

Indirect DM studies using VHE gamma-ray observations



Rubén López-Coto
FELLINI meeting, 31/05/22

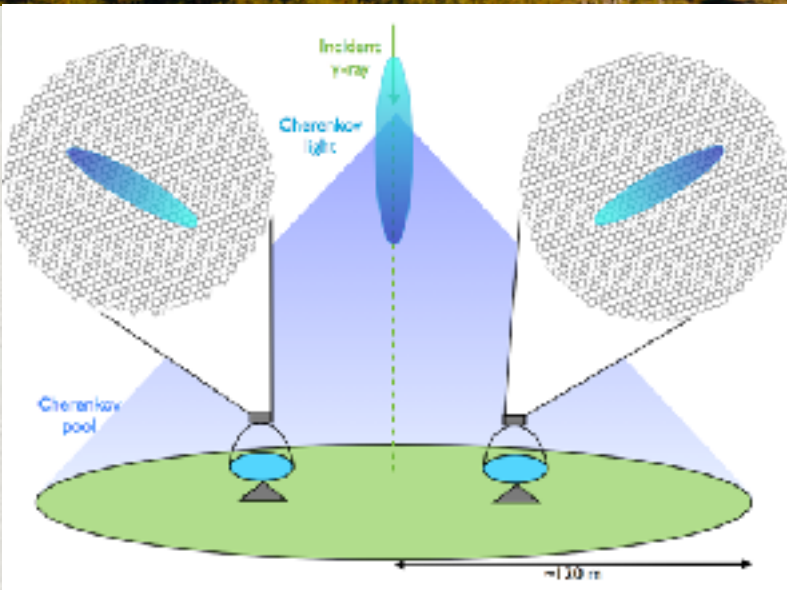
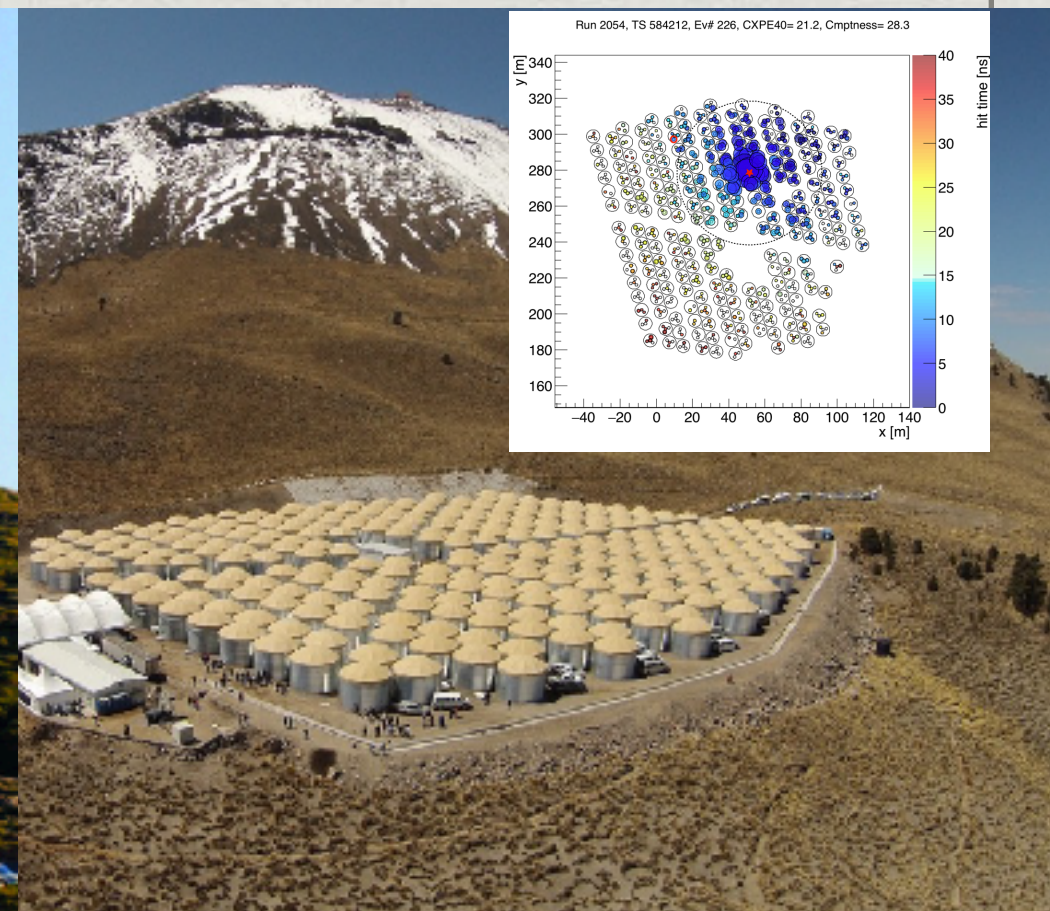


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Research Field

- * Particle acceleration using Very-High-Energy gamma rays



* Two techniques:

- * Imaging Atmospheric Cherenkov Technique (MAGIC, HESS, VERITAS and future CTA)
- * Particle Detection Technique (HAWC, ARGO, LHAASO and future SWGO)

Rubén López-Coto - Fellini annual meeting

Imaging Atmospheric Cherenkov telescopes

- Energy range: 100 GeV - ~tens of TeV
- Field of View ~ few deg
- Angular resolution ~0.1 deg
- Energy resolution ~15-20%



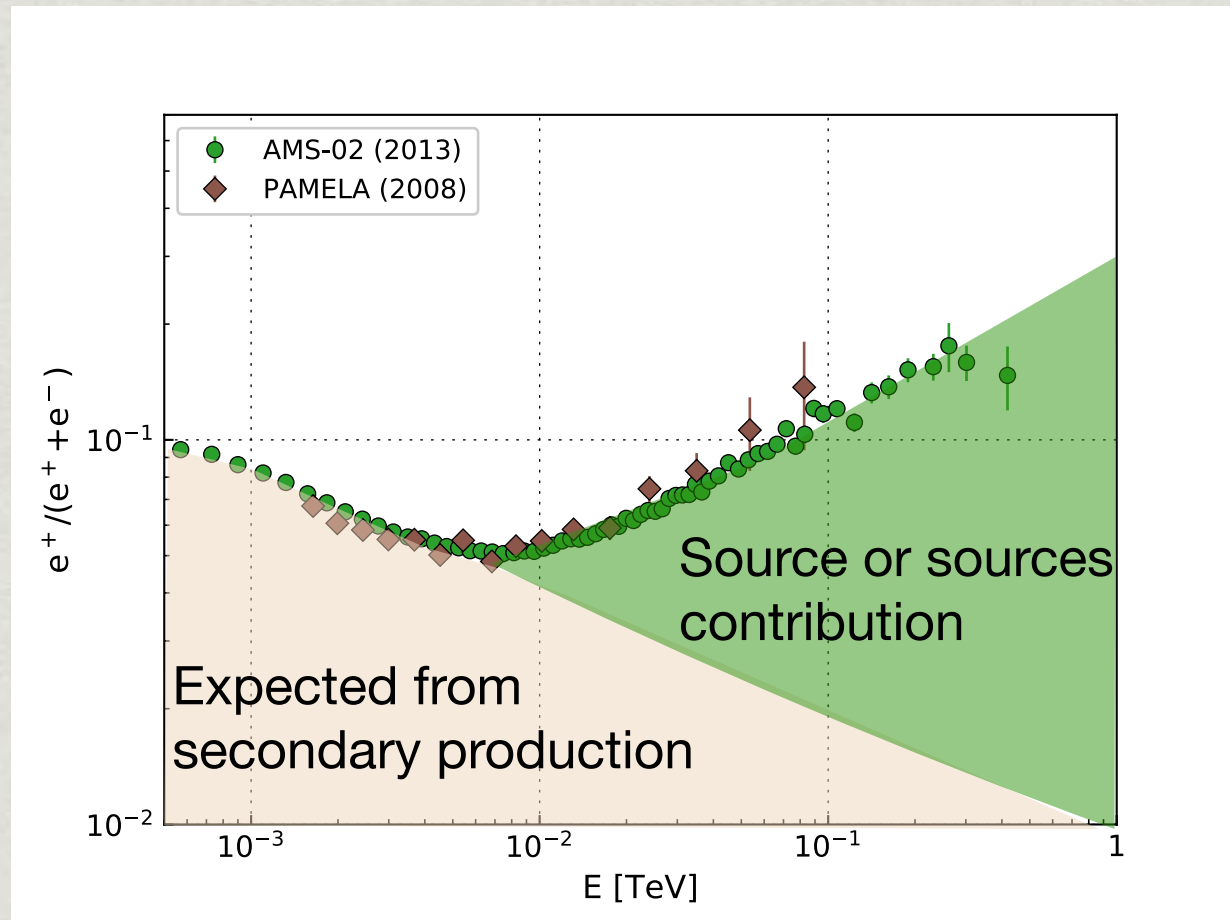
MAGIC and LST of CTA

Water Cherenkov detectors

- Energy range: 1 TeV - ~hundreds of TeV
- Field of View: ~ steradian
- Angular resolution >0.2 deg
- Energy resolution $>50\%$



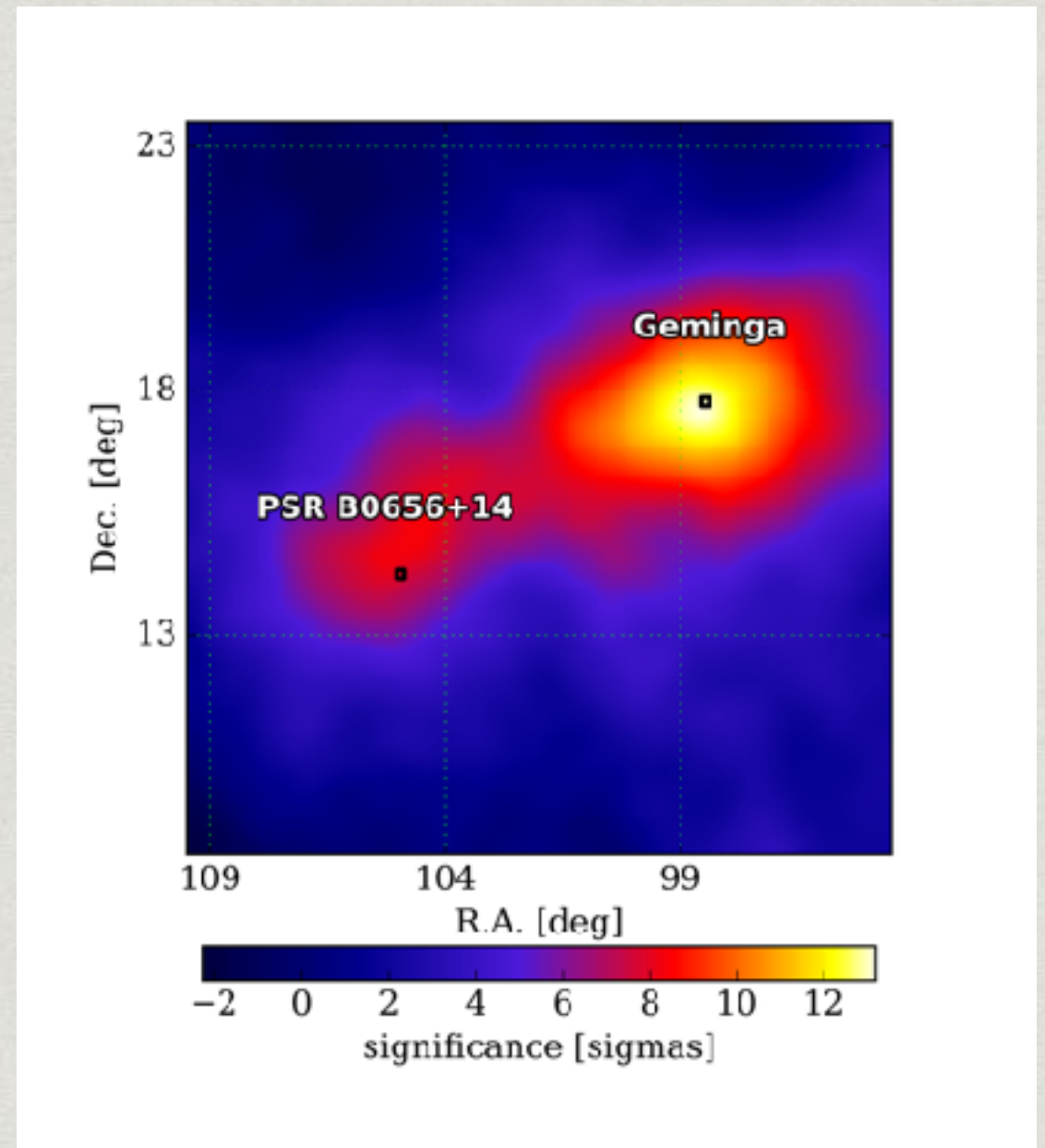
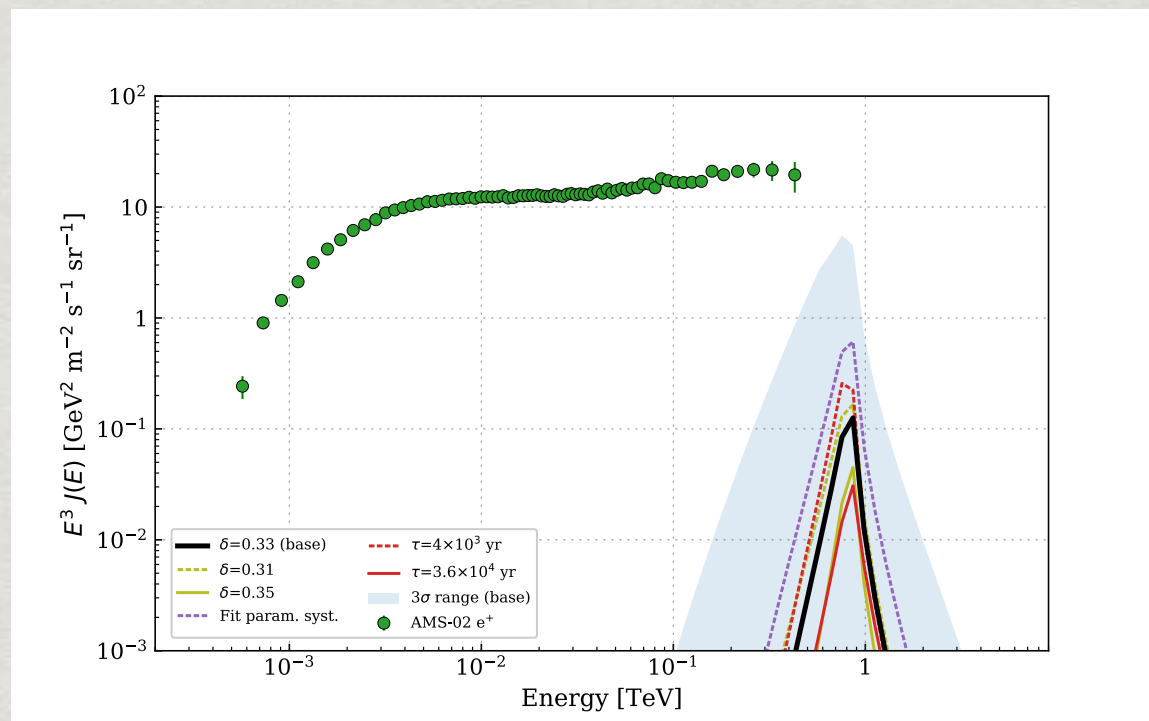
Study of CR anomalies through VHE gamma-ray observations



- The positron fraction is expected to decrease with Energy
- This is the case for energies below a few GeV
- At higher energies the positron fraction increases -> There has to be a source injecting them
- If we take the diffusion coefficient derived from the ratio between secondary to primary cosmic ray species, the highest energy electrons and positrons should come from a nearby source.
- **DM has been proposed as the origin of this excess**, to confirm/rule out this hypothesis, we need to deeply understand the background from cosmic sources.

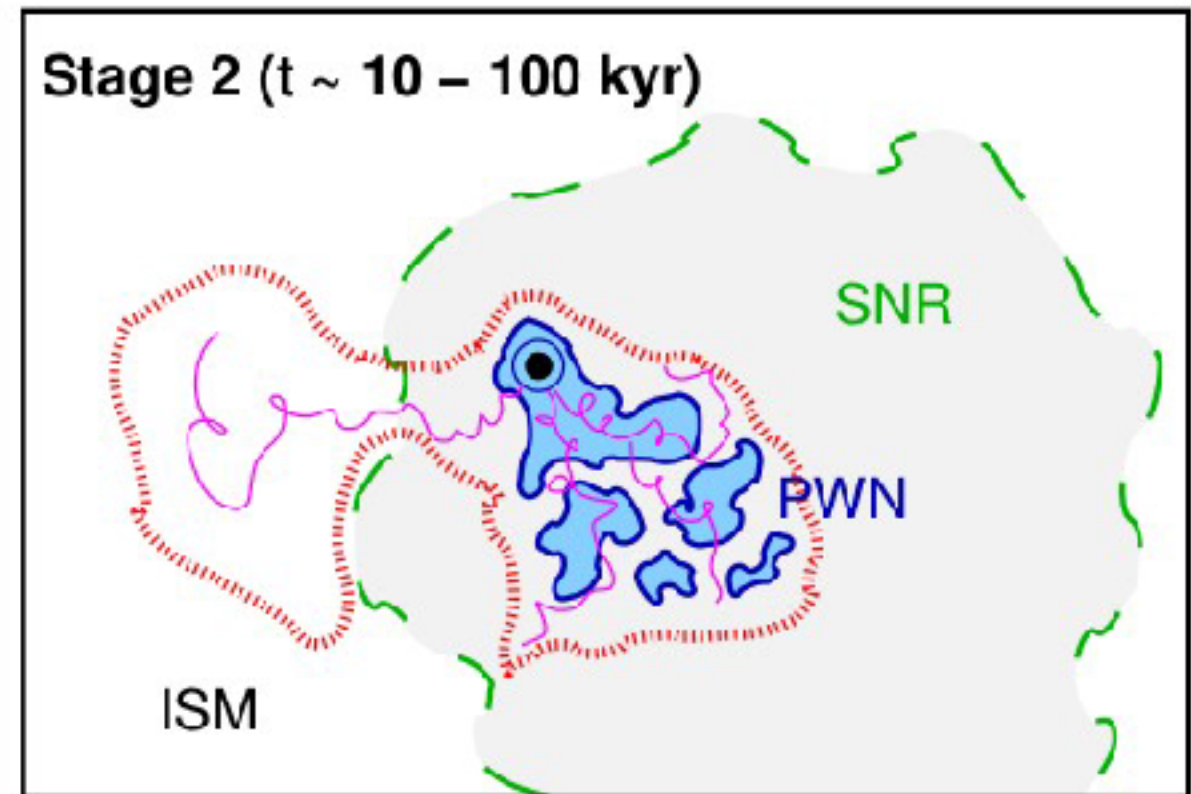
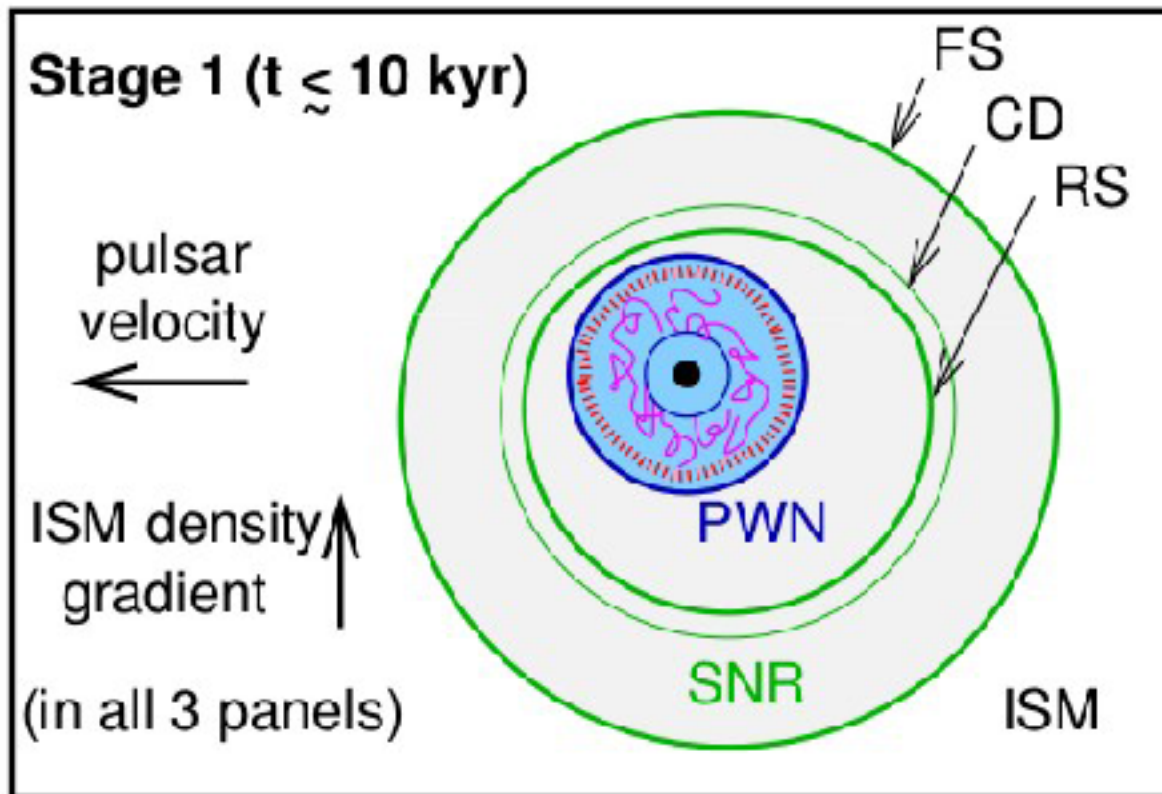
Detection of very extended sources







- Detection of two very extended gamma-ray sources coincident with two nearby pulsars.
- Emission coming from very high energy electrons/positrons (~ 100 TeV) inverse Compton upscattering CMB.
- How far are these electrons/positrons traveling?

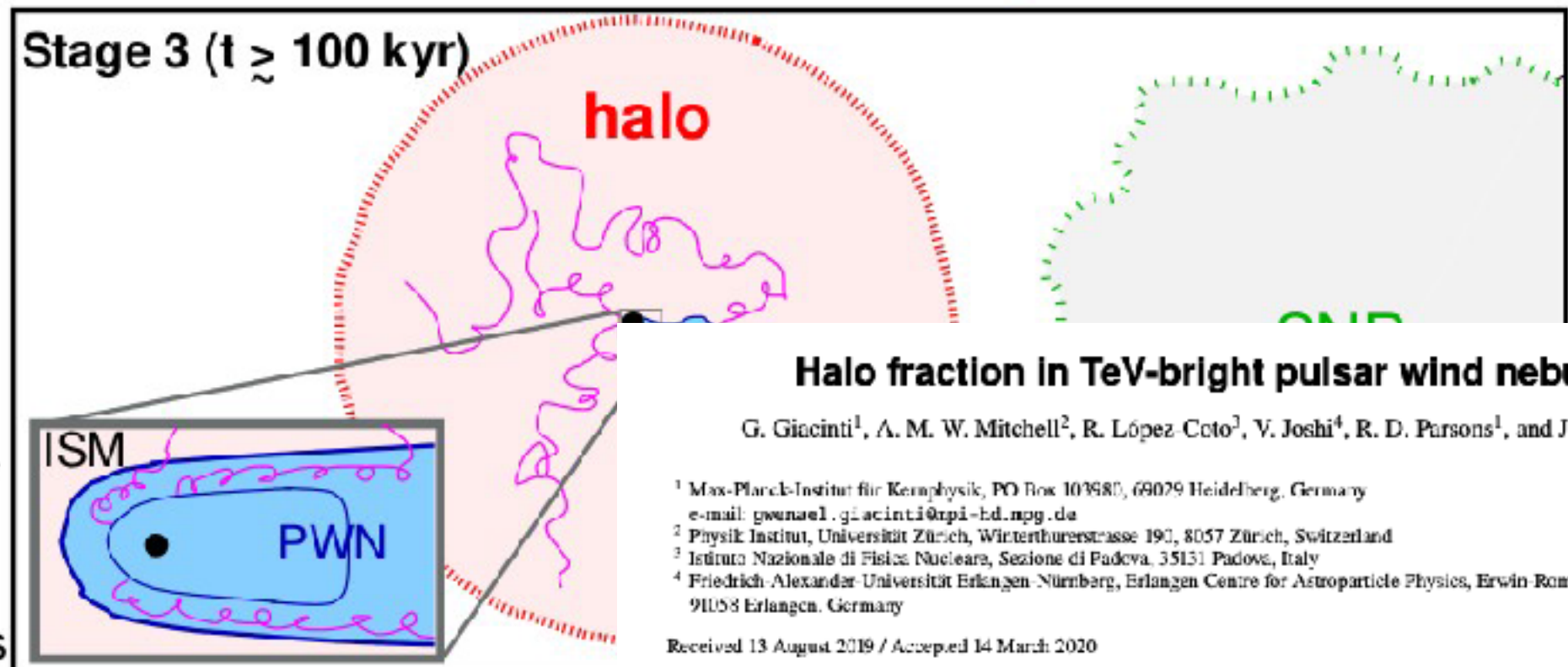


HAWC Coll., Science, 358, 911 (2017)

Definition of Pulsar halos



-  supernova remnant
-  pulsar
-  pulsar wind term. shock
-  pulsar wind nebula
-  > 10 TeV e^{\pm} trajectory
-  > 1 TeV gamma-rays



Halo fraction in TeV-bright pulsar wind nebulae

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International workshop

1st HONEST Workshop: Gamma-ray Halos around Pulsars

HONEST Workshops: Hot Topics in High Energy Astrophysics

1-3 Dec 2020
Europe/Rome timezone

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Overview

Important Deadlines

Call for Abstracts

Timetable

Contribution List

Connection details

My Conference

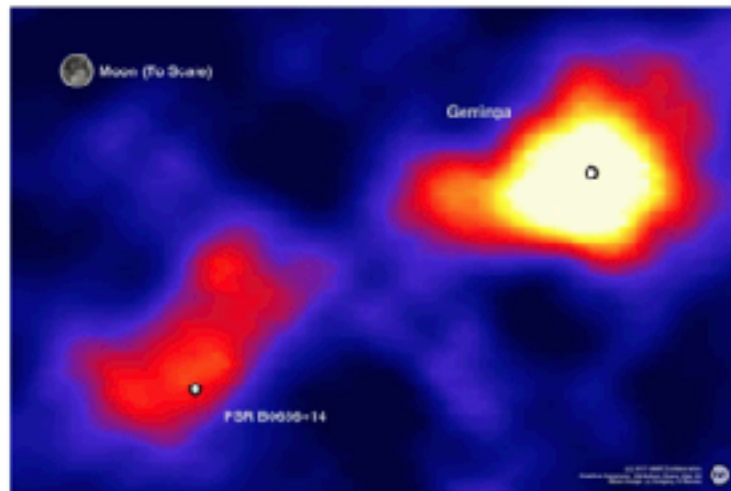
My Contributions

Registration

Participant List

Scientific Organizing
Committee

LOC



We are establishing a series of workshops on Hot Topics On High Energy Astrophysics (HONEST). The first workshop of the series will have be focused on Gamma-ray Halos around Pulsars.

Rationale: New gamma-ray observations in the GeV and TeV domain have revealed a new class of gamma-ray emission regions: the **gamma-ray halos**. Gamma-ray halos are characterized by regions in which electrons and positrons escape from the Pulsar Wind Nebula and produce a region

that is bright in gamma rays. In this Workshop, we aim to discuss the latest results from GeV and TeV instruments, their implications in the current propagation theories and the prospects for future observations. Image credit: John Pretz.

More than 180 participants

- * Warm welcome from the community

Need to understand these sources to evaluate what is the background for the indirect detection of DM

Review on Pulsar Halos

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Review Article | [Published: 14 February 2022](#)

Gamma-ray haloes around pulsars as the key to understanding cosmic-ray transport in the Galaxy

[Rubén López-Coto](#) ✉, [Emma de Oña Wilhelmi](#) ✉, [Felix Aharonian](#), [Elena Amato](#) & [Jim Hinton](#)

[Nature Astronomy](#) **6**, 199–206 (2022) | [Cite this article](#)

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observations. Image credit: © J. Hinton et al.

Primordial Black Holes

Definition

- * What are Primordial Black Holes (PBHs)?
 - * Predicted by S. Hawking in 1971.
 - * Black Holes that were originated in a radiation dominated era.
 - * They do not count for the total baryonic mass of the Universe.
 - * Their masses can range from the Planck scale up to supermassive BHs.
 - * PBH search regained interest after the detection of Gravitational Waves, being proposed as **possible contributors for DM**

Estimations with SWGO

Prospects for the Observation of Primordial Black Hole evaporation with the Southern Wide Field of View Gamma-ray Observatory

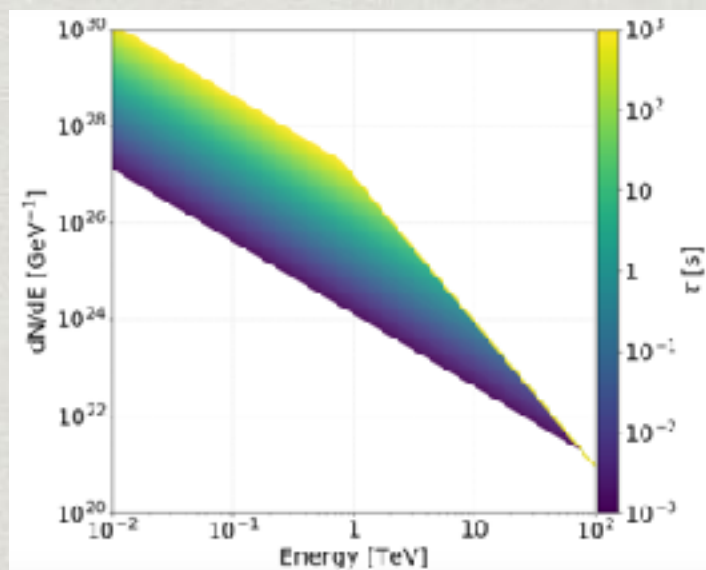
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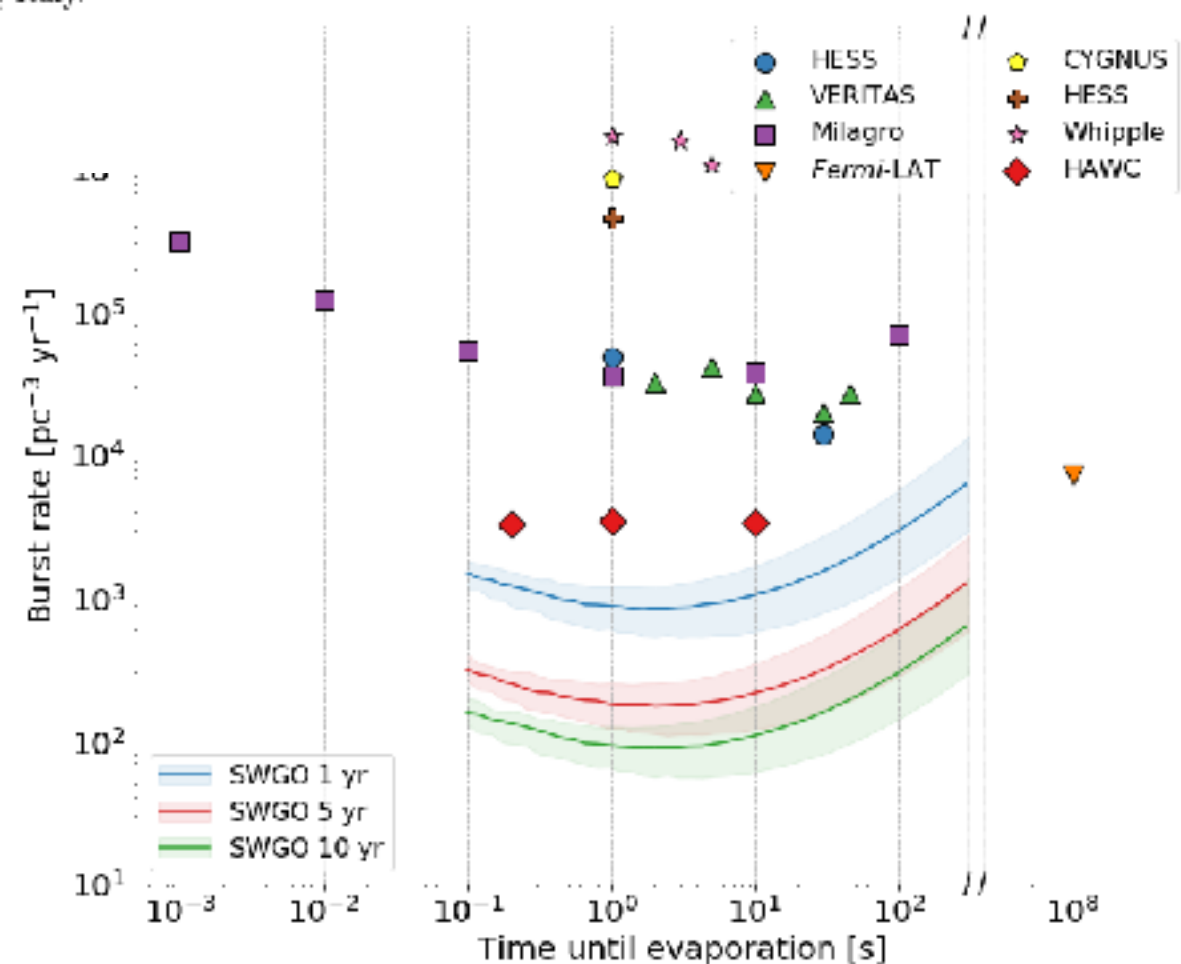
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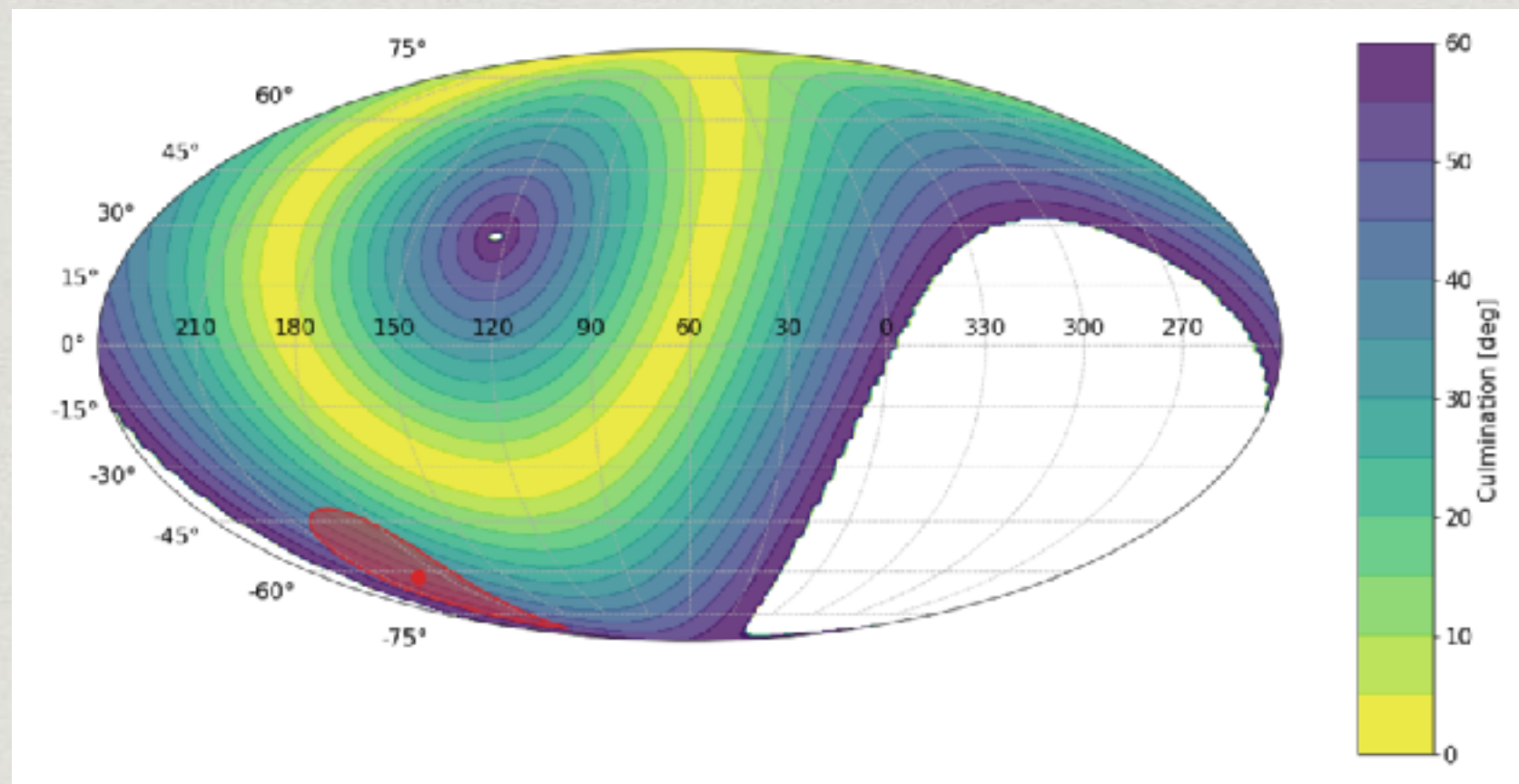


Rubén López-Coto



Bonus track: what if Planet 9 is a PBH?

- Hypothetical planet suggested to explain some anomalies in the orbits of trans-Neptunian objects.
 - To learn more: https://en.wikipedia.org/wiki/Planet_Nine
- Sky location already pinpointed:
 - ```
c = SkyCoord(ra=40*u.degree, dec=-15*u.degree, frame='icrs')
```
  - Although too large uncertainty (radius ~ 20 deg) to perform a direct search for it.





# Hypothesis: Planet 9 is a PBH

- Proposal: **Planet 9 is a Primordial Black Hole:**
  - <https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.125.051103>
- You cannot detect its direct emission because it has a very low temperature:
  - “On its own, a PBH of mass  $5M_{\oplus}$  has a Hawking temperature of 0.004 K, making it colder than the cosmic microwave background, and since its radius is  $r_{\text{BH}} \sim 5 \text{ cm}$ , the power radiated by the PBH alone is minuscule.”
- But you can detect the gamma-ray emission from its interaction with Dark Matter:
  - “However, the DM halo around this PBH can, if annihilating, provide a powerful signal. Annihilations in the PBH halo at the position of P9 would make for a potential FERMI-LAT source”
- Bachelor thesis searching for the amount of MAGIC data taken in the region (~50 hours) and making predictions on the minus flux that can be detected using those data
  - S. Fogliacco, [“A Primordial Black Hole origin of Planet 9 and its observability through dark matter indirect observations with the MAGIC telescopes”](#), 2021



# Summary

- \* Indirect search for dark matter by characterizing the cosmic ray background produced by several types of objects
  - \* Main focus on pulsar halos.
  - \* Also studied other Galactic sources.
- \* PBH searches using current and future VHE gamma-ray experiments
  - \* Prospects derived using future facilities like SWGO.
  - \* What if Planet 9 is a PBH? Preliminary searches using MAGIC.