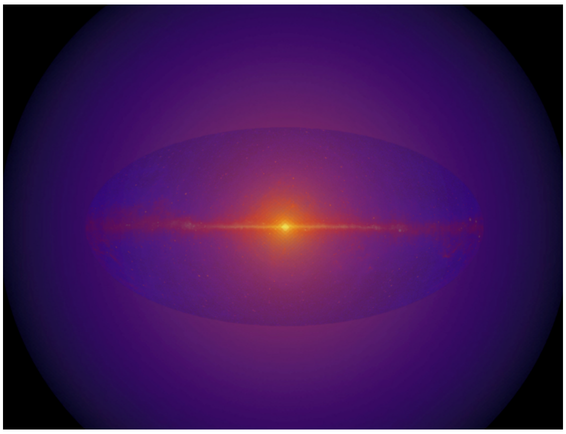
Hunting for dark matter with gamma rays



SUMMARY.

The nature of dark matter (DM) in the Universe is one of the greatest mysteries of our time, and its discovery is of utmost importance. While DM has not been directly detected in laboratories, its gravitational effects are evident at all astrophysical scales. Among the leading DM candidates, weakly interacting massive particles (WIMPs) are the most extensively studied. Indirect detection seeks to identify WIMP annihilation or decay products, such as gamma rays, neutrinos, or antimatter. In this project, the student will get an introductory yet complete view of state-of-the-art DM research in gamma rays. (S)he will i) compute predicted gamma-ray DM signals for a promising astrophysical source; ii) learn to download and analyze gamma-ray data collected by the NASA's Fermi satellite from that sky region; iii) search for DM signals in the Fermi data and, if absent, use it to constrain the DM particle's nature.

OBJECTIVES

- **Knowledge:** astroparticle physics; state-of-the-art DM research; theoretical modeling of astrophysical DM distributions; computation of DM-induced photon fluxes; γ-ray emission/absorption mechanisms in the Universe; γ-ray detection from space.
- **Skills:** Use of *CLUMPY* for DM modeling and DM-induced photon flux computations; retrieval and analysis of γ-ray data with *Fermipy*; standard likelihood data analyses for the search of DM signals; constraints on the DM parameter space if no signal.

INSTITUTE

- Instituto de Física Teórica (IFT UAM-CSIC) & Universidad Autónoma de Madrid (UAM).
- IFT URL & UAM URL.
- C/ Nicolás Cabrera 13-15, Campus Cantoblanco, Madrid, SPAIN.

THEORY

by Miguel Á. Sánchez-Conde

The student will review the DM problem, its observational evidence, and the most used recipes to model DM distributions. S(he) will get familiar with the WIMP as the preferred DM particle candidate and its expected standard model signatures, with emphasis in WIMP-induced γ-ray signals [1,2]. For the latter, the student will review γ-ray emission and absorption mechanisms in the Universe, and will get to know the NASA Fermi satellite, the most advanced γ-ray detector currently in operation (see figure below).

Illustration of the NASA Fermi satellite currently in orbit.

APPLICATIONS

by Miguel Á. Sánchez-Conde

The student will use the *CLUMPY* software to model the underlying DM distribution in a promising astrophysical source (to be chosen by the time of the project) and to compute its WIMP-induced γ-ray flux. With these predictions at hand, the *Fermipy* software will be used to analyze actual data collected by the NASA Fermi γ-ray satellite, and to search for DM signals from the source sky direction. Should no signal be detected, already available scripts will be utilized to set constraints on the nature of the DM particle using that information.

MAIN PROGRESSION STEPS

- Weeks 1-2: Lectures on astroparticle physics and DM.
- Weeks 3-4: Project - DM modeling and flux predictions (*CLUMPY*).
- Weeks 5-7: Project - *Fermipy* gamma-ray data analysis.
- Weeks 8-9: Project - Results' interpretation and DM constraints.

EVALUATION

- Theory grade [30%]
  - Oral exam (50%): basic questions on lectures' content.
  - Presentation of an article to the host group (50%): concepts digestion, critical spirit.
- Practice grade [30%]
  - Computing (30%): use of *CLUMPY* and *Fermipy*.
  - Project (70%): initiative, progress, interpretation.
- Defense grade [40%]
  - Oral and slides quality
  - Context
  - Project / Personal work
  - Answers to questions

BIBLIOGRAPHY & RESOURCES

(1) Bertone et al. 2005.
(2) Charles et al. 2016.
(3) Host group webpage.
(4) CLUMPY and Fermipy.

CONTACT

Miguel Á. Sánchez-Conde
☎ +34.912.999.867
✉ miguel.sanchezconde@uam.es