Prize Talk PV III Mon 12:30 HSZ/AUDI

Two milestones in the life of the Universe: Last Scattering Surface and Black Body Photosphere — •Rashid Sunyaev — Max Planck Institute for Astrophysics — Institute for Advanced Study, Princeton — Laureate of the Max-Planck-Medal 2023

Our Universe is filled by cosmic microwave background (CMB) radiation which is extremely isotropic and has an excellent black body spectrum with a temperature of 2.7 Kelvin, and no spectral deviations from the blackbody have yet been detected in the CMB monopole.

However, the theory of Thomson scattering by hot Maxwellian electrons predicts the shadows of the CMB toward galaxy clusters filled with dark matter and hot gas. This prediction (thermal SZ effect) dates back to 1970, and only in 2011, the first three unknown galaxy clusters were discovered using this method. Now many thousands of galaxy clusters are being discovered using such shadows. Any energy release in the early Universe (due to the decay or annihilation of unknown particles, dissipation of the low-scale density perturbations due to radiative viscosity, etc, hydrogen recombination at redshift 1300) should lead to the CMB spectral distortions. Detecting such specific spectral deviations is one of the key goals of microwave radioastronomy.

There are other theoretical predictions that led to the experimental discovery of the “acoustic peaks” in the power spectrum of the CMB angular fluctuations and enabled the measurement of key parameters of our universe with unprecedented accuracy. The kinematic SZ effect enabled the measurement of galaxy cluster velocities relative to the local coordinate system in which the CMB is isotropic. The kSZ effect permitted the proof of Copernicus’ principle up to redshift $z \sim 2$, where the most distant galaxy clusters and protoclusters are observed.

A decrease in the CMB temperature in the course of the Universe expansion leads to the recombination of hydrogen, transparency of the Universe for photons, and appearance of the “surface of the last scattering”. The “acoustic peaks” are formed due to the presence of this surface. The recombination rate (and the effective thickness of this “surface”) is determined by the two-photon decay of the 2s level of the hydrogen atom.

Emission of low-frequency photons due to the double Compton effect and their redistribution along the spectrum due to multiple Thomson scatterings on hot electrons manage to maintain the blackbody spectrum while the redshift exceeds $z=2$ million. This value determines the position of the “blackbody photosphere” of the Universe. Spectral distortions of the CMB can be observed only if the energy release occurred at redshifts of less than 2 million.