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PIANO NAZIONALE
DI RIPRESA E RESILIENZA



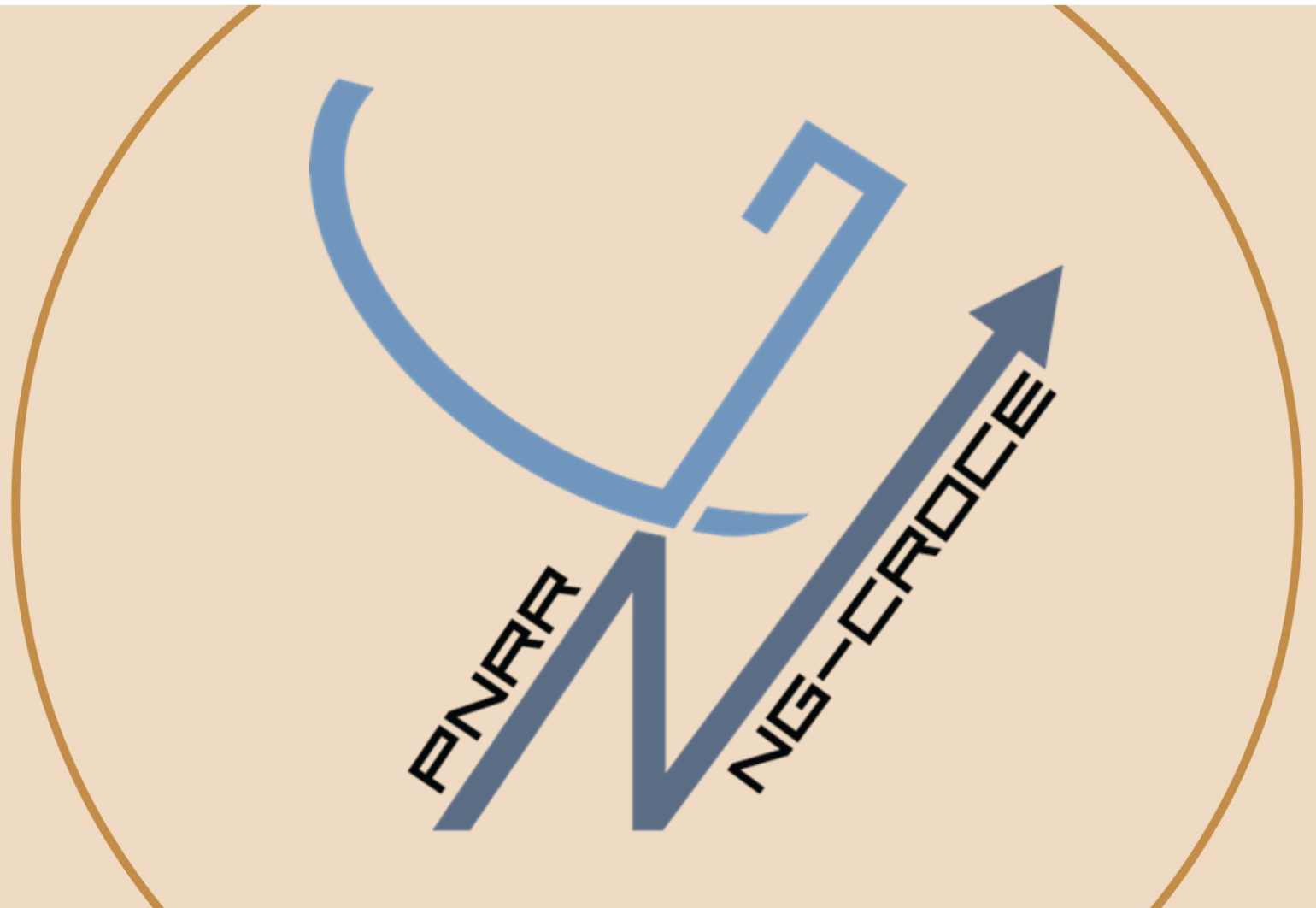
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Combining Noto
radiotelescope and
BIRALES in a multistatic
configuration: a new
generation of the Italian
radar SST infrastructure

Final Meeting

Martedì 30 Giugno – Giovedì 02 Luglio

OAC - Osservatorio Astrofisico di Arcetri



M.F. Montaruli



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OUTLINE

- 01 Multistatic configuration
- 02 Simulations
 - Stereoscopic Orbit Determination
 - Data-fusion Orbit Determination
- 03 Conclusions



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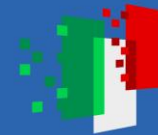
03 Conclusions



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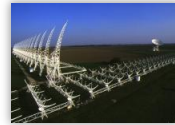


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Multistatic configuration



RX



Medicina radiotelescope

TX



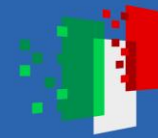
Trasmittitore Radio Frequenza (TRF)



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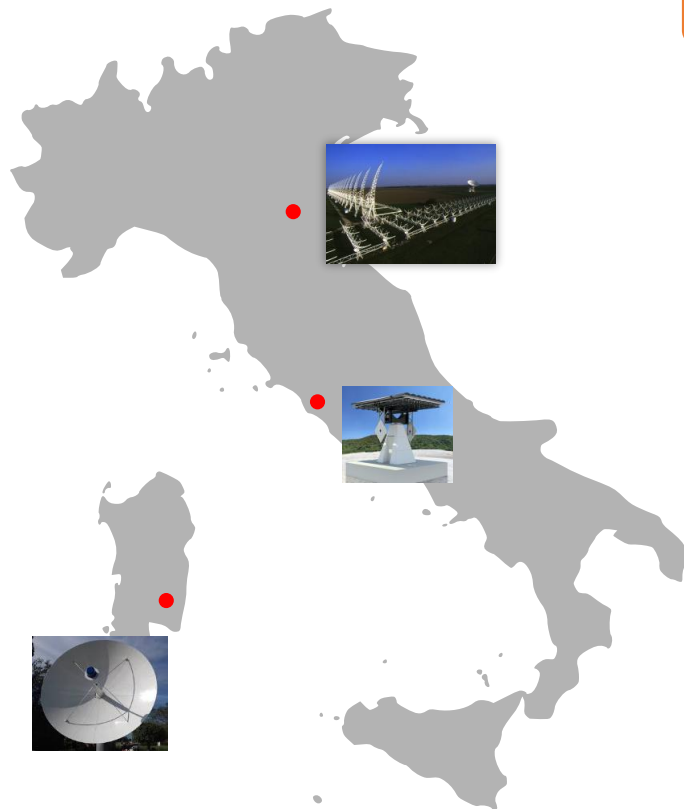


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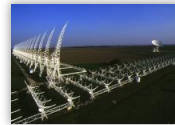


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Multistatic configuration



RX



Medicina radiotelescope

TX



New transmitter



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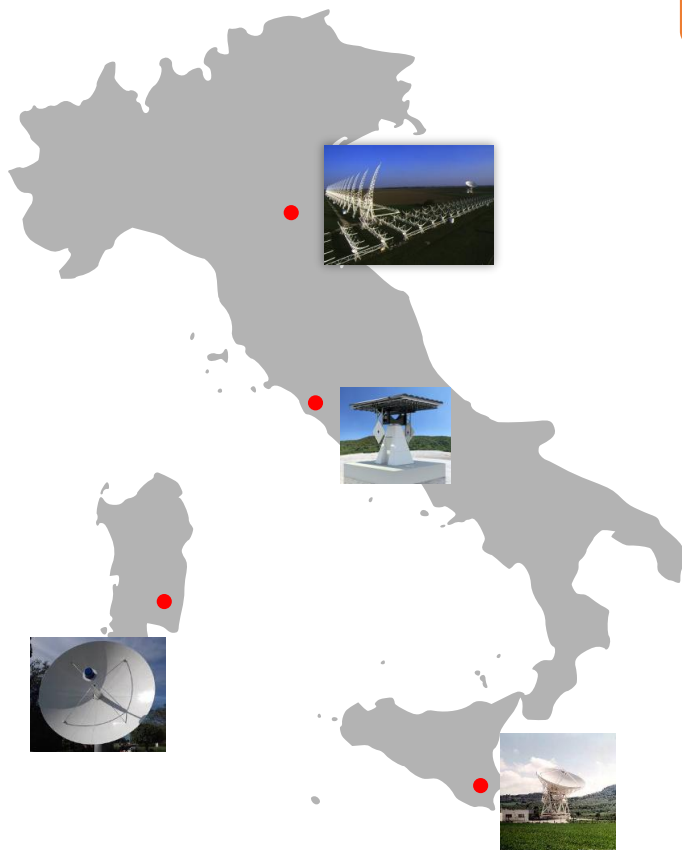


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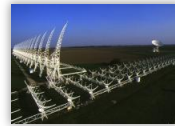


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Multistatic configuration



RX



Medicina radiotelescope



Noto radiotelescope

TX



New transmitter



Trasmettitore Radio Frequenza (TRF)

Research question

Can the stereoscopic observation improve
accuracy and confidence of the Orbit
Determination result?



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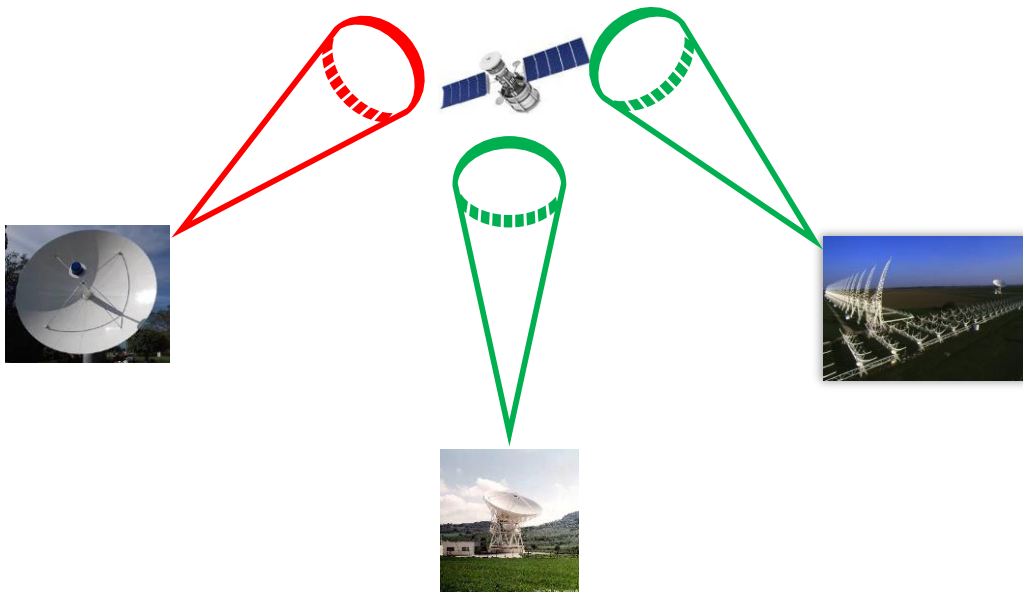


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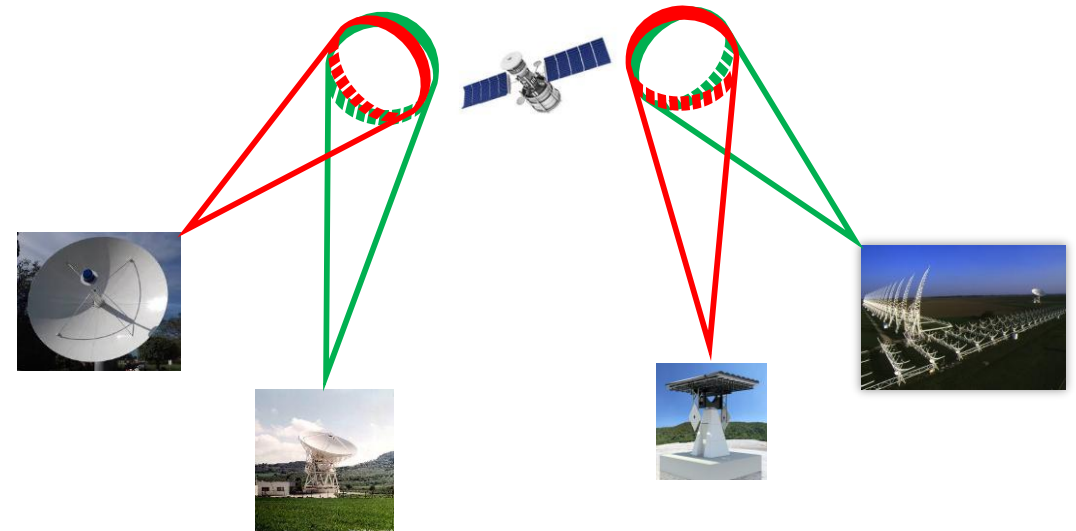
Operational modes

Orbit determination through a weighted batch filter

Stereoscopic Orbit Determination



Data-fusion Orbit Determination





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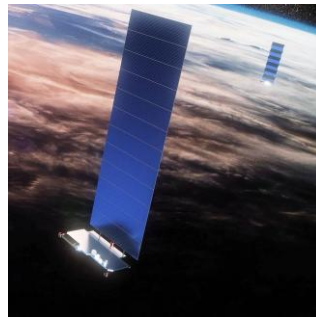
Simulation scenarios

- High-fidelity numerical propagation
- Mismatching in the orbit determination algorithm

RSO target

STARLINK-6051 (Norad ID 56463)

Semi-major axis [km]	6956
Eccentricity [-]	0.0009
Inclination [deg]	70.0
RAAN [deg]	198.7



Credits: ISPreview

Observation epoch: 2024-07-24T17:39:00

Re-entry target

CZ-5B R/B (Norad id 54217)

Semi-major axis [km]	6516.1
Eccentricity [-]	0.002
Inclination [deg]	41.6
RAAN [deg]	82.8



Credits: Wikipedia

Observation epoch: 2022-11-04T07:29:18.0

Prediction error

Position [km]	2.8e+00
Velocity [km/s]	3.2e-02

Sensor accuracy

	Angles [deg]	Range [km]	Range rate [km/s]
Medicina	0.01	0.050	0.007
Noto	1.4	0.050	0.007

Sensitivity analysis

- ✓ Medicina angular noise
- ✓ Medicina range noise
- ✓ Noto range noise

Prediction degradation





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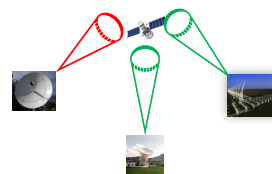
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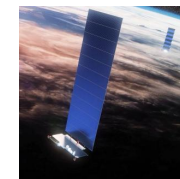
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Stereoscopic Orbit Determination

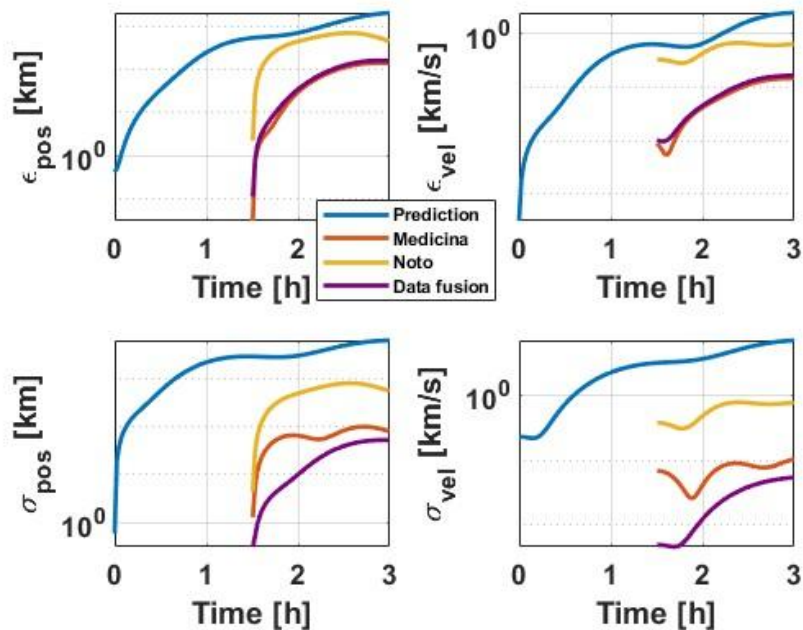
Noto: angles + range + range-rate



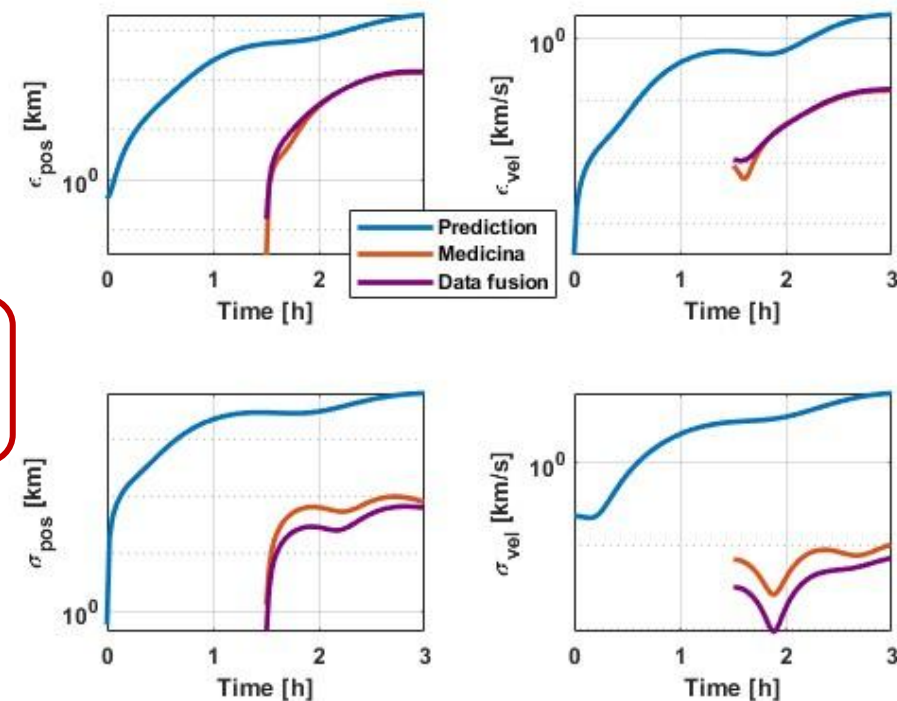
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Noto tracking mode



Noto survey mode



Noto low performance due to
coarse angular accuracy and
short measurement track



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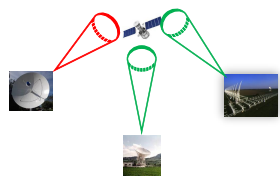


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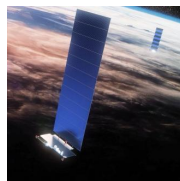
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Stereoscopic Orbit Determination



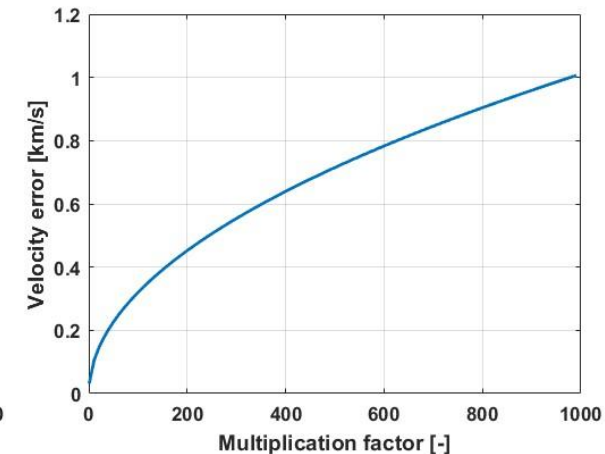
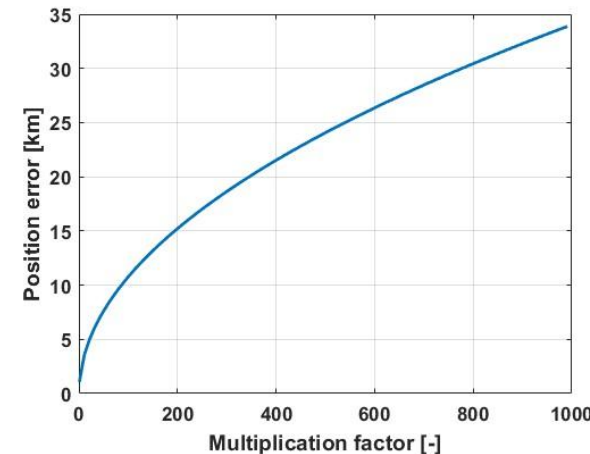
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Sensitivity Analysis

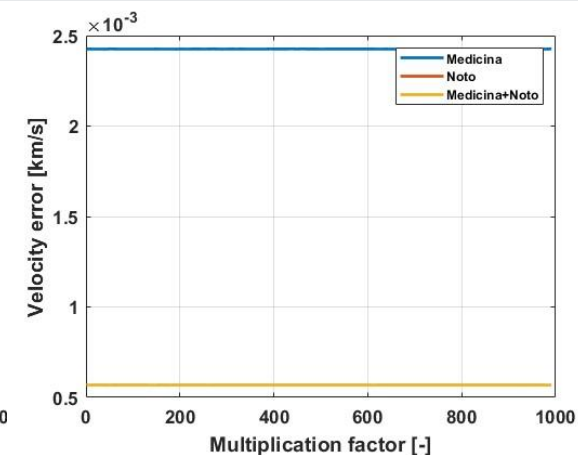
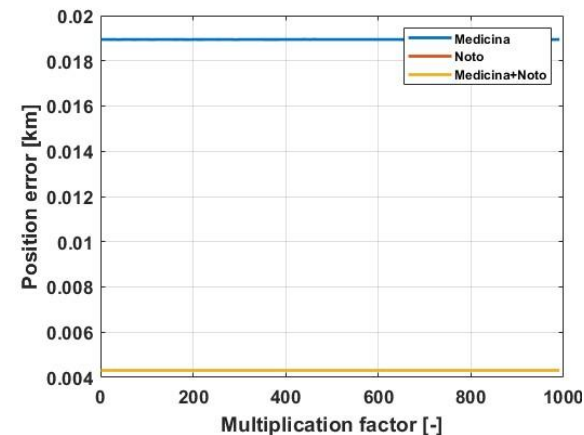
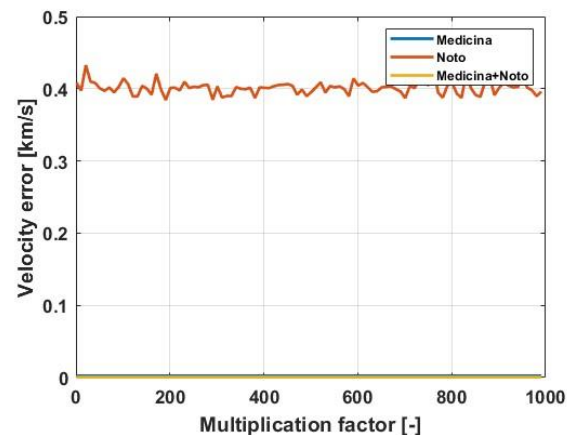
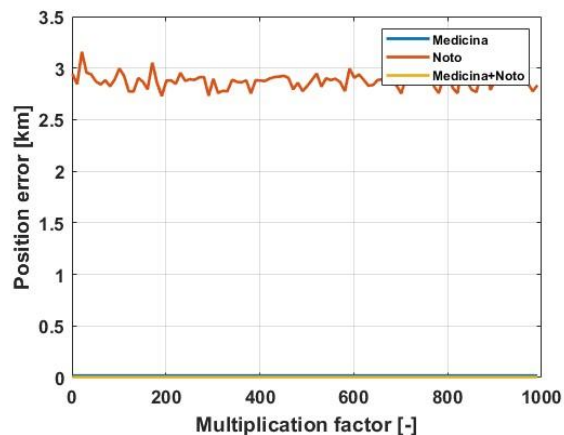


Noto: Tracking mode

Noto: angles + range + range-rate



Noto: range + range-rate

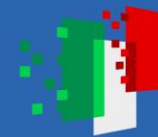




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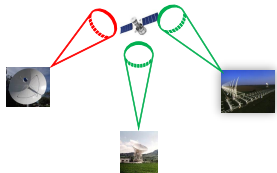


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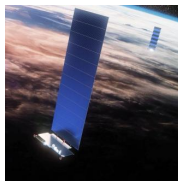
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Stereoscopic Orbit Determination



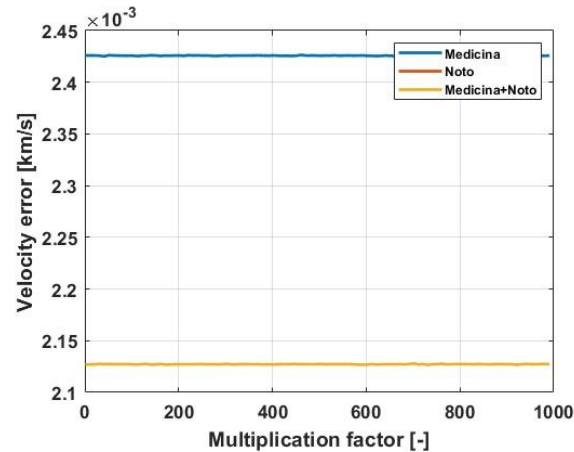
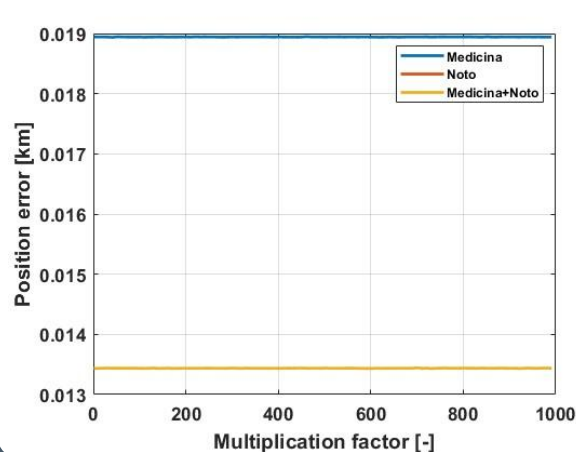
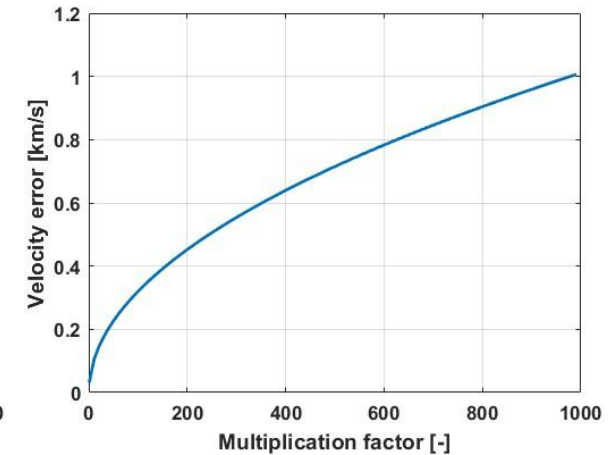
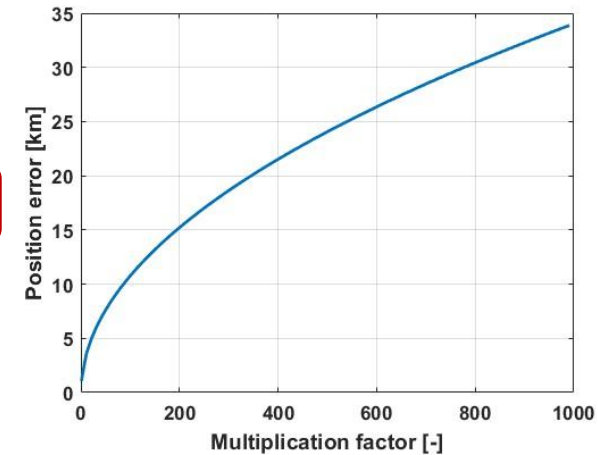
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Sensitivity Analysis



Noto: Survey mode

Noto: range + range-rate



Noto points towards the central epoch of the transit.



A single detection from Noto is sufficient to improve Medicina results.

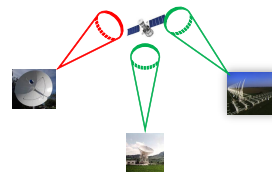


Similar performance either considering angles from Noto, or not.



Stereoscopic Orbit Determination

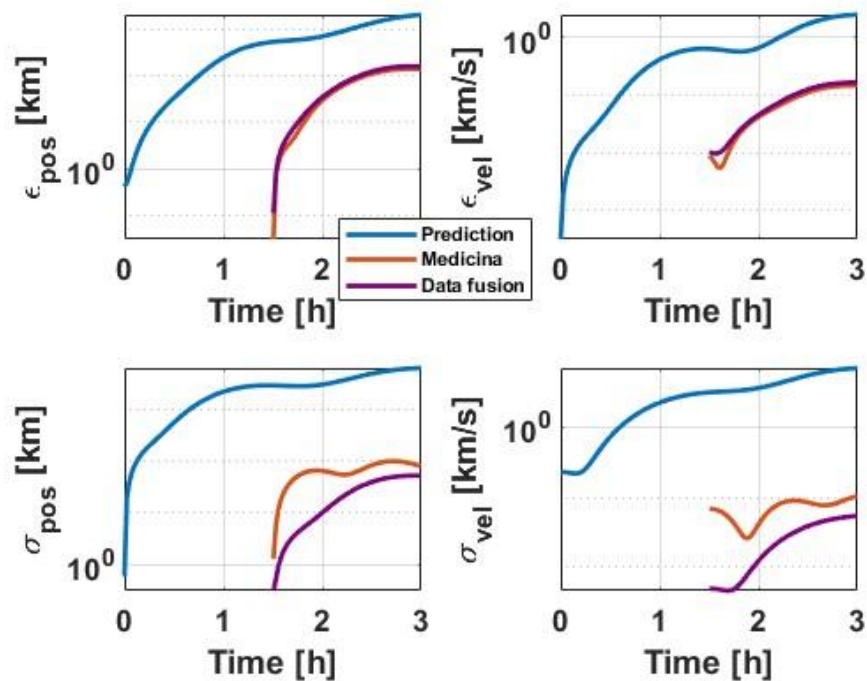
Noto: angles + range + range-rate



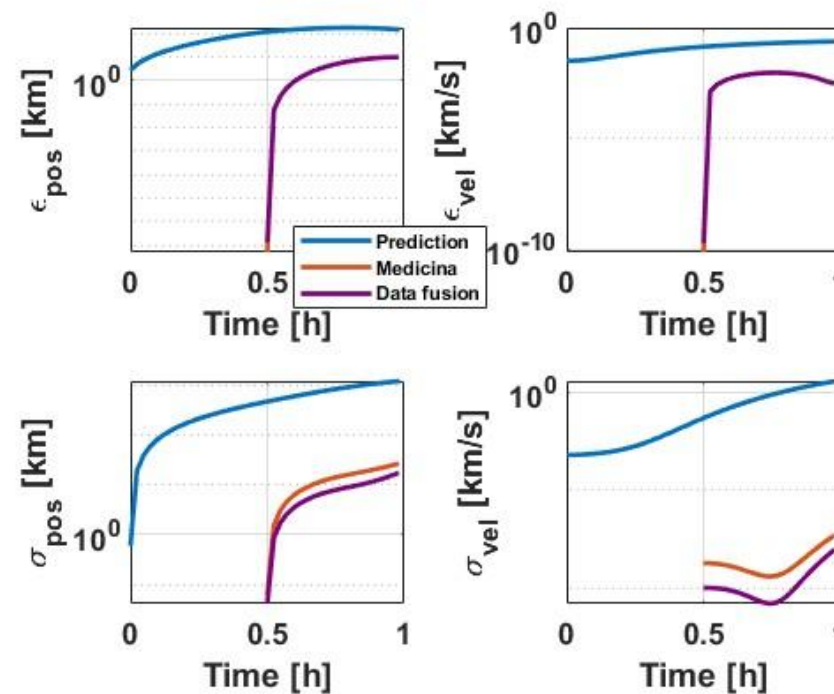
CZ-5B R/B



Noto tracking mode



Noto survey mode





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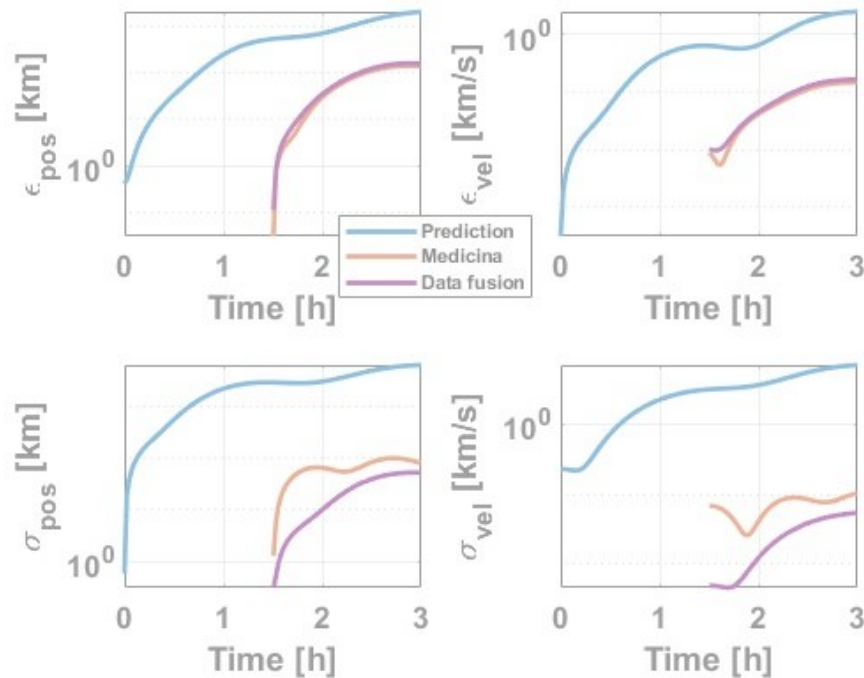


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Stereoscopic Orbit Determination

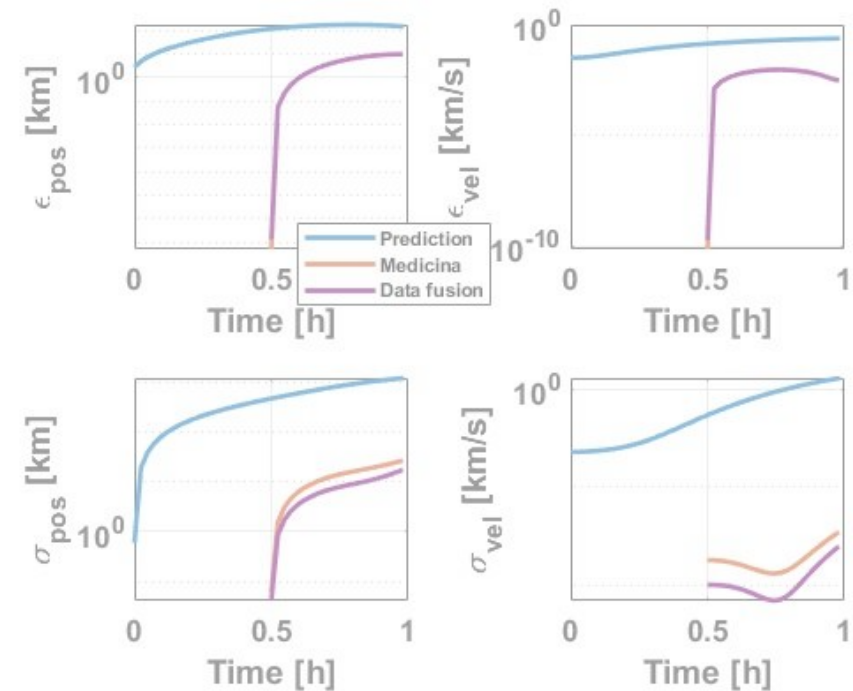
Noto: angles + range + range-rate

Noto tracking mode



- ✓ Both cases improve covariance.
- ✓ Stereoscopic Orbit Determination advantage is more appreciable in the tracking mode

Noto survey mode





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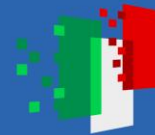
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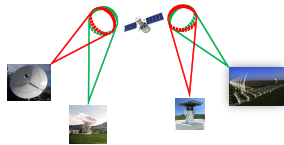


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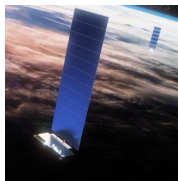


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Data-fusion Orbit Determination



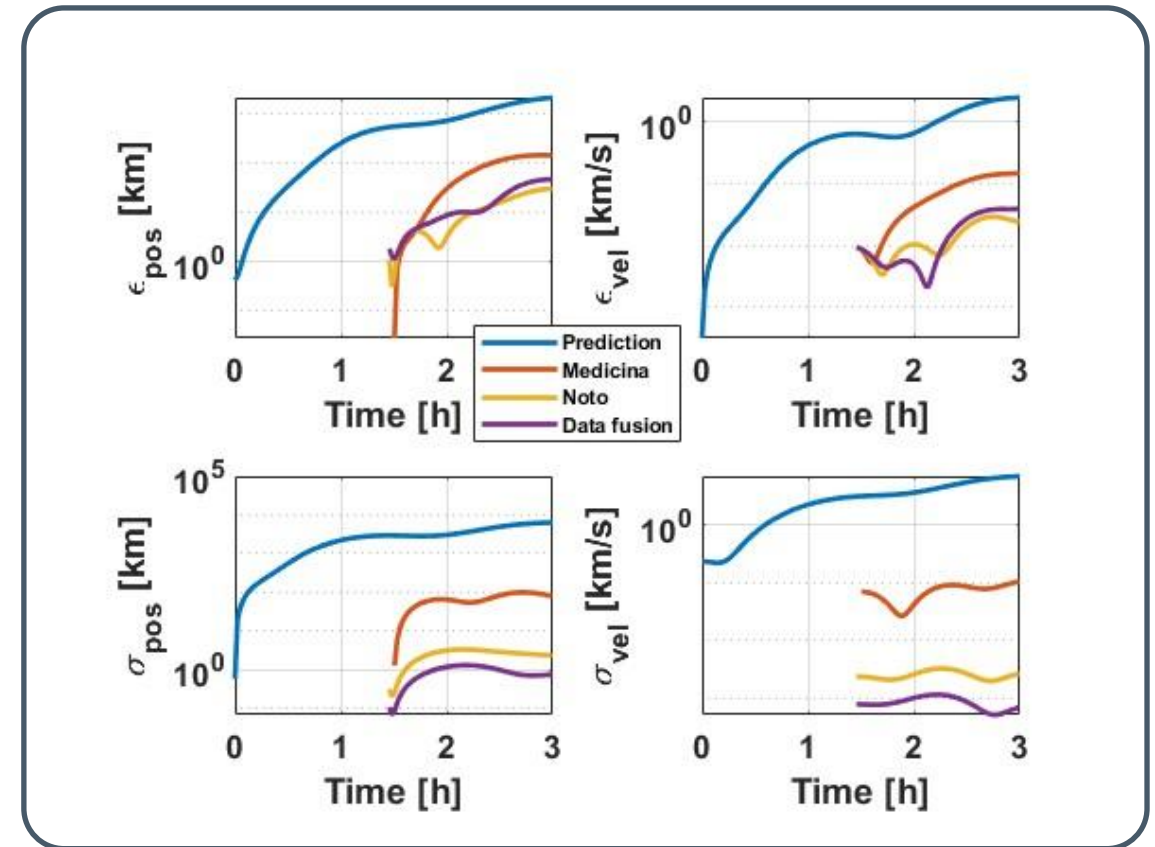
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Noto: Tracking mode

Noto provides longer measurements track

- ✓ Reduced uncertainties allow to keep the error low in the propagation after the detection.
- ✓ Data-fusion case is the most performing in terms of uncertainties, thanks to the data-fusion between Noto and Medicina measurements.





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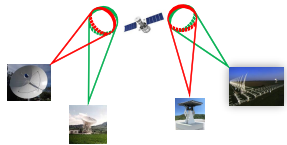


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Data-fusion Orbit Determination



CZ-5B R/B



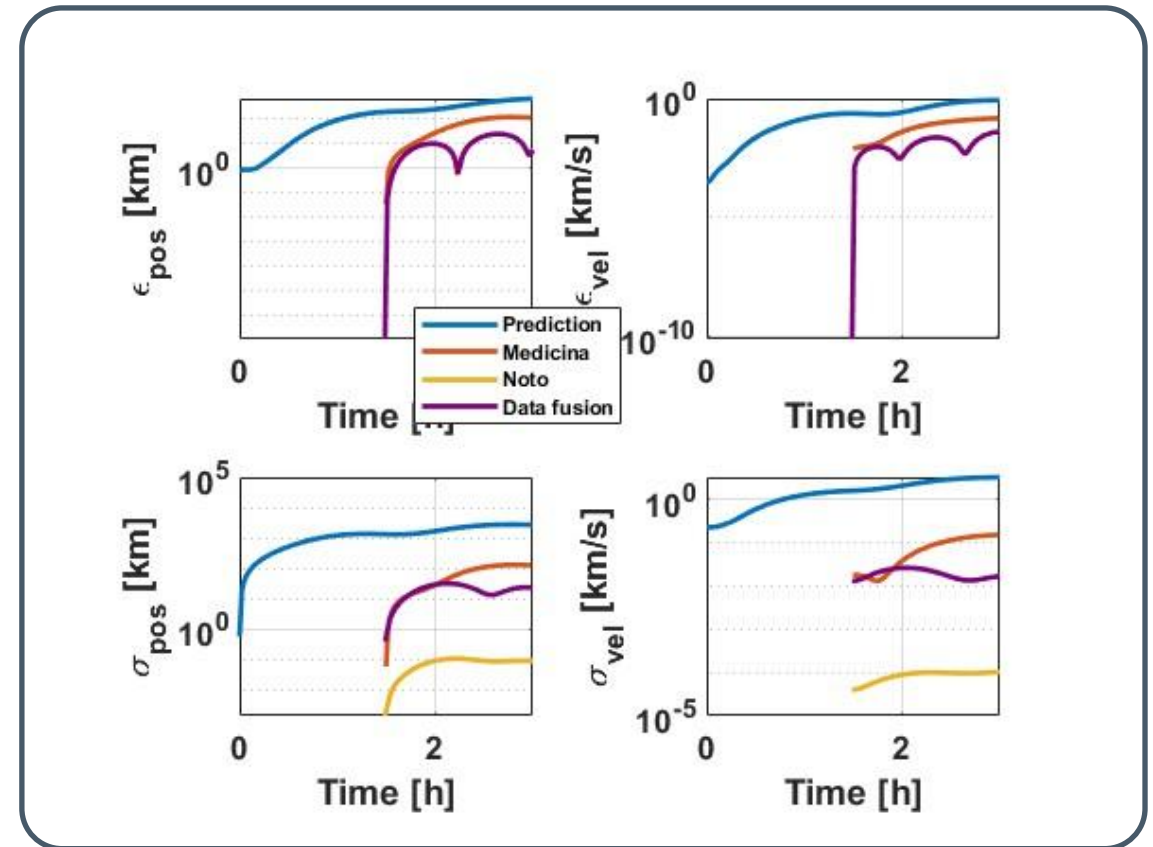
Noto: Tracking mode



Medicina provides large errors and uncertainties.



Noto case is the most performing.





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Conclusions

RSO target

- ✓ A single detection from Noto is sufficient to improve confidence of the OD result from BIRALES detections
- ✓ No need to include Noto angular measurements in the orbit determination

Re-entry target

- ✓ Stereoscopic orbit determination: joining Noto and Medicina measurements improves confidence of the OD result
- ✓ Data-fusion orbit determination: processing measurements from Noto remains the best option



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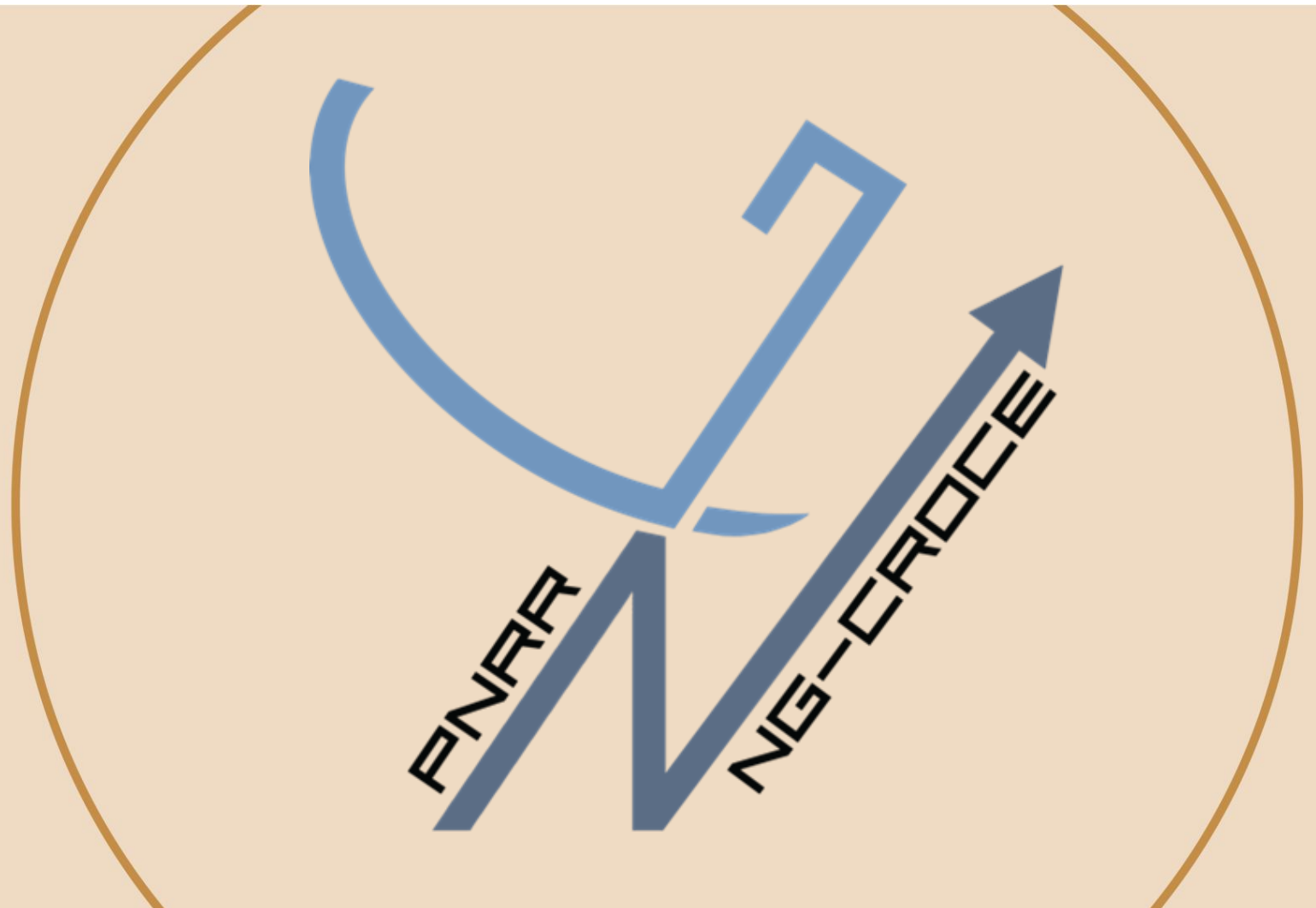
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Thank you

Final Meeting

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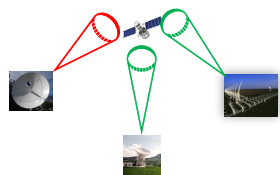


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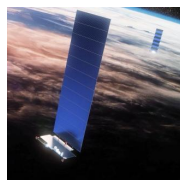


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Stereoscopic Orbit Determination

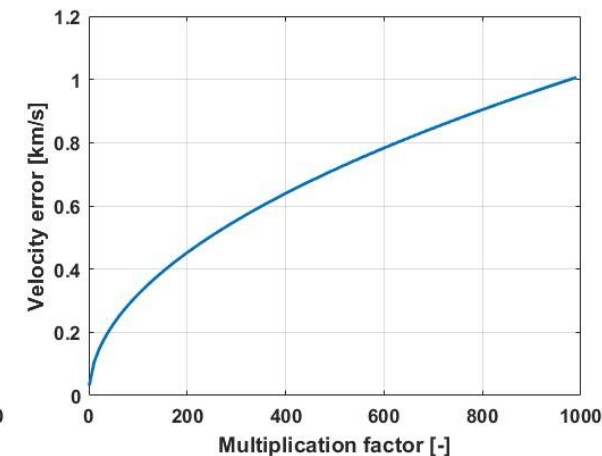
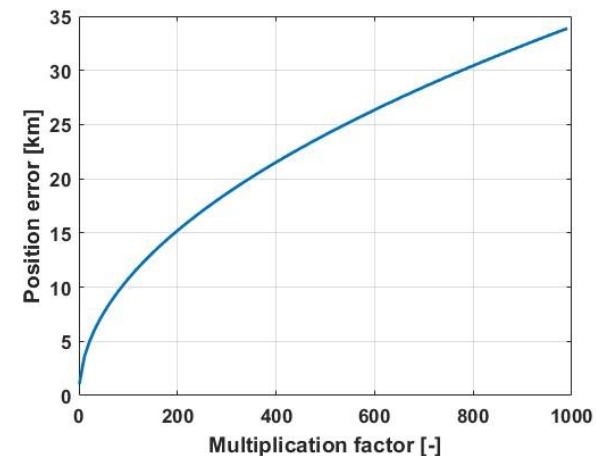


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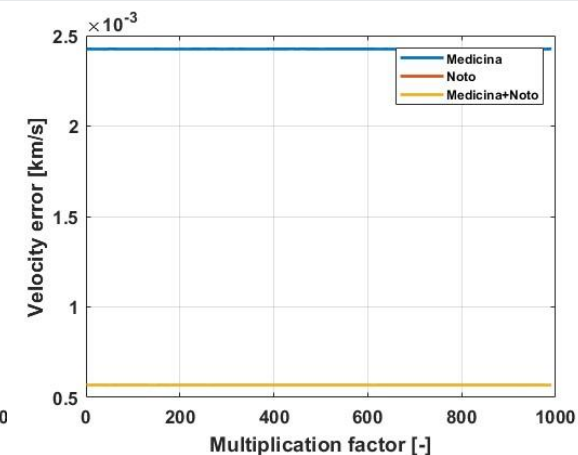
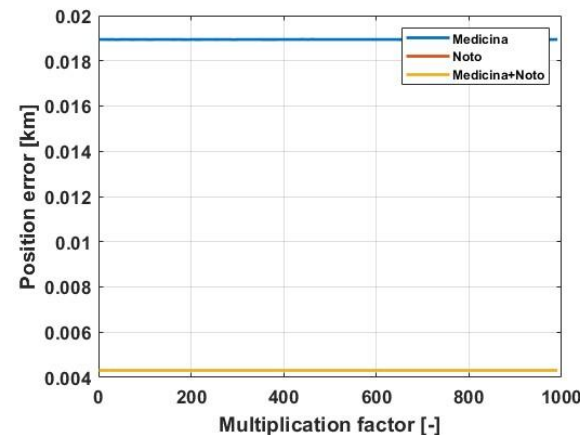
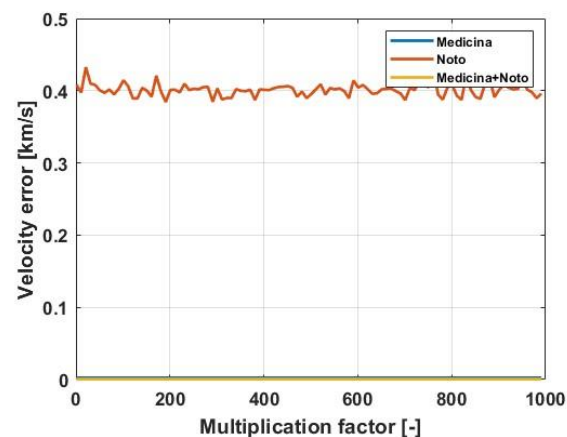
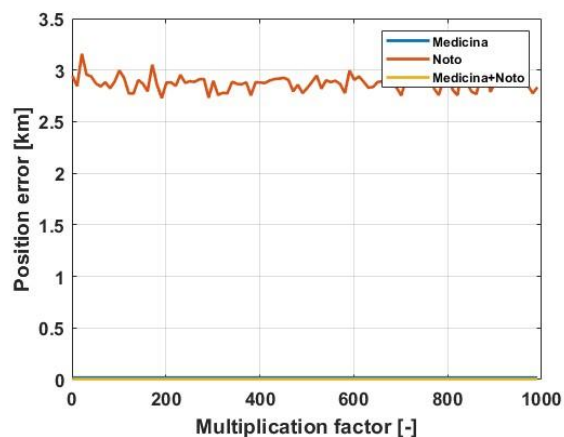


Noto: Tracking mode

Noto: angles + range + range-rate



Noto: range + range-rate





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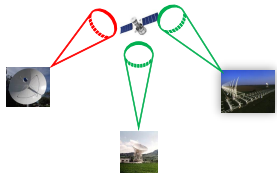


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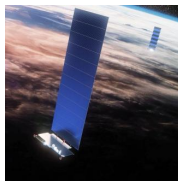


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Stereoscopic Orbit Determination

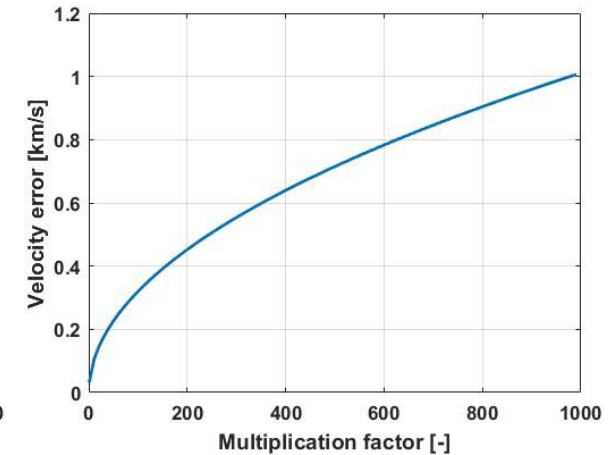
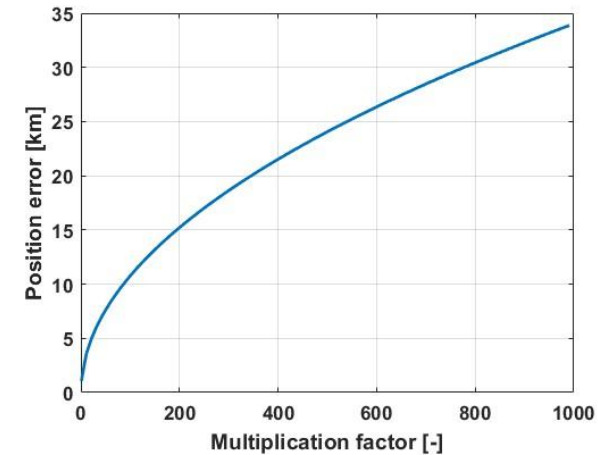
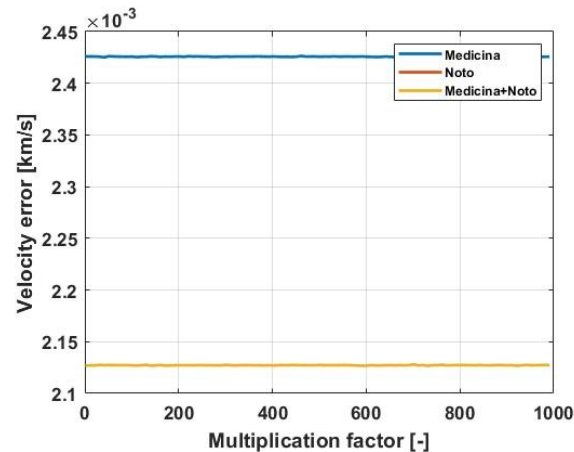
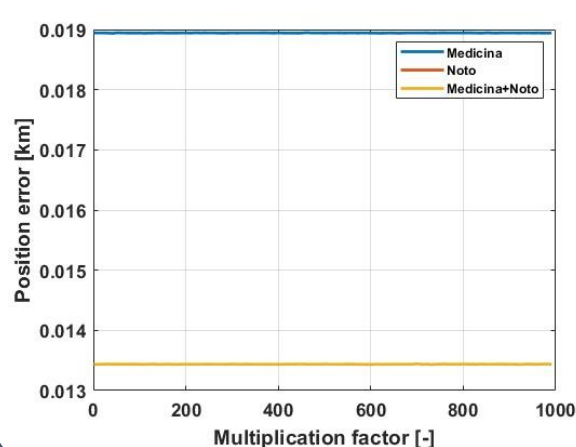


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Noto: Survey mode

Noto: range + range-rate



Noto points towards the central epoch of the transit.



A single detection from Noto is sufficient to improve Medicina results.



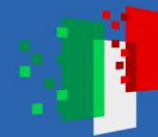
Similar performance either considering angles from Noto, or not.



Finanziato
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Ministero
dell'Università
e della Ricerca

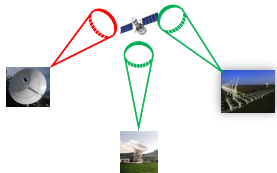


Italiadomani
PIANO NAZIONALE
DI RIPRESA E RESILIENZA



INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Stereoscopic Orbit Determination



CZ-5B R/B



Noto: Tracking mode

	Position error [km]	Velocity error [km/s]
Medicina	3.6e-02	7.9e-03
Noto	9.2e+00	1.8e+00
Medicina+Noto	2.4e-02	4.0e-03

Noto: Survey mode

	Position error [km]	Velocity error [km/s]
Medicina	3.6e-02	7.9e-03
Medicina+Noto	3.8e-02	8.7e-03