Multi-Messenger and Multi-Wavelength emission from Galaxy Clusters hosting AGNs

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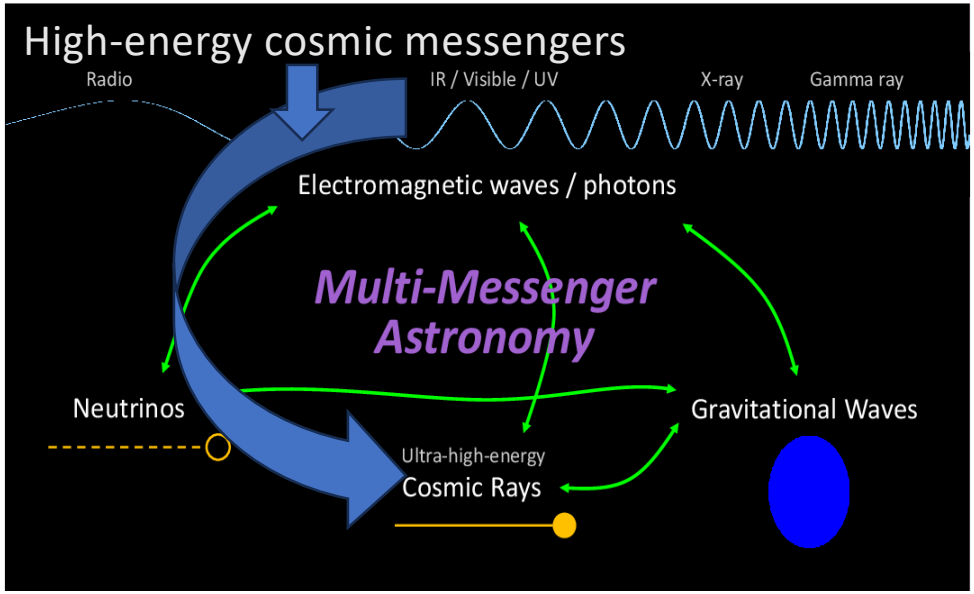
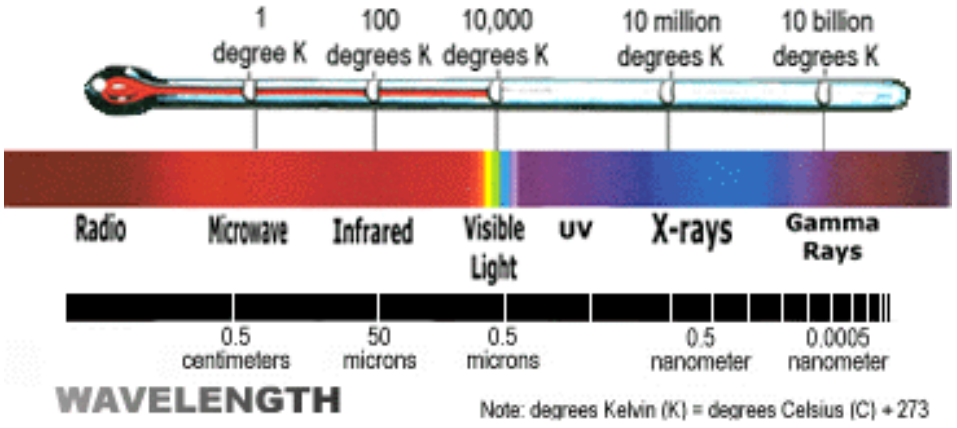
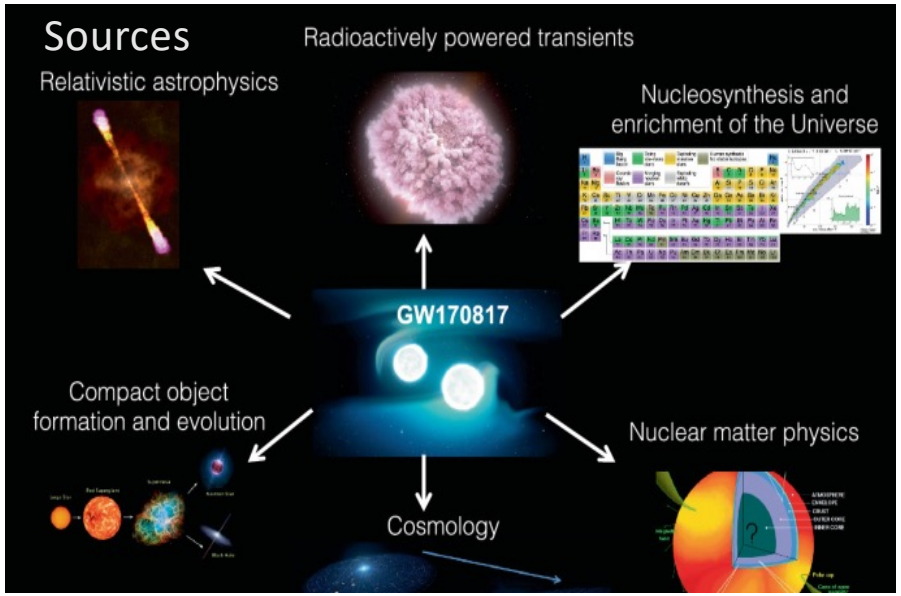
Introduction

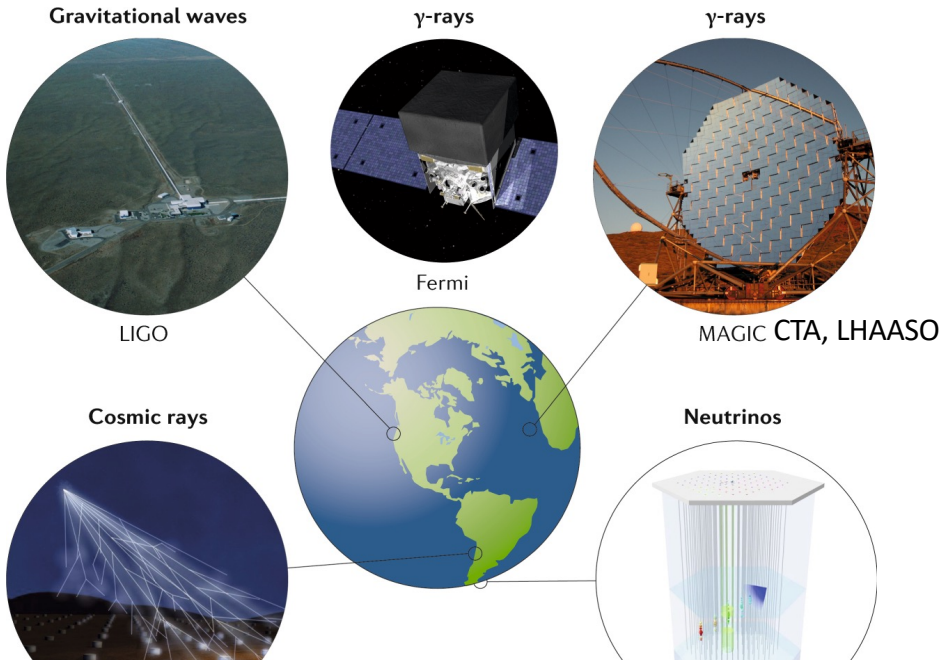
- Era of multi-messenger astronomy
- Sensitive experiments to observe
  MWL, gamma-rays, Neutrinos, CRs, and GW







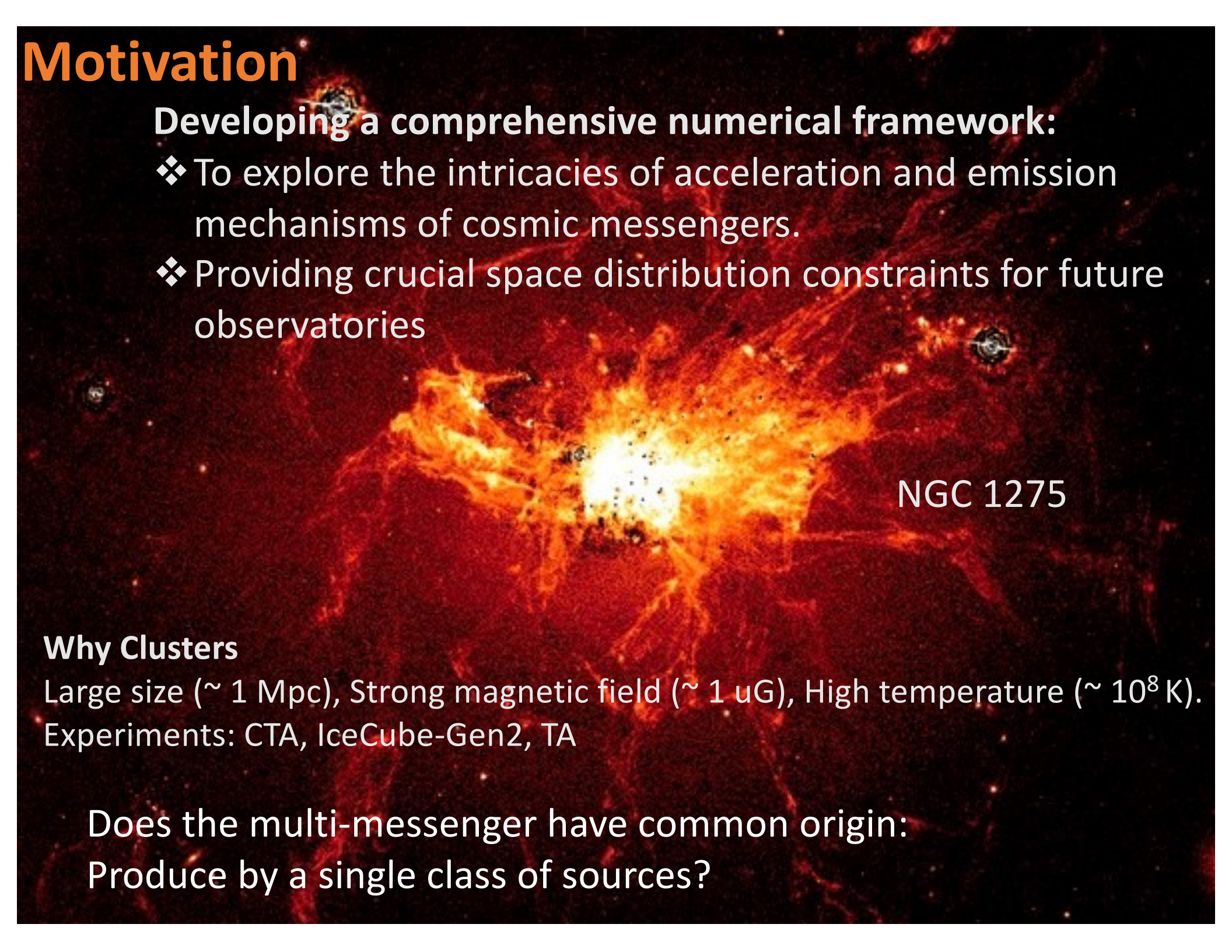
unprecedented sensitive observation facilities for multi-messengers



Motivation

Developing a comprehensive numerical framework:

- ❖ To explore the intricacies of acceleration and emission mechanisms of cosmic messengers.
- ❖ Providing crucial space distribution constraints for future observatories



NGC 1275

Why Clusters

Large size (~ 1 Mpc), Strong magnetic field (~ 1 uG), High temperature (~ 10^8 K).

Experiments: CTA, IceCube-Gen2, TA

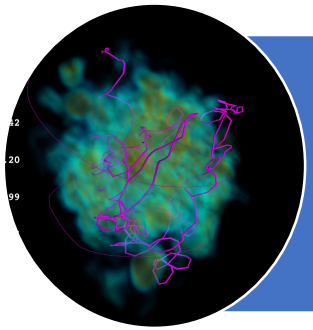
Does the multi-messenger have common origin:

Produce by a single class of sources?

Outline

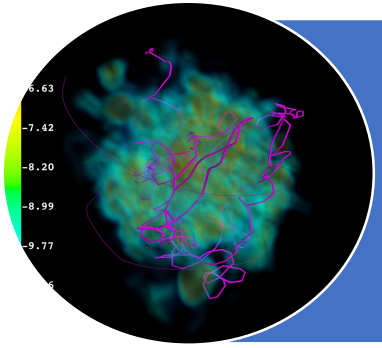
MHD Simulation to probe clusters across redshift

Implementing Machine Learning to speed-up the process



how cosmic-rays accelerated in clusters of galaxies?

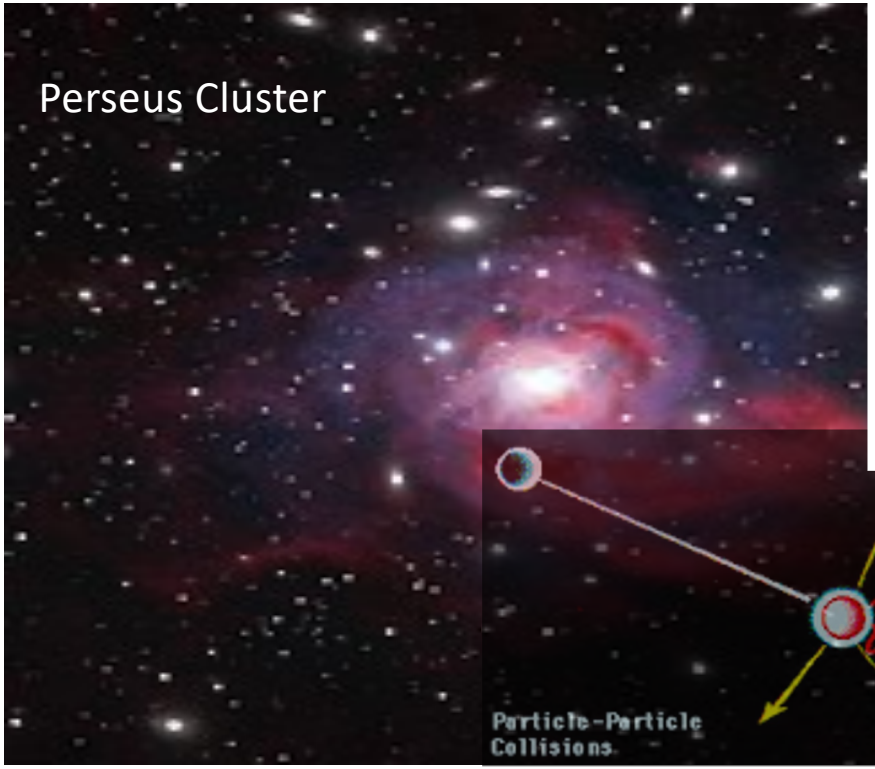
Gamma-rays and neutrinos production from Perseus cluster



Propagation and interactions of cosmic rays inside clusters

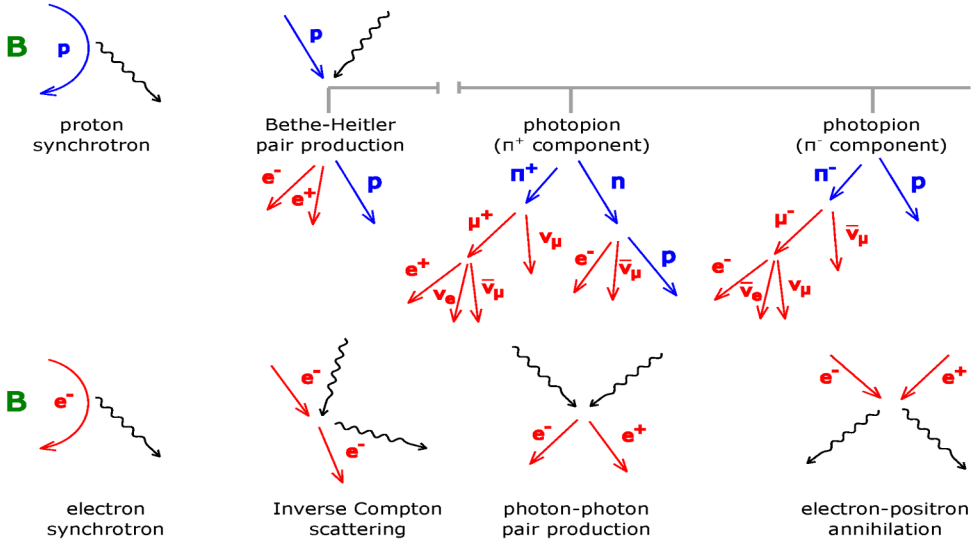
by combining MHD and Monte-Carlo simulations

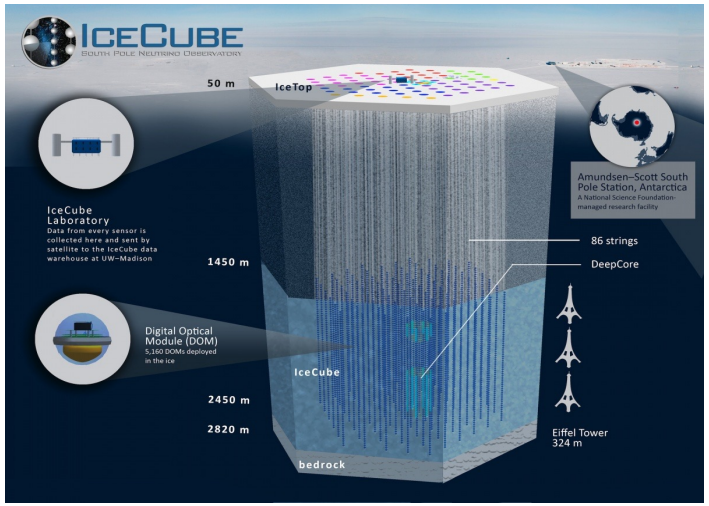
Methodology

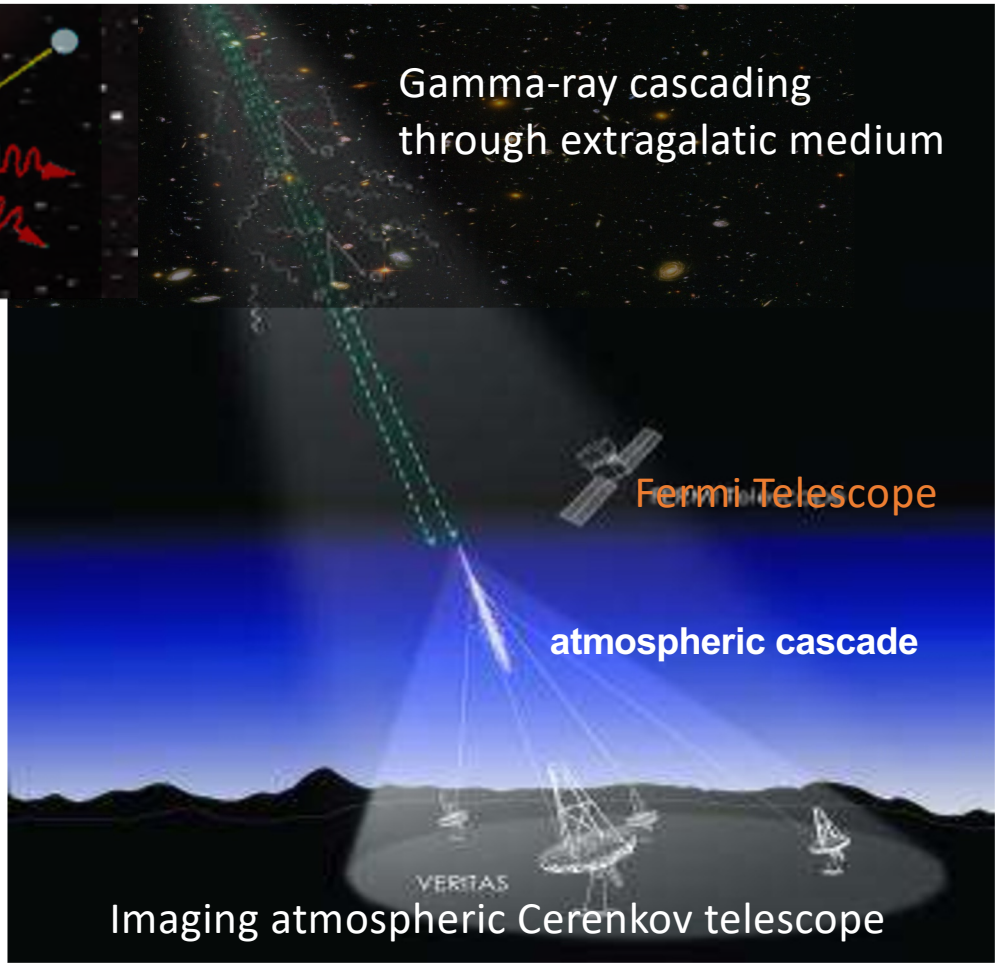


hadronic

leptonic

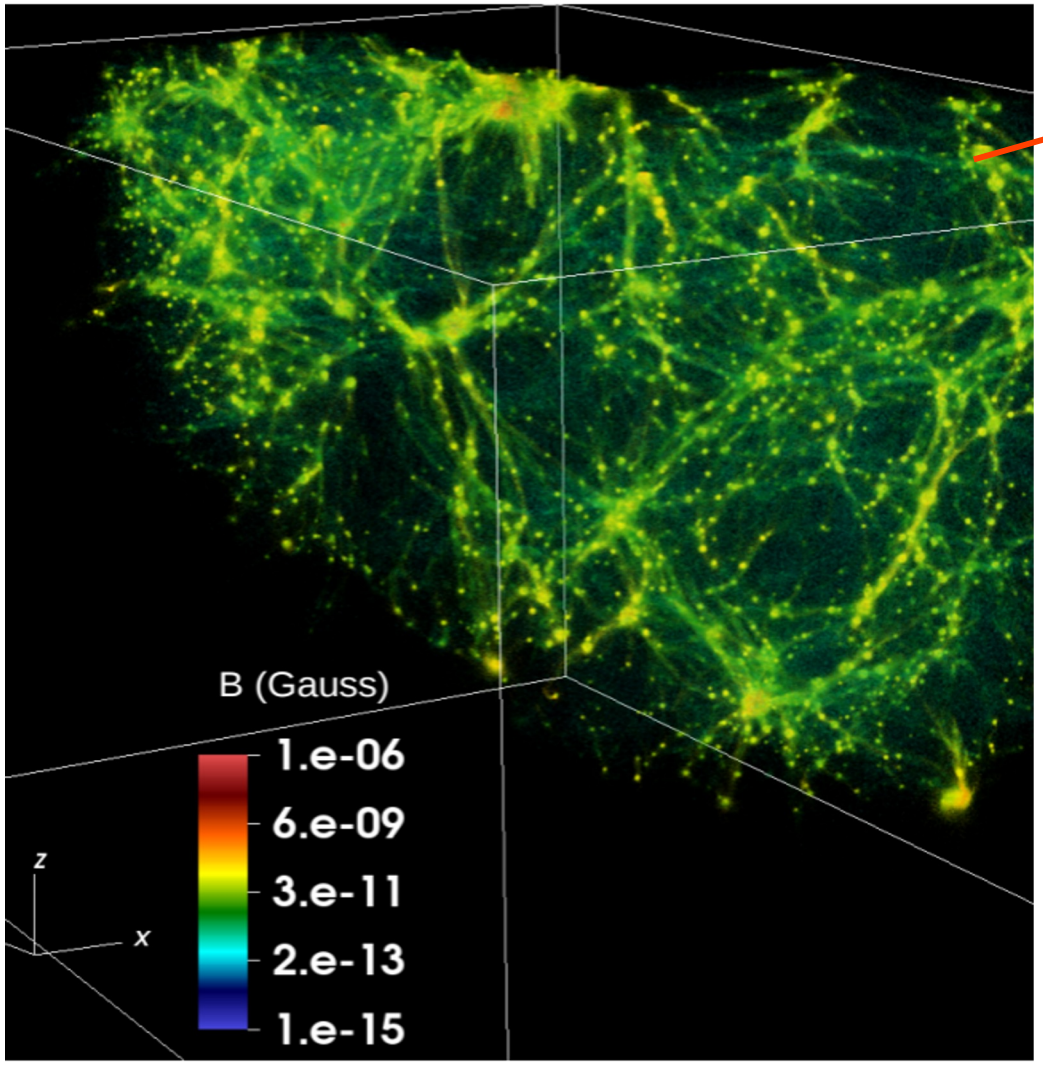


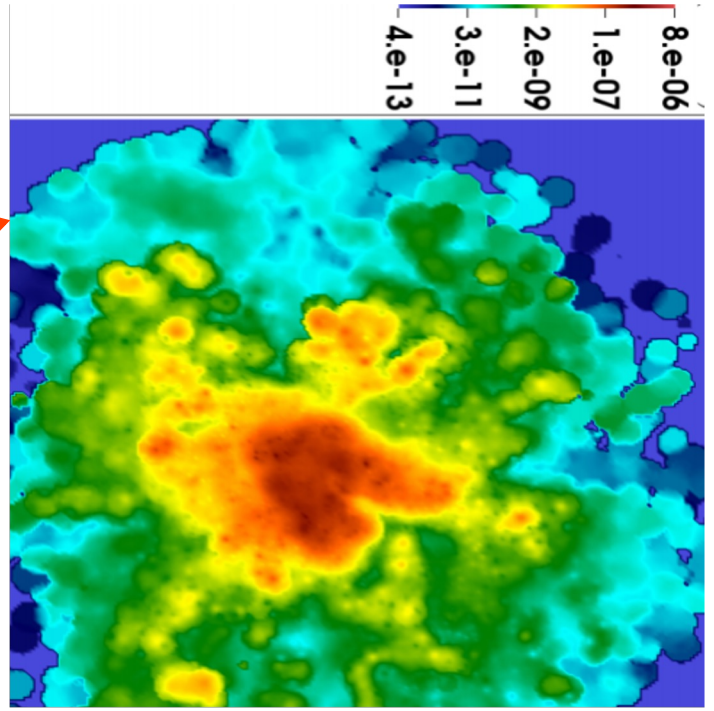




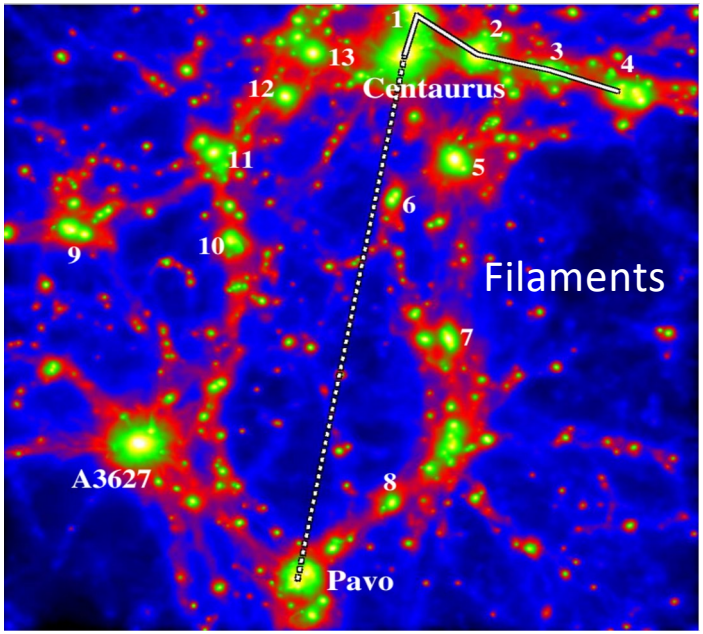
Multi messengers Emission and Observations

Cosmological 3D-MHD simulation



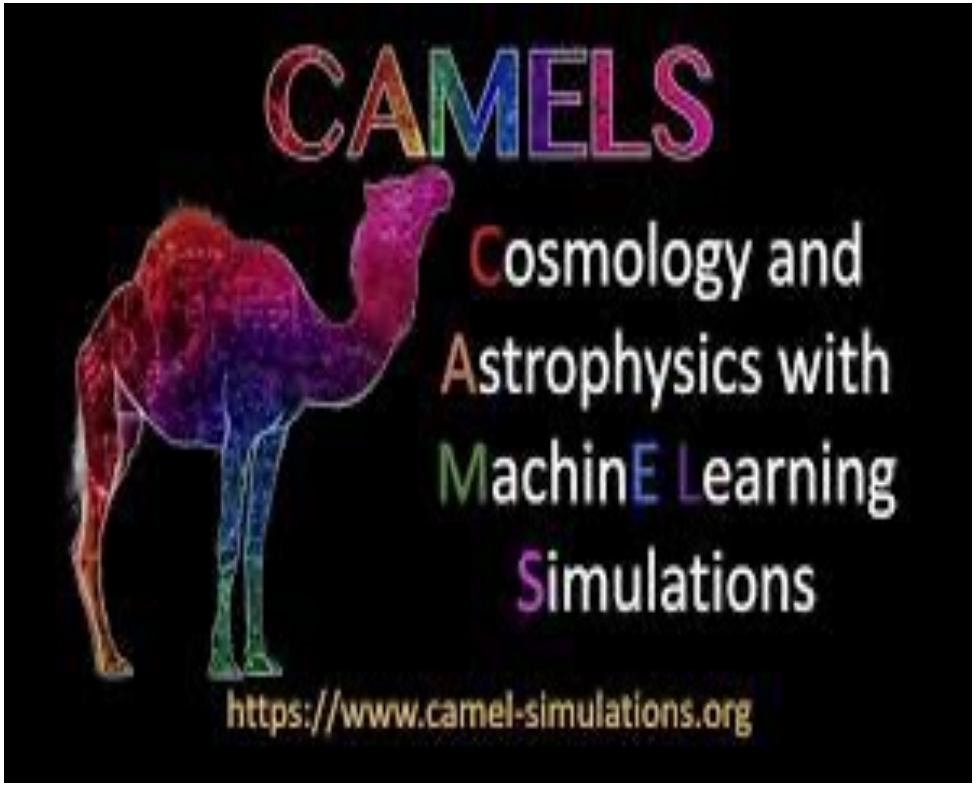


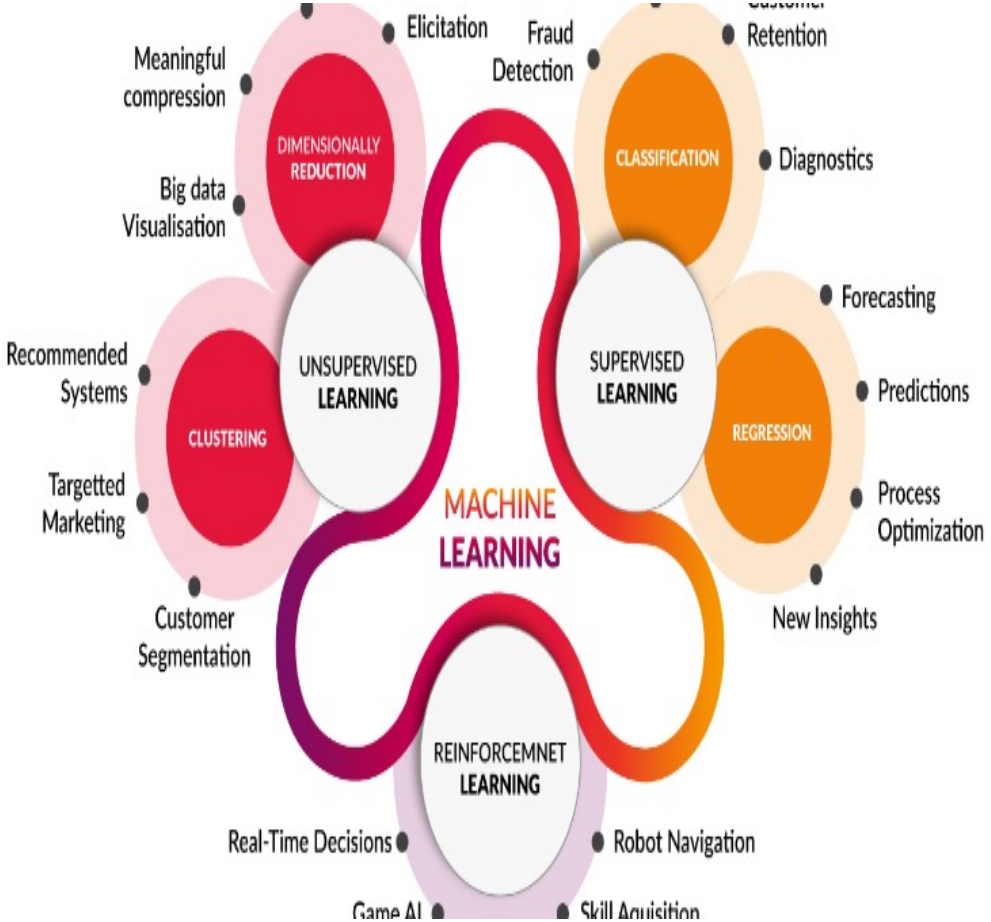
$M \sim 10^{14.5} M_{sun}$



SPH GADGET simulations (Springel 2005)
Large-scale structure, filaments, and clusters, $z < 5.0$
seed magnetic field ~ 10^{-12} [G], spatial resolution ~ 10 kpc

Machine Learning





- ML techniques: **clustering, classification, parameter estimation, non-linear interpolation, symbolic regression, and Anomaly Detection**
- Training neural networks to reduce computational time
- Using ML techniques is the trade-off between accuracy and speed-up

MHD simulations Combined with Monte Carlo simulations

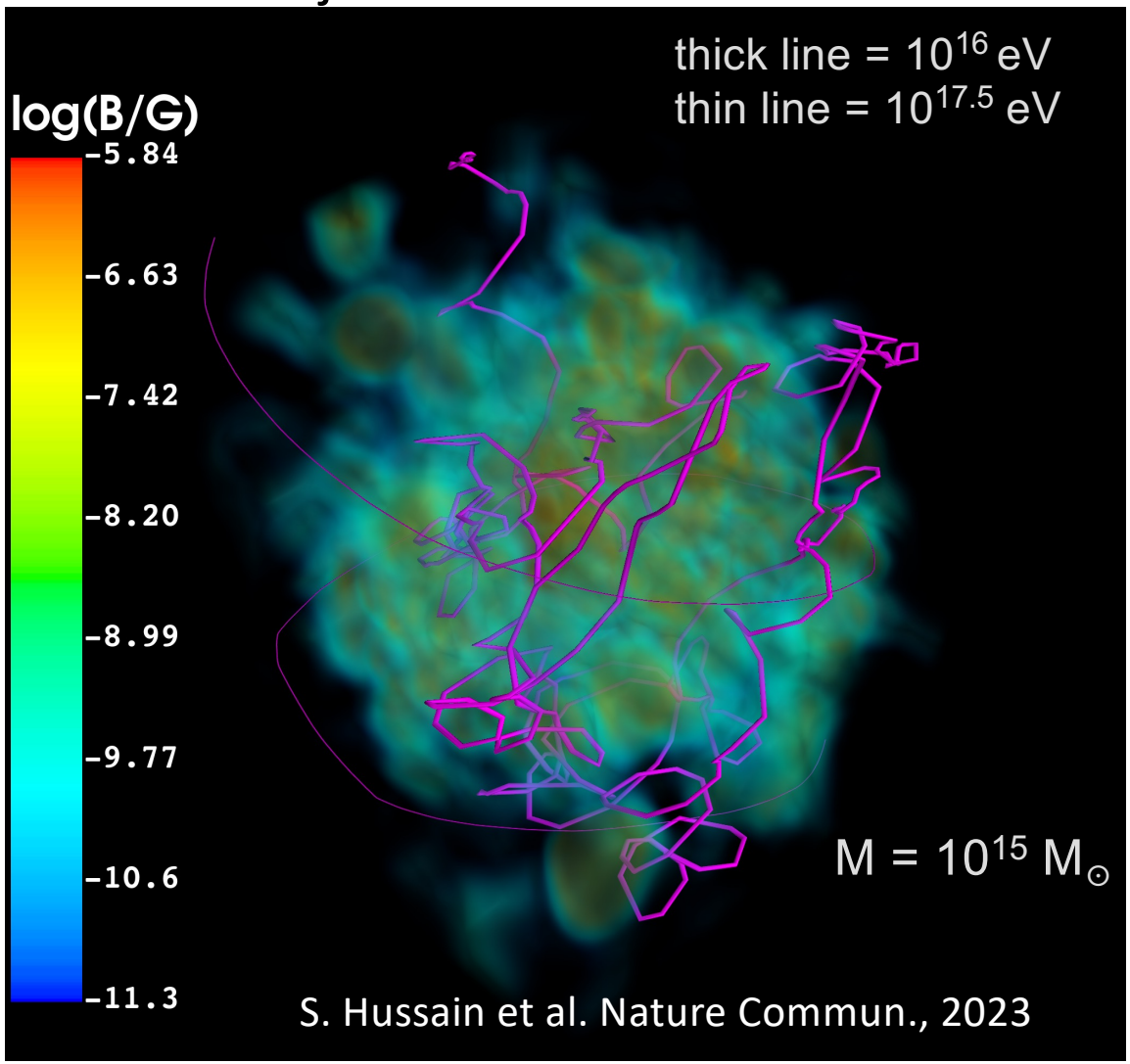
Background: Magnetic-field, Gas density, Bremsstrahlung, CMB, EBL, and Radio background

Cosmic Ray Propagation (Hadronic and leptonic)

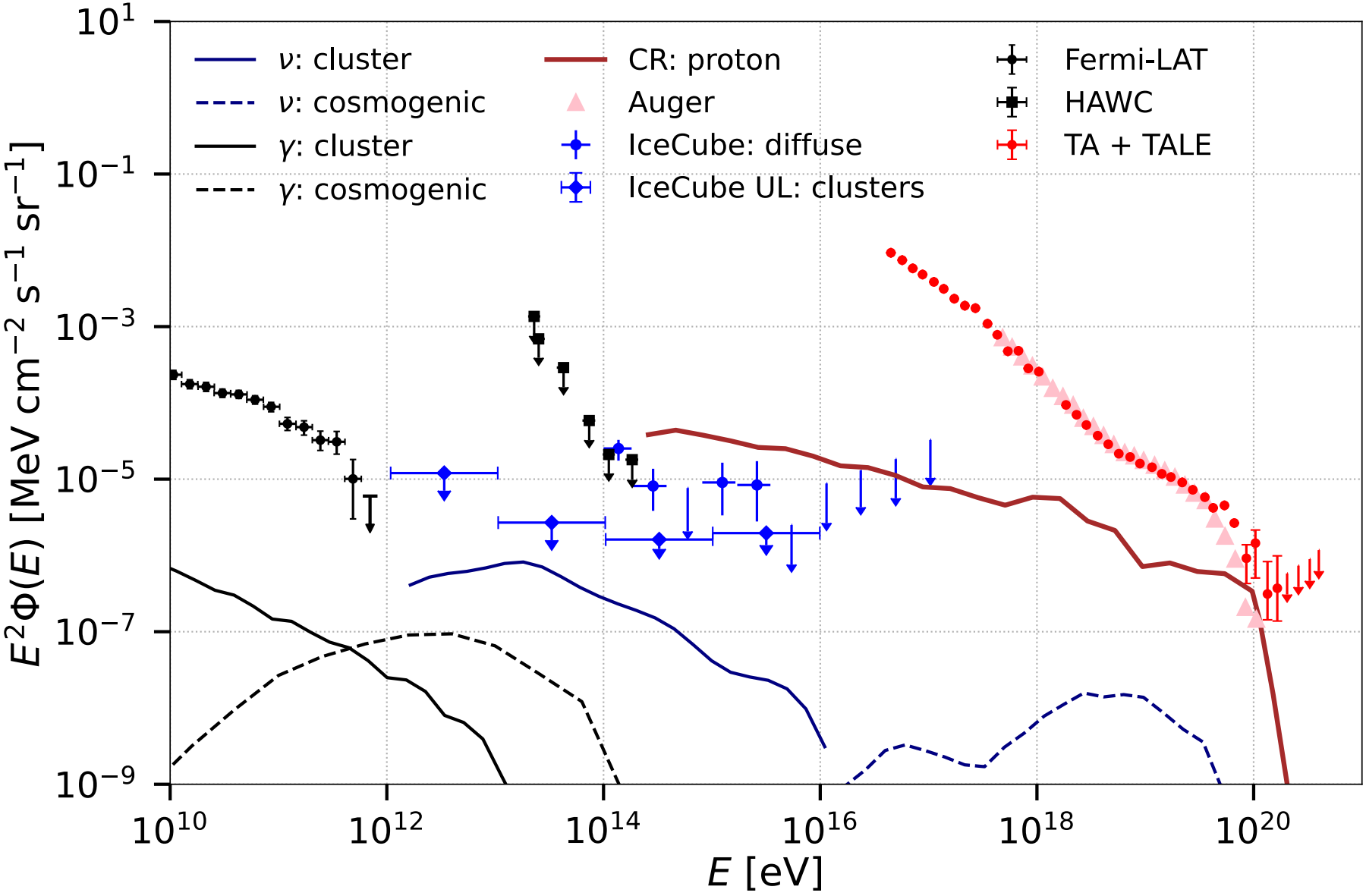
Low energy (<10^{17} eV) CRs: Diffusive

High Energy (> 10^{17} eV) CRs: Semi-diffusive or Ballistic

CR trajectories inside a Cluster



Multi-messenger picture of Perseus-like sources ~ 75 Mpc



Summary

- Potential to address pressing questions in the scientific field.
- Directly aligned with the current and upcoming astronomical experiments
- Attracting the attention of peers and the broad community.

SMASH

Exceptional research environment and scientific training programs offered by the SMASH are indispensable in ensuring the accomplishment of the proposed project.

Thanks