

# RFI Mitigation in the Era of Satellite Constellations

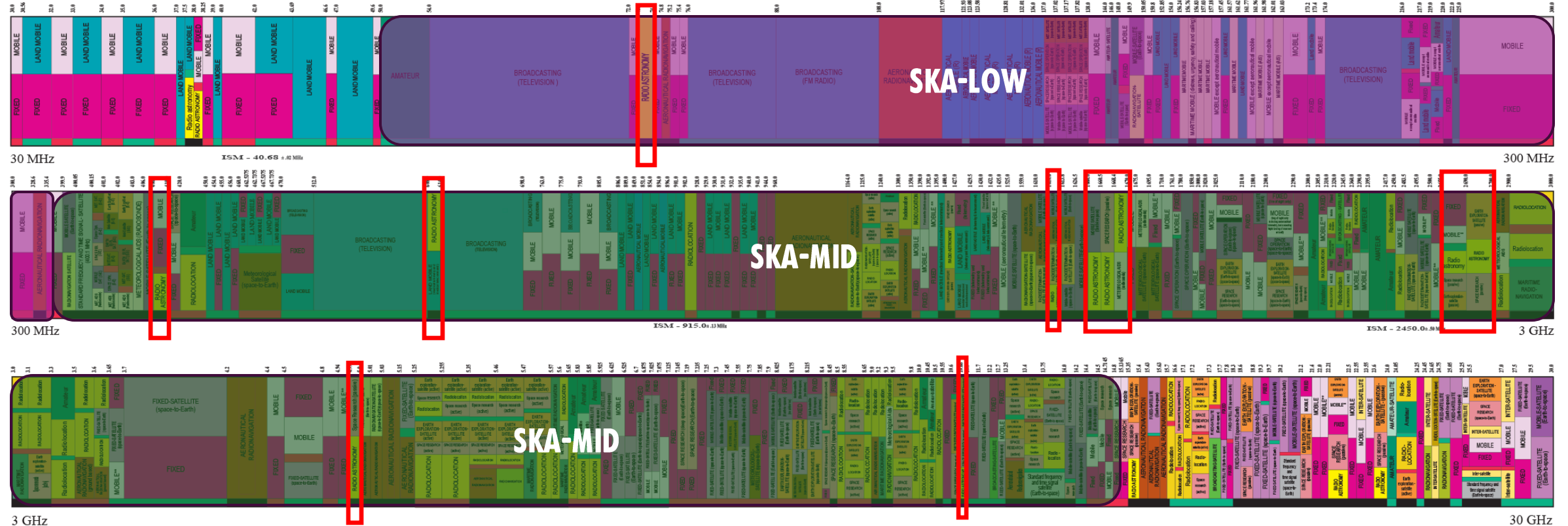


Emma Tolley, Chris Finlay & Nicolas Cerardi

**EPFL**



# We are not alone... on the radio spectrum

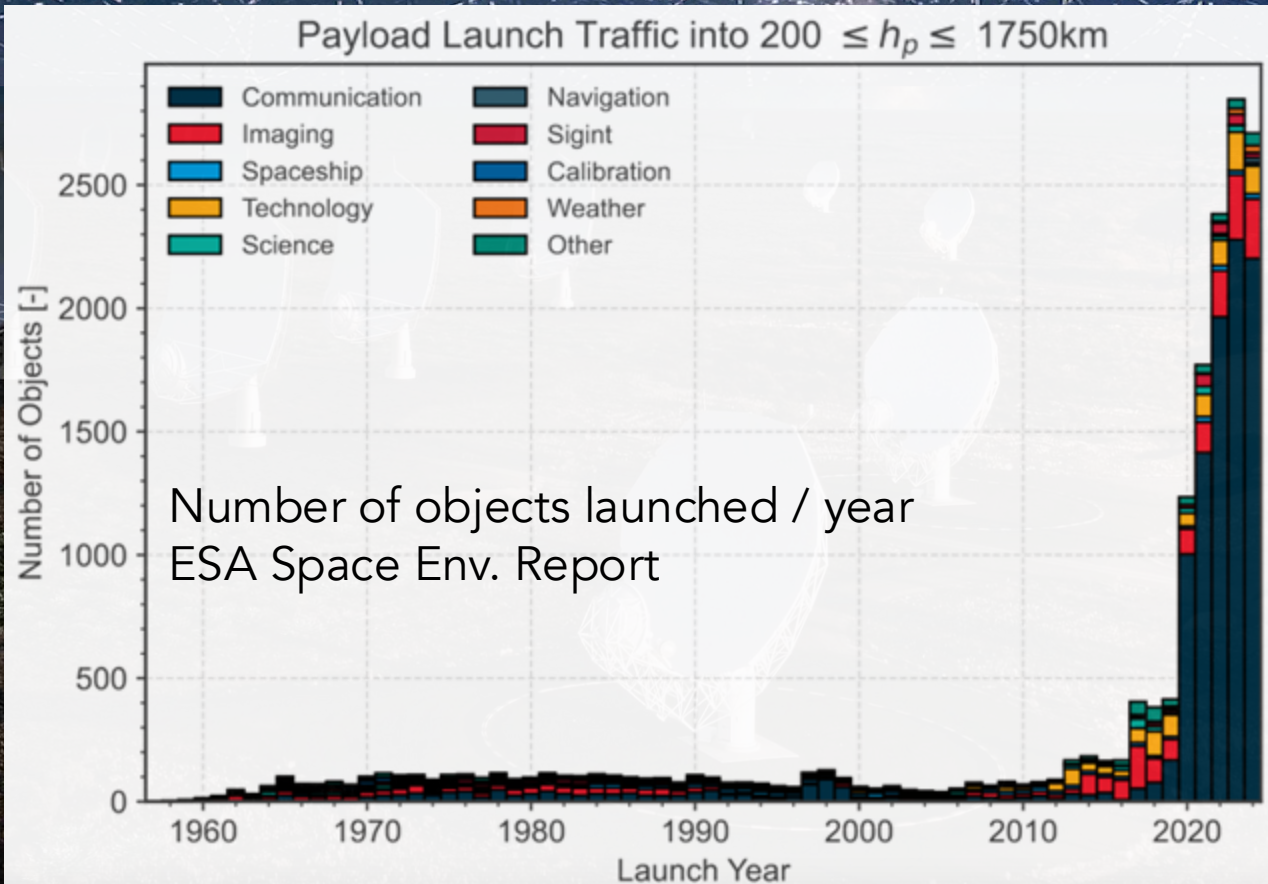


RAS protected bands



# Radio Quiet Zones ?

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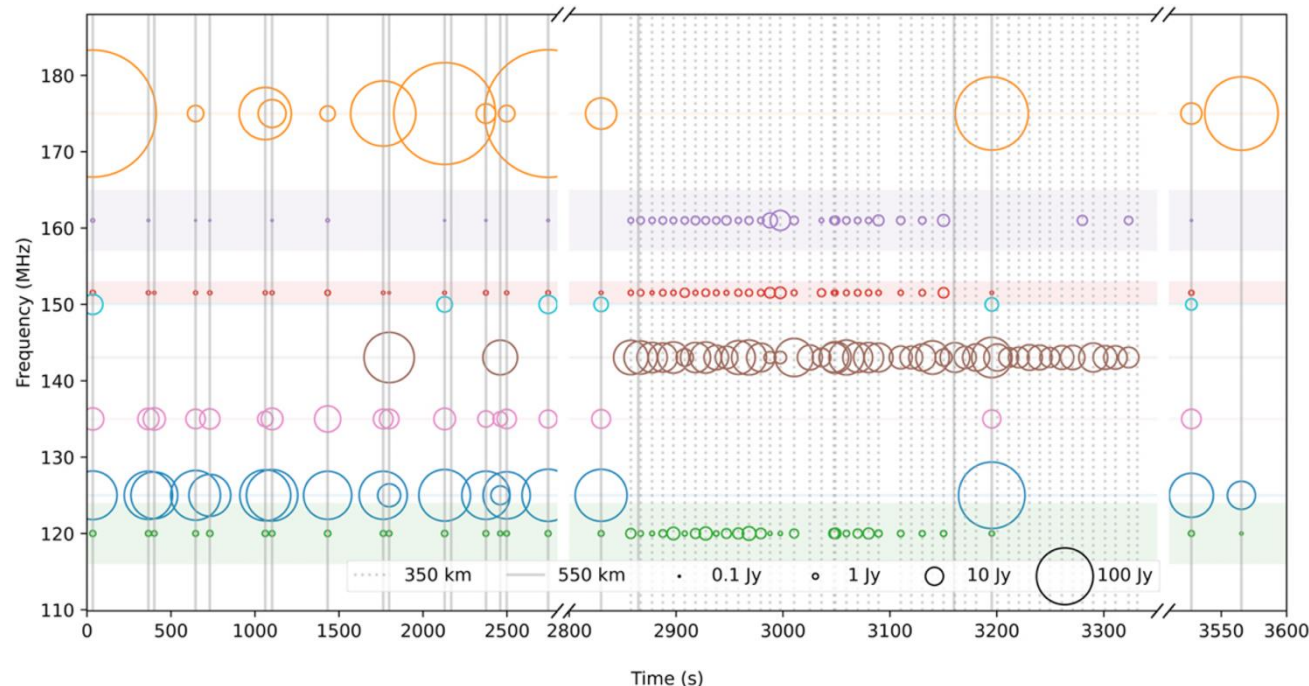


© SKAO



# Signals from satellites

- Intended emission (including out-of-band)
- Reflection (sunlight & terrestrial sources)
- Unintended radiation



116–124  
(MHz)

1.1(1)  
1.0(1)  
0.9(1)  
1.0(1)  
1.1(1)  
1.1(1)  
1.0(1)  
1.2(1)  
1.0(1)  
0.9(1)  
1.2(1)  
[Jy]

► With simple flagging, what is the observation time lost ?

Starlinks: both spectral lines and broad band features at low freqs (Di Vruno+23)

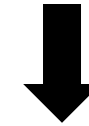
# Forecasting potential RFI exposure

Analytical model (from Bassa+21), order of magnitudes faster than discrete simulations.

These forecasts assume:

- Satellite *Shells*
- An effective beam: increases for more sensitive observations, decreases for fainter satellite RFI.

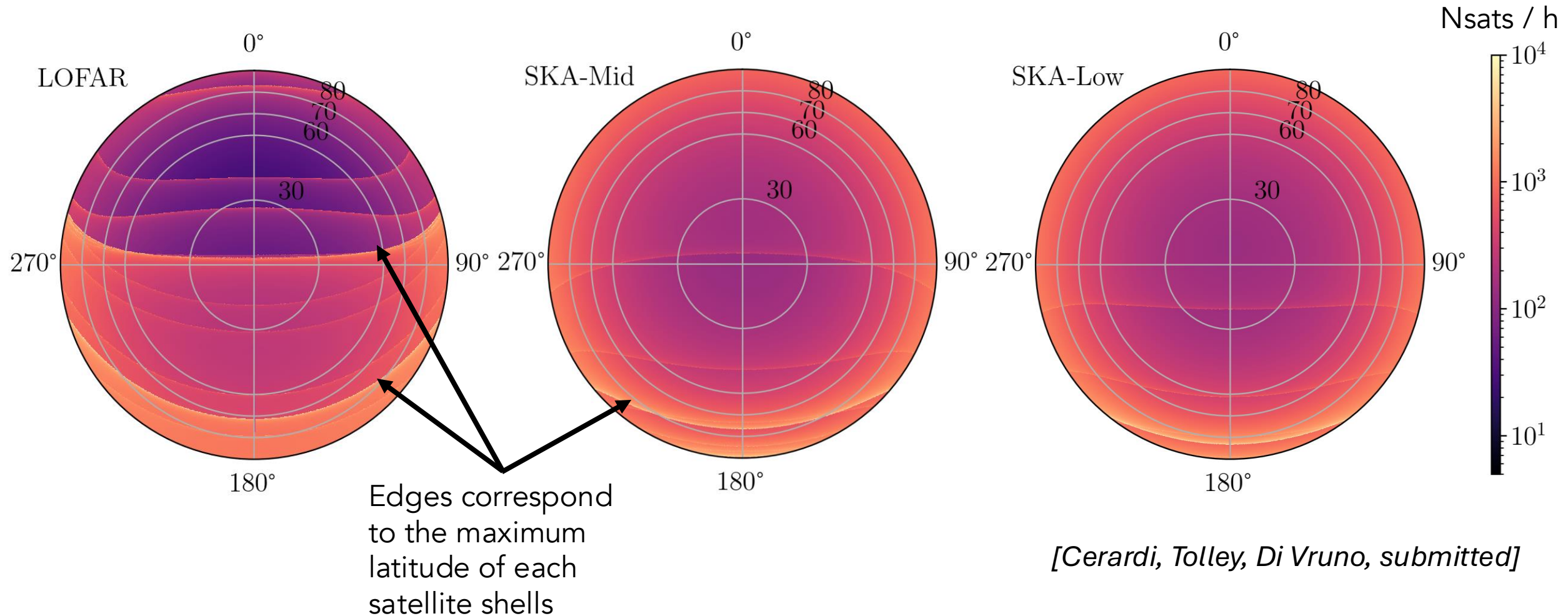
Constellation	Number of satellite
Starlink	~8000
One Web	~700



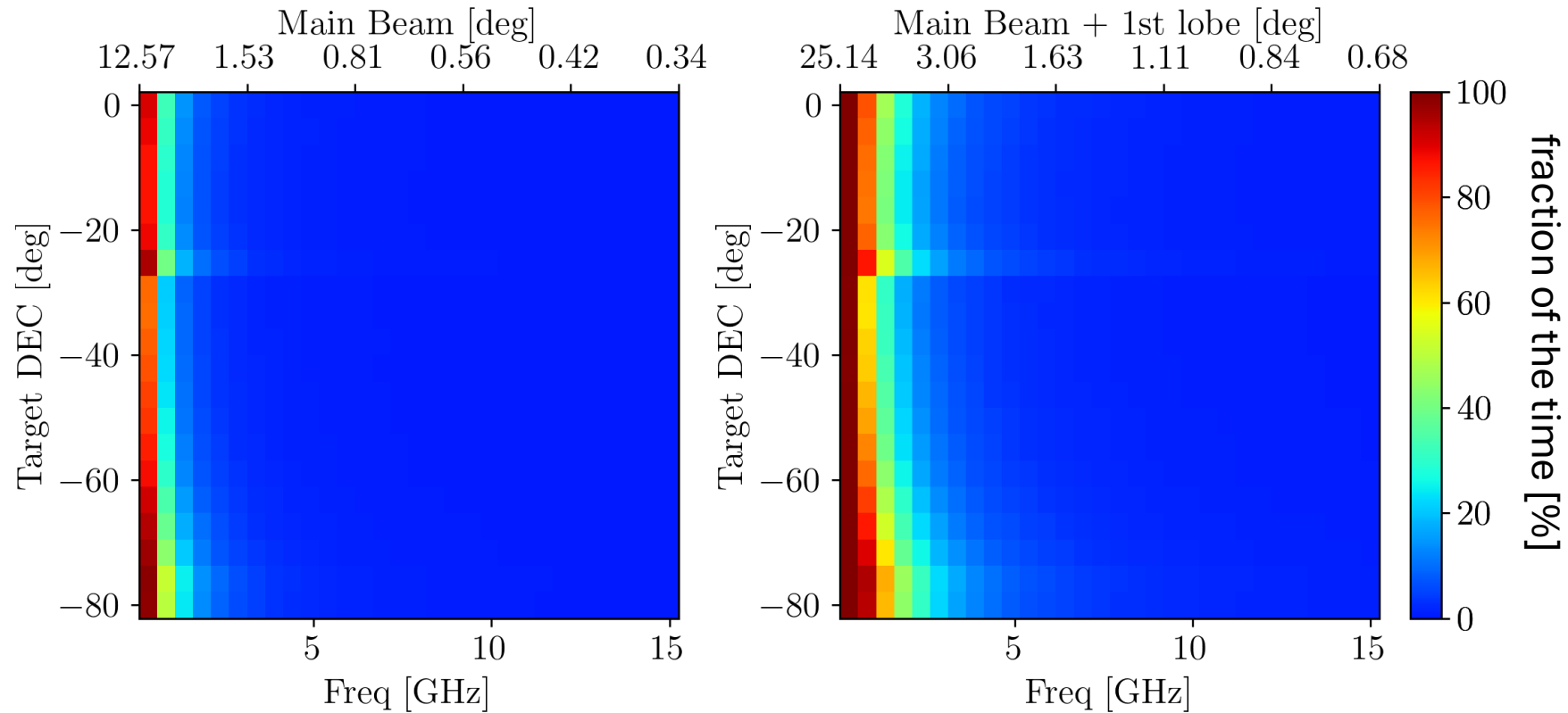
In 10 years ?

Constellation	Number of satellite
Starlink	~40000
One Web	~700
GuoWang	~6000
QianFan	~1000
...	...

# Sky occupancy maps



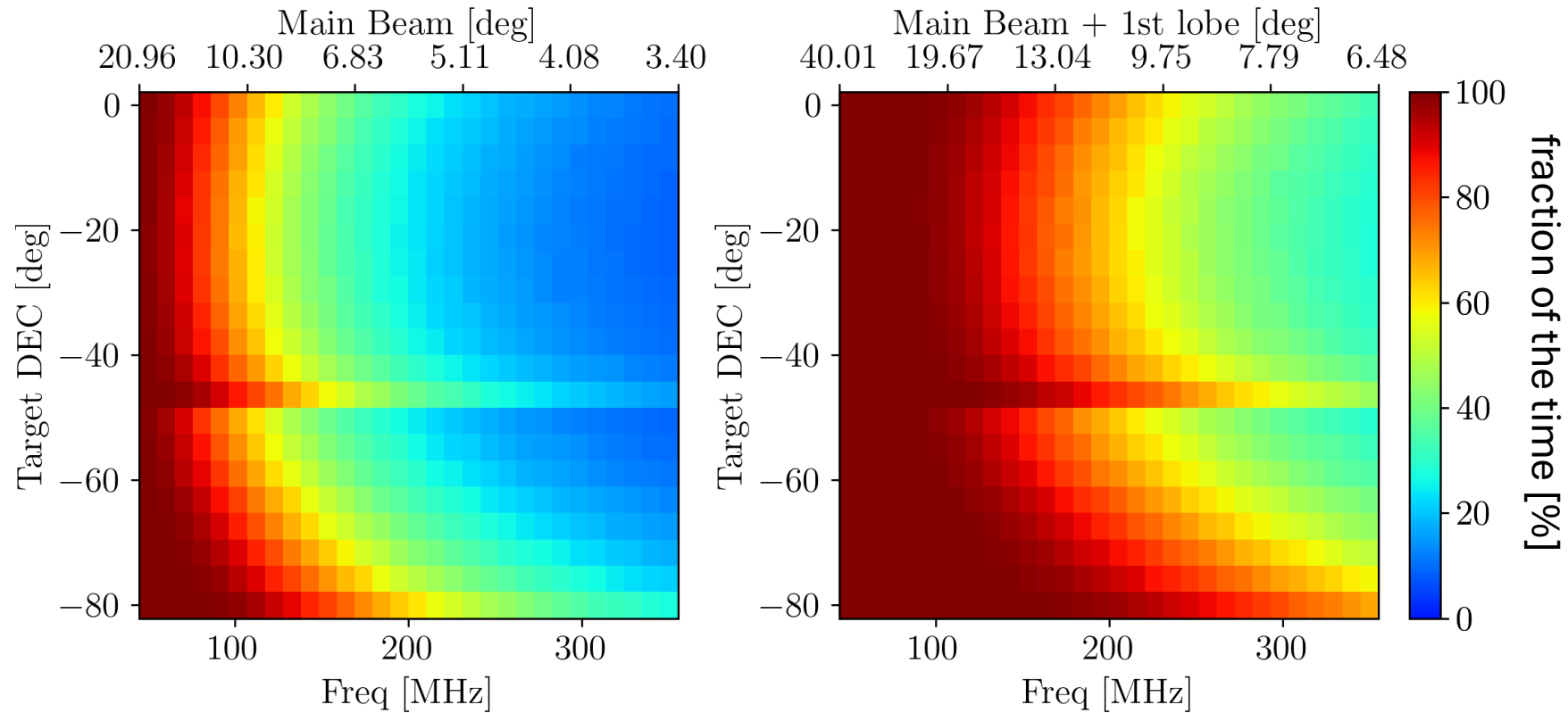
# SKA-Mid Forecasts



Significantly exposed to satellites below 1 – 3 GHz

*[Cerardi, Tolley, Di Vruno, submitted]*

# SKA-Low Forecasts



Significantly exposed to satellites at all frequencies, up to 100% below 100 MHz

► **We'll have to perform RFI subtraction**

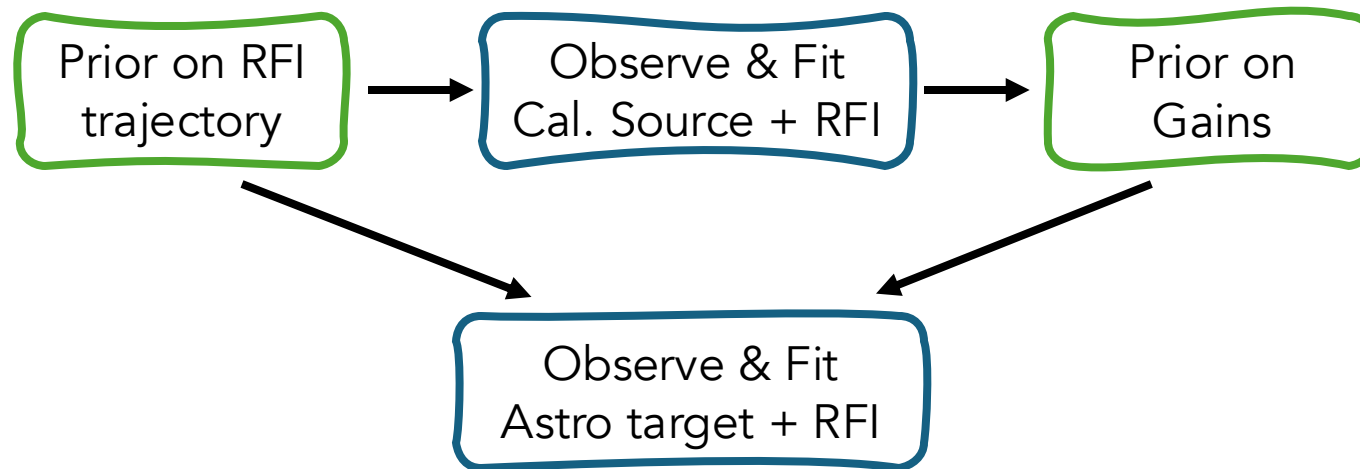
*[Cerardi, Tolley, Di Vruno, submitted]*



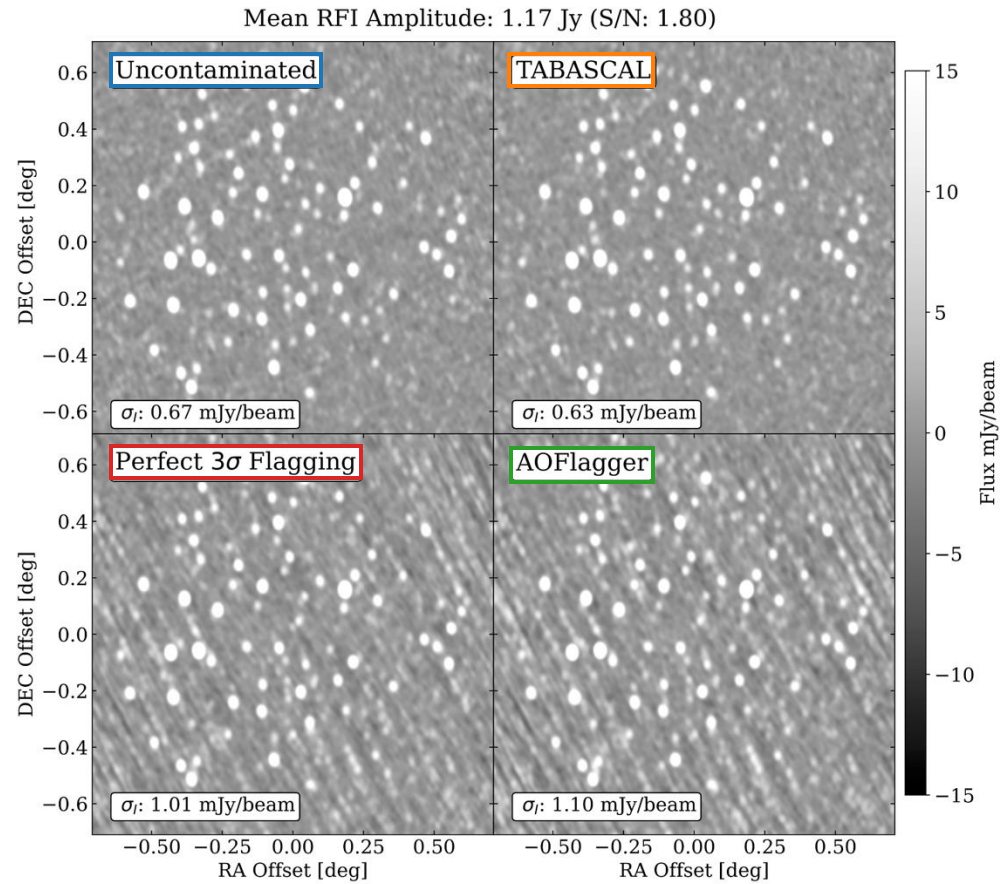
# Trajectory-based RFI Subtraction

**TABASCAL (Chris Finlay):** Bayesian forward modeling to fit satellite signal (arxiv:2301.04188, 2502.00106)

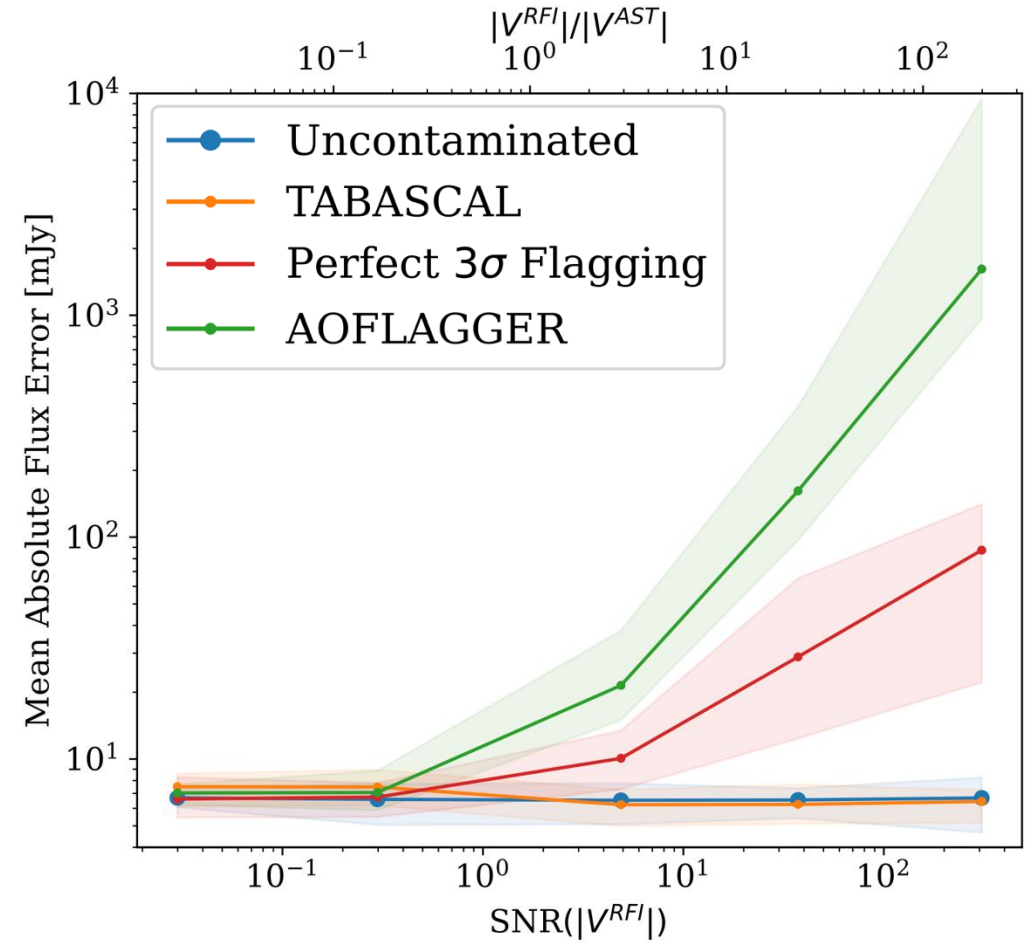
- Improves gain calibration
- Allows RFI subtraction



# TABASCAL: RFI Subtraction



Achieves lower noise on the reconstructed images

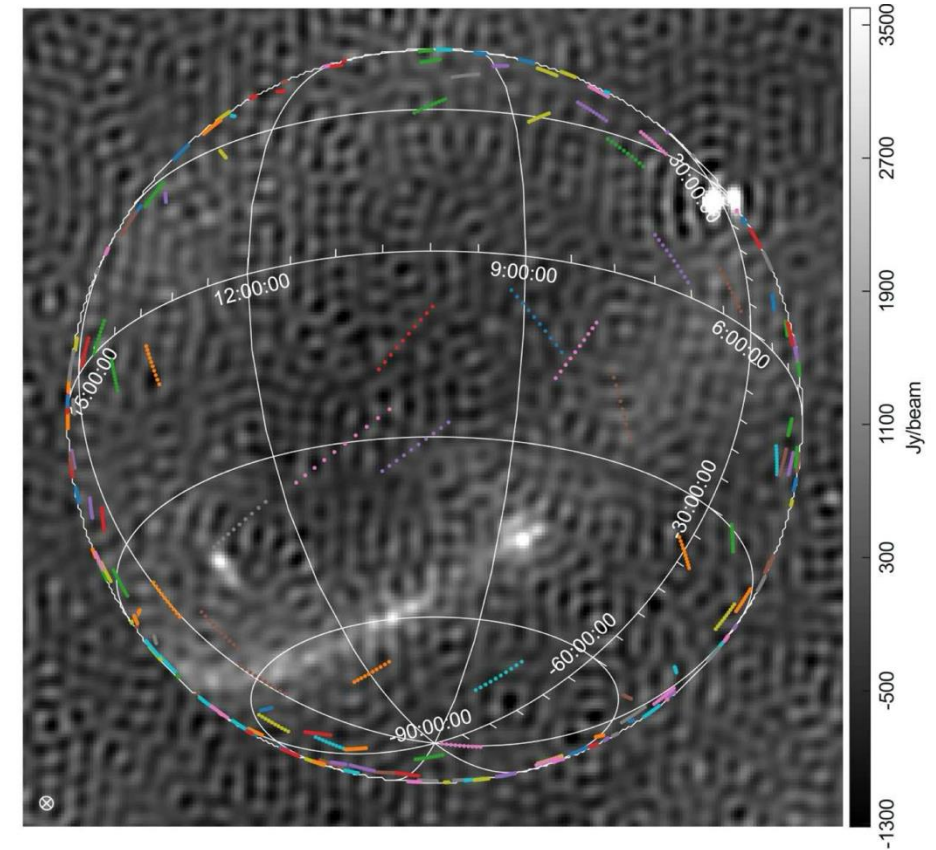


Lower error on flux measurements



# TABASCAL: future work

- Need to demonstrate that this **scales** to the problem size of the SKA & works on **real data**
- Beginning to work on HPC implementation of TABASCAL, funded by the Swiss Platform for Advanced Scientific Computing (PASC) & EPFL
- Applying to real observations (Finlay, Thums, Tolley, et al., in prep)



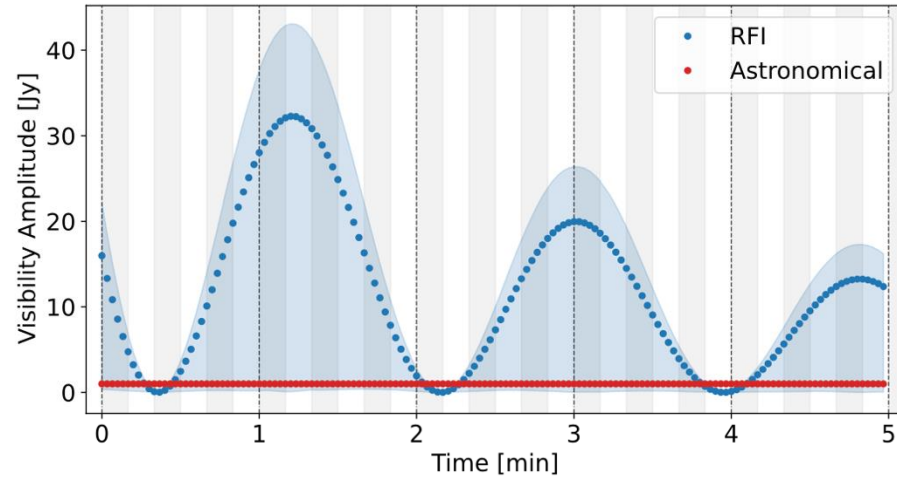
Expected starlink satellites in a 20s interval for the SKA EDA 2

- RFI from Mega Constellations is a serious **threat** for the SKAO.
- The SKA-Low will be strongly exposed to satellite RFI.
- **RFI subtraction** with joint RFI + Astro forward modelling ?
- Requires accurate satellite positions & HPC.
- Necessity to scale the method and test it on real observations.
- Science case-specific impact and mitigation methods?

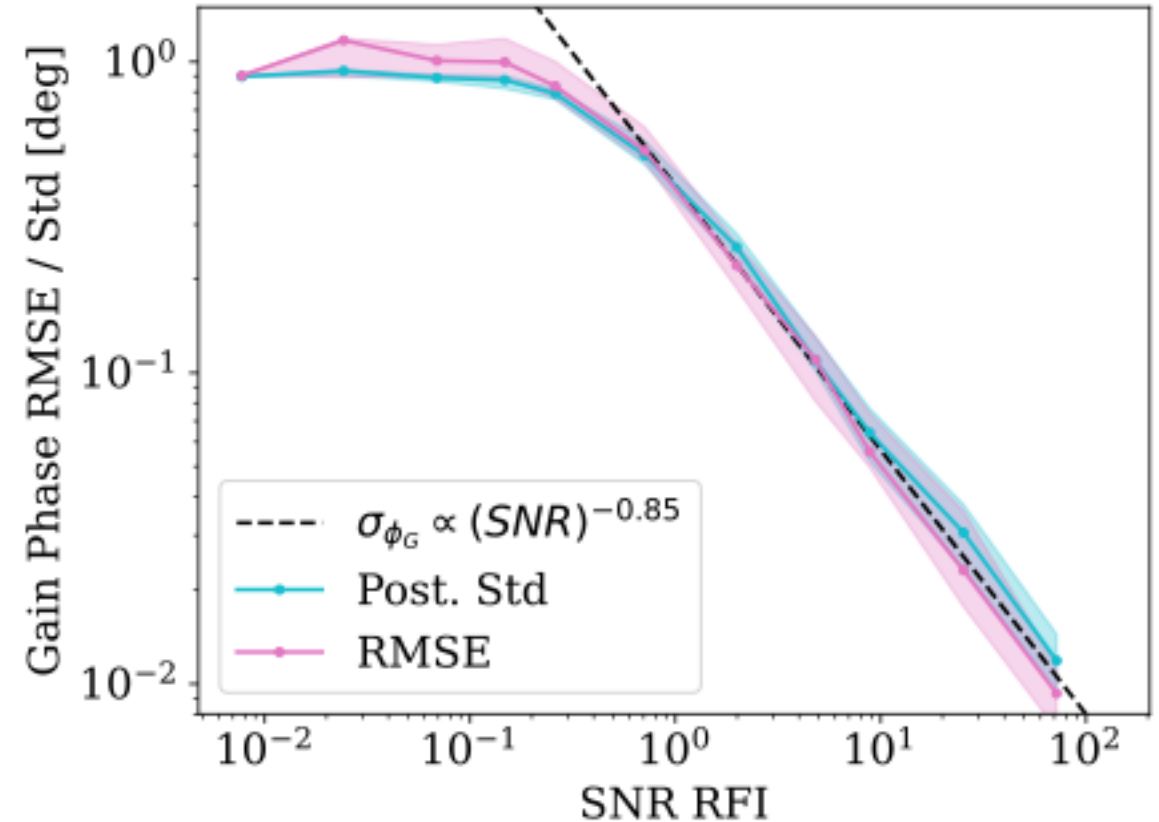
## Thanks for your attention



# TABASCAL: RFI Calibration



- Time-dependent gains can be fitted when observing calibration source with RFI contamination
- Then use Gaussian Process to produce prior on the gains during science observation



# Recovery of the visibilities

