ctools - Feature #2713

implementation of a time-variability search tool

11/05/2018 04:30 PM - Bonnefoy Simon

Status:	Closed	**Start date:**	11/05/2018
Priority:	Normal	**Due date:**	11/11/2018
Assigned To:	Bonnefoy Simon	**% Done:**	100%
Category:		**Estimated time:**	0.00 hour
Target version:	1.6.0		

Description

Implementation of a new tool to search for time variability.
The tool is intended to be used to search for variability over an event list.
The energy range and the time scale can be directly set by the user.
The tool is based on the algorithms used in HEGS and FAVA.

See here for more details:
https://cta-redmine.irap.omp.eu/attachments/download/2963/variability_presentation.pdf

History

#1 - 11/21/2018 11:13 AM - Bonnefoy Simon

- File skymap_three_sources.png added

- File skymap_variability.png added

- File variability_evolution.png added

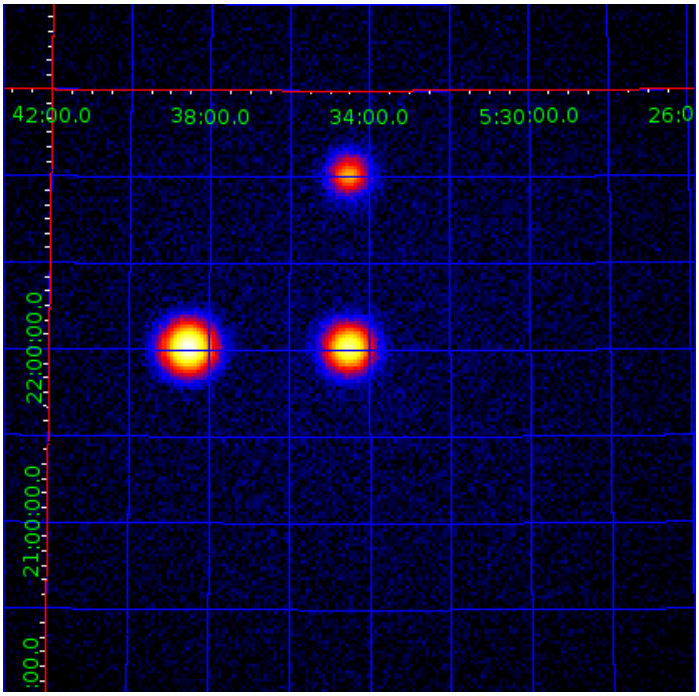
The ctfindvar tool has been implemented.

The tool searches for variability over a given field of view.
The user can provide some observation files or an event list.
The position of several sources can be specified in an xml file, or
only one source coordinate can be set as parameter.
In order to search for variability, the tool bins the events in time
for each pixel, and compares the number of events in each bin with respect
to the others bins, set as background.
Only bins with a significance lower than 4.5, with respect to the background sample,
are kept for the estimation of the background.
This significance threshold is a parameter of the tool and can be changed by the user.
The energy boundaries and the time scale can be set by the user as parameters.

The tool produces one FITS file as output containing:
-a skymap with the highest significance for each pixel
-the significance evolution of the source(s)
-the max significance in the field of view for each time bin.

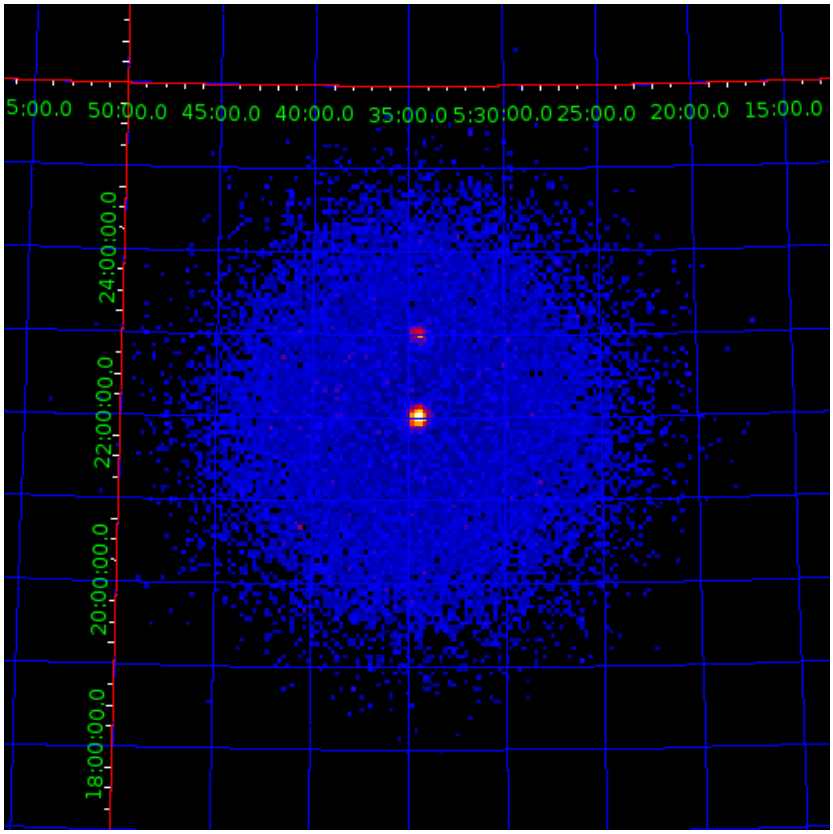
As an example, we simulated three sources:
-two sources with different level of variability
-one source is not variable

Here is the skymap obtained running ctskymap on the input files (count map).



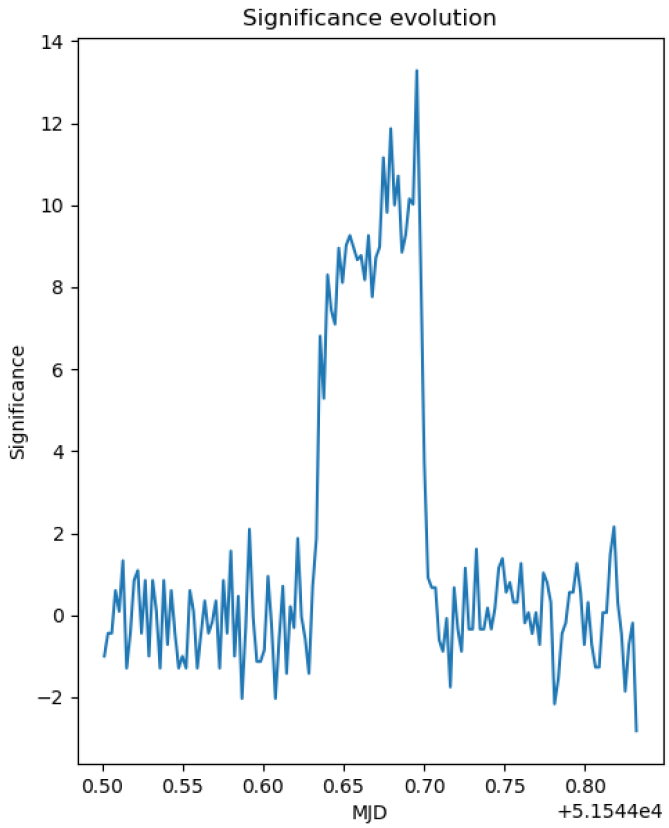
The three sources are visible with different intensities.

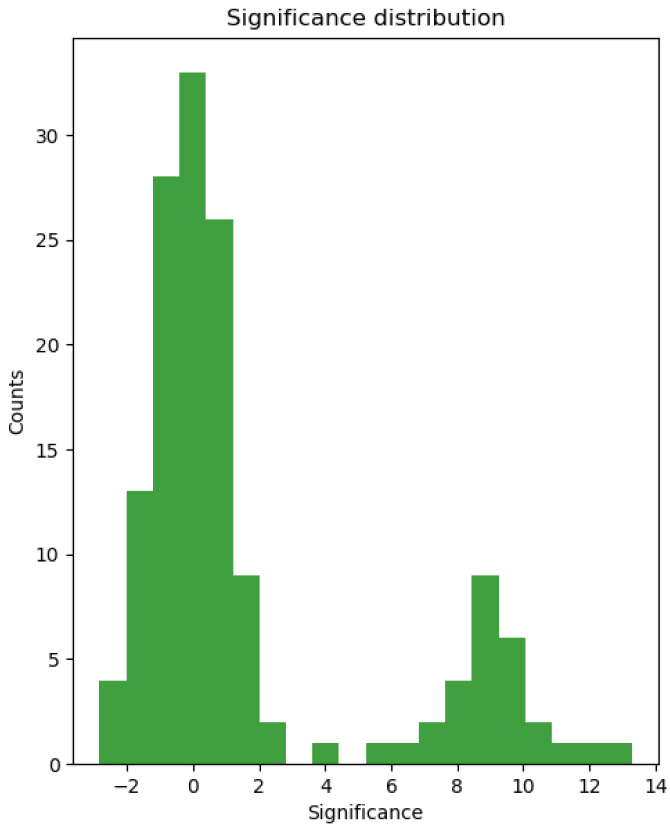
Below is the skymap representing the significance of the variability for each pixel



Here, only the two variable sources are detected, at different level,
given the distinct varibality set for the two sources.

For the sources set in a xml file, a list of the significance evolution
is contained in the output file. From this list, a lightcurve can be built
together with the significance distribution (see exmaples/show_variability_evolution.py).


Significance evolution
Significance
MJD
+5.1544e4
14
12
10
8
6
4
2
0
−2
0.50
0.55
0.60
0.65
0.70
0.75
0.80


Significance distribution
Counts
Significance
30
25
20
15
10
5
0
−2
0
2
4
6
8
10
12
14

#2 - 11/21/2018 03:42 PM - Bonnefoy Simon

- Status changed from New to Pull request

- % Done changed from 0 to 100

The final tool can be found here:

Pull repo: simonbonnefoy/ctools
Pull branch: 2713-variability-tool

#3 - 12/11/2018 02:30 PM - Knödlseder Jürgen

- Status changed from Pull request to Feedback

- Target version set to 1.6.0

I merged the code into the devel branch.

I did a bit of restructuring of the code to make it more modular. Specifically:

- I changed ctfindvar::init_cube to ctfindvar::create_cube that also includes the filling of the cube and the optional smoothing
- I added ctfindvar::analyse_cube that contains the analysis code that previously was in the ctfindvar::run method
- I added ctfindvar::get_pixels that returns a vector of sky map pixel indices
- I added ctfindvar::sky_model that builds a sky model for a given sky direction
- I changed the interface to ctfindvar::get_variability_sig that now returns the results in a GNdarray
- I changed ctfindvar::fill_alpha_vector to ctfindvar::get_alphas that now returns a vector of alpha values
- I added ctfindvar::get_tstart and ctfindvar::get_tstop methods to determine start and stop time
- I merged ctfindvar::write_srchist and ctfindvar::write_srchist_fits into a single ctfindvar::write_source_histograms method. The format of the binary table extensions was also changed, since it was not very clear what the content of the second position extension was. Now, the third extension contains three columns, a first with a source name, and two others with Right Ascension and Declination. One could image to store also TSTART and TSTOP in seconds, and to have the time reference saved in the header file, which would make the extension more OGIP compliant.

The interface of the class now looks as follows:

```
/*************************************************************************//**
 * @class ctfindvar
 *
 * @brief Time variability search tool
 *
 * @todo Add tool description.
 ****************************************************************************/
class ctfindvar : public ctobservation {
public:
   // Constructors and destructors
   ctfindvar(void);
   explicit ctfindvar(const GObservations& obs);
   ctfindvar(int argc, char *argv[]);
   ctfindvar(const ctfindvar& app);
   virtual ~ctfindvar(void);

   // Operators
   ctfindvar& operator=(const ctfindvar& app);

   // Methods
   void clear(void);
   void run(void);
   void save(void);

   // Get the information on the time interval from
   int          time2inx(const GTime& time);
   GGti         inx2gti(const int& indx);
   const GSkyMap& counts(void);

protected:
   // Protected methods
   void             init_members(void);
   void             copy_members(const ctfindvar& app);
   void             free_members(void);
```

```
    void              get_parameters(void);
    void              init_gtis(void);
    void              create_cube(void);
    void              fill_cube(GCTAObservation* obs);
    void              analyse_cube(void);
    std::vector<int>    get_pixels(void);
    GNdarray            get_variability_sig(const int& ipix);
    std::vector<double> get_alphas(const int& ipix) const;
    double              gti_overlap(const GGti& gti1, const GGti& gti2) const;
    GTime               get_tstart(void);
    GTime               get_tstop(void);
    GModelSky           sky_model(const GSkyDir& dir) const;
    void              write_source_histograms(GFits& fits);

    // Protected members
    GSkyMap           m_counts;          //!< Counts for each time interval
    std::vector<GGti> m_gti;             //!< List of time intervals
    GModels           m_inmodel;         //!< List of models for source positions
    GSkyDir           m_max_sig_dir;     //!< Sky direction associated with maximum significance
    double            m_minoff;          //!< Minimum counts for use in significance calculation
    double            m_sig_threshold;   //!< Minimum significance required to set source as variable
    GSkyMap           m_peaksigmap;      //!< Skymap holding the maximum significance
    GNdarray          m_pixsigsrc;       //!< Store distributions of the source significances
    GNdarray          m_pixsigmax;       //!< Store distribution for pixel with max significance
    GTime             m_tstart;          //!< Start time for variability study
    GTime             m_tstop;           //!< Stop time for variability study
    GEnergy           m_emin;            //!< Minimum energy for events
    GEnergy           m_emax;            //!< Maximum energy for events
    GModels           m_model_above_thr; //!< Model storing position with significance above thr

};
```

Furthermore, I changed some of the parameter names for compliance with the other ctools. Specifically:

- I removed the prefix parameter and replaced it by the explicit filename parameters outmap and outmodel
- I renamed sig_thr to threshold
- I renamed smoothkrnl to smooth_kernel
- I renamed smoothpar to smooth_rad

I addition, the emin and emax parameters can no longer be zero, since the energy limits are needed in the alpha computation. This should be changed in the future so that general background models can be supported, and not only the IRF background model. I created a new feature for that: #2769.

```
#
# General parameters
#==================
inobs,      f, a, events.fits,,, "Input event list or observation definition XML file"
inmodel,    f, h, NONE,,, "Input model definition file for extracting source positions"
outcube,    f, h, NONE,,, "Output counts cube file"
outmap,     f, a, map.fits,,, "Output map file"
outmodel,   f, a, model.xml,,, "Output model definition file"
caldb,      s, a, prod2,,, "Calibration database"
irf,        s, a, South_0.5h,,, "Instrument response function"

#
# Variability search parameters
#==============================
coordsys,      s, a, CEL,CEL|GAL,,"Coordinate system (CEL - celestial, GAL - galactic)"
xsrc,          r, a, 83.63,0,360, "First coordinate of the source of interest (RA or galactic l)"
ysrc,          r, a, 22.01,-90,90, "Second coordinate of the source of interest (DEC or galactic b)"
emin,          r, a, 0.1,,, "Lower energy limit (TeV)"
emax,          r, a, 100.0,,, "Upper energy limit (TeV)"
threshold,     r, h, 4.5,,, "Significance threshold for variability detection"
minoff,        r, h, 0,,, "Minimum required events in off bin for computing Noff and alpha"
smooth_kernel, s, h, NONE, GAUSSIAN|DISK|NONE,, "Smoothing kernel for counts maps"
smooth_rad,    r, h, 0.05,,, "Smoothing kernel radius (deg)"

#
# Time binning parameters
#==========================
tinterval, r, a, 300,,, "Time interval for each bin (seconds)"
tmin,      t, a, NONE,,, "Start time (UTC string, JD, MJD or MET in seconds)"
tmax,      t, a, NONE,,, "Stop time (UTC string, JD, MJD or MET in seconds)"
```

```
#
# Spatial binning parameters
#==========================
usepnt,   b, h, no,,, "Use pointing instead of xref/yref parameters?"
nxpix,    i, a, 200,,, "Size of the X axis in pixels"
nypix,    i, a, 200,,, "Size of the Y axis in pixels"
binsz,    r, a, 0.02,,, "Image scale (in degrees/pixel)"
proj,     s, a, CAR,AIT|AZP|CAR|GLS|MER|MOL|SFL|SIN|STG|TAN,, "Projection method"
xref,     r, a, 83.63,0,360, "First coordinate of image center in degrees (RA or galactic l)"
yref,     r, a, 22.51,-90,90, "Second coordinate of image center in degrees (DEC or galactic b)"

#
# Standard parameters
#===================
nthreads, i, h, 0,0,1000, "Number of parallel processes (0=use all available CPUs)"
chatter,  i, h, 2,0,4, "Chattiness of output"
clobber,  b, h, yes,,, "Overwrite existing output files with new output files?"
debug,    b, h, no,,, "Activate debugging mode?"
mode,     s, h, ql,,, "Mode of automatic parameters"
logfile,  f, h, ctfindvar.log,,, "Log filename"
```

From my side things look okay. Could you please double check that the code is also okay from your side.

#4 - 03/06/2019 01:56 PM - Knödlseder Jürgen

- Status changed from Feedback to Closed

Code was merged into devel.

Files

skymap_variability.png	56 KB	11/21/2018	Bonnefoy Simon
skymap_three_sources.png	74.2 KB	11/21/2018	Bonnefoy Simon
variability_evolution.png	189 KB	11/21/2018	Bonnefoy Simon