On Flexibeam for Radio Interferometry

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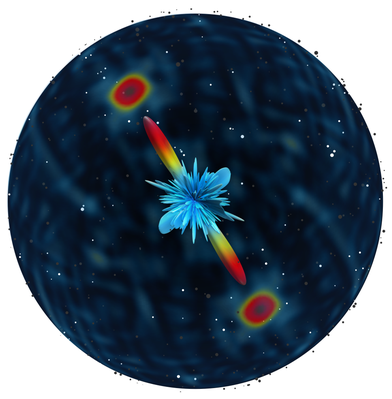
Abstract — Beamforming in radio astronomy focuses around a direction using **matched beamforming**. Such beamformers often result in large side-lobes, with influence from *undesired* directions. Moreover, they cannot target extended *regions*. We show how **Flexibeam** can be leveraged to survey large sky portions with substantially **more energy concentration** within the region-of-interest.

1. Matched Beamforming

Matched beamforming is *dual-purpose*:

- **Increase SNR** for a specific direction,
- **Reduce** amount of data sent to processor.



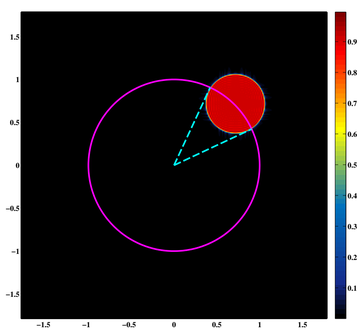
Typical beamshape

While simple, it has a few drawbacks:

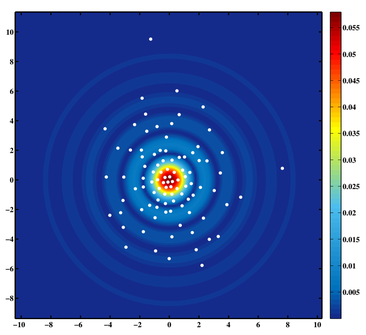
- **Large sidelobes** polluting the data,
- **Surveying** large portions of the sky requires scanning,
- Sensitive to **uncertainty** in target direction.

2. Flexibeam

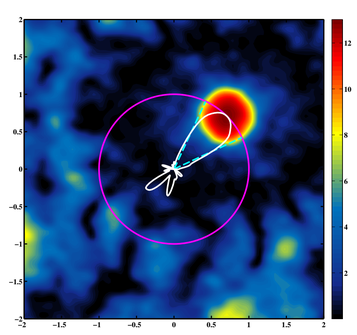
The **Flexibeam** framework [1] permits general spatial sky filters to be approximated. This beamforming strategy is **numerically stable** and **scalable**. The beamforming weights are sampled from a **beamforming function**.



Extended filter



Beamforming function



Empirical beamshape

3. Ball Indicator Beamshape

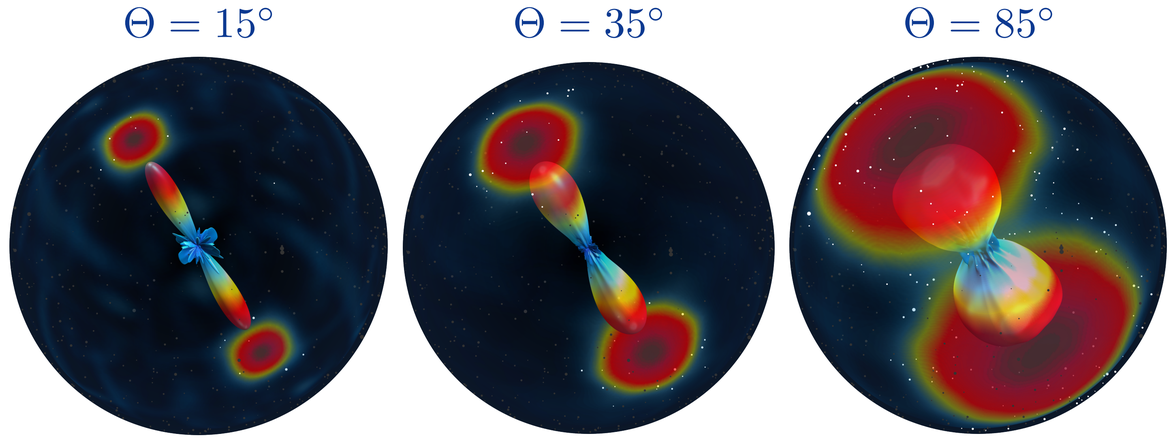
The **ball indicator beamshape** is well-suited for *surveying large portions* of the sky.

$$\hat{\omega}(\boldsymbol{r}) = \begin{cases} 1 & \text{if } \|\boldsymbol{r} - \boldsymbol{r}_0\| \leq R, \\ 0 & \text{otherwise.} \end{cases}$$

Its beamforming function is given by:

$$\omega(\boldsymbol{p}) = R^{-1/2} \|\boldsymbol{p}/\lambda\|^{-3/2} J_{3/2}\left(2\pi R \|\boldsymbol{p}/\lambda\|\right) e^{-j2\pi\langle \boldsymbol{r}_0, \boldsymbol{p}/\lambda\rangle},$$

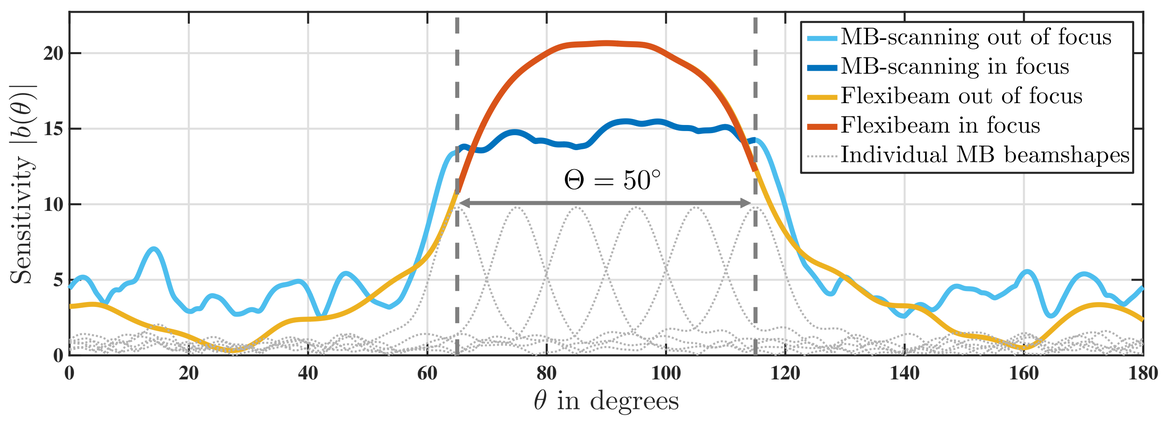
where $R = \sqrt{2}\sqrt{1-\cos\Theta}$.



Examples of Flexibeam beamshapes for a LOFAR LBA station

4. Surveying the sky with Flexibeam

Flexibeam dramatically **reduces sidelobes** while concentrating most of the energy where we want it (**signal amplified** by **26.2%**, **33% less** sidelobes).



MB scanning vs. Flexibeam surveying

5. References

1. P. Hurley and M. Simeoni, "Flexibeam: analytic spatial filtering by beamforming," in *International Conference on Acoustics, Speech and Signal Processing (ICASSP), IEEE*, March 2016.
2. M. Simeoni, "Towards more accurate and efficient beamformed radio interferometry imaging," Master's thesis, EPFL, Spring 2015.