DARK FLUX

PRESS START

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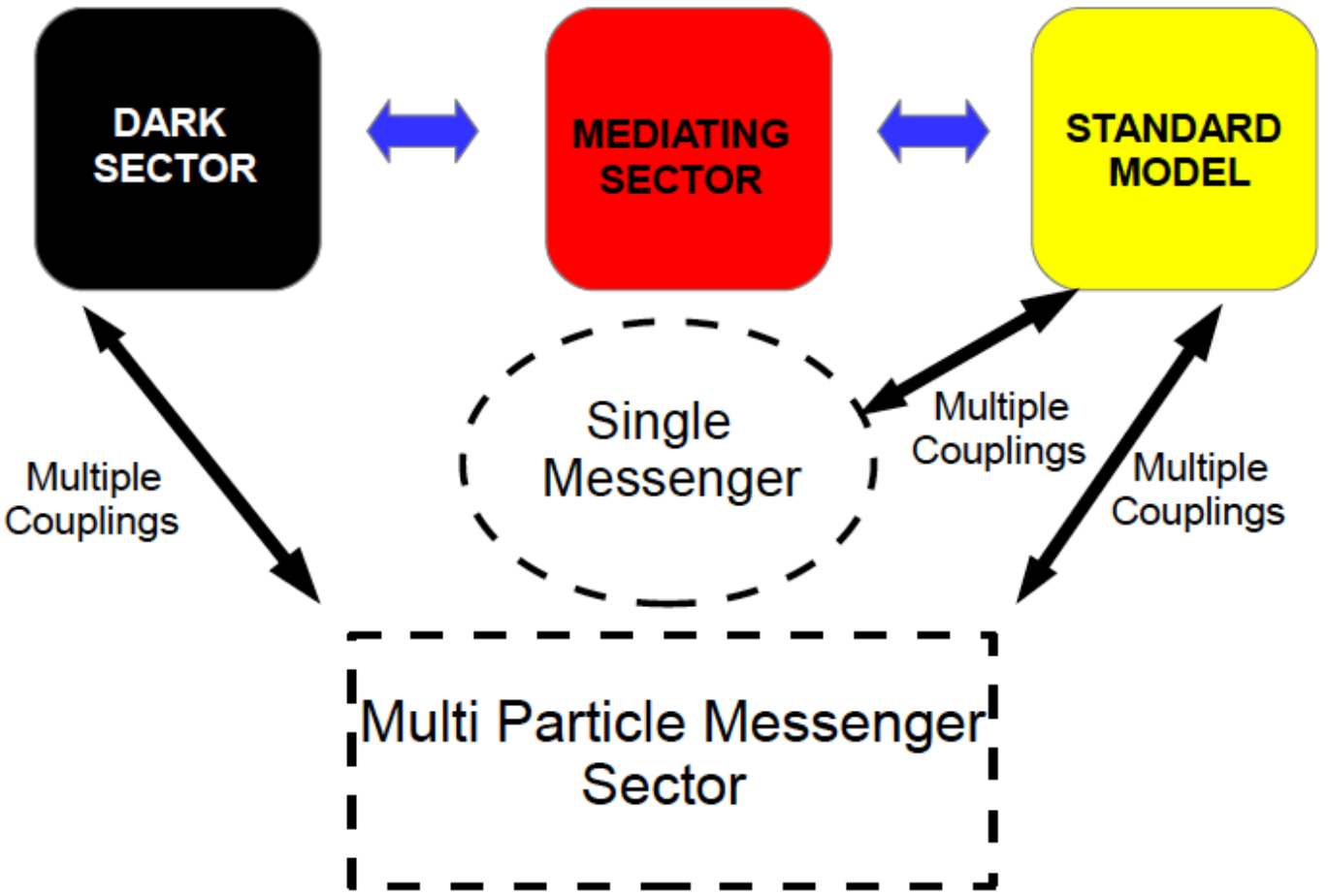
Built from Code written in *arXiv:1506.08841* and *arXiv:1606.04138* with Russell Colburn, Jessica Goodman and Tim Linden

Coupling to the Dark Sector

Next Generation Models

- **Theoretically consistent** extension of a simplified model
- Generic enough to be used in the context of broader, more complete theoretical frameworks
- Varied phenomenology to encourage comparison of different experimental signals and to search for DM in new, unexplored channels
- Be of interest beyond the DM community, to the point that other direct and indirect constraints can be identified.

ArXiv:1810:09420

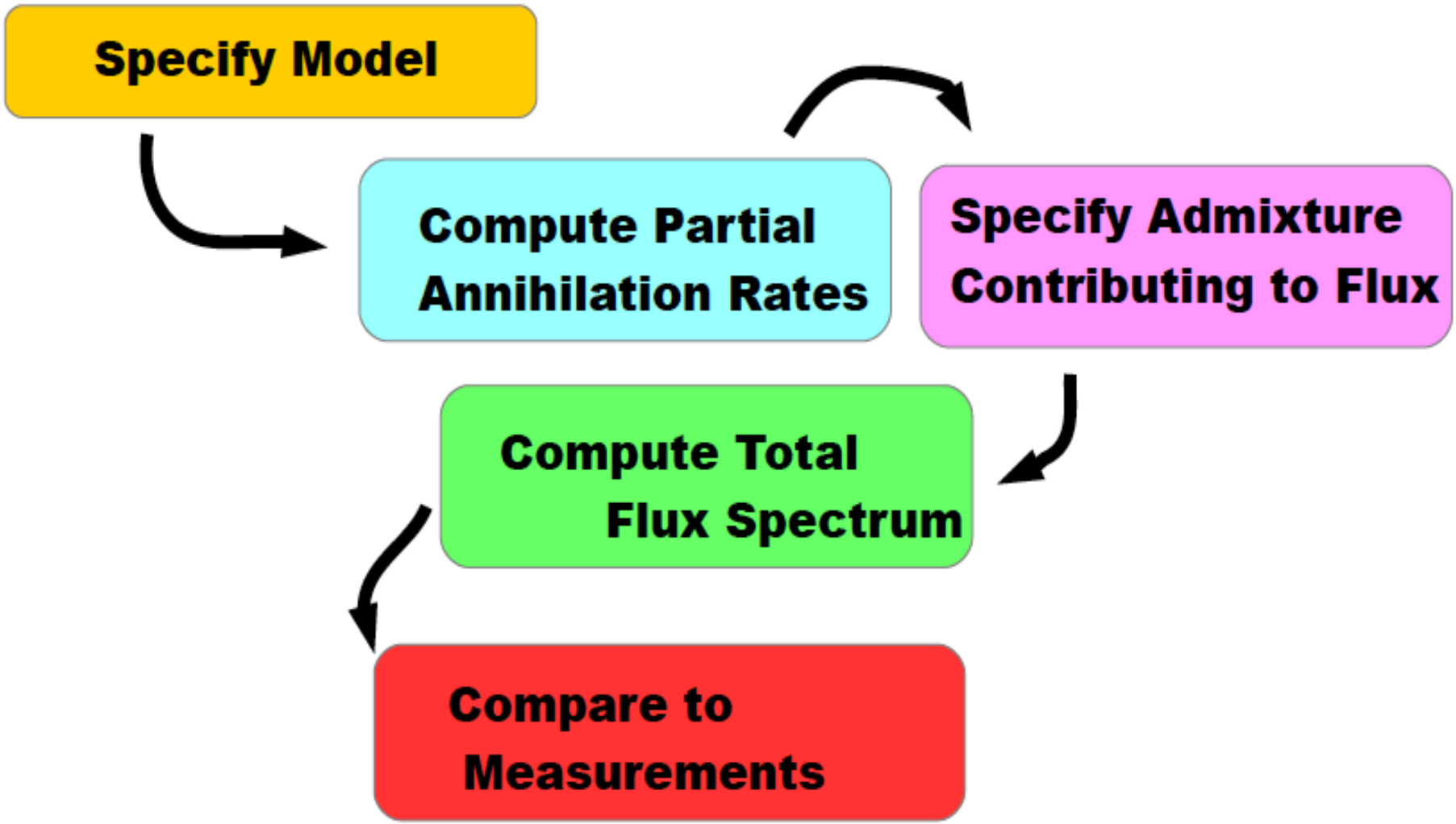

DARK SECTOR
MEDIATING SECTOR
STANDARD MODEL
Single Messenger
Multiple Couplings
Multiple Couplings
Multiple Couplings
Multi Particle Messenger Sector

Dark Flux

Computes the indirect annihilation spectrum for generic models with DM annihilations to multiple final state particles

- Currently handles total photon flux of 2-2 processes where DM annihilates to SM particles consistant with symmetries

ll,qq,gg,WW,ZZ,γγ, Zγ,Zh,hh


Specify Model
Compute Partial Annihilation Rates
Specify Admixture Contributing to Flux
Compute Total Flux Spectrum
Compare to Measurements

Partial Annihilation Rates

The total annihilation rate sums all channels

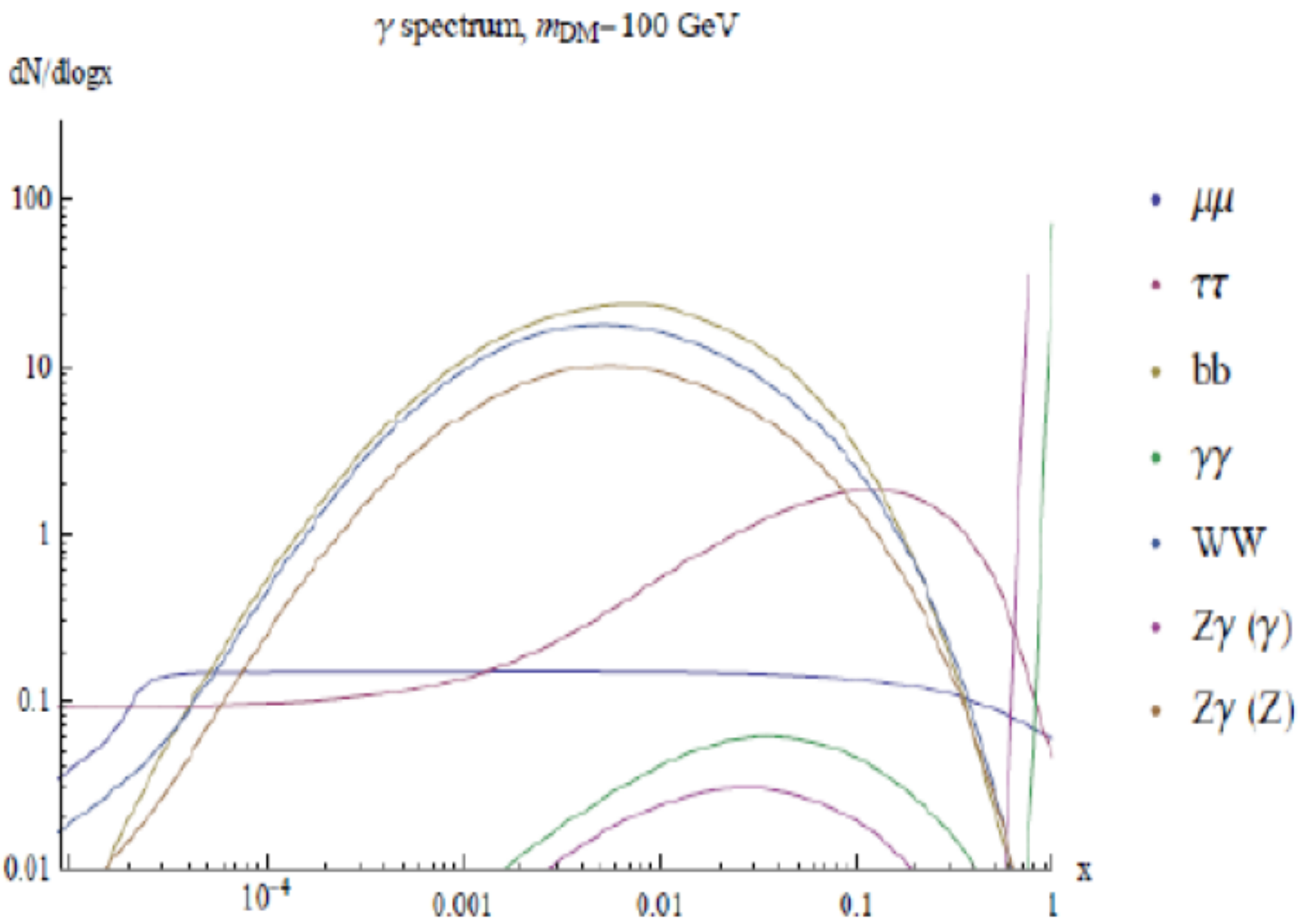
$$\Sigma \langle \sigma v \rangle_i = \langle \sigma v \rangle_{Total}$$

In analogy to branching fractions we define the partial rates R_i

$$R_i = \langle \sigma v \rangle_i / \langle \sigma v \rangle_{Total}$$

With the constraint

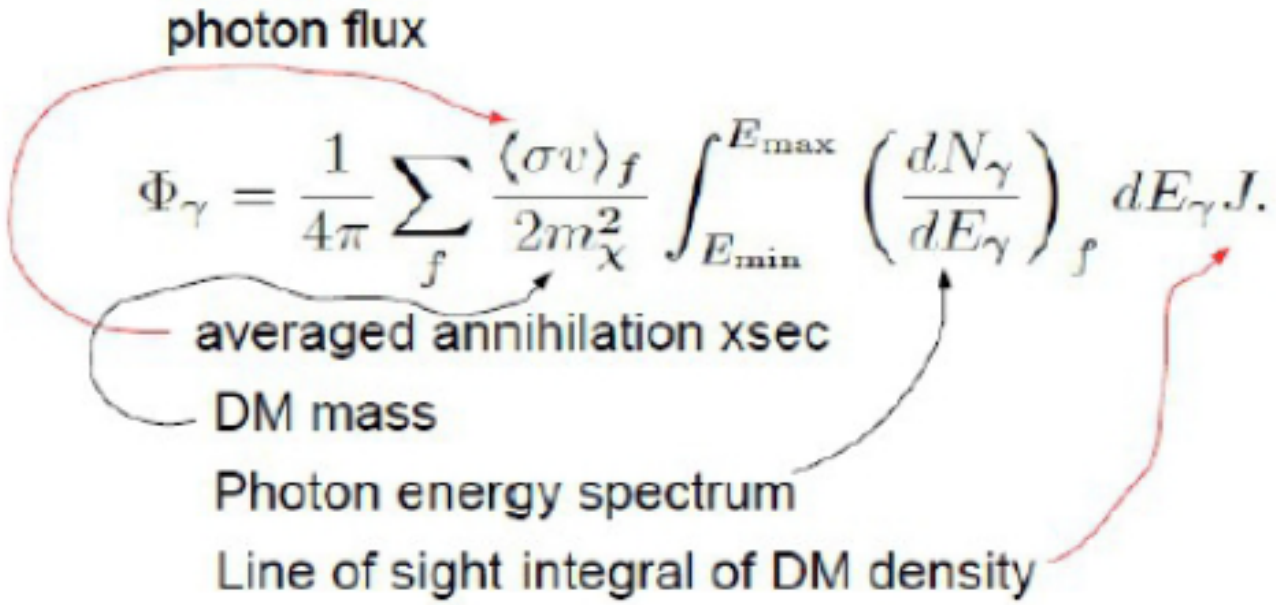
$$\Sigma R_i = 1$$


γ spectrum, m_{DM} = 100 GeV
dN/dlogx
100
10
1
0.1
0.01
10^{-4}
0.001
0.01
0.1
1
x
μμ
ττ
bb
γγ
WW
Zγ (γ)
Zγ (Z)

Fermi Dwarf Analysis

Dwarf Spheroidal Galaxies large amount of DM

Low Astrophysical Background

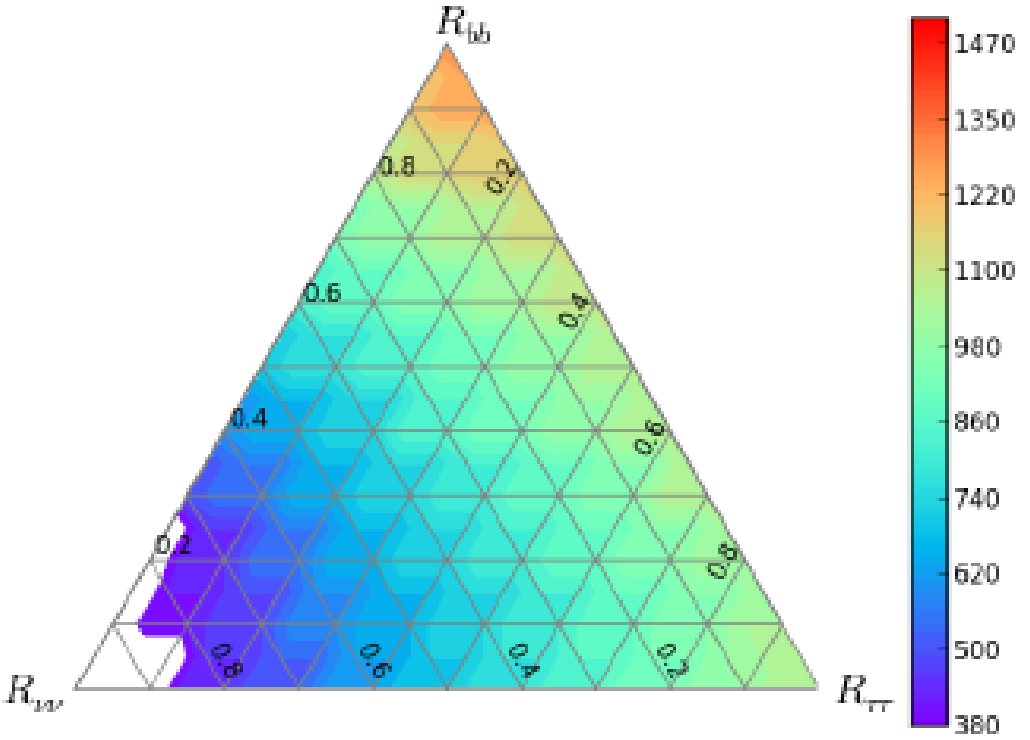


$$J = \int_{\Delta\Omega} \int_{l.o.s} \rho^2(\mathbf{r}) dl d\Omega'.$$

Example of effect of varying DM annihilationfraction

$$\mathcal{L}_{\mathrm{f}} = \frac{\kappa_f}{\Lambda_f^2} \chi \gamma^\mu \overline{\chi} f \gamma_\mu \overline{f}$$

Spin 1 simplified moel completion
Thermal annihilation rate

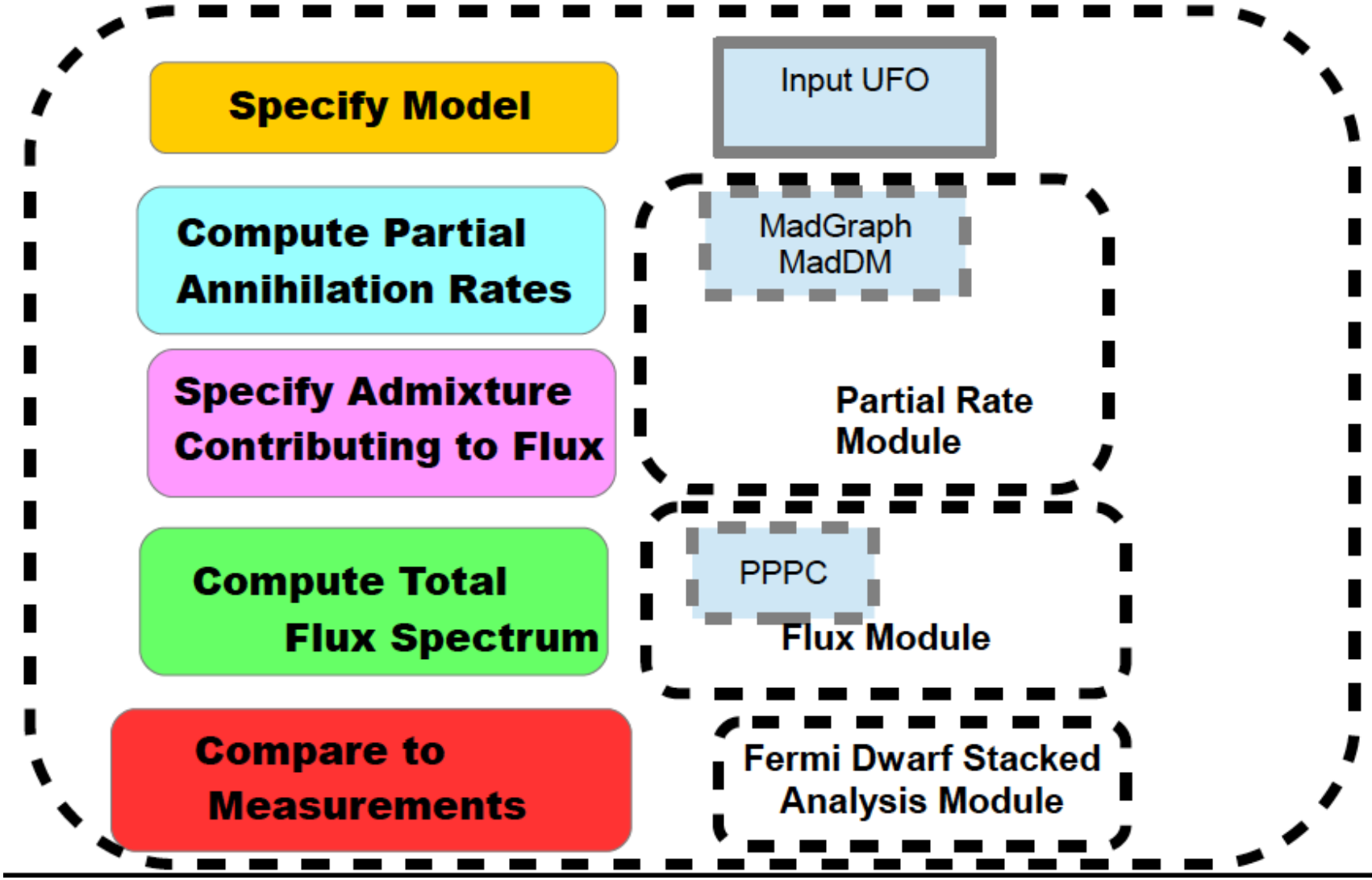


From 1606.04138

Input standard UFO file format

Scans DM masses to compute and plot annihilation fractions with options for mass step size

Uses stack of 15 Dwarf galaxies with highest J factors to compute flux for each DM mass and finds limit

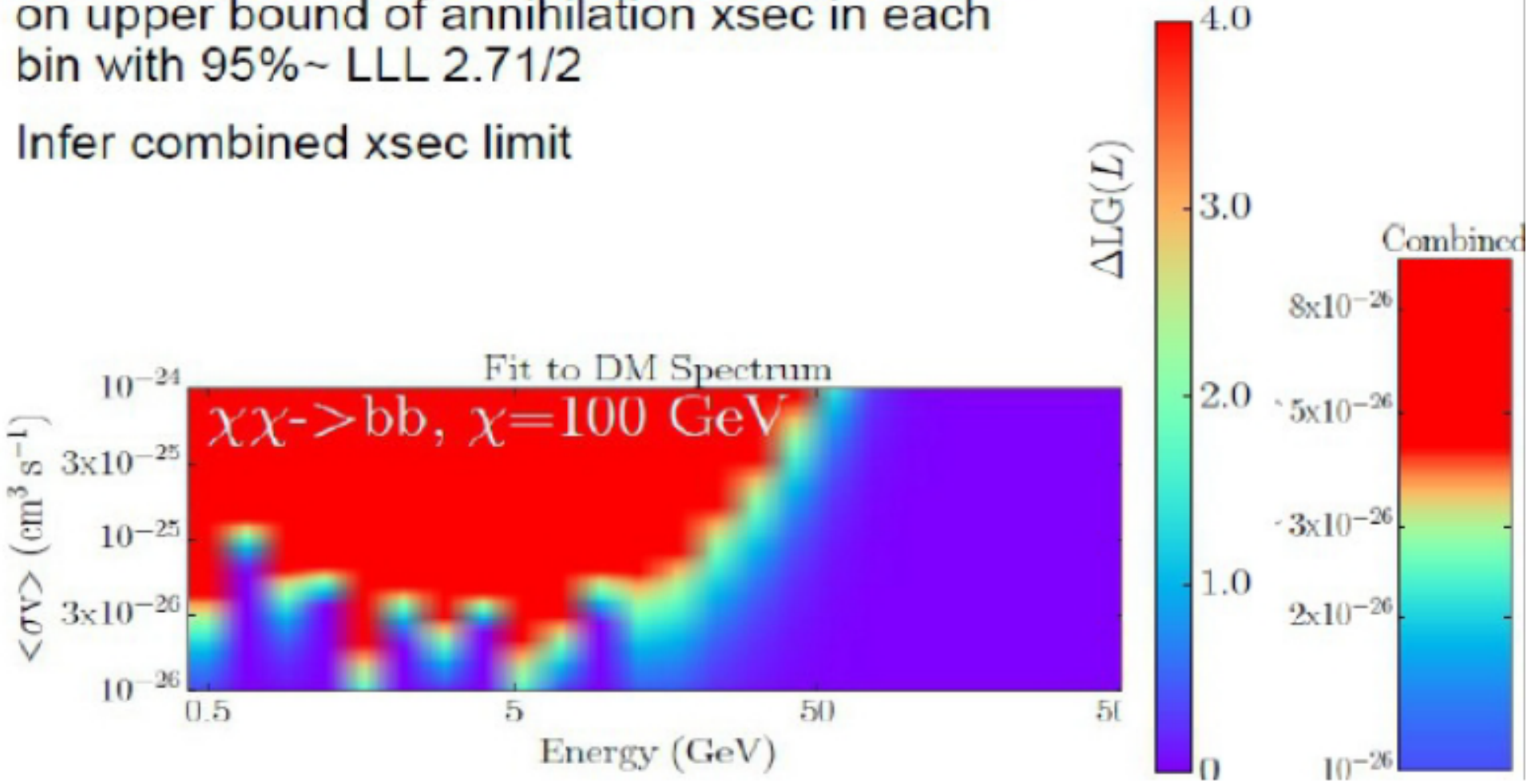

Specify Model
Input UFO
Compute Partial Annihilation Rates
MadGraph MadDM
Partial Rate Module
Specify Admixture Contributing to Flux
Compute Total Flux Spectrum
PPPC
Flux Module
Compare to Measurements
Fermi Dwarf Stacked Analysis Module

Choose DM mass and annihilation channel

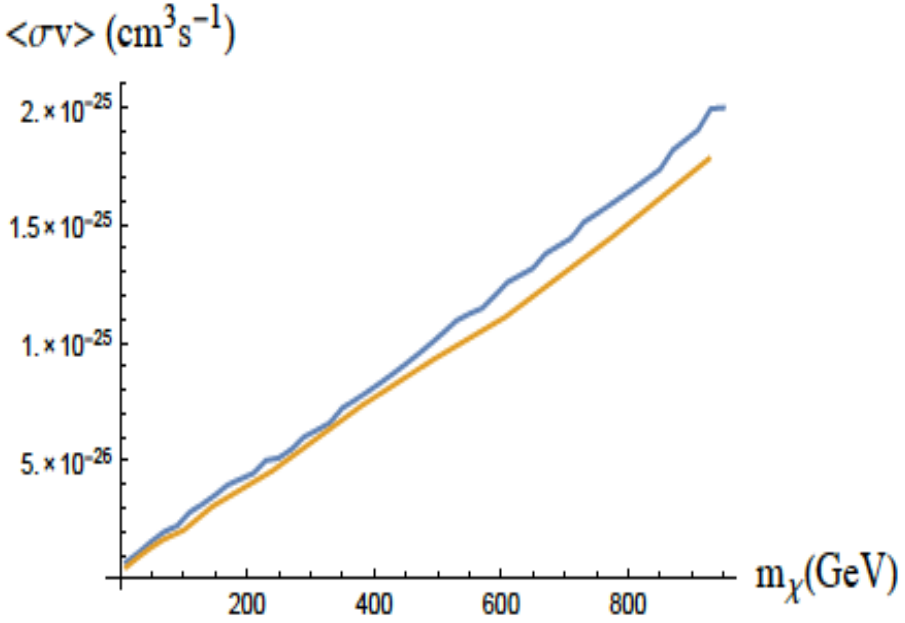
Allow J factor to float with Least Log Likelihood cost $\Delta LG(\mathcal{L}) = (J_{bf} - J_{meas})^2 / (2\sigma_j^2)$

Compare to null hypothesis no DM to set limit on upper bound of annihilation xsec in each bin with 95%~ LLL 2.71/2

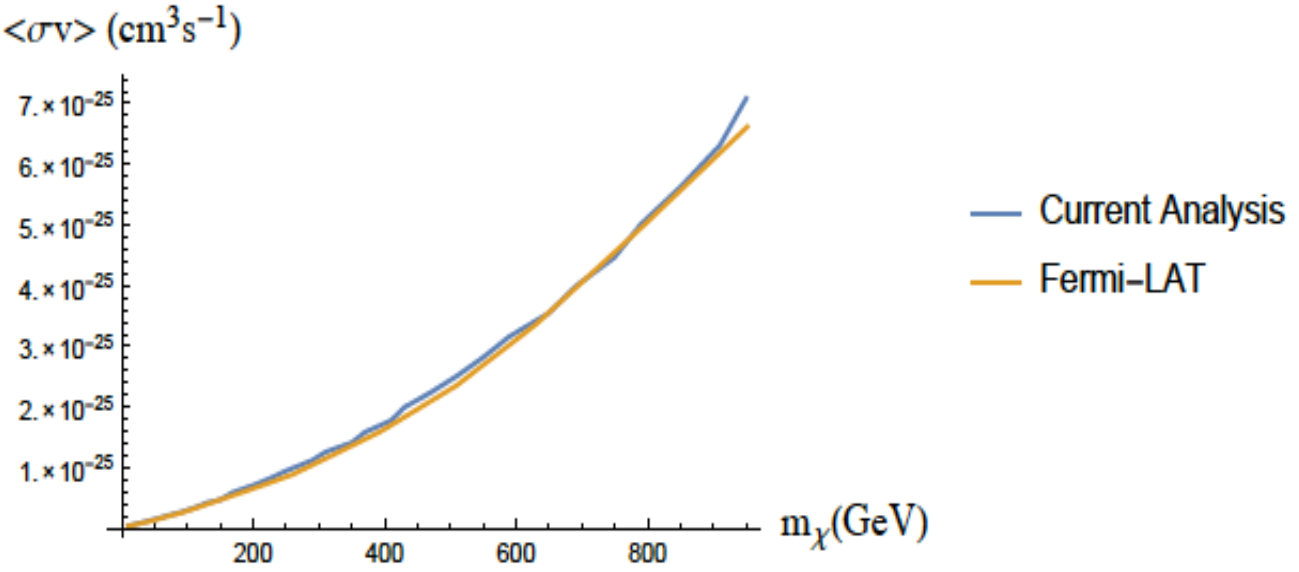
Infer combined xsec limit



$\chi\chi \rightarrow bb$



$\chi\chi \rightarrow \tau\tau$



run_inputs.dat

```
#*************************************************
# Scanning Dark Matter mass(GeV)                 *
#                                                *
# Steps and range for this tool                  *
# Mdm<=100: step = 5,10                          *
# 100<Mdm<1000: step = 10,50,100                 *
#                                                *
# limit indicates numbers of steps one will take *
#*************************************************
190 = Mdm_i
3 = limit
10 = step
```

```
DMsimp_s_spin1_MD = model_name
#********************
# Name tag for DM  *
#********************
~xd = dm_name
#************************
# Name tag for DM mass  *
#************************
MXd = dm_mass_name
```

Option to change model parameters

For example setvarious couplings to mediators

```
#*******************************************************
# Set other model parameters                           *
#                                                      *
# Please set as many as your model parameters below    *
# following the conventions                            *
# parameter_tag1 value_tag1 set                        *
# parameter_tag2 value_tag2 set                        *
# parameter_tag3 value_tag3 set                        *
#                  ...                                 *
#*******************************************************
```

outputs

- results.txt contains table of annihilation rates and flux bins for a given dark matter mass
- xsec_limits.dat contains a table of xsec vs DM mass
- xsecbymass.pdf plot of xsec limit vs. mass
- spectrabymass.pdf plot of total flux vs energy for each DM mass
- ratebymass.pdf plot of annihilation fraction vs. DM mass for each channel

results.txt

```
mass 190
rate1 0.196348
rate2 0.196348
rate3 0.196348
rate4 0.196348
rate5 0.196348
rate6 0.0182591
rate7 0
rate8 0
rate9 0
Rate10 0
Rate11 0
Rate12 0
Rate13 0
Rate14 0
Rate15 0
Rate16 0
sv 5.49540844E-26
```

DM mass

partial annihilation rates

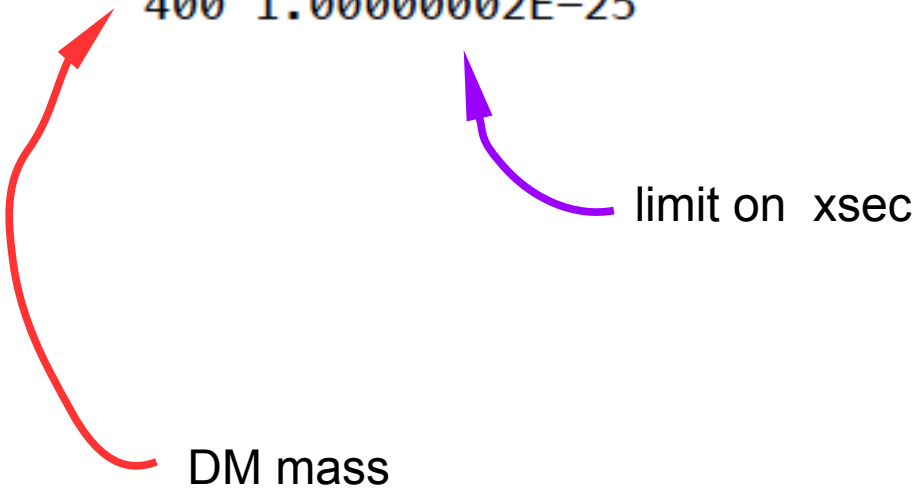
Total thermal average rate

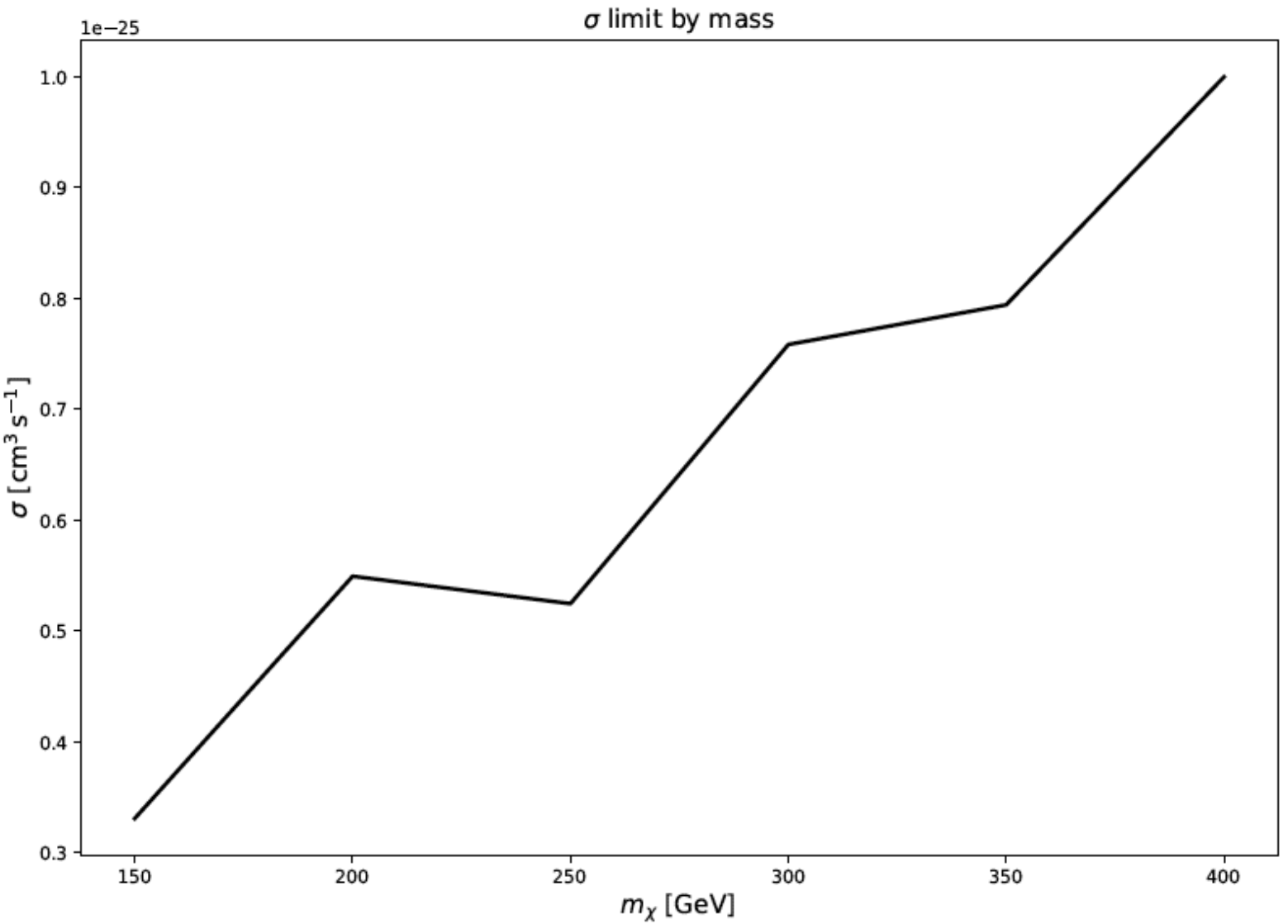
Bin range and flux

```
bin:11857-15811 0.36608405167299107
bin:15811-21084 0.20351096586609929
bin:21084-28117 9.9207994638178809E-002
bin:28117-37495 4.4814976745109925E-002
bin:37495-50000 1.6815571547390752E-002
bin:50000-66676 5.5827706452140219E-003
bin:66676-88914 1.3825324338837936E-003
bin:88914-118569 2.4834363157721196E-004
bin:118569-158114 2.5181134176800918E-005
bin:158114-210848 2.8668587517989261E-006
```

xsec_limits.dat

```
150 3.31131113E-26
200 5.49540844E-26
250 5.24807467E-26
300 7.58577583E-26
350 7.94328204E-26
400 1.00000002E-25
```




σ limit by mass
1e−25
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
σ [cm³ s⁻¹]
150
200
250
300
350
400
m_χ [GeV]

https://github.com/carpenterphysics/DarkFlux

Conclusions

Next Generation Models have complex annihilation spectra

DarkFlux inputs user genrated models and outputs data on annihilation spectrum including plots of partial annihilation rates, binned photon flux spectrum, computaion of DM mass limit from Fermi Dwarf Galaxy analyses

More capabilities soon