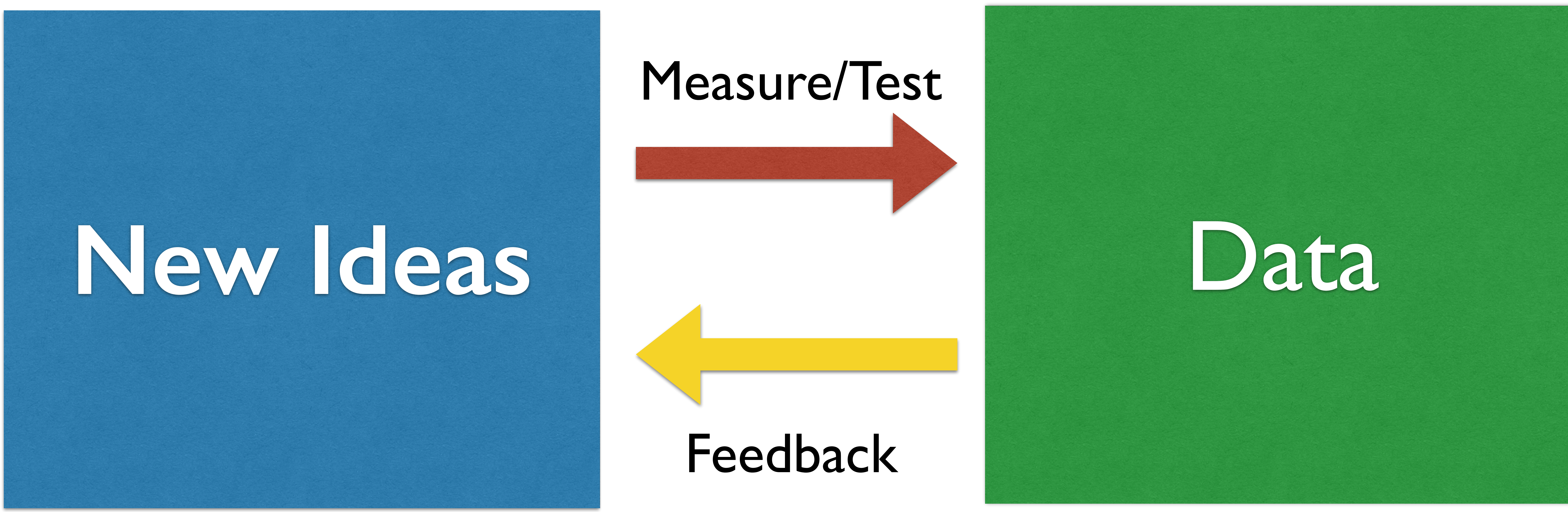

Physical
Cosmology
Group

Let me introduce myself...

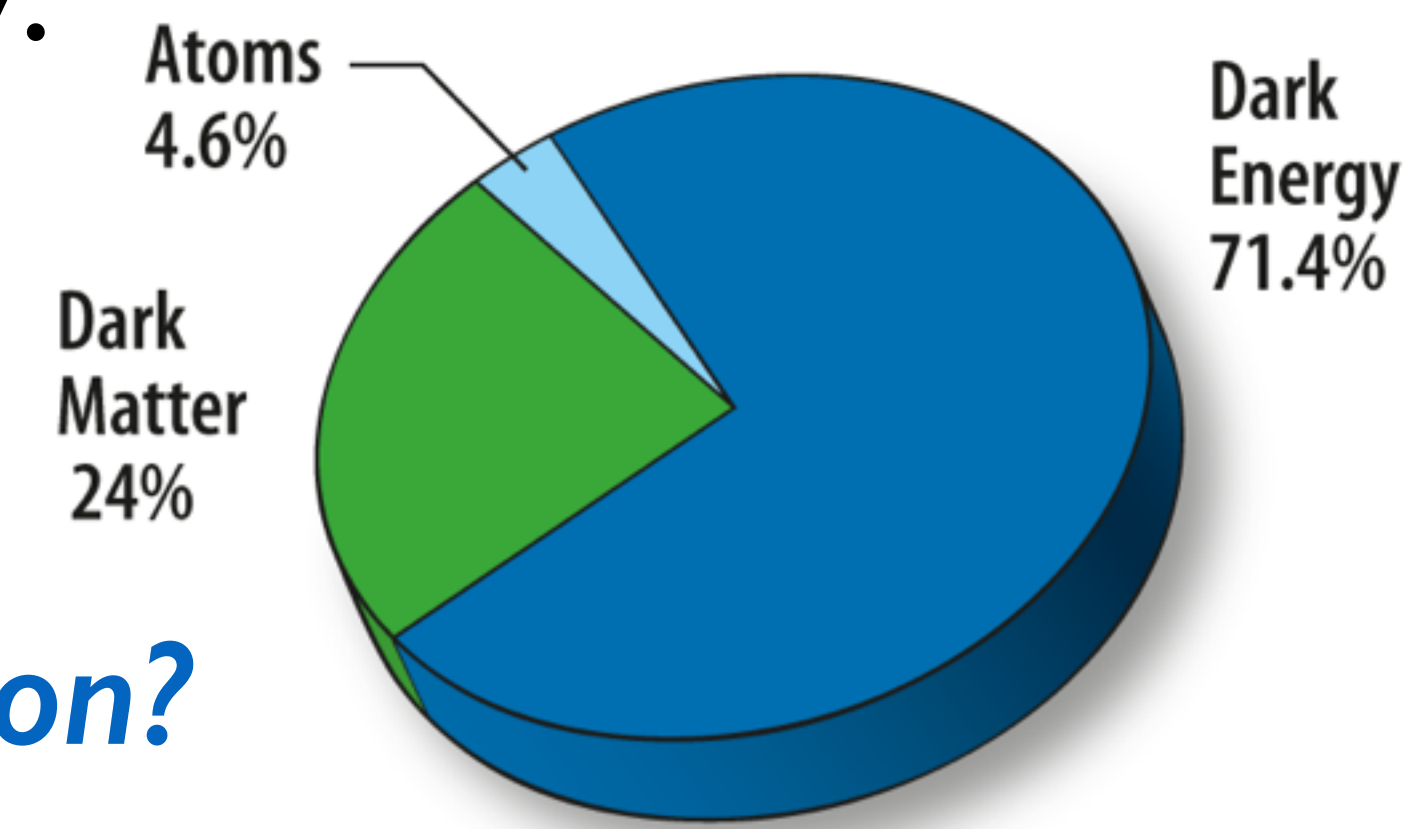
- I am a cosmologist
- I do theory, data analysis, as well as observations
  - ~2/3 theory; ~1/3 analysis; a bit of observation
- Area of research
  - Cosmic microwave background (CMB)
  - Large-scale structure of the universe (LSS)
  - Early universe physics (physics of inflation)
  - Intra-cluster medium and the Sunyaev-Zeldovich effect

Basic Routine



Four Big Questions in Cosmology

- Members of the Dept. of Physical Cosmology seek answers to **FOUR** big questions in cosmology:
  - *How did the Universe begin?*
    [What is the physics of inflation?]
  - *What is the origin of the cosmic acceleration?*
    [What is the nature of dark energy?]
  - *What is the nature of dark matter?*
  - *What is the mass of neutrinos?*

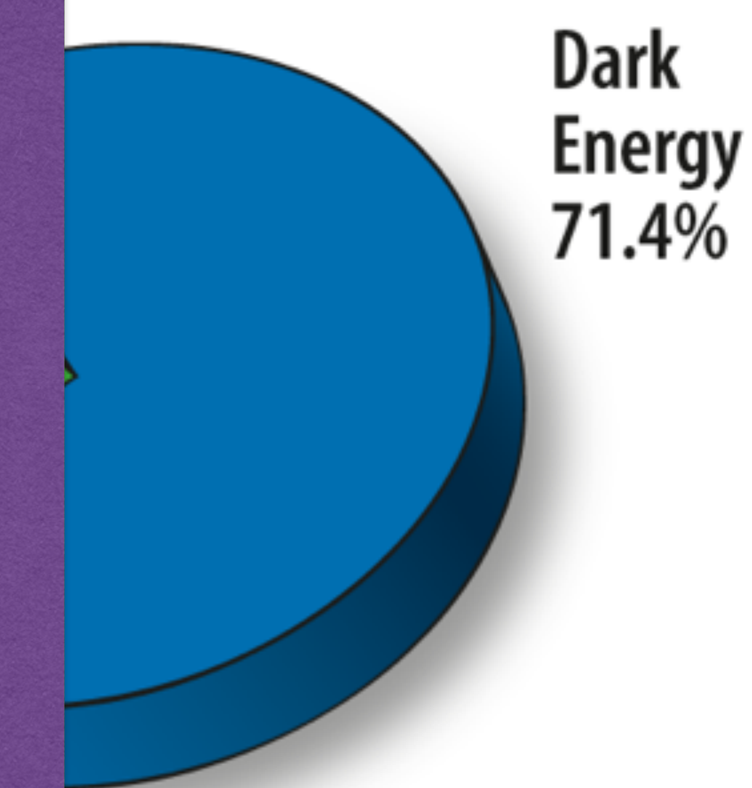


We use both theory and observational data to seek answers to these major questions

Four Big Questions in Cosmology

- Members
  answers
  - *How*
    [Wha
  - *What*
    [Wha
  - *What*
  - *What is the mass of neutrinos?*

And, do whatever we think are interesting at times



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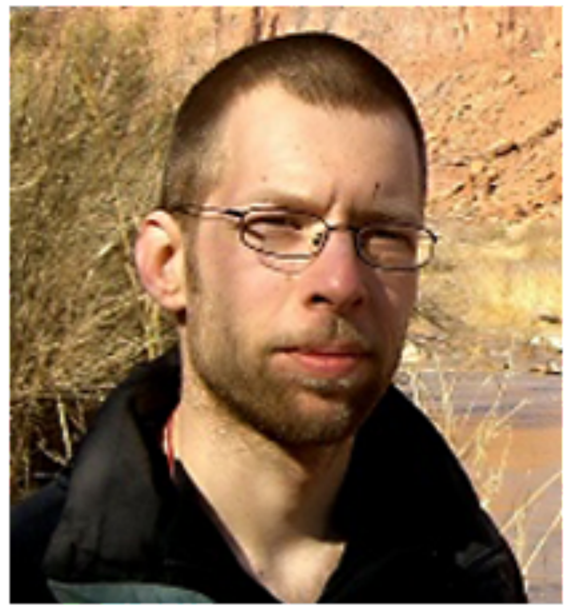
Physical Cosmology Group



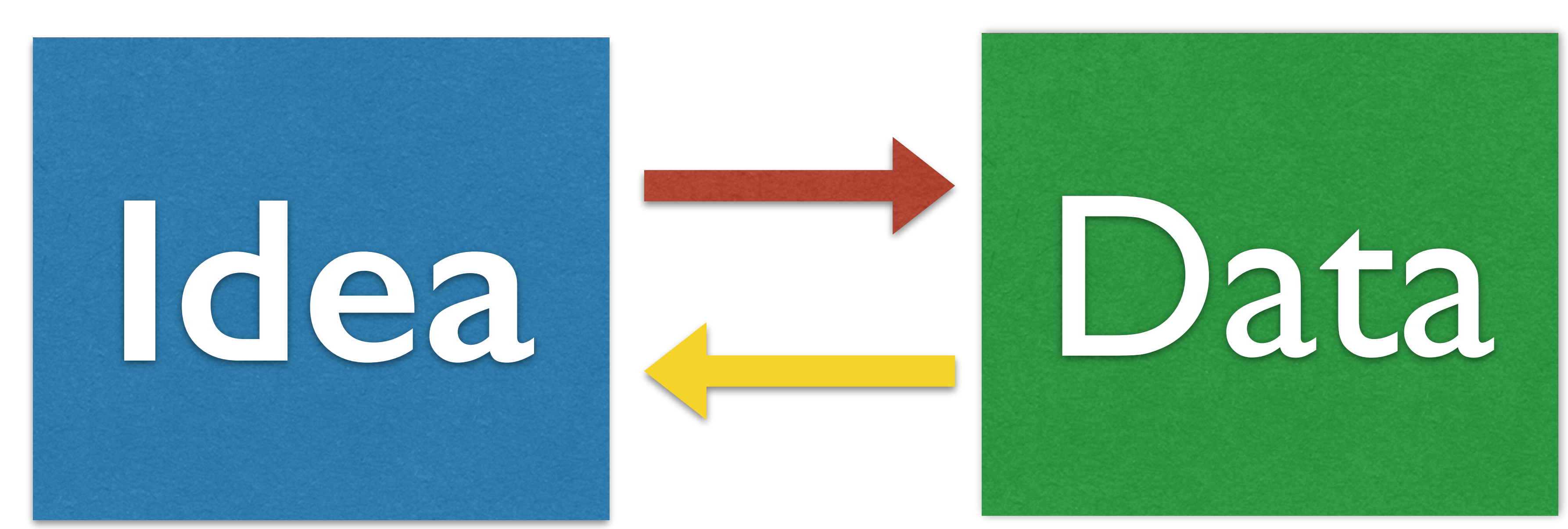
- Female: 4 / 12 = 33%

- One tenure-track staff
  - Fabian Schmidt [he will also start his own ERC-funded group]
- Six postdocs
  - Matteo Barnabe (lensing)
  - Alex Barreira (LSS)
  - Ryu Makiya* (LSS)
  - Marcello Musso* (LSS)
  - Shun Saito (LSS)
  - Xun Shi (galaxy clusters)
- Five PhD students
  - Aniket Agrawal (LSS)
  - Aoife Boyle (LSS)
  - Inh Jee (lensing)
  - Titouan Lazeyras (LSS)
  - Sam Ip (formal theory)

*3rd-party funding

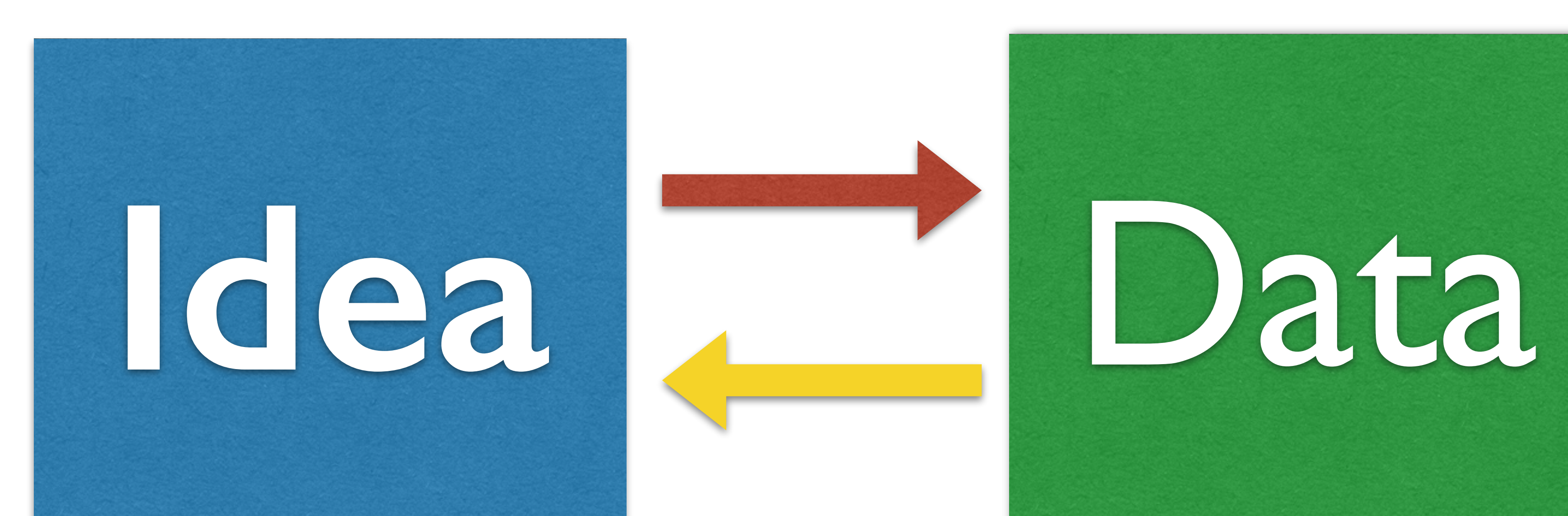
Research Style

1. Come up with new ideas (new tests; new methods; new observables), which will help make progress on the four questions
2. Write papers
3. Apply these ideas to extract new information from data; or collect new data if necessary
4. Write papers
5. Go back to #1

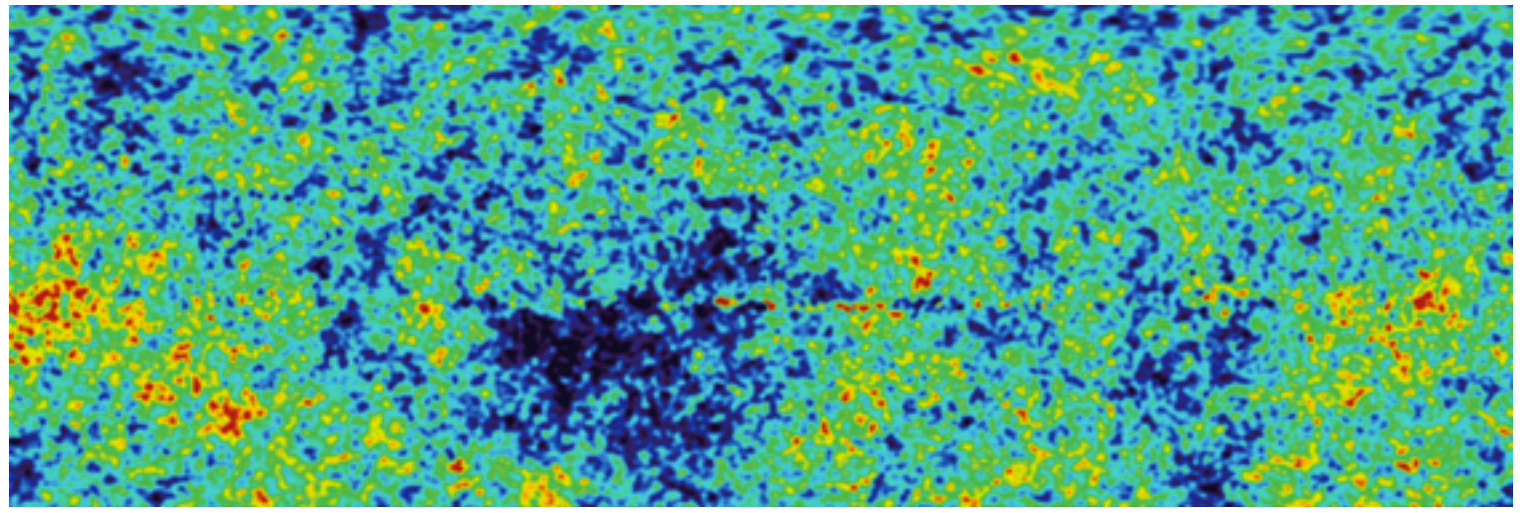


A Typical Student's Thesis Structure

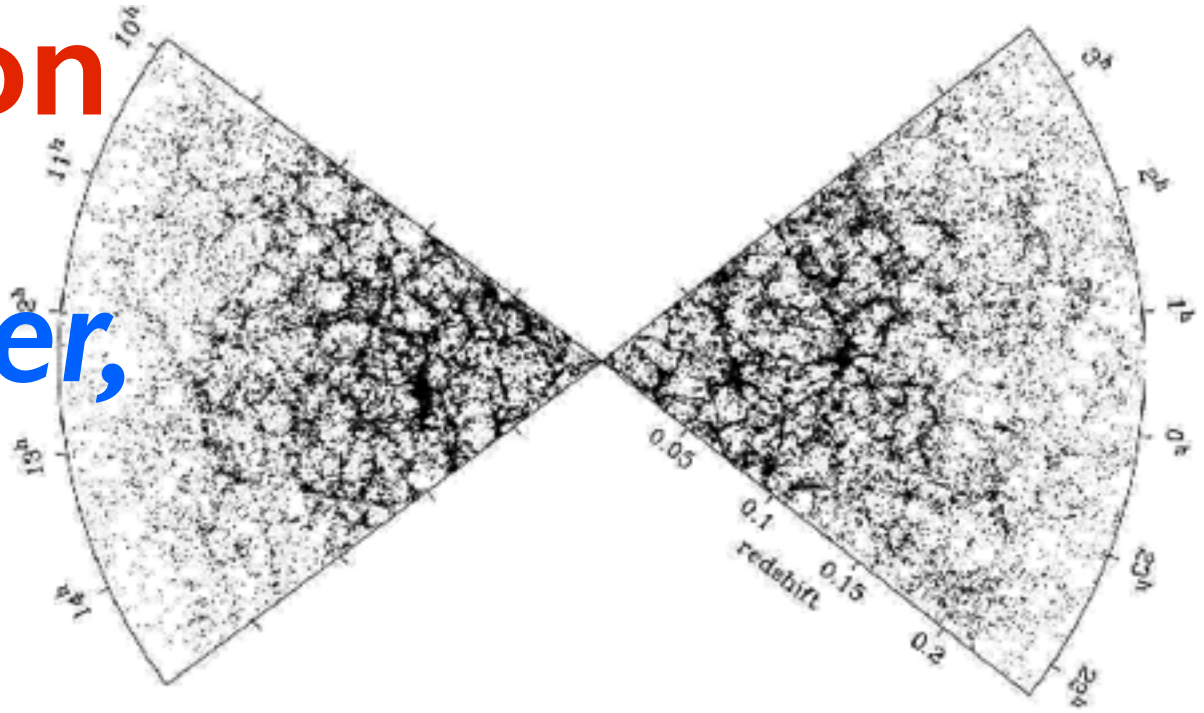
- Chapter 1: Introduction
- Chapter 2: Brilliant New Idea
- Chapter 3: Methodology and Tests
- Chapter 4: Application to the Real Data
- Chapter 5: Exciting New Results
- Chapter 6: Conclusions



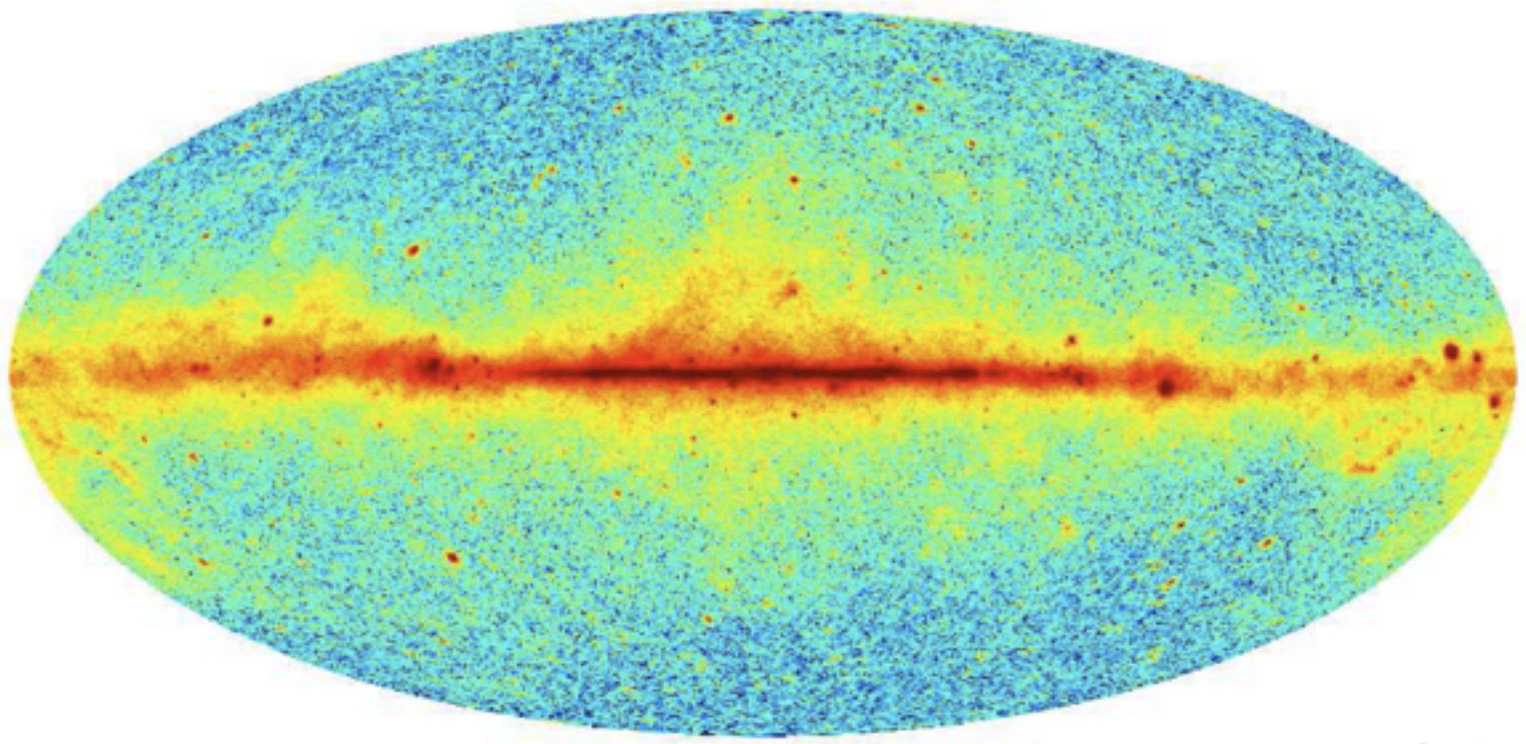
Main Tools



- *Cosmic Microwave Background (CMB)*
  - Fossil light of the Big Bang
  - Excellent probe of the early universe: **Inflation**



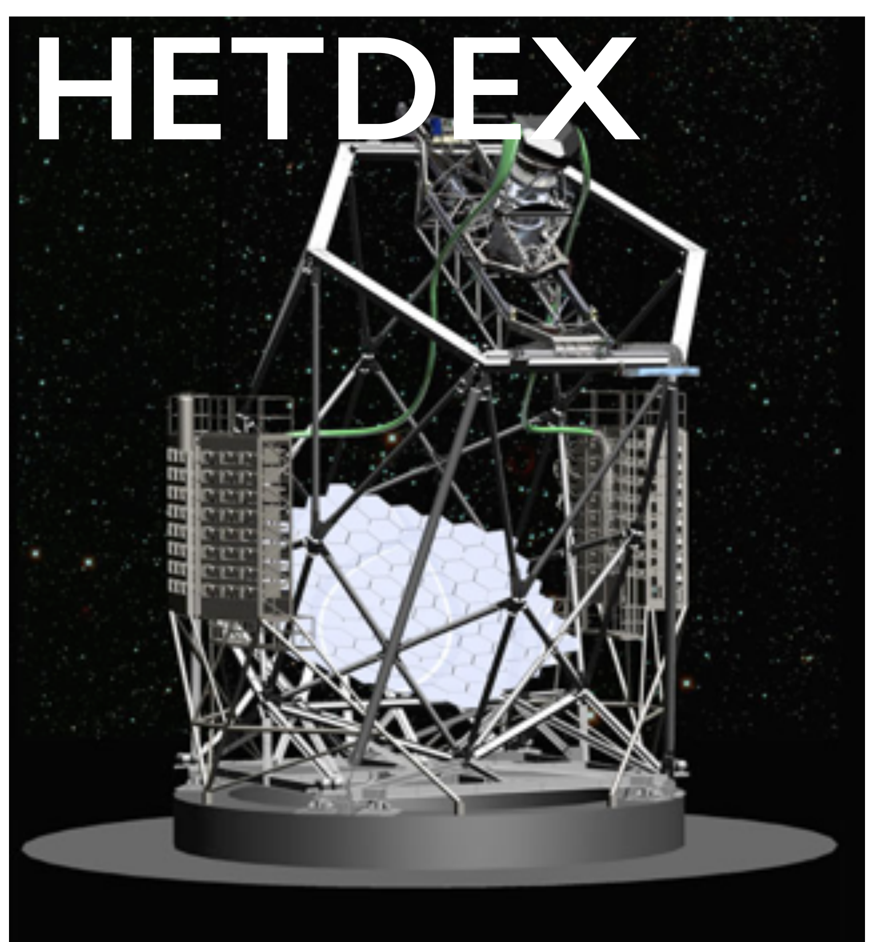
- *Large-scale structure (LSS): distribution of matter, galaxies, galaxy clusters, and strong lensing*
  - Probing the late-time universe: **dark energy** and **mass of neutrinos**



- *Gamma-ray*
  - Distribution of **dark matter**

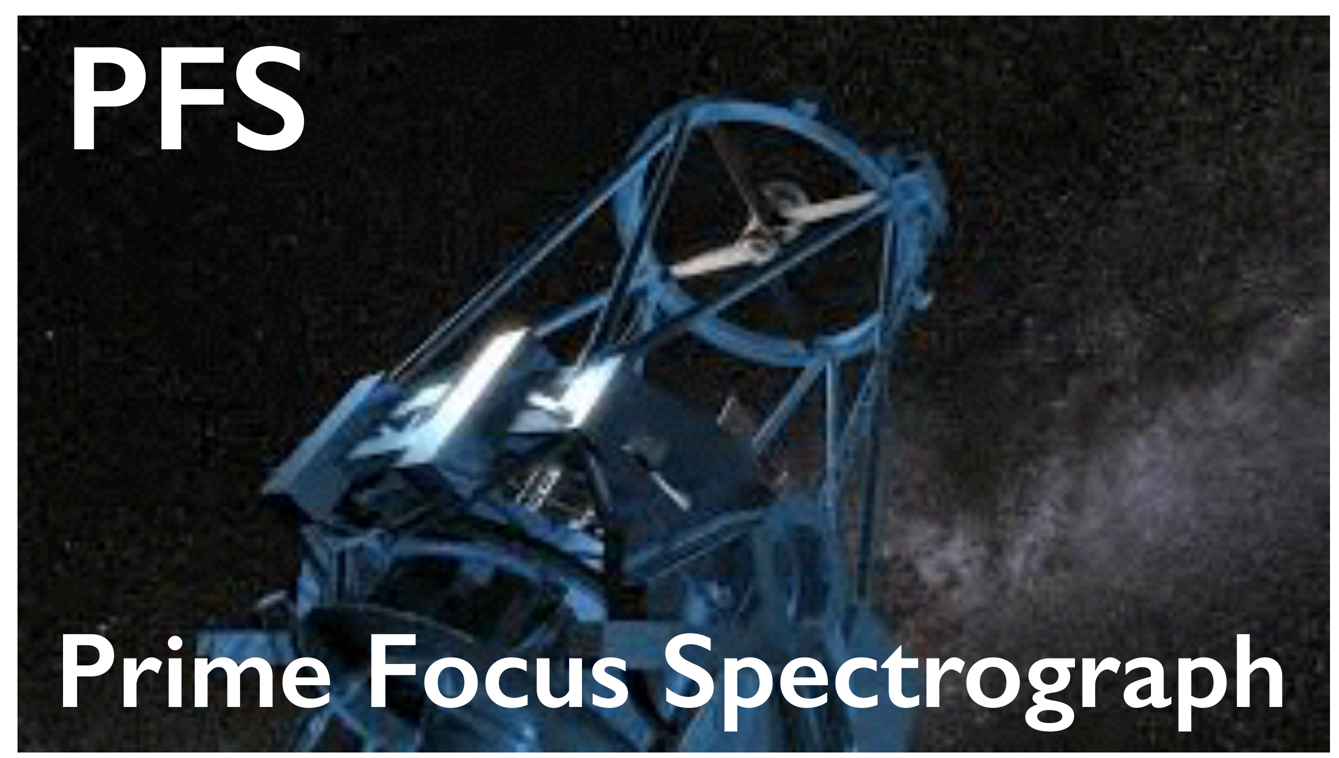
Future: Feeding hungry mouths with great new data

2016 2019 2024 2025 2030



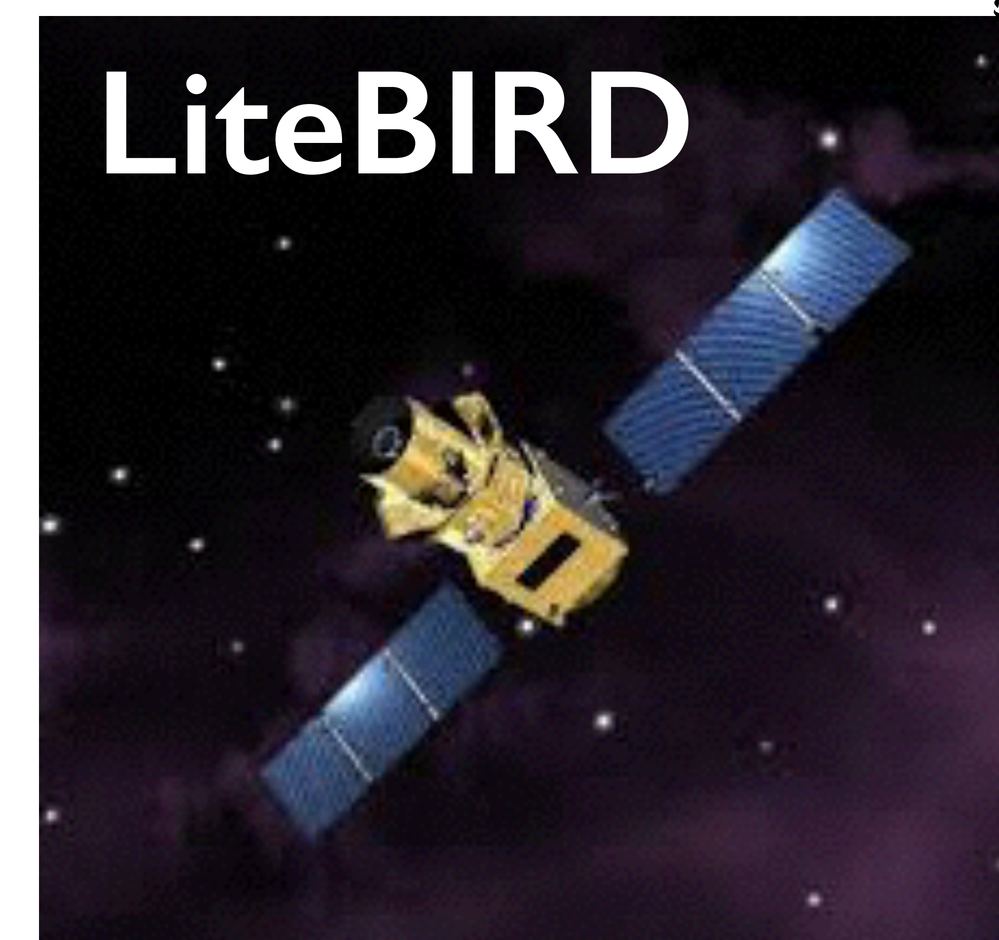
Galaxy survey in $1.9<z<3.5$ using a 10-m telescope in Texas

Dark energy, neutrino mass



Galaxy survey in $0.8<z<2.4$ using a 8-m telescope in Hawaii

Dark energy, neutrino mass



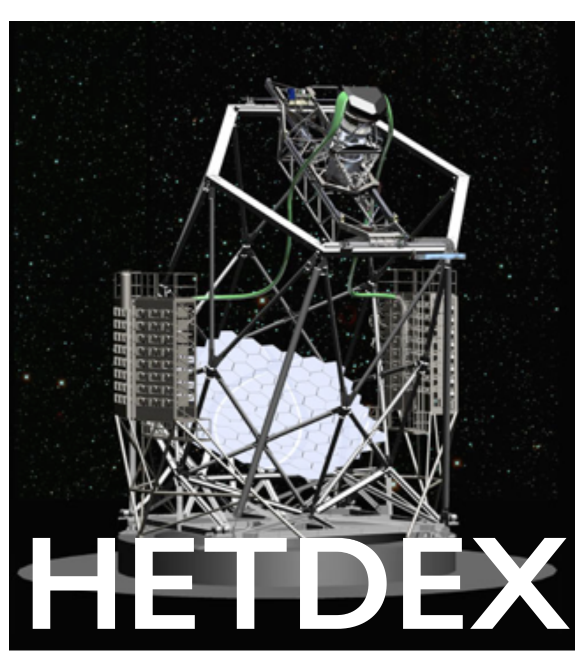
Polarisation of CMB to detect gravitational waves

Inflation

Vision, or "Wish List"

- By 2030, I would like to have made significant contributions to:

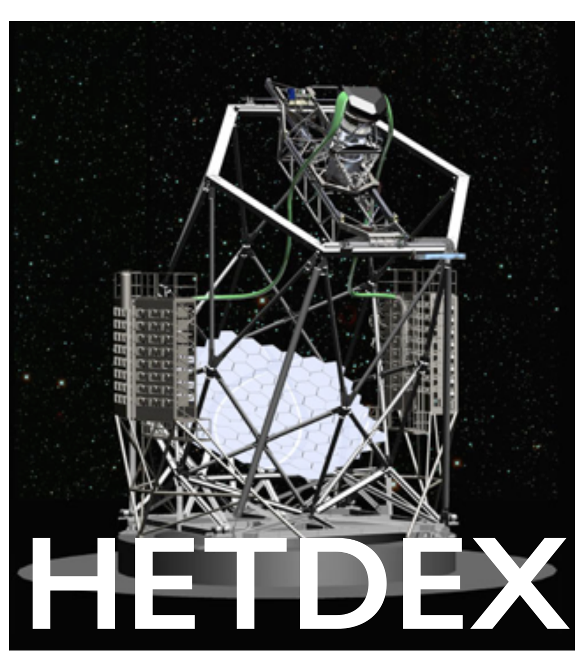
  - "Prove" inflation by detecting primordial gravitational waves in B-mode polarisation of the CMB



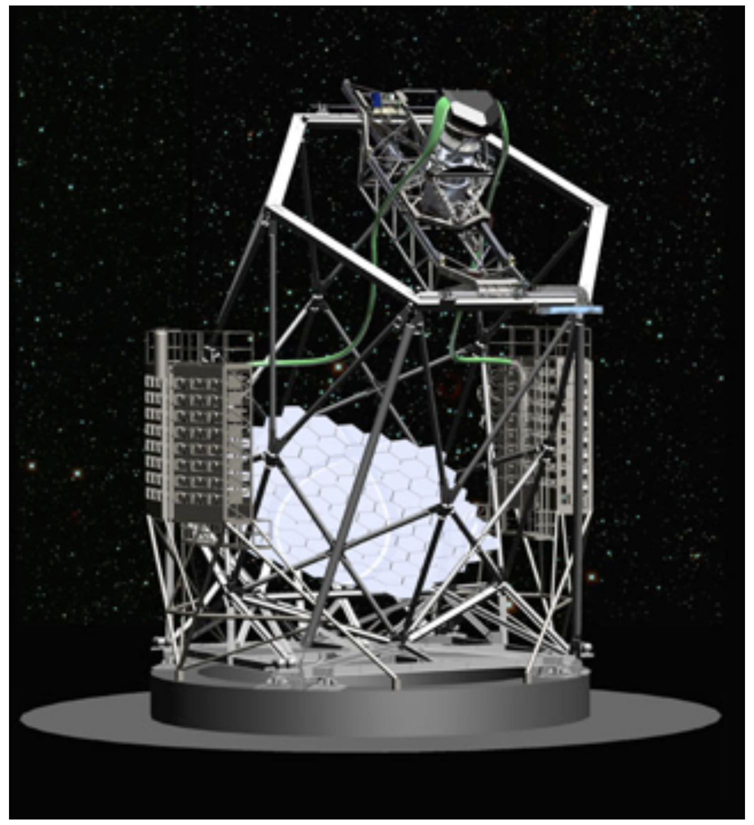
  - Measure the absolute value of the mass of neutrinos
  - Hopefully rule out the ΛCDM model by showing that Dark Energy is not a cosmological constant

    - Or, at least measure the cosmological distances and growth rates of the structures over all redshifts up to z=3.5

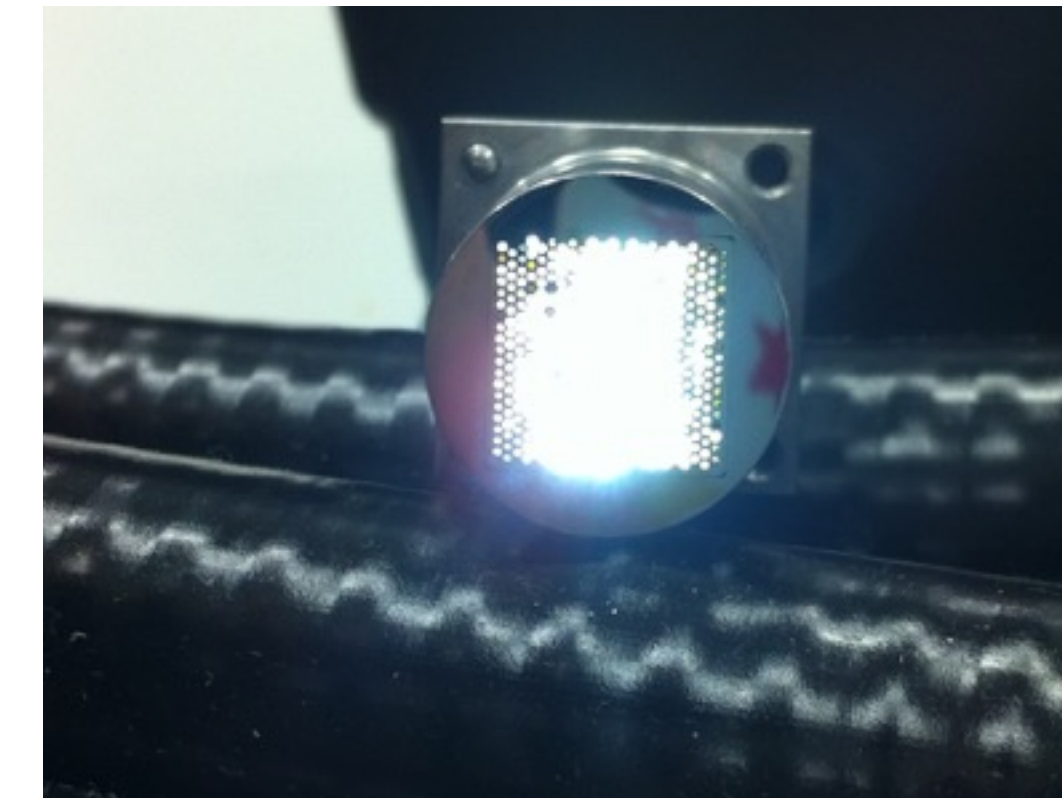
And, to-do list



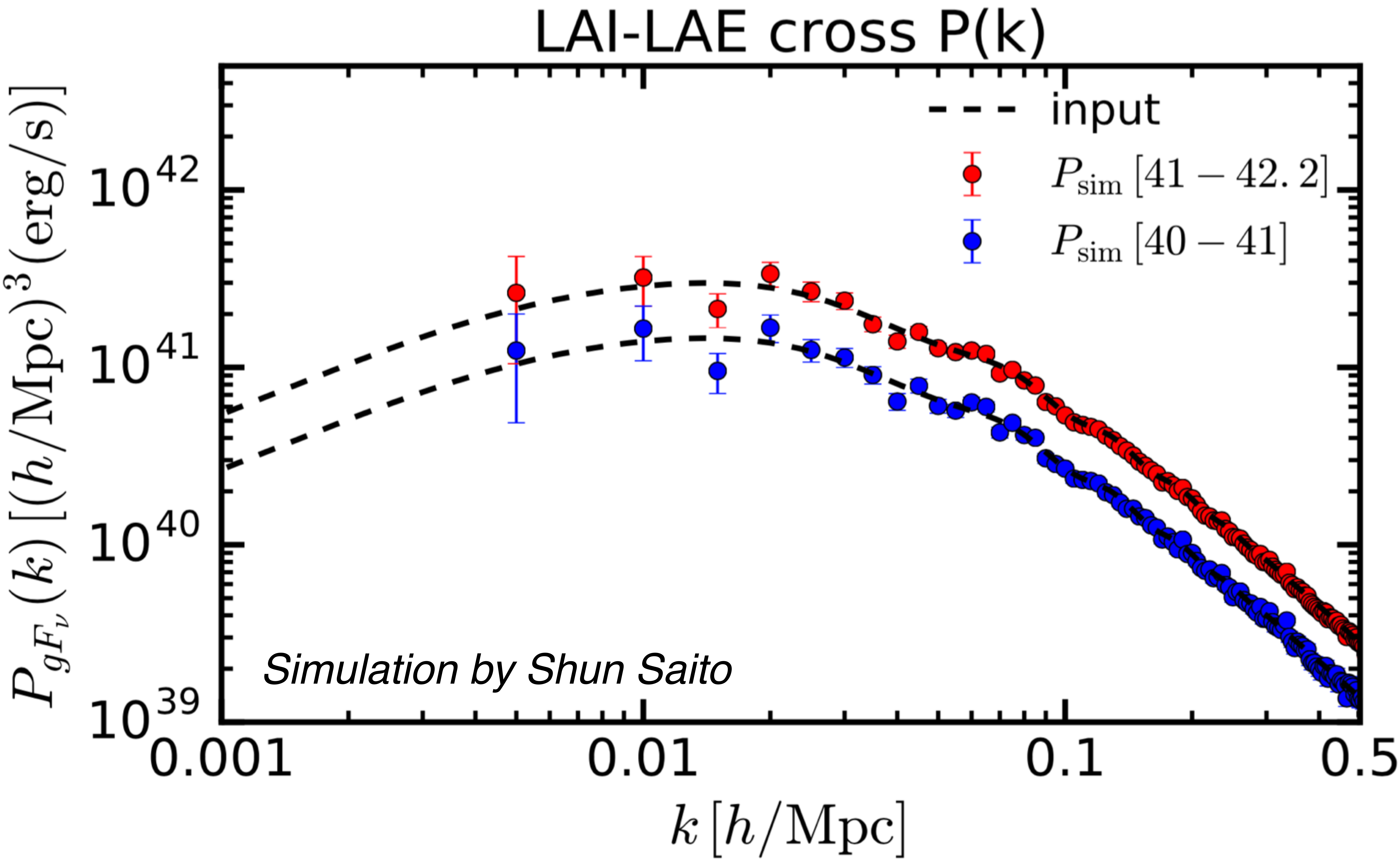
- My group is in charge of providing theoretical and analysis underpinnings for these experiments:
  - The Galactic foreground in B-mode polarisation must be subtracted by more than 99%. How can we do that?
  - How do we model non-linear evolution of matter density fields, velocity fields, and galaxy formation?
  - Do we understand how massive neutrinos affect the growth of structure in non-linear regime?



HETDEX Status

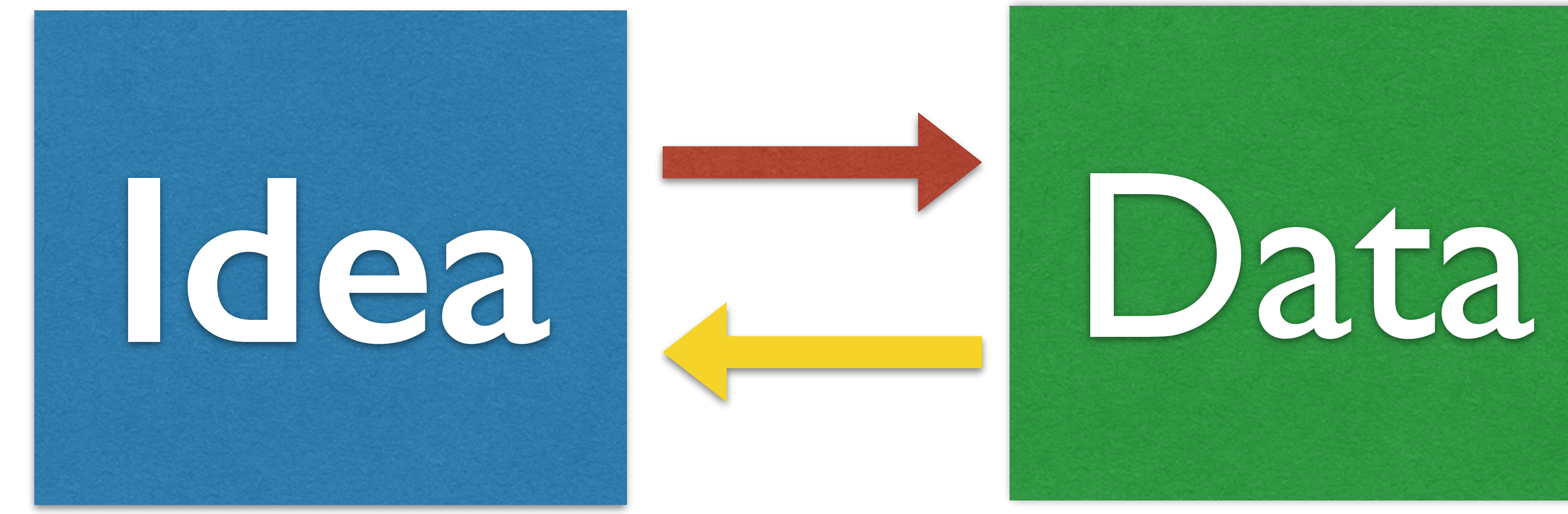


- **We are now doing Science Verification Run**
  - GOOD-N and Extended Groth Strip (EGS)
  - 16 / 78 IFUs are on the telescope
    - Already more than 7K fibers!
- Luminosity function and bias of Lyman-alpha emitters in $1.9<z<3.5$
- Really exciting: Lyman-alpha intensity mapping!



LAI-LAE cross P(k)
input
$P_{\rm sim}\,[41-42.2]$
$P_{\rm sim}\,[40-41]$
$P_{gF_\nu}(k)\,[(h/{\rm Mpc})^3({\rm erg/s})]$
10^{42}
10^{41}
10^{40}
10^{39}
0.001
0.01
0.1
0.5
$k\,[h/{\rm Mpc}]$
Simulation by Shun Saito

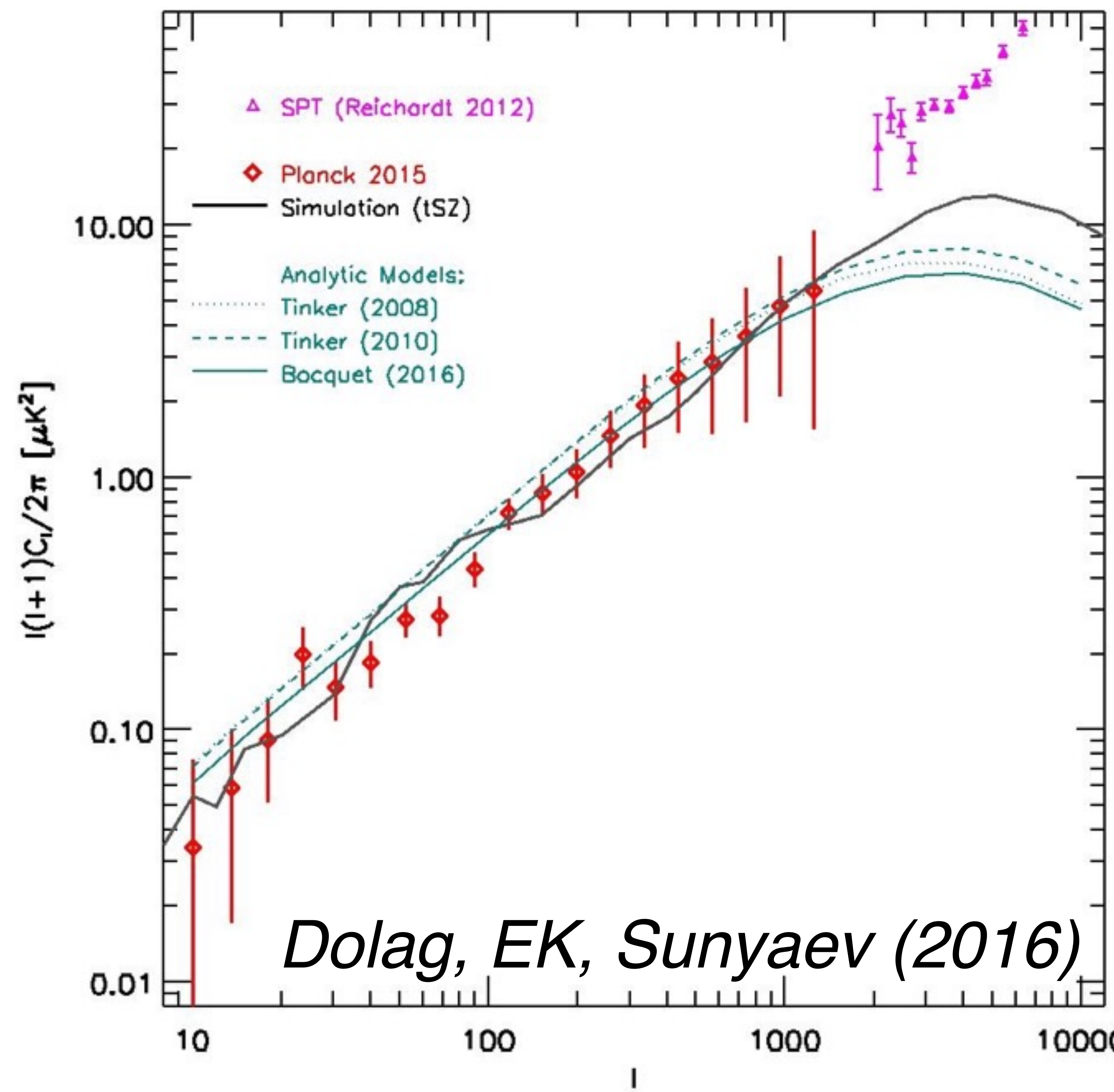
Recent Examples of



- The power spectrum of the Sunyaev-Zel'dovich effect is a powerful way to determine the amplitude of matter fluctuations (1999, 2002)

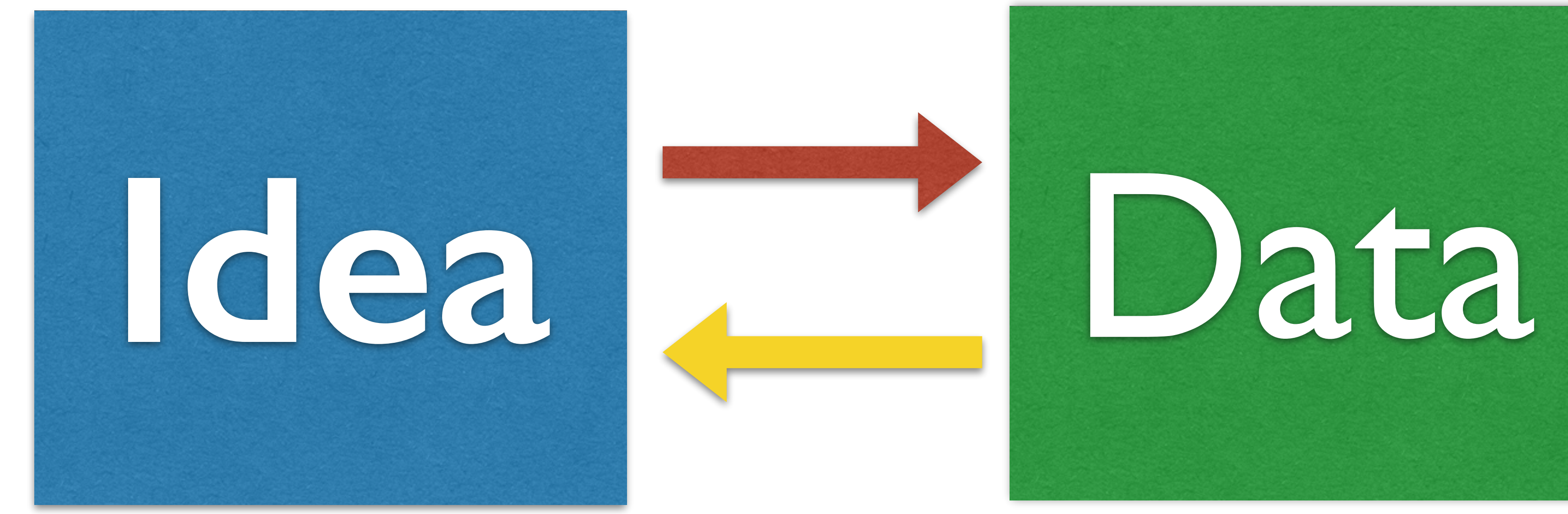
15 years later…

- The power spectrum of the SZE has finally been measured by Planck!
- And indeed, we show that σ_8=0.815 fits better than σ_8=0.834. Precision measurement!



Dolag, EK, Sunyaev (2016)

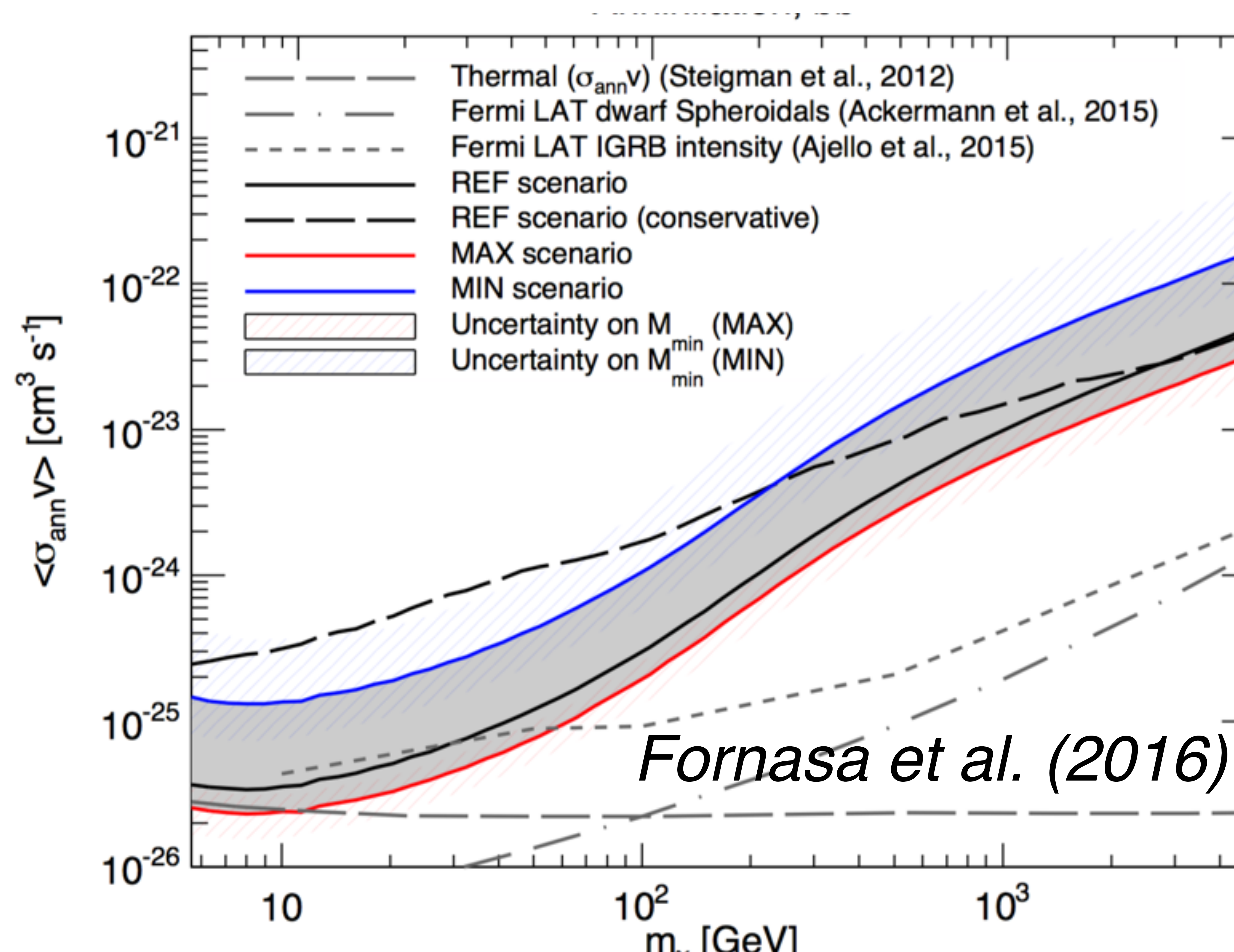
Recent Examples of



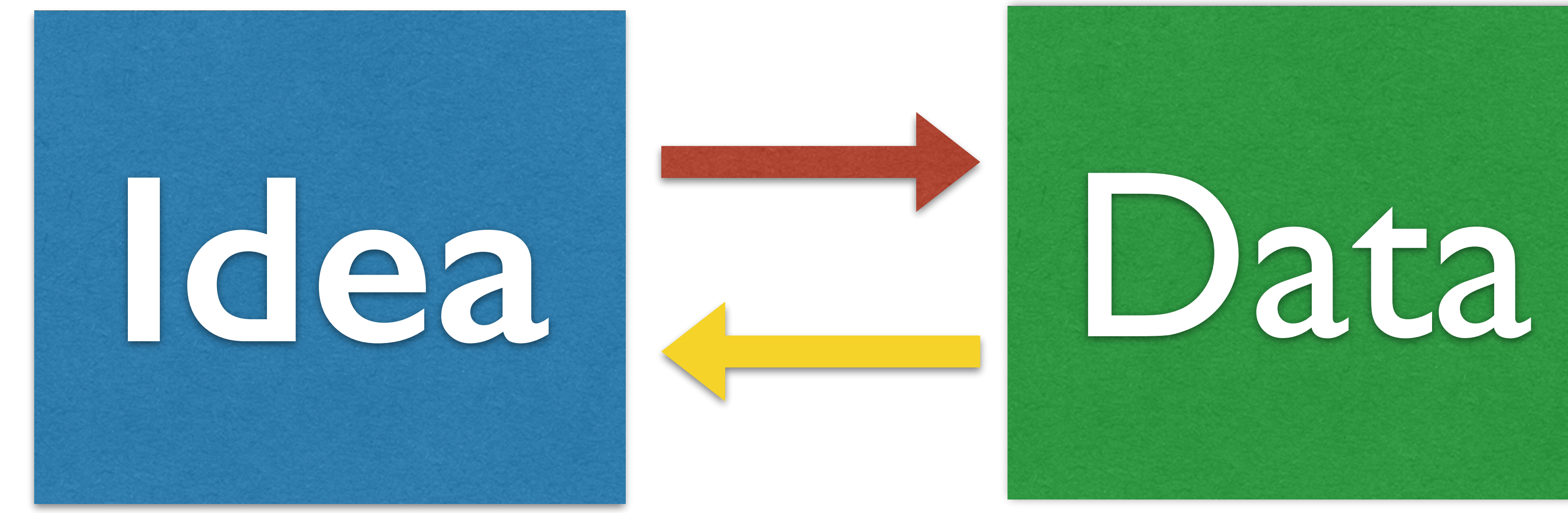
- Diffuse extra-galactic gamma-ray emission measured by Fermi must be anisotropic due to the matter distribution in the universe. We can use Fermi like WMAP (2006)

6 years later…

- We have made the first measurement of the power spectrum of Gamma-ray emission
- Convincingly showed that blazars cannot account for 100% of the diffuse gamma-ray emission



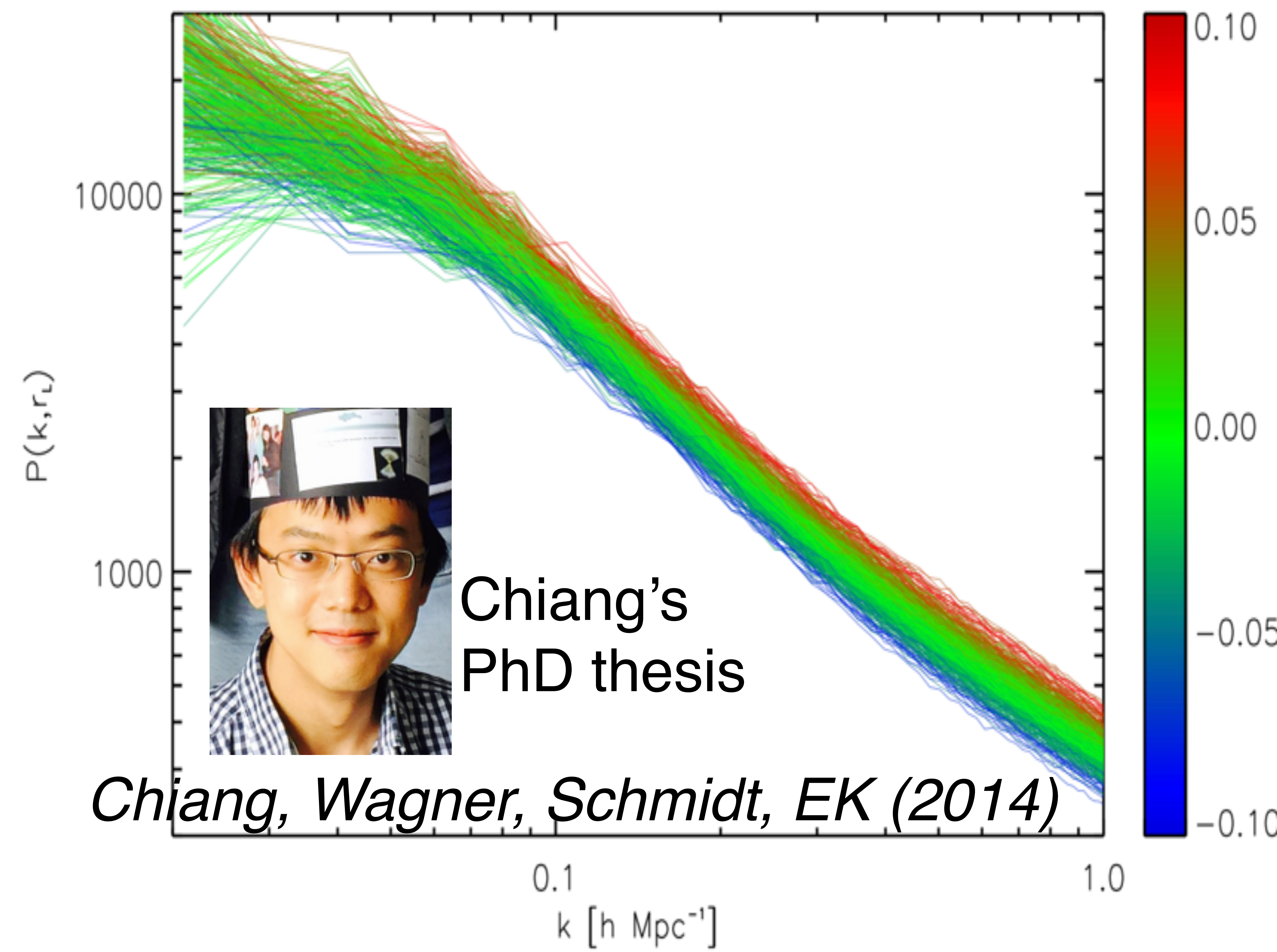
Recent Examples of



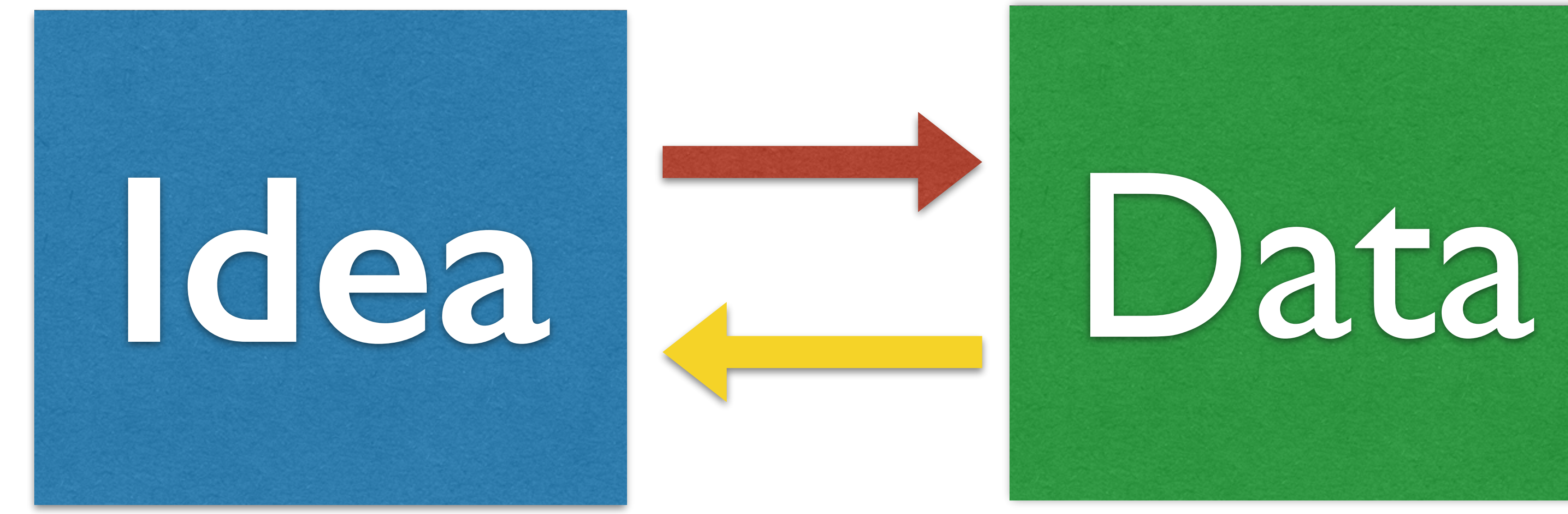
- The power spectrum of galaxies depends on the environment. This is the effect of a particular three-point function (2014)

2 years later…

- The first measurement (7σ!) of the position-dependent power spectrum from the SDSS-III/BOSS data (2016)



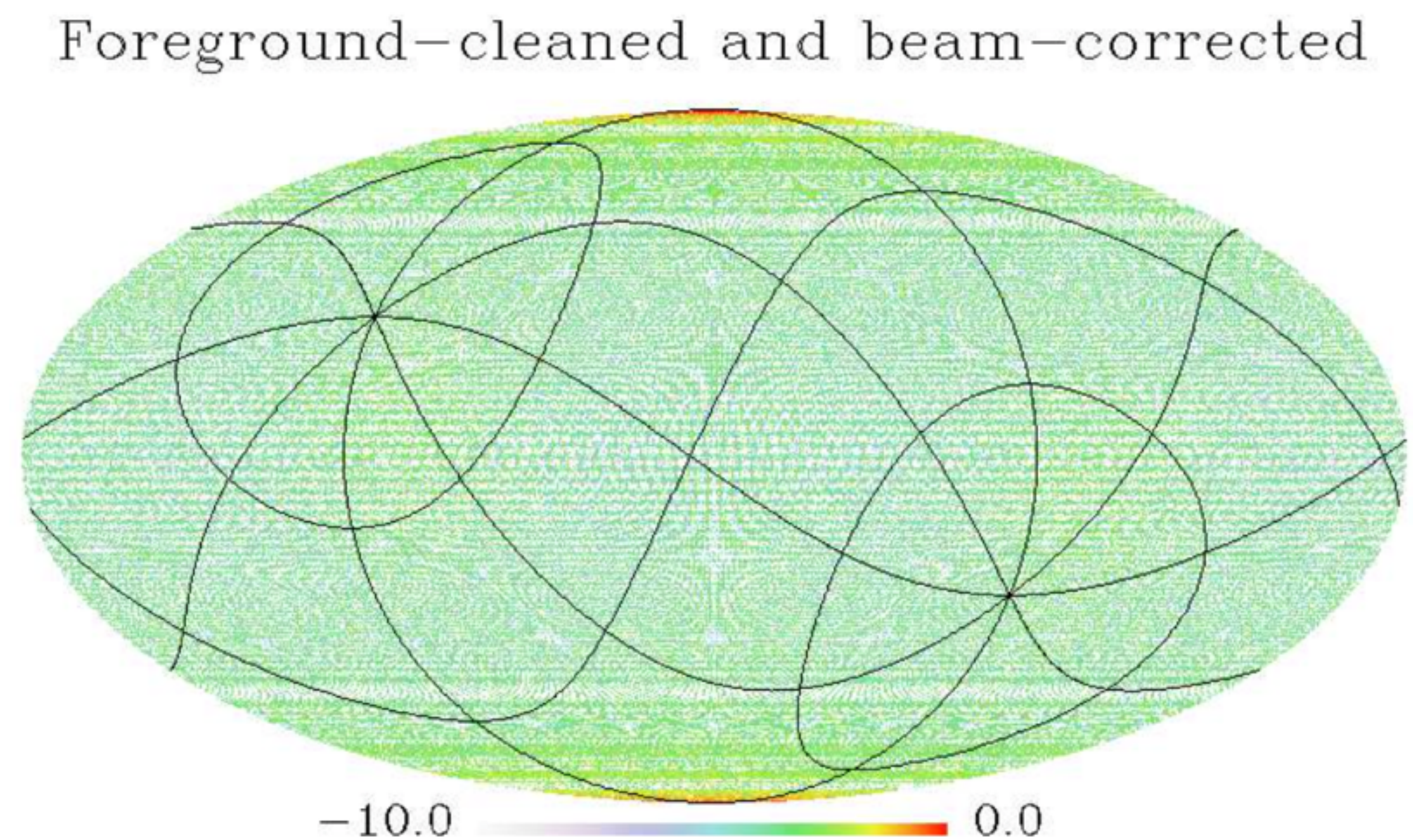
Recent Examples of



- The first upper bound on breaking of rotational invariance of space-time during inflation: Rotational invariance is respected with a deviation smaller than 10^{-9}! (2015)

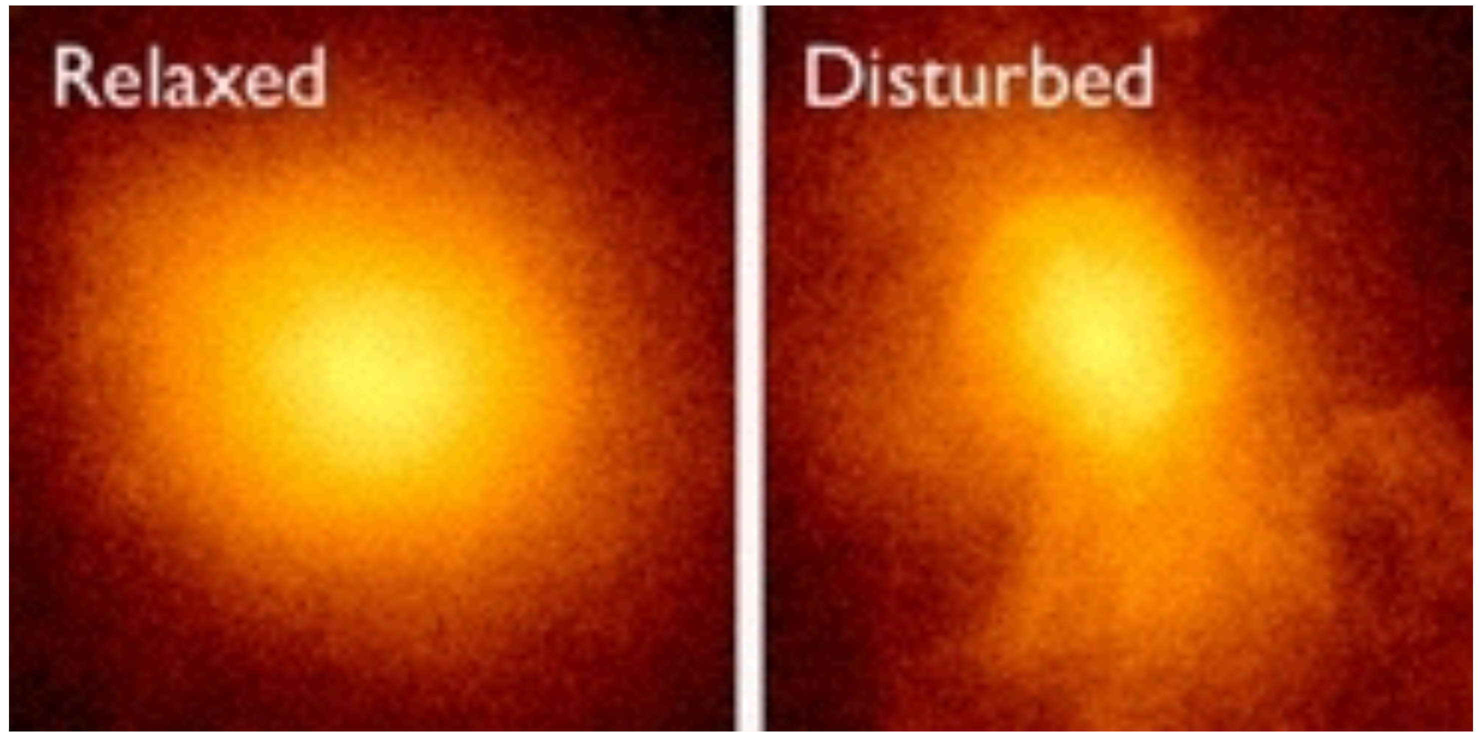
2 years later…

- No evidence for a preferred direction in the universe. The tightest bound on it from the Planck data (2013)

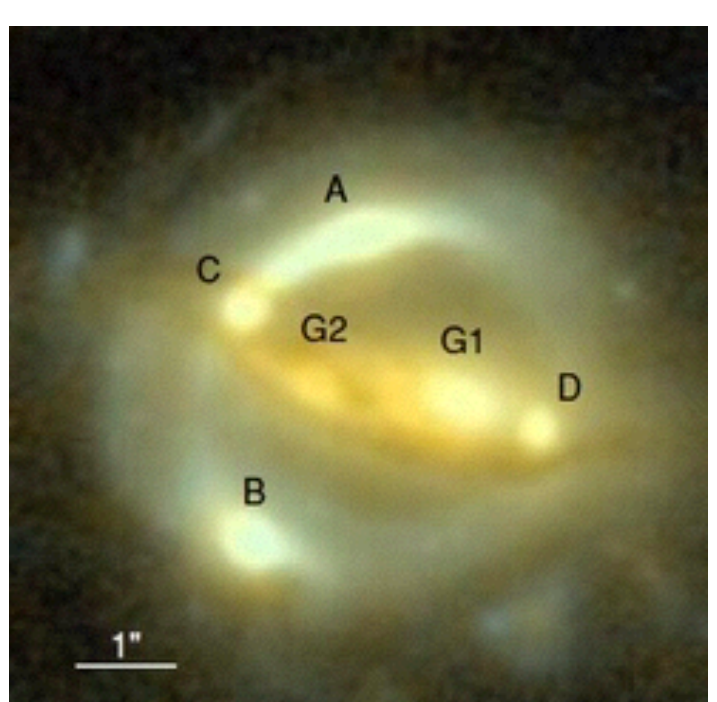


Kim & EK (2013)

The latest ideas not yet applied to the data



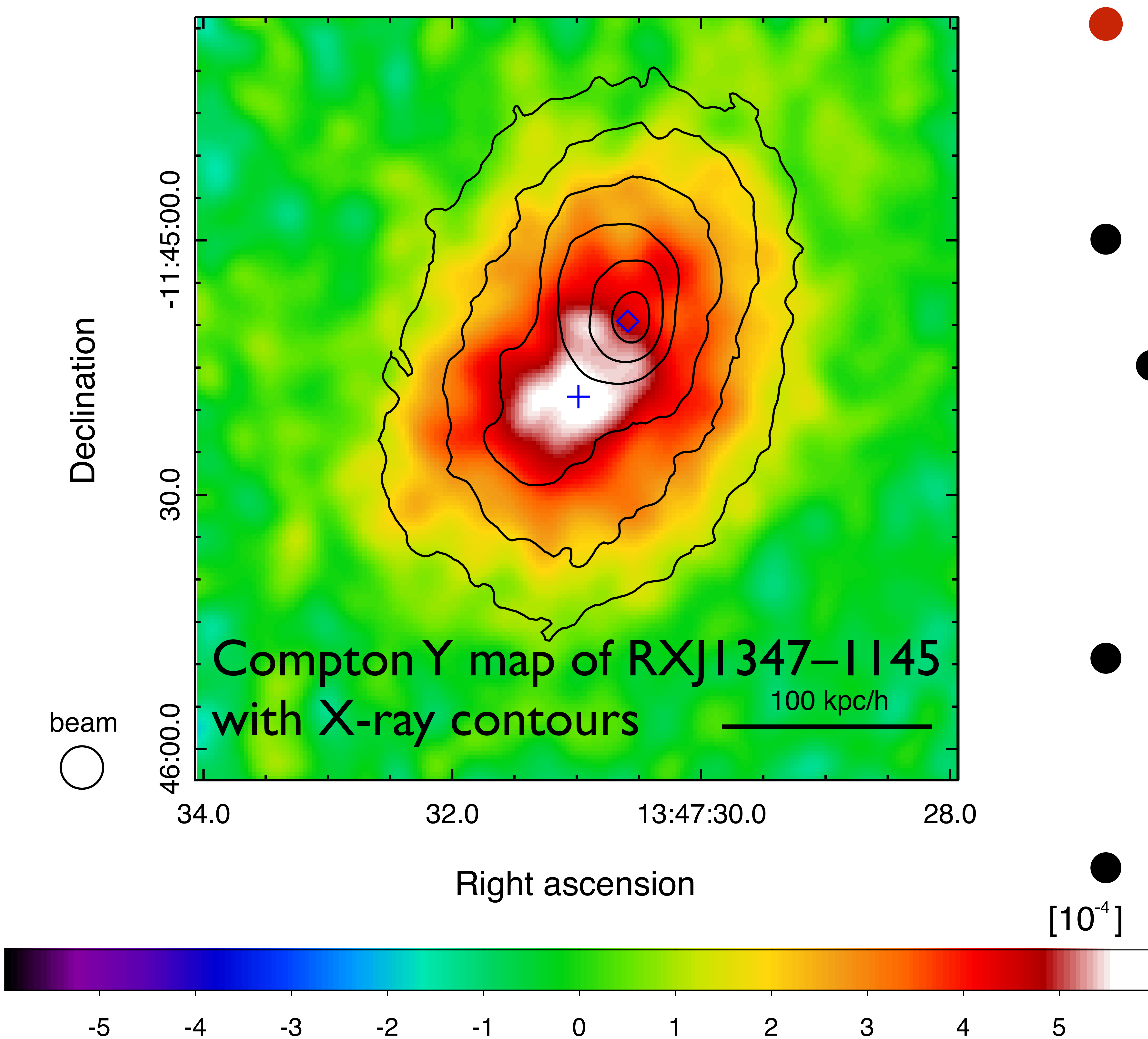
- **Analytical model for non-thermal pressure in galaxy clusters.** This can be used to understand pressure profiles measured by the SZE, and even to correct the "hydrostatic mass bias" - the biggest problem in cosmology using galaxy clusters (with postdoc Xun Shi)



- **New angular distance indicator**: Strong lensing. Being applied to Suyu's lens samples (Inh Jee's thesis)

Kitayama et al., submitted

Got the world-record back



- **The first ALMA image of the Sunyaev-Zeldovich effect!**
- 5" angular resolution: best ever
  - We were a record holder (12") for a decade until the MUSTANG (on GBT) got 9"
- Physical spatial resolution is 30 kpc: also best ever
- Incredible S/N and quality: fun cluster astrophysics!

Vision: Summary

- Over the next decade or so, I wish to make significant contributions to:
  - detect primordial gravitational waves from inflation
  - determine the neutrino mass
  - rule out ΛCDM (or map out the universe out to z=3.5)

Shorter Term Goals

- Finish the search for dark matter signatures in Fermi's gamma-ray data [in a year or so]
- HETDEX data analysis and interpretation! [over the next 3-4 years]
  - Hope to be able to show results at the next FBR
- In parallel, looking forward to making more new predictions, and testing them with the data to learn new things