NS50 - Scientific Proposal

How did the universe evolve?

Minerva Schools at KGI

NS50 – Scientific Proposal

Background and motivation:

The universe is always a mystery to curious human kind. The modern science develops our understanding in many aspects but coming from the stardust still, we still searching answer about our true origin: 'how all these things started?' and 'where are we heading to?'

Many experts worked in this field throughout the centuries. The modern technology gave us the chance to look to the furthest galaxies and getting information from there. In this proposal, I will be working based on a dataset of some selected galaxies from NASA/IPEC extragalactic database to understand the past of the universe.

Data Visualization:

The dataset mainly provides the recessional velocity of 43 observed galaxies with respect to Milky way in km/s and their accurate distance measured by 'Cepheid method' in Mpc (1 Mpc = 3.26 million light year) (Madore & Steer, 2008). It also gives the galactic coordinates of the galaxies and hubble type of them. It shows the differences of absolute and apparent magnitudes with its error from which the distances were calculated in the next column.

From the velocity vs. distance graph of all these galaxies, we can see a strong linear correlation at least for the galaxies nearer than 15 Mpc with a slop of 62 ± 2 (Fig. 1). But the trend started to deviate for the further galaxies. While generally, the further galaxies show a little less velocity than the trend, a group of galaxies from 15-20 Mpc distance have significantly higher velocities. We cannot even assume that there is much error in measured velocity or distance as they are quite accurate measurement aggregated from the published journals between

1990 to 2006 (Madore & Steer, 2008). So, it's hard to conclude something specially regarding the further galaxies from this graph.

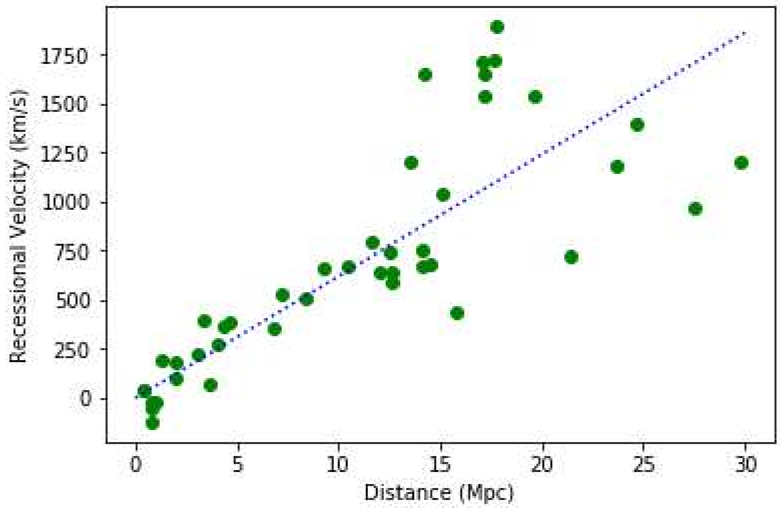

Figure 1: The recessional velocity vs. distance graph of 43 observed galaxies by cepheids method show a strong linear relationship until 15 Mpc and then deviate in both side for further galaxies.[1]

To get more insight into the data, we chose to plot the coordinates of galaxies according to their distance (Fig. 2). The first thing to notice that, though the observed galaxies are from the different region of the sky, the total sky is not covered. There is a significant gap of observation below the galactic longitude of 100-degree. Moreover, among the galaxies of distance in between 15-20 Mpc, most of them are from a specific region of the sky (upper right corner), which could bias the result.

[1] #dataviz: Visualized the data in proper format so that it can help me interpret the data more. Using of difference symbol in legend will ensure its effectivity in black and white format too.

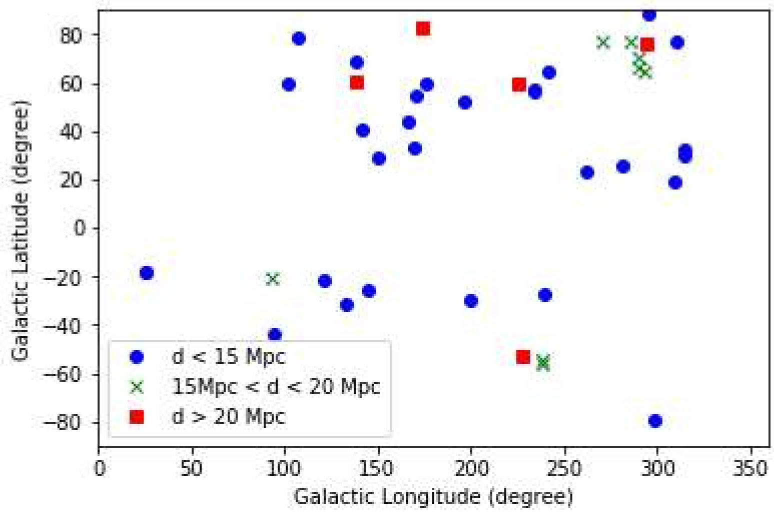

Figure 2: The sky map with the coordinates of observed 43 galaxies according to their distance shows that the galaxies of distance 15-20 Mpc are mostly from the same region and there is a lack of data for the region of sky less than 100-degree longitude

Interestingly, that special region near +70-degree latitude and 300-degree longitude, is the position of Virgo cluster, the closest galaxy clusters from our galaxy ("The Virgo Cluster", 2006). Even the coordinate of a minority region of observed galaxies at this distance merged with the coordinate of Fornax cluster (-60 degree and 250 degree), the second nearest one ("The Fornax and Eridanus Clusters", 2006). Galaxy clusters are a group of gravitationally bonded nearby galaxies which rotates around their cluster center at a very high speed. So, this speed can add up or drop down the value of the actual recession velocity shown by the other galaxies (Tully and Shaya, 1984). This information explains the variation in Fig. 1.

The velocity vs distance graph bears another information. When we observed light from galaxies at 15 Mpc or about 50 million light year away, we see how it was at 50 million year ago. So, the graph suggests that the hubble constant (i.e. the ratio of recessional velocity and distance of the galaxies) didn’t change at least in last 50 million year.

Hypothesis:

Based on this dataset, I propose that the velocity-distance ratio will be same and constant for all further galaxies and it would have an approximate value of 62.

The support behind is that the cepheid measurement works perfectly for nearer galaxies and almost all of them fitted in a single line in the graph. Also, the deviation for further galaxies can be analyzed by cluster properties.[2]

As seeing more distant object means looking through time, this hypothesis will increase our understanding of the properties of the past universe like its expansion rate, age and possibly the origin and ending.

Study Method:

Firstly, we need more precise data for more galaxies, especially the further ones. As an observational study, we would prefer to use Ia type supernova to calculate the distance of further galaxies as it is more precise method for measuring distance even more than 3000 Mpc (Richmond, 2006). We would observe the galaxies recessional velocity by doppler effect.

While measuring these variables, we need to make sure that we covered almost all the regions of the sky and took observation quite randomly and uniformly across the sky. If we observe a known cluster, then we will try to take only the velocity of the center of the cluster. If

[2] #plausibility: supported the hypothesis directly from the interpretation of provided data to make it plausible enough.

it is not possible, then we will take observations for as more galaxy as possible so that together they can cancel the peculiar or intrinsic motion of the individual galaxy.[3]

One major advantage is that we are not first in this work. Many experts and observers already observed many galaxies using Ia supernova and published paper. We will start our working by aggregating all these available observations. We will consider the methods, approach, and error of these data that how solid and precise they are, did they use any specific methods for clusters or phenomenon like that and what was their possible explanations. After choosing the observations, we would plot the coordinates to see which area of sky is not covered at all or observation from that region is not precise enough.

Beside of using a permanent observatory throughout our research, we should also use data from other observatories to reduce the effect of any confounding variable like airmass.[4] The most effective approach will be using the robotic telescopes throughout the world by Las Cumbres Observatory ("LCO Observation Portal," 2018). It will be better if we can use the space telescopes also as it will reduce the effect of atmosphere and provide more accurate measurement.

Though our strength is supernova can be detected from a very large distance, the universe is always a mystery. So, there may be many unexpected phenomena happened which will disrupt our measurements. So, having an updated and clear concept about measuring distance by the supernova is crucial to distinguish any abnormal measurements. Considering these factors to be accurate and precise, we would collect each data that we got no matter how outlier it seems to be.

[3] #observationalstudy: provided a clear observational study, where the real data will be observed without any type of manipulation to test the hypothesis.

[4] #variable: identified the to-be-measured variables and also took steps to decrease the possible confounding variables.

Expected result:

After collecting all the data, we need to plot these data with the errors and precisions. Then use computer programming, simulation or another modern method to analyze these data and possible explanation.

If our hypothesis is true, we would see on average all the data converge in a linear fit with some neglectable outliers. And the slope of the line will be about 62. But as we calculate the distance to compare the supernova brightness with the large magellanic cloud (LMC) and there are about 10% error in the calculating distance of LMC, this slope could very 10% or more (Richmond, 2006). This result will support my hypothesis but to make it stronger, we can do research using other methods too. This hypothesis will lead us another hypothesis that the expansion rate of the universe was constant throughout the very beginning.

If our data clearly shows that the convergent in a linear fit is not true after a certain distance, then my hypothesis will be falsified. But even then, our understanding will be developed that, after a certain distance, means before a certain period, the velocity vs distance ratio was slower than today. So, another hypothesis will come up that the expansion rate of universe is increasing, which will answer more questions regarding universe.[5]

For both new hypotheses, we could then also try to find evidence on other criteria like the matter distribution in universe or the received cosmic background radiation. We also can propose a 3rd level hypothesis about calculating the age of the universe and thus develop our ideas about how it evolved earlier and where would it possibly go.[6]

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[5] #testability: the specific test could be drawn from the hypothesis which can be tested and falsified.
[6] #hypothesisdevelopement: showed how a proper hypothesis always leads to some more hypothesis like an iterative cycle no matter if it became true or false.

References

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