Sur les traces de l'énergie sombre et de la masse manquante dans l'univers

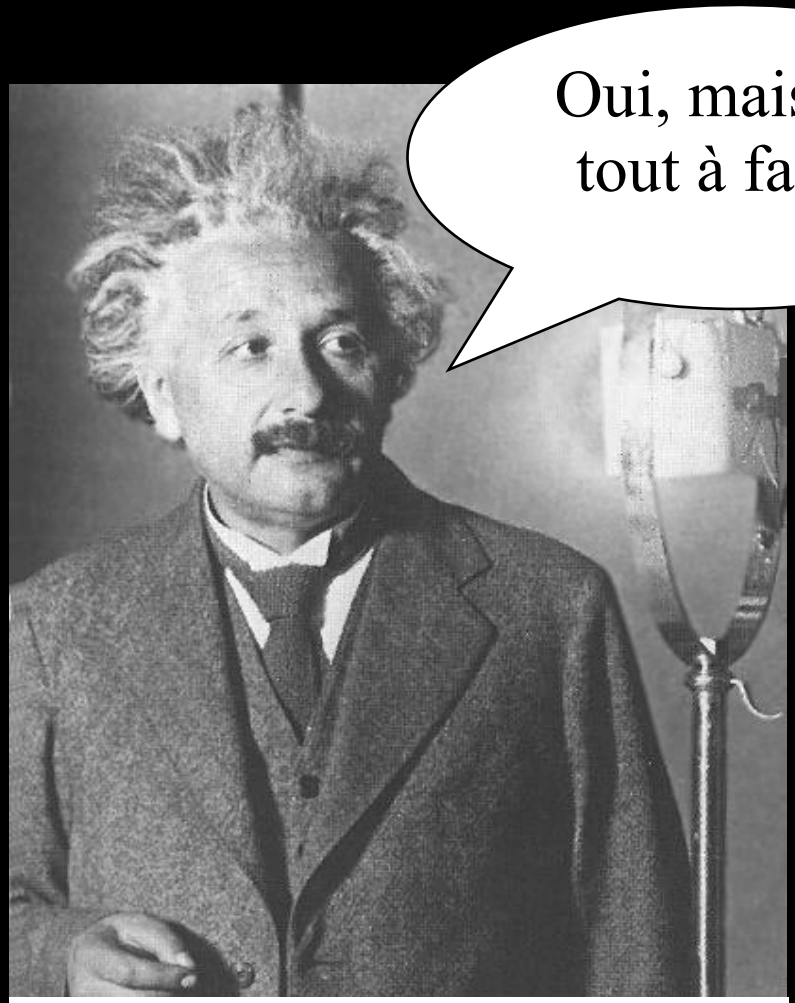
Steve Torchinsky
Observatoire de Paris

Théorie de la gravitation

Isaac Newton
1687

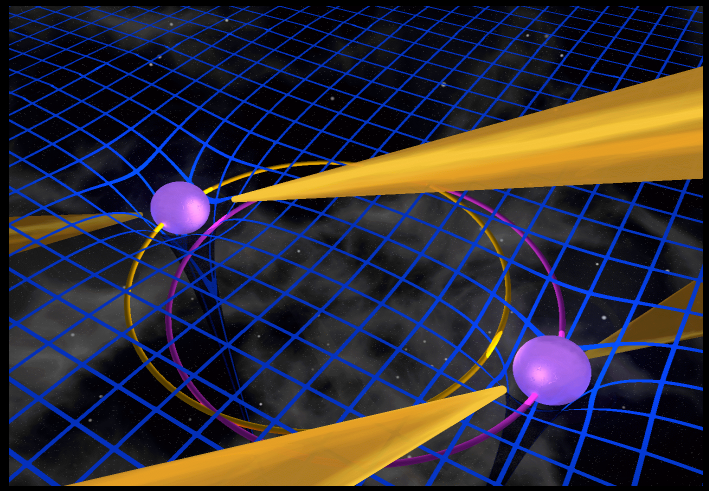
La gravitation est une ***force*** entre deux corps

Théorie de la gravitation



Albert Einstein
1915

Isaac Newton. Painting by Jean-Leon Huens, © National Geographic Society.

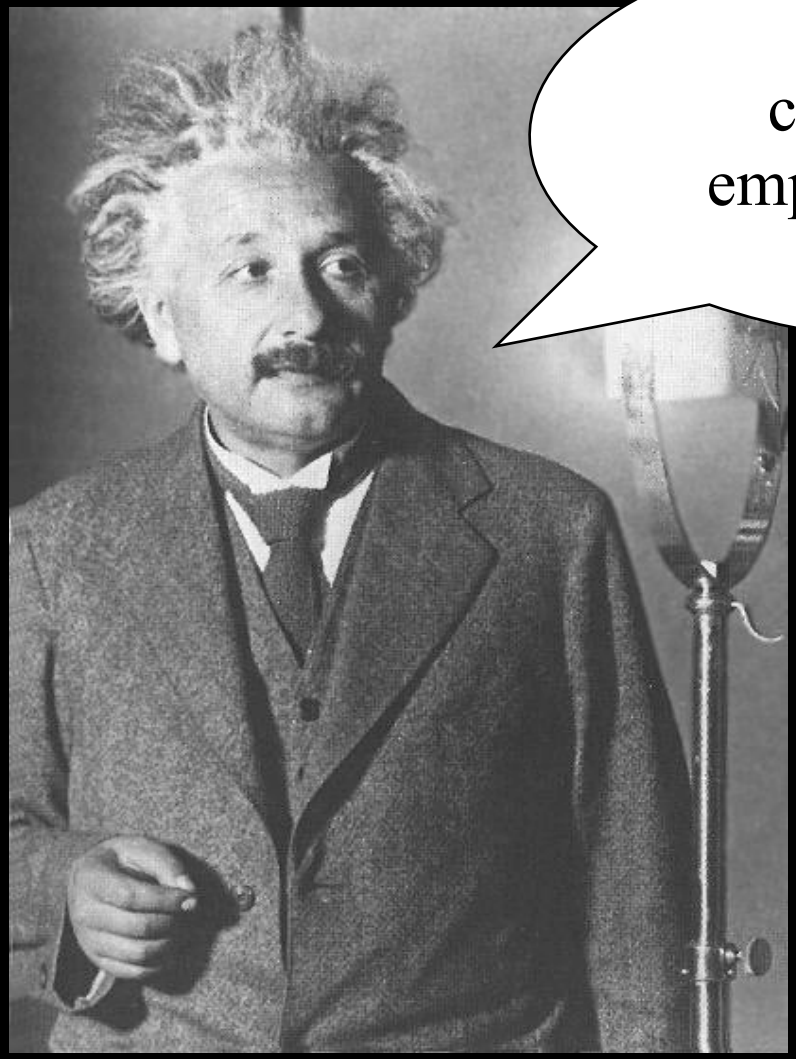


La gravitation est un effet de la ***géometrie*** de temps-espace

$$R_{\mu\nu} + \frac{1}{2} g_{\mu\nu} R = \frac{8\pi G}{c^4} T_{\mu\nu}$$

L’univers semble statique

La constante cosmologique

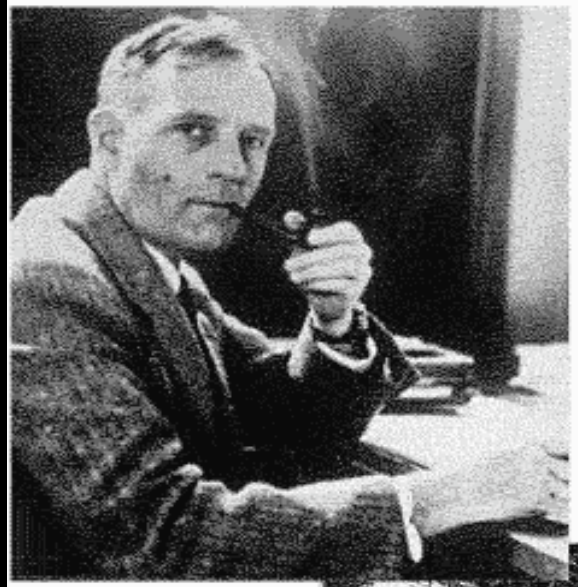


J'ajoute une constante pour empêcher l'univers d'imploser.

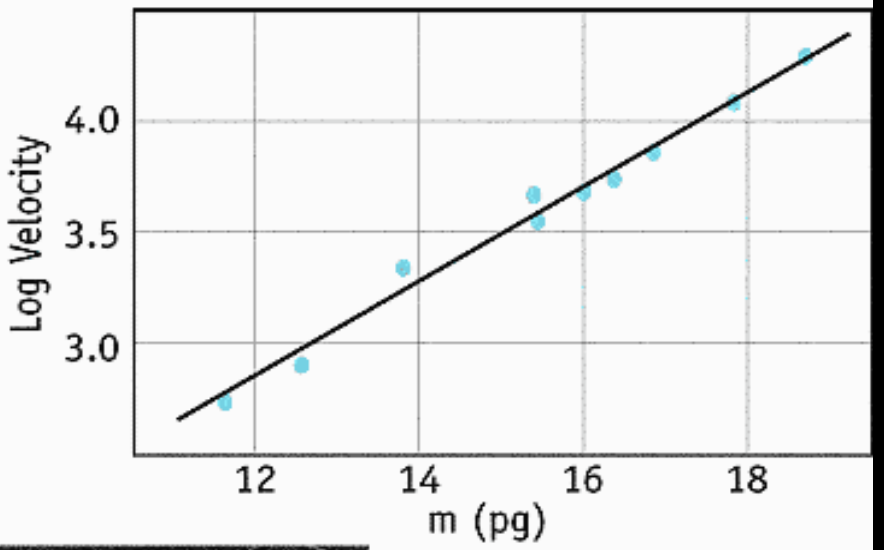
$$R_{\mu\nu} + \frac{1}{2} g_{\mu\nu}(R + \Lambda) = \frac{8\pi G}{c^4} T_{\mu\nu}$$

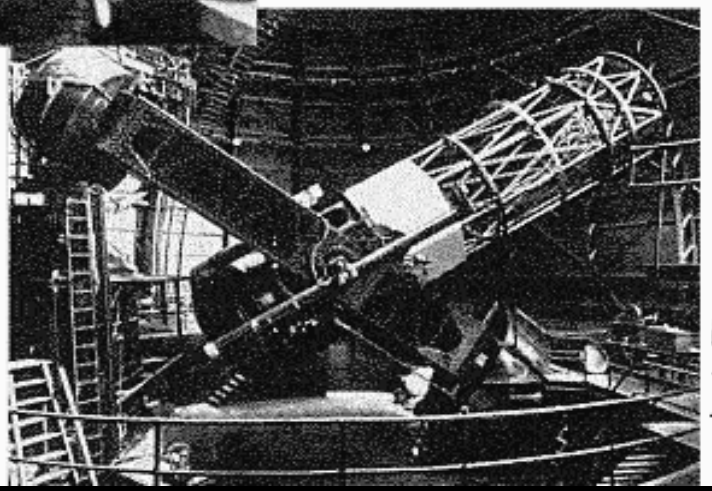
L'univers n'est pas stable !

Discovery of Expanding Universe



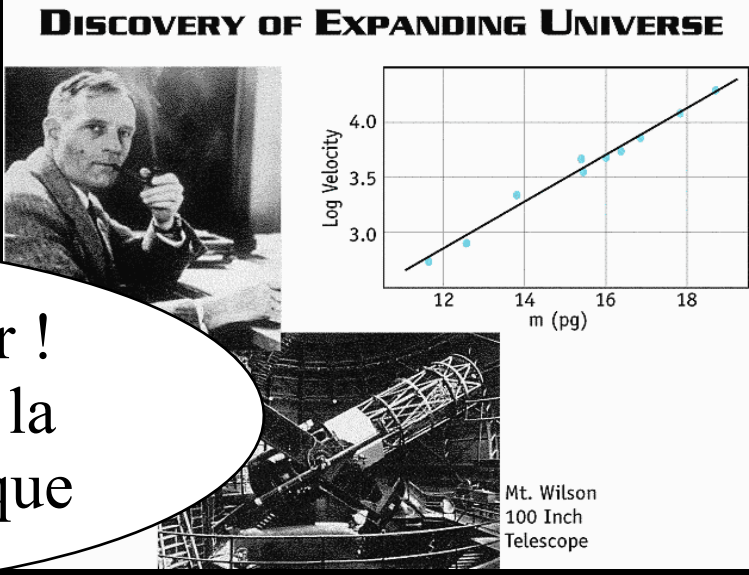
Edwin Hubble
1929

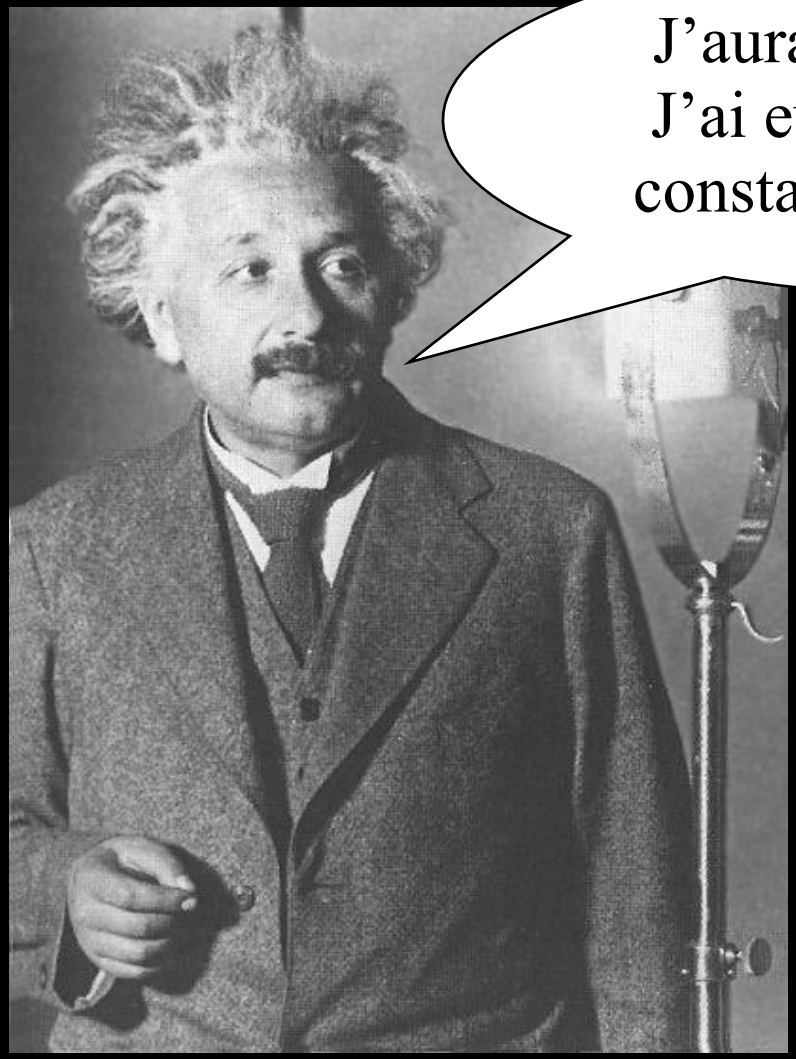




Mt. Wilson
100 Inch
Telescope

Erreur !



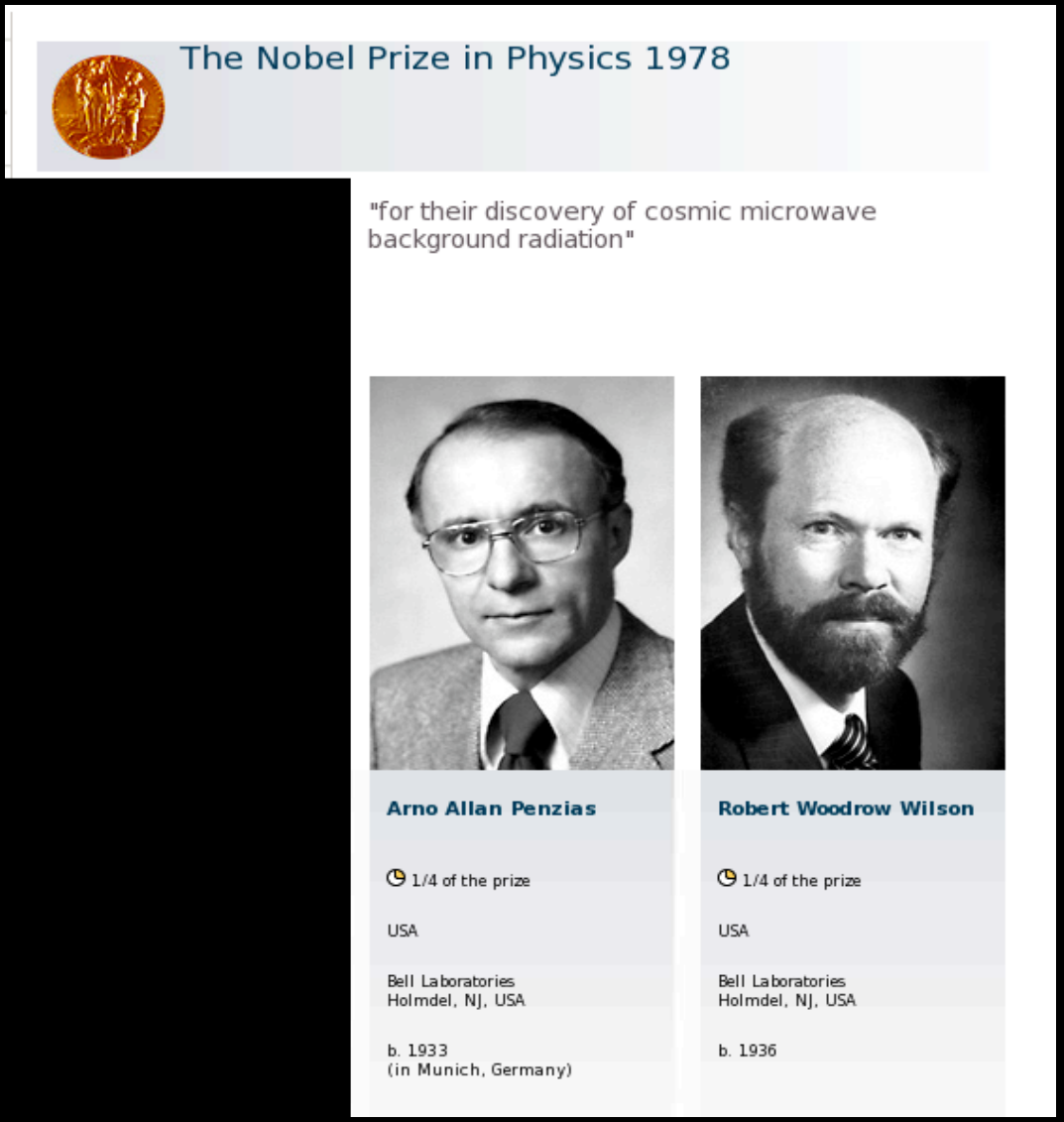


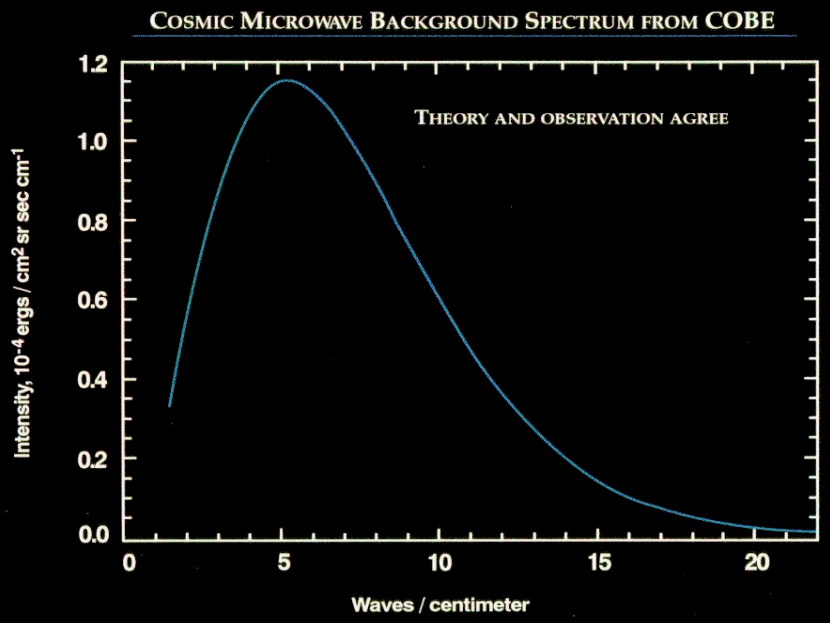
J'aurais pu le prévoir !
J'ai eu tort d'ajouter la constante cosmologique

L'univers est en expansion dû à l'explosion primordiale : le Big Bang

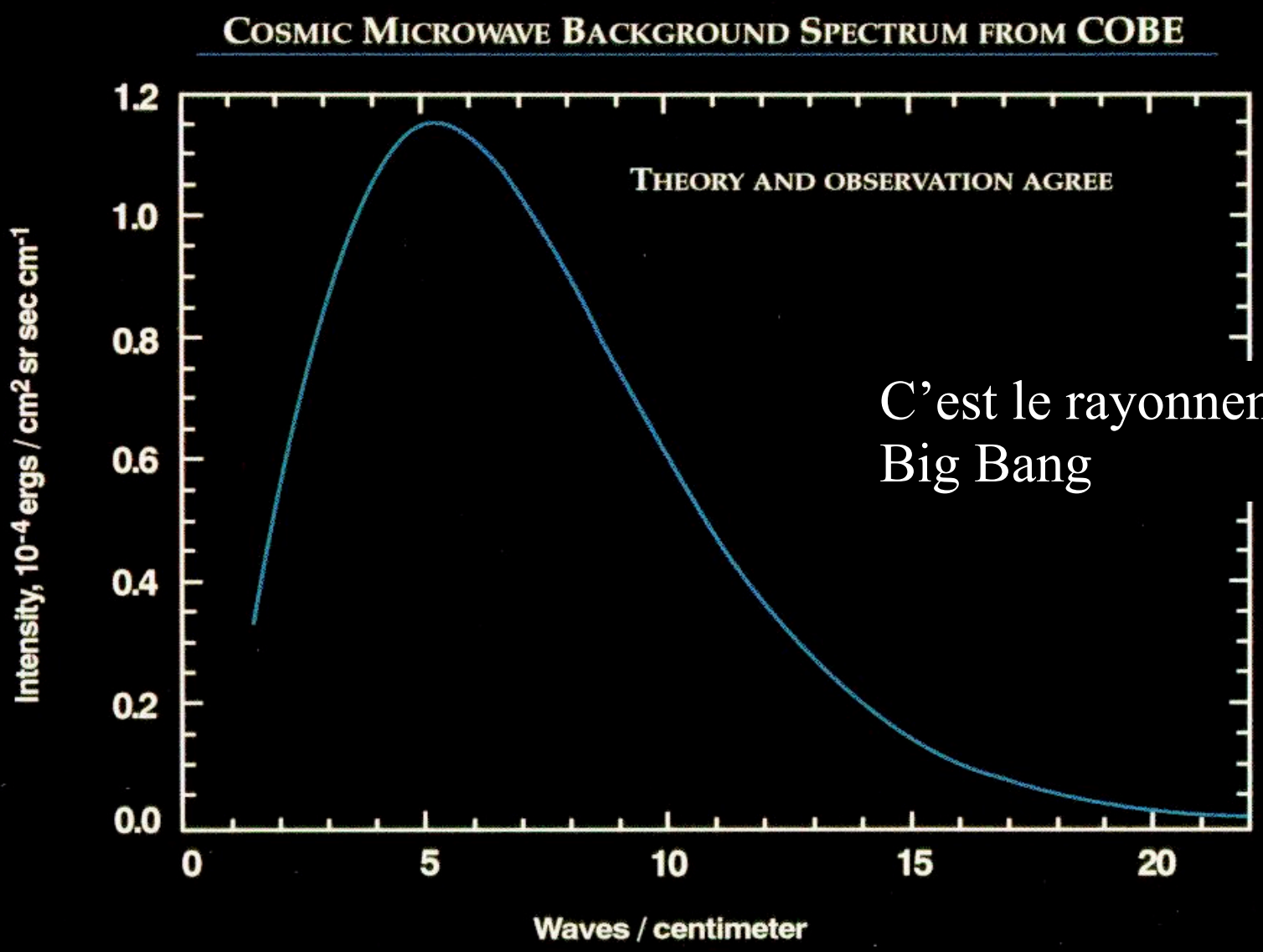
Ce mouvement doit ralentir avec le passage de temps, dû à la force de gravitation.

L'Univers est un four à 2.73K



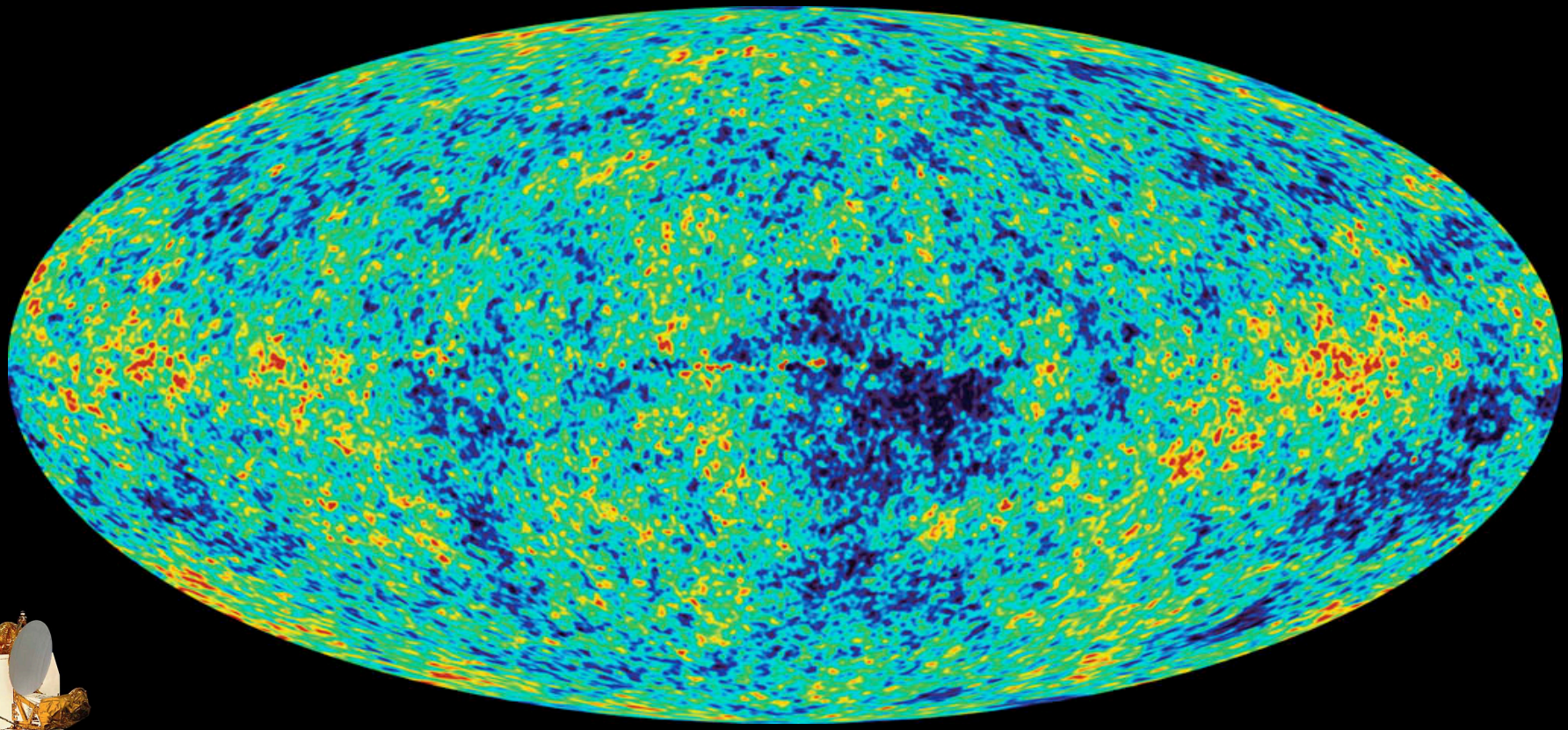


Température du fond cosmologique



C'est le rayonnement du Big Bang

Image du fond cosmologique



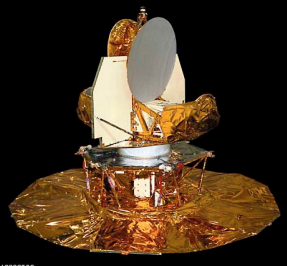
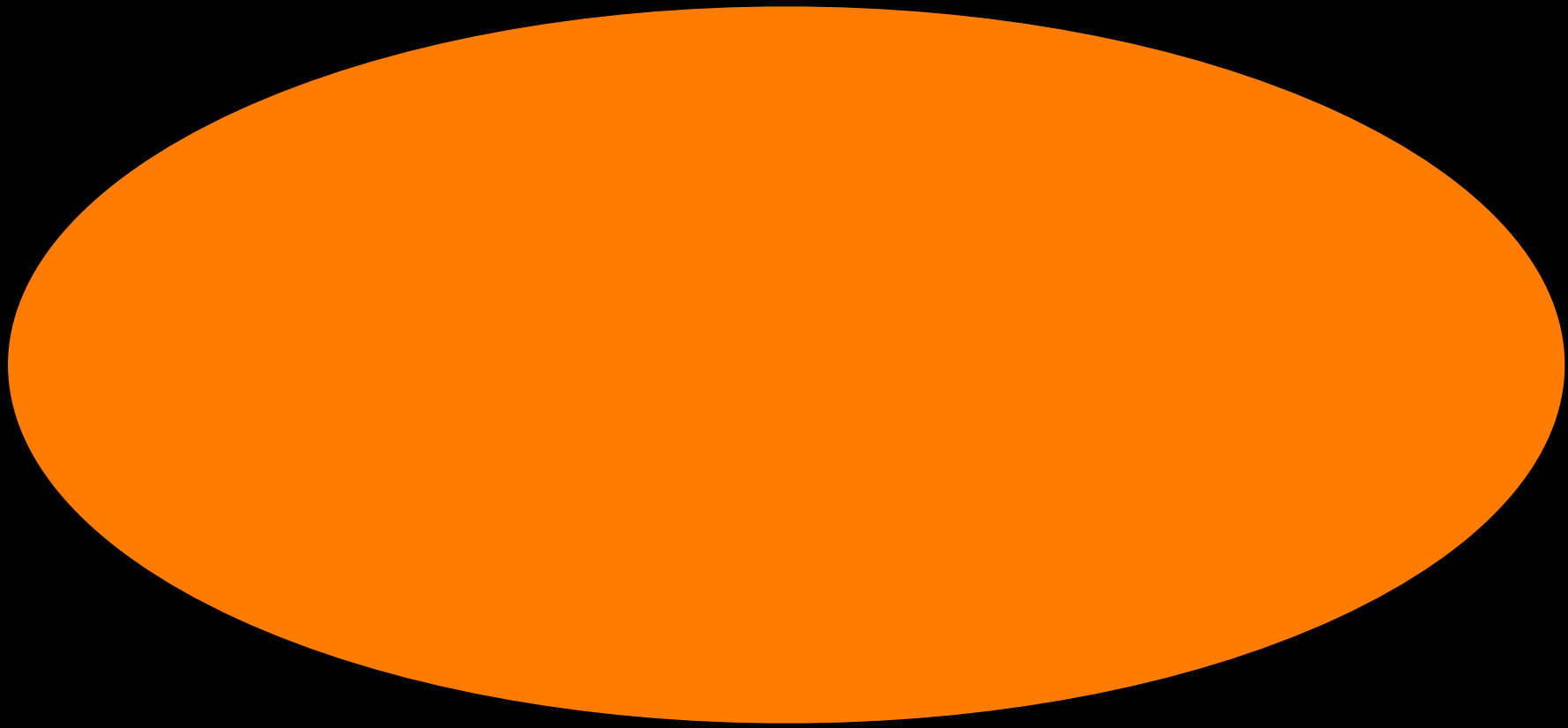
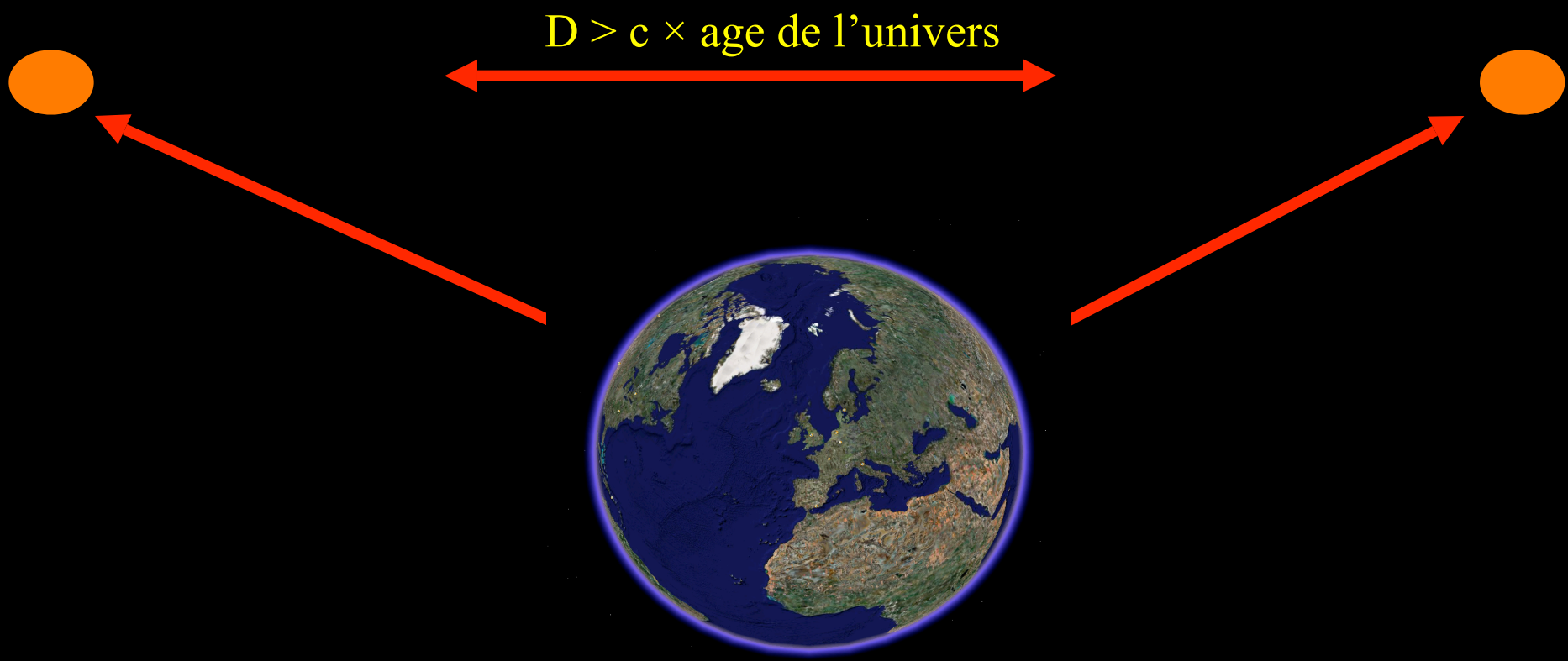


Image du fond cosmologique



Température partout pareille à une part pour 100 000 !

La même température partout



Inflation de l'Univers

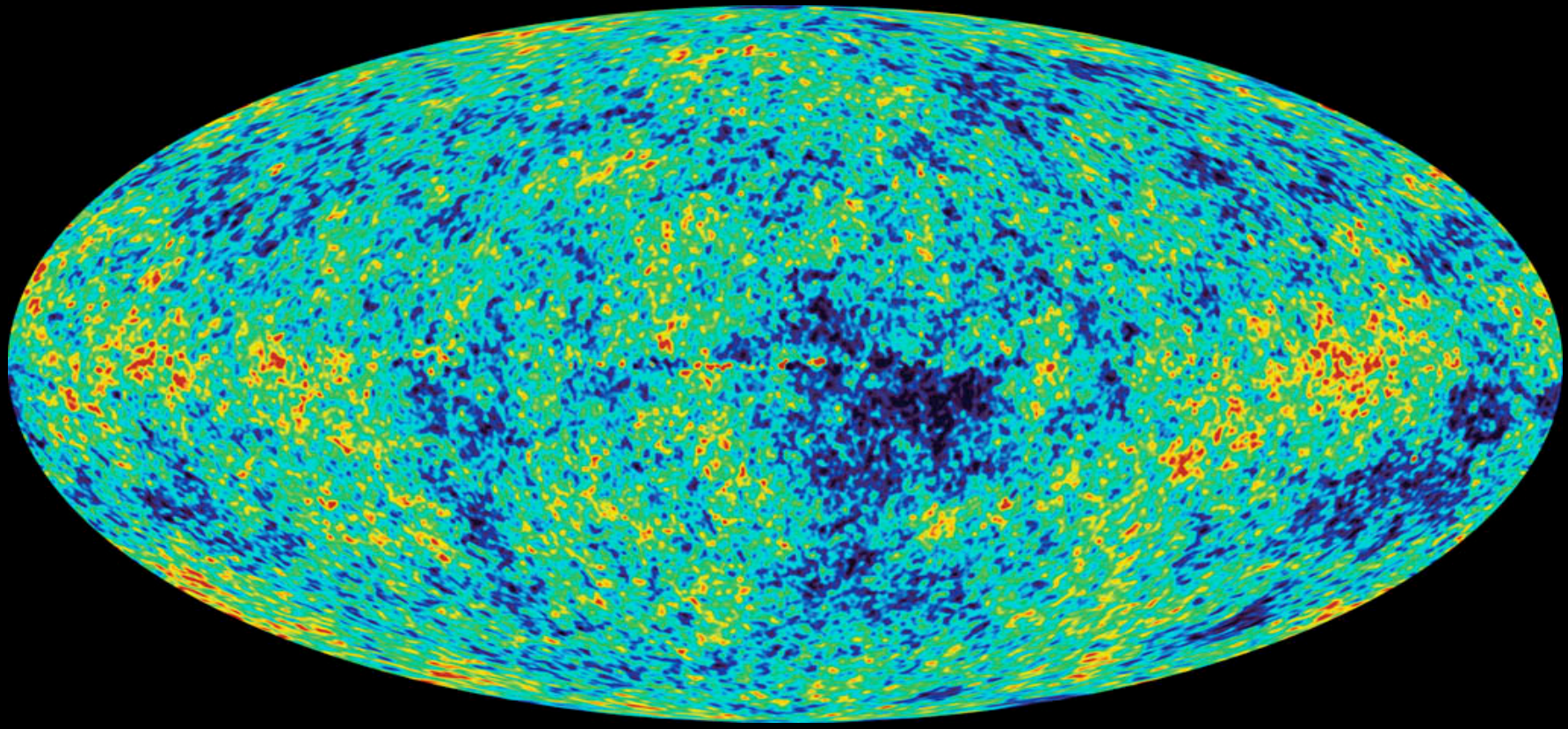
PHYSICAL REVIEW D VOLUME 23, NUMBER 2 15 JANUARY 1981

Inflationary universe: A possible solution to the horizon and flatness problems

Alan H. Guth*
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305
(Received 11 August 1980)

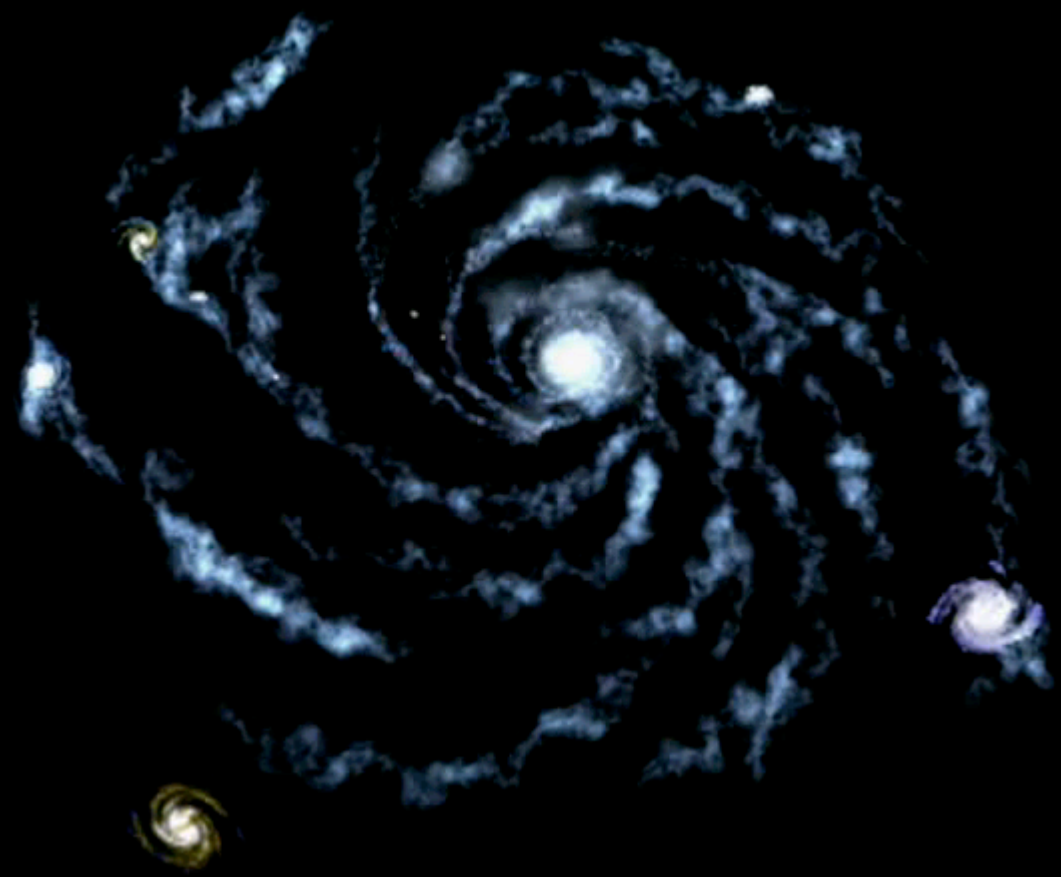
The standard model of hot big-bang cosmology requires initial conditions which are problematic in two ways: (1) The early universe is assumed to be highly homogeneous, in spite of the fact that separated regions were causally disconnected (horizon problem); and (2) the initial value of the Hubble constant must be fine tuned to extraordinary accuracy to produce a universe as flat (i.e., near critical mass density) as the one we see today (flatness problem). These problems would disappear if, in its early history, the universe supercooled to temperatures 28 or more orders of magnitude below the critical temperature for some phase transition. A huge expansion factor would then result from a period of exponential growth, and the entropy of the universe would be multiplied by a huge factor when the latent heat is released. Such a scenario is completely natural in the context of grand unified models of elementary-particle interactions. In such models, the supercooling is also relevant to the problem of monopole suppression. Unfortunately, the scenario seems to lead to some unacceptable consequences, so modifications must be sought.

Image du fond cosmologique

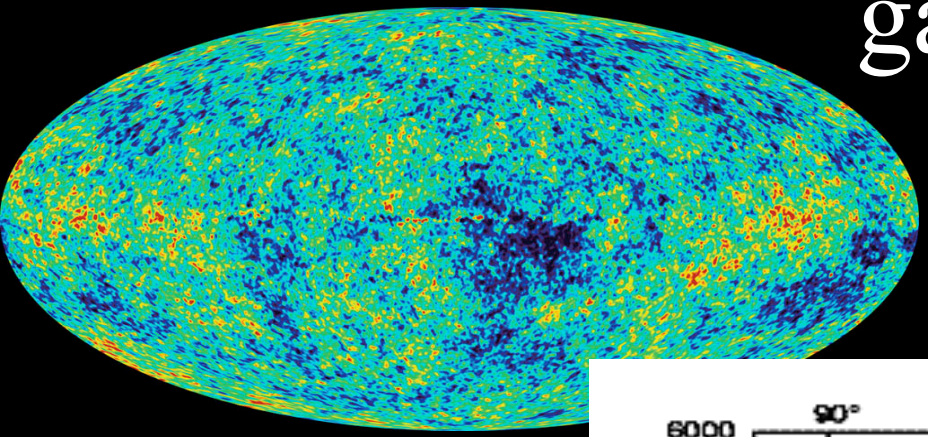


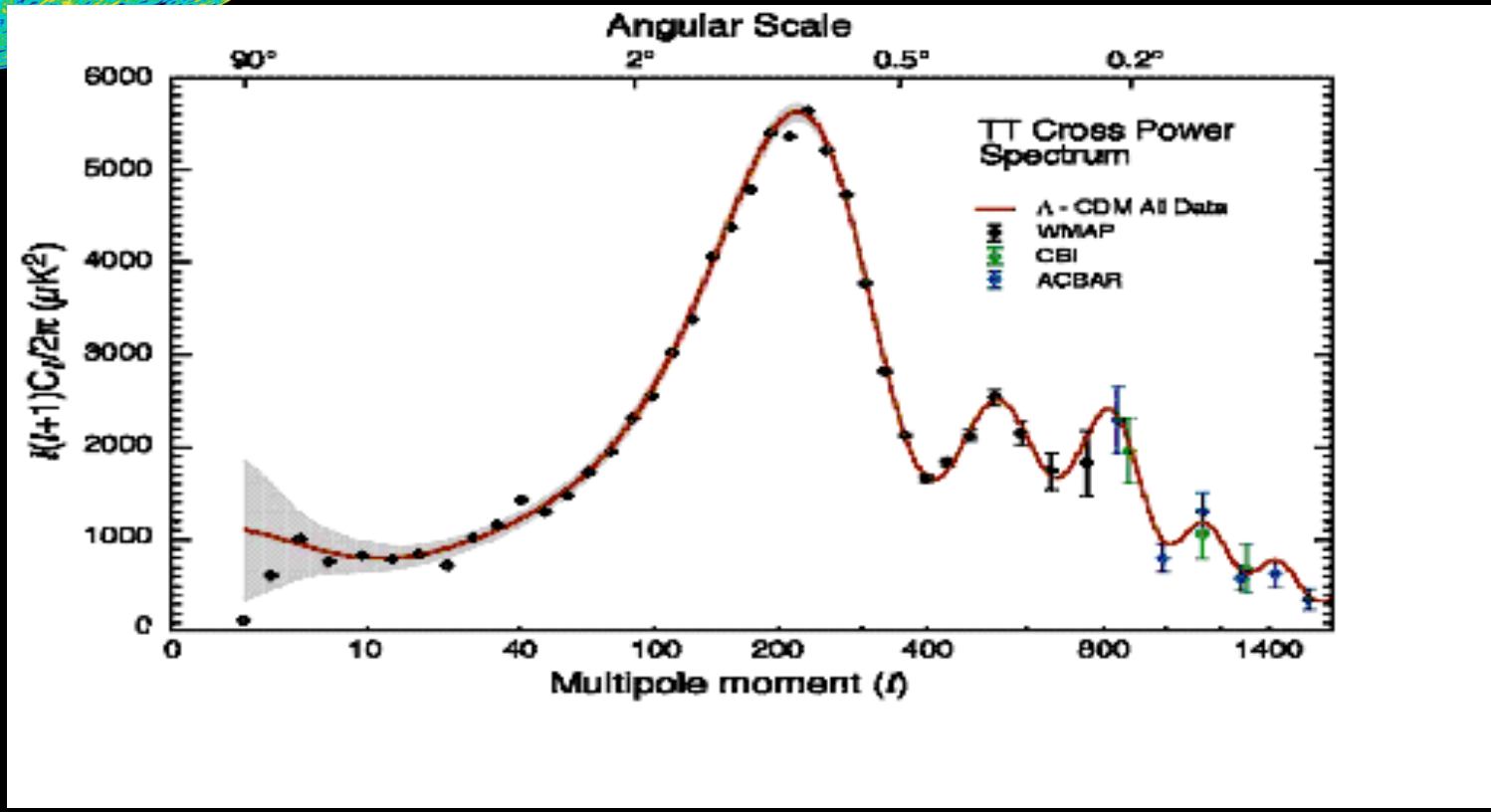
Température partout pareille à une part pour 100 000 !

Cartographie de tout le ciel

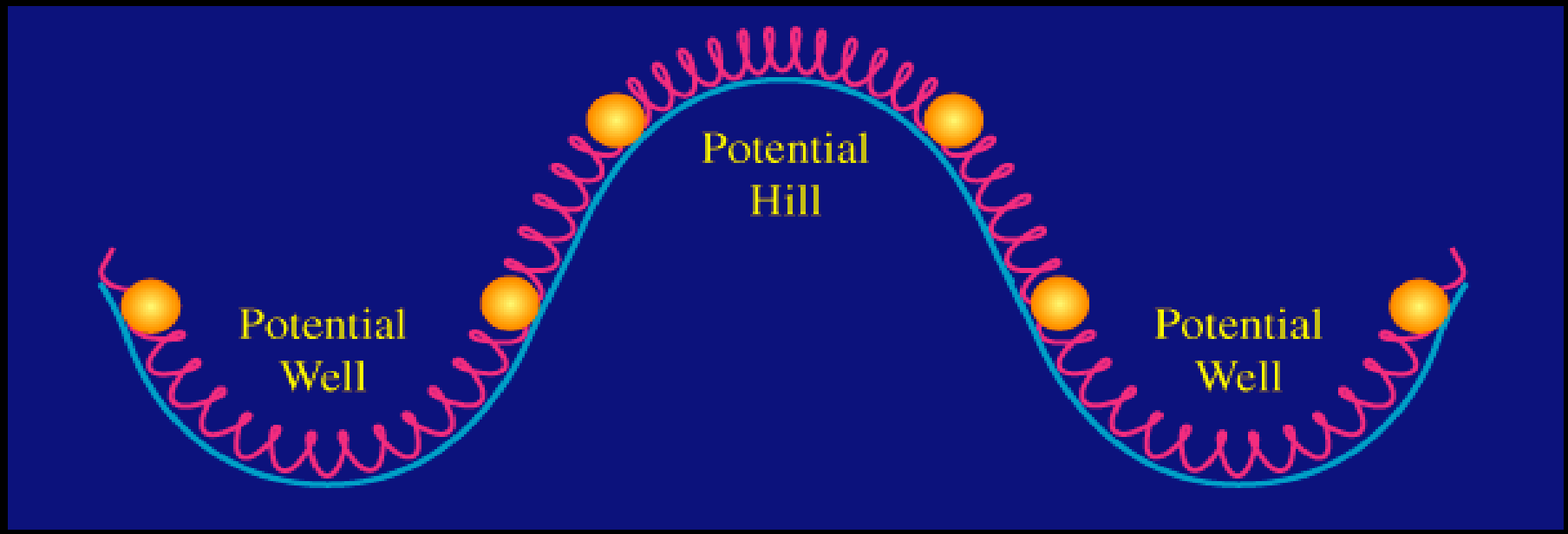


Perturbations qui produisent enfin les galaxies





Oscillations acoustiques



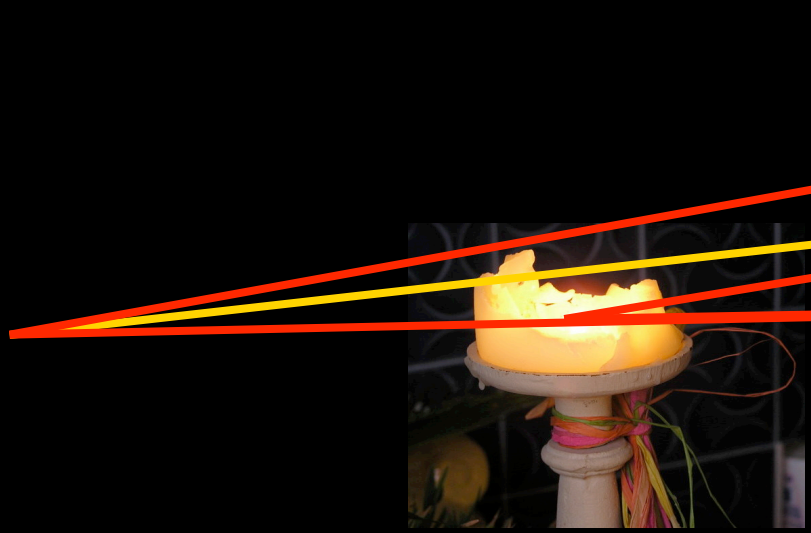
Oscillations Acoustiques

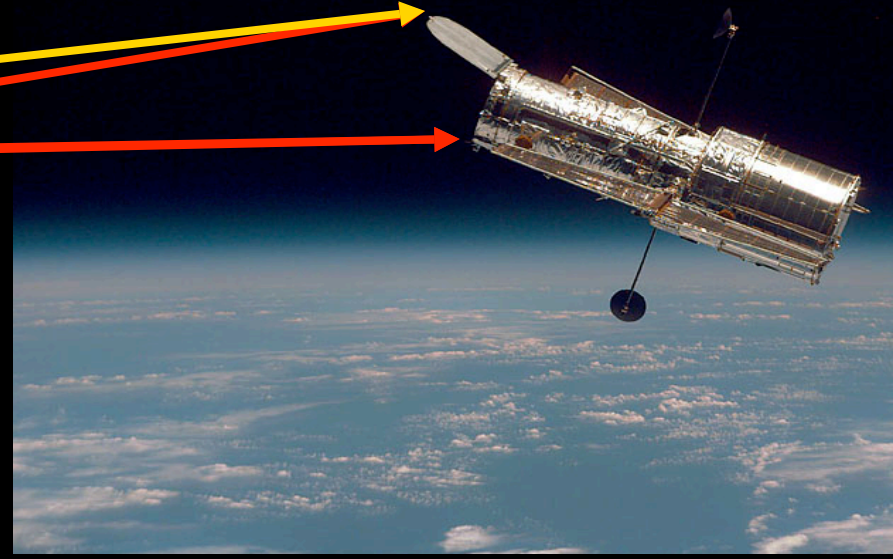
On doit retrouver la signature des oscillations acoustiques dans la distribution des galaxies

La distribution des galaxies dans l'univers

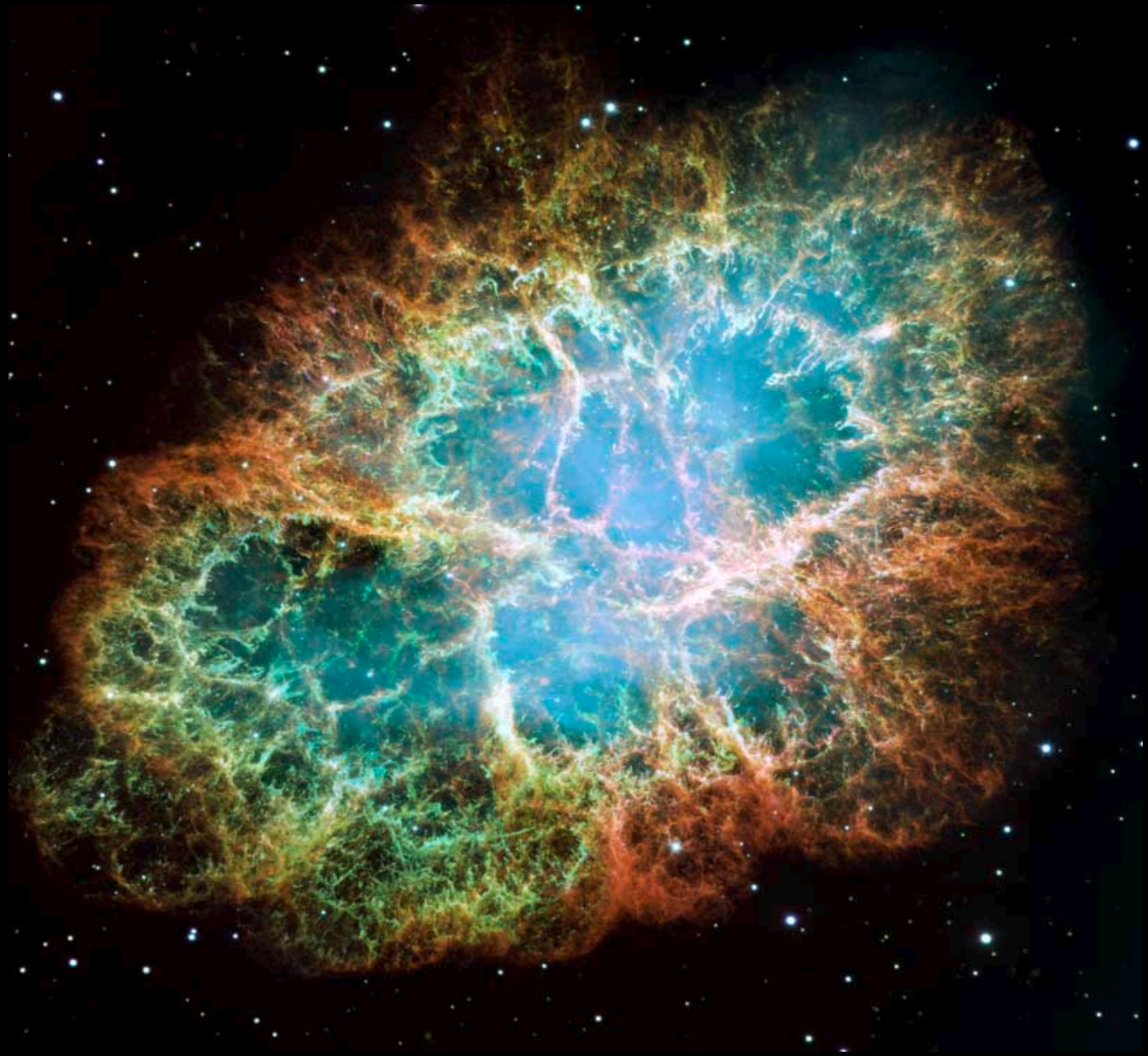
Comment mesurer les distances

Une bougie standard



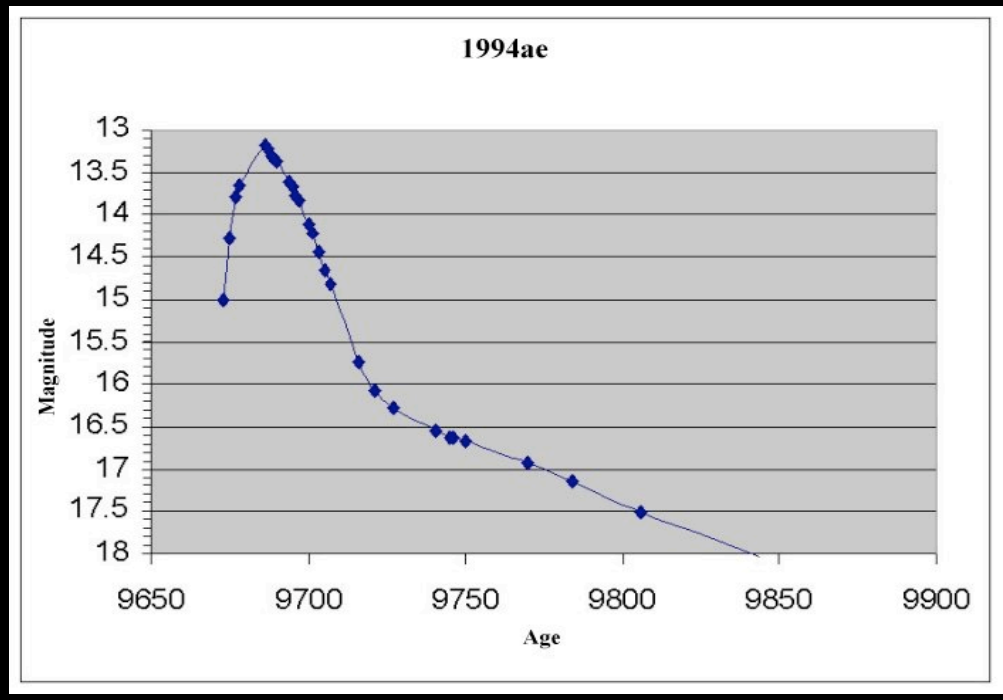


Supernova: une bougie standard

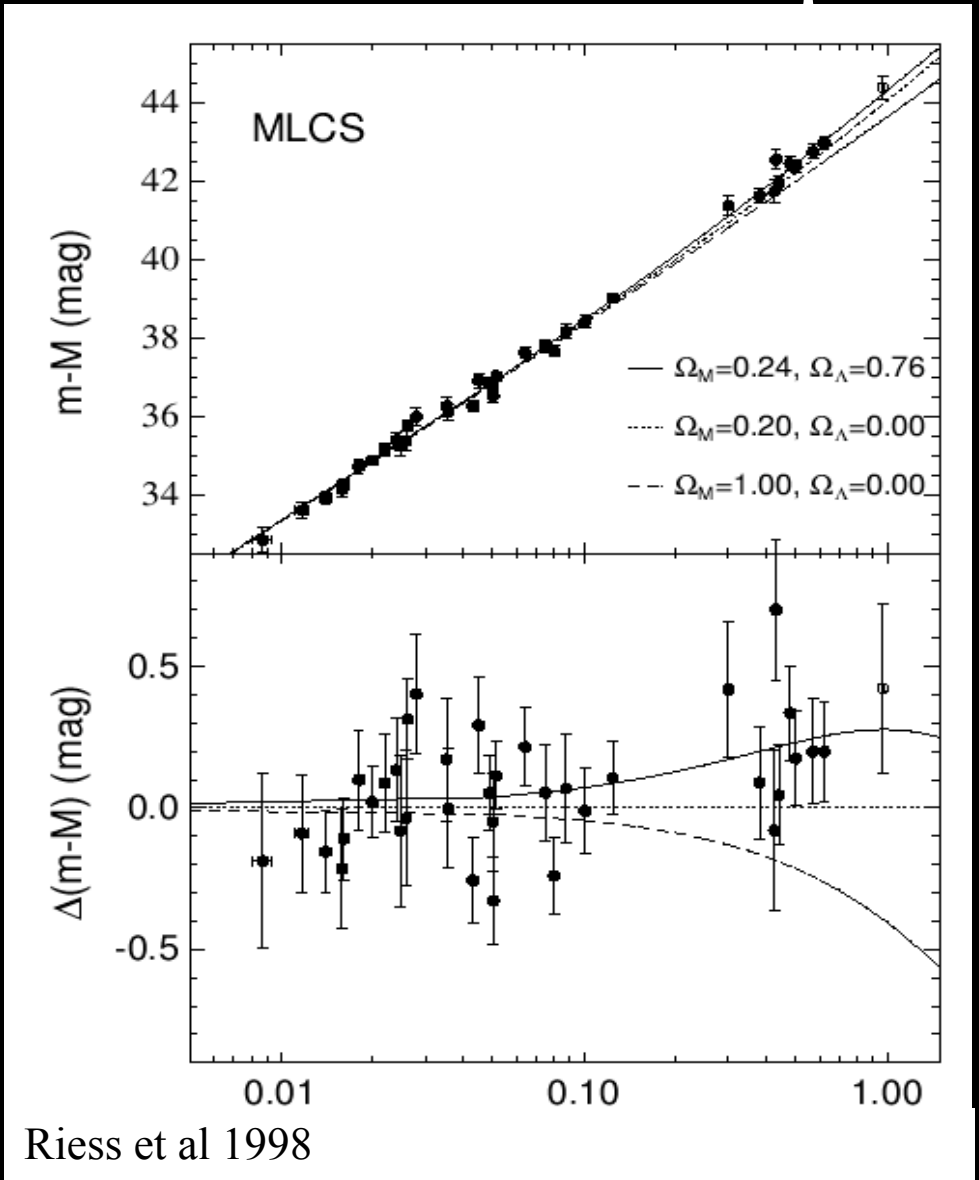


Supernova: une bougie standard

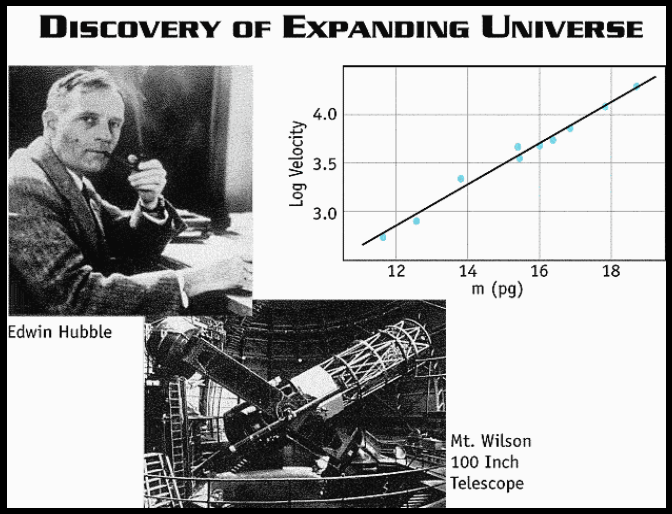

NGC3370



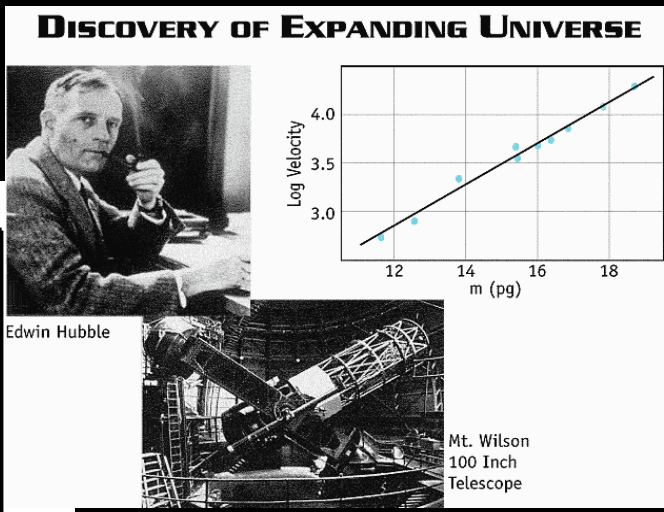
Distances d'après les Supernovae

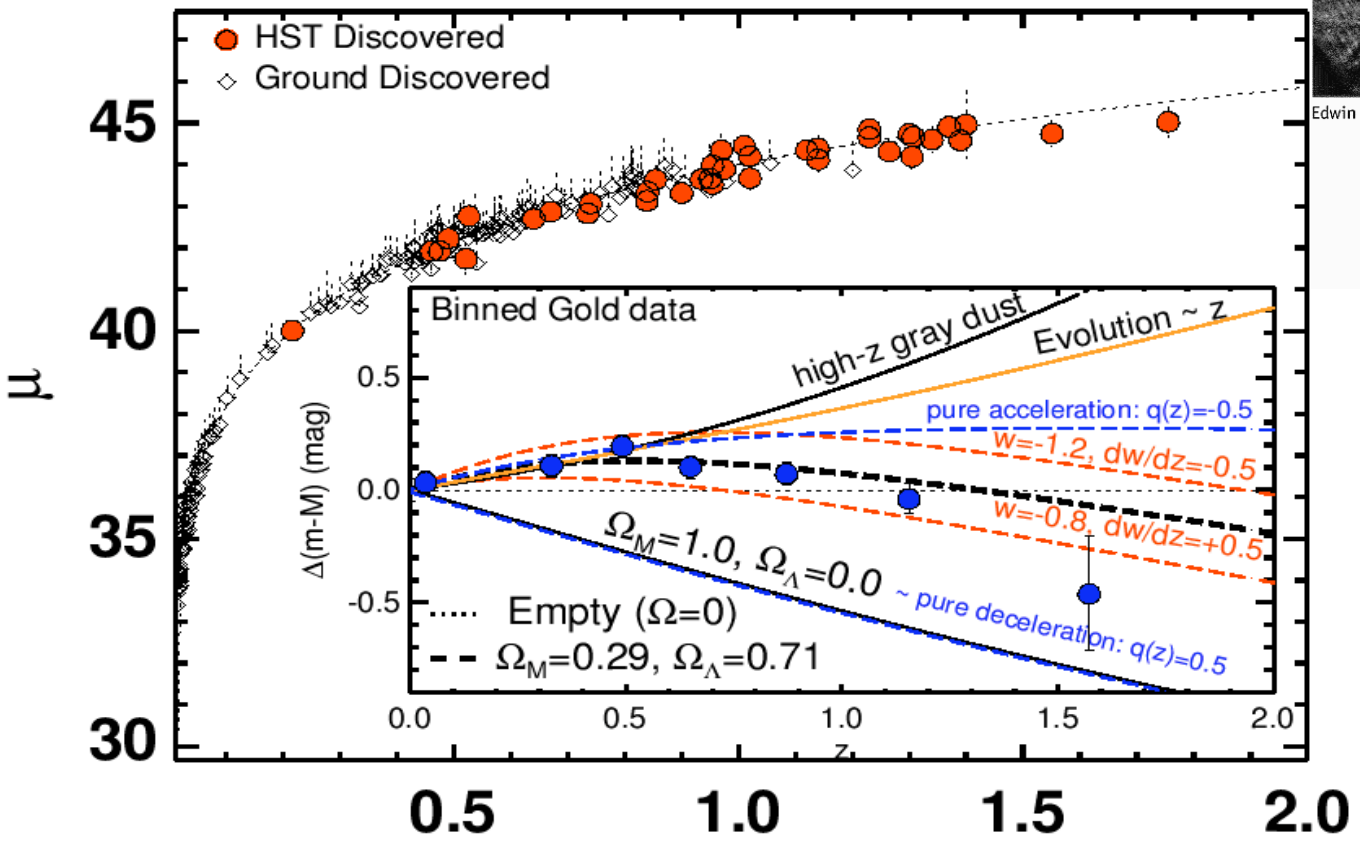


Riess et al 1998



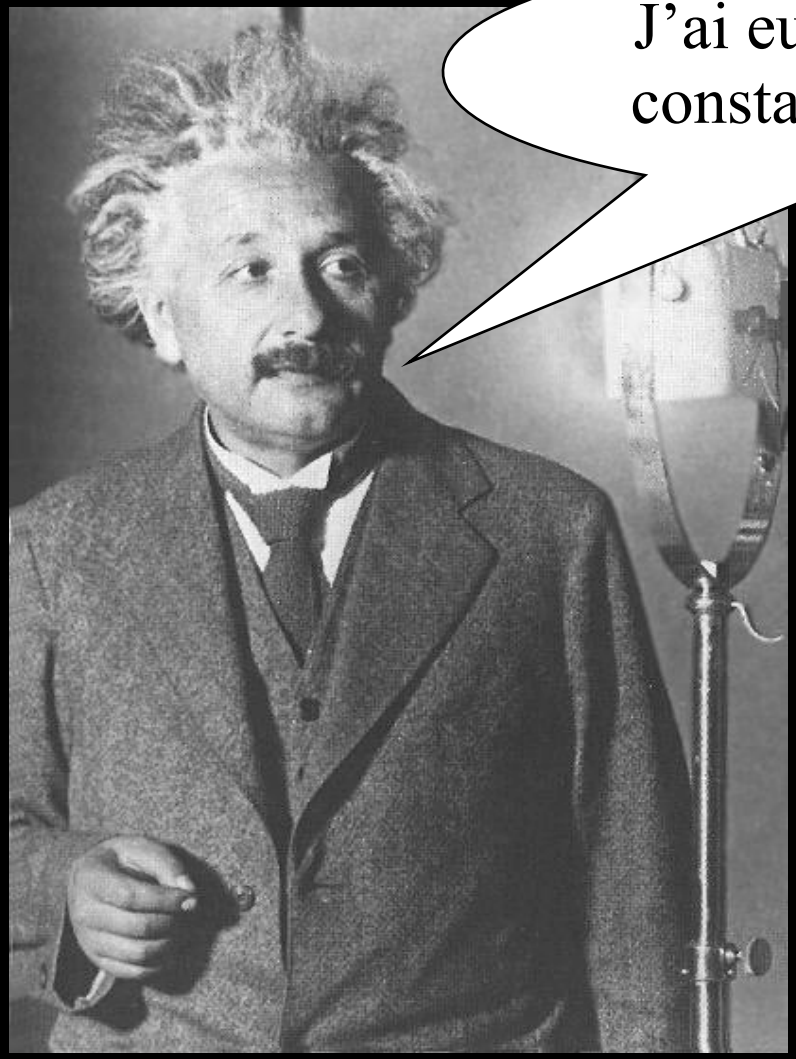
Distances d'après les Supernovae





Riess et al 2007

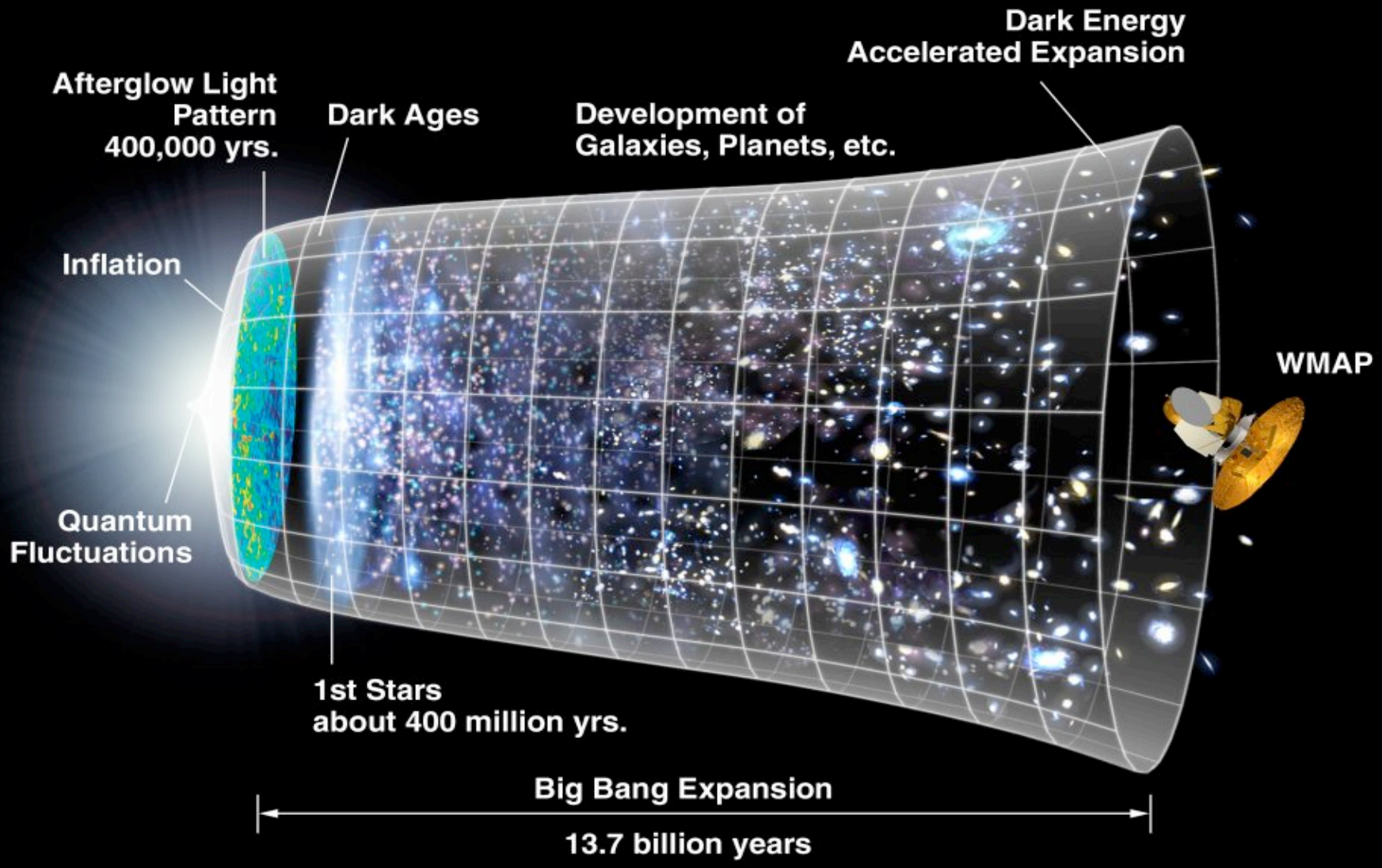
L’expansion de l’univers s’accelère !



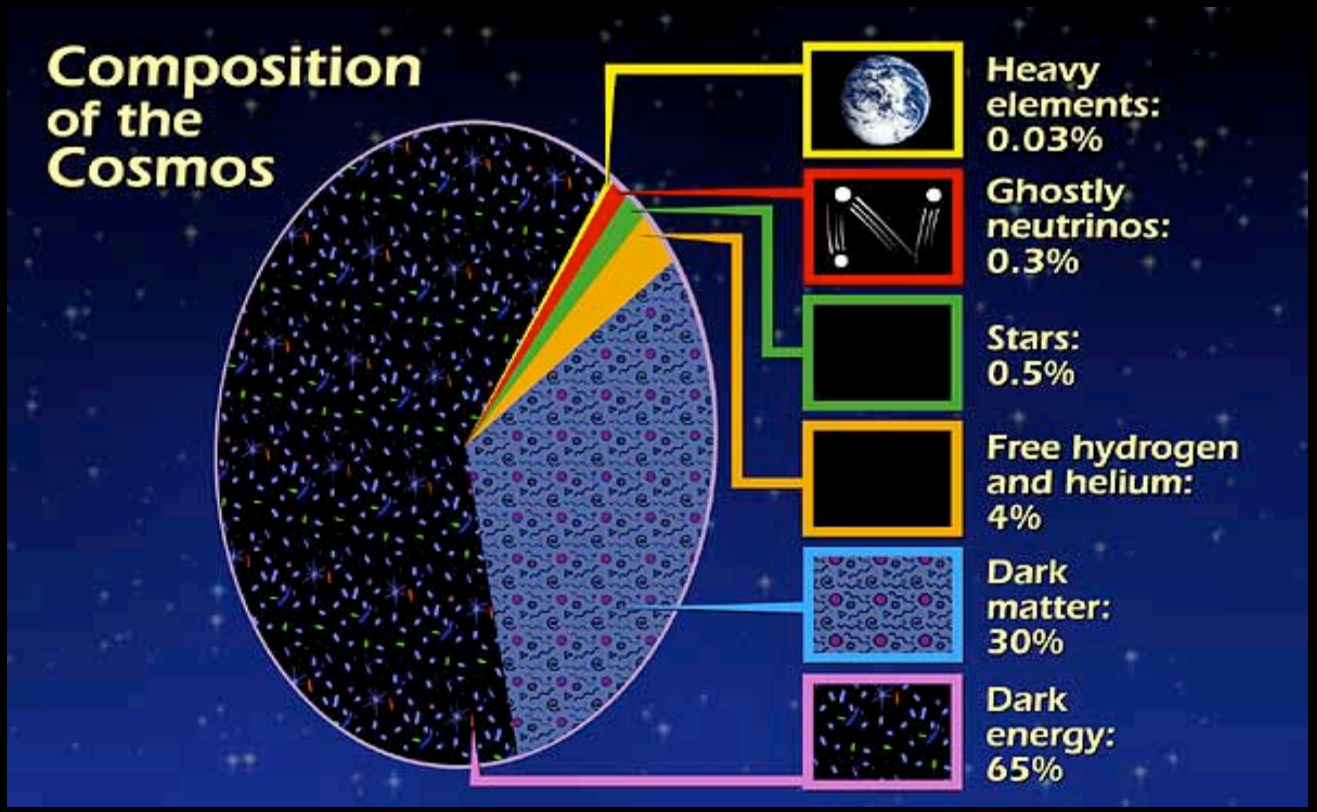
Einstein a eu tort de
dire qu’il a eu tort !

quoique…

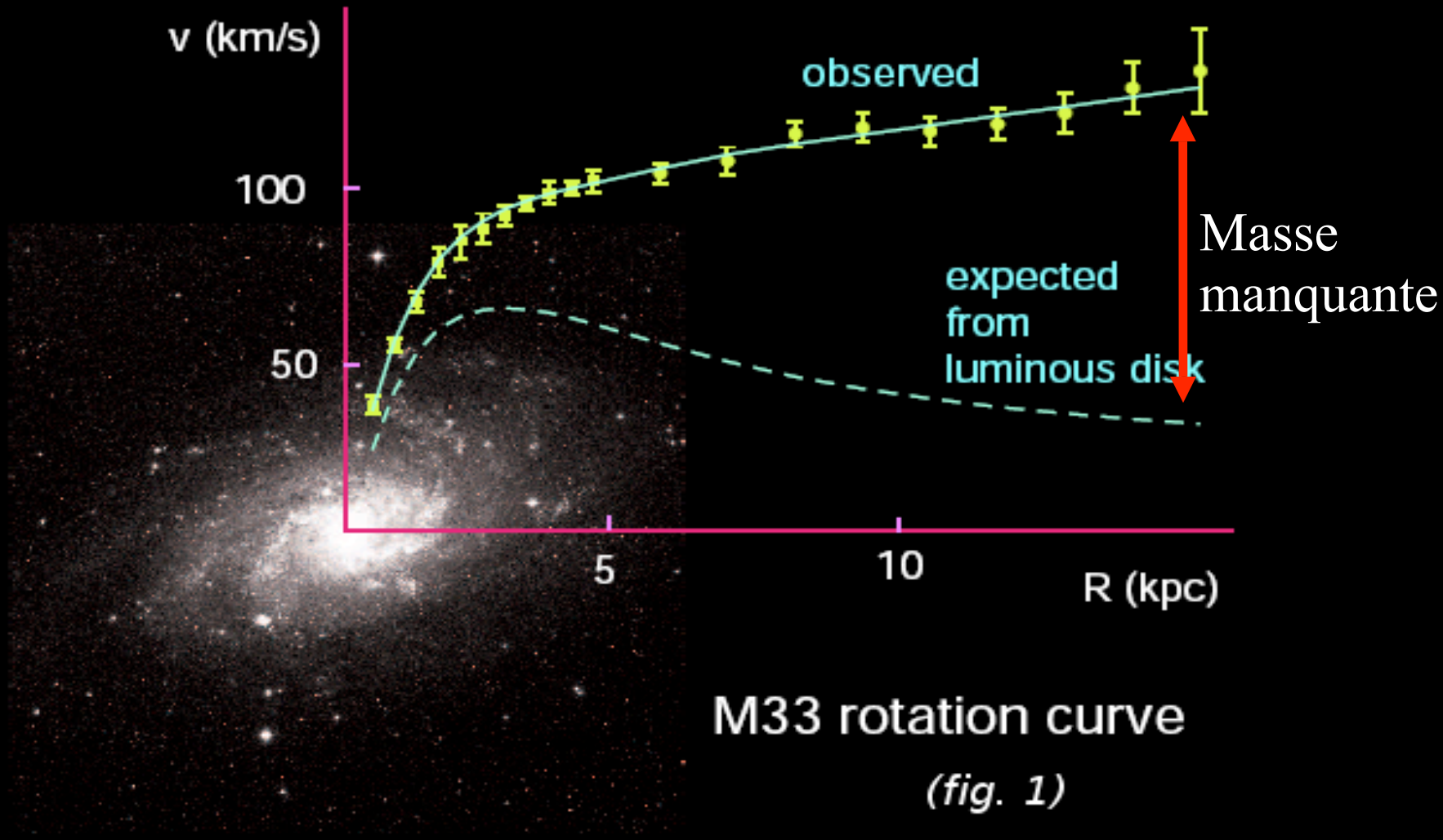
Histoire de l'univers



Composition de l'univers

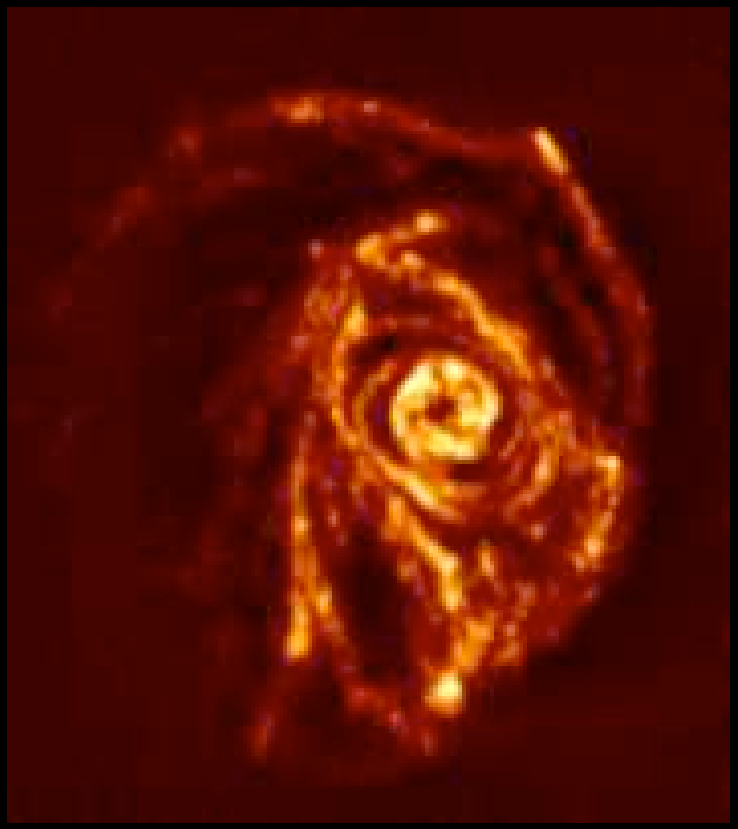


Matière sombre dans un galaxie



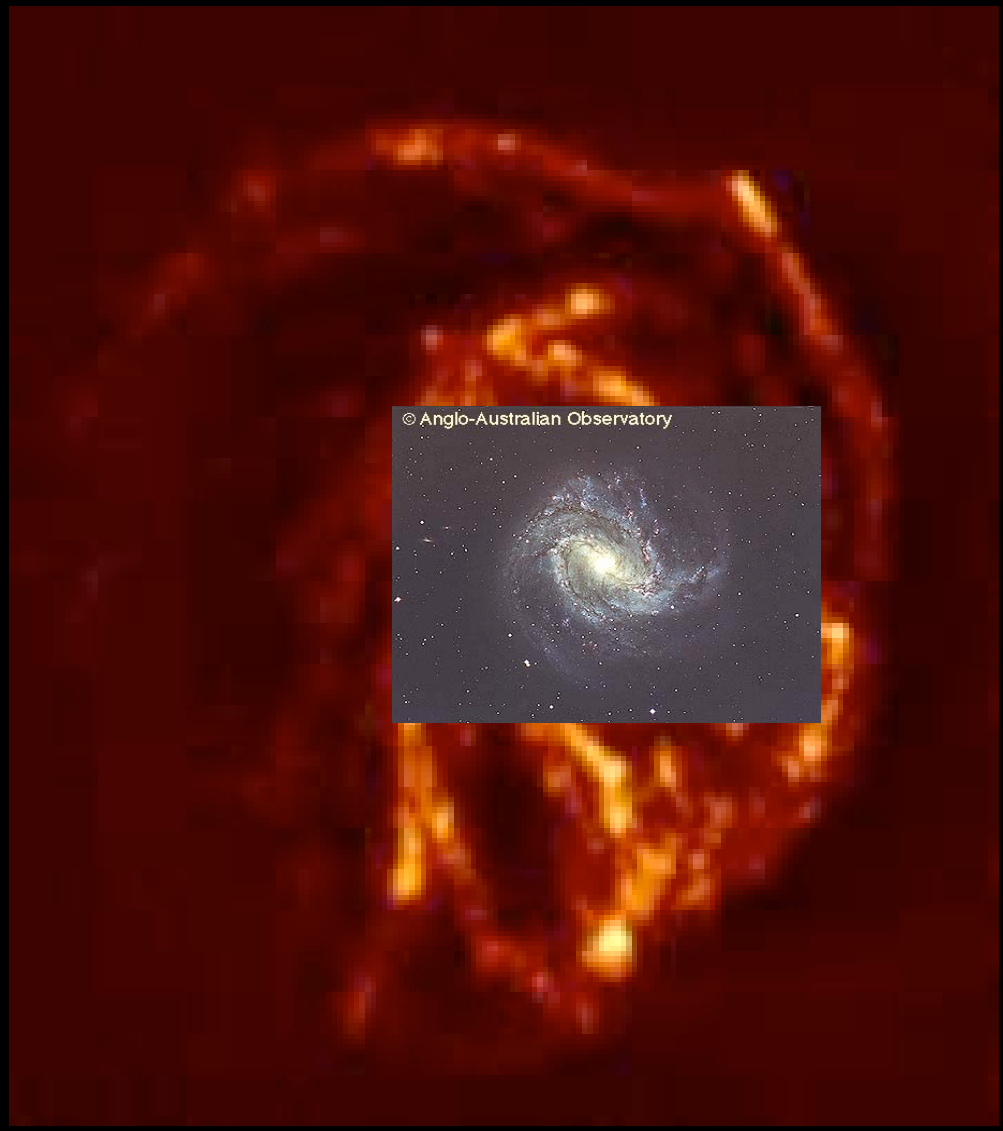
Messier 83

Ondes optiques

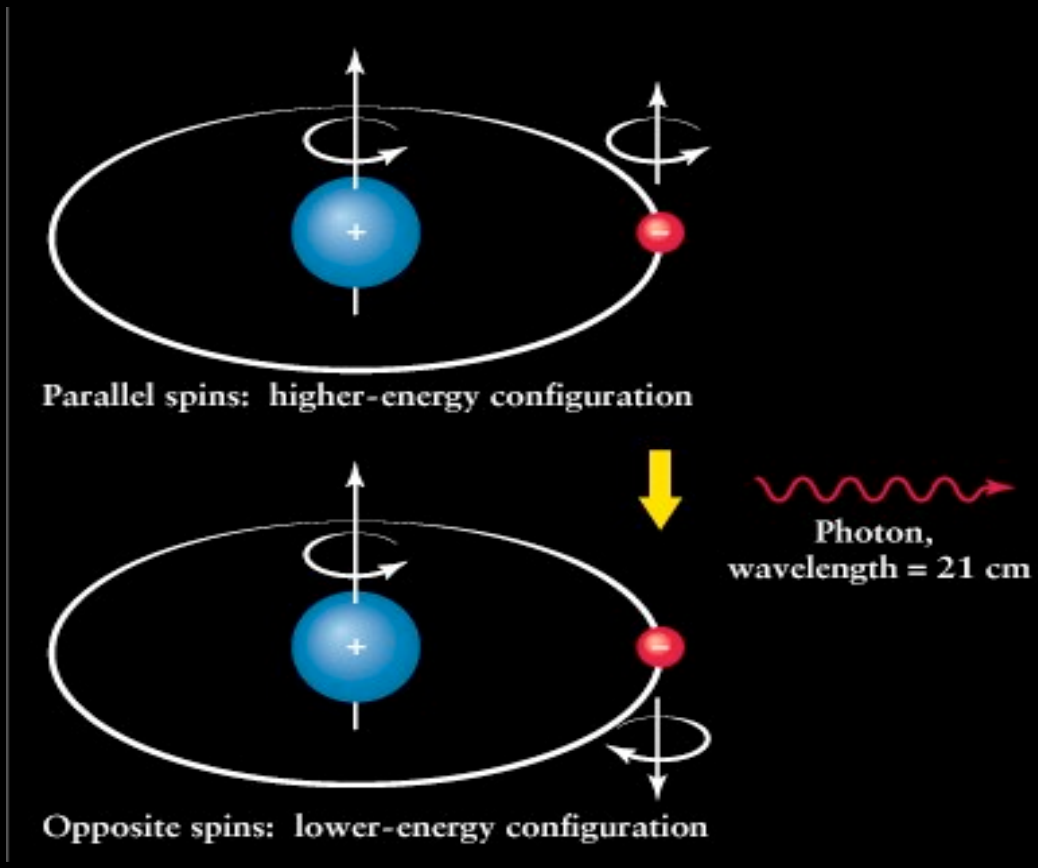


Ondes radio

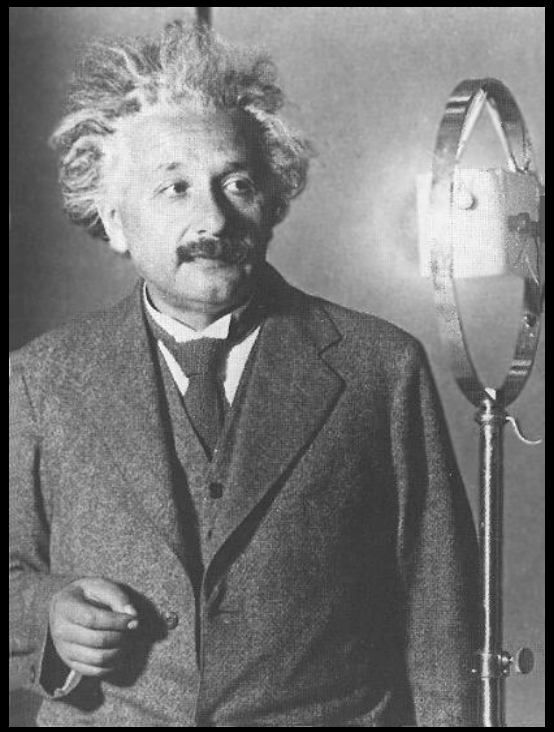
Le galaxie est 5 fois plus étendu



Hydrogène neutre



Un autre possibilité ?



Oui, mais peut être pas tout à fait…

Isaac Newton. Painting by Jean-Leon Huens, © National Geographic Society.

Il n'y a pas de masse sombre ?

Modification de la théorie Newtonienne

ASTROPHYSICAL JOURNAL, 270:365–370, 1983 July 15

A MODIFICATION OF THE NEWTONIAN DYNAMICS AS A POSSIBLE ALTERNATIVE TO THE HIDDEN MASS HYPOTHESIS[1]

M. MILGROM
Department of Physics, The Weizmann Institute of Science, Rehovot, Israel; and
The Institute for Advanced Study
Received 1982 February 4; accepted 1982 December 28

ABSTRACT

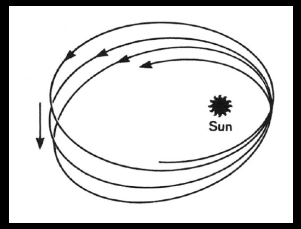
I consider the possibility that there is not, in fact, much hidden mass in galaxies and galaxy systems. If a certain modified version of the Newtonian dynamics is used to describe the motion of bodies in a gravitational field (of a galaxy, say), the observational results are reproduced with no need to assume hidden mass in appreciable quantities. Various characteristics of galaxies result with no further assumptions.

In the basis of the modification is the assumption that in the limit of small acceleration $a \ll a_0$, the acceleration of a particle at distance r from a mass M satisfies approximately $a^2/a_0 \approx MGr^{-2}$, where a_0 is a constant of the dimensions of an acceleration.

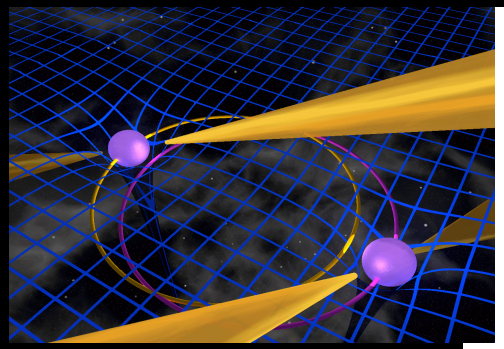
A success of this modified dynamics in explaining the data may be interpreted as implying a need to change the law of inertia in the limit of small accelerations or a more limited change of gravity alone.

I discuss various observational constraints on possible theories for the modified dynamics from data which exist already and suggest other systems which may provide useful constraints.

Les succès de la théorie d'Einstein

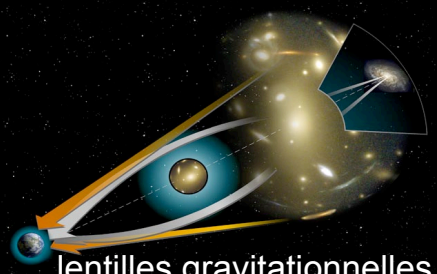


L'avance de l'apastron

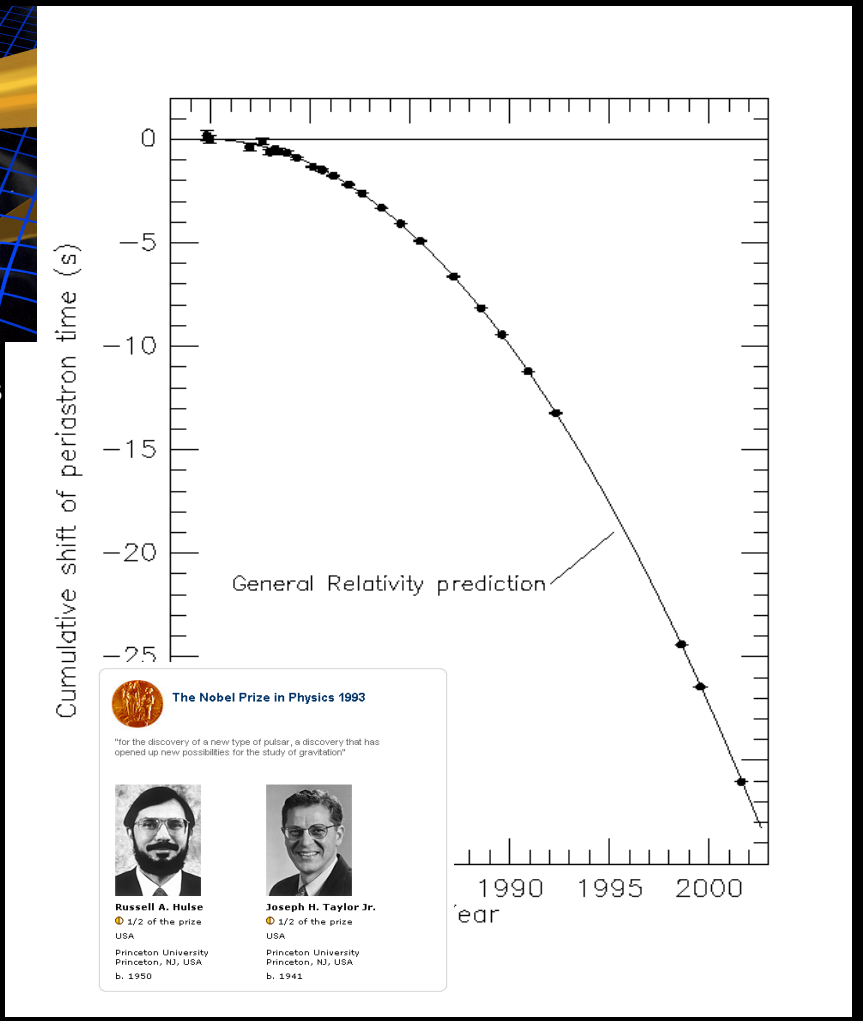


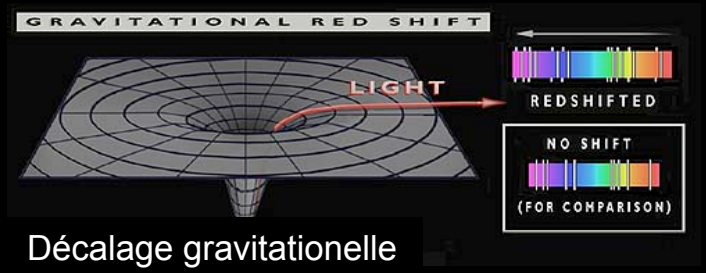
Émission des ondes gravitationnelles

Décalage de Shapiro



lentilles gravitationnelles

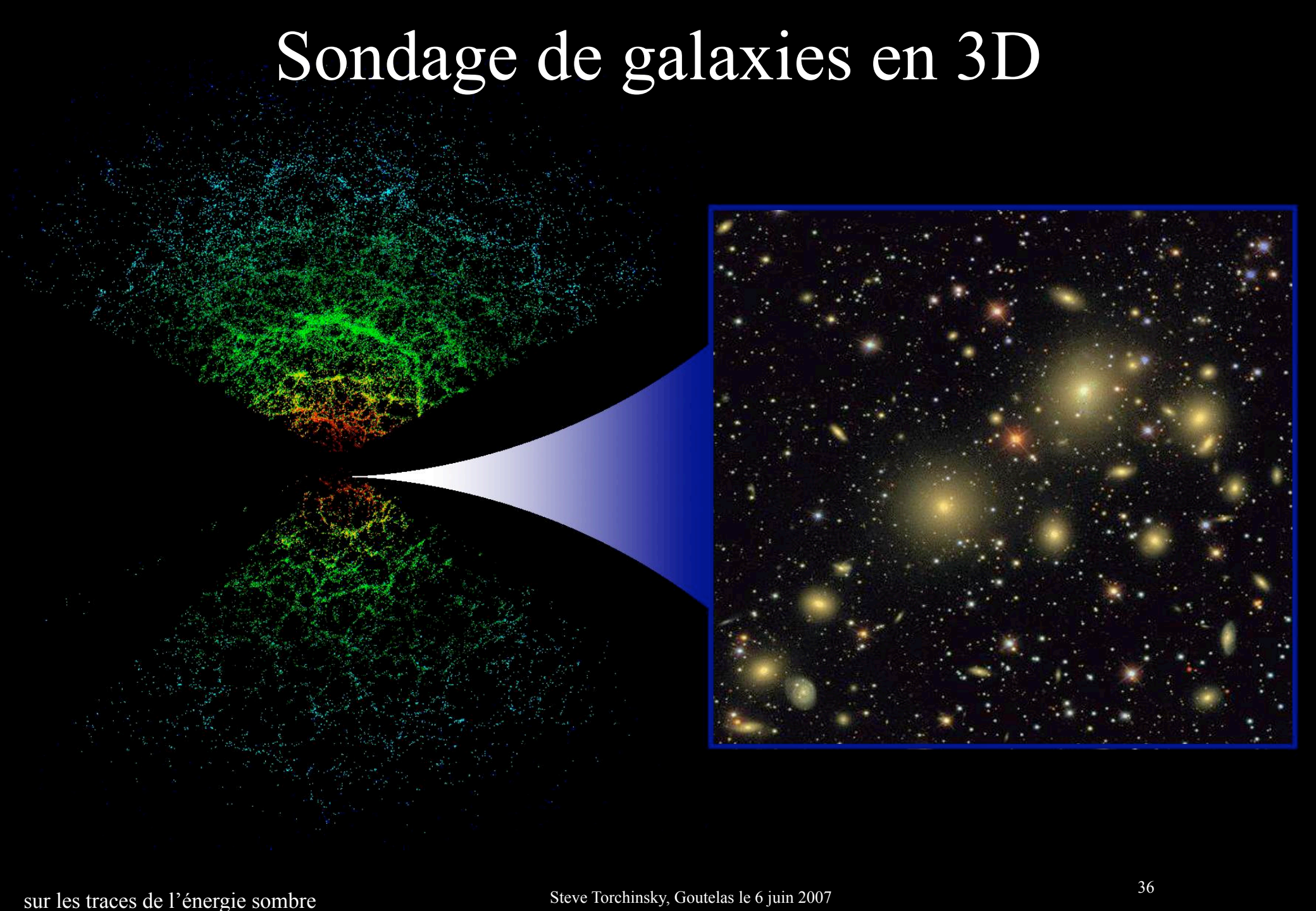




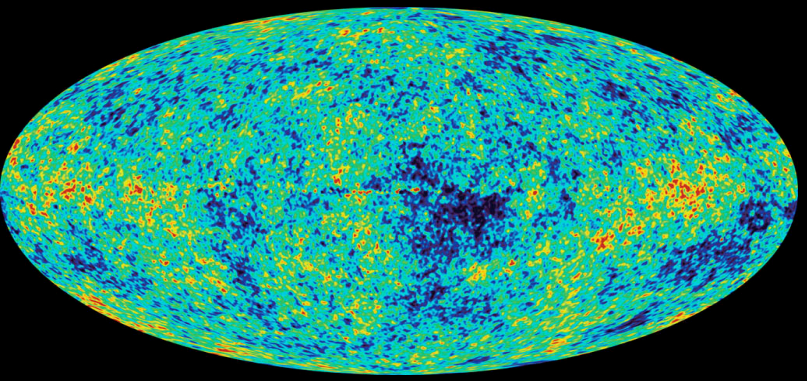
Décalage gravitationelle

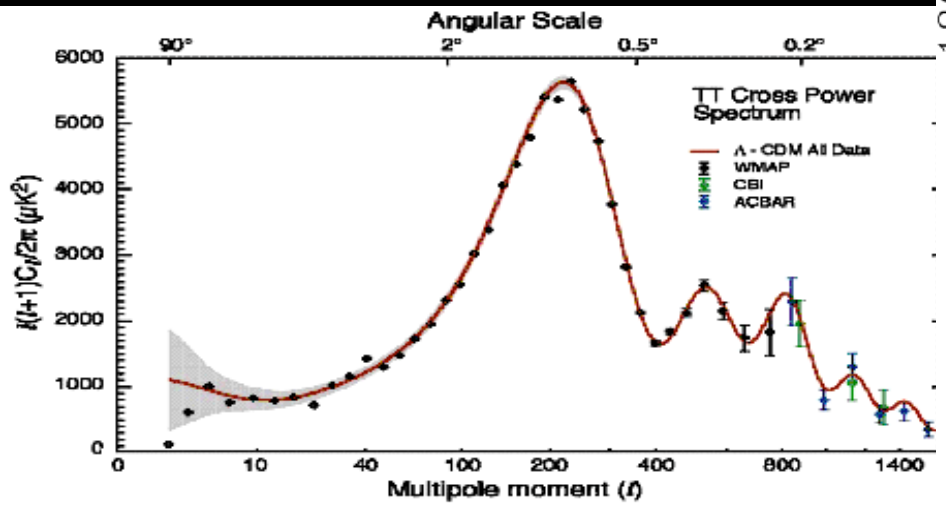
Deux outils pour sonder l'univers

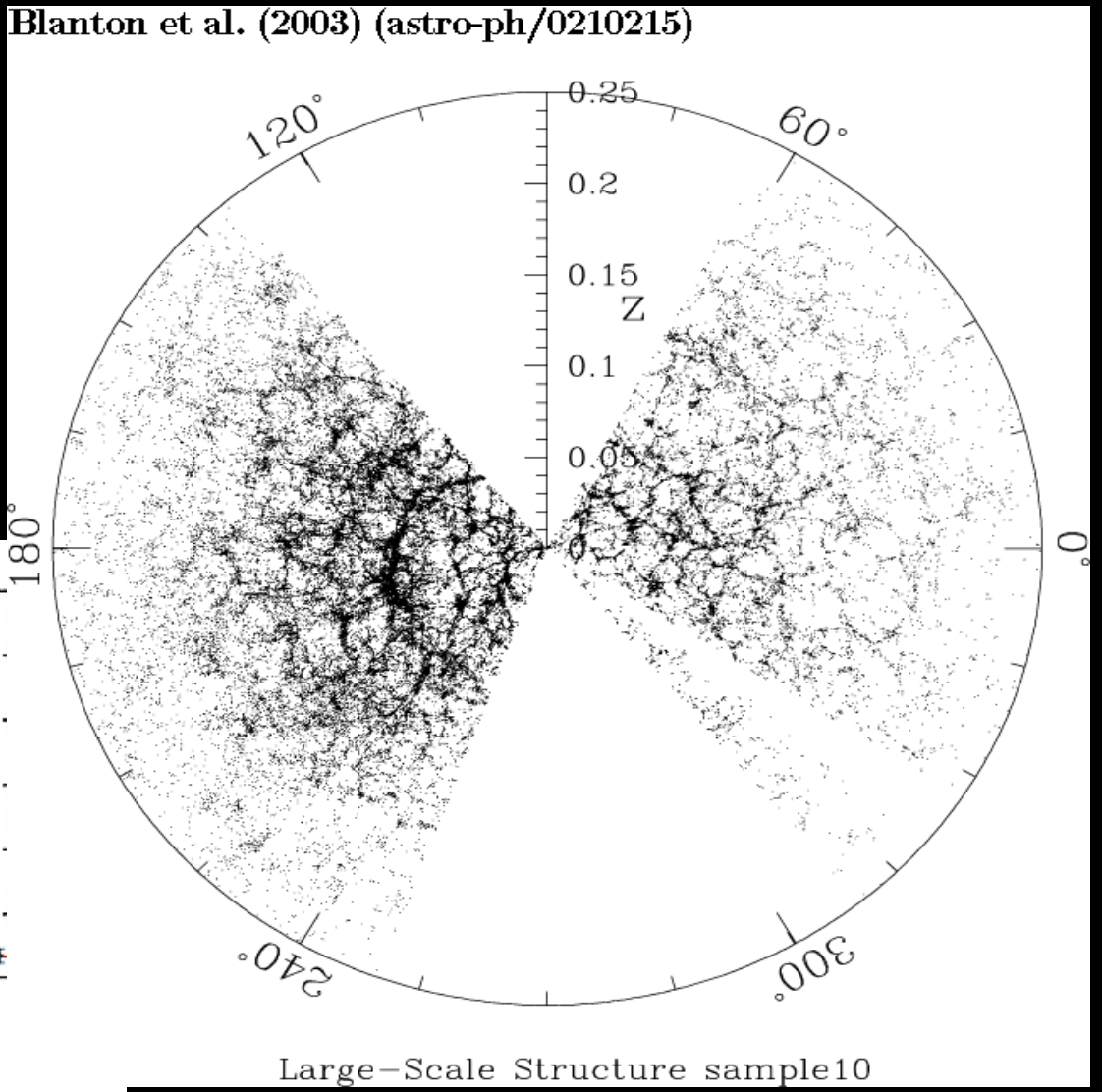
Sondage de galaxies en 3D



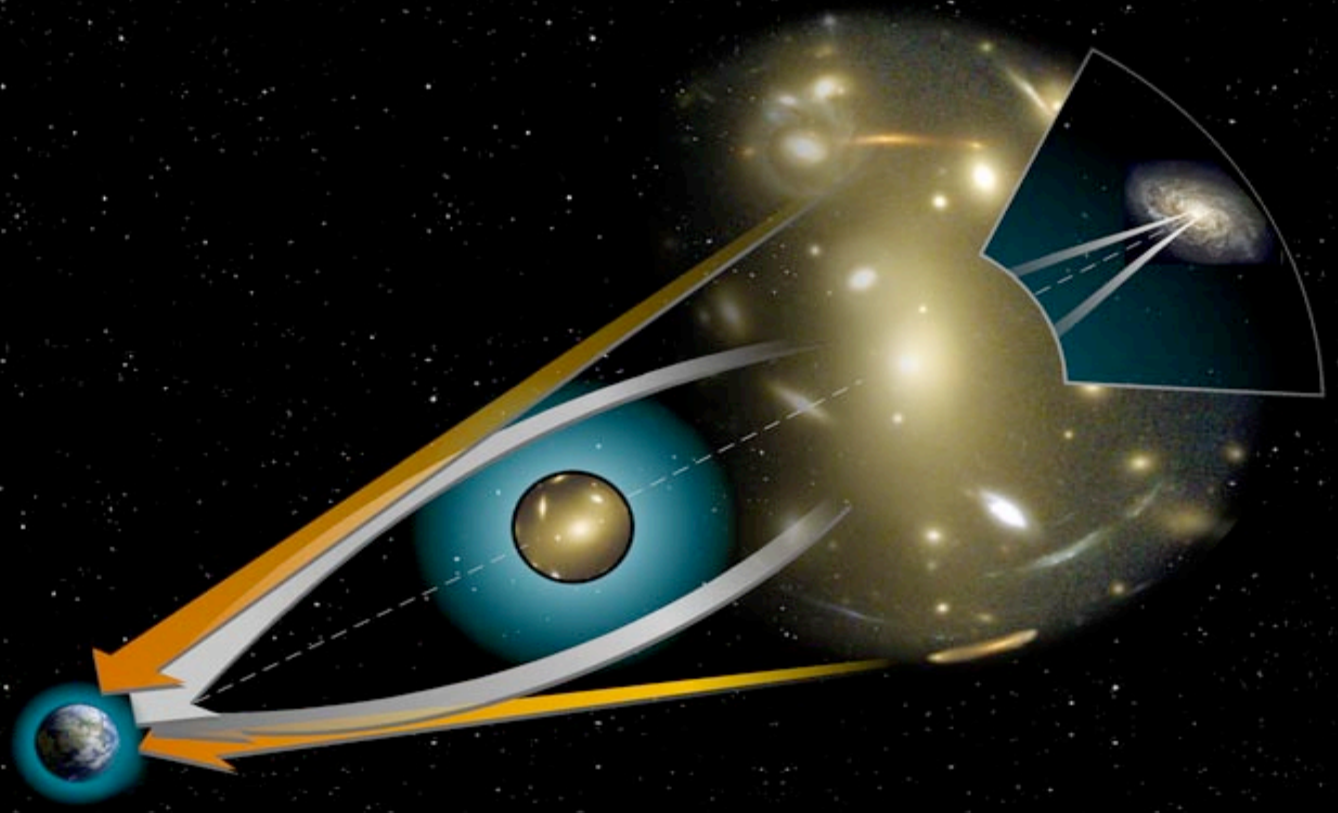
Oscillations acoustiques vue dans la



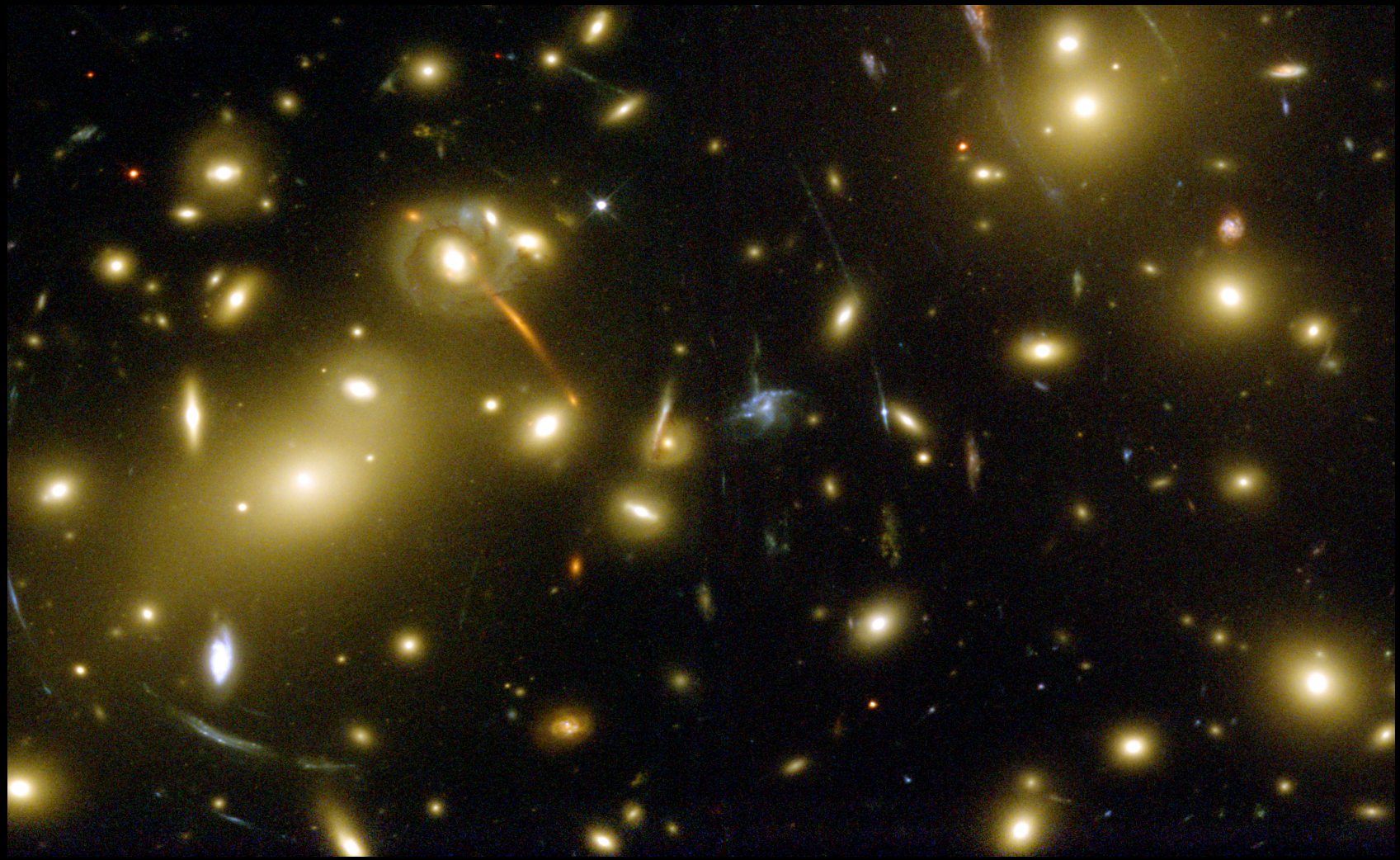




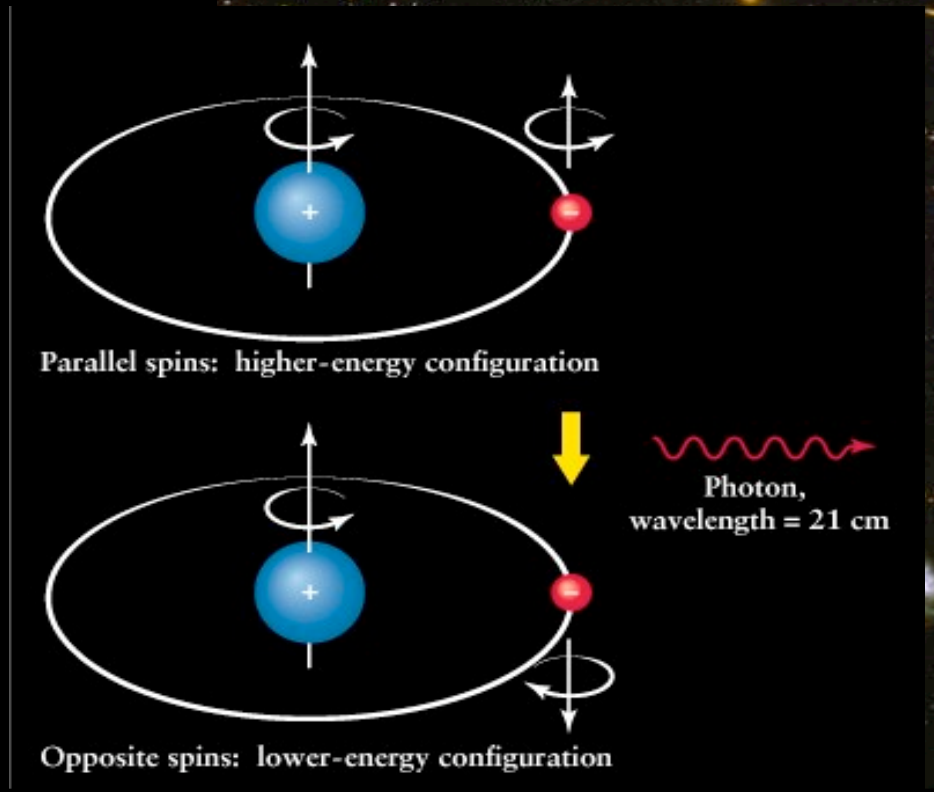
Effet de la gravitation sur les rayonnements



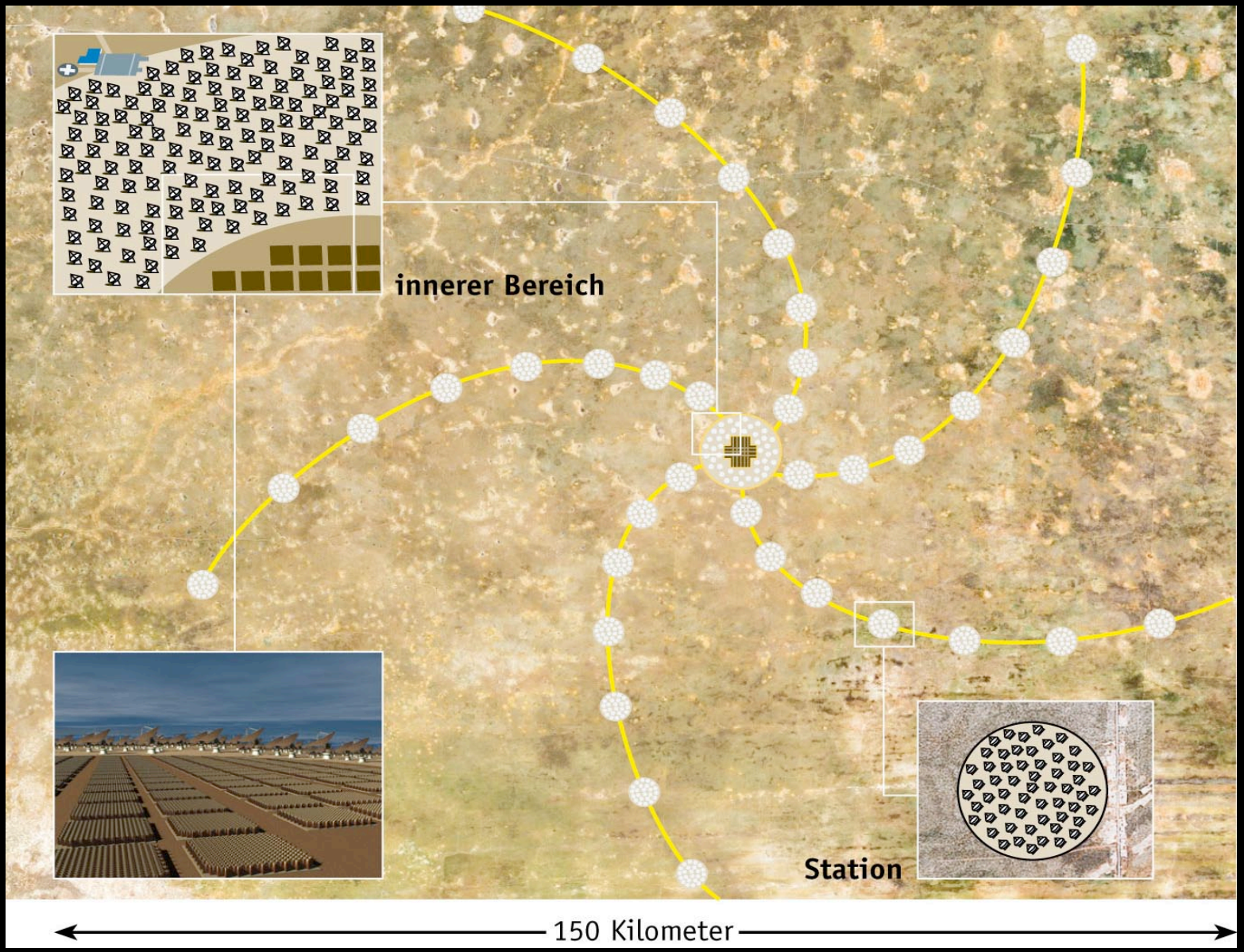
Effet de la gravitation sur les rayonnements



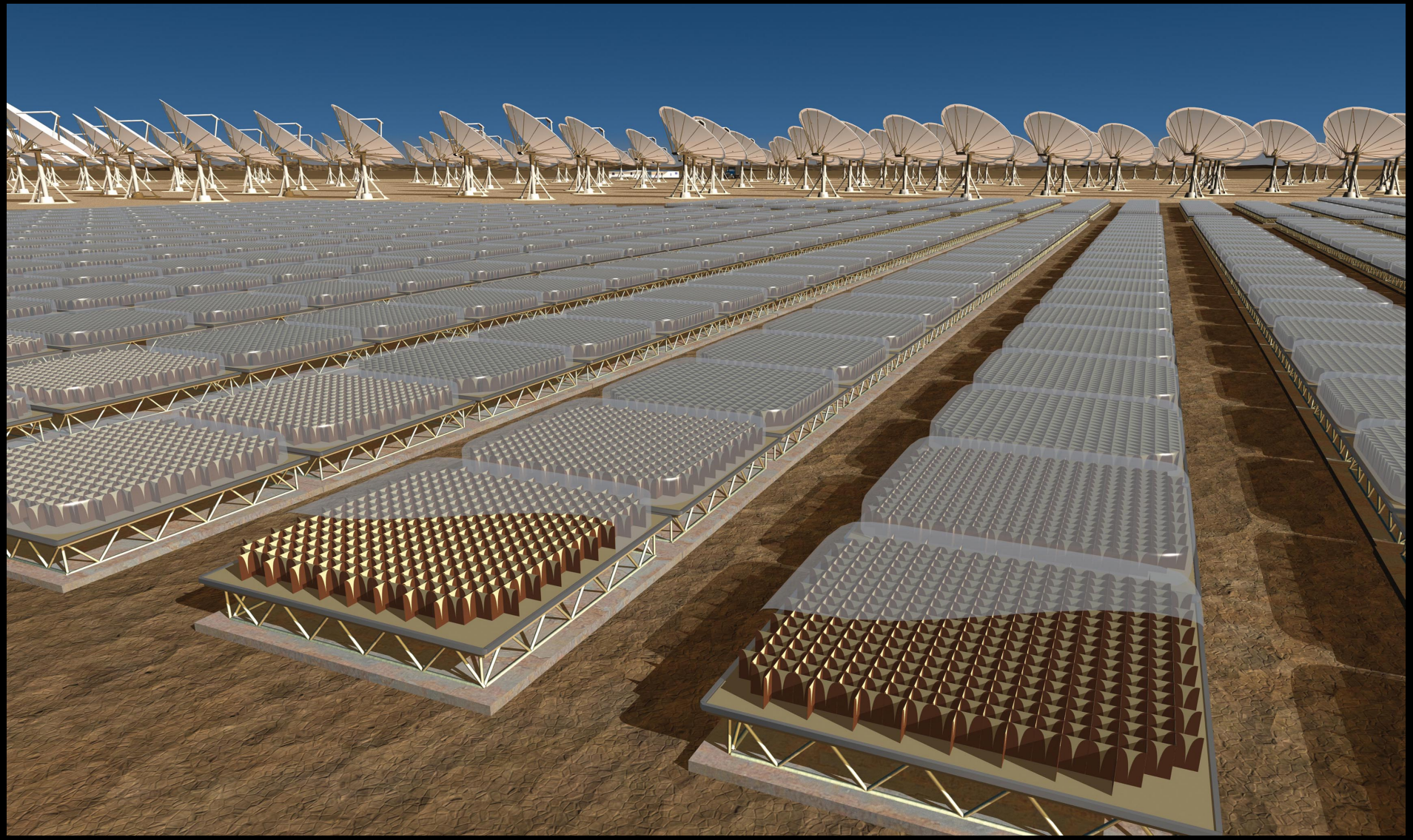
Comment faire un sondage d'un milliard de galaxies ?



Réseau d'un kilometre carré

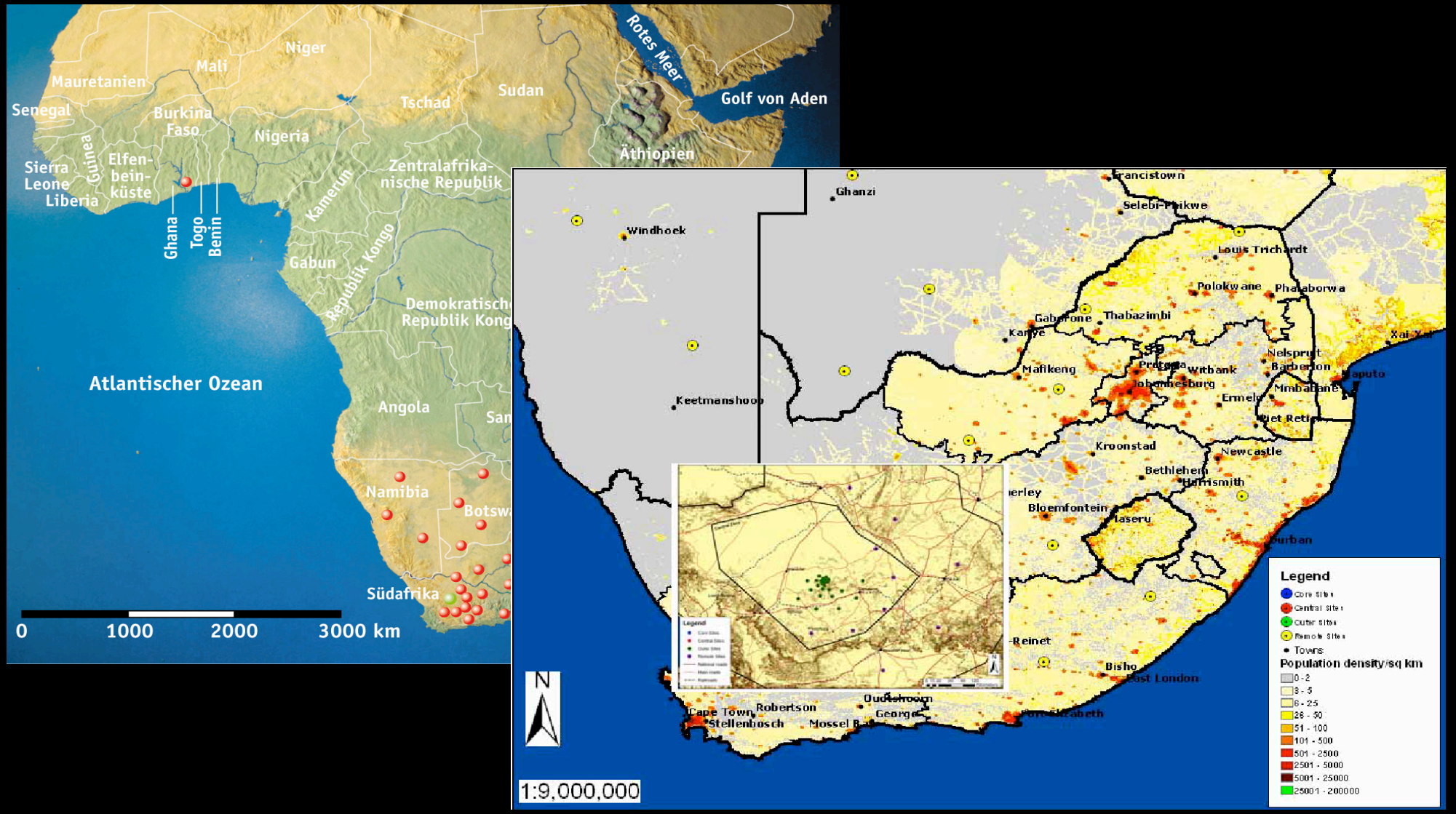


Un tapis d'antennes



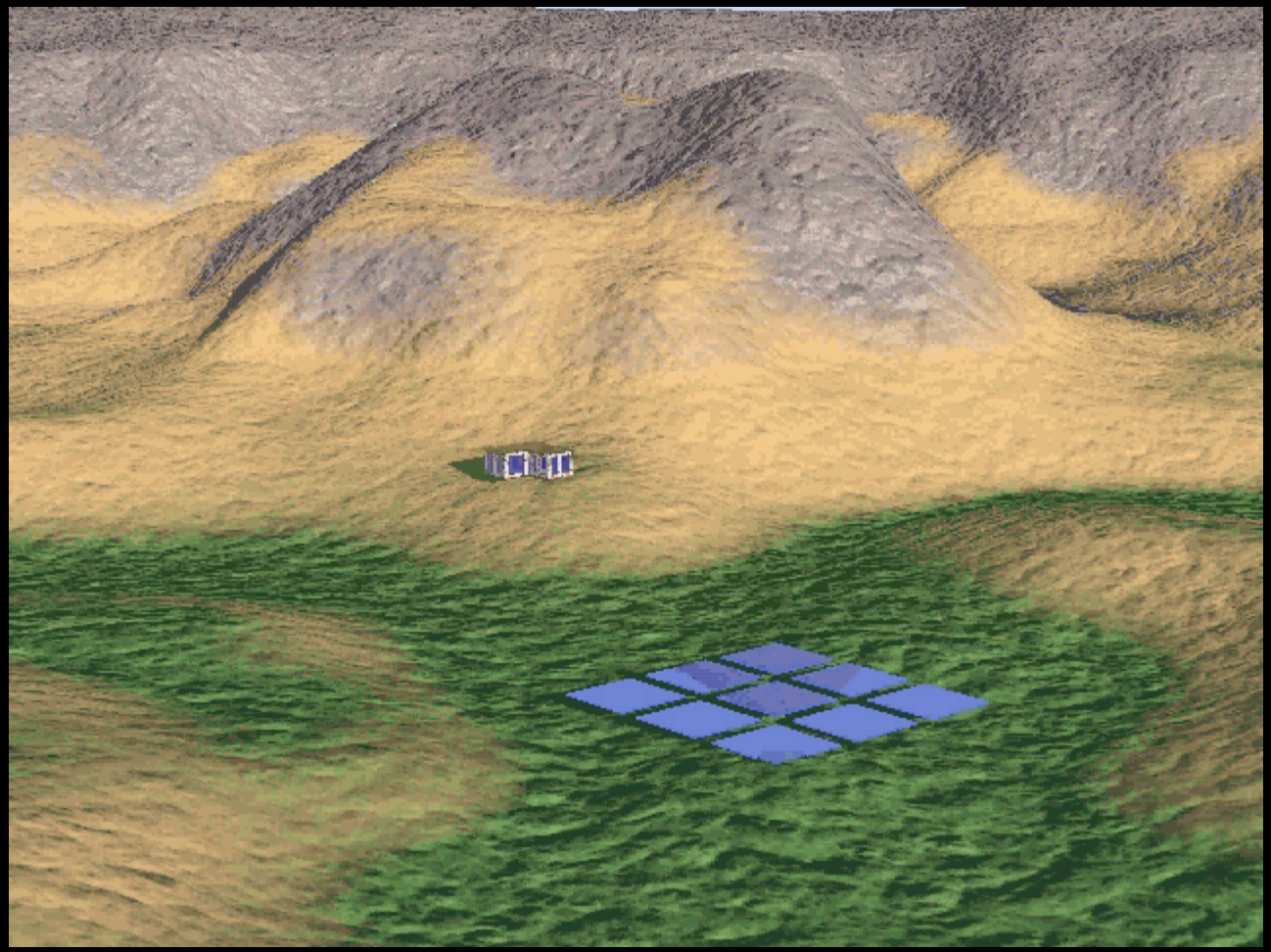
Square Kilometre Array

En Afrique du Sud …



Ou en Australie

Télescope multitâche !



Bientôt en kiosque !

Dossier “Pour la science” No. 56, juillet 2007
“Les Galaxies”

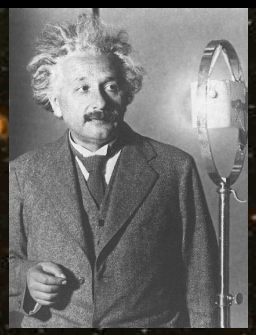
merci !

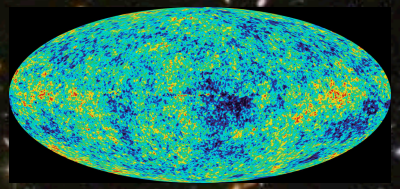
ressources

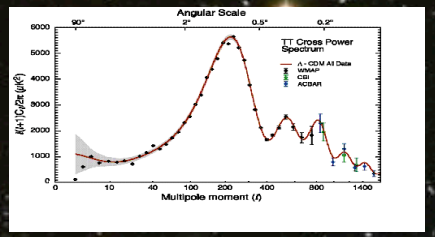
- **NASA**: http://wmap.gsfc.nasa.gov
- **Hubble**: http://hubblesite.org
- **Michael Kramer:** http://www.jb.man.ac.uk/research/pulsar
- **Wayne Hu**: http://background.uchicago.edu/~whu
- **Square Kilometre Array**: http://www. skatelescope.org
- **SKADS**: http://www.skads-eu.org

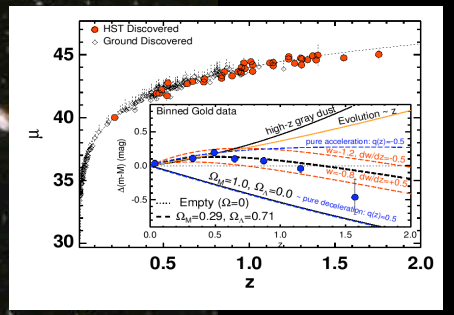
http://www.skads-eu.org


Isaac Newton. Painting by Jean-Leon Huens, © National Geographic Society.

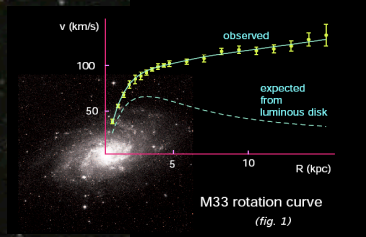




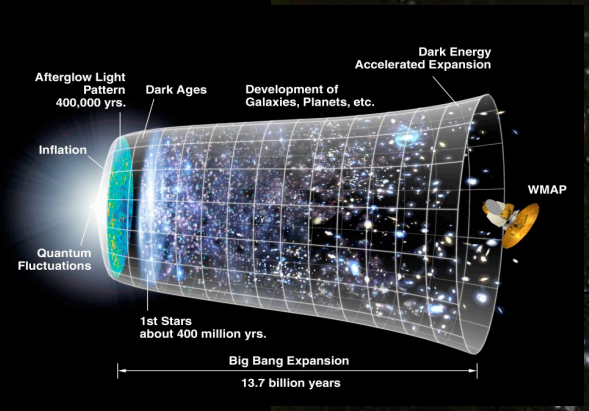


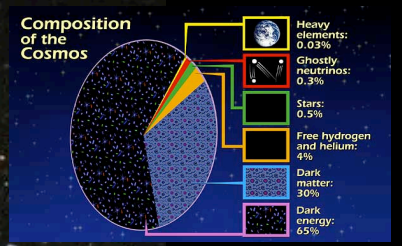


Sur les traces de l'énergie sombre et de la masse manquante dans l'univers

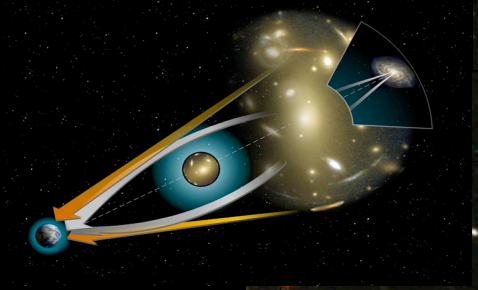


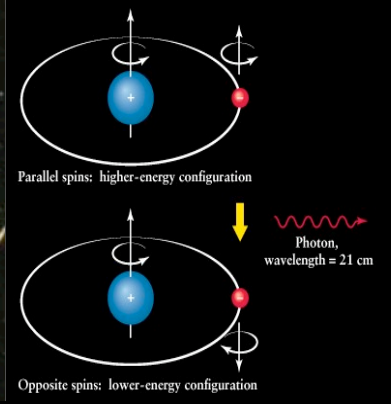
M33 rotation curve
(fig. 1)





Steve Torchinsky
Observatoire de Paris





Les Rencontres de Blois