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WISE Photometry (WPHOT)

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WISE Science Data Center CDR – January 29-30, 2008

TJ+KM - 1

Overview



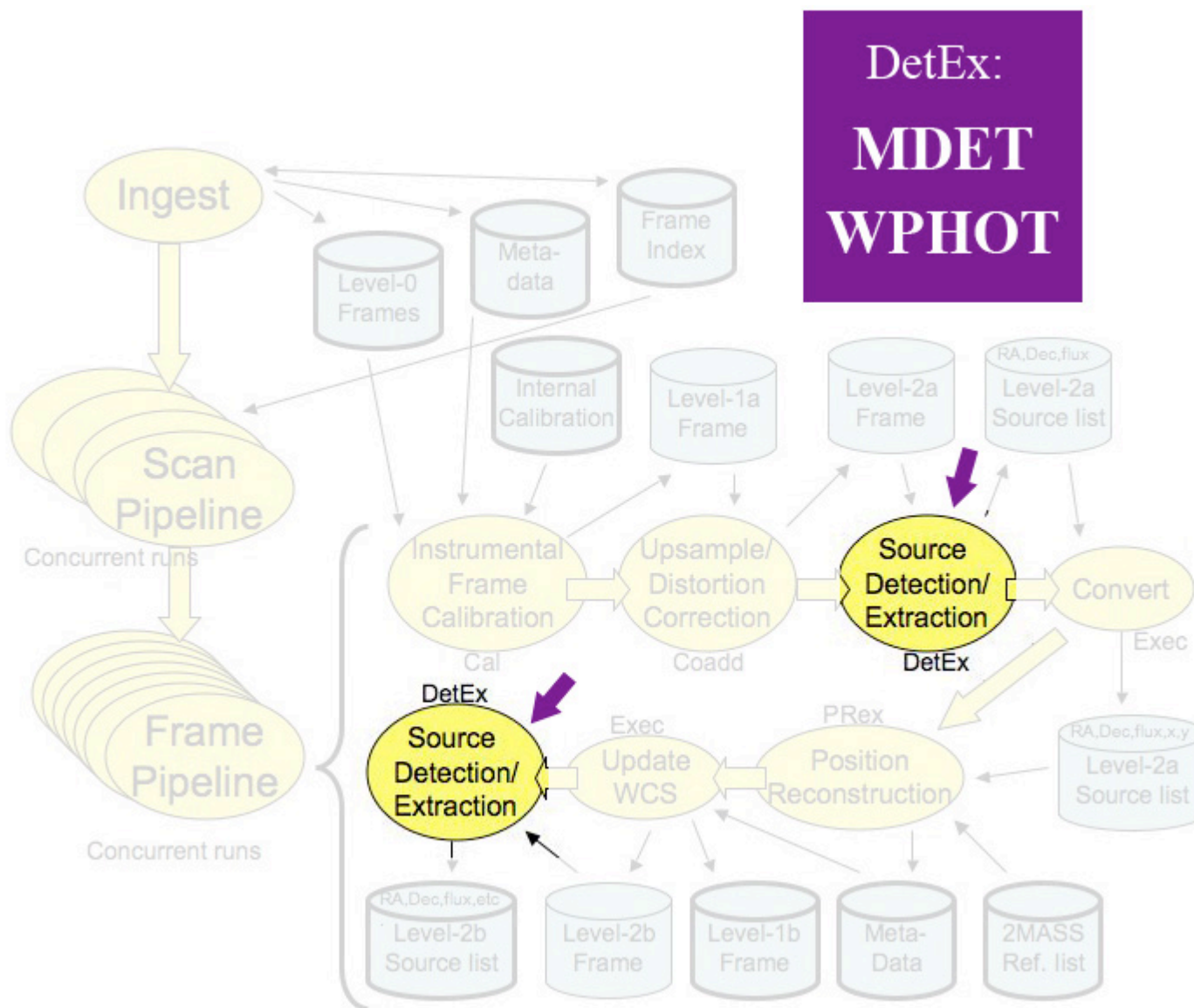
WPHOT is designed to perform the source characterization (source position & fluxes) associated with each of the three stages of source extraction during pipeline processing (single-frame, single-epoch 4-band frameset, and multi-frame stages).

The characterization is based on an input list of source candidate positions produced by MDET using a detection algorithm which makes use of the data at all bands simultaneously.

- Profile-fitting (WPRO)
- Aperture Photometry & Characterization (WAPP)

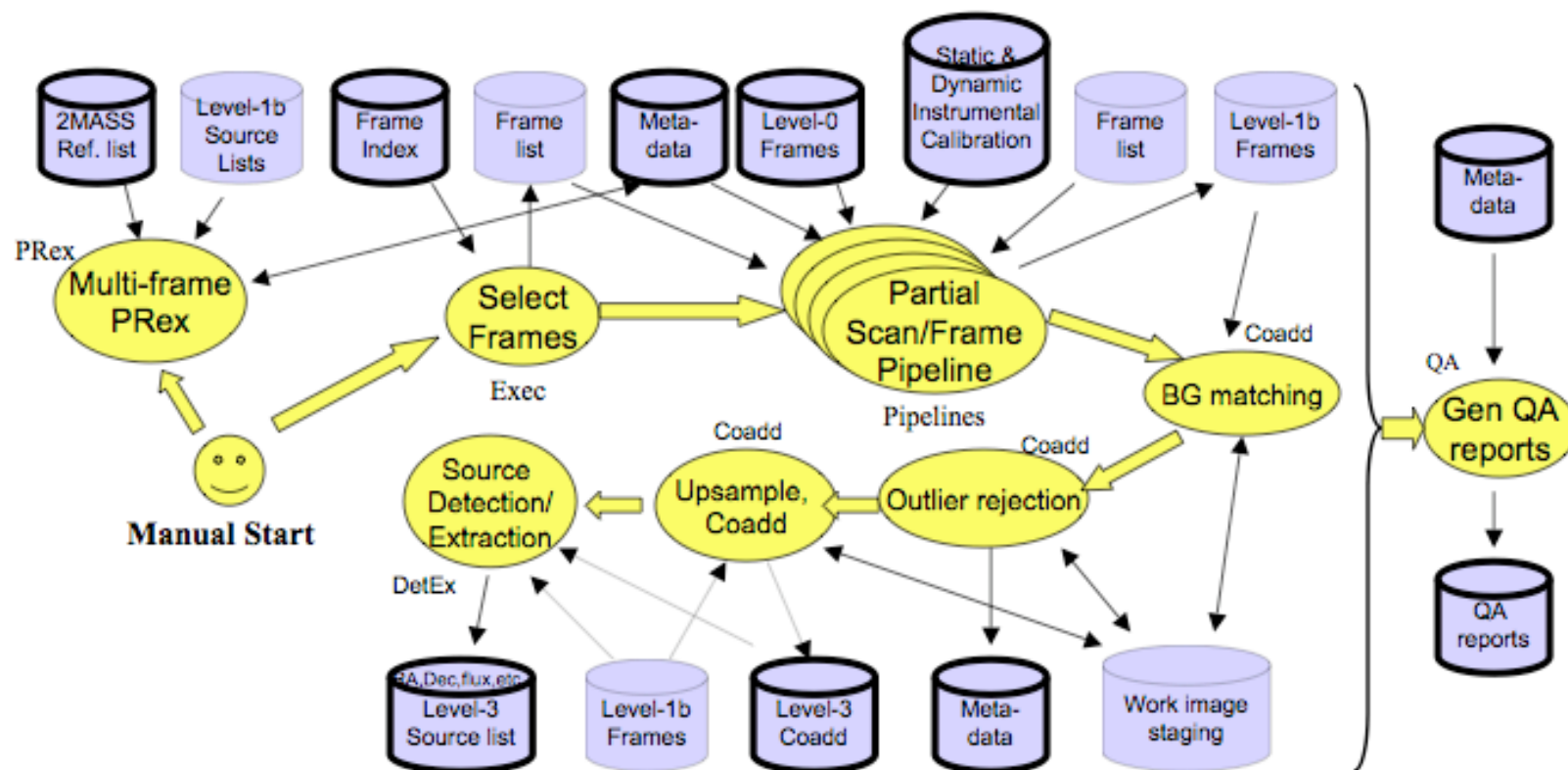


WSDS Scan/Frame Pipeline





Multi-frame Pipeline



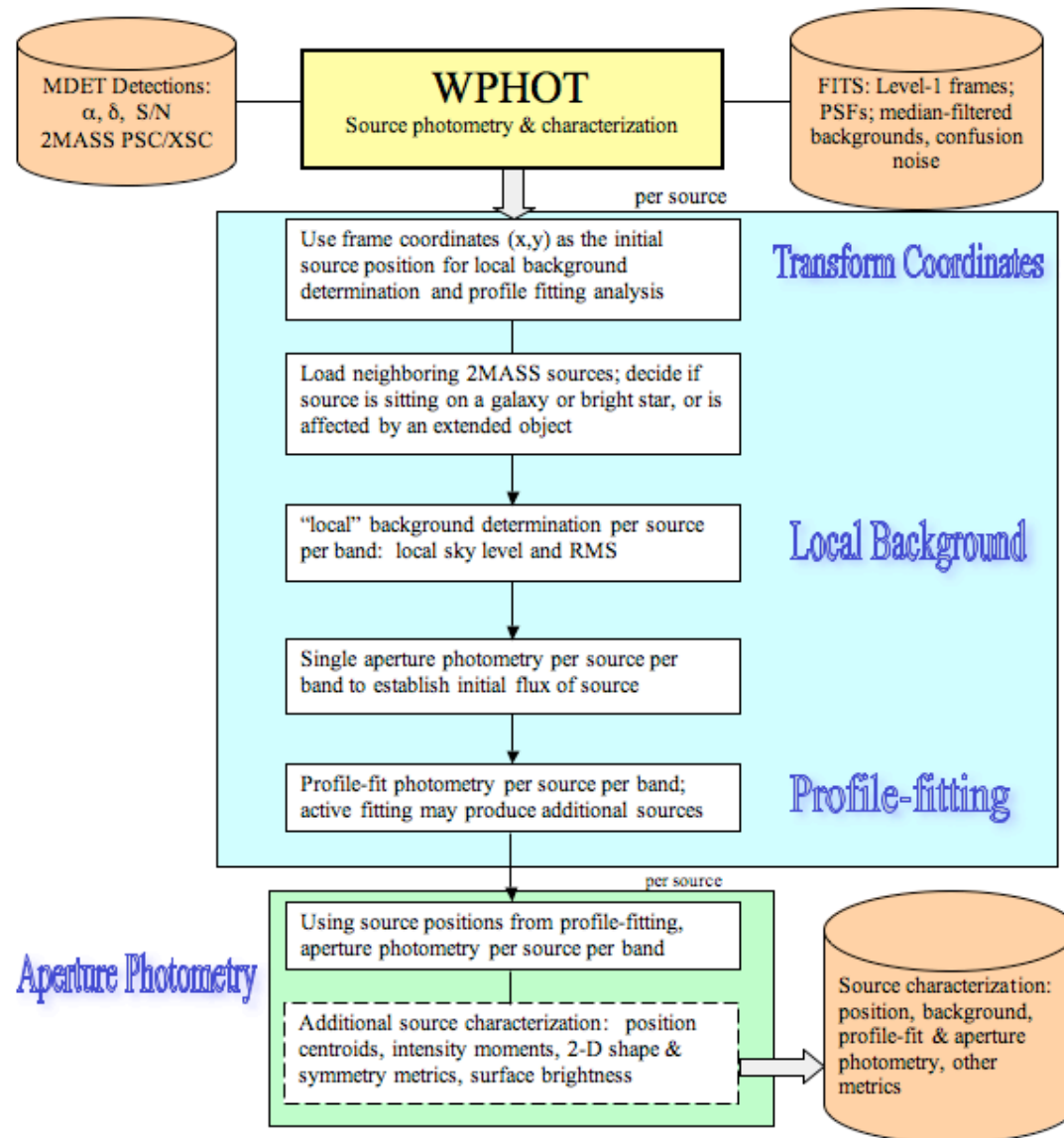
Driving Requirements



- [L4WSDC-002] The WSDC shall produce a Source Catalog derived from the images used to generate the WISE digital Image Atlas.
- [L4WSDC-080] The final WISE Source Catalog shall have greater than 99.9% reliability for sources detected in at least one band with $\text{SNR} > 20$, where the noise includes flux errors due to zodiacal foreground emission, instrumental effects, source photon statistics, and neighboring sources. This requirement shall not apply to sources that are superimposed on an identified artifact. [eliminate?]
- [L4WSDC-009] The final WISE Source Catalog shall be at least 95% complete for sources detected with $\text{SNR} > 20$ in at least one band, where the noise includes flux errors due to zodiacal foreground emission, instrumental effects, source photon statistics, and neighboring sources. This requirement shall not apply to sources that are superimposed on an identified artifact.
- [L4WSDC-010] The final WISE Source Catalog shall include sources down to $\text{SNR} = 5$ in any band, and the completeness and reliability of sources in the Catalog shall be characterized at all flux levels.
- [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 μm , 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 $\text{SNR} > 100$, 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-015] The WISE Source Catalog shall contain the measured in-band fluxes or flux upper-limits in the four WISE bands for objects detected in at least one band in the WISE Atlas Images.
- [L4WSDC-016] The WISE Source Catalog shall contain uncertainties in the flux measurements (one sigma) in all bands for which a source is detected.
- [L4WSDC-018] The WISE Source Catalog shall contain uncertainties in the coordinates measurements for each object.
- [L4WSDC-043] The WSDS Pipeline processing shall detect sources down to a threshold of at least five times the image noise from the calibrated image frames, and the combined Atlas Images.
- [L4WSDC-044] The WSDS Pipeline processing shall merge source detections in the four WISE bands into a single source catalog entry.
- [L4WSDC-049] The WSDS Pipeline shall be robust to data missing from one or more bands.



WPHOT Processing Flow



Profile-Fitting Photometry (WPRO)



- Based on maximum likelihood fit of PSFs to pixel values at all bands simultaneously
- Advantages of multiband fit:
 1. High resolution data at short wavelengths can guide the fitting procedure at the longer wavelengths where the resolution is poorer
 2. No post-extraction bandmerge step is required, thus avoiding cross-band matching ambiguities in crowded fields
 3. Optimal band-filling (valid measurement in band(s) that may not otherwise be detected)



Models for maximum likelihood estimation



Measurement model:

$$\rho_{\lambda i} = \sum_{n=1}^{N_B} (f_{\lambda})_n H_{\lambda}(\mathbf{r}_{\lambda i} - \mathbf{s}_n) + b_{\lambda} + \nu_{\lambda i}$$

↑
↑
↑
↑
↑

pixel value
flux
PSF
background
noise

Noise model:

$$\sigma_{\lambda i}^2 = \underbrace{(\rho_{\lambda i} - b_{\lambda})/g_{\lambda}}_{\text{[Poisson noise]}} + \underbrace{[(\rho_{\lambda i} - b_{\lambda})(\sigma_{\text{ff}})_{\lambda}]^2}_{\text{[Flat-fielding error]}} + \underbrace{(N_{\text{R}})_{\lambda}^2}_{\text{[Read noise]}}$$

$$+ \underbrace{(\sigma_b)_{\lambda}^2}_{\text{[background noise]}} + \underbrace{[(f_{\text{ap}})_{\lambda} \delta H_{\lambda}(\mathbf{r}_{\lambda i} - \mathbf{s}_n)]^2}_{\text{[PSF error]}}$$





Solution procedure



Construct parameter vector:

$$\mathbf{z} \equiv [\{\mathbf{s}_n, \{(f_\lambda)_n : \lambda = 1, \dots, N_\lambda\} : n = 1, \dots, N_B\}]$$

\uparrow \uparrow
 [Position of n th [fluxes at the multiple bands]
 blend component]

Maximize:

$$\ln P(\rho|\mathbf{z}, N_B) = -\frac{1}{2} \sum_{\lambda} \sum_i \frac{1}{\sigma_{\lambda i}^2} [\rho_{\lambda i} - b_{\lambda} - \sum_{n=1}^{N_B} (f_{\lambda})_n H_{\lambda}(\mathbf{r}_{\lambda i} - \mathbf{s}_n)]^2 + \text{const.}$$

Evaluate quality of fit:

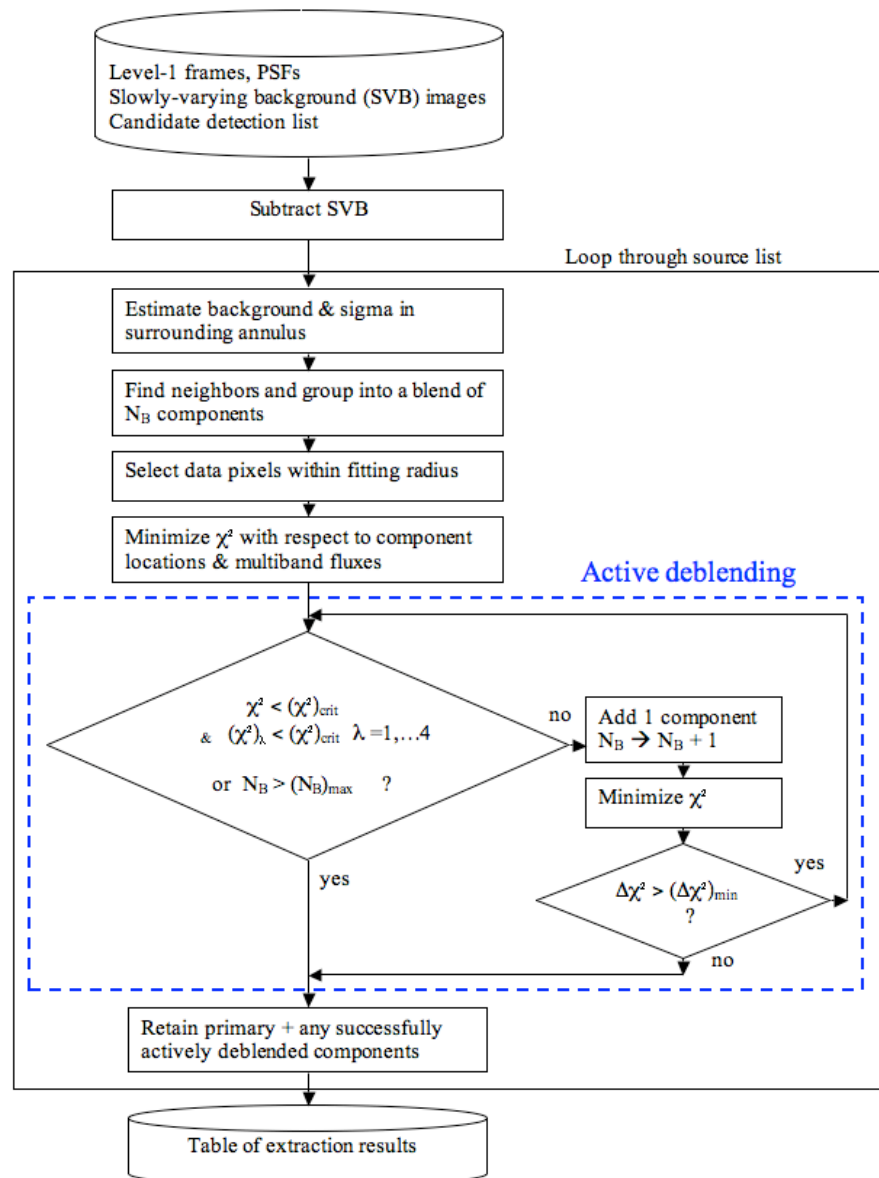
$$\chi_{\nu}^2 = \frac{1}{N_{\text{obs}} - n_p} \sum_{\lambda} \sum_i \frac{1}{\sigma_{\lambda i}^2} [\rho_{\lambda i} - b_{\lambda} - \sum_{n=1}^{N_B} (\hat{f}_{\lambda})_n H_{\lambda}(\mathbf{r}_{\lambda i} - \hat{\mathbf{s}}_n)]^2$$

\uparrow \uparrow
 Estimated fluxes and positions





WPRO flow





Aperture Photometry



The Aperture Photometry System (WAPP) performs multi-aperture photometry & additional source characterization.

Fixed aperture photometry serves several purposes, including:

- (1) source flux estimation in support of profile-fitting photometry,
- (2) construction of curve-of-growth data for aperture corrections,
- (3) more accurate flux determination for very bright sources,
- (4) serve as a 'truth' measurement to test the robustness of profile-fitting photometry, and
- (5) accurate source flux determination for extended sources in which the PSF does not accurately model the light distribution.

-- (Additional source characterization as resources permit)



WAPP continued ...

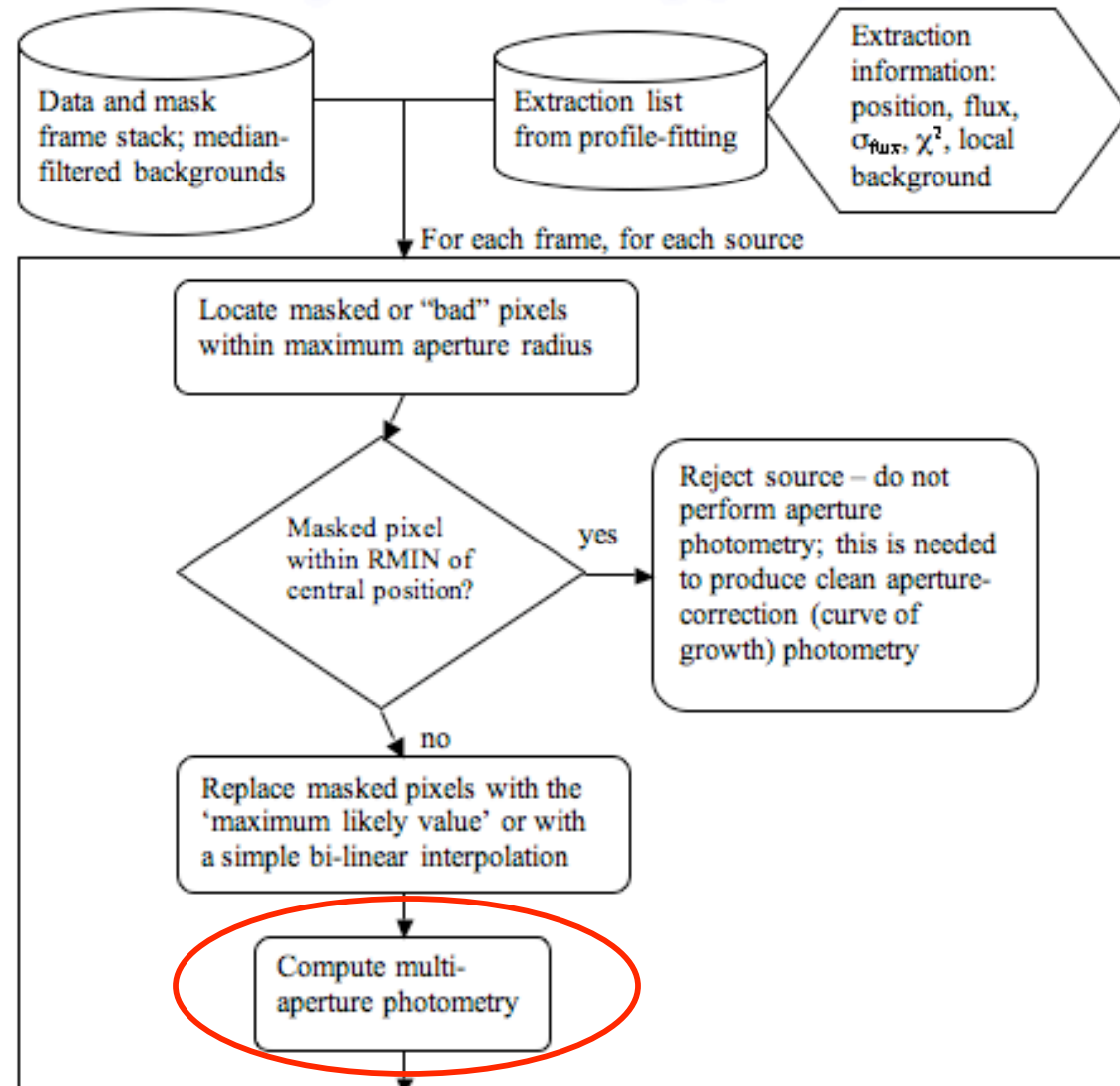


The WPRO extraction list is used as the input source list for WAPP. In this way every source extracted by WPRO using both passive and active deblending will have an aperture flux.

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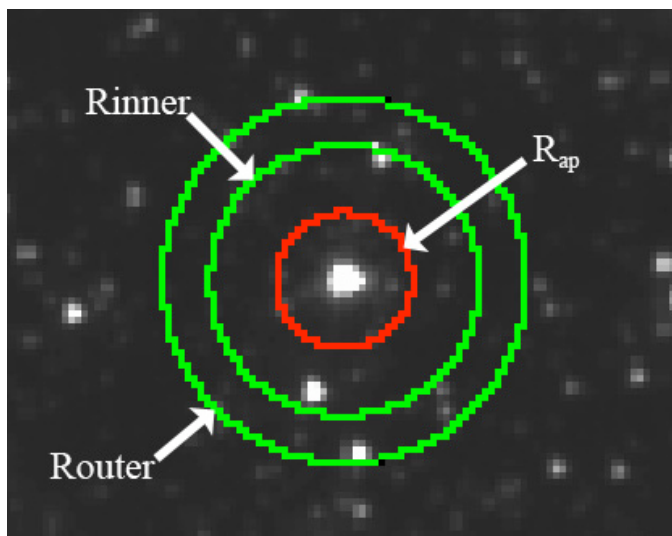


WAPP Flow

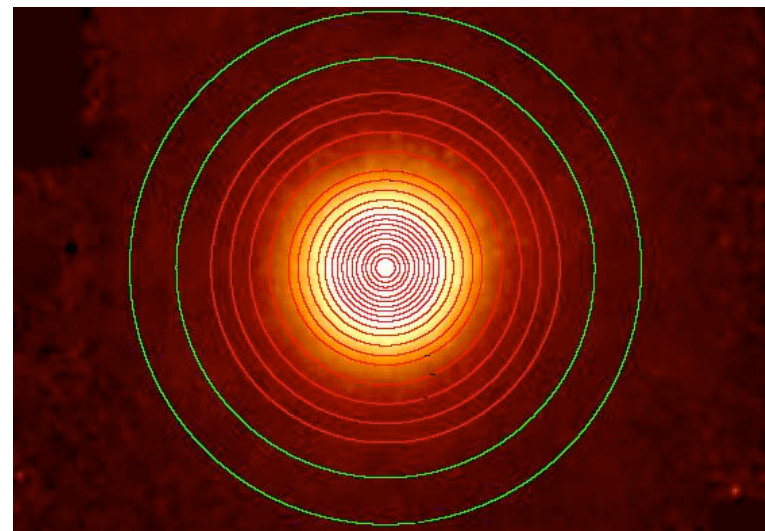




Aperture Photometry



- *bad* pixels replaced with maximum likelihood values
- Local background annulus
- Nested apertures to capture curve-of-growth
- Stellar confusion?



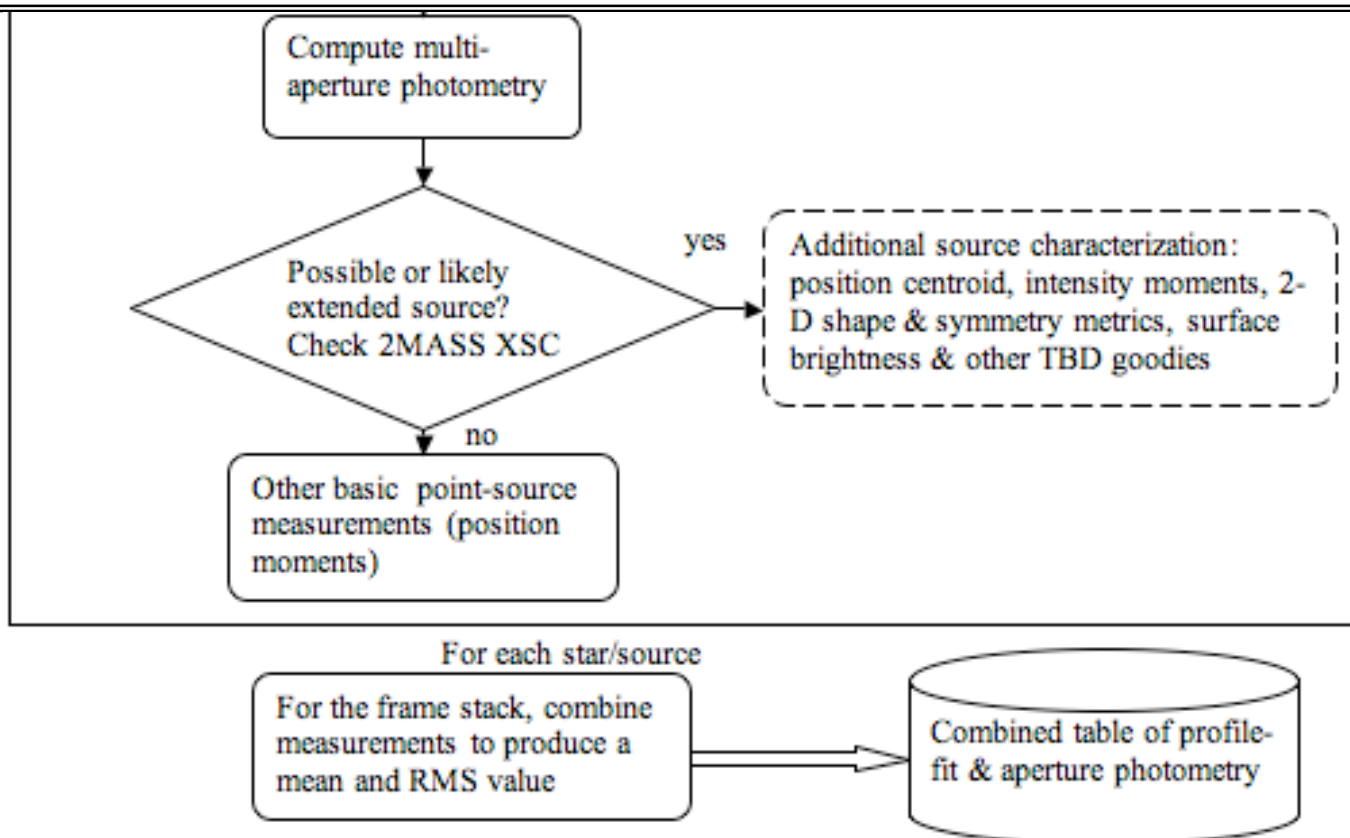
- Nested apertures to capture extended source emission
- Integrated flux and source characterization limited by local background annulus size



WAPP Flow



WPHOT





Test Description

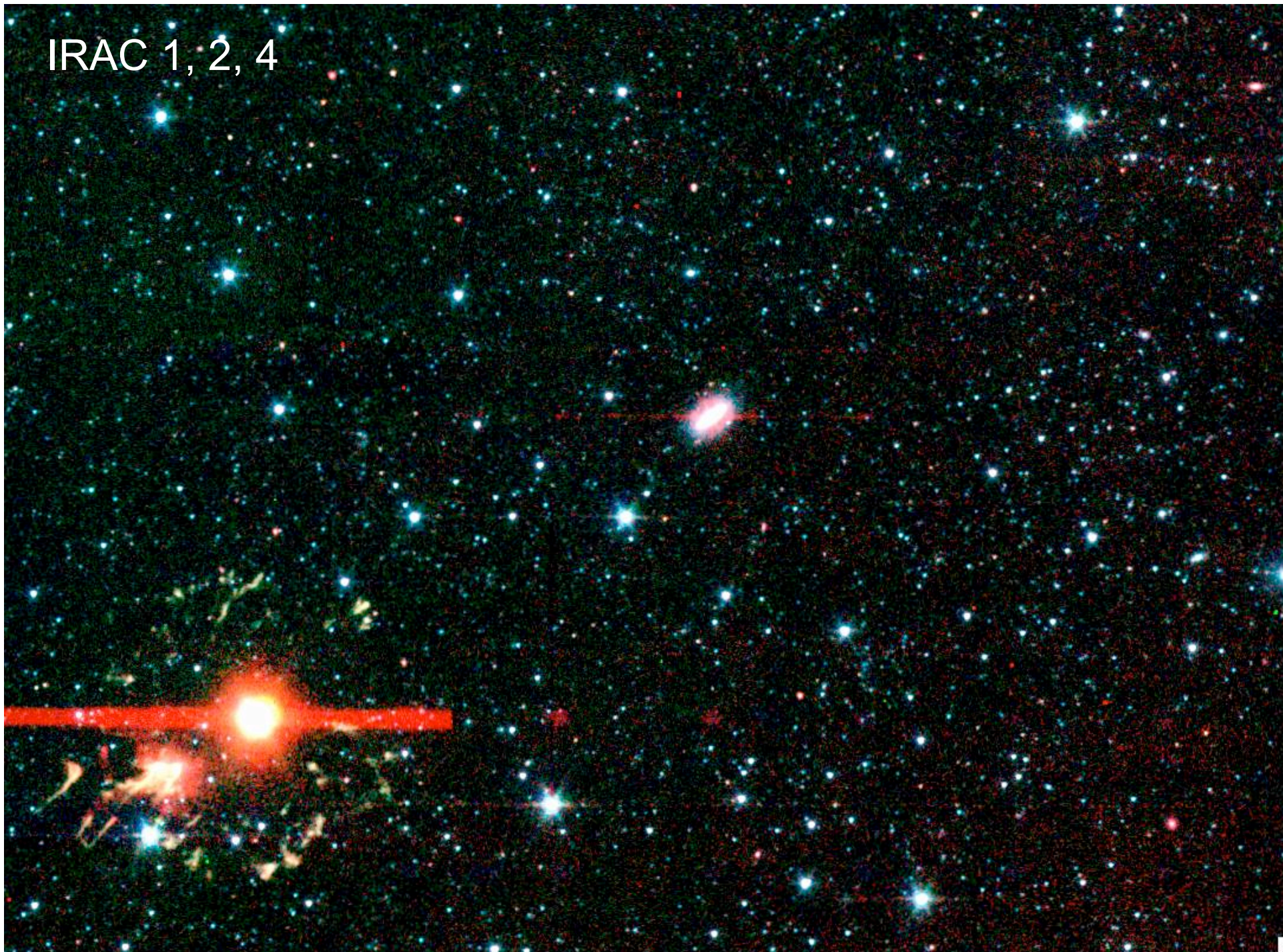


Test Data Sets: WISE image simulations; Spitzer NEP/SEP mini-surveys, GLIMPSE, SWIRE; M67 (2MASS & IRAC)

- Integrity & robustness of the algorithms
- Reliability (χ^2 metric; active deblending; N out of M)
- Completeness in confused instances (WPRO)
- Memory management for deep coverages
- Speed management (active deblending thresholding)



IRAC 1, 2, 4





Test Description -- WAPP



WAPP Annulus/Aperture testing

- Local background statistics; pixel-value histogram statistics.
- Small apertures, to test the fractional-pixel algorithm.
- Large apertures, to test the integrity of the system.
- Full range in fluxes, from noise to bright-saturated stars.
- Compare frame with coadd measurements
- Requirements (e.g., bright stars)





Test Description -- WPRO



WPRO testing:

- Validity of noise model: plots of χ_v^2 vs. magnitude
- Validity of quoted errors: repeatability tests based on multiple observations (e.g., Spitzer observations of NEP)
- Active deblending tests:
 - Verify performance (completeness and reliability as a function of SNR, recovery of sources missed during detection step)
 - Determine optimal values of deblending parameters
- Response to artifacts and extended sources:
 - Saturated stars, diffraction spikes, latent images, etc.
 - Effectiveness of χ_v^2 as discriminator



Development Schedule

- Peer Review (March, 2008)
- v0 2/27/08 prototype (single frame, multi-band), data flow testing
 - Input frames, masks & detection lists
 - Local backgrounds (stats)
 - Aperture photometry
 - Preliminary output table
- v1 6/19/08 payload ground testing; prototype multi-frame
 - Input median-filtered background images
 - Profile-fitting (active and passive deblending, isoplanatic PSF)
 - Coadded aperture photometry (prototype multi-frame)
 - Other source Characterization
 - Full output table
- V2 (multi-frame)
- V3 (IOC)
- V3.5 (flight PSFs)
- V4 (super-PSFs)

Things to Do/ Issues/Concerns

- PSF generation
- Focal Plane-dependent PSFs ??
- Focal Plane-dependent curve-of-growth measurements ?
- Parameter tuning
- Driving thresholds for active deblending
- Coadd measurements
- Upper limits
- Masked/bad-pixel recovery
- Extended Sources (no plan to properly deal with)
- Very bright stars & saturated stars