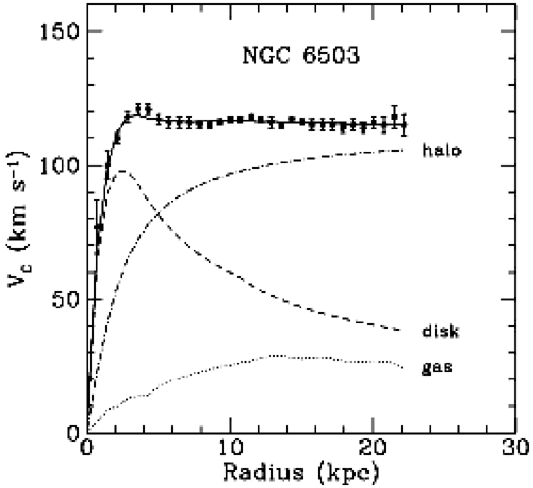
From Galactic to cluster scale

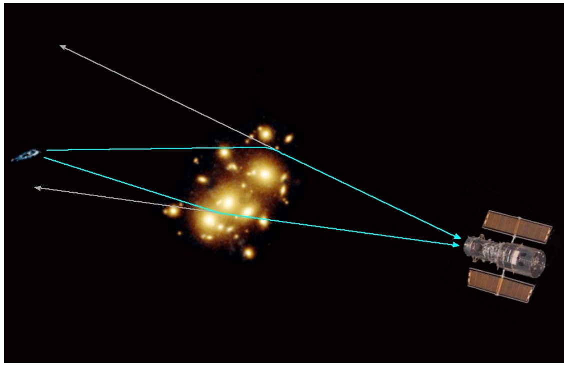
DM exists both within and between galaxies

- Galaxies: flat rotation curves

- Distribution is "mapped" in more than 1000 galaxies
- Excess is about 10 times and can be even more (also depends on the type)



- Clusters: velocity dispersion, X-ray, and lensing measurements



Three independent methods all in agreement
DM is 90% of the total matter

Cosmological evidences

- SNIa survey: Super Novae Legacy Survey

SNLS: Astier et al., A&A 447, 31 (2006)

- Galaxy surveys (formation of structures): 2dF, SDSS

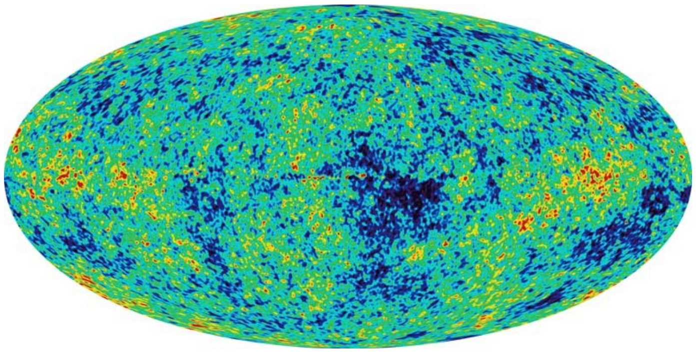
SDSS: Tegmark et al., PRD 74, 123507 (2007)

- Cosmic Microwave Background (CMB): WMAP

Almost perfect "black body" radiation (2.73 K). Deviations from the mean of about a part in million!

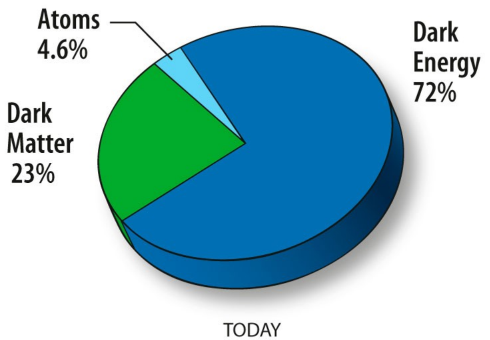
WMAP-5: Dunkley et al., ApJS 180, 306 (2009)

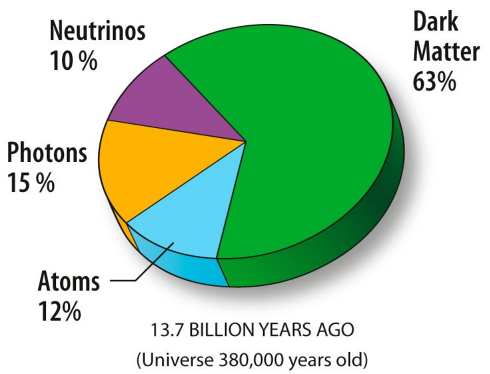
+ BAO, Weak lensing, Lyα...



=> Content of the universe

Relative constituents of the universe today (top), and for the universe 13.7 billion years ago (bottom). Neutrinos used to be a larger fraction of the energy of the universe than they are now.





Credit: WMAP Science Team

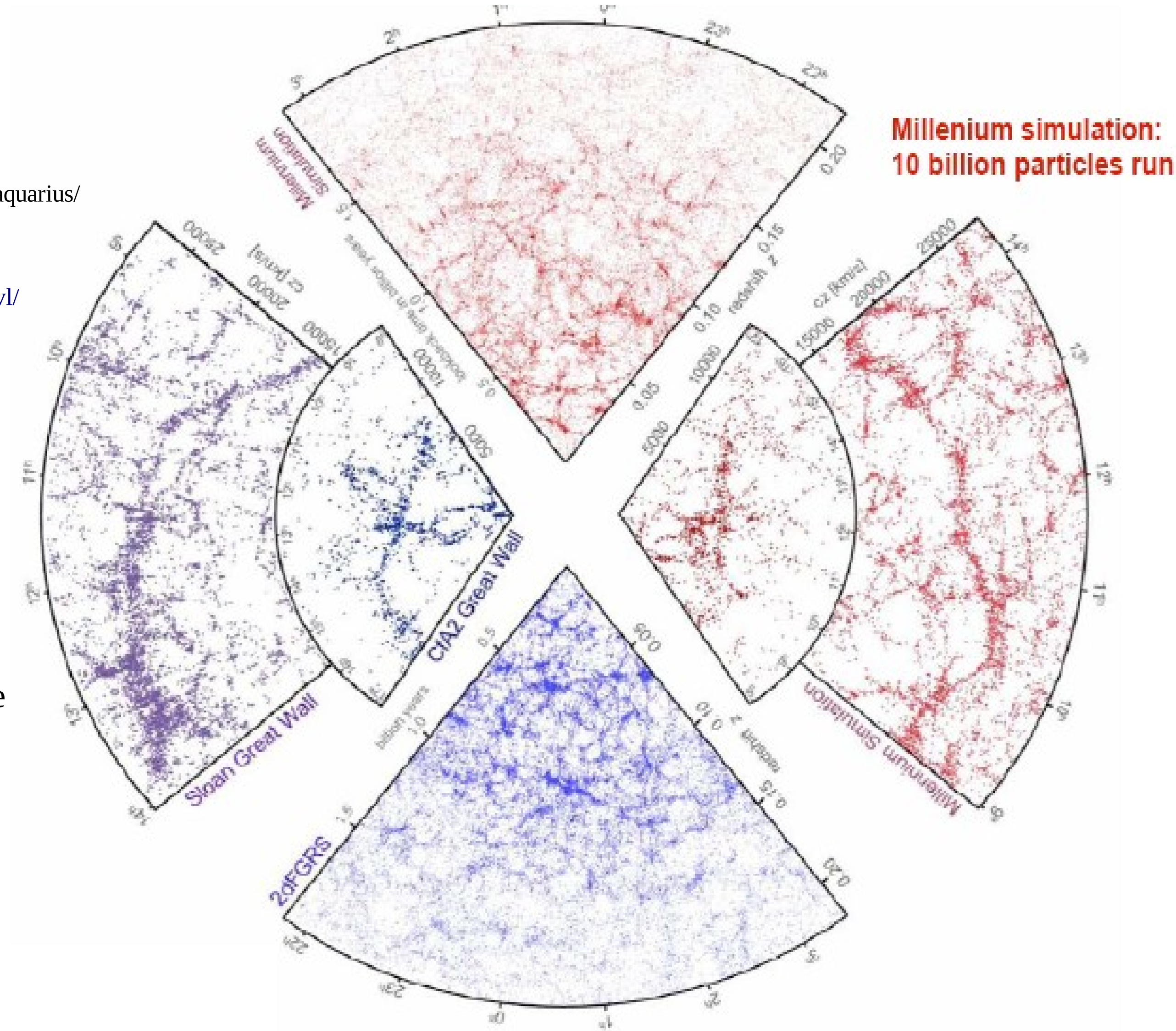
Dark energy is yet another puzzle…
But what is dark matter made of?

ΛCDM in numerical simulations

HORIZON project
http://www.projet-horizon.fr/

AQUARIUS
http://www.mpa-garching.mpg.de/aquarius/

Via Lactea II
http://www.ucolick.org/~diemand/vl/



Springel, Frenk, & White
Nature 440, 1137 (2006)

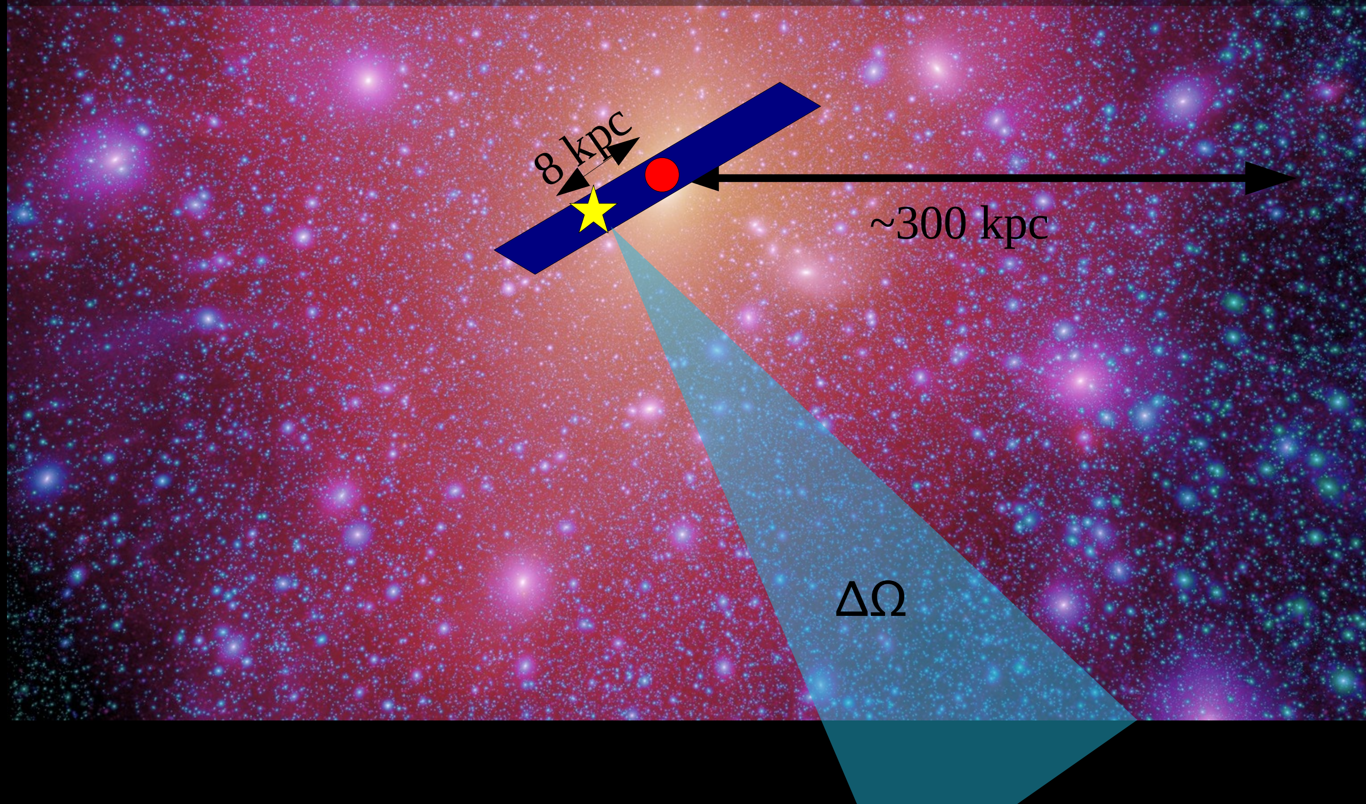
=> Hierarchical structure formation well reproduced in ΛCDM
+ prediction of DM clumps at all scales

The Galactic DM halo: targets

Aquarius, ΛCDM – Springel et al (2008)

Best targets: dense (~ $\int \rho^2$), close ($1/d^2$), no astro. background

- Galactic centre (GC)
- Dark halos (no baryons)
- Dwarf spheroidal Galaxies (dSphs)
- Galaxy clusters



Gamma-ray flux from DM annihilation

The γ-ray flux is given by

$$\frac{d\Phi}{dE}(E,\phi,\theta,\Delta\Omega) = \underbrace{\frac{d\Phi^{\rm pp}}{dE}(E)}_{\text{Particle physics}} \times \underbrace{\Phi^{\rm astro}(\phi,\theta,\Delta\Omega)}_{\text{Astrophysics}}$$

- Particle physics term

$$\frac{d\Phi^{\rm pp}}{dE} = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_\chi^2}\cdot\sum_f \frac{dN^f}{dE}B_f$$

- Bergstrom et al. (1998)
- Tasitsiomi et al. (2002)
- Bringmann et al. (2007), internal brems.

- Astrophysical term

$$J \equiv \Phi^{\rm astro} = \int_{\Delta\Omega}\int_0^{l_{\rm max}} \rho^2(l,\Omega)\,dl\,d\Omega$$

Depends on
- DM distribution (smooth + clumps)
- Integration angle