# 1 Inspiration

I was always interested in science and astrophysics, but I did not know what that might entail doing as a career. Before I got into college, I wanted to experience what a scientist would do. This was one reason I choose to go to my high school, because they offered a research program that would help foster skills related to understanding, conducting, and presenting scientific work. I started searching for a mentor after I joined the research track and found Dr. Thomas Paul at Lehman College, which was right down the street from my high school. This allowed for an easy commute so that I could talk to him after school a few times a week. He was associated with the EUSO collaboration, and the first few meetings were dedicated to finding an area in the collaboration that could be improved on and that I found interesting. Since cosmic rays had been studied in incredible detail and the main focus of the collaboration was on the detection of these high energy events, I choose to focus on an area that was a secondary goal and much less developed. This new research was at the forefront of particle physics, but I was attempting to detect them traveling through space. This intersection of astrophysics and particle physics into Astroparticle Physics opened a whole new door to me. I was completely fascinated and continued research into the theoretical physics attempting to explain our universe and what they predict.

The project did not require me to learn a lot more math, but as I learned it on my own separately, I was able to get a more complete idea of the project. As for science, I was able to gain a more visual representation of how objects work in the realm of physics as I imagined each stage of the process. Computer science in this project pushed me to learn more languages and work through lots of code written previously by other researchers. I would wholeheartedly recommend others to partake in a similar project and never be afraid to put themselves out there as it can give you wonderful opportunities and experiences in areas you are exploring or those which you might not have pictured yourself in. STEM in general pushes people to problem solve making research something everyone should try no matter what they end up doing.

# Atmospheric Fluorescence Detection of Subluminal Objects

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## Abstract

Meteorites and a multitude of theoretical particles are detectable with observatories above the atmosphere. Using a simulation and reconstruction of each event, velocity was added as a new degree of freedom to account for more than just ultra-high-energy cosmic rays in the Extreme Universe Space Observatory (EUSO) collaboration. In addition, preliminary data taken by EUSO-Super Pressure Balloon (EUSO-SPB) was analyzed to put limits on the fluxes of meteorites and candidates for particles. This analysis was extended to predict limits that will be obtained by mini-EUSO, which will launch in 2018 and attach to the International Space Station. Meteorite accretion on Earth was also calculated based on current models and compared to new observations from ground-based and orbiting observatories. Nuclearites, Q-Balls, and magnetic monopoles are taken into account for possible detection, with limitations on their mass and flux based on observation as well as limitations on their likelihood of being dark matter. This space-based atmospheric detection would utilize the large detector that is our atmosphere to gain more limitations on any candidates quicker than current direct detection experiments and could measure fainter signatures of particles that interact at higher altitudes.

# 2 Introduction

Our understanding of particle physics began with atmospheric studies. Victor Hess' balloon flights in 1911 kicked off this revolution when he discovered a new type of radiation [1]. By distinguishing ground radiation and extrasolar radiation, mainly from the sun, the new field of astroparticle physics was created. As detectors increased in their capabilities, individual cosmic ray showers could be spotted by coupling Geiger counters and cameras to photograph a cloud chamber [2]. This method allowed the observation of different components of cosmic rays. Within these components, new particles such as the muon, positron, and a multitude of particles with strange quarks. However, as man-made accelerators became more powerful, the focus turned to these controlled environments that could be studied in more depth. As accelerators reach their limits, it is imperative to look to the universe in order to find more exotic phenomena and remember that cosmic rays are not the only particles in the universe that pass through the atmosphere.

The search for cosmic rays has focused almost solely on close to light speed particles and in turn, has neglected a search for other particles. With the Extreme Universe Space Observatory (EUSO), the first collaboration to search for cosmic rays from above, as well as more proposed experiments such as the Probe of Extreme Multi-Messenger Astrophysics (POEMMA), other phenomena can be studied at higher altitudes. The higher altitude allows detectors to get above the distortion caused by layers of the atmosphere, allowing dimmer emissions to be seen. This helps especially with searches for theoretical particles and meteors. Meteors specifically micrometeorites start to burn up in the upper atmosphere, which would be closer to any detector in space than on earth, allowing smaller particles accreting onto the earth to be studied. Theoretical particles are also better studied from space as larger particles can act similarly to micrometeorites in energy loss. By achieving a higher altitude, the detector will also be able to observe a larger volume of atmosphere, increasing the possibility of observing rare events [3]. Dark matter particles could possibly also be observed by these detectors as they cover large areas and if something such as a Weakly Interacting Massive Particle (WIMP) passed through the earth and then traveled upward it could be better observed.

Observations of any type of subluminal object will vary with the time of year and day. As the earth heads into the galactic disk, from the spring to the fall, there will be an increase in the velocity of particles coming from the galactic disk and from fall to spring there will be a decreased velocity. There will also be peaks in the number of particles from the galactic disk during March as the sun's gravitational field focuses the particles to Earth [4]. The night-day cycle will also play a large role in both galactic particles and solar system objects. Any time one side of the earth is facing away from the stream of the galactic disk, there is a possibility of detecting cold particles that collide after they traverse the earth. The times facing directly into the galactic stream would vary at different times of the year as the earth orbits. Solar System objects would have a more precise timing as the maximum flux would be during the morning as the earth travels through the solar system while the side of the earth during the evening would be facing away from the stream. The frequency of any particles detected will help identify them as well as their speed.

Objects to be traveling at much slower speeds around solar system speeds ranging from 20 km/s to 70 km/s ($\beta = 10^{-4}$) include meteorites and micrometeorites. As of now, less than 1% of the Earth's surface is covered in detectors sensitive to meteors, with the proposed JEM-EUSO, this percentage would increase. At any one time, 0.1% of Earth could be monitored and 98% would be surveyed from the International Space Station (ISS). The detection of meteors would be a common event due to their high frequency and the atoms in the path would likely excite releasing UV light while the meteor itself is likely to emit infrared light to visible depending on its temperature.

Objects proposed to be traveling at galactic speeds around 300 km/s ($\beta = 10^{-3}$) include Nuclearites, Q-Balls, and Magnetic Monopoles. Previous studies for these particles such as AMS-02, MACRO, Superconducting Detectors, or IceCube measure relatively small volumes. These particles are more likely to be detected with the large volume of atmosphere being observed in air based detectors.

The theoretical search for more stable particles utilized the MIT Bag Model leading to the suggestion of nuclearites also known as strangelets or nuggets of Strange Quark Matter (SQM), a combination of equal parts up, down, and strange quarks. If these particles do exist, they are hypothesized to form in strange stars [5]. Strange stars are the remnants of massive stars, in which the core itself collapses from neutron stars into an even denser material [6]. Other theories suggest there are trace amounts of strangelets from the quark epoch [7] that possibly convert all matter it encounters into strangelets [8]. The vastly different proposals for when and where nuclearites are formed contributes to the uncertainty in the mass of the particle from atomic sizes to stellar sizes but the density stays constant at $3.5 \times 10^{14}\,\mathrm{g\,cm^{-3}}$ [9].

Q-Balls were proposed as a solution to a stable bosonic particle that was resistant to fission because of their low energy configuration. If these particles were, in fact, more stable than nickel-62, some suggestions propose these can be found in ultra compressed stars or quark stars, cousins of the white dwarf and neutron star. Nuclearites and Q-Balls have also been suggested as dark matter candidates [10] due to how massive they could be and their unusual subatomic makeup that might make them virtually invisible to telescopes.

Magnetic Monopoles have been proposed centuries ago as single poles instead of the dual pole found naturally. These monopoles have popped up as solutions to Maxwell's equations. Initially, these solutions were seen as mathematical flukes and not particles, but Dirac pushed this idea and found charge quantization is sometimes also allowed in quantum mechanics and helped explain electric quantization. Later, it was shown magnetic monopoles were predicted by many particles in Grand Unified Theories and Theories of Everything. The energies required for magnetic monopoles is incredible but the detection of one would help confirm theoretical predictions of these theories but disproving their existence will not necessarily lead to the demise of these theories [11]. As of now, accelerators cannot reach the required energies, but cosmic phenomena could plausibly reach them and given the right trajectories they could be detected with atmospheric telescopes.

While searching for these particles, it is incredibly difficult to distinguish each phenomenon. Meteors can be more easily separated out by their speed, but they can still be mistaken for theoretical particles which are within an order of magnitude of their speed.

The energy losses from each source can be completely different, especially for theoretical particles, which interact with matter differently and therefore have varying energy loss formulae. Meteors and SQM interact in the same manner, particle collisions that have an ionizing effect for air particles with occasional head-on collisions that could cause the object to fragment [12, 13].

The energy loss through this interaction can be modeled with

$$\frac{\mathrm{d}E}{\mathrm{d}x} = -A\rho v^2 \tag{1}$$

where A is the cross-sectional area of the SQM, $\rho$ is the density of the medium the particle traverses, and v is the velocity of the particle.

There are two types of Q-Balls: SECS (Supersymmetric Electrically Charged Solitons) and SENS (Supersymmetric Electrically Neutral Solitons). While they both can be considered Q-Balls, they differ in their nature with interactions with matter and therefore their detections will be different especially with energy losses [14]. SECS exhibit U(1) symmetry breaking, this leads to the formation of a superconductor and pushes the charge to the surface [15]. The charge can be neutralized if there is an electron cloud, however this feature is largely absent on Q-Balls of galactic speeds. SECSs have two paths to loose energy by, electric loses and nuclear loses. Electric energy loss can be caused by the interaction of electron clouds of the traversed medium and its own charge, modeled by:

$$\frac{dE}{dx} = \frac{8\pi a_0 e^2 \beta}{\alpha} \frac{Z_Q^{7/6} N_e}{(Z_Q^{2/3} + Z^{2/3})^{3/2}} \text{ For } Z_Q \geq 1 \tag{2}$$

$a_0$ is the Bohr radius, $\alpha$ is the fine structure constant, $\beta = v/c$, $Z_Q$ is the positive charge of SECS, $Z$ is the atomic number of the medium and $N_e$ is the density of electrons in the medium. SECS energy loss due to nuclear collision can be modeled by:

$$\frac{dE}{dx} = \frac{\pi \alpha^2 \gamma N E}{\varepsilon} S_n(\varepsilon) \tag{3}$$

Where $S_n(\varepsilon) \simeq \frac{0.56 ln(1.2\varepsilon)}{1.2\varepsilon - (1.2\varepsilon)^{-0.63}}$, $\varepsilon = \frac{aME}{Z_Q Z e^2 M_Q}$, $a = \frac{0.885 a_0}{(\sqrt{Z_Q} + \sqrt{Z_Q})^{2/3}}$, $\gamma = \frac{4M}{M_Q}$. $MQ$ is the mass of the incident Q-ball; $M$ is the mass of the target nucleus; $Z_Q e$ and $Ze$ are their electric charges; a is the screening radius and $a_0$ is the Bohr radius; it is assumed that $MQ \gg M^3$. The two energy loss equations must be added to calculate the total, but electric energy loss will dominate in the case of $\beta > 10^{-4}$, which should be the case if Q-Balls are dispersed in the galaxy so that the solar system moves into these particles.

SENS exhibits different energy loss behavior due to a layer underneath the surface where quark masses are less than $\Lambda_{QCD}$ and SU(3) is broken by vacuum expectation value of squarks [16]. When nuclei collide with this condensate, they dissociate into quarks through the process $qq \rightarrow \widetilde{q}\widetilde{q}$. Each nucleon in that nuclei will yield approximately 1 GeV that will be released in pions and occasionally kaons that will carry the charge of the dissociated quarks. For SENSs $10^{-4} < \beta < 10^{-2}$, the energy loss is constant and can be modeled by the set of equations:

$$\sigma = \pi R_Q^2 = \frac{16\pi^2}{9} M_Q^{-2} Q^2 \sim 6 \times 10^{-34} M_S^{-2} Q^{1/2} \ \text{TeV}^2\text{cm}^2 \tag{4}$$

where $\sigma$ is the cross section of the Q-Ball, $R_Q$ is the radius of the Q-Ball, $M_S^4$ is a constant in SUSY theory, and $Q$ is the Q-Ball number.

$$\lambda = \frac{1}{\sigma n} \tag{5}$$

where $\lambda$ is the mean free path and $n$ is the number of atoms per cm$^3$ in a medium.

$$\frac{dE}{dx} \sim \frac{\zeta}{\lambda} = \sigma n \zeta \sim 6 \times 10^{-34} Q^{1/2} n \zeta \tag{6}$$

where $\zeta = 1$ GeV. This energy loss is entirely due to nuclear collision where the Q-Ball absorbs the quarks.

Magnetic Monopoles can be sorted out from other particles because of their stability. This stability and charge allow the magnetic monopole to possibly initiate a shower through ionization or the fragmentation of other particles and then continuing to travel without decaying [17]. Detectors are therefore not limited to observing particles traveling down, but also upwards. Due to this, there is a larger range of masses that the super pressure balloon would have detected.

# 3 Detectors

The Extreme Universe Space Observatory (EUSO) collaboration works on the detection, reconstruction, and simulation of cosmic rays. Japanese Experiment Module EUSO (JEM-EUSO) would be the first long-term experiment to solely look down at the earth in the UV portion of the spectrum. As of now, there are 2 ground-based observatories put in place to detect cosmic rays, the Pierre Auger Observatory and Telescope Array EUSO (TA-EUSO). The Pierre Auger Observatory uses 1,660 ground-based detectors and 27 telescopes to determine the composition of the particle and is part of a separate project. TA-EUSO is located in Utah and also has ground-based detection in coordination with 3 fluorescence telescopes to cover an area of 700 $\text{km}^2$, [18] this project is part of the EUSO collaboration and uses a similar telescope to the design of the final space-based one. TA-EUSO uses two Fresnel lenses to focus the light, which creates a slightly fuzzier image than the final telescope, which will have two Fresnel lenses and a convex lens.

To test the concept of reconstruction and detection of showers while looking down at earth, a test flight in 2014 was done. The test flight balloon was sent up with only Fresnel lenses and prototype photodetector module. In the span of a few hours, the balloon flew at around 40 km pointing directly down to monitor an area of 50 $\text{km}^2$. The scaled down version of the optics measured a field of view of $12^\circ \times 12^\circ$ and took $400,000$ frames a second in the 290 nm to 430 nm range [19]. No naturally occurring events were recorded in that time, but a helicopter flew below the balloon and shot lasers within the UV range at different energies to calibrate the instruments and test the detection and reconstruction.

With the TA-EUSO field test of the instrumentation and programming, work on a follow-up telescope test was designed to record cosmic ray showers. The Super Pressure Balloon EUSO (SPB-EUSO) launched in March 2017 out of New Zealand and stayed up for 12.1 days while it flew over the Pacific Ocean. The instrument used on the SPB-EUSO flight was similar to the test balloon flight, but the electronics and the focal surface was improved [20].

With the completion of this flight, NASA will likely give the go-ahead to launch mini-EUSO which is just a miniature version of JEM-EUSO which should be attached to the ISS in 2018. Mini-EUSO will orbit approximately 400 km above the surface with a field of view of $40^\circ \times 40^\circ$ and have the same gate time unit of 2.5 µs as the EUSO collaborations previous detectors [3].

## 4 Simulations and Reconstruction

The code to analyze the frames and reconstruct the showers is a centralized system that can be applied to all of the project's telescopes with minor adjustments. This central framework called the Offline can be worked on separately and uploaded once work on a section is complete. The

Offline is programmed mainly in C++ and both simulates and reconstructs events based on the run controller, which sequences the modules. To test the aspects of each module, they can be swapped out and simulations of laser shots or showers can be produced. From the initiation of an event, whether it be a detected event, simulated laser shot, or simulated shower, the information is stored in the event data model. From there, a run controller dependent on the telescope being used is activated which holds the modules for each step in the reconstruction process. The modules all perform their specific task but they communicate with each other, getting information calculated in other parts through the Event, which holds the navigation needed to access different parts. Once all the modules are finished running, the shower should be dissected into numbers, which determine everything from its angle, energy, and distance away from the telescope.

As of now, the collaboration was only focusing on cosmic ray detection and reconstruction. One overarching goal was to analyze UV emissions traveling slower than the speed of light. To expand the type of research to include particles moving at slower speeds than the speed of light would open up the possibility of detecting particles traveling at galactic velocities as well as particles that the earth encounters on its orbit around the sun. Although each particle or object has a unique set of features that could help identify it without knowing the speed, it becomes much easier to record these events if a light curve can be drawn to match the detected data. A light curve is created by the equation:

$$t_i^{exp} = T_0 + \frac{RP}{c} tan(\frac{x_0 - X_i}{2}) \tag{7}$$

where $t_i^{exp}$ is the expected time for the particle to be at a certain angle, $X_i$ in the telescope's field of view, $T_0$ is the time when the event started, $Rp$ is the distance of the event from the telescope, and $X_0$ is the angle the event is from the ground. To determine the angle, distance, and initial time of the event required changing those values until the closest value to 0 was reached. This process is repeated for each angle and time so that the 3 parameters have the best fit to the curve observed. This fitting process is done with the equation:

$$x_{fl}^2 = \sum_i \frac{(t_i - t_i^{exp})^2}{(t_i^{err})^2} \tag{8}$$

where $x_{fl}^2$ is the minimum value achieved when changing the 3 parameters, $t_i$ is the measured time when the particle was at a certain angle, $t_i^{exp}$ is the expected time (calculated above), and $t_i^{err}$ is the signal strength and centroid error.

As of now, only close to light speed particles can be measured due to the short amount of time each image is kept for before being discarded. Since the discarding process is based largely on light curves, slow-moving particles are not kept because they do not traverse the field of view in less than a millisecond. By rewriting the module to keeping more frames before disregarding them, there will be sure to be some slow-moving particles captured in full transit. To make sure the frames are then thrown out, equation 7 needs to replace an assumption with another variable. The term $c$ in equation 7 refers to the speed of a particle, but since only cosmic rays were being measured, their speeds were all relatively close to $c$. Unfortunately solving the equations above to produce a light curve for random numbers produce almost linear graphs which make it very difficult to fit three parameters, let alone four. The solution to this problem lies in how slow these particles are moving. When one compares a perfect light curve for the same set of values, changing only the speed, the slopes change dramatically. This dramatic change shows that while a particle traveling at nearly the speed of light traverses a $90^\circ$ field of view within less than 40 μs, it takes particles traveling at 270 km/s traverse the same distance in less than 37000 μs, and particles traveling at 20 km/s traverse the distance in less than 500000 μs. To include the fourth variable in this equation, I wrote the term as a variable with only three possible velocities, c, 200 km/s, and 20 km/s. These speeds measure high-energy cosmic rays, objects moving at galactic speeds (such as nuclearites), and micrometeorites respectively.

With one frame every gate time unit (GTU = 2.5 μs), the tracks of any slow moving objects would get captured in great detail, leading to light curves that are more precious. With these data points, the modification of equation 7 will only help capture the event, but there is work that can be done to determine how energetic these showers are, which can help determine a possible cause of the shower. Showers from particles at galactic speeds are probable, but not necessarily common. Using earth's atmosphere as a detector and looking down results in a larger field of view, which is helpful for detecting particles that have low flux. Unfortunately, any air-based observation would not have the benefit of ground-based water tanks to reconstruct the initial particle from the decayed particles that passed through the tanks. Although it would be easier to reconstruct the original particle like this, the likelihood of ground-based telescopes and scintillator surface detectors detecting these particles is unlikely because of the small area they cover and the large area needed to be traversed in the atmosphere. Luckily the EUSO Offline design allows the modifications to be implemented throughout the instruments so TA-EUSO and future air-based telescopes will be able to search for particles traveling slower than the speed of light.

Without any implementation, the tests of these modules have to come from simulated laser shots where the speed at which the laser travels is slowed to other velocities. When doing this, a light curve is also necessary to determine where the speed of the simulated lasers and showers are set. The lasers also need to be modified so that the track of the simulated showers widens as it goes further into the atmosphere because the particles the shower decays into will travel faster and emit fluorescence light. The reconstructions must also take this into account and not contribute the spread of fluorescence light to the energy of the particle.

If found, objects traveling at galactic velocities can signal any number of theoretical particles, which may be hard to distinguish. It will require a number of these particles to point back to a common source with certainty, but if an abundance is seen in the galactic plane, it may significantly put a limit on which particles they could be. The amount of energy detected could also help narrow down the list of candidates for these particles. Rather than detect many of these objects and determine their composition, it is far more likely this will put limits on any particles theorized to be traveling at galactic velocities with enough energy to make it detectable. It seems that many particles would not have enough energy to trigger the telescopes, but if there is one at this speed, it is far more likely to have been caused by matter-antimatter annihilations than kinetic energy.

Another mystery is micrometeorites, which also do not have a limit on the number of them that enter the atmosphere. It is thought that these extremely tiny bits of cosmic dust in the solar system will be much more visible at higher altitudes. It will be easier to determine the properties of a meteorite than any other fluorescence event because the size correlates to how far it will be able to penetrate the atmosphere before heating up to energies where it will radiate light and how long this will be able to occur. Implementation to detect for objects traveling at different speeds makes the EUSO collaboration able to solve multiple problems at once at a scale that has never been done previously.

# 5 Fluxes

To set limits for the fluxes of meteors and theoretical particles, the amount of time spent observing a certain area must be calculated. The pathfinder EUSO-SPB mission was launched as a proof of concept but unfortunately ended its mission early due to errors in the super pressure balloon. However, the data that was collected can still be analyzed to gain insight and further predict later missions. The area observed by EUSO-SPB is approximately $70\,\mathrm{km}^2$ and the data spans for 10 days. There was no collection of data during the day and when the moon was out as almost any observation would be impossible because of the energies needed. This leaves only about 30 hours the detector could have observed an event. After analysis of the data, there appear to be no events of cosmic rays, meteors, or theoretical particles. With no detected events, the flux of all of these is placed at $3.36 \times 10^{-15}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}$ as upper limits, however, these limits are for different masses.

The mini-EUSO mission is very similar to EUSO-SPB, but it has an updated system and will attach to the International Space Station in 2018. Due to its location and larger field of view, it will be able to observe an area of approximately $85000\,\mathrm{km}^2$. This yields a much larger volume and will decrease the time needed on a super pressure balloon to reach the same conclusions. Within a day, the flux on subluminal objects can be placed at $1.36 \times 10^{-18}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}$ as upper limits.

Events that pass within 10 km of EUSO-SPB and mini-EUSO and are magnitude +7 or less will activate the trigger. For a nuclearite event 10 km away, the visual magnitude is mass dependent, following the equation:

$$m = 10.8 - 1.67 log_{10}(M/1\,\mu\mathrm{g}) \tag{9}$$

This results in nuclearites with masses $M > 190\,\mu\mathrm{g}$ being visible from EUSO-SPB and mini-EUSO. Figure 1 compares the fluxes extracted from this experiment and future experiments compared to other searches for nuclearites.

Q-Balls can be limited with the same fluxes in figure 1 but they will have different limiting criteria. As Q-Balls traverse the atmosphere, they will give both a primary light yield due to its combined electric and nuclear energy loss and a secondary light yield from recoiling particles. For the purpose of atmospheric detection, the component of secondary light yield is considered to be negligible. The equation for light production of SECS is given by:

$$\frac{dL}{dx} = A\left[\frac{1}{1+AB\frac{dE}{dx}}\right]\frac{dE}{dx} \tag{10}$$

where $\frac{dE}{dx}$ is the combined energy loss of electric and nuclear in equations 2 and 6, A is the difference in energy due to electron loss, and B is the saturation point of the light yield from surrounding particles. In this equation, A and B are both velocity dependent and can be set according to galactic velocities of $\beta = 10^{-3}$ to $A = 0.067$ and $B = 0.66$ cm/MeV. For $Z_Q = 1$, light yield will be 1.51 GeV/cm.

## 6 Conclusion

Subluminal simulations were created to identify meteors and theoretical particles such as nuclearites, Q-Balls, and magnetic monopoles. Applying this simulation to observation can make detection of such objects easier and provide a more comprehensive analysis than previous reconstructions.

In the time this mission was active, the detector was able to accumulate 30 hours of data that could possibly have fluorescence events. After analysis, there were no certain candidates so new fluxes of $3.36 \times 10^{-15}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}$ were added to meteors, nuclearites, Q-Balls, and magnetic monopoles. Future telescopes with advanced detectors placed in the right locations may be able to set new fluxes or detect objects. JEM-EUSO, mini-EUSO, and POEMMA will cover a larger area and will be much higher than the super pressure balloon detector. While the possibility of theoretical particles is exciting, the theoretical calculation is not enough and experimentation must be the true test of validity.

To close with Faraday: ”Still examine it by a few experiments. Nothing is too wonderful to be true, if it be consistent with the laws of nature; and in such things as these, experiment is the best test of such consistency.”

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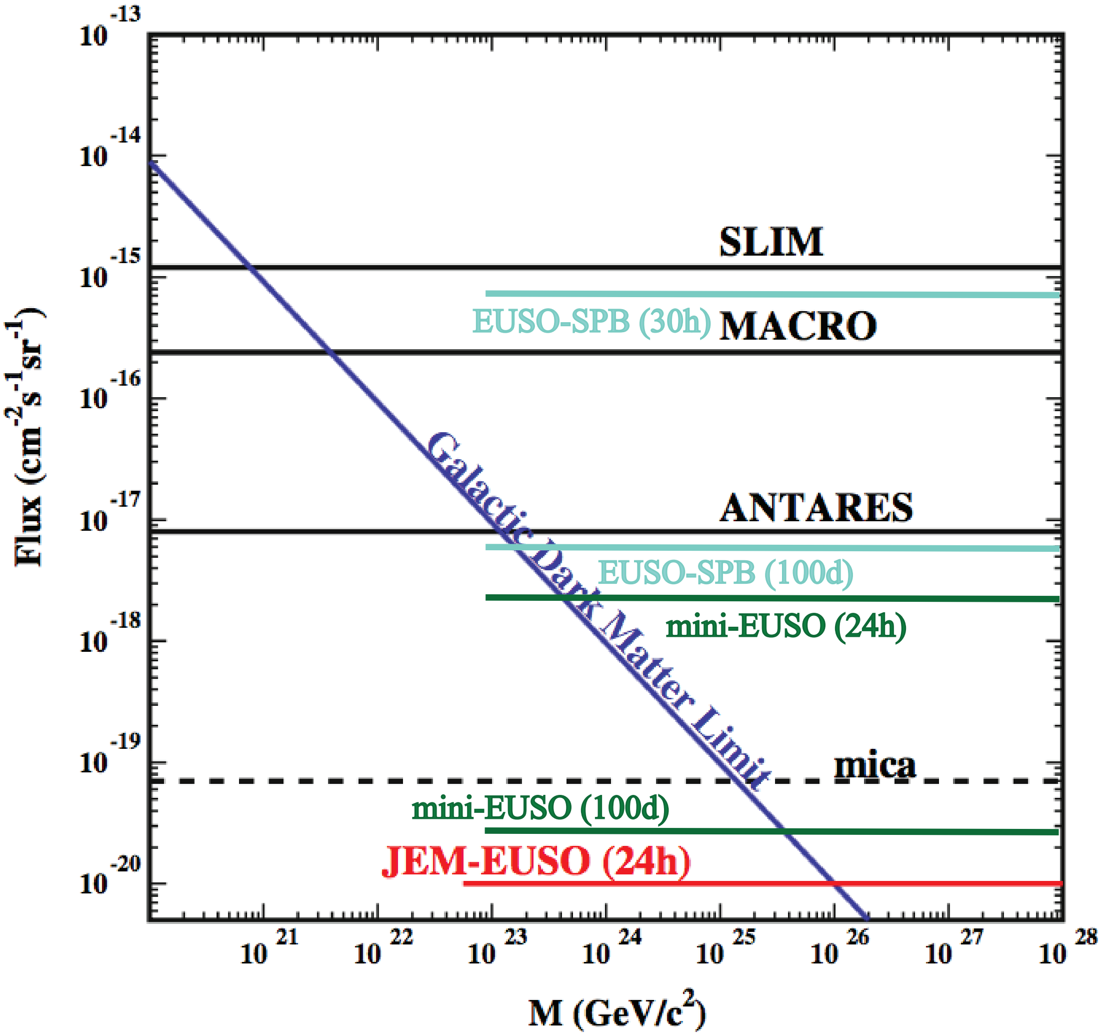

Figure 1: The fluxes for the 30 hour data collection of EUSO-SPB are included along with the fluxes for a 100 day period of data collection, which was originally proposed. Predictions for mini-EUSO's fluxes are included for 24 hours and 100 days. Included is the dark matter limits as well as fluxes from other experiments. [21, 22, 23, 24, 25]