Russian Academy of Sciences
Pulkovo Observatory

On systematic and stochastic errors of radio source position catalogues

Zinovy Malkin

Pulkovo Observatory and St. Petersburg State University

malkin@gao.spb.ru

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Topics to discuss

The following topics related to the radio source position catalogues are considered:

1. Formal uncertainties
2. External stochastic errors (see Malkin, A&A, 2013, DOI: 10.1051/0004-6361/201322334 for more detail)
3. Several points related to systematics

Assessment of external errors of catalogues

N-cornered-hat method

$$\sigma_{ij}^2 = \sigma_i^2 + \sigma_j^2 - 2\rho_{ij}\sigma_i\sigma_j$$

i = 1,n-1, j = i+1,n

σ_{ij} - variance of differences between catalogues

ρ_{ij} - correlation coefficient between catalogues

σ_i, σ_j - unknown external errors of catalogues

Estimation of ρ_{ij} is a key point of the method!

Correlation between catalogues

Let's consider the i-th and j-th catalogues. At the first step we compute the differences between these catalogues with all k-th catalogues, $k = 1, ..., n, k \neq i, k \neq j$ for sources common for all catalogues. After that, we compute the correlation ρ_{ij}^k between catalogue differences $\Delta_{ik} = Cat_i - Cat_k$ and $\Delta_{jk} = Cat_j - Cat_k$ for each k, where Cat_i, Cat_j, and Cat_k are vectors of the common source positions. Computations are made separately for right ascension (RA) and declination (DE). RA differences were multiplied by $\cos(DE)$. The average value of ρ_{ij}^k over all k is considered an approximation to the correlation ρ_{ij} between i-th and k-th catalogues.

Weighted correlation

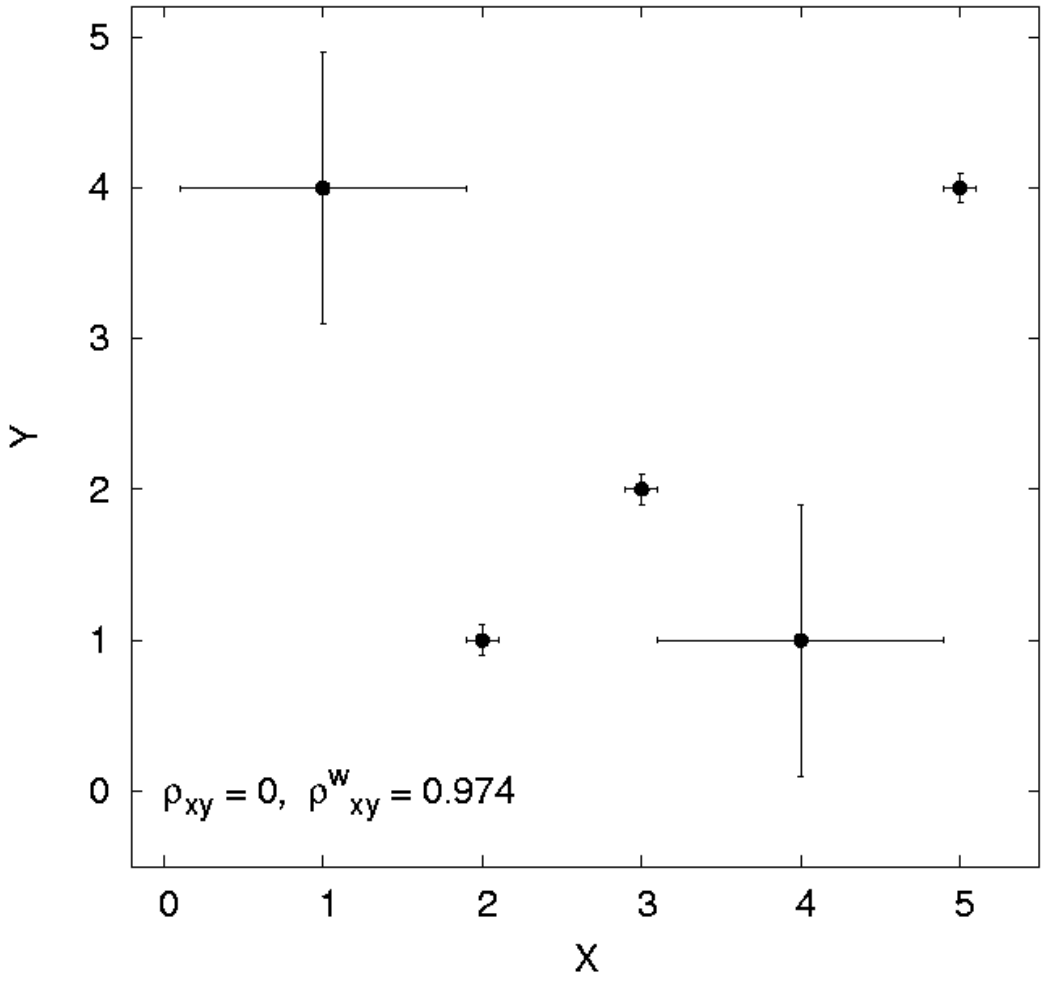
Standard correlation coefficient:

$$\rho_{xy} = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}}$$

Weighted correlation coefficient:

$$\rho^w_{xy} = \frac{\sum_i \sqrt{p_{x,i} p_{y,i}}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i p_{x,i}(x_i - \bar{x})^2 \sum_i p_{y,i}(y_i - \bar{y})^2}}$$

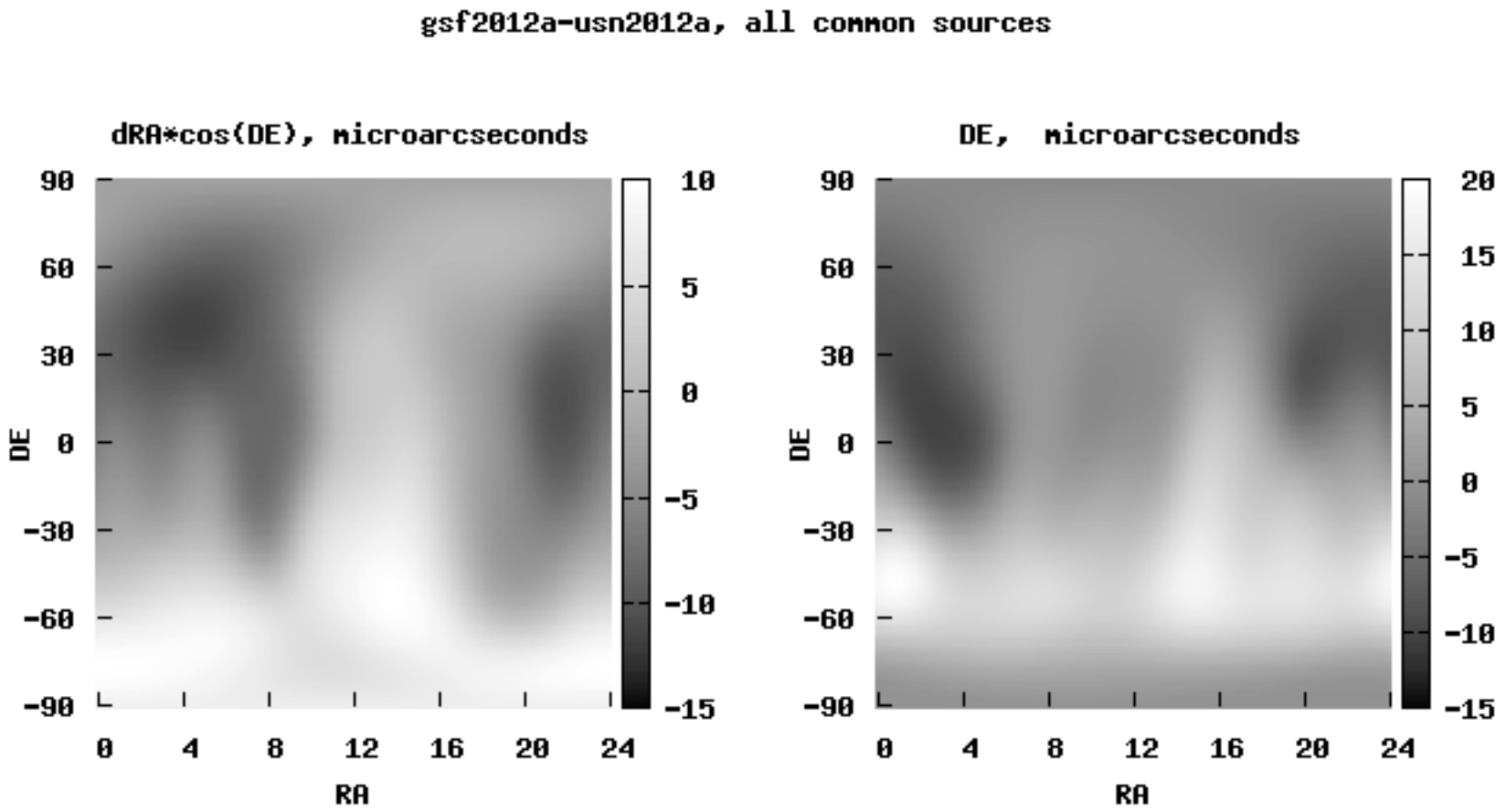
Weighted correlation



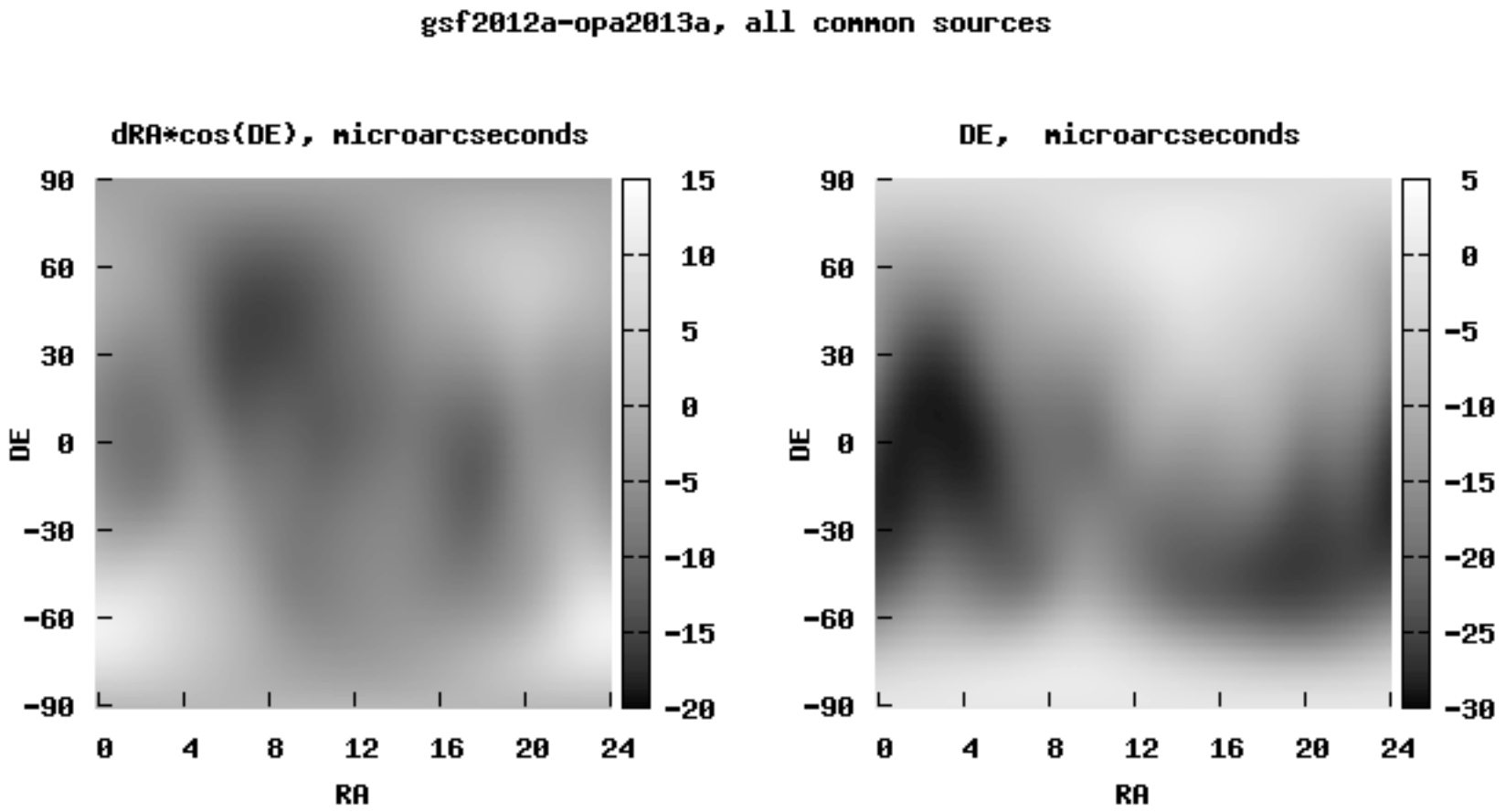
Weighted correlation

Catalogues	Standard corr. RA / DE	Weighted corr. RA / DE
AUS/GSF	+0.1861/+0.2032	+0.1125/+0.1129
BKG/GSF	+0.5082/+0.6095	+0.4794/+0.5038
CGS/GSF	+0.7711/+0.7746	+0.6395/+0.6348
GSF/IGG	−0.0193/+0.2334	+0.3732/+0.3693
GSF/OPA	+0.5210/+0.4823	+0.4711/+0.4931
GSF/RFC	−0.2497/−0.0311	+0.2184/+0.2582
GSF/SHA	+0.1528/+0.1270	+0.1218/+0.1195
GSF/USN	−0.0268/−0.0832	+0.0099/+0.0346

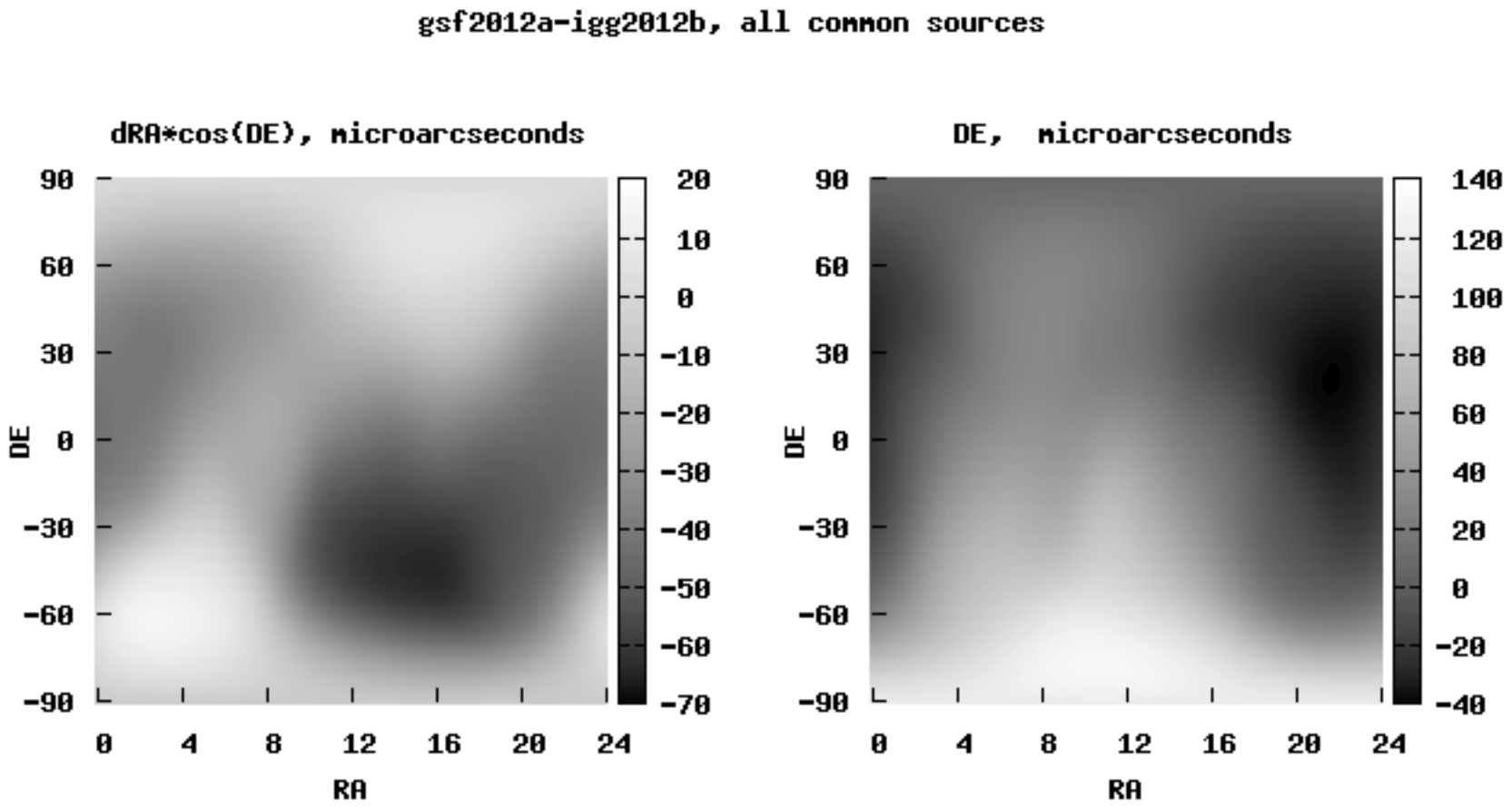
Systematic differences (small)



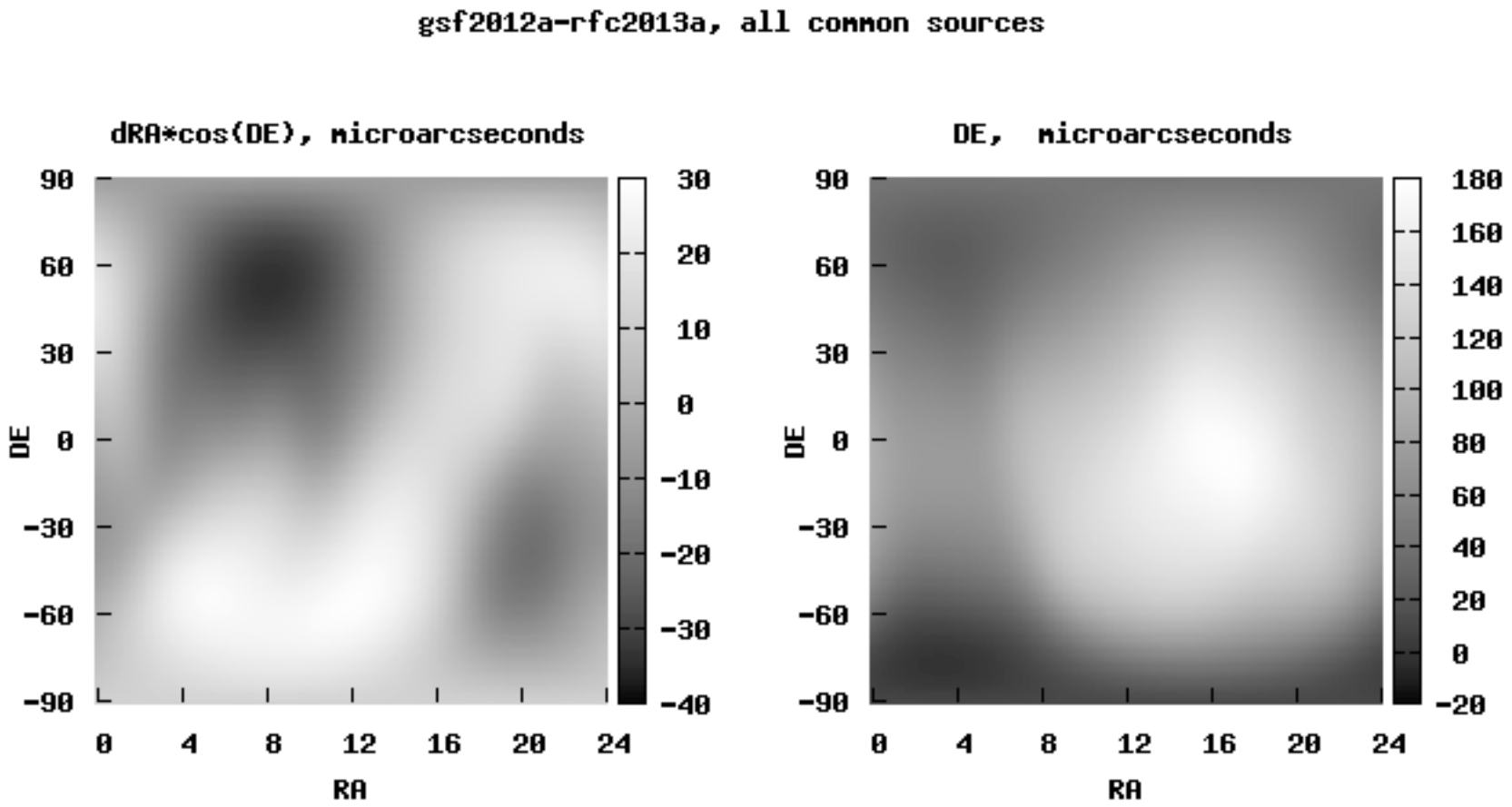
Systematic differences (small)



Systematic differences (large)



Systematic differences (large)



Correlation between catalogues

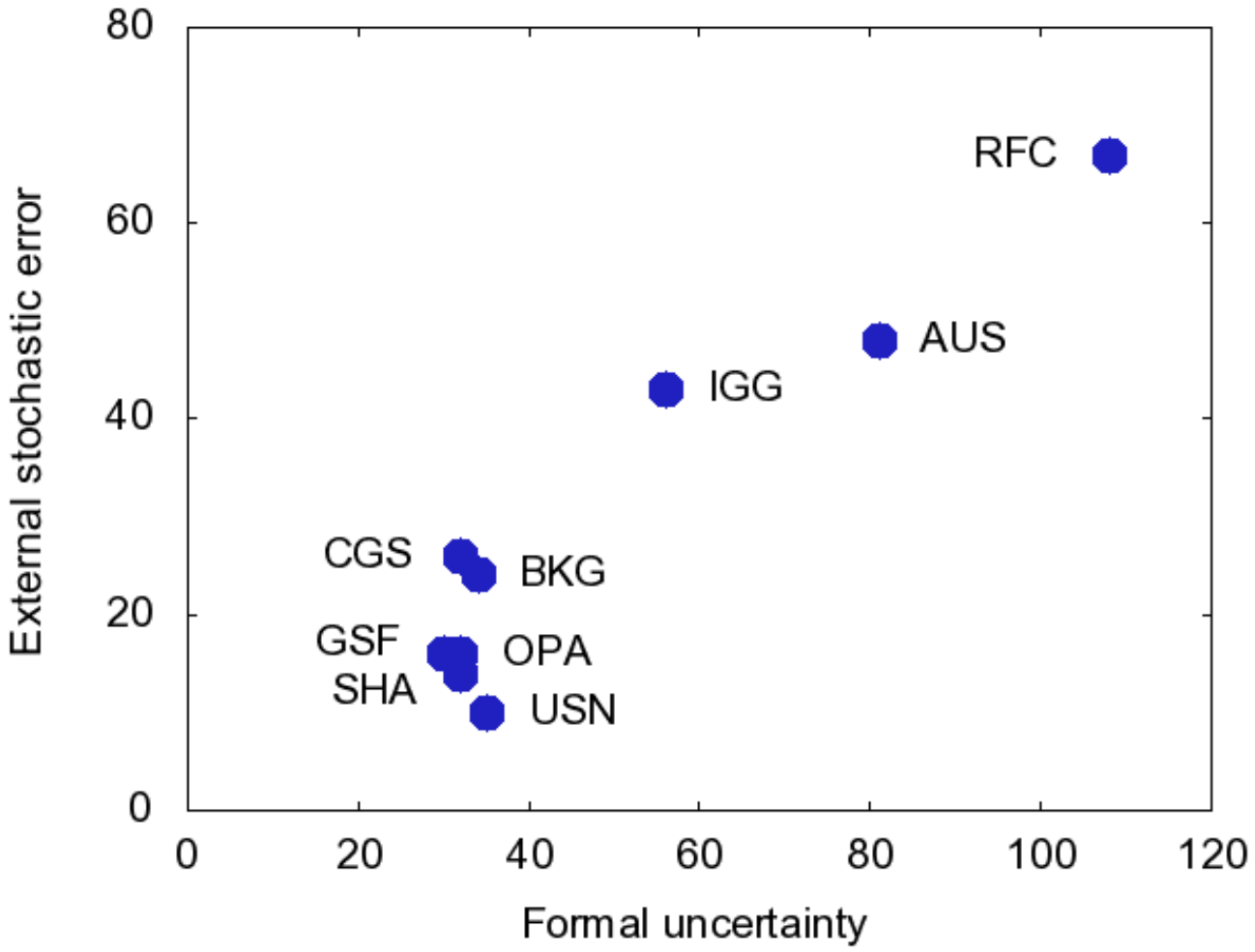
Catalogue	B09	B10	B11	B12	G09	G10	G11	G12	O09	O10	O11	O12	O13
ICRF2	0.458	0.227	0.128	0.065	0.315	0.077	0.009	-0.052	-0.244	-0.295	-0.276	-0.283	-0.258
BKG2009		0.784	0.676	0.586	0.220	0.187	0.152	0.130	-0.078	-0.085	-0.017	-0.009	0.003
BKG2010			0.929	0.808	0.136	0.281	0.256	0.229	-0.016	-0.054	-0.051	-0.057	-0.039
BKG2011				0.923	0.105	0.272	0.284	0.274	0.012	-0.024	-0.051	-0.074	-0.069
BKG2012					0.091	0.260	0.275	0.327	0.033	-0.003	-0.047	-0.087	-0.119
GSF2009						0.639	0.519	0.335	0.404	0.268	0.224	0.183	0.172
GSF2010							0.909	0.648	0.295	0.309	0.298	0.248	0.225
GSF2011								0.777	0.266	0.271	0.331	0.285	0.250
GSF2012									0.189	0.206	0.269	0.289	0.276
OPA2009										0.738	0.503	0.394	0.320
OPA2010											0.730	0.519	0.427
OPA2011												0.857	0.732
OPA2012													0.901

Correlation between catalogues from the same AC are shown in red

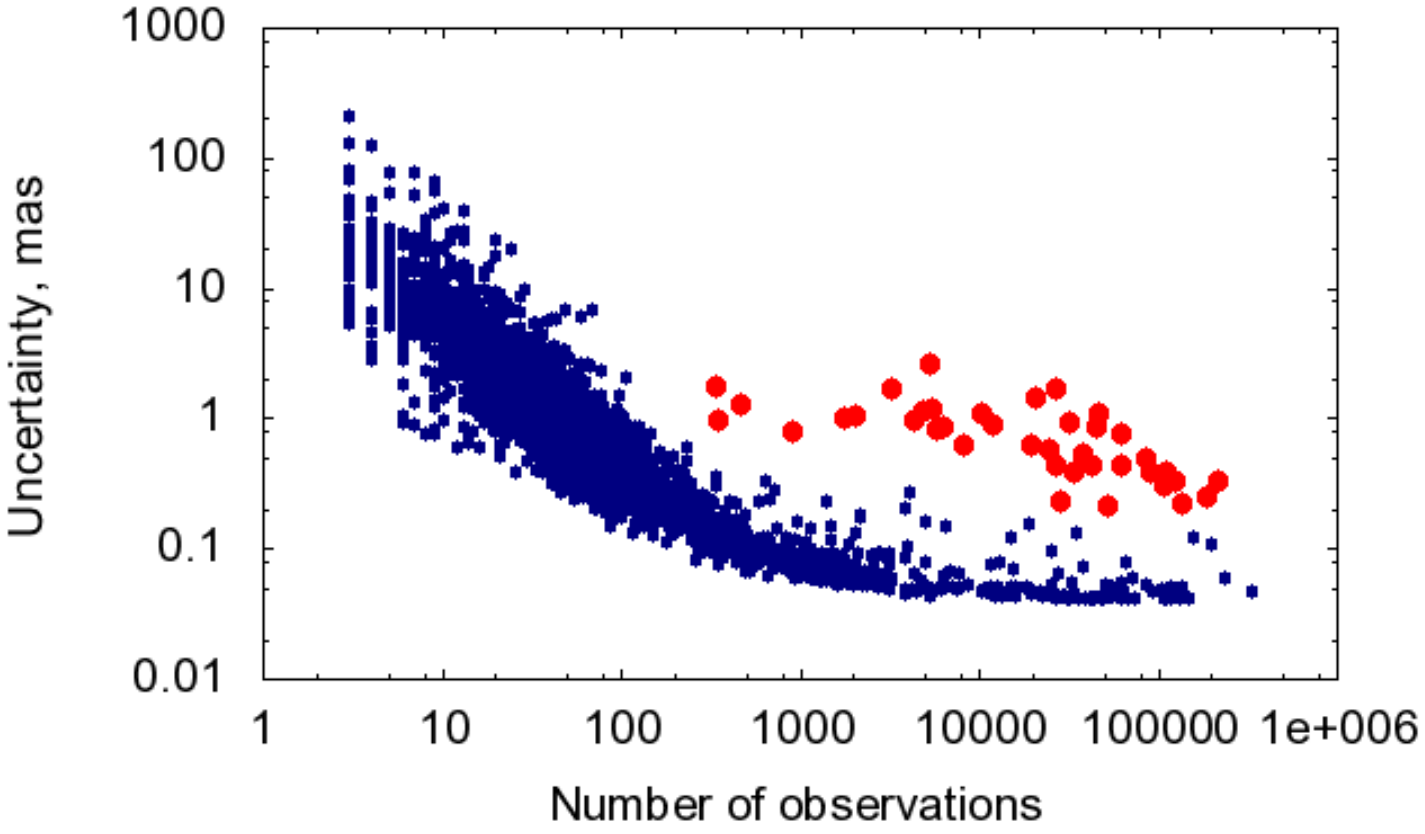
Catalogue errors [μas]

Catalogue	Median formal error α / δ	External stochastic error Original differences α / δ	External stochastic error Corrected differences α / δ
AUS	76 / 86	49 / 56	46 / 51
BKG	28 / 40	23 / 27	21 / 27
CGS	26 / 38	27 / 46	25 / 27
GSF	24 / 36	15 / 21	14 / 17
IGG	49 / 62	48 / 59	42 / 44
OPA	27 / 37	15 / 23	14 / 18
RFC	105 / 110	63 / 93	60 / 74
SHA	27 / 38	13 / 17	12 / 17
USN	29 / 41	10 / 12	10 / 10

External vs. formal error



ICRF2: position uncertainty vs. # of observations



Special handling sources are shown in red

STD of one-session measurement, not STD of mean?

Conclusions

1. A new approach to assess the external stochastic errors of radio source position catalogues has been presented. Using this approach, we obtained independent estimates of the stochastic errors of the nine recently published catalogues, some of them for the first time.

2. Modern radio source position catalogues show significant and complicated systematic differences, which must be accounted for during combination.

3. Catalogues obtained at the same AC are in close correlation with each other. This may show that AC-specific systematic errors do exist caused by specific modeling and analysis options.

4. The external catalogue stochastic errors closely correlate with the formal source position uncertainty, most probably because of the quality of the software used and analysis strategy details such as modelling and parameterization.

5. The ICRF2 source position uncertainties are not homogeneous for 'global' and 'arc' sources.

Thank you for your attention!