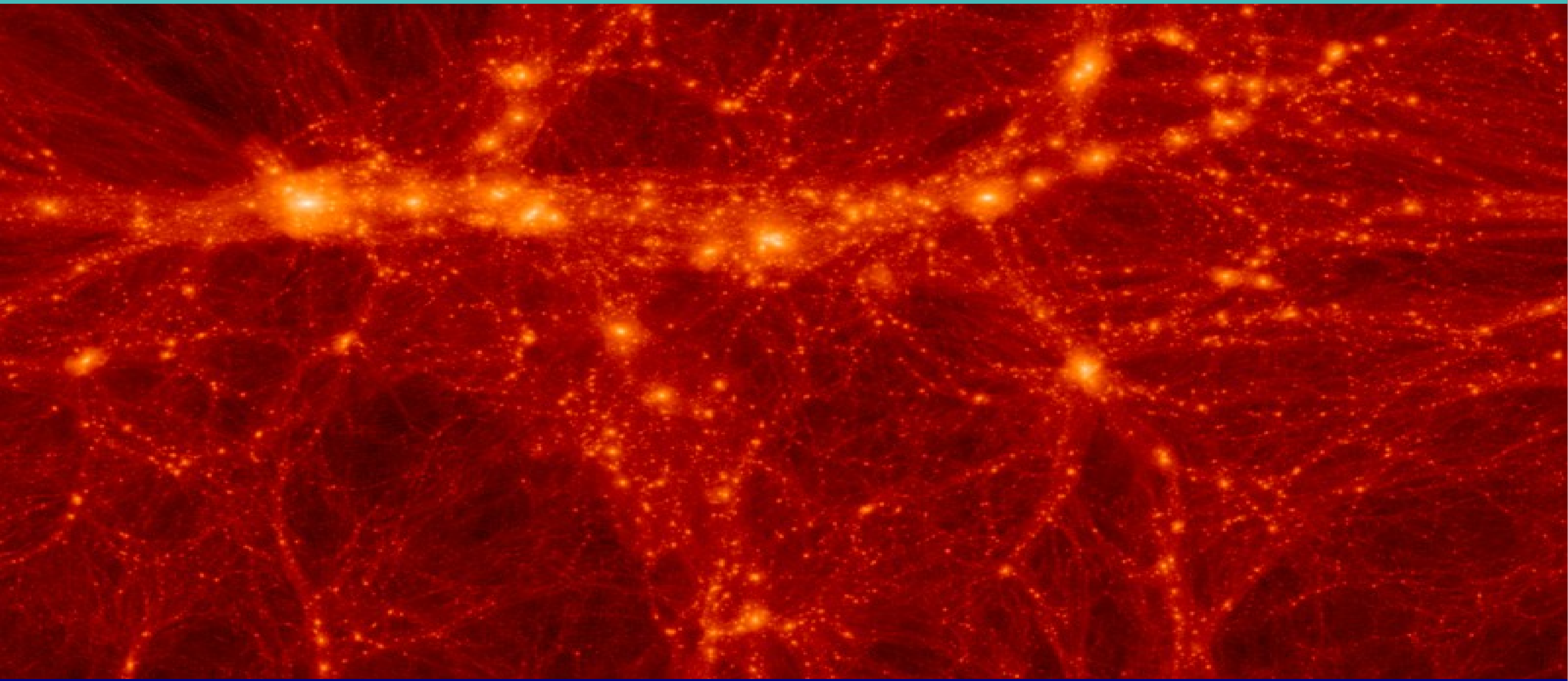
UNDERSTANDING DARK MATTER WITH FERMI AND CLUES NUMERICAL SIMULATION



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DARK MATTER GAMMA RAY SIGNAL

- We assume WIMP dark matter.

- Gamma ray flux expected from WIMPS annihilation.

- FERMI was launched in June 2008.

  - The orbit is almost circular, at 565 km altitude, and it provides a whole sky scan every 3 hours.
  - Energy range from 20 MeV to over 300 GeV
  - Field of view ≈ 2.4 sr, effective area ≈ 0.8 m2 (E > 1GeV)

DARK MATTER GAMMA RAY SIGNAL

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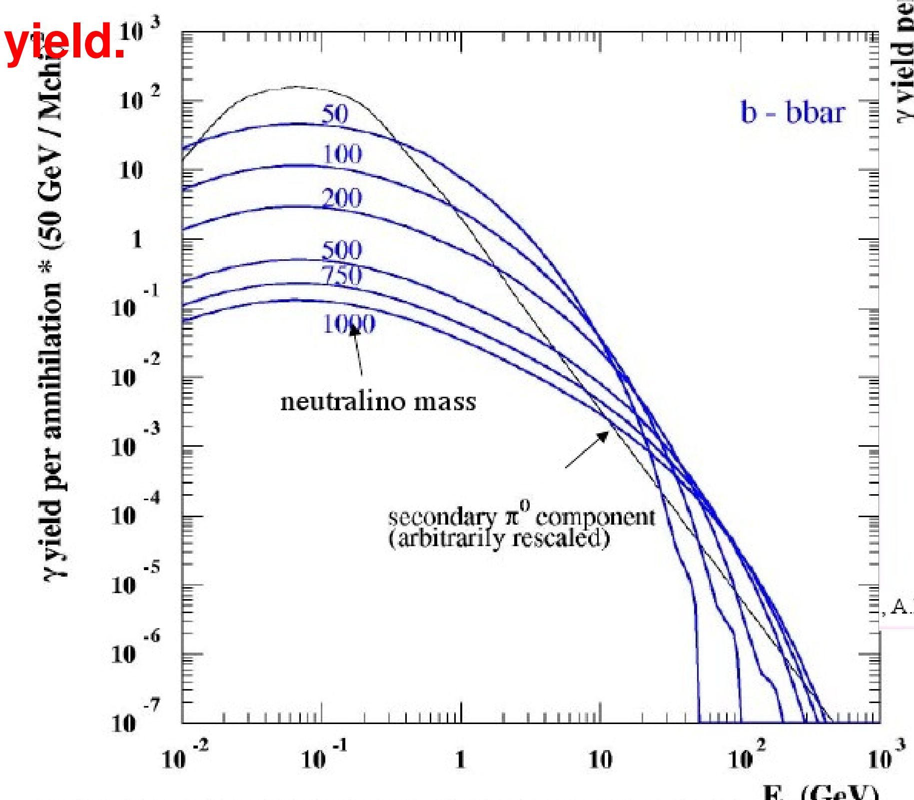
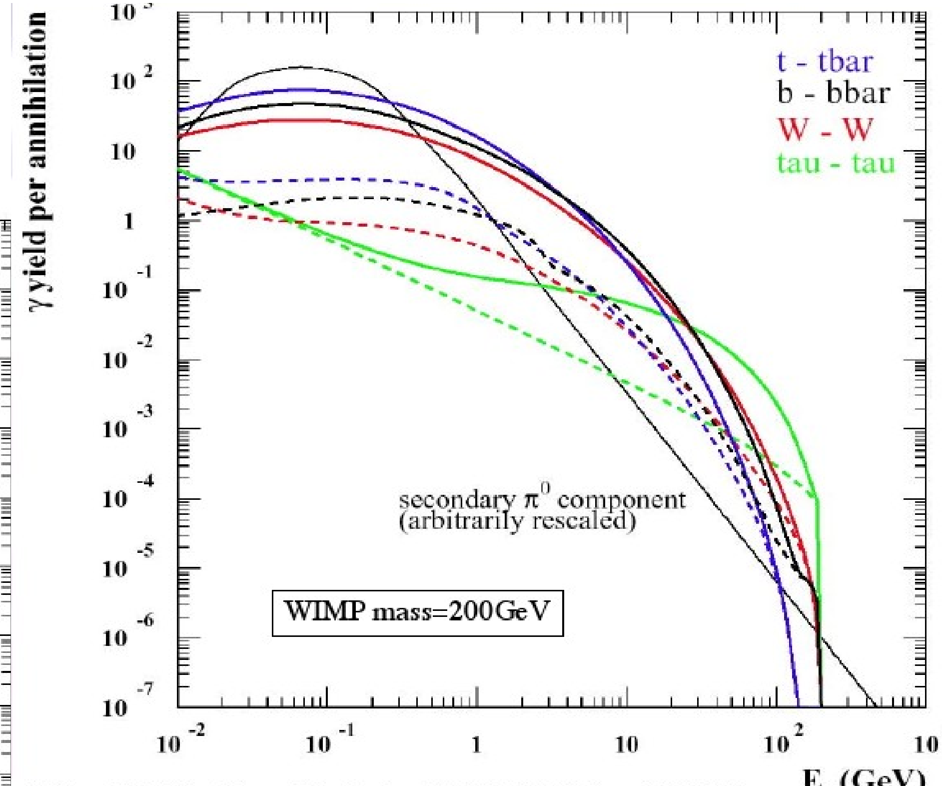
$$N_\gamma(\theta,\phi) = \frac{\Delta\Omega}{4\pi}\tau_{exp}\frac{\langle\sigma v\rangle}{2M_\chi^2}\left[\int_{E_{th}}^{M_\chi}\left(\frac{dN_\gamma}{dE}\right)A_{eff}(E)dE\right]\times\int_{los}\rho(l)^2 dl$$

PARTICLE PHYSICS

- **Thermally averaged cross section**
- **WIMP mass**
- **Photon yield.**



, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267-285, 2004 [astro-ph/0305075]



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PARTICLE PHYSICS

- **Thermally averaged cross section**
- **WIMP mass**
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ASTROPHYSICS

- **Analytical Profiles**
- **Numerical Simulations**

EXPERIMENTAL ISSUES

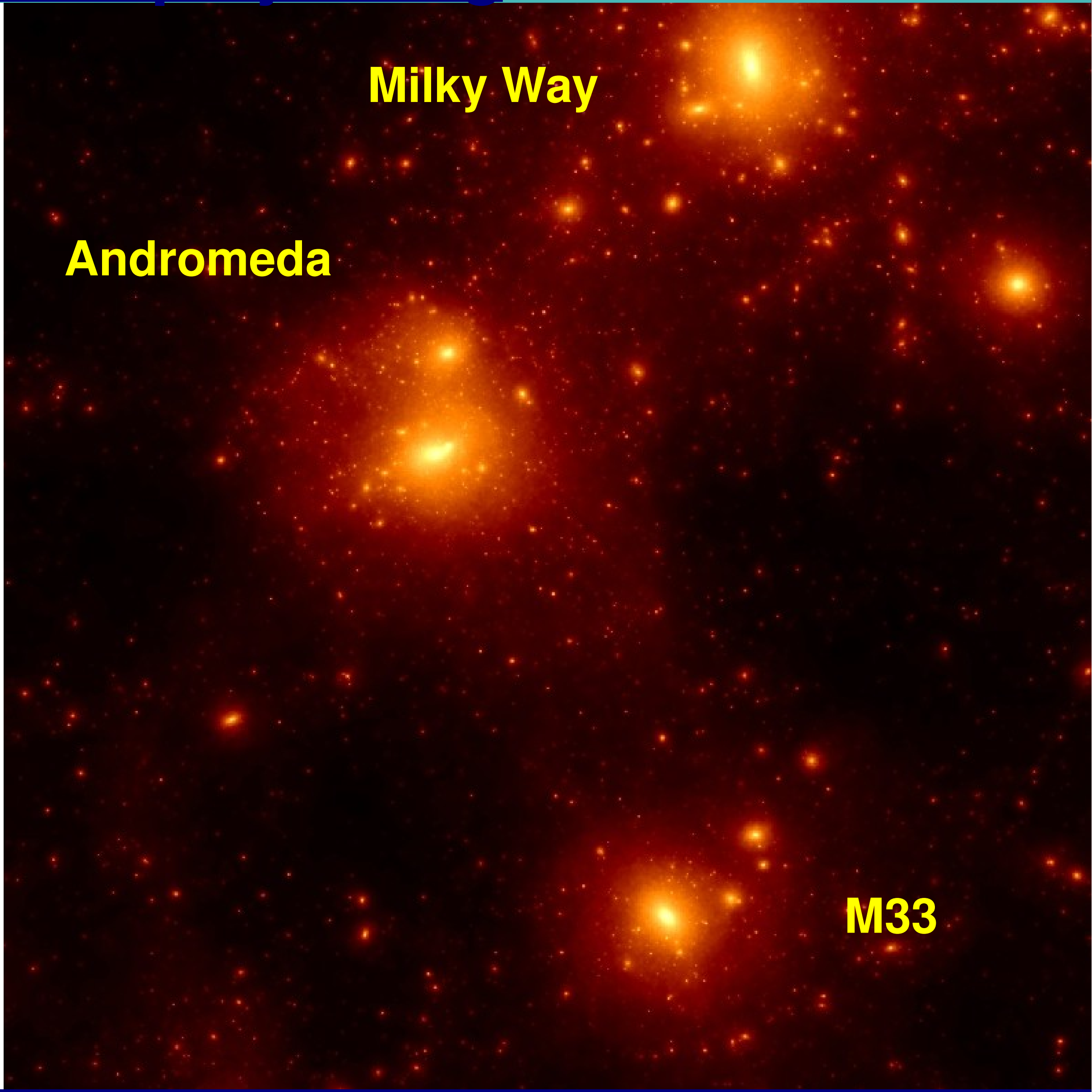
- **Satellite trajectory and pointing history**
- **Angular and energy resolution**
- **Effective area**

WHERE TO LOOK FOR DARK MATTER?
THE CLUES PROJECT
http://clues-project.org

64 Mpch^-1 simulation 256^3 particles, using WMAP3 data.

Zoomed resimulations with 4096^3 effective particles, of 2 Mpc box around LG-like objects, with and without baryons.

One of the highest resolution simulations including baryons to date.



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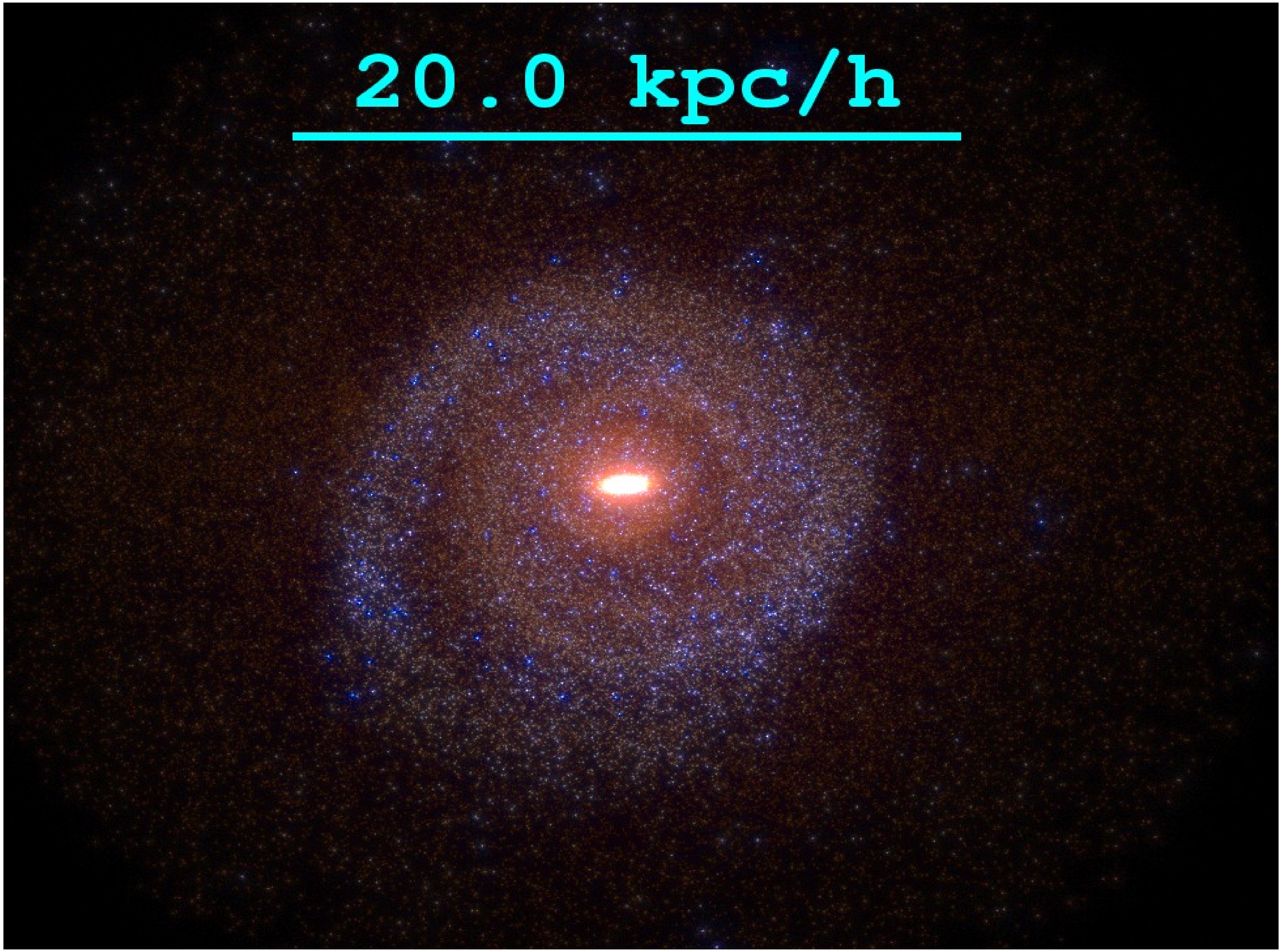
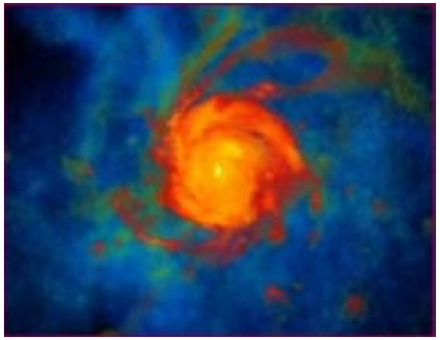
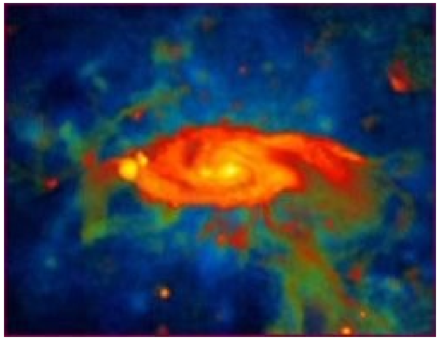
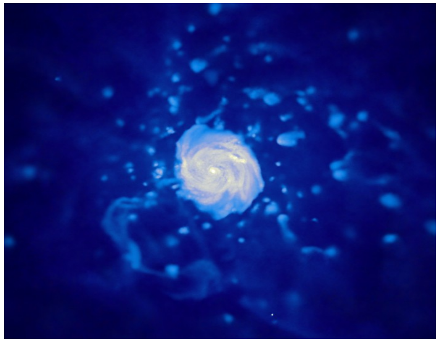


Gas distribution

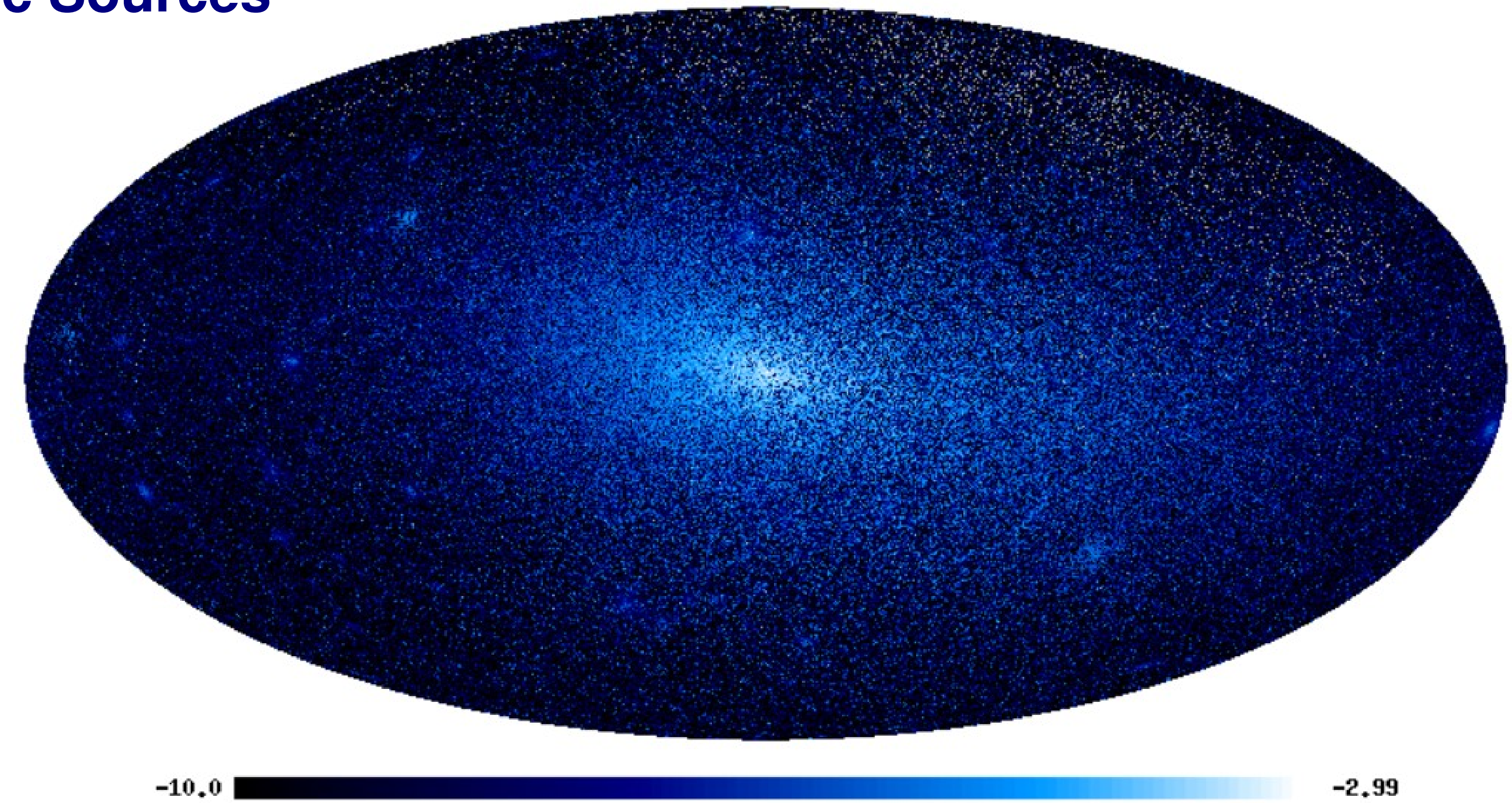






WHERE TO LOOK FOR DARK MATTER?

- Galactic Center
- Smooth halo
- Subhalos and clumps within our galaxy
- Dwarf galaxies
- Extragalactic Sources



THE GALACTIC CENTER

Baryons undergo compression mechanisms, leading to formation of disk or bulge of gas and stars.

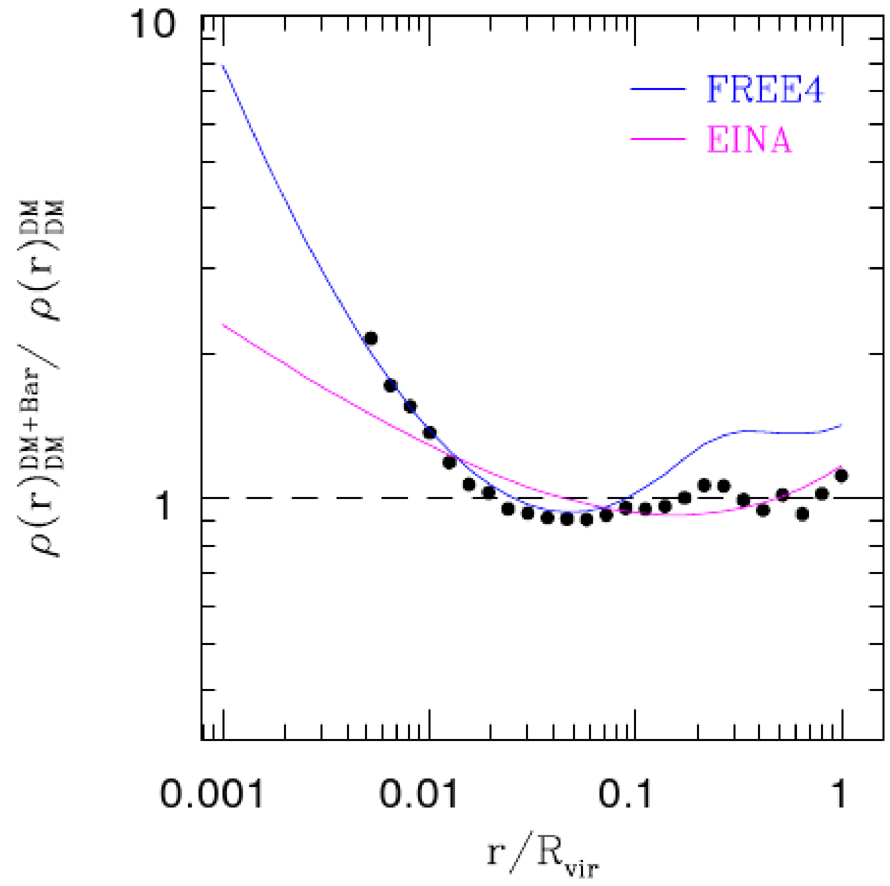
This concentration of baryons in the center of galaxies creates an enhanced gravitational potential well.

We fit our model to an spherical profile:

$$\rho_{prof}(y) = \frac{1}{y^{\alpha}(1+y^{\gamma})^{\frac{\beta}{\gamma}}}$$

Note that:

$$(\alpha, \beta, \gamma) = (1, 2, 1)$$ **NFW profile**



CALCULATION OF DENSITY MAPS I

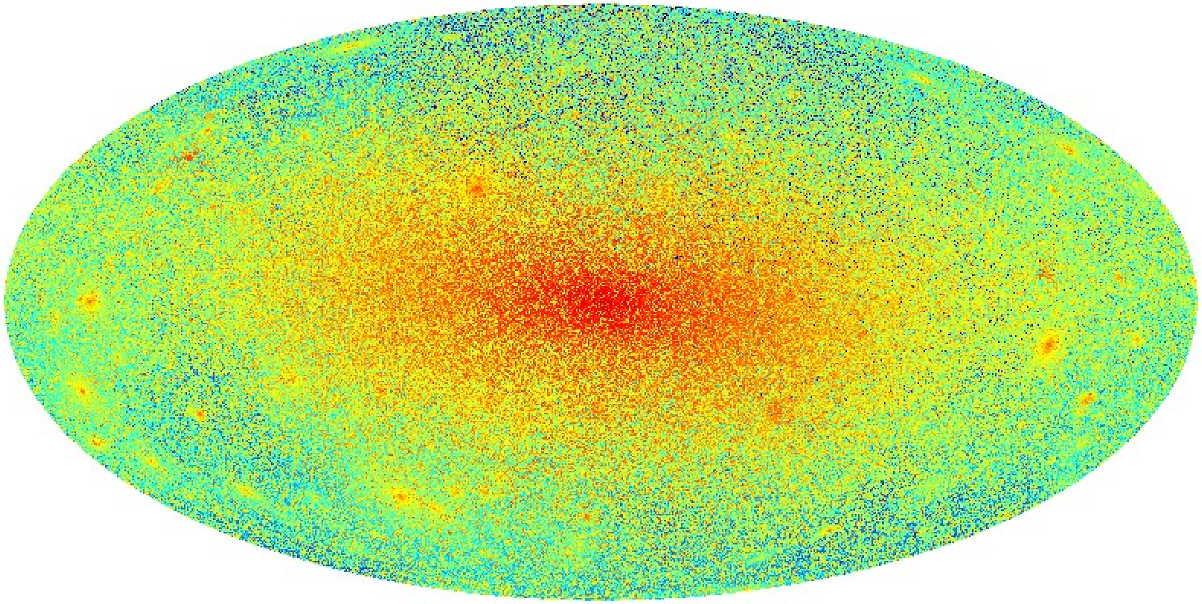
$$N_\gamma(\theta,\phi) = \frac{\Delta\Omega}{4\pi}\tau_{exp}\frac{\langle\sigma v\rangle}{2M_\chi^2}\left[\int_{E_{th}}^{M_\chi}\left(\frac{dN_\gamma}{dE}\right)A_{eff}(E)dE\right]\times\int_{los}\rho(l)^2 dl$$

The integral along the line of sight has been discretized:

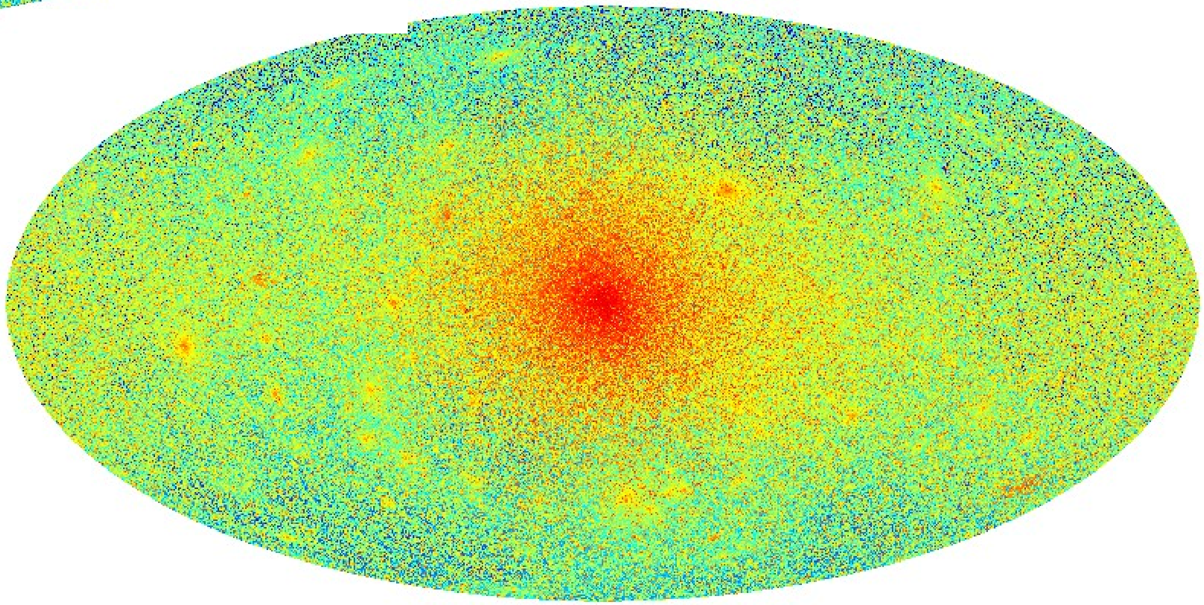
$$\int_{los,\Delta\Omega}\rho^2(l,\theta,\phi)\,dl\,d\Omega \approx \frac{1}{4\pi}\sum_i \frac{m_i\rho_i}{{r_i}^2}$$

SMOOTH HALO

Dark Matter only simulation



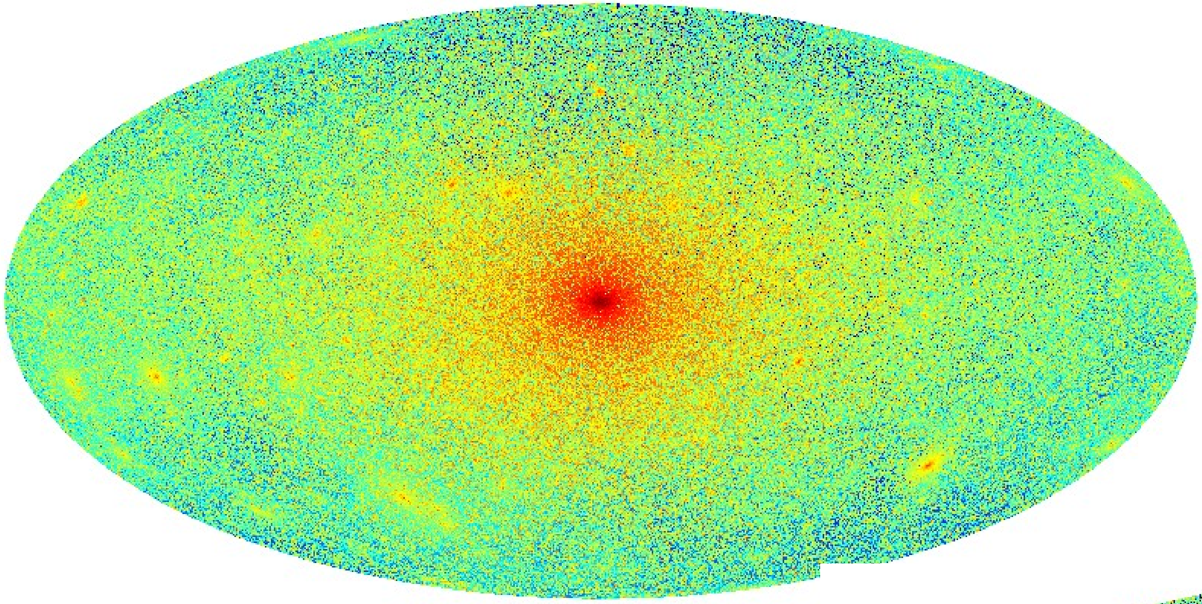
Observer aligned with main axis in the galaxy



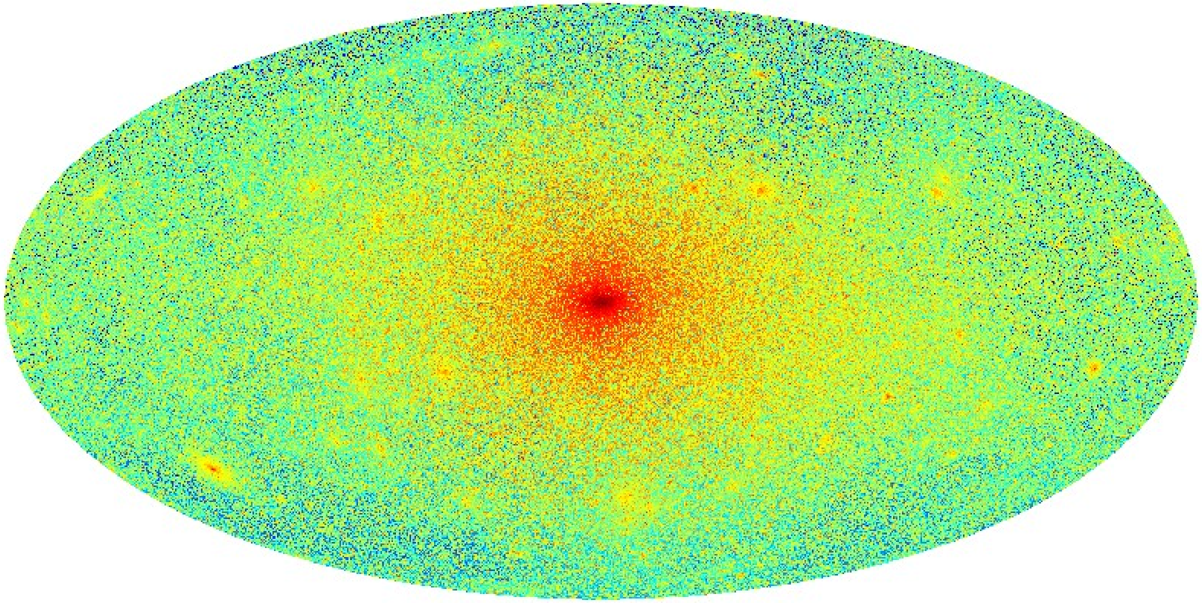
Observer placed 90 degrees respect main galactic disk axis

SMOOTH HALO

Dark Matter + Baryons simulation



Observer aligned with main axis in the galaxy



Observer placed 90 degrees respect main galactic disk axis

CALCULATION OF DENSITY MAPS II

$$N_\gamma(\theta,\phi) = \frac{\Delta\Omega}{4\pi}\tau_{exp}\frac{\langle\sigma v\rangle}{2M_\chi^2}\left[\int_{E_{th}}^{M_\chi}\left(\frac{dN_\gamma}{dE}\right)A_{eff}(E)dE\right]\times\int_{los}\rho(l)^2 dl$$

The integral along the line of sight has been discretized:

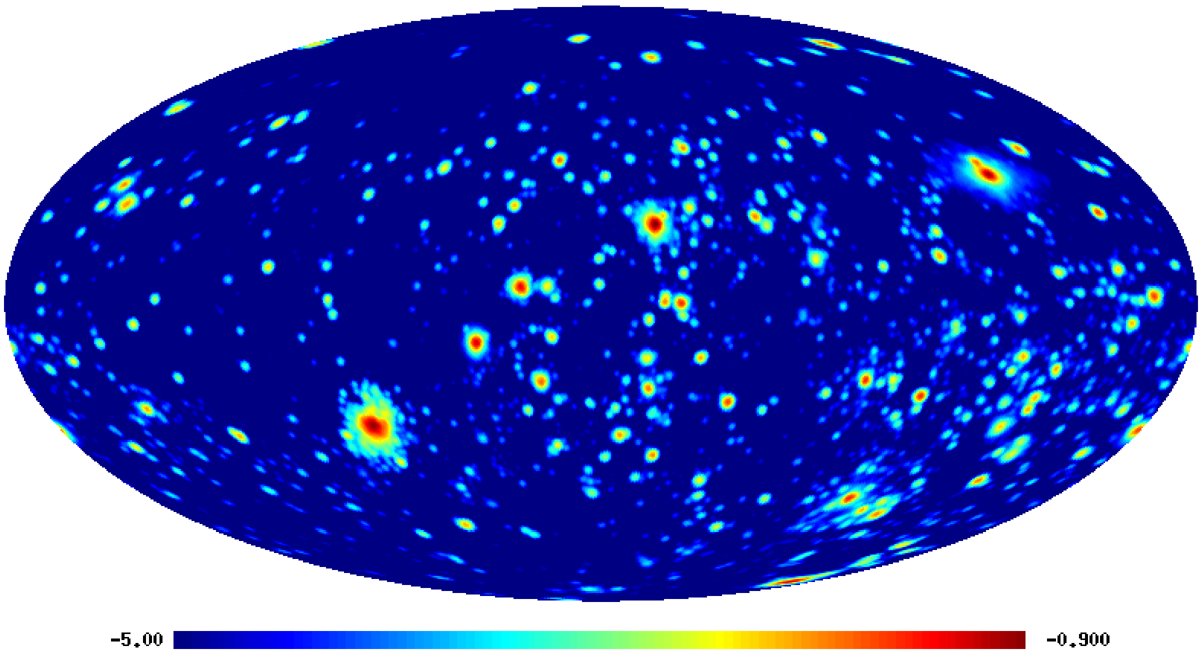
$$\int_{los,\Delta\Omega}\rho^2(l,\theta,\phi)dl d\Omega \approx \frac{1}{4\pi}\sum_i \frac{m_i\rho_i}{{r_i}^2}$$

Overall boost factor of 5 has been introduced

$$L(M) = [1 + B(M)]\,\tilde{L}(M)$$

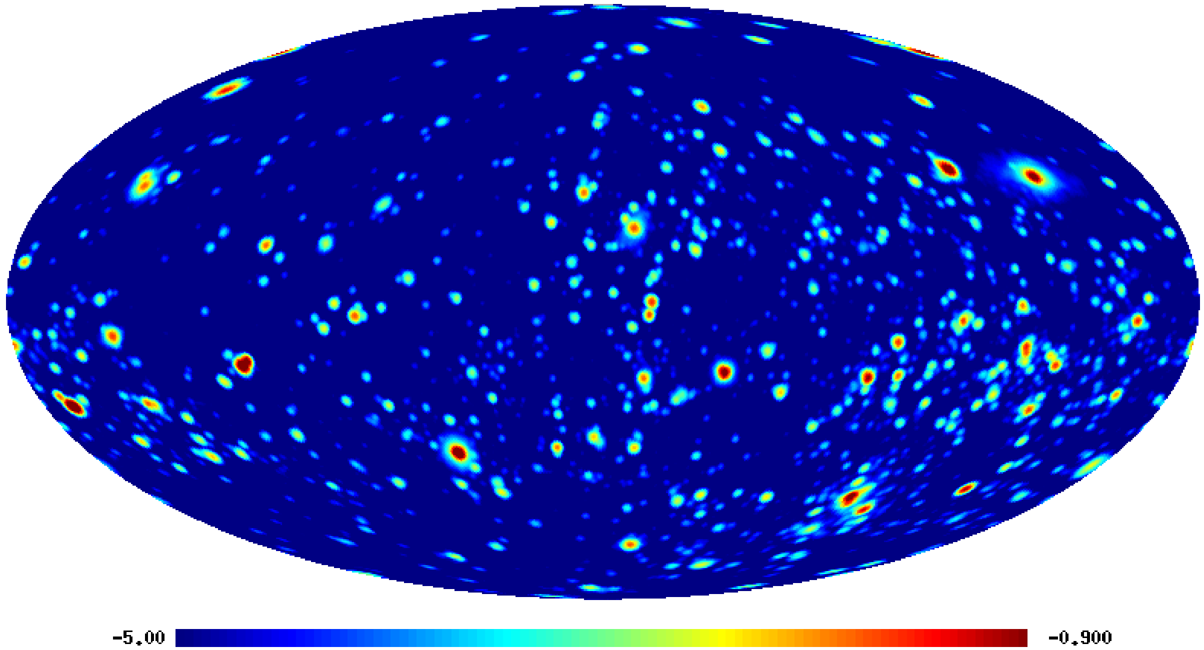
$$B(M) = \frac{1}{\tilde{L}(M)}\int_{m_0}^{m_1}\frac{dN}{dm}L(m)dm$$

DARK MATTER SUBSTRUCTURE – EFFECT OF BARYONS



Dark Matter Only Simulation

Dark Matter & Baryons Simulation



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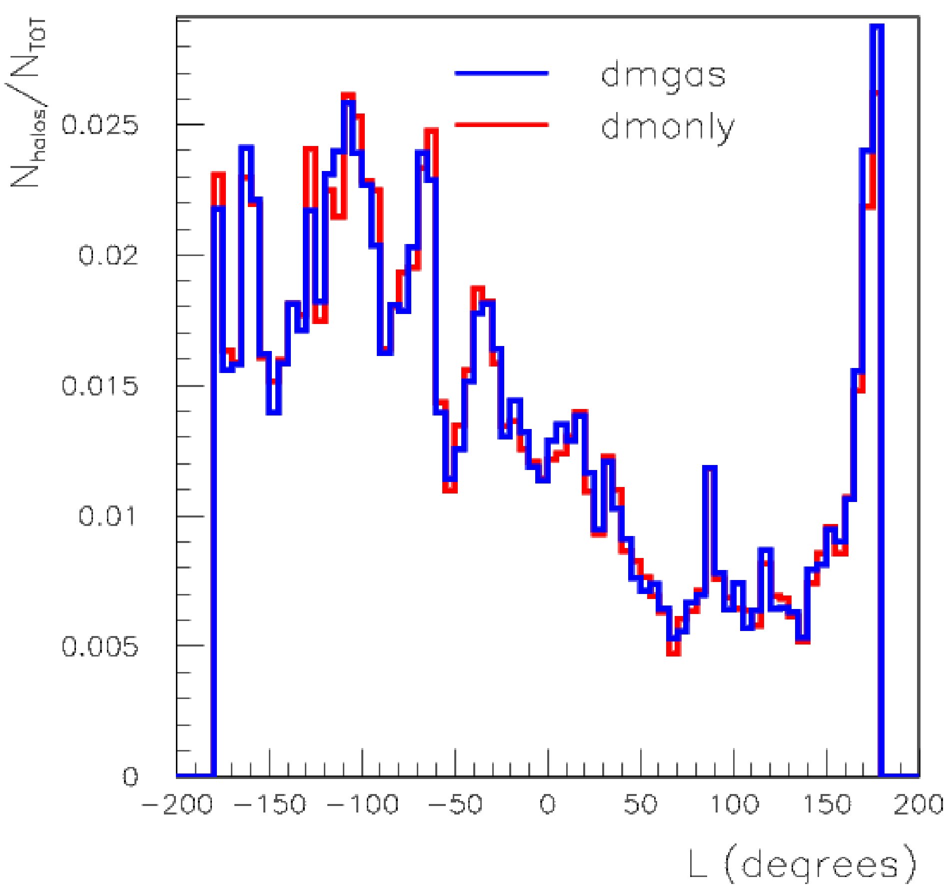
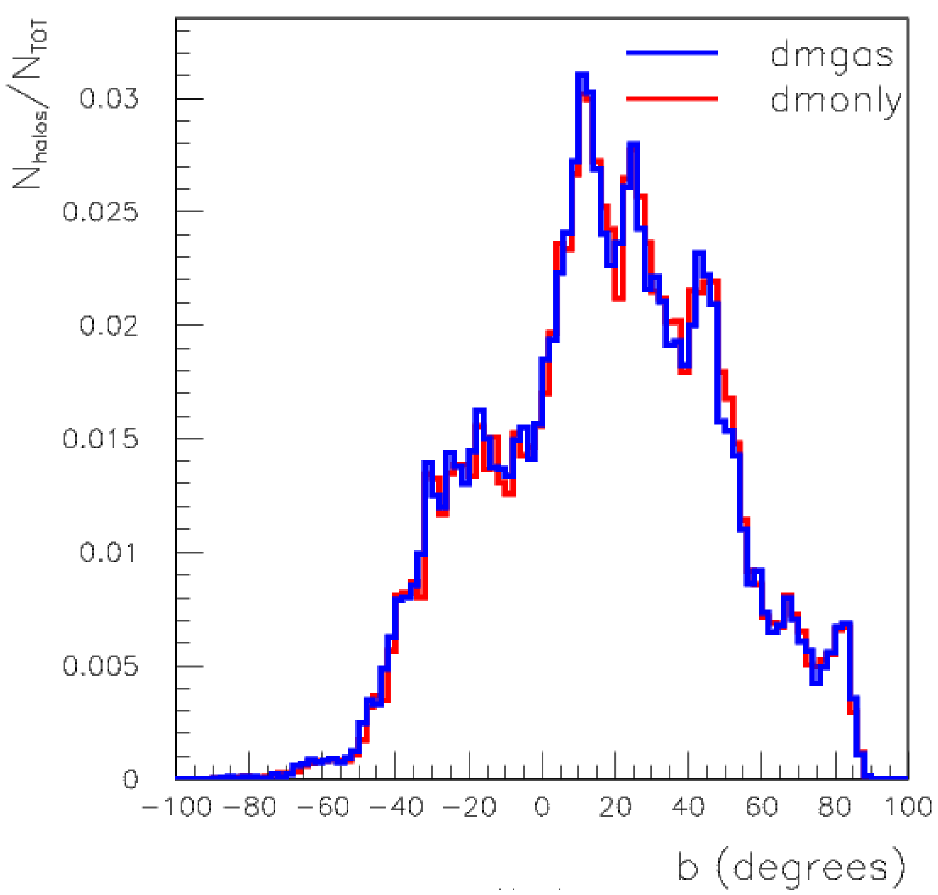




SIMULATION WITH FERMI TOOLS – INPUTS

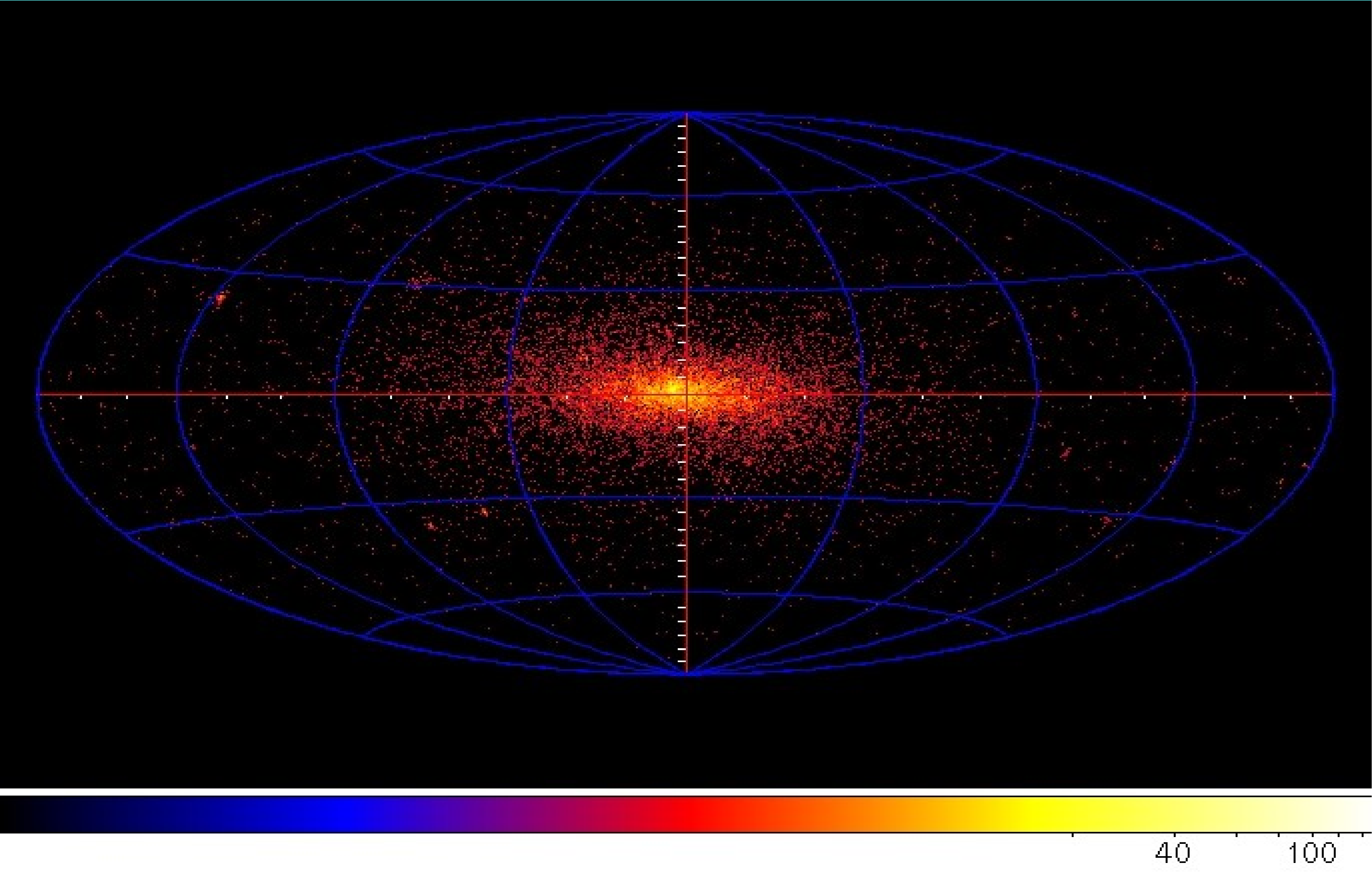
$$N_\gamma(\theta,\phi) = \frac{\Delta\Omega}{4\pi}\tau_{exp}\frac{\langle\sigma v\rangle}{2M_\chi^2}\left[\int_{E_{th}}^{M_\chi}\left(\frac{dN_\gamma}{dE}\right)A_{eff}(E)dE\right]\times\int_{los}\rho(l)^2 dl$$

Thermally averaged cross section: 3 x 10^-26 cm^3 s^-1

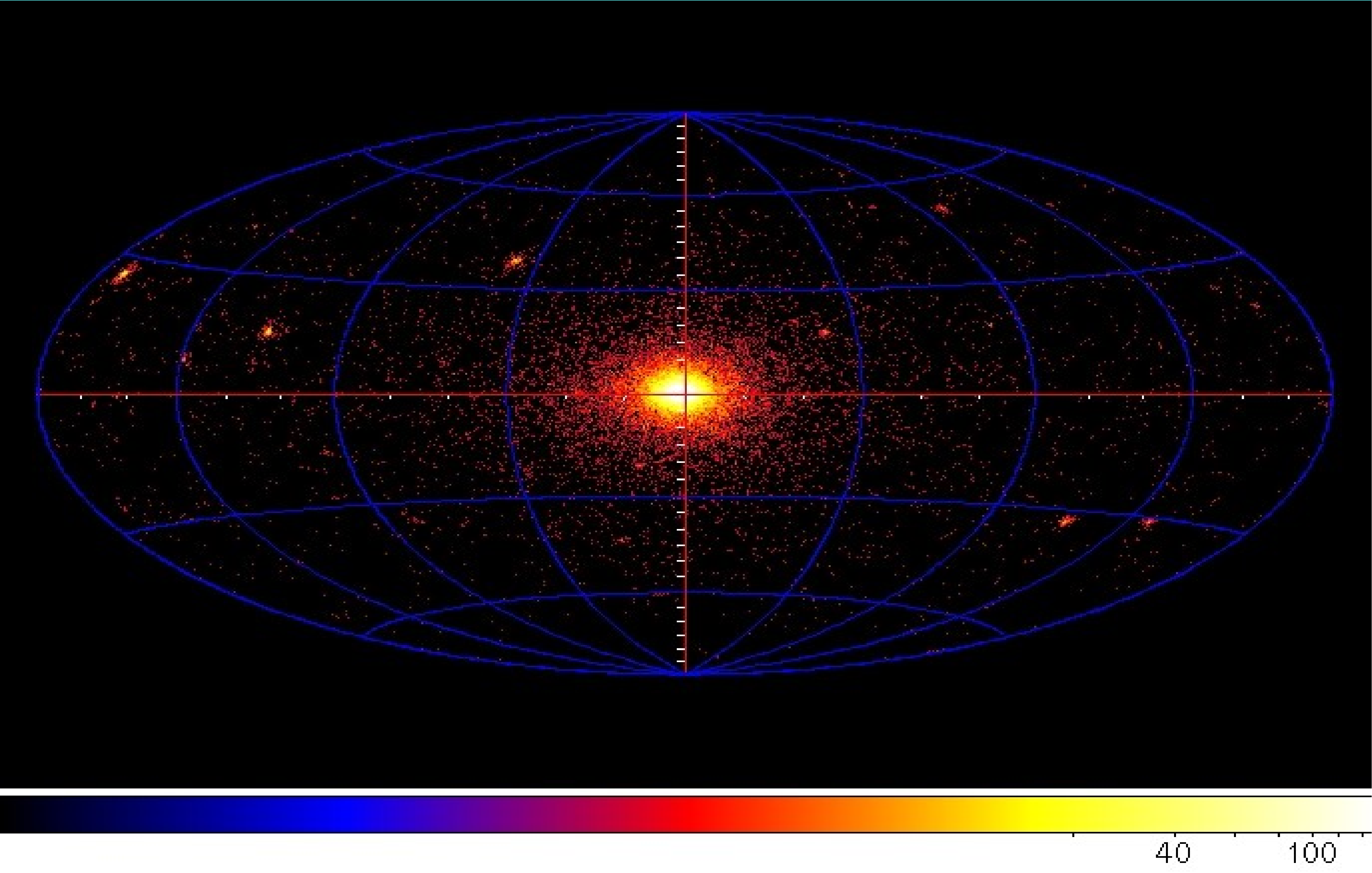
WIMP mass: 50 GeV

Annihilation channel: b - bbar

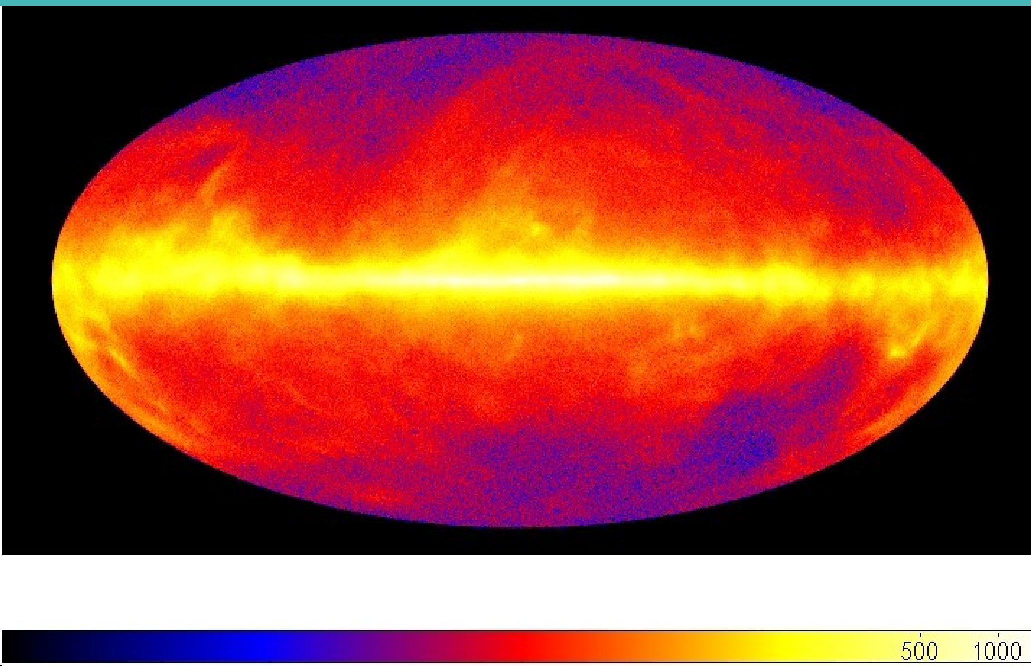
SIMULATION WITH FERMI TOOLS – DM ONLY

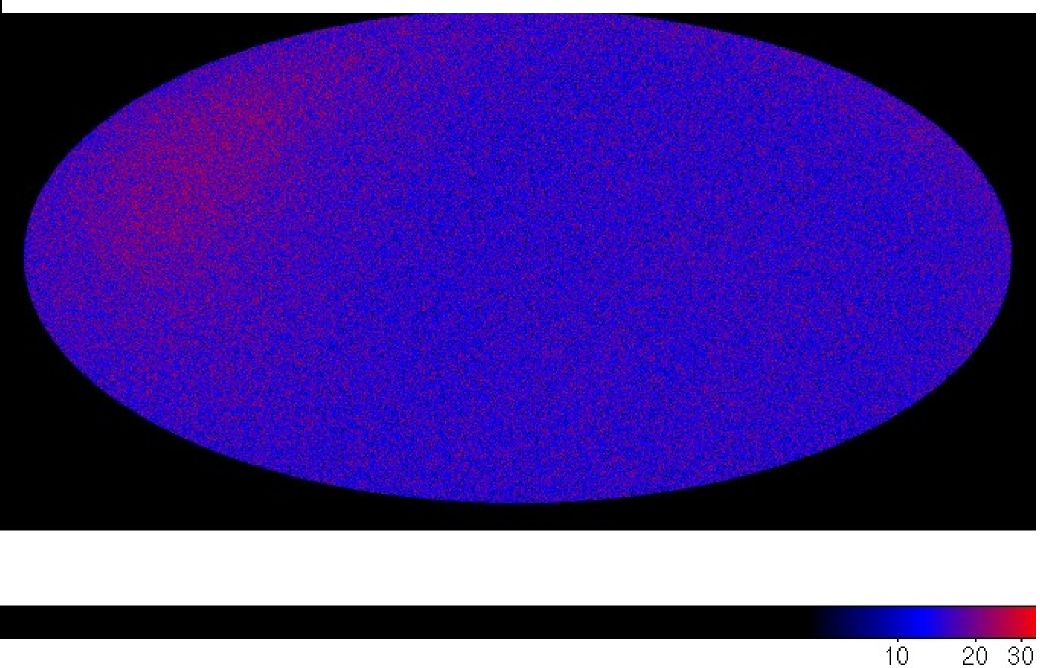


SIMULATION WITH FERMI TOOLS – DM & BARYONS



SIMULATION WITH FERMI TOOLS - BACKGROUND





Galactic and extragalactic backgrounds need to be considered.

We will concentrate on high latitude regions in order to avoid galactic background.

At high latitude,

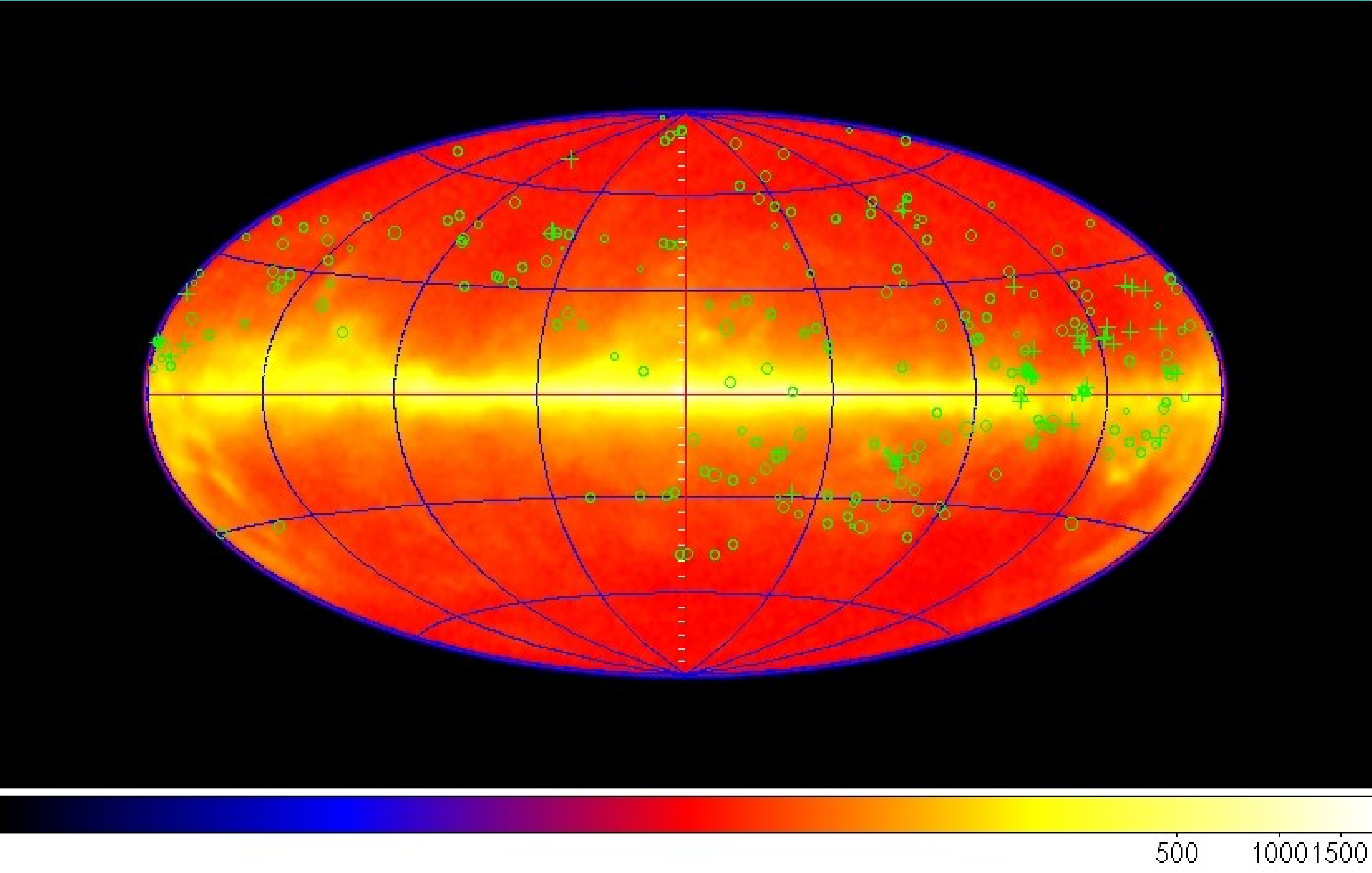
Galactic Background ~ 10 -30 counts/pixel

Extragalactic Background ~ 20 counts/pixel

We find subhalos with ~ 30 counts/pixel.

Detailed analysis needs to be performed.

SIMULATION WITH FERMI TOOLS - TOTAL



CONCLUSIONS

- Constrained N body simulations are a useful tool for dark matter studies: they give us information on how dark matter is distributed.

- Baryons play an important role regarding dark matter distribution, enhancing dark matter density towards the center. We are studying the effects on the distribution and profiles of substructures.

- Data analysis is fundamental :
  - Galactic Center
  - Dwarf Galaxies
  - Unidentified Sources
  - ....