Bluebild: A Next Generation Radio Interferometric Imager applied to Solar Observations

Shreyam Parth Krishna[1], Michele Bianco[1], Emma Tolley[1], Sepand Kashani[1], Matthieu Simeoni[1], Rohit Sharma[2]

1: École polytechnique fédérale de Lausanne (EPFL) 2: Fachhochschule Nordwestschweiz (FHNW)

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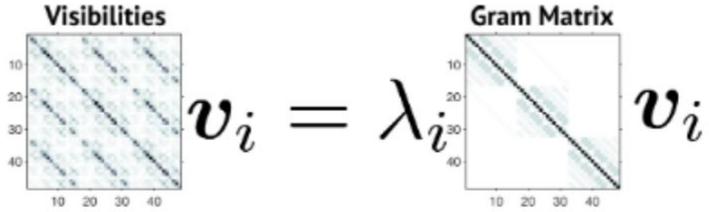
Bluebild Algorithm

- Flexible continuous spherical imager for interferometric applications
- Solves for I(r) in $\int_{\mathbb{S}^2} I(r)e^{-j<r,p_i-p_j>}dr = V_{ij}$ by framing a generalised eigenvalue problem and decomposing visibilities into different eigenfunctions, via fPCA ⟹ $\mathbf{E}[yy^*]v = \lambda G_B v$
- Eigenfunctions give eigenimages - independent and sorted by energy. Can be truncated (automatic denoising) or filtered.
- Low computational complexity and affinity for parallel execution



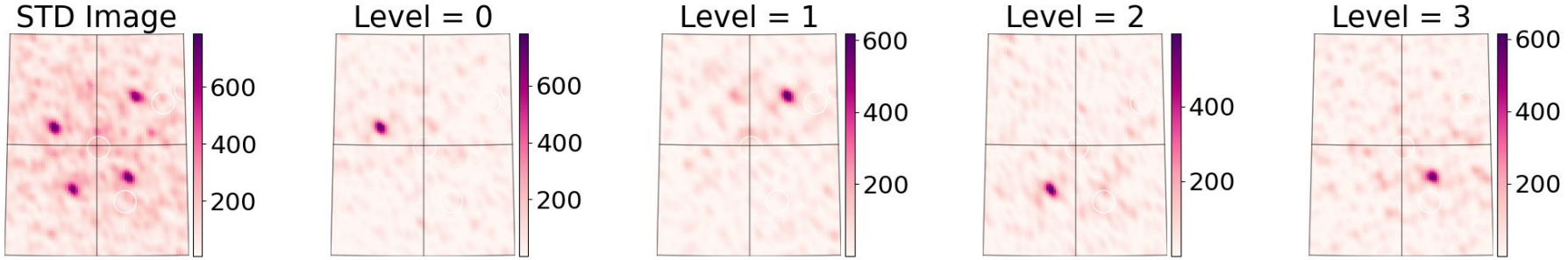
Normalised Eigenfunctions

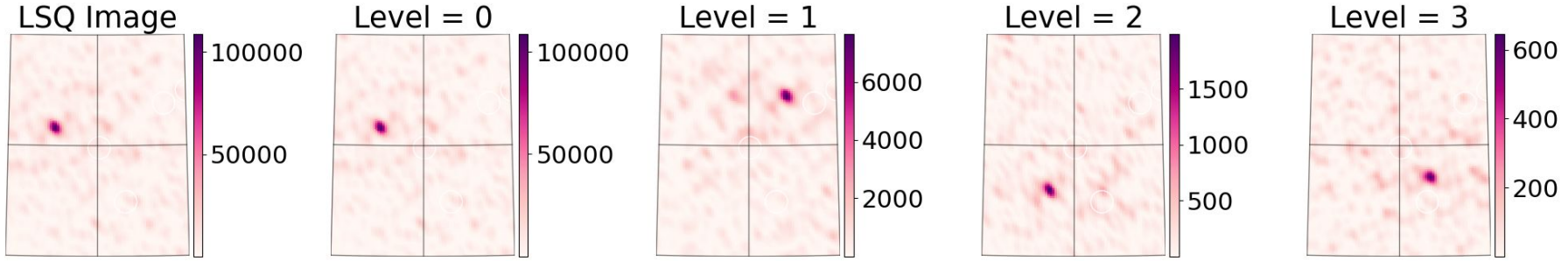
$$\epsilon_m = \frac{Bv_m}{||Bv_m||} = \frac{Bv_m}{\sqrt{v_m^H G_B v_m}} \qquad B = (W^H A)^* = A^* W$$

$$\hat{I}(r) = \sum_m \lambda_m |\epsilon_m(r)|^2 = \sum \lambda_m \frac{|Bv_m|^2}{v_m^H G_B v_m}$$

Bluebild Example

$$\hat{I}_{std} = \sum_m |\epsilon_m|^2$$

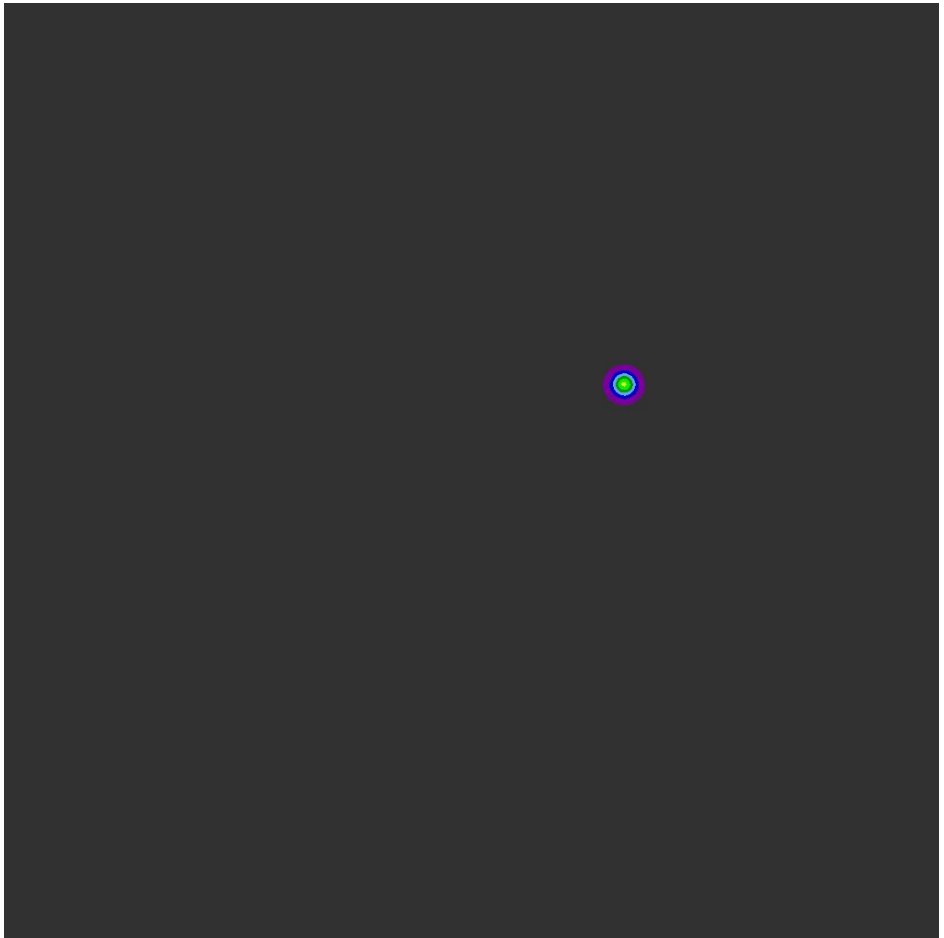




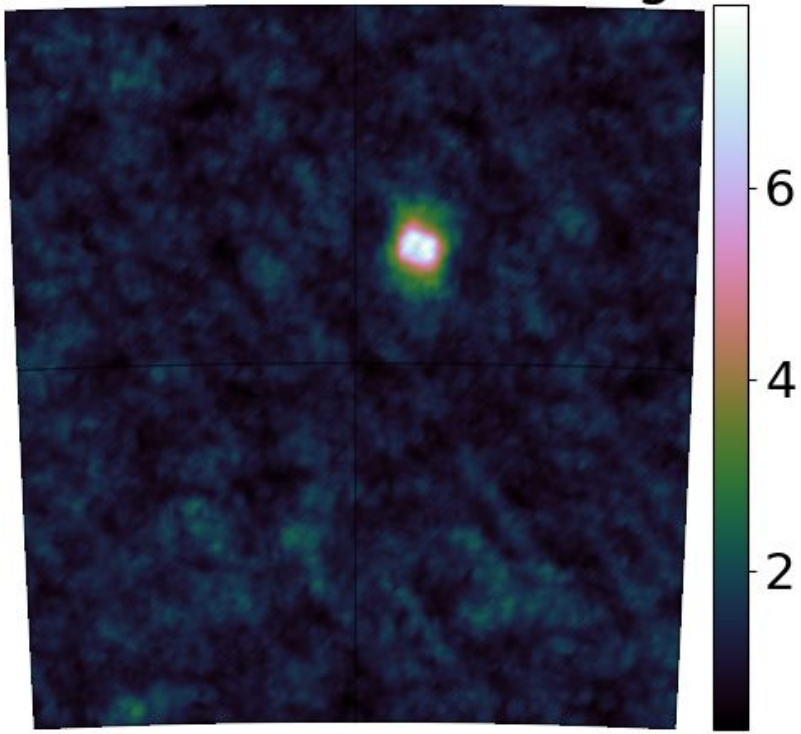
$$\hat{I}_{lsq} = \sum_m \lambda_m |\epsilon_m|^2$$

Solar Observations Using Bluebild

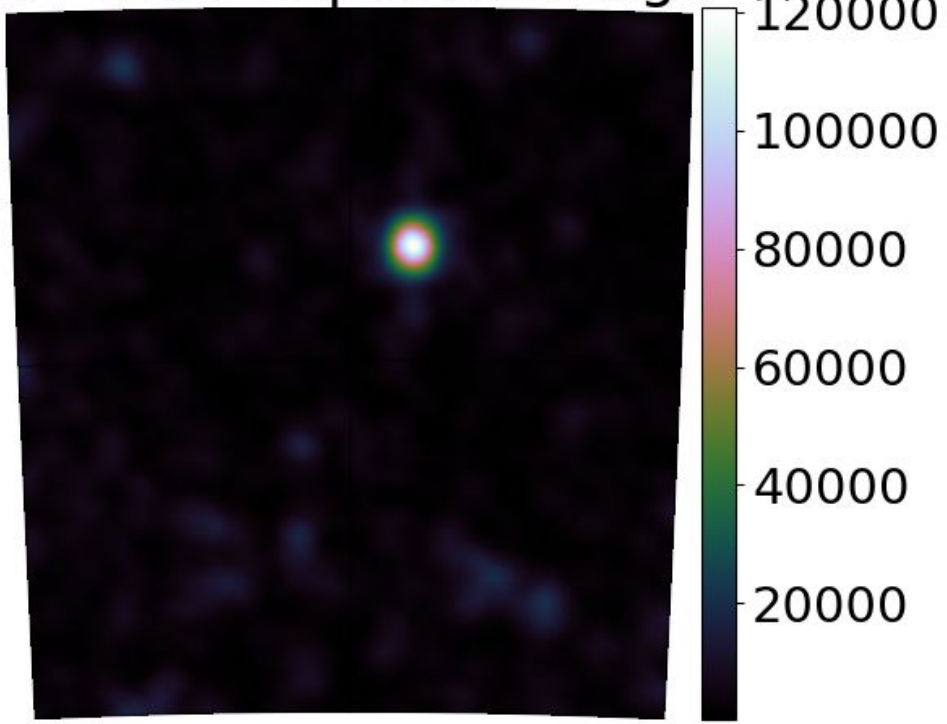
- Image of free-free emission from the solar corona, affected by anisotropic scattering and refraction due to coronal medium
- ~14.3° FOV
- 10s integration time, 0.5 second time steps
- MWA Phase I observation (128 phased arrays)
- 3’ in resolution, so diffuse features > PSF
- ν ~ 239-241 MHz, 64 Channels, Bandwidth 40 kHz
- Power scaled

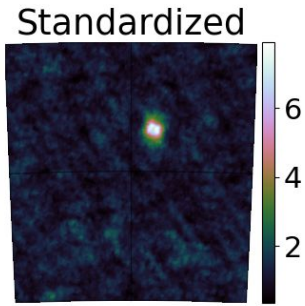


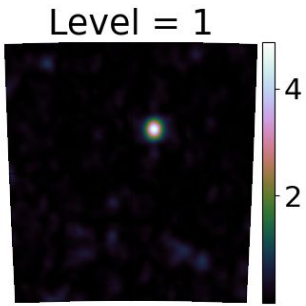
BB Standardized Image

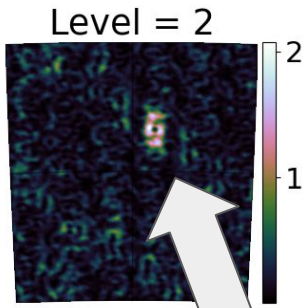


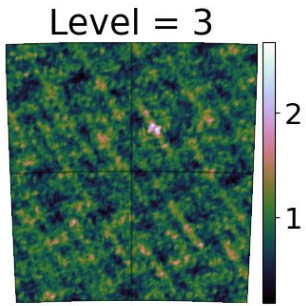
BB Least-Squares Image



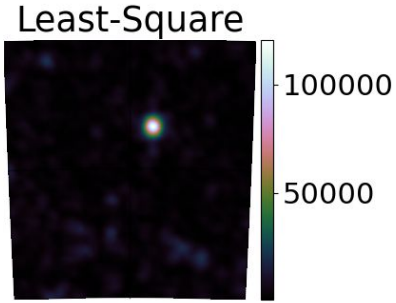


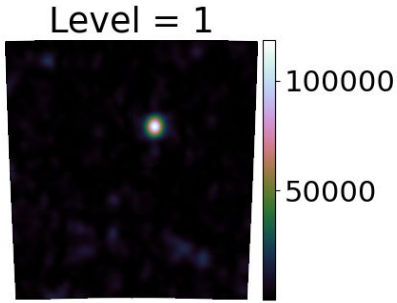


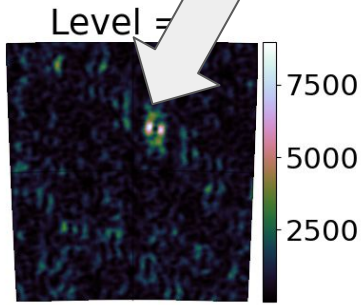


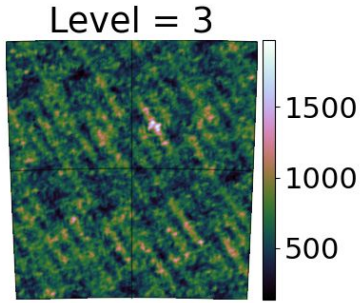


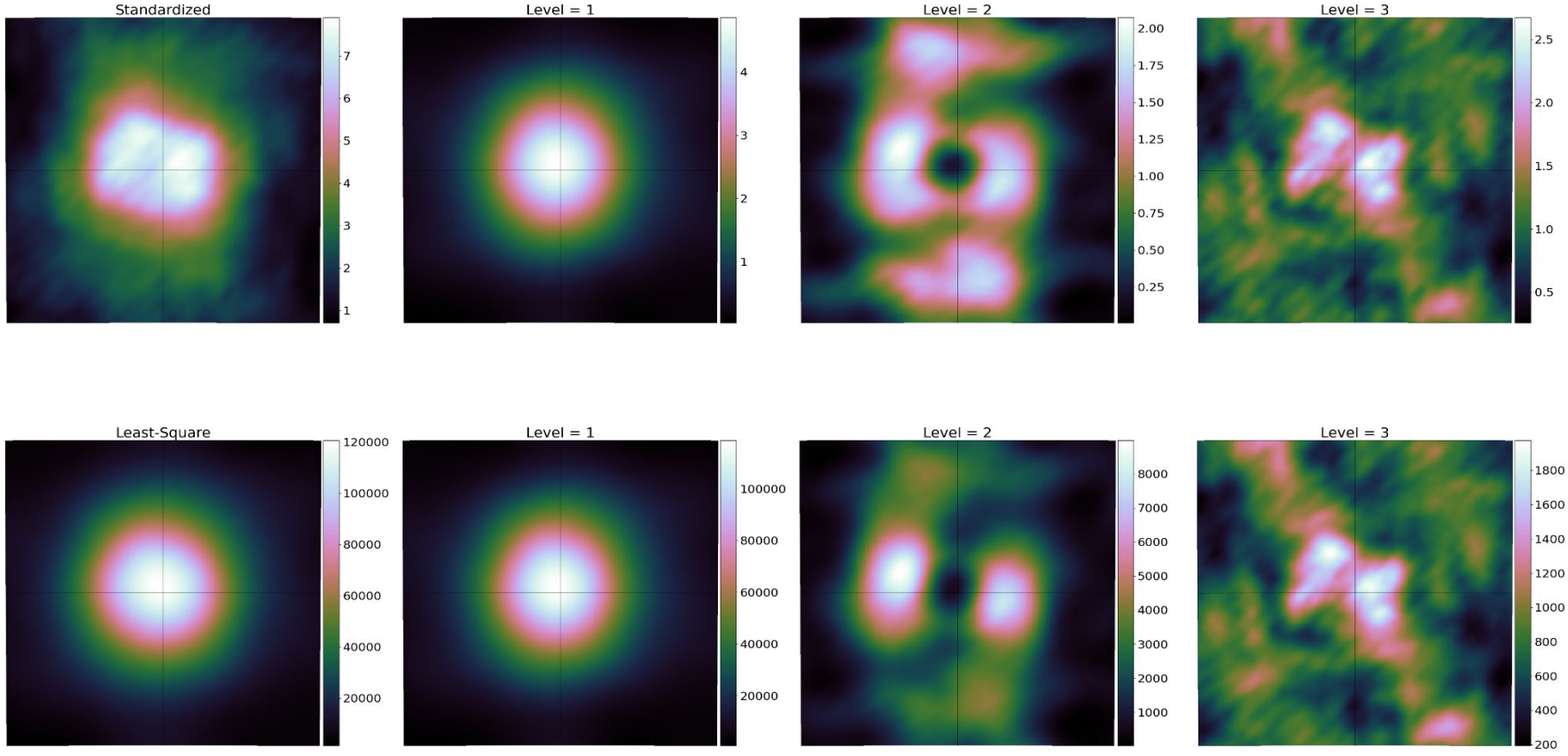
Unexpected extended emission










Standardized
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Least-Square
Level = 1
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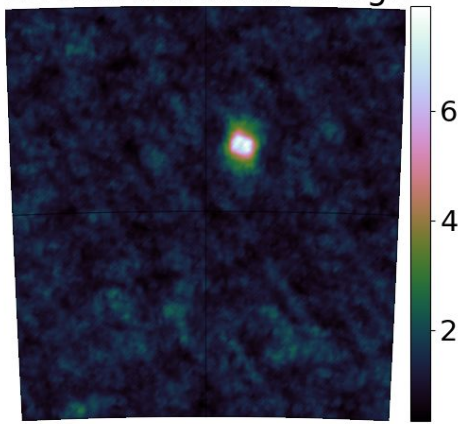
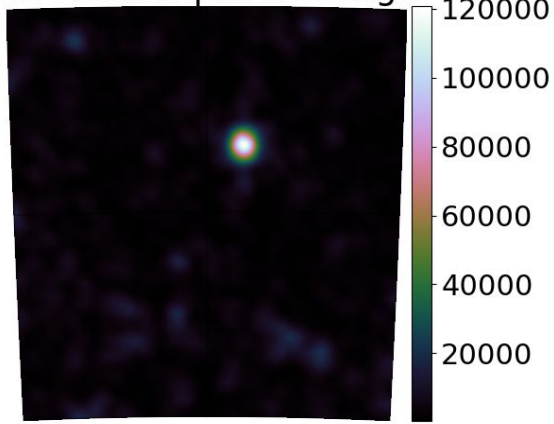
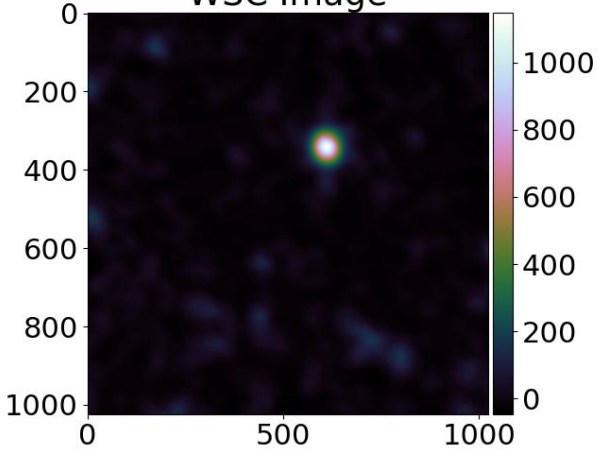
BB Standardized Image



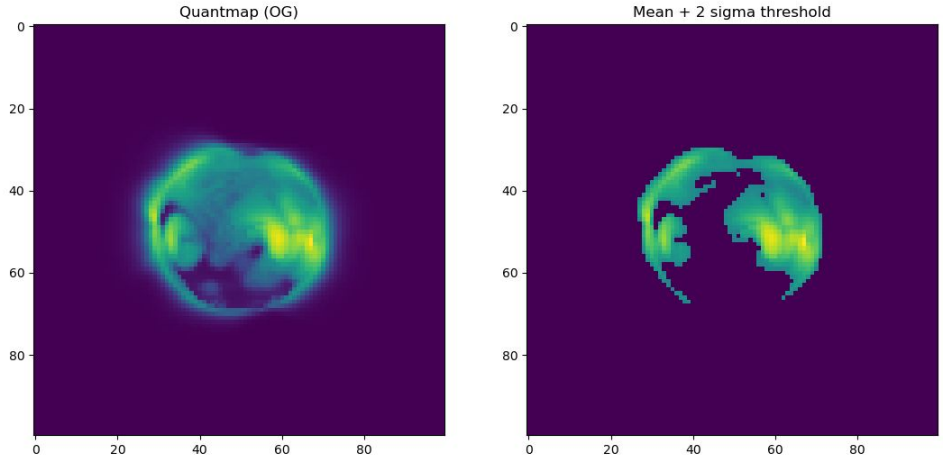
BB Least-Squares Image



WSC Image



Solar MWA Simulation

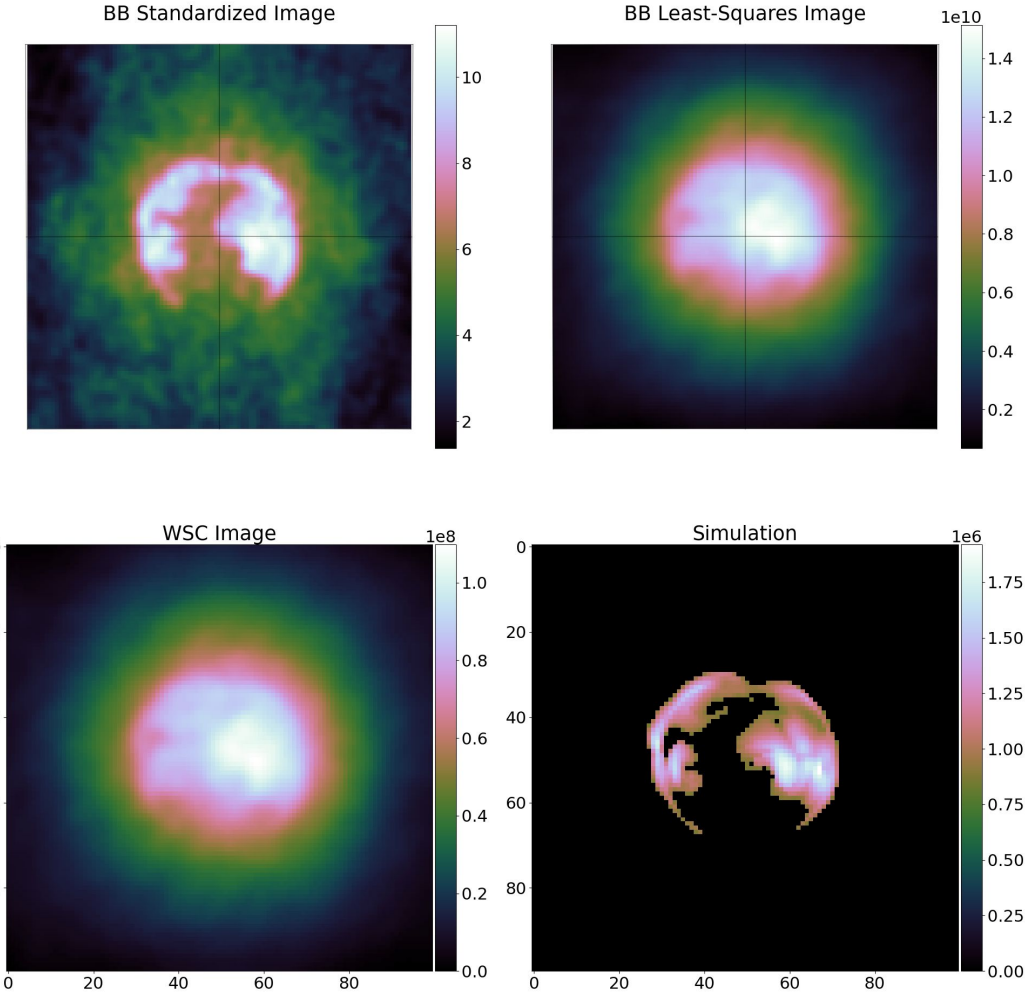


No objective truth with celestial observations

Mock observations of Solar simulation using OSKAR[2]:

- Simulated 1.4° FOV free-free maps using FORWARD[1] software.
- Forward uses a self-consistent Magnetohydrodynamic Algorithm outside a Sphere (MAS) coronal model.
- N_e, T_e and B evolved from input HMI magnetogram and normalised against photospheric values. Also calculated brightness temperature, T_B, in various Stokes parameters
- Propagation effects (scattering, refraction) not included.
- Stokes I parameter imaged using MWA Phase I configuration on OSKAR.
- Simulation thresholded **(μ + 2*σ)**, then imaged.

1: [Gibson et al. 2016] 2: [Mort 2010]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6
4
2
BB Least-Squares Image
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1.2
1.0
0.8
0.6
0.4
0.2
WSC Image
1e8
0
20
40
60
80
1.0
0.8
0.6
0.4
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Simulation
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0.50
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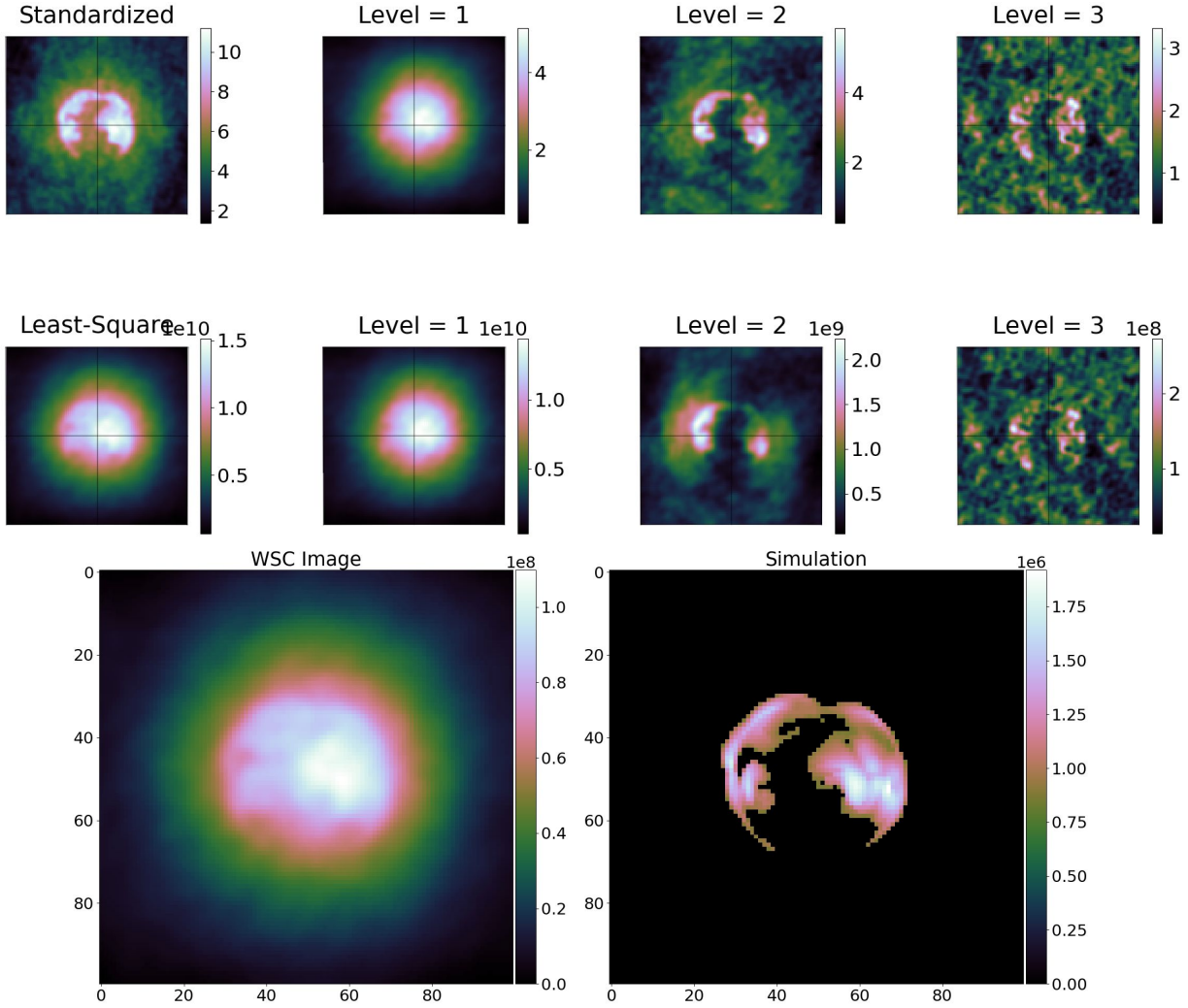
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Simulation
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