Title: Dark Sector Theory 4

Date: Jul 17, 2018 02:30 PM

URL: http://pirsa.org/18070026

Abstract:

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$$= 10^{-26}\,\mathrm{cm}^2 \cdot 10^{-4} \cdot 10 \quad O(1)$$
$$= 10^{-41}\,\mathrm{cm}^2$$

Large mass regime

$$\sigma_{n-S} = \frac{m_h^2 v^2 g_{hnn}^2}{m_h^4} \cdot \frac{\lambda^2}{m_S^2 \pi}$$

$$= \frac{4 m_N^2 v_{EW}^2 g_{hnn}^2}{m_h^4} \cdot (\sigma v)_{ann}$$

$$= 10^{-36}\,\mathrm{cm}^2 \quad 10^{-6} \cdot \frac{4 \cdot 2.46^2}{1.25^4} \times 10^{-4}$$

$$= 10^{-46} \times 10\,\mathrm{cm}^2 = 10^{-45}\,\mathrm{cm}^2$$

Simplest models of Higgs mediation

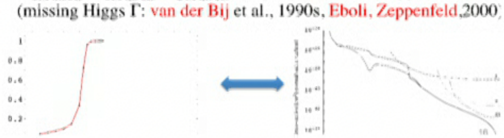
Silveira, Zee (1985); McDonald (1993); Burgess, MP, ter Veldhuis(200(

DM through the Higgs portal – *minimal model of DM*

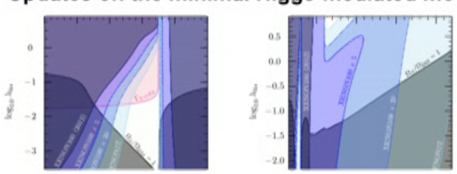
$$-\mathcal{L}_S = \frac{\lambda_S}{4} S^4 + \frac{m_0^2}{2} S^2 + \lambda S^2 H^\dagger H$$

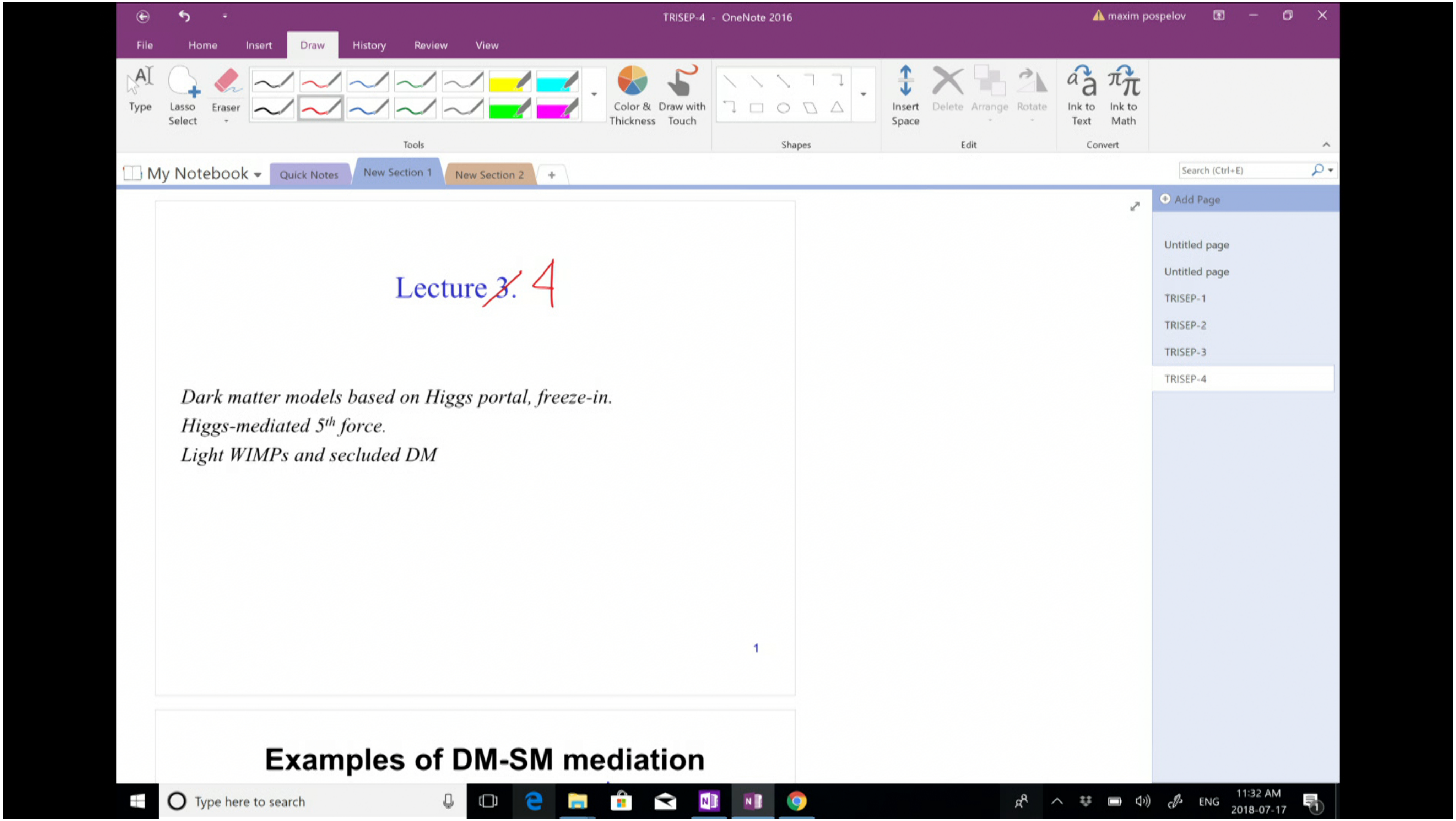
$$= \frac{\lambda_S}{4} S^4 + \frac{1}{2}(m_0^2 + \lambda v_{EW}^2) S^2 + \lambda v_{EW} S^2 h + \frac{\lambda}{2} S^2 h^2$$

125 GeV Higgs is "very fragile" because its with is ~ y_b^2 – very small
$R = \Gamma_{SM\ modes}/(\Gamma_{SM\ modes}+\Gamma_{DM\ modes})$. Light DM can kill Higgs boson easi
(missing Higgs Γ: van der Bij et al., 1990s, Eboli, Zeppenfeld,2000)



Updates on the minimal Higgs-mediated model:

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Dark matter models based on Higgs portal, freeze-in.
Higgs-mediated 5th force.
Light WIMPs and secluded DM
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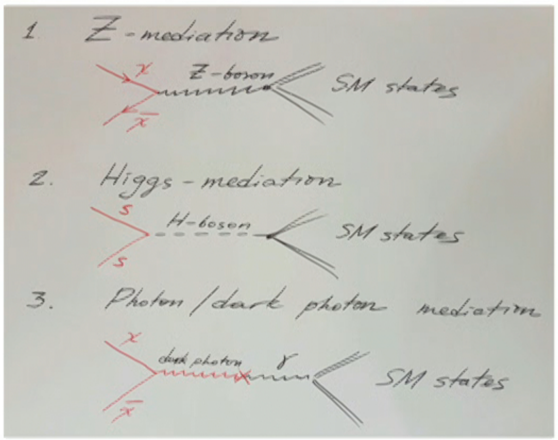
Examples of DM-SM mediation

Examples of DM-SM mediation

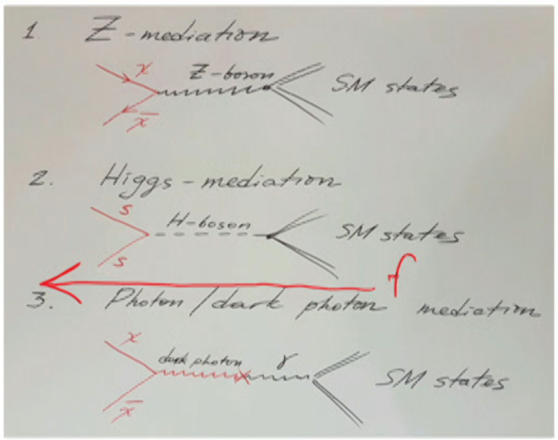


Very economical extensions of the SM.

DM particles themselves + may be extra mediator force. Can be very predictive.

If dark matter annihilation is mediated by weak scale particles, the mas of dark matter is confined to ~ 10 –to-10000 GeV (Lee, Weinberg)

Examples of DM-SM mediation



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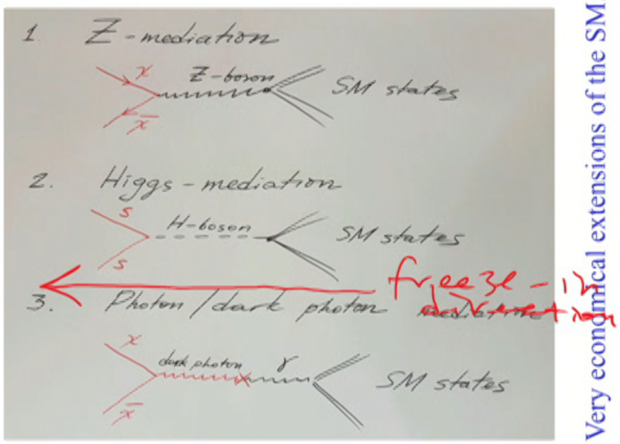
Let's take small λ

Examples of DM-SM mediation



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If dark matter annihilation is mediated by weak scale particles, the mas of dark matter is confined to ~ 10 –to-10000 GeV (Lee, Weinberg)

Freeze-in, scalar portal

$m_S \simeq 20$ GeV; Assume $SM \to SS$ creates $\Omega_S = \Omega_{DM}$

Find λ

Assume that main process $h \to SS$

$$\Gamma_{h \to SS} \simeq 1\,\text{GeV}\,\frac{\lambda^2}{0.1}$$

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3

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$$\left.\frac{n_s}{n_h}\right|_{T \sim m_h} \sim \Gamma_{h \to 2s} \times \Delta t_H \sim \frac{\Gamma_{h \to 2s}}{\text{Hubble rate}}$$

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$$H \sim \sqrt{\frac{8\pi}{3}G_N\rho_{tot}} \sim 1.6\,\frac{\sqrt{g_*}}{M_{pl}}\cdot T_{SM}^2$$

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$$\frac{n_s}{s} \sim \frac{n_h}{n_\gamma}\,\frac{\Gamma_{h\to 2s}}{H}$$

s: entropy density

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$\frac{n_s}{s} \sim \frac{n_h}{s} \frac{\Gamma_{h\to 2s}}{H}$, with $g_* \sim 100$

s (entropy density)

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$$\Gamma_{h\to ss} \simeq 1\,\mathrm{GeV}\,\frac{\lambda}{0.1}$$ ← think of this to be very small

Epoch with $T\sim m_h$ is the most important

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$$\frac{n_s}{s} \sim \left(\frac{n_h}{s}\right)\frac{\Gamma_{h\to 2s}}{H}, \qquad \left(\frac{n_h}{s}\right) \sim (100)^{-1}$$

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$$(S \approx) \frac{\rho_{DM}}{\rho_b} = \frac{m_s}{m_p}\,\frac{n_s}{n_b} = \frac{m_s}{m_p}\,\frac{n_s}{s}\,\frac{s}{n_p}$$

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3

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4

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(entropy density

$$(5\approx)\,\frac{\rho_{DM}}{\rho_b} = \frac{m_s}{m_p}\,\frac{n_s}{n_b} = \frac{m_s}{m_p}\,\frac{n_s}{s}\,\frac{s}{n_p}, \qquad \frac{s}{n_p} \simeq 10^{10}$$

$$H \sim \sqrt{\frac{8\pi}{3} G_N \rho_{tot}} \sim 1.6 \frac{\sqrt{g_*}}{M_{pl}} \cdot T_{SM}^2$$

$$\frac{n_s}{s} \sim \frac{n_h}{s} \frac{\Gamma_{h\to 2s}}{H}, \qquad \frac{n_h}{s} \sim (100)^{-1}$$

s (entropy density)

$$\frac{1}{100} \frac{\Gamma_{h\to ss}}{H} \sim 10^{10}$$

$$(s \approx) \frac{\rho_{DM}}{\rho_b} = \frac{m_s}{m_p} \frac{n_s}{n_b} = \frac{m_s}{m_p} \frac{n_s}{s} \frac{s}{n_p}$$

4

$T \sim m_h$

$$H \sim \sqrt{\frac{8\pi}{3} G_N \rho_{tot}} \sim 1.6 \frac{\sqrt{g_*}}{M_{pl}} \cdot T_{SM}^2$$

$$\frac{n_s}{s} \sim \underbrace{\frac{n_h}{s}}_{\sim (100)^{-1}} \frac{\Gamma_{h\to 2s}}{H}$$

(s: entropy density)

$$\frac{1}{100} \frac{\Gamma_{h\to ss}}{H} \lesssim 10^{10}$$

$$(5 \simeq)\ \frac{\rho_{DM}}{\rho_b} = \frac{m_s}{m_p}\frac{n_s}{n_b} = \frac{m_s}{m_p}\frac{n_s}{s}\frac{s}{n_p}$$

$$5 \simeq 20 \cdot \frac{1}{100} \cdot \frac{1\,\mathrm{GeV}\ \lambda^2/0.1}{1.6\cdot 10^4 \frac{(100\,\mathrm{GeV})^2}{M_{pl}}} \times 10^{10}$$

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$$= \frac{1}{5 \cdot 1.6 \times 0.1}\,\frac{10^{19}\,\text{GeV}}{10 \cdot 10^{4}} \times 10^{10} \times \lambda^2$$

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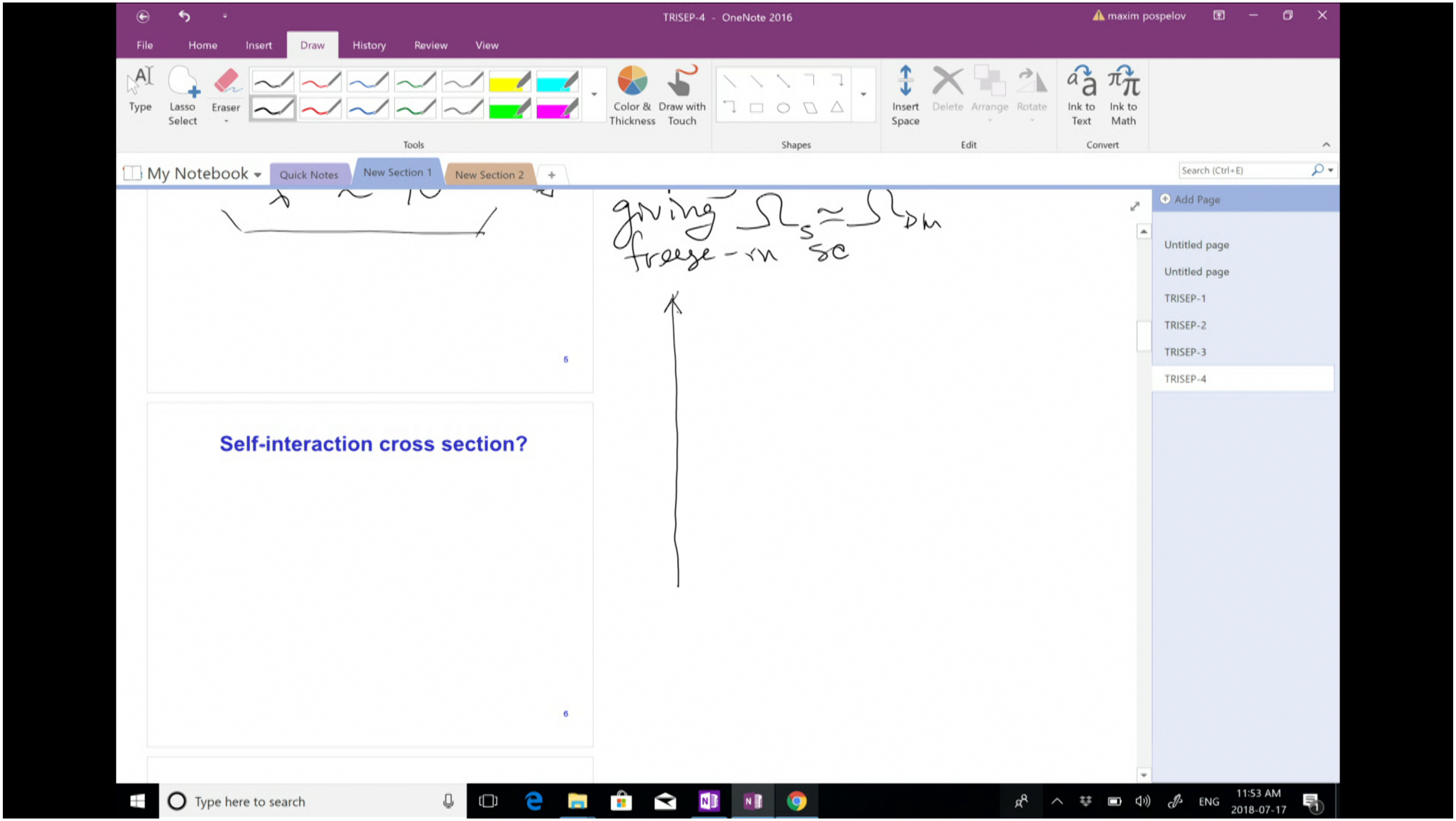
$$= \frac{1}{5 \cdot 1.6 \cdot 0.1}\,\frac{10^{19}}{10 \cdot 10^4} \times 10^{10} \times \lambda^2$$

$$= O(1)\ 10^{24}\,\lambda^2$$

$$\lambda^2 \sim 10^{-23}$$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Self-interaction cross section?
giving $\Omega_s \simeq \Omega_{DM}$
freeze-in sc
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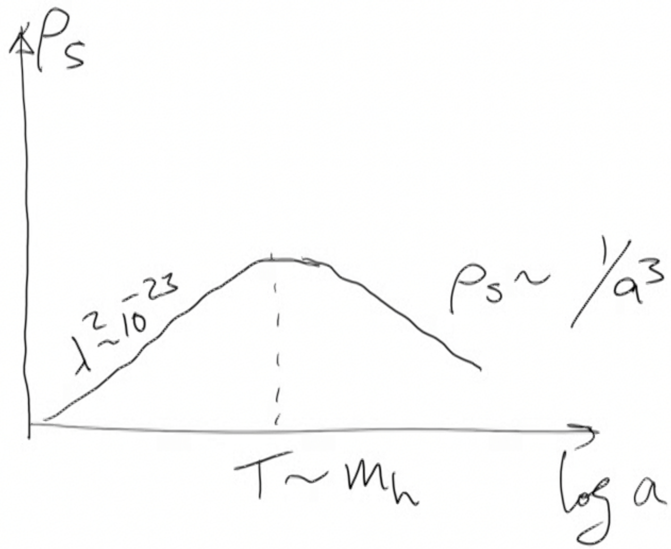
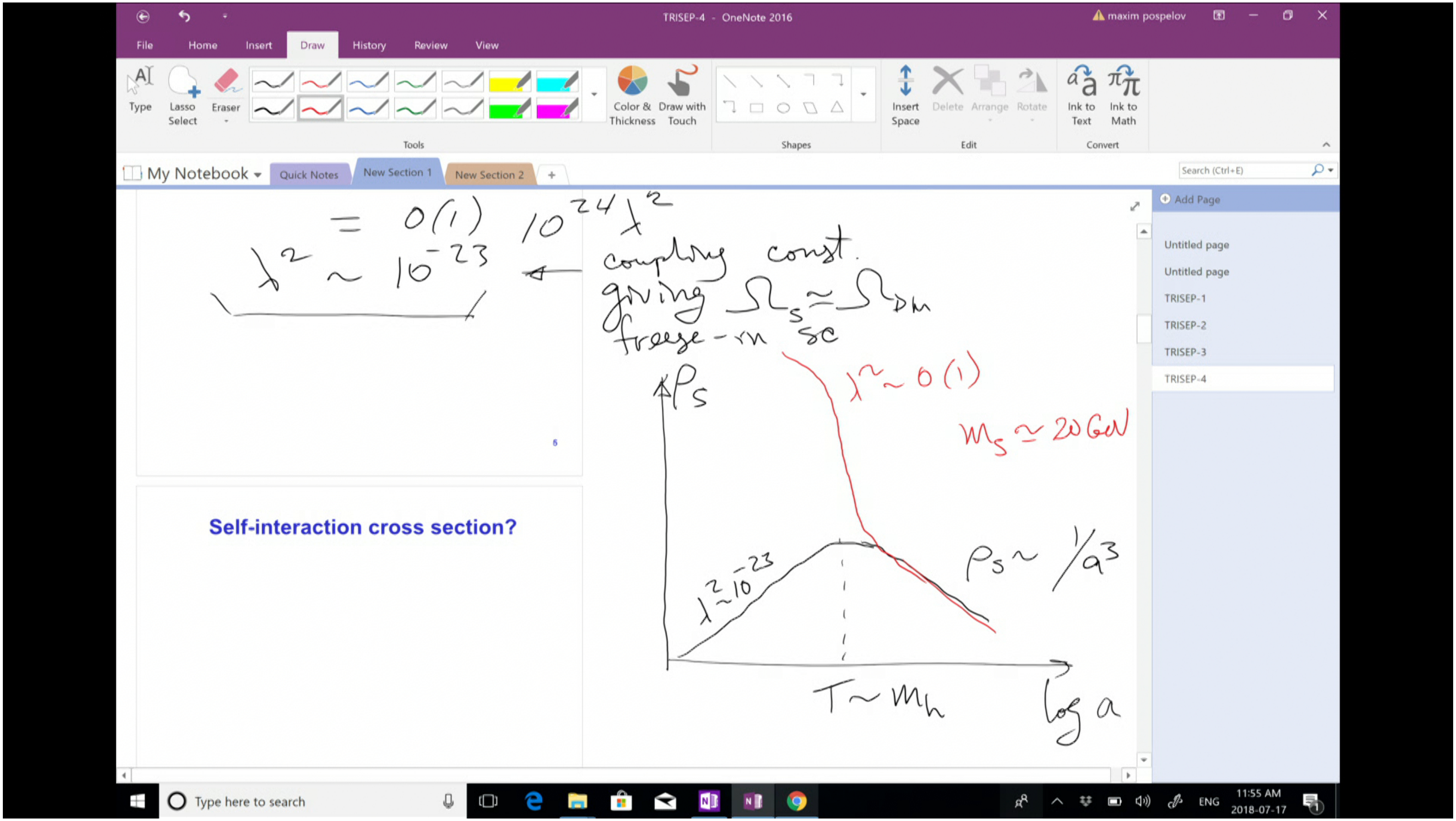
$$= O(1)\ 10^{24}\lambda^2$$

$$\lambda^2 \sim 10^{-23} \leftarrow \text{coupling const. giving } \Omega_s \simeq \Omega_{DM} \text{ freeze-in sc}$$



Self-interaction cross section?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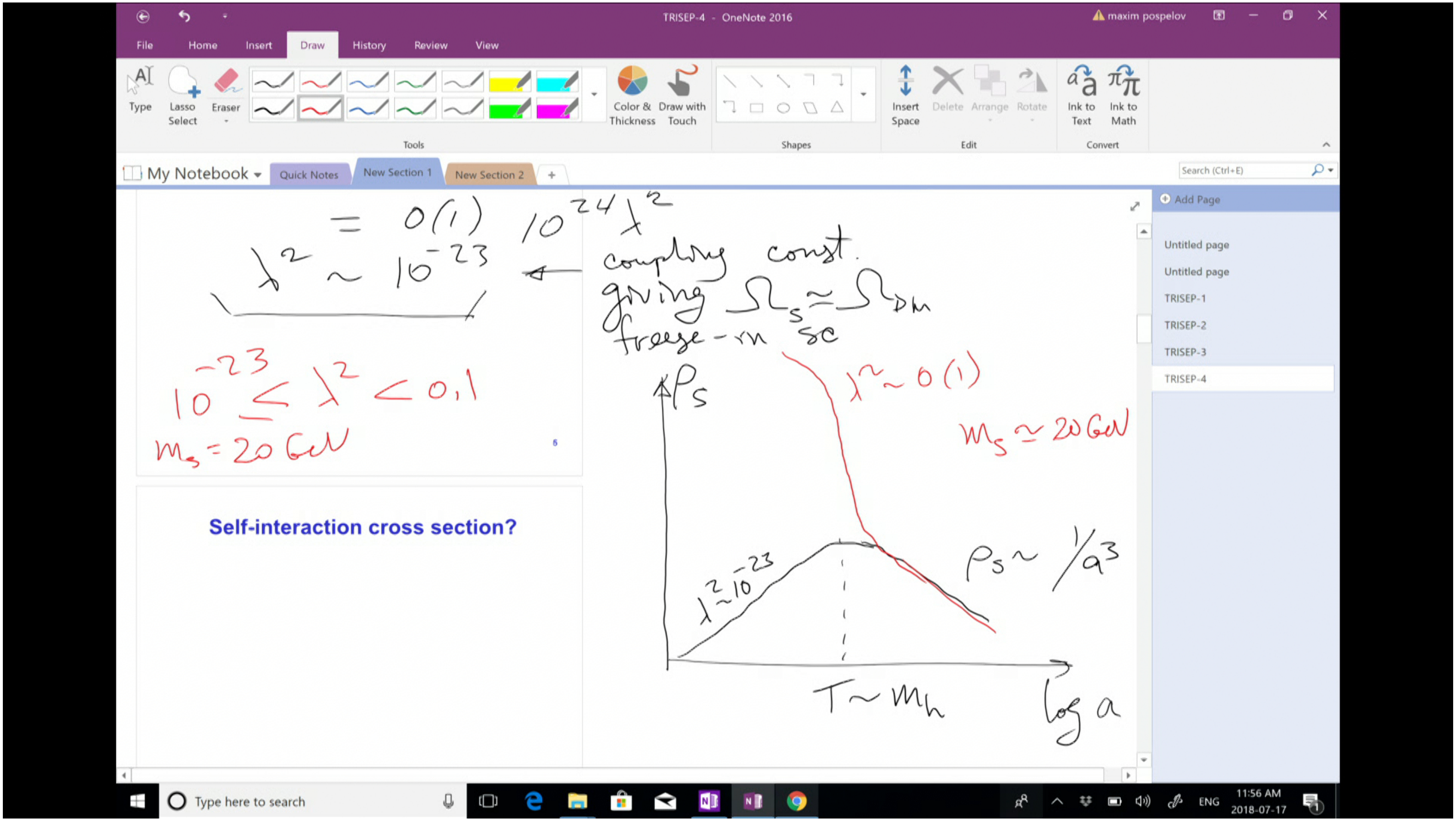
$= O(1)\ 10^{24} \lambda^2$
$\lambda^2 \sim 10^{-23}$
coupling const. giving $\Omega_s \simeq \Omega_{DM}$
freeze-in sc
ρ_s
$\lambda^2 \sim O(1)$
$m_s \simeq 20\ \mathrm{GeV}$
$\lambda^2 \sim 10^{-23}$
$\rho_s \sim 1/a^3$
$T \sim m_h$
$\log a$
Self-interaction cross section?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= O(1) 10^24 λ^2
λ^2 ~ 10^-23
coupling const. giving Ω_s ≃ Ω_DM freeze-in sc
10^-23 ≤ λ^2 < 0,1
m_s = 20 GeV
Self-interaction cross section?
ρ_s
λ^2 ~ O(1)
m_s ≃ 20 GeV
λ^2 ~ 10^-23
ρ_s ~ 1/a^3
T ~ m_h
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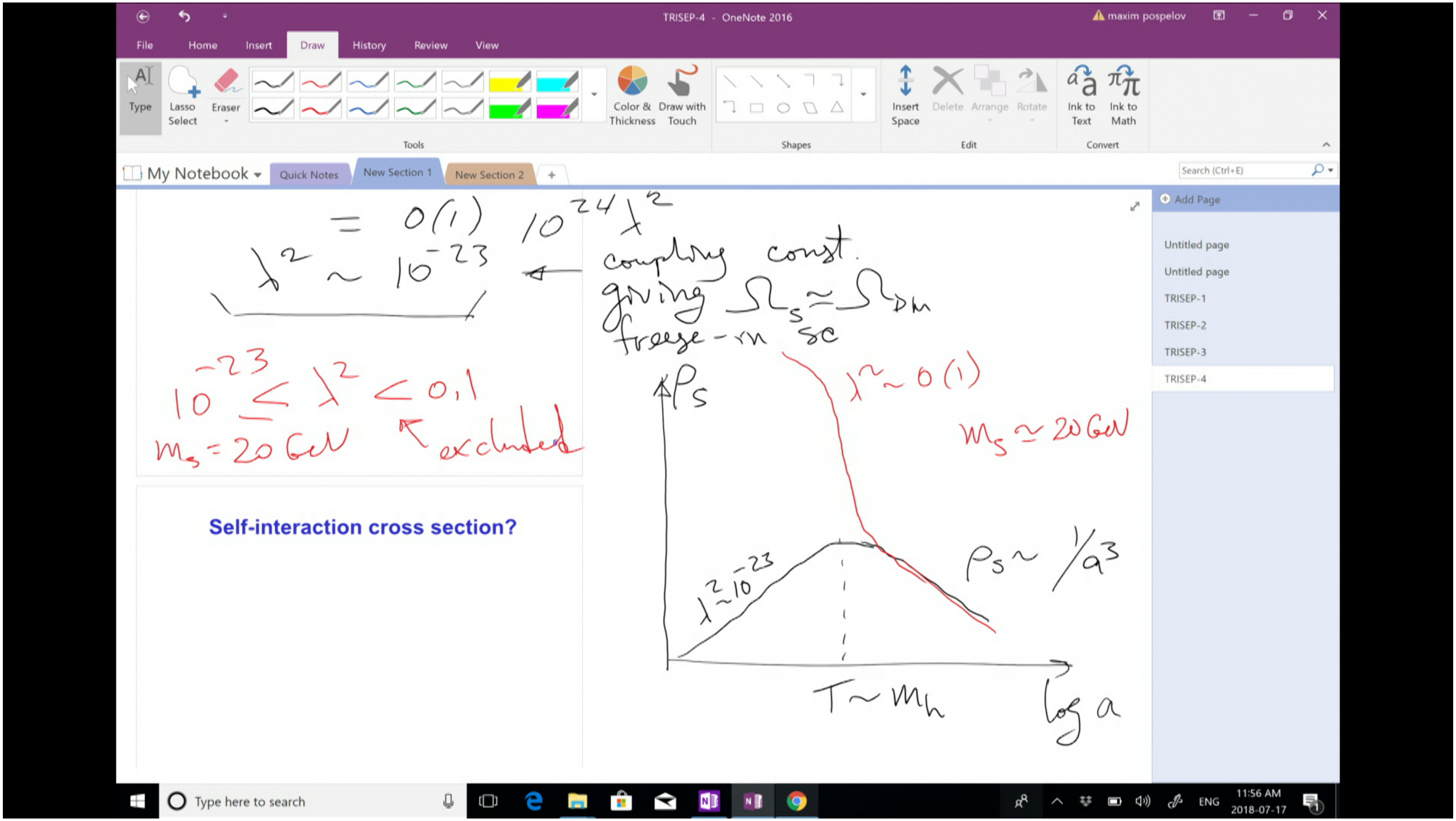
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$10 \leq \lambda < 0.1$

$m_s = 20$ GeV ↖ excluded

Self-interaction cross section?

Freeze-in DM is not limited to weak scale

$m_s \sim 10$ MeV range

← very suitable for self interacting DM with $\frac{\sigma}{m_s} \sim 10^{-24}\ \mathrm{cm^2/GeV}$

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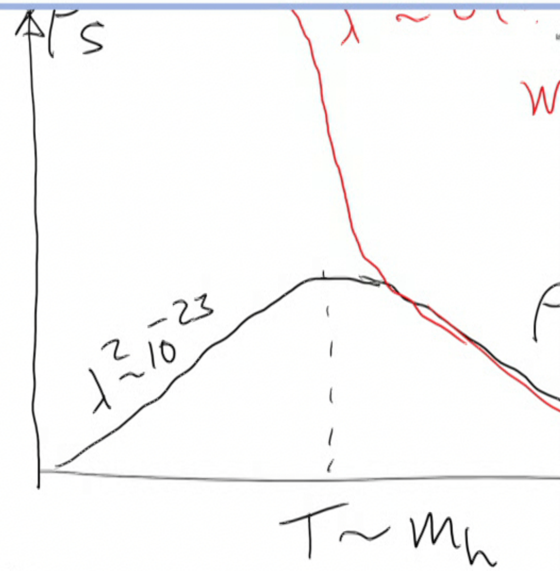

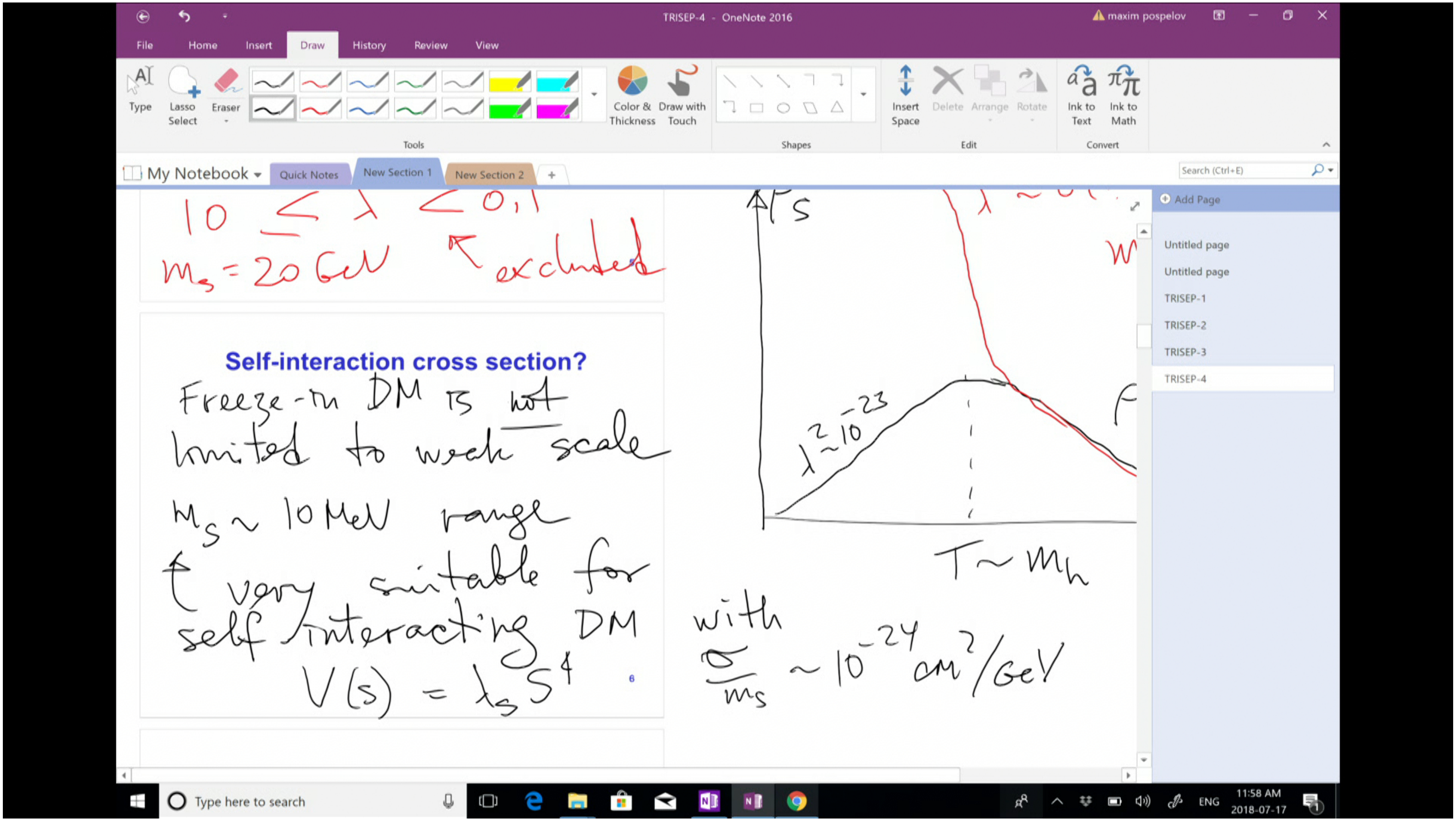
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$10^{-?} \lesssim \lambda \lesssim 0.1$
$m_s = 20$ GeV excluded
Self-interaction cross section?
Freeze-in DM is not limited to weak scale
$m_s \sim 10$ MeV range very suitable for self interacting DM
$V(s) = \lambda_s S^4$
with $\frac{\sigma}{m_s} \sim 10^{-24}$ cm^2/GeV
$\lambda^2 \sim 10^{-23}$
$T \sim m_h$
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ight) Higgs-like particle through the super-renormalizable portal

: new particle admixed with a Higgs. (I keep the lowest dim op

$$\mathcal{L}_{\text{Higgs portal}} = \underbrace{\frac{1}{2}(\partial_\mu S)^2 - \frac{1}{2}m_S^2 S^2}_{} - ASH^\dagger H$$

← dark matter

iggs Field = vev + fluctuation h), the actual Higgs boson mixes
S.

ngle: $$\theta = \frac{Av}{m_h^2}$$

del is technically natural as long as A is not much larger tha

8

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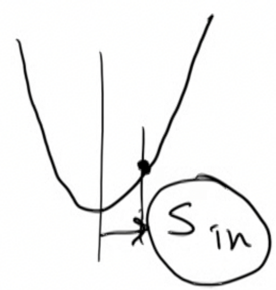
← dark matter

After (Higgs Field = vev + fluctuation h), the actual Higgs boson mixes with S.

Mixing angle: $$\theta = \frac{Av}{m_h^2}$$



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dark matter

After (Higgs Field = vev + fluctuation h), the actual Higgs boson mixes with S.

Mixing angle: $\theta = \dfrac{Av}{m_h^2}$

S h

$A \cdot v$

The model is technically natural as long as A is not much larger tha m_S (corrections go as $\Delta m_S^2 \sim A^2 * \log$)

Low energy: new particle with Higgs couplings multiplied by θ. Mixin; angle and mass can span many orders of magnitude.

New effects in Kaon and B-decays, 5th force etc.

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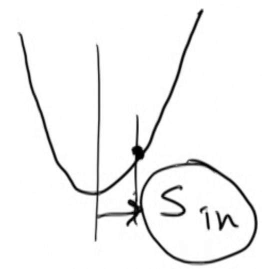
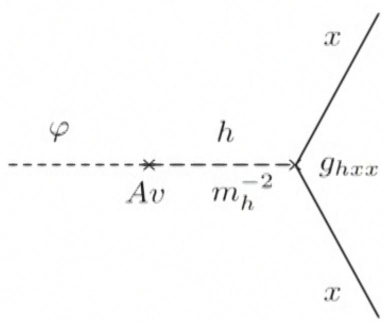


Scalar DM through super-renormalizable portal

$$V = -\frac{m_h^2}{2} H^\dagger H + \lambda (H^\dagger H)^2 + \underline{A H^\dagger H \phi} + \frac{m_\varphi^2}{2}\phi^2 \, .$$

There is no runaway direction if $A^2/m_\varphi^2 < 2\lambda$

After integrating out the Higgs, the theory becomes very similar to Brans-Dicke – but *better* because of UV completeness our theory.



$$g_{\varphi xx} = \frac{Av}{m_h^2} g_{hxx}$$

$$g_{hNN} \simeq \frac{200 - 500\,\text{MeV}}{v} \sim O(10^{-3})$$

Main consequence of such model is a new scalar force mediated by a scalar – that can be dark matter.

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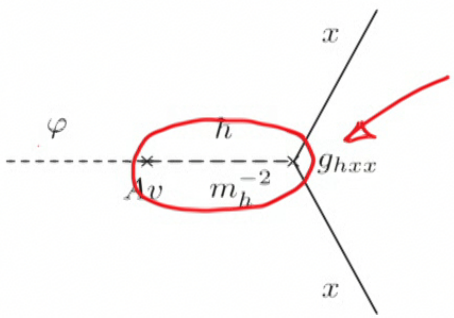

g_{hpp}

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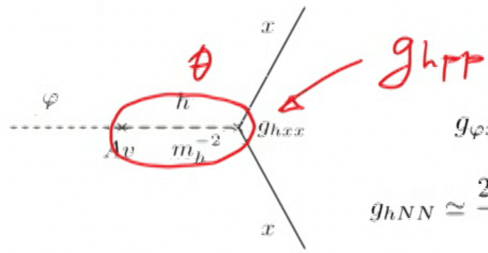

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5^{th} force from Dark Matter exchange

- The main observational consequence of this model: possibility to have an observable 5^{th} force (x= A/mass)
- For the traditional parametrization, $V(r) = -G\frac{m_A m_B}{r}(1 + \alpha_A \alpha_B\, e^{-m_\varphi r}$

we can derive the strength of coupling $\alpha = g_{hNN}\frac{\sqrt{2}M_P}{m_{nucl}}\frac{Av}{m_h^2}$

The model is technically natural as long as A is not much larger tha

m_S (corrections go as $\Delta m_S^2 \sim A^2 * \log$)

Low energy: new particle with Higgs couplings multiplied by θ. Mixing angle and mass can span many orders of magnitude.

New effects in Kaon and B-decays, 5th force etc.

9

Scalar DM through super-renormalizable portal

- Piazza, MP, 2010: *There is a unique portal in the SM*

$$V = -\frac{m_h^2}{2}H^\dagger H + \lambda(H^\dagger H)^2 + \underline{AH^\dagger H\phi} + \frac{m_\varphi^2}{2}\phi^2 .$$

- There is no runaway direction if $A^2/m_\varphi^2 < 2\lambda$
- After integrating out the Higgs, the theory becomes very similar to Brans-Dicke – but *better* because of UV completeness our theory.

5^{th} force from Dark Matter exchange

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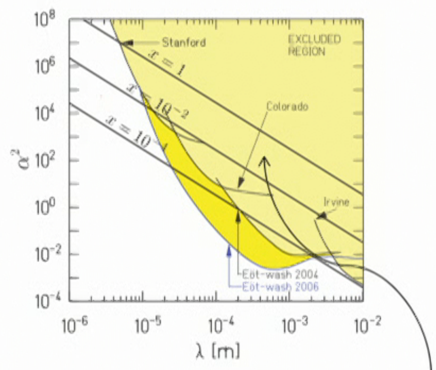
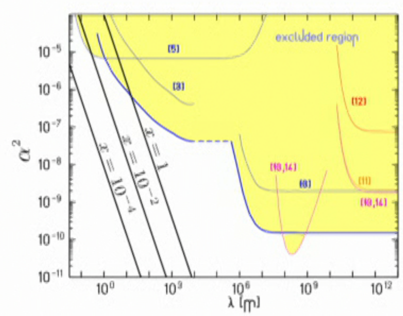
we can derive the strength of coupling
$$\alpha \;=\; g_{hNN}\frac{\sqrt{2}M_P}{m_{\rm nuc}}\frac{Av}{m_h^2}$$

(! *the second bracket* = 0.83)
$$\simeq\; 10^{-3}\left(\frac{m_h}{115\,{\rm GeV}}\right)^{-2}\frac{A}{10^{-8}{\rm eV}}.$$

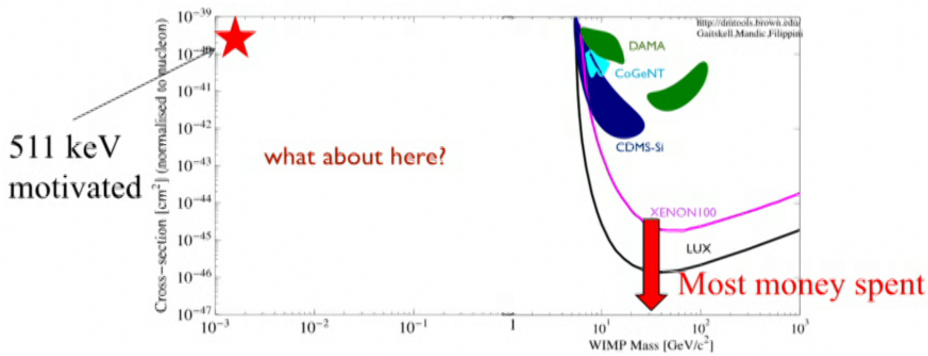




One can expect a "natural" 5^{th} force from DM in 10 micron – 100 m ran

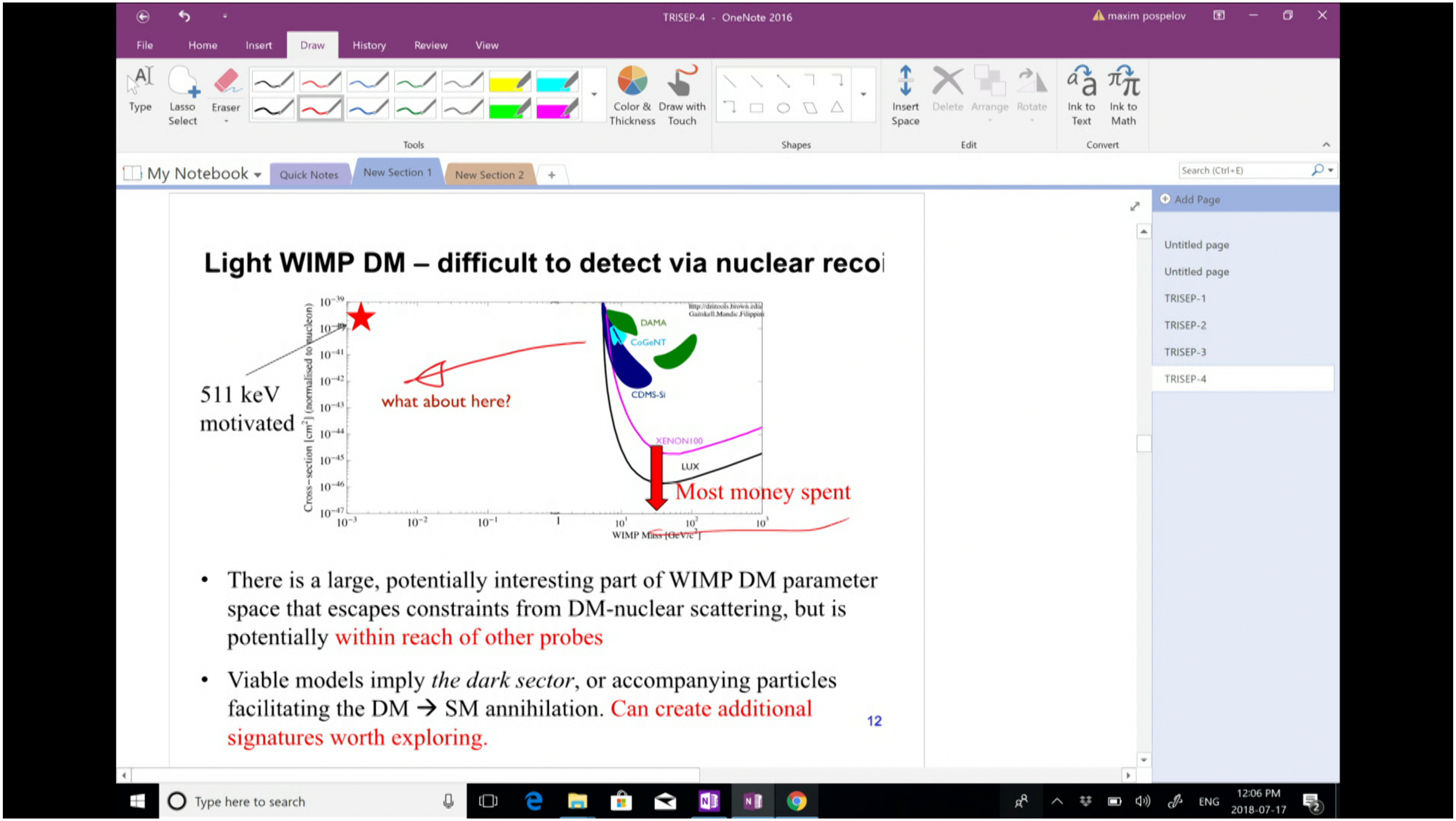
11

Light WIMP DM – difficult to detect via nuclear recoi



- There is a large, potentially interesting part of WIMP DM parameter space that escapes constraints from DM-nuclear scattering, but is potentially within reach of other probes
- Viable models imply *the dark sector*, or accompanying particles facilitating the DM → SM annihilation. Can create additional signatures worth exploring.

12


TRISEP-4 - OneNote 2016
Light WIMP DM – difficult to detect via nuclear recoi
511 keV
motivated
what about here?
DAMA
CoGeNT
CDMS-Si
XENON100
LUX
Most money spent
Cross-section [cm²] (normalised to nucleon)
WIMP Mass [GeV/c²]
• There is a large, potentially interesting part of WIMP DM parameter space that escapes constraints from DM-nuclear scattering, but is potentially within reach of other probes
• Viable models imply *the dark sector*, or accompanying particles facilitating the DM → SM annihilation. Can create additional signatures worth exploring.
12

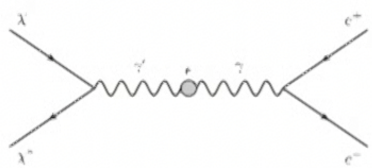
(Boehm, Fayet, MP, Kriz, Voloshin …) Light dark matter is not ruled out if one adds a light mediator.

WIMP paradigm: $\sigma_{\rm annih}(v/c) \sim 1 \text{ pbn} \implies \Omega_{\rm DM} \simeq 0.25,$

Electroweak mediators lead to the so-called Lee-Weinberg window,

$$\sigma(v/c) \propto \begin{cases} G_F^2 m_\chi^2 & \text{for } m_\chi \ll m_W, \\ 1/m_\chi^2 & \text{for } m_\chi \gg m_W. \end{cases} \implies \text{few GeV} < m_\chi < \text{few TeV}$$

If instead the annihilation occurs via a force carrier with light mass, DM can be as light as ~ MeV (and not ruled out by the CMB if it is a scalar)



$$\sigma_{\rm annih}(v/c) \simeq \frac{8\pi\alpha\alpha_D\epsilon^2(m_\chi^2 + 2m_e^2)v^2}{3(m_{A'}^2 - 4m_\chi^2)^2}\sqrt{1 - m_e^2/m_\chi^2}.$$

13

“Simplified models” for light DM

some examples

$$\sigma(v/c) \propto \begin{cases} G_F^2 m_\chi^2 & \text{for } \; m_\chi \ll m_W; \\ 1/m_\chi^2 & \text{for } \; m_\chi \gg m_W. \end{cases} \Longrightarrow \text{few GeV} < m_\chi < \text{fe}$$

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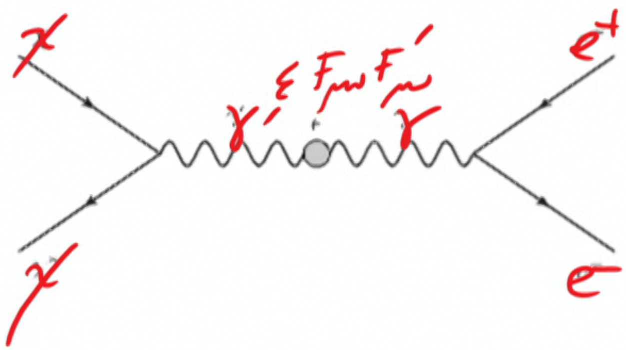

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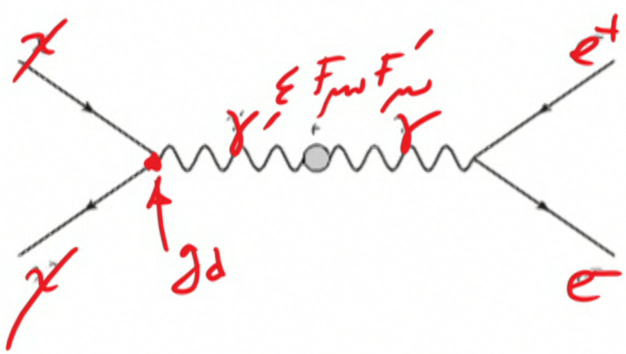

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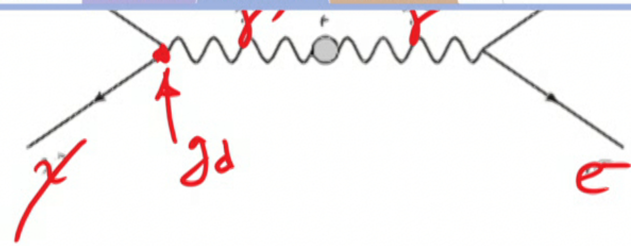
ε^2



$\sigma_{\rm annih}(v/c) \simeq \dfrac{\ldots}{3(m_{A'}^2 - 4m_\chi^2)^2}$

$m_{\gamma'}$ ~ can be few MeV, very light DM (MeV scale) is allowed

"Simplified models" for light DM

some examples

- Scalar dark matter talking to the SM via a dark photon (variants: L_{mu}-L_{tau} etc gauge bosons). With $2m_{DM} < m_m$

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$$\mathcal{L} = |D_\mu \chi|^2 - m_\chi^2 |\chi|^2 - \frac{1}{4} V_{\mu\nu}^2 + \frac{1}{2} m_V^2 V_\mu^2 - \frac{\epsilon}{2} V_{\mu\nu} F_{\mu\nu}$$

- Fermionic dark matter talking to the SM via a "dark scalar" that mixes with the Higgs. With $m_{DM} > m_{mediator}$.

$$\mathcal{L} = \overline{\chi}(i\partial_\mu \gamma_\mu - m_\chi)\chi + \lambda \overline{\chi}\chi S + \frac{1}{2}(\partial_\mu S)^2 - \frac{1}{2} m_S^2 S^2 - AS(H^\dagger H)$$

After EW symmetry breaking S mixes with physical h, and can be light and weakly coupled provided that coupling A is small. Let's

14

U is allowed

"Simplified models" for light DM

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DM

Mediator

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Simplified models "for light DM"

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DM Mediator

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charged under $U(1)$

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mixes with h-boson

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14

call it dark Higgs

Two different types of annihilation

- Model 1: one step process:

$$\chi\chi^* \;\rightarrow\; \text{off shell dark photon} \;\rightarrow\; e^+e^-$$

- Model 2: two-step process: annihilation to mediators with subsequent decay

$$\chi\overline{\chi} \;\rightarrow\; S+S \;\rightarrow\; \ldots \;\rightarrow\; (e^+e^-)+(e^+e^-)$$

In both cases, the annihilation proceed in *p-wave*, and is very suppressed at the recombination time → no CMB constraints.

Thus, (few MeV – to – GeV) range is not excluded by cosmology.

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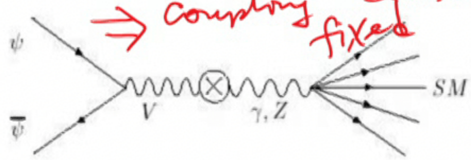
15

Two types of WIMPs

Un-secluded

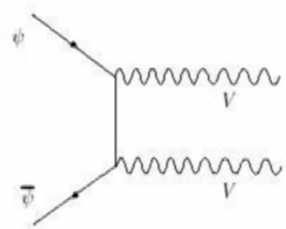
$v\sigma \sim 1\,\text{pbn}$

$\Rightarrow$ coupling constants fixed

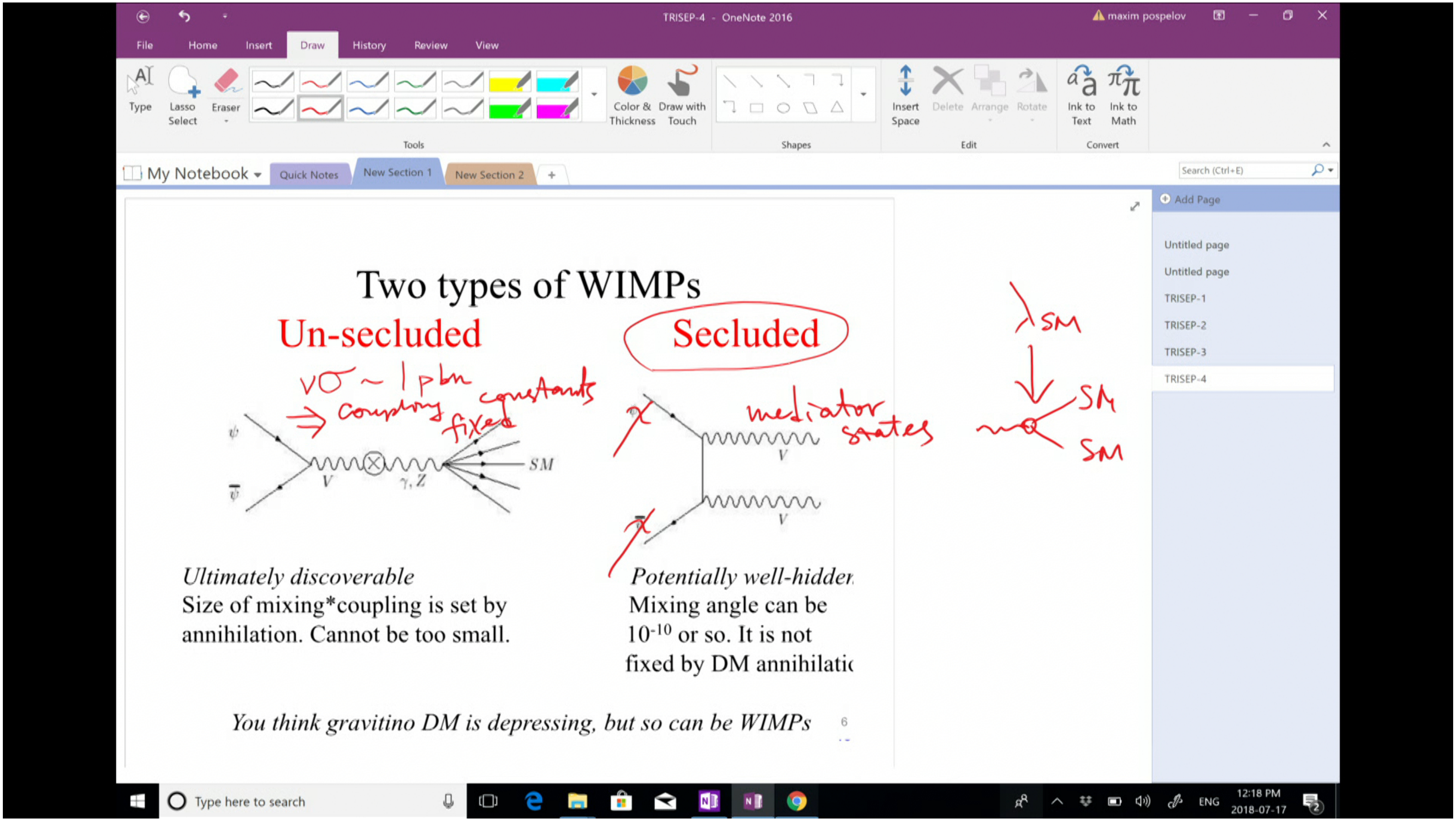


Ultimately discoverable
Size of mixing*coupling is set by annihilation. Cannot be too small.

Secluded



Potentially well-hidden
Mixing angle can be 10^{-10} or so. It is not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vσ ~ 1 pbn
⇒ coupling constants fixed
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You think gravitino DM is depressing, but so can be WIMPs
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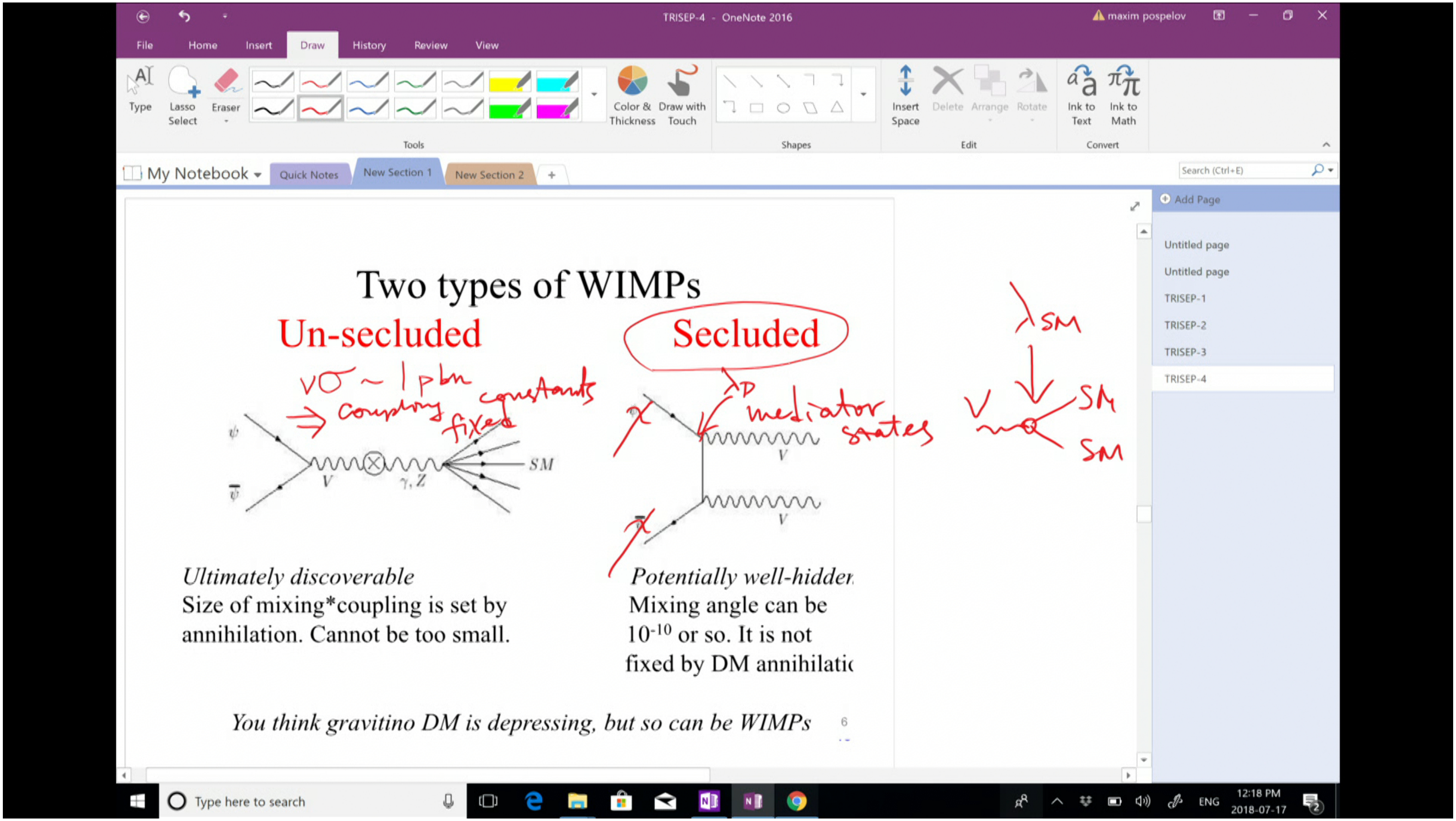
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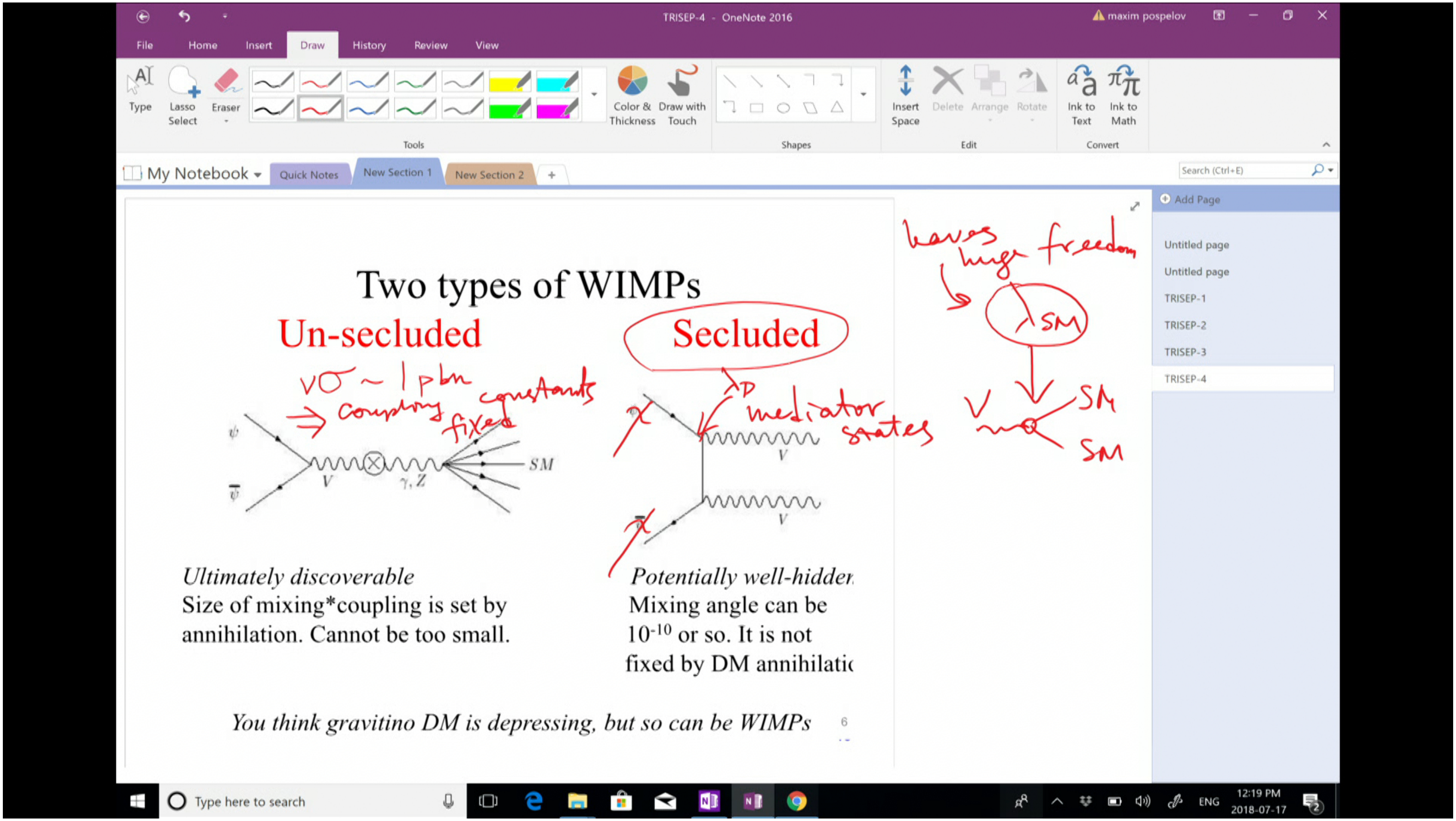
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Two types of WIMPs
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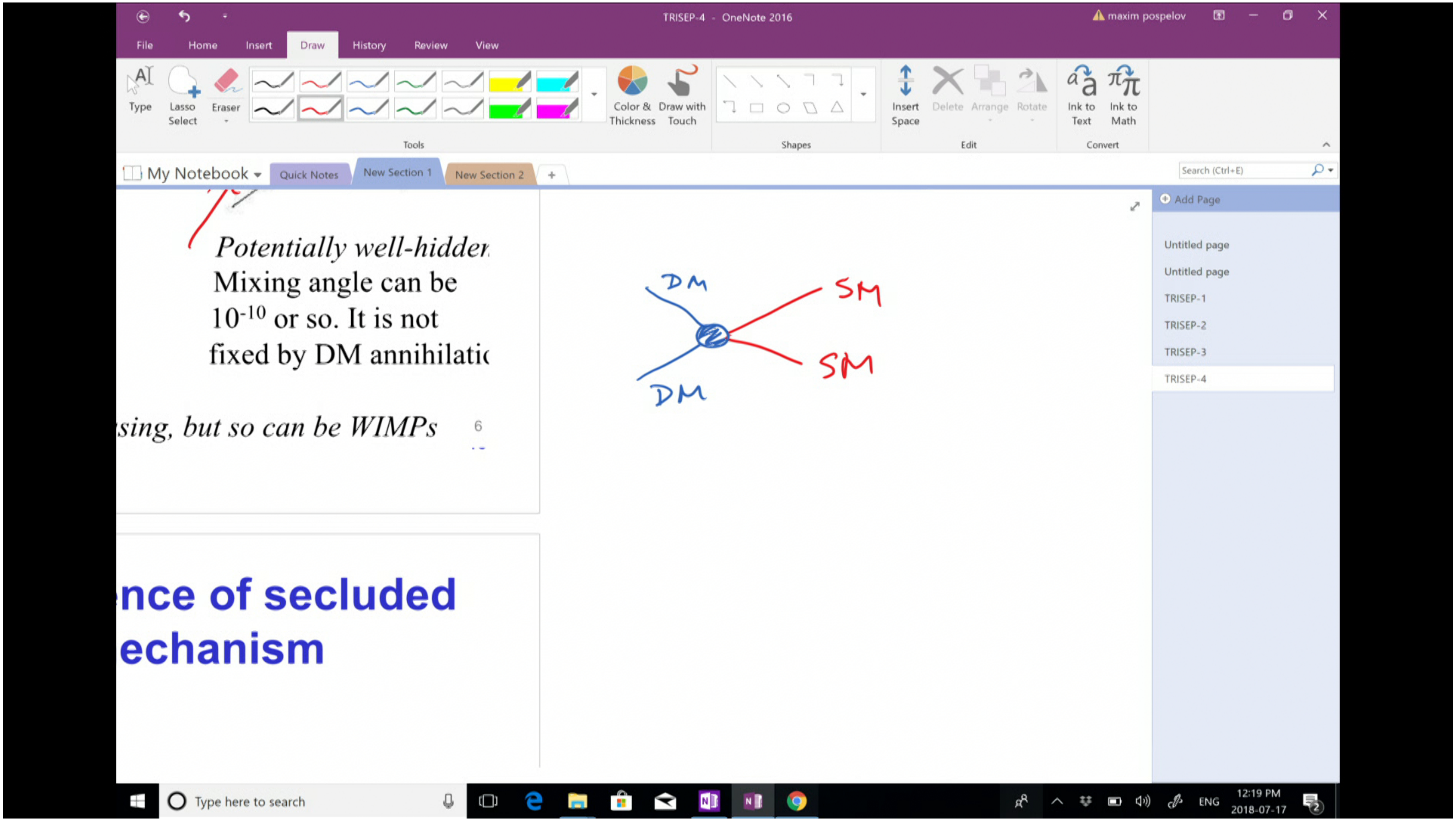
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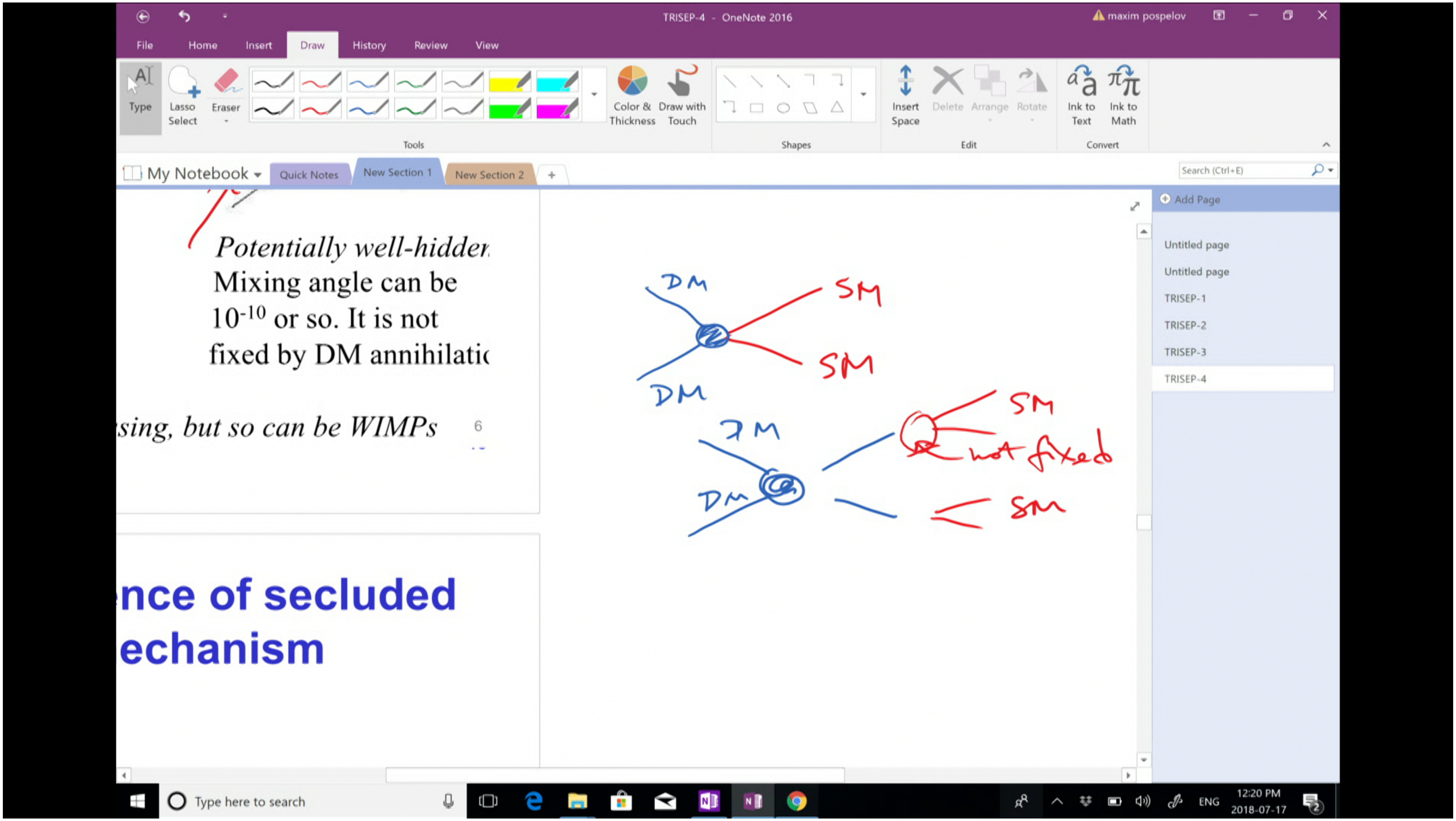
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How to look for light WIMP DM ?

1. Detect missing energy associated with DM produced in collisions of ordinary particles

2. Produce light dark matter in a beam dump experiment, and detect its subsequent scattering in a large [neutrino] detector

3. Detect scattering of light ambient DM on electrons, and keep lowering the thresholds in energy deposition.

All three strategies are being actively worked on, and pursued by severa ongoing and planned experiments.

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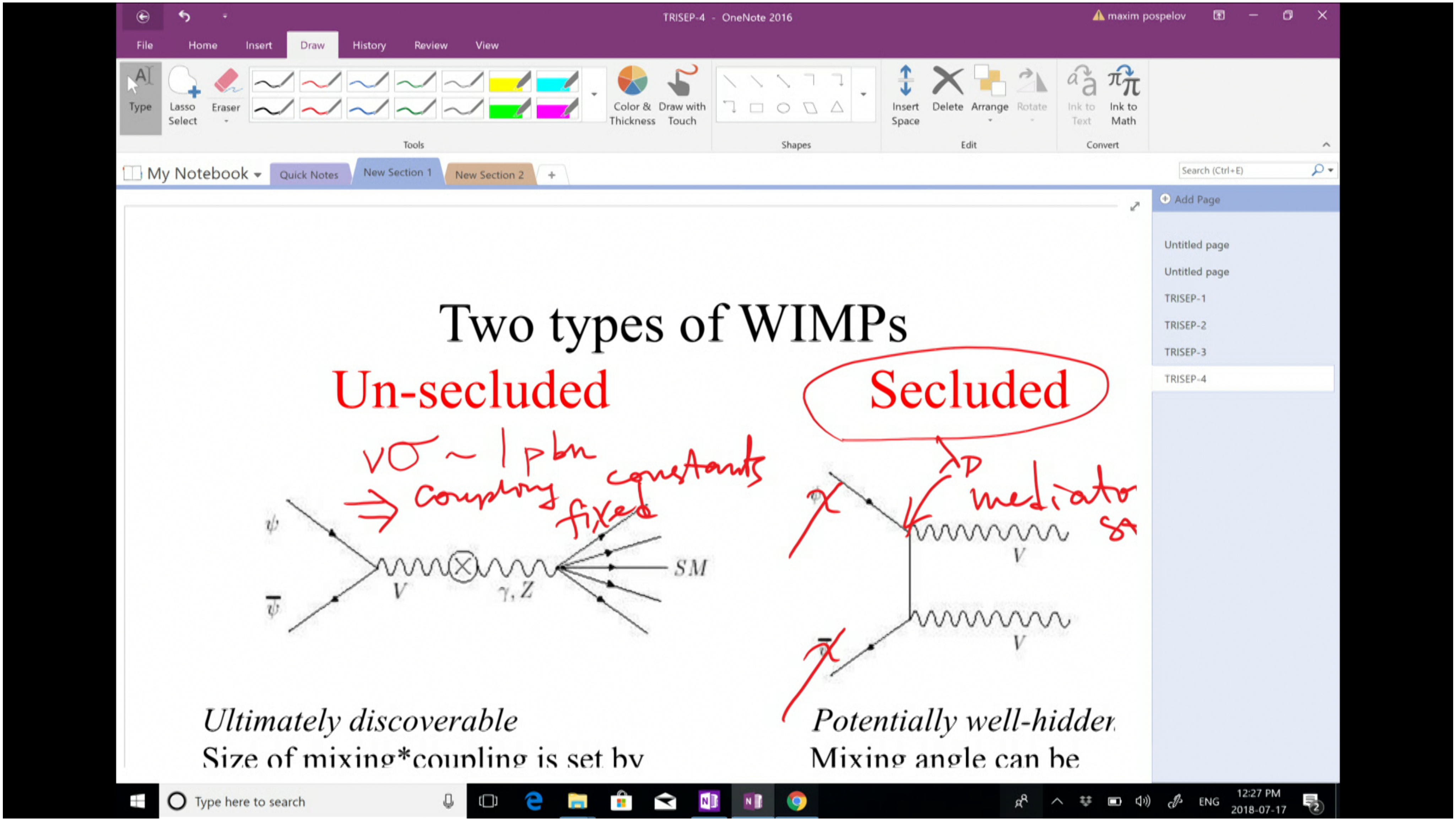
Anomalies? A simple concept of dark matter + mediator allows [speculatively] connecting DM to some on-going puzzles

Anomalies? A simple concept of dark matter + mediator allows [speculatively] connecting DM to some on-going puzzles

1. Unexpectedly strong and uniform 511 keV emission from galactic bulge could be fit by annihilation of a few MeV galactic WIMPs.
2. If DM is heavy and mediator is light, one can fit its annihilation to the famous positron-to-electron ratio rise (thanks to Sommerfeld enhancement at low velocity, bound states effects, as well as lepto-phylic composition of the final states)
3. Inner density profiles of galaxies can smoothed out by the self-scattering WIMPs with 10^{-24}cm^2/GeV. For EW scale WIMPs, light mediators can easily provide such cross section.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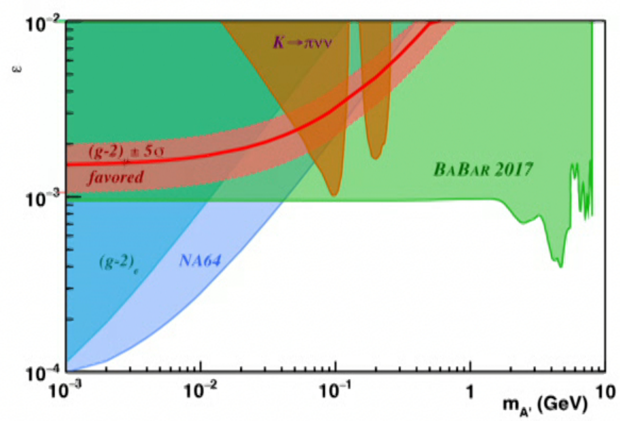
4. ….

These connections are all rather interesting but not necessarily compelling. We'd like a laboratory probe (Exclusion or confirmation).

Missing energy momentum searches

Missing energy momentum searches

BaBar collaboration has published new results two weeks ago, 1702.03327. Search of $e^+e^- \to \gamma + V \to \gamma + \chi\chi$



- Complementary to NA64

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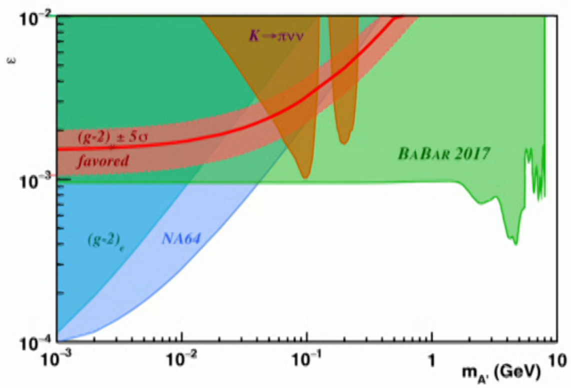

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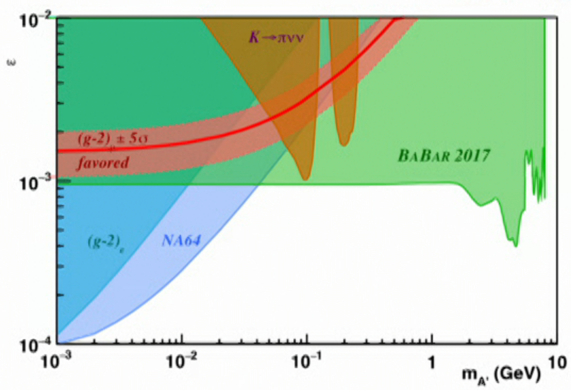

- Complementary to NA64
- Covers all of the dark photon parameter space, decaying invisibly, consistent with alleviating the muon g-2 discrepancy

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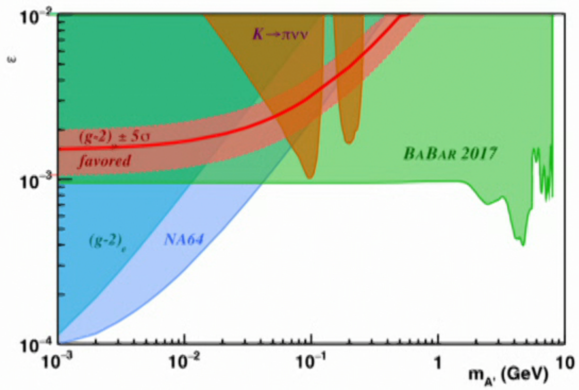

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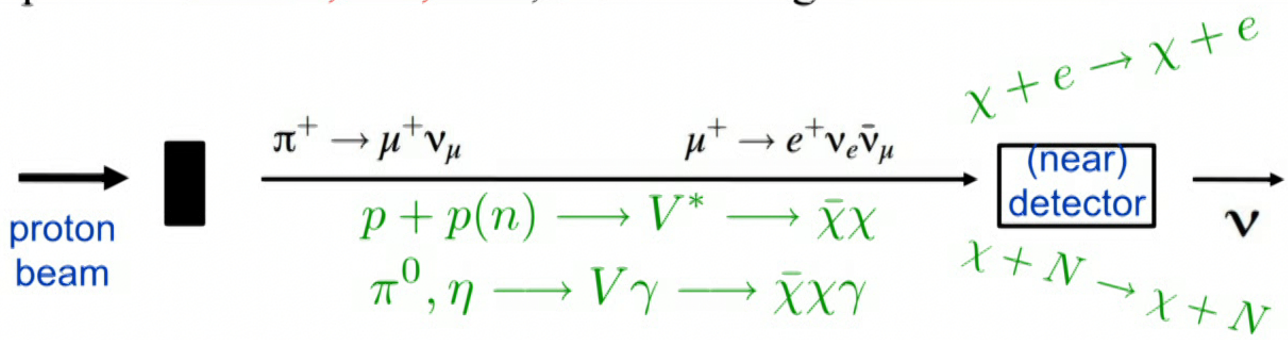
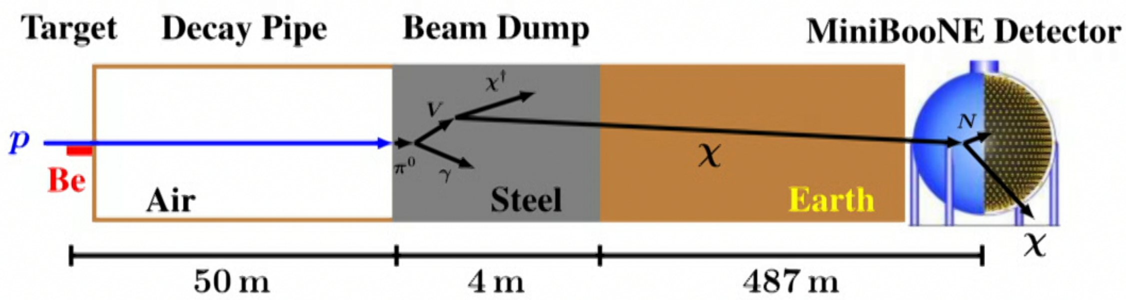
Fixed target probes - Neutrino Beams



We can use the neutrino (near) detector as a dark matter detector, looking for recoil, but now from a relativistic beam. E.g.

T2K	MINOS	MiniBooNE
30 GeV protons	120 GeV protons	8.9 GeV protons
(➠ ~5x10^{21} POT)	10^{21} POT	10^{21} POT
280m to on- and off-	1km to (~27ton)	540m to (~650ton)

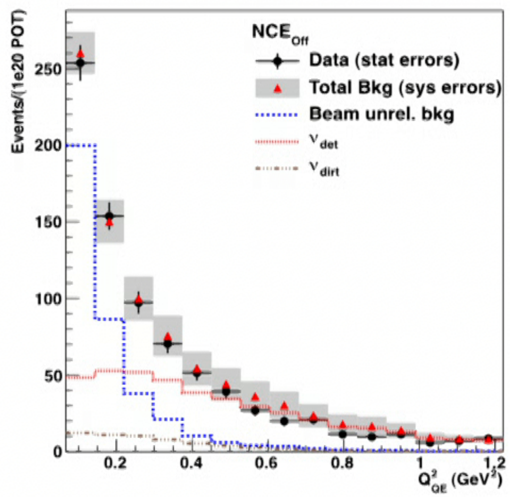
MiniBooNE search for light DM



MiniBoone has completed a long run in the beam dump mode, as suggested in [arXiv:1211.2258]

By-passing Be target is crucial for reducing the neutrino background

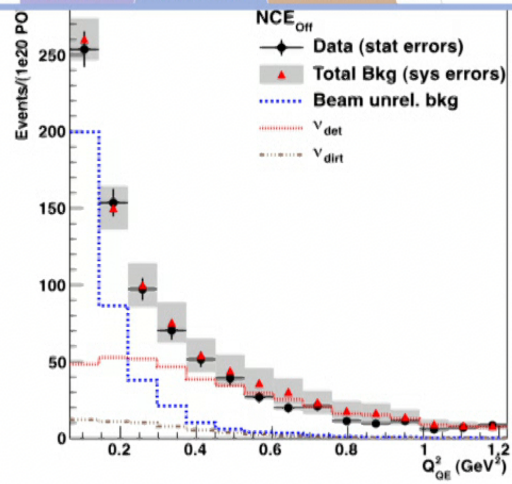
From the W & C talk by Thornton, and a new paper



	#events	uncertainty
BUB	697	
ν_{det} bkg	775	
ν_{dirt} bkg	107	
Total Bkg	1579	14.3% (pred. sys.)
Data	1465	2.6% (stat.)

The off-target run of MiniBoone is a success (despite the absence of signal!):

- Neutrino background from the beam is brought down to be



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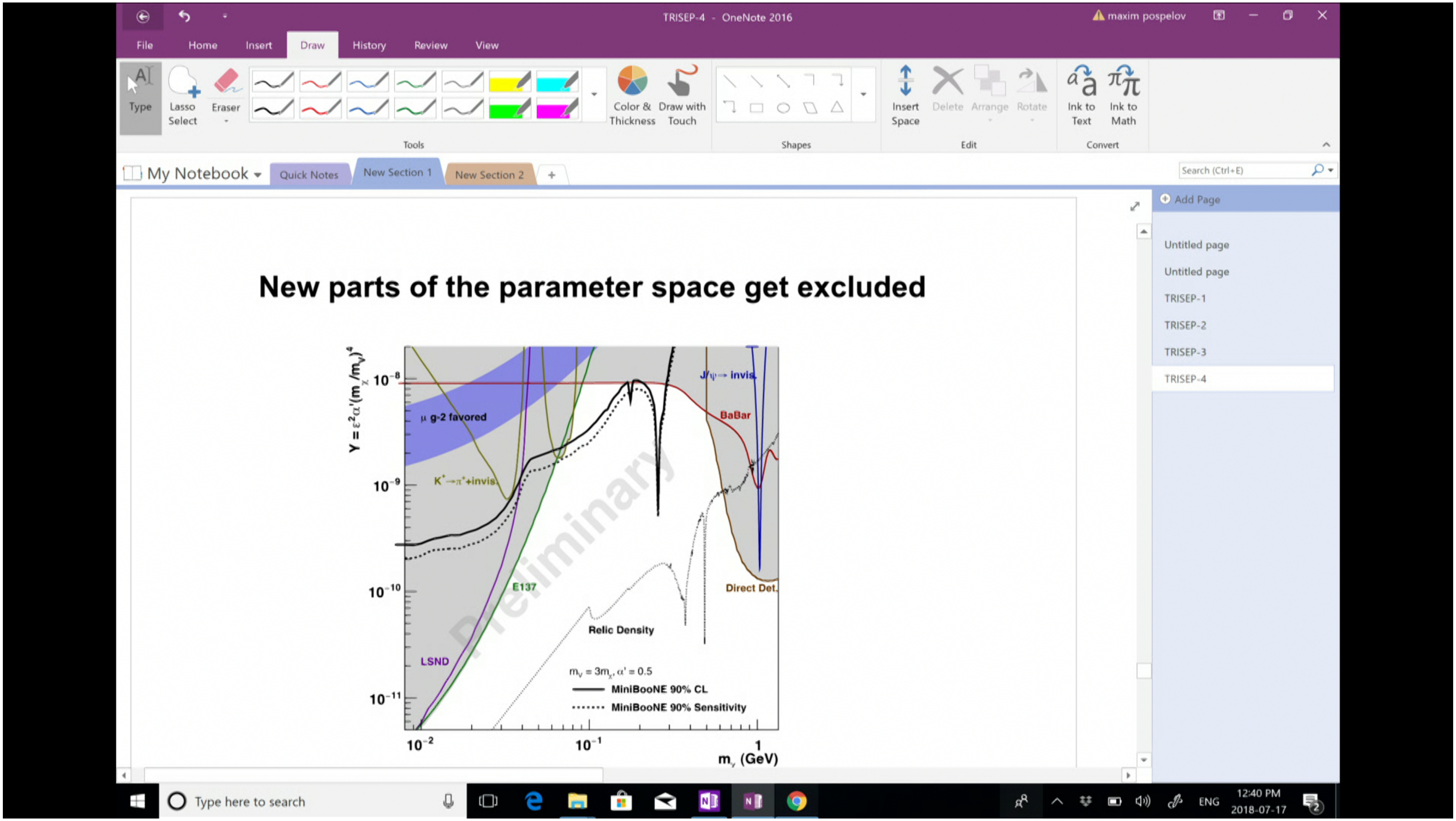
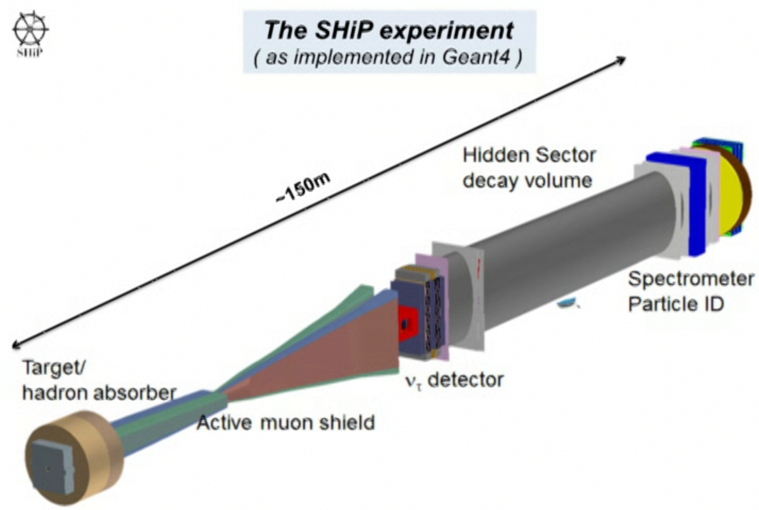
- Data are well described by MC

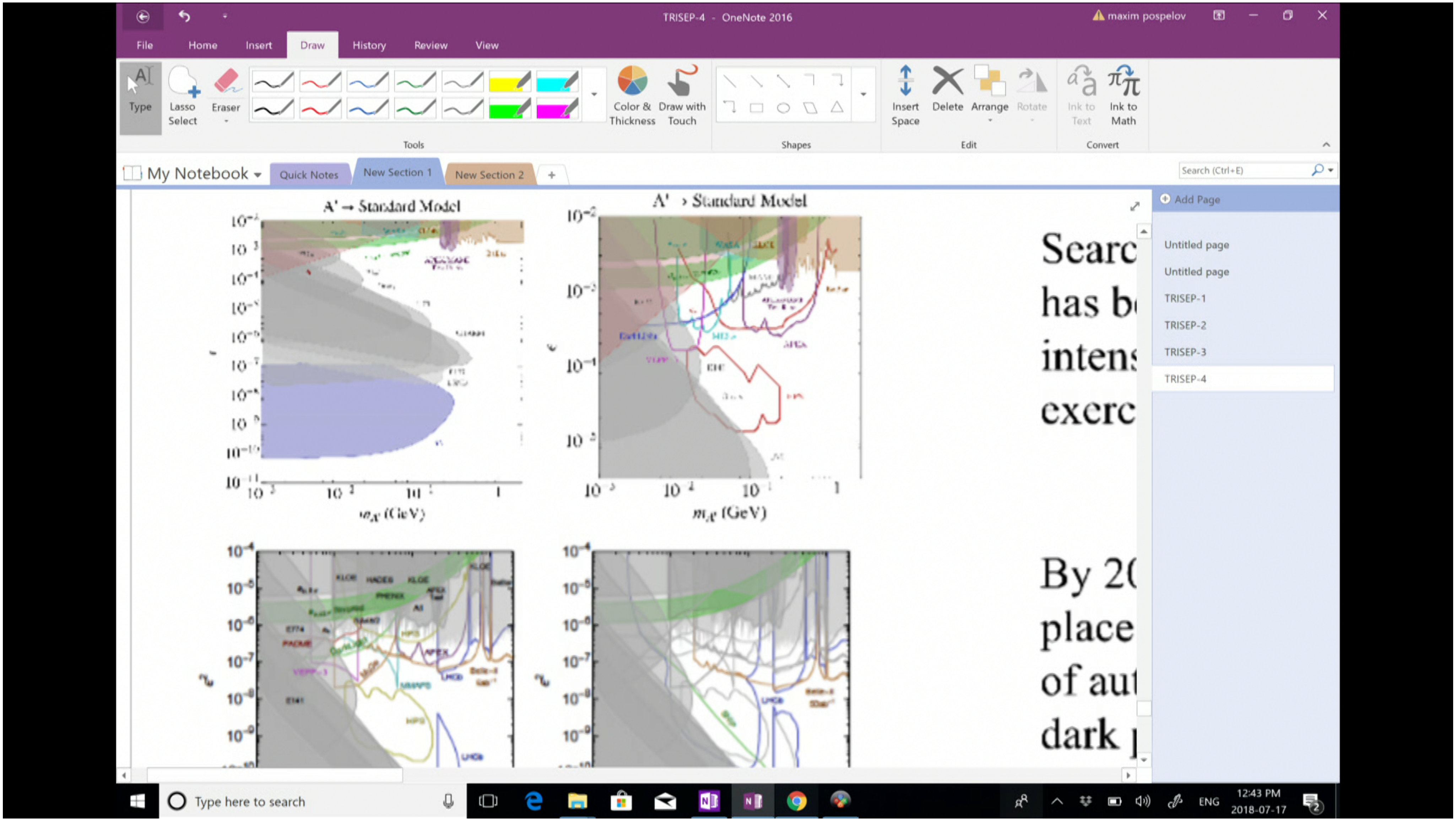

New parts of the parameter space get excluded
$Y = \epsilon^2 \alpha' (m_\chi / m_V)^4$
m_V (GeV)
μ g-2 favored
$K^+ \to \pi^+$+invis
J/ψ → invis
BaBar
E137
Direct Det.
Relic Density
LSND
Preliminary
$m_V = 3m_\chi$, $\alpha' = 0.5$
MiniBooNE 90% CL
MiniBooNE 90% Sensitivity

Future: SHiP project at CERN



A proposal for a large experiment at CERN SPS to look for all types of hidden particles: sterile neutrinos, axion-like particles, dark photons, dark Higgses. Can also be used to study scattering signature of light DM

26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A' → Standard Model
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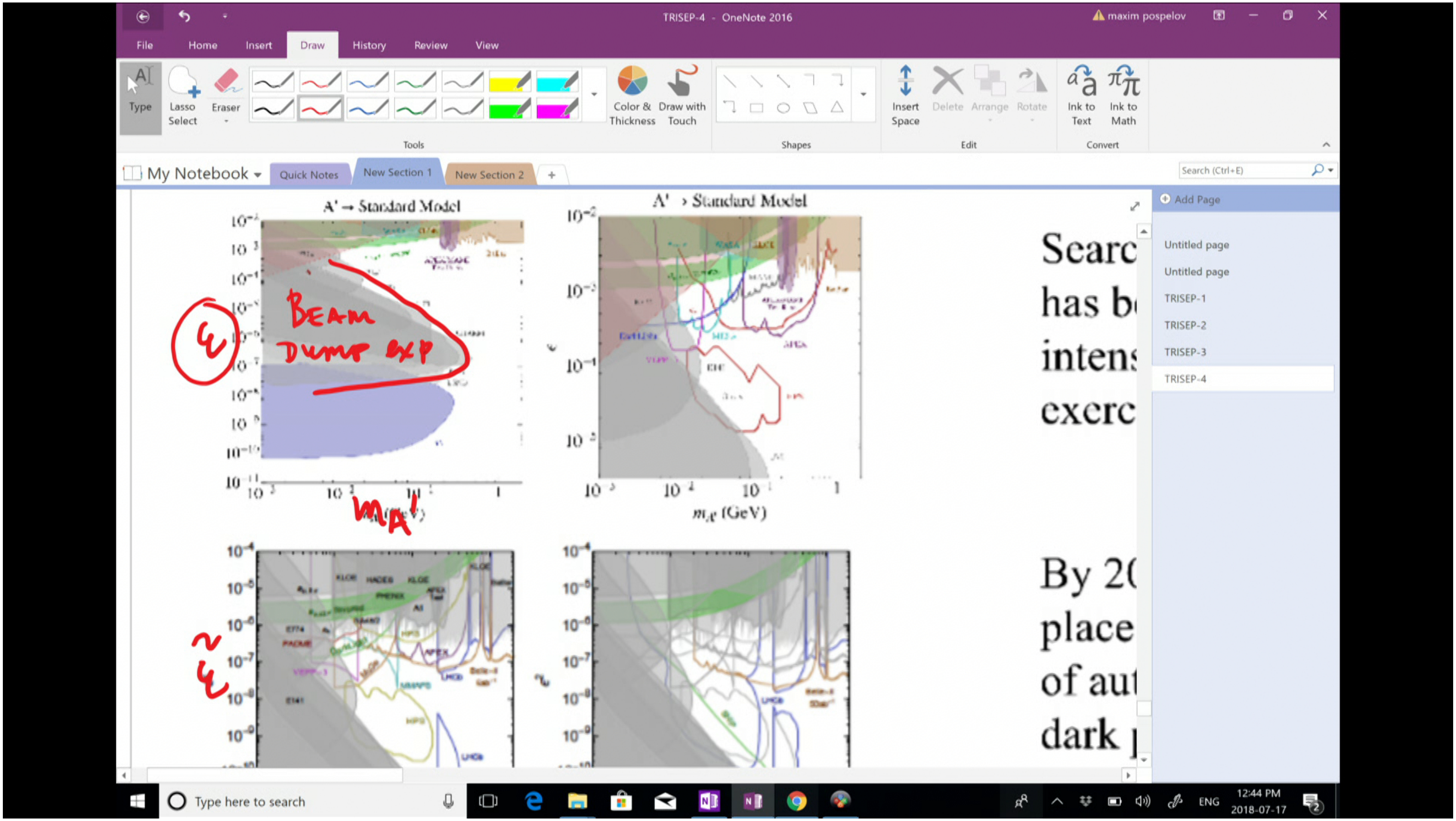
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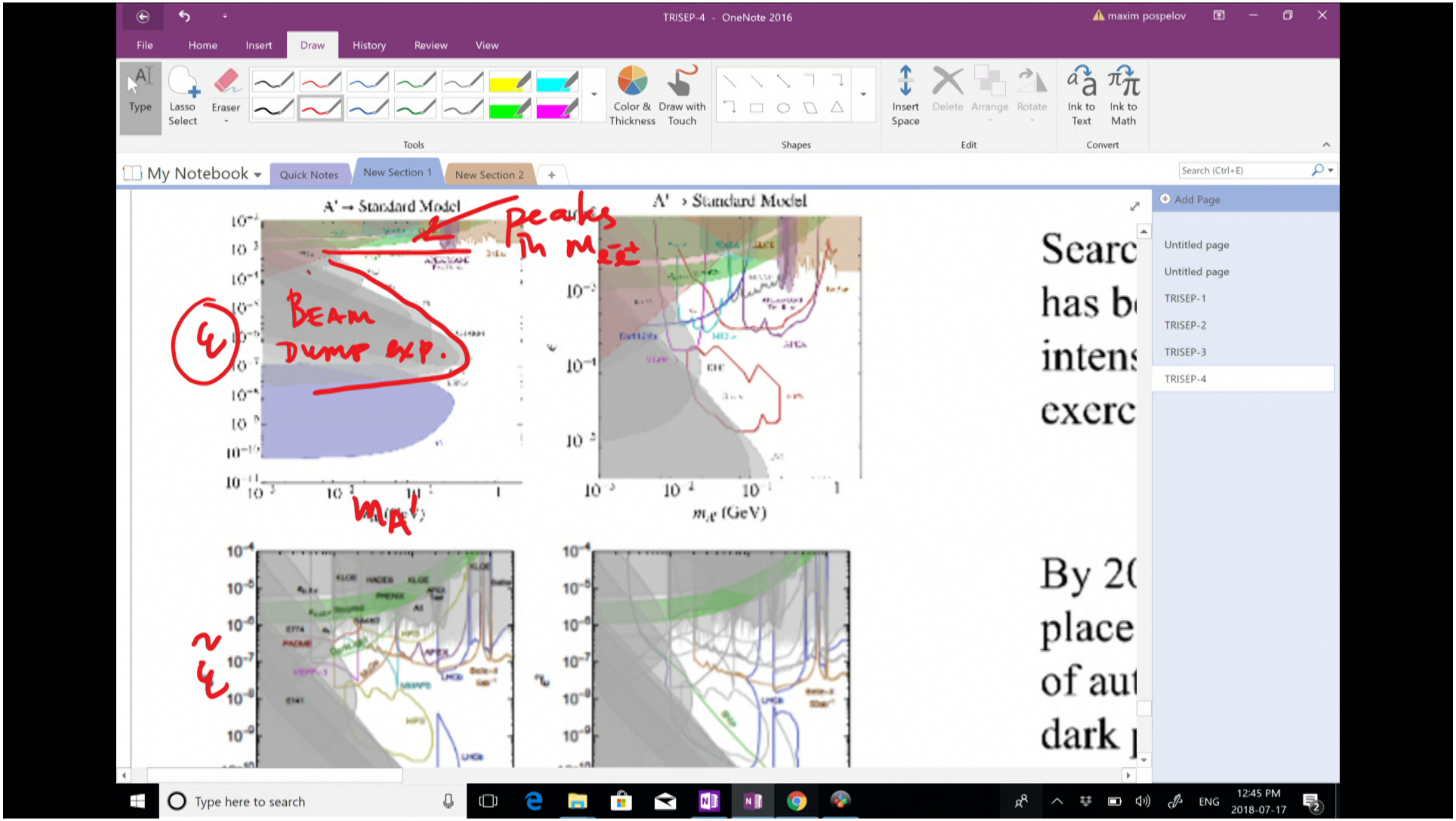
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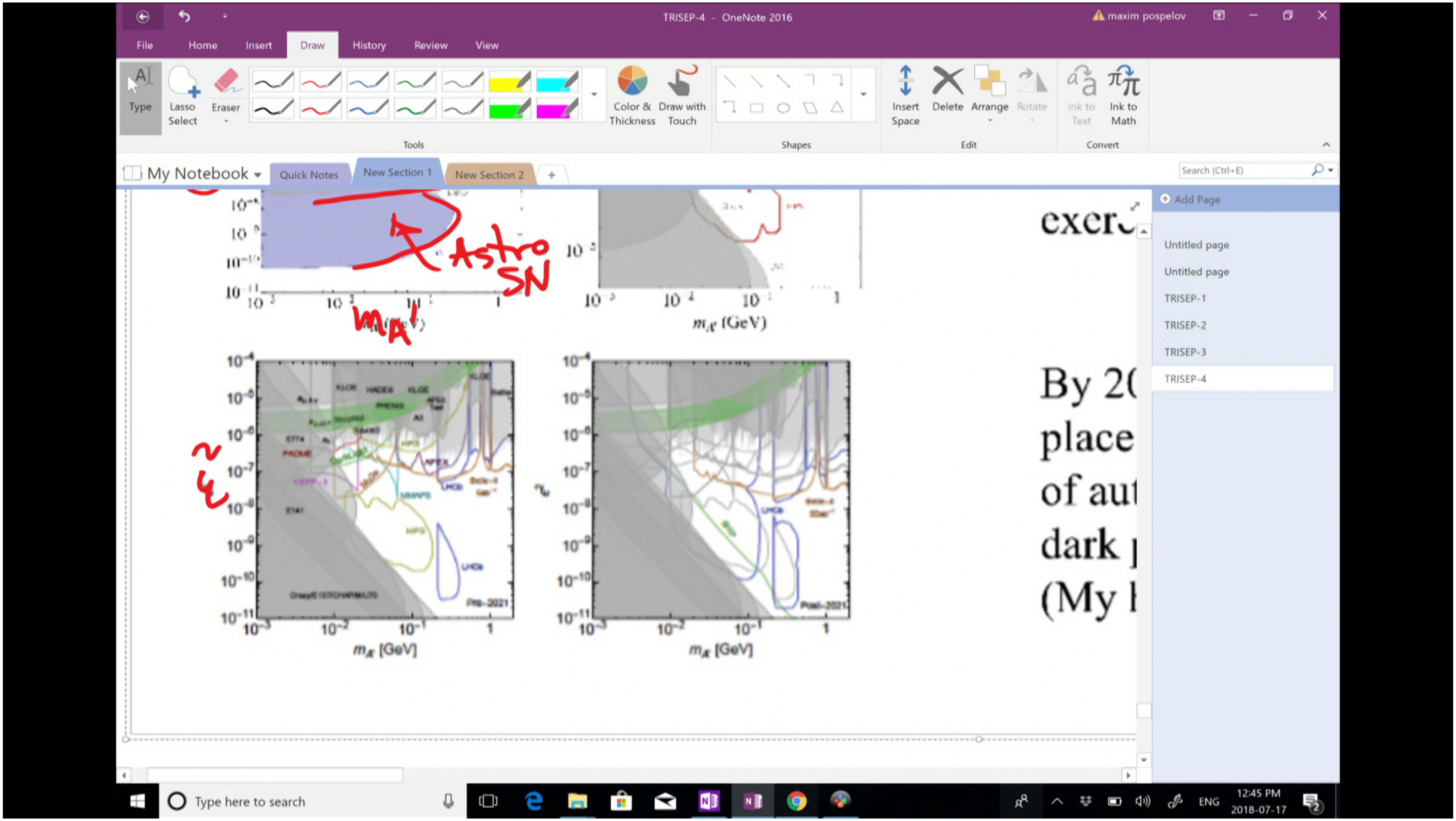

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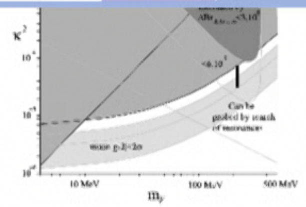
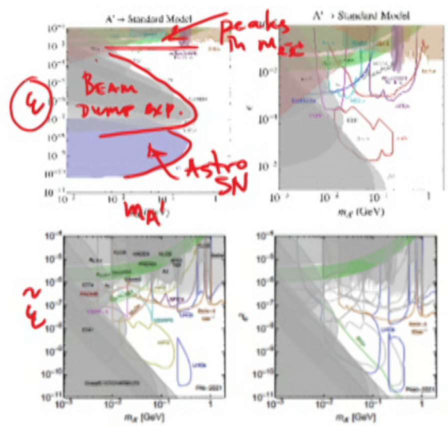


Dark photon with kinetic mixing ~ 10^{-3} is the simplest model that can account for anomalous $\Delta a_\mu \sim 3\ 10^{-9}$, MP, 2008

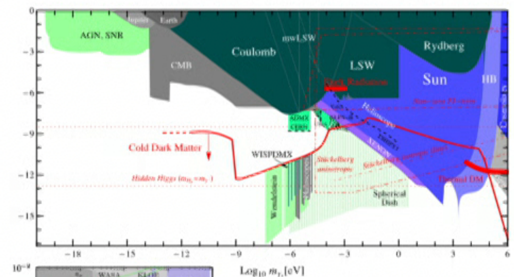


Search for dark photons ($A' \to e^+e^-$) has become an important part of the intensity frontier program, Snowmass exercise, Minneapolis, 2013

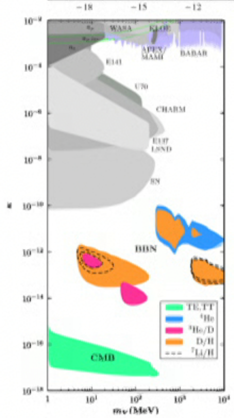
By 2018, there is a large community in place ("Cosmic Vision" summary, 100s of authors, 2017), where the search for dark photon is one of the priorities. (My hypothesis from 2008 is ruled out.

Constraints on dark photon in broader range

Constraints on dark photon in broader range



Going to smaller mass range (our group, An et al, 2013, has derived correct stellar energy loss constraints)



Going to smaller couplings: new primordial nucleosynthesis and CMB constraints from late decays of dark photons, (our group, Fradette et al, 2014)

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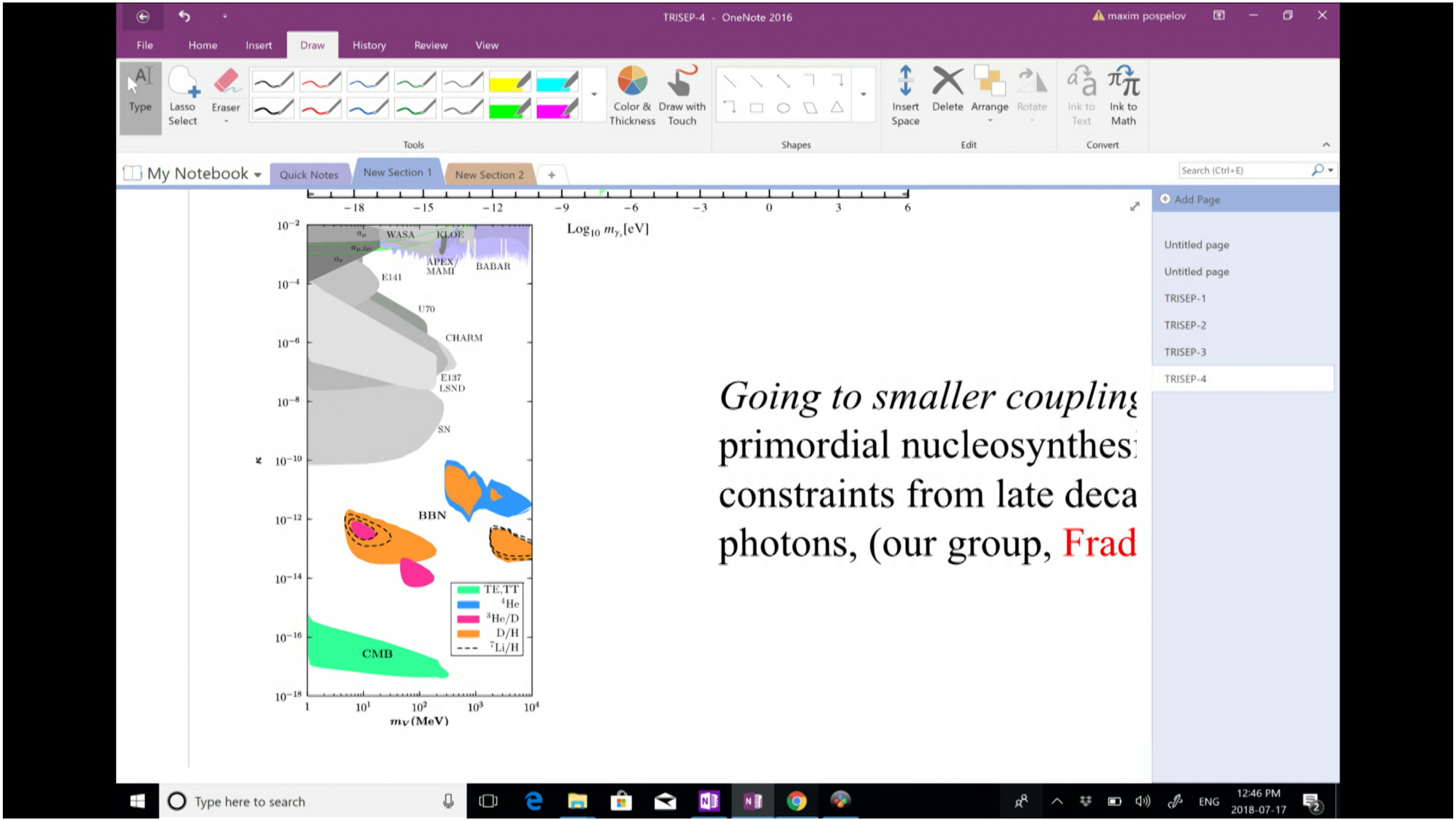
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Log10 mγs [eV]
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APEX/MAMI
BABAR
E141
U70
CHARM
E137
LSND
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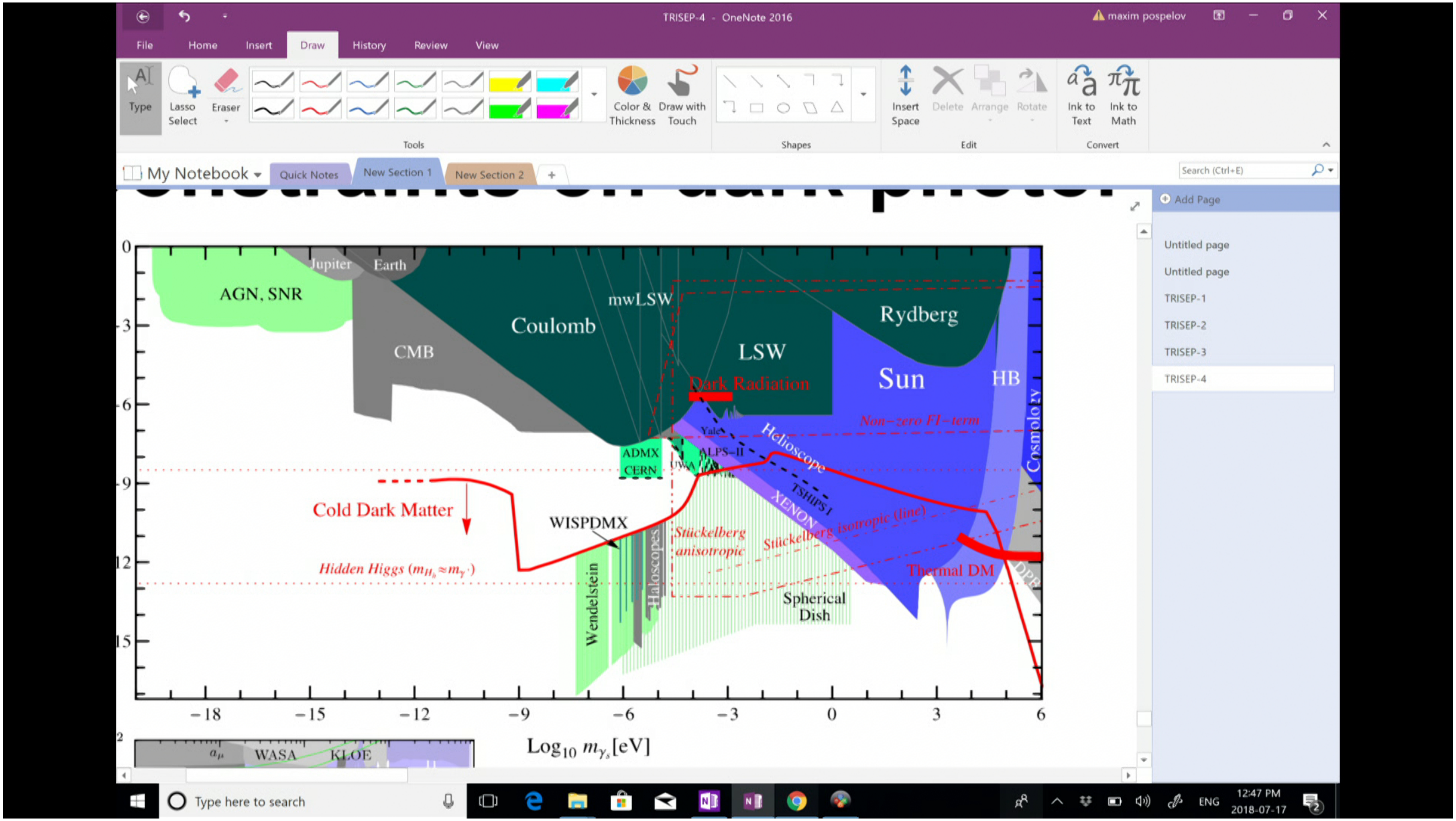
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AGN, SNR
Jupiter
Earth
CMB
Coulomb
mwLSW
LSW
Rydberg
Sun
HB
Cosmology
Dark Radiation
Non-zero FI-term
Helioscope
ADMX
CERN
Yale
ALPS-II
XENON
TSHIPS I
Cold Dark Matter
WISPDMX
Hidden Higgs $(m_{H_s} \approx m_{\gamma'})$
Stückelberg anisotropic
Stückelberg isotropic (line)
Thermal DM
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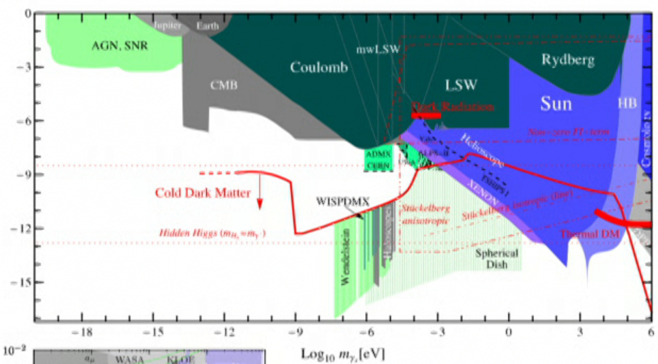

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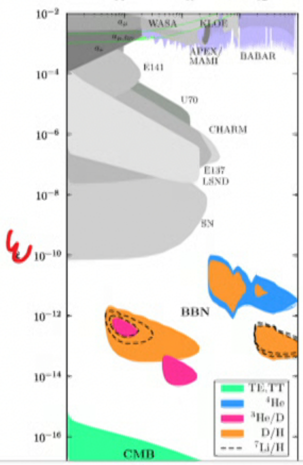
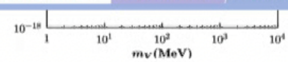
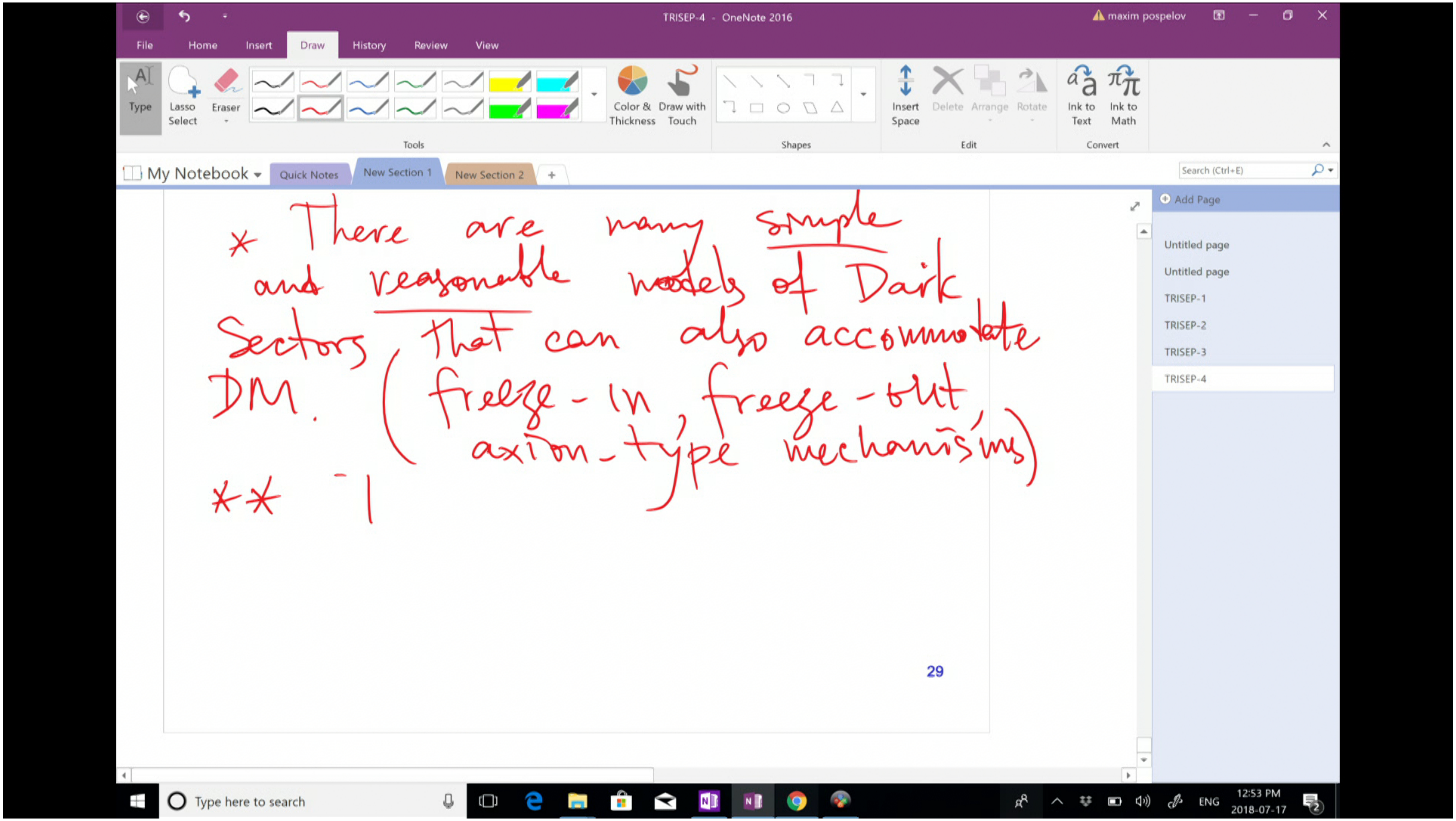


Going to smaller couplings: new primordial nucleosynthesis and CMB constraints from late decays of dark photons, (our group, Fradette et al, 2014)



Conclusions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* There are many simple and reasonable models of Dark Sectors that can also accommodate DM. (freeze-in, freeze-out, axion-type mechanisms)
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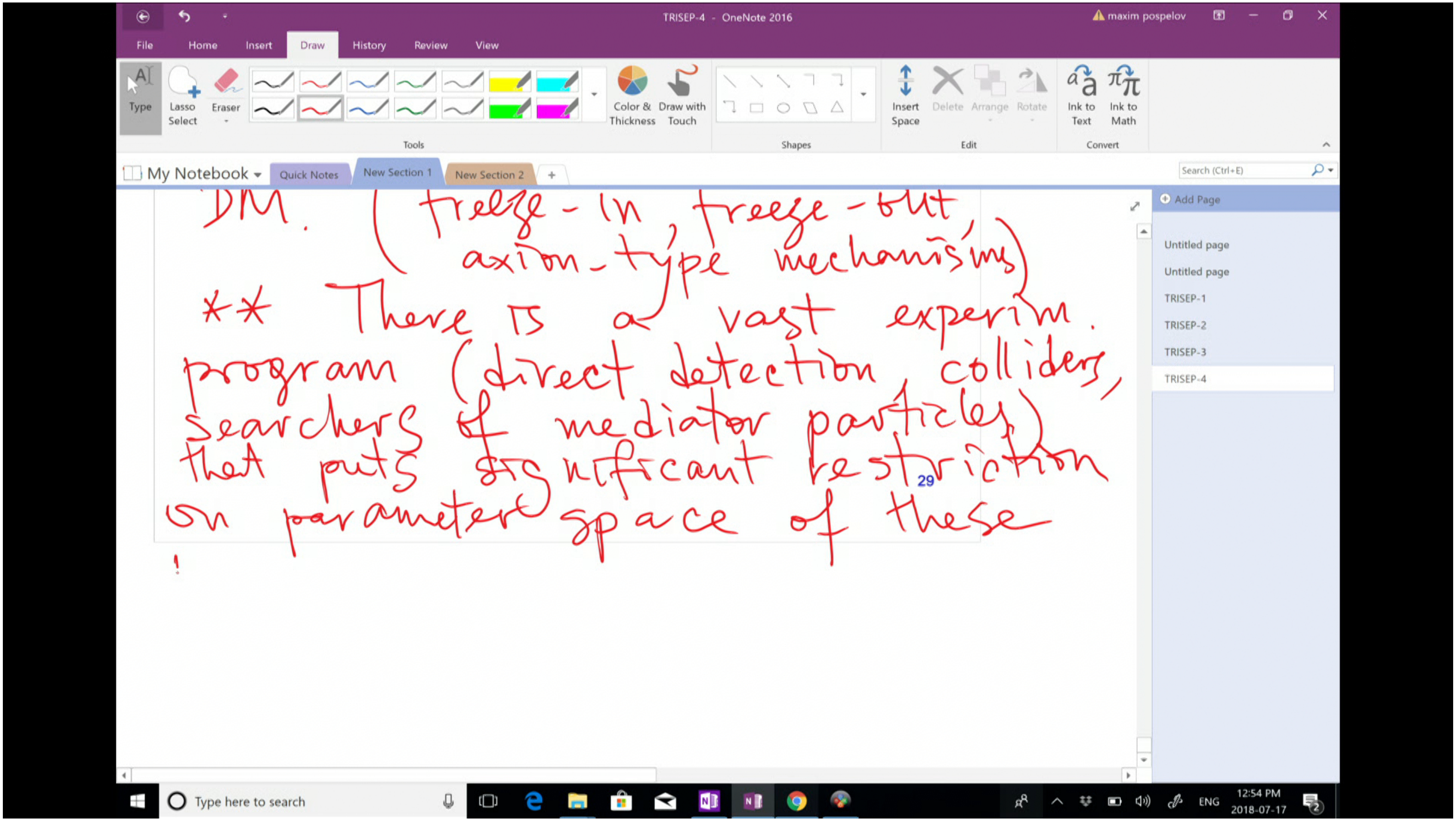
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DM. (freeze-in, freeze-out, axion-type mechanisms)
** There is a vast experim. program (direct detection, colliders, searches of mediator particles) that puts significant restriction on parameter space of these
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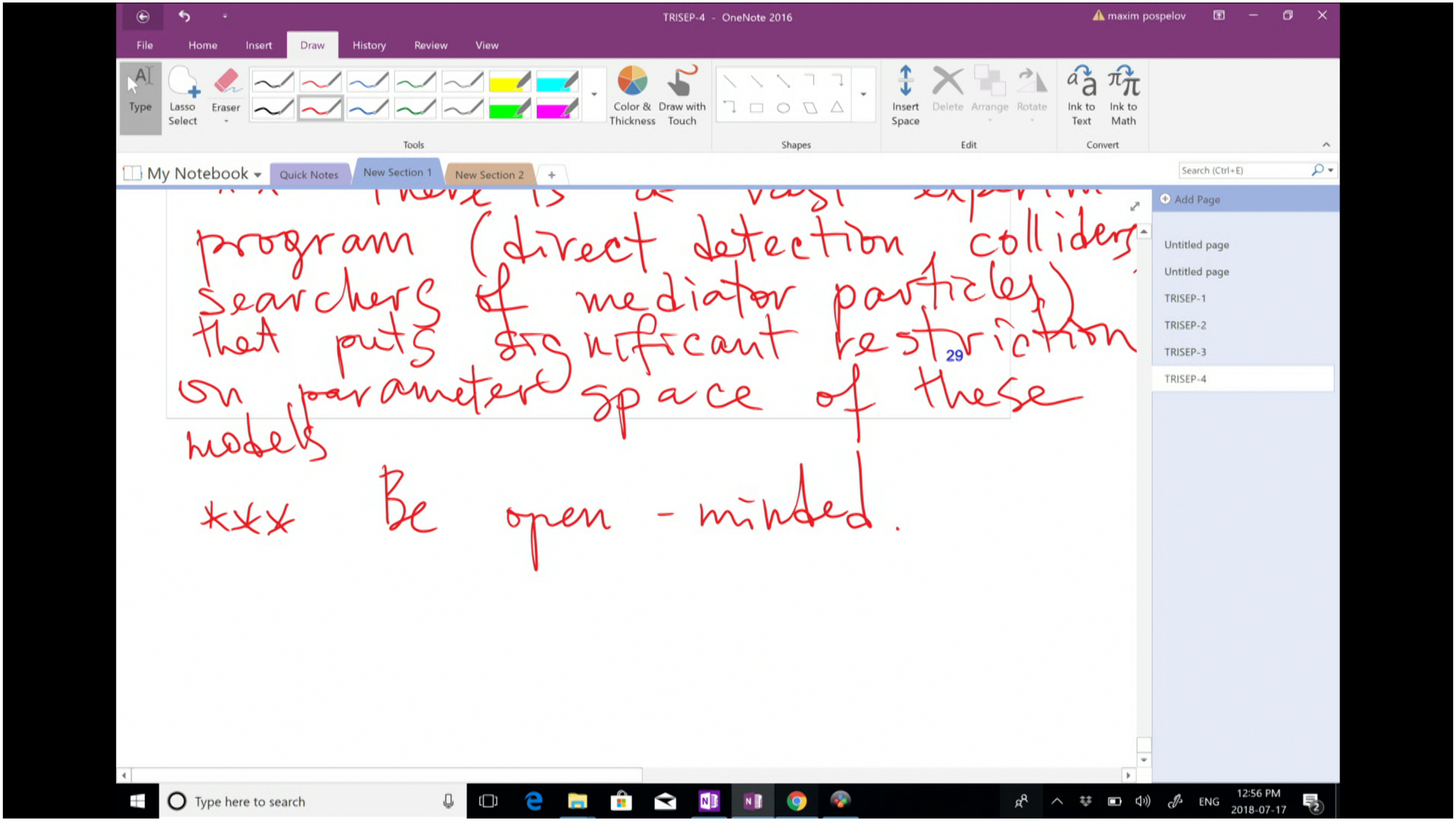

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program (direct detection, colliders, searchers of mediator particles) that puts significant restriction on parameter space of these models
*** Be open-minded.
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