ESCAPE

European Science Cluster of Astronomy & Particle physics ESFRI research Infrastructures

Towards a Dark Matter Test Science Project

Caterina Doglioni - Lund University

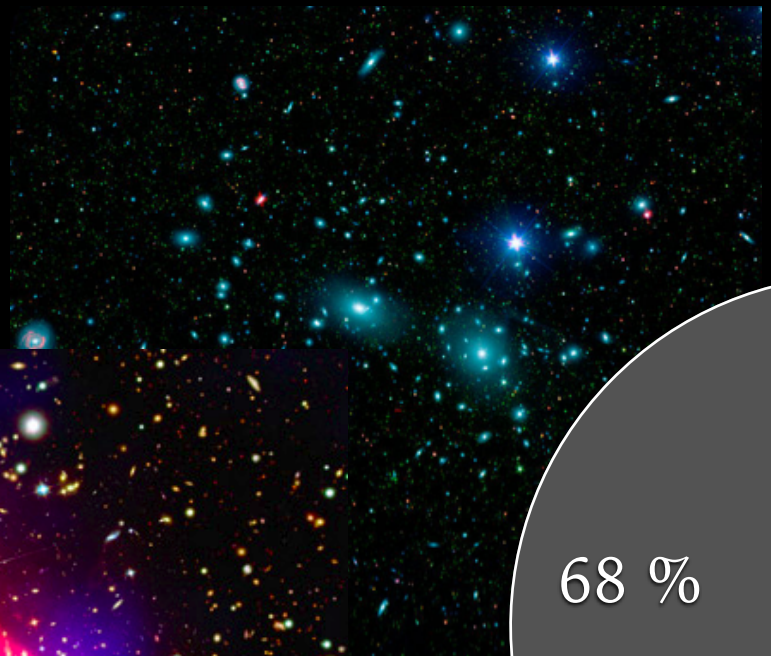
Input from: Antonio Boveia, Francesca Calore, Elena Cuoco, Lukas Heinrich, Samuel Meehan, Graeme Stewart, Pasquale Serpico, Vincent Poireau, Florian Reindl, Federica Petricca, iDMEu proponents

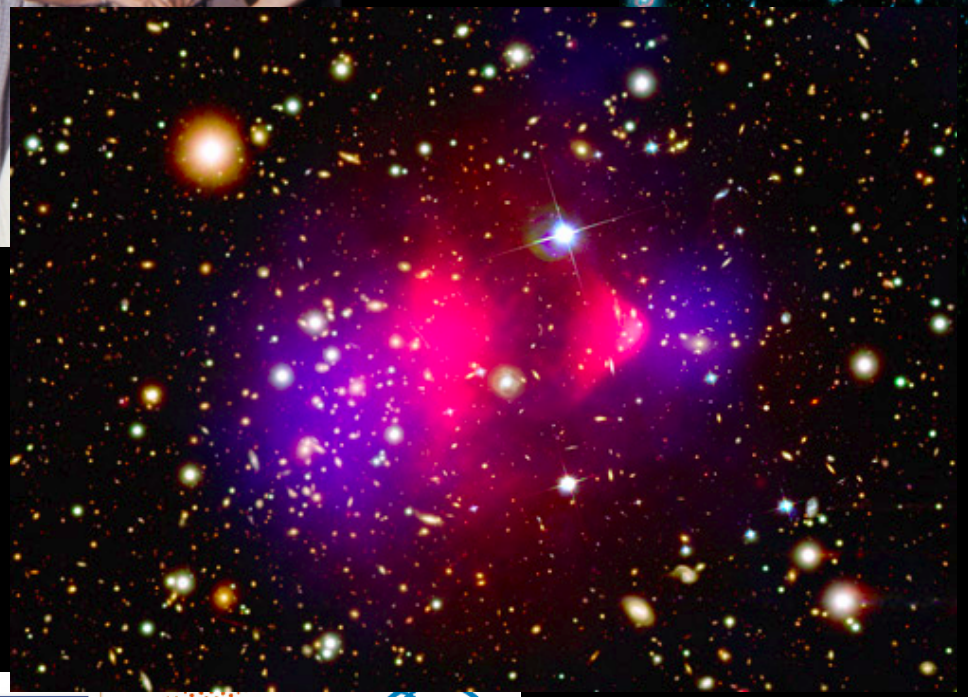
@CatDogLund, she/her

http://www.hep.lu.se/staff/doglioni/

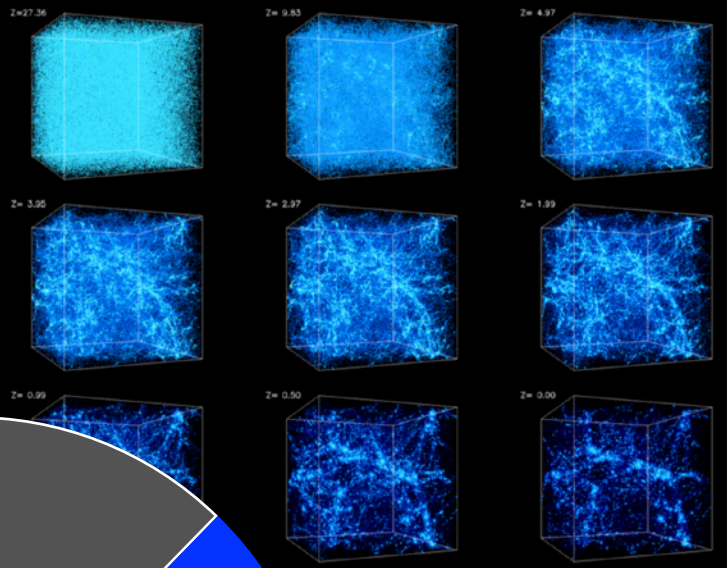
ESCAPE - The European Science Cluster of Astronomy & Particle Physics ESFRI Research Infrastructures has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement n° 824064.

Dark matter as a science case

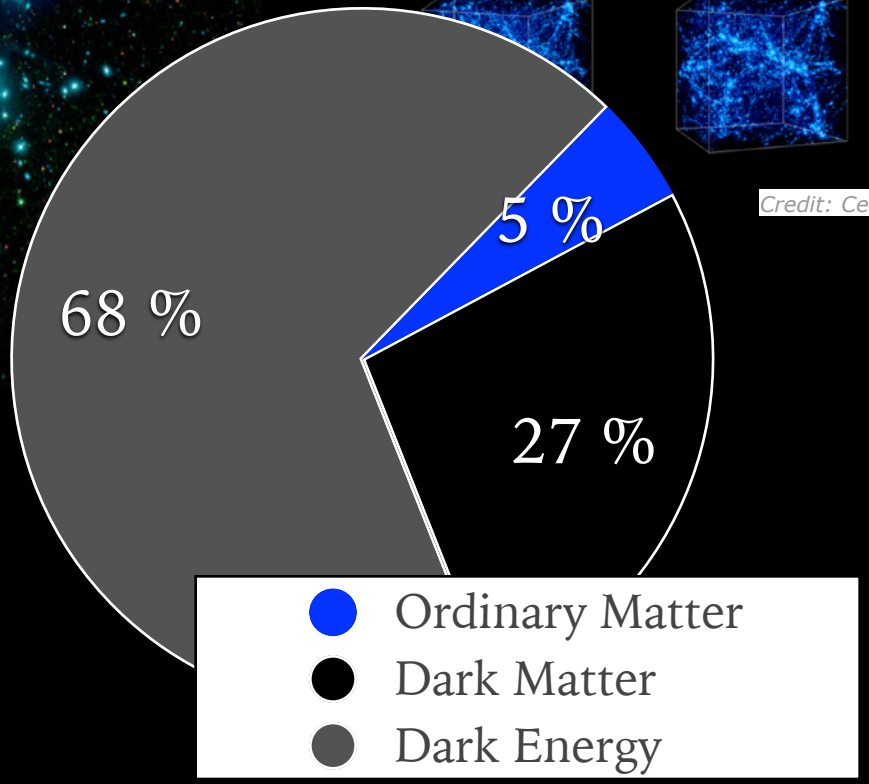




Credit: NASA, Carnegie Institution



Credit: Center for Cosmological Physics, A. Kravtsov



Different kinds of DM, and synergies

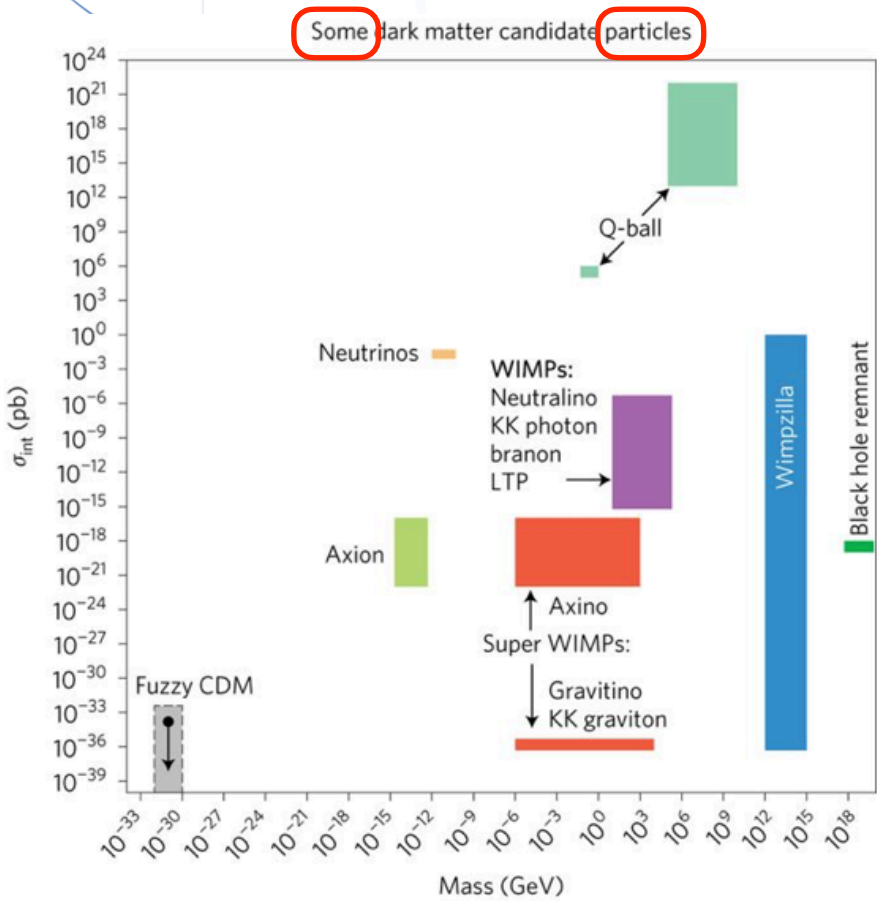
Many hypotheses for dark matter

→ many ways to detect it

→ many different experiments

→ many different data / workflow needs

→ many different data / result sharing policies



https://www.nature.com/articles/nphys4049
adapted from The Dark Matter Scientific Assessment Group

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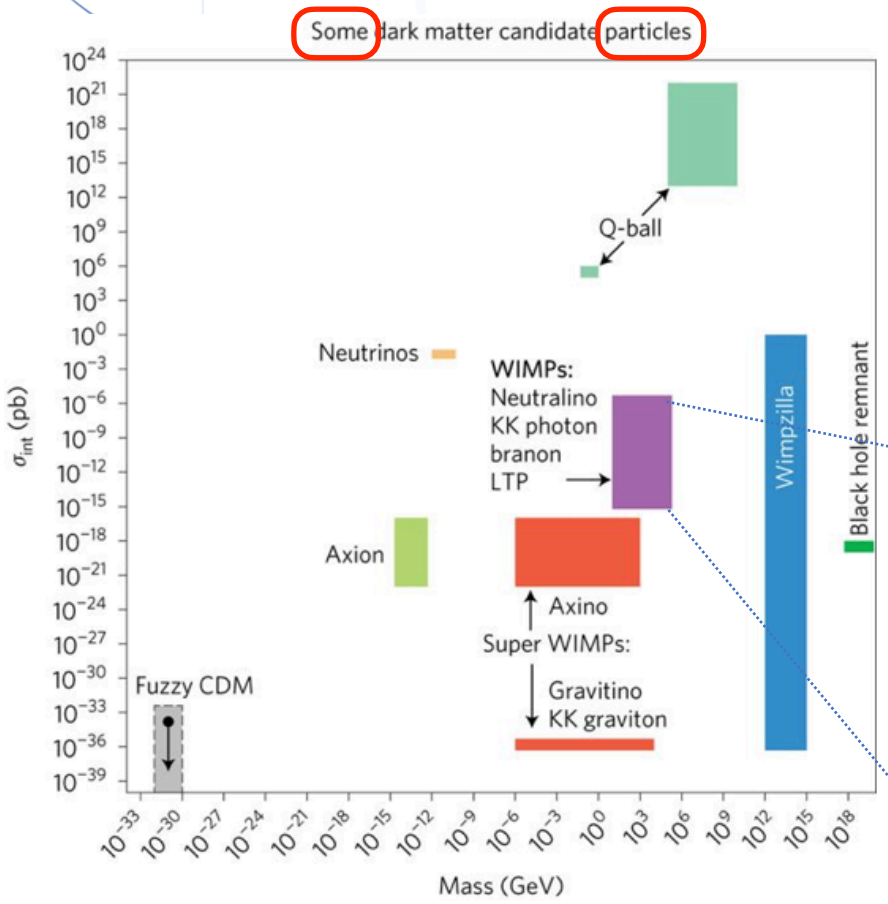

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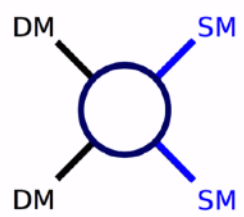
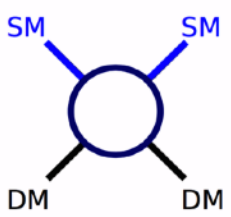
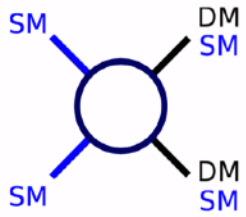
one of many models predicting **Weakly Interacting Massive Particles (WIMP)**



Indirect Detection

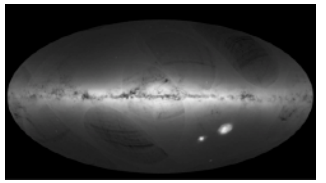


Direct Detection

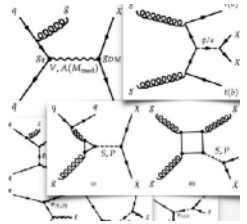


Colliders

Credit: ESA/Gaia/DPAC.



Astrophysics



Theory

- Well studied models, established complementarity
- WIMP-like models not yet completely excluded
- Tentatively take WIMPs as Test Science Project "grounding assumption"

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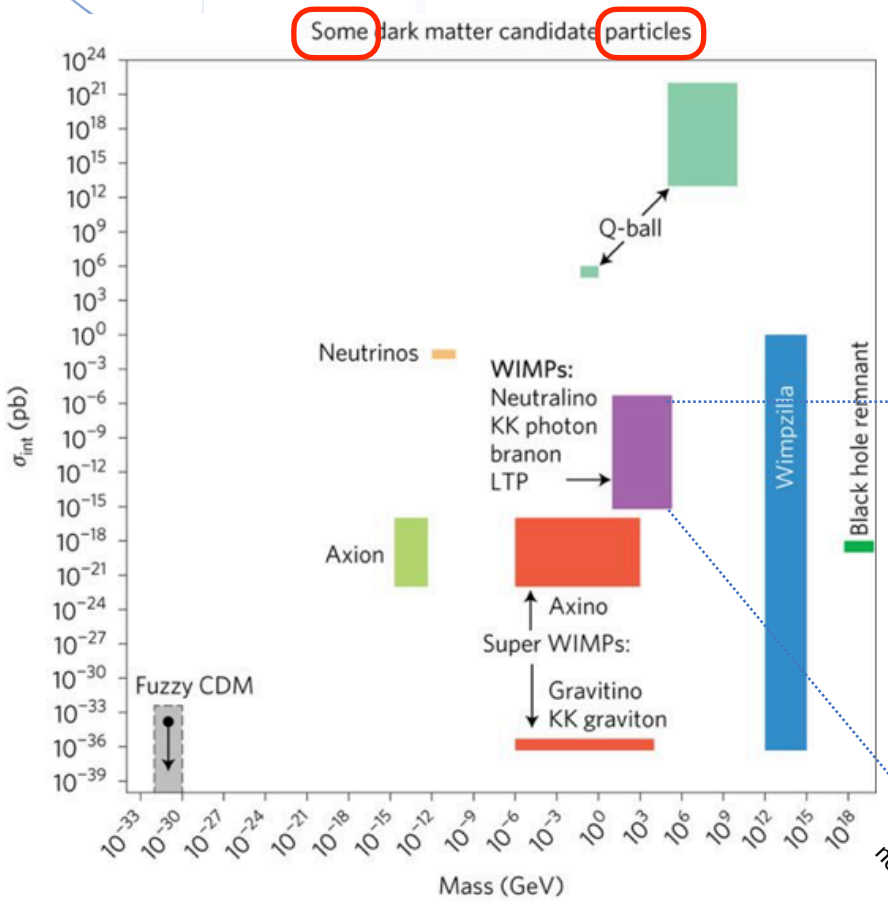

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for illustrative purposes
no 1:1 correspondence

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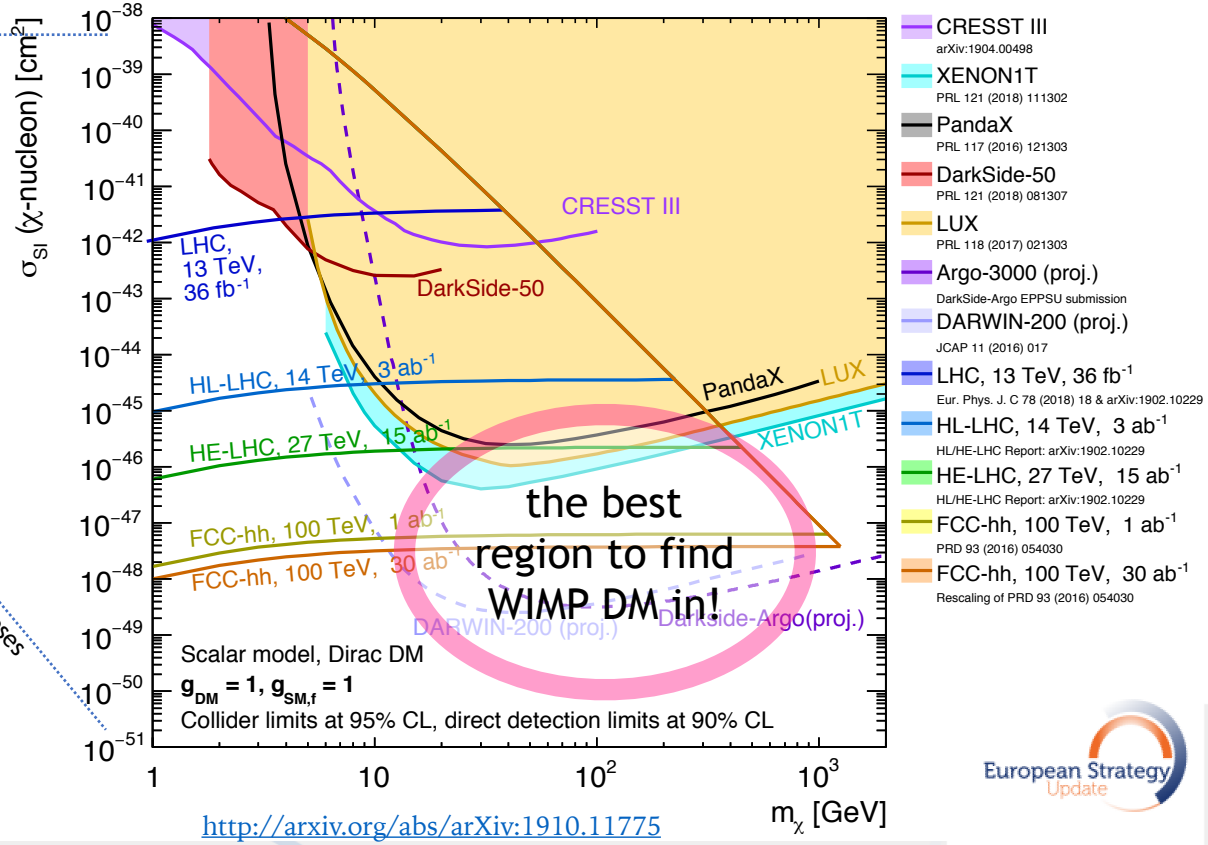
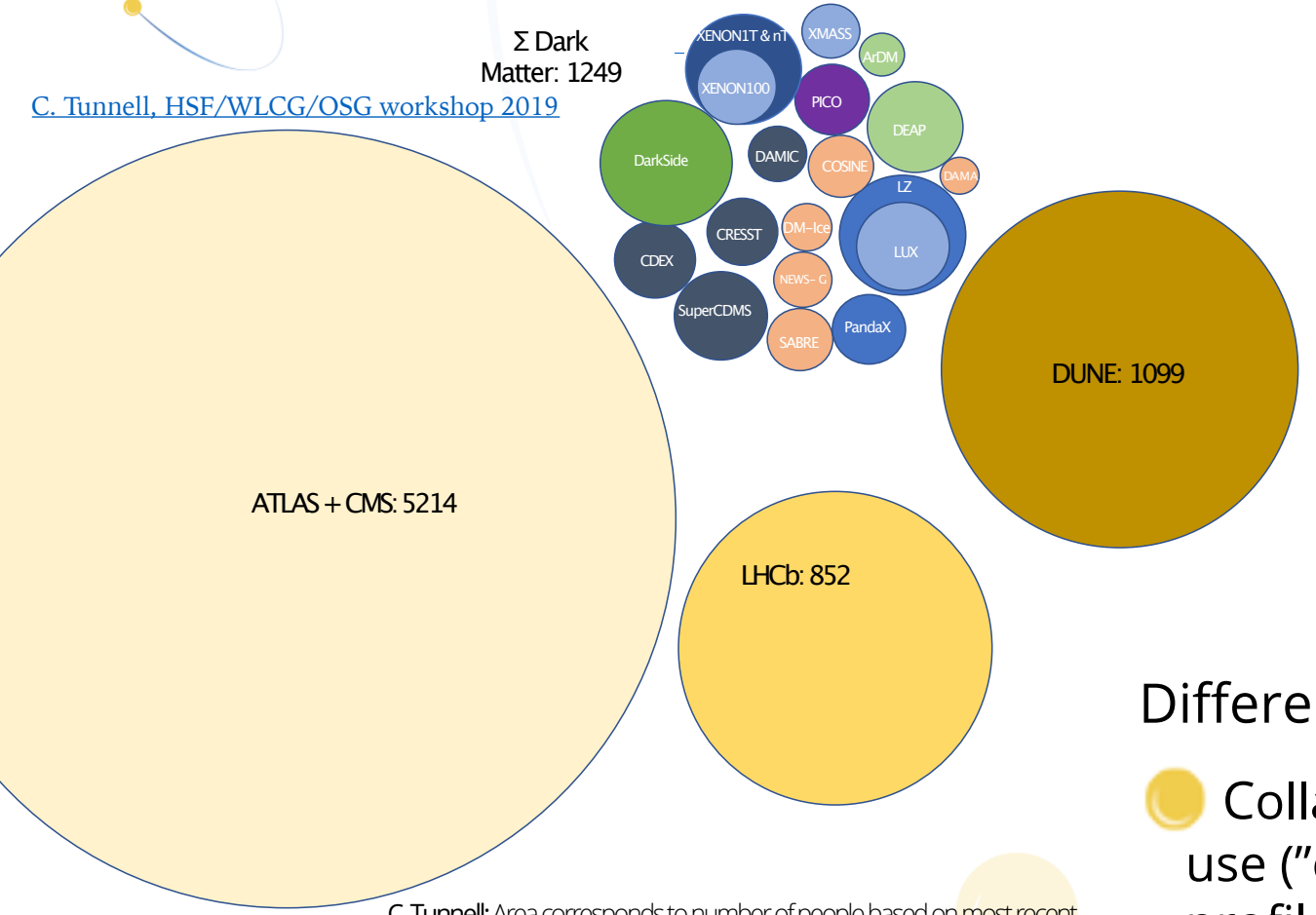


http://arxiv.org/abs/arXiv:1910.11775

Ca

Different kinds of (WIMP) communities



C. Tunnell, HSF/WLCG/OSG workshop 2019

C. Tunnell: Area corresponds to number of people based on most recent publication from any experiment that has published scientific papers in the last two years. This relied on Inspire-HEP. See gist for calculation notes. 16/ March/2019

Diagram only representing **collider and direct detection**

- Differences in collaboration variety and size
- Differences in data volumes:
  - Colliders: ”Big Data” volumes (>> PB)
  - DD: smaller data volumes (~TB/PB)
- Synergies in statistical analysis and interpretation of results

Different modus operandi for **indirect detection**

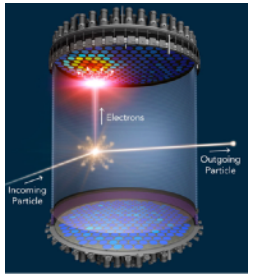
- Collaborations e.g. Fermi release data for general use (”observatory mode”), but also perform high-profile analyses themselves

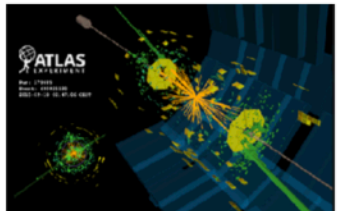
(Different) end-to-end WIMP analysis workflows

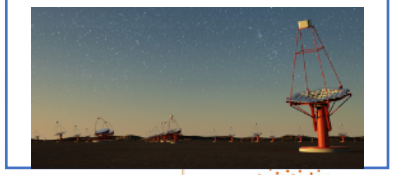
Simplified abstraction of workflows to fit in this slide, happy to receive feedback!

Generation & simulation of events

Experimental data







Credit: SLAC/LZ/ATLAS/CTA

Data **processing** (including reconstruction & calibration)

Analysis of events/ distributions (including background subtraction, background estimation, statistical analysis)

Interpretation of results

Combination of results with other searches/ experiments

Comparison of results with other searches / experiments

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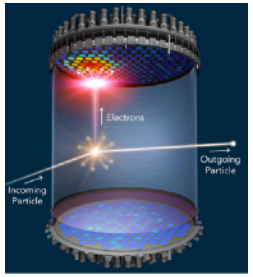

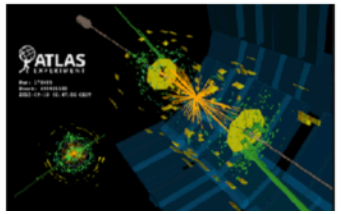

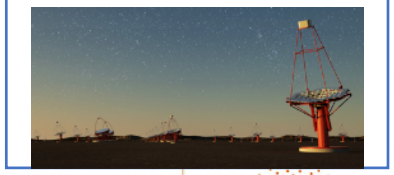

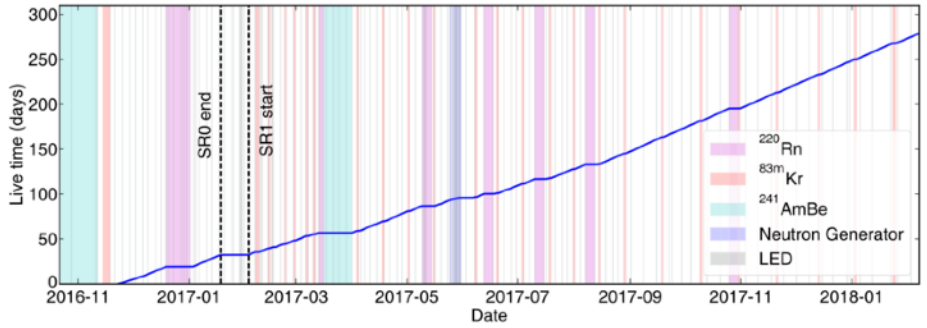

XENON 1T, PRD 100, 052014 (2019)

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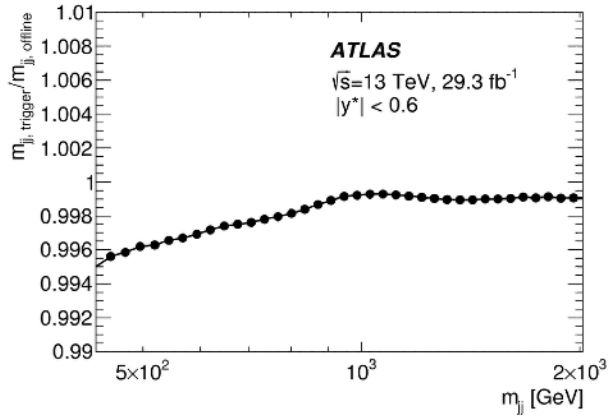

ATLAS, Phys. Rev. Lett. 121, 081801 (2018)

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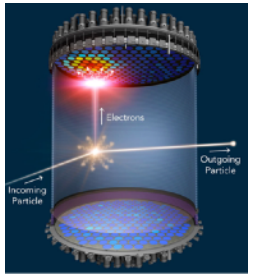

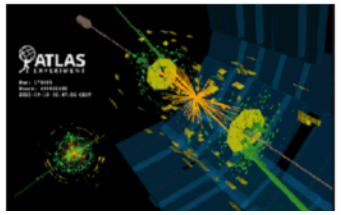

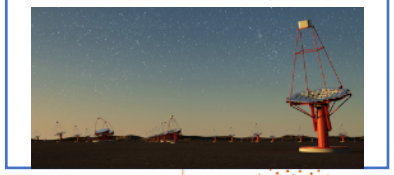

Credit: SLAC/LZ/ATLAS/CTA

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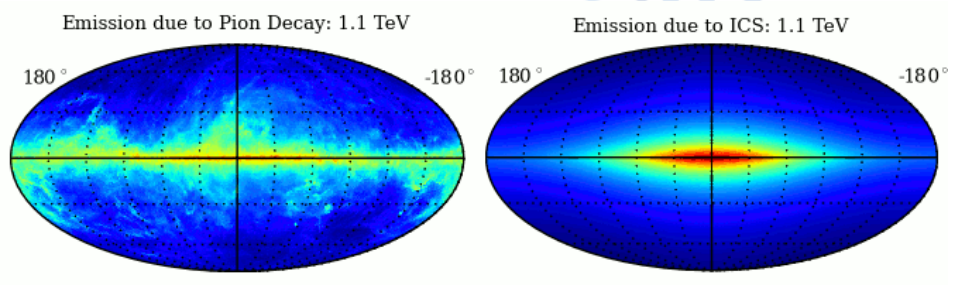
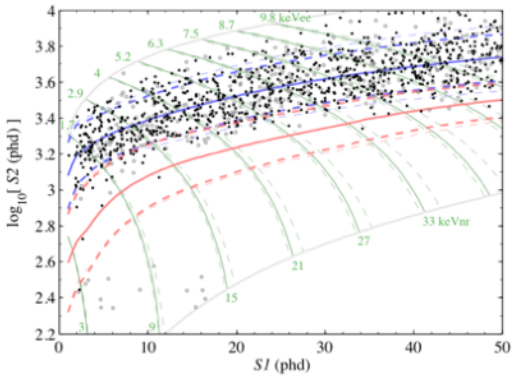


Credit: Galprop, HAWC website

Analysis of events/ distributions (including background subtraction, background estimation, statistical analysis)

PhystatDM, 2019

LUX, PRL. 118, 021303 (2017)



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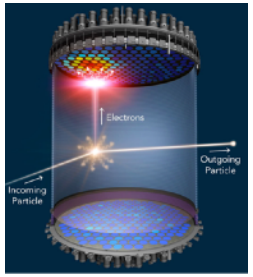

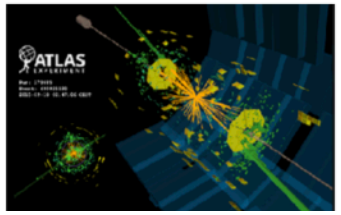

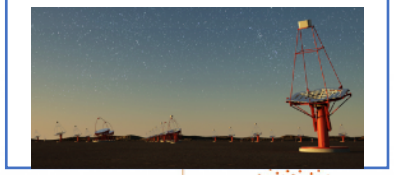

Credit: SLAC/LZ/ATLAS/CTA

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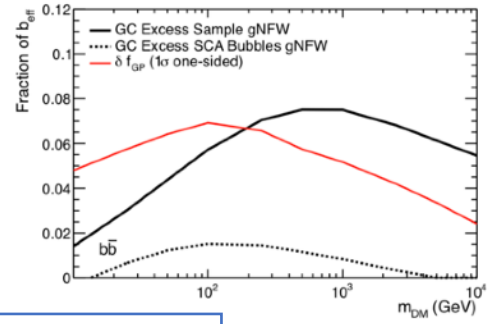
https://arxiv.org/abs/1704.03910



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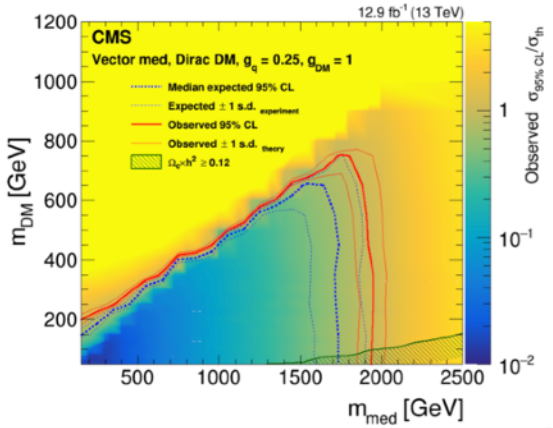

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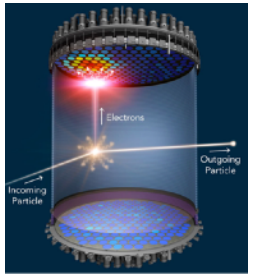

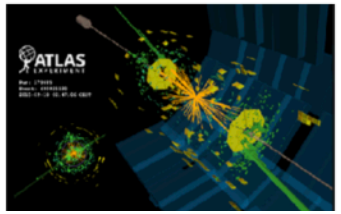

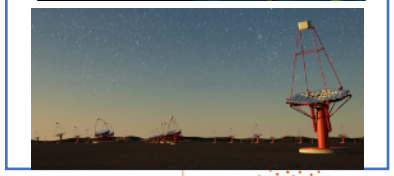

Credit: SLAC/LZ/ATLAS/CTA

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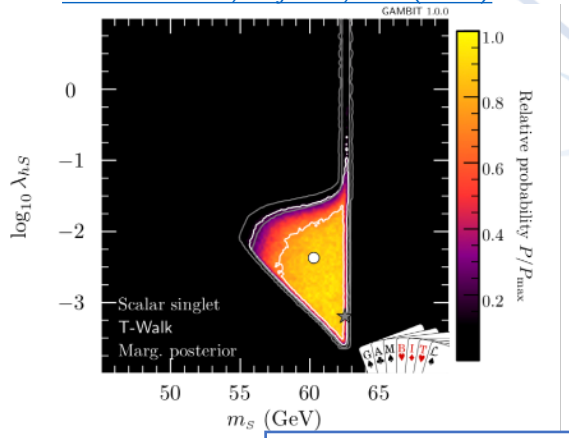
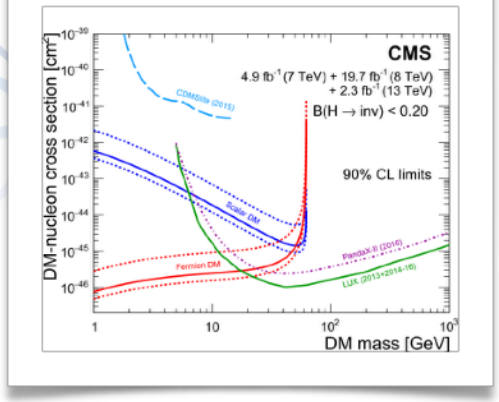
GAMBIT Coll., EPJC 77, 568 (2017)



CMS, JHEP 02 (2017) 135



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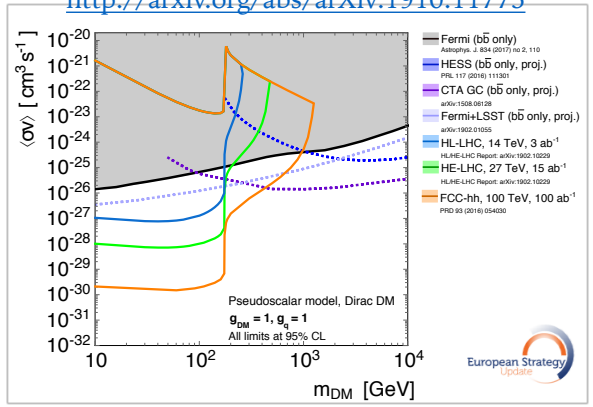
http://arxiv.org/abs/arXiv:1910.11775



Challenges for Test Science Project

- Not possible to find a one-size-fits-all solution in either case...so work in parallel
- Idea (not original, see DANCE workshop): review what is done by various collaborations, finding points of contact

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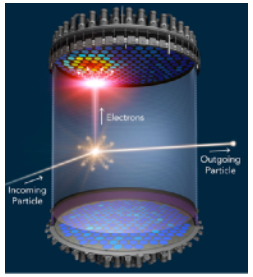
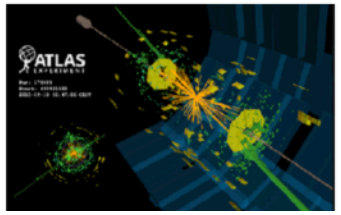
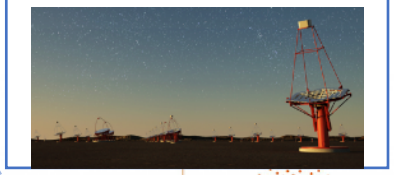






Credit: SLAC/LZ/ATLAS/CTA

Data sharing and data processing challenges

Data **processing** (including reconstruction & calibration)

RUCIO data management software shared across collaborations (LHC/ DUNE/KM3NeT/...)

ESCAPE WP2, WP4, WP5

Data analysis, preservation and interpretation challenges

Analysis of events/ distributions (including background subtraction, background estimation, statistical analysis)

Interpretation of results

Combination of results with other searches/ experiments

V. Poireau et al.

Ongoing work between Fermi-LAT, HAWC, HESS, MAGIC & VERITAS GitHub, ICRC Proceedings

Comparison of results with other searches / experiments

ESCAPE WP3, WP5, WP6

ATLAS experiment perspective

for now: L. Heinrich, S. Meehan, K. Cranmer, C. Doglioni
open to others if interested!

Data sharing & processing

Follow updates to **CERN-wide data sharing policies** (http://opendata.cern.ch)

Benefit from **HEP Software Foundation** as platform to understand shared solutions for data processing challenges & interactions with ESCAPE software catalogue

Data analysis & interpretation

Start working on test ”generic DM search”:

data analysis & data preservation

- Preserve workflow & analysis code with **RECAST**
  ATLAS Note, docs and **REANA**
  - Built around the idea of containerized workflows
- Preserve likelihood with **pyhf** Zenodo, docs
  - Discussions ongoing with **Fermi** data analysers

interpretation of results

- Deposit digitized data & likelihoods in **HEPData**
- Include LHC measurements with **CONTUR**
- Could use **GAMBIT** (& DDCalc) for combinations
- See next slide for more

Initiative for Dark Matter in Europe and beyond

- Many DM discussions, from **Granada** to the **ApPEC-ECFA-NuPECC JENAS meeting** held in Orsay in October 2019
  - Talk on ESCAPE (G. Lamanna) in plenary programme
  - HEP Software Foundation meeting on possible software synergies

- JENAS prompted a new initiative centered around **dark matter:** https://indico.cern.ch/e/iDMEu, also featured in ESCAPE newsletter
  - *iDMEu* aiming to build a discussion platform to facilitate collaboration of existing groups/efforts
  - *Dark Matter Test Science Project* targeting data, software and tools sharing where necessary/useful
  - Points of contact between *iDMEu* and *TSP*:
    - participation of DM community to software catalogue
    - help with common repositories of data and final results (e.g. versioning)
      - e.g. DMTools, DM Limit Plotter

Open questions and challenges

Collected from chats with members of DM community

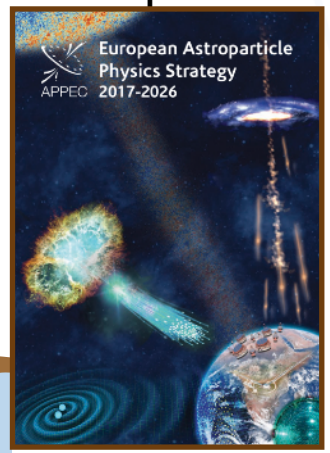
- It is our duty as scientists to make our research FAIR
  - But do we (PIs) / the system (funding agencies) offer sufficient reward?
    - A concern of many: maintaining code is necessary but is often done on a voluntary basis
  - Need a healthy system of incentives coming from within the researcher community
- How can the DM community interface itself effectively with the Software Catalogue and the other ESCAPE WPs?
  - See dedicated discussion, and input from HEP Software Foundation
- How does ESCAPE interface itself with other entities that support/develop DM research / open science in astronomy and astrophysics?
  - E.g. ESA, http://www.esa.int/About_Us/Digital_Agenda/Open_Science
- How can ESCAPE reach out to researchers? (today's discussion)

How to proceed towards a Test Science Project

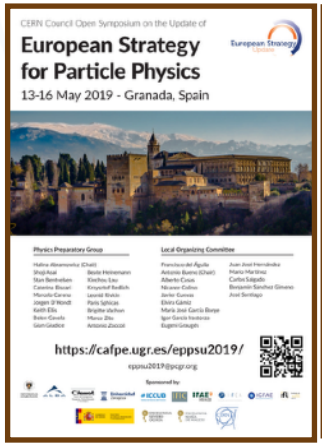
- Grounding assumption as an ”easy” DM case: WIMP dark matter
  - Not exhaustive in terms of DM hypotheses, but well studied (collider, DD, ID, theory, astrophysics)
  - Idea is to build on work already done/planned to create a TSP prototype
  - Will expand of on other kinds of DM / other experiments later
    - but we can work in parallel if there is interest and critical mass!
- In the process of collecting information
  - Collider community (ATLAS, CERN) on board, ID combination work ongoing
  - Need more input from non-collider community: direct detection, astrophysics, theory
  - Who in turn need more input from ESCAPE (discussion points)
- Start having regular discussions once main players identified
  - Happy to receive input on how to do so as non-ESCAPE members

Foundations needed to exploit synergies

APPEC Astroparticle



ECFA Particle



NuPECC Nuclear

Common theory ground

instrumentation (accelerators, beams, detectors, vacuum & cryogenics, control & automation...)

data acquisition, computing, data sharing & open science

HSF HEP Software Foundation

ESCAPE European Science Cluster of Astronomy & Particle physics ESFRI research Infrastructures

iris hep

& more...

EuCAPT

[Talk at EPS-HEP / ECFA session 2019](), [CERN EP Newsletter]()

For more chances to discuss…

Jointly organised between the HEP Software Foundation and the Worldwide LHC Computing Grid, the focus of this workshop is the challenge of **adapting our software and computing infrastructures to increased data rates, new computing technologies and facility evolution**. All of this is targeted to maximise the physics opportunities from future upgrades and new facilities.

The workshop will take a forward look at key topics for software and computing, reviewing progress, looking at new approaches, and discussing opportunities and challenges. There will be **plenty of time for discussion** and the development of R&D ideas that should be explored.

The workshop is **open to everyone in the field**, from LHC experiments to the intensity frontier, dark matter, astroparticle and other data intensive sciences. **Participation of Early Career Researchers is particularly welcome.**

ESCAPE

European Science Cluster of Astronomy & Particle physics ESFRI research Infrastructures

Backup slides

@CatDogLund, she/her
http://www.hep.lu.se/staff/doglioni/

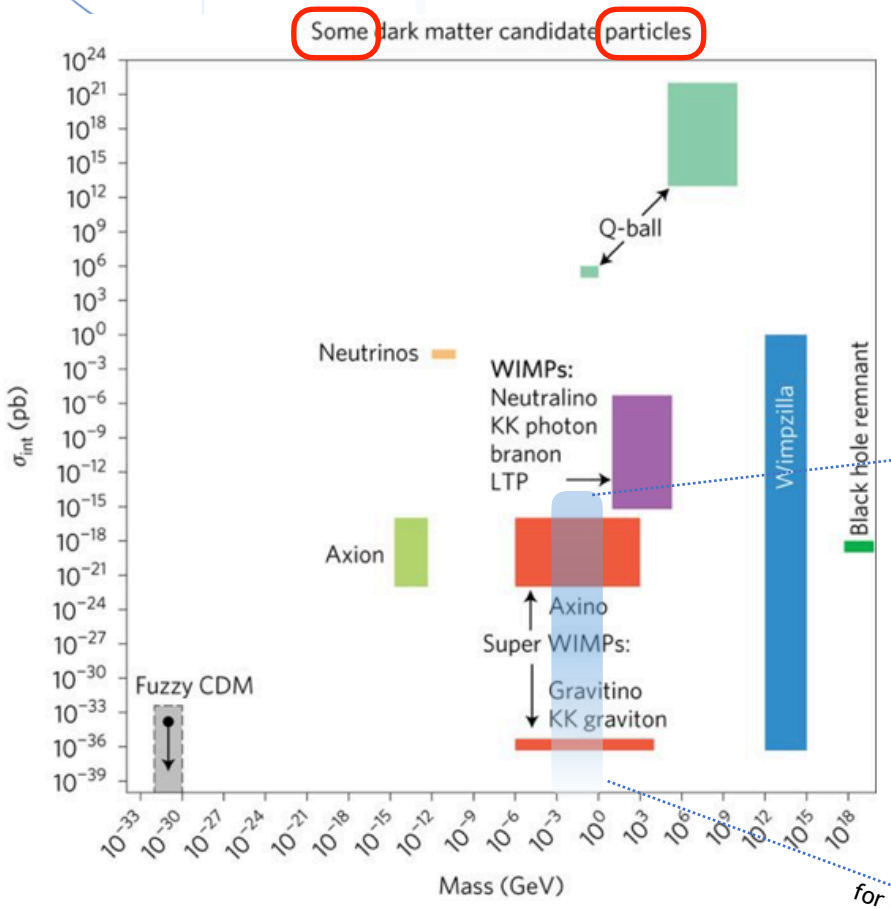
European Research Council
Established by the European Commission

ATLAS EXPERIMENT

ESCAPE - The European Science Cluster of Astronomy & Particle Physics ESFRI Research Infrastructures has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement n° 824064.

Different kinds of DM, and synergies

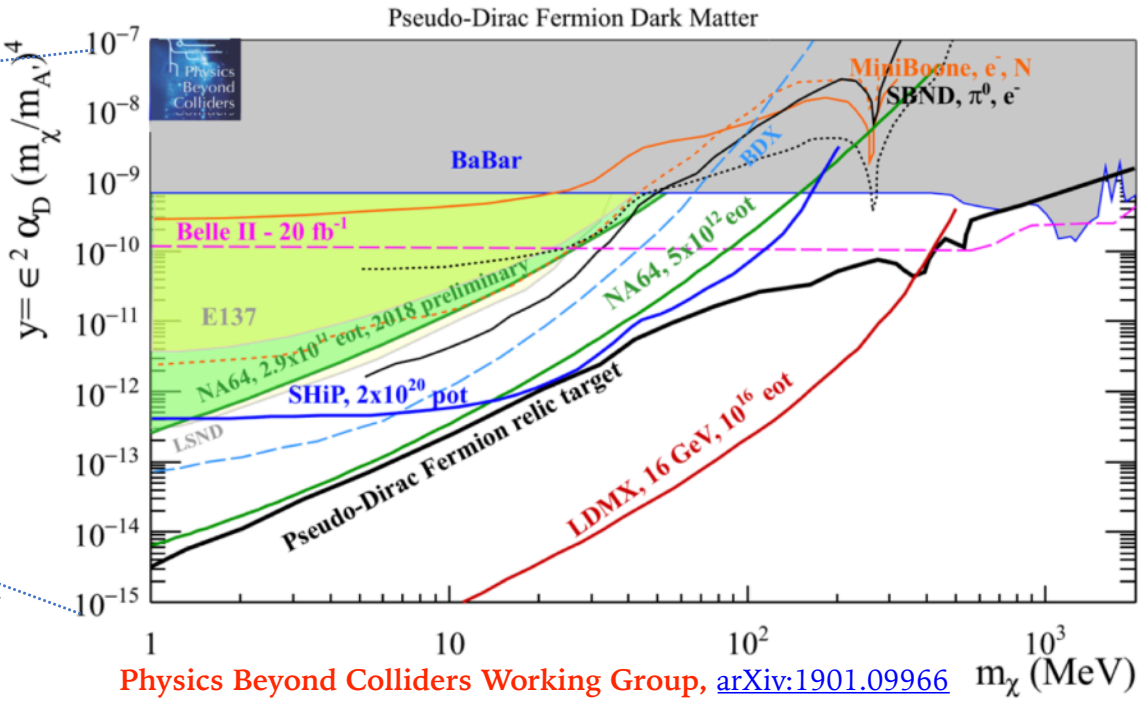
Many hypotheses for dark matter
→ many ways to detect it
→ many different experiments
→ many different data / result sharing policies
→ many different data / workflow needs



https://www.nature.com/articles/nphys4049
adapted from The Dark Matter Scientific Assessment Group

for illustrative purposes
no 1:1 correspondence

Dark photon portal model



Physics Beyond Colliders Working Group, arXiv:1901.09966

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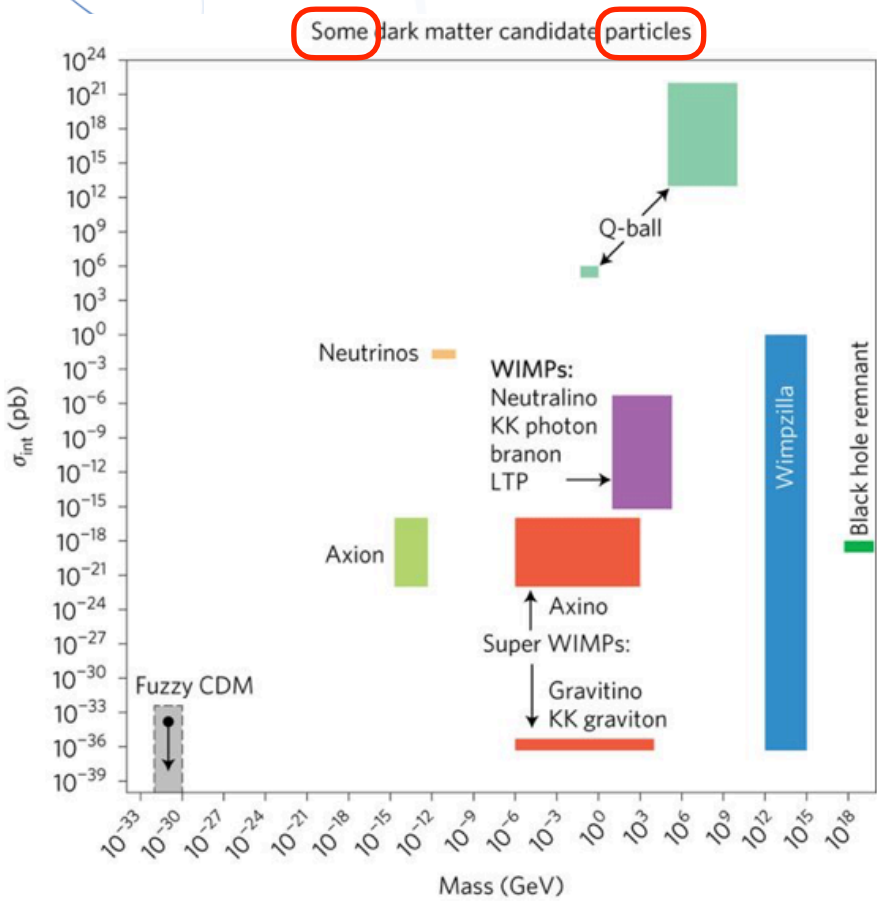

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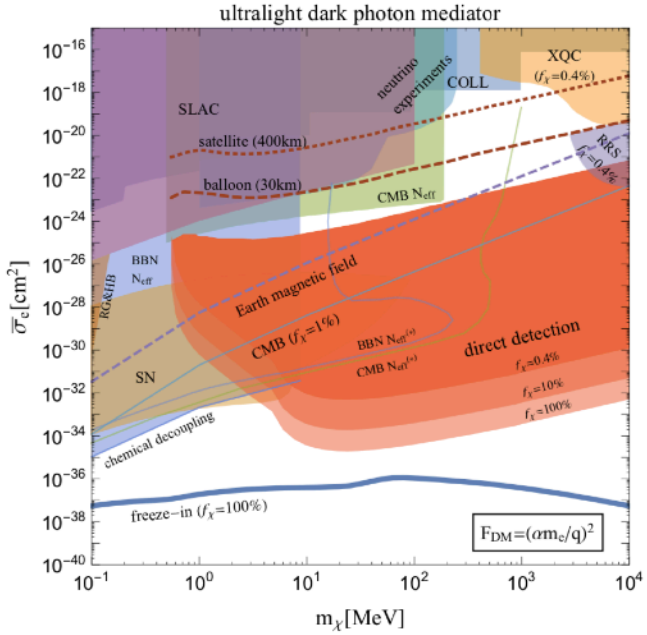
Constraints from astrophysics



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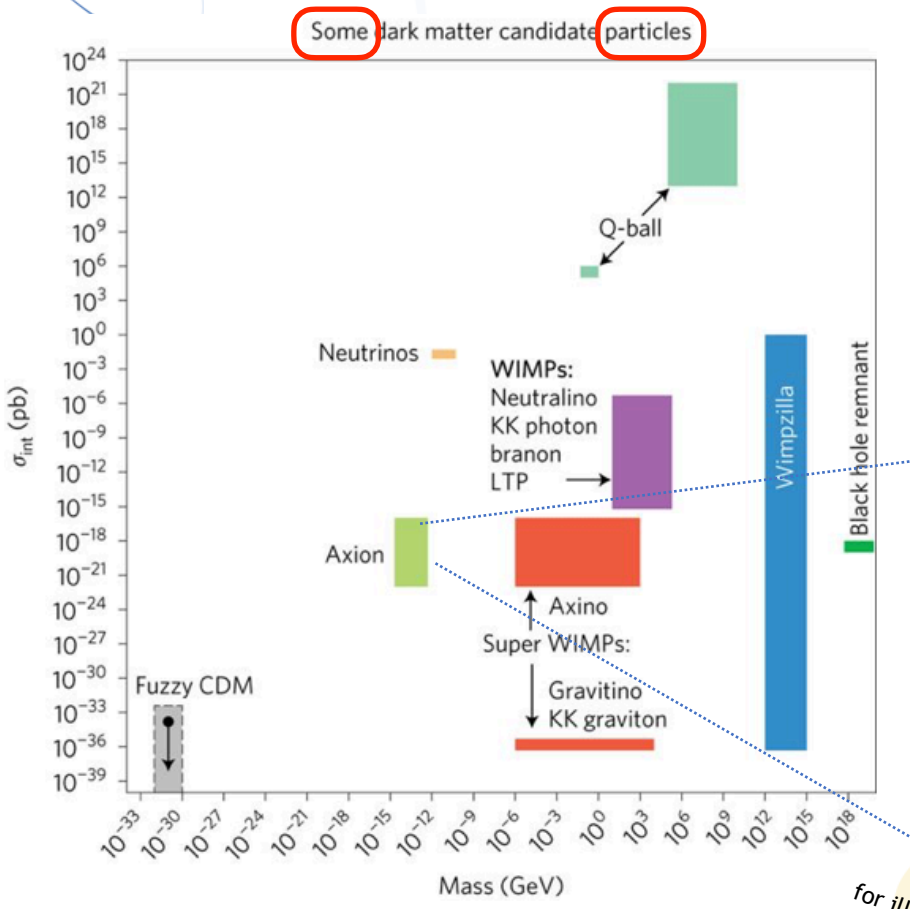

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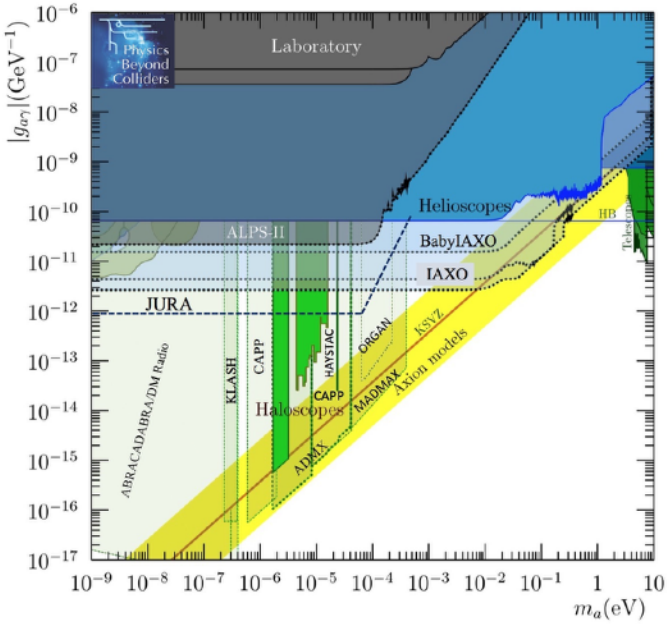
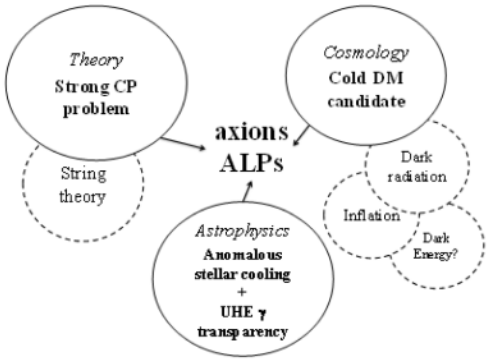
Axion models





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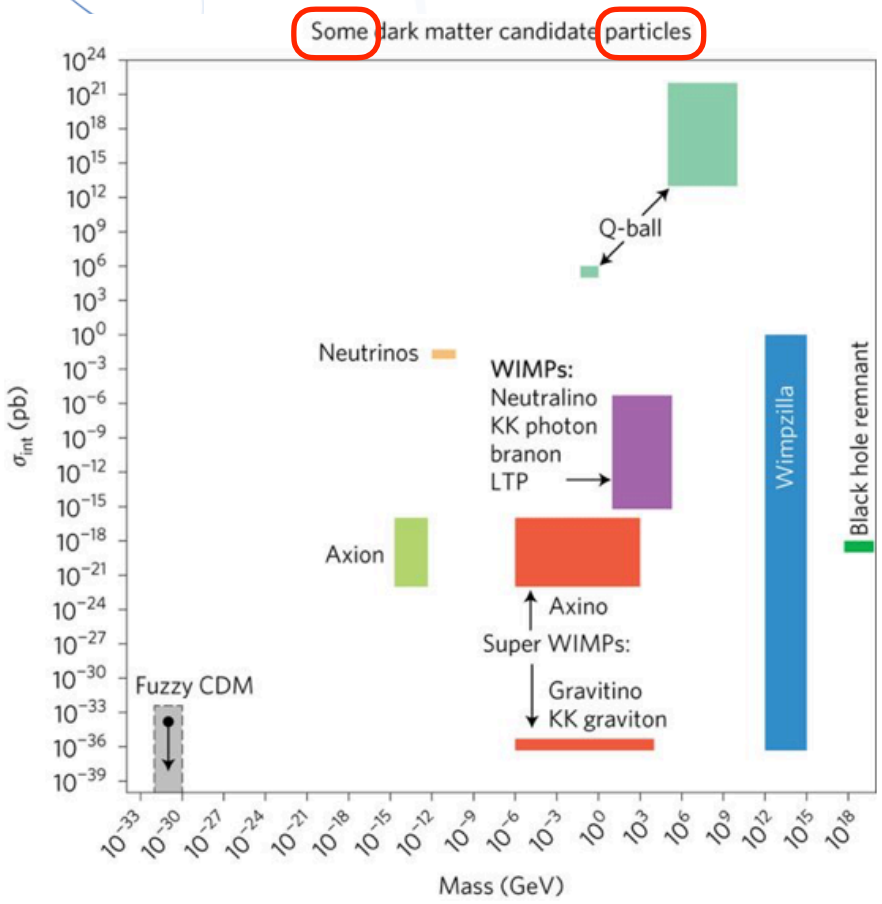

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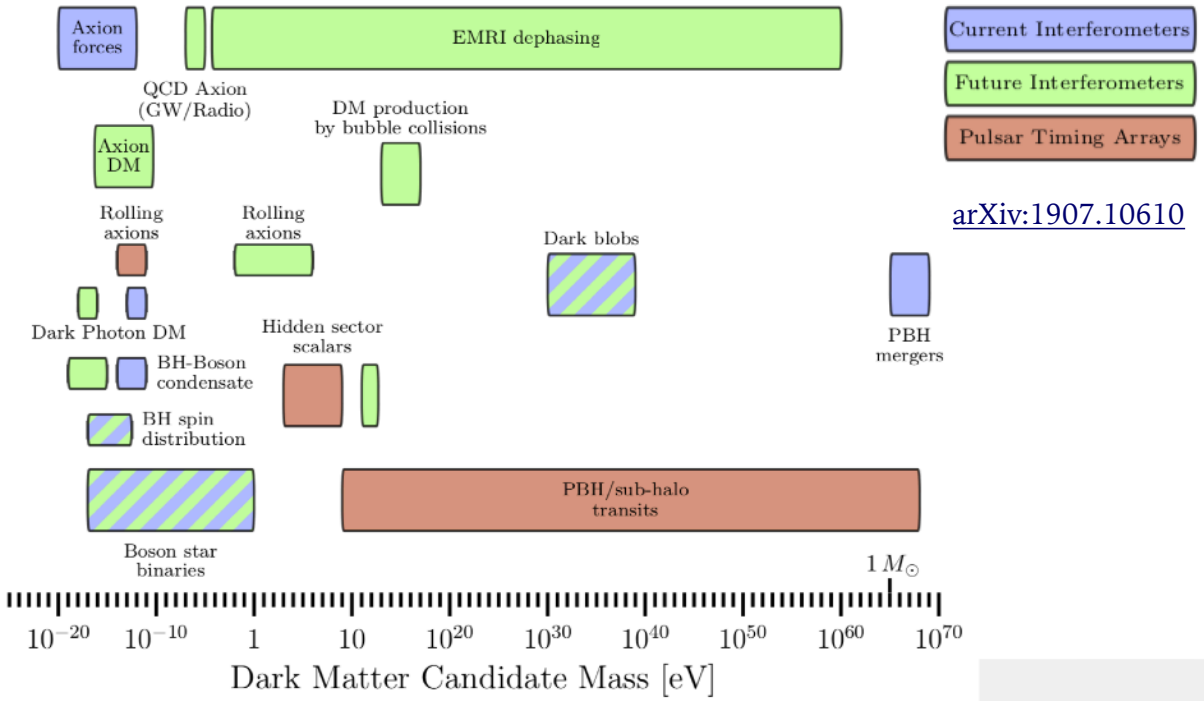
Models relevant for GW experiments



arXiv:1907.10610

Combination of ID results