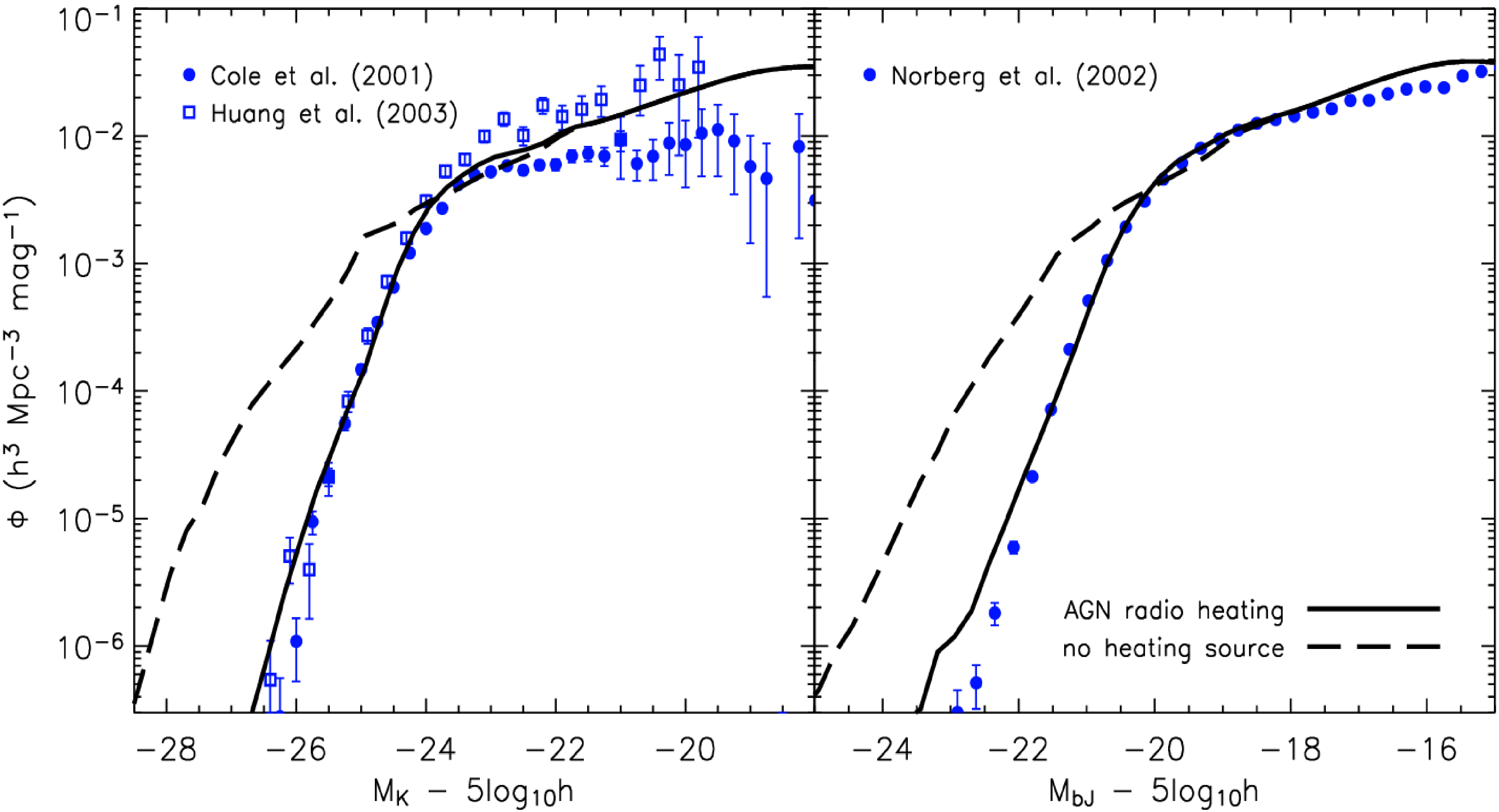
The inclusion of AGN feedback allows the semi-analytic model to reproduce a multitude of observational data

K-BAND AND Bj-BAND LUMINOSITY FUNCTIONS

Croton et al. (2006)

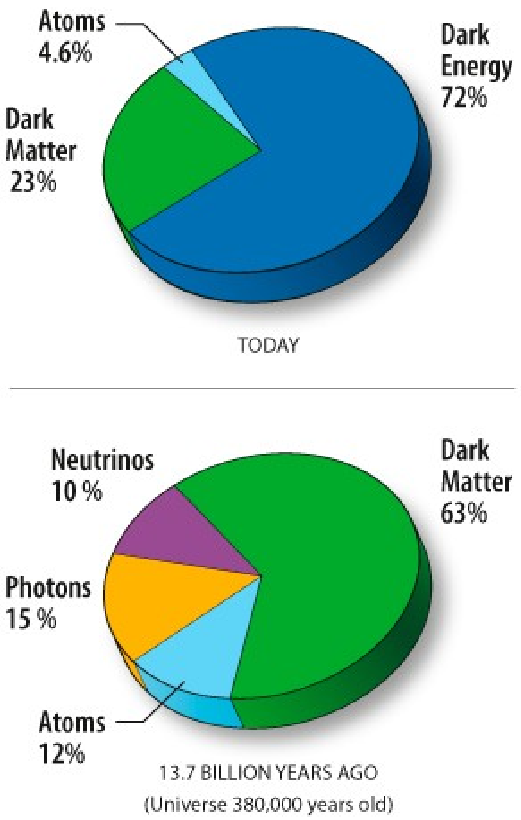


What is the Cold Dark Matter made of?

THERE ARE PROMISING CANDIDATES WITH MOTIVATION IN PARTICLE PHYSICS

Neutralino?

lightest supersymmetric particle
expected mass ~100 GeV
annihilation possibly observable
detectable through elastic scattering with nucleus

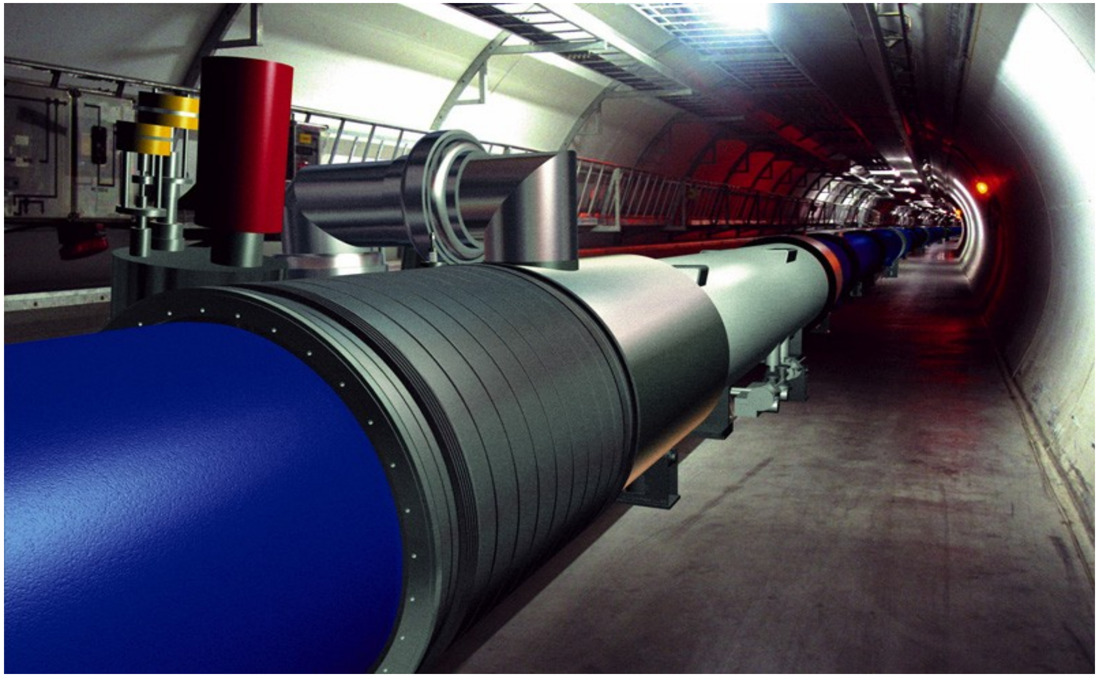


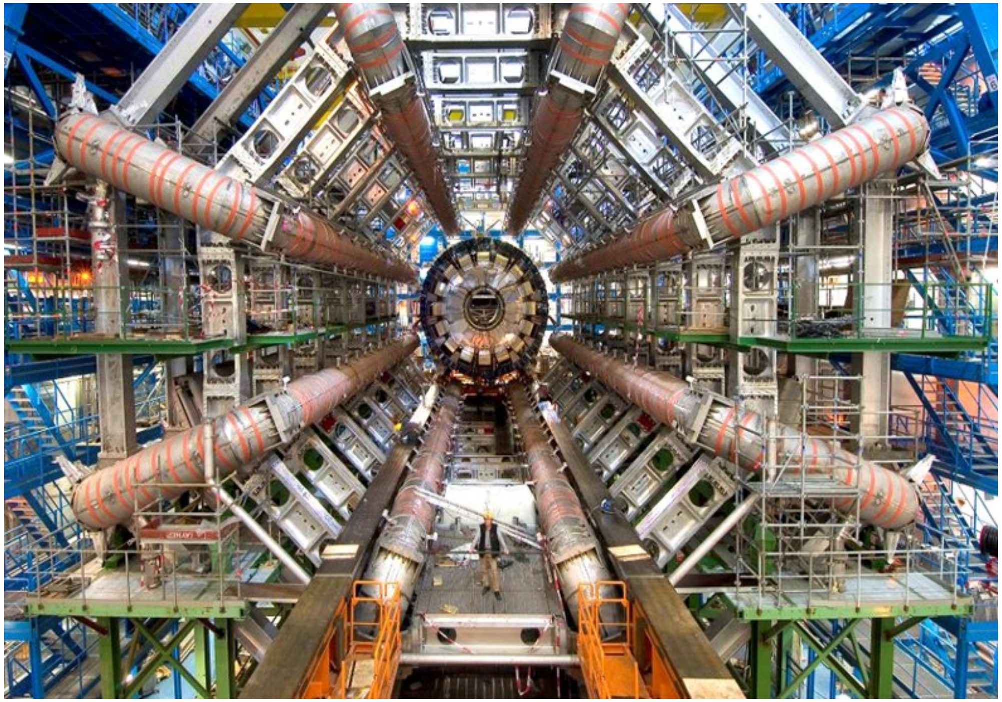
Axion?

mass ~ 10^{-5} eV
detectable through photon-conversion in strong magnetic fields

What is the dark matter made of?

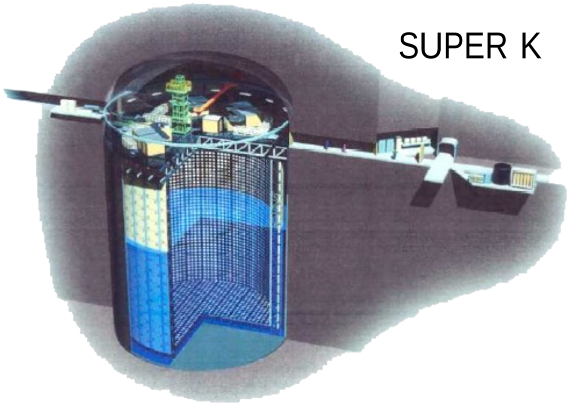
Accelerators may produce new particles that could be the dark matter



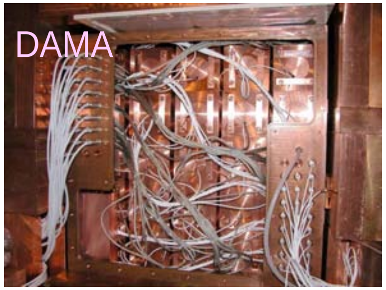


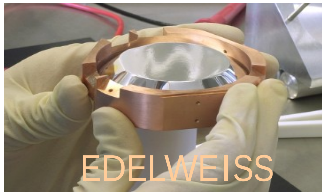
Large efforts have been started to experimentally detect dark matter

A FEW OF THE CURRENT EXPERIMENTS THAT SEARCH FOR DARK MATTER



SUPER K

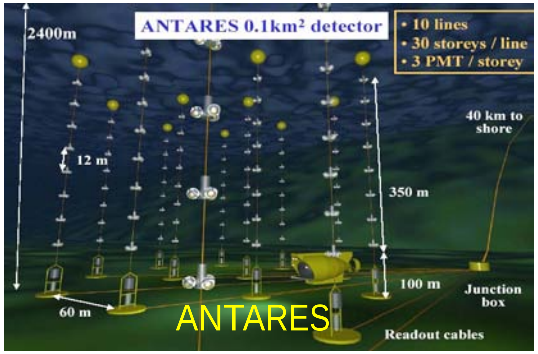




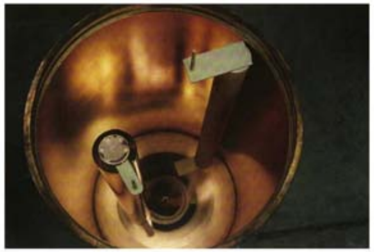
ZEPLIN

Indirect searches:
search for annihilation products

Direct searches:
measure nuclear recoil due to elastic scattering with nucleus

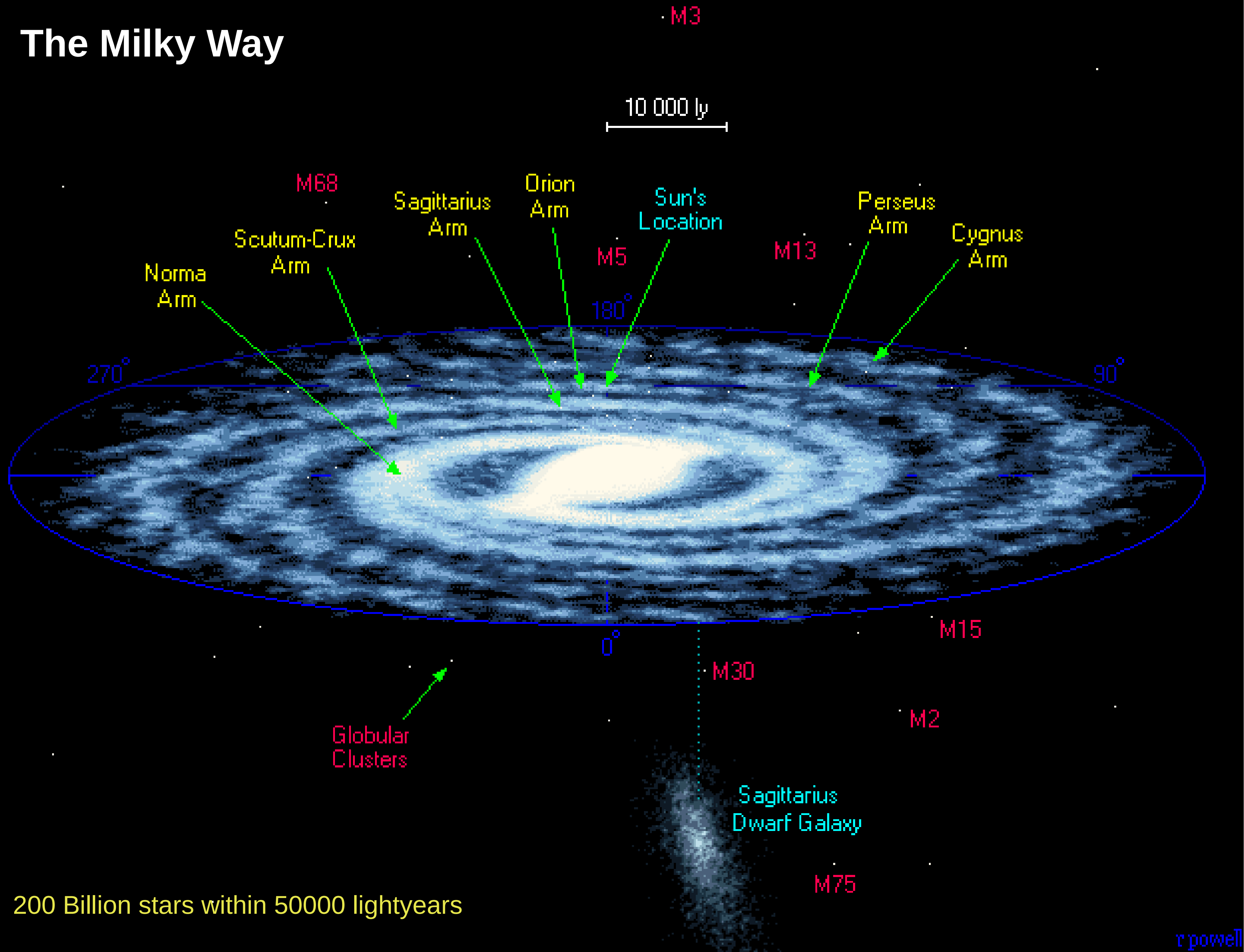


ADMX

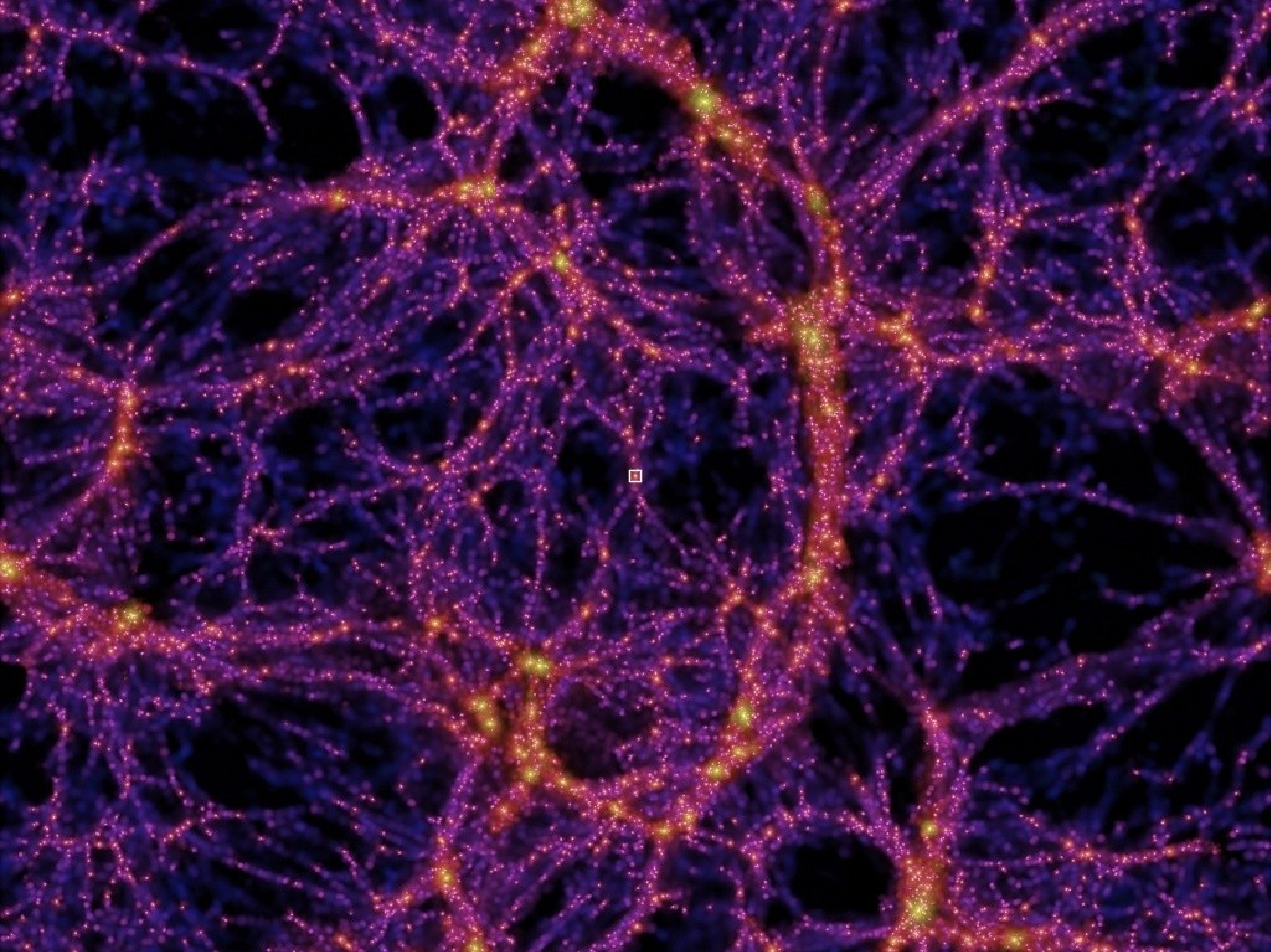


Typical cross sections of WIMPS: **~10^{-42}** cm^2 (10^{-6} pb)

The Milky Way

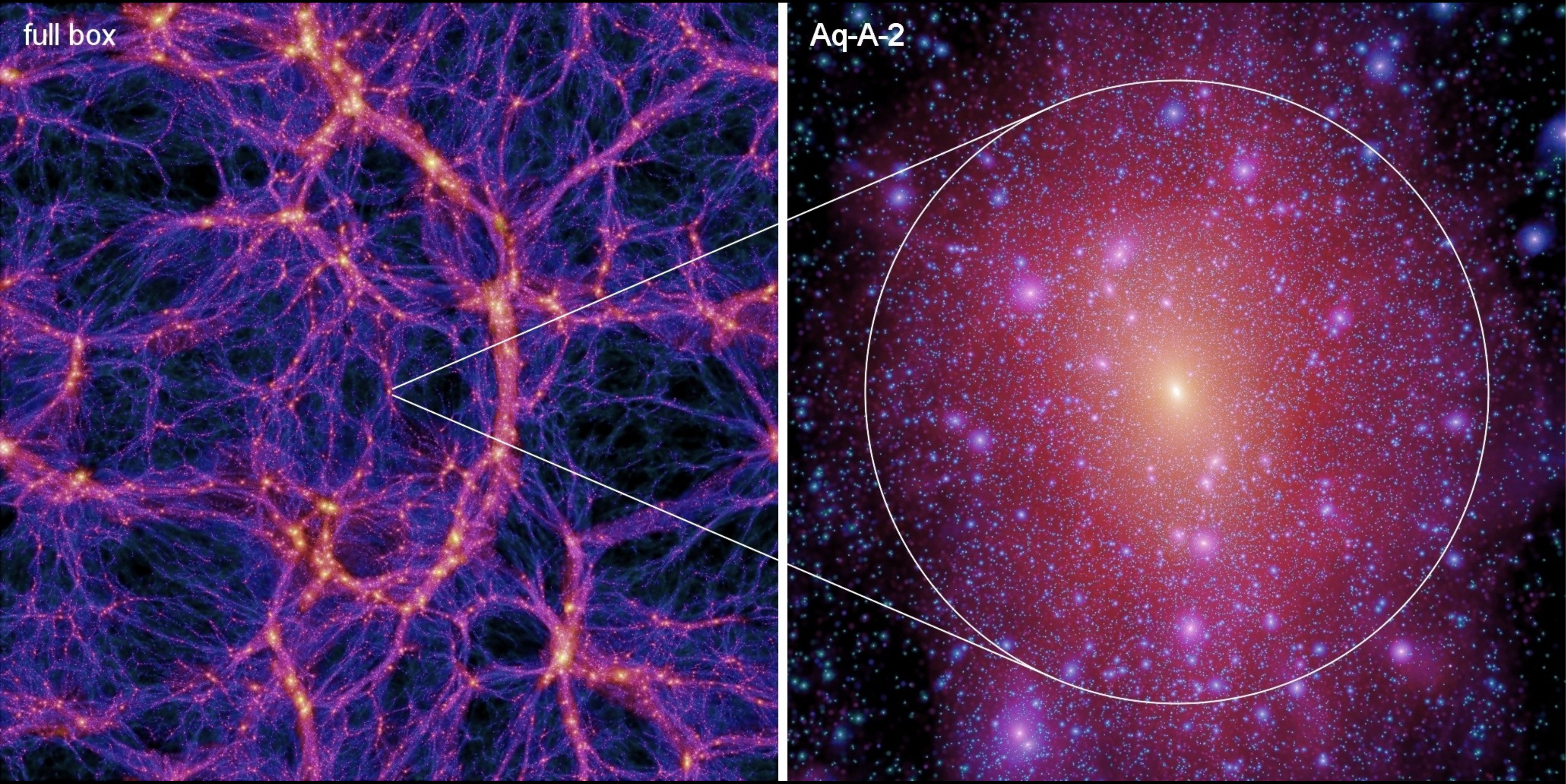


200 Billion stars within 50000 lightyears



Zooming in on dark matter halos reveals a huge abundance of dark matter substructure

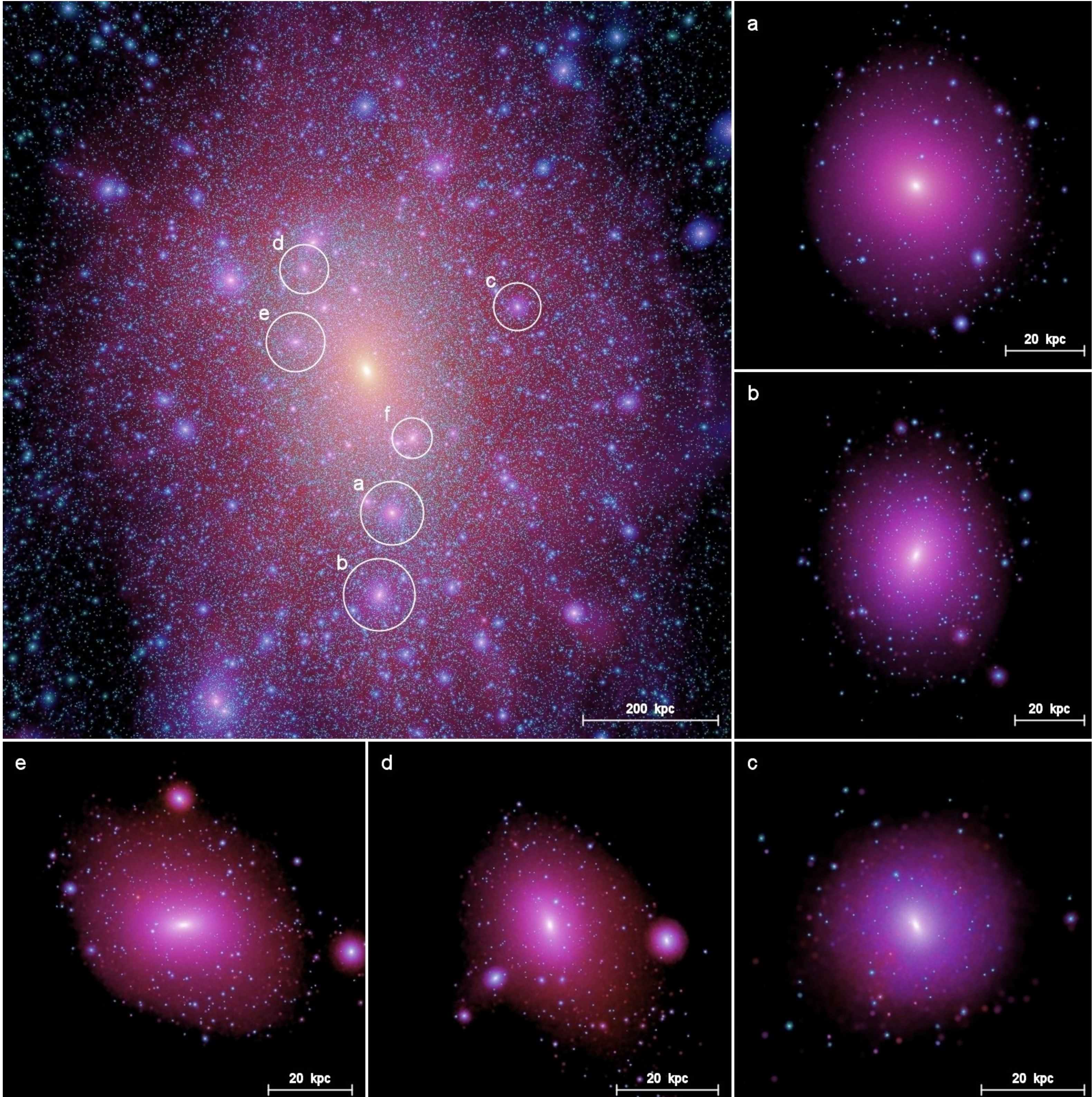
DARK MATTER DISTRIBUTION IN A MILKY WAY SIZED HALO



The movie...

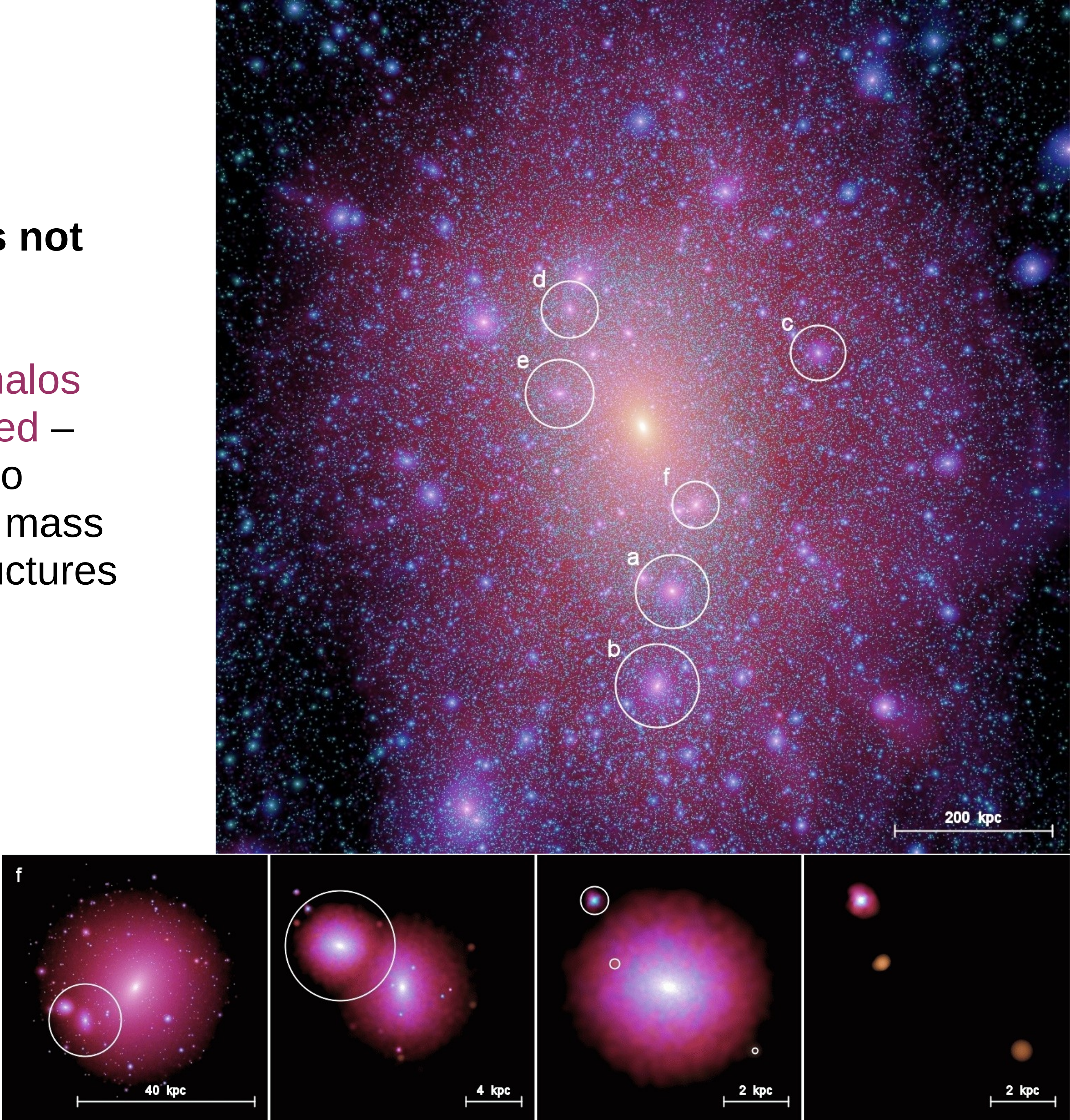
We detect up to four generations of substructures within substructures

HALO IN HALOS IN HALOS IN THE AQUARIUS SIMULATIONS



This hierarchy is not self-similar.

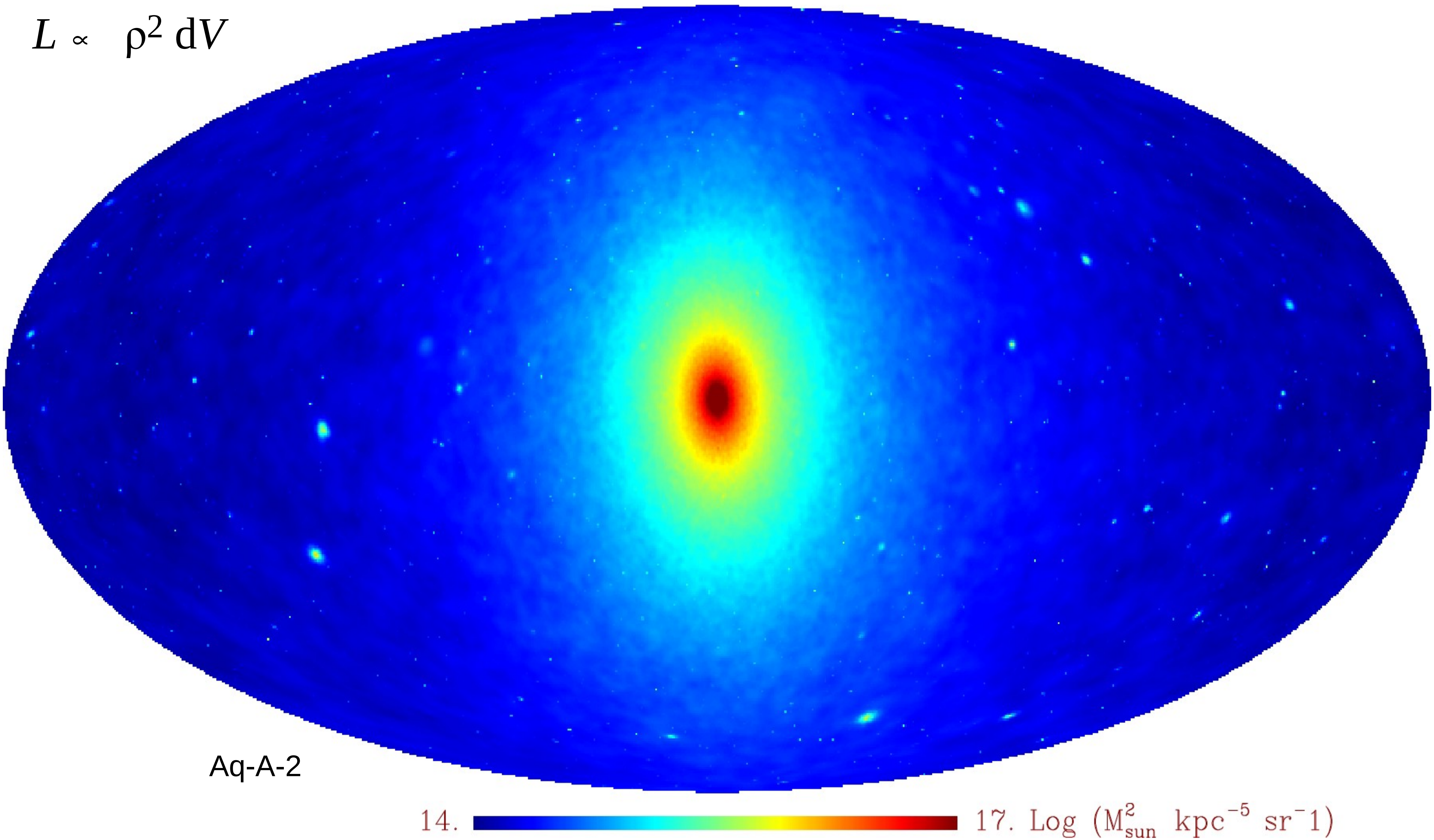
In particular, subhalos are tidally truncated – they are unlikely to contain the same mass fraction in substructures as main halos.



Is the dark matter annihilation flux boosted significantly by dark matter substructures?

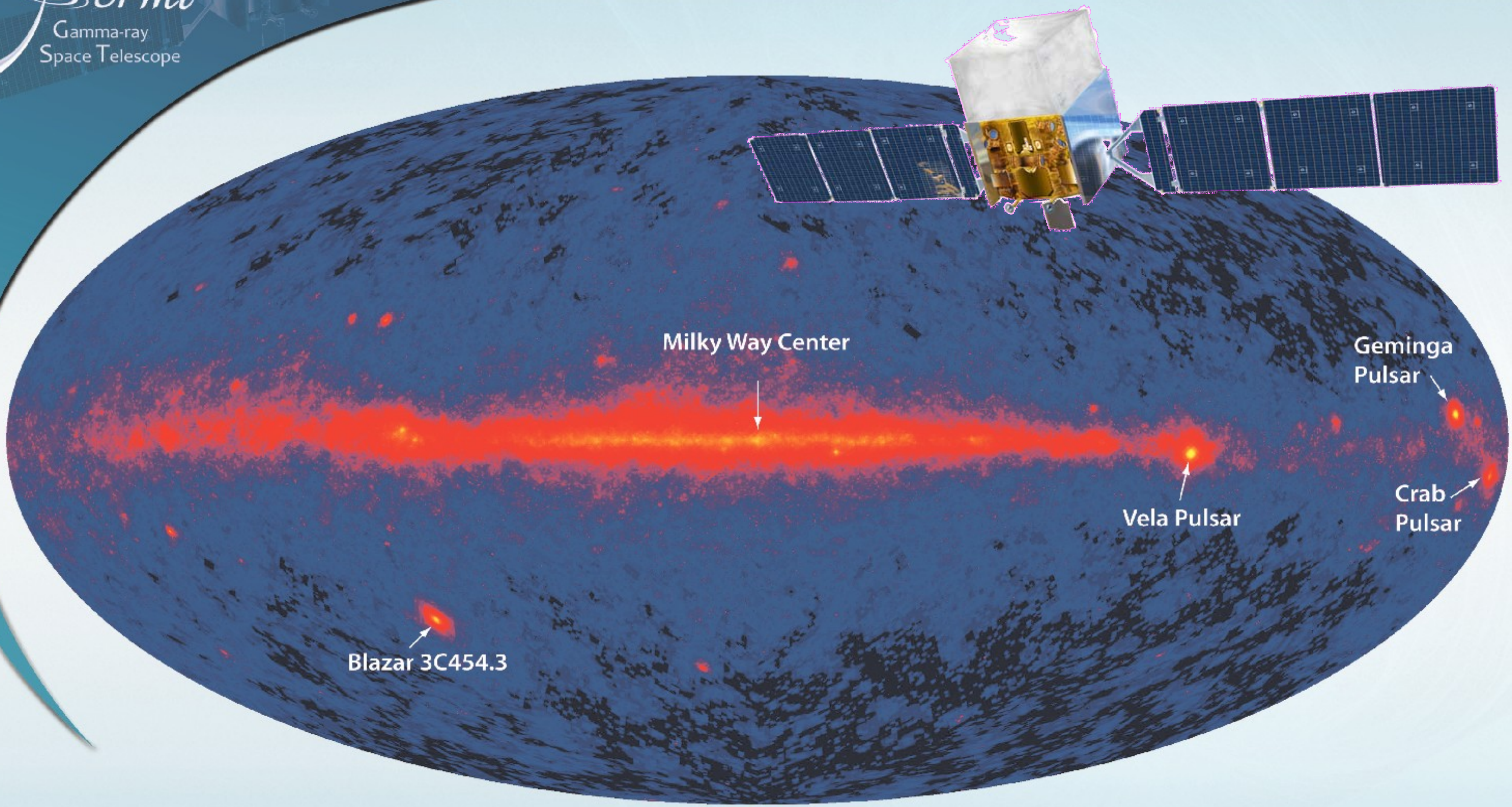
SIMULATED ALL-SKY MAP OF THE DM ANNIHILATION FLUX AROUND THE SUN IN THE MILKY WAY

$$L \propto \rho^2 \, dV$$



Aq-A-2

Fermi Gamma-ray Space Telescope



Fermi First Light Skymap

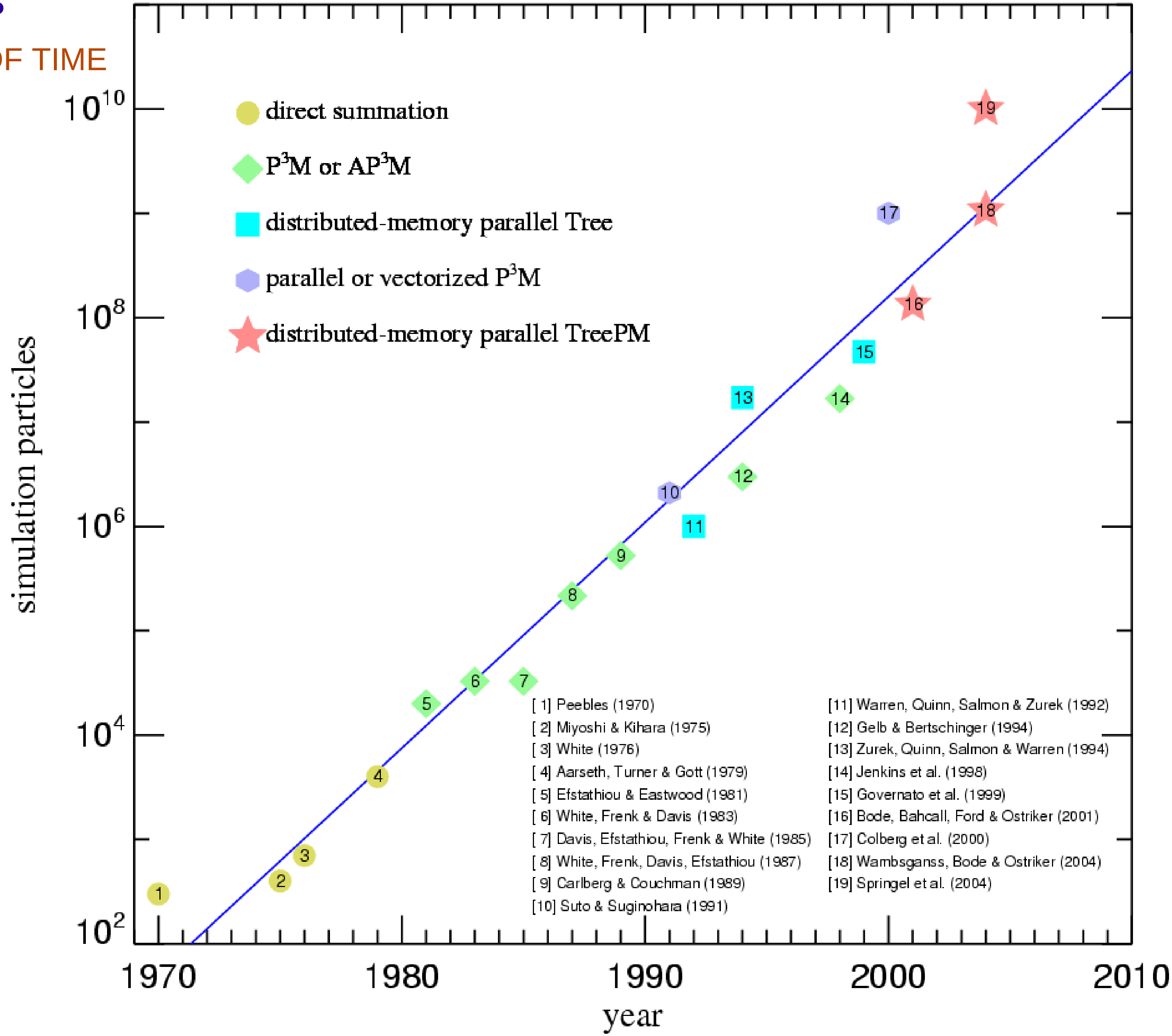
95 hours of data

Cosmological N-body simulations have grown rapidly over the last four decades

Millennium-XXL Project

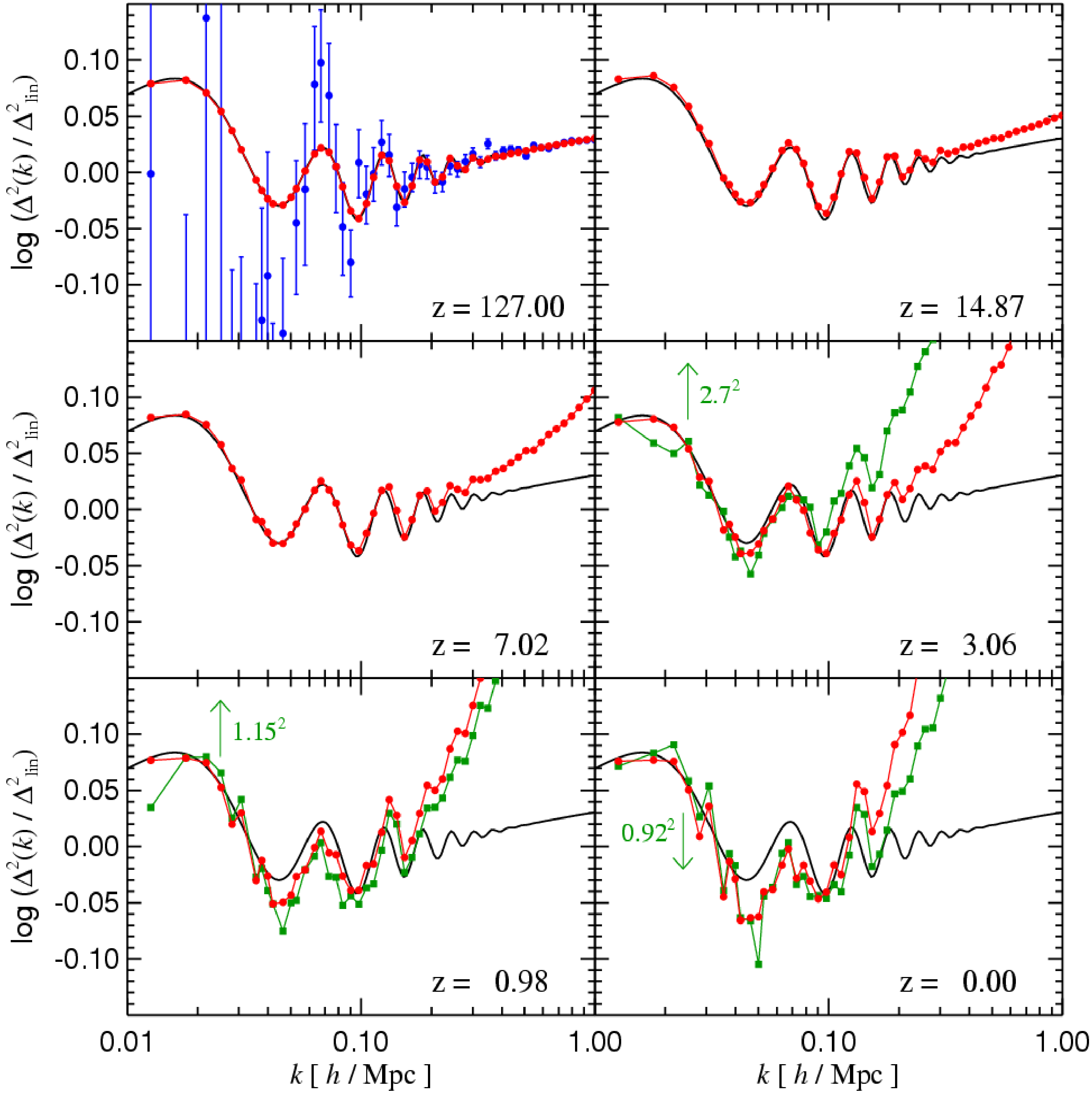
"**N**" AS A FUNCTION OF TIME

- Computers double their speed every 18 months (Moore's law)
- N-body simulations have doubled their size every 16-17 months
- Recently, growth has accelerated further.
  The Millennium Run should have become possible in 2010 – we have done it in 2004 !



The baryonic wiggles remain visible in the galaxy distribution down to low redshift and may serve as a "standard ruler" to constrain dark energy

DARK MATTER AND GALAXY POWER SPECTRA FROM THE MILLENNIUM SIMULATION IN THE REGION OF THE WIGGLES



Springel et al. (2005)

Millennium-XXL

Angulo et al. (2011)

Largest N-body simulation ever

303 billion particles

L = 3 Gpc/h

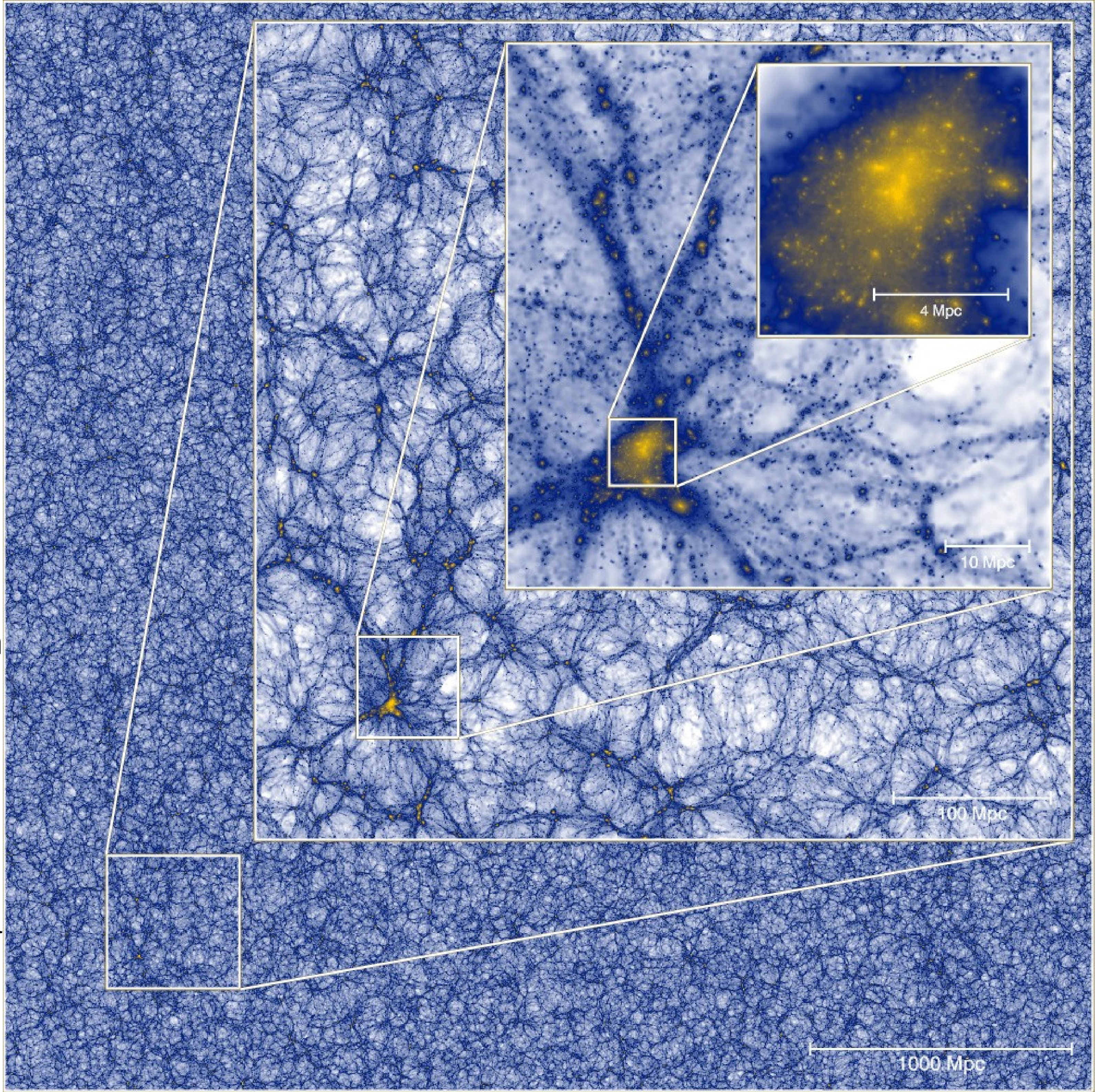
~700 million halos at z=0

~25 billion (sub)halos in mergers trees

$m_p = 6.1 \times 10^9\ M_\odot/h$

12288 cores, 30 TB RAM on Supercomputer JuRoPa in Juelich

2.7 million CPU-hours

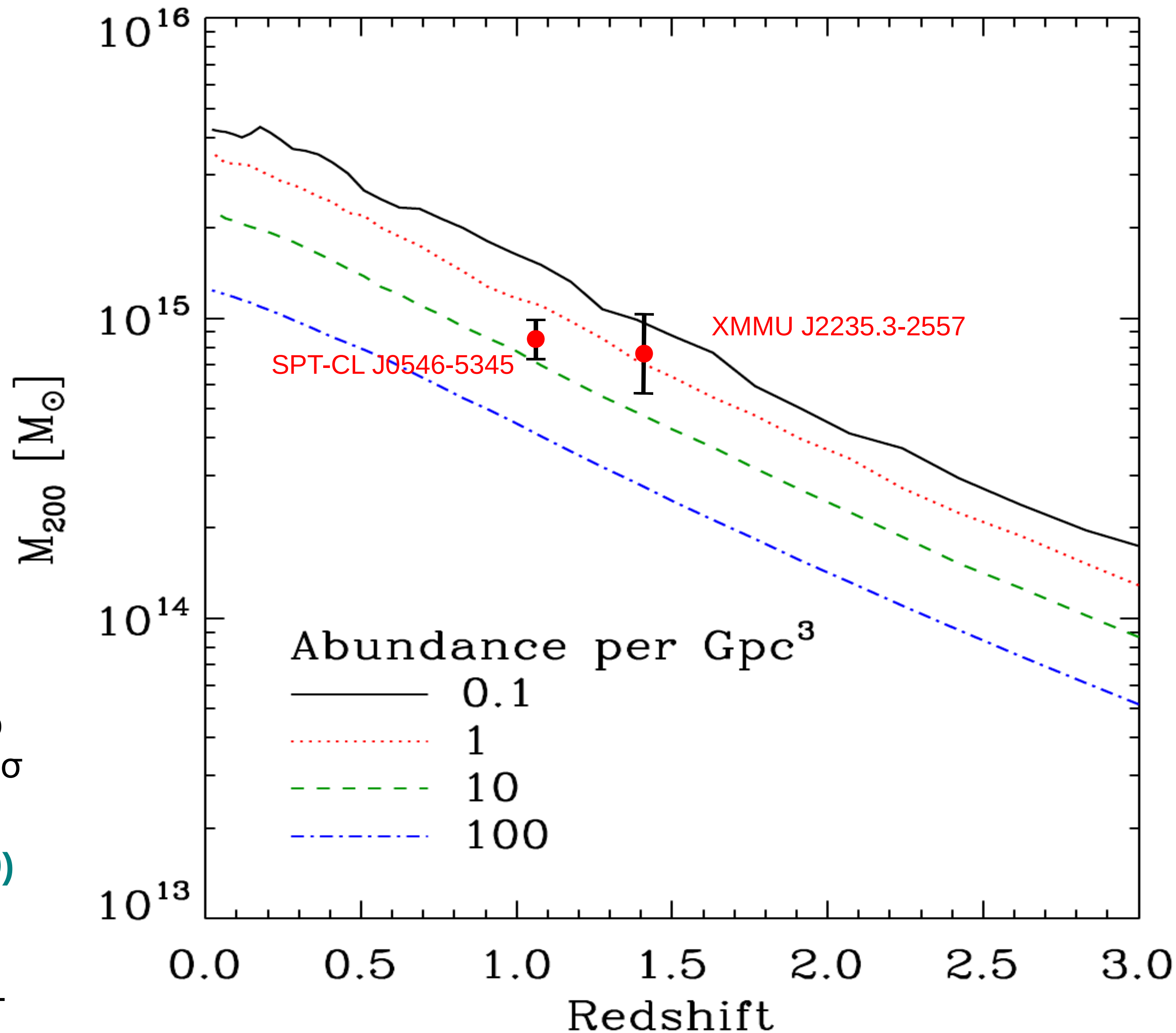


Are the presently known high-mass clusters still consistent with ΛCDM?

CLUSTER MASS FOR GIVEN ABUNDANCE AS A FUNCTION OF TIME

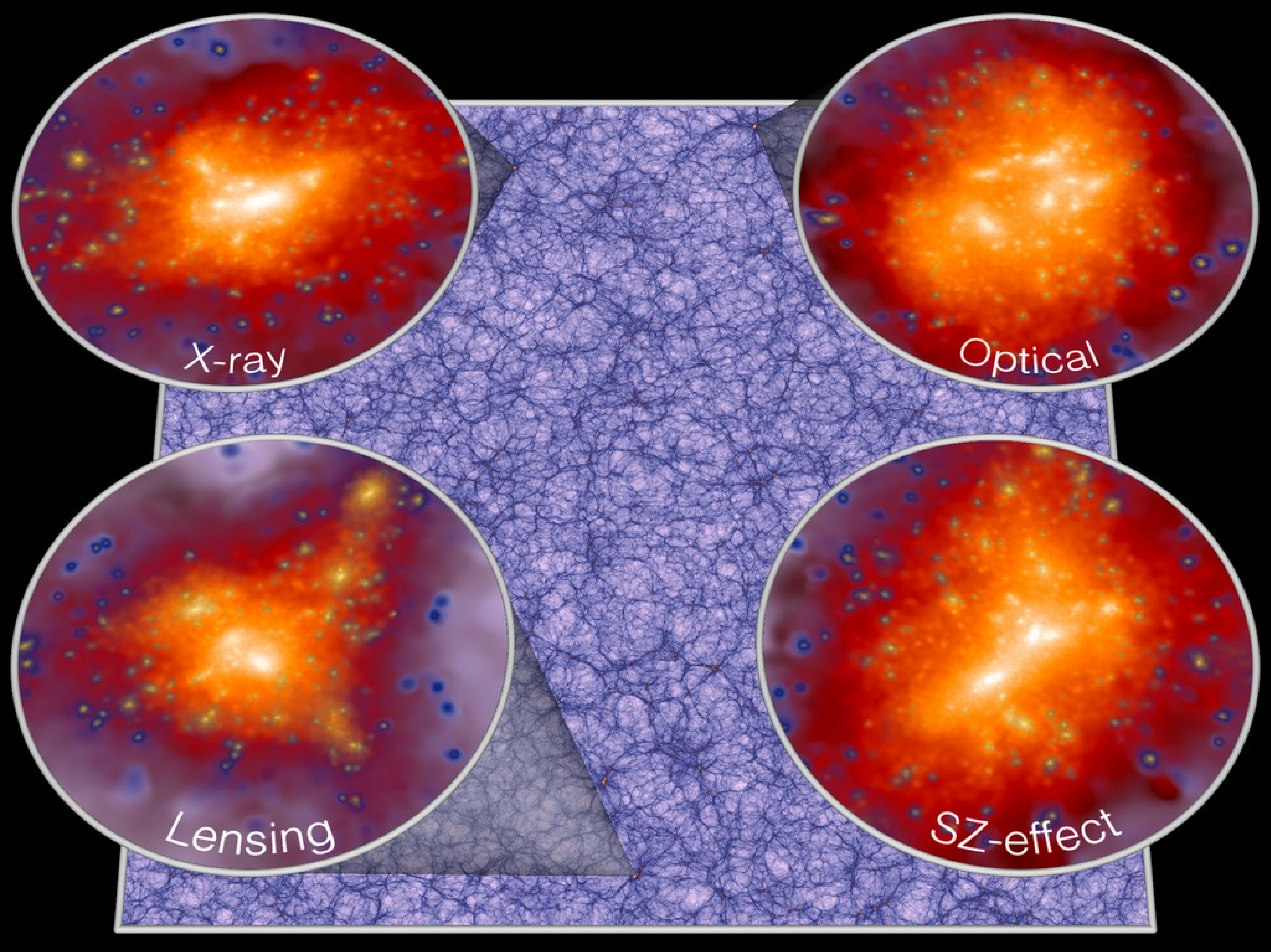
Angulo et al. (2011)

Detection of one violating cluster would invalidate ΛCDM



Holz & Perlmutter (2010) argued XMMU J2235.3-2557 to be inconsistent with ΛCDM at 3σ

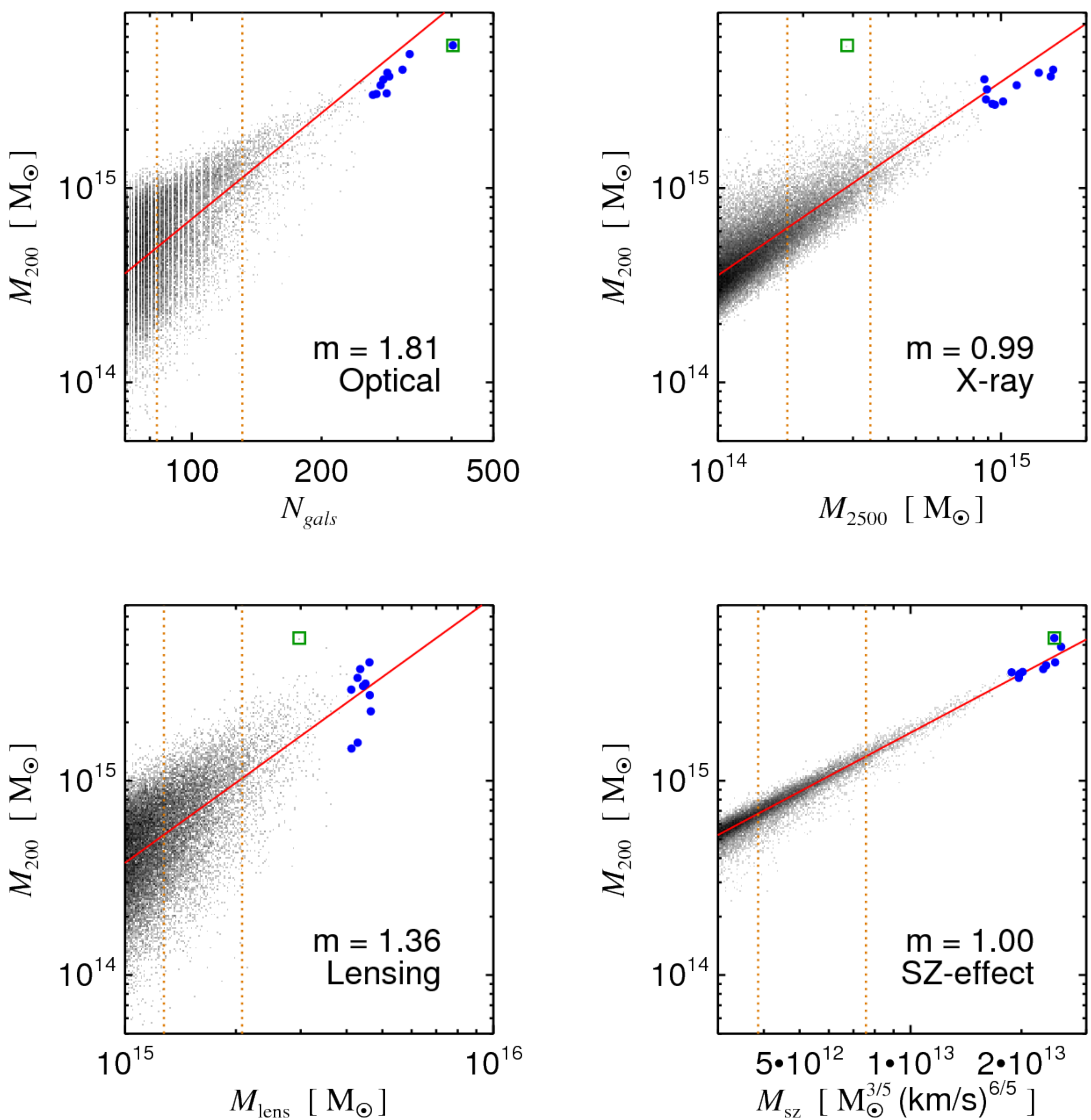
Boyle, Jiminez & Verde (2010) argue that σ_8 would have to be ~4σ higher to accommodate massive clusters. Suggest non-Gaussian ICs as a solution.


X-ray
Optical
Lensing
SZ-effect

Diversity in the Extreme

THE MOST MASSIVE AND RAREST CLUSTERS FOLLOW THE SCALING RELATIONS EXPECTED FROM MORE ABUNDANT SMALLER SYSTEMS

Angulo et al. (2011)



So far reported massive clusters not in conflict with ΛCDM (yet)

Conclusions

Cosmic large-scale structure arises from gravitational instability of primordial density fluctuations

- The cosmic web is a non-linearly sharpened version of the initial conditions created in the Big Bang. The local large-large scale structure still “remembers” these initial conditions.

- Numerical N-body simulations of cosmic structure formation based on the Lambda-CDM cosmological model reproduce the observed distribution of galaxies very well.

- So far, no convincing deviations from the Gaussian initial conditions predicted by the inflationary theory have been found. The biggest known galaxy clusters can still be accommodated by the LCDM theory.

- The non-linear structure of dark matter halos is characterized by a nested hierarchy of substructures, with partially self-similar character.