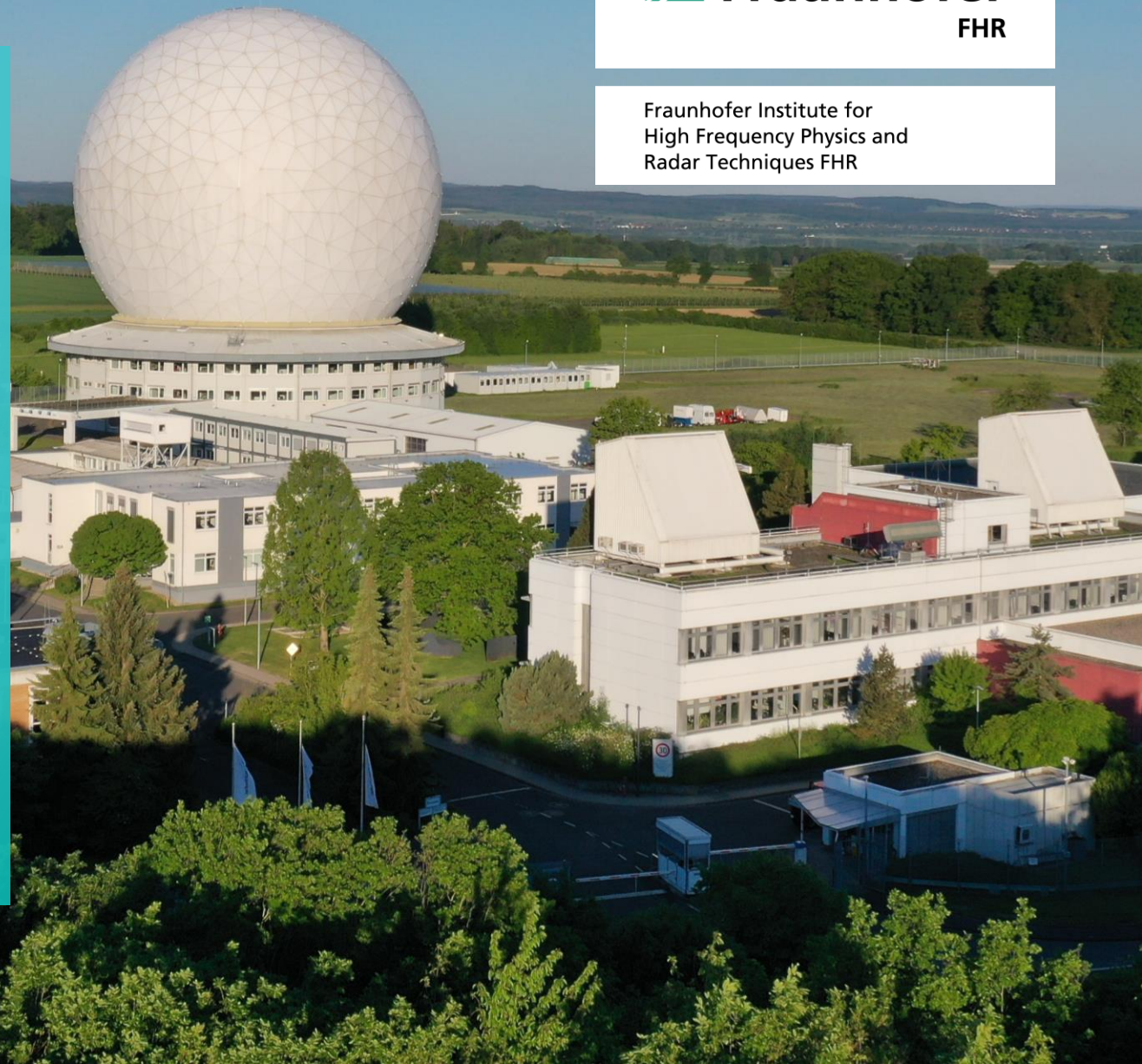
D. Cerutti-Maori, C. Carloni, J. Rosebrock, I. Maouloud

Improving the performance of the space observation radar TIRA through dedicated signal processing techniques and advanced experimental modes



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01

Tracking and Imaging Radar TIRA

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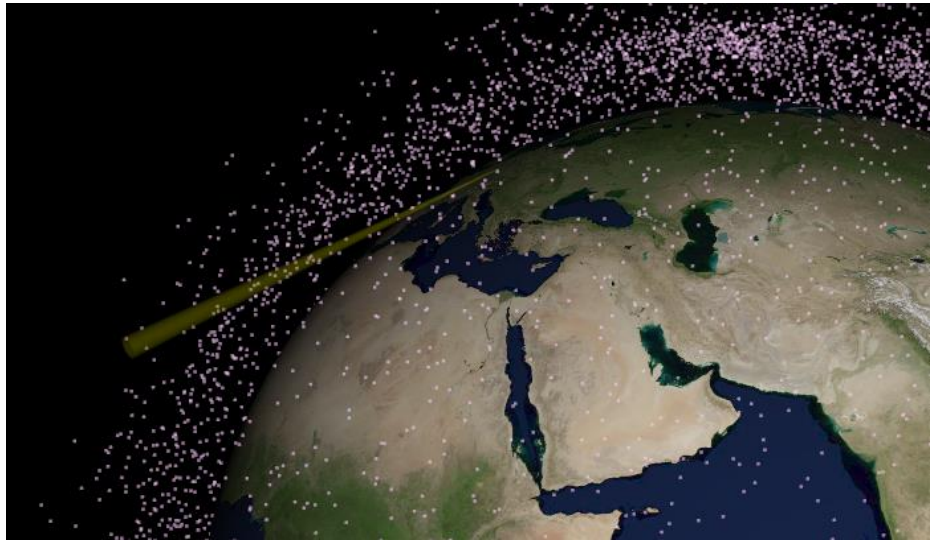
Tracking and Imaging Radar (TIRA)

Specifications

- **34 m parabolic dish in Cassegrain configuration**
  - High angular velocity (**24°/s in az., 6°/s in el.**)
  - Very high mechanical pointing accuracy: 0.6“ (**ca. 3 m at a range of 1000 km**)
- **L-band tracking radar**
  - Center frequency: **1.3 GHz**
  - Auto-tracking (monopulse)
  - Beamwidth: 0.49° (**8.6 km at R = 1000 km**)
  - Detection sensitivity (single pulse): **2 cm at R = 1000 km**
- **Ku-band imaging radar**
  - Center frequency: **16.7 GHz**
  - Beamwidth: 0.031° (**540 m at R = 1000 km**)



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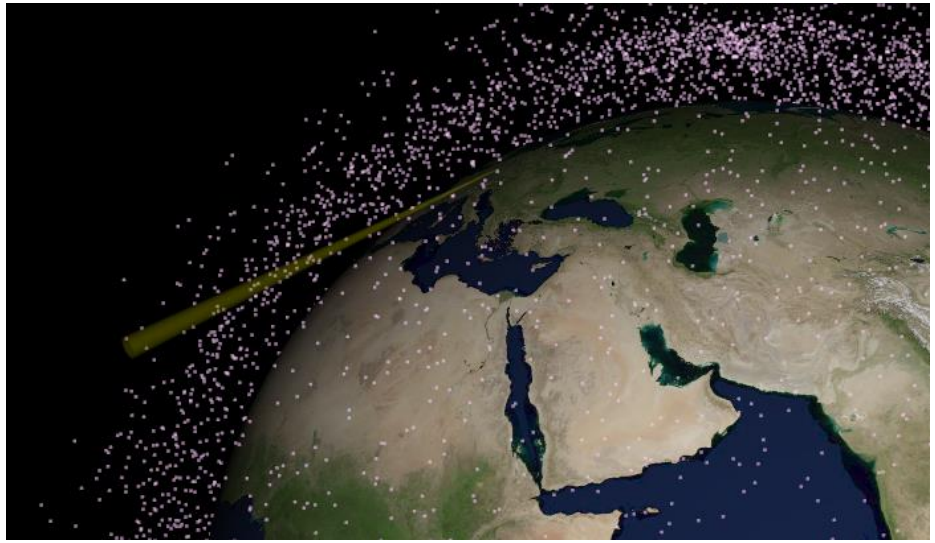
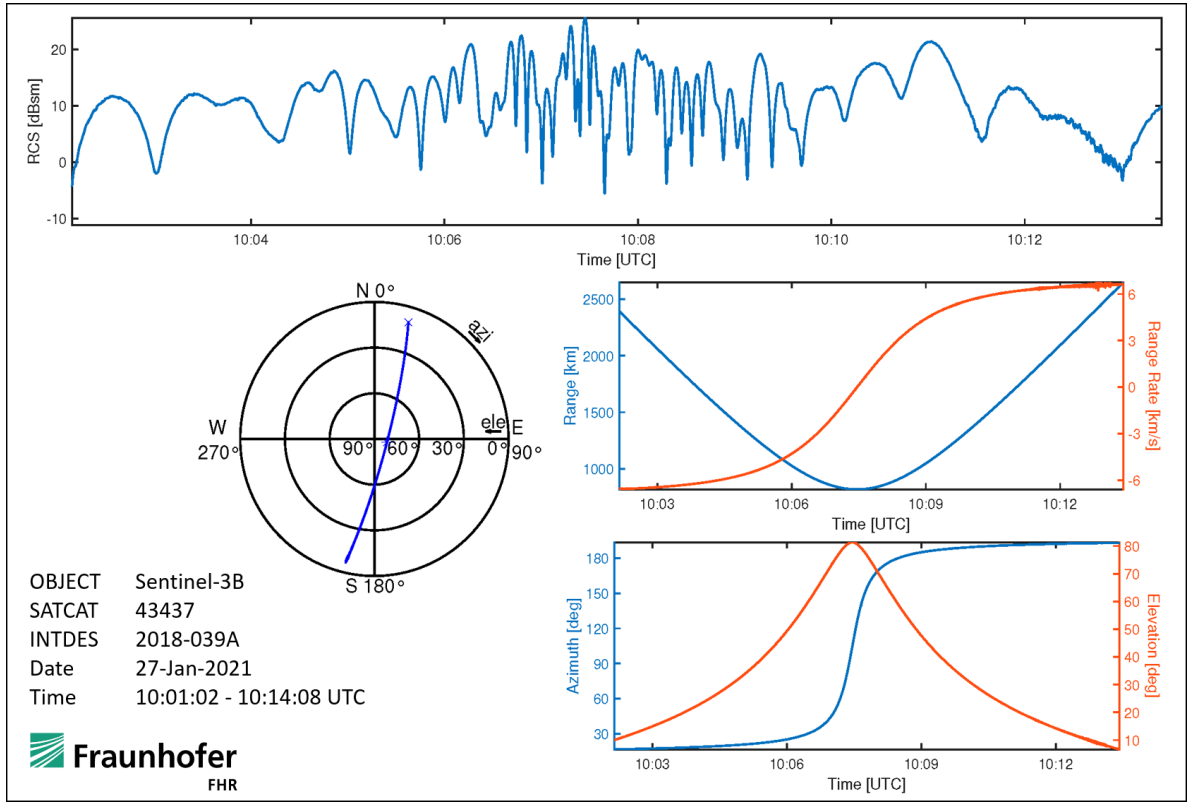
M. Albrecht et al. : “Space situational awareness using cooperative networks of phased-array radars”



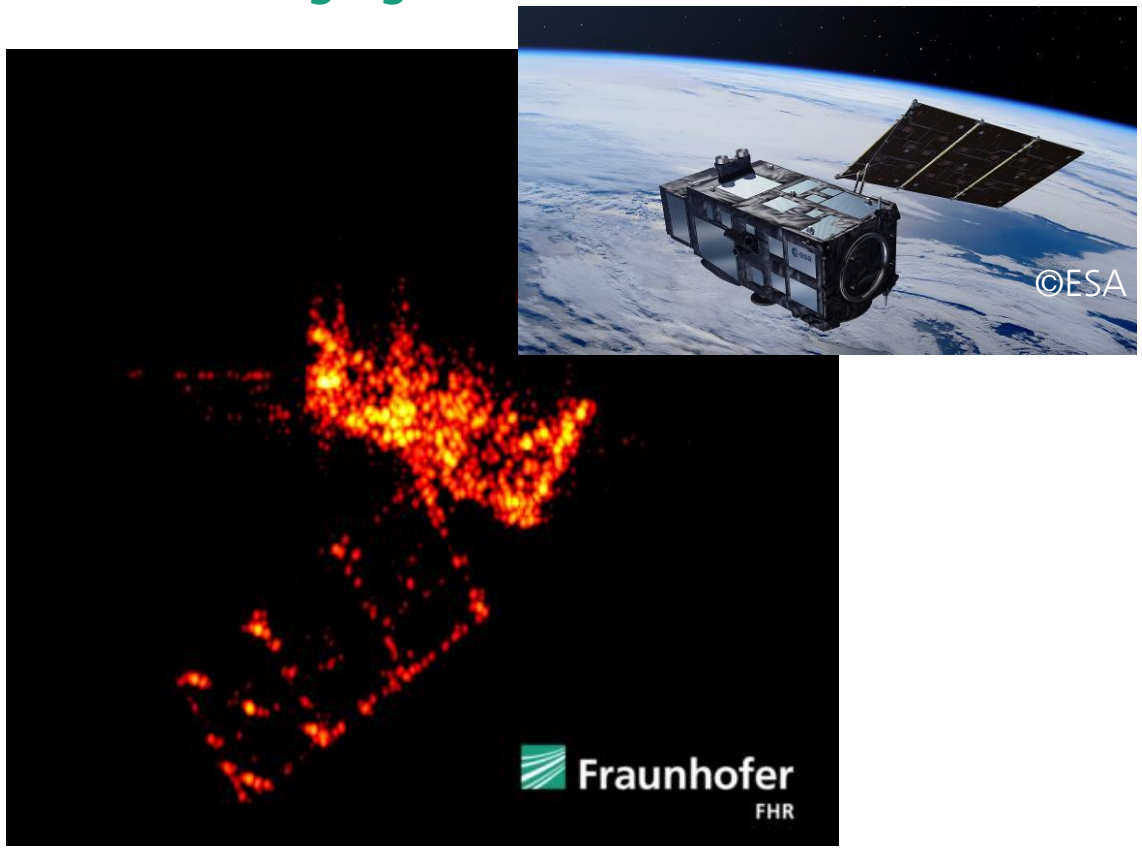
Tracking and Imaging Radar (TIRA)

Some typical products

- **L-band tracking radar**



- **Ku-band imaging radar**



Tracking and Imaging Radar (TIRA)

Performance improvement through signal processing

- Is it possible to improve the performance of the TIRA system **without modifying the system hardware**? If yes, how?
- Goal
  - Better support for the GSSAC, space agencies, and NATO operations
- Approach
  - Development of new observation modes
    - Joint exploitation of the data measured by the two radars
  - Derivation of advanced processing techniques
    - Improvement of the accuracy of the measured parameters
    - Estimation of additional parameters

02

Experimental high-resolution observation mode

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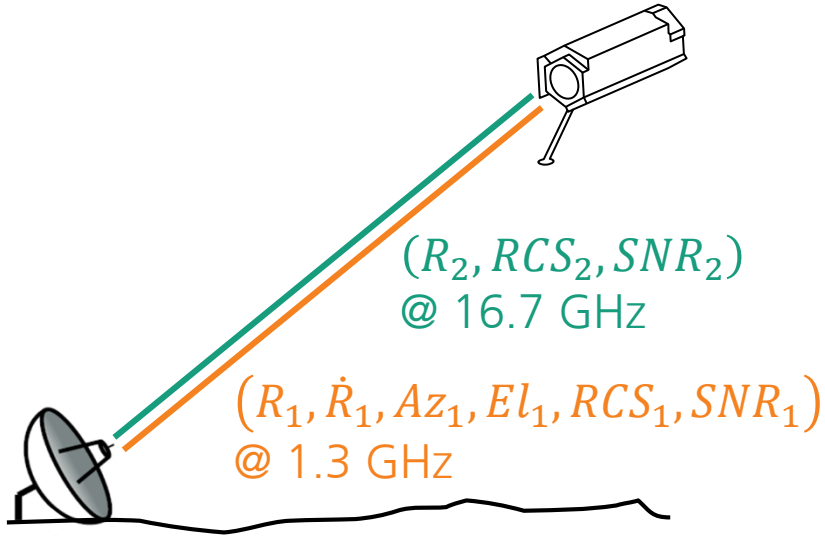
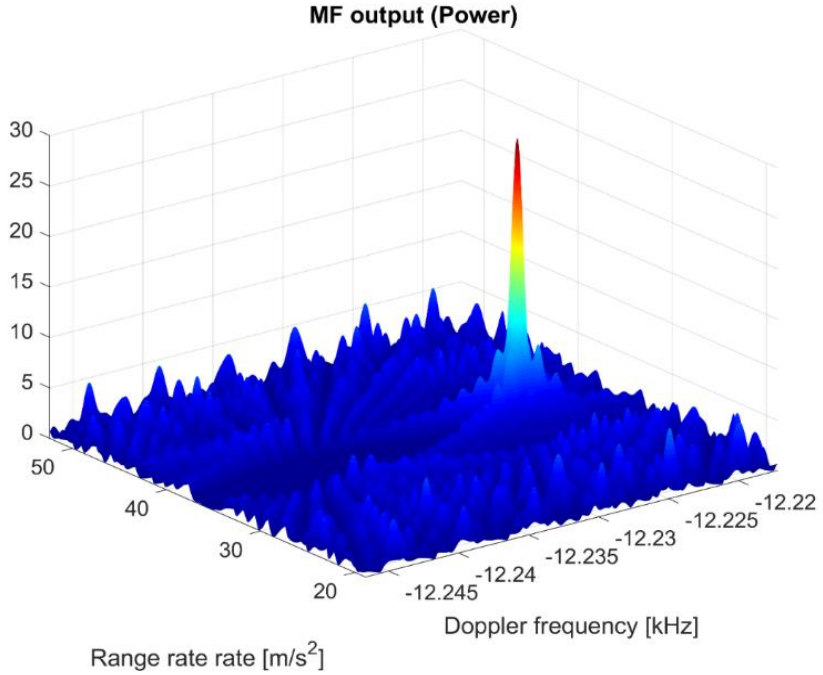
Experimental high-resolution observation mode

Objective and principle

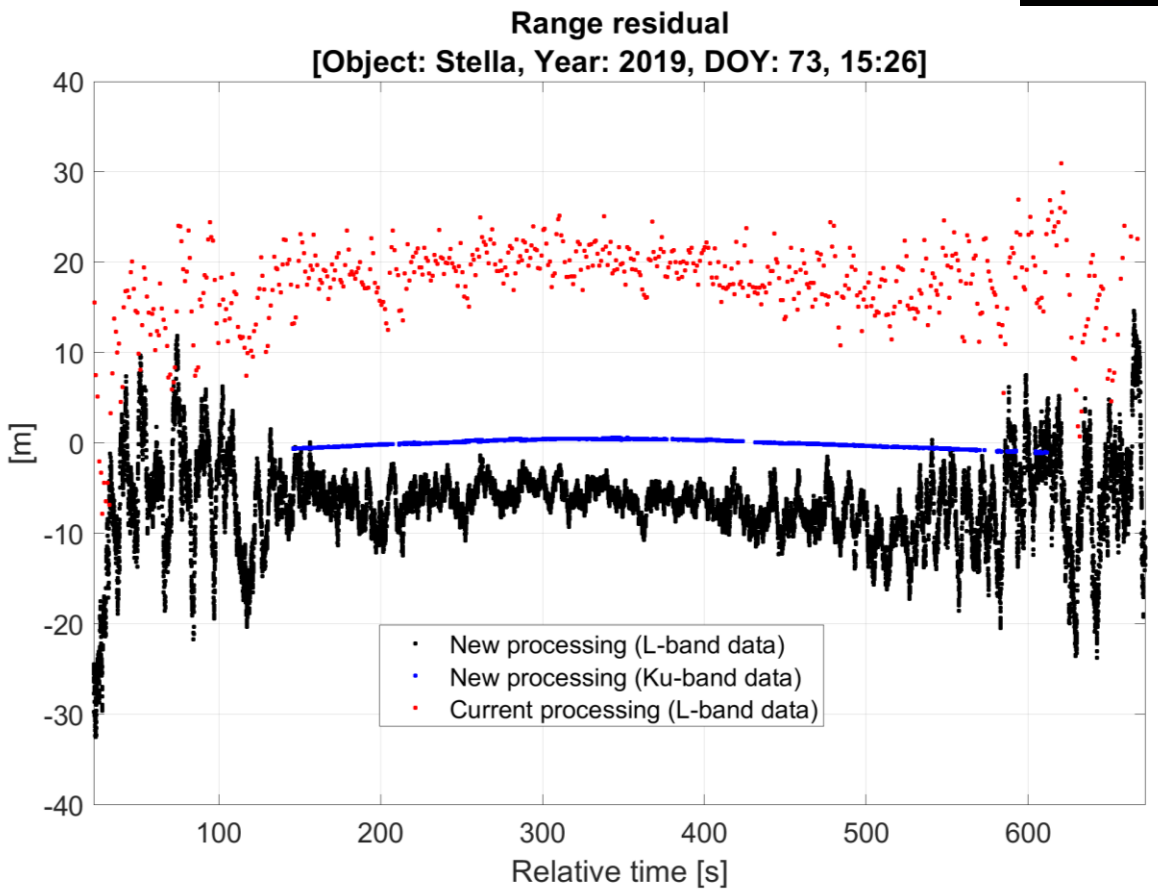
- **Objective**
  - Generation of high-quality observation vectors
- **The experimental mode uses the data measured by the two radars**
  - Precise measurement of the range using the imaging radar
  - Innovative processing of the tracking radar data
    - 3-step processing based on weighted LS, coherent processing and resolution of the range rate ambiguities
    - Estimation of new parameter, the range rate rate
- **Contribution to operation support**
  - All SSA tasks that require highly accurate orbital measurements

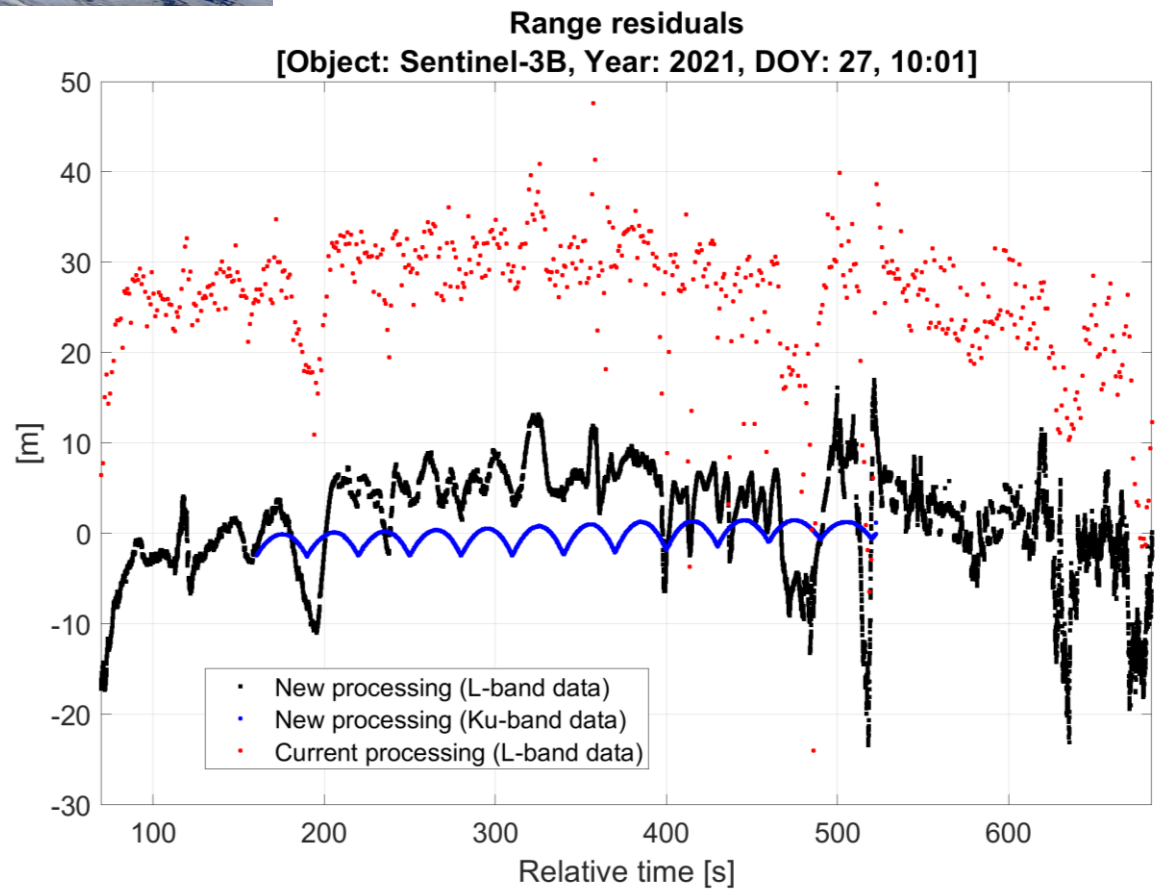




Experimental high-resolution observation mode

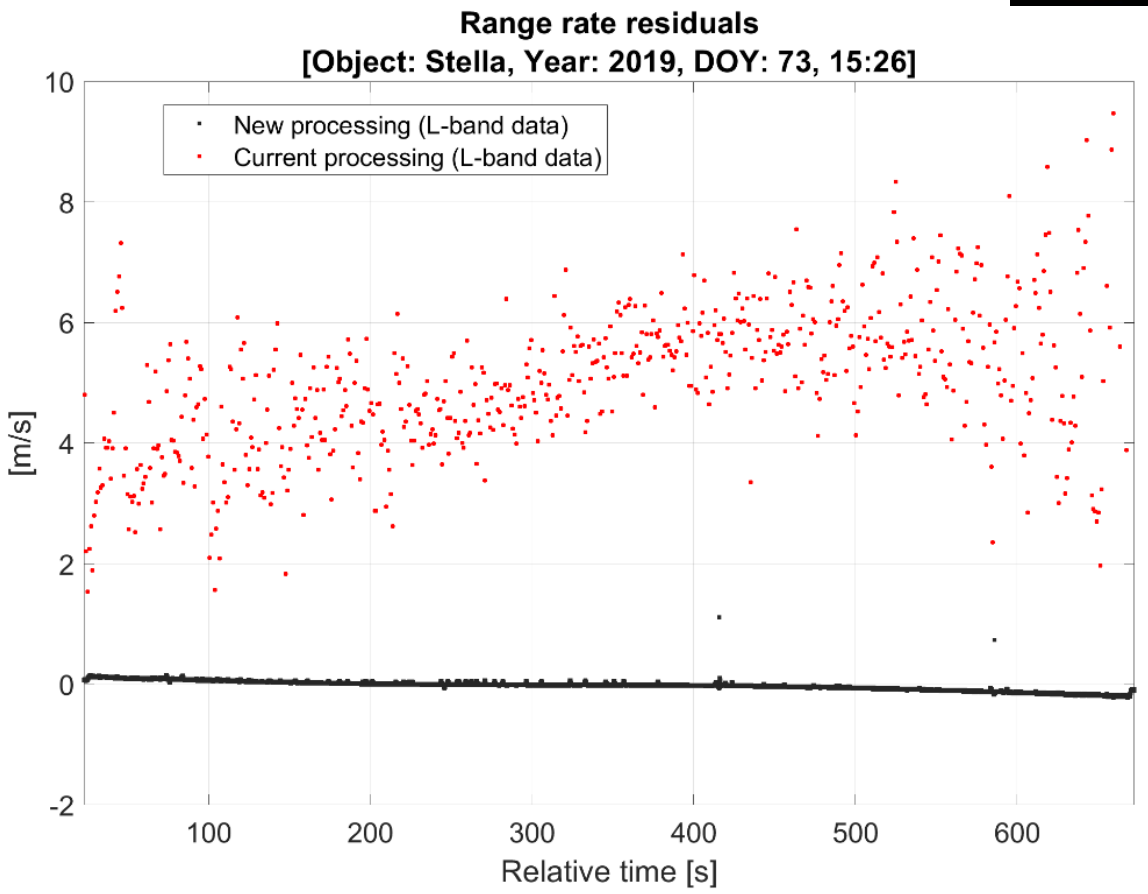
Range

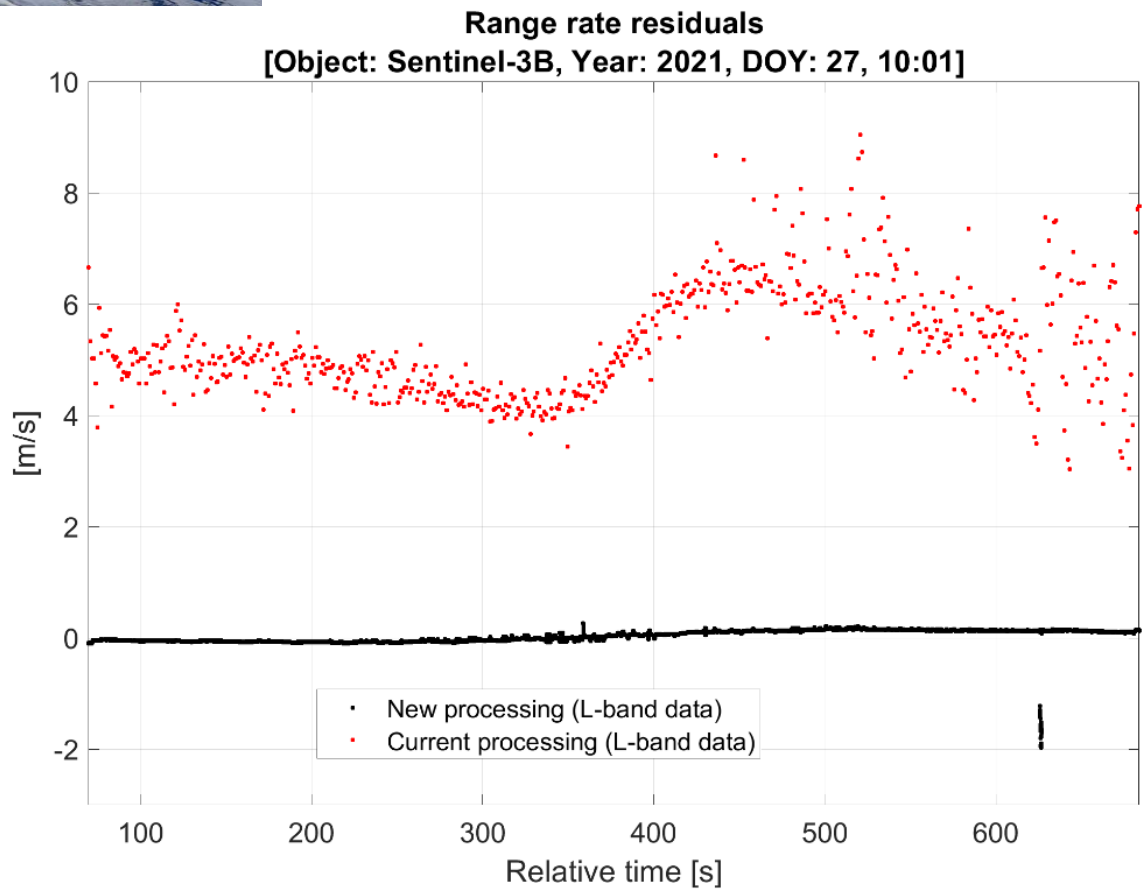




Experimental high-resolution observation mode

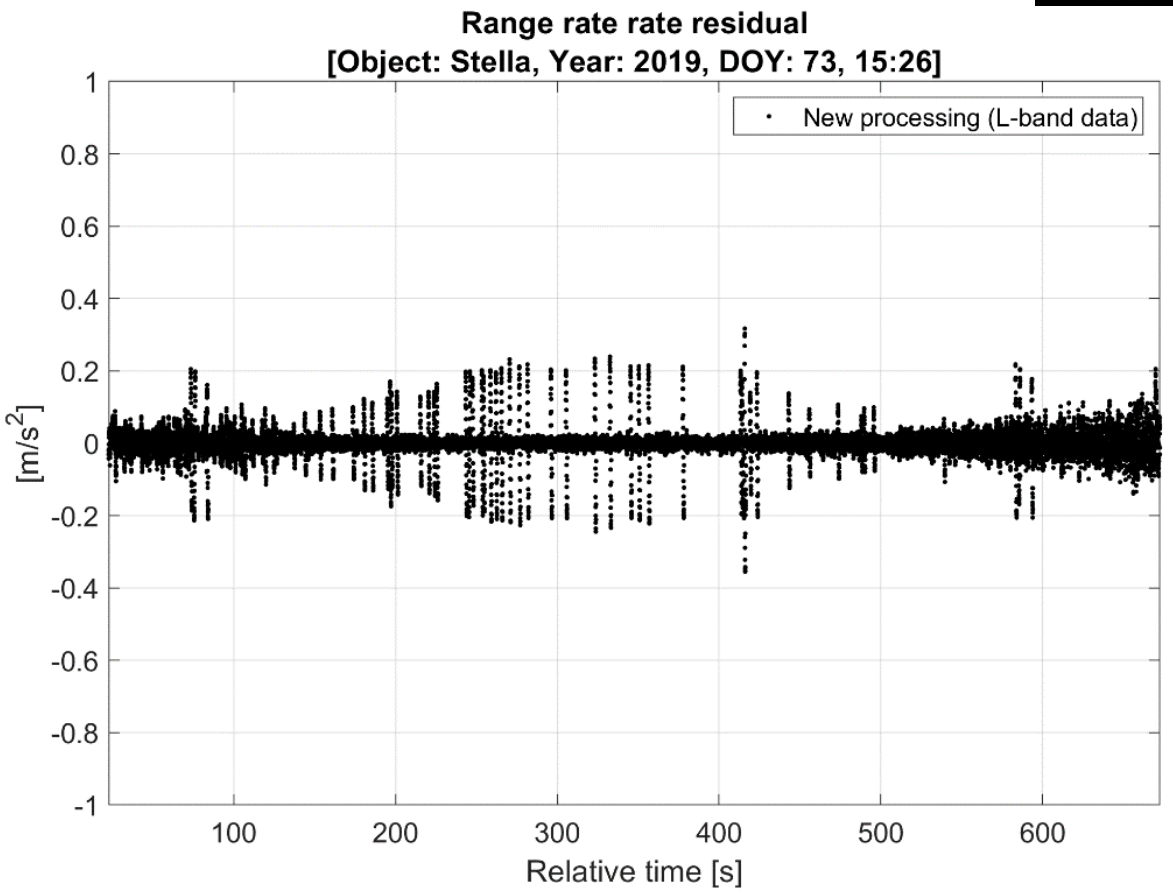
Range rate

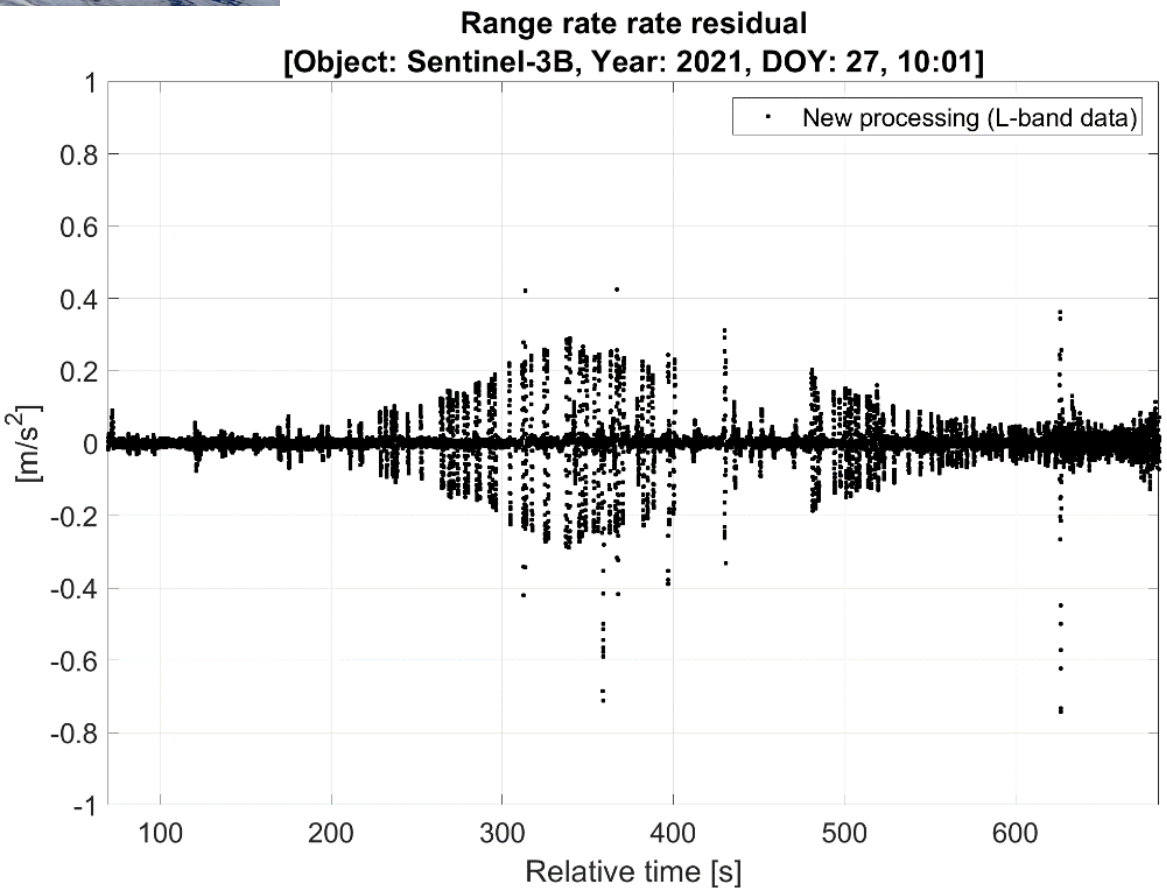




Experimental high-resolution observation mode

Range rate rate

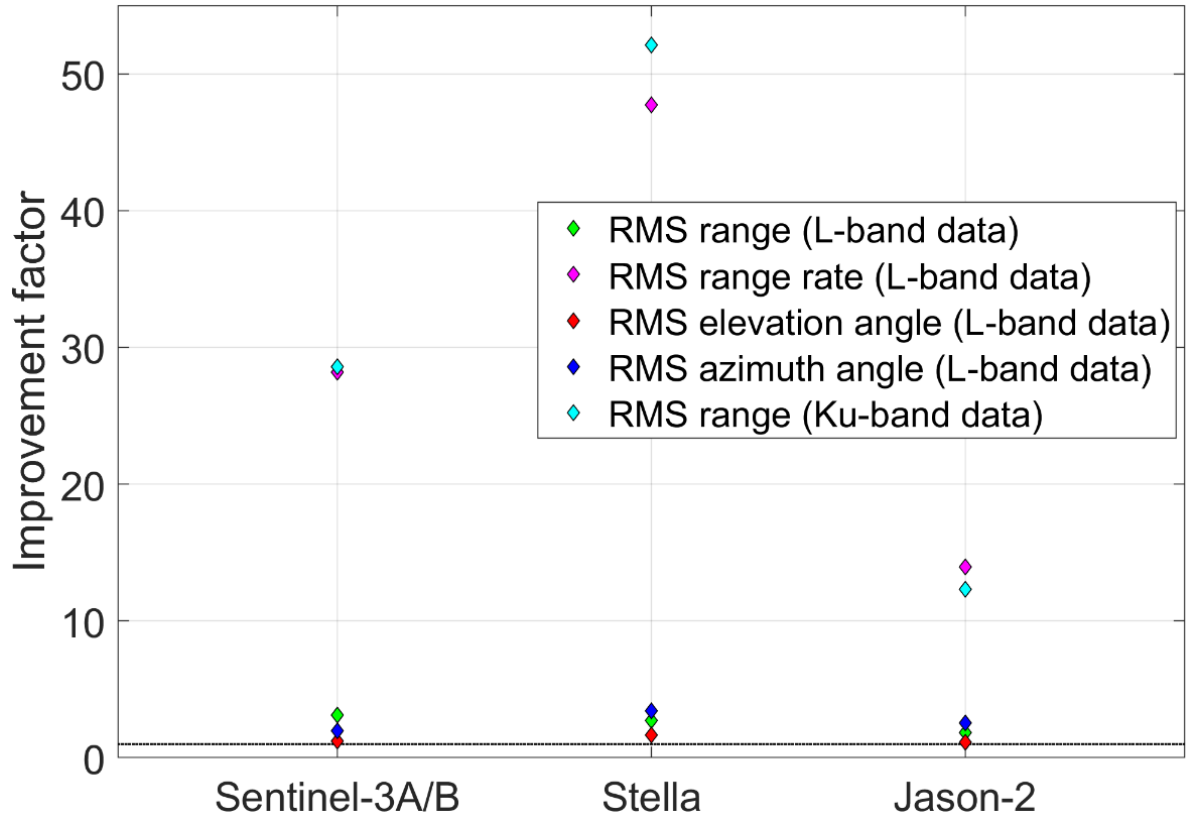




Experimental high-resolution observation mode

Statistical analysis

- Improvement factor over current processing (std)
  - Range (L-band data): 1.4
  - Range rate: 5.8
  - Elevation angle: 1.4
  - Azimuth angle: 1.4
  - Range (Ku-band data): 36.6
- A factor 1.4 in the estimation accuracy corresponds to a SNR improvement of 3dB



03

Initial Orbit Determination (IOD)

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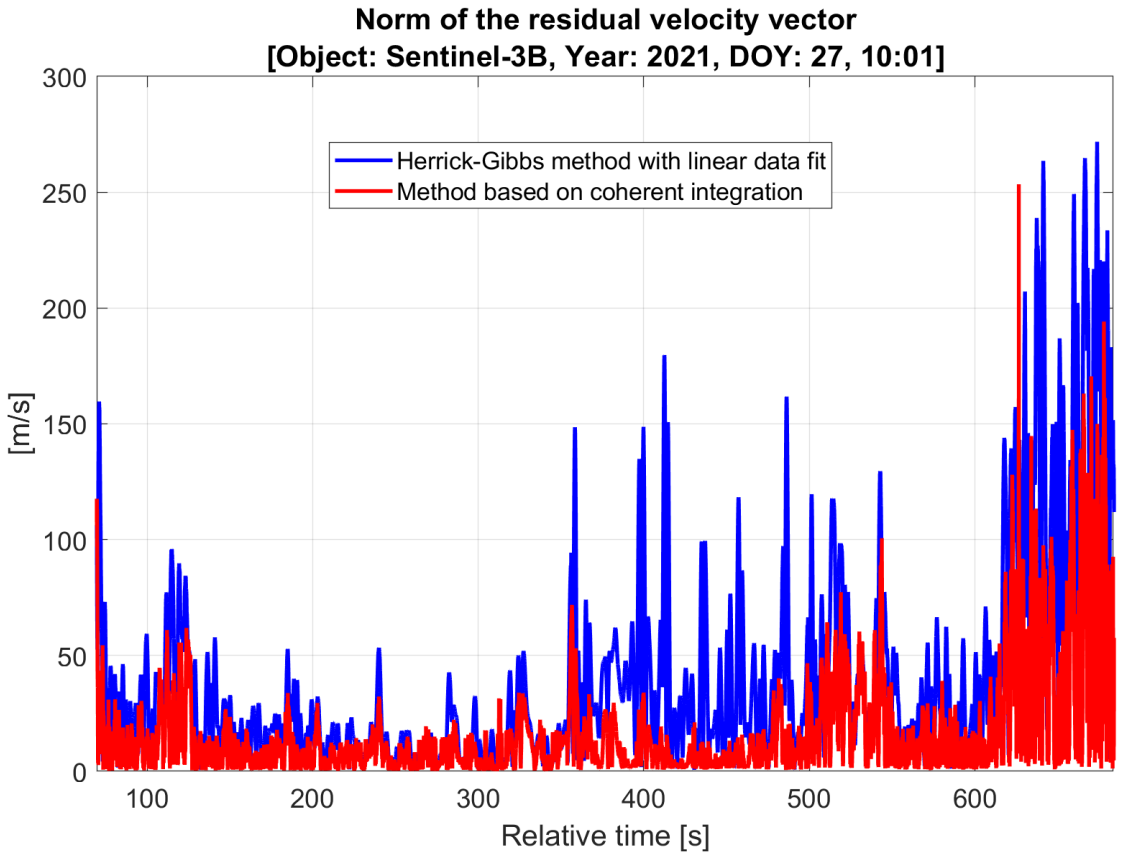
IOD

Objective and principle

- **Objective**
  - First orbital data of newly detected objects
- **Derivation of a new IOD method exploiting the range rate rate**
  - This parameter gives information about the velocity of a space object
- **Contribution to operation support**
  - Tracking of hostile satellites/unknown objects after their detection
  - Fragmentation events



04

Discrimination of multiple objects

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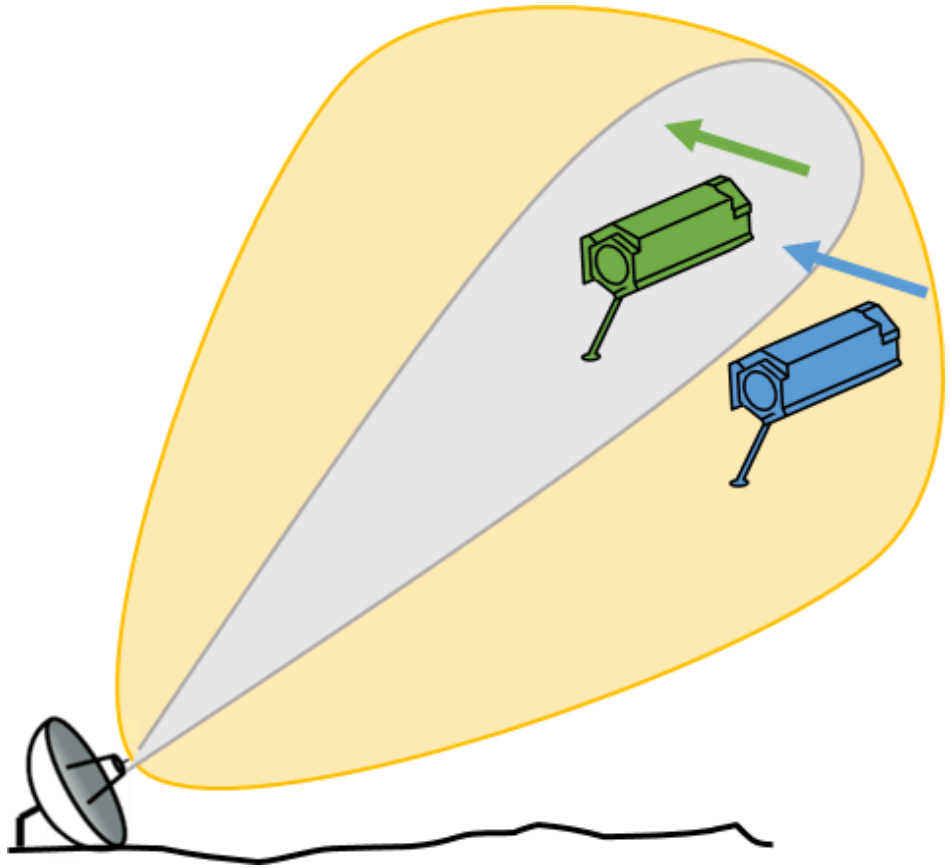
Discrimination of multiple objects

Objective and principle

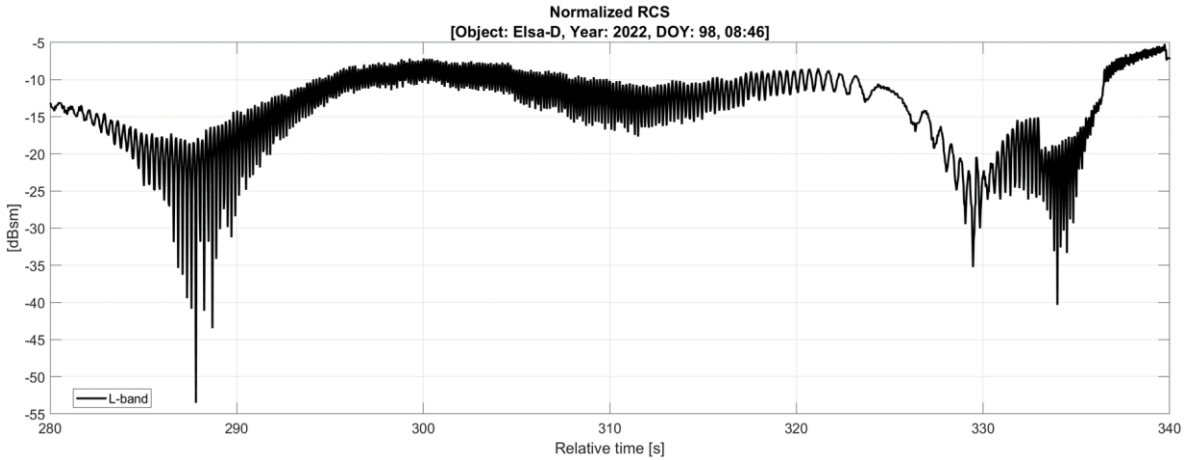
- **Objective**
  - Separation of multiple objects in the radar beam
  - Challenging case
    - Objects have similar orbit parameters and are located in the same range/Doppler resolution cell
- **Derivation of tailored coherent processing techniques**
  - Discrimination of objects in LEO and GEO
- **Contribution to operation support**
  - Detection and identification of hostile objects in the surrounding of an allied satellite
  - Surveillance of the early phase of space missions by monitoring the number of released objects

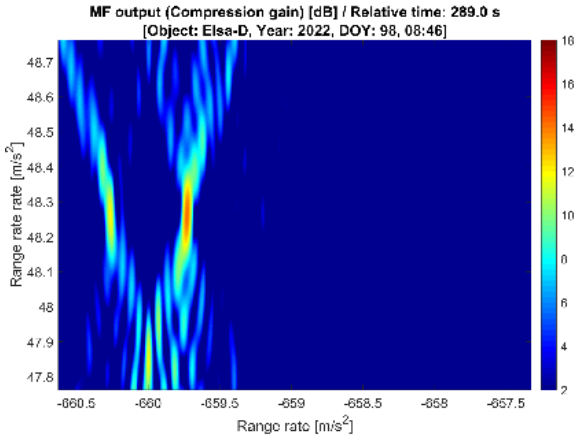


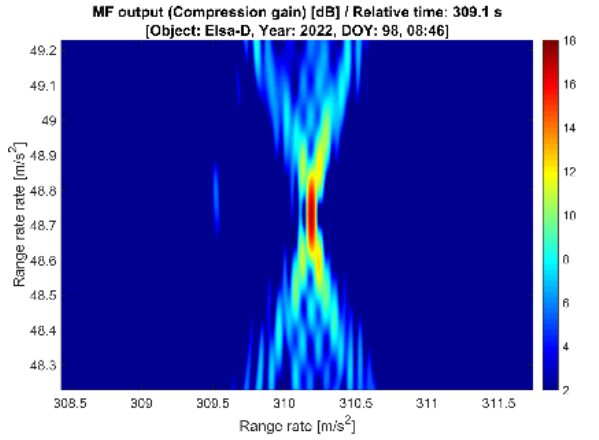
Discrimination of multiple objects

LEO

- Challenging aspects
  - Fast variation of the range rate and range rate rate
  - Objects with a large size difference
- Observation of the Astroscale mission
  - ELSA-D ~ 100 cm × 70 cm × 70 cm
  - ELSA-D CLIENT ~ 50 cm × 50 cm × 20 cm



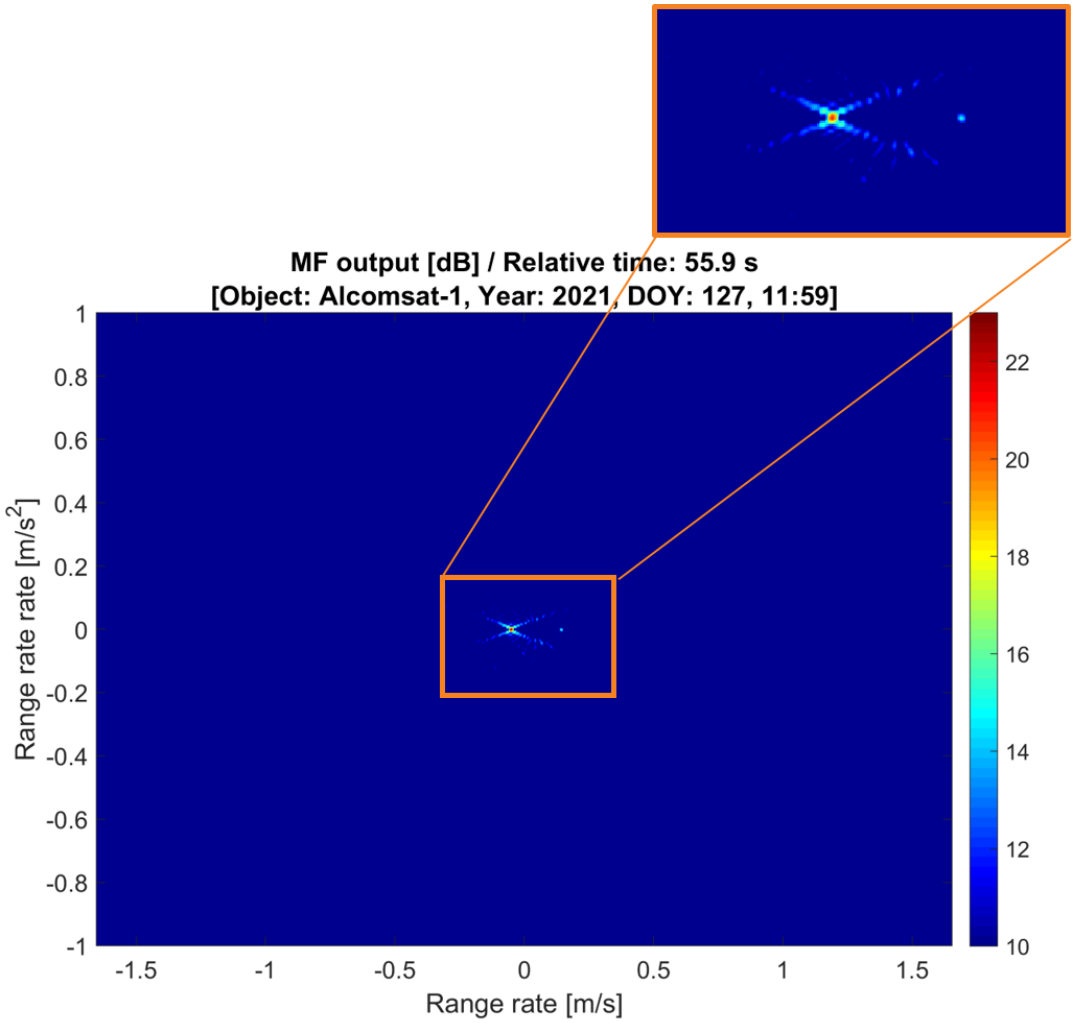




Discrimination of multiple objects

GEO

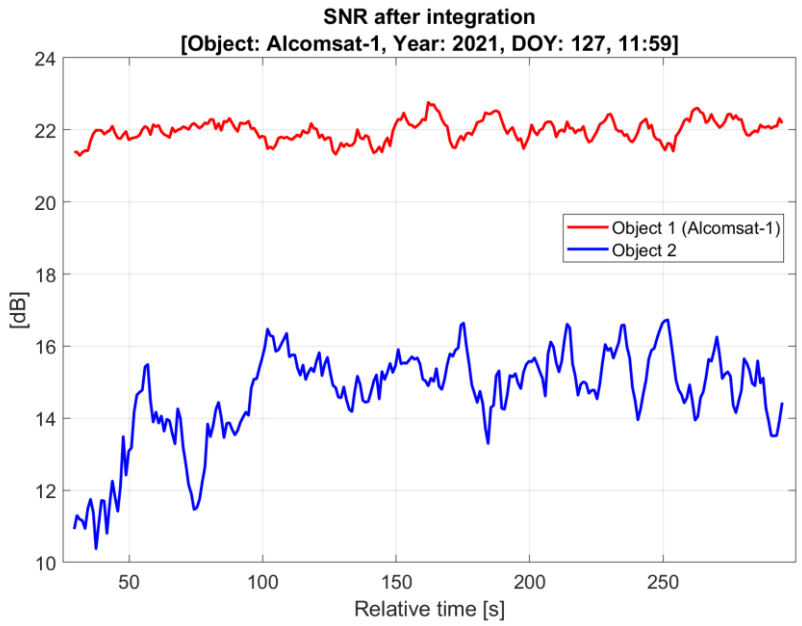
- Challenging aspects
  - Low SNR, single pulse detection is usually impossible
  - Objects with a large size difference
- Observation of Alcomsat-1
  - Integration over 8 s
  - Processing gain: ~24 dB
  - Another object could be detected
    - Unknown/uncorrelated object,
      object having performed a maneuver?

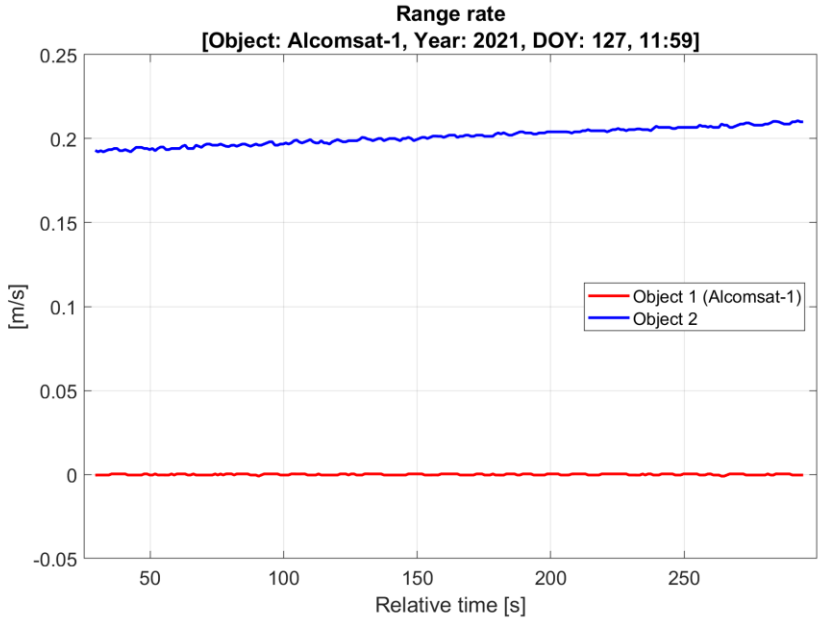


Discrimination of multiple objects

GEO

- Challenging aspects
  - Low SNR, single pulse detection is usually impossible
  - Objects with a large size difference
- Observation of Alcomsat-1
  - SNR of Alcomsat-1 after integration: ~23 dB
  - Precise estimation of the range rate and range rate rate of the objects

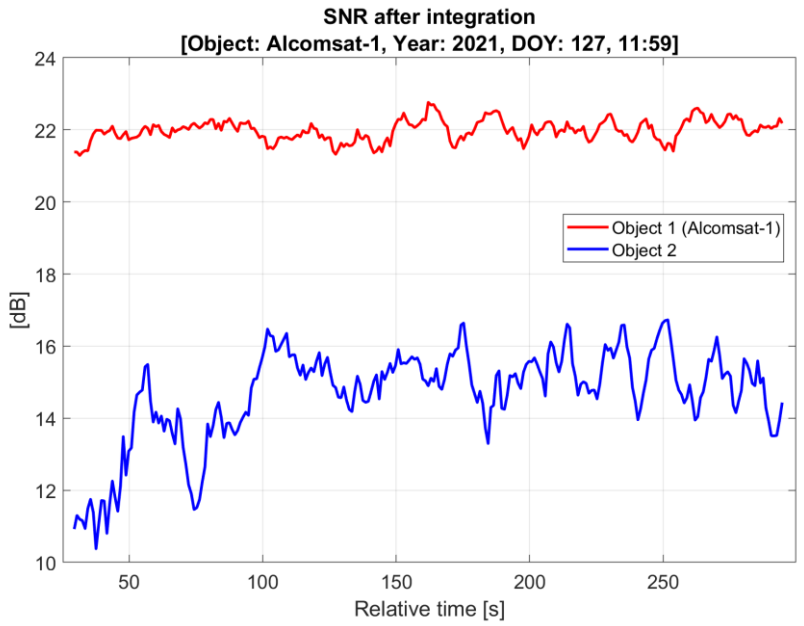


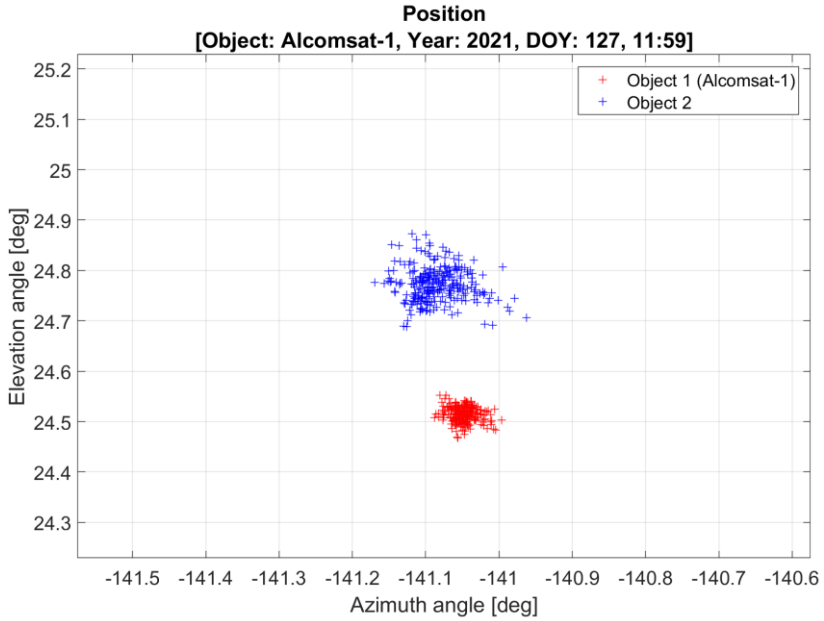


Discrimination of multiple objects

GEO

- Challenging aspects
  - Low SNR, single pulse detection is usually impossible
  - Objects with a large size difference
- Observation of Alcomsat-1
  - SNR of Alcomsat-1 after integration: ~23 dB
  - Precise estimation of the range rate and range rate rate of the objects
  - It is possible to estimate the LOS of the objects from the monopulse ratio





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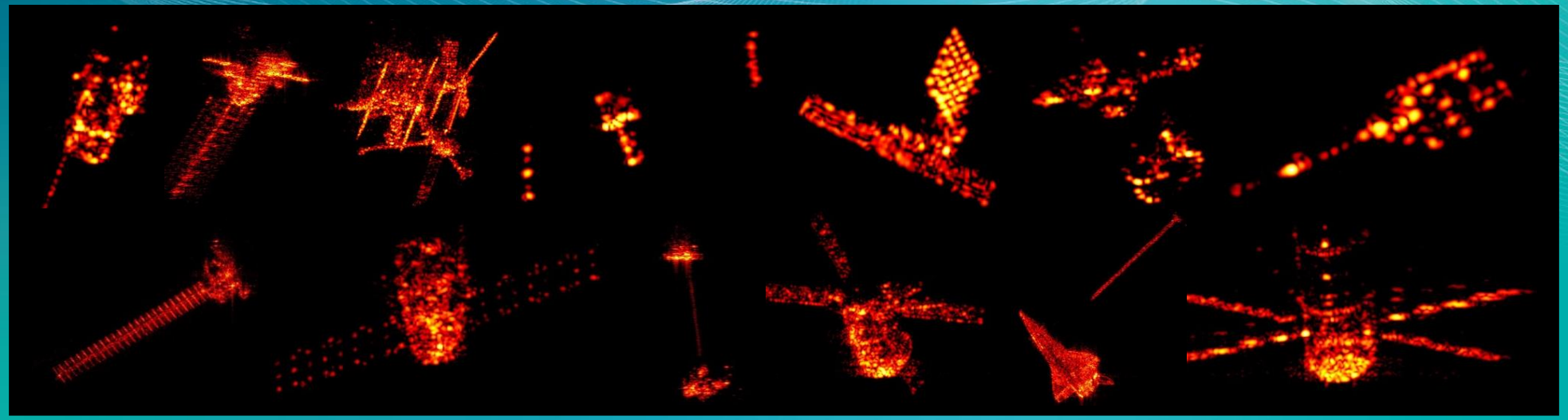
Thank you for your attention! Questions?



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