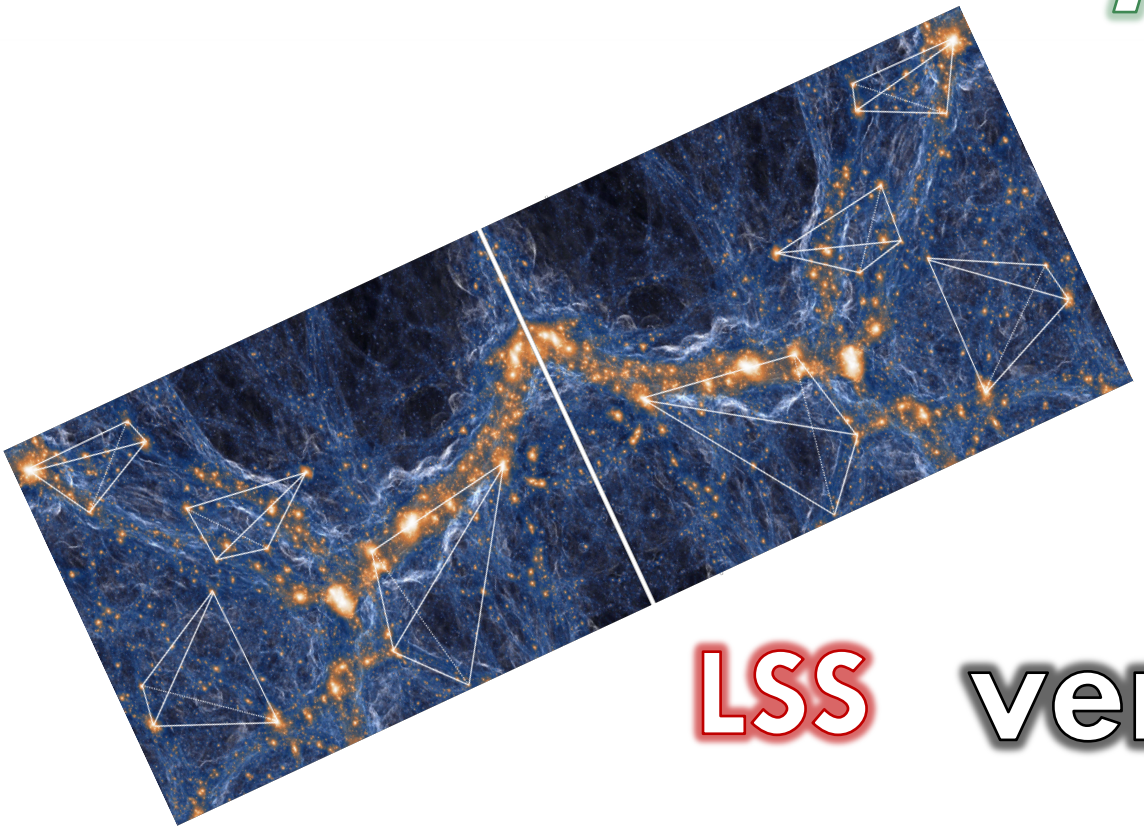
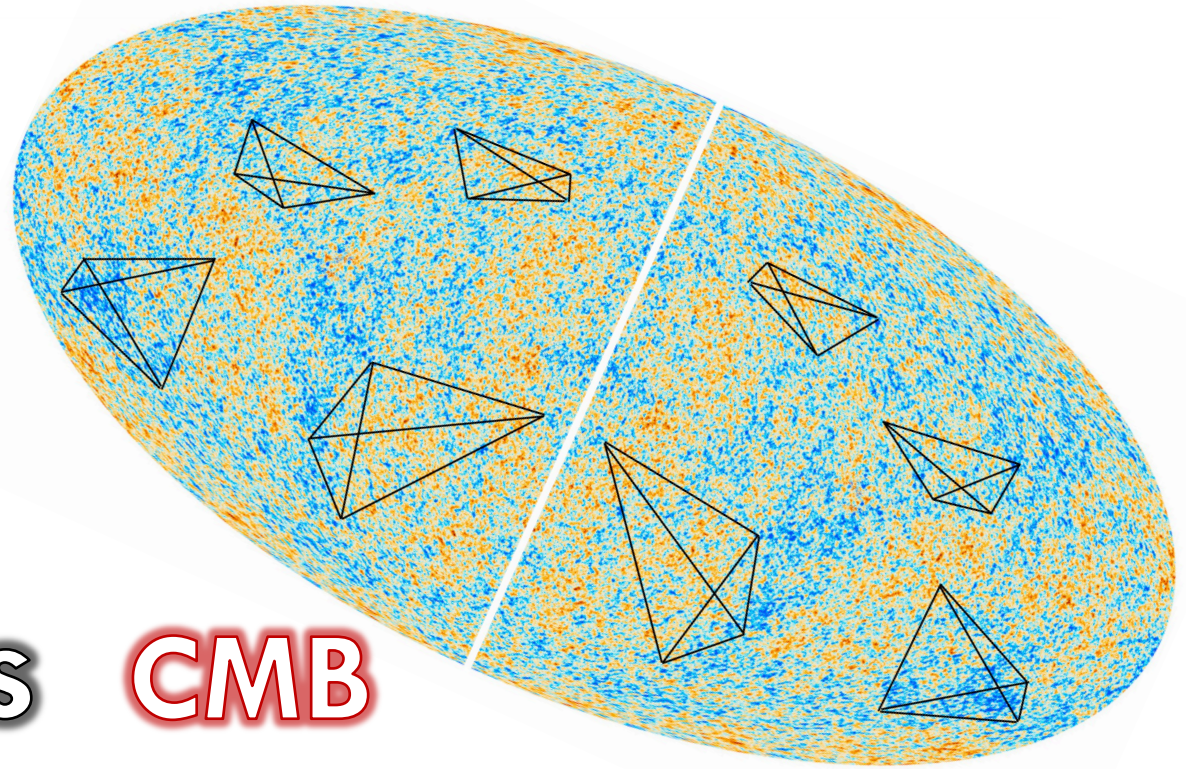
COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

SIMONS
FOUNDATION

Mirror Symmetries



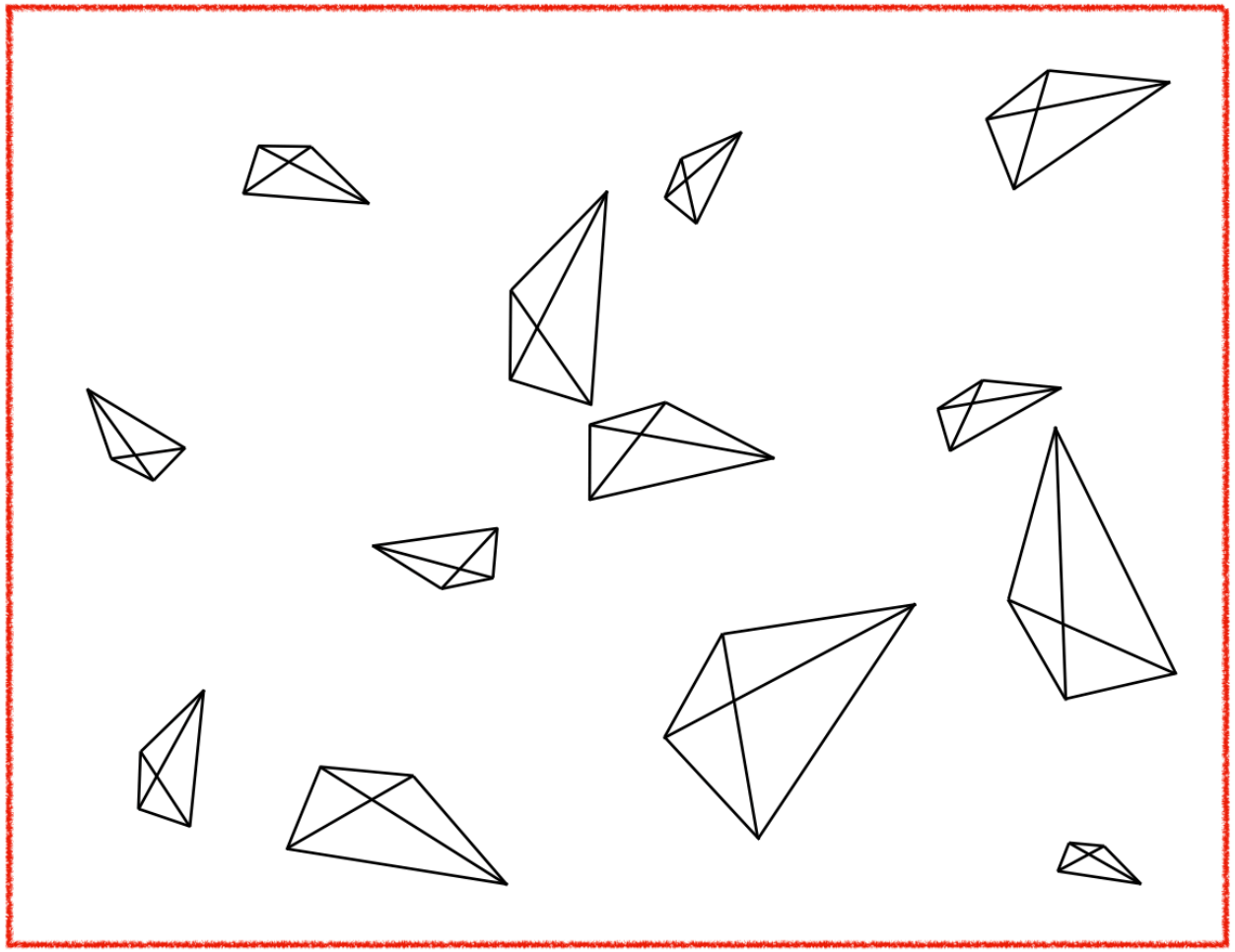


LSS versus CMB

Oliver Philcox

YITP, April 2023

WHAT IS PARITY?



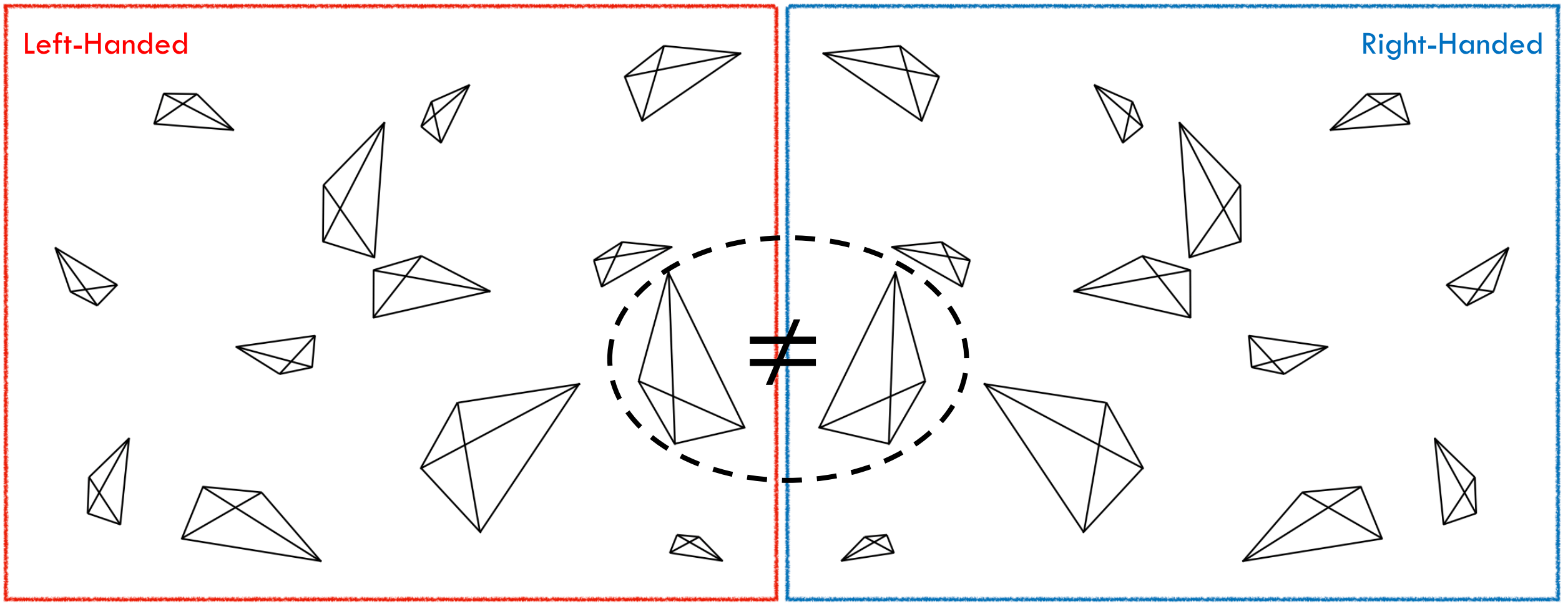
This distribution is:

- **Homogeneous** [translation symmetry]
- **Isotropic** [rotation symmetry]

This distribution *isn't*:

- **Parity-conserving** [mirror symmetry]

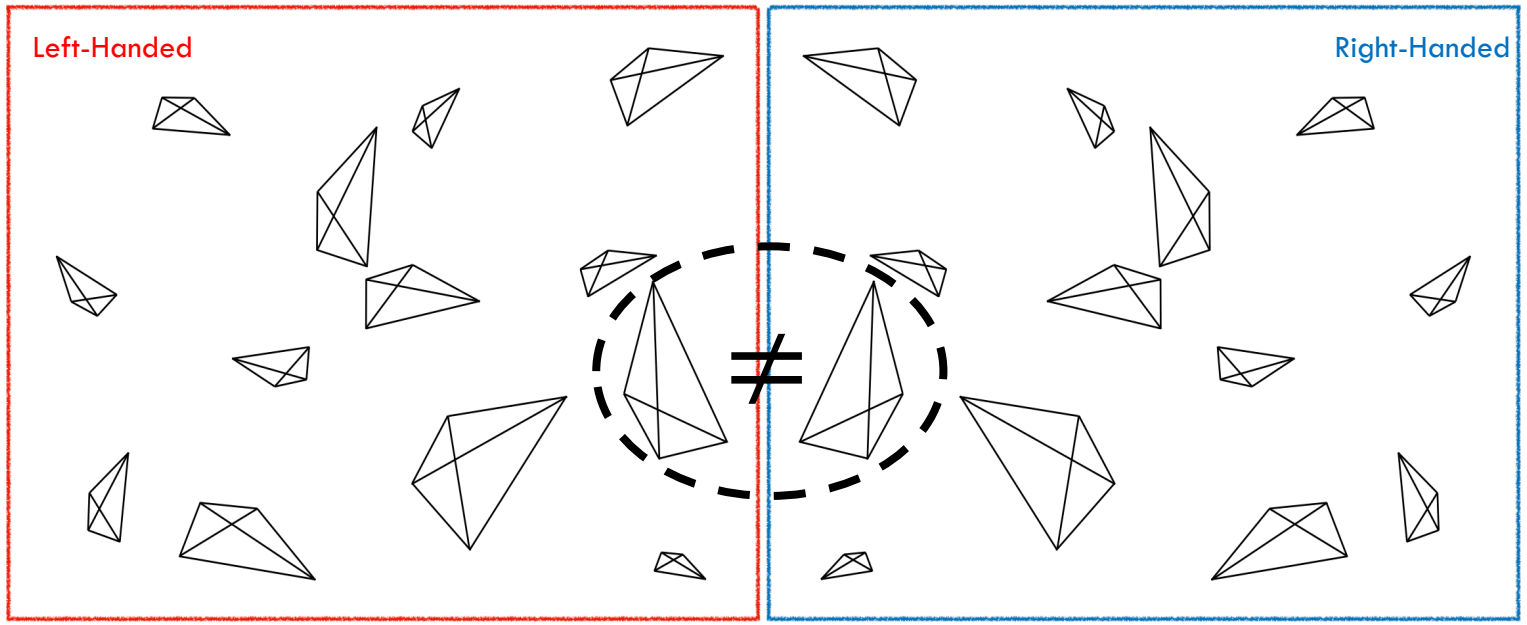
WHAT IS PARITY?



PARITY (A)SYMMETRY

There are **many** examples of parity-asymmetry:

- Amino Acids
- Neutrinos [via weak force]
- Baryogenesis [via CP+C-violation]

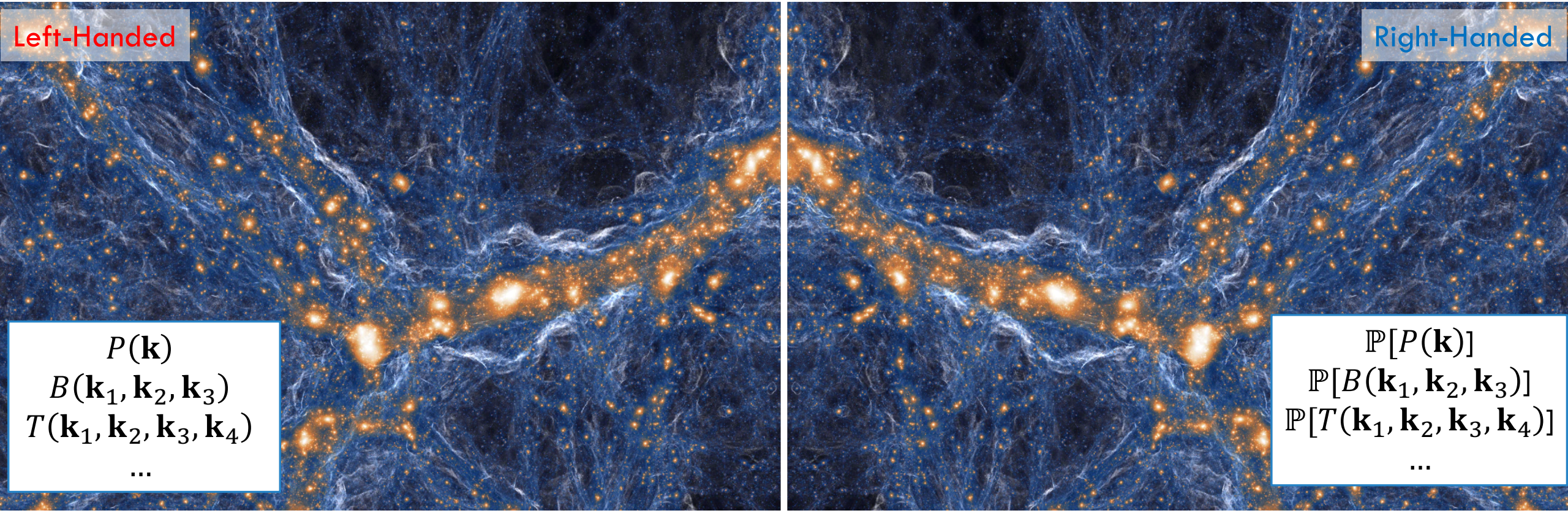


But, gravity **is** parity-conserving

Is the Universe mirror symmetric?

Luders & Pauli 1954, Alexander++

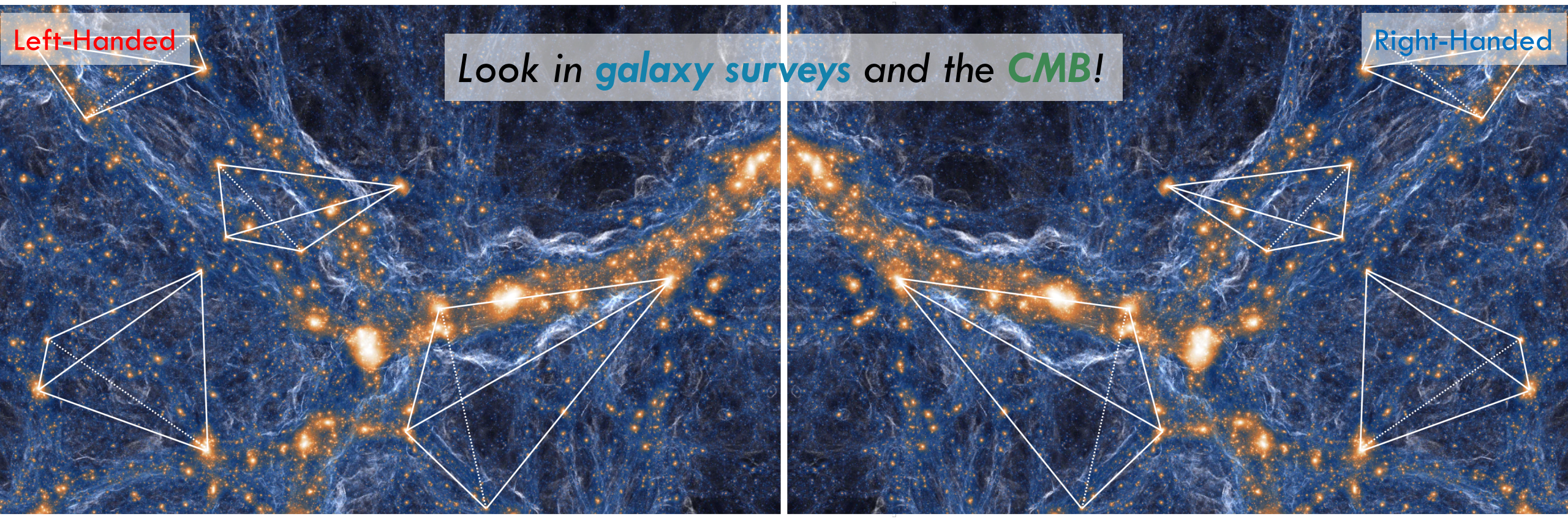
HOW TO SEARCH FOR PARITY VIOLATION



Which statistics are sensitive to parity?

$$X - \mathbb{P}[X] = ?$$

HOW TO SEARCH FOR PARITY VIOLATION



Statistic: four-point correlation functions / trispectra $\zeta_4 - \mathbb{P}[\zeta_4]$

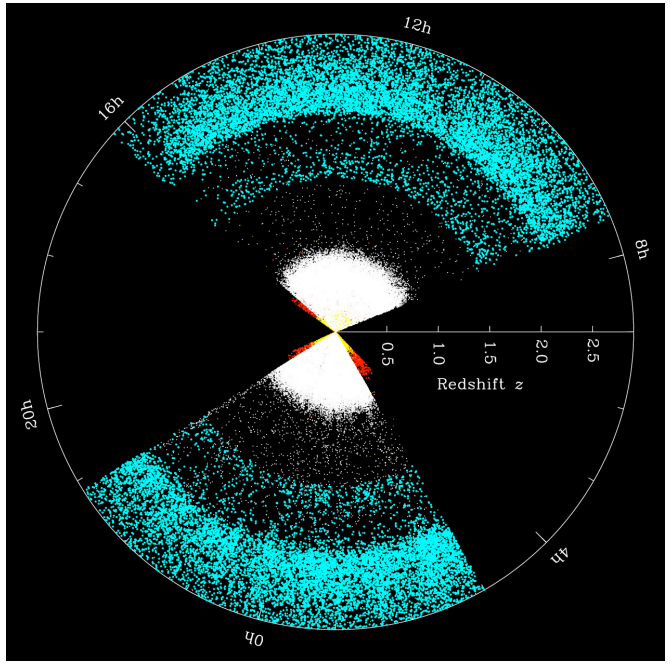
Rotational invariance ⇒ no signal in 2/3-point function!

Cahn+22, **Philcox** 22, 23ab

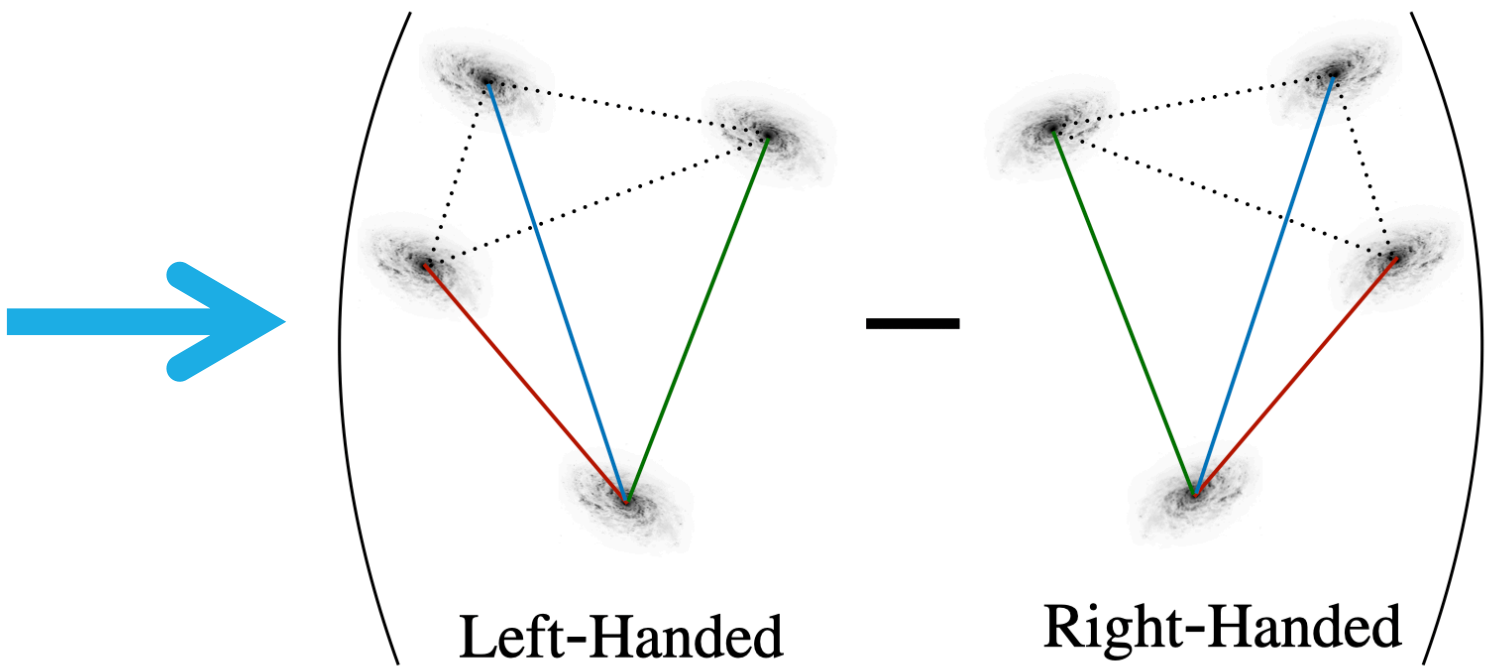
OBSERVATION #1: THE GALAXY 4-POINT FUNCTION

Measure the four-point function from $\approx 10^6$ BOSS galaxies

Zero without parity-violation!



Galaxy Positions



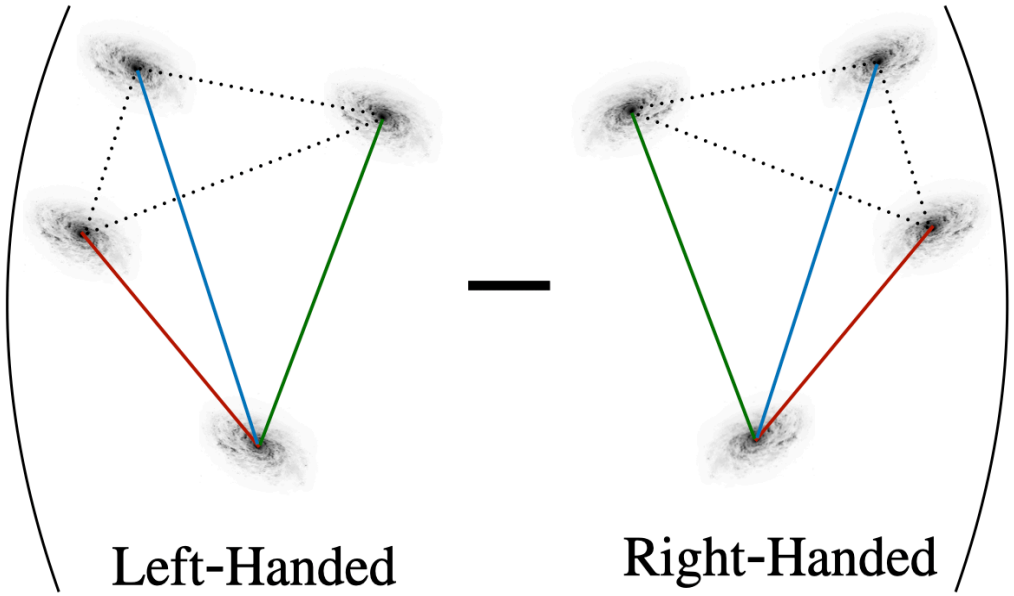
github.com/oliverphilcox/Parity-Odd-4PCF

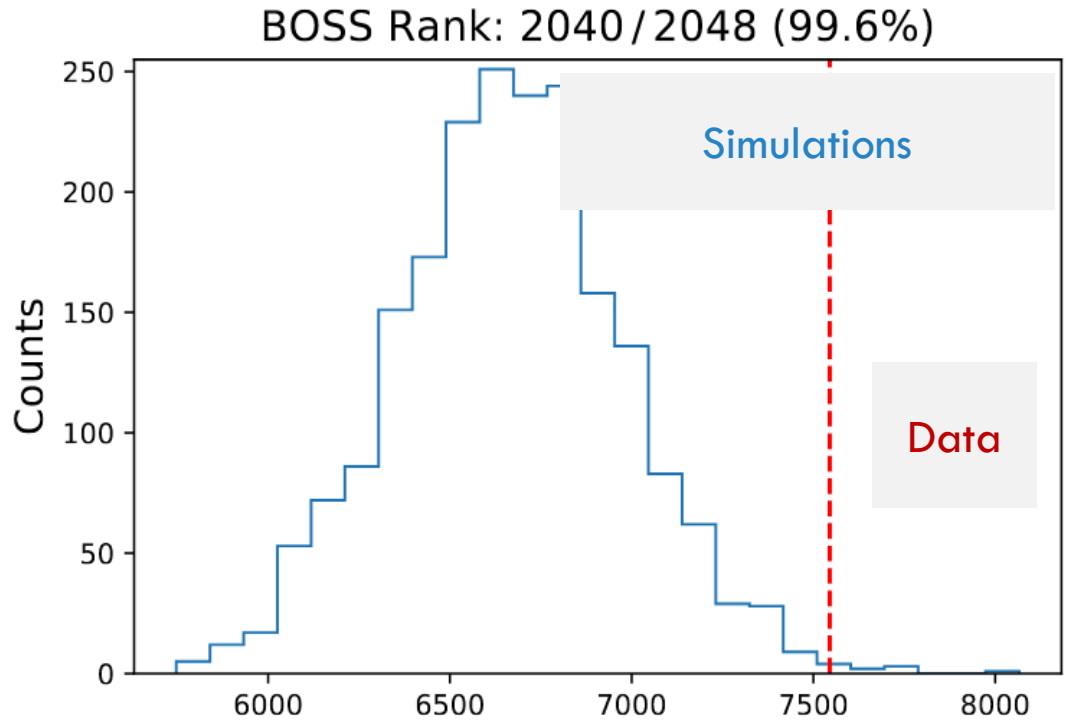
Philcox 22, Hou+22

OBSERVATION #1: THE GALAXY 4-POINT FUNCTION

Perform a χ^2 analysis of the observed data using **simulations**

3σ detection of parity-violation??





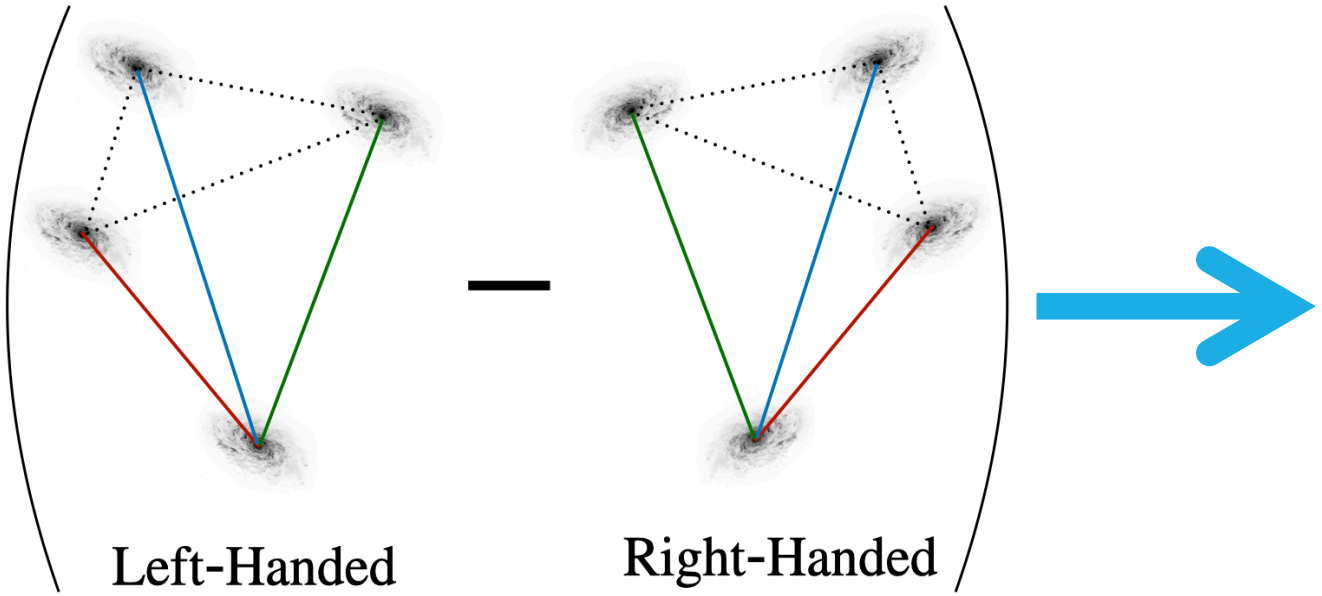
χ^2 distribution

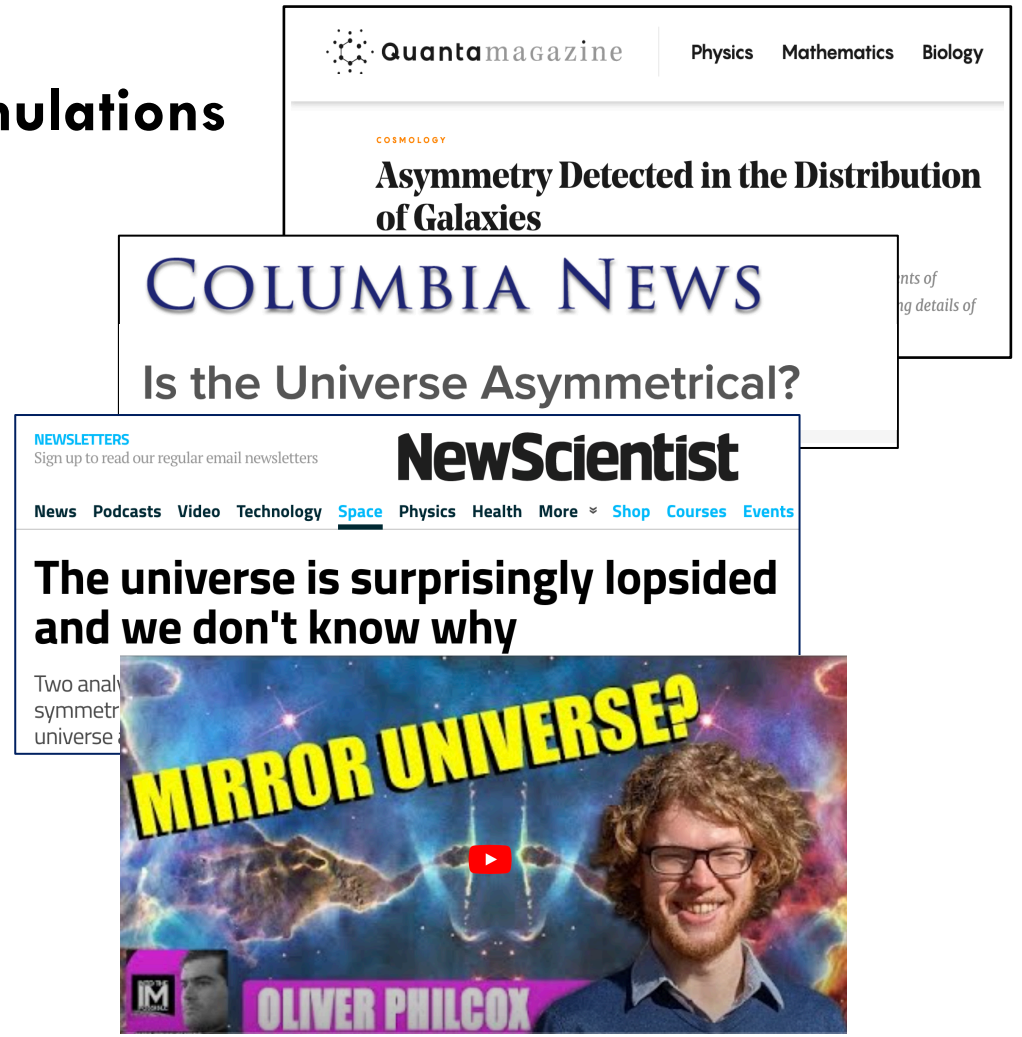
github.com/oliverphilcox/Parity-Odd-4PCF

Philcox 22, Hou+22

OBSERVATION #1: THE GALAXY 4-POINT FUNCTION

Perform a χ^2 analysis of the observed data using **simulations**





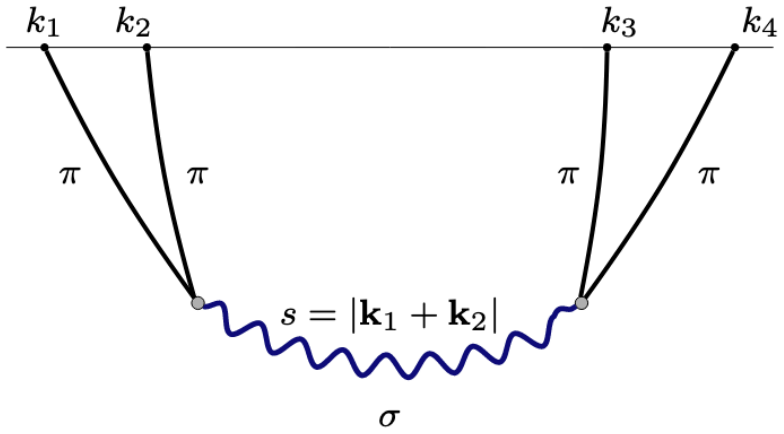
github.com/oliverphilcox/Parity-Odd-4PCF

Philcox 22, Hou+22

WHAT COULD SOURCE THIS?

1. Primordial Sources

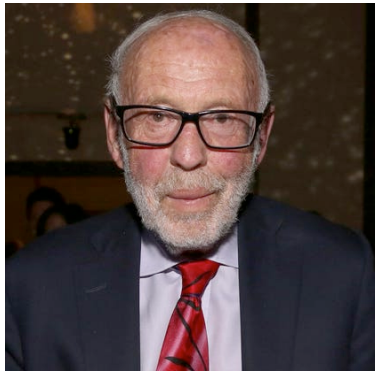
- New particles in inflation?
- Ghosts in inflation?
- Gravitational waves in inflation?



New particles!

Ghost inflation!

No evidence for an inflationary source from the 18 models we tried!



Chern-Simons inflation

Cabass, **Philcox**+22, Creque-Sarbinowski, **Philcox**+22

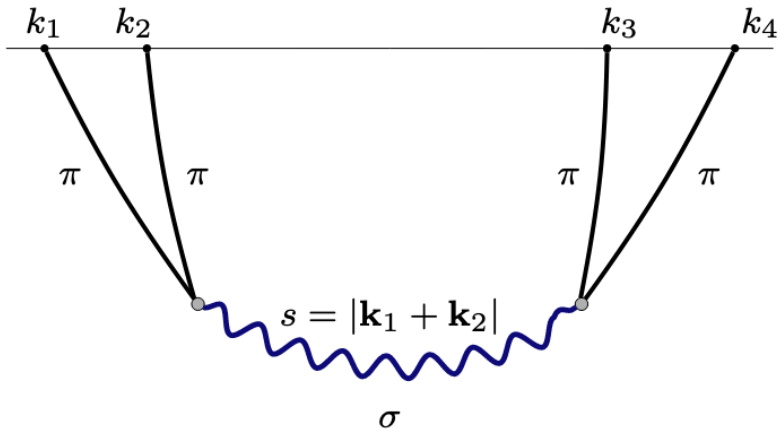
WHAT COULD SOURCE THIS?

1. Primordial Sources

- New particles in inflation?
- Ghosts in inflation?
- Gravitational waves in inflation?

2. Late-time Sources

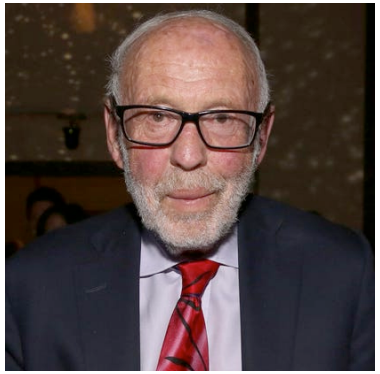
- Modified gravity?
- Magnetic fields?



New particles!

Ghost inflation!

Late-time physics has to happen on very large scales!



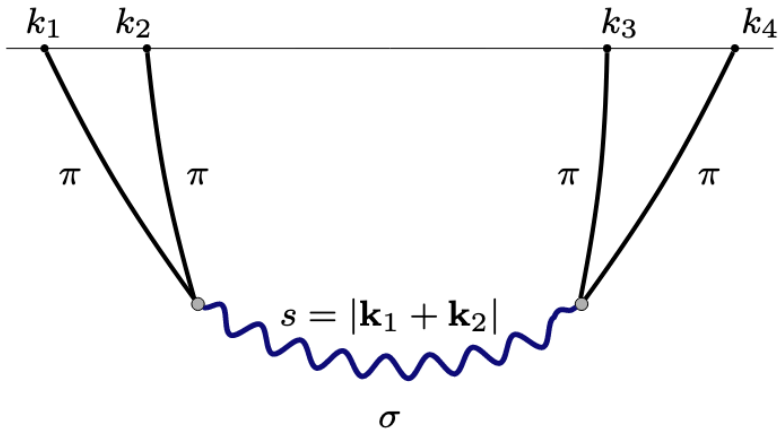
Chern-Simons inflation

Cabass, **Philcox**+22, Creque-Sarbinowski, **Philcox**+22

WHAT COULD SOURCE THIS?

1. Primordial Sources

- New particles in inflation?
- Ghosts in inflation?
- Gravitational waves in inflation?

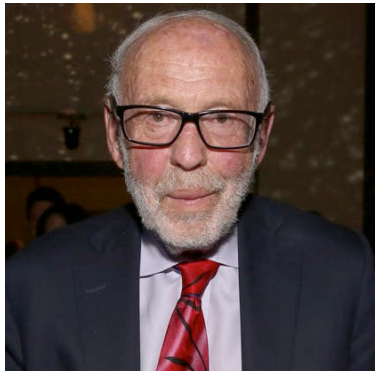


New particles!

Ghost inflation!

2. Late-time Sources

- Modified gravity?
- Magnetic fields?



Chern-Simons inflation

3. Systematics

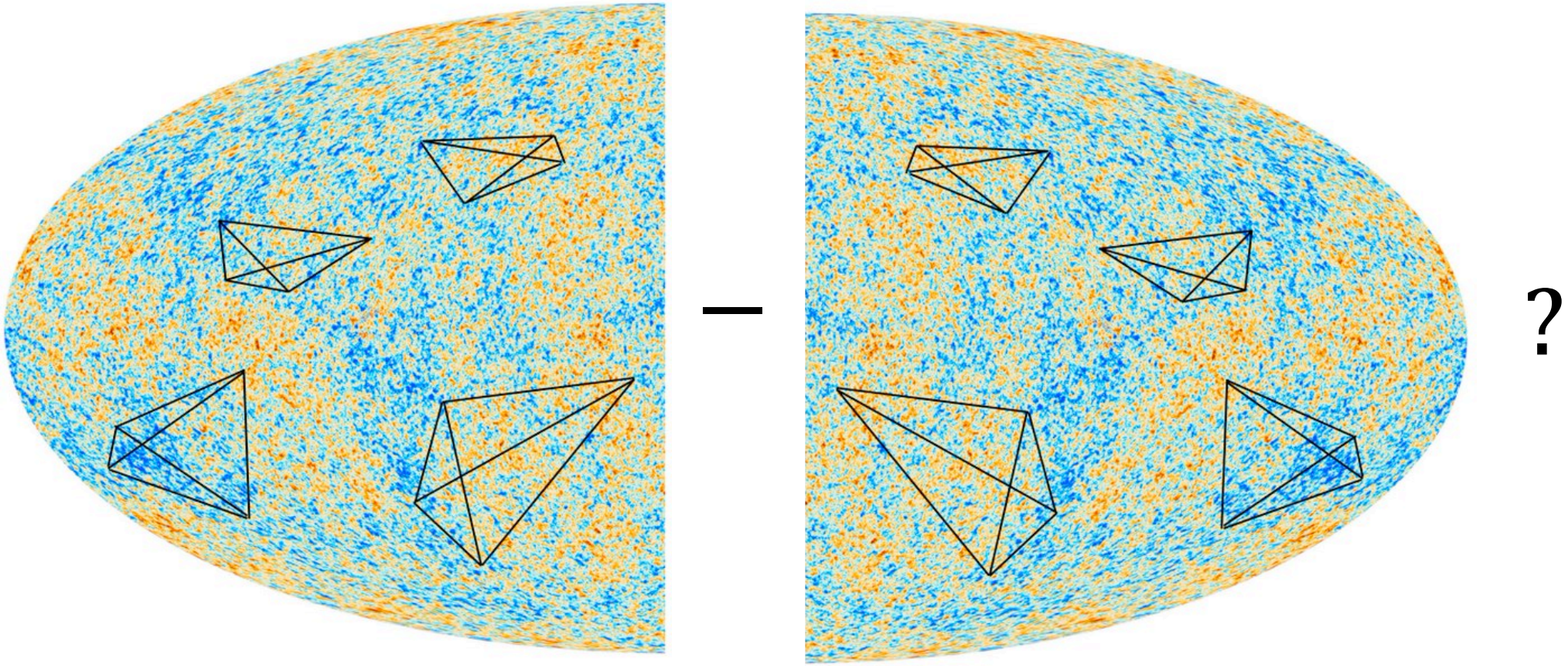
- Wrong covariance / likelihood?
- Observational effects?

Simulations could be wrong!

Cabass, **Philcox**+22, Creque-Sarbinowski, **Philcox**+22

OBSERVATION #2: THE CMB TRISPECTRUM

The CMB also probes parity-violation!



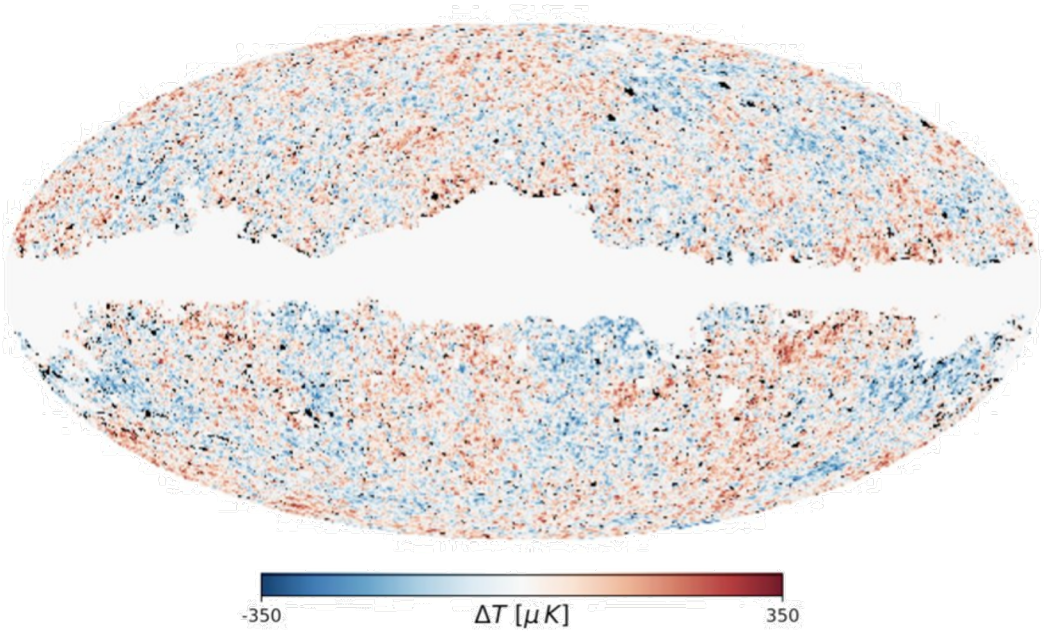
Observable: the **large-scale parity-odd temperature trispectrum**

Philcox 23ab

OBSERVATION #2: THE CMB TRISPECTRUM

PolyBin

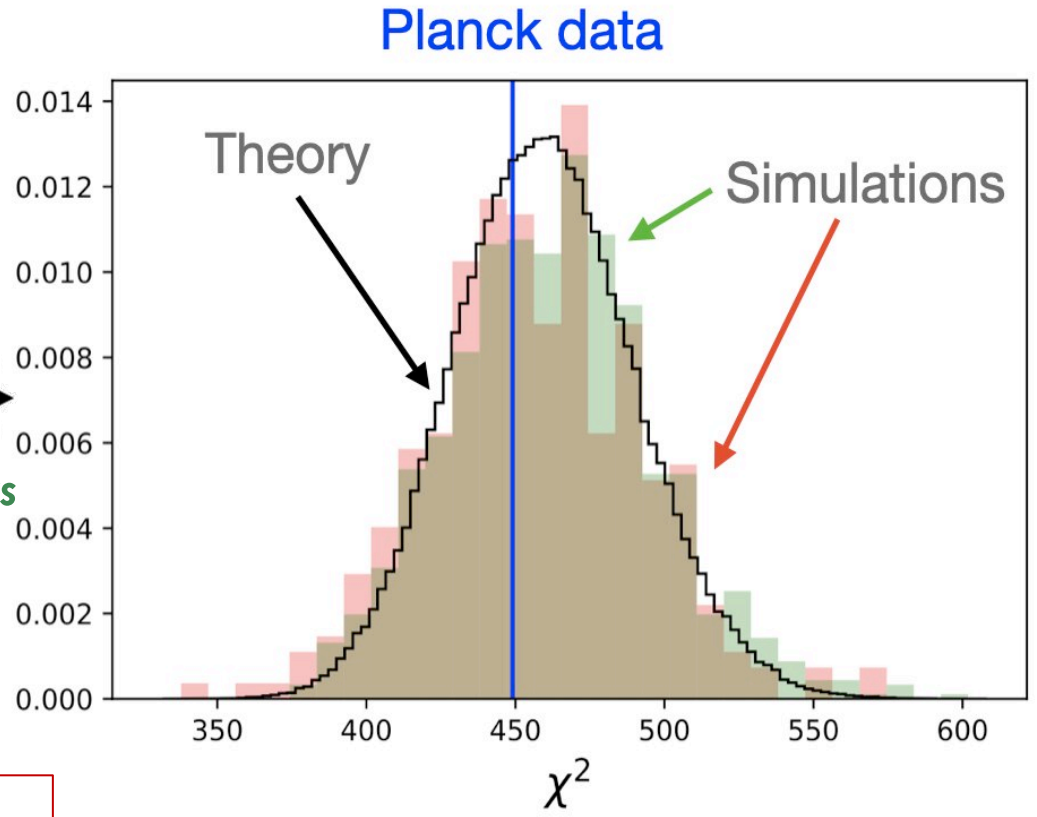
Planck CMB



New code!

Lots of tricks

χ^2 Test

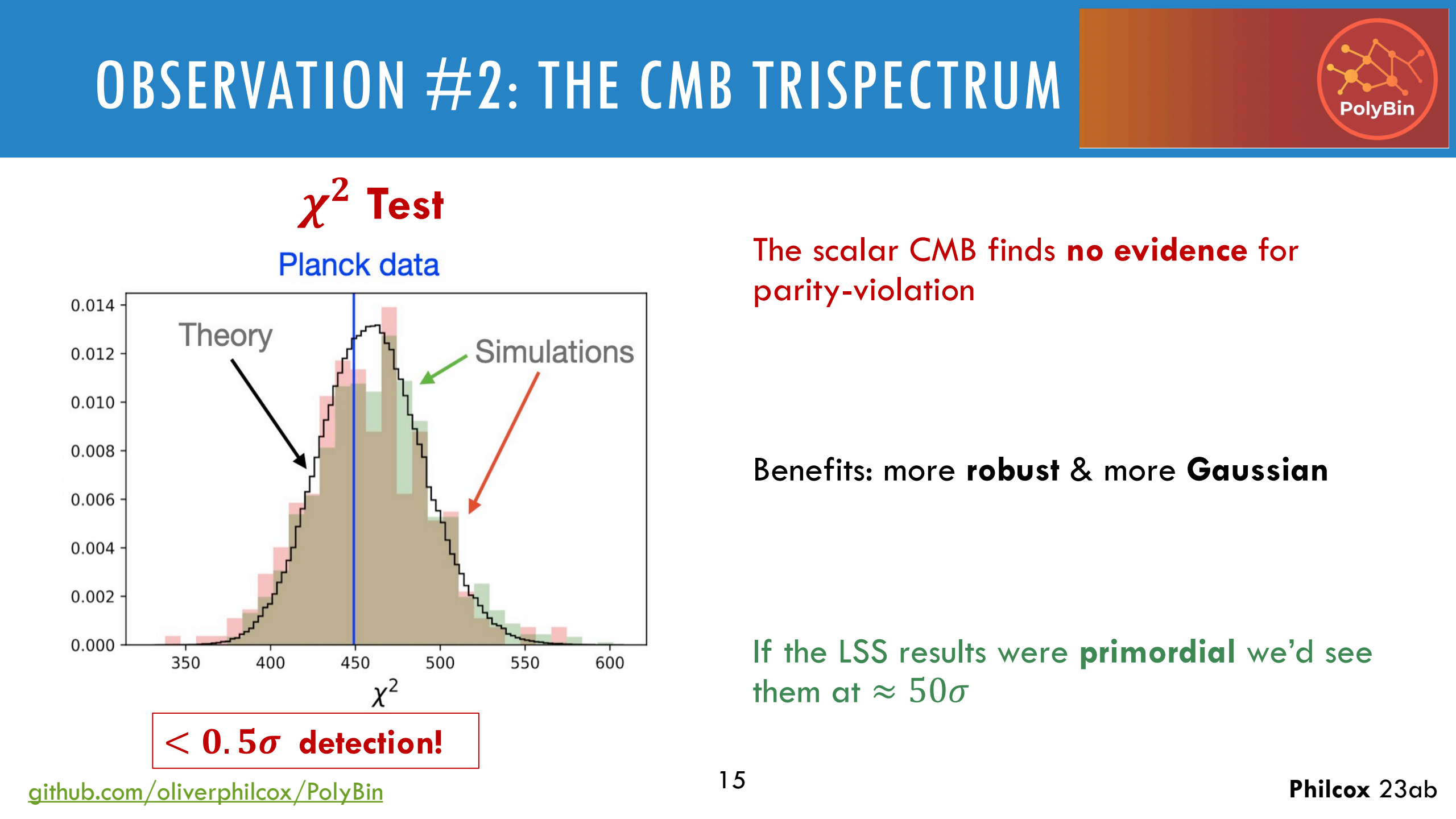


$< 0.5\sigma$ detection!

github.com/oliverphilcox/PolyBin

Philcox 23ab

OBSERVATION #2: THE CMB TRISPECTRUM



χ^2 Test

$< 0.5\sigma$ detection!

The scalar CMB finds **no evidence** for parity-violation

Benefits: more **robust** & more **Gaussian**

If the LSS results were **primordial** we'd see them at $\approx 50\sigma$

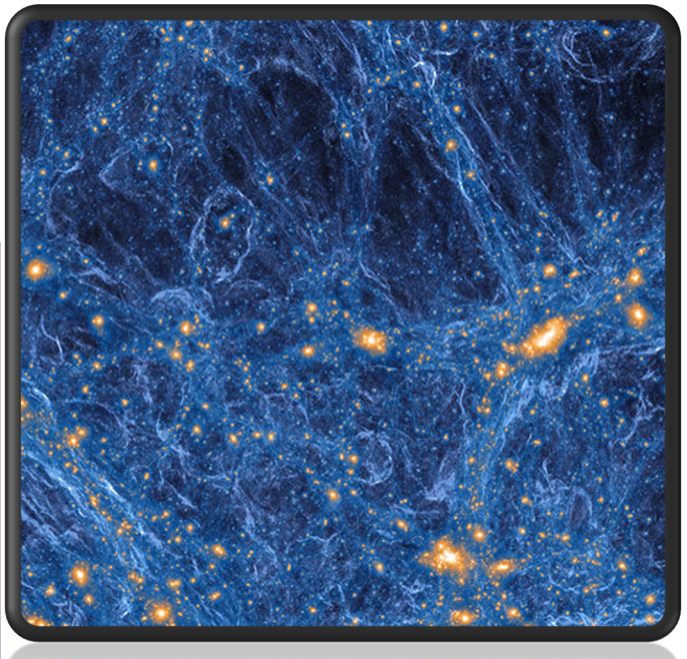
github.com/oliverphilcox/PolyBin

Philcox 23ab

CONCLUSIONS

arXiv

2206.04227
2206.03625
2210.02907
2303.04815
2303.08828
2303.12106



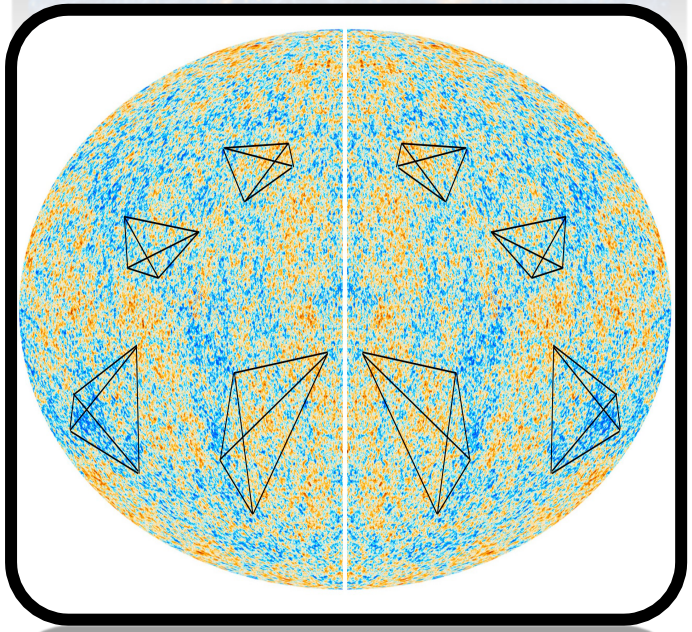
Is the Universe **mirror-symmetric?**

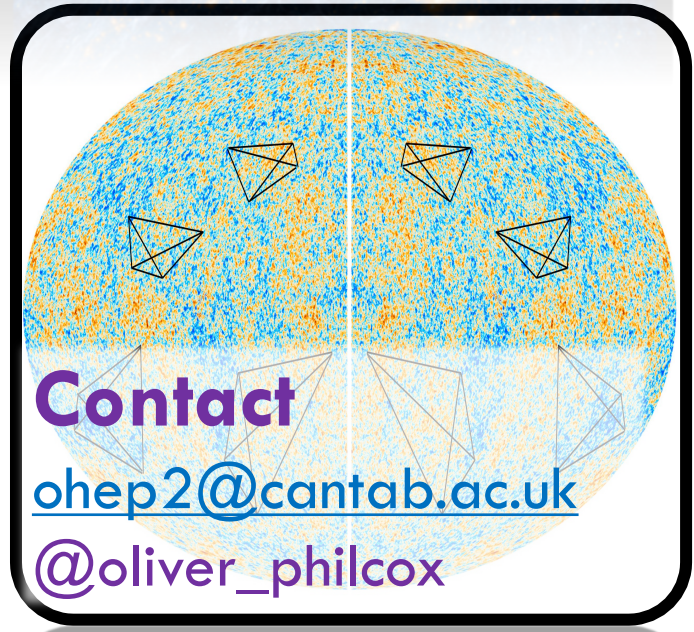
- **LSS:** No! [$3-7\sigma$]
- **CMB:** Yes! [$<0.5\sigma$]

Important if true:

- New physics in inflation?
- Weird late-time physics?

But seems unlikely...





Contact
ohep2@cantab.ac.uk
@oliver_philcox