SMOS solar flux product: Performance and applications to Space Weather

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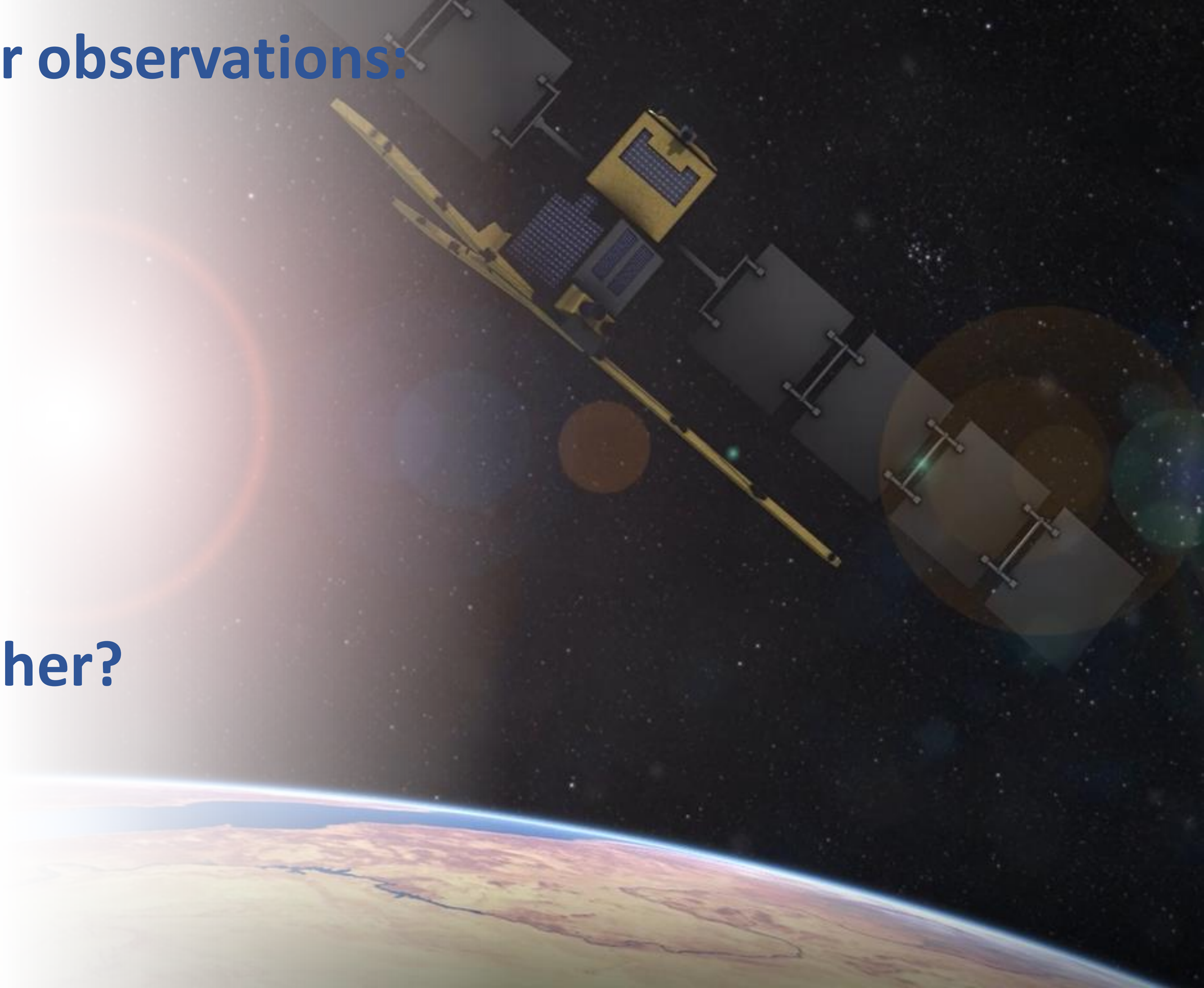
For the SMOS Flares Consortium

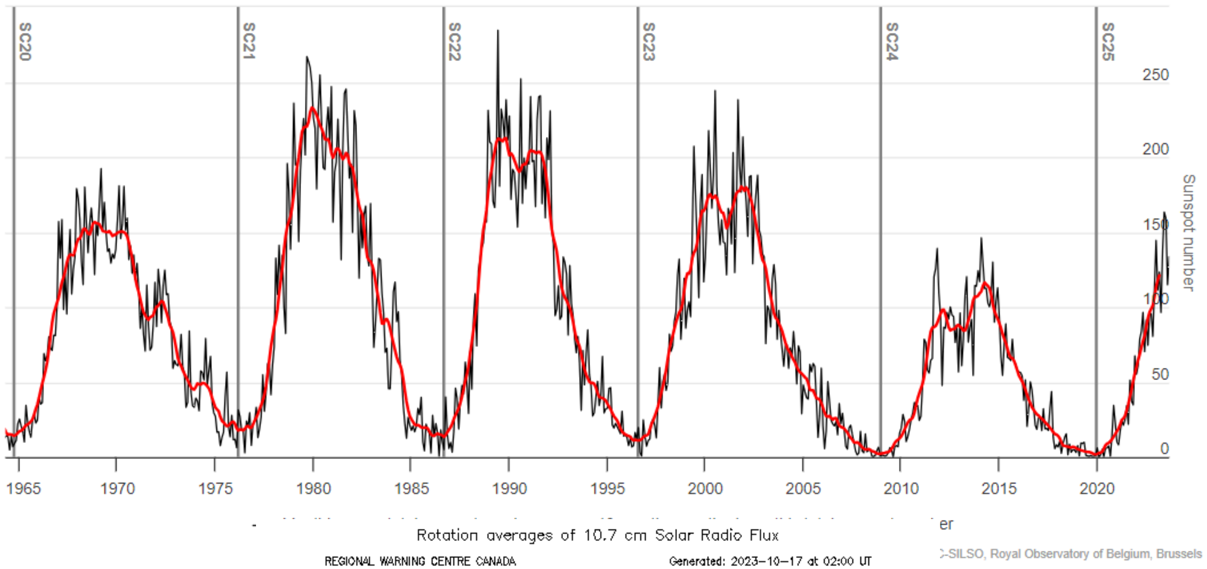
SMOS 1.4 GHz solar observations:

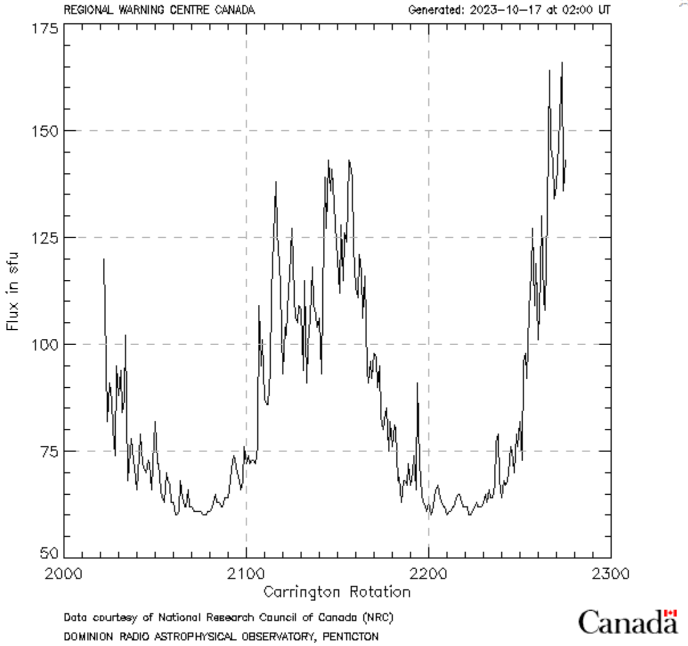
- How good?
- What for?
- Why even bother?

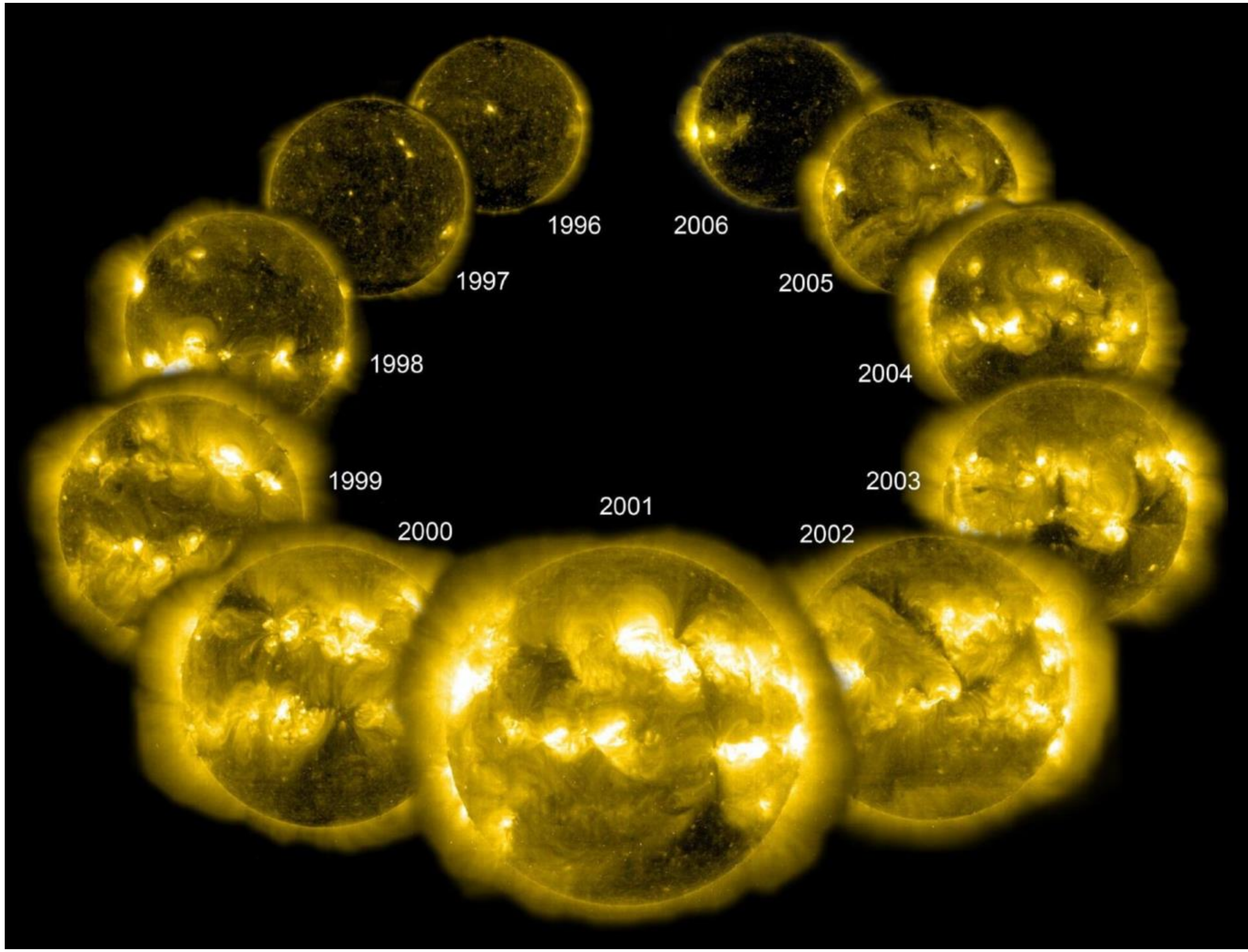


Solar processes observed by SMOS

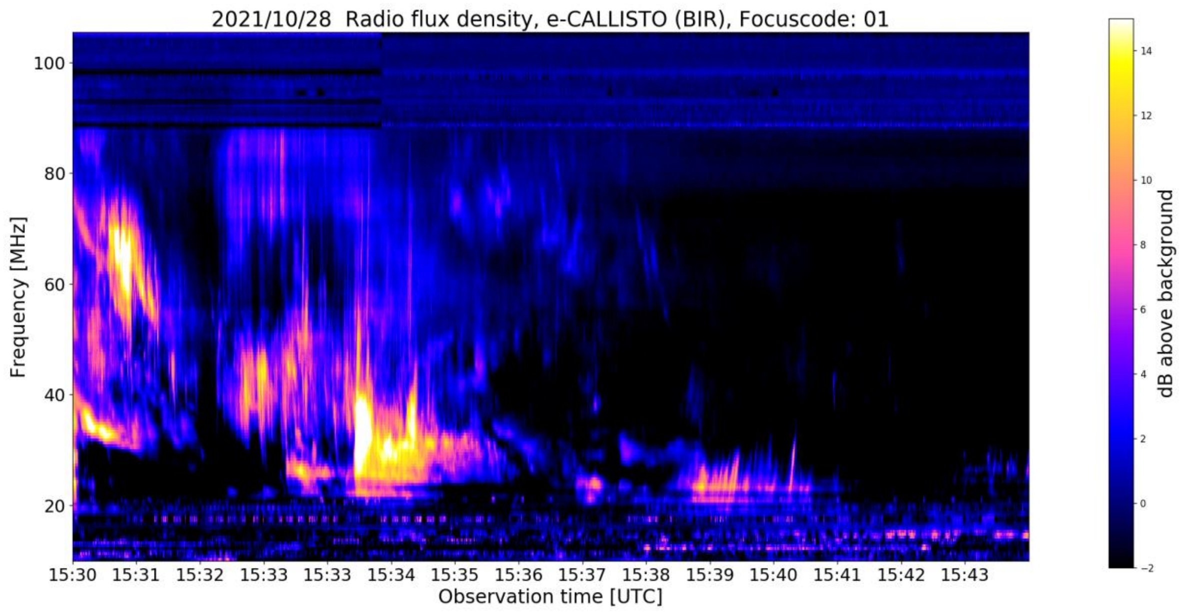
Solar activity cycle

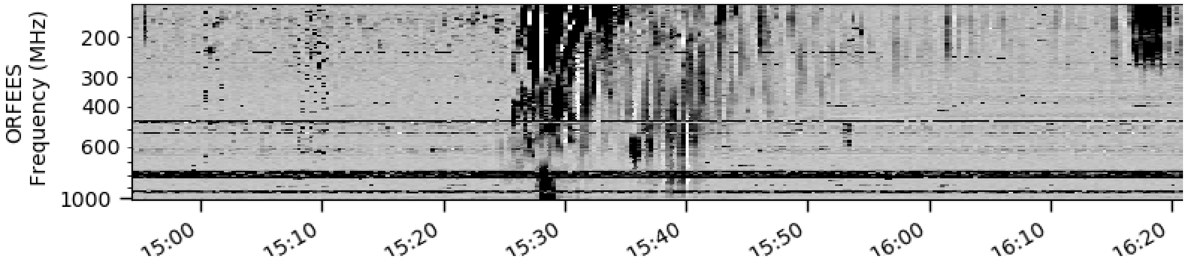


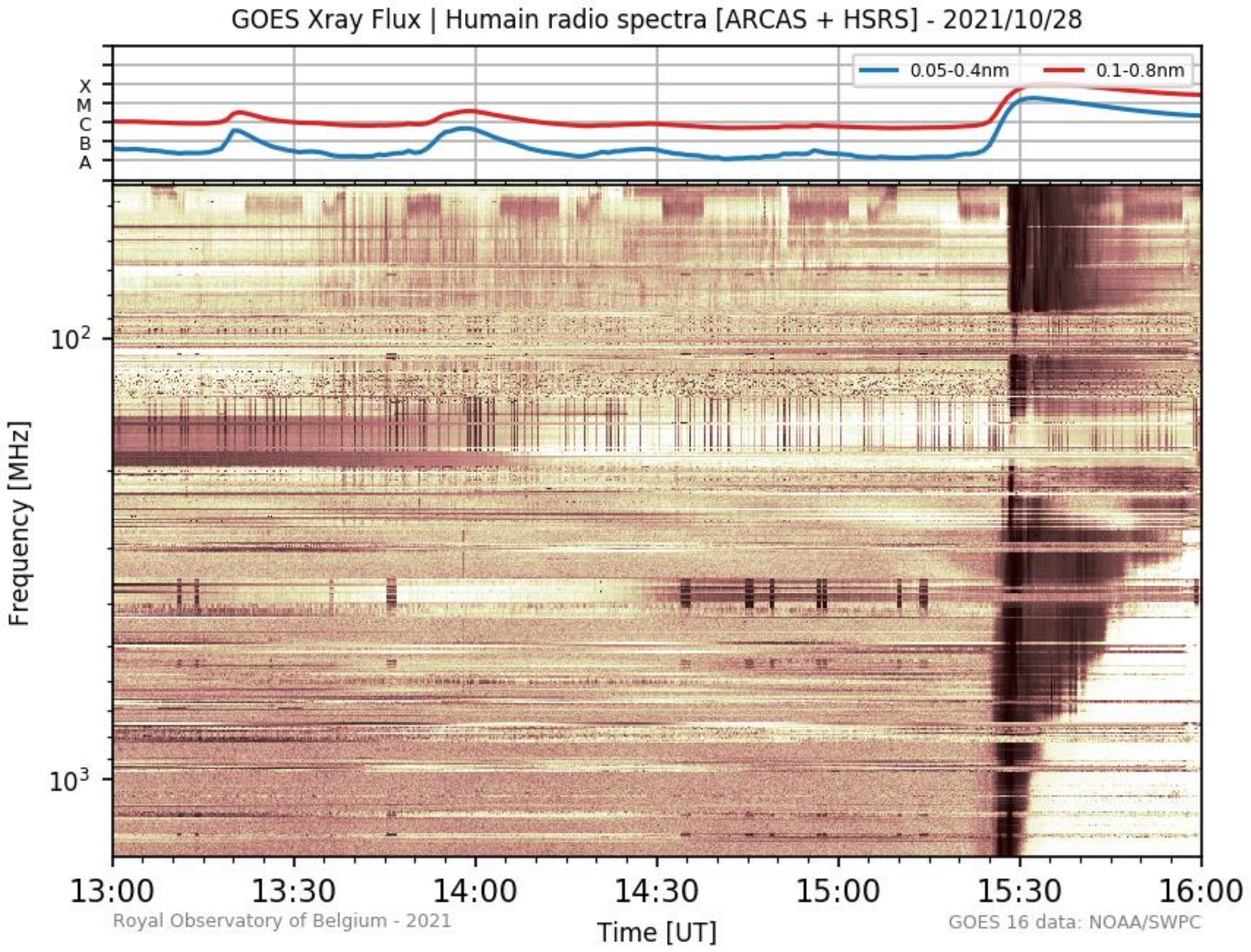




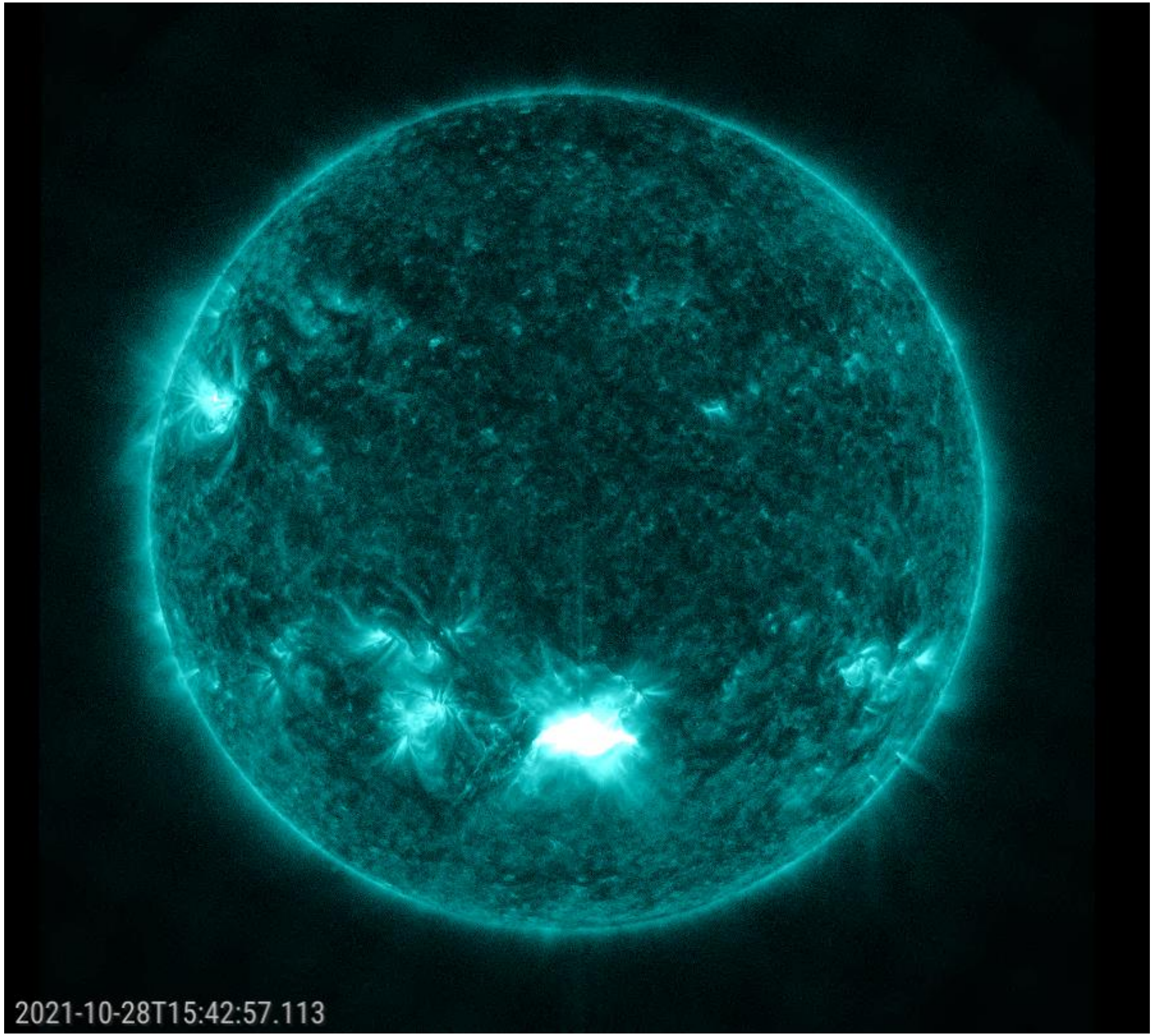
Solar radio bursts (SRB)

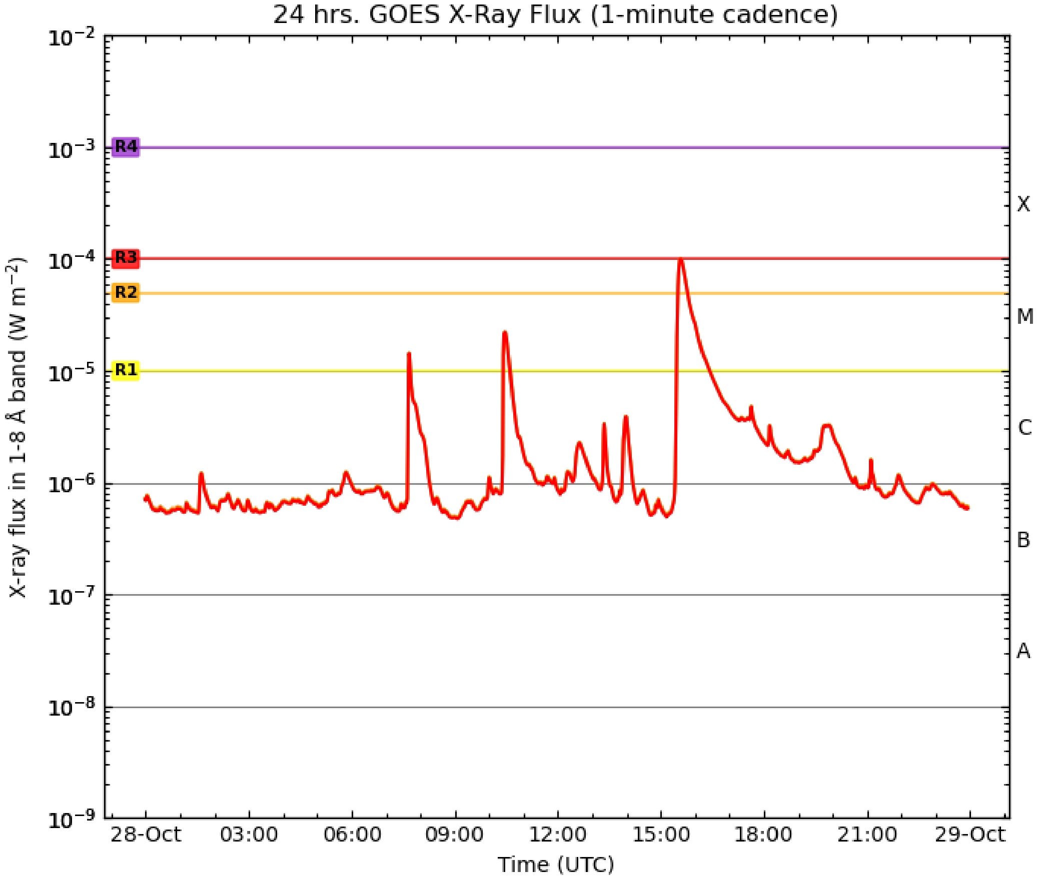




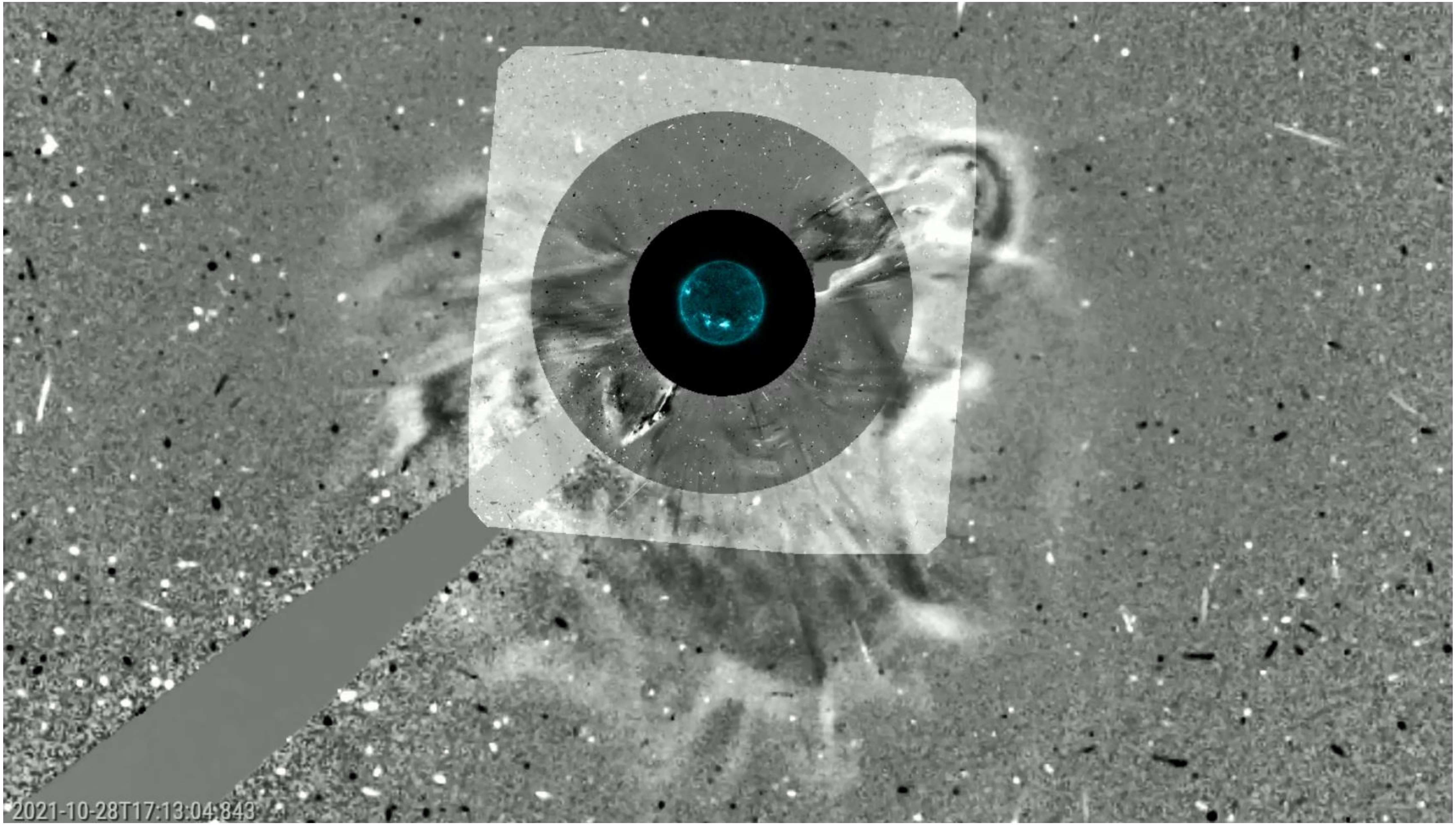


Solar flares

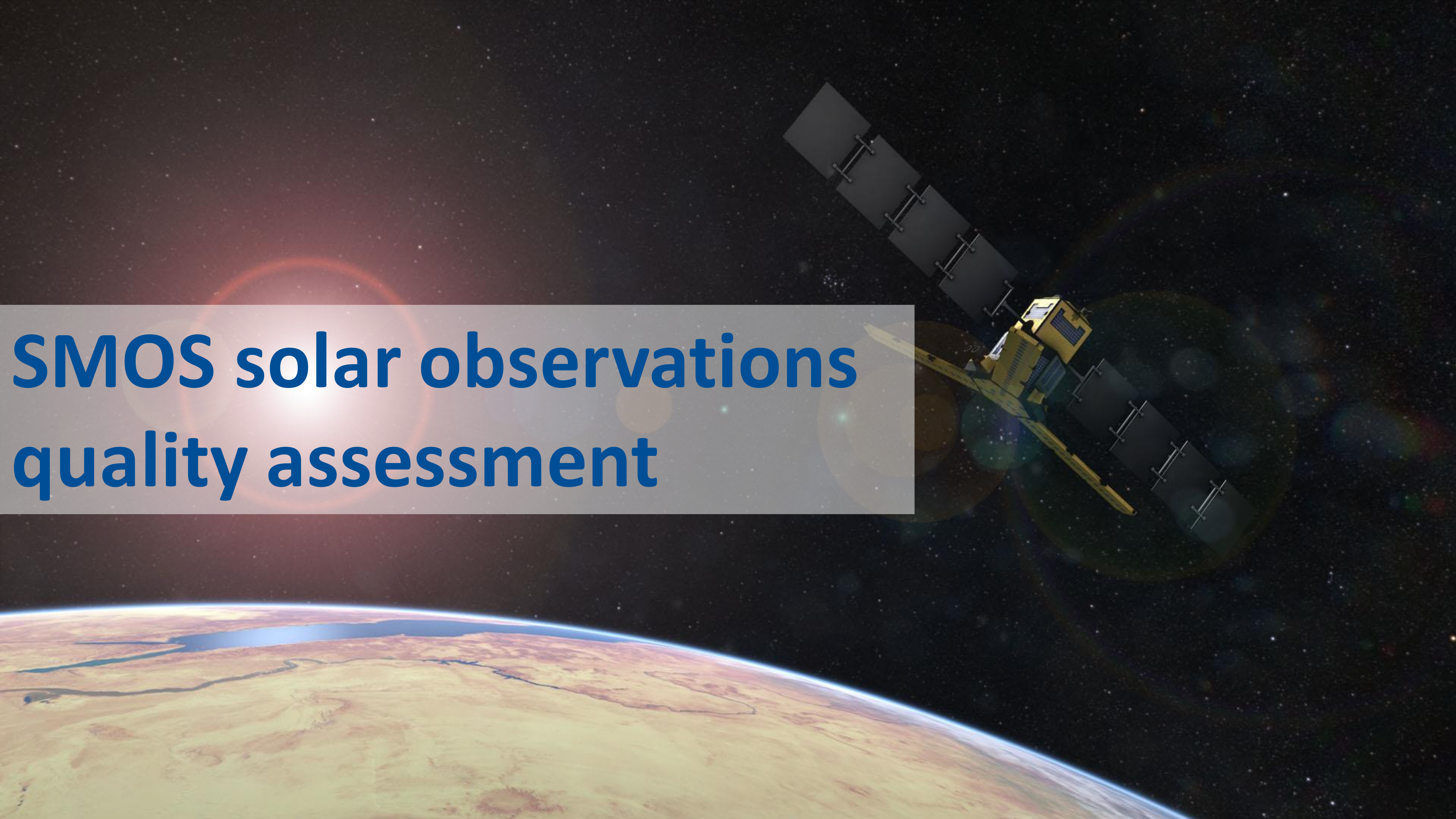




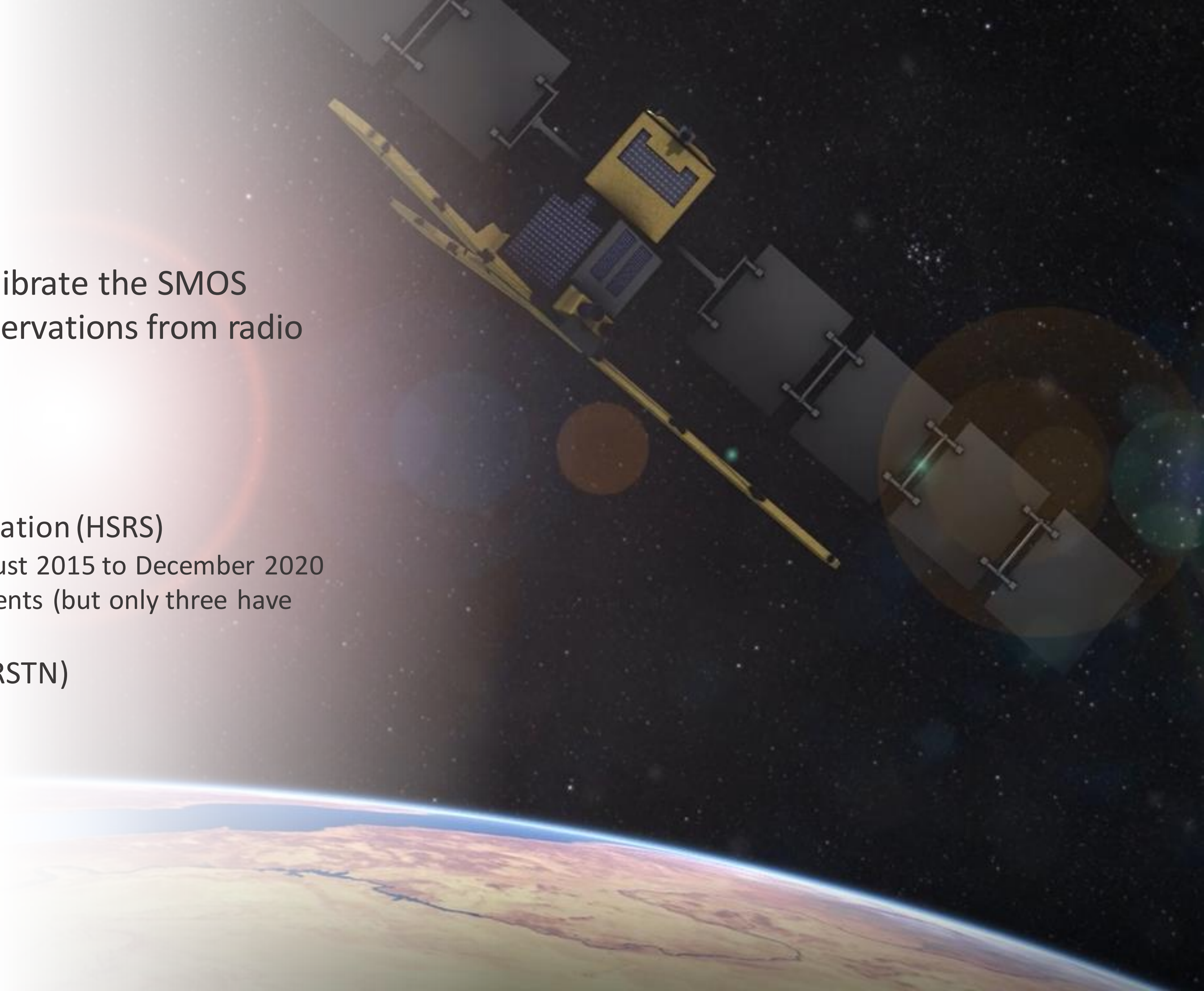
Coronal mass ejections (CME)



SMOS solar observations quality assessment



Data calibration



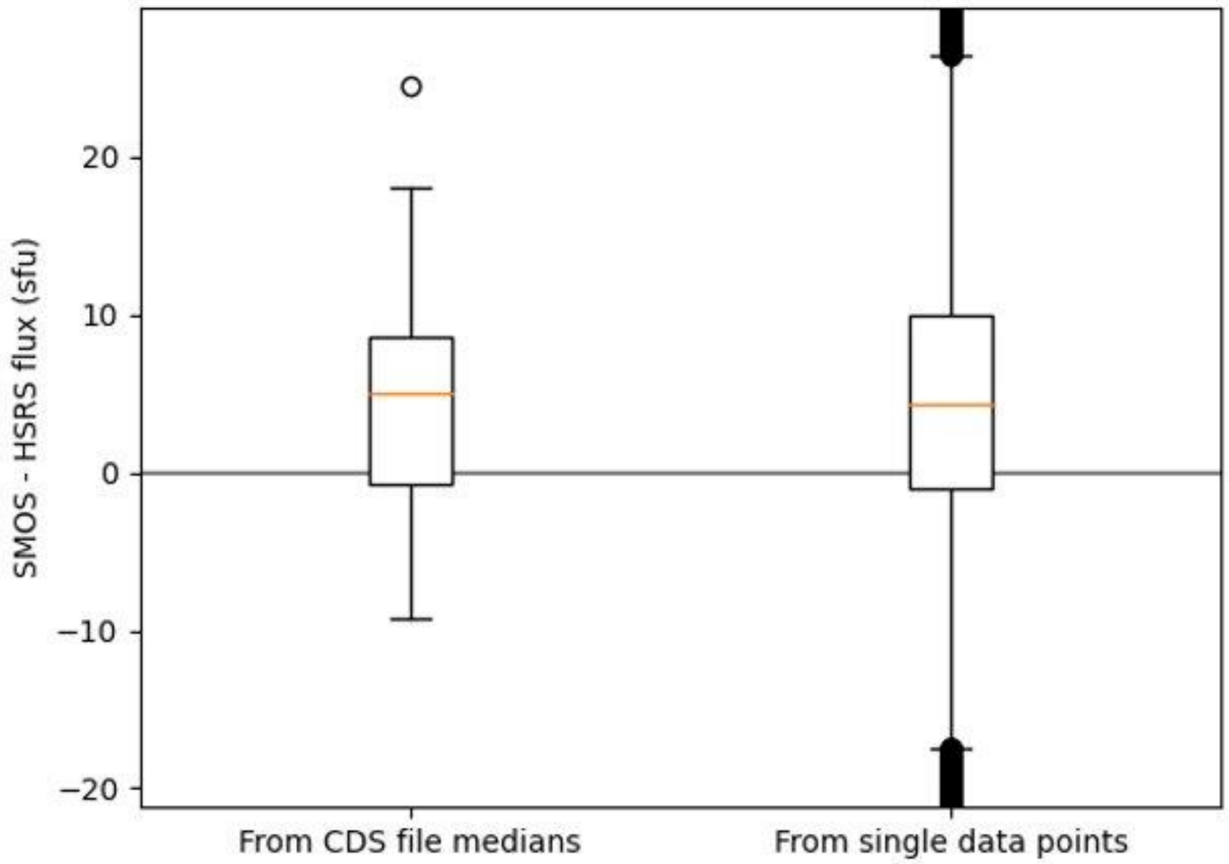
Objective:

Compare and (if necessary) recalibrate the SMOS observations with calibrated observations from radio telescopes

Reference ground data

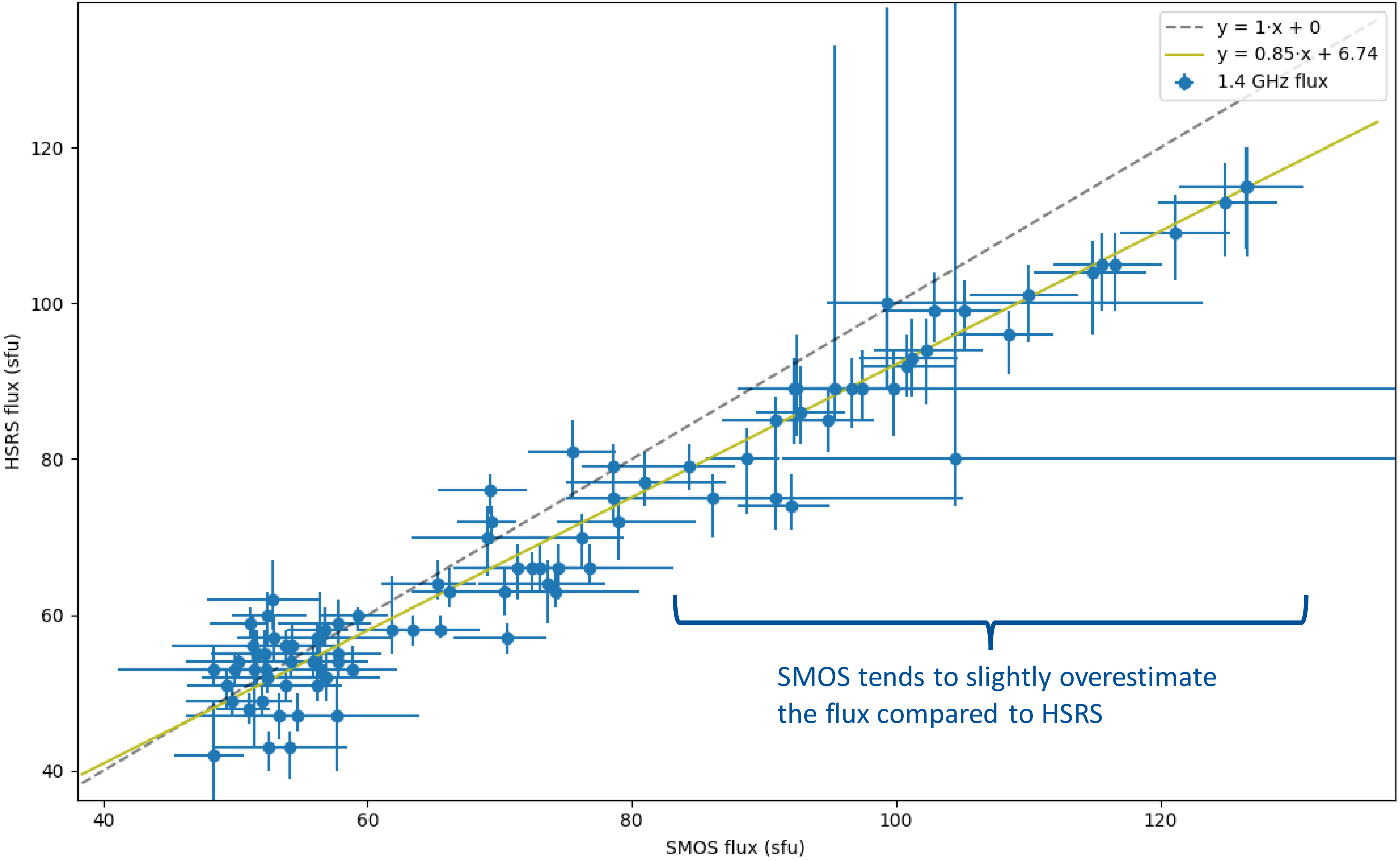
- Humain Solar Radioastronomy Station (HSRS)
    - Background emission from August 2015 to December 2020
    - SRBs observed by both instruments (but only three have intensity > 5000 sfu)
- Radio Solar Telescope Network (RSTN)

General discrepancies between SMOS and HSRS



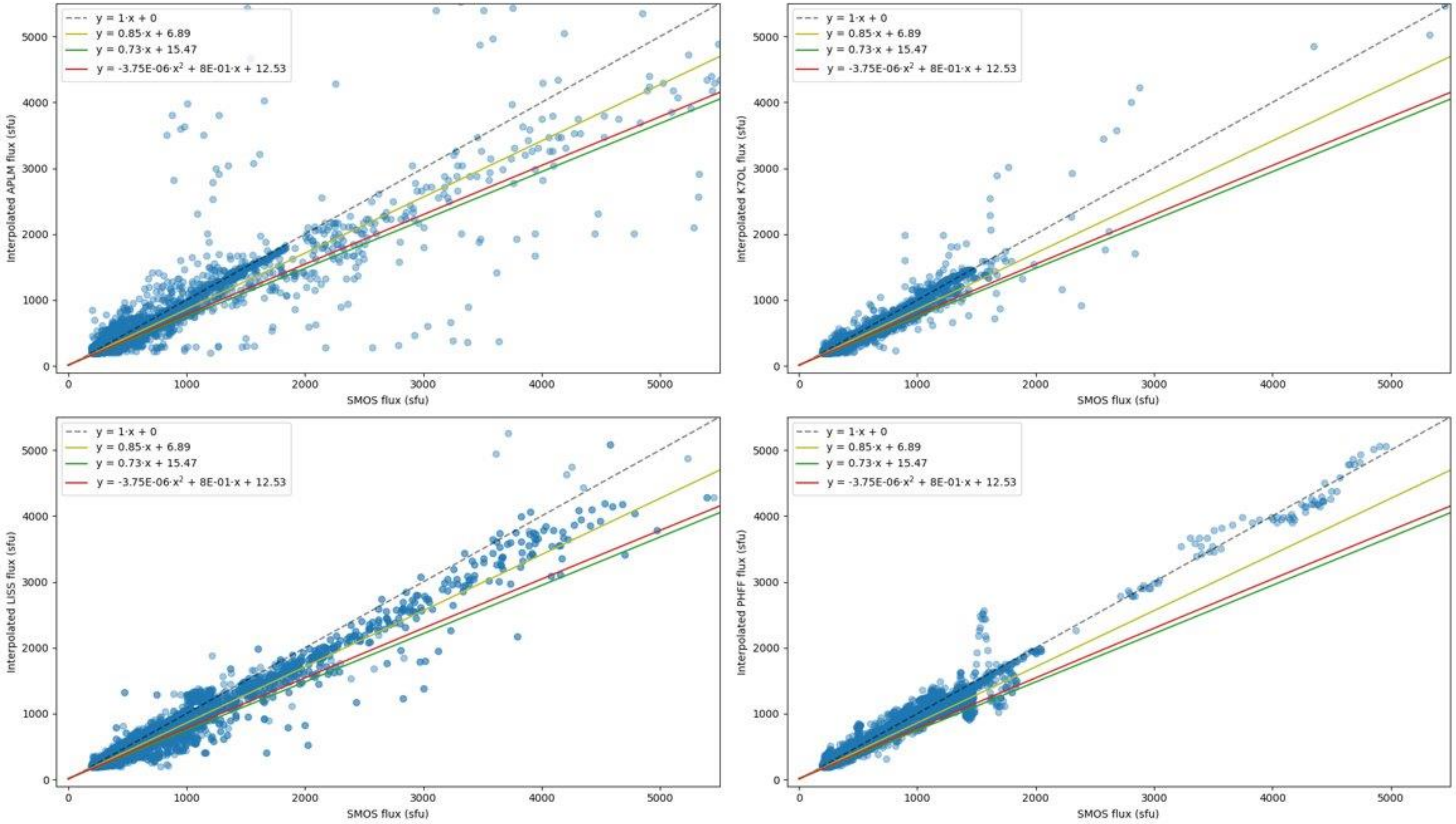
Very small differences on average (4-5 sfu)

SMOS vs HSRS depending on flux level

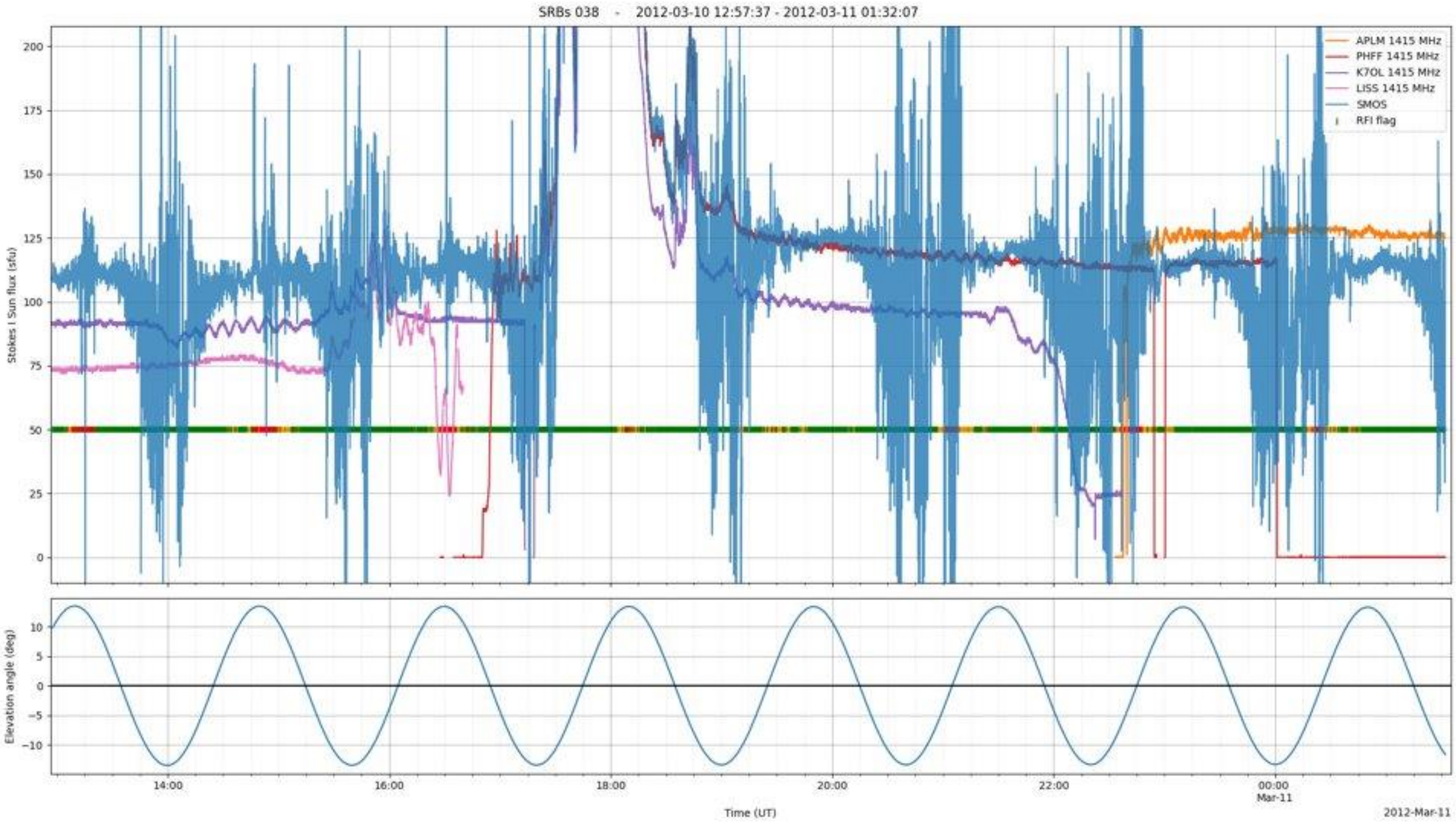


SMOS tends to slightly overestimate the flux compared to HSRS

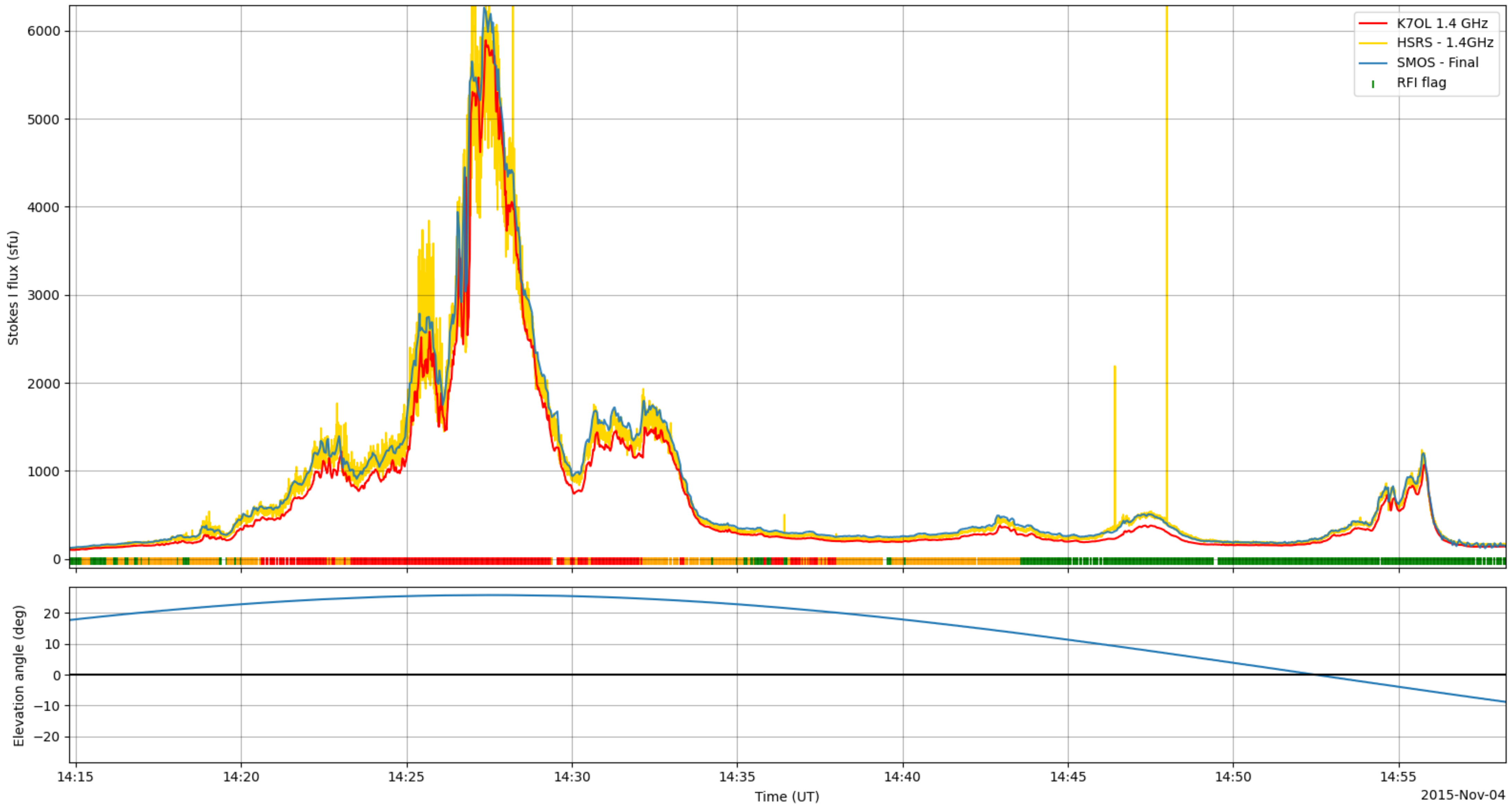
SMOS vs RSTN depending on flux level



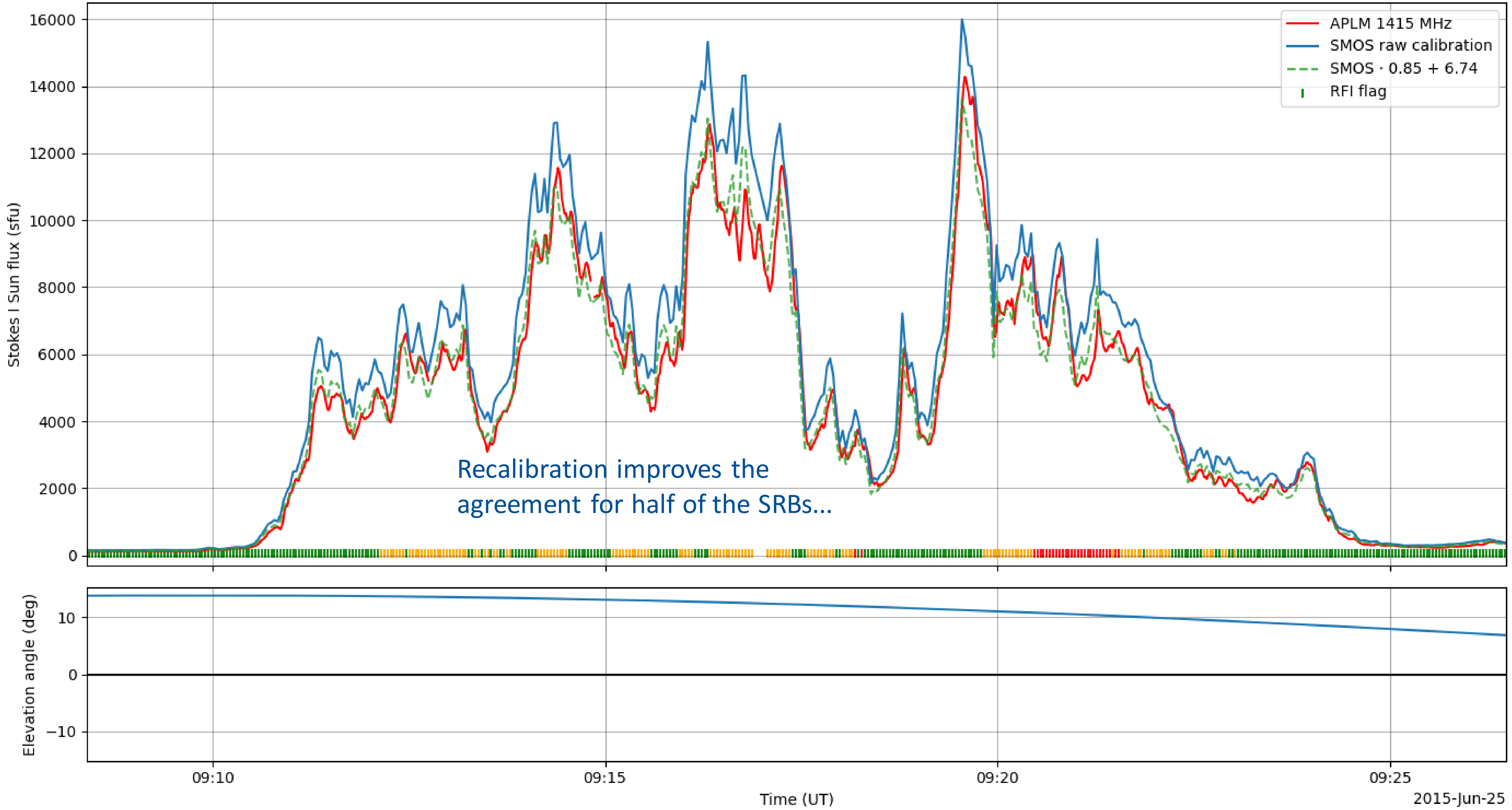
SMOS vs the 4 RSTN stations



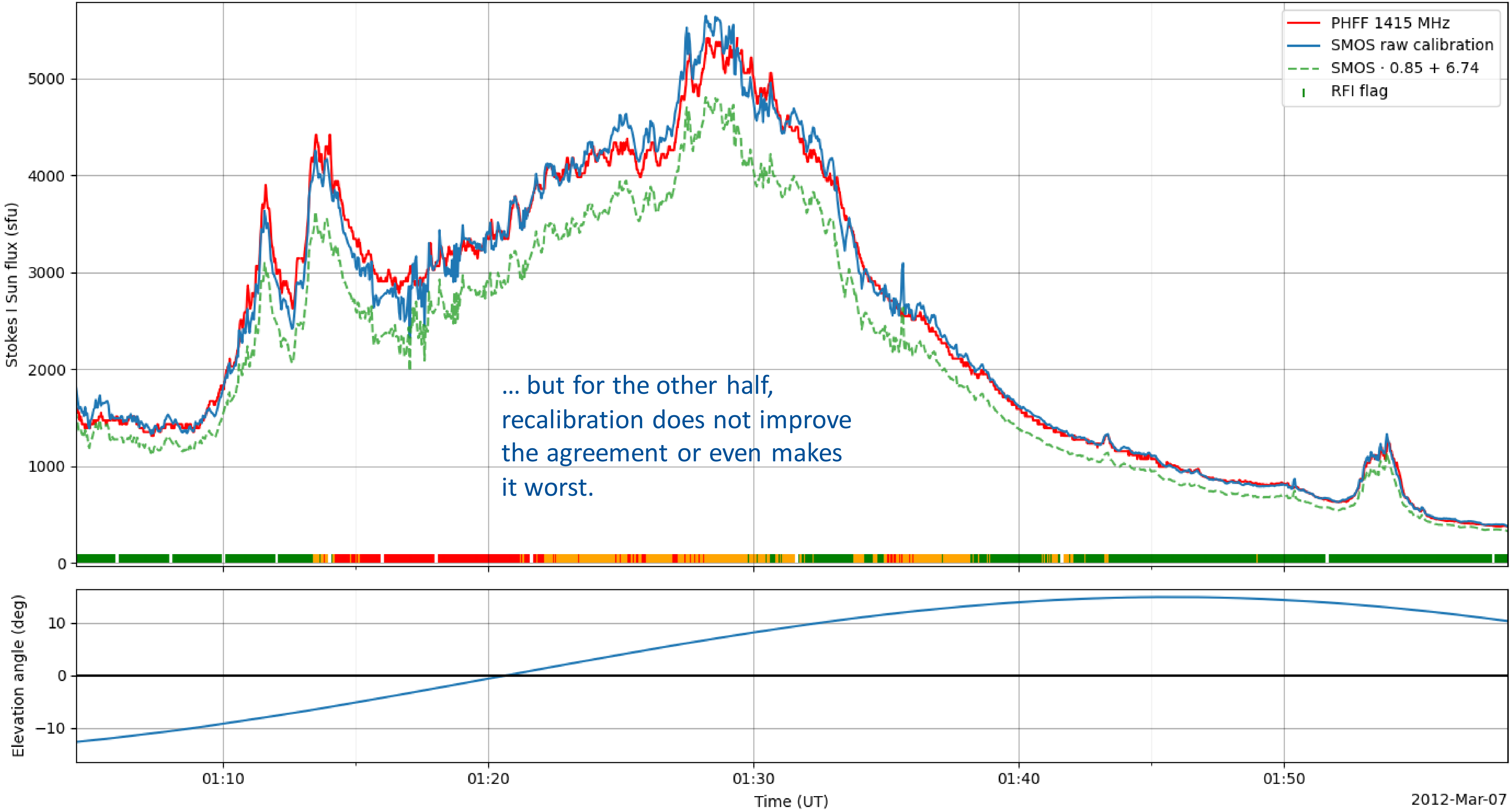
SMOS vs HSRS vs RSTN – Example



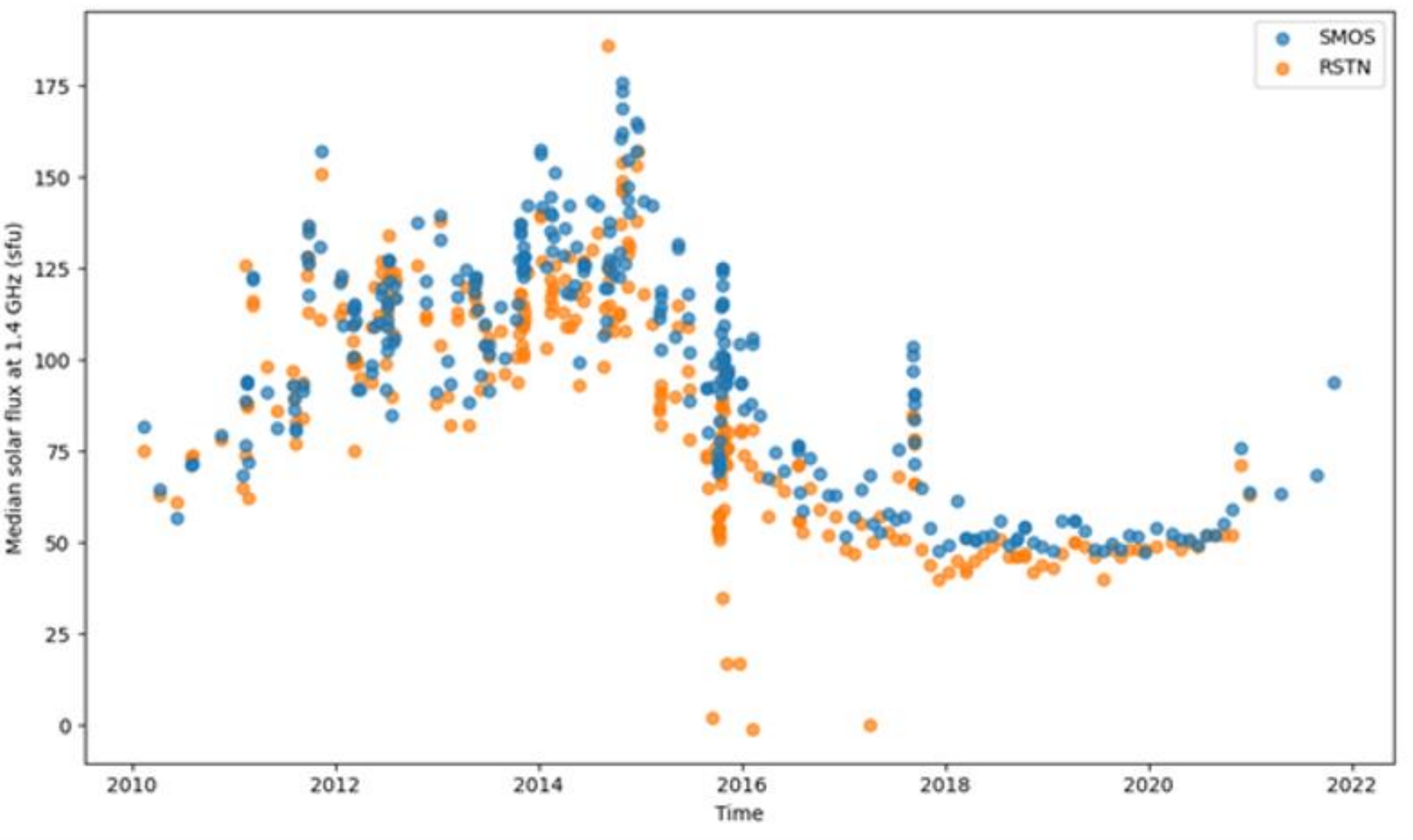
Is recalibration necessary?

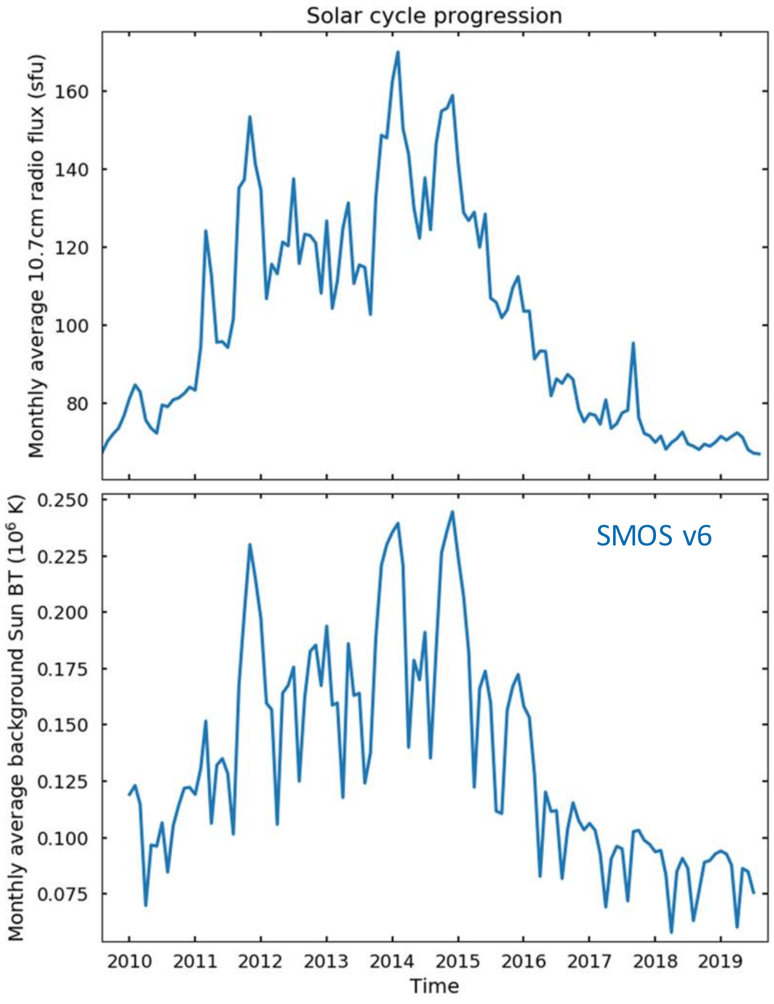


Is recalibration necessary?

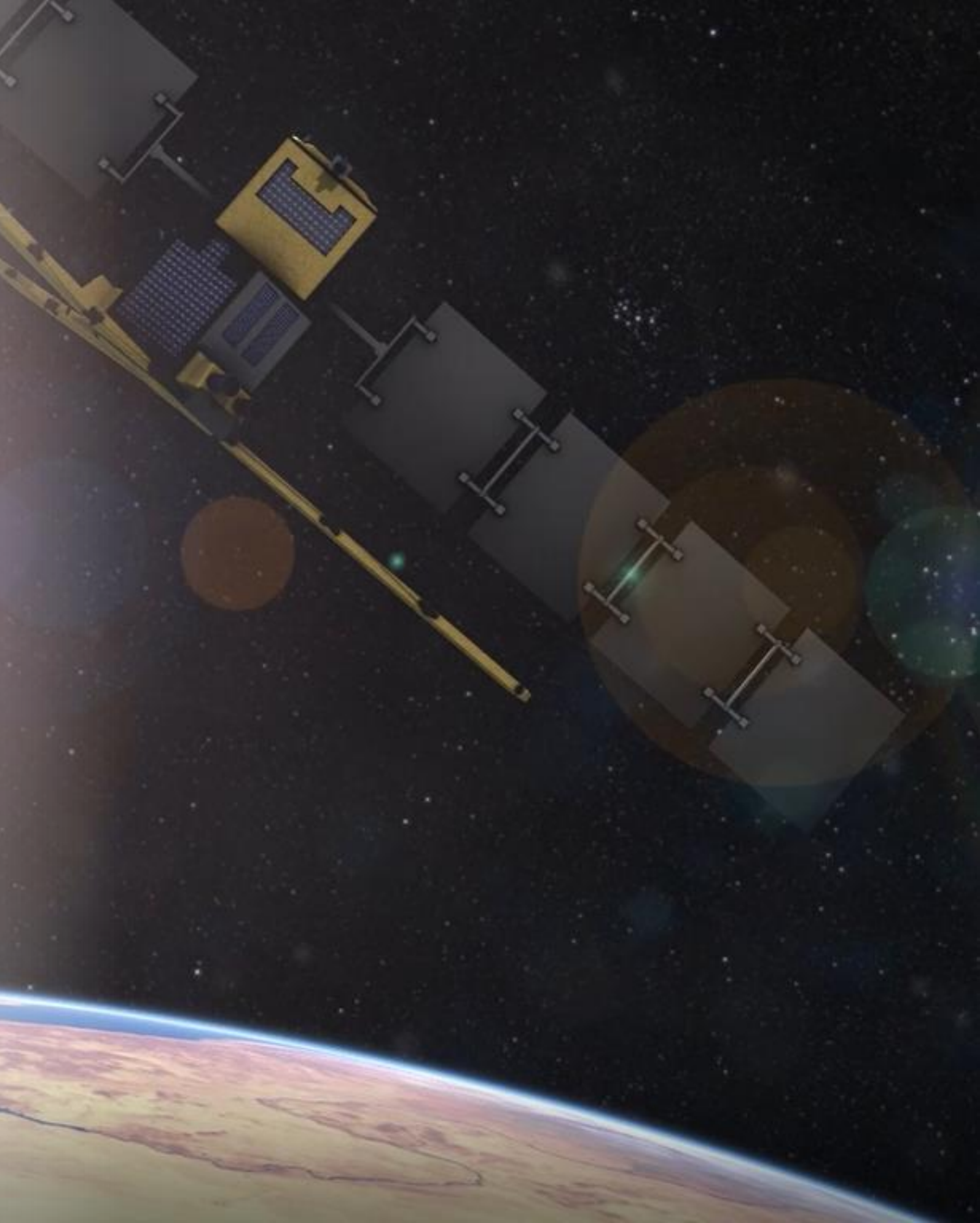


Seasonal signal drops no longer present





Data calibration



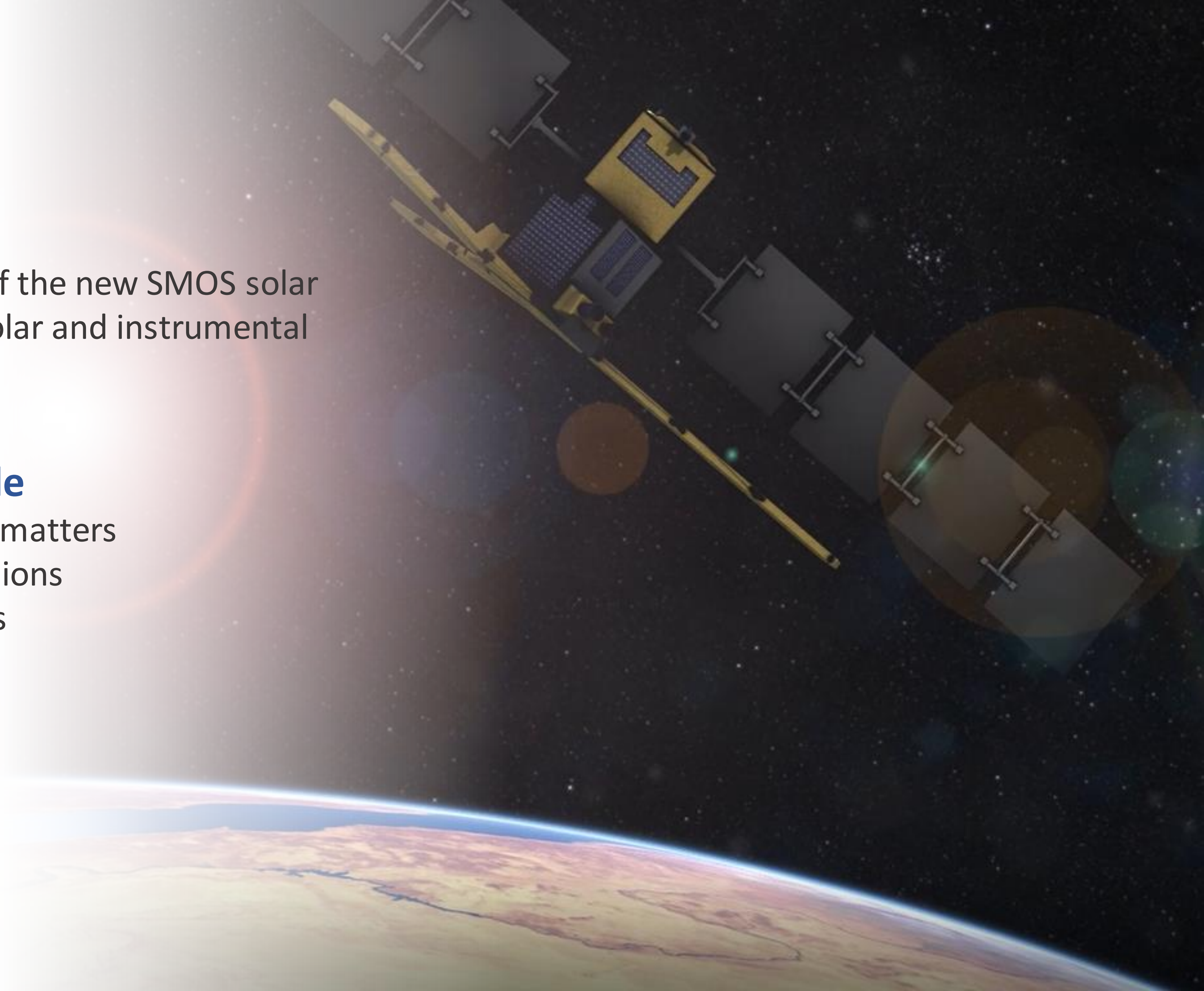
Conclusions

Discrepancies between SMOS and reference radio observatories generally not larger than discrepancies that the references have with each other.

Robust internal calibration, with potential for improvement by better understanding how SMOS forms the solar image, more than by comparing with reference observatories.

This new version removes known calibration problems from SMOS v6 and v7.

Data validation



Objective:

Evaluation of the performance of the new SMOS solar flux prototype under different solar and instrumental scenarios

Validation scenarios include

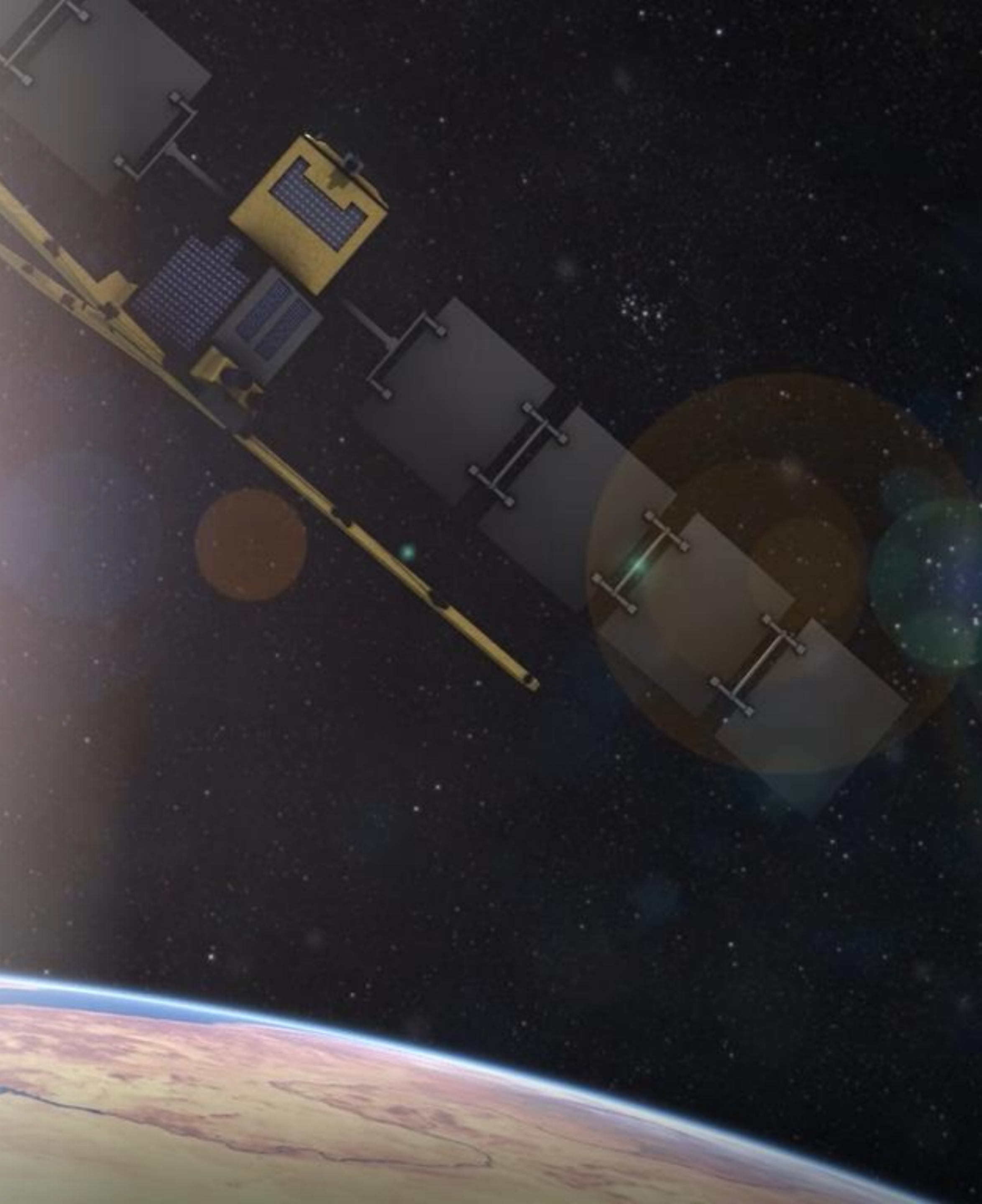
- Instrumental and algorithmic matters
- Response to weak solar emissions
- Response to solar radio bursts

Data validation

Instrumental and algorithmic matters:

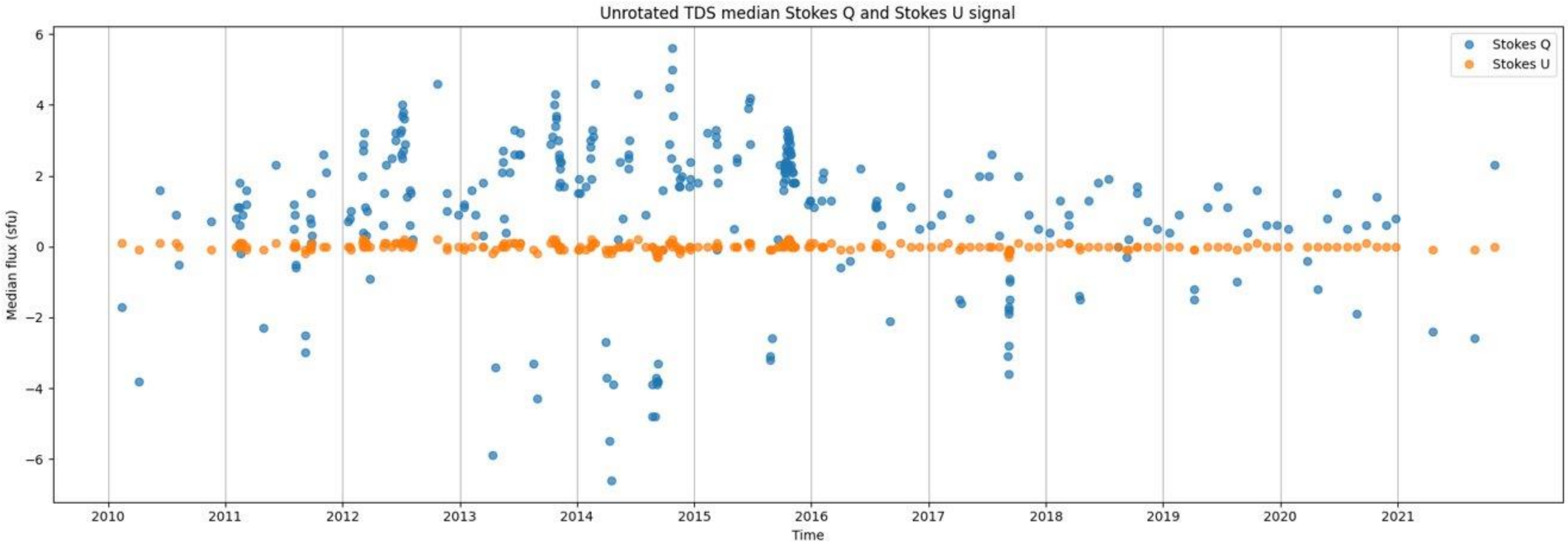
Some problems reported in Flores-Soriano et al. (2021).

- Artifacts during see-land transitions no longer present
- RFI flagging
    - SRBs no longer flagged as RFI
    - Excellent performance finding RFIs but also overreacting
- No signs of saturation during the strongest SRBs
- Three methods used for testing uncertainties (S/N) with good agreement between them
- No orbital nor seasonal dependencies found (with exception on the linear polarization)



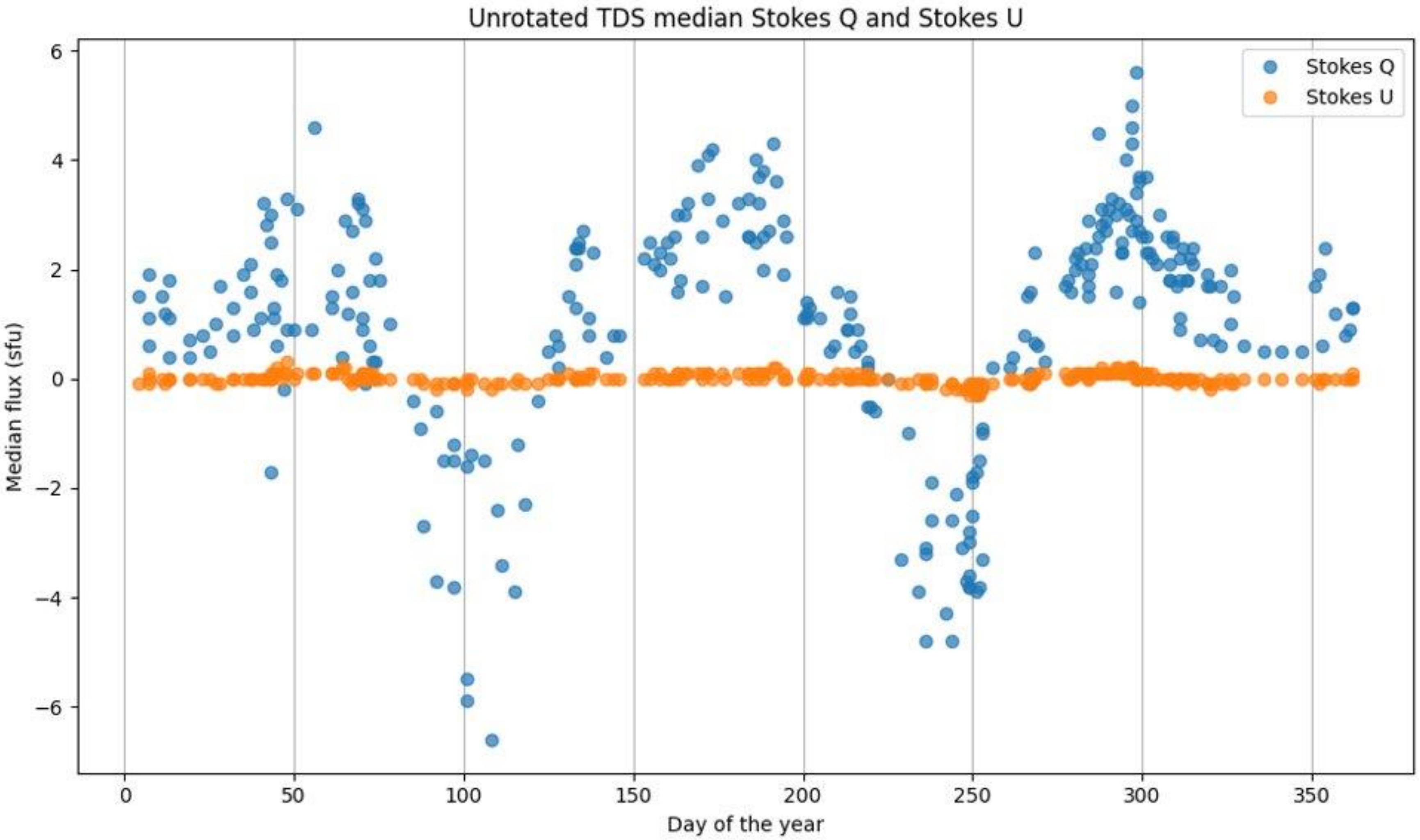
Unphysical excess linear polarization in Stokes Q

Correlation of Stokes Q with solar activity cycle



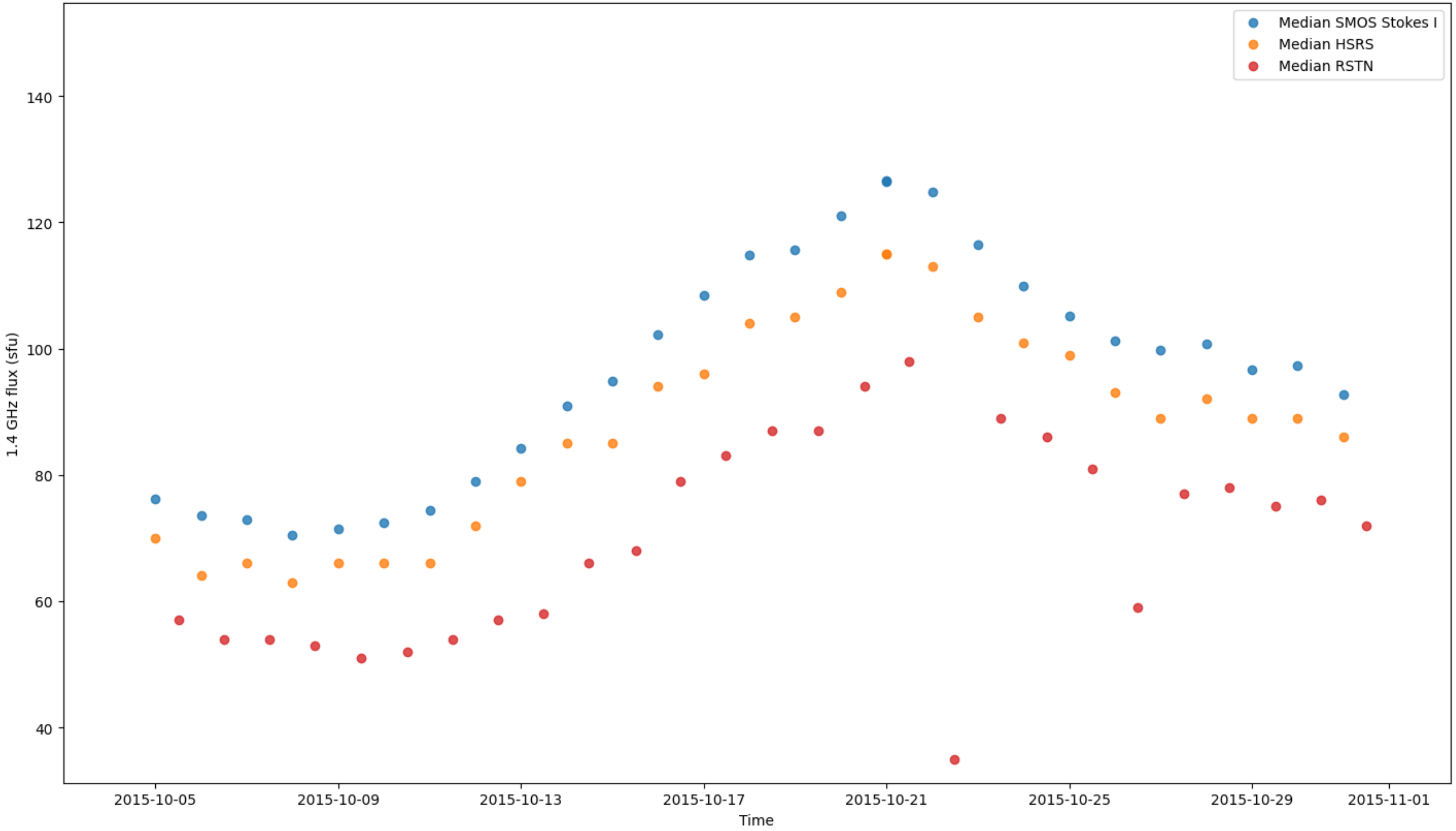
Unphysical excess linear polarization in Stokes Q

Seasonal dependence



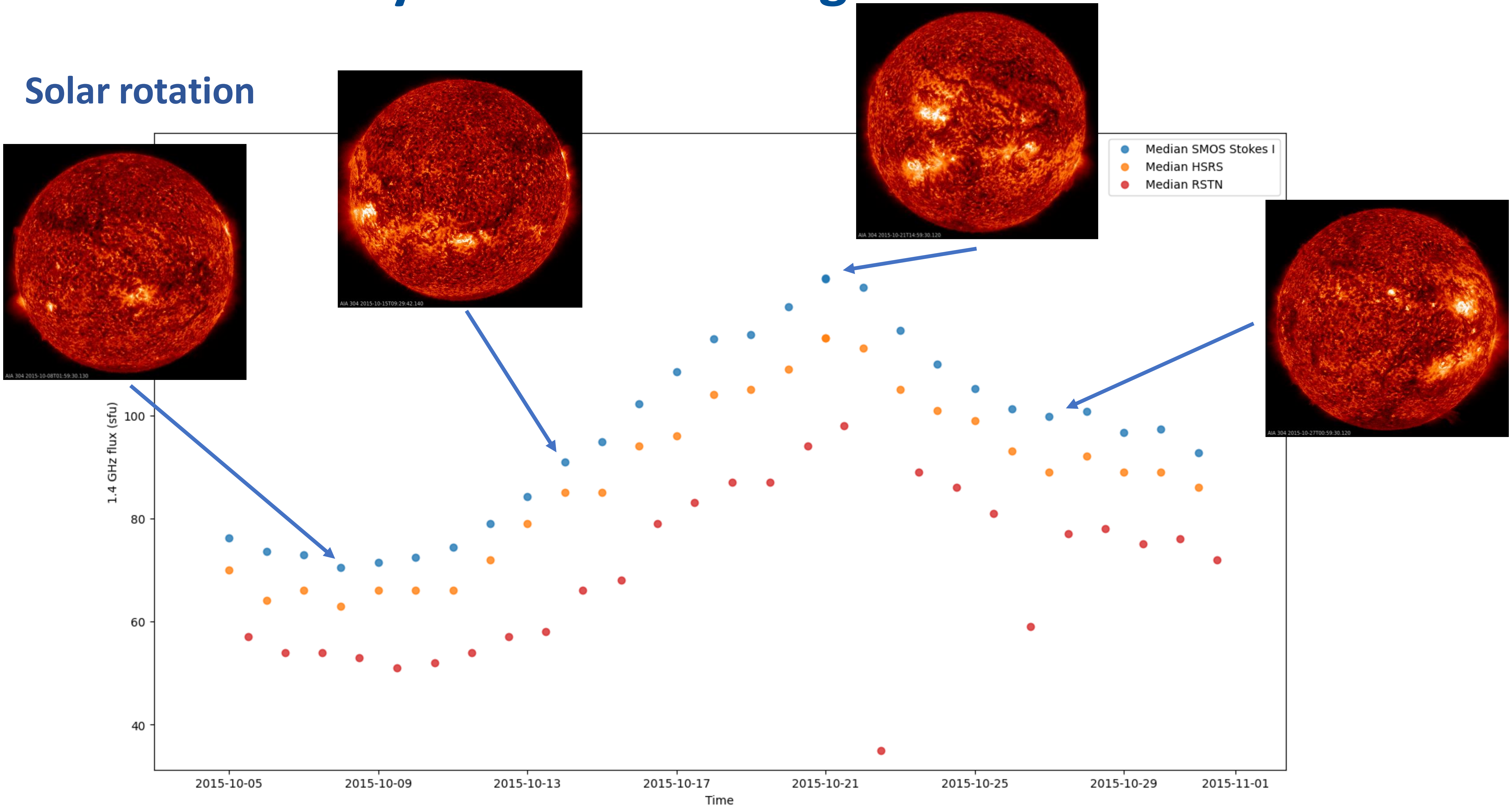
SMOS sensitivity to weak solar signals

Solar rotation



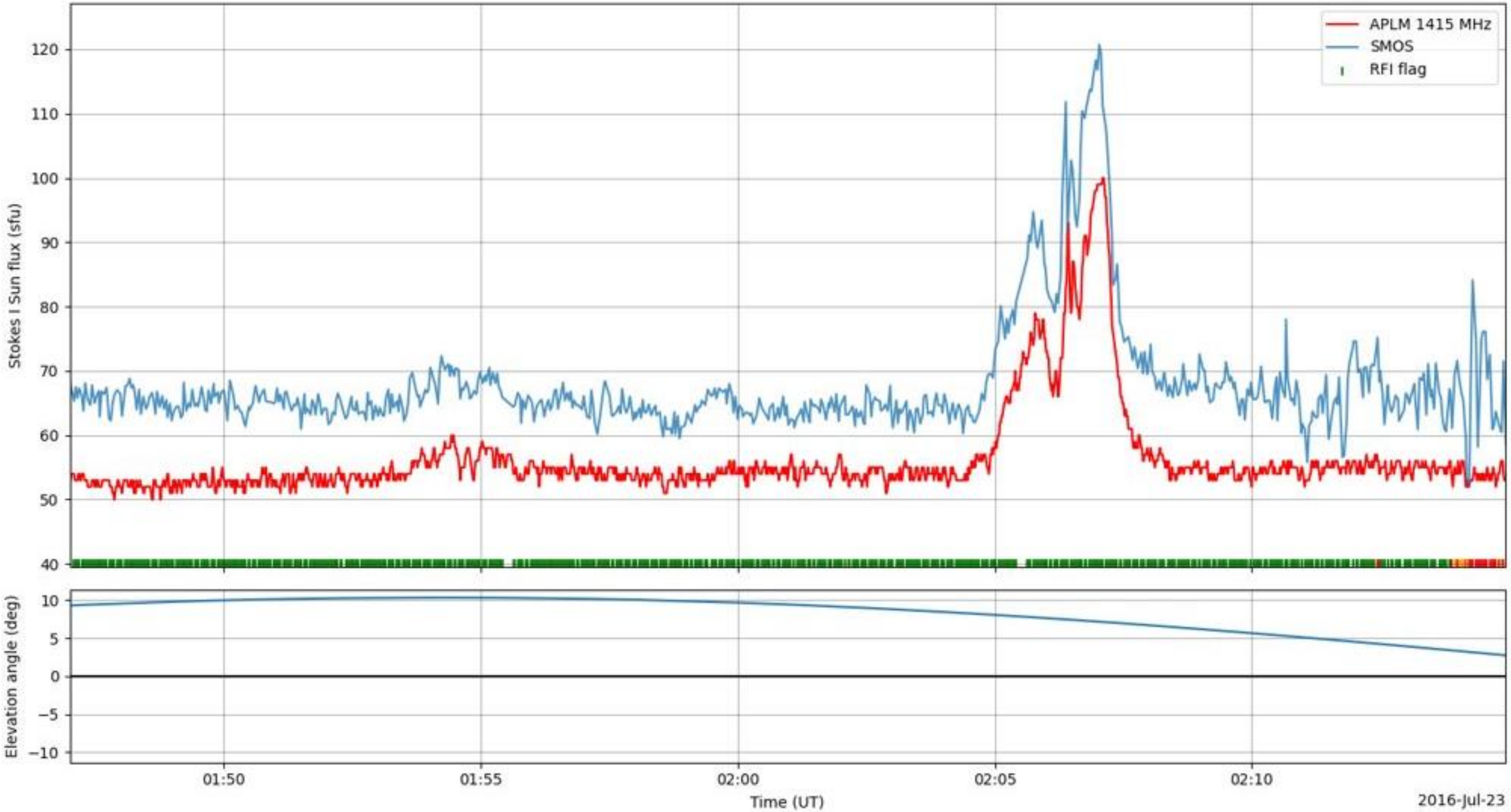
SMOS sensitivity to weak solar signals

Solar rotation

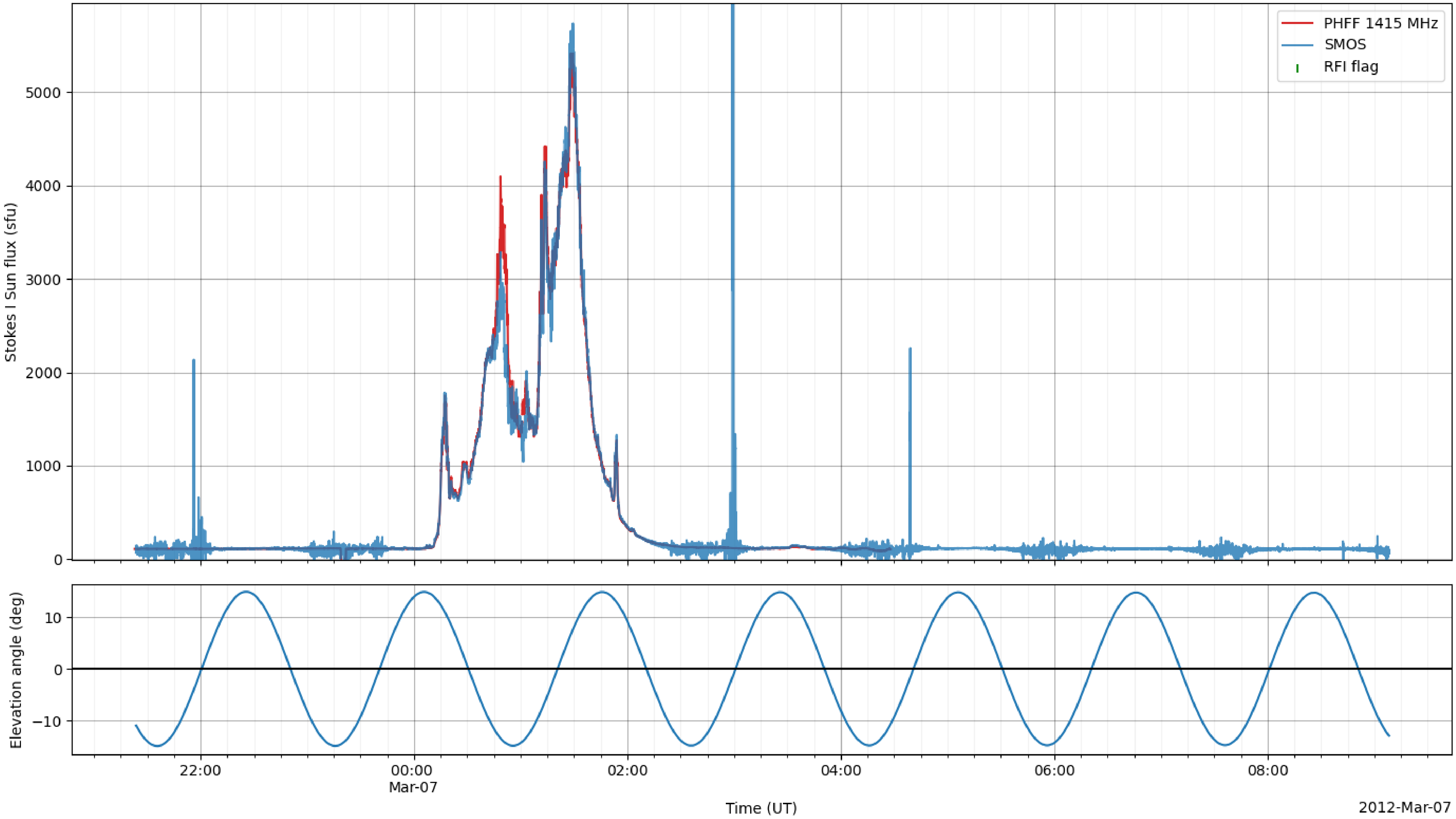


SMOS sensitivity to weak solar signals

Weak SRB (in good observing conditions)

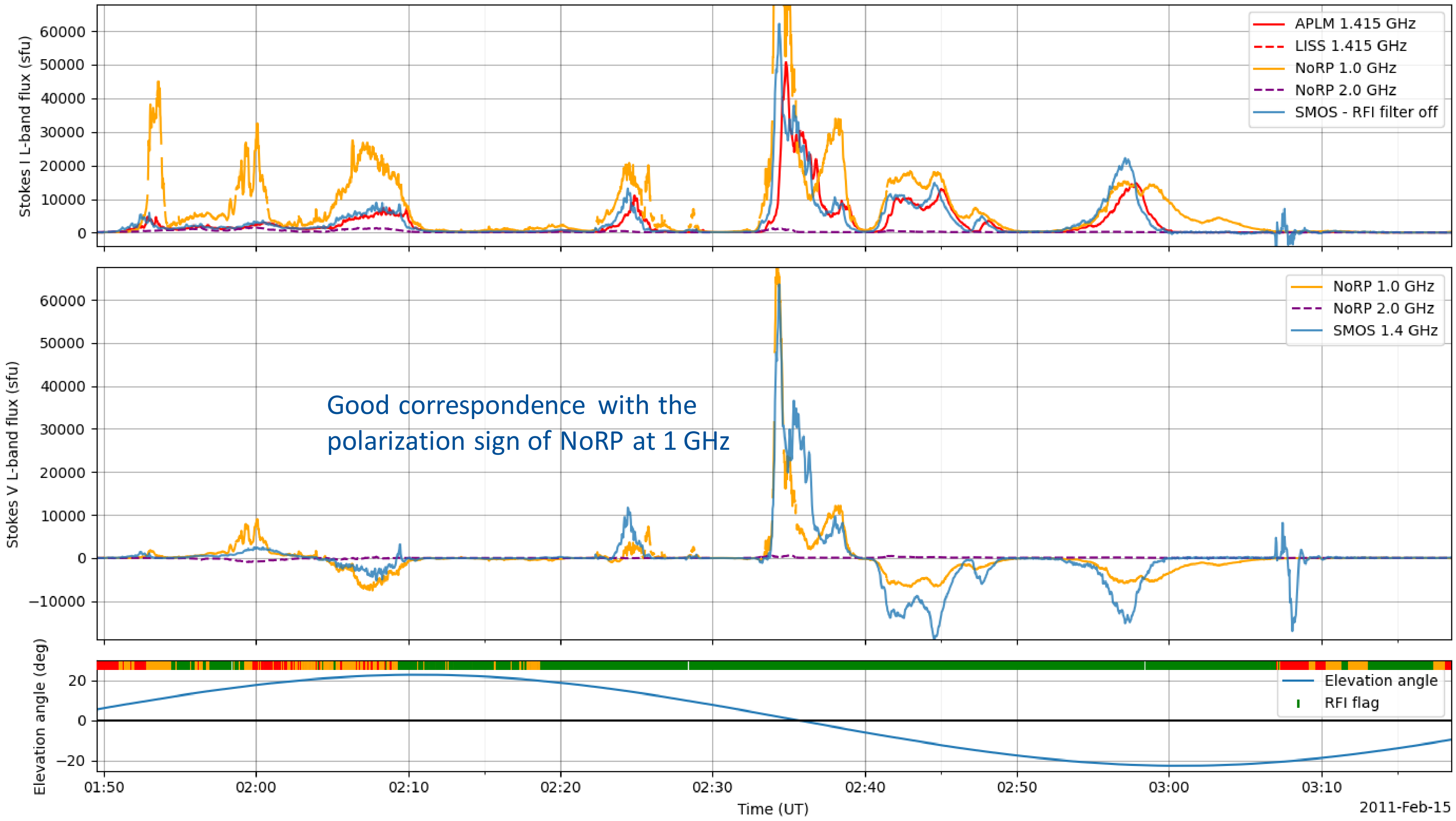


SRB with the Sun behind the antenna



SRB during worst-case scenario

Circular polarization of SRBs: Comparison with NoRP

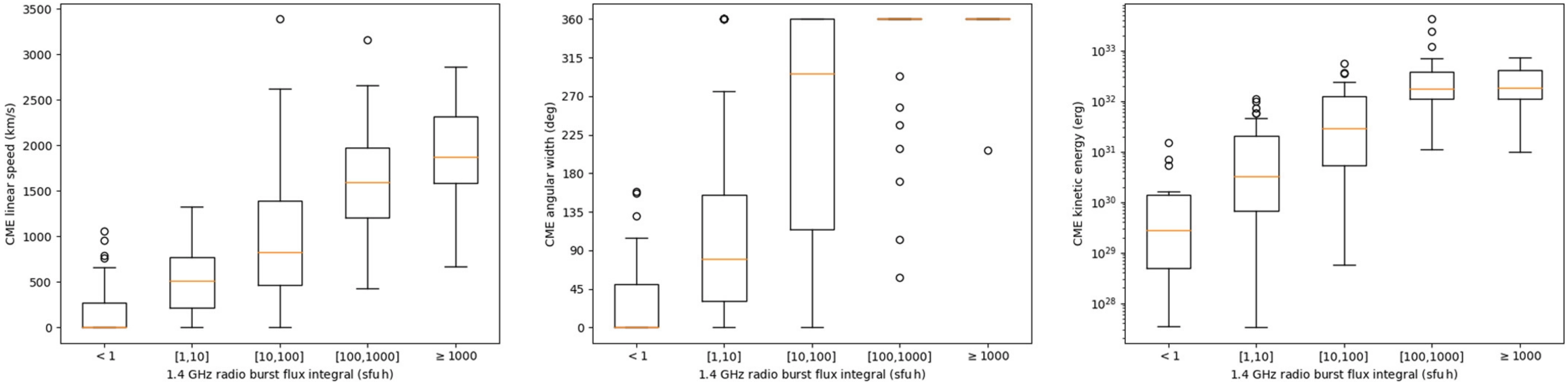


SMOS applications in space weather

Monitoring of CME occurrence

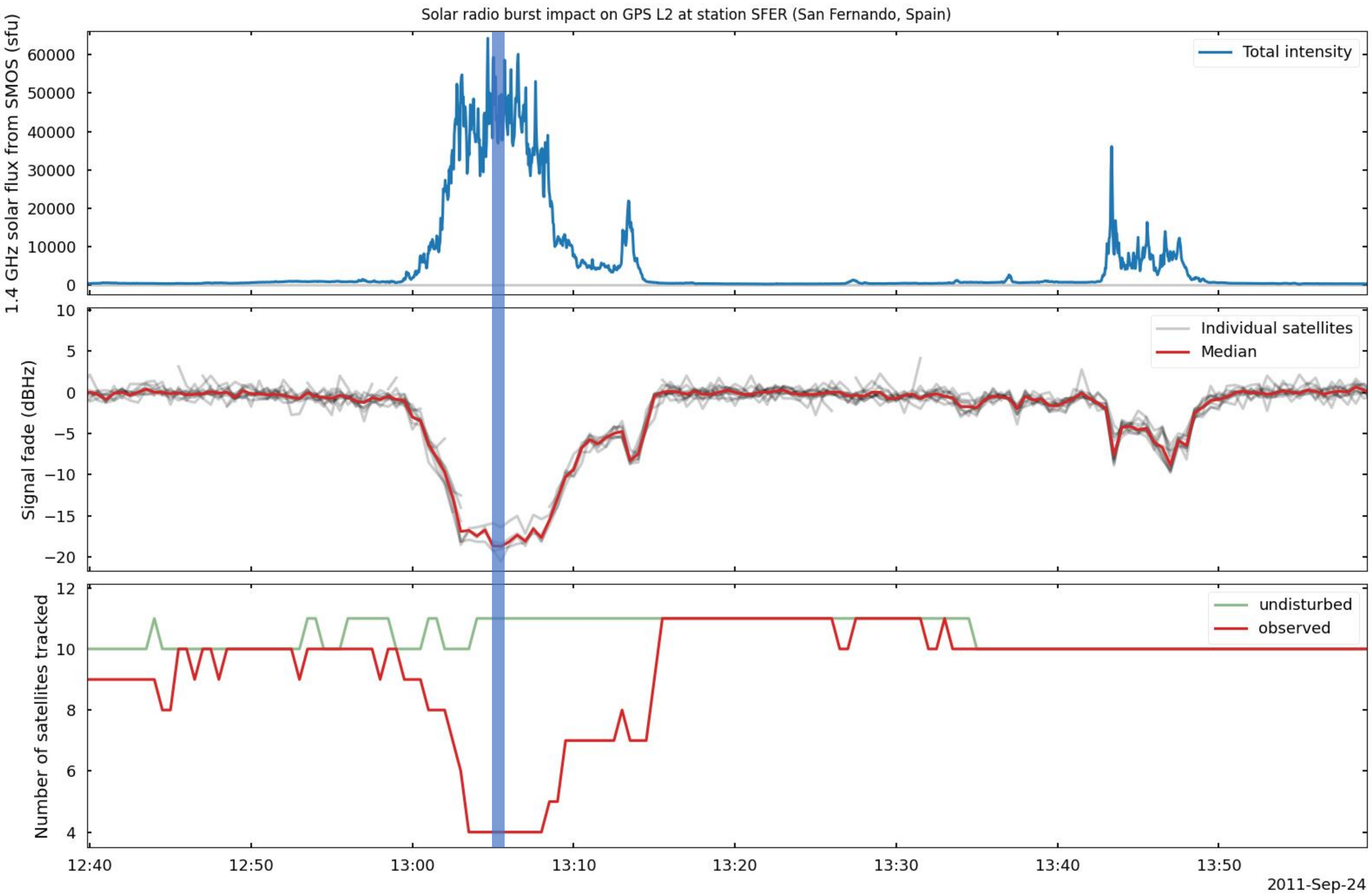
Almost every flare with a 1.4 GHz SRB is related to a CME

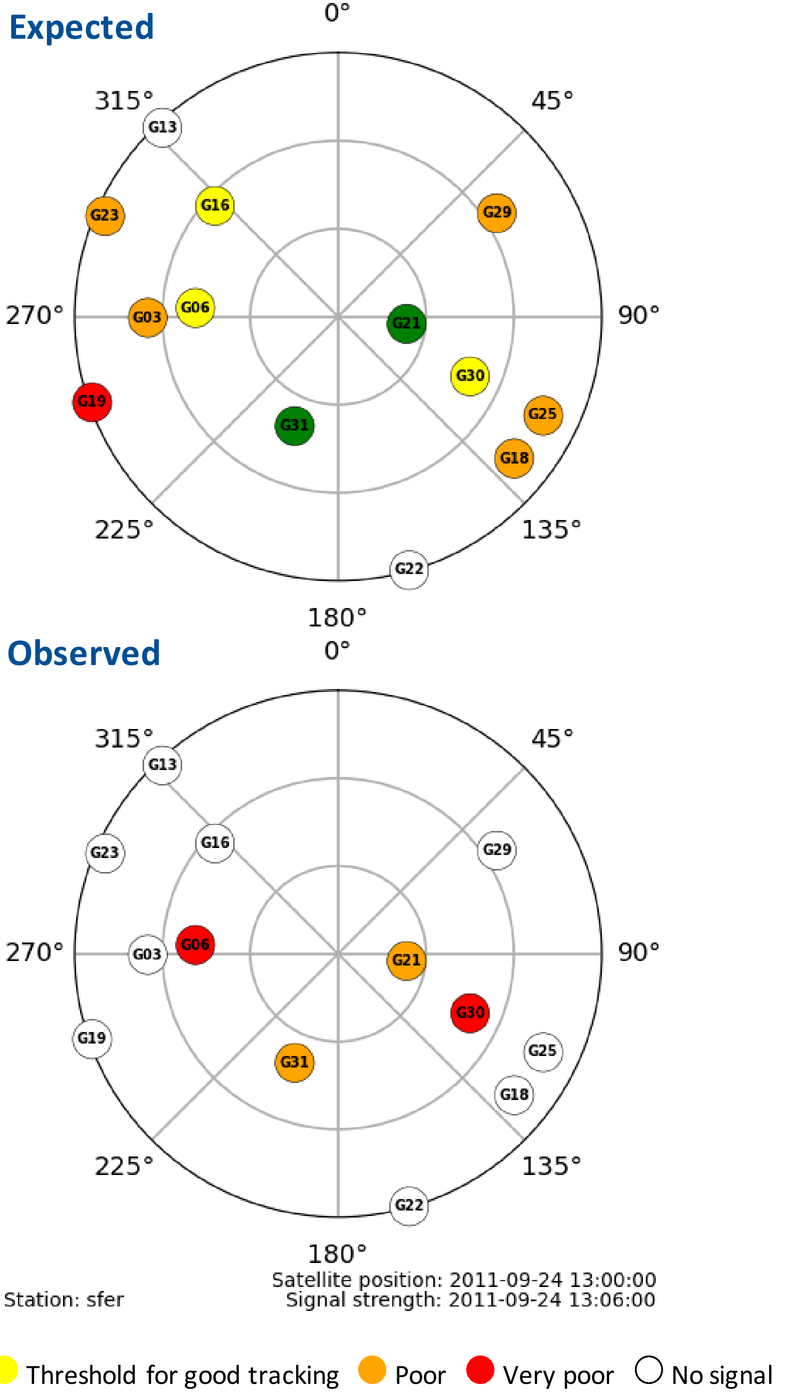
The amount of flux released at 1.4 GHz correlates with the speed, angular width and kinetic energy of the CMEs



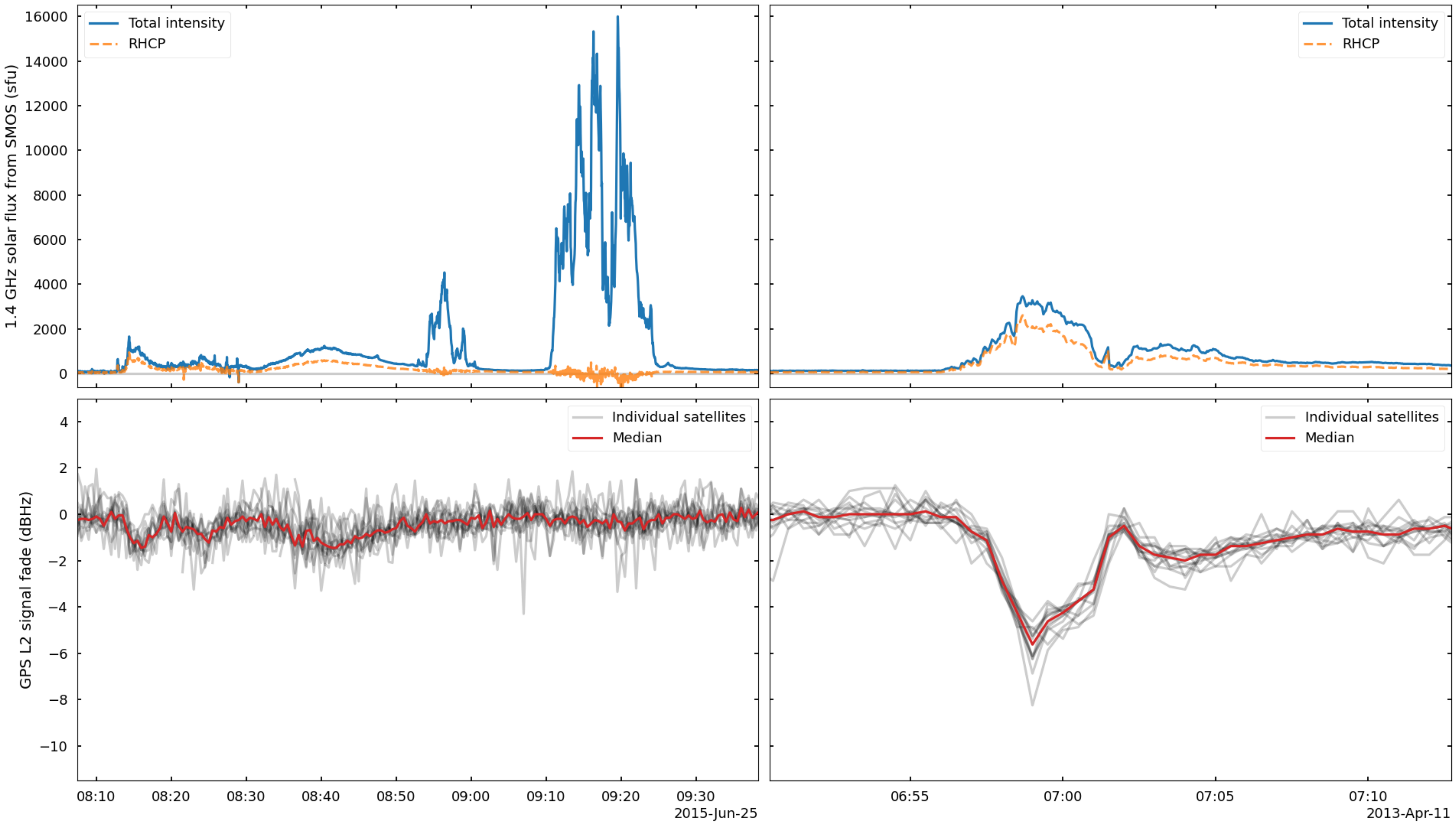
Flores-Soriano et al. (2021). https://doi.org/10.1029/2020SW002649
CME data from https://cdaw.gsfc.nasa.gov/CME_list/

SRB impact on GNSS - Example case

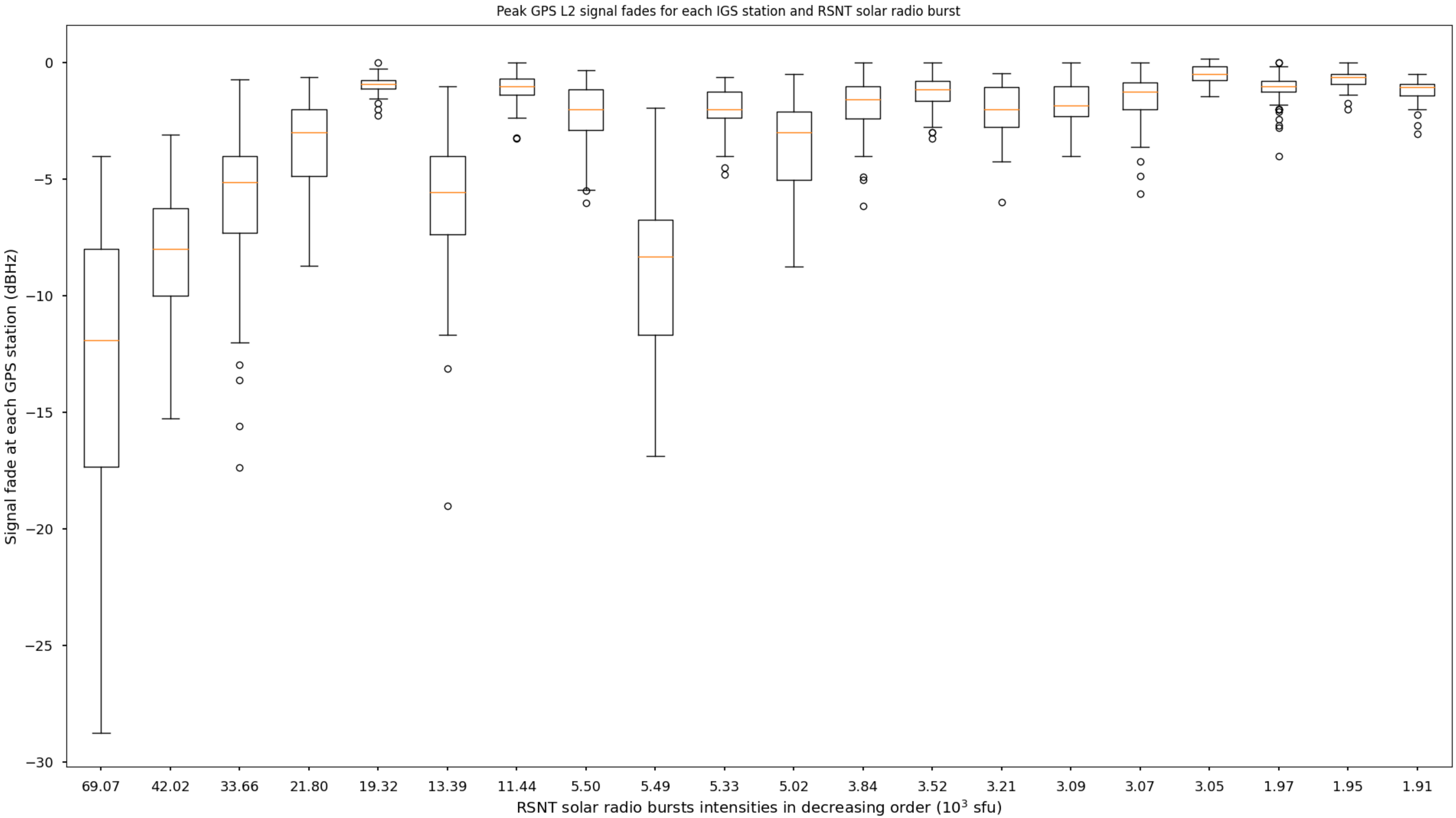




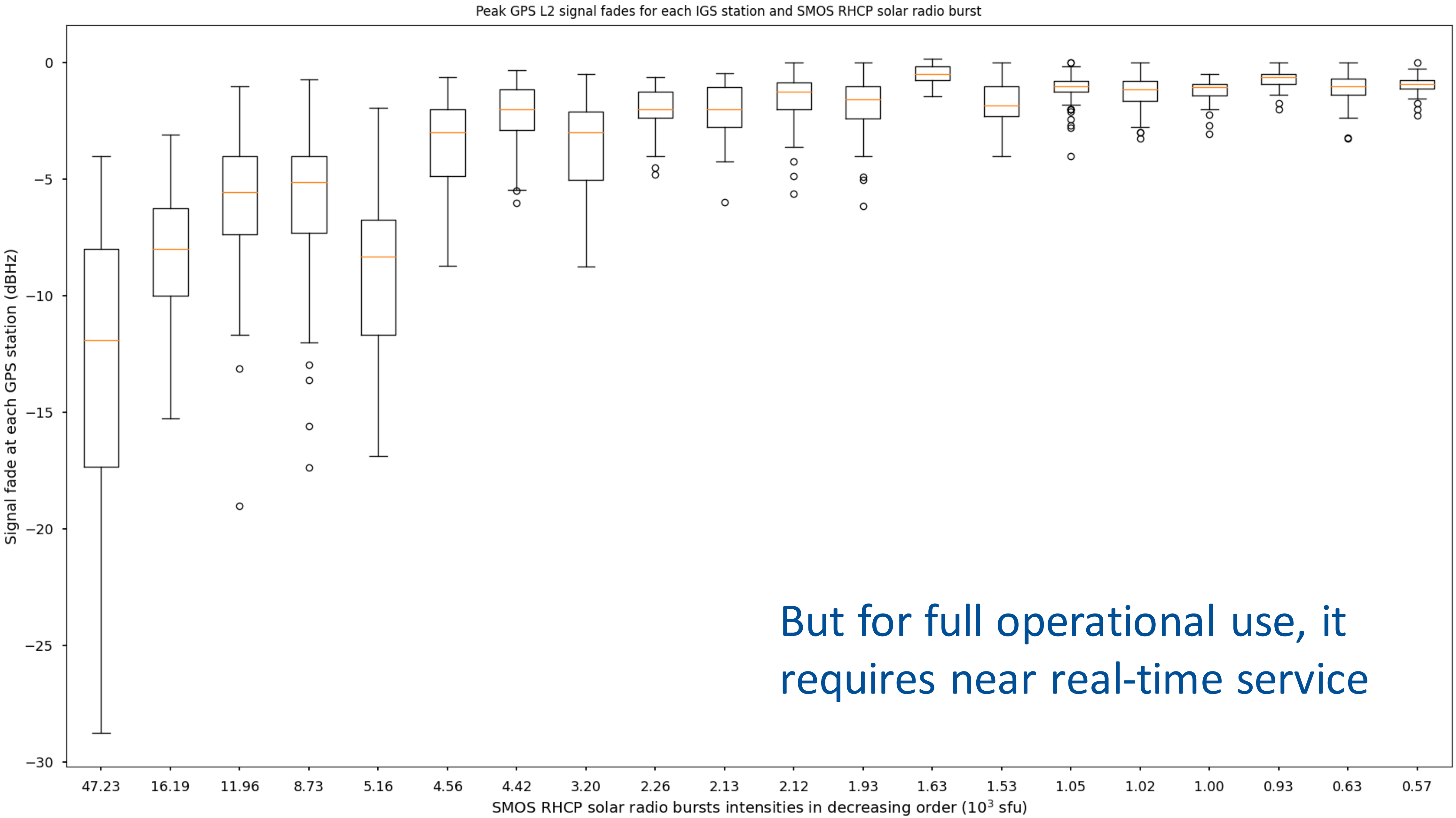
Importance of SRB polarization



Correlation between GPS L2 signal fades and RSTN SRBs (Stokes I)

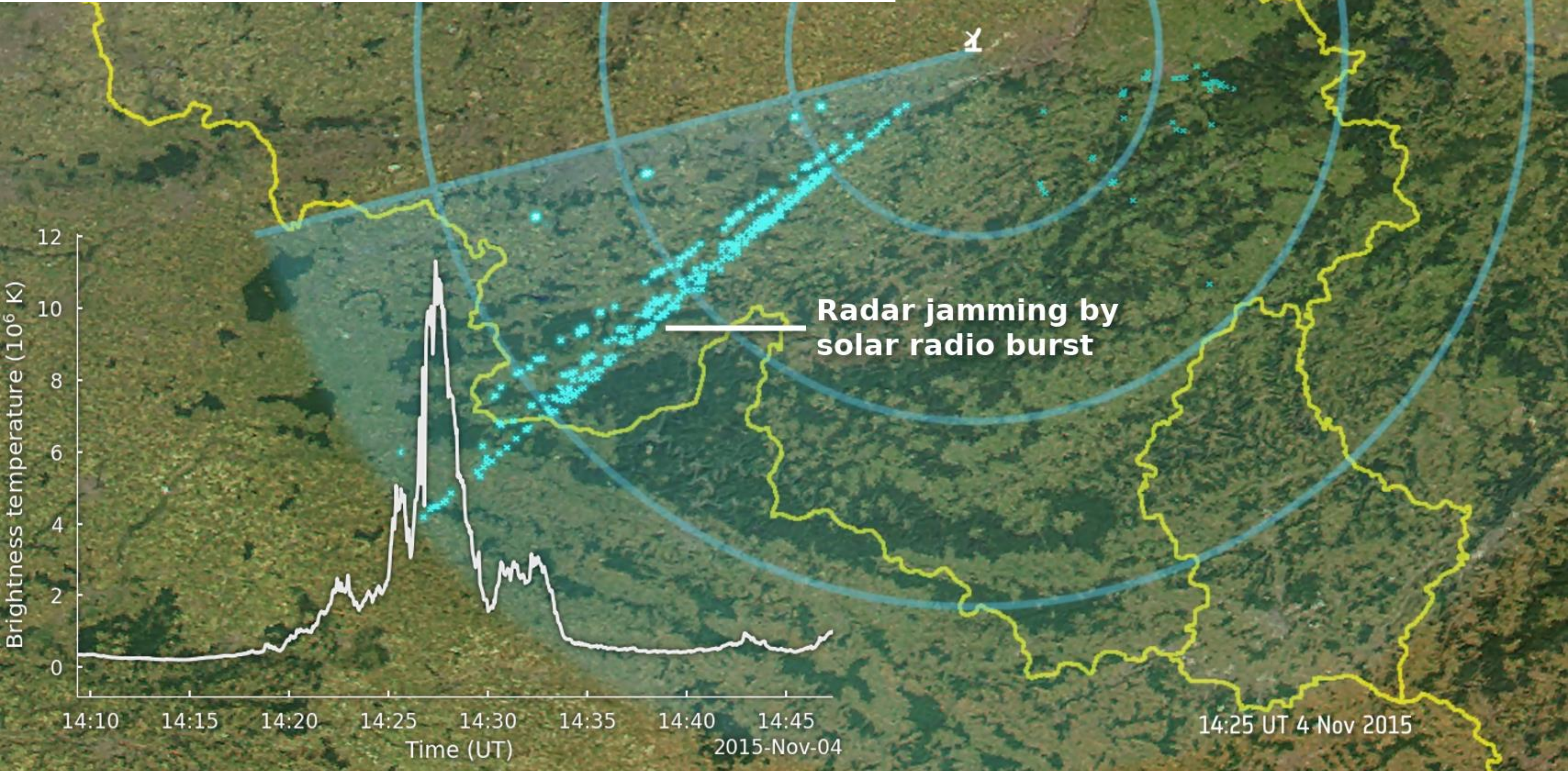


Correlation between GPS L2 signal fades and SMOS RHCP SRBs



But for full operational use, it requires near real-time service

Impact on L-band air control radars



Radar image credits: **ESA/Planetary Visions. Adapted from Marqué et al. 2018. Space Weather Space Clim. 8, A42.**

Conclusions

SMOS 1.4 GHz solar observations:

- **How good?**
  - Comparable with dedicated instruments
  - Not affected by day/night cycle
- **What for?**
  - Studies of 1.4 GHz SRBs with circular polarization
  - Space weather monitoring and post-event analyses (CMEs, GNSS, radar...)
  - Ionosphere and geomagnetic field modelling (complement to 10.7 cm Penticton radio observations)
- **Why even bother?**
  - No other instrument now with similar functionality
  - Potential for near real-time 24h operations
  - Data since 2010

Thanks for your attention!!

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