Perspective of Galactic dark matter subhalo detection on Fermi from the EGRET observation*

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Abstract The perspective of the detectability of Galactic dark matter subhaloes on the Fermi satellite is investigated in this work. Under the assumptions that dark matter annihilation accounts for the "GeV excess" of the Galactic diffuse γ-rays discovered by EGRET and the γ-ray flux is dominated by the contribution from subhaloes of dark matter, we calculate the expected number of dark matter subhaloes that Fermi may detect. We show that Fermi may detect a few tens to several hundred subhaloes in a 1-year all-sky survey. Since EGRET observation is taken as a normalization, this prediction is independent of the particle physics property of dark matter. The uncertainties of the prediction are discussed in detail. We find that the major uncertainty comes from the mass function of subhaloes, i.e., whether the subhaloes are "point like" (high-mass rich) or "diffuse like" (low-mass rich). Other uncertainties like the background estimation and the observational errors will contribute a factor of 2—3.

Key words dark matter, substructures, gamma-rays, Fermi telescope

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1 Introduction

The dark matter (DM) problem is one of the most important issues in modern physics and cosmology. Unfortunately, more than seventy years after the discovery of DM, the nature of the DM particle is still unclear. To identify the DM particles, it is necessary to "see" them in particle physics experiments beyond the gravitational measurements. There are usually three types of experiments suggested to capture the DM particles. The first one is to produce DM particle pairs by high energy particle collision at colliders such as the forthcoming Large Hadron Collider (LHC, [1—4]). The second method is the so-called direct search for DM particles by looking for the signals produced by DM scattering off the detector nuclei[5—8], which is thought to be the most direct way to show the existence and understand the properties of DM particles. Finally the indirect search for DM annihilation products in cosmic rays (CRs), including γ-rays[9—12], anti-particles[13—15] and neutrinos[16—19], is also an important complementary method for DM searches.

Among the annihilation products, γ-rays are the most attractive for detection. Compared with neutrinos, γ-rays are easier to record; while compared with charged anti-particles, γ-rays will not be deflected by the magnetic field and can trace back to the sites where the annihilation takes place. In this work we focus on the γ-rays from DM annihilation.

It is known that DM annihilation products are proportional to the density square of DM distributions. Therefore the highly concentrated regions are good sites for DM searches. Theoretically there are many such sites proposed to search for DM, such as the Galactic center (e.g., [20—23]), DM substructures[24—28], dwarf galaxies[29—32], and mini-spikes[33—35]. It has been recognized that DM subhaloes have several advantages for DM searches when compared with other sites[25, 36]. Firstly, the subhaloes distribute isotropically in the Galactic halo, and can easily be located in a low background environment away from the Galactic plane. Secondly, the subhalo may well decouple from baryon matter and

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give clean DM signals. Thirdly, a large number of subhaloes makes it possible to do a statistical study. Therefore, drawing attention to the signals from DM subhaloes should be a very important aspect for DM indirect searches.

From the observational point of view, the Energetic Gamma Ray Experiment Telescope (EGRET) on board the satellite Compton Gamma Ray Observatory (CGRO) surveyed the high energy γ-ray sky in 30 MeV—30 GeV. EGRET discovered 271 γ-ray sources[37] and measured the all-sky diffuse γ-ray emission[38, 39]. Among the 271 sources of the third EGRET catalog, only 101 ones are identified as known sources. There are 48 additional sources that are suggested to be associated with possible counterparts. A substantial fraction with over 120 sources is still unidentified. The DM subhaloes are thought to be possibly composed of one population of such unidentified sources. However, analysis of the luminosity and spatial distributions shows that no more than ~ 20 sources can be attributed to DM clumps[40, 41], while for the Galactic diffuse γ-ray emission, the spectrum shows an "excess" at energy $\sim$GeV compared with that predicted by the conventional CR model[38]. An appealing interpretation of the "GeV excess" is DM annihilation[42—44]. By fitting the all-sky diffuse γ-ray distributions, de Boer et al. found that the all-sky spectra can be well reproduced by 50—70 GeV supersymmetric DM annihilation, with an isothermal halo distribution and two additional ring-like structures[42]. However, a "boost factor" of ~ 100 is needed to match the absolute fluxes. The "boost factor" is proposed to be able to come from the enhancement of annihilation rate by DM subhaloes. Bi et al. have constructed a realistic model to explain both the diffuse γ-ray spectra and the CR observations, taking into account the DM subhaloes from numerical simulations[45, 46]. It is found that a strongly clumpy DM profile is needed to give such a large "boost factor". In order to further test this scenario we have to turn to experiments with higher sensitivity, such as the newly launched Fermi satellite[1)], which will follow in the footsteps of CGRO-EGRET to explore the high energy γ-ray sky. The Fermi-LAT (Large Area Telescope) is a high quality instrument with larger field-of-view (~ 2.5 sr), wider energy bands (10 MeV—300 GeV) and higher sensitivity compared with EGRET. It will be able to improve the sensitivity of the indirect search for DM annihilation greatly.

Considering the advantages of detecting DM annihilation from the Galactic subhaloes, it is now one of the most prominent scientific goals to search for DM subhaloes by Fermi. The perspective of DM detection from subhaloes on the Fermi satellite has been discussed extensively in literature (e.g., [47—50]). Assuming a specific DM model, Baltz et al. claimed that for 5-year exposure Fermi might detect $\sim$10 DM satellites (subhaloes) with significance $> 5\sigma$[50]. Kuhlen et al. found that, based on the numerical simulation of DM distributions, the number of subhaloes Fermi might detect was from a few to several dozen depended on the subhalo boost factor and DM annihilation parameters[49]. Bertone et al. showed that DM annihilation around intermediate mass black holes (mini-spikes) might be a population of bright γ-ray sources of Fermi[33]. However, all of these kinds of studies depend sensitively on the particle physics model of DM particles and suffer large uncertainties.

In the present work we try to investigate the performance of DM subhalo detection on Fermi, under the assumptions that the EGRET "GeV excess" comes from DM annihilation and the DM induced γ-ray emission is dominated by that from the subhaloes. Since the EGRET observation of diffuse γ-rays is adopted as a normalization, this prediction is expected to get rid of the uncertainties from the annihilation cross section and γ-ray yield spectrum. The degeneracy between the normalization factor of DM subhaloes and the annihilation cross section is discussed. Furthermore we discuss the uncertainties of this prediction.

The outline of the paper is as follows. We first introduce the model of the DM annihilation scenario to explain the EGRET "GeV excess" in Sec. 2. In Sec. 3 we give the prediction of the detectable number of subhaloes on Fermi based on this model. The uncertainties of the prediction are carefully discussed in Sec. 4. Finally we give a conclusion and a discussion in Sec. 5.

2 The model to account for the EGRET observations

One way to explain the EGRET "GeV excess" is the DM annihilation scenario[42—44]. This scenario has been extended to be a more realistic one to explain both the diffuse γ-ray and CR observations[45, 46]. For convenience of discussion in this work, we use the model of Ref. [46], however, the conclusion will not be limited to this detailed model. In the model of Ref. [46], the background γ-rays are

1) http://glast.gsfc.nasa.gov/

calculated using the package GALPROP[51, 52]. The parameters of GALPROP are adjusted to reproduce the EGRET data and the CR observations, especially the antiproton data, after including the contribution from DM annihilation. In Fig. 1 we show the differences between the observational spectra by EGRET and the predicted background (including the extra-galactic component) at different sky regions. The six sky regions are defined following Ref. [53]: region A corresponds to the inner Galaxy with $0^\circ < l < 30^\circ$, $330^\circ < l < 360^\circ$ and $|b| < 5^\circ$; region B is the Galactic plane excluding region A with $30^\circ < l < 330^\circ$ and $|b| < 5^\circ$; C is the outer Galaxy with $90^\circ < l < 270^\circ$ and $|b| < 10^\circ$; regions D, E, F cover the medium and high latitudes at all longitudes with $10^\circ < |b| < 20^\circ$, $20^\circ < |b| < 60^\circ$ and $60^\circ < |b| < 90^\circ$ respectively. From the figure we notice that the differences of the spectra at different regions are very similar, which implies that there may be some common origins of the lacked γ-rays, for example DM annihilation[42—44].

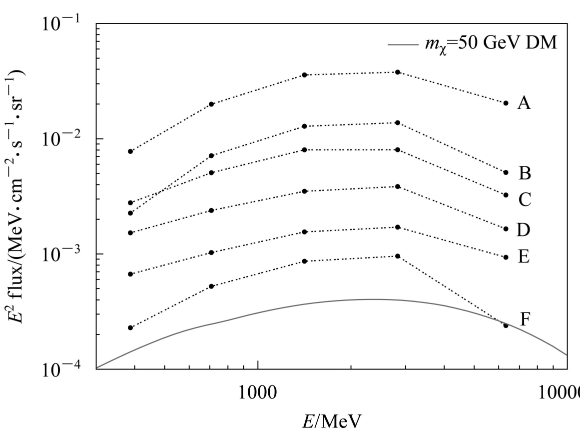

Fig. 1. The differences between the observational EGRET fluxes and the CR induced γ-rays predicted from GALPROP. Similar shapes of different sky regions indicate a common origin of the excess. The solid line shows the DM annihilation spectrum (with arbitrary normalization) for a neutralino with mass 50 GeV.

The diffuse γ-ray fluxes from DM annihilation are determined by two factors: the “particle factor” which describes the particle physics property of DM particles and the “astrophysics factor” which describes the spatial distribution of DM. In Ref. [46] the “particle factor” is calculated under the framework of the minimal supersymmetric extension of the standard model (MSSM[54]). The lightest particle neutralino in MSSM is adopted as the DM particle[1)]. The annihilation cross section and γ-ray production spectrum are calculated using DarkSUSY[2)], a package for MSSM DM calculation[55]. A random scan in the MSSM parameter space is performed and the adopted models are chosen to satisfy the relic density constraint and give large γ-ray fluxes. The annihilation spectrum for the neutralino with mass $m_\chi \approx$ 50 GeV, as shown in Fig. 1, is found to be in good agreement with the observations.

The “astrophysics factor” is mainly determined according to the numerical simulation of DM distribution. High resolution simulations show that a fraction of 10%—20% of the total mass survives in self-bound substructures[56—61]. The substructures of DM can effectively enhance the annihilation signals[24, 27]. The number density distribution of subhaloes from simulation can be fitted by an isothermal spatial distribution and a power-law mass function

$$\frac{\mathrm{d}N}{\mathrm{d}m_{\rm sub}\cdot 4\pi r^2\mathrm{d}r} = N_0\left(\frac{m_{\rm sub}}{M_{\rm vir}}\right)^{-\alpha}\frac{1}{1+(r/r_{\rm H})^2}\,, \quad (1)$$

where $M_{\rm vir}\approx 10^{12}$ M$_\odot$ is the virial mass of the Galaxy, $r_{\rm H} \approx 0.14 r_{\rm vir} = 29$ kpc is the core radius of the distribution of subhaloes[62], and N_0 is the normalization factor determined by the total mass of subhaloes. The slope α varies from 1.7 to 2.1 in various works[57, 58, 60, 63—65]. The intermediate value $\alpha \approx 1.9$ is favored by the recent highest resolution simulation Via Lactea[66]. In Ref. [46] $\alpha = 1.9$ is adopted. The masses of subhaloes range from the minimum $\sim 10^{-6}$ M$_\odot$ which is close to the free-streaming mass[61, 67, 68] to the maximum about $0.01 M_{\rm vir}$. The DM density distribution inside the subhalo follows a γ profile $\rho(r) = \dfrac{\rho_{\rm s}}{(r/r_{\rm s})^\gamma(1+r/r_{\rm s})^{3-\gamma}}$ with $\gamma = 1.7$, which is steeper in the center than the NFW type ($\propto r^{-1}$[69]) and Moore type ($\propto r^{-1.5}$[70]). A steeper inner slope for a small mass halo is suggested by numerical simulations[71, 72]. The profile parameters $r_{\rm s}$ and $\rho_{\rm s}$ are determined according to the halo mass $M_{\rm vir}$ and the concentration parameter $c_{\rm vir}$[73, 74]. The $c_{\rm vir}-M_{\rm vir}$ relation is adopted as the model of Bullock et al[73]. Finally the central density of a subhalo is truncated at a certain radius to avoid divergence. A characteristic radius $r_{\rm cut}$ is introduced within which the DM density is kept a constant $\rho_{\max}$ due to the balance between the annihilation rate and the in-falling rate of DM[75]. Typically we have $\rho_{\max} = 10^{18} \sim 10^{19}$ M$_\odot$ kpc^{-3}[76].

This configuration of DM distribution is then used to calculate the diffuse γ-ray emission. Tak-

1) However, it will be shown in the following that this assumption can be relaxed in the present work.

2) http://www.physto.se/ edsjo/darksusy/

ing $\rho_{\max} = 10^{19}$ $M_\odot$ kpc^{-3} and subhalo mass fraction 20%1) we find that the results can well reproduce the high latitude observations by EGRET (i.e., F region). It can be noted from Fig. 2 of Ref. [46] that for the direction far away from the Galactic center the contribution to γ-rays from subhaloes dominates that from the smooth halo. For example at the Galactic pole direction $b = \pm 90°$, the ratio of the astrophysics factors between the subhaloes and smooth halo is $f = \Phi_{\rm sub}/\Phi_{\rm sm} \approx 10^2$, which is consistent with the requirement of a boost factor ~ 100 of Ref. [42]. For other sky regions, especially for the Galactic plane regions, the enhancement of subhaloes is not enough, and two additional DM rings are needed[42]. The overall results including the DM rings are very consistent with the observations.

3 Detection performance of subhaloes on Fermi

In this section we calculate the γ-ray fluxes from massive DM subhaloes adopting the same DM model presented in Sec. 2 and discuss the detectability of these γ-ray sources on Fermi. The Monte-Carlo (MC) realization method is adopted to generate DM subhaloes with mass $\gtrsim 10^6 M_\odot$ in the Milky Way, following the distribution function Eq. (1). There are about 1.5×10^4 subhaloes found with mass heavier than $10^6 M_\odot$. In total 100 Milky Way like galaxies are generated. For each realization, we calculate the annihilation flux of each subhalo with energy threshold $E_{\rm th} = 100$ MeV and count the accumulative number as a function of the threshold flux Φ. The result is shown in Fig. 2.

The sensitivities of EGRET and Fermi for a 1-year all-sky survey at 5σ are 5×10^{-8} ph·cm^{-2}·s^{-1} (>100 MeV)[77] and $4{\times}10^{-9}$ ph·cm^{-2}·s^{-1} (>100 MeV) respectively2), which are shown by the vertical lines in Fig. 2. From the figure we find that the number of subhaloes that EGRET can detect is 18.7±4.4, which is consistent with the results of Refs. [40, 41]. For Fermi, the detectable number is 245.2±16.8, which is an order of magnitude more than EGRET. The scattering comes from different realizations. The probability distribution of the detectable numbers on Fermi is well fitted with a Gaussian distribution, as shown in the top-left panel of Fig. 3. We also plot the mass ($\log_{10}[m_{\rm sub}/M_\odot]$) distribution, the distance distribution and the directional skymap in Galactic coordinates of the detectable DM subhaloes on Fermi for one of the realizations in Fig. 3. It is shown that subhaloes with masses $\sim 10^8$ $M_\odot$ and distances within ~ 50 kpc are more likely to be detected by Fermi. The direction distribution is isotropic, which will be significantly different from other astrophysical populations of sources.

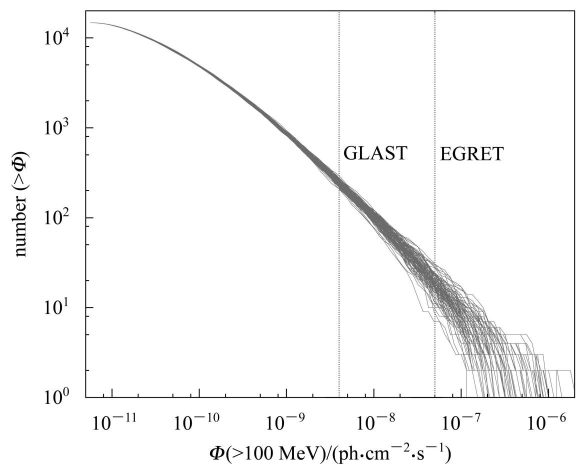

Fig. 2. The accumulative number of subhaloes as a function of integral flux for energy threshold $E_{\rm th}$ = 100 MeV. The two vertical lines show the sensitivities of EGRET and Fermi.

In Fig. 2 the threshold energy of the detector is adopted as 100 MeV. However, since the energy spectrum of DM annihilation is known, as shown in Fig. 1, the detector performance can be optimized by taking a proper energy cut. In Fig. 4 we show the ratio between the integral flux of DM annihilation spectrum and the integral sensitivity of Fermi. This will be more efficient for DM detection for larger ratios. It can be seen that for the energy threshold $E_{\rm th} \approx 1$ GeV, the detectability is most optimized. We show that for $E_{\rm th} = 1$ GeV the number of subhaloes that can be detected by Fermi is 620.4 ± 23.1. In the rest of this paper we will adopt the optimized threshold energy $E_{\rm th} = 1$ GeV for discussion.

4 Uncertainties

In the previous section, we showed our prediction of the detectable number of DM subhaloes on Fermi based on the EGRET observations of the Galactic diffuse γ-rays. It is about 250 (or 620 for an optimized energy cut) according to the model of Ref. [46]. In this section we discuss the possible uncertainties of this prediction.

1) Note that the parameter adoption is a bit different from Ref. [46], where $r_{\rm cut}$ instead of $\rho_{\max}$ is used.

2) http://www-Fermi.slac.stanford.edu/software/IS/glast_lat_performance.htm

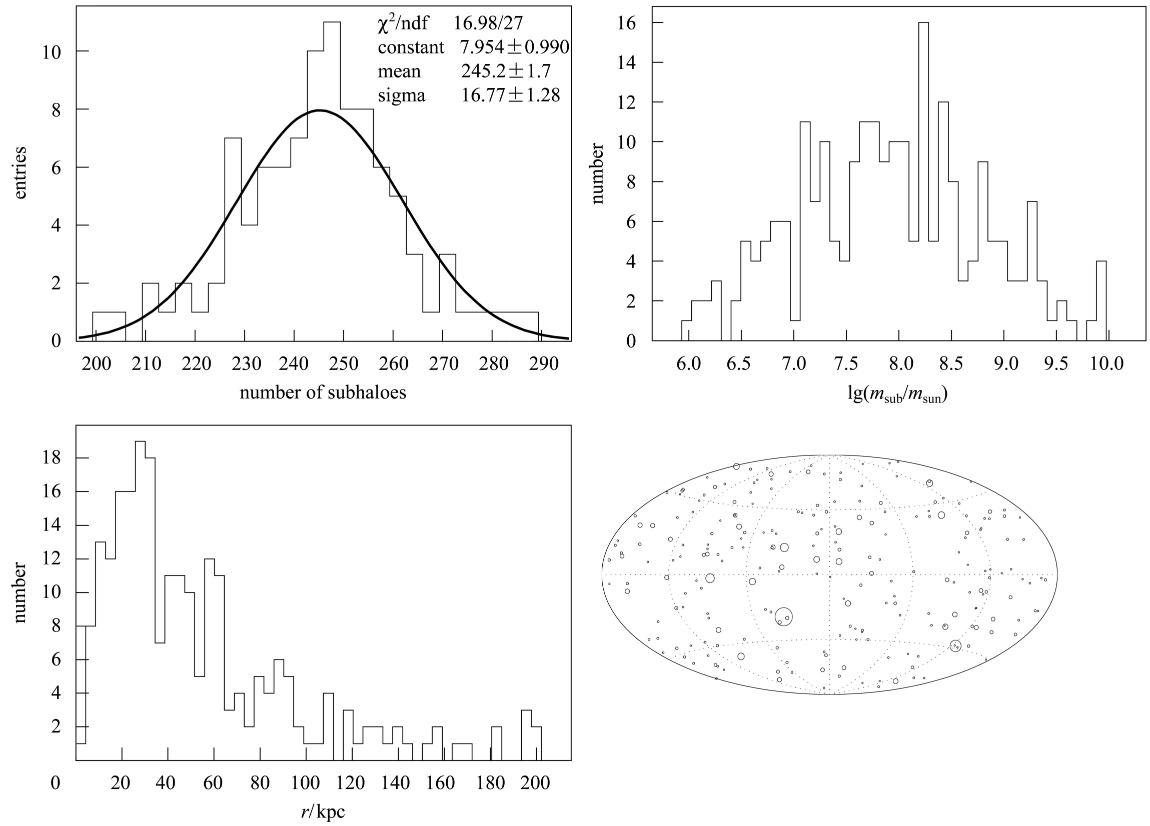

Fig. 3. Distributions of the detectable DM subhaloes on Fermi: detectable number distribution due to various realizations (top-left); mass (top-right), distance (bottom-left) distributions and skymap (bottom-right) of the detectable DM subhaloes in one realization. The area of the circle in the skymap is proportional to the flux.

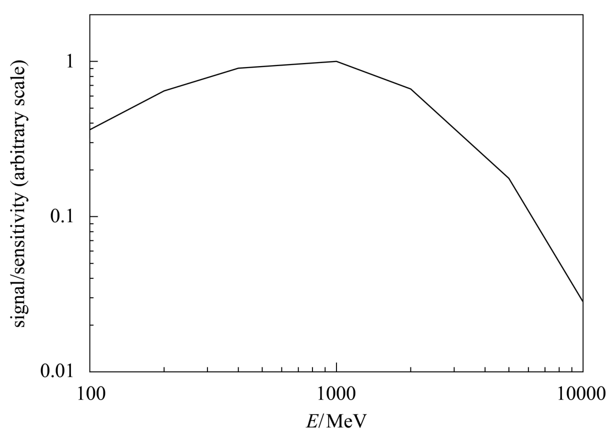

Fig. 4. Integral signal from DM annihilation to sensitivity of Fermi ratio as a function of threshold energy.

4.1 Particle factor

There are two quantities in the particle factor that affect the annihilation flux: the velocity weighted averaged cross section $\langle\sigma v\rangle$ and the γ-ray production spectrum per annihilation $\mathrm{d}N/\mathrm{d}E$. In Refs. [42, 46], the neutralino is adopted as the DM particle. $\langle\sigma v\rangle$ and $\mathrm{d}N/\mathrm{d}E$ are calculated under the MSSM model. However, from Fig. 1 it can be seen that the annihilation spectrum is fixed by the "gaps" between the observations and the background, and is independent of the DM particle models. We find that if we adopt a model independent spectrum by averaging the spectra of the 6 sky regions (normalized by the maximum value and extrapolated logarithmically to higher and lower energies) instead of the spectrum from neutralino annihilation, the results are almost the same.

The annihilation cross section $\langle\sigma v\rangle$ will affect the absolute flux of γ-rays. Since the absolute flux is determined by the EGRET observation, there is degeneracy between the cross section and the astrophysics factor. That is to say, a smaller cross section $\langle\sigma v\rangle$ needs to be compensated by a larger astrophysics factor. Therefore, if the total number of DM subhaloes stays the same, varying $\langle\sigma v\rangle$ is not expected to change the detectability of DM subhaloes significantly. We will show in the next section that even if the normalization of the total number changes, the conclusion still holds. However, it should be pointed out that if $\langle\sigma v\rangle$ is so large that the smooth contribution dominates the γ-ray emission from DM annihilation (i.e., $f = \Phi_{\rm sub}/\Phi_{\rm sm} \lesssim 1$), it will be more difficult to detect DM subhaloes.

4.2 Astrophysics factor

In the astrophysics factor, the normalization of the number of subhaloes, the mass function of subhalo number distribution, the inner profile of the DM subhalo and the concentration model may all lead to uncertainties of the predicted detectable number of subhaloes given in Sec. 3. We now investigate these issues one by one in detail.

The normalization of the total number of subhaloes, i.e., N_0 of Eq. (1), is determined by the mass fraction of clumps in the Galactic halo. It shows relatively large uncertainties in different simulations. However, we find that even though the factor N_0 is left free in the range of one or two orders of magnitude, the result of this work is still unchanged. The reason is that in order to keep the γ-ray emission of region F unchanged, varying N_0 by some factor needs to be compensated by the same factor of the annihilation flux of each subhalo (e.g., through the rescale of $\langle\sigma v\rangle$). From Fig. 2 we can see that the cumulative number $N(>\Phi) \propto \Phi^{-1}$, which means that a change in N_0 is equivalent to shifting the curves in Fig. 2 downward (or upward) while the change of $\langle\sigma v\rangle$ shifts the curves rightward (or leftward) by the same factor. Therefore the number of subhaloes with flux higher than the sensitivity of Fermi will remain the same.

The index of the mass function α in Eq. (1) will affect the mass distribution of subhaloes, and accordingly affect the $N(>\Phi) \sim \Phi$ relation. If α is smaller, the fraction of contribution to the diffuse γ-rays from high mass subhaloes becomes more important (see Fig. 4 of Ref. [76]), so we can expect that the subhaloes with higher fluxes are richer. The expected numbers of subhaloes on Fermi for energy threshold 1 GeV, for different α are listed in Table 1. For each case, we scale $\langle\sigma v\rangle$ to recover the EGRET observation at region F. The inner DM profile $\gamma = 1.7$, the central maximum density $\rho_{\rm max} = 10^{19}$ M$_\odot$ kpc^{-3} and subhalo mass fraction 20% are kept unchanged[1)]. It is shown that for different values of α the results differ from each other significantly. The parameter α determines the DM to be high mass rich ("point like") or low mass rich ("diffuse like"), which is the key factor for the detection of DM subhaloes. It should be noted that for the cases $\alpha = 1.7$ and 1.8, the most luminous DM subhalo is even brighter than the brightest unidentified EGRET source[37]. In order not to break the constraint from the EGRET source catalog we find $\alpha \gtrsim 1.9$. The index of the mass function of subhaloes α is actually the most important source of the uncertainties when predicting the detectability of DM annihilation from subhaloes.

Table 1. Detectable number of DM subhaloes on Fermi for energy threshold 1 GeV.

α	1.7	1.8	1.9	2.0	2.1
number	4068 ± 32.8	2147 ± 40	620.4 ± 23.1	110.9 ± 10.5	13.6 ± 3.6

The inner slope of a DM subhalo can also result in slightly different mass dependence of the annihilation flux, which may also change the detection performance of subhaloes on Fermi. This effect is not very important. We show that for a Moore profile, $N_{\rm det} = 410.8 \pm 20.0$, and for an NFW profile, $N_{\rm det} = 441.4 \pm 20.3$. From Fig. 3 of Ref. [27] we can see that for a $\gamma = 1.7$ profile the fraction of DM annihilation luminosity from high mass subhaloes is more important than that of Moore or NFW profiles. Therefore the detectable number 620.4 ± 23.1 for a $\gamma = 1.7$ profile (i.e., the benchmark model in this work), is slightly larger than that of NFW or Moore.

Finally, the concentration model adopted in Ref. [46] is from Ref. [73]. At present there is no good determination for the subhalo concentration, especially for the low mass haloes which are beyond the resolution of simulations. As a comparison, using another concentration model of Eke et al.[78] we find $N_{\rm det} = 794.6 \pm 26.3$. The model of Eke et al.[78] gives a larger concentration (and accordingly a larger annihilation flux) of heavier haloes, resulting in a more detectable number of subhaloes.

4.3 Background estimation

The background γ-ray emission from CRs is calculated based on the conventional CR propagation model. A discussion of the uncertainty of the background calculation is very complicated due to the uncertainties of the inputs, including gas distribution in the Galaxy, interstellar radiation field, nuclear intera-

1)The same treatment is also employed in the following discussion, i.e., we rescale $\langle\sigma v\rangle$ to cancel the effect by the relevant changes and keep other settings unchanged as in the benchmark model presented in Sec. 2.

ction cross section, CR measurements, CR source distribution, solar modulation and so on[53]. However, many of these factors are degenerated. For example, a lower gas density can be compensated by a higher CR source normalization. According to the CR and diffuse γ-ray measurements, the uncertainty of the estimation of γ-ray background can be limited to a few tens percent. Here we adopt a rough estimation of about 20%—30% uncertainty on background γ-rays based on the model fitting of propagation parameters using B/C ratio data[79]. If we change the background intensity by $\pm25\%$, the corresponding DM contribution will change by $\sim\pm50\%$ to compensate for this variation. The detectable number of DM subhaloes will also change by $\pm50\%$.

4.4 Observational uncertainties

The systematic errors of EGRET are estimated as $\sim$ 15%. If the statistical errors of the photon counts are taken into account the errors are larger. It is shown that even if the DM contribution varies $\pm50\%$, the total γ-ray emission is still consistent with EGRET observation in the 1σ level. This will correspond to $\sim 50\%$ uncertainty of the detectable number of DM subhaloes.

5 Conclusion and discussion

In this work we study the detection performance of DM subhaloes on Fermi under the assumption that the "GeV excess" discovered by EGRET comes from the DM annihilation. Considering that EGRET is the precursor of Fermi, it is quite natural to predict the perspective of Fermi based on the EGRET results. An additional assumption is that the excess part of diffuse γ-rays at high Galactic latitude is dominated by the contribution from DM subhaloes, i.e., DM subhaloes give a large boost factor. Then the EGRET observation is used as a normalization and we get the detection perspective of DM subhaloes on Fermi. We find the possible detectable number of DM subhaloes is from a few tens to several hundred after 1-year operation of Fermi. For the favored value of the mass function slope of DM subhaloes $\alpha \approx 1.9$ from recent highest resolution numerical simulation, there will be several hundred subhaloes that can be seen.

This prediction has relatively large uncertainties. A major uncertainty comes from the mass function of DM subhaloes, which is not well determined by numerical simulations. The mass function determines the ratio of γ-ray fluxes between low mass subhaloes and high mass ones. If the mass function is steep, i.e., low mass subhaloes dominate the γ-ray emission, then the γ-ray sky will be more "diffuse like" and the detectable number of DM point sources decreases. Otherwise more DM subhaloes can be detected. Our result shows that according to the current knowledge about the mass function from numerical simulations the detectable number can vary by orders of magnitude. Other uncertainties from the inner properties of DM subhaloes, background estimation and the observational errors will in total contribute a factor of 2—3. Unlike from previous studies on the DM indirect search, our result is independent of the particle physics property of DM particles.

In spite of the large uncertainties, our result shows that searching for DM subhaloes may be a promising way for the indirect search of DM on Fermi. It is believed that Fermi will open a new era in DM study and greatly enrich our knowledge about DM.

Finally we point out that this prediction is based on the assumption that the EGRET "GeV excess" completely comes from DM annihilation. If the CR processes contribute a fraction or the whole of the "GeV excess" as proposed in Ref. [53], or the "GeV excess" is due to the wrong sensitivity estimation of the detector of EGRET as pointed out in Ref. [80], the detectability of DM subhaloes on Fermi will not be as promising as we have discussed. The prediction becomes especially difficult due to the large uncertainties from particle physics and the distribution of DM.

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