



The Southern VLBI Operations Centre (SVOC)

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HartRAO
Hartebeesthoek Radio
Astronomy Observatory

Overview: Improving the S/X CRF



Update of “Improving the S/X Celestial Reference Frame” - IVS GM, Svalbard, 2018

- **History:** Catalogs of compact radio sources are generally weaker in the south by factors of 2 or more in both density and precision (e.g. Ma et al., ICRF-2, 2009).
- The current international standard S/X frame, the ICRF-3, has deficiencies by factors of 2-3 in the south (e.g. Charlot et al., ICRF-3, IVS GM, 05 June 2018).

We have started a collaboration to correct this:

- Increase data rate by factor of 4 or more, from 256 Mbps to 1 - 2 Gbps
- Increase in sensitivity, detection of weaker sources
- Scheduling optimised for astrometry & imaging instead of geodesy
- Improve precision by a factor of 2.5
- Mapping & monitoring of source structure
- Expand source list by a factor of 2, improve spatial coverage
- Improve overlap with K-band, Ka-band & Gaia optical CRF

Overview: Improving the S/X CRF



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**SVOC proposal approved by SARAO
and submitted to IVS DB**

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Network Stations: North vs South

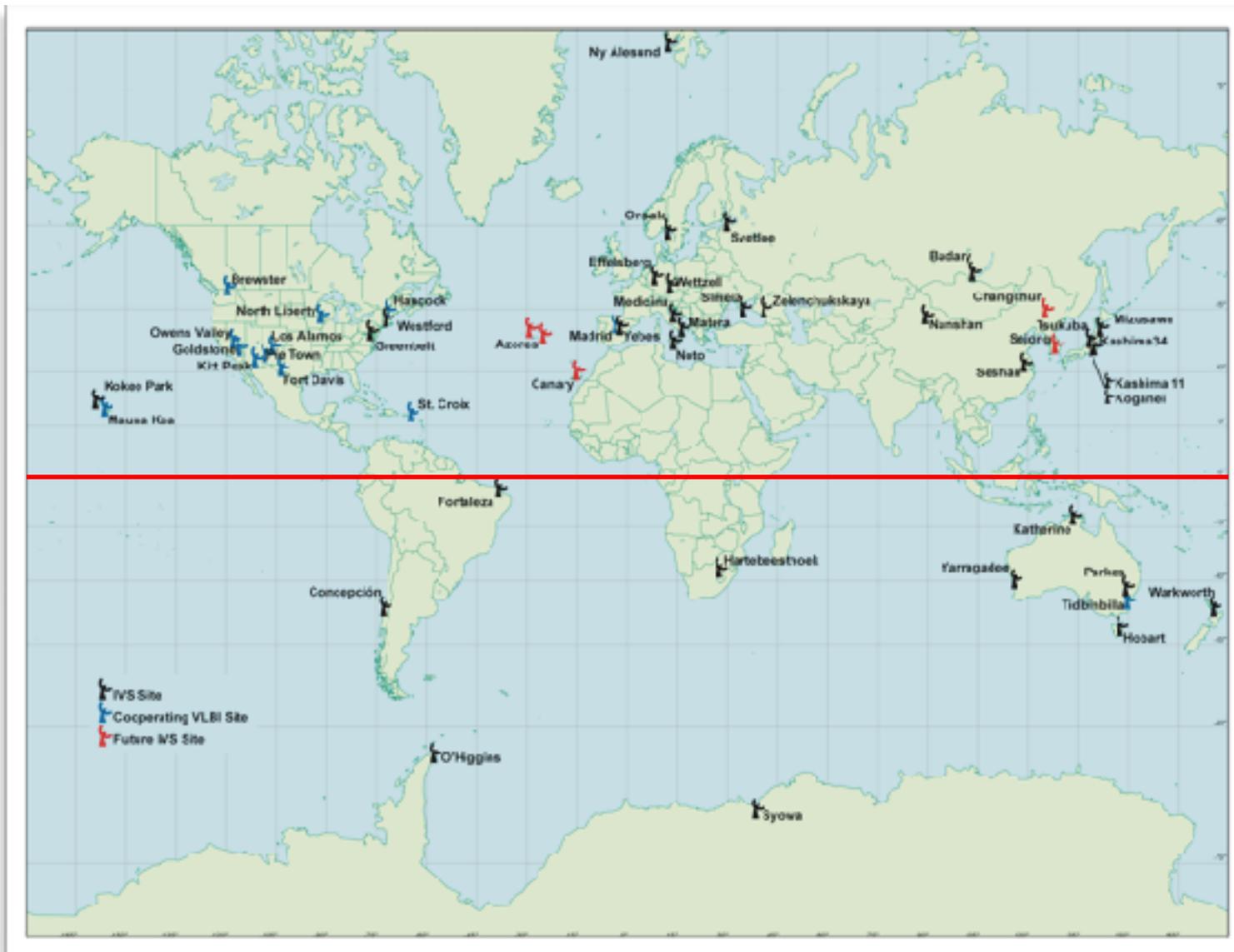


Image credit: <https://ivscc.gsfc.nasa.gov/stations/ns-map.html#maps>

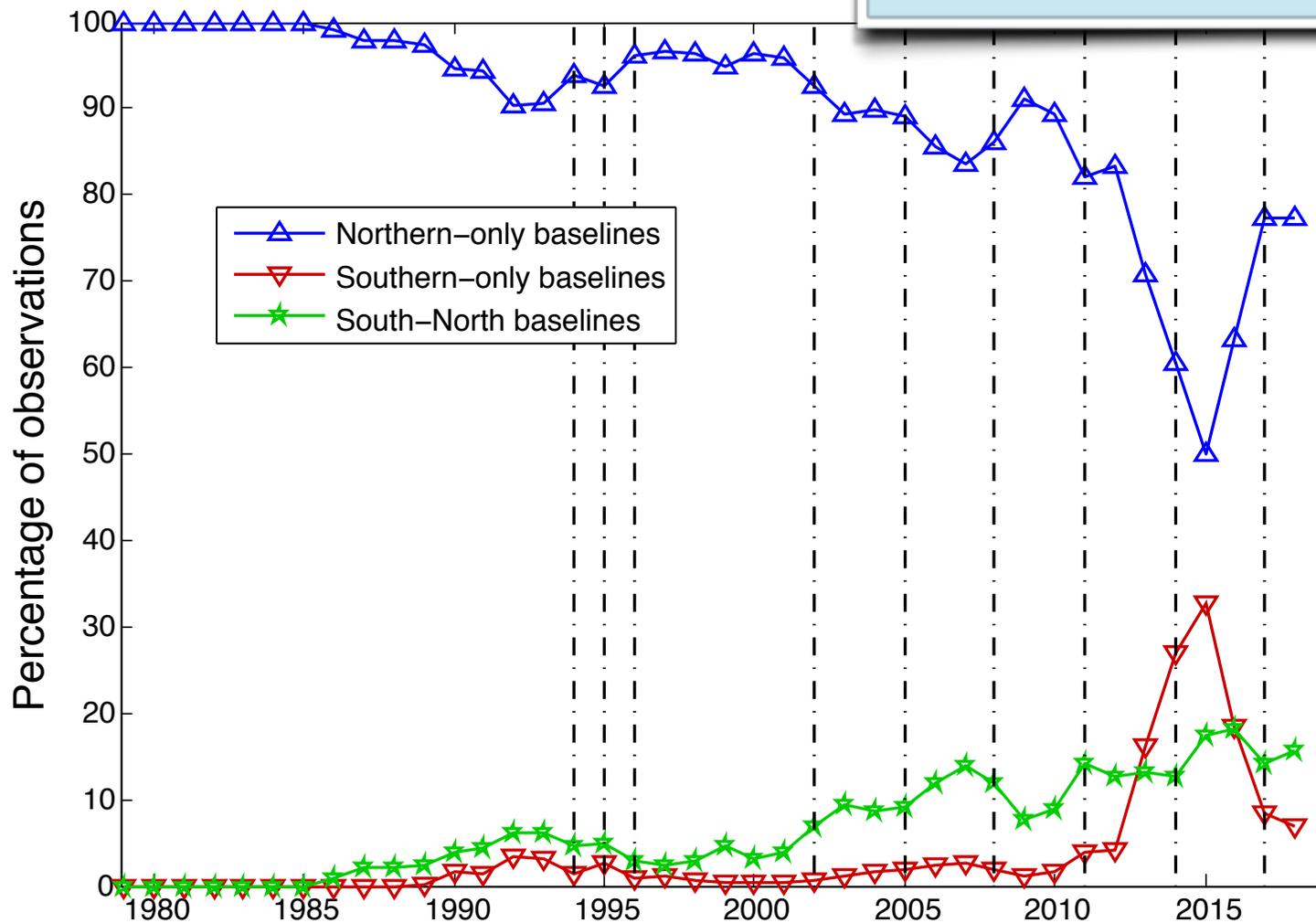
Network Stations: North vs South



Station distribution:
~80% Northern
~20% Southern

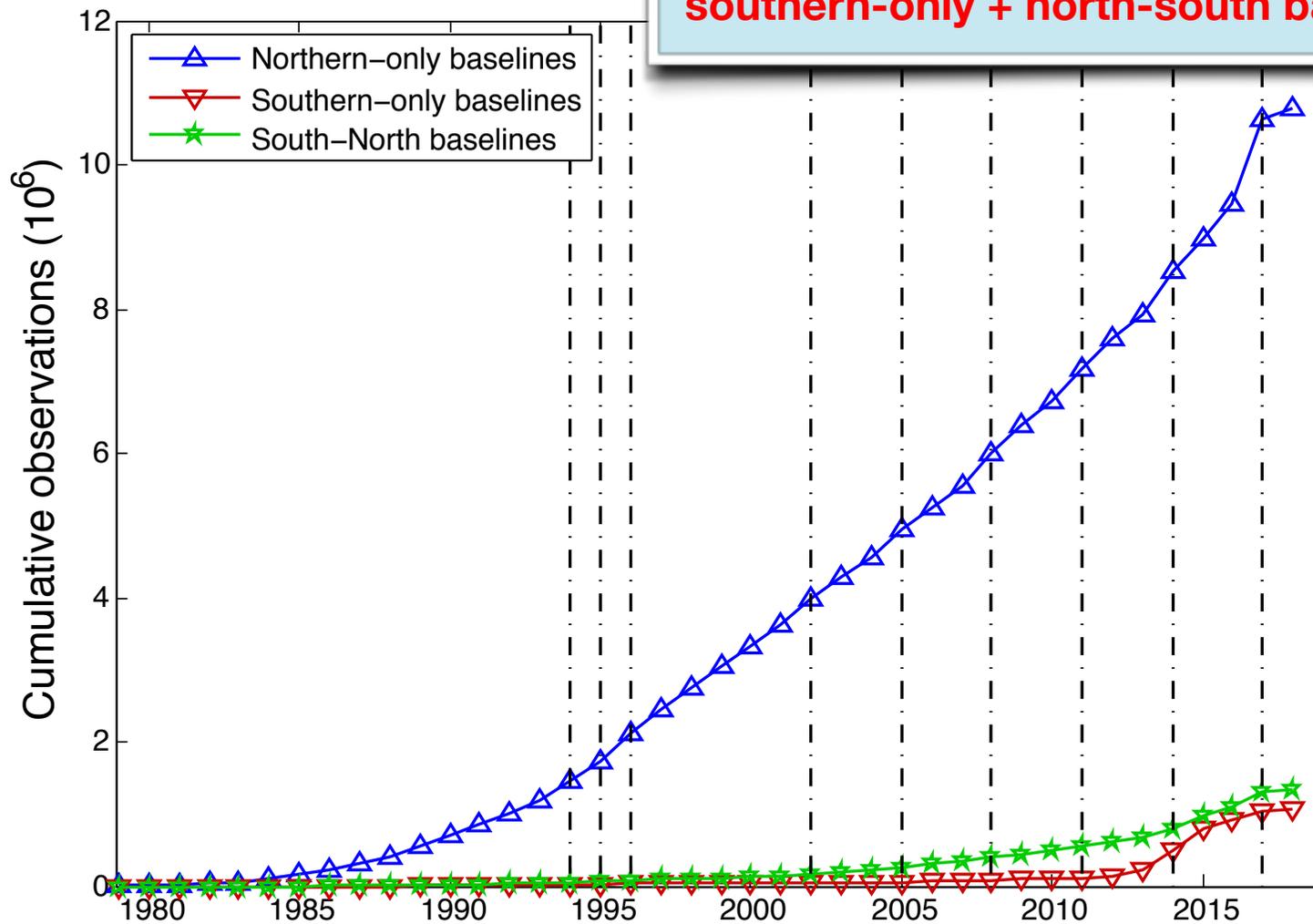
Observations: North vs South

**Baseline observation distribution:
~10% southern-only & 20% north-south**



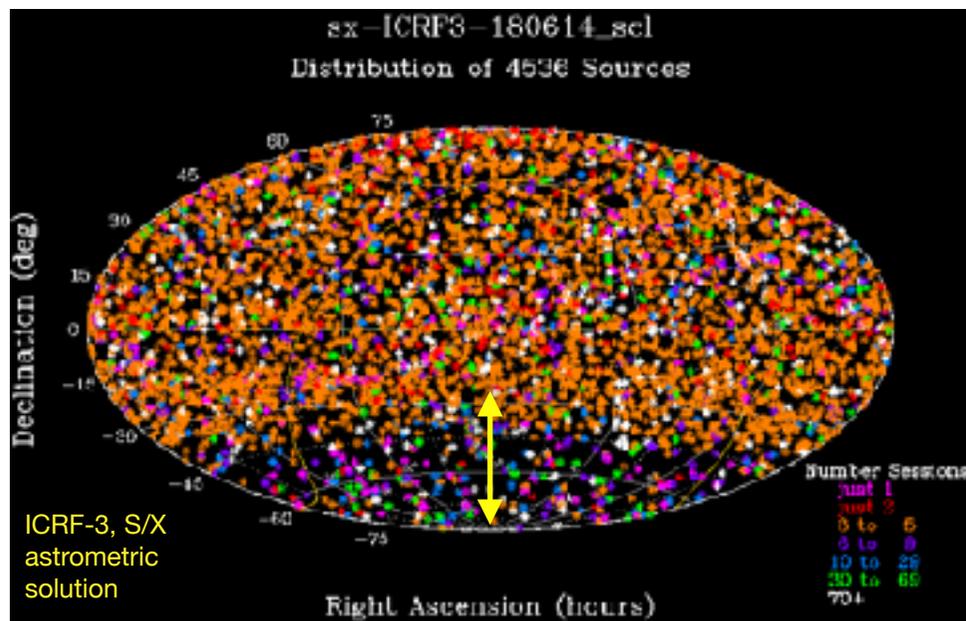
Observations: North vs South

**Growth of observations:
southern-only + north-south baselines ~15% of total**

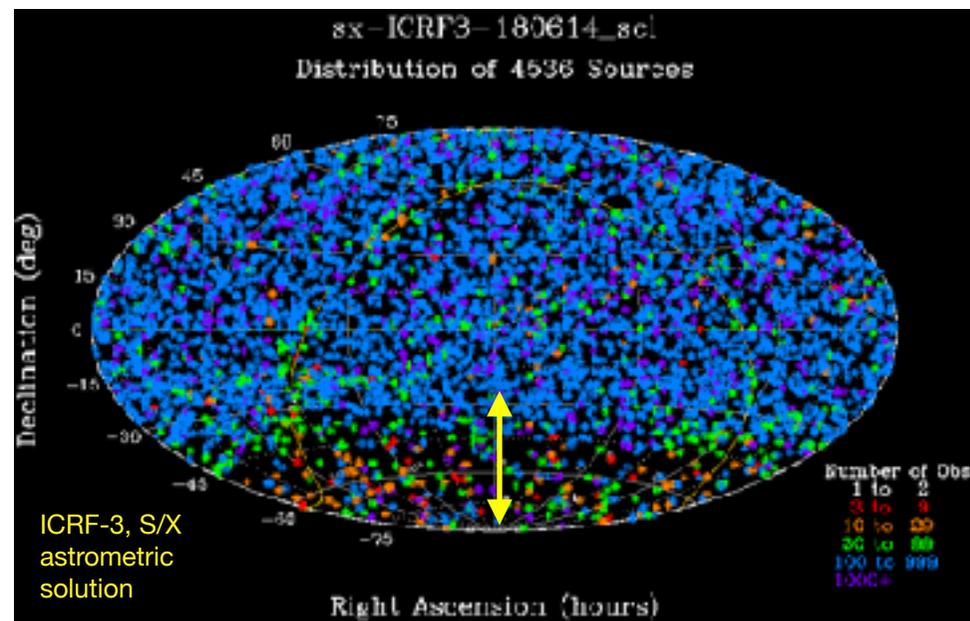


North-South CRF Statistics

Number of Sessions



Number of Observations

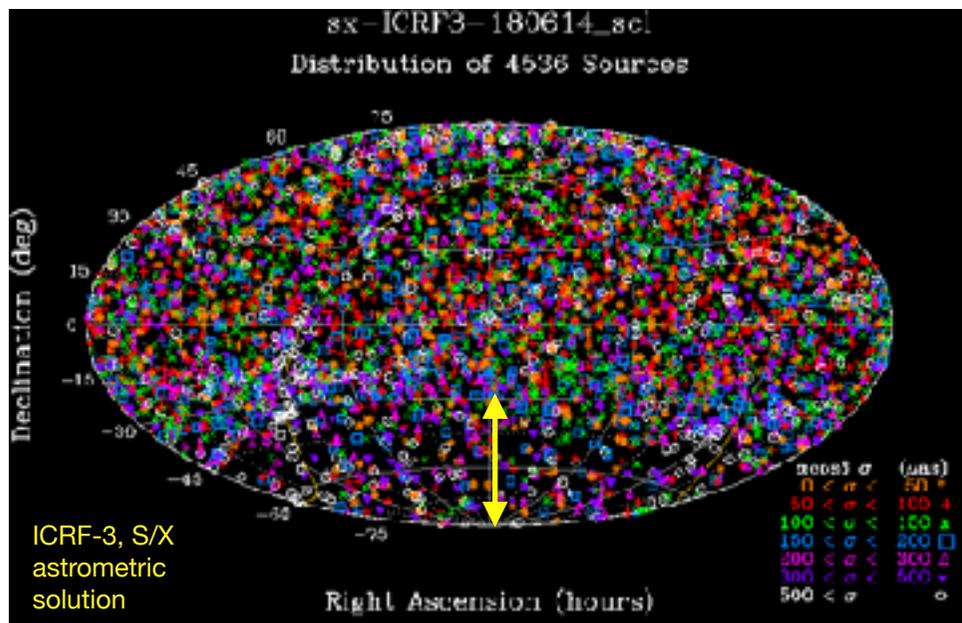


Number of sources factor of 2 less in far-south ($< -30^\circ\text{S}$) vs. far-north ($> +30^\circ\text{N}$)
Average number of sessions per sources is larger in far-south
Average number of observations per source is factor of 2 less in far-south

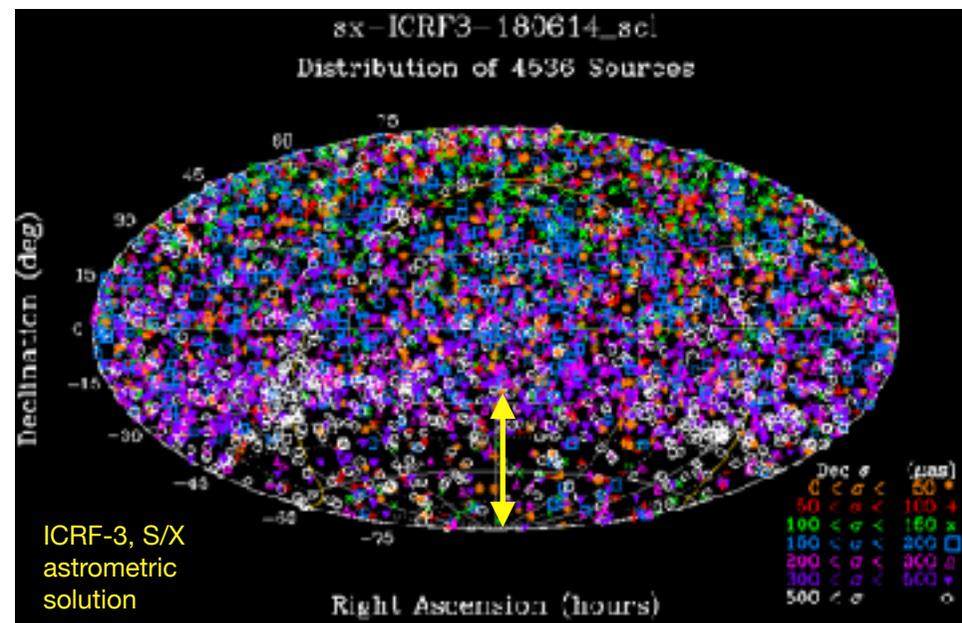
- ICRF-3 shows significant improvement over ICRF-2
- We need more sources in the South ($< -30^\circ$ South)
- We need to improve the spatial coverage in the South

North-South CRF Statistics

RA* precision



Dec precision



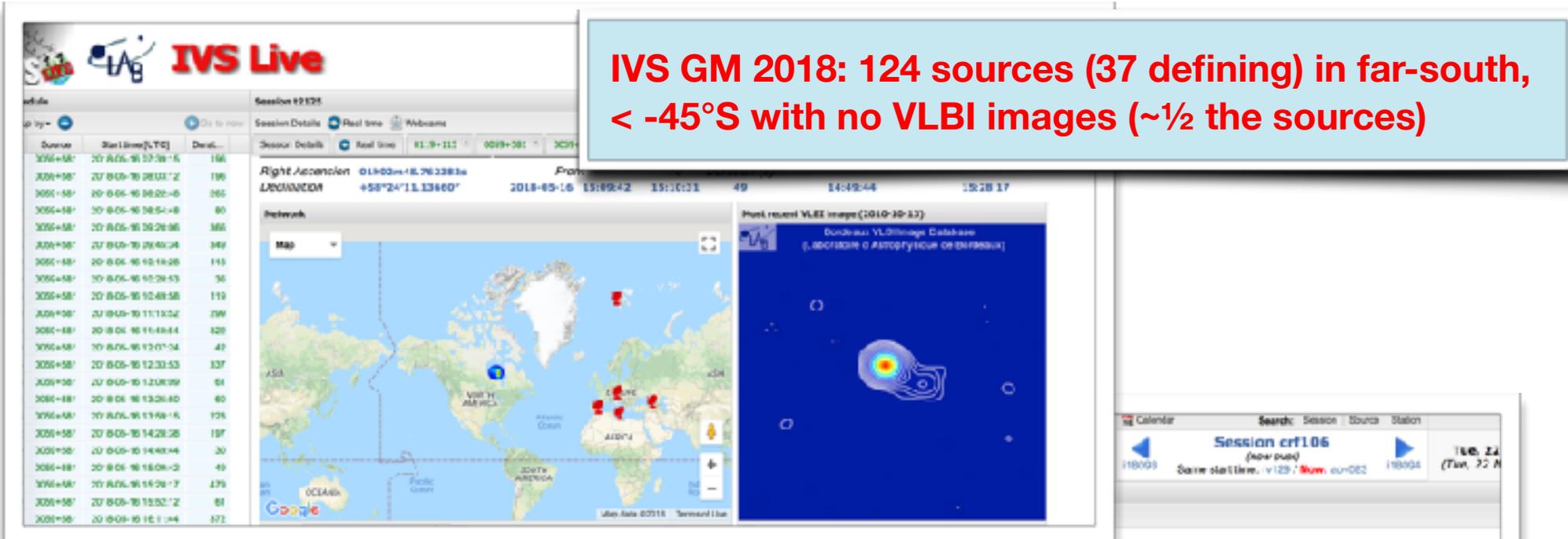
Median σ -RA factor of 1.5 weaker in far-south (<-30°S) vs. far-north (>+30°N)

Median σ -Dec factor of 2.7 weaker in far-south

- Need more southern baselines
- Declinations are consistently worse than RA even at equator
- Need more north-south baselines

Imaging North vs. South

IVS GM 2018: 124 sources (37 defining) in far-south, < -45°S with no VLBI images (~1/2 the sources)



Source 2333-415

Coordinates	Current observation	Previous observation	Next observation
Right Ascension: 21h 13m 33.389367s Declination: +81° 13' 21.98393"	From: 2018-04-04 21:09:57 To: 21:09:57 Duration: 423	None	2018-04-05 21:10:08

Network



Most recent VLBI image

No VLBI image available

Image Credit:
<http://ivslive.obs.u-bordeaux1.fr/index.php?session=t2125>

Improving the S/X CRF

Increase data rate of southern observing programmes by factor of 4 or more:

- IVS astrometric programmes, CRF and CRDS, at 128/256 Mbps

- ➔ Increase data rate to 1 - 2 Gbps
- ➔ Increase sensitivity by factor of 2 or more
- ➔ Detect weaker sources down to ~350 mJy or less
- ➔ Scheduling will become more efficient
 - more sources to choose from and shorter scan times
 - more scans/sources or more sources/schedule

IVS-CRDS (CRDS):

Celestial Reference Frame
Deep South

IVS-CRF (CRF) :

Celestial Reference Frame

AUS-AST (AUA) :

AUSTRAL, Australia (AuScope)
and New Zealand geodetic
VLBI network

Progress to date:

- **1 Gbps tested on AUS-AST sessions (at 1/month from Aug 2017)**
 - Southern Astrometry Project (SOAP, <http://astrogeo.org/soap/>)
- **1 Gbps observing mode tested and implemented for IVS-CRDS**
 - 1 Gbps from 24 Jan 2018 crds93 (crds94/95/96/97/98/99 and crd100)
 - Hobart12 & 26m, HartRAO15 & 26m, Warkworth12m, Yarragadee12m, Katherine12m
- **1 Gbps observing mode tested for IVS-CRF**
 - 1 Gbps narrow-band mode tested on 4 April 2018 crf106 (crf107/108/109)
 - Test 1 Gbps data rate on Fortleza, Kokee, Noto, Matera (Sked, using AOV setup)

Improving the S/X CRF

Scheduling optimised for astrometry & imaging instead of geodesy:

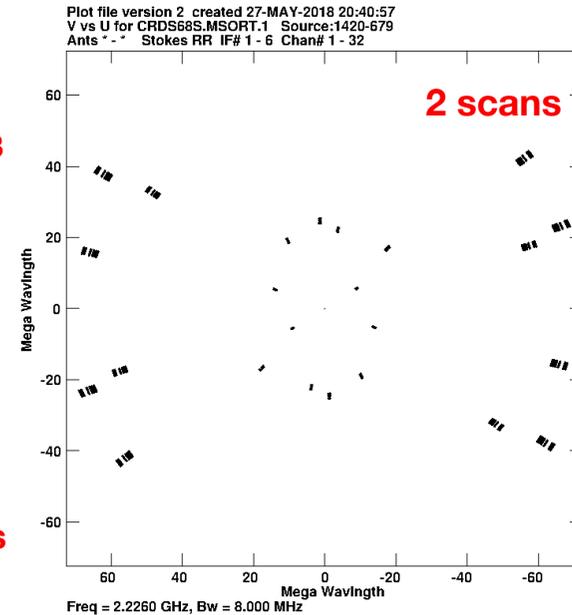
- Use full network when possible for every scan.
- Around 3-8 scans/source spread evenly over HA range.
- Include tropospheric calibrators, also used as ties and for amplitude calibration.
- Schedule a campaign not an experiment!

Progress to date:

- Optimised scheduling for all IVS-CRDS sessions since crds93 (sched, vex)
- VieVS group (Vienna) testing new scheduling software for astrometry & imaging (Schartner et al. see next talk).

crds68
27 Nov 2013

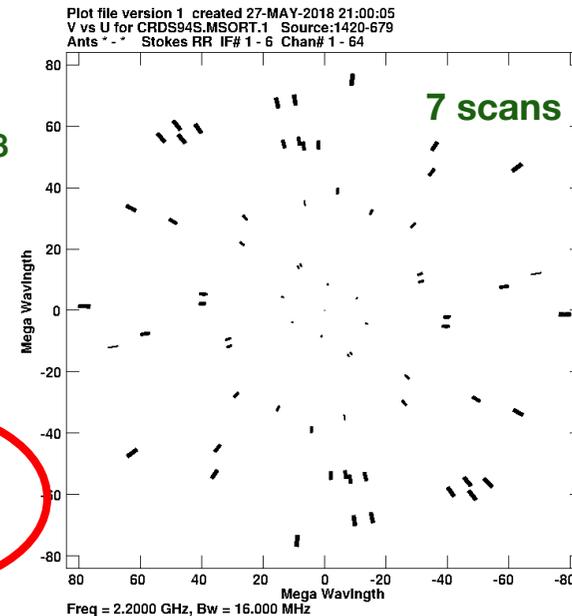
Total:
144 scans
38 sources



Hh
Ho
Hb
Yg
Ke
Ww

crds94
21 Mar 2018

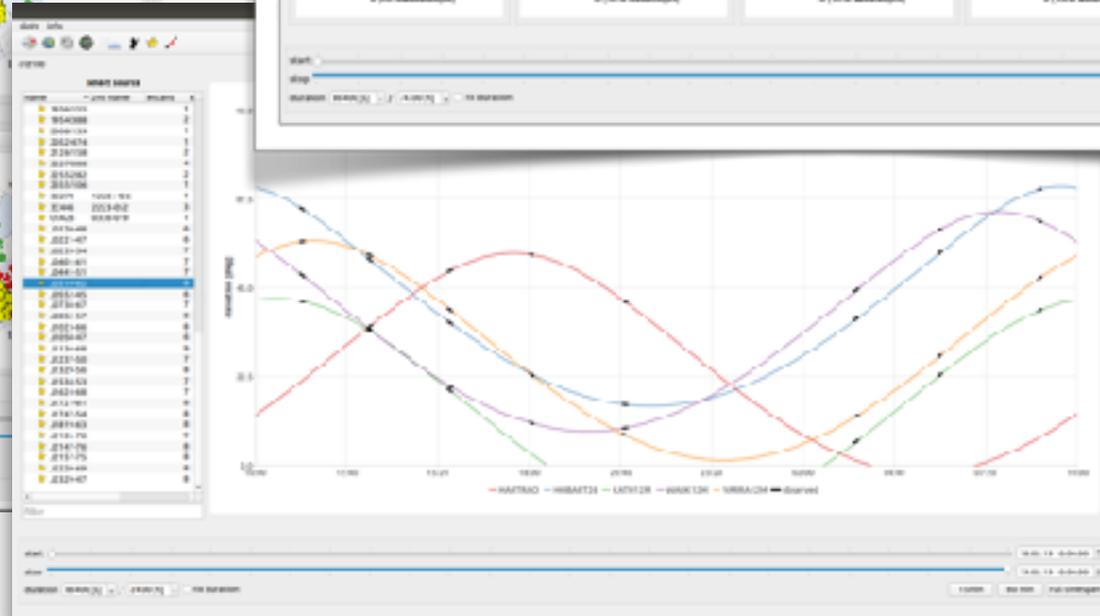
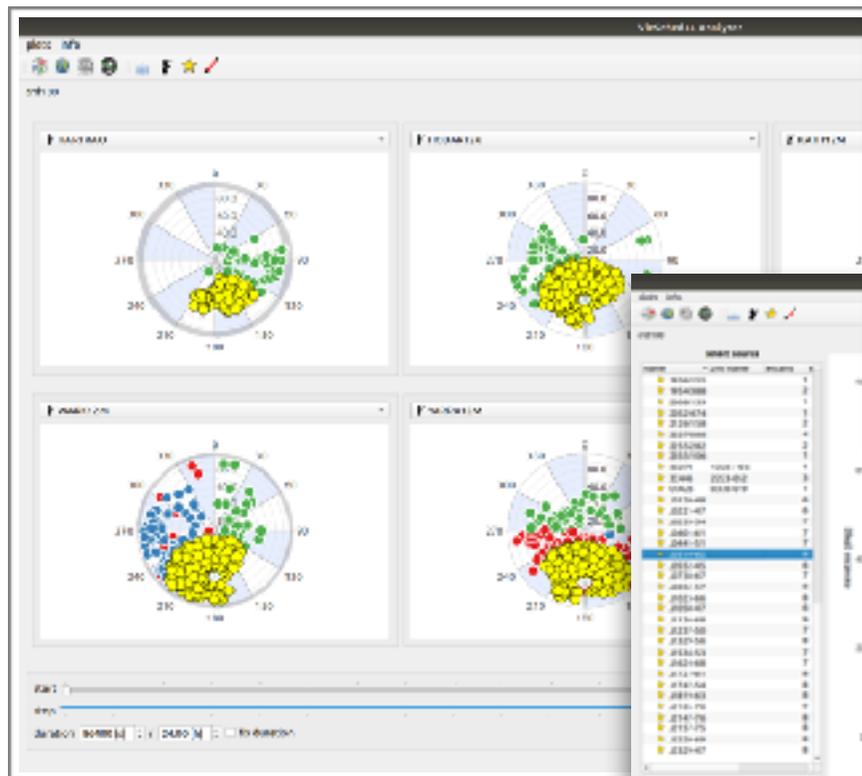
Total:
304 scans
51 sources



Hh
Ht
Ho
Yg
Ke
Ww

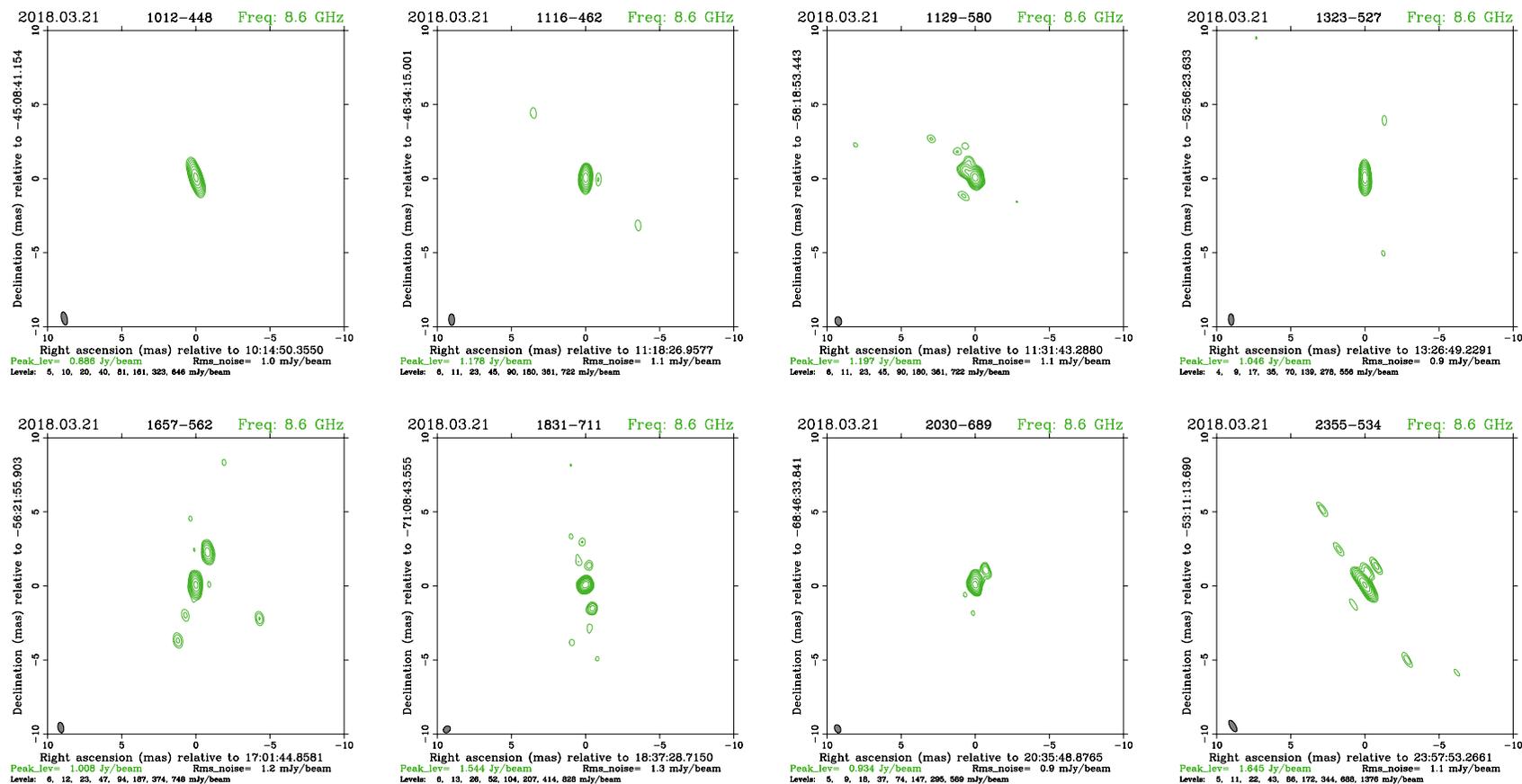
Improving the S/X CRF

Scheduling optimised for astrometry & imaging using VieSched++:



Improving the S/X CRF

Image sources in S/X-band to quantify non-pointlike structure:



Focus on 124 sources in far-south with NO VLBI images.
Completed imaging of crds63, 64, 66, 68 (e.g. Basu et al. 2016).
Imaging of first 1 Gbps session, crds94 (March 2018).

Improving the S/X CRF

Improve precision by a factor of 2.5:

- Only ICRF-2 DEF sources in CRDS & CRF

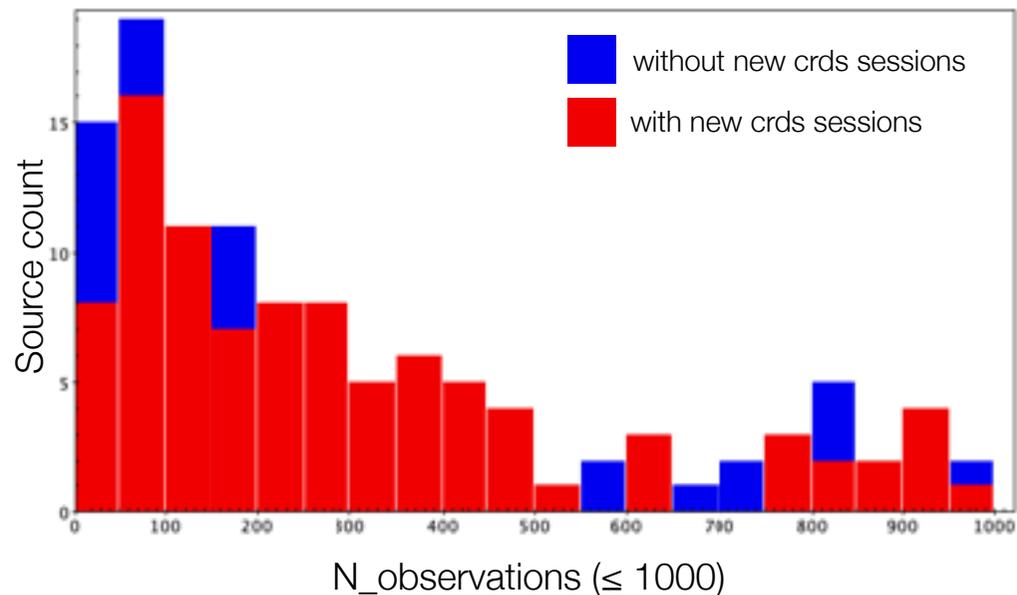
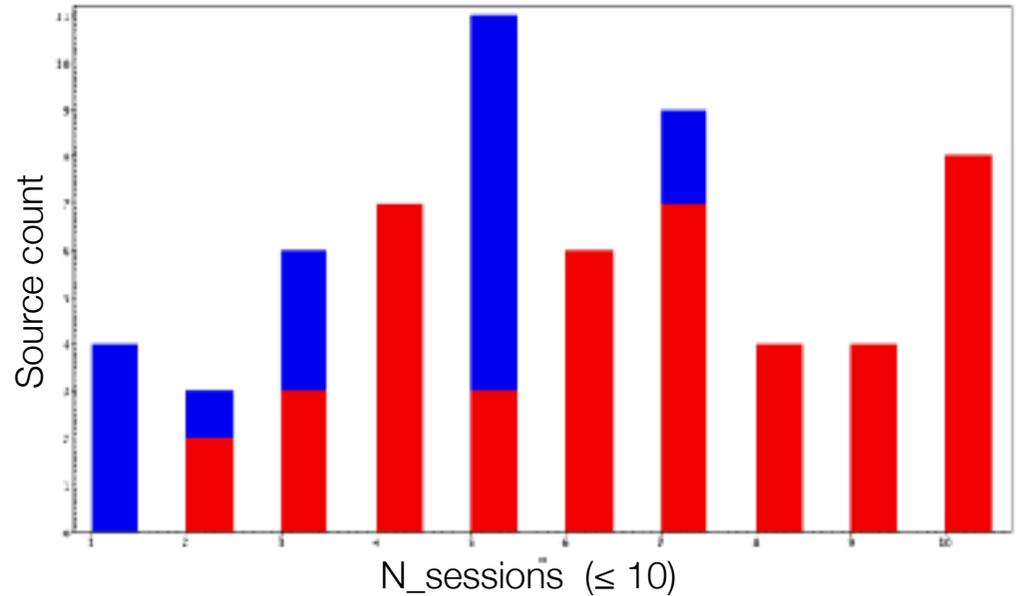
→ Re-observe ALL southern sources in current S/X CRF.

→ Improve source position accuracy in both coordinates.

→ From 1344 sources $< -15^\circ\text{S}$ we have 1091 sources with $N_{\text{ses}} < 10$
We will prioritise 216 sources with flux density > 350 mJy.

Progress to date:

- More sources added to CRDS & CRF
- Last 6 CRDS sessions (crds94/95/96/97/98/99) observed 137 sources.
- **Median σ in RA & Dec $\sim 20\%$ better.**
- **Three (3) sources already achieved a 2x improvement.**



Improving the S/X CRF



Improve the far-south by a factor of 2 in density:

- Expand source list in the south, specifically in the far-south $< -45^\circ\text{S}$.
- Improve spatial coverage in the south, specifically $< -30^\circ\text{S}$.
- Improve overlap with K- and Ka-band frames & Gaia optical frame.

Progress to date:

- **K- and Ka-band sources added to IVS-CRF & IVS-CRDS since Dec 2017**
 - We have ~80 K/Ka-band sources not in current S/X frame at $< -15^\circ\text{S}$.
 - From these we have ~20 sources with flux density > 350 mJy at S/X-band.

- **Additional 1 Gbps IVS-AUA sessions at 1/month from Aug 2017 - SOAP**
 - Follow-up to LBA Calibrator Survey ([LCS, Petrov et al., 2011, 2019](#)) at X-band.
 - Improve positions of **all known VLBI sources** $< -30^\circ\text{S}$ **by factor of 5** (~ 0.3 mas).
 - Derive images at S- and X-band and determine jet directions.
 - AUA sessions include all sources (215) brighter than 250 mJy and $< -45^\circ\text{S}$.
 - Priority is $\sim 1/2$ of the target sources that have a counterpart with Gaia.
 - Fifteen 24-hour experiments - **pool of candidate CRF sources!**

Summary: Improving the S/X CRF

- **Goal:** To improve the S/X-band frame in the south, by at least a factor of 2 in density and 2.5 in precision, to be about as good as the north.
- **Roadmap:**
 - Increase data rate of southern IVS sessions (CRDS, CRF, [AUA](#)) to 1 Gbps.
 - Optimise the scheduling of these sessions for astrometry & imaging vs. geodesy.
 - Increase the number of well observed sources ($N_{\text{ses}} > 10$) in the south.
 - Increase the number of south-south but also north-south baseline observations.
 - Image sources to quantify non-pointlike structure and measure jet directions.
 - Expand the southern source list and improve spatial coverage.
 - Get the far south precision about as good as the north.
- **Initial Steps are Succeeding:**
 - All IVS southern astrometric sessions now at 1 Gbps.
 - Improved scheduling for improved astrometry and imaging.
 - To date we have achieved our goal of at least 2x improvement for 3 sources
 - SOAP sessions to re-observe LCS sources - pool of candidate sources.
 - Revision of CRF network for improved uv-coverage - to start April 2019.



Thank You

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