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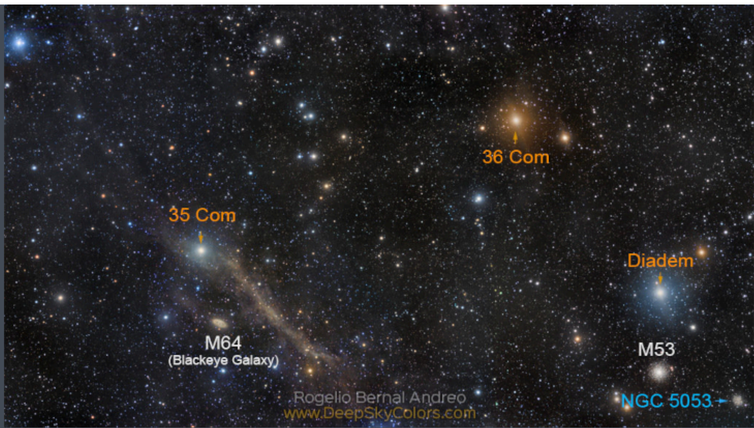
The second law of thermodynamics at cosmic scales



In an accelerating expanding universe, where galaxies are separating more and more rapidly, are the laws of physics valid beyond the solar system or our galaxy? With observational data from different moments of the universe's expansion, the Department of Physics has studied if the second law of thermodynamics, which assert that the entropy of the universe cannot diminish, holds at cosmological scales.

Observatorio.info - Rogelio Bernal Andreo (DeepSkyColors.com) https://observatorio.info/2017/06/de-la-cadena-de-markarian-a-messier-64/

From six hundred light-years on the visible universe appears isotropic, i.e., in whatever direction you look, no significant difference arises. Further, there are solid arguments to believe that the universe is homogeneous as well (all positions are equivalent); on average no difference should arise if we observe the universe from any other galaxy. About a century ago, the observation revealed that the universe is expanding (that is to say, the distance between every pair of distant galaxies increases with time), and more recently it has been noticed that the rate of this expansion is increasing. Then, one may wonder whether, in this situation, the physical laws are valid at these huge scales in the same way as they are at terrestrial scales, at the solar system, or even at galactic scales.

In a recent publication, *"Checking the second law at cosmic scales"*, we have studied this question for the case of the second law of thermodynamics (so familiar to everybody as it is of such frequent experience). The said law can be formulated as follows: Given two bodies in mutual contact and isolated from their environment, one of them hot and the other cold, heat will flow spontaneously from the former to the latter till their temperatures equalize. More sophisticated formulations of this law resort to the concept of entropy. Applied to our universe, they assert that its entropy cannot diminish. The cosmological horizon, whose entropy is proportional to its area and corresponds to our ignorance of what is going on beyond it, contributes the most. The contribution of galaxies, radiation, black holes, and so on, is much lower. As a consequence, the second law will also be fulfilled at cosmological scales if the area of the horizon does not decrease with time. This will be so if the deceleration parameter (which measures how accelerated our universe is) happens to be no less than the parameter of spatial curvature (which corresponds to the curvature of the space at large scales) minus unity. Both parameters can be estimated from data obtained about the rate of expansion at different epochs by the telescope. Obviously, these data are affected by error margins.

In our work, we made use of one thousand and sixty-four data points taken from different expansion epochs by several experimental teams. We reduced the errors affecting the data by a smoothing process (a statistical method frequently employed in different branches of science and industry). From these, we derived, as well as at different epochs, the parameters mentioned above. We found that at no moment during the expansion did the area of the horizon decrease; rather, it increased. In other words, according to our study, the second law of thermodynamics is satisfied at the largest scales of the observable universe.

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References

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