WSDC Subsystem Peer Review

Single Frame Position Reconstruction (SFPRex)

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SFPRex Purpose Related Requirements

- **Purpose**: Reconstruct Frame Position (RA & Dec), Orientation (PA) and Scale Factors (sfx &sfy) for Each of the Four Band-Frames Making Up a Single Frameset (along with uncertainties) Sufficient to Meet Related Requirements

- **Related Requirements**:
  - WISE catalog RMS of 0.5 asec per axis for SNR>20 in one or more bands
  - WISE catalog to contain uncertainties for each source
  - Will use 2MASS PSC as astrometric reference catalog
  - Will provide QA sufficient to validate
  - WISE catalog will provide equatorial coordinates (J2000 - ICRS)

Overall SFPRex Functional Flow Diagram

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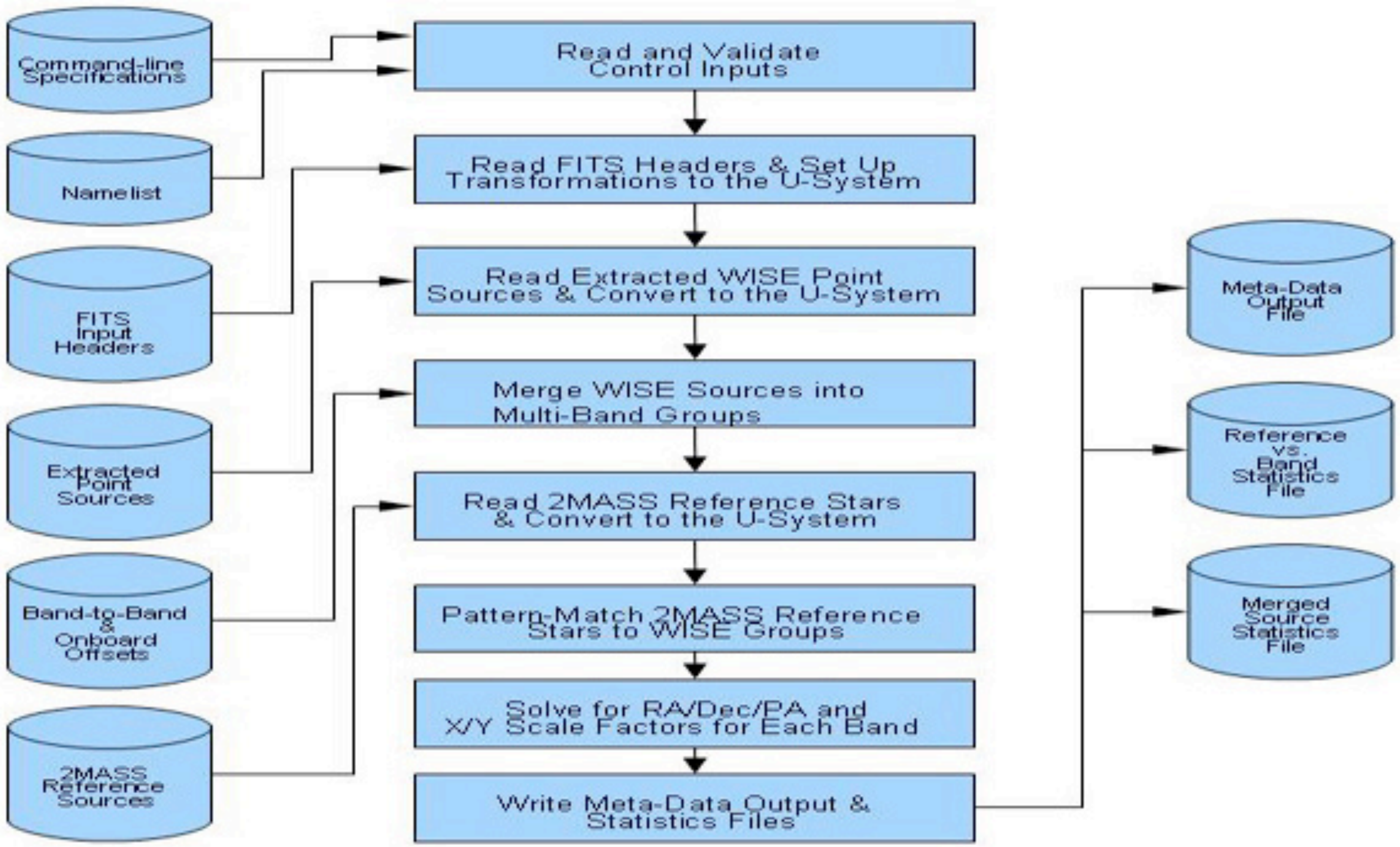
SFPRex



Going In and Out of FITS CD Matrix

$$\begin{pmatrix} CD_{11} & CD_{12} \\ CD_{21} & CD_{22} \end{pmatrix} = \begin{pmatrix} \cos\rho & -\sin\rho \\ \sin\rho & \cos\rho \end{pmatrix} \begin{pmatrix} 1/\cos\beta & 0 \\ -\tan\beta & 1 \end{pmatrix} \begin{pmatrix} s_1 & 0 \\ 0 & s_2 \end{pmatrix}$$

$$\rho = \tan^{-1}(-CD_{12}/CD_{22})$$

ρ = same as CROTA2 (pos WofN)

$$rCD = \begin{pmatrix} \cos\rho & \sin\rho \\ -\sin\rho & \cos\rho \end{pmatrix} (CD)$$

$$s_2 = rCD_{22}$$

s_2 = same as CDELT2 (scale factor in Y)

$$\beta = \sin^{-1}(-rCD_{21}/rCD_{11})$$

β = shew (amount by which angle between X & Y axes exceed 90°

$$s_1 = rCD_{11} * \cos\beta$$

s_1 = same as CDELT1 (scale factor in X)

Distortion Model

$$dx = A_{11} + A_{12}y + A_{13}y^2 + A_{14}y^3 + A_{21}x + A_{22}xy + A_{23}xy^2 + A_{24}xy^3$$
$$+ A_{31}x^2 + A_{32}x^2y + A_{33}x^2y^2 + A_{34}x^2y^3 + A_{41}x^3$$
$$+ A_{42}x^3y + A_{43}x^3y^2 + A_{44}x^3y^3$$

$$dy = B_{11} + B_{12}y + B_{13}y^2 + B_{14}y^3 + B_{21}x + B_{22}xy + B_{23}xy^2 + B_{24}xy^3$$
$$+ B_{31}x^2 + B_{32}x^2y + B_{33}x^2y^2 + B_{34}x^2y^3 + B_{41}x^3$$
$$+ B_{42}x^3y + B_{43}x^3y^2 + B_{44}x^3y^3$$

(blue) = used in distortion fit but not in pipeline

(green) = not used in 2MASS processing

Converting Band Frame Positions to U-System

$$\begin{pmatrix} {}^{i}X_{u} \\ {}^{i}Y_{u} \end{pmatrix} = \begin{pmatrix} {}^{i}X_{u0} \\ {}^{i}Y_{u0} \end{pmatrix} + \begin{pmatrix} \cos({}^{i}\theta) & \sin({}^{i}\theta) \\ -\sin({}^{i}\theta) & \cos({}^{i}\theta) \end{pmatrix} \begin{pmatrix} {}^{i}s_{x}\ {}^{i}X_{f} \\ {}^{i}s_{y}\ {}^{i}Y_{f} \end{pmatrix}$$

X_{uo}	X offset in arcsec of band-frame origin from U-system origin
Y_{u0}	Y offset in arcsec of band-frame origin from U-system origin
θ	Rotation in degrees of band-frame axes relative to U-system
s_x	X scale factor to convert from band-frame to U-system
s_y	Y scale factor to convert from band-frame to U-system

Converting Band Frame Covariance to U-System

$$T_f^u = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}$$

co-sigma xy $= \sigma_{xyf}$,

$$V_{xyf} = \sigma_{xyf} |\sigma_{xyf}|$$

$$V_{xf} = \sigma_{xf}^2$$

$$V_{yf} = \sigma_{yf}^2$$

$$\Omega \equiv \begin{pmatrix} V_{xu} & V_{xyu} \\ V_{xyu} & V_{yu} \end{pmatrix} = \left(T_f^u\right)^T \begin{pmatrix} s_x^2 V_{xf} & |s_x s_y| V_{xyf} \\ |s_x s_y| V_{xyf} & s_y^2 V_{yf} \end{pmatrix} T_f^u$$

$$\sigma_{xu} = \sqrt{V_{xu}} = \sqrt{s_x^2 V_{xf} \cos^2\theta + s_y^2 V_{yf} \sin^2\theta - 2|s_x s_y| V_{xyf} \sin\theta\cos\theta}$$

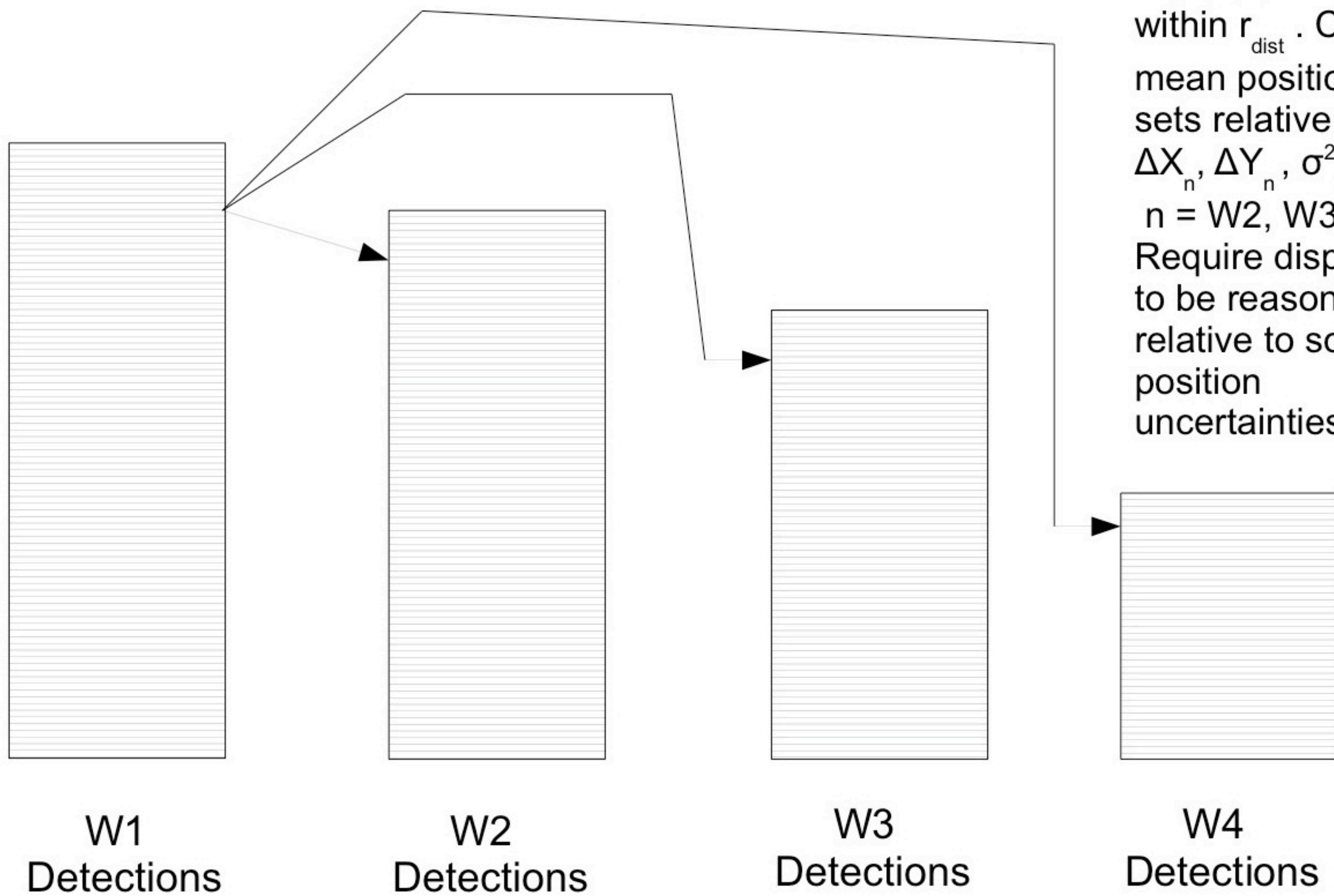
$$\sigma_{yu} = \sqrt{V_{yu}} = \sqrt{s_y^2 V_{yf} \cos^2\theta + s_x^2 V_{xf} \sin^2\theta + 2|s_x s_y| V_{xyf} \sin\theta\cos\theta}$$

$$V_{xyu} = (s_x^2 V_{xf} - s_y^2 V_{yf}) \sin\theta\cos\theta + |s_x s_y| V_{xyf} (\cos^2\theta - \sin^2\theta)$$

$$\sigma_{xyu} = sign(V_{xyu}) \sqrt{|V_{xyu}|}$$

Frame Adjustment - 1

For each W1 detection, find W2, W3, & W4 detections within r_{dist}. Reject all detections having more than 1 match within r_{dist}. Compute mean position off-sets relative to W1, ΔX_n, ΔY_n, σ^2_{xn}, σ^2_{yn}, n = W2, W3, W4. Require dispersions to be reasonable relative to source position uncertainties.



Frame Adjustment - 2

- Intended primarily for IOC
- Must have at least MinMatch (3) matches per band (if not, expand r_{dist} by 10% and try again, up to 100 times)
- RMS Dispersions must be <= Z*RMS Source Uncertainties (if not, repeat with cases rejected when offsets > Z*RMS Dispersion from 1st pass)
- Mean position offsets are subtracted from source coordinates when computing χ^2 for merge-group match test only
- Mean position offsets are returned for use in band-frame position correction

Merge Group Generation - 1

All cross-band pairings of sources are tested for position matching via 2-D χ^2 test

For source #m in band i and source #n in band j:

$$\Delta X = ({}^{i}X_m - \delta x_i) - ({}^{j}X_n - \delta x_j)$$

$$\Delta Y = ({}^{i}Y_m - \delta y_i) - ({}^{j}Y_n - \delta y_j)$$

$$\vec{\Delta} \equiv (\Delta X, \Delta Y)$$

$$\Omega = {}^{i}\Omega_m + {}^{j}\Omega_n = \begin{pmatrix} {}^{i}V_{xm} & {}^{i}V_{xym} \\ {}^{i}V_{xym} & {}^{i}V_{ym} \end{pmatrix} + \begin{pmatrix} {}^{j}V_{xn} & {}^{j}V_{xyn} \\ {}^{j}V_{xyn} & {}^{j}V_{yn} \end{pmatrix} \equiv \begin{pmatrix} V_x & V_{xy} \\ V_{xy} & V_y \end{pmatrix}$$

$$W \equiv \Omega^{-1} = \frac{1}{D}\begin{pmatrix} V_y & -V_{xy} \\ -V_{xy} & V_x \end{pmatrix} \equiv \begin{pmatrix} W_x & W_{xy} \\ W_{xy} & W_y \end{pmatrix}, \quad D \equiv V_x V_y - V_{xy}^2$$

$$\chi^2 = \vec{\Delta} W \vec{\Delta}^T = W_x \Delta X^2 + W_y \Delta Y^2 + 2W_{xy} \Delta X \Delta Y$$

$$= \frac{V_y \Delta X^2 + V_x \Delta Y^2 - 2V_{xy} \Delta X \Delta Y}{D}$$

Source pair is a match if $\chi^2 < \chi^2_{max}$ (6; implies 5% real matches sacrificed for reliability)

Merge Group Generation - 2

- Each source in a merge group must match at least one other source in that group
- No source may have more than one match in another band; if any does, all sources are rejected from membership in any group
- Merge groups are bookkept in arrays of source indexes, MG(N_g,4); for example, if group #17 consists of W1 source #21 and W3 source #9, then MG(17,n), n = 1 to 4, is {21, 0, 9, 0}
- Denoting the members of a given group as {G}, position refinement is performed to obtain the group position and uncertainties as follows:

$$W = \sum_{i \in \{G\}} {}^{i}\Omega^{-1} = \sum_{i \in \{G\}} \frac{1}{{}^{i}V_x \, {}^{i}V_y - {}^{i}V_{xy}^2} \begin{pmatrix} {}^{i}V_y & -{}^{i}V_{xy} \\ -{}^{i}V_{xy} & {}^{i}V_x \end{pmatrix}$$

$$\Omega_{refined} = W^{-1}$$

$$\begin{pmatrix} X \\ Y \end{pmatrix}_{refined} = \Omega_{refined} \sum_{i \in \{G\}} {}^{i}\Omega^{-1} \begin{pmatrix} {}^{i}X \\ {}^{i}Y \end{pmatrix}$$

2MASS Stars Selected for Use as Astrometric References

- Current Selection Criteria
  - Taken from Point Source Catalog (PSC)
  - Clean (Unconfused, not a known asteroid, ..)
  - Have Ks magnitudes between 5.5 and 12.0
  - Results in 30 million sources
  - Counts per frame vary with sky position (average 446)

- Some Uncertainty- % 2MASS Sources Visible/WISE Band

- Selection Can Be Expanded to Increase 2MASS References
  - Can increase Ks magnitude range to 4.5 to 14.5
  - Still retain 0.1 arc-second accuracy

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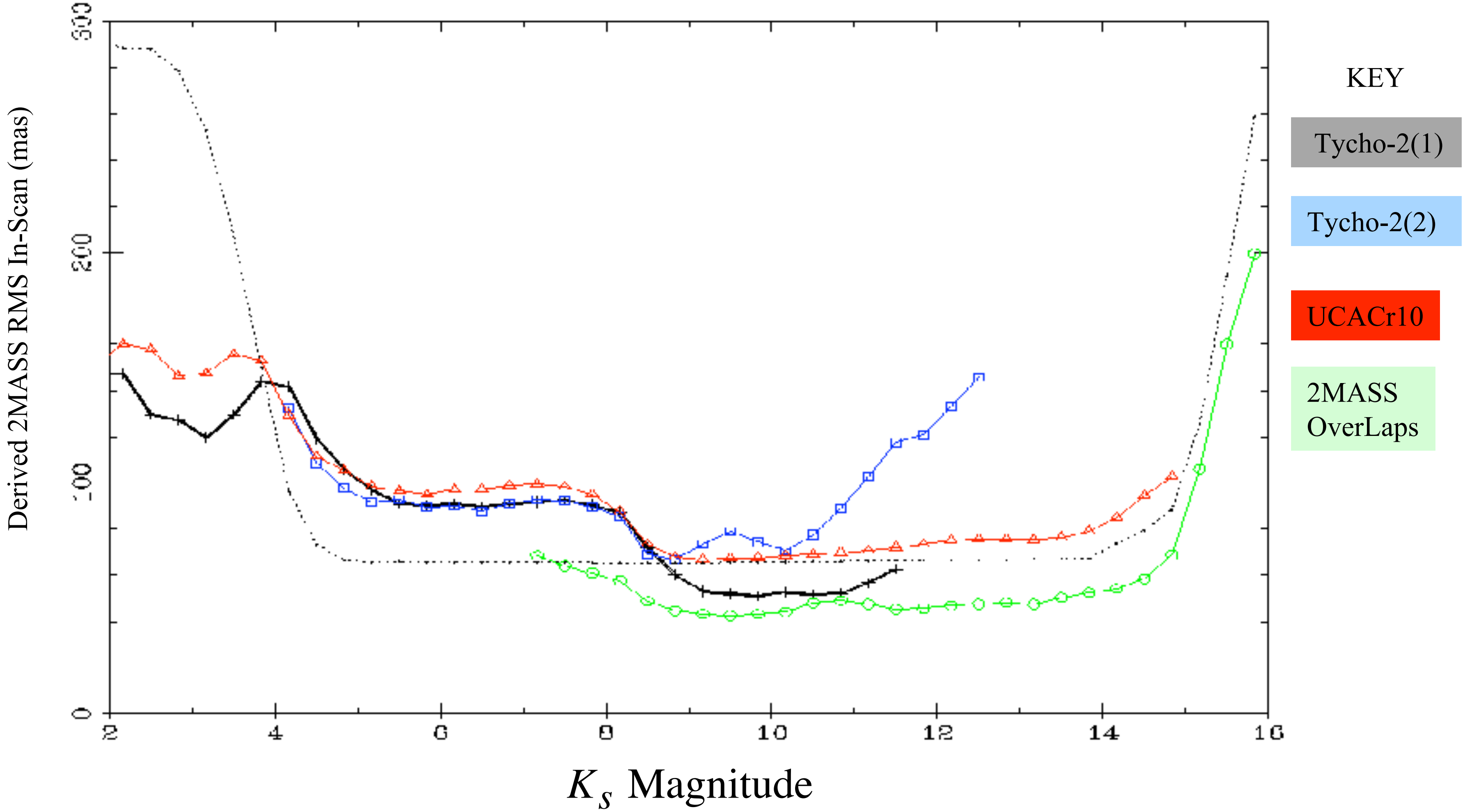
2MASS Positional Accuracy vs Magnitude

SFPRex



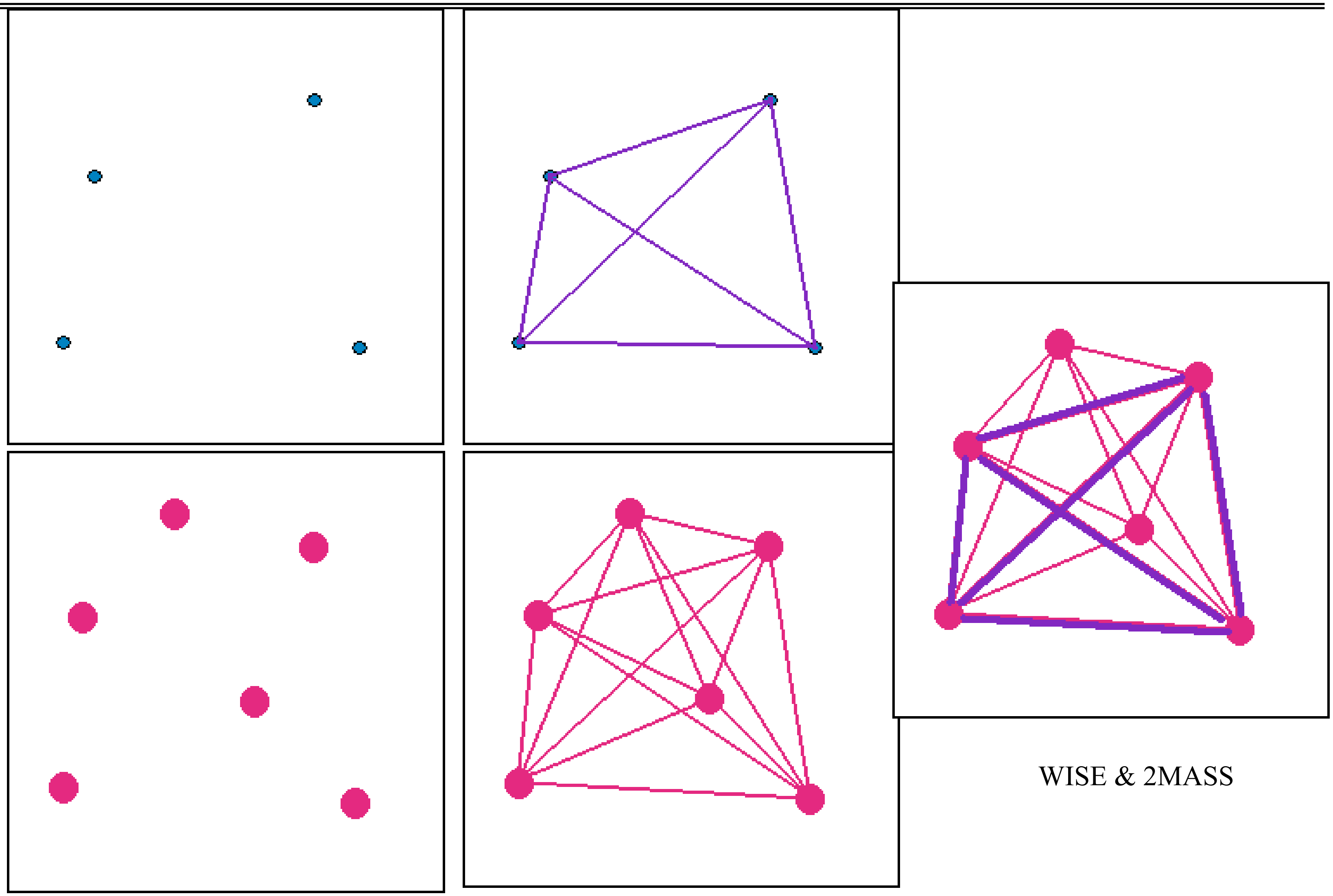
Pattern Matcher

- Set up Separation Bars Between Pairs of Sources
  - Consider all possible bars within 2MASS & WISE Merge Group sets
    - Brightest *ldepth* (set to 99) sources
    - Minimun separation of *sepmin* (set to 60 asec)
- Set up Bar Match Candidates Between 2MASS and WISE
  - Max difference in PA between candidate bar pairs of *toldpa* (set to 4000 asec)
  - Max difference from 1.0 of bar length ratio = *tolds* (set to .015)
- Force Exact Alignment of Candidate Separation Bar Pairs
  - Use Two-Peg approach from 2MASS to Torque WISE Merge Group Set
  - Compute and save source match counts & required adjustments $\Delta X,\ \Delta Y,\ \theta,\ sf$
- Evaluate Probability That All Source Matches Spurious
- Option controlled by *useals:*
  - Compute trimmed average of adjustments for bar pairs with best source match counts
- Option controlled by *twkmch*:
  - Do 5-parameter fit using all source match => $dx,\ dy,\ d\theta,\ ds_x,\ ds_y$

Separation Bar Matching (Simplified Illustration)

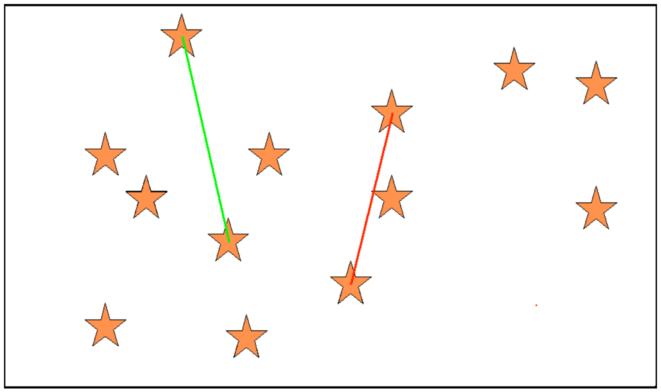
2MASS

WISE

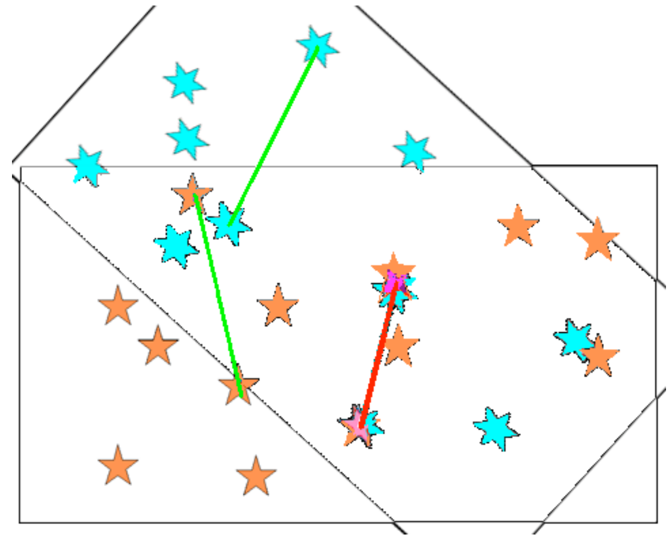


WISE & 2MASS

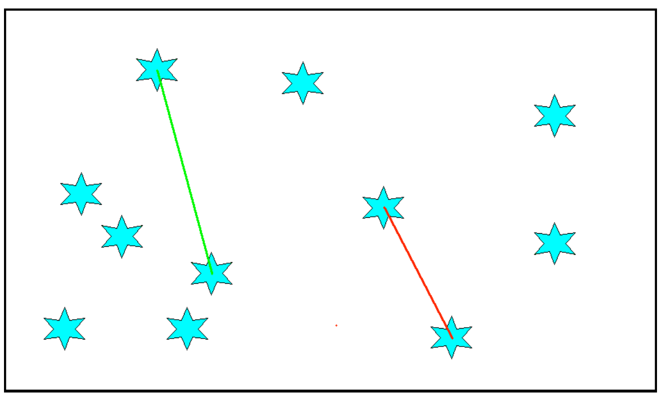
Two Peg Source Match Counts Identify Good Sep-Bar Match



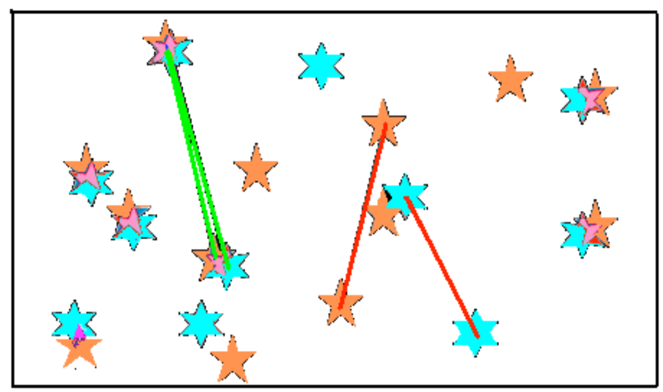
WISE Merged Groups



Source Match Count => Bad Bar Match



2MASS Reference Stars



Source Match Count => Good Bar Match

Two Peg Solution
Merge Group Adjustments

Force Merge Group Position to Match Reference Star Position at PEG Point 1

$$\begin{pmatrix} {}^{g}X_{u1} \\ {}^{g}Y_{u1} \end{pmatrix} = \begin{pmatrix} \Delta X \\ \Delta Y \end{pmatrix} + \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} sf * X_{f1} \\ sf * Y_{f1} \end{pmatrix} = \begin{pmatrix} {}^{r}X_{u1} \\ {}^{r}Y_{u1} \end{pmatrix}$$

Force Merge Group Position to Match Reference Star Position at PEG Point 2

$$\begin{pmatrix} {}^{g}X_{u2} \\ {}^{g}Y_{u2} \end{pmatrix} = \begin{pmatrix} \Delta X \\ \Delta Y \end{pmatrix} + \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} sf * X_{f2} \\ sf * Y_{f2} \end{pmatrix} = \begin{pmatrix} {}^{r}X_{u2} \\ {}^{r}Y_{u2} \end{pmatrix}$$

Provides 4 Equations in 4 Unknowns => $\Delta X, \Delta Y, \theta, sf$

Note: This solution does not depend on the parameters being small
It does assume equal scales in X and Y

Probability All Matches Spurious

Poisson probability for n events given an average of m events is

$$P(n \mid m) = \frac{e^{-m} m^n}{n!}$$

Probability that no random match will occur is

$$P(0 \mid N_{rand}) = \frac{e^{-N_{rand}} N_{rand}^0}{0!} = e^{-N_{rand}}$$

Probability that at least one random match will occur is

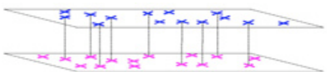
$$P(> 0 \mid N_{rand}) = 1 - e^{-N_{rand}}$$

If $N_{matches}$ are found, the probability all of them are spurious is

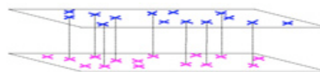
$$P(N_{matches} \mid N_{rand}) = \frac{e^{-N_{rand}} N_{rand}^{N_{matches}}}{N_{matches}!}$$

Linking Band-to-Band and Band-to-Ref

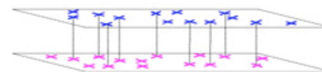
W1 vs REF



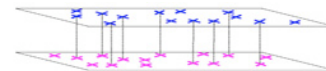
W1 vs W2



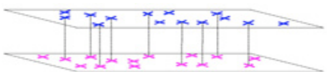
W1 vs W3



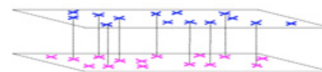
W1 vs W4



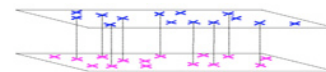
W2 vs REF



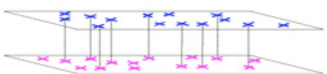
W2 vs W3



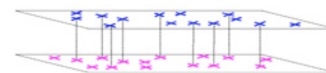
W2 vs W4



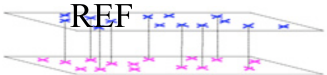
W3 vs REF



W3 vs W4



W4 vs REF



Small Adjustment Parameters

$$^{i}X_{u0} \Leftarrow {}^{i}X_{u0} + {}^{i}\Delta X$$

$$^{i}Y_{u0} \Leftarrow {}^{i}Y_{u0} + {}^{i}\Delta Y$$

$$^{i}\theta \Leftarrow {}^{i}\theta + {}^{i}\Delta\theta$$

$$^{i}s_{x} \Leftarrow {}^{i}s_{x}\left(1 + {}^{i}ds_{x}\right)$$

$$^{i}s_{y} \Leftarrow {}^{i}s_{y}\left(1 + {}^{i}ds_{y}\right)$$

$$P_1 \equiv {}^{1}\Delta X, P_2 \equiv {}^{1}\Delta Y, P_3 \equiv {}^{1}\Delta\theta, P_4 \equiv {}^{1}ds_x, P_5 \equiv {}^{1}ds_y$$

$$P_6 \equiv {}^{2}\Delta X, P_7 \equiv {}^{2}\Delta Y, P_8 \equiv {}^{2}\Delta\theta, P_9 \equiv {}^{2}ds_x, P_{10} \equiv {}^{2}ds_y$$

$$P_{11} \equiv {}^{3}\Delta X, P_{12} \equiv {}^{3}\Delta Y, P_{13} \equiv {}^{3}\Delta\theta, P_{14} \equiv {}^{3}ds_x, P_{15} \equiv {}^{3}ds_y$$

$$P_{16} \equiv {}^{4}\Delta X, P_{17} \equiv {}^{4}\Delta Y, P_{18} \equiv {}^{4}\Delta\theta, P_{19} \equiv {}^{4}ds_x, P_{20} \equiv {}^{4}ds_y$$

Setting Up χ^2 Minimization Equations

$$\chi^2 = \chi^2_{ww} + \chi^2_{wr} + \chi^2_{aw} + \chi^2_{ar}$$

$\chi^2_{ww} = \chi^2$ sum of all WISE - to - WISE (band - to - band) differences

$\chi^2_{wr} = \chi^2$ sum of all WISE - to - Ref differences

$\chi^2_{aw} = \chi^2$ sum of parameter changes from *apriori* values

$\chi^2_{ar} = \chi^2$ sum reflecting changes in *apriori* band - to - band alignments

$$\frac{\partial \chi^2}{\partial P_n} = 0 \, , \; n = 1 \; to \; 20$$

Provides 20 Equations in 20 Unknowns

χ^2 Summation (WISE to WISE)

$$\chi^2_{ww} = \sum_{i=1}^{3} \sum_{j=i+1}^{4} \sum_{n=1}^{N_i} \sum_{m=1}^{Nj} \left[{}^j_i W^m_{xn} \left({}^i X_{un} - {}^j X_{um} \right)^2 + {}^j_i W^m_{yn} \left({}^i Y_{un} - {}^j Y_{um} \right)^2 + 2\, {}^j_i W^m_{xyn} \left({}^i X_{un} - {}^j X_{um} \right) \left({}^i Y_{un} - {}^j Y_{um} \right) \right]$$

i = primary band number

j = secondary band number

n = WISE source number within primary band

m = corresponding WISE source number within secondary band

χ^2 Weighting Factors

$$ {}_i^j W_{xn}^m = \frac{{}^i V_{yu_n} + {}^j V_{yu_m}}{\left({}^i V_{xu_n} + {}^j V_{xu_m}\right)\left({}^i V_{yu_n} + {}^j V_{yu_m}\right) - \left({}^i V_{xyu_n} + {}^j V_{xyu_m}\right)^2} $$

$$ {}_i^j W_{yn}^m = \frac{{}^i V_{xu_n} + {}^j V_{xu_m}}{\left({}^i V_{xu_n} + {}^j V_{xu_m}\right)\left({}^i V_{yu_n} + {}^j V_{yu_m}\right) - \left({}^i V_{xyu_n} + {}^j V_{xyu_m}\right)^2} $$

$$ {}_i^j W_{xyn}^m = \frac{-\left({}^i V_{xyu_n} + {}^j V_{xyu_m}\right)}{\left({}^i V_{xu_n} + {}^j V_{xu_m}\right)\left({}^i V_{yu_n} + {}^j V_{yu_m}\right) - \left({}^i V_{xyu_n} + {}^j V_{xyu_m}\right)^2} $$

χ^2 Summation (WISE to Reference)

$$\chi^2_{wr} = \sum_{i=1}^{4}\sum_{k=1}^{N_r}\sum_{n=1}^{N_i}\left[{}^iW^k_{xn}\left({}^iX_{un} - {}^rX_{uk}\right)^2 + {}^iW^k_{yn}\left({}^iY_{un} - {}^rY_{uk}\right)^2 + 2\,{}^iW^k_{xyn}\left({}^iX_{un} - {}^rX_{uk}\right)\left({}^iY_{un} - {}^rY_{uk}\right)\right]$$

i = band number

n = WISE source number within band

k = corresponding reference (2MASS) source number

$W = 0$ when no match; otherwise as with WISE - to - WISE

χ^2 Summation (Apriori - Parameters)

$$\chi_{ar}^2 = \sum_{i=1}^{4} {}^{i}K_{ar}\left[\frac{{}^{i}\Delta X^2}{{}^{i}V_{x0}} + \frac{{}^{i}\Delta Y^2}{{}^{i}V_{y0}} + \frac{{}^{i}\Delta \theta^2}{{}^{i}V_{\theta 0}} + \frac{{}^{i}ds_x^{\,2}}{{}^{i}V_{dsx0}} + \frac{{}^{i}ds_y^{\,2}}{{}^{i}V_{dsy0}}\right]$$

${}^{i}K_{ar}$ = user supplied multipler for band i

${}^{i}V_{x0}$ = apriori variance ΔX of band i

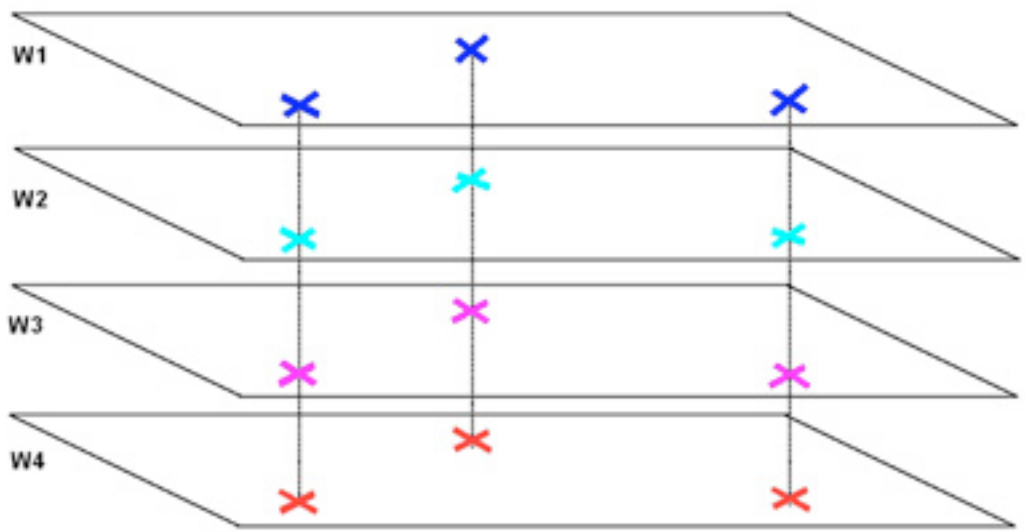
${}^{i}V_{x0}$ = apriori variance ΔY of band i

${}^{i}V_{x0}$ = apriori variance $\Delta \theta$ of band i

${}^{i}V_{dsx0}$ = apriori variance ds_x of band i

${}^{i}V_{dsy0}$ = apriori variance ds_y of band i

Manually Inserted Pseudo Sources



- $$ {}^{1}_{p}X_{f1} = 512.0 \times {}^{1}s_x \,, \quad {}^{1}_{p}Y_{f1} = 853.3 \times {}^{1}s_y $$
$$ {}^{1}_{p}X_{f2} = 216.4 \times {}^{1}s_x \,, \quad {}^{1}_{p}Y_{f2} = 341.3 \times {}^{1}s_y $$
$$ {}^{1}_{p}X_{f3} = 807.6 \times {}^{1}s_x \,, \quad {}^{1}_{p}Y_{f3} = 341.3 \times {}^{1}s_y $$

χ^2 Summation (Apriori - band to band)

$$\chi_{aw}^2 = \sum_{i=1}^{3} \sum_{j=i+1}^{4} {}_j^iK_{aw} \sum_{n=1}^{3} \begin{bmatrix} {}_i^jW_{px}^n({}_p^iX_{un} - {}_p^jX_{un})^2 + {}_i^jW_{py}^n({}_p^iY_{un} - {}_p^jY_{un})^2 \\ +2\,{}_i^jW_{pxy}^n({}_p^iX_{un} - {}_p^jX_{un})({}_p^iY_{un} - {}_p^jY_{un}) \end{bmatrix}$$

$i =$ primary band number

$j =$ secondary band number

$n =$ manually inserted proxy source number

${}_j^iK_{aw} =$ user supplied multiplier on band i to band j coupling

${}_i^jW_{px}^n =$ x component weight of band i vs j for manually inserted point n

Assigning Uncertainties to the 20 Parameters

The matrix equation for the χ^2 minimization takes the form:

$$Ax = b$$

The equation can be solved by taking the inverse of matrix A

$$x = A^{-1}b$$

Fortunately for a linear system the the error covariance matrix Ω_p is just A inverse

$$\Omega_p = A^{-1}$$

Taking square-roots of the diagonal elements of Ω_p provides sigmas for all parameters

Single Band χ^2 Minimization Eqn (without constraints)

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{pmatrix} \begin{pmatrix} \Delta X \\ \Delta Y \\ \Delta\theta \\ ds_x \\ ds_y \end{pmatrix} = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ b_5 \end{pmatrix}$$

Single Band χ^2 Minimization Eqn (with fixed parameters)

Assume it is desired to fix ds_x and ds_y at their *a priori* values ds_{x0} and ds_{y0}; the reduced matrix equation becomes:

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} \Delta X \\ \Delta Y \\ \Delta\theta \end{pmatrix} = \begin{pmatrix} b_1 - a_{14}\, ds_{x0} - a_{15}\, ds_{y0} \\ b_2 - a_{24}\, ds_{x0} - a_{25}\, ds_{y0} \\ b_3 - a_{34}\, ds_{x0} - a_{35}\, ds_{y0} \end{pmatrix}$$

Single Band χ^2 Minimization Eqn (constrained: $ds_x = ds_y$)

Consider forcing the x and y scale changes to be equal (solving for $ds \equiv ds_x = ds_y$)

Achieved by adding together the rows and the columns associated with scale changes

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14}+a_{15} \\ a_{21} & a_{22} & a_{23} & a_{24}+a_{25} \\ a_{31} & a_{32} & a_{33} & a_{34}+a_{35} \\ a_{41}+a_{51} & a_{42}+a_{52} & a_{43}+a_{53} & a_{44}+a_{45}+a_{54}+a_{55} \end{pmatrix} \begin{pmatrix} \Delta X \\ \Delta Y \\ \Delta\theta \\ ds \end{pmatrix} = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \\ b_4+b_5 \end{pmatrix}$$

Testing and Parameter Tuning

- Testing:
  - Robustness testing of pattern matcher
    - High and low source densities
    - Large *apriori* position errors
    - Sensitivity to brightest WISE sources matching brightest 2MASS
  - Testing of 20-parameter frameset fitter
    - Explore band-to-band and band-to-ref count parameter space
    - Consider effect of no band-to-ref counts for band 4
- Parameter Tuning:
  - Set pattern match parameters such that
    - Unlikely a good match will be rejected
    - Very unlikely a bad match will be accepted
  - Set K_{aw} weighting factors

SFPRex Liens

- The 20-parameter fit not yet implemented in SFPRex.
- Outlier detection and rejection algorithms have not yet been designed.
- SIS's have not yet been written for any output files.
- How to handle lack of proper motions in 2MASS PSC
- Uncertainties coming out of pattern matcher (*apriori* inputs to frameset fitter)