Composite Likelihood Overview

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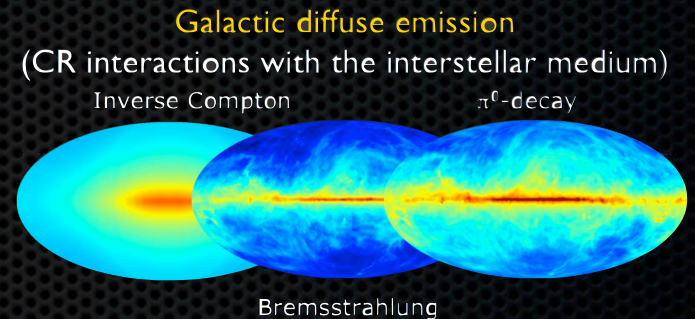NASA Goddard Space Flight Center

Composite Likelihood

- Likelihood source stacking technique

  - Search for dark matter in dwarf galaxies (Ackerman et al. 2011)

  - Study of the extragalactic background like (Ackerman et al. 2012)

  - GRB stacking analysis

- Expands upon established likelihood framework

- Implemented via the *Composite2* routine in science tools

  - First available in July, 2010

  - Likelihood v16-10-00, pyLikelihood v01-25-00
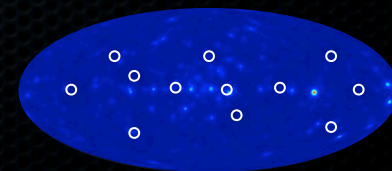
Likelihood Analysis

- Compute the probability that the observed photons are due to an assumed diffuse emission model (i.e. templates) plus a point source

- Vary the photon flux and spectral shape of the point source in order to estimate the parameters which make the observed data the most probable given the model, i.e. maximize the likelihood that the data are consistent with the model

- The difference between the maximum likelihoods with and without a point source at an assumed position gives you the test statistic (TS)

Galactic diffuse emission
(CR interactions with the interstellar medium)
Inverse Compton π^0-decay

Bremsstrahlung

Isotropic extragalactic diffuse emission

Resolved point sources

Likelihood Analysis

- Compute the probability that the observed photons are due to an assumed diffuse emission model (i.e. templates) plus a point source

$$L\left(\Theta|X\right) = \prod_i P\left(x|\Theta\right)$$

- Vary the photon flux and spectral shape of the point source in order to estimate the parameters which make the observed data the most probable given the model, i.e. maximize the likelihood that the data are consistent with the model

- The difference between the maximum likelihoods with and without a point source at an assumed position gives you the test statistic (TS)

L

Flux

Index
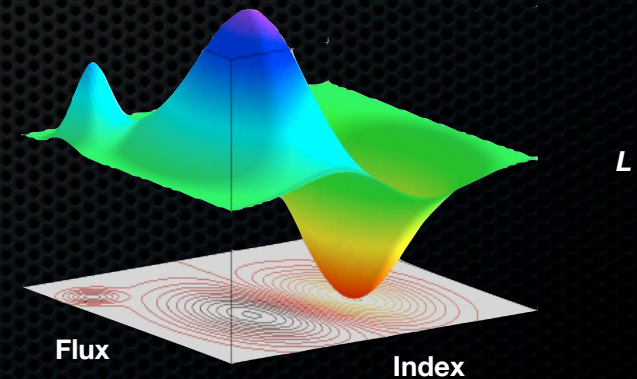
Composite Likelihood

- The maximum likelihood technique can be expanded to apply to multiple sources to estimate a set of parameters that are common to all sources

- Each source can be modeled individually in source-specific likelihoods, which are then added to yield a composite likelihood surface

- This is essentially like adding additional observations of a single source

- The composite likelihood function can then be scanned like any likelihood surface
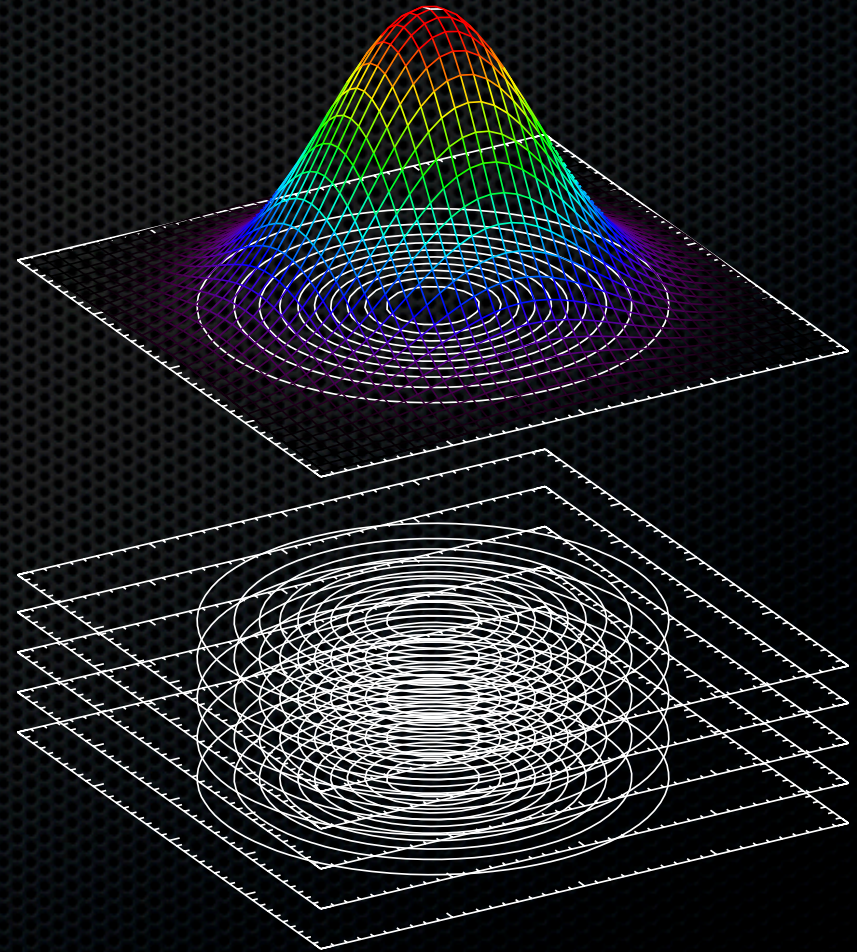
Limitations
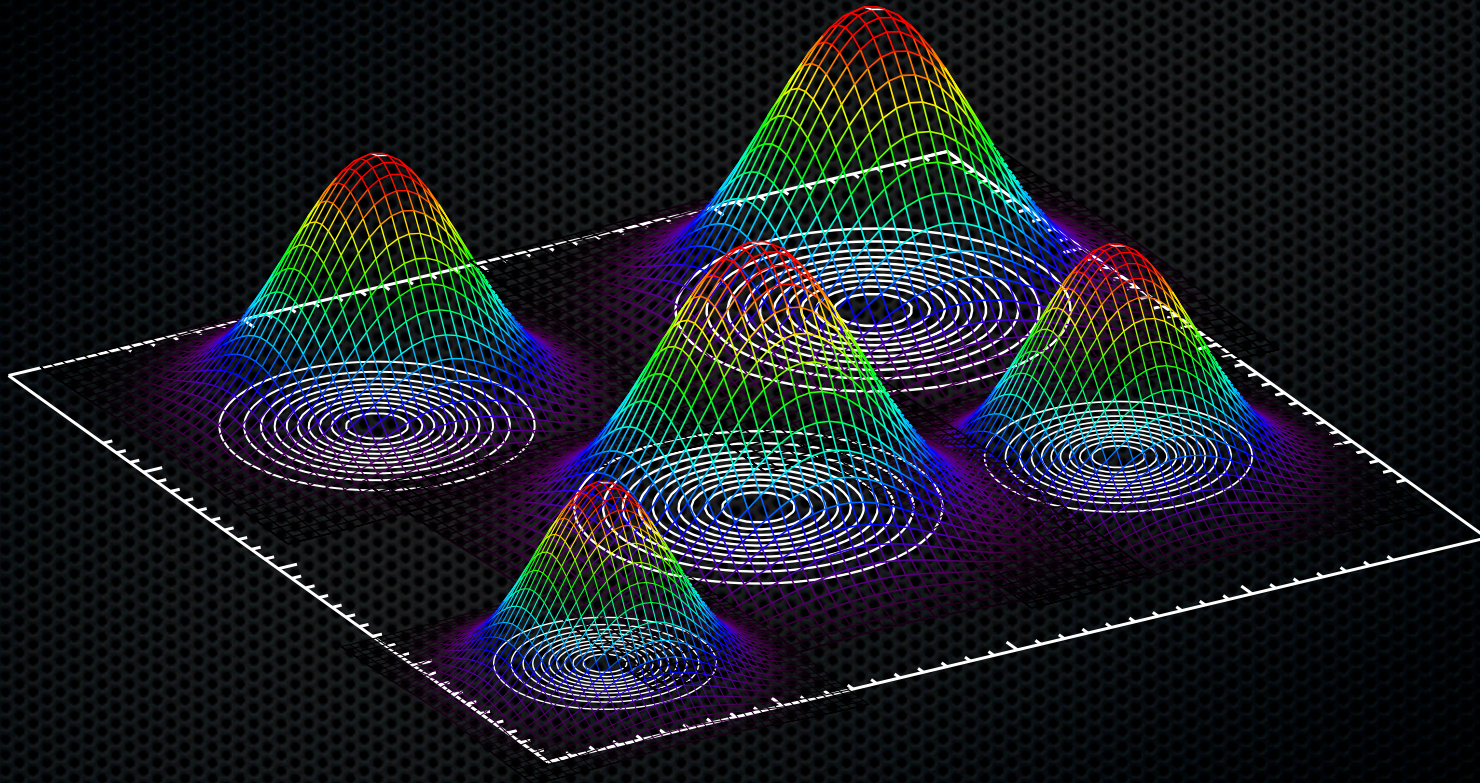
- The sources must have common parameter distributions, otherwise the composite likelihood function may not be well defined

Implementation

Standard Likelihood

```
from BinnedAnalysis import *

# Define required variables
target = 'my_3EG_J0530p1323'
irfs='P8_SOURCE_V2'   # To be used with P301 data
optimizer='Minuit'
level = 2.71

# Set up the filenames
srcmap=target+'_srcmap.fits'
ltcube=target+'_ltcube.fits'
binnedExpMap=target+'_binnedExpMap.fits'
srcModel=target+'_sourceModel.xml'

# Set up the likelihood
likeObs = BinnedObs(srcmap, ltcube, binnedExpMap, irfs)
like = BinnedAnalysis(likeObs, srcModel=srcmodel)

# Make the fit
like.optimizer = optimizer
minuit = eval("pyLike.%s(like.logLike)" % optimizer)
minuit.setStrategy(2)
like.setFitTolType(1)
like.fit(covar=True,tol=1.e-5,optimizer=optimizer)
```

Composite Likelihood

```
from BinnedAnalysis import *
from Composite2 import Composite2

CompositeLike = Composite2(optimizer=optimizer)
like={}

target1 = 'my_3EG_J0530p1323'
target2 = 'my_3EG_J0534p2200'
targets = [target1, target2]
irfs='P8_SOURCE_V2'   # To be used with P301 data
optimizer='Minuit'
level = 2.71

for target in targets:
    srcmap=target+'_srcmap.fits'
    ltcube=target+'_ltcube.fits'
    binnedExpMap=target+'_binnedExpMap.fits'
    srcModel=target+'_sourceModel.xml'
    likeObs = BinnedObs(srcmap, ltcube, binnedExpMap, irfs)
    like[target] = BinnedAnalysis(likeObs, srcModel=srcmodel)
    CompositeLike.addComponent(like[target])

for target in targets:
    tiedParams = tiedParams+((like[target], target, 'Index'),)
CompositeLike.tieParameters(tiedParams)

minuit = eval("pyLike.%s(CompLike.composite)"%optimizer)
minuit.setStrategy(2)
CompositeLike.fit(covar=True,tol=1.e-5,optimizer=optimizer)
```
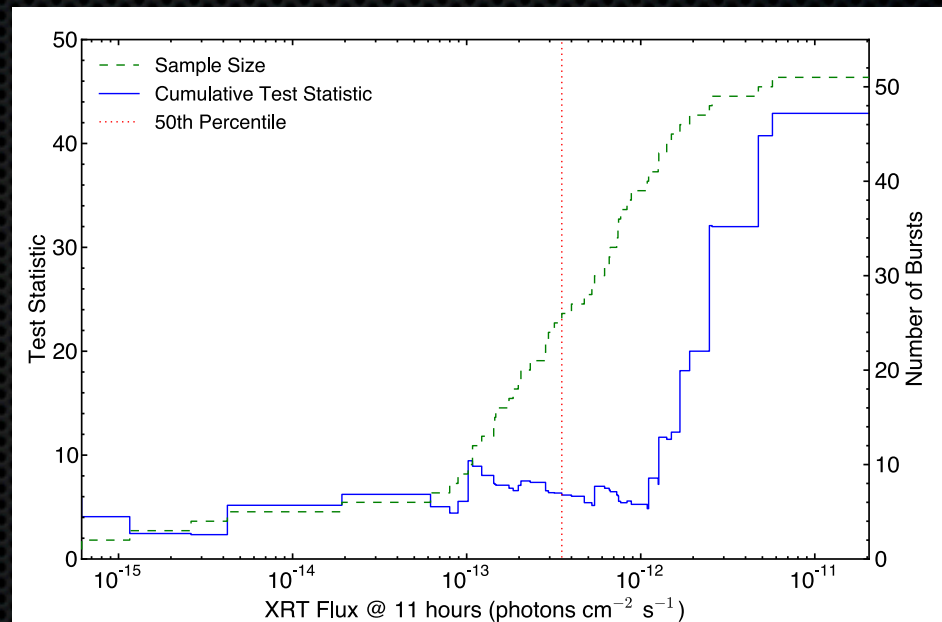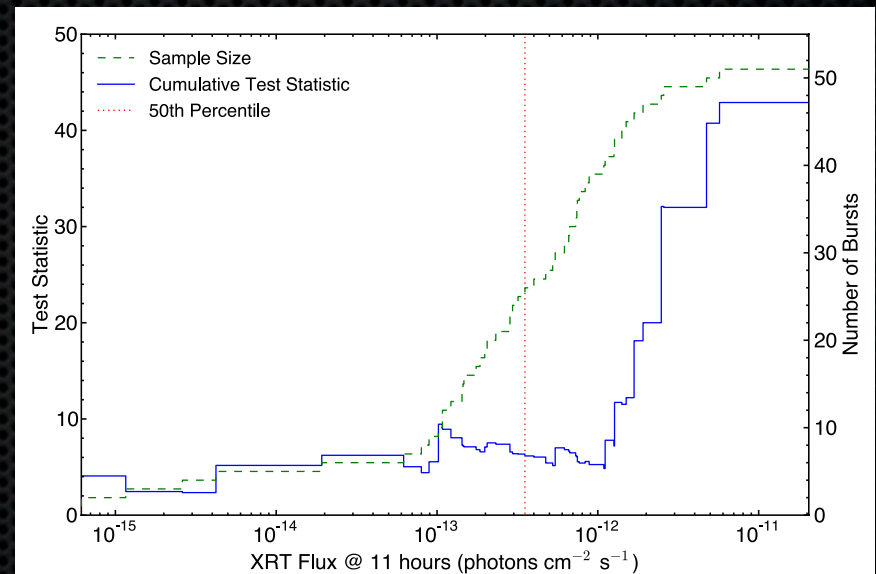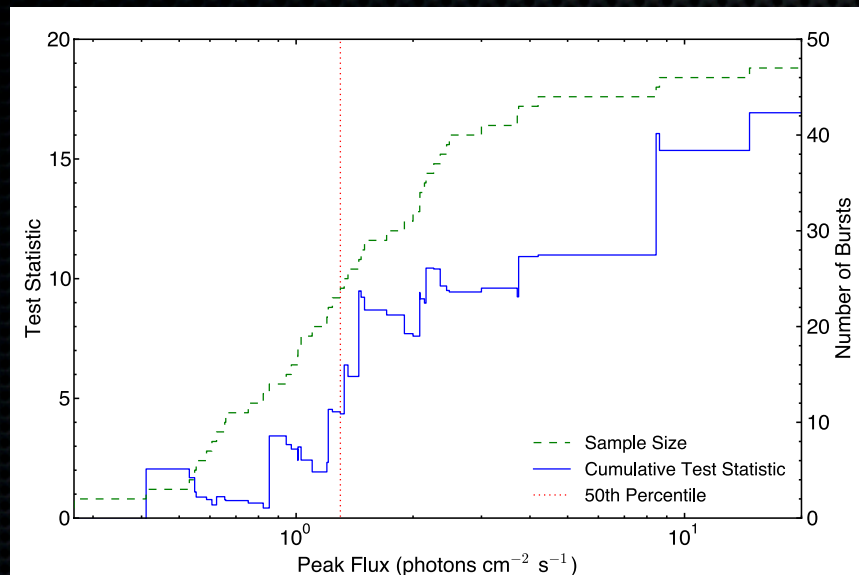
Cumulative Likelihood

- The order in which you add new sources to be fit is arbitrary, but can give you additional information

- You can sort the sources by some external parameter and redo the composite likelihood fit for each additional sources

- You can then plot TS or some best fit variable vs this external parameter

- Example: Very strong correlation between composite TS and a GRB's X-ray flux @ 11 hrs

GRB Stacking & Pass 8

- Can we use cumulative likelihood to distinguish between prompt and afterglow contributions by looking below 100 MeV?

- Prompt flux currently does not correlate with the LAT signal > 100 MeV