

Searching for the origin of ultra-high-energy cosmic rays

Luciana Andrade Dourado

Supervisor: Prof. Carmelo Evoli



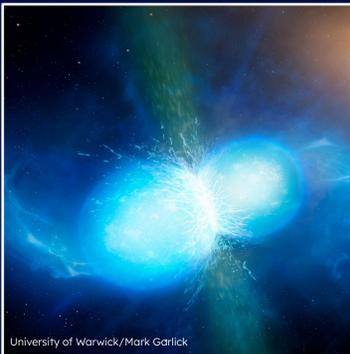
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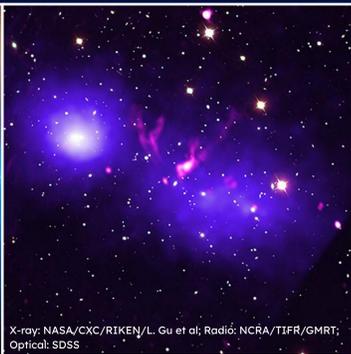
Istituto Nazionale di Fisica Nucleare

Several source candidates on the market

Binary neutron star mergers



Galaxy clusters



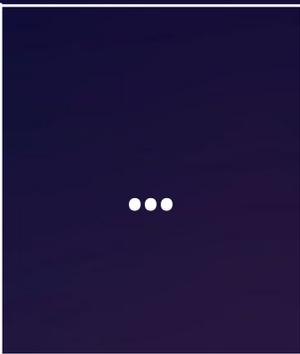
Gamma-ray bursts



Starburst galaxies



Ultra-fast outflows



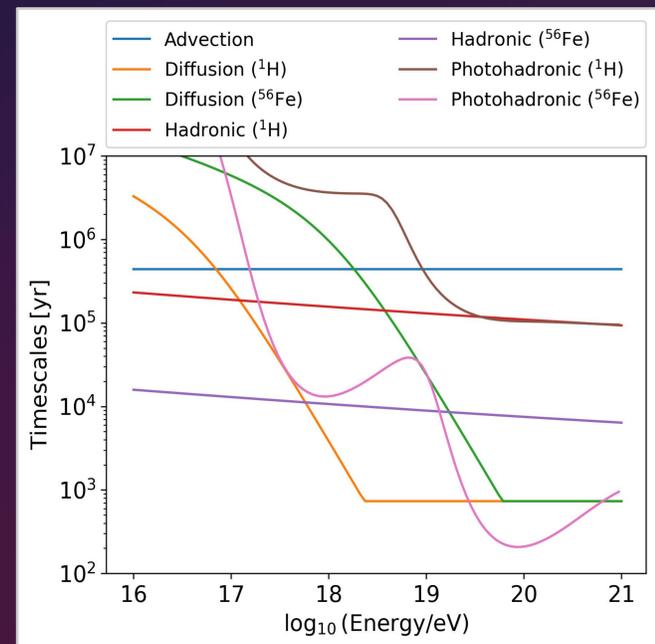
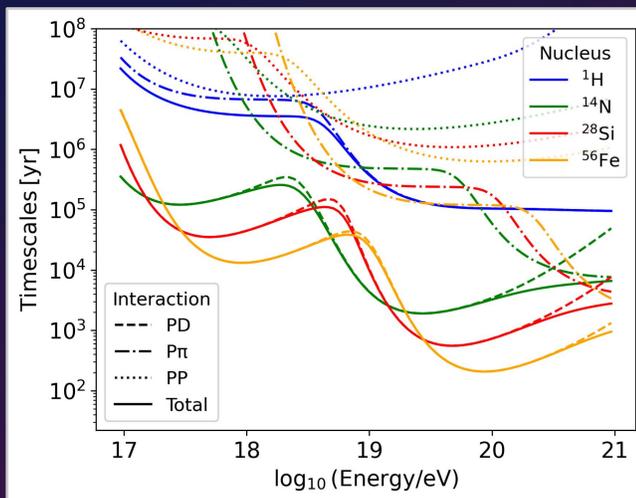
These are the environments I am studying in my PhD

How can we study the propagation of cosmic rays in these environments?

- Inferring their physical properties (e.g., magnetic fields, gas density, radiation fields) from multi-wavelength observations

- Comparing energy-loss and escape timescales to understand particle transport

- Obtaining the equilibrium and escape number densities of cosmic rays in the sources either **analytically** or **numerically**



Solving the cosmic-ray transport equation

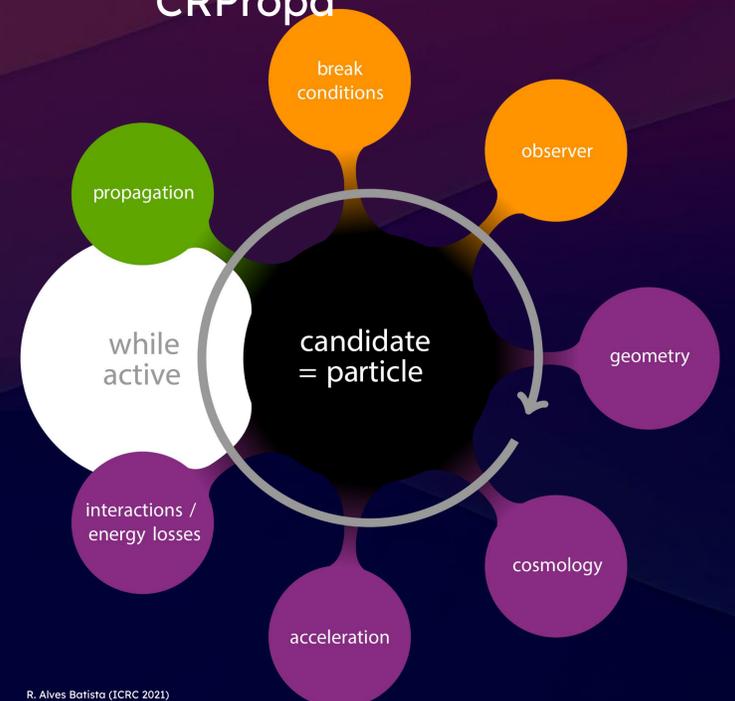
$$\frac{\partial N}{\partial t} = \nabla \cdot (D \nabla N) - \frac{\partial}{\partial E} (\dot{E} N) - \frac{N}{\tau_{esc}} + Q$$

Using Monte Carlo propagation codes, such as CRPropa

How can we evaluate the model results?

- The extragalactic propagation of particles can be treated analytically or numerically to obtain the energy spectrum and mass composition at Earth

- The resulting energy spectrum and mass composition can be compared with measurements from the Pierre Auger Observatory and the Telescope Array



R. Alves Batista (ICRC 2021)