United States Naval Observatory

VLBI Source Positions at 24 GHz

- K/Q-band Project Collaborators:
  - **Dave Boboltz**, Alan Fey (USNO)
  - Gabor Lanyi, Chris Jacobs, Charles Naudet, Liwei Zhang (JPL)
  - Chopo Ma, David Gordon (NASA - GSFC)
  - Patrick Charlot (Bordeaux Obs.)
  - Ed Fomalont, Jon Romney (NRAO)
  - Ojars Sovers (RSA Systems)
  - Barry Geldzahler (NASA - HQ)

- Outline
  - K/Q-band project background
  - K-Band (24 GHz) CRF Source Catalog
  - K-Band (24 GHz) Time Series of Source Positions

United States Naval Observatory

Background

- Reasons to go to higher frequencies:
  - NASA will use Ka-band (32 GHz) for spacecraft communications in the future (i.e. future DSN).
  - Phase-referencing very useful for spacecraft navigation.
  - RFI decreased at higher frequencies.
  - Ionospheric effects decreased at higher frequencies.
  - Source structure simpler at higher frequencies.

- Goals of the K/Q-band Program
  - Investigate the feasibility of a high-frequency CRF.
  - Develop a high-freq. CRF for use in spacecraft navigation.
  - Investigate the frequency dependence of source structure.
  - Develop astrometric and image databases for use by the astronomical community.

United States Naval Observatory

K/Q-band VLBA Observations

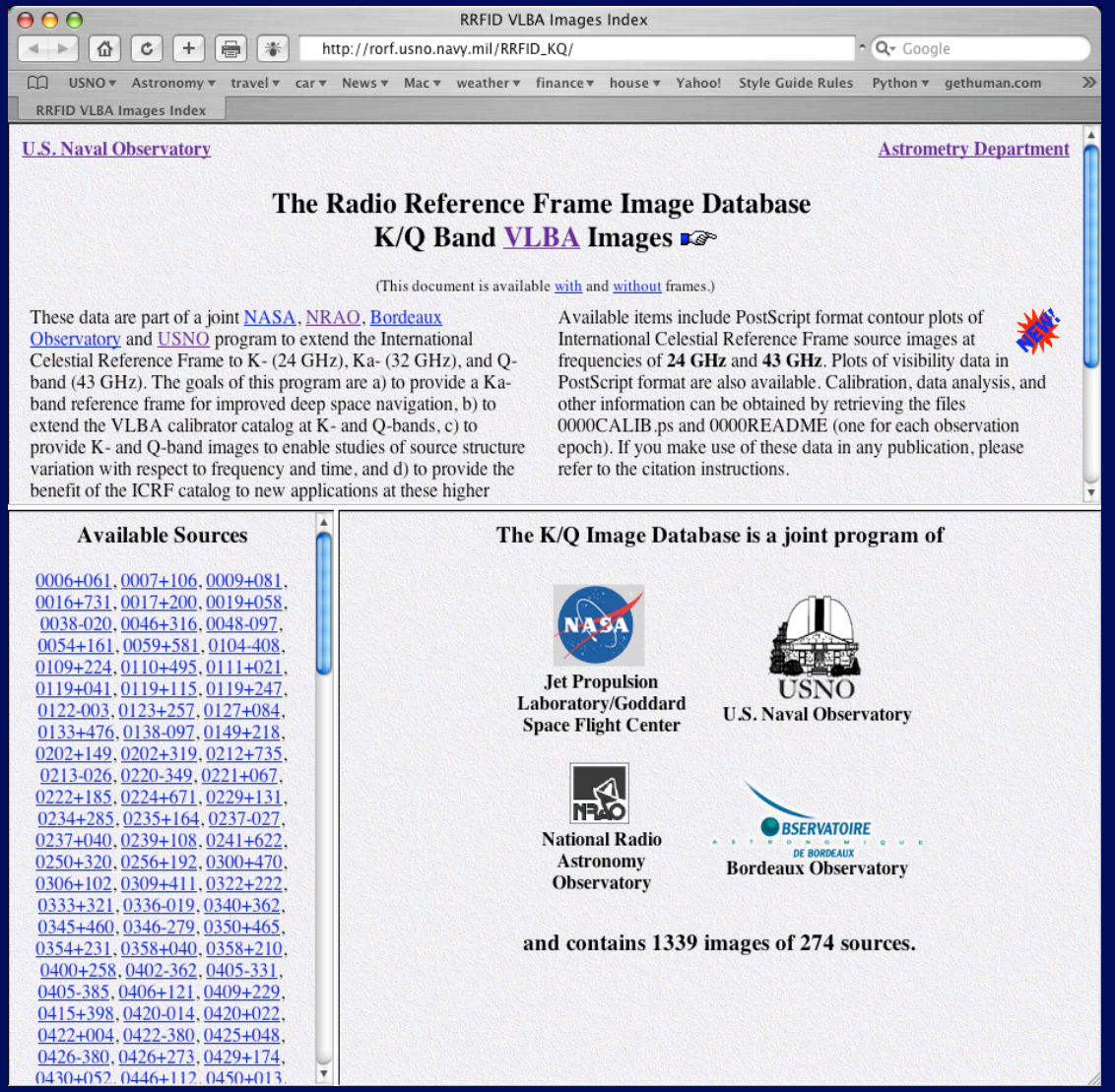
Epoch	Observed Bands	Flux Limit (Jy)	Number of Sources				Notes
			Observed	Imaged	Overlap	New	
2002May15	K/Q	0.6	65	65	…	…	…
2002Aug25	K/Q	0.6	65	65	65	…	…
2002Dec26	K/Q	0.6	67	67	24	43	…
2003May22	K	0.3	249	184	62	122	Survey
2003Sep13	K/Q	0.5	70	70	70	…	…
2004Feb15	S/X/K	0.6	65	65	65	…	…
2004Dec14	K	0.6	101	101	101	…	…
2005Aug26	S/X/K	0.6	101	92	67	25	…
2006Jul09	K	0.6	193	178	163	15	…
2007Mar30	K	0.6	193	185	181	4	…

- Thus far, a total of 385 sources have been observed with the VLBA at K band and 133 sources at Q band.
- All 10 epochs calibrated (AIPS), imaged (DIFMAP), and analyzed (CALC/SOLVE).

United States Naval Observatory

VLBA K/Q-Band Data

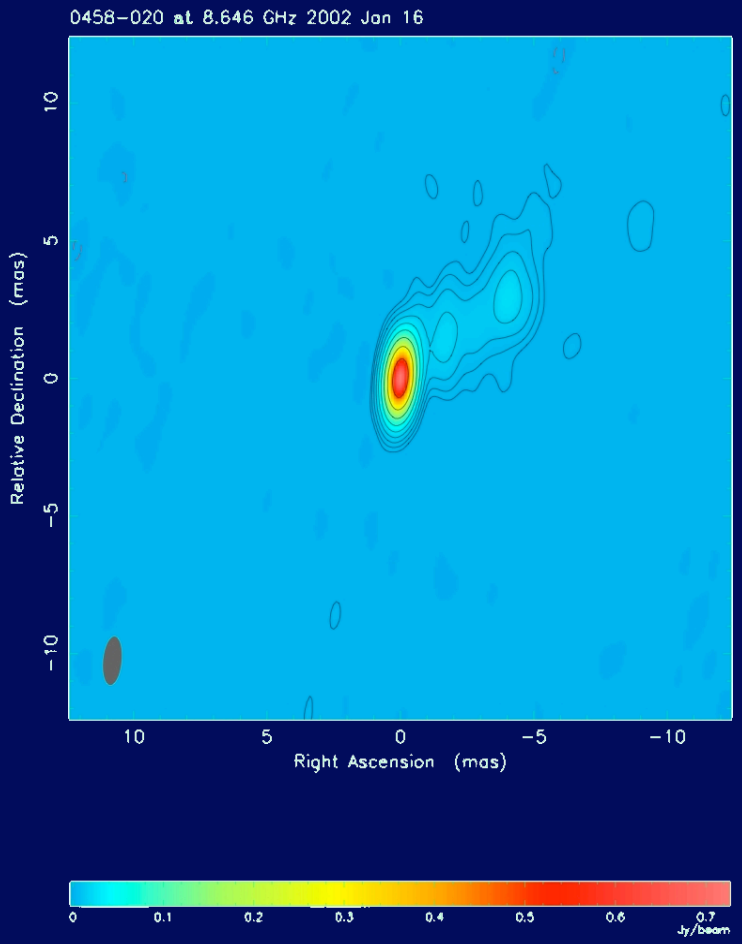
- Image data available via the RRFID web page.
- The image database currently contains:
  - 1339 images
  - 274 sources at K band.
  - 108 sources at Q band.
- Databases available from GSFC



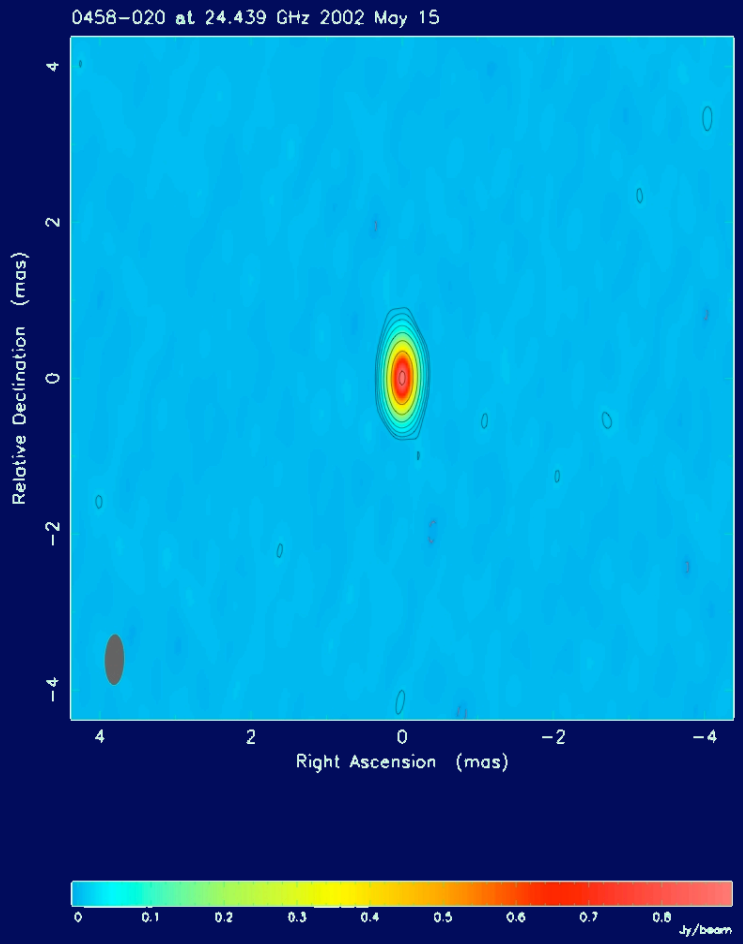
United States Naval Observatory

Less Source Structure at Higher Freq.

X-band



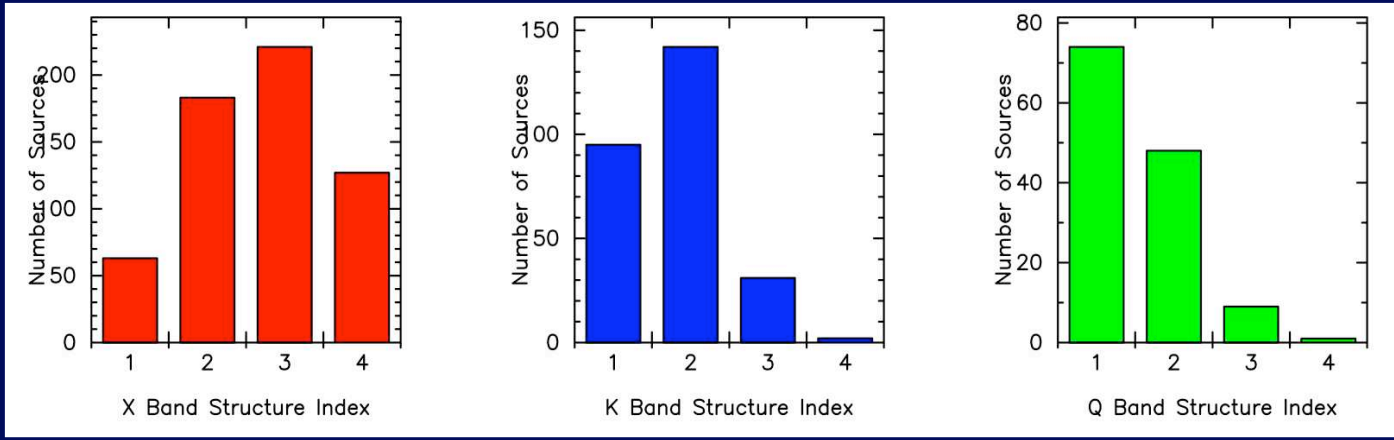
K-band



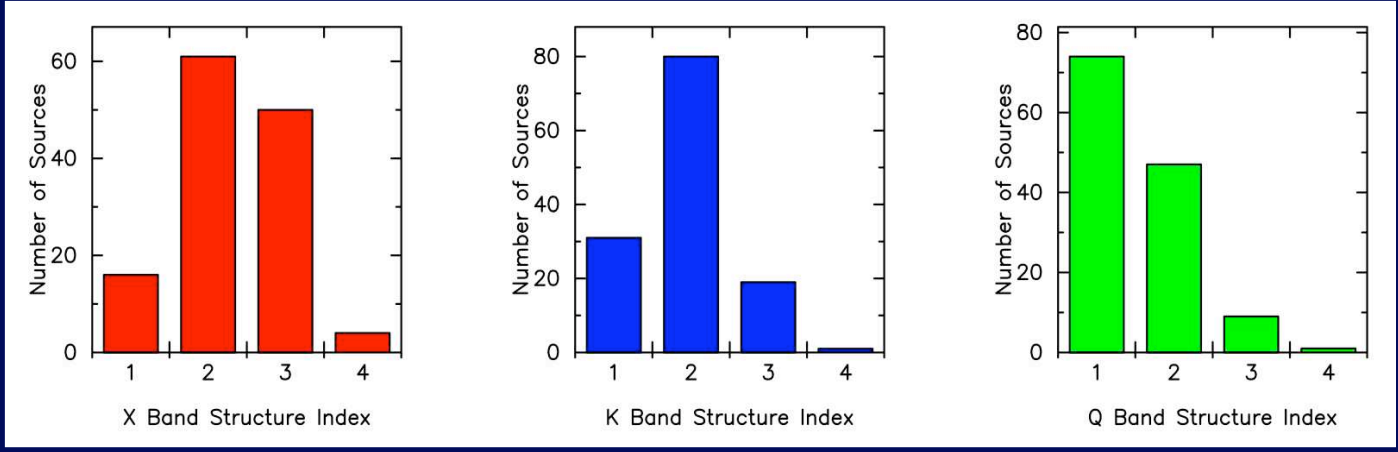
United States Naval Observatory

Structure Indices

- All Sources.



- 131 Sources Common to X/K/Q bands.



United States Naval Observatory

CRFK 2007a Astrometric Solution

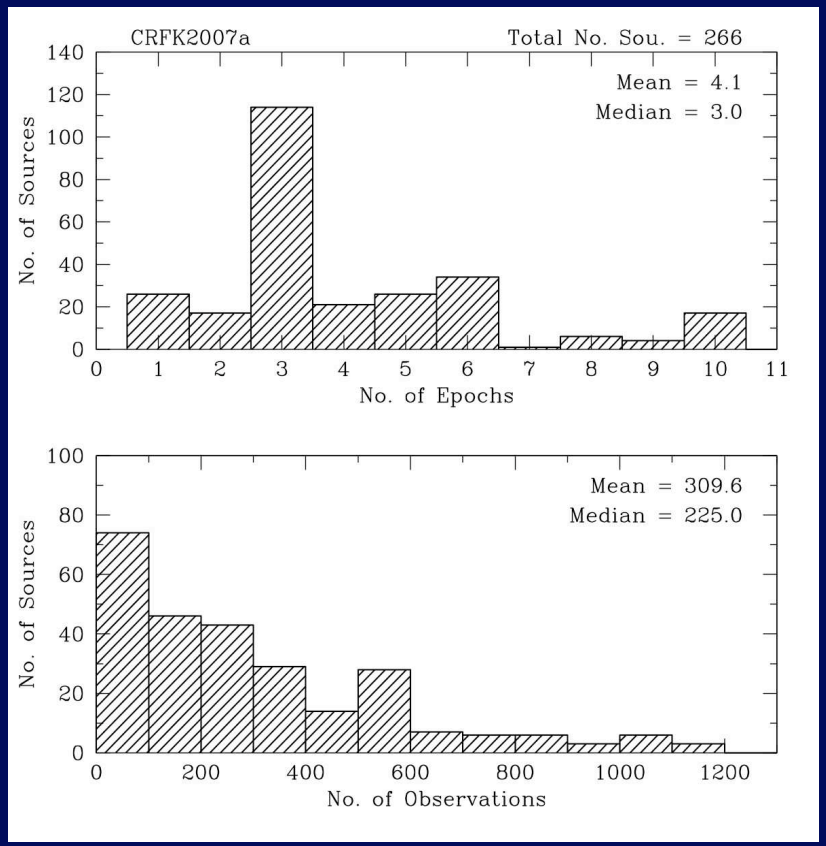
- 10 K-band databases used.
- 288 sources available, but 12 sources with <3 observations were eliminated leaving 266.

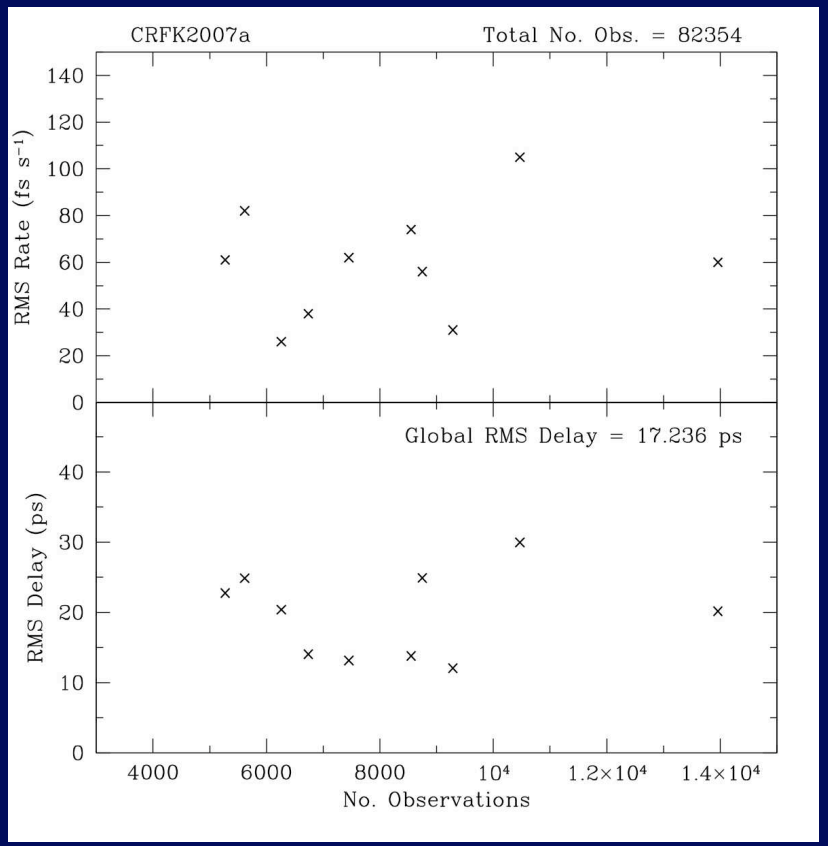
- Used 5 degree elevation cutoff.
- Parameters solved for:
  - Source positions (all 266 sources treated as ``global").
  - Atmospheres (20 min), Clocks (60 min)
  - Tropospheric gradients (6 hr)
- Parameters NOT solved for (fixed):
  - VLBA station positions and velocities
  - Axis offsets
  - UT1/PM, Nutation

United States Naval Observatory

CRFK 2007a Astrometric Solution

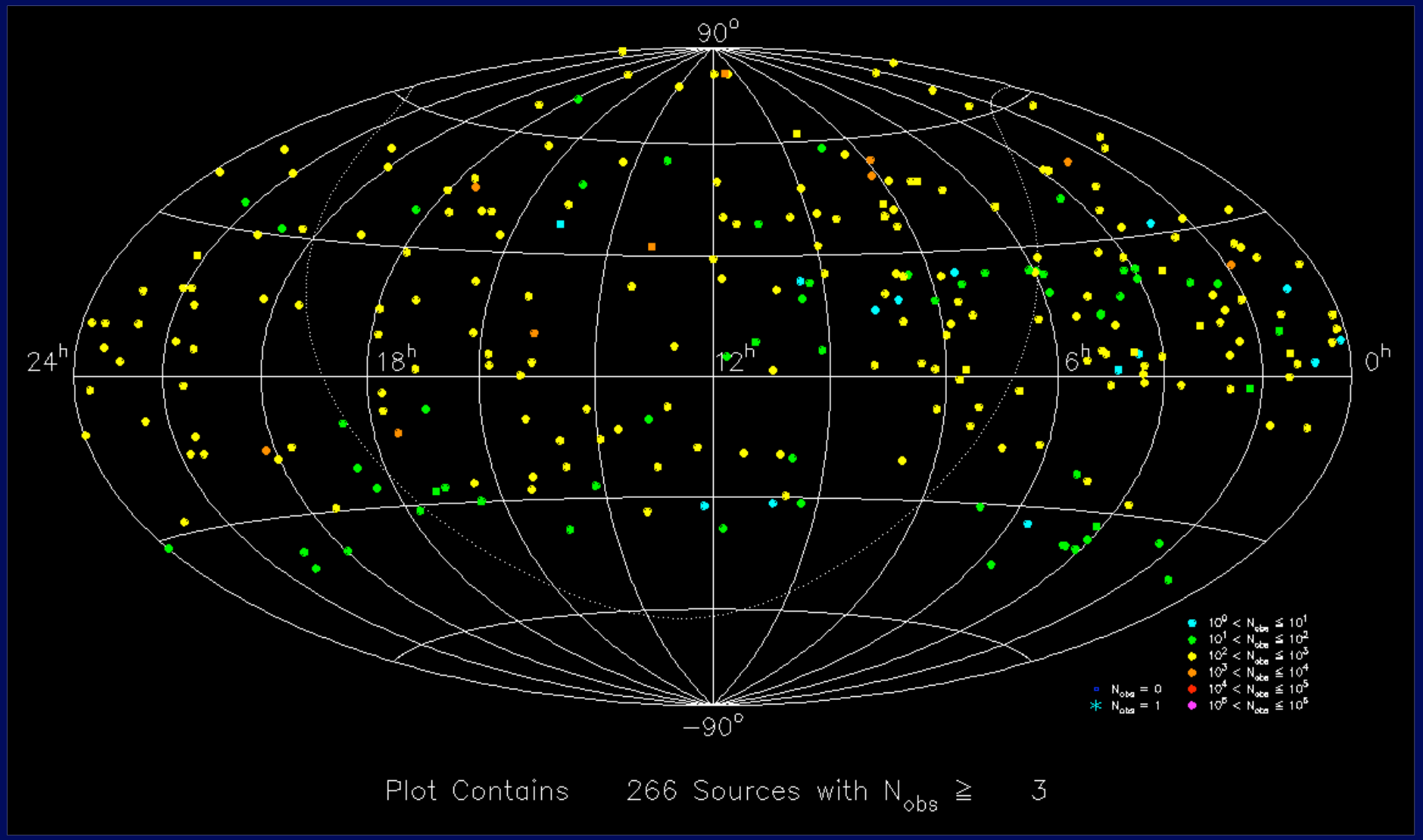
- Total Number of Observations = 82354
- Global rms Delay = 17.236 ps





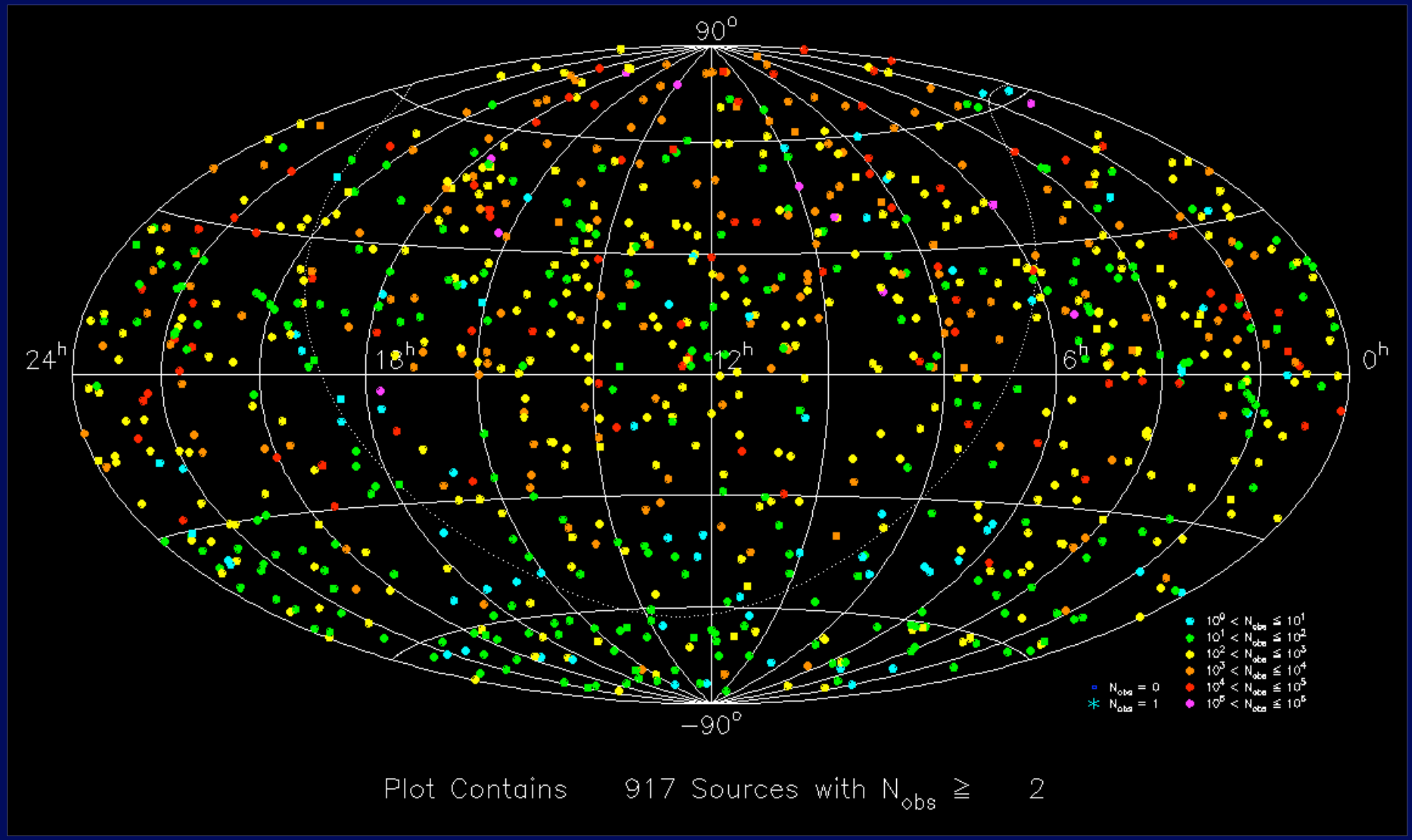
United States Naval Observatory

CRFK 2007a Source Catalog



United States Naval Observatory

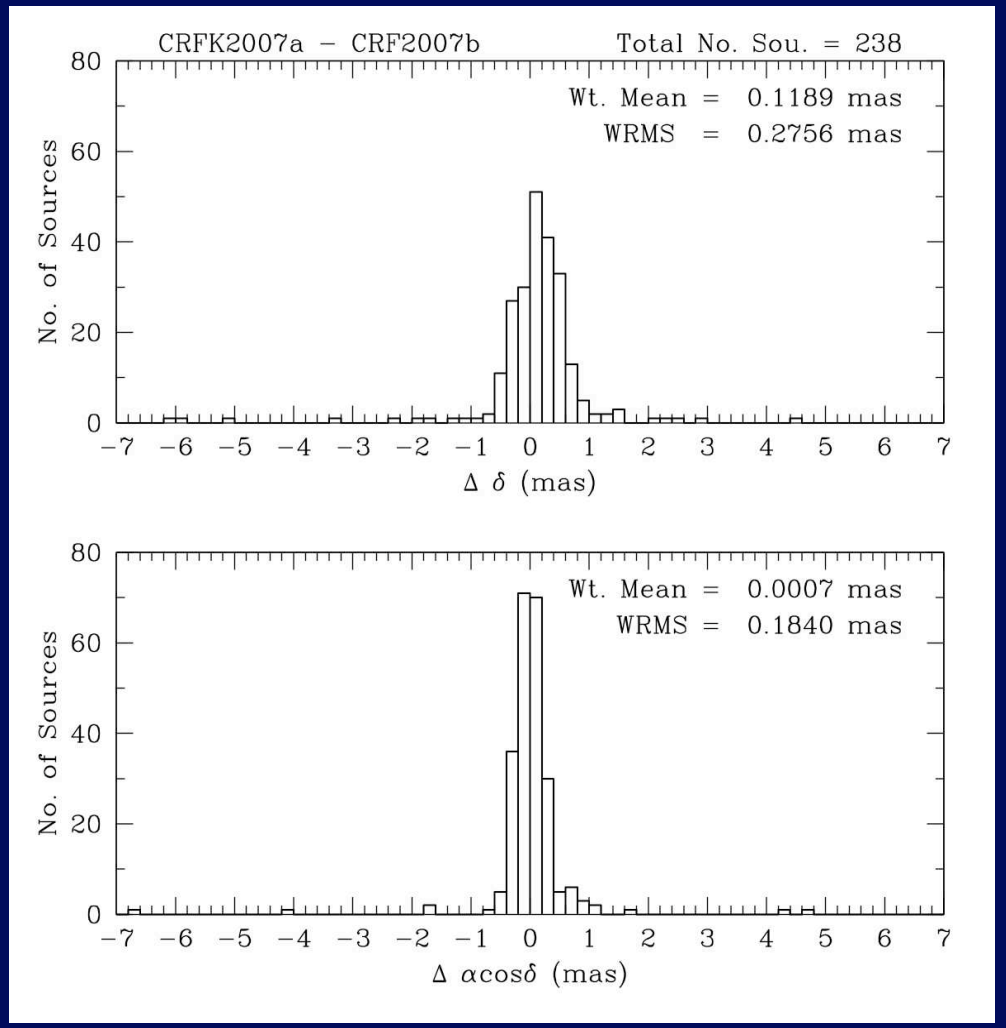
CRF 2007b Sources for Comparison



United States Naval Observatory

CRFK 2007a - CRF 2007b

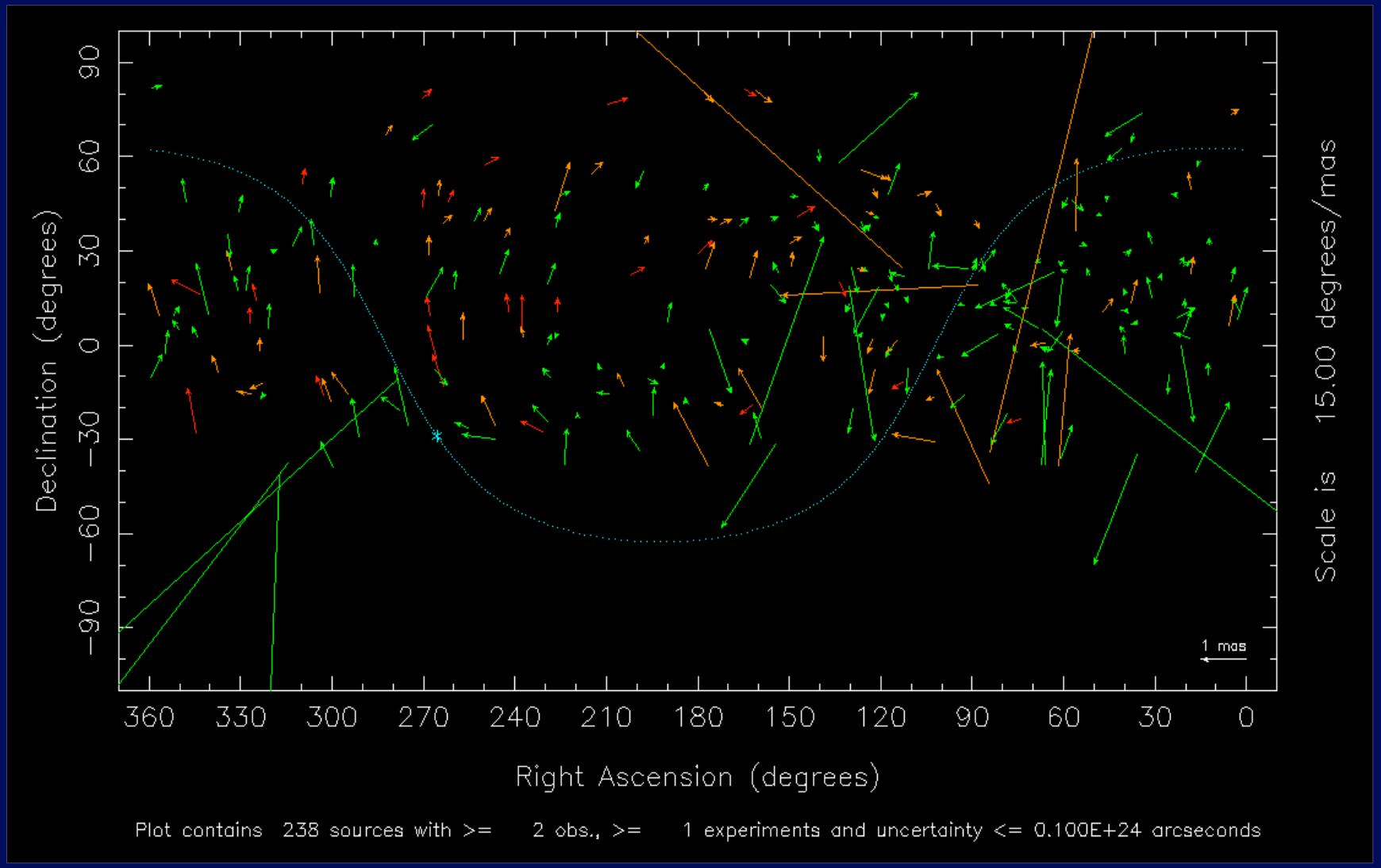
- Comparison to most recent USNO catalog CRF 2007b.
- 238 sources overlap.
- Shown are source position differences in R.A. (bottom) and Dec. (top).



United States Naval Observatory

CRFK 2007a - CRF 2007b

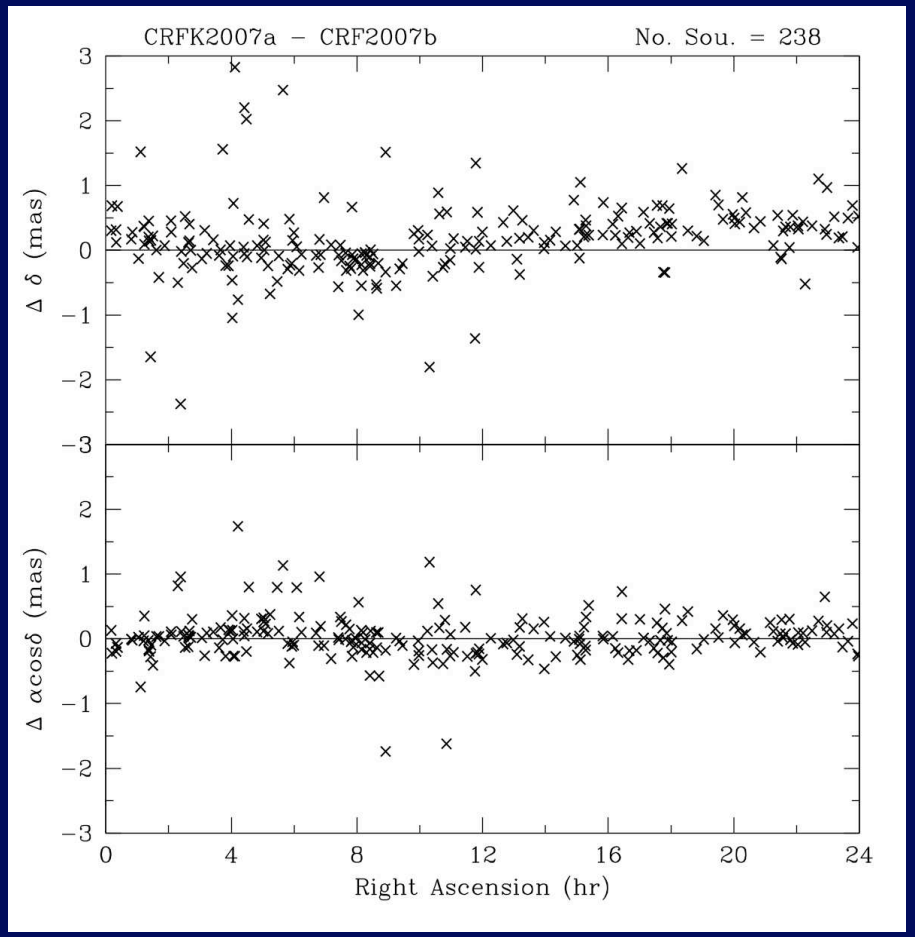
Green < 3σ Orange 3-5σ Red > 5σ

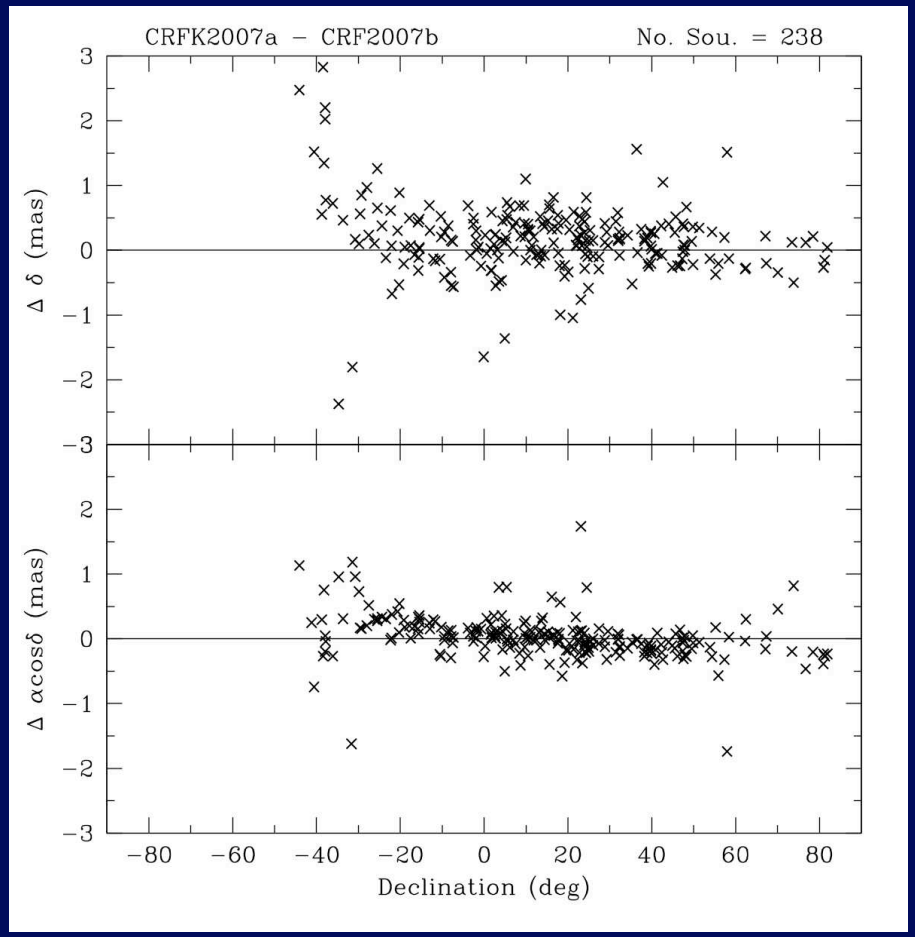


United States Naval Observatory

CRFK 2007a - CRF 2007b

- Position differences vs R.A. and Dec.

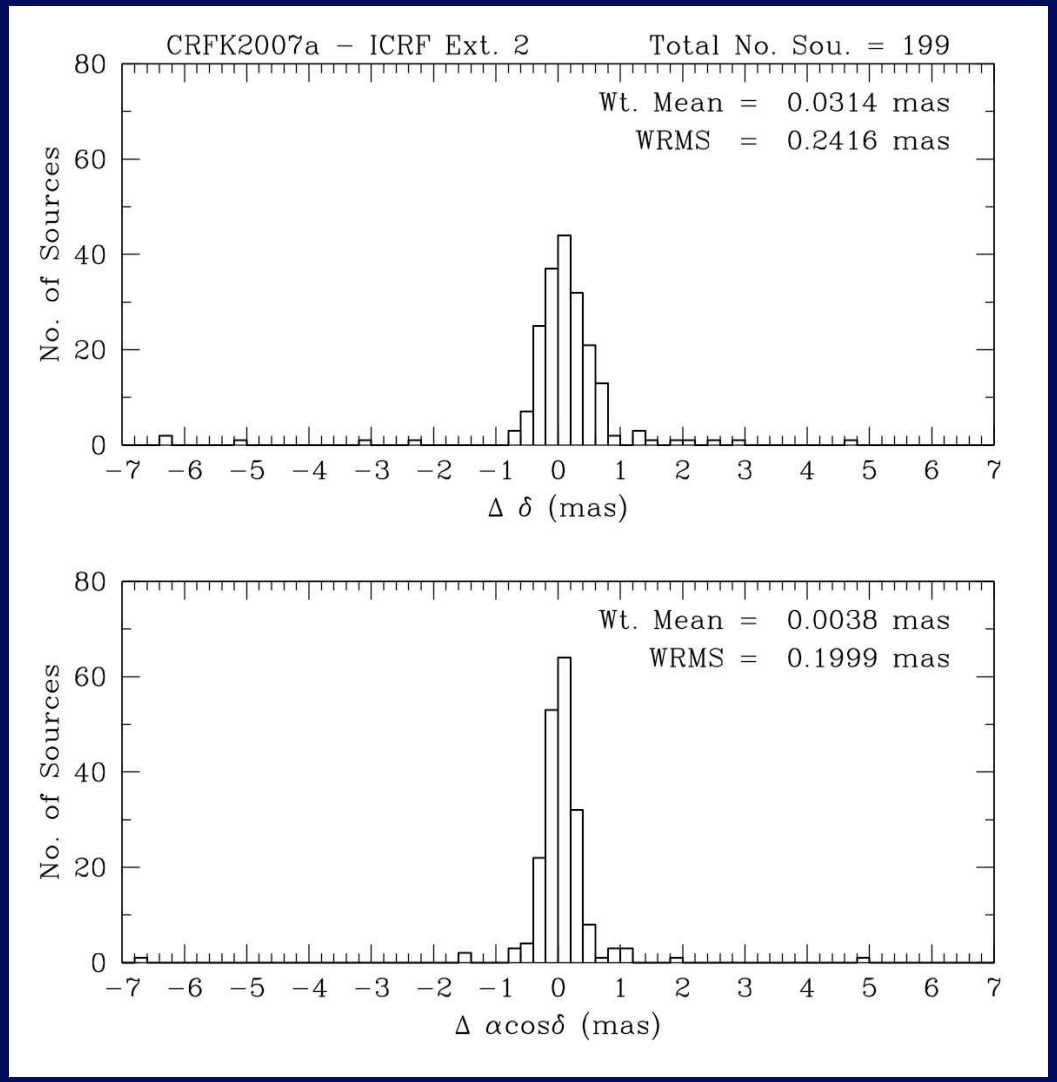




United States Naval Observatory

CRFK 2007a - ICRF Ext. 2

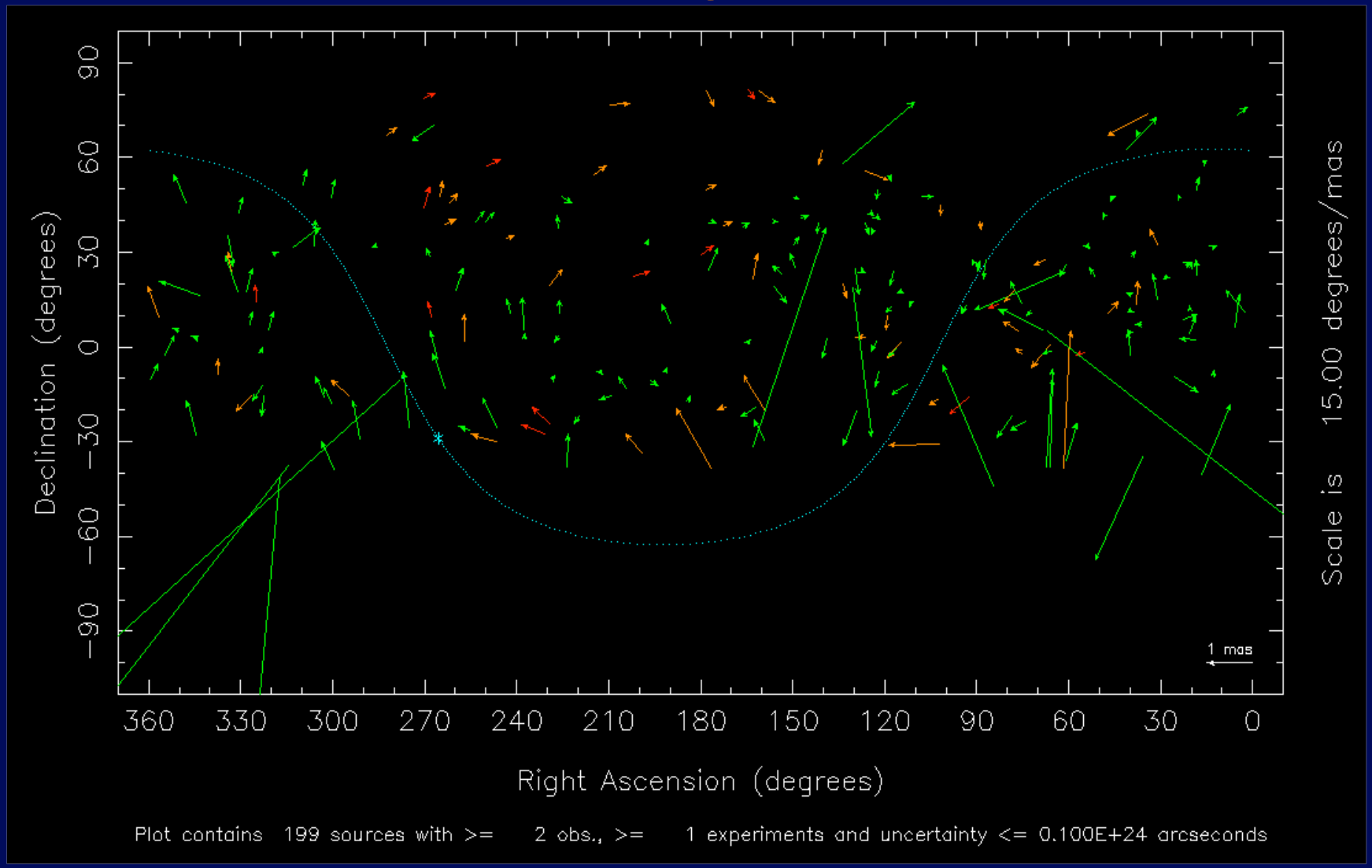
- Comparison with ICRF Extension 2.
- 199 sources overlap.
- Shown are source position differences in R.A. (bottom) and Dec. (top).



United States Naval Observatory

CRFK 2007a - ICRF Ext. 2

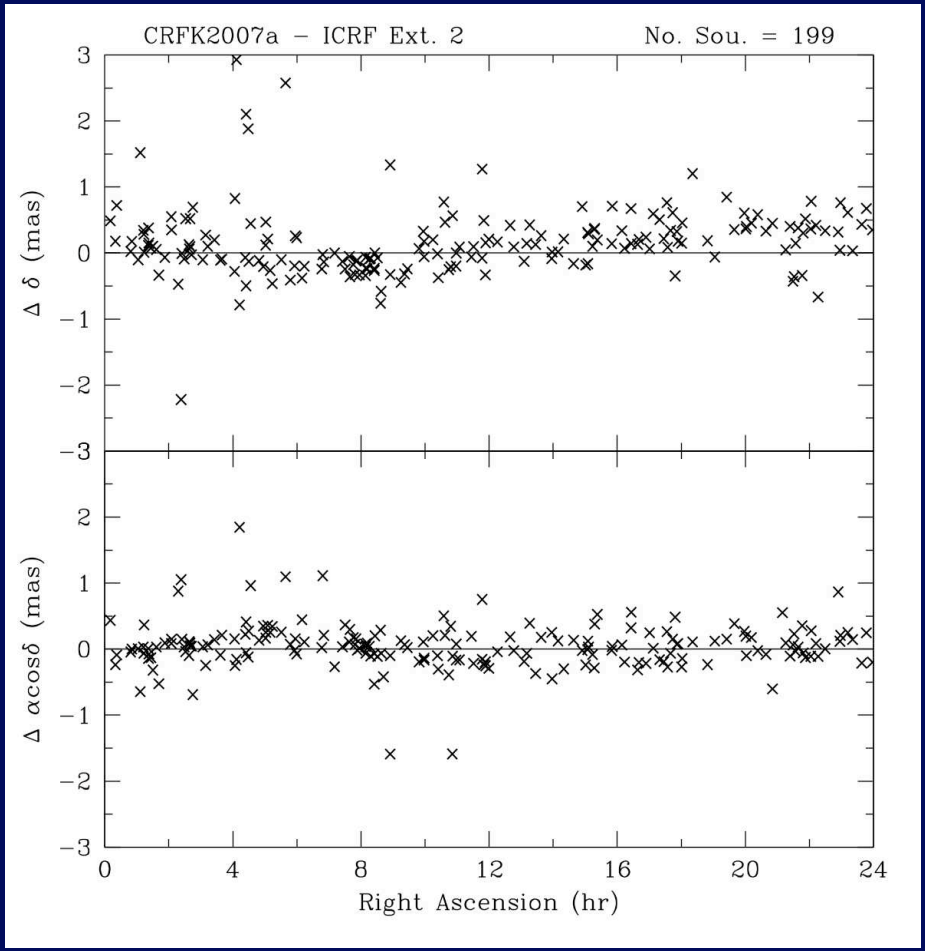
Green < 3σ Orange 3-5σ Red > 5σ

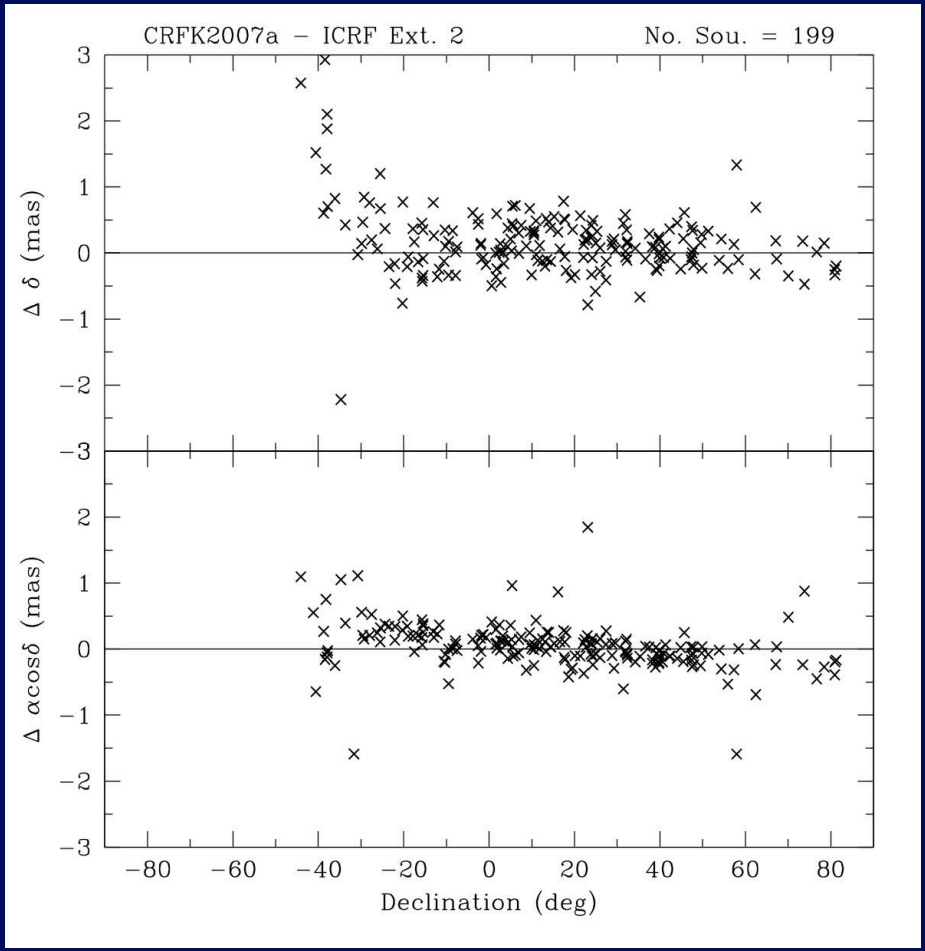


United States Naval Observatory

CRFK 2007a - ICRF Ext. 2

- Position differences vs R.A. and Dec.





United States Naval Observatory

CRF Comparison Summary

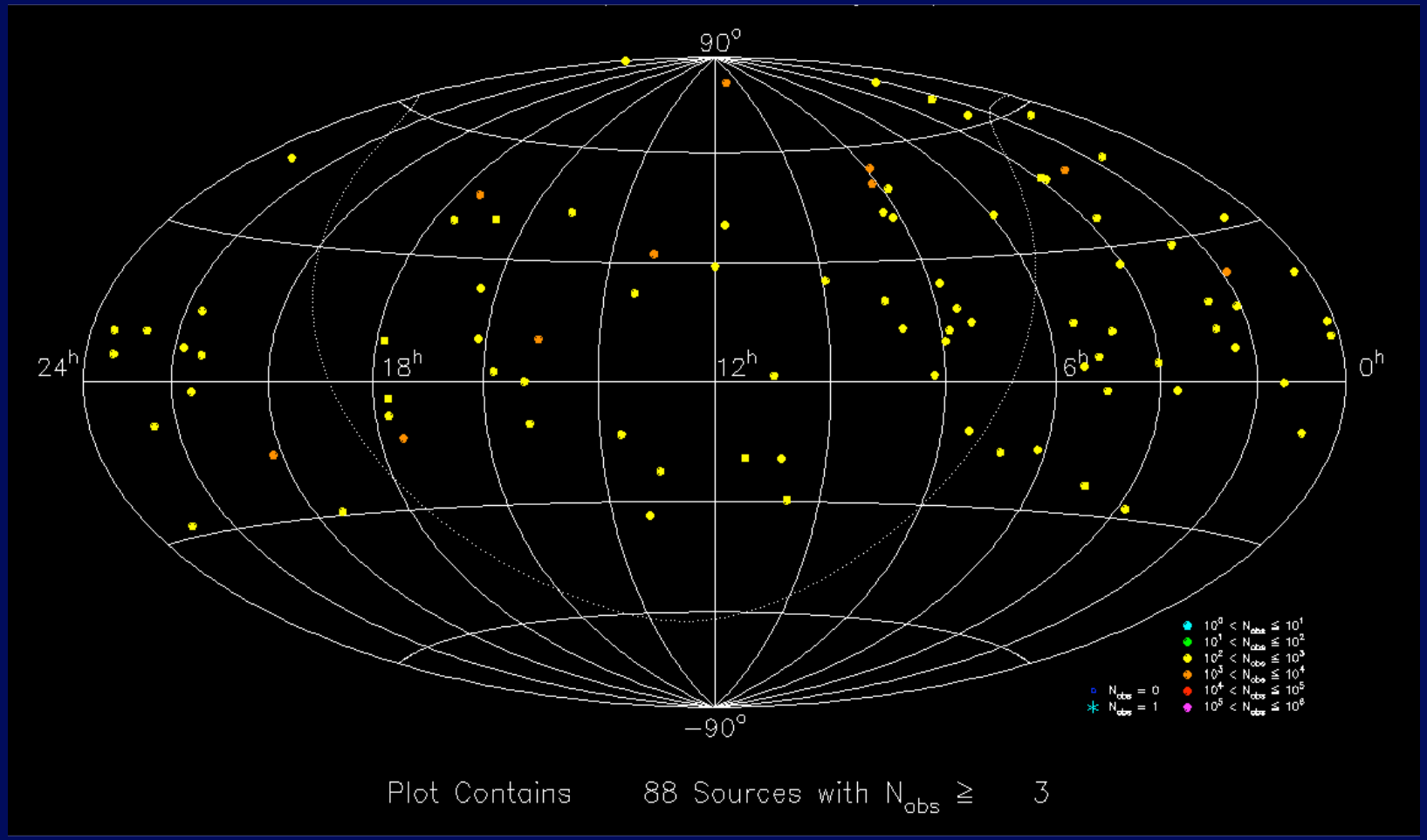
Catalogs	No. of Exper.	No. of Observ.	No. of Sources Matching	R.A. Difference		Dec. Difference	
				Wt. Mean (μas)	WRMS (μas)	Wt. Mean (μas)	WRMS (μas)
crfk 2006a - ICRF Def.	8	57,925	75	2.1	**309.4**	78.0	**389.3**
crfk 2007a - ICRF Def.	10	82,354	77	-55.2	**259.0**	79.5	**352.8**
crf 2007b - ICRF Def.	4170	5,238,056	212	-2.3	**220.8**	7.5	**254.6**
crfk 2006a - ICRF Ext. 1	8	57,925	187	-0.8	**346.4**	93.3	**428.0**
crfk 2007a - ICRF Ext. 1	10	82,354	192	-46.1	**283.6**	80.1	**337.0**
crf 2007b - ICRF Ext. 1	4170	5,238,056	667	-21.0	**179.9**	-10.0	**342.8**
crfk 2006a - ICRF Ext. 2	8	57,925	193	61.0	**230.4**	40.7	**260.6**
crfk 2007a - ICRF Ext. 2	10	82,354	199	3.8	**198.7**	31.4	**239.3**
crf 2007b - ICRF Ext. 2	4170	5,238,056	717	24.0	**74.7**	-33.3	**83.7**
crfk 2007a - crf 2007b			238	0.7	183.2	118.9	273.8

- CRFK 2007a shows improvement in the wrms position offsets with the addition of only two experiments over CRFK 2006a.
- CRFK 2007a compares favorably to CRF 2007b considering the number of experiments / observations.

United States Naval Observatory

CRFK 2007a Position Time Series

- 88 of 266 sources were observed in ≥5 epochs.
- Considered suitable for the time series.



United States Naval Observatory

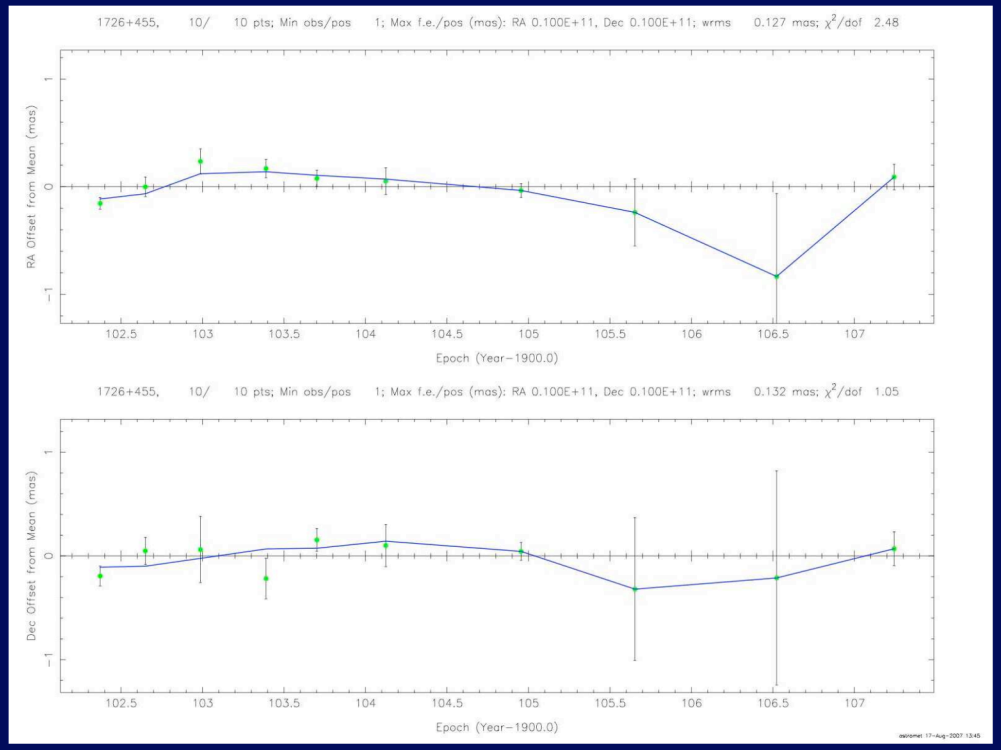
Position Time Series Solutions

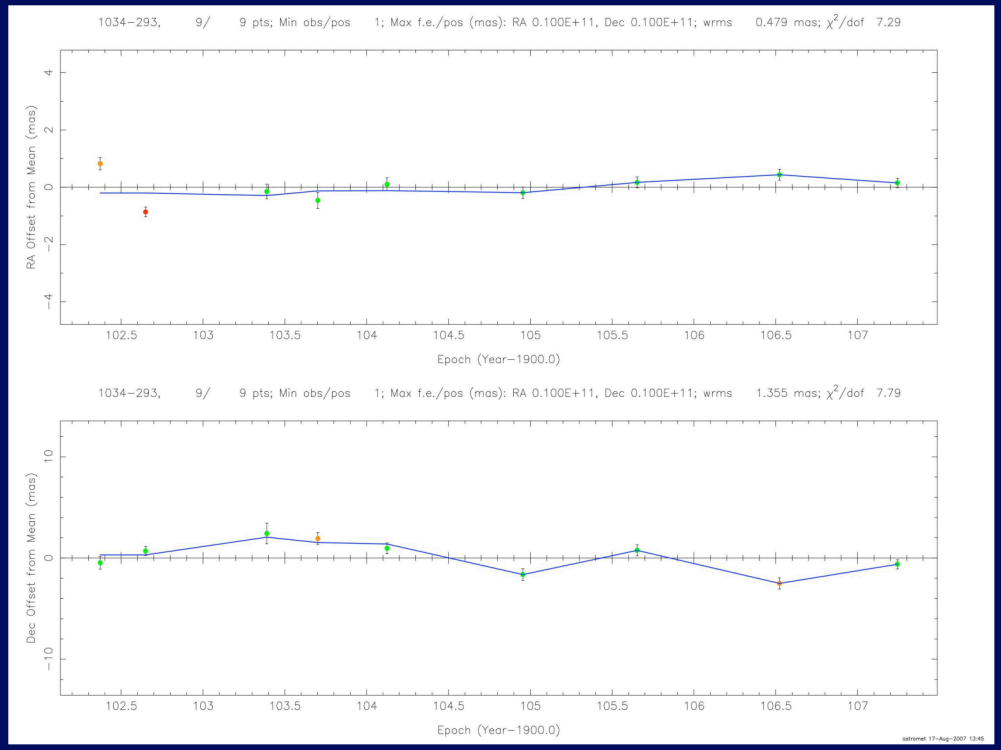
- 5 solutions were produced with parameterization identical to the CRFK 2007a solution except:
- For each solution:
  - 1/5 of the 88 sources observed in 5 or more sessions were treated as ``arc'' parameters.
  - Remaining (~250) sources were treated as ``global''.
- Position time series were produced for all 88 sources.
- Weighted mean positions and the wrms were computed from the time series.

United States Naval Observatory

Example Position Time Series

- Good: 1726+455
  - 10 epochs, ~5 yrs
  - wrms R.A. = 0.127 mas
  - wrms Dec. = 0.132 mas
- Not so good: 1034-293
  - 9 epochs, ~5 yrs
  - wrms R.A. = 0.479 mas
  - wrms Dec. = 1.355 mas

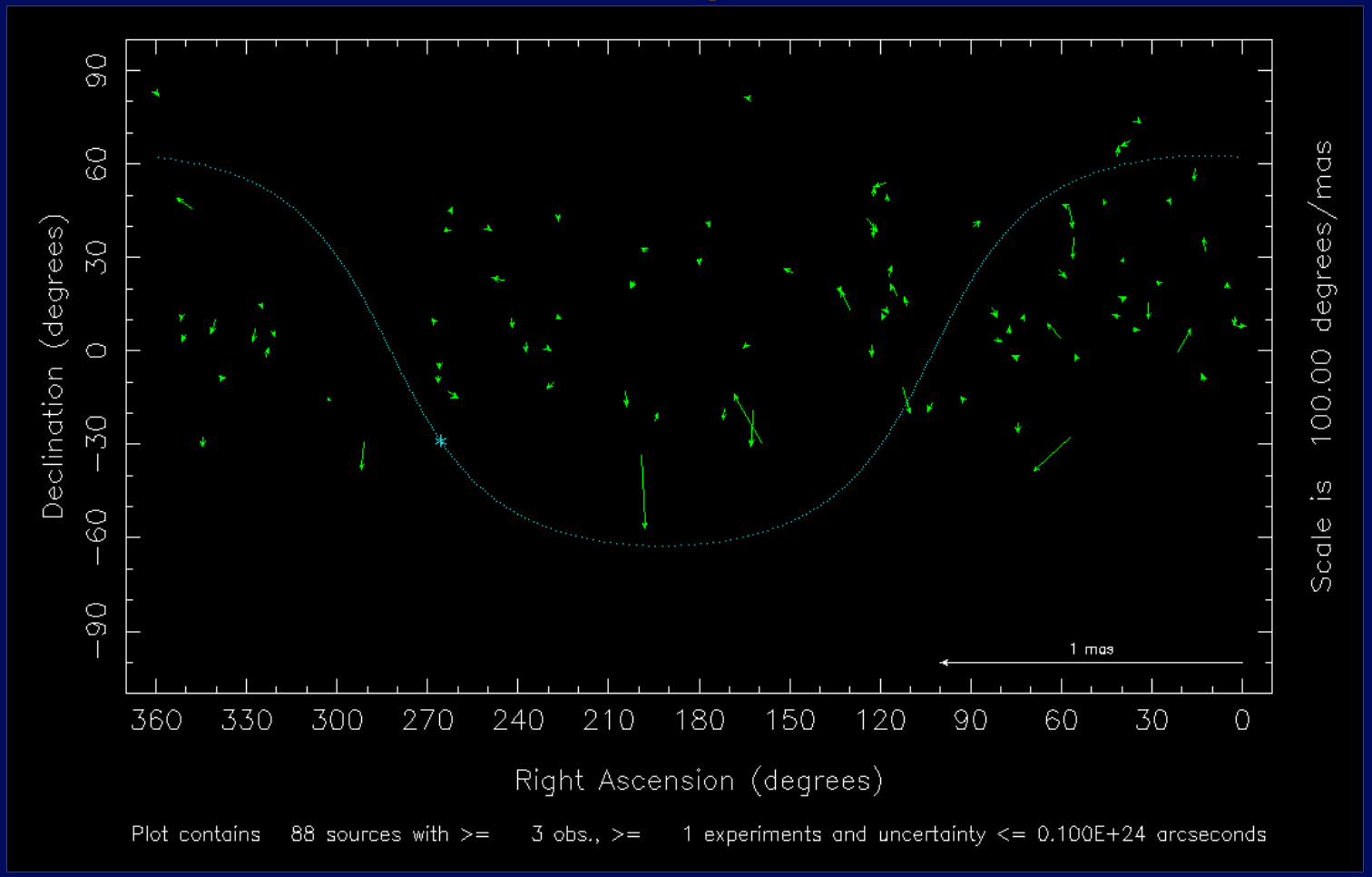




United States Naval Observatory

CRFK 2007a - Wgt. Mean Time Ser. Pos.

Green < 3σ Orange 3-5σ Red > 5σ

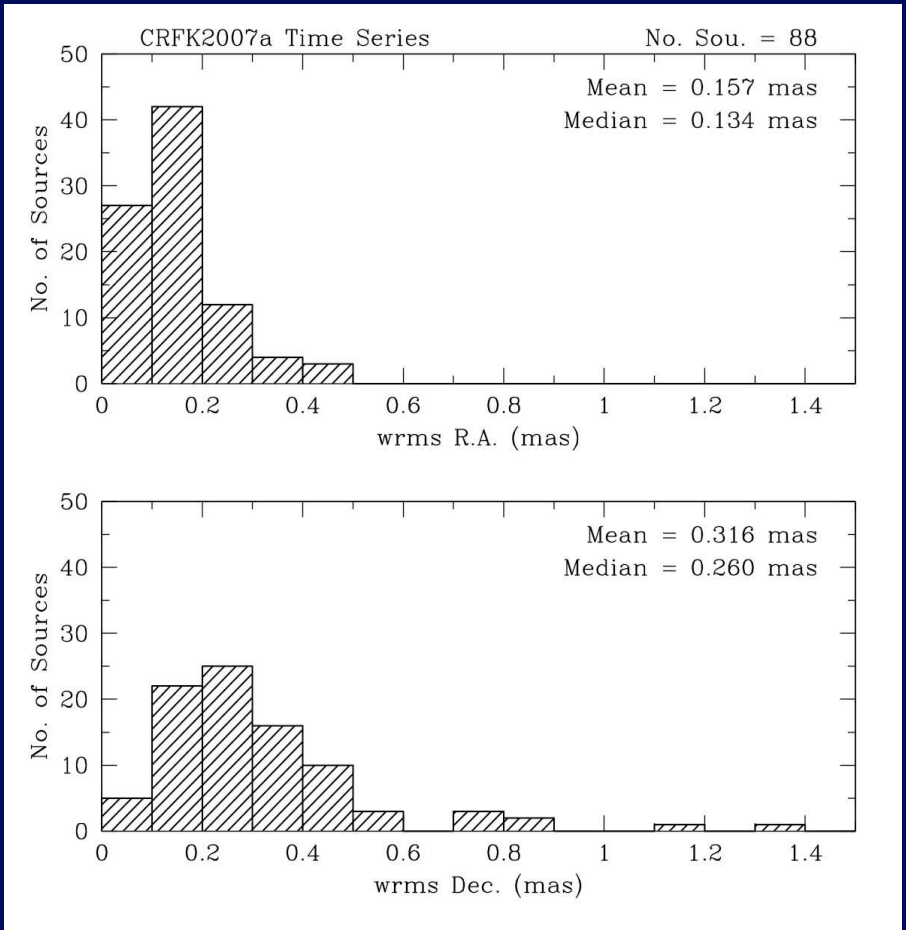


Differences are very small as expected.

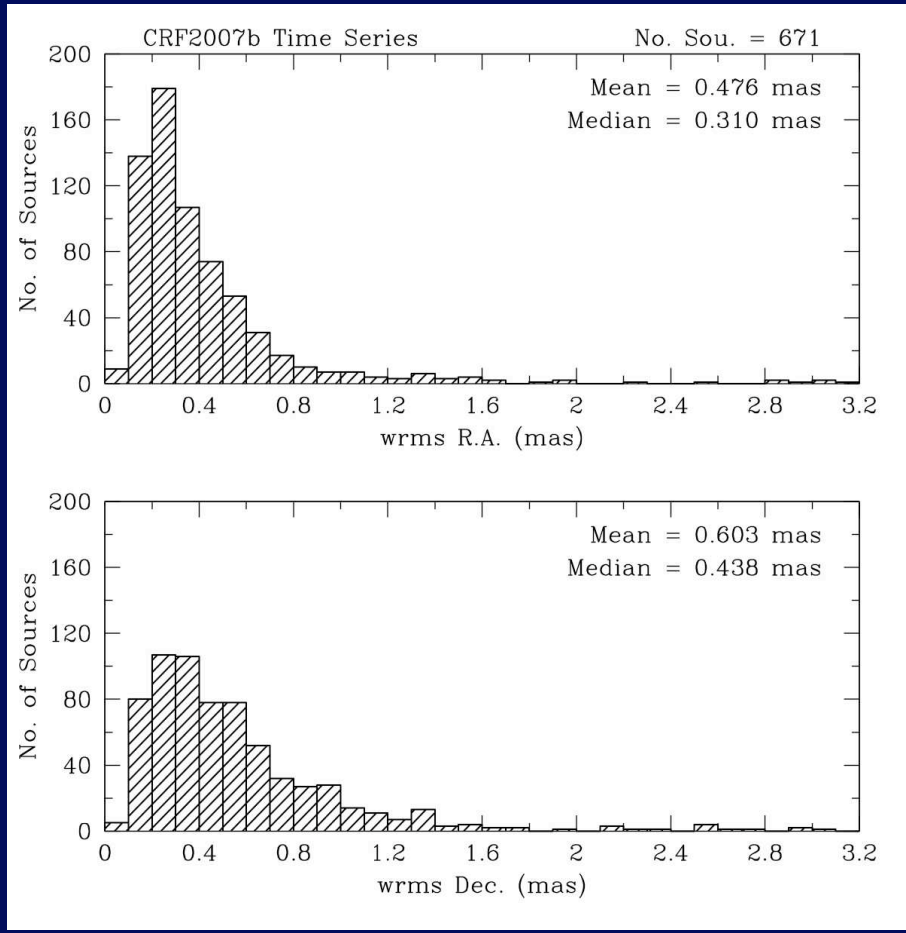
United States Naval Observatory

WRMS Position Variations

- K-band Time Series



- X/S-band Time Series

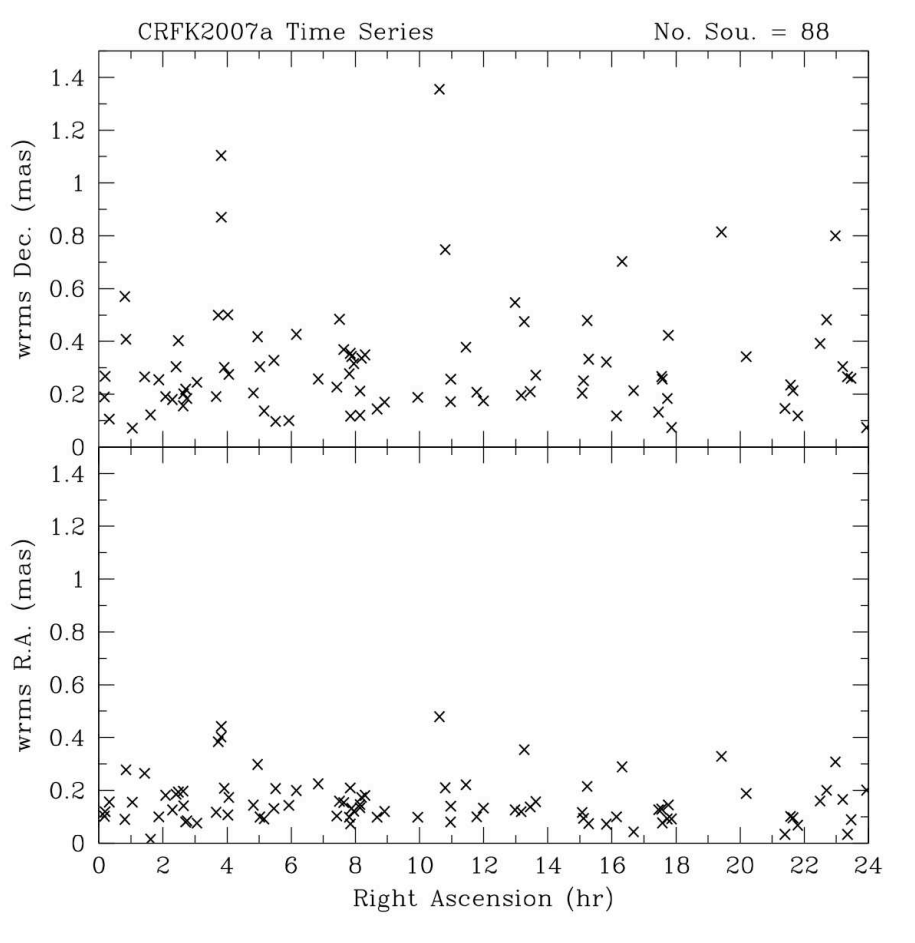


- Looks good, but probably should compare same 88 sources.

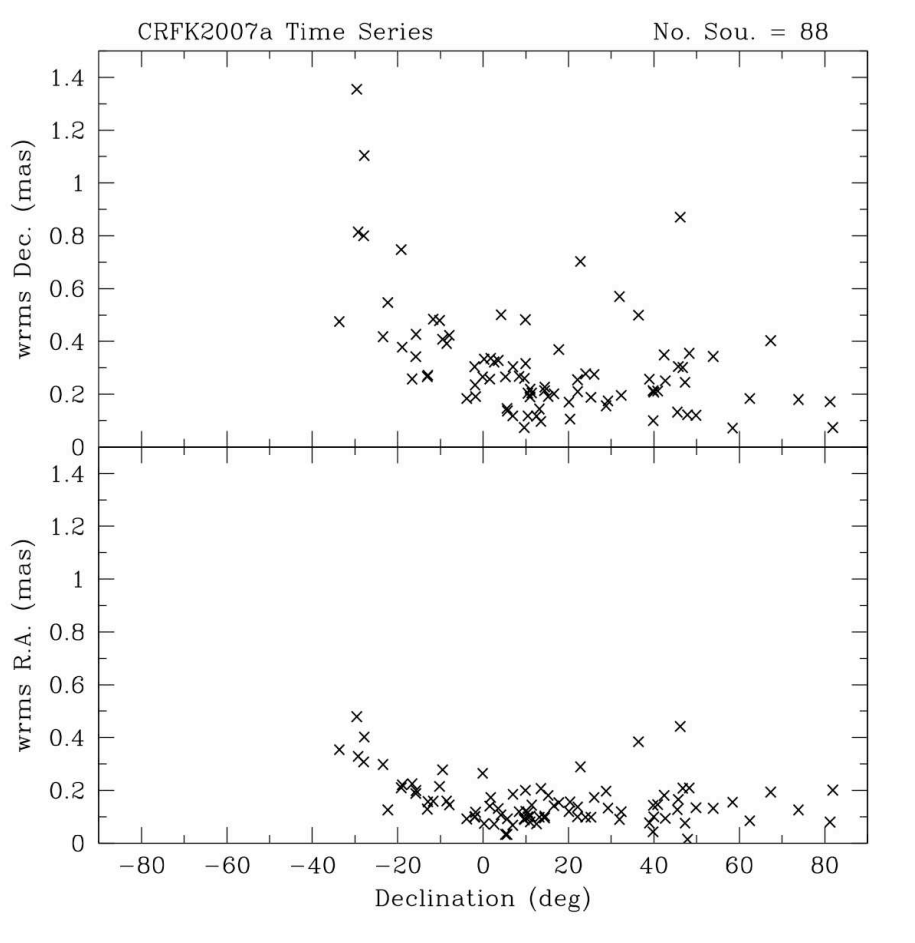
United States Naval Observatory

WRMS vs Wgt. Mean Source Position

wrms vs. R.A.



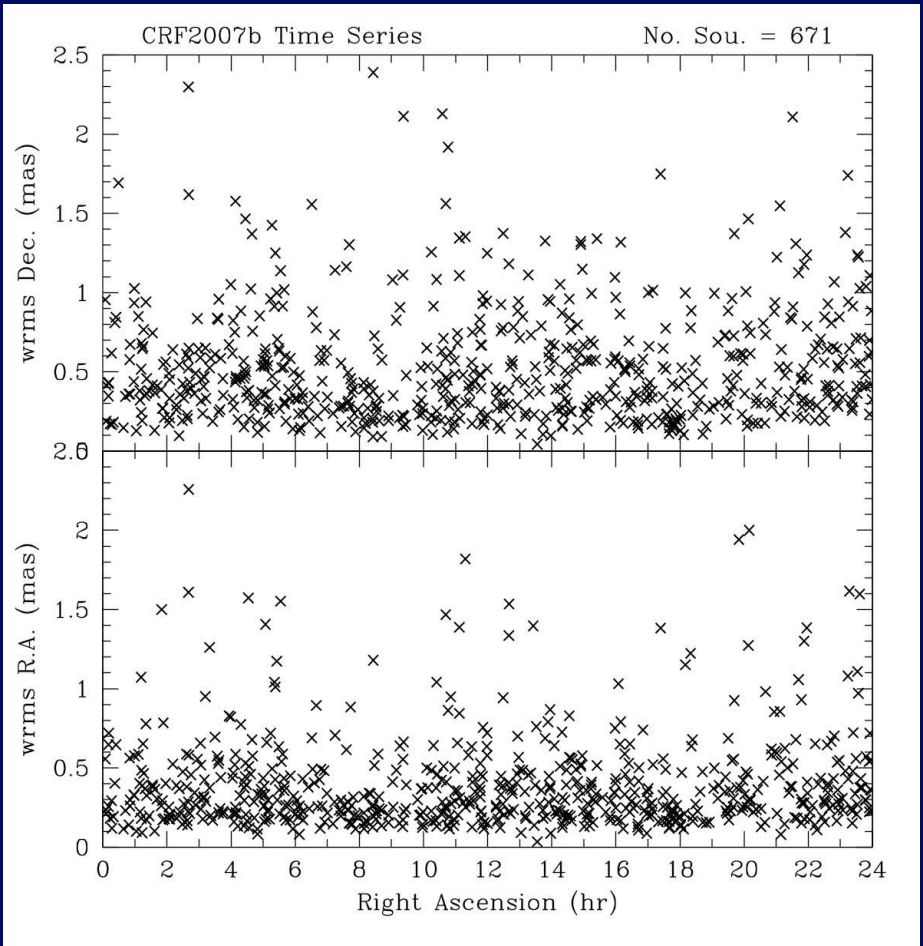
wrms vs. Dec.

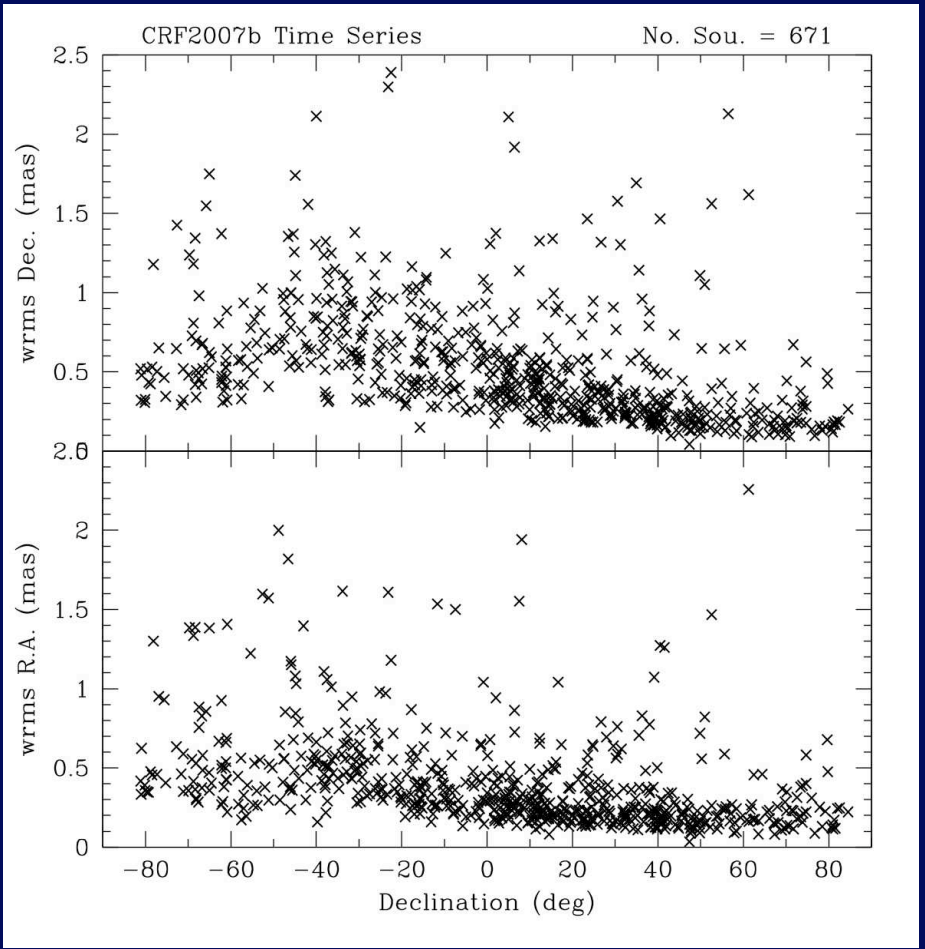


United States Naval Observatory

WRMS vs Wgt. Mean Source Position

- X/S-band values for sources in ≥5 epochs.





United States Naval Observatory

Summary and Future Work

- The high-frequency (24 GHz) CRF shows promise.
- Look for a paper (Lanyi et al. 2007, in preparation).

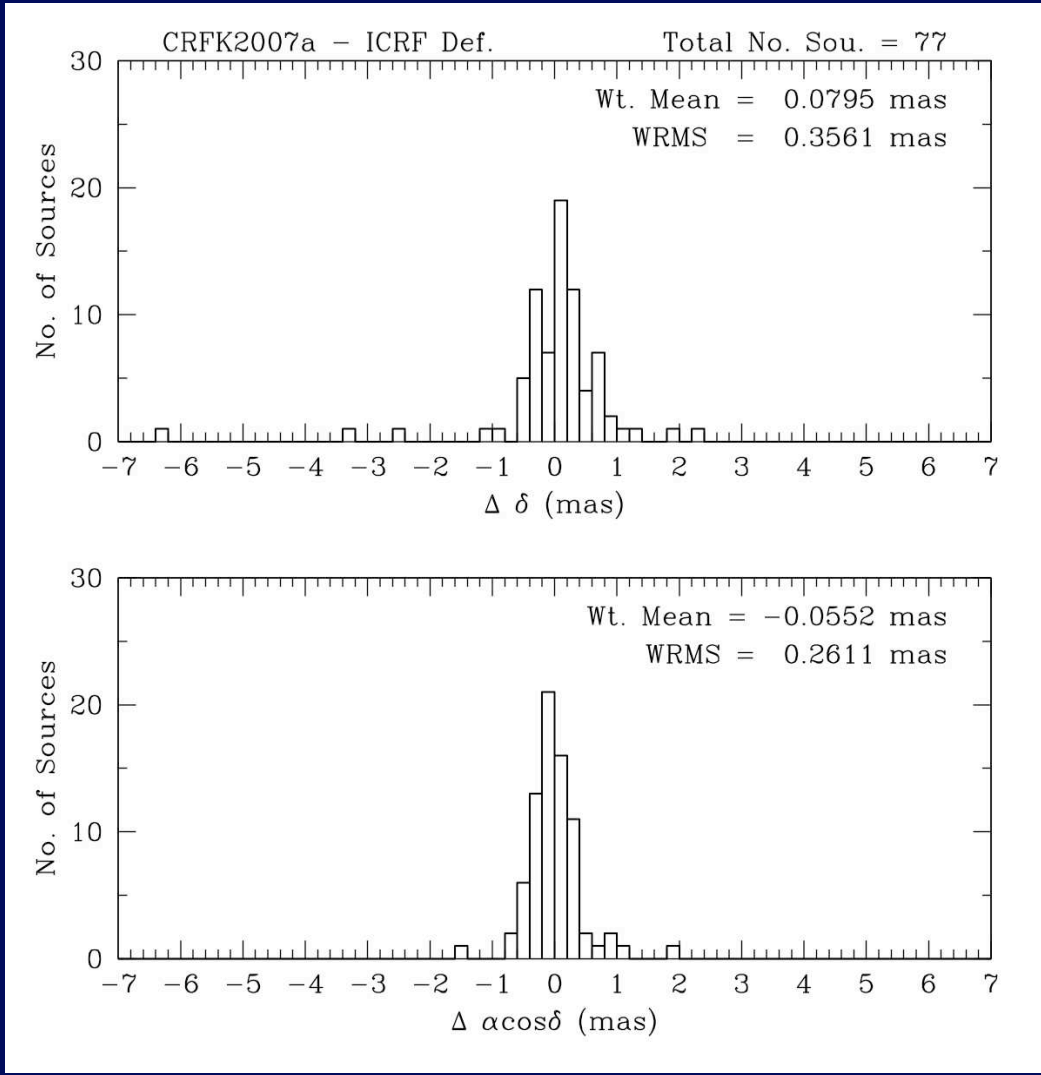
- Investigate correlations between catalog/time series and:
  - Source flux density
  - Jet angle
  - Source structure index

- Continue VLBA observations (primarily at K-band).
- Eventually move to Ka-band (32 GHz)
  - VLBA maybe.
  - Future DSN.
- Future wide-band receivers should help with sensitivity.

United States Naval Observatory

CRFK 2007a - ICRF Defining

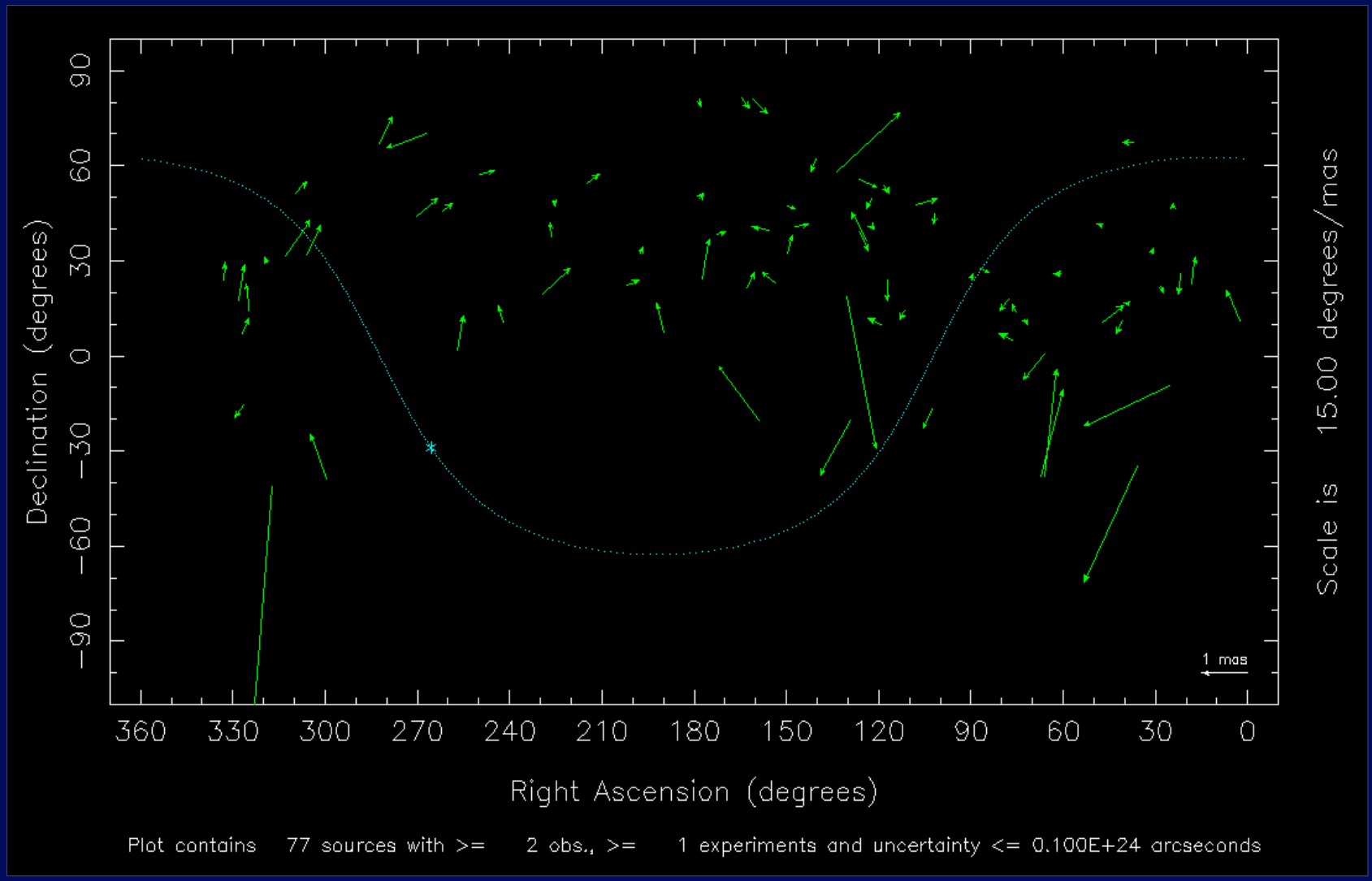
- Comparison with the ICRF Defining sources.
- 77 sources overlap.
- Shown are source position differences in R.A. (bottom) and Dec. (top).



United States Naval Observatory

CRFK 2007a - ICRF Defining

Green < 3σ Orange 3-5σ Red > 5σ



United States Naval Observatory

CRFK 2007a - ICRF Defining

- Position differences vs R.A. and Dec.