The Southern VLBI Operations Centre (SVOC)

Aletha de Witt

The 24th Meeting of the EVGA
Las Palmas, Gran Canaria, Spain
17-19 March 2019

NRF National Research Foundation
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

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SVOC proposal approved by SARAO and submitted to IVS DB

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SVOC Members and Co-authors

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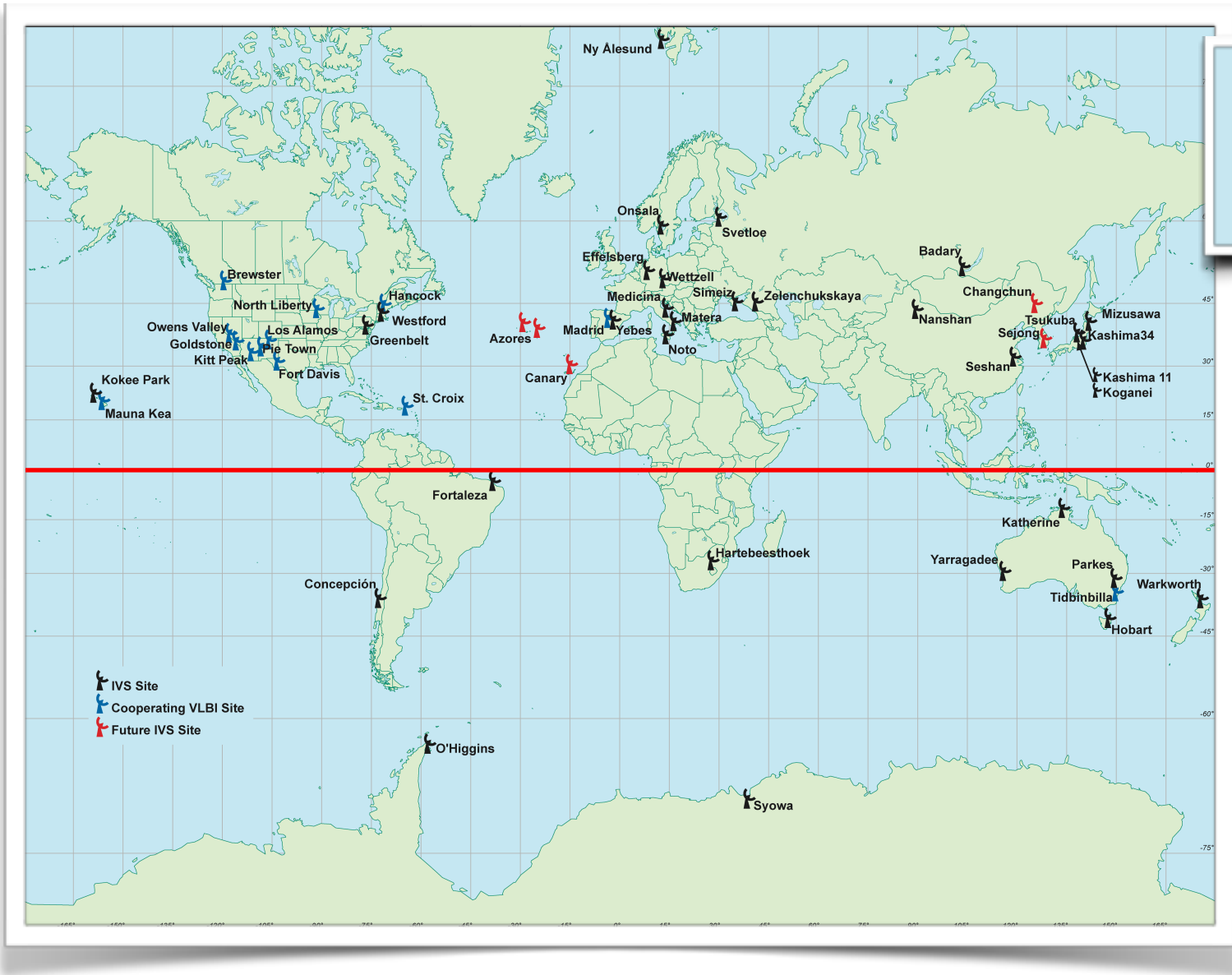
Network Stations: North vs South



Station distribution:
~80% Northern
~20% Southern

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

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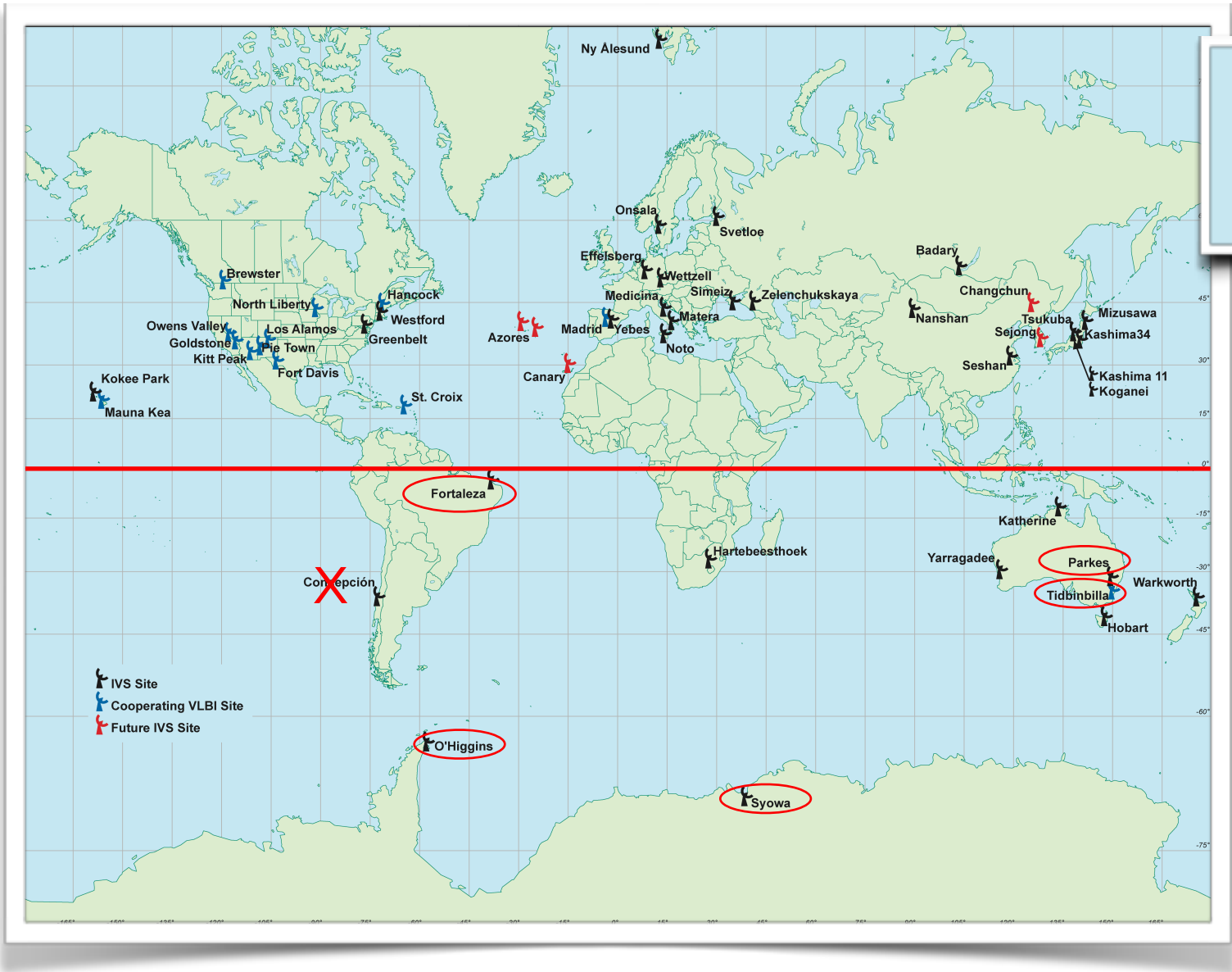

Station distribution:
~80% Northern
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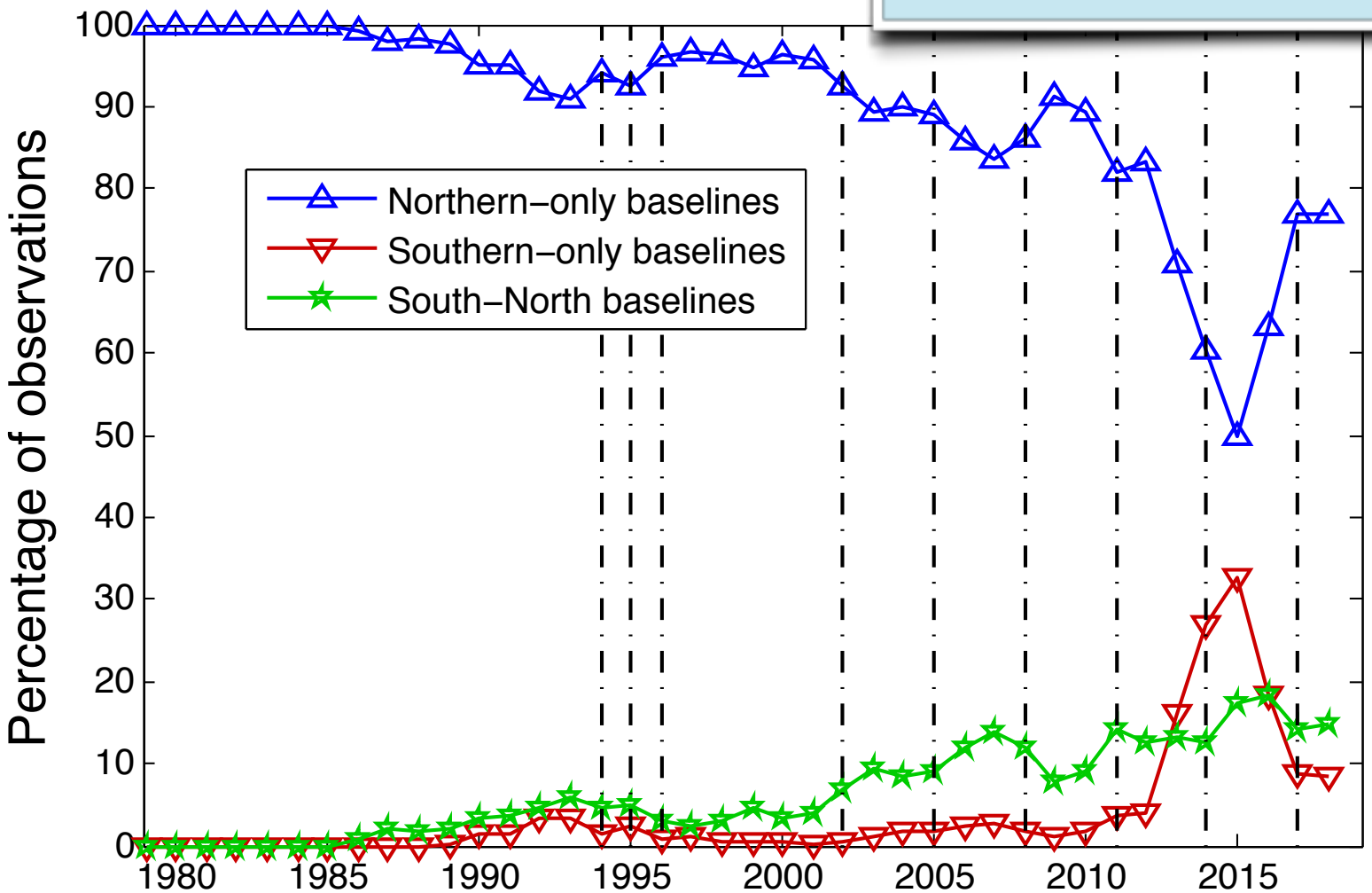
Image credit: https://ivscc.gsfc.nasa.gov/stations/ns-map.html#maps

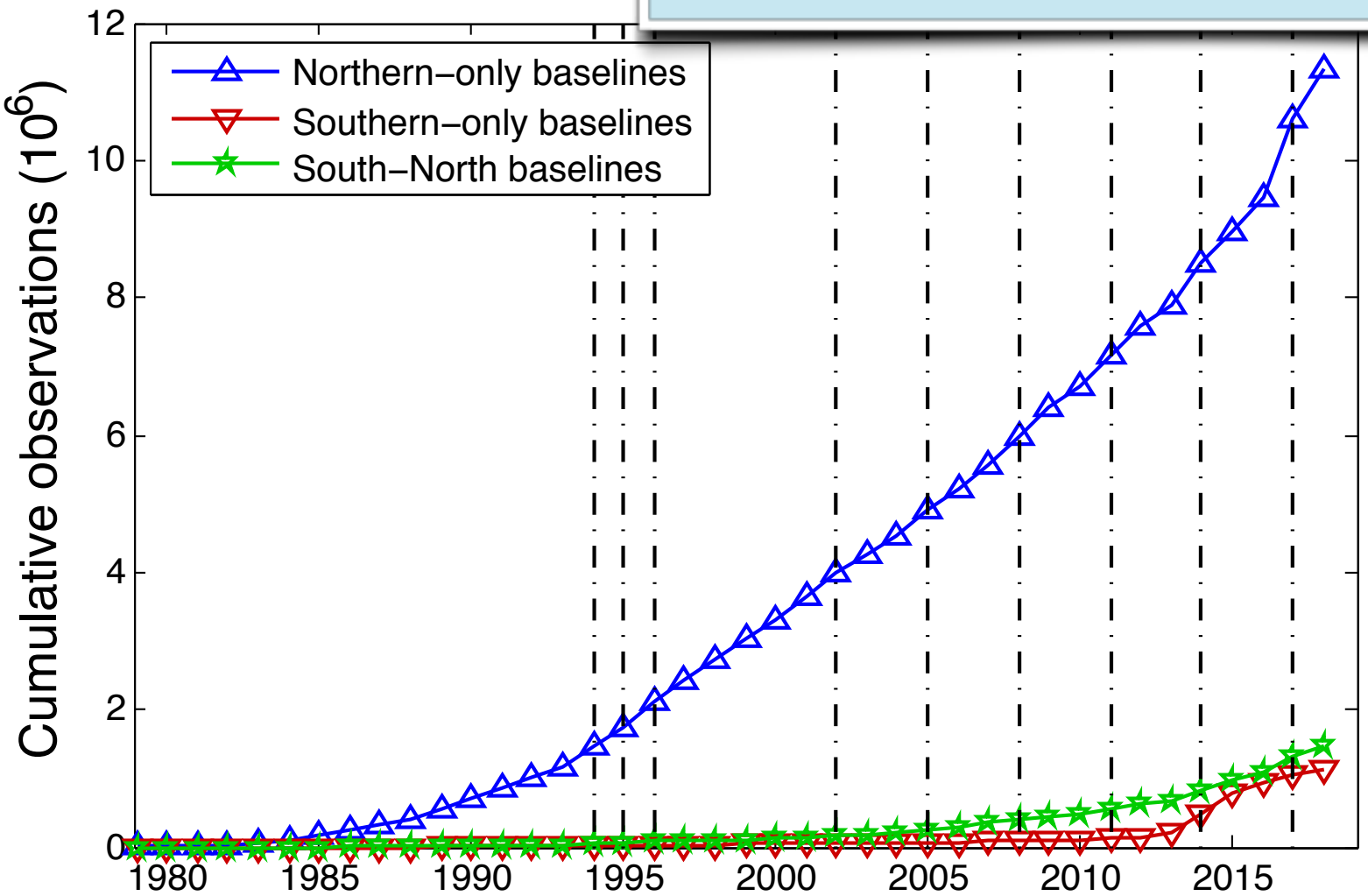
Observations: North vs South

Baseline observation distribution:
~10% southern-only & ~15% north-south



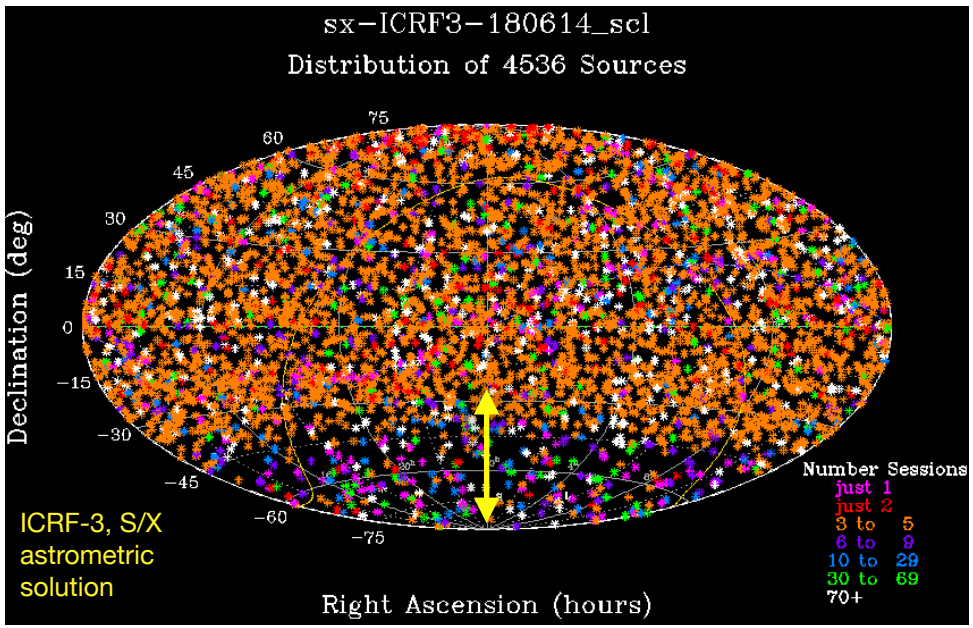
Observations: North vs South

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

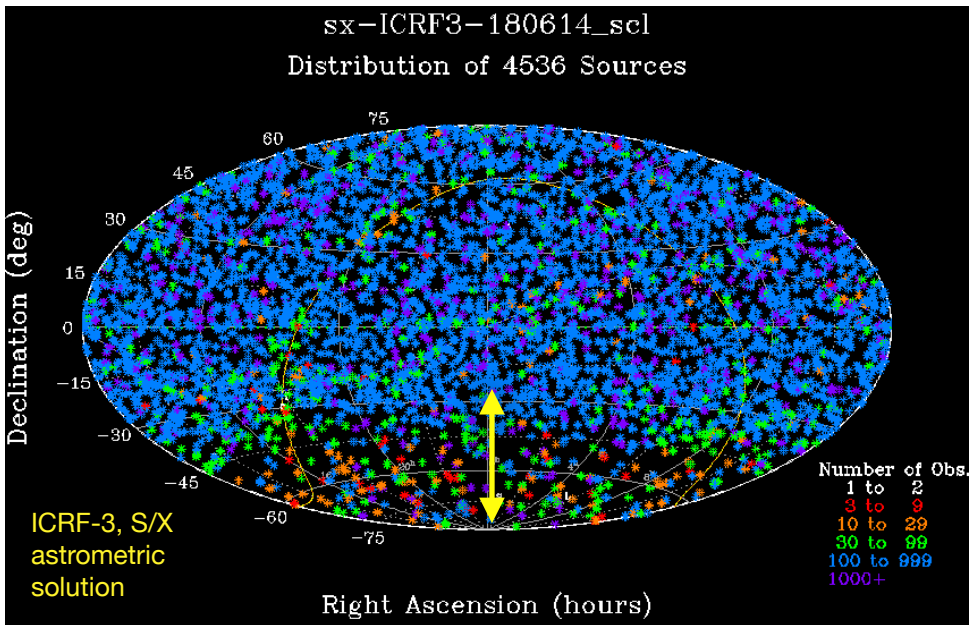


North-South CRF Statistics

Number of Sessions



Number of Observations



Number of sources factor of 2 less in far-south (<-30°S) vs. far-north (>+30°N)

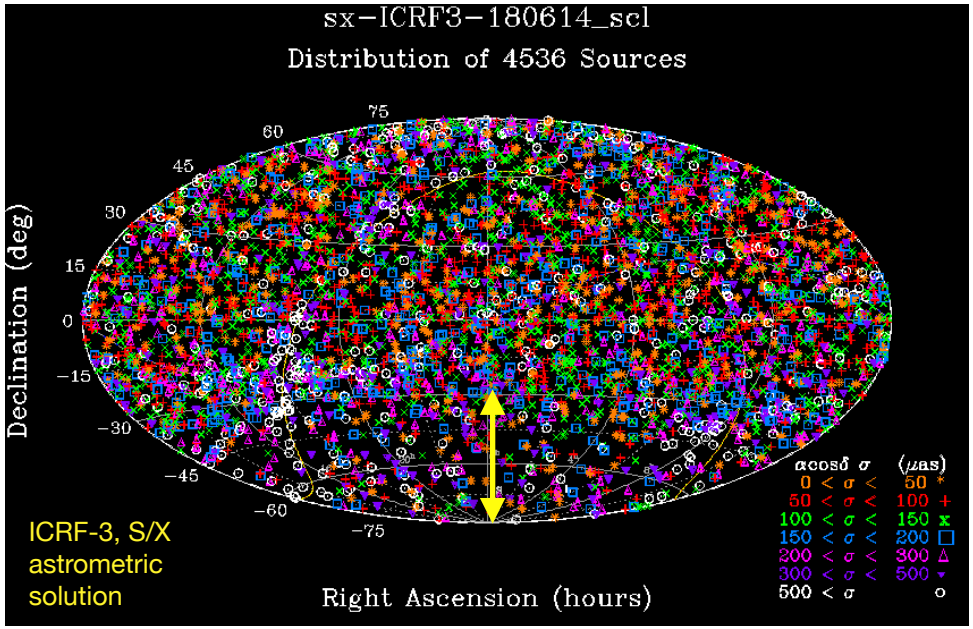
Average number of sessions per sources is larger in far-south

Average number of observations per source is factor of 2 less in far-south

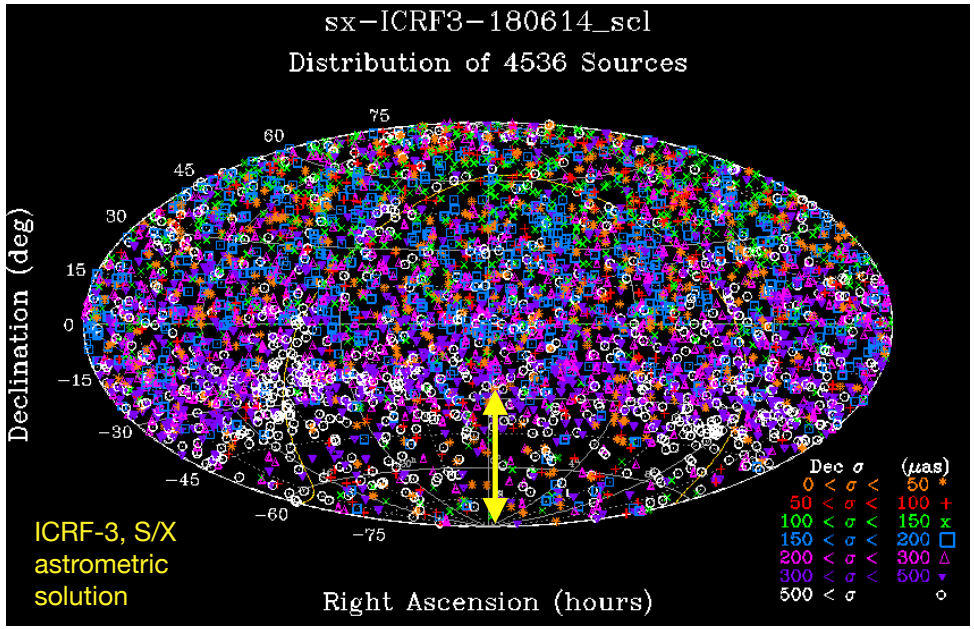
- **ICRF-3 shows significant improvement over ICRF-2**
- **We need more sources in the South (< -30° South)**
- **We need to improve the spatial coverage in the South**

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 (~½ the sources)

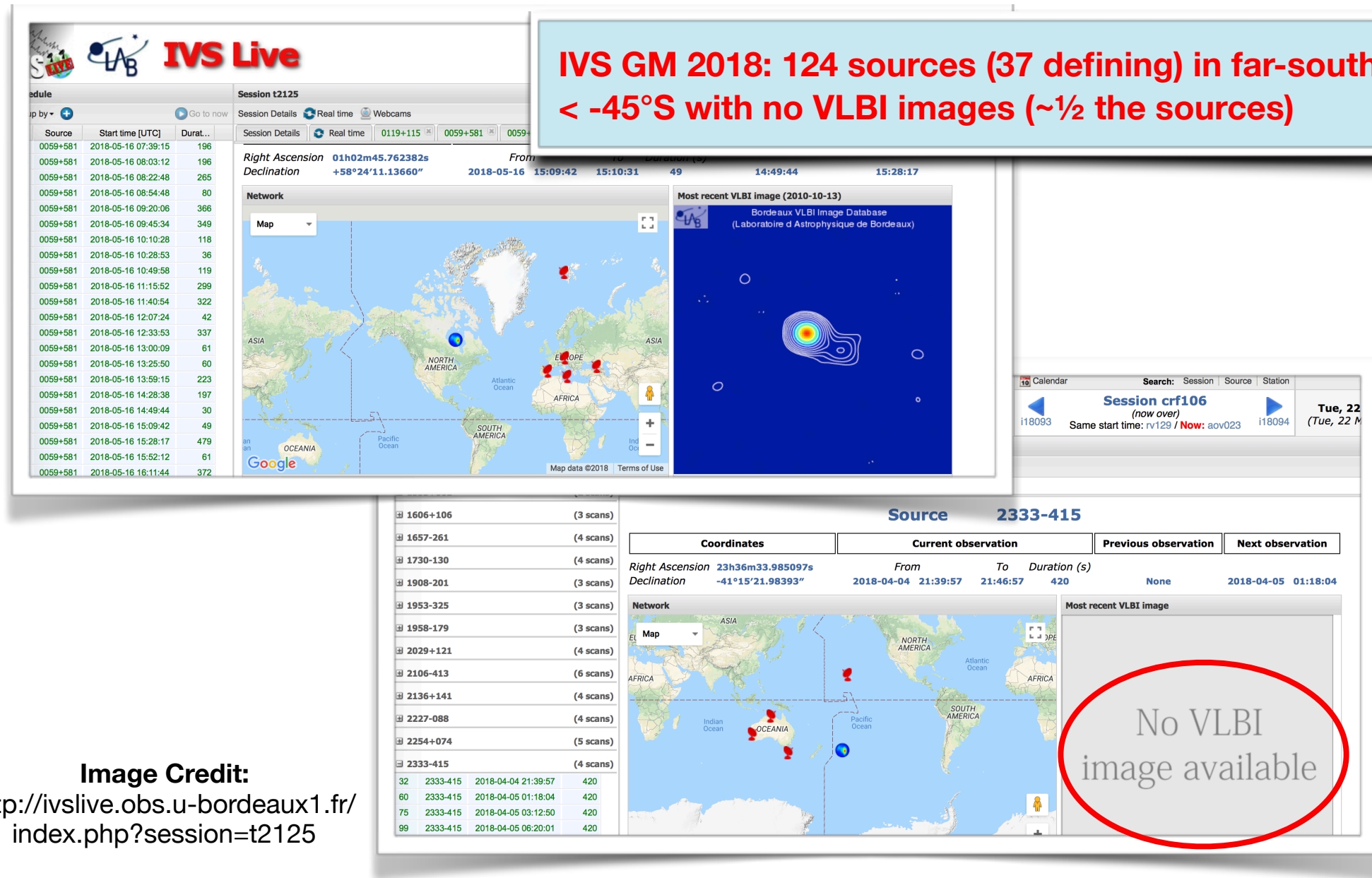


Image Credit:
http://ivslive.obs.u-bordeaux1.fr/index.php?session=t2125

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/source 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

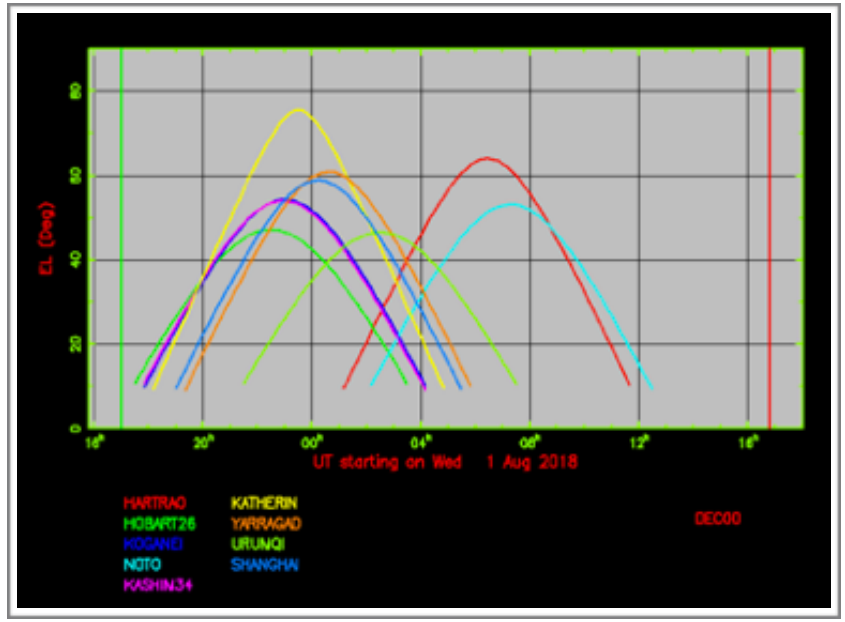
Progress to date:

- **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)

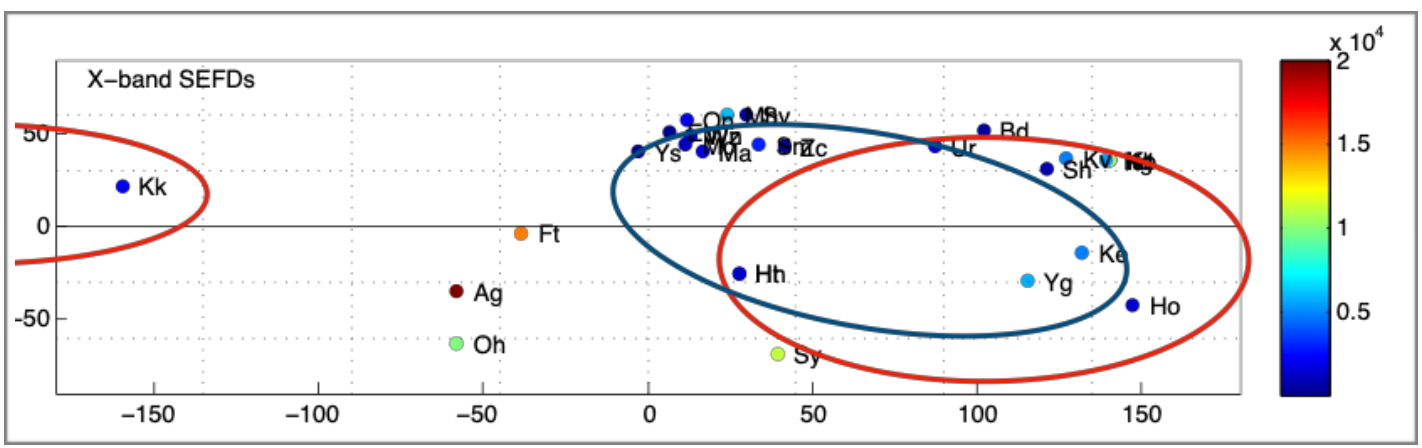
Improving the S/X CRF

Progress to date:

- **1 Gbps observing mode tested for IVS-CRF**
  - All six (6) CRF 2019 sessions will be observed at 1 Gbps
  - Networks were optimised to increase mutual visibility
  - We have 5-7 stations per network
  - All stations to observe in wide-band (Noto transitioning from narrow to wide-band)
  - 1 Gbps still to be tested for Yebes40m



Hh Ke Ma Yg Zc ~~Nt~~
Hh Ma Nt Ys Zc
Hh Ma Nt Yg Ys Zc
Hh Ho Is Kb Kg Kk Ur
Hh Ho Is Kg Kk Km Ur



Improving the S/X CRF

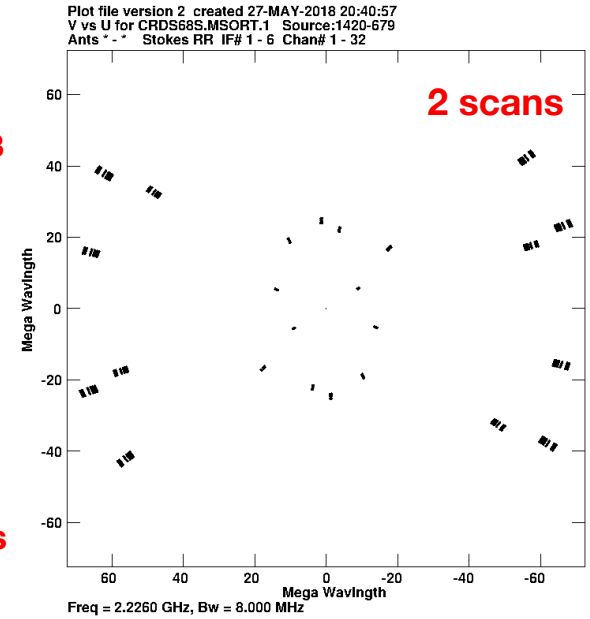
Scheduling optimised for astrometry & imaging instead of geodesy:

- 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).

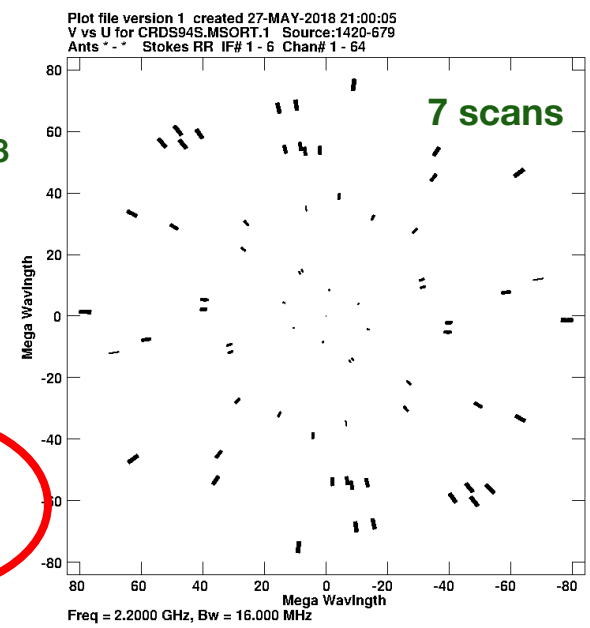
crds68
27 Nov 2013



Total:
144 scans
38 sources

Hh
Ho
Hb
Yg
Ke
~~**Ww**~~

crds94
21 Mar 2018



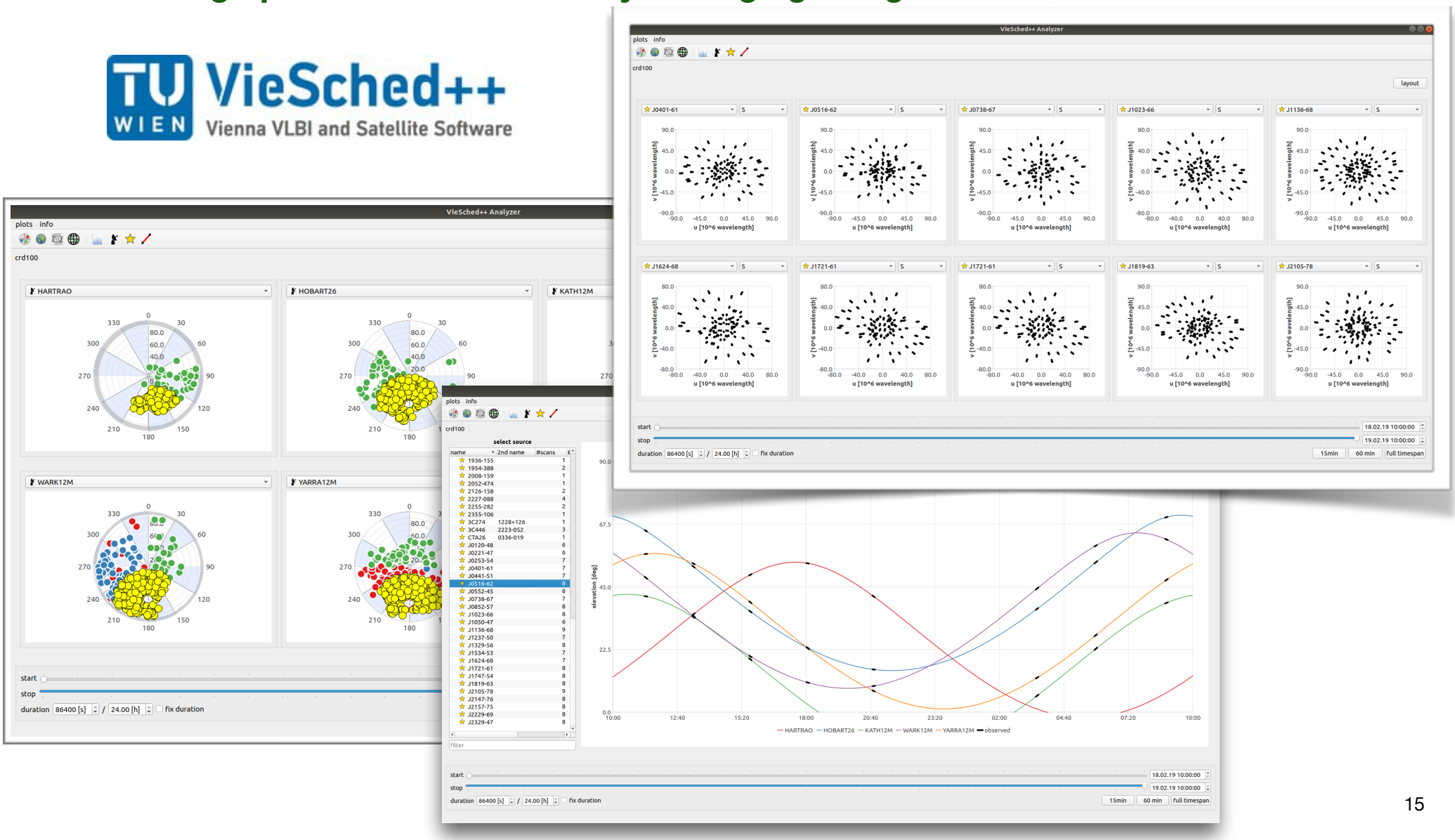
Total:
304 scans
51 sources

Hh
Ht
~~**He**~~
Yg
Ke
Ww

Improving the S/X CRF

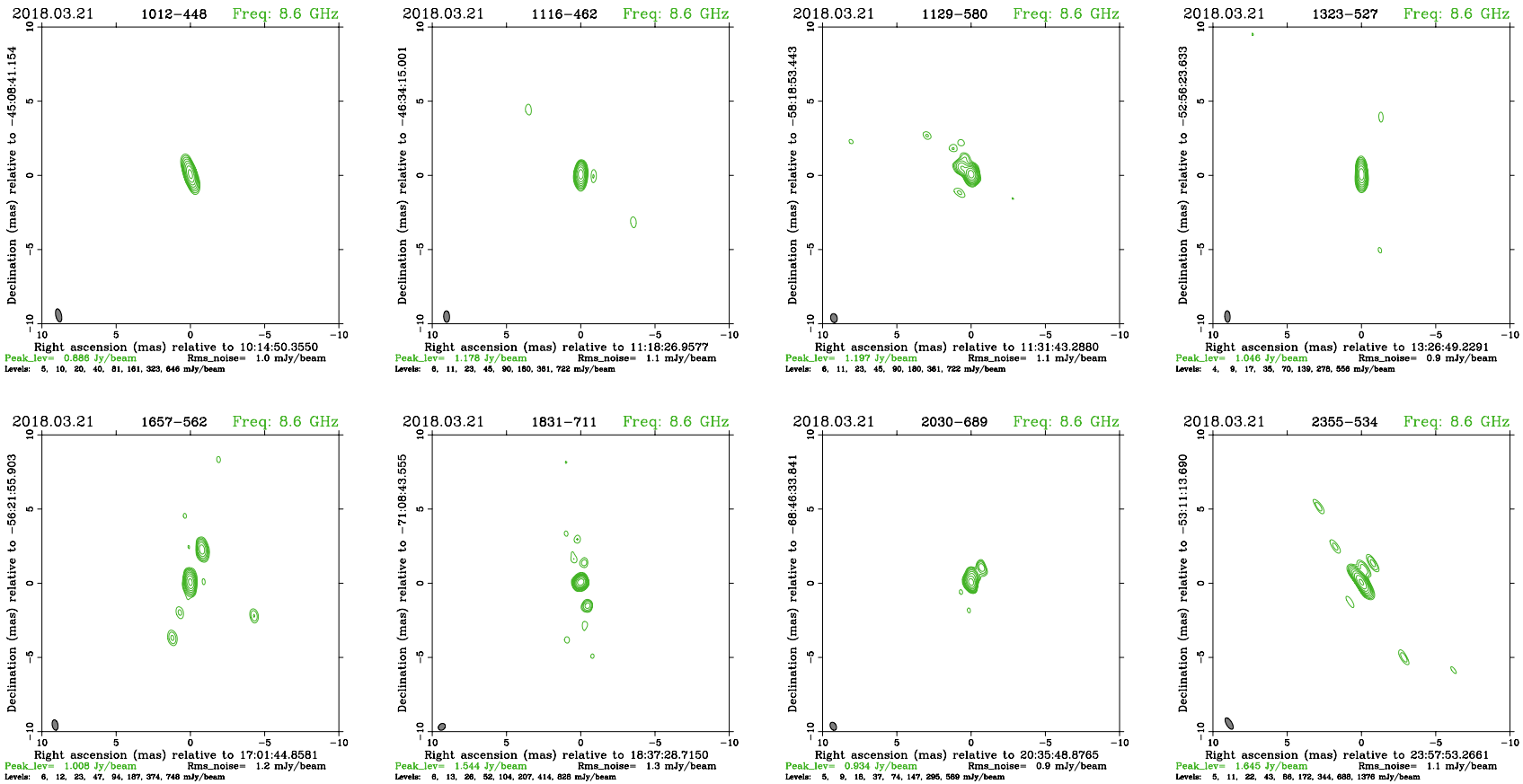
Scheduling optimised for astrometry & imaging using VieSched++:

TU WIEN VieSched++
Vienna VLBI and Satellite Software



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**

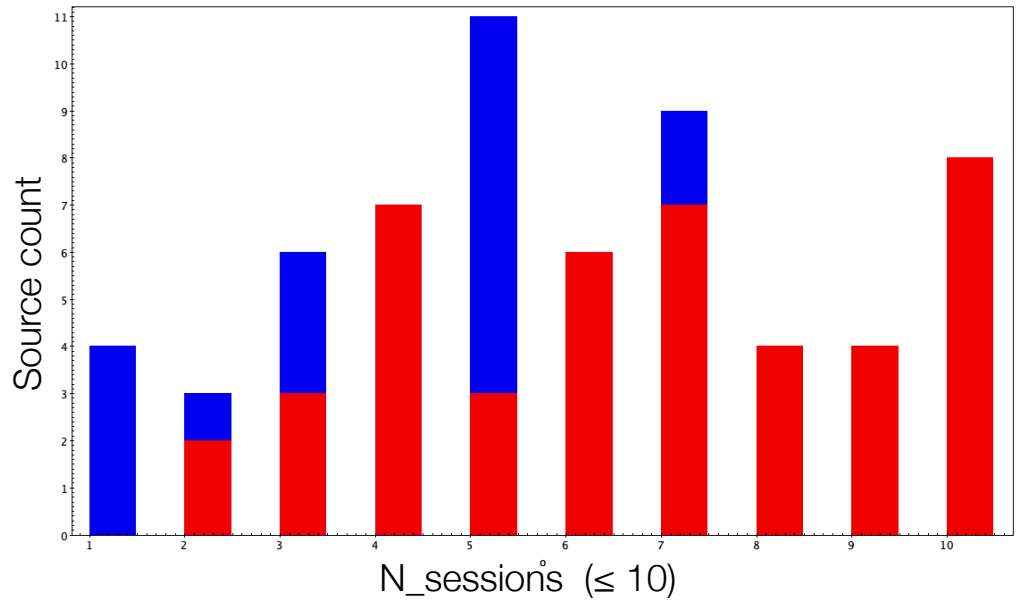
→ Re-observe ALL southern sources in current S/X CRF.

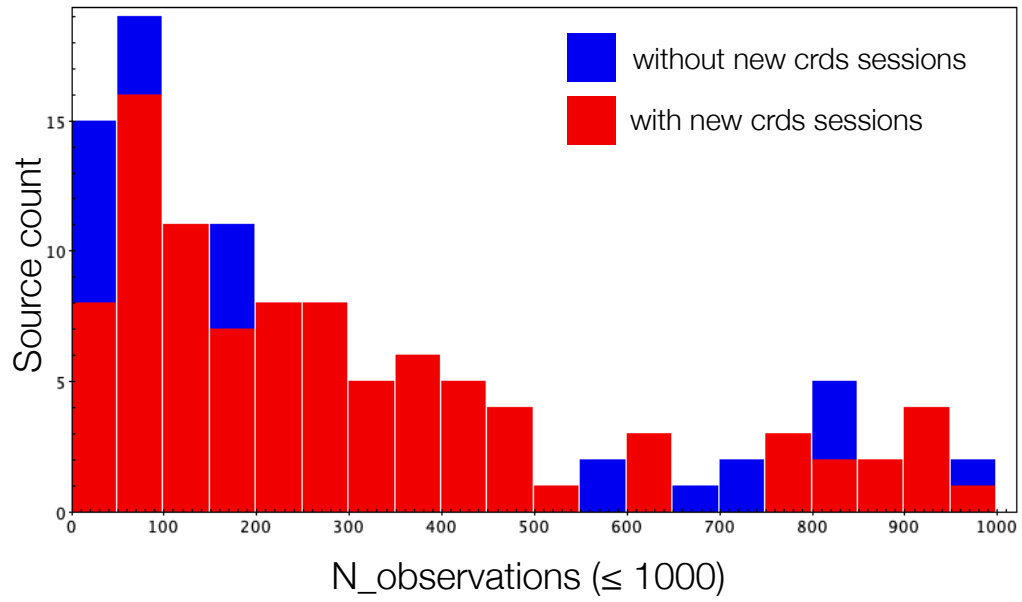
→ Improve source position accuracy in both coordinates.

→ From 1344 sources < -15°S we have 1091 sources with Nses < 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 ~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°S.
- Improve spatial coverage in the south, specifically <-30°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°S.
  - From these we have ~20 sources with flux density > 350 mJy at S/X-band.

- **1 Gbps IVS-AUA (SOAP) sessions at 1/month from Aug 2017**
  - Follow-up to LBA Calibrator Survey (LCS, Petrov et al., 2011, 2019).
  - Fifteen 24-hour experiments - **pool of candidate CRF sources!**
- **1 Gbps IVS-AOV sessions**
  - weak sources in mid southern hemisphere and ecliptic plane.
  - 30 observations in the past 4 years (Poster 210, Fengchun Shu).

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, others) to 1 and then 2 Gbps.
  - Optimise the scheduling of these sessions for astrometry & imaging vs. geodesy.
  - Increase the number of well observed sources (Nses > 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 in precision for 3 sources
  - Revision of CRF network for improved uv-coverage - to start April 2019.

Thank You

Contact Details

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Image credit: Ani Vermeulen, NASSP student 2014