DARK PHOTONS FROM THE SUN
A NEW DARK MATTER SIGNAL FOR AMS

[work with Jordan Smolinsky and Philip Tanedo, 1602.01465]

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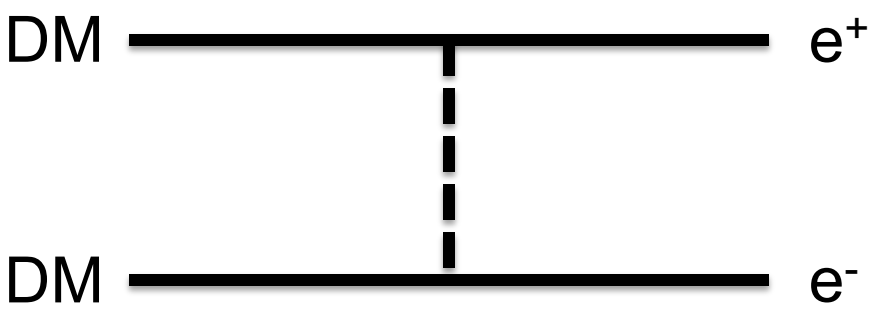
THE CONVENTIONAL DARK MATTER SIGNAL

- There is now overwhelming evidence for dark matter.
- A promising search method is indirect detection, particularly dark matter annihilating to positrons and detected by AMS:



- The signal is nearly isotropic, coming from the whole halo.
- Is there a smoking gun signal that makes better use of AMS's remarkable angular resolution?

AMS Days at CERN, 2015

DARK SECTOR

- Dark matter *X* may be part of a dark sector, with its own matter and forces.

- Consider a simple example, where the dark sector contains dark matter, but also a U(1) gauge interaction, "dark electromagnetism."

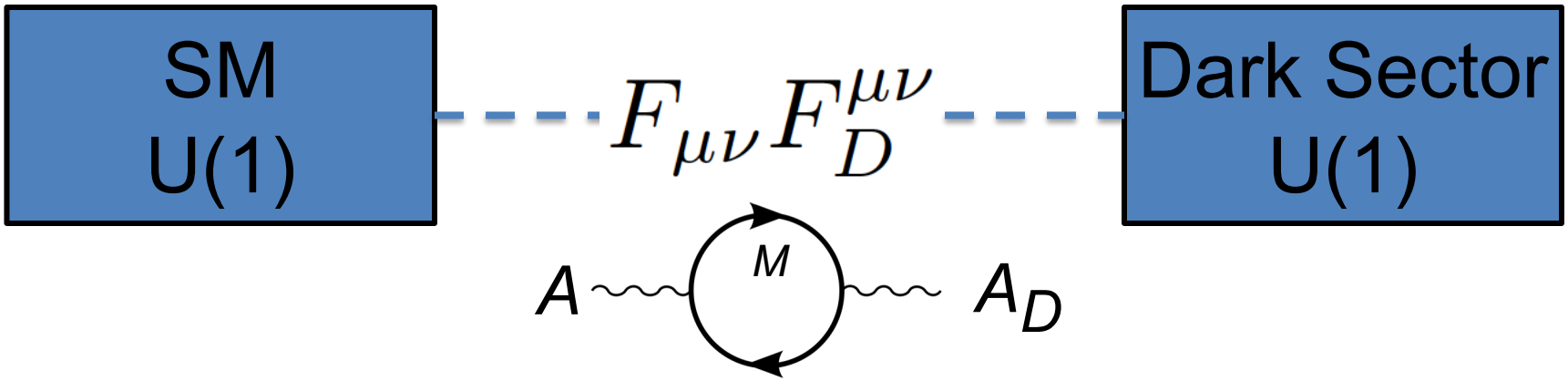
SM

Dark Sector
X, U(1)

SM-DARK SECTOR INTERACTIONS

- If the dark matter doesn't interact with us, then it only has gravitational signals.

- However, generically, there will be a mixing between our U(1) gauge boson A and the dark U(1) gauge boson A_D.



- This mixing will be generated by any matter field that has both standard model EM charge and dark EM charge.

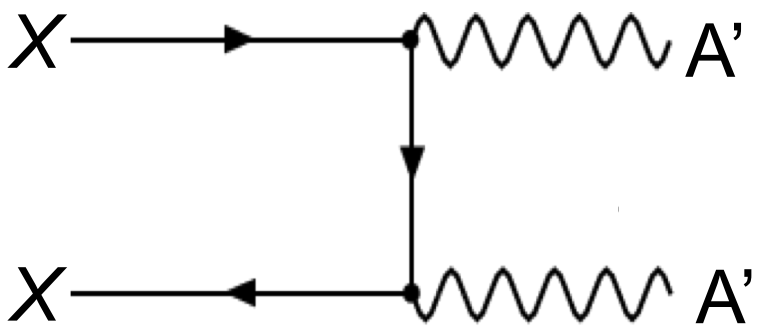
- It is typically small, since it is induced by a loop.

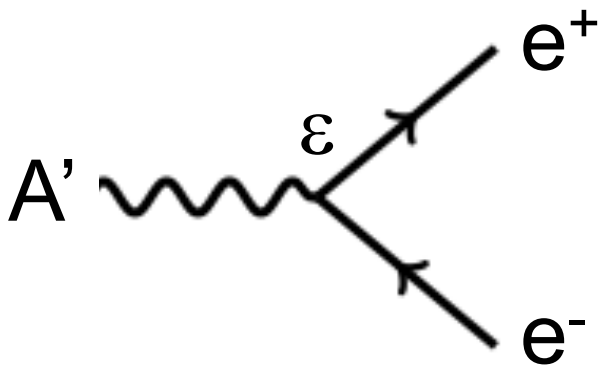
Okun (1982), Galison, Manohar (1984), Holdom (1986)

DARK PHOTONS

- We can re-define fields to remove the mixing. The result is two physical particles: our SM photon γ, and a new particle, the dark photon A'.

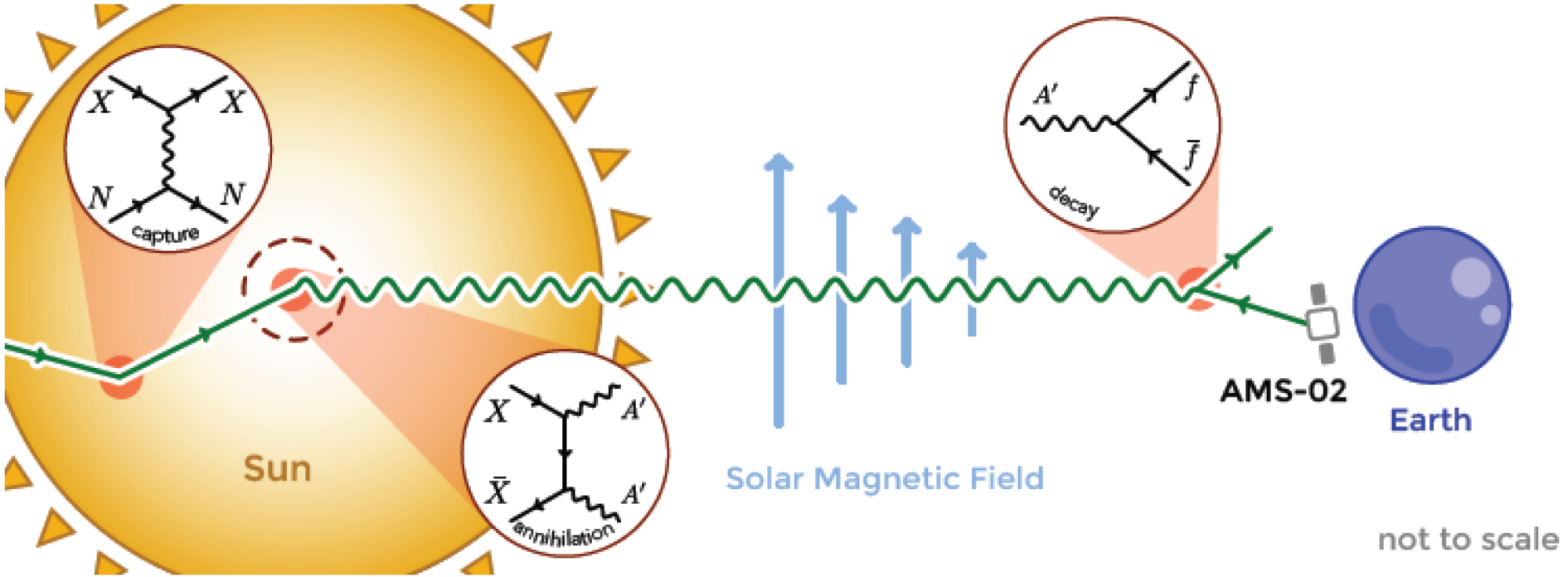
- The dark photon is like the SM photon, but
  - It can have a mass $m_{A'}$
  - Its coupling to dark sector particles is large
  - Its coupling to SM particles is suppressed by a small coupling ε





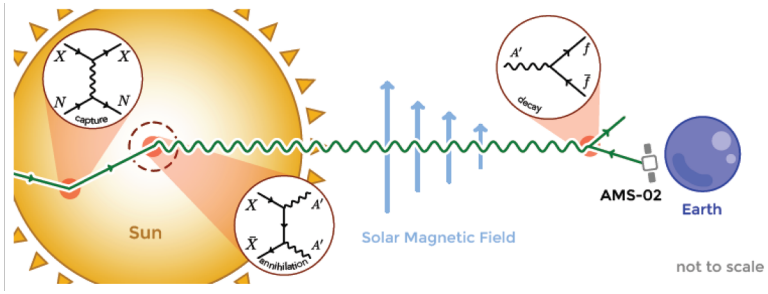
A NEW DARK MATTER SIGNAL

- In this dark matter model, dark matter collects in the Sun and then annihilates to dark photons ("dark sunshine").
- These can then travel out of the Sun and decay to e^+e^-.
- A new DM signal for AMS: high energy positrons from the Sun.



SIGNAL CHARACTERISTICS

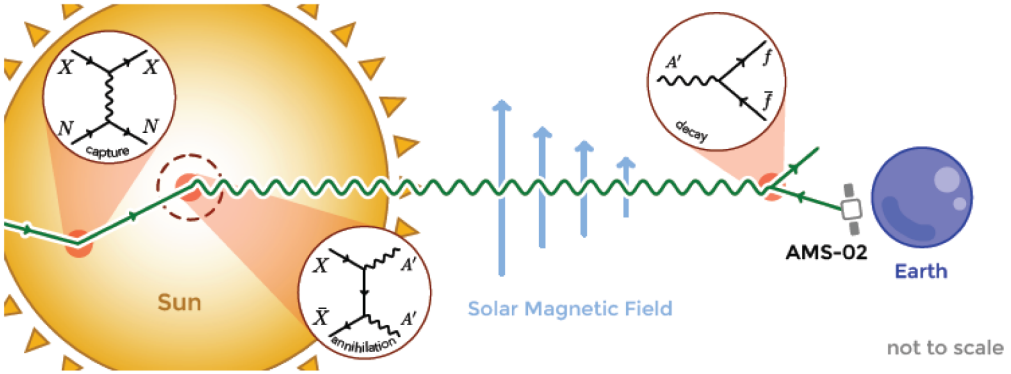
- We will consider parameters
  - Dark matter m_X ~ 100 GeV – 10 TeV
  - Dark photon $m_{A'}$ ~ MeV – GeV
  - Couplings $\varepsilon \sim 10^{-12} – 10^{-6}$

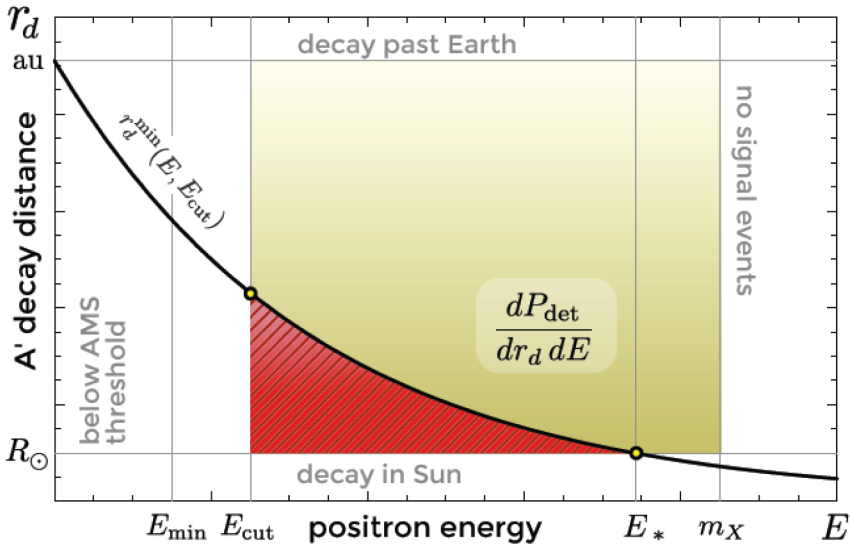


- The typical positron energy is ~100 GeV – 10 TeV
- The size of the DM population at the core of the Sun is ~1° .
- AMS's angular resolution: $\Delta\theta_{68} \simeq \sqrt{5.8^{\circ 2}/(E \text{ in GeV}) + 0.23^{\circ 2}}$ from ECAL (and even better with tracker); negligible.
- The signal is essentially a point source of TeV positrons from the center of the Sun. No background looks like this!

MAGNETIC FIELDS

- In more detail, TeV positrons are bent in the magnetic fields of the Sun and Earth.
- The Sun's magnetic field is not well understood. Conservatively, we can consider only dark photons that travel far enough before decaying.
- The Earth's magnetic field is well understood. Assume we can deconvolute for this effect. (But note, without deconvoluting, the signal will not appear point-like.)





ISOTROPIC BACKGROUND AND EXPOSURE

- The background isotropic positron flux from AMS is

$$\frac{d\Phi}{dE} \approx \frac{1.5 \times 10^{-9}}{\text{GeV cm}^2 \text{ sr s}} \left(\frac{E}{100 \text{ GeV}} \right)^{-2.8}$$

We consider an energy and angle window that fixes $N_{background} = 1$ and maximizes signal.

- Last, of course, the Sun is not always in AMS's field of view. In 924 days, the exposure for E > 50 GeV was

$$\xi_\odot \simeq 1.6 \times 10^5 \text{ m}^2 \text{ s}$$

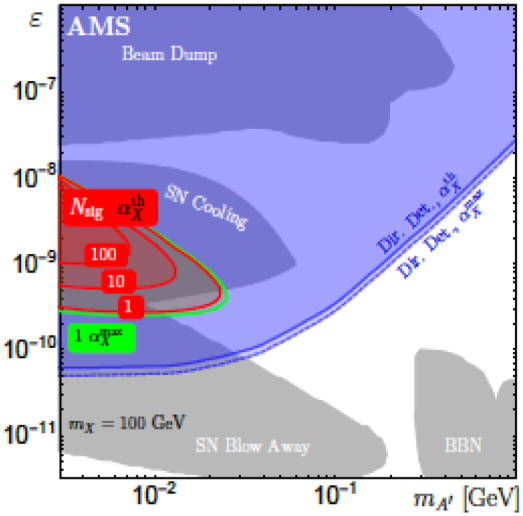
The effective area is ~20 cm^2, would be 80 times larger if AMS pointed at the Sun continuously.

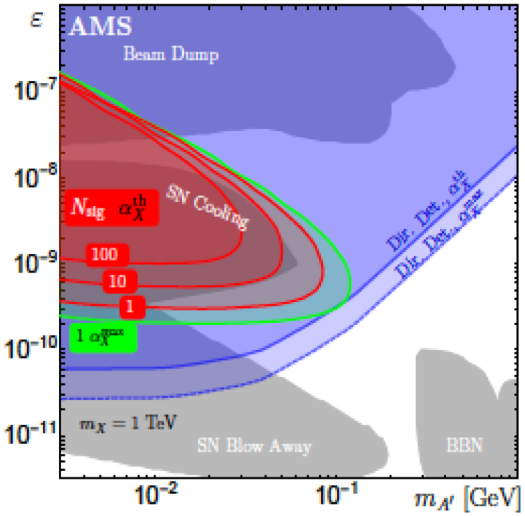
Machate, Gast, Schael for the AMS Collaboration (2016)

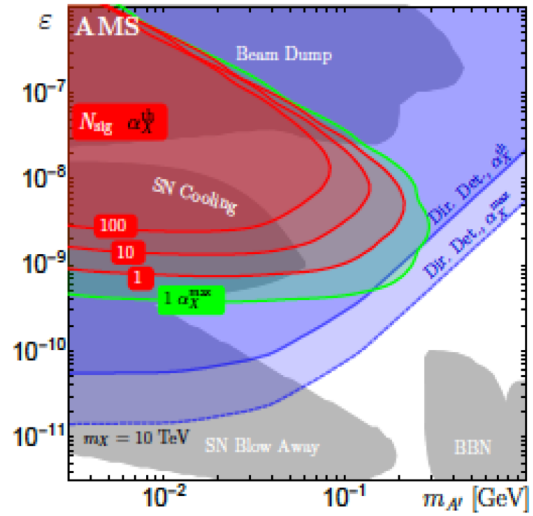
RESULTS

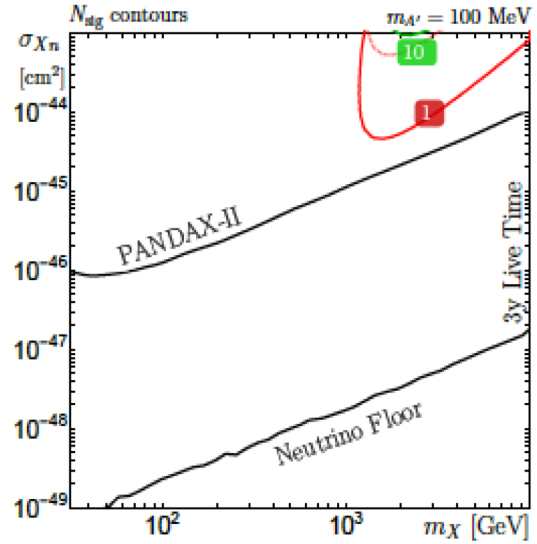
- For 3 years of AMS data, AMS probes new regions of parameter space beyond existing constraints.
- Direct detection constraints are competitive, but model-dependent.

Smolinsky, Tanedo, 1701.03168



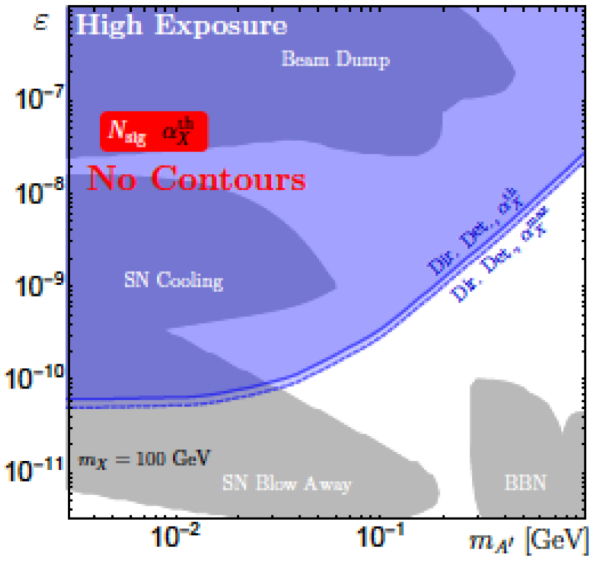


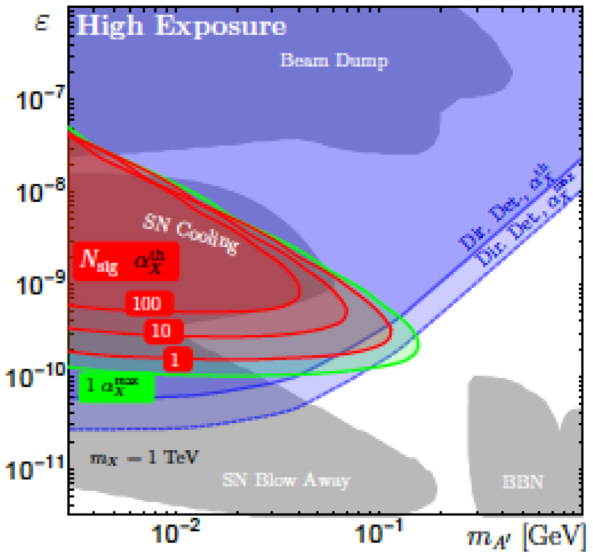


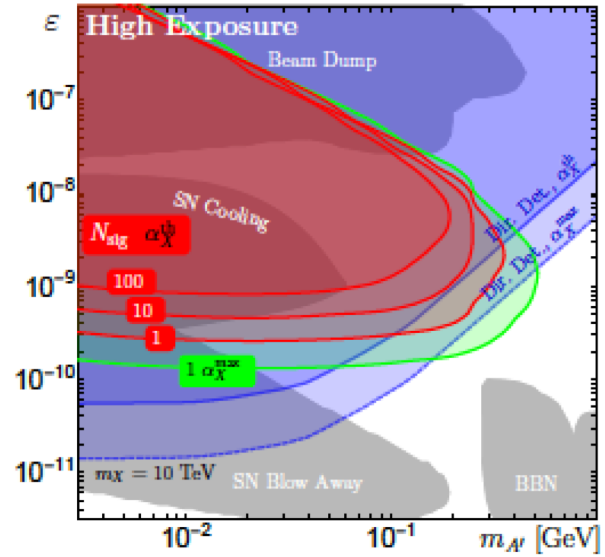


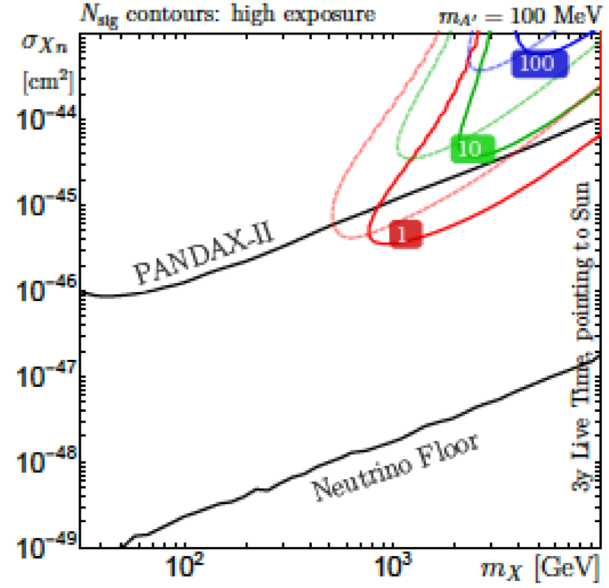
RESULTS

- Same as above, but for high exposure (80 times larger).
- All results can be greatly improved with knowledge of Sun's magnetic field.









CONCLUSIONS

- If dark matter is generalized to a dark sector with its own forces, many new dark matter signals are possible.
- For AMS, an interesting one is “dark sunshine,” dark photons from the Sun, which decay to positrons and electrons.
- Exploits AMS’s fantastic angular resolution and event rates. Potentially a smoking gun signal with no astrophysical background.