Bolocat

Object identification in Bolocam Data

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This is the cursory documentation for the Bolocat package which developed the catalog for the Bolocam Galactic Plane Survey. The BGPS and the catalog are described in full detail at

http://irsa.ipac.caltech.edu/data/BOLOCAM_GPS/ and this is the scattered attempt to allow YOU the user to go ahead and use the software.

What you will need

Bolocat runs in IDL. It was designed in v.7 and earlier versions may or may not work. The core package in which is document resides contains all the homebrew code you'll need to run the package. However, bolocat depends on

- The IDL astronomy user's library -- http://idlastro.gsfc.nasa.gov/
- MPFIT -- http://www.physics.wisc.edu/~craigm/idl/fitting.html
- The core IDL interpreted routines

You will need to make sure that all these things are in your IDL path.

How to run it

Start IDL in a working directory, perhaps where the files reside.

```
IDL> bolocat, 'bolocam_map.fits', props = p
```

This will process the data with the defaults (not necessarily what you want) and store the catalog objects in an array of IDL structures called `p`. Each element of p corresponds to a single object and the tags in p are the many calculated properties of the object, which are described below.

TAG NAME	Description
FILENAME	Original File Name
NAME	Name of the source.
CLOUDNUM	Running cloud number for this FILE
NPIX	Number of pixels for cloud
XDATA	X location in the original data file
YDATA	Y location in the original data file
XDATA_ERR	Error in X-location (pixels)
YDATA_ERR	Error in Y-location (pixels)
XERROR_AS	X-error in arcsec
YERROR_AS	Y-error in arcsec
RA	Right Ascension of centroid (by header astrometry)
DEC	Declination of centroid (by header astrometry)

TAG NAME	Description
GLON	Galactic Longitude (centroid)
GLAT	Galactic Latitude (centroid)
GLON_MAX	Gal .long of max in cloud
GLAT_MAX	Gal lat of max in cloud
FLUX	Total flux in the object. Requires BUNIT, BMAJ and BMIN to be set correctly to work.
MAXXPIX	X position of maximum
MAXYPIX	Y position of maximum
MAXRA	RA of maximum
MAXDEC	DEC of maximum
MOMXPIX	2nd Moment in the data X-direction
MOMYPIX	2nd Moment in the data Y-direction
MOMXPIX_ERR	error in 2nd moment, x-direction
MOMYPIX_ERR	error in 2nd moment, y-direction
MOMMAJPIX	2nd Moment along the major axis of the object
MOMMINPIX	2nd moment along the minor axis of the object
MOMMAJ_AS	2nd Moment along the major axis of the object
MOMMIN_AS	2nd moment along the minor axis of the object
POSANG	Position angle IN THE ORIGINAL DATA!
RAD_PIX	Radius measured in pixels
RAD_PIX_NODC	Radius measured in pixels, no deconvolution
RAD_AS	Radius in arcseconds
RAD_AS_NODC	Radius in arcsec, no deconvolution
CONCEN	Concentration parameter
RMS	Median error value
MAX	Maximum data value over all included pixels.
PPBEAM	Pixels per beam used in flux calculation
RMS2RAD	Scale factor from 2nd moment -> Radius
DECOMP_ALG	Decomposition algorithm used
THRESHOLD	Threshold for identifying emission.
EXP_THRESH	Expansion threshold for padding out significant regions.
DELTA	Rejection interval to determine significant peaks. This is the distance above a saddle point a local max must be to be counted as significant.
MINPIX	Minimum number of pixels for siginificant regions.
PK_S2N	Peak S/N value
MN_S2N	Median S/N value
FLUX_OBJ	Flux of object determined in an aperture based on its derived size.

TAG NAME	Description
FLUX_OBJ_ERR	Error in Flux of object determined in an aperture based on its derived size.
FLUX_40	Flux in 40" aperture
EFLUX_40	Error in Flux in 40" aperture
FLUX_40_NOBG	Flux in 40" aperture w/no bgs
EFLUX_40_NOBG	Error in Flux in 40" aperture w/no bgs
FLUX_80	Flux in 80" aperture
EFLUX_80	Error in Flux in 80" aperture
FLUX_120	Flux in 120" aperture
EFLUX_120	Error in Flux in 120" aperture
GAUSS_AMP	Gaussian amplitude
GAUSS_MAJ	Gaussian fit major axis
GAUSS_MIN	Gaussian fit minor axis
GAUSS_XC	Gaussian fit x centroid
GAUSS_YC	Gaussian fit y centroid
GAUSS_PA	Gaussian fit position angle
GAUSS_FLUX	Gaussian fit integrated flux density
GAUSS_CHISQ	Chisq of gaussian fit

How to tune up the process

The repository contains the program cataloger.pro which was the driving program in the Bolocam Galactic Plane Survey catalog. This tweaks several features of bolocat and uses some wrapper routines to produce a systematized catalog. The core of the routine is a call to bolocat that looks like this:

```
bolocat, maps[i], props = props, /zero2nan, obj = obj, $
             /watershed, delta = [0.5], $
             all_neighbors = 0b, expand = [1.00], $
             minpix = [ppbeam], thresh = [2.0], $
             error = error, corect = corect, round = [1], $
             sp_minpix = [2], smoothmap = smoothdata, $
             id_minpix = 2, beamuc = 1/33.
```

In the above call, maps is a string of file names in a different directory with a fully qualified path to those files. In the BGPS reduction, the pipeline produces several other useful maps. In particular, there is a signal-free estimate of the noise which is used for a refined estimate of pixel-by-pixel error estimate. This is fed in as an error map called ERROR. The error estimate is fairly important. Bolocat will try to estimate it for you, but the best strategy is to make sure

your RMS maps reflect the data sufficiently well. If you choose to let bolocat estimate errors for you, the estimate will be returned in the variable ERROR.

Working through the other parameters from the top, the /ZERO2NAN flag sets pixel values of identically zero of floating point NaN values.

OBJ is a named variable into which bolocat returns a label map of the identified objects. /WATERSHED calls the watershed algorithm for decomposition.

DELTA determine the minimum contrast required to break up two peaks in a composite object into separated objects. This is in units of the noise rms! Similarly, THRESH and EXPAND establish that the initial object identification will start at the THRESH = 2 sigma level and expand to all connected regions above EXPAND = 1 sigma. Increasing either of these will make the algorithm less sensitive to low surface brightness features.

ID_MINPIX is the minimum number of pixels required above the threshold level to count as a detection after the initial thresholding. SP_MINPIX requires both peaks in a split object to have more than SP_MINPIX = 2 pixels uniquely associated with that maximum. CORECT returns the number of objects cataloged.

ROUND is an image processing parameter which eliminates noise. Larger values of ROUND translate into more filtering of small scale structures. This is the primary noise spike suppression parameter in the BGPS processing.

BEAMUC is the fractional uncertainty in the *radius* of the telescope beam which controls the error flux density.

Once processing is completed, the routines BGPS2KVIS and BGPS2DS9 will export catalog structures to KVIS and DS9 region files respectively for visualization.

The BGPS also uses a culling routine since the survey consists of many overlapping tiles. Each tile is assigned a section of the galactic plane which is the primary data source. These are defined in a boundary file (bounds.txt) which is a series of entries consisting of filename, then the min and max in longitude and latitude respectively. A few lines are shown below. Most of the infrastructure in the CATALOGER file is built around getting the sets of overlapping images all set up to catalog without overlap. Nice multiple boxes in the data can be set for a single file. All sources outside boxes will be removed from the analysis. This can be used to manually suppress edge effects if necessary.

```
v1.0.2_l354_13pca_map50.fits          352.5   355.5   -0.55   0.55
v1.0.2_l357_13pca_map50.fits          355.5   358.5   -0.55   0.5
v1.0.2_super_gc_13pca_map50.fits              358.5   360     -0.6    0.5
v1.0.2_super_gc_13pca_map50.fits              0       2.5     -0.6    0.5
```