GammaLib - Change request #2659

Do not require a background model template for On/Off fitting with wstat

08/02/2018 10:41 PM - Knödlseder Jürgen

Status:	Closed	**Start date:**	08/02/2018
Priority:	Normal	**Due date:**	
Assigned To:	Knödlseder Jürgen	**% Done:**	100%
Category:		**Estimated time:**	0.00 hour
Target version:	1.6.0		

Description

On/Off fitting with wstat does not need to assess the absolute background rate using the GCTAOnOffObservation::N_bgd() method, but only requires access to the background scaling factor alpha, computed by GCTAOnOffObservation::compute_alpha() and stored in the On spectrum. Although the later currently requires a background template to cope with spatial variations in the background rate, one could in the absence of a background template simply assume the same background rate in the On and Off regions, which is the standard analysis method when taking for example the reflected region method.

The usage of the IRF background template should therefore be optional, and the code should also be able to cope with an IRF that has no background template.

For the first, a flag should be added to the GCTAOnOffObservation constructor and GCTAOnOffObservation::set() method to

```
GCTAOnOffObservation::GCTAOnOffObservation(const GCTAObservation& obs,
                                           const GModelSpatial&   spatial,
                                           const GEbounds&        etrue,
                                           const GEbounds&        ereco,
                                           const GSkyRegions&     on,
                                           const GSkyRegions&     off,
                                           const bool&            use_irf_bkg = true)
```

and

```
void GCTAOnOffObservation::set(const GCTAObservation& obs,
                               const GModelSpatial&   spatial,
                               const GSkyRegions&     on,
                               const GSkyRegions&     off,
                               const bool&            use_irf_bkg = true)
```

In that way, csphagen can take control over the IRF background template usage.

The flag needs then also to be added to

```
void GCTAOnOffObservation::compute_bgd(const GCTAObservation& obs,
                                       const GSkyRegions&     off,
                                       const bool&            use_irf_bkg = true)
```

and the method should fill the BACKRESP column of the Off spectrum with zeros in case that the flag is set to false. In that way the client knows that no background rate information is available, and GCTAOnOffObservation::N_bgd() will simply return zeros.

The flag needs also to be added to

```
void GCTAOnOffObservation::compute_alpha(const GCTAObservation& obs,
                                         const GSkyRegions&     on,
                                         const GSkyRegions&     off)
                                         const bool&            use_irf_bkg = true)
```

and here the background rate should be assumed constant so that the alpha factor simply reflects the difference in the solid angles between On and Off region. Note that in this case, alpha is energy independent, hence no loop over reconstructed energy is actually needed.

The dealing with IRFs without template should then be straight forward, the code should enter the same branch in absence of the background template as with use_irf_bkg = false.

History

#1 - 08/02/2018 11:58 PM - Knödlseder Jürgen

- Subject changed from Do not require a background model template for On/Off fitting with @wstat@ to Do not require a background model template for On/Off fitting with wstat

- Status changed from New to In Progress

- % Done changed from 0 to 50

I implemented the use_irf_bkg parameter in GCTAOnOffObservations, yet the code does not autodetect the absence of the IRF background template. The code works in a way that no background template is needed if use_irf_bkg=false. Hence if no background template exists, the code will throw an exception, except if use_irf_bkg=false.

#2 - 08/03/2018 11:33 AM - Knödlseder Jürgen

I added a hidden use_irf_bkg parameter to csphagen to make use of the new functionality. Running now csphagen with use_irf_bkg=no will ignore the IRF background template and assume that the background rates in On and Off regions are identical.

Here a usage example:

```
$ csphagen prefix=onoff_const use_irf_bkg=no
Input event list or observation definition XML file [events.fits]
Calibration database [prod2]
Instrument response function [South_0.5h]
Input model definition XML file (if NONE, use point source) [$CTOOLS/share/models/crab.xml]
Algorithm for defining energy bins (FILE|LIN|LOG) [LOG]
Start value for first energy bin in TeV [0.1]
Stop value for last energy bin in TeV [100.0]
Number of energy bins [20]
Stack multiple observations into single PHA, ARF and RMF files? [no]
Output observation definition XML file [onoff_obs_ref.xml] onoff_obs_const.xml
Method for background estimation (REFLECTED|CUSTOM) [REFLECTED]
Coordinate system (CEL - celestial, GAL - galactic) (CEL|GAL) [CEL]
Right Ascension of source region centre (deg) (0-360) [83.63]
Declination of source region centre (deg) (-90-90) [22.01]
Radius of source region circle (deg) (0-180) [0.2]
```

Fitting the resulting data using the cstat statistic will result in a singular curvature matrix:

```
2018-08-03T08:46:58: +=========================================+
2018-08-03T08:46:58: | Maximum likelihood optimisation results |
2018-08-03T08:46:58: +=========================================+
2018-08-03T08:46:58: === GOptimizerLM ===
2018-08-03T08:46:58:  Optimized function value ..: 0.000
2018-08-03T08:46:58:  Absolute precision .......: 0.005
2018-08-03T08:46:58:  Acceptable value decrease .: 2
2018-08-03T08:46:58:  Optimization status .......: singular curvature matrix encountered
2018-08-03T08:46:58:  Number of parameters ......: 10
2018-08-03T08:46:58:  Number of free parameters .: 4
2018-08-03T08:46:58:  Number of iterations ......: 101
2018-08-03T08:46:58:  Lambda ....................: 0.001
2018-08-03T08:46:58:  Maximum log likelihood ....: -0.000
2018-08-03T08:46:58:  Observed events  (Nobs) ...: 3086.000
2018-08-03T08:46:58:  Predicted events (Npred) ..: 0.000 (Nobs - Npred = 3086)
```

Fitting with wstat however works:

```
2018-08-03T08:47:34: +=========================================+
2018-08-03T08:47:34: | Maximum likelihood optimisation results |
2018-08-03T08:47:34: +=========================================+
2018-08-03T08:47:34: === GOptimizerLM ===
2018-08-03T08:47:34:  Optimized function value ..: 9.713
2018-08-03T08:47:34:  Absolute precision .....: 0.005
2018-08-03T08:47:34:  Acceptable value decrease .: 2
2018-08-03T08:47:34:  Optimization status .......: converged
2018-08-03T08:47:34:  Number of parameters ......: 10
2018-08-03T08:47:34:  Number of free parameters .: 4
2018-08-03T08:47:34:  Number of iterations ......: 2
2018-08-03T08:47:34:  Lambda ....................: 1e-05
2018-08-03T08:47:34:  Maximum log likelihood ....: -9.713
2018-08-03T08:47:34:  Observed events  (Nobs) ...: 3086.000
2018-08-03T08:47:34:  Predicted events (Npred) ..: 3086.872 (Nobs - Npred = -0.871702810702573)
2018-08-03T08:47:34: === GModels ===
2018-08-03T08:47:34:  Number of models ..........: 2
2018-08-03T08:47:34:  Number of parameters ......: 10
2018-08-03T08:47:34: === GModelSky ===
2018-08-03T08:47:34:  Name ......................: Crab
2018-08-03T08:47:34:  Instruments ................: all
2018-08-03T08:47:34:  Instrument scale factors ..: unity
2018-08-03T08:47:34:  Observation identifiers ...: all
2018-08-03T08:47:34:  Model type ................: PointSource
2018-08-03T08:47:34:  Model components ..........: "PointSource" * "PowerLaw" * "Constant"
2018-08-03T08:47:34:  Number of parameters ......: 6
2018-08-03T08:47:34:  Number of spatial par's ...: 2
2018-08-03T08:47:34:   RA .......................: 83.6331 [-360,360] deg (fixed,scale=1)
2018-08-03T08:47:34:   DEC ......................: 22.0145 [-90,90] deg (fixed,scale=1)
2018-08-03T08:47:34:  Number of spectral par's ..: 3
2018-08-03T08:47:34:   Prefactor ................: 5.78794235100673e-16 +/- 1.16894725927285e-17 [1e-23,1e-13] ph/cm2/s/MeV
 (free,scale=1e-16,gradient)
2018-08-03T08:47:34:   Index ....................: -2.44692021286776 +/- 0.0166311257112595 [-0,-5]  (free,scale=-1,gradient)
2018-08-03T08:47:34:   PivotEnergy ..............: 300000 [10000,1000000000] MeV (fixed,scale=1000000,gradient)
2018-08-03T08:47:34:  Number of temporal par's ..: 1
2018-08-03T08:47:34:   Normalization ............: 1 (relative value) (fixed,scale=1,gradient)
```

For comparison, here the Crab model results for wstat without ignoring the IRF background template. The results are very similar:

```
2018-08-03T08:45:43: === GModelSky ===
2018-08-03T08:45:43:  Name ......................: Crab
2018-08-03T08:45:43:  Instruments ................: all
2018-08-03T08:45:43:  Instrument scale factors ..: unity
2018-08-03T08:45:43:  Observation identifiers ...: all
2018-08-03T08:45:43:  Model type ................: PointSource
2018-08-03T08:45:43:  Model components ..........: "PointSource" * "PowerLaw" * "Constant"
2018-08-03T08:45:43:  Number of parameters ......: 6
2018-08-03T08:45:43:  Number of spatial par's ...: 2
2018-08-03T08:45:43:   RA .......................: 83.6331 [-360,360] deg (fixed,scale=1)
2018-08-03T08:45:43:   DEC ......................: 22.0145 [-90,90] deg (fixed,scale=1)
2018-08-03T08:45:43:  Number of spectral par's ..: 3
2018-08-03T08:45:43:   Prefactor ................: 5.78797906772499e-16 +/- 1.16894538223252e-17 [1e-23,1e-13] ph/cm2/s/MeV
 (free,scale=1e-16,gradient)
2018-08-03T08:45:43:   Index ....................: -2.44692374255593 +/- 0.0166310559574436 [-0,-5]  (free,scale=-1,gradient)
2018-08-03T08:45:43:   PivotEnergy ..............: 300000 [10000,1000000000] MeV (fixed,scale=1000000,gradient)
2018-08-03T08:45:43:  Number of temporal par's ..: 1
2018-08-03T08:45:43:   Normalization ............: 1 (relative value) (fixed,scale=1,gradient)
```

#3 - 08/03/2018 04:42 PM - Knödlseder Jürgen

- % Done changed from 50 to 100

Merged into devel.

#4 - 09/13/2018 11:27 AM - Knödlseder Jürgen

- Status changed from In Progress to Closed