

DISTANT GALAXIES AND COSMOLOGICAL MODELS

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Other Aspects of the Models

There are some other interesting aspects of these models. Using Model III, since it is widely used and the equations are simple, we can ask "What is the maximum proper distance away a light source can be **now** whose light has just reached us **now**?" For sources further away, there has not been time in the whole age of the universe for light to reach us. This proper distance is called the particle horizon, D_{ph} . For Model III this distance is $3ct_0$ and a particle now at this distance is receding at a velocity of $2c$.

Note that the distance is not ct_0 , as many books and journal articles suggest but $3ct_0$. (Maybe they are using the light travel distance or not grasping these concepts.) This result clearly implies that a galaxy can be receding from us at a proper velocity due to the expansion of space itself greater than the speed of light and still be seen by us since the redshift is not given by the relativistic Doppler shift equation but by equation (3) for a galaxy at rest in its own space. Our Model V is now the one most cosmologists use. In this model, the farthest galaxy whose light has just reached us is not now at $3ct_0$ but more like $5.7ct_0$ since the expansion rate has been increasing for the last 7 or so billion years. For a universe of present age 13.7 billion years this makes the distance some 78 billion light years and the width of the visible universe some 156 billion light years. This is discussed in the Physical Review Letters article in May, 2004.

Another concept is called the event horizon. There are two meanings of event horizon in cosmology. Usually it refers to the event horizon about a **black hole**. This event horizon is the boundary around the hole such that an object being sucked into the hole cannot emit radiation which ever gets out after the event horizon is crossed. No light emitted inside the event

horizon can ever be seen outside.

The other event horizon applies to the **universe as a whole**. This horizon is the minimum distance away a particle can be now so that the light it emits now will not reach our location in any finite time in the future. For our Model III there is no event horizon, the light emitted now by any particle in the universe will eventually reach our location. In this model, the expansion rate of the universe slows down toward a stop so a light pulse from far away can eventually start moving toward our location and reach it.

In a universe with much lower mass density than our Model III and with or without a cosmological constant the universe will continue to expand rapidly and an event happening now at a sufficiently distant location will never be seen at our location; there will be an event horizon. For a universe expanding at a constant rate this event horizon is at a distance ct_0 where t_0 is the present age of the universe. **Figure X** illustrates this case for two events, one at 99% of the distance to the event horizon and the other at 101% of this distance. The first event will be seen at our location when the universe is 5.6 times its present age. The other event will never be seen at our location.

Another interesting effect is that the angular size of distant galaxies is less as they get further away (as would be expected) for distances up to a certain distance. Beyond that distance, however, the angular size **increases** with increasing distance. This effect is shown in **Figure VII** as a function of z , again for Model III.

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