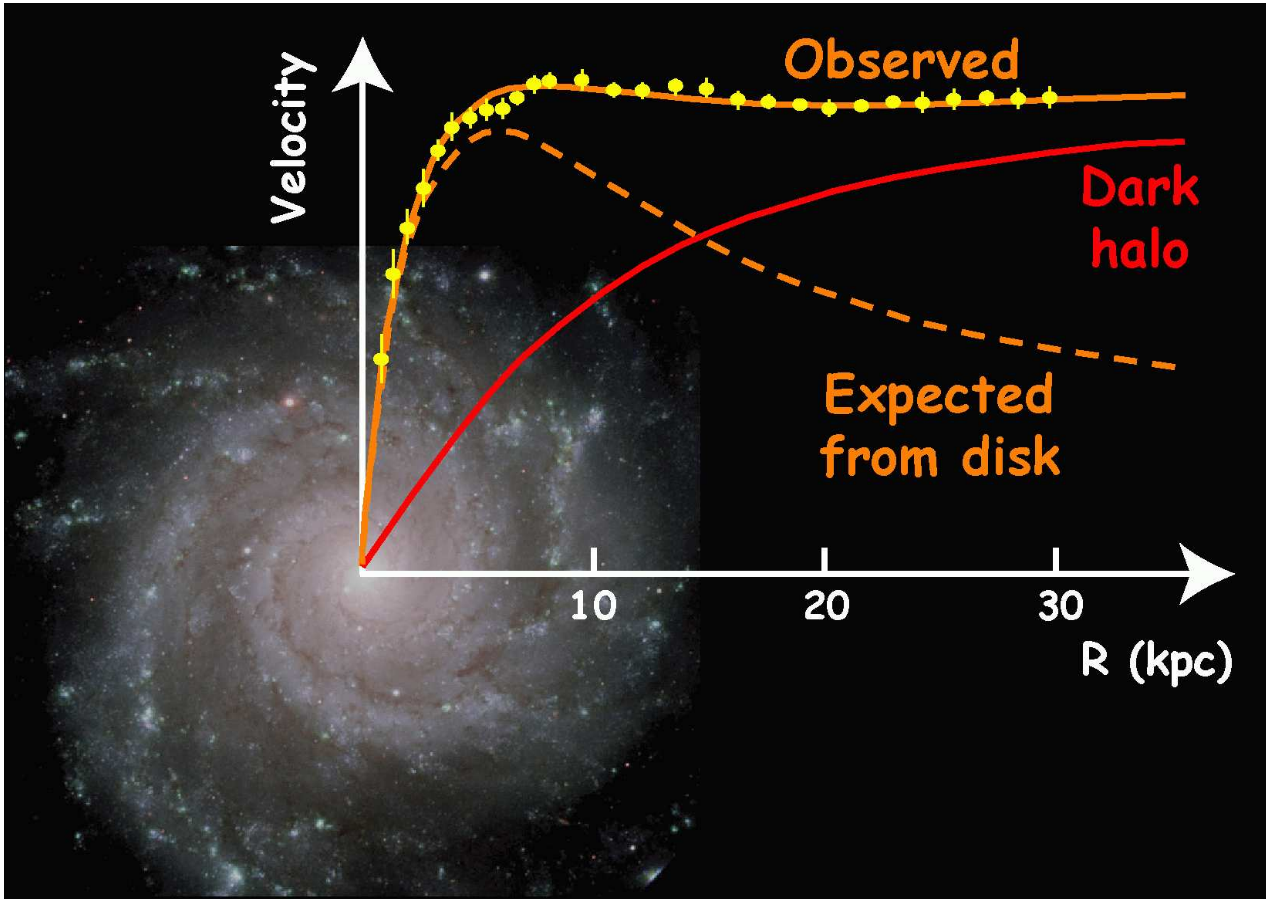
Quoi de neuf autour de la matière noire ?

- galaxy-galaxy lensing (SDSS 2006)
- CMB polarization (QUAD 2009)
- The anthropic axion
  (Tegmark, Aguirre, Rees, Wilczek 2006)

Rotation Curves ⇒ Dark Matter (?)

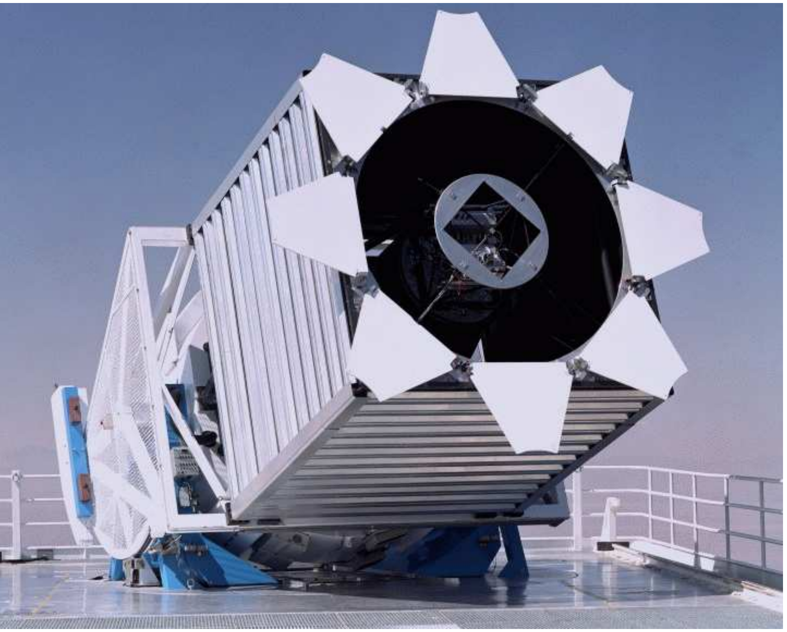


Rotation Curves ⇒ Dark Matter

OR

MOdified Newtonian Dynamics (F$\neq GMm/r^2$)

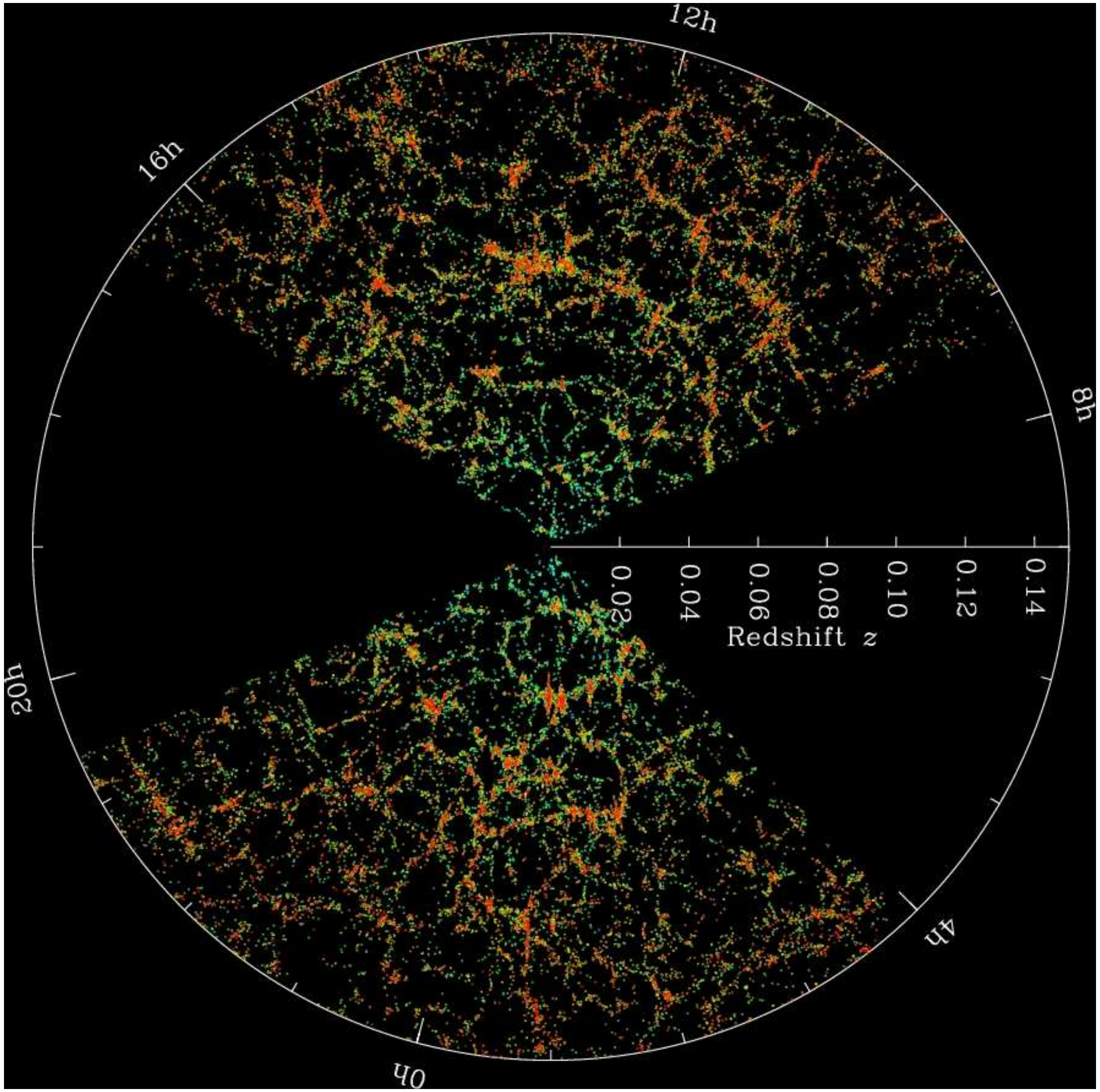
Sloan Digital Sky Survey



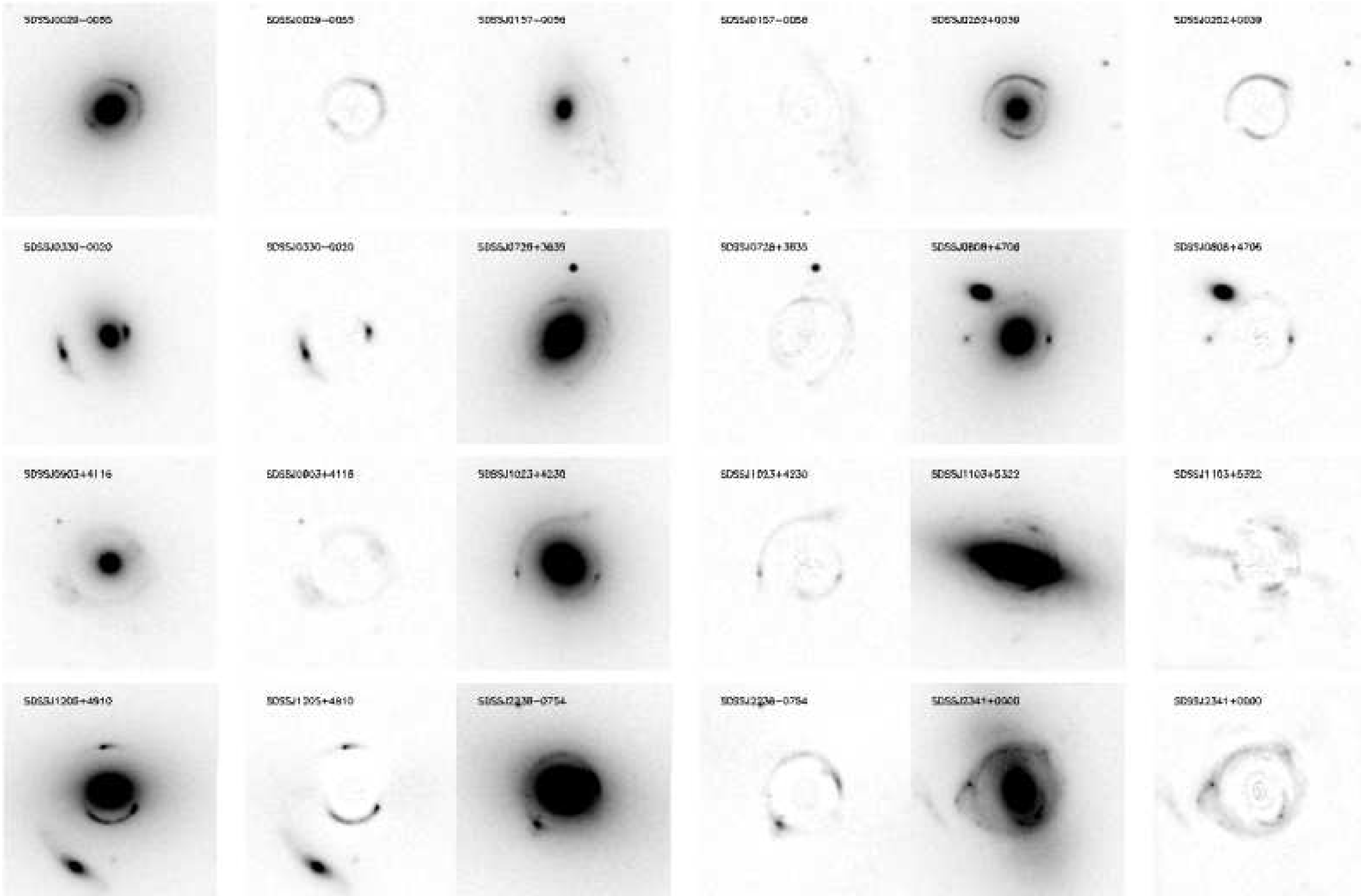
10^6 redshift galaxy survey
Apache Peak, New Mexico, USA

U. of Chicago, Fermilab, the Institute for Advanced Study,
the Japan Participation Group, The Johns Hopkins U.,
the Korean Scientist Group, Los Alamos National Lab.,
the Max-Planck-Institute for Astronomy (MPIA),
the Max-Planck-Institute for Astrophysics (MPA),
New Mexico State U., U. of Pittsburgh, U. of Portsmouth,
Princeton U., the United States Naval Observatory,
and the U. of Washington.

SDSS : slices of the Universe



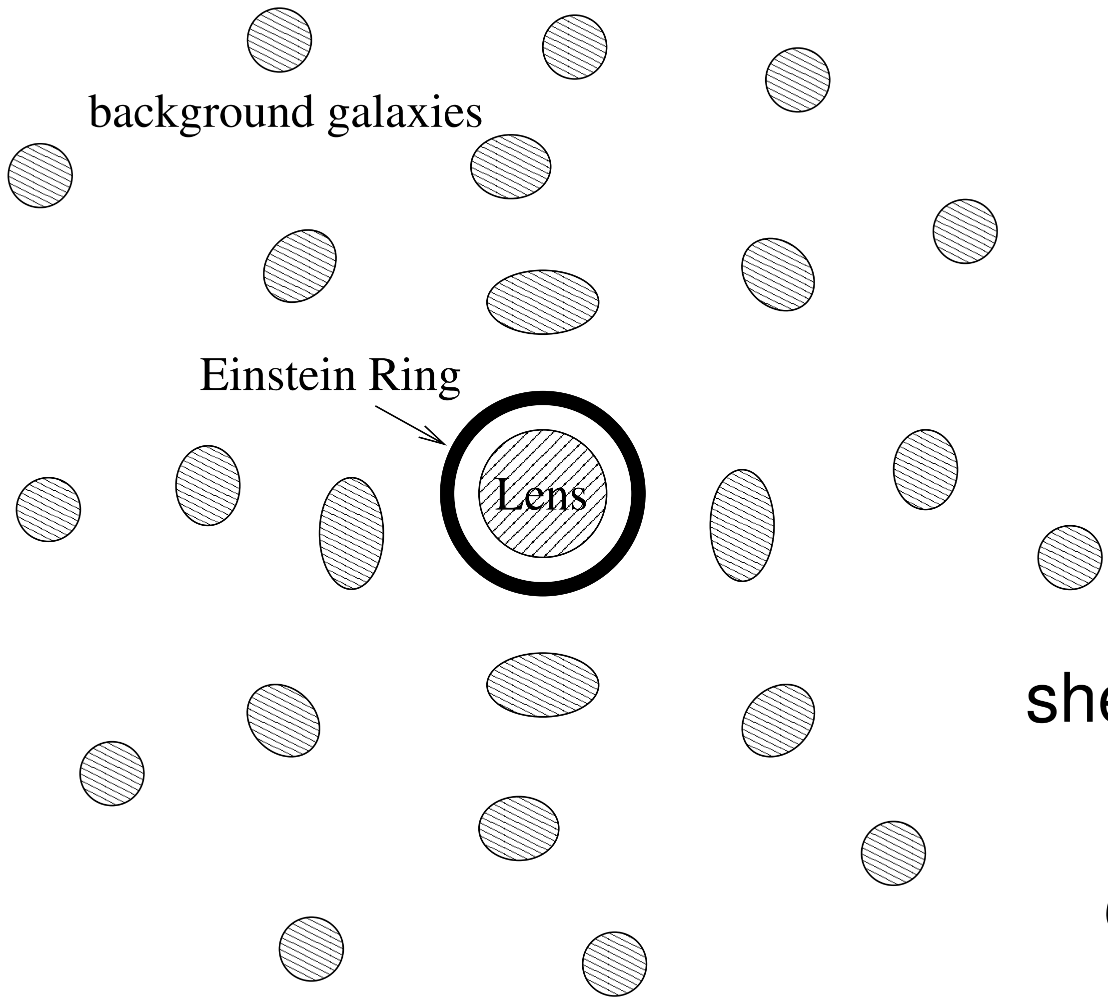
HST images of strange SDSS galaxies



Foreground galaxy $=$ gravitational lens

$\Rightarrow$ Einstein rings of background galaxies

Weak shear (tangential stretch factor)

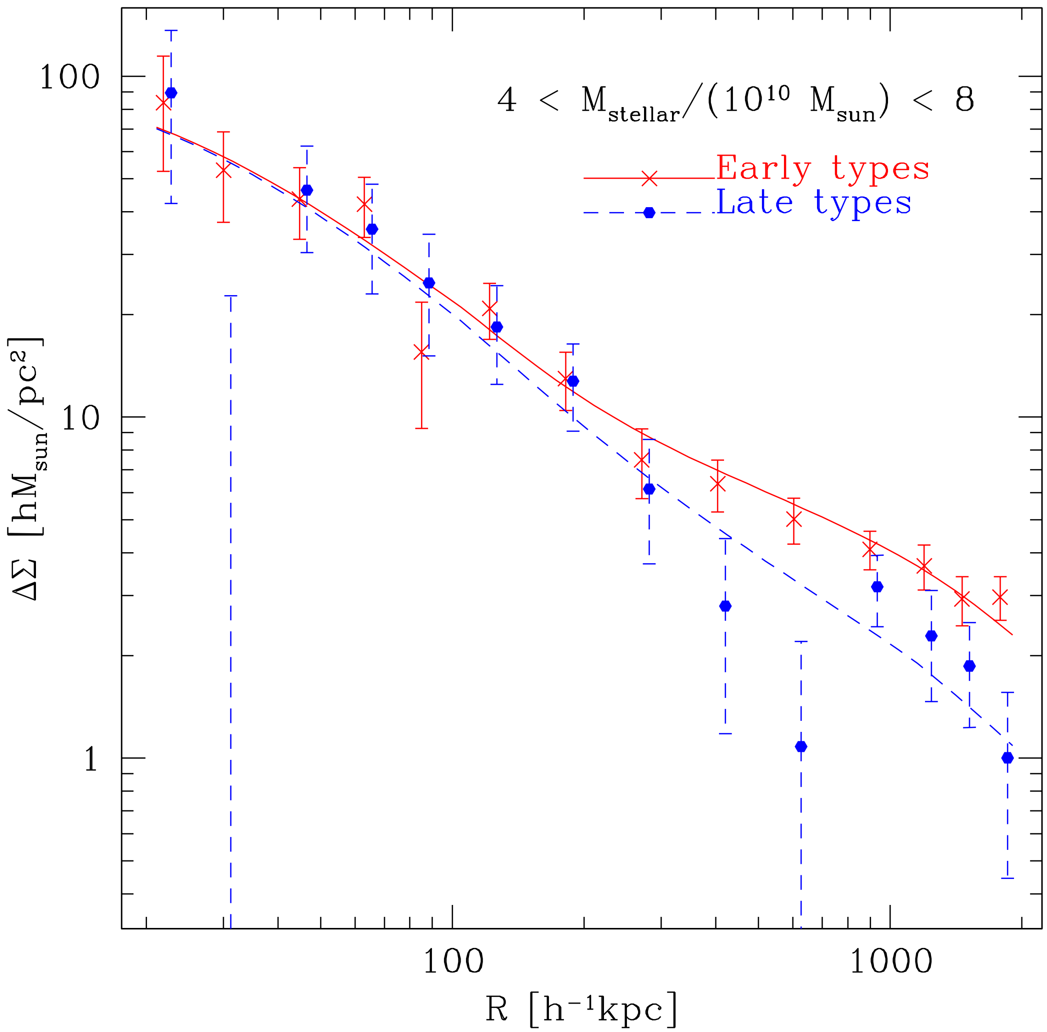


shear $\sim \theta_E/\theta$
(flat rotation curve)

$\theta =$ distance to lens

$\theta_E \sim (v_{rot}/c)^2$

Galaxy mass profiles from weak shear

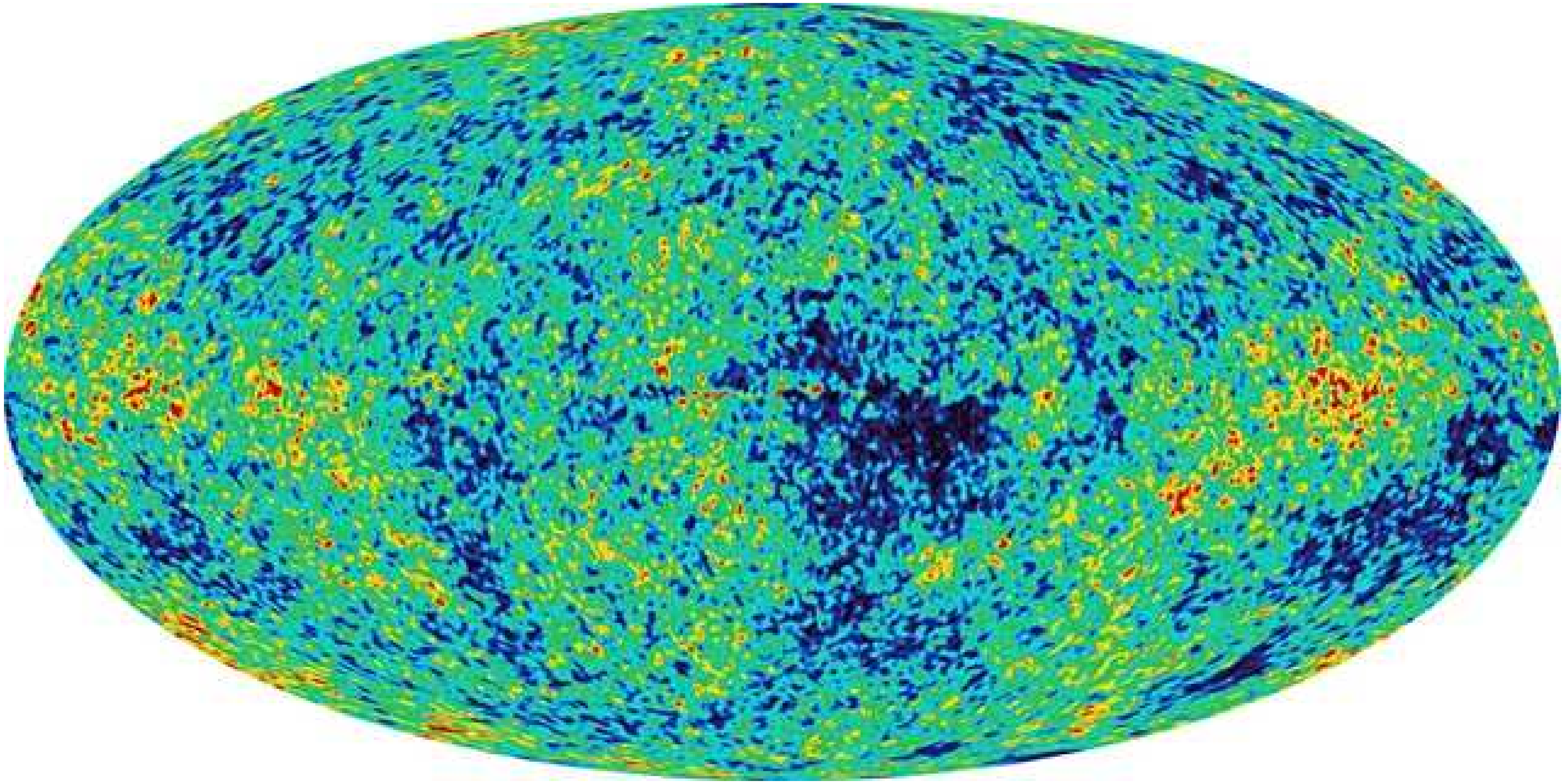


SDSS

shear averaged over many galaxies

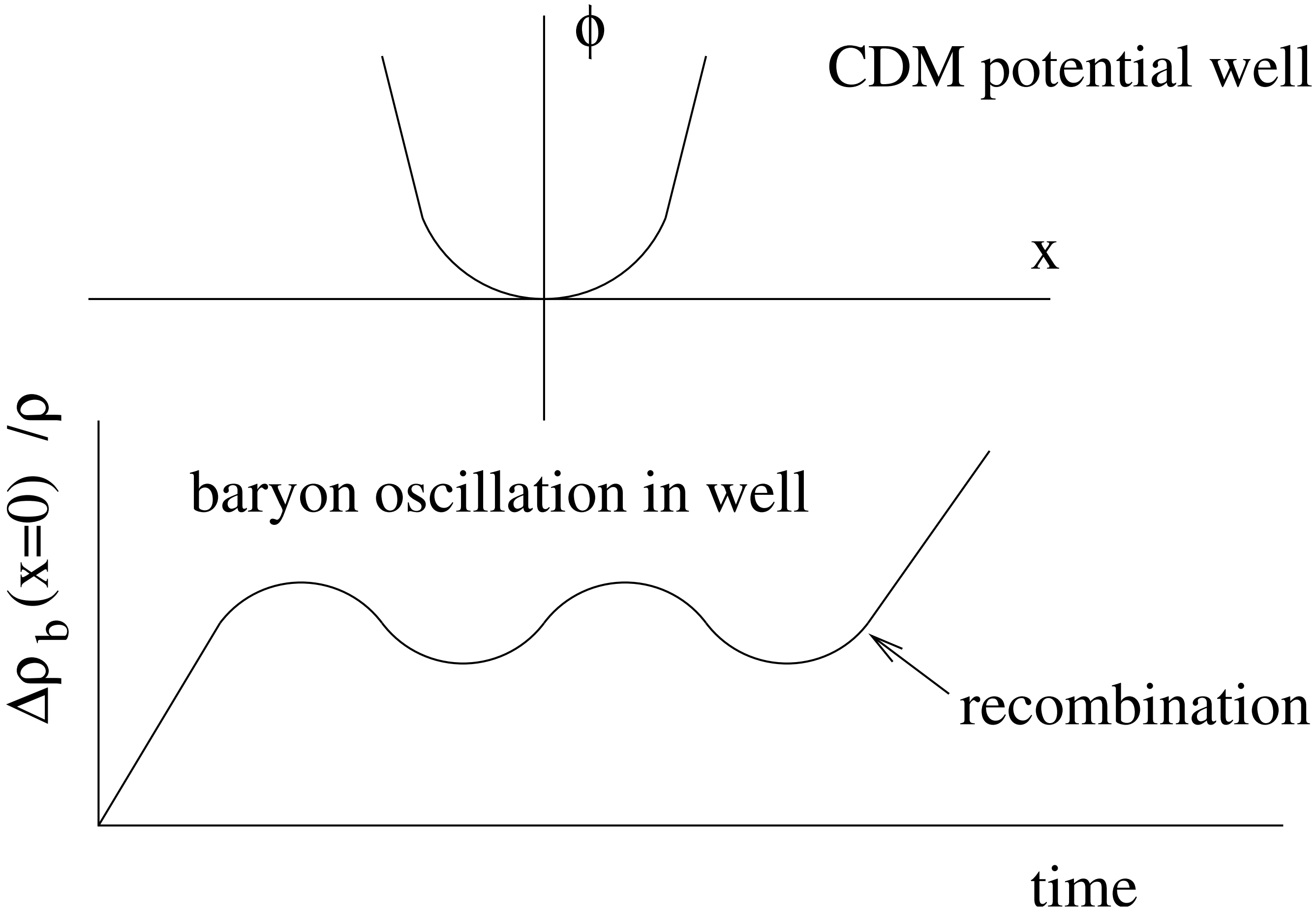
Mandelbaum et al (2006) $\Rightarrow$ flat rotation curve to $\sim$Mpc.

WMAP photo of photon-baryon plasma

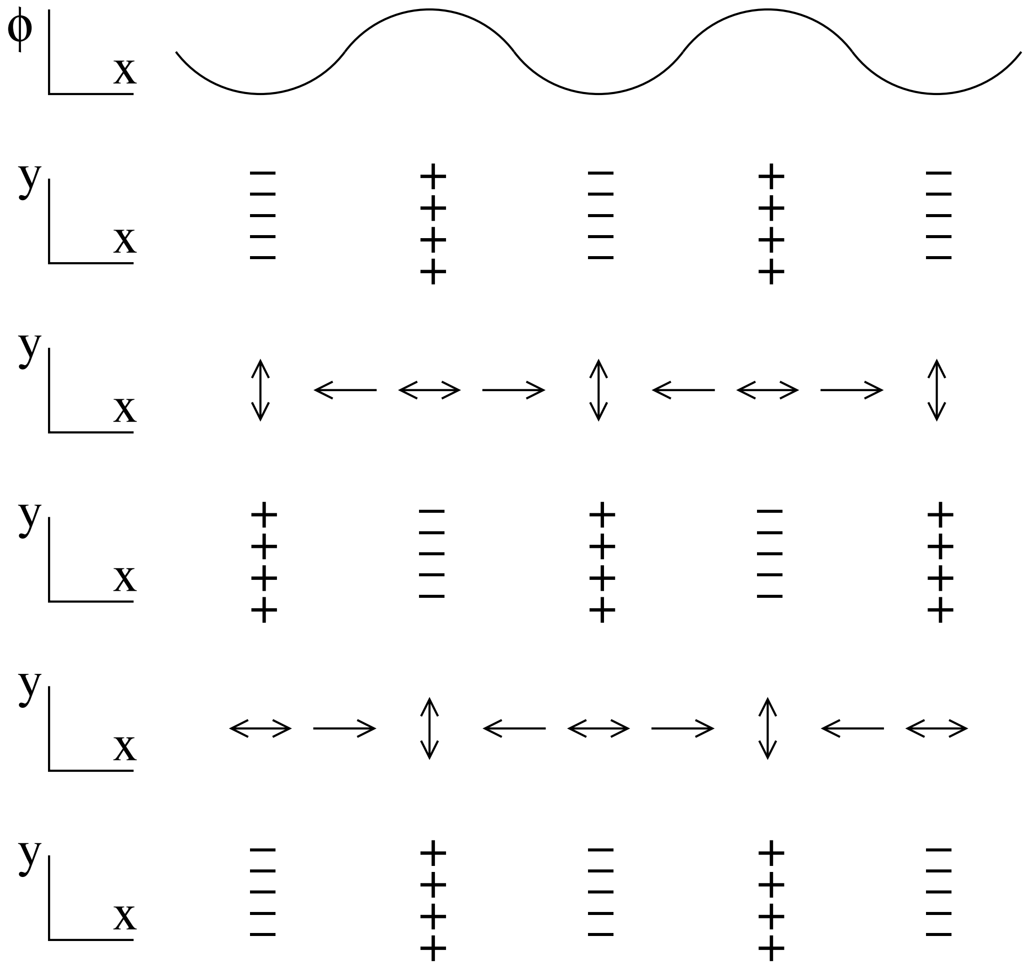


Where : “our last scattering surface” $R = 14.3 Gpc$
When : “recombination” $t = 380000 yr$
What : acoustic vibrations in CDM gravitational
potential. (vibrations stop at recombination)

Baryon photon oscillation in CDM well



One oscillation mode *vs.* time



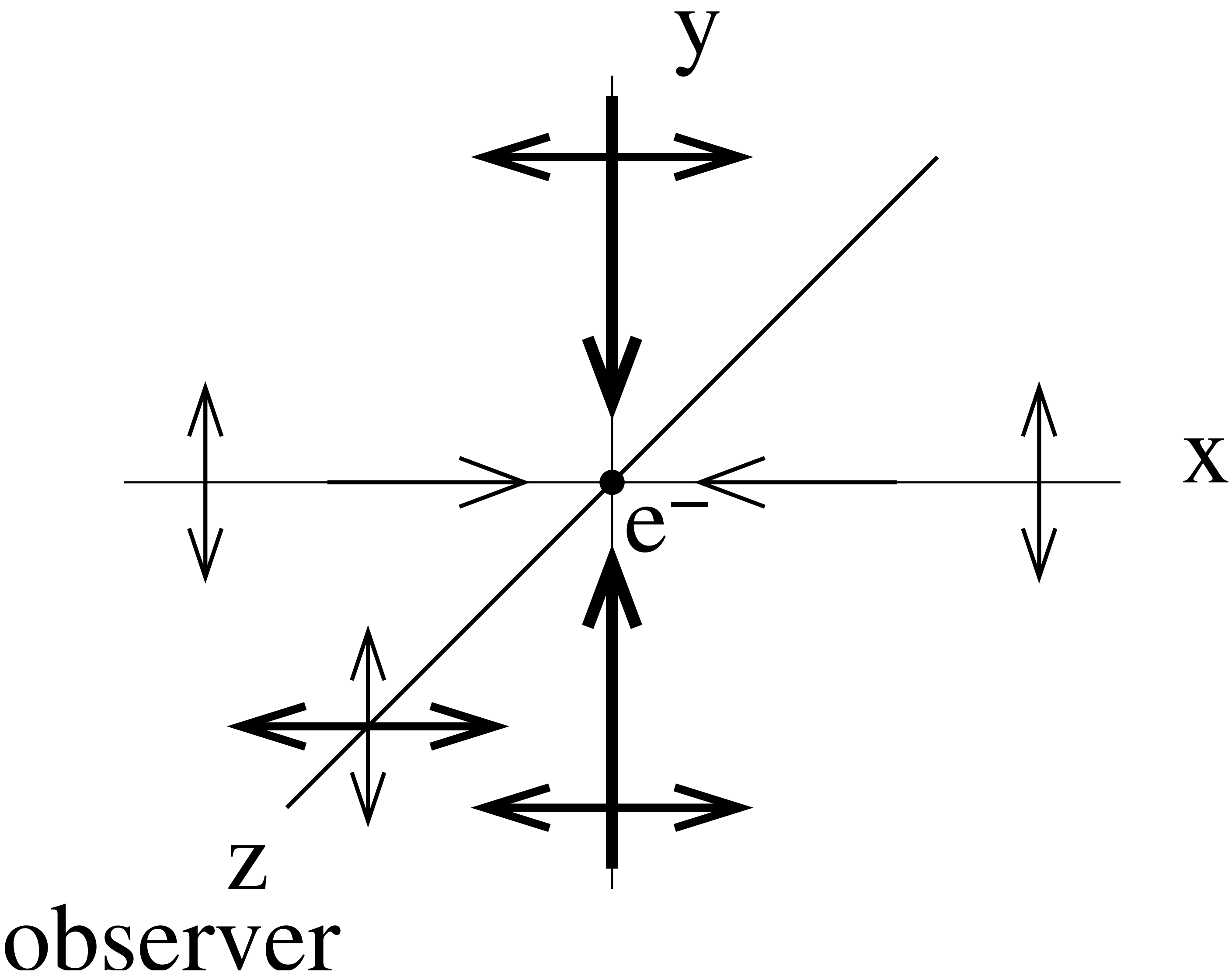
and so on until recombination

+=hot −=cold → =velocity ↕ =polarization

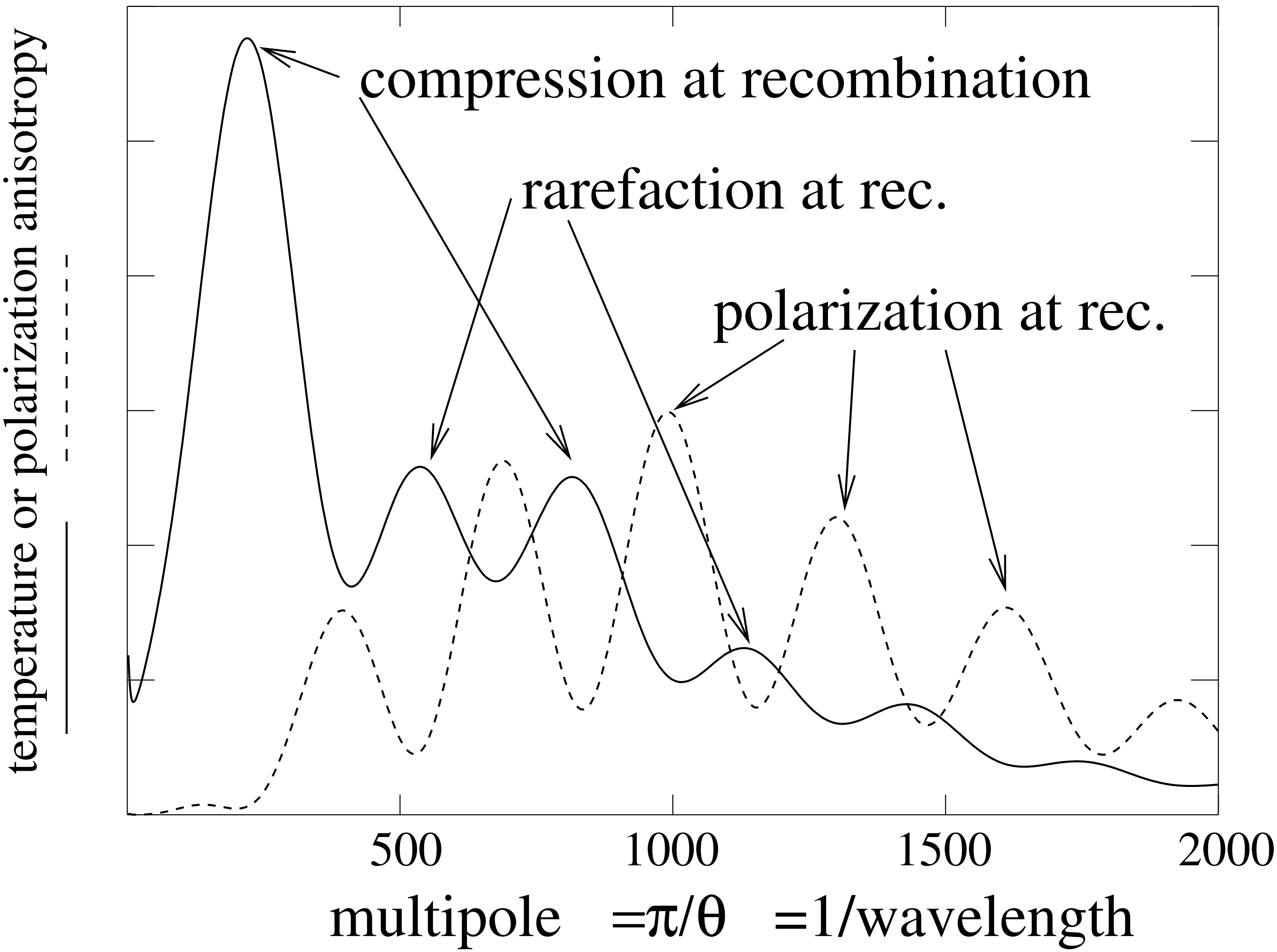
Doppler ⇒ polarization

Plasma converging toward xz plane

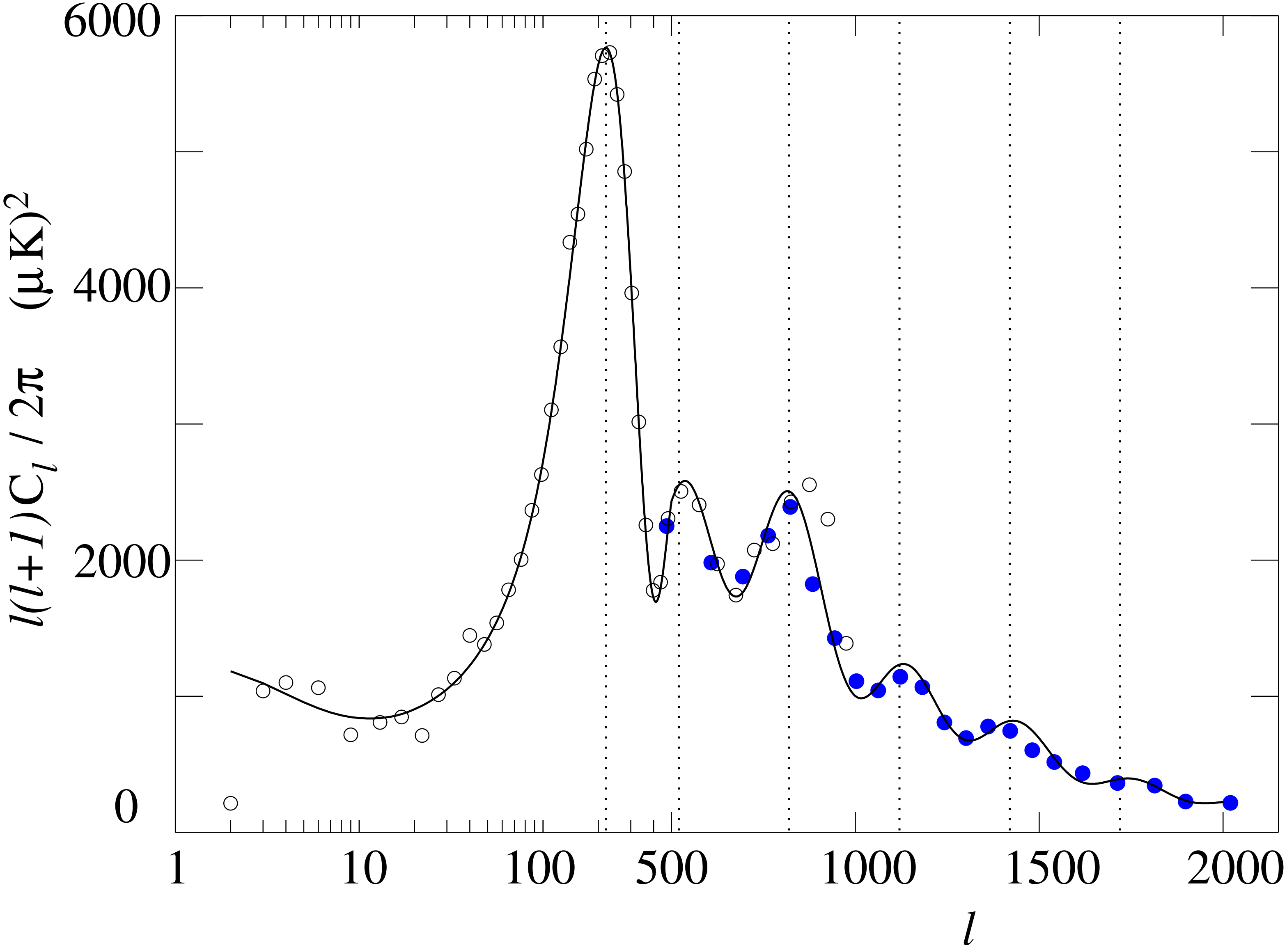
⇒polarization in x direction



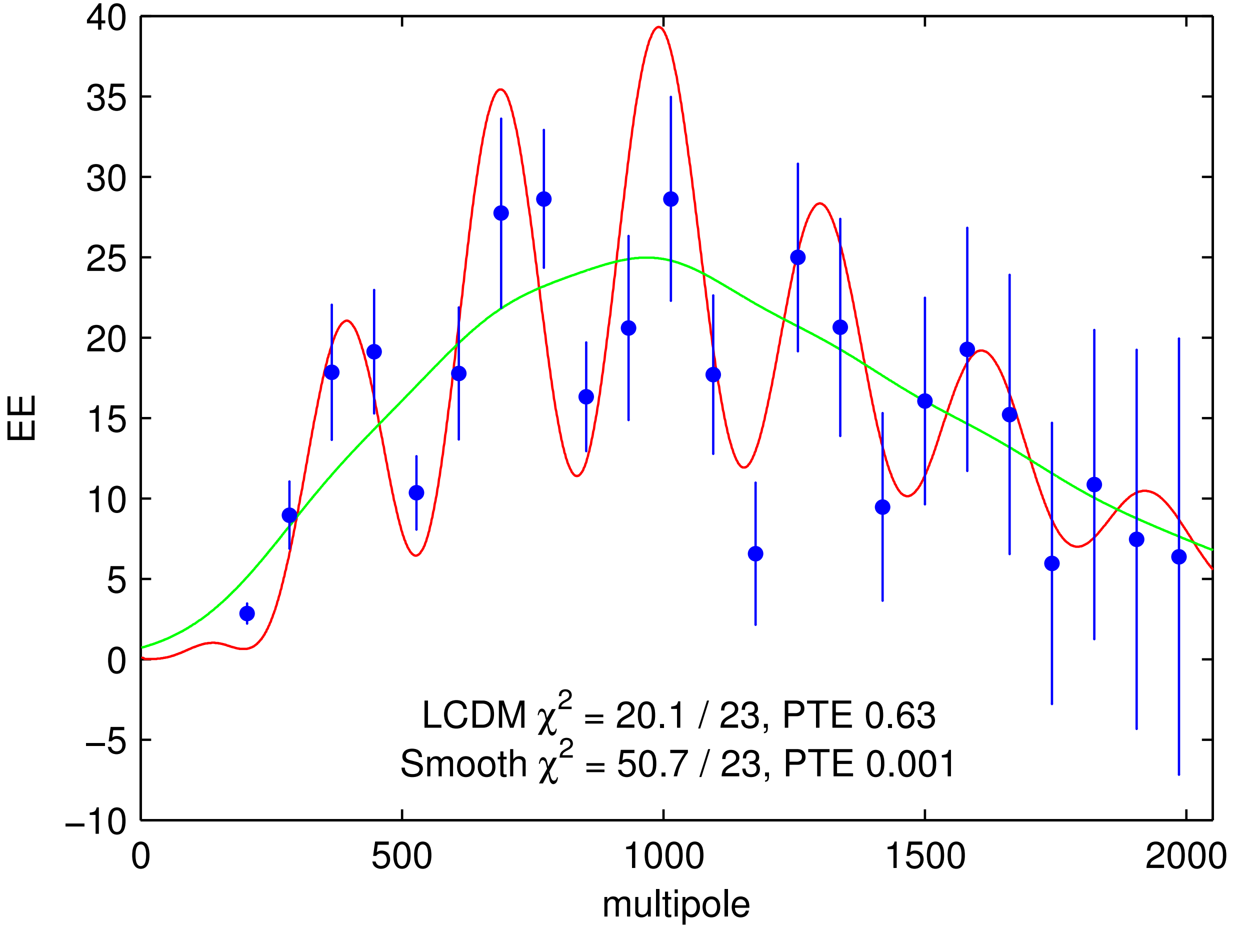
Predicted anisotropies



WMAP/ACBAR TT anisotropy spectrum



QUAD EE anisotropy spectrum



Dark matter : the ususal suspects

- Lightest supersymmectric particle
  CDMS, XENON10, Edelweiss........
- Axion Livermore axion search (+CAST)
- MACHOs (dim stellar objects)
  eliminated by microlensing searches (EROS)

Axions as dark matter

- particle invented to prevent strong CP violation

$$m_a \sim \frac{f_\pi m_\pi}{f_{pq}} \sim 10^{-5} eV \frac{10^{12} GeV}{f_{pq}}$$

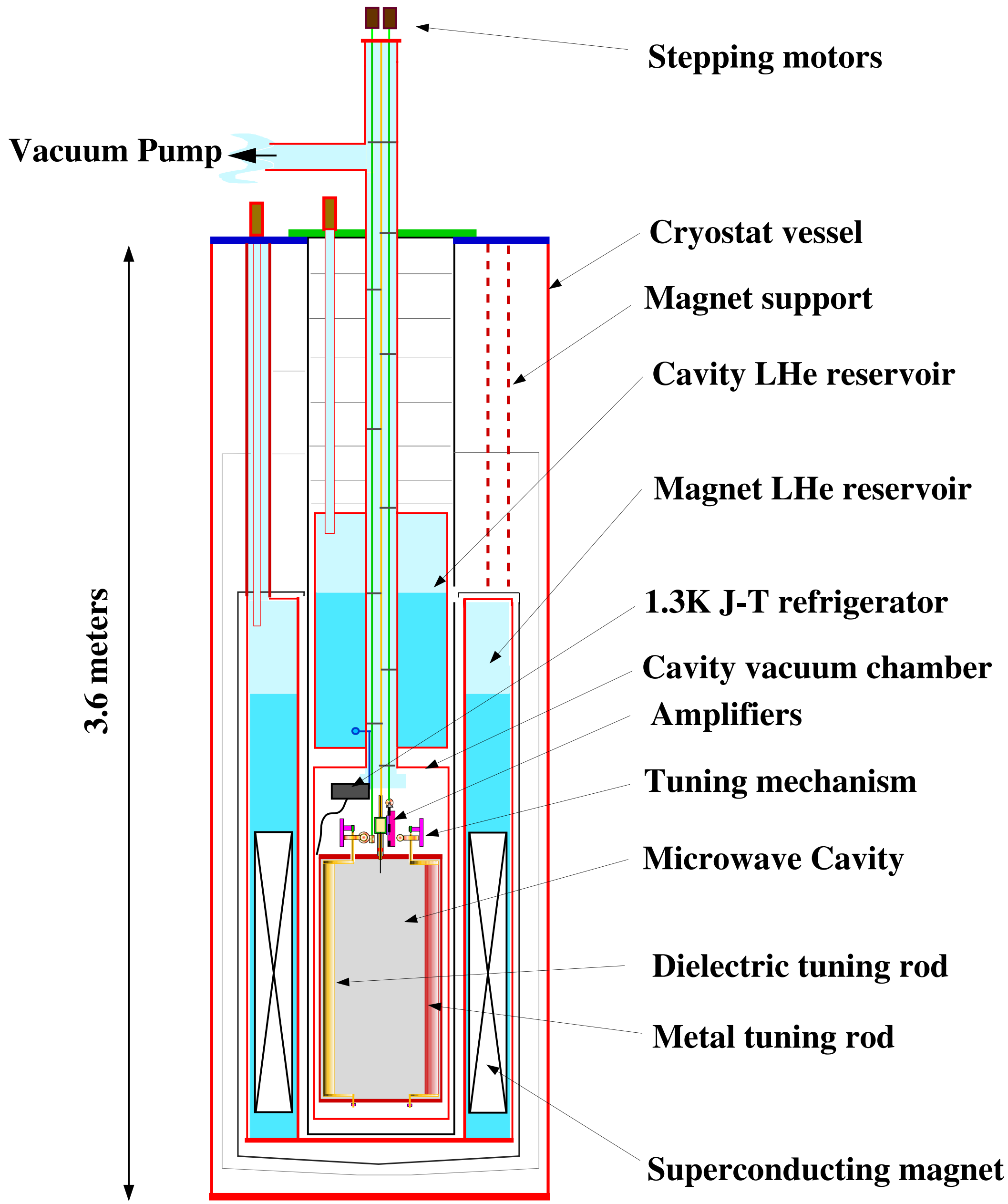
$f_{pq} =$ "Pecci-Quinn symmetry-breaking energy scale"

- Dark matter : Bose-Einstein Condensate

$$\Omega_a \sim \Theta_1^2 \frac{10^{-5} eV}{m_a} \sim \Theta_1^2 \frac{f_{pq}}{10^{12} GeV}$$

$-\pi < \Theta_1 < \pi$ (initial axion-field oscillation amplitude)

Axion conversion in magnetic field



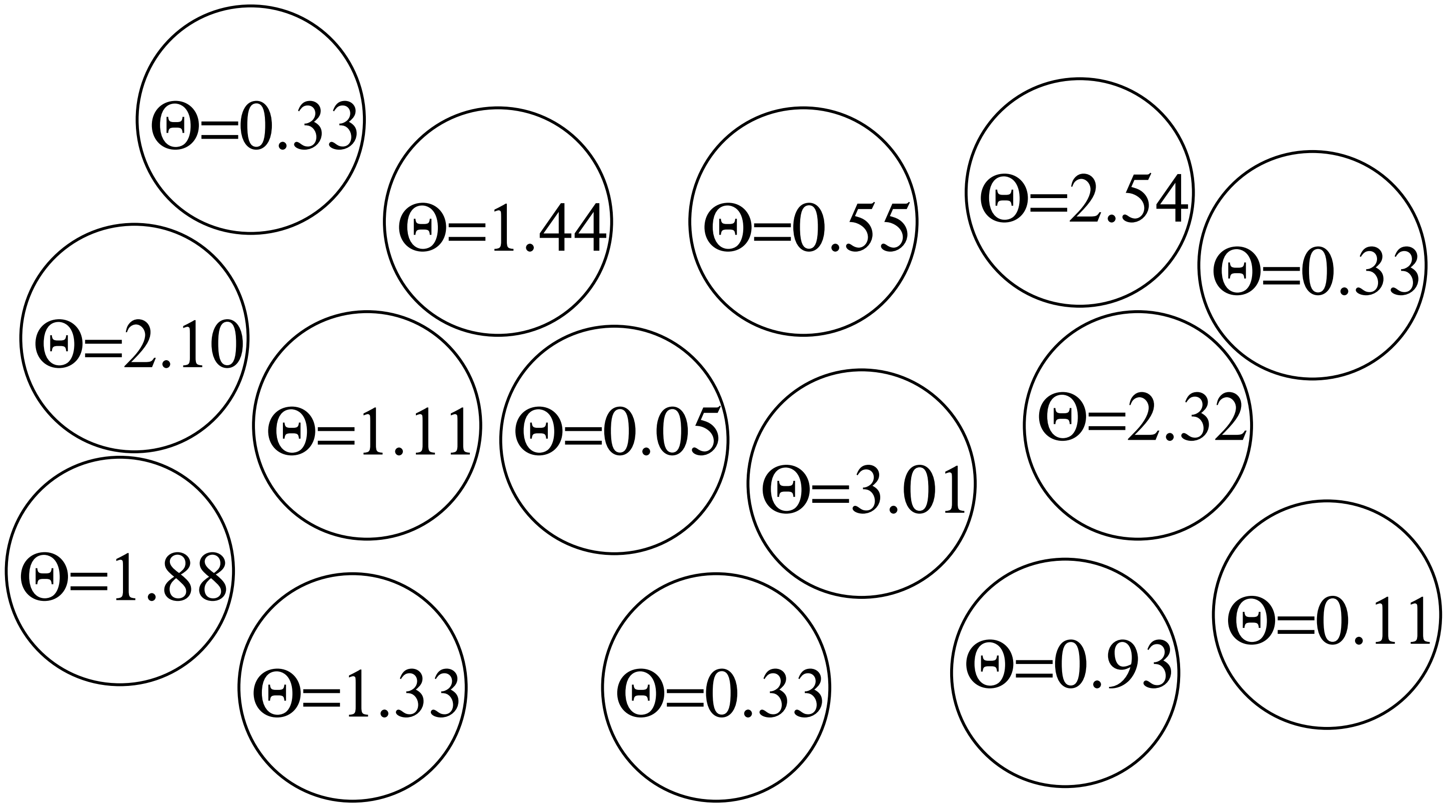
Livermore Axion search

axions absorbed by microwave cavity tuned to axion mass

$$\nu = m_a c^2/h$$
$$\sim 2Ghz(m_a/10^{-5}eV)$$

$\Rightarrow$sensitive to non-anthropic axion

Axion domains with independent Θ_1

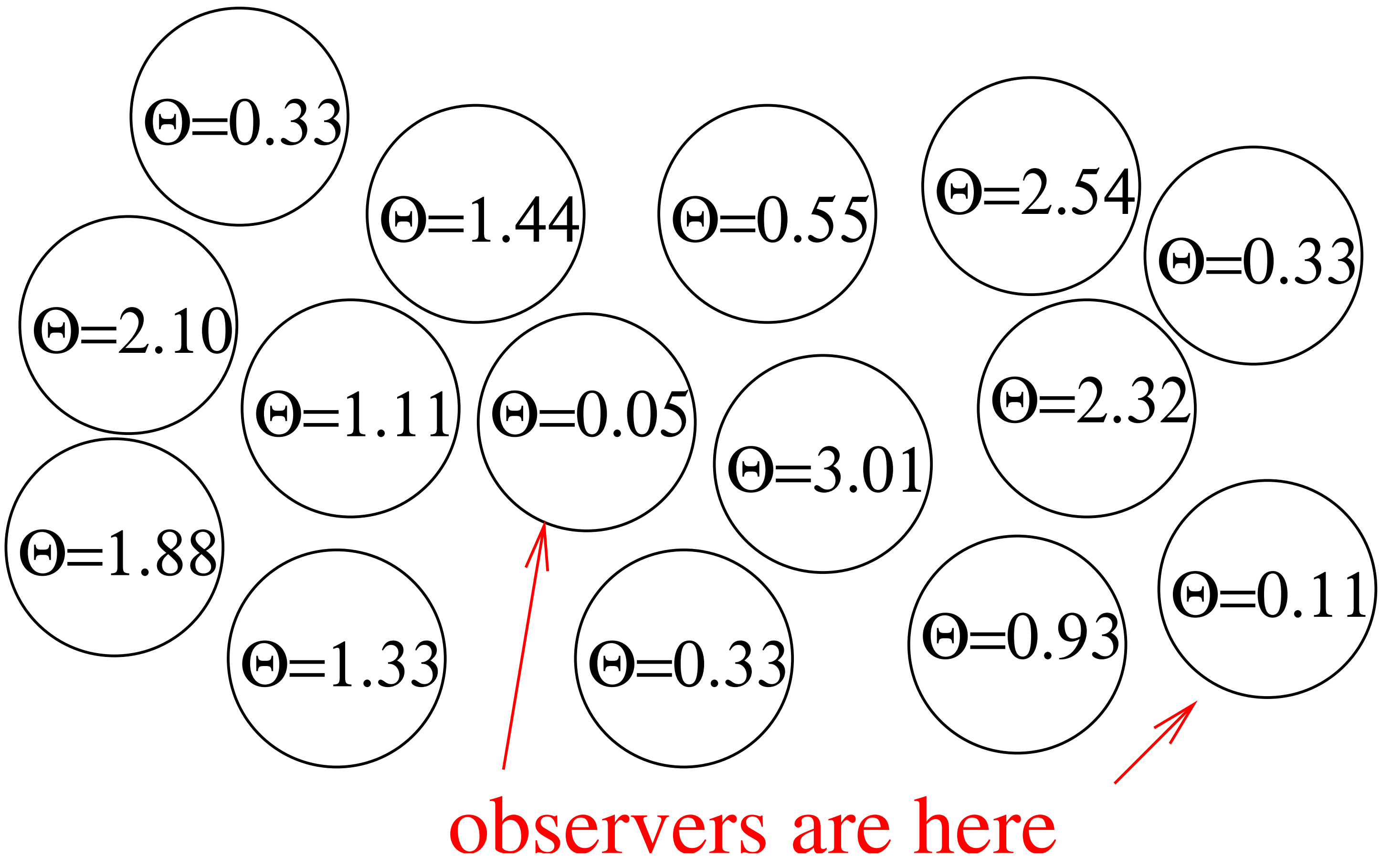


Radius of domain = horizon at PQ symmetry breaking

$\sim 1pc$ (inflation before PQ) $\Rightarrow \Omega_a \sim \langle\Theta_1^2\rangle 10^{-5}eV/m_a$

$\sim 10^{20}pc$ (inflation after PQ) $\Rightarrow \Omega_a \sim \Theta_1^2 10^{-5}eV/m_a$

Inflation after PQ : Where are you ?



$f_{pq} \gg 10^{12} GeV \quad \Rightarrow m_a \ll 10^{-5} eV$

$\Omega_a \sim \Theta_1^2 10^{-5} eV/m_a \quad \Rightarrow$ Observed $\Theta_1 \ll 1$

(unless life can be formed from a Bose-Einstein condensate)

$\Rightarrow$ need new idea to detect anthropic axion