ANAIS and the wind of dark matter

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The "dark matter problem" settled down by accumulating evidences from the dynamics of galaxies within clusters and of stars in spiral galaxies' arms. The latter is analysed for a particular case in section A. The dark matter could consist of Weakly Interacting Massive Particles (WIMPs). ANAIS-112 is an experiment searching for dark matter at the Canfranc Underground Laboratory, under the Spanish Pyrenees. Section B proposes to analyse the dark matter direct detection approach followed by ANAIS and other experiments.

A. Evidences on the existence of dark matter in spiral galaxies

Consider the galaxy as a mass distribution with spherical symmetry, where R_g is the galactic radius. Consider M_g as the mass of the galaxy up to the radius R_g, and assume a constant density of matter ρ between 0 and R_g.

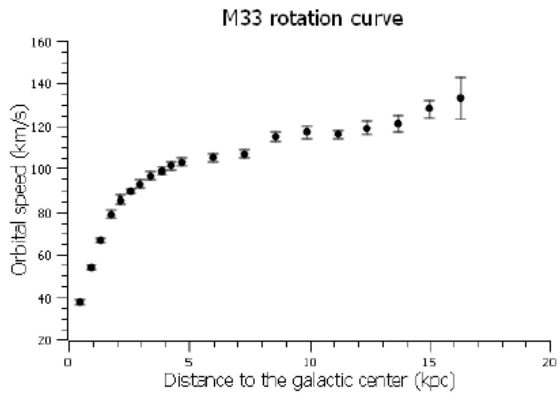
A1. Determine the rotation velocity of stars, v, as a function of the distance r to the galactic center in terms of M_g and R_g, for $r < R_g$ and $r > R_g$. Plot schematically $v(r)$. (1 pt)

However, observations for most of the galaxies provide very different rotation curves, showing constant or increasing velocities up to the largest distances measured ($r \gg R_g$).

Then, as the model of galaxy proposed in A1 does not explain the observations, we will build in the following a different model. First, a constant rotation velocity v_{rot}, for $r \gg R_g$ would require a dark halo with density $\rho(r)$ extending much beyond R_g. Consider R_g as the radius of the "visible" galaxy and this dark halo as the only component in the galaxy.

A2. Determine the density $\rho(r)$ of the halo mass distribution explaining a constant v_{rot}. Use a power law, $\rho(r) = \alpha r^n$, and determine both α and n. (1 pt)

M33 is one of the nearest galaxies, part of the Local Group. It is the third in size, after Andromeda and the Milky Way. The rotation curve of M33, like those of many spiral galaxies is more complicated than the simplification previously considered (see Table).



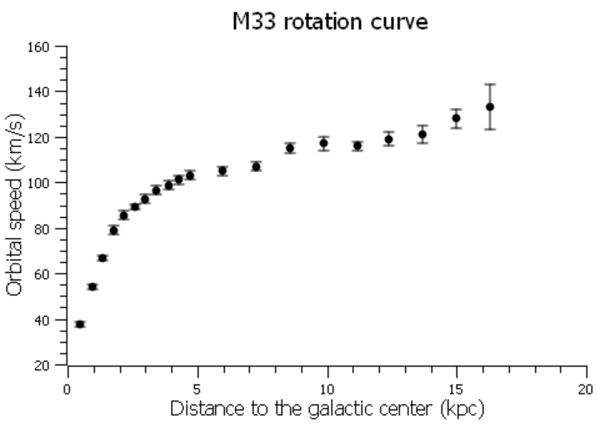
Distance to the galactic center (kpc)	Orbital speed (km/s)	Error (km/s)
0,464	37,4	1
0,956	53,9	1
1,34	66,6	1
1,78	78,9	2
2,16	85,6	2
2,62	89,3	1
3,01	92,7	2
3,44	96,4	2
3,88	98,6	2
4,29	101	2
4,7	103	2
5,96	105	2
7,27	107	2
8,58	115	2
9,89	117	3
11,2	116	2
12,4	119	3
13,7	121	4
15	128	4
16,3	133	10

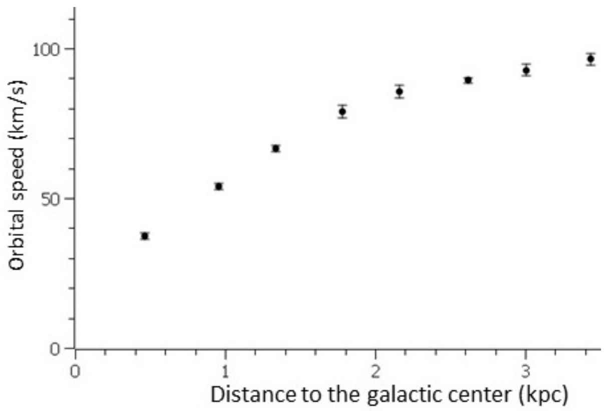
A3. Obtain numerical estimates for v_{rot} and the total mass M of the dark halo, following the galaxy model analysed in A2, using the mean value of the rotation velocities measured between 5 and 17 kpc. (0.5 pts)

Assume we can simplify the M33 mass distribution to have three components:

1. An inner mass accumulation called "cusp" for $r < 0.4$ kpc.
2. A core with constant mass density ρ_c, extending up to $R_c = 2$ kpc.
3. The halo.

Consider the halo contributes only at large r, beyond the core, and has the power law density determined in A3, and neglect the effect of this halo in the rotation velocities observed in the inner part of the galaxy.





A4. Linearly approach the speed below 2 kpc as $v(r) = Ar + B$ using the data in the table and the figure. You can determine A and B by plotting the straight line through the points graphically. Using this $v(r)$, estimate the velocities at $r = 1$ kpc and $r = 2$ kpc and obtain numerical estimates for the density of the galactic core, ρ_c, and the cusp mass, M_0, for M33 in the proposed model. (1 pt)

Assume our galaxy is similar to M33 but more massive, and it has a halo with a power law like that used in A2 and A3. Consider the Sun is moving inside the galactic halo (outside the core) at 8.5 kpc with an orbital speed of $v_S = 230$ km/s around the galactic center.

A5. Estimate the matter density at the position of the Solar System in the Milky Way's halo. (0.5 pts)

The matter density obtained by this procedure is too large to be accounted by the visible matter alone. We can conceive strategies to detect this dark matter directly with experiments on Earth.

B. Direct Detection of Dark Matter

Consider a WIMP having a mass m_W and moving with velocity v_W, and a detector consisting of nuclei with mass M in rest. Assume elastic scattering between the WIMP and one of the nucleus of the detector.

B6. Express the recoil energy of the nucleus in terms of m_W, v_W, M and the recoil angle in the center of mass system, θ. (1 pt)

B7. Express the maximal transfer of energy from the WIMP to the target nucleus in terms of m_W, v_W, and M. (0.5 pts)

Different detectors have been used in dark matter direct searches. The experiment ANAIS uses sodium iodide detectors, containing two different nuclei: Na and I. Consider M(Na)=23 u, and M(I)=127 u, and the relative velocity WIMP-nucleus, $v_W = 300$ km/s.

B8. Estimate the maximal energy depositions in ANAIS detectors for WIMPs of mass $m_w = 100$ GeV, for elastic scattering off Na and I. (0.5 pts)

However, WIMPs are not expected to have a single velocity in the galactic halo, but a distribution of velocities. The easiest halo model assumes a spherical, isotropic and isothermal distribution of velocities $\vec{v}_{Wg}$ for the WIMPs in the galactic halo reference system. Assume a 3D isotropic Maxwellian distribution for v_{Wg} with root mean squared velocity of 270 km/s:

$$f(\vec{v}_{Wg})\; d\vec{v}_{Wg} = A\; e^{-\frac{v_{Wg}^2}{v_0^2}}\; d\vec{v}_{Wg}.$$

B9. Calculate A to have a normalized distribution, the corresponding v_0, and the mean value of WIMP velocities, v_{Wg}. (1 pt)

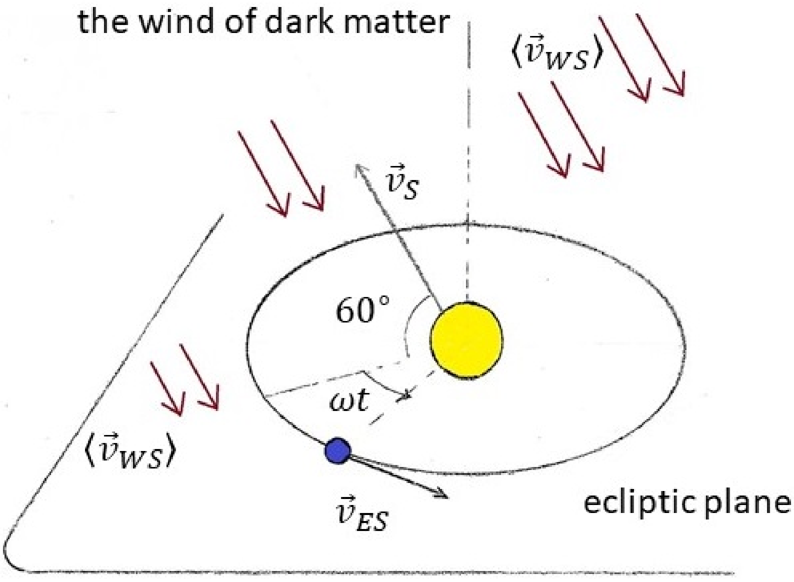
Assume the Sun (and the Earth, and our detector, with it) is moving through this distribution with $v_S = 230$ km/s.

B10. Estimate the average value for the modulus of the relative velocity WIMP-Sun $\vec{v}_{WS}$. (1 pt)

WIMPs interact with nuclei with a low probability, represented by σ. Take for σ, the nucleus cross-section seen by the WIMPs as they approach a target nucleus, a value of σ =1 pbarn for Na nuclei, and consider a flux of WIMPs with a constant velocity. Assume that 80% of the matter density calculated in A5 is dark matter.

B11. Estimate the flux of WIMPs, j_w, arriving to ANAIS detectors as a function of the WIMP mass, m_W. Estimate the rate of interactions between WIMPs and Na nuclei in one of the ANAIS detectors (12.5 kg of mass) as a function of the WIMP mass, m_W. (1 pt)

Consider that the Earth is moving with $v_{ES} = 30$ km/s around the Sun, and that the ecliptic plane forms an angle of about 60° with the velocity of the Sun around the center of the Milky Way, $\vec{v}_S$.



B12. Taking into account the Earth's motion around the Sun, the Earth is moving in the WIMPs' halo with a velocity:

$$\vec{v}_{Eg}(t) = \vec{v}_S + \vec{v}_{ES}(t).$$

Now, approximating to the first order, profiting from $|\vec{v}_{ES}| \ll |\vec{v}_S|, |\vec{v}_{WS}|$, estimate the time dependence of $|\vec{v}_{WE}(t)|$, considering circular orbits. Finally, express the annually modulated interaction rate produced by WIMPs in one of the ANAIS-112 detectors (following the result in B11). (1 pt)

$$\int_0^\infty x^n e^{-x^2} dx = \begin{cases} \frac{(2k-1)!!\ \sqrt{\pi}}{2^{k+1}} & \text{for } n = 2k, k \text{ integer} \\ \frac{k!}{2} & \text{for } n = 2k+1, k \text{ integer} \end{cases}$$

Being the double factorial, $(2k-1)!! = (2k-1)\cdot(2k-3)\cdots 3\cdot 1$

$$\int_0^\infty x^2 e^{-x^2} \cosh(2ax)\ dx = \frac{e^{a^2}\sqrt{\pi}}{4}\ (2a^2+1)$$

UNIT CONVERSION:

1 kpc $= 3.086\ 10^{19}$ m
1 barn $= 10^{-24}$ m^2
1 eV $= 1.6\ 10^{-19}$ J
1 u $= 1.66\ 10^{-27}$ kg

SOLUTION

A1. Assuming spherical symmetry for the galaxy, only the mass inside a sphere of radius r, $M_g(r)$, contributes to the gravitational attraction on a star of mass m_s found at distance r from the galactic center. We use $M_g = M_g(r \geq R_g)$ for the total mass of the galaxy.

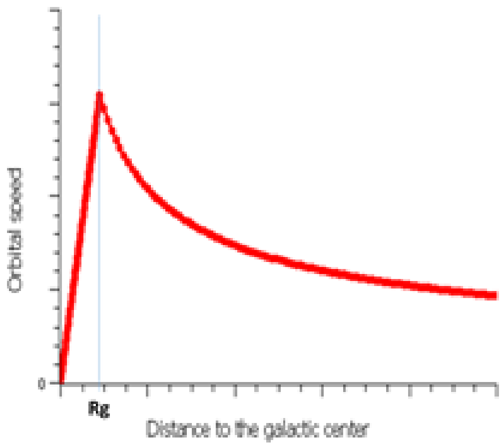
For $r < R_g$

$$\frac{GM_g(r)m_s}{r^2} = m_s\frac{v(r)^2}{r}, \ M_g(r) = \frac{4}{3}\pi r^3 \rho = M_g\frac{r^3}{R_g^3} \Rightarrow$$

$$v(r) = \sqrt{\frac{4\pi G\rho}{3}}\, r = \sqrt{\frac{GM_g}{R_g^3}} r$$

For $r > R_g$

$$\frac{GM_g m_s}{r^2} = m_s\frac{v(r)^2}{r} \Rightarrow v(r) = \sqrt{\frac{GM_g}{r}}$$



A2. We call $M(r)$ the total mass (visible and dark) in the sphere of radius r, with $r \gg R_g$

$$\frac{GM(r)m_s}{r^2} = m_s\frac{v_{rot}^2}{r} \Rightarrow M(r) = \frac{v_{rot}^2 r}{G} \tag{1}$$

Using for the density of the mass distribution a power law

$$\rho(r) = \alpha r^n \tag{2}$$

$$M(r) = \int_o^r \rho(r')4\pi r'^2 dr' = \int_o^r \alpha r'^n 4\pi r'^2 dr' = 4\pi\alpha\frac{r^{n+3}}{n+3} \tag{3}$$

Combining Eq. (1) and Eq. (3), we obtain for a constant velocity v_{rot}

$$M(r) = \frac{v_{rot}^2 r}{G} = 4\pi\alpha \frac{r^{n+3}}{n+3} \Rightarrow n = -2 \text{ and } \alpha = \frac{v_{rot}^2}{4\pi G} \quad (4)$$

A3. From the rotation curve of M33, considering the velocities measured from 5 to 17 kpc, we can determine a mean velocity of 116.4 km/s, with a standard deviation of 8.9 km/s.

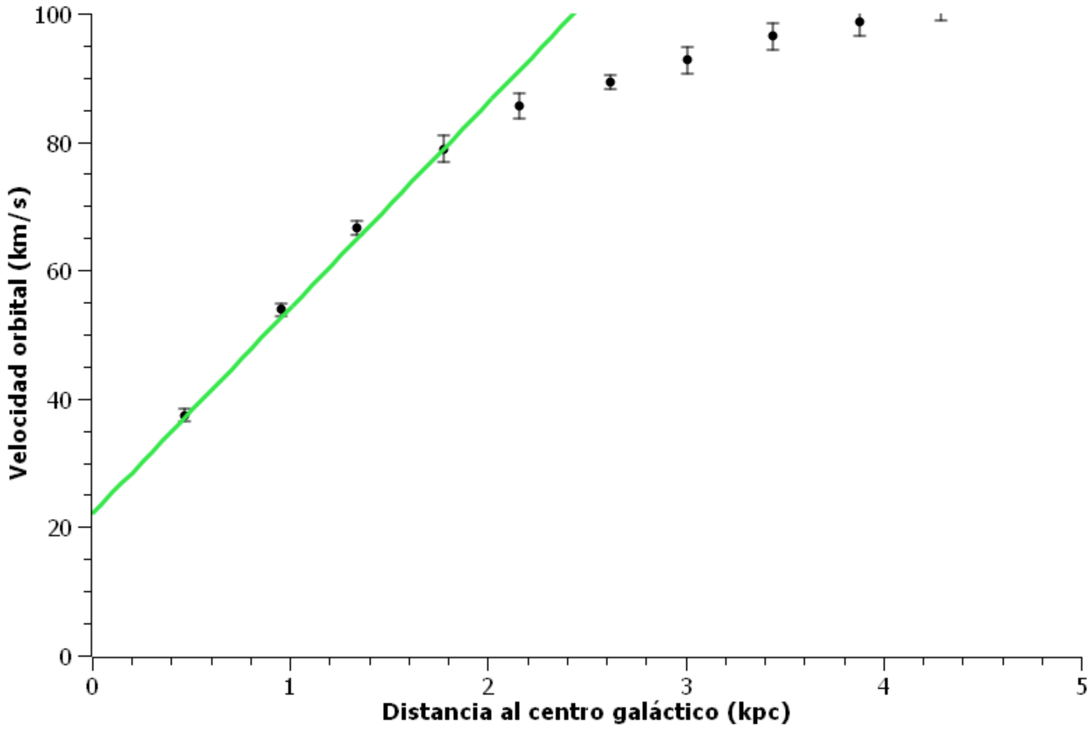
$$v_{rot} = 117.9 \text{ km/s}$$

Following Eq. (3) and Eq. (4), it corresponds to

$$\alpha = 1.7\ 10^{19}\text{kg/m}$$

$$M = M(r = 17\text{kpc}) = 1.1\ 10^{41}\text{kg}$$

A4. We approach the linear behaviour of velocities between 0.4 and 2 kpc:



by:

$$v(r) = A + Br \quad (5)$$

$$A = 22 \text{ km/s}, B = 32\frac{\text{km}}{\text{s kpc}} = 1.0\ 10^{-15}\text{s}^{-1}$$

We call M_c the mass up to 2 kpc.

$$M_c = \frac{4}{3}\pi\rho_c R_c^3.$$

Using the same procedure followed in A1 but considering that now for $r < R_c$, $M(r) = M_0 + 4/3\pi\rho_c r^2$, we derive for $v(r)$:

$$v(r) = \sqrt{\frac{G(M_0 + \frac{4}{3}\pi\rho_c r^3)}{r}} \tag{6}$$

We calculate using Eq. (5) the velocity at 1 and 2 kpc:

$$v(r = 1 \text{ kpc}) = A + B\ 1 \text{ kpc} = 54 \text{ km/s}, \quad v(r = 2 \text{ kpc}) = A + B\ 2 \text{ kpc} = 86 \text{ km/s},$$

and we derive using Eq. (6):

$$M_0 + M_c = 6.84\ 10^{39}\text{kg}, \quad M_0 + 0.125 M_c = 1.35\ 10^{39}\text{kg}$$

$$M_0 = 5.6\ 10^{38}\text{kg}, \quad M_c = 6.27\ 10^{39}\text{kg}$$
$$\rho_c = 6.4\ 10^{-21}\text{kg/m}^3$$

A5. Using Eqs. (2) and (4) for $r = 8.5$ kpc and $v_{rot} = 230$ km/s, we obtain:

$$\alpha_{MW} = \frac{v_{rot}^2}{4\pi G} = 6.3\ 10^{19} \text{ kg/m}$$
$$\rho_{MW}(8.5\text{kpc}) = \alpha_{MW}\ (8.5\text{kpc})^{-2} = 9\ 10^{-22}\text{kg/m}^3 = 5\ 10^{14}\text{eV/m}^3 = 0.5 \text{ GeV/cm}^3 \tag{7}$$

These evidences of the existence of dark matter do not tell too much on its nature. However, other evidences point at non-dissipative behaviour and non-baryonic character, meaning that these particles have to be searched for beyond the Standard Model of Particle Physics.

B. Direct Detection of Dark Matter

Direct detection of dark matter relies on the hypothesis that it consists of a new species of elementary particle with mostly unknown properties. It should be massive and very weakly interacting with ordinary matter. The so-called WIMPs (Weakly Interacting Massive Particles) are a category of dark matter candidates. They can be detected because of the small, but non-zero, coupling to ordinary matter. Since the eighties of the past century there are experiments searching for those WIMPs with dedicated detectors of increasing sensitivity.

B6. We can consider non-relativistic kinematics for typical WIMPs and solve the scattering in the center of mass system, CM, which is moving with velocity

$$\vec{V}_{CM} = \vec{v}_W \frac{m_W}{M + m_W}$$

Assuming the conservation of kinetic energy and momentum in the scattering, the final velocities of the WIMP, $\vec{v}_{Wf}$, and nucleus, $\vec{v}_{Nf}$, with respect to the CM will be aligned in a direction $\hat{n}_f$ forming an angle θ with the direction of the incoming WIMP

$$\vec{v}_{Wf} = v_W \frac{M}{M+m_W}\hat{n}_f \quad \vec{v}_{Nf} = -v_W \frac{m_W}{M+m_W}\hat{n}_f$$

The final energy of the WIMP in the laboratory system would be:

$$\begin{aligned} E_{Wf} &= \frac{1}{2}m_W(\vec{V}_{CM} + \vec{v}_{Wf})^2 = \frac{1}{2}m_W(V_{CM}^2 + v_{Wf}^2 + 2\ V_{CM}\ v_{Wf}\ \cos\theta) \\ &= \frac{1}{2}m_W \frac{v_W^2}{(M+m_W)^2}(m_W^2 + M^2 + 2M\ m_W\ cos\theta) \end{aligned}$$

The energy deposited in the detector is the energy of the recoiling nucleus, while the scattered WIMP escapes:

$$\begin{aligned} E_{Nf} = E_{Wi} - E_{Wf} &= \frac{1}{2}m_W v_W^2 - \frac{1}{2}m_W \frac{v_W^2}{(M+m_W)^2}(m_W^2 + \ M^2 + 2\ M\ m_W\ \cos\theta) \\ &= \frac{m_W^2\ M\ v_W^2}{(M+m_W)^2}(1-\cos\theta) \end{aligned}$$

B7. The maximal value of this energy corresponds to $\theta = \pi$. It can be calculated independently from B6 by considering that the maximal transfer of energy corresponds also to backscattering in the laboratory reference system.

$$(E_{cNf})_{max} = \frac{2\ m_W^2\ M\ v_W^2}{(M+m_W)^2}$$

B8. We apply this expression to the case of Na and I as target nuclei using v_W= 300 km/s=0.001c. We work with mass in units of energy, as usual in particle physics context, and in c units for the velocities.

$$M_{\rm Na} = 23\ u\ 1.66\ 10^{-27}{\rm kg/u}\frac{(3\ 10^8{\rm m/s})^2}{(1.6\ 10^{-19}{\rm eV/J}} = 21.5\ {\rm GeV}$$

$$M_{\rm I} = 127\ u\ 1.66\ 10^{-27}{\rm kg/u}\frac{(3\ 10^8{\rm m/s})^2}{(1.6\ 10^{-19}{\rm eV/J}} = 118.6\ {\rm GeV}$$

For m_W=100 GeV,

$$(E_{c\rm Na}\ )_{max} = \frac{2\cdot(100{\rm GeV})^2 21.5{\rm GeV}(10^{-3})^2}{(121.5{\rm GeV})^2} = 29.12\ {\rm keV}$$

$$(E_{c\rm I}\ )_{max} = \frac{2\cdot(100{\rm GeV})^2 118.6{\rm GeV}(10^{-3})^2}{(218.6{\rm GeV})^2} = 45.39\ {\rm keV}$$

The typical range targeted to search for WIMP signals is of tens of keV, mostly below 100 keV.

B9. The WIMP velocity in the galactic frame v_{Wg} follows a a Maxwellian distribution:

$$f(\vec{v}_{Wg})\ d\vec{v}_{Wg} = A\ e^{-\frac{v_{Wg}^2}{v_0^2}}\ d\vec{v}_{Wg}$$

$$1 = \int_0^\infty A\ v_{Wg}^2 e^{-\frac{v_{Wg}^2}{v_0^2}}\ 4\pi\ dv_{Wg} \Rightarrow A = \pi^{-3/2} v_0^{-3}$$

Using the root mean squared velocity v_{rms}:

$$v_{rms}^2 = \left\langle v_{Wg}^2 \right\rangle = \int_0^\infty A\ v_{Wg}^4 e^{-\frac{v_{Wg}^2}{v_0^2}}\ 4\pi\ dv_{Wg} = 4\pi\ A \frac{3\sqrt{\pi}}{8} v_0^5$$

$$v_{rms} = \sqrt{\left\langle v_{Wg}^2 \right\rangle} = \sqrt{\frac{3\pi\sqrt{\pi}}{2} \frac{v_0^{-3}}{\pi^{3/2} v_0^5}} = \sqrt{\frac{3}{2}} v_0$$

$$v_0 = \sqrt{\frac{2}{3}} v_{rms} = \sqrt{\frac{2}{3}} 270\ \ \text{km/s} = 220\ \ \text{km/s},$$

while the mean value for the velocities of the WIMPs in the galactic halo system is:

$$\left\langle v_{Wg} \right\rangle = \int_0^\infty A\ v_{Wg}^3 e^{-\frac{v_{Wg}^2}{v_0^2}}\ 4\pi\ dv_{Wg} = 4\pi A \frac{v_0^4}{2} = 2\frac{v_0}{\sqrt{\pi}} = 248\ \text{km/s}$$

B10. The WIMP-Sun relative velocity is

$$\vec{v}_{WS} = \vec{v}_{Wg} - \vec{v}_S \tag{8}$$

We calculate the average of the modulus $\langle|\vec{v}_{WS}|\rangle$, following the distribution of v_{Wg} analysed in B9.

$$\begin{aligned}
\langle|\vec{v}_{WS}|\rangle = &\int A|\vec{v}_{Wg} - \vec{v}_S| e^{-\frac{v_{Wg}^2}{v_0^2}}\ d\vec{v}_{Wg} = A \int |\vec{v}_{WS}| e^{-\frac{(\vec{v}_{WS}+\vec{v}_S)^2}{v_0^2}}\ d\vec{v}_{WS} \\
=&A \int |\vec{v}_{WS}|^3 e^{-\frac{v_{WS}^2+v_S^2+2v_{WS}v_S\cos\theta}{v_0^2}} 2\pi\ d\cos\theta\ dv_{WS} \\
=&2\ A\ \pi\ \frac{v_0^2}{v_S}\ e^{-\frac{v_S^2}{v_0^2}} \int v_{WS}^2\ e^{-\frac{v_{WS}^2}{v_0^2}} \cosh\left(\frac{2v_{WS}v_S}{v_0^2}\right)\ dv_{WS} = \frac{v_0^2}{2v_S}\ \left(1 + 2\frac{v_S^2}{v_0^2}\right)
\end{aligned}$$

$$\langle|\vec{v}_{WS}|\rangle = 335\ \text{km/s} \tag{9}$$

B11. The probability that a WIMP interacts with a nucleus, the interaction cross-section, σ, is unknown and strongly dependent on the WIMP model details, but it has to be very low because over decades, experiments do not see these interactions. Very sensitive detectors, well shielded from environmental and cosmic radiation, are looking for these interactions, providing up to present only upper limits on those cross sections. The flux of WIMPs arriving to our detectors, number of WIMPs per unit of time and area, can be expressed as:

$$j_W = \frac{\rho_{DM}}{m_W} v_{WS}$$

We can calculate the number of interactions per unit of time produced by a beam of particles with constant velocity arriving to the detector by multiplying the number of target nuclei by the probability of one interaction and the flux of particles:

$$N_{int} = j_W \sigma_{WN} N_N = \frac{\rho_{DM}}{m_W} v_{WS} \sigma_{WN} N_N \tag{10}$$

The number of WIMPs arriving to the detector depends strongly on the WIMP mass, which is unknown. Using the results obtained before in Eq. (7) and Eq. (9), and considering that ANAIS detectors have 12.5 kg mass:

$$N_{int} = \frac{0.8 \cdot 0.5\ \mathrm{GeV/cm}^3}{m_W}\ 335\ \mathrm{km/s}\ 10^{-12}\ \mathrm{barn}\ \mathrm{N}_A = \frac{6.7\ 10^{-4}}{m_W(\mathrm{GeV})} \mathrm{s}^{-1} = 58.06/(m_W(\mathrm{GeV}))\mathrm{d}^{-1}$$

B12. ANAIS studies the annual modulation expected in the interaction rate of WIMPs as result of the motion of the Earth around the Sun.

The Earth velocity in the galactic reference system can be written as:

$$\vec{v}_{Eg}(t) = \vec{v}_S + \vec{v}_{ES}(t)$$

and then, the WIMP-Earth velocity:

$$\vec{v}_{WE}(t) = \vec{v}_{Wg} - \vec{v}_{Eg}(t) = \vec{v}_{Wg} - \vec{v}_S - \vec{v}_{ES}(t) = \vec{v}_{WS} - \vec{v}_{ES}(t)$$

$$|\vec{v}_{WE}(t)| = \sqrt{\vec{v}_{WS}^2 + \vec{v}_{ES}^2 - 2\vec{v}_{WS} \cdot \vec{v}_{ES}},$$

which can be approximated as

$$|\vec{v}_{WE}(t)| \approx |\vec{v}_{WS}| \left(1 - \frac{\vec{v}_{WS} \cdot \vec{v}_{ES}}{\vec{v}_{WS}^2} + \frac{v_{ES}^2}{2\vec{v}_{WS}^2}\right) \approx |\vec{v}_{WS}| \left(1 - \frac{\vec{v}_{WS}^2 \cdot \vec{v}_{ES}}{\vec{v}_{WS}^2}\right)$$

because $\frac{v_{ES}^2}{2\vec{v}_{WS}^2} = 0.004 \ll 1$.

To account for the annual modulation due to the rotation of the Earth around the Sun, we can average over WIMP velocities. Then we can replace

$$\vec{v}_{WS} \to -\langle|\vec{v}_{WS}|\rangle \frac{\vec{v}_S}{v_S}, \quad \text{hence,} \quad \frac{\vec{v}_{WS}\cdot\vec{v}_{ES}}{\vec{v}_{WS}^2} = -\frac{\vec{v}_S\cdot\vec{v}_{ES}}{v_S\ \langle|\vec{v}_{WS}|\rangle} = \frac{v_{ES}}{\langle|\vec{v}_{WS}|\rangle}\cos 60^\circ \cos\omega(t-t_0)$$

Where we took into account that the Sun velocity makes a 60° angle with the galactic plane, while the Earth rotates with angular velocity ω around it, so that t_0 is the moment when the projection of the Sun velocity on the ecliptic plane and the Erth velocity are parallel. All this leads to a WIMP-Earth velocity

$$|\vec{v}_{WE}(t)| \approx \langle|\vec{v}_{WS}|\rangle + v_{ES}\cos 60^\circ \cos\omega(t-t_0) \approx \langle|\vec{v}_{WS}|\rangle\ \ (1 + 0.045\cos\omega(t-t_0))$$

Finally, Eq.(10) becomes:

$$\begin{aligned} R_{int}(t) &= \frac{\rho_{DM}}{m_W}\,\sigma_{WN}\ N_N\langle|\vec{v}_{WS}|\rangle\,(1+0.045\cos\omega(t-t_0)) \\ &= \frac{58.06}{m_W\ (\text{GeV})}\ d^{-1}(1+0.0045\cos\omega(t-t_0)) \end{aligned}$$

ANAIS-112 is an experiment searching for dark matter at the Canfranc Underground Laboratory, under the Spanish Pyrenees. ANAIS is one of many efforts in the world devoted to unravelling the nature of the dark matter required to explain the dynamics of the galaxies and clusters of galaxies, and understand the evolution of the Universe, from the anisotropies in the cosmic microwave background to the large-scale structures. ANAIS-112 consists of 112.5 kg of NaI(Tl) detectors well protected against environmental radioactivity and cosmic radiation and aims at observing the annual modulation in the detection rate which is expected in the dark matter signal. The detector is moving with the Earth, accompanying the Sun while travelling through the Milky Way's dark halo. The corresponding relative motion would produce a wind of dark matter crossing the detector, which should show such a modulation due to the motion of the Earth around the Sun. One experiment in the Italian Gran Sasso National Laboratory, DAMA/LIBRA, has observed such a modulation for more than 20 annual cycles. However, other experiments do not observe any hint of dark matter particle interactions. ANAIS-112 would bring some light into this puzzle, trying to reproduce DAMA/LIBRA experiment and then, either to confirm or refute the modulation observation.