Faraday Tomography with LOFAR

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5 Apr 2016

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Background: IC342 as seen by LOFAR (Stokes I)

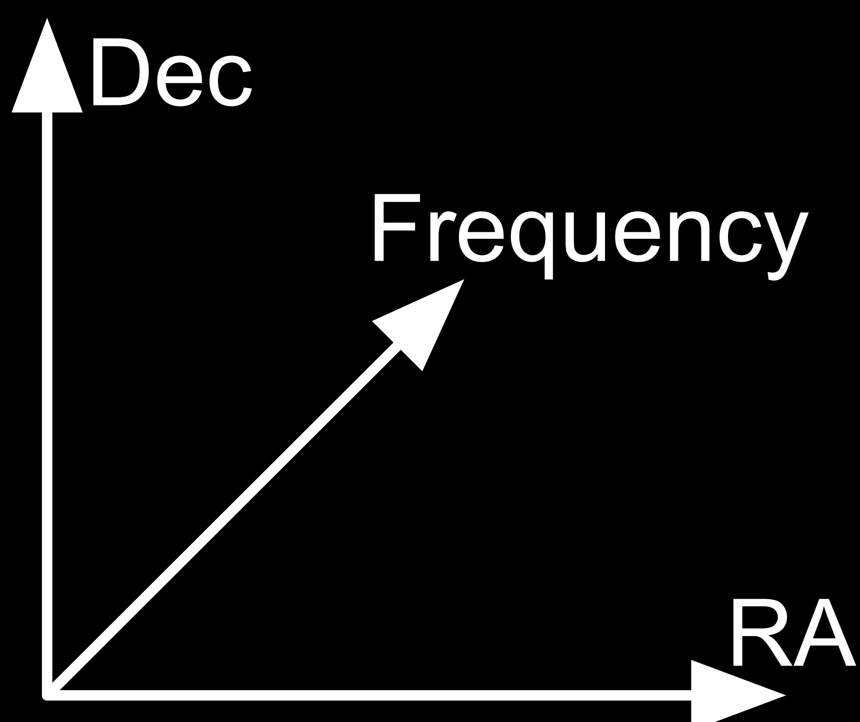
Detecting Magnetic Fields

- cosmic rays + magnetic field = polarized synchrotron emission
- polarization + free electrons + magnetic field = Faraday rotation

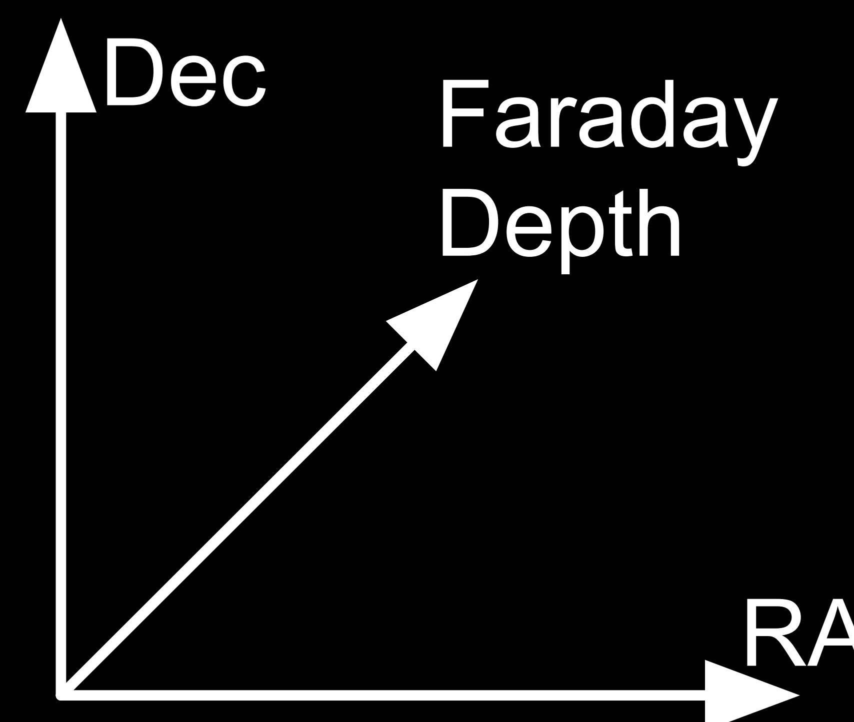
$$\text{Change in polarization} \propto \lambda^2 \underbrace{\int_0^d n_e \vec{B} \cdot \vec{dl}}_{\text{Faraday depth, } \phi}$$

Faraday Tomography

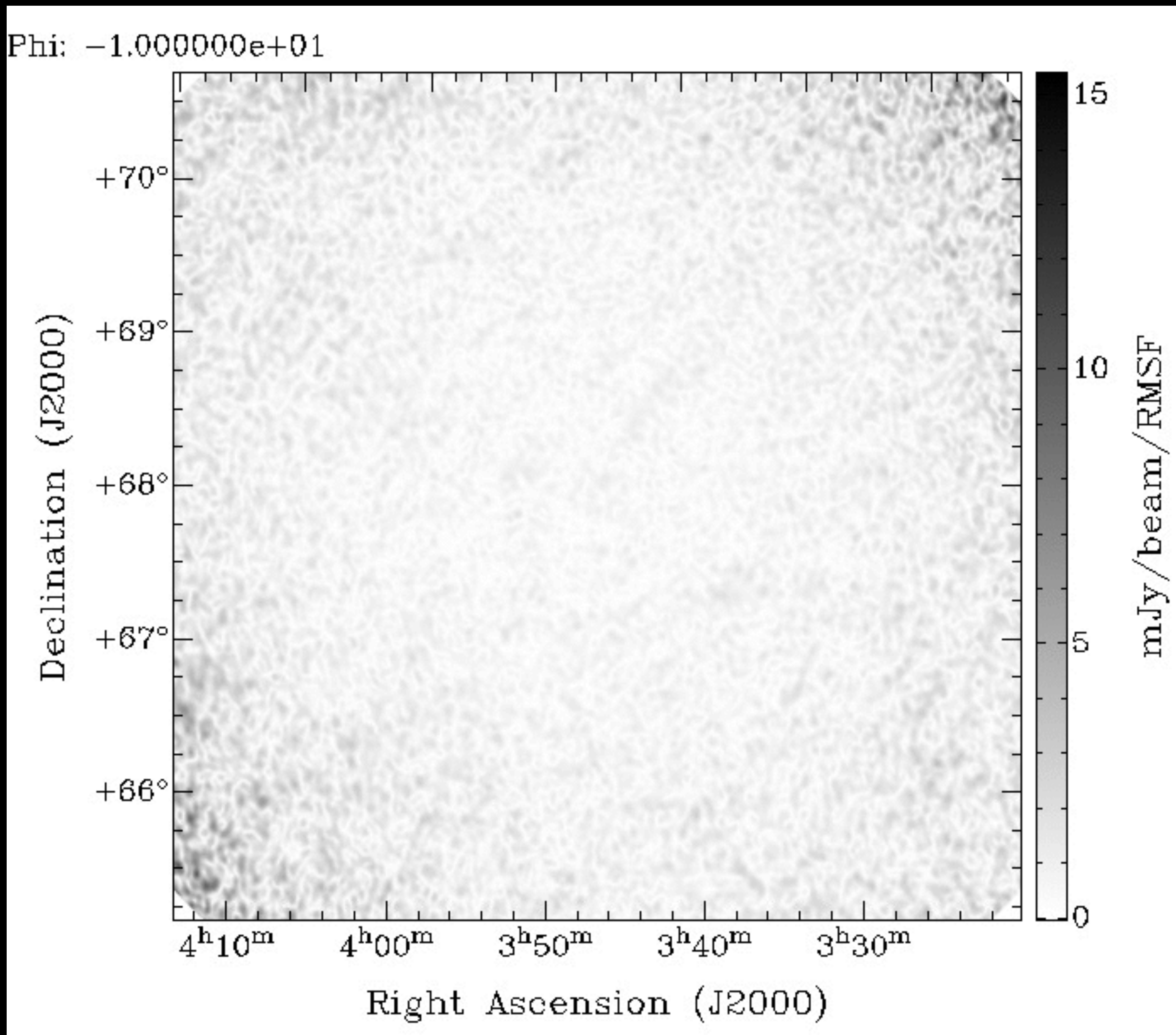
- Broad-band radio polarization cubes can be transformed into Faraday depth cubes:



$$P(\lambda^2) \xrightarrow{\mathcal{F}} P(\phi)$$



The IC342 field

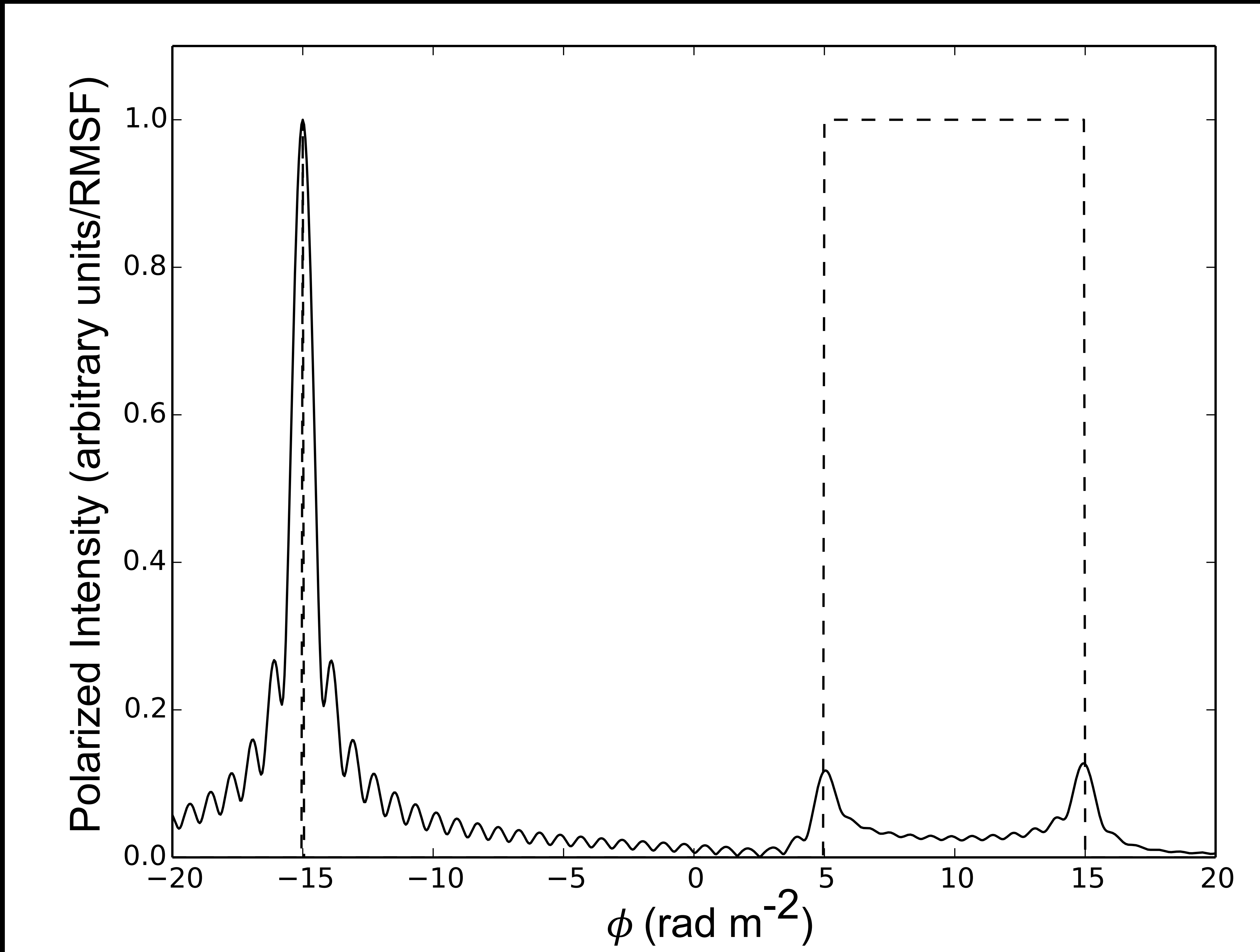


The Problem with (low-frequency) Polarization

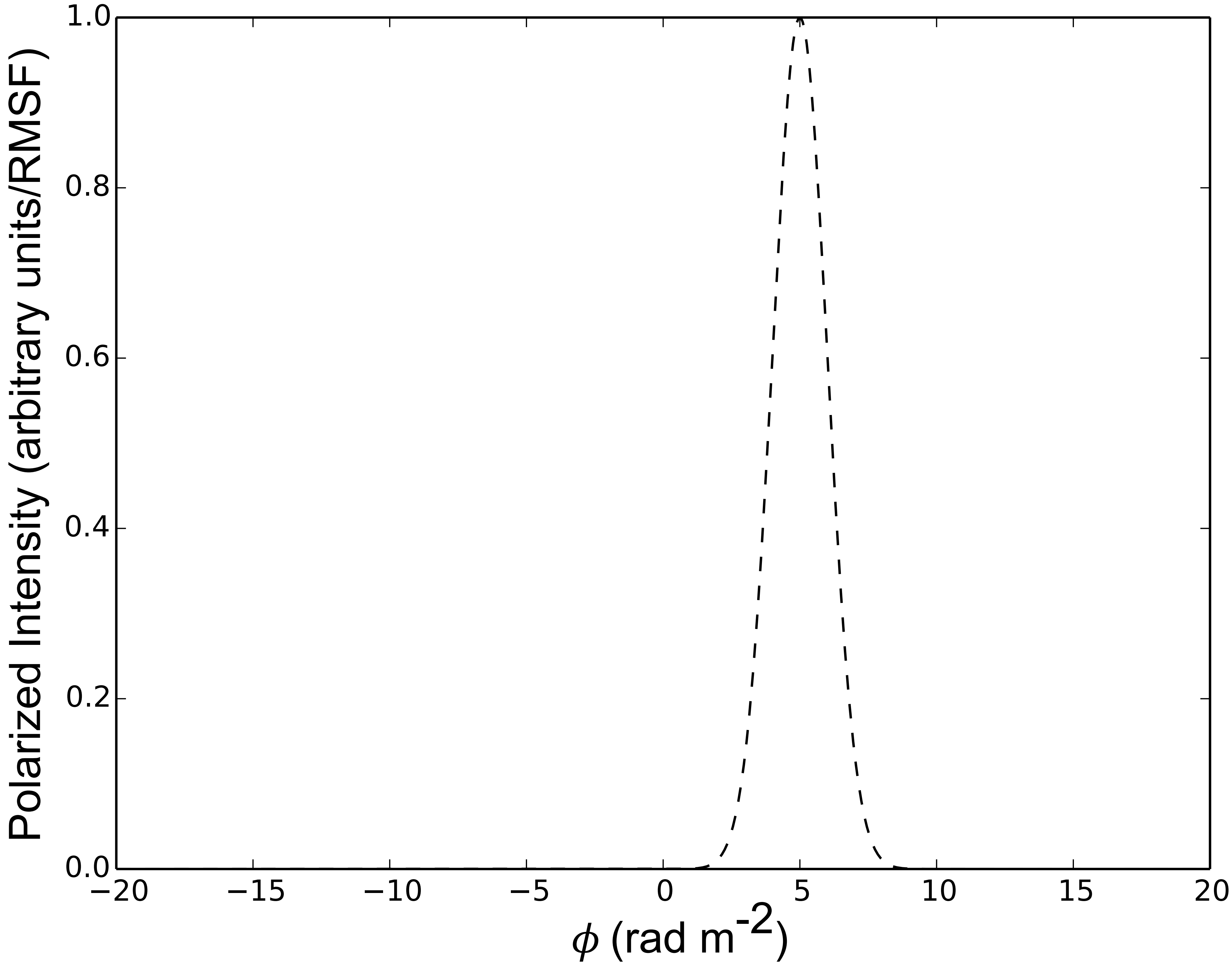
- Faraday tomography is a Fourier-based technique: incomplete sampling leads to a PSF, sidelobes, missing short spacings/large structures.

- Modelling needs to account for this: how do physical features get transformed?

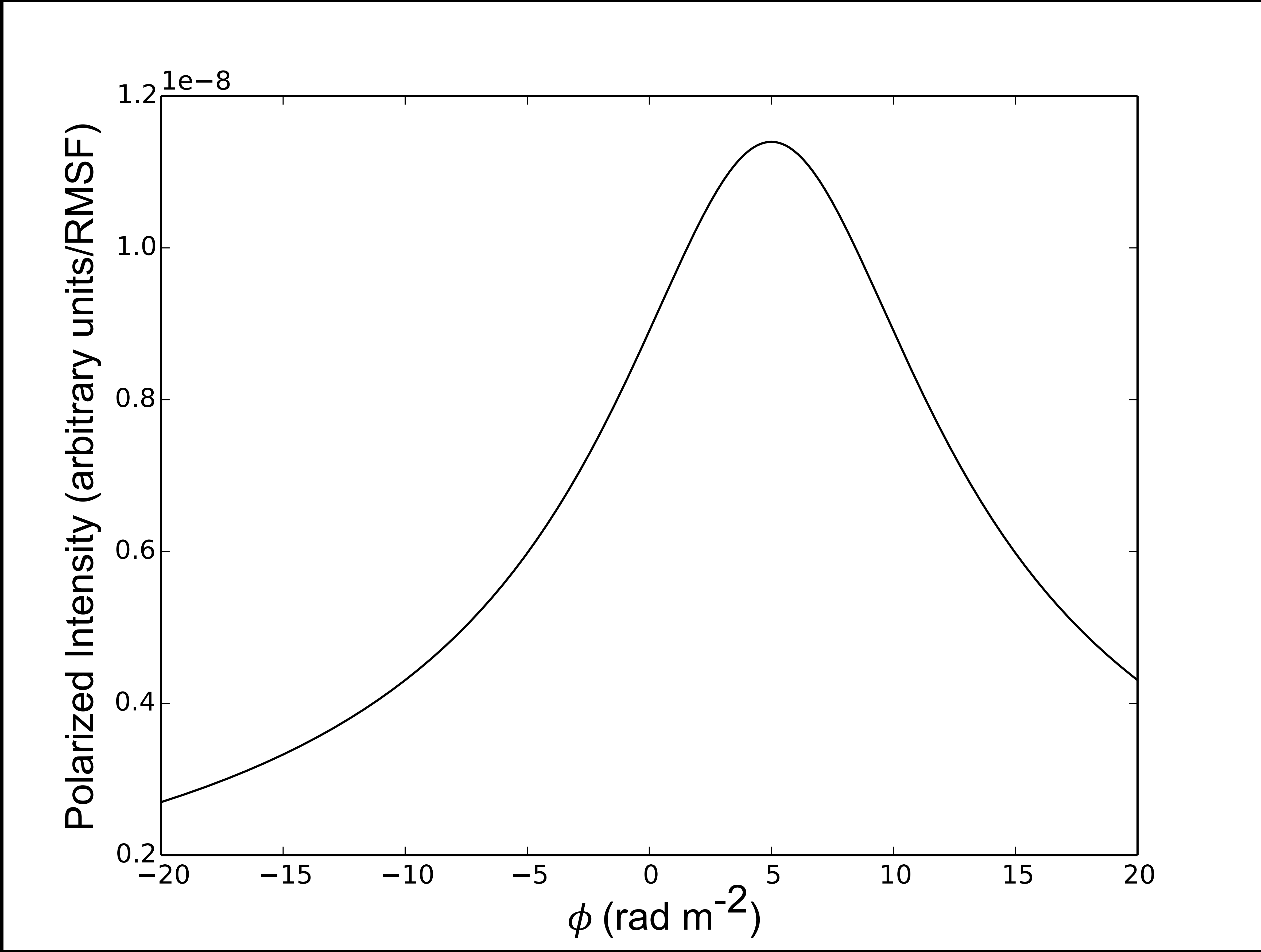
Simulated Spectrum - Tophat slab



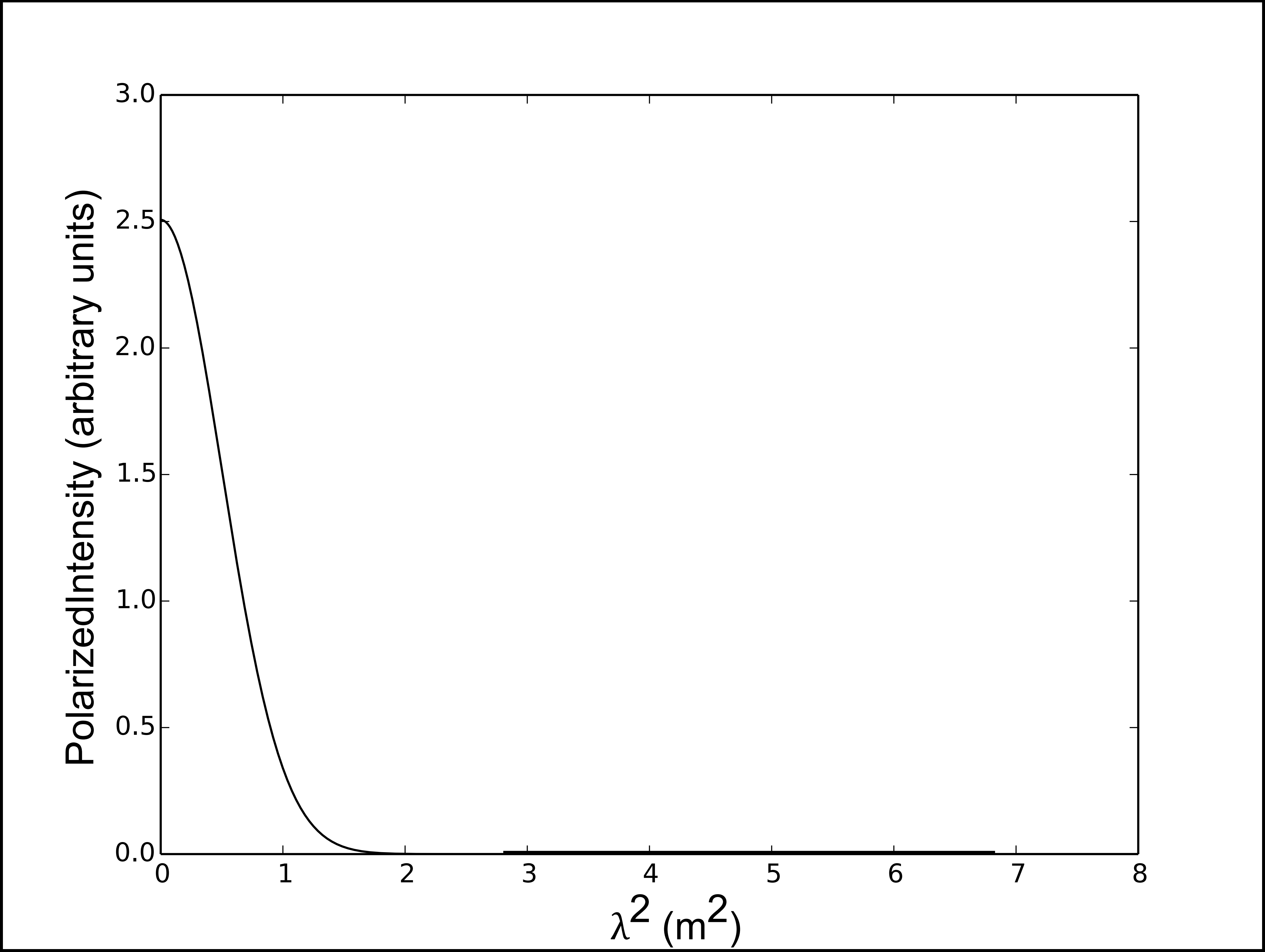
Simulated Spectrum - Gaussian



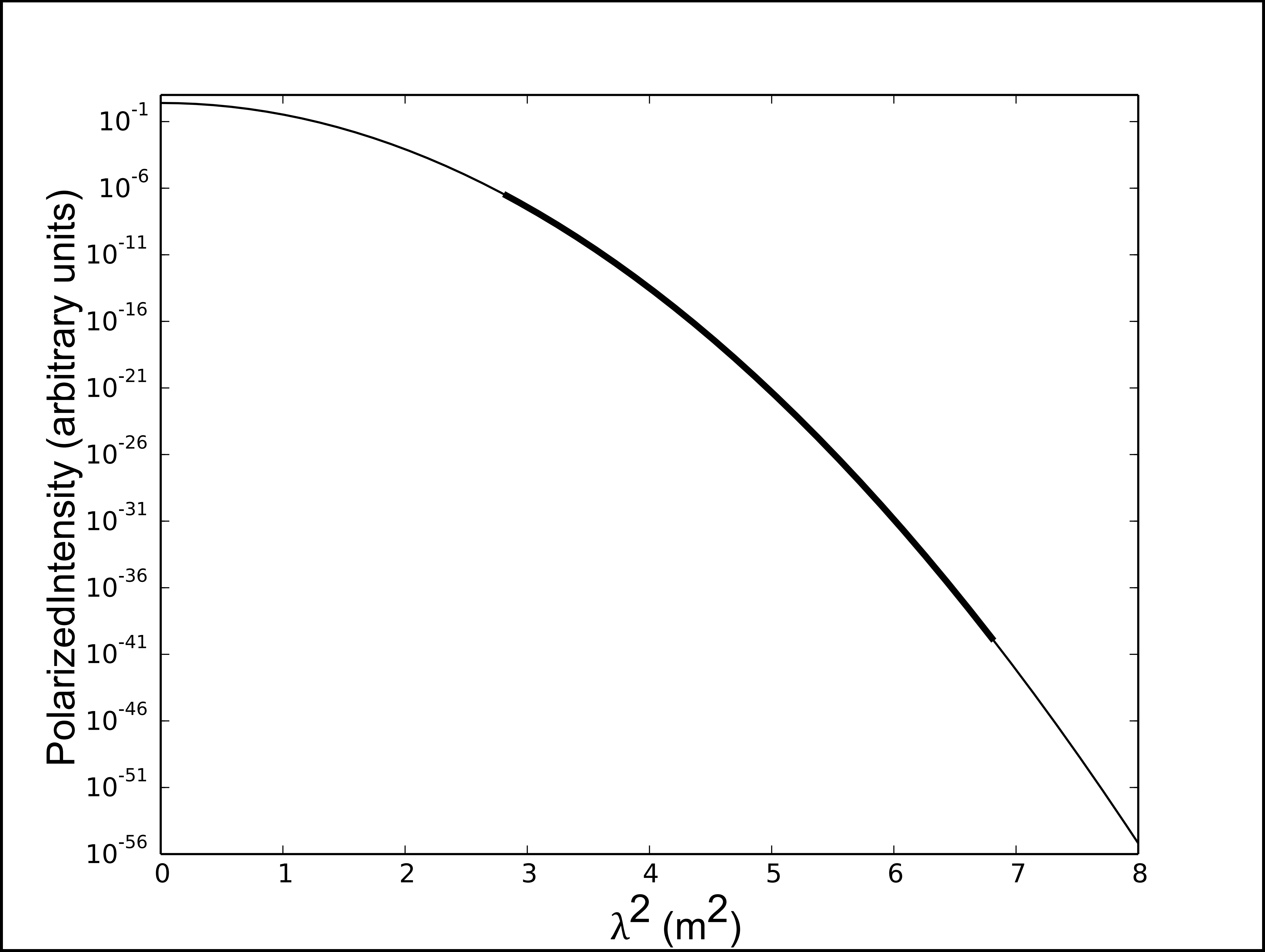
Simulated Spectrum - Gaussian



Simulated Spectrum - Gaussian



Simulated Spectrum - Gaussian



LOFAR 3.0

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Image credit: “Shield World Construction” by Adam Burn

LOFAR 3.0

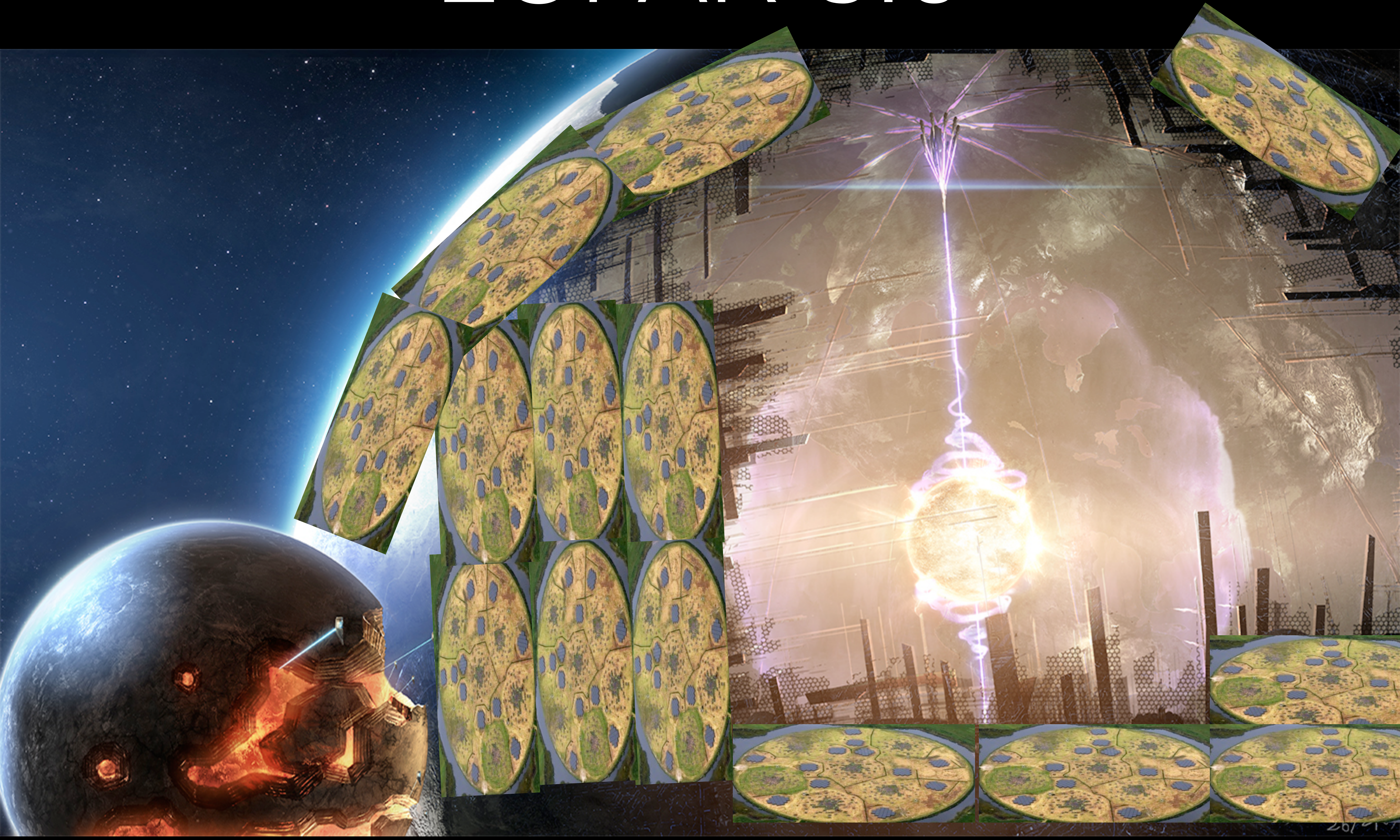
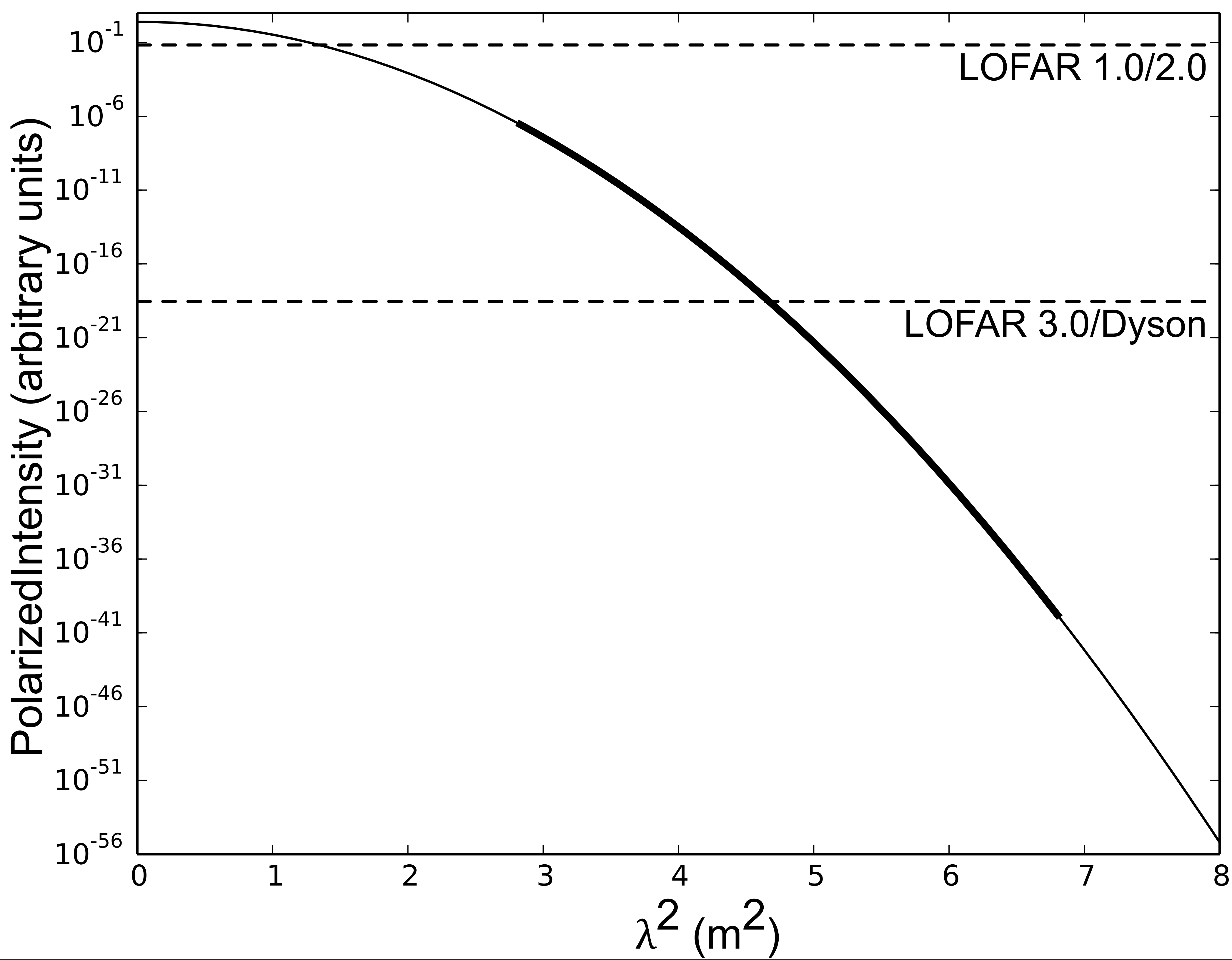


Image credit: “Shield World Construction” by Adam Burn

Image credit: astron.nl

Detecting a Gaussian



LOFAR 4.0?

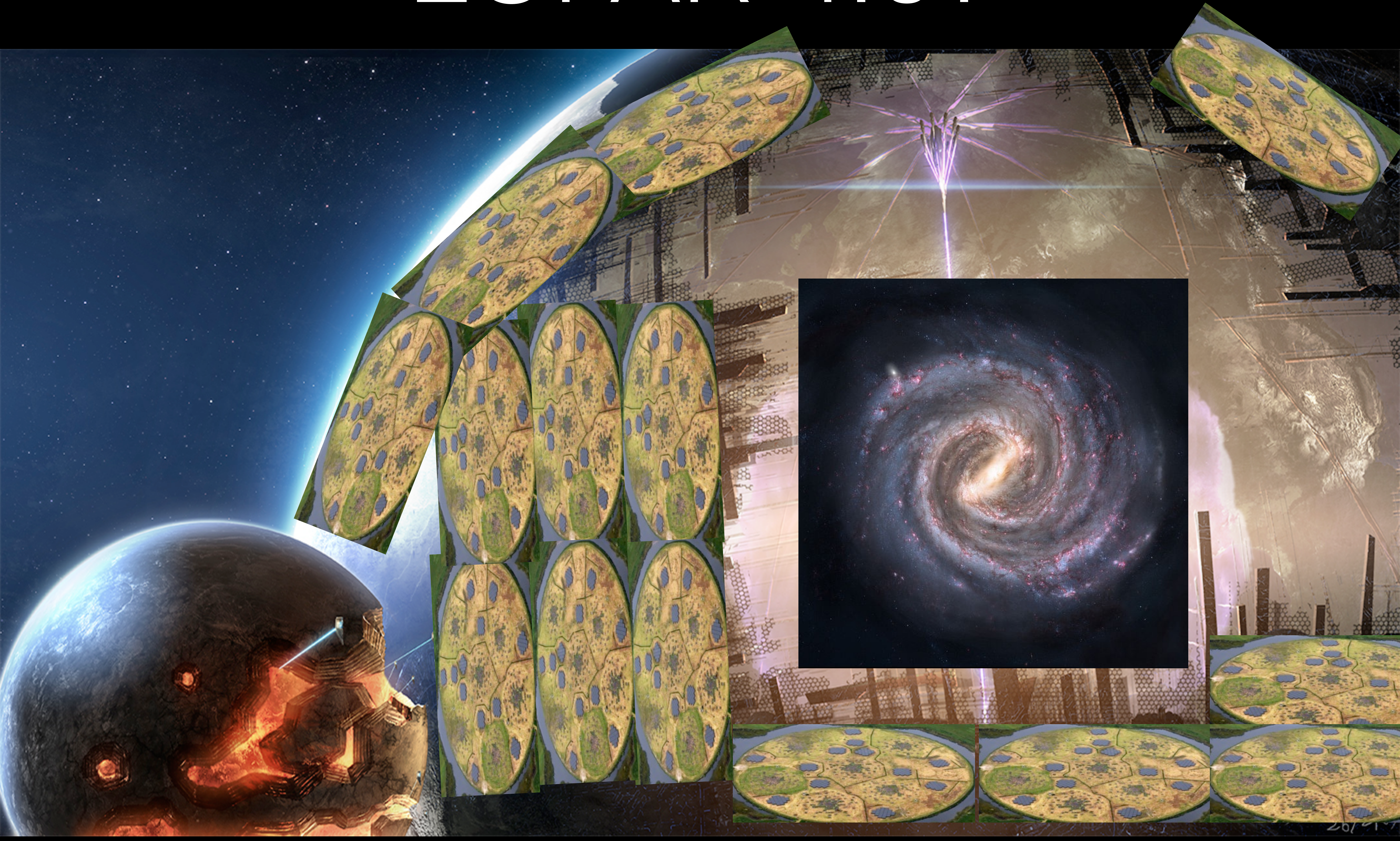
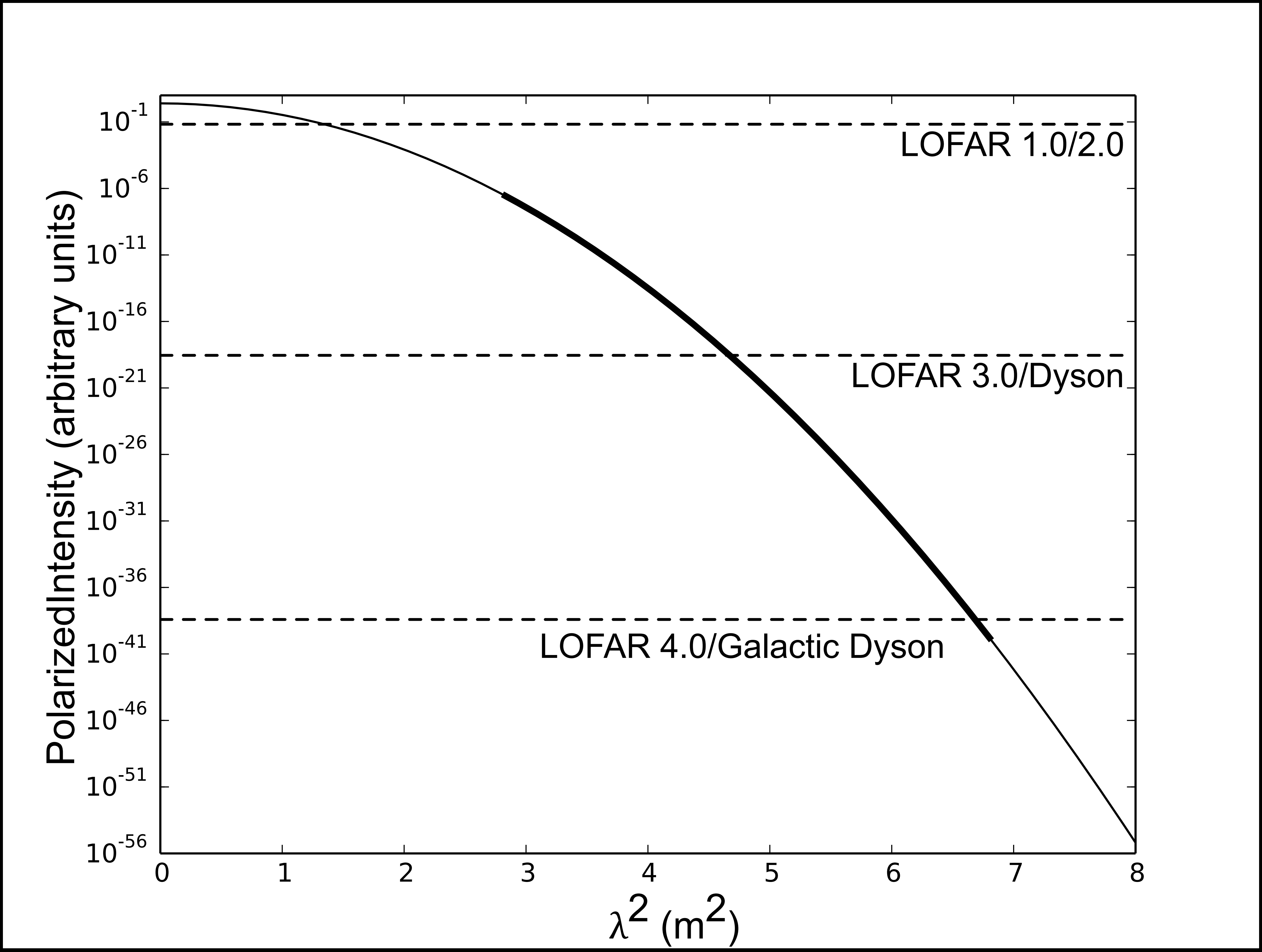


Image credit: “Shield World Construction” by Adam Burn   Image credit: Nick Risinger/Wikimedia   Image credit: astron.nl

Detecting a Gaussian



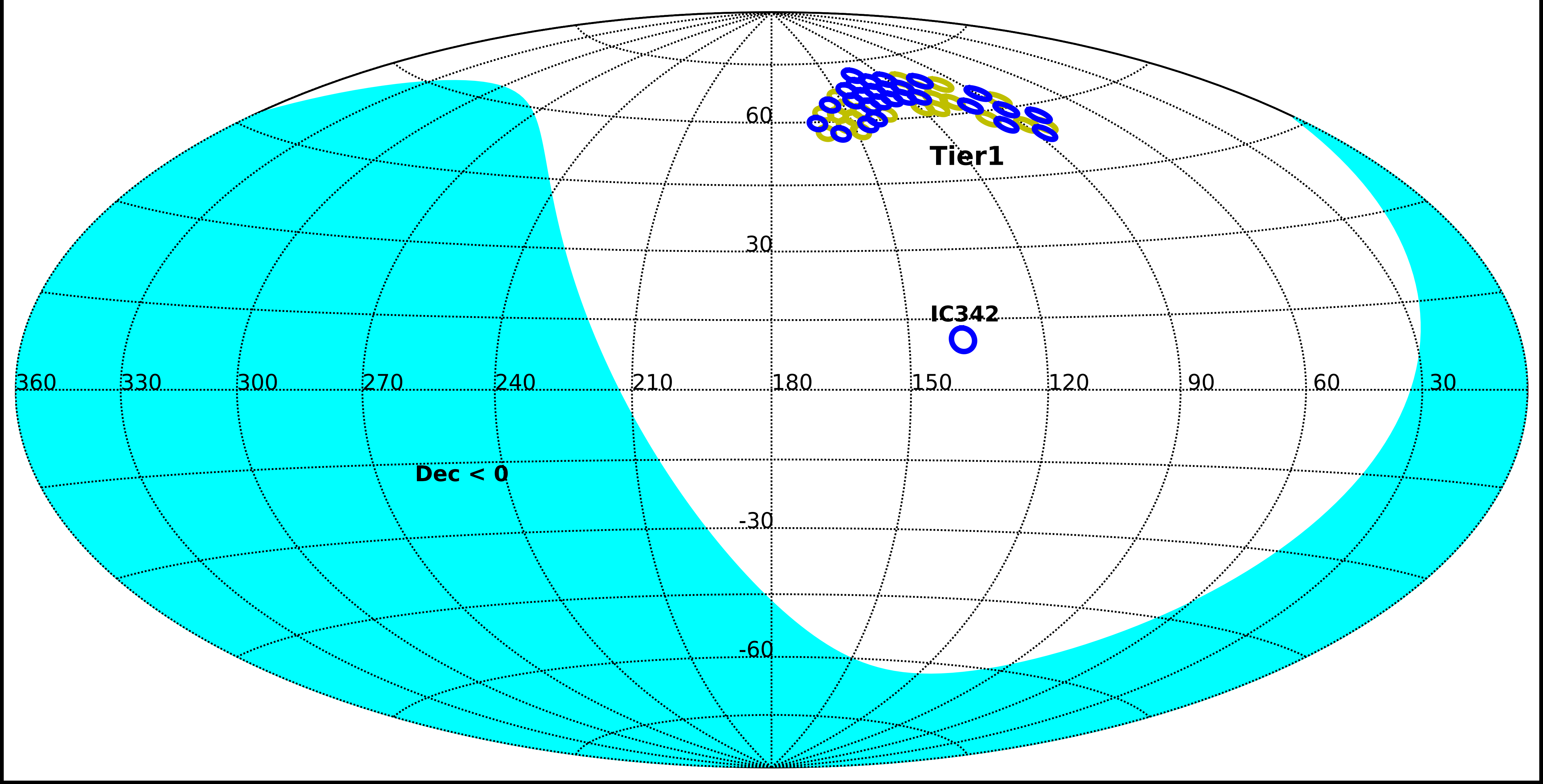
Depolarization

- Delta function: λ^0
- Tophat: λ^{-2}
- Triangle/Quadratic/etc: λ^{-4}
- Gaussian: $e^{-\sigma_\phi^2 \lambda^4}$

Requires volume with no Faraday rotation:

$$\phi \propto \int_0^d n_e \vec{B} \cdot \vec{dl}$$

Tier 1 Faraday Tomography



Faraday cubes made

Data available

Summary

- We're finding a wealth of diffuse polarized structure with LOFAR
- Faraday tomography has the same limitations as interferometry: missing large scales
- LOFAR may be most sensitive to emission from neutral clouds
- Big thanks to Tim Shimwell and Surveys KSP for sharing their Tier 1 data