Advancing the orbit model for Galileo satellites during eclipse seasons

D. Sidorov, R. Dach,
L. Prange and A. Jäggi

Astronomical Institute, University of Bern

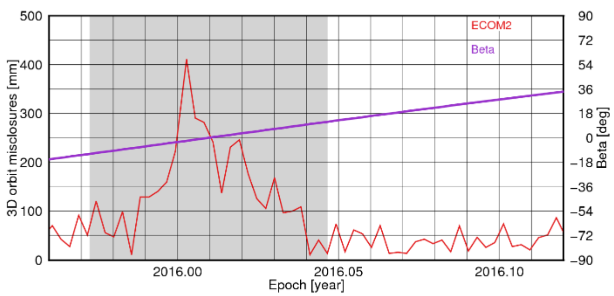
The EGU General Assembly 2018

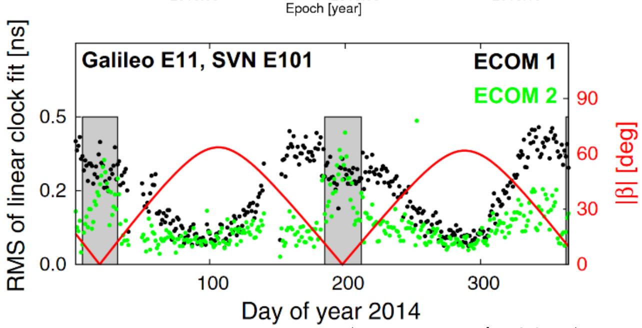
Vienna, 08–13 April 2018

Motivation

- Poor (Galileo) orbit modelling during eclipse seasons using Empirical CODE Orbit Model (ECOM2; Arnold et. al., 2015):
  - elevated orbit misclosures at day boundaries;
  - artifacts in SLR residuals at low β angles;
  - elevated RMS of linear clock fits during eclipses.

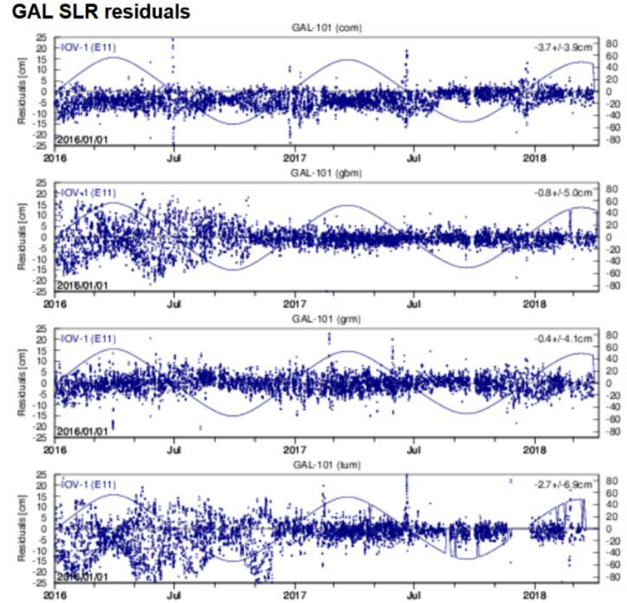
Gal E11





(Prange et al., 2017)

GAL SLR residuals



(http://mgex.igs.org/analysis/slrres_GAL.php)

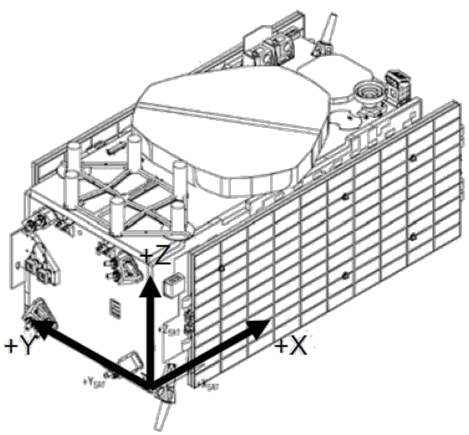
Possible reasons

- Incorrect modelling of satellite attitude (nominal instead of the “true”).
  - Corrected thanks to the metadata of Galileo IOV and FOC satellites published by GSA.
- Insufficient SRP model parameterization.
  - More demanding to the modelling due to low satellite weight, but reasonably solved by ECOM2.
- Thermal effects are not fully absorbed (e.g., during eclipse seasons).
  - All empirical (SRP) parameters are switched off in eclipses.

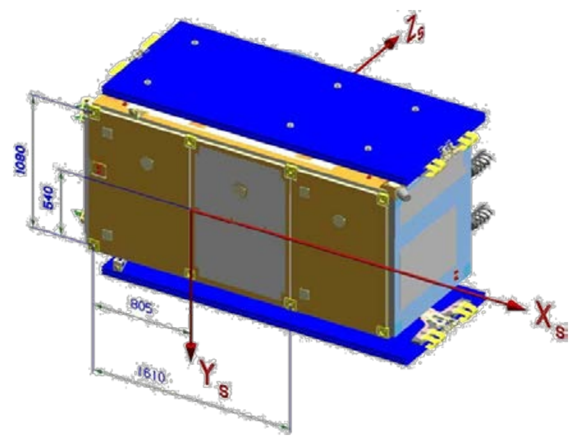
Galileo Satellites

- From the metadata* published by GSA:
  - thermal radiators on +X, +Y, -Y, -Z (FOC only) faces of the satellite body;
  - Galileo satellite mass ~700 kg.

IOV



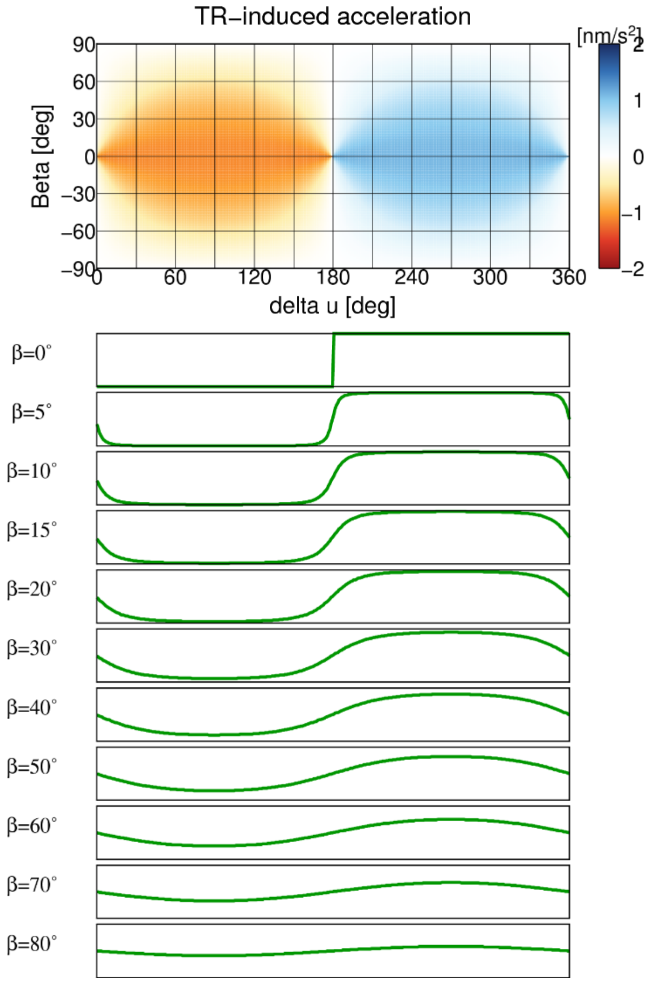
FOC

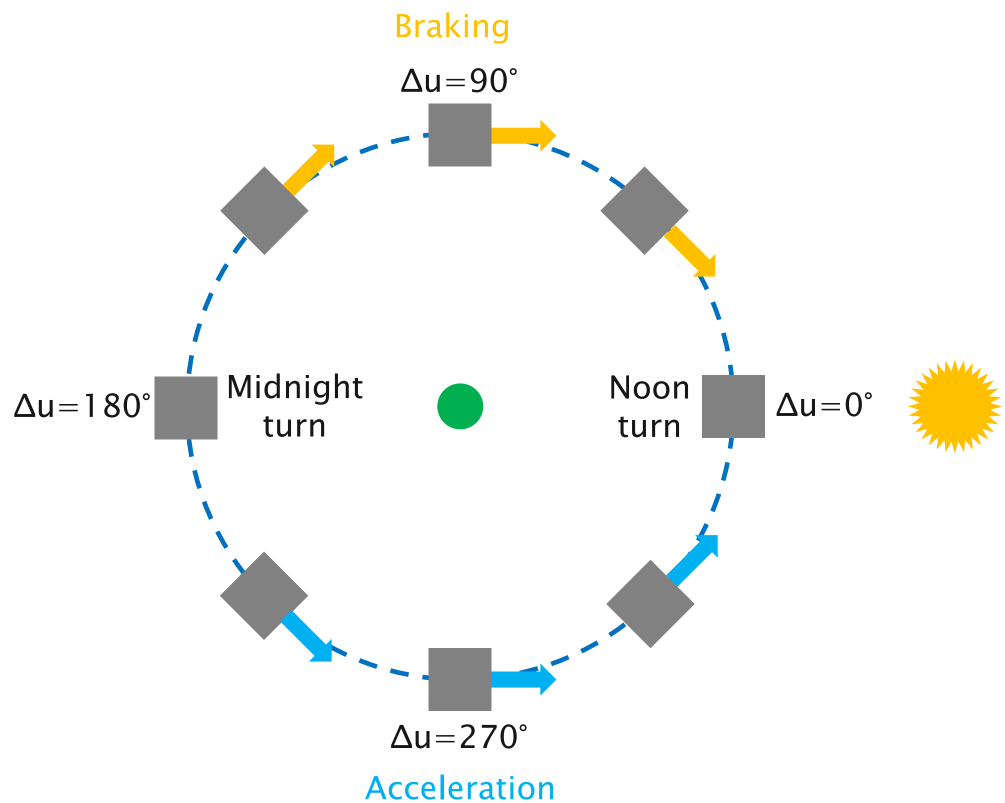


(*) https://www.gsc-europa.eu/support-to-developers/galileo-satellite-metadata

Simulations of +X radiator effects

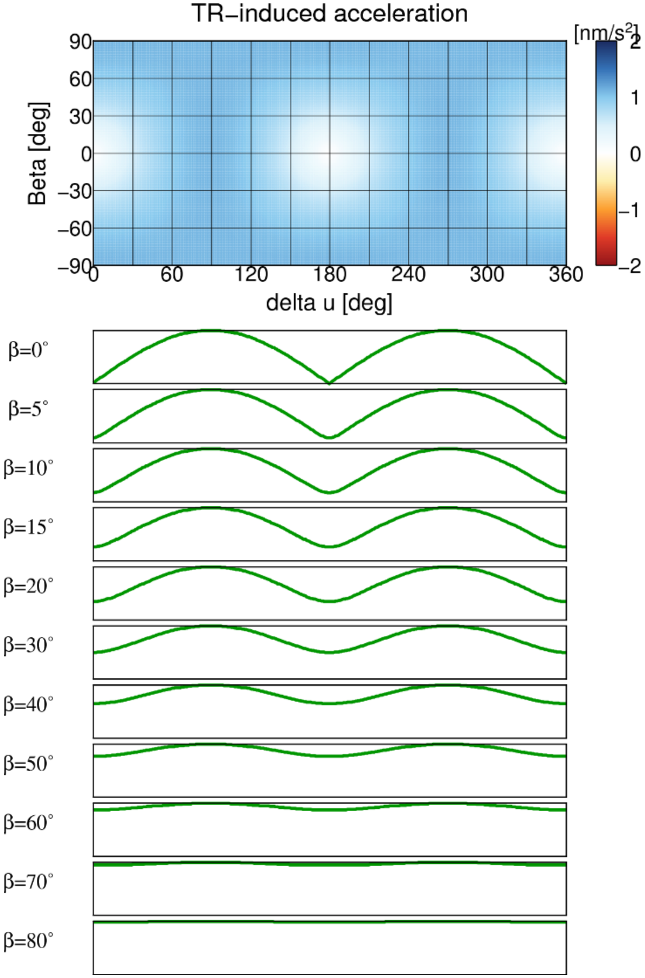
Along–track component





Additional terms in ECOM2 (D1S)

Projection on ECOM2 *D* axis (satellite–Sun)



To be accounted by ECOM2:

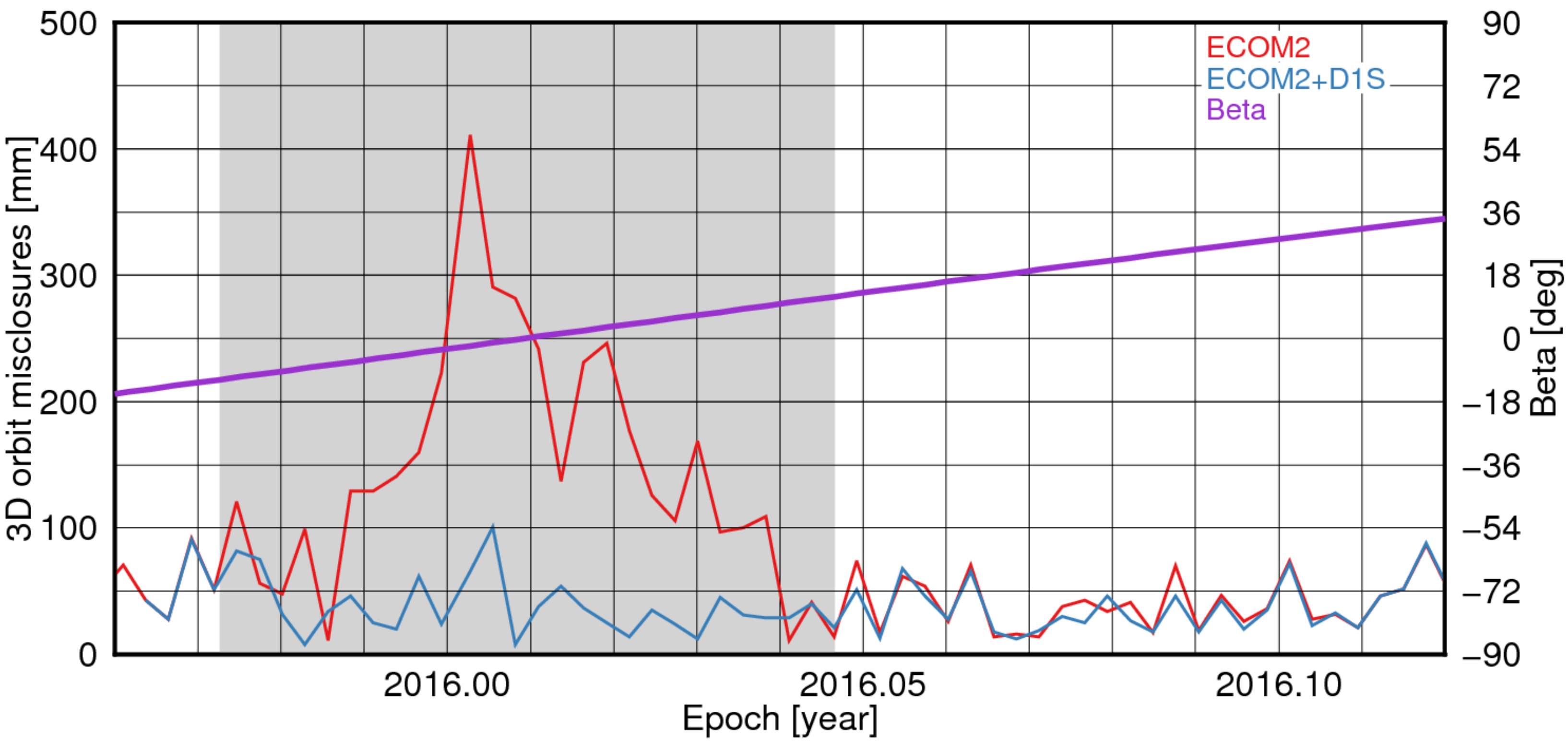
- for low β angles requires a once–per–rev sine term in *D*,
- for high β angles a constant term in *D* is sufficient.

Actions taken:

- introduced D1S for $|\beta|<12°$ for Galileo satellites,
- reprocessed the data from one eclipse season for Galileo.

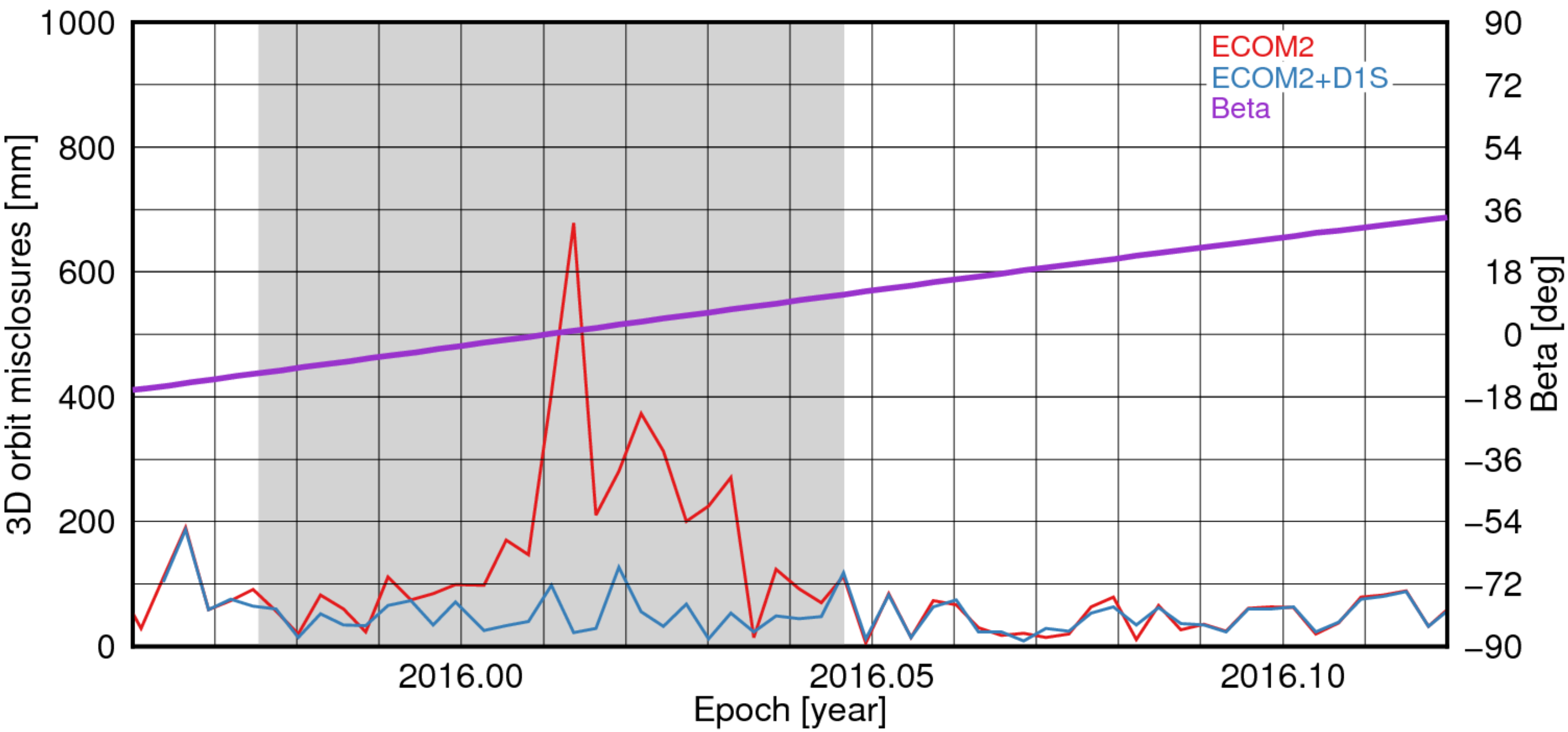
Results: Orbit Misclosures

- Orbit misclosures for E11 during eclipse phase in Dec 2015 – Jan 2016:



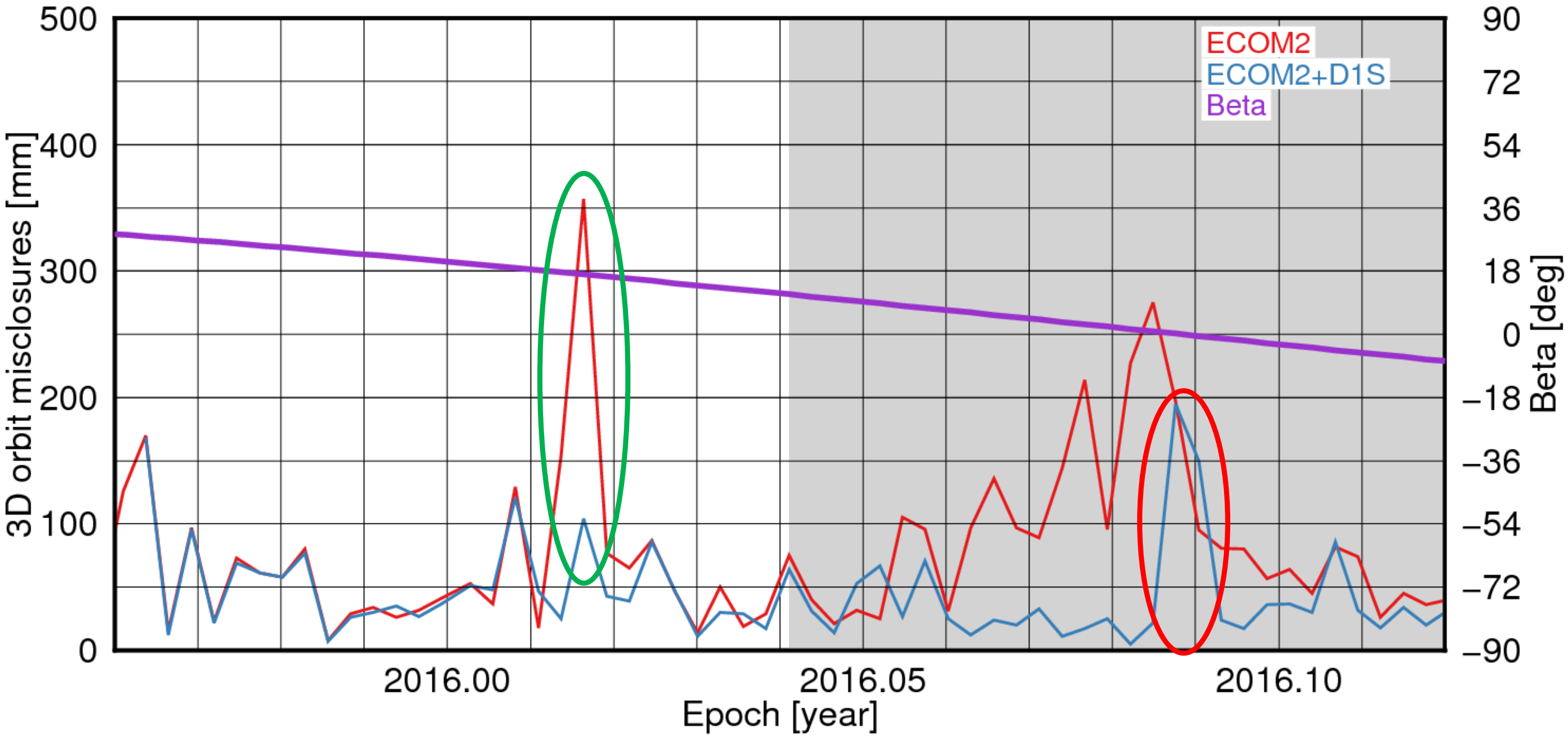
Results: Orbit Misclosures

- Orbit misclosures for E26 during eclipse phase in Dec 2015 – Jan 2016:



Results: Orbit Misclosures

- Orbit misclosures for E30 during eclipse phase in Jan – Feb 2016:



Results: SLR Residuals

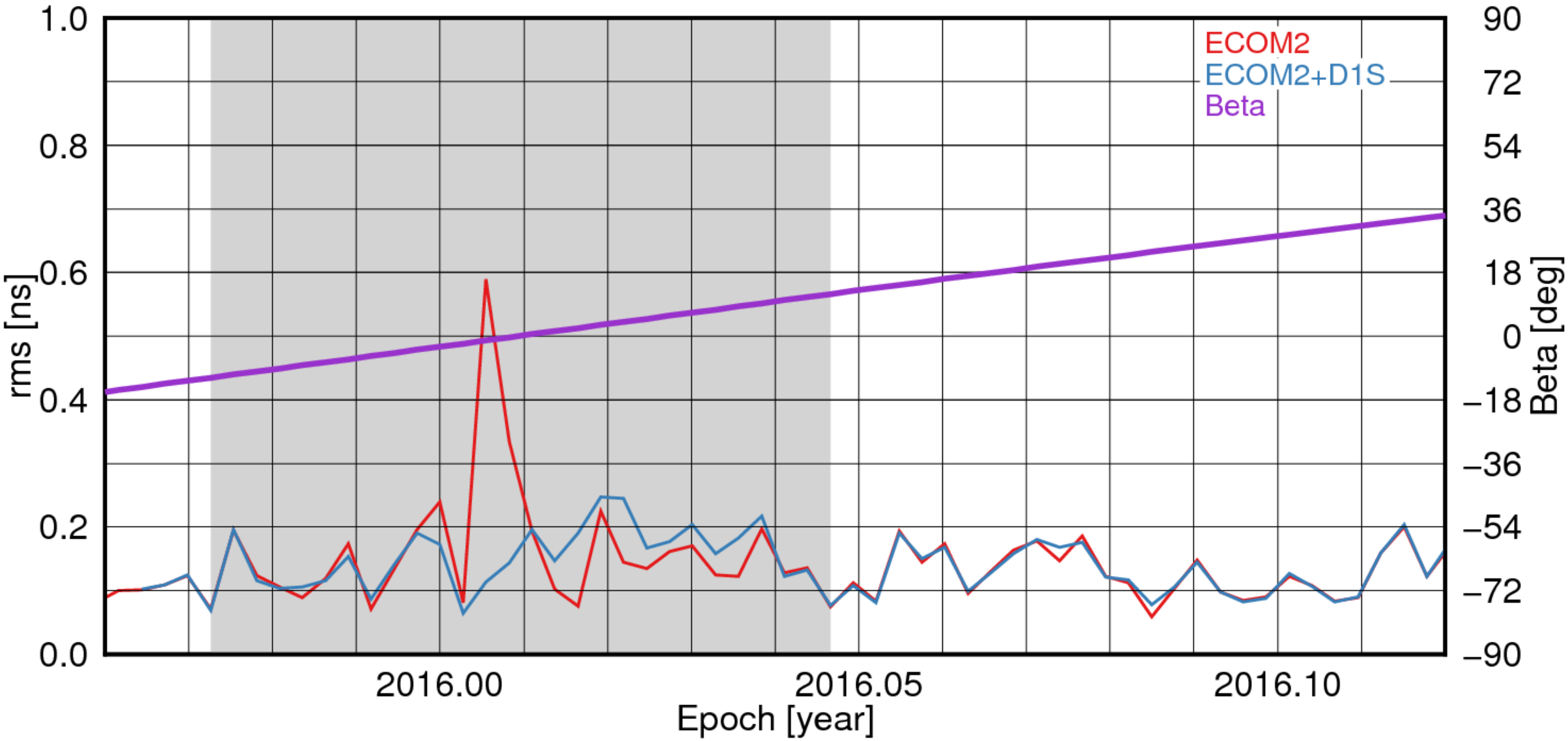
Summary on the SLR residuals:

- **the pattern is left unchanged (shrinking at orbit noon and expansion at orbit midnight);**
- **the scatter of the SLR residuals is reduced during eclipse phases in Dec 2015 – Feb 2016:**

	ECOM2	ECOM2+D1S
IOV	−12.7 ± 57.3	−16.7 ± 53.8
FOC	−9.7 ± 49.0	−11.5 ± 46.7
IOV+FOC	−10.6 ± 52.3	−13.4 ± 49.6

Results: Satellite Clocks

- RMS of the linear clock fit for E11 in Dec 2015 – Feb 2016:

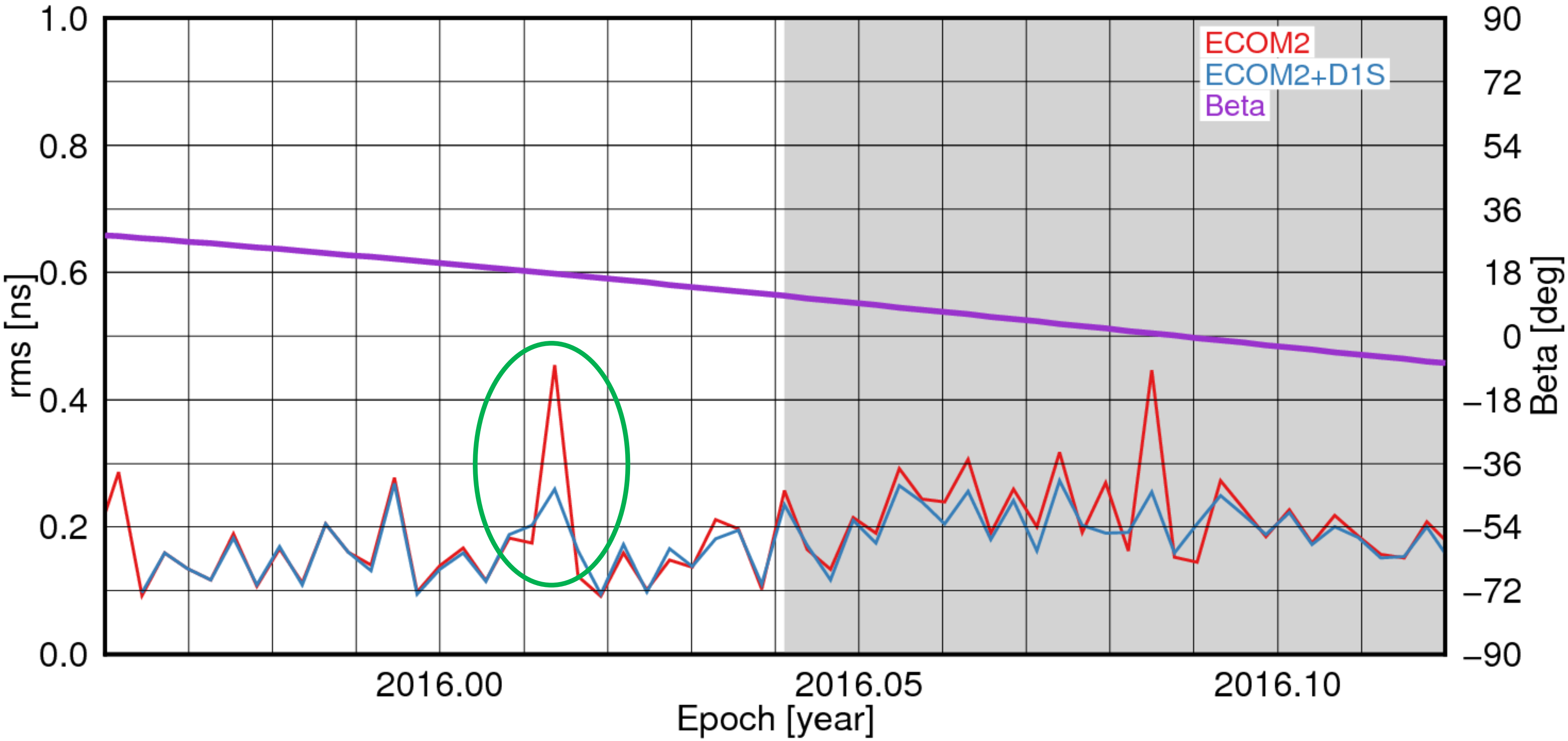


D. Sidorov et. al.: Advancing the orbit model for Galileo satellites during eclipse seasons
The EGU General Assembly 2018, Vienna, 08–13 April 2018

 Astronomical Institute University of Bern

Results: Satellite Clocks

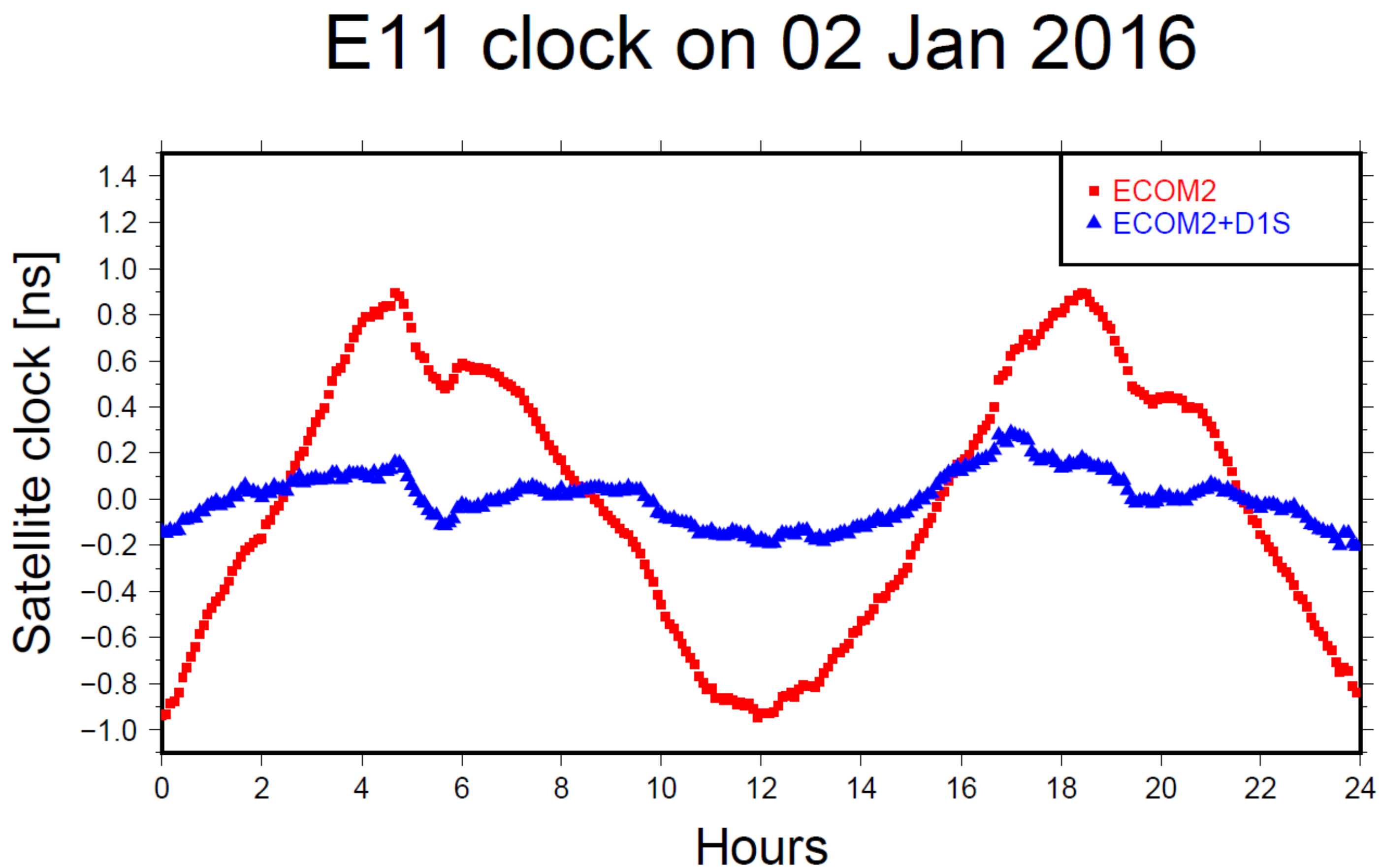
- RMS of the linear clock fit for E30 in Dec 2015 – Feb 2016:



D. Sidorov et. al.: Advancing the orbit model for Galileo satellites during eclipse seasons
The EGU General Assembly 2018, Vienna, 08–13 April 2018

Results: Satellite Clocks

- Estimated satellite clocks (extreme case):



Conclusion

- The recently published Galileo metadata shed light on how to model shadow crossings of the satellites, e.g.,
  - attitude control,
  - complete antenna correction models,
  - surface properties.
- Details on the internal temperature management of the satellites are appreciated.
- The unaccounted thermal effects may significantly deteriorate the estimated orbit.
- Addition of once-per-rev sine term in D to ECOM2 during eclipses significantly improves orbit modelling of Galileo satellites (should be added only for small β angles).