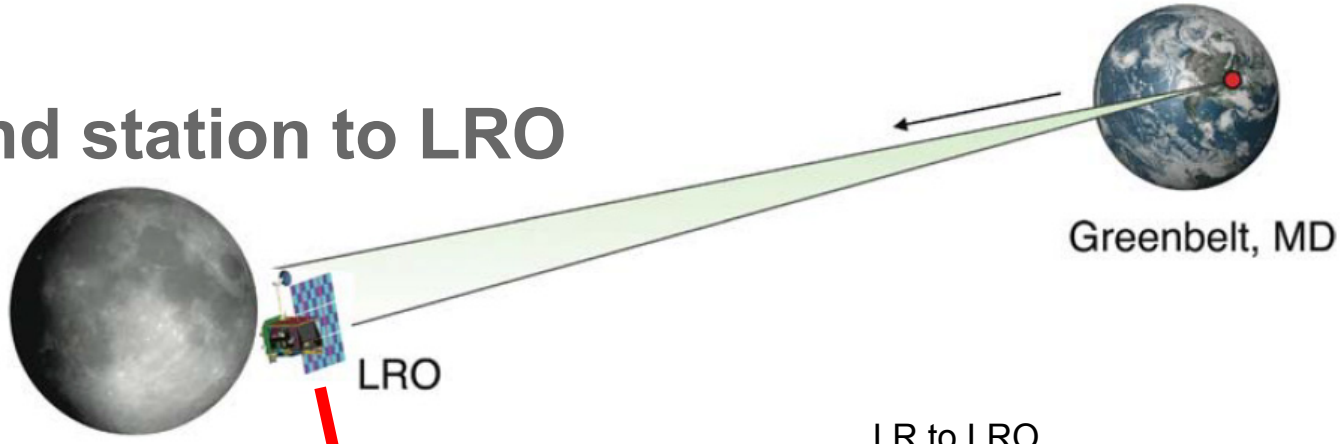
Analysis and application of 1-way laser ranging data from ILRS ground stations to LRO

S. Bauer (1), D. Dirkx (2),
J. Oberst (1,3), D. Mao (4), G. Neumann (5), E. Mazarico (5),
M. Torrence (6), J. McGarry (5), D. Smith (7), M. Zuber (7)

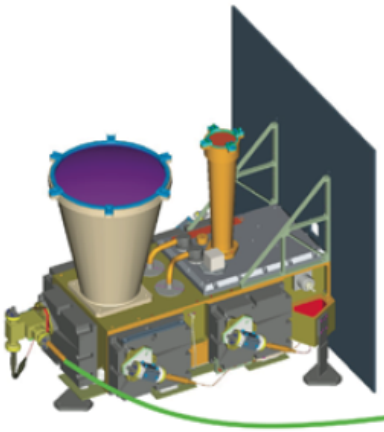
(1) DLR, Berlin Germany, (2) TU Delft, (3) TU Berlin, Germany,
(4) Sigma Space Corporation, MD USA,
(5) Goddard Space Flight Center, NASA, MD USA,
(6) SGT Inc., MD USA, (7) MIT, MA USA

Facts
LR from ground station to LRO

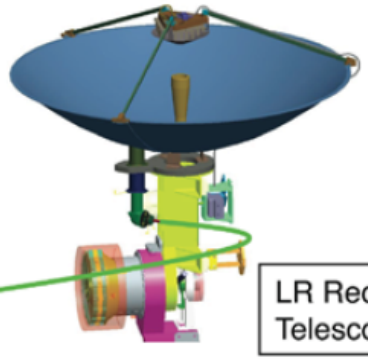


LR to LRO
From Zuber2009

Receiver telescope on HGA
routes LR signal to LOLA

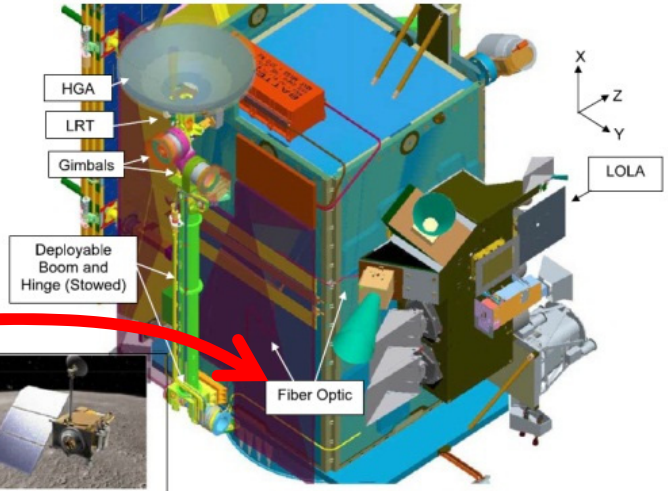


LOLA channel 1
Detects LR signal



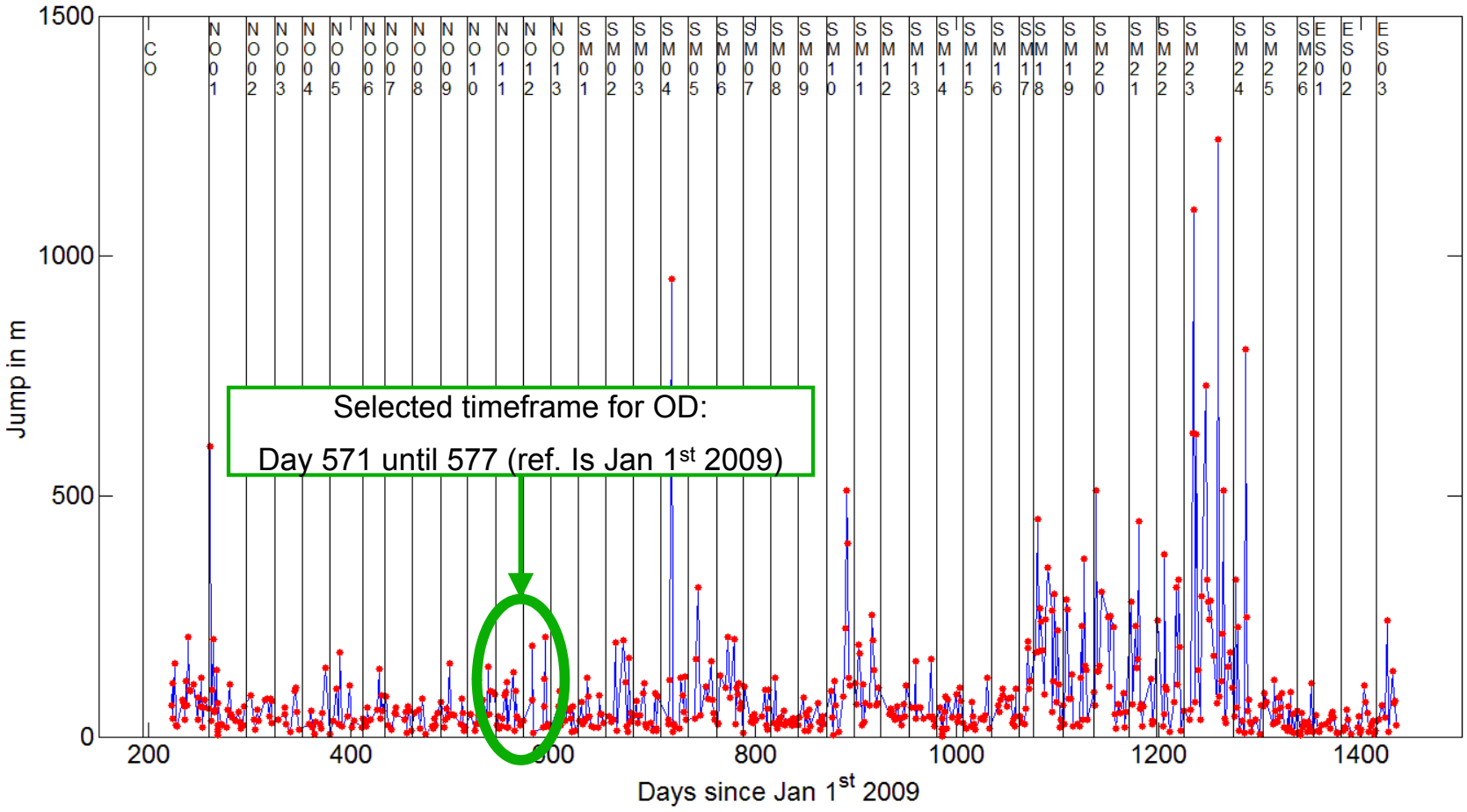
Fiber Optic Bundle

LR Receiver
Telescope



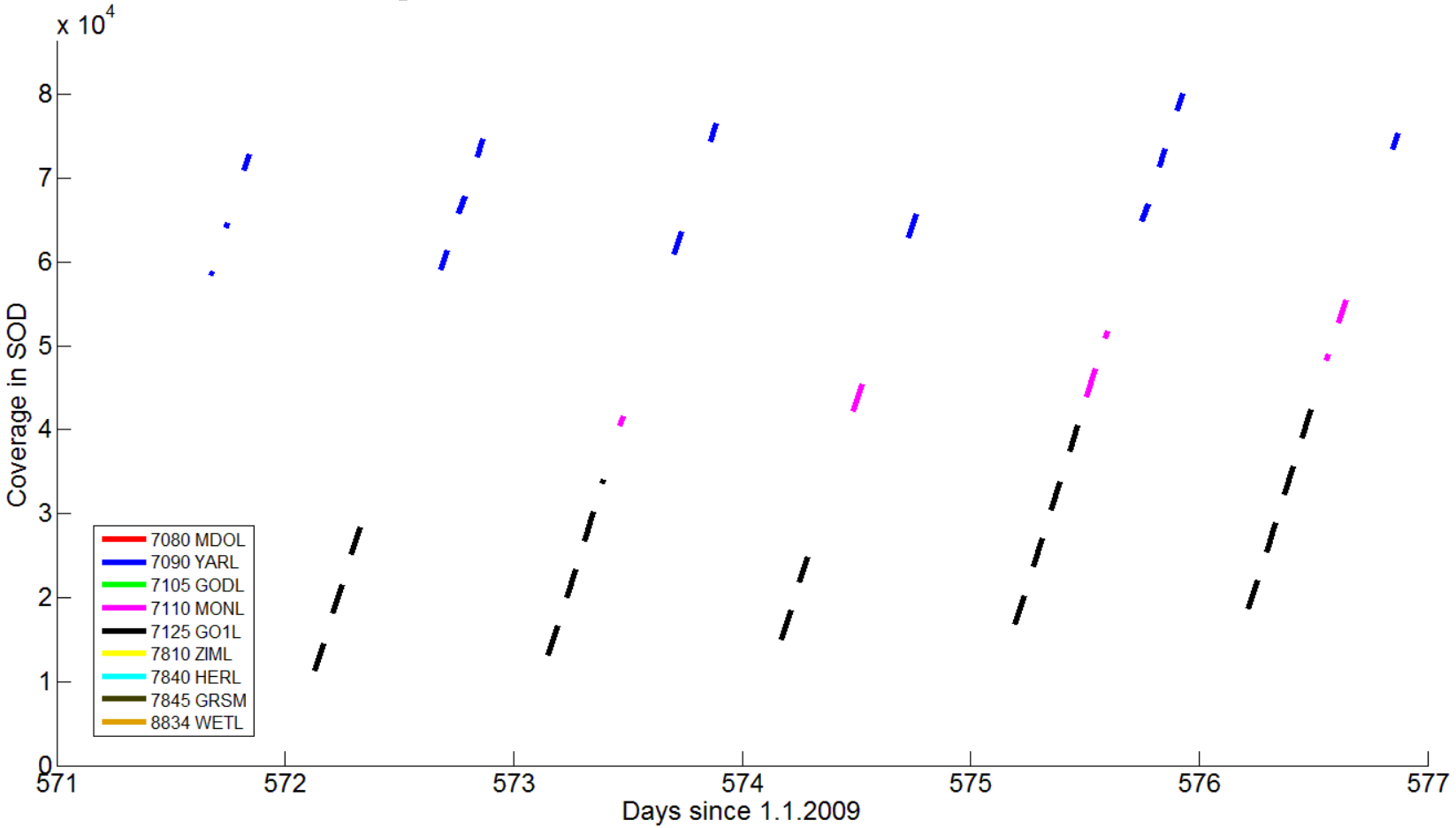
LRO with Boom Deployed

Data selection
LRO SPK Jumps



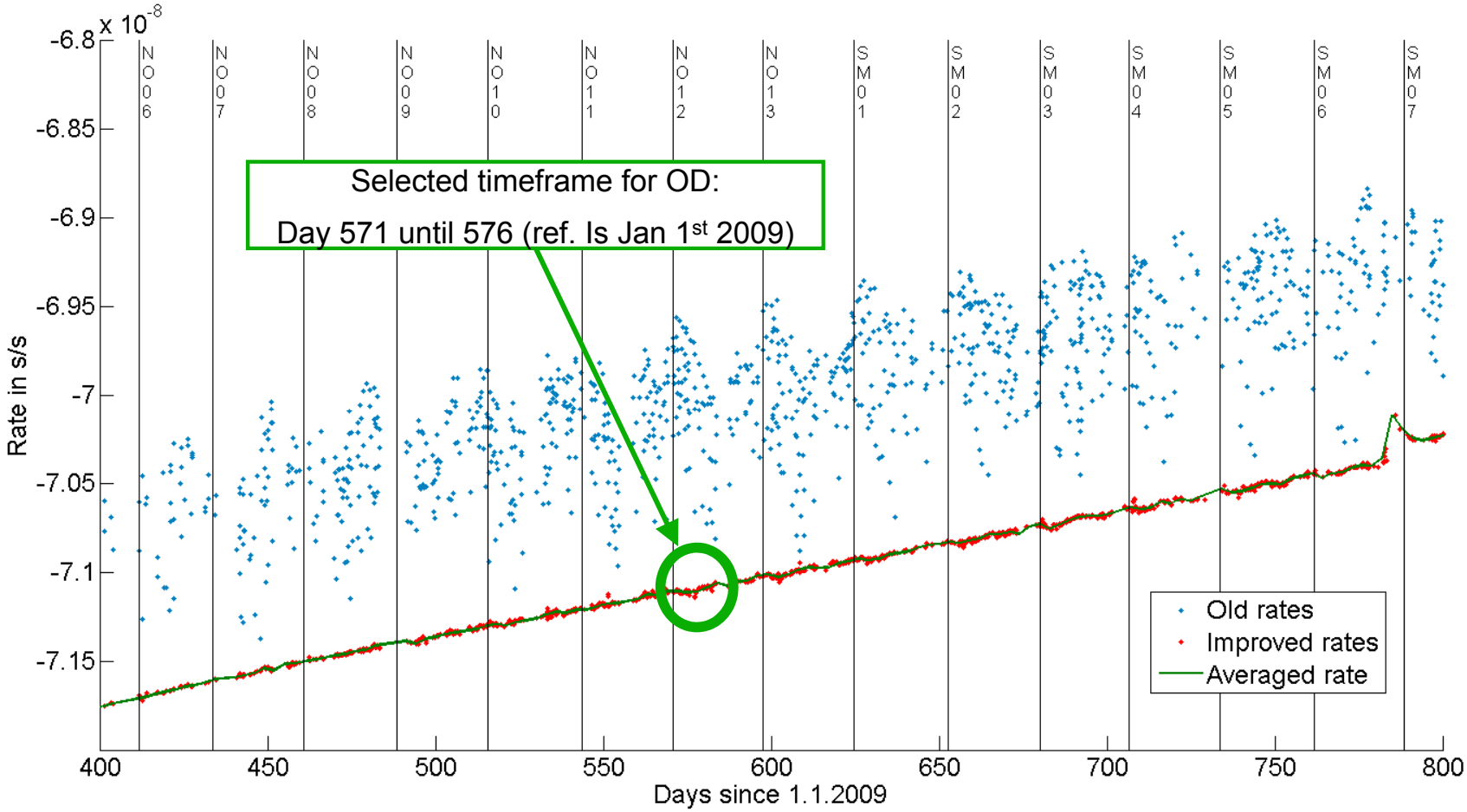
LRO SPK Jumps throughout the mission

Data selection
Observation passes



Observation passes in the selected timeframe

Data selection
Clock



Ratio matched to fired shots of the observation passes
In the selected timeframe

Estimation setup
Approach

- Software
  - TUDAT & ILR from **TU Delft**
- Estimation
  - Adjustment of parameters of interest via batch least squares
- Trajectory
  - Initially usage of SPK, afterwards numerical integration
- Data
  - Matched shots from **DLR Berlin**
- Preliminary data analysis
  - Apriori covariance for parameters and their variation
  - Weights for balancing data quality and quantity
- Comparison of the resulting trajectory to the SPK‘s

Estimation setup
Cases

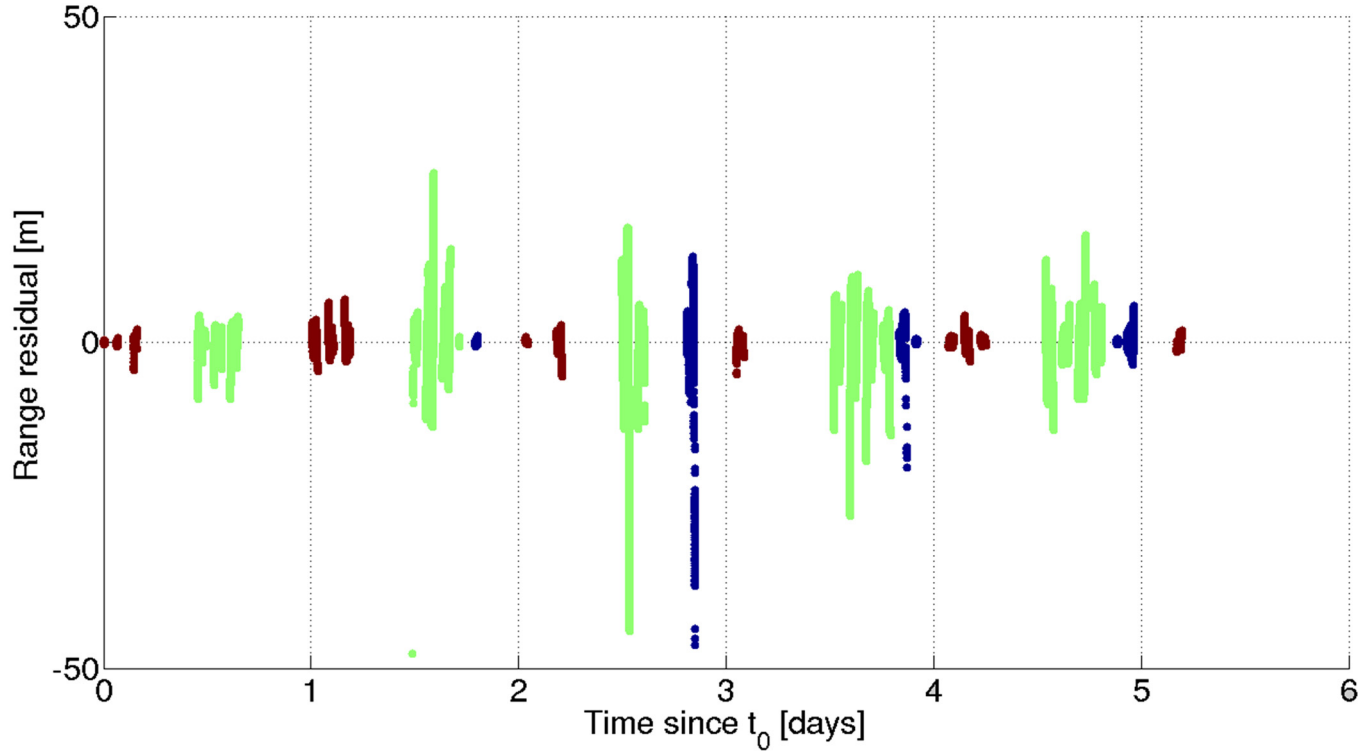
Clock	Clock, Initial state	Clock, Initial state
Clock	**Clock, Initial state**	**Clock, Initial state Empirical accelerations**
Variation of Weights	Variation of Weights	Variation of Weights
Variation of Apriori COV	Variation of Apriori COV	Variation of Apriori COV

Clock parameters per day

Clock parameters per pass

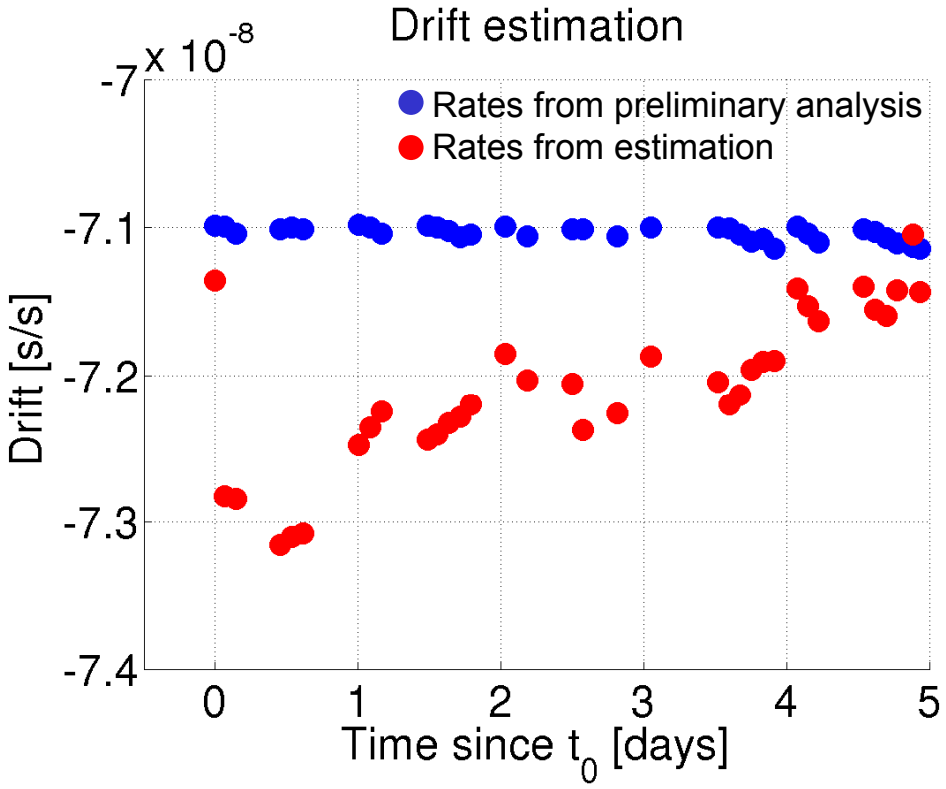
Analysis: looking at the estimated parameters, the residuals, the covariance and the correlations

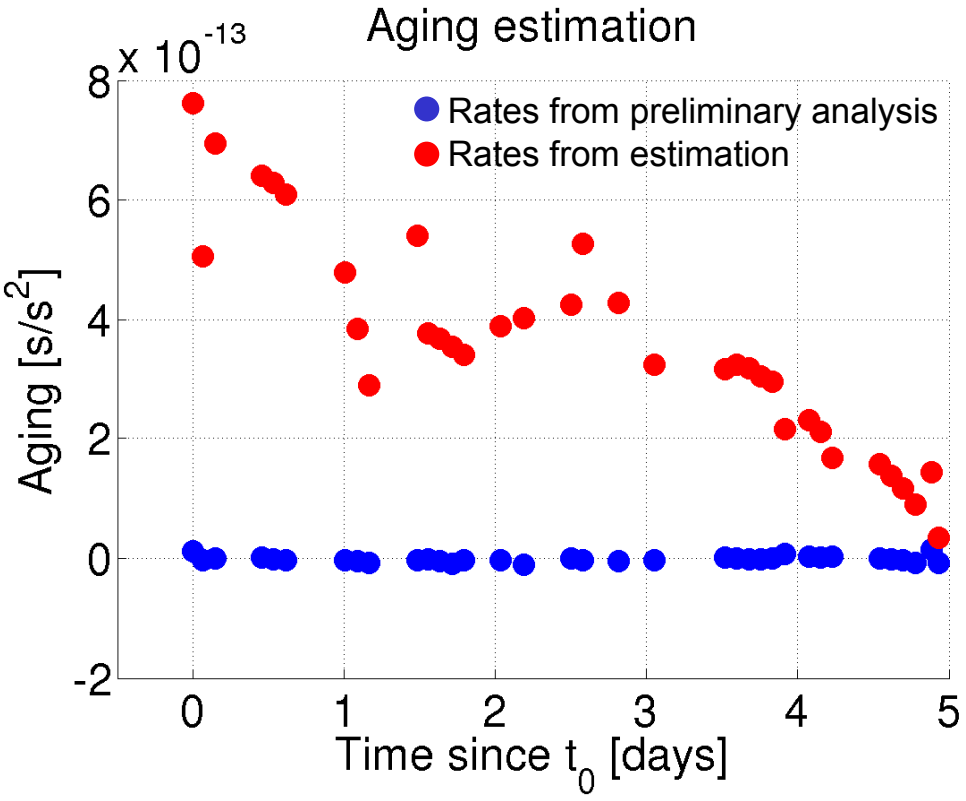
Estimation results
Initial state and per pass clock



– Residuals are low (std ~5 m) but realism of orbit is questionable

Estimation results
Initial state and per pass clock





- Large scatter of clock parameters indicates orbit error absorption

Estimation results
Main conclusions

- Application of LR data
  - data is very suitable for clock synchronization but results in high correlation for the estimated parameters
  - Further referencing needed
- Application of weights and apriori covariance
  - Helps to balance data quality & quantity as well as to reduce the correlations of the estimated parameters
- Application of clock approximation over longer timespan
  - Reduces number of parameters to be estimated
  - Optimal length has to be determined
- Application of empirical accelerations
  - Helps to decorrelate the estimated clock parameters and therefore seems to be the right approach

Summary

- Successful linking of our work/approaches (data & estimation)
- Successful application of real data into ILR (modifying ILR & data)
- Validation of models by comparison (relativistic effects, GS position)
- Assessment of LRO orbit quality by the checking the jumps in the SPK
- OD improvement is not yet feasible by only using LR data
    - All miss modeling is influencing all estimated parameters
    - Total referencing in time is not very precise
- But from using only LR we get
    - Clock characterization that is very precise
    - A strategy how to process the data for enabling OD improvements

Next steps & outlook

- Developing more sophisticated models to remove errors in the OD that come from miss modeling (solar radiation pressure, planetary albedo, meteo data)
- Incorporate more details as maneuvers and HGA/LOLA reference points
- Incorporate passes that contain LR data from multiple stations
- Use simulated radio Doppler data to access improvement in the correlations
- Usage of NPT data
- Update the ILR software interfaces and incorporate the stated changes

Thank you for your attention!
Questions?