Dark Matter Science with LSST

LSST Community & Project Workshop

August 16 2017

Scribe Needed

wadawson Will Dawson 5d

I am looking for a scribe for the dark matter session next week. I am sure your effort will be rewarded with **fame and fortune**! Please let me know if you are available.
Thanks,
Will

Reply

Session Objectives

- Engage the LSST dark matter community beyond just the Dark Energy Science Collaboration
  - Provide the community with a summary of current DESC efforts
  - Provide some examples of current work ongoing in various LSST Science Collaborations
  - Have an open discussion
- Identify the next step

Agenda

- Introductory Remarks and Summary of DESC Effort; Will Dawson (10 min)
- Strong Lensing Constraints on Dark Matter; Nicola Napolitano (10 min)
- Milky and Local Volume Constraints on Dark Matter; Keith Bechtol (10 min)
- Transients/Variable Constraints on Dark Matter; Will Dawson (10 min)
- Discussion (50 minutes)

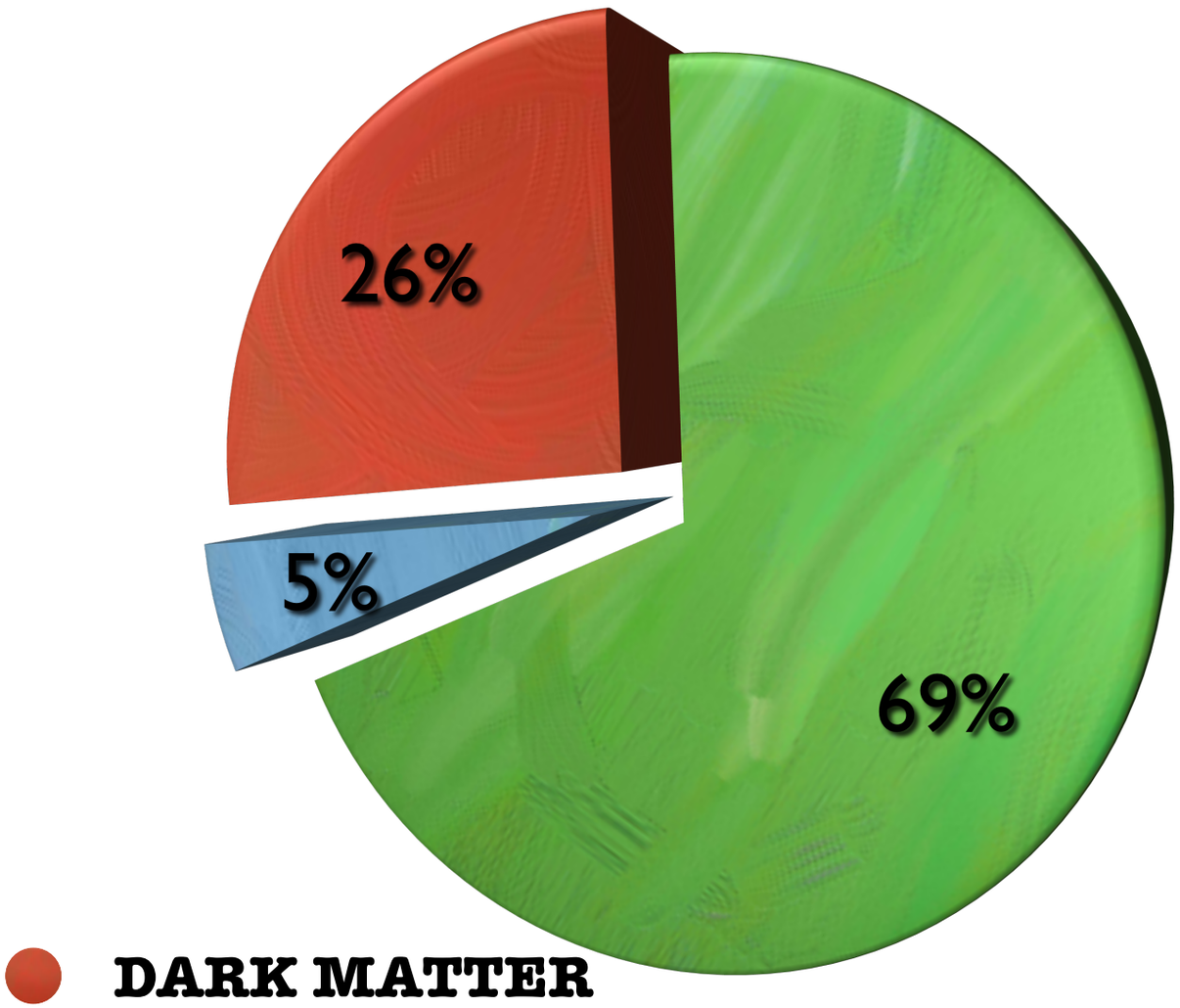
Probing the Nature of Dark Matter with LSST

WITH (RELEVANT) ANNOTATIONS
BY WILL DAWSON

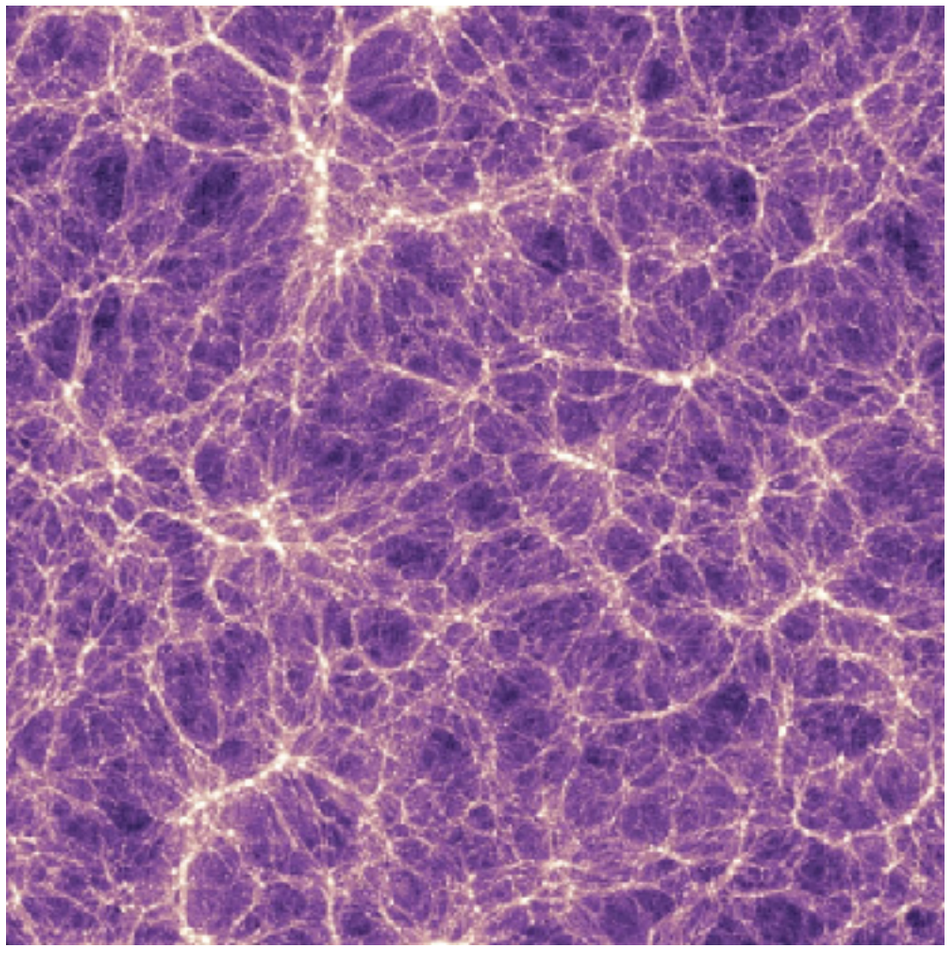
Alex Drlica-Wagner
LSST DESC Meeting
July 12, 2017

The Dark Matter Problem

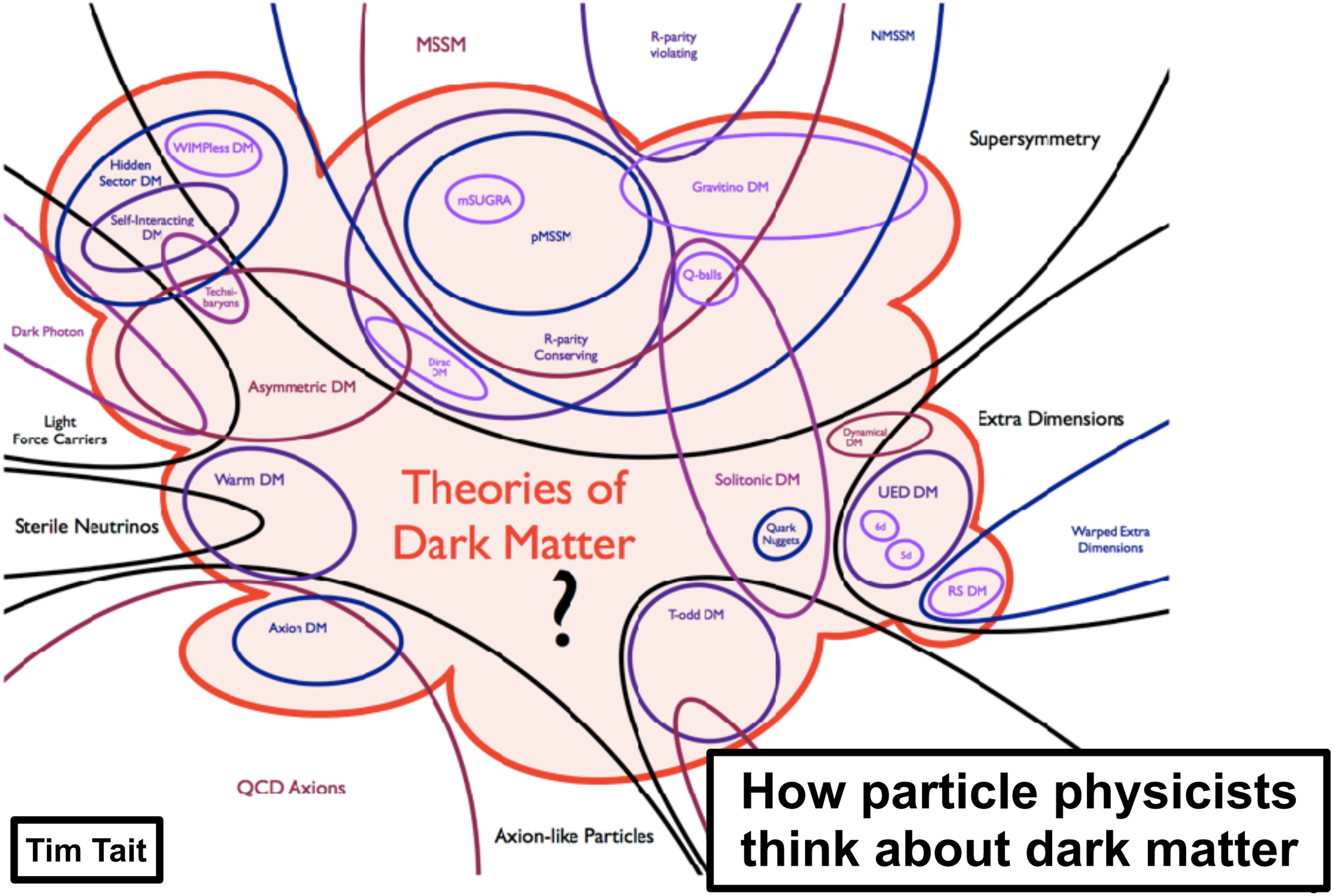
Plank Collaboration (2016)



How DESC usually thinks about dark matter



The Dark Matter Problem



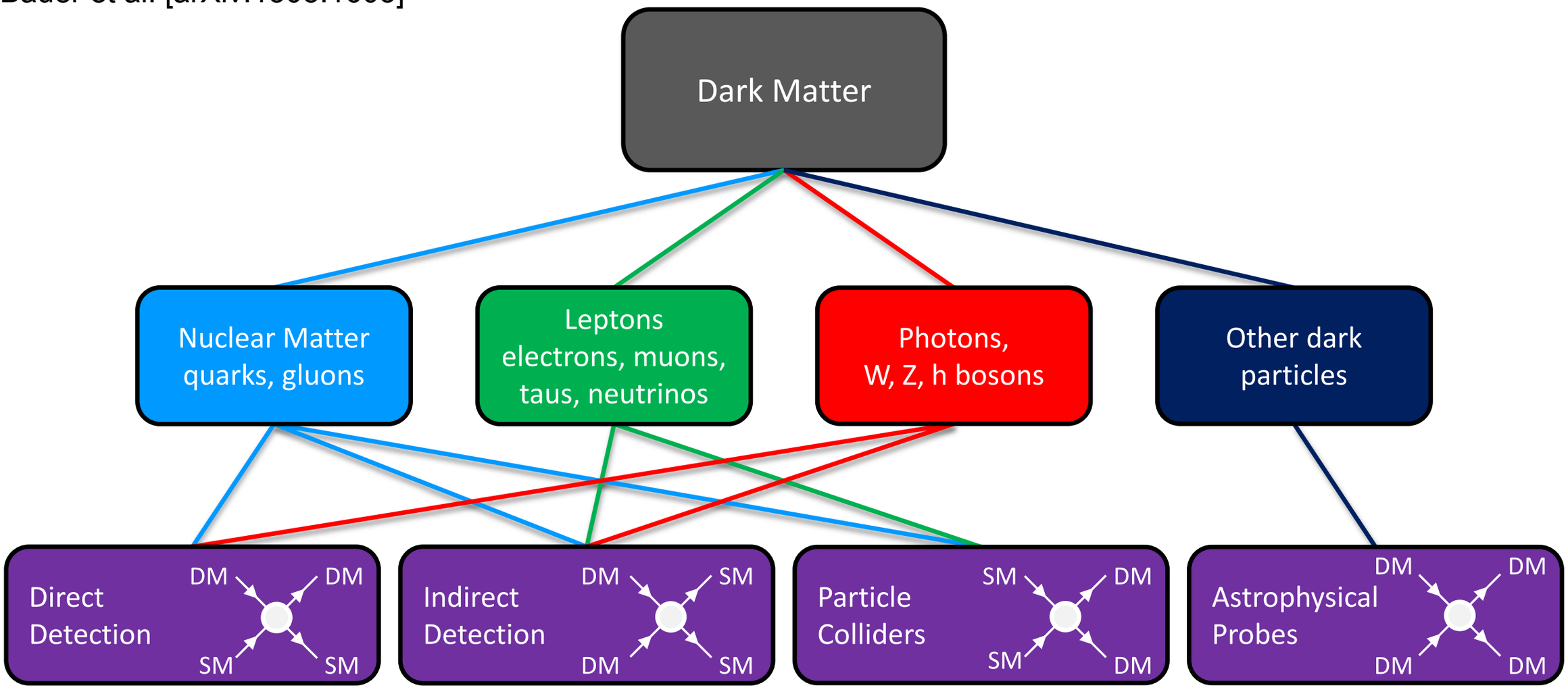
Tim Tait

How particle physicists think about dark matter

The Dark Matter Search

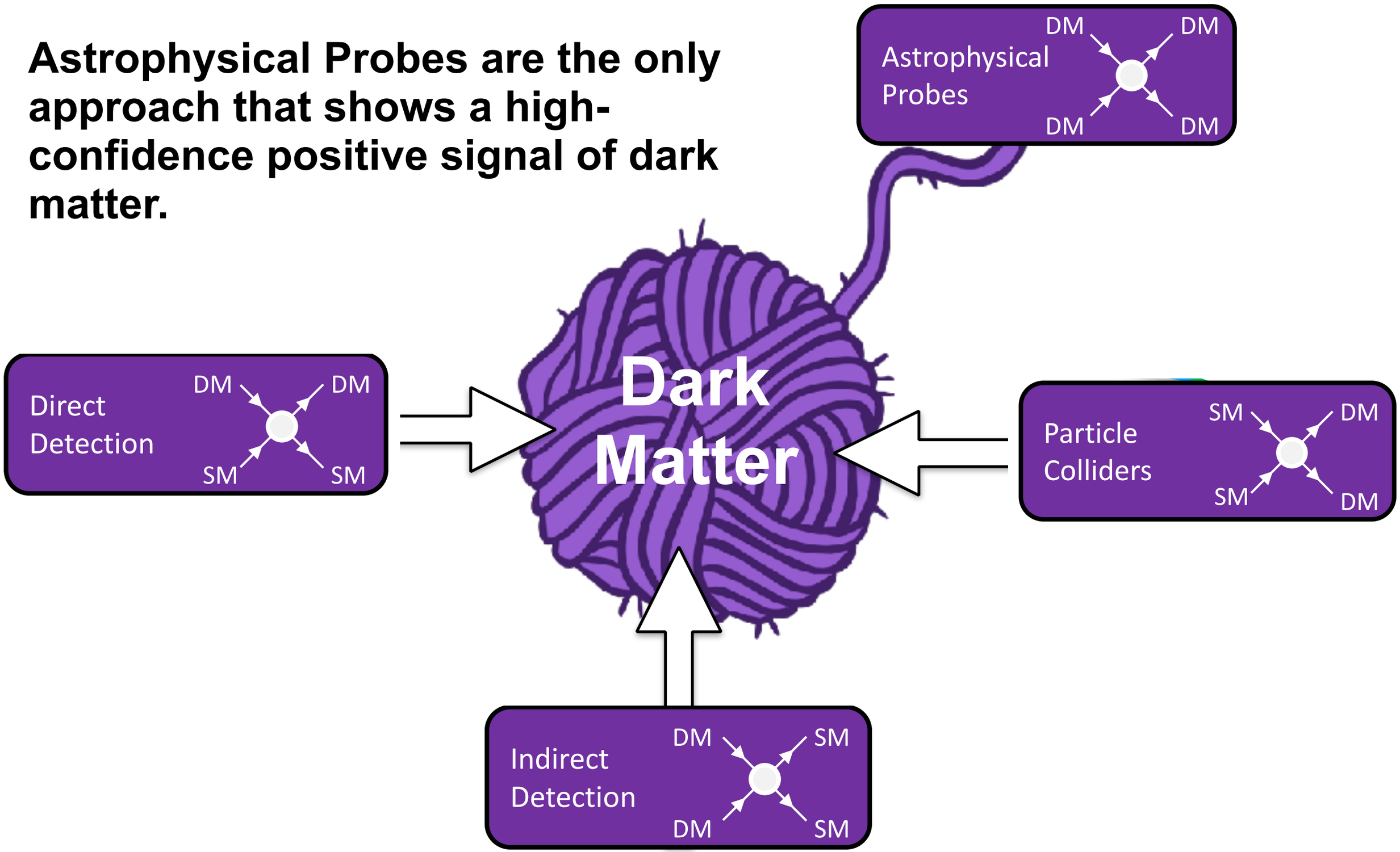
Snowmass: Cosmic Frontier Report

Bauer et al. [arXiv:1305.1605]



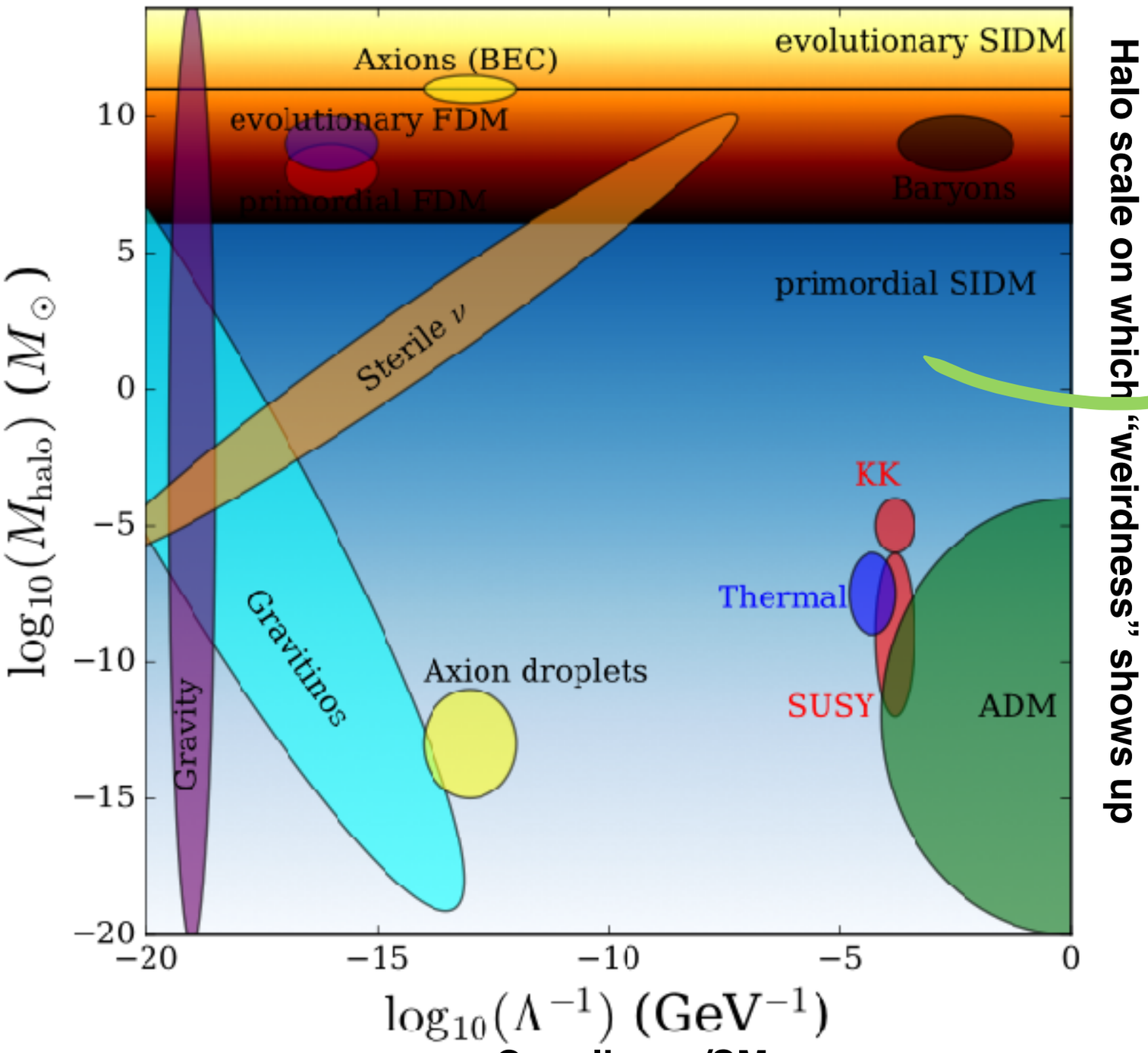
The Dark Matter Search

Astrophysical Probes are the only approach that shows a high-confidence positive signal of dark matter.



Dark Matter: Micro to Macro

Dark Matter Micro-Physics



Dark Matter Macro-Physics

Coupling w/SM

Halo scale on which "weirdness" shows up

PRIMORDIAL BLACK HOLES

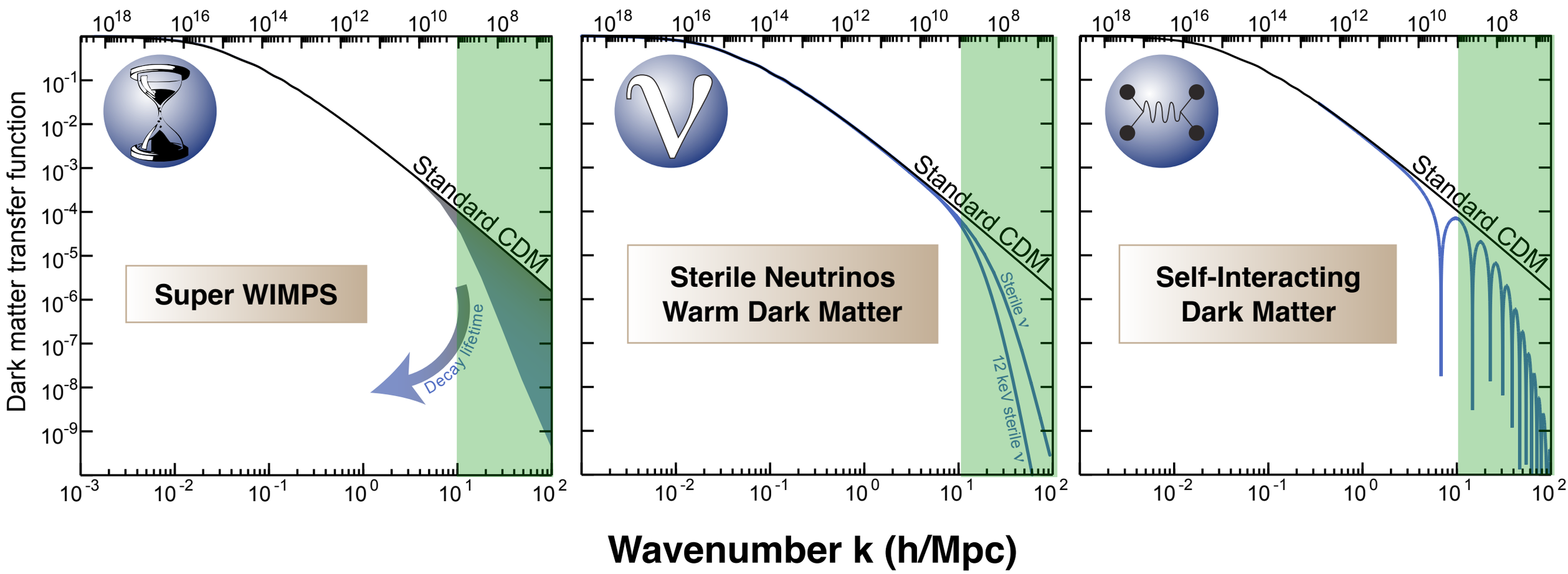
Matt Buckley & Annika Peter, in prep

ALTHOUGH NOT MUCH DARK MATTER FUNDAMENTAL SCIENCE MENTIONED IN THEIR ROADMAP

Small Scale Structure

GALAXIES SC

STARS, MW, & LOCAL VOLUME SC



Deviations from Cold Dark Matter would be detected in the abundance of the smallest structures.

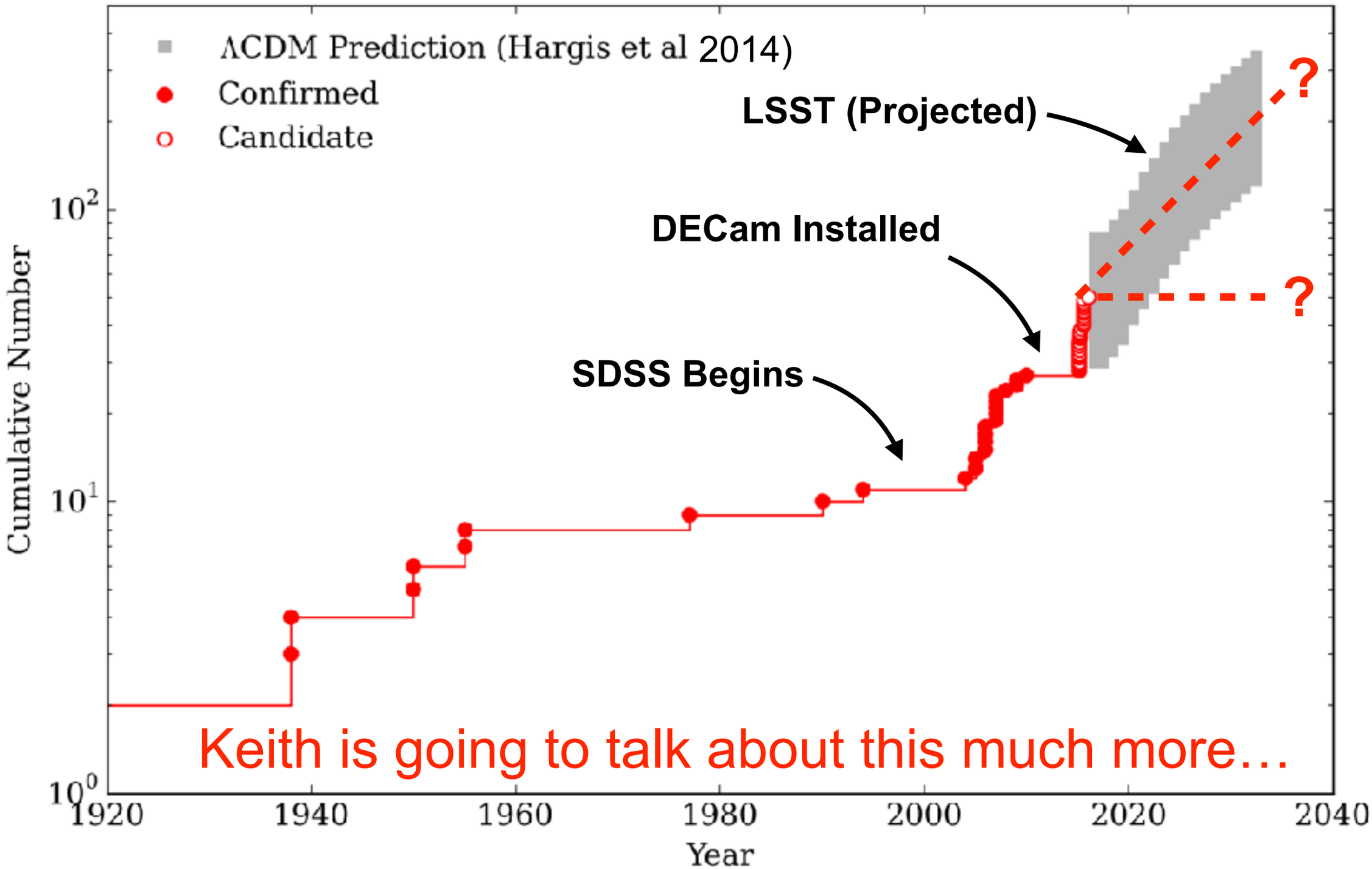
Image Credit: Massey & Moustakas

Small Scale Structure: Local Volume

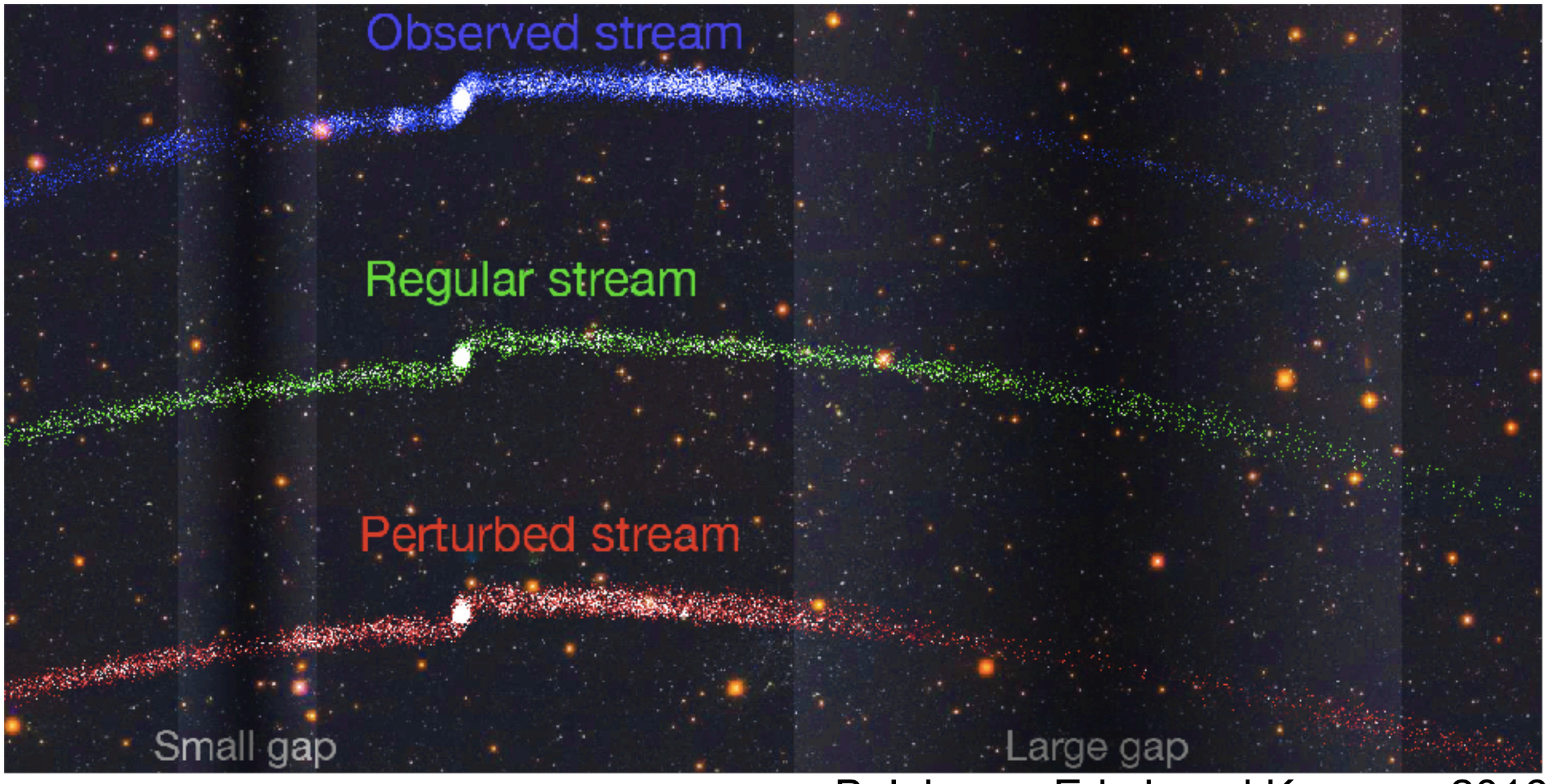
GALAXIES SC

STARS, MW, & LOCAL VOLUME SC

INFORMATICS & STATISTICS SC



Gaps in Stellar Streams



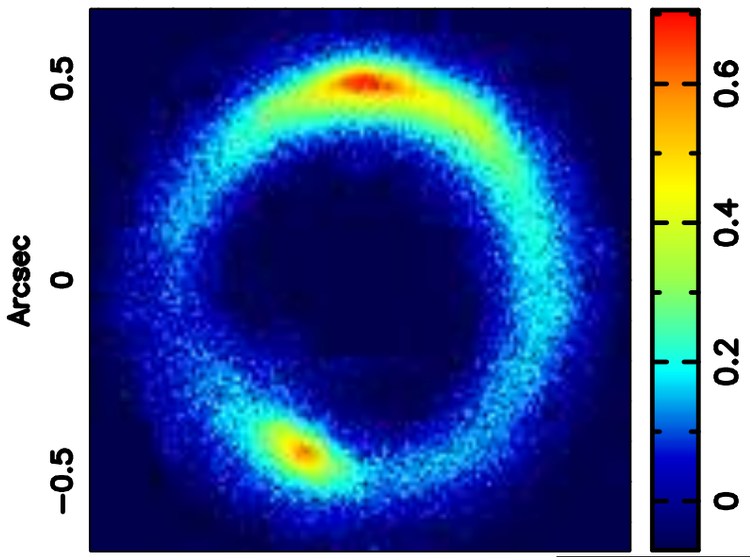
Belokurov, Erkal, and Koposov 2016

Galaxy formation is expected to turn off for halo masses $<10^8\ M_\odot$; gaps in stellar streams may allow us to probe lower masses.

Small Scale Structure: Strong Lensing

STRONG LENSING SC
DESC

Vegetti et al. (2012) [1201.3643]

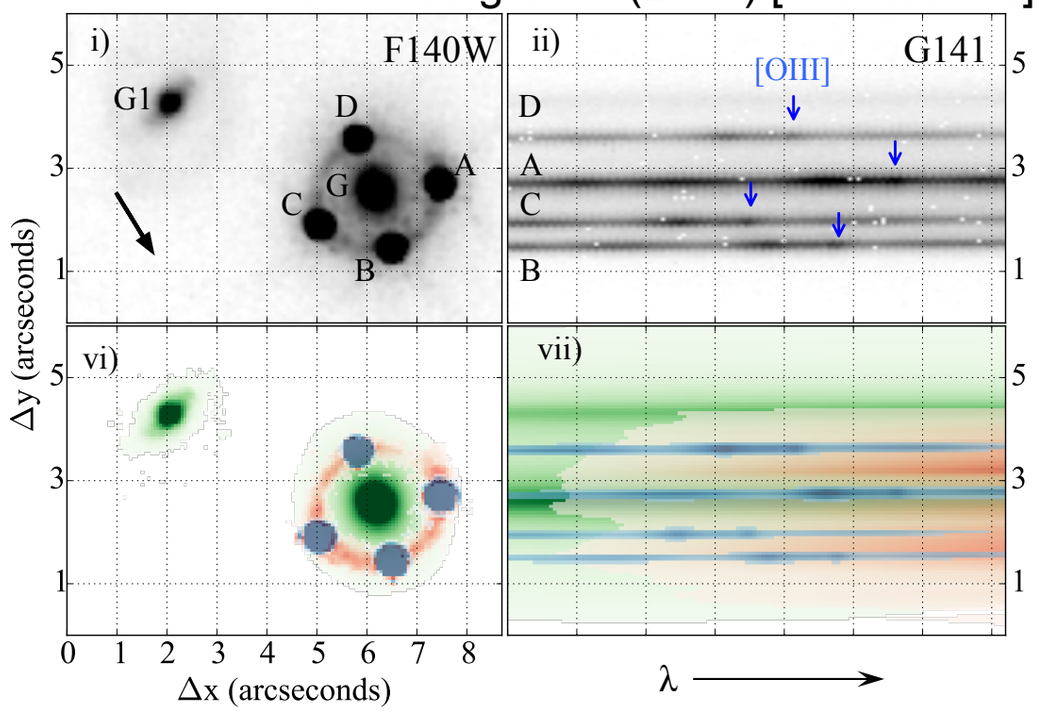


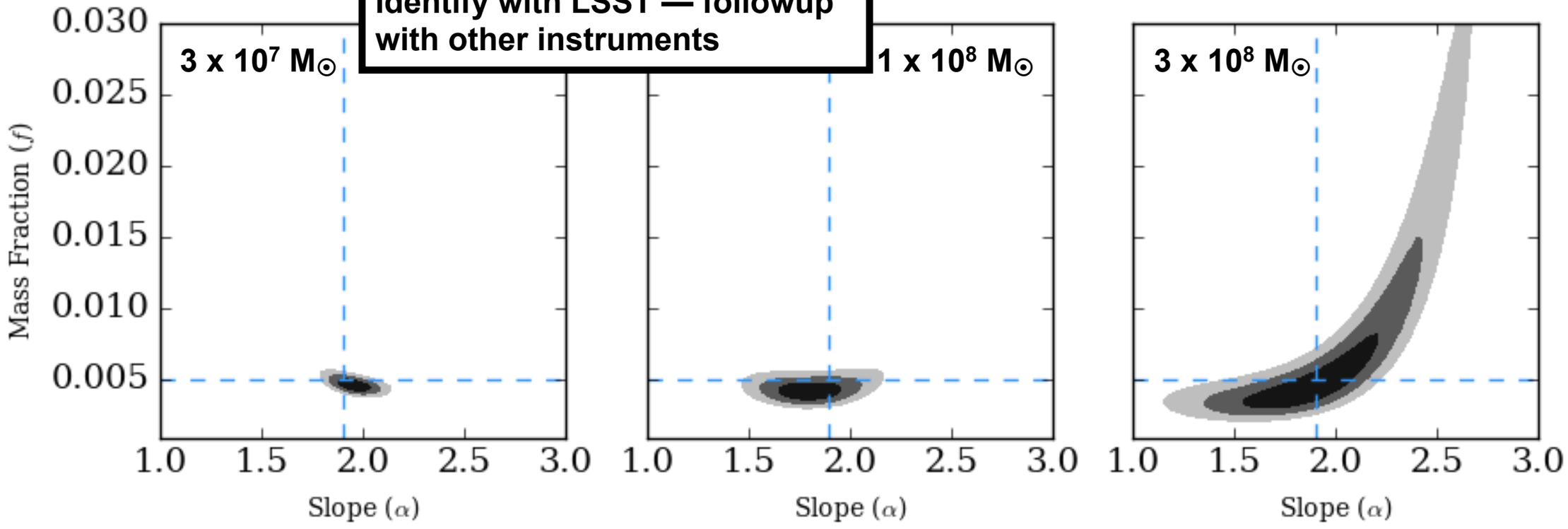
Mass Modeling Anomalies

Flux Ratio Anomalies

200 Galaxy-Galaxy Lenses Identify with LSST — followup with other instruments

Nierenberg et al. (2017) [1701.05188]



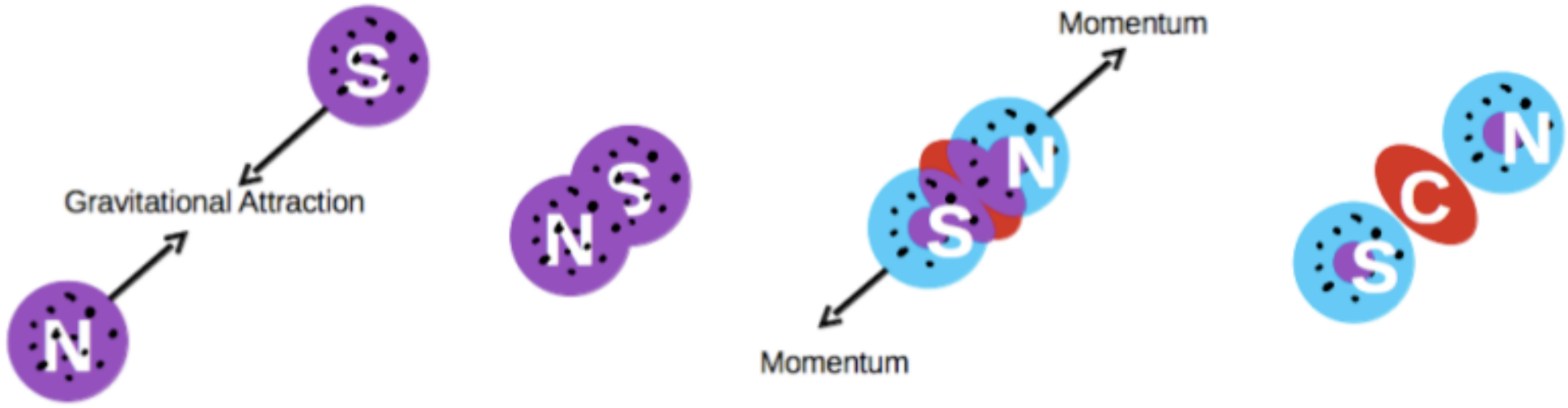


https://github.com/LSSTDESC/LSSTDarkMatter/blob/master/stronglens/SubstructureLikelihood.ipynb

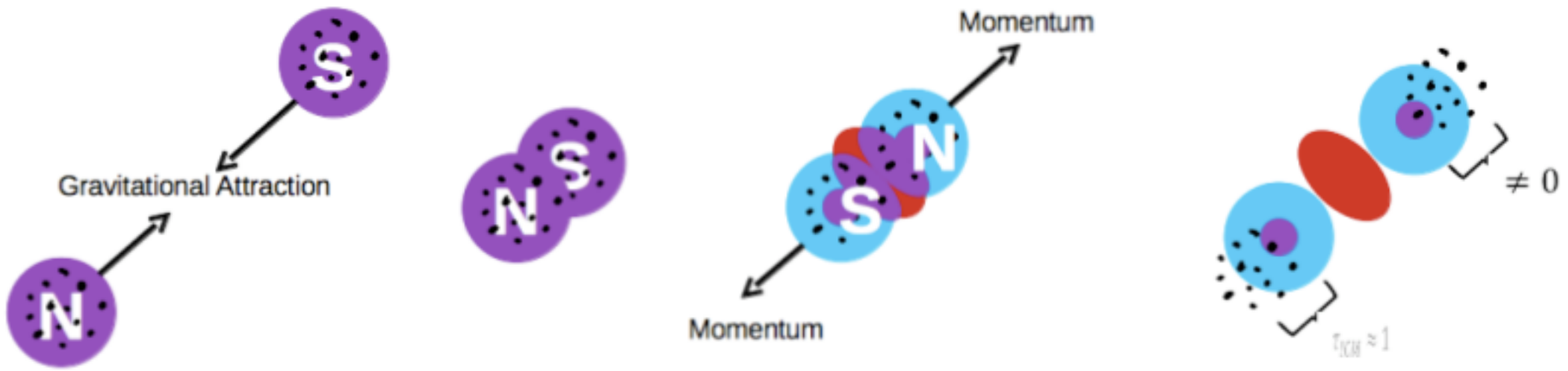
Galaxy Clusters

GALAXIES SC
DESC

Non-Interacting Dark Matter



Self-Interacting Dark Matter

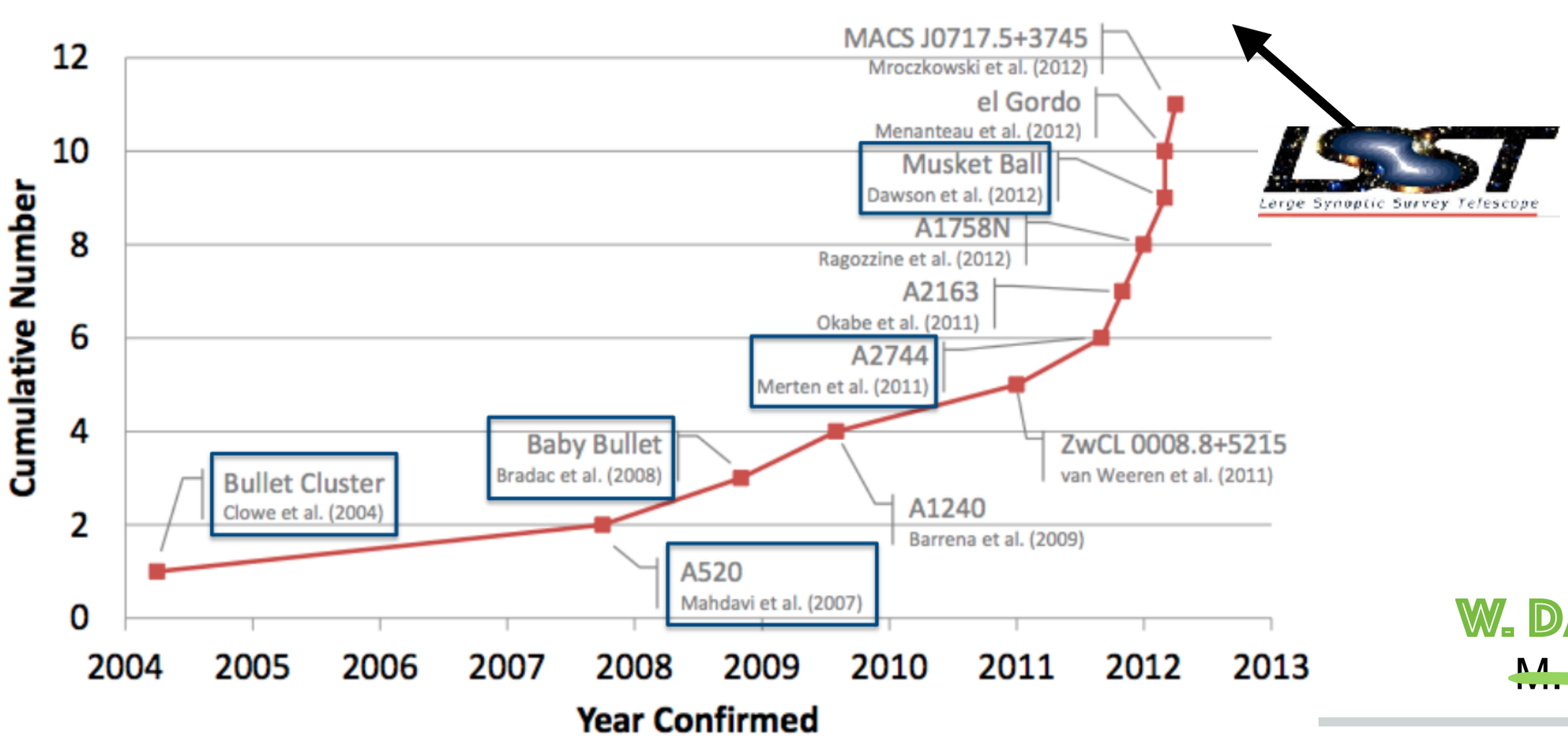


W. DAWSON D. Wittman

Galaxy Clusters

GALAXIES SC
DESC

(Clowe et al. 2006) (Jee et al. 2012) (Bradac et al. 2008) (Dawson et al. 2012) (Rocha et al. 2012)



W. Dawson

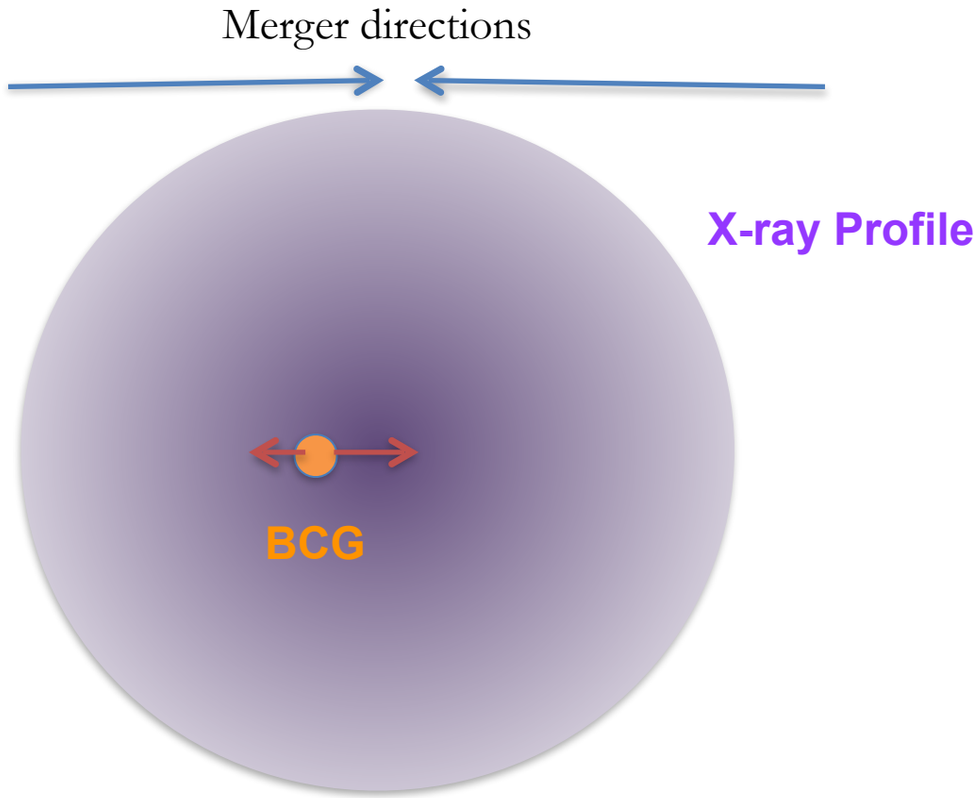
Large Synoptic Survey Telescope

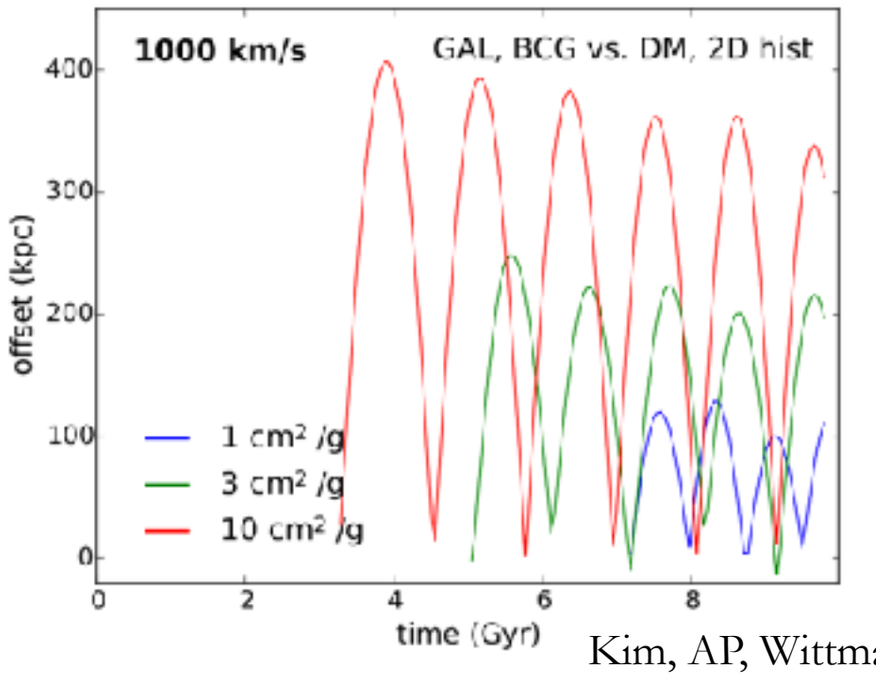
W. DAWSON
~~M. Rocha~~

Galaxy Clusters

GALAXIES SC
STRONG LENSING SC
DESC

- Many probes related to the galaxy cluster mass profile
  - Wobbling BCGs
  - Splash back radius
  - Core/Cusp
- Follow up (spectroscopic, space-based, and multi-wavelength, etc.) will be important





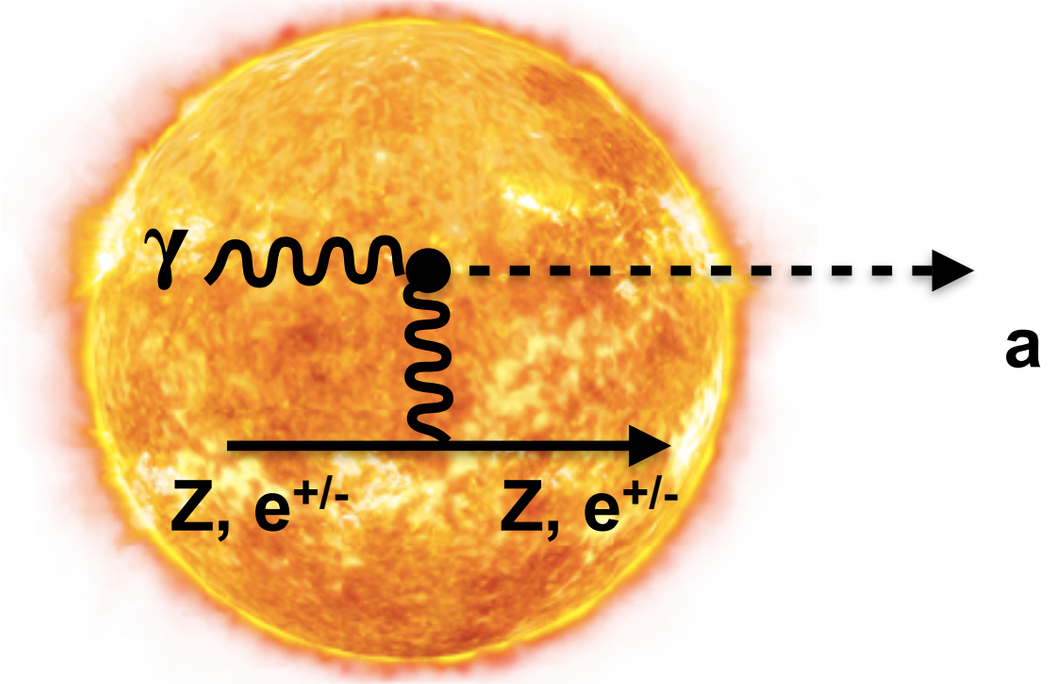
Kim, AP, Wittman 2016

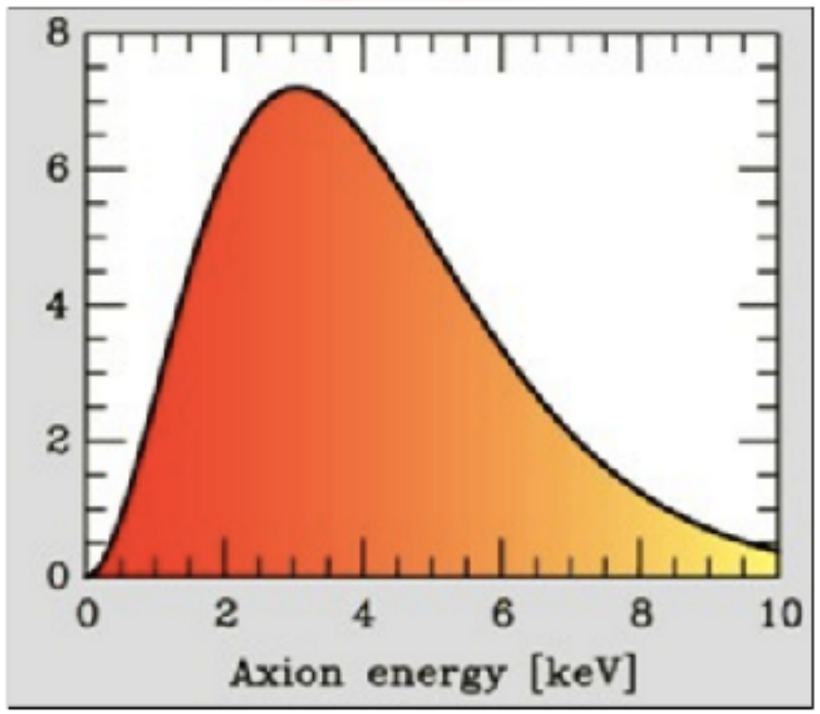
Image Credit: Annika Peters

Axions

STARS, MW, & LOCAL VOLUME

- Photon-axion conversion can happen in the vicinity of charged particles and magnetic fields
- Axions offer an alternative (and faster) mechanism for cooling the interiors of stars.



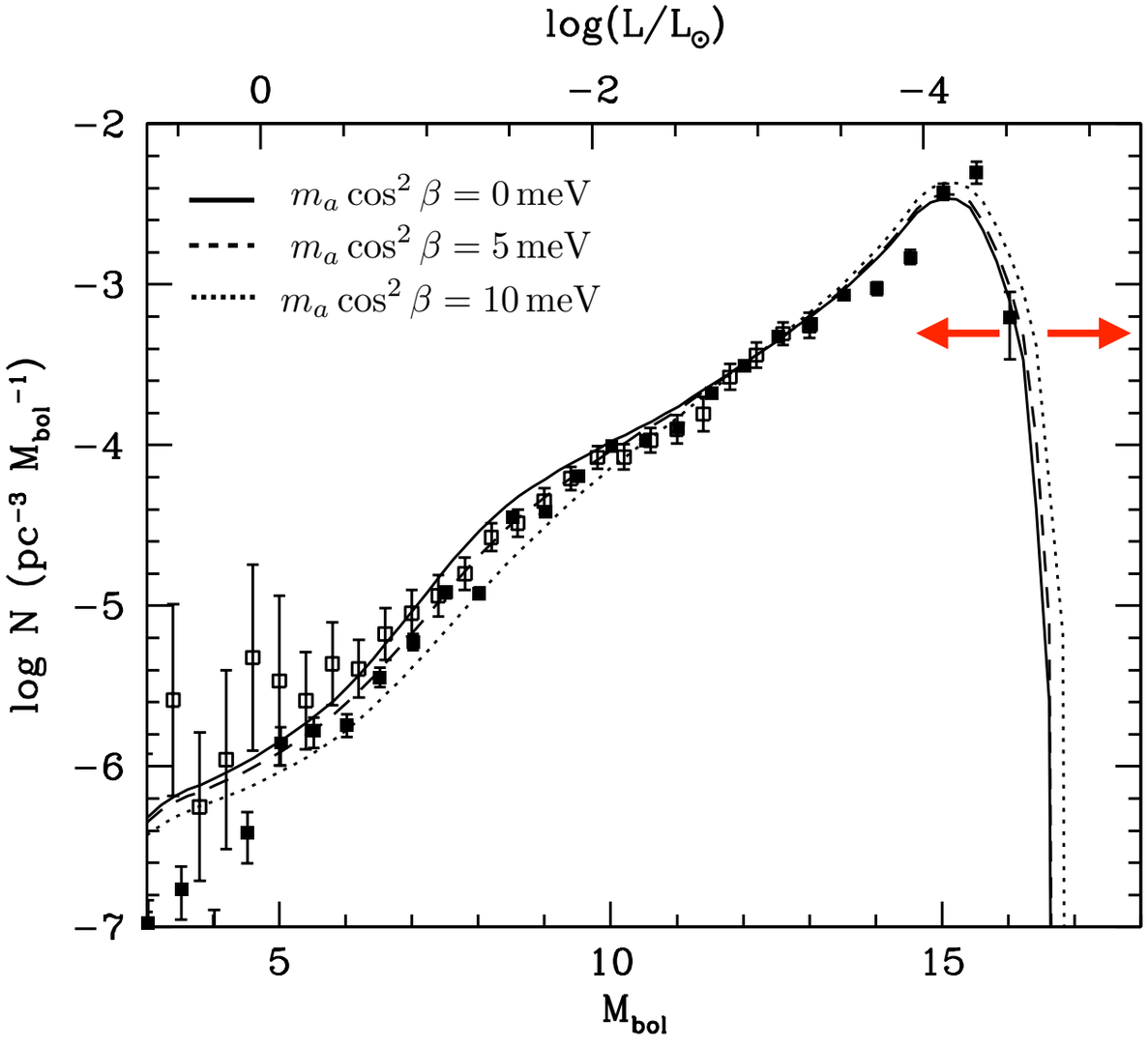


Credit: George Raffelt

Axions

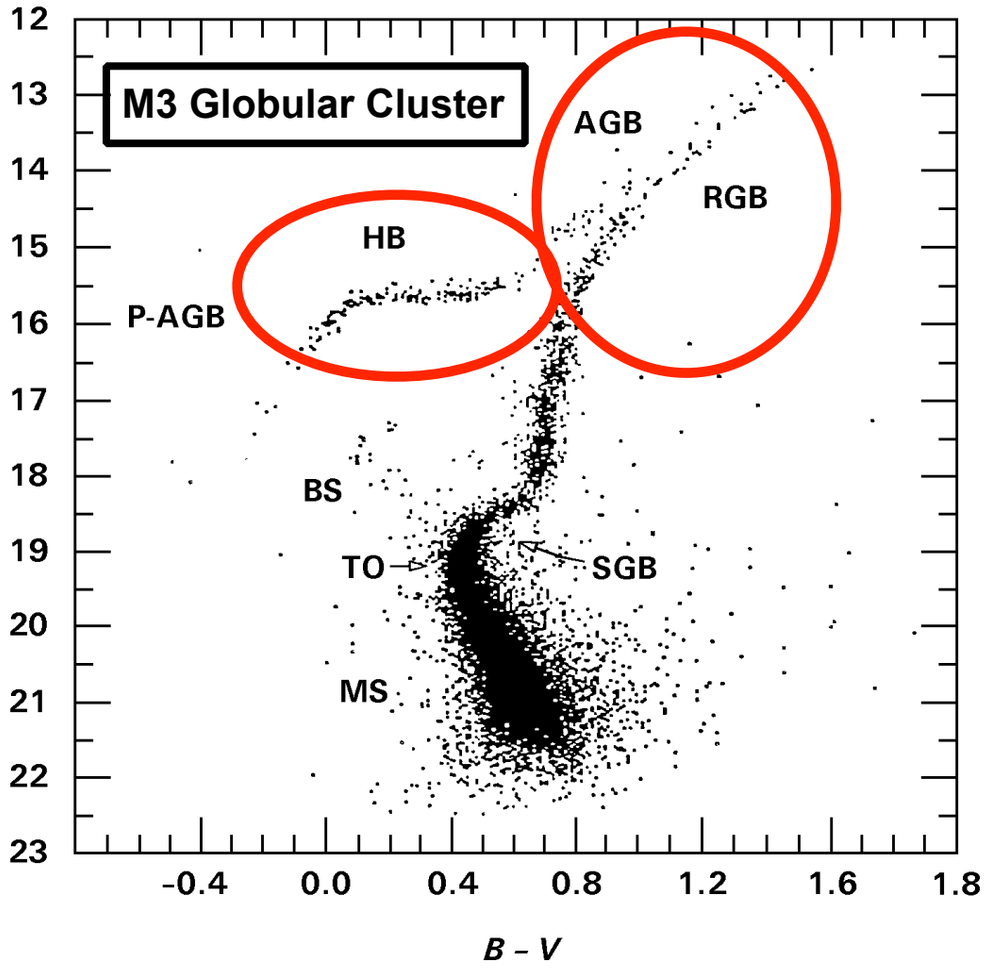
STARS, MW, & LOCAL VOLUME

Axion cooling increasing white dwarf cooling rate shifting the white dwarf luminosity function



Isern et al. (2008) [0812.3043]

Ratio of Number of Stars in Red Giant Branch vs Horizontal Branch (Helium Burning)

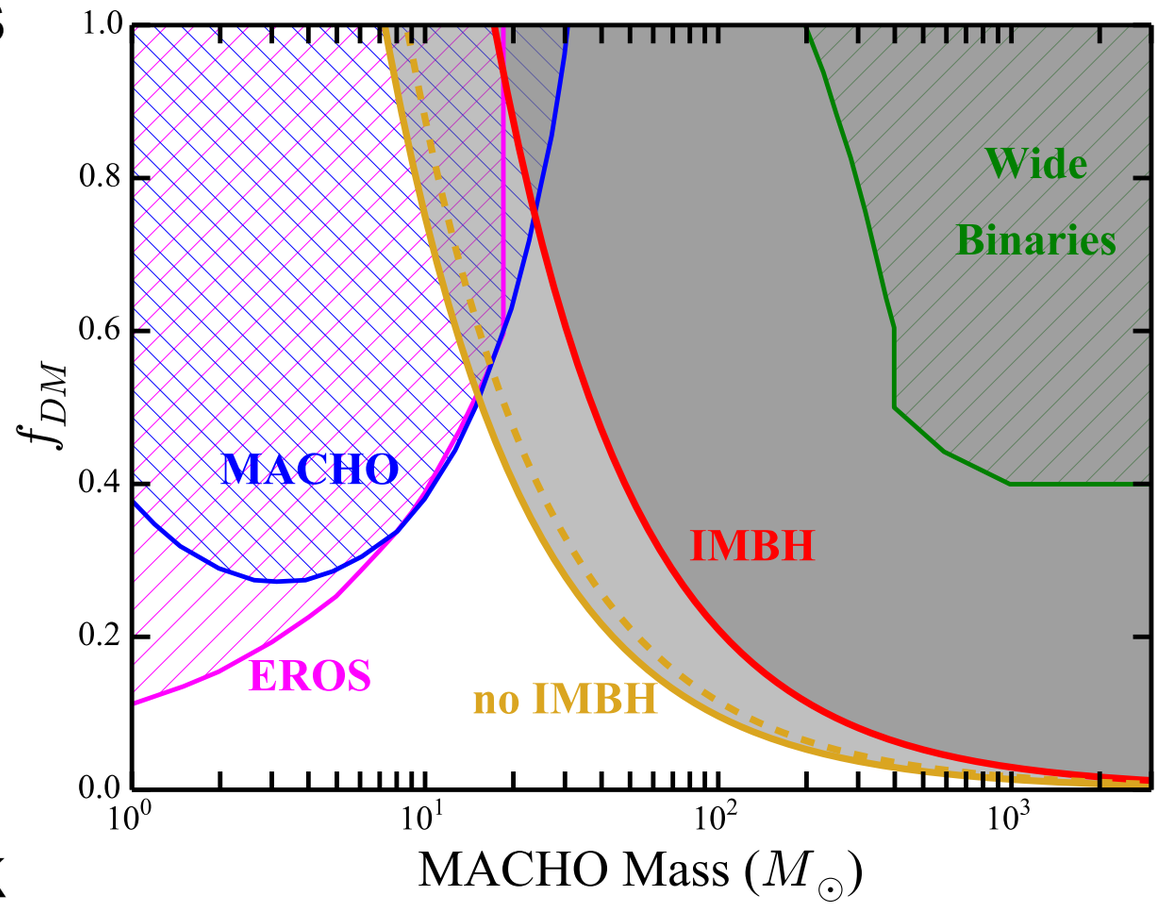


Raffelt 2006 [0611350]

MACHOs

TRANSIENTS/VARIABLE STARS

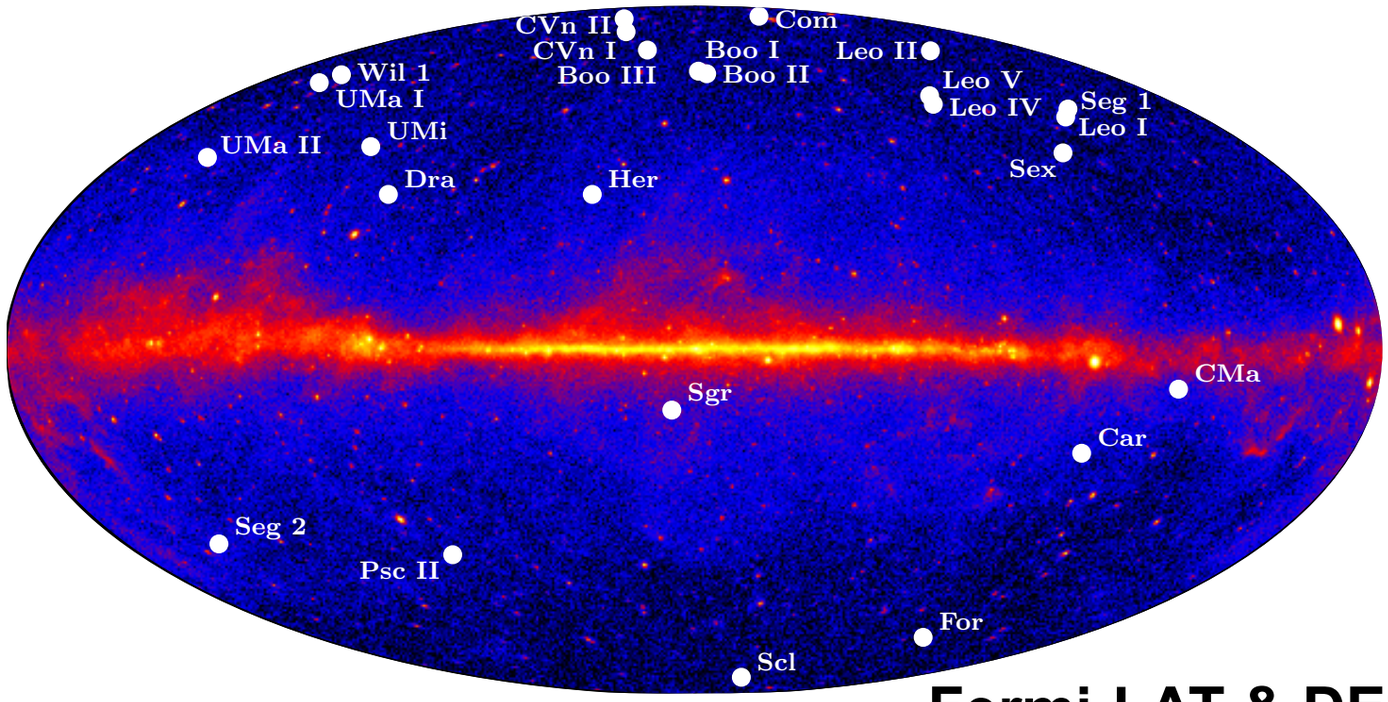
- BBN and CMB set strict limits on the fraction of dark baryons
- Recent discoveries by LIGO have renewed interest in primordial black holes, which would not be counted in the baryon budget
- This has caused the community to resist previous constraints on primordial black holes (discarding some and adding others)



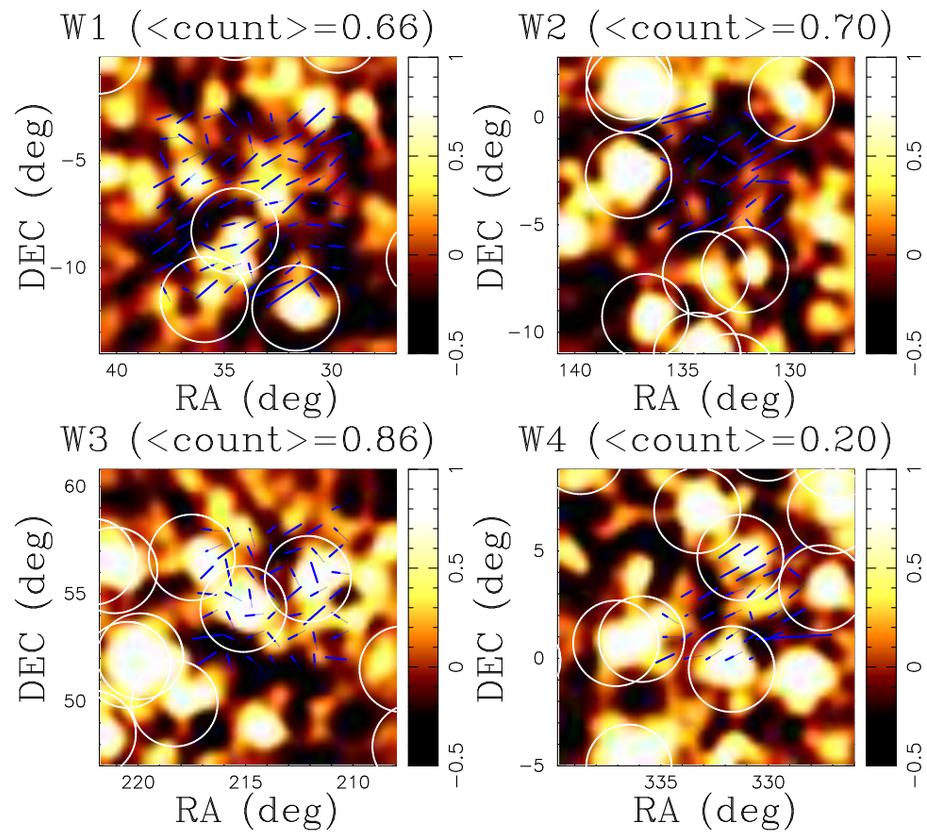
Will is going to talk about this much more…

Cross Correlations

MOST SC



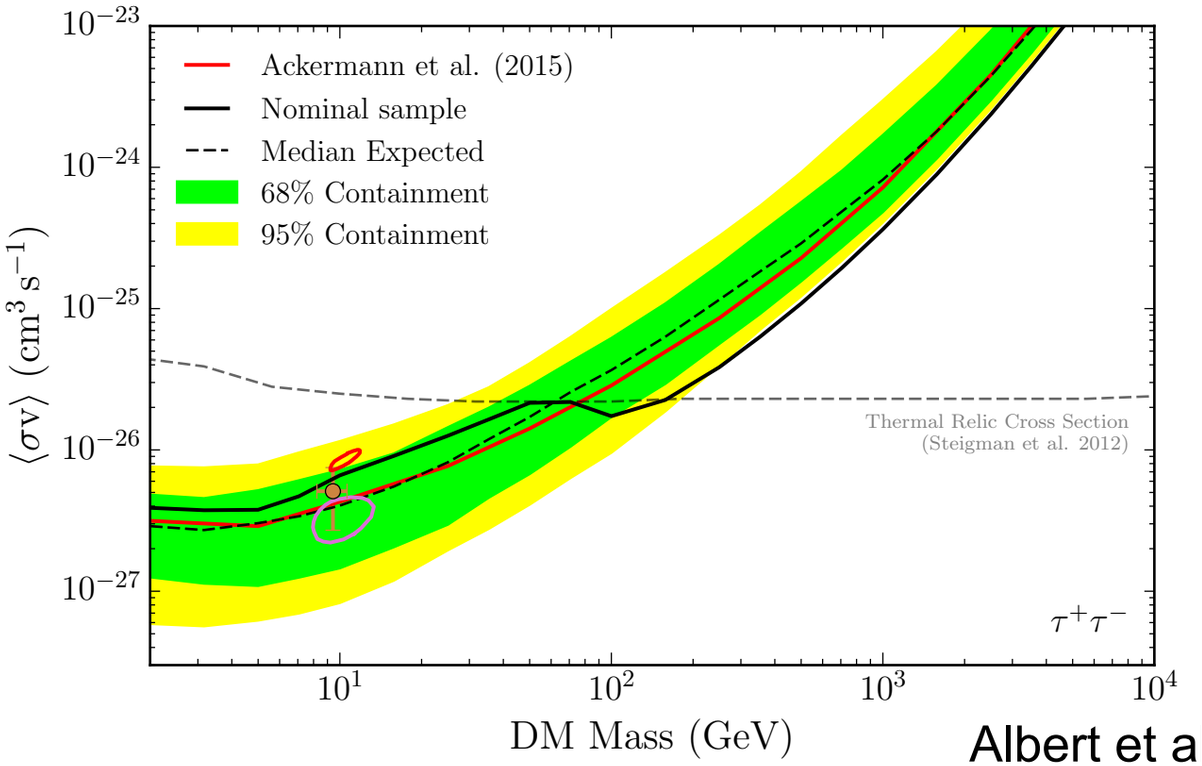
Fermi-LAT x CFHTLenS



Shirasaki et al. (2014) [1404.5503]

Also se Troester et al [1611.03554]

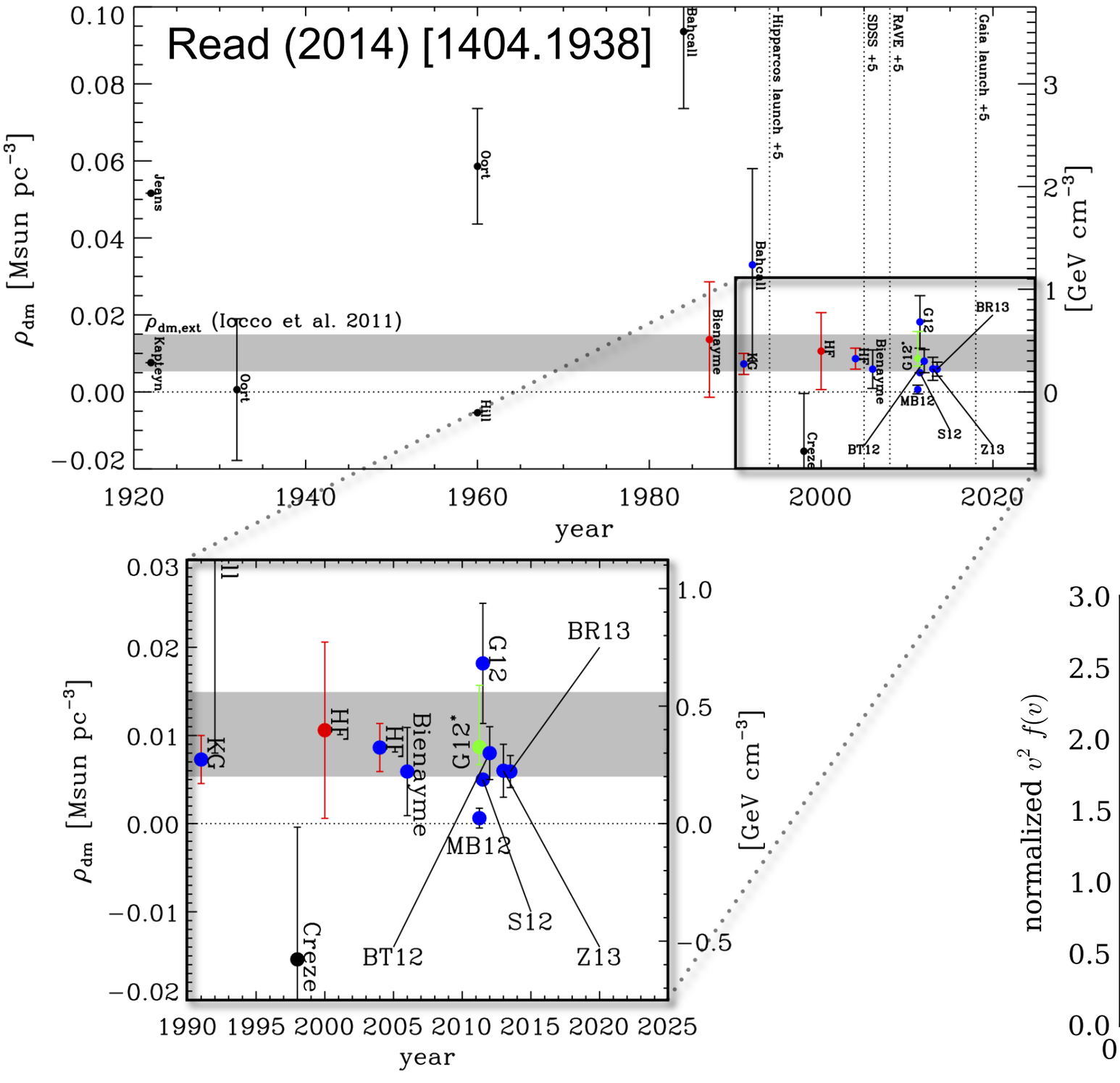
Fermi-LAT & DES



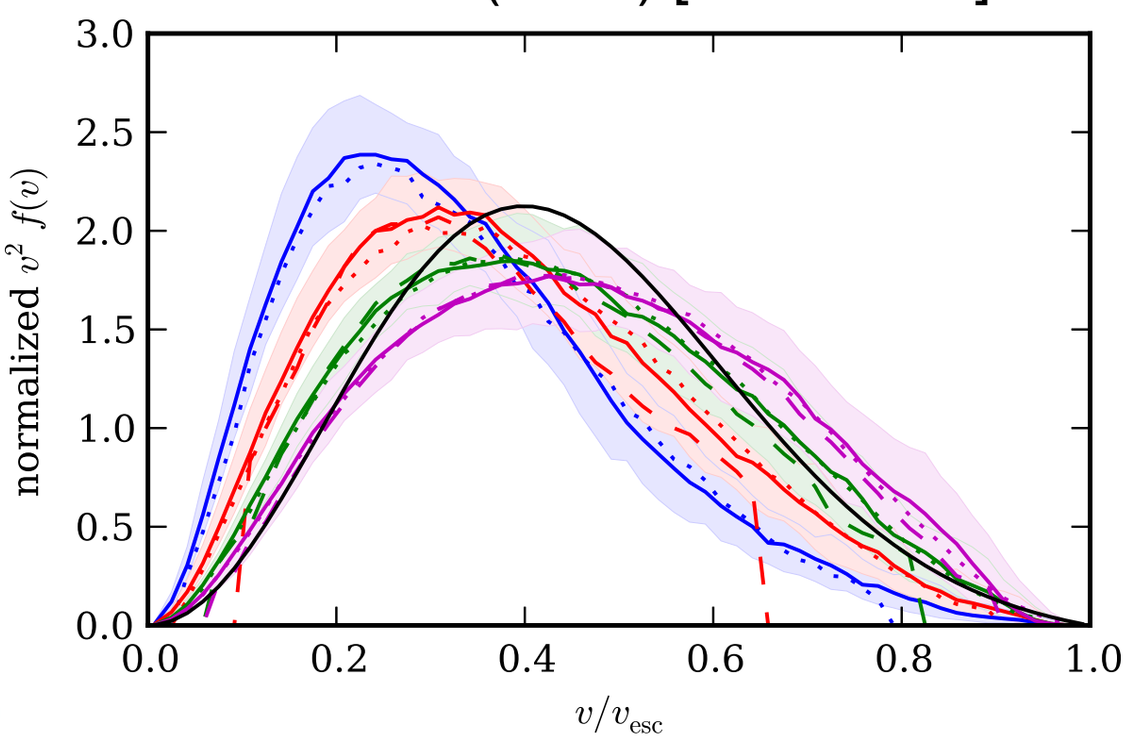
Albert et al. (2016) [1611.03184]

Local Dark Matter Density

STARS, MW, & LOCAL VOLUME



Understanding the dark matter distribution in our Galaxy is essential for interpreting results from direct detection experiments



Dark Matter in DESC?

According to the SRM, the goal of DESC is to:

"use of LSST to study observable signatures of 'dark sector' physics, including dark energy, dark matter, neutrinos, and signatures of inflation"

However, many of the topics discussed today have significant overlap with other LSST science collaborations

DOE P5 REPORT: "ELUCIDATE THE NATURE OF DARK MATTER INTERACTIONS USING COSMIC SURVEYS (2016–2025)."

Does dark matter science benefit from having a single home, and should DESC be that home?

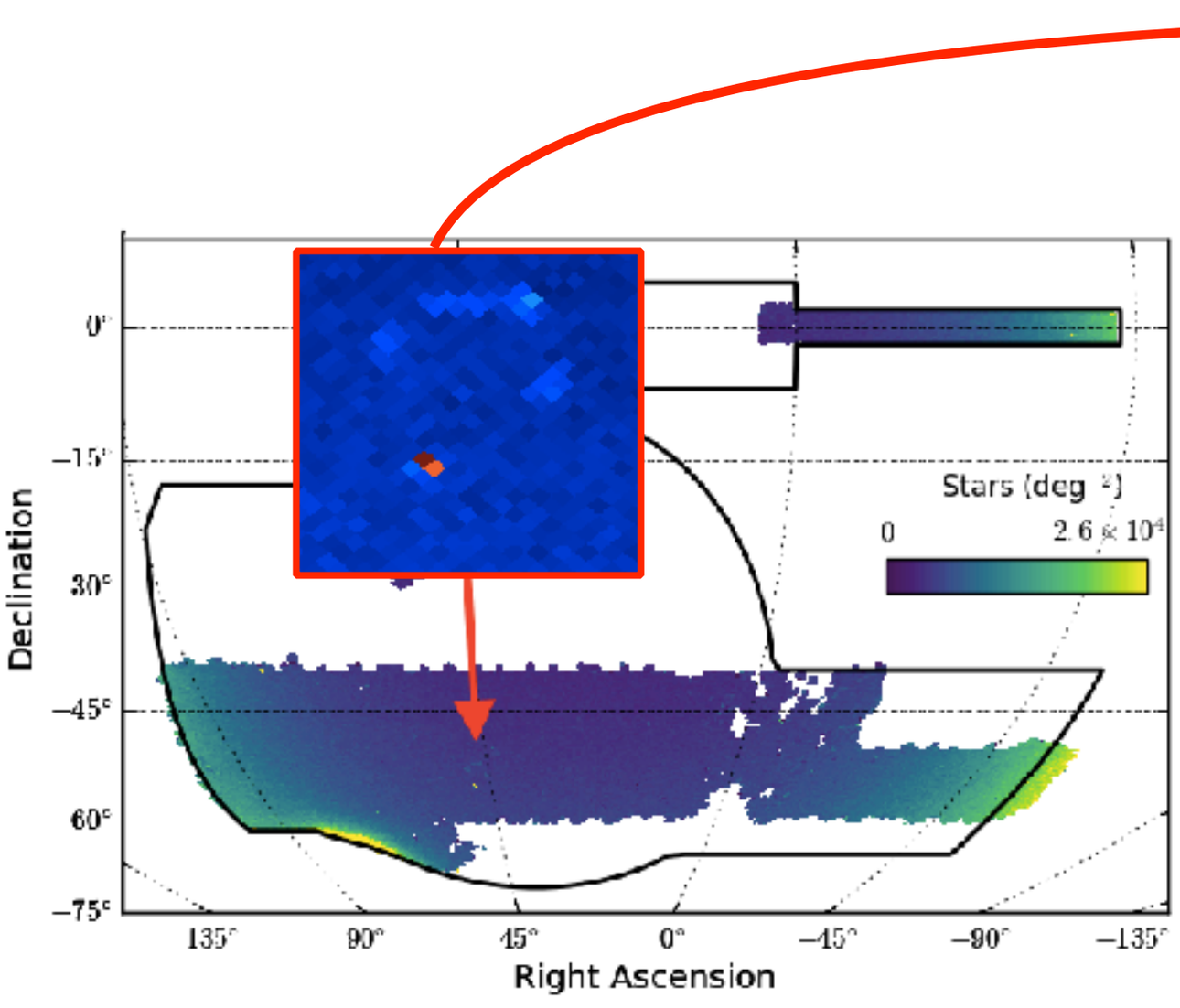
How to Integrate with DESC?

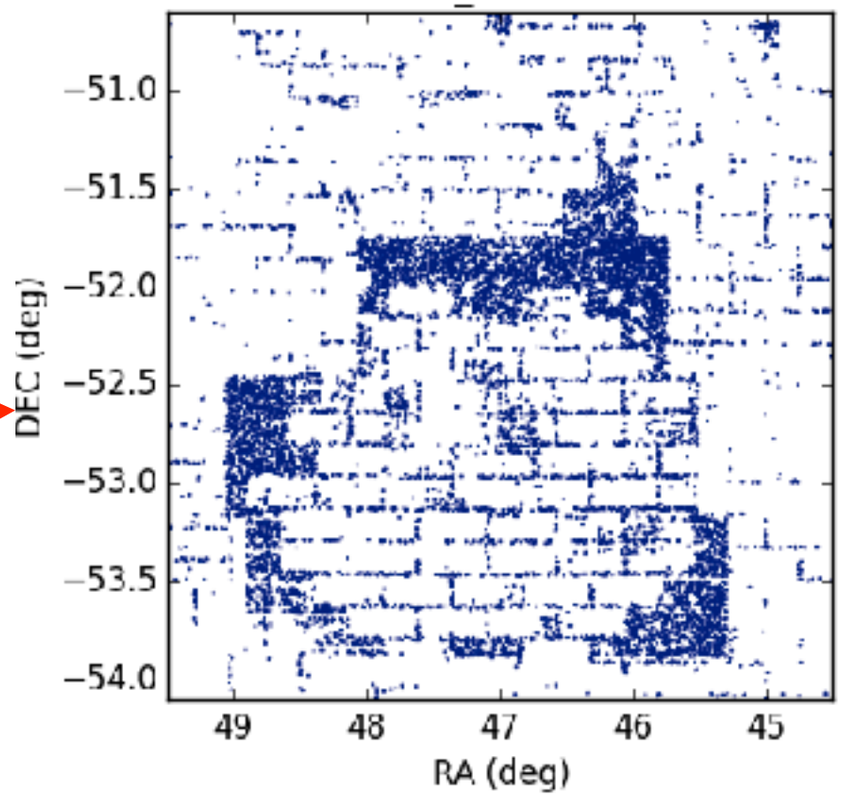
- **One example: Many dark matter studies will analyze point-like sources (local group, MACHOs etc.)**
  - **Model and examine stars in DC1/DC2**
  - **Star/Galaxy separation**
  - **Deblending in crowded fields**
  - **Photometric calibration (SLR, ubercal, etc.)**

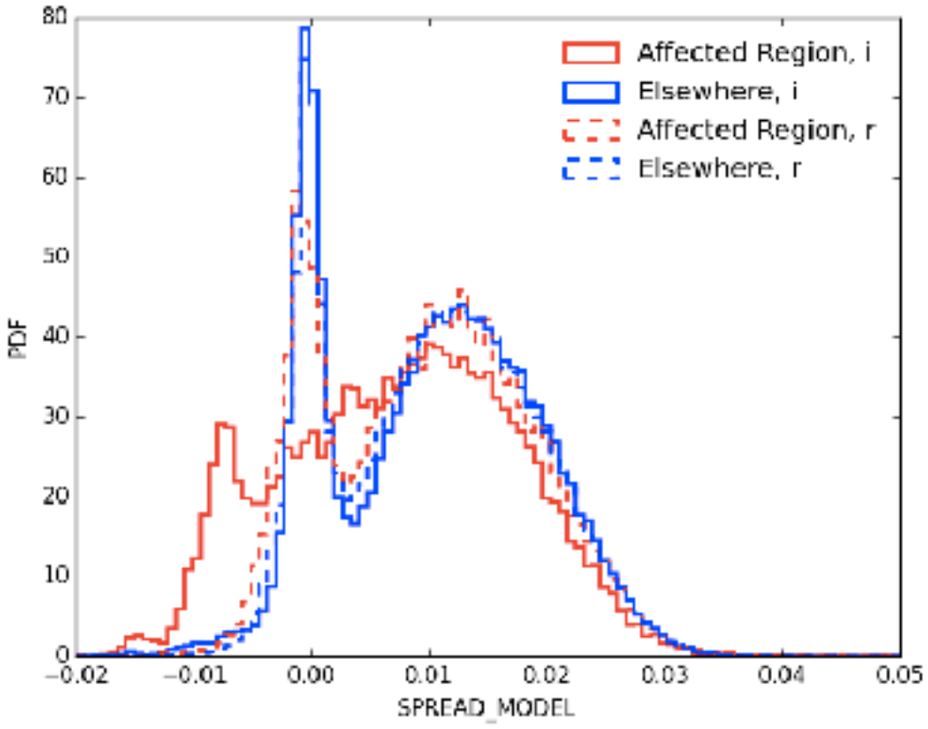
Will has a longer list in his to talk; topic for discussion…

How to Integrate with DESC?

A concrete example (and some dirty laundry from DES)…
Stars: a canary in a coal mine







Some Resources

Slack Channel:
#desc-dark-matter

Email List:
<lsst-desc-darkmatter@slac.stanford.edu>

Github Repo:
https://github.com/LSSTDESC/LSSTDarkMatter

Living Bibliography:
https://www.overleaf.com/10295894rskjrcqgwntz

Research Scientist

Location: Livermore, CA
Category: Science & Engineering
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