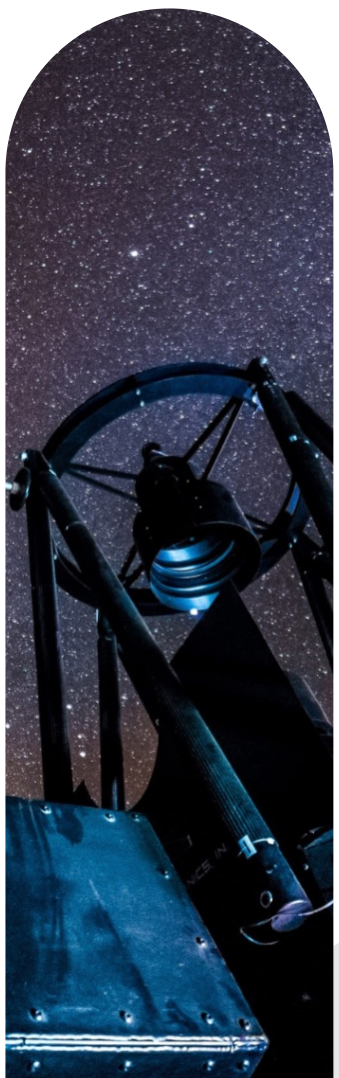
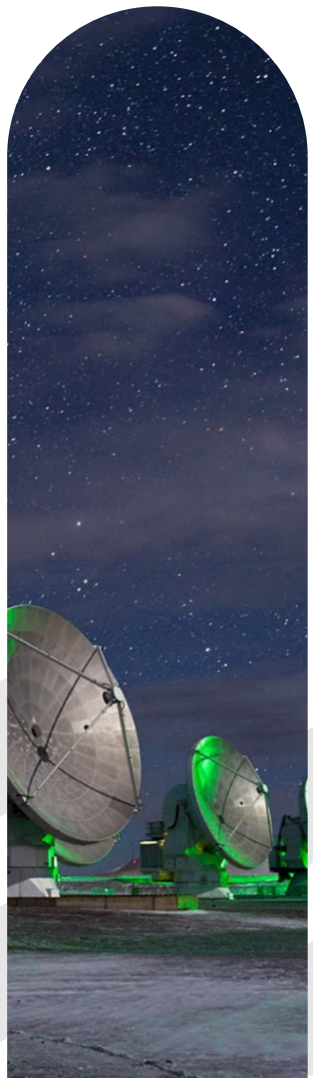
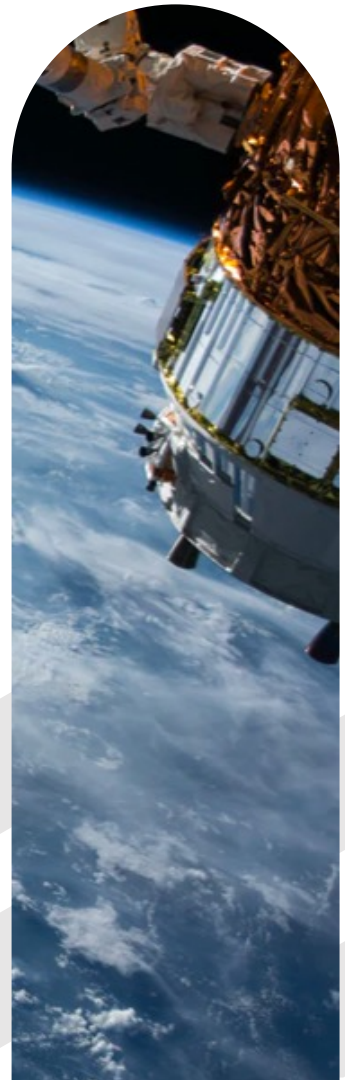
RECENT DEVELOPMENTS ON THE RADAR SENSOR BIRALES

M. Montaruli, P. Di Lizia,
M. Massari, S. Tebaldini,
G. Pupillo, G. Naldi, G. Bianchi



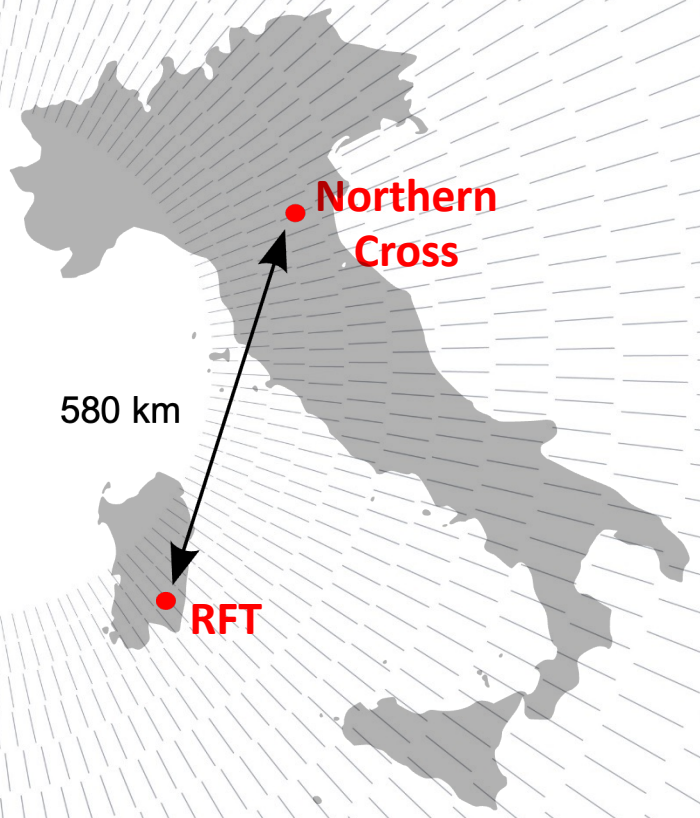




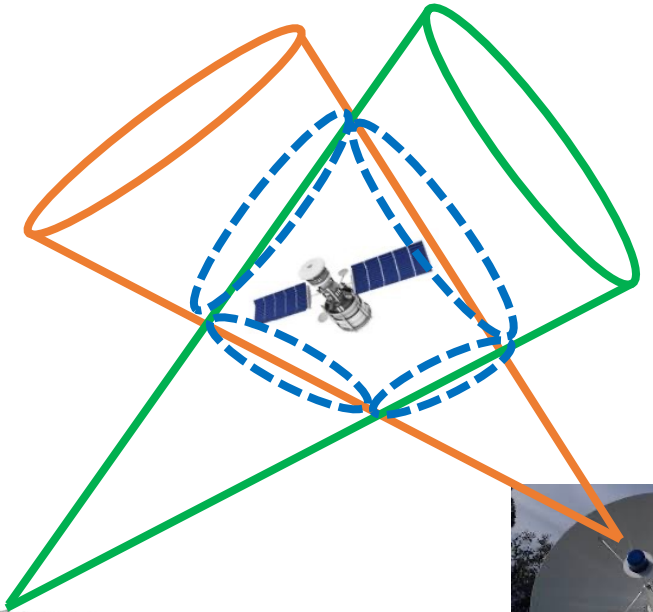
Inter-Agency Space Debris Coordination Committee Meeting

Darmstadt, 12-15 June 2023

BIstatic Radar for Leo Survey (BIRALES)



Northern Cross
(Bologna)

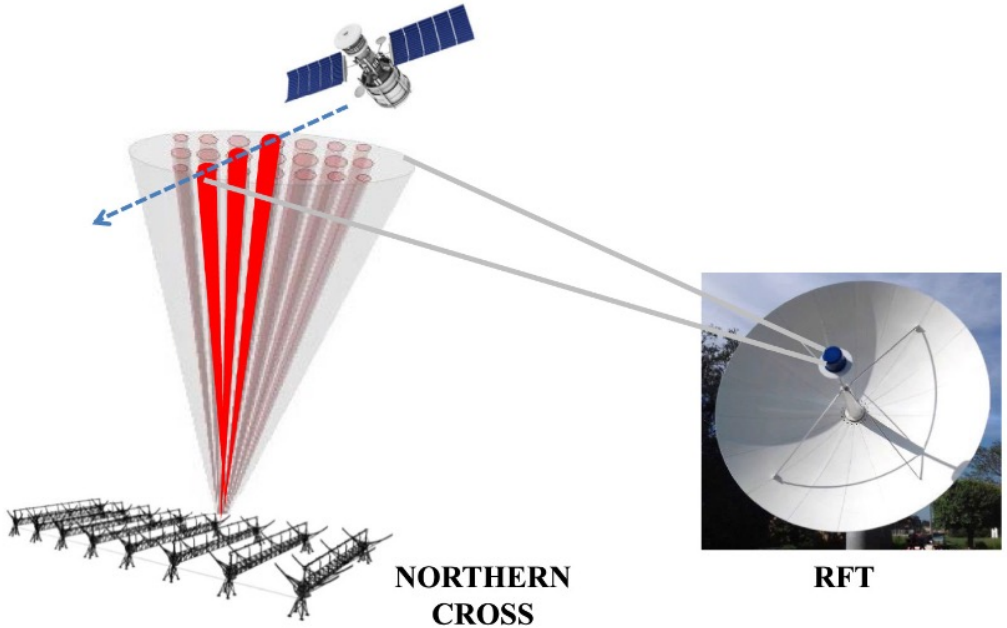


RFT
(Sardinia)

- Angular profile
- Slant Range
- Doppler Shift

BIRALES: ADAPTIVE BEAMFORMING APPROACH

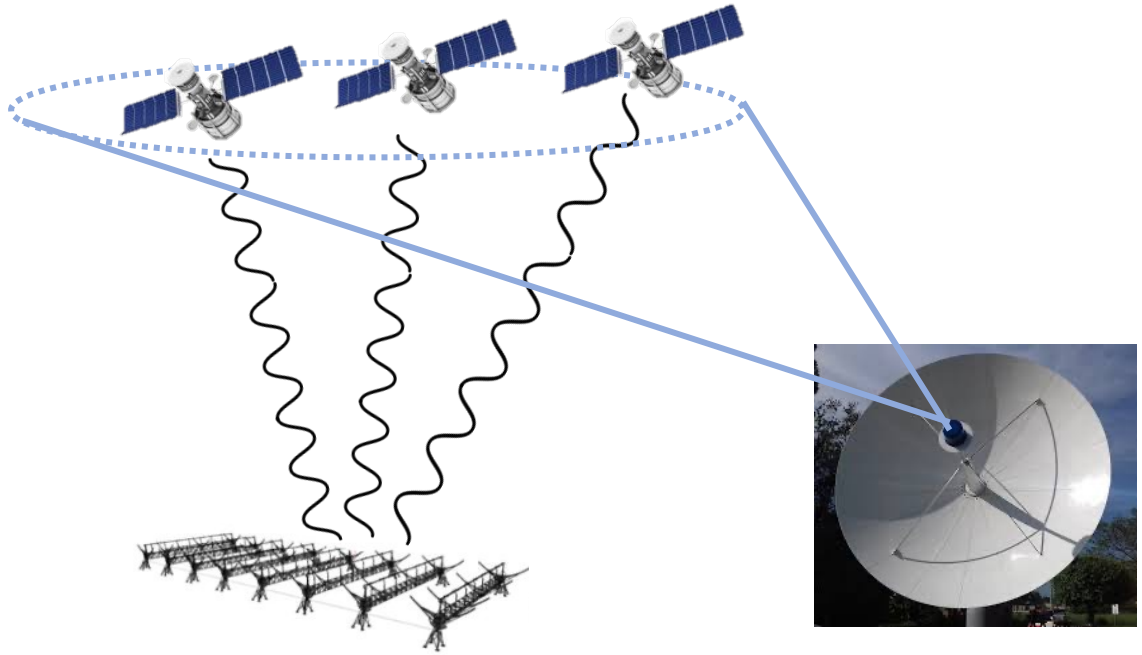
Static beamforming [1]



Medicina
(Bologna)

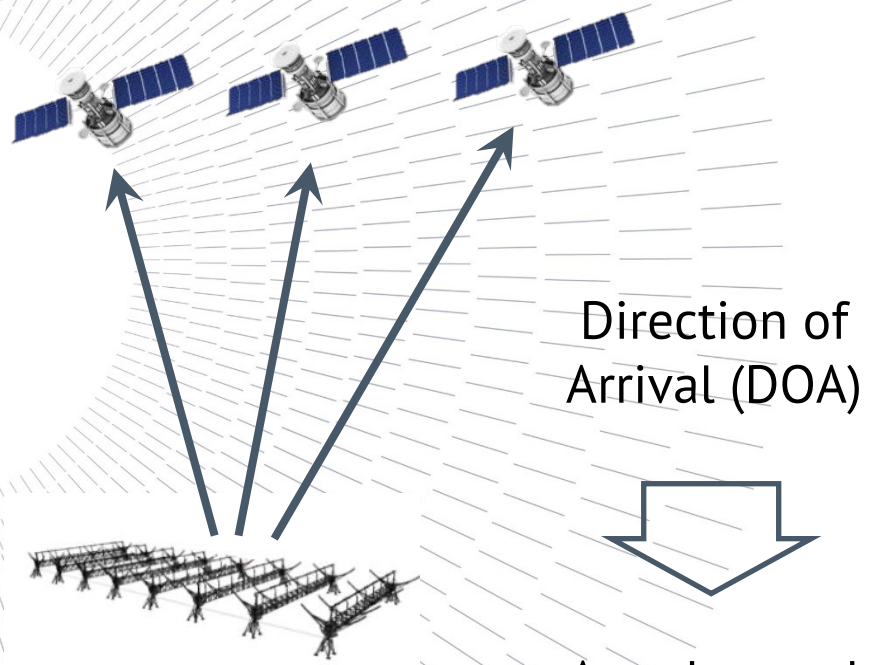
Salto di Quirra
(Sardinia)

Adaptive beamforming

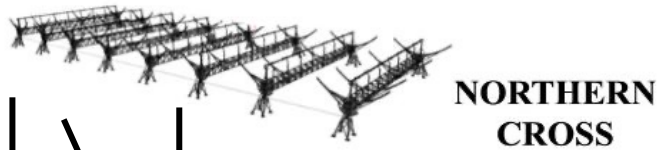


[1] *M. Losacco et al., Acta Astronautica, 2020*

BIRALES: ADAPTIVE BEAMFORMING APPROACH



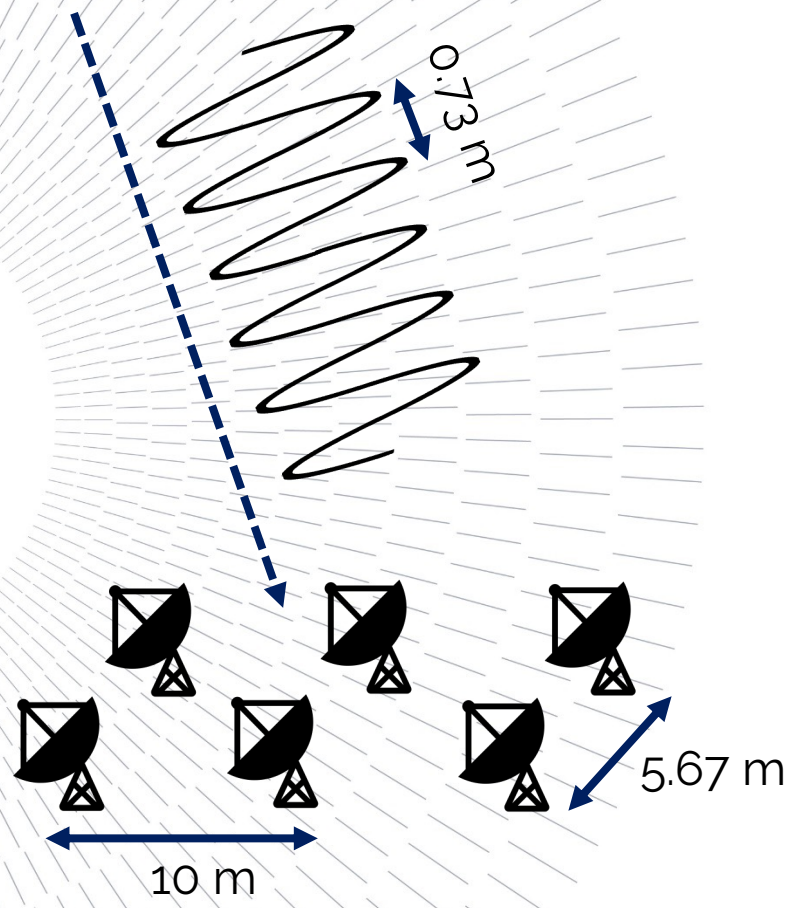
MUSIC - *MUltiple SIgnal Classification* [2]



Raw signal

[2] *R. Schmidt et al., IEEE Transactions on Antennas and Propagation, 1986*

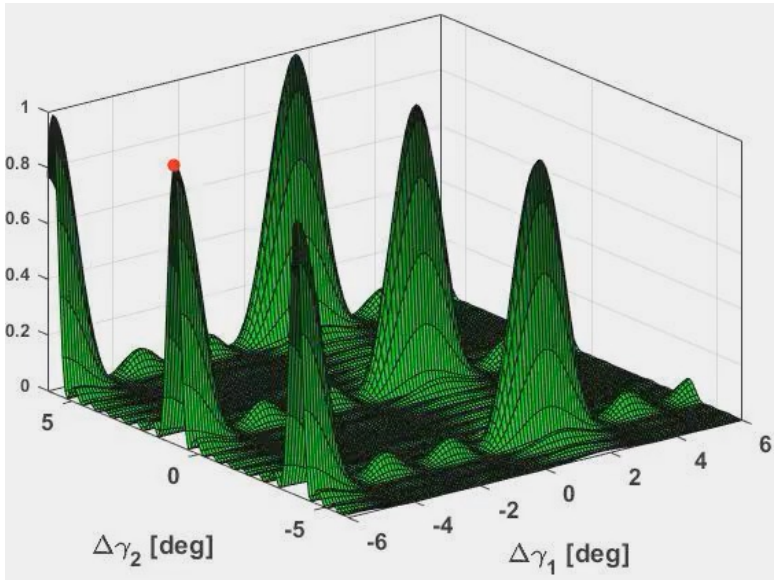
DOA AMBIGUITY PROBLEM



DOA solution is unique if distance between antennas is less than $\lambda/2$

⇨ Presence of multiple DOA estimates

⇨ Ambiguity solving criteria needed



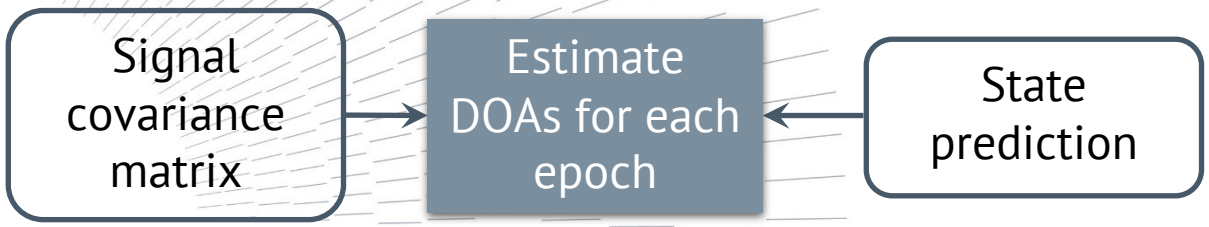
● Signal DOA

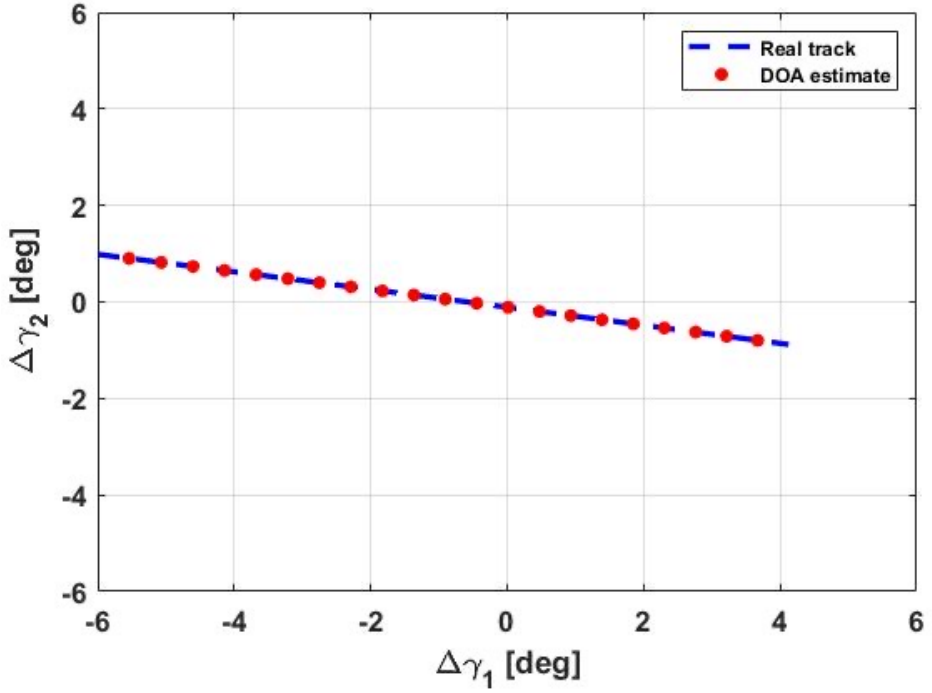
MATER
CATALOGUED OBJECT

S4U
POLITECNICO MILANO 1863

Music Approach for Track Estimate and Refinement (MATER)

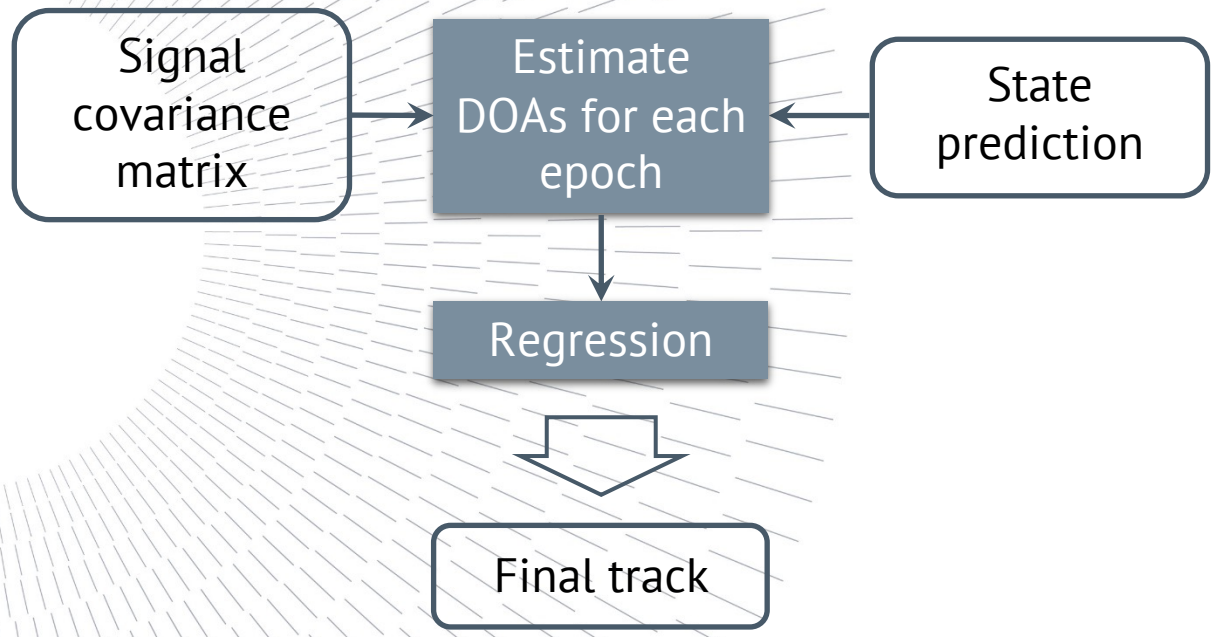
Catalogued case

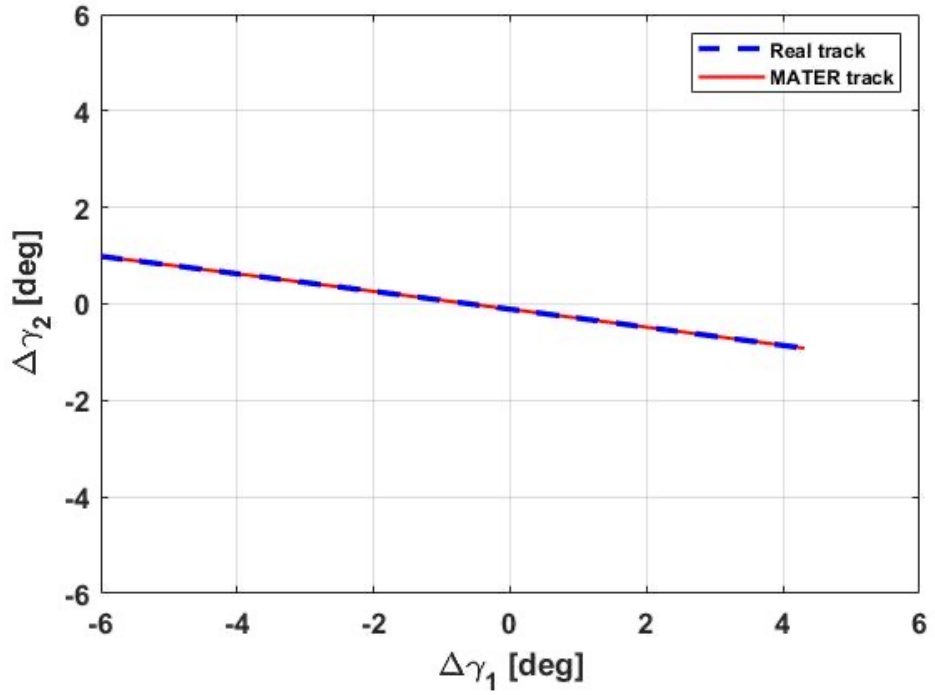




Music Approach for Track Estimate and Refinement (MATER)

Catalogued case





MATER

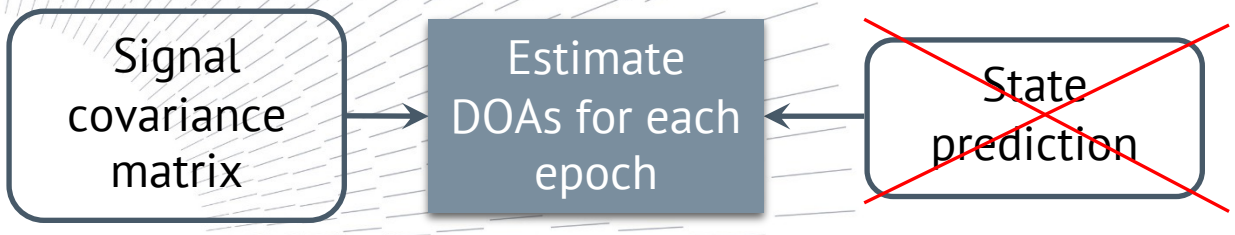
UNCATALOGUED OBJECT

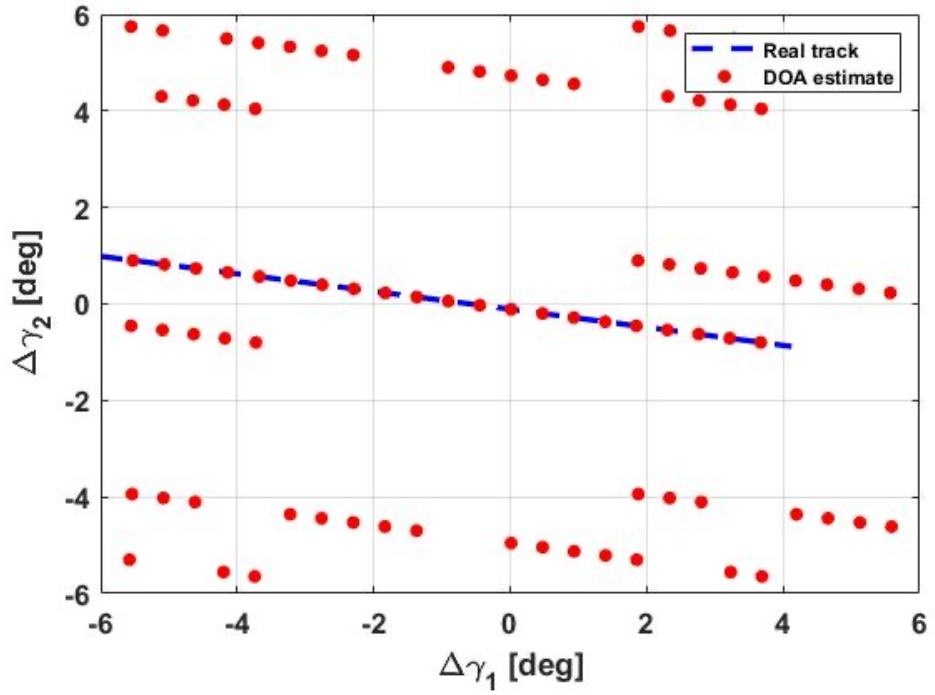
S4U

POLITECNICO MILANO 1863

Music Approach for Track Estimate and Refinement (MATER)

Uncatalogued case

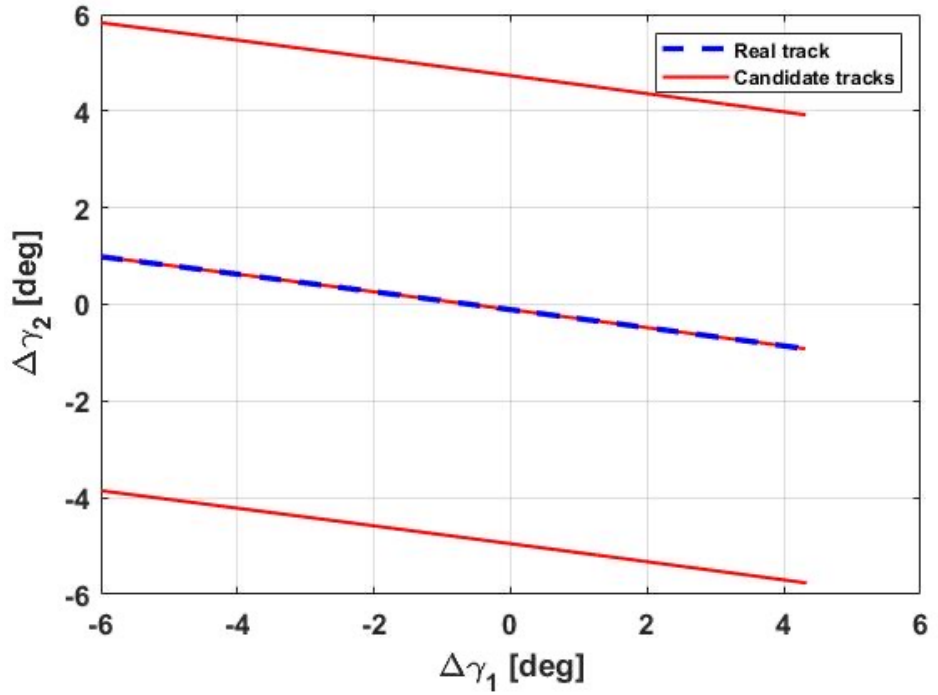




Music Approach for Track Estimate and Refinement (MATER)

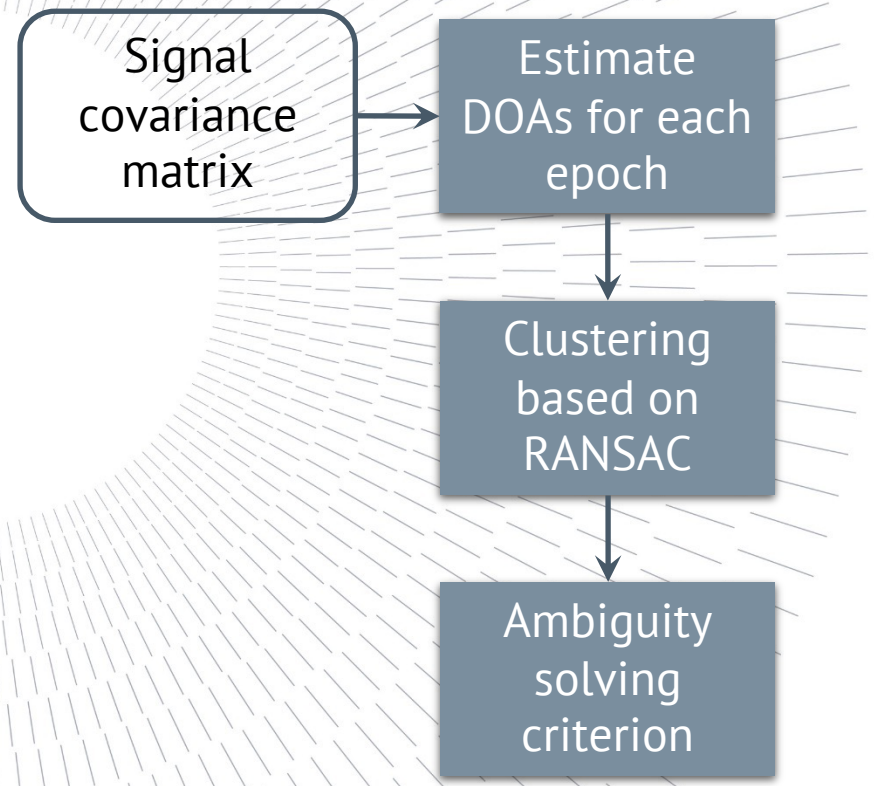
Uncatalogued case

Signal covariance matrix → Estimate DOAs for each epoch → Clustering based on RANSAC → Ambiguity solving criterion



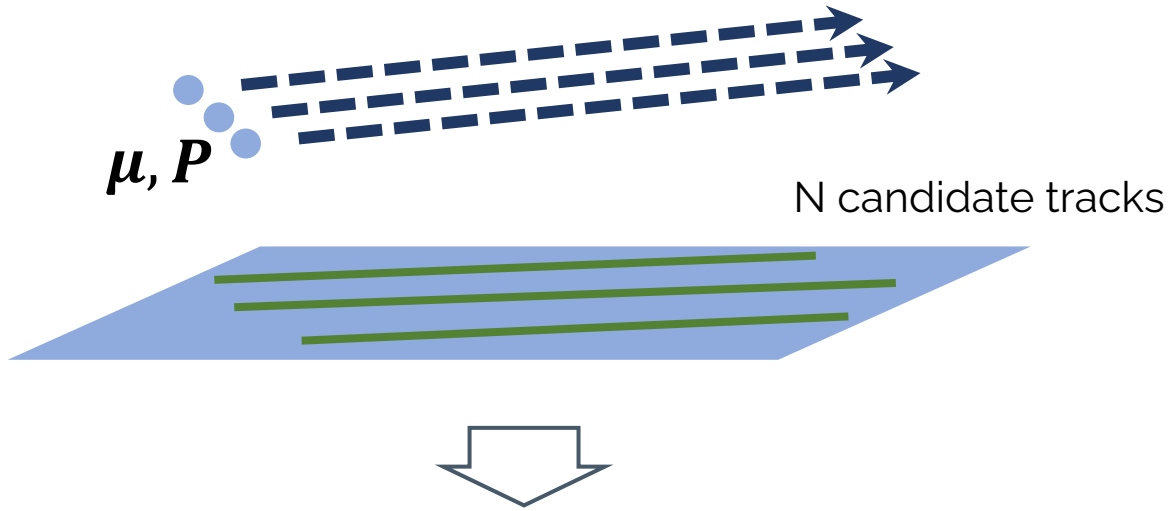
Music Approach for Track Estimate and Refinement (MATER)

Uncatalogued case



Proposed approach:

- For each candidate track, use measured DS and SR to perform an initial orbit determination (IOD)



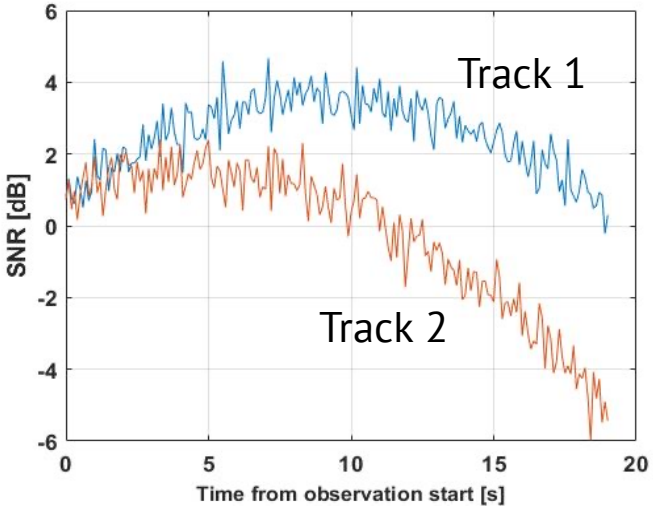
- Compute all predicted SNR profiles and compare with measured SNR

Music Approach for Track Estimate and Refinement (MATER)

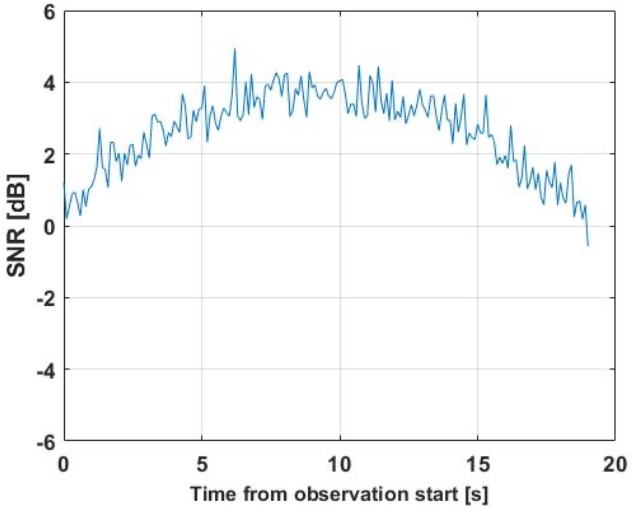
Uncatalogued case

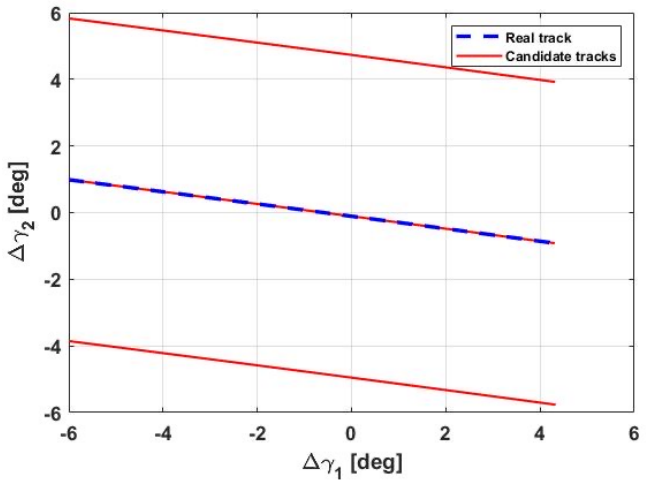
Signal covariance matrix → Estimate DOAs for each epoch → Clustering based on RANSAC → Ambiguity solving criterion

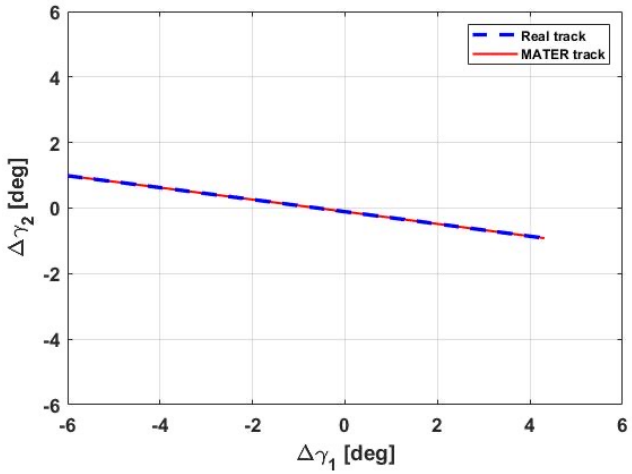
Predicted



Measured







REAL OBSERVATIONS

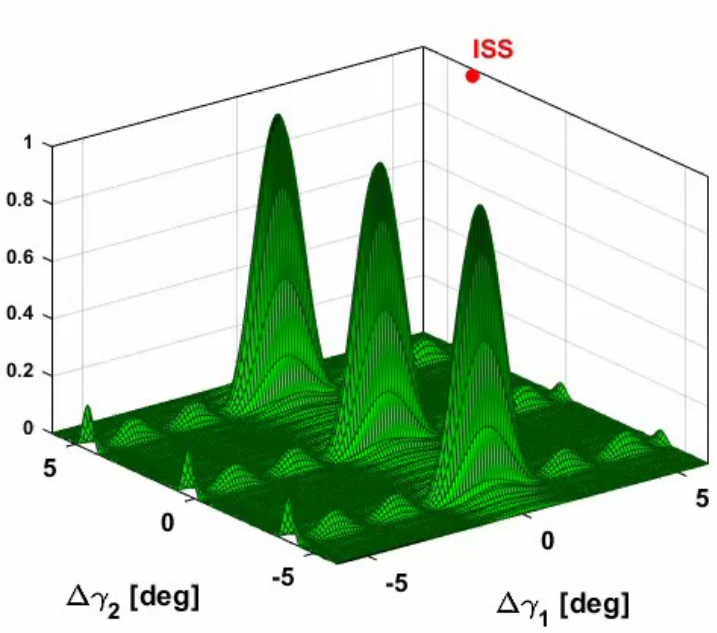
ISS passage (April 28, 2021)

Past signal processing chain not suitable:

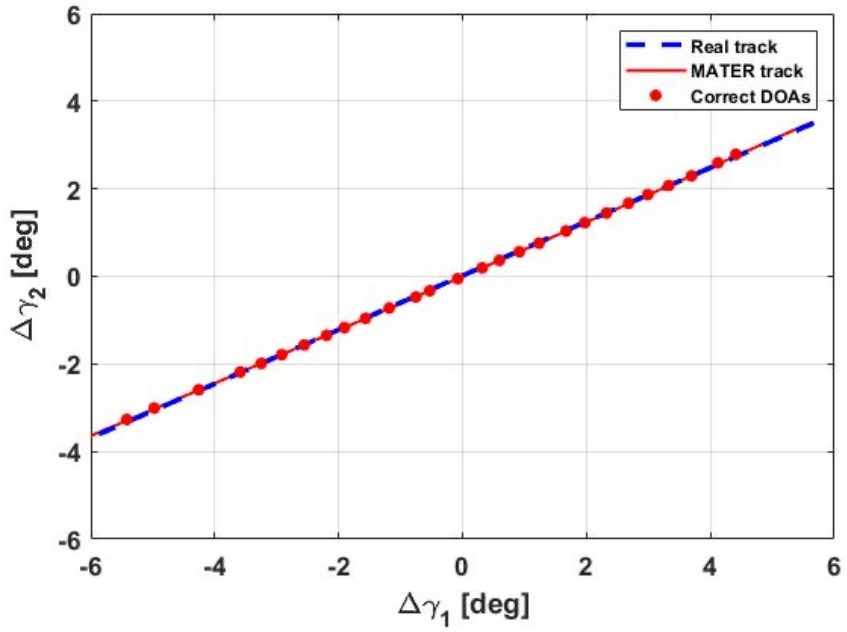
- Still designed for multibeam
- Very noisy covariance matrices

Only large objects with small SR

MUSIC pattern



Accuracy	1e-02 - 1e-01 deg

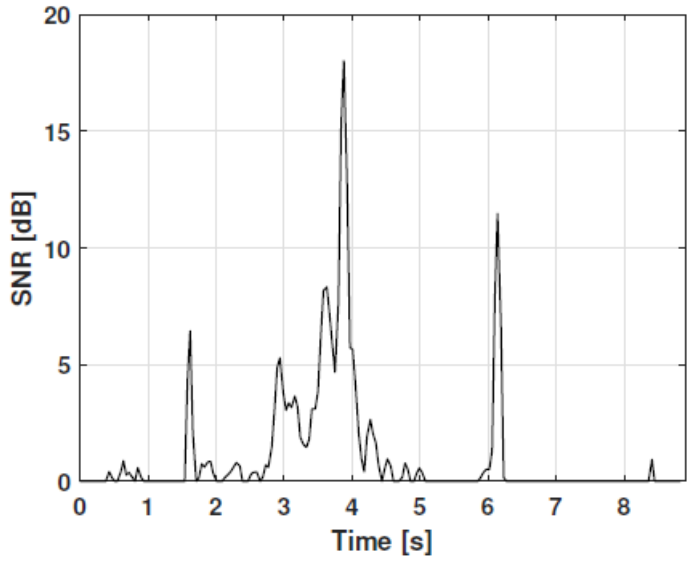


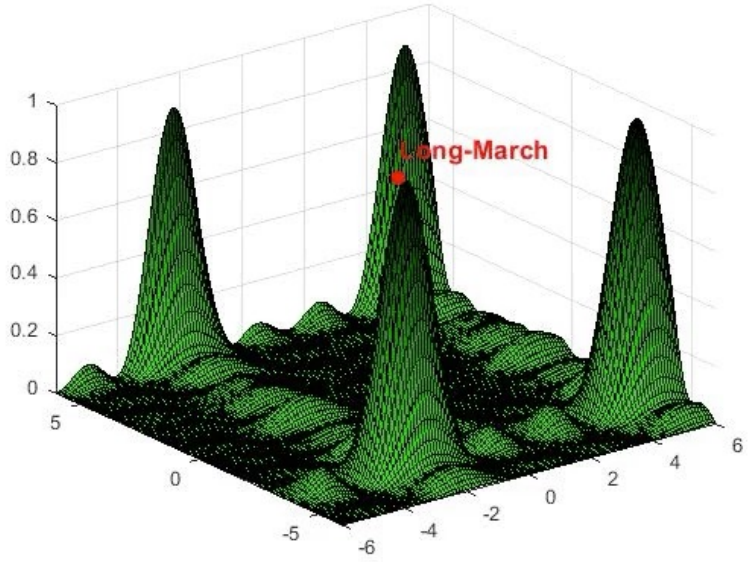
REAL OBSERVATIONS

Long March reentry (May 9, 2021)

Challenging conditions:

- No accurate passage prediction
- Weak signal
  - Transit was low on the horizon
  - No proper signal processing chain



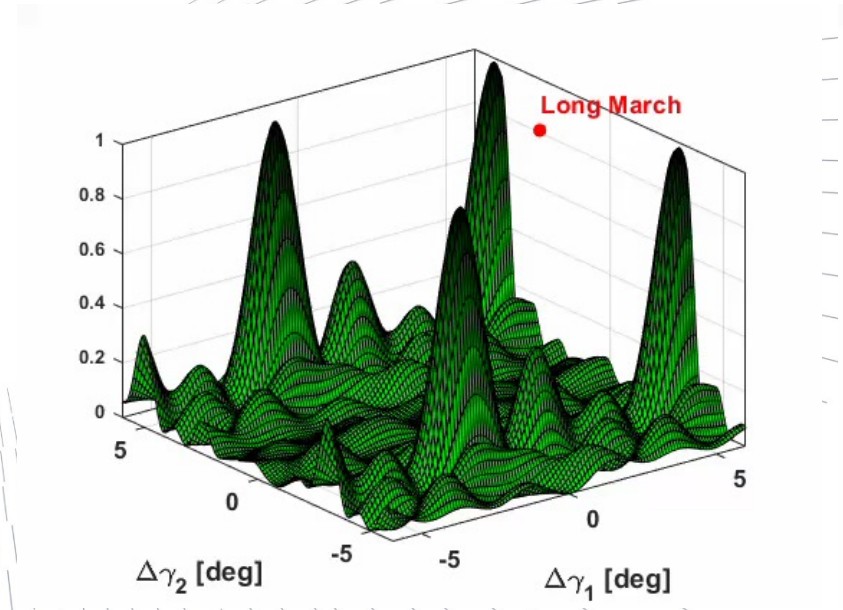


REAL OBSERVATIONS

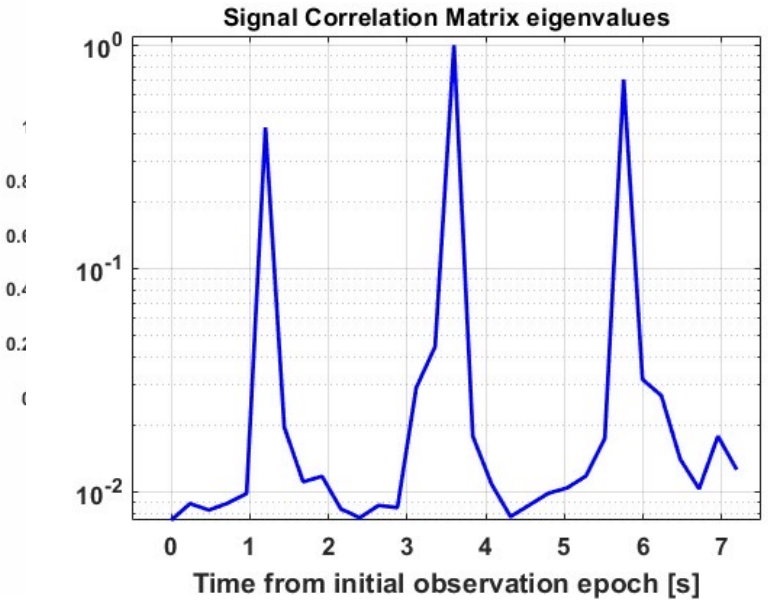
Long March re-entry

- From October 31st to November 4th, 2022
- First operational involvement in SST service

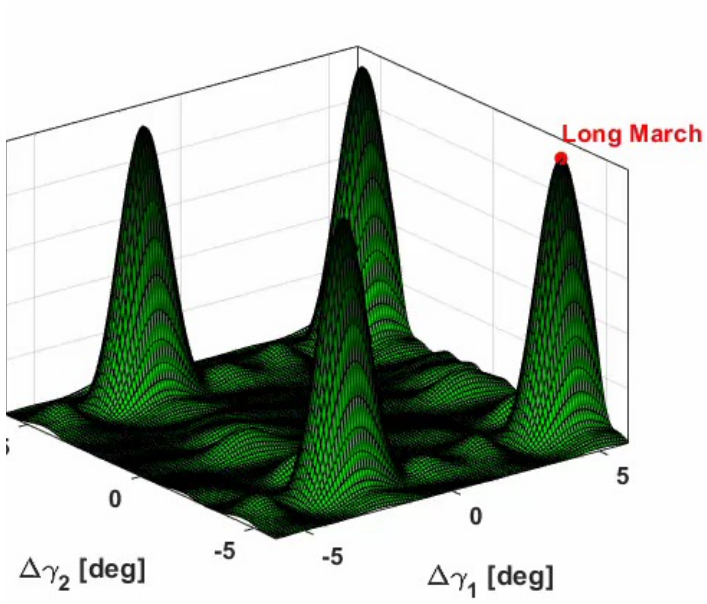
November 1st, 2022
h. 08:40 UTC



November 2nd, 2022
h. 08:24 UTC



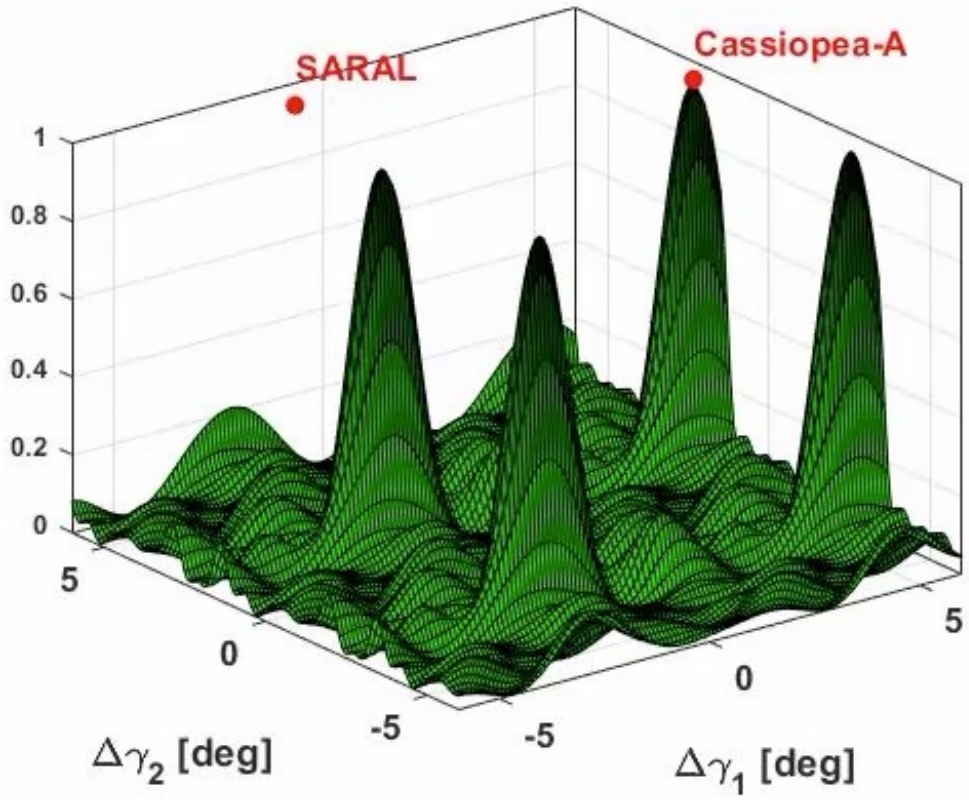
November 4th, 2022
h. 07:29 UTC

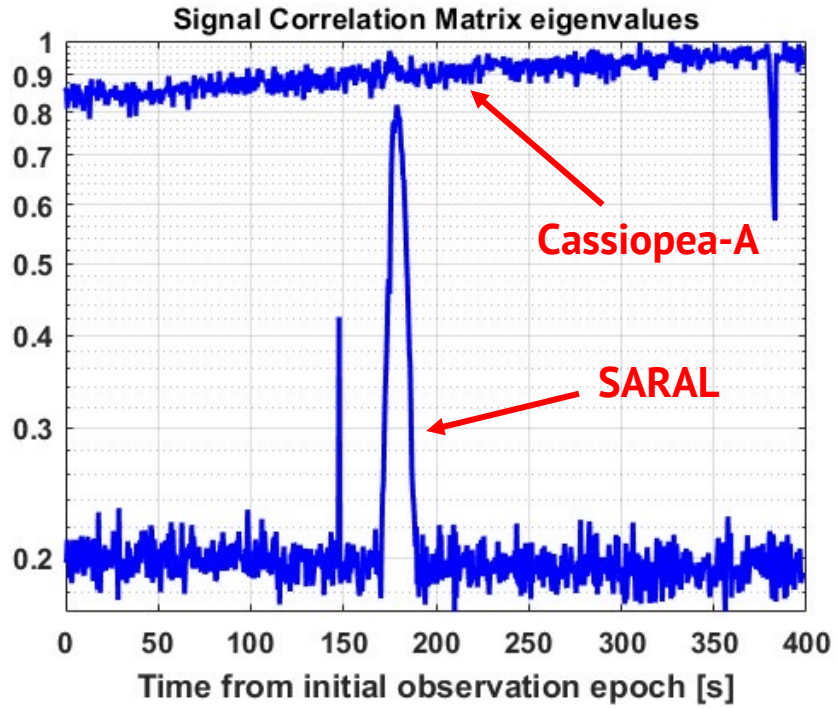


REAL OBSERVATIONS: Multiple Sources

SARAL transit (December 2nd, 2022)

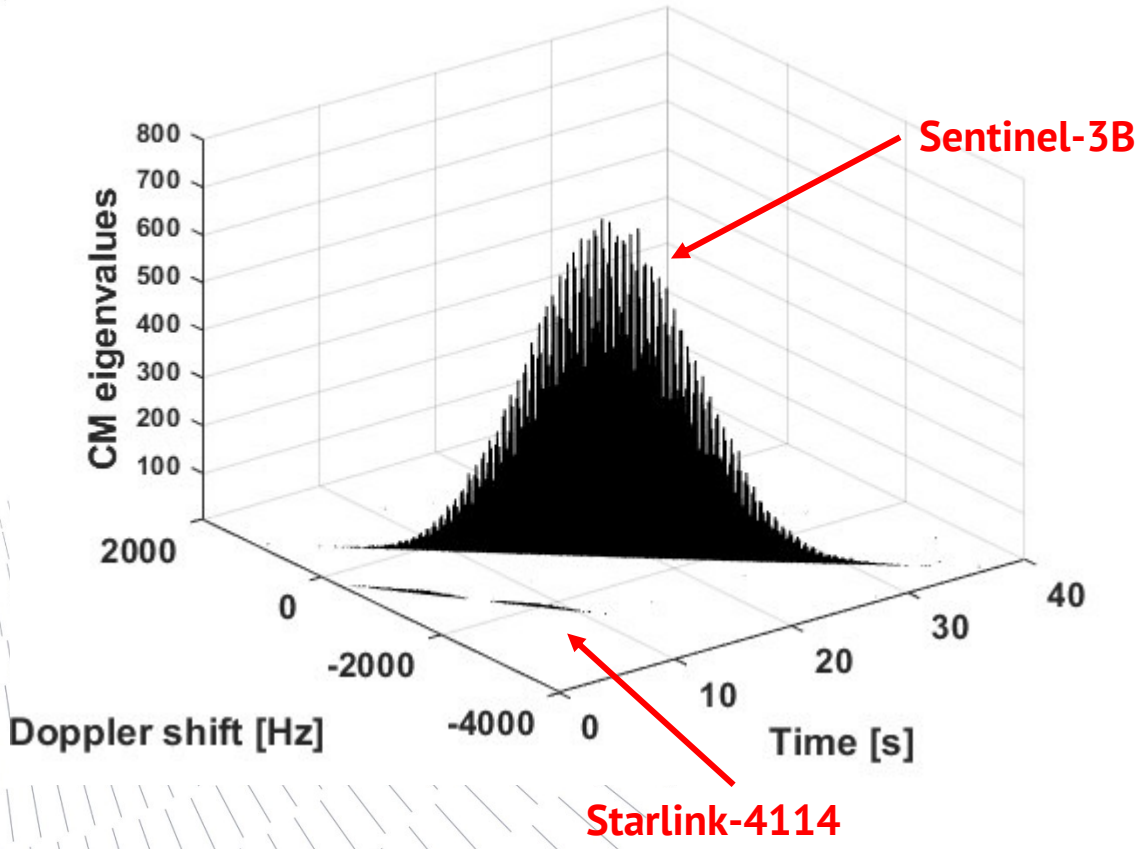
- Target: SARAL (norad ID 39086)
- Radiosource: Cassiopea-A



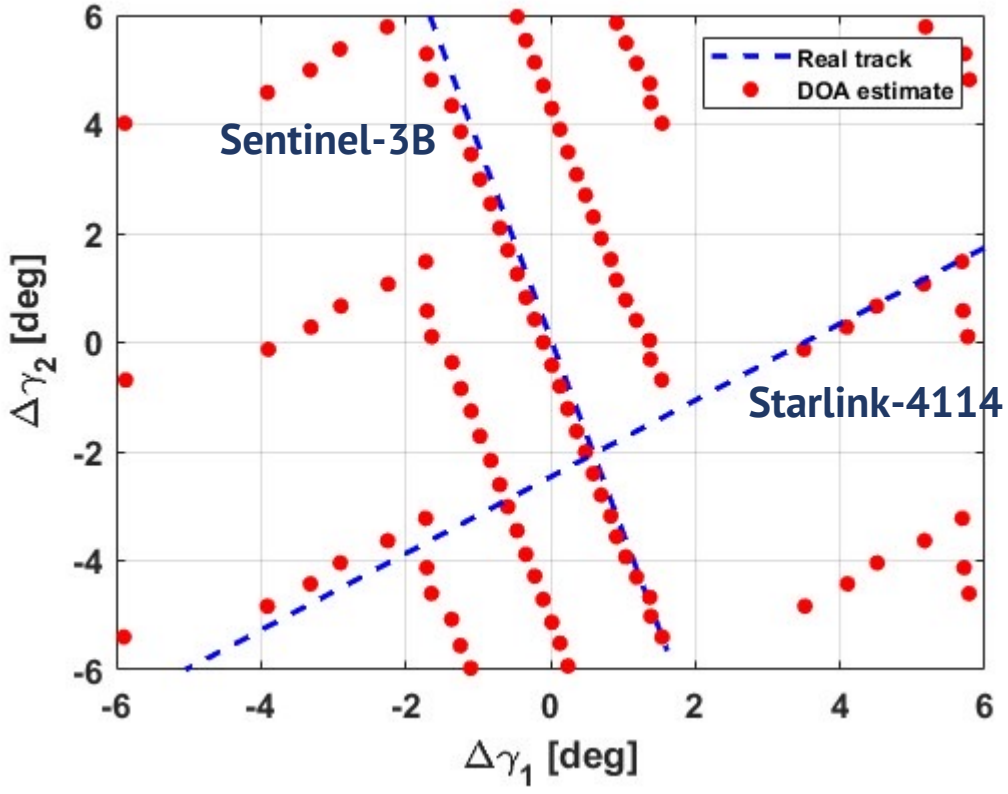


REAL OBSERVATIONS: Multiple Sources

Sentinel-3B transit (April 18th, 2023)



- Channelization strategy
- Target: Sentinel-3B (norad ID 43437)
- Other target detected: Starlink-4114 (norad ID 53162)



CONCLUSIONS

CONCLUSIONS

- Promising results from the new BIRALES data processing pipeline, also on real data

Ongoing activities:

- Validation of BIRALES backend upgrade
- Implementation in operational procedures
- Solution of the ambiguities
- RCS estimation

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Agenzia Spaziale Italiana

INAF – Istituto Nazionale di Astrofisica – National Institute for Astrophysics

POLITECNICO MILANO 1863

Inter-Agency Space Debris Coordination Committee Meeting

Darmstadt, 12-15 June 2023

THANK YOU

Acknowledgments

*Research performed within the **European Commission** Framework Programme H2020 and Copernicus "SST Space Surveillance and Tracking" contracts N. 952852 (2-3SST2018-20) and N. 237/G/GRO/COPE/16/8935 (1SST2018-20) with further support from the **Italian Space Agency** through the grant agreement n. 2020-6-HH.0*