ALPs searches: Galactic sources

...

*Alvaro Pratts *(IF-UNAM)* Rubén Alfaro (IF-UNAM)
Sergio Hernández (IF-UNAM) J.A García (ITESM)
and for HAWC collaboration

IWARA 2022
(Antigua, Guatemala)

Introduction

Axion like Particles (ALPs)

The QCD axion and ALPs are particles with similar properties and are excellent candidates to be the cold dark matter of the Universe. There are light particles m < 10e-3 eV

The main difference between QCD axion and ALPs is that ALPs do not necessarily need to solve the strong CP problem. Which gives widder parameter space of m and g

ALPs: coupling

The ALP lagrangian is :

$$\mathcal{L}_{ALP} = \frac{1}{2}(\partial_\mu a \partial^\mu a - m_a^2 a^2) + \frac{1}{4f_a} a F_{\mu\nu} \tilde{F}^{\mu\nu}.$$

And the electromagnetic coupling is given by:

$$\mathcal{L}_{a\gamma\gamma} = \frac{1}{4f_a} a F_{\mu\nu} \tilde{F}^{\mu\nu} = a g_{a\gamma\gamma} \vec{E}.\vec{B}$$

ALPs: Conversion Probability

Due to this coupling it is possible (under certain conditions) to obtain an expression for the conversion probability. (MIRIZZI 2009)

$$P_{\gamma\to a}(E_\gamma) = \left(1 + \frac{E_c^2}{E_\gamma^2}\right)^{-1} sin^2\left(\frac{g_{a_\gamma\gamma} B_T L}{2}\sqrt{1 + \frac{E_c^2}{E_\gamma^2}}\right),$$

With the critical energy

$$E_c = \frac{|m_a^2 - \omega_{pl}^2|}{2 g_{a\gamma\gamma} B_T}$$

HAWC Observatory

HAWC OBSERVATORY

High Altitude Water Cherenkov

Located at 4100 m a.s.l. Puebla, México

300 WCD

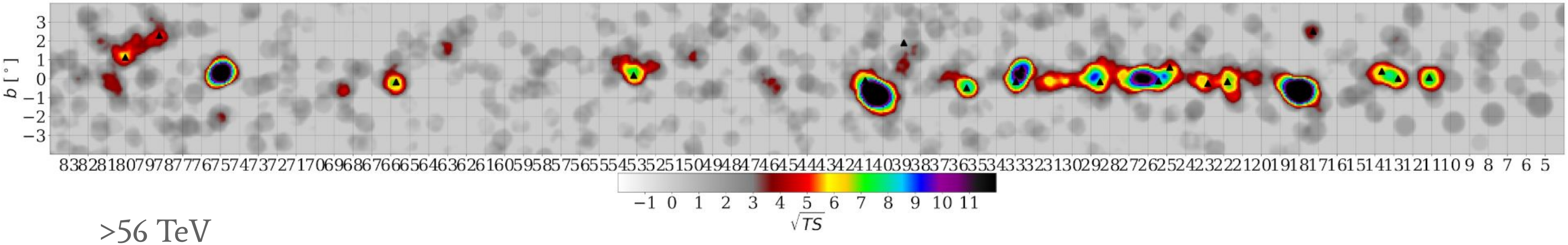
FoV = 2 sr

High Duty Cycle >90%

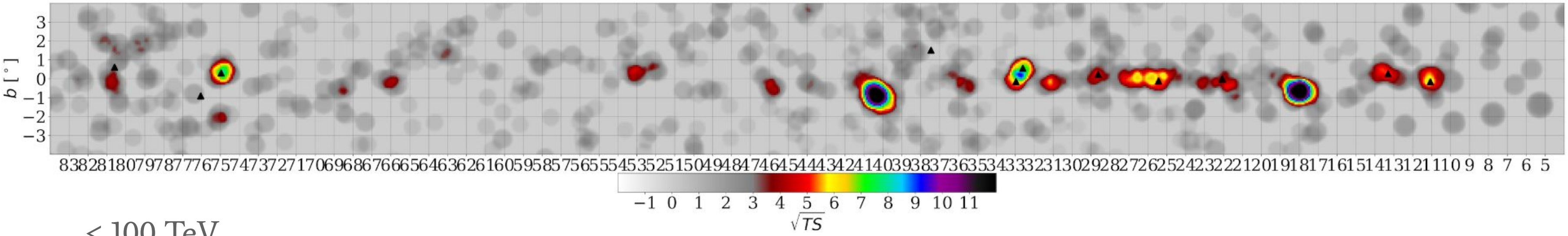
Energy range (gamma rays) :

100 GeV ~ 250 TeV

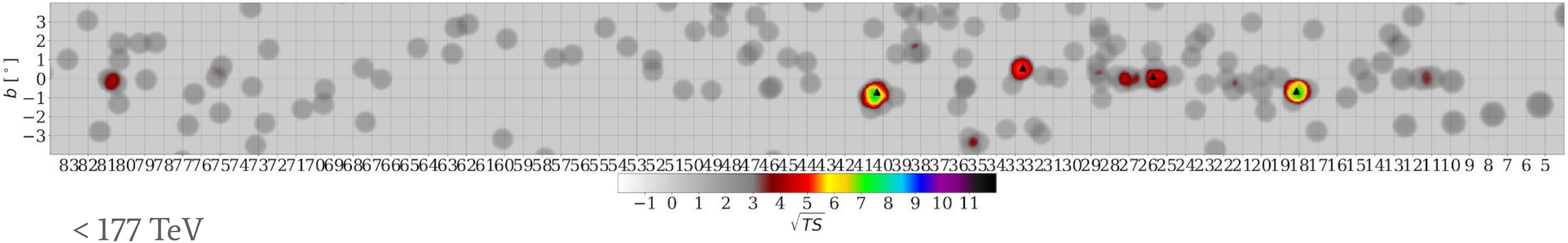
HAWC, High energy maps



>56 TeV

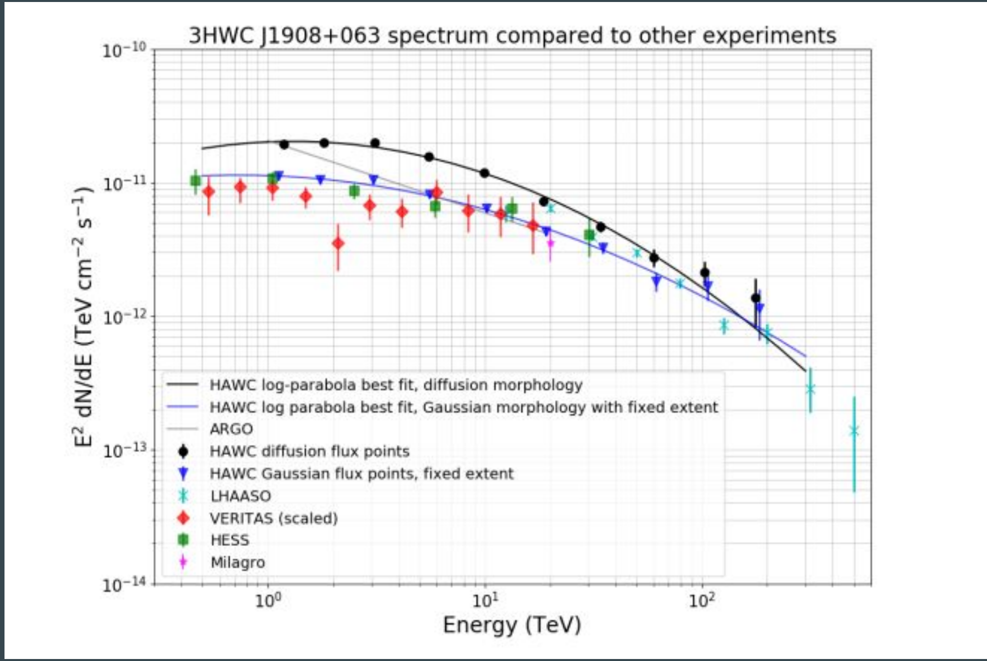


< 100 TeV



< 177 TeV

Galactic source: 3HWC J1908 +063



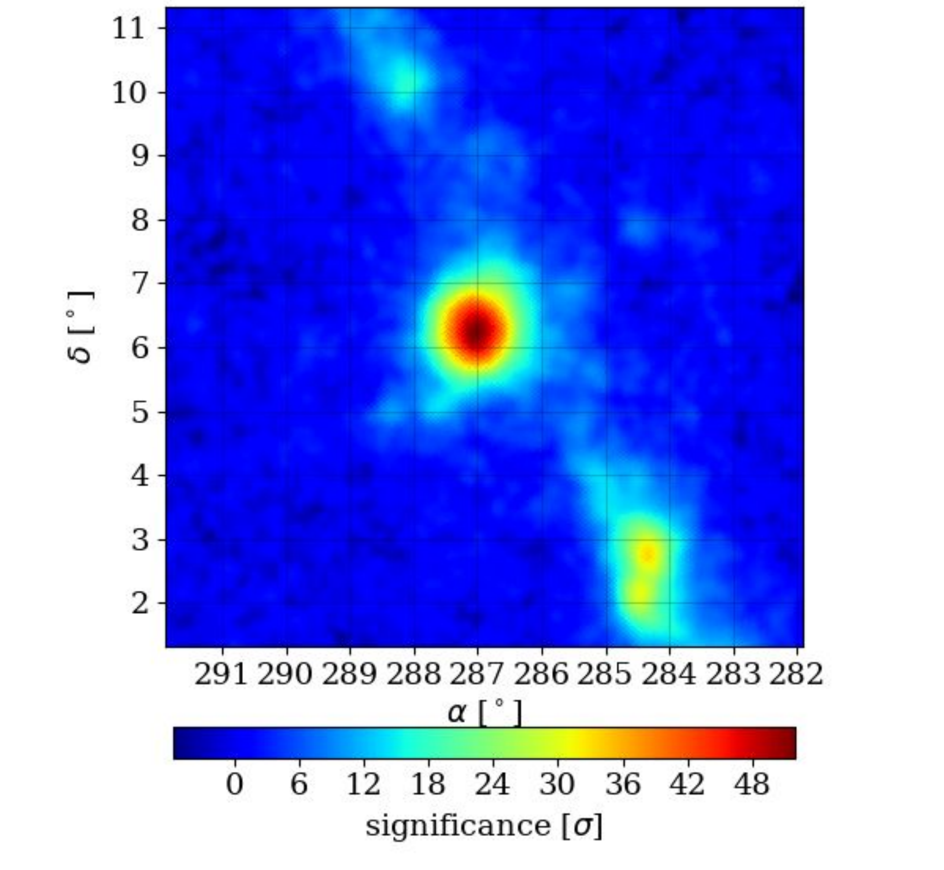
Parameters of the source:

Distance: 2.3 kpc
Extension: 1.4 degrees (Halo?)

Spectrum: LogParabola

N= 6.69 ± 0.05 e-14 TeV cm^{-2} s^{-1}
a = 2.45 ± 0.03
b=0.09 ± 0.01

Galactic source: 3HWC J1908 +063



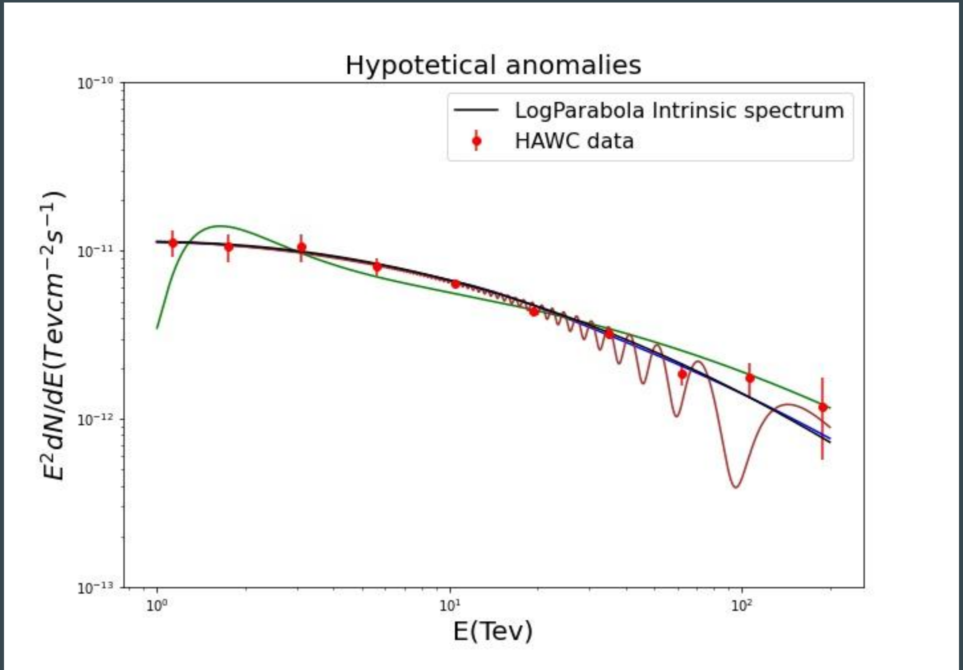
Galactic parameters.

Magnetic field B_T= 1μG

Electron density = $0.1/cm^3$

Hypothetical anomalies

Hypothetical anomalies on the spectrum.



If we consider the possible effect of conversions to ALPs, the expression for observed flux becomes:

$$\frac{d\phi}{dE_\gamma} = (1 - P_{\gamma \to a}) \cdot f_{att} \cdot \frac{d\phi}{dE_\gamma}|_{Source}$$

where f_{att} it's an attenuation factor that includes the effect of the EBL and the extinction due to the galaxy dust. In our case, this factor becomes 1 because EBL and extinction are neglectable due to distance and energy.

Analysis

Analysis.

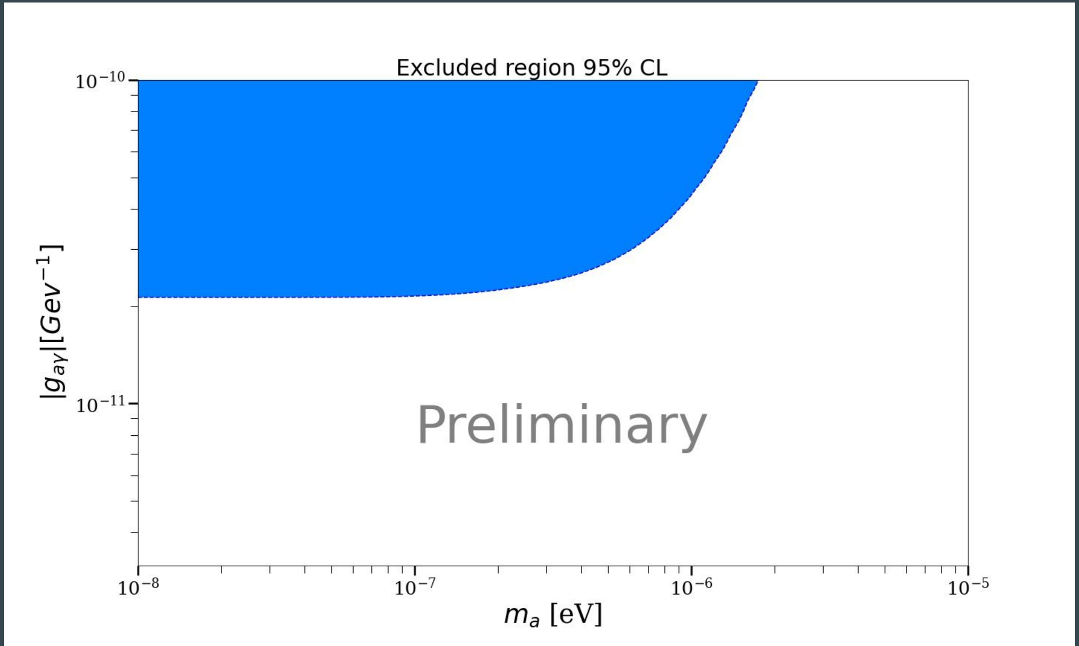
We can use the LLR method to obtain an exclusion region in the parameters of m and g.:

$$LLR = -2\left(ln\mathcal{L}(\theta_0; m, g = 0) - ln\mathcal{L}(\hat{\theta_{m,g}})\right)$$

Where $ln\mathcal{L}(\theta_{0;m,g=0})$ is the Log Likelihood of the model Log Parabola w/o ALPs and $ln\mathcal{L}(\hat{\theta}_{m,g})$ is the Log Likelihood with ALPs with pair m and g.

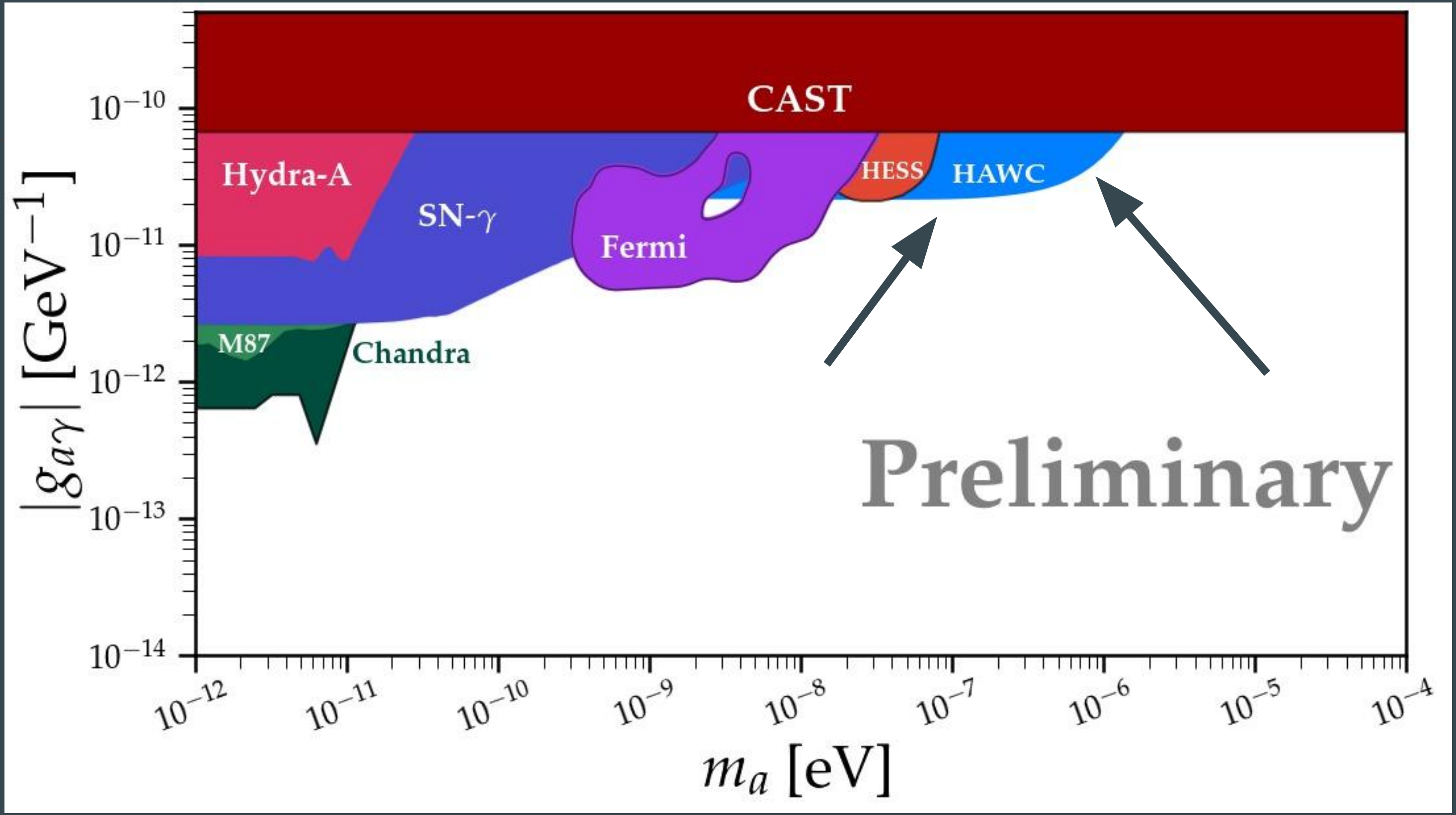
We can obtain the LLR values for a mesh of different m and g values.

Exclusion criteria



We obtained a preliminary plot of the exclusion region, the LLR values were taken whose difference from the maximum is greater than or equal to 5.99, which gives us a **95% CL.**

Excluded regions



Conclusions:

- Due to source distance and very high energy of the gamma ray emission, it would be possible to observe the effects of the conversions of photons to ALPS.

- We obtained a preliminary exclusion region which complements previous studies