What is the manifestation of a "quasar" at $z > 10^{10}$?

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Abstract

The process of forming an image of a cosmological point source (CPS) in condition of high optical depth is considered accounting for all types of interactions. It is shown that the energy conservation law causes the size of this image which is keeping constant over all redshifts of the CPSs. This effect must be taken into account for the consideration of the angular power spectrum of the CMBR. In particular, distant point sources and small scale fluctuations which were damping before recombination will contribute their energy in the region of angular scale $\theta_0 \approx 20'$.

1. One of the main processes in the evolution of matter in the Early Universe is a process of increasing and dissipation any density fluctuations which may be adiabatic fluctuations produced by inflation, primordial black holes, inhomogeneous of distribution of matter and antimatter, etc. Many of them are relatively small in size and rapidly evolve. We consider those of them which become smaller then the horizon before the hydrogen recombination. It seems that they does not produce any observable effects. A lot of articles claim their invisibility. The simplest argument is that the optical depth by the Thomson scattering $\tau \gg 1$. It becomes larger than unity at redshift $z \geq 1100$ and rapidly increase at higher $z$:

$$\tau = n_e \sigma_T c t \approx 10^{-2} (1 + z),$$

(1)

where $n_e$ is the concentration of free electrons (and positrons), $\sigma_T$ the cross section of the Thomson scattering, $c$ the speed of light, and $t$ the cosmological time.

2. But in our case there is a different situation. It is not a point source which is obscured by very thick cloud. Our source is surrounded by homogeneous matter with a very small free path for photons. This situations leads to a very slow diffusion of photon from the point where it was emitted. It means, that photon cannot move far away from the initial point. In a medium with a constant $n_e$ it can spread for the time interval $t$ in a bubble with the radius $R$

$$R \approx ct/\tau^{1/2}.$$

(2)
In the expanding Universe, where \( n_e \sim 1/t^2 \) the free path for photon increases in time and \( R \sim t^{3/2} \). But in any case \( R \) stays always less than the radius of the horizon, \( L \). The upper limit of \( R \) is \( R_0 \) at the moment of the hydrogen recombination. At this moment the electron density becomes so small that photons after the last scattering become free. Therefore \( R_0 \) is the last free path for photons before they become free. The simple numerical estimates give \( R_0 \approx (0.15 - 0.2)L_0 \), with \( L_0 \) being the horizon size at \( z = 1100 \). This value of \( R_0 \) corresponds to the angular size \( \theta_0 \approx 20' \). It is easy to show that this result does not actually depend on the initial radius \( R_i \) and \( z_i \) of the CPS (for \( z_i \gg 10^3 \)).

3. It is very important that the intensity of radiation \( I \) of these bubbles does not depend, in fact, on detail of energy transfer and transport. Indeed, if the radiation of the CPS may convert in several forms such as heating of matter, new electron-positron pairs, shocks or any hydrodynamic motions, then always the total energy within the bubble is keeping constant.

Then, the expansion of the Universe leads to the dissipation of hydrodynamic motions, annihilation of electron-positron pairs and total thermalisation of matter and radiation within the bubble with radius \( R_f \leq L \). This final radius \( R_f \) is formed at the moment really not less than \( z = 10^7 \). It is obvious that all energy emitted by this object will be trapped within this radius. The only part of the total energy which is transfered into neutrino will escape the bubble. But due to the thermodynamic equilibrium condition, this part cannot be more than 10-20%.

So, we may conclude, that approximately all energy will be in photons, and all variants of energy transformations do not influence \( R_0 \) and \( I_0 \) – the luminosity of bubble at \( z = 1100 \).

4. Due to the effect of redshift, the value of \( I_0 \), in contrast to \( R_0 \), depends on \( z_i \) under any other equal conditions. The spatial distribution of \( I \) within the bubble caused by diffusion is

\[
I = I_0 \exp\left(-r^2/2R_0^2\right),
\]

where \( r \) is a distance from the center of the bubble. Such a distribution is independent on the variations in time of intensity of primordial point source. But \( I_0 \) is the function of time corresponding to the time variations of initial \( I_i \).

5. The redshifts indicated in the title are not specific for this effect. In fact we can consider all other intervals \( 10^{40} \geq z \geq 10^4 \). However, there appears to be a new effect at smaller redshifts. It is the effect of a non-total energy thermalisation. Any spectrum of photons emitted in the interval of redshift \( 10^8 \geq z \geq 10^5 \) will be converted to the so called \( Y \)-distortions (see Sunyaev i& Zel’dovich 1970; Illarionov & Sunyaev 1974a, 1974b). The energy spectrum of objects irradiated after \( z \approx 10^5 \) remains approximately without changes.

6. Another aspect of this problem is the possibility of consideration of the evolution of energy distribution from extended sources. Really we can use all previous reasons to
describe all extended objects which have sizes smaller than the current value of $L$. It means that we can consider a small scale fluctuations of matter distribution from the tail of the primordial spectrum, caused by inflation. Nowadays there is a wide spread opinion that these fluctuations disappear due to viscosity and their energy are totally redistributed in space (see Silk 1968). So one cannot get any information about this part of the spectrum directly from observations.

What is really happened? All small wavelength sound waves are really damped, but all their energy are not transported far from the initial region. It is transformed from the kinetic into the thermal energy of matter (the smallest part of it) and mainly in the energy of the CMBR. The final size of the bubble where this energy will be distributed is $R_0$.

So on the base of our new result we can say, that actually all small scale fluctuations after dissipation will influence the spectrum of angular scale fluctuations on the scale size $\theta_0 \approx 20'$. The amplitude of this contribution may depend on the frequency of photons (see point 5). If statistic of these fluctuations is taken into account, one can get some changes in the angular spectrum at the scales $\theta \geq \theta_0$ with relatively lower amplitude.

7. In conclusion we would like to emphasize that the correct consideration of the process of energy transfer and transportation from a point like source or a small extended object in highly dense medium leads to a very slow expansion of region where all energy is concentrated.

From this it follows that the observations of the angular fluctuations of the CMBR at the angular scale $\theta_0 \simeq 20'$ will show up the presence of the primordial CPSs, their statistics and their physical properties. Besides one can obtain the information about the small scale density fluctuations caused by inflation.

References

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