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# Scheduling of VLBI observations to satellites with the Vienna VLBI Software (VieVS)

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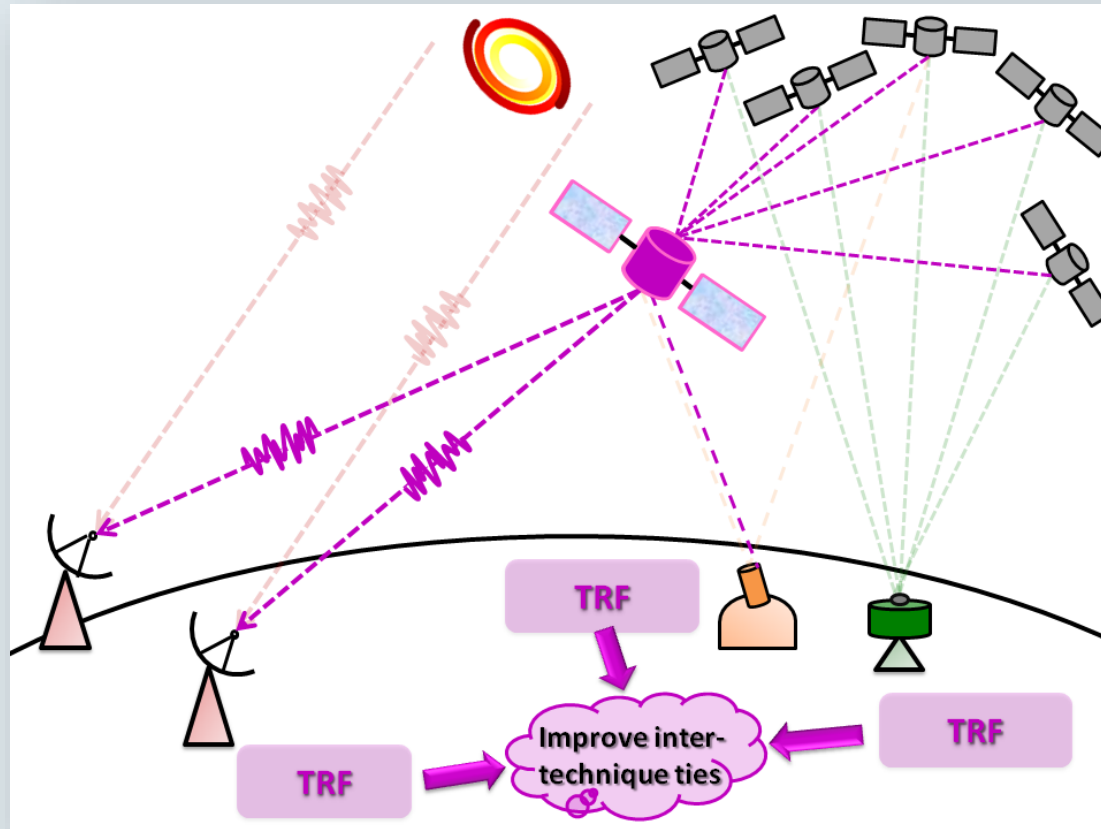
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<sup>4</sup> University of Tasmania, Australia

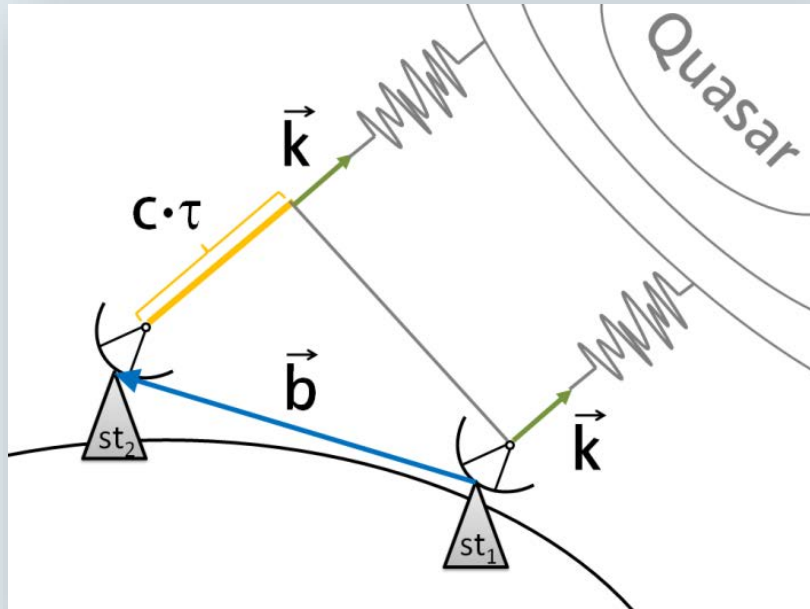
# VLBI satellite observations (1)

- Motivation for geodesy:
  - Establish inter-technique ties in space
  - Improved future ITRF realizations



„Co-Location in space“ (Plank L, 2014)

## Standard VLBI

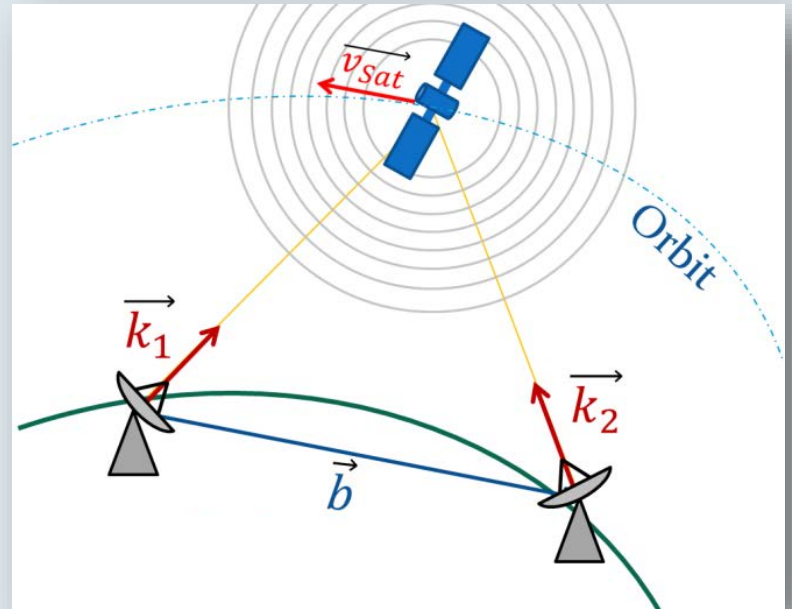


### Natural radio sources (quasars)

- At an infinite distance
- Parallel view directions  $\vec{k}$
- Fixed points in the sky
- S/X-band



## Satellite observations



### Artificial signal sources

- In the Earth's near field
- Different view directions ( $\vec{k}_1 \neq \vec{k}_2$ )
- Moving fast
- e.g. L-band for GNSS

# VLBI satellite observations (2)

- Suitable observation plans („**Schedules**“) are required
  - Defining the time sequence of a VLBI experiment
  - Generated by dedicated VLBI scheduling software
    - SKED (*Gipson J, 2012*)
    - VIE\_SCHED (*Sun J, 2014*)
  
- ➔ **Problem:** Available scheduling programs for geodetic VLBI did not support satellites as radio sources routinely.
  
- ➔ **Idea:** Development of a **satellite scheduling module** for the Vienna VLBI Software (*VieVS; Böhm et al., 2012*).



# VieVS satellite scheduling module

**Station network**

**Satellites**

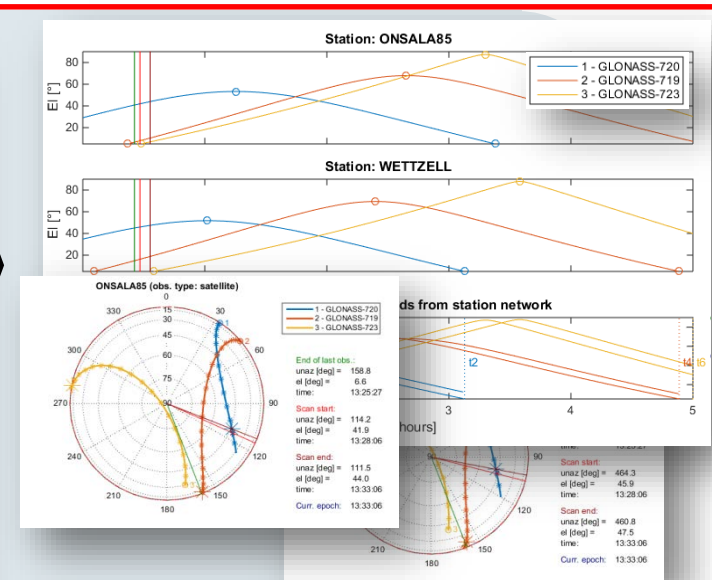
**Observation Time & parameter**

**Graphics & Visibility information**

**User-interface**

**Input data**

The screenshot shows the 'Vienna VLBI Software 2.3' interface. It features a 'Station network' panel with 'Available' and 'Predefined' lists. The 'Parameters' section includes 'Sundist [°]' (4), 'Cut-off el [°]' (5), and 'Source flux' (0.25). The 'Satellites' panel shows a list of GLONASS satellites with 'Selected' and 'Available' sub-lists. A 'Time options' section shows a start time of 13:00:00. The 'Strategy' section has radio buttons for 'Source-based strategy', 'Station-based strategy', and 'Satellite observations'. A 'Manual Satellite Scheduling Approach' dialog box is also visible, showing a menu of actions like 'Add a scan to the the current schedule (append)'. Red boxes and arrows highlight these key areas.



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##### Manual Satellite Scheduling Approach #####

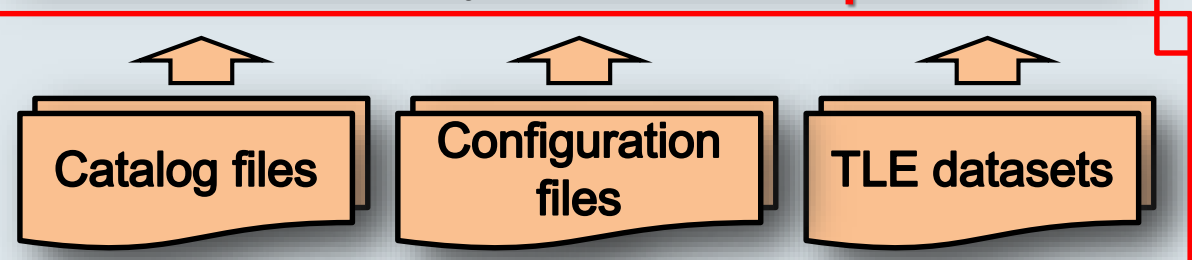
#### Type in an Experiment Name ####
=> Input Length: Between 1 and 4 characters
=> Legal characters: "A-Z", "a-z", "0-9", "-" and "-"
Experiment name: zt

#### Main menu: Choose an action ####

1 - Add a scan to the the current schedule (append)
2 - Get further information
3 - Edit current schedule
4 - Finish user input and create VEX file
5 - Exit

Please select: 1
#### Add scan to current Schedule (append) ####
1 - Add a satellite scan
2 - Add a quasar scan
Please select: 1
    
```

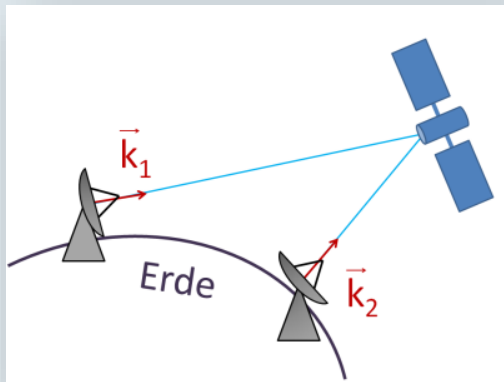
**Generation of VEX files**



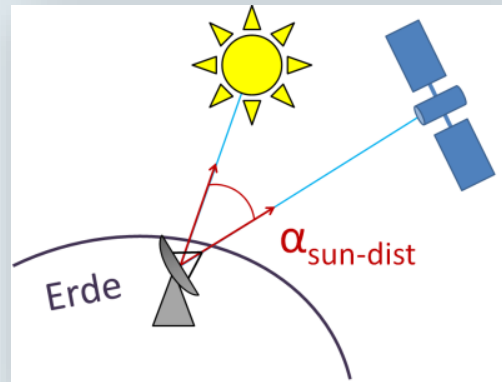
# Satellite observation conditions

- Conditions for the temporal availability of satellites as observation targets:

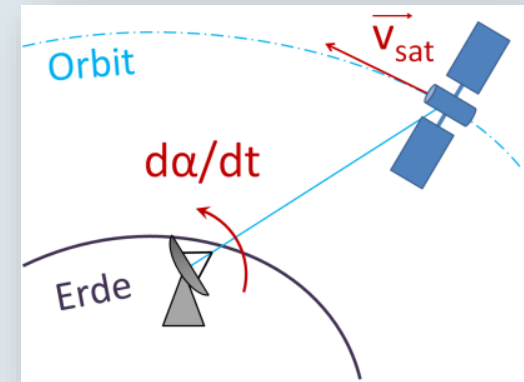
Common visibility?



Sun distance?



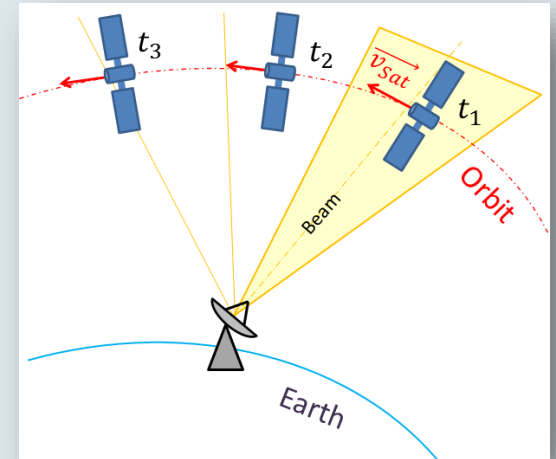
Antenna slew speeds?



- Tracking of the **cable wrap**
  - ➔ Calculation of slew times between scans
  - ➔ Check cable wrap limits

- VEX = Standard file format for VLBI observation plans
- Provide all required information to carry out a VLBI session
  - Observation sequence, source positions, receiver setup, etc...

- “Stepwise” satellite tracking with VEX files
  - Sequence of discrete positions (topo. Ra/Dec)
  - Feasible for standard VLBI antennas

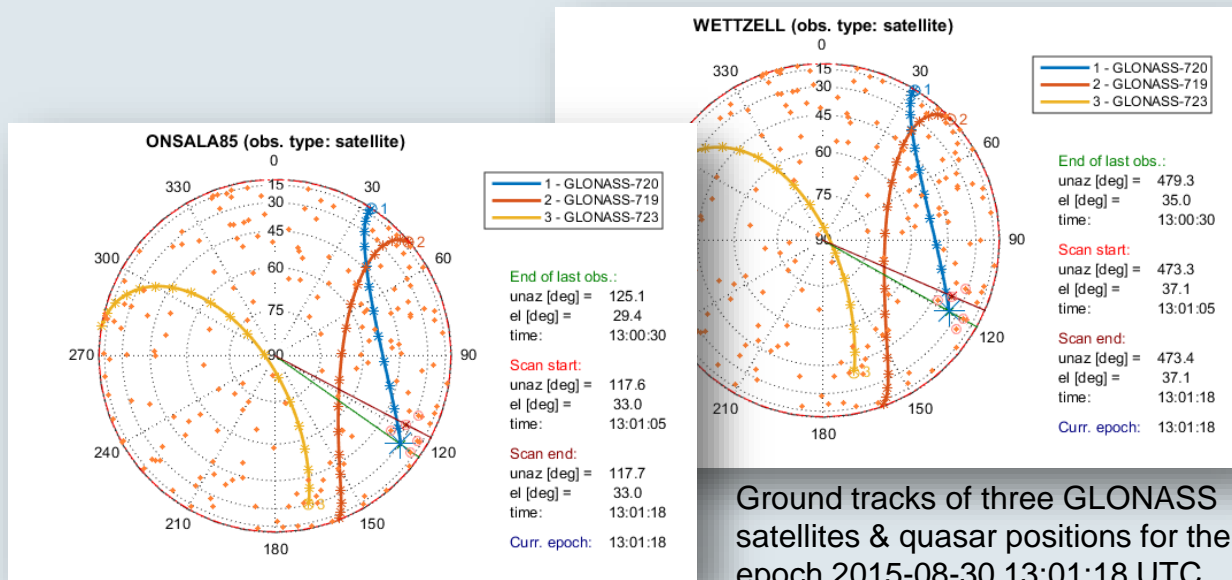


Principle of stepwise satellite tracking

- “VEX 2.0” (<https://safe.nrao.edu/wiki/bin/view/VLBA/Vex2>)
  - Inclusion of TLE orbit data
  - ➔ Improved satellite tracking in combination with satellite tracking features of the Field System

# Combined schedules

- **Combination of quasar- and satellite-scans in one schedule**
- New possibilities:
  - Satellite positions in the CRF, reveal gaps in the local ties, etc...
- Observation restrictions due to limited receiver capabilities
  - e.g. S/X- versus L-band (GNSS)



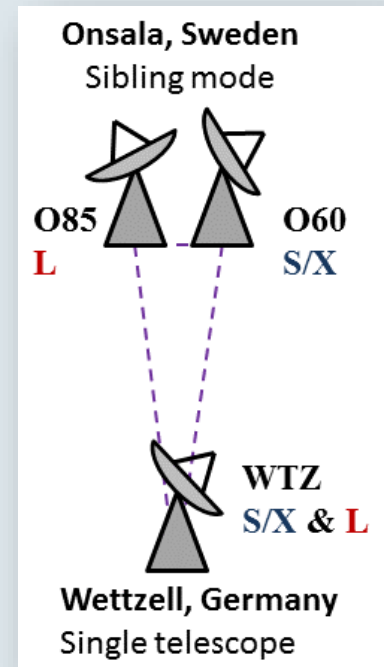
Ground tracks of three GLONASS satellites & quasar positions for the epoch 2015-08-30 13:01:18 UTC



# Future scheduling strategies

- Open questions:
  - How to **combine satellite and quasar observations** reasonably to improve the derived geodetic parameters?
    - Scan sequence, source distribution, etc...
  - How to handle station-depended **restrictions in the observable frequency bands**?
  - etc...

Possible S/X- & L-band observation configuration on the baseline Onsala-Wettzell



➔ Next step: **Combination of scheduling and simulation/analysis** (*Plank, 2014*) tools in VieVS to investigate suitable scheduling strategies for satellites.

# Experiments: WTZ – ONSALA85

- Scheduled with

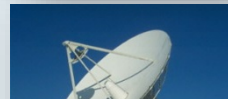


- Onsala, Sweden:

- R. Haas
- 25 m antenna, L-band feed

- Wetzell, Deutschland

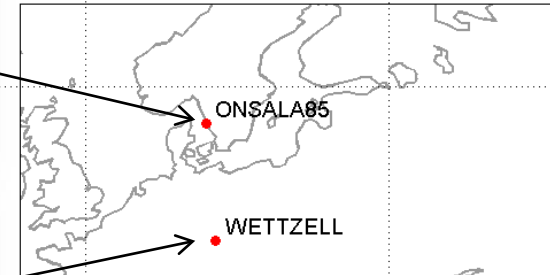
- A. Neidhardt



→ GLONASS satellites

- L1 band signals  
(1602.56 - 1615.5 MHz)

Observation network



## Data correlation and preliminary results

→ Next talk: R. Haas et al., *GLONASS-VLBI: Onsala-Wetzell test observations*

- Four test sessions, one hour duration each
  - 16. January 2014: G140116a, G140116b
  - 21. January 2014: G140121a, G140121b

(Hellerschmied et al., 2014)

- **VieVS Satellite Scheduling Module**
  - ✓ Planning of real VLBI satellite observations
  - ✓ Generation of schedule files (VEX Format)
  - ✓ Combination of quasar- and satellite scans
  - ✓ Successfully applied for test observations in January 2014
    - No automatic source selection so far
- Planned **simulation studies** with VieVS based on realistic schedules to find suitable scheduling strategies for VLBI satellite observations

# Questions?

## Contact:

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## References:

- Böhm J et al. (2012)**, The New Vienna VLBI Software, Proceedings of the 2009 IAG Symposium, Buenos Aires, Argentina, 31 August 2009 - 4 September 2009, Series: International Association of Geodesy Symposia, Vol. 136, Kenyon S, Pacino MC, and Marti U (eds.), ISBN 978-3-642-20337-4, pp. 1007-1012.
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- Hellerschmied et al. (2014)**, Observing satellites with VLBI radio telescopes – practical realization at Wettzell, 8th IVS General Meeting, Shanghai, March 2014.
- Kodet J et al. (2014)**, Co-locations of Space Geodetic Techniques on Ground and in Space, 8th IVS General Meeting, Shanghai.
- Plank L (2014)**, Precise station positions from VLBI observations to satellites: a simulation study, J Geod, 88: 659–673.
- Sun J et al. (2014)**, New VLBI2010 scheduling strategies and implications on the terrestrial reference frame, J Geod, 88: 449-461