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# DarkMachines: Accelerating the Search for Dark Matter with Machine Learning

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# Who We Are and What We Are After

A growing group of researchers studying dark matter from different angles

- astronomers, astrophysicists, HEP experimentalists and phenomenologists, computer scientists interested in DM

→ A highly multi-disciplinary group

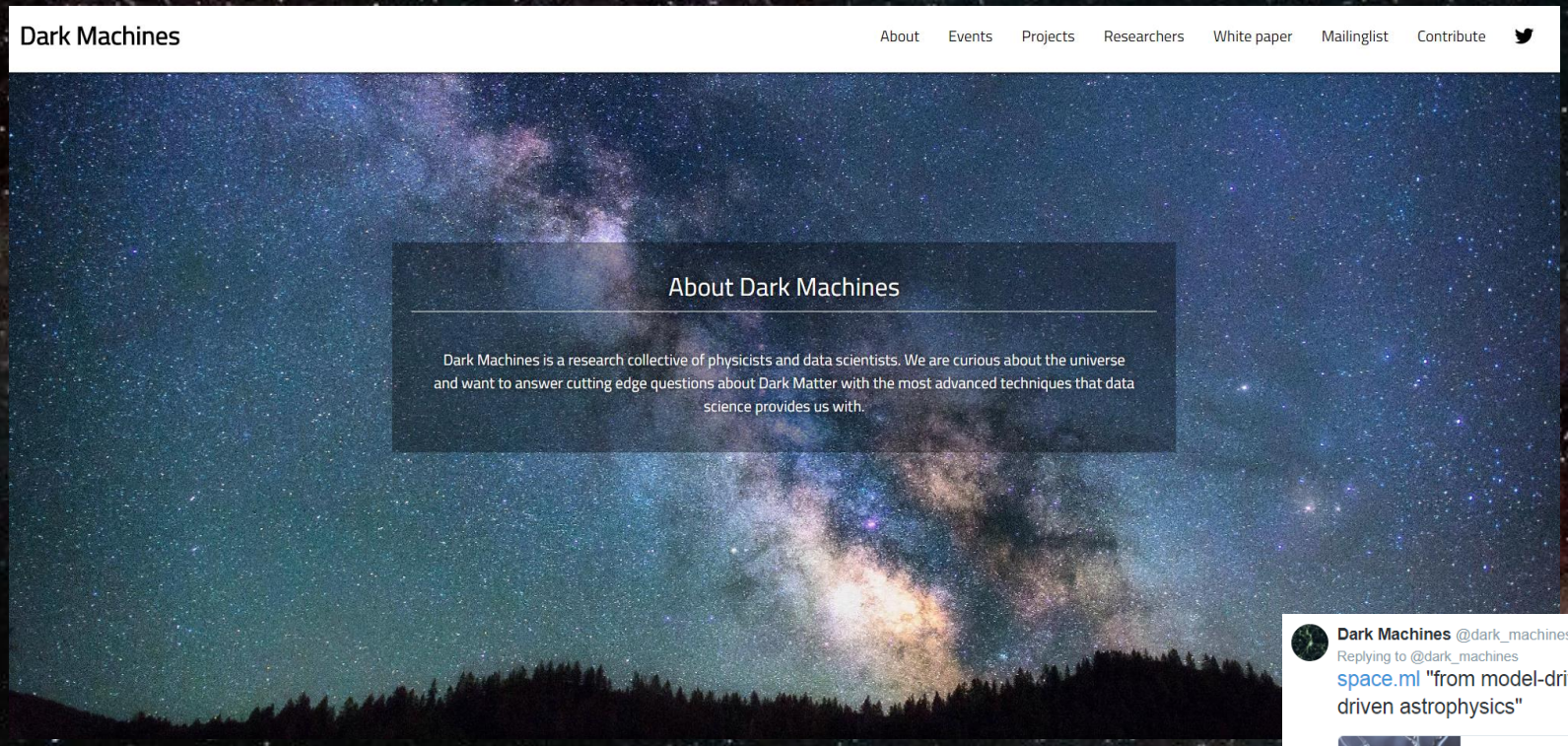
- Several dozen participants from over 40 institutions
  - Many ML experts, all ML enthusiasts
- Recently met in Leiden
  - laid down plan of investigation: how to **best exploit** the recent advances in ML for DM searches ?

# DARK MACHINES

Universiteit van Amsterdam, IFC Valencia, Fermi National Accelerator Laboratory, University of California Irvine, Istituto Nazionale di Fisica Nucleare, Université de Liège, Pennsylvania State University, University of Santa Cruz, Imperial College London, SISSA Trieste, Radboud Universiteit Nijmegen, University of Oregon, LAPTh Annecy, Astrophysics Research Institute, Universidad Complutense Madrid, University of Manchester, IAAT, Technion Haifa, Tecnhische University Wien, Tecnhische Universiteit Eindoven, IFCA Cantabria, Pontificia Universidad Catolica de Chile, CAC/UNG, Università di Torino, University of Adelaide, Università di Padova, NASA, University College London, New York University, INAF-OAR and ASI-SSDC, Grappa Institute, Deep Mind, Leiden University, Academia Sinica, National Center for Science and Research "Demokritos", Nikhef, NITheP, University of the Witwatersrand, IAAT, Astrophysics Research Institute, and many others...

# Web Site

http://www.darkmachines.org




Also follow us on twitter:

@dark_machines

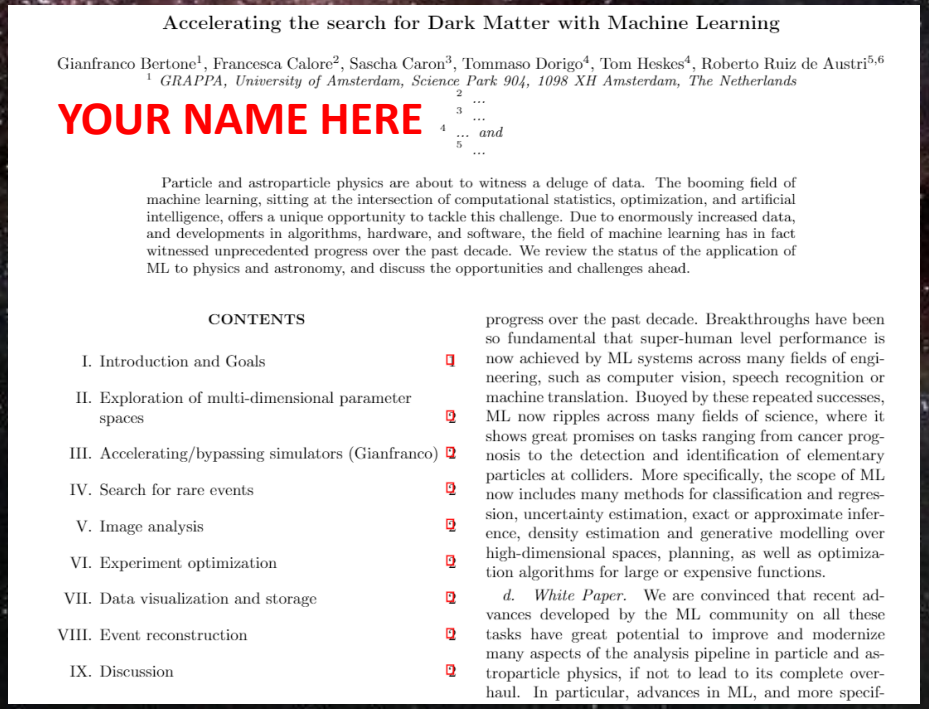
# Plan

- The initiative aims to cover a number of themes:
  - ML for Astronomical Data
  - Deep learning & Image Analysis
  - ML for Direct and Indirect Searches
  - LHC Searches for DM Particles
  - Semi- Supervised Learning Applications
  - Dark Matter Modeling
  - Active Learning & Experimental Design

We are writing a **white paper** to organise our attack to the largest current challenges in the search for dark matter and to nurture ideas on how they can profit from use of specialized ML tools
→ Open to contributions from you!

Several projects/challenges have been initiated (next slide)

We will organize periodic workshops to oversee progress and foster close-range discussions



Accelerating the search for Dark Matter with Machine Learning

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YOUR NAME HERE [2] ... [3] ... [4] ... and [5] ...

Particle and astroparticle physics are about to witness a deluge of data. The booming field of machine learning, sitting at the intersection of computational statistics, optimization, and artificial intelligence, offers a unique opportunity to tackle this challenge. Due to enormously increased data, and developments in algorithms, hardware, and software, the field of machine learning has in fact witnessed unprecedented progress over the past decade. We review the status of the application of ML to physics and astronomy, and discuss the opportunities and challenges ahead.

CONTENTS



progress over the past decade. Breakthroughs have been so fundamental that super-human level performance is now achieved by ML systems across many fields of engineering, such as computer vision, speech recognition or machine translation. Buoyed by these repeated successes, ML now ripples across many fields of science, where it shows great promises on tasks ranging from cancer prognosis to the detection and identification of elementary particles at colliders. More specifically, the scope of ML now includes many methods for classification and regression, uncertainty estimation, exact or approximate inference, density estimation and generative modelling over high-dimensional spaces, planning, as well as optimization algorithms for large or expensive functions.

*d. White Paper.* We are convinced that recent advances developed by the ML community on all these tasks have great potential to improve and modernize many aspects of the analysis pipeline in particle and astroparticle physics, if not to lead to its complete overhaul. In particular, advances in ML, and more specif-

# Challenges / Projects

- Particle tracking with ML
- Inclusive analysis of Fermi/LAT point sources
- Exploit full information on DM signals from multi-wavelength and multi-messenger observations
- Unsupervised learning for indirect detection
- Unsupervised learning for strong lensing analysis
- Use cases for GAN and measurement optimization
- Exploration of high-D parameter spaces
- Comparison of models with different parameter sets
- Supervised and unsupervised learning for collider searches of DM

Each of the above efforts will produce a publication in the time scale of several months/end of the year

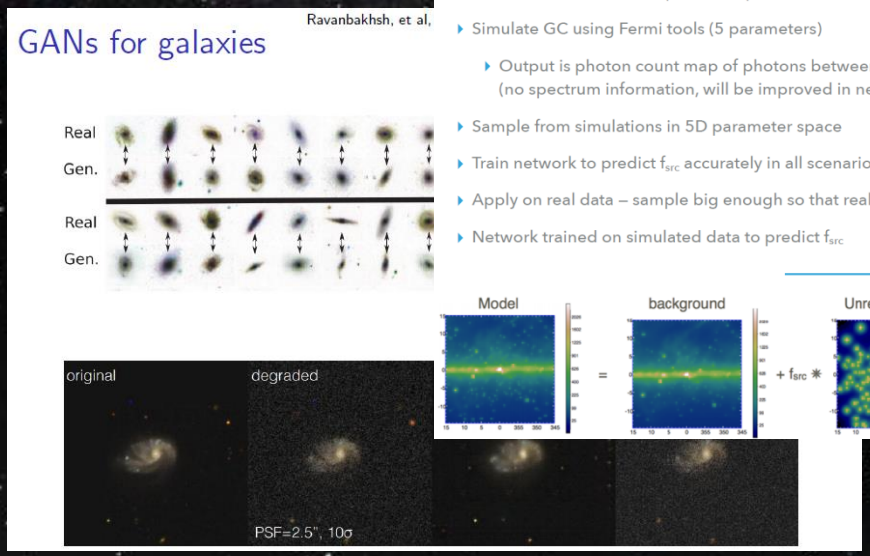
We are getting organized in working groups, with conveners and regular meetings

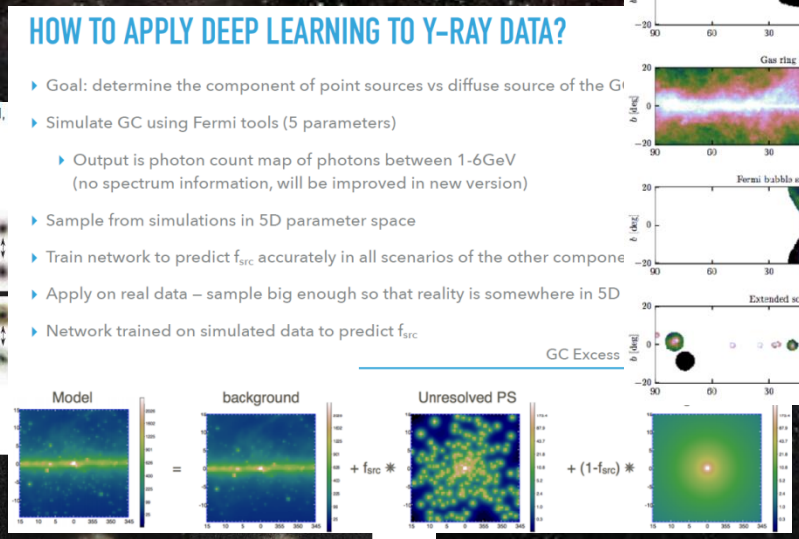
- A Slack group has been set up for participants, for fast exchange of ideas and material
- Mailing list: news@darkmachines.org
  → subscribe by visiting web site www.darkmachines.org

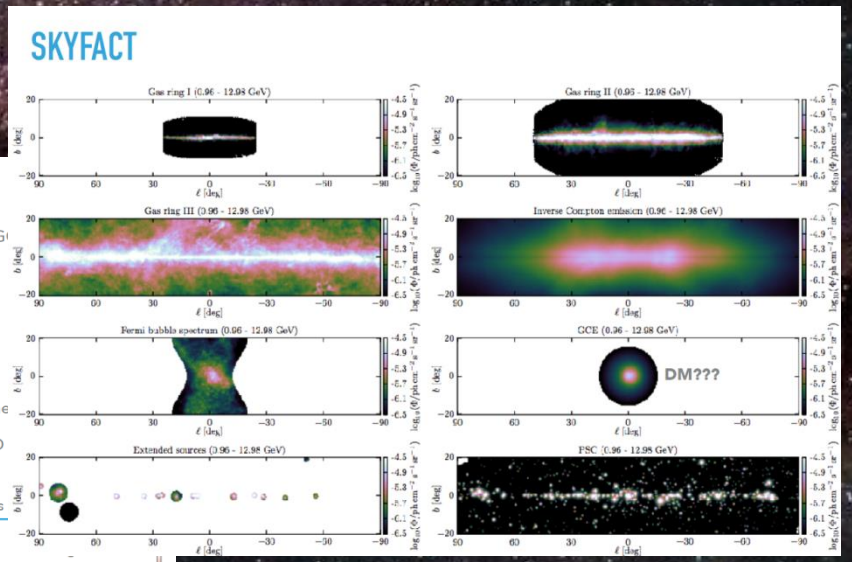
# Flashes from Leiden Workshop


Many interesting ideas and proposals arose during the workshop of last January - new ways to attack DM searches with ML tools

→ see indico page at https://indico.cern.ch/event/664842/



# Conclusions

- A pool of leading experts in DM searches and in the related physical/astronomical research has been organizing an effort to exploit the large available datasets to the fullest, using Machine Learning tools

- Join us and contribute if the following applies:
  - you have/want to build expertise in Machine Learning
  - you want to solve the DM puzzle
  - you have time to invest in a new collaborative effort