Macro Dark Matter Experiments

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- We take a phenomenological approach and look for signs of macros if they did constitute a reasonable fraction of the Dark Matter.

Macro Paramater Space circa 2018

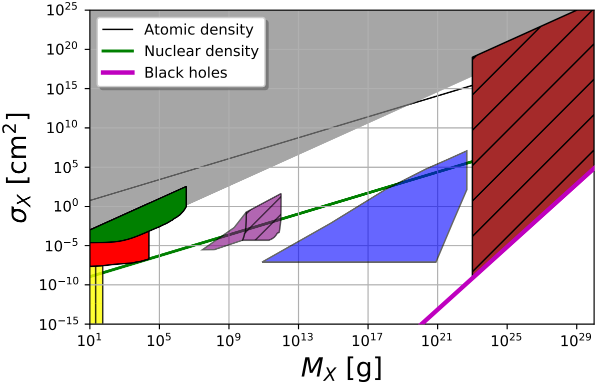

Figure: Constraints on macro parameter space. Lack of microlensing events in brown, Lack of bolides in green, CMB in grey, ancient mica in yellow, the continued existence of white dwarfs in blue, the period between back-to-back superbursts from 4U-1820-30 in purple and lack of peculiar human deaths in red.

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- We must understand the relevant energy scales in the problem, such as ionization energies, phase transition temperatures etc.

Fluorescence arXiv: 1808.06978

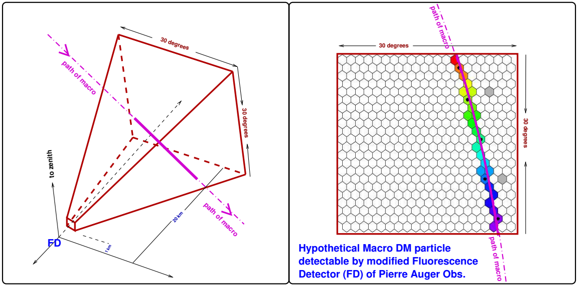

Figure: Conceptual diagram delineating the plausible detection of a macro dark matter particle by a modified version of a Fluorescence Detector (FD) such as that of the Pierre Auger Observatory.

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- We calculated the luminosity produced by the passage of a single macro as a function of σ_x.
- For two specific detectors, we then calculated the regions of parameter space that could be probed.

Macro Paramater Space that Can be probed by Auger and JEM-EUSO

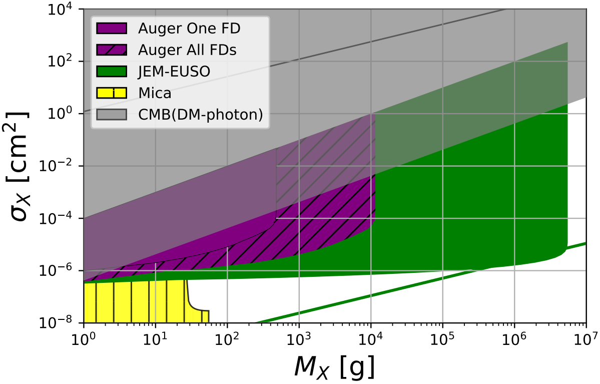

Figure: Region of parameter space that can be explored by Auger and JEM-EUSO

FD time binning changes

- Macros would move at 10^{-3} c, (c is the speed of ultra high energy cosmic rays). We will require modifications to the time binning mechanism. This is related to the time the object takes to cross the field of view of a pixel.

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- Using the ADC on the Zedboard development kit, we have successfully produced one pixel that is capable of detecting a passing macro. The next steps will include both scaling up and chronologically tracking the trajectory of the macro.

Bolides arXiv:1908.00557

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- From our work involving FDs we had understood this problem.
- We found that much denser objects of the same mass were constrained by this null result.

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- There are plans to expand the DFN as part of a global fireball network over the coming years.
- Assuming an expansion to 10 x the current area, and an observation for roughly 10 x longer than has been currently running, we estimate the parameter space that could be probed.

Constraints from a lack of extrasolar bolides

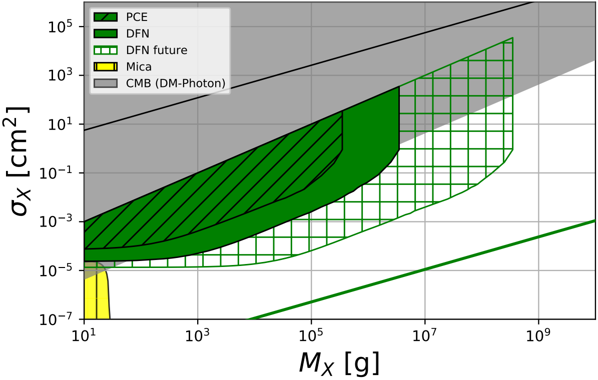

Figure: Constraints from the older network that is no longer active, the currently running DFN and projections based on the expected final size of the DFN.

Straight Lightning

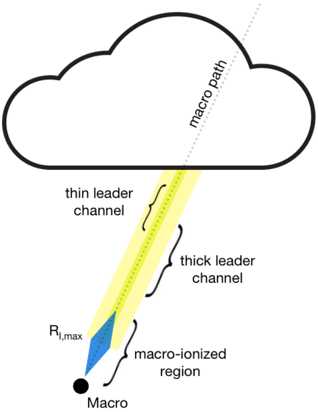

Figure: Schematic figure of ion channel formed by macro passage.

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- Macro induced plasma trail can mimic this behavior by forming channels for charge to move.
- These strikes would be very straight unlike any lightning ever seen.

Combined results

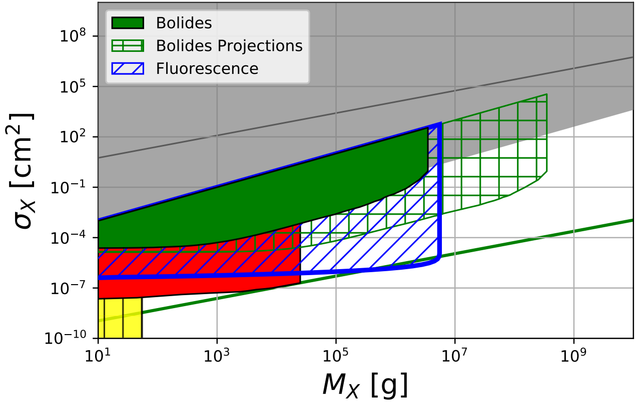

Figure: Combined projections and constraints for low mass macros.

Conclusions

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- An interesting corollary to the bolide parameter space estimation of the future parameter space that could be probed by the DFN is that on the scale of human lifetimes, it seems unlikely that macro masses beyond $\sim 10^{10}\,\mathrm{g}$ could be probed by any purpose built terrestrial detector.

Additional Material

Elastic vs. Inelastic Cross Sections

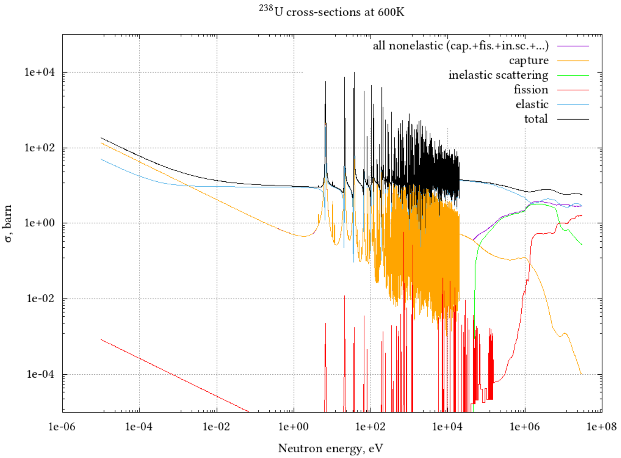

Figure: The microscopic cross-sections for the neutron reactions in uranium-238 at 600 K.