



# ESCAPE

European Science Cluster of Astronomy &  
Particle physics ESFRI research Infrastructures



# ESCAPE to the Future 25-26 October 2022

Royal Belgium Institute  
of Natural Sciences  
[Brussels, Belgium]

# ESCAPE & Open Science



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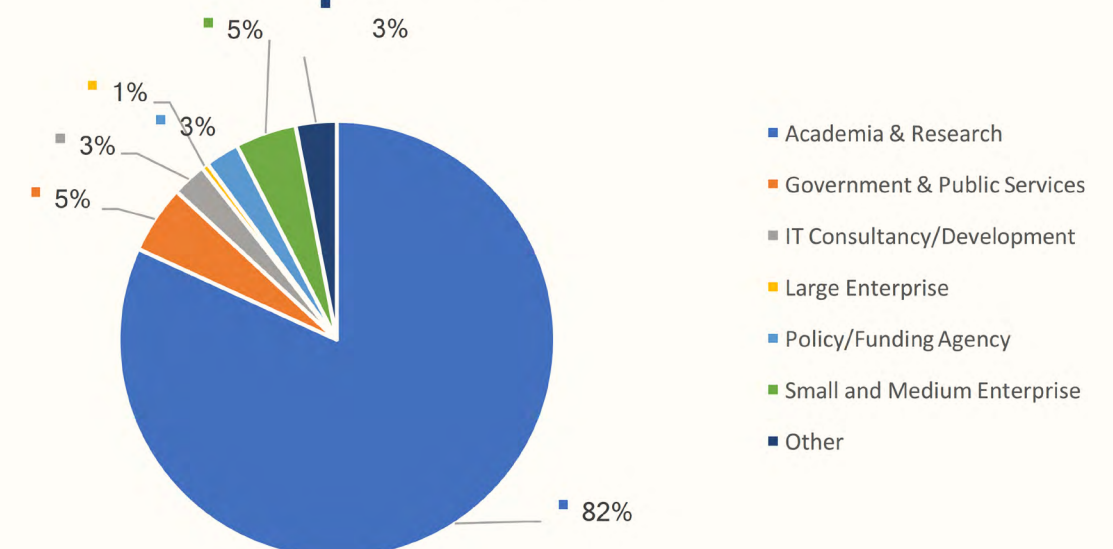
Since February 2019, ESCAPE (European Science Cluster of Astronomy and Particle Physics ESFRI research infrastructures) has been promoting Open Science through smooth cross-border and multi-disciplinary Open-Science environment, bringing the scientific data research also available to society.

The “ESCAPE to the Future” event showcased the five ESCAPE versatile solutions that allow management, curation and deposition of data, to unlock the driven science economy, while following FAIR principles in the different stages of the scientific process. Each one of these five services demonstrated how they have been helping research infrastructures from astronomy, astrophysics, particle and nuclear physics in doing science discoveries while addressing profound questions about the structure and evolution of the universe.

“ESCAPE to the Future” had on its stage the Science Projects, being developed jointly with EOSC Future initiative, which are being integrated in the EOSC (European Open Science Cloud) environment so scientists can exploit synergies and complementarities across different communities for mutual benefits.

The “ESCAPE to the Future” brought together around 200 individuals (half in Brussels, half online) from 20+ different countries, to discover how ESCAPE has been strengthening Open Science in astronomy, astrophysics, particle and nuclear physics, mostly from Academia and Research but also from Policy Funding Agencies and Public Services, IT Consultancy/Development, amongst others, as shown in the figure below.

Audience Profile



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# Organising Committee



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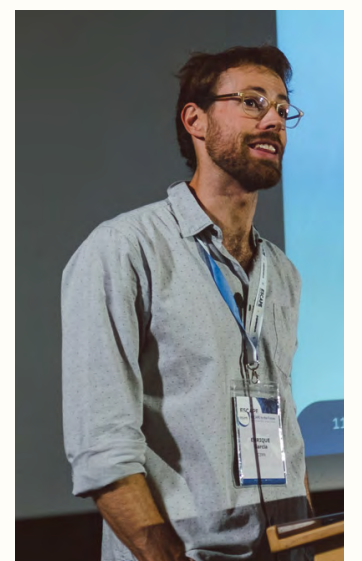
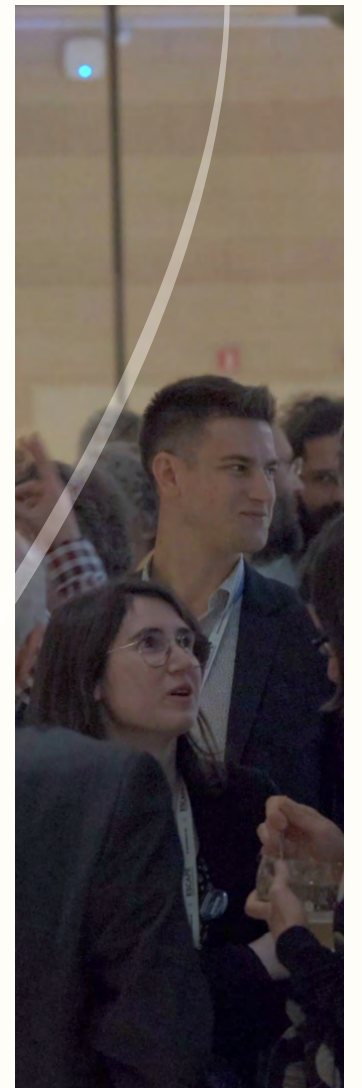


**Stephen Serjeant**  
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#ESCAPEtotheFuture





# Welcome Plenary: ESCAPE a wager and an adventure & with Open Science technical challenges

The opening session provided an overview of ESCAPE mission towards open science, the main technical challenges that had to overcome and what were the main results achieved.

## Main Takeaways

### ESCAPE – a wager and an adventure

- **A wager mission:** where 10 world-class ESFRIs (European Strategy Forum on Research Infrastructures) and Pan-European Research Infrastructure from Astronomy and Particle Physics joined ESCAPE, supported by 4 European consortia, to both rise research productivity and lead to new insights and innovative activities thanks to open data intensive drive science;
- **An ESCAPE EOSC-cell serving multiple needs:** a cross-border and multidisciplinary environment to enable EOSC to adopt services, e-infrastructures and data stewardship of ESFRIs. This cell, composed of the five ESCAPE services (ESCAPE DIOS, ESCAPE OSSR, ESCAPE VO, ESCAPE ESAP and ESCAPE CS), supports European researchers in increasing scientific value, while maximizing the benefits of their research through data-driven science;
- **Addressing ESFRIs common needs through open science:** where their operations require global, open access to data, long term curation and sustainability, by implementing data FAIRness on scientific data and linking the ESFRIs to EOSC for a cross-border open innovation environment;
- **Many challenges to be addressed as a cluster:** bring astrophysicists and particle physicists together and support new generation of researchers towards a cross fertilisation for multi-probe fundamental research. Also important to build an inter-research infrastructures (RIs) Virtual Research Environment (VRE) on top of dominant RIs, while combining the continuous support to the implementation of ESFRIs with a strategy to uptake the EOSC concept;
- **Clear expectations and contributions to EOSC and European Research Area:** delivery of position statements along with the other thematic EOSC clusters (Environment, Photon and Neutron Sciences, Social Sciences and Humanities, Life Sciences);
- **International recognition:** in the "European Strategy of Particle Physics" as an example of a real synergistic cooperation scheme, as well as on the ESFRI 2021 Roadmap "Making Science Happen" and "Consolidation of The European RI Landscape" as an example scheme for new coordinated focus by ESFRIs;
- **Fostering synergies for EOSC:** in EOSC Future between Science Clusters and e-infrastructures to bring scientific content into EOSC, as well as strengthening multidisciplinary collaborations among young researchers on open science projects.

### ESCAPE – Open Science technical challenges

- **Scalable infrastructure for the next generation of experiments:** suitable to deal with the increasing magnitude of data volumes to serve the needs of the community;
- **Full Exabyte scale data management prototype:** for storage, transfer and access with a common Authentication and Authorisation Infrastructure (AAI) framework for distributed scientific computing;
- **Catalogue of digital scientific products and new interoperability standards:** to support the onboarding of ESCAPE services into EOSC, with a reusable analysis toolkit for integrating diverse service offerings;
- **Citizen Science for engagement and new knowledge:** built upon ESCAPE developments, which attracted significant interest and involvement from a large number of individuals;
- **Two innovative Science Projects (SP):** from Dark Matter and Extreme Universe fields, to demonstrate the power of Open Science in ESCAPE, with their consequent integration with the EOSC platform through EOSC Future;
- **Contribution to the EOSC Task Forces:** by having ESCAPE members in 8 task forces, shaping the future of EOSC: Researcher Engagement and Adoption; Semantic Interoperability; Rules of Participation Compliance Monitoring; Upskilling Countries to Engage in EOSC; Infrastructures for Quality Research Software; Technical Interoperability of Data & Services; Financial Stability; Long Term Data Preservation;
- **Ensure that the technical direction of the EOSC architecture delivers open science:** share ESCAPE products through EOSC, enable re-use, ensure broader exploitation, encourage open science and FAIR data, share expertise on both exabyte scale data management and globally federated compute infrastructures.

## Speakers



**Giovanni Lamanna**  
ESCAPE Project Coordinator and Director of LAPP



**Ian Bird**  
ESCAPE Technical Coordinator and Senior Scientist at LAPP



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# ESCAPE DIOS - Building a data lake for Open Science

This session showcased the ESCAPE DIOS (Data Infrastructure for Open Science (DIOS) developments, achievements and future plans, how it hides the complexities of data management and data access in a distributed environment from the end users, as well as how it provides capabilities for managing large volumes of data and making them accessible to very distributed communities, while optimizing the cost of storage.

## Main Takeaways

- **A Data Lake to manage data:** ESCAPE DIOS is a reliable, policy driven, distributed data infrastructure, capable of managing Exabyte scale data sets, and deliver data on demand at low latency to all types of processing facilities, with real time follow up for data transfers;
- **A sandbox hands-on platform to do experiments:** where users can experience what is a high level data management system and explore how to do data management file transfers in a reliable way;
- **Meeting the ESFRIs/RI requirements:** thanks to a continuous assessment and evolution of the ESCAPE DIOS pilot with the user community, which resulted in a fully working system;
- **Easing user experience with a single and global authentication point:** spearheading token-based authentication to boost its integration in several layers of the infrastructure;
- **Data life-cycle accommodation:** ESFRI/RIs users are able to define data replication rules, lifetimes, access policies, data location and storage quality of service (adjusting storage cost with data);
- **Flexible way to interact and integrate with other storage resources:** thanks to protocols that ease data access from heterogeneous compute platforms and end user devices;
- **Integration of heterogeneous resources:** where the infrastructure interfaces not only with research organisations, but also commercial clouds, public clouds and high performance computing centres.

## Considerations for the Future

- **Increase collaborations:** to foster involvement with other scientific communities and strengthen cooperation with related EC initiatives and projects, by bringing together RIs, sites and service providers;
- **Become an anchor for scientific community:** Identify common needs and engage with RIs by focusing efforts on well identified common needs related to data management, file transfer services, range transfers, analysis platforms and frameworks, as well as the consolidation of a global AAI frameworks;
- **Continuous growth with upcoming technologies:** by getting valuable advice and previews from developers and operators that will greatly benefit next iterations of ESCAPE DIOS;
- **Consider different "user processing":** based on different types of hardware environments. The content delivery and caching for access to remote data may be useful addition to processing at larger compute systems that are further away from the data archive.

## Speakers

### Session Chair



**Xavier Espinal**  
CERN

### ESFRIs



**Gareth Hughes**  
CTAO



**Fabio Hernandez**  
IN2P3



**Yan Grange**  
ASTRON



# ESCAPE OSSR - Foster collaboration to create FAIR software for science

The session dedicated to the ESCAPE Open-source Scientific Software and Service Repository (OSSR) presented the developments and achievements towards a FAIR multi-messenger data-driven cooperative approach. Exemplary benefits of ESCAPE OSSR integration in astro-particle-physics and adjacent scientific fields were presented by ESFRI experts focusing on cross-community software developments, workflows for scientific re-use of data challenges, and the exploration of scientific data with innovative techniques.

## Main Takeaways

- **A sustainable one entry point for software open access:** ESCAPE OSSR is a repository to share scientific software and services to the science community and enable open science. It houses astro-particle-physics related scientific software and services for data processing and analysis, as well as test data sets, user support documentation, tutorials, presentations and training activities;
- **An open innovation environment for “solutions” rather than “services”:** with FAIR principles implemented for software and derivatives, as well as open standards on workflows and data-formats, common regulations, shared-novel software for multi-messenger & multi-probe data. Here, the community can use and test the software;
- **A forum for software development and cross-ESFRIs fertilization:** forums and schools for both developers and user communities, with a strong user-support, to enhance the software quality and usage, that allow ESFRIs to increase their user-base;
- **Built by the community:** on the agreed definitions of software metadata, software, developments, software training and schools, with valuable set of standards which can be used as guidelines by the ESFRIs;
- **Software as “first class citizen”:** by fostering software interoperability, re-use and cross-fertilisation between ESFRIs through FAIR principles to enable open science, thanks to a community-based and inclusive approach.

## Considerations for the Future

- **Keep doing technical developments:** extend further the metadata scheme, support the integration with an analysis platform and VRE in EOSC Future, expand the eOSSR library with advanced search and additional development platforms and archives;
- **Enlarge the usage scope:** service to become part of the EOSC Exchange Layer and strive the engagement with HORIZON-INFRA-2023-EOSC-01-02 "Development of community-based approaches for ensuring and improving the quality of scientific software and code";
- **Keep sustaining ESCAPE OSSR:** continue the cross-fertilisation and cooperation in software development, as well as collecting and preserving all software and services generated in ESCAPE.

## Speakers

## Session Chair



**Jutta Schnabel**  
Friedrich-Alexander  
University Erlangen-  
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**Kay Graf**  
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**Matthias Fießling**  
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 **ctao** CHERENKOV  
TELESCOPE  
ARRAY the observatory for  
ground-based gamma-ray astronomy



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# ESCAPE VO - A European Virtual Observatory

The ESCAPE Virtual Observatory (VO) was dedicated to present how this ESCAPE tool has been supporting ESFRIs by allowing cross-border and multidisciplinary research, as well as by ensuring that the needs of the ESFRI projects are taken into consideration in the development of VO standards.

## Main Takeaways

- **Integration of astronomy data into the EOSC using VO interoperability:** Using the VO registry and the experience of EUDAT/B2FIND, VO services are integrated to the EOSC;
- **Implementation of FAIR principles for ESFRI data:** Through implementation of VO standards and protocols for publishing data, ESFRIs have built new data publishing services, or extended existing ones;
- **ESFRI and RI priorities represented at IVOA level:** ESFRIs have become actors in the development of standards of interoperability. ESFRIs as data publishers have built capacity to use existing standards. The impact is shown by the establishment of the IVOA Radio Astronomy Interest Group, but also by development of new standards for: data provenance, accessing tabular data, spatial-temporal-sky coverage as well as updates of data models;
- **Community Training events for scientists and data providers:** Two schools for "Science with interoperable data" were organized to raise awareness in the scientific community on how to use FAIR data. Also, at the "ESCAPE European Data Provider Forum and training event" fostered best data stewardship practices and technologies;
- **Adding value to trusted content in astronomy archives:** Jointly with the OSSR, Deep Learning methods were applied in the context of ESFRI data archives, demonstrating the potential for value-added archive services.

## Speakers

### Session Chair



**Mark Allen**  
Strasbourg  
Astronomical  
Data Centre



**François Bonnarel**  
Strasbourg  
Astronomical  
Data Center



**Martino Romaniello**  
ESO's & Chair  
of ESCAPE General  
Assembly



**Véronique Delouile**  
Royal Observatory  
of Belgium



**Giuseppe Greco**  
INFN - Perugia



**Mark Kettenis**  
JIVE



## Considerations for the Future

- **EOSC integration:** Integrate ESCAPE VO astronomy data and services into the 'enhanced EOSC Resource Catalogue', and the IVOA standards into the EOSC Interoperability Framework;
- **Wider integration into ESFRI/RI and community services:** ESCAPE enabled the ESFRI/RIs to become actors in building international standards. It is essential that the framework continues to evolve in response to new instruments and new science cases, and that the whole community is engaged in this endeavour;
- **Integration in platform and virtual research environments:** Future instruments will raise the astronomical data volume well above the current capacities. This challenge is addressed by the development of science platforms and virtual research environments. VO standards will play a role in the interoperability of science platforms, and will require future development and innovations that build on the ESCAPE achievements;
- **Training:** To make the most of the data, scientists need to be trained in FAIR concepts and techniques. At the same time, best data stewardship practices need to evolve and be taught to data providers. With the expertise from the ESCAPE project, the partners are well prepared to lead such initiatives;
- **European Collaboration:** ESCAPE has emphasised the importance and impact of collaboration at the European level. Bringing together scientists, data providers, and developers to work together to create a FAIR research data environment through projects like ESCAPE is recognized by the international community, and European actors represent a driving force of interoperability in astronomical research data.



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# ESCAPE ESAP - Common standards to access and use data with a science platform toolkit

Science platforms are central hubs where users can access and analyse data, collaborate with their colleagues, and publish their results. The ESCAPE ESAP (ESFRI Science Analysis Platform) session provided an overview of how ESCAPE ESAP system and various services, data products, and tools from across the ESCAPE project have been integrated into it.

## Main Takeaways

- **A single toolkit to provide access to a range of powerful data analysis capabilities:** ESCAPE ESAP makes it easy for ESFRIs and other data and service providers to integrate a diverse range of capabilities — data products, software tools, and workflows — and present them to their user community as a unified whole;
- **Simple to use, avoiding technical complexity:** ESAP is designed to be easy for users to get to grips with, and also for projects and RIs to set up and use. It provides a user-friendly interface to a range of capabilities;
- **Maximum versatility:** building blocks tailored to specific purposes, complemented with plugins, to allow service providers to expand ESCAPE ESAP to provide better alignment with the specific needs of their user community;
- **Cross-collaboration:** ESCAPE ESAP is designed to enable users to combine data and workflows from different institutions, research infrastructures, and projects, thereby fostering collaborative and open science;
- **Reproducible results:** ESCAPE ESAP is designed to facilitate reproducibility and open science;
- **Capitalising on existing technologies:** ESCAPE ESAP builds upon the rich open scientific software ecosystem, integrating existing technologies and services to provide the maximum benefit to researchers and impact to service providers;
- **Federated authentication through ESCAPE IAM:** users can login with their own credentials from their home institutions, without requiring a new login credentials.

## Considerations for the Future

- **Opportunities for further technical enhancement:** ESCAPE ESAP provides a powerful range of core functionality while — crucially — inviting further expansion and development. We envision improved support for provenance, PIDs, data sharing and collaborative workflows, and more;
- **Open-source approach:** We will build upon the work performed in ESCAPE to turn ESAP into a community-driven open source project with a nucleus of core developers — our aim is to make the project sustainable for the long term;
- **Further service integration:** ESAP's plugin-based design makes it possible to integrate and incorporate new services from ESFRIs and other providers as they become available;
- **Federated science platform network:** ESAP's innovative approach points the way towards future federated networks of science platforms building on open standards;
- **Focus on security and safety:** Modern scientific environments, providing access to valuable data and powerful computing capabilities, are a tempting target for malicious actors. We plan to harden and audit ESAP to make it robust and reliable in every possible environment.

## Speakers

### Session Chair



**John Swinbank**  
ASTRON

### ESFRIs



**Matthias Fueßling**  
CTAO



**James Collinson**  
SKAO



**Aard Keimpema**  
JIVE





# ESCAPE Citizen Science to enhance scientific research

Crowdsourced data analysis by volunteers, like citizen science, are key for the direct involvement of fellow citizens in the scientific discoveries. They are also critical for many science goals involving a wide range of data analysis problems that cannot easily be solved algorithmically. This session gave an overview on how ESCAPE CS (Citizen Science) has been helping ESFRIs in solving the deepest secrets of the universe.

## Main Takeaways

- **Greater access and more detailed interpretation of data:** ESCAPE CS increases science knowledge through better data mining, via crowdsourcing experiments, where machine learning has limitations;
- **New computational tools:** deciding autonomously when subjects are well characterised and when volunteer classification is needed to keep data classification reliable;
- **Harmonised suite of mass participation experiments:** for facilities in the ESCAPE remit, related ESFRIs and also beyond;
- **Powering people into science:** by giving everyone the opportunity to contribute meaningfully to scientific discovery, with built-in dialogue between participant volunteers and professional scientists. This improves scientific process transparency and allow real-time study of phenomena;
- **Machine learning and legacy resources:** recorded notebooks and documentary materials for setting up active learning frameworks to continuously train machine learning models using volunteer classifications;
- **Technical collaboration within ESCAPE suite:** data coming from ESCAPE DIOS can feed ESCAPE CS experiments via ESAP and ESCAPE has a suite of easy-to-use workflows to manage Zooniverse Citizen Science projects.

## Speakers

### Session Chair



**Stephen Serjeant**  
Open University

### ESFRIs



**Gwenhaél de Wasseige**  
KM3NeT



**Martin Hardcastle**  
University of Hertfordshire  
SKAO



**James Pearson**  
Open University  
LSST



**Hugh Dickinson**  
Open University  
LSST


## Considerations for the Future

- **Closer cooperation with EOSC:** increase ESCAPE CS integration with EOSC services, expand CS domains through EOSC, and create a CS task force within EOSC communities such as the EOSC Association;
- **Deeper technology integration:** develop VO tools for seamless exploration of astronomical data starting from within ESCAPE CS and out into the ESCAPE VO;
- **Domain-aware platforms:** connecting CS platforms with science platforms (e.g. ESCAPE ESAP), to facilitate multi/inter-disciplinary science, possibly with a dedicated CS ESAP instance;
- **Open Data Standards:** create registry of terminology, models/formats, reporting guidelines, data policies, and identifier schemas related to CS;
- **Improve CS synergies with EOSC machine/deep learning:** more multi-disciplinary worked examples of plug-and-play CS notebooks with embedded machine learning integration, to facilitate CS uptake throughout EOSC science domains.



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# ESCAPE Panel - The valuable return of investment of the H2020 ESCAPE project and the rationale for a long-term engagement of the astrophysics and particle physics community in the ERA

The panel brought together representatives of ESFRI projects and the European Commission, who jointly debated what has been the main value of ESCAPE experiences and what are the major expectations for the future work programme of the science clusters. The session also focused on how ESCAPE can play a role in the European Research Area (ERA) Actions, how the ESFRIs communities plan to keep working with ESCAPE in the future and which priorities and domains ESCAPE should focus in the future.

## Considerations for the Future

- **Collaboration by "Design" and not by "Opportunity"**: define joint-actions, find similar research values and combine research fields not limited to the scope of research infrastructures;
- **Expand partnerships by bringing new members to the group**: involve research community and members from industry, education, employment and social area, as well as other relevant stakeholders from Europe and beyond;
- **New way to do investments**: focus on technology infrastructures, research assessment, industrial policy and open science, to affect indirectly the RI work in a positive way;
- **Focus and expand the Landscape Analysis**: understand today's reality, list all existing disciplines and define joint actions depending on joint future goals. Focus on each domain area and find commonalities;
- **A journey towards one common legacy**: support specific different needs of distinct RIs while identifying joint needs (specially related to EOSC and other cross-cutting transversal elements) to answer similar questions, to bring economies of scale and achieve transversality and interdisciplinary;
- **Support the Digital Transition**: expand the scope of activities by going beyond EOSC through deep tech, data digitalisation, greening infrastructures, remote control, software and hardware innovation, to name a few;
- **New Innovation Ecosystems**: by supporting flagship areas and create Innovation Valleys in new areas (e.g semiconductors, hydrogen production) towards the creation of Europe of the future;
- **Transfer knowledge to today and future generations**: ensure the legacy from RIs of today are maintained and further upgraded in the next decades, by having structured training partnerships with;
- **Match organisations' expectations with the priorities of future Work Programs**: demonstrate the optimal combination of knowledge with an efficient management of workplans;
- **Build-up the work on successes**: exploit what the community already delivered, because science innovation is done when humans work together;
- **Do things differently**: create more regional centers to enable science and scale the volume of data managed/processed, through distributing processing and making data available into archives, so a wider number of users can access it.

## Speakers

### Session Chair



**Ian Bird**  
ESCAPE Technical Coordinator and LAPP

### Panellists



**Christophe Arviset**  
ESA and on behalf of E-EAB



**Antonio Chrysostomou**  
SKAO



**Paco Colomer**  
JIVE  
Joint Institute for VLBI ERIC



**Federico Ferrini**  
CTAO



**Apostolia Karamali**  
European Commission



**Martino Romaniello**  
ESO and Chair of ESCAPE General Assembly

- **More international shared standards**: continue joint work with IVOA to build up standards on interoperability, FAIR data and open science, that address different sciences and disciplines at once;
- **Create research competence centres and platforms**: develop sustainability plans for RIs for the long term, based on hybrid cooperation formats, without relying uniquely on public funds. These centres and platforms should be managed jointly by academia and industry, with secondary support from regional and European governance actions;
- **Better career path perspectives in Academia by combining European and Regional Actions**: higher salaries and better employment conditions for scientists to reduce leaky pipelines where trained researchers move from Academia to Industry due to higher salaries and better career perspectives which are not dependent on temporary research grants;
- **Expand the scope of career acknowledgements**: this needs to go beyond "Publications" and consider new ways to evaluate career, especially for engineers and domain scientists specialized on software/computing, whose time is focused on learning and applying new technologies. The ERA Research Assessment is being reformed towards this direction;
- **Create more value from data**: make data available to the world with the right format and algorithms, to generate spin-offs. Combine European initiatives with local initiatives.



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# The Virtual Research Environment (VRE) for ESCAPE Science Projects

The VRE is an ecosystem of tools and services developed under the ESCAPE project to serve the scientific needs of the community. Currently, the EOSC Future Science Projects are getting on-boarded and are making use of the platform to perform their science. This session went through the different elements of the VRE infrastructure, the new elements that are or will be added soon and the integration of the platform within EOSC.

## Speakers



Enrique Garcia  
LAPP & CERN



Elena Gazzarrini  
CERN



Alba Vendrell  
CERN

## Main Takeaways

- **A collaborative platform to fulfil the needs of EOSC Future Science Projects members:** The VRE is a collaborative online platform where researchers from the EOSC Future Science Projects (SPs) are able to develop and share end-to-end analysis and workflows, having access to all the digital content needed to produce a scientific result, in compliance with FAIR principles;
- **One single platform for multiple needs:** a single platform where users can perform analyse, preserve, (re)run and share data, with easy access to multiple services and tools;
- **A user-friendly interface to connect to storage and computing services:** The VRE is composed of a data lake infrastructure, taking care of all the data management. It has a user interface, allowing the user to easily connect with all the storage sites of the data lake, as well as a computing site, allowing users to send jobs to external applications;
- **An analysis platform of data from multiple sources:** The objective of the VRE is to build an analysis platform with data from the different ESCAPE experiments, managed by storage sites, and from the platform, analyze and combine and compare results;
- **Secure data storage:** supporting all types of data, while ensuring its security, quality and access, where data transfer and access is done with gridFTP, HTTP(S) and xroot protocols;

- **Data Lake as a service:** hiding the complexity, so scientists can easily browse data, with a computing environment software pre-installed which is connected to heterogenous cloud, high performance computing and other resources;
- **Easy to interpret results:** by combining results from different experiments, as well as comparing results with other searches.

## Considerations for the Future

- **Connecting the VRE with different EOSC resources:** The VRE has already been connected with some resources provided by EOSC with Cloud storage, and Reana installation;
- **Disseminating expertise:** Many other teams are trying to achieve platforms like the VRE. It would be useful for the whole community to share the knowledge and expertise gained from the project;
- **Add specific community software:** as a future development of the VRE, allowing as well the deployment and the operation of the platform to any kind of open science projects.



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# The Dark Matter Science Project

Very little is known about the nature of dark matter, but data from astrophysics, nuclear and particle physics research infrastructures, combined with theoretical models and interpretations, would help shed new light. The Dark Matter Science Project (SP), from EOSC Future, is further understanding the nature of dark matter by performing new analyses within the research infrastructures involved. It is enhancing the researchers' participation in the EOSC to uptake the added value of open science and FAIRness of data. All the digital objects within the Dark Matter are being implemented within the ESCAPE and EOSC Future. This session focused on this topic.

## Main Takeaways

- **Providing tools to maximise science outputs:** The Dark Matter SP provides the community with tools to: create new analyses, datasets and results; combine multiple results studying the same question, reinterpret existing studies for new questions. It allows access to data and software on the EOSC through ESCAPE infrastructure;
- **Towards a joint discovery of the nature of dark matter:** A joint discovery of the nature of dark matter requires different experiments and inputs (indirect detection, direct detection and collider searches). It requires interoperable and reproducible analyses. The Dark Matter SP built a prototype that fulfills these requirements;
- **Dissemination activities have been done:** the Dark Matter SP has achieved many dissemination activities in order to share their results and achievements;
- **Collaborative research:** comparing and combining results from different experiments, while providing other communities with the necessary understanding to reproduce the analysis. It is crucial to strengthen the cooperation and sharing experiences across science projects;
- **A prototype cell for EOSC:** by integrating the different infrastructure components of ESCAPE and providing a testing ground for software & computing that can be explored by future experiments.

## Speakers

### Session Chairs – SP Coordinators



**Caterina Doglioni**  
Lund University  
and University of  
Manchester



**Francesca Calore**  
LAPTh



**Lukas Heinrich**  
Technical University  
Munich

### Speakers



**Jared Little**  
LAPP



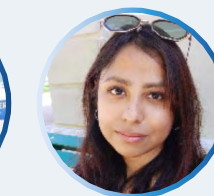
**Valerio Ippolito**  
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**Axel Gallen and Alex Ekman**  
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**Pooja Bhattacharjee**  
LAPP & LAPTh



**Christopher Eckner**  
LAPP

## Considerations for the Future

- **Defining the computing resources needed for future discoveries:** With the Dark Matter SP within the EOSC, one aim is to work with the scientific software communities to pave the way to defining the computing resources and analysis needed for future discoveries;
- **Onboarding new challenging analyses:** New analyses require very large amounts of data and more complex workflows. There is a need to stress-test the VRE and EOSC cell and use new resources;
- **Guarantee restricted data access:** Data should be protected until embargos are lifted. The Dark Matter SP will use the EOSC core authentication;
- **Widening the participation of scientists:** with dissemination and training, the aim is to involve more scientists into Open Science tools;
- **Make easier to recognise of software work:** since software may be the research output itself, it is important to find a proper way to credit software curators;
- **Consolidation work on EOSC for lasting infrastructure:** by integration services into EOSC core.



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# The Extreme Universe Science Project

The new frontier of astrophysics is to transcend light via so-called multi-messenger astronomy, capable to answer questions about "extreme matter" and help better understand how particles behave in spacetime. ESCAPE is supporting the Extreme Universe SP, from EOSC Future, in its frontier in science through its data services and potentially introducing new paradigms for data analysis. This session demonstrated how ESCAPE is implementing an integrated platform for Multi-Messenger Astronomy where data from different wavelengths/messengers can be easily gathered, analyzed and modelled holistically, and not remain fragmented as at present.

## Main Takeaways

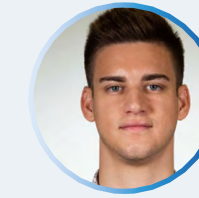
- **Opening windows to new perspectives:** scientists working in Gravitational Waves astronomy and multi-messenger astronomy can take advantage of the tools and infrastructures developed inside ESCAPE, as well as build innovative innovations from these tools;
- **Innovative multi-messenger observations:** providing key insights from data collected from new observations of energetic events, thanks to the collection of new data formats that may have impact in future science discoveries;
- **Setting the collaboration in data sharing:** the Extreme Universe science project consists of different pilot projects of distinct disciplines brought together, requiring that this collaboration needs to have a strong ground for future research activities;
- **Leveraging EOSC:** by removing barriers and exploiting complementarities across different communities, as well as building a transversal environment through artificial intelligence, new analysis methods and a cloud-based analysis dashboard, to allow users to exploit services from the e-infrastructures;
- **Functional e-infrastructures:** enabling research teams and individuals to perform complex analyses on large, complex, and potentially heterogenous data through compute facilities, data, and software platforms. For instance, the virtual research environment (VRE) allows to access data and perform compute on a cloud;

## Session Chairs - SP Coordinator



**Elena Cuoco**  
Scuola Normale Superiore  
& European Gravitational  
Observatory (EGO)

## Speakers



**Alberto Iess**  
Scuola Normale  
Superiore



**Alessandro Parisi**  
Scuola Normale  
Superiore



**Mikhail Smirnov**  
Friedrich-Alexander  
University



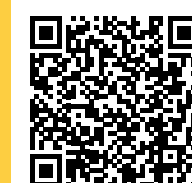
**Dany Vohl**  
University of  
Amsterdam

## Considerations for the Future

- **Science Project to be fully integrated in the VRE:** which will include the integration of the developed software into ESCAPE catalogue, as well as into EOSC Core and EOSC Exchange;
- **Documentation and tutorials to support user on-boarding procedures:** to ensure the sustainability of the work and help other scientists use the tools and venture themselves into new fields of science;
- **Work on the alert systems for low latency and real-time analysis:** by using cutting-edge technologies, without compromising the shareability the tools, so all these solutions and expertise can be shared with the community;
- **Training young scientists:** senior scientists need to teach the younger generations (e.g. master students) with the diverse skills of physics, computer science, data science, and infrastructure management;
- **Curriculum impact:** where young undergraduates students are being trained with these new approaches of doing research in science. Academia and networks of research schools can have a crucial role in innovation how things are done in the next years.



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# ESCAPE to the Future

The new Open Collaboration Agreement, publicly announced during this session, was signed by all the Directors of all the RIs partners and will take effect from January 2023. It will also help continue the synergies and joint work of all five domain-based Science Clusters involved in the implementation of EOSC. This agreement is expected to maintain the collaborative and human experience represented by the Science Cluster and strengthen the role and impact of astronomy and nuclear/particle physics in the field of open science and, more broadly, in the ERA. The agreement is also open to further research infrastructures to join.

## Speaker



**Giovanni Lamanna**  
ESCAPE Project  
Coordinator and  
Director of LAPP

## Main Takeaways

- **New ESCAPE Collaboration Agreement for Open Science:** Nine Research Infrastructures signed a new "Open Collaboration Agreement" to keep supporting Open Science, the implementation of the EOSC and the establishment of new sustainable cooperative schemes within Horizon Europe and the European Strategy for Data and Excellence Science;
- **Persisting with the mission of connecting the ESFRIs:** and keep the main focus of «Open data science strategy to rise excellence research and innovation» in EOSC and in the ERA program;
- **Opening up the ESCAPE work programme:** The collaboration will continue to work as a "domain-based" Science Cluster, while being open to new Research Instruments. National partner institutes and concerned scientific community are invited to join and support this effort, transforming this into a global effort;
- **Open Data and Open Research approaches:** to change the research paradigm and create new challenging opportunities, enabling new expectations, defining new commitments, establish new cooperations and promote inclusiveness of different stakeholder profiles;
- **Two pillars approach to support EOSC and Horizon Europe:** Developing inter-cluster common data services (through the ESCAPE services and approach such, as the VRE, and develop cross-cluster services) and Delivering content to EOSC (manage open call for disciplinary and multi-disciplinary science projects as well as sustain composable EOSC-onboarded services);
- **Taking further beyond ESCAPE legacy:** by continuing and improving the VRE services and the development of 4 new programmes and 2 new instances aiming at strengthening Research Infrastructures and their role in the European Research Area:
  - COSO: Challenging "Open Science Objectives" by RI commitments in Open Science Projects (OSP) as well as Cross-Cluster Open Science Projects (COSP);
  - SDSS: Building synergies on "Sector Data Spaces" for Society: Green deal, Health, Manufacturing, Education and Skills;
  - TECH: Bring the FAIRness within technology, R&D and innovation projects as well as explore new "close-to-sensors" low-latency open-data science services;
  - CARS: Career development and rewarding for researcher committing in Open Science. Planning, tracking, and assessing scientific knowledge production;
  - Competence Centre: Operating the community-based "Competence Centre" for EOSC-alignment, train and support, extended outreach, financial model for services and networking with other SCL-CCs;
  - European Virtual Institute for Research Software: R&I for an "European Virtual Institute for Research Software" for advanced technologies

## The new ESCAPE Collaboration work programme



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[Listen to Giovanni Lamanna about the new ESCAPE Open Collaboration](#)



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# ESCAPE Panel Discussion - Science clusters and the EOSC Association: cooperation and new challenges

Representatives of the 5 Science Clusters, European Commission and EOSC Association Board were brought together to discuss how the Science Clusters and their RIs can ensure that their cross RI services and open science projects can be consolidated into EOSC, while having a significant role in ERA. Another important discussion was also related to how to have an efficient operational pan-European RI landscape and a collaboration with e-infrastructures in order to foster an implementation of Open Science more aligned to scientists' expectations.

## Considerations for the Future

- **Bringing communities together within EOSC:** the 5 science clusters have had a very important successful role to federate efforts and build cohesion among Research Infrastructures (RIs) for the benefit of the implementation of the EOSC concept and the uptake of open science practices by the research community. All types of participants should be able to find their role and use the services according to their needs;
- **Moving towards cross-disciplinary science and interoperability:** FAIRness of data and openness of science are aimed to facilitate cross border and cross disciplinary research. Data services and open practices developed in one science cluster or customized for one RI need to be extended or made available through cross-RI and/or cross-domain science projects. It is necessary to link the science cluster communities together to participate in the interoperability framework, that is one of the major objectives of EOSC;
- **Increase interoperability levels:** not just from the service level but also on technical, legal, semantic aspects, as well as on FAIR Digital Objects. All of these need to fit into the EOSC Interoperability framework. Future activities towards the consolidation of the synergy among the five science clusters are expected to support it;
- **Aligning the bottom-up approach and the strategic agenda:** collaboration with other infra-EOSC projects and EOSC governance is key to link the activities to the strategic agenda that has already been agreed;
- **Creating a new Open Science:** Open Science implies support FAIR data-intensive research, involve fellow citizens in the scientific research process and enhance scientists' commitment in socio-economic challenges. creating new ways to work together within and between communities. The science clusters are an excellent model to bring together different communities and organize them towards these goals;
- **An EOSC for cross border and cross disciplinary science:** based on data and services serving common interest, for science-driven workflows and giving equal opportunities to researchers, regardless the size of their research infrastructure, to make use of research facilities;
- **Consolidating and Sustaining EOSC:** by requiring interoperability for cross-domain science, as well as by collaboration with the organisations involved in the EOSC Governance (European Commission, EOSC Association and all member states). Consider in-kind funding to be complemented with co-funding model from member-states;
- **Reducing fragmentation by creating a Pan-European network:** to enable advanced data analysis practices and promote a wider access to excellence science. RIs can be distributed and bring together national facilities with different specialisations, allowing scientists to access, without leaving their home institutions, the RIs advanced facilities;
- **Harmonising data management and data stewardship systems:** by using standards to make these systems FAIR compliant and more interoperable, especially on the RI and architecture levels, so future VREs can be built to answer complex questions across sub and cross-domain borders;
- **Sharing experience, expertise and resources with new communities:** from other scientific domains, namely those that are less structured and less equipped. Crucial for the 5 science clusters to go beyond their communities, to embrace all science areas;
- **Building good software development services:** in order to face the challenge of mobilizing data from various sources and being able to use it, open software could be developed and shared for all the communities;
- **A Horizon Europe Programme to impact European programs:** by pushing the research communities towards the uptake of open science practices and the creation of data management plans.

## Speakers

### Session Chairs



**Giovanni Lamanna**  
ESCAPE Project  
Coordinator and  
Director of LAPP

### Panellists



**Niklas Blomberg**  
ELIXIR and EOSC-Life



**René Buch**  
EOSC Association



**Paco Colomer**  
ERIC Forum



**Ron Dekker**  
Technopolis Group Belgium  
and EOSC Future



**Franciska de Jong**  
CLARIN and SSHOC



**Jean-Francois Perrin**  
ESRF and PANOSC



**Andreas Petzold**  
Forschungszentrum  
Jülich and ENVRI-FAIR



**Michel Schouppe**  
European  
Commission



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# What ESCAPE to the Future delegates say about the conference

*"The possibility to network with people from different sectors was very useful! Gaining insight from different views is great!"*

*"I enjoyed the networking opportunities. They were awesome opportunities to discuss what was presented during the various sessions in a less formal context"*

*"I am inspired to contribute to future open science policies"*



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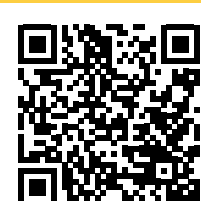
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Thank you for joining  
us from Giovanni  
Lamanna – ESCAPE  
Coordinator







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