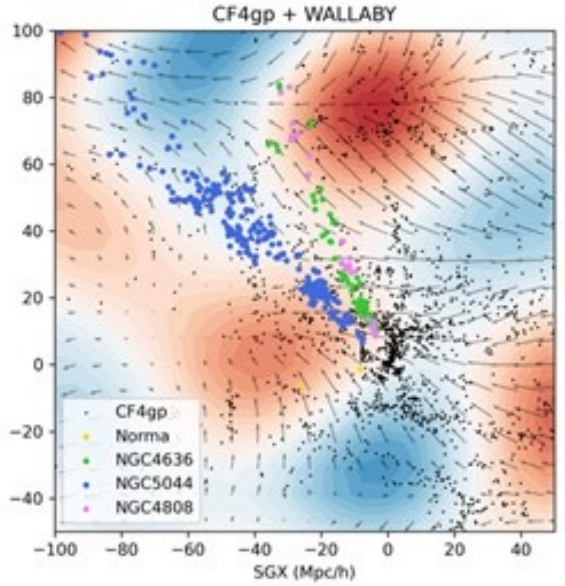
Distance moduli



photometry



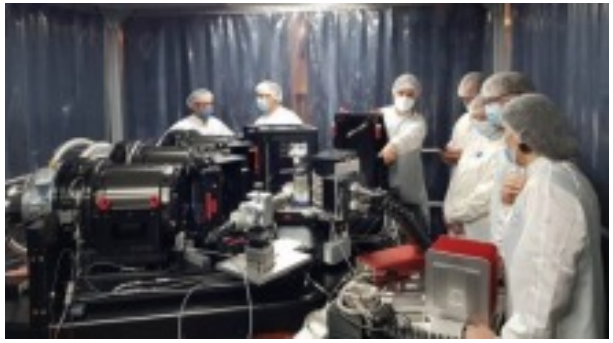


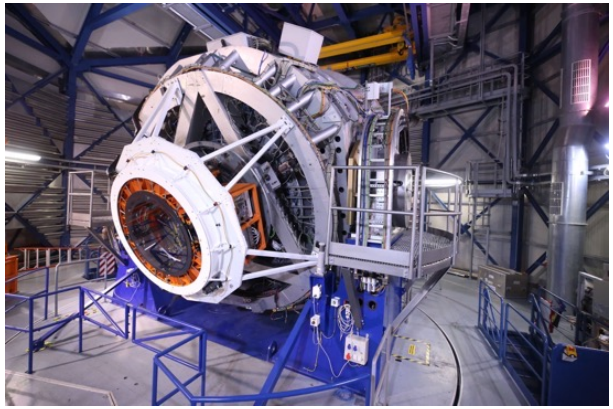


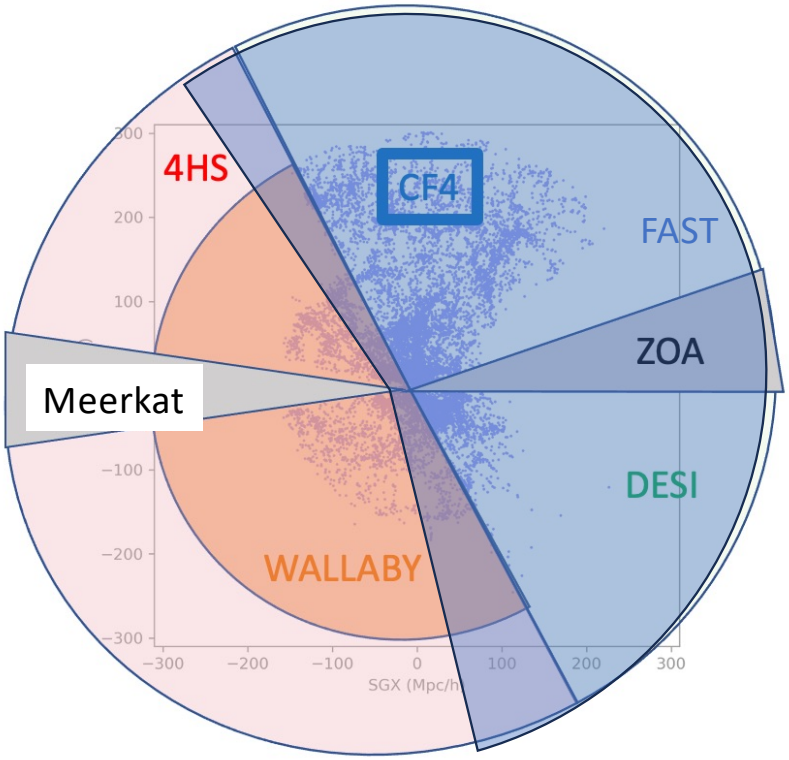
Courtois et al. 2023 MNRAS.519.4589C
Mould et al. 2024 MNRAS.533..925M

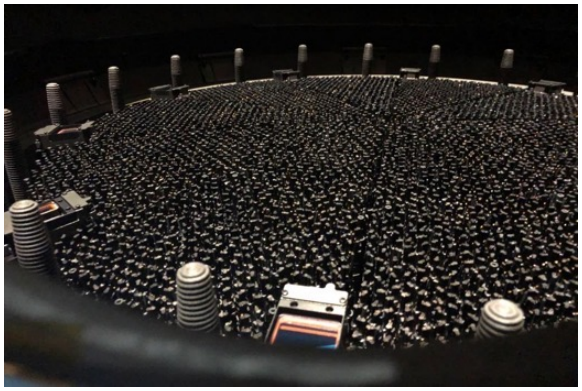
Upcoming peculiar velocity large datasets

WALLABY [22-27] : 90 000 spirals up to z=0.1
DESI-BGS-PV [21-26] : 500 000 ellipticals up to z=0.15
4MOST-4HS-PV [24-29] : 500 000 ellipticals up to z=0.15





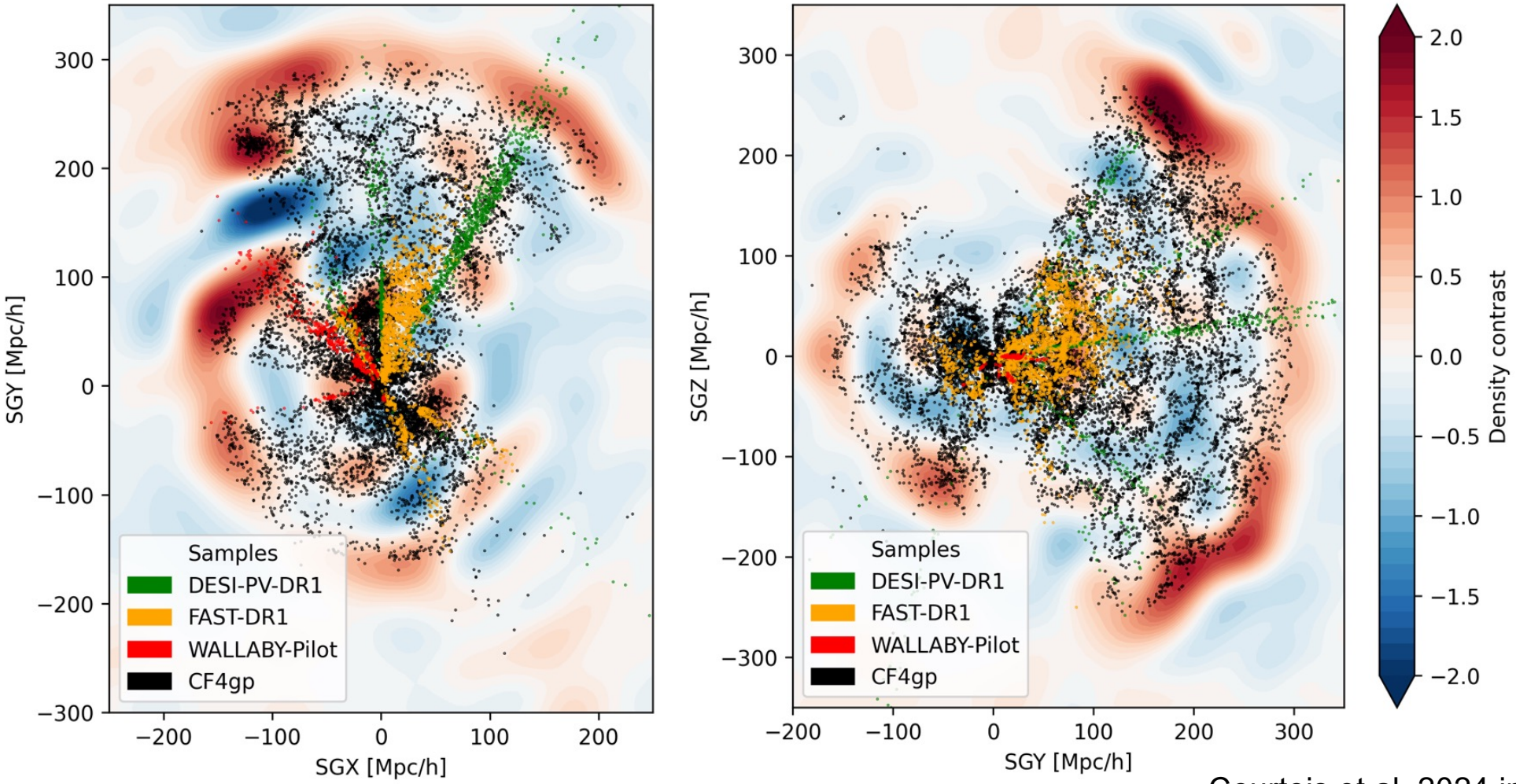






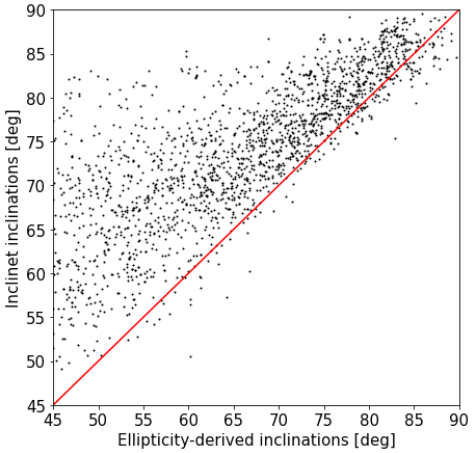
4 MOST PV survey : Taylor et al.
https://www.eso.org/sci/publications/messenger/archive/no.190-mar23/messenger-no190-46-48.pdf

Meanwhile the upcoming large surveys : CF4++ (additions yet done + upcoming MeerKat)

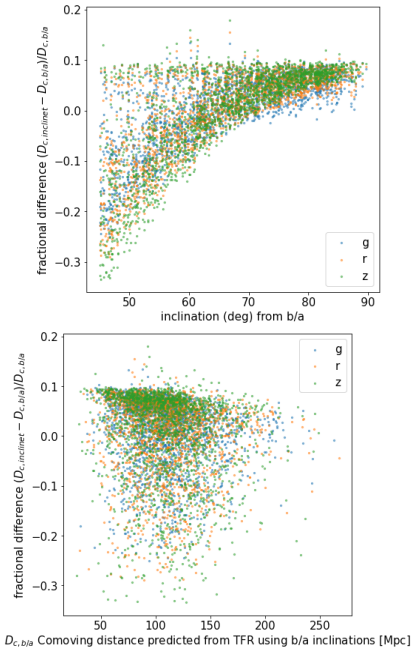


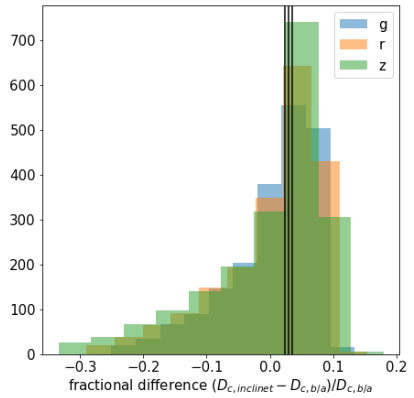
Courtois et al. 2024 in prep.

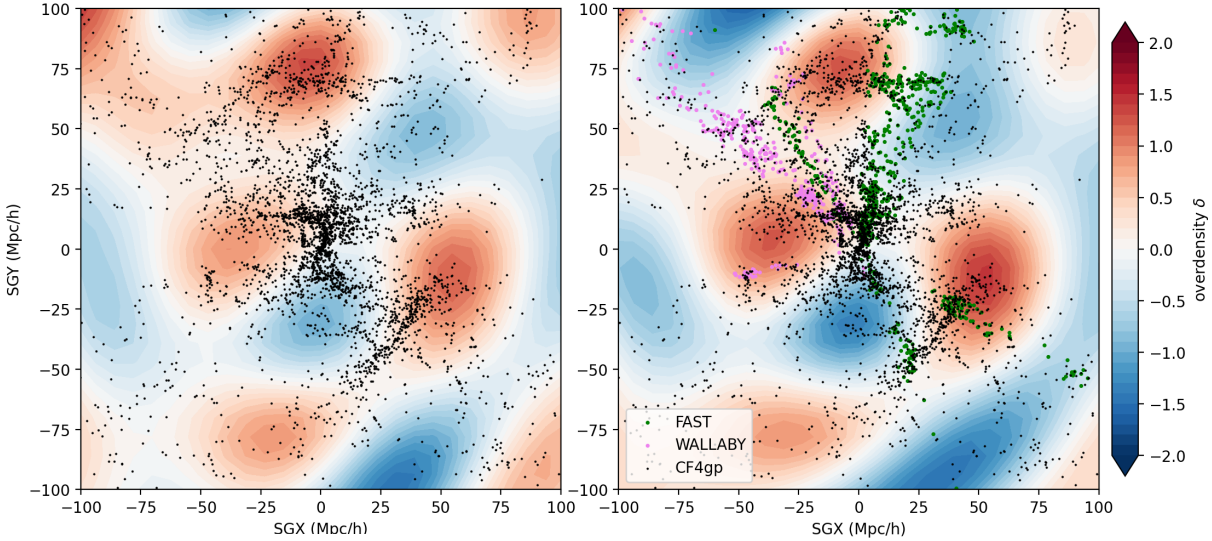
Meanwhile the large surveys : CF4++ / Great Attractor / Improving the data treatment

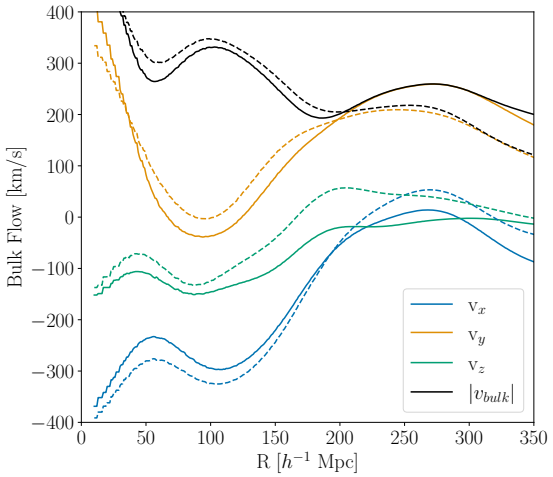


Galaxies inclinations probably the largest source of error





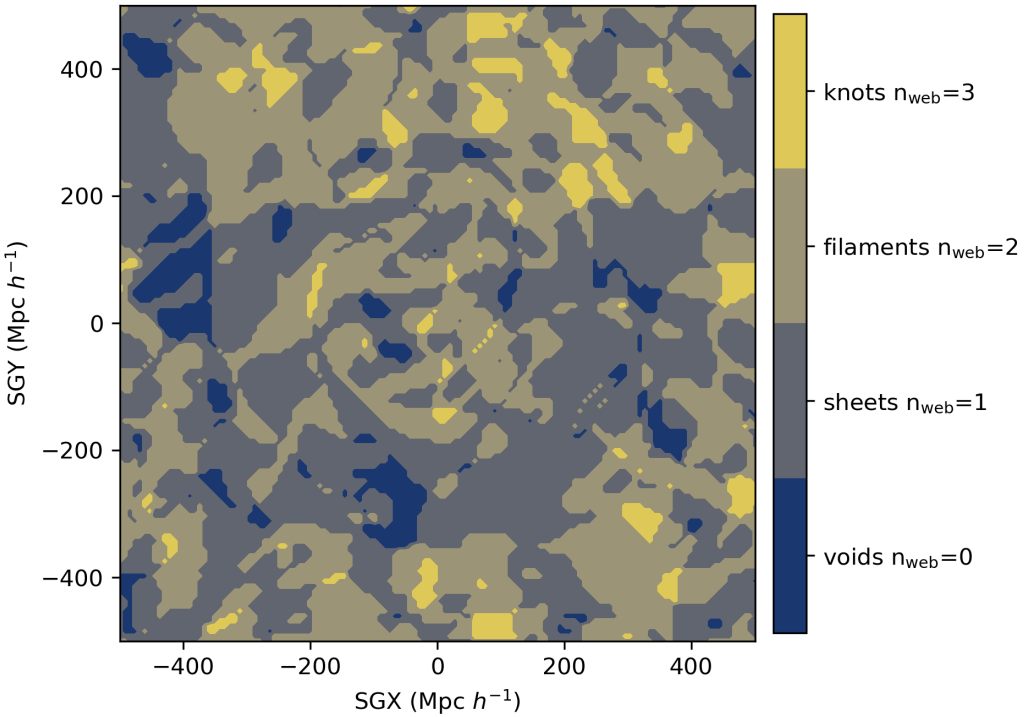




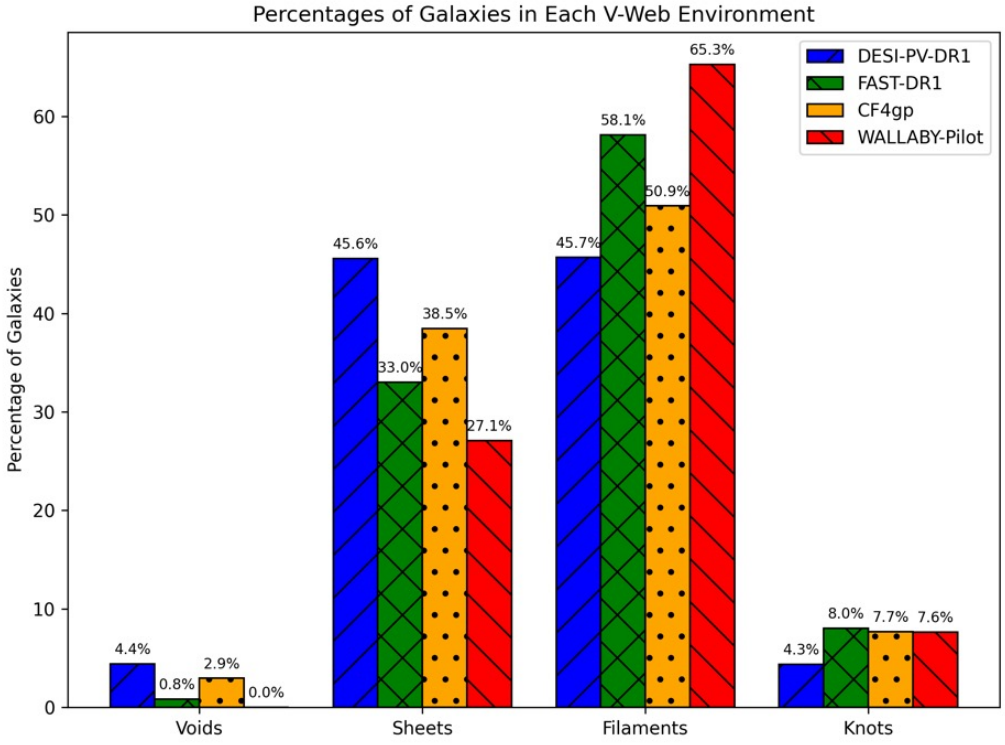
Preliminary : Bulk flow solid line : Including WALLABY Pilot phase and FAST-DR1

Courtois et al. 2024 in prep.

Meanwhile the large surveys : CF4++ / V-web analysis

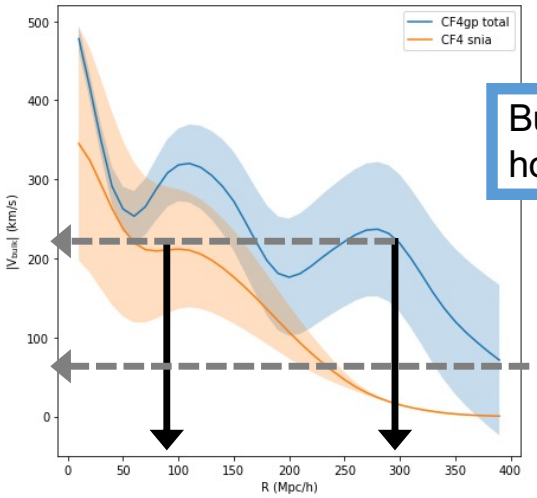


V-web : shear tensor of the velocity field

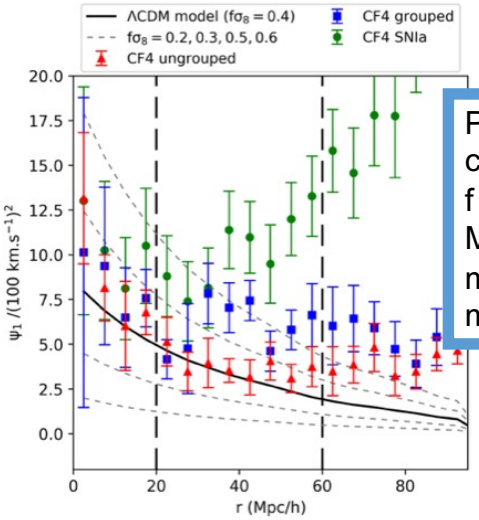


Velocity field Tracers

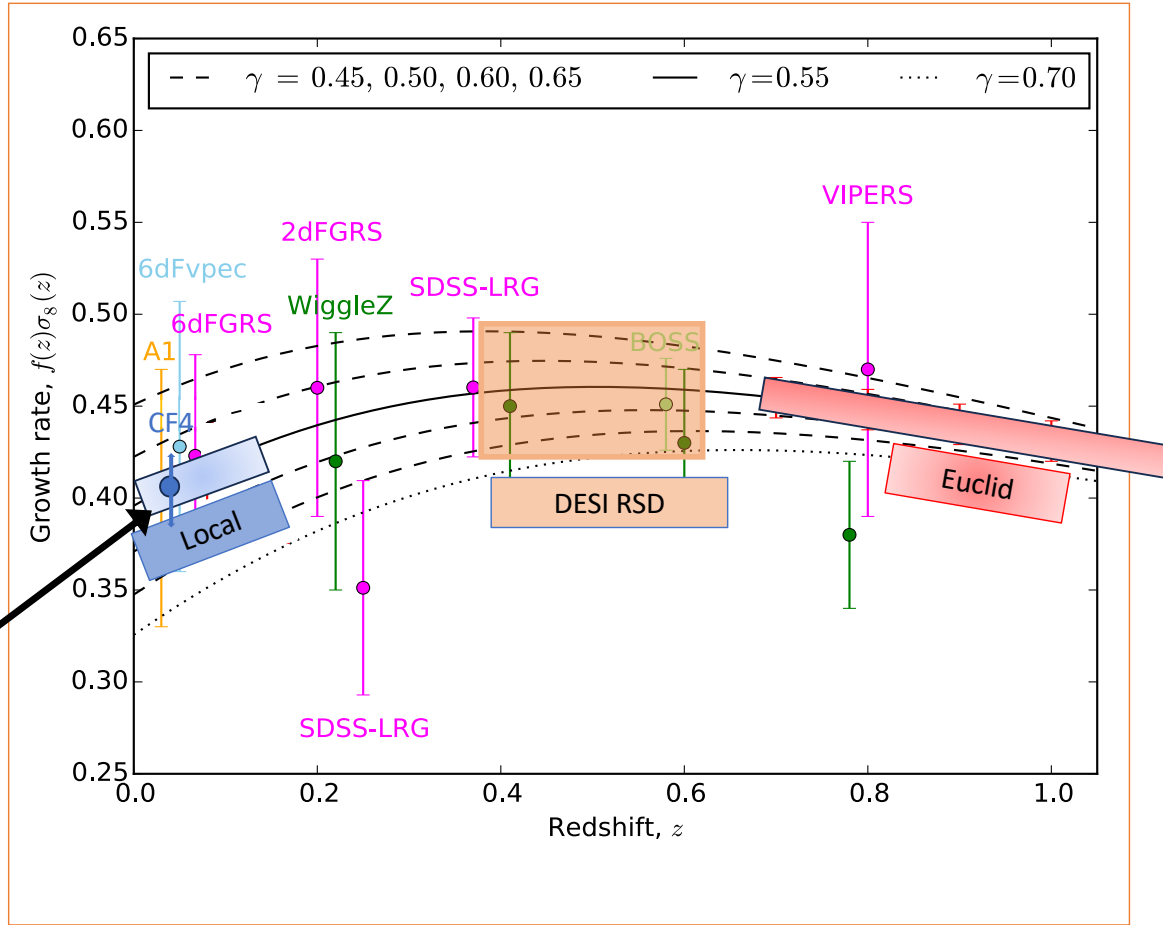
Homogeneity and growth rate of large scale structures as tests for general relativity / gravitation



Bulk flow to test homogeneity scale



Pairwise velocity correlations to compute f sigma_8
Most accurate measurement in the mature universe



Courtois, Dupuy et al. 2023 A&A...670L..15C