NenuFAR with LOFAR : High sensitivity, high resolution imaging

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Outline

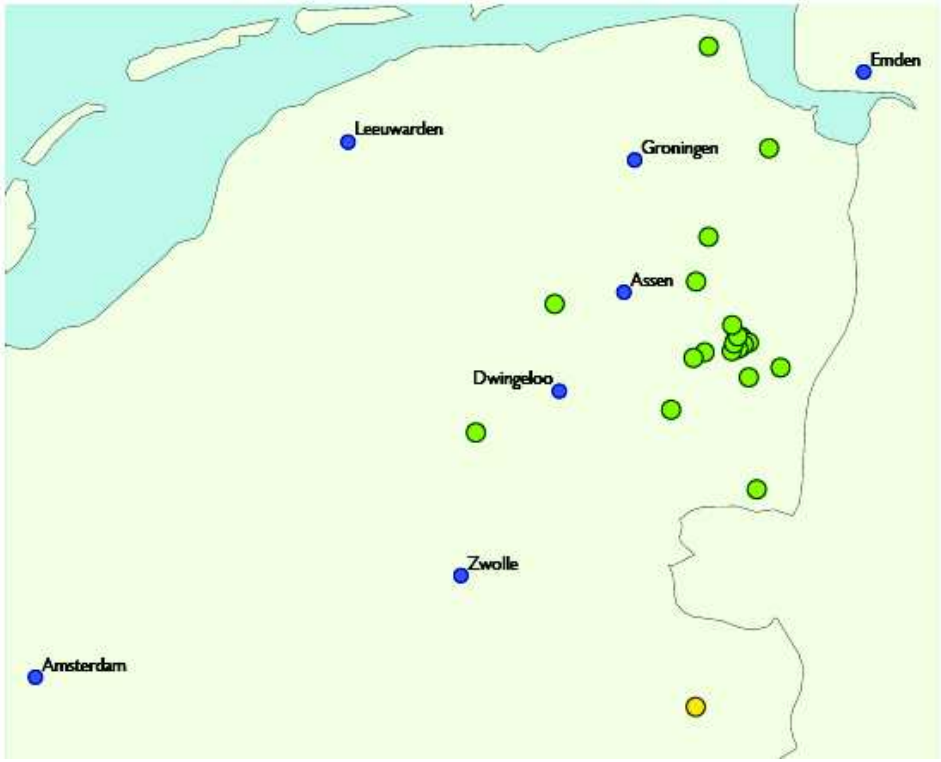
A qualitative discussion of LOFAR+NenuFAR imaging properties

1. LOFAR
   - configuration
   - sensitivity distribution in the *uv*-plane
2. Main limitation to high resolution imaging with LOFAR
   - extremely concentrated *uv*-distribution
   - $\Rightarrow$ synthesized beam with high sidelobes
3. Possible solutions
   - reweighting
   - NenuFAR

LOFAR stations

Netherland stations

4 km

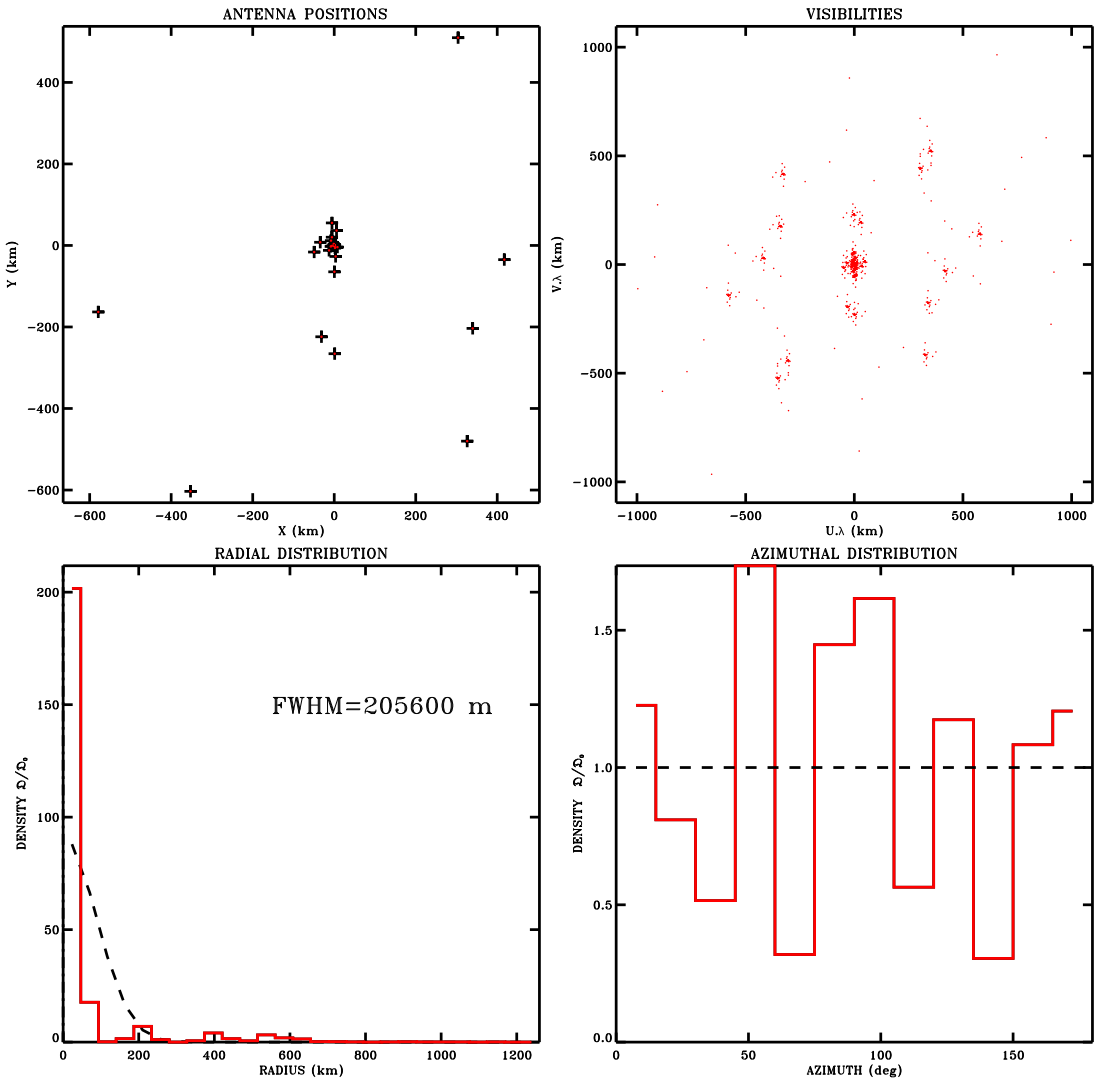


200 km

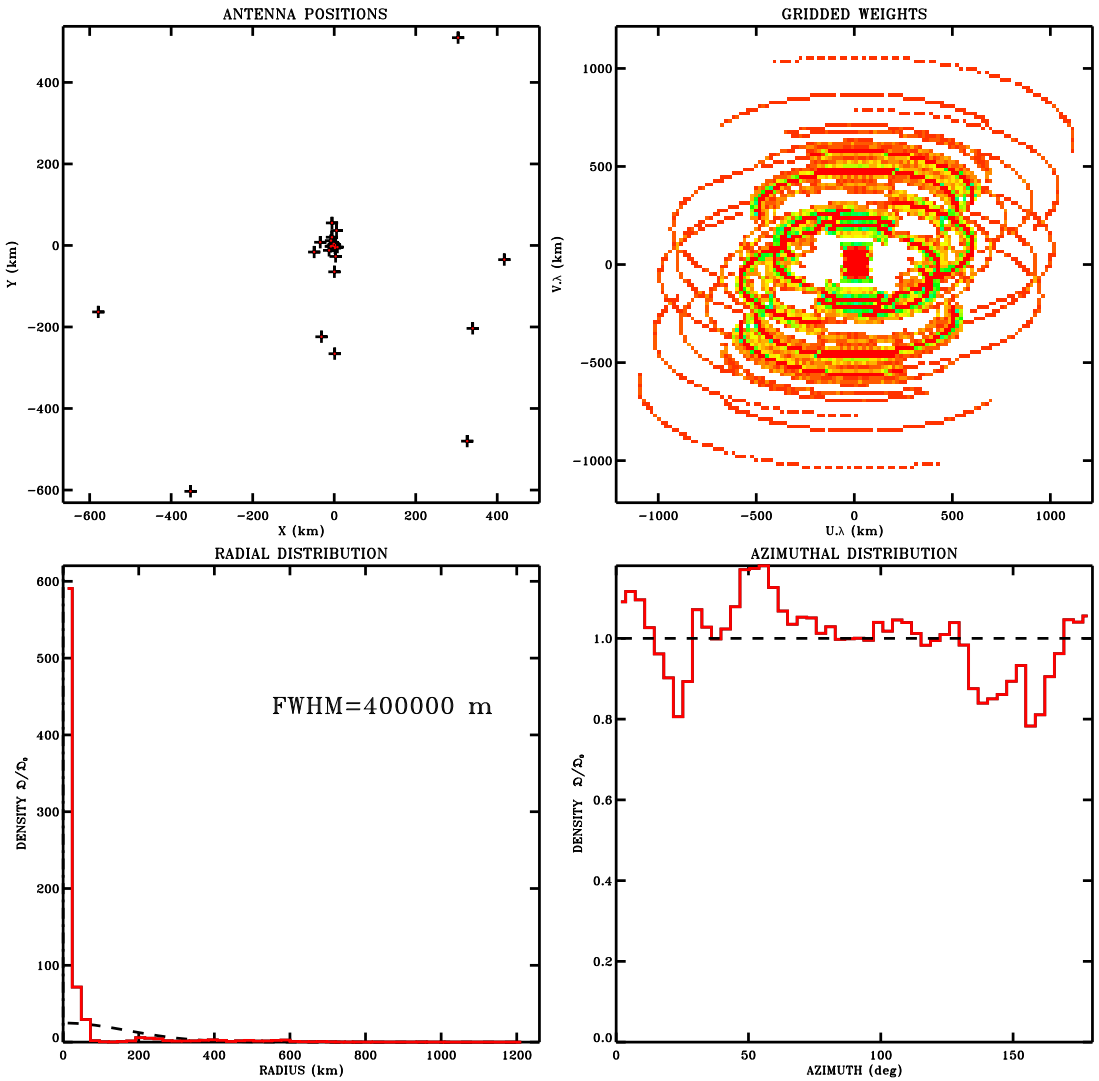
LOFAR stations

Remote stations

LOFAR uv-plane sensitivity distribution in snapshot



LOFAR uv-plane sensitivity distribution in 8h



LOFAR uv-plane sensitivity distribution

Main limitation of the *uv*-coverage:
extremely concentrated distribution

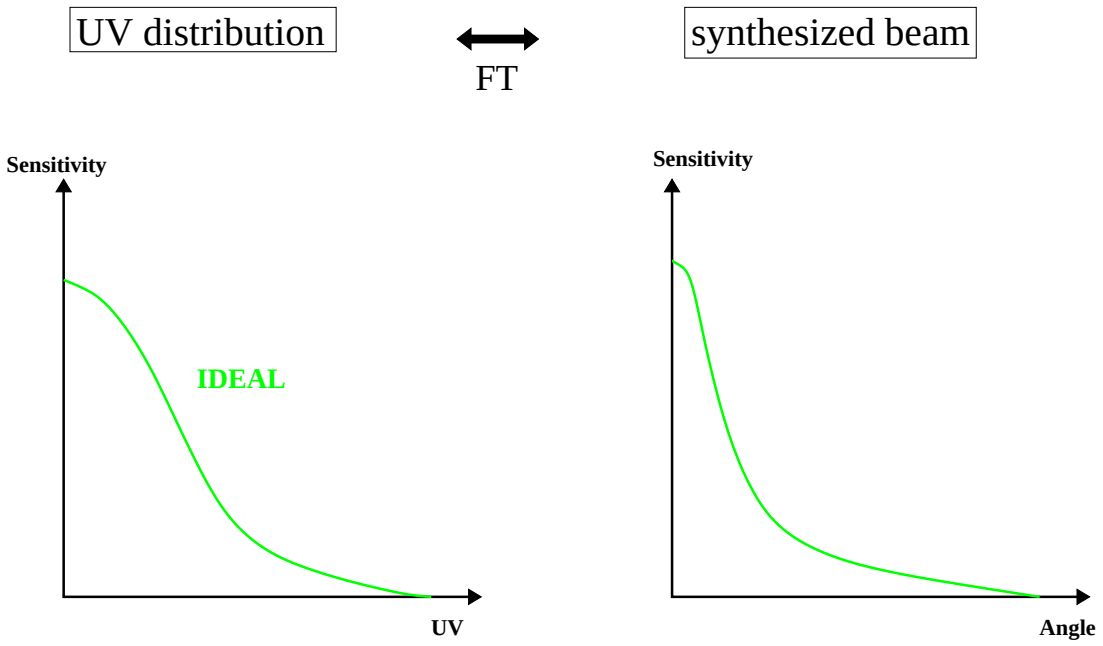
Table 1. Overview of stations and antennas.

Station configurations	Number of stations	LBA dipoles	HBA tiles	Signal paths	Min. baseline (m)	Max. baseline (km)
Superterp	6	2×48	2×24	96	68	0.24
NL Core Stations	24	2×48	2×24	96	68	3.5
NL Remote Stations	16	2×48	48	96	68	121.0
International Stations	8	96	96	192	68	1158.0

Notes. The 6 stations comprising the central Superterp are a subset of the total 24 core stations. Please note that the tabulated baseline lengths represent unprojected values. Both the LBA dipoles and the HBA tiles are dual polarization.

$\sim$30% of the sensitivity within 0.3% of the largest baseline
$\sim$70% of the sensitivity within 10% of the largest baseline
$\Rightarrow$ Not optimal for high resolution imaging

LOFAR uv-plane sensitivity distribution



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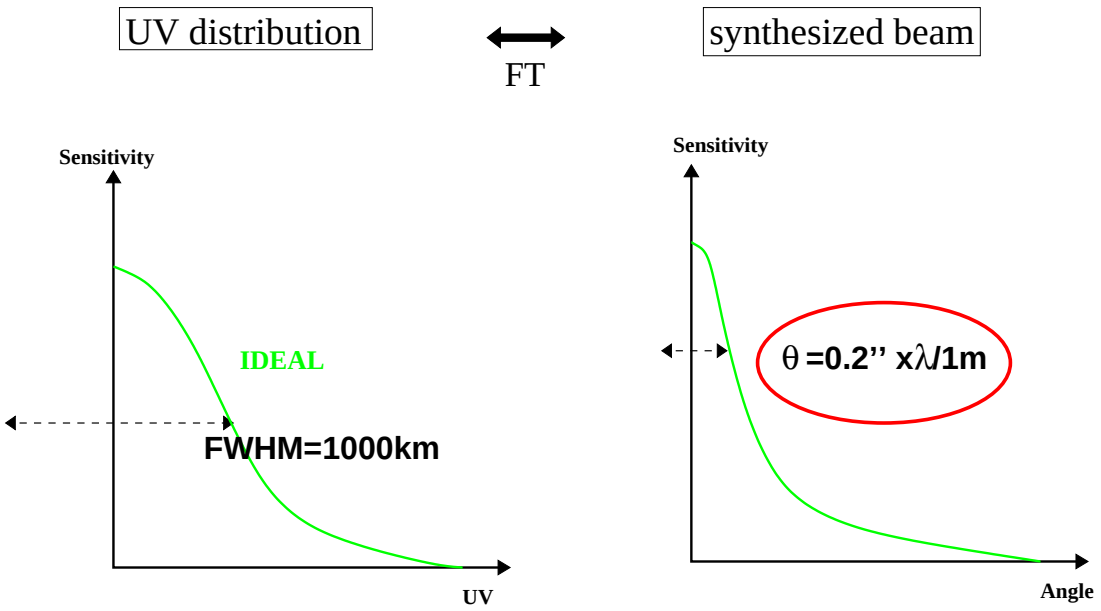
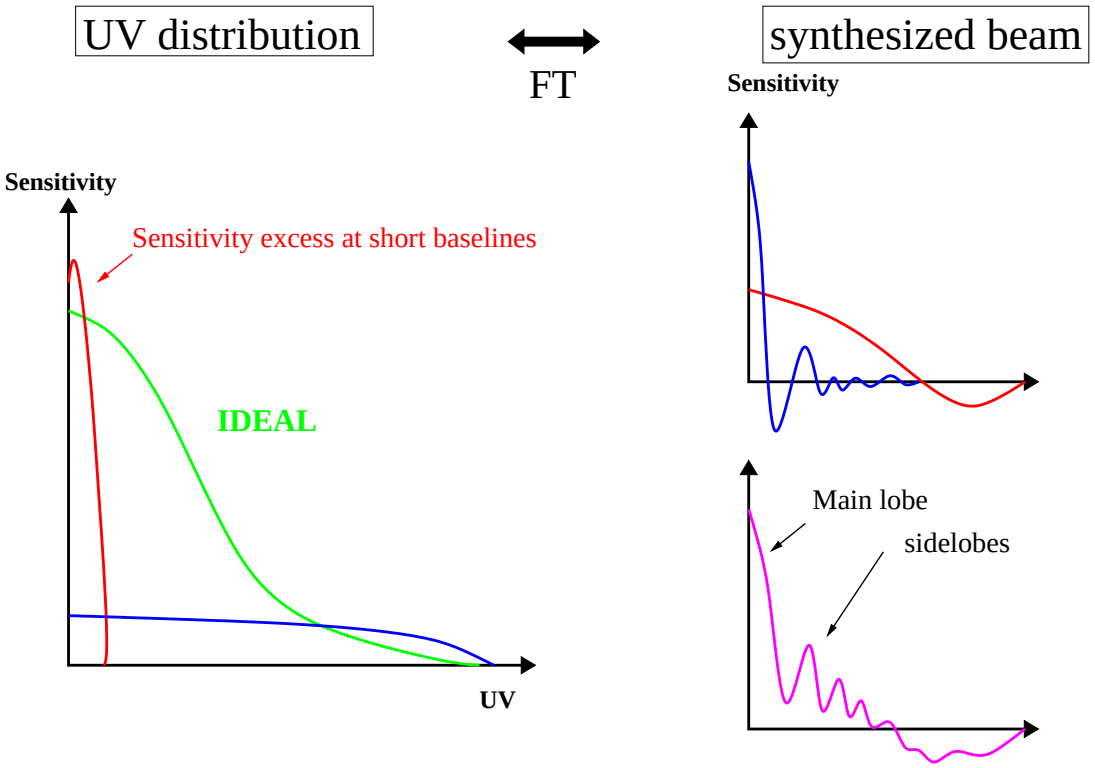
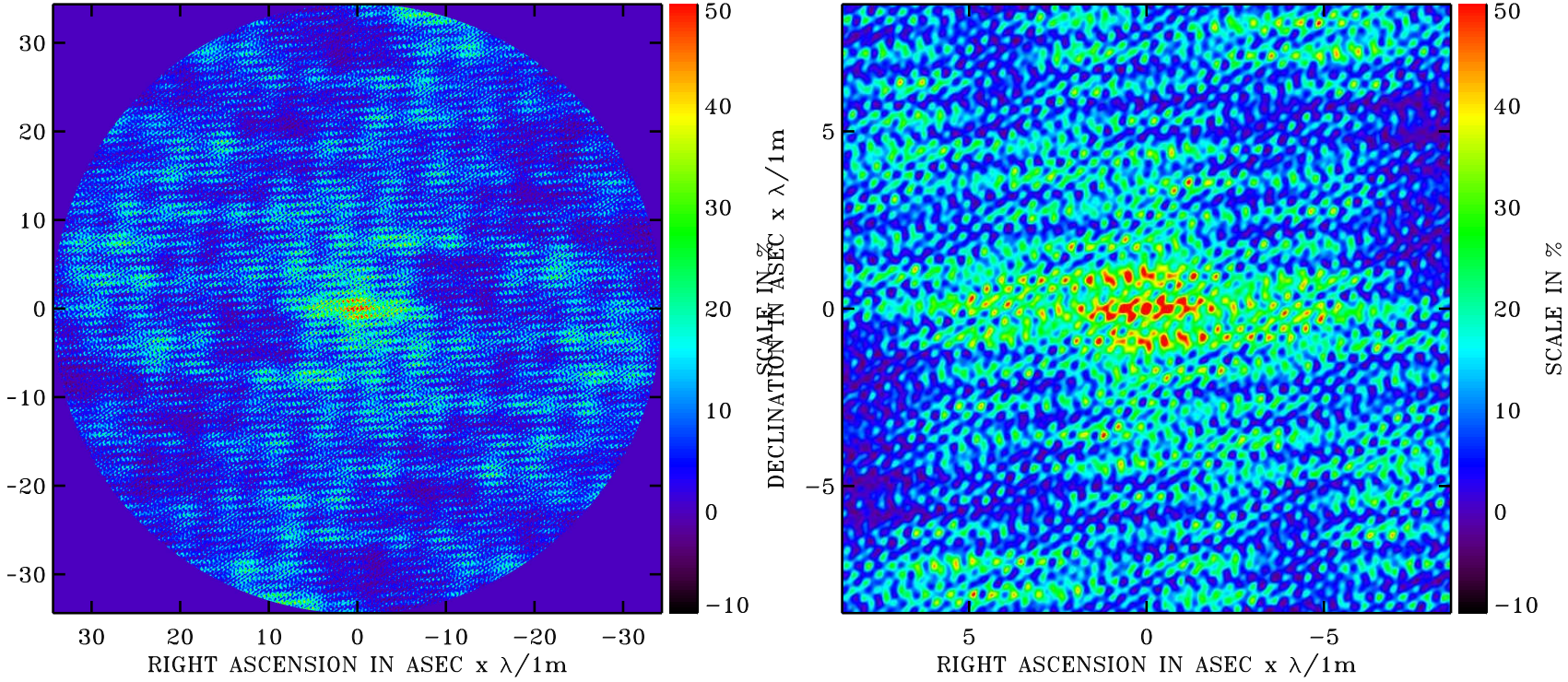


LOFAR uv-plane sensitivity distribution

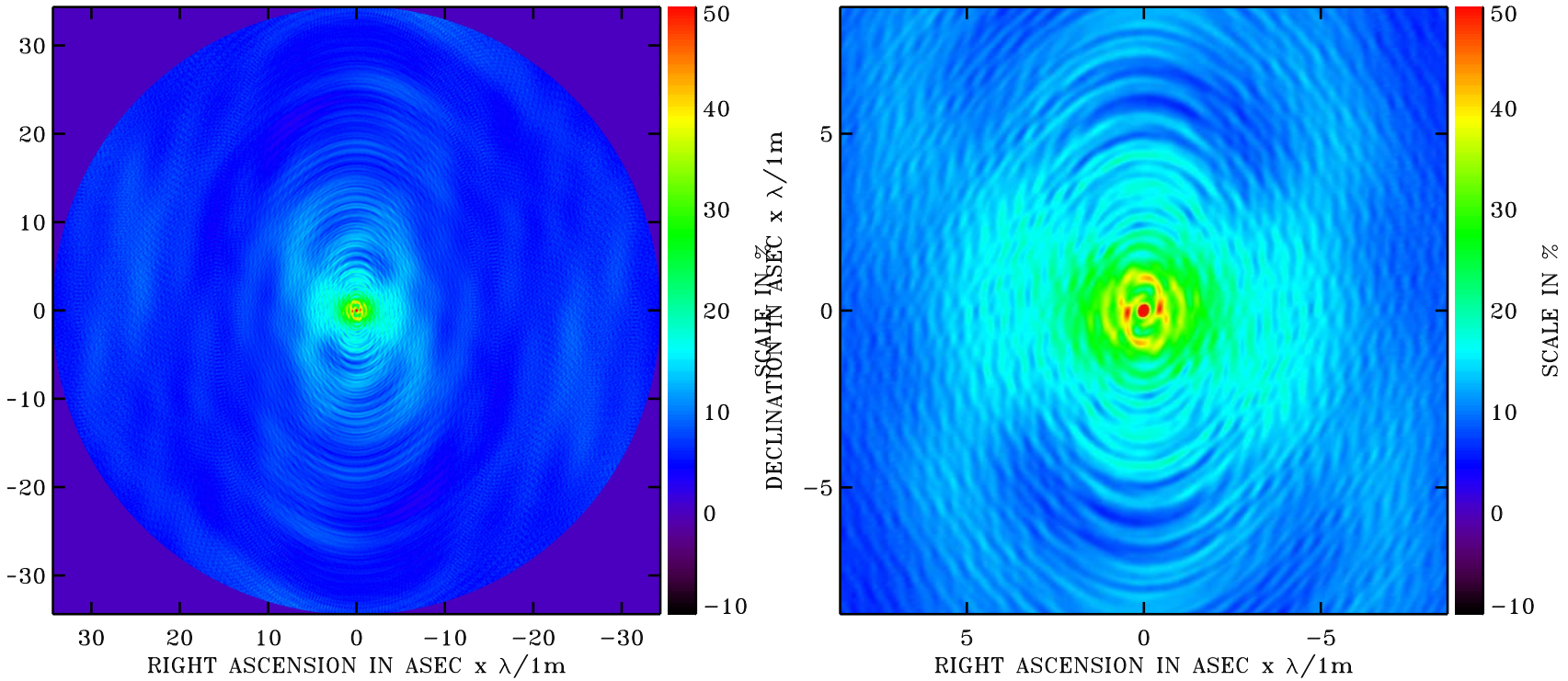
extremely concentrated distribution ≡ high sidelobes



LOFAR synthesized beam in snapshot



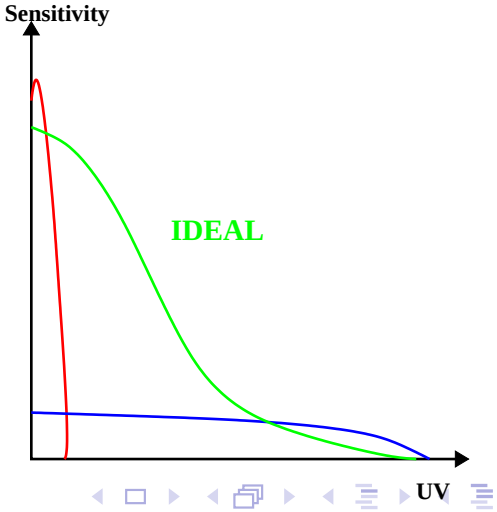
LOFAR synthesized beam in 8h



We are far from the 0.2”$\times\lambda/1$m resolution!
Sidelobes $>$ 50% of the main peak.

Limitation to high-resolution imaging and solutions

- As if there were a very big antenna at the center correlated with 10x smaller antennas
- There are two ways to deal with the excess of sensitivity at short baselines
  - software: downweight the NL stations ⇒ lose sensitivity
  - hardware: increase the sensitivity (effective area) of the international stations by x10 ⇒ NenuFAR



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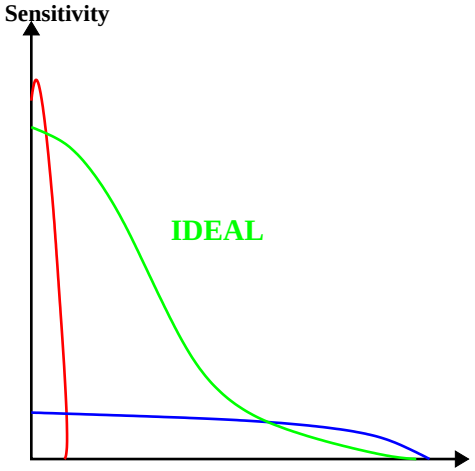

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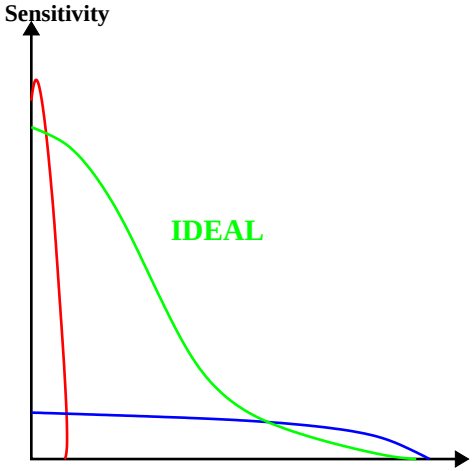

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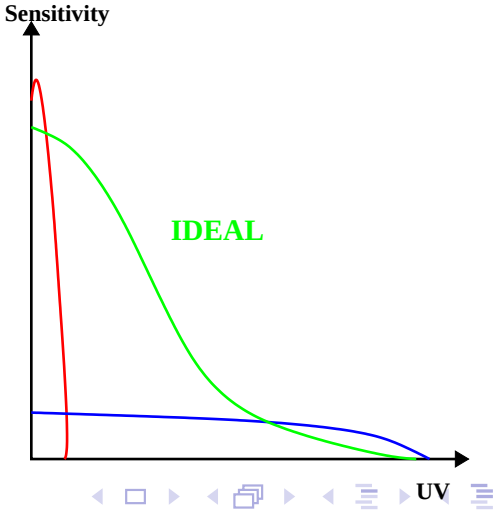
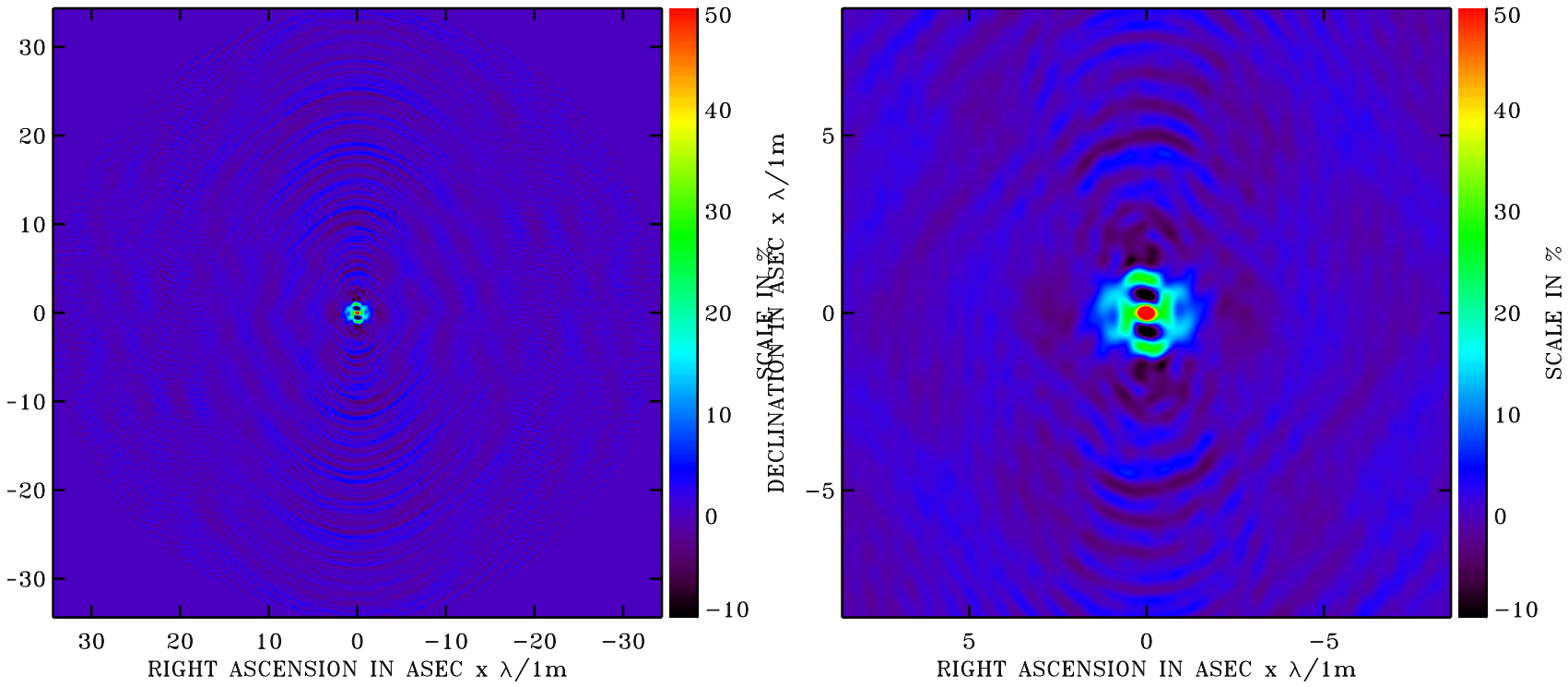
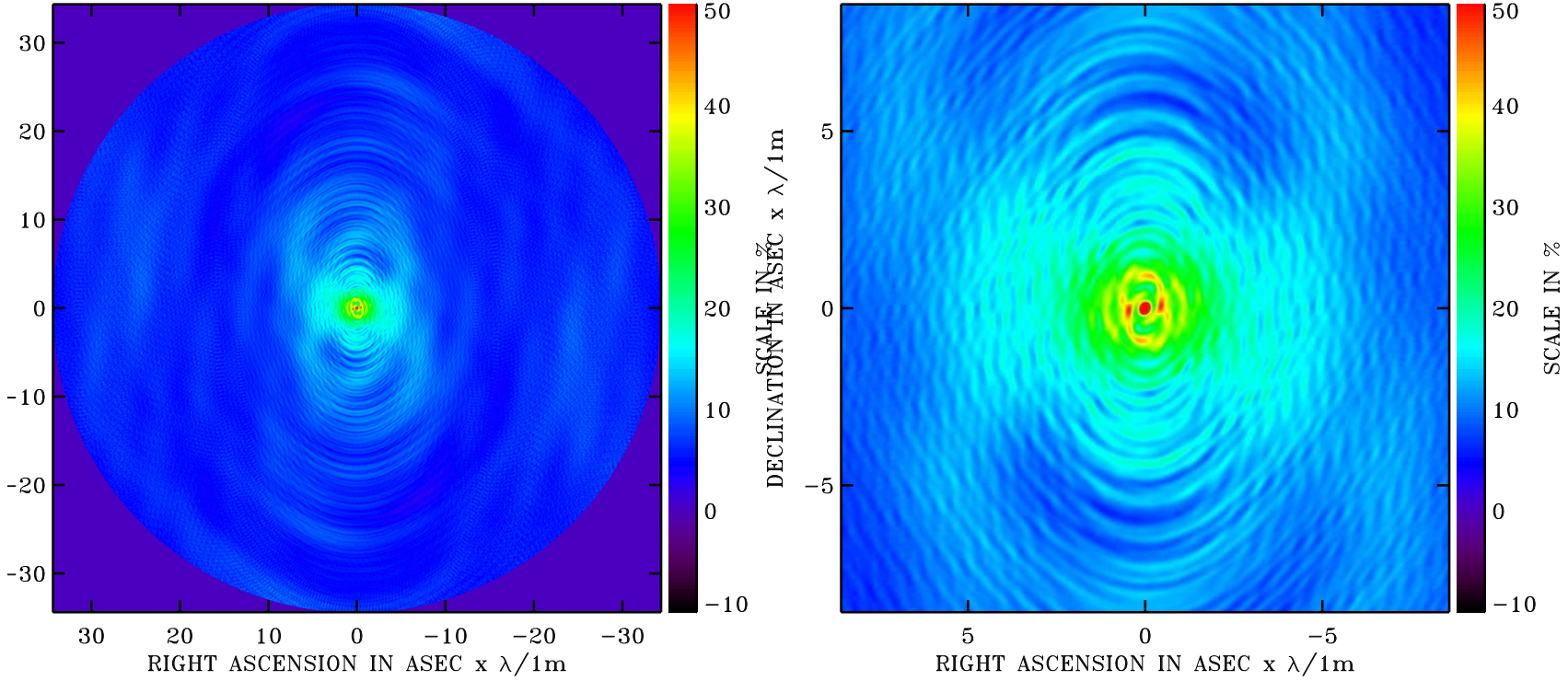


LOFAR 8h + reweighting

sensitivity lower by a factor **2**
$\Rightarrow$ sidelobes below 25% (i.e. 2x lower than with natural weighting)

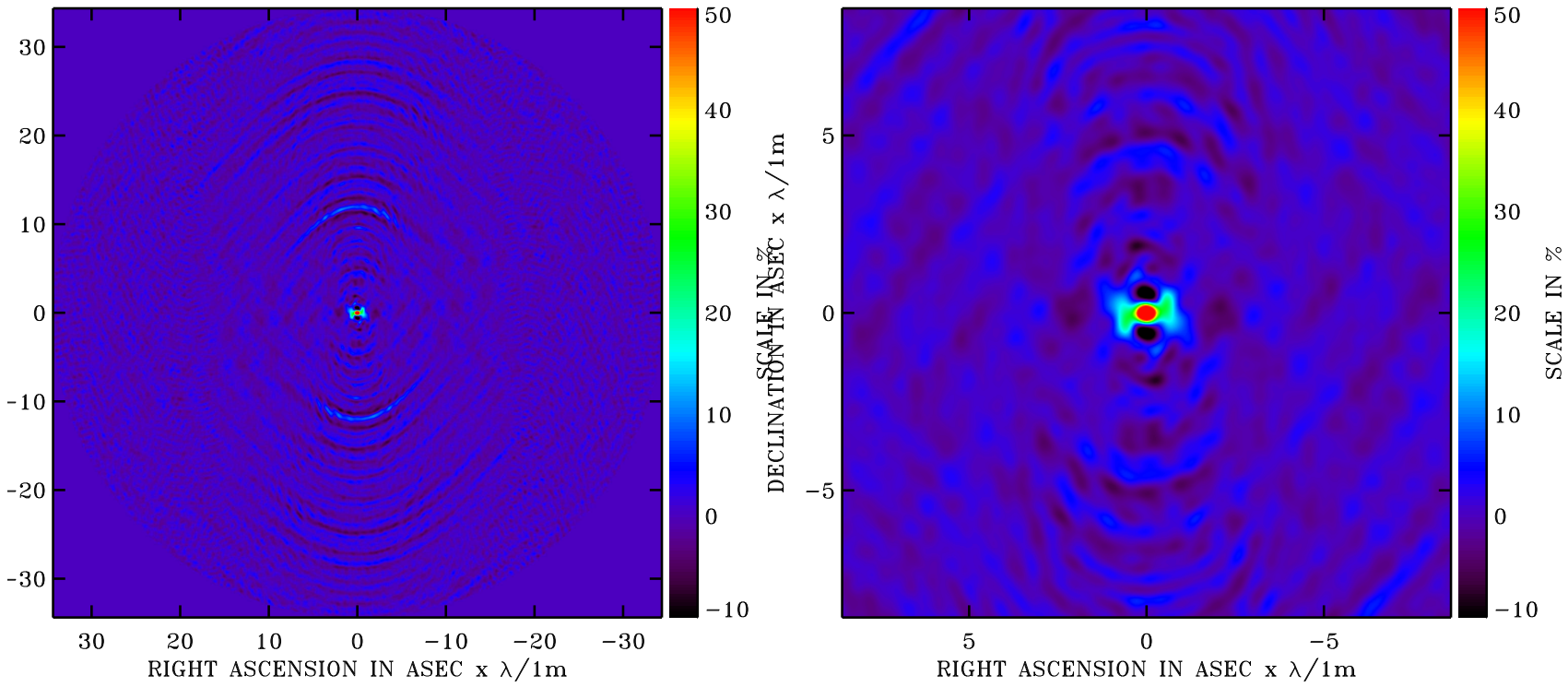


LOFAR 8h natural weighting



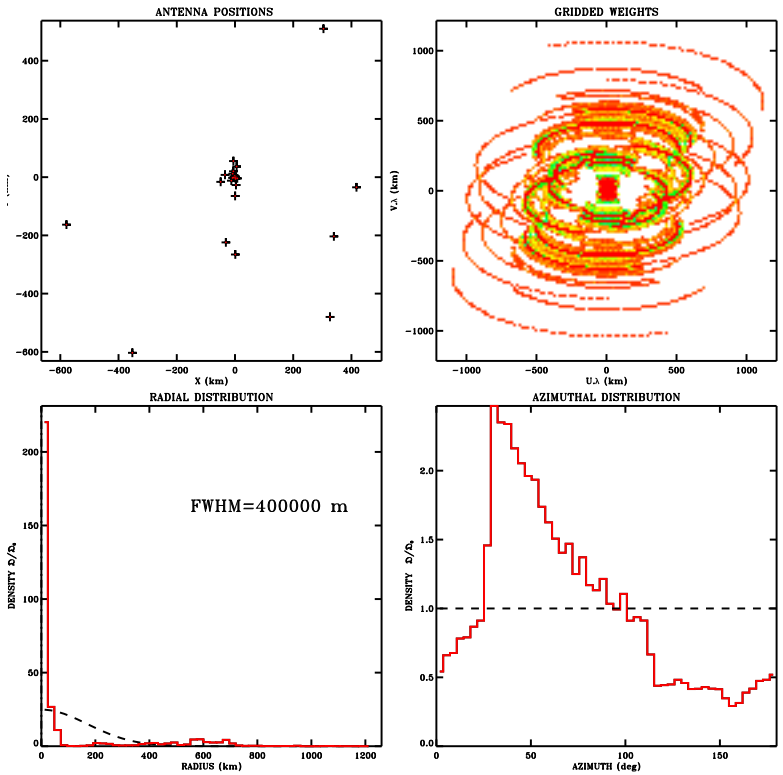
LOFAR 8h + reweighting

sensitivity lower by a factor **4**
$\Rightarrow$ sidelobes below 10% (i.e. 4x lower than with natural weighting)

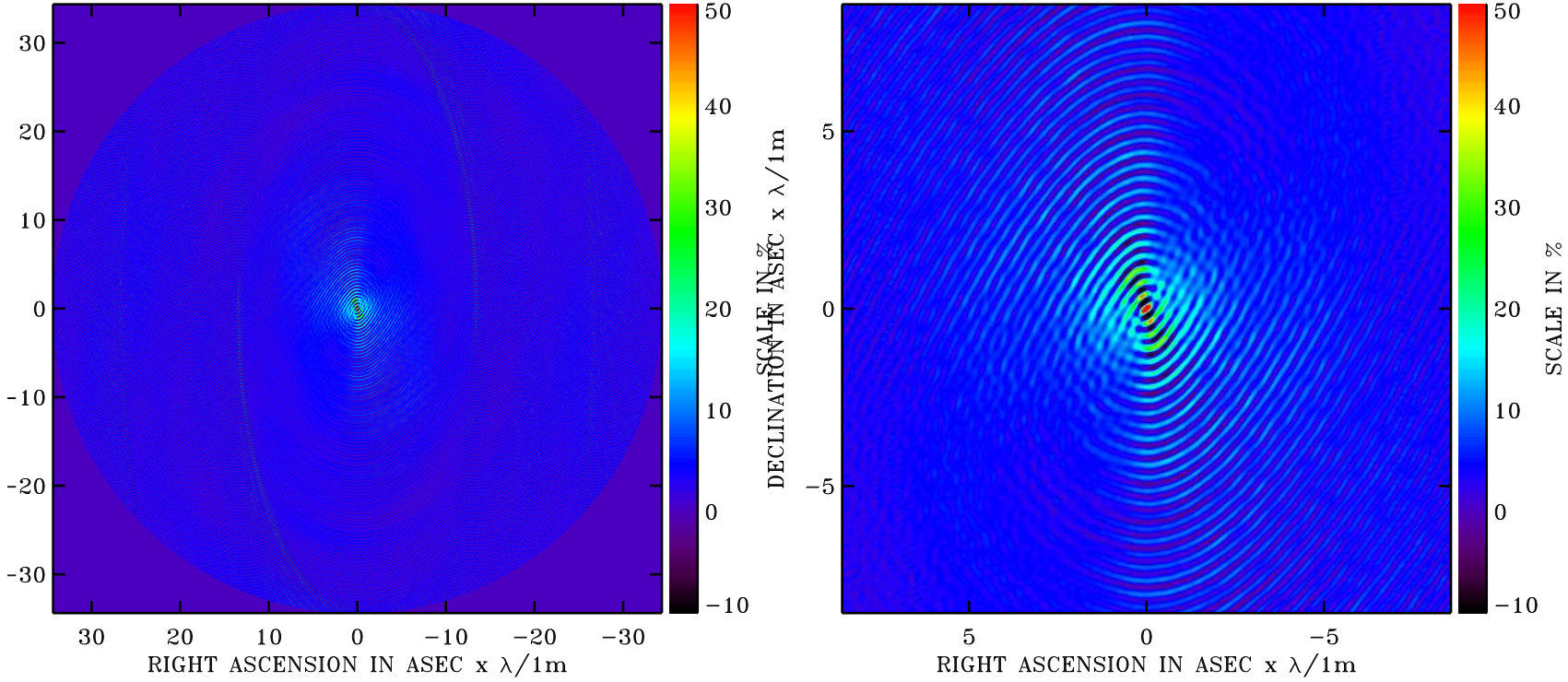


LOFAR+NenuFar with natural weights

NenuFAR is **19 times** more sensitive than the other remote stations

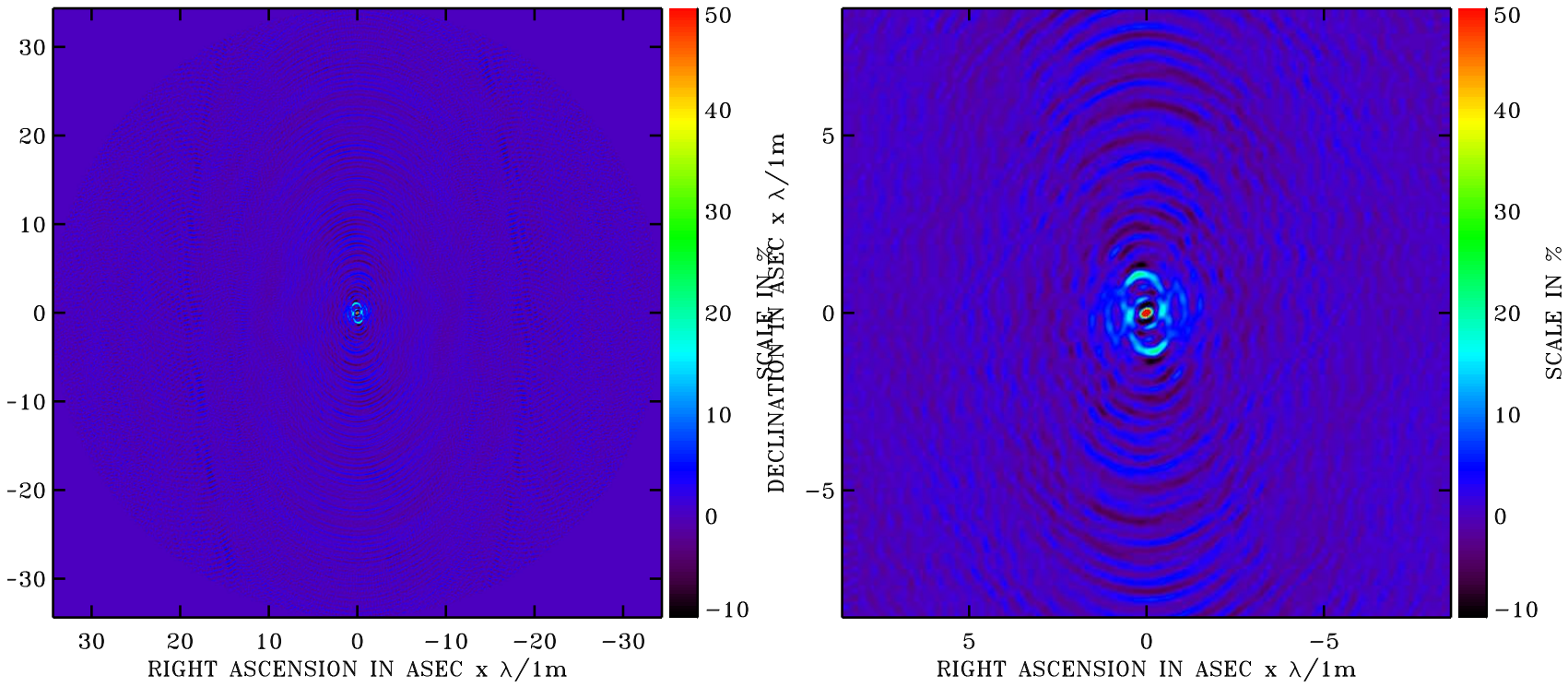


LOFAR+NenuFAR with natural weights

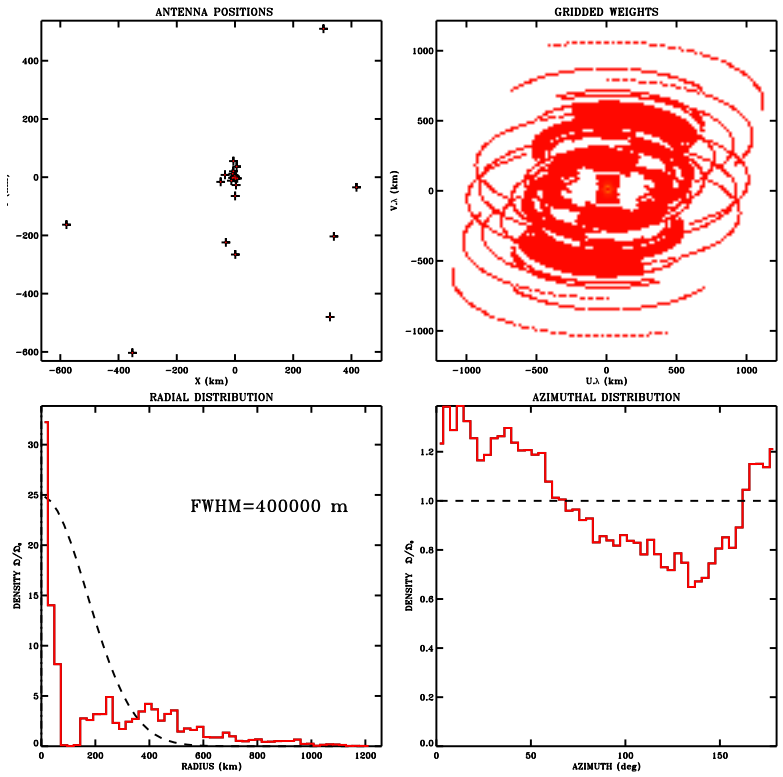


LOFAR+NenuFAR + reweighting

sensitivity lower by a factor **1.5**
$\Rightarrow$ sidelobes below 20% (i.e. 2x lower than with natural weighting)

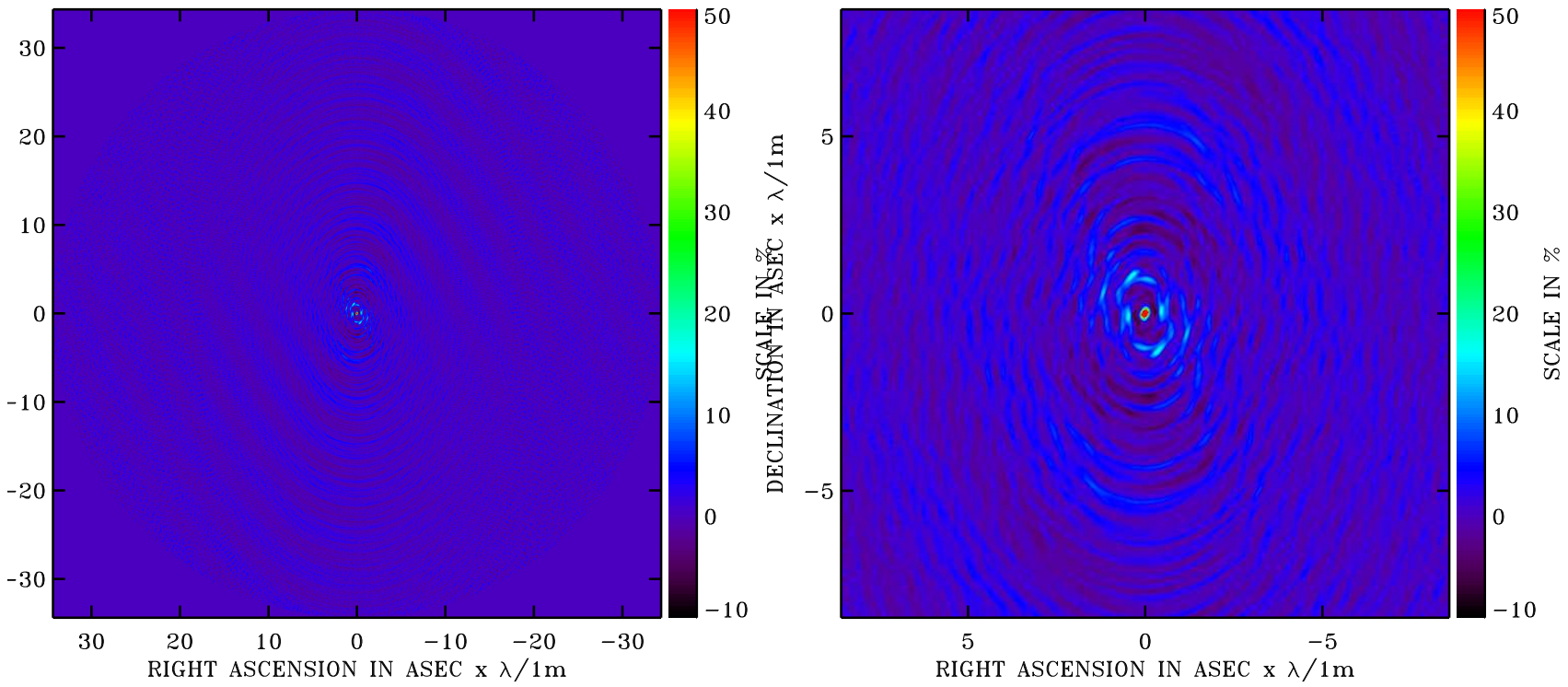


LOFAR with 8 NenuFAR international stations



LOFAR with 8 NenuFAR international stations

Full sensitivity and sidelobes <20%



Conclusion

- The NenuFAR station can improve the sensitivity balance between short and long baselines in LOFAR.
- Sensitivity increased by $\sim$2 and lower sidelobes.
- Would be even better if all international stations were like NenuFAR!