CTA prospects for annihilating dark matter from observations of nearby spiral galaxies

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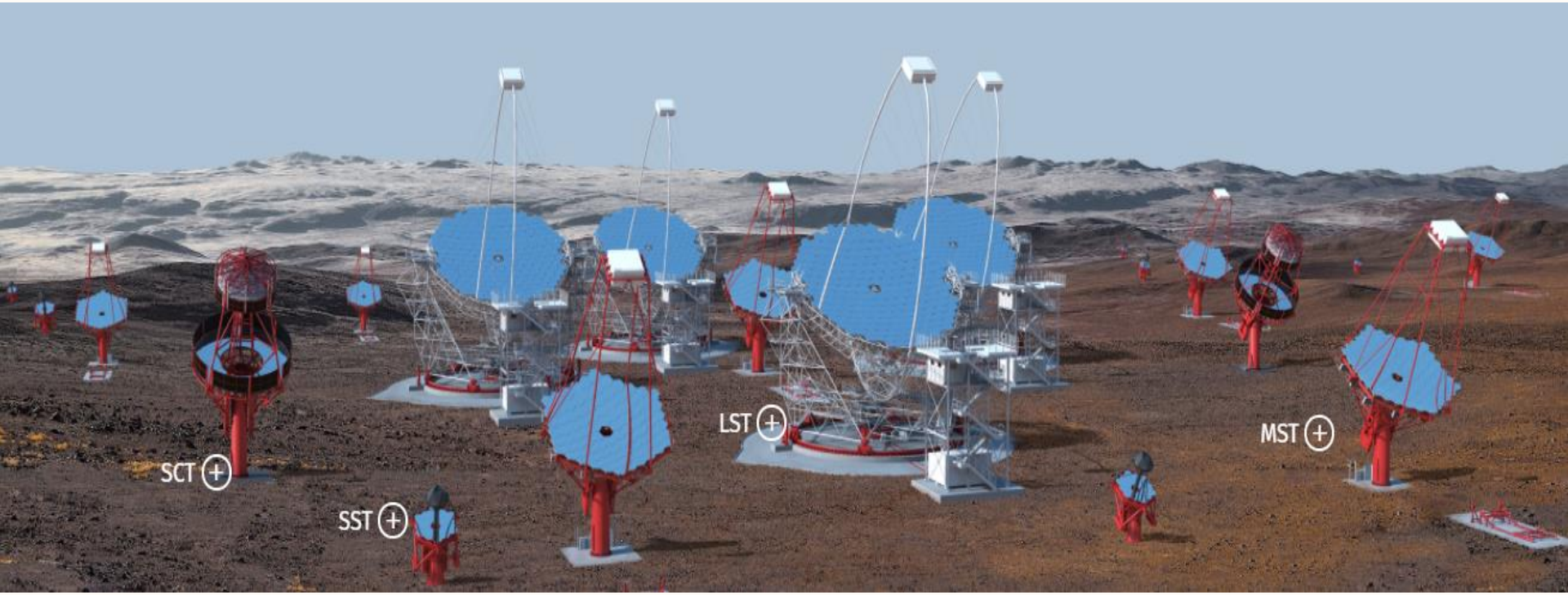


Instrument introduction and DM targets

- CTA: A next generation ground-based observatory operating at very high energies (10 GeV to 100 TeV).
- A size for every energy- more than 100 telescopes with mirror diameters ranging from 4 to 23 m.
- Two arrays for full sky coverage:
  - Northern- La Palma (pointing towards northern extragalactic sources)
  - Southern- Paranal (mainly pointing towards galactic sources)
- It foresees a factor of 5-10 improvement in sensitivity in the energy domain of 100 GeV to 10 TeV in comparison to current generation IACTs: HESS, MAGIC and VERITAS and therefore it gives the opportunity for Dark Matter (DM) searches with unpresented sensitivity.
- DM searches towards promising DM dominated targets such as the Galactic Center, dwarf spheroidal galaxies (dSphs), galaxy clusters have already been included in CTA observational campaign.
- In this study we propose CTA DM searches towards not that frequently studied objects in the DM sector (i.e., nearby M 31 and M 33 spiral galaxies).

Simulation/analysis details

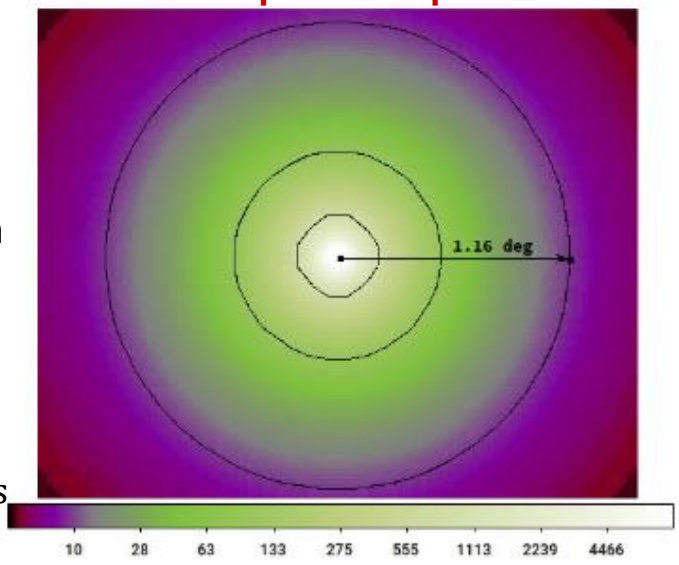
- ctools software was used with a fixed simulation time of: **100 hours (both targets)**

- For the simulations we consider in the field of view:

1. **Residual Cosmic ray Background**
2. **Astrophysical Background emission from sources in the near vicinity of the targets (i.e., 6 point sources for M 31, 4 point sources for M33 and diffuse M 31 emission originating from the Inner M 31 bulge)**

Aiming in constraining the parameters of WIMP DM we did not include any contribution from the annihilating DM to the simulated data.

Template sample:



For the derivation of upper limits**:**

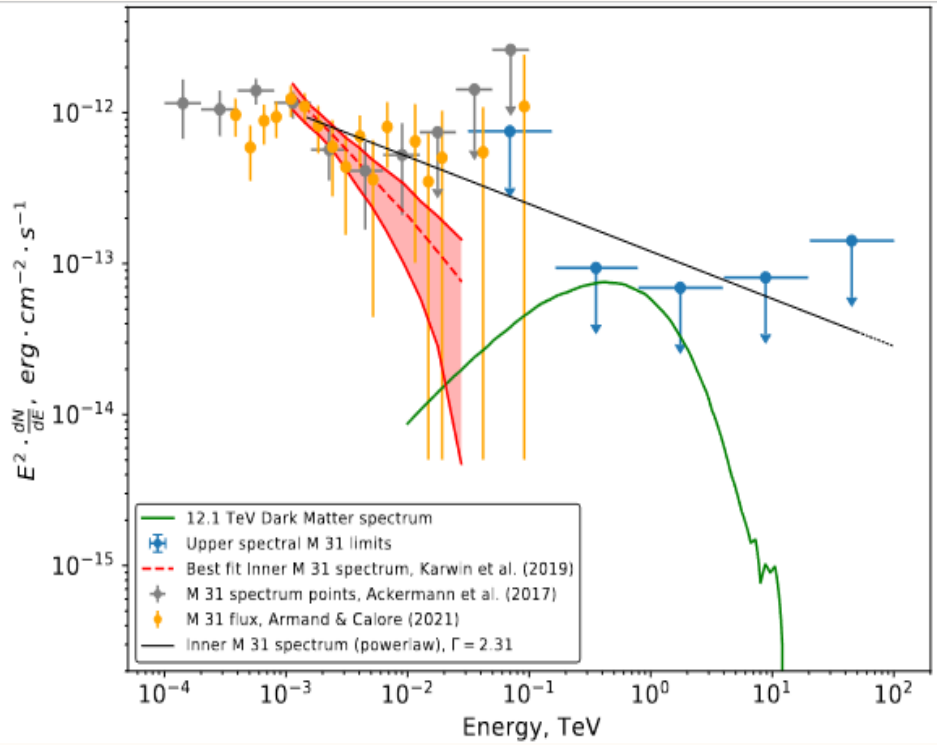
DM source template– template fitting analysis based on the J-factor calculations derived by CLUMPY software were used (different for each DM profile i.e., 13 profiles for M 31 and 7 for M 33)

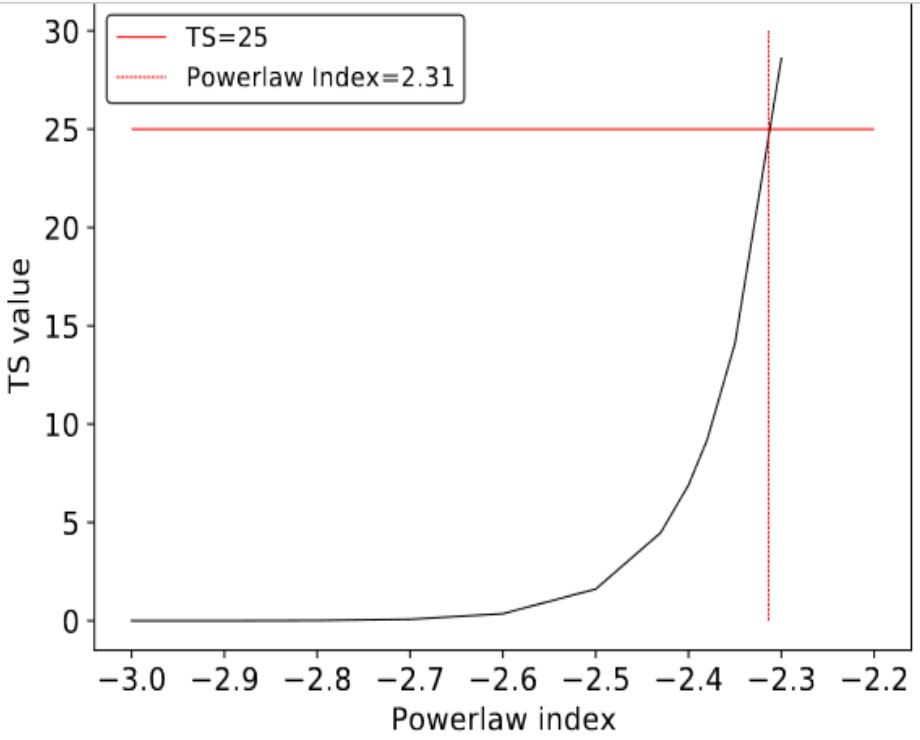
<u>Take away message</u>:

- ❑ Astrophysical emitting sources do not seem to strongly affect upper limits results (minor contribution to the obtained DM signal)

Detection of the Inner M 31 source by CTA?

A dedicated search towards Inner M 31 was conducted to check whether or not this extended source (previously detected by Fermi-LAT) is detectable by CTA.



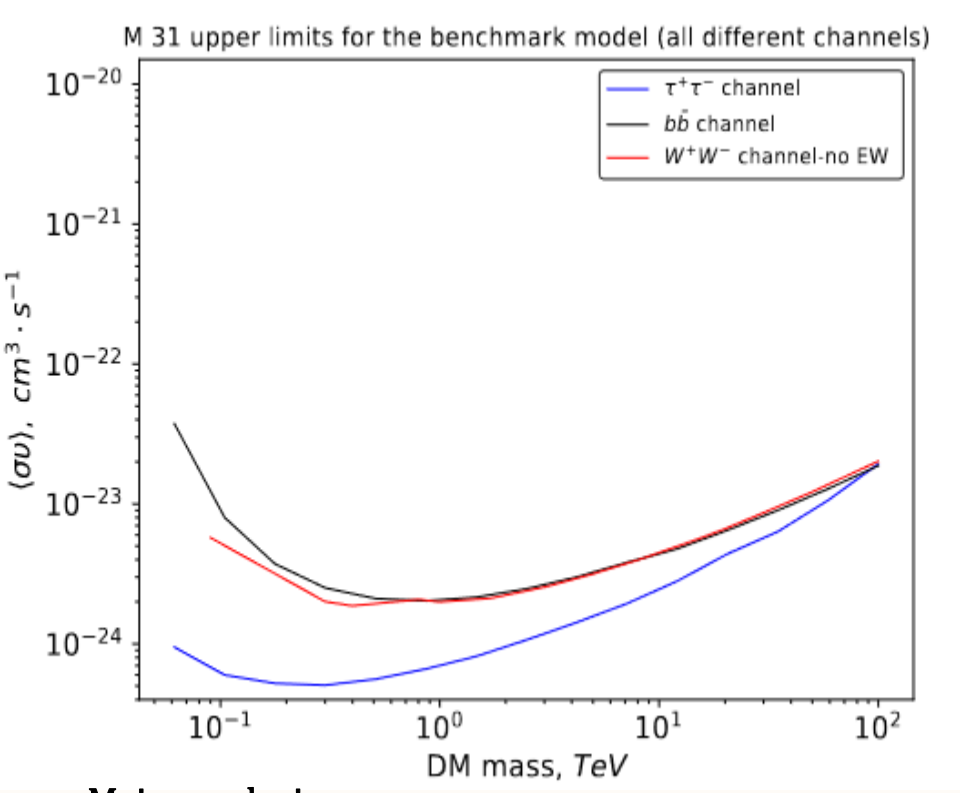


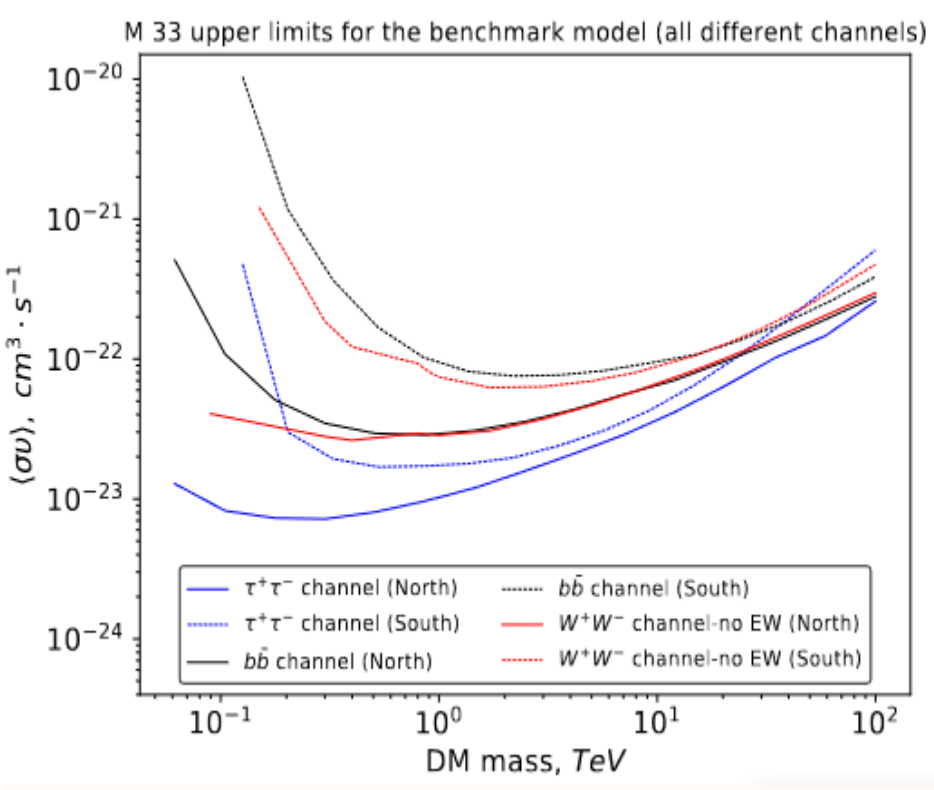
Main result:

- We got **a power index value of -2.31 or harder** for a high significance detection of the extended Inner M 31 bulge (illustrated with the black solid line in the left panel of the figure above).

Main results

Upper limits results for the benchmark profiles considered in this work; reported in Di Mauro et al. (2019)





Main conclusions:

- Higher sensitivity of CTA towards M 31 DM target.
- CTA will be able to probe annihilation cross section upper limits up to $< \sigma v > = 5 \cdot 10^{-25}\ \mathrm{cm^3 s^{-1}}$, for the $\tau^+\tau^-$ annihilation channel (for M 31, at **0.3 TeV**).

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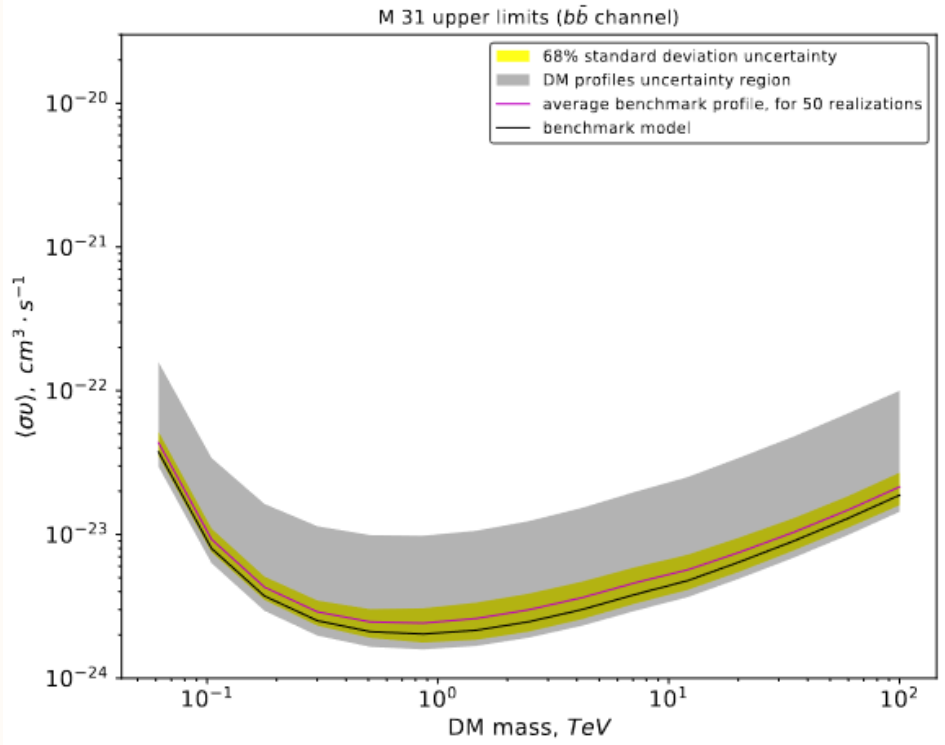
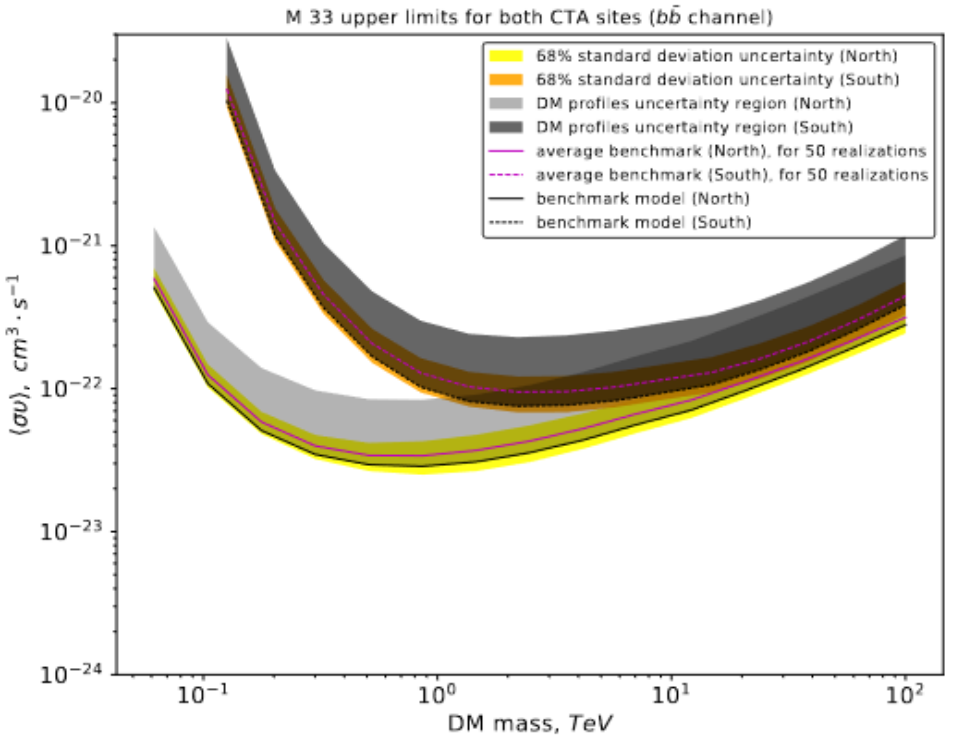
Profiles uncertainty in upper limits calculation

How the lack of knowledge of the exact DM density distribution and the randomization of the event data affect our results?





<u>Uncertainty results</u>:

- The lack of knowledge of the exact DM density distribution in our DM targets caused an order of magnitude worsening of the upper limits.
- Randomization of the event data due to different realization values results in an uncertainty region much smaller than the DM density distribution uncertainty.

Implementation of systematic uncertainty methodologies

Assessment of the impact of the systematic uncertainty of instrumental origin and/or related to miss-identified CR.

❑ **Two methods:**

- DM GC consortium publication **Acharyya et al. (2021)**; based on a modified Poissonian**.**
- An alternative method- **time limiting method**- by choosing the energy/spatial binning size for which systematic uncertainty becomes equal to the statistical uncertainty.

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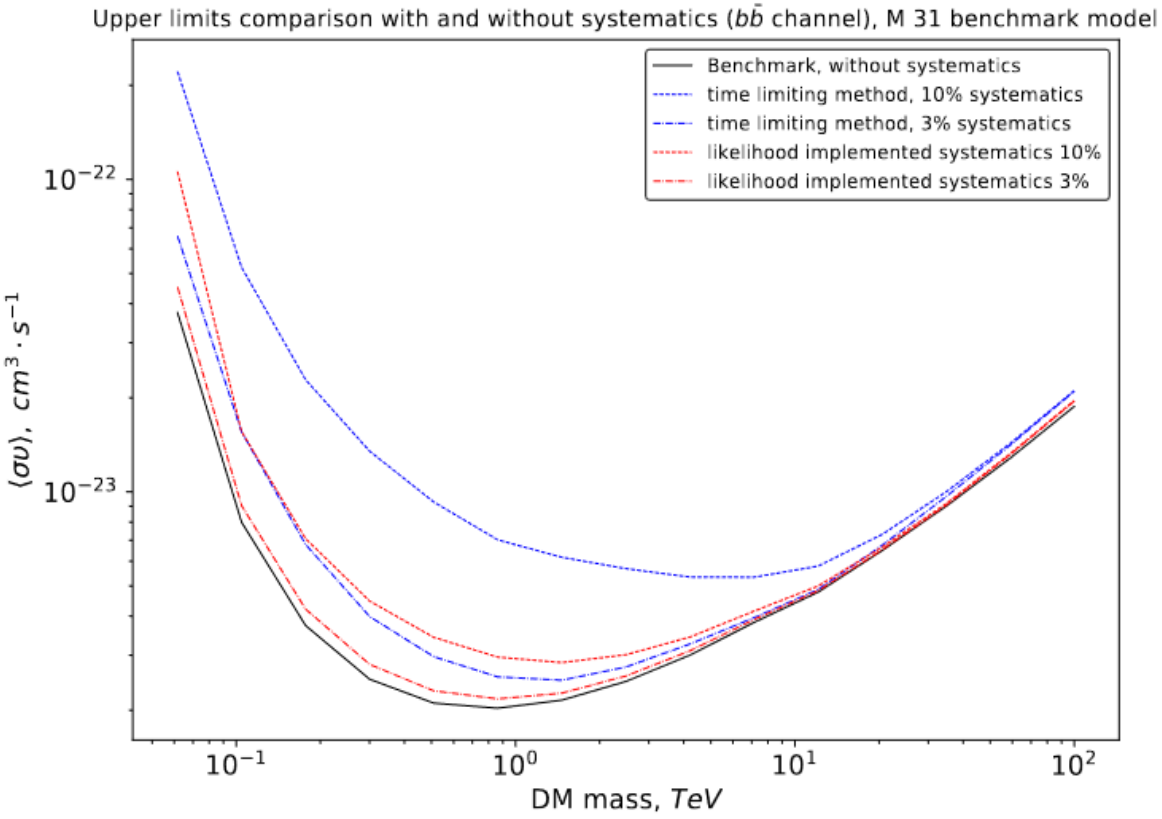
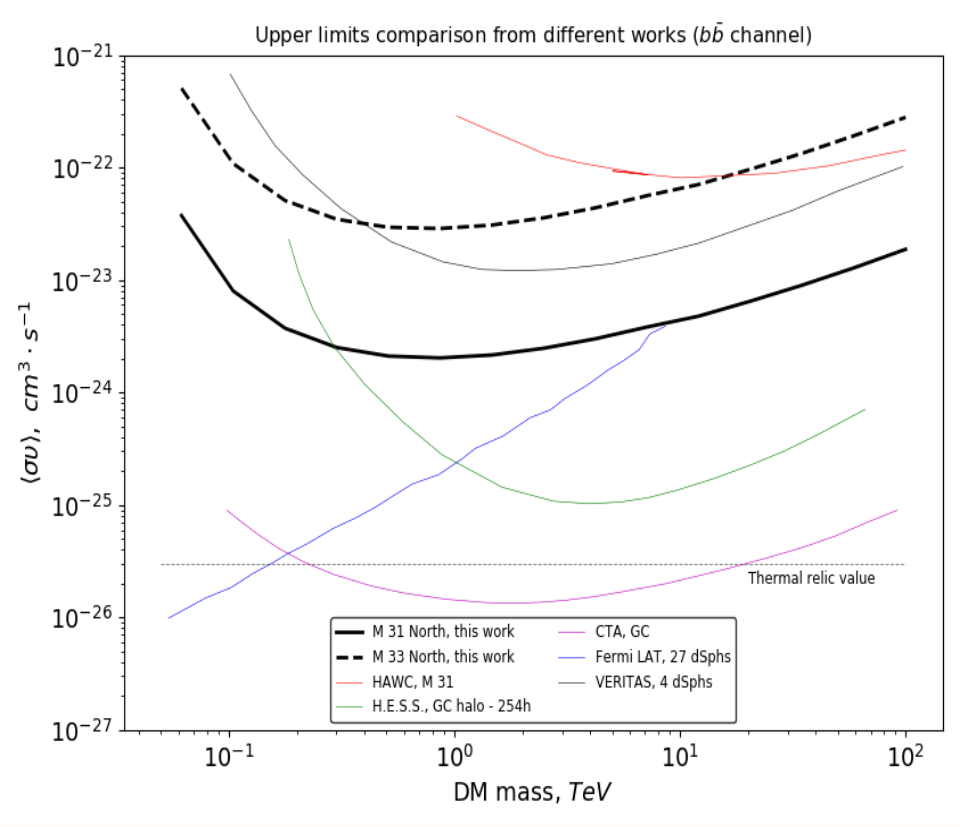


- **Likelihood implementation → red**
- **Time limiting method → blue**

Systematic uncertainty results:

- We considered 10% energy scale systematic uncertainties which resulted up to an order of magnitude worsening of the upper limits.
- We however explored lower levels of systematics (i.e., 1% and 3%) to illustrate the scientific gain of the decreased level of systematics which can be achieved with the next-generation instruments.
- Introducing the time limiting method allows us to propose a special CTA observation mode without entering the systematic uncertainty dominated region i.e., different targets can be observed by different types of CTA telescopes and by different time scales; managing to "free" some CTA time which can be dedicated to searches of other targets.

Is CTA sensitive enough?



Comparison of our work with the latest DM studies

Main conclusions:

- CTA does not appear sensitive enough to detect DM for the two targets considered in this work, for 100 hours exposure time.
- Current studies may present better sensitivity results (e.g., H.E.S.S. towards the GC), but they are targeting DM dominated regions at a much closer distance.
- CTA appears to be more sensitive than current IACTs (e.g., VERITAS) even when the latest perform stacked analysis towards DM dominated targets (e.g., dSphs).
- When considering common DM target (i.e., M 31) and assuming the same DM density distribution in that target (i.e., the Einasto benchmark profile for M 31 in this work) CTA is expected to be an order of magnitude more sensitive than HAWC (Albert et al. , 2018b).

Thank you!

Room for questions and discussion…