Constraints to the dark matter lifetime with 270 hours of observations of the Perseus cluster with the MAGIC telescopes

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Outline

- The MAGIC Telescopes
- Indirect Dark Matter Searches
- Decaying Dark Matter in Perseus → Donut MonteCarlo
- Conclusions → Global Dark Matter Search
The MAGIC Telescopes

Observatorio del Roque de los Muchachos, La Palma (Spain)

- Collaboration of ~160 scientists (Germany, Spain, Italy, Switzerland, Finland, Croatia, Bulgaria, Poland, India & Japan)

- 2-telescopes stereoscopic system (MAGIC-I 2004, MAGIC-II 2009)
  → 17m diameter reflector each

- Pointed observations (field of view ~3 deg)

- Angular resolution 0.1°; Energy resolution ~15-25%

- ~50 GeV energy threshold (with standard trigger)
  → sensitivity (E>220 GeV) 0.66% Crab Nebula flux
Rotational Curves

Gravitational Lensing

Overwhelming Evidences for Dark Matter

CMB

The Bullet Cluster (Smoking Gun)
WIMPs

- Possible explanation to all these observations

- Many theories predict WIMPs:
  ** Mass: from GeV to multi-TeV
  ** Weak interactions

- Self-annihilating and/or decaying WIMPs produce gamma-rays
Indirect DM Searches

Aim at detecting Standard Model products (including gamma rays) from annihilation or decay of dark matter particles.

✦ Unique spectral features of dark matter processes

✦ Neutral SM messengers point back to dark matter sites

✦ Needed to confirm that signals found in accelerator or direct searches are THE dark matter

Expected **GAMMA-RAY** fluxes for a given target:

\[
\frac{d\Phi_\gamma}{dE} = \frac{d\Phi_{\gamma}^{PP}}{dE} \times J(\Omega)
\]

Annihilation

\[
\frac{d\Phi_{\gamma}^{PP}}{dE} = \frac{\langle ov \rangle}{8\pi m^2} \frac{dN_\gamma}{dE}
\]

\[
J(\Omega) = \int \int \rho^2(r) \, dr \, d\Omega
\]

Decay

\[
\frac{d\Phi_{\gamma}^{PP}}{dE} = \frac{1}{4\pi m_\chi \tau_\chi} \frac{dN_\gamma}{dE}
\]

\[
J(\Omega) = \int \int \rho(r) \, dr \, d\Omega
\]
Indirect DM Searches

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Expected **GAMMA-RAY** fluxes from a given target:

\[
\frac{d\Phi_\gamma}{dE} = \frac{d\Phi_{\gamma \gamma}^{PP}}{dE} \times J(\Omega)
\]

Specific spectral features
Indirect DM Searches

Aim at detecting Standard Model products (including gamma rays) from annihilation or decay of dark matter particles.

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Expected **GAMMA-RAY** fluxes from a given target:

\[
\frac{d\Phi_\gamma}{dE} = \frac{d\Phi_{\gamma}^{PP}}{dE} \times J(\Omega)
\]

~distribution of dark matter wrt the Earth
Where to look for Dark Matter?

Dwarf Spheroidal Galaxies:
- Nearby sources
- High concentration
- Background free
- Large uncertainties in J

Cluster of Galaxies:
- Very massive
- Low uncertainties in J
- Far away
- Astrophysical background

- Clusters of Galaxies are excellent targets for decay dark matter searches
- Diversification is THE strategy due to large uncertainties in J
  → Following JCAP 1210 (2012) 032
Decaying DM in Perseus

- The brightest in X-ray
- 77.7 Mpc (z=0.0183)
- $10^{14} - 10^{15} \, M_\odot$
- 80% dark matter
- Observations 2009-2017(...)
- >270 h collected

**MAGIC results on Perseus:**
- **strongest limits in CR acceleration**

- **NGC1275** discovered and modeled

- **IC310**: discovered, black hole CR acceleration mechanisms

- **Indirect Dark Matter Searches**
  Indirect Dark Matter Searches: MAGIC Coll., in preparation
Decaying DM in Perseus

- Extended Source
- Tailored MonteCarlo for extended morphology

DM Decay Halo
(~ MAGIC FoV)

VHE Sky map of the Perseus Cluster

NGC1275
IC310

Pointing
Decaying DM in Perseus

- Extended Source
- Tailored MonteCarlo for extended morphology
- Signal Region Optimization

DM Decay Halo (~ MAGIC FoV)

VHE Sky map of the Perseus Cluster

NGC1275

ROI

IC310

Pointing
Decaying DM in Perseus

- Extended Source
- Tailored MonteCarlo for extended morphology
- Signal Region Optimization
- Account for Backgrounds:
  **NGC1275 astrophysical DM Leakage
  **DM Leakage

\[ \mathcal{L}(g(\tau_{DM}), f, b, g_{OFF}, \nu | N_{ON}, N_{OFF}) \sim \frac{(g(\tau_{DM}) + f + b)^{N_{ON}}}{N_{ON}!} e^{-(g(\tau_{DM}) + f + b)} \times \frac{(\tau b + g_{OFF})^{N_{OFF}}}{N_{OFF}!} e^{-(\tau b + g_{OFF})} \]

For each E bin (binned likelihood)
We find **NO evidence of dark matter** decay over 270h good quality data.

Reach sensitivities on decay life times of \(8 \cdot 10^{25}\) seconds for both channels.
Decaying DM in Perseus

Compared with previous results

- Almost **10 times better sensitivity** than previous MAGIC results (*Segue)*
- **BEST LIMITS** on decay lifetimes for $\chi \rightarrow \tau \tau$ for DM masses above **2 TeV**
- **FIRST EVER** results for DM masses above **20 TeV**
Conclusions

● Clusters of galaxies are **excellent targets for decaying** indirect dark matter searches

● Search on Perseus Cluster over **270 hours of data**
  → **No hint** of dark matter emission

● These results are:
  → Almost **10 times better sensitivity** previous MAGIC results
  → Reach **sensitivities of** $8 \cdot 10^{25}$ **seconds** for decays in both channels
  → **BEST LIMITS** for $\chi \rightarrow \tau \tau$ for DM masses **above 2 TeV**
  → **FIRST EVER** results **above 20 TeV**

● A paper on **indirect searches in Perseus coming** soon (stay tuned!!!)

*Look for universal effects for which results from different instruments can be easily combined following JCAP 1210 (2012) 032:*  
  → We invite **YOU** to this cooperative effort*