



# Contur: a tutorial

by  
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on behalf of the →[Contur team](#)

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Illustration by Chris Wormell from "A Map of the Invisible"



# Getting started

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```
$ docker pull hepstore/contur-herwig:2.0.0-py3
2.0.0-py3: Pulling from hepstore/contur-herwig
da7391352a9b: Already exists
[...]

$ unzip contur_tutorial.zip
$ cd contur_tutorial
$ docker run -it -v $PWD:/contur_tutorial hepstore/contur-herwig:2.0.0-py3

-----
Contur environment successfully enabled
-----

root@34d102de55ac:/contur#
```

pull docker image (we're going to generate events as well, so use contur-herwig:2.0.0-py3 instead of contur:2.0.0-py3)

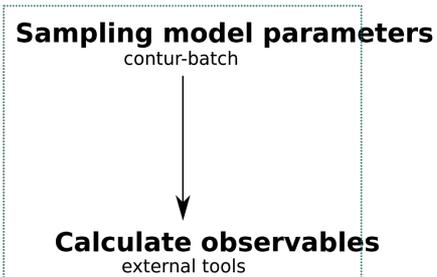
(download and) extract tutorial files

run docker image, binding directories

ready to go!







**Evaluating the likelihood for a model**  
contur

**Visualisation of parameter space**  
contur-plot

- many BSM models encoded in → [Universal Feynrules Output \(UFO\)](#) format
- switching between models easy

1. Event generation
2. Effect on existing measurements?
  - many (~150) LHC measurements available as **Rivet routine** (runnable plugin that preserves analysis logic)
  - Rivet optimised for speed, can evaluate impact in hundreds of routines with negligible runtime compared to event generation

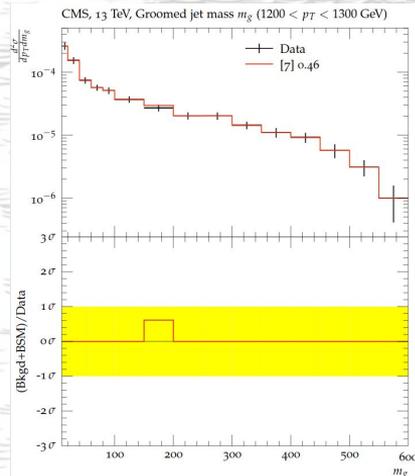
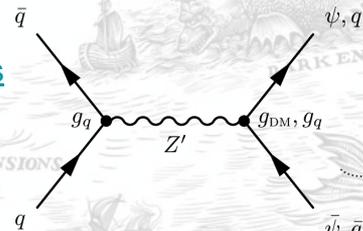
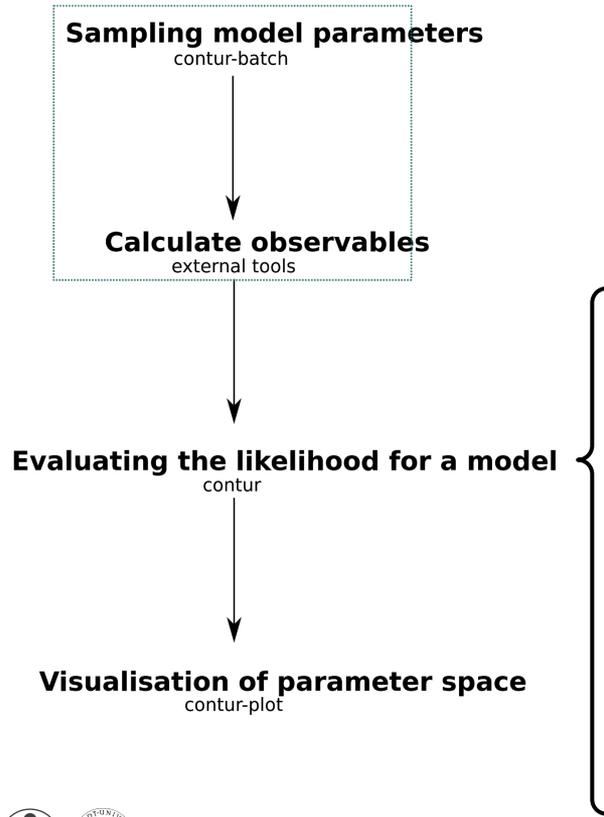


Illustration by Chris Wormell from "A Map of the Invisible"





- group Rivet routines into orthogonal pools
- use  $CL_s$  method to determine confidence level of excluding **signal(+bkg)** considering **data** and **uncertainties**

$$L(\mu) = P(n_{\text{obs}} | \mu) = \frac{(\mu s + b)^{n_{\text{obs}}}}{n_{\text{obs}}!} e^{-(\mu s + b)}$$

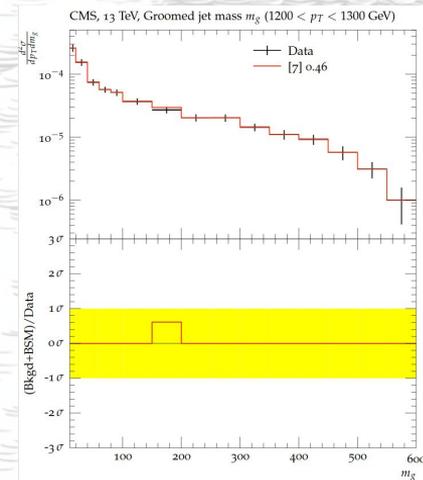
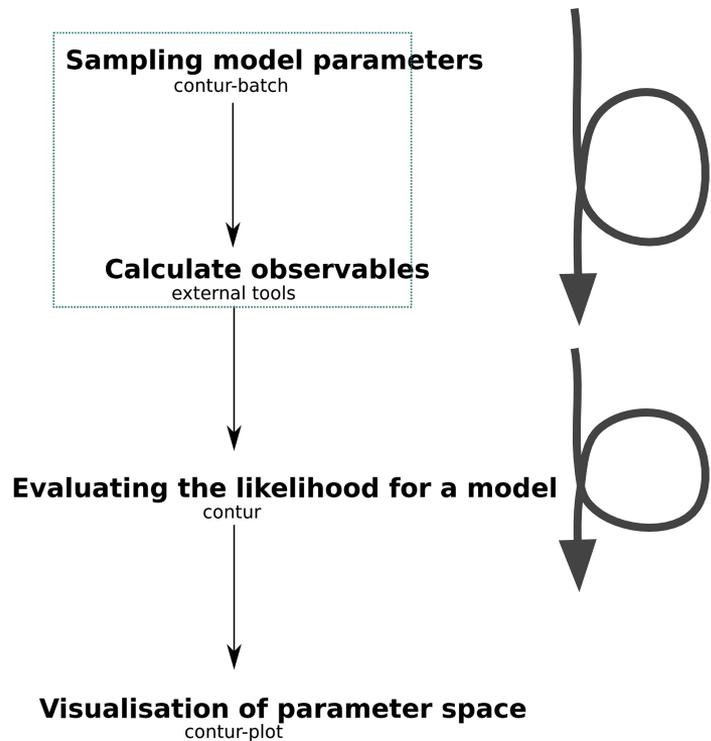


Illustration by Chris Wormell from "A Map of the Invisible"





## Repeat for each point in parameter space

- book-keeping and steering machinery provided by Contur

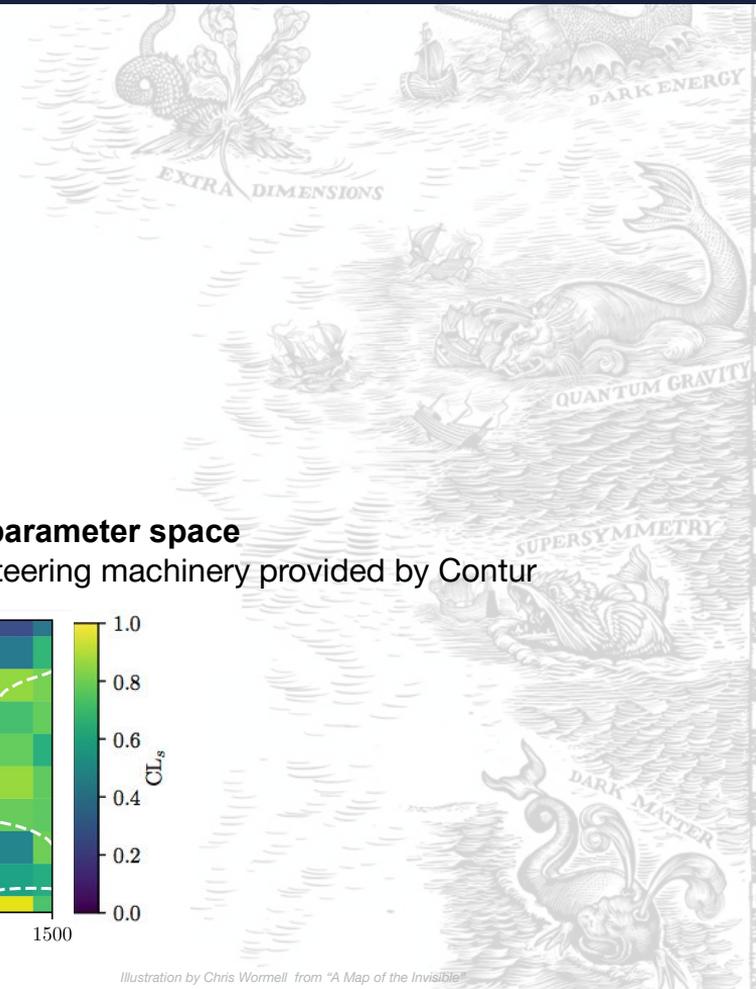
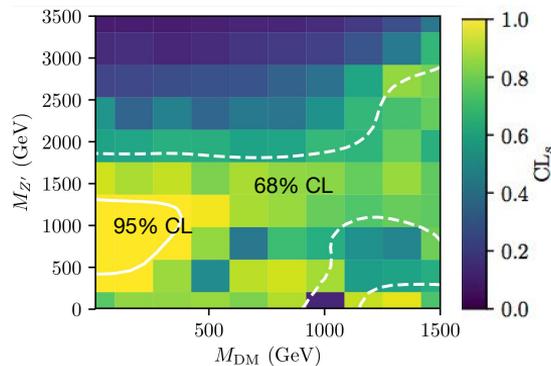
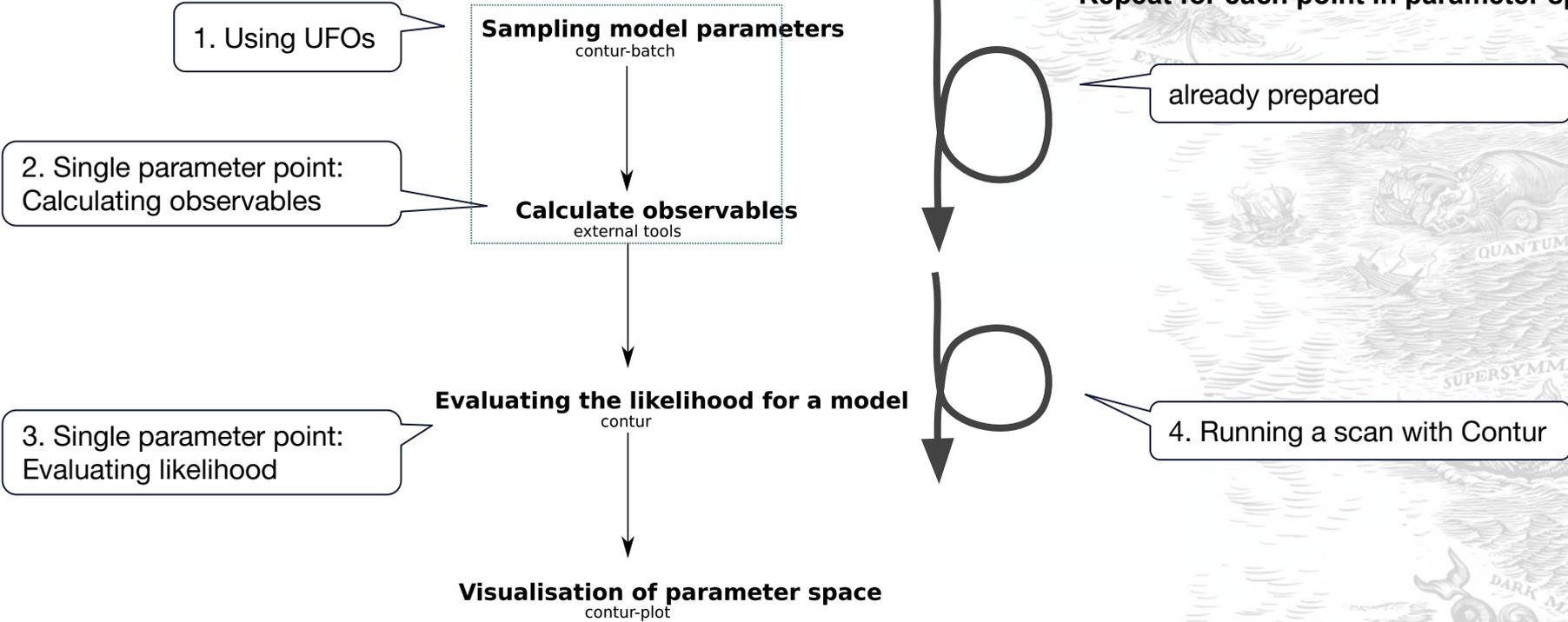


Illustration by Chris Wormell from "A Map of the Invisible"



# Outline of tutorial





# A look at the directory contents

```
# cd /contur_tutorial
# ls
LHC_example.in  LHC.in  myscan00  param_file.dat
```

command file for Herwig  
for a single grid point

command file for Herwig  
when running a scan

signal grid

scan file for Contur

both files can also be found at  
\$CONTUR\_ROOT/data/Models/<model>/LHC\*.in  
for the model of your choice





# 1. Using UFOs

```
# cp -r $CONTUR_ROOT/data/share RunInfo
# cd RunInfo/
# cp -r $CONTUR_ROOT/data/Models/DM/DM_vector mediator UFO .
# python2 $HERWIG_ENV/bin/ufo2herwig DM_vector_mediator_UFO/
```

```
=====
LENGTH 1
finished generating model:   FRModel
model directory:           DM_vector_mediator_UFO/
generated:                  122 vertices
=====
library:                    FRModel.so
input file:                 LHC-FRModel.in
model file:                 FRModel.model
=====
```

To complete the installation, compile by typing "make".  
An example input file is provided as LHC-FRModel.in,  
you'll need to change the required particles in there.

DONE!

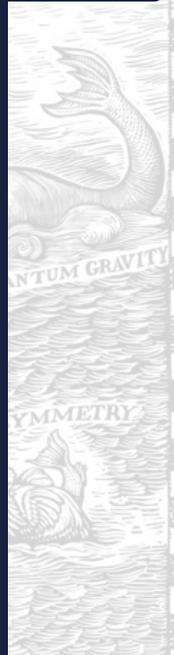
```
=====
# make
g++ -std=c++11 -fPIC -I/herwig/include -I/herwig/include -I/herwig/include -Wall -Wextra -pedantic -O2 -DBOOST_UBLAS_NDEBUG -c
FRModel.cc -o FRModel.o
[...]
```

copy "GridPack" which tells Contur/ Rivet which analyses to use

choose and copy model UFO

convert UFO to Herwig-readable format

compile UFO





## 2. A look at LHC.in

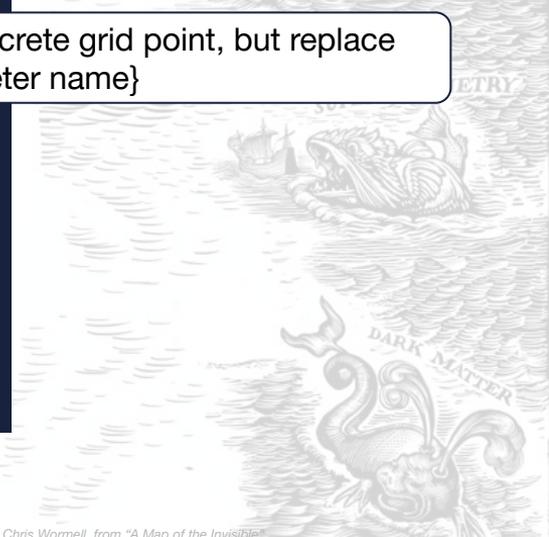
```
# cd /contur_tutorial
# cat LHC_example.in
read FRModel.model
set /Herwig/FRModel/Particles/Y1:NominalMass 1280*GeV
set /Herwig/FRModel/Particles/Xm:NominalMass 400*GeV
set /Herwig/FRModel/FRModel:gYXm 1.0
set /Herwig/FRModel/FRModel:gYq 0.25
```

```
#####
#
# Modify the required process here
#
#####
[...]
```

```
# cat LHC.in
read FRModel.model
set /Herwig/FRModel/Particles/Y1:NominalMass {mY1}*GeV
set /Herwig/FRModel/Particles/Xm:NominalMass {mXm}*GeV
set /Herwig/FRModel/FRModel:gYXm {gYXm}
set /Herwig/FRModel/FRModel:gYq {gYq}
```

```
#####
#
# Modify the required process here
#
#####
[...]
```

≈ same structure as for concrete grid point, but replace parameter value → {parameter name}





## 2. Single parameter point: Calculating observables

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```
# Herwig read LHC_example.in -L RunInfo/ -I RunInfo/  
# Herwig run LHC.run -N 1000  
event> 1000 1000
```

```
BasicConsistency: maximum 4-momentum violation: 0.249 MeV
```

```
HepMCFile: generated HepMC output.
```

```
# rivet -a CMS_2018_I1682495 LHC.hepmc
```

```
Rivet.AnalysisLoader: WARN Ignoring duplicate plugin analysis called 'CMS_2016_I1454211'
```

```
Rivet 3.1.3 running on machine 02f4ac2fea7f (x86_64) at 2021-02-15 16:43:26
```

```
Rivet.AnalysisHandler: INFO Using named weights
```

```
Reading events from 'LHC.hepmc'
```

```
Event 1000 (0:00:15 elapsed)
```

```
Finished event loop at 2021-02-15 16:43:41
```

```
Cross-section = 1.282444e+01 pb
```

```
Rivet.Analysis.CMS_2018_I1682495: WARN Skipping histo with null area /CMS_2018_I1682495/d33-x01-y01
```

```
Rivet.Analysis.CMS_2018_I1682495: WARN Skipping histo with null area /CMS_2018_I1682495/d45-x01-y01
```

```
Rivet.Analysis.CMS_2018_I1682495: WARN Skipping histo with null area /CMS_2018_I1682495/d34-x01-y01
```

```
Rivet.Analysis.CMS_2018_I1682495: WARN Skipping histo with null area /CMS_2018_I1682495/d46-x01-y01
```

```
Rivet.Analysis.CMS_2018_I1682495: WARN Skipping histo with null area /CMS_2018_I1682495/d36-x01-y01
```

```
Rivet.Analysis.CMS_2018_I1682495: WARN Skipping histo with null area /CMS_2018_I1682495/d48-x01-y01
```

```
Rivet run completed at 2021-02-15 16:43:41, time elapsed = 0:00:15
```

```
Histograms written to /contur_tutorial/Rivet.yoda
```

generate events, make available as LHC.hepmc

analyse events with Rivet, using measurement CMS\_2018\_I1682495 \*

both steps are merged into one when using the .in files from  
\$CONTUR\_ROOT/data/Models/<model>

\* information about measurements can be found [→here](#)





# 3. Single parameter point: Evaluating likelihood

```
# contur --ana-match CMS_2018_I1682495 Rivet.yoda
INFO - Running Contur version 2.0.0
INFO - See https://hepcedar.gitlab.io/contur-webpage/
Contur version 2.0.0
INFO - Run Information
Contur is running in /contur_tutorial
on analysis objects in ['Rivet.yoda']
Excluding Higgs to WW measurements
Excluding secret b-veto measurements
Excluding ATLAS WZ SM measurement
No correlations being built, using single bins in tests
Building default background model from data, ignoring (optional) theory predictions
Only using analysis objects whose path includes ['CMS_2018_I1682495'].

INFO - Found 100 analysisobjects in Rivet.yoda
INFO - Loading reference and theory data from all yoda files in $RIVET_DATA_PATH matching paths in input yoda
Processing reference/theory YODAs: 0it [00:00, ?it/s]

[...]
```

do statistical analysis with Contur, only using measurement CMS\_2018\_I1682495 for now

information about Contur run





# 4. A look at param\_files.dat

```
cat param_file.dat
```

```
[Run]
```

```
generator = "/path/to/Herwig-7.2.1/bin/activate"
```

```
contur = "/path/to/contur/setupContur.sh"
```

```
[Parameters]
```

```
[[mXm]]
```

```
mode = LIN
```

```
start = 10.0
```

```
stop = 1500.0
```

```
number = 10
```

```
[[mY1]]
```

```
mode = LIN
```

```
start = 10.0
```

```
stop = 3500.0
```

```
number = 10
```

```
[[gYXm]]
```

```
mode = CONST
```

```
value = 1.0
```

```
[[gYq]]
```

```
mode = CONST
```

```
value = 0.25
```

tell Contur which generator etc. to use and where to find them

tell Contur to vary dark matter mass from 10 to 1500 GeV in ten equidistant steps

mediator mass is second scan parameter

tell Contur to treat couplings as constant

with this setup, signal grid generated with

```
# contur-batch -p param_file.dat -P -b 13TeV -w 2:00
```





# 4. Running a Contur scan

now run Contur by calling

```
# contur -g myscan00
INFO - Running Contur version 2.0.0
INFO - See https://hepcedar.gitlab.io/contur-webpage/
Contur version 2.0.0
INFO - Run Information
Contur is running in /contur_tutorial
on files in myscan00
Excluding Higgs to WW measurements
Excluding secret b-veto measurements
Excluding ATLAS WZ SM measurement
No correlations being built, using single bins in tests
Building default background model from data, ignoring (optional) theory predictions

INFO - Removing unnecessary files from grid
INFO - Merging yoda files (myscan00/13TeV)
-----
WARNING - NO YODA FILES FOUND IN DIRECTORY 13TeV
WARNING - runpoint_0000.yoda.gz already exists.

[...]

INFO - Found valid yoda file contur_tutorial/myscan00/13TeV/0000/runpoint_0000.yoda.gz
INFO - Sampled at:
gYXm: 1.0
gYq: 0.25
mXm: 10.0
mYl: 10.0
```

(this will take some time)

information about Contur run

files would be compressed (but that was already done when preparing the tutorial)

information about current grid point



## 4. Running a Contur scan

(continued)

```
INFO - Found 1474 analysisobjects in /contur_tutorial/myscan00/13TeV/0000/runpoint_0000.yoda.gz
INFO - Loading reference and theory data from all yoda files in $RIVET_DATA_PATH matching paths in input yoda
Processing reference/theory YODAs: 0it [00:00, ?it/s]
```

[...]

```
Processing reference/theory YODAs: 0it [00:00, ?it/s]
INFO - Done loading static data
WARNING - Negative CLs -0.002172, setting to zero for /ATLAS_2017_I1609448/d01-x01-y01. BSM+SM is in better
agreement with data.
```

[...]

```
INFO - Added yodafilename with reported exclusion of: 0.7404989651618201
INFO - Found valid yoda file contur_tutorial/myscan00/13TeV/0001/runpoint_0001.yoda.gz
```

[...]

[...]

```
INFO - Found 100 yoda files
INFO - Merging maps
INFO - Writing output map to : ANALYSIS/contur.map
```

loading histograms (and theory inputs, but only once)

if CLs negative, ignore those histograms

report exclusion for grid point and go to next one

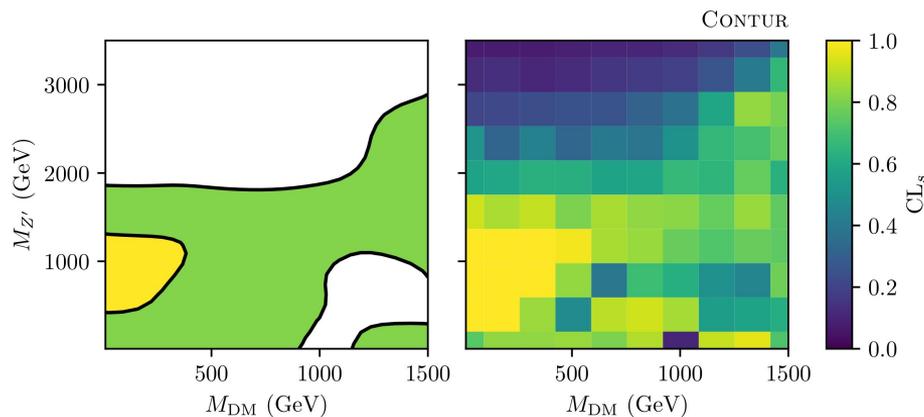
summarise run and give output



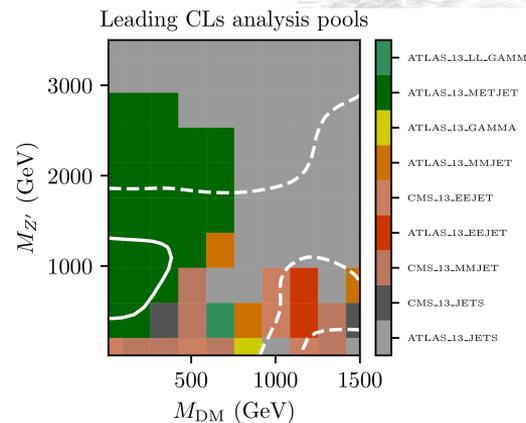
# 4. Plotting with Contur

to plot do

```
# cd ANALYSIS
# contur-plot contur.map mXm mY1
Starting plotting engine, outputs written to conturPlot
plot combined exclusion limit grid
plot dominant pools level 0 (1/1)
Done
```



conturPlots/combinedHybrid.pdf



conturPlots/dominantPools0.pdf





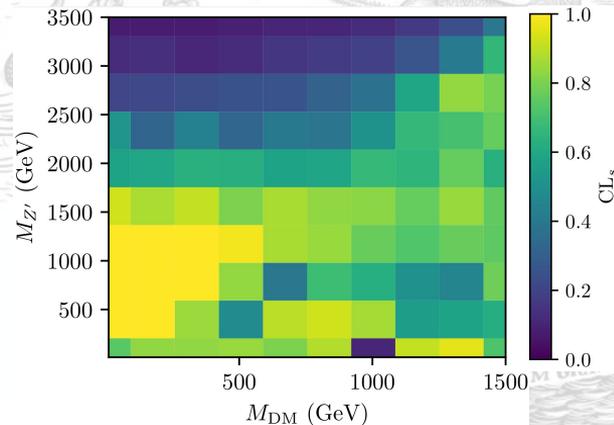
# 4. Plotting with Contur

to plot the exclusion for each pool

```
# contur-plot contur.map mXm mYl --pools
Starting plotting engine, outputs written to conturPlot
plot combined exclusion limit grid
plot dominant pools level 0 (1/1)
Requested plotting of individual analysis pools, found 16 pools to plot
plot ATLAS_13_EEJET (1/16 done)

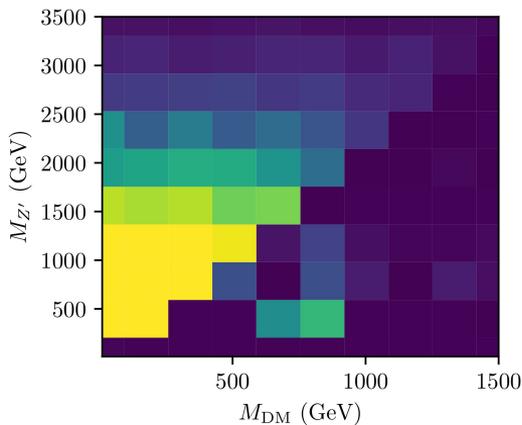
[...]

Done
```

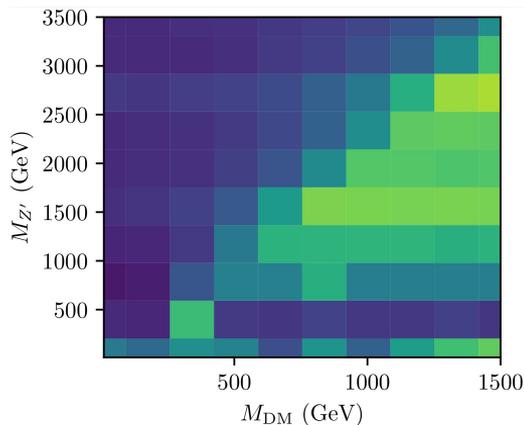


total exclusion

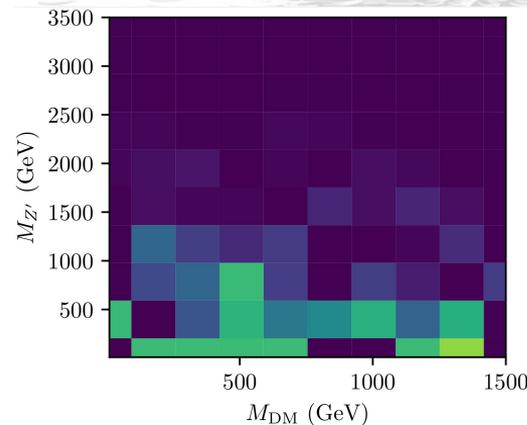
and find your plots at ANALYSIS/conturPlot/pools



ATLAS\_13\_METJETMesh.pdf



ATLAS\_13\_JETSMesh.pdf

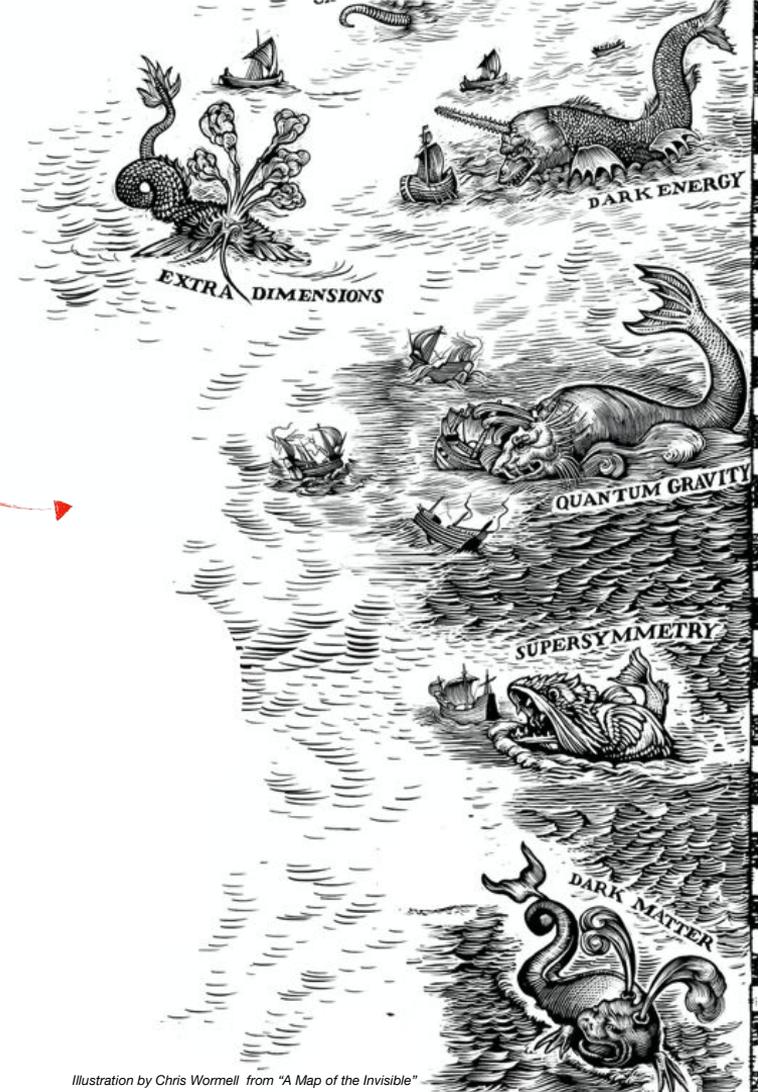
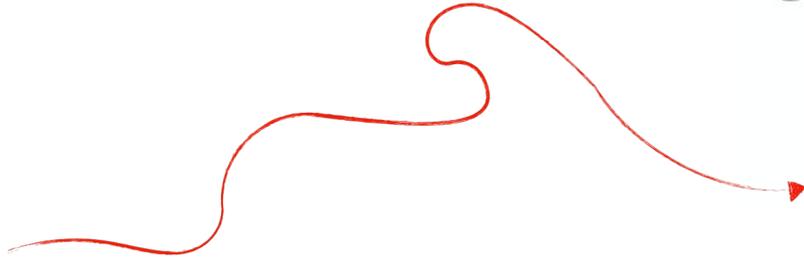


CMS\_13\_MMJETMesh.pdf



# The End

(of this tutorial)



For more information check out the → [Contur webpages](#).