Wide-field Infrared Survey Explorer (WISE)

PCal Subsystem Design Document

Version 2.0

14 September 2009

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WSDC D-D010

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Revision History

Date	Version	Author	Description
June 3, 2008	draft		Initial Draft
September 18, 2008	1.0		Added documentation on SPCal
January 5, 2009	1.1		Documentation of v2 delivery
September 14,2009	1.2		Documentation of V3 delivery

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1 Introduction

1.1 Subsystem Overview

This document presents the requirements, design, algorithms, and state of implementation of the PCal (Photometric Calibration) subsystem of the WSDC data processing system. PCal consists of two major sections, FPCal (Frame Photometric Calibration) and SPCal (Scan Photometric Calibration), which run in the frame and scan pipelines, respectively.

1.1.1 Requirements

The PCal subsystem is required to determine a scan level photometric offset for each WISE band. A set of point sources determined a-priori from the Northern and Southern Hemispheres are assigned as Primary Calibrators in each WISE band. This set will expand as additional stars are identified as secondary calibration sources[1] , see Section 2.3.1.2. WISE extracted point source positions are compared to the positions of the known calibrators for each WISE band. Matches are found based on a given threshold of the radial separation. All acceptable matches found in a scan contribute to the derivation of the photometric offset for the scan. Pertinent information from each scan will be maintained in a local PCal database table for the purpose of trending and analysis. PCal will re-write the point source extraction file to include the calibrated magnitudes for each band. PCal will in addition put the photometric zero point and associated uncertainty into the point source file for the purpose of backing out the un-calibrated magnitudes.

1 (Selected source from SPITZER IRAC/MIPS-24 survey of NEP and SEP fields)

The Level 4 requirements supported by this processing are as follows.

> L4WSDC-012: Flux measurements in the WISE Source Catalog shall have a SNR of five or more for point sources with fluxes of 0.12, 0.16, 0.65 and 2.6 mJy at 3.3, 4.7, 12 and 23 micrometers, respectively, assuming 8 independent exposures and where the noise flux errors due to zodiacal foreground emission, instrumental effects, source photon statistics, and neighboring sources
>
> L4WSDC-013: The root mean square error in relative photometric accuracy in the WISE Source Catalog shall be better than 7% in each band for unsaturated point sources with SNR>100, where the noise flux errors due to zodiacal foreground emission, instrumental effects, source photon statistics, and neighboring sources. This requirement shall not apply to sources that superimposed on an identified artifact.
>
> L4WSDC-022: The photometric calibration of the final WISE Image Atlas shall be tied to the photometric calibration of the final WISE Source Catalog.
>
> L4WSDC-045: The WSDS Pipeline processing shall measure the brightness of sources detected on the calibrated WISE images relative to the brightness of calibration stars measured on-orbit.

1.1.2 Current Description

The PCal subsystem is broken onto two modules FPCal and SPCal.

The FPCal module is called by the WSDS Frame Pipeline and operates on a single frame. Using a set of frame level source extractions provided by WPHOT, FPCal finds associations with pre-defined Primary and Secondary Calibration stars. This association is based on position match within a given radius in arcsecs. Each match within a frame is output to a frame file providing extracted source position, mag and mag uncertainties for both psf and aperture photometry. In addition, the Primary or Secondary Calibrator name, position, mag and radial difference is written. If more than a single match appears for a calibrator, a confusion flag is set.

The SPCal module is called by the WSDS Multi-Scan Pipeline and operates on the output of FPCal for all frames within the scan. A list of calibration match files and metadata files produced by FPCal associated with a single scan are inputs to SPCal. SPCal will examine each match pair and accept or reject based on a variety of conditions (3.2.2). SPCal will determine a

photometric offset for each WISE band from the accepted matches. If no matches are found for a band or all matches are rejected, a band zero point value will be assigned by either attaining an estimate using the zero points from a scan that has already been processed and is the best choice for the desired scan, or by assigning a default value. The algorithm to determine which scan is the best choice is an on-going process that will evolve during the WISE mission as trending information and analysis assist in understanding the detector behavior. To assist the analysis, a local calibration database will contain information for each processed scan. Specifically, the database will have a zero point history table. The current wisdom is that the best estimate of zero point comes from a scan nearest in time to the scan in question and falls after the same anneal event. If an historic zero point estimate is not possible then a default value is assigned.

1.1.3 Support Modules

Several modules are written to support PCal .

Rdwrtwphot: This module appends columns to the WPHOT source extraction file. These columns contain artid result flags and calibrated aperture and psf magnitudes. See Section 6 for more information.

Database modules: PCal maintains information in a local calibration database for the purpose of trending analysis, examining quality of calibrators, quality of zero point offsets and for estimating a zero point for a scan based on historical zero point offset information. See Section 6 for more information on the individual modules that support this process.

1.1.4 Liens

- PCal historic database description sis has not been written.
- Implement confusion check with using a wider radius match for all associations with calibrators.
- Final algorithm for assigning a zero point offset from the zero point history table.

1.2 Applicable Documents

This subsystem conforms to the specifications in the following project documents:

- WISE Science Data Center Functional Requirements Document, WSDC D-R001
- WISE Science Data System Functional Design, WSDC D-D001
- Software Management Plan, WSDC D-M003

1.3 Acronyms

2MASS	Two-Micron All-Sky Survey
FRD	Functional Requirements Document
FPCal	Frame Photometric Calibration
PCal	Photometric Calibration
SDS	Subsystem Design Specification
SPCAL	Scan Photometric Calibration
SIS	Software Interface Specification
W1	WISE wavelength channel 1, 3.3 microns
W2	WISE wavelength channel 2, 4.7 microns
W3	WISE wavelength channel 3, 12 microns
W4	WISE wavelength channel 4, 24 microns
WISE	Wide-field Infrared Survey Explorer
WSDC	WISE Science Data Center
WSDS	WISE Science Data System

2 Input

FPCal and SPCal control information using command-line parameters.

2.1 FPCal Command Line Parameters

FPCal requires the source extraction file (WPHOT) and the Calibration Standard Star file specified on the command line. The Perl Wrapper will assign an output filename for calibrator matches found in the frame plus a metadata filename for the given frame. Additional control parameters include the scan name, frame name, hemisphere, frame utc, time from anneal, radial separation threshold in arcseconds, plus min and max frame declination.

2.1.1 FPCal Command-Line Parameters

The command-line parameters for FPCal are given by its tutorial display:

```
fpcal: Frame Photometric Calibration

 usage:  fpcal <flags> <specifications>

 where <flags> <specifications> must be:

     -i1  srcfilename(extracted sources from  WPHOT)
     -i2  calfilename(calibration stars file)
     -s   scan id
     -f   frame id
     -h   hemisphere
     -u   frame UTC (seconds)
     -a   time from anneal (seconds)
     -d1  fmndec     (frame minimum declination)
     -d2  fmxdec     (frame maximum declination)
     -r   sradius    (search radius in arcsec)
     -o   ofilename   (output match file for frame)
     -m   metadatafile (output metadatafile for frame)
     [-dbg]  debug flag to turn on print output for debugging code
```

The extracted source file (i1) is an output of WPHOT. The calibration file (i2) contains the total set of primary and secondary calibration stars. The minimum (d1) and maximum (d2) frame declination values are determined in the Perl wrapper and placed on the command line. The search radius (-r) is a value in arcsec that defines the match radius. Additional information includes scan (-s), frame (-f), hemisphere (-h), frame UTC (-u) and time in seconds from anneal (-a). The output (-o) and metadata (-m) filenames are supplied by the Perl wrapper. The output file contains all extracted sources from the frame that match a WISE calibrator within the -r radial position distance. The debug output is controlled by the optional *–dbg* flag.

2.2 SPCal Command Line Parameters

SPCal requires a list of all frame match files created in FPCal associated with the given scan. It also requires a list of all the corresponding metadata files from FPCal. These file lists, produced by a Perl wrapper, are available to SPCal on the command line. In addition, the SPCal command line supplies the name of the frame QA file, the scan QA file, the Zero Point Offset output file name, scan meta file name, the name of the output zero point history file, the directory path to the local calibration database, the name of the local calibration database and the zero point history table name. A parameter will control the on/off switch for using the zero point history file to estimate a scan zero point offset.

2.2.1 SPCal Command-Line Parameters

The command-line parameters for SPCal are given by its tutorial display:

```
spcal: Scan Photometric Calibration

 usage:  spcal <flags> <specifications>

 where <flags> <specifications> must be:


     -i1  matchfilelist(list of matched source files from FPCal)
     -i2  metatablelist(corresponding list of metadata tables from FPCal)
     -o   ofilename   (output file for scan containing zero points)
     -m   metadatafile (output metadatafile for scan)
     -g1  individual calibrator QA filename
     -q2  scan level QA filename
     -hw  range in seconds used in zero point history database search
     -p   full path to local calibration database
     -d   local calibration database name
     -t   local calibration database table for zero point history information
     -oh  output zp history file for scan of interest
     -n   number of frames expected in scan list
     -dbg  debug flag to turn on print output for debugging code
```

At the scan level, all frames associated with a scan have been processed through FPCal, and match files and metafiles produced for each frame. These filenames are gathered into two lists, one for match files (i1) and another list for associated metafiles (i2). It is required that there is a one to one association between the match file and the metadata file and that the order of the files is the same. File *n* in the match list references the same scan-frame number as file *n* in the metadata list..

Information for QA is output in the files indicated by –q1 and –q2 . Output filenames for SPCal zero point offsets and meta information are given with the (-o) and (-m) parameters.

The zero point history information is extracted from a local calibration database table defined by –p, -d and –t. The range of zero point information pulled from the database table is controlled by –hw which is a value representing the number of seconds to look forward and backward for potential best scans. If –hw is zero then there is no information desired from the zero point history table and default values will be assigned where appropriate.

The parameter –oh provides the name of the output table file containing zero point offset information for processed scan. These values will be inserted in the local calibration database, zero point history table in a separate step. See Section 6.0.

The –n parameter provides the number of frames to expect for given scan. This is used as a verification that n filenames exist in the input lists (i1) and (i2).

The debug output is controlled by the optional *–dbg* flag

2.3 File Input

2.3.1 FPCAL

2.3.1.1 Source Extraction Input

FPCal reads source extraction table file conforming to the WISE SIS http://web.ipac.caltech.edu/staff/roc/wise/docs/sis/WPHot.sis. Source extractions are generated in an upstream module (WPHOT) in the single-frame pipeline.

2.3.1.2 Photometric Calibrators Input

FPCal reads the photometric calibrators from a file defined by WISE SIS http://web.ipac.caltech.edu/staff/roc/wise/docs/sis/Cal_sis_v1.2 . The calibration input file contains the position of each calibrator (primary and secondary) and associated magnitudes for each applicable WISE band.

2.3.2 SPCAL

2.3.2.1 Source Match Input File List

This file is a list of calibration match files output from FPCal, one file per frame for each frame in given scan. See Section 4.1.1 for a description of the individual frame match file.

2.3.2.2 Metadata Input File List

This file is a list of metadata files output from FPCal, one file per frame for each frame in a given scan. The metadata table contains information regarding the quality of the frame match sets. It provides information as to number of matches with anomalies, near edge, latent. See Section 4.1.2 for a description of the individual frame metadata file.

3 Processing

3.1 FPCal Processing

3.1.1 Initialization

The FPCal module initializes itself by:

A.) reading and processing its control inputs from the command line;

B.) reading all WISE calibration stars from designated input file and selecting only those calibrators which fall within the min and max declination of the input WISE frame;

3.1.2 Source Matching

FPCal module will read from the WPHOT frame-level source extraction list. For each source extraction a radial distance is determined to each active calibration source.

There is no filtering of extraction sources (SNR or Chi2) at this point in the processing.

The radial separation is determined using the dot product of two vectors. The RA, Dec positions of the extracted source and the calibration star are converted to vector space prior to the dot product determination.

All sources within the assigned radial distance to a calibrator position are assumed a match. If a calibration star has more than a single match within a frame, all matches are flagged confused and another indicator will mark the closest match. It is assumed the closest match is the true association.

The search radius used is greater than the expected astrometric accuracy of WISE. The larger value is roughly based on the FWHM of the PSF in arcsecs for WISE bands 1,2 and 3. Using the FWHM distance will provide information as to potential photometric contamination around the calibration star. Additional tests made in SPCAL will determine the level of contamination from the outlying sources and whether to reject the match before determining the scan zero point value.

The match sets are output to the frame-level output file. The FPCal output file is defined in Section 4.1.1.

3.2 SPCal Processing

3.2.1 Initialization

SPCal module initializes by:

A.) reading and processing its control inputs;
B.) inputting all frame level metadata tables and storing information into designated structures
C.) inputting all frame level match files and storing information into designated structures
D.) checking the number of frames read are the number expected and verifying that all frames are associated with the same scan.

3.2.2 Match Rejection Criteria

Prior to computing the zero point for a scan, each WISE band of a match pair is examined for quality based on the following criteria. If a source does not meet all criteria, it is flagged as rejected (for the offending band) and is not used in the zero point computation for that band. A character flag is assigned to the match set to indicate reason for rejection.

Criteria for rejecting:

Confusion due to multiple associations	"C"
Confusion due to blending flag (nb) > 1 or Active deblending flag (na) > 0	"B"
Band has an invalid magnitude (NULL)	"N"
PSF upper limit indicated in WPHOT (psf only)	"U"
Aperture flag non-zero in WPHOT (ap only)	"F"
Fails the SNR threshold test	"S"
Fails CHI2 threshold test (psf only)	"X"
Artifact contamination per ARTID subsystem	"A"
Distance to edge threshold failure in x or y	"E"
Fraction of latent pixels per ICAL subsystem	"L"
Fraction of saturated pixels > 0	"T"

3.2.3 Zero Point Computation

SPCal computes several averages for the purpose of estimating the final zero point for a scan. These averages help determine the integrity of the calibrators both primary and secondary, the stability of the zero point throughout the scan. The statistics will be recorded in an ongoing PCal database and QA output plots.

Delta magnitudes are computed for each accepted match pair, for each appropriate band. The delta magnitude is defined as (standard magnitude – instrumental magnitude). The delta magnitudes are placed into categories as defined below and a simple average and standard deviation of the mean is computed for each category.

The categories for which average delta magnitudes are computed follow:

psf magnitudes for primary, secondary and all calibrators in Northern Hemisphere.

psf magnitudes for primary, secondary and all calibrators in Southern Hemisphere

psf magnitudes for all primary, secondary and all calibrators in both hemispheres.

ap corrected magnitudes for primary, secondary and all calibrators in Northern hemisphere.

ap corrected magnitudes for primary, secondary and all calibrators in Southern hemisphere.

ap corrected magnitudes for all primary, secondary and all calibrators in both hemispheres.

The selected scan zero point [psf or ap] is assigned using all accepted calibrators from both hemispheres.

If a zero point is not attained due to insufficient data then either a default zero point is used which is based on information taken during IOC or an estimate is assigned based on historic zero point information kept in the local calibration database. Initially, the former approach will be used.

The algorithm for estimating the zero point based on historical information is evolving. The process is designed to build an historic zero point table for use in analysis and development of an

algorithm that would be based on real zero point information. It is assumed that the final algorithm will require knowledge of scan UTC and time from anneal. No averaging of multiple zero points over time will be done. It is assumed that the zero point will have slight variation over time therefore the closest scan in time is currently assumed to be the best estimate. However, due to the nature of the WISE scan pipeline processing, the prior scan zero point information may not be available when needed. To determine the closest scan in time of the current processed scans, records are pull from the zph table based on a window of time (seconds) around the scan in question UTC. This window value is input on the command line –hw in seconds and added and subtracted from the current scan's UTCS. All processed scans that fall within the computed time window are potential candidates. The scan from this set closest in time to the current scan is used in estimating a zero point for the current scan. The time-from-anneal factor is another parameter in determining the best scan to use. Ideally it is best to select a scan that not only is closest in time but also falls after the same anneal event.

In summary, there are currently three methods of assigning a zero point offset for each band in a scan for psf and ap photometry. The first is by straight average of all data obtained, the second is by using an estimate from the history file and the third is by using a default value which does not change. In order to understand where the zero point offset came from it is flagged as "d" for default, "h" for history or # for actual calculation using calibrator matches.

3.2.4 Zero Point Quality Tracking

The quality of the zero point will be tracked with QA plots. In addition, calibration information will be kept in a database to be used for trending analysis.

The QA plots will be output after each scan is processed and will show the individual calibrator delta magnitudes vs. the magnitude of the standard. Symbols and color will differentiate primary vs. secondary calibrators and northern vs. southern calibrators. There will be two sets of plots of this type, one for the psf magnitudes and one for the aperture magnitudes. Each set will have one plot per band.

From the local calibration database, trending information can be plotted at any point in the processing to monitor the individual calibrators over time and the health of the zero point throughout the mission.

4 Output

4.1 FPCal Output Files

4.1.1 Calibrator Match Output File

Frame level Photometric Calibration (FPCal) module outputs the match sets found for each calibration star within the frame. The file is ascii, IPAC Table formatted. A description of the file is found at

http://web.ipac.caltech.edu/staff/roc/wise/docs/sis/FPCal_sis_v1.6

4.1.2 Metadata Output File

The metadata table contains detailed information regarding the quality of the frame match sets. It provides information as to number of matches with anomalies, near edge, latents. This is done for both the primary matches and the secondary matches for all bands.
A description of the file is found:

http://web.ipac.caltech.edu/staff/roc/wise/docs/sis/FPCal_meta_sis_v1.2

4.2 SPCal Output

4.2.1 Zero Point Output File

Scan level Photometric Calibration module (SPCal) outputs the computed zero point in an ascii IPAC Table format file that has the following information. A description of the file is found at:

http://web.ipac.caltech.edu/staff/roc/wise/docs/sis/SPCal_sis_v1.4

4.2.2 Zero Point History Output File

This file contains zero point history file information for the current scan.
Module pcaldb_in will insert information from this file into the ZPH table into the local calibration DB. If the scan is a re-run, pcaldb_in will replace the record in the DB table after incrementing its version number. Older versions of the scan are not kept in zph table. A description of the file is found at:

http://web.ipac.caltech.edu/staff/roc/wise/docs/sis/ZPHISTout_sis_v1.3

4.2.3 Calibration Match QA File

Information in this file is for QA plots of calibration standards within given scan. All matched standards, both primary and secondary, are recorded along with the delta psf and aperture magnitudes (catalogue magnitude – instrument magnitude).

http://web.ipac.caltech.edu/staff/roc/wise/docs/sis/SPCLQA_sis_v1.4

4.2.4 Scan Zero Point QA File

This file contains all the frame level zero point information for a scan. It is intended for QA to plot the individual north and south zero points for a scan.

http://web.ipac.caltech.edu/staff/roc/wise/docs/sis/SPCLQA2_sis_v1.4

4.2.5 Scan Meta Data File

The SPCal metadata file contains summary information plus the actual zero point offsets assigned the scan. In addition, the instrumental zero point is given plus the instrumental zero point plus offset as computed by SPCal. The latter rows are added by the Perl Wrapper outside the SPCal processing.

http://web.ipac.caltech.edu/staff/roc/wise/docs/sis/SPCal_meta_sis_v1.0

5 Testing and Parameter Tuning

5.1 FPCal Testing

5.2 FPCal Parameter Tuning

5.3 SPCal Testing

TBS

5.4 SPCal Parameter Tuning

TBS

6.0 Support Modules:

6.1 Database Modules:

The following modules are used for creating and maintaining the local calibration database.

Pcaldb : Creates local calibration database tables
Pcaldb_in: Inserts records into local calibration database tables
Del_calmatch: Deletes specific records from calmatch table
Del_zph: Deletes specified records from zph table
Del_qa2: Deletes specified records from qa2 table

6.2 Other Modules: