ESCAPE

European Science Cluster of Astronomy & Particle physics ESFRI research Infrastructures

The Dark Matter Test Science Project

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European Research Council
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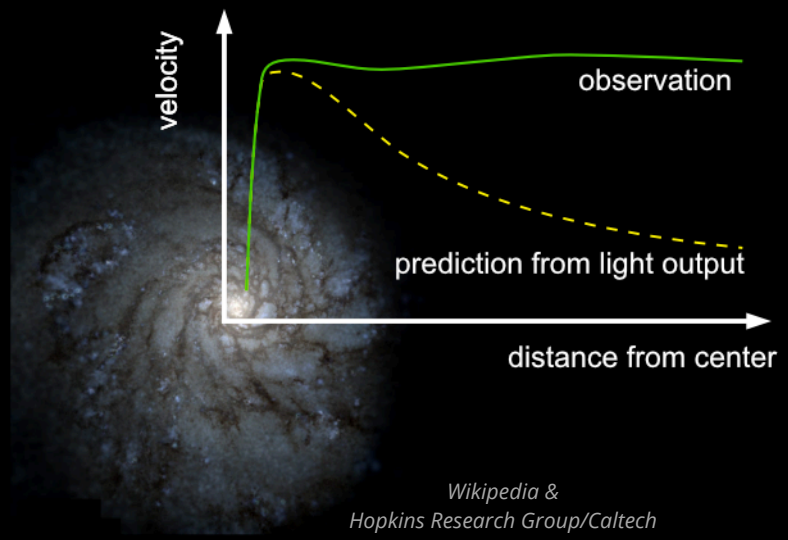
ATLAS EXPERIMENT

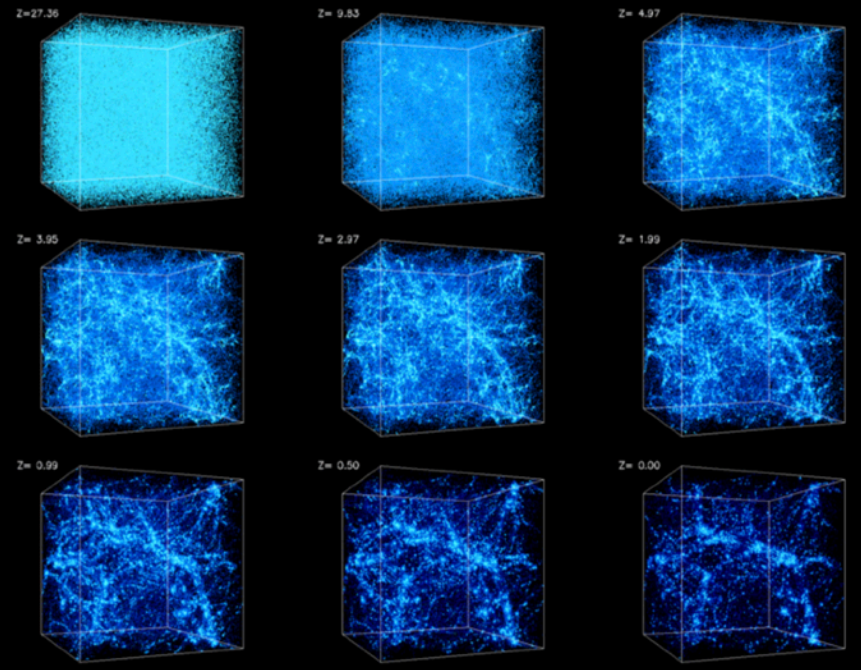
ESCAPE - The European Science Cluster of Astronomy & Particle Physics ESFRI Research Infrastructures has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement n° 824064.

Big science question: Dark Matter

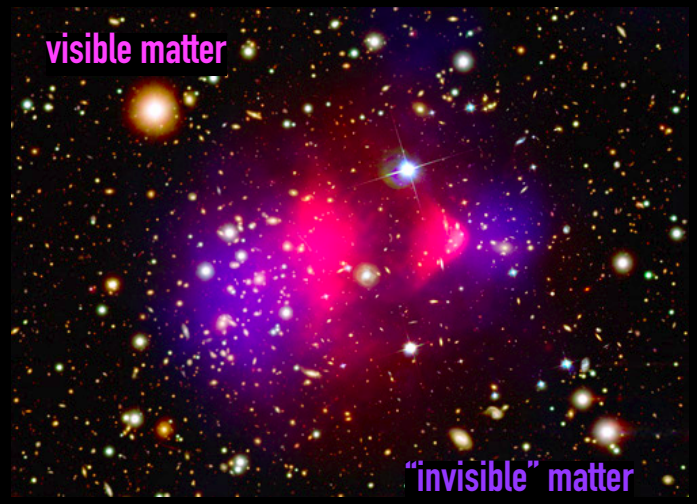


Wikipedia &
Hopkins Research Group/Caltech

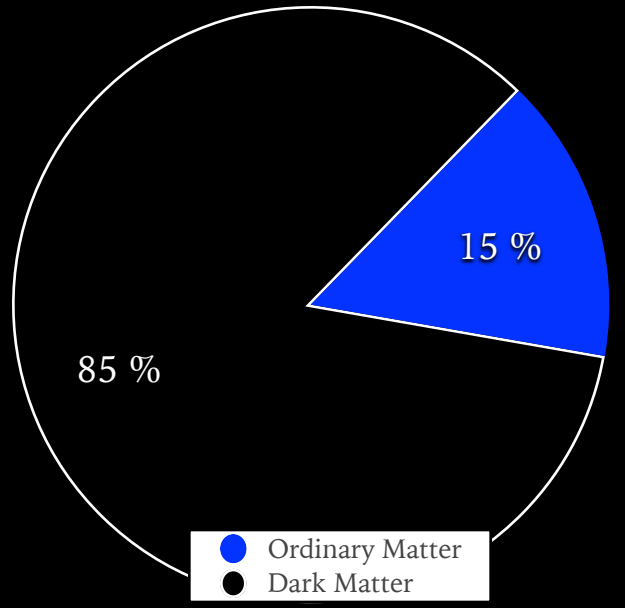
Vera Rubin,
© Washington Times & Zuma



Simulations were performed at the National Center for Supercomputer Applications by A. Kravtsov and A. Klypin.



NASA/CXC/M. Weiss



https://cordis.europa.eu/project/id/679305

How/why Test Science Projects?

Slide from G. Lamanna

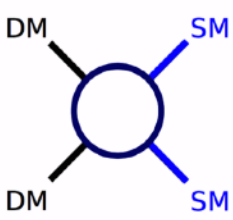
- Propose **Test Science Projects** to demonstrate multi-domain science integration across ESCAPE / EOSC
- **Involve researchers** to **demonstrate** new cutting edge **open science capabilities**, making use of the services implemented within EOSC
  - researchers can give feedback on the capabilities delivered by ESCAPE/EOSC
  - researchers can exploit synergies between the ESFRIs and among the scientific communities of Astrophysics/Astroparticle, accelerator-based Particle and Nuclear Physics
- Supported by consortia of EU member states research agencies and institutes within the **J**oint **E**CFA **N**uPECC **A**PPEC **A**ctivities (JENAA)

Different kinds of DM, and synergies

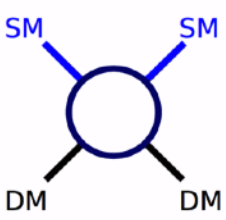
Many hypotheses for dark matter
→ many ways to detect it
→ many different experiments
→ many different data / workflow needs
→ many different data / result sharing policies

Scientific added value of DM-TSP:
New plots of dark matter discoveries / constraints

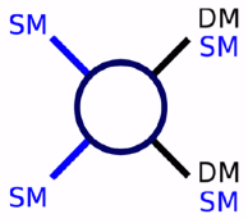
one of many models predicting **Weakly Interacting Massive Particles (WIMP)**



Indirect Detection

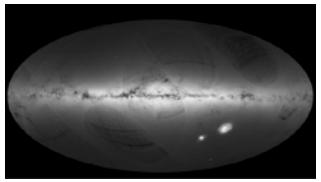


Direct Detection

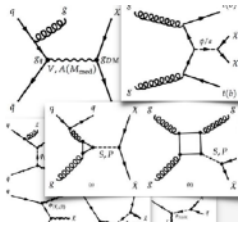


Colliders

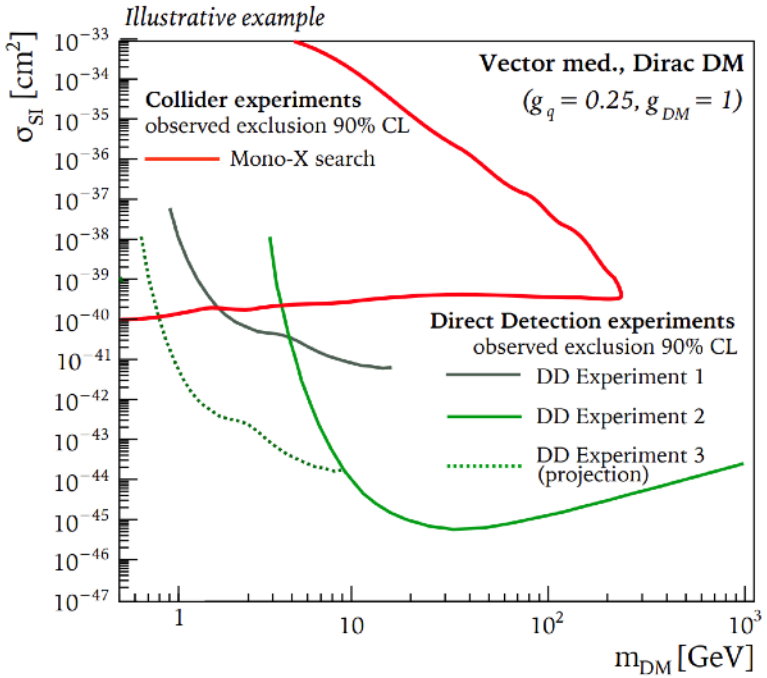
Credit: ESA/Gaia/DPAC.



Astrophysics



Theory



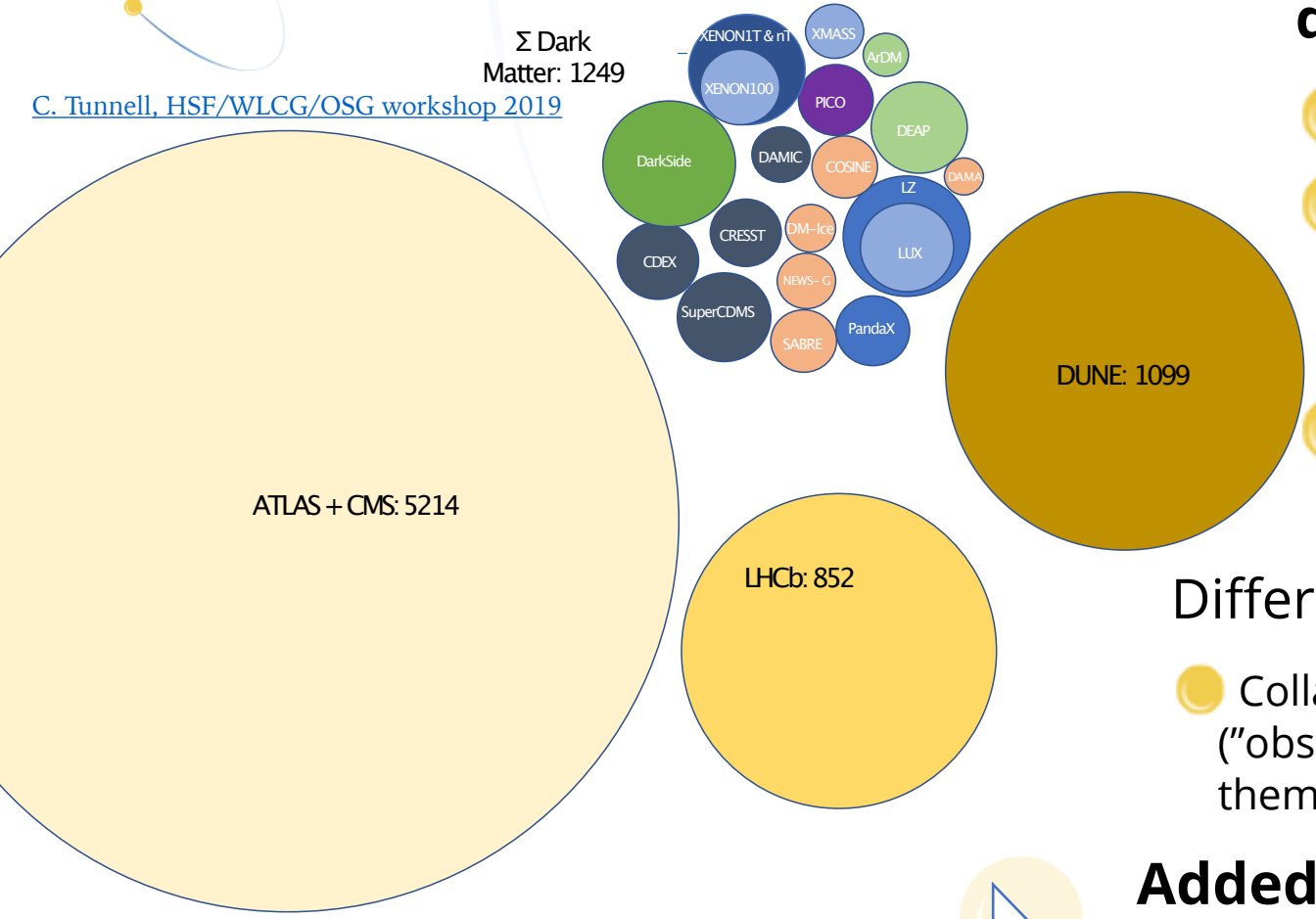
https://arxiv.org/pdf/1912.12739.pdf

There are many combinations of results on the market...
but none that sees them all work together with FAIR data & end-to-end workflows!

Different kinds of (WIMP) DM communities & data/software needs

(full table uploaded by Ian Bird in Teams)

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

Added value of DM-TSP:

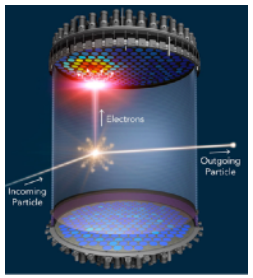
Proof that communities with different data needs can use a common platform —> further demonstration of EOSC versatility, encourages future use by the entire scientific community

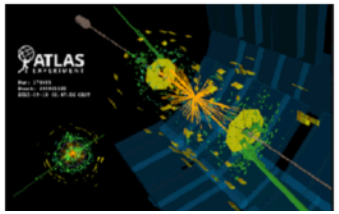
Analysis workflows for DM-TSP

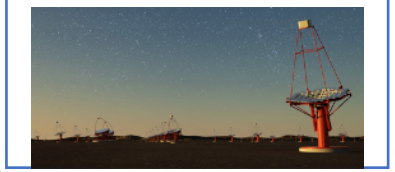
Integration work, foreseen in EOSC-Future

Generation & simulation of events

Experimental data







Credit: SLAC/LZ/ATLAS/CTA

Data sharing and data processing challenges

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

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

Data analysis, preservation and interpretation challenges

Interpretation of results

Combination of results with other searches/ experiments

Comparison of results with other searches / experiments

Consolidation work in EOSC-Future and ESCAPE

Data Lake

Software Catalogue
Analysis Platform

The TSP, in a nutshell

Experimental method	Partners	EOSC Tools	DA Tools (AI/ML)	Project outcome
Producing DM in the lab (collider): ATLAS @ CERN	CERN LAPP	Data Lake Software Catalogue Analysis Platform	ML algorithms for: 1. Data compression 2. Data reconstruction (e.g. pattern recognition) 3. Background rejection	Constraints(/projections) on dark matter cross-section / DM mass plane and on dark matter velocity-averaged xsection / DM mass plane
Detecting dark matter from the sky (direct detection): DARKSIDE @ INFN	INFN	Data Lake Software Catalogue Analysis Platform	TBC	Constraints(/projections) on dark matter interaction cross-section/mass plane
Detecting interactions of dark matter using neutrinos (indirect detection): KM3NeT	FAU	Data Lake Software Catalogue Analysis Platform	TBC	Constraints(/projections) on dark matter cross-section/mass plane
Detecting interactions of dark matter in space (indirect detection)	LAPP	Data Lake Software Catalogue Analysis Platform	TBC	Constraints(/projections) on dark matter velocity-averaged xsection / DM mass plane
Surveying dark matter in the universe (astrophysical probes)	Open University [not in WP6 in EOSC-Future]	Data Lake Software Catalogue Analysis Platform	TBC	Combination of constraints on different models using simulation + statistical analysis software (Gambit)
[TSP2] Exploiting the gravitational interactions of DM (GW probes)	See GW TSP	Software Catalogue Analysis (multimessenger) Platform	See GW TSP	TBC

- Table, originally designed by ESCAPE-TSP-GW, is still as a work in progress
- Idea of Data Analysis Tools column: algorithms that can be **shared beyond a single infrastructure / field**
- IWAPP was very useful in terms of food for thought on **how to implement these common algorithms** (especially ML)
- How to follow up?

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Backup slides

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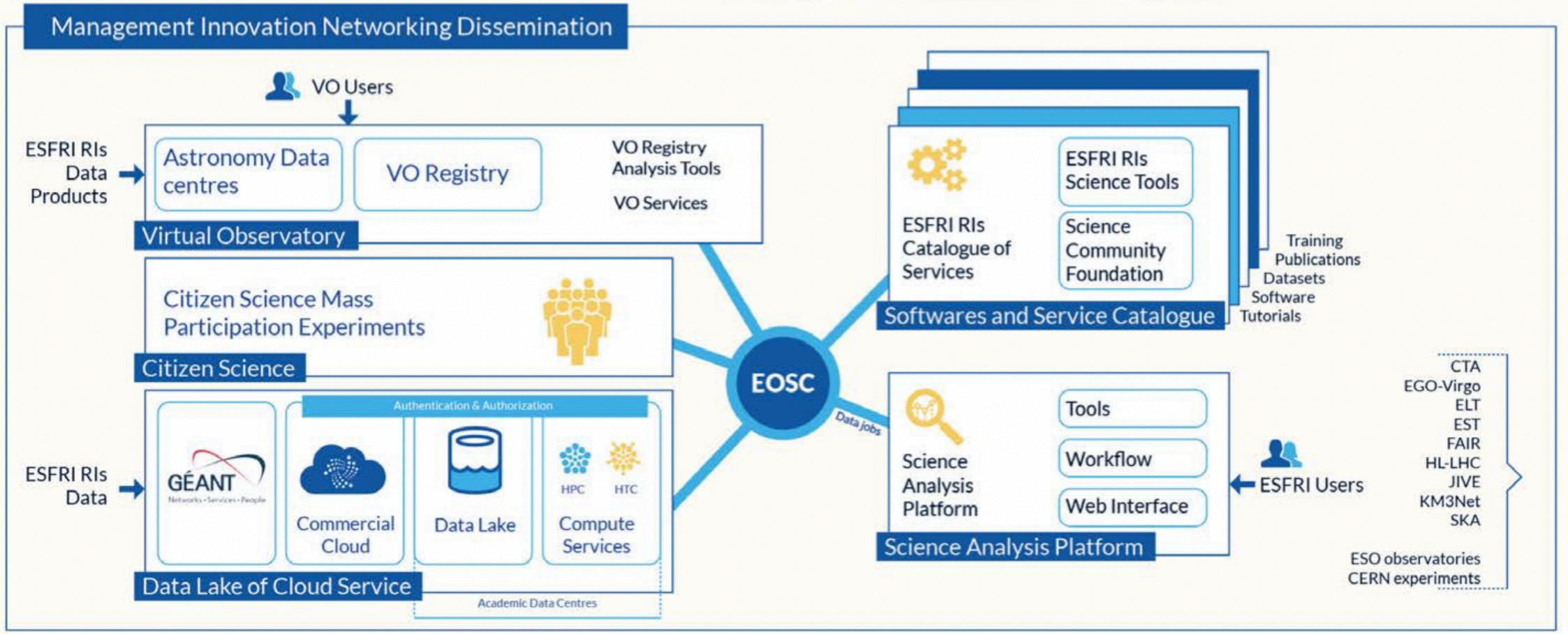
Services towards the European Open Science Cloud (EOSC)

Slide from G. Lamanna



ESCAPE services

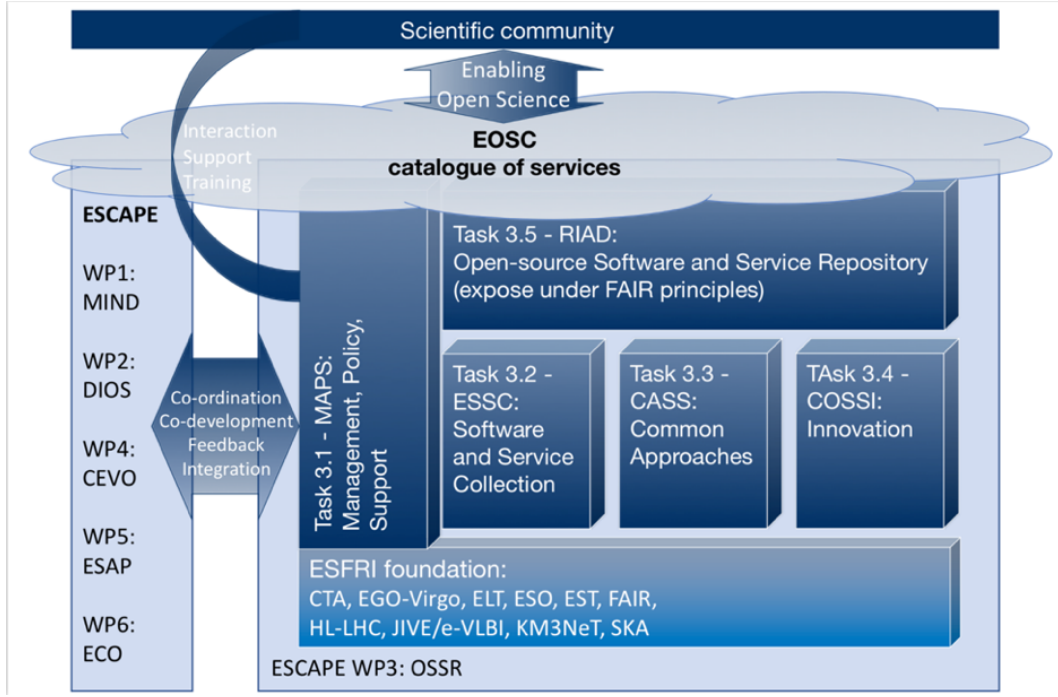
Slide from G. Lamanna

- **Data Lake**:
  - Build a scalable, federated, data infrastructure as the basis of open science for the ESFRI projects within ESCAPE. Enable connection to compute and storage resources.
- **Software Repository**:
  - Repository of "scientific software" as a major component of the “data” to be curated in EOSC. Implementation of a community-based approach for the continuous development of shared software and for training of researchers and data scientists.
- **Virtual Observatory**:
  - Extend FAIR standards, methods, tools of the Virtual Observatory to a broader scientific context; demonstrate EOSC ability to include existing platforms
- **Science Platforms**:
  - Flexible science platforms to enable the analysis of open access data
- **Citizen Science**:
  - Open gateway for citizen science on ESCAPE data archives and ESFRI community CS projects

ESCAPE software catalogue

Slide from K. Graf

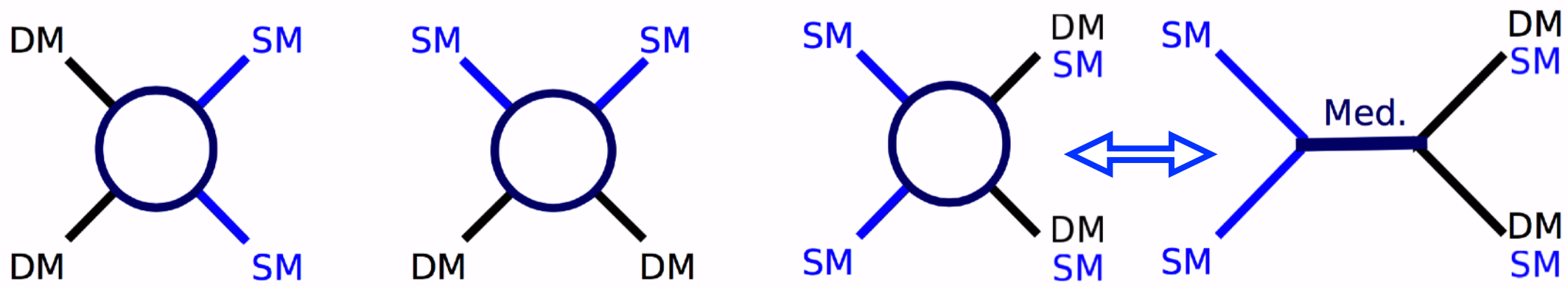
OSSR Overview



ESFRI/RI	Institute/SME
CTA	CNRS-LAPP
CTA	CTAO
CTA	IFAE
CTA	MPG-MPIK
CTA	UCM
EGO-Virgo	EGO
ELT	HITS
EST	AIP
EST	NWO-I-CWI
EST	UNITOV
FAIR	GSI
HL-LHC, CERN	CERN
JIVE	JIVE
KM3NeT	CNRS-CPPM
KM3NeT	FAU
KM3NeT	INFN
KM3NeT	NWO-I-Nikhef
SKA	SKAO
SME	OROBIX
9 ESFRI / RI	**19 Partners**

Dark matter complementarity

- DM discoveries need complementary experiments that involve DM with **cosmological origin** / can **produce DM**
  - Direct detection can **discover DM that interacts** inside the detector
  - Indirect detection can see **annihilating/decaying DM** through its decays
  - Accelerators/colliders can produce DM and **probe the dark interaction**



Indirect Detection (+ cosmic surveys) Direct Detection Particle Accelerators (colliders & extracted beam lines)

- Work on "common language / common resources" (plots, scenarios, tools) ongoing in Snowmass / iDMEu JENAA EOI / many other communities

Synergistic initiatives following European Strategy Update

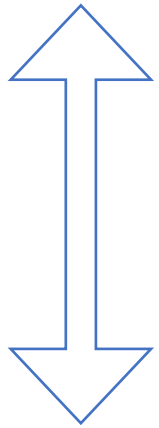
searches & interpretation

JENAS EoI: Initiative for Dark Matter in Europe and beyond: Towards facilitating communication and result sharing in the Dark Matter community (iDMEu)

https://indico.cern.ch/event/869195/
ESCAPE newsletter APPEC newsletter

build a discussion platform to facilitate collaboration of existing groups/efforts on **dark matter searches** and **interpretation**

*provides a discussion platform for the **comparison of common DM interpretations***



software & data

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

data acquisition, software, computing, data sharing & open science

Towards a Dark Matter Test Science Project

ESCAPE Progress Meeting, 2020

compare **end-to-end analysis workflows** for WIMP searches, towards their implementation in a common **Software Catalogue** and as input to the design of the **European Open Science Cloud**

*allows to **create experimental curves** by **example ESCAPE experiments,** comparing and contrasting analysis pipelines that use ESCAPE / EOSC tools*

More initiatives and links in backup slides

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