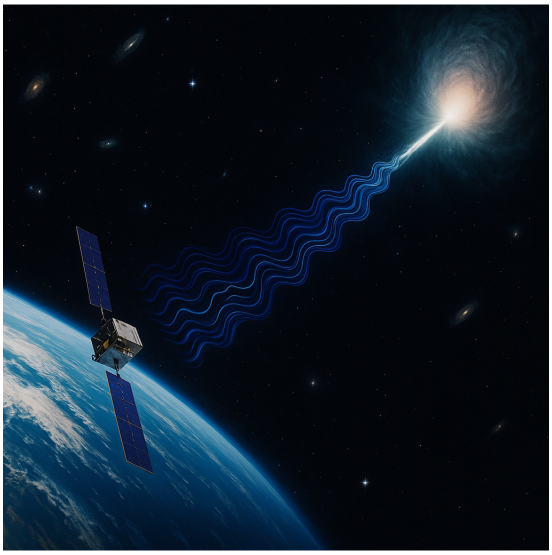
Dark matter searches with gamma-ray telescopes



SUMMARY.
Deciphering the particle nature of dark matter, which constitutes over 80% of all matter in the Universe, remains one of the most fundamental problems in physics. A leading hypothesis is that dark matter consists of a new class of fundamental particles called axions or axion-like particles (ALPs). In a process similar to neutrino oscillations, ALPs and photons could convert into each other in the presence of an external magnetic field. If these particles exist, they could therefore leave to distinct signatures in observations of high-energy gamma-ray sources. For example, photon-ALP oscillations in astrophysical magnetic fields could lead to distinct features in the gamma-ray spectra of distant galaxies. In this project, the students will learn (i) about evidence for dark matter and the fundamentals of axion phenomenology; (ii) learn about astrophysical gamma-ray sources and (iii) analyze data of gamma-ray telescopes to search for signatures of these particles. (Image credit: Mohammadpour Mir / ChatGPT)

OBJECTIVES

- *What will student learn? (**Knowledge**: astrophysical sources for high-energy gamma rays, evidence for dark matter, indirect searches for new fundamental particles)*
- *What will students learn to do? (**Skills**: running simulations of photon-axion oscillations, analyzing gamma-ray data, e.g., from the Fermi* Large Area Tele*scope, statistical analysis and maximum likelihood estimation)*

INSTITUTE

- University of Southern Denmark (SDU)
- Institute URL
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THEORY

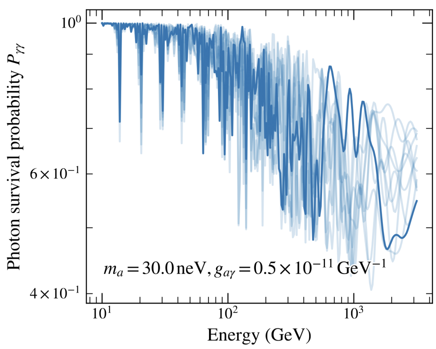
by Manuel Meyer

Blazars are the brightest gamma-ray emitters in the extragalactic sky and thousands of these objects have been detected with the *Fermi* Large Area Telescope. During their journey to Earth, gamma rays cross many different magnetic field environments (e.g., in the blazar jet, the host galaxy, in the intergalactic medium, in the Milky Way) where they could convert into ALPs. Depending on the unknown ALP mass and coupling strength to photons as well as the intervening magnetic fields, the photon-ALP oscillations could lead to energy-dependent wiggles in the gamma-ray spectra of these sources. This would constituts a smoking-gun signal for the existence of these particles, see, e.g., [**biteau_gamma-ray_2022**] for a review.

APPLICATIONS

by Manuel Meyer

Using the `gammaALPs` code, the student will model the photon-ALP oscillations along the line of sight to one blazar or AGN, e.g., NGC 1275 at the heart of the Perseus galaxy cluster, which has been used previously to search for ALPs [**2016PhRvL.116p1101A**]. Equipped with the theoretical predictions of the ALP signature, the student will then analyze data of either the *Fermi* Large Area Telescope or H.E.S.S. telescope array to search for hints for this effect.



MAIN PROGRESSION STEPS

- `Week 1-2`: Literature review
- `Week 3`: Familiarizing with `gammaALPs` code
- `Week 4`: Familiarizing with gamma-ray analysis
- `Week 5-9`: project work and attending master lever course "Astroparticle Physics" at SDU

EVALUATION

- `Theory grade [20%]`
  - Exercises (as part of Astroparticle Physics course, 40%)
  - Presentation of an article (60%): critical thinking
- `Practice grade [40%]`
  - Project (100%): initiative, progress, analysis
- `Defense grade [40%]`
  - Oral and slides quality
  - Context
  - Project / Personal work
  - Answers to questions

BIBLIOGRAPHY & RESOURCES

- `gammaALPs documenation`

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