DARK MATTER: DIRECT AND INDIRECT DETECTION

G. CHARDIN
DSM/DAPNIA/SPP, CEA/Saclay
F-91191 Gif-sur-Yvette Cedex, France
gabriel.chardin@cea.fr

Recent precision cosmological measurements indicate that the density of our universe is critical within a few percent, and that its matter content, approximately one third of its total density, is mostly non baryonic. Supersymmetric particles represent the best motivated candidates to fill this gap, and are actively hunted by a number of competing experiments. Recent results, testing for the first time SUSY models compatible with accelerator constraints, are discussed and the evidence reported by the DAMA experiment for a WIMP with mass approximately 60 GeV is critically discussed. The sensitivities of direct and indirect detection techniques for both present experiments and future projects are compared. Finally, axion experiments, which are beginning to test the most popular axion models, are briefly reviewed.

1 Introduction : motivations

The present situation of our knowledge of cosmological parameters is paradoxical. Recent measurements by the BOOMERANG, MAXIMA and DASI experiments[1-3] have shown that the density of our Universe is very close to being critical. After the recent Archeops CMB measurements[4], the precision on the universe density is now approximately 1.00 ± 0.03 (Fig. 1) and, in this sense, the case for Dark Matter, which could still be considered as arguable a few years ago, appears compelling. The total baryonic density, ?$_{\text{baryon}}$, is impressively constrained by primordial nucleosynthesis and cosmological constraints[5] to be approximately 4 percent, implying that matter is composed at nearly 90% from an as yet unobserved and mostly non interacting component, rather generically predicted by supersymmetric (SUSY) theories models.

On the other hand, the recent apparition in the cosmological landscape of a non zero cosmological constant[6, 7] or some other quintessential component has brought some uneasiness to this Standard Cosmological Model: our Universe appears to be a strange mixture of 2/3 of some cosmological repulsive component, 1/3 of matter component almost entirely comprised of exotic matter, with only a few percent of ordinary, baryonic, matter. And although Cold Dark Matter (CDM) still represents today the best candidate for this exotic matter component, it stubbornly escaped detection until now. Worse, although CDM appears essential to produce cosmic structures observed at our present epoch, agreement with observations is problematic or even marginal without additional components, such as neutrinos. The Dark Matter recipe then appears so elaborate that it seems that we miss some essential ingredient, which could possibly explain much more simply the missing matter enigma.

On the positive side, for the first time, direct detection experiments are beginning to test regions of supersymmetric model parameter space compatible with cosmological and accelerator constraints. We summarize here the important effort undertaken by several groups, in both direct and indirect searches, to test a larger, if possible exhaustive, sample of SUSY parameter space.

2 WIMPs: model predictions and phenomenology

Supersymmetric (SUSY) models provide well motivated candidates for Weakly Interacting Massive Particles (WIMPs), which could fill the gap between the cosmologically observed matter density of ˜ 35%, and the baryonic density derived from nucleosynthesis[5]:

$$?_{\text{baryon}} \tilde{} \; 0.04 \pm 0.005 \text{ (for } H_0 = 70 \text{ km/s/Mpc).}$$

Decoupled much earlier than ordinary matter, and their stability justified by conserved R-parity in a large fraction of SUSY models, the electroweak scale provides a wealth of models which might provide an elegant explanation for the missing matter component. Of course, supersymmetric particles are as yet unobserved and partially constrained by accelerator data, mostly coming from the LEP experiments[8]. On the other hand, the exact nature of supersymmetry is not known, with more than 100 free parameters available. Imposing a compatibility with accelerator constraints results in WIMP-nucleon cross-sections below a few 10^{-6} picobarn. Although this sensitivity has been reached by the EDELWEISS experiment[9], model predictions extend down to immeasurable rates, with interaction cross-sections as small as 10^{-12} picobarn, or even smaller[10] if all the free parameters of MSSM are allowed to vary.

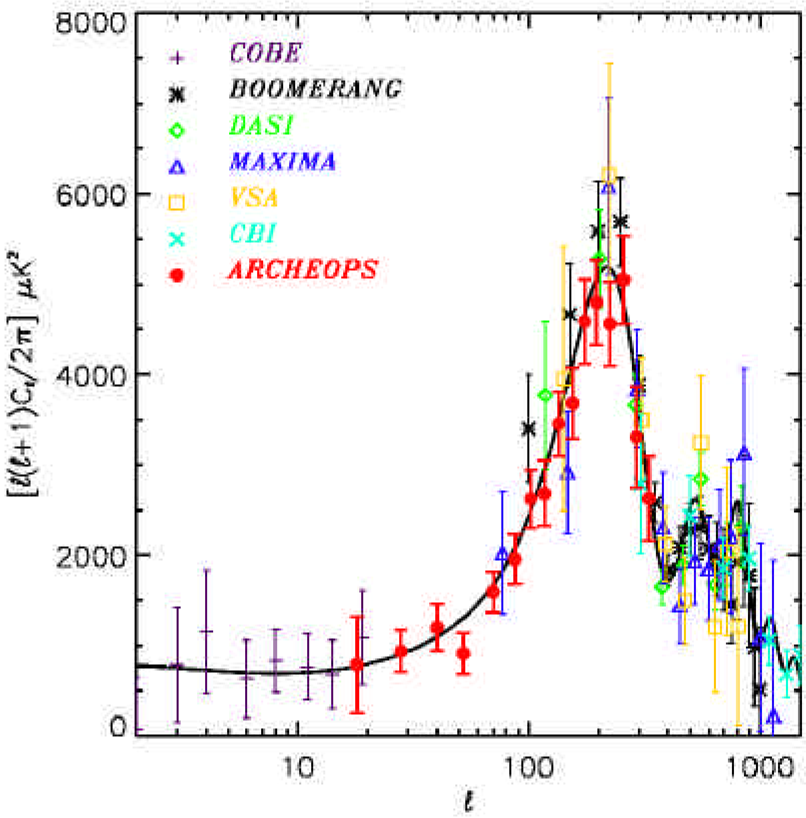

Fig. 1 : Power spectrum of the CMB fluctuations (from ref. 4). Combined with the HST Hubble flow determination, these measurements demonstrate that the universe density is critical within 3%, and that the baryon density is close to 4 percent.

Pragmatically, we expect that a fraction of these remnant particles are trapped in the gravitational potential well of the galaxy. Since these particles, unlike ordinary matter, can hardly dissipate their kinetic energy, the halo formed by these particles is usually considered to be grossly spherical and non rotating, although Sikivie has argued that the infall of Dark Matter might result in strong inhomogeneities or even caustic structures[11]. This halo would then extend at much larger distances that the ordinary and dissipative matter and explain the rotation curves observed in galaxies. In our galaxy, the standard parameters used[12] to describe the WIMP halo include its local density in the 0.3-0.7 GeV/cm^3 range, an assumption of a virialized Maxwellian velocity distribution with r.m.s. velocity $v_{rms} \sim 270$ km s^{-1} and a WIMP escape velocity from the halo $v_{esc} \sim 650$ km s^{-1}. Using this picture of a WIMP halo, and following the seminal paper by Drukier and Stodolsky[13] on coherent neutrino interactions, Goodman and Witten[14] proposed the method of WIMP direct detection involving elastic collisions of these particles with nuclei.

3 WIMP direct detection : initial results and the DAMA candidate

Initial direct detection experiments used detectors dedicated to other purposes, e.g. double-beta decay search, using conventional germanium detectors[15], or sodium iodide NaI scintillating crystals[16-18]. In a first series of measurements, the Heidelberg-Moscow experiment, using a set of ultrapure isotopically enriched Ge crystals, established that massive neutrinos could not represent the solution to Dark Matter over essentially all the cosmologically relevant mass interval[15]. Further improvements of the sensitivity of this experiment were mostly due to the passive reduction of internal ^{68}Ge cosmogenic activation by deep-undeground storage[19]. Attempt to use an anti-Compton strategy resulted in the HDMS well-type germanium detector[20] which, although efficient at MeV energy, resulted in only factor two gain at the low energies (a few keV) relevant for WIMP searches. On the other hand, massive sodium iodide crystals have been used, notably by the DAMA, the UKDMC and the Saclay groups, to reach sensitivities of the order or below 10^{-5} picobarn.

Despite the NaI inefficient discrimination at low energies, where the number of collected photons is small and the scintillation time constants are less separated, the DAMA experiment, using a total mass of ~ 100 kg of high purity NaI crystals, has reported in 1998[21] a first indication of an annual modulation using a data set of ~ 12.5 kg × year, recorded over a fraction of a year. Apart from the ELEGANT-V experiment[22], which is using NaI scintillators of total mass 730 kg, the DAMA experiment is presently running the largest experiment for WIMP direct detection. Compared to ELEGANT-V, DAMA is using NaI crystals with a lower radioactive background, with differential rates at low energies of ~ 2-3 events/kg/keV/day down to an energy of 2 keV electron equivalent (e.e.), or ~ 25 keV recoil energy.

After its initial report and a first confirmation of an annual modulation using a second data set of ~ 41 kg × year[21], the DAMA group published in 2000 an analysis involving a 160 kg × year data sample recorded over a three year time interval[23]). Taken at face value, the DAMA observation presents a 4.5 sigma statistical significance, with both phase and amplitude consistent over a period of three years with a WIMP signature. Interpreted in terms of a WIMP candidate, the mass appears to be ~ (52 ± 10) GeV and the WIMP-nucleon cross-section ~ (7 ± 1) 10^{-6} picobarn. The allowed region, delimited by a three sigma contour, is represented in Fig. 2 together with the constraints of the present most competitive experiments.

4 Should we believe the DAMA signal ?

Despite the considerable interest generated by the DAMA announcement which, if verified, would entail the discovery of the first supersymmetric particles, a number of criticisms have been raised against the DAMA analysis[24, 25]. The WIMP annual modulation is induced by the motion of the Earth around the Sun and is at most of the order of 7%, under the optimistic assumption of a pure WIMP population. With very limited or no background discrimination capabilities at the low energies characteristic of WIMP interactions, the limited signal-over-noise ratio will correspondingly reduce the already small amplitude of the modulation.

A reliable detection of the annual modulation in the interaction rate then requires a stability of the detector performances much better than 1%. It is therefore clear that the control of spurious modulations is essential. In fact, temperature and environmental effects are expected to present seasonal and yearly effects. An example is provided by the seasonal effects on the atmospheric decay region induced by the barometric pressure variations, which result in a modulation of the high-energy muon flux, observed for example by the MACRO experiment, or on the rock water content in the Gran Sasso laboratory[26], both effects resulting in seasonal variations of the neutron background in deep underground laboratories.

A more mundane, and a priori much more dangerous, spurious modulation results from the variation of the trigger rate close to threshold, an effect which must be carefully monitored by looking at event rate modulations below or close to the physical threshold. Although the DAMA group has tested the stability of its data taking conditions by using as a reference population the high energy event population (E > 90 keV), the data stability very close to threshold is of greater concern. In particular, the stability of the selection cut between the physical events and the photomultiplier noise is essential and should be tested against the presence of not only annual, but modulations at all frequencies, using a Fourier analysis.

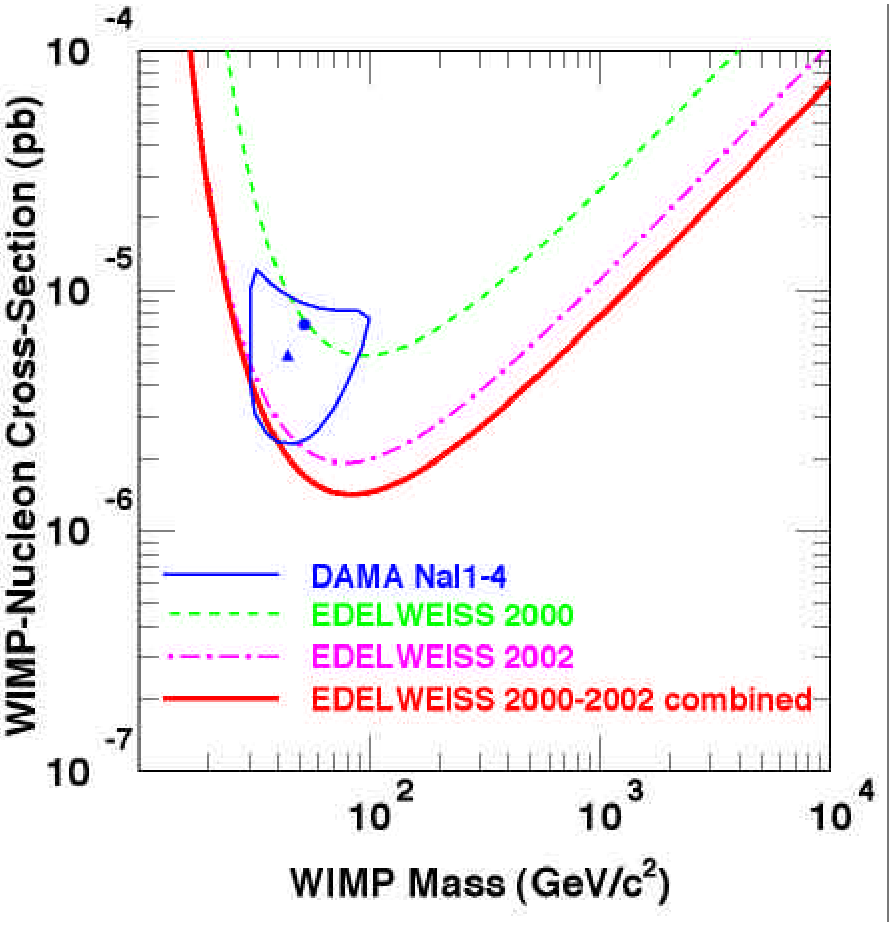

Fig. 2 : Experimental sensitivities of the present most sensitive WIMP direct detection experiments. The EDELWEISS result, without background, now excludes the full 3-sigma zone of the DAMA signal. This exclusion has been shown by Copi and Krauss (2002) to be independent of the WIMP halo model parameters.

Other authors have also noted[24, 25] that the initial claim of an annual modulation by the DAMA group[27] presented several inconsistencies: the signal appeared to be significant in only two out of the nine crystals, and the excess events attributed to the candidate WIMP presented an energy distribution extending well beyond that expected from a 60 GeV WIMP. It is then difficult to understand how an initially inconsistent observation was later confirmed with the same parameters.

More fundamentally, it appears unlikely that a single experiment will convincingly demonstrate the existence of a WIMP signal through the annual modulation technique if it cannot demonstrate by some discrimination procedure that a reasonably pure sample of nuclear recoils has been selected.

5 WIMP direct detection : discriminating experiments

Much of the progress of recent direct detection experiments is related to background discrimination capabilities of a new generation of detectors. Three main techniques have been developed successfully over the last ten years. Cryogenic experiments, EDELWEISS[28], CDMS[29], CRESST[30] and ROSEBUD[31], have built detectors capable of the simultaneous detection of two signals: ionisation and phonon signals for CDMS and EDELWEISS, scintillation and phonon signals for the CRESST and ROSEBUD experiments. On the other hand, the ZEPLIN-I collaboration[32] has developed a liquid xenon 5-kg detector, with a discrimination based on the different scintillation time constants for nuclear and electron recoils.

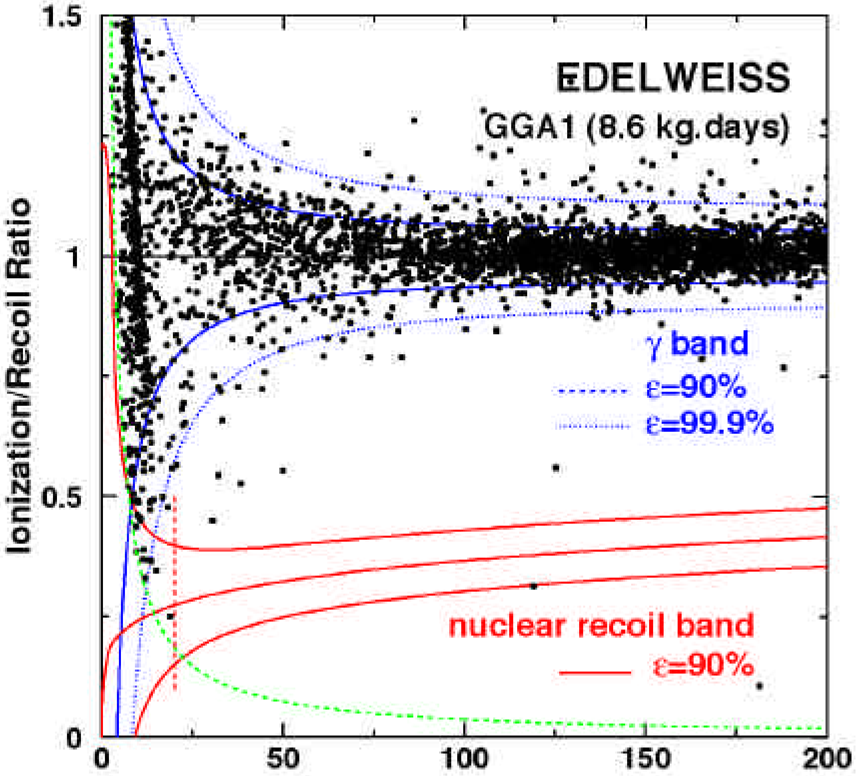

Fig. 3 : Scatter diagram of the ionisation efficiency, normalized to electron recoils, as a function of recoil energy for all events with energy < 200 keV recorded by the EDELWEISS experiment in the fiducial volume of a 320 gram Ge detector. With an effective mass 600 smaller than the DAMA NaI crystals, and an exposure 10 000 times smaller, this detector exceeds by a factor > 5 the sensitivity of the DAMA experiment (from ref. 9)

In 2000, shortly after the DAMA confirmation of its observation of an annual modulation in its event rate, CDMS published a result[33], based on a 13-kg × day exposure in the shallow Stannford Underground Facility, appearing to exclude most of the 3-sigma DAMA zone. However, this result was based on a sophisticated neutron background subtraction, difficult to achieve with the present uncertainties in neutron Monte-Carlo simulations, and with a controversial neutron background estimate using the silicon detectors. A recent reanalysis of the CDMS result[34] has led to a more conservative estimate, confirming the initial sensitivity at low mass, but leading to a limit a factor two higher for WIMP mass above 50 GeV approximately. In 2001, EDELWEISS[35], using a single 320 gram germanium detector, and in a background free run with a fiducial 5 kg × day exposure, excluded at more than 90% confidence level the central value of the DAMA claim, but leaving open the possibility of a compatibility with unconventional WIMP halo parameters.

The result obtained by the EDELWEISS collaboration[9] in a second run in 2002 is again background free (Fig. 3) but with a lower energy threshold and a longer exposure, and clearly excludes the whole DAMA region compatible with accelerator constraints (Fig. 2). The DAMA group has contested this contradiction, basing its argumentation upon the uncertainty in the WIMP halo parameters[36]. But Copi and Krauss[37] have recently shown that, irrespective of the halo models, the EDELWEISS result is now clearly incompatible with the whole DAMA region at more than 90% confidence level when the relative sensitivity of both experiments is compared for each set of WIMP halo model parameters.

Therefore, unless unconventional WIMP-nucleon couplings are used, the DAMA candidate must now be considered as excluded, not so surprisingly if one considers the relative position of the DAMA candidate region and of the SUSY models compatible with accelerator constraints (Fig. x).

Using a liquid xenon target, the UK-US ZEPLIN-I collaboration[32] has recently obtained a promising result since, with a 90 kg × day data sample using a 4.5 kg liquid cell, reaching a sensitivity within a factor 2 of that of EDELWEISS. But the liquid xenon discrimination is, in the present version of the experiment, not able to discriminate efficiently nuclear from electron recoils at low energies, although this electronic background rate, probably due to an internal krypton contamination, is 50 times higher than the CDMS or EDELWEISS gamma-ray background rate. Also, the energy resolution is much poorer than that of the cryogenic detectors. For example, at 50 keV nuclear recoil energy (10 keV electron equivalent), the energy resolution is $\sim$ 50%. As a consequence, in its present version, ZEPLIN suffers from an essential identification degeneressence at low energies, since the nuclear and electronic spectrum components cannot be reconstructed even with infinite statistics, leading to a limited confidence for a WIMP identification at low WIMP mass, below $M_{wimp} \lesssim 50$ GeV. Also, the quenching factor of the light yield for nuclear recoils needs to be measured reliably at low energies. In particular, there exists no direct measurement of the quenching factor below 50 keV recoil energy, and there is a considerable discrepancy — a factor three… — between the quenching factor measurements realized by the DAMA and by the ZEPLIN groups. A reliable determination of this fundamental parameter and of the temporal structure of the events below 50 keV recoil energy is then clearly required before the present ZEPLIN sensitivity can be considered as established.

5 WIMP direct detection : future projects

The present EDELWEISS result[9] corresponds to a total absence of nuclear recoil candidate event over a three month period with a fiducial detector mass of 180 gram. In terms of interaction cross-section, this corresponds to $\sigma \sim 10^{-6}$ picobarn, providing an idea of the difficulty to reach the 10^{-8} picobarn or, for that matter, the 10^{-10} picobarn milestone required to sample, respectively, the more realistic SUSY models[38] or most of the SUSY parameter space[10]. It is important to note that the latter milestone represents of the order of 10 events per ton of detectors and per year…

Two non discriminating experiments, CUORE[39] and GENIUS[40] are proposing to meet the challenge of direct detection at the level of 10^{-8} pbarn or below. But reaching this sensitivity will require three orders of magnitude improvement over the presently achieved background levels, which appears as a fantastic leap of faith. Also, these experiments are unable, if they observe candidate events, to demonstrate that these are due to WIMP interactions, except through the challenging annual modulation technique. The DAMA example, with an assumed signal-over-noise ratio of $\sim$ 1, and a detector mass of 100 kg, shows that demonstrating the existence of a WIMP signal through this signature will soon require a target mass larger than one ton.

Within the next three years, CDMS, CRESST and EDELWEISS will be upgrading in their second phases to detector mass between 10 kg for CDMS and CRESST, to 35 kg for EDELWEISS. ZEPLIN will be moving to a two-phase (liquid-gas) operation allowing scintillation and ionisation to be measured simultaneously, with a xenon target mass of 30 kg. These four experiments all promise about two orders of magnitude improvement in the next few years, with a target sensitivity of the order of $2\ 10^{-8}$ pbarn. This is just at the level of the models considered as realistic by Ellis et al.[38] These experiments, if successful, will then have to be upgraded to tonne-scale experiments, either to confirm with high statistics the existence of a signal, or to sample lower cross-section SUSY models. By using different target nuclei, they will allow the determination of the WIMP mass and type of interaction if candidate WIMP interactions are detected. In fact, plans are already in place in Europe, in the US and in Japan to build tonne-scale cryogenic and xenon detectors with the GENIUS, CryoArray, Majorana and XMASS projects. Clearly, the scientific impact of a detection will be much higher and more robust if complementary informations are recorded using at least two target nuclei. Further confirmation from LHC and, if possible, from the indirect detection experiments looking for neutrino and antiparticle fluxes from neutralino annihilation, will finally be required to get a full picture of supersymmetric dark matter.

6 WIMP indirect detection : main experiments and present results

Despite their small interaction cross-section with ordinary matter, WIMPs can be captured by celestial bodies, such at the Sun or even the Earth[41]. Since neutralinos are massive Majorana particles, they can annihilate and release various particles. Most particles will remain invisible from the outside, but copious fluxes of neutrinos can be produced in several annihilation and decay channels, and give rise to observable signals in large-size terrestrial detectors. Annihilation at the galactic center, in the vicinity of the massive black hole at the center of our Milky Way, has been also considered as a possible copious source of annihilations, but although an interesting target, the uncertainties in the density enhancement factor makes its flux extremely imprecise.

The overwhelming muon background coming from the above horizon hemisphere imposes to have a detector with directional capabilities, to distinguish upward going muons, associated to neutrino interactions, from the down-going cosmic-ray remnants. Cerenkov detectors provide an elegant solution to this experimental challenge, with large and unexpensive target mass.

Present experiments[42-46] include Baksan, Macro, now dismantled, and SuperKamiokande for the deep underground detectors, and AMANDA and Baikal for under-ice and underwater, respectively, detectors. Future experiments include ANTARES, a European collaboration in the Mediterranean sea, and ICECUBE, a km^2 extension of the second generation AMANDA-B detector.

The AMANDA-B detector, in the Antarctic, has achieved a first celestial map of neutrino interactions, with a total of about one thousand high-energy neutrino interactions. At lower neutrino energies, SuperKamiokande[46] has reached a similar sensitivity with a 50 kton target mass, and Baksan, through an impressive continuous data taking of more than twenty years, has reached with a ˜ 250 m^2 detector, a similar sensitivity using liquid scintillating detectors[47]. The sensitivity limits reached by these experiments, ultimately limited by the fluctuations of the atmospheric neutrino background within their angular resolution, are presently comparable to those obtained by WIMP direct detection experiments.

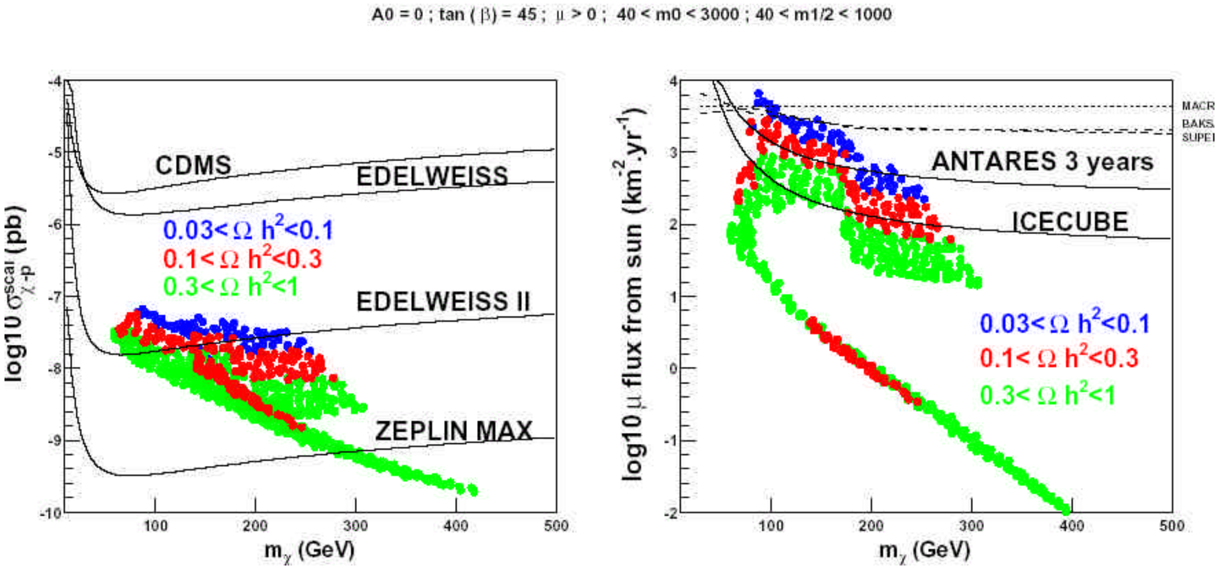

Fig. 4: Sensitivity limits reached by the present indirect detection experiments (from ref. 49). The ANTARES 0.1 km^2 detector will improve the present SuperKamiokande sensitivity by a factor 3, ICECUBE by a factor ˜ 10. Present sensitivities of direct and indirect detection experiments are comparable, with EDELWEISS being a factor 2 more sensitive than the current SuperKamiokande result.

As a matter of comparison between direct and indirect detection experiments, the most sensitive present experiment for spin-independent WIMP interactions, Super-Kamiokande, has recently published[46] a sensitivity limit, based on the analysis of Kamionkovski et al.[48], of the same order but somewhat less sensitive than the recent EDELWEISS result[9], using a 3.5 years data sample. AMANDA-B and Baksan are reaching similar sensitivities, with a higher energy threshold for the former experiment.

ANTARES, in its 0.1 km^2 version, plans to increase the present indirect detection sensitivity by a factor ˜ 3. ICECUBE, on the other hand, is expected to reach a sensitivity a further factor ˜ 3 compared to ANTARES, particularly at high WIMP mass. This experiment benefits from a larger detection area, in the km^3 range, but the diffusion of Cerenkov photons in the ice is expected to lead to a partially degraded angular resolution at low muon energies.

Faced to the increased sensitivity of the next generation direct detection experiments, which plan to improve their present sensitivity by nearly two orders of magnitude, indirect detection experiments may compete with their much larger sensitivity in purely axial, or spin-dependent, couplings. In particular, the ANTARES group has recently released an analysis[49] showing that, for a fraction of models with significant spin-dependent interactions, ANTARES can compete with the EDELWEISS-II stage and be complementary in some cases, which would bring fundamental indications on the nature of stable SUSY remnants.

7 Axions

Axions represent a completely different solution to the Dark Matter problem. Their theoretical justification lies in the so-called “strong CP problem”[50]. In the Standard model, CP violation appears in electroweak interactions through the existence of a complex phase in the CKM matrix. On the other hand, in strong interactions, the QCD lagrangian requires an additional term related to the existence of instanton solutions in non abelian gauge theories:

$$\frac{\bar{q}}{16p^2}\mathrm{Tr}F_{mn}\tilde{F}^{mn}$$

But since the neutron electric dipole moment is experimentally very small:

$$d < 1 \times 10^{-25}\ e\ \mathrm{cm},$$

the dimensionless $\bar{q}$ parameter must be less than ≈ 10^{-10}, which seems quite unnatural and corresponds to the strong CP problem. To solve this fine tuning conundrum, the idea is then to introduce a dynamical axion field so that the q parameter is driven to a very small value. This dynamical mechanism leads to a coherent emission of axions at zero momentum in the very early universe, an example of a dynamical symmetry breaking.

The precise nature of the coupling of axions to ordinary particles is model dependent, however, and two generic class of axions are usually considered: the KSVZ model[51], or heavy quark model, and the DFSZ model[52], where the lagrangian includes, in addition, a term corresponding to an axion-lepton-lepton coupling.

Independently of the solution to the strong CP problem, it was later realized that axions represented a possible dark matter candidate in the mass range between approximately 10^{-6} to 10^{-2} eV. Outside this mass interval, a severe astrophysical bound comes from star core cooling, which must remain consistent with our knowledge of stellar evolution and energy production. The most severe constraint in this respect comes from the observation of the time structure, in the tens of seconds range, of neutrino emission in supernova SN1987A. A strong axion energy loss would then reduce the duration of the neutrino emission. Two further bounds come from helioseismological data, and from the globular cluster limit which imposes a stringent upper bound $g_{ag} = 0.6 \times 10^{-10}\ \mathrm{GeV}^{-1}$ on the coupling.

The main experimental method for detecting axions, initially proposed by Sikivie[53], relies on the *agg* coupling which makes it possible to convert axions into detectable radiation in resonant electromagnetic cavities. The emitted power is extremely small for tractable electromagnetic fields and is given by the expression:

$$P \approx 10^{-26}\,\mathrm{Watt}\left(\frac{V}{1\ \mathrm{m}^3}\right)\left(\frac{B_0}{10\,\mathrm{Tesla}}\right)^2\left(\frac{r_A}{0.4\times 10^{24}\ \mathrm{g/cm}^3}\right)\left(\frac{m_a}{10\,\mu eV}\right)\min(Q_c, Q_a)$$

where V is the volume of the cavity, B_0 is the magnetic field strength, ρ_a is the local axion density, Q_c is the quality factor of the cavity and $1/Q_a \approx 10^{-6}$ is the width of the axion energy distribution. This width is directly related to the expected velocity dispersion of galactic axions and its inverse is roughly of the same order of magnitude as the quality factors of electromagnetic cavities which have been developed.

Several experiments have been developed over the last ten years, which appear to be able to test, for the first time, part of the available phase space of the axion models. The LLNL axion search experiment[54] has recently reached the sensitivity required to test the KSVZ model in the 2-3 μeV window, and plans to extend its range of operation to the 1-10 μeV mass range in the next few years. Using SQUID-based amplifiers will be required, however, to extend its sensitivity down to that required to test the less favorable DFSZ model, requiring an additional factor of ≈ 2.7 in sensitivity.

The Kyoto group is involved in the CARRACK (Cosmic Axion Research with Rydberg Atoms in a Cavity at Kyoto)[55], using the selective ionization of Rydberg atoms and the detection of electrons produced. But the stability of these highly excited atoms requires the use of a dilution refrigerator to reach a temperature of ≈ 10 mK in the CARRACK-II phase of the experiment. Although the CARRACK experiment intends to exceed the sensitivity required to test, over the [2-30] μeV axion mass interval, the KSVZ and DFSZ cosmologically relevant mass range, no constraining results have been published until now by this experiment.

CAST, searching for keV axions produced in the solar core, is using a decommissioned LHC test magnet at CERN[56] and will greatly improve the present sensitivity to solar axion. First results of this experiment are expected over the next few months, and should be able to test a small fraction of the axion models

Also, single crystal coherent conversion of axions[57] in dark matter experiments: NaI, TeO_2 and germanium, are able to set constraints of the axion density, which are not able, however, to test the cosmologically relevant axion mass range. Even CUORE will hardly reach sensitivity able to compete with astrophysical constraint. Nevertheless, these experiments are interesting in their own right since they propose a completely different axion detection method.

8 Conclusions

WIMP direct detection experiments are finally reaching sensitivities allowing to sample SUSY models compatible with accelerator constraints, although models respecting an accurate unification at GUT scale probably require at least a factor ten increase in sensitivity. The first WIMP candidate proposed in 2000 by the DAMA experiment is now excluded by the EDELWEISS result, without any background subtraction and independently of galactic WIMP models unless unconventional interaction models are used.

During the forthcoming year, the sensitivity reached by the EDELWEISS and the CDMS-II experiments is expected to increase by nearly an order of magnitude. Over the next three years, a second generation of experiments, CDMS-II, EDELWEISS-II, CRESST-II and ZEPLIN-II, using mass targets in the 10-kg range, intend to reach the impressive sensitivity of 10^{-8} picobarn. Corresponding to less than one interaction per kilogram and per year, this will allow to test a much larger fraction of realistic SUSY models. Direct searches with a detector mass of the order of one ton should be able to test most of the SUSY parameter space. Reaching a sensitivity of 10^{-10} picobarn, however, will require oustanding background discrimination capabilities, as well as a control of the neutron background, and particularly of the fast neutron background induced by muon showers in underground sites.

Although a test of the complete SUSY parameter space is out of reach of even 1-km^3 indirect detection experiments, such as ICECUBE or ANTARES-II, these experiments, by being more sensitive to the spin-dependent part of the interaction, are complementary to direct detection experiments and may help determining the nature of a WIMP candidate, if observed.

Axion searches are just beginning to test a small fraction of the cosmologically relevant axion parameter space compatible with astrophysical constraints. Solid state detectors provide interesting constraints, but are not sensitive enough, however, to compete with the astrophysical constraints or to test the KSVZ and DFSZ models.

Improvements in sensitivity by WIMP and axion experiments will hopefully allow to detect and identify the nature of Dark Matter within the next few years.

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