Dark Matter Distribution in the Shapley Supercluster

Author: Sunhaeng Hur

Department of Physics
sunhh@vt.edu

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Supercluster

- Supercluster is a cluster of galaxy clusters
- Superclusters are currently in the process of being formed.
- A region is considered to have a supercluster if the overdensity ratio in that region which has at least three clusters is greater than twice the average density. (Zucca et al. 1993)

Supercluster Map

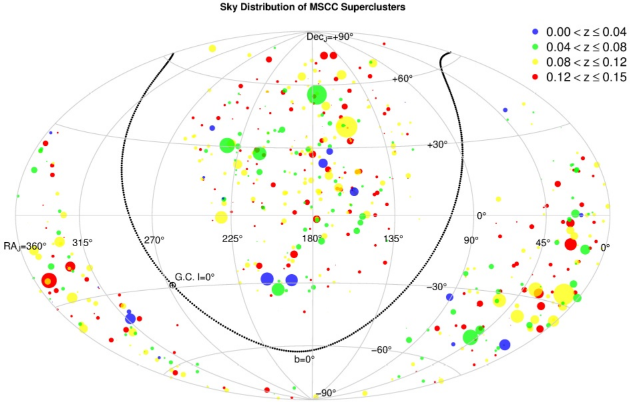


Figure: Supercluster map of Main SuperCluster Catalogue (MSCC) in equatorial coordinates. (Chow-Martí nez et al. 2014)

Shapley supercluster

- Shapley supercluster is the largest supercluster within 300*Mpc*.

Figure: The Shapley supercluster in the Planck survey.(P. A. R. Ade et al. 2014)

Density map of Shapley supercluster

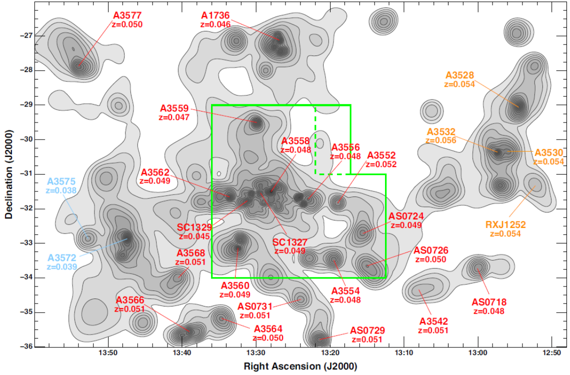


Figure: K-band luminosity-weighted density map of the Shapley supercluster region (Higuchi et al. 2020)

Shapley supercluster

- The Shapley Supercluster is the most studied supercluster. There is a lot of data on the distribution of baryonic masses and clusters velocities within the superculster
- we can take advantage of to guess the dark matter distribution.

My work

1. working out the expected velocity distribution of point masses moving inside the gravitational potential of a given mass distribution.
2. Constraining the mass distribution of Shapley supercluster by comparing that to the observed velocities.

Power law

- I chose the simplest model, power law to get theoretical velocity dispersion of baryonic matter in Shapley Supercluster.
- If there are errors, we could develop from the simplest model to complicate model by adding assumption.

$$\rho(r) = Ar^{-\alpha}$$

Data for analysis

- I chose data from this paper.(Filippis, Schindler, and Erben 2005)

$$M(r) = 4\pi \int_0^r dr' r'^2 \rho(r')$$

R (Mpc)	M_x $(10^{14} M_\odot)$
13.6	23.5
16.7	28.8
40	57.7
60.8	72.3

Table: M_x is the total mass of clusters detected by x-ray within the radius.

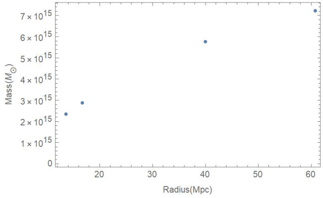
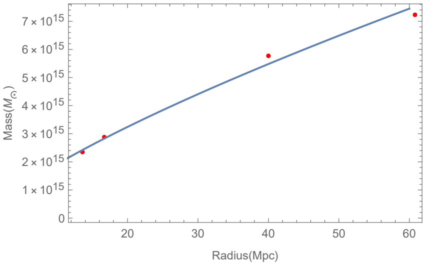


Figure: Plot of data

Fitting data

$$\rho(r) = 2 \times 10^{13} r^{-2.243}$$



Assumption to get distribution function

- Our goal is getting the distribution function f(**x**,**v**). Distribution function gives the probability that a star or cluster is at **x** with **v**.

- Assumption
  - All clusters are identical and there is a single distribution
  - Mass density that generates the system's gravitational potential is proportional to the probability density $\nu(\mathbf{x})$

$$\rho(\mathbf{x}) \propto \nu(\mathbf{x}) \equiv \int d^3\mathbf{v} f(\mathbf{x}, \mathbf{v})$$

Probability density $\nu(\mathbf{x})$ gives the probability that a star or cluster is at **x**.

Distrbution function

After introducing relative potential and relative energy,

$$\Psi \equiv -\Phi + \Phi_0 \qquad \epsilon \equiv -H + \Phi_0 = \Psi - \frac{1}{2}v^2$$

The probability density can be written

$$\nu(r) \to \nu(\Psi) = 2\sqrt{8}\pi \int_0^{\Psi} d\epsilon f(\epsilon)\sqrt{2(\Psi - \epsilon)}$$

and the distribution function becomes

$$f(\epsilon) = \frac{1}{\sqrt{8}\pi^2}\left[\int_0^{\epsilon} \frac{d\Psi}{\sqrt{\epsilon - \Psi}} \frac{d^2\nu}{d\Psi^2} + \frac{1}{\sqrt{\epsilon}}\left(\frac{d\nu}{d\Psi}\right)_{\Psi=0}\right] \approx 1.43 \times 10^{-49}\epsilon^{7.73}$$

Velocity Dispersion

When the distribution function depends only on Hamiltonian, the velocity-dispersion tensor of supercluster becomes isotropic.

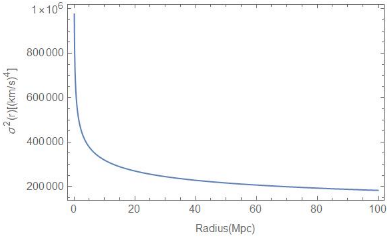


Figure: σ^2 from the power law

$$\sigma^2(r) = \frac{4\pi}{3\nu(r)} \int dv v^4 f(\Psi - \frac{1}{2}v^2)$$

The number of cluster for each radius bin

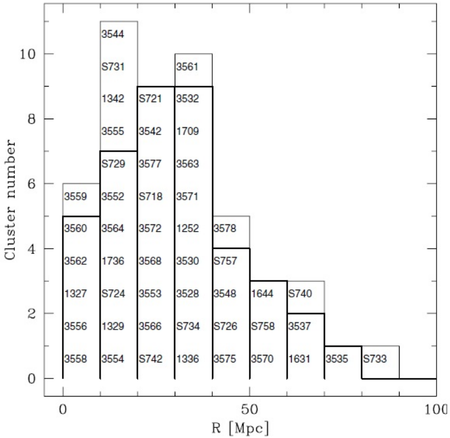
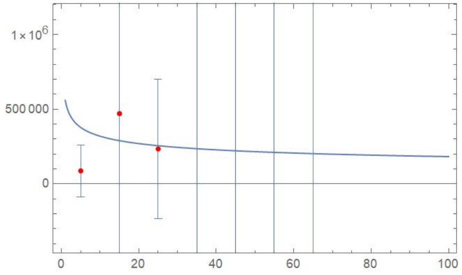
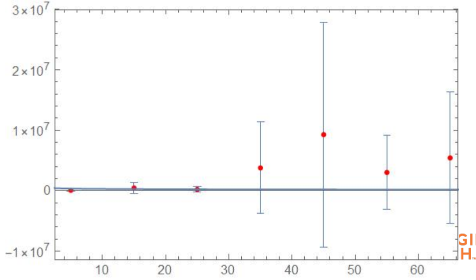


Figure: x-axis is the radius of Shapley Supercluster and y-axis is the number of cluster in each radius range(Filippis, Schindler, and Erben 2005)

Comparison with observed data

- Due to large error, it is hard to constrain dark matter distribution in Shapley supercluster.





Conclusion

- Since the error bar is too large, it is difficult to say that we need dark matter to explain velocity dispersion of Shaply supercluster.
- To constrain dark matter in Shapley supercluster, we need more data such as intercluster galaxy data in Shapley supercluster.
- Since the velocity dispersion function diverges at the origin, the plot doesn't seem physical
- We will develop our model into a complex model.

Questions?