Zimmerwald Laser Observations to Determine Attitude States of Space Debris

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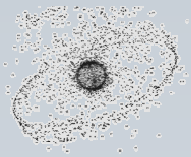

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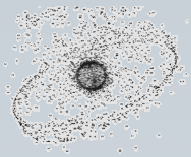


SLR SD Observations: Objectives

General Objectives:

- Improve orbits of space debris
  - Catalogue maintenance
  - Conjunction assessment
  - Re-entry predictions
- Monitoring the attitude state of space objects (spin rate, spin rate evolution, spin axis orientation)
  - Critical parameter for Active Debris Removal mission; long term attitude evolution monitoring, attitude modeling
  - Contingency support
  - Diagnostics, e.g. satellite functional but not behaving nominally
  - Study of specific perturbations, torques on space objects (physics)

Targets:

- Cooperative targets; minority (today)
- Non-cooperative targets

Supplementing Optical/Radar Observations

With RRA ("cooperative")

- LEO to MEO objects
- Reasonable quality a priory orbits required
- Day and night (weather)
- Attitude state determination
- "Standard" SLR system

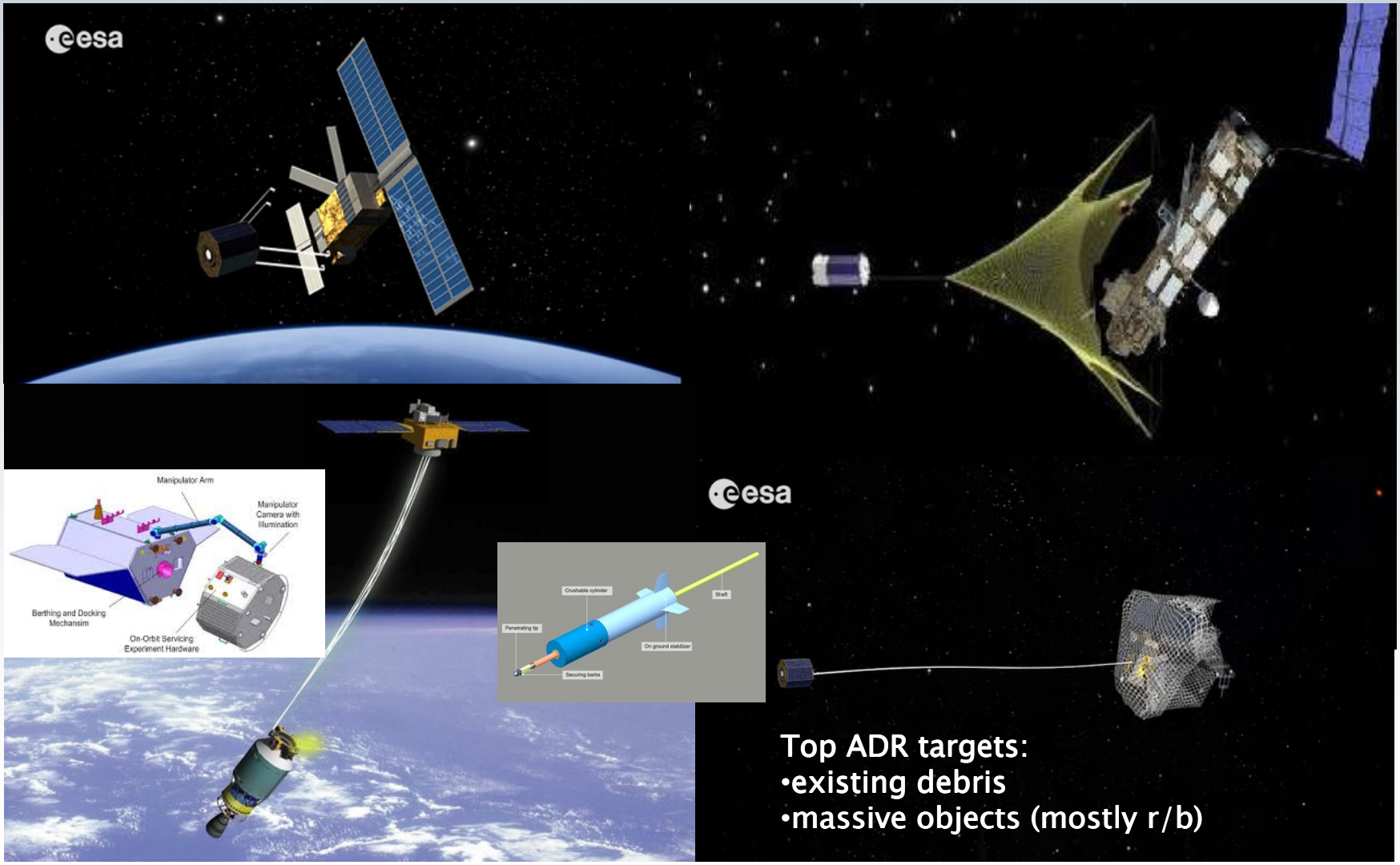
W/o RRA ("non-cooperative")

- LEO
- Small divergence → good a priory orbits required; optical observations for first acquisition and orbit improvement
- Day? Attitude?
- High power Lasers

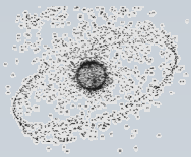
Fusion of range (SLR) and angle (optical) data

- Improves OD substantially
- Attitude state for non-cooperative targets

Attitude States of Space Debris …



AIUB

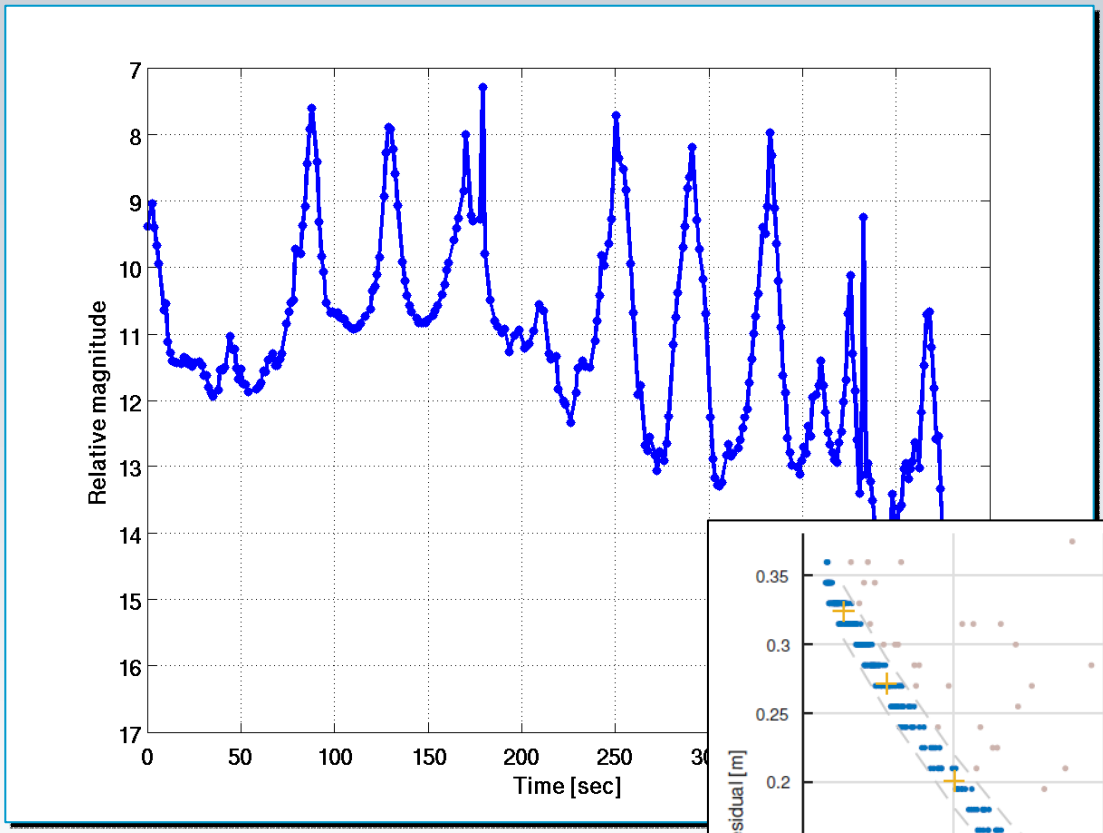


Attitude States of Space Debris

Objectives:

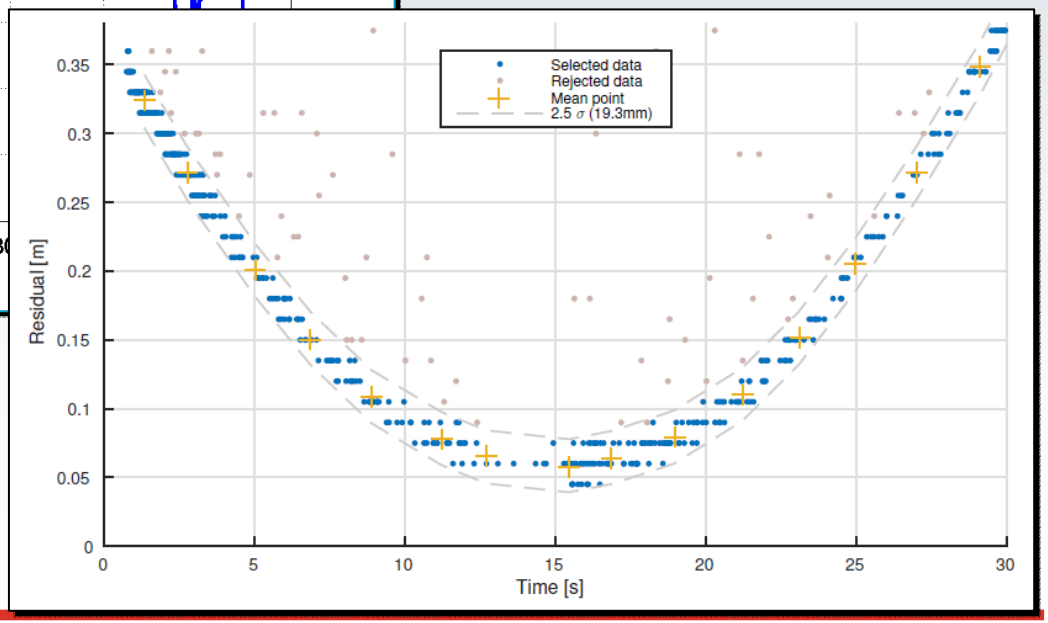
- Monitoring the attitude state of space objects (spin rate, spin rate evolution, spin axis orientation)
- Attitude determination (cooperative targets):
  - Observation of motion of RRA w.r.t. center of mass of debris object
  - Analysis of residuals w.r.t. (improved) orbit
  - Analysis of visibility of RRA
  - Results support development and validation of attitude models → attitude evolution modelling (ADR!)
  - Validation/refinement/support of other attitude determination techniques, e.g. radar, ISAR, and optical → radar and optical required for non-cooperative objects (majority of potential ADR targets)

Envisat Photometry & SLR



Optical Light Curve
P=123s

apparent period changing within light curve (changing geoemetry)!



SLR Residuals

Envisat: Detrending Residuals

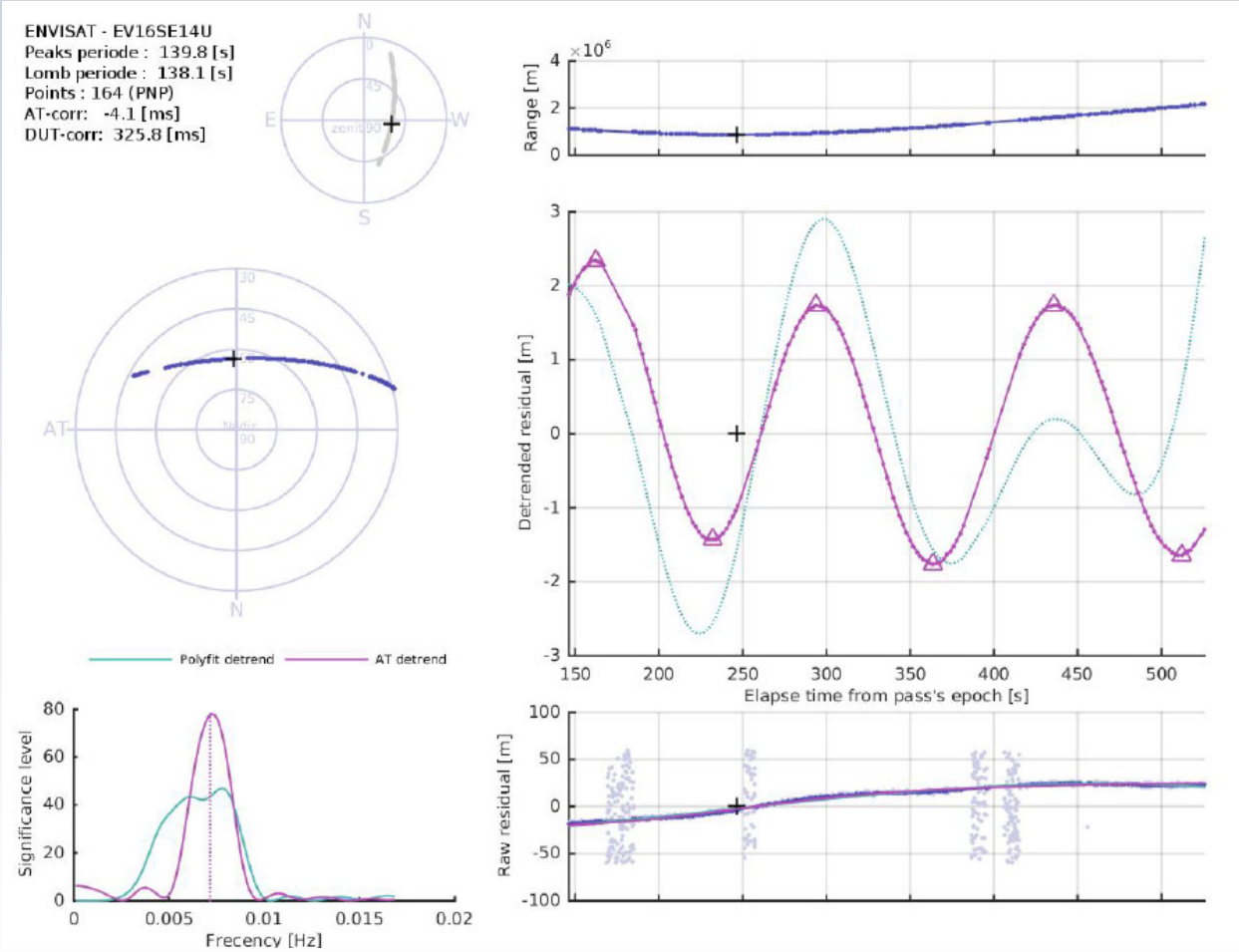
Detrending

- Estimate along-track error (physical model)

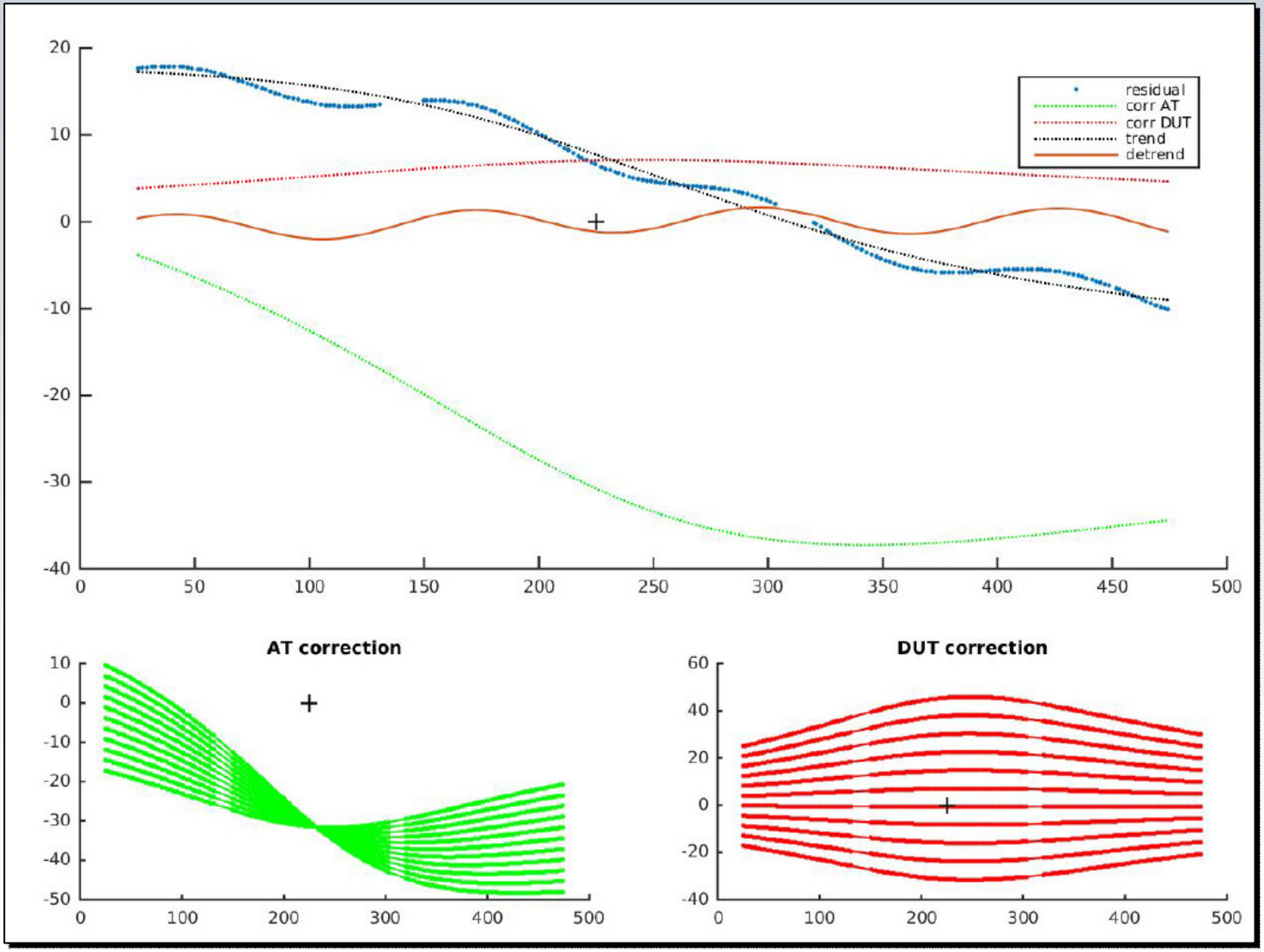
→ removes trend

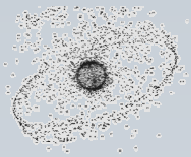
- Period estimation

→ Less susceptible to missing data than polynomial fits!



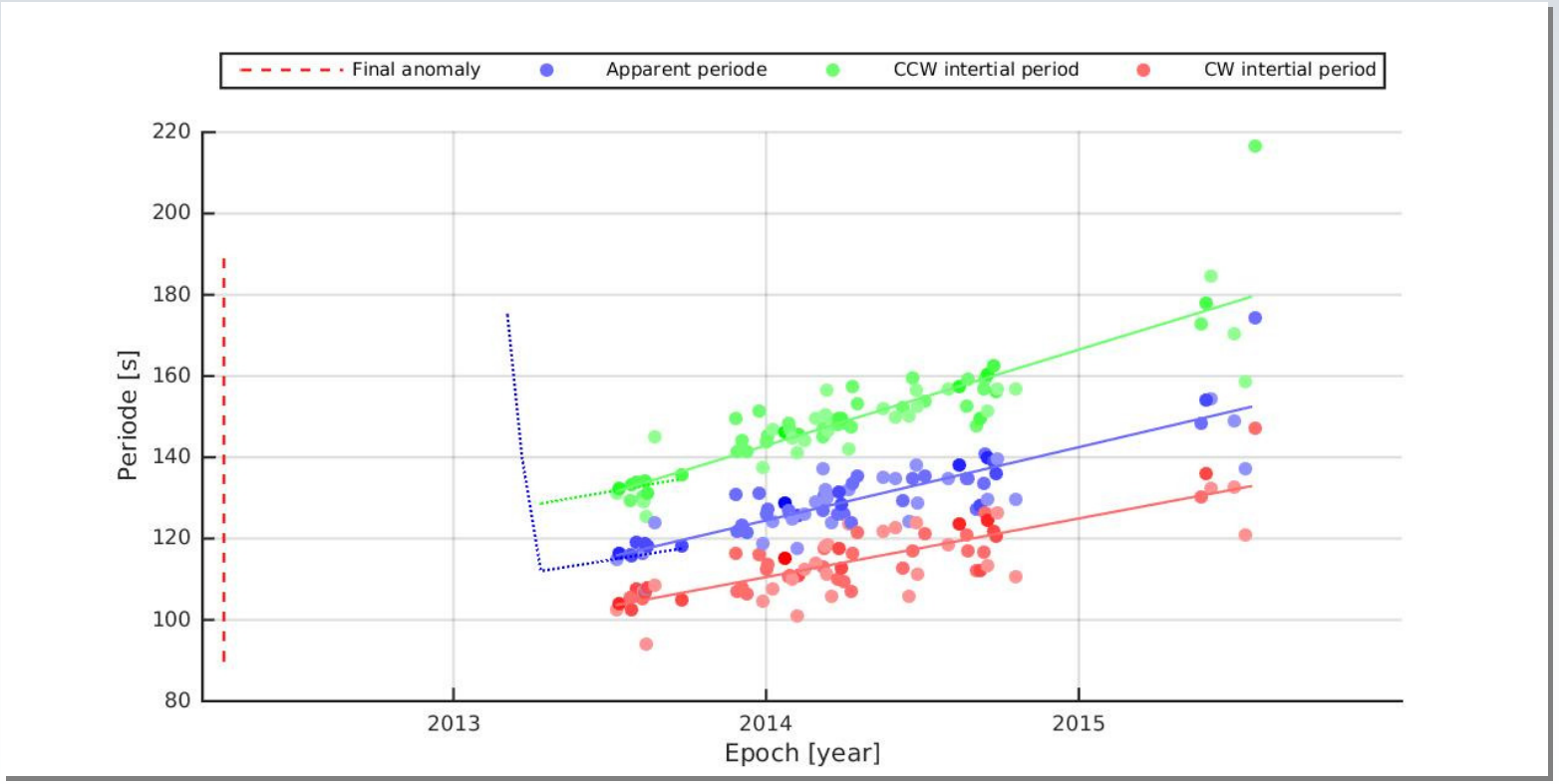
Envisat: Detrending Residual





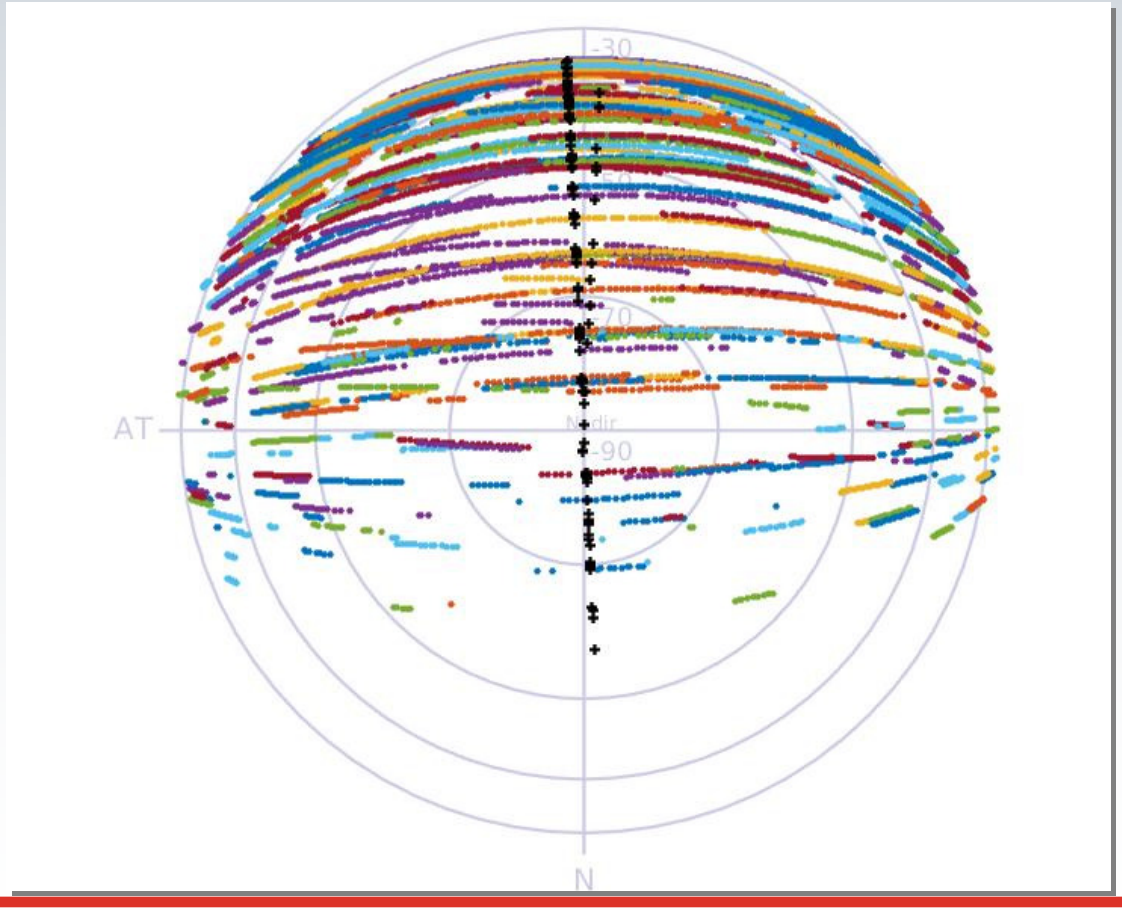
Envisat: Spin Rate Evolution

- Peak to peak approach
- apparent → inertial requires assumption on spin axis orientation
  => We assumed a spin axis fixed in RSW (as other teams).



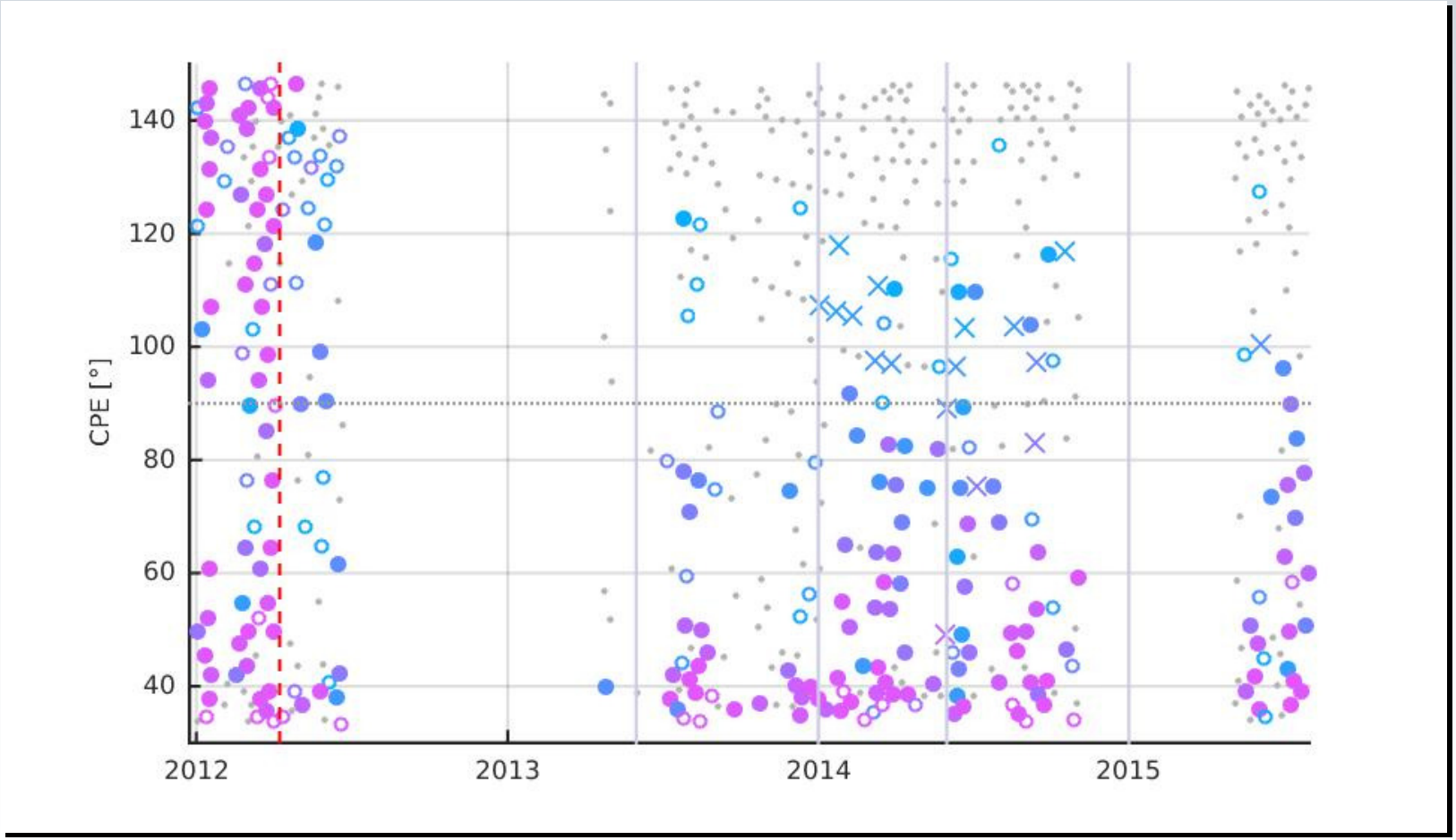
Envisat: Characteristic Pass Elevation

- CPE: Characteristic Pass Elevation → maximum elevation of the observatory seen from the target

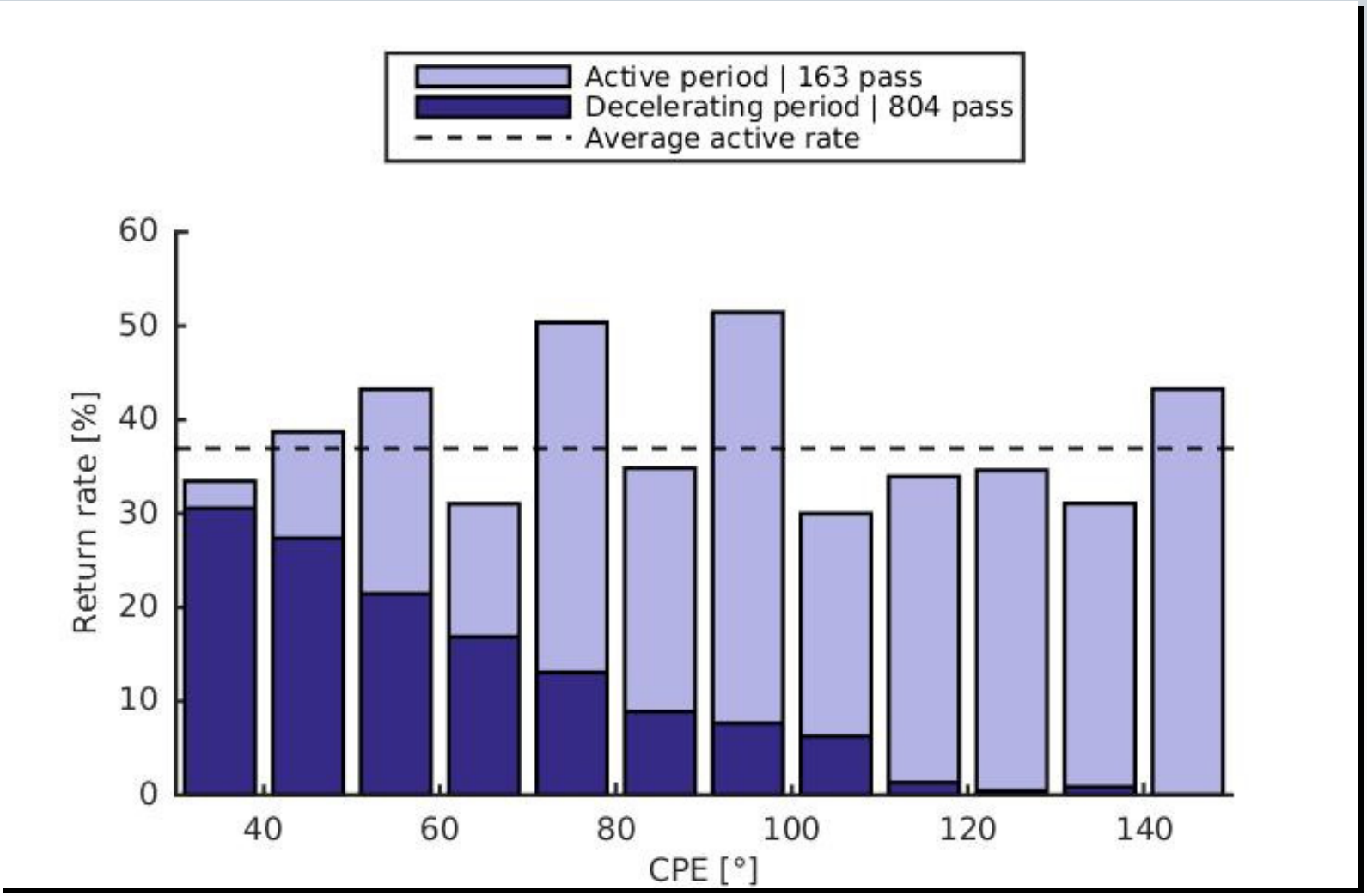


Envisat: Characteristic Pass Elevation

- return rate over time as f(CPE) → attitude evolution

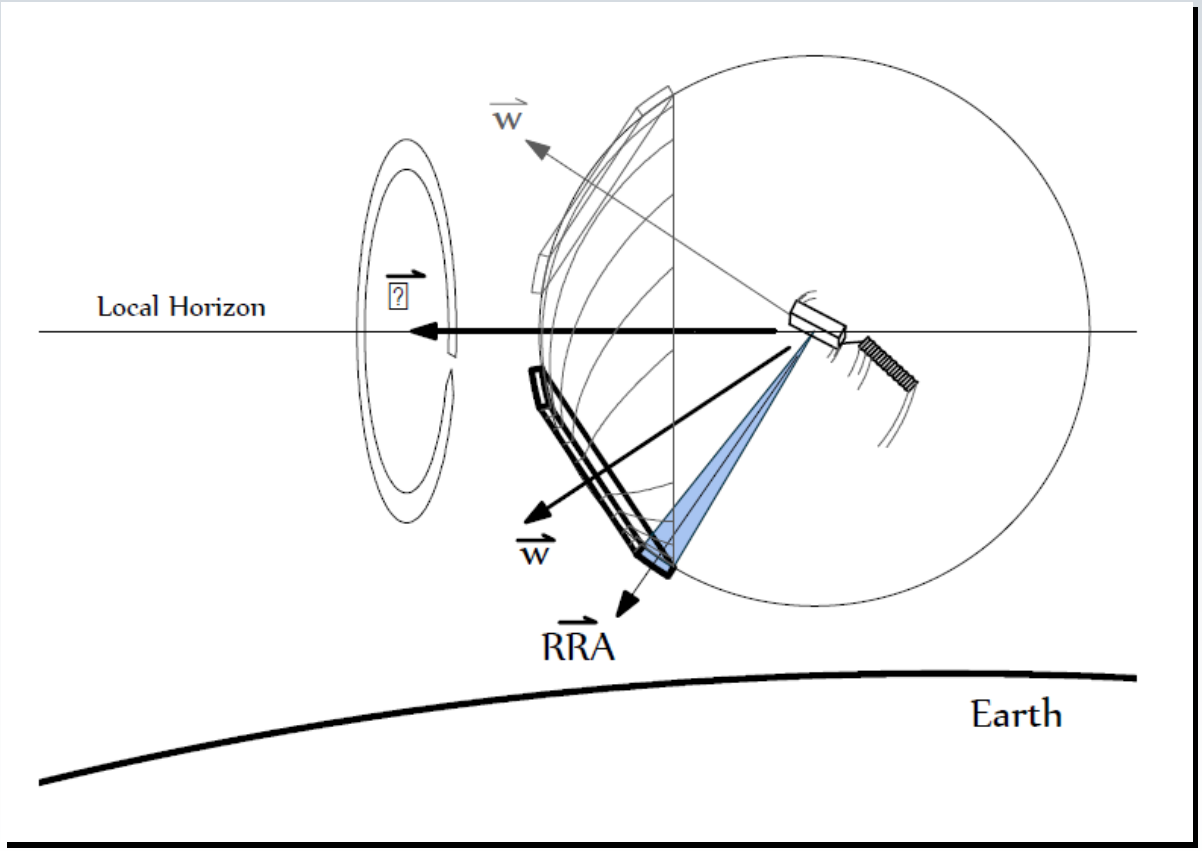


Envisat: Return Rate as f(CPE)



Envisat: Spin and Visibility Model

- New approach, free of assumptions on spin axis orientation (e.g. fixed in RSW system)



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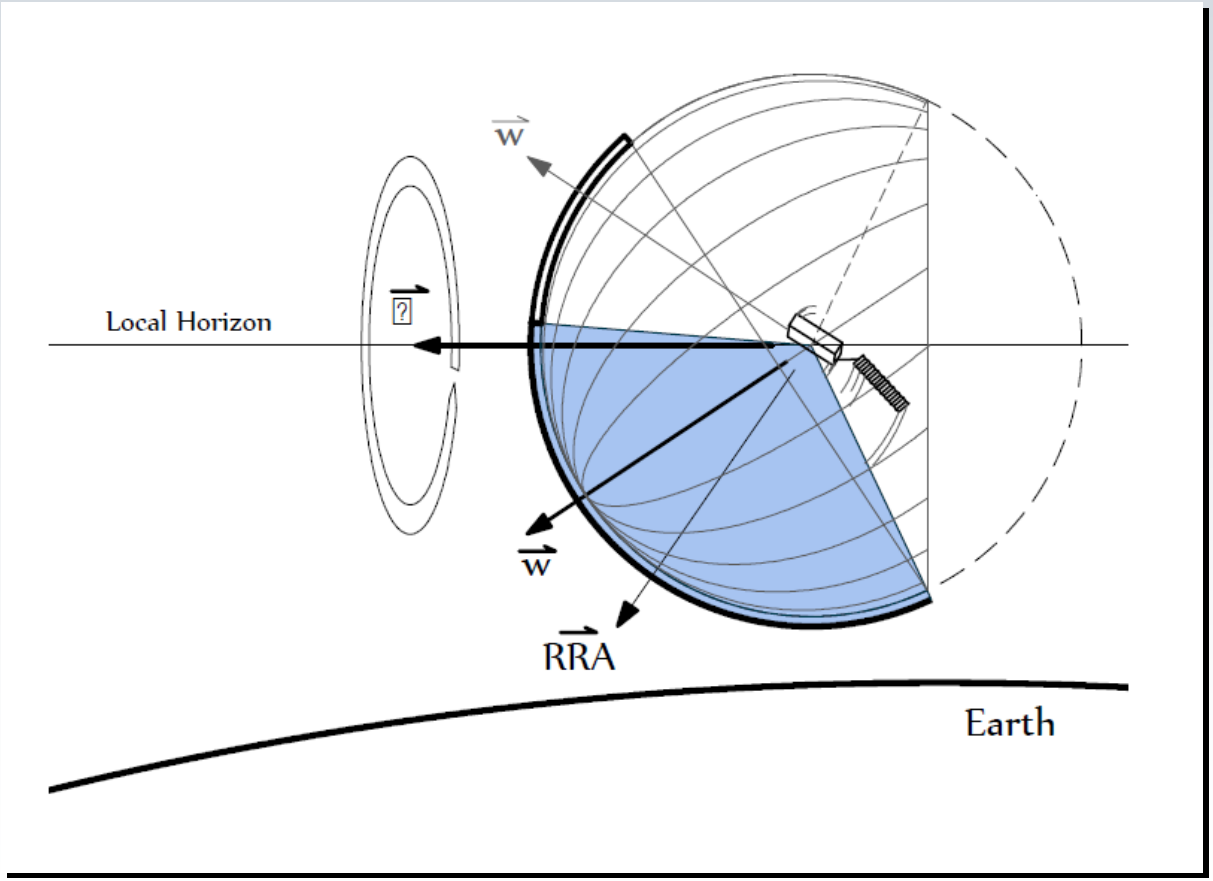
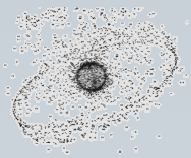
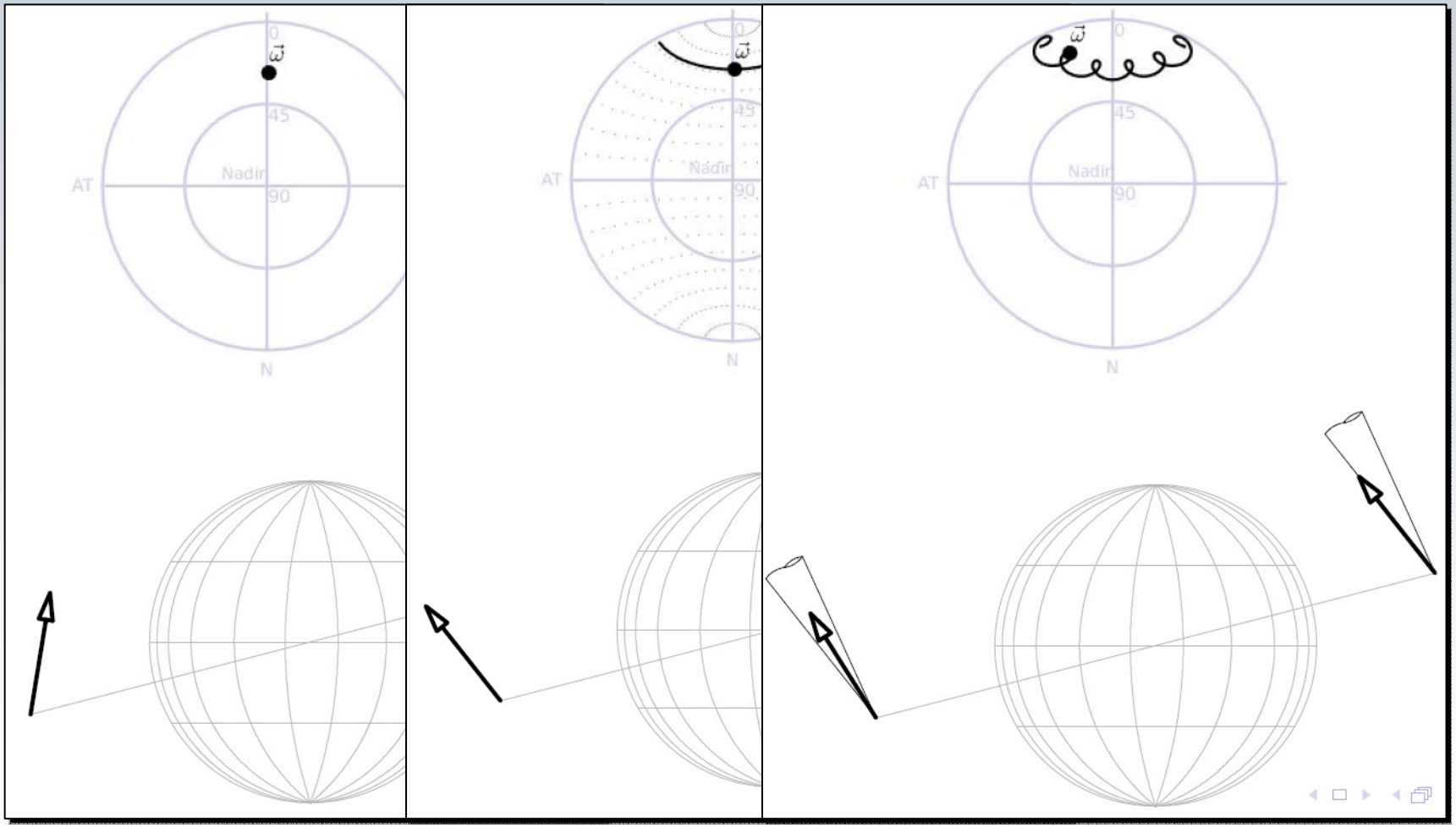
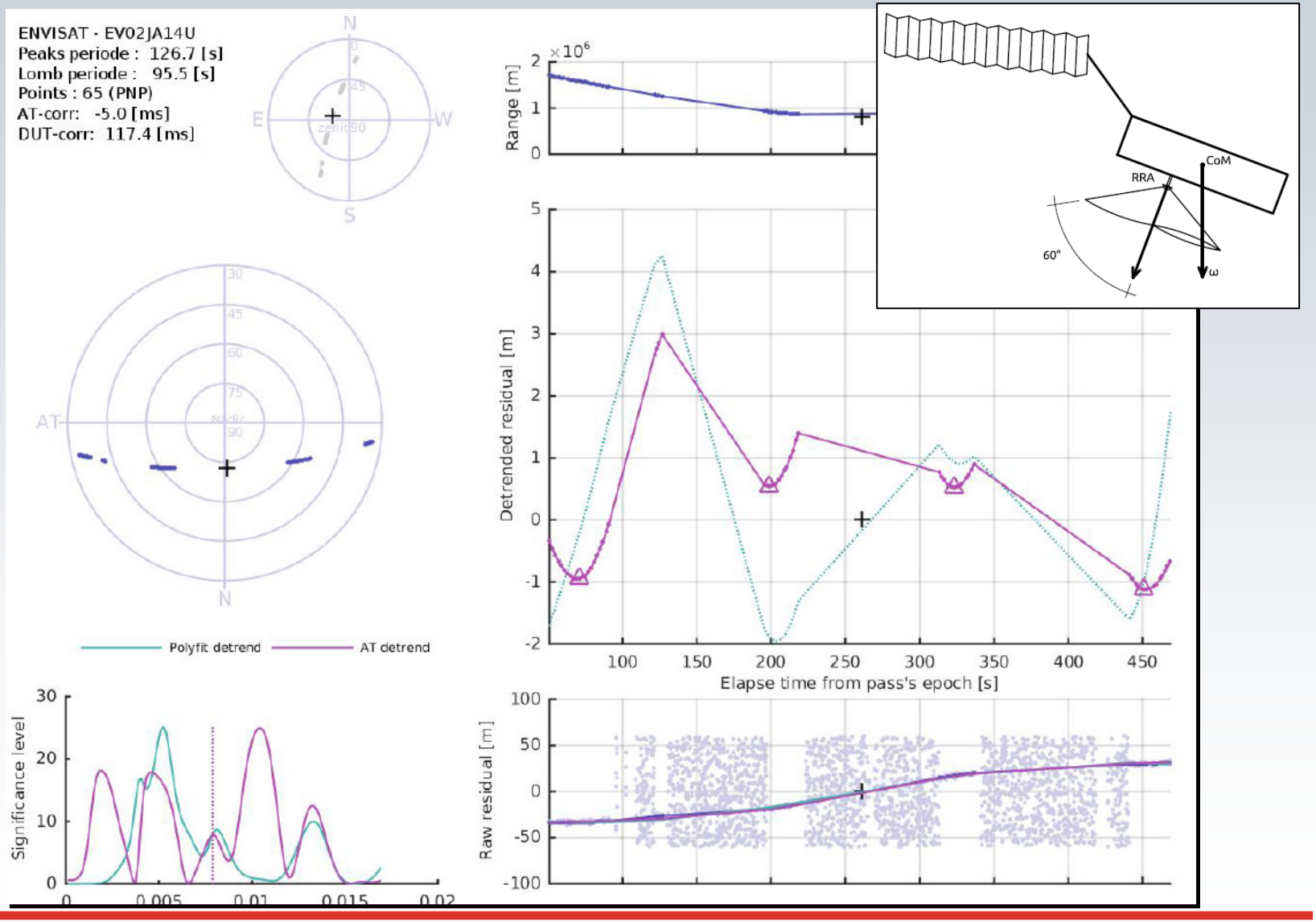


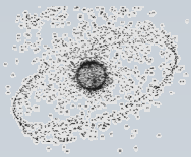


Envisat: Spin and Visibility Model



Envisat: «On Edge» of Visibility

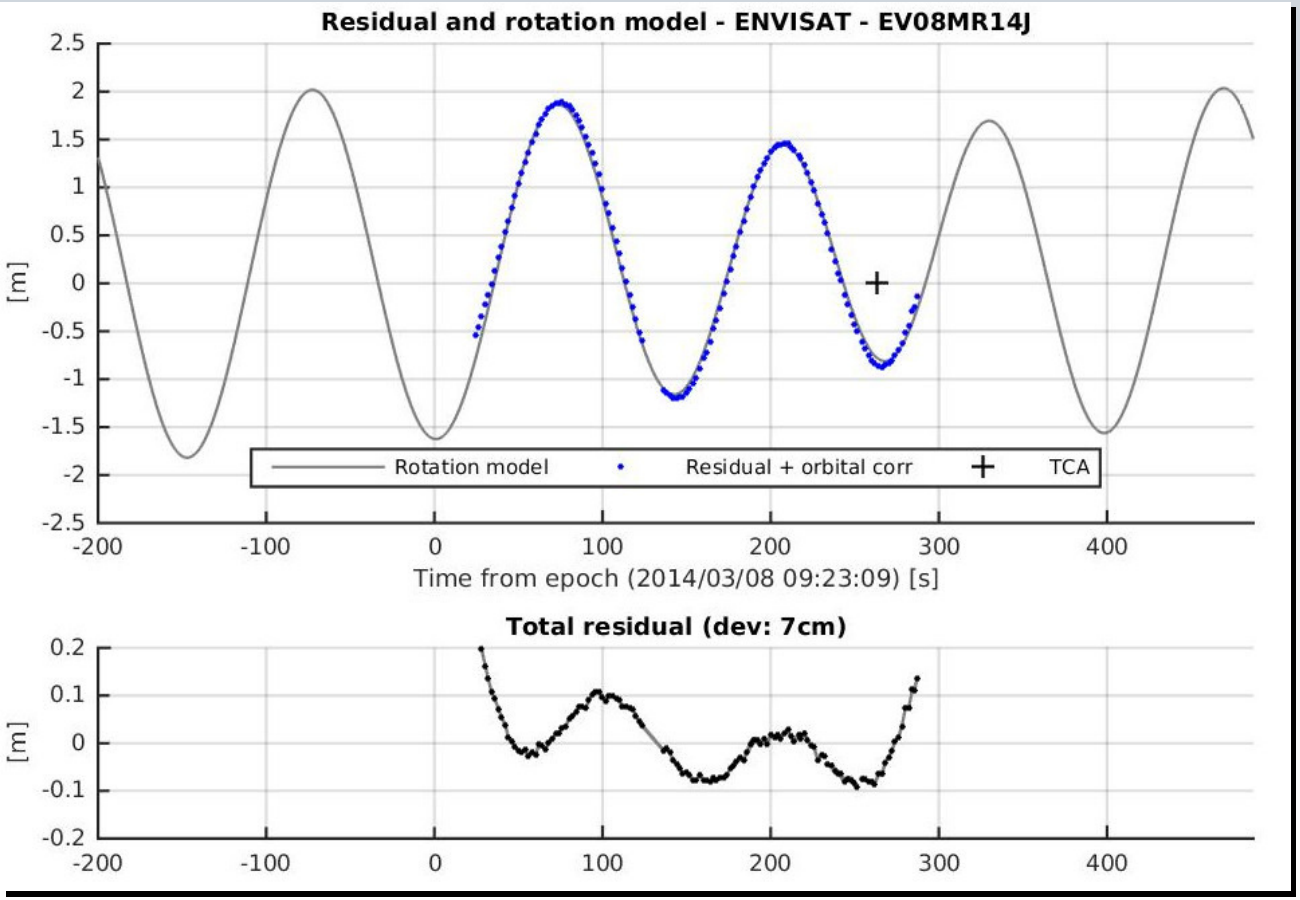




Envisat: Forward Modeling

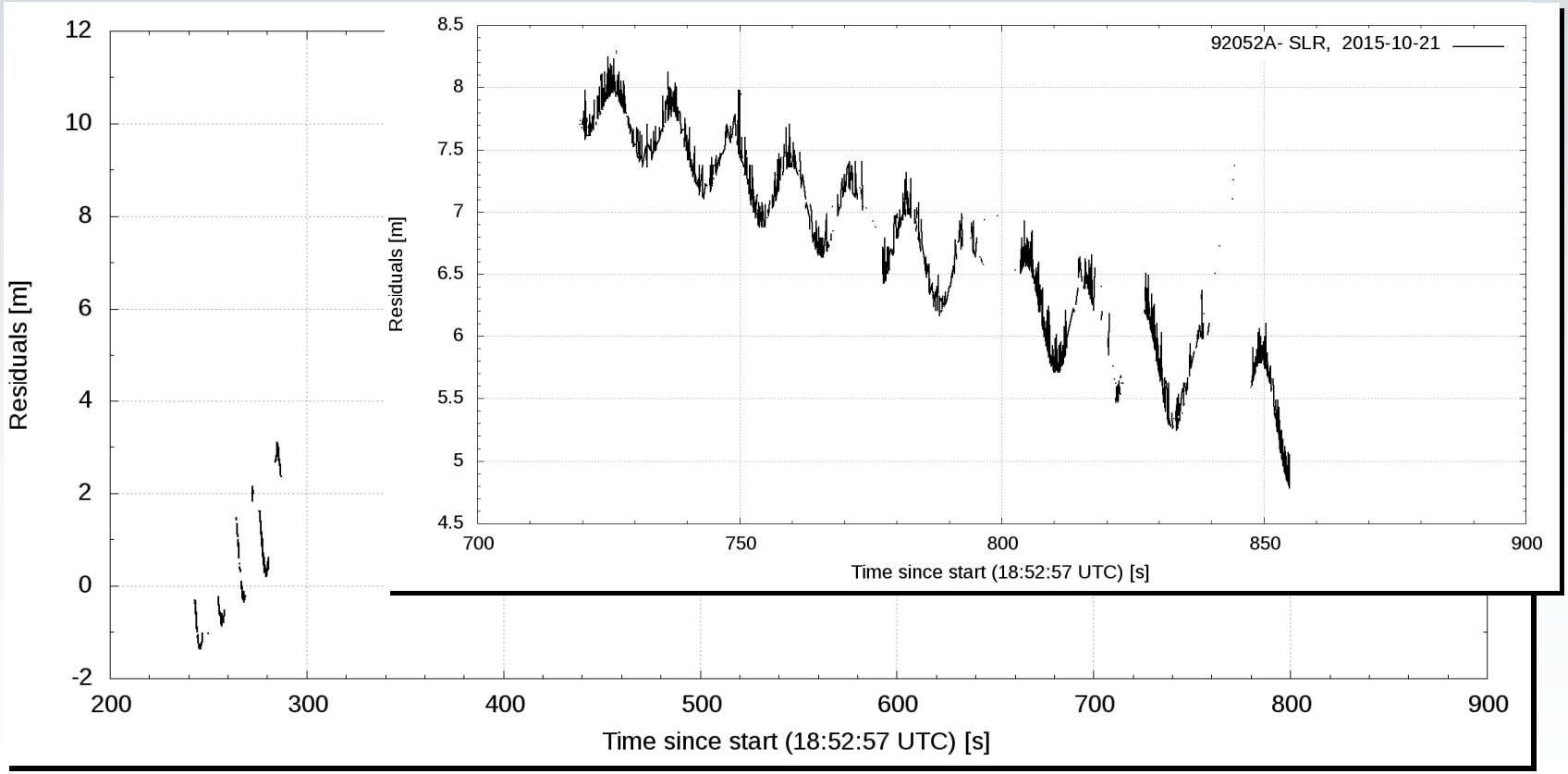
Refined values:

- Spin rate
- 2 angles (spin axis orientation)
- 2 fit parameters related to detrending



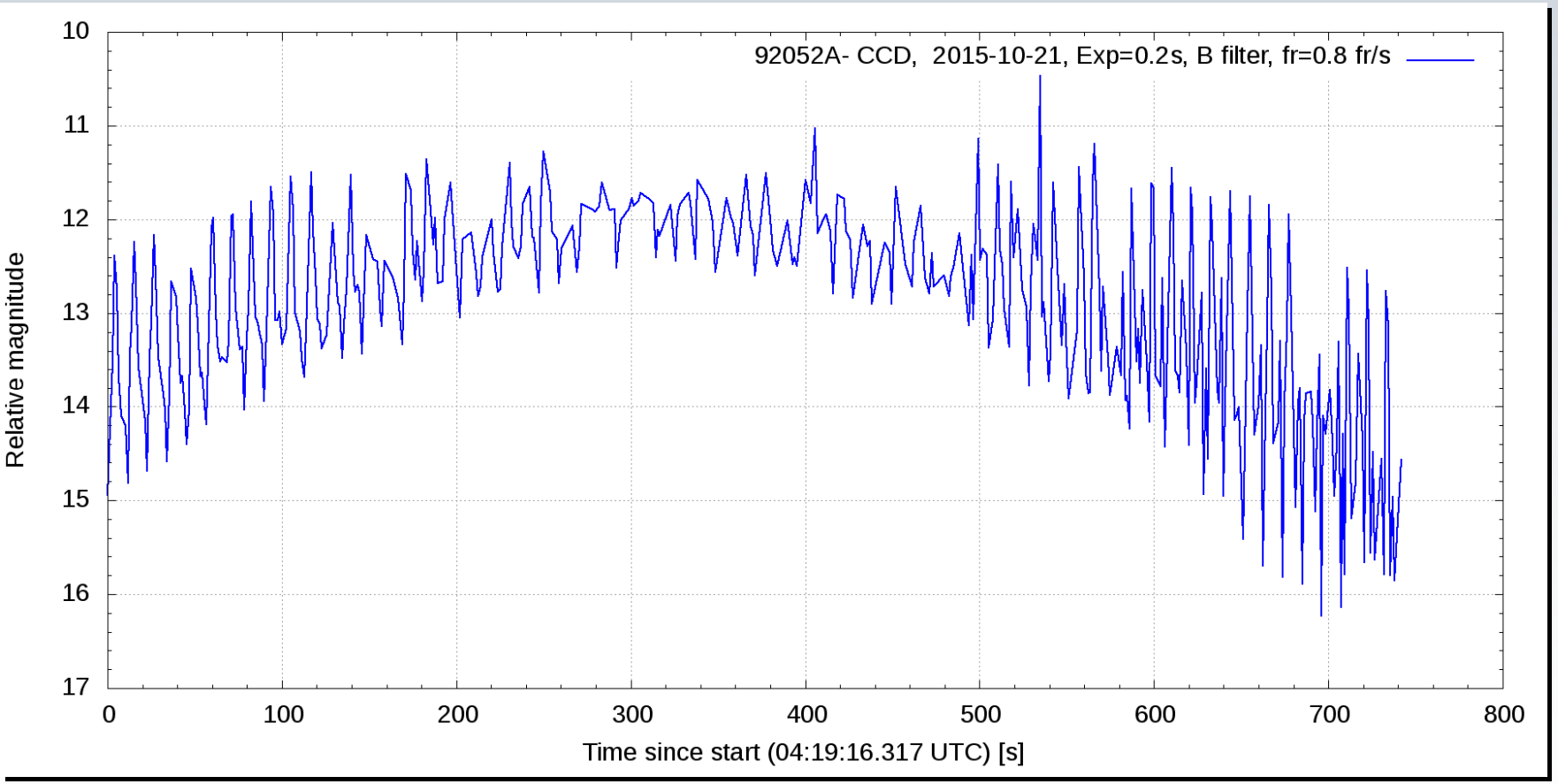
Topex

- Currently predictions from Graz/SDSG used
- for other targets own orbits – astrometry, ranges



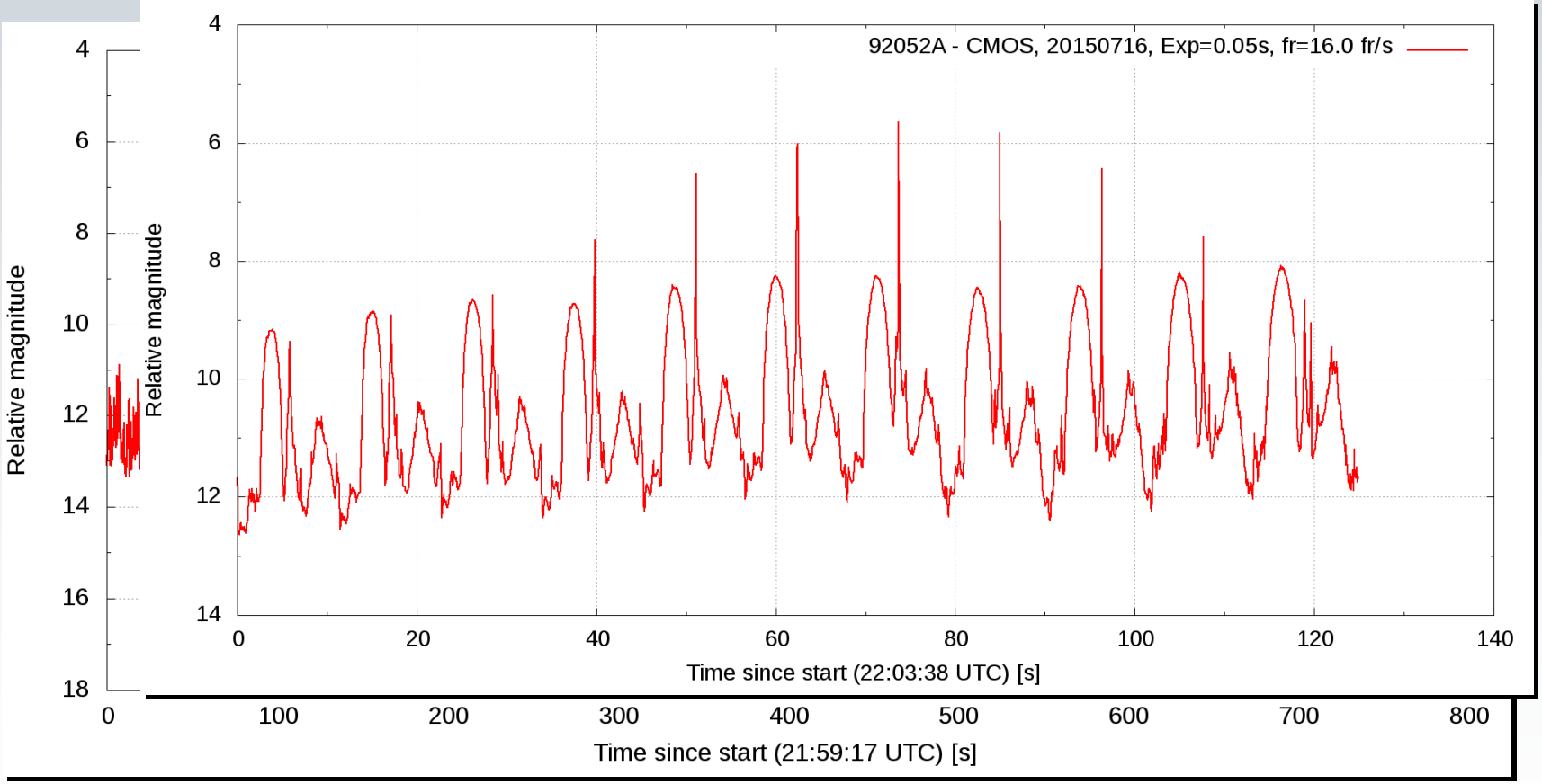
Topex

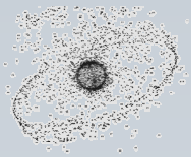
- Typical TOPEX light curve (full pass)



Topex

- CMOS TOPEX light curve, specular reflections visible





Summary

- Zimmerwald SLR observations of a series of cooperative targets
- Zimmerwald light curves
  - for >100 LEO objects
  - >1000 light curves from high-altitude r/b, s/c and fragments including objects with SLR retroreflectors
- SLR attitude state determination for Envisat (Topex, more to come)
  - physical model for «detrending»
  - fusion of SLR and optical data (attitude state and orbit)
  - forward modeling
- Validation/refinement of other attitude determination techniques, e.g. radar, ISAR, and optical to be used for non-cooperative targets