Search for dark matter with the Cherenkov Telescope Array

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for the CTA Consortium
CTA PROJECT

- Next generation ground based Gamma-ray observatory
- Open observatory
- Two sites with more than 100 telescopes
  - Southern Site: Near Paranal, Chile
  - Northern Site: La Palma, Canary Islands, Spain
- 31 nations, \(~300\text{M}\text{\euro}\) project +\(100\text{M}\text{\euro}\) manpower
CTA sites and example telescope layouts different deployment strategies
CTA Headquarters and Science Data Centre

CTA Headquarters
for Admin and observatory operations
INAF Bologna, Italy

CTA Science Data Centre
for science operations and science products
DESY Zeuthen/Berlin, Germany
CTA PERFORMANCE

Southern Site:
4 Large-size telescopes
25 Medium-size telescopes
70 Small-size telescopes

Northern Site:
4 Large-size telescopes
15 Medium-size telescopes
CTA and Fermi

Good complementarity, covering 6 orders of mag. in energy.
In 1933, the astronomer Zwicky realized that the mass of the luminous matter in the Coma cluster was much smaller than its total mass implied by the motion of cluster member galaxies.

Since then, even more evidence:

- Rotation curves of galaxies
- Gravitational lensing
- Bullet cluster

Structure formation as deduced from CMB

Data by WMAP imply:

\[ \Omega_b h^2 \approx 0.02 \]

\[ \Omega_{DM} h^2 \approx 0.1 \]
Little or no astrophysical uncertainties, but low sensitivity because of expected small branching ratio.
Dark Matter Search Targets and Strategies

(Another way to see it)
Classical Dwarf spheroidal galaxies: promising targets for DM detection
2015: New DES Dwarf Spheroidal Galaxies Candidates

LAT Collaboration – DES Collaboration agreement – Feb 2015
  - analysis of observations of 8 new Dwarf Spheroidal Galaxies found by DES:
    - also found by Koposov, et al. arXiv:1503.02079

Nine new dwarf galaxies full of dark matter found just chilling around the Milky Way

By Rachel Feltman  March 10

For the first time in a decade, astronomers have found new dwarf galaxies -- ones with just billions of stars or even less compared with the hundreds of billions in our own -- orbiting the Milky Way. And they’ve found nine of them. That’s the most that have ever turned up at once. The findings were published Tuesday in the Astrophysical Journal.
Dwarf Spheroidal Galaxies: Growing number of known targets

Progression of the Number of Discovered Dwarf Galaxies

- **Cumulative Number**

  - **Year**: 1920, 1940, 1960, 1980, 2000, 2020

- **Confirmed Candidates**
  - DES Year 2 Data: Drlica-Wagner+, arXiv:1508.03622
  - DES Year 1 Data: Bechtol+: arXiv:1503.02584

- **Key Dates**
  - SDSS Begins
  - DECam Installed

- **Timeline**
  - 2015 Jan 1
  - 2015 Jul 1
  - 2016 Jan 1
Dwarf Spheroidal Galaxies: CTA Sensitivity

500h, Sculptor, different channels

500h, bb, different dSphs

Carr et al. 2015 (CTA Consortium)arXiv:1508.06128
Dwarf Spheroidal Galaxies: CTA Sensitivity

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N.B. recent doubts on Segue 1 J-factor due to interlopers in stellar-kinematic samples. V. Bonnivard et al., arXiv:1506.08209
Dwarf Spheroidal Galaxies: CTA Sensitivity

There are several of the newly discovered dSph that have a better case for being a promising target, e.g. Reticulum II (arXiv:1504:03309) or Ursa Major II (arXiv:1605.02793)

Will choose most promising targets before observations with the latest knowledge.

Carr et al. 2015 (CTA Consortium) arXiv:1508.06128
CTA 500 hr, statistical only, NFW, 30 GeV

Together Fermi and CTA will probe most of the space of WIMP models with thermal relic annihilation cross section

Carr et al. 2015 arXiv:1508.06128
CTA sensitivity curve from Carr et al. 2015 500 hr, statistical only, NFW, 30 GeV threshold arXiv:1508.06128

Together Fermi and CTA will probe most of the space of WIMP models with thermal relic annihilation cross section
## CTA DM DETECTION STRATEGY

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galactic halo</td>
<td>175 h</td>
<td>175 h</td>
<td>175 h</td>
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<tr>
<td>Segue 1 (or best) dSph</td>
<td>100 h</td>
<td>100 h</td>
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</tbody>
</table>

*in case of detection at GC, large $\sigma_V$*

| Segue 1 (or best) dSph | 150 h | 150 h | 150 h | 150 h | 150 h | 150 h | 150 h | | |
| Galactic halo | 100 h | 100 h | 100 h | 100 h | 100 h | 100 h | 100 h | | |

*in case of detection at GC, small $\sigma_V$*

| Galactic halo | 100 h | 100 h | 100 h | 100 h | 100 h | 100 h | 100 h | | |

*in case of no detection at GC*

| Best Target | 100 h | 100 h | 100 h | 100 h | 100 h | 100 h | 100 h | | |

### First 3 years
- The principal target is the Galactic Center Halo (most intense diffuse emission regions removed);
- Best dSph as “cleaner” environment for cross-checks and verification (if hint of strong signal).

### Next 7 years
- If there is detection in GC halo data set (525h)
  - Strong signal: continue with GC halo in parallel with best dSph to provide robust detection.
  - Weak signal: focus on GC halo to increase data set until systematic errors can be kept under control.
- In no detection in GC halo data set
  - Focus observations on the best target at that time to produce legacy limits.
DEEP OBSERVATIONS OF GC REGION

Deep 525 h exposure in the inner 5° around Sgr A*;

Extended 300 h survey of 10°\times10° region;

Produce CTA legacy data set for large range of scientific topics, which include

- GC and GC DM halo
- Understand “backgrounds” pin down VHE sources and map diffuse emission
- Astrophysics of SNRs (multiple sources, e.g. G1.9, …)
- Astrophysics of PWNe and Pulsars
- Extended objects such as Central Radio lobes (central \pm 1°) and arc features.

CTA legacy data set
Complementarity and Searches for Dark Matter in the pMSSM

Cahill-Rowley et al. arXiv: 1305.6921
CTA CONTRIBUTION TO DM RESEARCH (SUMMARY)

• CTA has good prospects to probe for the first time WIMP models with thermal relic cross-section and masses above 200 GeV;
• Together with Fermi CTA will be able to exclude thermal WIMPs within the mass range from a few GeV up to a few tens of TeV.
• For heavy WIMPs (>TeV) CTA will provide unique observational data to probe parameter space not reachable by the other experiments.
• CTA is complementary instrument to LHC and direct DM searches probing some non-overlapping regions of DM particle parameter space.
• If DM is detected by CTA, it will also be possible to explore some properties of DM particle through the study of annihilation channels, etc.
• Control of systematics in deep observations of GC halo and dSph(s) is critical for the success of these studies and will require full knowledge of the instrumentation (hence CTA KSP)
• Better understanding of J factors is essential for interpretation of observational data and derivation of limits.