
cta
cherenkov
telescope
array
Gambit (Taylor Kitsch)
CoEPP
ARC Centre of Excellence for
Particle Physics at the Terascale
MONASH
University
ANCORA · IMPARO
GAMBIT

Outline

Dark matter indirect detection with CTA

Dark matter models: effective and simplified

CTA sensitivity for simplified models

Prelim results

What is GAMBIT?

Why global fit?

How to global fit?

What is DarkBIT?

DD & ID in GAMBIT

Prelim results

What ...

CTA science goals

Theme 1: Cosmic Particle Acceleration

How and where are particles accelerated?

How do they propagate?

What is their impact on the environment?

Theme 2: Probing Extreme Environments

Processes close to neutron stars and black holes?

Processes in relativistic jets, winds and explosions?

Exploring cosmic voids

Theme 3: Physics Frontiers beyond the SM

What is the nature of dark matter?

How is it distributed?

Is the speed of light constant for high energy photons?

Do axion-like particles exist?

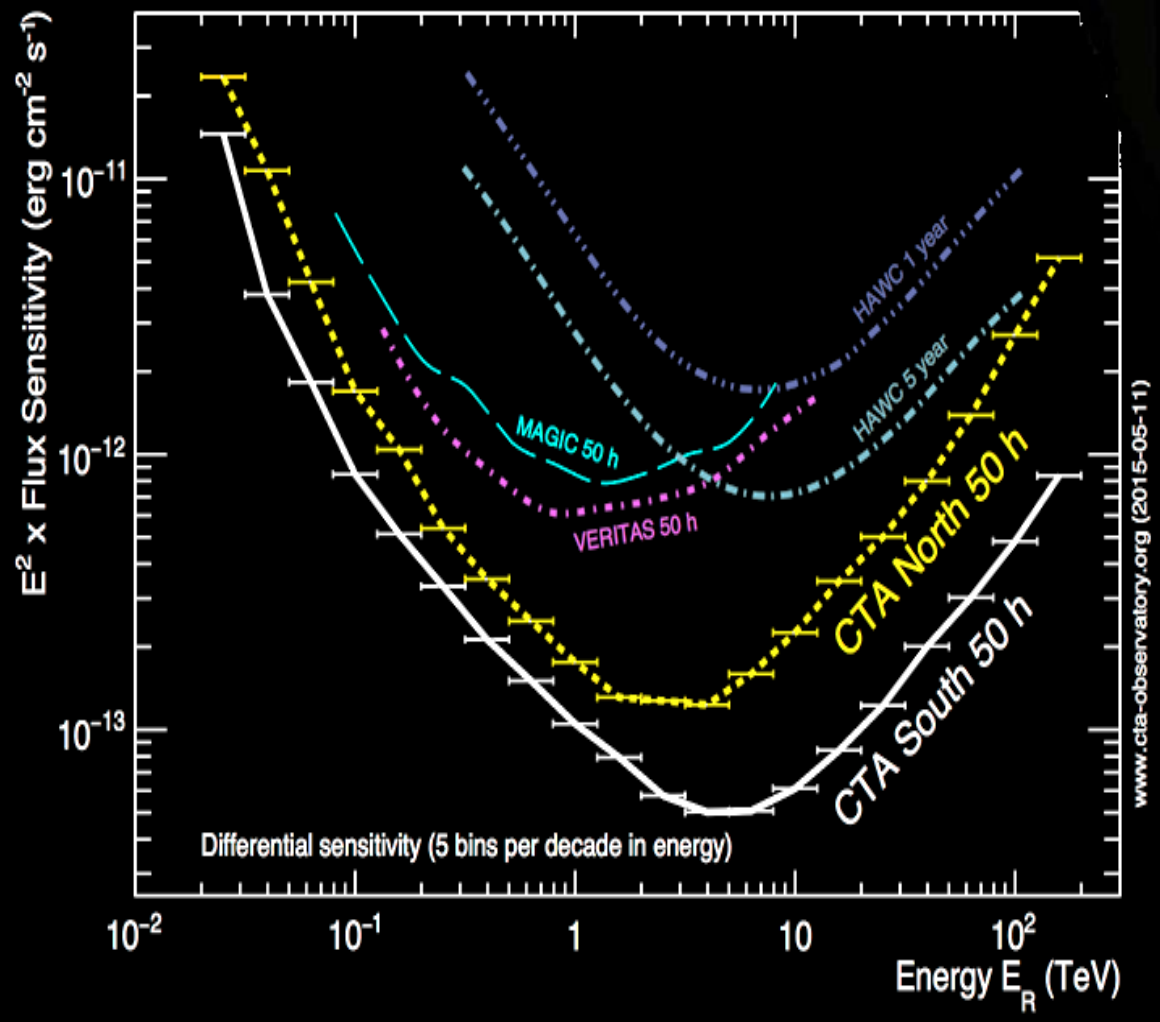
Global And Modular BSM Inference Tool collaboration

- **P. Athron, C. Balázs, F. Bernlochner, T. Bringmann, A. Buckley, M. Chrzaszcz, J. Conrad, J. Cornell, J. Edsjö, B. Farmer, A. Fowlie, T. Gonzalo, J. Harz, S. Hoof, L. Hsu, P. Jackson, F. Kahlhoefer, A. Krislock, A. Kvellestad, F. Mahmoudi, G. Martinez, J. McKay, M. Pato, A. Putze, A. Raklev, C. Rogan, R. Ruiz, P. Scott, N. Serra, R. Trotta, C. Weniger, S. Wild, M. White**
- ***theory: DarkSUSY, FlexibleSUSY, SoftSUSY, SuperBayes, SuperISO +***

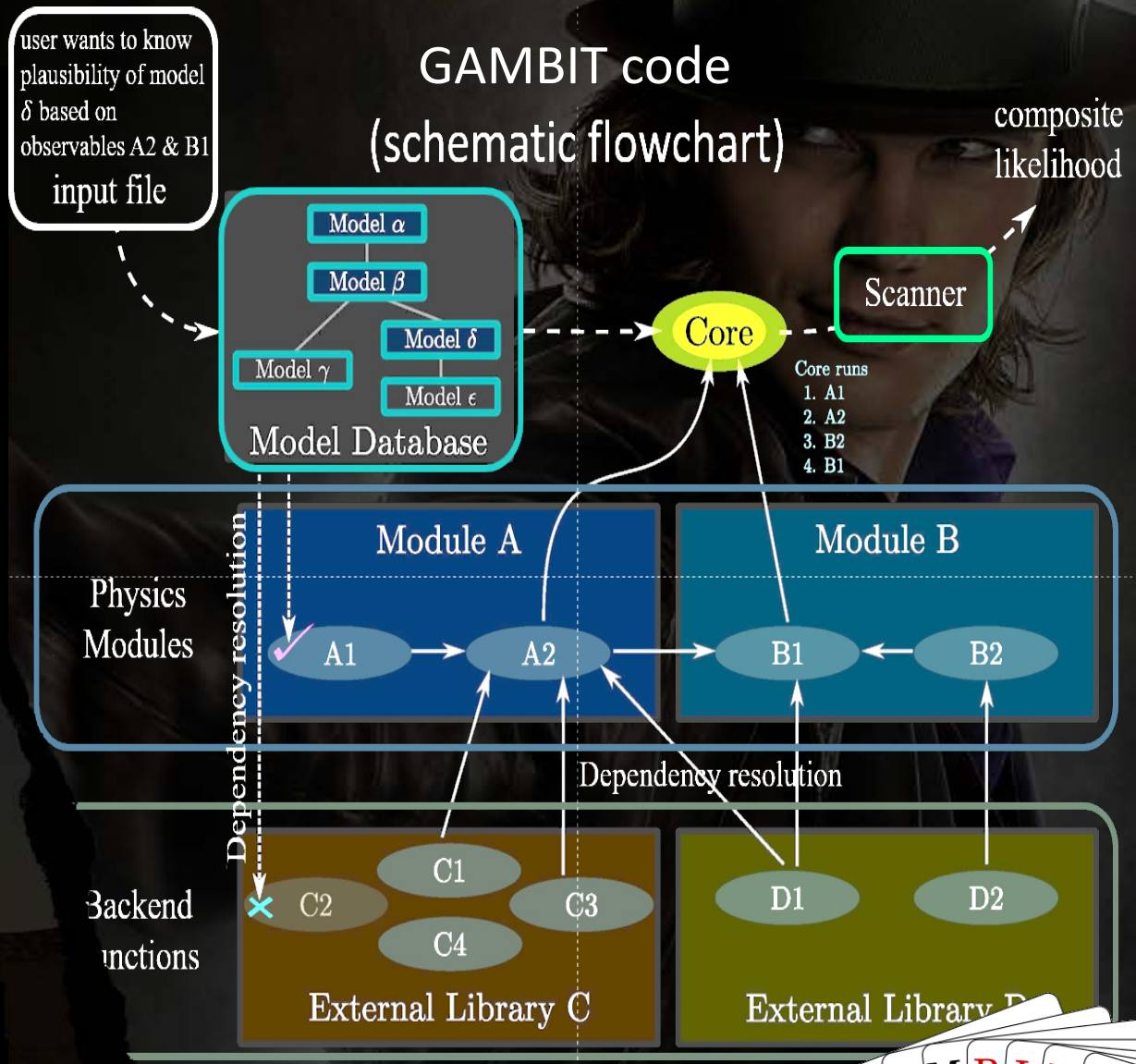
experiment: AMS-02, ATLAS, CDMS, CMS, CTA, DARWIN, DM-ICE, Fermi-LAT, HESS, IceCube, LHCb, XENON

What ...

CTA sensitivity



GAMBIT code (schematic flowchart)



Why …

Indirect detection with CTA

DM distribution in source & location relative to observer

Observation time

Detector effective area

$$N_{\gamma,DM} = \frac{t_{obs} J_{region} \langle \sigma v \rangle}{8\pi M_{\chi}^{\,2}} \int_{E_{min}}^{E_{max}} \frac{dN_{DM}}{dE}(E) A_{eff}(E) dE$$

No. of observed events

Energy spectrum of gamma rays produced in annihilation

Average DM to SM annihilation or decay rate

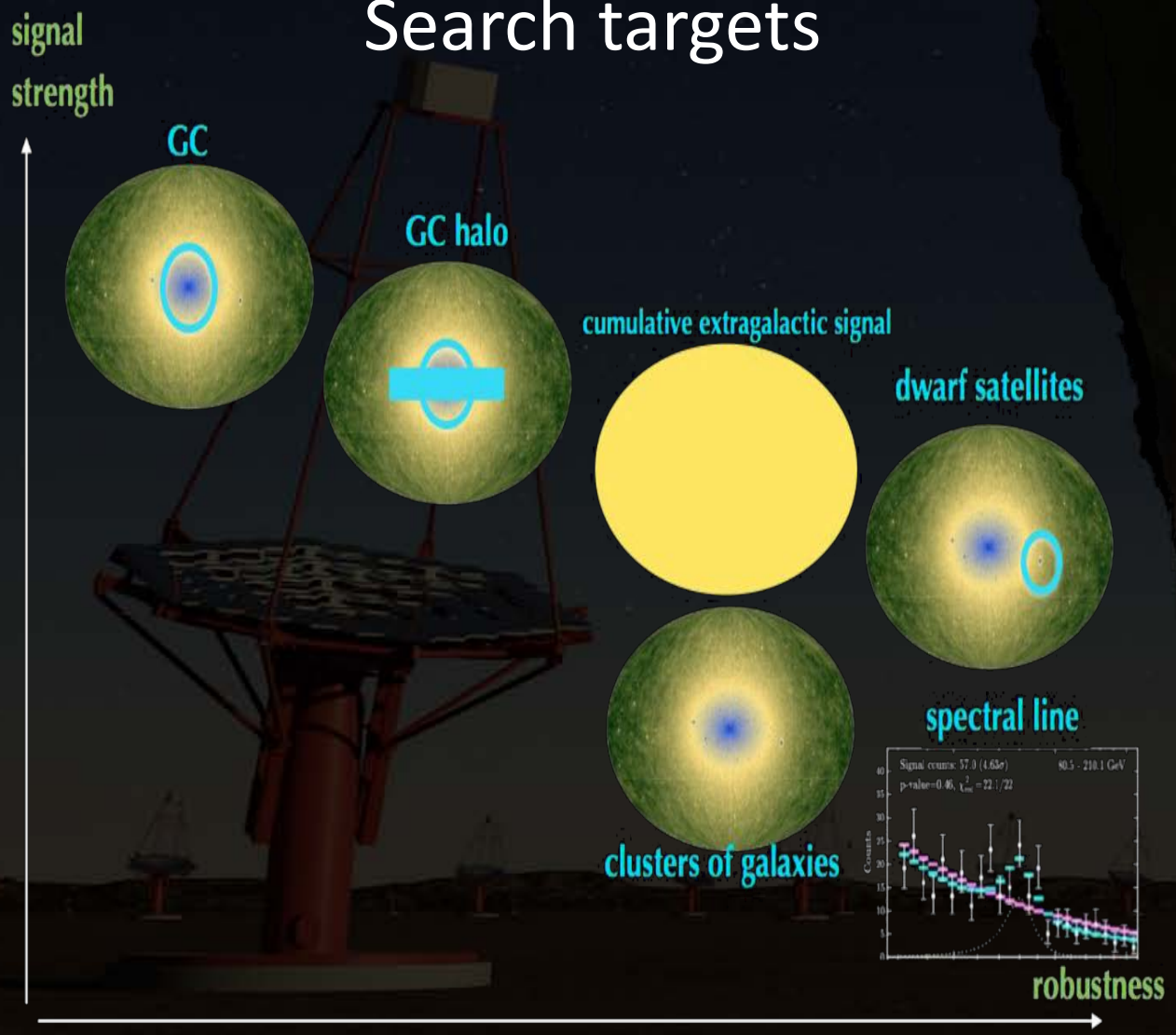
Global fit

- Will CTA find dark matter?
- Will SABRE detect dark matter?
- Can the LHC produce dark matter?
- What is dark matter?
- What is the meaning of life?
- etc…

Nobody knows that!

Why …

Search targets



Global fit

- What kind of dark matter can CTA find?
- Will SABRE be able to cover the mainstream dark matter models?
- What are the chances that the LHC produces dark matter in these models?

Which known dark matter model fits the best the data?

GAMBIT can calculate that!

How ...

Adopted pointing schemes

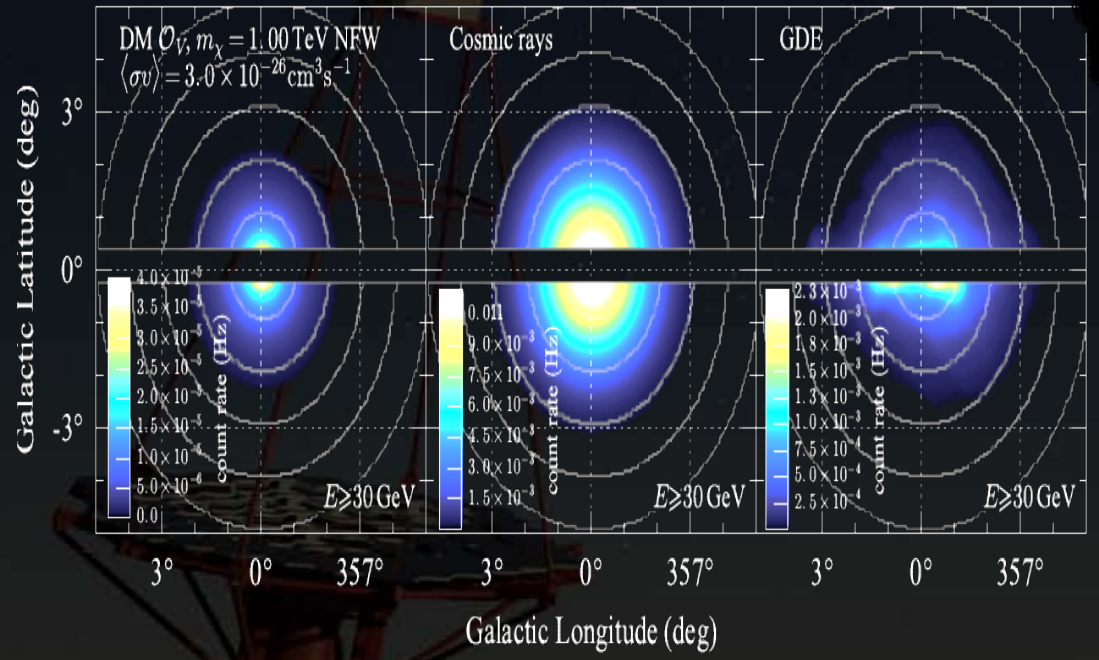


Figure 4. Adopted pointing schemes. From left to right the panels show the expected count rate for the different model components included here with (DM, CR, and GDE). For the DM, we show the expected rate for the $\mathcal{O}_V$ operator and $m_\chi = 1\,\text{TeV}$ with $\langle\sigma v\rangle = 3 \times 10^{-26}\,\text{cm}^3\text{s}$. *Top:* Pointing schemes for the morphological analysis adopted for the NFW profile. *Bottom:* True On/Off pointings for the cored Einasto profile.

GAMBIT workflow

0 choose a model, any model

1 calculate predictions for as many running or past experiments as humanly possible

2 extract the best fitting values of the model parameters

3 calculate the reach of near future experiments

4 answer the questions on the previous slide

5 take the next model and goto 1


THEORIES
PREUVES

How ...

Models in GAMBIT

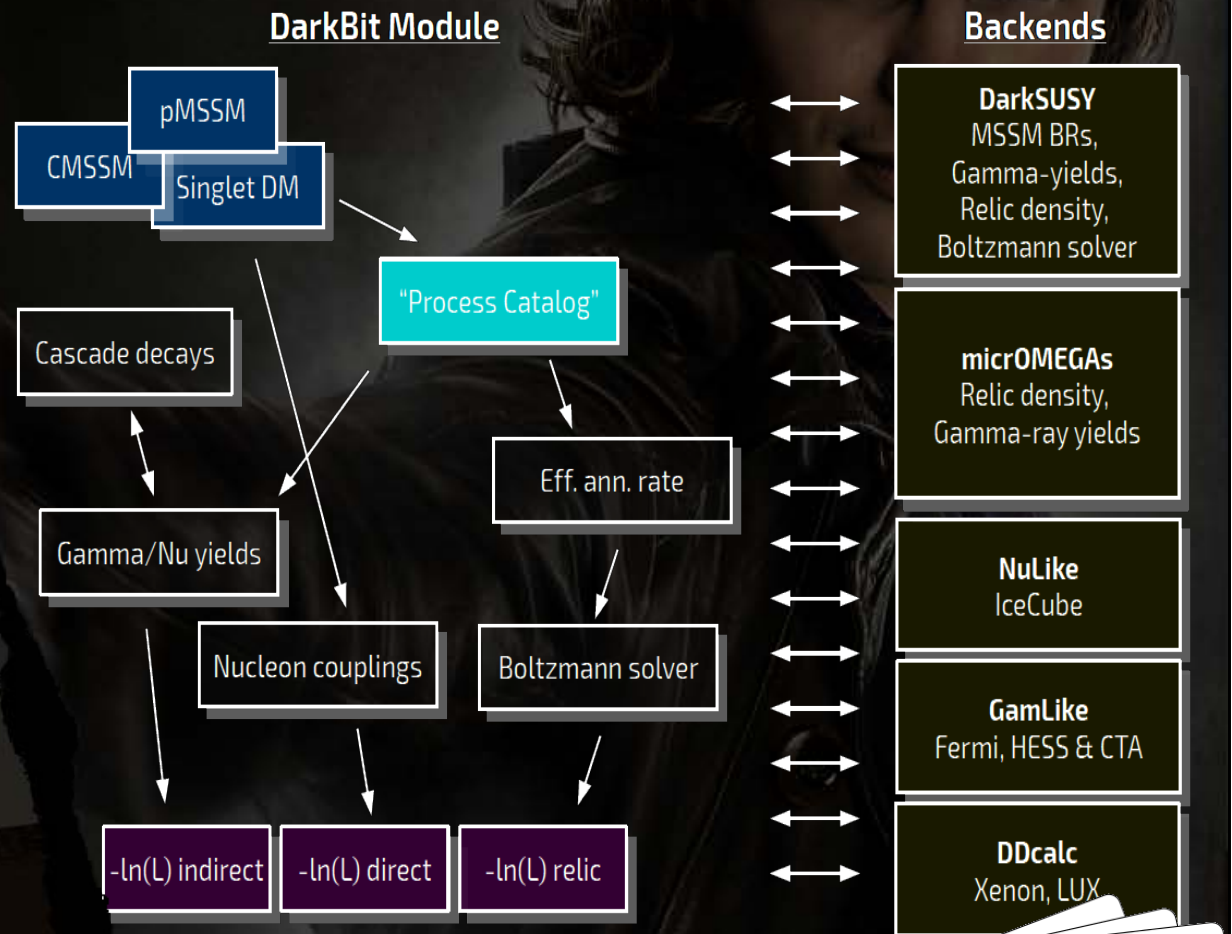
- models are crucial in global fitting
- selecting a narrow set of models biases the answers to the big questions
- GAMBIT has a model database, and
- by construction GAMBIT
  - accepts new models
  - accepts new observable calculators
  - can take the next model and goto 1
- GAMBIT puts the global into global fitting

How ...

Dark matter models

arXiv:1506.03116

GAMBIT DarkBit



cherenkov telescope array

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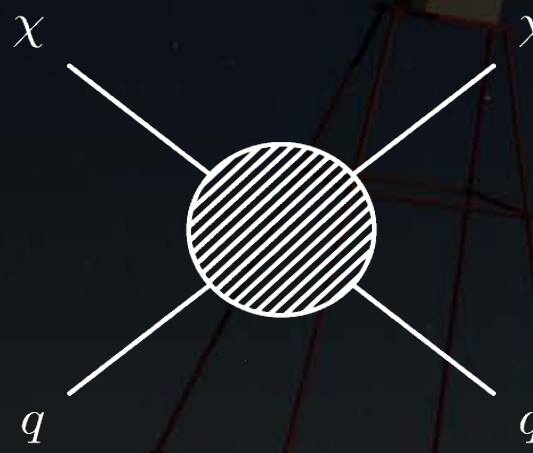
Effective and simple DM models



$$\mathcal{O}_S = \frac{m_q}{M_\star^3}(\bar{\chi}\chi)(\bar{q}q)$$

$$\mathcal{O}_P = \frac{m_q}{M_\star^3}(\bar{\chi}\gamma^5\chi)(\bar{q}\gamma^5 q)$$

$$\mathcal{O}_V = \frac{1}{M_\star^2}(\bar{\chi}\gamma^\mu\chi)(\bar{q}\gamma_\mu q)$$

$$\mathcal{O}_A = \frac{1}{M_\star^2}(\bar{\chi}\gamma^\mu\gamma^5\chi)(\bar{q}\gamma_\mu\gamma^5 q)$$

$$\mathcal{L}_S = -g_\chi\phi\bar{\chi}\chi - \sum_q g_q\phi\frac{m_q}{\text{vev}}\bar{q}q$$

$$\mathcal{L}_P = -ig_\chi\phi\bar{\chi}\gamma_5\chi - \sum_q ig_q\phi\frac{m_q}{\text{vev}}\bar{q}\gamma_5 q$$

$$\mathcal{L}_V = -g_\chi Z'_\mu\bar{\chi}\gamma^\mu\chi - \sum_q g_q Z'_\mu\bar{q}\gamma^\mu q$$

$$\mathcal{L}_A = -g_\chi Z'_\mu\bar{\chi}\gamma^\mu\gamma_5\chi - \sum_q g_q Z'_\mu\bar{q}\gamma^\mu\gamma_5 q,$$

DarkBit: indirect detection

- annihilation yield calculation: DarkSUSY, micrOMEGAs, PPPC, BYO!

input: DM model, output: $\langle\sigma v\rangle$

- interface to most relevant Fermi-LAT, Cherenkov, line-search likelihood fn.s covering the GC (HESS, Fermi, CTA), dSphs and more

input: $\langle\sigma v\rangle$, output: likelihood

orrect treatment of energy dispersion spectral singularities

ncertainties are marginalized over

cherenkov telescope array

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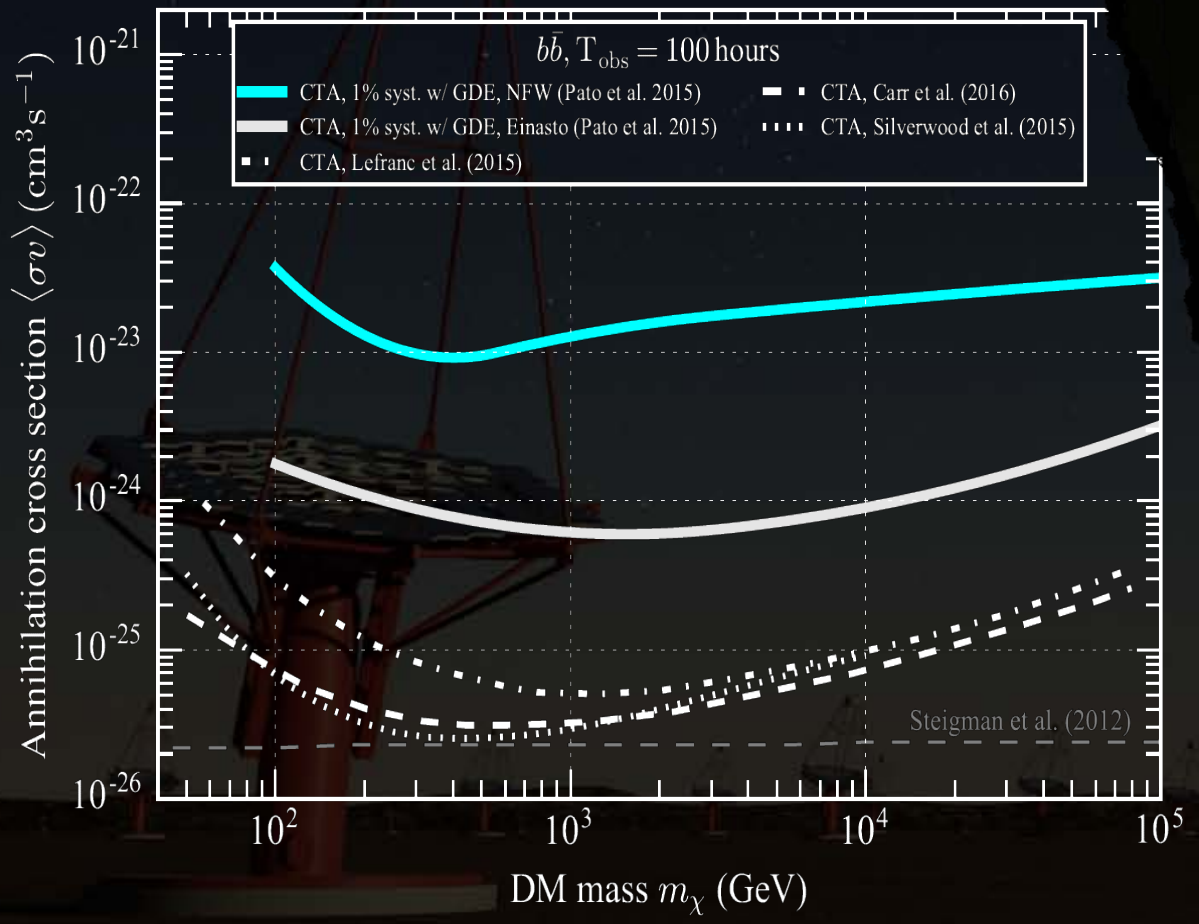
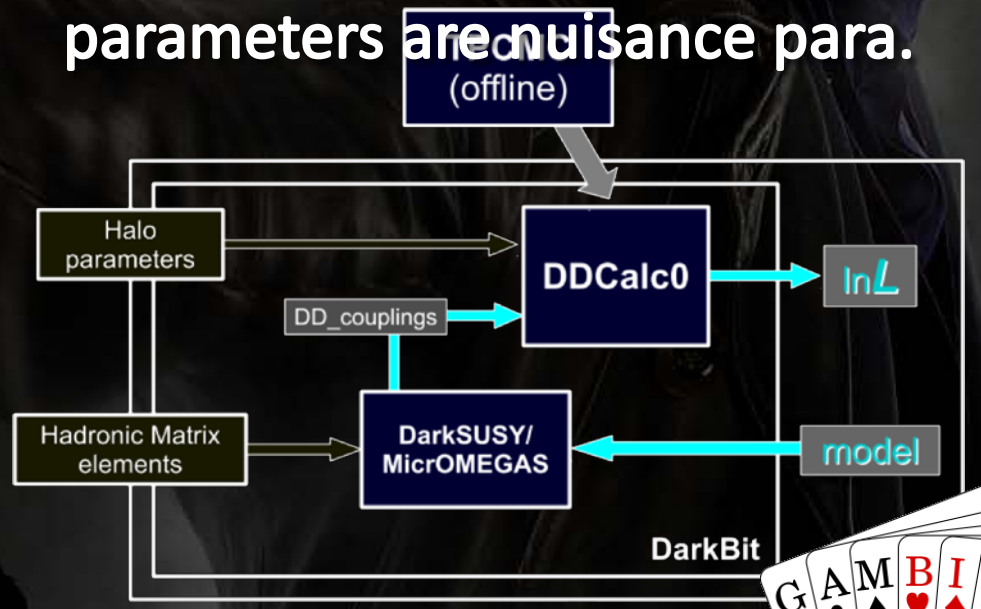
Upper limits on annihilation into bb̄



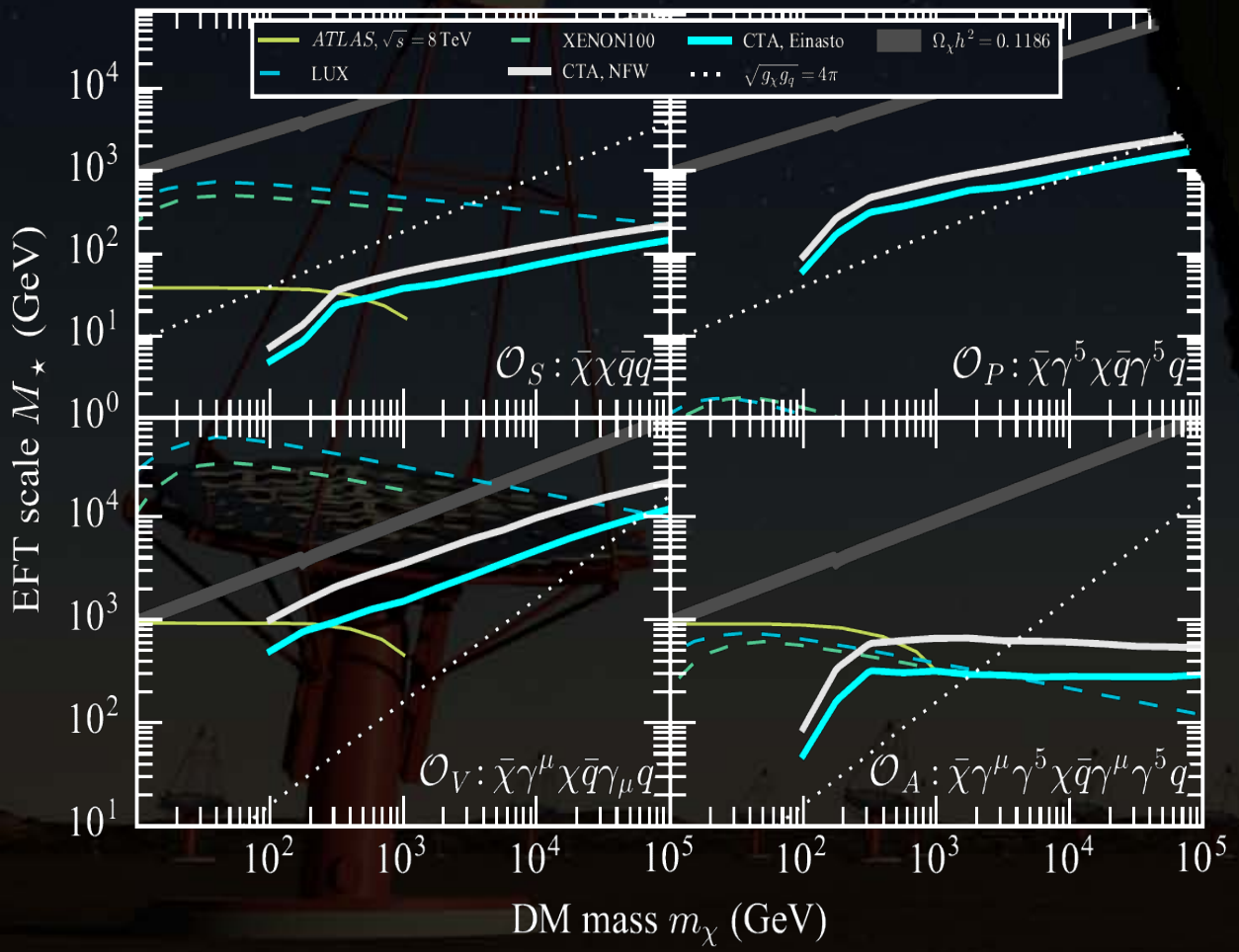
DarkBit: direct detection

- accurate likelihoods for XENON, LUX, SuperCDMS, DARWIN-Ar, DARWIN-Xe
- DM-nucleon cross section by DarkSUSY, micrOMEGAs, or BYO!
- hadronic matrix elements, halo parameters are nuisance para.

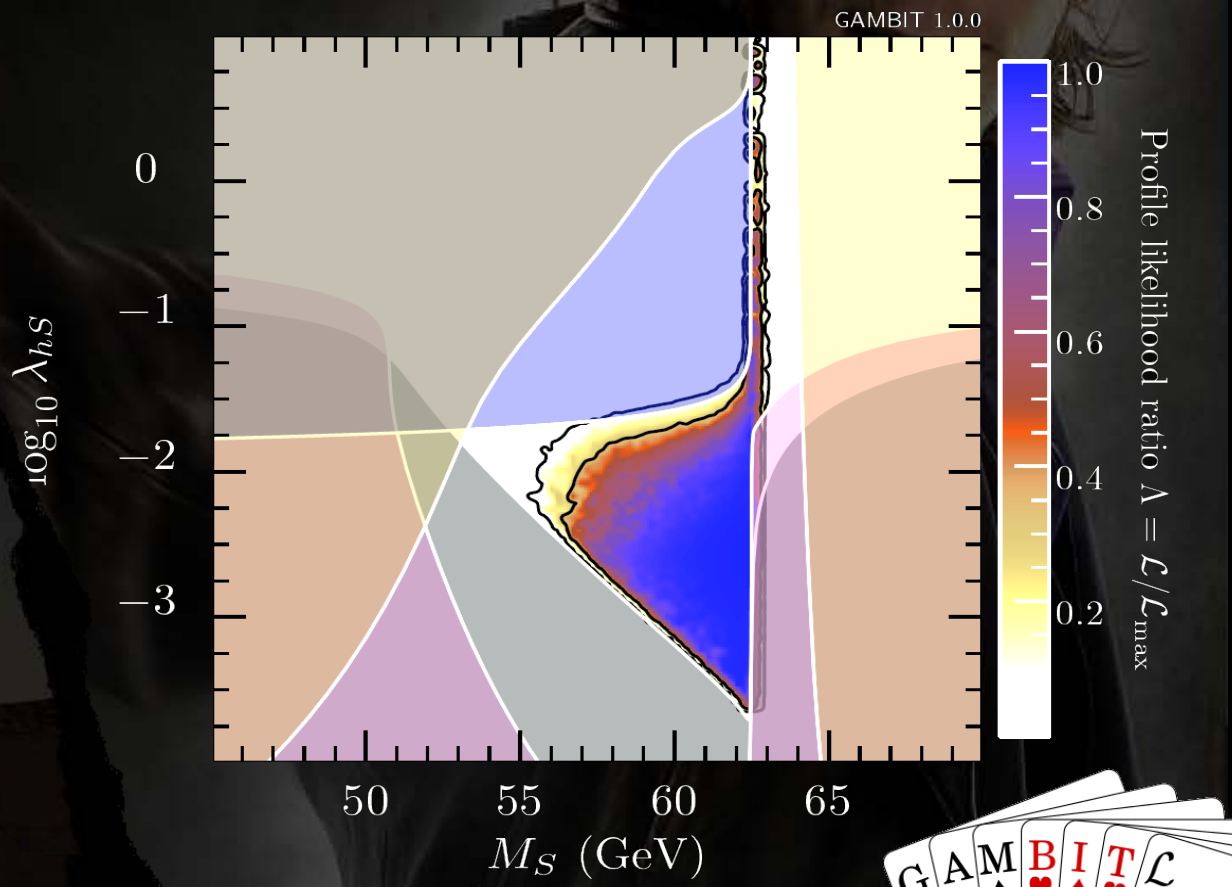


Results

Limits on new physics scale



GAMBIT results are in for 2HDM, SM+SS, axions, Higgs portal, CMSSM, NUHM1, NUHM2, MSSM7, flavor EFTs, …



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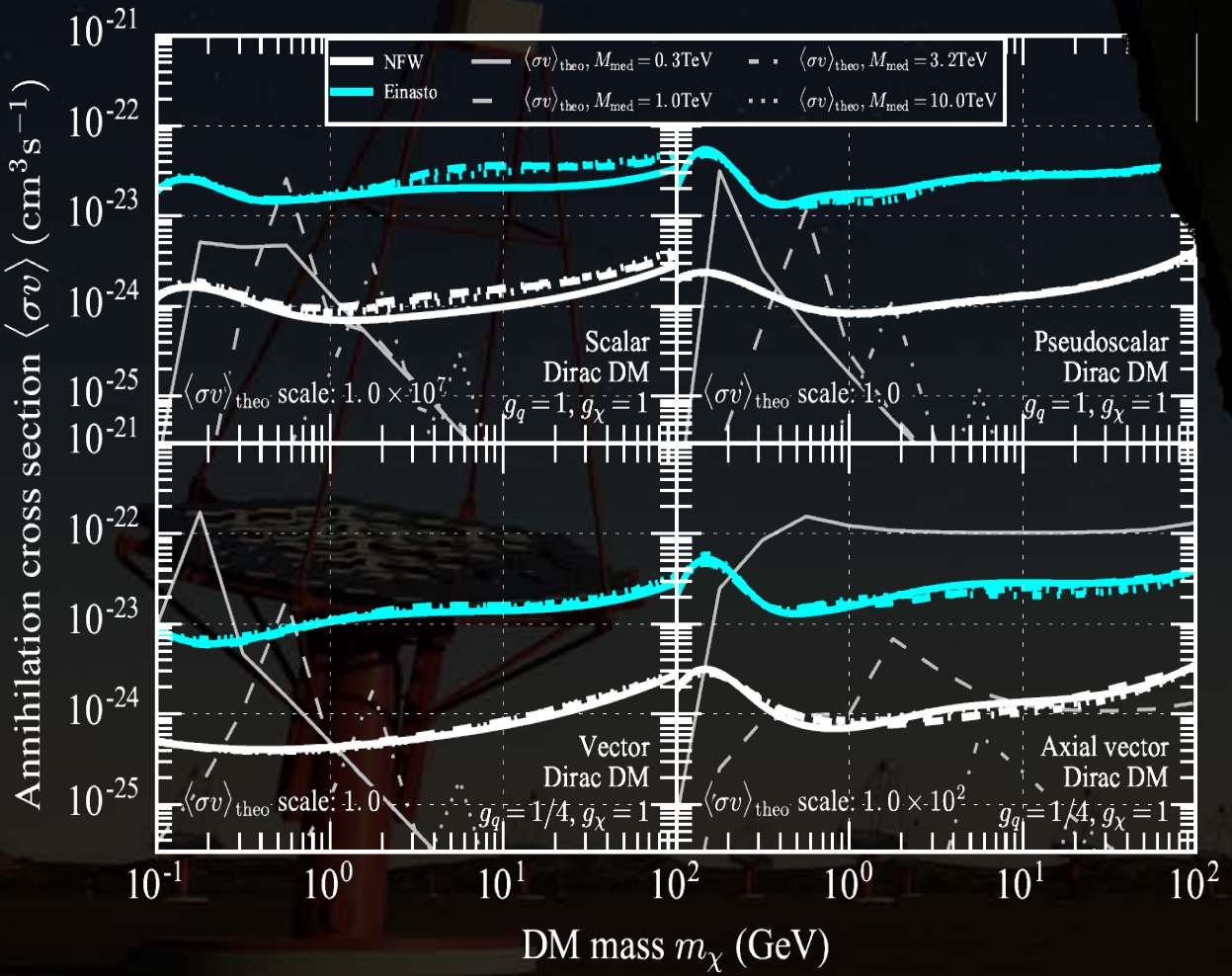

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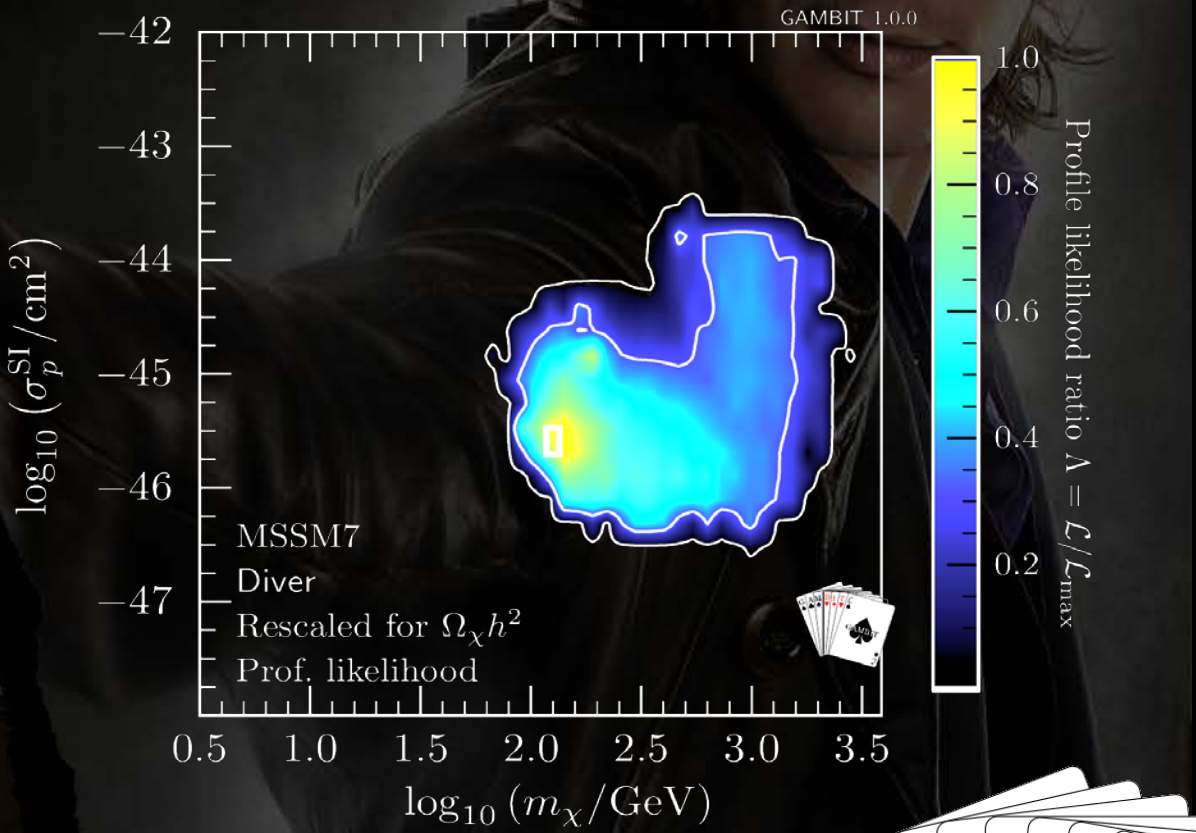

Summary

- CTA will be the most sensitive instrument for high energy gamma rays
- Indirect dark matter search appears to be the most promising by pointing CTA to the Galactic Centre
- The devil of dark matter detection with CTA are in the details

- GAMBIT is a next generation global fitting tool
- GAMBIT is flexible to accommodate any models and any observable calculators
- By design GAMBIT is able to address a wide rage of questions of (dark matter) phenomenology
- Stay tuned: GAMBIT the movie is coming soon!