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Extragalactic Gamma Ray Excess from Coma Supercluster Direction

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Abstract. The origin of extragalactic diffuse gamma ray is not accurately known, especially because our suggestions are related to many models that need to be considered either to compute the galactic diffuse gamma ray intensity or to consider the contribution of other extragalactic structures while surveying a specific portion of the sky. More precise analysis of EGRET data however, makes it possible to estimate the diffuse gamma ray in Coma supercluster (i.e., Coma\A1367 supercluster) direction with a value of $I\,(E > 30\,\mathrm{MeV}) \simeq 1.9 \times 10^{-6}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$, which is considered to be an upper limit for the diffuse gamma ray due to Coma supercluster. The related total intensity (on average) is calculated to be ~5% of the actual diffuse extragalactic background. The calculated intensity makes it possible to estimate the origin of extragalactic diffuse gamma ray.

Key words. Cosmic rays—galaxies: clusters: individual: Coma\A1367, general—diffuse radiation—gamma rays: theory.

1. Introduction

The interaction of very high energy protons with 2.7 K Cosmic Microwave Background (CMB) create halos of γ rays around the galaxy clusters (Wdowczyk & Wolfendale 1990a) which can be observed as diffuse γ ray background. Evidence for the existence of diffuse gamma ray background was first reported by Kraushaar *et al.* (1972) on the basis of data from OSO-3 satellite. It was followed by SAS-2 satellite (Fichtel *et al*. 1975, 1977; Fichtel 1977; Fichtel *et al.* 1978) which indicated the presence of a residual, apparently isotropic emission that interpreted as not being associated with the galaxy. It was followed by EGRET (Sreekumar *et al*. 1998) which provided the opportunity of studying the extragalactic emission in greater detail.

Amongst the largest structures of cosmos, superclusters – groups of gravitationally associated clusters of galaxies – have been the subject of interest since their discovery (de Vaucouleurs 1953; Abell 1961; Jõeveer & Einasto 1978; Gregory & Thompson 1978). Two of the most-studied superclusters are located at the northern galactic pole (i.e., Virgo and Coma superclusters).

Virgo cluster, the central member of the local supercluster (or Virgo supercluster), is a rich cluster which is located at $l = 280°$, $b = 74.5°$ (Binggeli *et al.* 1987) with a distance of ~20 Mpc and a diameter of ~40 Mpc (Oort 1983). Coma supercluster consists of two much richer clusters: Coma or Abell 1656 at $l = 58°$, $b = 88°$ (Abell *et al.* 1989) and Abell 1367 at $l = 235°$, $b = 73°$ (Abell *et al.* 1989) and is the nearest massive supercluster consisting of more than 3000 galaxies. The official (NASA/IPAC Extragalactic Database) coordinates of Coma supercluster are: J2000 RA = $12^h\ 24^m\ 6.79^s$ and Dec = $23°55'22.9''$. The plan of Coma supercluster is defined by Coma cluster and Abell 1367 and is located at a distance of about ~100 Mpc with diameters of about ~ 91 and 160 Mpc (Oort 1983).

As the intracluster medium (ICM) of galaxy clusters is composed of magnetic fields as well as thermal gas (Ferrari *et al*. 2008; Bonafede *et al*. 2010), the strength and structure of magnetic fields have a key role in the production of diffuse gamma rays (Blasi *et al.* 2007). Consequently, the observation of diffuse gamma rays from superclusters or determining an upper limit for diffuse gamma ray from superclusters, indicates the existence of ICM magnetic fields.

Usually, radio observations of galaxy clusters allow us to measure intracluster magnetic fields. Diffuse and extended radio emissions in galaxy clusters were first reported by Large *et al.* (1959), who mapped the Coma cluster at radio wavelengths. The existence of an extended radio source at the center of Coma cluster was then confirmed by Willson (1970) and the possible origins of magnetic field in the extended radio and X-ray source in Coma cluster was mentioned by Perola & Reinhardt (1972). In 1970, the existence of a radio halo in Coma cluster was suspected (Willson 1970) and mapped later (Jaffe *et al.* 1976; Wielebinski 1978; and others). In 1981, Ballarati *et al*. reported three extended sources of a halo type detected in the Coma\A1367 supercluster.

These observations made it possible to estimate the cluster and intracluster magnetic fields depend on the different models were considered. Deep radio observations revealed the presence of diffuse, extended (~1 Mpc) and non-thermal radio sources in about 50 merging clusters. Power-law radio spectrum indicates the synchrotron nature and presence of relativistic electrons and weak magnetic fields.

Bazzano *et al*. (1990) estimated a lower magnetic field strength of ~ 0.04 μG for the intracluster magnetic field consistent with a volume averaged intracluster magnetic field of ~0.2 μG (Fusco-Femiano *et al*. 1999, 2004; Fusco-Femiano 2002), ~1 μG (Ferrari *et al*. 2008) and ~ 0.7–1.9 μG assuming equipartition (Thierbach *et al.* 2003). In a region well outside the Coma cluster in the direction towards A1367, Kim *et al*. (1989) observed a bridge of synchrotron emission with the same direction of about 0.3–0.6 μG. A good discussion can be found in Enßlin & Biermann (1998).

The strength of the local supercluster (i.e. Virgo supercluster) magnetic field is assumed to be ~ 0.1 μG (Sigl *et al.* 1998). The smaller intracluster field of Virgo was deduced from the comparison of other properties of Virgo and Coma, for example the magnetic fields in the clusters themselves (Wdowczyk & Wolfendale 1990a). Wdowczyk & Wolfendale (1990a) considered the lower total luminosity of Virgo calculated in this field to be ~ 0.03 μG.

Though Coma supercluster is located about 100 Mpc away, as it has a stronger magnetic field in comparison to Virgo supercluster (i.e., 0.3–0.6 μG (Kim *et al*. 1989) against ~0.1 μG (Sigl *et al.* 1998); ~0.03 μG (Wdowczyk & Wolfendale 1990a)), we hope to find a considerable γ ray flux in the Coma supercluster direction.

Using putative models for producing γ ray in the galaxy (Osborne *et al.* 1994), a model for γ ray flux produced by Virgo cluster (Wdowczyk & Wolfendale 1990a) and the experimental data from Compton Gamma Ray Observatory (CGRO) the preliminary results of which are given by Osborne *et al.* (1994), the diffuse γ ray excess from Coma supercluster direction is calculated.

2. Methods

In this research, the model presented by Osborne *et al.* (1994) was used. They have used the EGRET data in the energy range of 35 MeV to over 10 GeV. As a result of their work they have presented diffuse γ ray intensity versus column density of gas and these results are in galactic latitudes $|b|$ = 10–20, 20–30, 30–40, 40–60 and $|b| > 60°$. A corrected version of their results (Smialkowski *et al.* 1997) used by Fatemi (1996) to calculate diffuse γ ray intensity in the Virgo direction and is adopted again to calculate diffuse γ ray excess in Coma supercluster direction.

It is usually been assumed that, for galactic latitudes above 10° the galactic γ ray intensity is proportional to the column density of gas (Osborne *et al.* 1994; Lequeux 2005). For our case, γ ray energy bands were chosen to be 30–50, 50–70, 70–100, 100–150 and 150–300 MeV, 0.3–0.5, 0.5–1, 1–2, 2–4 GeV. We looked at different galactic quadrants and energy bands for excess of extragalactic diffuse γ rays.

These results are used for four galactic quadrants and galactic latitudes $b > 60°$ associated with Virgo and Coma superclusters and also for $b < -60°$ (related to galactic poles). The latter is used as diffuse γ ray background considering the fact that there is no important near supercluster on $b < -60°$ (The nearest galaxy cluster is the Fornax cluster which extends only by 2°).

In Fig. 1, an example of these data sets is shown (Fatemi 1996; Osborne *et al.* 1994). The straight line in Fig. 1 shows the intensity of diffuse γ rays produced in the galaxy versus column density of gas. The idea is that for evaluation of extragalactic fluxes in the presence of a galactic component, the flux must be determined as a function of a parameter, hopefully proportional to the galactic component and extrapolated to the zero of this parameter.

The points with error bars show the total diffuse gamma ray observed by EGRET (Experimental data from CGRO). At $N_H = 0$ (where it shows the galactic edge) determining the intercept gives a parameter I_0 which is equal to $I_0 = I_{\mathrm{EG}} + I_{\mathrm{IC}}$, where I_{EG} and I_{IC} are referred to as extragalactic and inverse Compton components. Such a procedure was first used in the early analysis of SAS II data (Fichtel *et al.* 1978).

In fact $I_\gamma = N_H \cdot \varepsilon_\gamma$, where emissivity or ε_γ is a function of E_γ. For galactic latitudes above 10° the plots were produced for EGRET energy ranges, assuming the emissivity is constant for each energy range. This interpretation leads to the straight line in Fig. 1. A good reason to use this approximation is that the diffuse emission is dominated by the contribution of nuclear interactions and Bremsstrahlung. Both are proportional to the product of the matter density and cosmic ray flux of nuclei and electrons, respectively. In the energy range of EGRET the contribution of IC is considered as a small correction. This approximation has also been used to determine the mass of the interstellar medium (Lequeux 2005).

It must also be considered that this standard procedure is "somewhat" inaccurate when used to calculate the extragalactic gamma ray flux (Smialkowski *et al.* 1997).

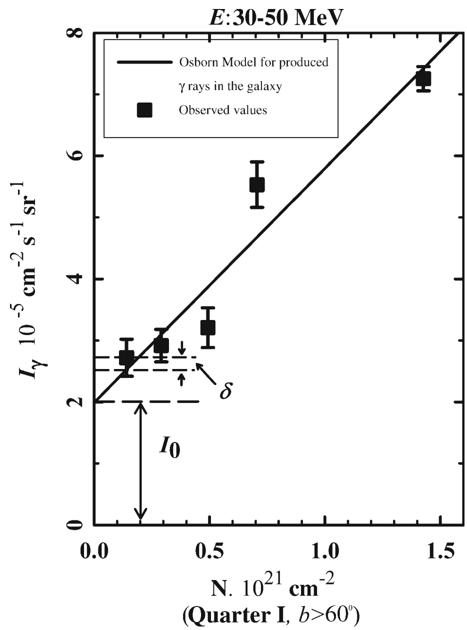

Figure 1. γ ray intensity versus column density of gas. Quarter I, $b > 60°$, E: 30–50 MeV. For each energy range, δ_i shows the extragalactic excess of diffuse gamma rays and $I_{0i} = I_{EG}+ I_{IC}$ relevant quantity for that energy range and quadrant (explained in the text). (Experimental data from CGRO http://cossc.gsfc.nasa.gov/cossc.html; Osborne *et al.* (1994) and Fatemi (1996).)

To avoid the difficulties arising from this procedure, we introduced a parameter δ which shows the extragalactic excess of diffuse γ rays (or the difference between the total observed γ ray and its relevant galactic intensity). By using similar plots, one can get all these values for all energy ranges in all quadrants. Using this procedure we estimated the excess in different quadrants. In doing so we assumed that IC component is homogenous and isotropic in different quadrants near the galactic poles, for $b > 60°$ and $b < -60°$. Smialkowski *et al.* (1997) have mentioned about the possibility of IC anisotropy from northern and southern hemispheres which however does not affect our calculations since we assume that the IC component of each quadrant is equal.

First we will consider the method used to calculate the γ ray excess from the Virgo cluster. As the Virgo cluster is spread over the 3rd and 4th galactic quadrants, we use a parameter, Δ, $\Delta = \delta_3 + \delta_4 - \delta_1 - \delta_2$, which shows the total extragalactic excess over the 3rd and 4th quadrants of the northern galactic pole. Each δ_i represents the extragalactic excess of the relevant quadrant.

The parameter I_0 has been calculated for each quadrant as I_{01}, I_{02}, I_{03}, I_{04} and $I_{0,\text{ mean}} = (I_{01} + I_{02} + I_{03} + I_{04})\,/4$ shows the mean of $I_0 = I_{EG} + I_{IC}$. Here the values of Δ and $I_{0,\text{mean}}$ are calculated for 10 energy ranges and shown in Table 1. The errors are calculated using those estimated by Osborne *et al.* (1994), Fatemi (1996) and Smialkowski *et al.* (1997) to compute EGRET diffuse gamma ray flux. A sample of these errors is shown in Fig. 1. For example, for each energy range there is an error corresponding to its δ_i . These errors are used to calculate the total error considering the relation introduced for Δ in each table.

Table 1. Calculated parameters for different γ ray energy ranges and $b > 60°$. Similar parameters are derived for $b < -60°$.

E	Δ (10^{-5} cm^{-2} s^{-1} sr^{-1})	$I_{0,\mathrm{mean}}$ (10^{-5} cm^{-2} s^{-1} sr^{-1})	Quarter IV excess (Virgo direction) (cm^{-2} s^{-1} sr^{-1} eV^{-1})	Error (cm^{-2} s^{-1} sr^{-1} eV^{-1})
30–50 MeV	0.4933	2.4304	1.233e-13	1.836e-14
50–70 MeV	0.4904	1.3072	8.174e-14	1.872e-15
70–100 MeV	0.3390	0.8707	3.988e-14	1.616e-16
100–150 MeV	0.2257	0.6552	1.805e-14	4.275e-15
150–300 MeV	0.1948	0.6113	8.656e-15	8.985e-16
0.3–0.5 GeV	0.1311	0.2275	3.278e-15	4.748e-16
0.5–1.0 GeV	0.1024	0.1619	1.366e-15	9.760e-18
1.0–2.0 GeV	0.324e-1	0.731e-1	2.160e-16	2.424e-17
2.0–4.0 GeV	0.222e-1	0.586e-1	7.397e-17	5.787e-18
4 GeV < E	0.018e-1	0.173e-1	3.400e-19	2.226e-19

Table 2. Calculated parameters of extragalactic γ ray background for $b < -60°$.

E	Δ (10^{-5} cm^{-2} s^{-1} sr^{-1})	$I_{0,\mathrm{mean}}$ (10^{-5} cm^{-2} s^{-1} sr^{-1})	b < −60° excess (cm^{-2} s^{-1} sr^{-1} eV^{-1})	b < −60° error (cm^{-2} s^{-1} sr^{-1} eV^{-1})
30–50 MeV	0.1078	1.6677	−2.695e-14	1.743e-14
50–70 MeV	0.1462	1.1110	2.437e-14	6.417e-16
70–100 MeV	0.7210	0.7387	8.482e-15	4.865e-15
100–150 MeV	−0.211e-1	0.4157	−1.688e-15	3.560e-16
150–300 MeV	0.362e-1	0.3707	1.609e-15	6.089e-16
0.3–0.5 GeV	0.164e-2	0.1387	4.100e-16	2.125e-17
0.5–1.0 GeV	−0.610e-2	0.792e-1	−8.133e-17	5.333e-18
1.0–2.0 GeV	0.123e-1	0.325e-1	8.200e-17	1.667e-18
2.0–4.0 GeV	−0.750e-1	0.467e-1	−2.500e-17	1.090e-19
4.0 GeV < E	−0.210-2	0.160e-1	−4.038e-19	4.038e-19

In Table 2, Δ is the mean excess for $b < -60°, \Delta = (\delta_1 + \delta_2 + \delta_3 + \delta_4)/4$ and $I_{0,\text{mean}} = (I_{01} + I_{02} + I_{03} + I_{04})/4$. Using this definition for Δ is due to the consideration of this postulate that the superclusters in the southern hemisphere are more distant that we observe any diffuse gamma ray with that origin. I_{01} is the value of $I_0 = I_{EG} + I_{IC}$ for Quarter I, 30 MeV $< E <$ 50 MeV and $b < -60°$, δ_1 is the extragalactic excess of γ rays for Quarter I, 30 MeV $< E <$ 50 MeV and $b < -60°$, other values have similar meanings. However, in the above definition of Δ the IC component will not eliminate but this average value is sufficient for the plan, unless the calculated excess for the northern hemisphere be less than this value (which was higher).

As the two important superclusters (Virgo and Coma), which are candidates to produce diffuse high energy γ rays are located on $b > 60°$ (i.e., galactic latitude), in the last stage $b <$ –60° data are used as extragalactic background to see if the excess is considerable or not.

2.1 *The models*

Now we assume a predicted model for γ ray produced by Virgo cluster. Wdowczyk & Wolfendale (1990a) developed the model of Giler *et al.* (1980) where a significant fraction of extragalactic cosmic rays come from Virgo. They calculated the γ ray intensity at 10^{14} eV with respect to the angular deviation from the direction of Virgo, with the diffusion coefficient

$$D = 10^{35} E_{20}\,\text{cm}^2\,\text{s}^{-1} \tag{1}$$

named as A-Model and

$$D = 10^{34} E_{20}^{1/2}\,\text{cm}^2\,\text{s}^{-1} \tag{2}$$

as B-Model (E_{20} unit, 10^{20} eV). They assumed that other clusters emit radiation at the same level as Virgo.

To compare with theoretical models, the expected spectrum for Virgo at energy 10^{14} eV was also converted to integral (approximate integral of γ ray intensity for 0–30 degree from Virgo direction (Wdowczyk & Wolfendale 1990a)). This value was extrapolated to a lower energy assuming non cosmological model of γ ray energy spectrum (no drastic change in extragalactic proton spectrum with energy) (Wdowczyk & Wolfendale 1990b) so that the predicted γ ray intensity from Virgo is calculated.

Comparing background (Table 2) with the observed flux (Table 1) shows a considerable excess in the Virgo direction, comparable with A-Model as mentioned before by Fatemi (1996), so we used A-Model as the accepted model for computing the flux produced by Virgo. (Fig. 2)

There are a few points about choosing model A. The two models A and B are different in their diffusion coefficients (formula (1) and (2)). Giler *et al.* (1980) mentioned that the scale of intracluster magnetic field irregularities is in the range of 0.1–1 Mpc and D is proportional to momentum or energy in the power range of 0.5 to 1.5. Wdowczyk & Wolfendale (1990a) mentioned that the value of λ (the mean free path for scattering, i.e., $D = \frac{1}{3}\lambda$) for the supercluster space in Virgo will be considerably greater than the cell size in Coma because of the lower gas density, greater separation of galaxies and generally lower degree of disturbance. They mentioned

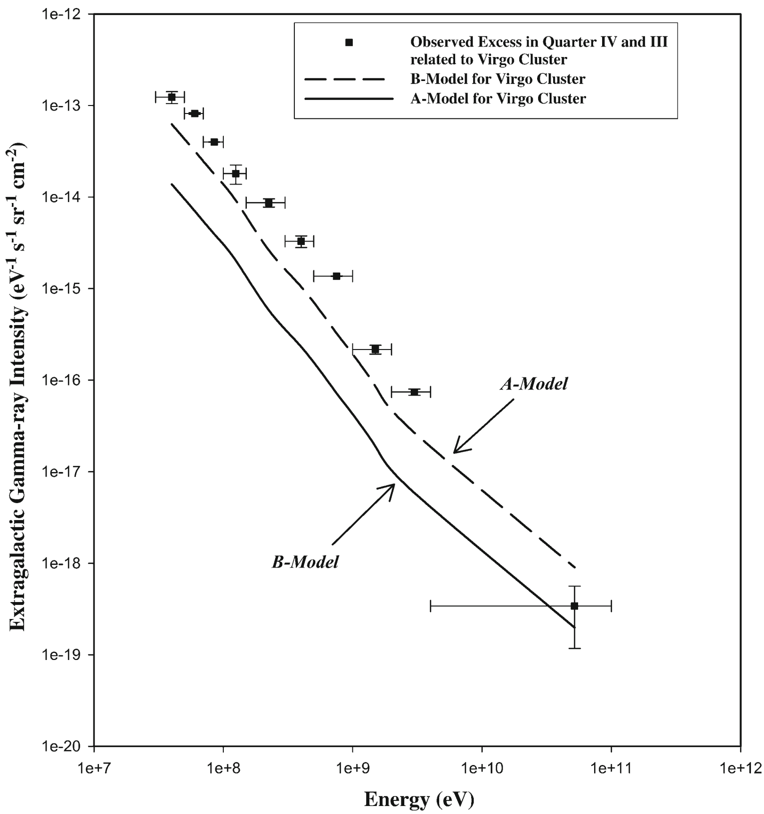

Figure 2. Extragalactic γ ray excess observed in Quarter IV plus III, $b > 60°$, compared with A and B models for Virgo cluster (Wdowczyk & Wolfendale 1990a).

that a value of λ_{max} of order 1 Mpc is indicated. They showed that this corresponds to $D = \frac{1}{3}\lambda C \approx 3 \times 10^{34}\,\mathrm{cm^2\,s^{-1}}$ and case A is nearest to being acceptable as $D_L = \frac{1}{3}\lambda_L C = 10^{35} E_{20}$ which is more acceptable. On the other hand, Fig. 2 shows that the calculated values using model A is also closer to EGRET results.

2.2 *Calculating Coma supercluster parameters*

Now we can compute similar parameters (as in Tables 1 and 2) for Coma supercluster.

In Table 3, Δ, the excess corresponds with the energy bands of the 3rd quadrant, which is: $\Delta = \delta_3 - (\delta_1 + \delta_2)/2$. Again we used the definition so that the effect of IC component is eliminated. $I_{0,\mathrm{mean}}$ is equal to $I_{0,\mathrm{mean}} = (I_{01} + I_{02} + I_{03})/3$. The fact that we have not considered the 4th quadrant data will not affect our results since we assume that the IC components of each quadrant are equal as mentioned before.

By Virgo, in the fourth and third quarters and Coma supercluster in the third quarter, it is necessary to assume that one of them is the stronger extragalactic γ ray source.

Table 3. The 3rd quadrant excess, Virgo excess in Quarter III and the Coma direction excess. Coma direction excess is equal to Quarter III excess – Virgo excess in Quarter III.

E	Δ (10^{-5} cm^{-2} s^{-1} sr^{-1})	$I_{0,\mathrm{mean}}$ (10^{-5} cm^{-2} s^{-1} sr^{-1})	Quarter III excess (cm^{-2} s^{-1} sr^{-1} eV^{-1})	Virgo excess in Quarter III (cm^{-2} s^{-1} sr^{-1} eV^{-1})	Coma direction excess (cm^{-2} s^{-1} sr^{-1} eV^{-1})
30–50 MeV	0.1143	2.4842	(2.858 ±0.224)e-14	1.591e-14	(1.267 ± 0.224)e-14
50–70 MeV	0.1500	1.3119	(2.500 ± 0.091)e-14	6.255e-15	(1.874 ± 0.091)e-14
70–100 MeV	0.1143	0.9042	(1.345 ± 0.128)e-14	3.802e-15	(9.648 ± 1.282)e-15
100–150 MeV	0.8335e-1	0.6828	(6.672 ± 0.556)e-15	1.802e-15	(4.870 ± 0.556)e-15
150–300 MeV	0.7995e-1	0.6728	(3.556 ± 0.853)e-15	8.023e-16	(2.754 ± 0.853)e-15
0.3–0.5 GeV	0.4310e-1	0.2613	(1.078 ± 0.039)e-15	2.964e-16	(7.816 ± 0.387)e-16
0.5–1.0 GeV	0.3245e-1	0.1881	(4.333 ± 0.327)e-16	8.023e-17	(3.531 ± 0.327)e-16
1.0–2.0 GeV	0.4550e-2	0.814e-1	(3.067 ± 1.000)e-17	2.041e-17	(1.026 ± 1.000)e-17
2.0–4.0 GeV	0.6950e-2	0.602e-1	(2.333 ± 0.333)e-17	5.523e-18	(1.781 ± 0.333)e-17
4.0 GeV $< E$	0.1395e-1	0.171e-1	(2.697 ± 0.029)e-18	3.026e-20	(2.662 ± 0.029)e-18

It is assumed here that Virgo produces all observed diffuse γ ray in the fourth quarter and also produces a part of the observed γ ray in the third quarter.

As we noted before, Coma supercluster is located at the third quarter as well as Virgo, so observed diffuse γ ray excess in the third quarter resulted from both Virgo and Coma supercluster.

To estimate the possible γ ray excess from Virgo in the third quarter, first the predicted intensity from Virgo models has been calculated as described earlier in section 2.1, and then we chose A-Model for our computations.

Subtracting the predicted Virgo intensity from the total γ ray excess of quarter 3, the diffuse γ ray excess in the Coma direction (mentioned in Table 3 as Quarter III excess) is obtained. Compared to the background (Table 2), the resulted excess is considerable enough.

In Fig. 3 the total observed extragalactic excess in quadrant 3, the produced Virgo intensity from A-Model (in quadrant 3) and calculated Coma supercluster excess are shown. Also we have compared our results with a theoretical model by Kuo *et al.* (2004).

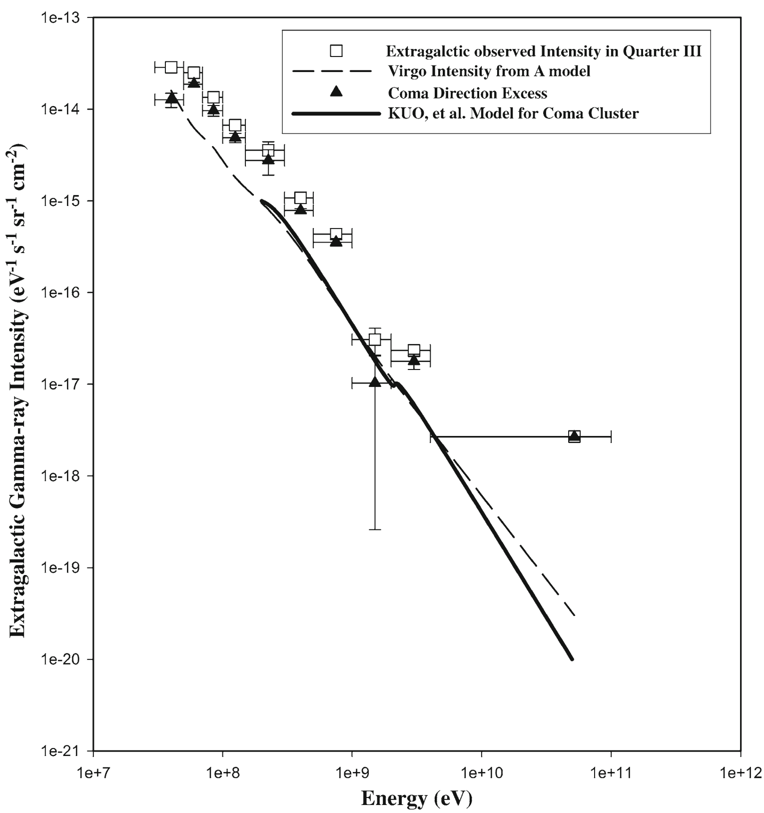

Figure 3. Computed γ ray excess in Quarter III, computed γ ray flux from A-model for Virgo in Quarter III and resulted diffuse γ ray excess in Coma supercluster direction. The results are also compared with a model presented by Kuo *et al.* (2004) for Coma cluster.

3. Discussion

Houston & Wolfendale (1984) did a review on γ rays from galaxy clusters; they claimed that a significant γ ray signal from galaxy clusters from a distance of about 590 Mpc is detectable. They also mentioned that the intensity of extragalactic gamma rays above 35 MeV is approximately 5×10^{-5} cm^{-2} s^{-1} sr^{-1}, so the contribution of galaxy clusters in the extragalactic gamma ray flux is important.

Dar & Shaviv (1995) and Dermer & Rephaeli (1988) have predicted γ ray fluxes for $E_\gamma > 100$ MeV from Coma supercluster up to about 10^{-7} cm^{-2} s^{-1} sr^{-1}, which is lower than our result (for $E > 100\,\text{MeV} \sim 1.0 \times 10^{-6}\,\text{cm}^{-2}\,\text{s}^{-1}\text{sr}^{-1}$).

Dar & Shaviv (1995), Dermer & Rephaeli (1988) and Dar (2007) have assumed a power-law spectrum for γ rays from extragalactic sources and concluded a power-law index between 1.4 and 3 with values between 1.8 and 2 being the most common.

Scharf & Mukherjee (2002) used data obtained by the Compton γ ray observatory spacecraft. They found a "fog" of γ rays associated to the galaxy clusters. They also mentioned that the majority of γ rays outside our galaxy are probably emitted by galaxy clusters and other massive structures which are the origin of the universe's diffuse γ ray background.

Our computation shows that the Coma supercluster γ ray intensity for $E >$ 30 MeV is

$$I\,(E > 30\text{ MeV}) \simeq 1.9 \times 10^{-6}\text{cm}^{-2}\text{s}^{-1}. \tag{3}$$

The total observed excess in quarter III is

$$I_{\text{total}}\,(E > 30\text{ MeV}) \simeq 8.3 \times 10^{-6}\text{cm}^{-2}\text{s}^{-1}. \tag{4}$$

The result is such that about $\sim 22.9\%$ of the total observed flux (in quarter III) comes from Coma direction. If we assume a power-law form ($I\,(E) \propto E^{-\gamma}$) for Coma intensity and assume that Coma is the source of these γ rays, then

$$\gamma = 1.8 \pm 0.4 \tag{5}$$

is resulted for Coma direction which is in the range of the predicted values (Dar & Shaviv 1995; Dermer & Rephaeli 1988).

4. Conclusion

The observed energy spectrum of Coma cluster is shown in Fig. 3. Its γ ray intensity on average is calculated to be $\sim 5\%$ of the actual diffuse extragalactic background ($\sim 10^6 E_\gamma^{-2.11}$ cm^{-2} s^{-1} sr^{-1} GeV^{-1}) (Osborne *et al.* 1994). Some discrepancy with the predicted models especially at lower energies could be due to uncertainty of the parameters chosen in the predicted models (i.e., magnetic field of extragalactic space and its scale of irregularities, diffusion coefficient and the other cluster parameters as the local cluster density). However it must be mentioned that as shown in Fig. 3, for Coma supercluster the diffuse gamma ray values are higher than that predicted by Kuo *et al.* (2004) as it also contains the rich cluster of A1367. Our result can be treated as an upper limit for diffuse gamma ray excess in the Coma supercluster direction.

In conclusion, there is considerable experimental evidence in favour of Virgo and Coma supercluster model for the origin of ultra high energy cosmic rays.

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