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WIMPs Search require new track

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Abstract: *Weakly interacting massive particles (WIMPs) are believe to be most promising dark matter candidates by various groups of theorists and experimentalists working in the field. Search for dark matter become debatable as till today no direct evidence is available of any dark matter candidate from various group. Recent investigations of Large Underground Xenon (LUX) experiment and Particle and Astrophysical Xenon Detector-II (PandaX-II) got null result though LUX and PandaX-II experiments are sensitive to a wide range of WIMP candidates from approximately 5–1000 GeV/c^2 [1,2]. In the present paper a brief investigation of reasons of not detecting Wimps at any experiment is presented. The analysis will help the experimentalist and theorists to make necessary up gradation in their work in designing the advance detectors of Wimps search.*
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I. Introduction

The search of dark matter candidates in the detectors as well as at universe reaches to the level where strong concrete evidences only can reveal the mystery behind structure of universe, where it is believed that 24% of matter is dark matter. There are many models and candidates proposed by many investigators and in these models Weakly Interacting Massive Particles (WIMPs) are accepted as major contributors and promising candidates to the dark matter. But in recent investigations [1,2] the null result create worry in the community that either something goes wrong with the theory or with the experimental investigation. In this paper we are investigating the possible reasons behind negative results of these recent experimental outcomes.

Friedmann Equation : By cosmological principle Universe is homogeneous and isotropic on large scales (for example about 1Gpc). The most general metric satisfying the cosmological principle is the Friedmann-Robertson-Walker metric [3,4].

$$ds^2 = dt^2 - at^2\left[\frac{dr^2}{1-kr^2} - r^2(d\theta^2 + sin\theta d\phi^2)\right]$$

In modern cosmology the flat, open or closed structure of the universe is expressed by simple equation and called Friedmann universe.

$$H(t)^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{R^2} + \frac{\Lambda}{3}$$

or

$$H(t)^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{k}{a^2} + \frac{\Lambda}{3}$$

where H= Hubble constant, ρ=matter density of the Universe, c= speed of light, k= curvature of Universe, G= Gravitational constant, Λ = cosmological constant and R= radius of the Universe. In this equation, `R' represents the scale factor of the Universe (think of it as the radius of the Universe in 4D spacetime), and H is Hubble's constant, how fast the Universe is expanding. Everything in this equation is a constant, i.e. to be determined from observations. These observables can be broken down into three parts gravity (matter density), curvature and pressure or negative energy given by the cosmological constant. In above equation first term represent matter density, second represent curvature of universe and and third term in equation is standing for the dark energy. It was considered in earlier investigation that only gravity play a major role in the universe hence the cosmological constant is zero. Thus, if we measure the density of matter, then we could extract the curvature of the Universe (and its future history) as a solution to the equation. New data has indicated that a negative pressure, or dark energy, does exist and we no longer assume that the cosmological constant is zero.

On the basis of empirical and theoretical foundations the standard cosmological model has been generally accepted today. It is sometimes called the concordance model, and is often referred to as ΛCDM abbreviation, where Λ stands for the cosmological constant and CDM for the so-called cold dark matter.Weakly interacting massive particles are considered as most suitable candidates because they are neutral with a long lifetime and with mass range from few GeV to 100 GeV range they will have crosssectional area of interaction in the range of $\sigma < 10^{-40}$ cm^2 as they are weakly interacting. Axions are also considered too as suitable candidates for CDM but here we are discussing the WIMPs only.

Now we discuss the results of the experiments.

Experiments: The WIMPs interact through gravitational interaction with ordinary material hence produce detectable signals by recoiling atomic nuclei of the matter. Due to this reason dual-phase xenon time-projection chambers (TPC) emerged as a powerful technology for WIMP searches both in scaling up the target mass, as well as in improving background rejection[5-7]. From space-based detectors for astrophysical gamma-rays, to detectors located at accelerators or deep underground in search of rare decays expected from physics beyond the standard model, liquid xenon remains the preferred medium for many reasons. Among liquid rare gases, liquid xenon has the highest stopping power for penetrating radiation, thanks to its high atomic number and density. It also has the highest ionization and scintillation yield, the latter comparable to that of NaI(Tl) and with a faster time response. Compared to all other detector media, liquid rare gases have the unique feature of responding to radiation with both ionization electrons and scintillation photons. Detectors which use both signals with high detection efficiency have a significant advantage in the measurement of the properties of the radiation. In recent years, much progress has been made in the development of photodetectors with high quantum efficiency at the 178 nm wavelength of the liquid xenon scintillation.

PandaX-II: Particle and Astrophysical Xenon detector is situated at China Jinping Underground Laboratory (CJPL) in Sichuan, China. The PandaX-II experiment, a half ton scale dual-phase xenon experiment. In their various results published for experiments at 90% CL they reach new benchmark; in a result WIMP-nucleon cross section with a lowest excluded cross section of 2.97×10^{-45} cm^2 at a WIMP mass of 44.7 GeV/c^2[8] while later best upper limit on the scattering cross section is found 2.5×10^{-46} cm^2 for the WIMP mass 40 GeV=c^2[9] and in recent results the most stringent upper limit on spin-independent WIMP-nucleon cross section was set for a WIMP mass greater than 100GeV/c^2, with the lowest exclusion at 8.6×10^{-47}cm^2 at 40GeV/c^2.The collaboration released the official WIMP search results using 54 ton-day exposure on Aug. 23, 2017[10]. No excess events were found above the expected background.

LUX: The Large Underground Xenon (LUX) experiment searches for direct evidence of weakly interacting massive particles (WIMPs), in this experiment a dual phase xenon time projection chamber is used in which 250kg ultrapure active xenon is used. When WIMPs interact with LXe then two signals in the form of S1photons and electron are generated which are results of scintillation and ionization respectively. The S1 photons are emitted from the interaction

site and detected by top and bottom arrays of photomultiplier tubes (PMTs). Electrons liberated by the interaction drift to the surface of the liquid via an applied electric field. They are extracted into the gas and accelerated by a larger electric field, producing secondary electroluminescence photons collected in both arrays with localization in the top PMTs (S2). The PMT signals from both light pulses, S1 and S2, allow for the reconstruction of interaction vertices in three dimensions. The ratio of the S1 and S2 signals is used to discriminate between electronic recoils (ER) and nuclear recoils (NR). WIMP interactions in the detector would primarily appear as nuclear recoils of energy $\lesssim$100 keV. To reduce background noise in the signal the detector is immersed in ultrapure watertank. This search yields no evidence of WIMP nuclear recoils. At a WIMP mass of 50 GeV c^{-2}, WIMP-nucleon spin-independent cross sections above 2.2×10^{-46} cm^2 are excluded at the 90% confidence level. When combined with the previously reported LUX exposure, this exclusion strengthens to 1.1 $\times 10^{-46}$ cm^2 at 50 GeV c^{-2}.

The above experimental setup till today have negative results but reaches the highest values of sensitivity of experiment in the dark matter search experiments.

A summary of performance of the best direct detection experiments,for spin independent and spin dependent couplings is given in the table below. For the "low mass" section, in most cases, there is no minimum in the exclusion curve and a best "typical" WIMP mass cross section point has been selected.

Table: 1.1

Name of Experiment	Target Material	Fiducial Mass[kg]	Cross Section[pb]	WIMP Mass[GeV]	Refrence
Xenon 1t	Xe	1042	7.7×10^{-11}	35	11
PANDAX II	Xe	364	8.6×10^{-11}	40	12
LUX	Xe	118	1.1×10^{-10}	50	13
SuperCDMS	Ge	12	1.0×10^{-8}	46	14
DEAP	Ar	2000	1.2×10^{-8}	100	15
LUX	Xe	118	2×10^{-9}	10	13
Xenon 1t	Xe	1042	2×10^{-9}	10	11
PANDAX II	Xe	364	2×10^{-9}	10	12
PICO60	C_3F_8-F	46	2×10^{-7}	10	16
SuperCDMS	Ge HV	0.6	3×10^{-5}	3	14
CRESST	$CaWO_4$-O	0.25	1×10^{-2}	1	17
NEWS-G	Ne	0.3	6×10^{-2}	1	18

Table:1.2

Spin dependent						
Name of Experiment	Target Material	Channel particle	Fiducial Mass[kg]	Cross Section[pb]	WIMP Mass[GeV]	Refrence
PICO60	C_3F_8-F	P	54	3.4×10^{-5}	30	16
Spin dependent						
LUX	Xe	n	118	1.6×10^{-5}	35	19

New track for WIMPs detection: Till now we understand that whether it is spin dependent or spin independent search null results are obtained therefore it require ultra sensitive experiments to develop or a new way of design is required. The dark matter particles also annihilate like other particles. It is believe that the dark matter was dominating in early era of formation of the universe but as the dark matter annihilate the dark energy starts to dominate in present state approximately about 27% of dark matter and 68% of dark energy and 5% of the other matter is existing in the universe.

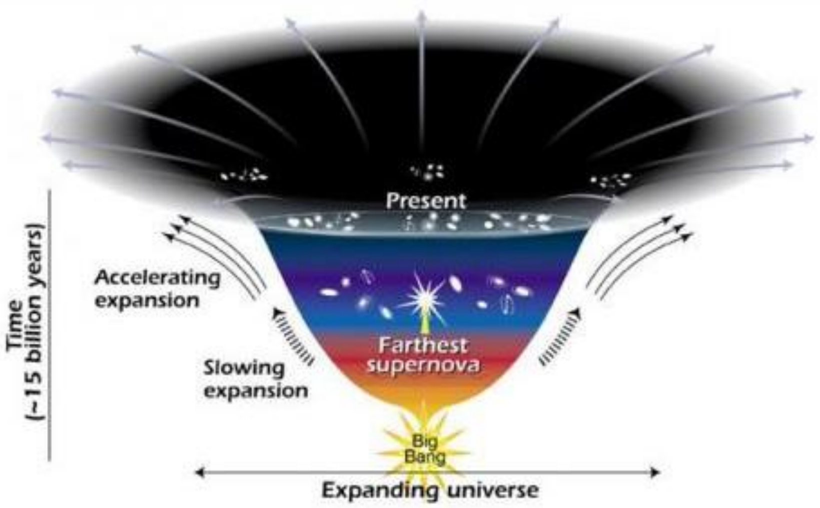

Figure:1.1 Courtesy*NASA/STSci/Ann Field*

The above figure 1.1 shows changes in the rate of expansion since the universe birth , which is 15 billion year ago. About 7.5 billion year ago universe starts to expand with a great rate which theorist believe that is due to presence of dark forces. It may be concluded that about 7.5 billion year ago dark energy starts dominating the dark matter and causes the acceleration in the expansion rate of universe. Recent finding of XMM-Newton also suggest the existence of dark matter and dark energy with some concrete proof. What we believe is that we should move ahead with approach for searching evidence of dark matter annihilation than the conventional experiments. Annihilation of WIMPs produces neutrinos, gamma rays, positrons, antiprotons and antinuclei [20]. Many details of particle dark matter is available in the reference [20]. The methods of detecting these particles are complimentary to the direct detection search and will be able to explore the higher masses. In the search of annihilated product of WIMPs it is believe that WIMPs can be slowed down and get captured inside the celestial objects like Earth or Sun when their density increased, they starts to annihilate and become source of upward moving muons. These muons can be detected in large neutrino telescopes such as MACRO, BAKSAN, SuperKamiokande, Baikal, AMANDA, ANTARES, NESTOR, and the large sensitive area IceCube [20]. In the experiments related to the Galactic Halo the continuous spectrum of gamma ray is example of WIMPs annihilation.

II. Conclusion

The analysis of whole data collected from spin dependent and spin independent search, the data collected from baryonic dark matter search and experiments to search annihilated product integrated might be able to explain mystery of dark matter. Author like to thanks editors of Particle Data Group[21], their efforts helps a lot in determining this work to get accomplished.

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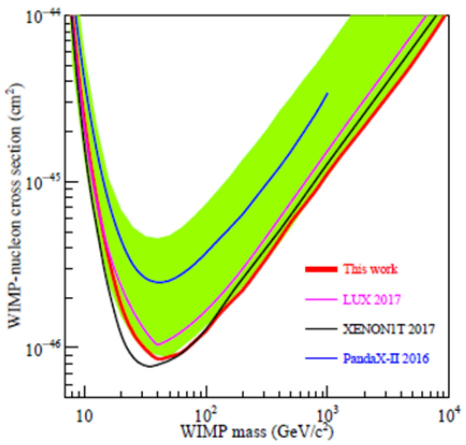
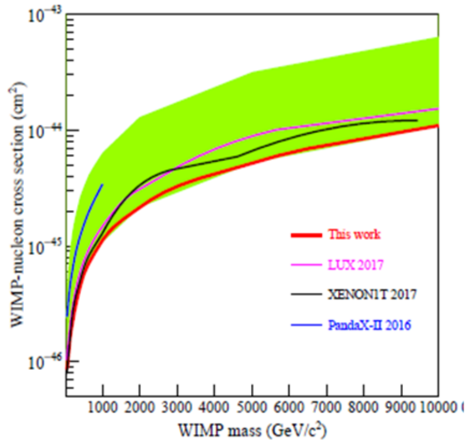
Figure: New limits of sensitivity of WIMPs by PandaX II [10].



Fig(a) The 90% C.L. upper limits versus WIMPs mass m log scale[10].



Fig(b) The 90% C.L. upper limits versus WIMPs mass m linear scale[10].

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