# AWAIC: A WISE Astronomical Image Co-adder

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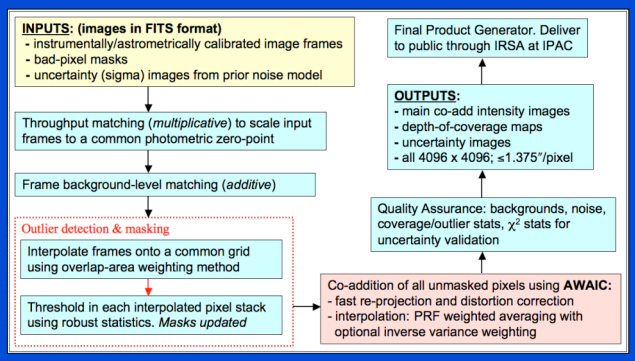
## Goals and Products

- The **W**ide-field **I**nfrared **S**urvey **E**xplorer will perform an all-sky survey at 3.3, 4.7, 12, & 23 microns with up to 3 orders of magnitude more sensitivity than previous surveys [see review poster #459.01 by P. Eisenhardt]. WISE is scheduled for launch in November 2009.

WISE will deliver to the scientific community:
- A digital Image Atlas containing ~220,000 calibrated images, or co-adds of the survey frame exposures covering the whole sky in 4 mid-IR bands;
- Ancillary co-add products: depth-of-coverage (from all good pixels) and uncertainty maps;
- Atlas Image tiles are ≈ 1.56° × 1.56° ($4096^2$ pixels) re-sampled at 1.375″/pixel;
- A Source Catalog of ≈ $5 \times 10^8$ objects merged across all 4 bands to photometric S/N = 5, all astrometrically and photometrically calibrated

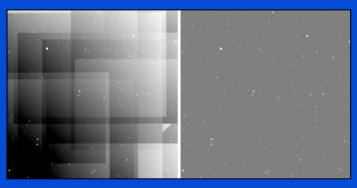
- To support the creation of an Image Atlas, we have developed an image co-addition framework at the WISE Science Data Center. The processing steps are as follows:




## Background Matching

- Instrumental transients lead to varying background levels between frames
- **Goal:** obtain seamless (or smooth) transitions between frames across overlaps but preserve natural background variations as much as possible
- **Simple method:** fit a "robust" plane to each frame, subtract to equalize frames, then add back a common plane or level to all frames computed from a median over all the fits

*Simulated background offsets and gradients*:



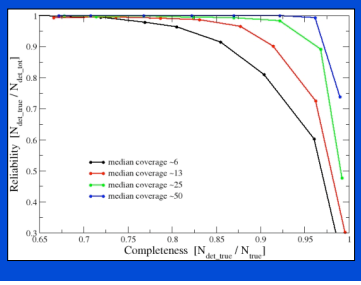
*co-add - no prior matching* *with background matching*

## Outlier Detection/Masking

- Use the redundancy in multiple frame exposures to flag outlying measurements
- Project and interpolate frames onto a common grid, apply an outlier identification algorithm to each pixel stack. Mask pixel $p_i$ if $| p_i - \text{median}\{p_i\} | > n^*\sigma$ where $\sigma$ is a robust measure
- Need good sampling of the PSF for method to be reliable! All bands >~ critically sampled

- Simulations show that for depths of coverage >~ 8 (where 8 = median on the ecliptic for WISE), completeness and reliability are > 80% for outlier thresholds of ~5σ

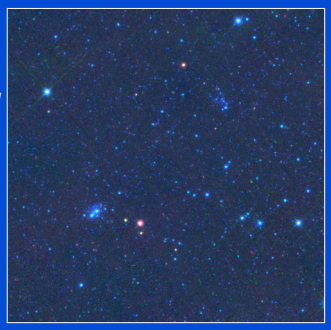
- N.B: moving objects and highly variable sources will also be flagged as outliers in WISE co-adds unless they're moving (or varying) slowly across frames
  ⇒ Atlas Images will represent the "static" inertial sky.




*"WISE Touchstone Field" at the South Ecliptic Pole - visited once per orbit. Spans a region covering part of the LMC*:

*Combines AWAIC mosaics made from Spitzer images at:*
- *4.5μm (blue)*
- *8μm (green)*
- *24μm (red)*

*Proxy for WISE bands 2, 3 and 4*




## AWAIC's Interpolation Method

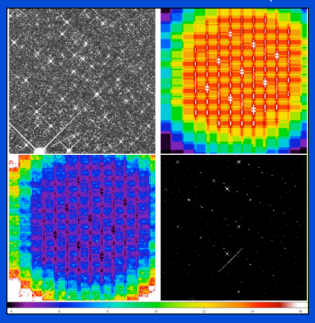
- AWAIC uses the detector's **P**oint **R**esponse **F**unction (PRF) as the interpolation kernel
- **PRF** = *Point Spread Function (PSF) ⊗ pixel response;* response is usually a top hat. Each pixel collects light from its vicinity with an efficiency described by the PRF
- Flux in a co-add pixel *j* is estimated using PRF and inverse-variance weighted averaging:

$$f_j = \frac{\sum_i \frac{r_{ij}}{\sigma_i^2} D_i}{\sum_i \frac{r_{ij}}{\sigma_i^2}}$$

Input detector (pixel) measurements
PRF (volume normalized to unity)
Variance from propagated noise model (optional)

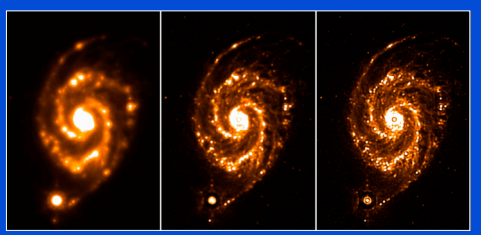
- Using the PRF as an interpolation kernel:
  – reduces impact of bad/masked pixels if the data are well sampled, even close to critical
  – defines a linear matched filter optimized for point source detection (a bonus for WISE!)
  – allows for resolution enhancement where PRF can be "deconvolved" (see below)

*Co-add products from simulated 3.3μm frames of a mid-ecliptic latitude region - typical of a proposed WISE Atlas Image*:
***Top left:*** *intensity co-add*
***Top right:*** *depth-of-coverage map (see color-bar for values)*
***Bottom left:*** *uncertainty co-add (based on priors)*
***Bottom right:*** *outlier map (flags mostly cosmic-rays and latents in this simulation)*



- AWAIC is also capable of resolution enhancement (HiRes). This is not in the WISE automated processing plan. It is purely to support offline research. This uses the Maximum Correlation Method (MCM), originally used to boost the scientific return of data from IRAS
- MCM yields a 'model' of sky that is consistent with the observations to within measurement error on convolution with the PRF

*M51 from Spitzer MIPS 24μm*:
***Left:*** *co-add (first iteration)*
***Middle:*** *HiRes after 10 iterations*
***Right:*** *HiRes after 40 iterations*



AWAIC is generic enough for use on an any astronomical image data that supports the FITS and WCS standards, with optional distortion represented in the SIP convention

## Further Reading

- *More examples*: http://web.ipac.caltech.edu/staff/fmasci/home/wise/awaic.html
- *Paper on AWAIC*: http://web.ipac.caltech.edu/staff/fmasci/home/wise/awaic_adass08.pdf