A new vocabulary for textures

and its astronomical applications

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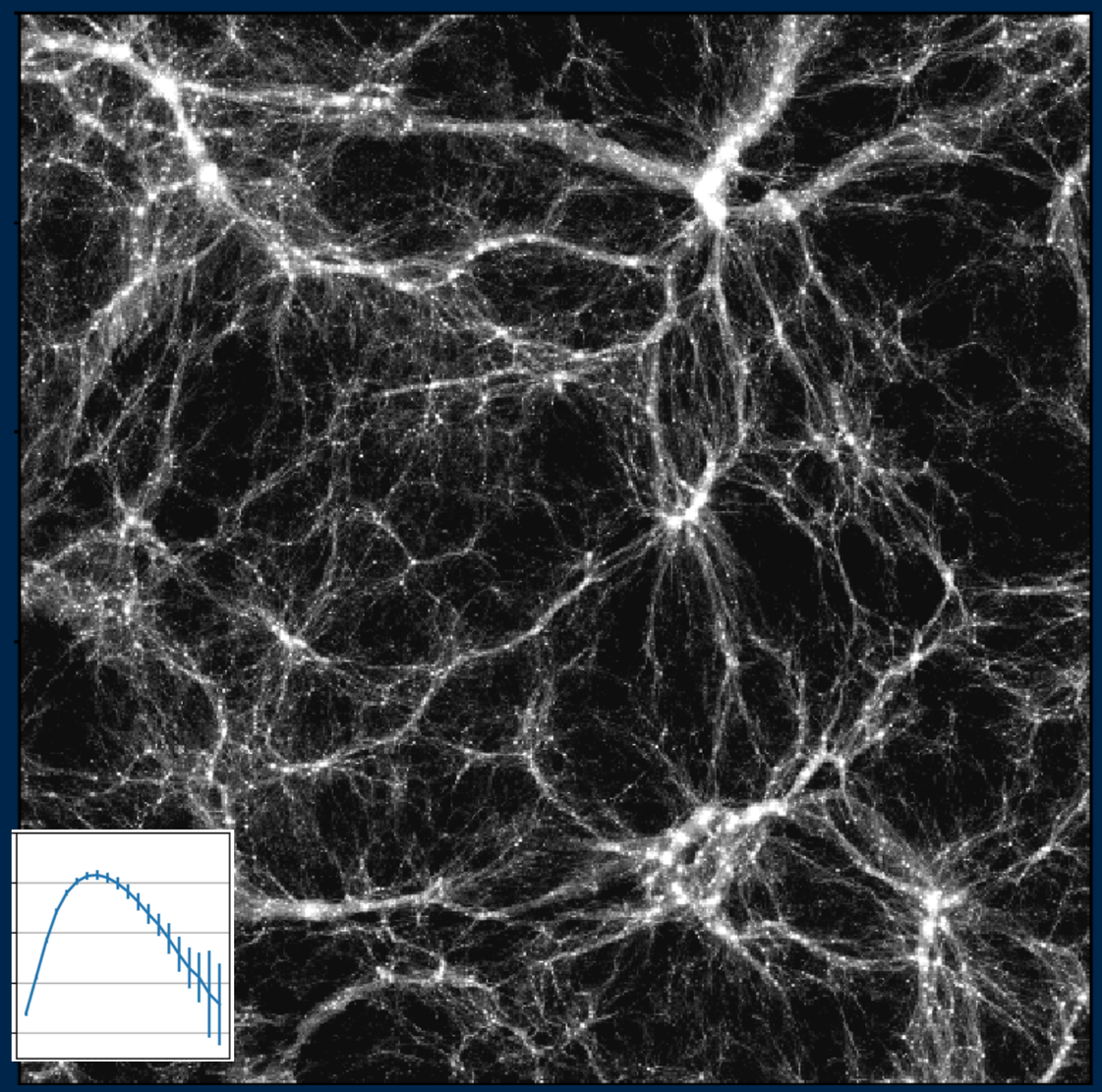
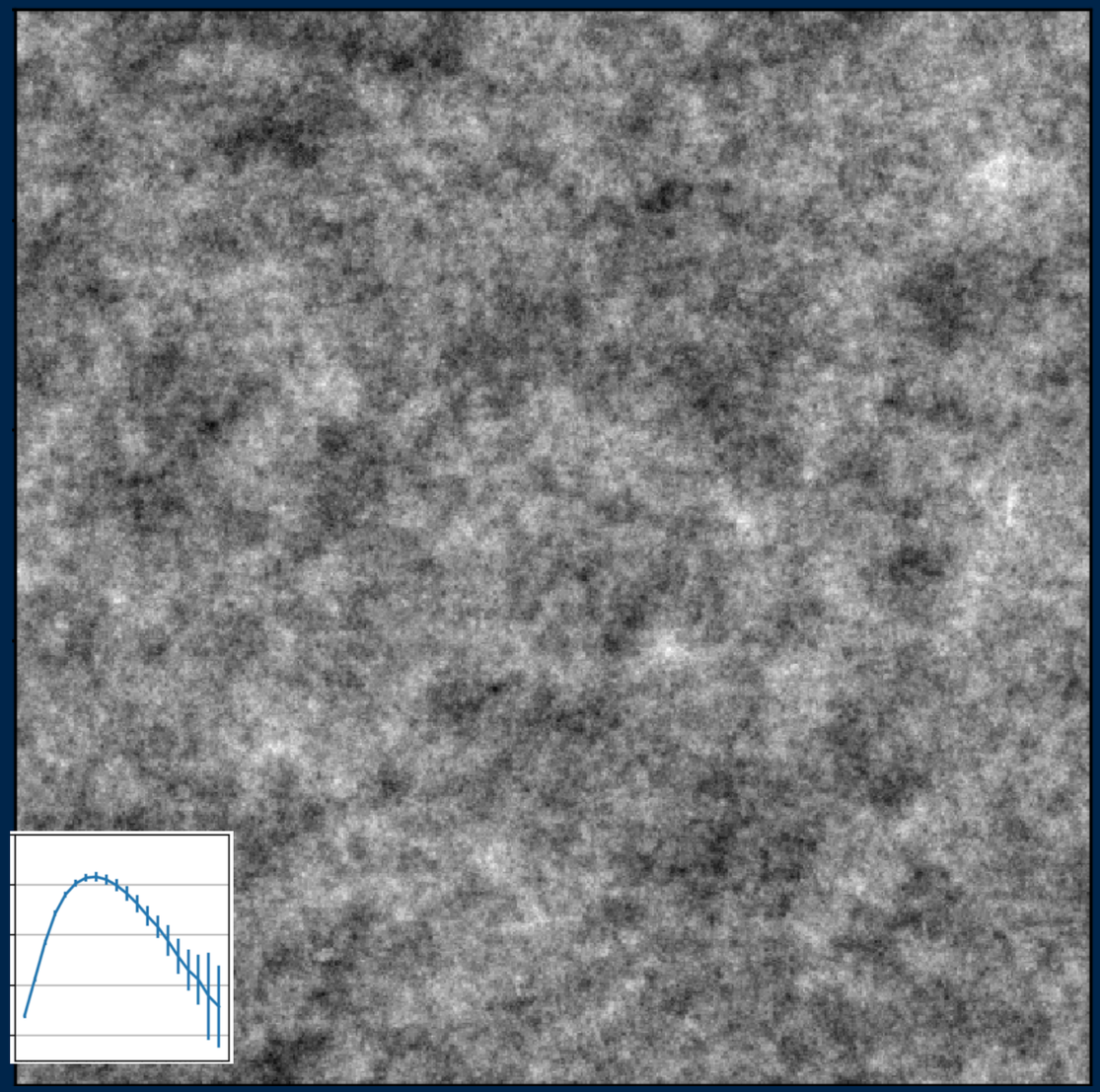
Johns Hopkins University

Where the Earth Meets the Sky
May 28

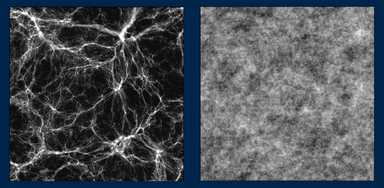
with Brice Ménard, Yuan-Sen Ting, & Joan Bruna





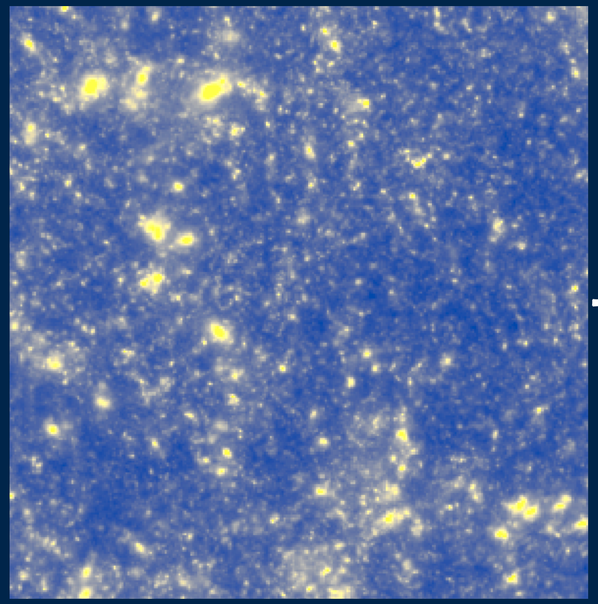
We need to go beyond power spectrum to capture non-Gaussianity.

How do we characterize a field?



power spectrum

and others



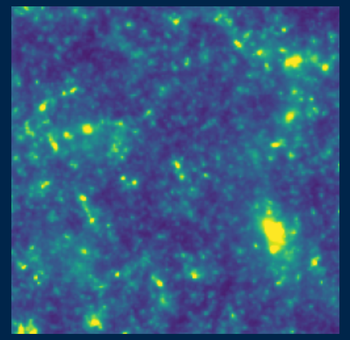
scattering transform

(Mallat 2012)

CNN

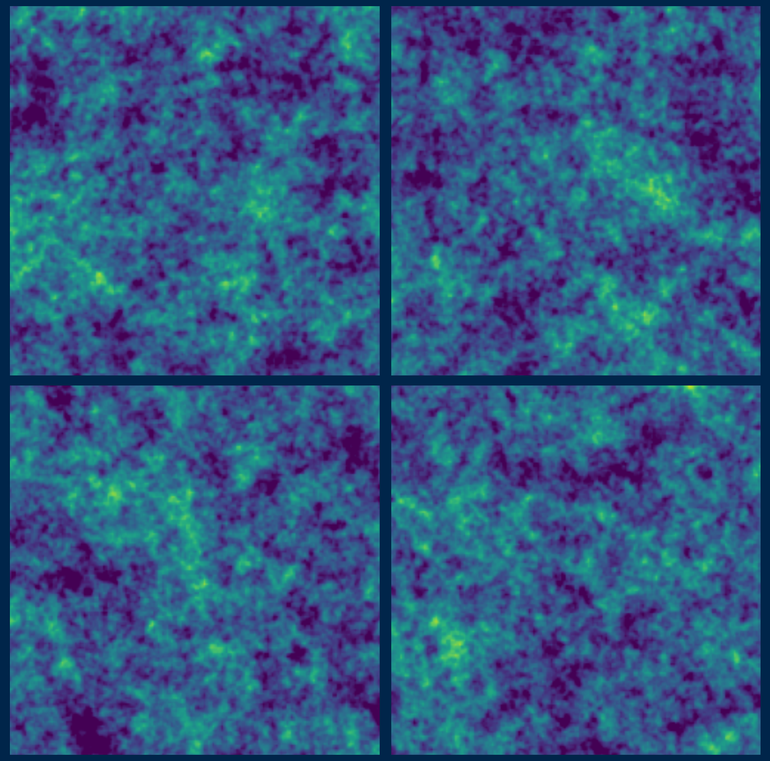
powerful,
but less interpretable or controllable

physical parameters

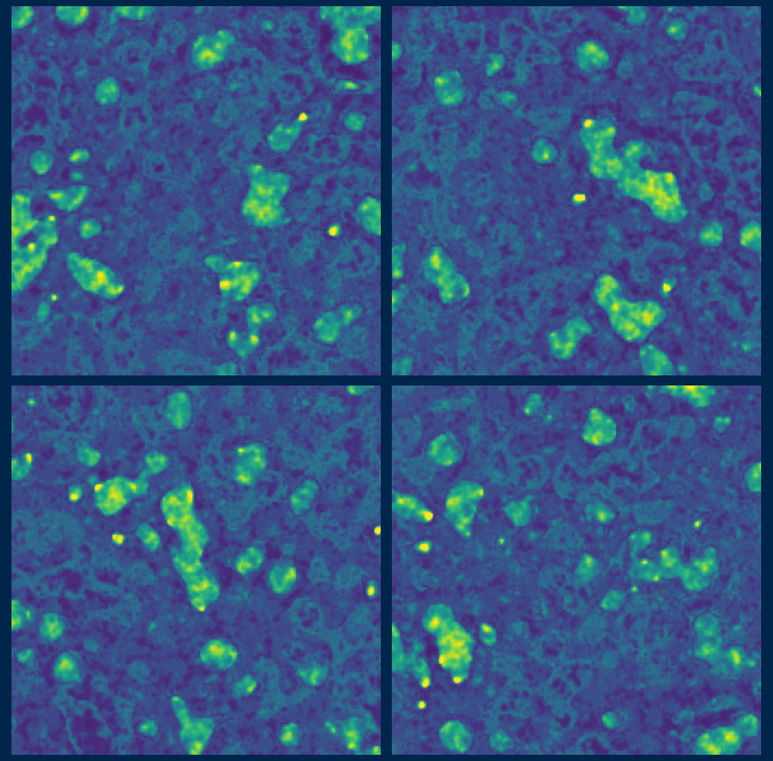


cosmic mass map

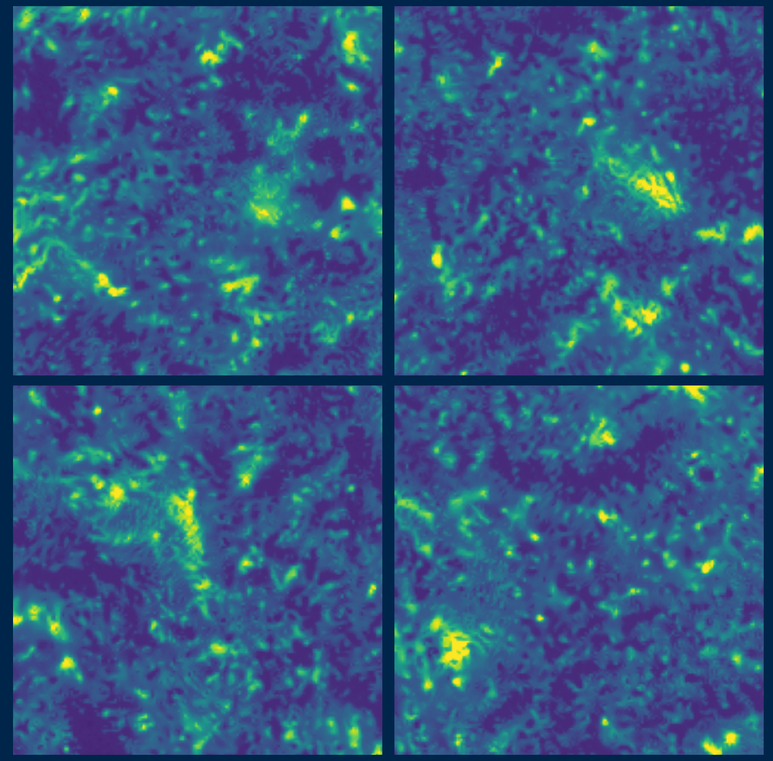
with power spectrum P(l)

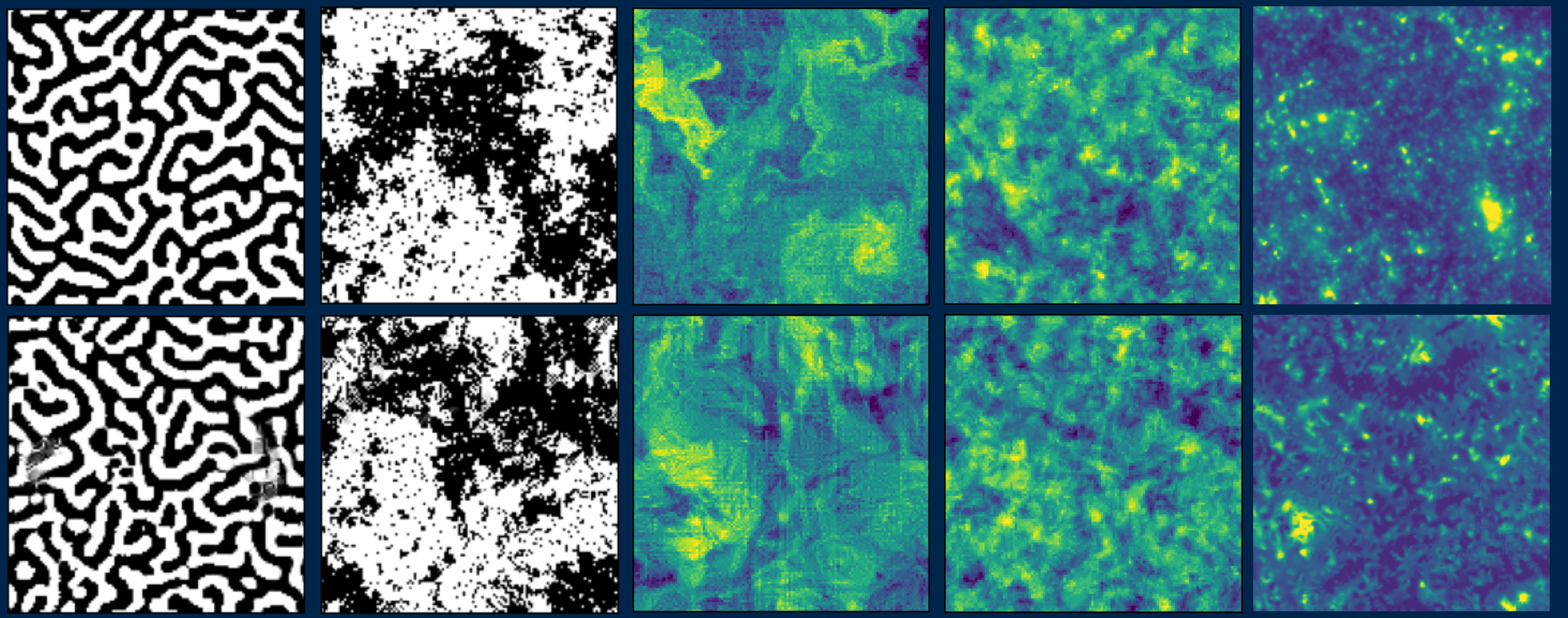


with P(l) and bispectrum

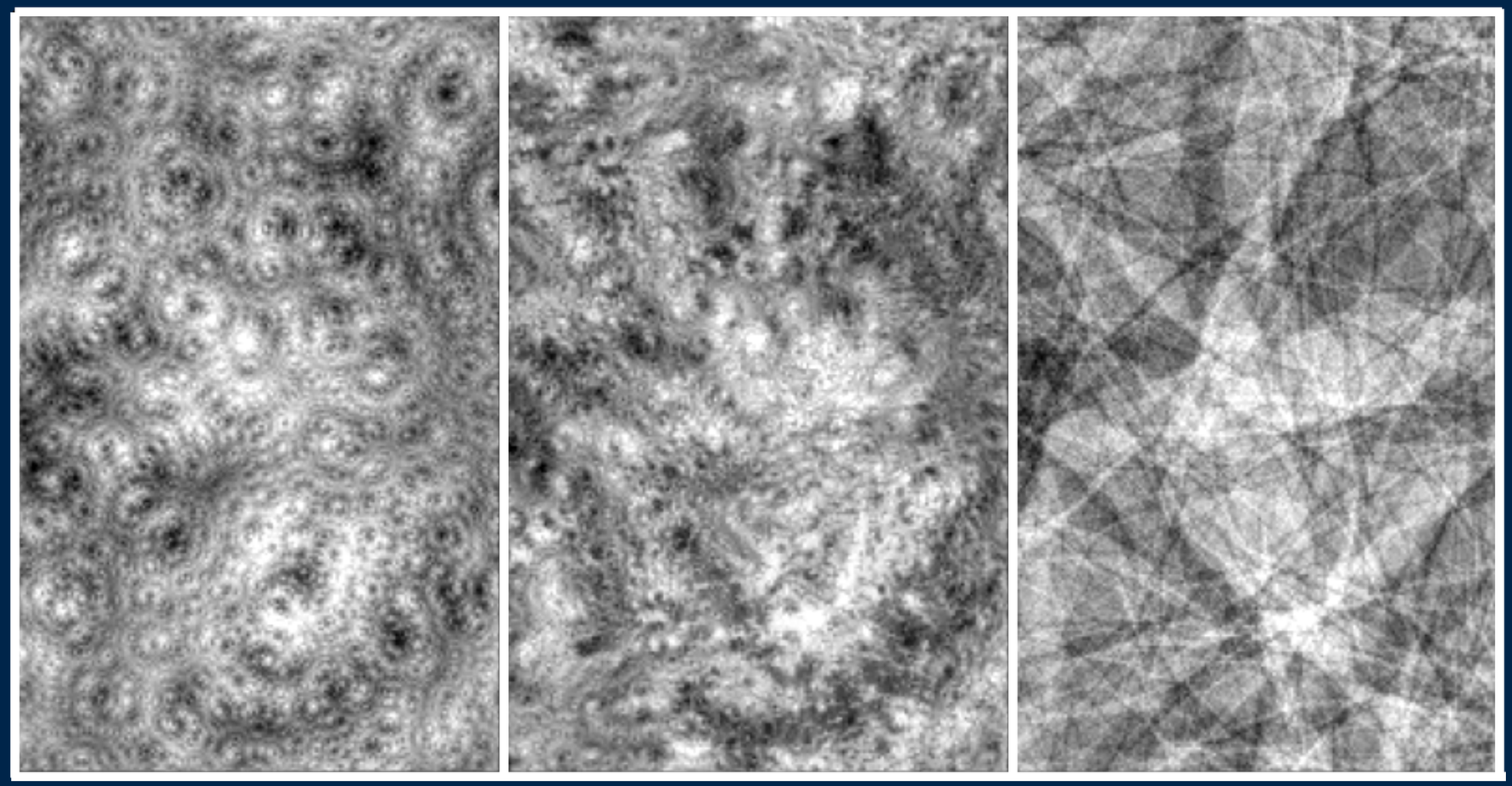


with scattering statistics




Turing pattern
Ising model
sea temperature
solar UV image
cosmic matter

Swirls vs. Origami $S_2^{\parallel} / S_2^{\perp}$



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Fourier oscillations

$$P(\overrightarrow{k}) = \langle \left| I \star e^{k \cdot x} \right|^2 \rangle$$

local kernels (wavelets)

$$S(\overrightarrow{k}) = \langle \left| I \star \psi_k \right| \rangle$$

Fourier oscillations

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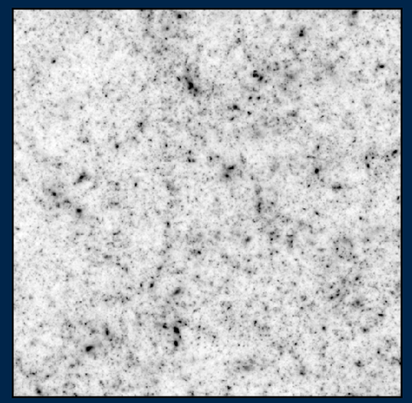
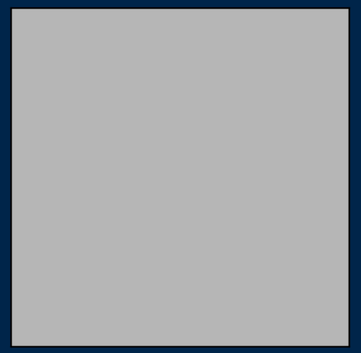
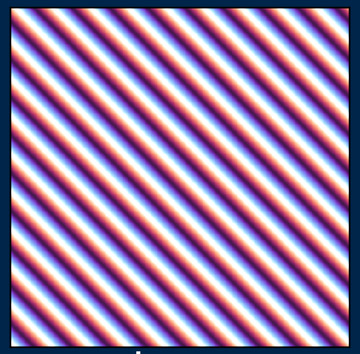


convolution

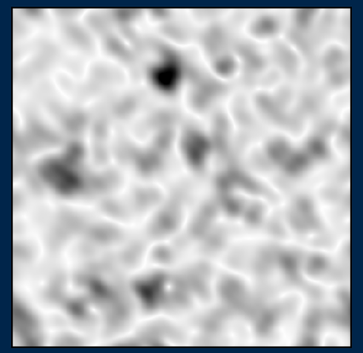
convolution



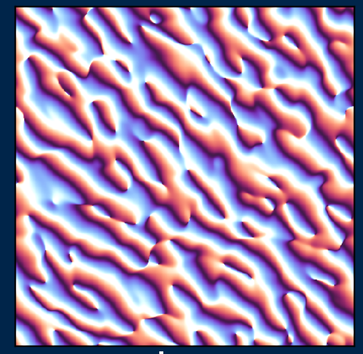
modulus



phase



modulus



phase

Fourier oscillations

local kernels (wavelets)

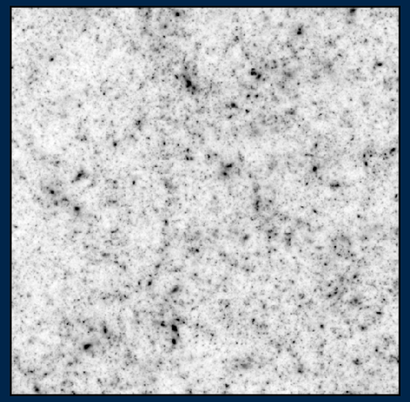
$$P(\vec{k}) = \left\langle \left| I \star e^{k \cdot x} \right|^2 \right\rangle$$

$$S_0 = \langle I \rangle$$

$$S_1(\vec{k}) = \left\langle \left| I \star \psi_k \right| \right\rangle$$

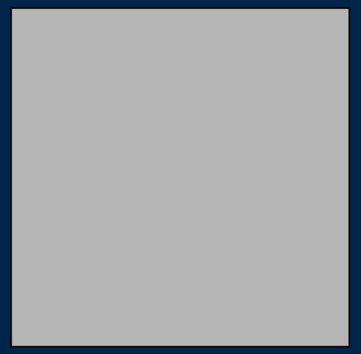
$$S_2(\vec{k_1}, \vec{k_2}) = \left\langle \left| \, | I \star \psi_{k_1} | \star \psi_{k_2} \right| \right\rangle$$

$$\dots$$

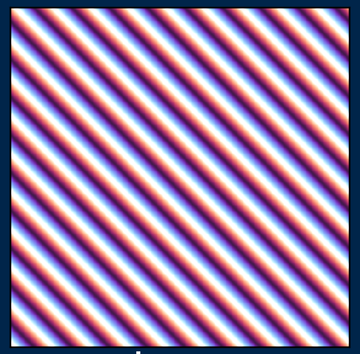


convolution

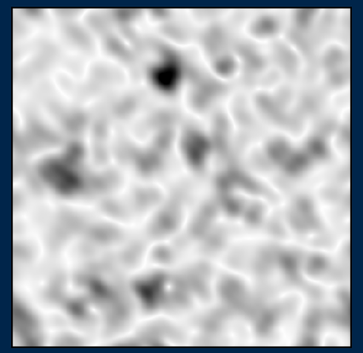
convolution



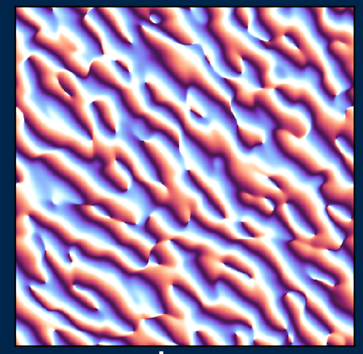
modulus



phase

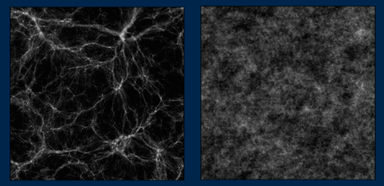


modulus



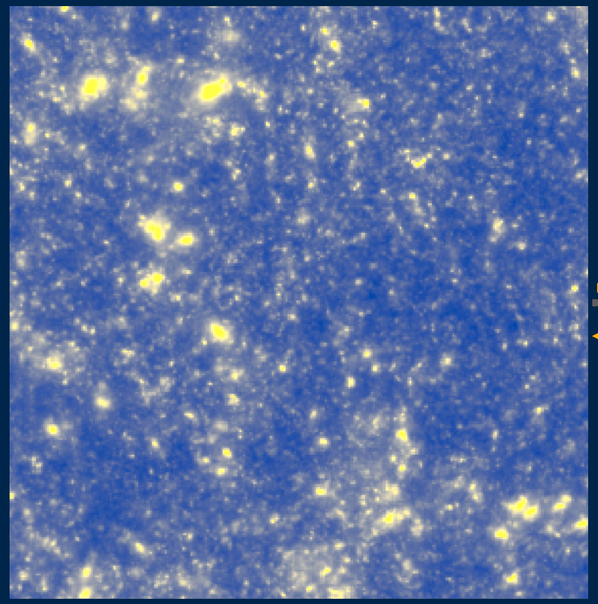
phase

How do we characterize a field?

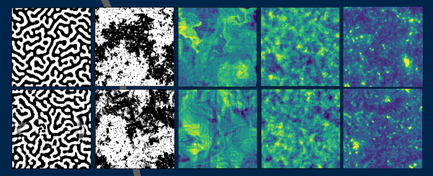


power spectrum

and others



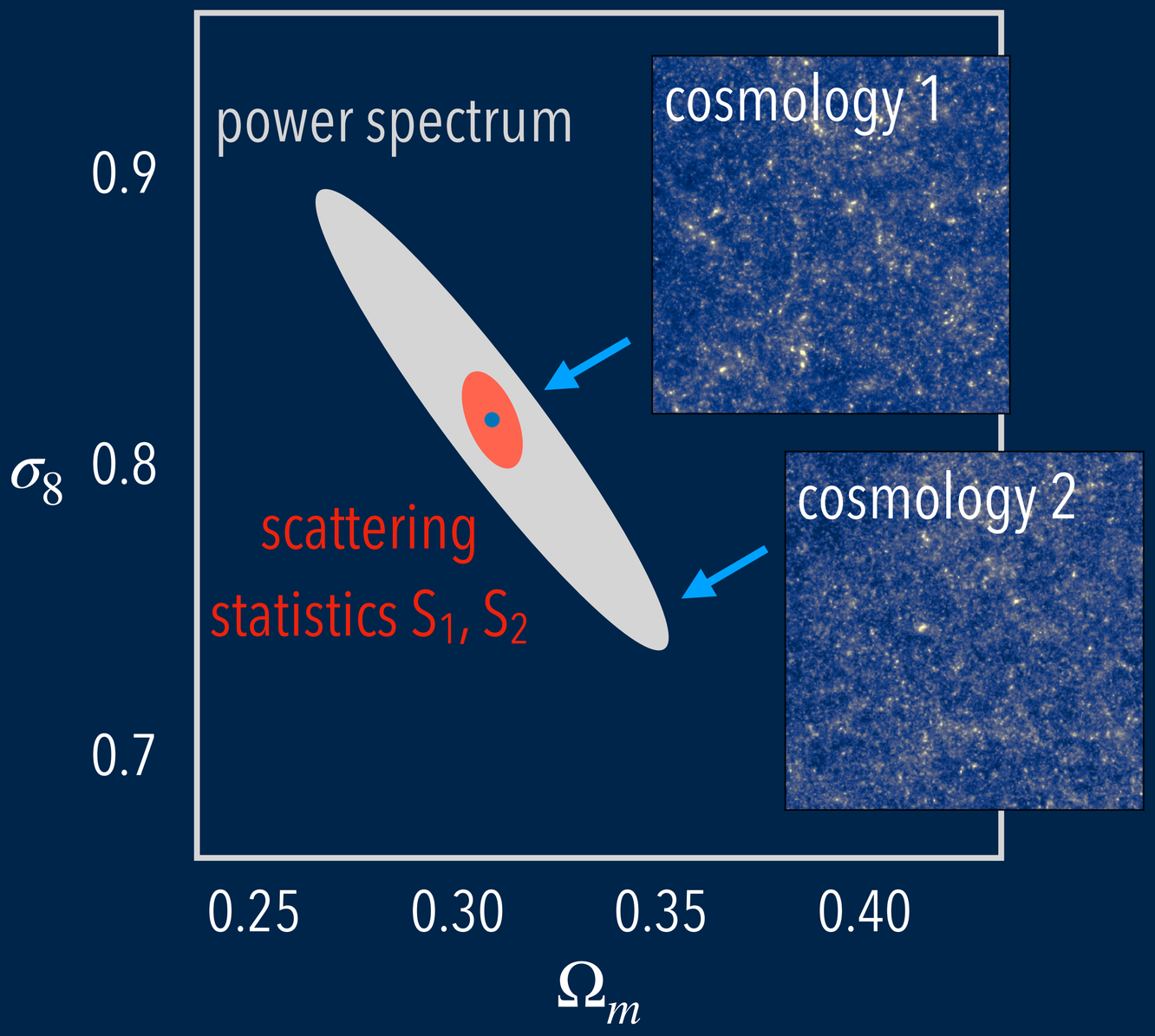
scattering statistics

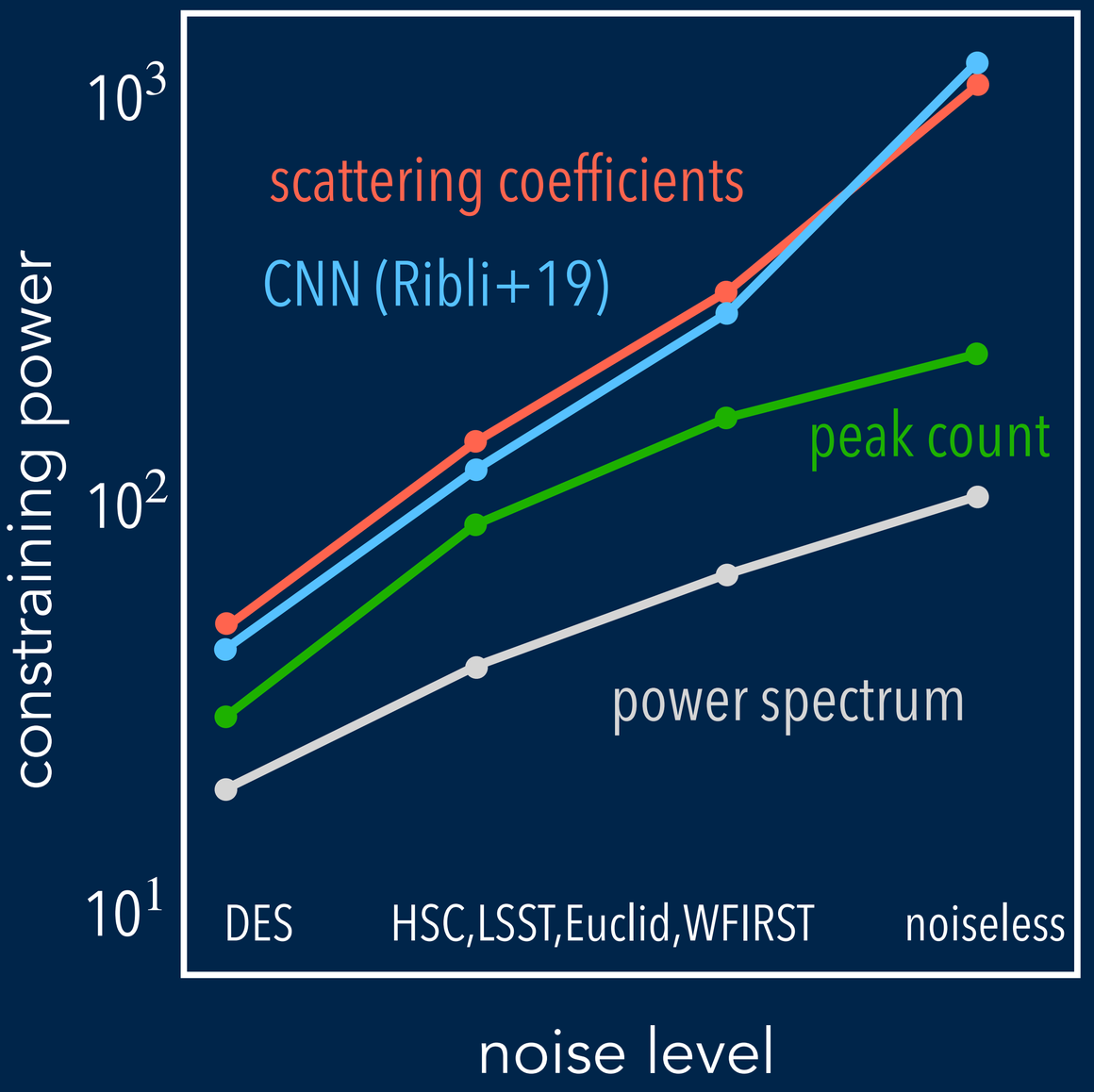


physical parameters

CNN

scale range: 1 arcmin to 3.5 deg





arXiv: 2006.08561 arXiv: 2103.09247

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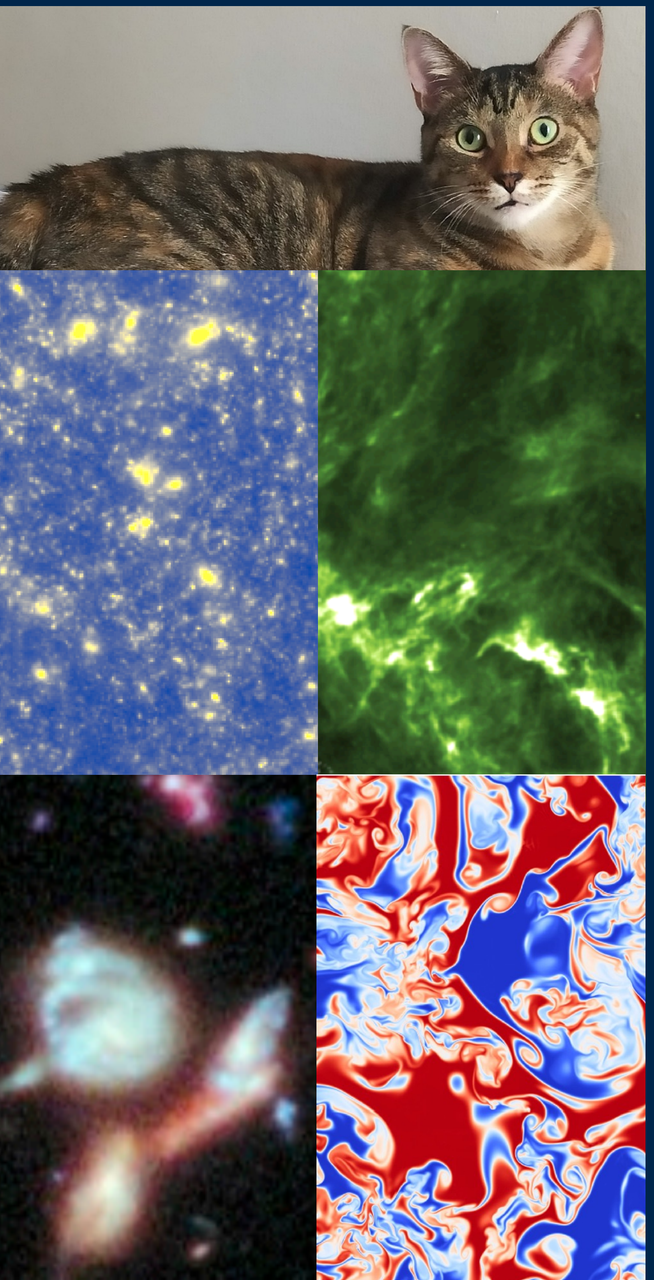
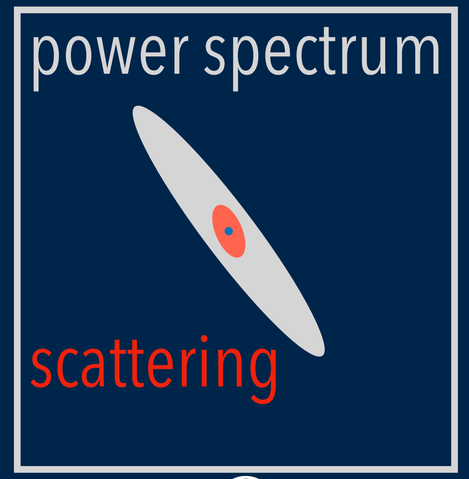


power spectrum

scattering transform

efficient, interpretable, robust

CNN



physical parameters

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interpretations (coming soon)