7th IVS General Meeting 2012

Prospects of IVS-Intensive Sessions with Twin-Telescopes

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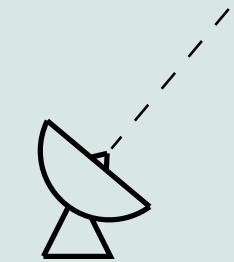
Introduction

INT3



NYALES20

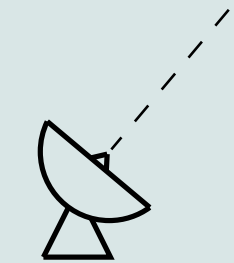
WETTZELL

TSUKUB32

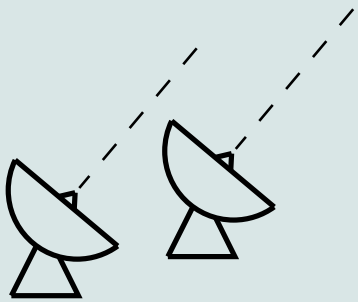
- weekly intensive session
- 3 stations
- estimate dUT1

Introduction

INT3 with Twin-Telescope Wettzell



NYALES20



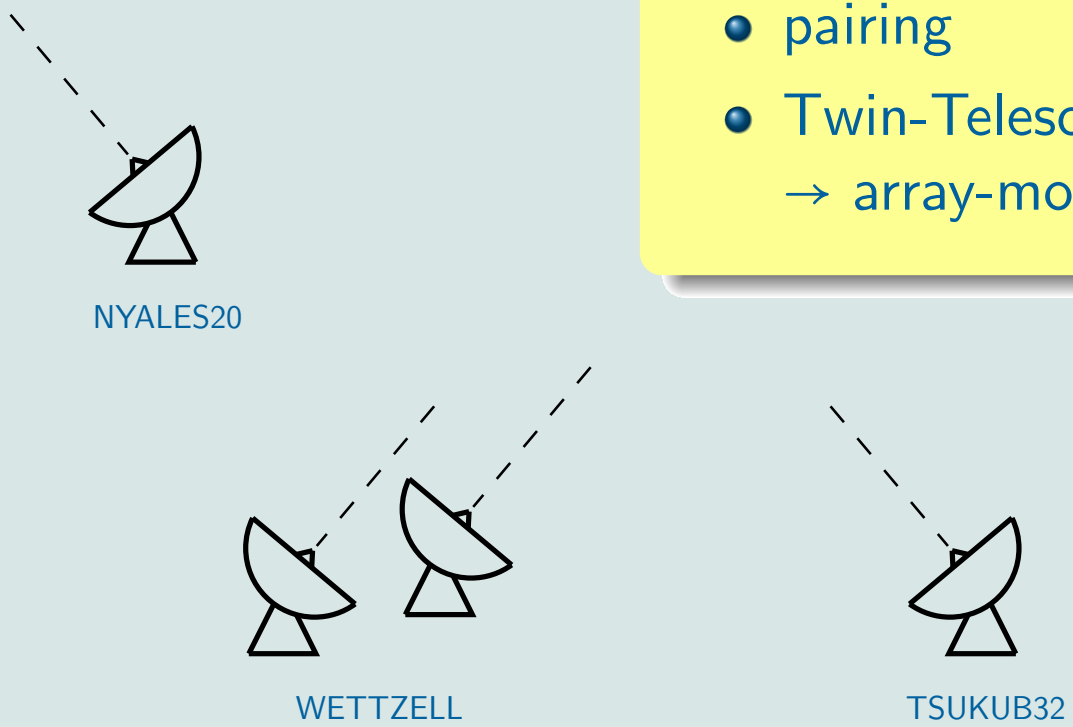
WETTZELL

TSUKUB32

- Twin-Telescope Wettzell
  → 4 stations
- various constellations

Introduction

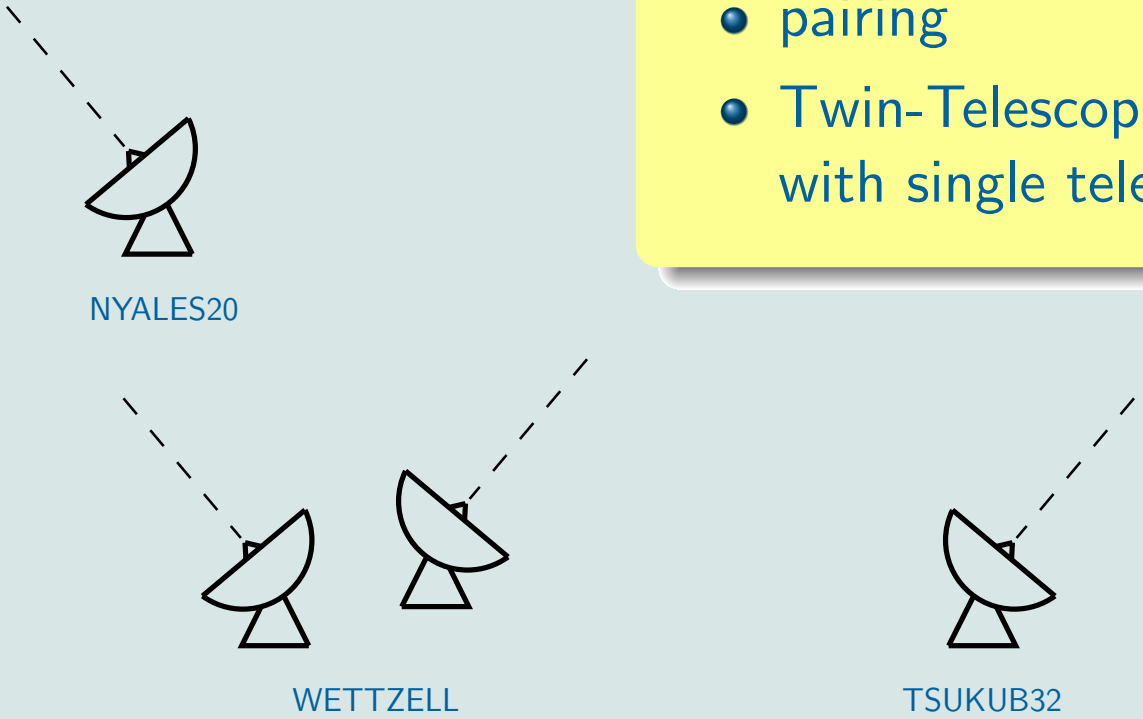
INT3 with Twin-Telescope Wettzell



- pairing
- Twin-Telescope Wettzell
  → array-mode

Introduction

INT3 with Twin-Telescope Wettzell



- pairing
- Twin-Telescopes with single telescopes

Improvement of dUT1?

Scheduling

Scheduling concept based on singular value decomposition

- choosing observations subsequent according to a criterion of singular value decomposition (SVD)
- stepwise optimization of the geometry
- objective criteria

Parametrization

target parameter:

- the phase of the earth rotation dUT1

other parameters:

- clock offset CL_0, clock rate CL_1 and frequency drift CL_2 per station w.r.t. one reference clock
- atmospheric wet zenith path delays AT per station

Jacobian Matrix

$$\mathbf{X} = \begin{pmatrix} \frac{\partial \tau_1}{\partial CL_{0,A}} & \frac{\partial \tau_1}{\partial CL_{1,A}} & \frac{\partial \tau_1}{\partial CL_{2,A}} & \cdots & \frac{\partial \tau_1}{\partial AT_A} & \cdots & \frac{\partial \tau_1}{\partial dUT1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{\partial \tau_m}{\partial CL_{0,A}} & \frac{\partial \tau_m}{\partial CL_{1,A}} & \frac{\partial \tau_m}{\partial CL_{2,A}} & \cdots & \frac{\partial \tau_m}{\partial AT_A} & \cdots & \frac{\partial \tau_m}{\partial dUT1} \end{pmatrix}$$

Singular Value Decomposition

$$\mathbf{X} = \mathbf{U} \cdot \mathbf{S} \cdot \mathbf{V}^T$$

Singular Values σ_i

- $\mathbf{S} = diag\begin{pmatrix}\sigma_1 & \sigma_2 & \dots & \sigma_r & 0 & \dots & 0\end{pmatrix}$
- $r = rank(\mathbf{X})$

Left Singular Vectors $\mathbf{u}_i$

$$\mathbf{U} = \begin{pmatrix} \vdots & & \vdots & \vdots & & \vdots \\ u_1 & \dots & u_r & u_{r+1} & \dots & u_m \\ \vdots & & \vdots & \vdots & & \vdots \\ \underbrace{\qquad\qquad}_{\mathbf{U}_r} & & & \underbrace{\qquad\qquad}_{\mathbf{U}_0} & & \end{pmatrix}$$

- columns of the $m \times m$ orthogonal matrix $\mathbf{U}$
- $\mathbf{U}_r = \{\mathbf{u}_1, ..., \mathbf{u}_r\}$ span a basis for the column space $R(\mathbf{X})$ (*data space*) of $\mathbf{X}$

Singular Value Decomposition

Data Resolution Matrix / 'Hat Matrix'

$$\mathbf{H} = \mathbf{U}_r \mathbf{U}_r^T$$

- elements indicate how much weight each observation has on the adjusted observations
- main-diagonal elements of $\mathbf{H}$ are called *impact factors* h_i

$$h_i = diag(\mathbf{H})$$

- close relation between impact factors and partial redundancies

$$r_i = 1 - h_i = (\mathbf{I} - \mathbf{H})_{ii}$$

the higher the impact factor, the bigger the effect on the observing geometry

Choice of the observations

wanted: scan with the greatest impact (factors)

problem: subnets

- varying number of observations (depend on the number of observing baselines)
- compare unequal number of impact factors
- the greater the number of impact factors the lower the values of the impact factors

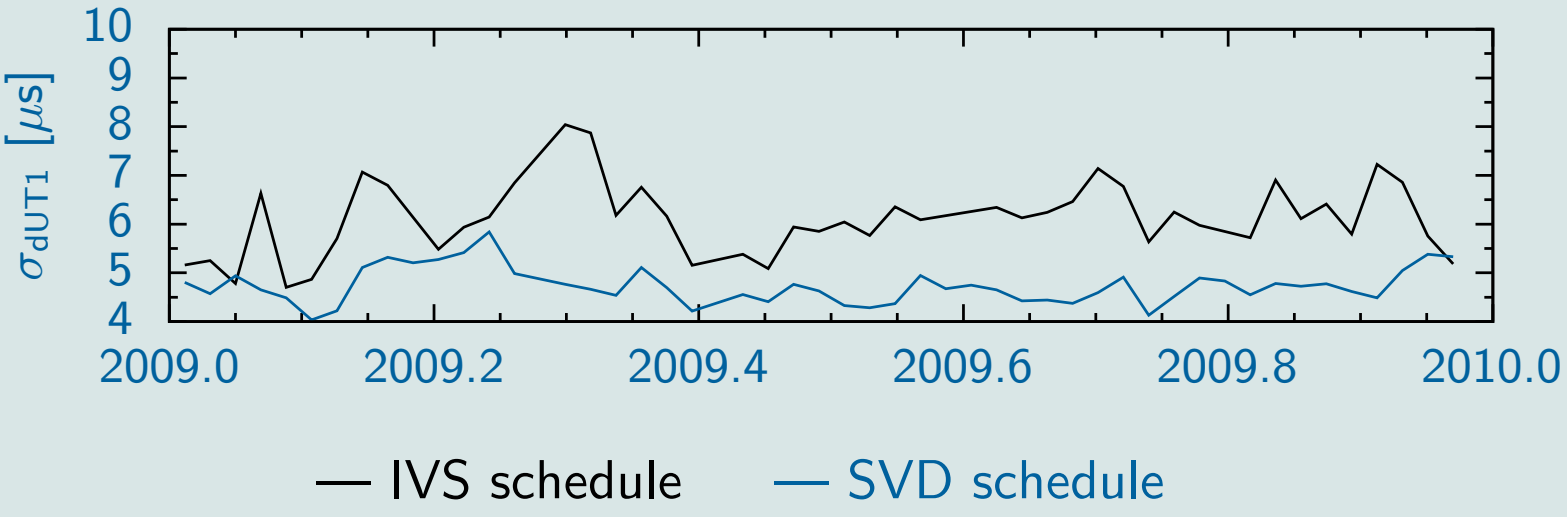
solution: $\frac{1}{n}\sum_{i=1}^{n} IF_i \cdot \sqrt{n}$

n : number of impact factors per scan

(other solutions feasible)

Validation

formal errors (INT3)



- only geometry
- no information of the variance of unit weight

⇒ **simulation of observations**

Simulation of observations

Monte-Carlo Simulator (VieVS)

$$o - c = (zwd_2 \cdot mfw_2(e_2) + clk_2) - (zwd_1 \cdot mfw_1(e_1) + clk_1) + wn$$

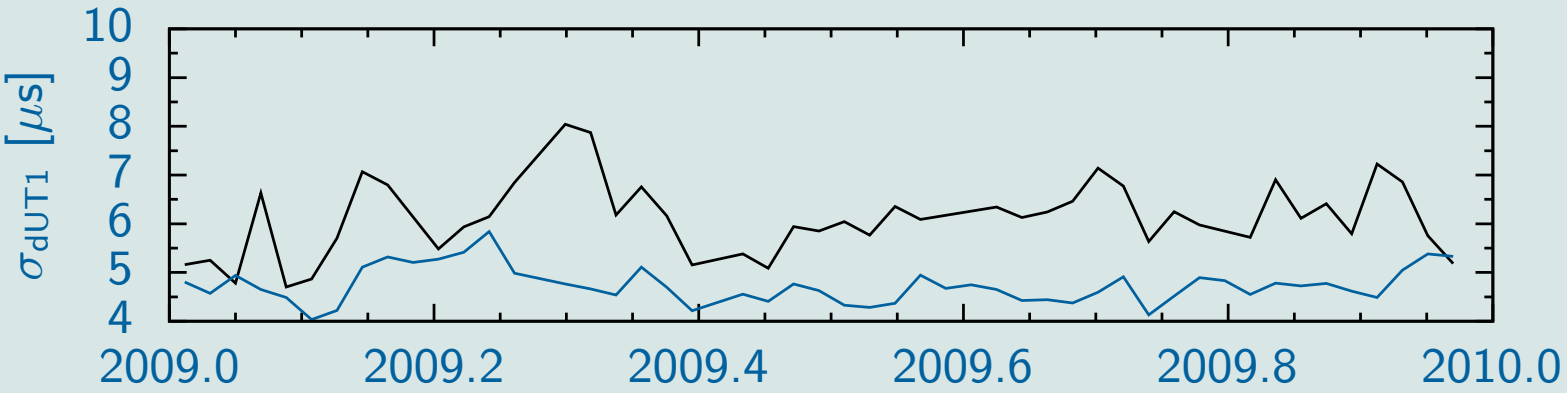
- zenith wet dalay $zwd_{1,2}$
  → *turbulence model*
- station clock $clk_{1,2}$
  → *random-walk and integrated-random-walk*
- baseline dependent white noise wn

$$\boldsymbol{\Delta}\tilde{\mathbf{x}} = \left(\mathbf{X}^T\boldsymbol{\Sigma}_{ll}^{-1}\mathbf{X}\right)^{-1}\mathbf{X}^T\boldsymbol{\Sigma}_{ll}^{-1}\Delta\mathbf{l}, \qquad \mathbf{v} = \mathbf{X}\boldsymbol{\Delta}\tilde{\mathbf{x}} - \Delta\mathbf{l}$$

$$s^2 = \frac{\mathbf{v}^T\boldsymbol{\Sigma}_{ll}^{-1}\mathbf{v}}{f} \cdot \sigma^2 \qquad f\text{: degree of freedom}$$

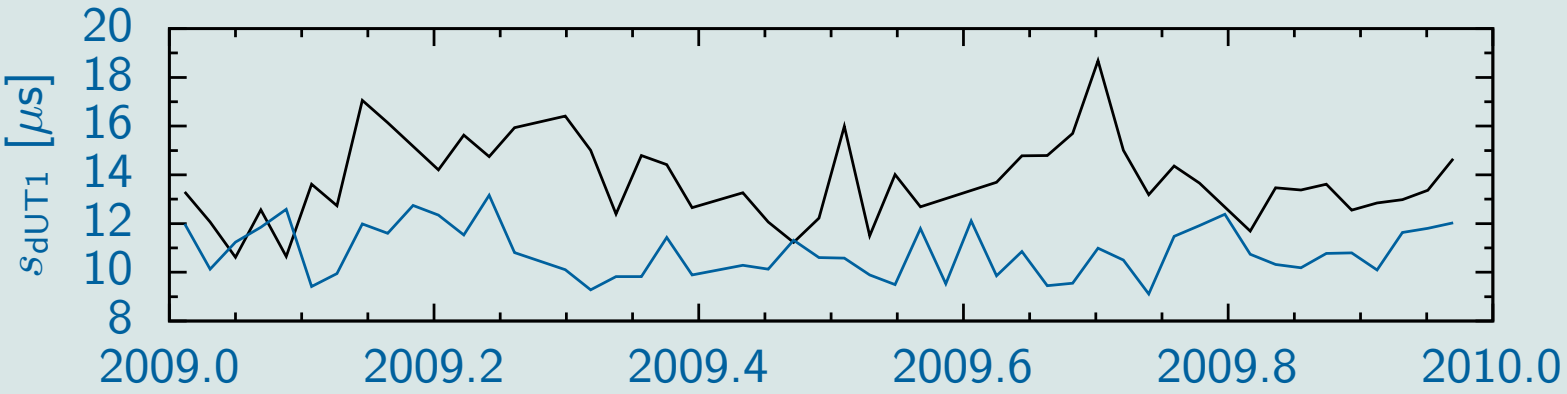
Simulation (INT3)

formal errors



— IVS schedule — SVD schedule

standard deviations



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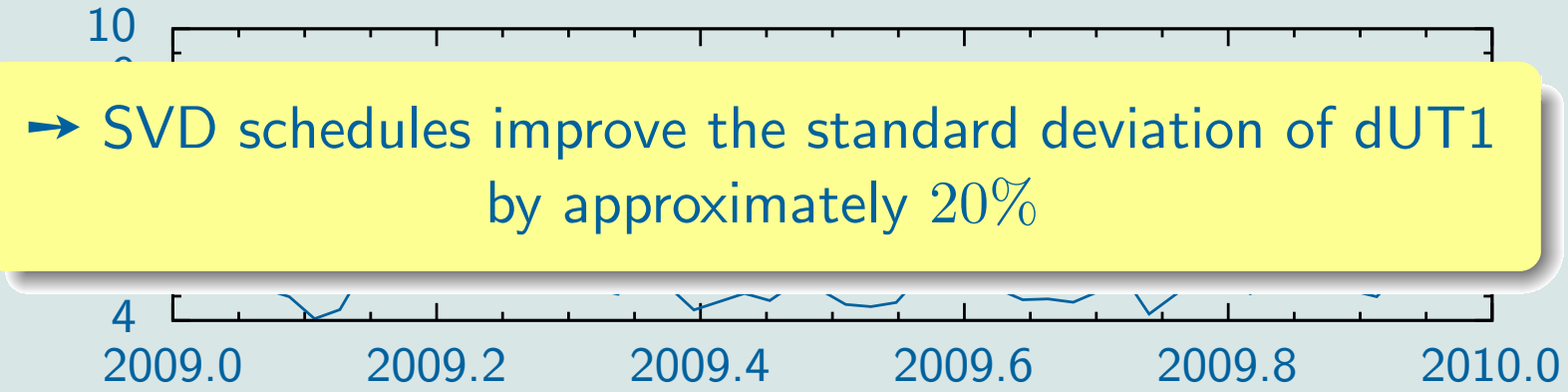
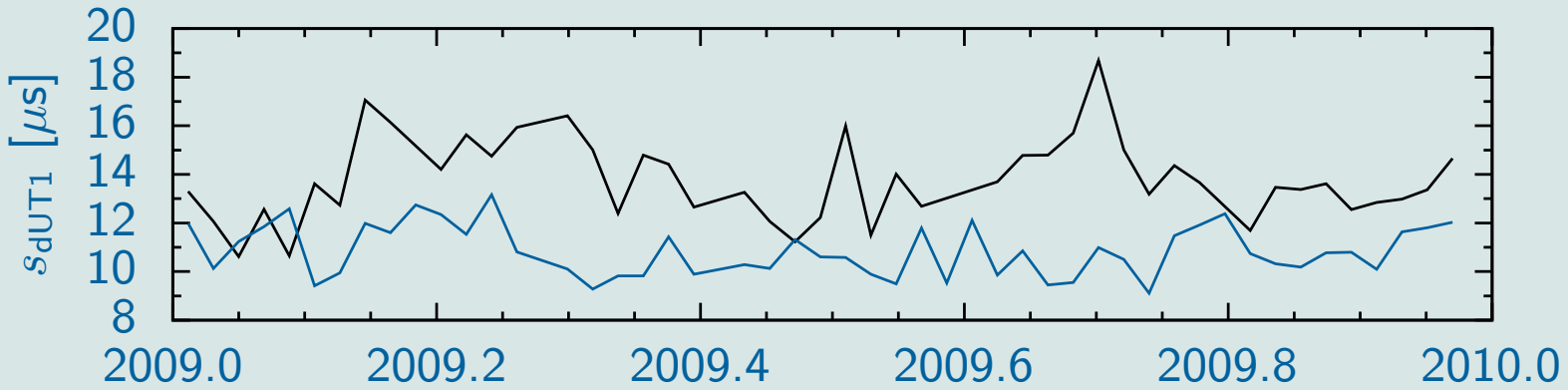


➡ SVD schedules improve the standard deviation of dUT1 by approximately 20%

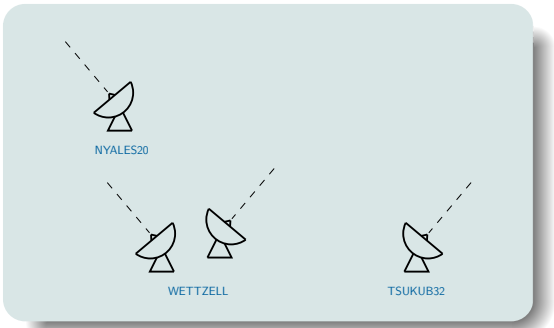
— IVS schedule — SVD schedule

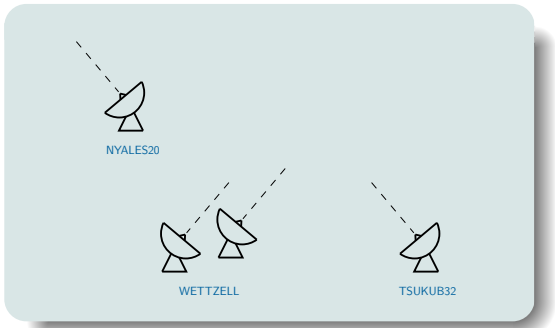
standard deviations

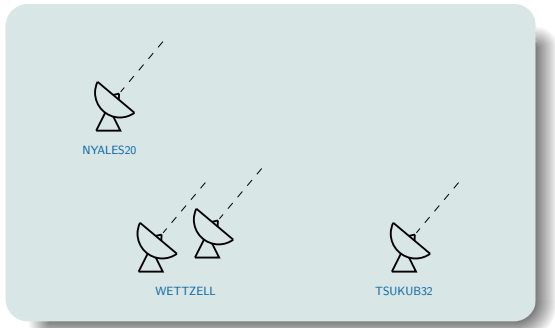


Twin-Telescope Scenarios

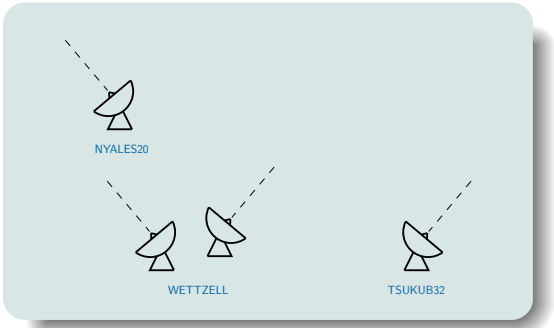
1. allow all possible subnets

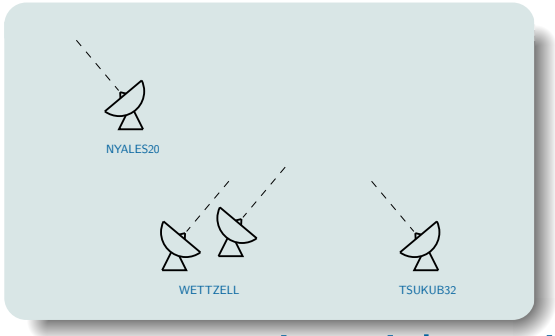




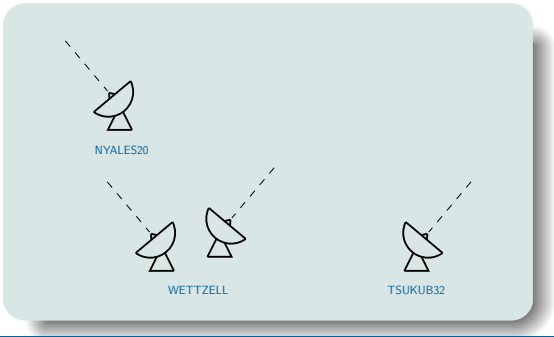


2. force pairing (allow all baseline combinations)





3. force pairing (always one twin with a single telescope)



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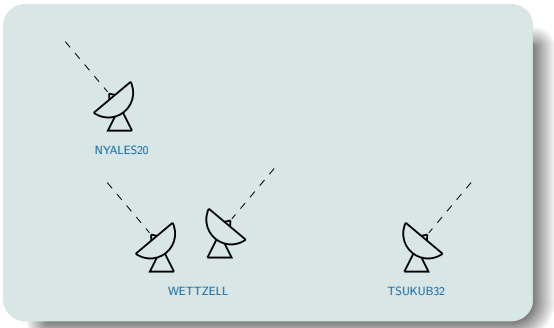

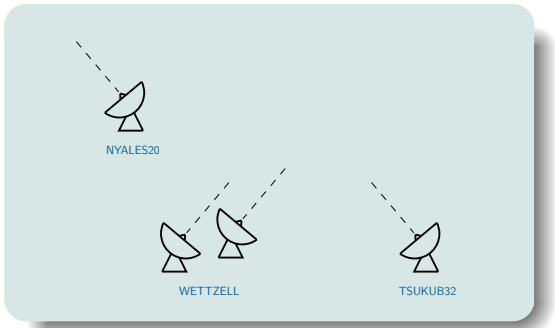

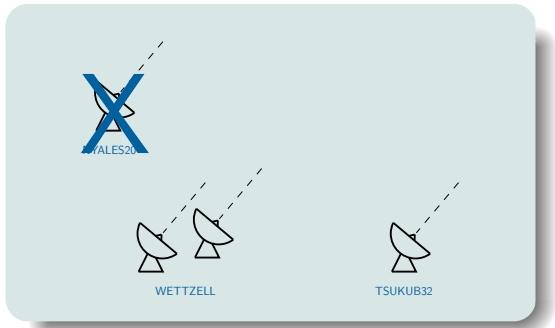

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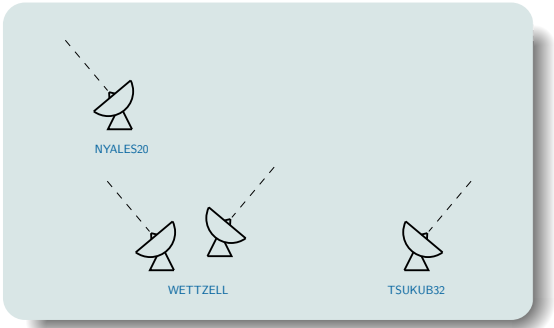

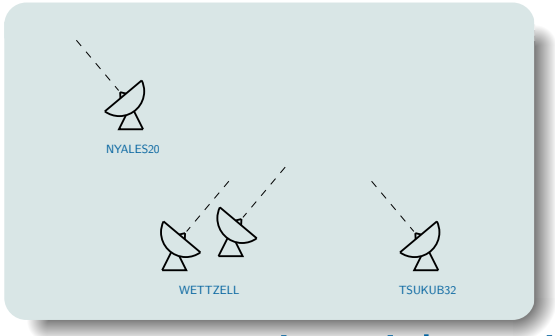

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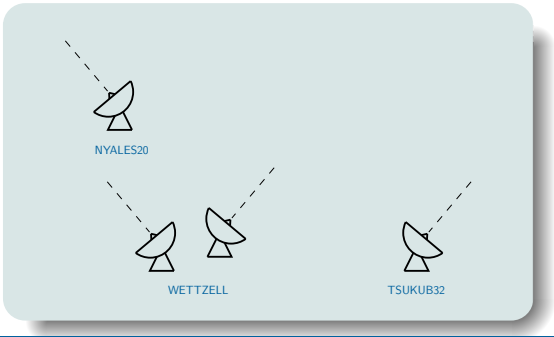
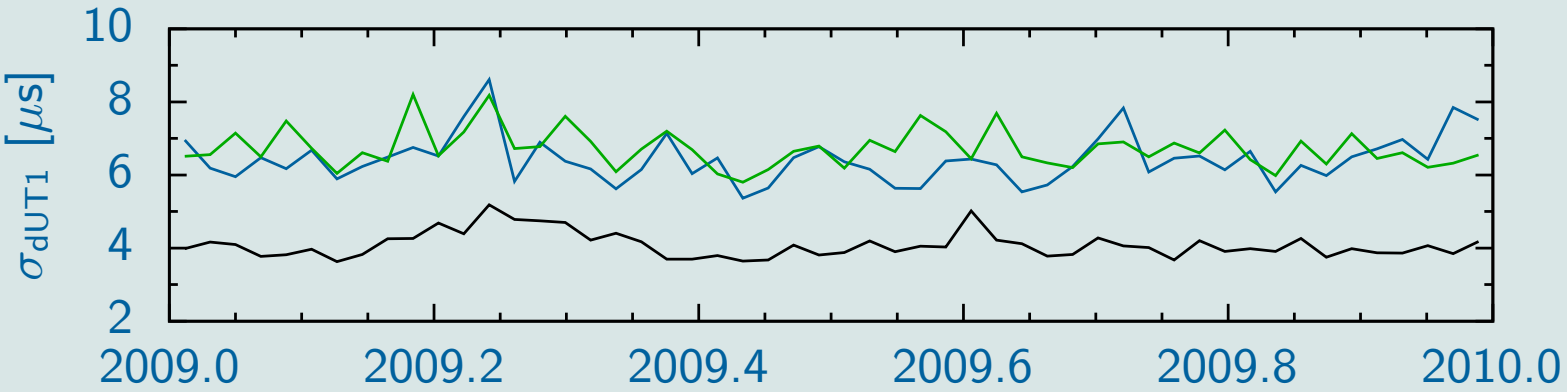


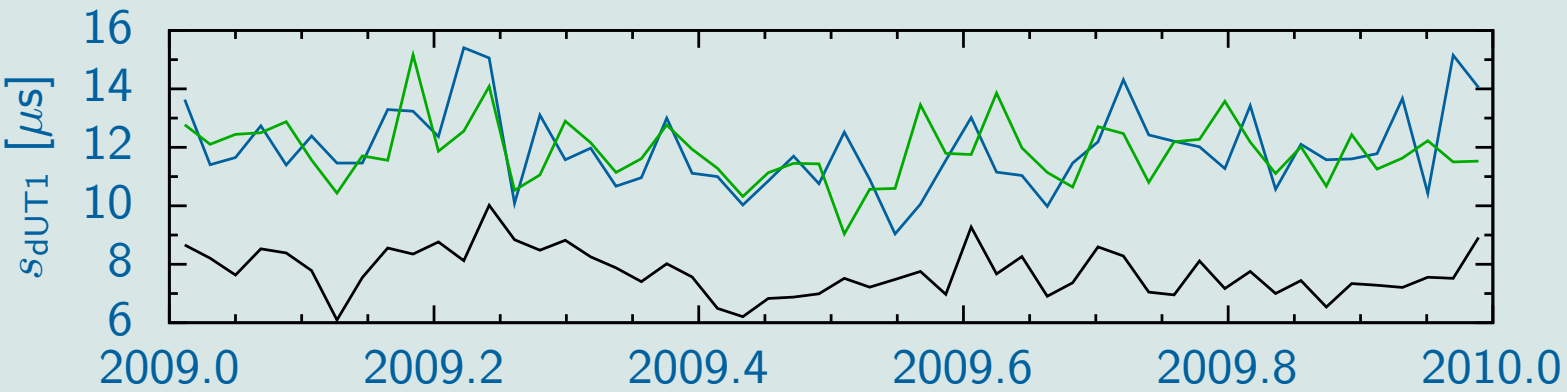
INT3 with Wettzell Twin-Telescopes

formal errors



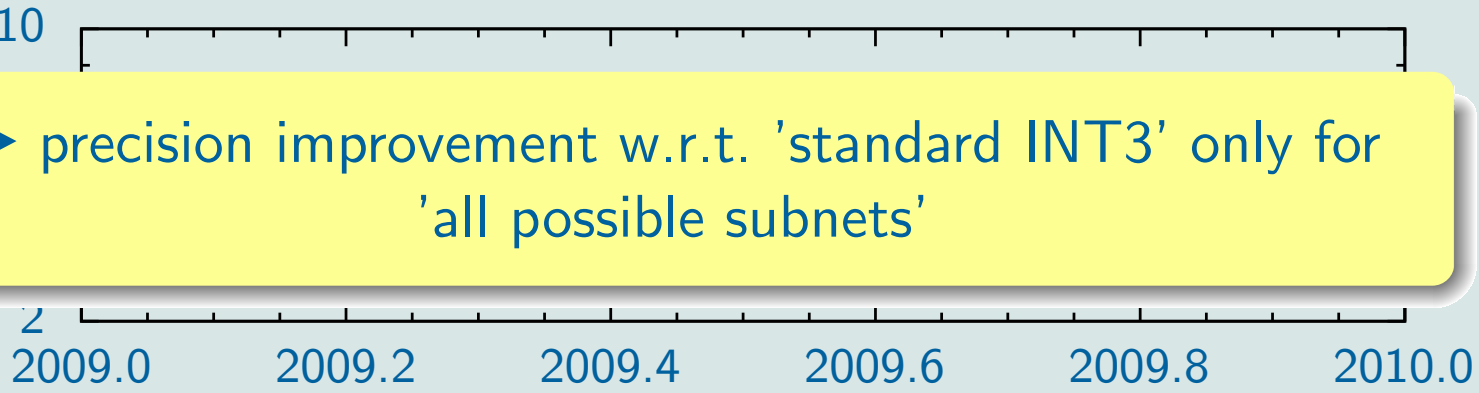
— all possible subnets — pairs 1 (all) — pairs 2 (twins)

standard deviations



INT3 with Wettzell Twin-Telescopes

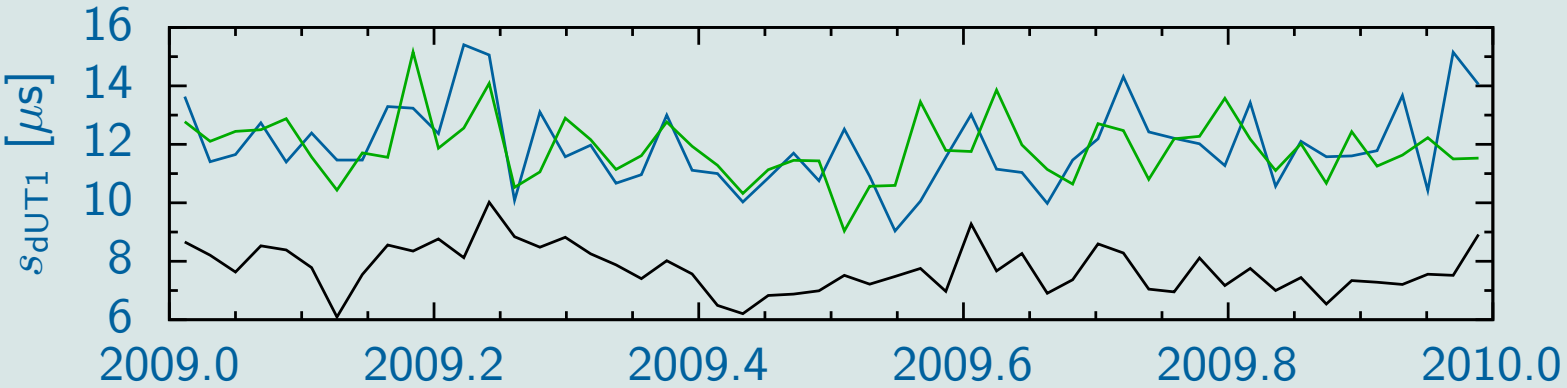
formal errors



➡ precision improvement w.r.t. 'standard INT3' only for 'all possible subnets'

— all possible subnets — pairs 1 (all) — pairs 2 (twins)

standard deviations



Twin-Telescope Parametrization

individual setup:

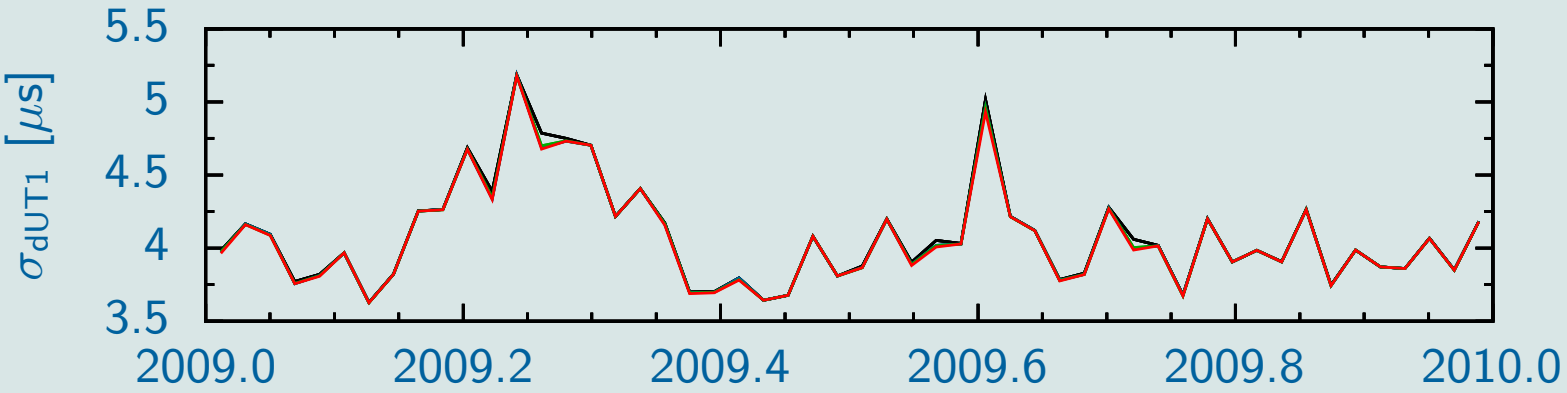
- clock and atmospheric parameters per twin-telescope
  $cl0_{t_1}$, $cl1_{t_1}$, $cl2_{t_1}$, at_{t_1} & $cl0_{t_2}$, $cl1_{t_2}$, $cl2_{t_2}$, at_{t_2}

common setup:

- clock parameters per twin-telescope and common atmospheric parameter for both
  $cl0_{t_1}$, $cl1_{t_1}$, $cl2_{t_1}$, ~~at_{t_1}~~ & $cl0_{t_2}$, $cl1_{t_2}$, $cl2_{t_2}$, ~~at_{t_2}~~
  $\rightarrow$ at_{twin}
- common clock parameters for both and atmospheric parameter per twin-telescope
  ~~$cl0_{t_1}$~~, ~~$cl1_{t_1}$~~, ~~$cl2_{t_1}$~~, at_{t_1} & ~~$cl0_{t_2}$~~, ~~$cl1_{t_2}$~~, ~~$cl2_{t_2}$~~, at_{t_2}
  $\rightarrow$ $cl0_{\text{twin}}$, $cl1_{\text{twin}}$, $cl2_{\text{twin}}$
- common clock parameters and common atmospheric parameter for both
  ~~$cl0_{t_1}$~~, ~~$cl1_{t_1}$~~, ~~$cl2_{t_1}$~~, ~~at_{t_1}~~ & ~~$cl0_{t_2}$~~, ~~$cl1_{t_2}$~~, ~~$cl2_{t_2}$~~, ~~at_{t_2}~~
  $\rightarrow$ $cl0_{\text{twin}}$, $cl1_{\text{twin}}$, $cl2_{\text{twin}}$, at_{twin}

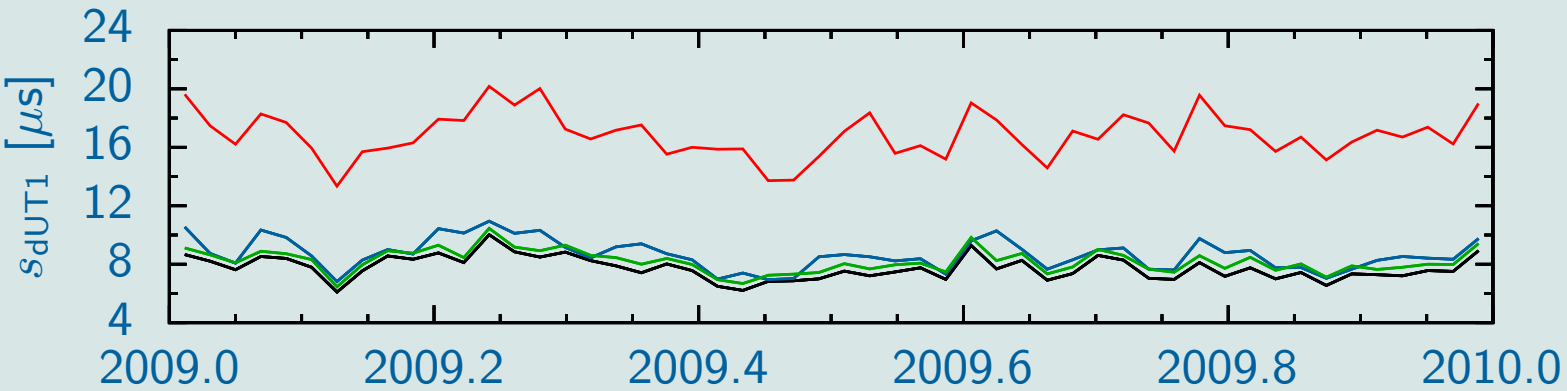
e.g. all possible subnets

formal errors



— all parameters — AT — CL — AT & CL

standard deviations



Conclusions

scheduling based on SVD

- improvement of the standard deviations of dUT1 for INT3 sessions

INT3 sessions with Wettzell Twin-Telescopes

- standard deviations w.r.t. 'all possible subnets' worse for 'pairing' by approx. 35%
- precision improvement w.r.t. 'standard INT3' for 'all possible subnets'
- loss of precision at 'pairing' w.r.t. 'standard INT3'

➙ number of observations for 'all possible subnets' more than twice than for 'pairing'

➙ ignored correlations between the Twin-Telescope observations

Conclusions

various Twin-Telescope parametrization

- common AT parameter → observation errors are absorbed by the clock parameters
- common CL parameter → observation errors are absorbed by the atmospheric parameters
- common AT & CL parameters → increased residuals