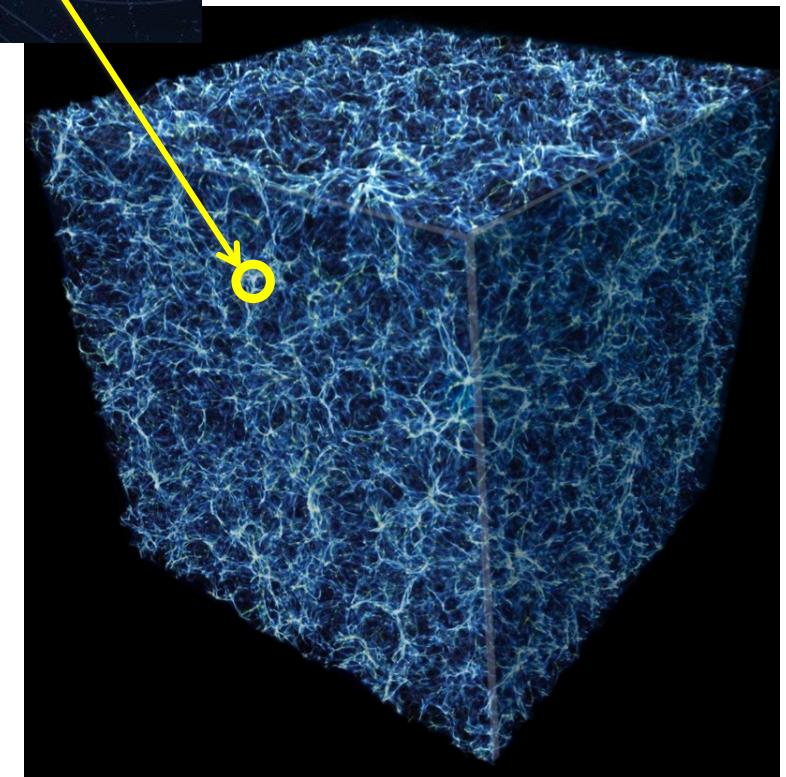
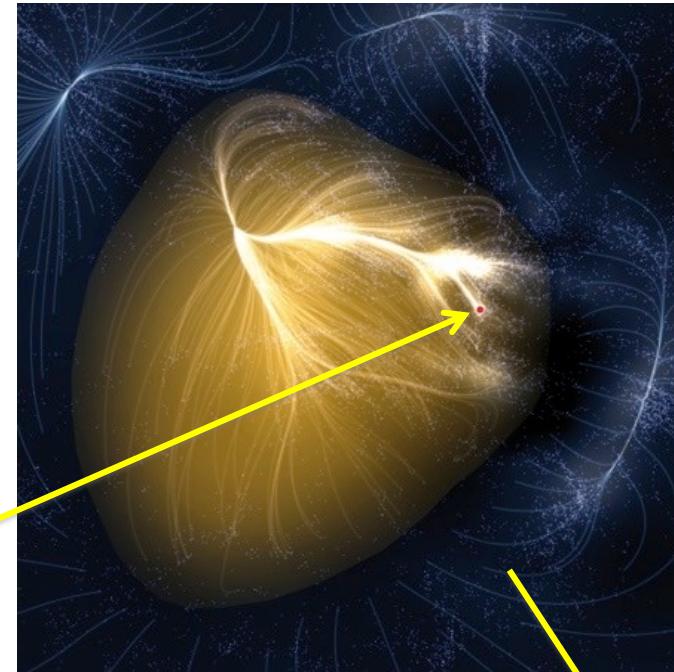
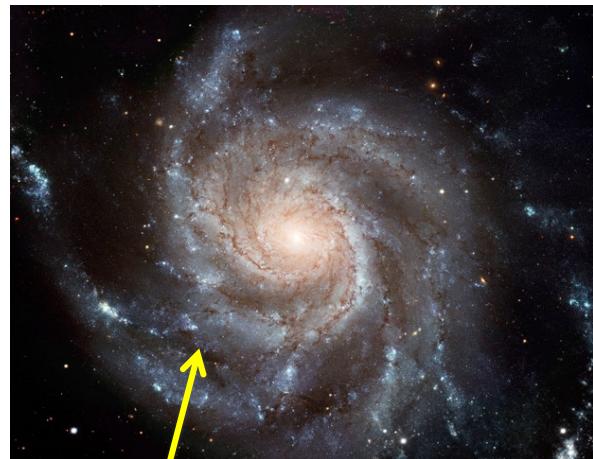
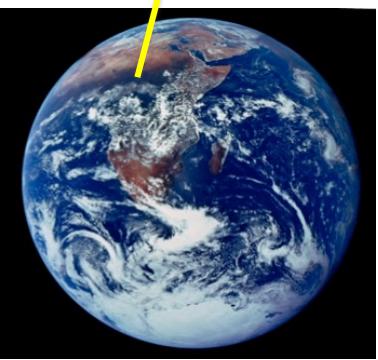




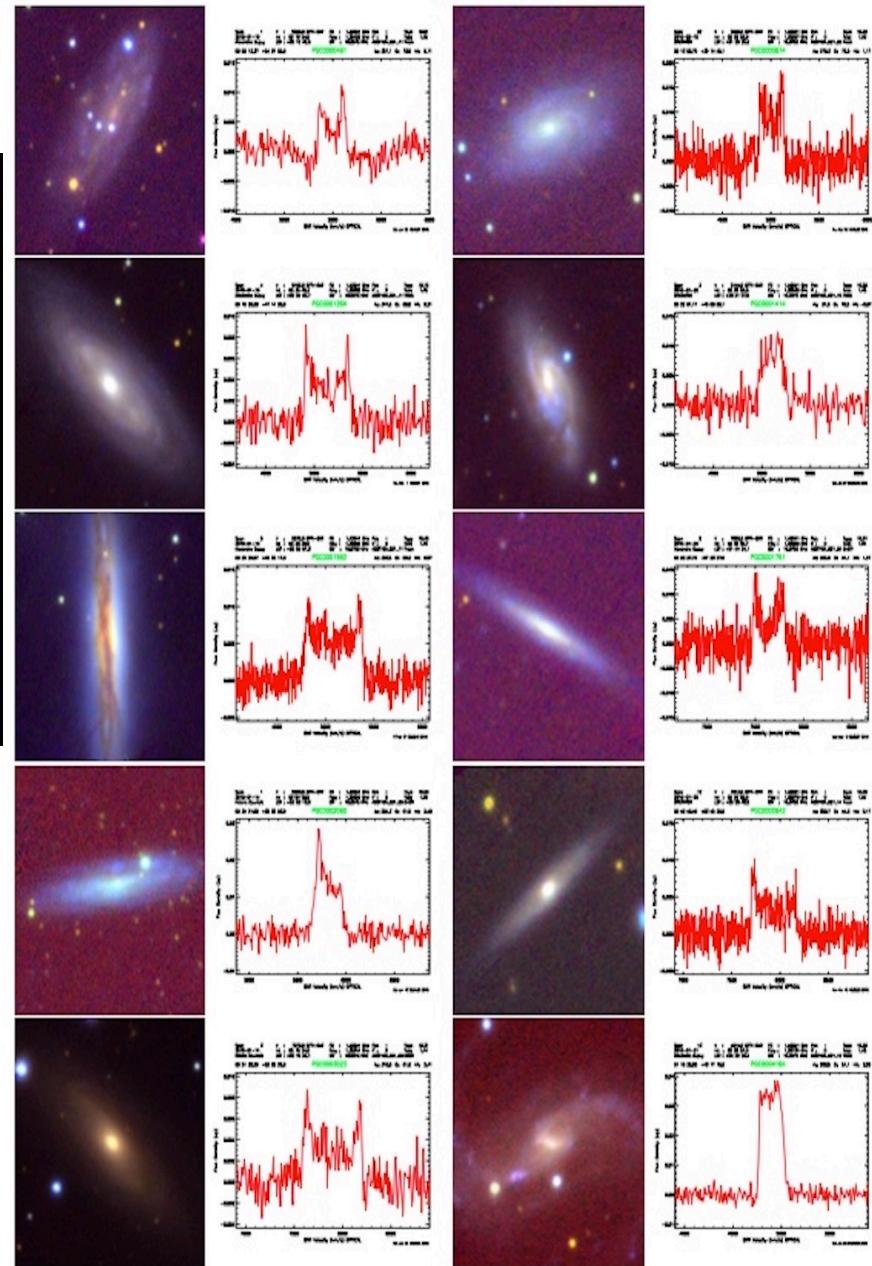
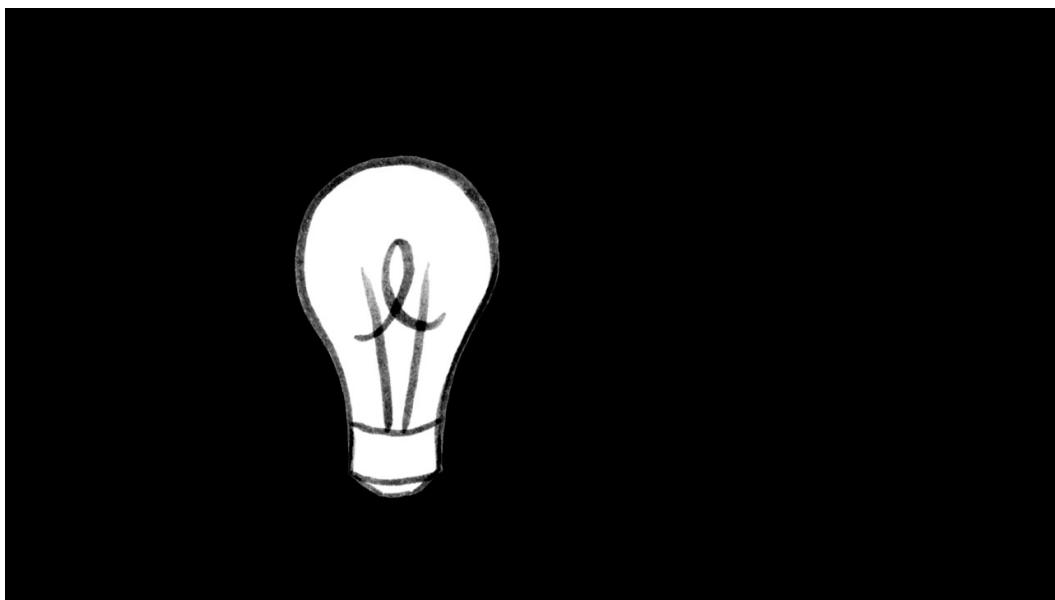
Voyage sur les flots de galaxies

Prix du livre Cosmos 2024

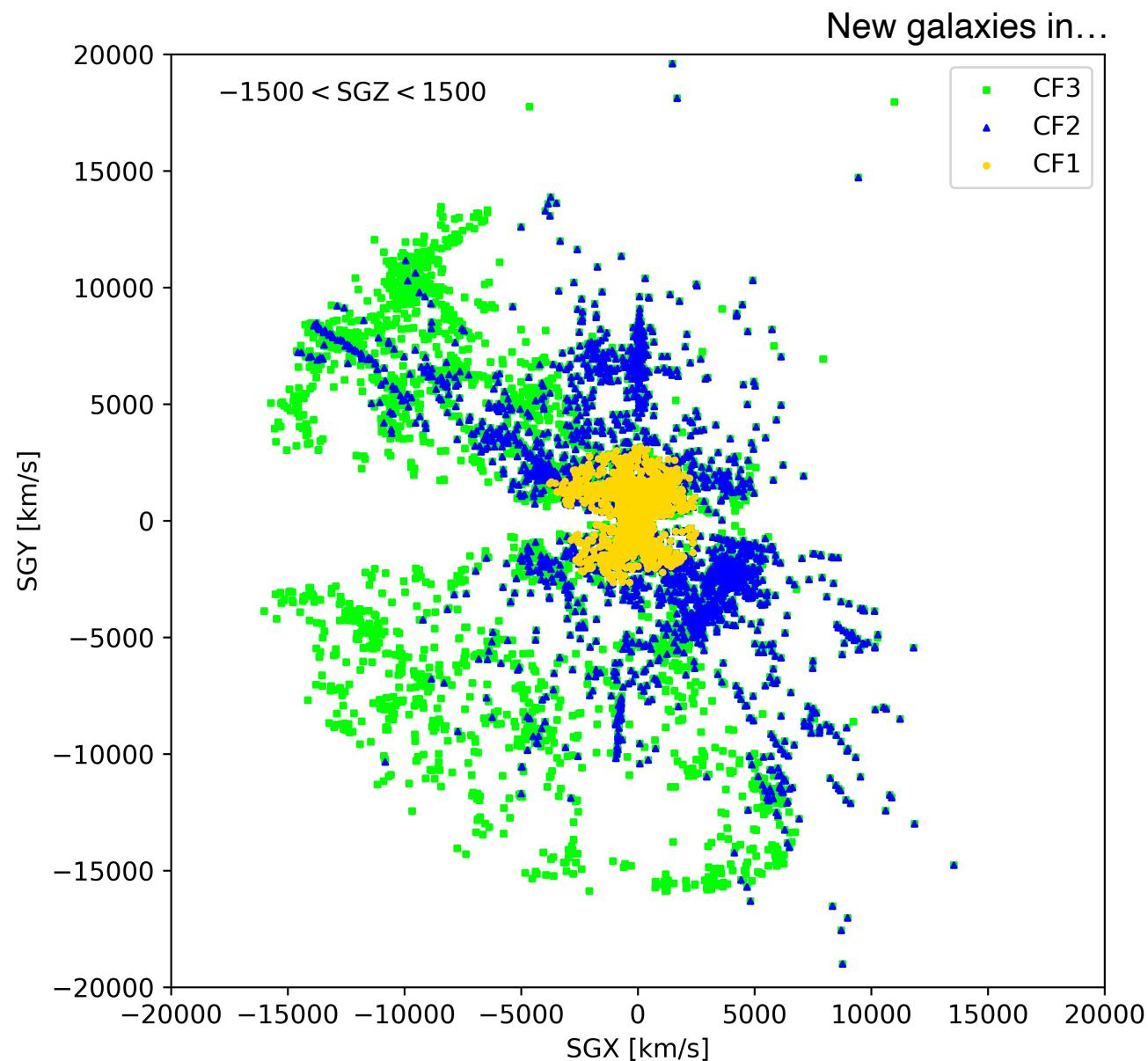
Prof. Hélène Courtois
IP2I, Université Lyon 1





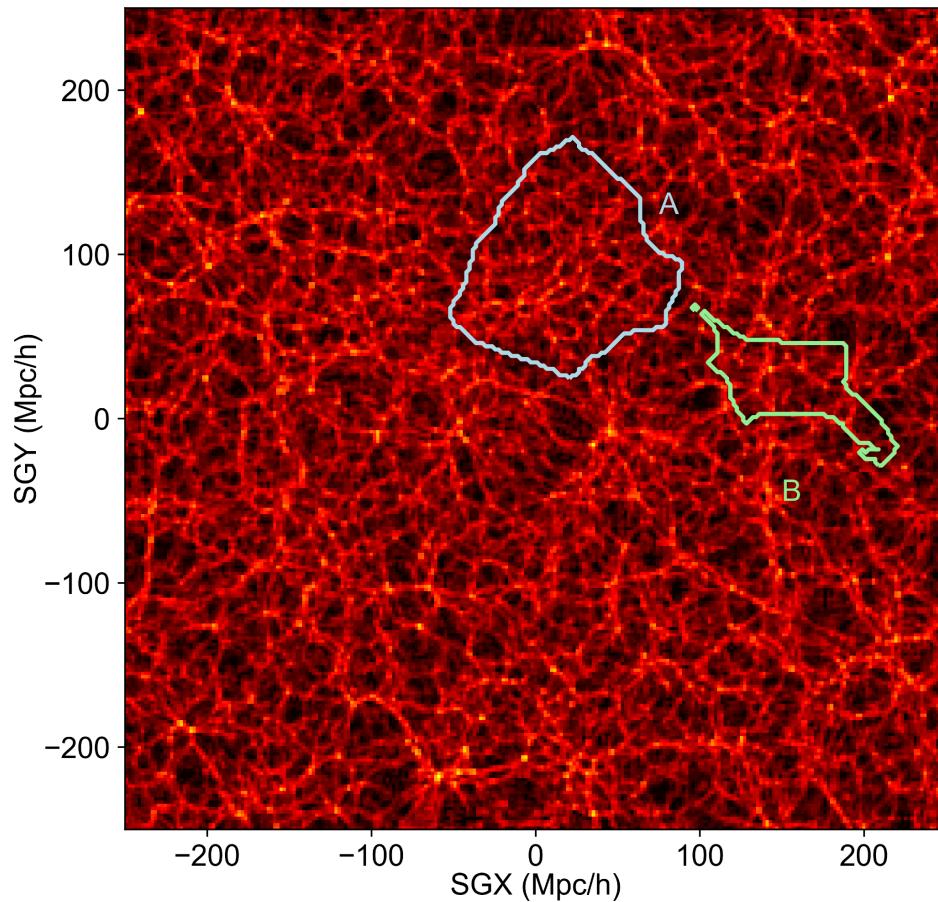


- 1988: Faber
400 galaxies
- 1999: End of all
programs
1,500 galaxies
- 2008: Cosmicflows-1
1,800 galaxies
- 2013: Cosmicflows-2
8,000 galaxies
- 2016: Cosmicflows-3
18,000 galaxies
- 2022: Cosmicflows-4
56,000 galaxies

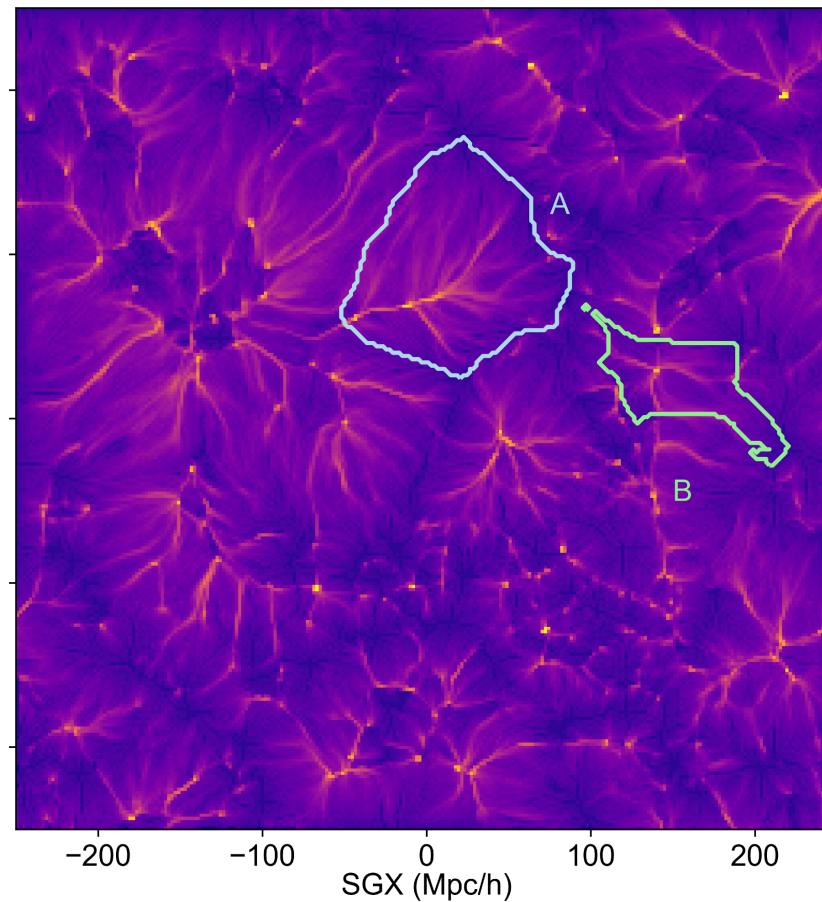


Cartographie statique/dynamique-bassins versants

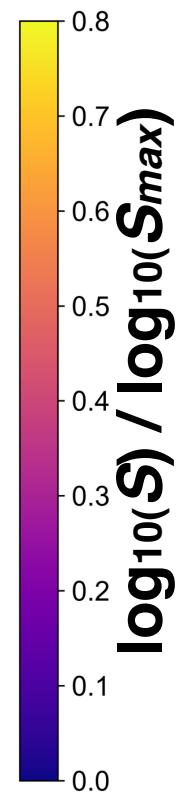
Dupuy, Courtois et al. 2019



Density field ρ



Density of streamlines



$$\{u_i^o\}_{i=1,\dots,N} \quad u_i^o = \mathbf{v}(\mathbf{r}_i) \cdot \hat{\mathbf{r}}_i + \epsilon_i \equiv u_i + \epsilon_i.$$

observed peculiar velocity

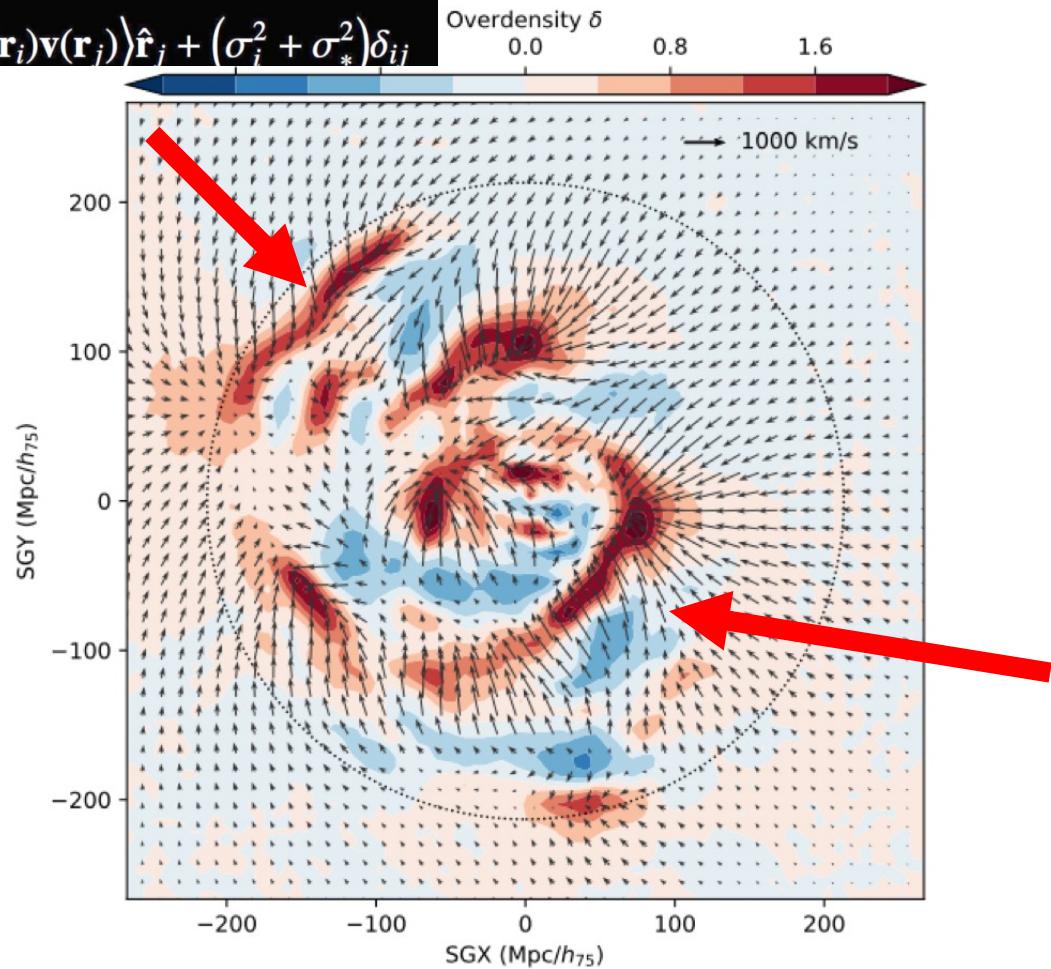
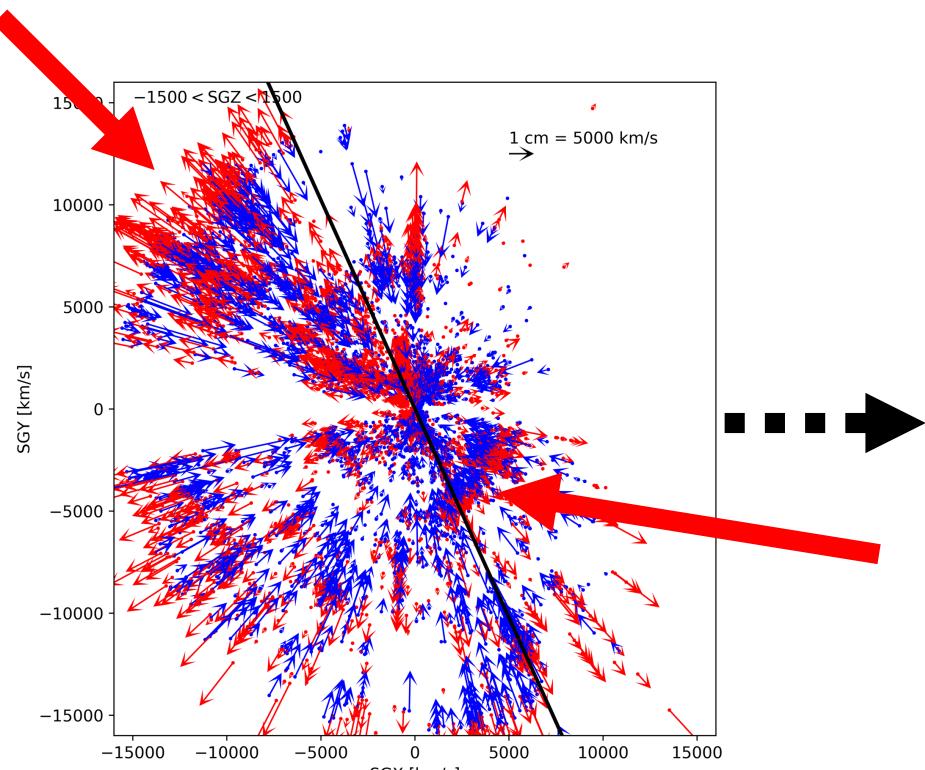
$$\langle \epsilon_i \epsilon_j \rangle = (\sigma_i^2 + \sigma_*^2) \delta_{ij} \quad \text{errors covariance matrix diagonal}$$

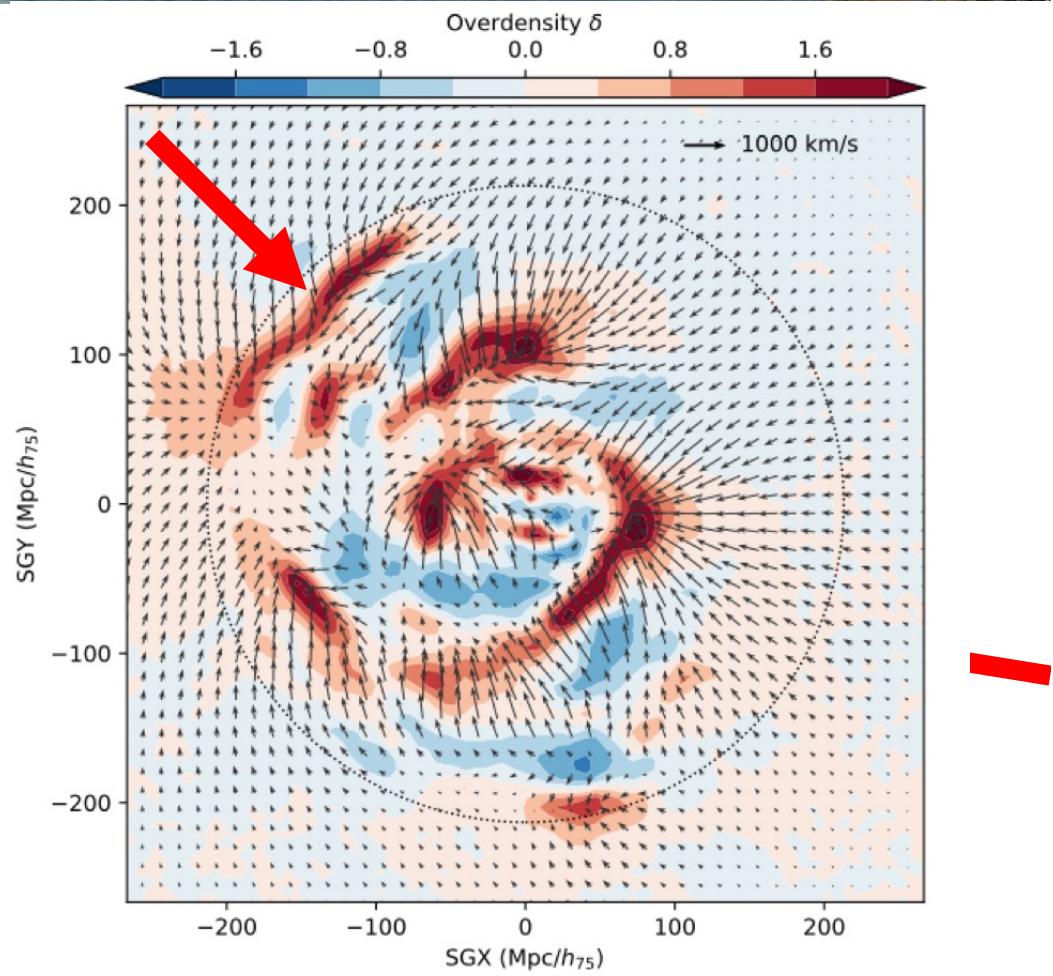
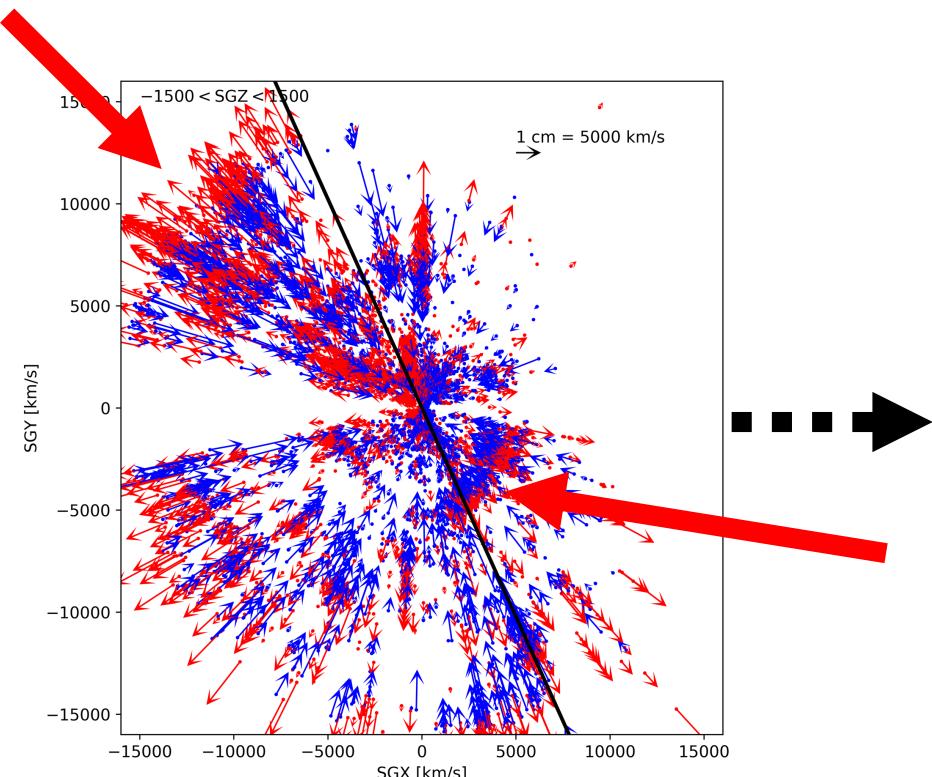
$$\mathbf{v}^{\text{WF}}(\mathbf{r}) = \langle \mathbf{v}(\mathbf{r}) u_i^o \rangle \langle u_i^o u_j^o \rangle^{-1} u_j^o \quad \text{estimated WF velocity field}$$

$$\mathbf{v}^{\text{CR}}(\mathbf{r}) = \tilde{\mathbf{v}}(\mathbf{r}) + \langle \mathbf{v}(\mathbf{r}) u_i^o \rangle \langle u_i^o u_j^o \rangle^{-1} (u_j^o - \tilde{u}_j^o) \quad \text{const. realization}$$

$$R_{ij} \equiv \langle u_i^o u_j^o \rangle = \langle u_i u_j \rangle + \langle \epsilon_i \epsilon_j \rangle = \hat{\mathbf{r}}_i \langle \mathbf{v}(\mathbf{r}_i) \mathbf{v}(\mathbf{r}_j) \rangle \hat{\mathbf{r}}_j + (\sigma_i^2 + \sigma_*^2) \delta_{ij}$$

Oversensity δ
0.0 0.8 1.6





Analyse de données au CC ou sur GPU multi-coeurs



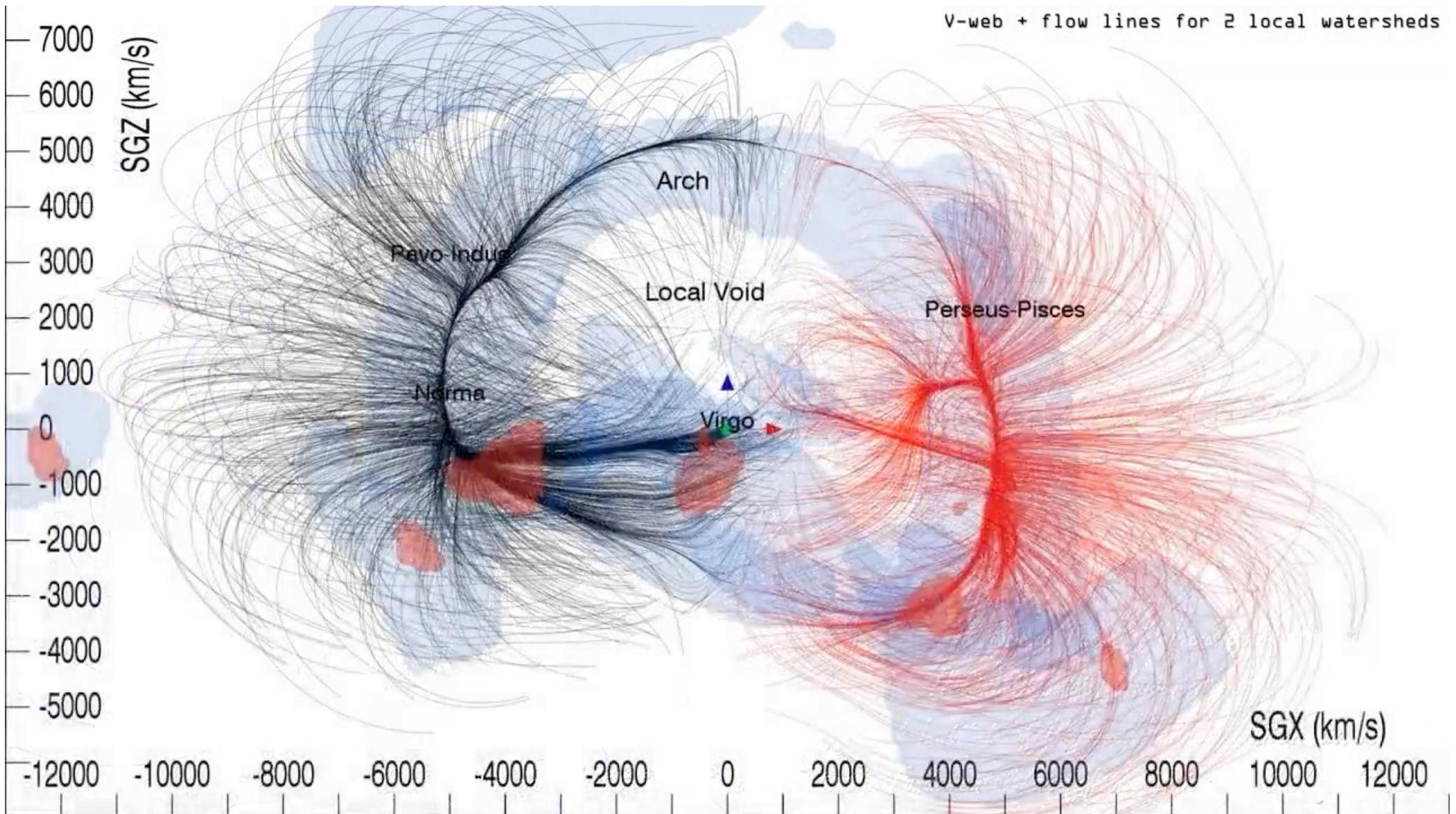
Serveur de l'institut :

- CPU : 61 x Intel Xeon @ 2.5GHz (total + 1500 coeurs)
- RAM : 9 TB
- Stockage : 1.8 TB sur SSD
- GPU : 3 * NVIDIA Quadro RTX 6000 = 96 coeurs

Centre de Calcul National de Physique des Particules :
capacité de 20 pétabytes sur disque et
340 pétabytes sur bandes magnétiques

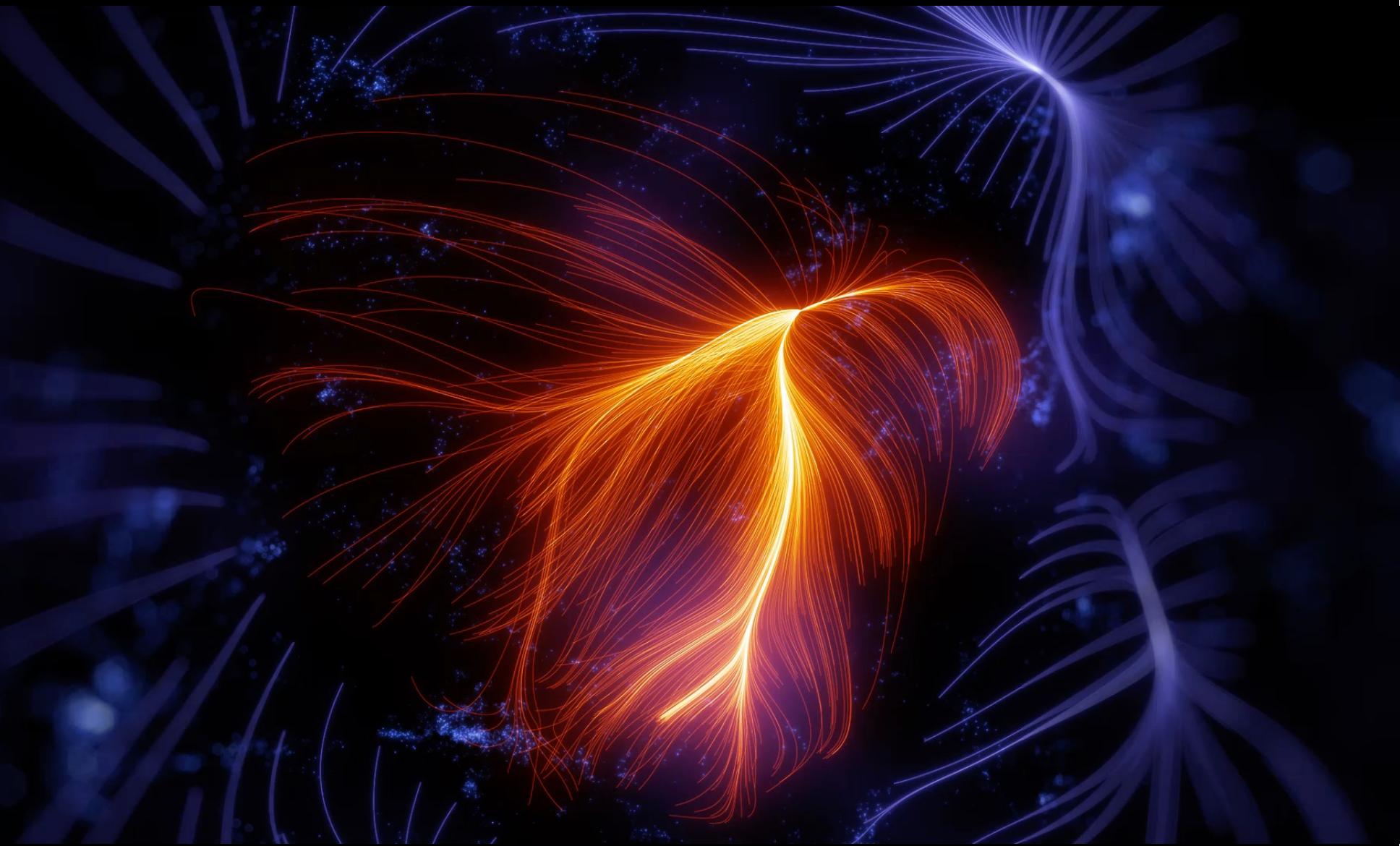
Deux salles de calcul de 850 m²

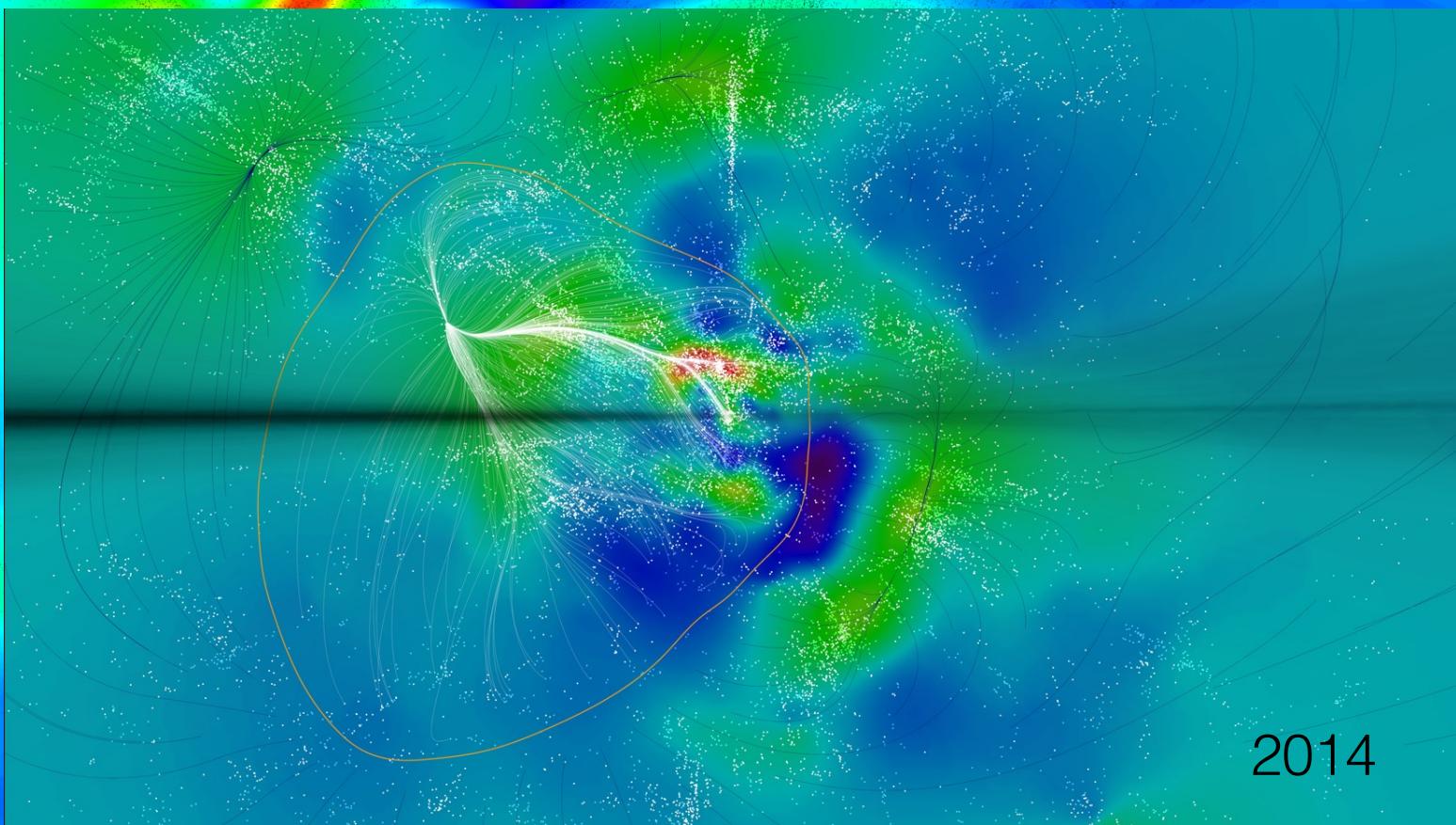
Changement de conceptualisation des grandes structures par la cartographie dynamique et la terminologie hydrographique



Où sommes nous ?

10



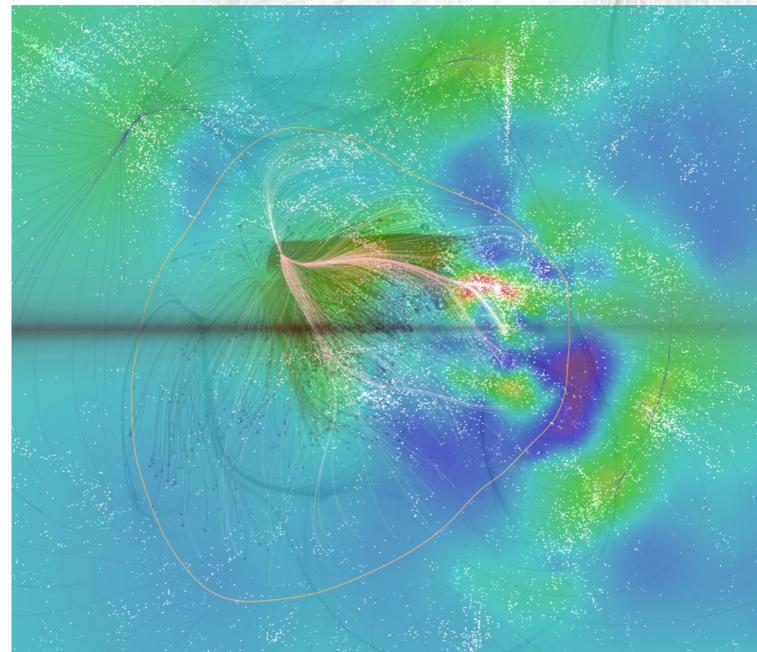


2014

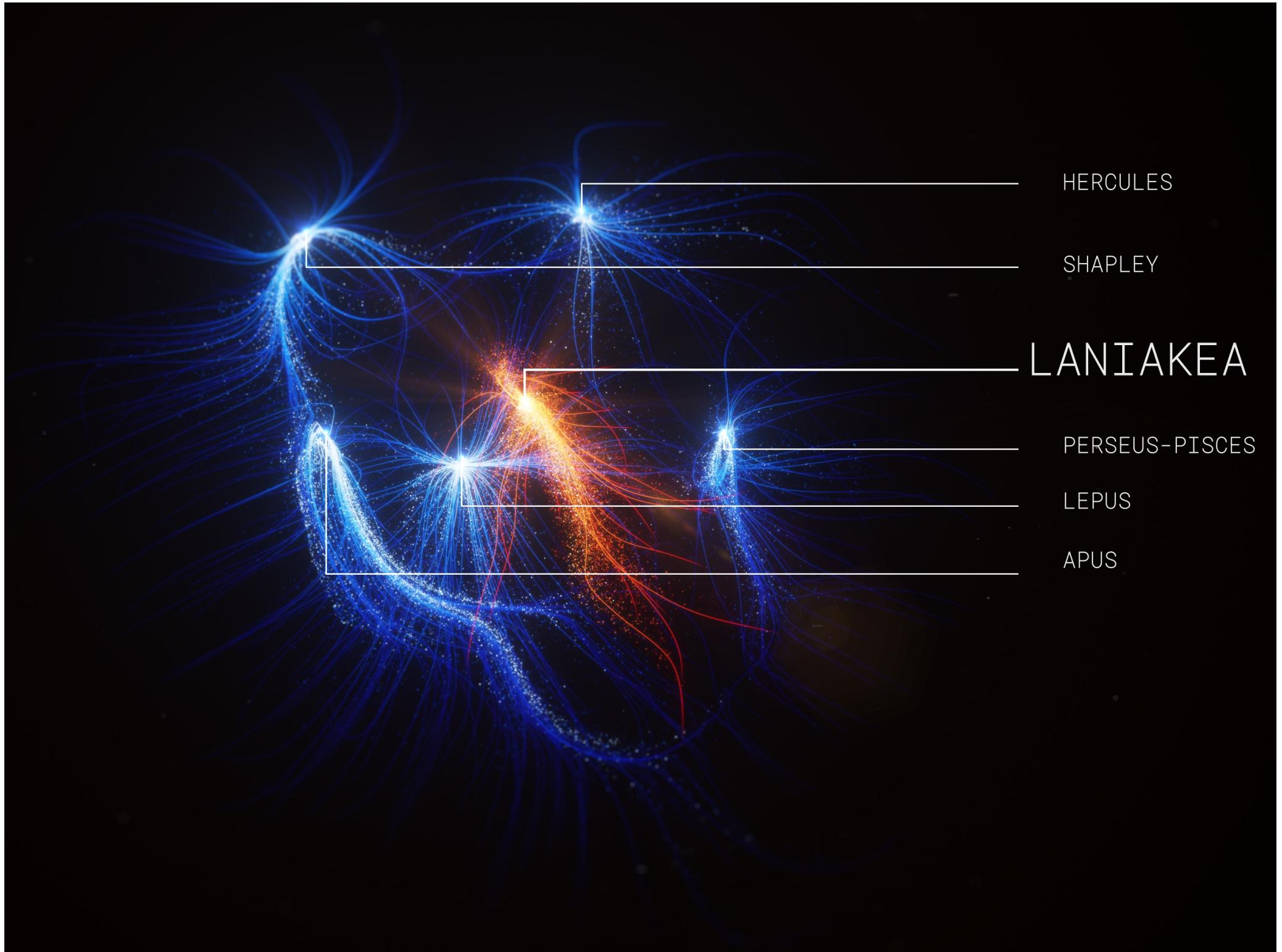
2019

-2500 < SGZ (km/s) < 2500

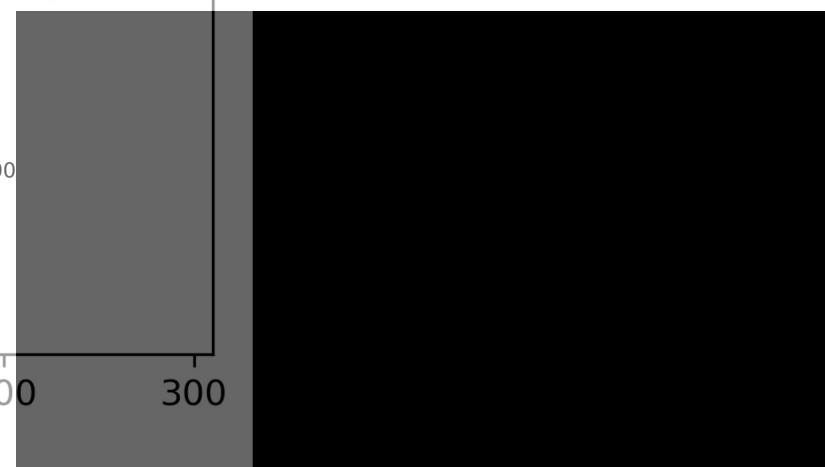
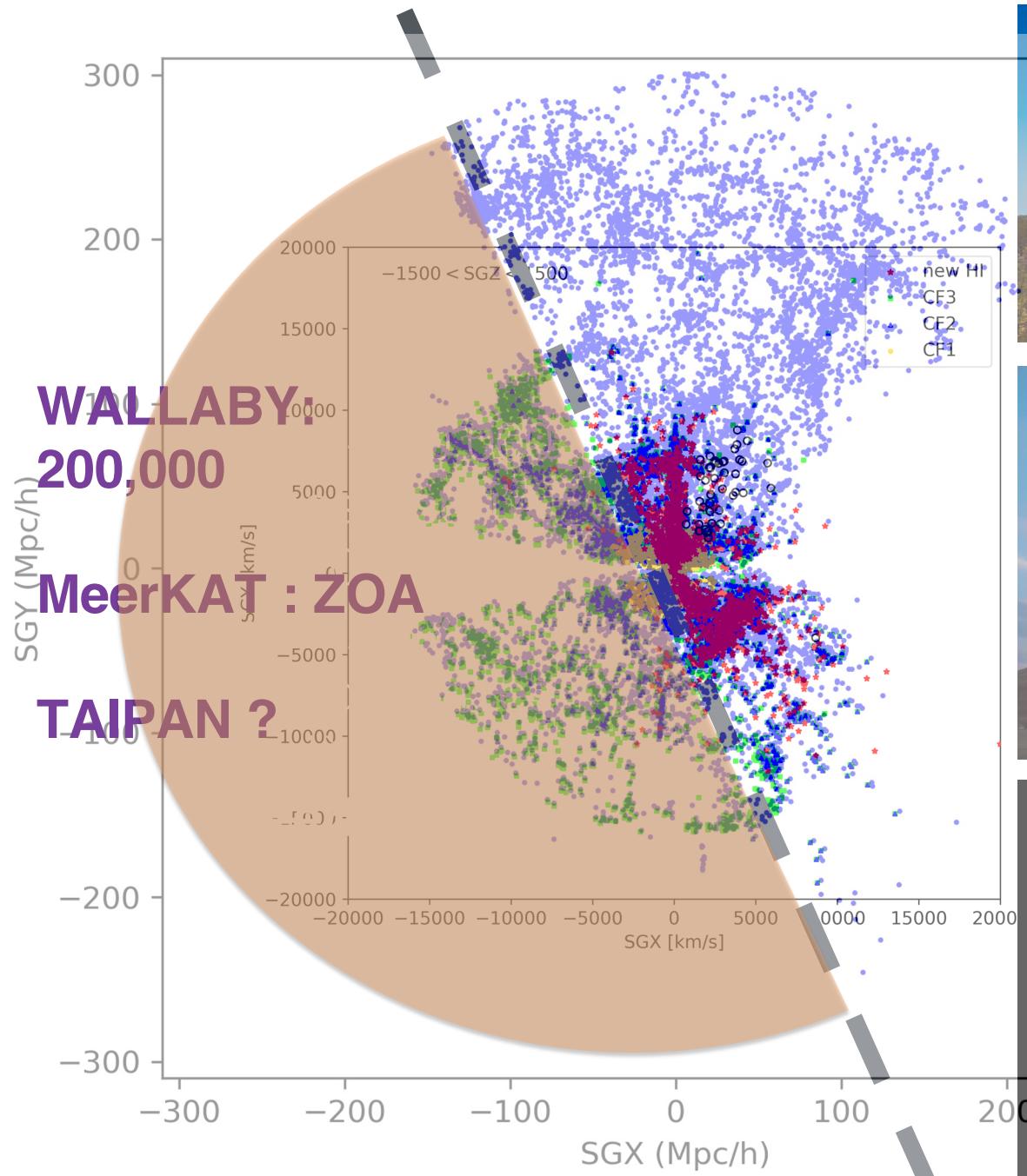
2024



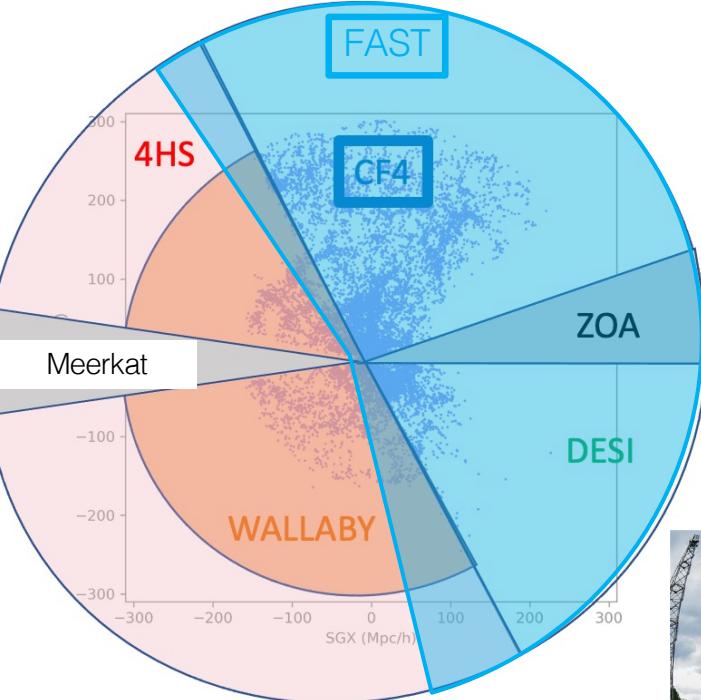
2014



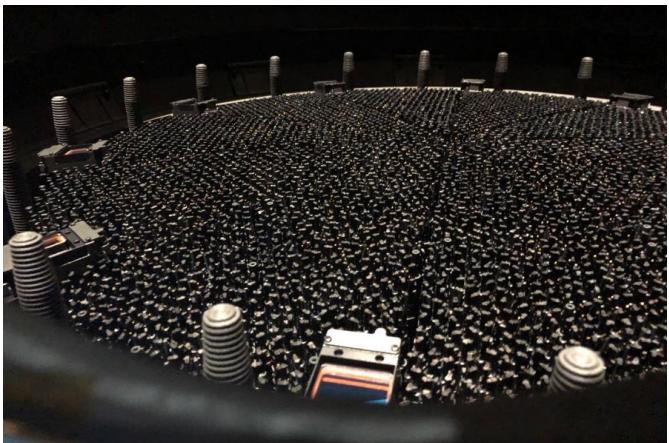
Et maintenant ?



La cosmographie va être révolutionnée grâce à de nouvelles technologies : 1 millions de galaxies (CF4x20)



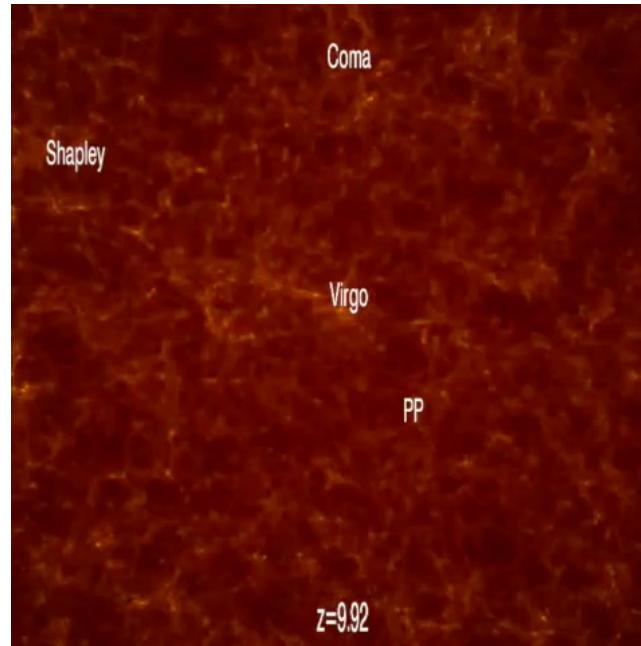
4HS: Vista Chili (500,000)
DESI : USA (200,000)
FAST : Chine (100,000)



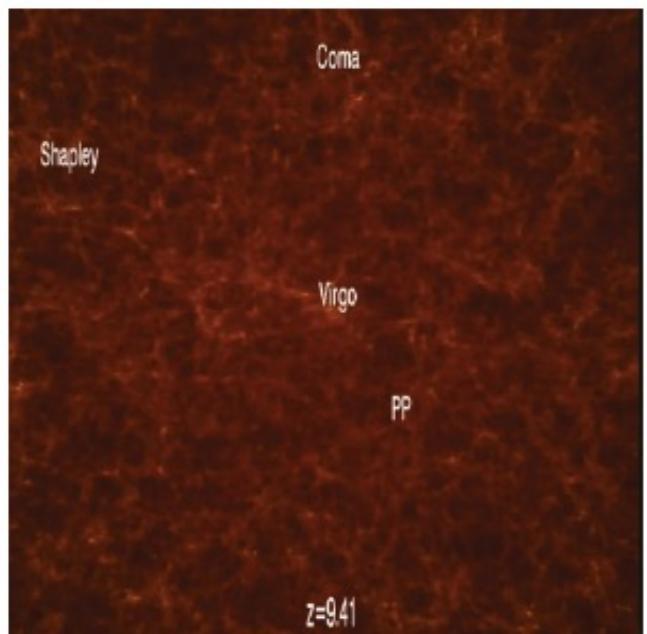
WWW.NEWS.CN

Simulation numérique de la formation de notre coin d'Univers

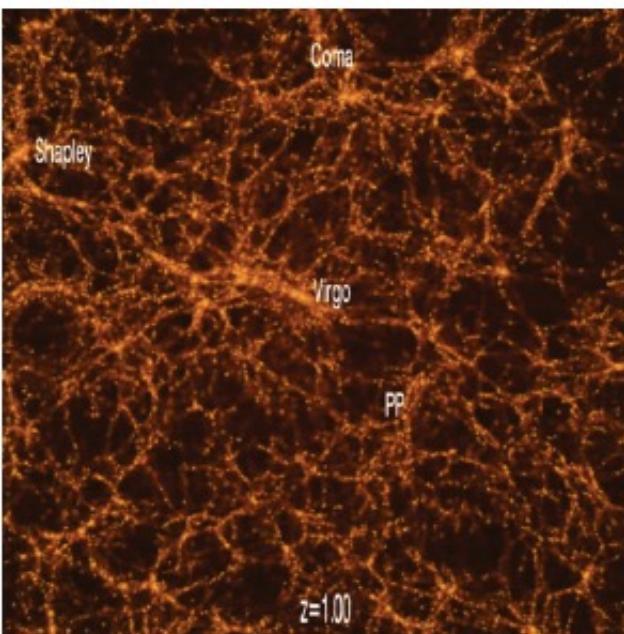
D'où venons nous?
Le tir à la corde entre expansion et gravitation



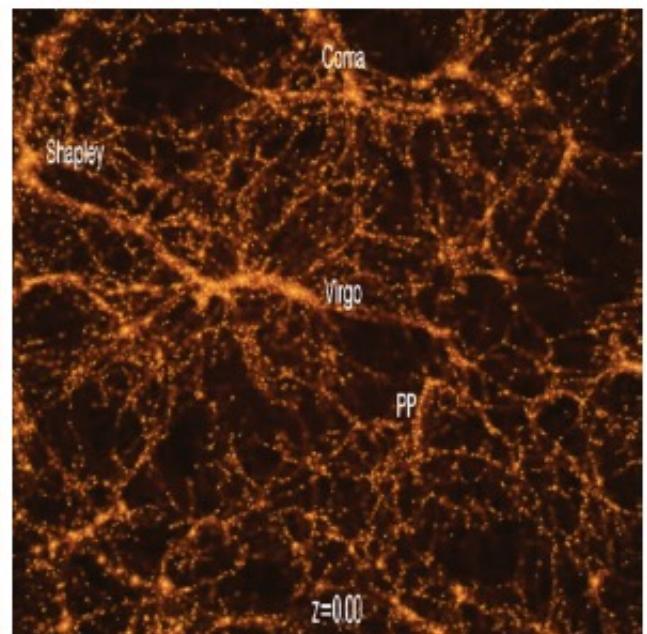
Sorce et al. 2016



500 million d'années



6 milliards d'années



13,8 milliards d'années

Taux de croissance des structures : un test de la relativité générale / gravitation

