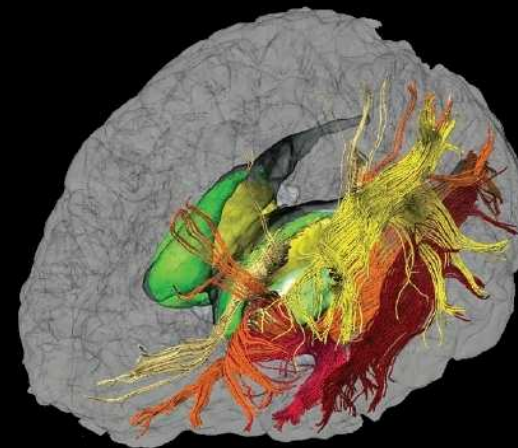
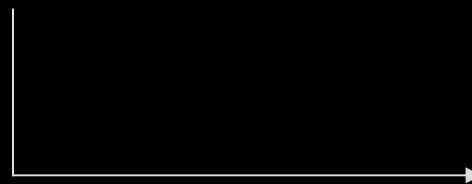


# Modélisation de la Connectivité Anatomique Cérébrale par Tractographie Géodésique

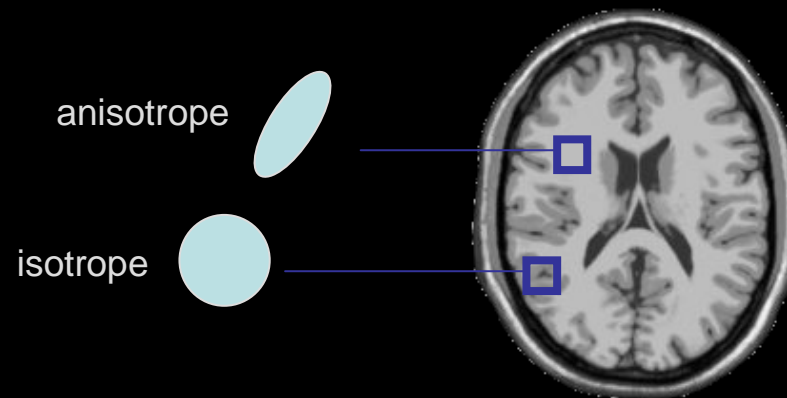
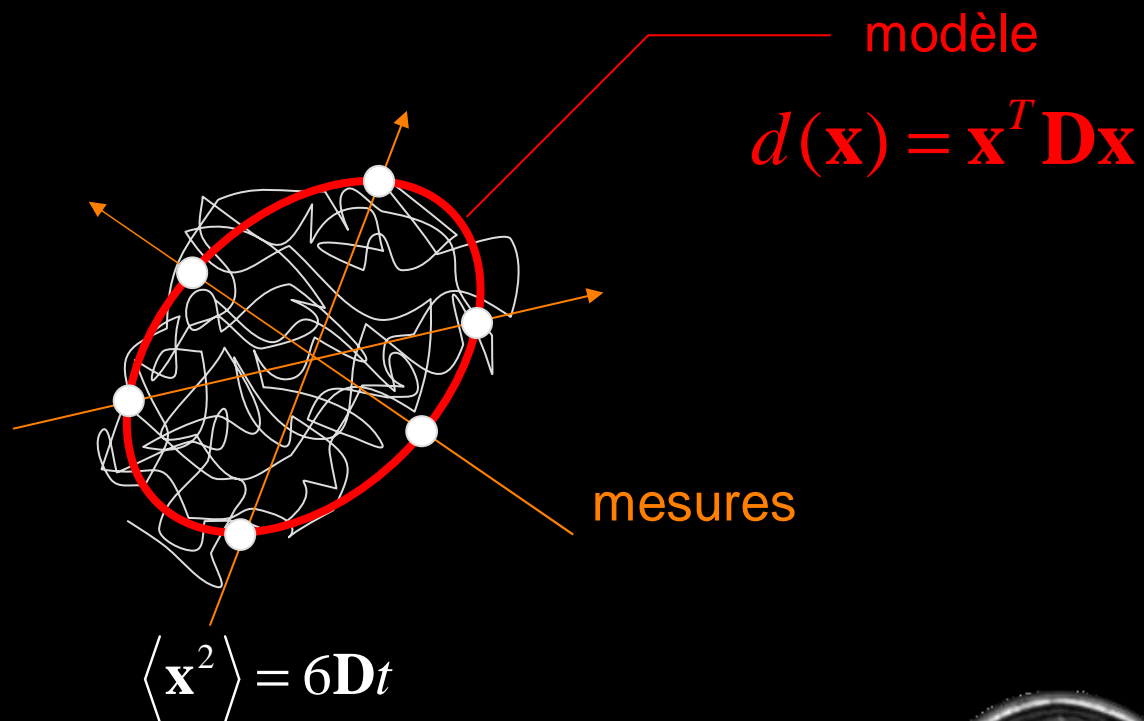
---

# IRM de diffusion

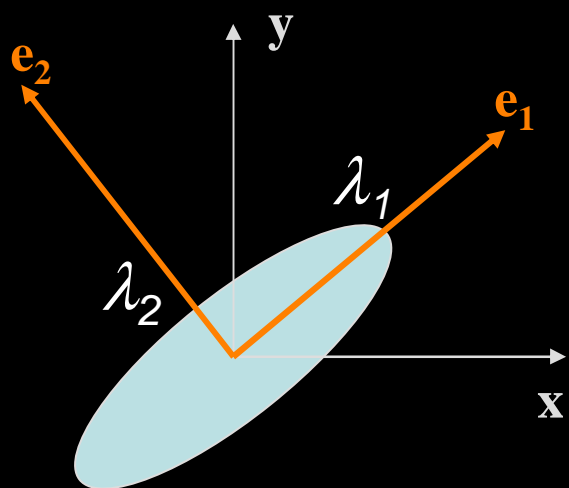
---



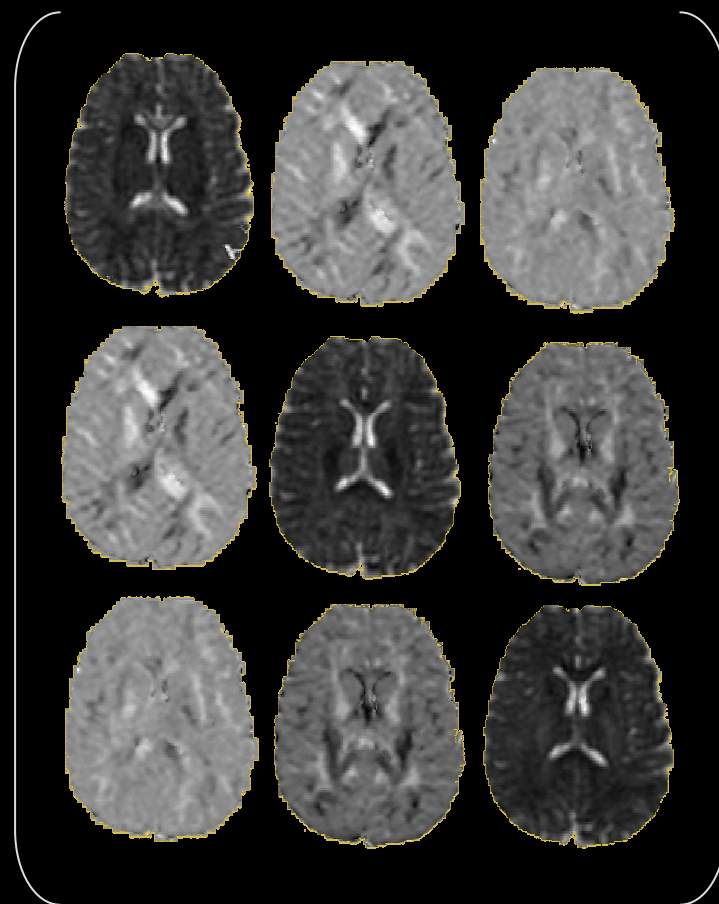
# IRM de diffusion



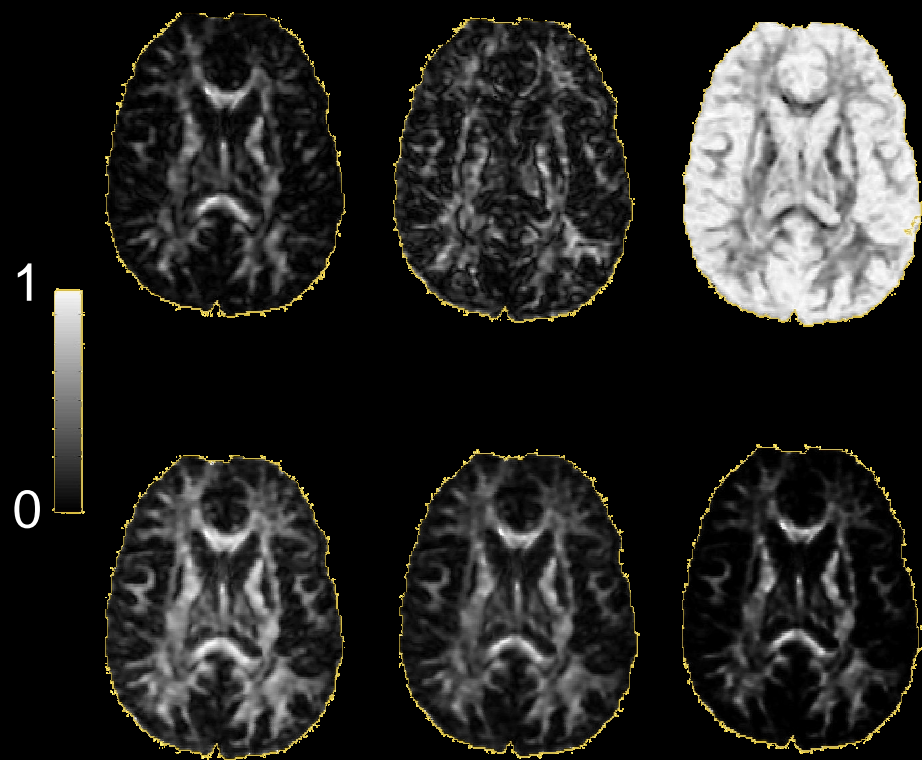
# Tenseur de diffusion



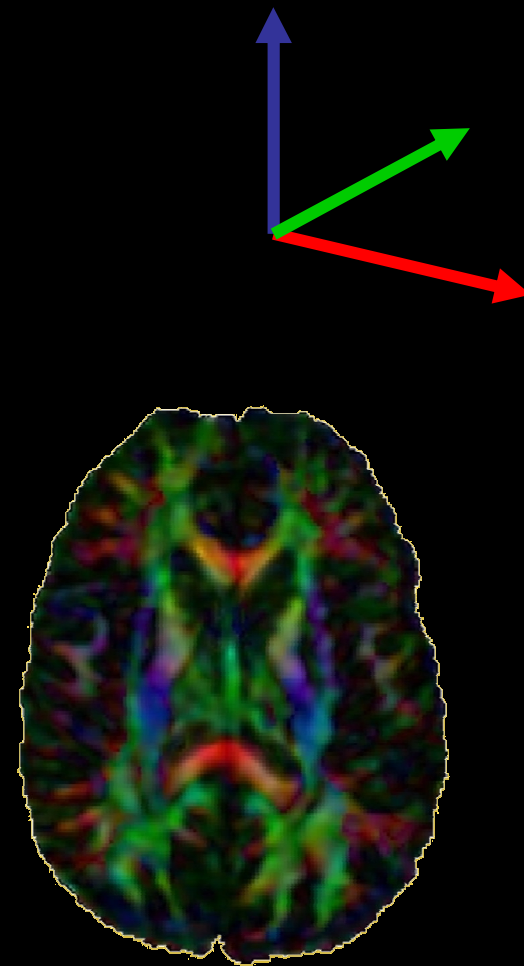
$$\mathbf{D} = \sum \lambda_i \mathbf{e}_i \mathbf{e}_i^T$$



# Tenseur de diffusion



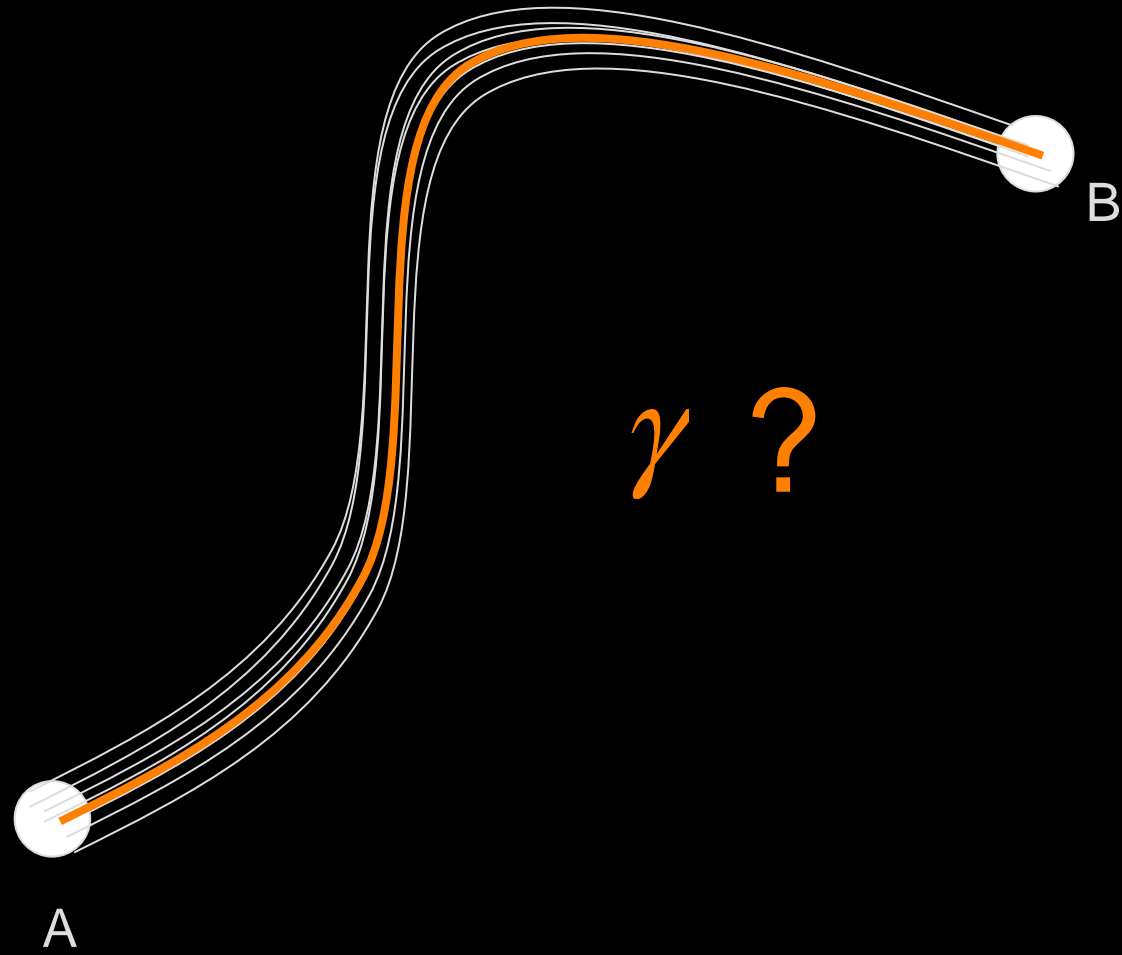
Indices scalaires



Orientation

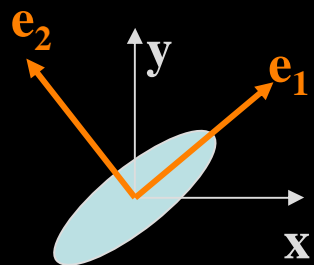
# Tractographie

---

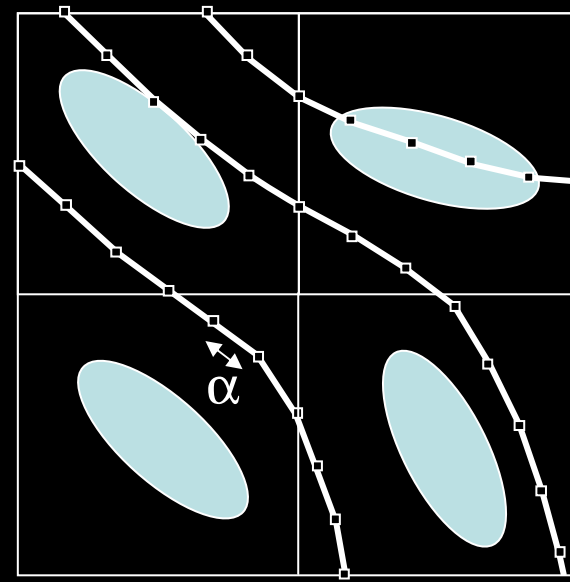
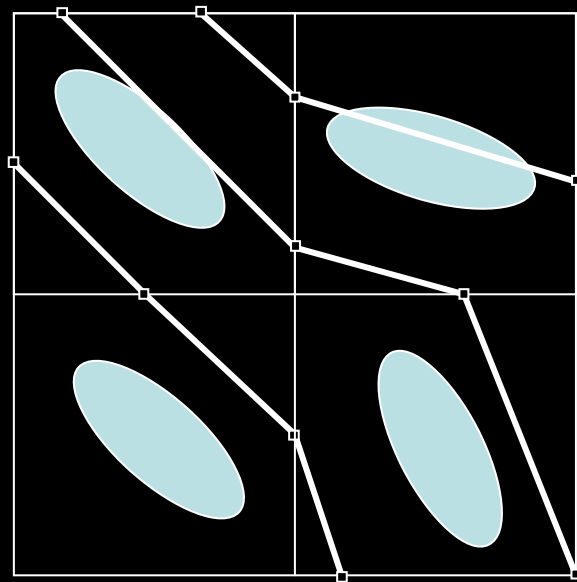


# Tractographie conventionnelle

## Méthodes de type *streamline*

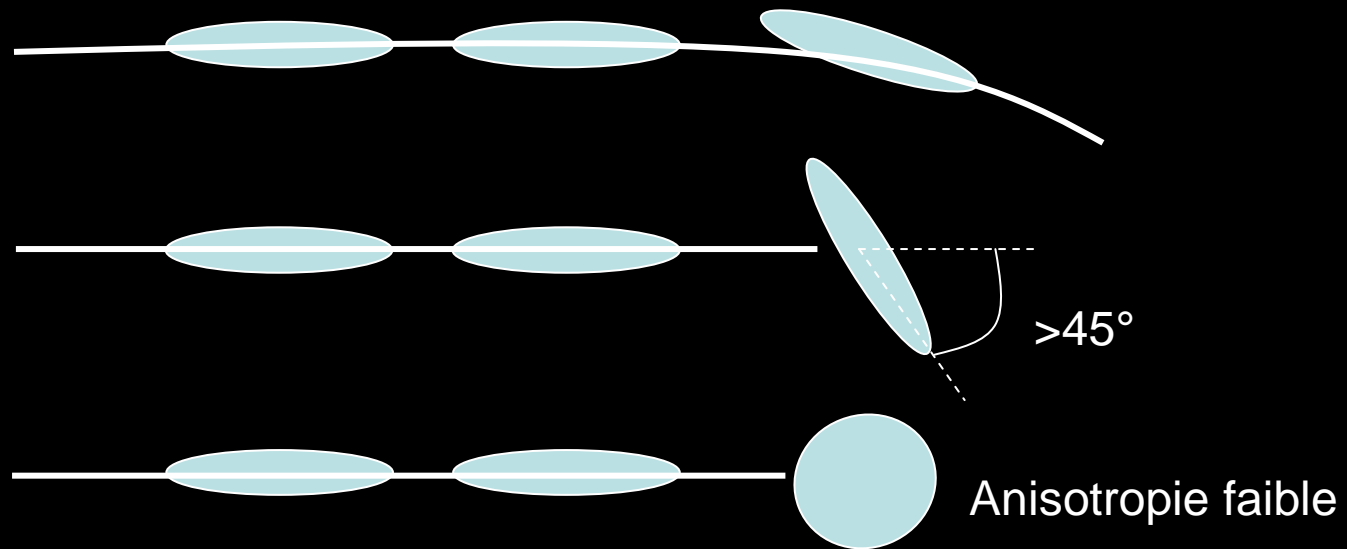


$$\gamma' \propto e_1$$



# Tractographie conventionnelle

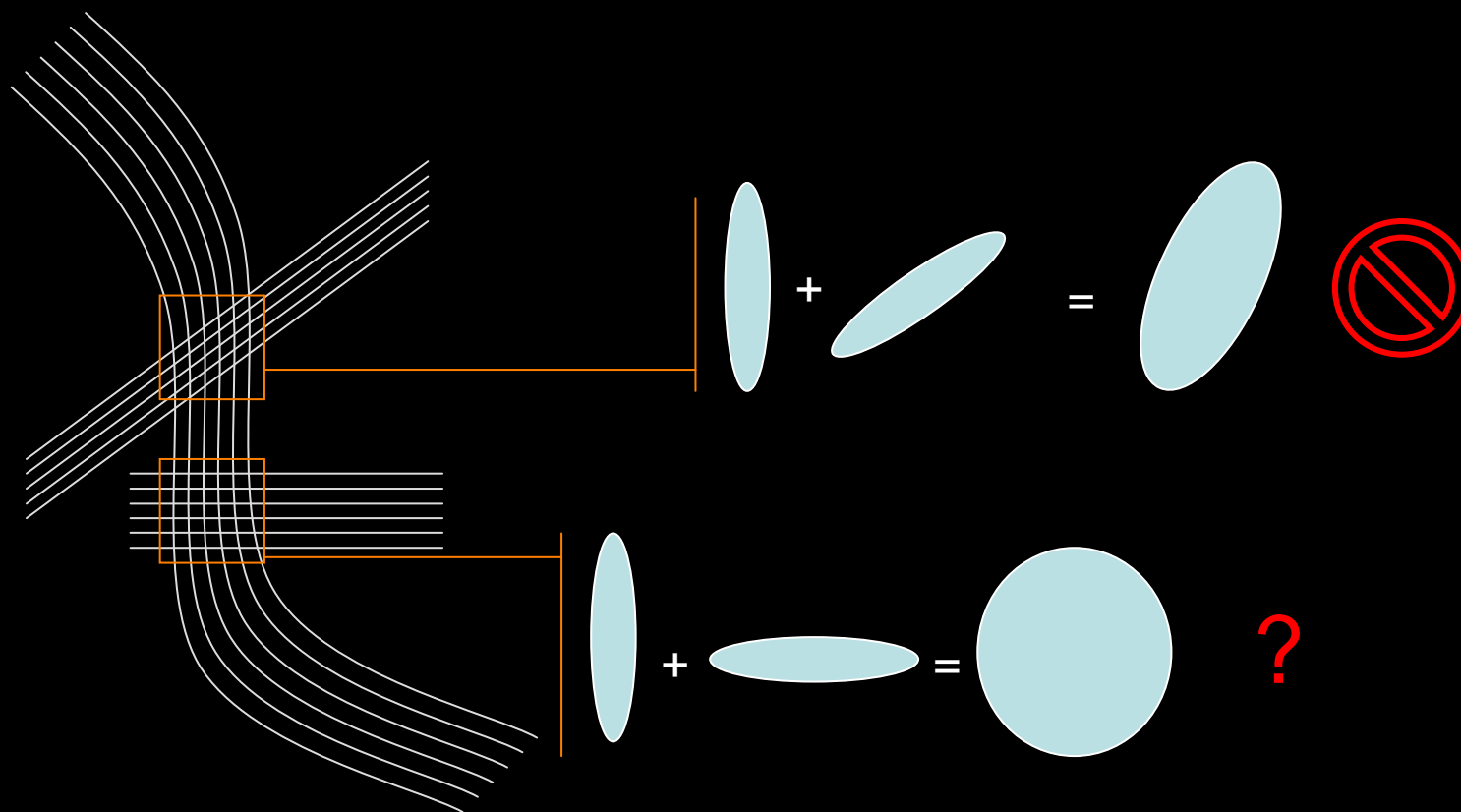
## Critères d'arrêt





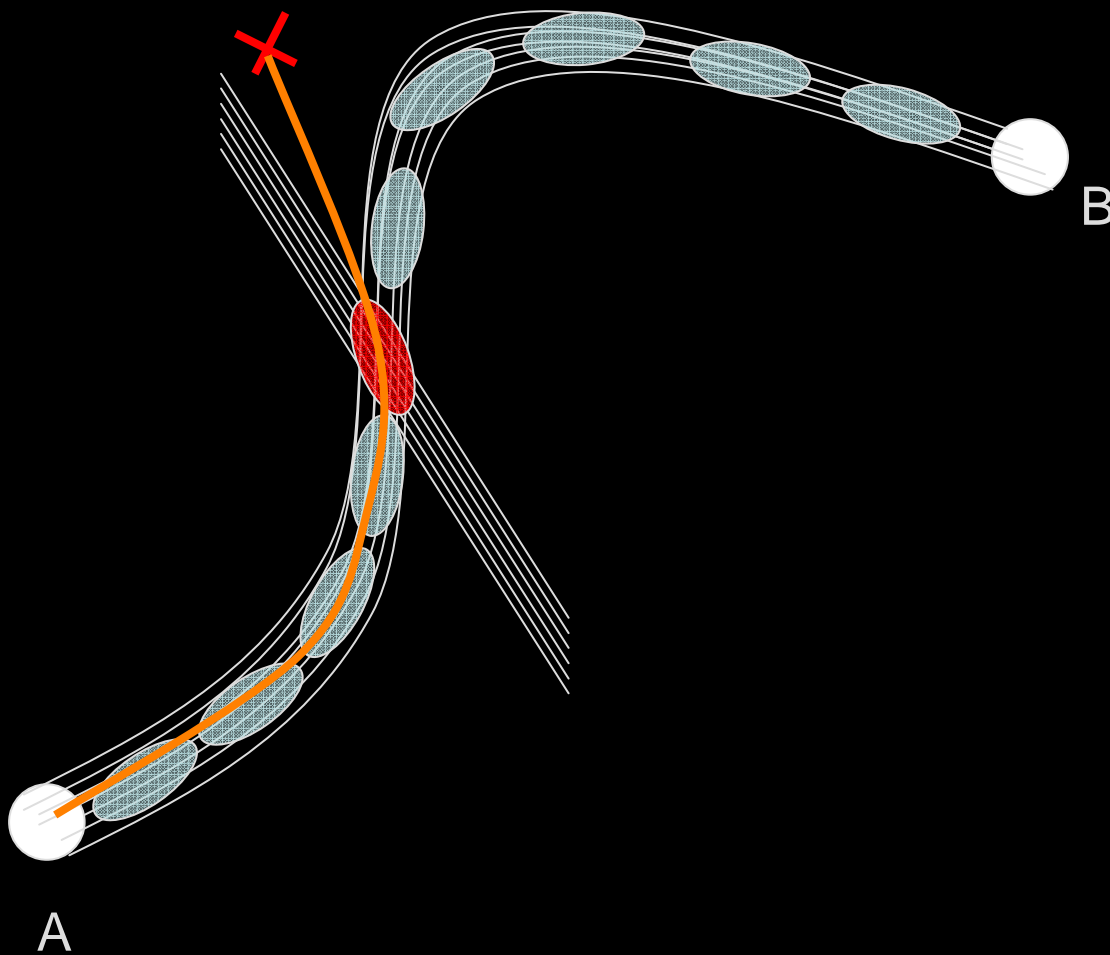
# Problèmes de la tractographie

## Croisements de fibres – perturbations locales



# Problèmes de la tractographie

Tractographie conventionnelle  
Trajectoire déviée



## Problèmes de la tractographie

---

- ✓ Méthodes rapides
  - Faciles à implémenter
  - Faciles à généraliser à la diffusion à haute résolution (HARD, Qball)
- ✗ Perturbations locales
  - Nécessité de régularisation
  - A priori sur les trajectoires
  - Sélection de régions dans la matière blanche

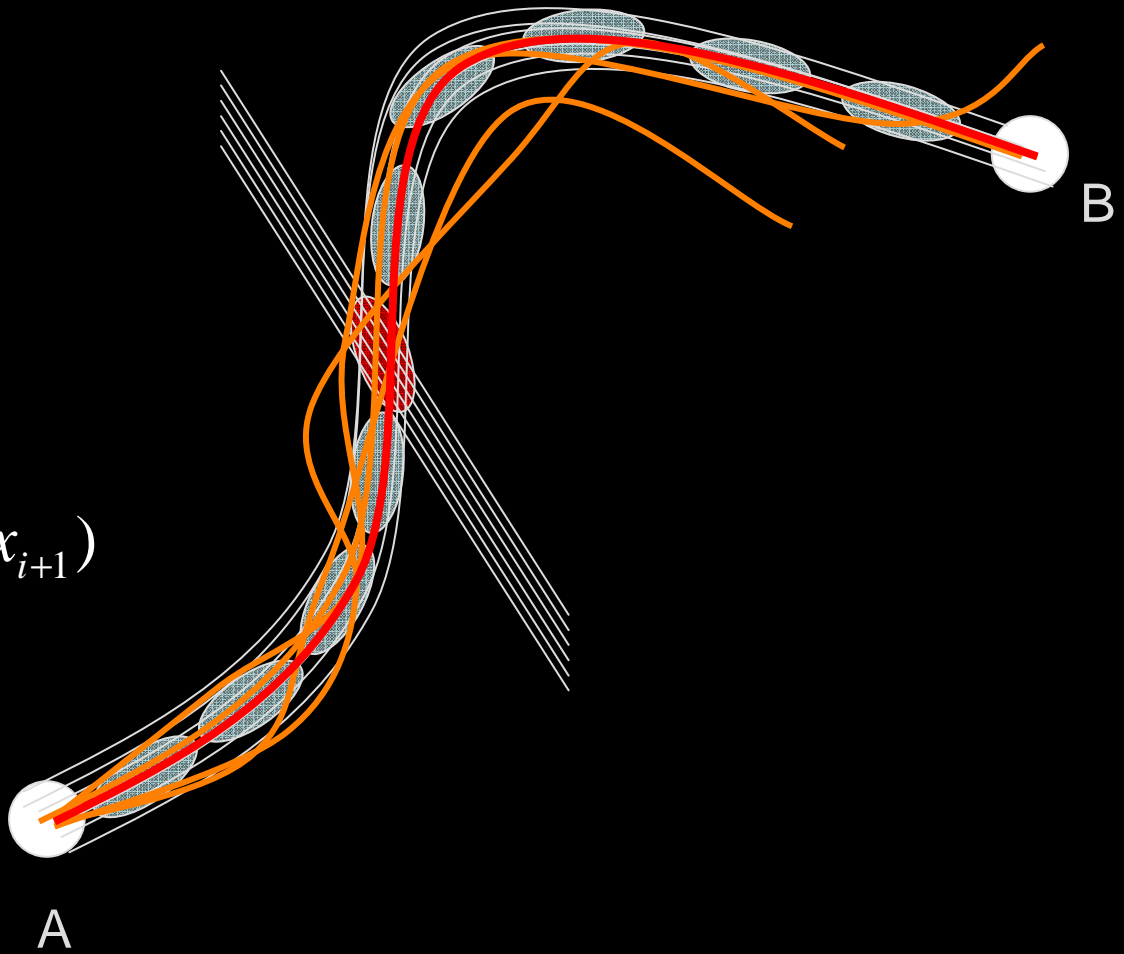
# Tractographie probabiliste

Probabilité de déplacement

$$p(x_i \rightarrow x_{i+1}) = f(\mathbf{D})$$

$$p(A \rightarrow B) = \frac{n}{N}$$

$$\zeta = \arg \max \prod_A^B p(x_i \rightarrow x_{i+1})$$



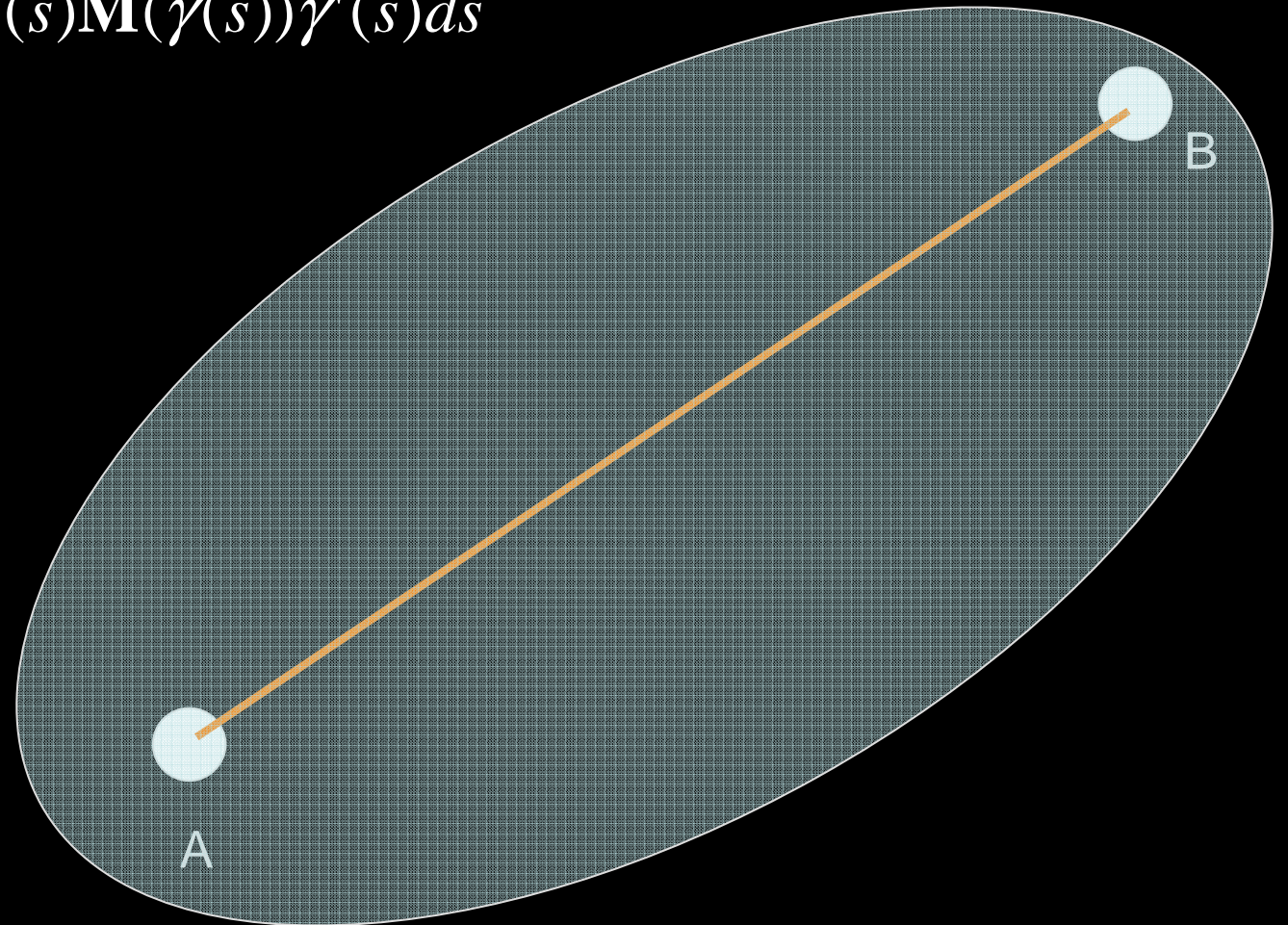
Tractographie géodésique

# Tractographie géodésique

Plus court chemin entre deux points  
Géométrie Euclidienne

$$\left\{ \begin{array}{l} \zeta = \arg \min_{\gamma} \int \sqrt{\gamma'^T(s) \mathbf{M}(\gamma(s)) \gamma'(s)} ds \\ \mathbf{M} = \mathbf{I} \end{array} \right.$$

$$\mathbf{M} = \mathbf{I}$$

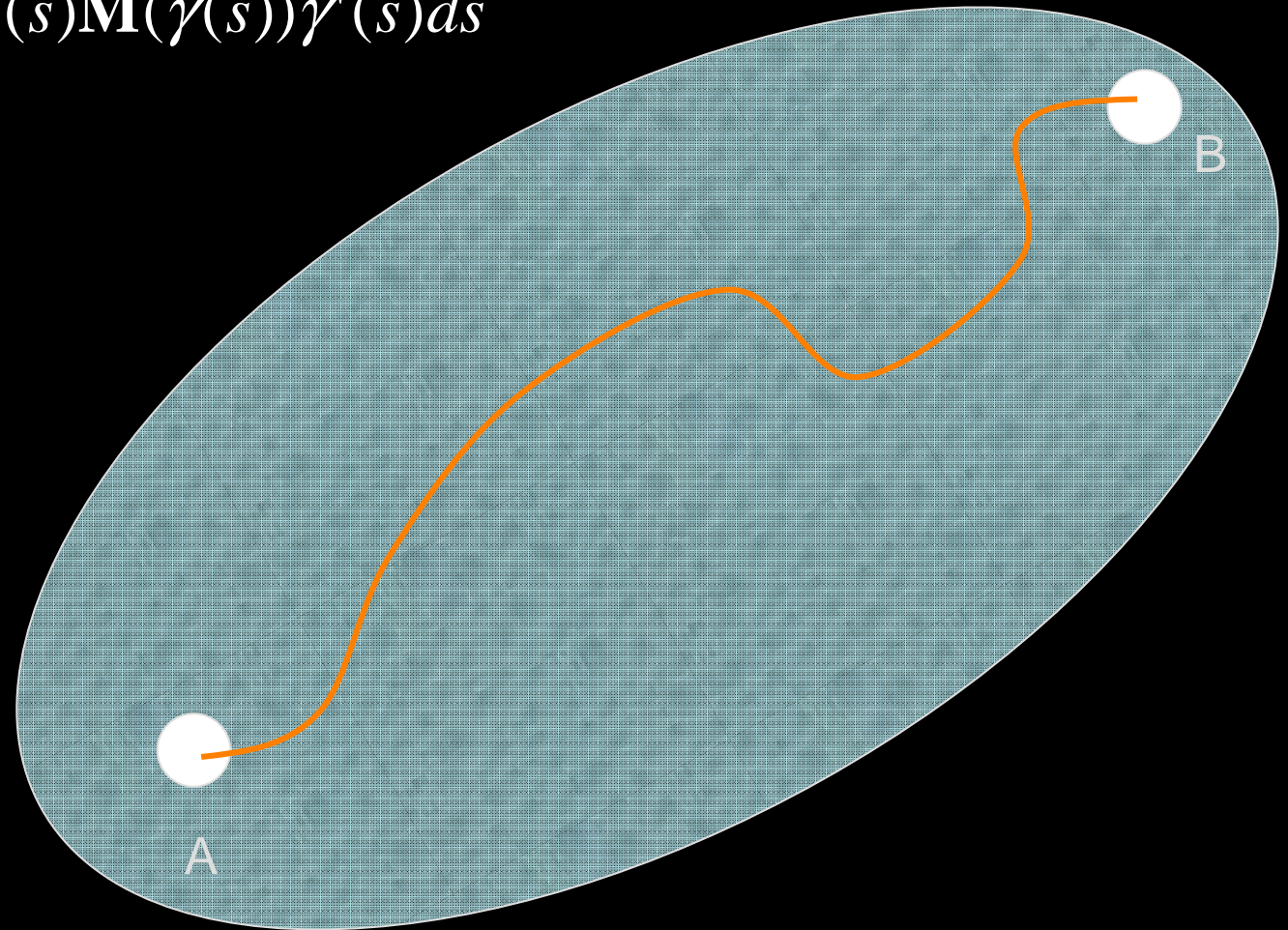


# Tractographie géodésique

Plus court chemin entre deux points  
Géométrie Riemannienne

$$\gamma = \arg \min_{\gamma} \int \sqrt{\gamma'^T(s) \mathbf{M}(\gamma(s)) \gamma'(s)} ds$$

$\mathbf{M} \neq \mathbf{I}$

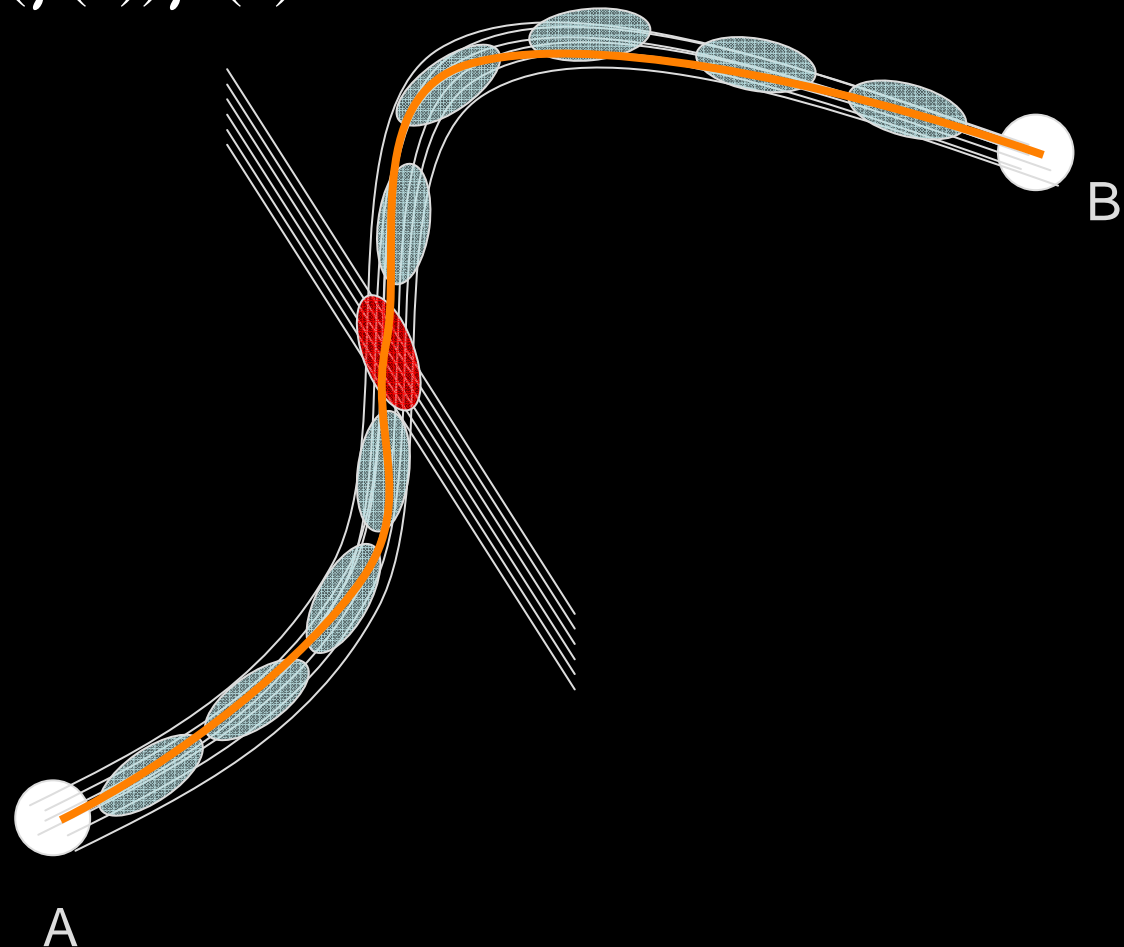


# Tractographie géodésique

Plus court chemin entre deux points  
Géométrie Riemannienne

$$\zeta = \arg \min_{\gamma} \int \sqrt{\gamma'^T(s) \mathbf{M}(\gamma(s)) \gamma'(s)} ds$$

$$\mathbf{M} = \mathbf{D}^{-1}$$



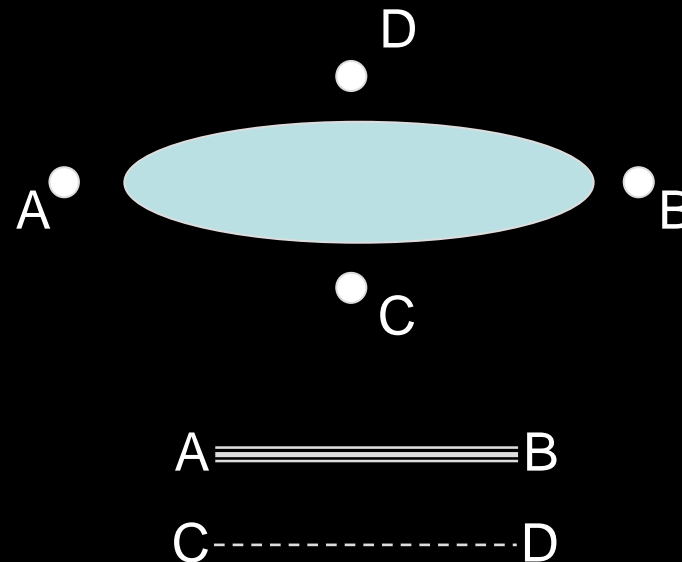


# Tractographie géodésique

Plus court chemin entre deux points  
Géométrie Riemannienne

$$\zeta = \arg \min_{\gamma} \int \sqrt{\gamma'^T(s) \mathbf{M}(\gamma(s)) \gamma'(s)} ds$$

$$\mathbf{M} = \mathbf{D}^{-1}$$

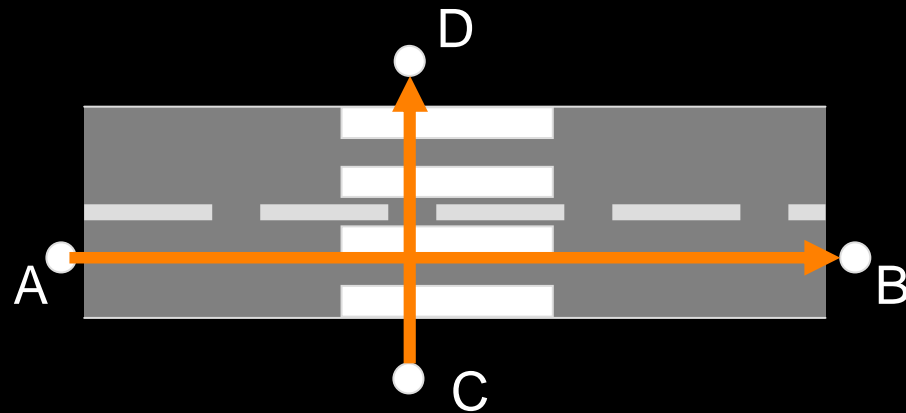


# Tractographie géodésique

Plus court chemin entre deux points  
Géométrie Riemannienne

$$\zeta = \arg \min_{\gamma} \int \sqrt{\gamma'^T(s) \mathbf{M}(\gamma(s)) \gamma'(s)} ds$$

$$\mathbf{M} = \mathbf{D}^{-1}$$



# Tractographie géodésique

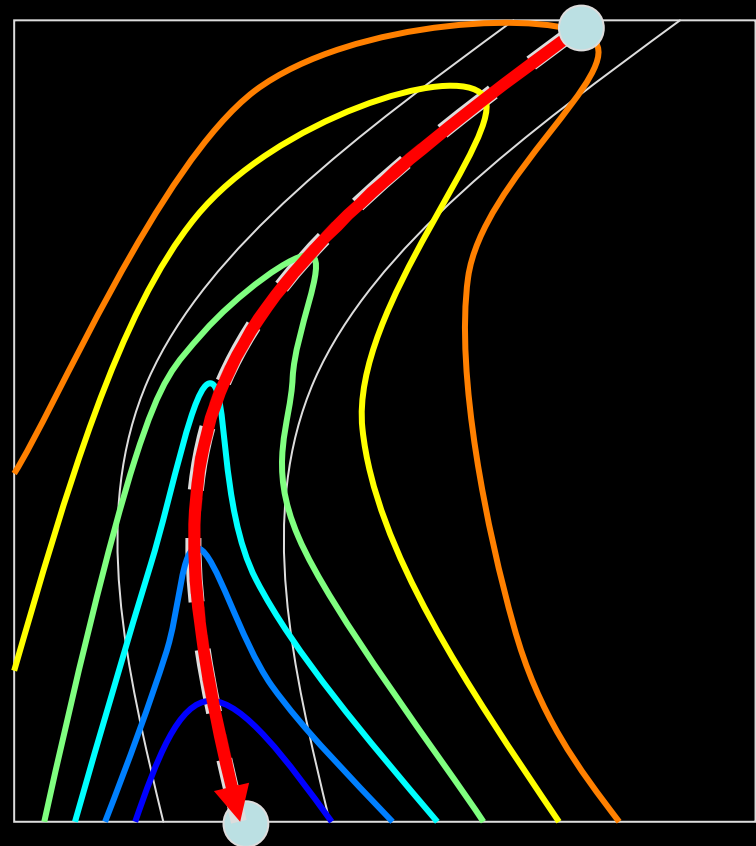
$$u = \min \int \sqrt{\gamma'^T(s) \mathbf{D}^{-1}(\gamma(s)) \gamma'(s)} ds$$

$$\nabla u^T \mathbf{D} \nabla u = 1$$

Equation iconale  
Fast marching Anisotrope

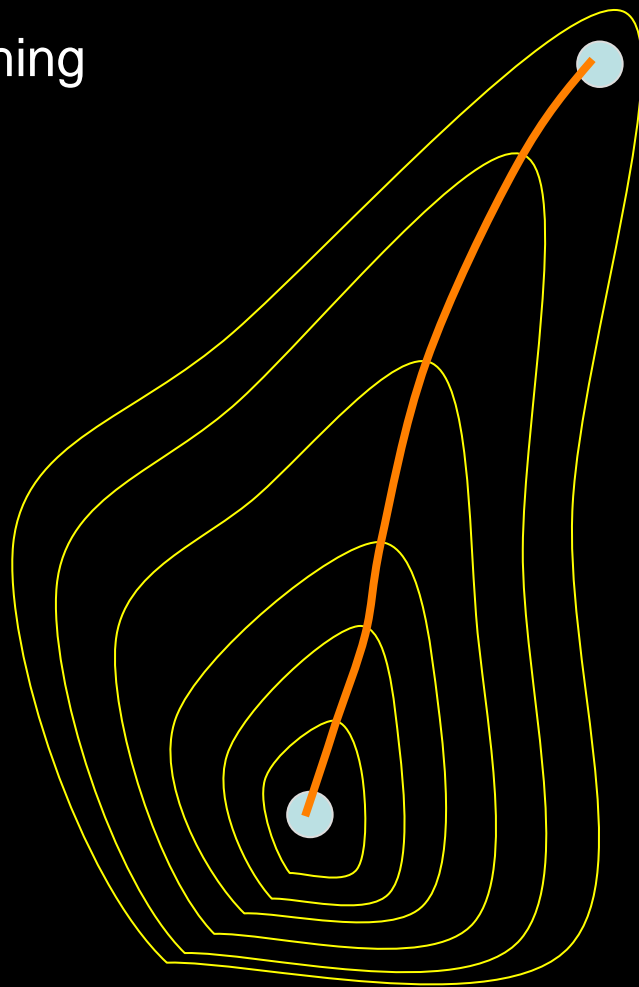
$$\gamma' \propto \mathbf{D} \nabla u$$

Rétropropagation  
Descente de gradient

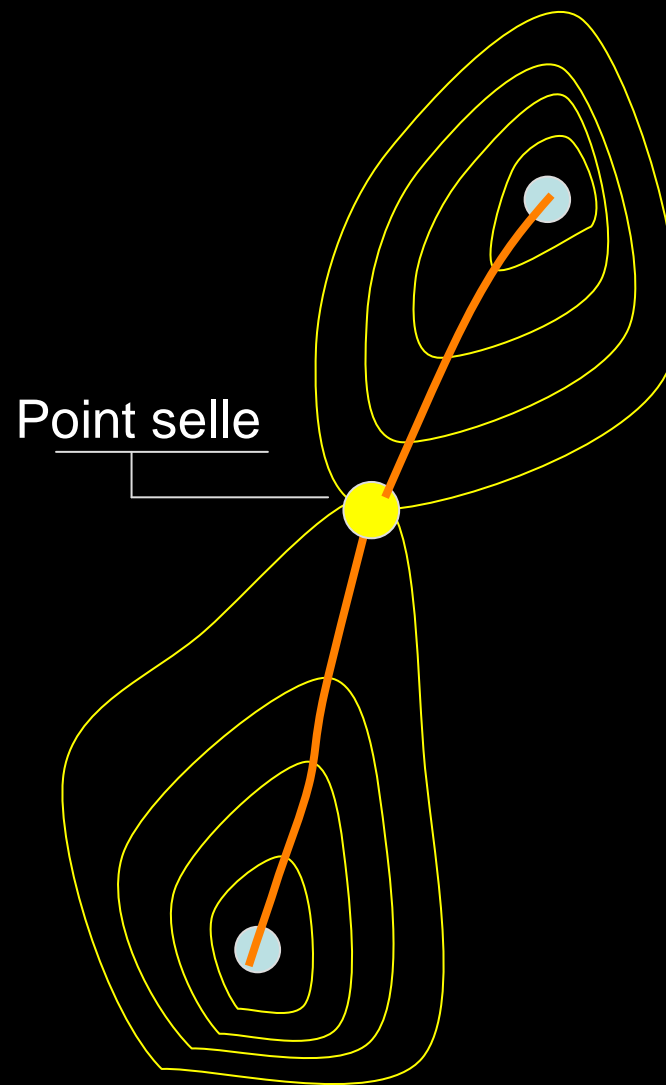


# Tractographie géodésique

Fast marching



Un point source



Point selle

Deux points sources

# Tractographie géodésique

---

## Méthodes probabilistes

---

- ✗ Calculs lents
- ✓ Incertitude sur les connexions

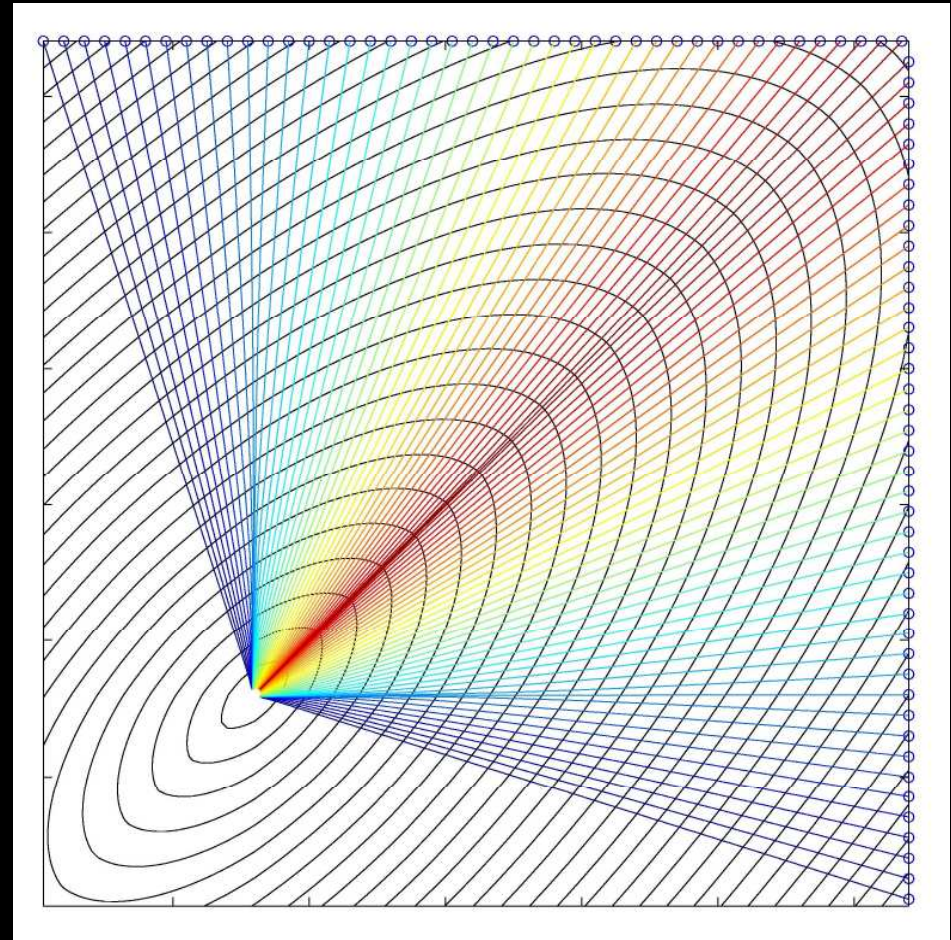
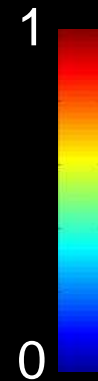
## Méthode géodésique

---

- ✓ Calculs rapides
- ✗ Méthode déterministe

# Tractographie géodésique

Indice de connectivité



$$p(\zeta) = \exp \left\{ - \frac{\int \sqrt{\zeta'^T(s) \mathbf{D}^{-1}(\zeta(s)) \zeta'(s)} ds}{\int ds} \right\}$$

# Applications

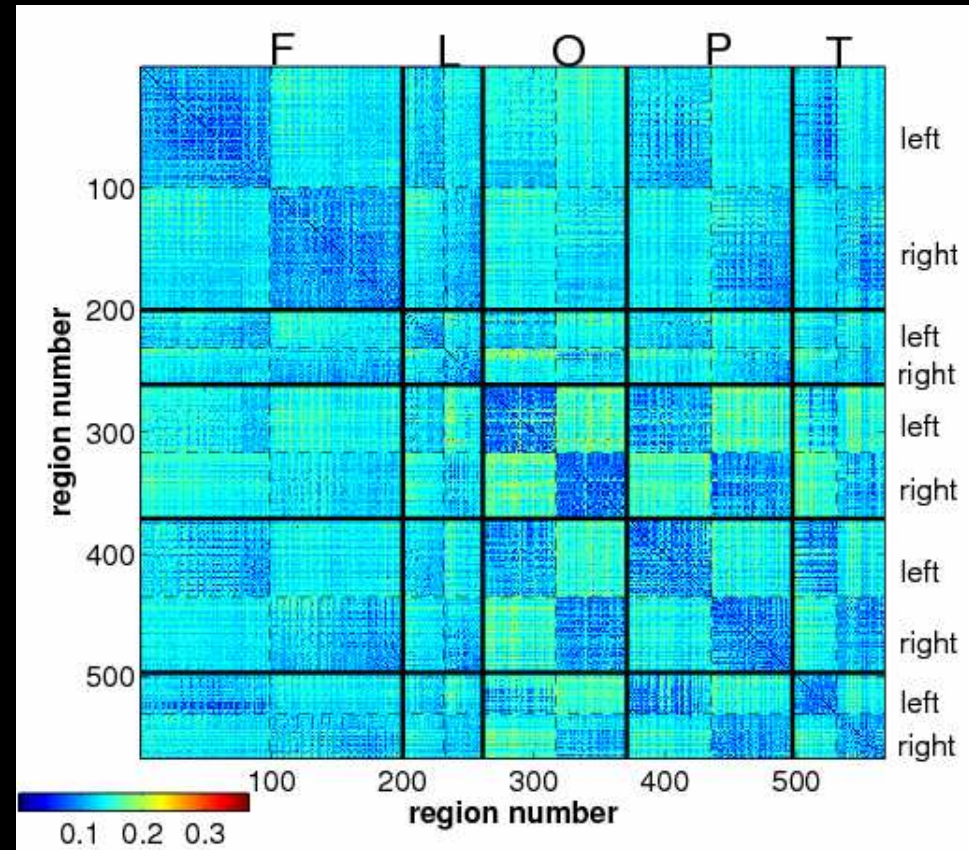
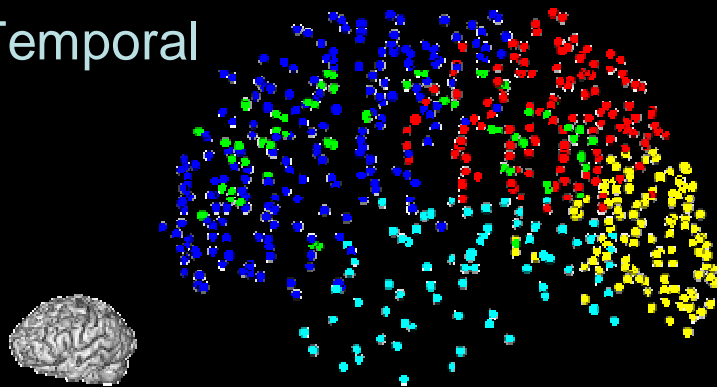
---

Connexions cortico-corticales

Connexions cortico-sous corticales

# Connexions cortico-corticales

Frontal  
Limbique  
Occipital  
Parietal  
Temporal

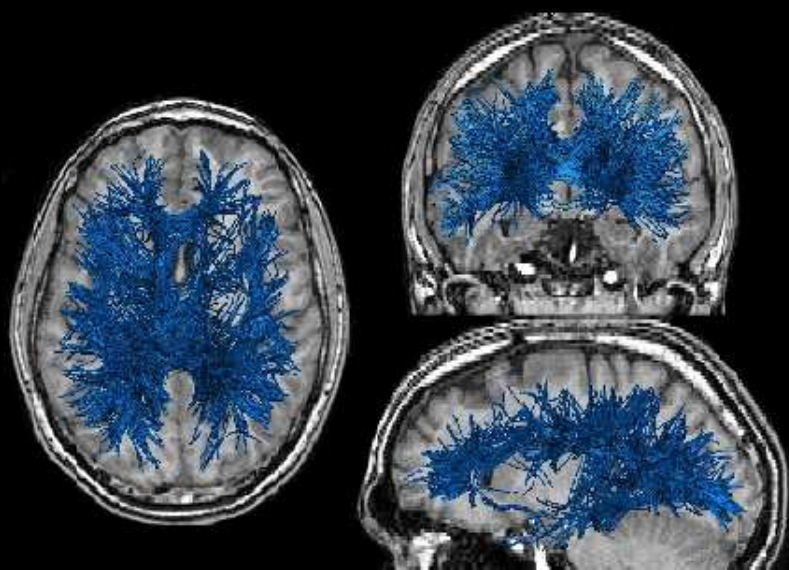


Matrice de connectivité anatomique

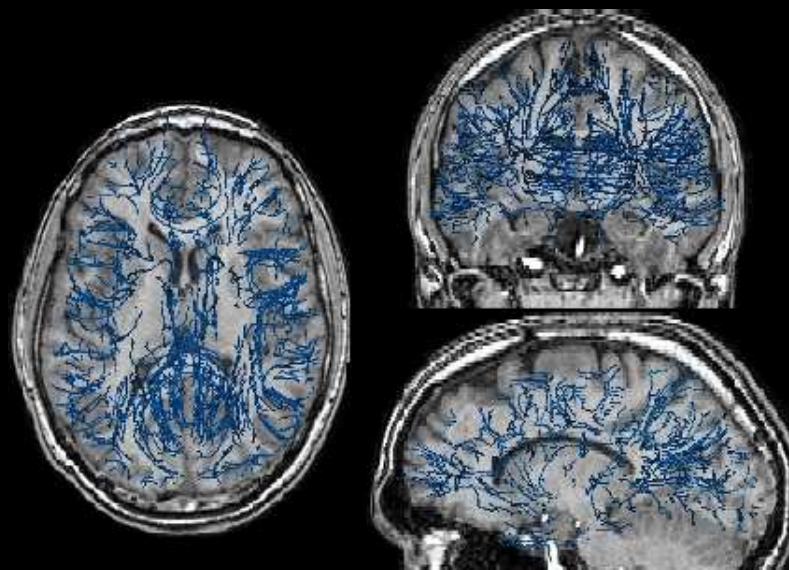


# Connexions cortico-corticales

---



Méthode géodésique



Méthode streamline