The detection of dark matter has made great progresses in recent years. We give a brief review on the status and progress in dark matter detection, including the progresses in direct detection, collider detection at LHC and focus on the indirect detection. The results from PAMELA, ATIC, Fermi-LAT and relevant studies on these results are introduced. Then we give the progress on indirect detection of gamma rays from Fermi-LAT and ground based Cerenkov telescopes. Finally the detection of neutrinos and constraints on the nature of dark matter are reviewed briefly.

**Keywords** dark matter, annihilation, cosmic rays, gamma rays

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## Contents

1 Introduction 794
   1.1 Astronomical evidence 794
   1.2 Detection methods 795
2 Status of direct detection 796
   2.1 Recoil event rate 796
   2.2 Experimental results 796
3 Status of collider detection 797
   3.1 Direct production 798
   3.2 Indirect production 799
4 Status of indirect detection-charged particles 800
   4.1 Introduction 800
   4.2 Experimental status 800
   4.3 Explanations 802
      4.3.1 Astrophysics origins 802
      4.3.2 Dark matter 803
   4.4 Mechanisms to enhance DM annihilation rate 804
      4.4.1 Substructures 804
      4.4.2 Non-thermal DM 805
      4.4.3 Breit–Wigner enhancement 805
      4.4.4 Sommerfeld enhancement 806
      4.4.5 Decaying dark matter 806
   4.5 Discrimination between astrophysical and dark matter scenarios 806
5 Status of indirect detection-gamma rays 809
   5.1 Fermi 809
      5.1.1 Dwarf galaxies 809
5.1.2 Galaxy clusters 810
   5.1.3 Star clusters 810
   5.1.4 Galactic center 811
   5.1.5 Milky Way halo and subhalos 811
   5.1.6 Extragalactic gamma-ray background 812
   5.1.7 Line emission 813
5.2 Ground based telescopes 815
6 Status of indirect detection – neutrinos 815
   6.1 High energy neutrino telescopes 815
   6.2 Solar neutrinos from DM 816
   6.3 Cosmic neutrinos from DM 817
5.1.2 Galaxy clusters 810
6 Summary 818
Acknowledgements 818
References and notes 818

## 1 Introduction

### 1.1 Astronomical evidence

The standard cosmology is established in the last decade, thanks to the precise cosmological measurements, such as the cosmic microwave background (CMB) radiation measured by WMAP [1, 2], the distance-redshift relation of the Type Ia supernovae [3–5] and the large scale structure (LSS) survey from SDSS [6, 7] and 6df [8]. The energy budget in the standard cosmology consists of 4% baryonic matter, 23% dark matter (DM) and 73% dark energy (DE) [9, 10]. To unveil the mystery of the dark
side of the Universe is a fundamental problem of modern cosmology and physics. In this review we focus on the progress in DM detection.

Actually the existence of DM has been established for a much longer time. The most direct way that indicates the existence of DM is from the rotation curve of spiral galaxies [11]. The rotation curve shows the rotation velocity of an object around the galaxy center as a function of radius $r$, which scales like $\sqrt{M(r)/r}$ with $M(r)$ the mass within the orbit $r$. The rotation curve should decrease as $1/\sqrt{r}$ if $r$ is beyond most of the visible part of the galaxy. However, most measured rotation curves keep flat at large distances. The large rotation velocity implies a dark halo around the galaxy to provide larger centripetal force that exerts on the object.

At the scale of galaxy clusters, evidence of DM is also ample. The first evidence of DM was from the observation of the Coma cluster by Zwicky in 1930s [12]. He found unexpected large velocity dispersion of the member galaxies, which implied the existence of “missing mass” to hold the galaxies [12]. The observation of X-ray emission of hot gas in the clusters can give precise measurement of the gravitational potential felt by the gas to keep the hot gas in hydrostatic equilibrium. Other measurement of weak lensing effect on the background galaxies by the clusters gives direct indication of DM component in clusters. Especially the bullet cluster gives strong support to the DM component in cluster. The Bullet cluster consists of two colliding galaxy clusters. The X-ray image, which reflects the gas component of the colliding system, shows obvious lag compared with the gravitational lensing image, which traces the mass distribution [13]. It is easy to understand that the gas is decelerated due to the viscosity, while the DM component can pass through each other without collision. The Bullet cluster was regarded as the most direct evidence of DM.

The existence of DM in the cosmological scale is inferred by a global fit to the CMB, supernovae and LSS data. The WMAP data give the most accurate determination of the DM component in the universe with $\Omega_{\text{CDM}} h^2 = 0.112 \pm 0.006$ [9], with $h$ the Hubble constant in unit of 100 km-s$^{-1}$-Mpc$^{-1}$.

### 1.2 Detection methods

All the current evidence of DM comes from the gravitational effect by DM. From the point of view that all the matter in the universe comes from a big-bang a sole DM component with only gravitational interaction is hard to properly account for the observed DM. A popular DM candidate is the weakly interacting massive particle (WIMP). In such scenario the WIMPs can reach thermal equilibrium in the early universe and decouple from the thermal equilibrium when the temperature decreases. The relic density of WIMPs can be calculated by solving the Boltzmann equation. A good approximate solution of the Boltzmann equation gives

$$\Omega_{\text{DM}} h^2 \sim \frac{3 \times 10^{-27} \text{cm}^3 \cdot \text{s}^{-1}}{\langle \sigma v \rangle}$$

where $\Omega_{\text{DM}} = \rho_{\text{DM}}/\rho_0$ is the DM density over the critical density, $h$ is the Hubble constant, $\langle \sigma v \rangle$ is the thermal averaged DM annihilation cross section times velocity. We often refer $\langle \sigma v \rangle$ as the DM annihilation cross section. It represents the interaction strength of the DM particles and the standard model (SM) particles. $\langle \sigma v \rangle = 3 \times 10^{-26} \text{cm}^3 \cdot \text{s}^{-1}$ gives the correct relic density and is often taken as the benchmark value for the DM annihilation cross section. It is found a WIMP with mass and interaction strength at the weak scale can easily give correct relic density. If such a scenario is confirmed, it will become the third evidence supporting the hot big bang cosmology after CMB and the big bang nucleosynthesis. Probing such a decoupling process enables us to study the universe as early as its temperature was $\sim$GeV. It has become a fundamental problem to detect the DM particles and determine its nature in cosmology and particle physics. WIMPs, interacting weakly with the SM particles, make it possible to detect the DM in experiments. A great deal of WIMP candidates have been proposed, such as the lightest neutralino in the supersymmetric (SUSY) model and the lightest Kaluza-Klein particle in the Universal extra dimension model (for a review see Ref. [14]).

Figure 1 shows the scheme to probe the DM particles. To determine the nature of DM particles we have...