Studying the distortions in the CMB from large scale structure with N-body simulations

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We study the Rees-Sciama effect making use of N-body simulations. We compute the evolution of the effect with redshift and compute the power spectrum. All sky maps are presented. The results are preliminary and will be improved with larger simulations.

The Planck mission will measure the CMB primary anisotropies from space and over the entire sky with unprecedented sensitivity and resolution. Other ground experiments like ACT or SPT are currently observe smaller portions of the sky with increased spatial resolution. The CMB experiments are reaching an era where new effects (secondary anisotropies) will be detected in the data. Among these new effects we can include the Sunyaev-Zel'dovic effect, gravitational lensing, the Integrated Sachs-Wolfe effect and its non-linear equivalent, the Rees-Sciama effect. In this project we focus on the Rees-Sciama effect.The Rees-Sciama effect is due to changes in the gravitational potential along the path of the CMB photons. The effect is maximum around dense regions like galaxy clusters with potentials which evolve quickly with time. For instance, massive structures which are collapsing or merging present non-symetric potentials along the path of the photons (as opposed to gravitationally relaxed structures) which will produce a net effect. Also structures which are moving with high tangential velocities (with respect to the trajectory of the photons) may cause a significant effect. This phenomenon is known as the butterfly effect since the effect is positive in the direction of movement of the gravitational potential and negative in the opposite direction. The simulation consists of a box of comoving size 300 Mpc/h with 256^3 particles. We started the simulation at redshift 50 and evolved it until redshift 0. The Rees-Sciama effect is computed in a regular grid of 256^3 cells using Fouirer methods where the integraql of the derivative of the potential is solved in Fourier space. We studied the errors due to the cell approximation used in the Fourier convolution and found that the error is of the order of one percent when the Rees-Sciama effect is projected over the line of sight. We use HEALPIX to project the effect over the ntire sky placing the observer in the middle of the box at redshift z = 0. The projected density of particles of the box is shown in figure 1.

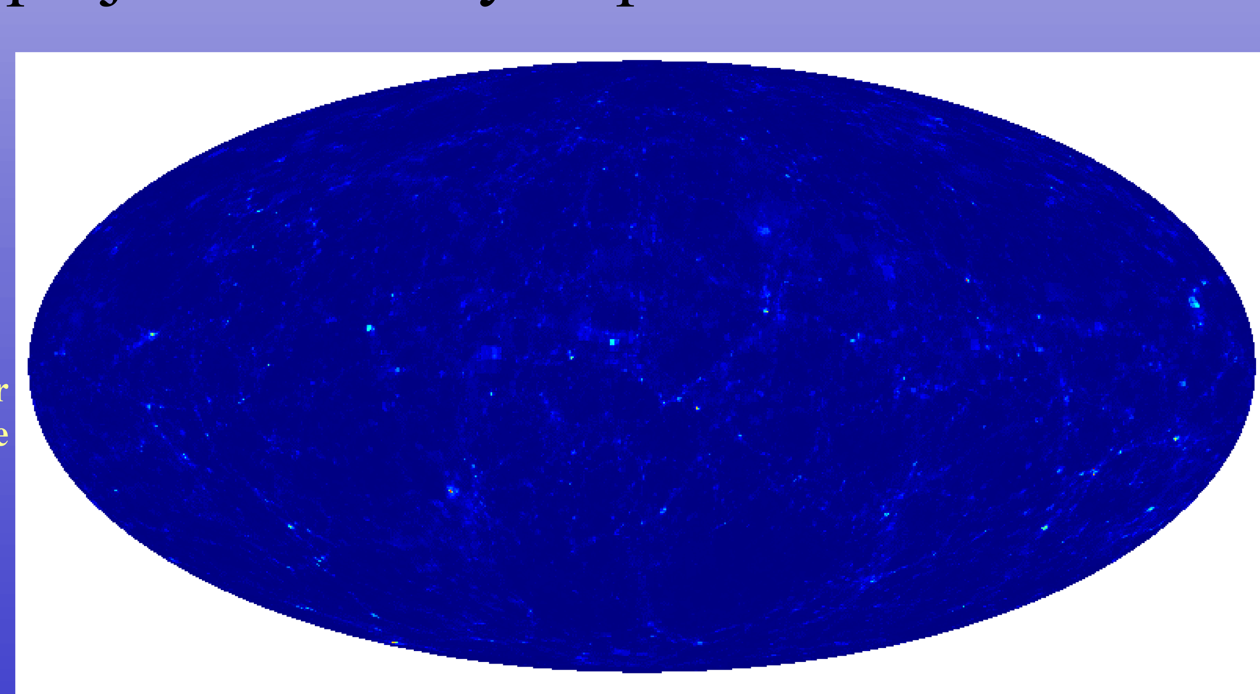

Figure 1. Projected mass distribution of the simulation box at redshift z=0. Note the massive structures in the ecuatorial plane. The evolution of these structures with timecan cretaes a significant Rees-Sciama effect. Other effects like gravitational lensing can be easily predicted from this matter distribution although these effects will not be presented in this work.

We computed the projected Rees-Sciama at different redshifts by integradting the efefct over the entire box. For each projection we compute the maximum and minimum values as well as the mean value and dispersion. The result is shown in figure 2.

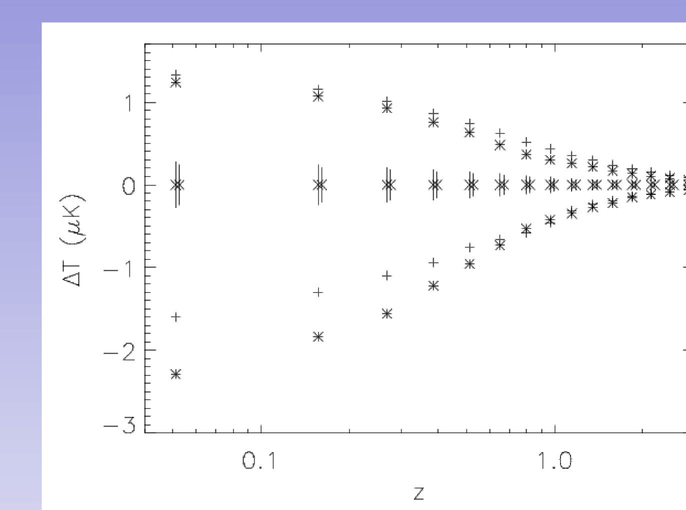

Fig 2. Rees-Sciama effect as a function of redshift. Maximum (top), minimum (bottom) and dispersion (middle) for two projections.

At high redshift the effect is small and starts to be significat at redshifts z < 1. The maximum effect occurs at low redshift (z=0) although the probabilities of having a large effect near the observer reduces as the volume is smaller. We place the observer in the center of the 300 Mpc/h simulation box at z=0 and project the Rees-Sciama effect from the observer to the 150 Mpc/h in all directions. In figure 3 we show the result pf the projection. By replicating the box at an earlier epoch we

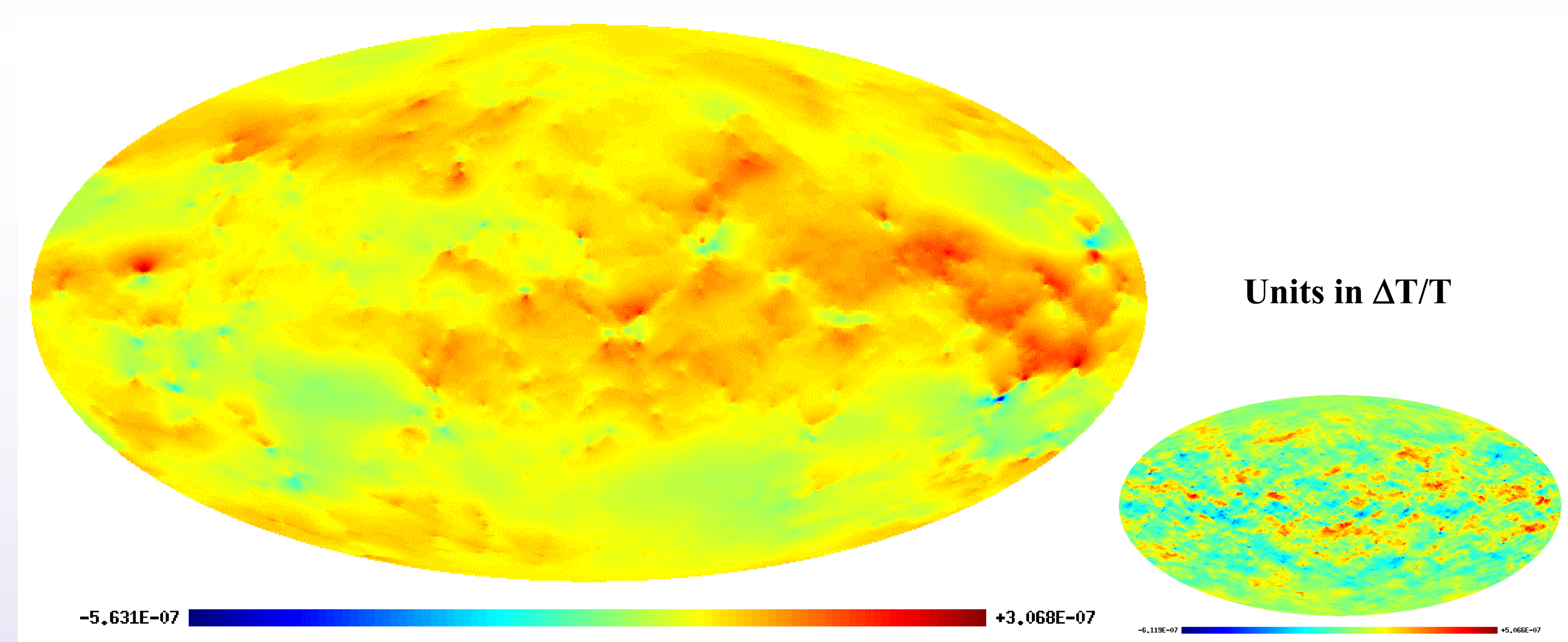

Fig 3. Rees-Sciama effect projected in Healpix format. The big projection corresponds to a maximum redshift of 0.05 and the small projection to a maximum redshift of 0.15. The small projection was obtained after multiple replications of the original box. In the small projection one can appreciate the effects of the periodical box in the north and south poles.

can extend the projection a bit further in redshift (small projection in figure 3). However, due to the periodical conditions of the simulation box the projected effect along the north and south poles suffers a larger compensation (between positive and negative Rees-Sciama) than in other directions where the lines of sight are less likely to cross the same point twice. When looking at the powr spectrum (figure 4) we see that the Rees-Sciama effect increases with the integrated volume. It is expected that the power spectrum shown in figure 4 increases at leats one or two orders of magnitude at l=10 when the integration is performed up to. Redshift z=1. However, a much larger simulation than the one used in this work is required to compute this power spectrum (to avoid the replication problems discussed above). We plan to analize a larger simulation to study this and other effects.

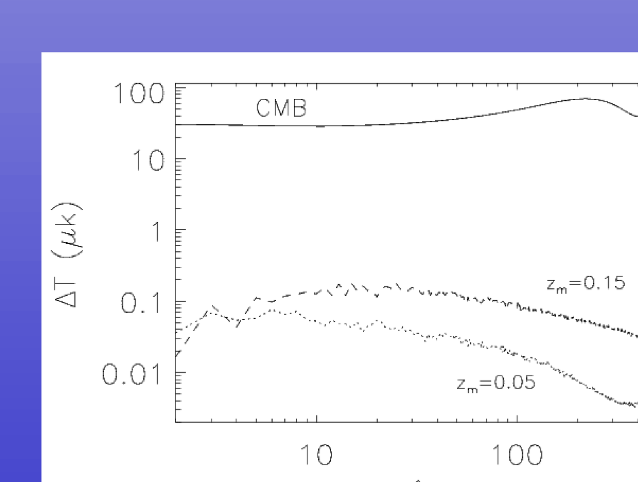

Figure 4. Power spectrum of the Rees-Sciama effect up to redshift z=0.05 and z=0.15.

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