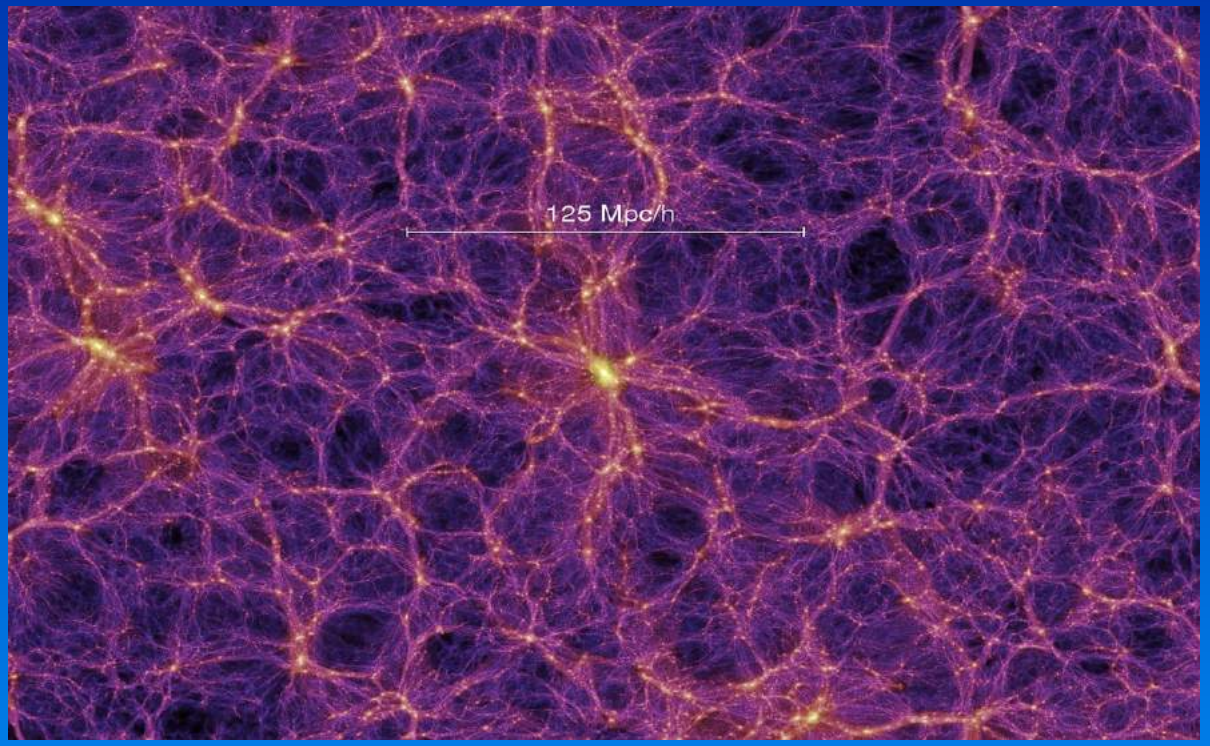
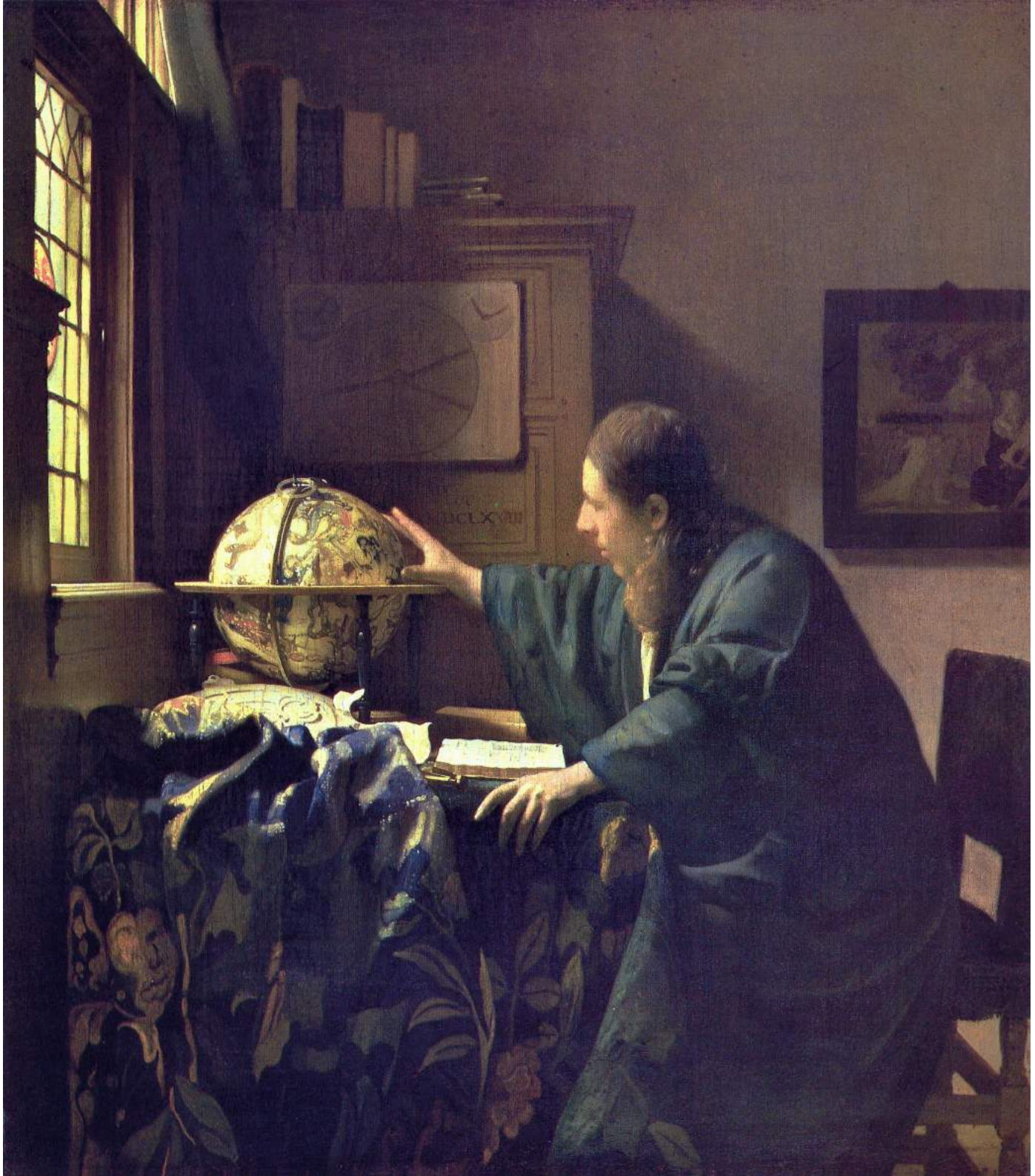
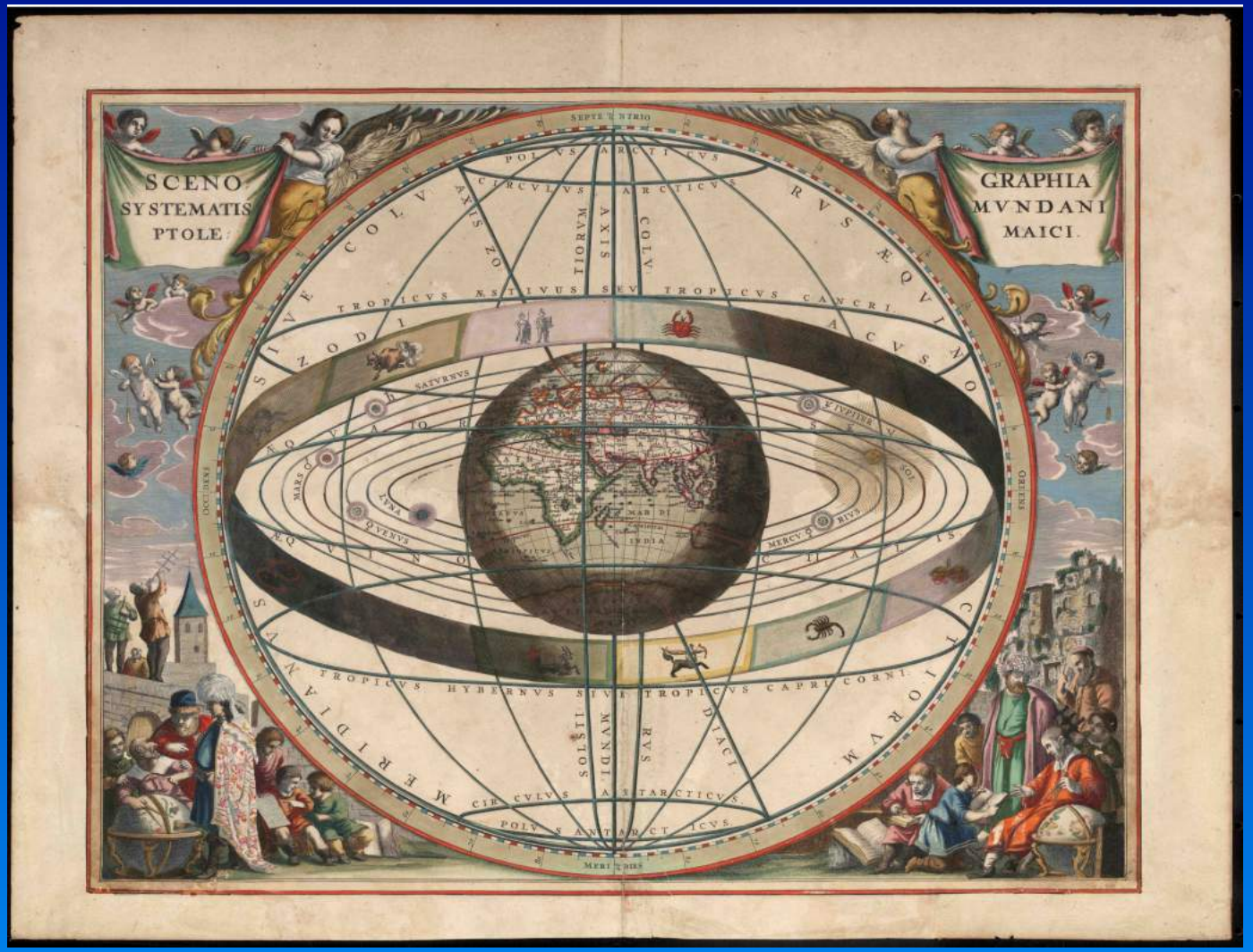
La structuration à grande échelle
Les amas de galaxies





Vision du Monde

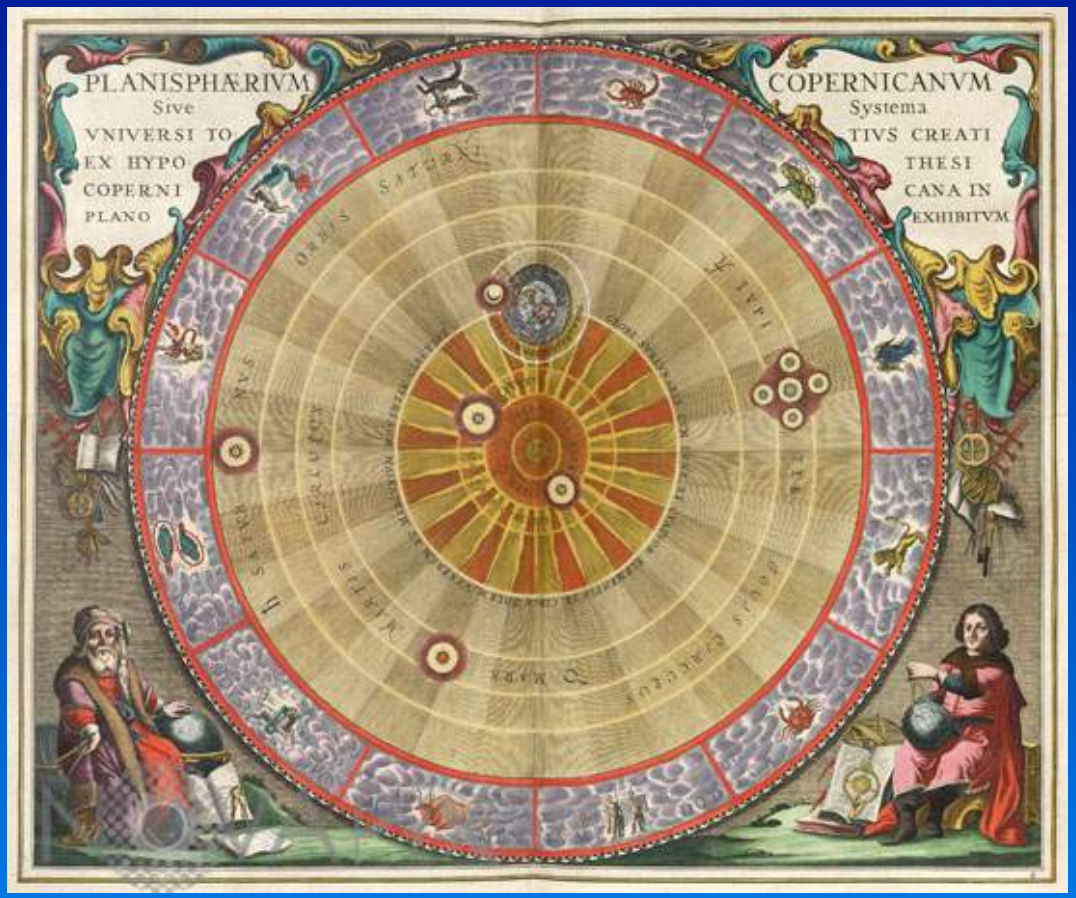


géocentrisme (Aristote...)

Copernic (1473-1543)

La Révolution...

Copernic



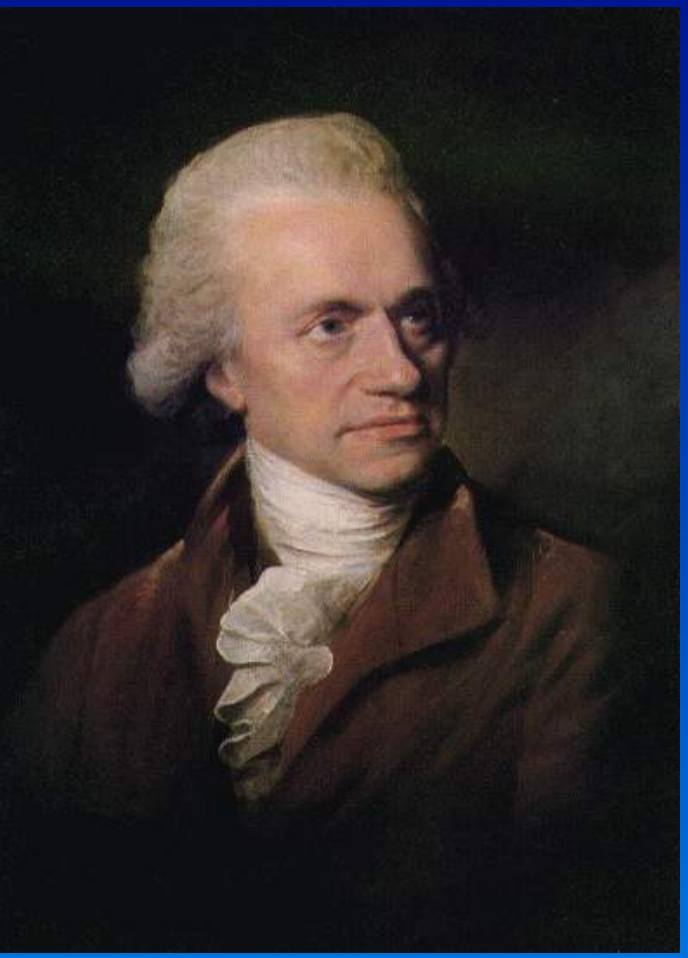
…en partie seulement !

Giordano Bruno

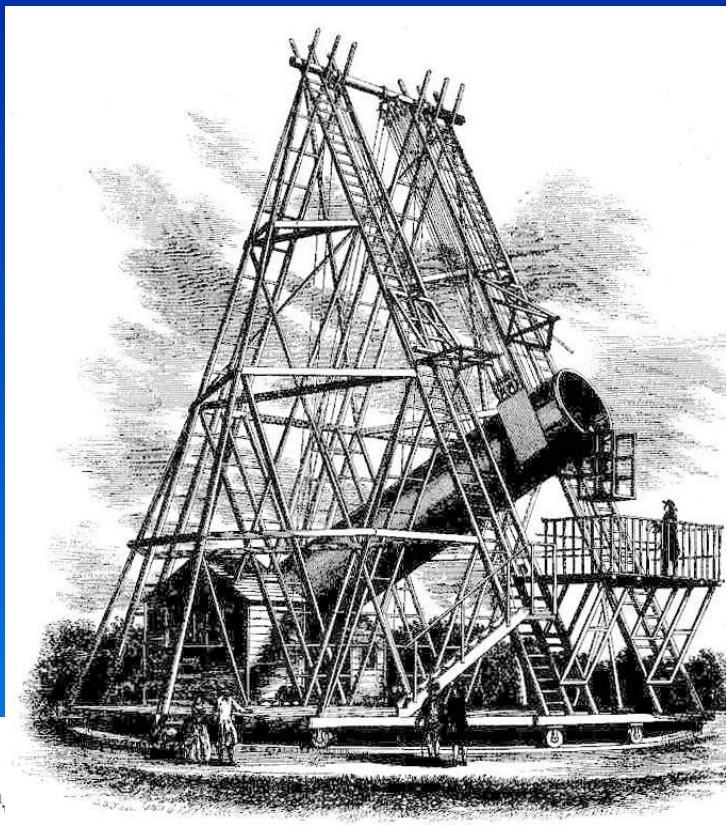
Vision cosmologique :

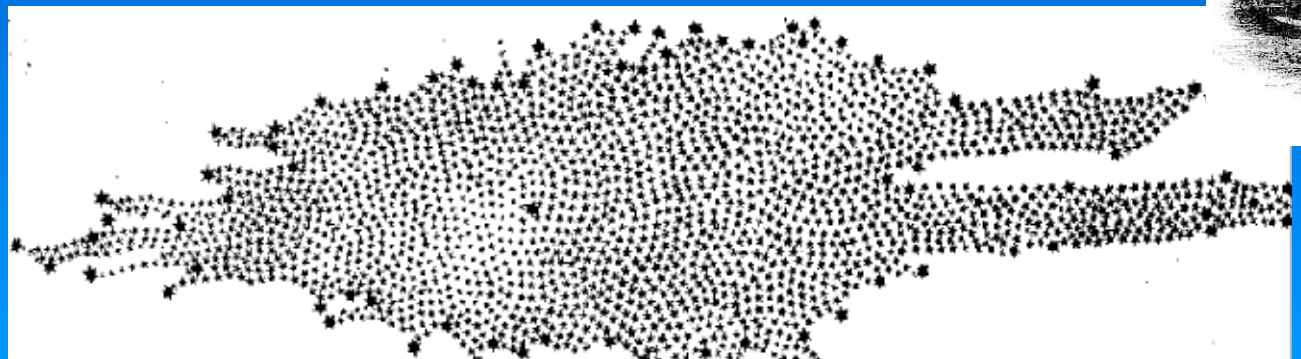
Abandon de l'Héliocentrisme

Univers infini « homogène »



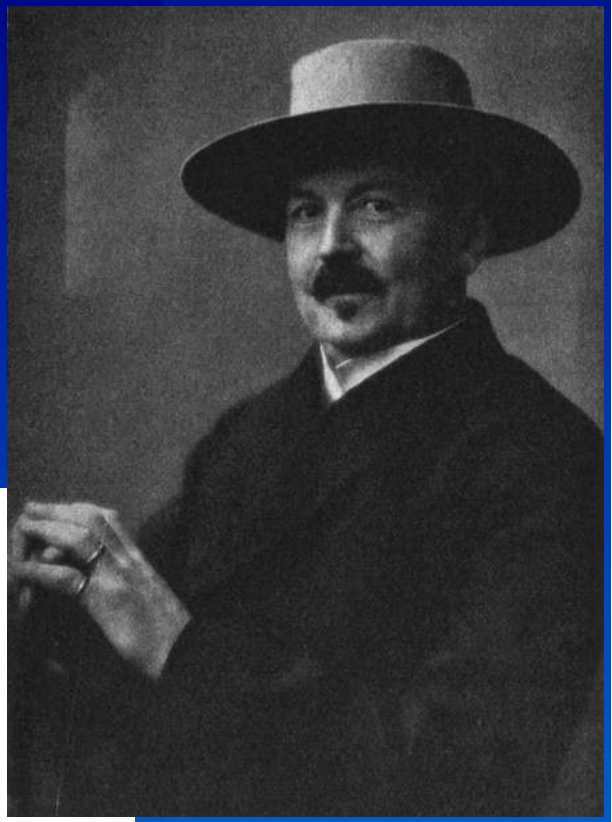
Herschel

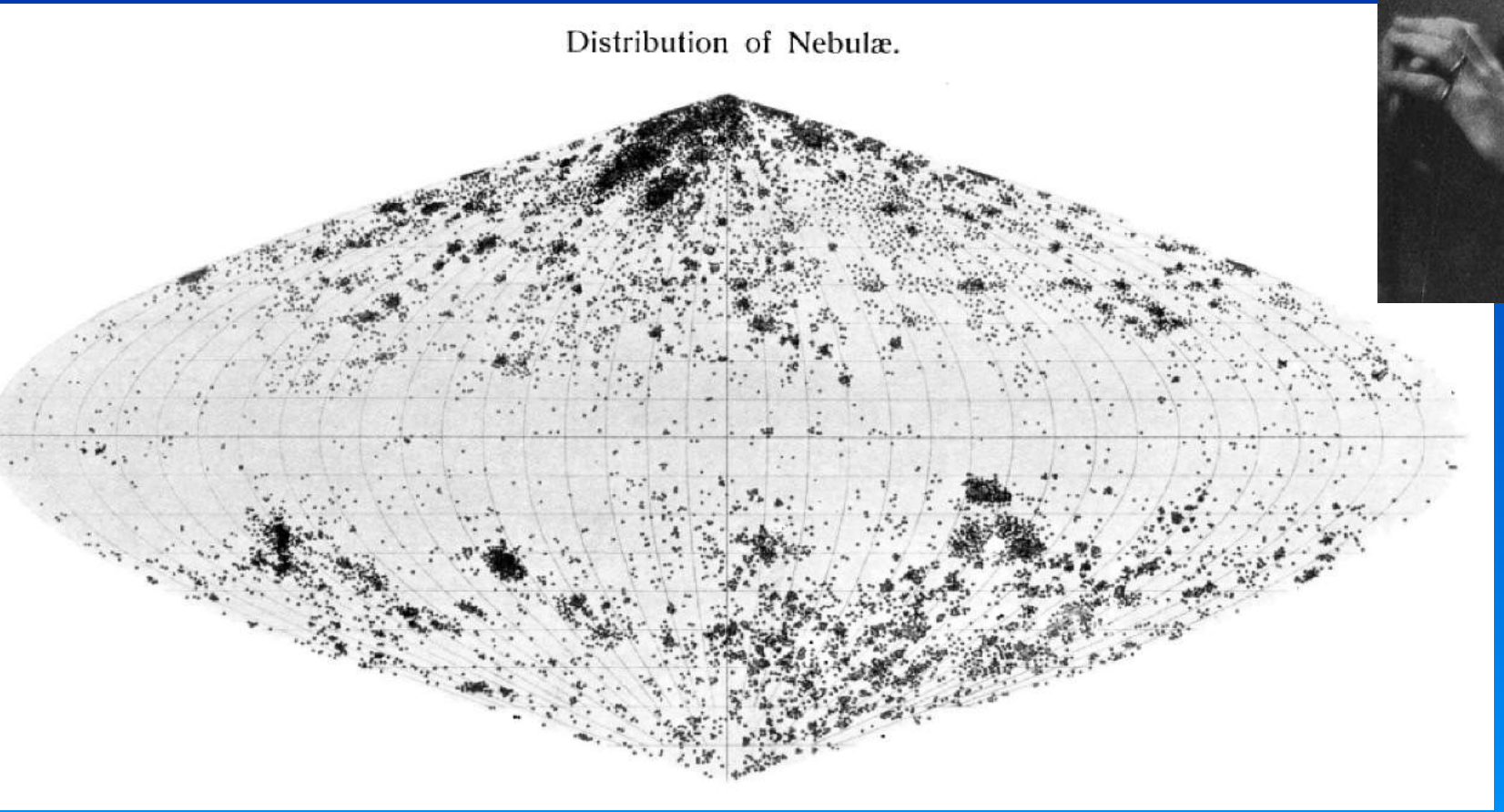


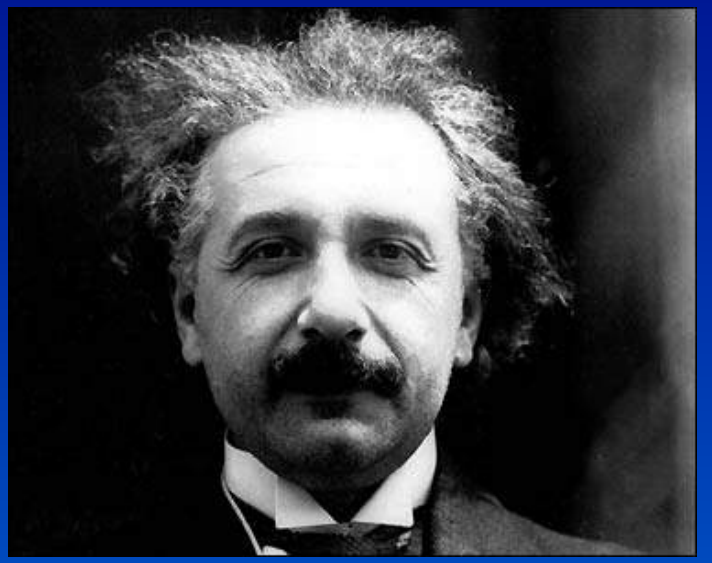


Charlier

« How an infinite world may be build up. » 1922. ark. math. astr. fys., 16, no. 22.



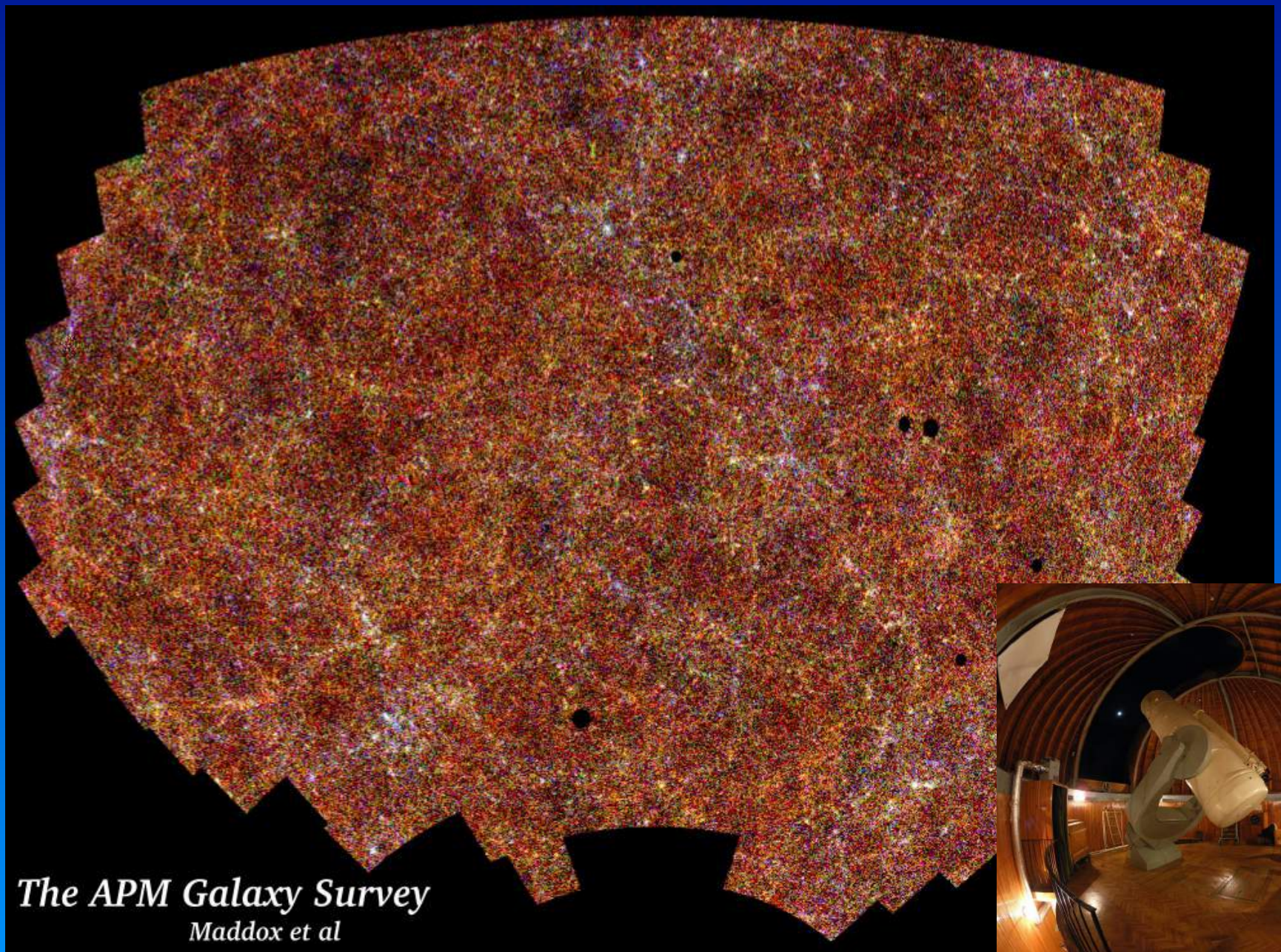




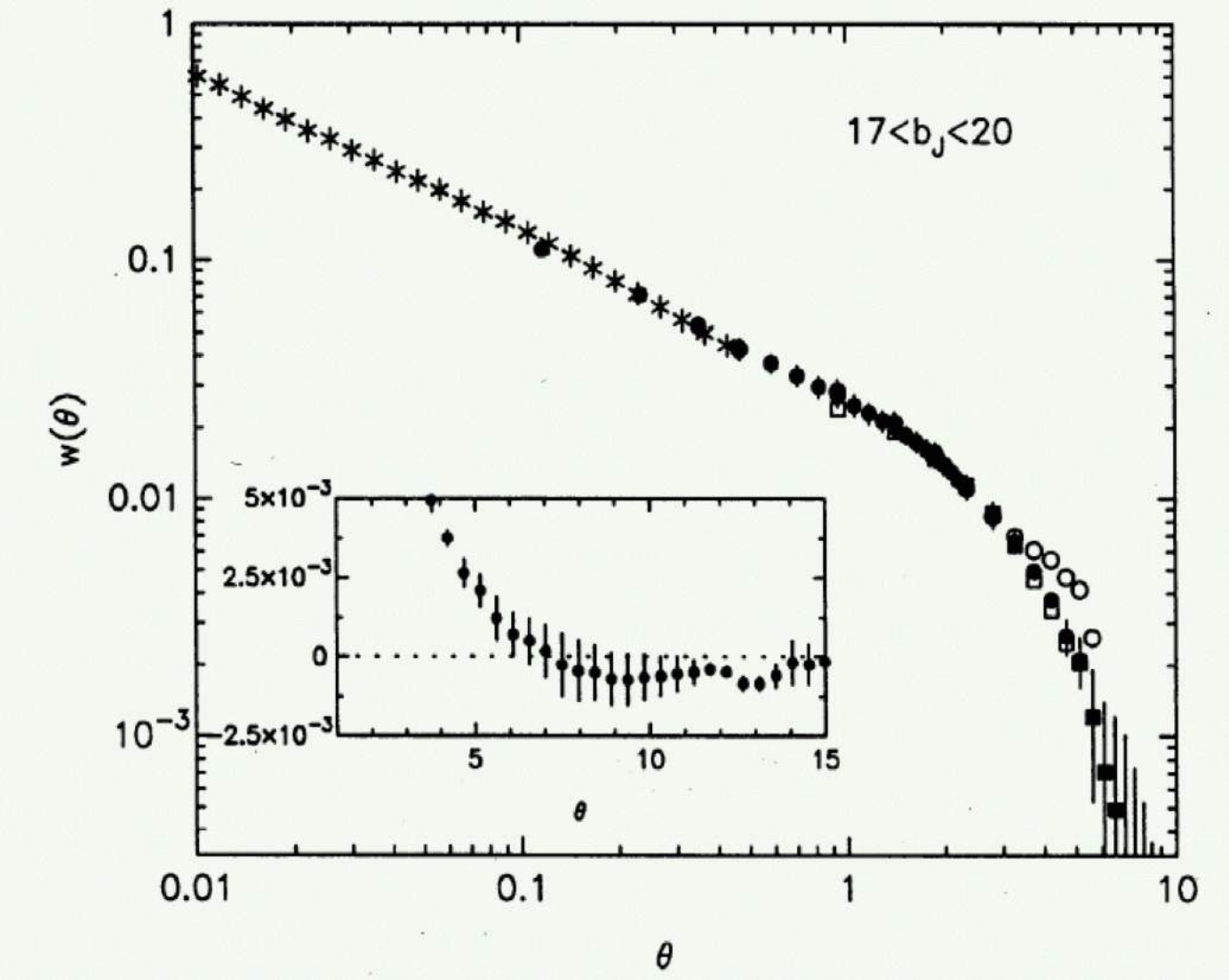
L'Univers est homogène

Principe cosmologique d'Einstein

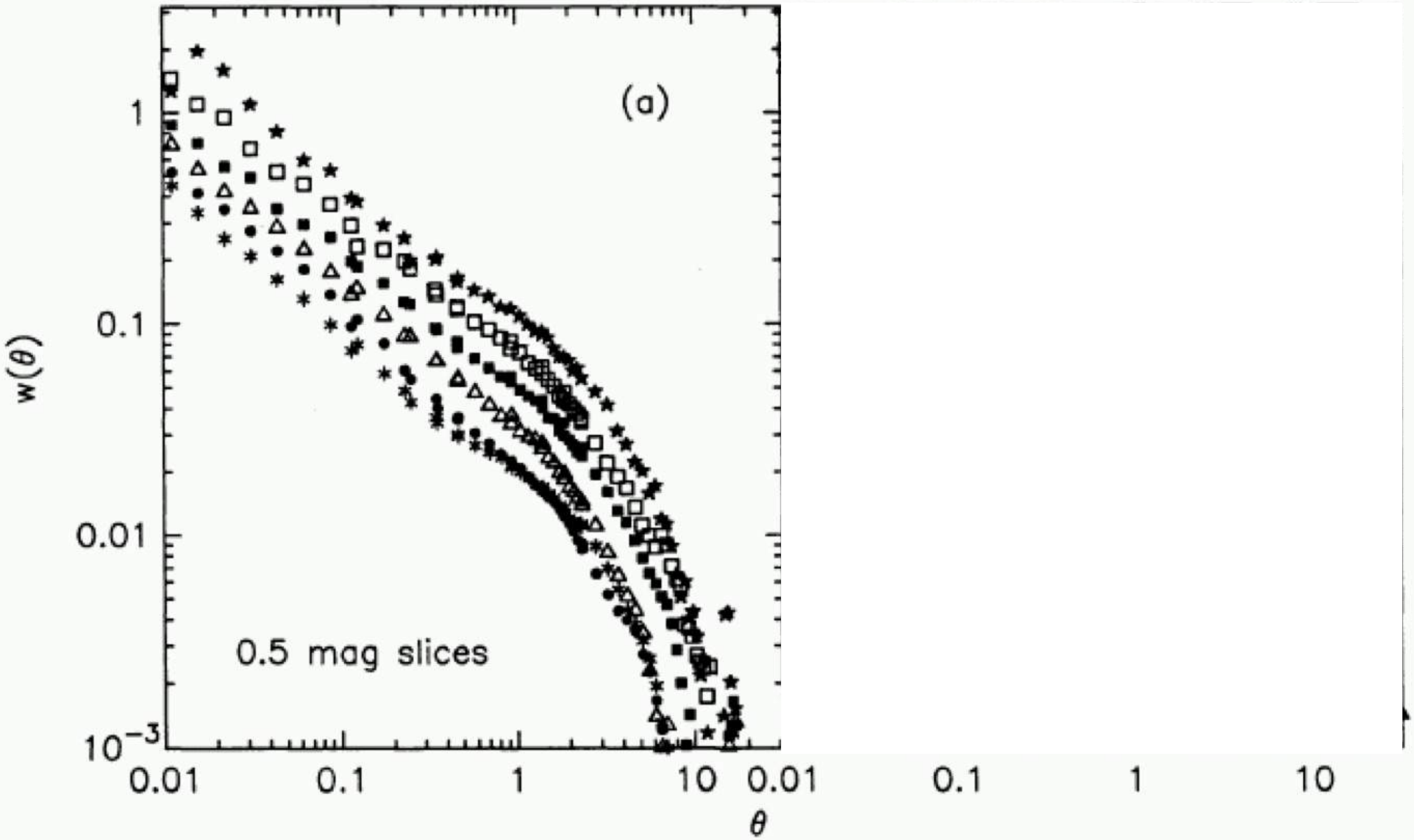
Catalogues 2D



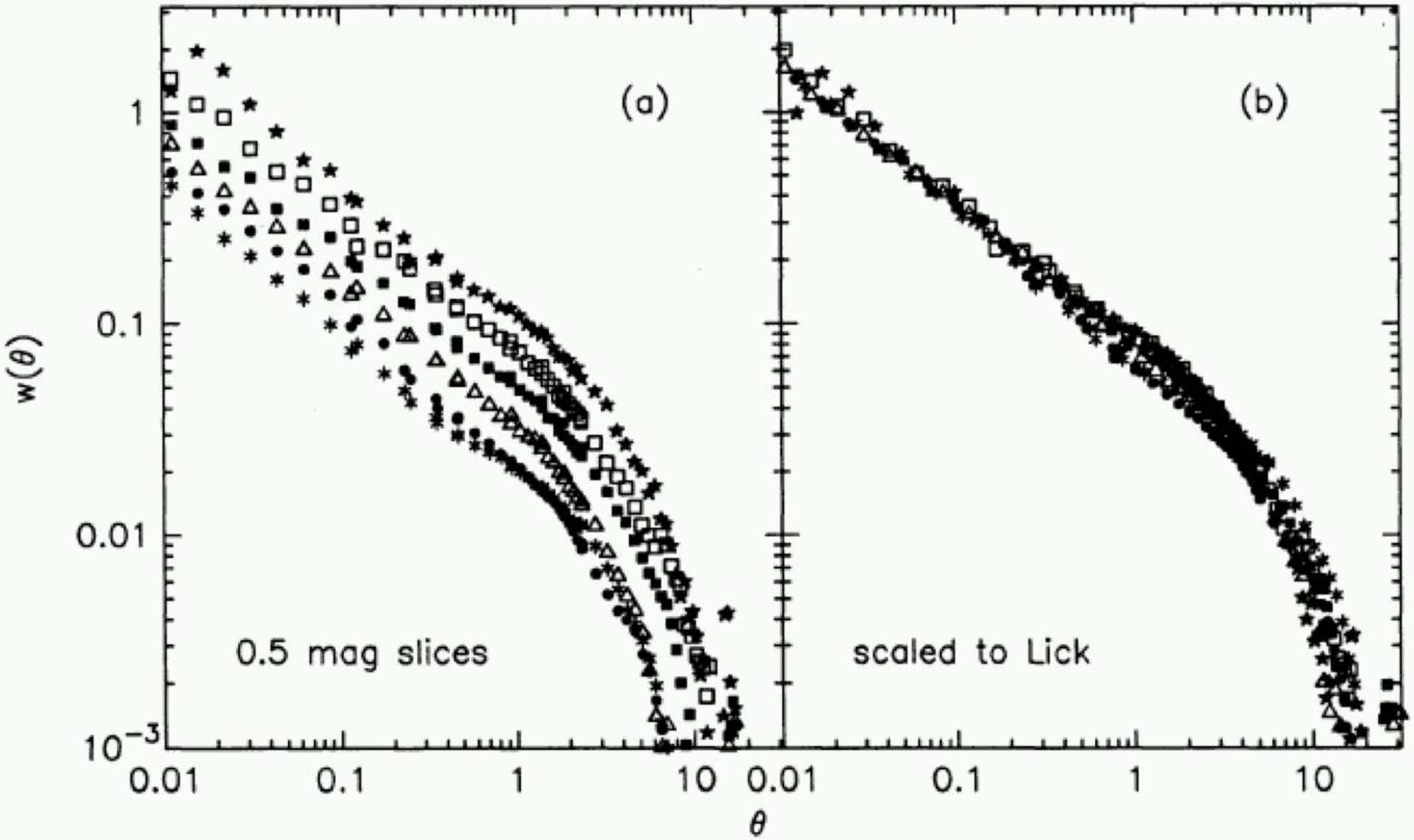
Catalogues 2D



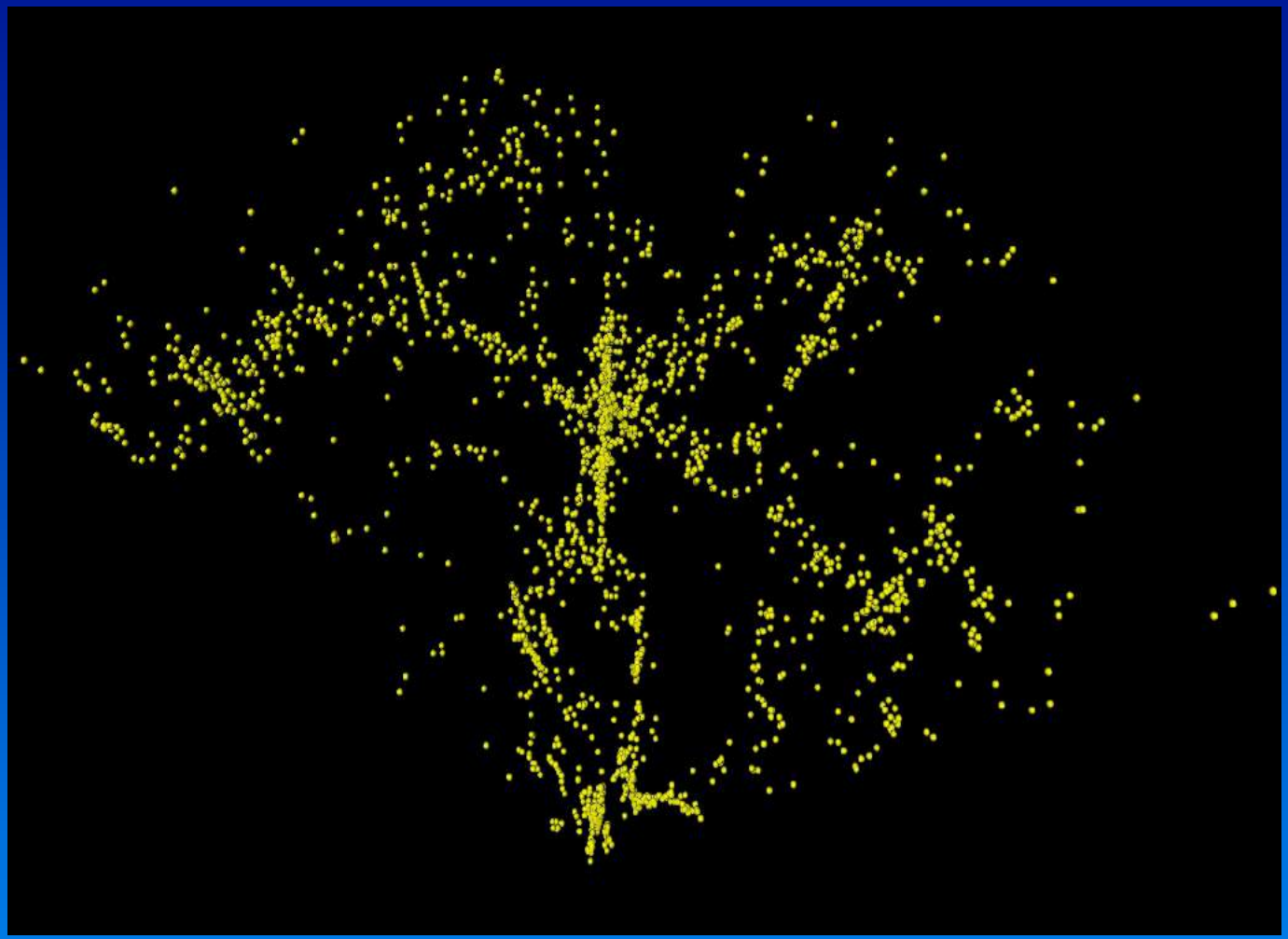
Auto-similarité des fonctions de corrélations



Auto-similarité des fonctions de corrélations



Accès à la troisième dimension...

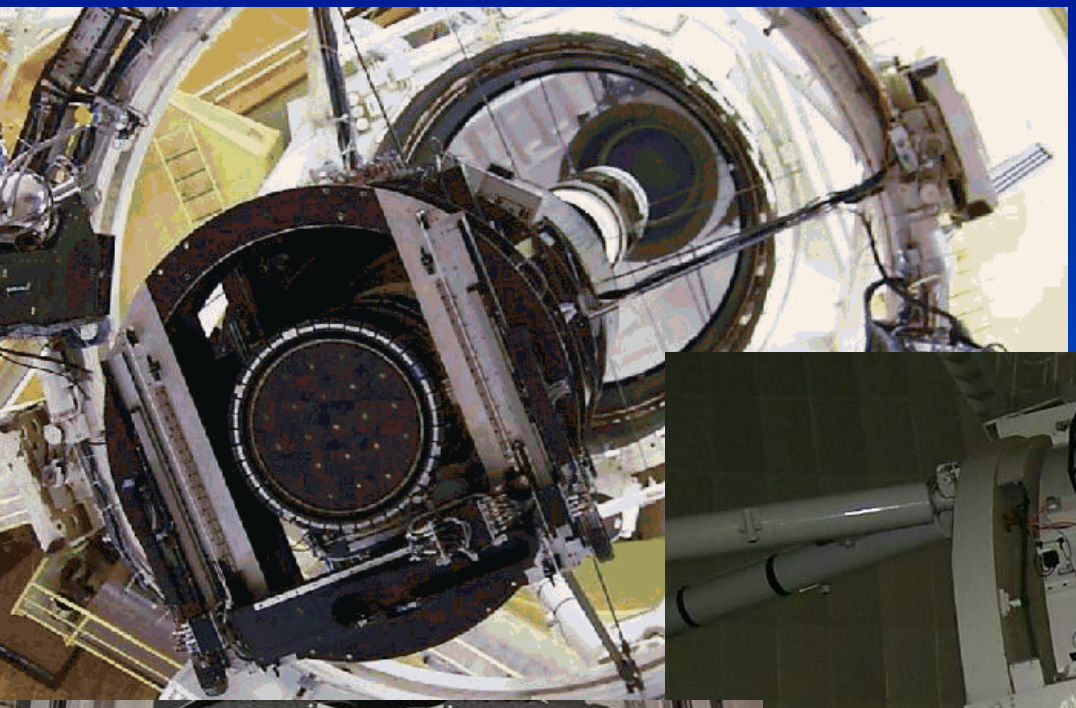


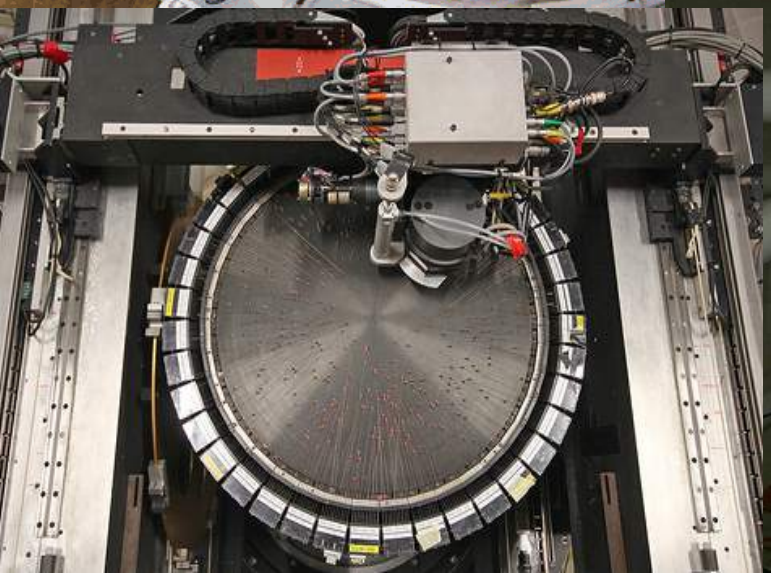
Vitesse $D = V/H_0$

Accès à la troisième dimension... de façon massive !

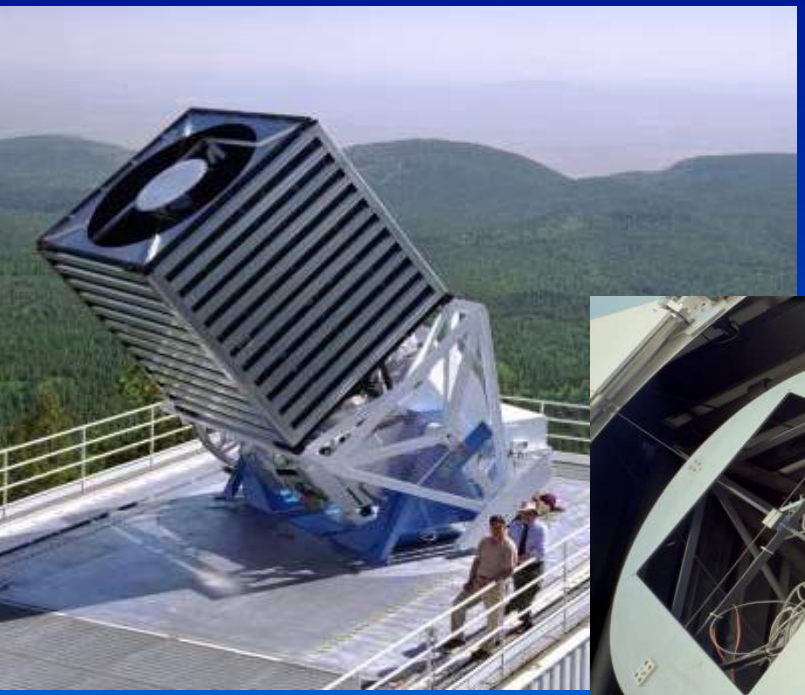
Multiplexage
Grands télescopes dédiés
Grand champ

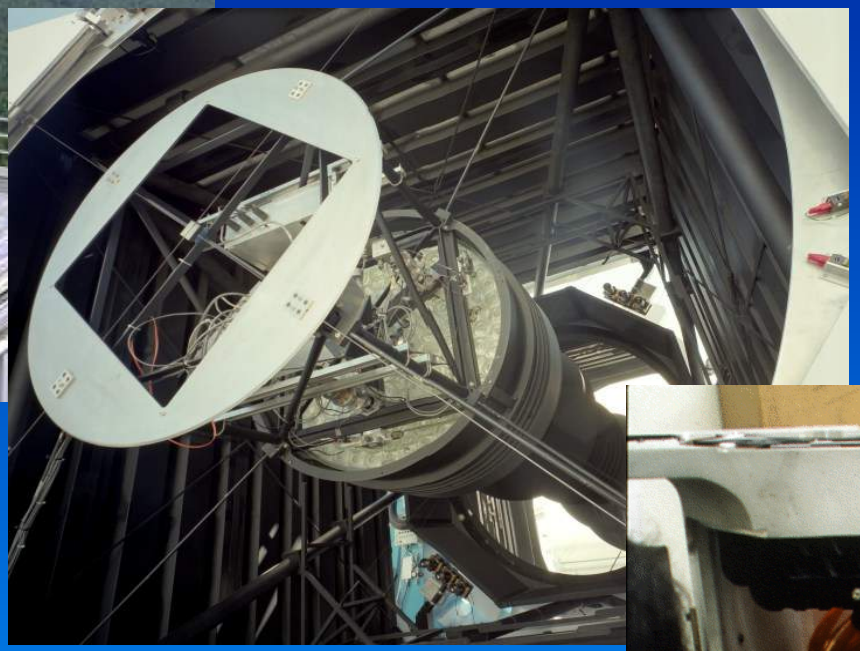
Accès à la troisième dimension...
de façon massive !



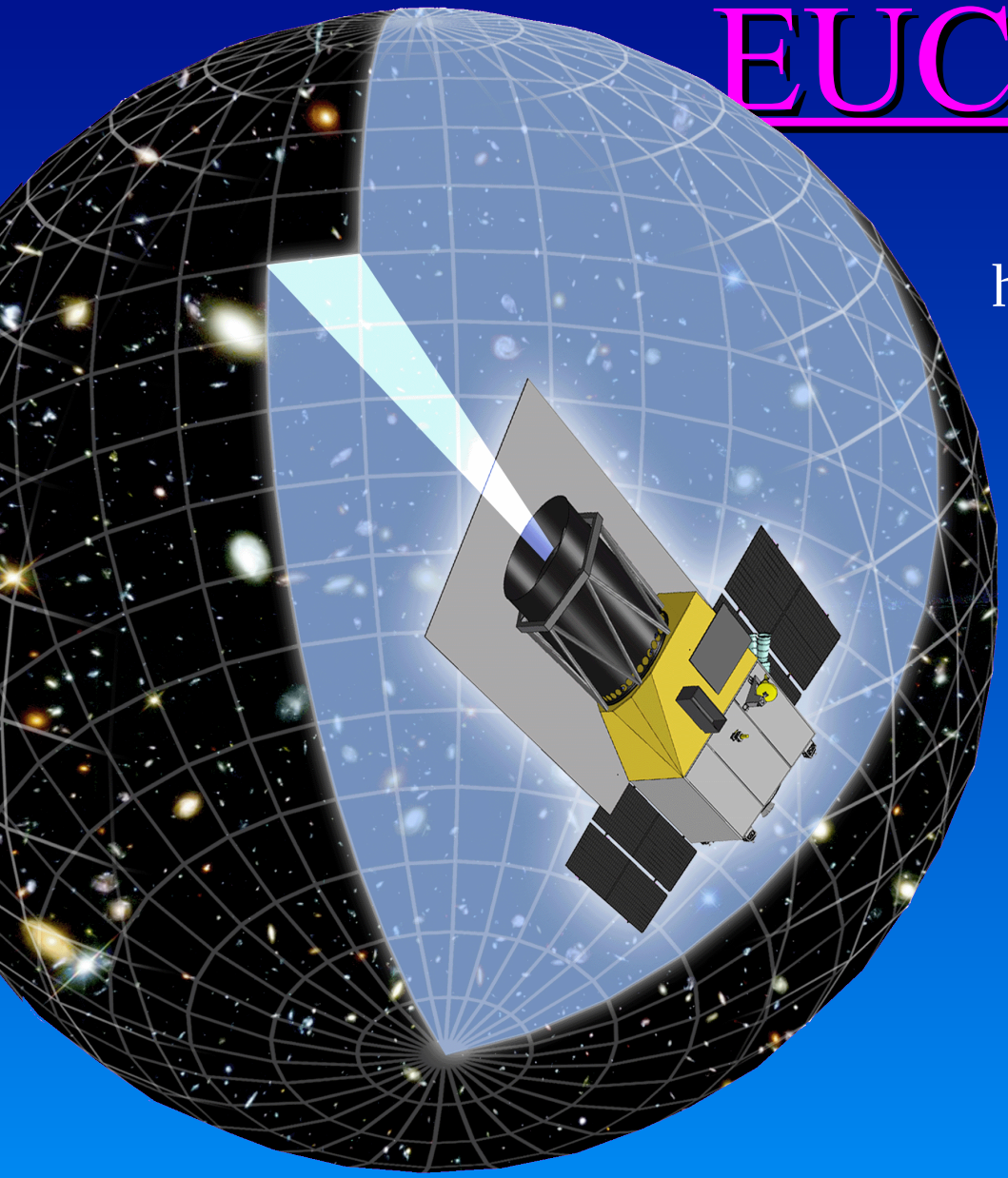


Accès à la troisième dimension... de façon massive !





Sélection du projet de satellite EUCLID



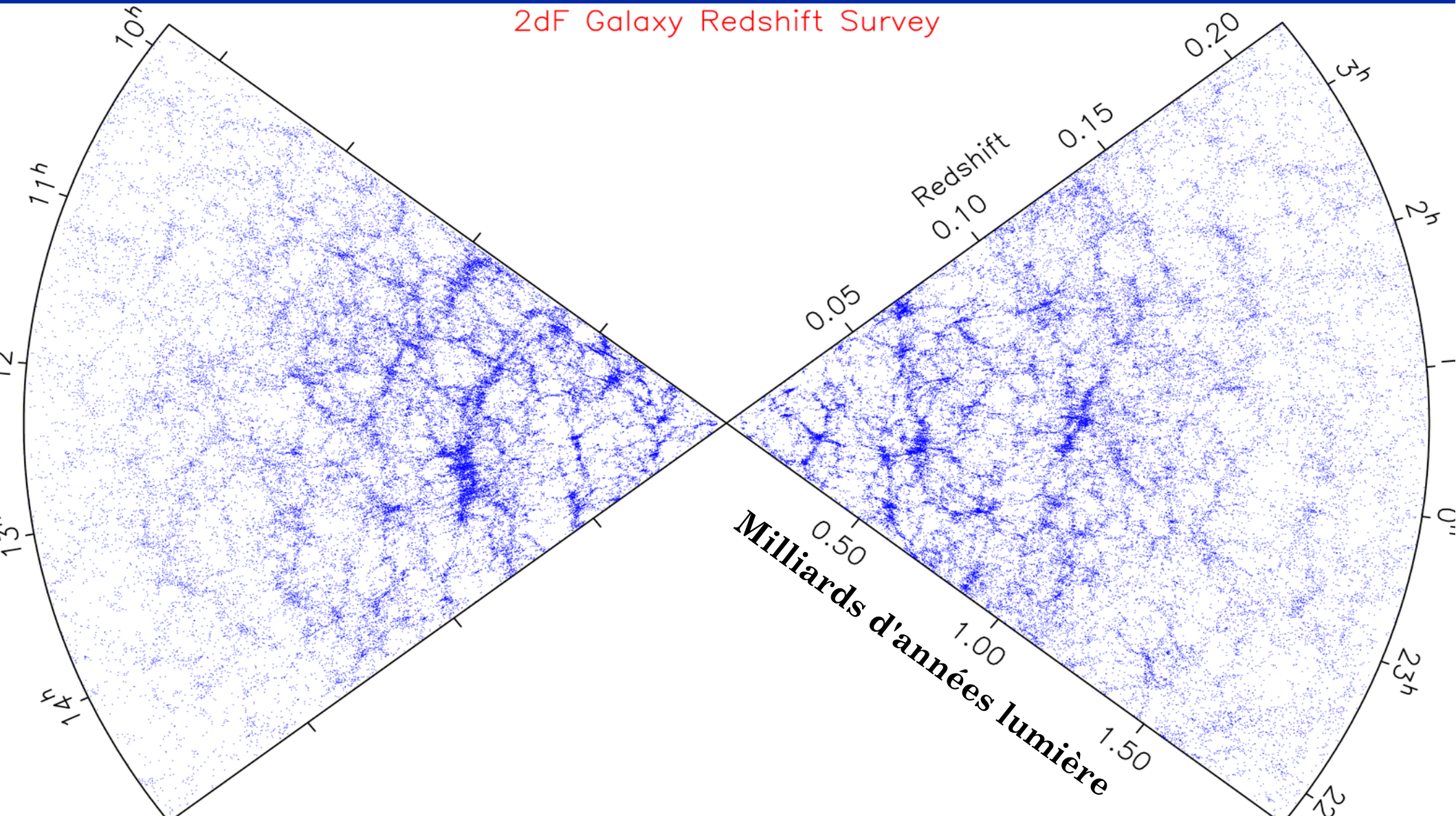
http://www.euclid-ec.org/
http://smsc.cnes.fr/EUCLID/Fr/index.htm

euclid consortium

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

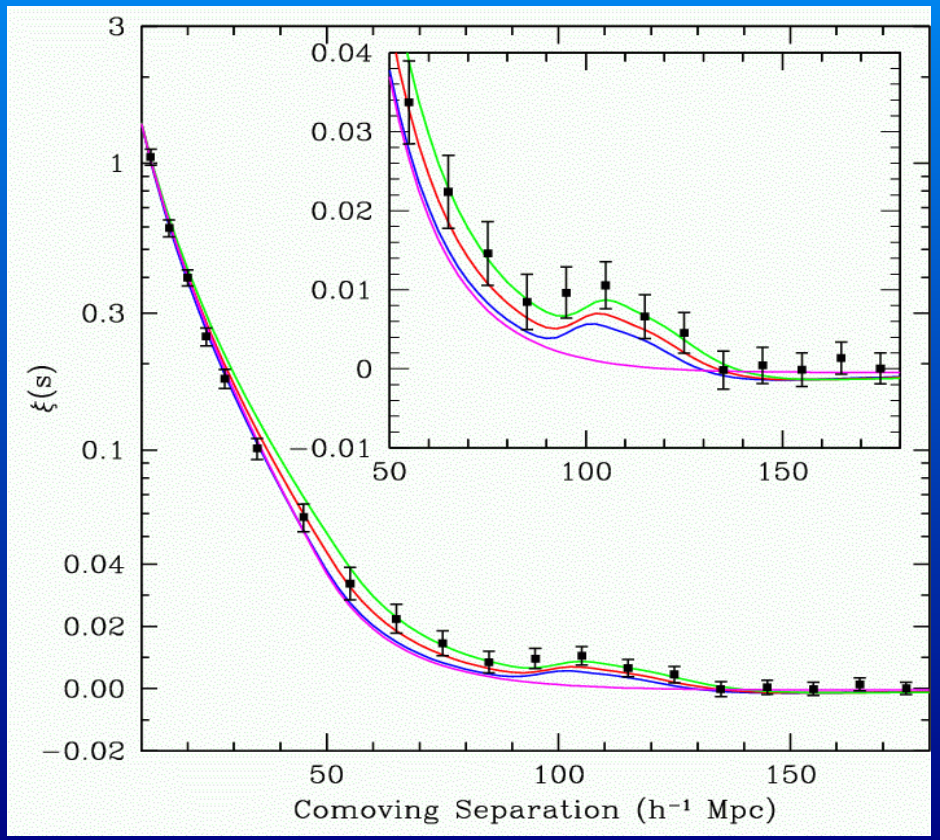
esa

Structure de l'univers à grande échelle



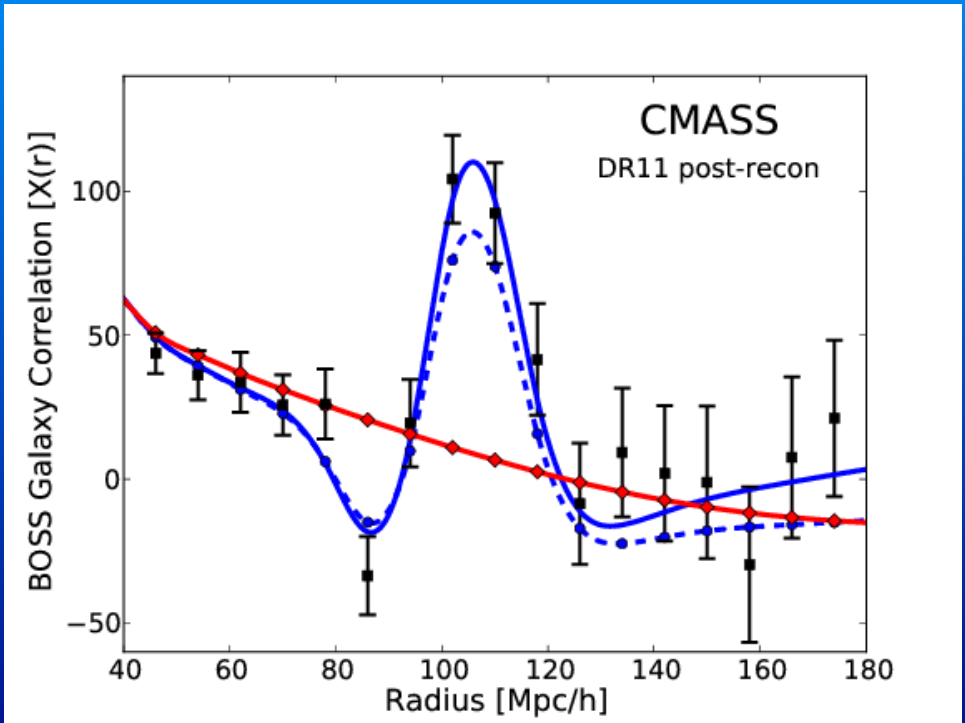
Fonction de corrélation à grande échelle

SDSS (2005)

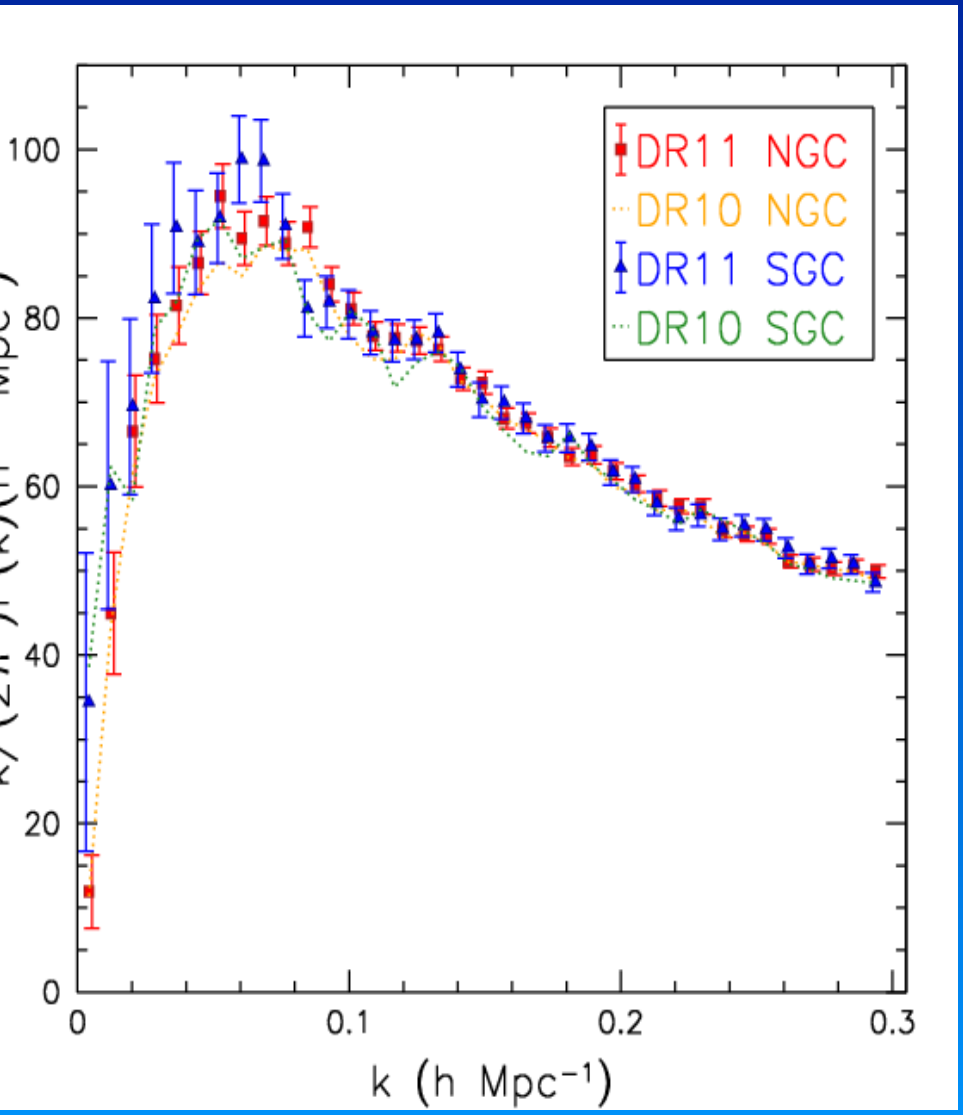


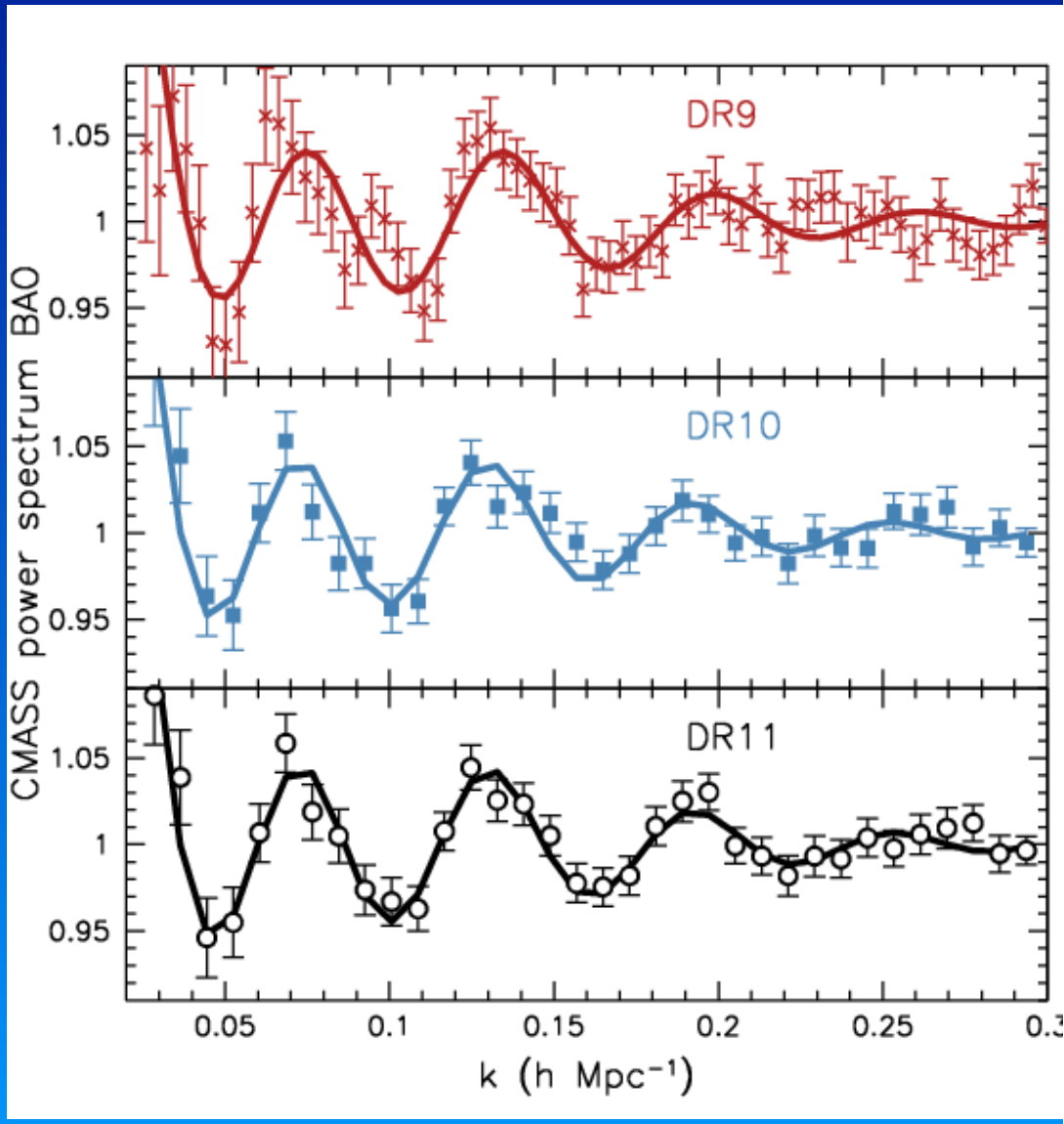
Fonction de corrélation à grande échelle

SDSS (2014)

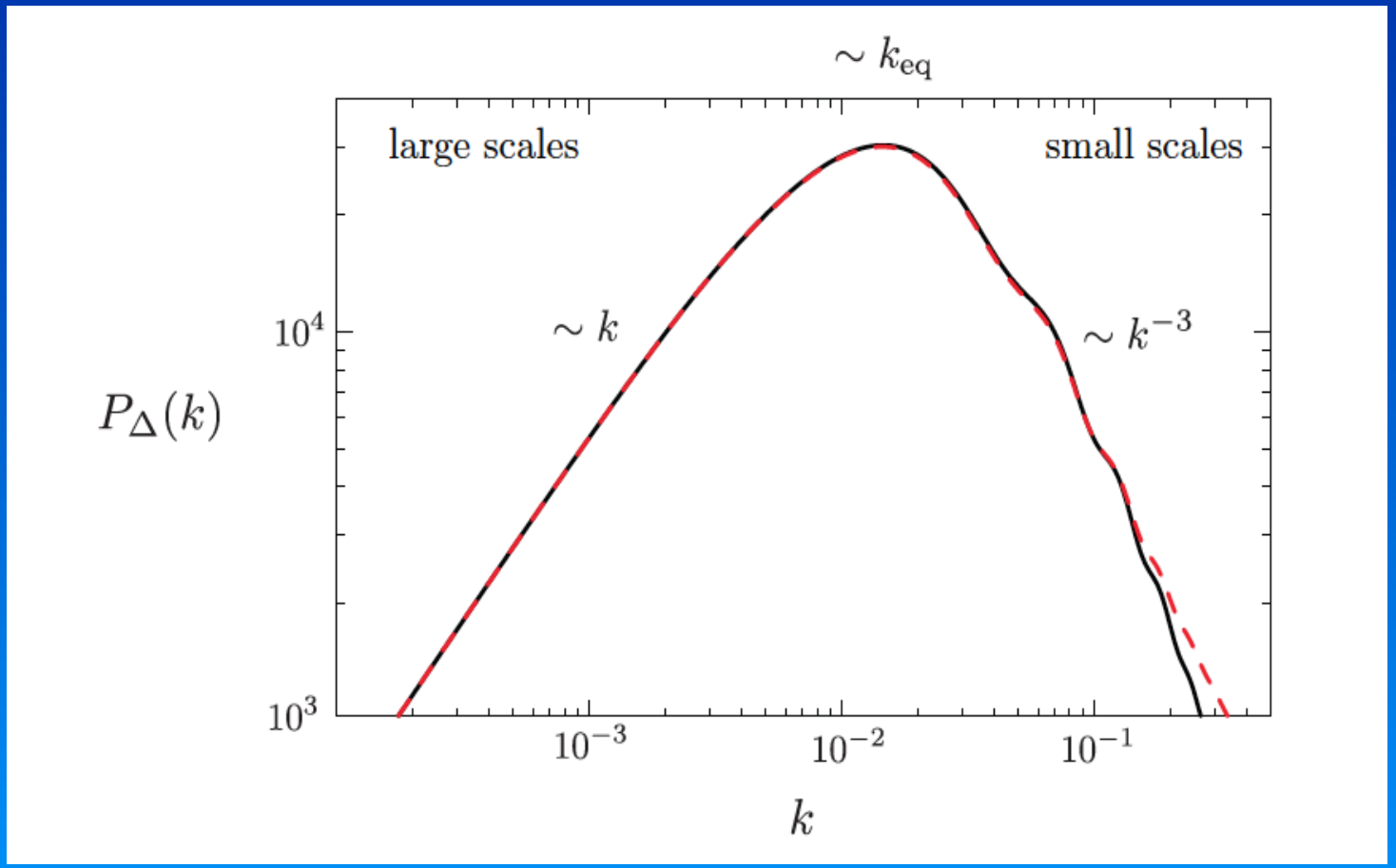


Spectre de puissance



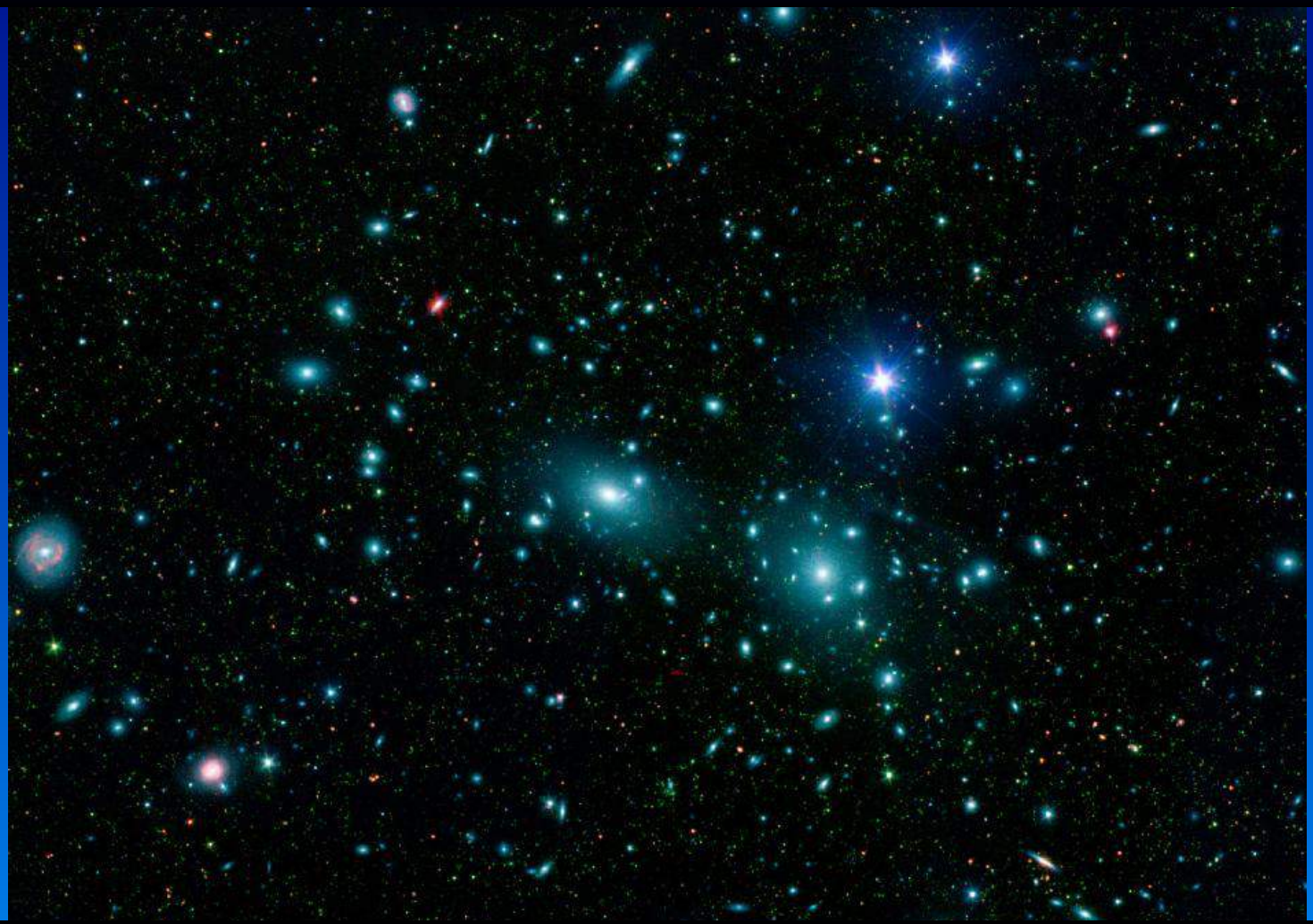


Interprétation dans le cadre ΛCDM



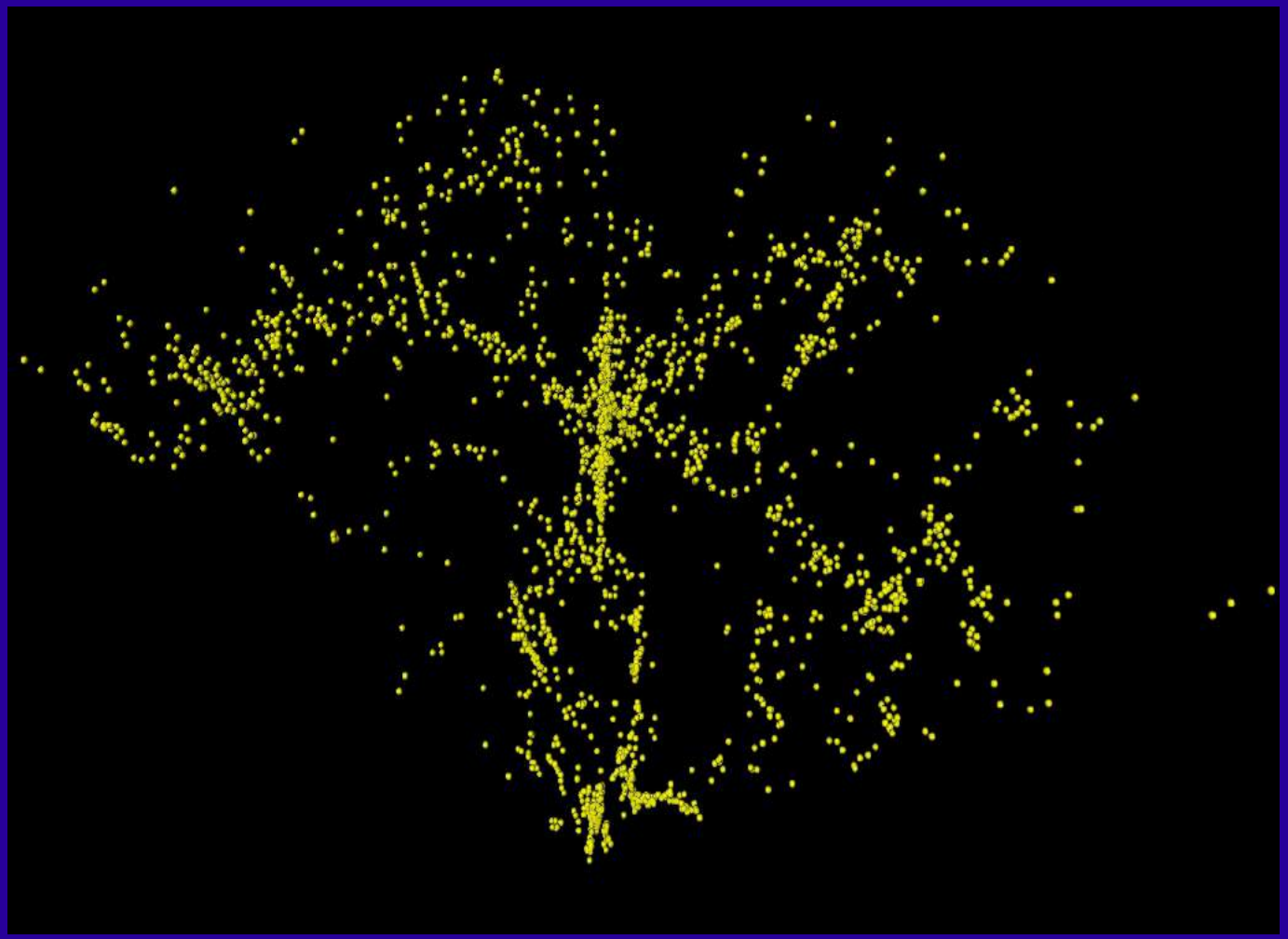
Les amas de galaxies

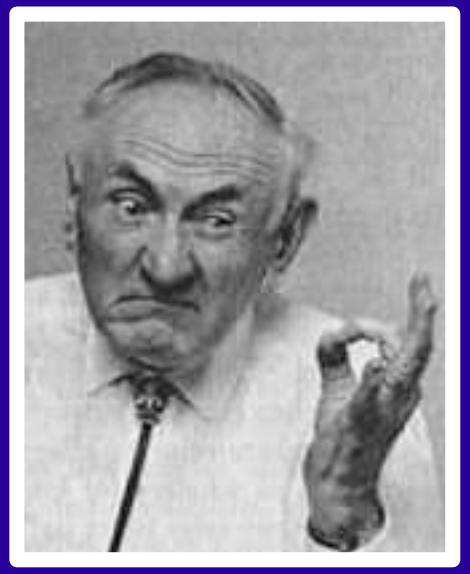
Les amas de galaxies...



...vus en opique.

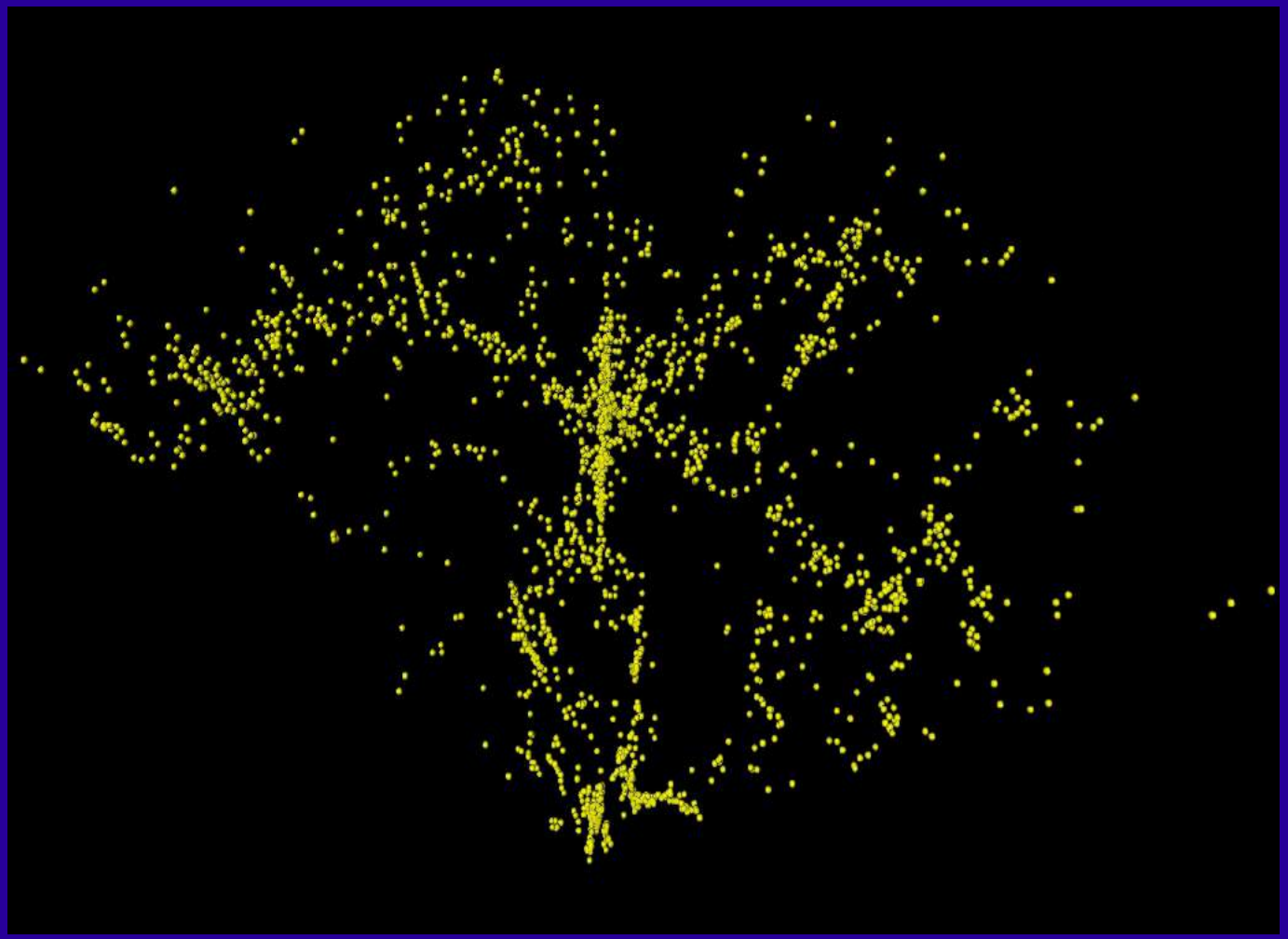
Les amas de galaxies...

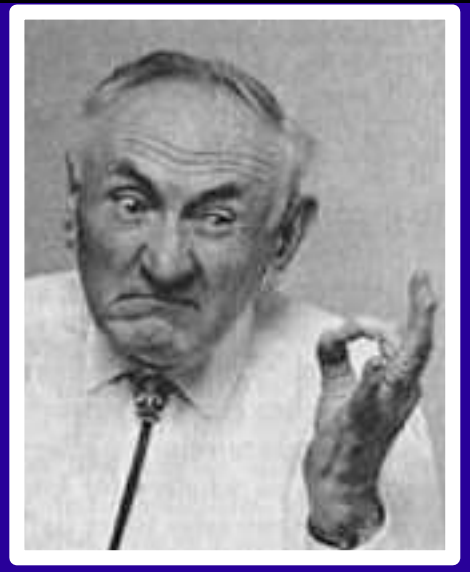




...détectés par les vitesses de dispersion.

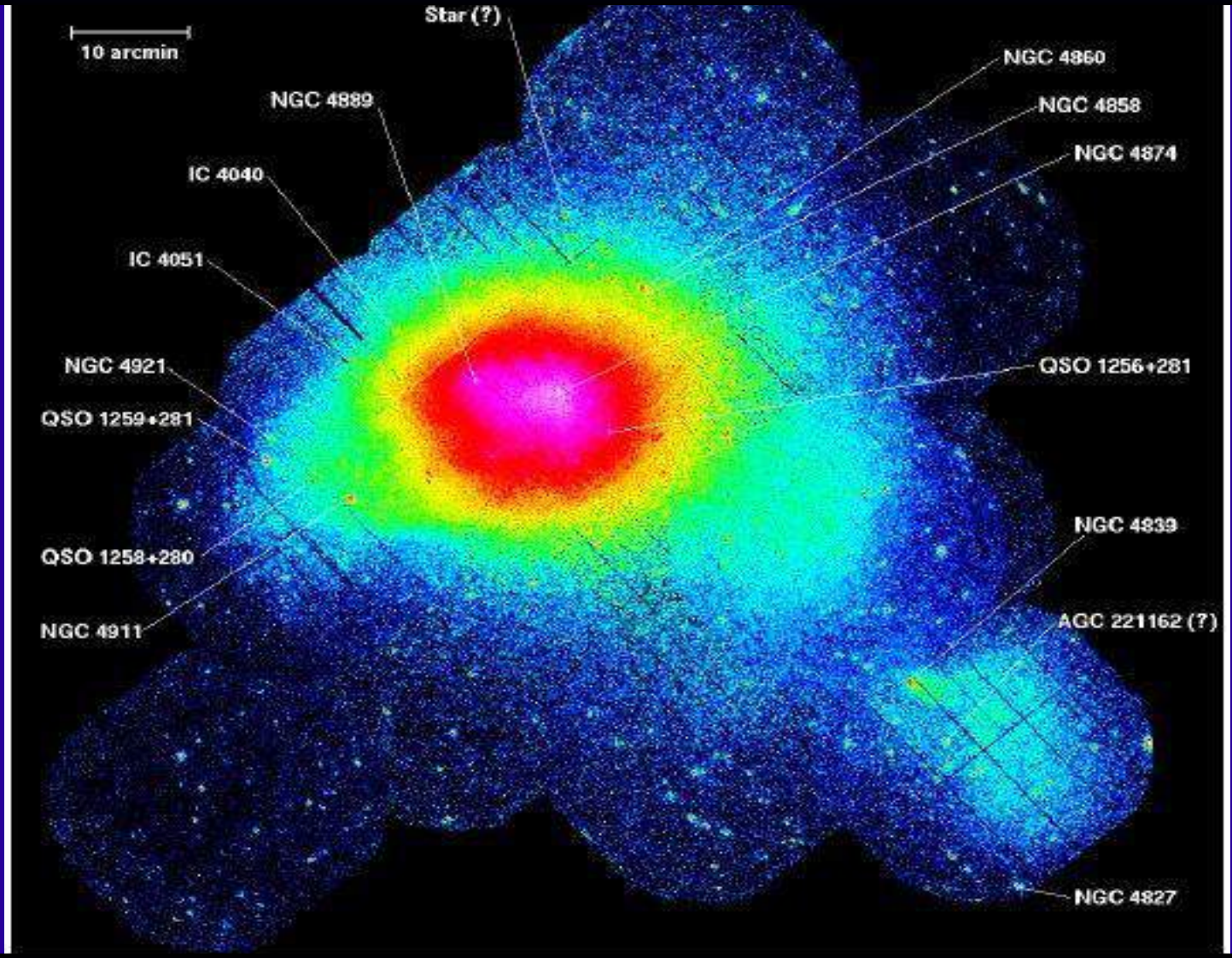
La matière noire dans les amas de galaxies...





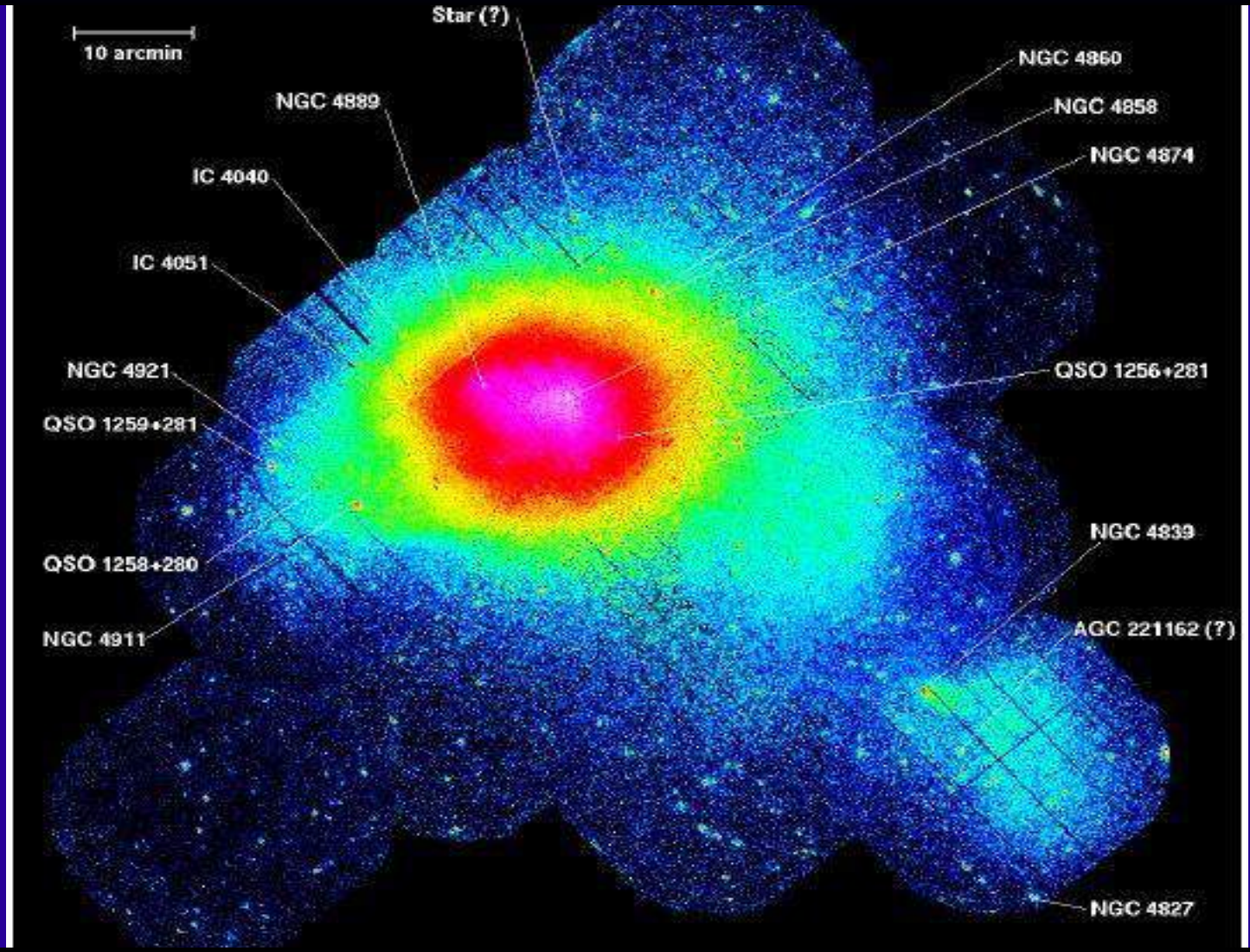
...détectés par les vitesses de dispersion.

La matière noire dans les amas de galaxies...



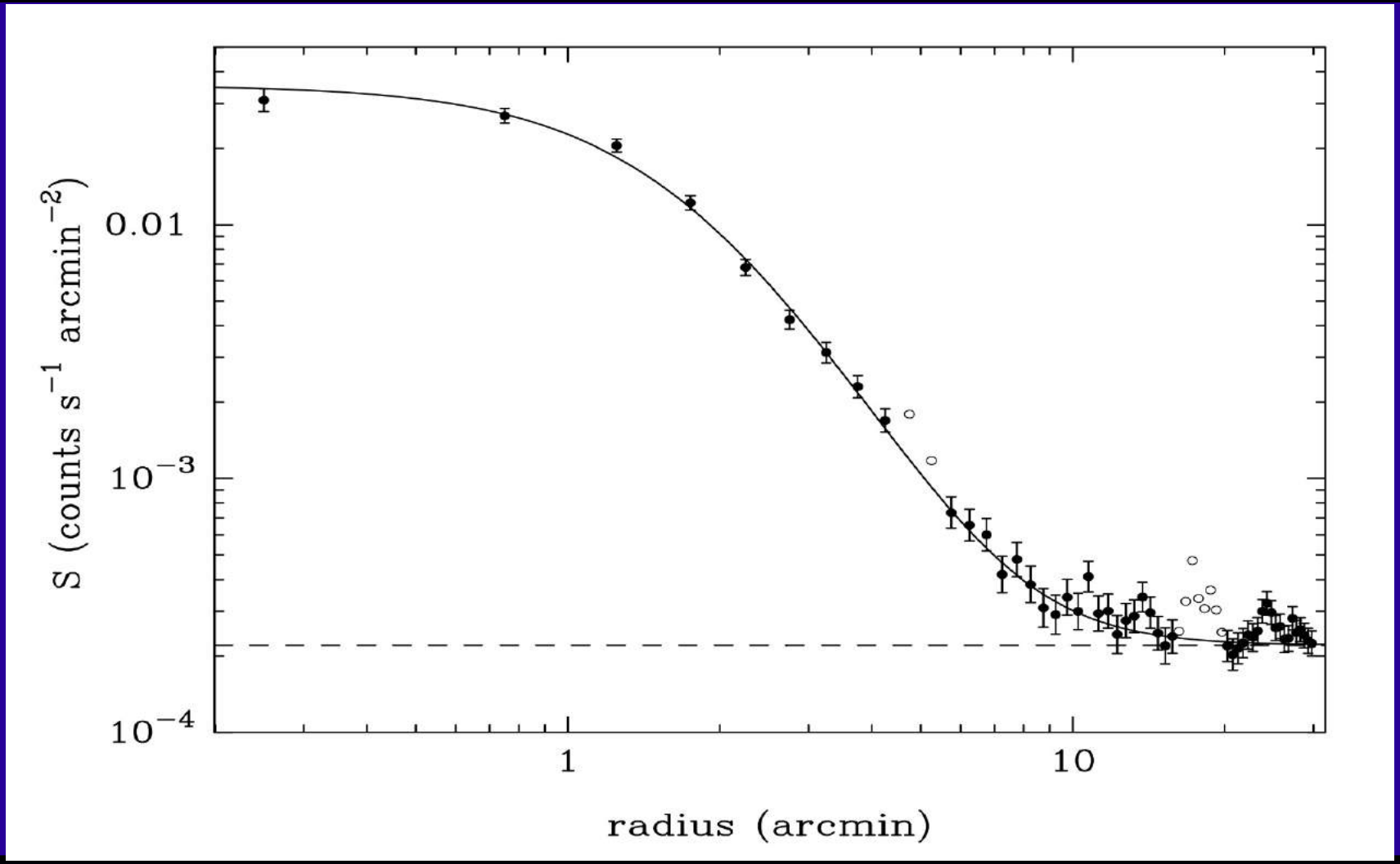
...visualisée par l'émission de rayons X.

La matière baryonique dans les amas de galaxies...



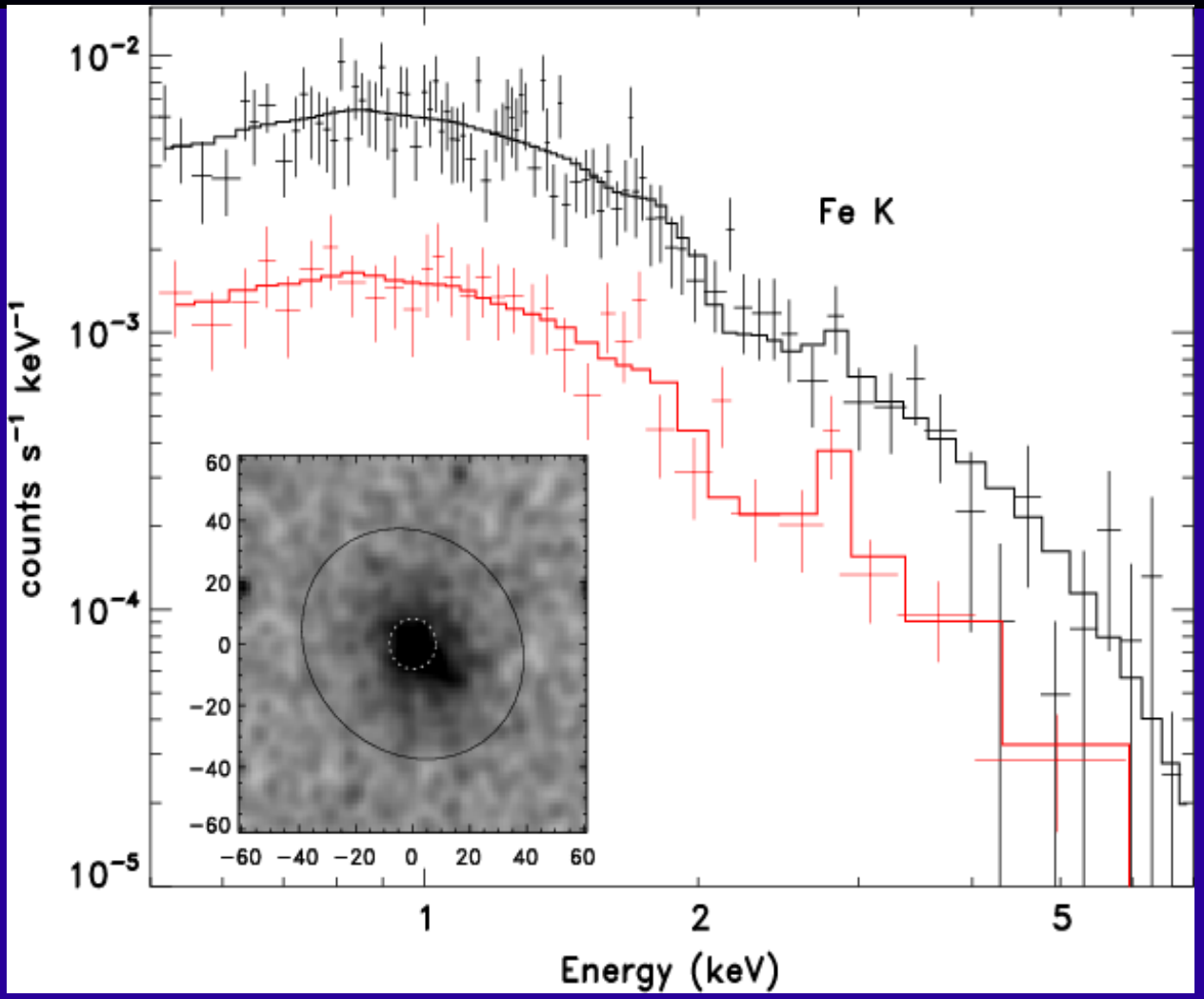
...visualisée par l'émission de rayons X.

La matière baryonique dans les amas de galaxies...



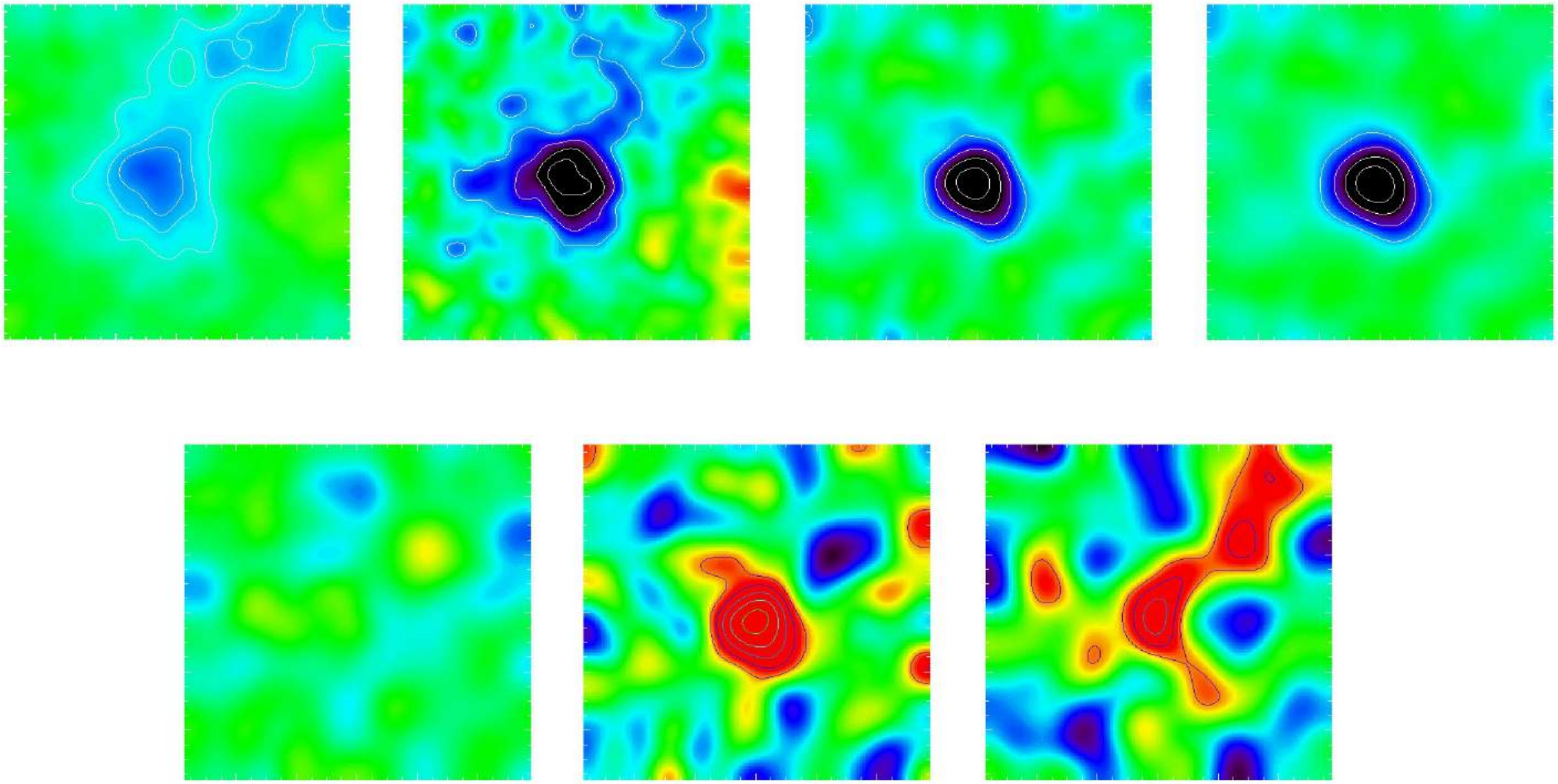
...visualisée par l'émission de rayons X.

La masse des amas de galaxies...



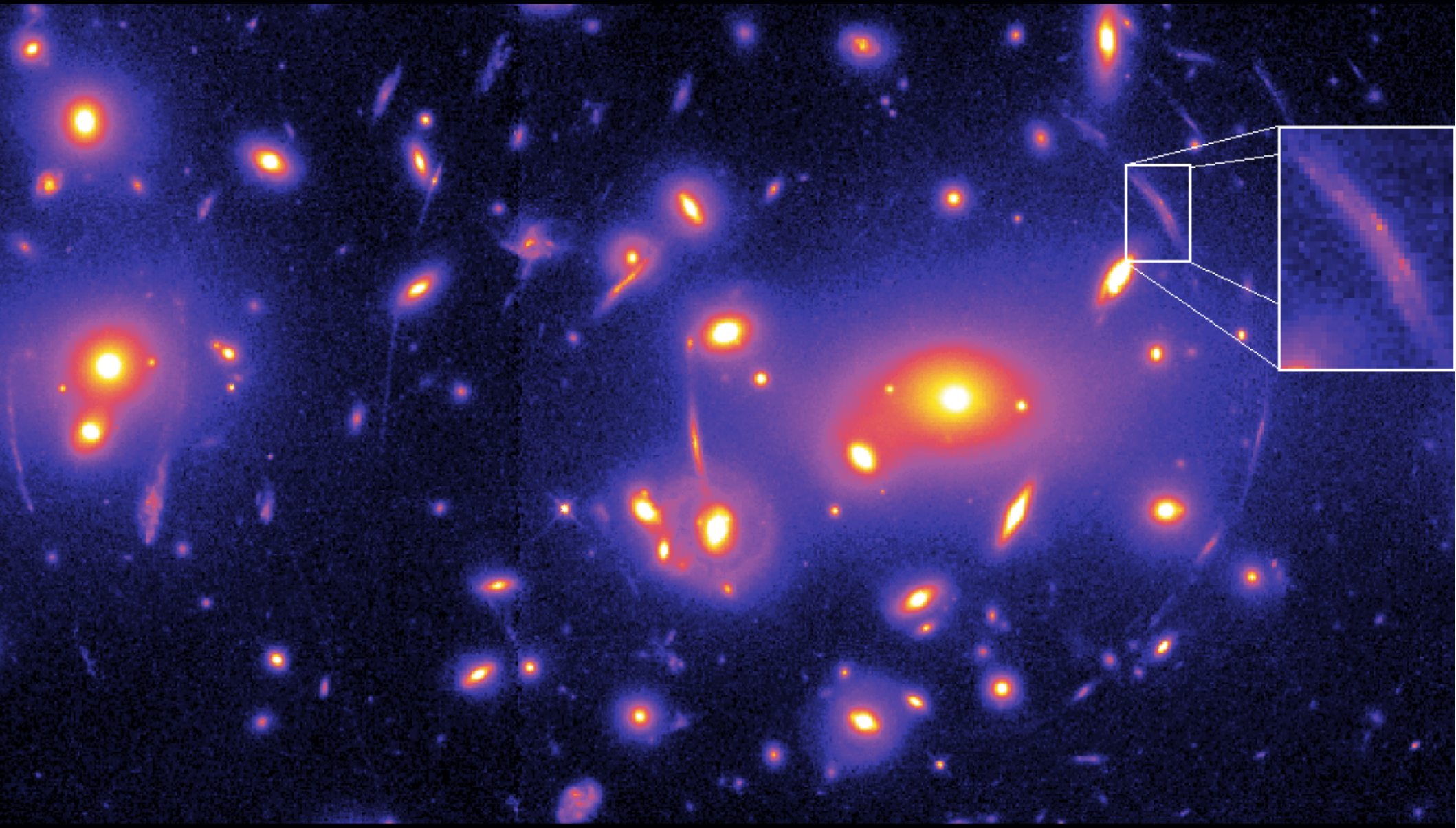
...visualisée par l'émission de rayons X.

Les amas de galaxies...



...vus en micro-ondes (effet SZ).

La matière noire dans les amas de galaxies...



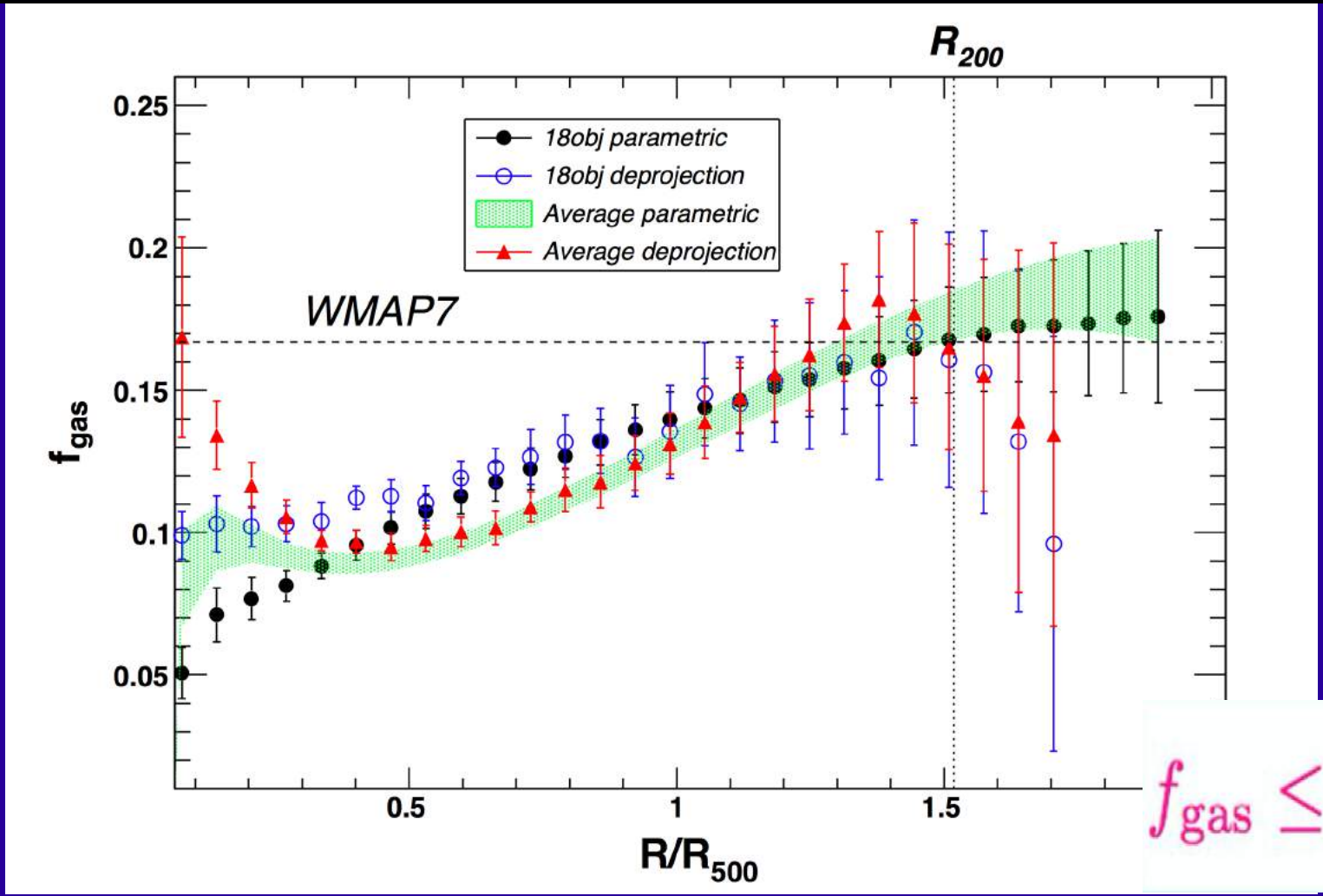
...visualisée par les arcs gravitationnels.

Les amas de galaxies...

- Masse totale des amas
- Masse stellaire des amas
- Masse de gaz des amas
- (Métaux ...)

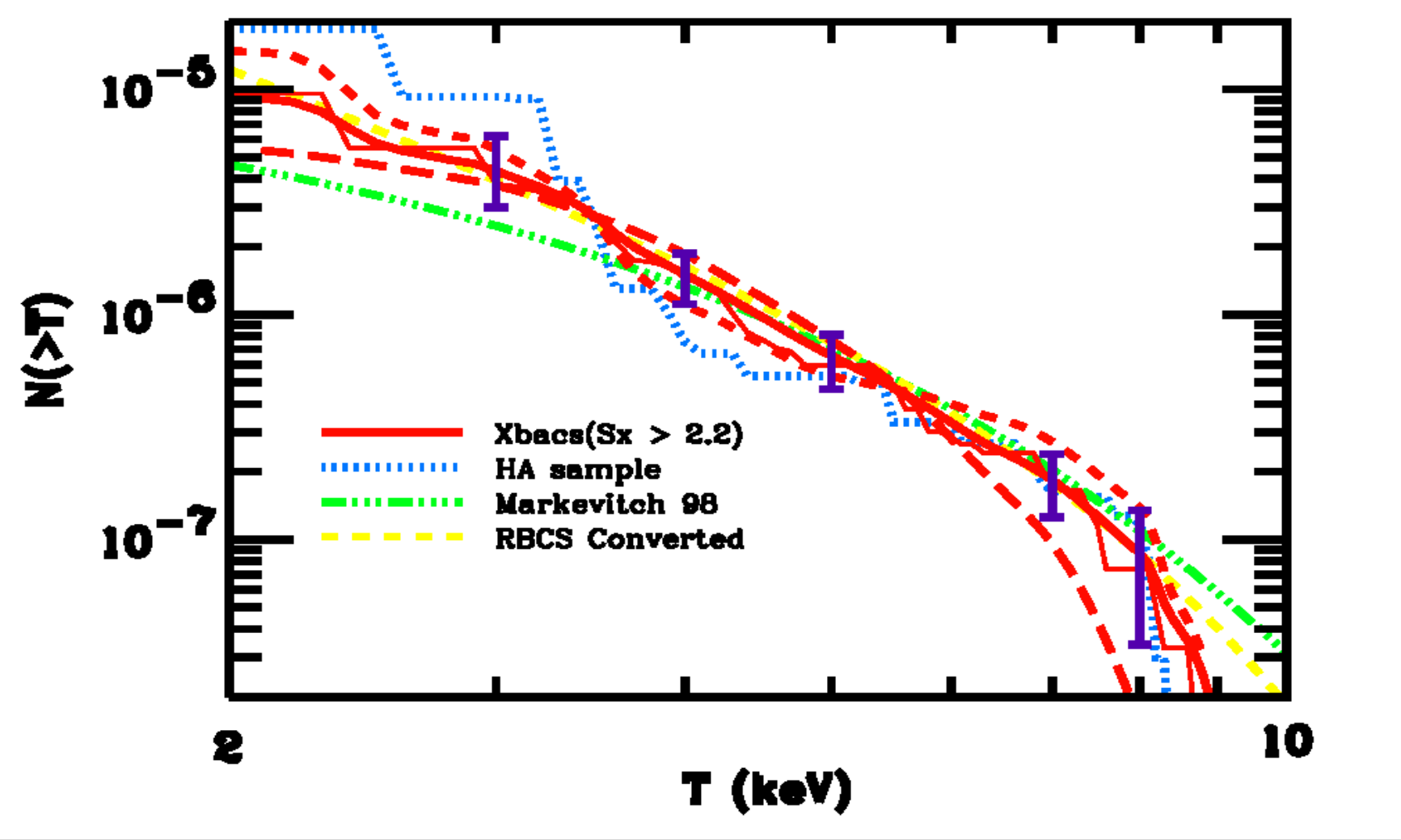
...objets uniques pour la cosmologie.

Fraction de baryons



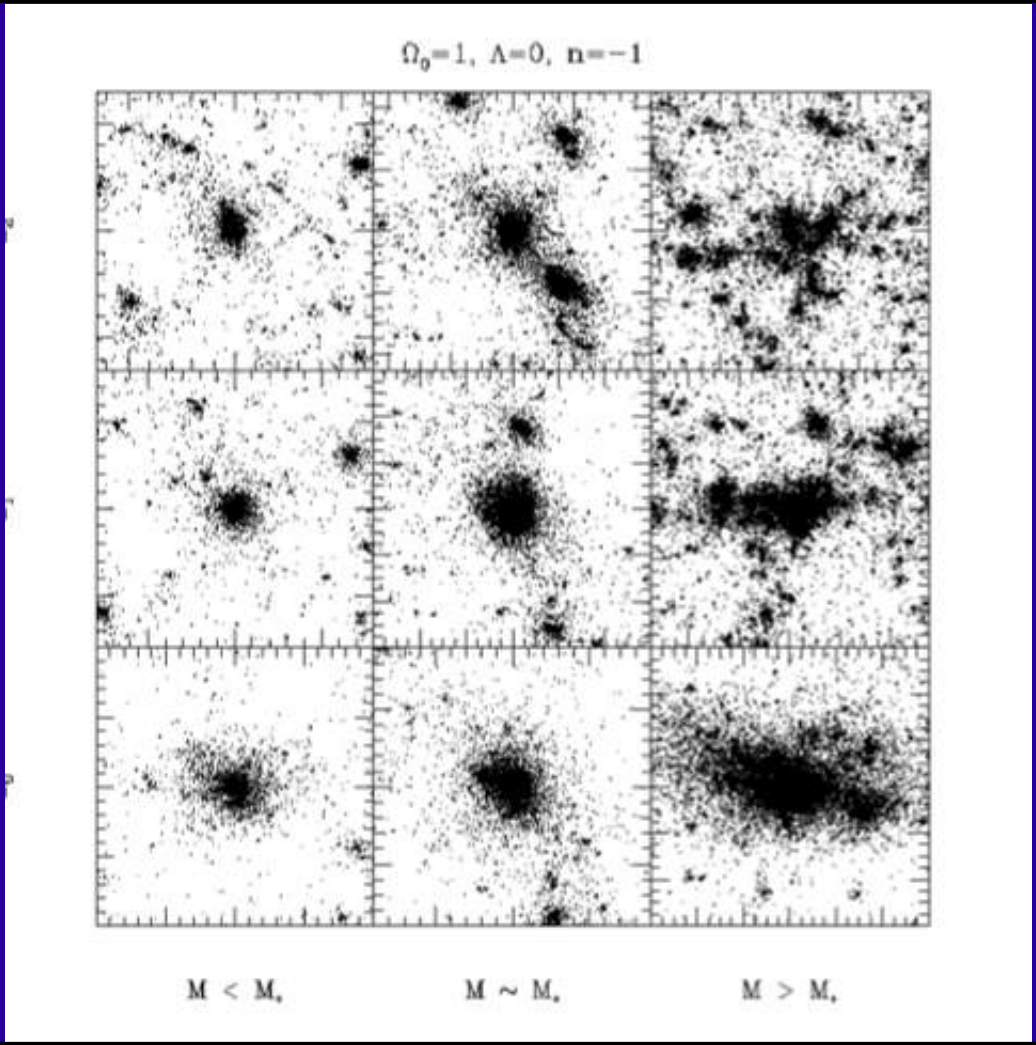
$$f_{\rm gas} \leq f_{\rm B} \equiv \frac{\Omega_{\rm B}}{\Omega_{\rm M}}$$

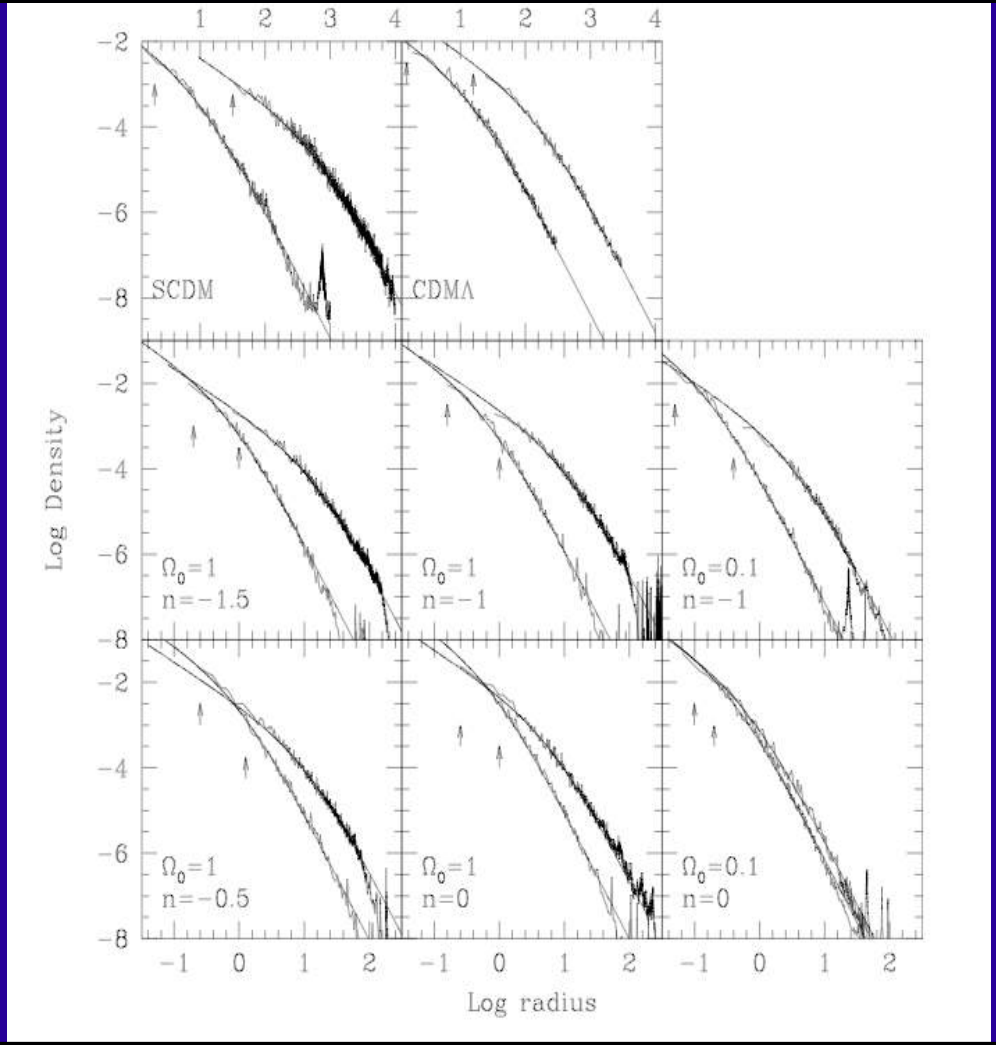
Comptages d'amas de galaxies...



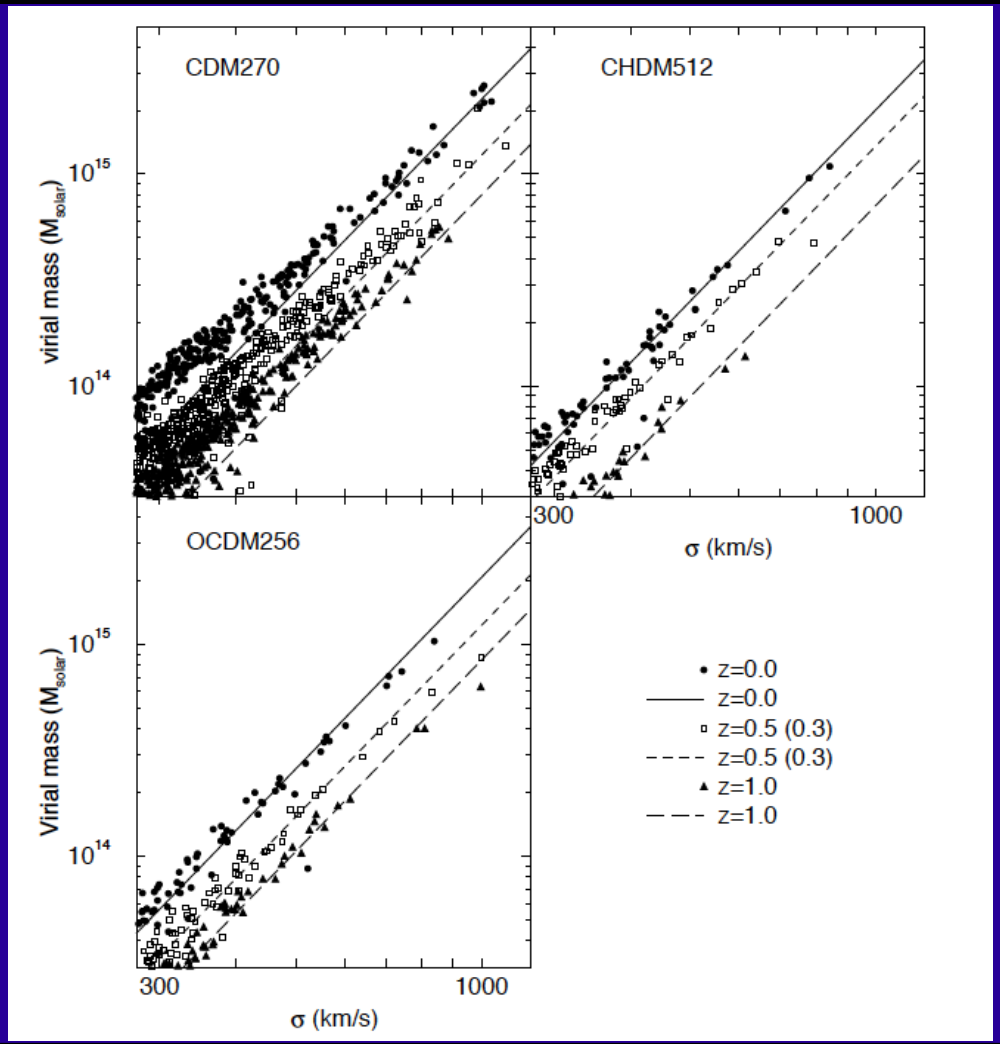
Auto similarité des amas de galaxies...

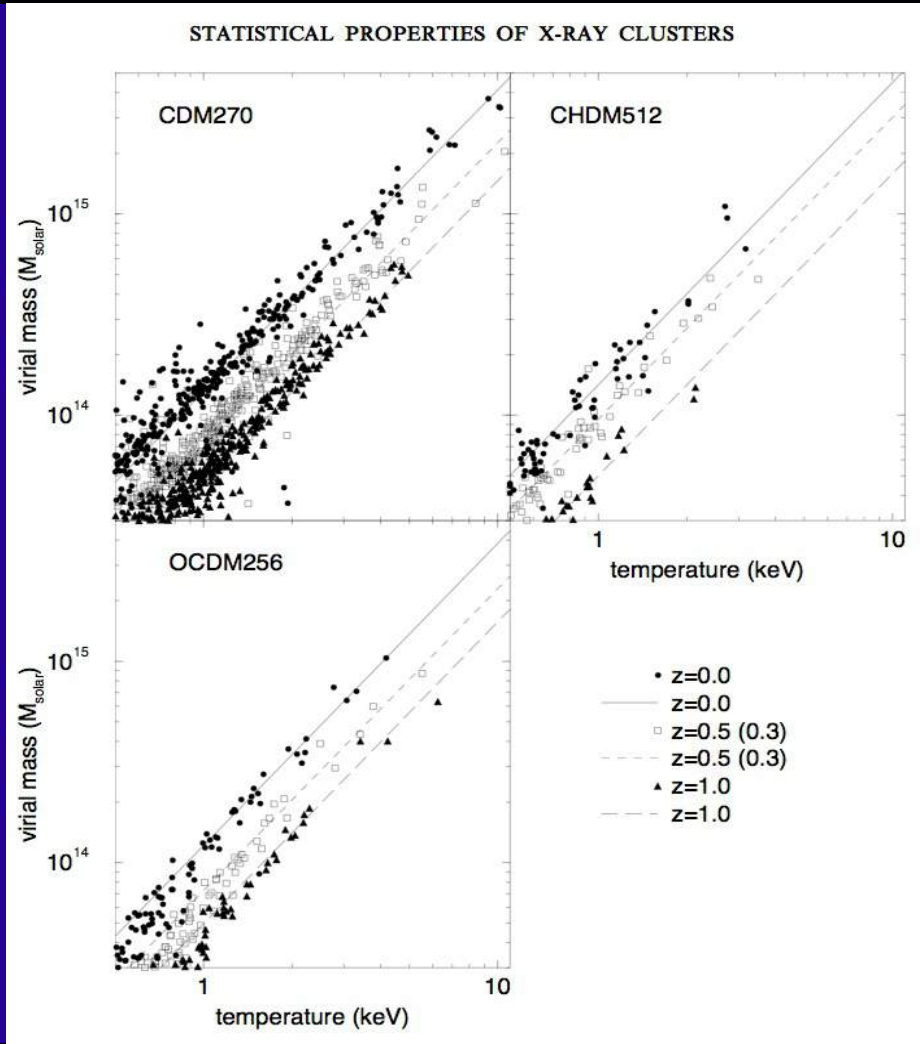
Auto similarité des amas de galaxies...



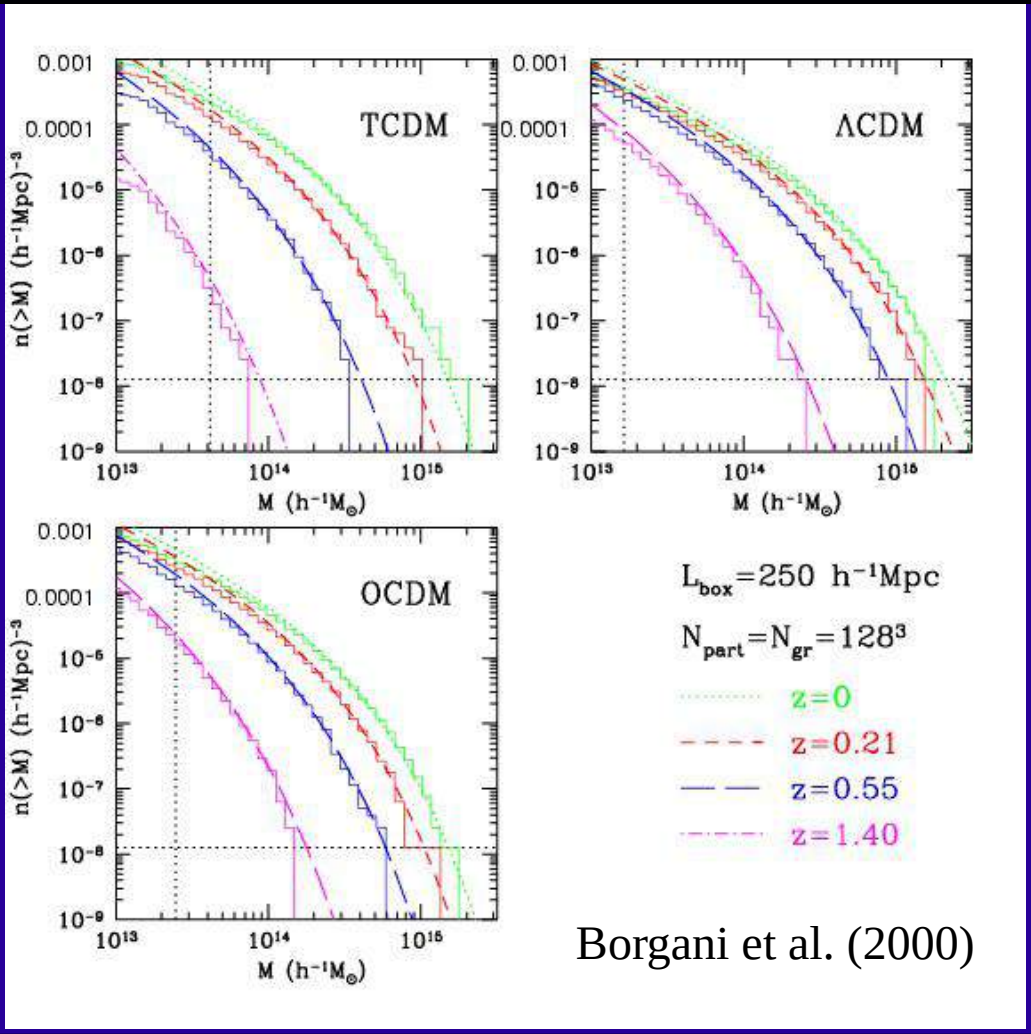


Auto similarité des amas de galaxies...

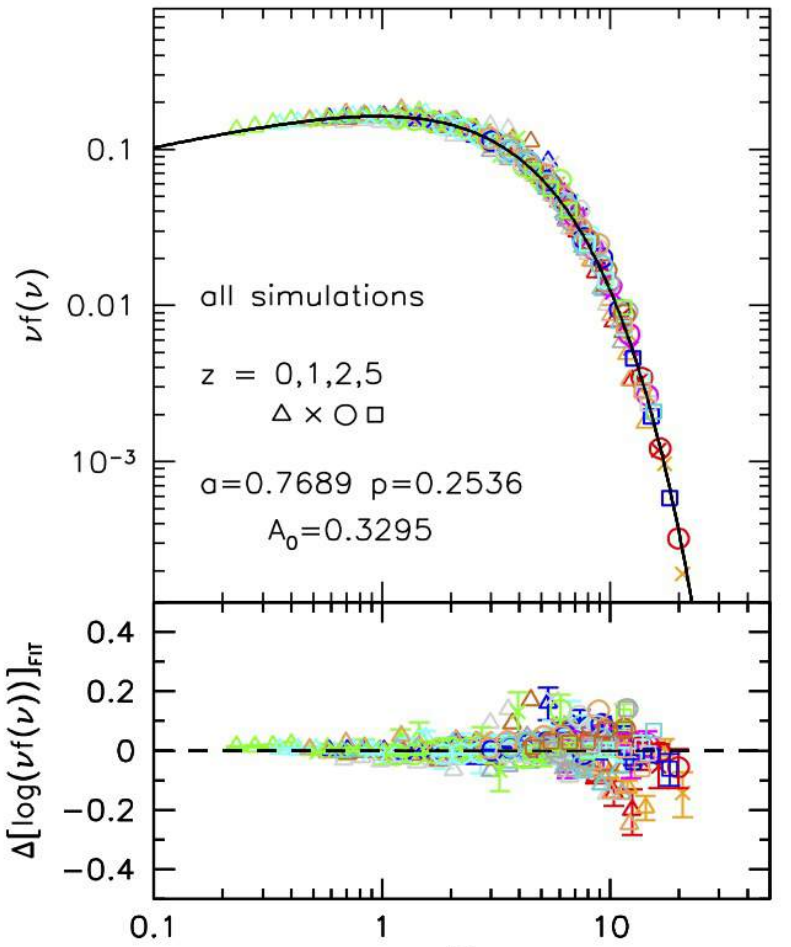




Fonction de masse

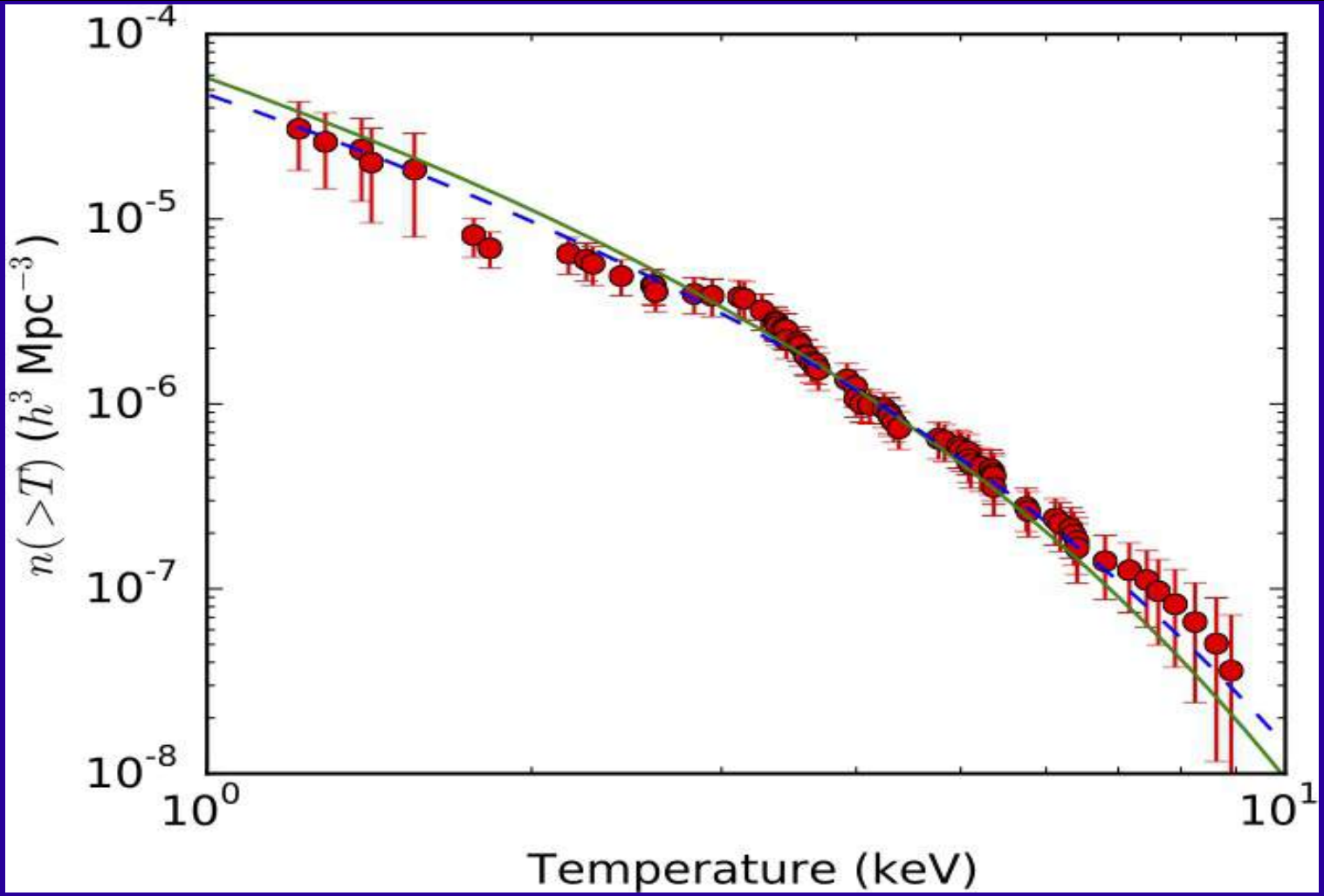


Borgani et al. (2000)

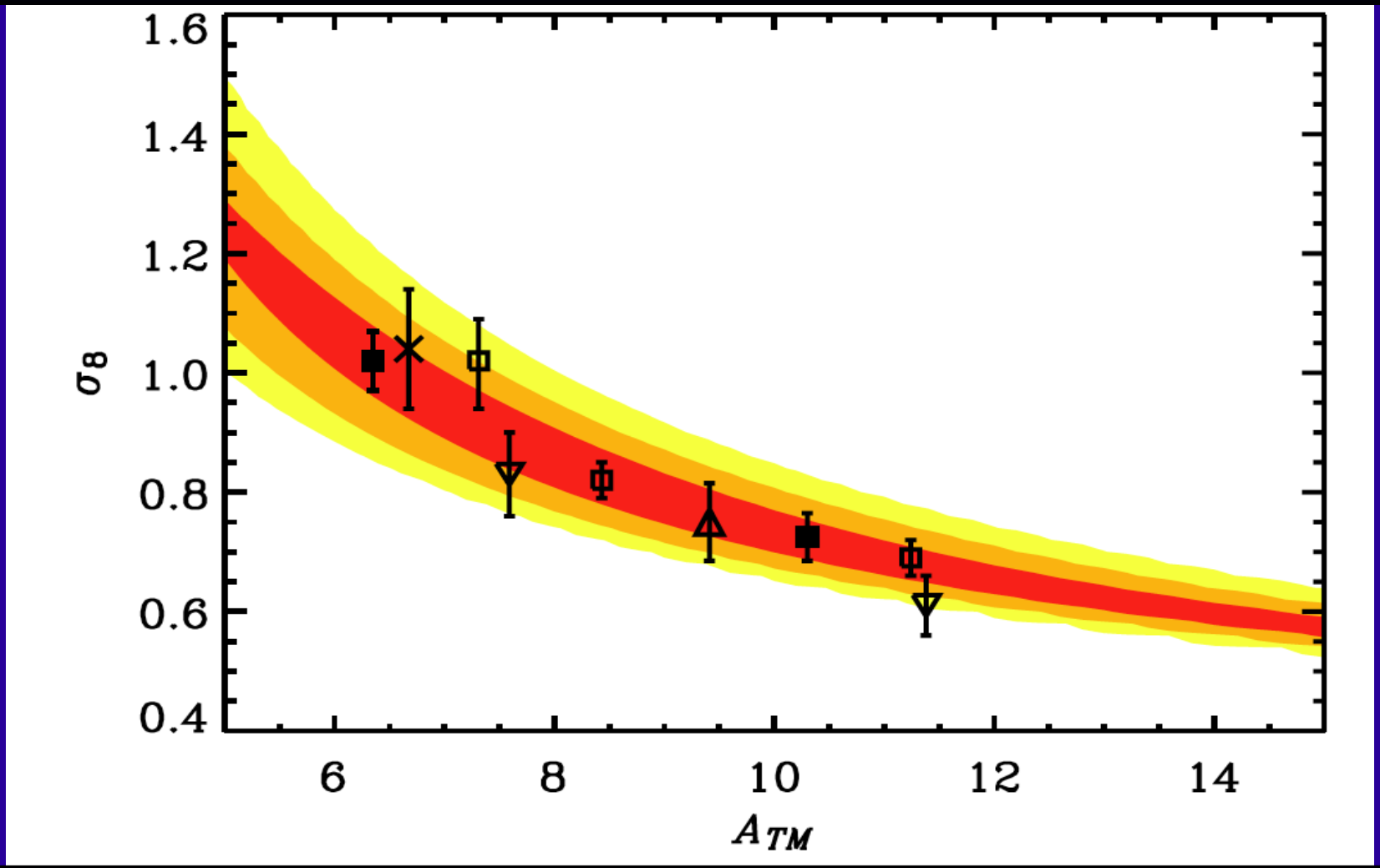


Despali et al. (2015)

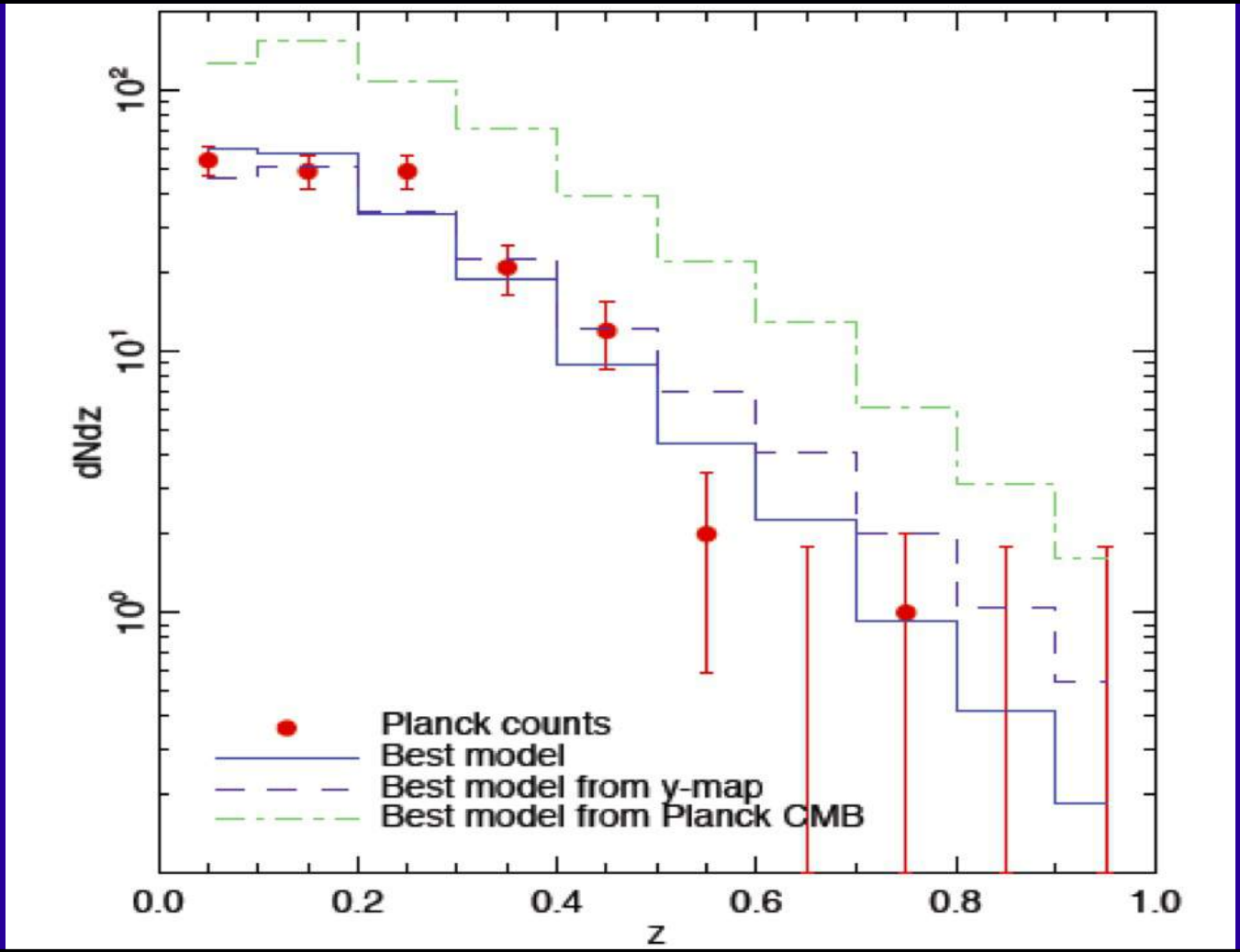
Fonction de température des amas X



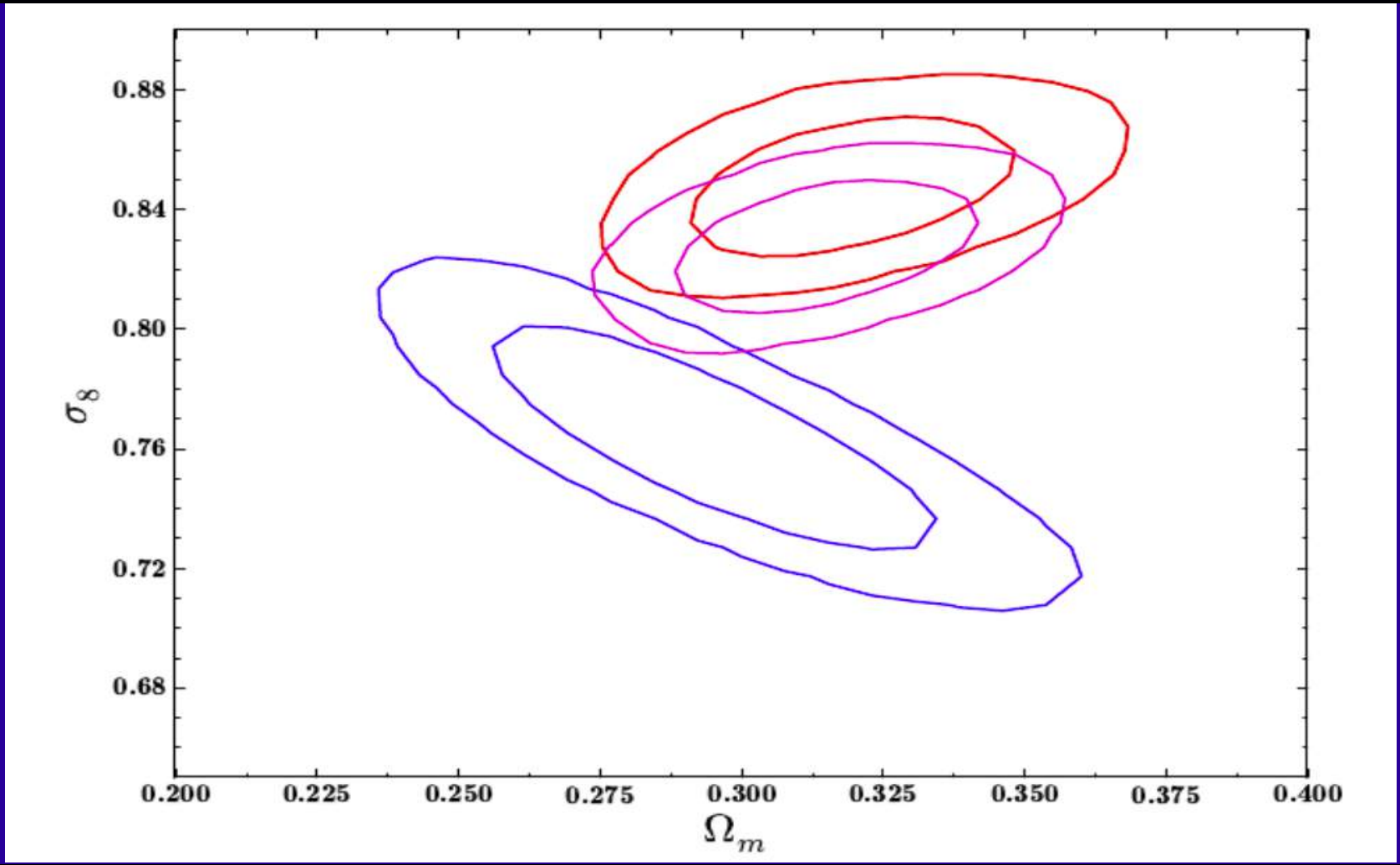
Fluctuations de matière



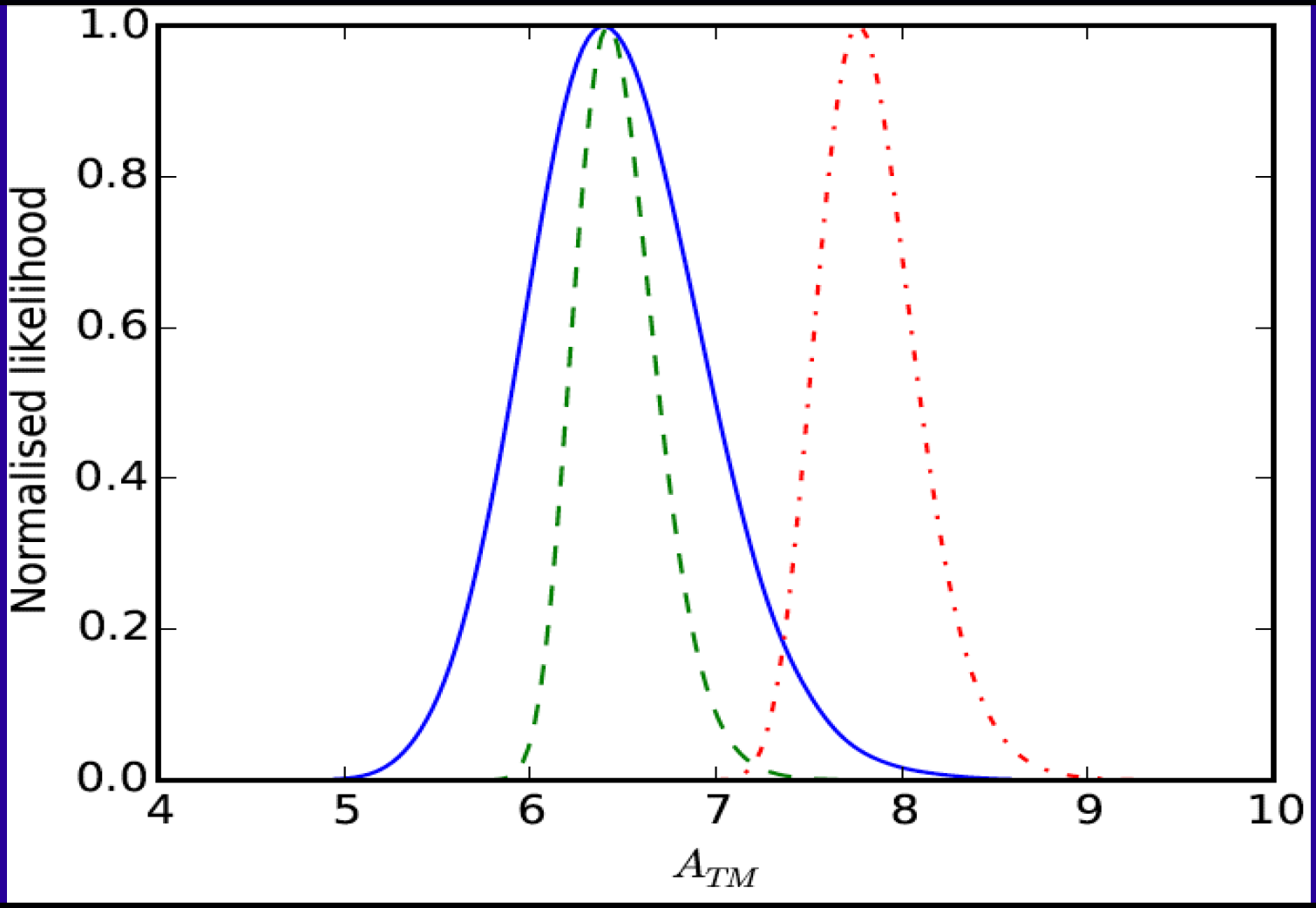
« Tension » Planck-CMB/Planck-Amas



« Tension » Planck-CMB/Planck-Amas



No-Tension ? Planck-CMB/Planck-Amas



Conclusions

► L'étude de la structure de l'Univers à grande échelle est une question fondamentale en cosmologie.

Les observations actuelles de la distribution des galaxies complètent les informations du FDC

Les amas, structures non-linéaires, ont un potentiel complémentaire spécif que