# Presentation of a new VLBI scheduling software VieSched++

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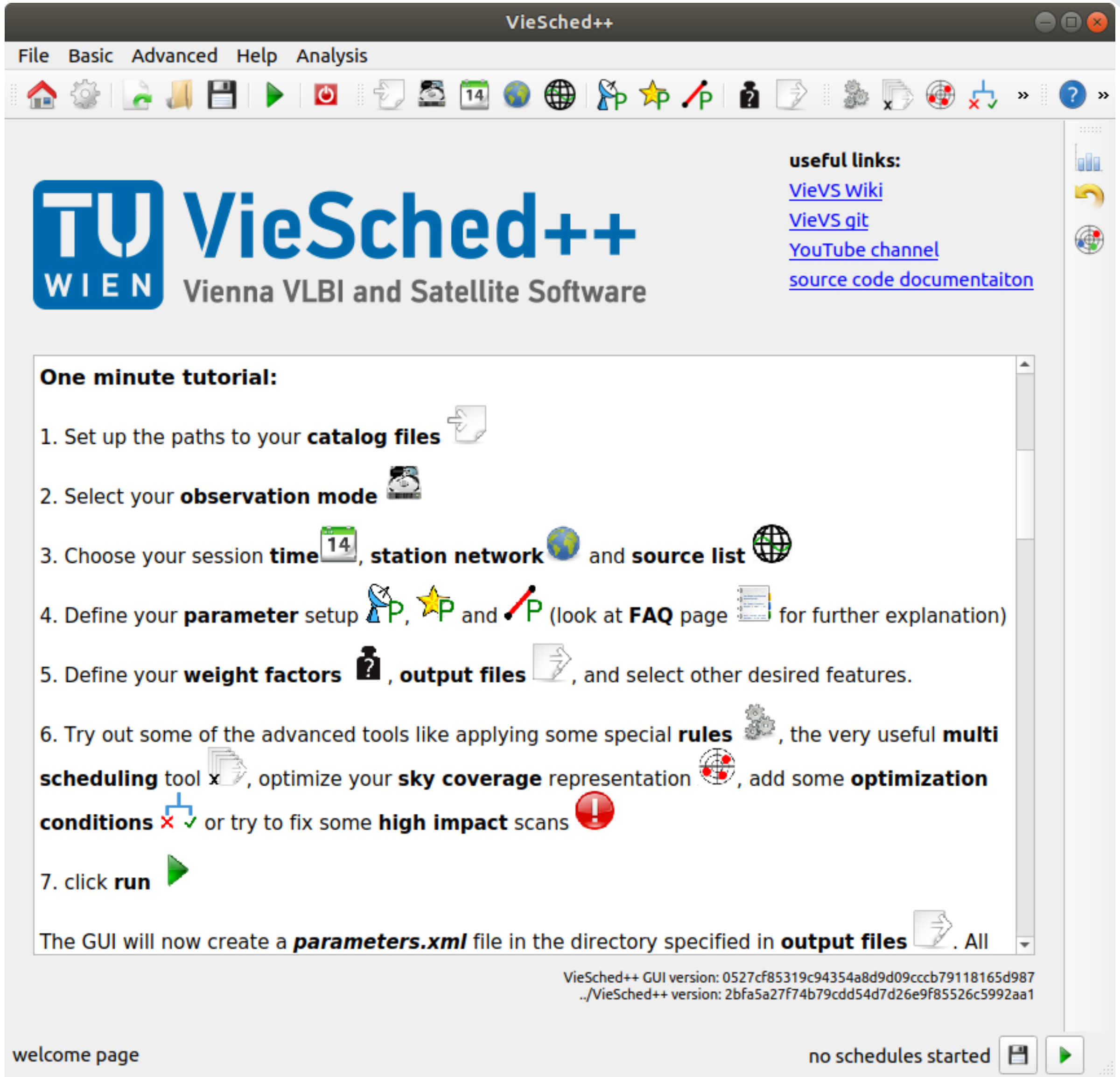
# Why?

VLBI scheduling:

- SKED (Geodesy)
- SCHED... (Astronomy)

## VieSched++

- written in C++
- main focus was geodetic VLBI
- GUI + YouTube tutorials
  [https://www.youtube.com/channel/UCl2VPe7OrnznNtrh0_lwrqQ](https://www.youtube.com/channel/UCl2VPe7OrnznNtrh0_lwrqQ)



**One minute tutorial:**

1. Set up the paths to your **catalog files**

2. Select your **observation mode**

3. Choose your session **time**, **station network** and **source list**

4. Define your **parameter** setup P, P and P (look at **FAQ** page for further explanation)

5. Define your **weight factors**, **output files**, and select other desired features.

6. Try out some of the advanced tools like applying some special **rules**, the very useful **multi scheduling** tool, optimize your **sky coverage** representation, add some **optimization conditions** or try to fix some **high impact** scans

7. click **run**

The GUI will now create a ***parameters.xml*** file in the directory specified in **output files**. All

VieSched++ GUI version: 0527cf85319c94354a8d9d09cccb79118165d987
../VieSched++ version: 2bfa5a27f74b79cdd54d7d26e9f85526c5992aa1

welcome page

no schedules started

# Geodetic VLBI scheduling (I)

- 24-hour sessions with fixed station network
- list of suitable sources (typically 300 for geodesy)
- we typically observe 60-110 sources during the 24-hour session
- every station has different observing time $T$ (per baseline and band)

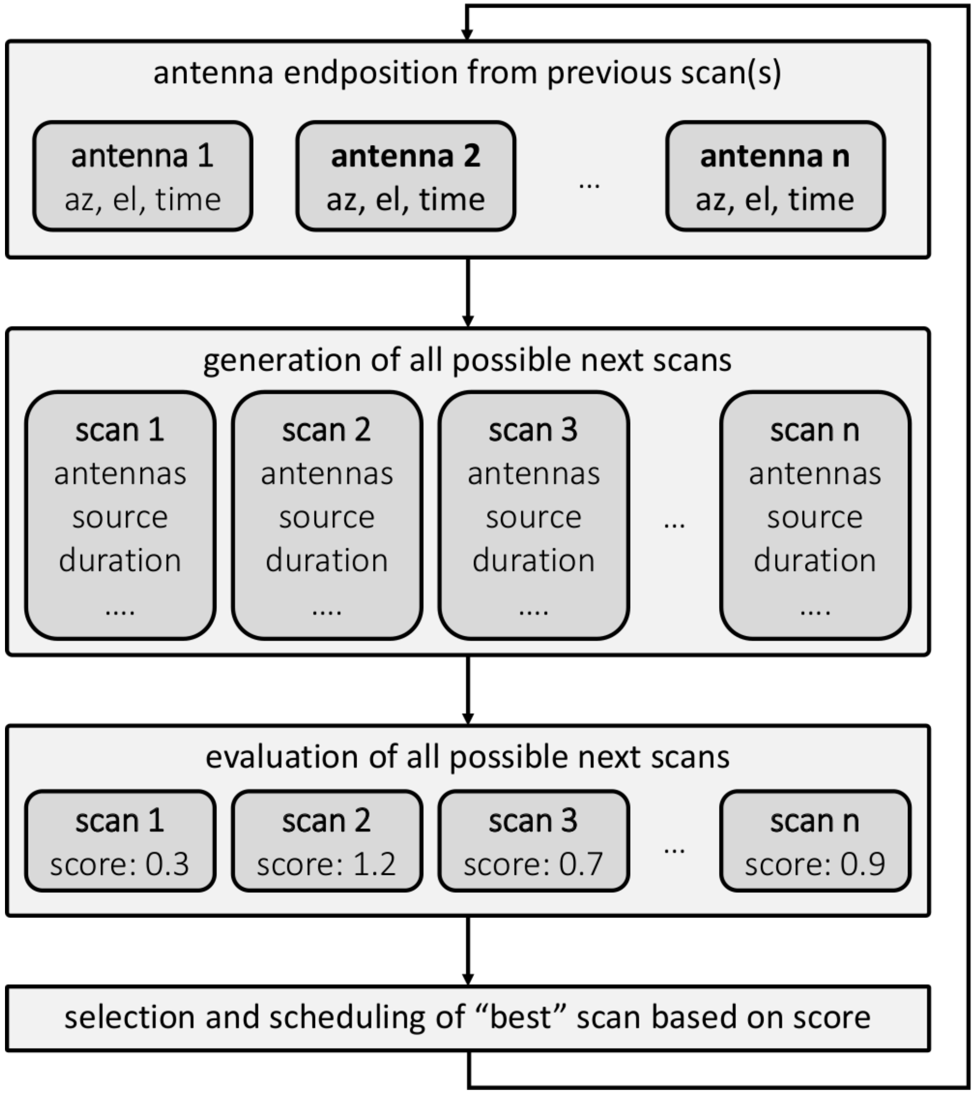
$$\mathrm{T}_{1,2,\mathrm{Band}} = \left(\frac{SNR_{Band}}{\eta F_{Band}}\right)^2 \cdot \left(\frac{SEFD_{1,Band} \cdot SEFD_{2,Band}}{rec_{Band}}\right)$$

$$\begin{aligned}
&SNR && = \mathit{target\ signal\ to\ noise\ ratio} \\
&\eta && = \mathit{efficiency\ factor} \\
&F && = \mathit{source\ flux\ density} \\
&SEFD && = \mathit{station\ sensitivity} \\
&rec && = \mathit{recording\ rate}
\end{aligned}$$

# Geodetic VLBI scheduling (II)

- schedule generated scan after scan
- testing all possibilities
- calculate scores per scan based on optimization criteria $score_i$
  - number of observations
  - sky-coverage
  - scan duration…
- selection of “best” scan based on weighted sum of these scores
  → **“weight factors” $\boldsymbol{\omega_i}$**

$$score = \sum_i \omega_i \cdot score_i$$



antenna endposition from previous scan(s)

**antenna 1** az, el, time | **antenna 2** az, el, time | … | **antenna n** az, el, time

generation of all possible next scans

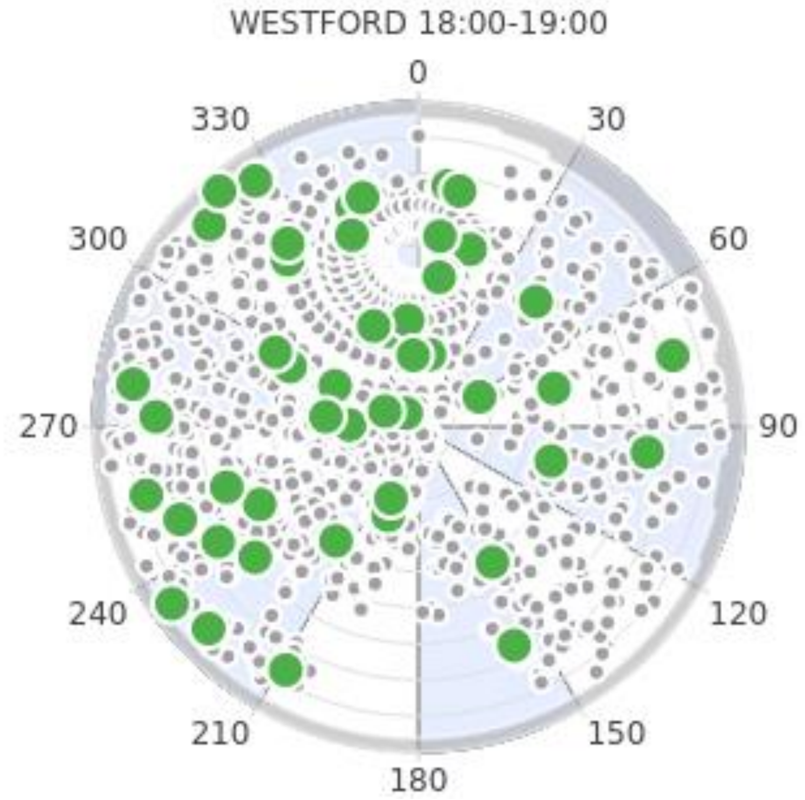
scan 1 antennas source duration …. | scan 2 antennas source duration …. | scan 3 antennas source duration …. | … | scan n antennas source duration ….

evaluation of all possible next scans

scan 1 score: 0.3 | scan 2 score: 1.2 | scan 3 score: 0.7 | … | scan n score: 0.9

selection and scheduling of “best” scan based on score

# Challenges



- Multiple optimization criteria compete against each other
  - sky-coverage and #observations
- Best combination of optimization criteria varies based on network, sources, scientific goal...
- We have not found our “dream” optimization criterion
- We cannot determine if the schedule is good based on the schedule
  - simulations

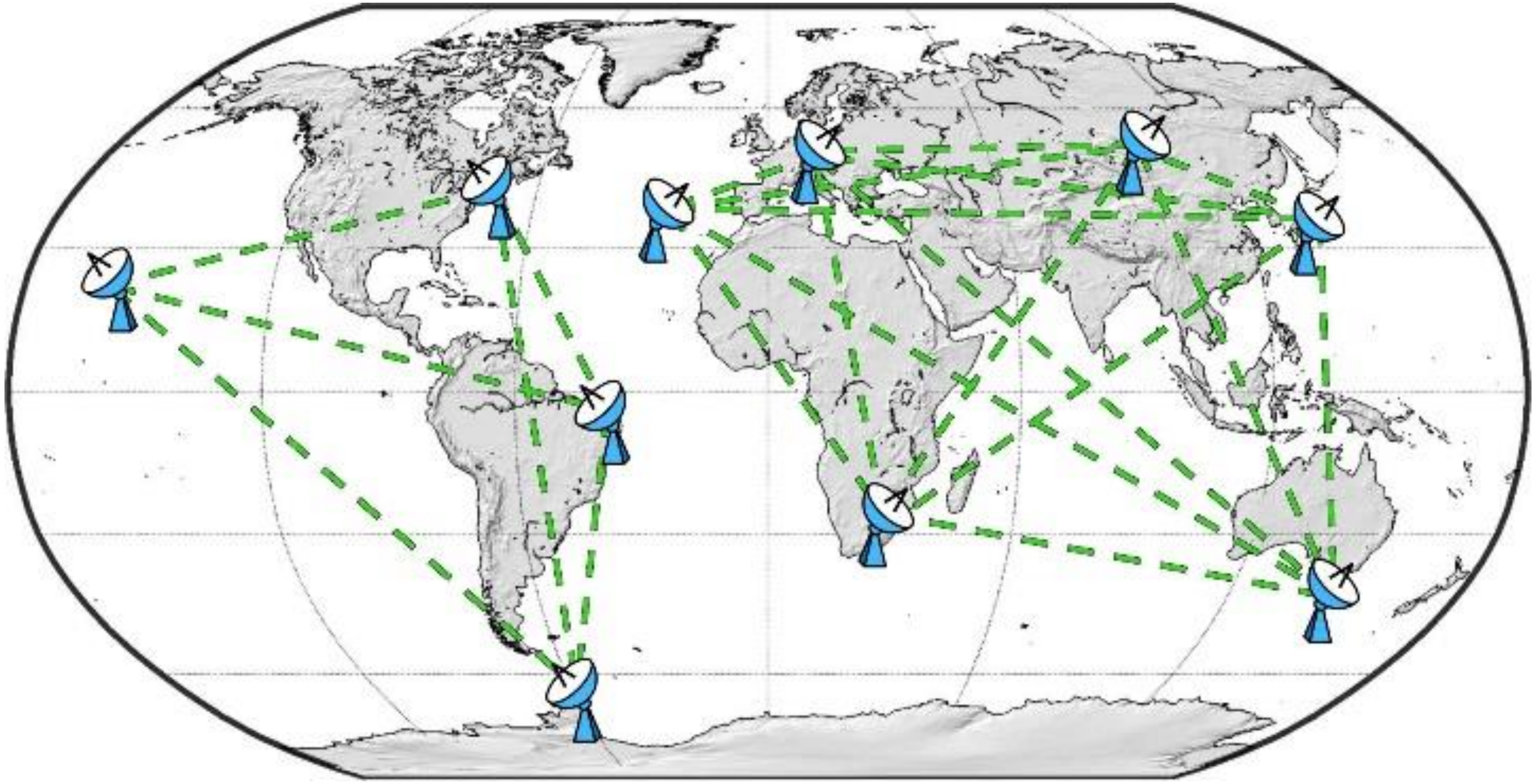
# Subnetting

- global network

→ source visibility

→ split network

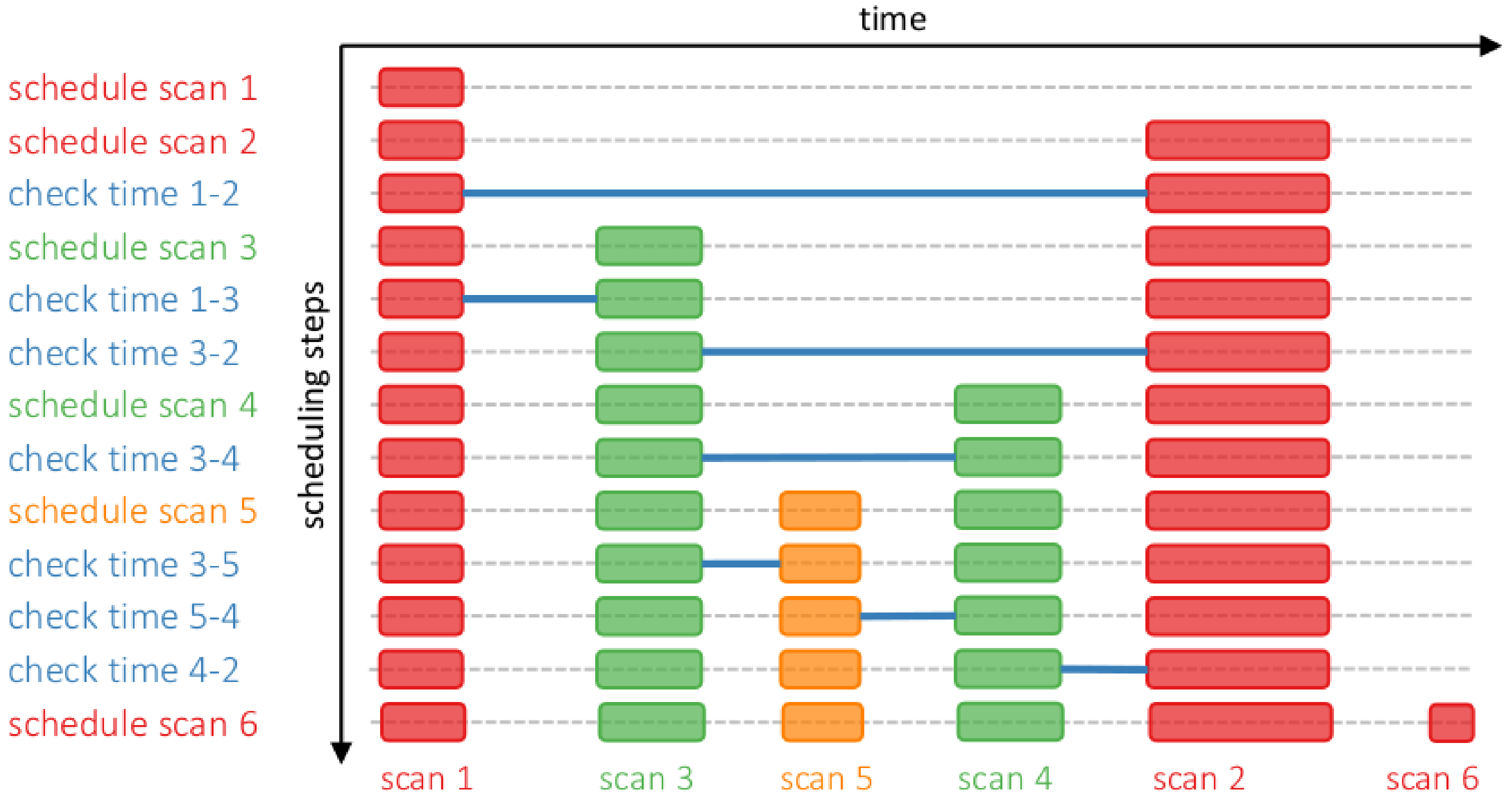
- observe
  multiple sources
  simultaniously



# Recursive scan selection

- recursively generate schedule
- minimizes idle time

- possible to start by fixing the most important scans and build schedule around



# Sequence of observed sources is important!

- not generating only one schedule
- instead generating hundreds of schedules per session
- simulating each schedule (1000 times)
- analyze every simulation
- decide based on simulation result which schedule is best

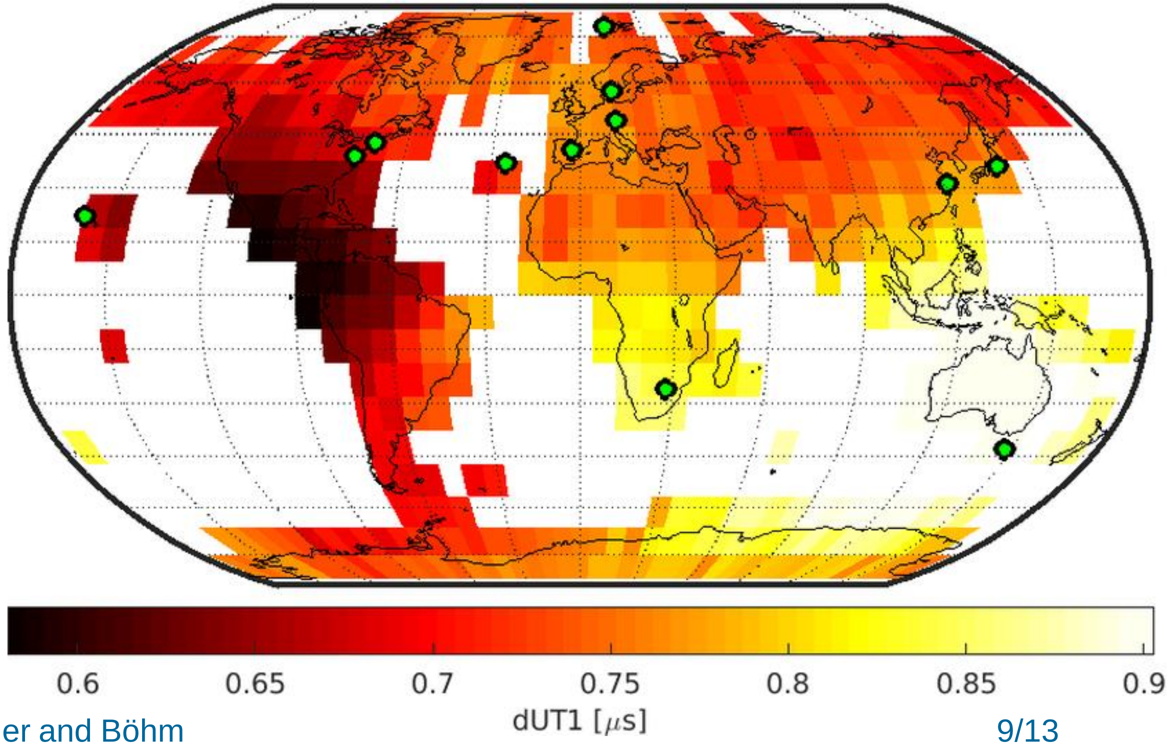
# Some numbers

24-hour experiment:

- scheduling
  - testing 100.000.000 scans
  - with 1.000.000.000 observations
- simulations and analysis
  - simulating 100.000.000 scans
  - with 1.000.000.000 observations

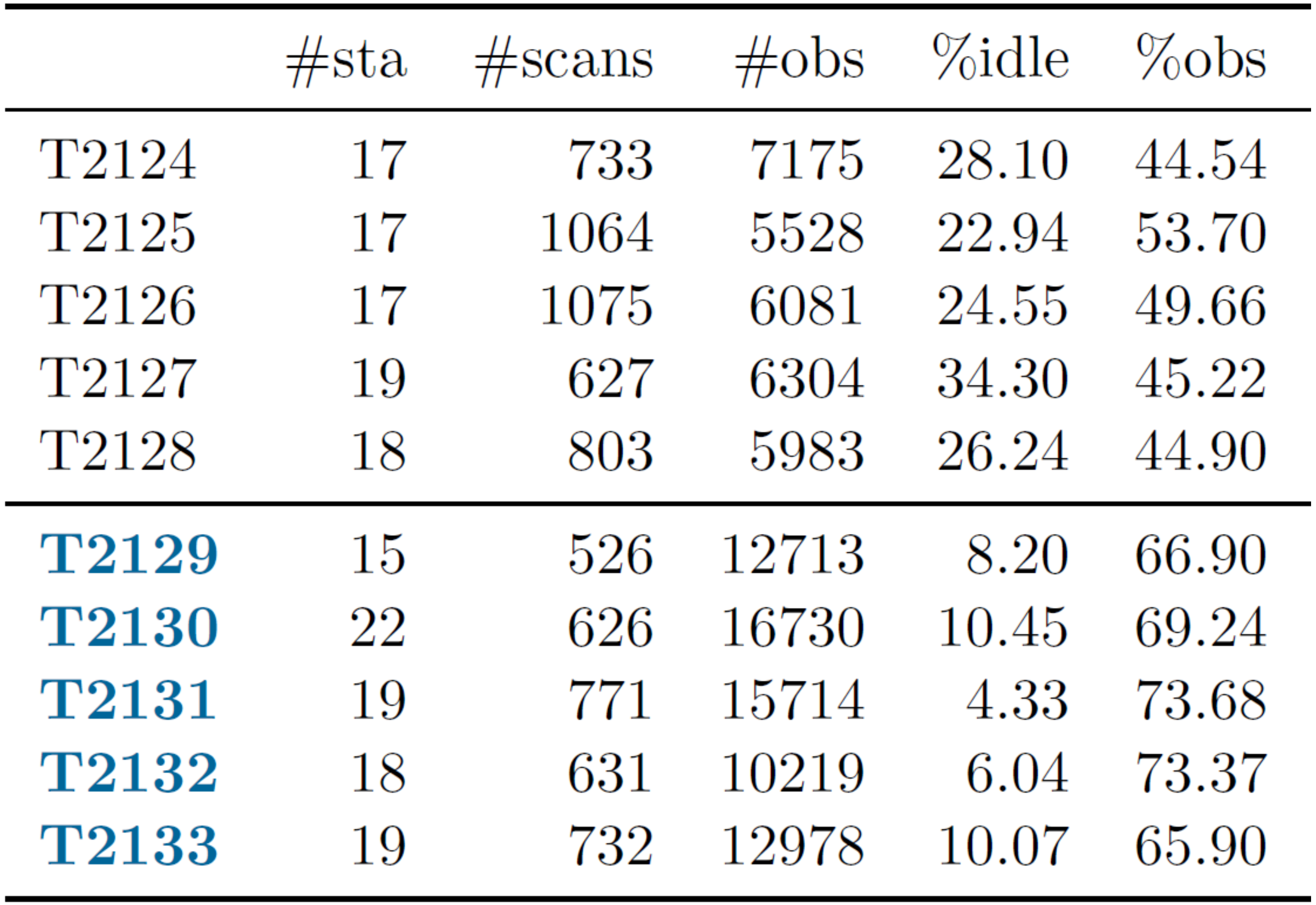
## Monte-Carlo simulations

- testing $2.2e12$ observations during scheduling
- simulating $5.0e12$ observations for analysis



# Results (I)

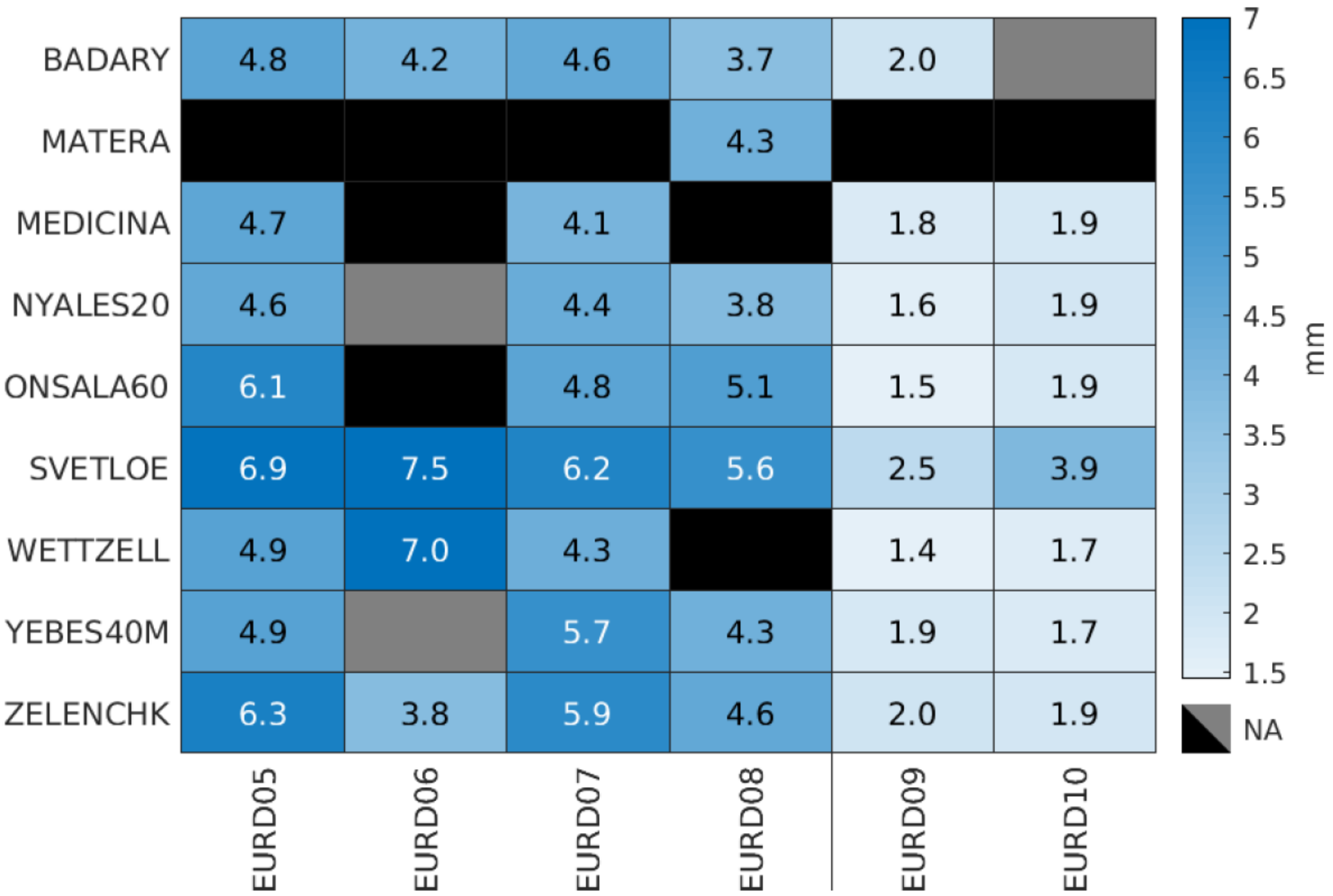
- T2 observing program
- blue: Scheduled with **VieSched++**
- 2-3 times more observations
- 3 times less idle time
- more observing time



| | #sta | #scans | #obs | %idle | %obs |
|---|---|---|---|---|---|
| T2124 | 17 | 733 | 7175 | 28.10 | 44.54 |
| T2125 | 17 | 1064 | 5528 | 22.94 | 53.70 |
| T2126 | 17 | 1075 | 6081 | 24.55 | 49.66 |
| T2127 | 19 | 627 | 6304 | 34.30 | 45.22 |
| T2128 | 18 | 803 | 5983 | 26.24 | 44.90 |
| **T2129** | 15 | 526 | 12713 | 8.20 | 66.90 |
| **T2130** | 22 | 626 | 16730 | 10.45 | 69.24 |
| **T2131** | 19 | 771 | 15714 | 4.33 | 73.68 |
| **T2132** | 18 | 631 | 10219 | 6.04 | 73.37 |
| **T2133** | 19 | 732 | 12978 | 10.07 | 65.90 |

# Results (II)

- EURD observing program
- goal: station coordinates
  - lower numbers are better
- **VieSched++** was used for EURD09 and EURD10
- improvement is almost factor of 3



|  | EURD05 | EURD06 | EURD07 | EURD08 | EURD09 | EURD10 |
|---|---|---|---|---|---|---|
| BADARY | 4.8 | 4.2 | 4.6 | 3.7 | 2.0 |  |
| MATERA |  |  |  | 4.3 |  |  |
| MEDICINA | 4.7 |  | 4.1 |  | 1.8 | 1.9 |
| NYALES20 | 4.6 |  | 4.4 | 3.8 | 1.6 | 1.9 |
| ONSALA60 | 6.1 |  | 4.8 | 5.1 | 1.5 | 1.9 |
| SVETLOE | 6.9 | 7.5 | 6.2 | 5.6 | 2.5 | 3.9 |
| WETTZELL | 4.9 | 7.0 | 4.3 |  | 1.4 | 1.7 |
| YEBES40M | 4.9 |  | 5.7 | 4.3 | 1.9 | 1.7 |
| ZELENCHK | 6.3 | 3.8 | 5.9 | 4.6 | 2.0 | 1.9 |

# Conclusion

- scheduling is critical step in geodetic (and astrometry) VLBI
- determines the observations which are available during analysis
- often overlooked
- big improvements possible

- available at GitHub
  https://github.com/TUW-VieVS/VieSchedpp

VieSched++
Vienna VLBI and Satellite Software

# Outlook

- optimize scheduling for imaging (done/testing)
- combination of imaging sources and geodetic scans (testing)
- schedule observations to satellites (in development)
- extend VieSched++ for astronomy needs (planned)

- more information about **VieSched++**

Schartner M, Böhm J (2019) VieSched++: A New VLBI Scheduling Software for Geodesy and Astrometry. Publications of the Astronomical Society of the Pacific 131(1002):084,501, DOI 10.1088/1538-3873/ab1820

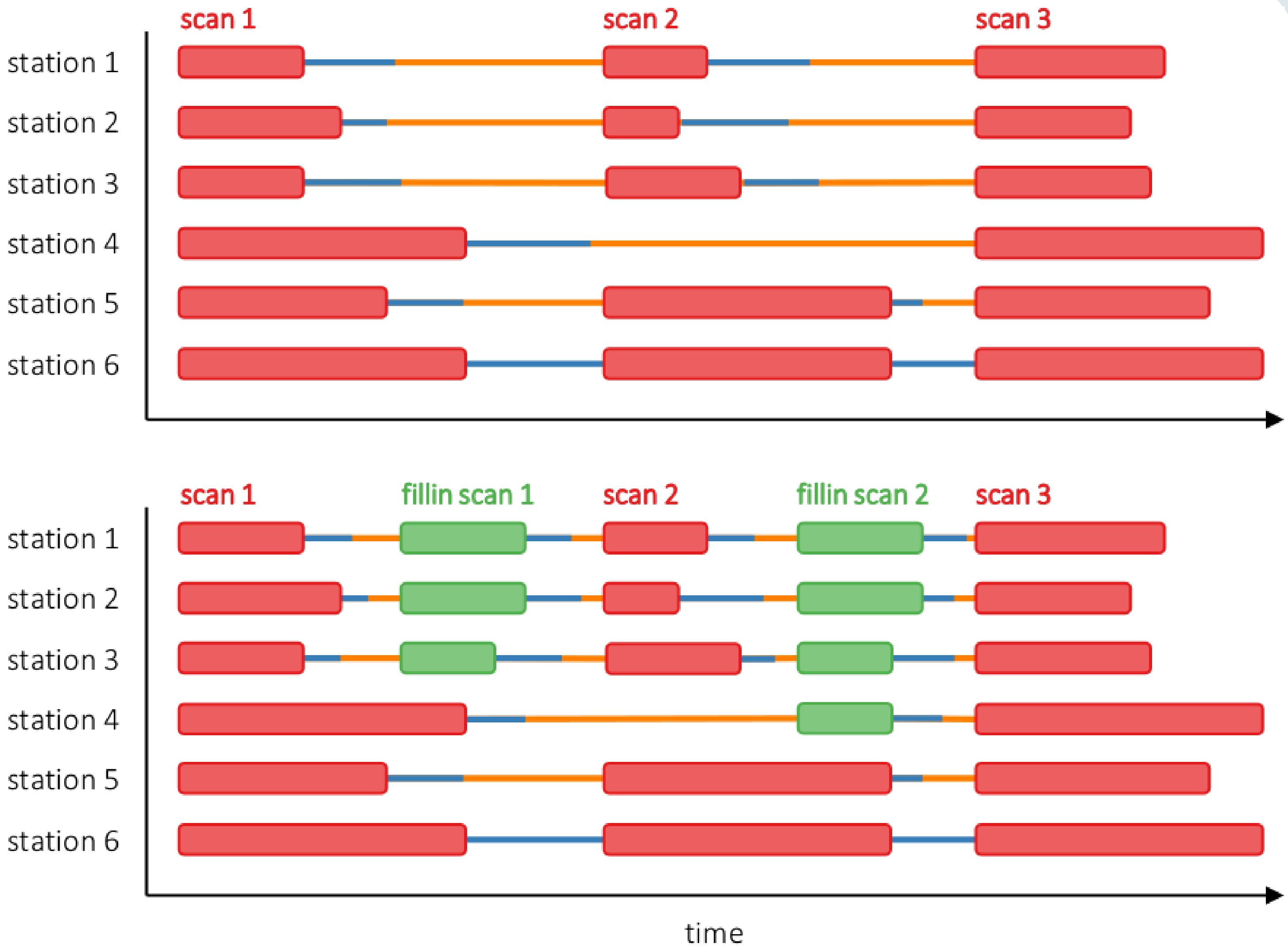
# Fillin-modes

- different observing time per station
- different slew time per station

→ introduces idle time

→ fillin-mode scans

| | |
|---|---|
| *red:* | *“standard” observing time* |
| *green:* | *fillin-mode observing time* |
| *blue:* | *slew time* |
| *orange:* | *idle time* |


scan 1
scan 2
scan 3
station 1
station 2
station 3
station 4
station 5
station 6
scan 1
fillin scan 1
scan 2
fillin scan 2
scan 3
station 1
station 2
station 3
station 4
station 5
station 6
time