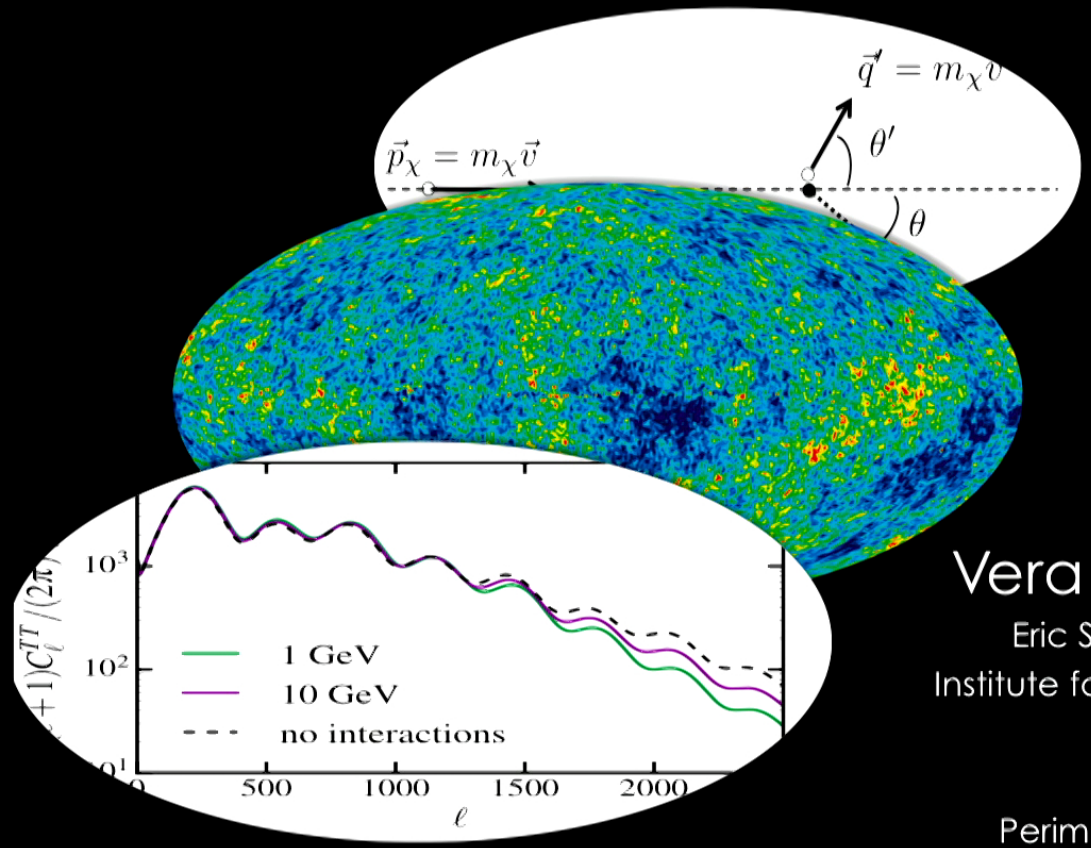
Title: First CMB constraints on dark matter effective theory

Date: Jul 21, 2017 04:50 PM

URL: http://pirsa.org/17070026

Abstract:

CMB constraints on dark matter EFT



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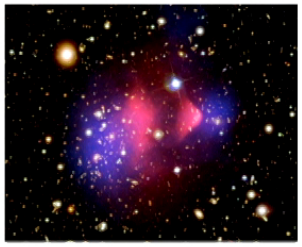
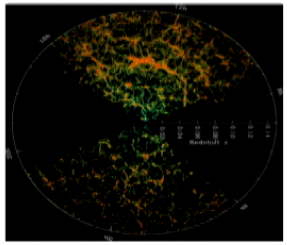
Perimeter * July 2017

What do we (want to) know?

Lots of evidence for a consistent picture:
~6x more invisible matter than baryons.

It's not a lot of things
(~~hot~~, ~~interacting much~~, ~~decaying much,~~…)

It could be a lot of things
(WIMPs, WIMP-like, axion, sterile neutrino,...)

How does it interact with the SM?

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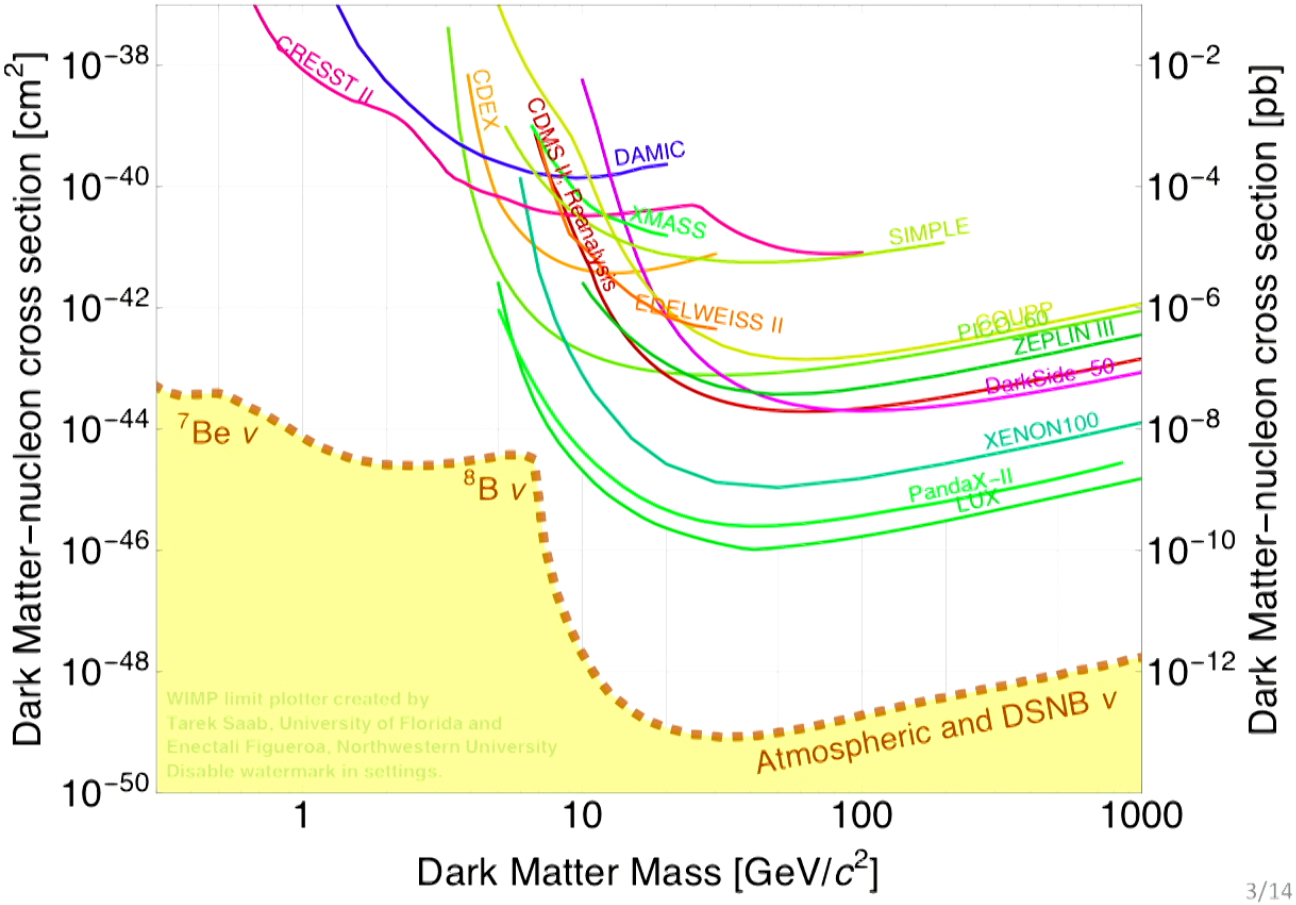
Current status



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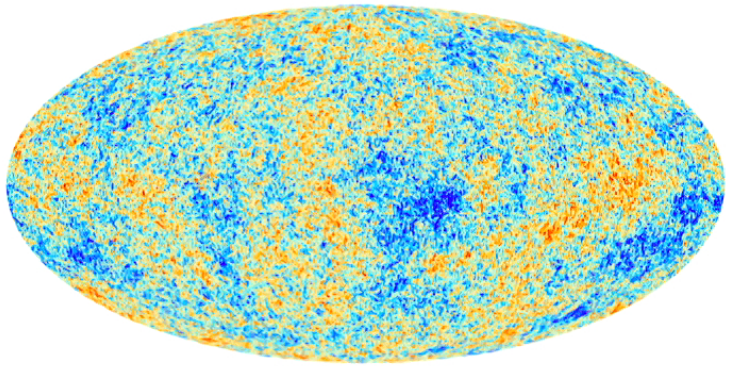
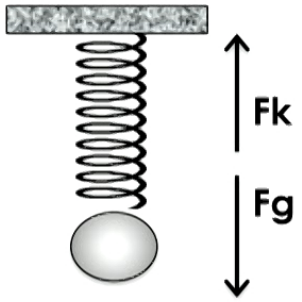
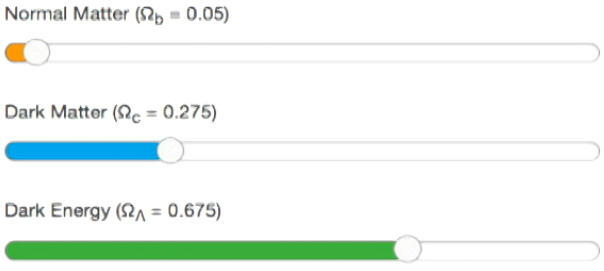
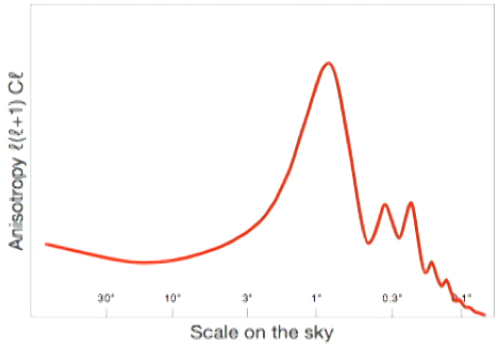
DM in CMB anisotropies





Acoustic oscillations





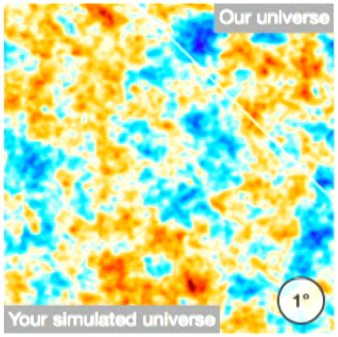
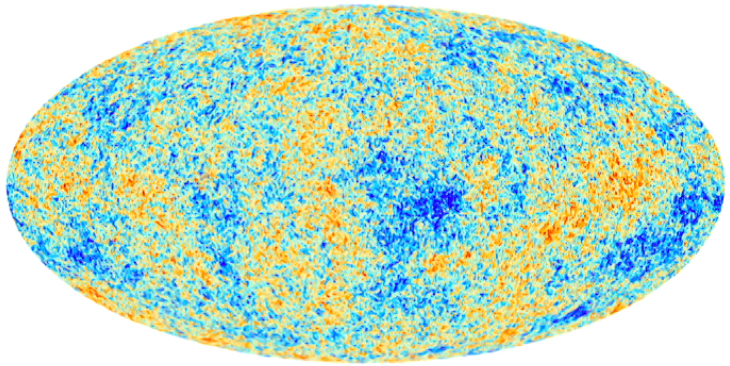
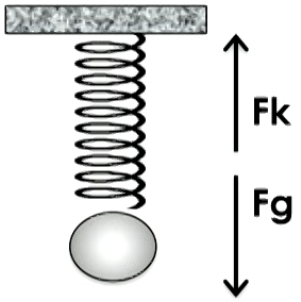


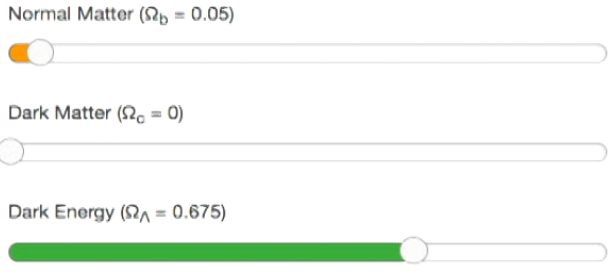
Image credits: Amanda Yoho, Planck CMB simulator at http://strudel.org.uk/planck/#; ESA/Planck

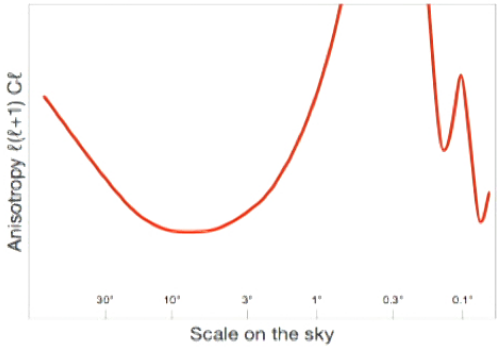
DM in CMB anisotropies

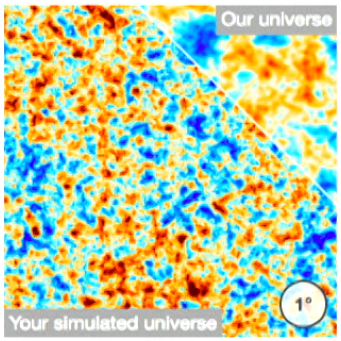




Acoustic oscillations







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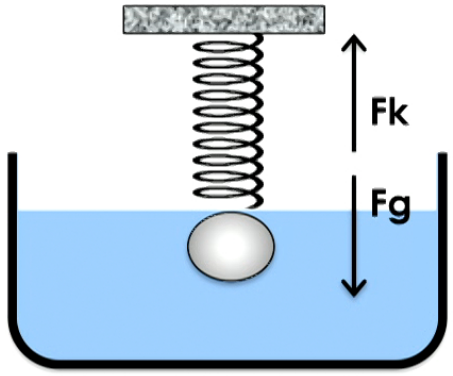
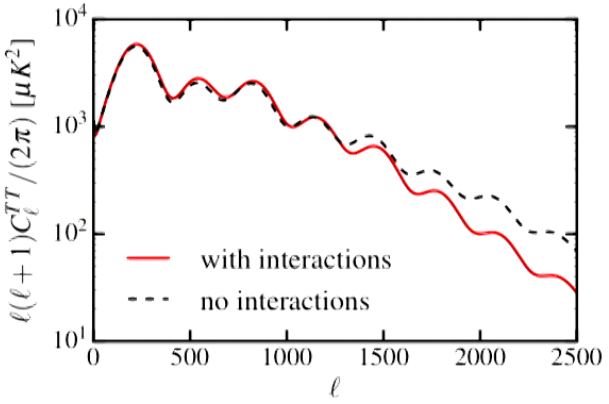
DM-proton scattering and the CMB

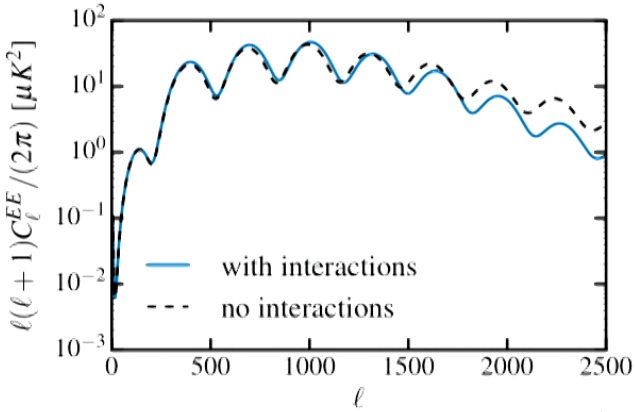
scattering →drag force→
suppression of small scales



Temperature



Polarization



Plots: VG and Boddy, in prep; Previous work: Chen et al (2002), Sigurdson et al (2004); Dvorkin et al (2014); etc.

Non-relativistic EFT

[Fan et al, 2010; Fitzpatrick et al, 2012; Anand et al, 2013]

✧ Instead of a model, start with Galilean Hermitian invariants:

$$i\vec{q}, \qquad \vec{v}^{\perp} \equiv \vec{v} + \frac{\vec{q}}{2\mu_N}, \qquad \vec{S}_\chi, \qquad \vec{S}_N$$

Momentum transfer | Relative velocity | Spins

✧ Write down all operators derived from these => ~15 for elastic scattering through scalar or vector mediator, to second order in q; 2 free parameters per operator:

$$\mathcal{L}_{\rm int} = \sum_{N=n,p} \sum_i c_i^{(N)} \mathcal{O}_i \chi^+ \chi^- N^+ N^-$$

Non-relativistic EFT

[Fan et al, 2010; Fitzpatrick et al, 2012; Anand et al, 2013]

- Consider the full set of non-relativistic operators coupling DM to nucleons, including velocity and momentum dependence.
- Parametrize all possible interactions at low energies through operator coefficients.
- Provided a mapping between these "observables" and specific high energy theories for DM => model-independent approach to covering the space of theoretical possibilities.

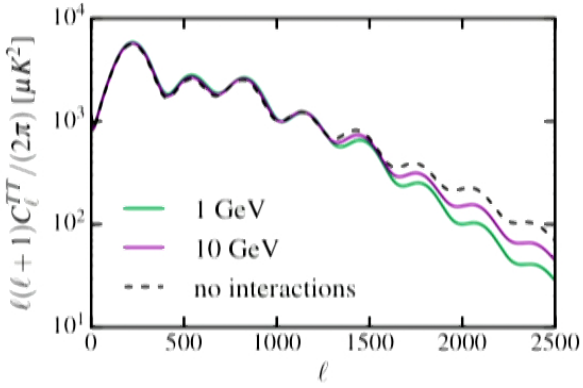
DM EFT in cosmological context

Work in progress with Kimberly Boddy (UH)

- For each operator → momentum transfer cross section: $\sigma(v)$.
- Integrate over velocity distribution at a given redshift → momentum exchange R(z) [params: **m_χ, couplings to p and n**]
- Include R into Boltzmann equations → effect on cosmological perturbations.
- Implement into Boltzmann code to compute Cl's.
- Analyze all available CMB data.

DM EFT in cosmological context

Extra drag force between baryon-photon fluid and DM



$$\dot{\delta_\chi} = -\theta_\chi - \frac{\dot{h}}{2}, \qquad \dot{\delta_b} = -\theta_b - \frac{\dot{h}}{2},$$

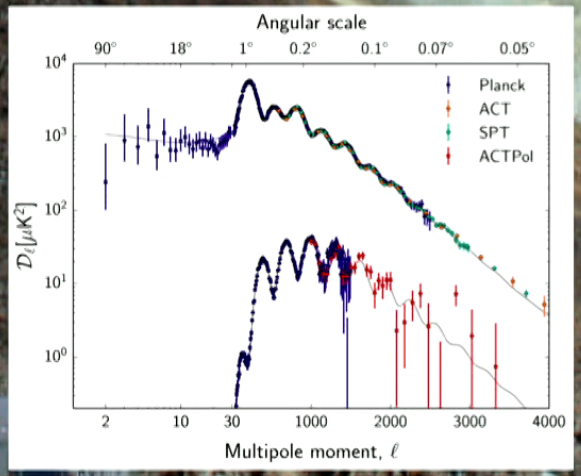
$$\dot{\theta_\chi} = -\frac{\dot{a}}{a}\theta_\chi + c_\chi^2 k^2 \delta_\chi + R_\chi\,(\theta_b - \theta_\chi)\,,$$

$$\dot{\theta_b} = -\frac{\dot{a}}{a}\theta_b + c_b^2 k^2 \delta_b + R_\gamma\,(\theta_\gamma - \theta_b) + \frac{\rho_\chi}{\rho_b} R_\chi\,(\theta_\chi - \theta_b)$$

Gluscevic and Boddy (in prep);
see also: Chen et al (2002), Sigurdson et al (2004); Dvorkin et al (2014); etc.

$$R_\chi = \frac{a\, c_n\, \rho_b\, \sigma_0}{m_\chi + m_{\rm H}} \left(\frac{T_b}{m_{\rm H}} + \frac{T_\chi}{m_\chi}\right)^{\frac{n+1}{2}} \mathcal{F}_{\rm He}$$

Data: Planck & ACTPol



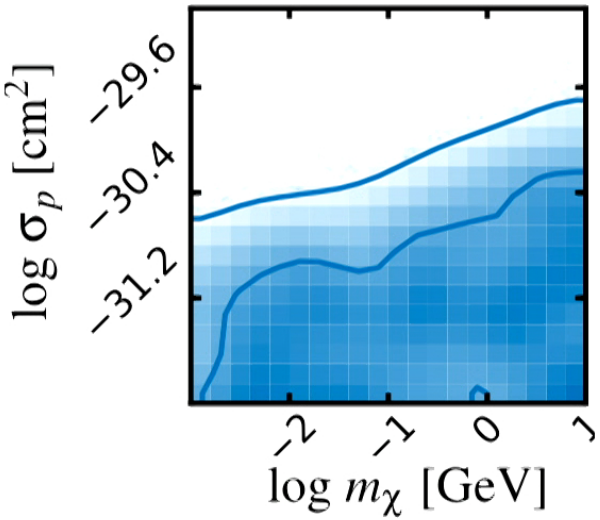
Background by: S. Aiola, Map from: Lous et al (2016)
Plot by E. Calabrese (all for ACTPol)

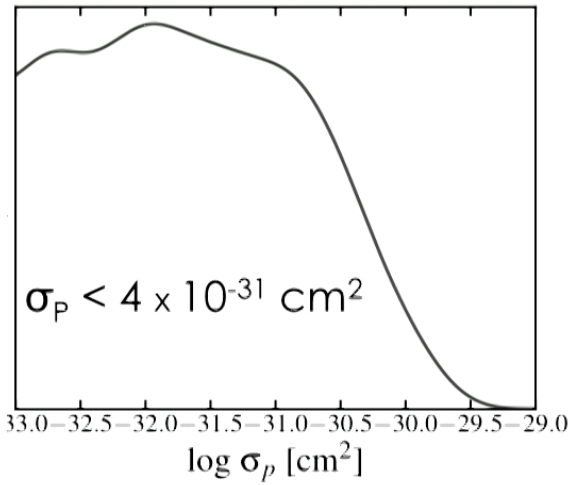
Cosmological constraints on DM EFT

Work in progress with Kimberly Boddy (UH)

Projections for Planck [preliminary!]

(spin- and velocity-independent scattering):





New parameter space: down to mass ~MeV
(independent of local astrophysical DM properties)

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Cosmological constraints on DM EFT

Work in progress with Kimberly Boddy (UH) & ACTPol collaboration

Next steps:

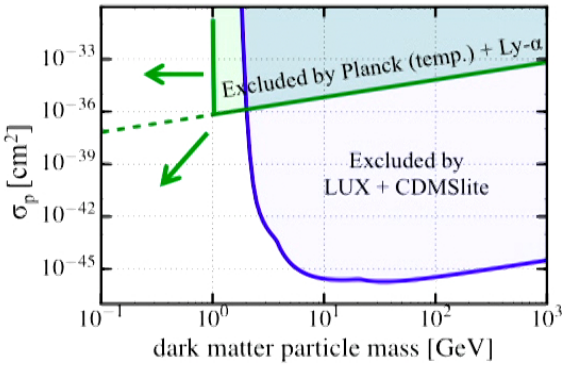
- Planck constraints on all non-relativistic interaction operators.
- Co-analyze Planck & small-scale CMB polarization from ACTPol.
- Future:

consider large-scale structure probes of the matter power spectrum; include scattering off electrons; consider spectral distortions

Comparison with nuclear recoils

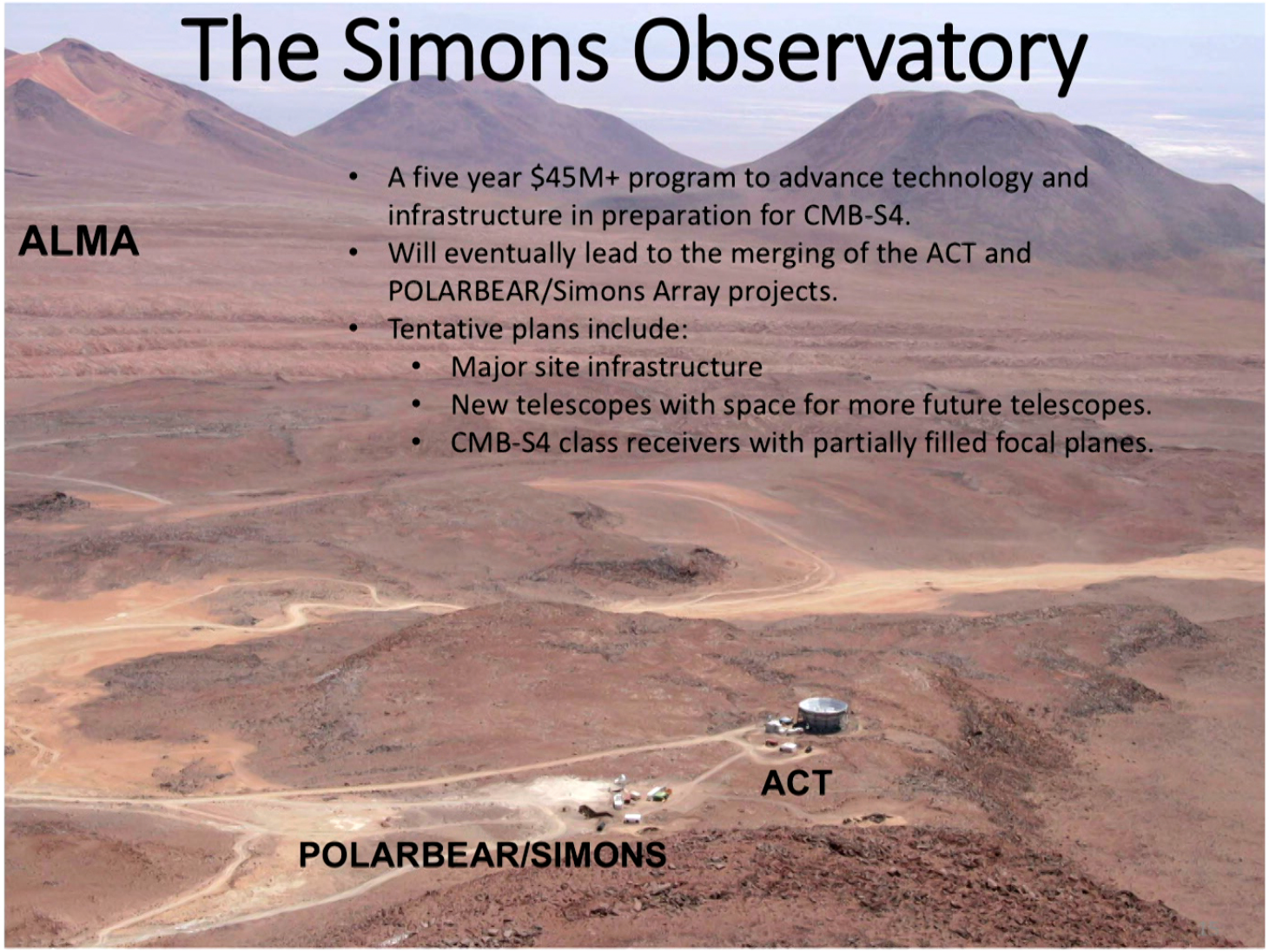
Cosmology far less sensitive to traditional WIMPs, but….

- Current DD insensitive to m<< 1GeV for proton scattering (though there are other ideas!)
- Covering the range of cross sections inaccessible to underground experiments
- DD relies on assumptions about <u>local</u> astrophysical properties of dark matter (not observable).
- DD has limited ability to unveil the nature of the interaction in agnostic analysis (Gluscevic et al 2015).



[Just for illustration: VG et al (2015) and Dvorkin et al (2014)]

The Simons Observatory



- A five year $45M+ program to advance technology and infrastructure in preparation for CMB-S4.
- Will eventually lead to the merging of the ACT and POLARBEAR/Simons Array projects.
- Tentative plans include:
  - Major site infrastructure
  - New telescopes with space for more future telescopes.
  - CMB-S4 class receivers with partially filled focal planes.