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ABSTRACT - The SMOS (Soil Moisture and Ocean Salinity) space mission, currently undergoing a phase A study in the frame of the Earth Explorer Program of the European Space Agency, will be the first attempt to apply, to remote sensing of the Earth, the concept of imaging interferometric radiometry by aperture synthesis.

The apodization function, to be applied to the complex visibilities obtained from raw data inside a star-shaped window over an hexagonally sampled grid, should be optimized for ensuring the best spatial resolution performances at ground level, accounting for criteria relevant for extended sources typical of Earth surface scenes.

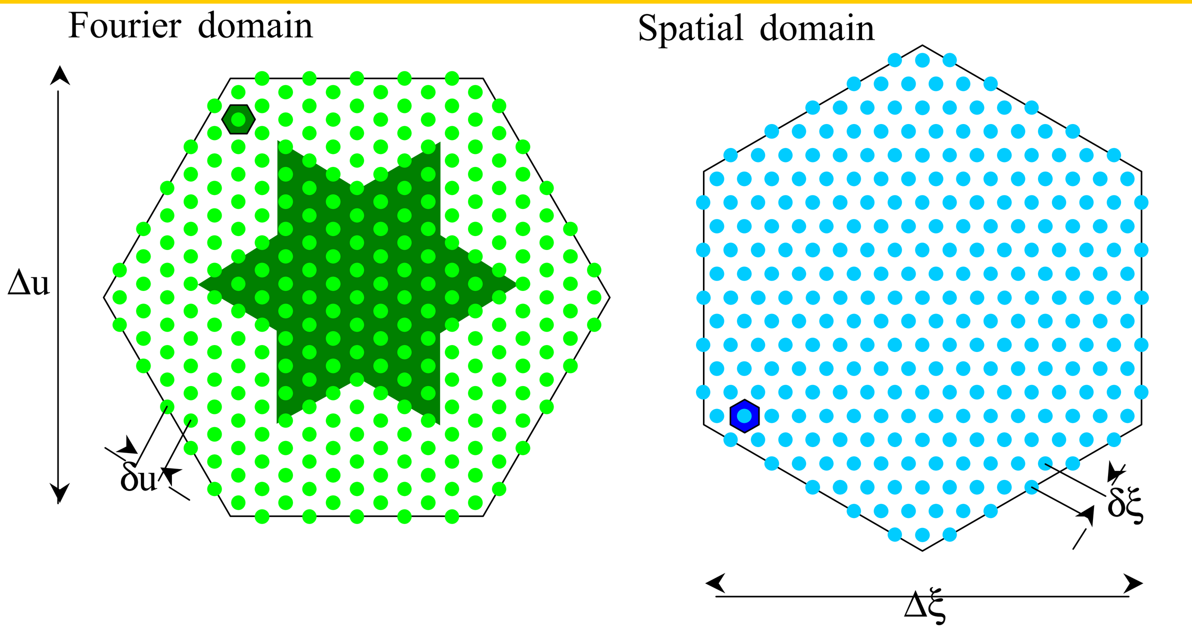
Furthermore, in order to reduce the Gibbs phenomenon produced by the finite extent of the star-shaped frequency coverage and the resulting sharp frequency cut-off, experimental complex visibilities similarly have to be tapered with an appropriate apodization function. Selecting this function impacts upon both radiometric sensitivity and spatial resolution; at the same time it influences the practical limits of the alias-free field of view whenever aliasing boundaries are present.

HEXAGONAL PERIODIC LATTICES

Interferometer measurements, also termed complex visibilities, are obtained by cross-correlating signals collected by two spatially separated antennae with overlapping fields of view.

In the SMOS case, where the synthesized antenna consists of a planar Y-shaped structure with equi-spaced radiating elements, the visibility functions are sampled over an hexagonal grid inside a star-shaped area in the Fourier domain.

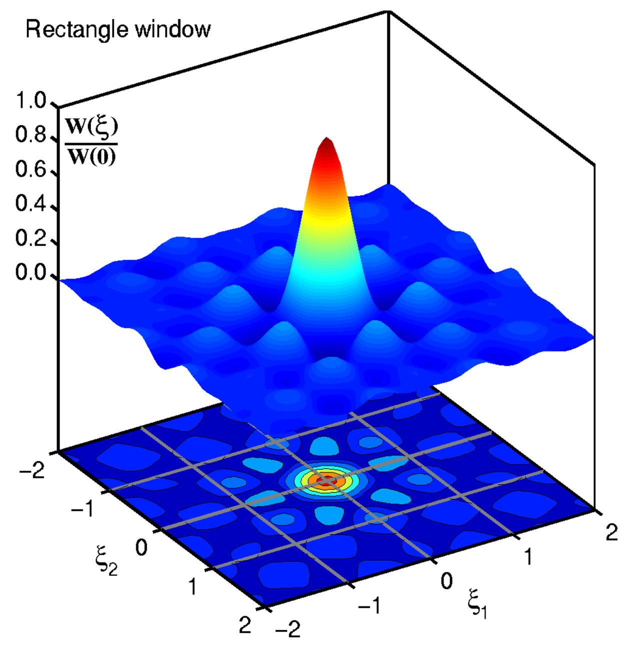
It has been demonstrated that hexagonal discrete Fourier transforms could be implemented by re-using a standard FFT algorithm designed for Cartesian grids, thus making the development of a specific algorithm unnecessary.



$$\Delta\xi\,\delta u = \Delta u\,\delta\xi = \frac{2}{\sqrt{3}} \text{ with } \Delta\xi = n\,\delta\xi \text{ and } \Delta u = n\,\delta u.$$

APODIZATION WINDOWS

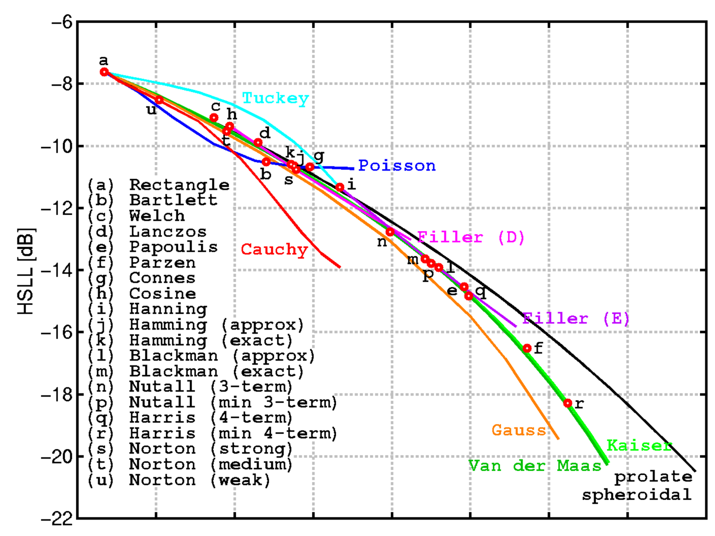
Traditional one-dimensional windowing functions can be adapted easily to the two-dimensional hexagonal case.

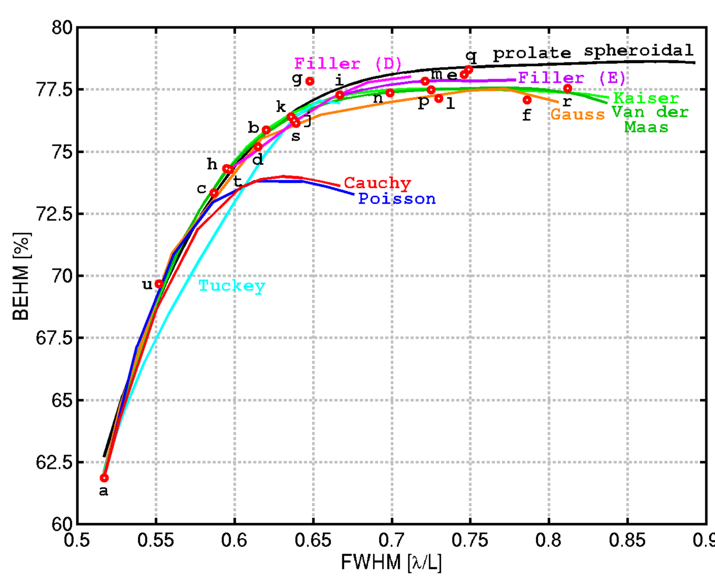


Standard figures of merit :

- Full Width at Half-Maximum (**FWHM**)
- Highest Side Lobe Level (**HSLL**)
- Beam Efficiency at Half-Maximum (**BEHM**)

More than 20 classical windowing functions (including families) are assessed with respect to their **BEHM & HSLL** *vs* **FWHM** performances.

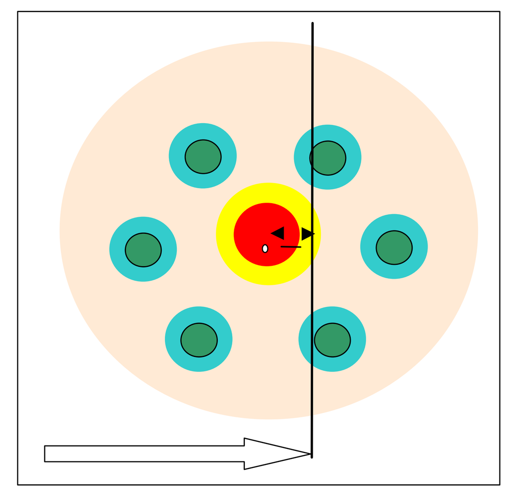




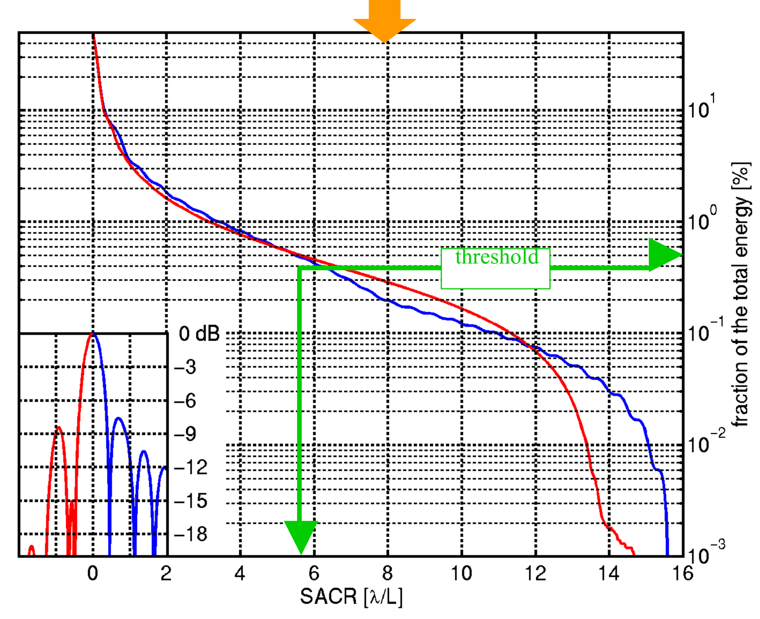
Optimized apodization functions : prolate spheroidal wave functions achieve maximal efficiency in the least square sense

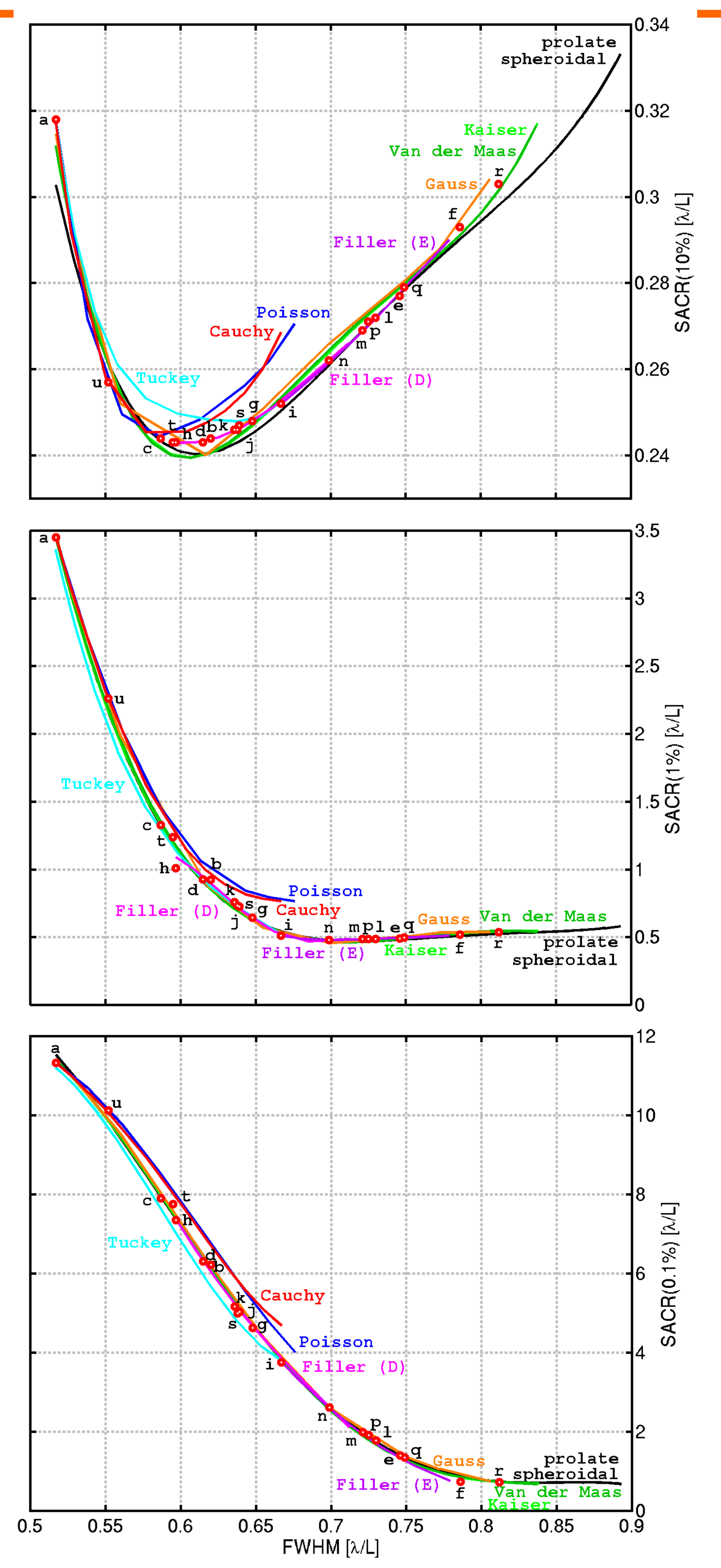
A figure of merit suited to extended target on Earth surface : the **Side Area Contribution Radius (SACR)**.

SACR : the distance of closest approach, such that integrated relative contributions from a zone beyond a straight line is smaller than a given threshold, is relevant for scenes including a **discontinuity** (e.g. a **coastline**).

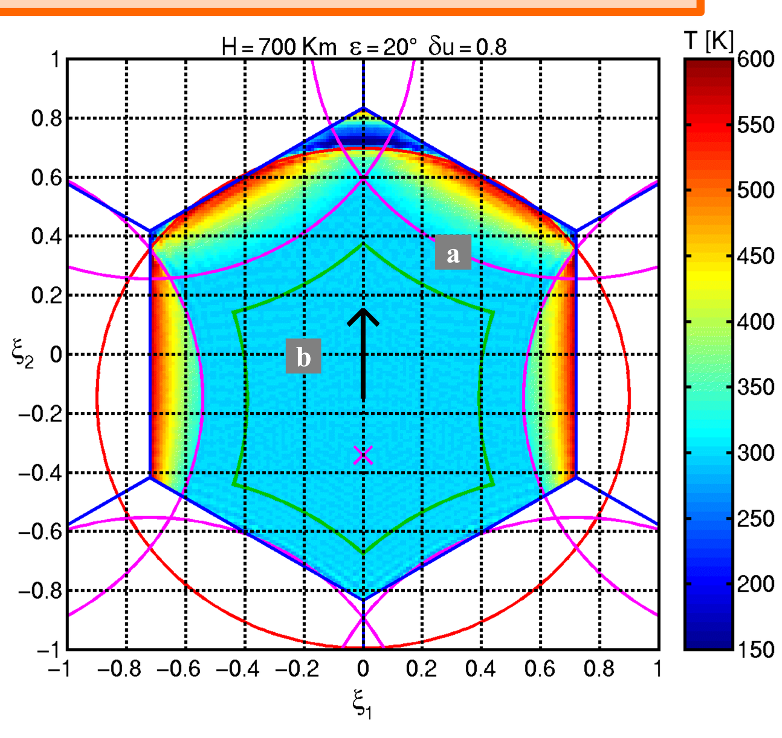


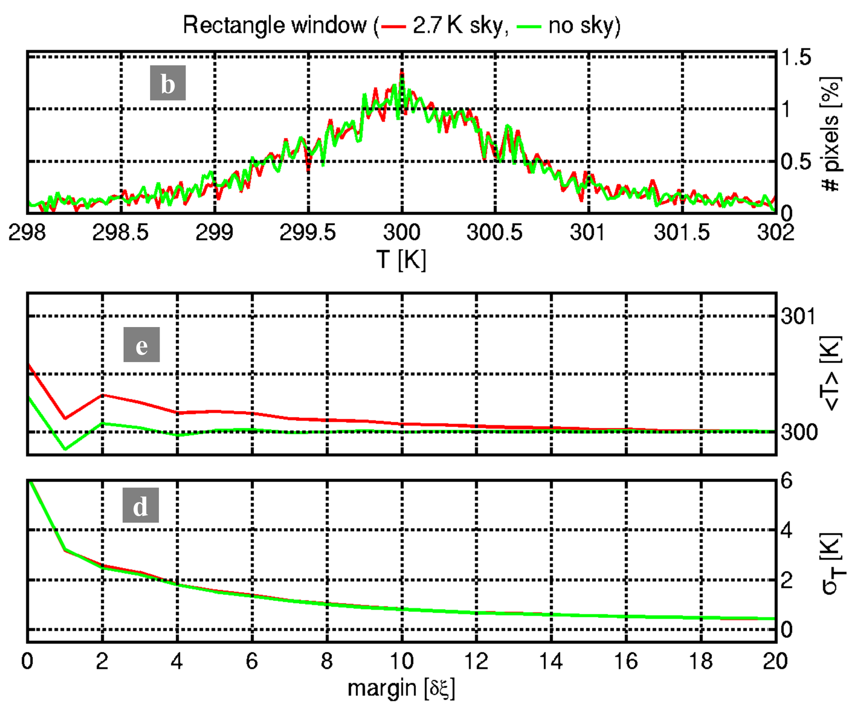
Since distinct threshold values (ranging between 2 % and 0.05 %) apply for sea and land scenes, an optimal processing should make use of **different** apodization windows according to the target of interest.





ALIAS-FREE FIELD OF VIEW





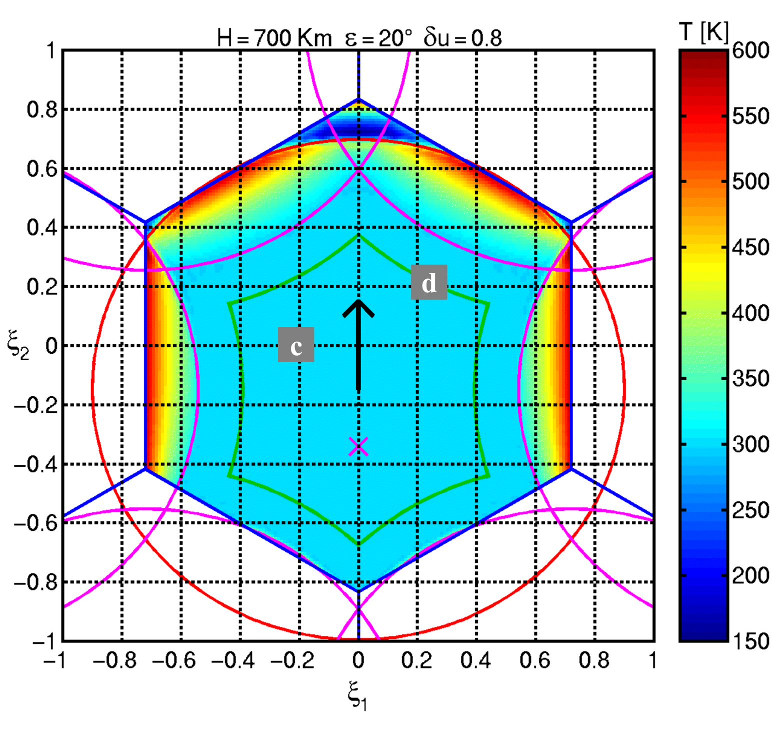
a In the direction cosines plane, the FOV is bounded by elliptical replicas of the Earth horizon.

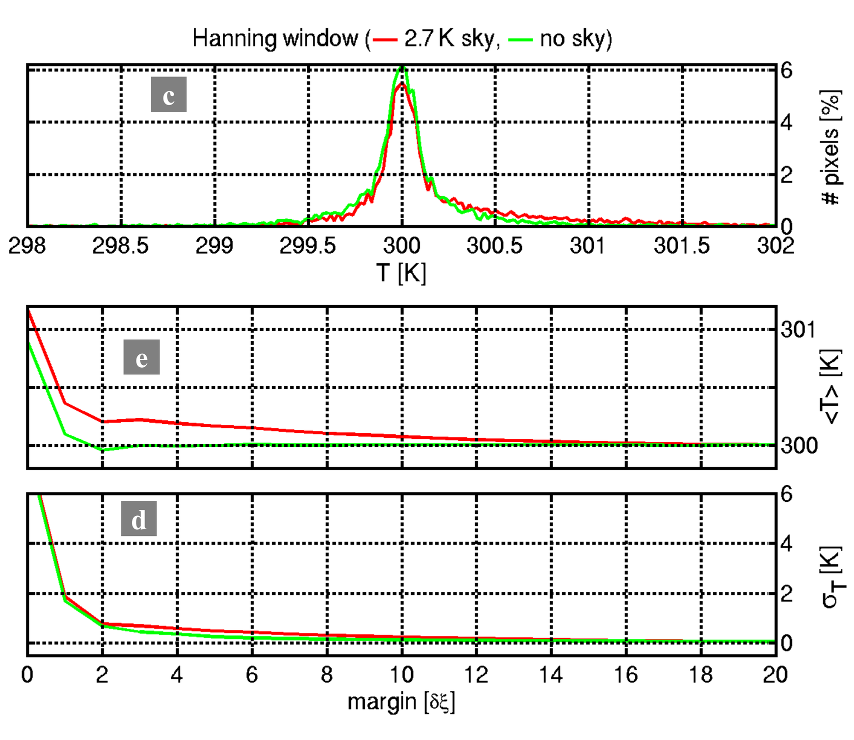
b These steep boundaries generate Gibbs oscillations, of sizeable amplitude when no window is applied.

c Apodization substantially reduces the amplitude of Gibbs phenomena.

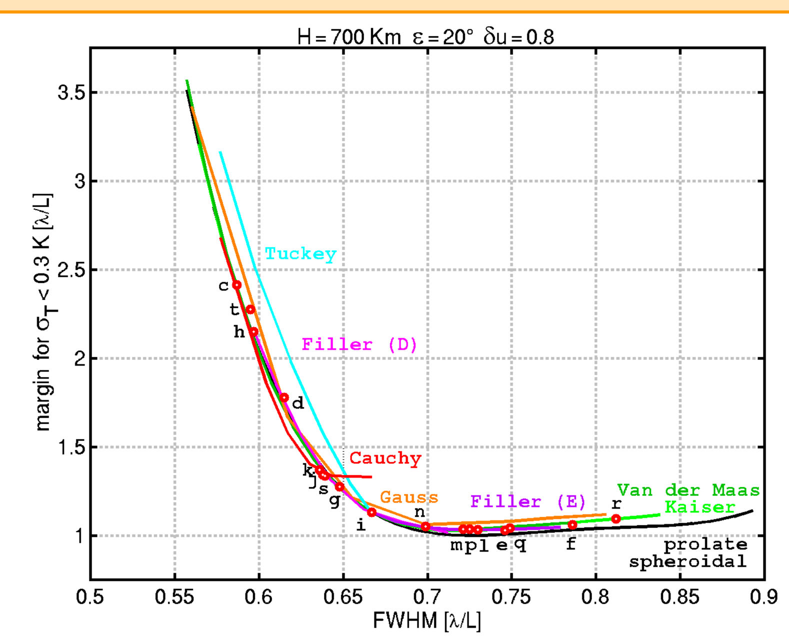
d Hence applying a window allows to narrow the margin by which one should reduce the FOV size in order to achieve a stipulated standard deviation on reconstructed brightness temperatures

e It is possible to extend the FOV by including aliased sky regions, provided the sky contributions are properly corrected for ; otherwise biases appear.

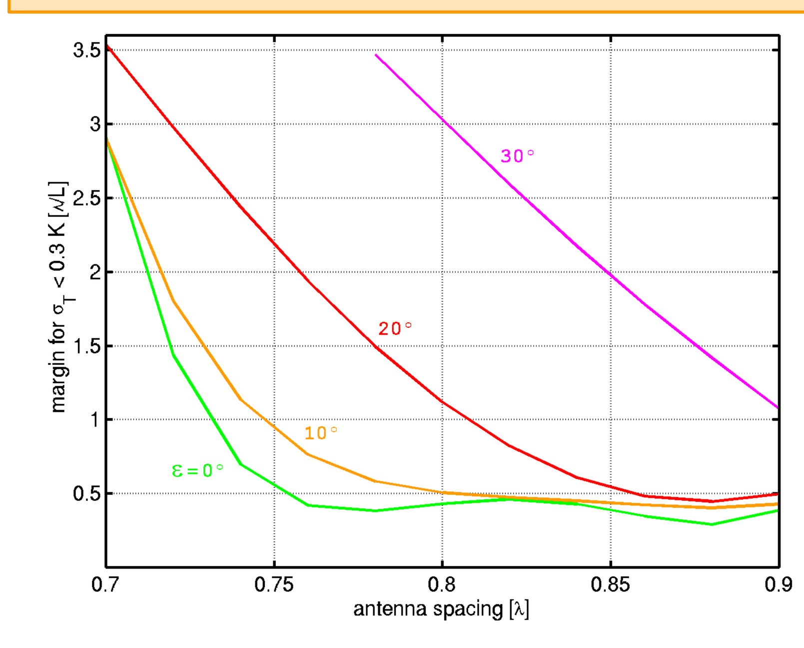




Estimating the margin required when using various window functions for a specified standard deviation threshold over the FOV (here 0.3 K, to be compared to a 300 K homogeneous scene temperature) yields results similar to the SACR test above. The prolate spheroidal functions achieve the best result.



The margin width, for a specified standard deviation threshold (here 0.3 K), depends both on the element spacing ratio and the tilting angle of the antenna plane with respect to the horizontal plane.



CONCLUSION - This work can be viewed first as a benchmark for assessing the performances of apodization functions in terms of spatial resolution and discrimination as well as radiometric sensitivity, when observing extended, inhomogeneous targets with an interferometric antenna.
A specific criterion (the SACR) has been introduced in order to explicit the requirement that zones separated by a discontinuity line across the observed scene can be explored as fully as possible, i.e. keeping contamination by the neighbouring zone within acceptable limits.
It is then found that an optimal window width can be defined ; since this width depends on the severity of the contamination criterion, the optimal window choice will differ depending on the target of interest.

Whenever the field of view of the interferometer is bounded by aliased replicas of the scene (because technical reasons lead to choose, for the spacing between interferometric elements, values exceeding the Nyquist requirement), discontinuities appear similarly at the edges of the alias free zone, and generate Gibbs oscillations throughout the FOV. Again, the apodization window should be selected in order to keep the FOV as large as possible while keeping the errors due to Gibbs oscillations smaller than a stipulated threshold.
Future work is required in order to optimise the observing configuration, accounting for the effect of the antenna plane tilting angle and the radiating element spacing ratio. While it is possible to extend the « alias free » FOV by including zones contaminated by sky replicas, this requires accounting accurately for sky contributions.

ACKNOWLEDGMENTS
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