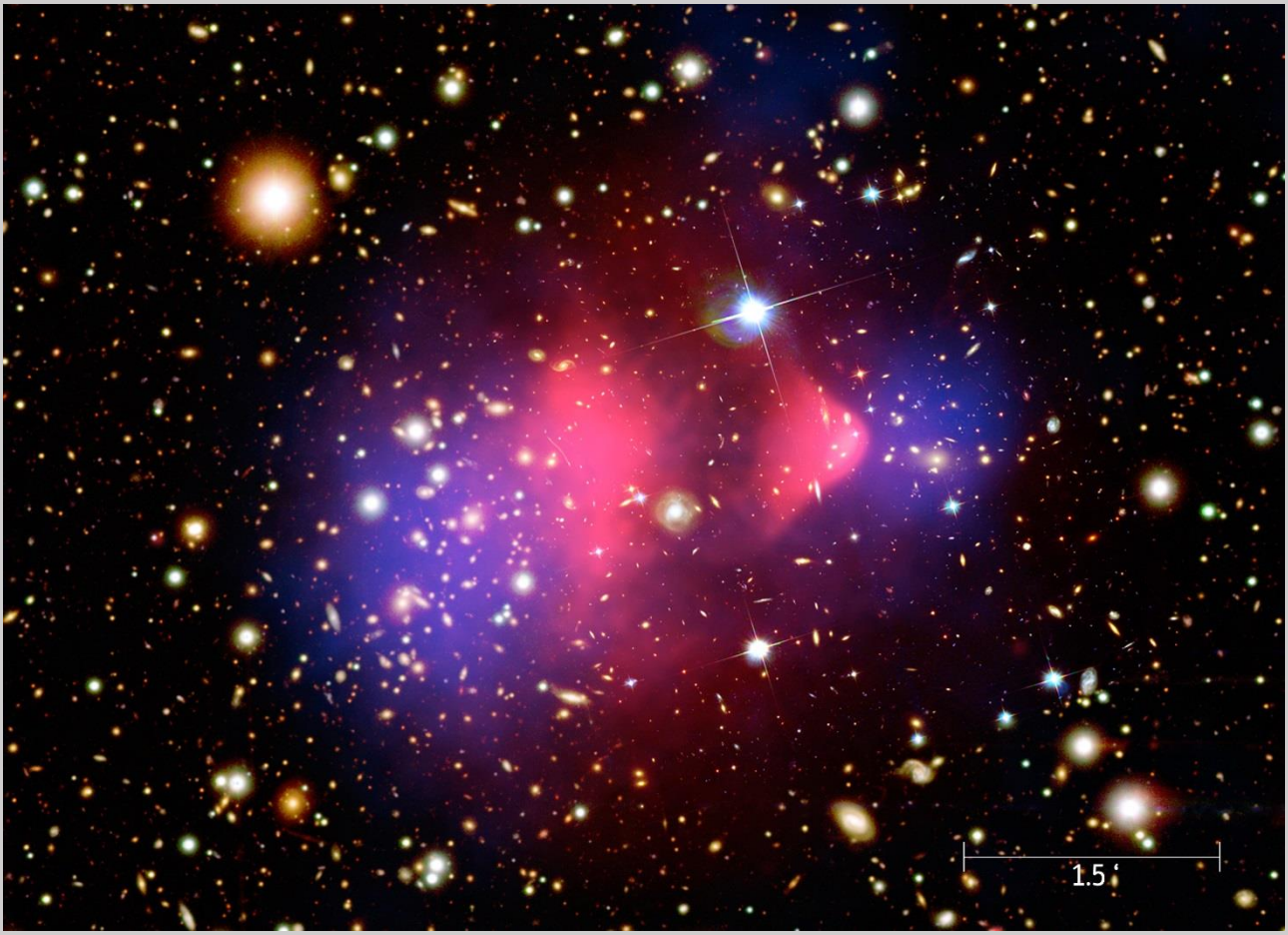
II.IV.I Bullet Cluster

By the time I started writing this book and even until reaching to the previous section of gravitational lensing, I did not take the case of Bullet Cluster seriously. I had the simple confidence that if dark matter is successfully excluded from cluster dynamics[1], galactic rotations[2] and gravitational lensing[3] then it must also not actually be found in the case of Bullet Cluster. I almost reached to this topic under the impression that Bullet Cluster section would be a simple task and not going to pose much problem.

But the case of Bullet Cluster actually appeared quite impenetrable. At time, I even thought to write that though Bullet Cluster problem seems like a fool proof case in favor of dark matter regime but I still disagree on account of the fact that after all dark matter is not found in problems bigger in ranking to this one.

The case for the Bullet Cluster in support of dark matter regime was published by a group of Astronomers in a 2006 paper titled "A Direct Empirical Proof of the Existence of Dark Matter"[4] and NASA website had released the news about this upcoming research finding in advance[5]. The paper almost starts with the assumption that stellar component of galaxies make up only 1 ~ 2% of the mass. I checked this point – and found that the up-to-date estimate is around 4% stellar mass, 12% gas and 84% dark matter[6]. In principle, the assumption was right but the baffling thing was that the presentation of so-called proof of dark matter had already assumed the presence of dark matter in galaxies. But the later study showed that the results of the paper did not depend on pre-supposition of the existence of dark matter. The story line was perfect – and the conclusion based on the given story line does reach to the affirmation of dark matter. So let us first go through the official story:

The story is largely inspired by some famous action movie and following is the action scene:



X-ray image (pink) superimposed over a visible light image (galaxies), with matter distribution calculated from gravitational lensing (blue). Image credit: NASA

The action story is that right side sub-cluster originally belonged to the left side and then penetrated to the larger sub-cluster at very high speed of few thousand KM/sec. Like a fast moving bullet, the small sub-cluster entered into the larger one from left side and came out from the right side. We now see this cluster when the collision is already over; now the high momentum of both sub-clusters is taking them away from one another on opposite directions, though at reduced speed than before; and at the tail of the small sub-cluster now moving towards right side, shape of “bullet” can be seen even now.

Plot of the story is that two sub-clusters were heading towards one another at very high velocity like few thousand KM/sec. Both sub-clusters were made of three components (i) Stars of Galaxies, (ii) Dark Matter and; (iii) Hot Gas of galaxy clusters.

As these sub-clusters collided, (i) galaxies with stars and (ii) dark matter simply passed through one another as both these entities behaved like collision-less particles for this

enormous scale collision. However the third component i.e. hot gas or plasma of both sub-clusters physically collided with one another; applied drag or 'ram pressure' on one another then slowed down and congested in the central (pink) location while the first two components (blue on both sides) have now reached quite away from one another on opposite directions. Aftermath of this collision is that central (pink) location is now jam packed with hot gas or plasma and emitting x-rays on enormous scales and due to x-rays, this area has been marked in pink color.

Theory is that central gas portion should represent majority of baryonic matter (normal matter other than dark matter) because gas component of clusters is regarded as far more massive than the stellar component.

It is held in this paper that this is the unique setup where dominant baryon component has been physically separated from the potential dark matter area and therefore provides an opportunity to physically check mass profiles of both these separated areas. The argument is that if dark matter does not exist then central gas area will show up as more massive.

In order to physically check the mass profiles or mass distribution of these two separated areas, the research team employed the methodology of analyzing weak gravitational lensing of background galaxies and found that actually galaxies component is more massive which is possible only if something like dark matter does exist.

Plot of the story seemed perfect. We cannot question the collision because of astounding x-ray emitting middle component and the results do not depend on the pre-supposition of the existence of dark matter.

I noticed, however some issues like other than the x-ray emitting middle component, there was no other trace of such a complete progression of two complete sub-clusters from within one another. But this point had a 'proper' cover-up in the form of the assumption that galaxies and stellar mass behave like collision-less particles for such enormous scales. I could point out other missing gravitational effects such as absence of physical disturbance or deformation of individual galaxies or whole sub-clusters but these facts could be used as supporting points only once a bigger loophole comes to surface.

Eventually, I found a clue that hot gases of clusters do normally emit x-rays and that the thermal radiation of those gases is normally around 10 million K. An academic paper[7] about hot gases of clusters contains following important information:

> Rich (Abell-like) clusters have X-ray luminosities ranging from as low as those of individual bright galaxies up to 1000 times higher: 10^{42} - 10^{45} ergs sec^{-1} (Jones et al. 1979; Abramopoulos and Ku 1983; Jones and Forman 1984). Gas temperatures range from a few 10^{7} to 10^{8} K (Mushotzky et al. 1978) and gas masses can exceed 10^{14} M⊙ within the central few Mpc. The gas densities in the cores of rich clusters lie in the range 10^{-2} - 10^{-3} cm^{-3} and the inferred cooling times of the gas can be as small as 10^{9} years (Fabian, Nulsen and Canizares 1982).

According to the Wikipedia article titled 'Bullet Cluster', the x-ray emitting gas temperature of this cluster is 70 million K which is within the range of 10^{7} to 10^{8} K.

In another online source[8], a PhD in Galaxy Clusters person Mr. Kholay Elgeneina has provided following crucial information:

> Clusters' gas is in the region of a few to tens of millions of degrees Kelvin. (our local)[9] Group's temperature are much lower, in the regions of 10's of thousands of Kelvin. It should just depend on the mass of the object you're talking about. Larger masses compress the gas to higher temperature. But it also depend on how long this object has existed, and did have enough time to thermalize the gas in it.

Equipped with above given information, now we no more find Bullet Cluster as a unique mysterious case where a complete transparent collision of galaxies, excluding gas component, has already taken place and where the gas component is now emitting high intensity x-rays whereas temperature of that gas is as high as 70 million K. Now our simple interpretation of Bullet Cluster is that collision has not already taken place. These two sub-clusters are still at their original sides i.e. larger on left and smaller on right and still exist in original perfect shape and also there is no sign of gravitational deformation of individual galaxies or sub-clusters as a whole. These two sub-clusters are now heading towards one another and what we are observing now is a phase which is prior to the actual collision. Due to approaching of two sub-clusters, the hot gas of clusters has been compressed between these two sub-clusters and thus gas temperature has risen to almost 70 million degree kelvin and also that's why this portion is emitting high intensity x-rays.

The shape of bullet at the tail of right smaller sub-cluster is due to compression being faced from the other side. The compressed gas of both sides is interacting electromagnetically (this point is mentioned in Wikipedia article) and may be also electrically as large solar flare type structures are visible on both sides of gas. Really there is something unusual going on in this cluster and dark matter supporters even now can point out that after all gravitational lensing had found mass distribution of galaxy area and not that of gas area therefore proof in favor of dark matter stands. Actually due to this reason, initially the case of Bullet Cluster did seem like impenetrable and appeared like a fool proof evidence in support of dark matter regime. However the main argument of Bullet Cluster is based on the claim that this cluster provides a unique setup where dark matter has already been separated from the major component of baryonic matter. Therefore, in case collision has not already taken place then claim of unique setup does not hold and mere fact that gravitational lensing has found out mass distribution of only galaxies and not that of gas area will have no link with the supposed dark matter because then dark matter should be existing on both the areas.

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1 Rafique, Khuram. (2019). Cluster of Galaxies and Dark Matter - Book: "Philosophy Unscrambles Dark Matter". In Philosophy Unscrambles Dark Matter. Zenodo. http://doi.org/10.5281/zenodo.3546610

2 Rafique, Khuram. (2019). Sections about Galactic Rotation - Book: "Philosophy Unscrambles Dark Matter". In Philosophy Unscrambles Dark Matter. Zenodo. http://doi.org/10.5281/zenodo.3530781

[3] Rafique, Khuram. (2019). Gravitation Lensing Section - Book: "Philosophy Unscrambles Dark Matter". In Philosophy Unscrambles Dark Matter. Zenodo. http://doi.org/10.5281/zenodo.3544830

[4] https://arxiv.org/abs/astro-ph/0608407

[5] https://www.nasa.gov/centers/marshall/news/news/releases/2006/06-096.html

[6] https://www.vox.com/science-and-health/2019/4/2/18282606/milky-way-mass-stars-dark-matter

[7] https://ned.ipac.caltech.edu/level5/Forman2/Forman1.html

[8] https://www.quora.com/Is-the-Local-Group-filled-with-hot-gas-like-the-large-galaxy-clusters/answer/Kholy-Elgeneina

[9] Bracket words added by me to match the context.